COMPREHENSIVE RADAR INTEGRATION TESTING

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ROHDE&SCHWARZ

Make ideas real

TESTING THE ROBUSTNESS OF AUTOMOTIVE RADAR SENSORS TO INTERFERERS

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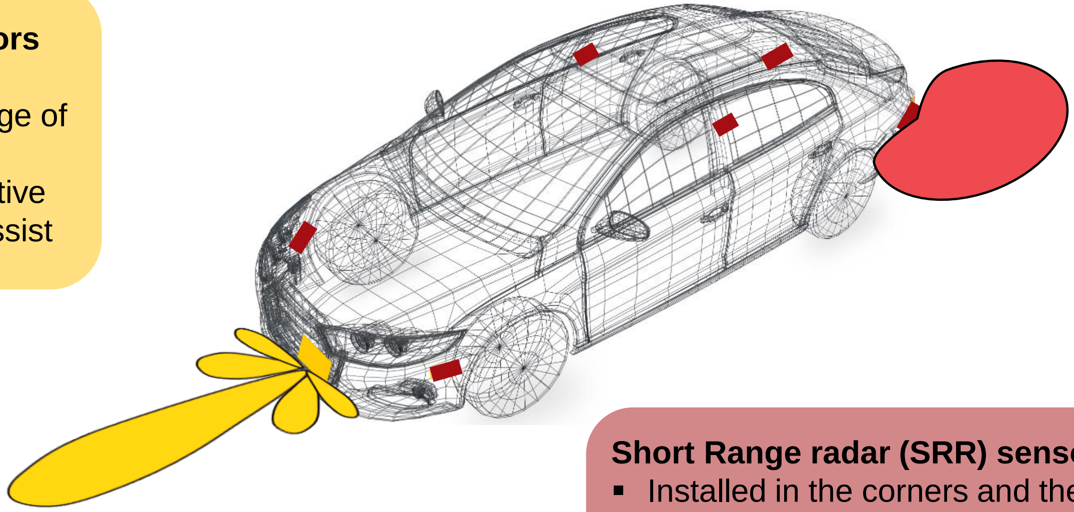
THE SITUATION

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



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

potential installation point of SRR sensors

potential installation point of LRR sensor

THE TRENDS

More complex and powerful sensor technology

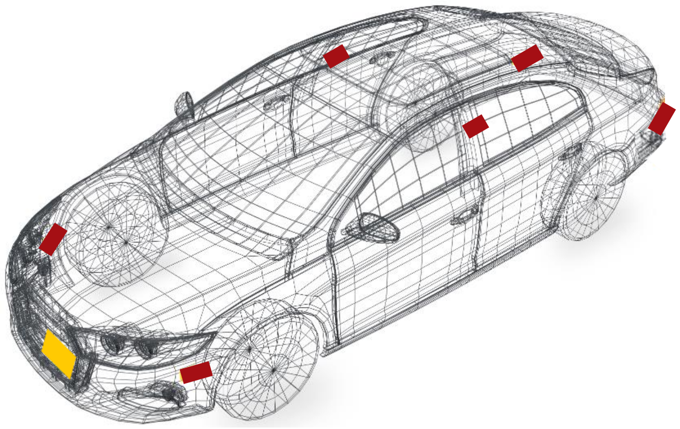
- Sensors e.g. LRR will use MIMO technology
- Advanced beamforming algorithms will help to provide better angular resolution
- Detailed and accurate imaging of the scenery especially for autonomous driving will become possible

Bandwidth increases up to 4 GHz in the 79 GHz band

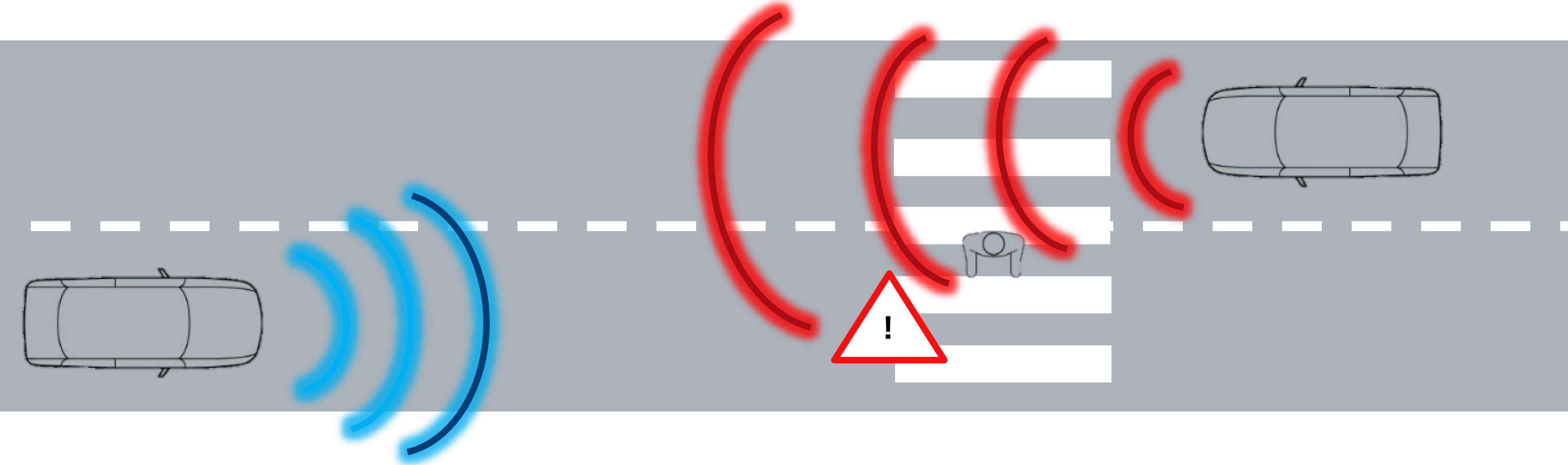
- Recognize and resolve objects in ultra short range
- Frequency hopping within automotive band to avoid mutual interference

Increase of number of radar sensors

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



THE CHALLENGE



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
- Spurious emissions - In-band signal handling (receiver robustness to interferers) - Out-of-band signal handling	- OBW - Power level - Unwanted emissions (out-of-band and spurious)

