ENABLING THE NEXT LEVEL OF AUTONOMOUS DRIVING WITH ADVANCED OBJECT GENERATION

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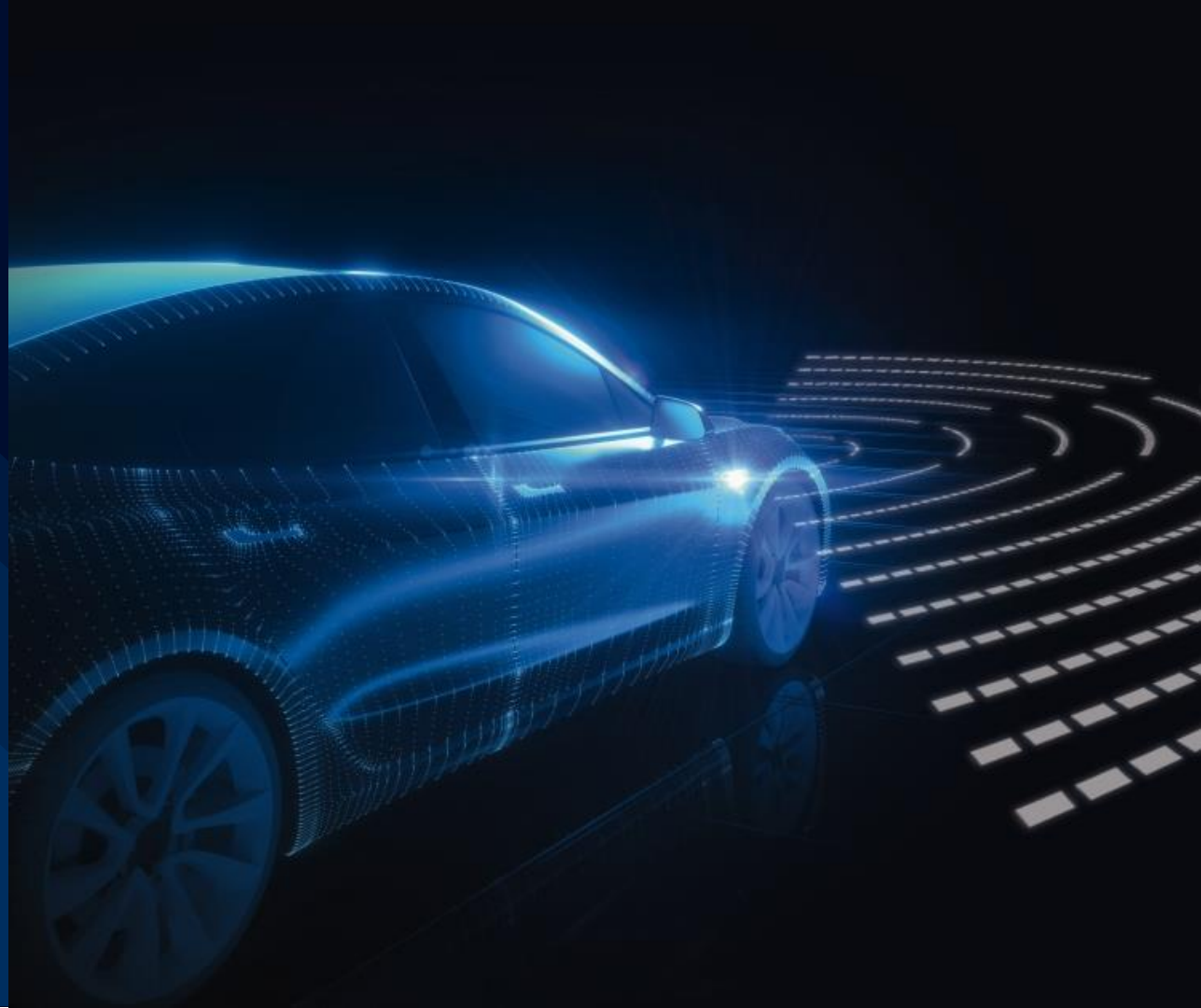
ROHDE&SCHWARZ
Make ideas real

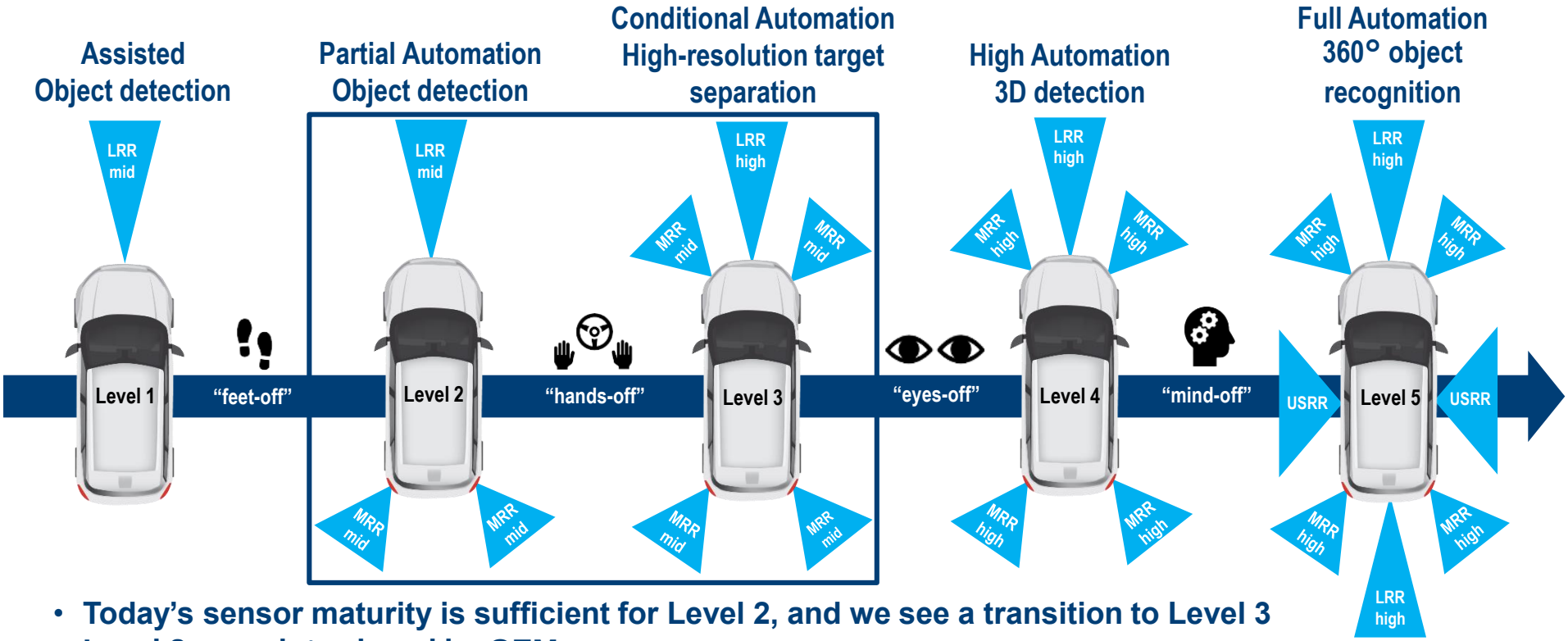
AGENDA

- **Automotive radar technology and market update**
- QAT100 Electronically steerable antenna array
- AREG800A advanced automotive radar echo generator
- Applications and solutions
- Automotive radar testing product portfolio
- Summary and learnings



RADAR BASED AUTONOMOUS DRIVING

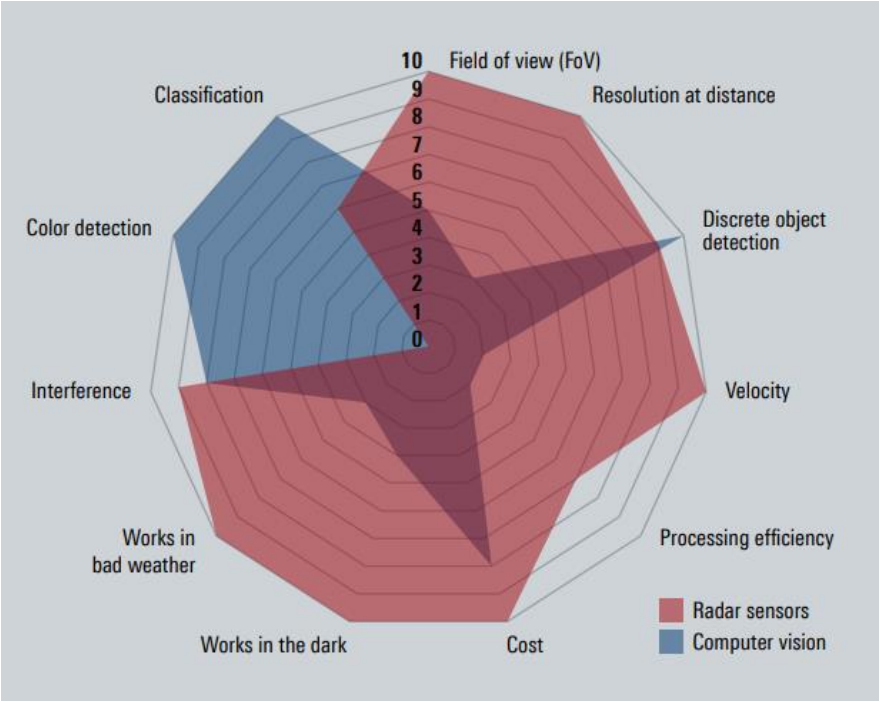
AUTOMOTIVE RADAR EVOLUTION



- **Today's sensor maturity is sufficient for Level 2, and we see a transition to Level 3**
- **Level 2+ was introduced by OEMs**

RADAR BEING PART OF SENSOR FUSION

PILLAR OF AUTONOMOUS DRIVING



Strengths of Radar Sensors versus other ADAS Sensors

- Instantaneous measurement of distance, vertical angle, horizontal angle and velocity (4D)
- Works in the dark and with adverse conditions such as smoke, fog and dust
- Combines well with camera in redundant systems due to different operating frequencies
- Cost efficient due to high volume and market penetration
- Radar still has strong innovation potential towards imaging radar

RADAR TECHNOLOGY TRENDS

TYPICAL SENSOR PARAMETERS

Radar Module Parameters	Short-Range Radar	Standard Mid-Range Radar	Premium Mid-Range Radar	Standard Long-Range Radar	Premium Long-Range Radar	Imaging Radar
Frequency Range [GHz]	24,76-77,77-81	76-77	77-81	76-77	76-77	76-81
Typical Bandwidth [MHz]	200, 1000, 4000	1000	2000	500	1000	2000
Range [m]	80	150	150	250	300	300
Range Resolution [cm]	300, 30, 3.5	30	7.5	75	30	60, 9.5
FOV Azimuth / Elevation [°]	±60 / ±0	±30 / ±0	±50 / ±15	±15 / ±5	±15 / ±10	±50 / ±15
Typical Channel Number [Transmit / Receive]	3 TX / 4 RX	4 TX / 8 RX	8 TX / 12 RX	4 TX / 8 RX	12 TX / 16 RX	48 TX / 48 RX

(Data sheet values of commercially available sensors from various suppliers)

RADAR TECHNOLOGY TRENDS

Technology Trends

- 5/6th generation radar sensors dominate the market
- Single Chip CMOS with 5 GHz bandwidth and more complex modulation
- High priority on interference mitigation
- Radar antenna aperture is increasing
- Very short distance object simulation required during radar sensor R&D and validation
- Need for complex moving object scenarios to be emulated in a lab environment is increasing
- OEMs want an improved test coverage:
  - Scenario validation (HIL, VIL)
  - Electromagnetic susceptibility testing
- AI will improve object detection and tracking capabilities

Business Trends

- Highly dynamic radar chip supply chain
  - Large TIER1s develop own chips
  - New Asian suppliers for mainstream ICs
- Imaging radar takes off, and 30% market share is expected in 2027
- Radar sensor market is growing with 13%.
- Many new players in the radar supply chain

