Deliverable D2.1

ASEAN NCAP Motorcycle Target (AMT) Specifications

WP2: Target Development

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Contents

1 Introduction

1.1 General Information

Autonomous Emergency Braking (AEB) systems, dedicated to avoid or mitigate car-to-Vulnerable Road Users (VRU) collisions, are being introduced over the last years, covering pedestrians and bicyclist crashes. The third group of VRU's that have a high percentage on road accidents are motorcyclists. South-East Asian countries have a very higher rate of seriously injured death among riders of motorized 2- and 3-wheelers, therefore in the year 2020 UTAC initiated the OASIM-project joining forces of around 11 industry partners, aiming to develop protocols and appropriate test equipment helping to reduce accident numbers in Asian countries.

Investigation on different representative real scooter models and considering internal and external measurement resources resulted in the design of the scooter-dummy. The dummy is representing a real scooter object regarding sensor relevant properties like RADAR response, IR-reflectivity (LIDAR-systems) and visual appearance (Camera systems) but is a very lightweight structure to avoid damage to the dummy and the test vehicle in case of a crash.
The following specification defines a powered two- wheeler target representing a human being riding a scooter.

1.2 Definitions

AEB .... Autonomous Emergency Braking
AMT .... ASEAN NCAP Motorcycle Target
VT .... Vehicle Target
VUT .... Vehicle Under Test
VRU .... Vulnerable Road User
STA .... Scooter Target ASIA

2 Scooter Rider and Scooter Target

The ASEAN NCAP Motorcycle Target (AMT) described in this document, mimic a real scooter with a rider. It reflects a scooter model with maximum nominal speed of 120 kph, in relation to the vulnerable road users (VRU) detection sensors used in vehicles. The requirements relate, unless not specified otherwise, to the STA itself. Target carrier system and resulting motion of the vehicle target should minimally affect target characteristics (radar, optical signature, etc). The AMT is designed to work with the following types of automotive sensors technologies: RADAR, Video, Laser and Near-IR-based systems like the definition by ACEA Articulated Pedestrian Target Specifications[1]. The AMT must be a full 3D-dimensional representation of a real motorcyclist and scooter.

Figure 1 Scooter rider and scooter target

2.1 TARGET DIMENSIONS

The dimensions of the scooter target are based on representative data for the ASEAN market from the last 3 years (2017-2019) [1].
Typical dimensions are indicated in Table 1 and Table 2. The middle point between the wheel centres will be used as reference 0-point in X-direction and the floor level as reference 0-

[1] ACEA: Articulated Pedestrian Target Specifications Version 1.0

point in Z-direction.

Figure 2 Scooter target dimensions and dummy posture

Table 1: Scooter Target Dimensions [mm]

No.	Measurement	Minimum	Maximum	Mean
1	Wheelbase	1230	1280	1255
2	Front Wheel Diameter	510	530	517
3	Front Wheel Inner Diameter	380	390	387
4	Rear Wheel Diameter	520	540	533
5	Rear Wheel inner Diameter	390	400	393
6	Ground Clearance	130	130	128
7	Wheel Ground Clearance	0	25	0
8	Total Height	1600	1660	1630
9	Seat Height	740	780	760
10	Front Height	1050	1090	1070
11	Rear Height	820	850	835
12	Number Plate Lower Edge	450	470	460
13	Rear Reflector Height	570	590	580
14	Front Reflector Height	660	690	672
15	Side Reflector Height	580	600	590
16	Pedal Height	310	320	315
17	Knee Width	550	570	560
18	Pedal Width	390	410	399
19	Shoulder Width	410	430	420
20	Total Width	660	690	675
21	Head Width (incl. Helmet)	250	260	250
22	Front Wheel Width	100	100	100
23	Rear Wheel Width	110	110	110
24	Number Plate Width	240	250	245
25	Number Plate Height	150	160	155
26	Chest Dimension	210	210	210
27	Upper Body Length	470	490	480
28	Upper Leg Length	390	410	400
29	Lower Leg Length	390	410	400
30	Foot Length	210	220	215
31	Back Radius	650	670	660

Figure 3 Scooter target dimensions and dummy posture

Table 2: Scooter Target Dimensions [deg]

No.	Measurement	Minimum	Maximum	Mean
32	steering fork angle	24	28	26
33	upper body angle	10	20	15
34	upper leg angle	10	20	15
35	lower leg angle	0	10	5
36	foot angle	0	10	5
37	number plate angle	32	36	34
38	upper leg front angle	40	50	45
39	arm angle	24	28	26

Dimensions of the scooter rider target are based on mean values of statistical data from adult ASEAN population [1].

2.2 Visual and Infrared Properties

Like the adult pedestrian target specified by ACEA[2], the Motorcycle rider shall be look like clothed with long-sleeved t-shirt and trousers in different colours: t-shirt in black, jeans in blue and shoes in black. The clothing has to be made from tear-proofed and water-resistant material. Skin surface parts have to be finished with a non-reflective flesh-coloured texture.
Colours based on measurement method described in annex A.1 must be in the range described in Table 3 (sRGB 0-255, Observer = 2°, Illuminance = D65).
The IR reflectivity from 850 to 950 nm wavelength of clothes and the motorcycle parts must be within the range defined in Table 4 based on measurement method described in appendix A.1. At the selection of measured parts, it has to be ensured, that the IR reflectivity measured with the 45° probe must not differ for more than 20% from the reflectivity measured with the 90° probe.

Figure 4 infrared and visual properties of scooter target

[2] ACEA: Articulated Pedestrian Target Specifications Version 1.0

Table 3 Visual Properties

Number	Segment		Colour	Red	Green	Blue	Appearance
1	Main Body	min		229	230	224	Glossy
		mean		239	240	234	
		max		249	250	244	
2	Black Top, Shoes	min		35	36	37	Matt
		mean		45	46	47	
		max		55	56	57	
3	Trousers	min		0	90	133	Matt
		mean		0	110	153	
		max		20	130	173	
4	Skin, Face, Hands	min		112	95	72	Matt
		mean		182	165	142	
		max		252	235	212	
5	Steering Fork	min		231	229	231	Glossy
		mean		241	239	241	
		max		251	249	251	
6	Helmet	min		5	5	5	Glossy
		mean		15	15	15	
		max		25	25	25	
7	Tires, Rubber Parts	min		35	34	36	Matt
		mean		45	44	46	
		max		55	54	56	
8	Number Plate	min					Retroreflecting
		mean					
		max					
9	Side Mirrors Glass	min		55	55	55	Matt
		mean		65	65	65	
		max		75	75	75	

Table 4 IR Properties

Number	Segment	IR – Reflectivity 850 – 950 nm [%]
1	Main Body	≥ 70
2	Black Top, Shoes	40 - 60
3	Trousers	40 - 60
4	Skin, Face, Hands	40 - 60
5	Steering Fork	10 - 40
6	Helmet	≤ 50
7	Tires, Rubber Parts	≤ 15
8	Number Plate	≥ 85
9	Side Mirrors Glass	≤ 30

2.3 RADAR PROPERTIES

The scooter target should be able to represent the radar reflectivity characteristics of a human being riding on a scooter. The method for measuring the radar properties is described in A.2.

2.3.1 RADAR CROSS SECTION

The radar cross section (RCS) of a vehicle may vary significantly with observation angle. Theoretically there is no RCS variation with the distance. However, due to the limited field of view of the radar sensor and the implemented free space loss compensation, the measured RCS significantly varies over distance, and in near distances the vehicle is not scanned over its complete height. The measured RCS is also influenced by geometrical effects (i.e., multi path with constructive and destructive interferences).
Therefore, in this document RCS refers to the measured RCS by a given radar sensor with its specific parameter set, while recognizing that it does not necessarily correspond to the physical RCS.
Example RCS measurements are shown in appendix A.3.

2.3.2 RCS BOUNDARIES FOR FIXED RANGE, VARIABLE VIEWING ANGLE MEASUREMENTS

For Fixed Range Measurements (procedure described in A.2.1.4) at least 95 % of the filtered data points should lie within the boundaries shown in Figure 5.The boundaries are defined using cubic spline interpolation of the data breakpoints provided in Table 5.

Table 5 Fixed- range RCS boundary breakpoints

Angle [deg]	Lower Boundary [dBsm]	Upper Boundary [dBsm]
0	-3	5
30	-3	5
60	-2	6
70	-1	7
80	3	12
90	8	18
100	3	12
110	-1	7
120	-4	5
150	-4	5
180	-1	9

