AUT

REDUCE VEHICLE SAFETY FUNCTION DEVELOPMENT TIME WITH RADAR, C-V2X CONNECTIVITY AND SENSOR FUSION TESTS (RADAR TEST FOCUS)

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Sr. Application Engineer, Automotive

ROHDE&SCHWARZ
Make ideas real

OVERVIEW

- Vehicle safety functions overview
- Introduction to Automotive Radar
- R&S Radar Target Simulator (AREG800A) Base unit
- R&S CATR Chamber Test Solution: ATS1500C
- Scenario-based Testing using QAT100 Frontend
- HiL and ViL Test solution
- Radome Testing using the QAR/QAR50/QAR50-R

VEHICLE ARCHITECTURE WITH HIGH PERFORMANCE COMPUTERS

Road side unit
- Cellular V2X
- 4G / 5G
- Wi-Fi

Telematics control unit / Intelligent antenna
- Broadcast TV / radio
- Cellular V2X, 4G / 5G
- eCall
- GNSS
- Wi-Fi, BLE

Further digital services e.g. from TIER1

Digital map server e.g. HERE

OEM Back-end
- Traffic information
- Parking information

Camera Sensor

Corner radar

Body domain controller

Powertrain domain controller

Infotainment domain controller

Vehicle access
- UWB
- RKE

Chassis or ADAS/AD domain controller

Ethernet

Lidar

Gateway

Front radar

Corner radar

Automotive Test Solutions

- Radar
- Connectivity
- Network Quality Analysis
- Infotainment
- Ethernet & Other In-Vehicle Networks
- ECU / DCU Testing
- EMC / Full-Vehicle Antenna Testing

OUR PERCEPTION OF MARKET & TRENDS

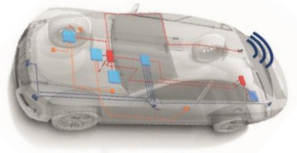
The future mobility is

- The “Software Defined Vehicle” and the “Shift Left” require more integration efforts from OEMs

- The market for battery electric cars is developing faster then expected
  - Inverters generate EMC challenges which are dependent on speed, torque, voltage, power, …
  - Wireless battery management systems are spreading fast

TEST NEEDS IN CONNECTED MOBILITY DEVELOPMENT

- Automotive Test: Multi-step for multi-component functionality



Type of Test	Device(s) Under Test (DUT)
Drive Test	Vehicle
Vehicle Level OTA Test	VIL, EMC
Application Test- ADAS/WC	HIL, 5G, BT, C-V2X, AEB
System Test	HIL, Wireless Tx/Rx +TCU + Brake
Sub-system Test	Sensor + ECU, Wireless Tx/Rx +ECU, HIL
Component Test	ADAS Sensors, Wireless Modules, C-V2X Modules
Chip Test	ICT/FCT for ADAS chip, ECU chip, TCU chip

Drive Test

Lab Test

R&S AUTOMOTIVE TEST SOLUTIONS

Radar	Connectivity	Infotainment	ECU/DCU + In-Vehicle Networks	EMC / Antenna Test
				
Providing target simulation and testing signal quality including interference, ensuring radome and bumper material quality	Testing conformance and performance of UWB, 5G, C-V2X, eCall, GNSS, WLAN, Bluetooth etc.	Testing audio and video including compliance across various broadcast standards	Development of Ethernet and other busses, Domain Controllers (DCUs) and other Electronic Control Units (ECUs) and testing them in production	Providing turnkey solutions, including RF chambers, test receivers, broadband amplifiers, signal generators, turn tables and vehicle lifts.
Supporting chip suppliers, TIER1s, OEMs and certification organizations from R&D to production including hardware-in-the-loop test	Ensuring robust connectivity of the vehicle to consumer electronics, the cloud, network infrastructure and other road users	Efficient testing of all relevant broadcast standards in R&D and production	Offering compliant test solution for in-vehicle networks and connectors, one-box test systems for DCU/ECU R&D and functional test systems for production	Designing and delivering systems to measure antenna characteristics, electromagnetic susceptibility (EMS), immunity (EMI) and coexistence

OUR SOLUTIONS FOR CONNECTIVITY TESTS

eCall/ERA Conformance

EN 16454:2015

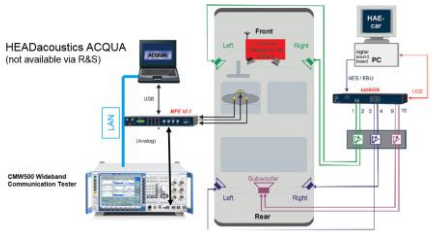
NGeCall Conformance

CEN/TS 17240:2018

GNSS Positioning

EU2017/79 Annex VI , UN-R 144

Audio quality testing



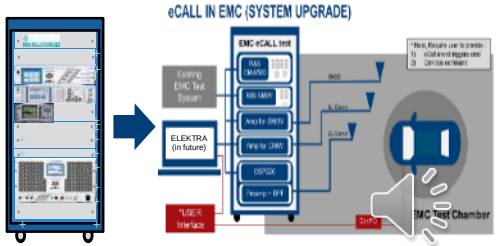
GOST R 55531 / GOST 33468

Scalable

Precise & Repeatable

Performance optimized

EMC testing



(awaiting UN ECE R10 Rev. 7 standard completion expected 2023)