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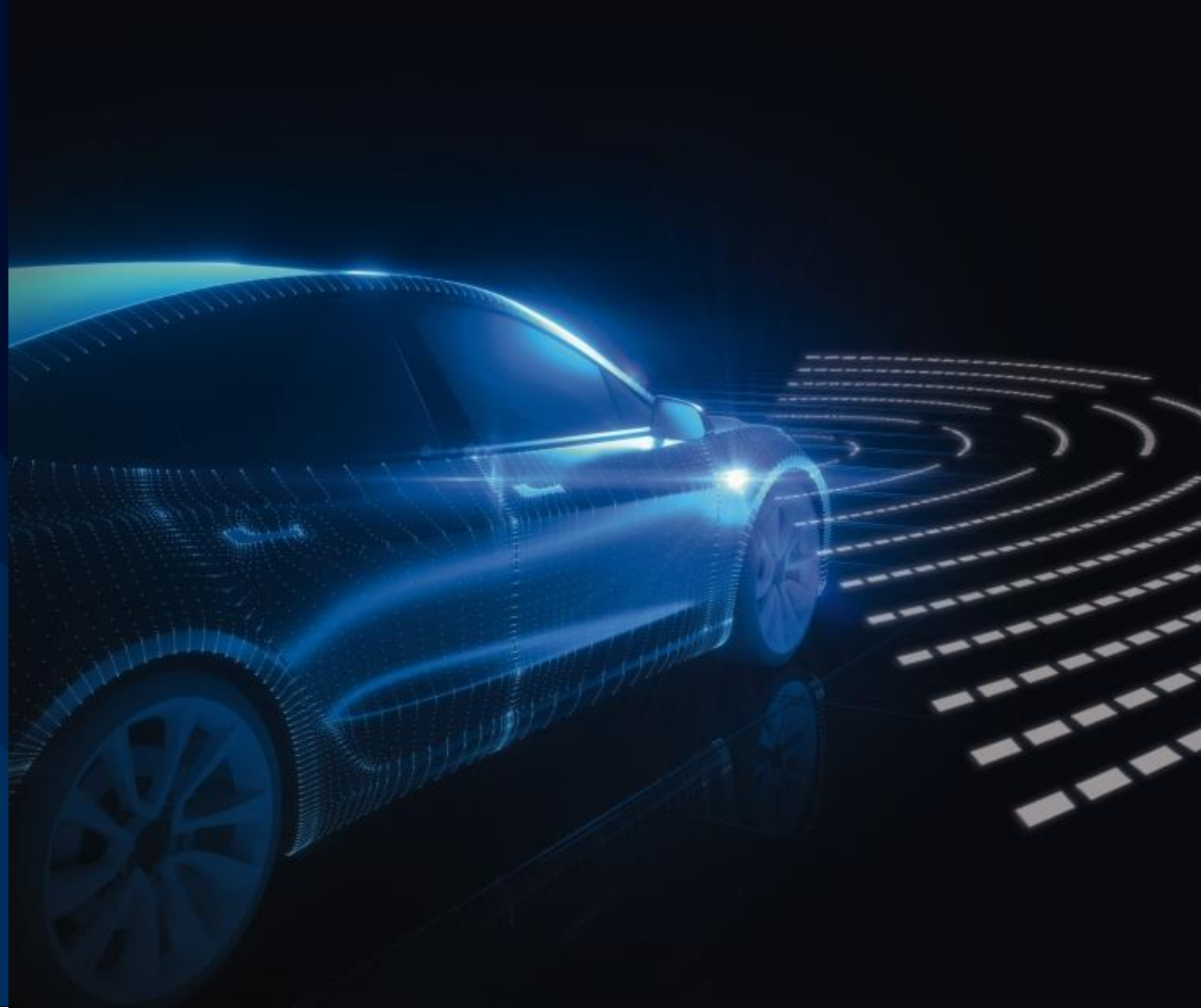


ADVANTAGES

R&S®QAT100 VS. MECHANICAL APPROACH

No mechanical movement

OTA radar stimulation with azimuth simulation without needing to physically move antennas:

- **Less wear and tear**
- **Better RF performance**
- **No mechanical handovers required**

Immune to vibration

Perfectly fitted for ViL testbed mounting:

- **Reduced amount of RF connections**
- **Reliable due to vibration robust design**

Precise and repeatable

96 TX antennas guarantee a precise and repeatable azimuth simulation without the need of physical movement:

- **High precision**
- **Great repeatability**
- **High resolution**

Scalable solution

Several Frontends can be stacked to simulate up to 360° of radar environment.

- **Highly flexible and ready for expansion**
- **Radar FOV of several sensors can be simulated by one or multiple frontends**

Clean RF - no reflections from FE

The PCB antennas have a much lower RCS as the standard gain horns used in other systems. Together with the QAT-B50 shielding system, a shielded RF environment can be guaranteed

- **Reliable operation**
- **Reduced influence of other T&M equipment**
- **No testbed mode required for the radar**

R&S®QAT100
FRONTEND VERSIONS

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

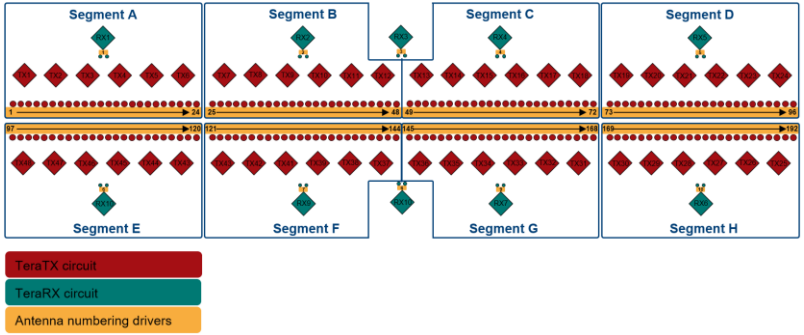
- 96 transmit & 5 receive antennas
- Optional second independent TRX line
- Simulation of up to 8 echoes from different directions

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

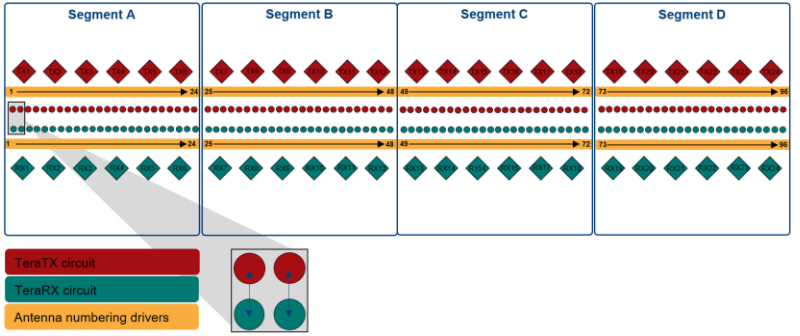
- 96 transmit / receive antenna pairs
- Optimized for MIMO technology
- Simulation of up to 4 echoes from different directions

R&S®QAT100
FRONTEND VERSIONS

R&S®QAT100
QAT-B11 / -B2 ANTENNA NUMBERING



R&S®QAT100
QAT-B21 ANTENNA NUMBERING



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

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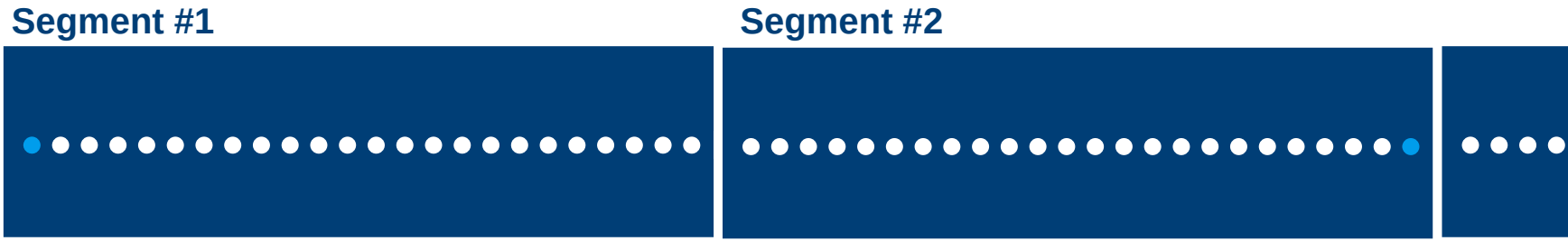
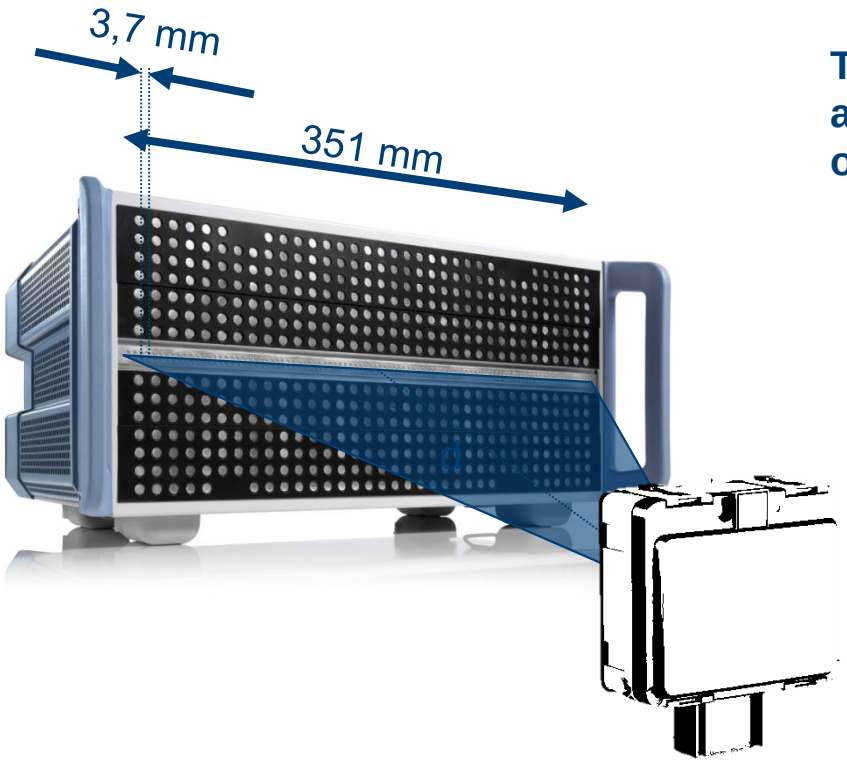
R&S®QAT100 WITH QAT-B21



- **Segment mode still available**
- **Intersecting targets only at certain positions**

FIELD-OF-VIEW & ANGULAR RESOLUTION



The field-of-view (FOV) and angular resolution achievable with the R&S®QAT100 are dependent on the setup but can be calculated as follows:

Field-of-view:

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

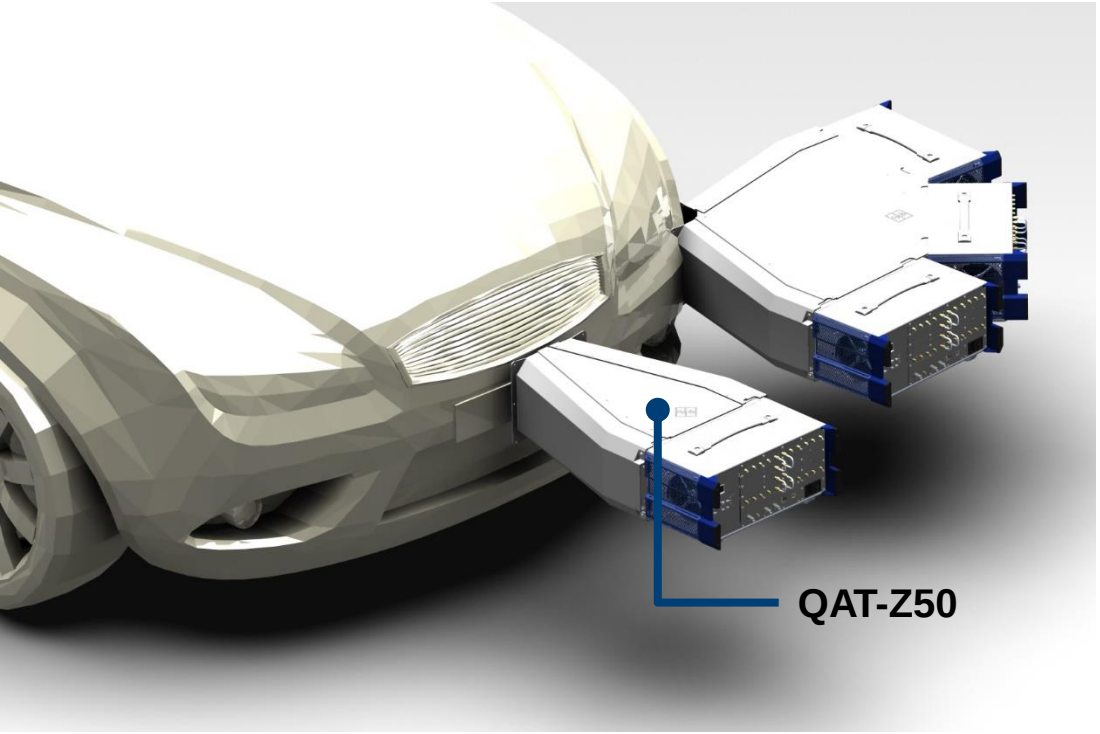
Angular resolution:

$$\Delta\alpha = \tan^{-1}\left(\frac{3.7mm}{d}\right)$$

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°

R&S®QAT100 ADVANCED ANTENNA ARRAY

QAT-Z50 SHIELDING SYSTEM



- **QAT-Z50 shielding system**
  - 50 cm long, 10° opening
  - Direct mounting kit for QAT
- **Challenges**
  - Car mounting kit respectively QAT stand in front of car
  - Customization based on e.g. CAD required