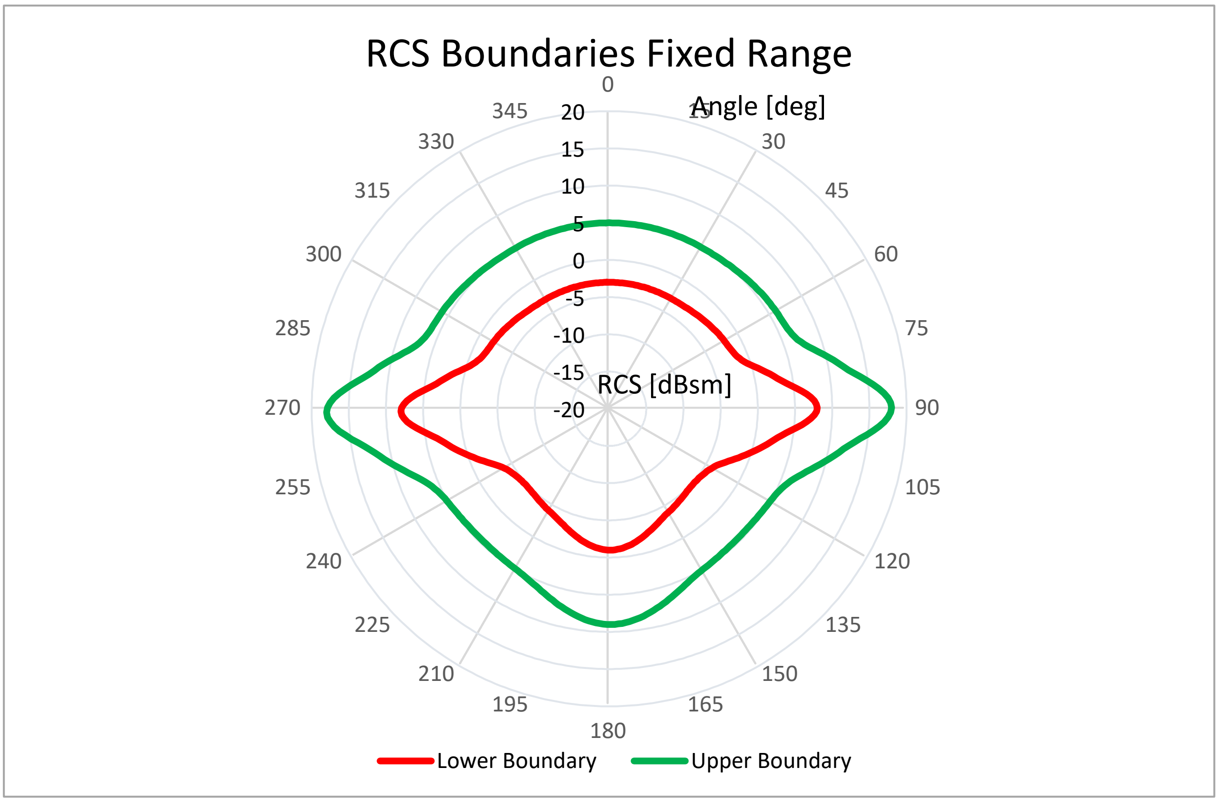


Figure 5 Scooter Rider and Scooter Target RCS-Boundaries (77GHz Sensor Continental ARS400)

2.3.3 RCS Boundaries for Fixed Viewing Angle, Variable Range Measurement

RCS for fixed viewing angles measurement as described in A.2 should stay within a defined range. At least 95 % of the filtered data points should lie within the boundary depicted in Figure 6 to Figure 12.The boundaries are defined using formulas (1) and (2) and the parameters from Table 6

$$Upper\ Boundary = RCS_{far} - K_{dec} \cdot \min(R - R_{far}, 0)^2 + \Delta_{RCS} \quad (1)$$

$$Lower\ Boundary = RCS_{far} - K_{dec} \cdot \min(R - R_{far}, 0)^2 - \Delta_{RCS} \quad (2)$$

Table 6 Fixed Angle RCS boundary parameters

Angle [deg]	K_{dec}	R_{far} [m]	RCS_{far} [dBsm]	Δ_{RCS} [dBsm]
0	0.007	40	3	6
30	0.008	40	2	6
60	0.005	40	4	6.5
90	0.01	40	17	7
120	0.009	40	5	6
150	0.006	40	1	5
180	0.008	40	2	6

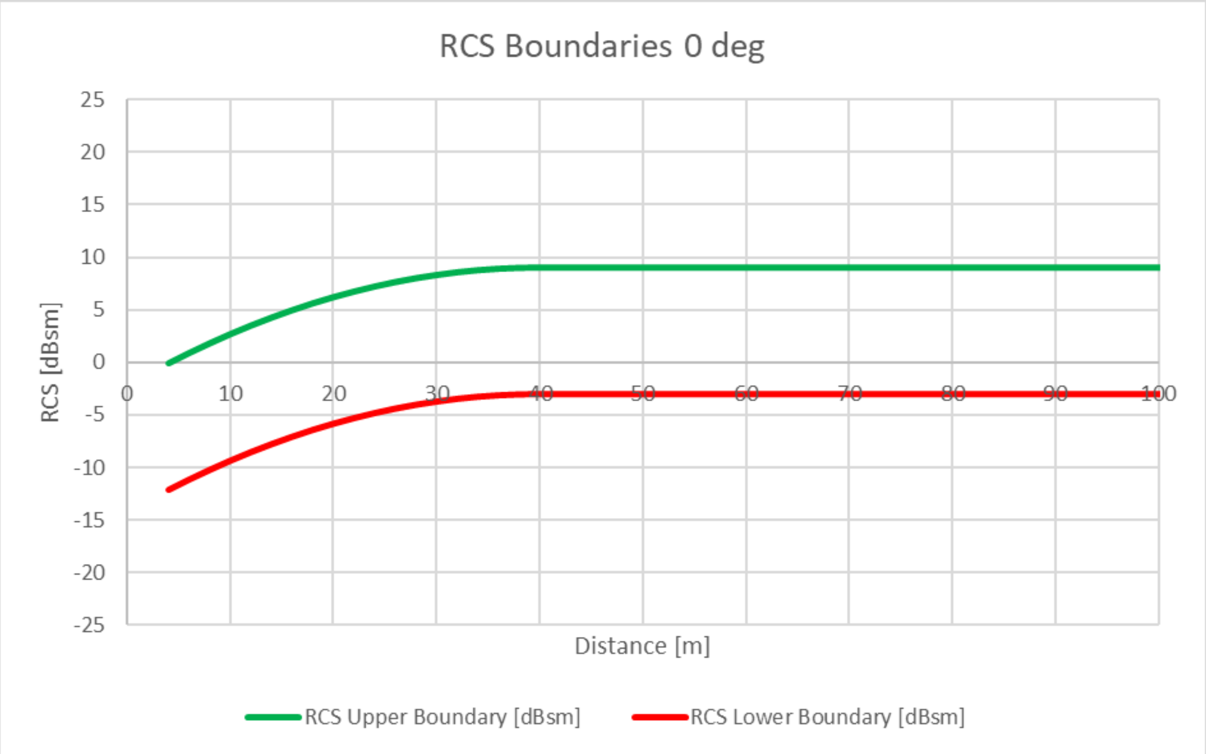


Figure 6 Scooter Rider and Scooter Target RCS-Boundaries (77GHz Sensor Bosch MRR-SGU) 0 deg

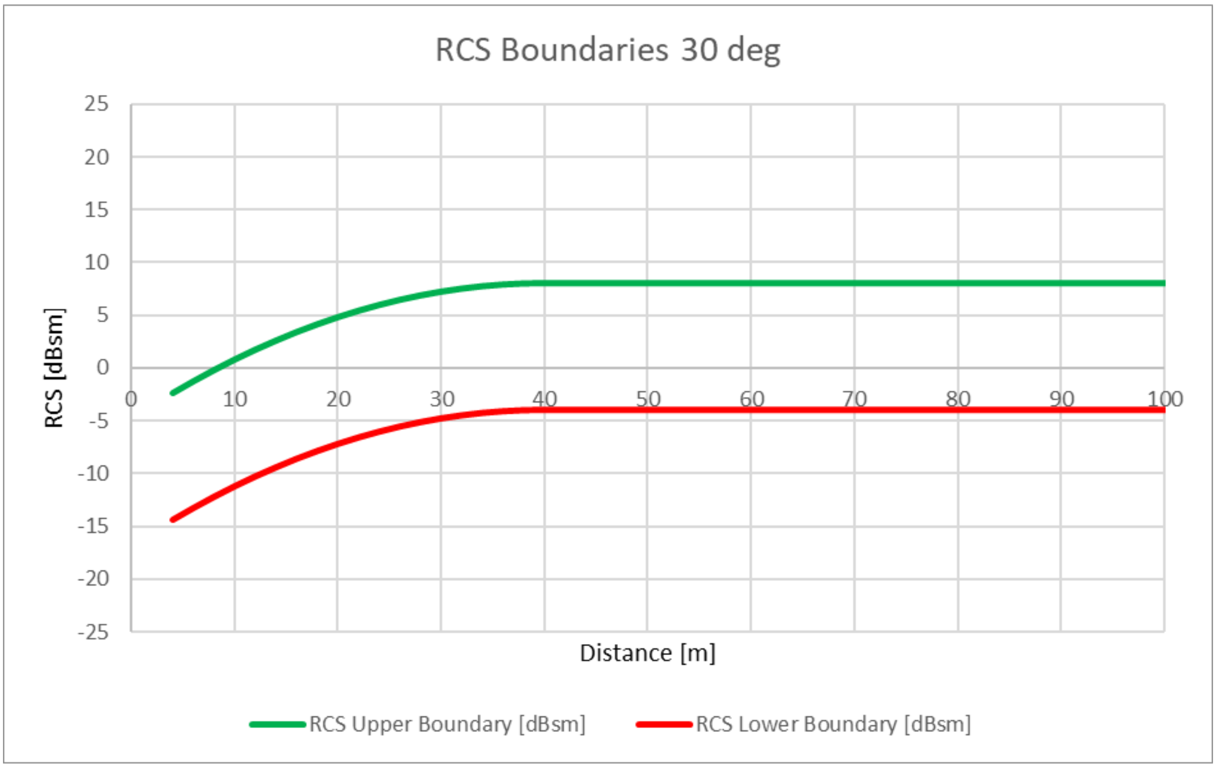


Figure 7 Scooter Rider and Scooter Target RCS-Boundaries (77GHz Sensor Bosch MRR-SGU) 30 deg

