

Reliable and simple testing of automotive radar sensors

Automotive Technology Day

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Product Manager Signal Generators – A&D, Automotive, Components

Automotive Radar Testing

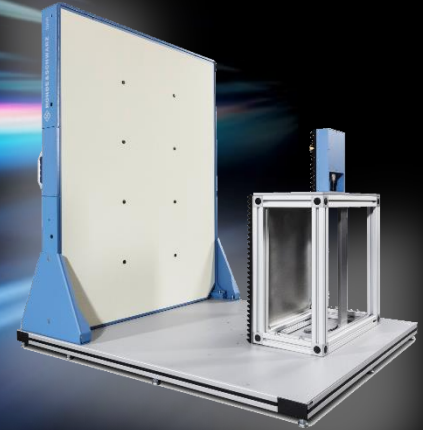
Target Generation



Interference Testing



Radome Testing



Signal Analysis



Agenda

- Automotive radar – Evolution, trends and challenges
- Solution for testing automotive radar sensors – R&S®AREG100A
 - Radar echo generation principle
 - Key facts and technical insights
- Over the air and conducted testing of automotive radar sensors
- Automotive radar sensor validation – Compliance to applicable standards



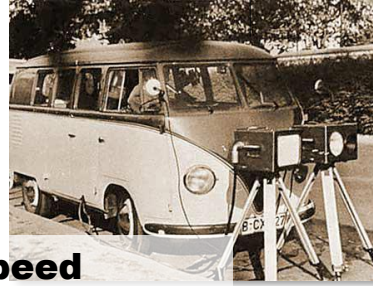
Automotive radar

Evolution, trends and challenges



Radar?

- Measurement of
 - Range
 - Radial Velocity
 - Azimuth Angle
 - Elevation Angle
- Object Properties
- e.g. size, class



**Speed
enforcement**



**Air Traffic
Control (ATC)**



Weather



Imaging



**Tracking and
localization**



Automotive

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

RADIO SERVICES COLOR LEGEND

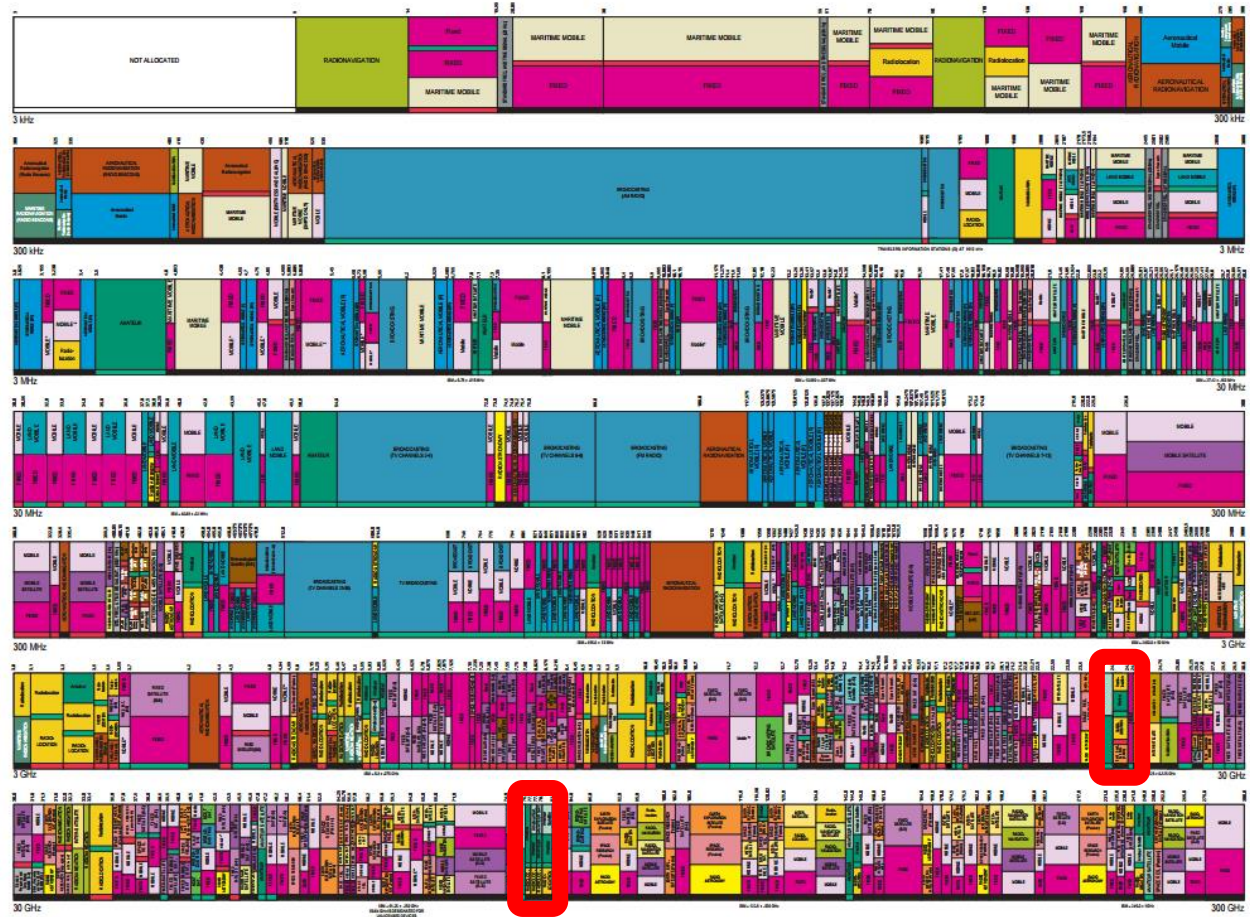
AERONAUTICAL MOBILE	INTER-SATELLITE	RADIOFREQUENCY
AERONAUTICAL MOBILE SATELLITE	LAND MOBILE	RADIO-TERMINATION SATELLITE
AERONAUTICAL RADIO-NAVIGATION	LAND MOBILE SATELLITE	RADIOLOCATION
AMATEUR	MARITIME MOBILE	RADIOLOCATION SATELLITE
AMATEUR SATELLITE	MARITIME MOBILE SATELLITE	RADIO-NAVIGATION
BROADCASTING	MARITIME RADIO-NAVIGATION	RADIO-NAVIGATION SATELLITE
BROADCASTING SATELLITE	METEOROLOGICAL AERIAL	SPACE OPERATION
EARTH-ORBITATION SATELLITE	METEOROLOGICAL SATELLITE	SPACE RESEARCH
FIXED	MOBILE	STANDARD-FREQUENCY AND TIME SIGNAL
FIXED SATELLITE	MOBILE SATELLITE	STANDARD-FREQUENCY AND TIME SIGNAL SATELLITE

ACTIVITY CODE

GOVERNMENT EXCLUSIVE	GOVERNMENT/NOT-GOVERNMENT SHARED
NON-GOVERNMENT EXCLUSIVE	

ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	F1000	Channel 1000
Secondary	M000	For Control with Lower Class Intents



Automotive Radar Evolution



First automotive radar in
1978



Technical University
Hamburg-Harburg
1999

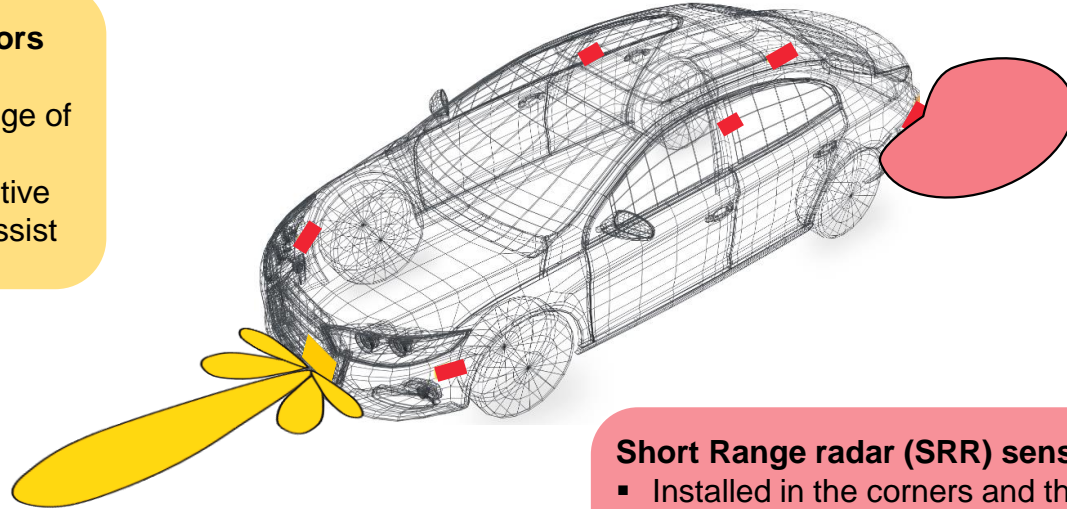


today

The situation

Long Range Radar (LRR) sensors

- Installed in the front of a car
- Used to detect objects at a range of 200 m and beyond
- Provide services such as adaptive cruise control and traffic jam assist



- potential installation point of SRR sensors
- potential installation point of LRR sensor

Short Range radar (SRR) sensors

- Installed in the corners and the B pillars of a car
- Provide services such as blind spot detection and lane change assist
- Form a 360° radar cocoon around the car

The trends

Bandwidth increases up to 4 GHz in the 79 GHz band

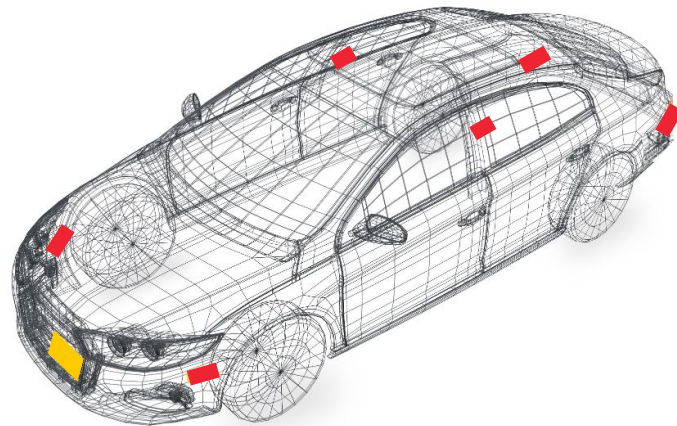
- Recognize and resolve objects in ultra short range
- Frequency hopping within automotive band to avoid mutual interference

More complex and powerful sensor technology

- Sensors e.g. LRR will use MIMO technology
- Advanced beamforming algorithms will help to provide better angular resolution
- Detailed and accurate imaging of the scenery especially for autonomous driving will become possible

Increase of number of radar sensors

- Interfering signals originate from transmit signals from oncoming traffic
- Mutual interference and interference from multipath



- potential installation point of SRR sensors
- potential installation point of LRR sensor

Our solution for testing of automotive radar sensors

The R&S®AREG100A for production testing and validation of automotive radar sensors

Automotive radar sensor production tester with E-band front end



Automotive radar sensor production tester with 24 GHz ISM band front end



19"
3 height
units



24 GHz
or
77 / 79 GHz



Automotive radar
sensor
(regular operation mode)



Radar Signal



Echo Signal



Our solution

Key facts of the R&S®AREG100A production tester

#ProductionTester#Flexible#Simple

- 4 meter minimum object distance incl. air gap of 80 cm
- Flexibility with up to 4 independent echoes from 4 independent fixed objects
- Define fixed delay at time of order
- Configure RCS of objects as required
- Additional Doppler offsets for radial velocity

