CELLULAR VEHICLE TO EVERYTHING (C-V2X)
TESTING CONNECTED VEHICLES IN THE LAB

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ROHDE & SCHWARZ
Make ideas real
SIX LEVELS OF DRIVING AUTOMATION

**No Automation**
- Performs driving control at all times
- System: Doing support
- Driver: Performs driving control at all times
- System-in-the-loop

**Driver Assistance**
- Performs driving control at all times
- System: Temporarily performs limited control
- Driver: Monitors all driving tasks at all times
- Human-in-the-loop

**Partial Automation**
- Monitors all driving tasks at all times
- System: Temporarily performs complete control
- Driver: Performs limited control in certain scenarios
- System-in-the-loop

**Conditional Automation**
- Must be able to intervene (10s)
- System: Performs all tasks in certain scenarios
- Driver: Performs all tasks in certain scenarios
- Human-in-the-loop

**High Automation**
- Not responsible to intervene
- System: Performs all tasks in certain scenarios
- Driver: Responsible at all times
- System-in-the-loop

**Full Automation**
- Might not be in the car
- System: Responsible at all times
- Driver: System
- Human-in-the-loop

SAE J3016 Level of Automation (LoA) specified by Society of Automobile Engineers (SAE)
SIX LEVELS OF DRIVING AUTOMATION
THE ROLE OF WIRELESS COMMUNICATION

SAE J3016 Level of Automation (LoA) specified by Society of Automobile Engineers (SAE)

Wireless communication allows sharing of assistant information and warnings

Wireless communication helps to smartly control the vehicle

Human-in-the-loop
System-in-the-loop
COOPERATIVE INTELLIGENT TRANSPORTATION SYSTEM (C-ITS) SHORT-TERM DEPLOYMENT

- Emergency Electronic Brake Lights
- Intersection Movement Assist
- Left Turn Assist
- Queue Warning

Testing Connected Vehicles In The Lab
COOPERATIVE INTELLIGENT TRANSPORTATION SYSTEM (C-ITS) MID-TERM DEPLOYMENT

- See-Through
- Real-Time Awareness
- Vulnerable Road User Discovery
- Speed Harmonization
- Sensor Sharing

Testing Connected Vehicles In The Lab
COOPERATIVE INTELLIGENT TRANSPORTATION SYSTEM (C-ITS) LONG-TERM DEPLOYMENT

- Cooperative Maneuver
- Remote Controlled Parking
- Data Sharing for Autonomous Driving
- Data Offloading
3GPP LTE-V2X

- 3GPP LTE-V2X Release 14
- V2V published in 2016, V2X in 2017
- Industry term: Cellular V2X (C-V2X)
- Peer-to-peer ad-hoc communication:
  - service continuity, to operate independent of any centralized system
  - Backend connectivity through mobile network
  - V2V targets 5.9GHz ITS frequency band

IEEE 802.11p

- Amendment to IEEE 802.11 (derived from 11a)
- Ratified in 2010
- EU: Car-to-Everything (C2X), ITS-G5
- U.S: Dedicated Short Range Communication (DSRC), WAVE
- Peer-to-peer ad-hoc communication
- Backend connectivity through Road Side Units
- 5.9GHz ITS frequency band
### COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS (C-ITS): 3GPP APPROACH

#### Testing Connected Vehicles In The Lab

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<thead>
<tr>
<th>Application</th>
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Rohde & Schwarz

Testing Connected Vehicles In The Lab

COMPANY RESTRICTED
### Cooperative Intelligent Transport Systems (C-ITS): 3GPP Approach

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- **BSM** Basic Safety Message
- **SC-FDMA** Single Carrier Frequency Division Multiple Access
- **DENM** Decentralized Environment Notification Message
- **CAM** Cooperative Awareness Message
- **ADLayer** Adaptation Layer

- **WSMP** – WAVE Short Message Protocol
- **BTP** Basic Transport Protocol
- **GeoNet** Geonetworking
- **DSMP** DSRC Short Message Protocol

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3GPP RELEASE 14: PHASE I LTE-V2X

Collaborative Awareness
- Support direct V2X communication, distributed random and reservation based resource usage to exchange basic traffic safety information

Extended Visual Horizon
- Hazardous Information

Traffic Warning

Broadcast transmission service w/o network subscription

Direct PC5 and mobile network Uu communication

Operation in licensed-exempt ITS 5.9GHz frequency spectrum

Semi-persistent scheduling yields spectral efficiency
3GPP RELEASE 15: PHASE II LTE-V2X

Vehicle Platooning
Extended Sensors
Support of low latency, high data rate links to exchange data for enhanced automotive applications

Advanced Driving
Collaborative Perception

Transmit diversity
Support of 64QAM for higher data rate
Reduce the max. time between L1 packet arrival and resource selected for transmission from 20 to 10 ms
Aggregation of up to 8 PC5 carriers (TM3 & TM4)
3GPP RELEASE 16: PHASE III 5G NR V2X

- High Density Platooning
- Advanced Sensors Data Sharing
- Support broadcast, groupcast, unicast communications for advanced automotive applications
- Intention Sharing
- Remote driving
- Flexible numerology
- Operates Multiple Input Multiple Output (MIMO) transmission
- Distance based Hybrid Automatic Repeat Request (HARQ)
- V2X communication in FR1 and FR2
V2X – The global view

5.855GHz – 5.925GHz
7x10MHz
SRD

5.905GHz – 5.925GHz
20MHz
China

5.850GHz – 5.925GHz
3x10MHz
United States

5.875GHz – 5.905GHz
2x10MHz (under investigation)