SCALE YOUR C-V2X INVESTMENT FROM LAB TO ROAD

In the Lab

VECTOR
CANoe .Car2x

Radio Communication Tester
R&S® CMW500

Simulated Cars

Device Under Test

TCU/OBU

GNSS Satillites

Vector Signal Generator for GNSS
R&S® SMVB100B

On the Track

VECTOR
CANoe .Car2x

GNSS Satillites

Radio Communication Tester
R&S® CMW500

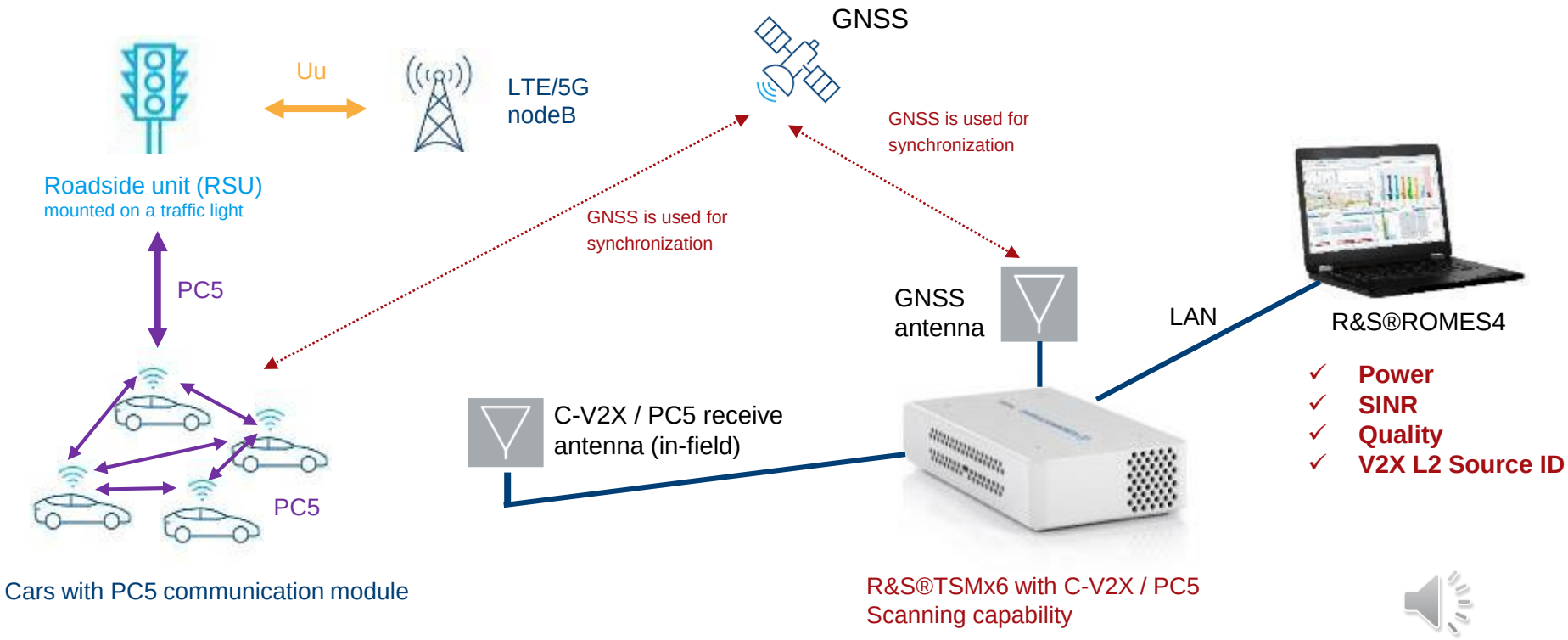
Device Under Test

Simulated Cars

Amplifier
R&S® BBA150-Exxx

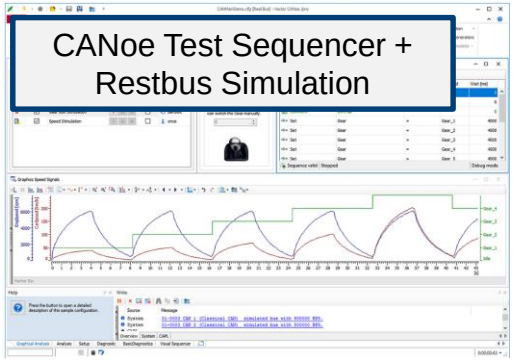
Antenna
R&S® HFxxx Family

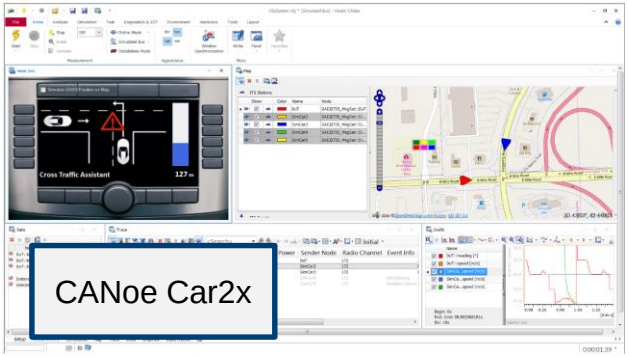
C-V2X / PC5 scanner prototype - measurement scenario

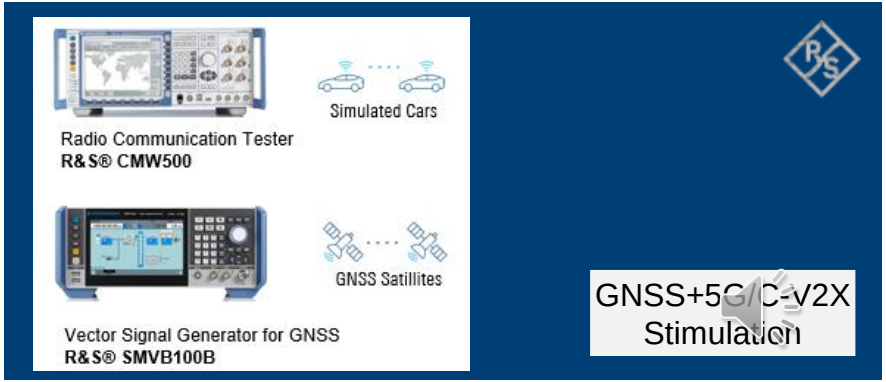


HARDWARE-IN-THE-LOOP – A COOPERATION WITH VECTOR

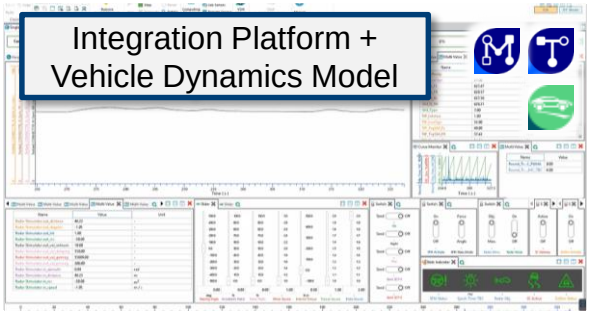
VECTOR

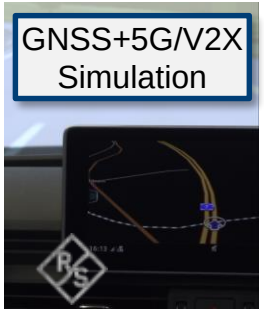


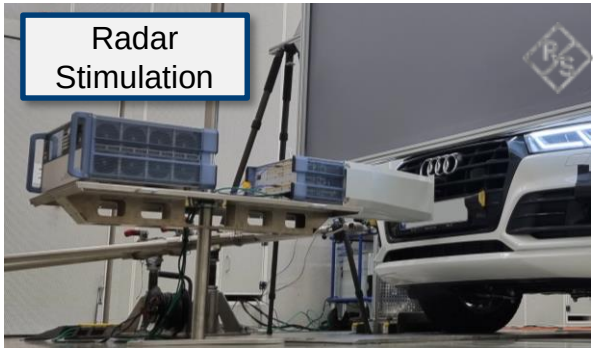




VEHICLE-IN-THE-LOOP ON THE TEST BED – SYSTEM LEVEL TEST FOR ADAS+ECU







AUT

AUTOMOTIVE RADAR TEST

June 2024

NISHANTH ONKARAPPA
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AUTOMOTIVE RADAR TEST

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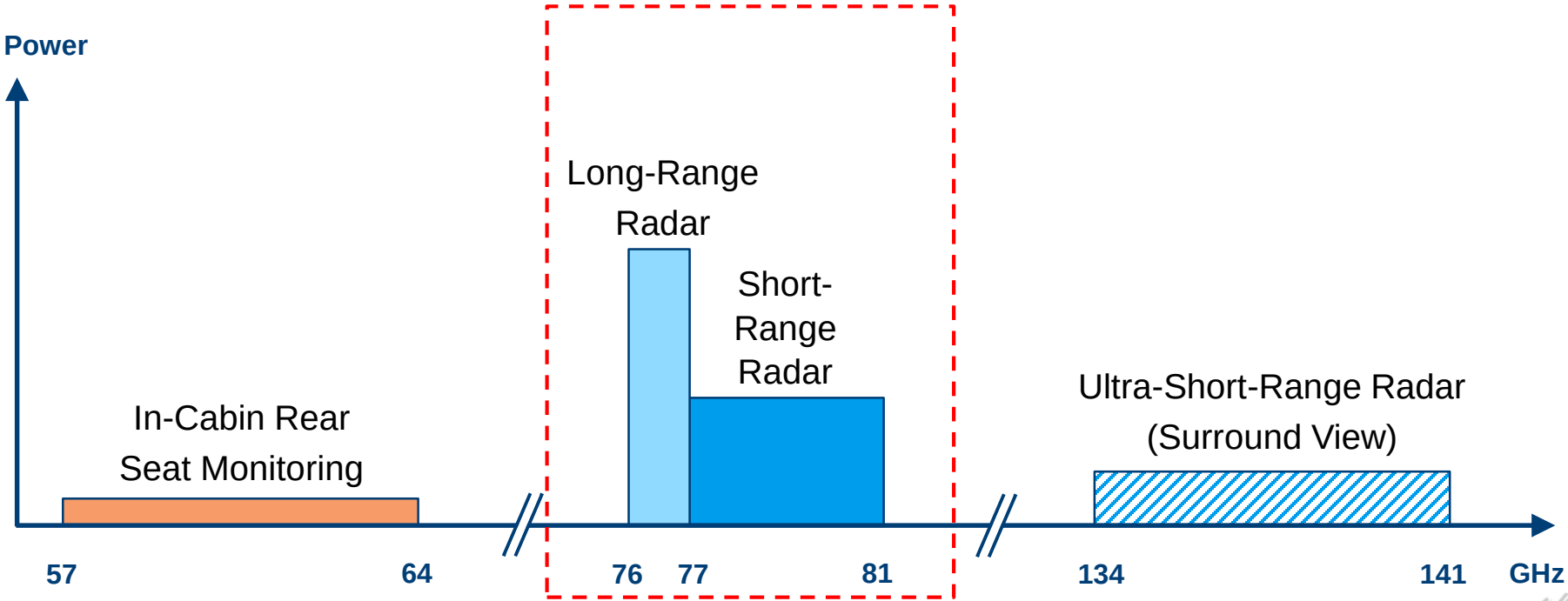
AUTOMOTIVE RADAR FREQUENCY MAP
76-81 GHz GLOBALLY AVAILABLE