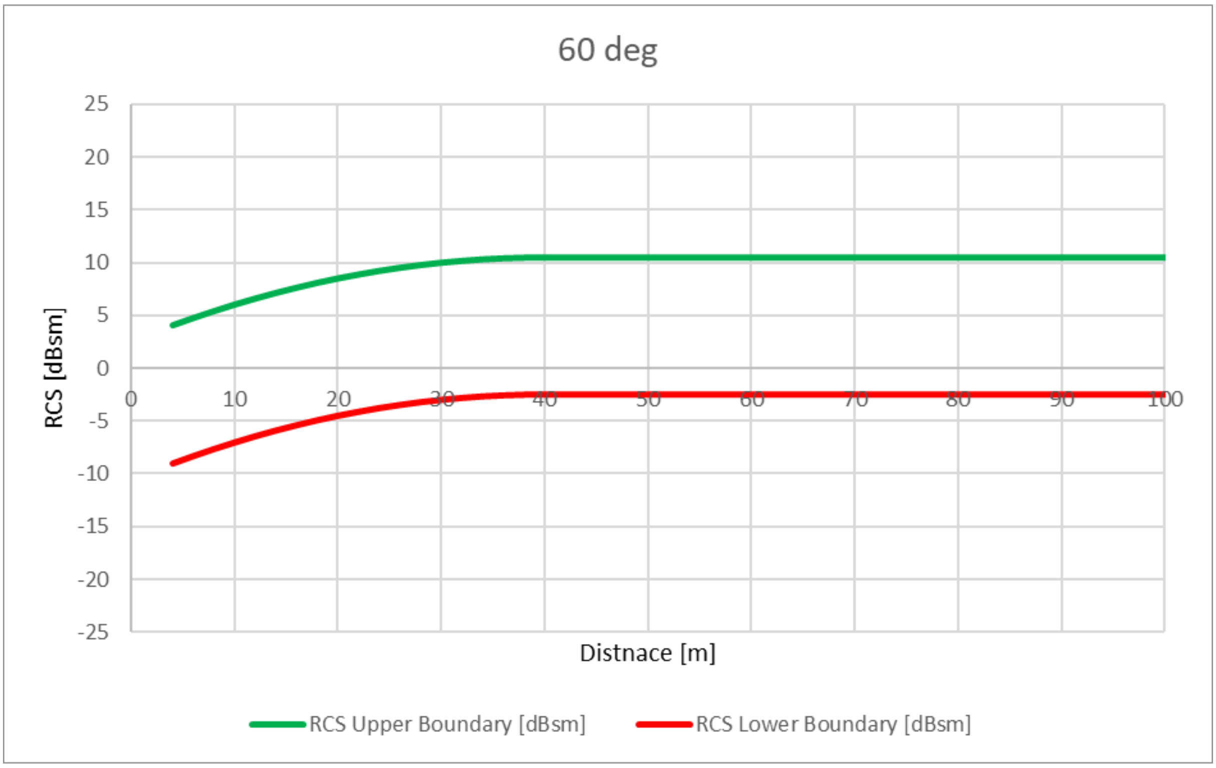


Figure 8 Scooter Rider and Scooter Target RCS-Boundaries (77GHz Sensor Bosch MRR-SGU) 60 deg

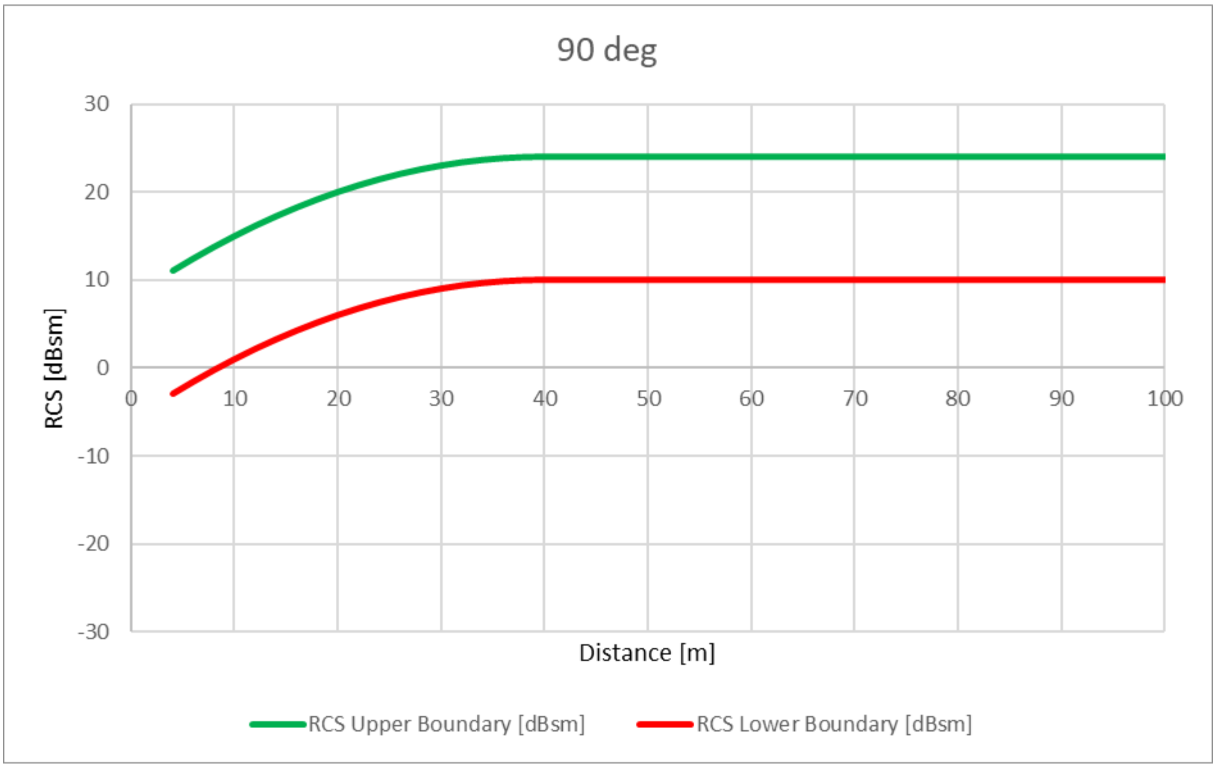


Figure 9 Scooter Rider and Scooter Target RCS-Boundaries (77GHz Sensor Bosch MRR-SGU) 90 deg

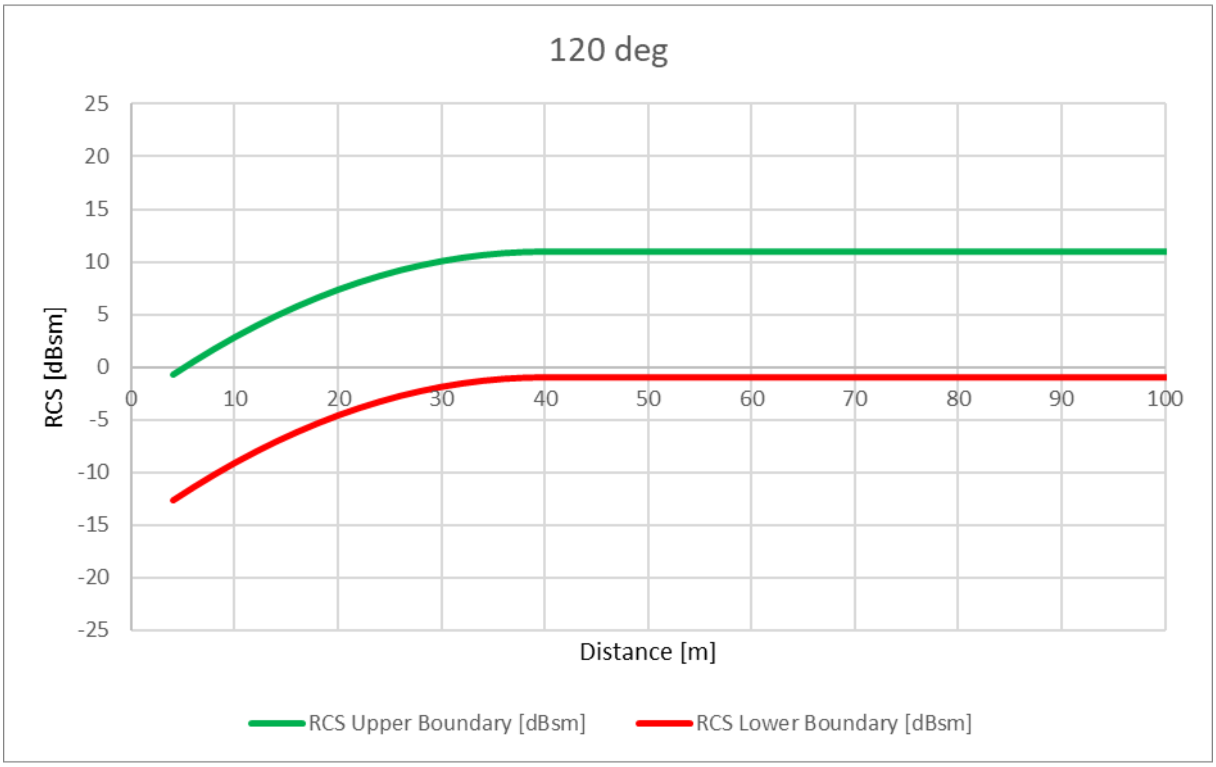


Figure 10 Scooter Rider and Scooter Target RCS-Boundaries (77GHz Sensor Bosch MRR-SGU) 120 deg

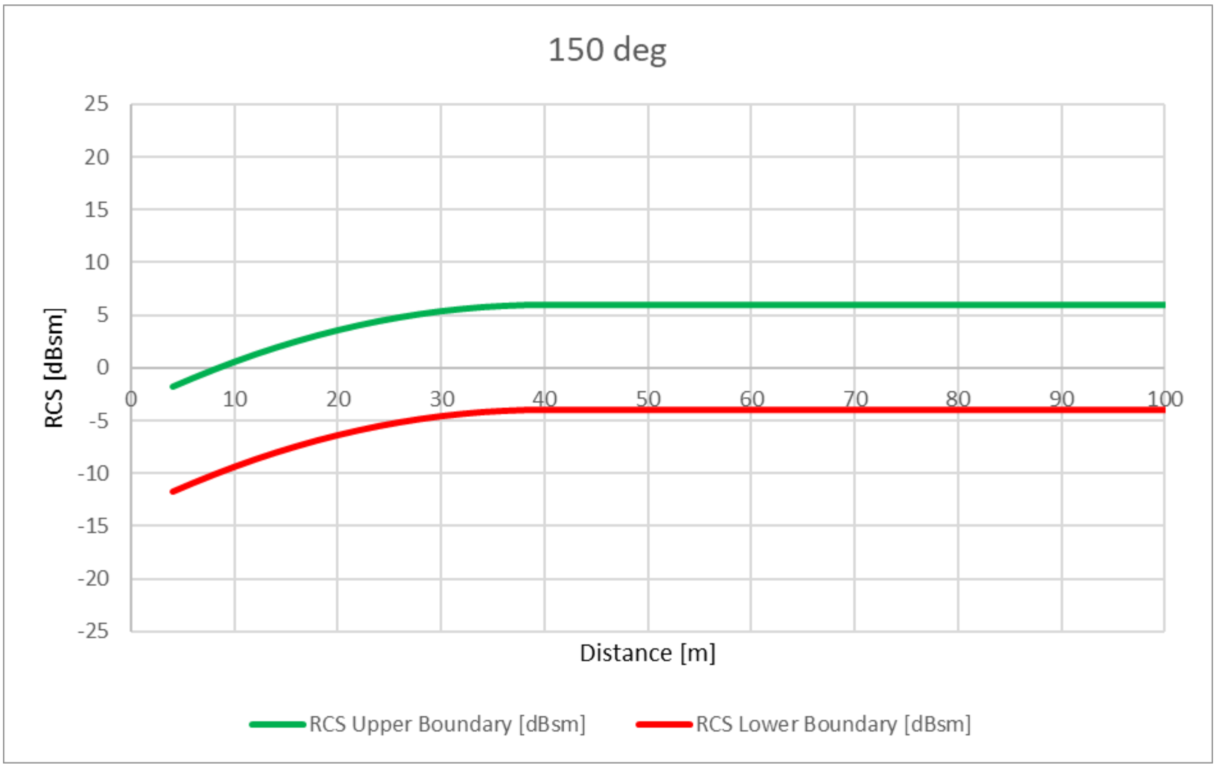


Figure 11 Scooter Rider and Scooter Target RCS-Boundaries s (77GHz Sensor Bosch MRR-SGU) 150 deg

