COMPACT AND EFFICIENT AUTOMOTIVE RADAR TESTING

Andreas Ibl, Systems development engineer, Microwave Imaging

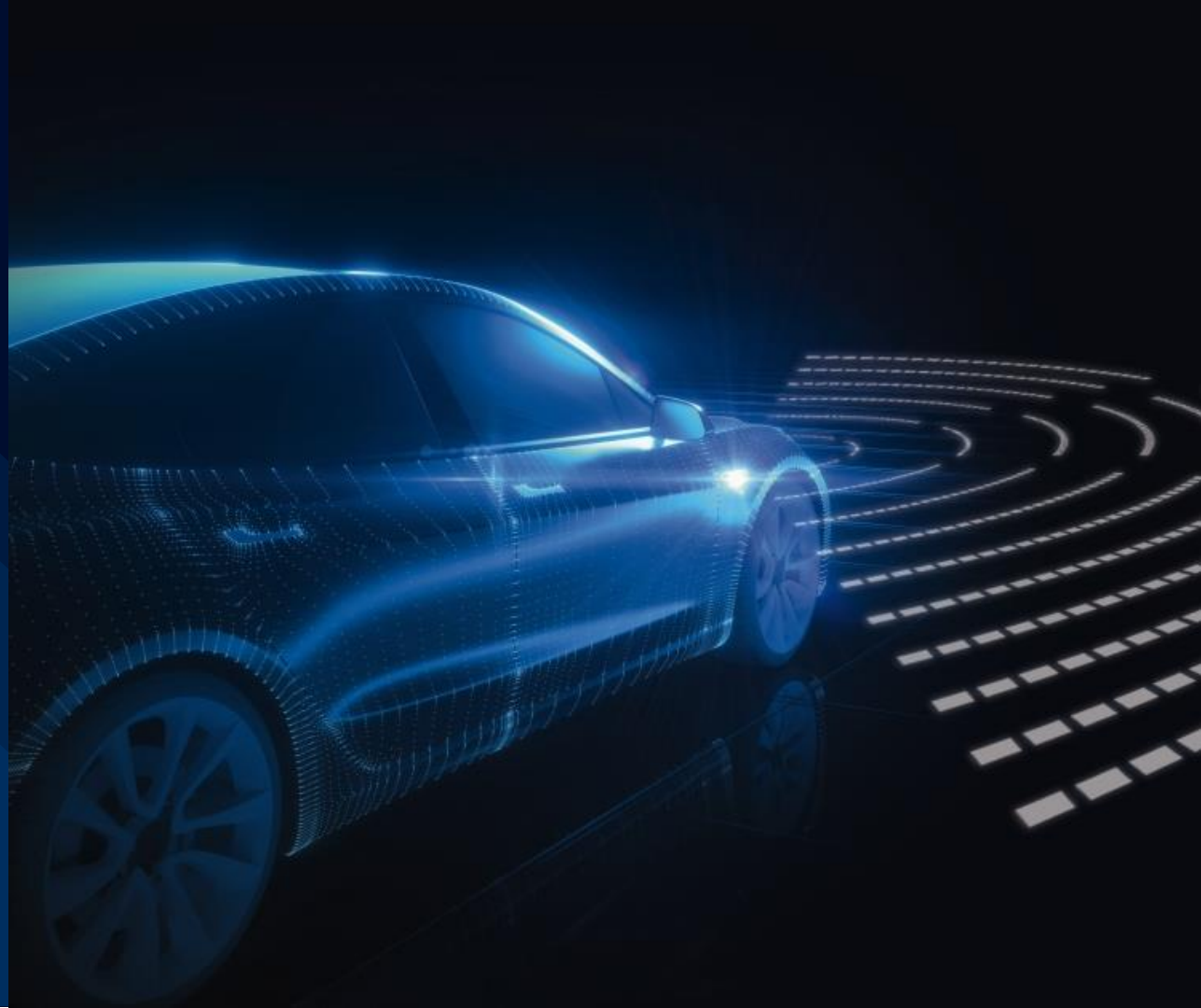
Jeremy Carpenter, Technology marketing expert

ROHDE&SCHWARZ

Make ideas real

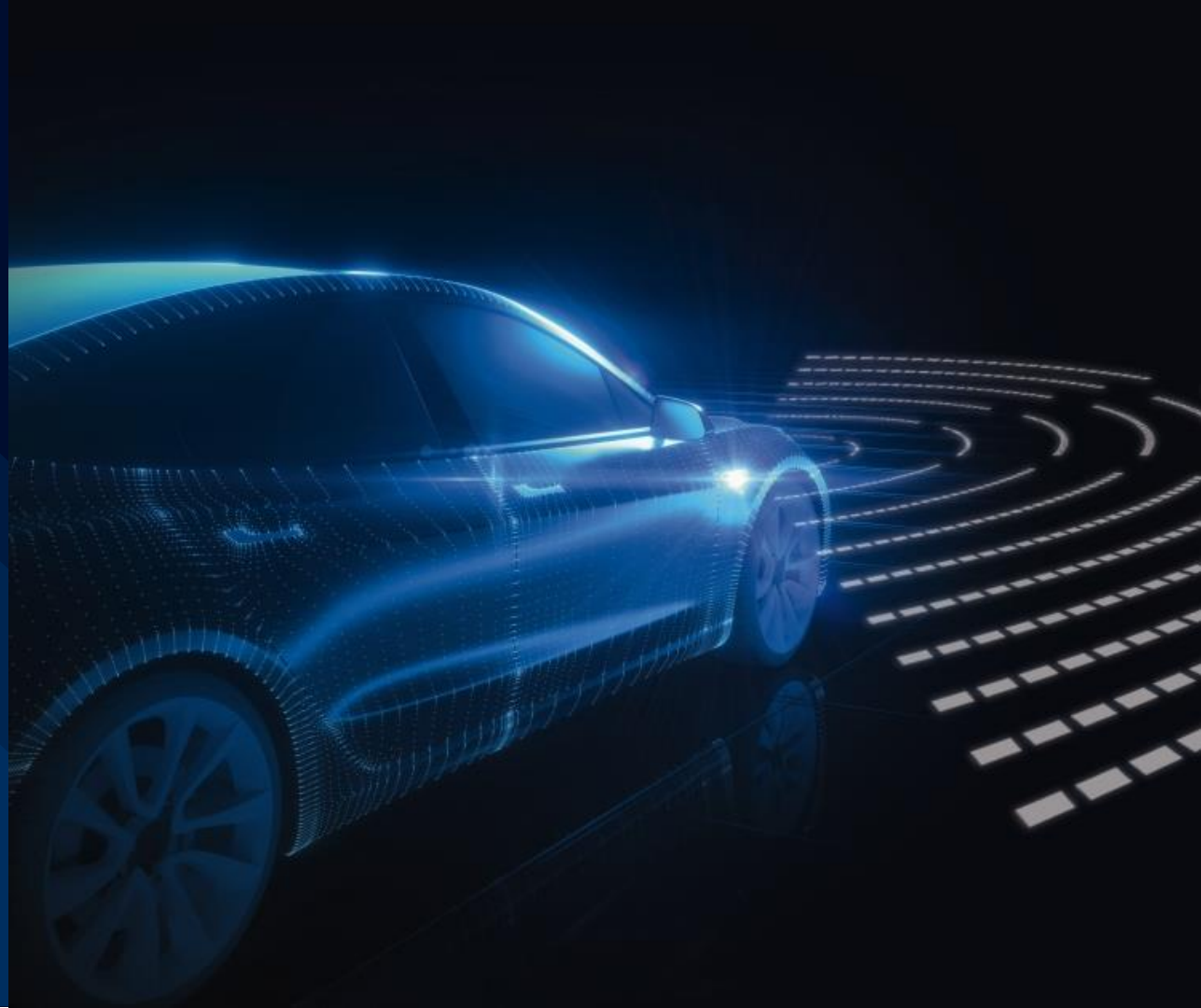
AGENDA

- Automotive radar technology overview
- Radar object simulation test challenges
- The possibilities of benchtop radar sensor testing
- Practical demonstration
- Summary and learnings