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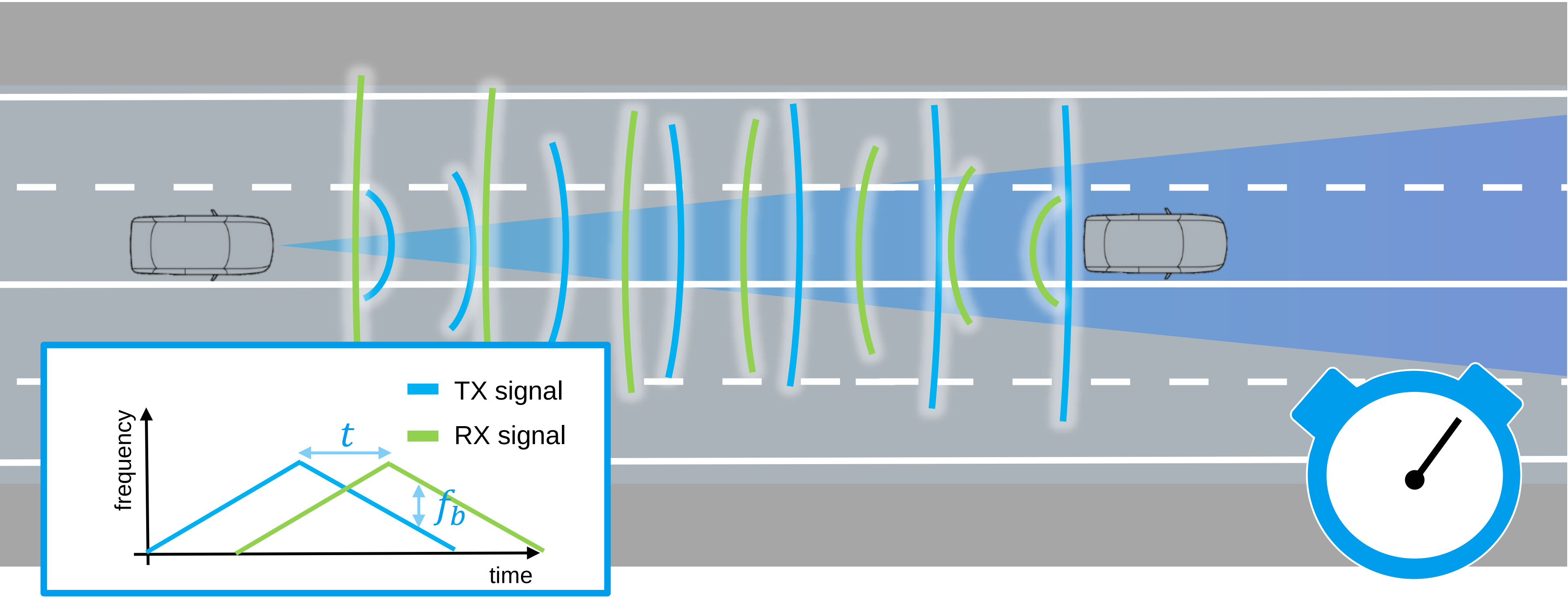
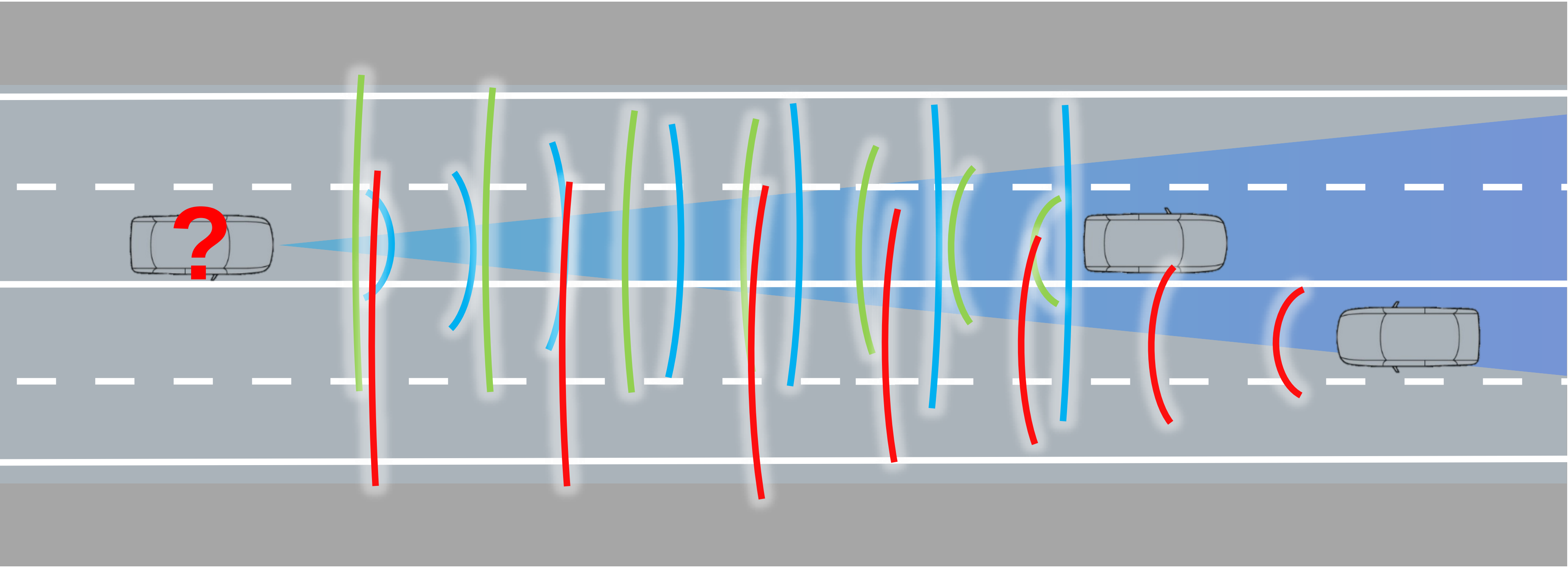
AUTOMOTIVE RADAR – PRINCIPLE OF OPERATION AND EFFECTS OF INTERFERERS