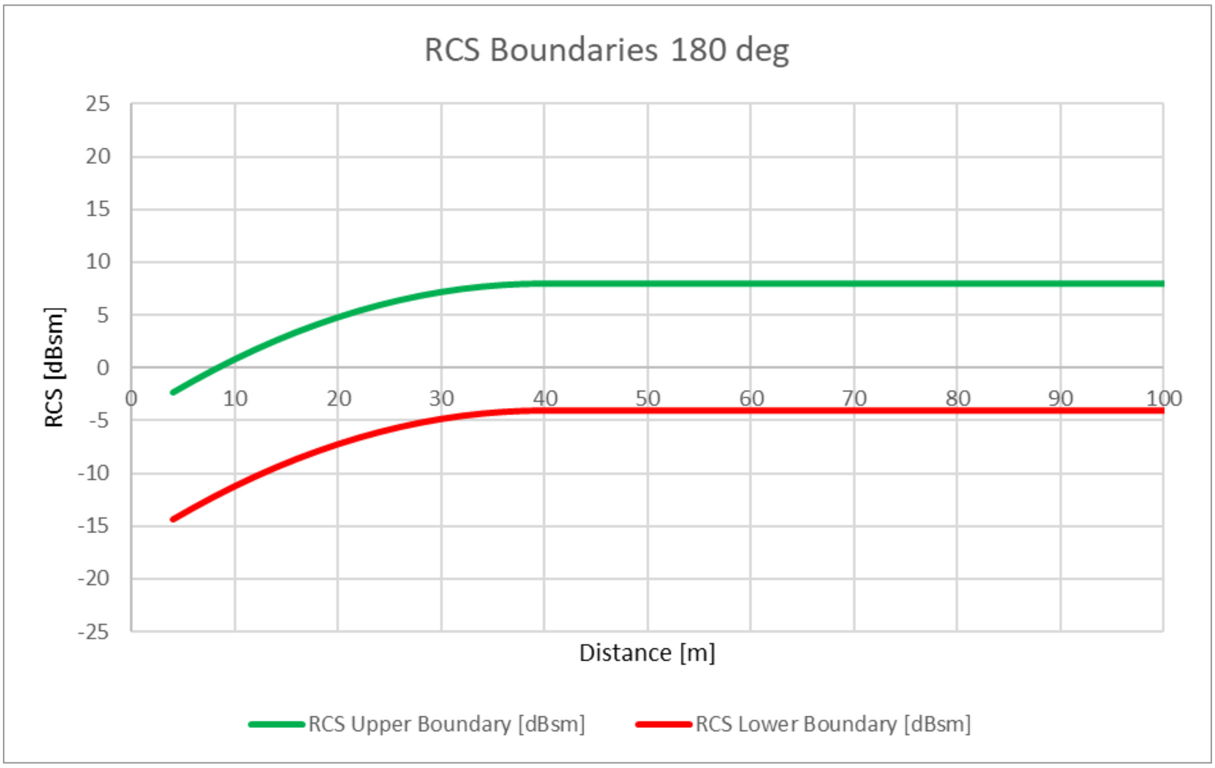


Figure 12 Scooter Rider and Scooter Target RCS-Boundaries (77GHz Sensor Bosch MRR-SGU) 180 deg

2.3.4 Micro-Doppler Properties

Micro-Doppler effects generated by the rotating wheels are an important identification characteristic of PTWs. The AMT target shall provide a means of producing appropriate micro-Doppler effects associated with rotating wheels, and these must be analogous to those produced by a rotating wheel appropriate for the AMT target speed. Monitoring of correct corresponding rotational speed is mandatory. The micro-Doppler spread shall be appropriately distributed referencing to the two rotation centres, i.e. the front and rear axles. Detectable differential speeds must have the correct geometrical distribution in the horizontal plane. Reflectivity observed when approaching in line with the wheels should be below 20 percent of the maximum reflectivity detected. Figure 31 to Figure 35 in appendix A.3 show examples for the Micro-Doppler distribution of a rotating wheel on static objects (real scooter and STA). Only rear wheel is rotating at a speed of 20 kph.

2.4 Mounting and Guidance System

- All visible parts of the AMT mounting and guidance system must be coloured in grey. In case of a uniform background the colour shade of the background can be used.
- It must be ensured that the AMT mounting and guidance system is not influencing radar return.
- Any supporting ropes or tubes for fixing the dummies position must not interfere with the VRU emergency braking system.
- No parts of the AMT should be covered by the guidance system with reference to the approaching VUT.

2.5 Weight and Collision Stability

After a collision the correctness of the AMT posture and dimension have to be checked before starting a new test. The most relevant AMZ parameters are defined in Table 1 and Table 2 and are requested during the testing phase (wind, acceleration).

- The AMT must not have any hard impact points to prevent damage of the VUT.
- Max. relative collision velocity of 60km/h (oncoming, crossing) / 60km/h (longitudinal).
- Max AMT weight: 16kg

After a series of test repetitions and previous collisions the target must not show relevant changes in its shape and other sensor relevant properties.

Appendix

A.1 Measurement of the IR Reflectivity

The measurement of the IR reflectivity must be carried out using a measuring device according to the following specification.
Required measurement equipment:

- a spectrometer capable of covering wavelengths from 850 to 950 nm, such as the Ocean Optics Flame-S spectrometer (shown in Figure 13) or the Jaz Miniaturspectrometer
- a light source
- a 90-degree and 45-degree probe
- a calibration standard

The spectrometer should be calibrated using the calibration procedure specified by the device manufacturer. The calibration shall then be confirmed using a calibration standard with a known reflectivity.

Figure 13 IR Measurement Equipment

The IR measurements shall be taken at three locations for each feature to be measured, and shall be averaged across the three measurements for wavelengths in the range of 850 to 950 nm.

A.2 Measurement of Radar Reflectivity

The scooter rider and scooter target should be able to represent the radar reflectivity characteristics of a human adult riding on a real scooter with dimensions described in 0. Therefore, the difference between the target dummy and a real motorbike should be as small as possible.
The method for measuring those features is described below. See examples of measurements according to this methodology in A.3.

A.2.1 Measurement Setup

A.2.1.1 Radar Sensor

The sensor used for radar measurements should have the following parameter values:

- Frequency bandwidth: 76- 81 GHz
- Sensor range: >100 m
- Range gate length: <0,6 m
- Field of view, horizontal: 10° minimum (-3 dB amplitude limit)
- Field of view, elevation: 5° minimum (-3 dB amplitude limit)

The sensor shall be capable of being mounted on a fixture between 230 mm and 900 mm above ground level and should be aligned parallel to the ground within +/- 1°.
The required relative motion (distance or viewing angle) can be either achieved by moving the sensor fixture or by moving the target.

A.2.1.2 Sensor calibration

Reference measurements of two objects of the same shape and known RCS (e.g. dihedral or trihedral corner reflectors) should be performed at distances ranging from 5 m to 100 m to calibrate the sensor.
The calibration objects should be mounted with their centres at 480 mm +/-10 mm above the ground. Reduce the reflectivity of the fixture either by using non-reflecting material or radar absorbers.
In order to ensure that the sensor provide linear results in the RCS range of interest, one calibration object should have a known RCS within the range of 5 dBm^2 to 20 dBm^2 and the other object a much lower RCS of -20 dBm^2 to 0 dBm^2. Within a sensor field of 10°consistent results should be provided. Variations within +/- 3 dB are acceptable.

