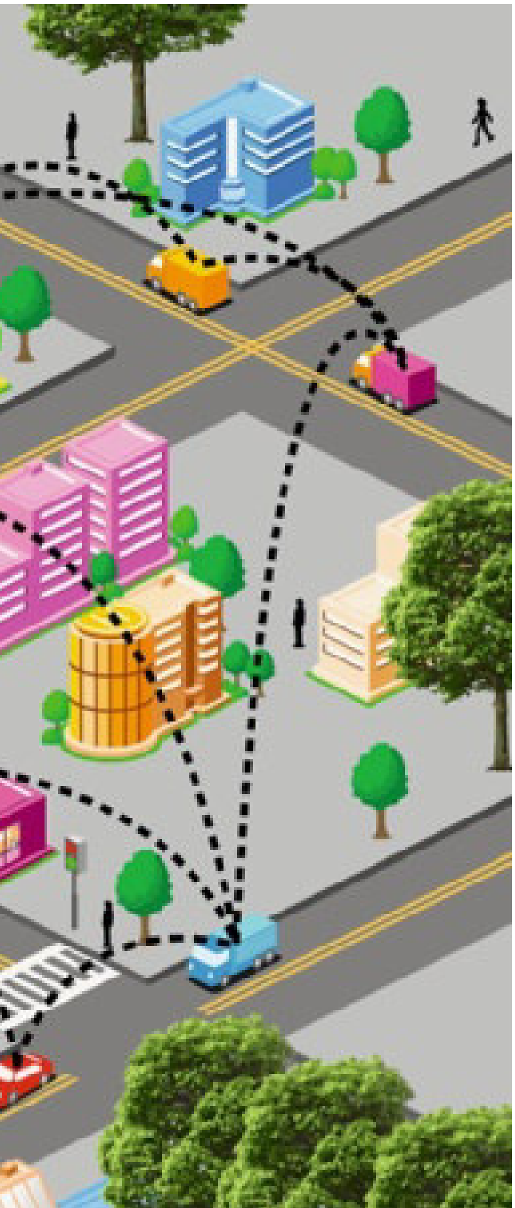
MOBILE COMMUNICATION TEST METHODS FOR CAR-TO-CAR TEST BENCHES

Car-to-X communication is about to leave research laboratories behind and to go into live operation. However, it still lacks reliable, automated test methods. Field tests are a laborious task that requires a lavish amount of resources and results are often hard to reproduce. Qosmotec introduce approaches employed in mobile telephony which can provide efficient solutions to these problems.



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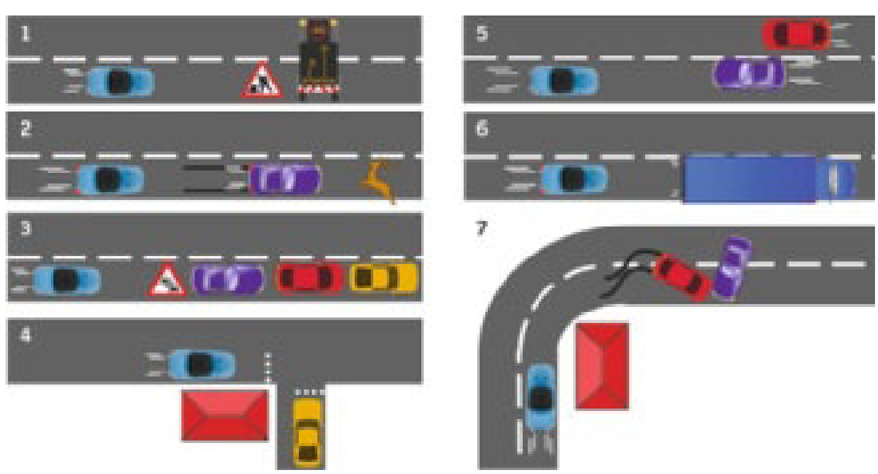
BASIC SITUATION

Imagine you are driving on a motorway approaching the end of a traffic jam, with a 16 ton truck following close behind. Does the truck driver react quickly enough or has he been driving for hours and is exhausted and tired? Every motorist would feel safer, if vehicles themselves could react appropriately in such situations. Car-to-car communication is the key-technology that makes it possible for vehicles to intervene automatically. Nearly every car maker currently works on Car-to-car communication technology.
It shall enable cars to warn other road users or be warned in critical traffic situations, and to even react autonomously in case of an emergency.

