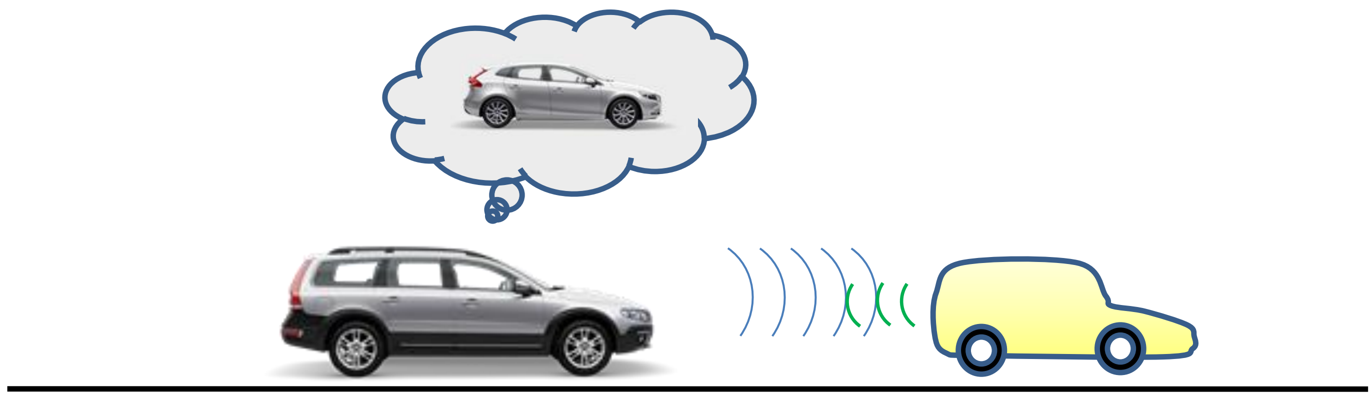
HiFi Radar Target



Kristian Karlsson (RISE)

Outline

- HiFi Radar Target:
  - Overview
  - Background & goals
- Radar introduction
- RCS measurements:
  - Setups
  - Uncertainty contributions (ground reflection)
  - Back scattering → Spatial profile

HiFi Radar Target - overview

- Four partners:
  - VCC
  - Autoliv
  - RISE
  - AstaZero

- Start: 2015-12-01
- End: 2018-06-30

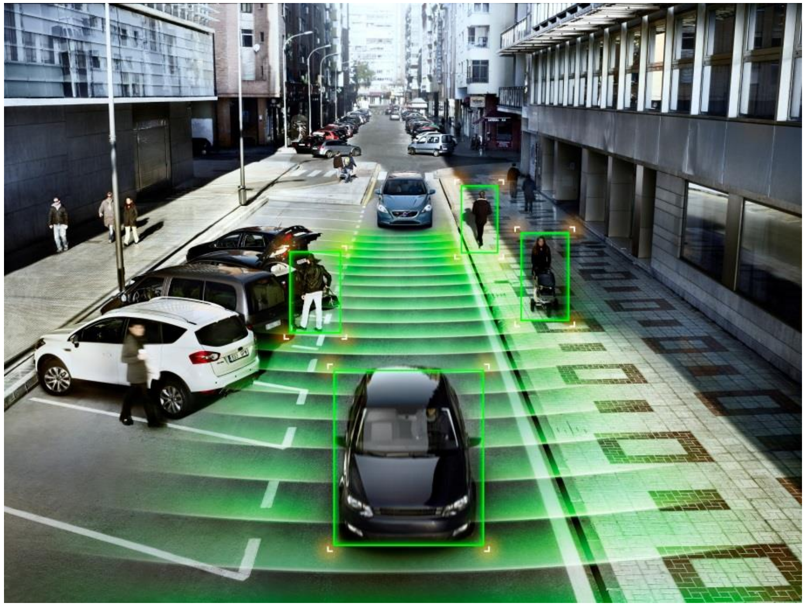
- Financed by:

Background

- Active safety systems and AD systems are necessary:
  - In normal traffic situations
  - In critical situations

- Reliable sensors are needed:
  - Visible spectrum, infrared cameras, laser scanners, ultrasonic sensors, and radars

- Radar importance: long range give early detection and time to react, even in adverse weather



Background cont.

To ensure reliable performance, extensive testing of radar-based safety systems is required.

✓ Vehicle testing at test tracks (AstaZero) with soft surrogate targets:
- RCS difference (real vs surrogate)
- Different radar detection performance → different activation of the functions.
- HiFi soft targets are a prerequisite for vehicles to use the radars' full potential.

✓ Virtual testing
- Tools for comprehensive virtual testing of radar-based ADAS and AD systems including radar are not available.

VOLVO

Autoliv

RI. SE

ASTAZERO
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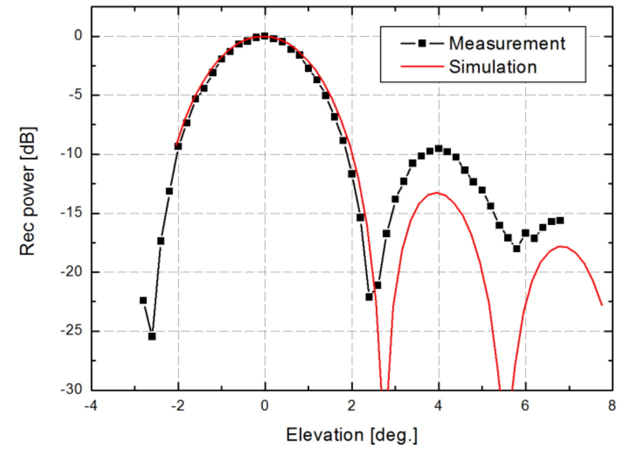
Goals

- RCS measurement methods, setup and required measurement hardware
  - Reference objects and EM simulations
  - Measure RCS (real and soft targets)
  - Validation
- Define a methodology to construct HiFi soft surrogate targets that improve current state-of-the-art
- Input to international standardization (ISO)
- Implement and validate a comprehensive simulation tool-chain for radar system testing in that complements test-track testing



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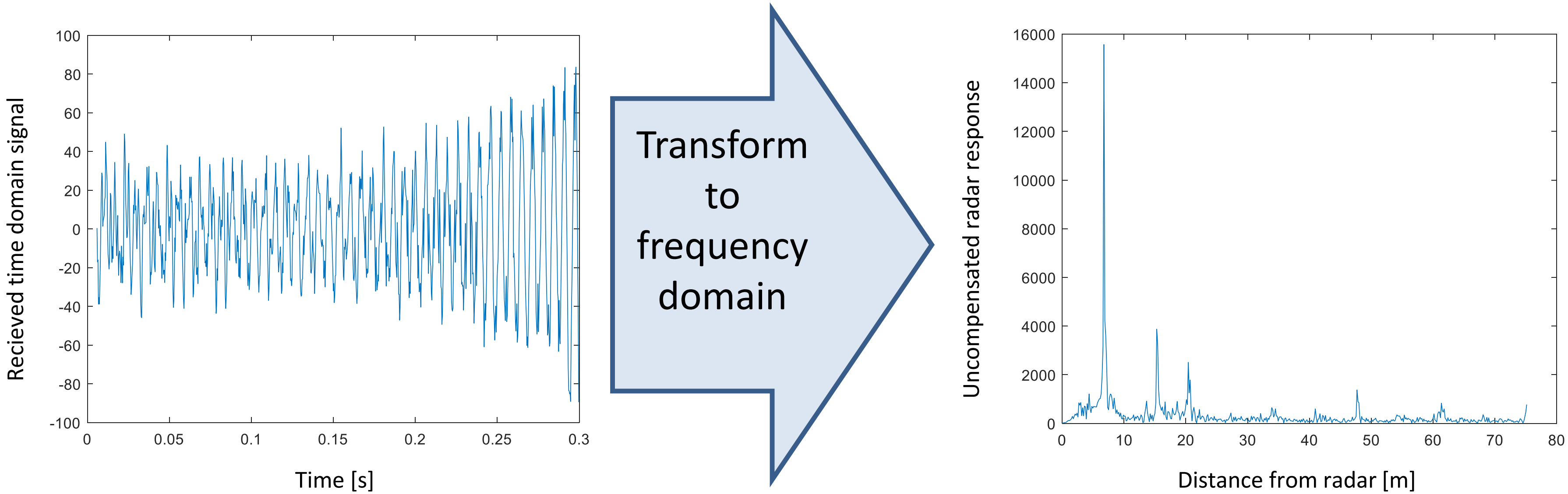
SFCW Radar

