OVER-THE-AIR TESTING OF AUTOMOTIVE COMMUNICATION SYSTEMS AT VEHICLE LEVEL

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ROHDE & SCHWARZ
Make ideas real
INTRODUCTION, MOTIVATION & CHALLENGES

- New Technologies entering the car:
  - Safety
  - Information
  - Entertainment
  - Connectivity
  - Vehicle Electrification
  - Autonomous Driving
Introduction, Motivation & Challenges

Key requirements of a test concept

RED
Combined Radio

Receiver Testing
• Proximity
• Coexistence

Transmitter Testing
• Antenna System
• Spurious Emission
• RF output power

Functionality
• User Experience
• Security

Parallelization
&
Test time optimization
Introduction, Motivation & Challenges

- **Vehicle level measurement challenges:**
  - Conducted or over-the-air (OTA)
  - Size of the vehicle
  - Number of radio systems and electronic systems in the vehicles
  - Source of Interference and use case reproduction
Introduction, Motivation & Challenges

Antenna Position

- **External embedded antenna**
  - Wi-Fi, GPS, RKE, TPMS, BMS, Cellular communication

- **Internal Embedded Antenna**
  - Wi-Fi, Bluetooth
Introduction, Motivation & Challenges

Coexistence Source
- From Bus
  - Wi-Fi
  - Bluetooth
- From Pedestrian
  - Wi-Fi
  - Bluetooth
Introduction, Motivation & Challenges

Coexistence Sources
- Portable Tablets, Phones and Smartwatches
  - Bluetooth
  - Wi-Fi
Introduction, Motivation & Challenges

- Test & Measurement challenge
  - Field to lab (Anechoic Chamber)
  - Over-the-air (OTA) setup
  - Interference Signal Type
Measurement Parameters

Combined Radio Equipment
- Inside (in-car)
- Outside

- RF Output power
- Spectral power density
- Transceiver spurious emissions
- Receiver blocking
- Coexistence

ETSI EN 301893 at 5GHz
- 10 Parameters
ETSI EN 300 328 at 2.4 GHz
- 13 Parameters

RED parameters assessment (complementary with BS)
Transmitter Testing
Measurement Method

1. RF output power
2. Spectral density
3. Spurious Emission
OTA test setup for vehicle level testing

- Over-the-Air **chamber calibration** setup
WIRELESS CONNECTION TECHNOLOGIES

LTE-M
LTE Advanced
NB-IoT
LoRa
Sigfox
Wi-Fi
Zigbee
OTA test setup for vehicle level testing

Test instrument rack

10m EMC chamber

RX antenna

Cellular & non-cellular connection

Interference antenna

Switch

Spectrum Analyzer

COM. TESTER

Signal Generator

Power Amplifier
Measurement Results

(a) Effective radiated power (a) and equivalent isotropic radiated power (b) (c) of radio equipment for the three measured sub bands.
Receiver Testing
4. Receiver Blocking
5. Co-existence
TYPES OF COEXISTENCE

In-device Coexistence
- Bluetooth
- WLAN

Connected sensor

Compliance Certification & testing responsibility on chipset manufacturer

Proximity Coexistence
- Other devices in the vicinity transmitting on the same frequency
- Source of interference
  - smartphones
  - smartwatches
  - Bluetooth headphones
  - robot vacuum
  - smart lights

Compliance Certification & testing responsibility on Device manufacturer
HOW TO PERFORM COEXISTENCE MEASUREMENTS

► Test Plan

• **Risk Assessment**
  • Type of device (critical to user health)
  • Technologies supported
  • Frequencies of interest

• **Intended Use**
  • Interference signal
  • Antenna radiation pattern

• **Determination of functional performance & worst case scenario definition**
  • Physical layer KPI (Throughput, PER, BLER) or Application Layer KPI (audio & video quality)

• **RF Environment Recreation**

• **Testing under worst case condition**

• **Report and Documentation**
TEST PLAN: RISK ASSESSMENT

► Type of device:

<table>
<thead>
<tr>
<th>Tier 4</th>
<th>Tier 3</th>
<th>Tier 2</th>
<th>Tier 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washing machine</td>
<td>Navigation Device</td>
<td>Cooking Stove</td>
<td>Medical Implant</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>Smart Light</td>
<td>Coffee Maker</td>
<td>Remote Surgery</td>
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<tr>
<td>Smart Meter</td>
<td>Robot Vacuum</td>
<td>Microwave</td>
<td>Automotive infotainment</td>
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► Technologies supported: Bluetooth, WIFI, LTE, LORA, Sigfox

► Frequencies:

<table>
<thead>
<tr>
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<th>LTE800</th>
<th>LTE2600</th>
<th>WLAN</th>
<th>Bluetooth</th>
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WANTED SIGNAL AND INTERFERENCE SIGNAL APPROACH 1

- Technologies supported: Bluetooth, WIFI, LTE, LORA, Sigfox

- Risk Assessment:

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</tbody>
</table>

Wanted Signal : WLAN ➔ Interference Signal : WLAN, Bluetooth , LTE2600
Wanted Signal : Bluetooth ➔ Interference Signal : WLAN, Bluetooth , LTE2600
Wanted Signal : LTE800 ➔ Interference Signal : LTE800, LPWAN, ZIGBEE
WANTED SIGNAL AND INTERFERENCE SIGNAL APPROACH 2

\[ f_c - \frac{BW}{4} \leq f \leq f_c + \frac{BW}{4} \]

\[ f_c - \frac{BW}{2} \leq f \leq f_c + \frac{BW}{2} \]
WIRELESS STANDARDS AND FREQUENCIES

Technologies:
- sigfox
- LoRa
- WiFi
- Bluetooth
- zigbee
- LTE-M
- LTE
- NB-IoT

Global
- LoRa
- sigfox

North America
- zigbee
- LoRa

Europe
- LoRa
- sigfox

Frequency Bands:
- 400MHz
- 600MHz
- 800MHz
- 1GHz
- 1.2GHz
- 1.4GHz
- 1.6GHz
- 1.8GHz
- 2GHz
- 2.2GHz
- 2.4GHz
- 2.6GHz
- 2.8GHz
## SIGNAL PARAMETERS

### Wanted Signal Parameters
- WLAN (QPSK, 16QAM, 64QAM)
- LTE (QPSK, 16QAM, 64QAM)

<table>
<thead>
<tr>
<th>Data Rate (Mbps)</th>
<th>Modulation</th>
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<td>For 802.11a/b/g/j/p 20 MHz Channel Bandwidth</td>
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</tr>
<tr>
<td>6</td>
<td>BPSK</td>
</tr>
<tr>
<td>9</td>
<td>BPSK</td>
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<tr>
<td>12</td>
<td>QPSK</td>
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<td>18</td>
<td>QPSK</td>
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<tr>
<td>24</td>
<td>QAM-16</td>
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<tr>
<td>36</td>
<td>QAM-16</td>
</tr>
<tr>
<td>48</td>
<td>QAM-64</td>
</tr>
<tr>
<td>54</td>
<td>QAM-64</td>
</tr>
</tbody>
</table>

### LTE Modulation Scheme
- Data Rate (Mbps) | Modulation |
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>2</td>
<td>QPSK</td>
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<tr>
<td>4</td>
<td>QAM-16</td>
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<tr>
<td>6</td>
<td>QAM-64</td>
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<td></td>
<td>QAM-256</td>
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<tr>
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<td>QAM-1024</td>
</tr>
</tbody>
</table>

### Interference Signal Parameters
- Bandwidth (important)
- Power (important)
- Modulation (not important)
TEST PLAN: INTENDED USE

► Define Use Case of Product
  – Cars: on the road, at charging station, at the factory, at garage, at the mechanics
  – Trucks: Highway, Loading docks, Garage, Customs check, Border Crossings
  – Bus: on the road, parking Area, Bus Stops etc

► Interference Signal:
  – Type: wideband modulated, bandwidth, in-band or out-of-band
  – Quantity: 1, 2, 3 or more