Introducing Car-to-car communication is the largest cooperation between manufacturers the automotive industry has ever witnessed. The new technology can only succeed, if vehicles can exchange information regardless of model or make. Therefore, car manufacturers and equipment suppliers agreed on functionalities and standards for communication between vehicles spanning all brands. Currently, Car-to-car communication is set to go into live operation, and adequate test methods have become an urgent necessity. Tests in the field are time-consuming, costly, and hardly reproducible. Thus, they are not appropriate to analyse weaknesses and eradicate malfunctions. Instead, more reliable methods have to be established that enable comprehensive tests of Car-to-car communication in test plants, as it is common practice with crash tests.

Adequate test benches have to be designed, in order to implement such a methodology. Engineers must be able to emulate radio propagation effects realistically and reproducibly. In addition, they need methods to simulate road user mobility and typical traffic situations, ❶. Testers have to replicate the effects that occur when radio signals are transmitted over the air.



❶ Typical use cases for Car-to-Car communication (from top left): 1) road constructions ahead, 2) emergency braking, 3) traffic jam, 4) crossroads with restricted visibility, 5) oncoming traffic on the same lane, 6) slow vehicle ahead, 7) obstacle behind curve

VIRTUALISATION OF DRIVE TESTS IN TESTING FACILITIES

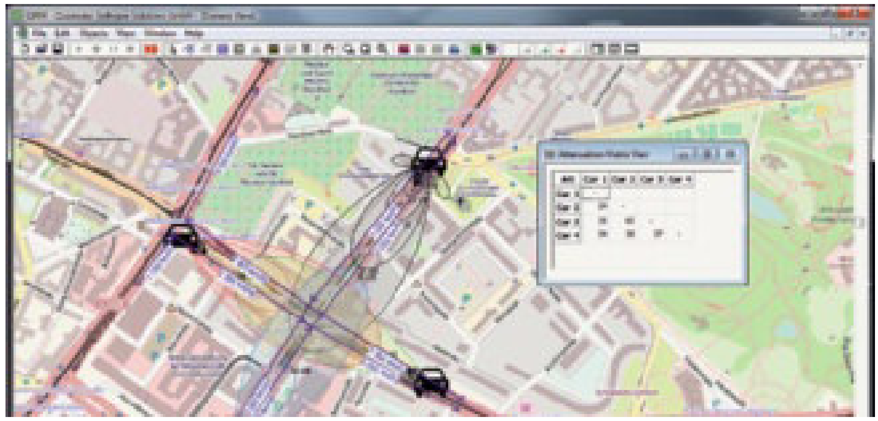
A dip into other technologies promises a solution: It is common practice in the mobile telephony sector to test communication of subscribers that are moving. For this kind of tests, Qosmotec has developed the Virtual Drive Test approach, and currently adjusts it to the needs of communication in the automotive sector. Using this approach, radio signals are transmitted via cable, and radio propagation effects are replicated in manageable setups, allowing precise and reproducible emulation. Radio modules are fully shielded against high-frequency interference on the air-interface. Coaxial cables feed radio signals to the Qosmotec Propagation Effects Replicator QPER. QPER hardware consists of an attenuator matrix that allows manipulating radio signals between connected devices.

Testers can employ phase shift and signal attenuation to each link according to the specific requirements of their use cases. QPER provides $n \times (n-1)/2$ individual radio links where n denotes the number of connected radio devices. The system is designed to host up to 17 radio devices. Signal strength can be adjusted digitally on each path with a dynamic range of 0 to 95.5 dB in steps of 0.5 dB. Considering the additional internal attenuation (so-called insertion loss) of the system, which depending on system size varies between 20 and 50 dB, distances d between radio devices of more than 2 km can be replicated at the IEEE 802.11p frequency range f, assuming a simple model for free space path loss

EQ. 1	$P = 20 \cdot \lg(4\pi d \cdot f/c)$ [dB]

where c denotes speed of light.
The constant insertion loss of the system does not form an obstacle. A signal broadcasted on a frequency of 5.9 GHz loses about 50 dB or 98 % of its radiant emittance on the first metre. However, this first metre is not relevant for any road traffic scenario.