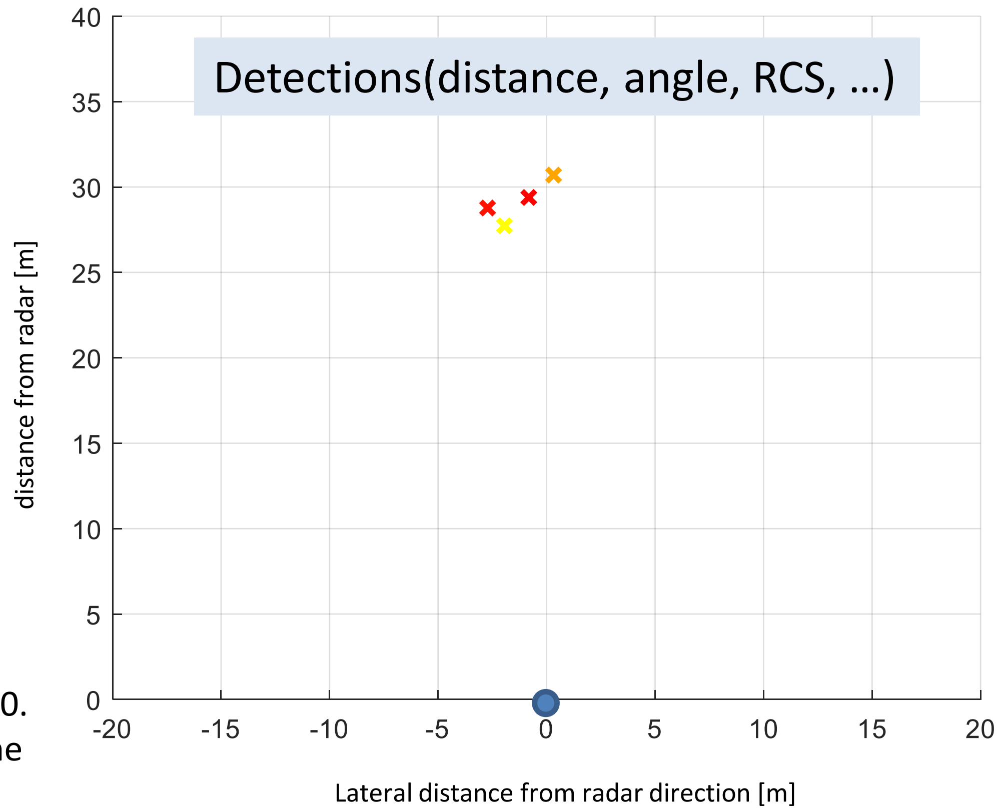
Pulse, CW, FM,FMCW,…

Time domain data



Stepped Frequency Continuous Wave (SFCW): sensor output corresponds to the cosine of the phase difference between the echo signal and the radiated signal: $S = cos(\Phi)$