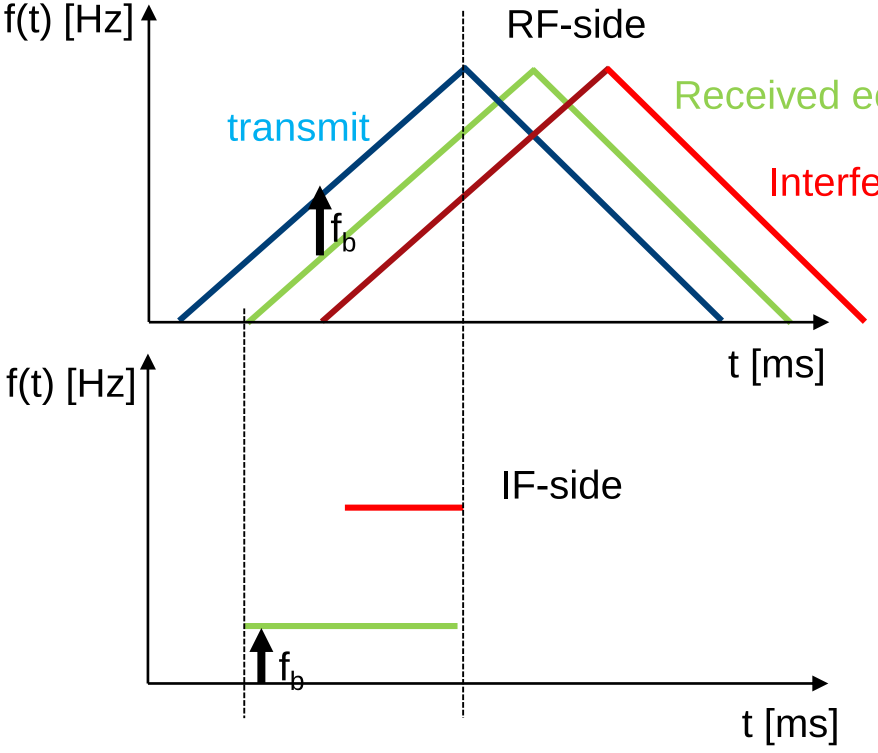
Automotive radar - FMCW

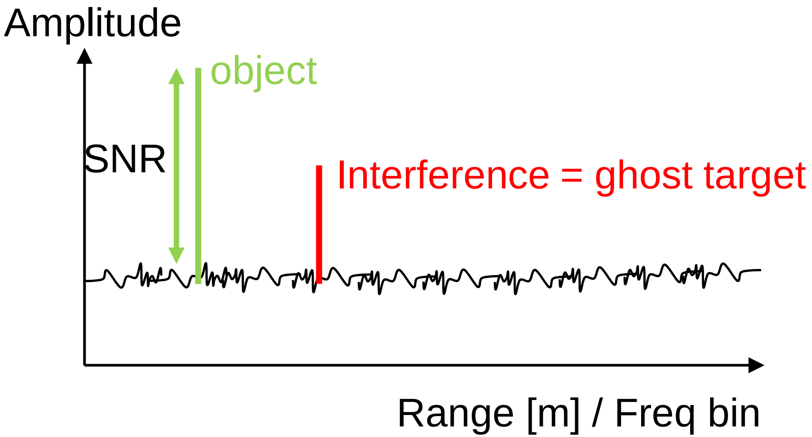


Automotive radar - FMCW

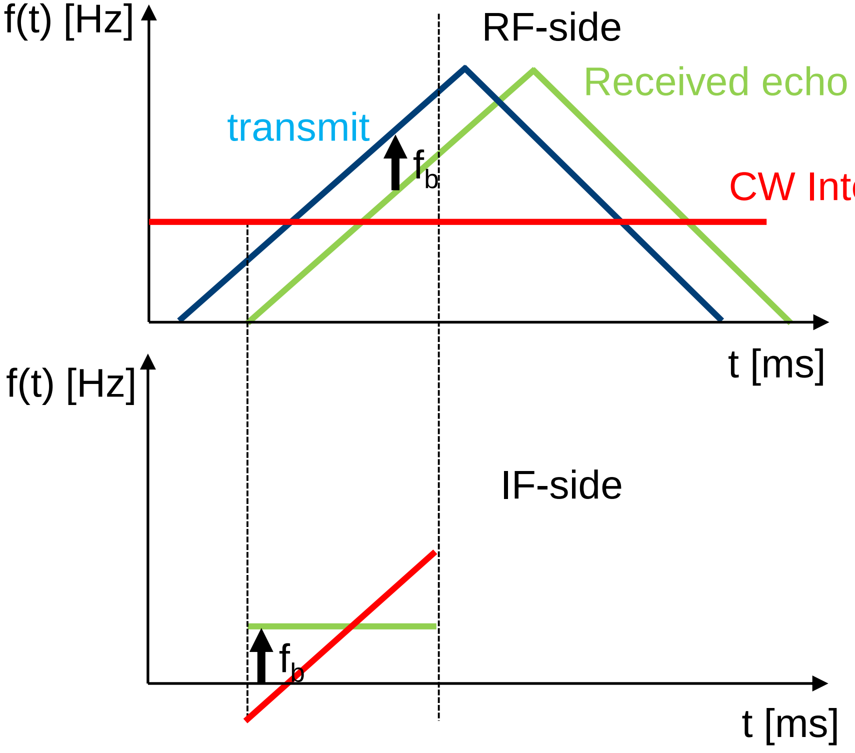


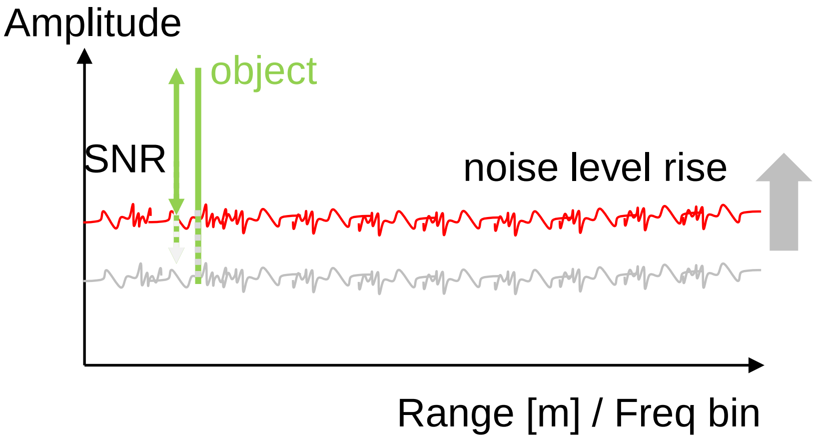
INTERFERERS - RADAR ECHO'S AND TIME ALIGNED CHIRPS





INTERFERERS – CW SIGNALS WITHIN THE RADAR SENSOR'S BANDWIDTH





REVIEW - INTERFERER MITIGATION TECHNIQUES

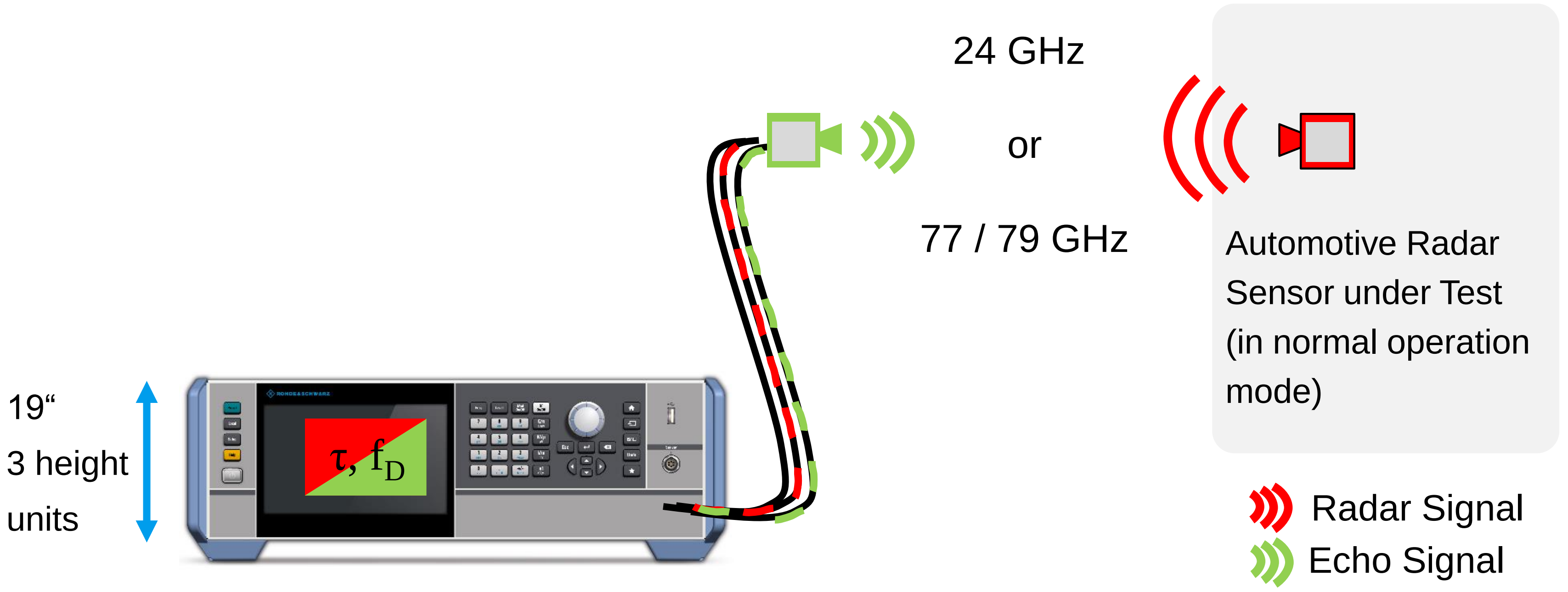
<table>
<tr><th>Interferer type / waveform</th><th>Impact on automotive radar sensors</th><th colspan="2">Mitigation technique and principle</th><th>Effectiveness and applicability</th></tr>
<tr><td>CW</td><td>Deterioration of SNR</td><td rowspan="2">Hopping within the assigned radar band</td><td>STFT – restoring the received signal</td><td>Very effective – easy realization with signal processing</td></tr>
<tr><td>FMCW (chirp)</td><td>Additional ghost object</td><td>FMCW with phase coding</td><td>Good – higher effort needed</td></tr>
</table>

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

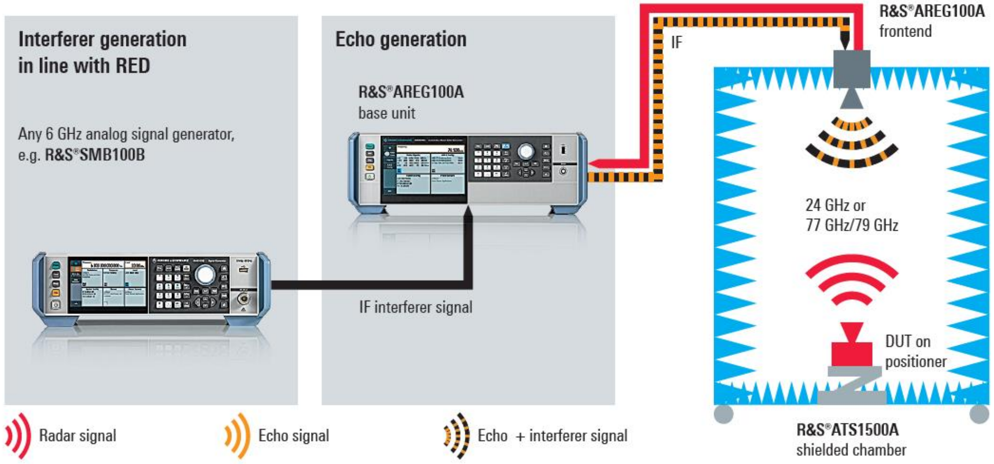
R&S REFERENCE SOLUTION FOR TESTING ROBUSTNESS OF AUTOMOTIVE RADAR SENSORS TO INTERFERERS

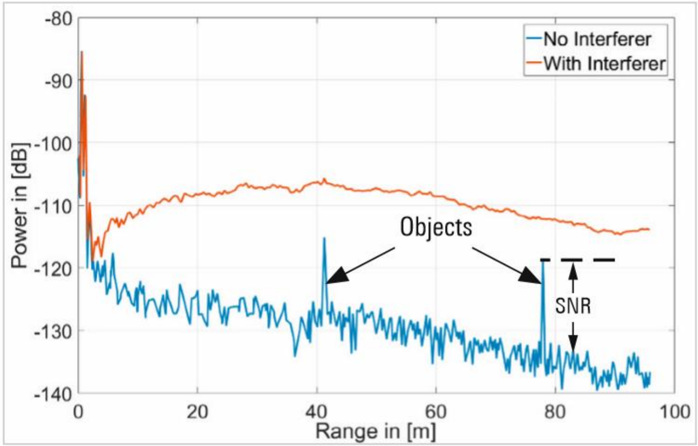
TESTING THE ROBUSTNESS OF AUTOMOTIVE RADAR SENSORS

Reference solution for simultaneous radar echo and interferer generation based on the R&S®AREG100A Automotive Radar Echo Generator


19“
3 height
units
τ, f_D
24 GHz
or
77 / 79 GHz
Automotive Radar
Sensor under Test
(in normal operation
mode)
Radar Signal
Echo Signal