Users can control variable delay elements of 0 to 705 picoseconds in steps of 5.55 ps. This emulates phase shifts in multi-antenna systems that occur when multiple antennas are attached to one vehicle. The dynamic range exceeds the necessary spread of a complete phase four times in the frequency range concerned.



❷ Straightforward modelling by software: Signal strength scenarios between multiple traffic participants can be emulated simultaneously; different antenna radiation patterns are taken into account

To feed the HF components with appropriate radio power, signal propagation over the air is modelled in software, ❷. Antenna positions on vehicles and their radiation patterns are considered in addition to propagation models. Radiation patterns differ depending on vehicle type and antenna (e.g., roof antennae, exterior mirror antennae). This means particular antenna radiation patterns can be prescribed by manfucturers and imported into the software. Antenna pointing, travel direction, and differential altitude between sender and receiver are considered.

An important aspect affecting radio signal propagation is fast fading, which occurs especially in inner city zones, where reflections at buildings lead to interference between different radio paths from the sender to the receiver. Constructive and destructive interference alternate at a distance of merely half a wavelength. In Car-to-car communication this means distances of just 2.5 cm, which are covered in less than 2 ms by a vehicle driving at a speed of 50 km/h.

QPER's attenuator control allows up to 4,000 settings per second. An internal FPGA ensures that all settings applying to multiple links are carried out in parallel and at equal intervals. This method ensures that effects of multipath propagation on signal strength are emulated by the system with adequate accuracy. Therefore, QPER provides the necessary precision to model complex high-frequency signal propagation effects on realistically.

Test engineers can operate the system via a user friendly graphical user interface (GUI) that masks the complexity described above pertaining to all these effects occur in signal propagation over the air. Engineers just draw the itineraries and set the speeds of the vehicles involved via the GUI to model required traffic situations and line-ups, which means they conduct virtual drive tests involving multiple vehicles on their workstations. High frequency parameters are calculated automatically and are exactly reproducible.

REALISTIC SIMULATION SCENARIOS FOR HIGH-DENSITY AREAS

Drive tests are sometimes meant to even reproduce the peculiarities of a specific location, which requires a higher degree of realism than can be provided by a simple path loss model enhanced with fast fading effects. Qosmotec co-operates with RWTH Aachen University in a joint R&D project funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) to meet this requirement. The Institute of Theoretical Information Technology at RWTH Aachen University has an exploratory focus on radio channel emulation. The institute's scientists research hybrid approaches of modelling radio channels between vehicles to integrate particular building data and information on physical environments. Prevalent approaches parameterise environments in a way that statistic properties are in agreement with the real channel. Some of these statistical factors are swapped for deterministic information dependent on information on real life environments. Line-of-sight, other vehicles acting as mobile scatterers, and static scatterers such as buildings, road signs, and vegetation, are incurred in this model. A ray-tracing approach is employed to calculate different deterministic paths between radio transmitter and receiver. This serves as a basis for multipath propagation on the radio channel. The following information is evaluated to calculate the signal strength at a receiver:

- delay in relation to the line-of-sight path
- angle of departure and arrival in combination with transmitting and receiving antenna radiation pattern
- complex-valued amplitude
- distance-induced signal phase shift.

Channel models can be rendered more precise by taking cadastral and environmental information into account. Comparisons between these predictions applied to common mobile telephony networks and real drive tests prove that this approach is far superior to stochastic models. Still, predictions cannot be exactly congruent with results from real drive test nor is congruence desirable, as the results of individual conducted drive tests differ as well to some degree. Therefore, predictions are ideal, if median and variance of measured deviations are in the same order as those of two drive tests. The quality of a prediction can be measured by comparing how close the mean squared error of drive test and prediction is to that of two drive tests among each other, ❸. The researchers achieved the best known results for predictions in third and fourth generation public mobile networks. They now aim to produce more of the same in Car-to-X communication.