A.2.1.3 Test Environment

Guidelines for the test Environment:

- no additional objects/buildings in the observation area
- proving ground surface completely covered with tarmac or concrete
- ground conditions: flat, dry street
- no metallic or other strong radar-reflecting parts in-ground or surrounding area shown in

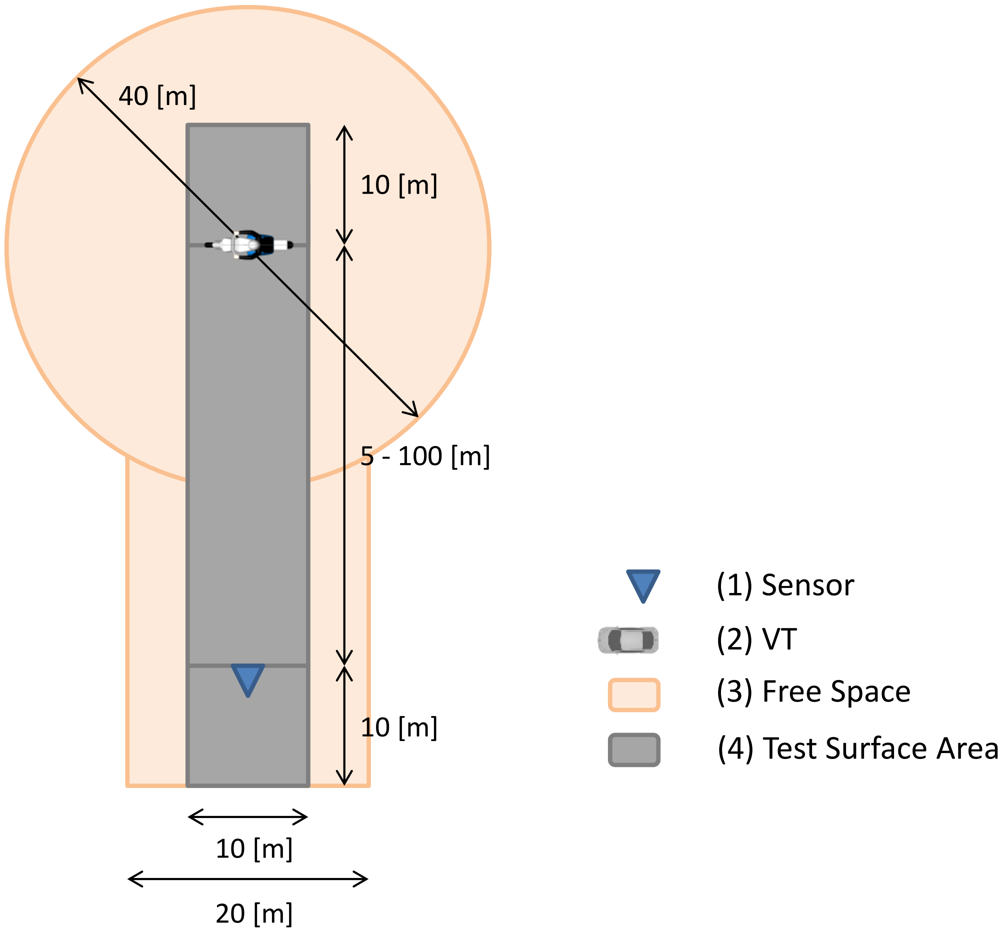


Figure 14 Test Environment

A.2.1.4 Measurements Scenario 1: Fixed Range, Variable Viewing Angle

The radar reflectivity of the scooter target is very sensible to the viewing angle. Therefore, fixed range measurements should be performed to characterize the radar reflectivity of the scooter target from all angles.

Guidelines for Fixed Range Scan:

- target on 360°turntable with static sensor setup
- distance sensor to target: 30 m
- three different sensor heights: 220 mm +/-10 mm, 480 mm +/-10 mm, 900 mm +/-10 mm
- low pass filtering using a moving average window of 2,5° over all sensor heights
- averaging filtered RCS at each angle across the three sensor height measurements.

A.2.1.5 Measurements Scenario 2: Fixed Angle, Variable Range

The aim of the Fixed Angle Scan is the characterization of the overall magnitude reduction that occurs as the sensor approaches the target.
Guidelines for Fixed Angle Scan:

- static target with moving vehicle
- measure distance spanning 5 m to 100 m
- max. approaching speed 10km/h, no abrupt deceleration
- measurement angles: 0°, 30°, 60°, 90°, 120°, 150°, 180° (static AMT facing direction relative to vehicle, assuming symmetry)
- three different sensor heights: 220 mm +/-10 mm, 480 mm +/-10 mm, 900 mm +/-10 mm
- low pass filtering using a moving average window of +/-2,5m over all sensor heights

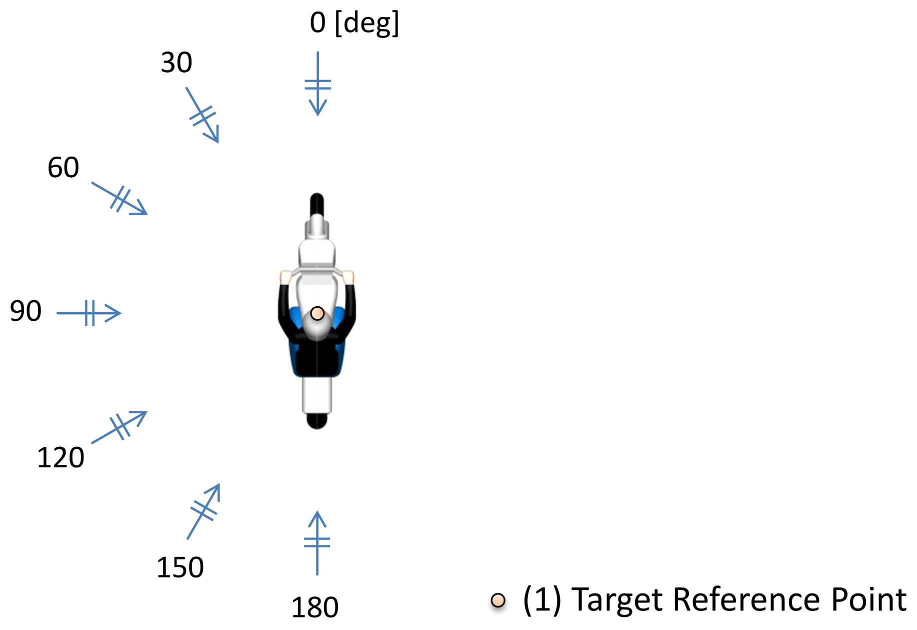


Figure 15: Fixed Angle Scan

A.3 RCS Measurement Examples

The following figures provide example measurements using the evaluation methodology of appendix A.2.

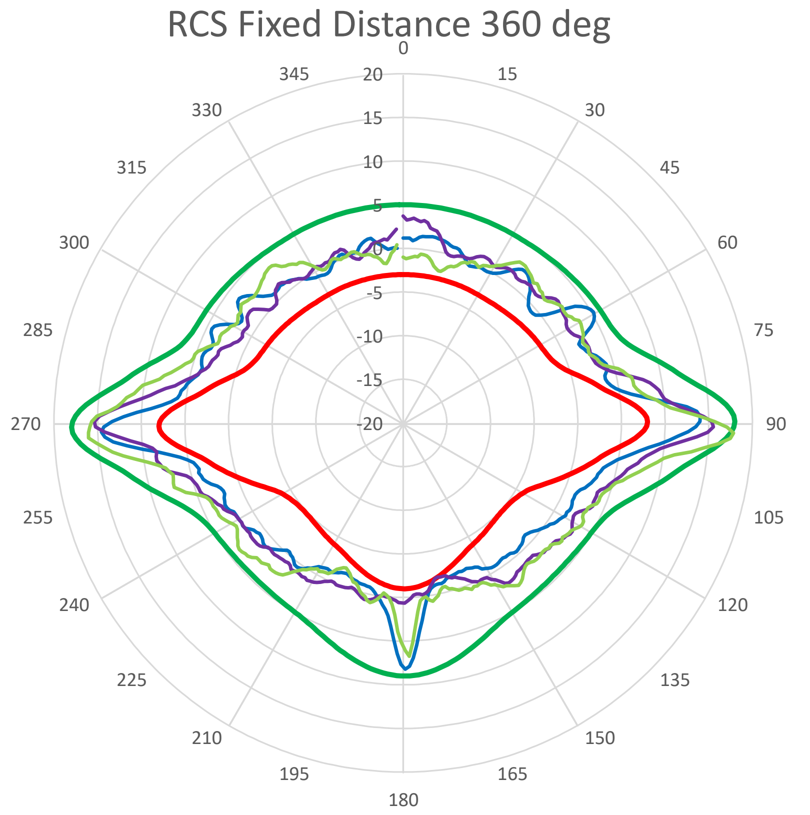


Figure 16 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS400) 360 deg FD

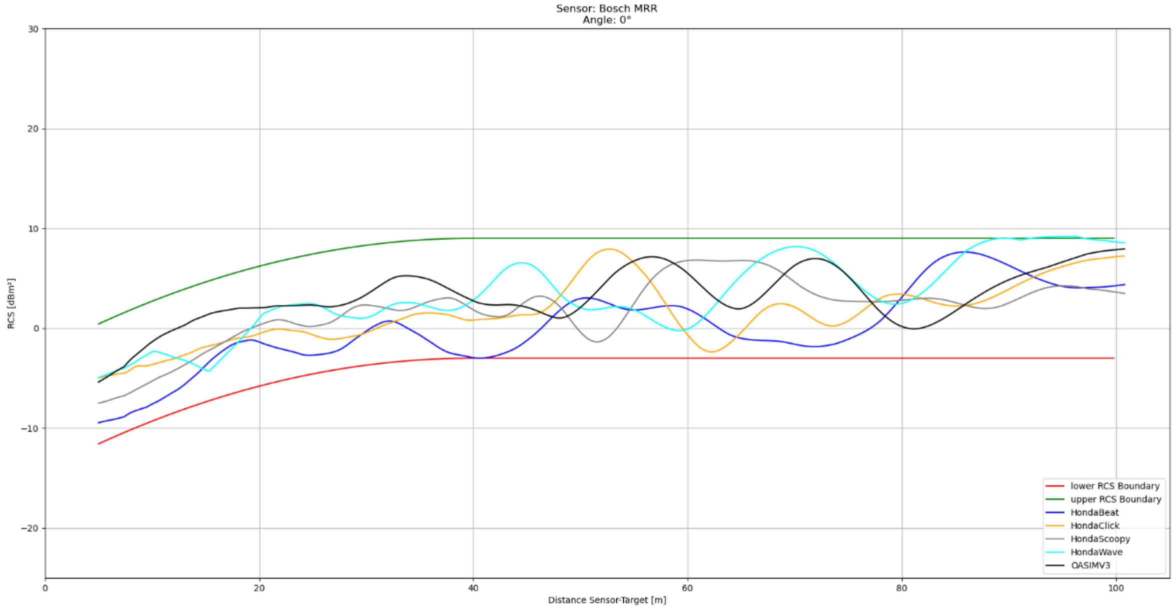


Figure 17 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Bosch MRR-SGU) 0 deg FA