RADAR BASED AUTONOMOUS DRIVING

PILAR OF AUTONOMOUS DRIVING

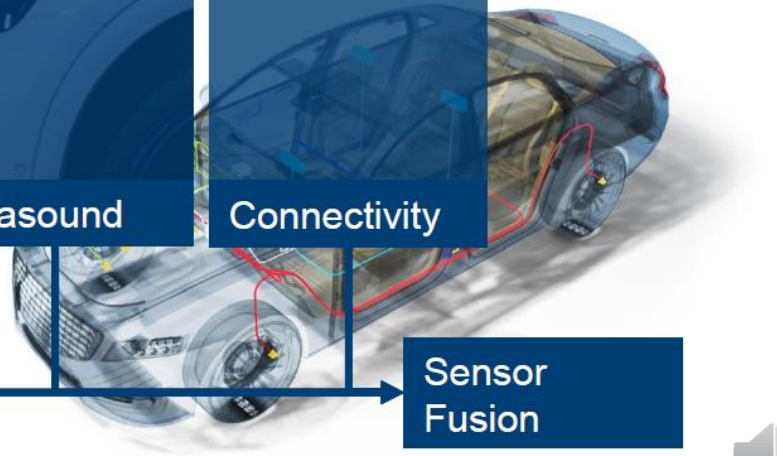
Radar

Camera

Lidar

Ultrasound

Connectivity



Sensor Fusion

RADAR BASED AUTONOMOUS DRIVING

TEST INSTRUMENTS HARMONIZATION ALONG THE WHOLE TESTING LIFECYCLE PROVIDES A HIGHER LEVEL OF TRACEABILITY

Component Development				System Integration			Homologation		Production			Workshop & Periodical Test Inspection	
RF Interference Test	Radar Module Calibration	Radar Module(SW) Functional Test on Target Level	Radar Module System Test on Target Level	ADAS Sub-System Functional Test	ADAS System Functional Test Vehicle Level	Vehicle EMC Test	Module Approval Test (e.g. ETSI, FCC)	Vehicle Homolo-gation (e.g. NCAP)	Radar Module Calibration	Radar Module Functional Test	End-of-Line Vehicle Radar Test	Radar Module Parameter Test	Functional ADAS System Test

R&S®AREG800A & AREG-P

R&S®AREG mmW remote Frontends

R&S®NRP8S(N)

R&S®ATS1500C

R&S®SMW200A

R&S®AREG100A

R&S®QAT100

R&S®FSW85

R&S®AREG100A AREG800A, & AREG-P

- AREG (Automotive Radar Echo Generator) is a Radar Target Simulator used for generation of digital (simulated) targets

- Radar Essential Tester (RADEST): Upcoming RTS from R&S (Stay tuned till the end of PPT for more info!)

R&S®AREG800A AUTOMOTIVE RADAR ECHO GENERATOR

APPLICATIONS AND SOLUTIONS – ALL IN ONE FOR AUTOMOTIVE RADAR TESTING

EOL Production Test and Calibration

R&S®AREG100A or R&S®AREG-P

Research and Development

R&S®AREG800A with various frontends

Hardware-in-the-Loop

R&S®AREG800A and R&S®QAT100

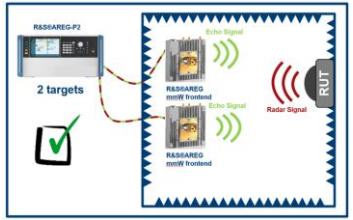
Vehicle-in-the-Loop (together with AVL)

R&S®AREG800A and R&S®QAT100

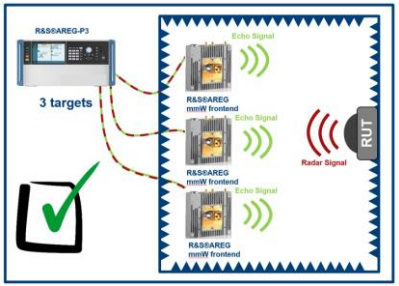
AREG-P FIXED PRODUCT CONFIGURATION PACKAGES FOR AUTOMOTIVE RADAR TIER1 PRODUCTION

Product type - based on the AREG platform	Product configuration - fixed package
AREG-P1	**1xBackend base unit**
	1xDigital board (1 channel with 1 target per channel)
	5 GHz bandwidth in IF (all the BW modes (1 GHz, 2 GHz and 5 GHz) available in the AREG for the channel A1)
	Near object range for FMCW radars (patented and unique feature from R&S. Using this feature, all the generated targets (1) can be generated in the range: air gap radar unde test(minimum distance) - 350m(maximum distance))
	1 x mmW monostatic(suitable for testing MIMO radars)/bistatic frontend (250 MHz, 4 GHz or 5 GHz bandwidth in RF)
	analog IF output interface

Product type - based on AREG platform	Product configuration - fixed package
AREG-P2	**1xBackend base unit**
	2xDigital boards (2 channels with 1 target per channel, so 2 targets in total)
	5 GHz bandwidth in IF (all the BW modes (1 GHz, 2 GHz and 5 GHz) available in the AREG for the channels A1 and B1)
	Near object range for FMCW radars (patented and unique feature from R&S. Using this feature, all the generated targets (2) can be generated in the range: air gap radar unde test(minimum distance) - 350m(maximum distance))
	2 x mmW monostatic(suitable for testing MIMO radars)/bistatic frontend (250 MHz, 4 GHz or 5 GHz bandwidth in RF)
	analog IF output interface

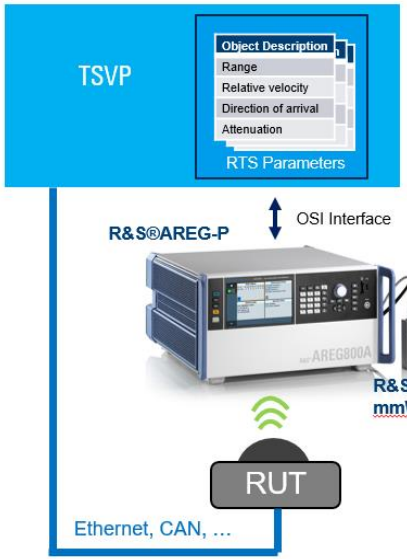


Product type - based on AREG platform	Product configuration - fixed package
AREG-P3	**1xBackend base unit**
	3xDigital boards (3 channels with 1 target per channel, so 3 targets in total)
	5 GHz bandwidth in IF (all the BW modes (1 GHz, 2 GHz and 5 GHz) available in the AREG for the channels A1, B1 and C1)
	Near object range for FMCW radars (patented and unique feature from R&S. Using this feature, all the generated targets (3) can be generated in the range: air gap radar unde test(minimum distance) - 350m(maximum distance))
	3 x mmW monostatic(suitable for testing MIMO radars)/bistatic frontend (250 MHz, 4 GHz or 5 GHz bandwidth in RF)
	analog IF output interface



AREG-P FIXED PRODUCT CONFIGURATION PACKAGES FOR AUTOMOTIVE RADAR TIER1 PRODUCTION

Parameters	AREG-P1/-P2/-P3 for Production
Range	Air gap – 350m
Range step size	1cm
Range accuracy	±5cm
Doppler range	±500km/h
Doppler step size	0.05km/h
Doppler accuracy	≤0.05km/h
RCS range	90dB
RCS step size	0.1dB
RCS accuracy	±2dB IF attenuation accuracy



R&S®AREG800A - UNIQUE FEATURES

Generation of dynamic objects

Extremely short object distances

Multiple independent objects

Synchronization of multiple QATs and AREG800As

High instantaneous bandwidth

Built-in real time interface

Fully harmonized with frontend

Scalable solution

R&S®AREG800A AUTOMOTIVE RADAR ECHO GENERATOR

FULLY HARMONIZED WITH THE FRONTENDS

1)

AREG mmW Frontends

R&S®AREG8-24S/D

R&S®AREG8-81S/D

IF Interface

Ctrl. Interface

R&S®AREG800A

HIL Interface

2)