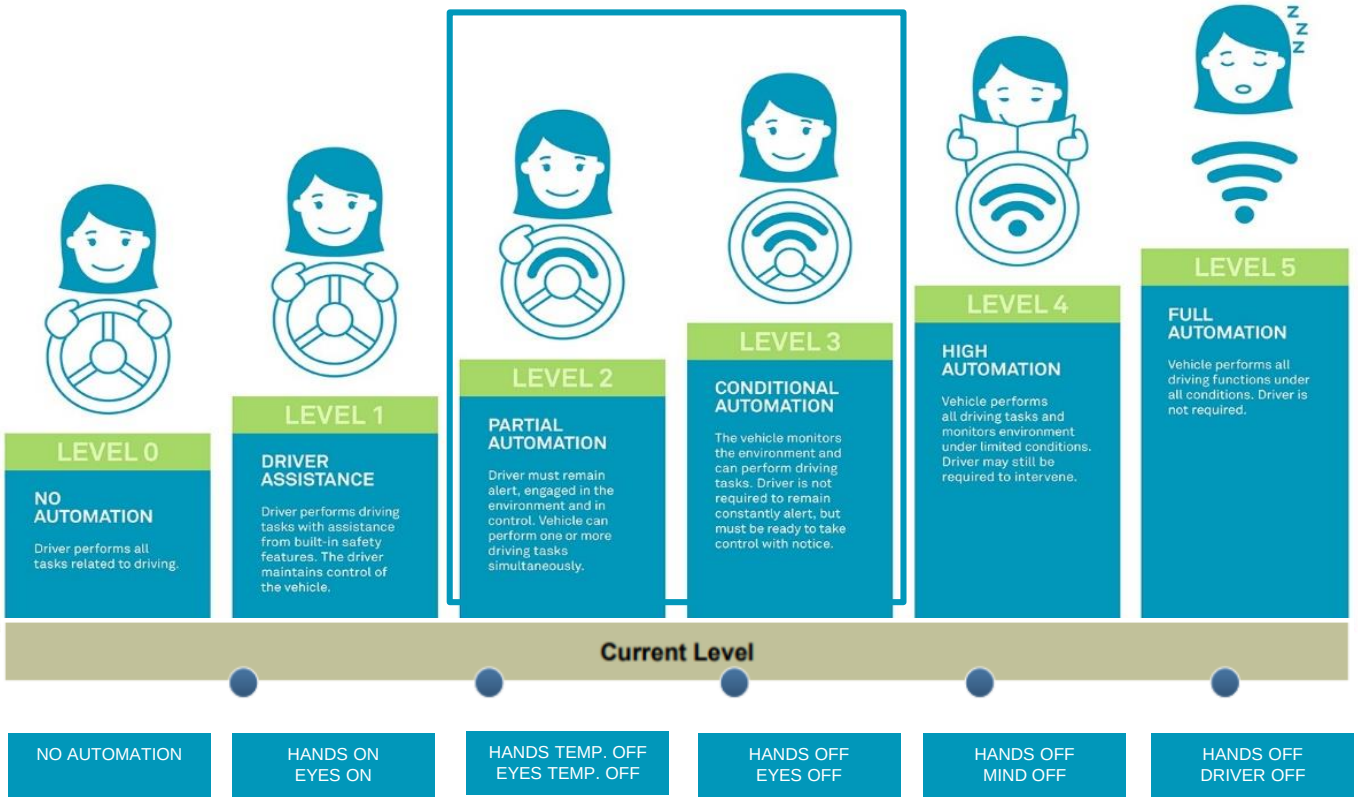


AGENDA

- **Automotive radar technology overview**
- Radar object simulation test challenges
- The possibilities of benchtop radar sensor testing
- Practical demonstration
- Summary and learnings

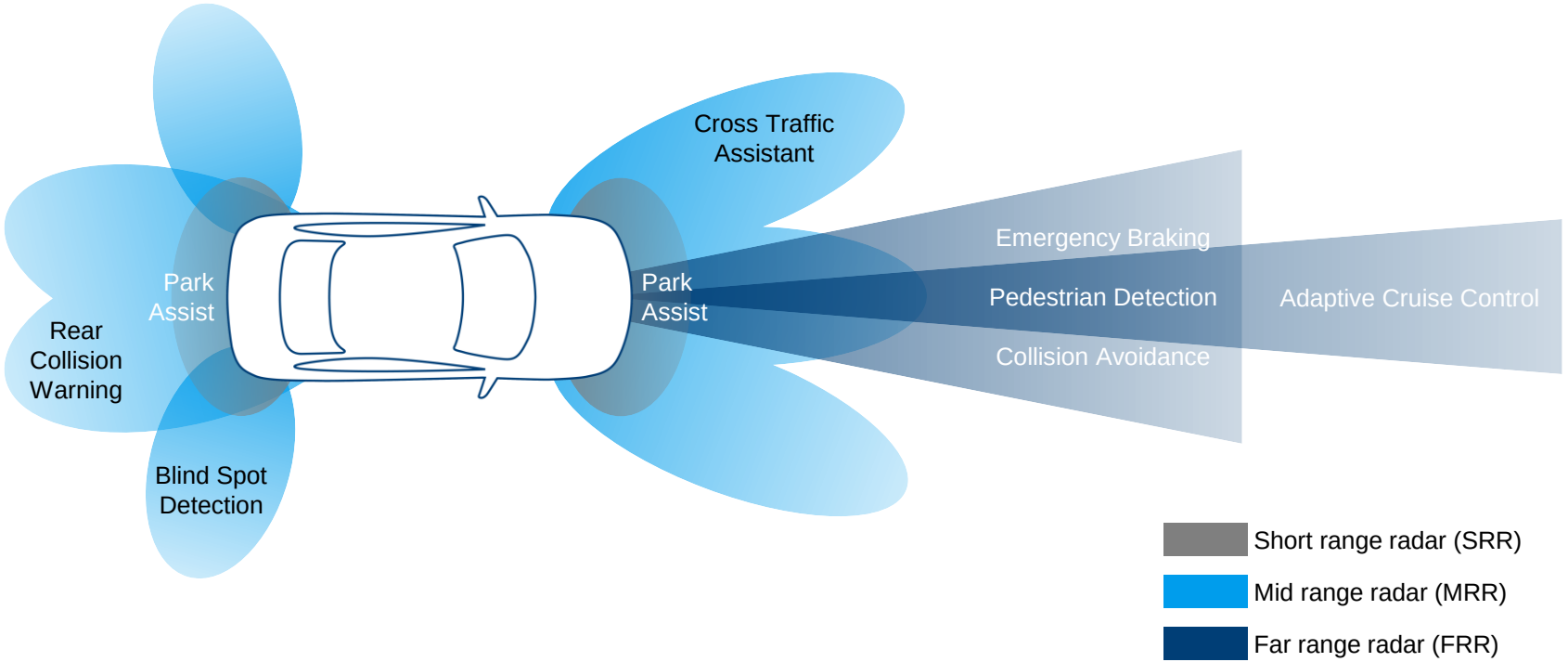


LEVELS OF DRIVING AUTOMATION (SAE J3016™)



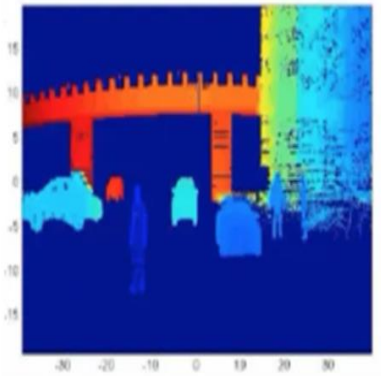
- **L2+** introduced by OEMs
- L3-like functions with restrictions to comply with missing legal framework
- Today's sensor maturity is sufficient for L2

RADAR BASED AUTONOMOUS DRIVING

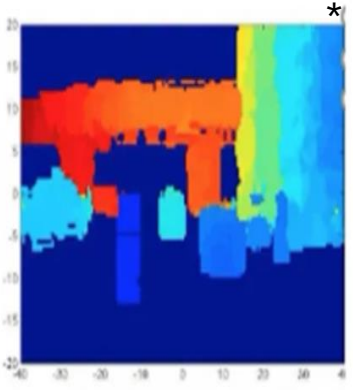


RADAR INNOVATION IS THE KEY ENABLER FOR AUTONOMOUS DRIVING

- **4D radar**
  - Can reach Lidar-like 3D resolution in the range of 100k detectable reflections (distance and angle)
  - Instantaneous hi-resolution velocity information for every reflection as 4th dimension