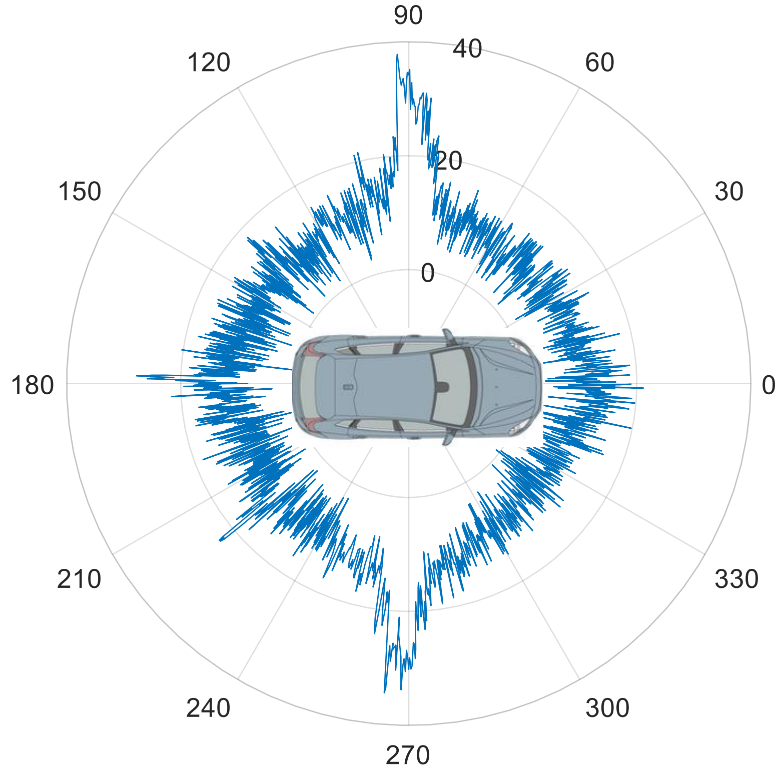
Automotive radar



Radar is located at x,y = 0,0. View angle is straight in the y-direction

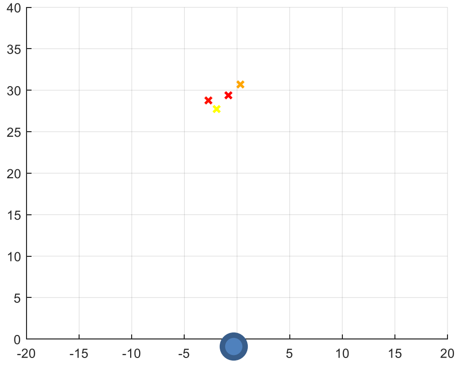
Radar Cross Section

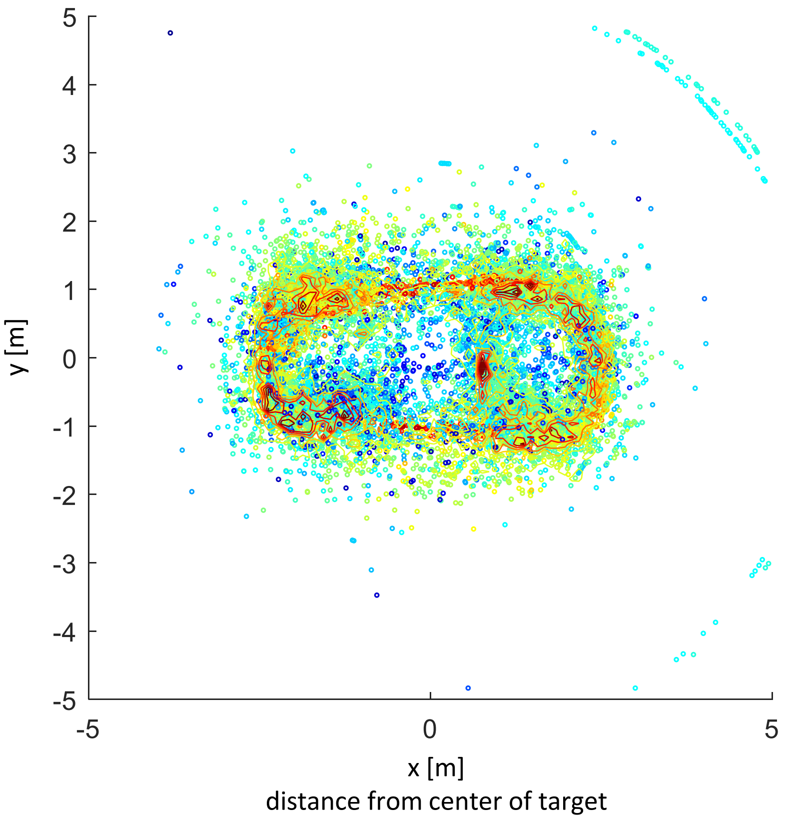
$$\sigma = \lim_{r \to \infty} 4\pi r^2 \frac{|\boldsymbol{E}_s|^2}{|\boldsymbol{E}_i|^2}$$



Extract max RCS detection from each sample point

Backscattering





Scatter color corresponds to RCS.

Color of contour is density of detections

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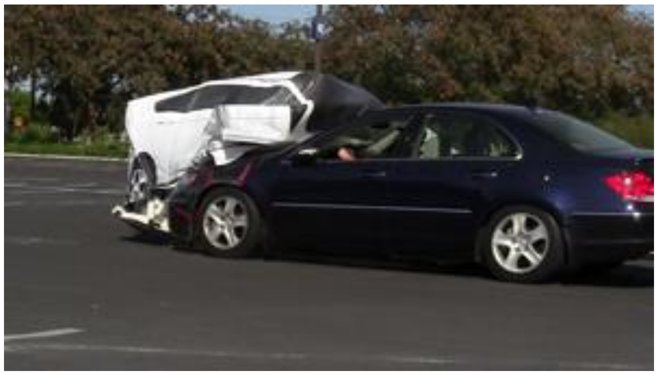
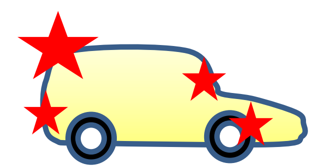
Several types of measurement methods

Fast validation of RCS → use on test track on crashed targets



Careful measurement of RCS (comparing surrogate targets with real vehicles) → Target knowledge, input to ISO

Characterization of multiple scattering centras of real and surrogate targets → target models incl. propagation



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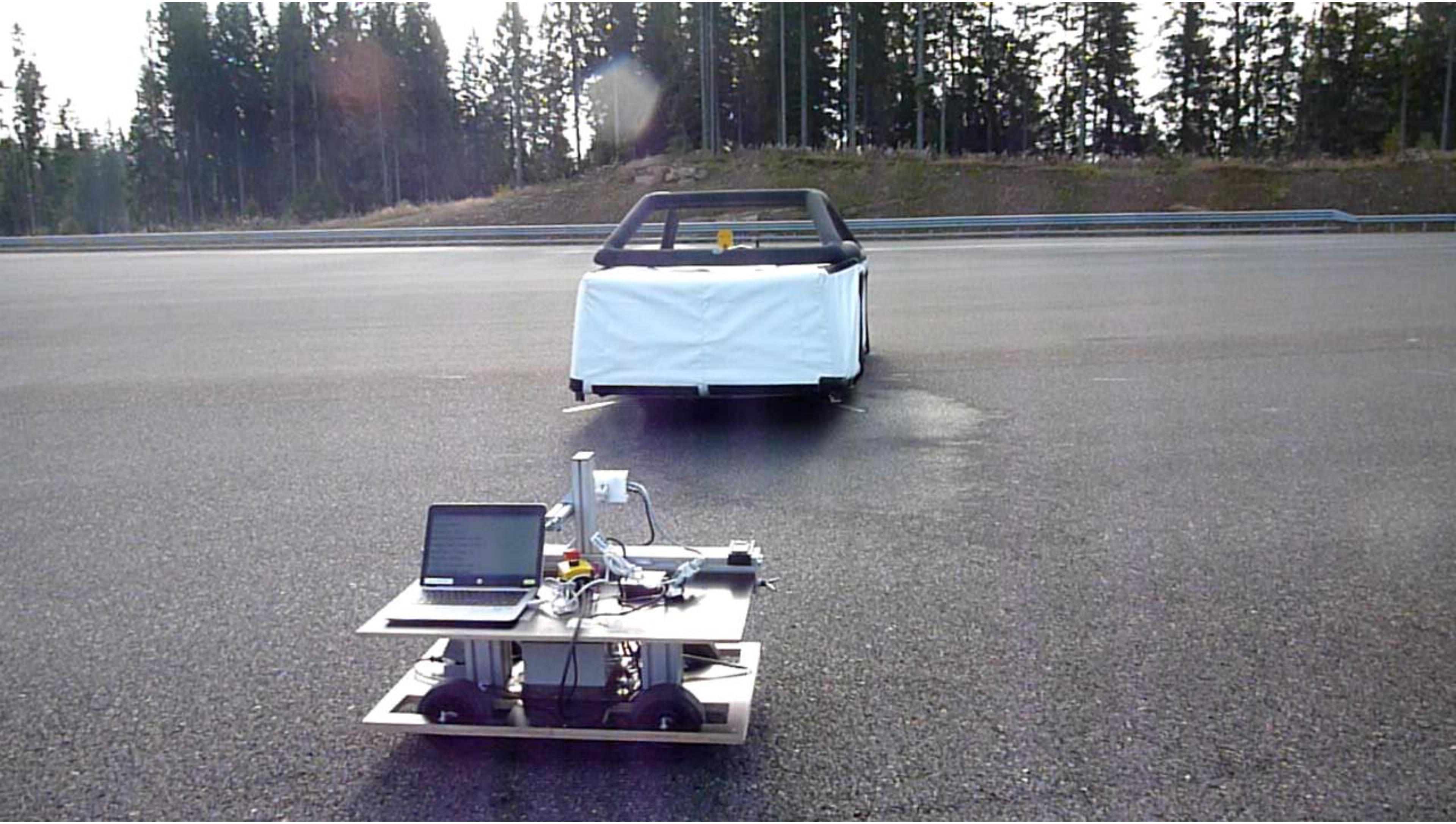
Fast validation