R&S®QAT100

R&S®QAT100 MIMO

R&S®QAT100 SIMO

IF Interface

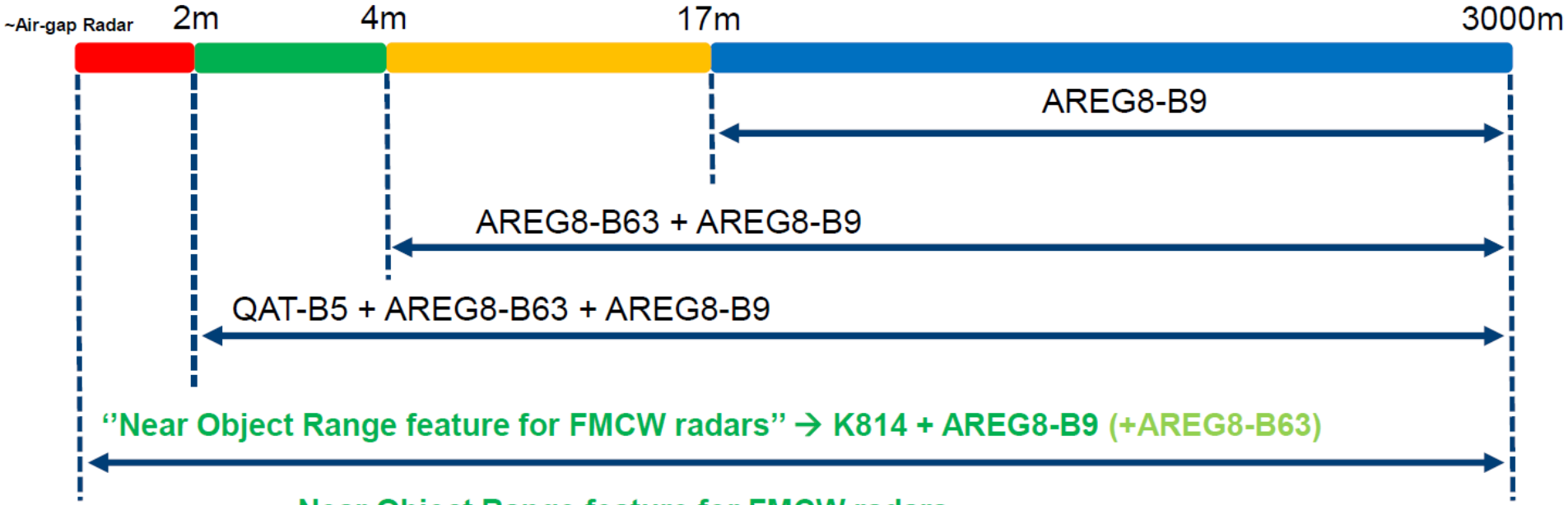
RTC Interface

R&S®AREG800A

HIL Interface

AREG800A- NEW FEATURE

DIGITAL SIMULATION OF RANGE AS CLOSE AS 0.50m

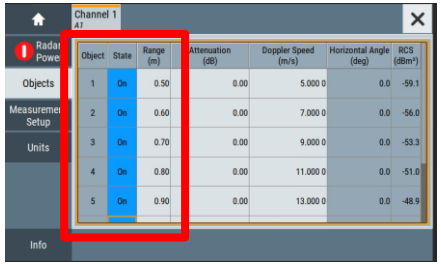


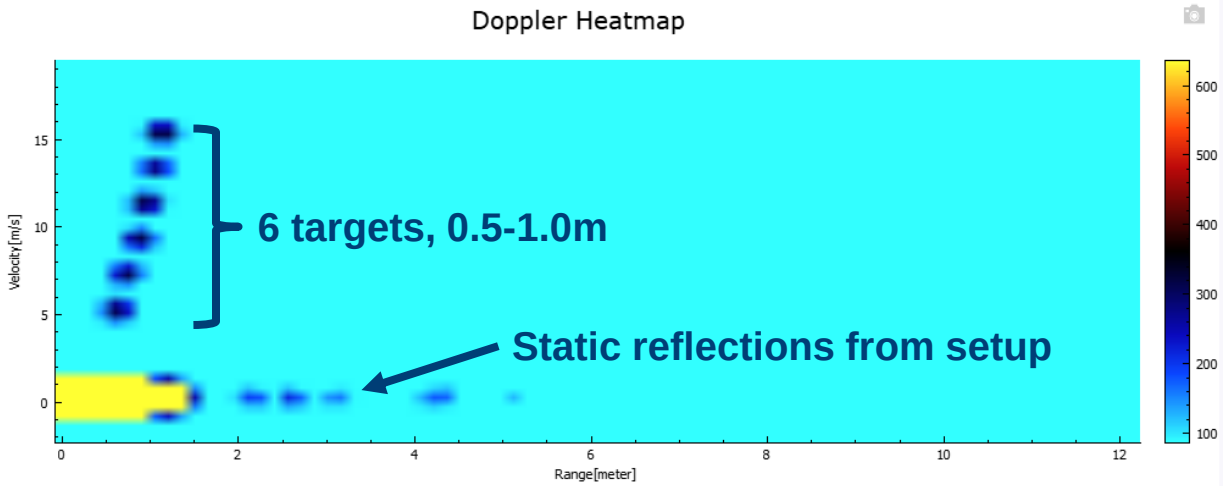
- Near Object Range feature for FMCW radars
- K814 can be used for the combinations:
  AREG800A + mmW frontends and AREG800A + QAT100

R&S®AREG800A ALLOWS EXTREMELY CLOSE OBJECT DISTANCE FOR FMCW RADARS

FULLY DIGITAL IMPLEMENTATION. HYBRID OBJECT GENERATION IS STILL POSSIBLE

- Up to 8 targets per channel
- Minimum distance >= air gap value of the radar under test
- Example below with a Tier 2 DUT





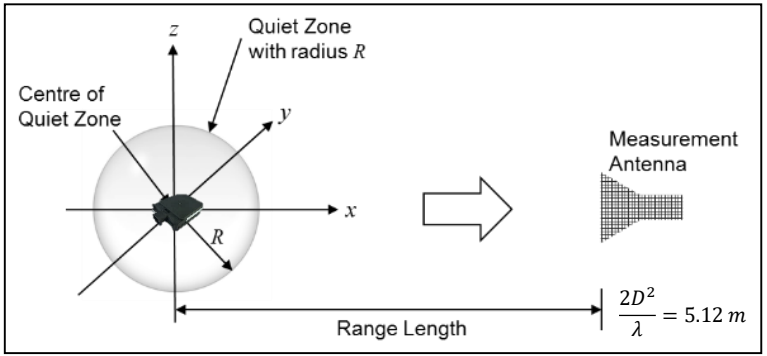
CATR CHAMBER (R&S ATS1500C)

- Compact Antenna Test Range (indirect far-field) chamber

CATR REFLECTOR TRANSFORMS SPHERICAL FIELD TO PLANAR WAVES, REDUCING TEST DISTANCE

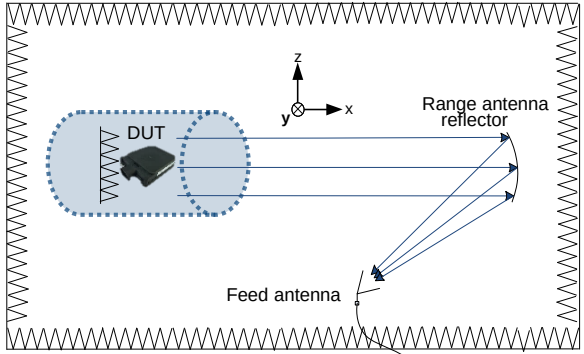
Direct Far Field (DFF)

Quiet zone typically **smaller,** require **bigger** test distance



Indirect Far Field (IFF)

Quiet zone typically **bigger,** require **smaller** test distance



Indirect Far Field (IFF) ➔ Compact antenna test range (CATR):

- Path loss ~ 0 between reflector ⇔ DUT
- QZ diameter = 25…50% of reflector (strongly depends on edge treatment !), cylindrical shape
- CATR reflector is a bi-directional device

R&S®ATS1500C CATR BASED AUTOMOTIVE RADAR CHAMBER INTERIOR

State-of-the-art CATR Reflector

- Gold Plated
- Ø 30cm quiet zone
- < 1μm RMS surface roughness

High precision 3D tilt-tilt Positioner

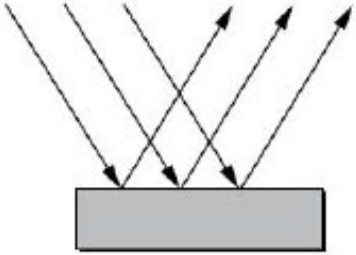
- Azimuth: +/-180º
- 0.03º Angular resolution
- 120º/s Max rotation speed