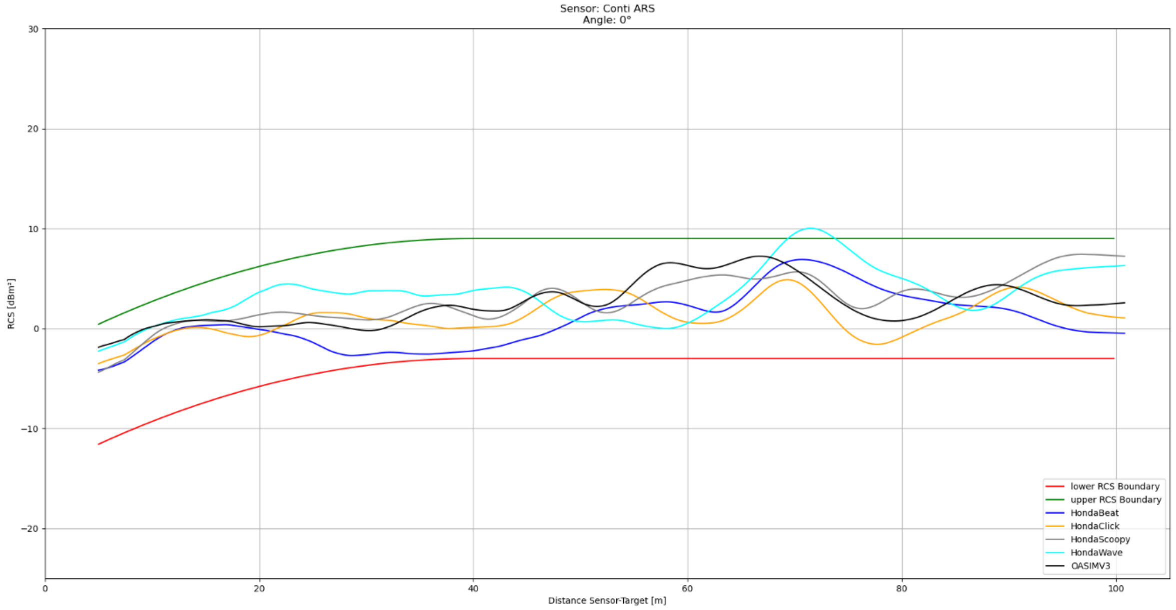


Figure 18 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS410) 0 deg FA

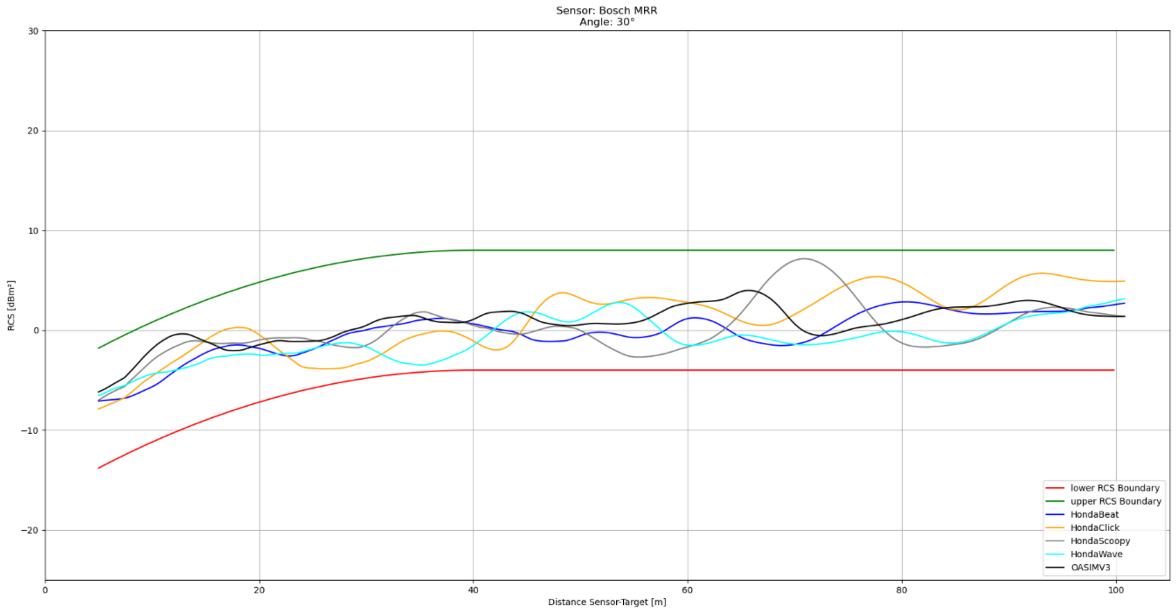


Figure 19 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Bosch MRR-SGU) 30 deg FA

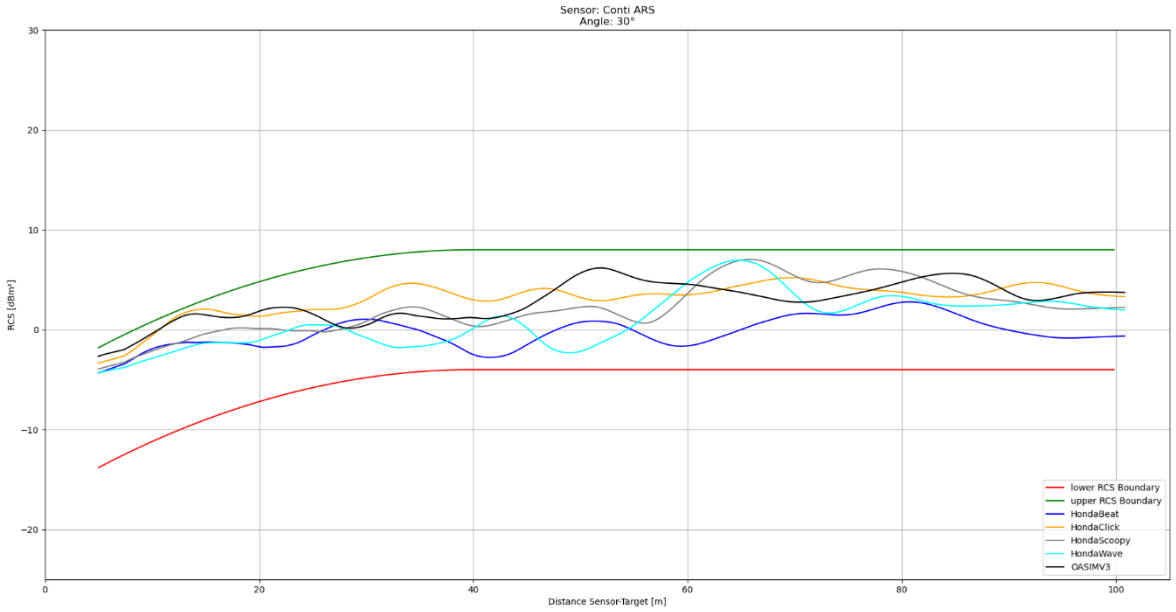


Figure 20 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS410) 30 deg FA

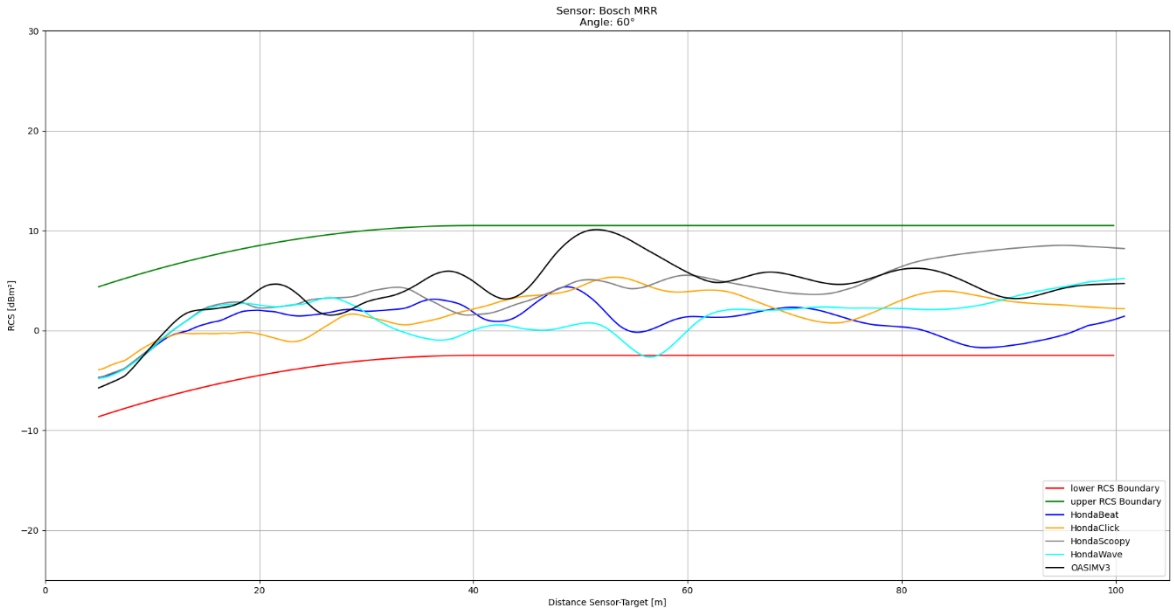


Figure 21 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Bosch MRR-SGU) 60 deg FA