#Futureproof#SaveInvest

- 24 GHz ISM band front end
- E-band frontend from 76 GHz – 77 GHz
- Wideband E-band front end from 76 GHz – 81 GHz *)
- For any FMCW or I/Q modulated radar signal
- Single antenna or two antenna front ends
- Use 24 GHz front ends or E-band front ends with same base unit

*) under development

#RED#Ready#CostOptimized

- Calibrated IF input / output ports
- Measure EIRP with a connected NRP8S(N) power sensor
- Use any analog or vector signal generator up to 6 GHz to impose interferences onto the wanted echoes
- Share the AREG front ends for up/down conversion to E-band or ISM band
- Easy testing without extra mmW T&M equipment

#Stability#UserFriendly

- Linux-based operating system for maximum software stability
- Optimized for minimal footprint of just 3 HU
- Intuitive GUI for user-friendly operation



Over the air testing of automotive radar sensors









Solution for testing of automotive radar sensors

R&S®AREG100A – Principle, key facts, technical insights



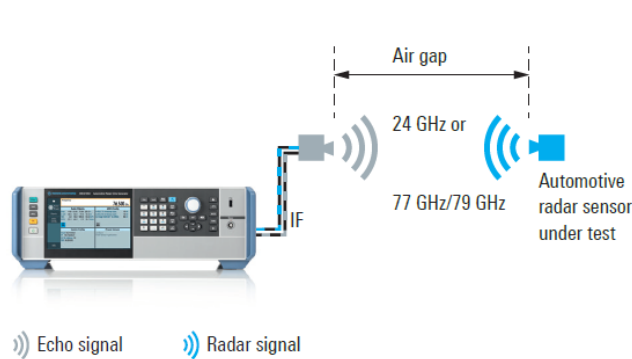
Solution for testing of automotive radar sensors

Typical performance indicators for automotive radar sensors	Testable with R&S®AREG100A (+ add. T&M equipment)?	Additional T&M equipment
Probability of detection and dynamic range		-
Range, Az., El. and Doppler accuracy		-
EIRP (transmit power level)		Power meter
Occupied bandwidth (OBW) and spectral masks		Spectrum analyzer or Oscilloscope
Az. and El. scan coverage		Positioner
Az. and El. antenna pattern		Positioner and power meter
...		

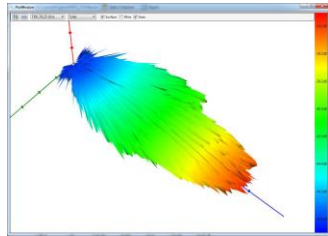


Easy validation and End-of-line testing of radar sensors

Ensure continuous product quality control at end of production line



Band	24 GHz ISM, 76-77 GHz, 76-81 GHz
Distance	4m, 5 m - 300 m, all incl. 80 cm air gap
Delay	Define when ordering

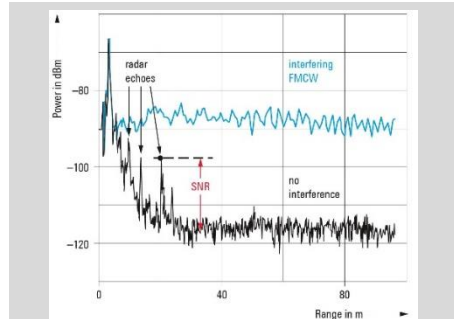


AREG and test system configuration:

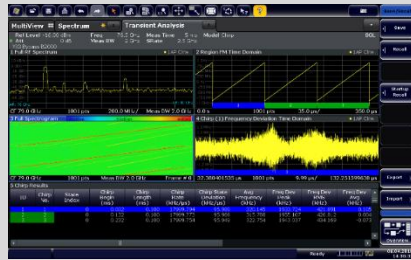
- Select up to 4 fixed delays and configure velocity together with RCS of artificial objects
- Configure test case for different OEMs
- Sensor passes if detected range, Doppler and RCS are within the test limits
- Fast and simple definition of test routines thanks to the R&S®QuickStep test executive software
- Shielded environment for reproducible testing

Easy validation and End-of-line testing of radar sensors

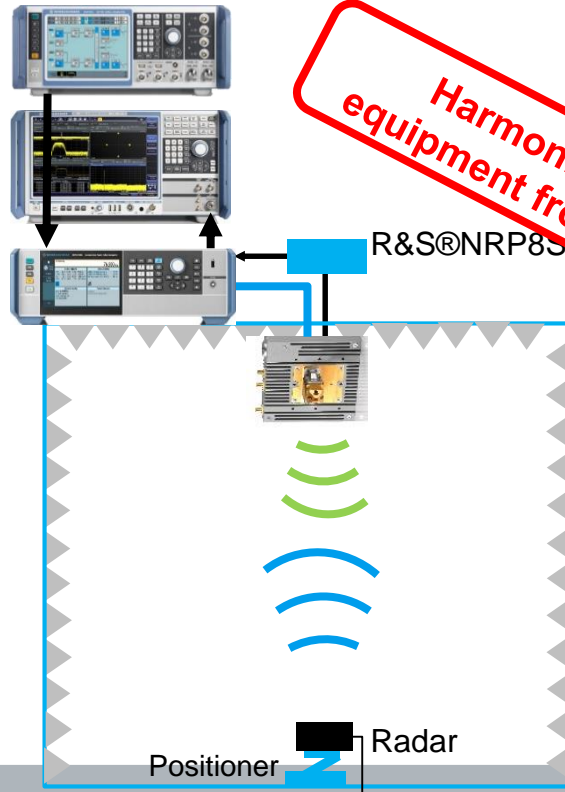
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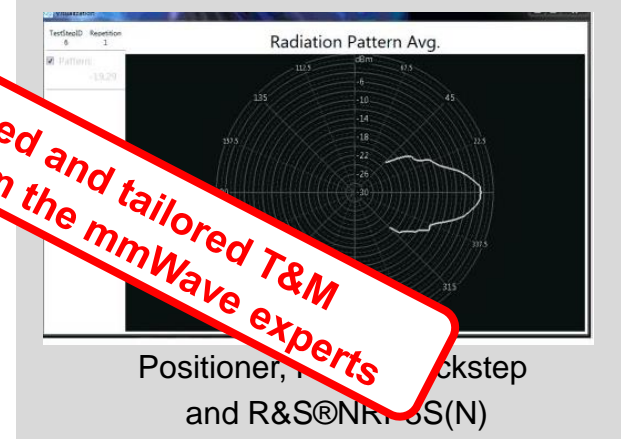
R&S®SMW200A
Vector signal generator



R&S®FSW8
spectrum analyzer



R&S®ATS1500
shielded chamber

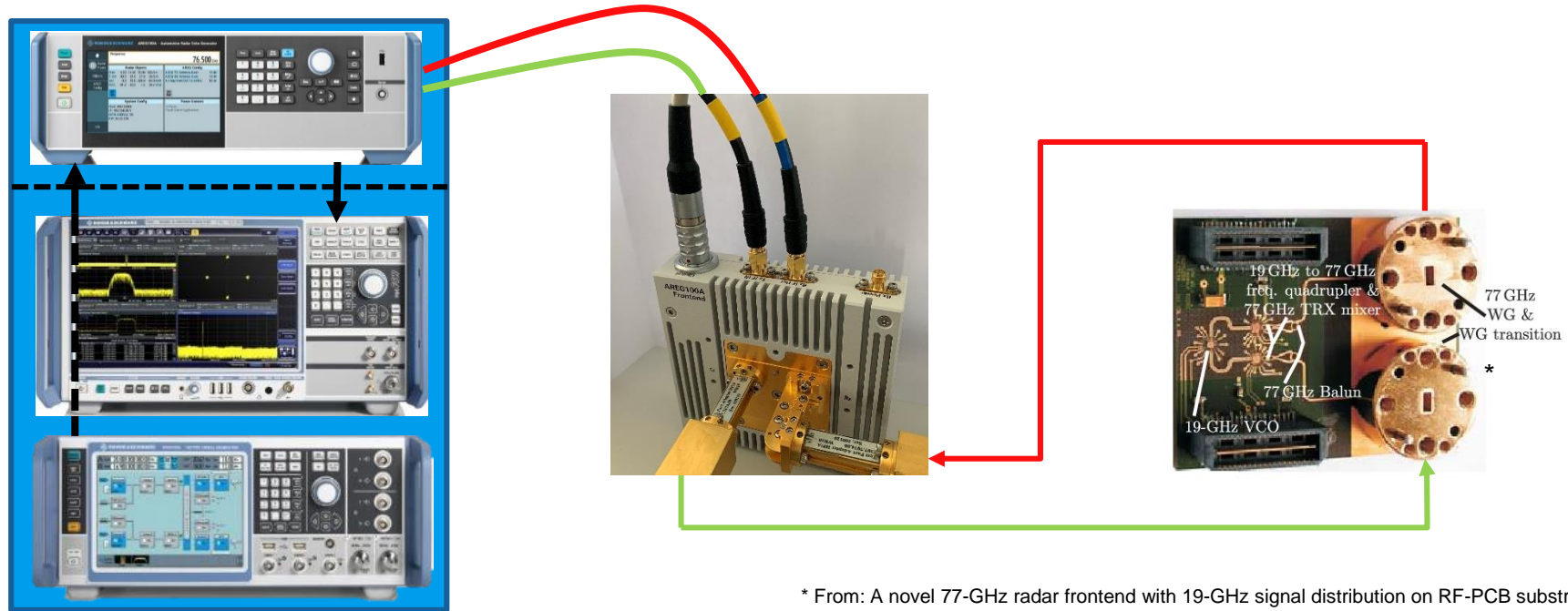


Conducted testing of automotive radar sensors



Easy validation and End-of-line testing of radar sensors

Conducted chipset testing

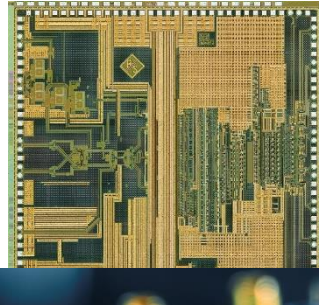


* From: A novel 77-GHz radar frontend with 19-GHz signal distribution on RF-PCB substrate
F. Starzer, H. Forstner, C. Wagner, R. Feger, S. Scheiblhofer, A. Fischer, H. Jager, A. Stelzer
Published in IEEE Radio and Wireless Symposium (RWS)

Easy validation and End-of-line testing of radar sensors

Conducted chipset testing with the R&S®AREG100A– a perfect match

- Conducted measurement for radar chipset testing – directly connect the waveguide ports to the DUT
- Key performance indicators for required T&M equipment - the RF performance:
 - Low phase Noise
 - No / Very low “harmonics”
 - Good VSWR
 - Good frequency response over the whole instantaneous bandwidth



The R&S®AREG100A is the perfect solution for



Automotive radar sensor validation

Compliance to applicable standards



RED – Radio Equipment Directive in terms of automotive radar

The Radio Equipment Directive (2014/53/EU) establishes a regulatory framework for placing radio equipment on the market. It is **mandatory** since June 2017 in Europe.