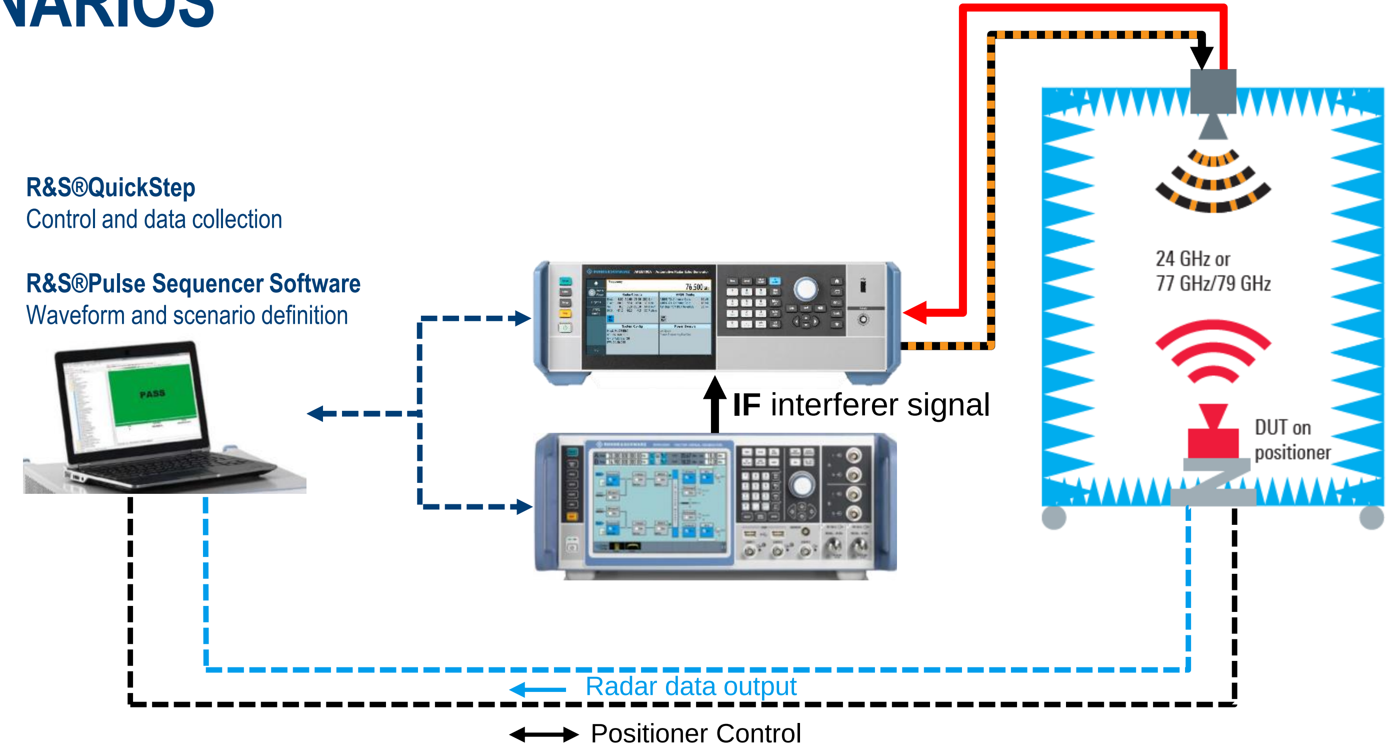
SIMULATE INTERFERENCE IN LINE WITH RED





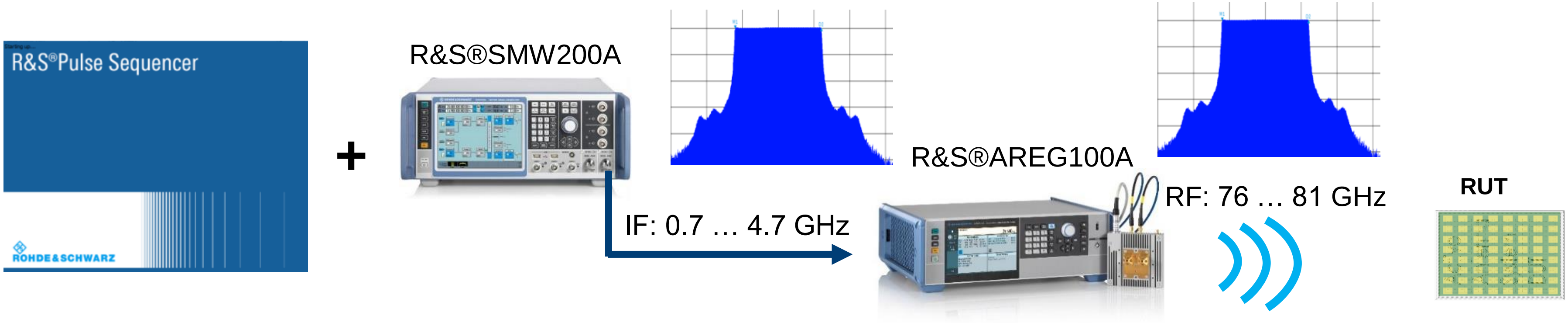
- Connect any analog or vector signal generator up to 6 GHz to the AREG I/F input port
- Impose interferes onto the wanted echoes and share the AREG frontend for up conversion for both signals
- Cost optimized and simple solution for simulation of wanted echoes together with interferers

SIMULATION SETUP FOR ADVANCED INTERFERENCE SCENARIOS



ADVANCED INTERFERER GENERATION – FLOW CHART

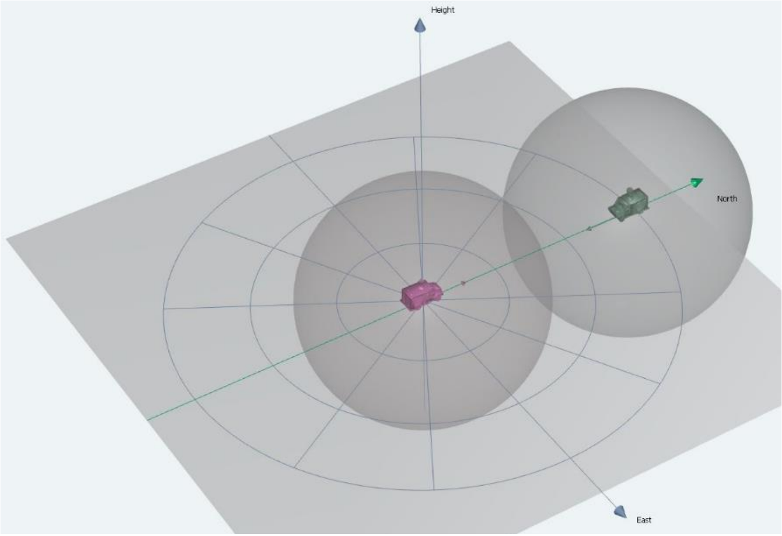
Generate interferer or the entire RF environment in software → Replay the signal with a R&S®SMW200A vector signal generator → Upconvert to E-band using the R&S®AREG100A → Evaluate the radar sensor under test