Elevation: +/- 45º
0.02º Std. Deviation

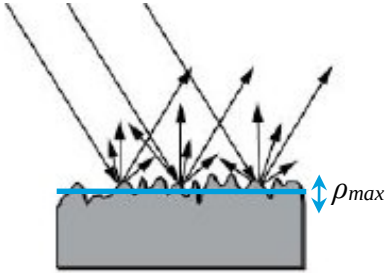
AREG Frontend as Feed Antenna

- Supports 77/79 GHz automotive radars
- Supports a full 5GHz bandwidth

CATR REFLECTOR ERROR: SURFACE ROUGHNESS



Ideal

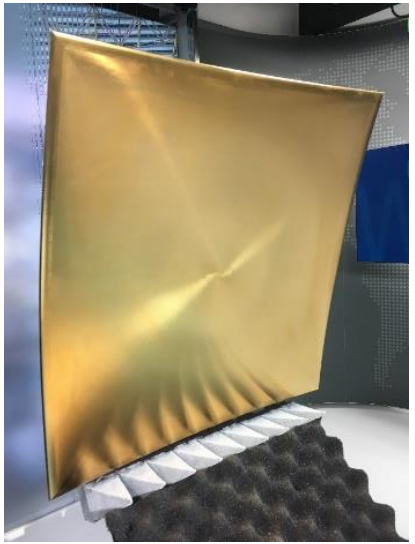


Actual

Maximum Surface Deviation

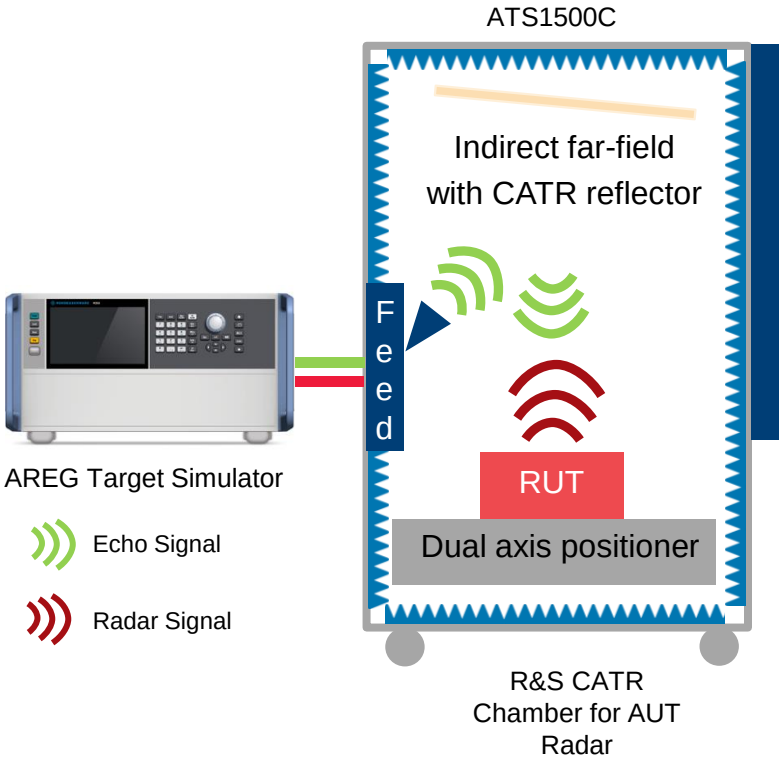
$\rho_{max} = 0.007\,\lambda$

Maximum Frequency	Surface Deviation (µm)
28 GHz	75
43 GHz	**49**
77 GHz (λ = 3.9 mm)	27



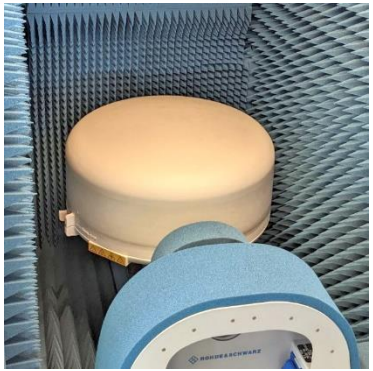
The R&S® reflector has a 1µm RMS surface accuracy

RADAR COMPLIANCE TESTING USING THE ATS1500C AND AREG800A



CLIMATE OPTION ARC-TEMP

- Covering full automotive radar module temperature range -40 to 85°C
- Retrofittable on existing ATS1500C positioner: Rotation restricted to ±90° for outer and ±15° for inner axes with ARC-TEMP installed
- DUT sizes up to Ø 150 x 170 mm and Ø 375 x 135 mm including fixture
- DUT weight up to 4 kg centered including fixture
- Thermal airstream system has to be separately sourced (e.g. MPI ThermalAir TA-5000A)
- ARC-TEMP enables fully automated radar module characterization and significantly reduces test time compared to separate climate cabinet



SCENARIO BASED TESTING USING THE AREG800A WITH QAT100

R&S®QAT100 UNIQUE FEATURES

No mechanical movement

Immune to vibration

96 TX antennas per frontend

4GHz instantaneous bandwidth

Extremely short distances

Scalable solution

Azimuth and elevation simulation

Precise and repeatable

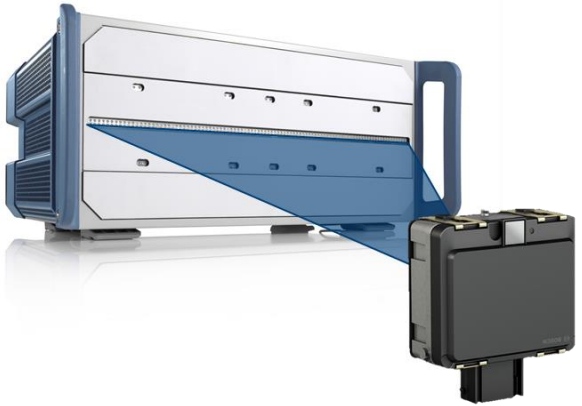
Clean RF - no reflections from FE

R&S®QAT100 – B11 AND B21 FRONTENDS

R&S®QAT100 with QAT-B11 (SIMO) frontend

$$\Delta\alpha = \tan^{-1}\left(\frac{3{,}7mm}{d}\right)$$

$$\alpha = 2 \cdot \tan^{-1}\left(\frac{351mm}{2 \cdot d}\right)$$

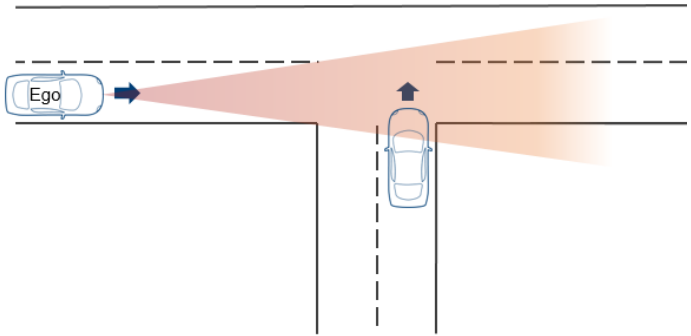


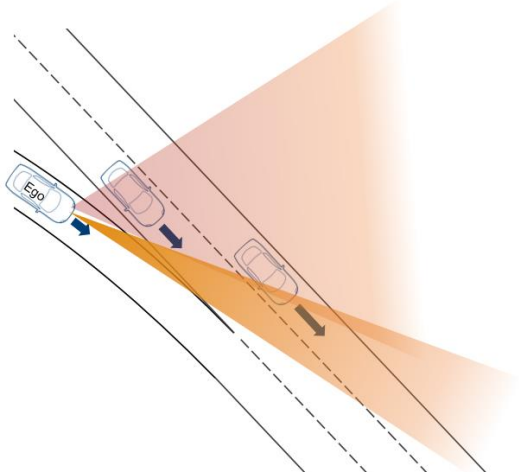
R&S®QAT100 with QAT-B21 (MIMO) frontend

Distance (d)	Field-of-view (α)	resolution ($\Delta\alpha$)
500 mm	38,7°	0,42°
700 mm	28,1°	0,30°
1000 mm	19,9°	0,21°
1500 mm	13,34°	0,14°
2100 mm	10,0°	0,10°