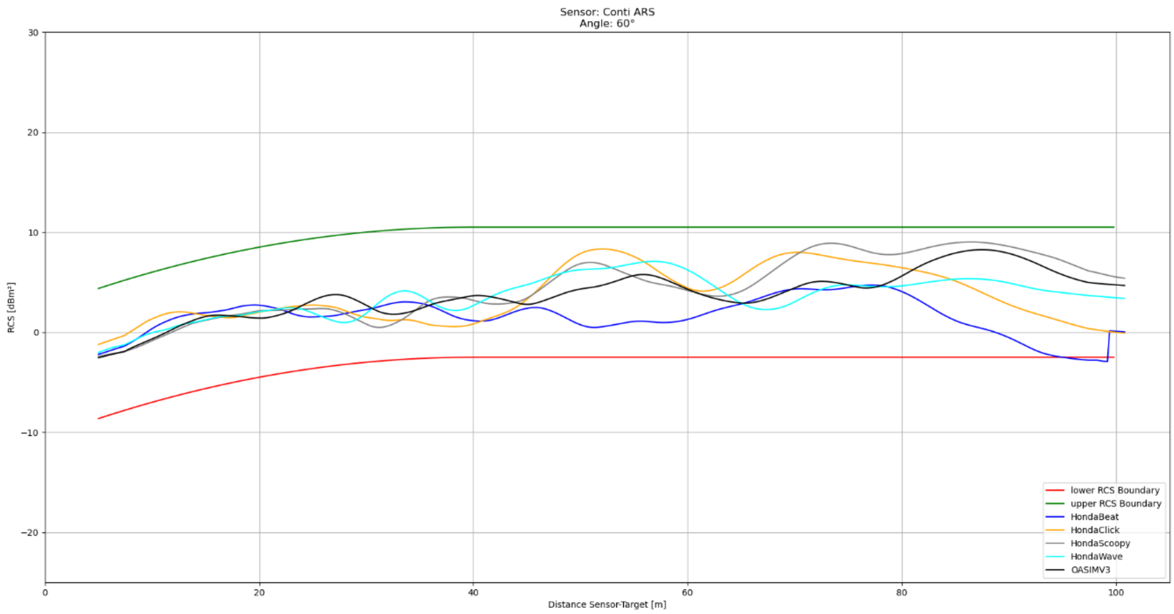


Figure 22 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS410) 60 deg FA

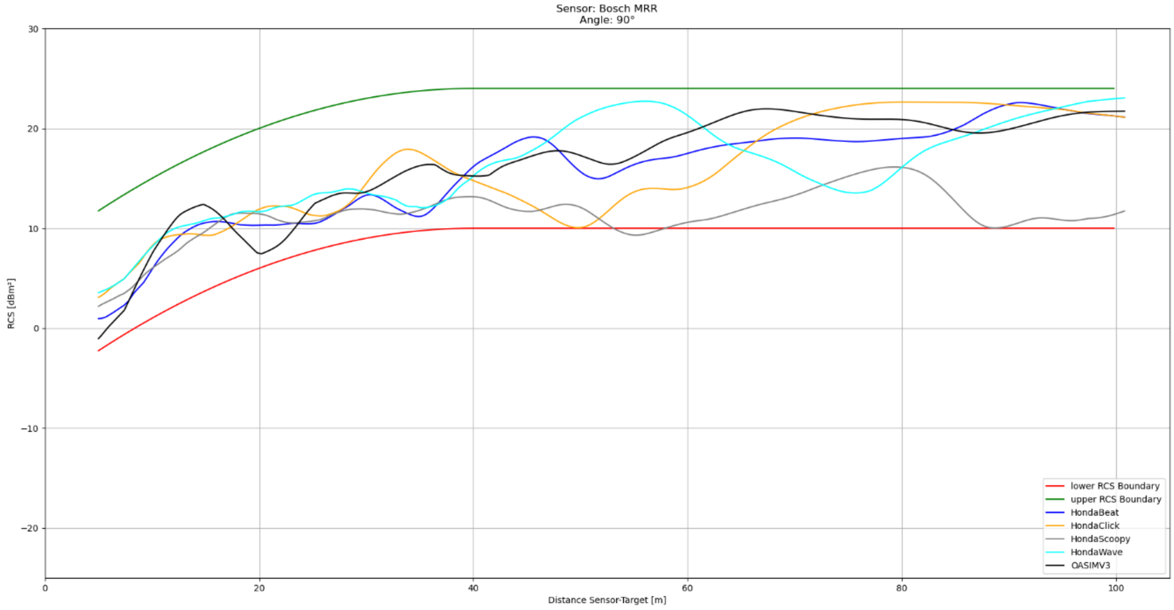


Figure 23 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Bosch MRR-SGU) 90 deg FA

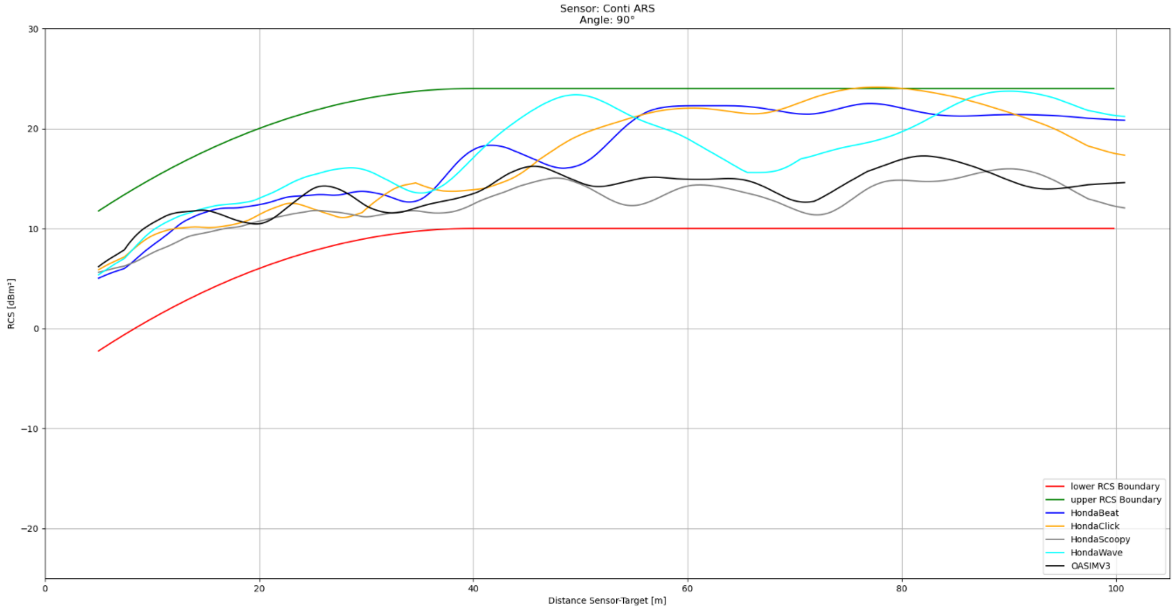


Figure 24 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS410) 90 deg FA

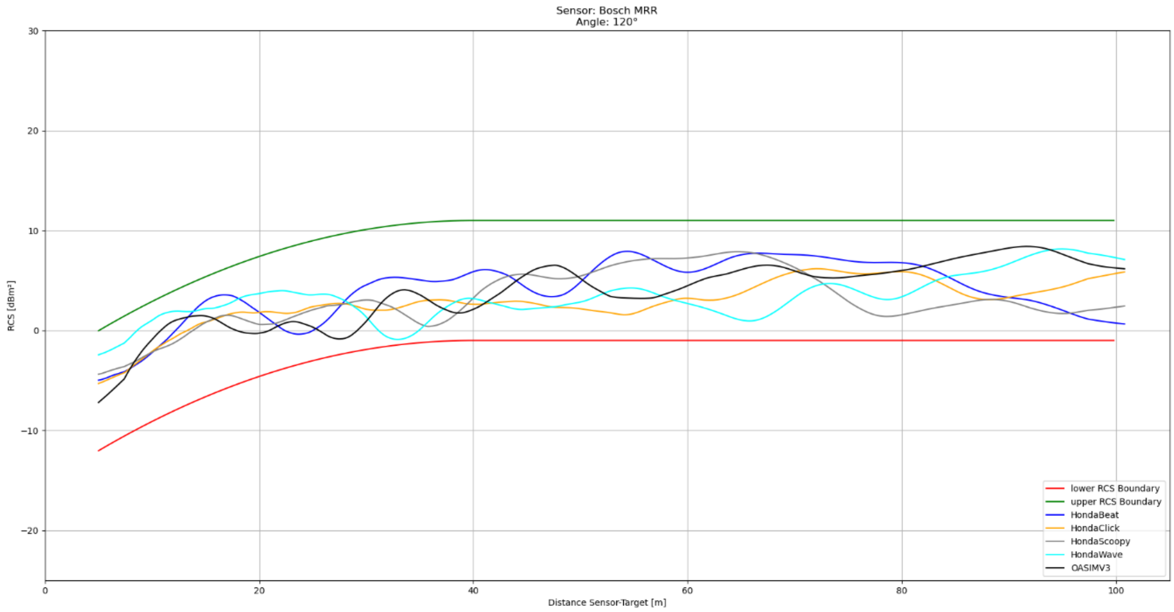


Figure 25 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Bosch MRR-SGU) 120 deg FA