Fast validation of RCS → use on test track on crashed targets



Careful measurement of RCS

Comparing surrogate targets with real vehicles → Target knowledge, input to ISO

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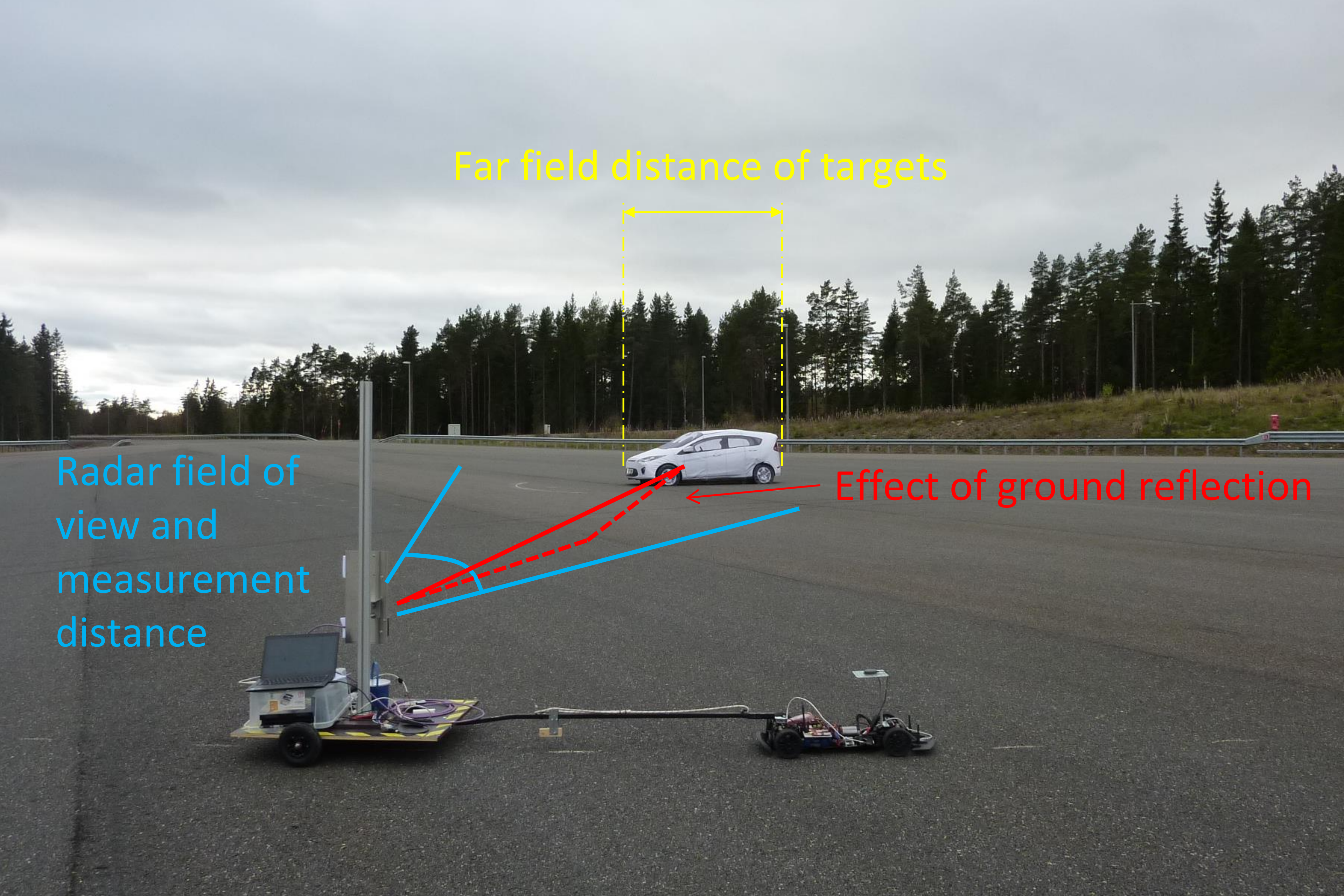
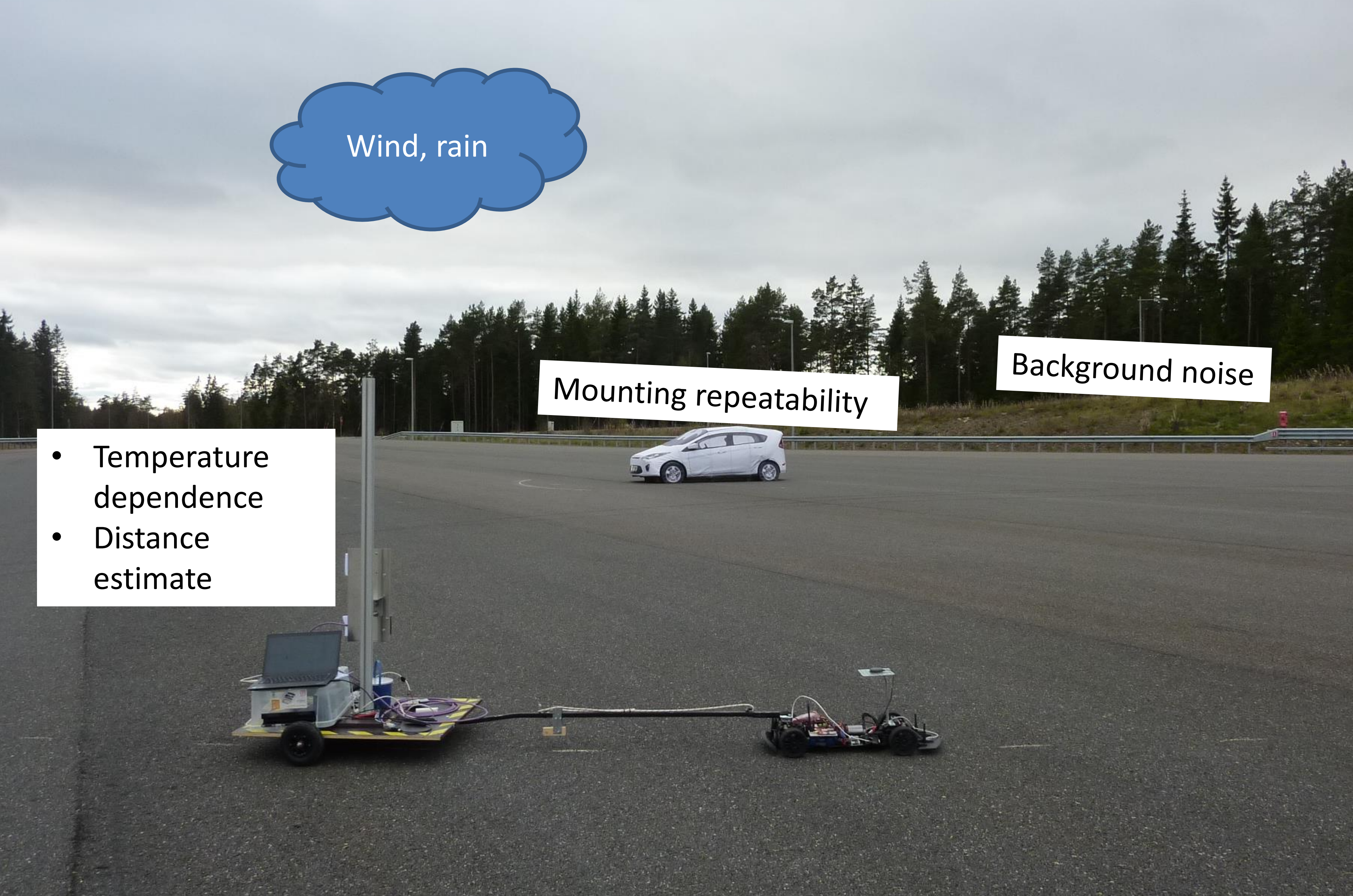
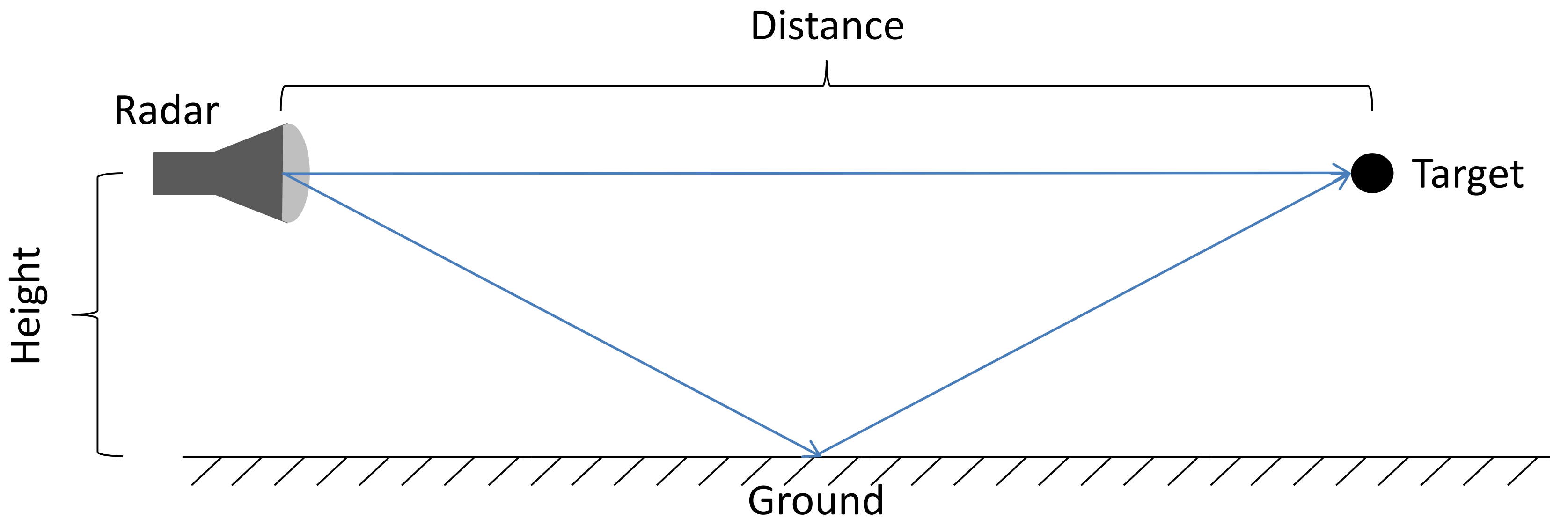
Important properties of the measurement site