Lidar



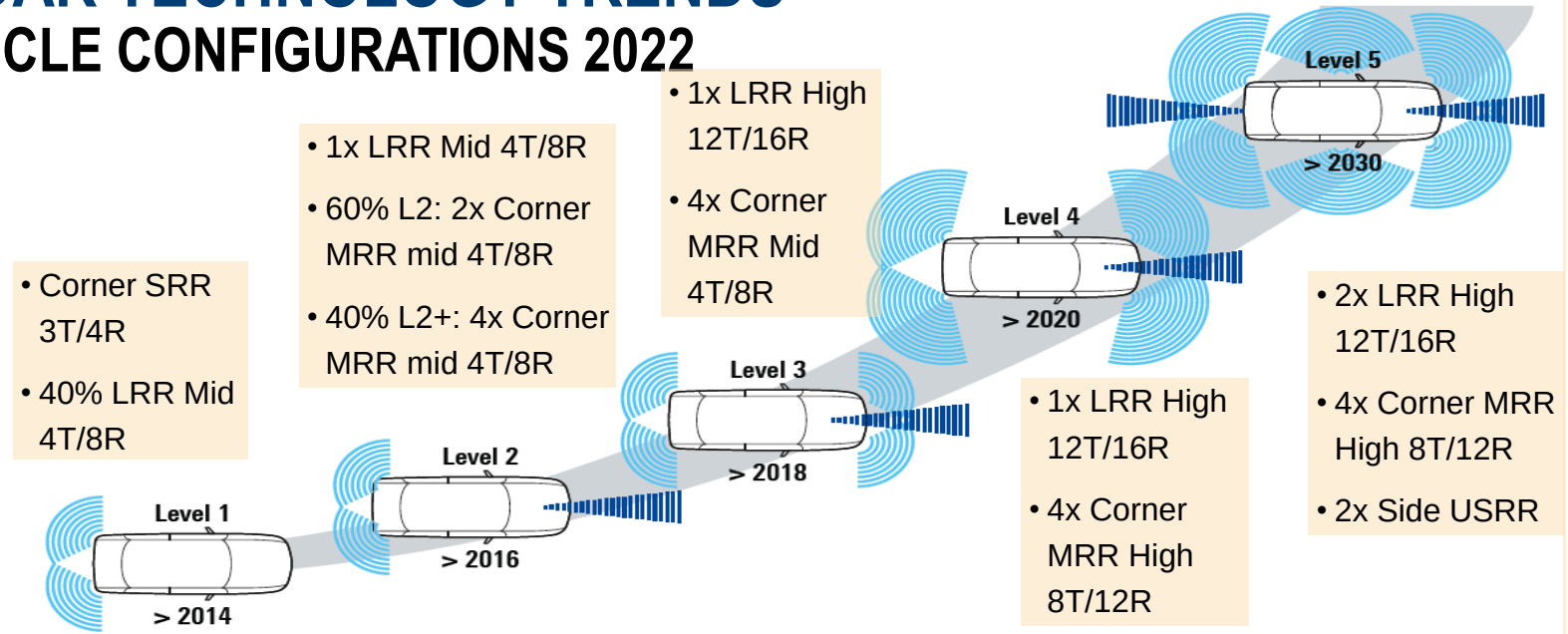
High Resolution Radar*

- **New modulations** schemes like PCMW or OFDM will enhance robustness against interference
- **Virtual aperture** can significantly increase resolution and field of view
- **Artificial intelligence** will improve object detection and tracking capabilities

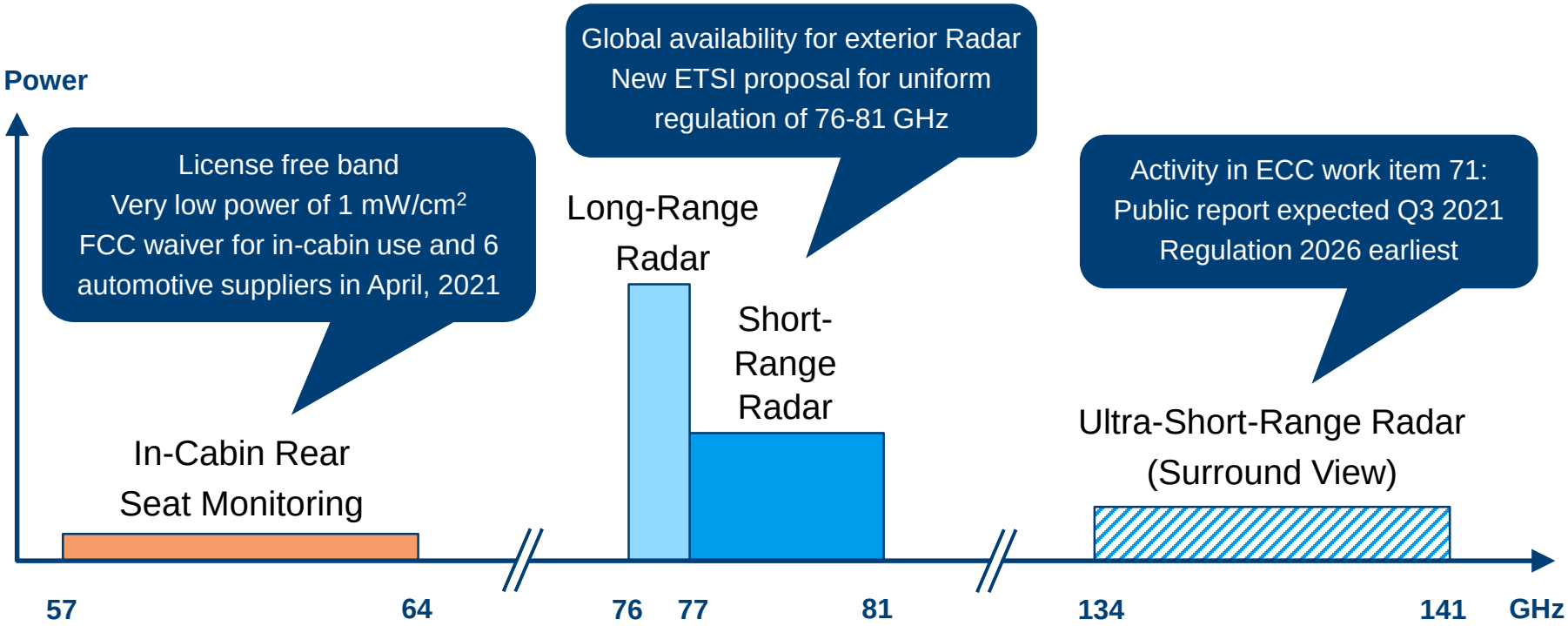
*image courtesy of NXP

RADAR TECHNOLOGY TRENDS

VEHICLE CONFIGURATIONS 2022



AUTOMOTIVE RADAR FREQUENCY MAP
76-81 GHZ GLOBALLY AVAILABLE



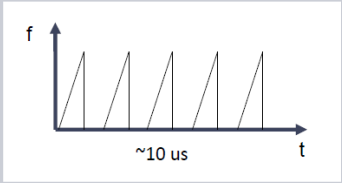
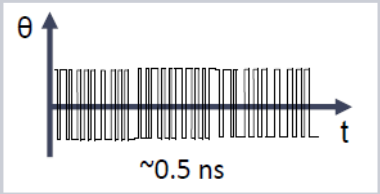
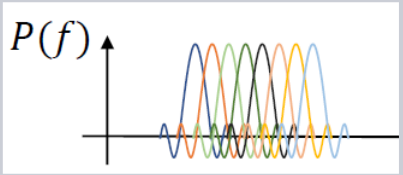
RADAR TECHNOLOGY TRENDS

