V2X Day 1 Use Case Testing with IPG CarMaker

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www.sea-gmbh.com/v2x
Topics

• S.E.A. Company Introduction
• V2X Basics
• Challenges of V2X Testing
• SEA V2X Test System and Tools Portfolio
• Scenario Based Testing
  • CarMaker as Scenario Simulator
  • Open Loop – Replay
  • Closed Loop - HIL
• Day 1 Use Case Test Catalog
• Conclusion and Key Take Aways
S.E.A Datentechnik GmbH
- Company introduction -
S.E.A. Datentechnik GmbH

- German system engineering company
  - System engineering
  - Test & measurement solutions
  - Hardware & software development
  - Hardware & software products
- Founded 1995, 45+ employees
- NI Specialties
  - RF & Wireless Specialty Partner
  - Embedded Specialty Partner
- Multiple NI Awards
## Wireless Competence

<table>
<thead>
<tr>
<th>RF-Measurement systems</th>
<th>Customized RF-Test systems</th>
<th>V2X &amp; ADAS test products &amp; solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Hardware products for drive testing of mobile and WiFi networks</td>
<td>• Automated test systems validation of ECU with proprietary wireless communication protocols</td>
<td>• RF measurement systems</td>
</tr>
<tr>
<td>• Software for data management and visualization of geo-mapped telemetry data (SpaceMaster® GEO)</td>
<td>• Signal analysis implementation</td>
<td>• Signal analysis</td>
</tr>
<tr>
<td></td>
<td>• Protocol implementation</td>
<td>• Test and validation of V2X communication</td>
</tr>
<tr>
<td></td>
<td>• Customer specific test &amp; measurement systems for RF &amp; LF</td>
<td>• HIL ADAS test systems</td>
</tr>
</tbody>
</table>

![Wireless Competence Banner](image)
V2X Engagement

- Member of
  - Car-2-Car Communication Consortium (C2CC)
  - VDT Alliance
  - IWPC
  - OmniAir Consortium

- Participation in various research projects (e.g. SAFIR)

- Foundation member of ADAS iiT – Innovation in Test for Autonomous Driving
Global Partners

Regional Integration Partners
- China
- Japan, Singapore, Vietnam...
- United States

Technology Partner
- NI
- M3 Systems
- IPG
- ADAS iiT partners
V2X Direct Connected Traffic
- Basics -
Vehicle-to-Everything with Everything

- **V2V** Vehicles
- **V2I** Infrastructure
  - traffic signs
  - traffic lights
  - RSU
- **V2M** Motorbike
- **V2P** Pedestrian
V2X Approach

- Share traffic specific information between all traffic objects
- Increase of safety
- Improvement of traffic flow
- Mandatory information for sensor fusion autonomous driving
  - No line-of-sight required
  - Mid-to-long range sensor
  - Independent of weather and light
## V2X Implementation

### V2X Day 1 Use Cases

<table>
<thead>
<tr>
<th>Region</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>ETSI TS 101 539-1</td>
</tr>
<tr>
<td>US</td>
<td>J2945 (US)</td>
</tr>
<tr>
<td>China</td>
<td>T/CSAE 53-2017 (China)</td>
</tr>
</tbody>
</table>

### V2X Protocol & Signaling Standards

<table>
<thead>
<tr>
<th>Region</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>ETSI ITS-G5 (EU)</td>
</tr>
<tr>
<td>US</td>
<td>WAVE IEEE 1609 (US)</td>
</tr>
<tr>
<td>Japan</td>
<td>ARIB STD-T109 (Japan)</td>
</tr>
<tr>
<td>China</td>
<td>CSAE/CCSA (China)</td>
</tr>
</tbody>
</table>

### V2X Communication Standards

<table>
<thead>
<tr>
<th>Type</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wifi</td>
<td>802.11p/DSRC</td>
</tr>
<tr>
<td>LTE-based</td>
<td>LTE-V / c-V2X</td>
</tr>
</tbody>
</table>
V2X
Test Challenges
V2X Products and Services