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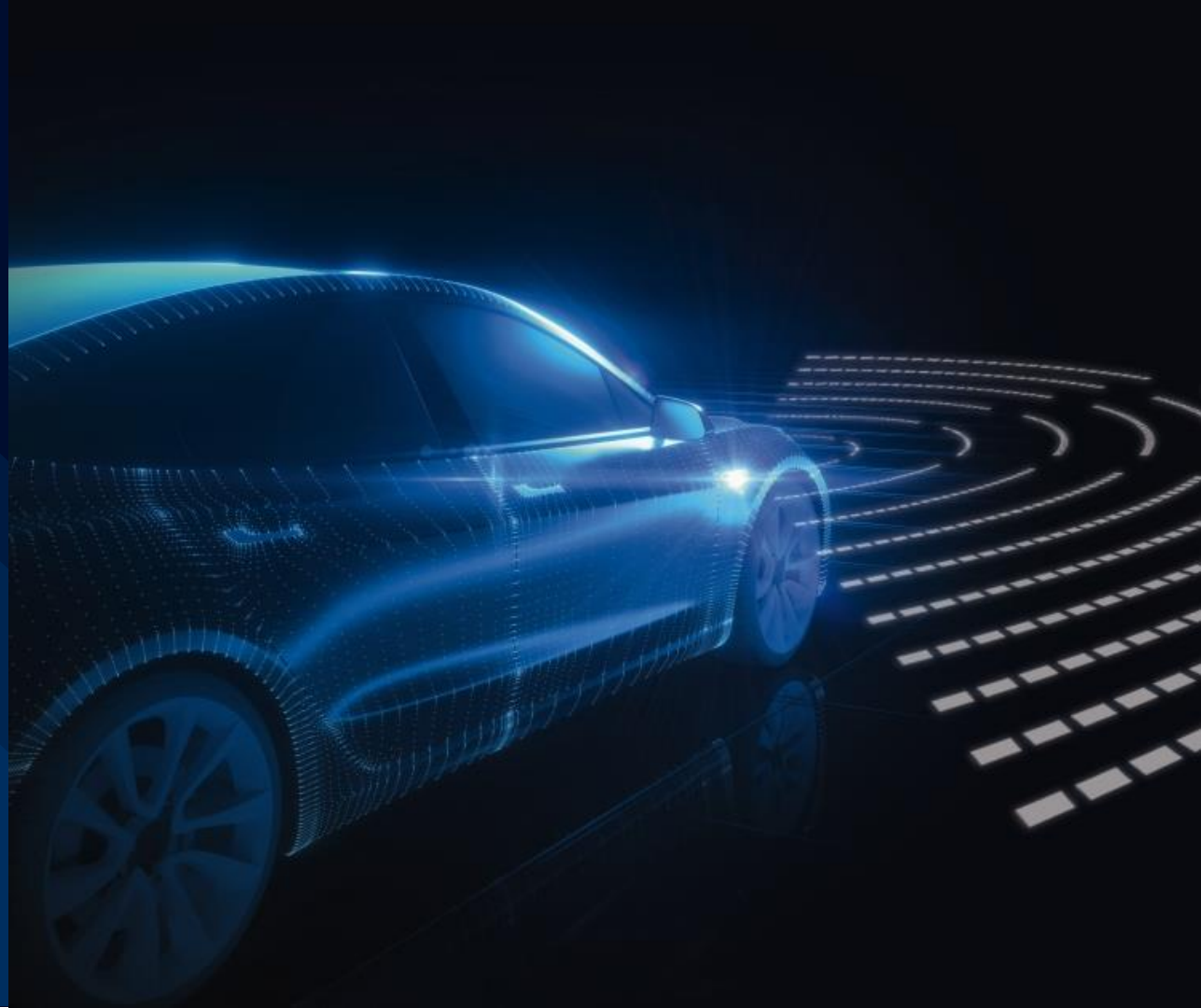


R&S®AREG800A AUTOMOTIVE RADAR ECHO GENERATOR

MODERN TEST SETUP CORE ELEMENT. R&S®AREG800A UNIQUE FEATURES FOR THE BACKEND

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

Standardized OSI (Open Simulation Interface) HIL Interface

Fully harmonized with frontend

Scalable solution

R&S®AREG8-81S/D MMW FRONTEND

UNIQUE FEATURES FOR THE AREG FRONTEND

Multiple objects with the same direction and independent RCS, range and doppler

Suitable for MIMO Radars
Common RX/TX antenna and integrated circulator

SNR performance
RCS accuracy

High instantaneous bandwidth

Short artificial object distances

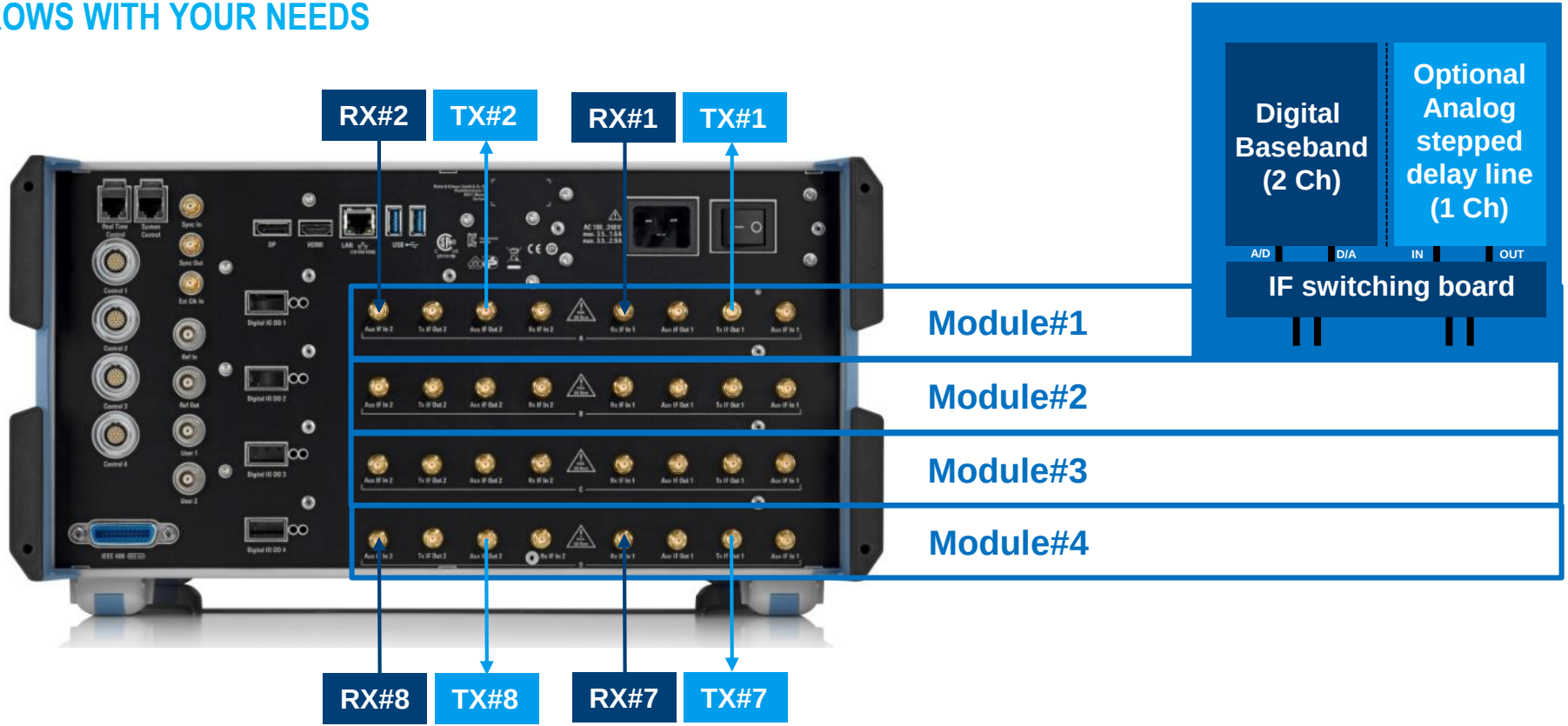
Scalable solution

Precise and repeatable

Suitable for EMC environments

R&S®AREG800A SCALABILITY, FLEXIBILITY AND MODULARITY

GROWS WITH YOUR NEEDS

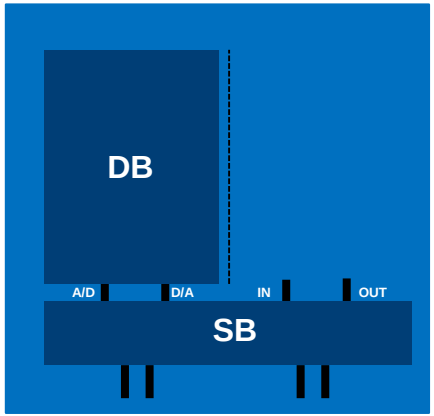


R&S®AREG800A SCALABILITY, FLEXIBILITY AND MODULARITY

MODULAR CONCEPT

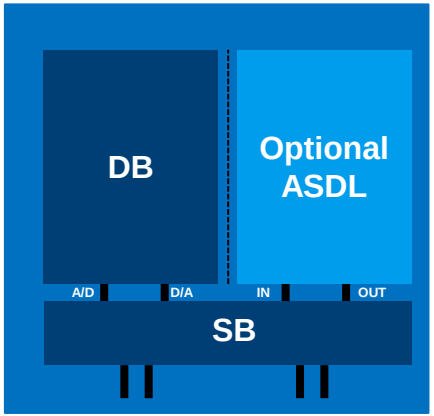
- The Digital Board (DB), the IF Switching Board (SB) and the optional Analog Stepped Delay Line Board (ASDL) are forming the smallest backend module
- A module has one (for 5GHz bandwidth) or two (for 2GHz bandwidth) IF paths, each with individual A/D and D/A conversion