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
Frequency Range [GHz]	24,76-77,77-81	76-77	77-81	76-77	76-77
Typical Bandwidth [MHz]	200, 1000, 4000	1000	2000	500	1000
Range [m]	80	150	150	250	300
Range Resolution [cm]	300, 30, 3.5	30	7.5	75	30
FOV Azimuth / Elevation [°]	±60 / ±0	±30 / ±0	±50 / ±15	±15 / ±5	±15 / ±10
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

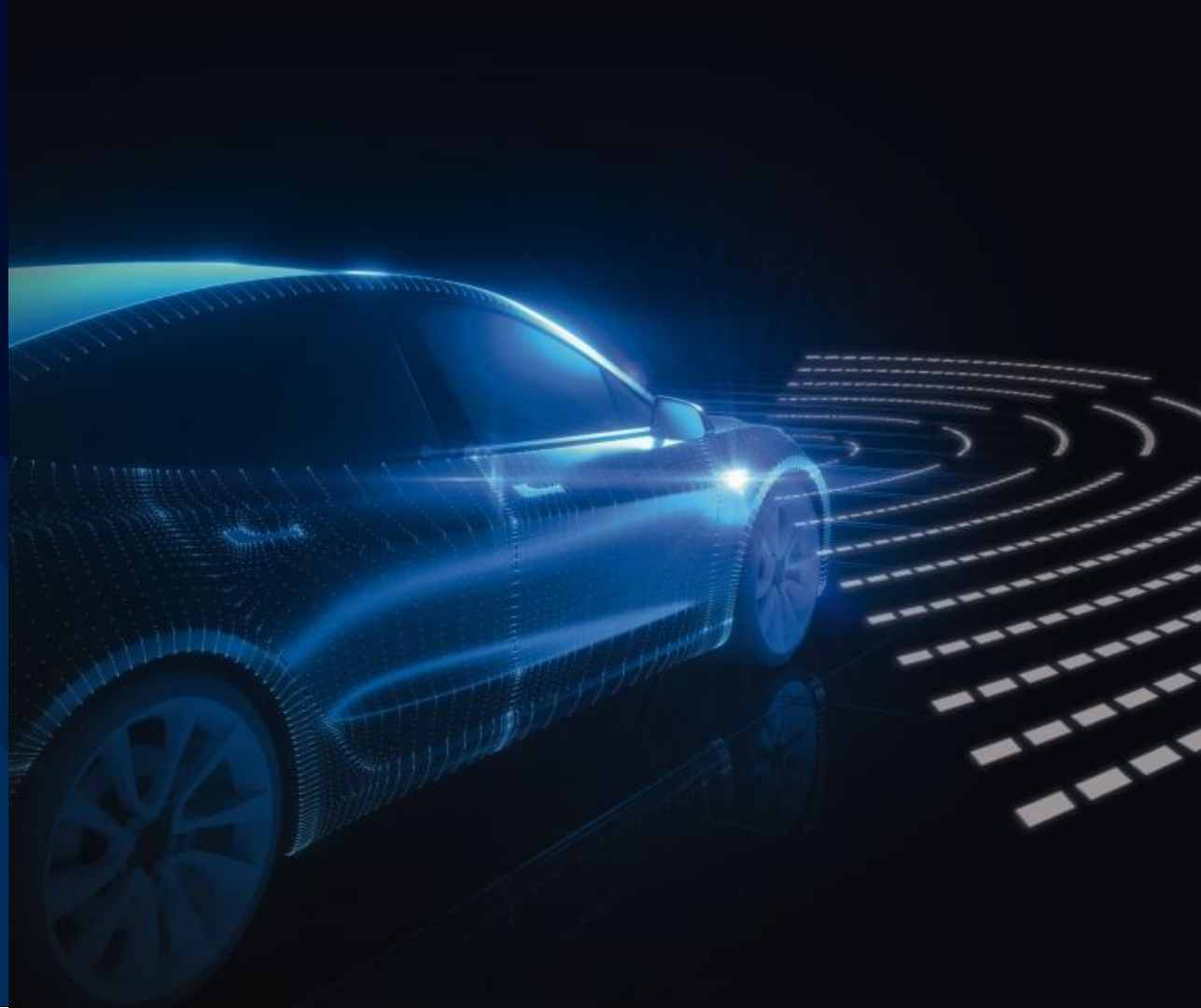
RADAR TECHNOLOGY TRENDS

NEW MODULATION SCHEMES FOR BETTER INTERFERENCE IMMUNITY

Modulation Technique	Today: FMCW	Near Future: PMCW	Long term: OFDM
Waveform			
Waveform Duration	~10 µs	~1 µs	~1 µs
ADC Sample Rate	~50 MSample/s IQ	>1 GSample/s IQ	>1 GSample/s IQ
Interferer Robustness	Good	High	High
Massive MIMO	Multi-Phase, Chirp Coded	Phase Coded	Orthogonal Sub-Carrier

AGENDA

- Automotive radar technology overview
- **Radar object simulation test challenges**
- The possibilities of benchtop radar sensor testing
- Practical demonstration
- Summary and learnings



TEST IMPLICATIONS OF TECHNOLOGY DEVELOPMENTS

- New frequency bands, modulation schemes, higher bandwidths and complex modulation schemes and MIMO
- L3 and beyond systems requires Virtual Integration and Vehicle-in-the-Loop validation
- Advanced tests during R&D of automotive radar sensors and testing of ADAS features require multiple dynamic artificial objects
- These artificial objects must be dynamic in terms of:
  - Distance
  - Size (Radar Cross Section – RCS)
  - Radial velocity (Doppler frequency shift)
  - Angular direction
- Higher levels of autonomous driving require multiple radar sensors in a single vehicle which have to be stimulated simultaneously

RADAR OBJECT SIMULATION CHALLENGES

Limitation of current laboratory test options
- OTA sensor stimulation required
- Limited scenario testing capabilities
- Azimuthal moving targets challenging to simulate

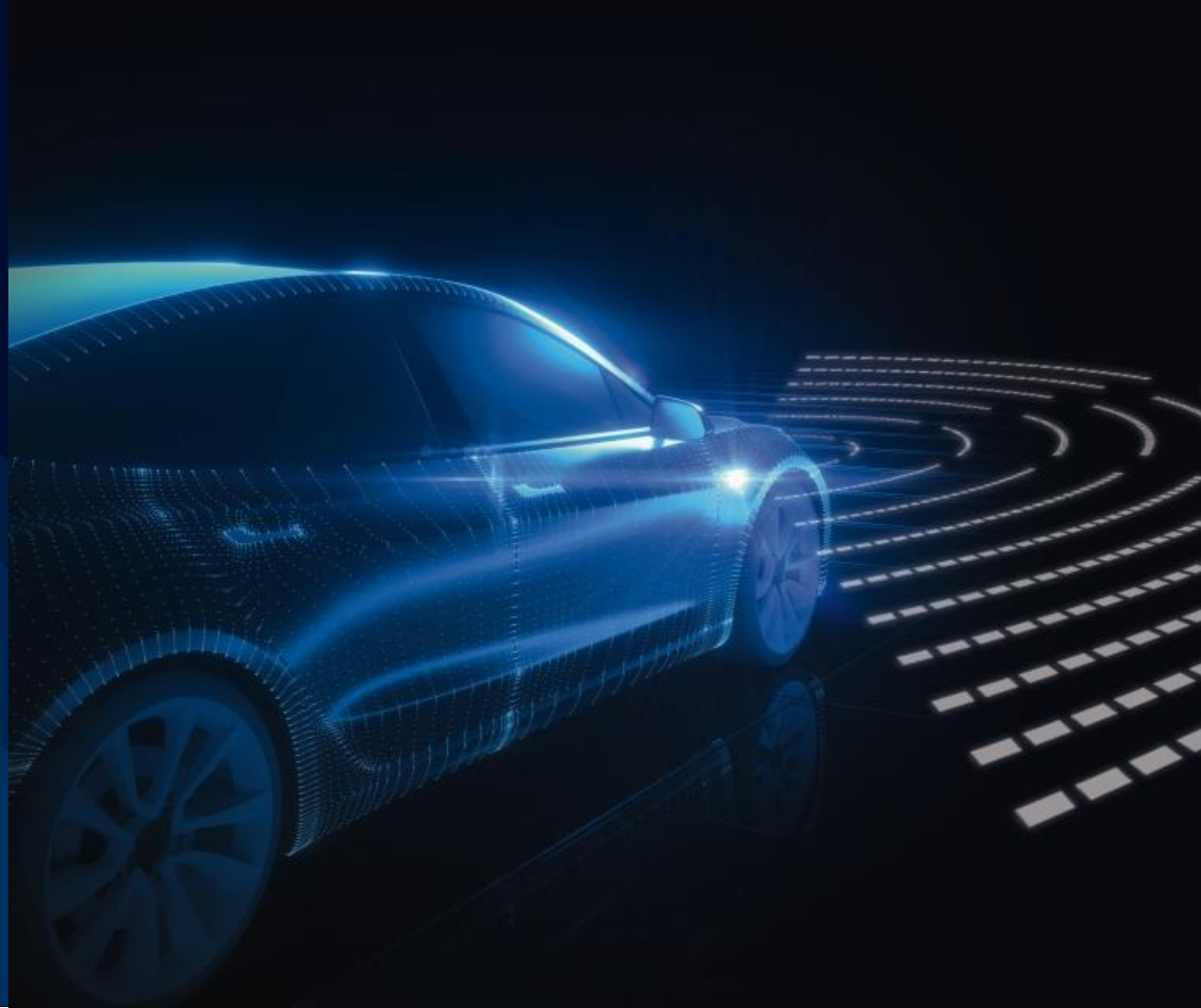
Reproducible and standardized testing
- Millions of test kilometers on test track
- Increased ADAS capabilities