Important in context of automotive radar (but not limited to):

ETSI EN 303 396	(Short Range Devices – Meas. Techniques for Automotive Radar)
ETSI EN 302 858	(Short Range Devices – Radar Eq. in the 24-24.25GHz range)
ETSI EN 301 091-1/2	(Short Range Devices – Radar Eq. in the 76-77GHz range)
ETSI EN 302 264	(Short Range Devices – Radar Eq. in the 77-81GHz band)

Tests required:

Receiver Conformance	Transmitter Conformance
<ul style="list-style-type: none">- Spurious emissions- In-band signal handling (receiver robustness against interferers)- Out-of-band signal handling	<ul style="list-style-type: none">- OBW- Power level- Unwanted emissions (out-of-band and spurious)



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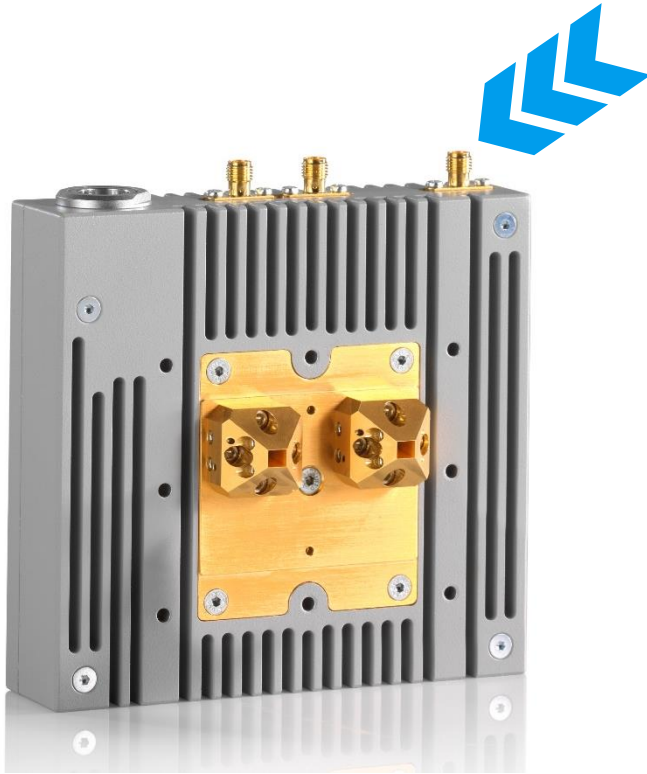
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Accurately measure the sensor's transmit power and EIRP

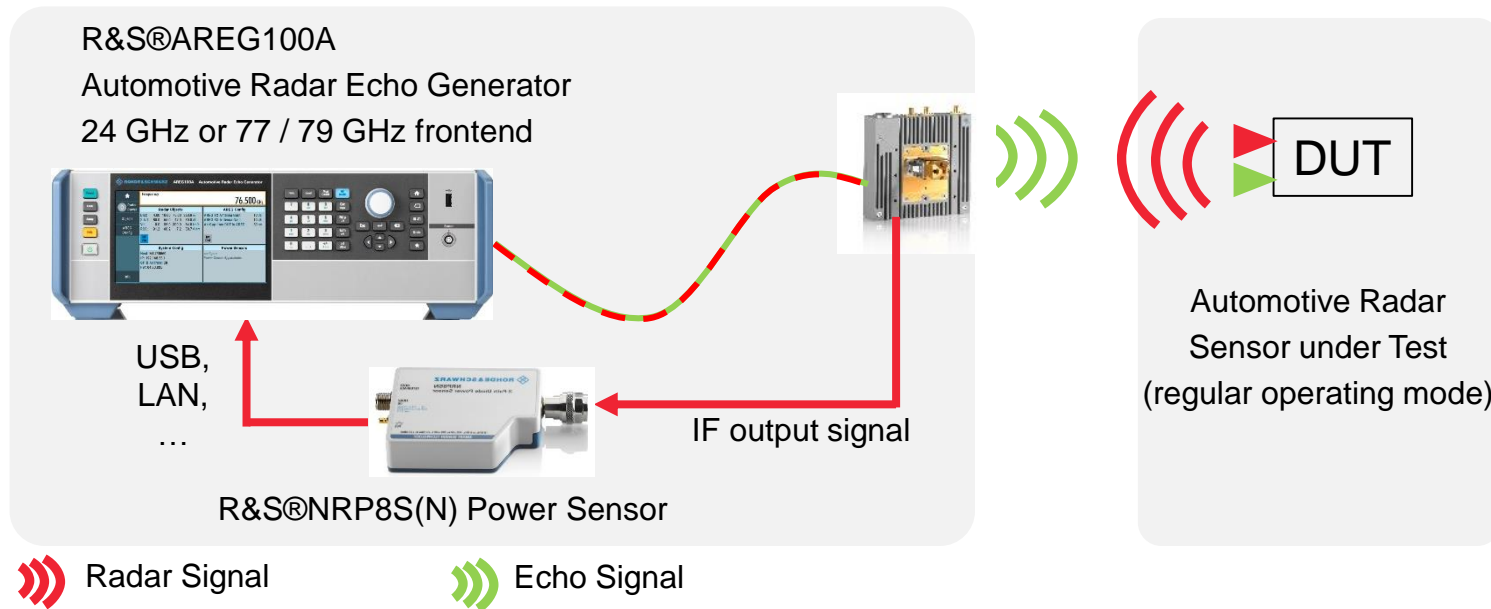
Comply to the Radio Equipment Directive and exploit the maximum EIRP



- Connect a power sensor with upper frequency limit of 6 GHz
- The AREG front end takes care of the down conversion from the ISM- or E-band into the IF band (0.7 GHz – 4.7 GHz)
- Receive path from front end to I/F output port is calibrated
- Read the measured EIRP of the radar sensor directly at the GUI of the AREG base unit

Accurately measure the sensor's transmit power and EIRP

Comply to the Radio Equipment Directive and exploit the maximum EIRP



Accurately analyze the automotive radar sensor's transmit signal

Comply to the Radio Equipment Directive and optimize sensor performance

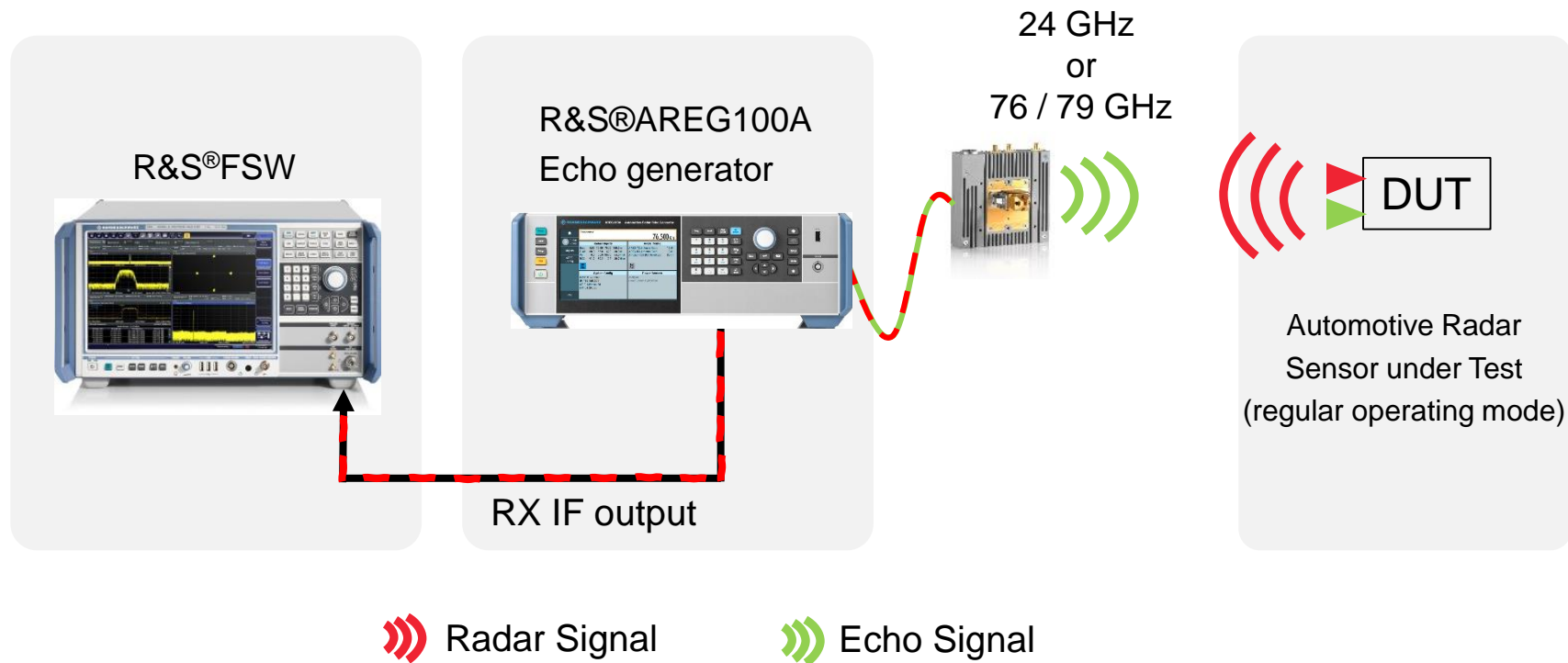
Radar signals analysis – key parameters:

- Occupied Bandwidth
- Chirp linearity
- Chirp duration
- ...



Accurately analyze the automotive radar sensor's transmit signal

Comply to the Radio Equipment Directive and optimize sensor performance





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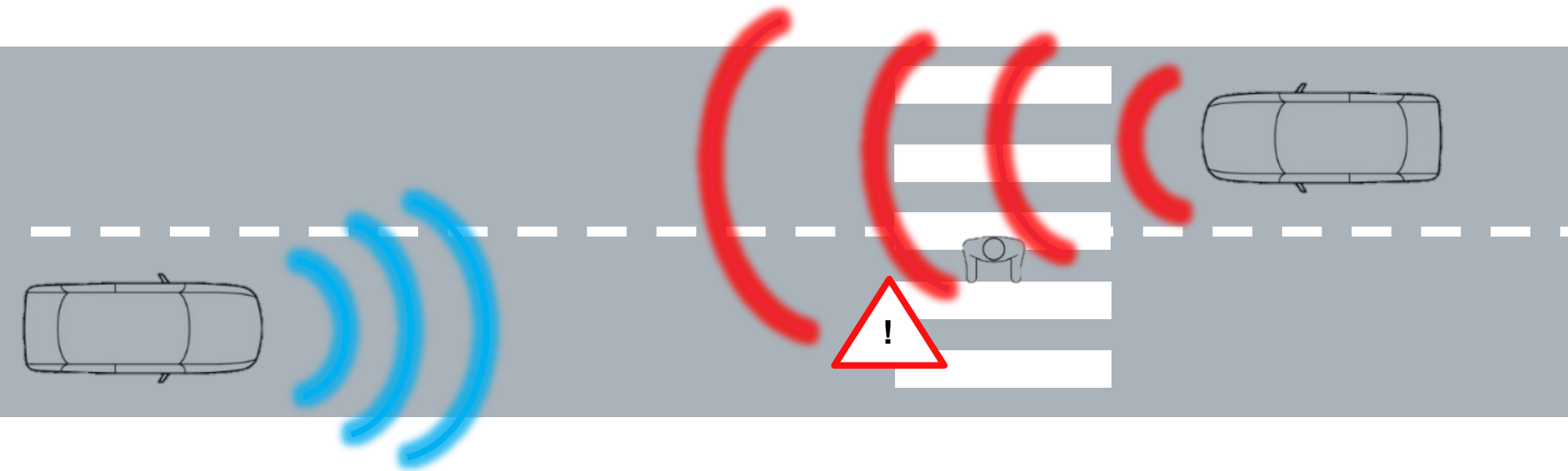