5.905GHz – 5.925GHz
20MHz

5.855GHz – 5.925GHz
7x10MHz

3GPP LTE-V2X

IEEE 802.11p

Technology neutral

IEEE 802.11p

Modified IEEE 802.11p

Others

Testing Connected Vehicles In The Lab
C-V2X CERTIFICATION

- Quality Testing
  - Manufacturer A: Manufacturer specific requirements
  - Manufacturer B: Manufacturer specific requirements
  - Manufacturer C: Manufacturer specific requirements

- Conformance Testing
  - Industry recognized and harmonized requirements

- Compliance Testing
  - Regulatory requirements
R&S C-V2X TEST SOLUTIONS

C-V2X Application Testing

R&S at the 5GAA C-V2X Plugfest

Rohde & Schwarz delivers 3GPP C-V2X device testing for GCF protocol conformance
Automakers are now well positioned to accelerate cellular vehicle-to-everything (C-V2X) device verification with Global Certification Forum (GCF) protocol conformance testing supported in the R&S CMW500 wideband radio communication tester.

Munich | 18-Jul-2019 | Test & Measurement

C-V2X Protocol and Protocol Conformance Testing

Rohde & Schwarz collaborates with Vector to deliver Cellular-V2X end-to-end application layer test solution

Munich | 18-Feb-2019 | Test & Measurement

Rohde & Schwarz demonstrates test capability of 3GPP C-V2X technology in preparation for GCF certification toward commercialization
At Mobile World Congress 2018 in Barcelona, Rohde & Schwarz will showcase their CMW500 wideband radio communication tester and a pre-commercial Qualcomm® 9150 C-V2X chipset solution, that implements 3rd Generation Partnership Project (3GPP) Release 14 cellular vehicle-to-everything (C-V2X) direct communications technology. Rohde & Schwarz, working with companies including Qualcomm Technologies, aim to support an official global certification scheme based on 3GPP standardized conformance tests selected by the Global Certification Forum (GCF) in preparation of commercialization.

Munich | 27-Feb-2018 | Test & Measurement

COMPANY RESTRICTED
R&S C-V2X TEST SOLUTIONS

**PRODUCTION**

CMW100 K06

- Production Test
- Frequency range up to 6GHz,
- 160MHz Bandwidth
- High accuracy
- Parallel test up to 8 RF ports
- CMW-KM570 C-V2X PC5 Meas.

**CONFORMANCE**

CMW500 PT + SMBV100A

- Protocol Test
- Data Transmission
- Data Reception
- Performance Testing (Fading)

GCF Protocol Conformance

- GCF Work Item 281 (V2V)
- GCF Work Item 282 (V2X)

**APPLICATION**

CMW500 PT + SMBV100B + CANoe .Car2x

- C-V2X Scenario Based Testing
- Development and Test of C-V2X Scenarios
- Graphical Scenario Editor
- Reproducible test scenarios
- Test of all layers
- Support of all common automotive bus connectivity
FCW
ICW
LTA / RTA
BSW / LCW
DNPW
EBW / EEBL
AVW
CLW
HLW
SLW
RLVW
VRUCW
GLOSA
IVS
TJW
EVW

CHINA DAY-1-USE CASES
CANOE LOOK AND FEEL
CANoe imports scenario file
- **Start and stop** a scenario
- **Callback functions** if keypoints changes or scenario status changes

Interpretation of ITS relevant protocols

Support of relevant standards
- ETSI (EU), WAVE/SAE (US), GB31024 (CN)
- Security header generation

Application message support
- CAM, DENM, Spat/MAP, IVI, BSM,…

Map window for visualization of the scenario

Trace/Graphic/Data window for specific measurement and DUT specific data

Internal programming environment for advanced stimulation and analyzing (CAPL)

The test solution allows bus connectivity
- CAN, LIN, FlexRay, Ethernet to analyze results or stimulate the ECU remotely
SCENARIO EDITOR

- GUI for easy and fast traffic scenario configuration
- Multiple virtual cars
- GNSS route definition
- Flexible parameter configuration (speed, signal strength…)
- CAPL interface for fine adjustment of the scenario
- Scenario loaded and played back by CANoe – C-V2X communication and waypoints created according to scenario
C-V2X SERVING SCENARIO
CMW-KAA550

- Abstract the CMW500 and SMBV to “Callbox like operation”
- Offers a dedicated interface to Vector’s CANoe .car2x
- Features on the interface will grow over time
- Customer feedback and requirements is required
LTE SIDELINK TX MEASUREMENTS – KM570
100% REPRODUCIBLE TESTING OF C-V2X IN A LAB ENVIRONMENT

R&S CMW500 Wideband Communication Tester
- C-V2X Signaling LTE Rel-14 TM4 (3GPP Rel.14, PSCCH, PSSCH)
- Multi-technology protocol tester with a layer 1 to layer 3 stack implementation
- Extendable with CMX500 for 5G
- Verify Transmitter characteristics under signaling conditions in combination with KM570 measurements (power, EVM...) and ready to use test packages for transmitter, receiver and performance verification

R&S SMBV100B
- GNSS synchronization and route simulation
- Frequency range from 8 kHz to 3 GHz or 6 GHz
- Signal generation for all major digital communication standard incl. 5G NR, LTE and WLAN
- GNSS simulator with GPS, Glonass, Galileo, BeiDou and QZSS/SBAS

VECTOR CANoe .car2x
- Simulation, analysis and test of C-V2X applications following EU, US and CN standards
- Quick and easy scenario design with CANoe .car2x scenario editor
QUESTIONS???