Complex and time critical driving tests
- Limited test capability on public roads
- A roadworthy prototype is required

→ Historically bulky, expensive & inflexible test systems

AGENDA

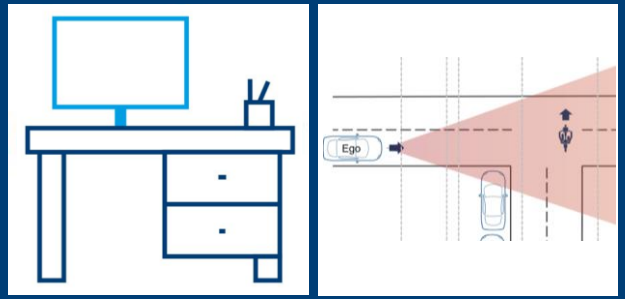
- Automotive radar technology overview
- Radar object simulation test challenges
- **The possibilities of benchtop radar sensor testing**
- Practical demonstration
- Summary and learnings



RADAR OBJECT SIMULATION
APPLICATIONS

Functional Testing

Benchtop & Scenario testing



Hardware-in-the-Loop

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

RADAR OBJECT SIMULATION
APPLICATIONS & SOLUTIONS

Functional Testing

R&S®QAT100

Benchtop & Scenario testing

R&S®AREG800A R&S®QAT100

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

FUNCTIONAL TESTING

Compact and efficient automotive radar testing

FUNCTIONAL TESTING

Echo detection

Azimuth estimation

Angular separation

SCENARIO TESTING

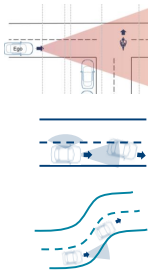
Compact and efficient automotive radar testing

EXEMPLARY DRIVING SCENARIOS

MATCHING 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.



ELECTRONICALLY STEERABLE FRONTEND FOR VERIFYING AUTOMOTIVE RADAR

R&S®QAT100
FRONTENDS 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

ADVANTAGES
R&S®QAT100 VS. MECHANICAL APPROACH

No mechanical movement

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

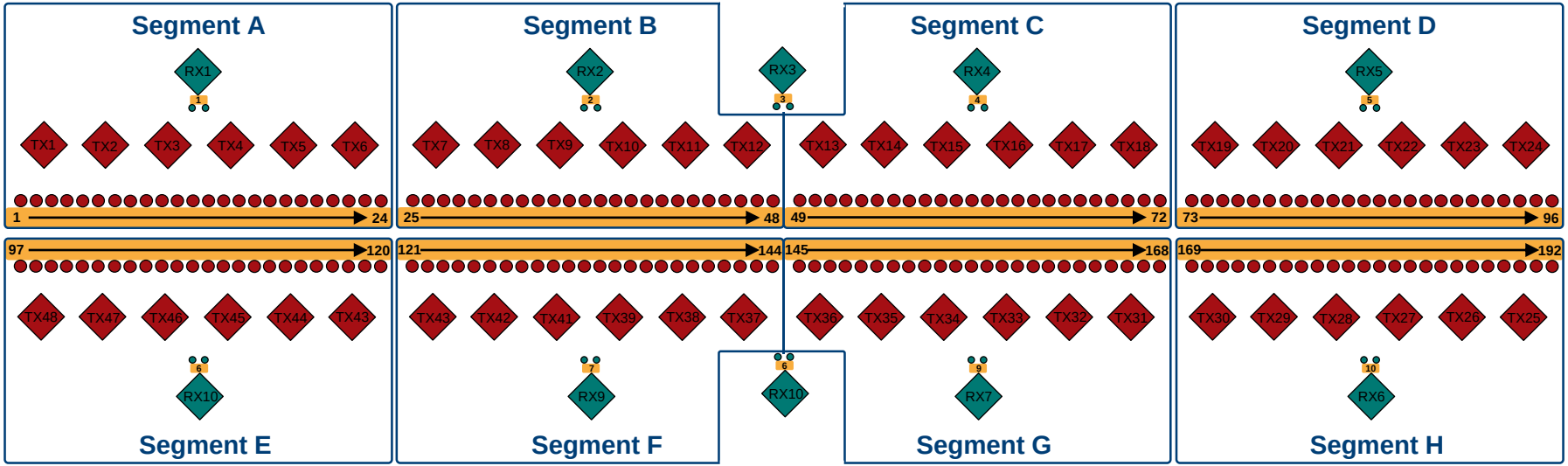
Scalable solution

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
QAT-B11 / -B2 ANTENNA NUMBERING