Digital Concept

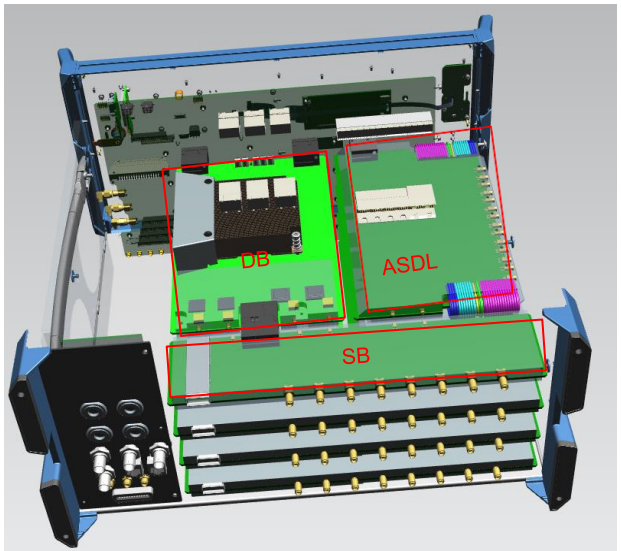


Range: <17 m to 3000 m

Hybrid Concept: Digital + Analog



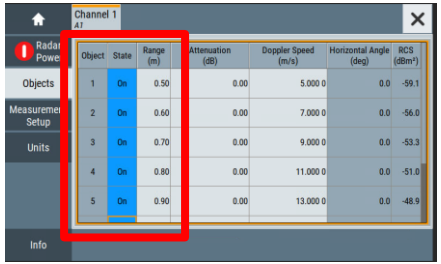
Range: <4 m to 3000 m

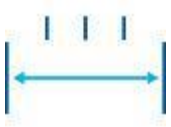


R&S®AREG800A ALLOWS EXTREMELY CLOSE OBJECT DISTANCE FOR FMCW RADARS

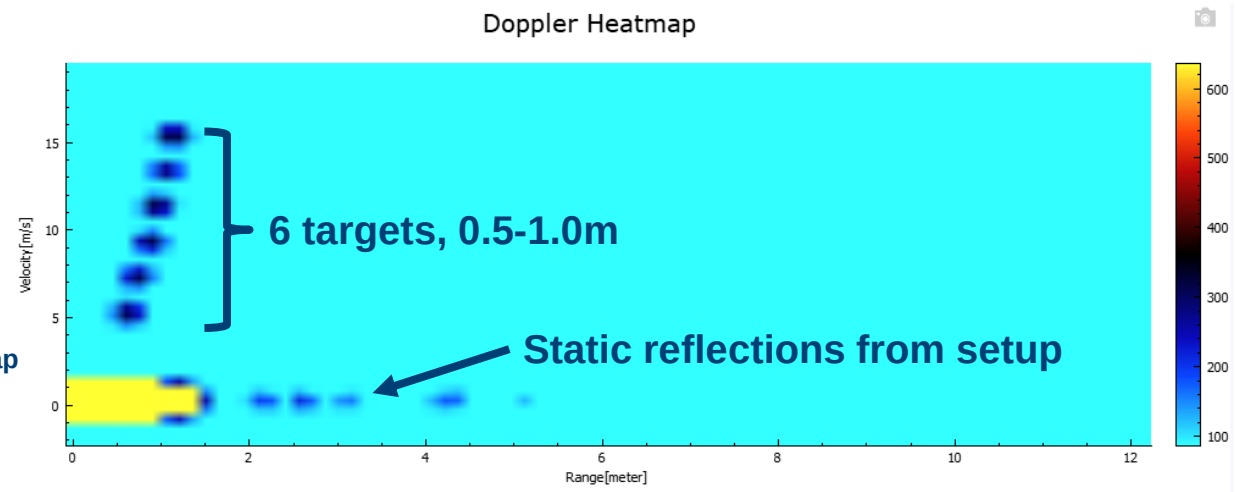
FULL DIGITAL IMPLEMENTATION. HYBRID OBJECT GENERATION IS STILL POSSIBLE

- Up to 4 channels with up to 8 targets per channel
- Minimum distance >= air gap value of the radar under test
- Example below with a Tier 2 DUT



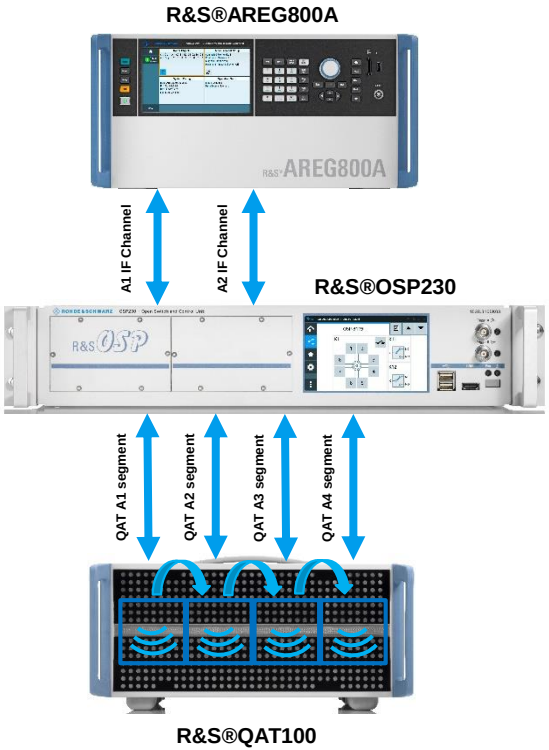


R&S Patent
Minimal Distance = Air Gap

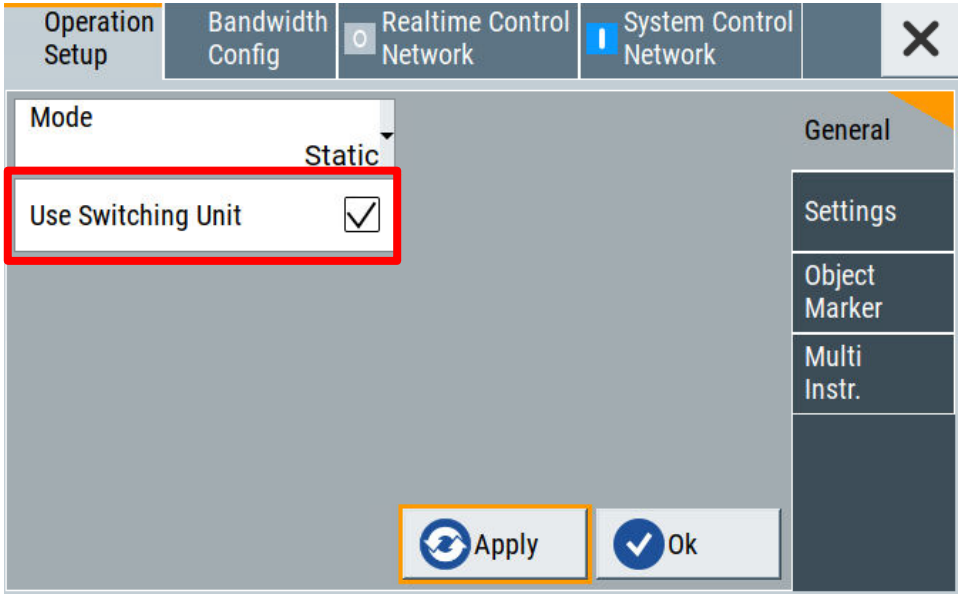


R&S®AREG800A AUTOMOTIVE RADAR ECHO GENERATOR

OSP Integration

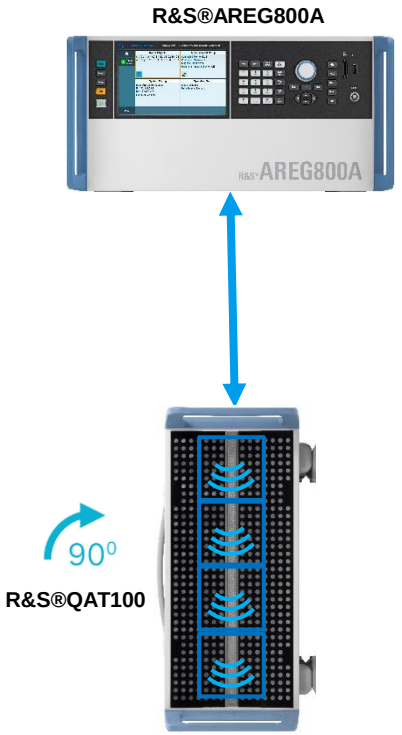


Use less channels in the R&S®AREG800A than in the R&S®QAT100 and control the whole FOV of the frontend