Automotive radar sensor validation

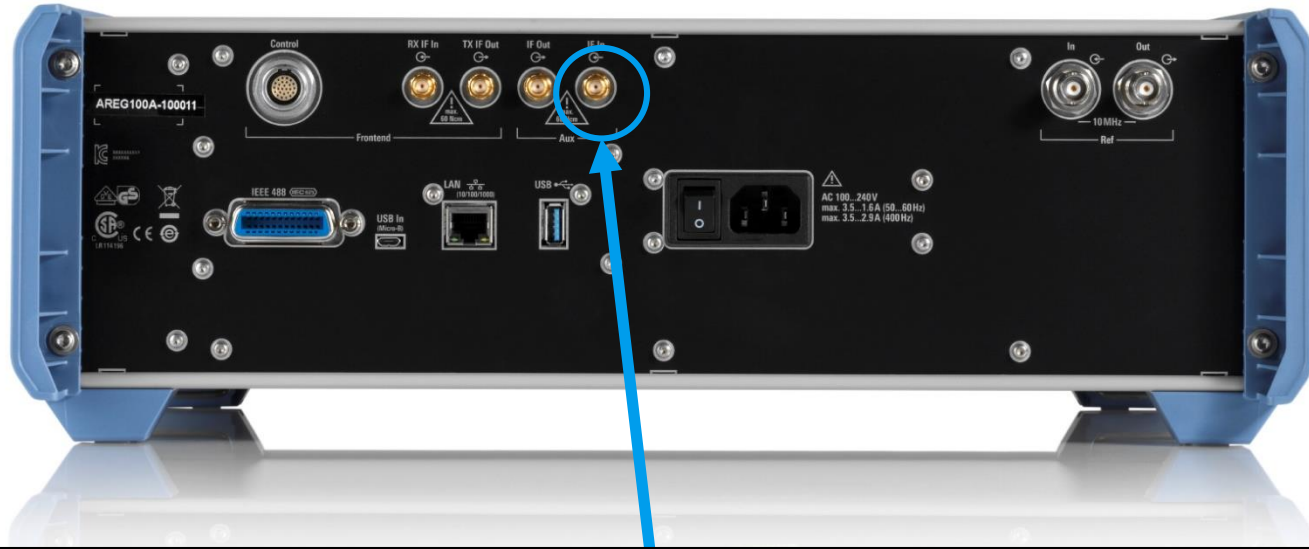
Testing the robustness of automotive radar sensor's to interferers



The challenge

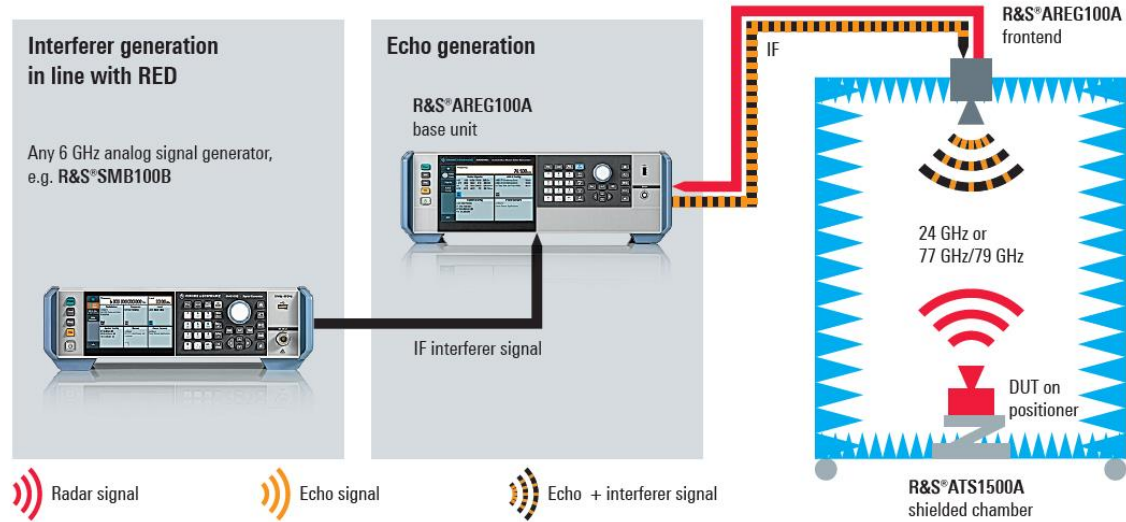


R&S®AREG100A – IF interferer input port



- Connect any Analog or Vector Signal Generator with an upper frequency limit of 6 GHz
- The AREG takes care of the upconversion in the ISM- or E-band
- In band interferers in the E-band can be realized with interferer power levels of up to 18 dBm!

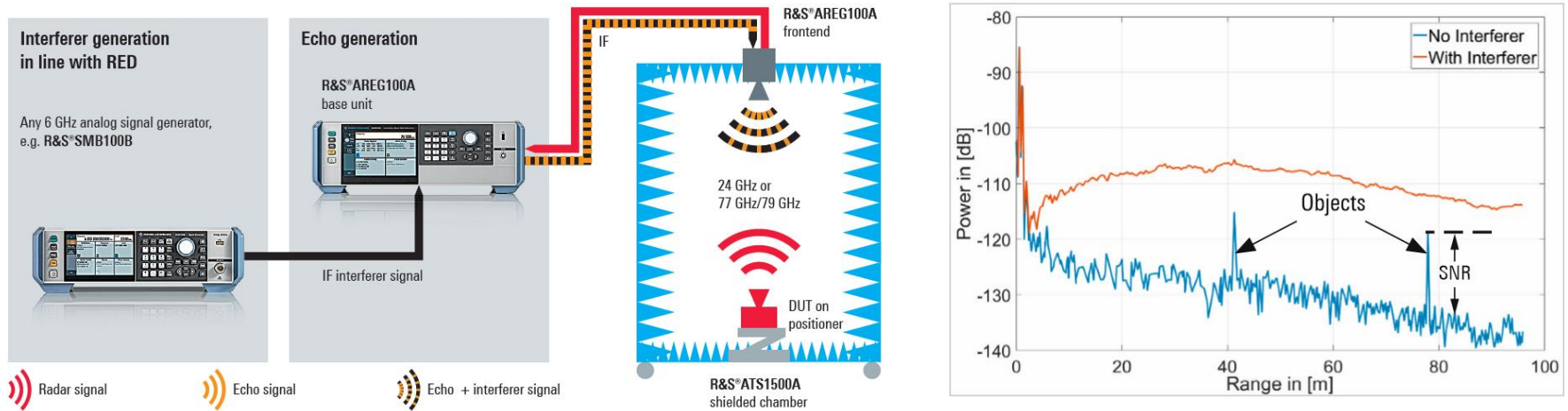
Simulate interference in line with RED



- Connect any analog or vector signal generator up to 6 GHz to the AREG I/F input port
- Impose interferes onto the wanted echoes and share the AREG frontend for up conversion for both signals
- Cost optimized and simple solution for simulation of wanted echoes together with interferers