► Antenna Radiation Pattern
  – Antenna pattern after integration changes
  – Angle of higher coupling
ANTENNA MEASUREMENTS

- Passive & active OTA antenna measurements
- Standard frequency range is 400 MHz to 6 GHz
- Extended frequency range up to 90 GHz
- Size of chamber, turntable and gantry is customer specific
- Solution with a moving gantry arm (half or full gantry)
- One probe antenna

![Gantry and turntable](image)

**Absorbers**

Electric surface current density from inverse current solution (FIAFTA)

204 028 sample locations on ellipsoidal surface $a = b = 20$ m $c = 30$ m
SPHERICAL POSITIONER – AVAILABLE MEASUREMENT MODES

- **Step-Step**
  Measurement at every individual point (mechanical positioning between each measurement)

- **Step-Swept**
  Measurement at every point in a semi-successive fashion (points along AZ are measured using a sweep, while EL is stepped)

- **Spiral Scan**
  Measurement on random points in a highly successive fashion (AZ and EL are swept)

⇒ **During continuous movement real-time triggers are sent to the selected measurement device**

Not possible with Energy chain!
TEST PLAN: FUNCTIONAL PERFORMANCE & WORST CASE SCENARIO DETERMINATION

► Data based wireless technology KPI on the physical layer
  - Data throughput, PER, BLER
    - WLAN : PER 20%, LTE: 2% PER, Data throughput: 21Mbit/s or 84Mbit/s
    - Received modulation signal quality: Error Vector Magnitude EVM

► Application Level KPI (data rate reduced but AV experience not acceptable)
  - Video Quality (Frame Freeze, dead pixels)
  - Audio Quality (upper frequency or lower frequency elements missing)

► Worst Case Scenario
  - Cell Edge condition
  - Multiple Interference Sources
TEST PLAN: RF ENVIRONMENT RECREATION

End-to-End network emulation
- Cellular
  - LTE, 3G, e-call, 2G, NB-IOT
- Non-Cellular
  - Bluetooth, WLAN, Zigbee

Interference Generation
- Cellular
  - LTE, 3G, e-call, 2G, NB-IOT
- Non-Cellular
  - Bluetooth, WLAN, Zigbee
- LPWAN
  - Sigfox, LORA, others
- Custom Signal

- Blocking antenna
- Adjustable position
Interference: Bluetooth
Wanted Signal: WLAN

Interference: LTE
Wanted Signal: WLAN
PHYSICAL LAYER MEASUREMENT RESULTS

Interference : Bluetooth
Wanted Signal: WLAN

Interference : LTE
Wanted Signal: WLAN
APPLICATION TESTING WIRELESS COEXISTENCE

Go to webbrowser
Visit localhost CMW website
Start hockey video

CMW500
SMW200A
FSV3000

Microphone
HD Webcam

R&S®AdVISE
Control & Analysis Software

R&S®AdVISE
Inspection Software

hockey_720p30_1
kHz-120s.mp4
Additional Measurements

1. IP connection security analysis
IP CONNECTION SECURITY ANALYSIS
TEST SOLUTION

R&S®CMW500

Ethernet
IP data traffic

RF channel (LTE, WCDMA, WLAN, etc.)
IP data traffic

R&S®CMW-KM052 measurement parameters

- Endpoint geolocation (country)
- Endpoint domain name
- Analysis of encrypted vs. unencrypted traffic
- Strength of encrypted channels
- Certificate detail
- Keyword search in the IP stream
- Device under test IP port analysis
OVERVIEW SCREEN

1: Application

2: Connection group

3: Domain name

4: Geolocation of server - Country

5: Protocol / Indication encrypted or unencrypted channel

6: Data statistics

7: Connection Details

8: Details about SSL/TLS Handshake
IP-BASED GEOLOCATION
MAPPING OF AN IP ADDRESS TO THE REAL-WORLD GEOGRAPHIC LOCATION

Connection Details:
94216.51.104
DE, Munich
Lat: 48.466284
Long: 11.3890101

http://172.22.3.201/user.html
Thank you for your attention 😊

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Find more about wireless coexistence testing on our website www.rohde-schwarz.com