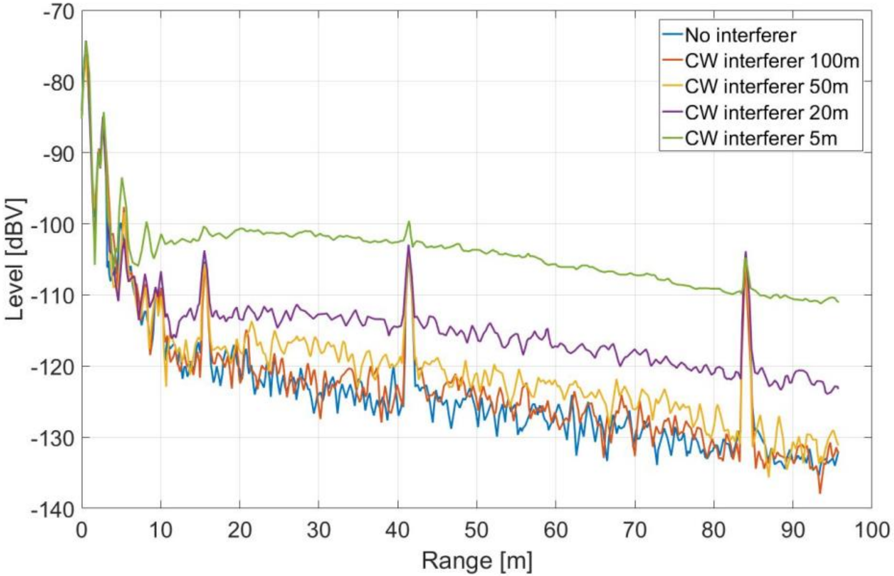


CW INTERFERER TEST CASE – SIMPLIFIED STREET SCENARIO

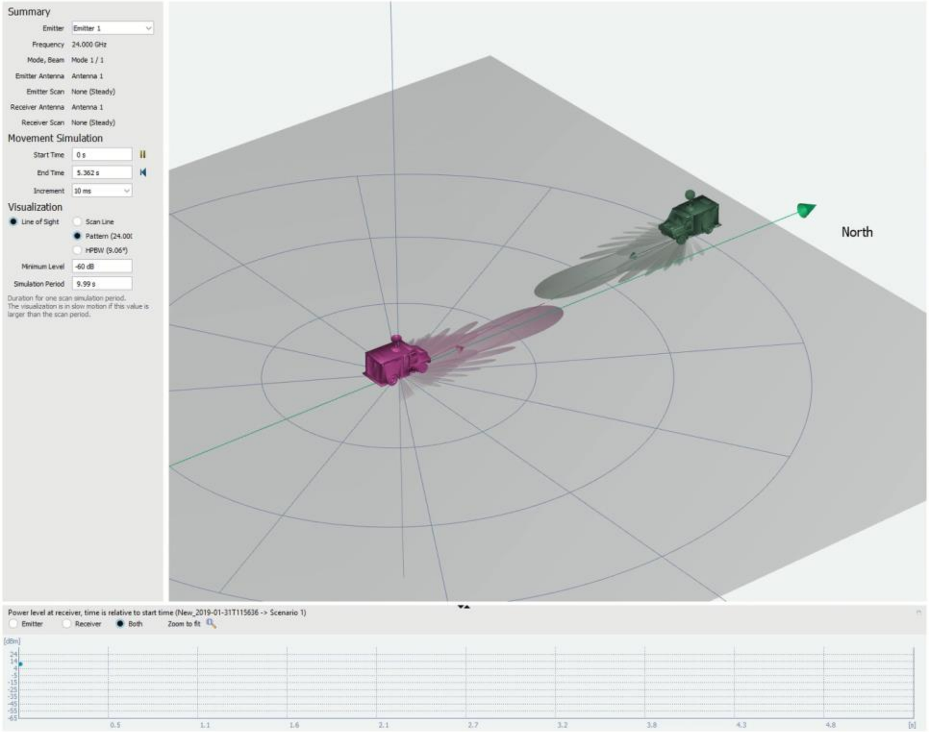
Definition of scenarios using Pulse Sequencer software:

Oncoming car with a radar interferes with the radar under test in a simplified street scenario





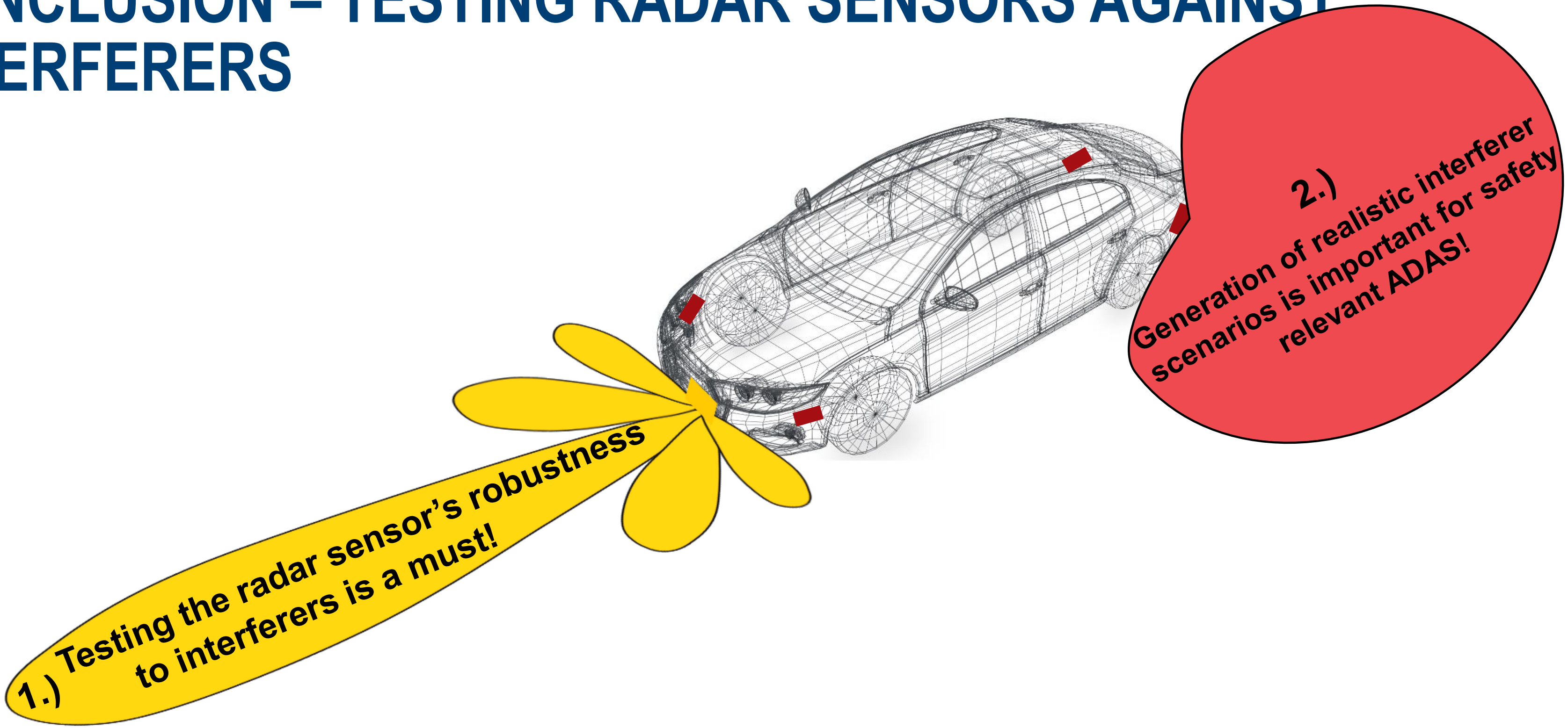
EXTENSION TO REALISTIC STREET SCENARIO



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
- …

CONCLUSION – TESTING RADAR SENSORS AGAINST INTERFERERS



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AUTOMOTIVE RADAR INTEGRATION TESTING

Your requirements

Throughput
Fast
Precise
Interface
Accurate
Reliable

Our solutions

Radomes and Bumpers

Mounting accuracy

Spatial RCS measurement

RADOMES AND BUMPERS

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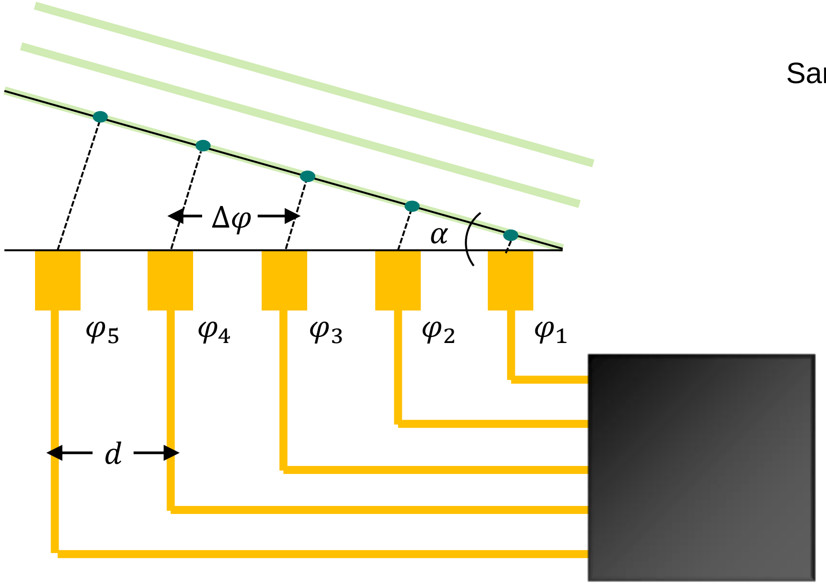
RADAR ANGULAR MEASUREMENT TECHNOLOGY