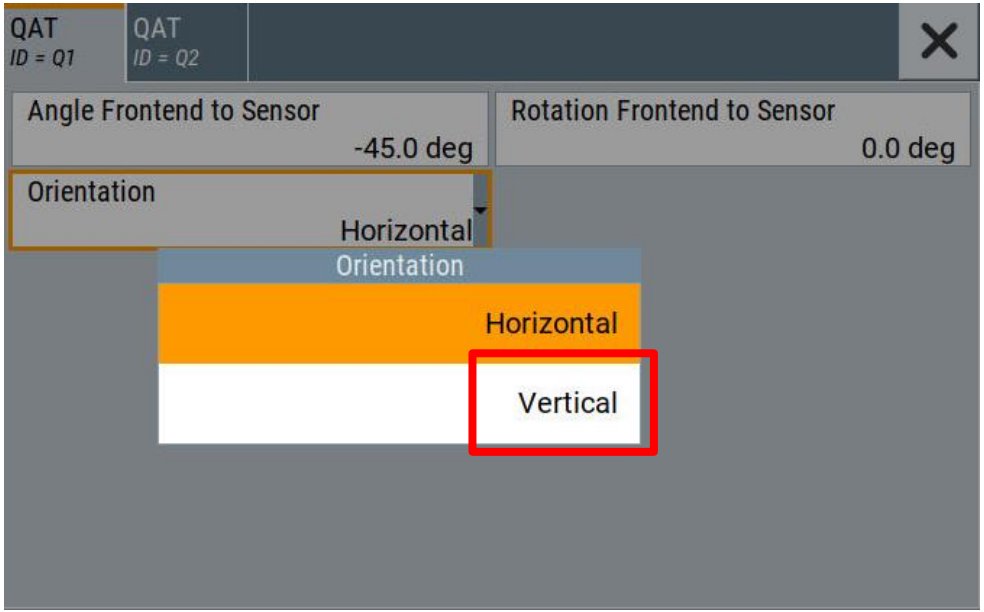


R&S®AREG800A AUTOMOTIVE RADAR ECHO GENERATOR

Elevation Angle Support

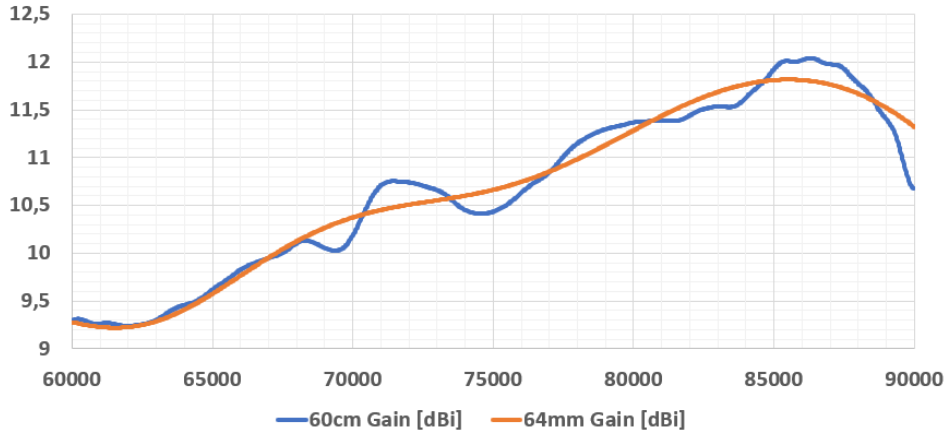


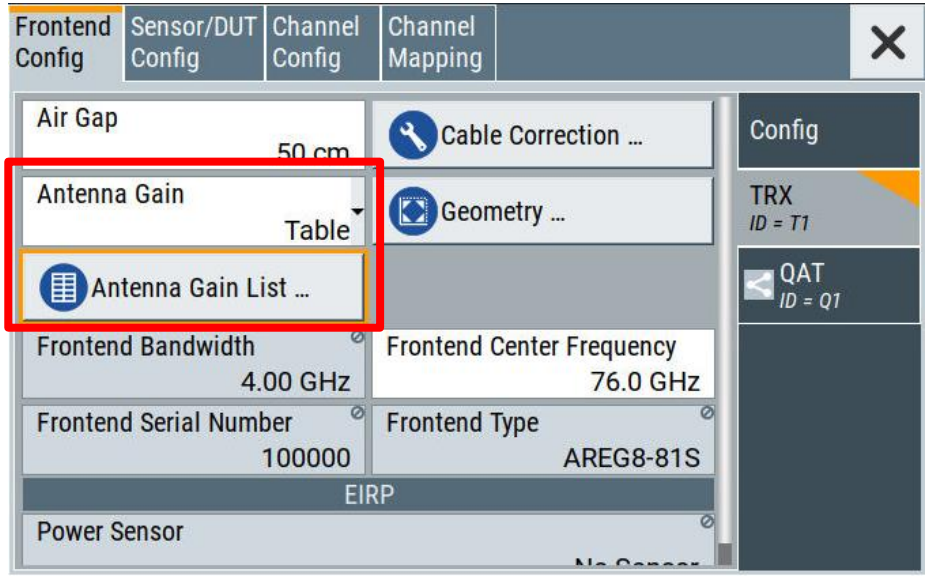
Elevation angle simulation capability



R&S®AREG800A AUTOMOTIVE RADAR ECHO GENERATOR

Improved mmW TRX FE Antenna Characterization

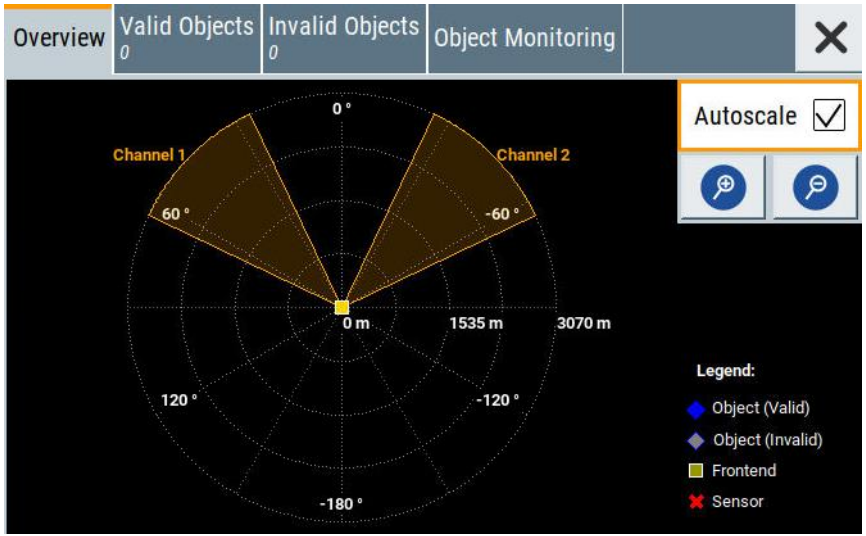


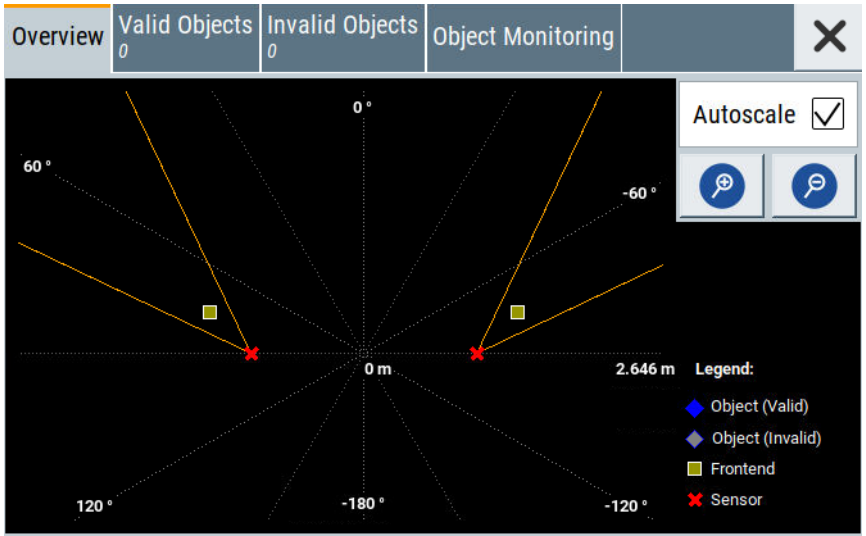


Increase the accuracy of your measurement

R&S®AREG800A AUTOMOTIVE RADAR ECHO GENERATOR

Improved calculations for overview geometrical distance-angle

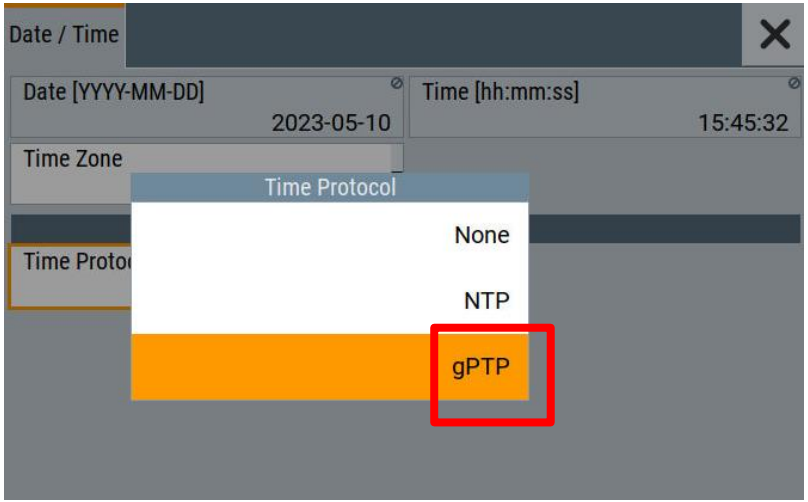




Define a digital twin of your physical setup and test more than 1 radar at the same time

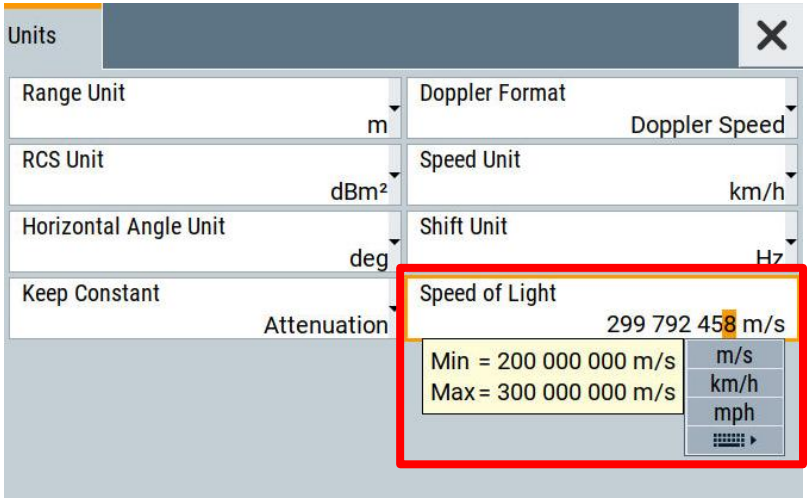
R&S®AREG800A AUTOMOTIVE RADAR ECHO GENERATOR

gPTP for HiL



System time synchronization using the generic precision time protocol

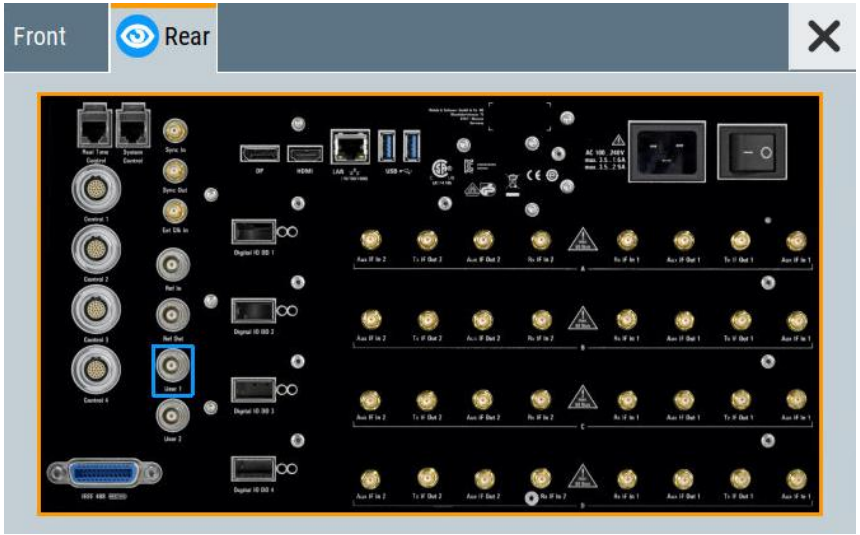
Adjustable speed of light

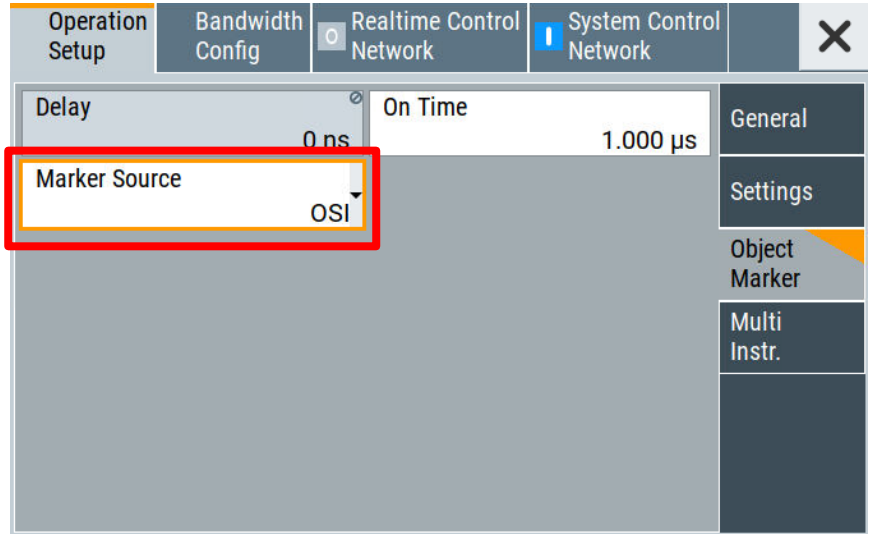


Fit the radar sensor design and increase the accuracy of your measurement

R&S®AREG800A AUTOMOTIVE RADAR ECHO GENERATOR

Command output signal to trigger external devices





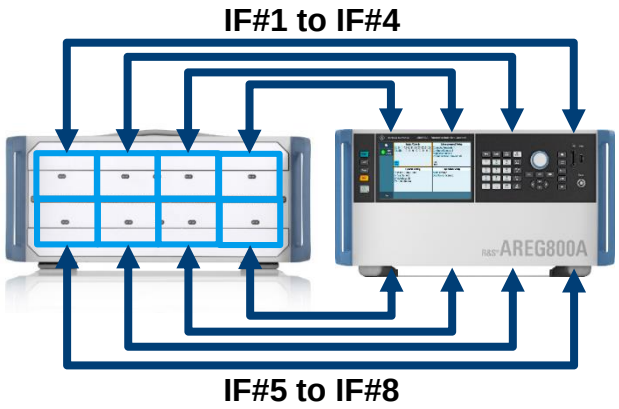
Increase the capability of your measurement setup in HiL mode

R&S®AREG800A IS HARMONIZED WITH THE FRONTENDS

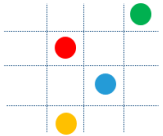
SIGNAL DISTRIBUTION OVERVIEW

A – One QAT100 and one AREG800A
For simulation of dense scenarios

Up to 8 objects



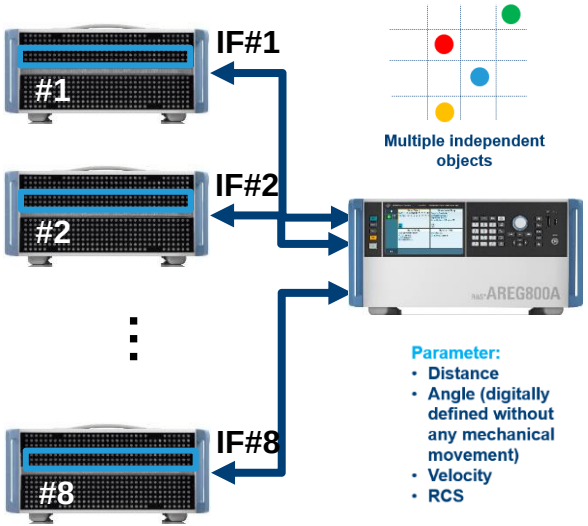
Parameter:
- Distance
- Angle (digitally defined without any mechanical movement)
- Velocity
- RCS



Multiple independent objects

B – Multiple QAT100s and one AREG800A
For covering wide Field-of-Views

Up to 8 objects

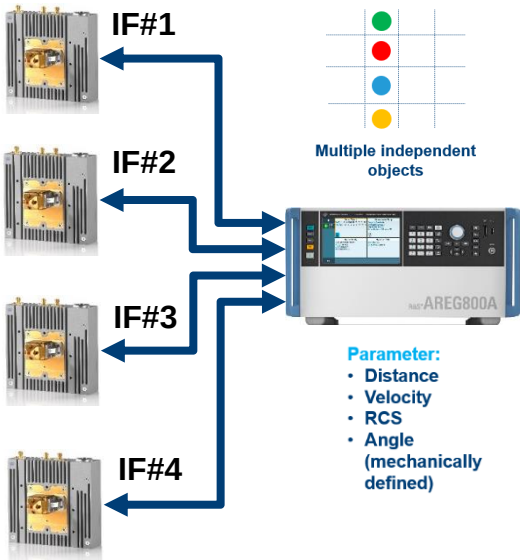


Multiple independent objects

Parameter:
- Distance
- Angle (digitally defined without any mechanical movement)
- Velocity
- RCS

C – mmW Frontends and AREG800A
For performance test cases

Up to 32 objects



Multiple independent objects

Parameter:
- Distance
- Velocity
- RCS
- Angle (mechanically defined)