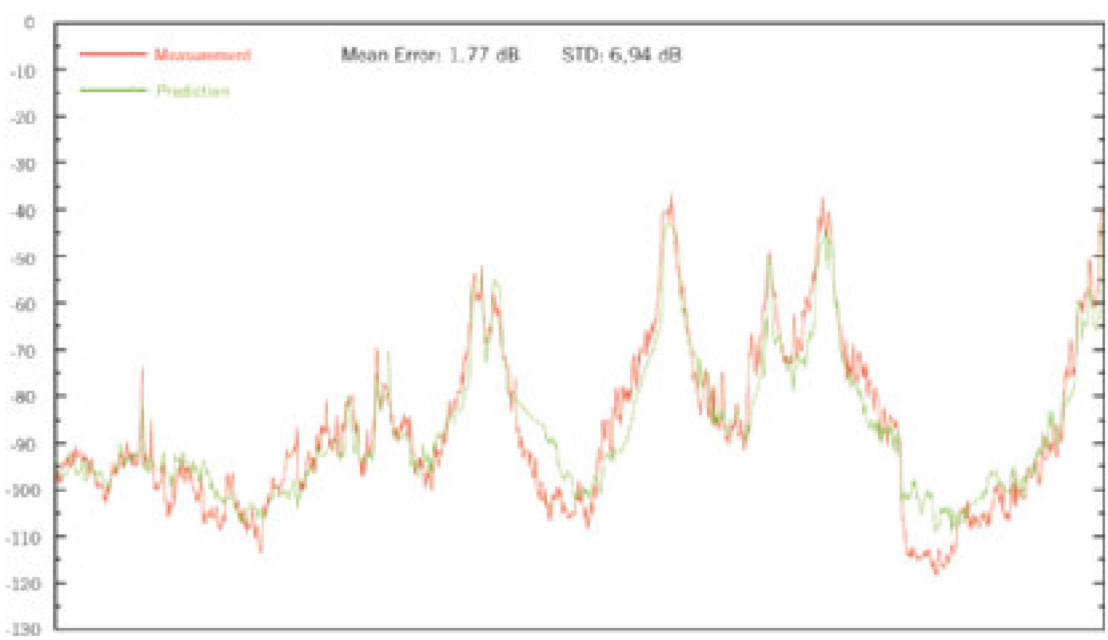
It is a significant step ahead for Car-to-car communication to conduct virtual drive tests in the test plant as this limits the resources required for testing to a reasonable amount. Several pilot schemes, especially simTD (Sichere Intelligente Mobilität – Testfeld Deutschland) in Germany, revealed how laborious test drives are.

It is inevitable for a comprehensive test bench setup to access and manipulate the wireless equipment involved. Concerning this point QPER's abilities are limited, as it is designed to emulate the air interface but not to control wireless equipment. Therefore, Qosmotec is working on the integration of a widely-used standard tool to control on-board electronics in the automotive industry: Vector Informatik's software CANoe. CANoe transmits GPS-positions simulated in QPER to such components and wireless equipment used on the test bench. Jürgen Klüser, head of Car-to-X Development at Vector explains why: " A vehicle always discloses its current position via Cooperative Awareness Messages (CAM) and Decentralised Environment Notification Messages (DENM) which are exchanged by all participants in an intelligent transportation system. In the real world, vehicles obtain their positions via GPS signals. It is therefore necessary to disclose a simulated position to a signal transmitter that can be forwarded to other traffic participants by radio in order to emulate drive tests on a test bench."