EXEMPLARY DRIVING SCENARIOS

ADVANCED INSTRUMENT CONFIGURATIONS



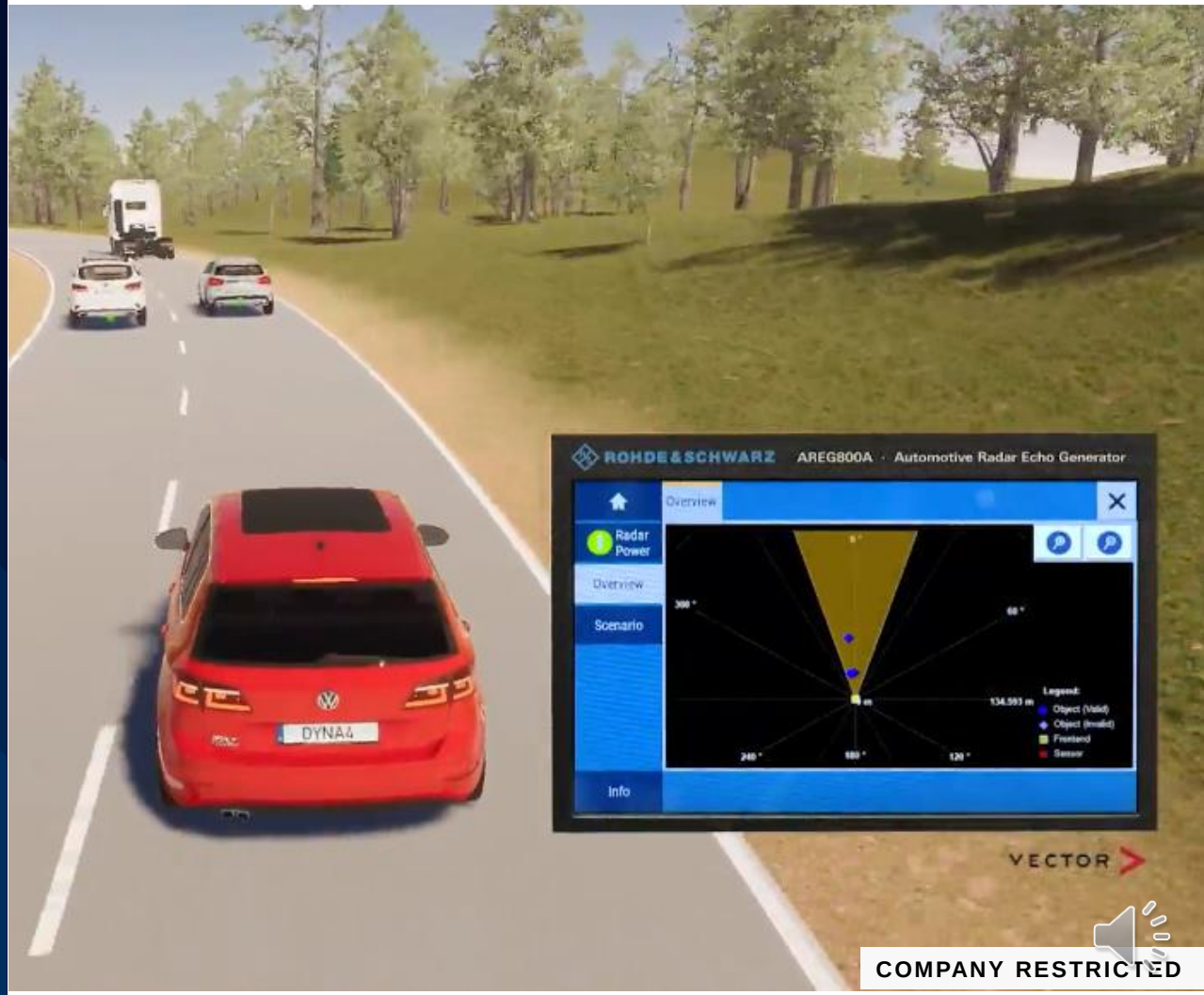


Enables advanced NCAP, AEB, ACC and other scenarios

- Simulation of targets moving in azimuth, range, radial velocity and target size.
- Simultaneous stimulation of multiple radar sensors.

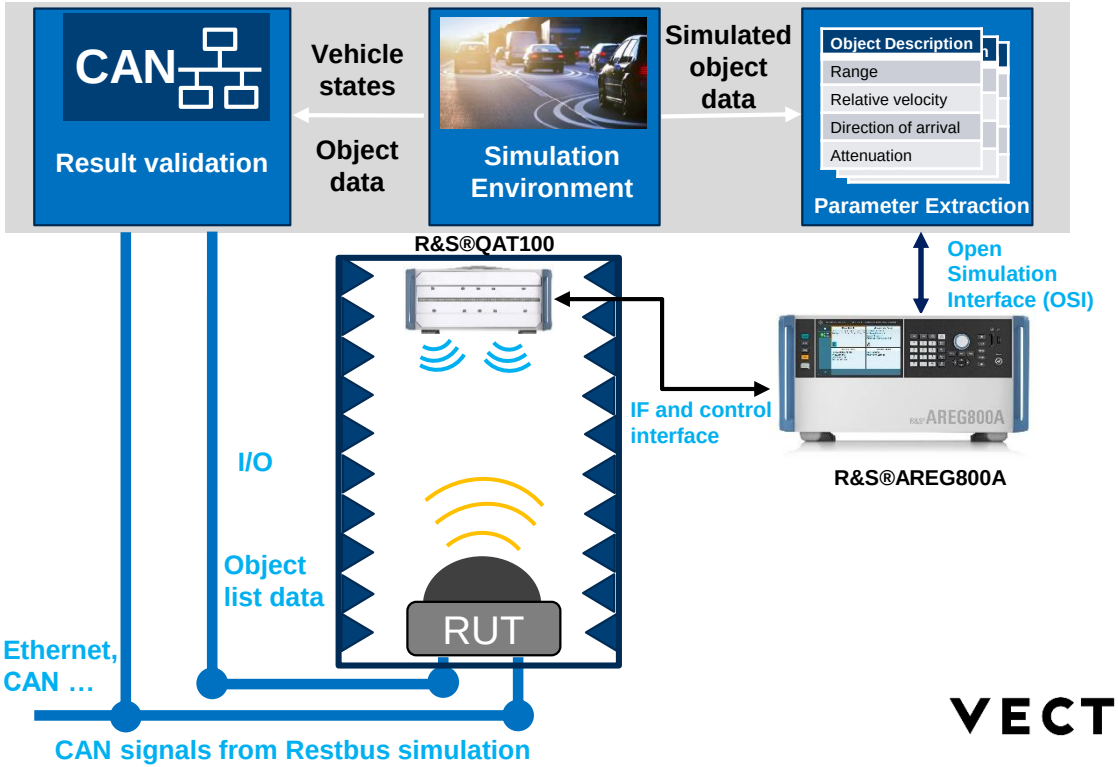
HARDWARE-IN-THE-LOOP (HiL)

VEHICLE-IN-THE-LOOP (ViL)



HARDWARE-IN-THE-LOOP

PARTNERSHIP WITH VECTOR DYNA4 AND IPG CARMAKER.