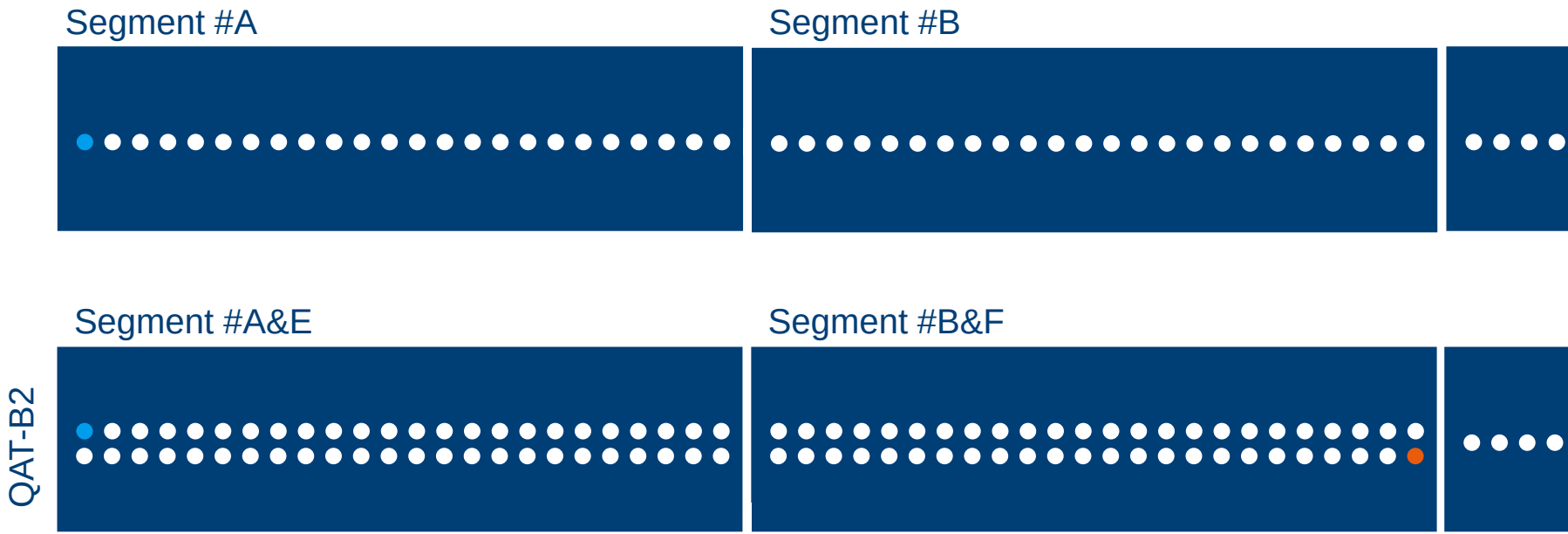


TeraTX circuit

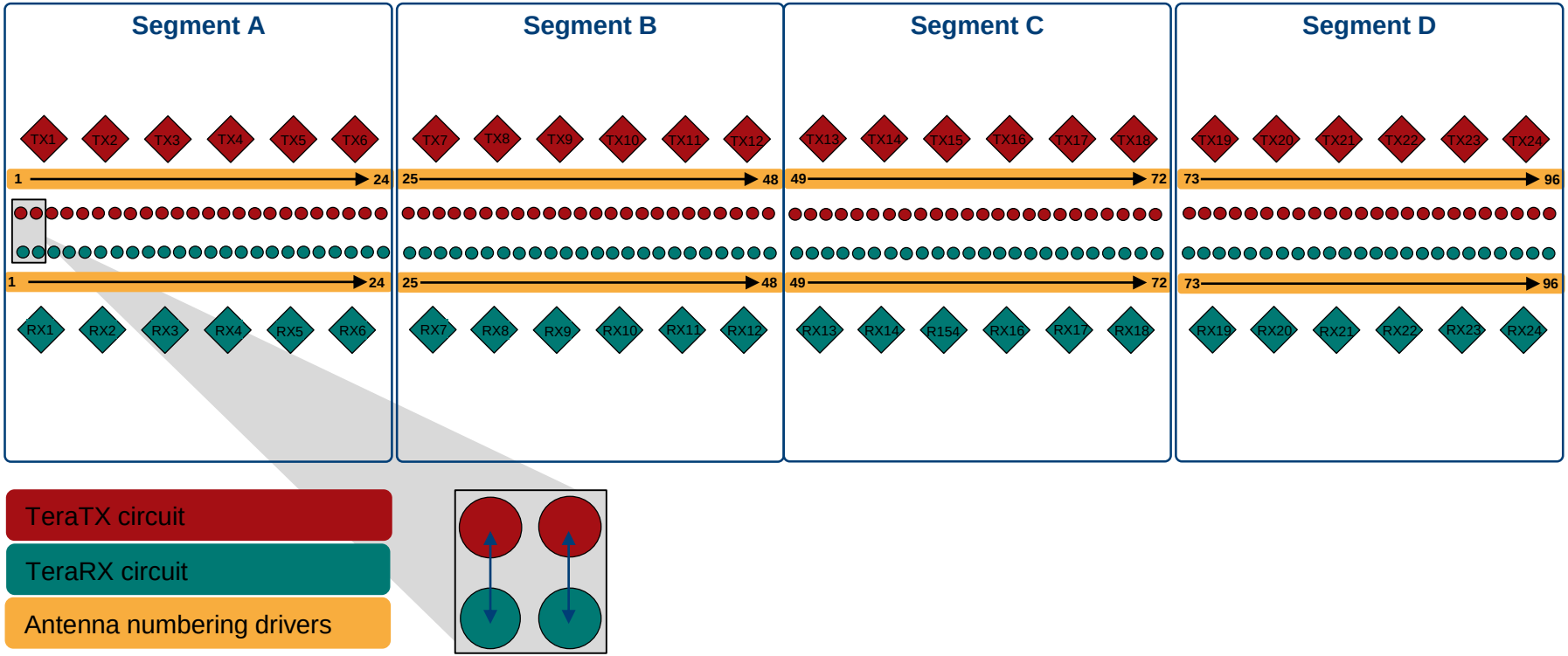
TeraRX circuit

Antenna numbering drivers

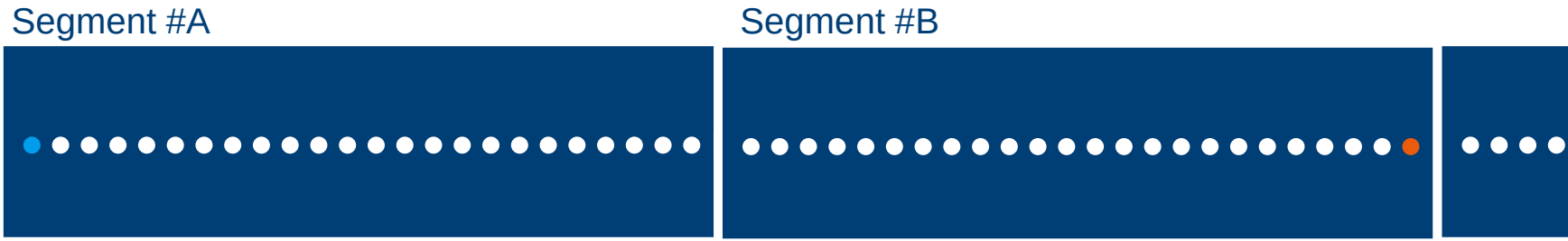
R&S®QAT100
QAT-B11 / -B2 SIMULATION



R&S®QAT100
QAT-B21 ANTENNA NUMBERING

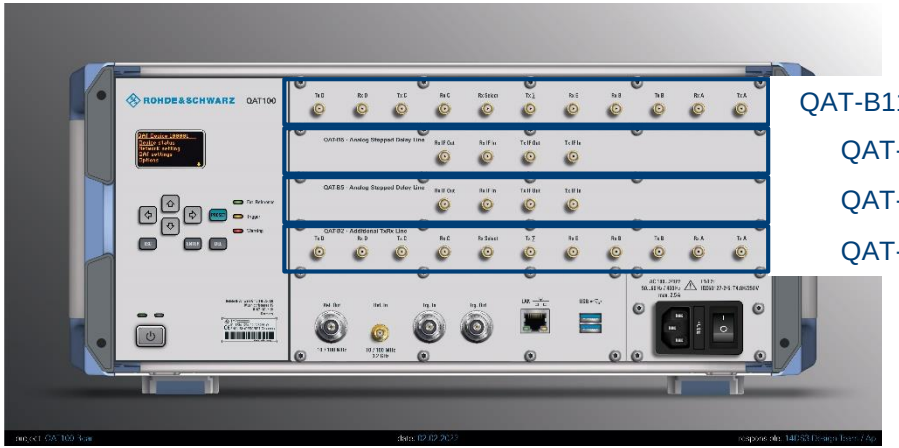


R&S®QAT100
QAT-B21 SIMULATION

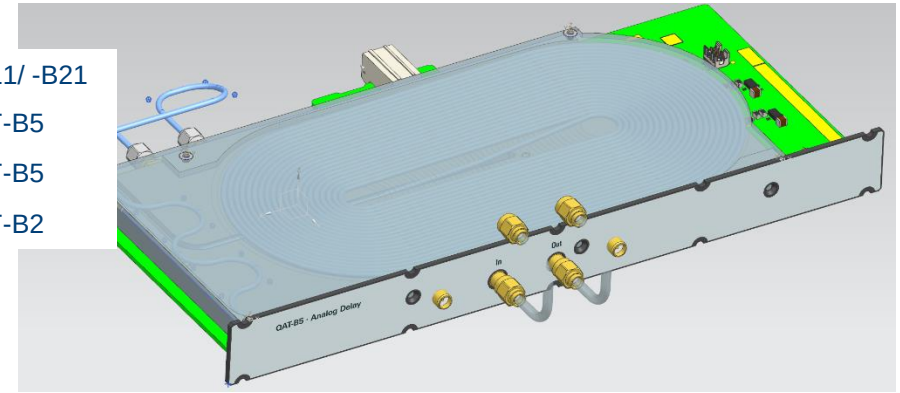


- Segment mode available
- Intersecting targets at certain positions

R&S®QAT100
EQUIPPED WITH QAT-B5 ANALOG STEPPED DELAY LINE



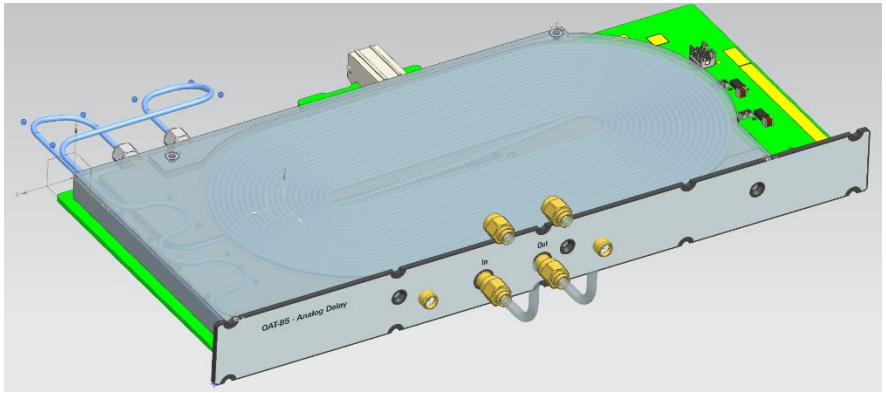
R&S®QAT100 with QAT-B11, QAT-B2 and 2x QAT-B5