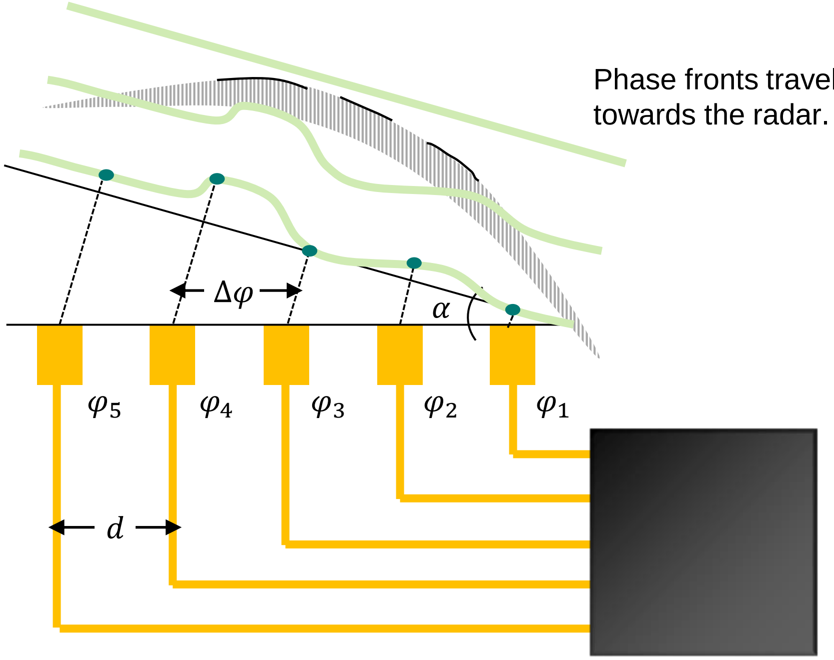
Sampling points

d	Physical distance between antennas
$\Delta\varphi$	Phase difference
α	Angle of arrival
λ	wavelength

$$\alpha = \sin^{-1}\left(\frac{\lambda \cdot \Delta\varphi}{2\pi d}\right)$$

Estimate azimuth / elevation angles from phase differences / amplitudes at the receive antennas of the phased array

RADAR ANGULAR MEASUREMENT TECHNOLOGY



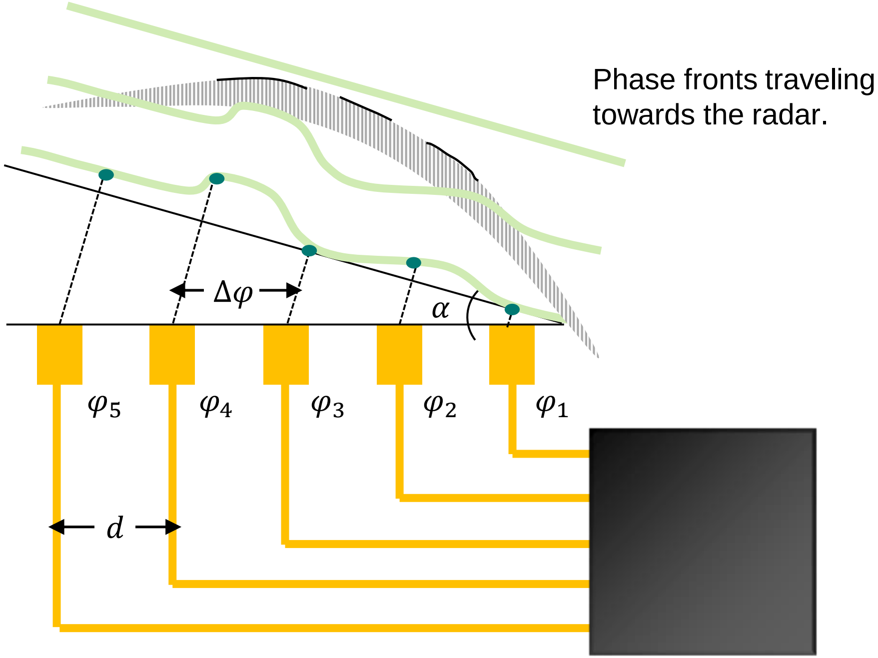
d	Physical distance between antennas
$\Delta\varphi$	Phase difference
α	Angle of arrival
λ	wavelength

$$\alpha = \sin^{-1}\left(\frac{\lambda \cdot \Delta\varphi}{2\pi d}\right)$$

$$\Delta\varphi_1 \neq \Delta\varphi_2 \neq \Delta\varphi_3 \neq \Delta\varphi_4 \neq \Delta\varphi_5$$

Phase estimation is wrong

RADAR ANGULAR MEASUREMENT TECHNOLOGY



Measuring the angle error does not lead to useful results, if:

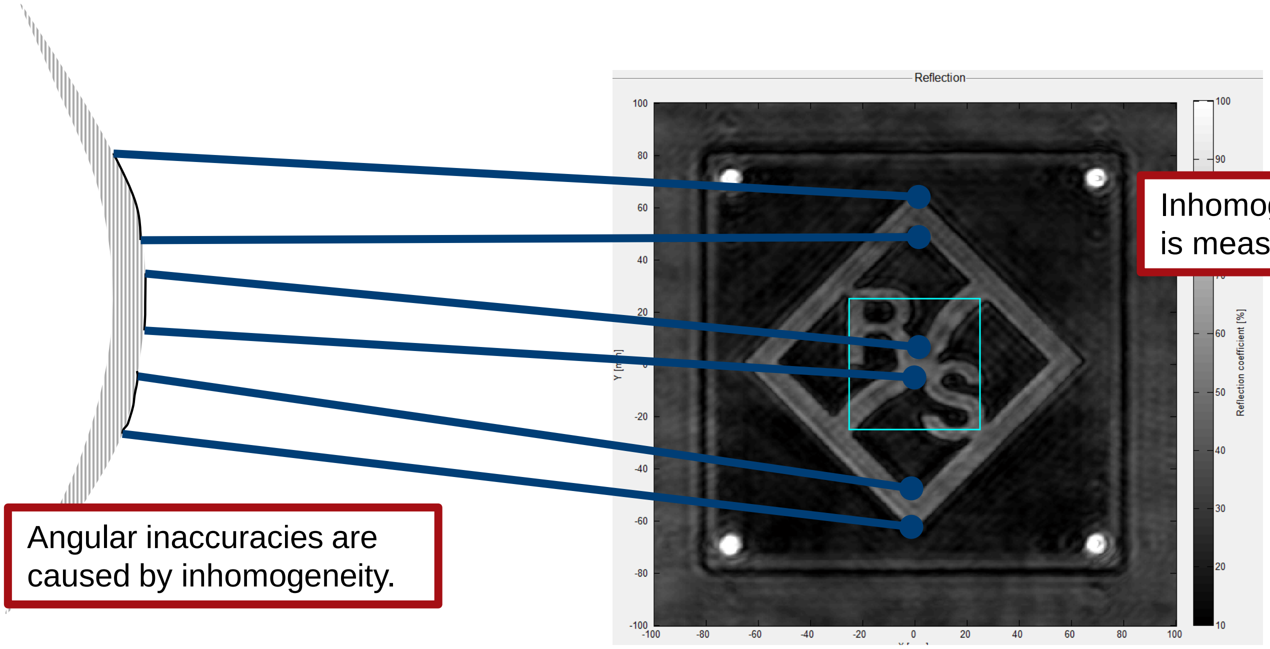
- The radar is slightly moved.
- The distance between the antennas is changed.
- Another algorithm is used for angle of arrival estimation during post processing.

Or, more general, if:

- Another radar / radome combination is used.

An alternative method has to be used.