Other properties of the measurement site



Ground reflection

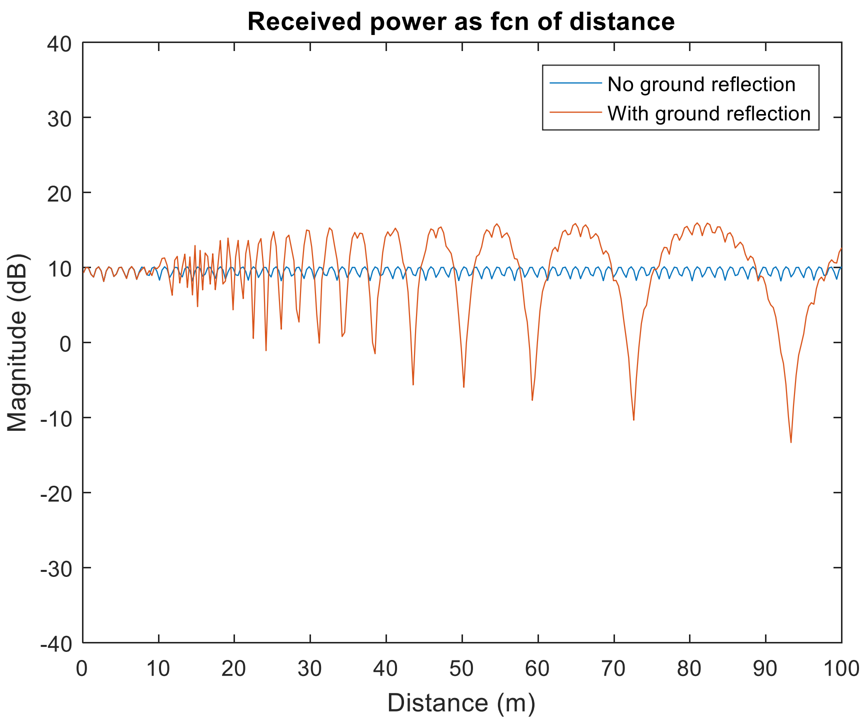


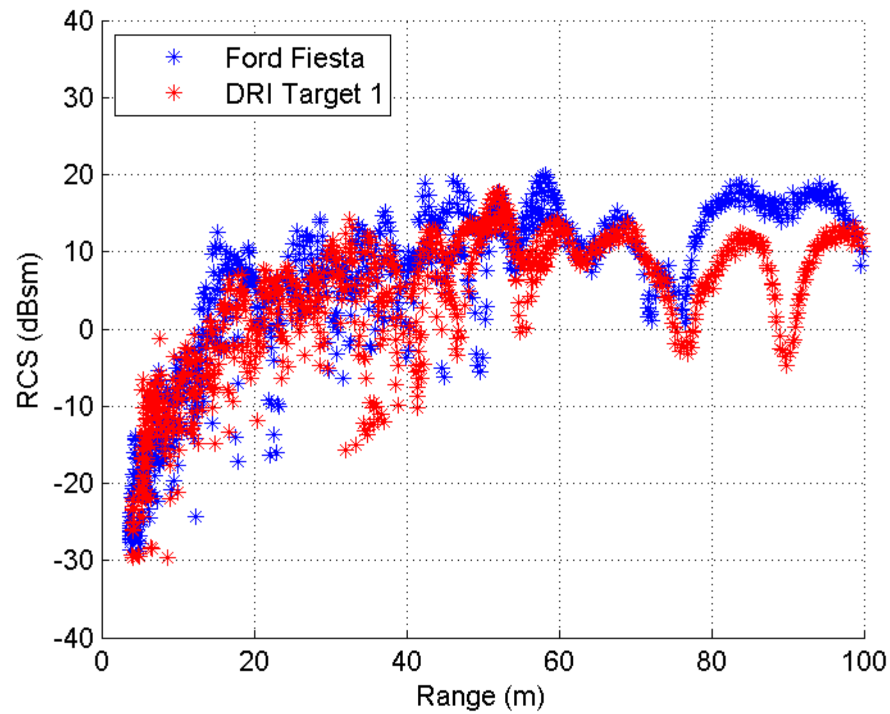
Important properties

- Beam width (in elevation)
- Four propagation paths
- Height over ground plane
- Distance