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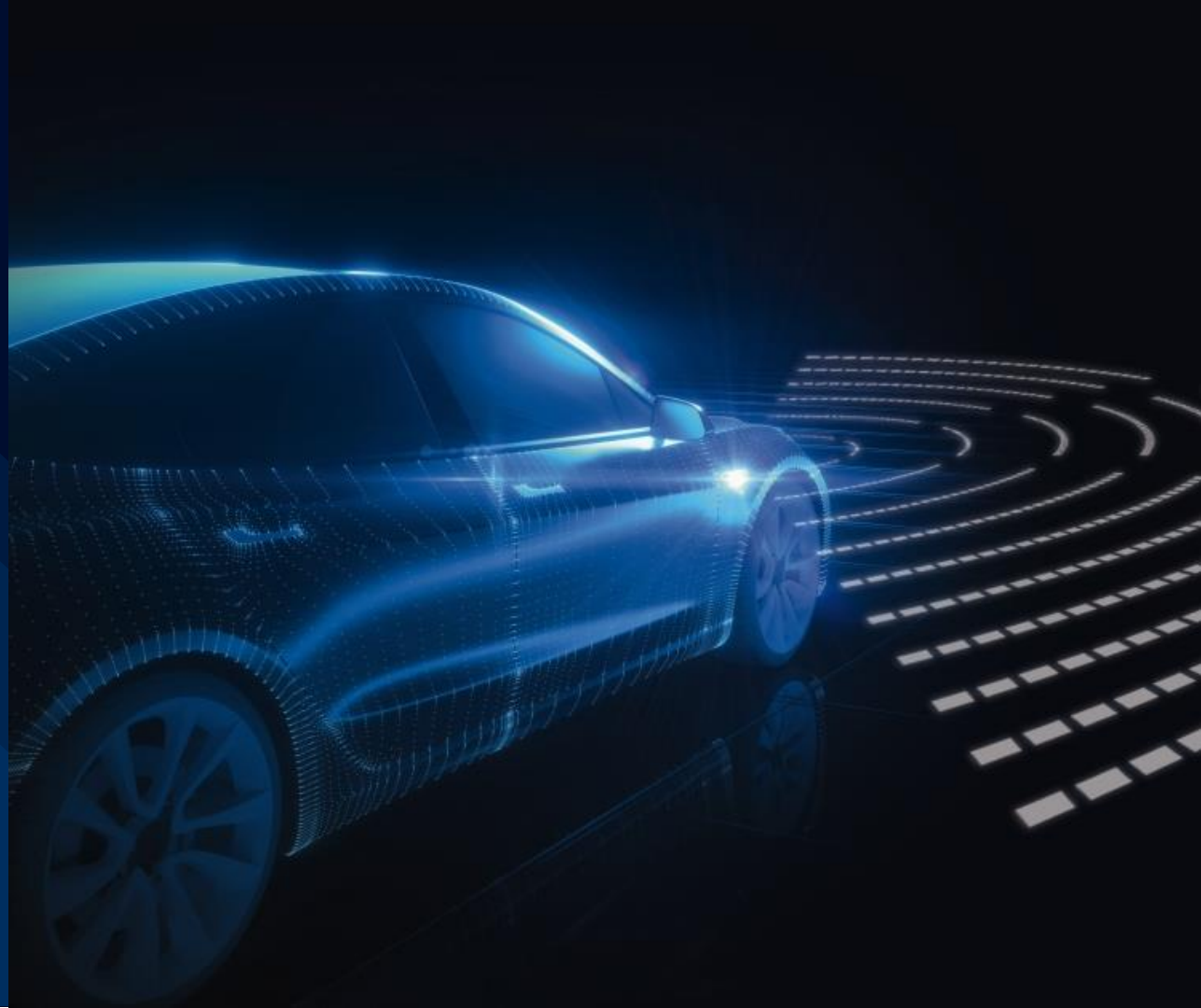


R&S®AREG800A AUTOMOTIVE RADAR ECHO GENERATOR

APPLICATIONS AND SOLUTIONS – ALL IN ONE FOR AUTOMOTIVE RADAR TESTING

EOL Production Test and Calibration

R&S®AREG100A or R&S®AREG800A

Research and Development

R&S®AREG800A with various frontends

Hardware-in-the-Loop

R&S®AREG800A and R&S®QAT100

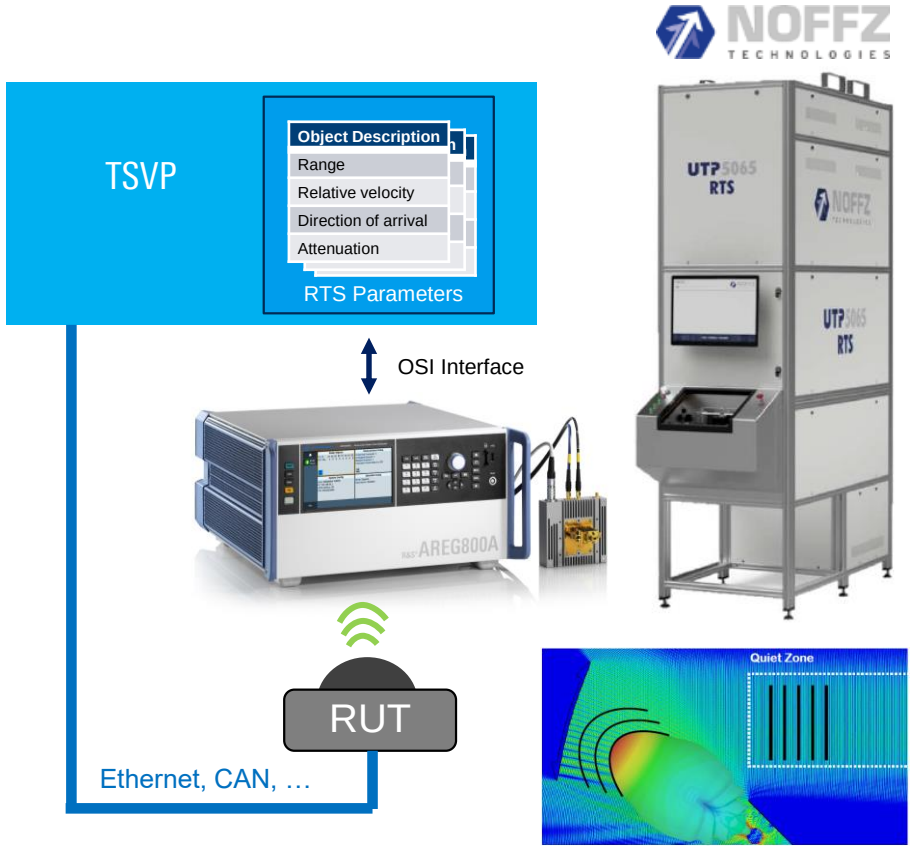
Vehicle-in-the-Loop (together with AVL)

R&S®AREG800A and R&S®QAT100

RADAR MODULE PRODUCTION TESTER FOR TIER 1

PARTNERSHIP WITH NOFFZ TECHNOLOGIES

- Generate echoes with defined Doppler, RCS and Range
- Perform radar sensor calibration
- Future-proof CATR reflector technology for growing antenna apertures
- Seamless CATR production tester solution for developing radar in ATS1500C
- Combine CATR and AREG ensures best quiet zone



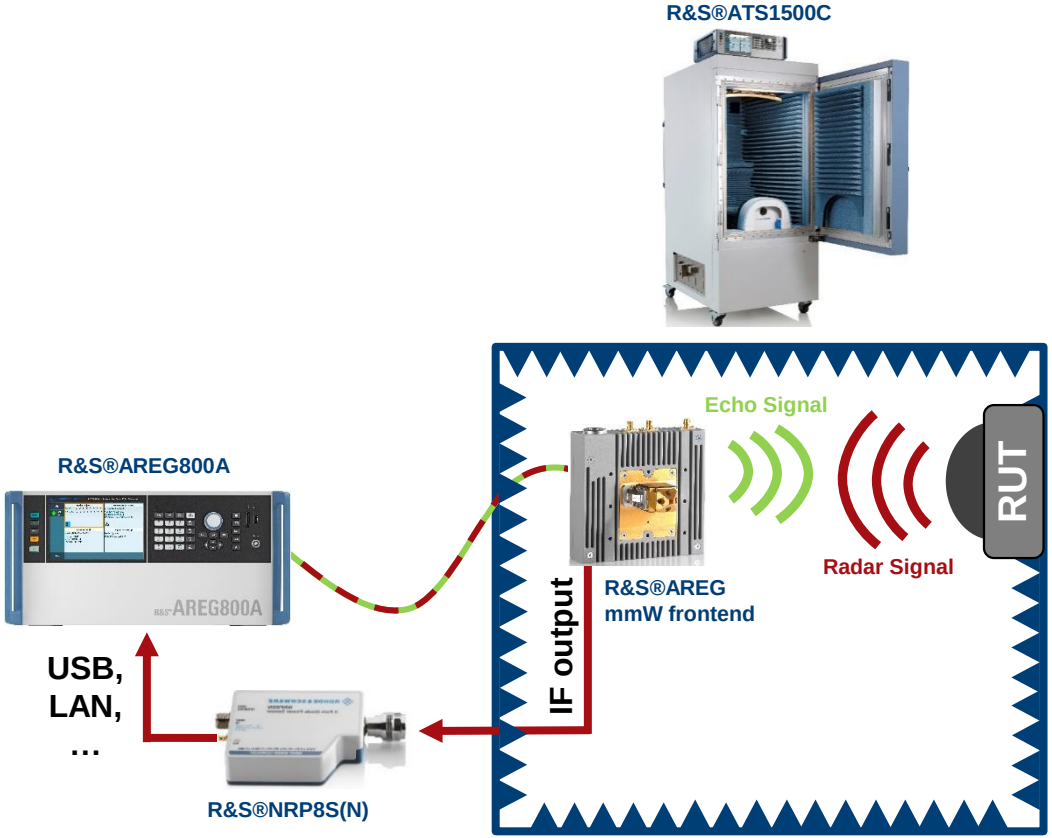
AUTOMOTIVE RADAR VALIDATION IN EMC ENVIRONMENTS

AREG800A AND AREG MMW FRONTENDS ARE SUITABLE FOR TESTING RADARS IN COMPREHENSIVE AND DYNAMIC EMC ENVIRONMENTS

- Testing of radar operation under EMC stress
- Simulation of driving scenarios using R&S®AREG800A

MEASURE THE SENSOR'S TRANSMITTED POWER AND EIRP

COMPLY TO THE RADIO EQUIPMENT DIRECTIVE AND EXPLOIT THE MAXIMUM EIRP



- Connect a power sensor with upper frequency limit of 6 GHz
- Receive path from frontend to IF output port is calibrated
- Read the measured EIRP of the radar sensor directly on the GUI of the AREG base unit

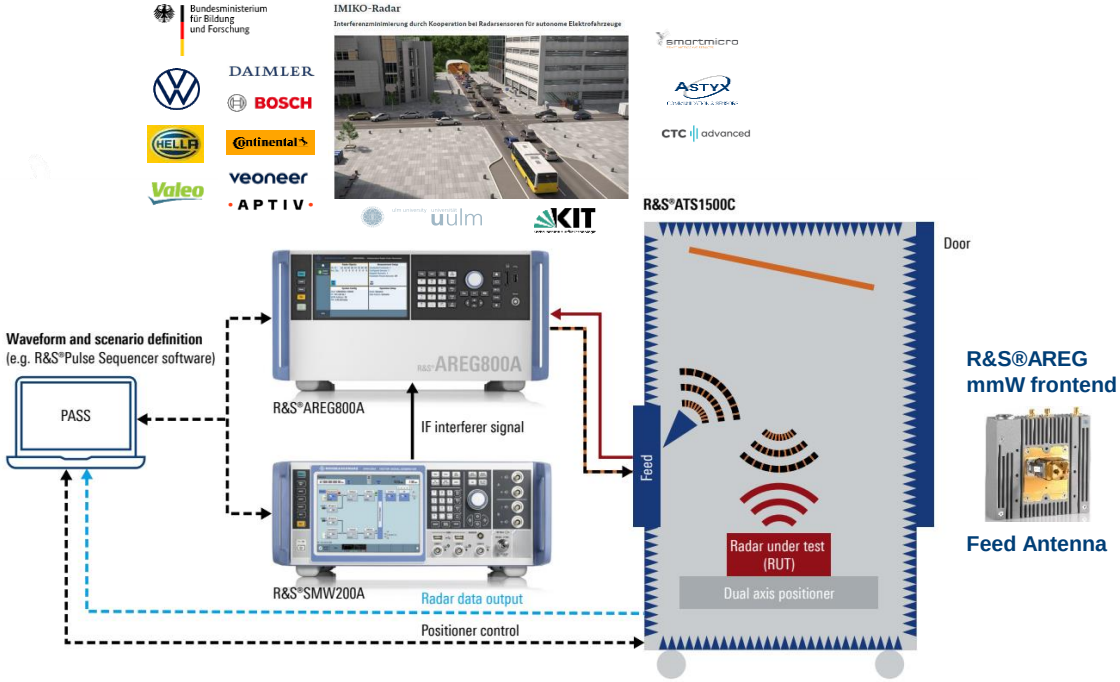
HIGH SENSITIVITY SIGNAL ANALYSIS MEASUREMENTS