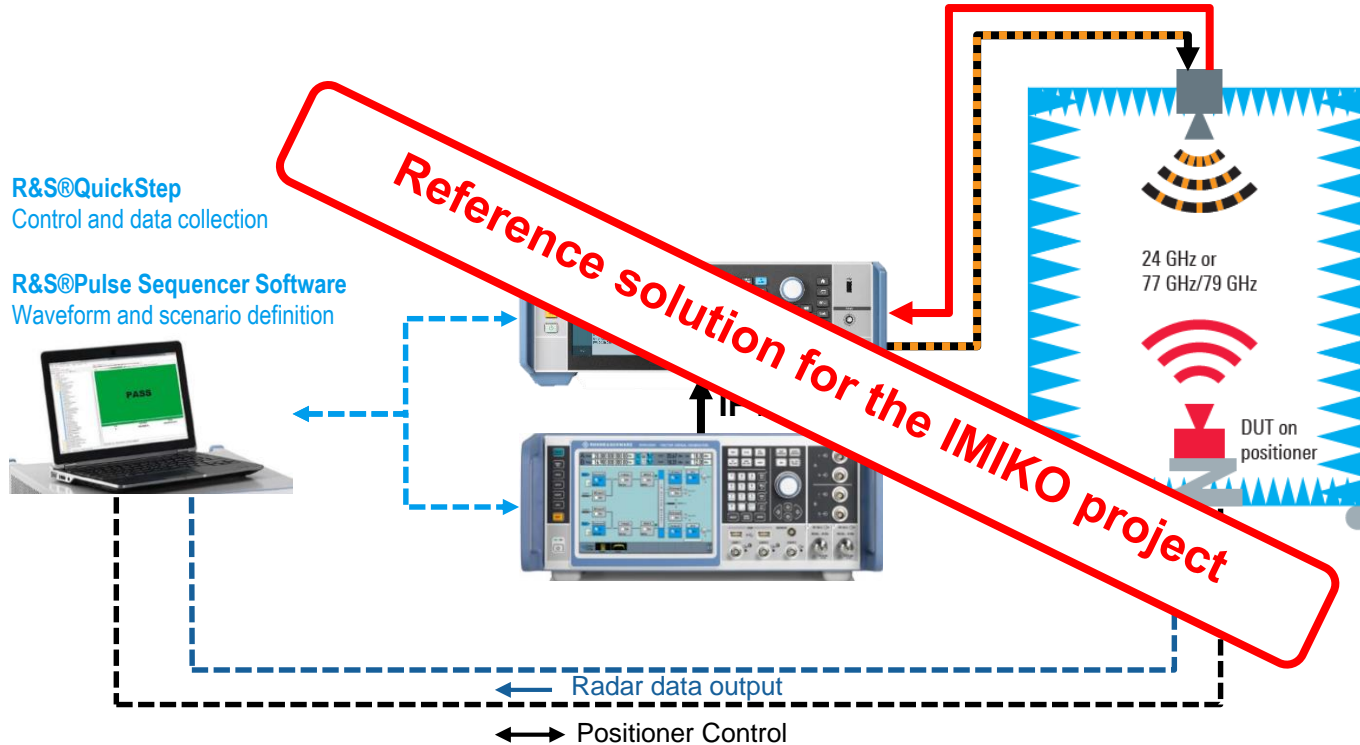


Simulate interference in line with RED

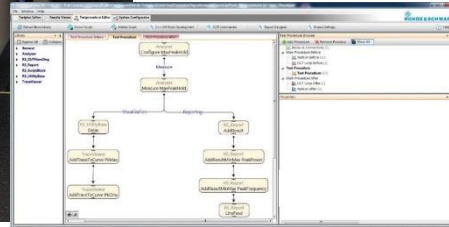
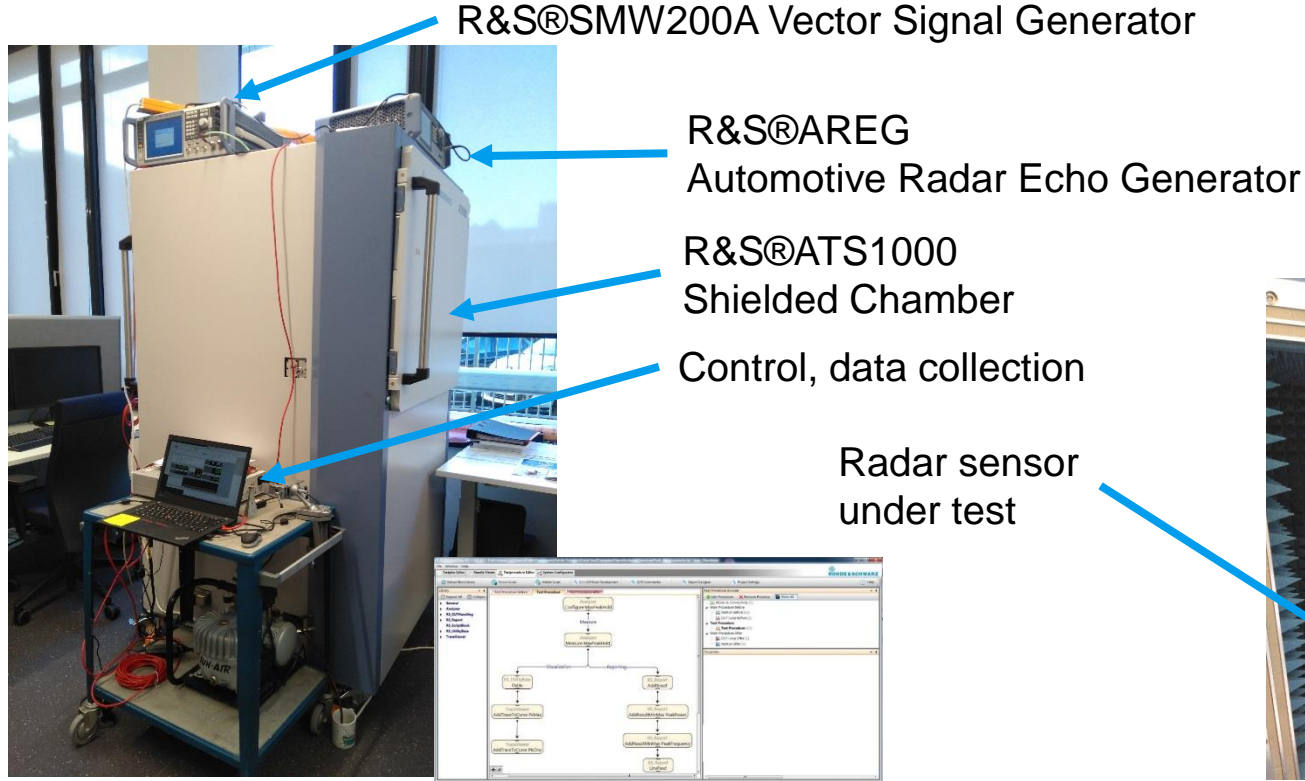


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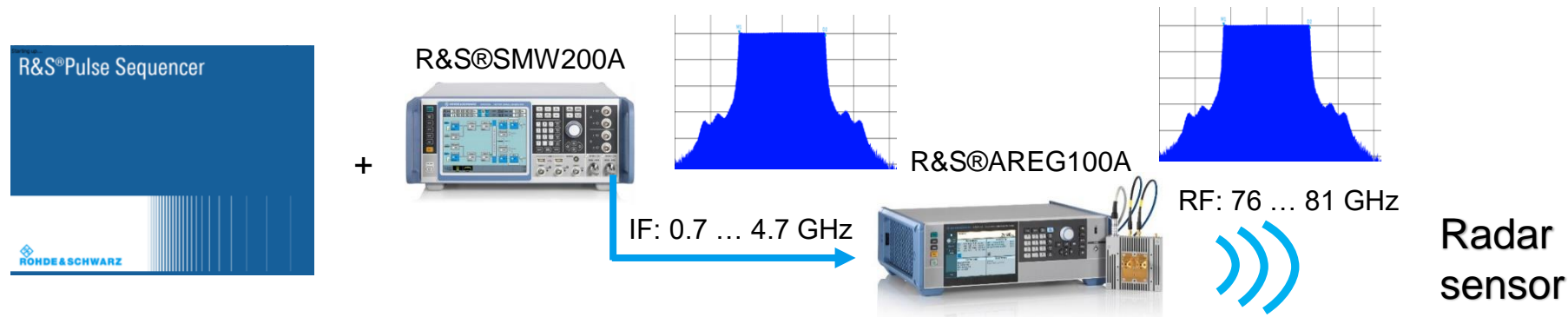
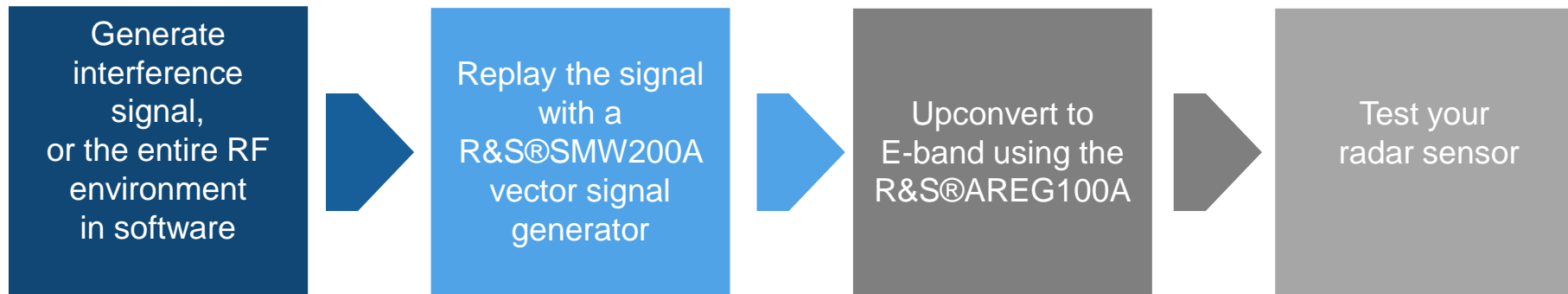
Simulation setup for advanced interference scenarios



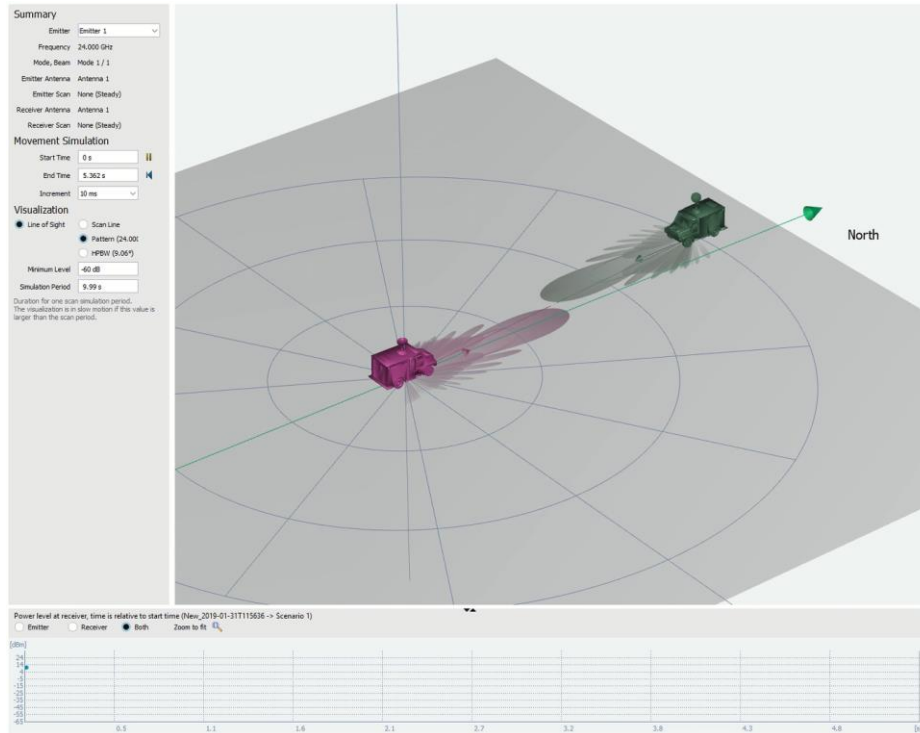
Simulation setup for advanced interference scenarios



Advanced interferer generation – Flow chart



Extension to realistic street scenario



The R&S®Pulse Sequencer can generate realistic scenarios, including but not limited to following parameters:

- Antenna patterns
- Any IQ modulated waveforms
- Driving tracks
- Velocities and accelerations
- Hopping
- ...

Harmonized portfolio for all applications

R&S is your one stop shop partner for T&M solutions in the automotive radar world



R&S®ATS1500A shielded chamber



R&S®FSW8 Signal and Spectrum Analyser



R&S®SMW200A
Vector Signal Generator



R&S®NRP8S(N)
Power Sensors

Automotive radar technology, market and test requirements

White paper

Download from R&S website:
www.rohde-schwarz.com

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Summary and take aways

Automotive radar sensors have to be comprehensively tested, because...

- RED framework requires testing key parameters:

- Occupied bandwidth
- EIRP
- Sensor robustness



- it is necessary in production to ensure a continuous product quality of safety relevant sensors



Automotive Radar Testing

Target Generation



Interference Testing

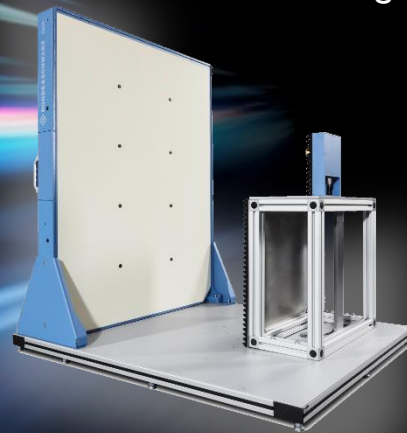


Thank you!

Signal Analysis



Radome Testing



BU P

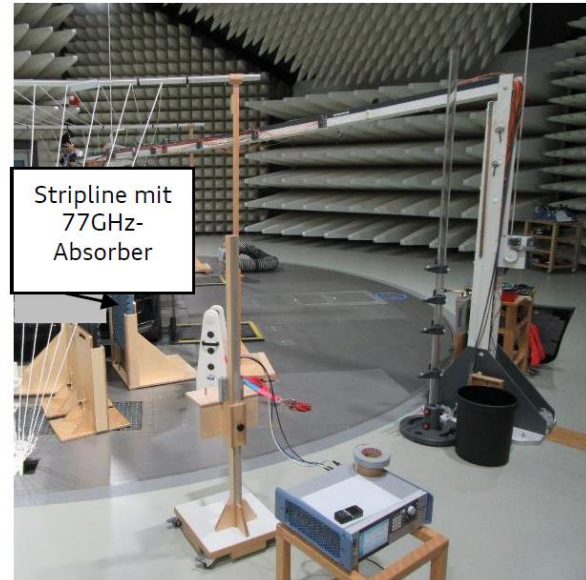
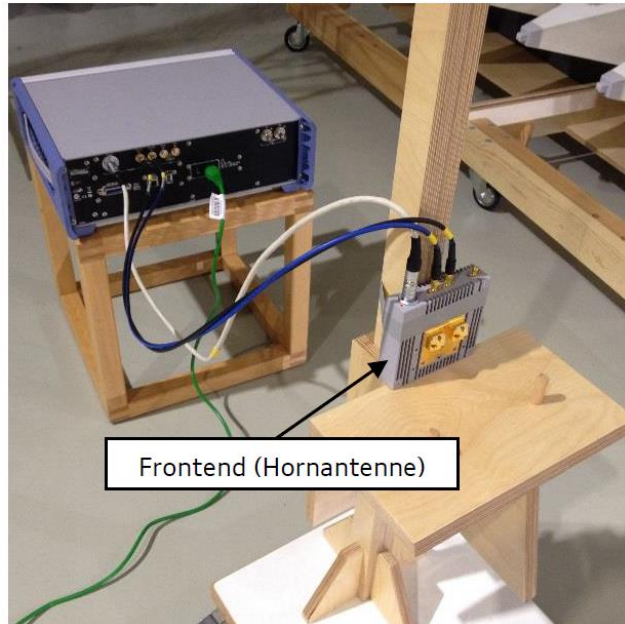