RADAR ANGULAR MEASUREMENT TECHNOLOGY

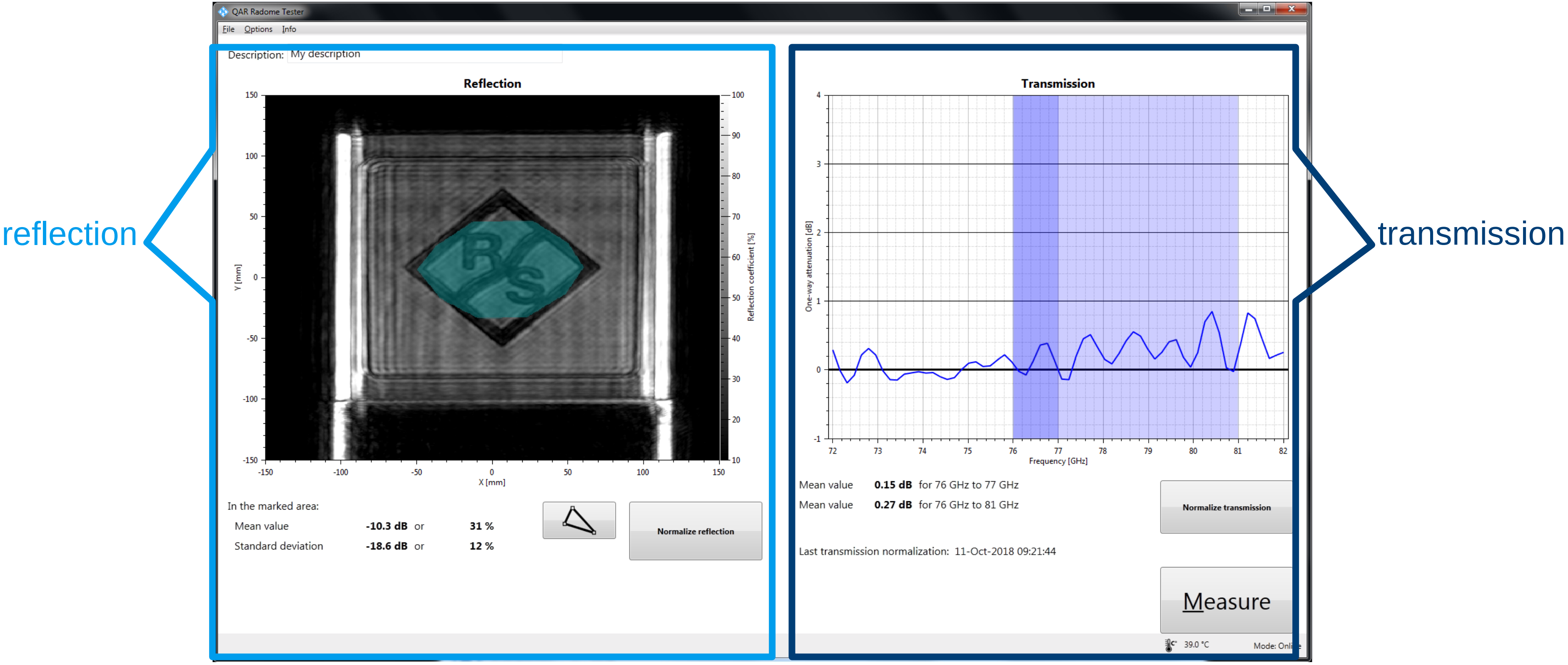


Inhomogeneity of the radome is measured by the QAR.

Angular inaccuracies are caused by inhomogeneity.

A threshold can be defined for either each car, or the whole fleet. Every radar is then measured using the same technique.

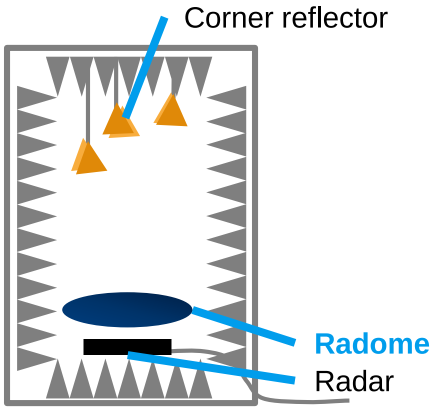
MEASUREMENT RESULT - RADOMES

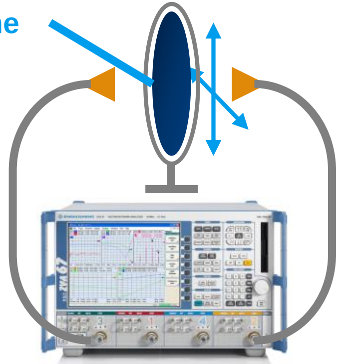


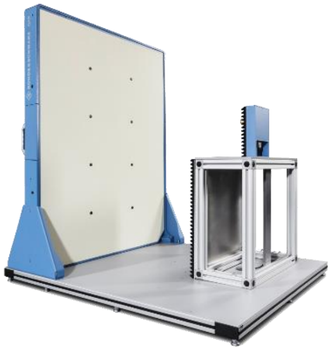
Comparison of measurement methods

Method	Corner reflectors	Network Analyzer	R&S®QAR

Descr.

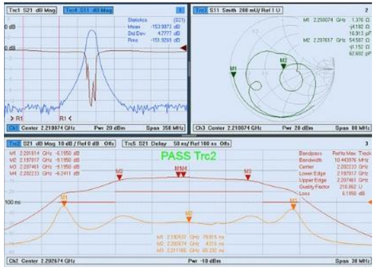


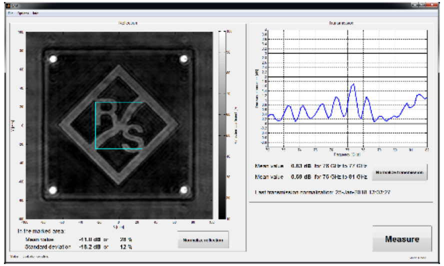




Result

Meas. Point	2way att.	Azimuth Error
#1	1.2dB	0.2°
#2	1.4dB	0.1°
#3	1.6dB	0.3°





Comparison of measurement methods

Method	Corner reflectors	Network Analyzer	R&S®QAR
Descr.	Corner reflector / Radar 👍 Cheap & Quick 👎 Estimation & selective, Radar dependent	Radome 👍 Precise measurement 👎 Slow and selective Calibration required Experts for operation	👍 Spatially resolved Easy to operate Time saving 👎 Equipment necessary
Result	see measurement table below		

Meas. Point	2way att.	Azimuth Error
#1	1.2dB	0.2°
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MOUNTING ACCURACY

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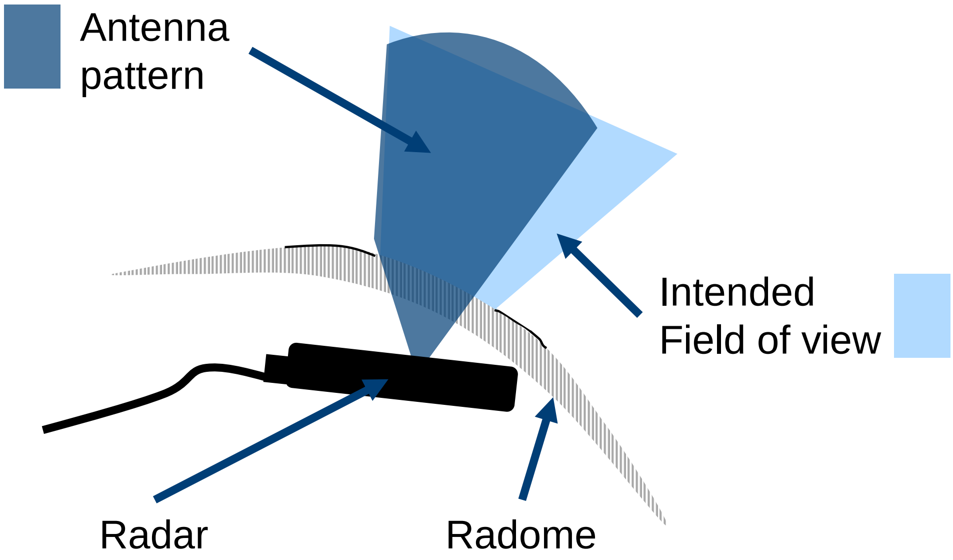
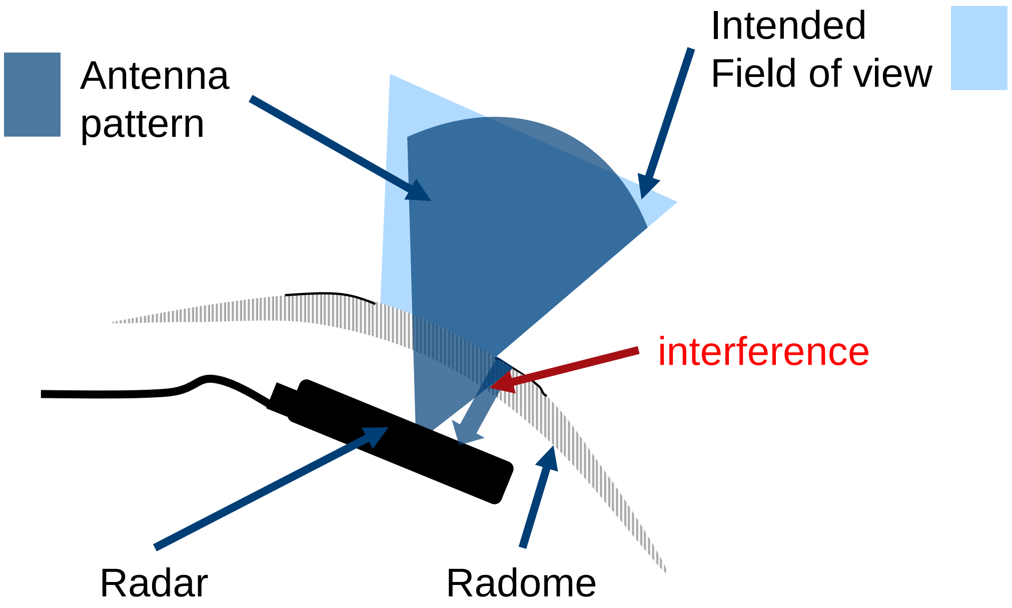
Mounting accuracy measurement

Why is it necessary?



- The radar is not necessarily fixed to the bumper or radome.
- It has to be ensured that the antenna pattern lies inside the intended FOV.

Mounting accuracy measurement
Why is it necessary?