Effect of ground reflection

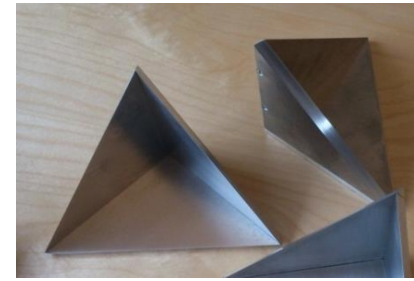
Range measurement is one (of several) characterizations that has to be made for targets

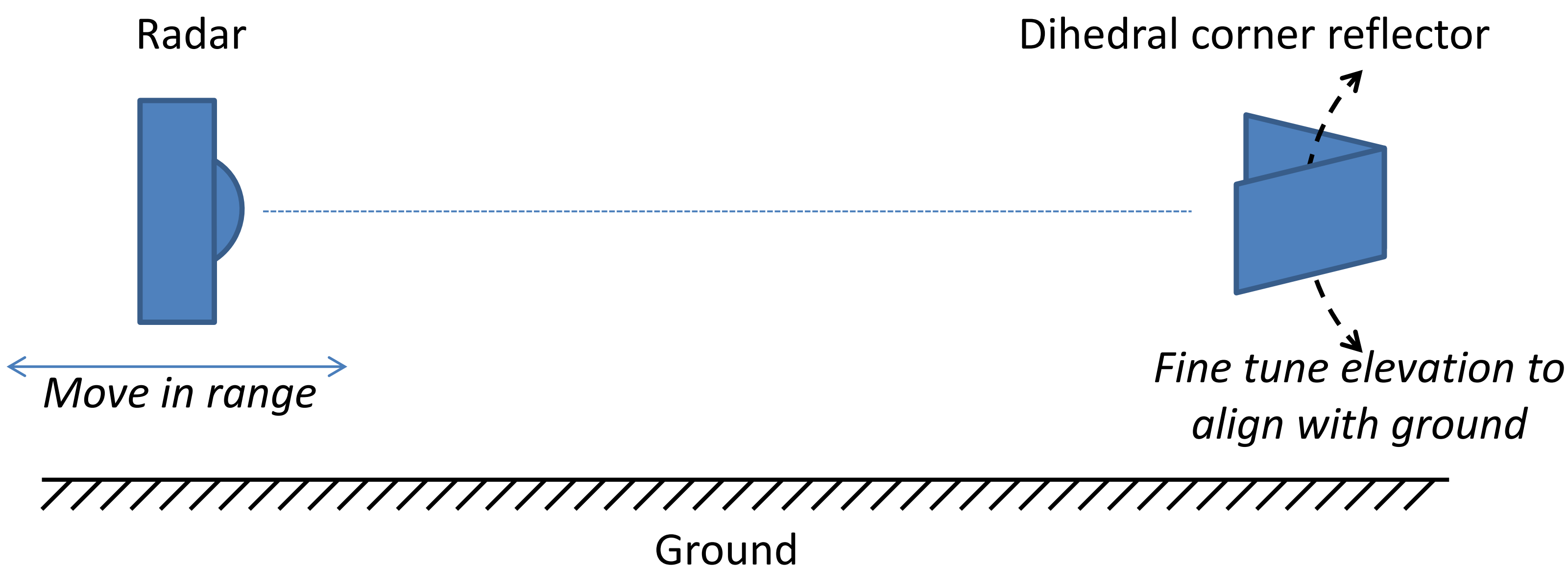




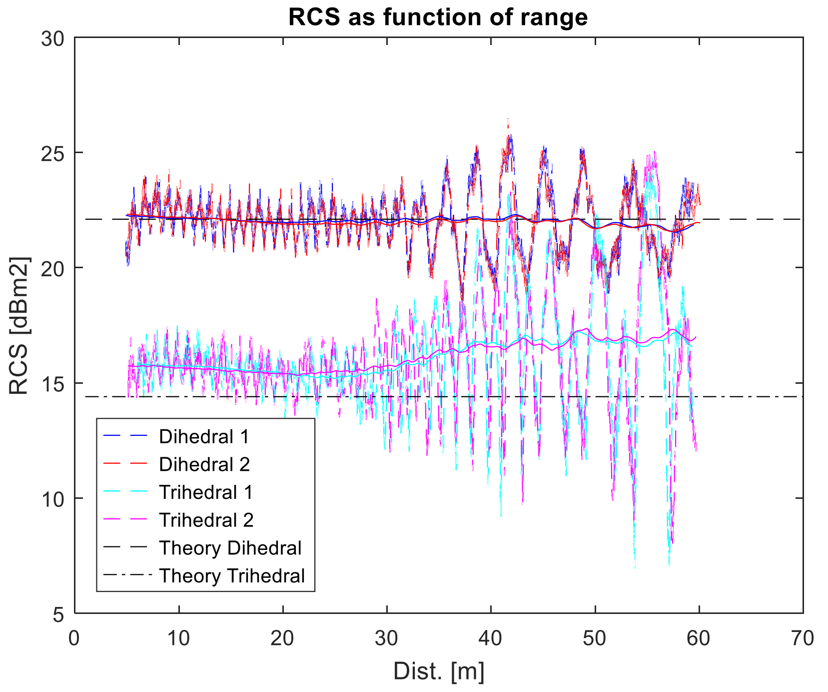
Ground reflection: Radar sensor calibration

- Triangular corner reflector reflects the power back to the radar from ‘all’ directions.
- A metallic plate reflects only in a narrow angular span. Good, but extremely hard to position (vertically & horizontally).
- Dihedral corner reflector reduces the positioning problem in horizontal plane.





Calibration with dihedral corner reflector

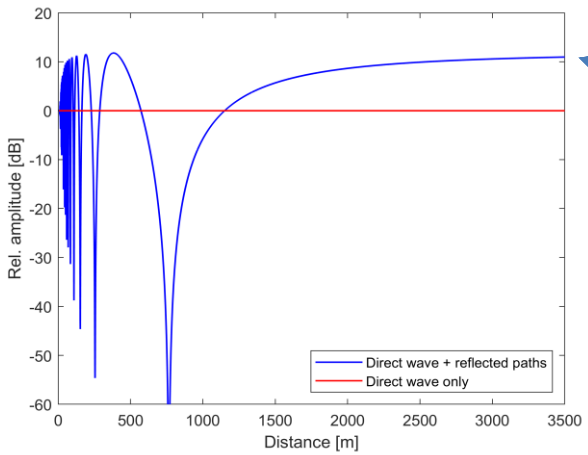


Dihedral: ± 3 dB
Trihedral: ± 9 dB

…but what about the test object?
It is not a dihedral corner reflector…

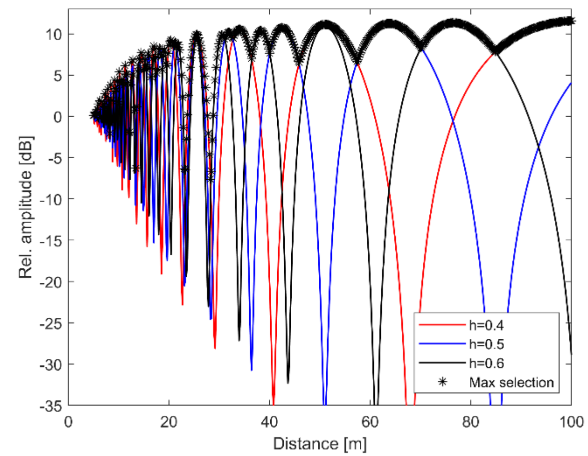
First step: height “diversity”

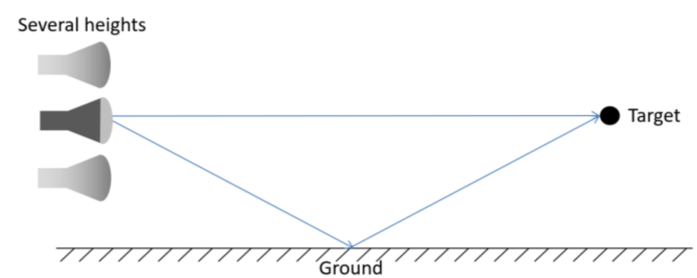
Single measurement, radar height 0.5m.
Note: Long distance to far-field!