AREG - EMC environments

- New ISO Standard ISO11451-2 planned – Testing radar sensor during EMC certification will be mandatory
- EMC frequency range: 100 kHz – 6 GHz; Field strengths (160 V/M; peaks up to 200 V/m)
- Typically 3 indicators will be checked:
 - Phantom detection – Another object appears beside the reference object during exposure to E field
 - Object loss – Sensor loses reference object
 - Freezes – Scenario freezes during exposure to E field
- Important parameter for the reference object: Stability (RCS, distance and radial velocity)



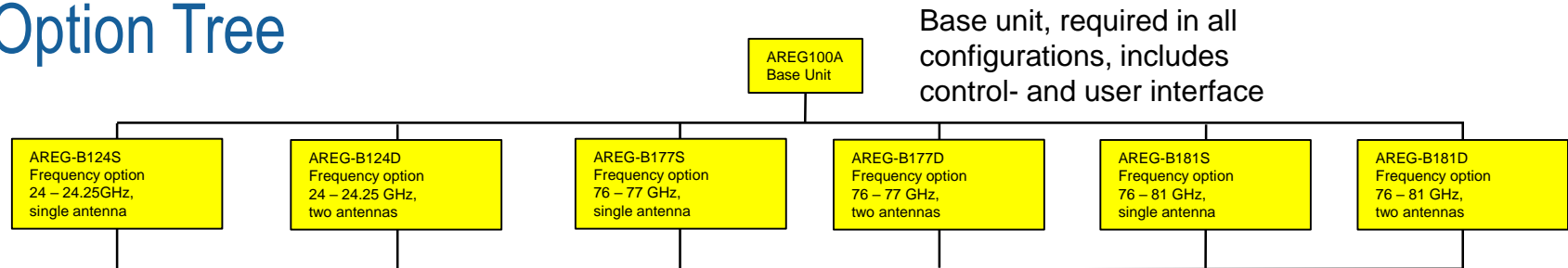
AREG - EMC environments



Configuration



Option Tree

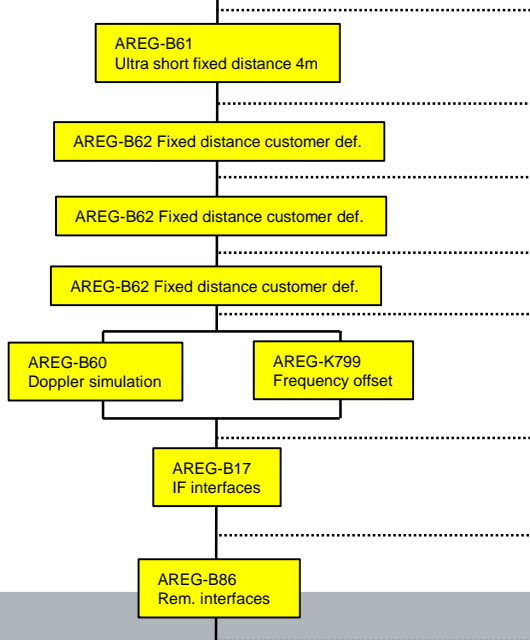


At least one of the frontends

One base unit supports one frontend at a time (possibility to run the 24 GHz and 76 GHz frontends sequentially)

Optional: Doppler modulation either common or individual for each of the equipped distances (+/- 500 km/h).

Optional: Additional GPIB and USB interface for remote control



Up to 4 different fixed distances can be installed in one base unit.
One ultra short (4 m) and up to 3 customer def. (5m – 300m)

At least one must be installed!

Optional: Analog IF input/output interfaces:

- monitoring the Radar TX sending power (with R&S NRP8SN power sensor)
- applying an additional interferer to the generated echo signal (with R&S SMW200A and Pulse Sequencer)

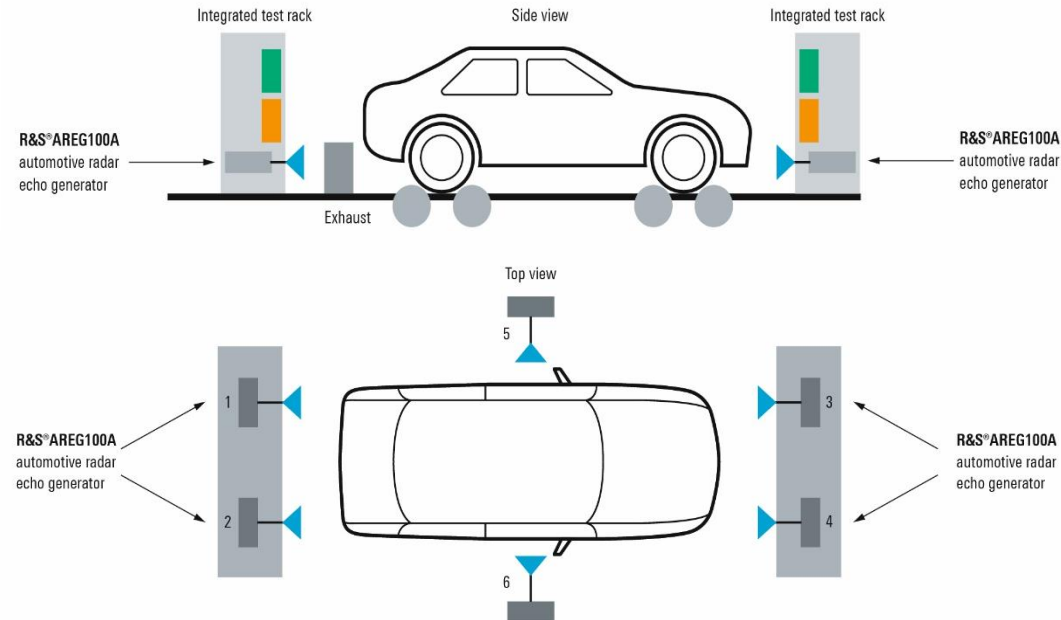
Radar Calibration at the End of Assembly Lines at OEM

Verify correct installation of sensors

After final installation of the radar sensors into the bumpers

- Verify proper sensor function
- Check correct sensor mounting and antenna pointing
- Generate echoes with Doppler offset for testing MTI sensors

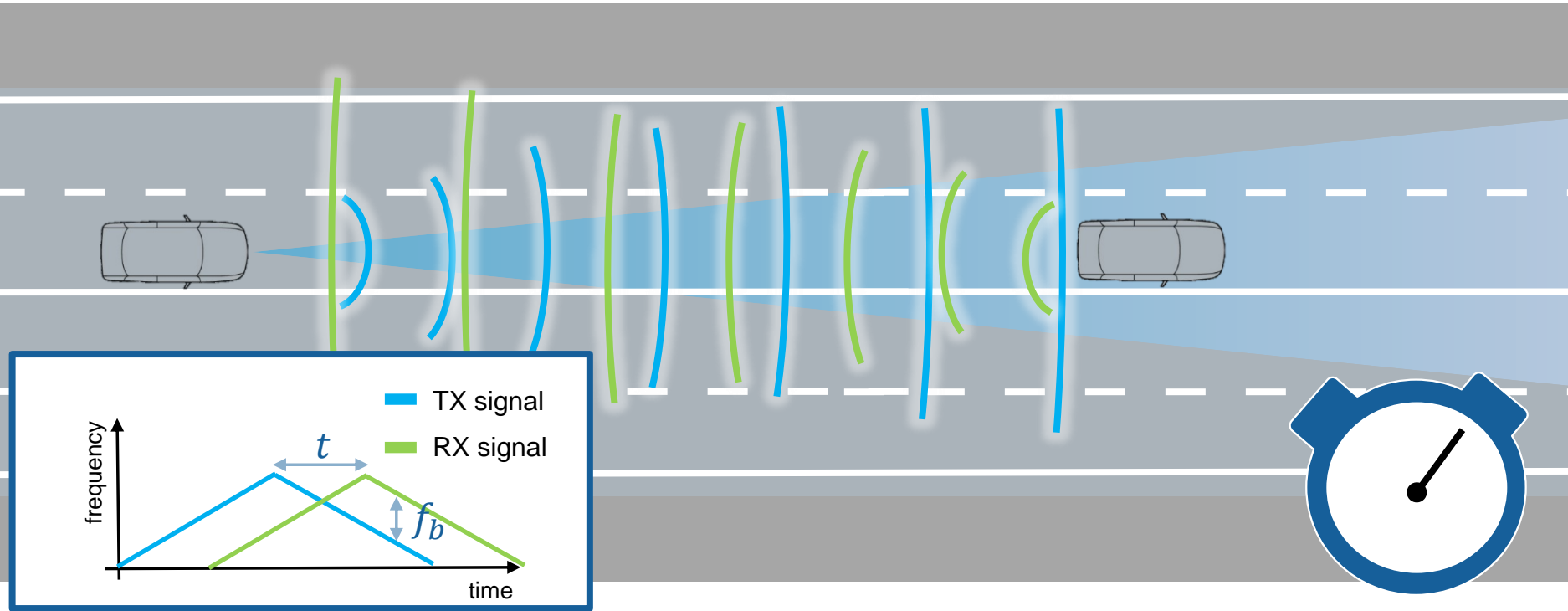
Use several AREGs in the test stand for optimization of the production-sequence and condense the test cycle times for cost optimized testing



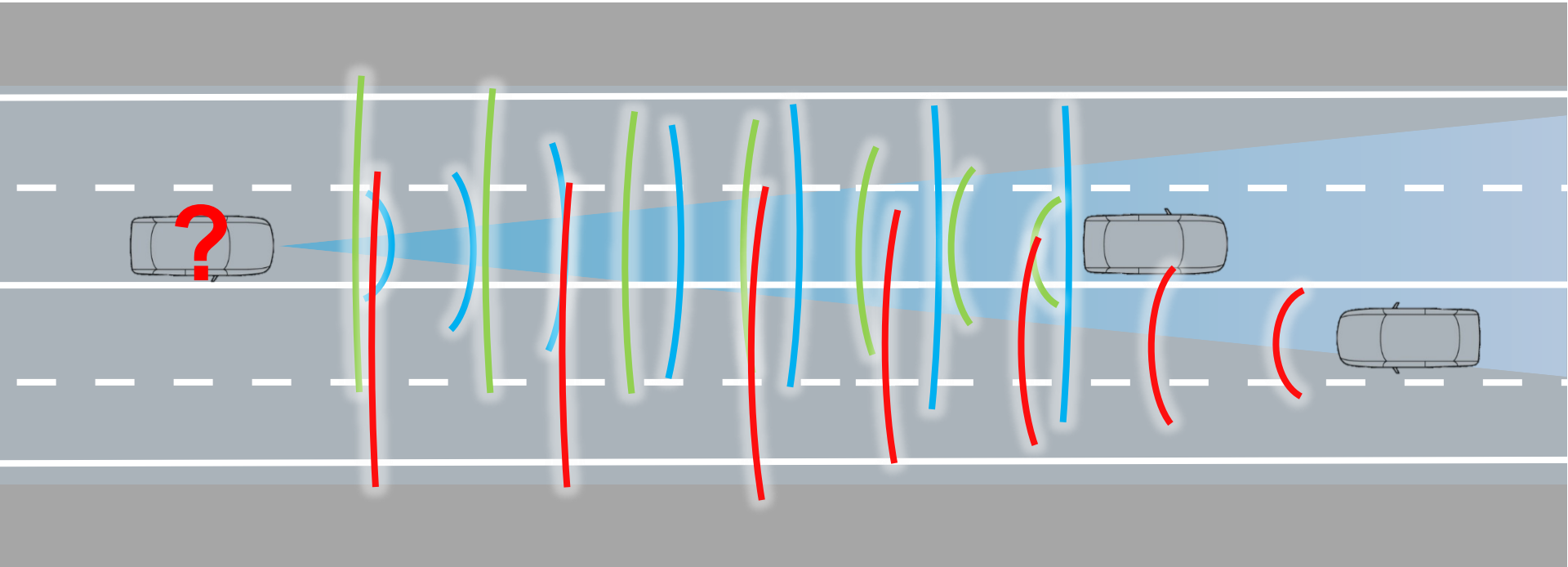
Automotive radar – Principle of operation and effects due to interferers