- Day 1 Test
  - Catalogs
- Open Loop
  - Closed Loop (HIL)
- Protocol Test
  - Conformance
- Mobile Sniffer
  - Mobile Logger
- RF-Measurement
  - RF-Conformance
- Channel Emulation

Day 1 Use Cases
- Application Layer
  - Speed, Longitude, Latitude...
- Signaling Layer
  - WAVE, ITS-G5, CSAE
- Protocol Layer
  - 802.11p, DSRC, LTE-V, C-V2X
- RF-Layer

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Scenario Based Testing
- Open Loop and Closed Loop/HIL -
Emulation for Functional Application Level Testing

Test System

- Test Case Catalog
  - Scenario and Test Descriptions
- Environment vehicles
- Scenario Simulation
- Ego vehicle position & time
- Ego vehicle internal state

V2X System under Test

- V2X
- GNSS
- CAN

DUT

OBU / RSU / Vehicle
V2X Test System

Automated and interactive simulation and evaluation
Open Loop Test

Scenario definition

User defined scenarios

Calculated Scenario Data

Congestion

Events

Signal preparation

S.E.A. V2X Scenario Synthesis

User defined tests

V2X Packet stream

GNSS route

CAN Packet stream

Test Execution

V2X Open Loop Test system

physical signals

Recorded data

S.E.A. V2X Logger

DUT
Open Loop Test Example
ITS Example Use Cases

Virtual Brake Light (decentralized)

Platooning
Example Day 1 Test Case

Emergency Brake Light (ITS-G5 EU)

<table>
<thead>
<tr>
<th>Test case TX</th>
<th>Simulated scenario triggering condition</th>
<th>DUT’s reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEBL (EU)</td>
<td><strong>In vehicle</strong></td>
<td>Send DENM with correct use case specific parameters within tolerated lag time after event</td>
</tr>
<tr>
<td></td>
<td>- Strong deceleration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Emergency brake light</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test case RX</th>
<th>Simulated scenario triggering condition</th>
<th>DUT’s reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEBL (EU)</td>
<td><strong>Received from other vehicle</strong></td>
<td>Driver information after relevance check (position, time, lane, driving direction)</td>
</tr>
<tr>
<td></td>
<td>- DENM with valid position and time and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- EEBL cause code received</td>
<td></td>
</tr>
</tbody>
</table>
V2X Application Testing

S.E.A. V2X Application Test Case Catalog

- Predefined, executable test cases for standard V2X Day 1 applications
- Covers V2X reaction (V2X Rx) and action (V2X Tx) of DUT with permutations of scenario parameters
- For functional test of OBU's and Applications
- Simply configurable for customer DUT CAN Bus assignments
- Applicable with S.E.A. Open Loop and Closed Loop test products
S.E.A. Day 1 Test Catalog – Open Loop

Scenario definition:
- SEA Day 1 Test Catalog
  - User parameters

Signal preparation:
- V2X Test Generator
  - Test script
  - Parameter

Test Execution:
- V2X Open Loop Test system
  - V2X Packet stream
  - GNSS route
  - CAN Packet stream

Physical signals

Congestion
Events

Calculated Scenario Data
V2X Scenario Synthesis
## Coverage of SEA V2X Day 1 Use Case Test Catalog

<table>
<thead>
<tr>
<th>Use Case</th>
<th>ETSI</th>
<th>SAE</th>
<th>CSAE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCW</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ICW / IMA</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>LTA</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>BSW/LCW</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>DNPW</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>EBW /EEBL</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>AVW</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>CLW</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>HLW</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>SLW</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>EVW / EVA</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>VRUCW</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>IVS</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>TJW</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>RWW</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AWC</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Test Catalog – Test Case Selection
Test Catalog – Test Case Selection
Conclusion and Take Aways

- Comprehensive tool set based on the modular NI platform
- Complete test catalog for immediate results and fast ramp-up
- Extendable turn-key solutions for different V2X test goals, future requirements, standards and adaptions
- SDR based implementation advantages
  - ensures support of changed and upcoming communication standards
  - Additional capabilities (Congestion, Failure injection....)
  - Reasonable cost and footprint
  - Early availability of new standards, 5G
- S.E.A. is available for implementation and integration of customer specific test systems
Thank you very much for your attention!