Over-estimate ≈ 12 dB

Height “diversity”
Radar height 0.4, 0.5, and 0.6 m



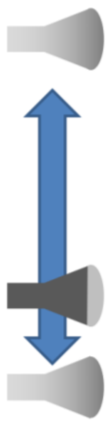


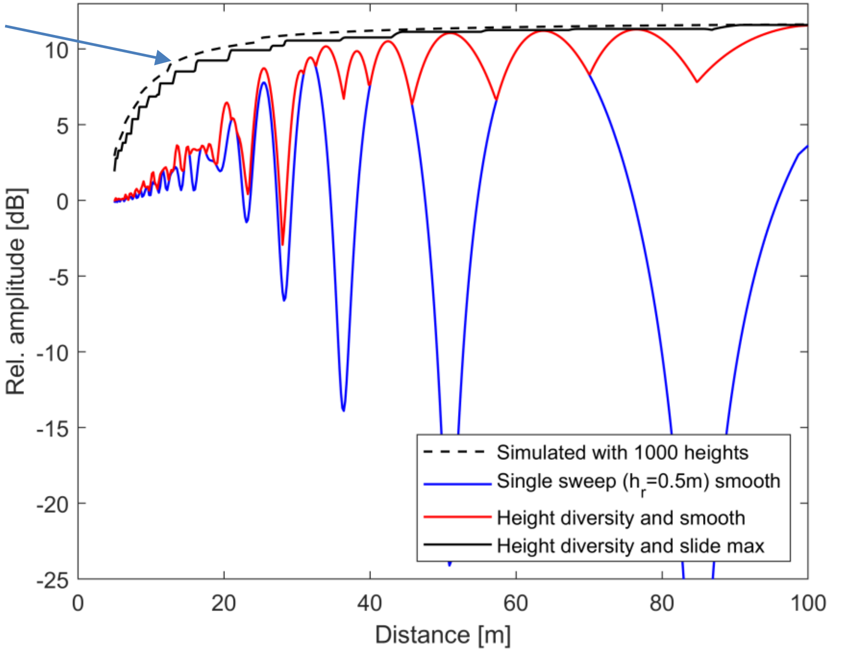
Second step: process over range

Moving average proposed by standard (±2.5 m).

We propose height diversity + sliding max: $w = \max\left\{\sqrt{d}, w_0\right\}$ (w_0 = 2.5 m).

Reference = the over-estimate:
max(1000 heights from 0.1 to 1.5 m)





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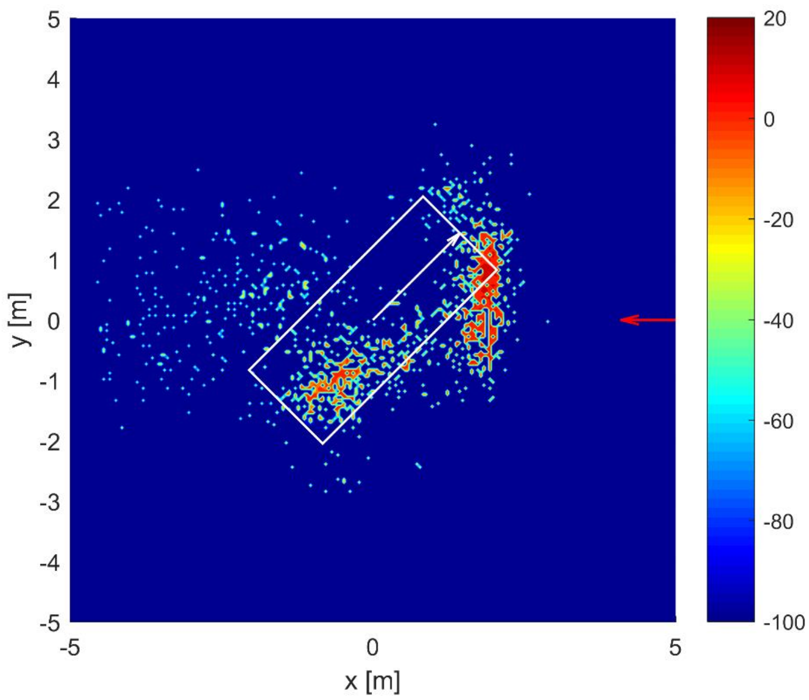
Back projected RCS

Radar knows its position + distance and angle to detection→ back projection onto target



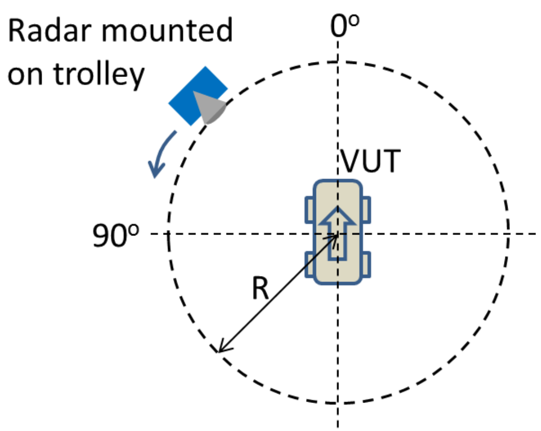
Is this good or bad?

How to put limits in, e.g., a standard?