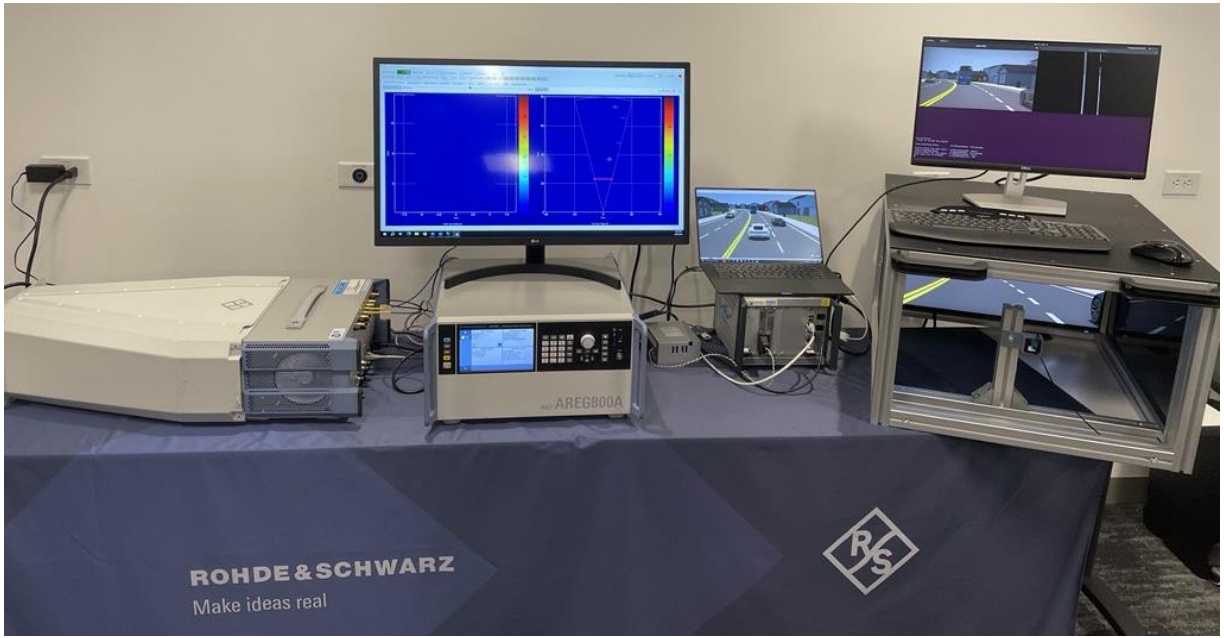
Closed-loop radar module validation using realistic road scenarios or artificial test cases

Open Simulation Interface (OSI) ensures future-proof and smooth software integration

Vector CANoe for rest-bus simulation via CAN or Ethernet connectivity in real-time

RADAR & CAMERA HiL (SENSOR FUSION TEST)

IN PARTNERSHIP WITH IPG AUTOMOTIVE



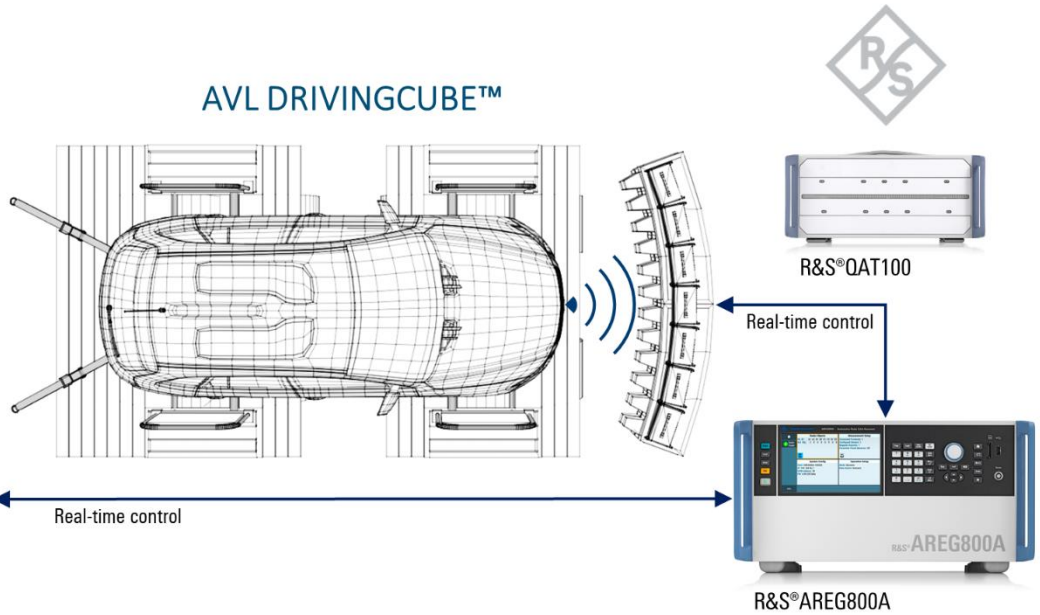
Add a Network Emulator (eg: R&S CMX500 OBT) to test Connectivity-in-the-loop (4G & 5G) along with radar & camera sensor fusion test (XiL test)