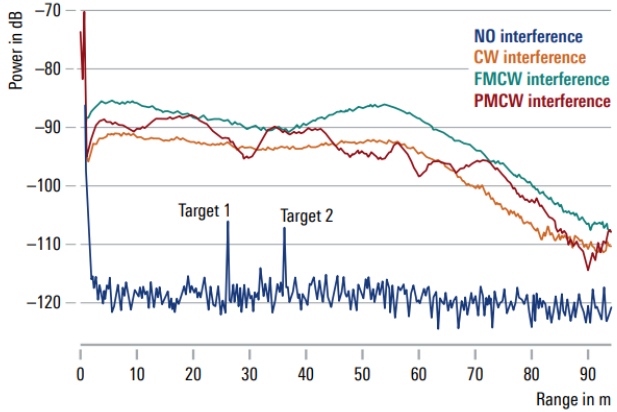
COMPREHENSIVE RADAR SIGNAL ANALYSIS

- Measuring frequency linearity, length, long-term stability and power of chirp to improve accuracy and fulfill regulatory requirements
- Measuring phase noise to increase sensitivity

AUTOMOTIVE RADAR CONFORMANCE TESTING

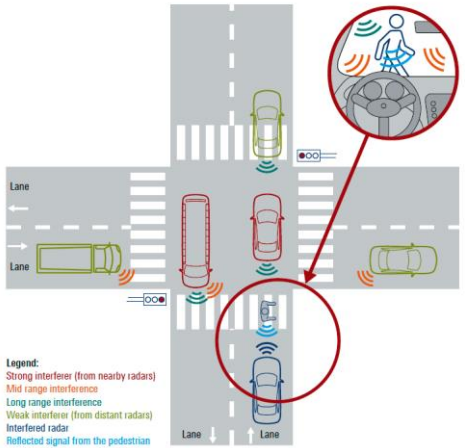
TEST THE RADAR INTERFERENCE MITIGATION ALGORITHM PERFORMANCE





R&S®AREG mmW frontend

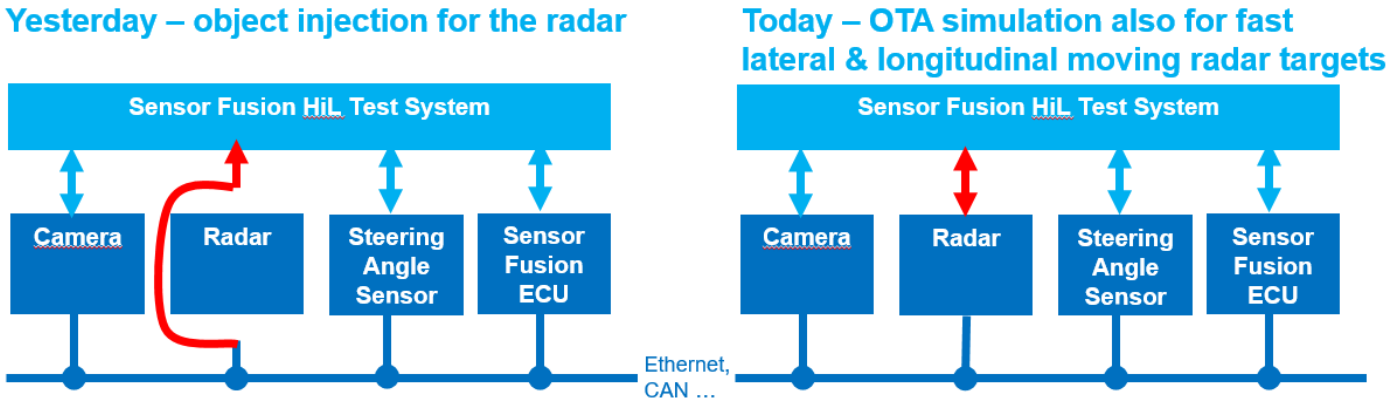
Feed Antenna



- "IMIKO Radar" Research Project (11/2018 – 10/2021) investigated and minimized radar interference
- Test robustness of radar sensors against interferers for all automotive radar bands
- All-in-one test solution with highest reliability and repeatability
- Cost efficient as a 6GHz signal source is sufficient for interferer simulation
- Synchronization of interfering signal with radar sensor is possible
- Simulate advanced interference scenarios, including sophisticated waveforms such as FMCW, PMCW, OFDM

OBJECT SIMULATION FOR HIL AND VIL TEST SYSTEMS

- New radar sensors based on SoCs require over-the-air stimulated black box testing
- NCAP will require increased testing of radars not only on the road and proving grounds, but also on the rig (vehicle-in-the-loop ViL) and in the lab (hardware-in-the loop HiL)



- Over-the-air stimulation of radar sensors for component and integration HiL testing
- Electrical simulation of lateral moving targets
- Simulation of longitudinal moving targets also in very low distance

AREG800A AND QAT100 FOR SCENARIO TESTING

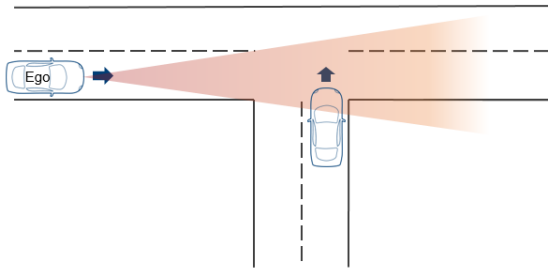
STANDARD CONFIGURATIONS

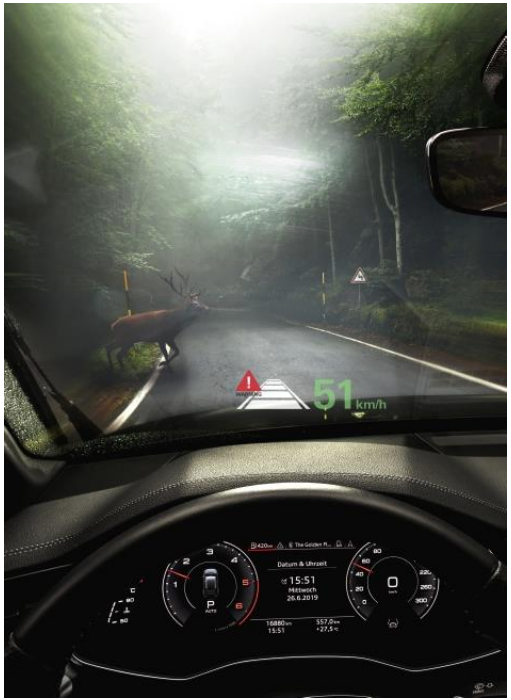
Configuration	Targets	FOV *	Typical Use Cases
Entry	1	39°	Test of front radars in scenarios like Automatic Emergency Braking, Adaptive Cruise Control, …
Basic	up to 2	39°	Test of front radars in scenarios like highway ALKS, country road, …
Medium	up to 4	39°	Test of front radars in scenarios like highway ALKS, country road, …
Advanced	up to 6	117°	Test of front and corner radars in scenarios like city thoroughfare, highway construction sites, …
Complex	up to 8	117°	Test of front and corner radars in scenarios like urban intersections, Highway Construction sites, …

* 50 cm airgap

EXEMPLARY DRIVING SCENARIOS

BASIC INSTRUMENT CONFIGURATIONS





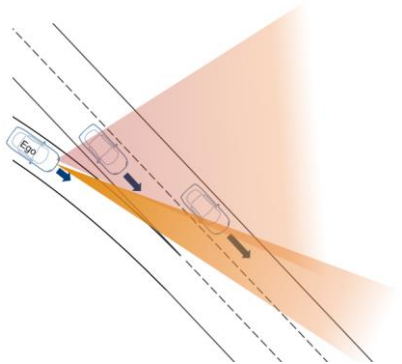
Application:

- Enables selected NCAP, AEB and ACC scenarios
- Simulation of targets moving in azimuth, range, radial velocity and target size (RCS)
- Stimulation of a single radar sensor
- Test of front radars in scenarios like Automatic Emergency Braking, Adaptive Cruise Control, …
- Up to 1 target
- 39° Field-of-View @ 50cm airgap

Frontend	#	Backend	#	Switch	#
QAT100	1	AREG800A	1	OSP220	-
B21 (MIMO)	1	B9 (Digital)	1	B128.3	-
B5 (ASDL)	-	K570 (2nd IF)	-		
		B63 (ASDL)	1		
		K814	1		

EXEMPLARY DRIVING SCENARIOS

ADVANCED INSTRUMENT CONFIGURATIONS



Application:

- Enables selected NCAP, AEB and ACC scenarios
- Simulation of targets moving in azimuth, range, radial velocity and target size (RCS)
- Stimulation of multiple radar sensors
- Test of front and corner radars in scenarios like urban intersections, Highway Construction sites, …
- Up to 8 targets
- 117° Field-of-View @ 50cm airgap

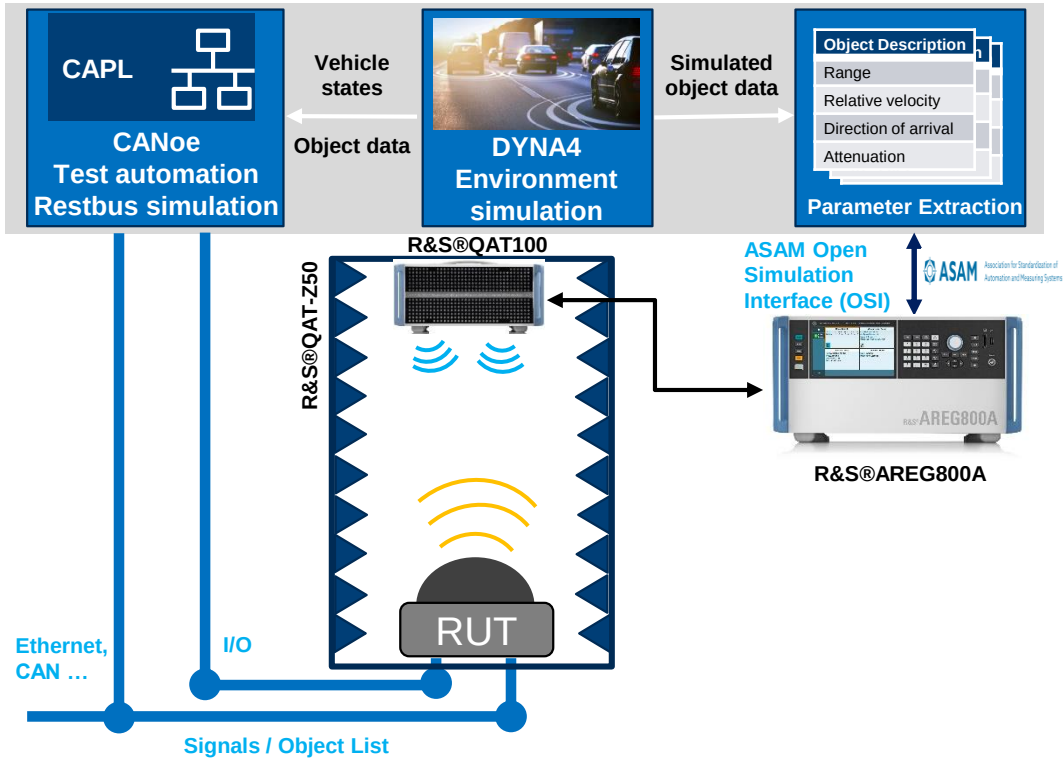
Frontend	#	Backend	#	Switch	#
QAT100	3	AREG800A	1	OSP220	2
B21 (MIMO)	3	B9 (Digital)	4	B128.3	4
B5 (ASDL)	-	K570 (2nd IF)	4		
		B63 (ASDL)	-		
		K814	4		

HARDWARE-IN-THE-LOOP COMPONENT TEST

PARTNERSHIP WITH VECTOR

VECTOR

- Closed-loop radar module component validation using realistic road scenarios or artificial test cases
- CANoe for test automation and restbus simulation via CAN / Ethernet in real-time
- Environment simulation via DYNA4 (optional)