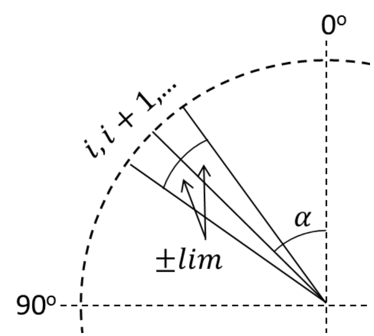
Back projected RCS

Solution: convert to a line plot which can have limits…

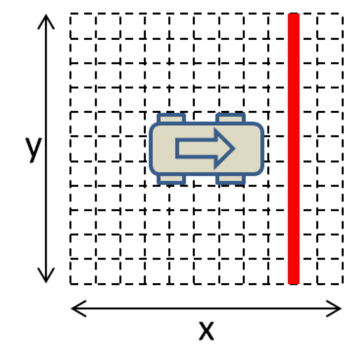
1. Collect samples



2. Take all samples over an angular window



3. Integrate in one dimension



4. Results in a spatial profile

Spatial profile – real vehicle vs surrogate target

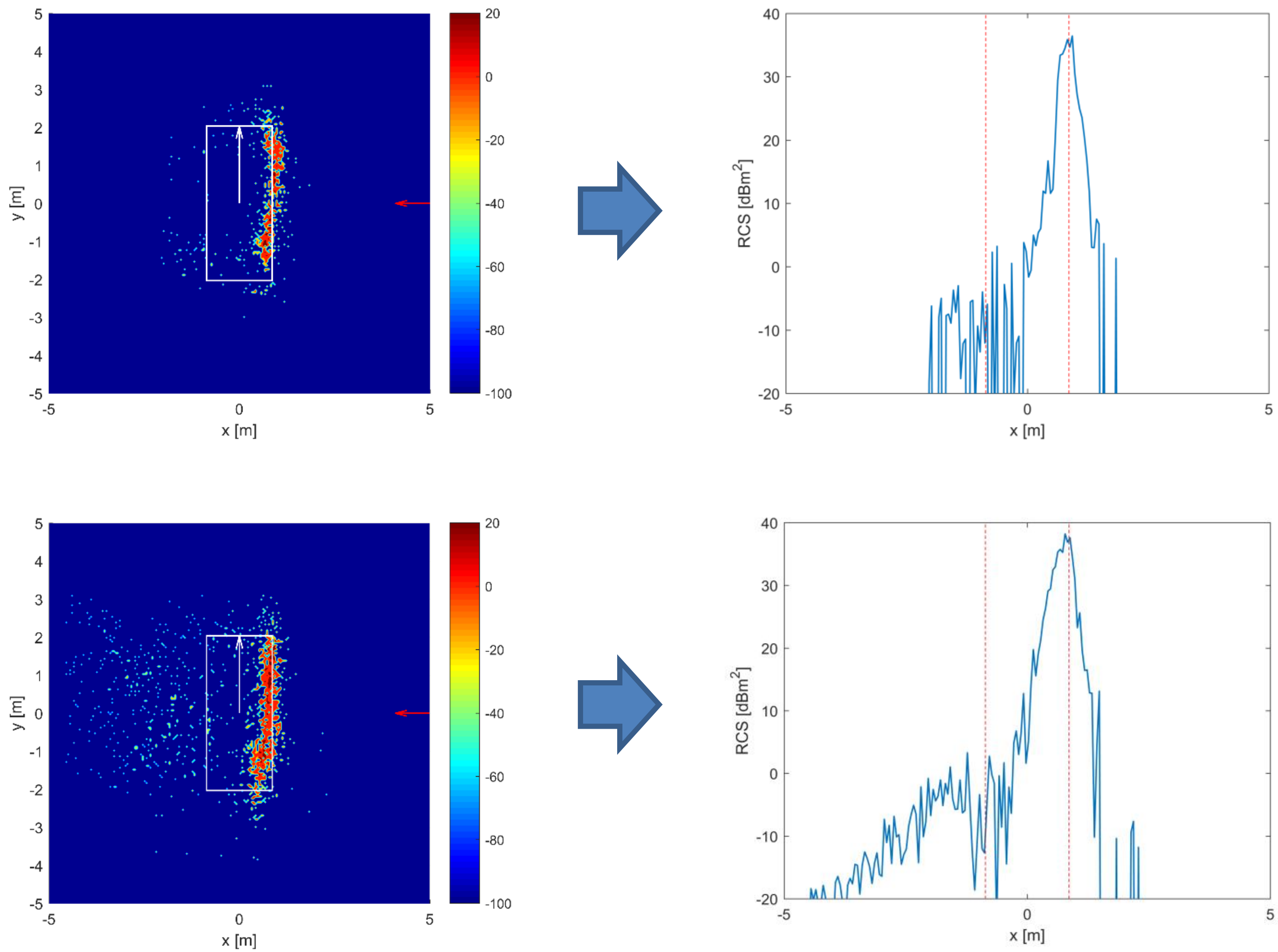
Radar is located at 90°±15° relative to the target

Back projection

Spatial profile

Real vehicle

Surrogate target



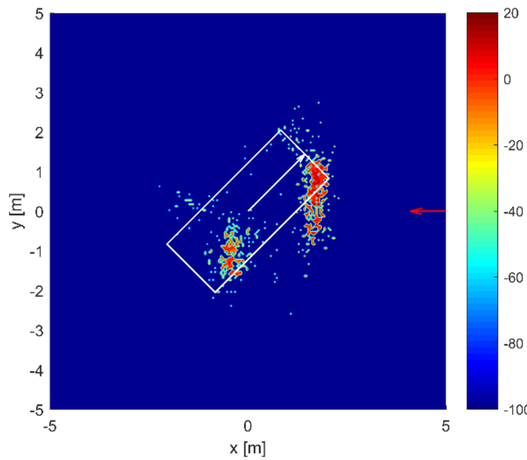
Spatial profile – real vehicle vs surrogate target

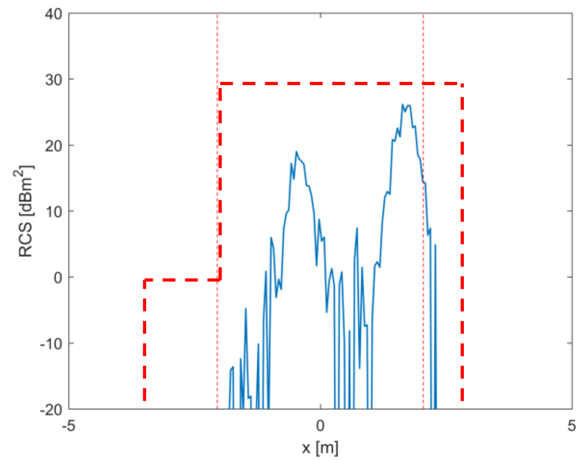
Radar is located at 45°±15° relative to the target

Back projection

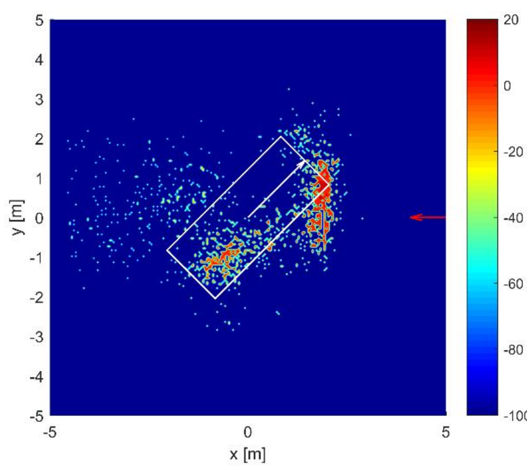
Spatial profile

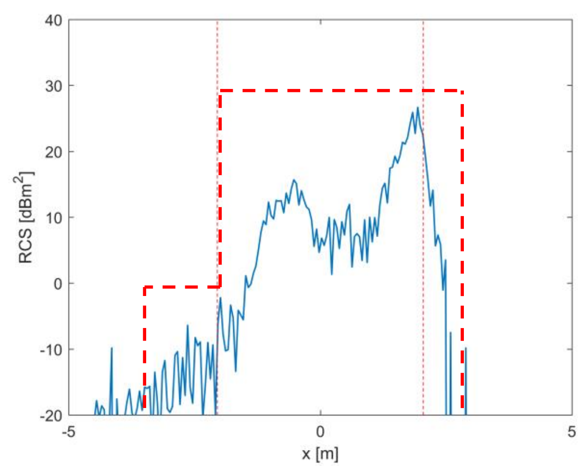
Real vehicle





Surrogate target





Thank you!

Questions?

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