R&S®QAT-B5 ASDL module

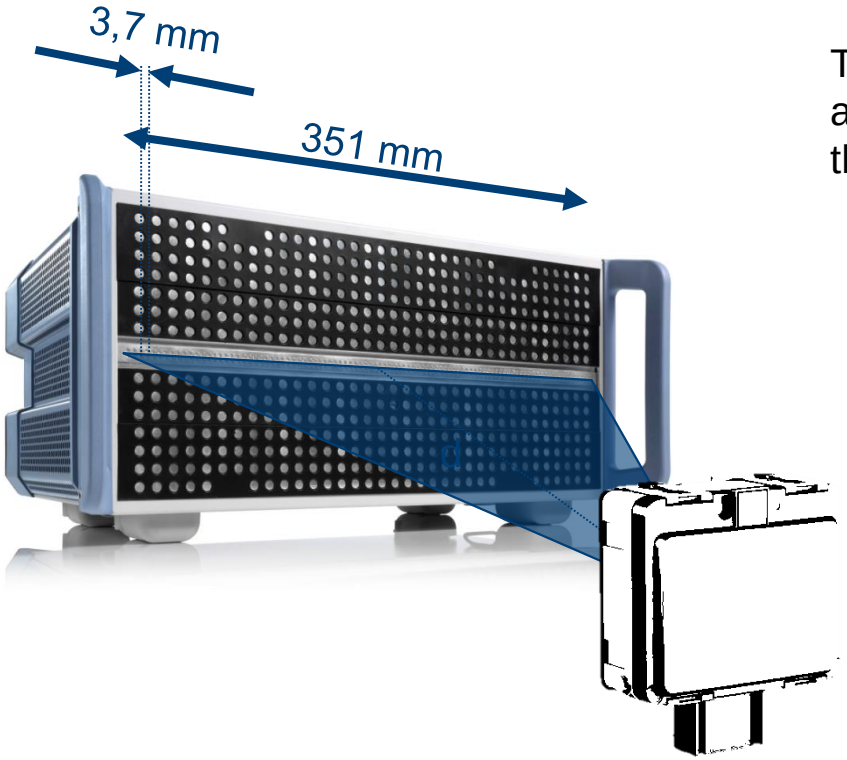
R&S®QAT100
EQUIPPED WITH QAT-B5 ANALOG STEPPED DELAY LINE

- Enables QAT100 „standalone-mode“
- Simulates echoes from ~2m … 13m (including 0.5m airgap)
- Extendable with fibre optic cables
- Supported step size 0.1m
- No Doppler simulation possible



R&S®QAT-B5 ASDL module

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:

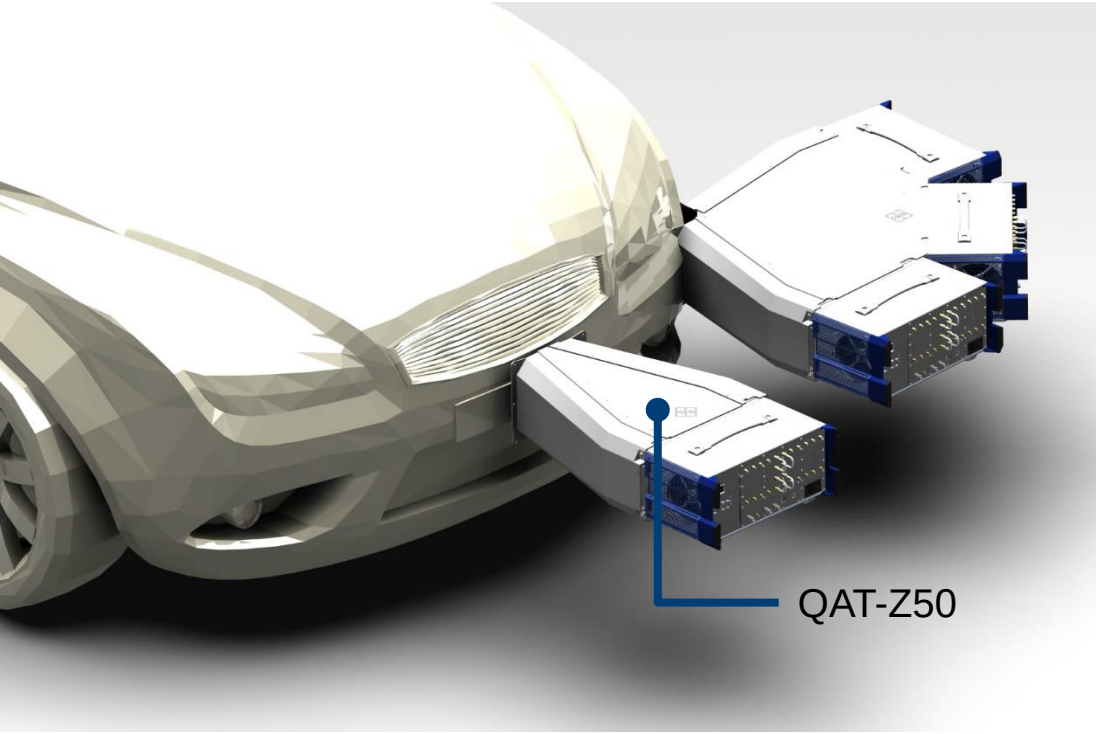
$$\alpha = 2 \cdot \tan^{-1}\left(\frac{351mm}{d}\right)$$

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

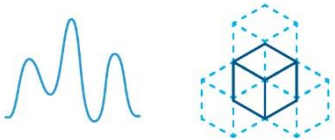


- **QAT-Z50 shielding system**
  - 50 cm long, 10° opening
  - Direct mounting kit for QAT
- **Challenges**
  - Car mounting kit respectively QAT stand in front of car
  - Customization based on e.g. CAD required

R&S®QAT100 FEATURES

Azimuth and elevation simulation
without mechanical movement
& immune to vibration

Extremely short distances
precise and repeatable

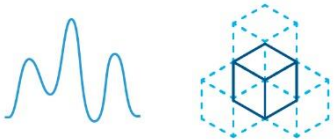


4GHz instantaneous bandwidth
across scalable FOV

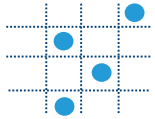
R&S AUTOMOTIVE RADAR TEST SYSTEM
R&S®QAT100 + R&S®AREG800A

Azimuth and elevation simulation
without mechanical movement
& immune to vibration