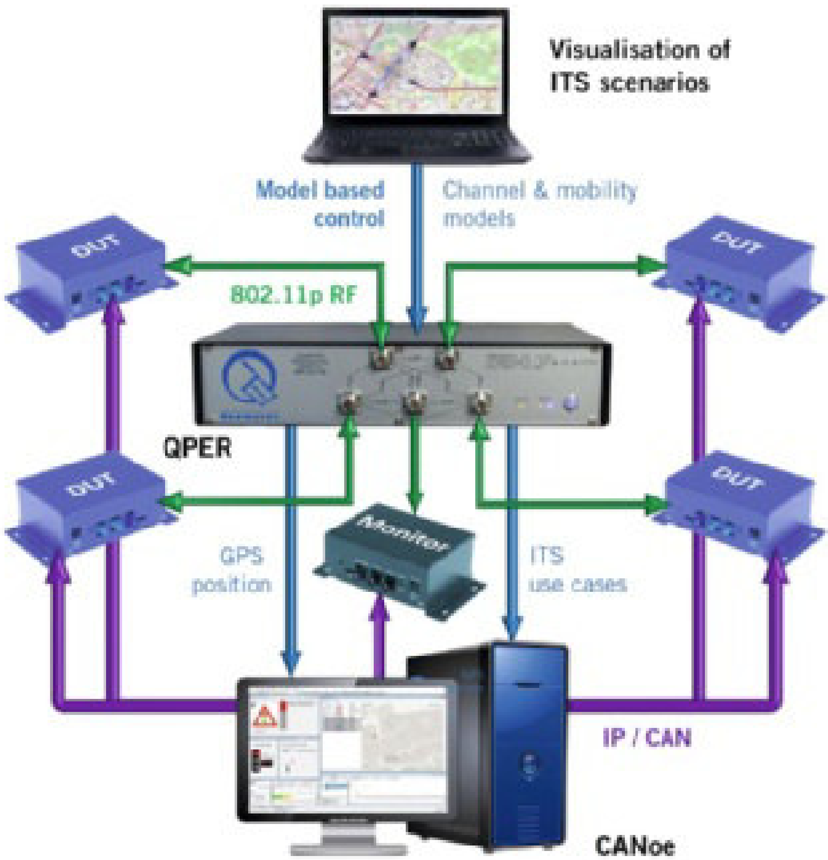
FULLY AUTOMATED TESTS WITH QPER AND CANOE

Vector has also recently adapted its software to the new requirements of Car-to-X technology. A new component, CANoe.CAR2X, has been developed to control on-board units and road-side units. This extension is included in the test bench setup.

All messages transmitted via radio communication can be recorded and displayed by CANOe.CAR2X. A comprehensive result view for analysis displays all exchanged information both at the physical and application layer. Users can employ freely configurable filters to get a quick overview of relevant results. Joining CANoe's Car-2-X extension with the air interface simulator QPER provides the necessary test setup to enable testers to run virtual drive tests in their lab. It offers a method of analysis that



❸ Prediction close to reality: median and variance of measured deviation of drive test and prediction have be in the same order as median and variance of two drive tests



❹ Joining signal-strength emulator and test automation: radio devices (Devices under Test, DUT) exchange information under varying signal strength (green arrows); simultaneously, they receive positions and tasks via CANoe (pink arrows) that records data traffic

gives test engineers a precise overview what will happen at prescribed positions under specific radio conditions.

CANoe's simulation capacity is used at the test bench for comprehensive tests of communication technology in real traffic situations, ❹. Thus, testing can be extended to test specific road user behaviour or infrastructure as well as reactions of devices employed in the test setup. Standard scenarios are supplied, such as road constructions, emergency braking, traffic jams, approaching or slow vehicles, obstacles, or crossroads with restricted visibility. This enables engineers to verify under real life conditions whether the technology reacts as desired in potentially dangerous situations. Test bench setups can be kept simple and easily operable with a manageable amount of connected traffic participants. Still, engineers can model complex traffic situation including a large number of participants. Even a huge amount of radio traffic can be dealt with, as radio modules still have to be able under such conditions to establish and keep stable mutual connections, and to process information crucial for the vehicle in which they are mounted. Ultimately, joining QPER and CANoe.CAR2X makes an efficient test bench setup for Car-to-car communication. It allows engineers to conduct virtual drive tests including complex interaction of traffic participants, ④. First and foremost, the setup outlined above makes tests and all environment parameters repeatable and reproducible.

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