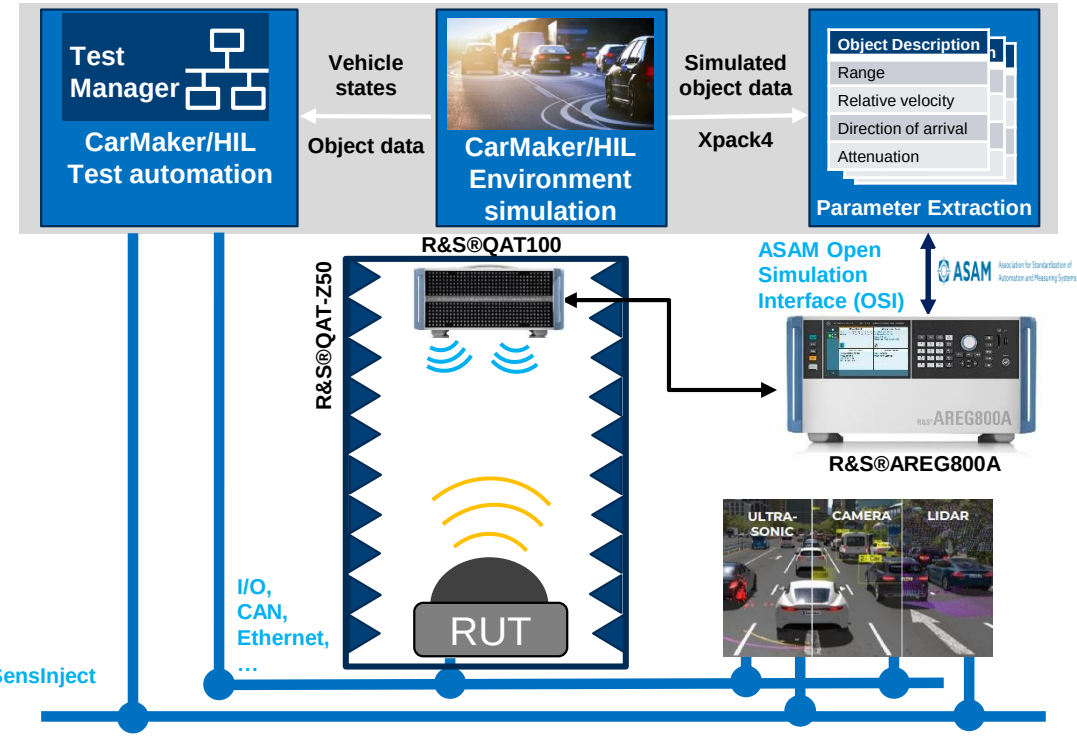
HARDWARE-IN-THE-LOOP INTEGRATION TEST

PARTNERSHIP WITH IPG

Closed-loop integration test / validation using realistic road scenarios or artificial test cases

Test automation via TestManager (IPG) or ECU-Test (TraceTronic) or EXAM (MicroNova)

Environment simulation via CarMaker (IPG)



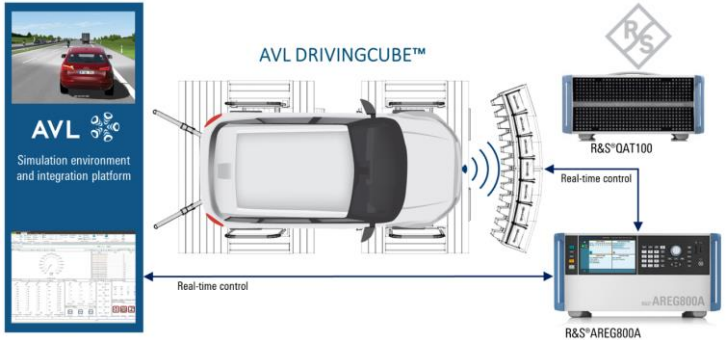
VEHICLE-IN-THE-LOOP VALIDATION

PARTNERSHIP WITH AVL

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

Test automation via PUMA

Environment simulation via Model.CONNECT using various tools using e.g. VTD, CarMaker, CarSim



R&S AUTOMOTIVE RADAR TEST SYSTEM

R&S®QAT100 + R&S®AREG800A

Azimuth and elevation simulation
without mechanical movement
& immune to vibration

Extremely short distances
precise and repeatable

4GHz instantaneous bandwidth
across scalable FOV

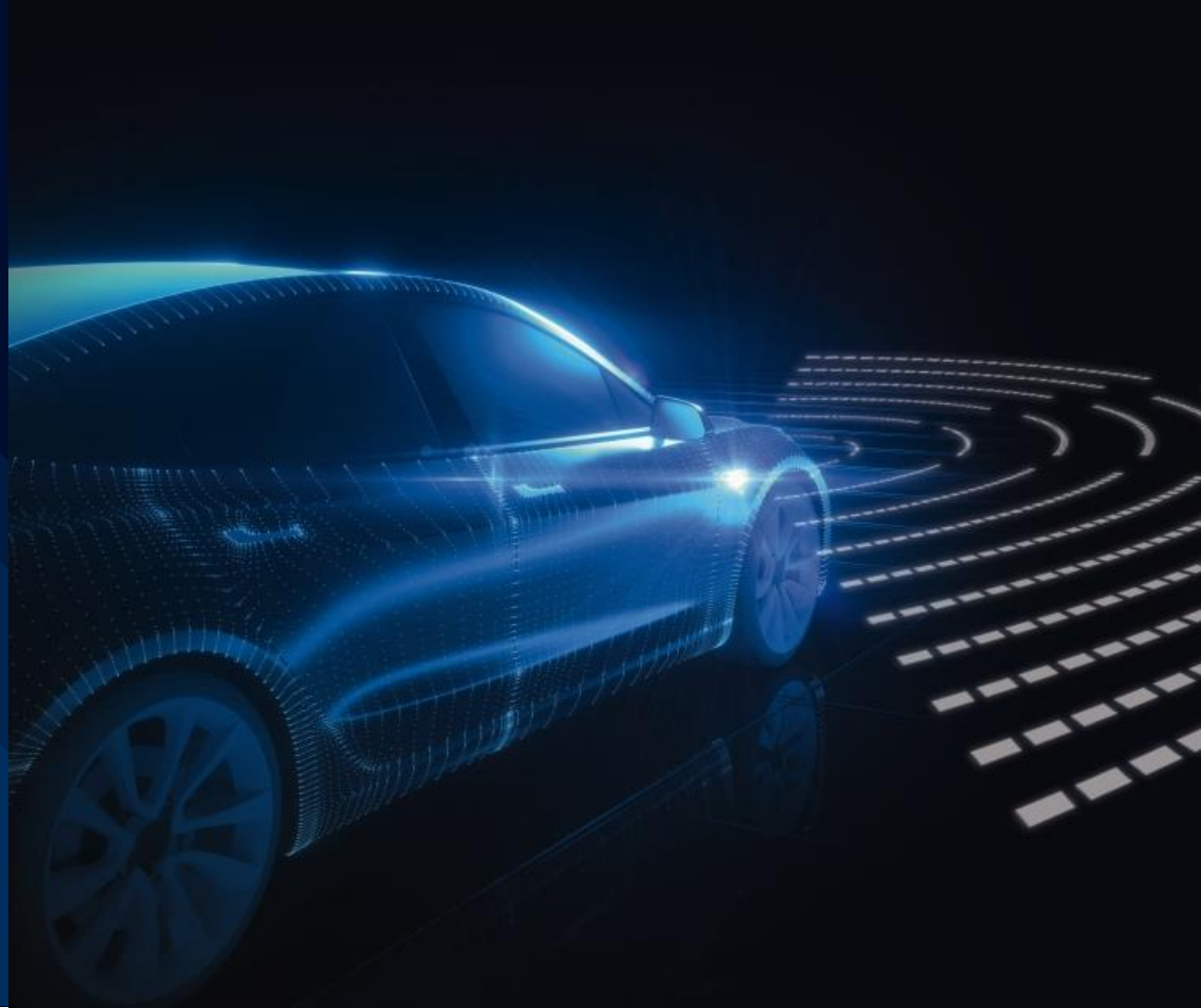
Multiple independent
dynamic objects

HiL interface via Open
Simulation Interface

Performance
optimized system

AGENDA

- Automotive radar technology and market update
- QAT100 Electronically steerable antenna array
- AREG800A advanced automotive radar echo generator
- Applications and solutions
- **Automotive radar testing product portfolio**
- Summary and learnings



RADAR BASED AUTONOMOUS DRIVING

COMPREHENSIVE TEST AND MEASUREMENT PORTFOLIO FROM R&S

Characterization at Chip Suppliers / TIER1s

Validation at TIER1s / OEMs

Radome/bumper test in R&D and production at TIERxs / OEMs

Production test at TIER1s

AGENDA

- Automotive radar technology and market update
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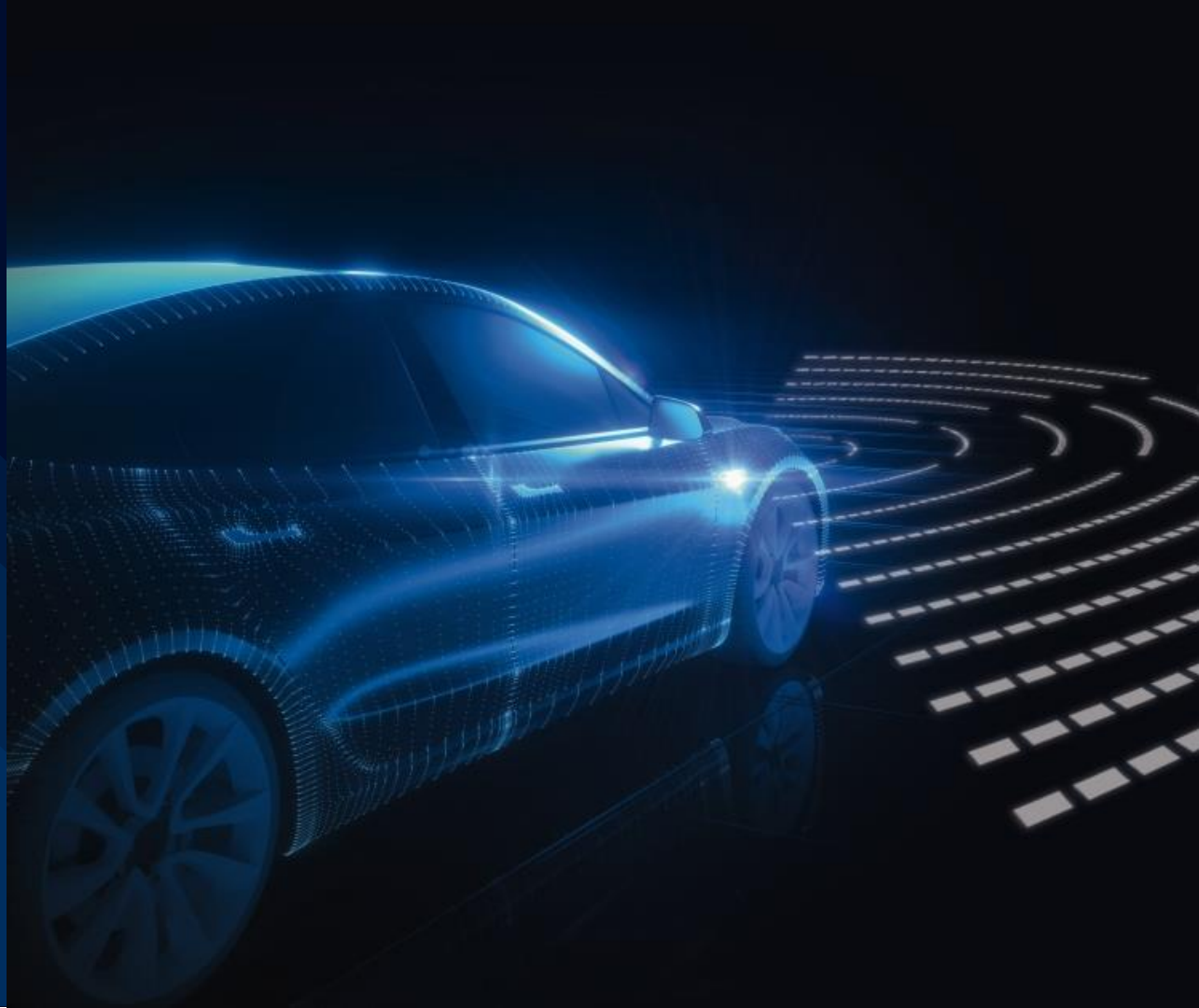

SUMMARY AND LEARNINGS

- Realization of higher levels of ADAS is driving up number and complexity of automotive radars
  - Higher bandwidth, complex modulation, MIMO, virtual aperture
- 5/6th generation radar sensors enter market (trend to single chip CMOS, 5GHz bandwidth) with more complex modulation
- Need for complex moving object scenarios to be emulated in a lab environment is increasing
- Very short distance object simulation required during radar sensor R&D and validation – addressed with the R&S®AREG800
- Future increased testing requirements at functional and ADAS application level – a perfect fit for the very powerful and scalable R&S Radar Test System

THANK YOU!

Find out more: www.rohde-schwarz.com/automotive/radar