- The radar is not necessarily fixed to the bumper or radome.
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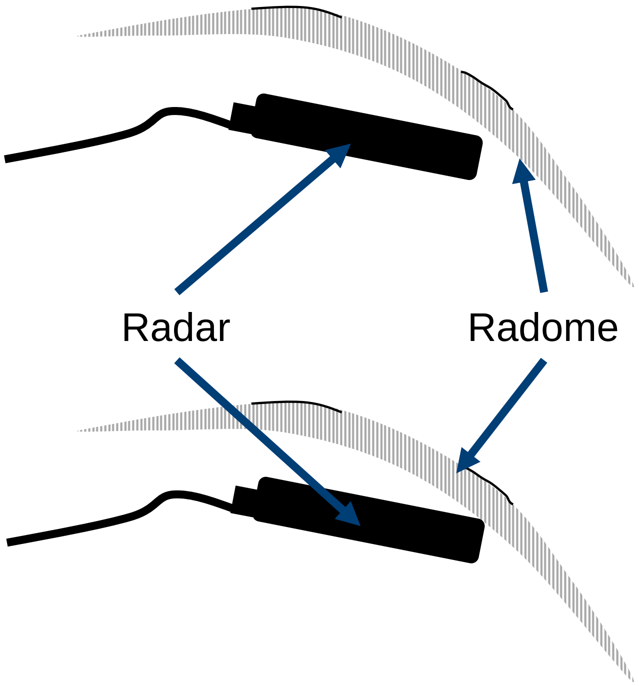
Mounting accuracy measurement
What can possibly happen?

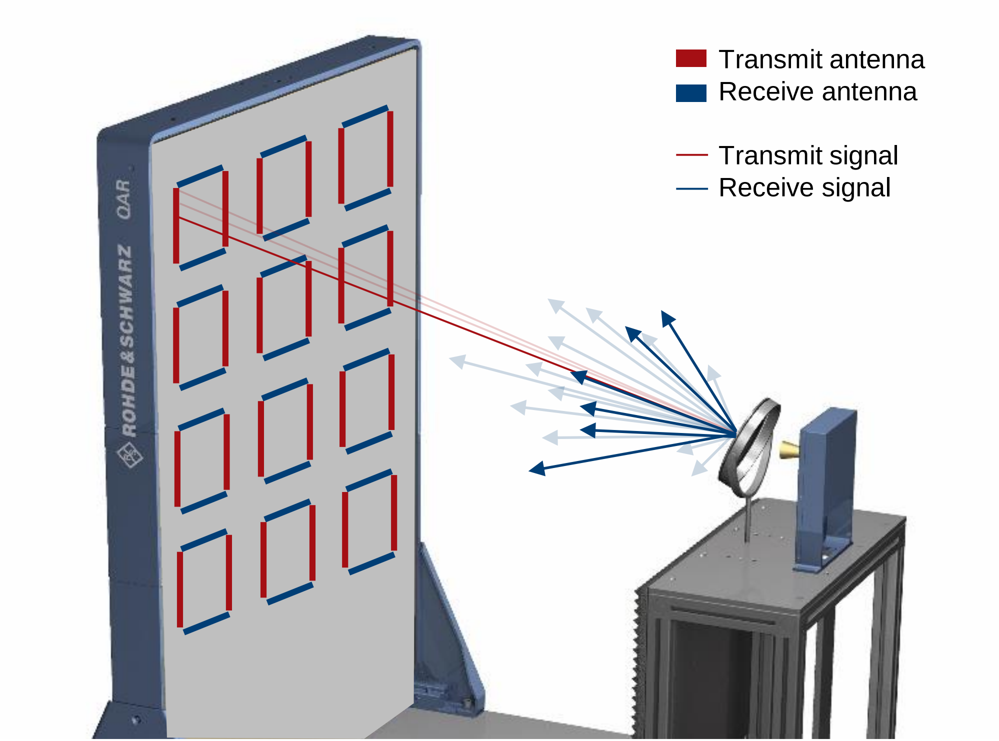


Possible misalignment in azimuth or elevation.

Possible misalignment in absolute positioning.

Mounting accuracy measurement

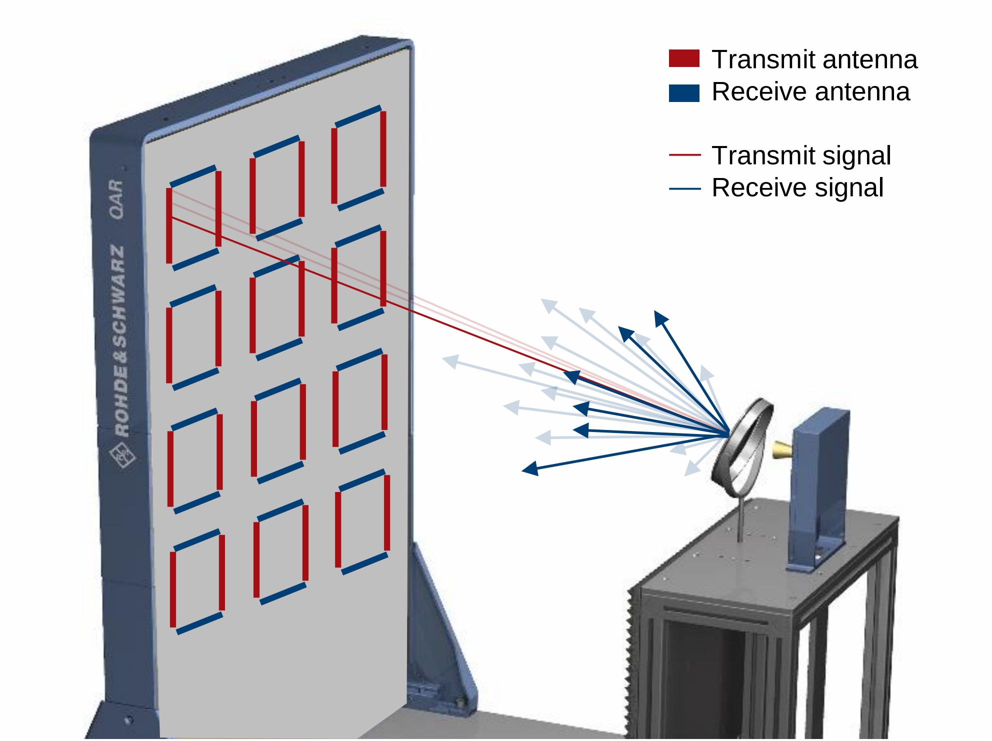
How can the QAR be of help?

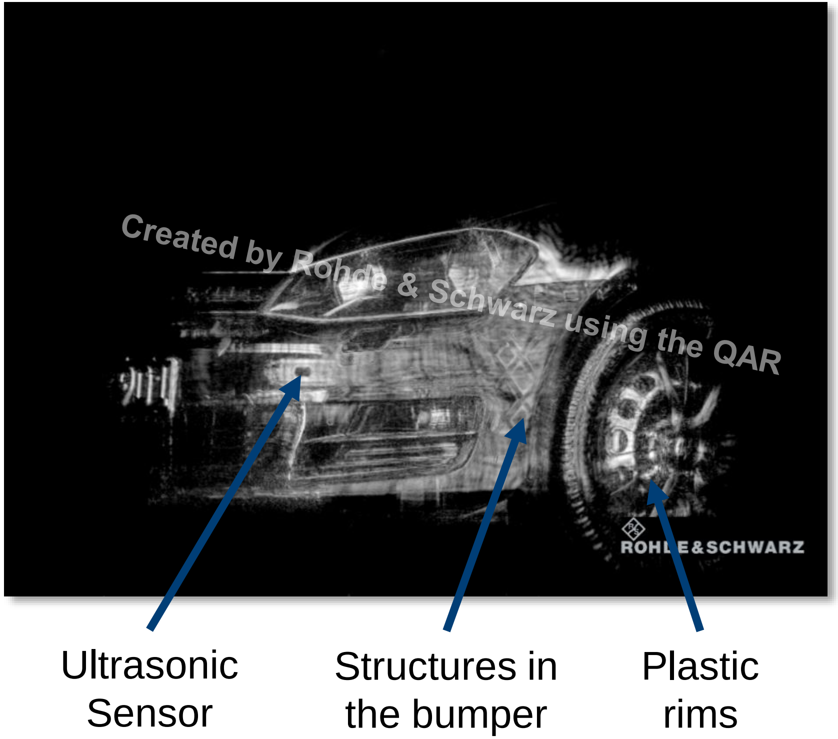


- Imaging: Imaging bumpers and radomes
- Processing: intentionally transparent parts
- Evaluation: Objects behind can be detected

Mounting accuracy measurement

How can the QAR be of help?





MOUNTING ACCURACY MEASUREMENT
HOW CAN THE QAR BE OF HELP?

- The QAR can look through the bumper.
- Raw data is used to locate x, y and z-position of the radar together with azimuth and elevation angle of the device.
- CAD data is necessary for correct classification.