VEHICLE-IN-THE-LOOP TESTING BRINGS THE ROAD INTO THE LAB – PARTNERSHIP WITH AVL

Scalable solution

No mechanical movement

Multiple independent objects



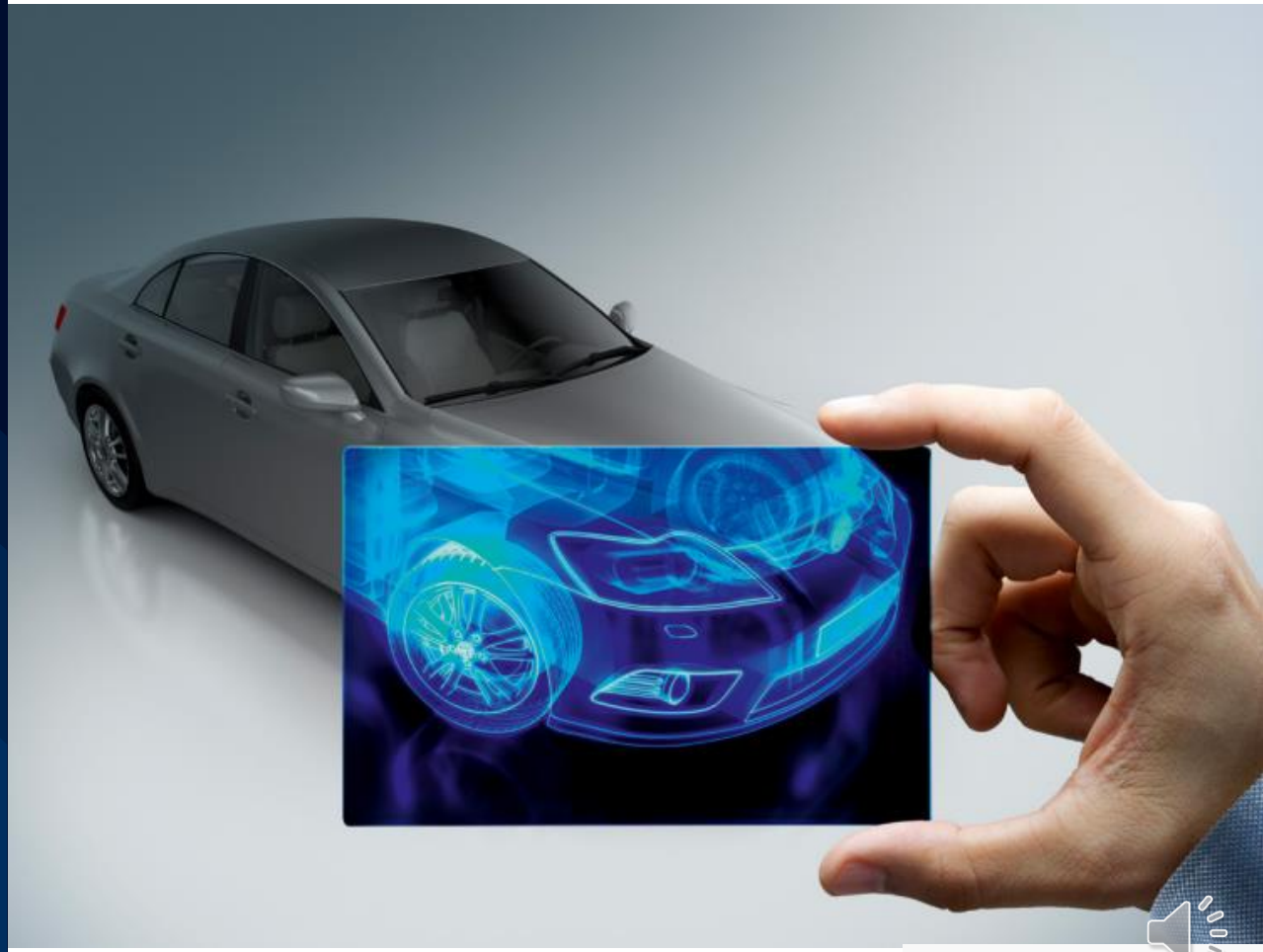
Seamless integration

Precise and repeatable

Performance optimized

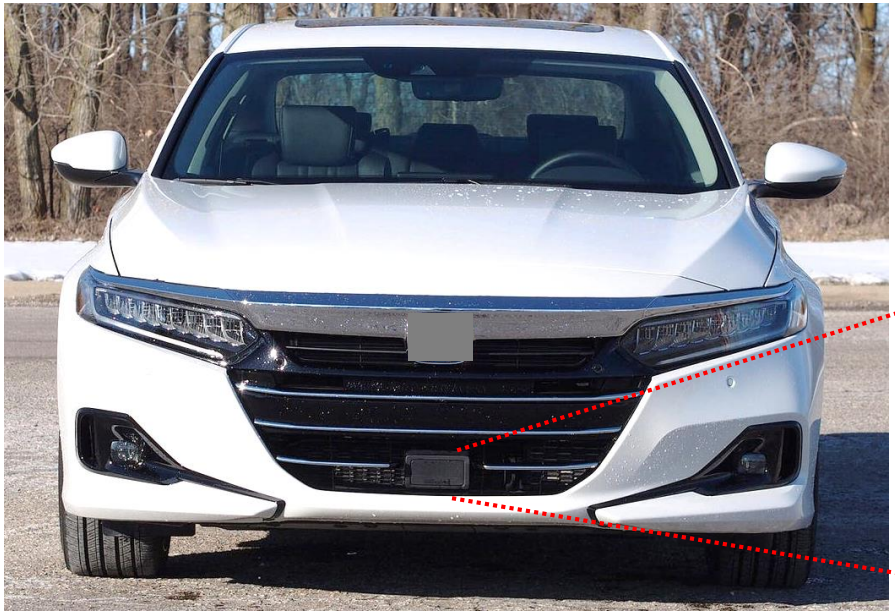
VEHICLE-IN-THE-LOOP DEMONSTRATION

RADOME TESTING USING R&S QAR50



RADOME, BUMPER AND EMBLEM

Bumper



Car with front radar

Automotive radar without cover

Automotive radar with Radome cover

Emblem

Source: Google images

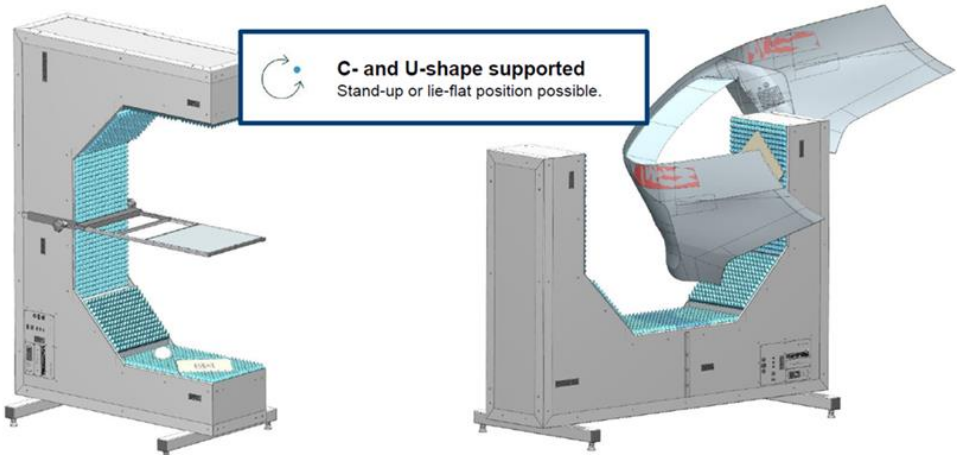
MICROWAVE IMAGING SOLUTION FOR TESTING RADOME, BUMPER OR RADAR MOUNTING ACCURACY

What?	Design Emblem	Bumper	Cover / Sheet
	✓ **Homogeneity**	✓ **Transmission**	✓ **Epsilon R**
	✓ Transmission	✓ Reflection	✓ S-Parameters
	✓ Reflection	✓ Homogeneity	

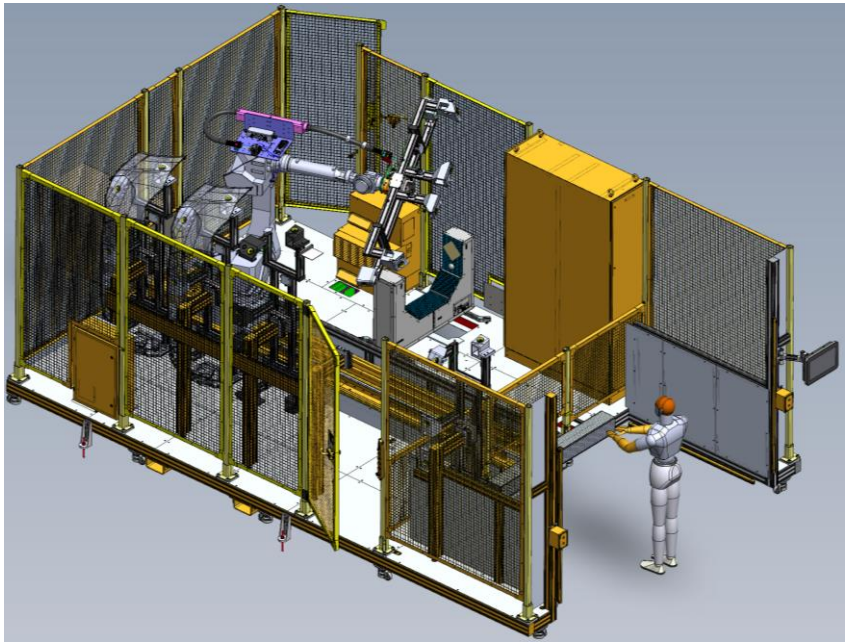
R&S®QAR50

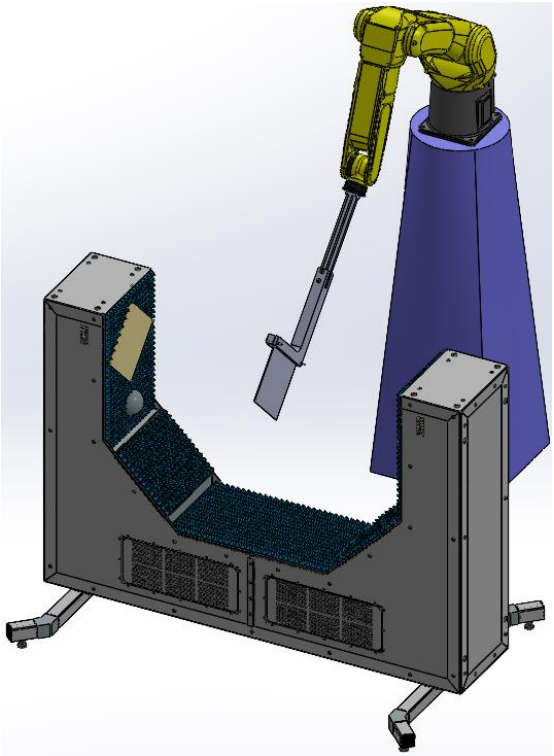
QAR50 SETUP AND GUI

- Has two mm-wave clusters (antenna array) on either ends.
- Distance between the clusters is 1m and the DUT/Sample is placed right in between the antenna arrays.
- Clusters can be of two polarization- vertical or horizontal
- Can measure the following parameters using the QAR50:
  - Transmission
  - Reflection
  - Phase



BUMPER MATERIAL TEST AS A SERVICE





RADAR ESSENTIAL TESTER (RADEST)
FEATURES AND ADVANTAGES

Test radar distance and angular accuracy; also suitable for MIMO sensors

Simulate reflections from different types of road users

Optionally extendable for longer distances & velocity

Future proof due to 5 GHz instantaneous bandwidth

Verify radar signal level

Compact size, intuitive to use for workshop employees

Compatible with multiple models and makers

Battery powered device for maximum flexibility

Temperature and dust proof results

Outstanding value for money proportion

SUMMARY

- Vehicle safety functions require system level test.
- Radar sensor is a key component of safety functions.
- R&S Radar Target Simulator (AREG800A) Base unit for radar functional test.
- R&S CATR Chamber Test Solution: ATS1500C for radar calibration.
- Scenario-based Testing using QAT100 Frontend for controlled functional test.
- HiL and ViL Test solution for sub-system and system level tests.
- Radar “transparency” test with the QAR/QAR50/QAR50-R

AUT Radar

Q&A

THANK YOU!