Extremely short distances
precise and repeatable



4GHz instantaneous bandwidth
across scalable FOV



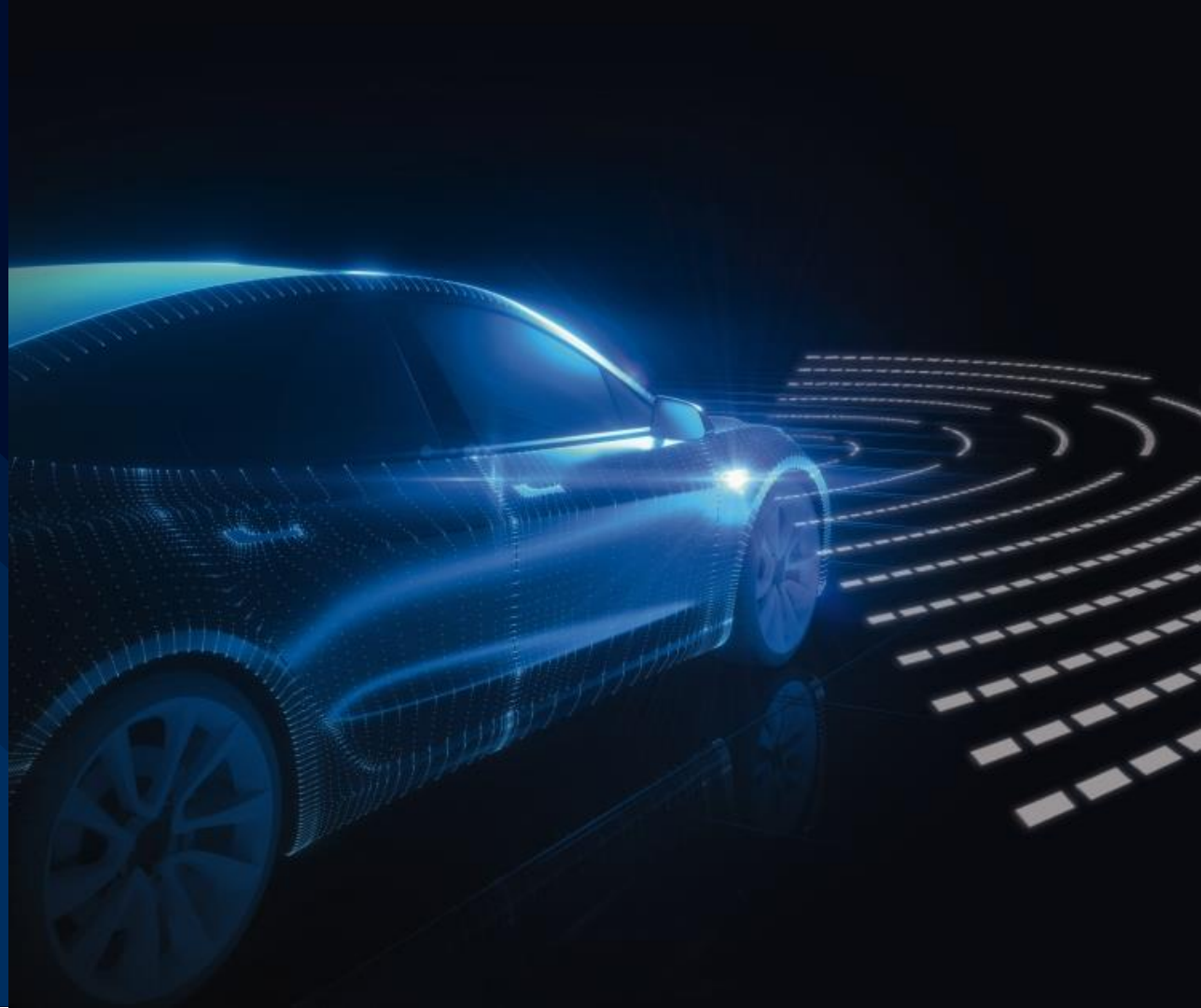
Multiple independent
dynamic objects

HiL interface via Open
Simulation Interface

Performance
optimized system

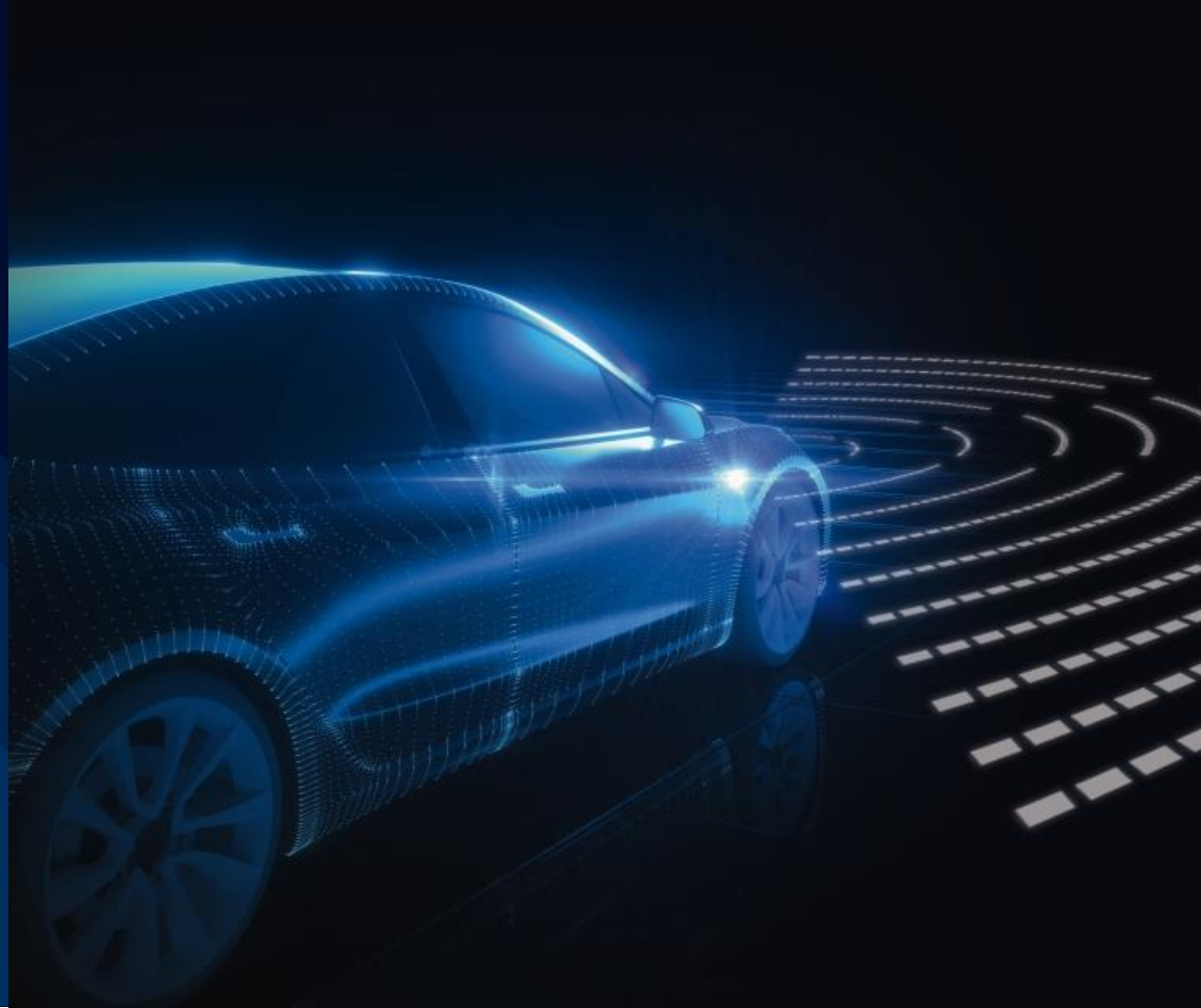
AGENDA

- Automotive radar technology overview
- Radar object simulation test challenges
- The possibilities of benchtop radar sensor testing
- **Practical demonstration**
- Summary and learnings



AGENDA

- Automotive radar technology overview
- Radar object simulation test challenges
- The possibilities of benchtop radar sensor testing
- Practical demonstration
- **Summary and learnings**



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
- Need for complex moving object scenarios to be emulated in a lab environment but also for functional verification testing
- New possibilities for benchtop testing using standalone electronically-steered antenna arrays
  - Expandable to 360^0 complex traffic scenario test systems for sensor development, HiL and ViL with addition of radar echo generator
- Future increased testing requirements at functional and ADAS application level


Find out more
www.rohde-schwarz.com/automotive/radar
Automotive
TEST IT. TRUST IT.

Find out more

www.rohde-schwarz.com/automotive/radar

ROHDE&SCHWARZ

Make ideas real