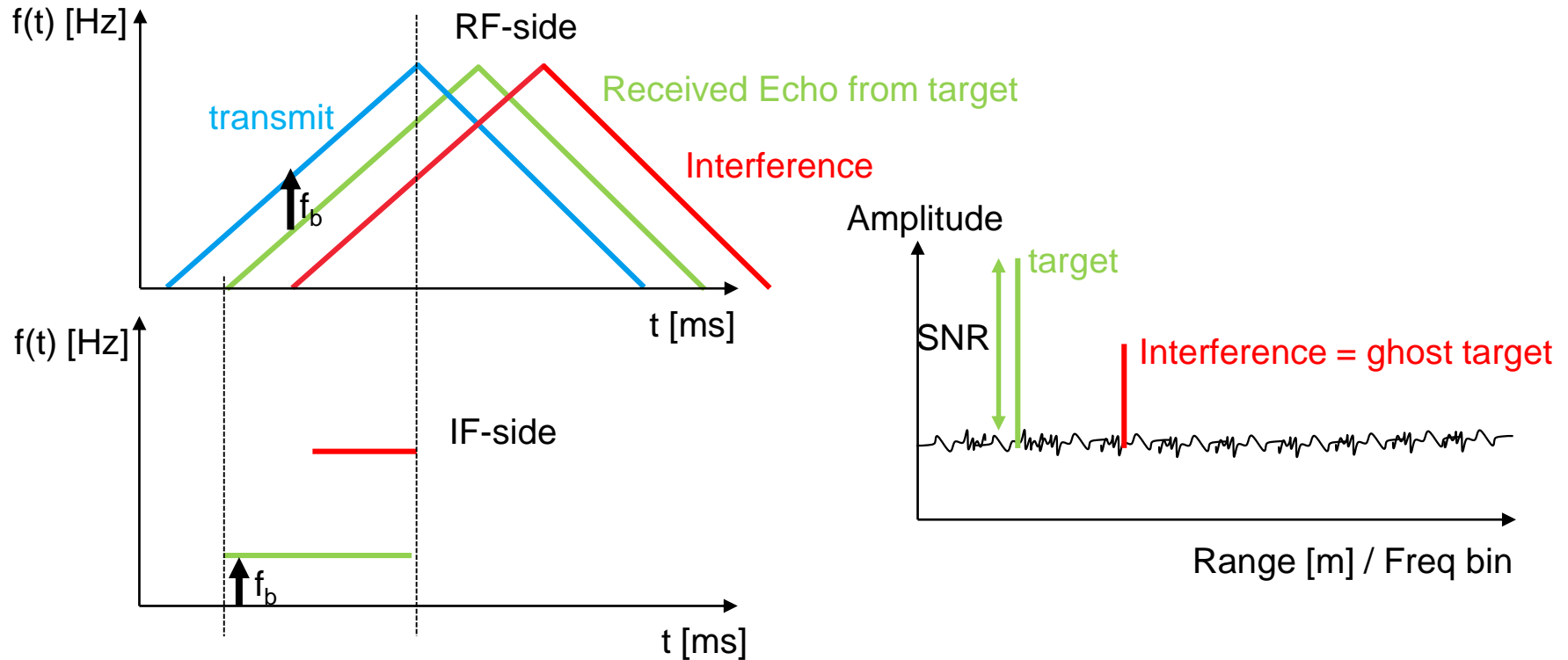
Automotive radar - FMCW



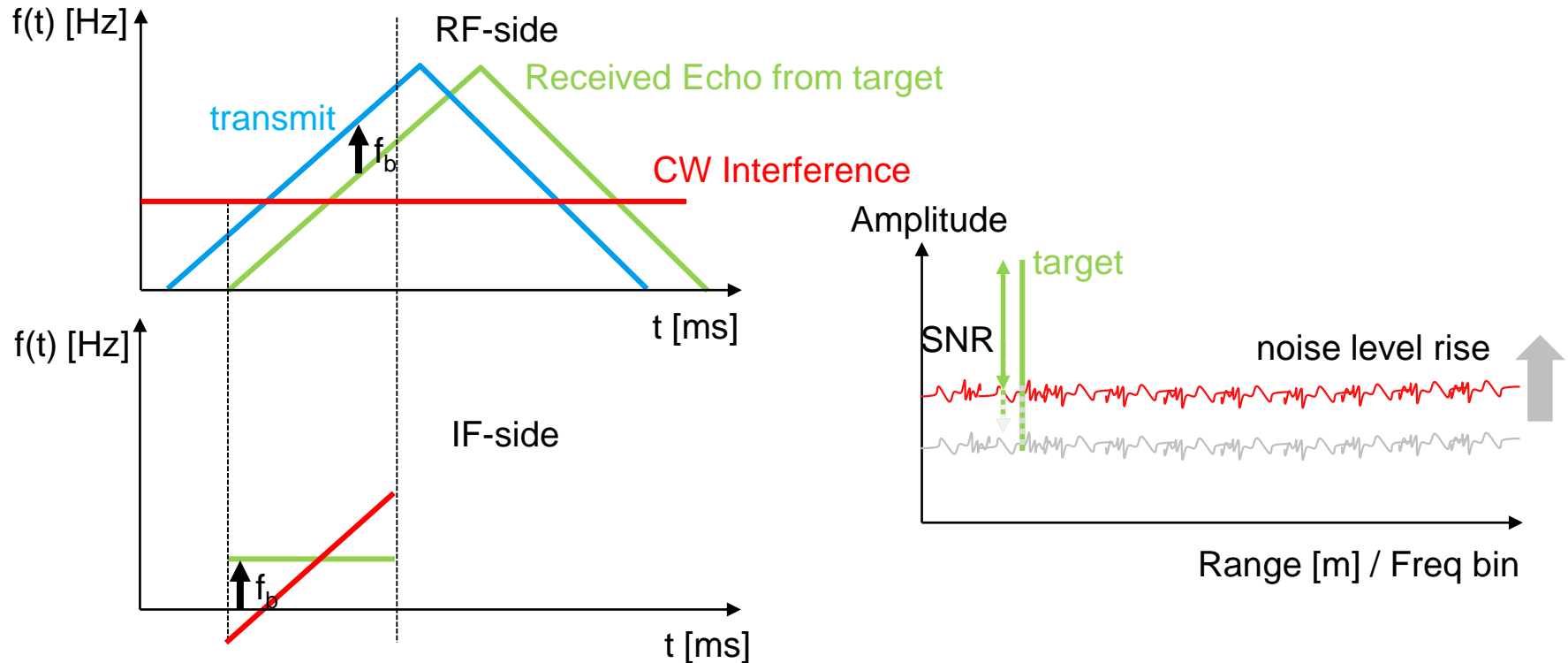
Automotive radar - FMCW



Interferers - Radar echo's and time aligned chirps



Interferers - Other RF signals within the radar bandwidth



Interferer mitigation techniques

Interferer type / waveform	Impact on radar sensor under test	Mitigation technique and principle	Effectiveness and applicability
CW	Deterioration of SNR	STFT – restoring the received signal	High
FMCW (chirp)	Additional ghost object	FMCW with phase coding	Good



How to test and evaluate the mitigation techniques after implementation in the sensor?



R&S reference solution for testing robustness of automotive radar sensors to interferers

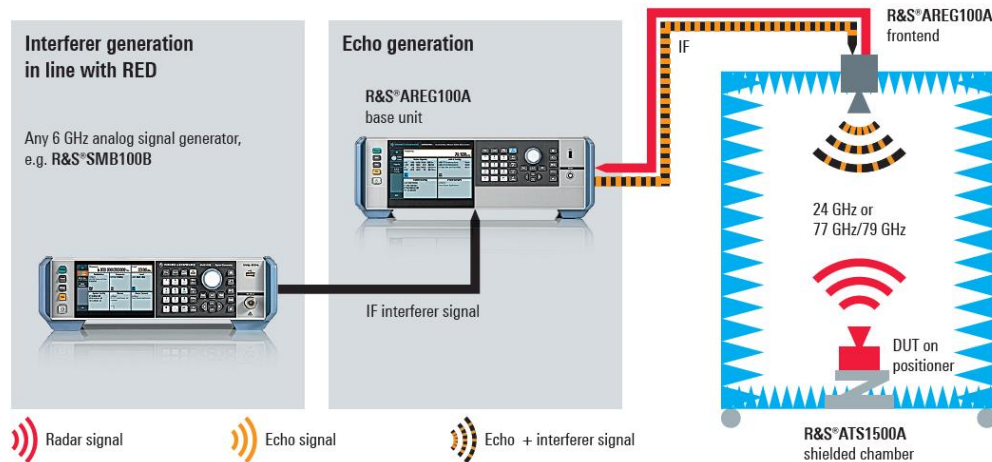
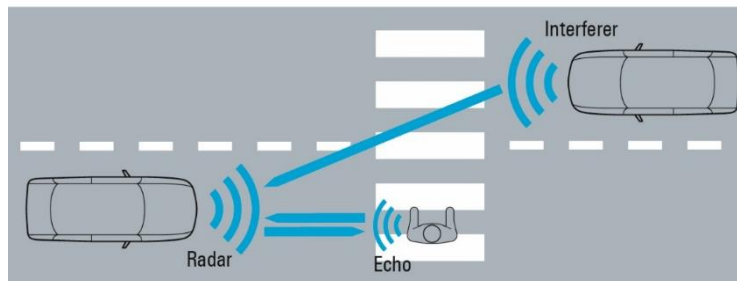


Road to rig - Simulate interference scenario with R&S AREG100A

Test the sensor's robustness against interferers in the lab and stay ahead of competition

Example of a possible interferer test case

	ECHO 1	ECHO 2	ECHO 3	ECHO 4
Object	Car	Pedestrian	Car	Truck
Range	Close	Close	Medium	Far
RCS	Large	Small	Medium	Medium
Velocity	Low	No	Yes	Yes
Interferer	Strong			



Interference Testing



Bundesministerium
für Bildung
und Forschung

IMI-KO-Radar

Interferenzminimierung durch Kooperation bei Radarsensoren für autonome Elektrofahrzeuge



Verbundkoordinator

Robert Bosch GmbH, Gerlingen-Schillerhöhe

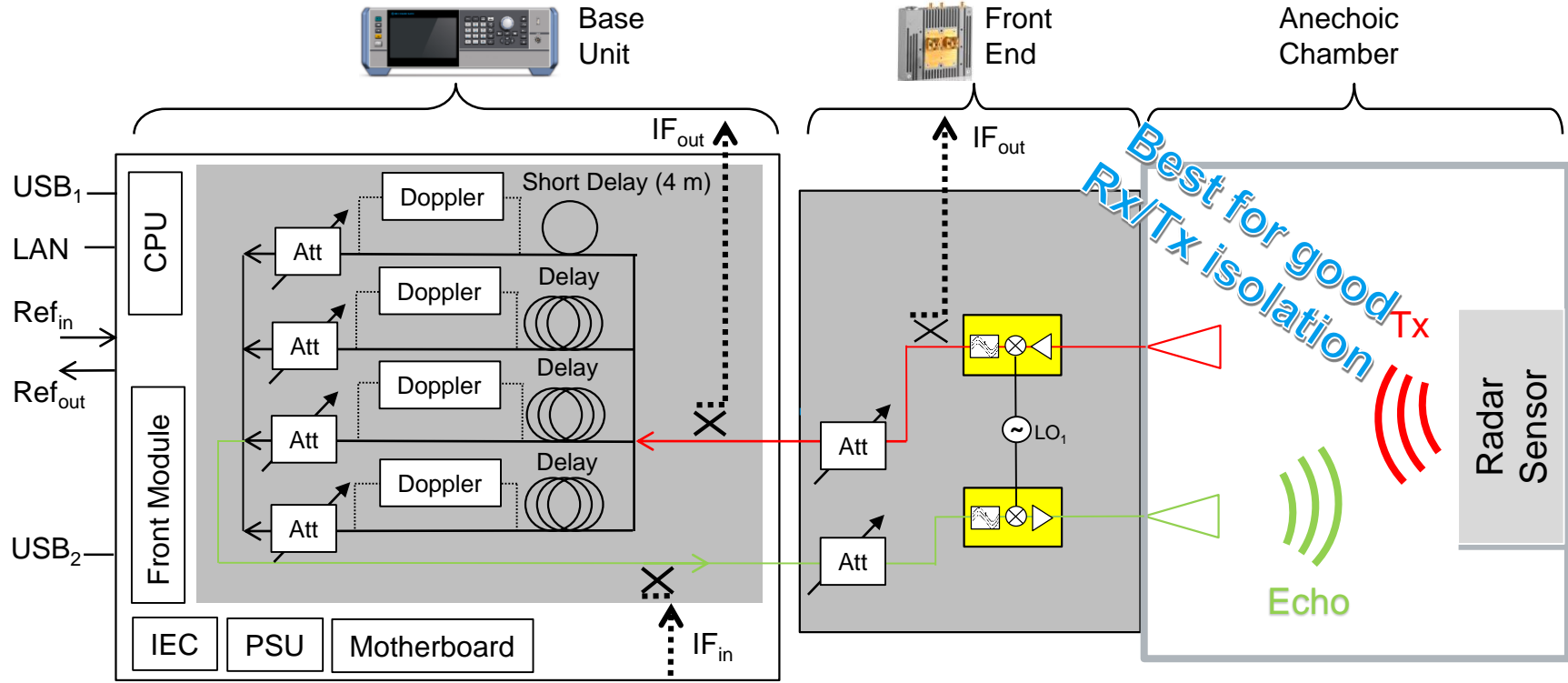
Partner

- Astyx GmbH, Ottobrunn
- ADC GmbH, Lindau
- CTC advanced GmbH, Saarbrücken
- Aptiv Services GmbH, Wuppertal
- Hella GmbH & Co. KGaA, Lippstadt
- Karlsruher Institut für Technologie (KIT), Karlsruhe
- s.m.s. GmbH, Braunschweig
- Universität Ulm
- Valeo Schalter GmbH
- Veoneer Germany GmbH

+ associated partners (OEMs like VW, Daimler, ...)

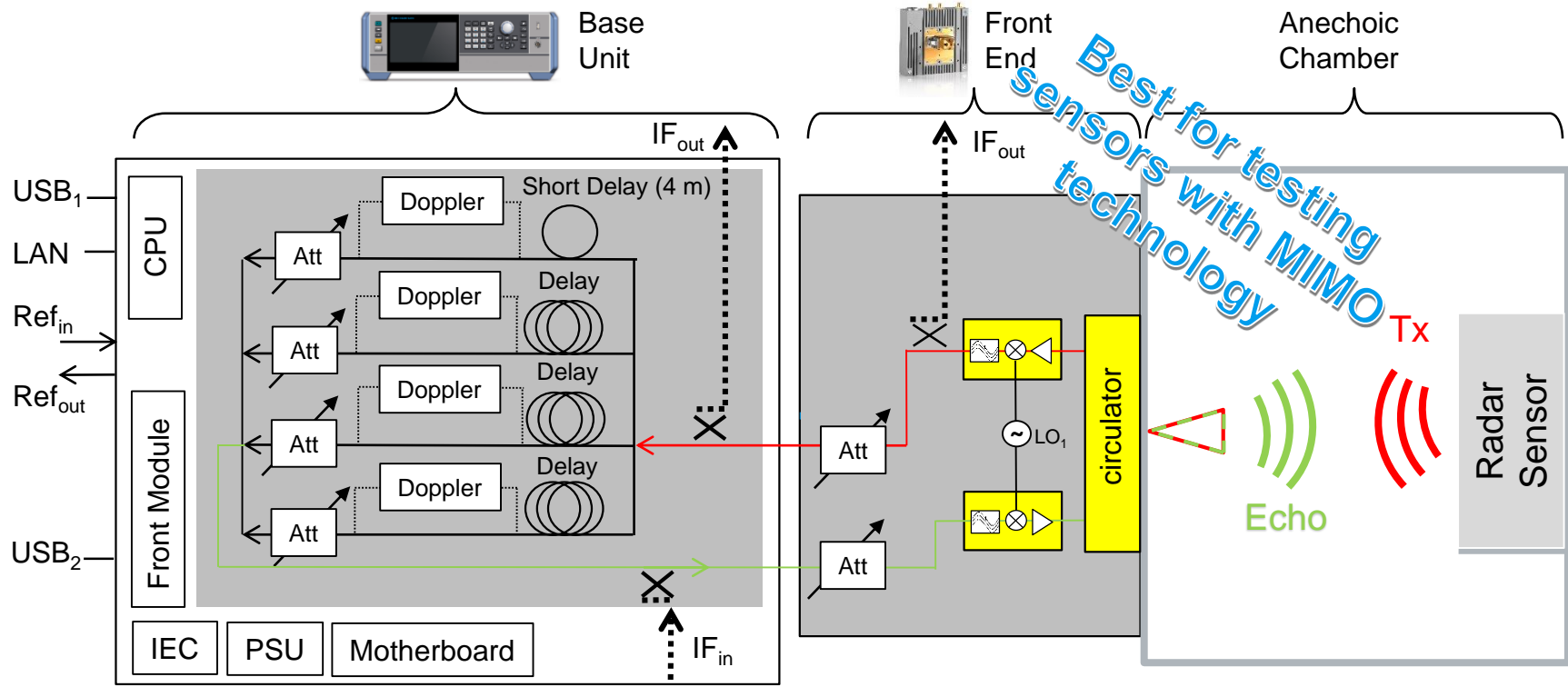
Our solution

Key facts of the R&S®AREG100A for production tester – two antenna front end



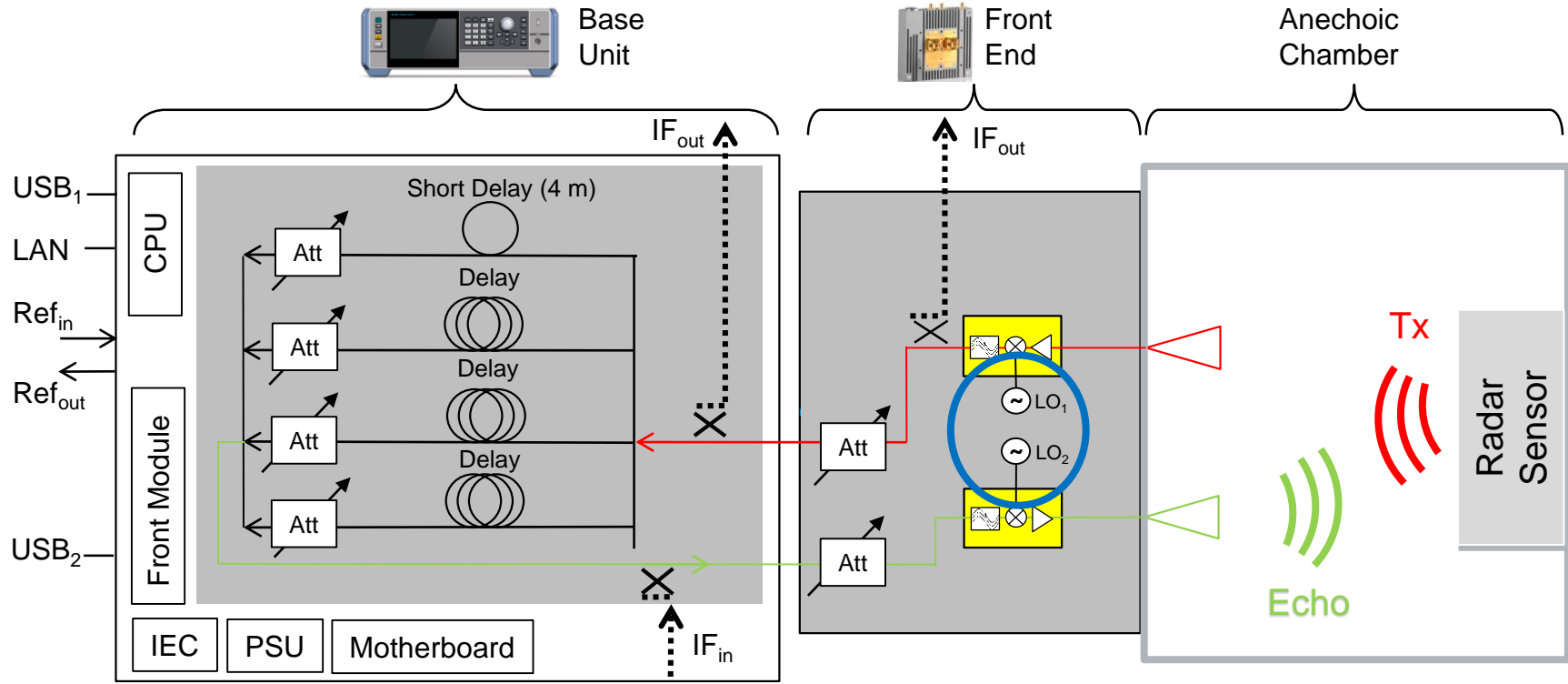
Our solution

Key facts of the R&S®AREG100A for production tester – single antenna front end



Technical insights

Key facts of the R&S®AREG100A for production tester – Frequency Offset



ATS1500C – Indirect Far-Field Chamber

Key features as planned

- Frequency range 18 – 87 GHz → for 24 GHz & 77/79 GHz radars
- Compact size (2m x 0.9m x 1.5m), movable (on wheels)
- High-precision 3D tilt-tilt positioner ideal for linear polarized DUTs
 - Elevation: $\pm 45^\circ$ Azimuth: $\pm 180^\circ$
 - Communication & power interfaces at RUT mounting
 - Resolution: 0.05°
- CATR reflector with a quiet zone of 30cmx30cm → for large DUTs
- High shielding effectiveness → no interference from or to the outside
- Best absorbers in class → lowest reflections → no ghost targets
- Interfaces: DSub, Ethernet, BNC, Banana Jacks
- Measurement instruments mounted on the backside of chamber
- RF shielded ventilation system