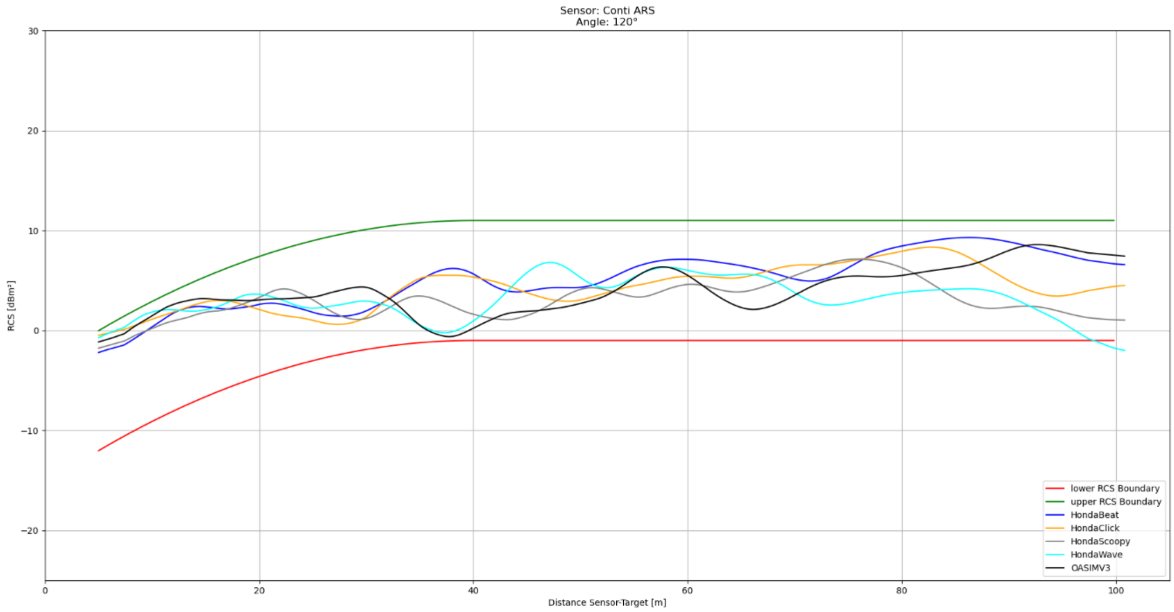


Figure 26 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS410) 120 deg FA

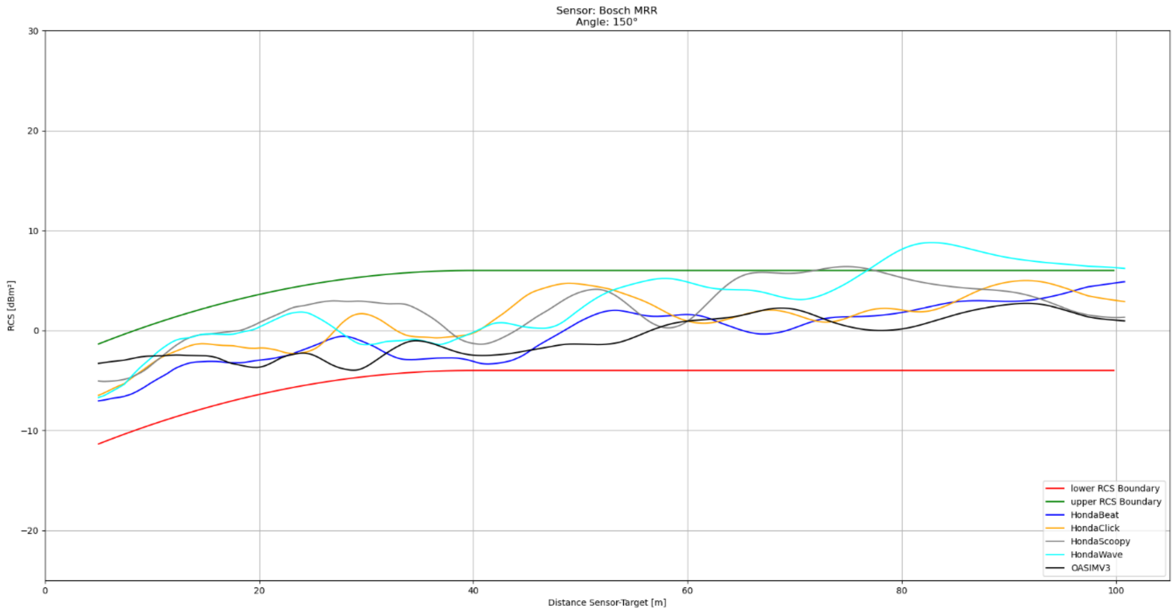


Figure 27 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Bosch MRR-SGU) 150 deg FA

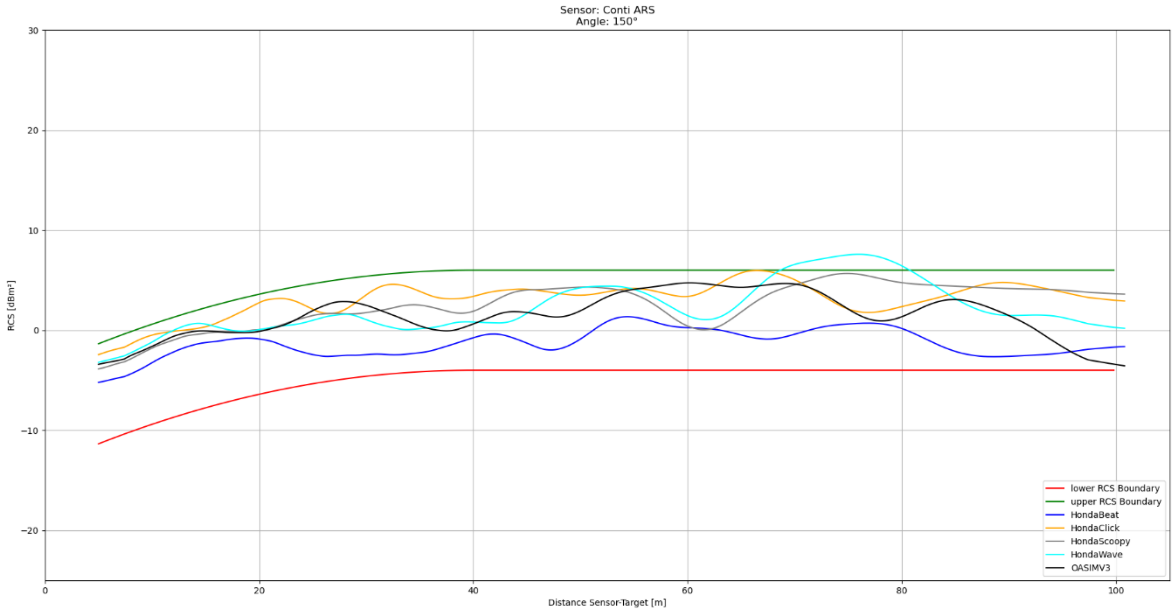


Figure 28 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS410) 150 deg FA

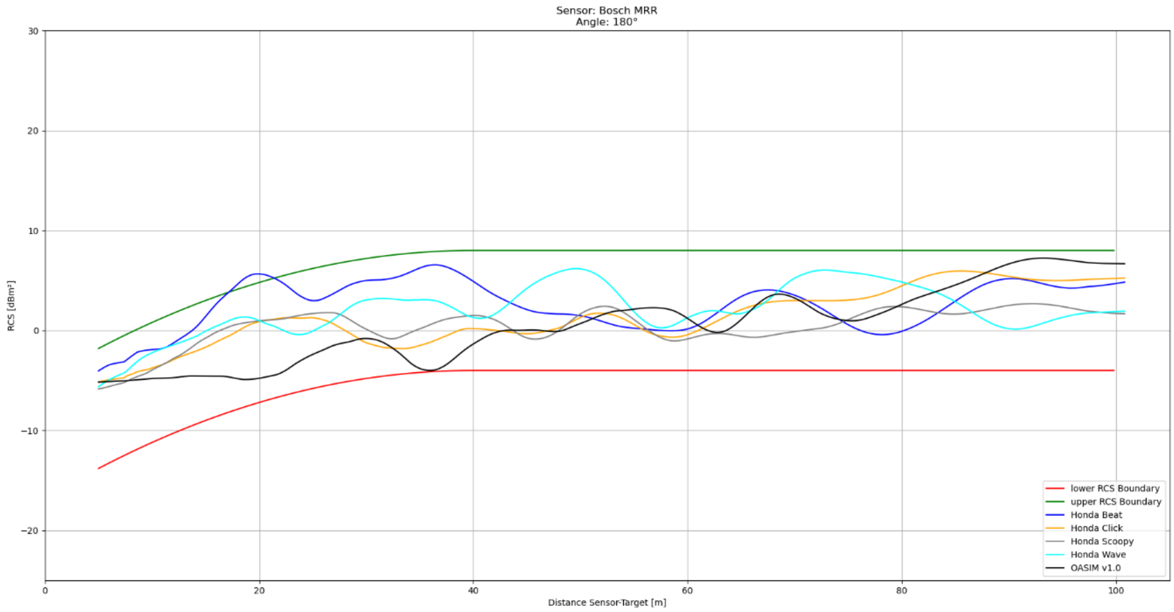


Figure 29 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Bosch MRR-SGU) 180 deg FA

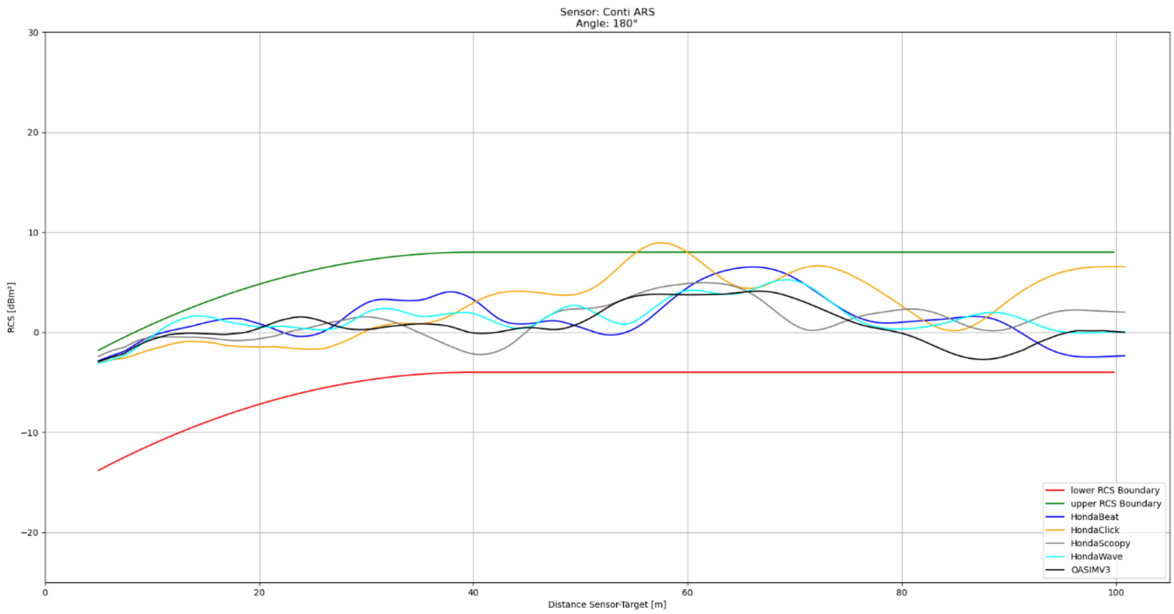


Figure 30 Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS410) 180 deg FA

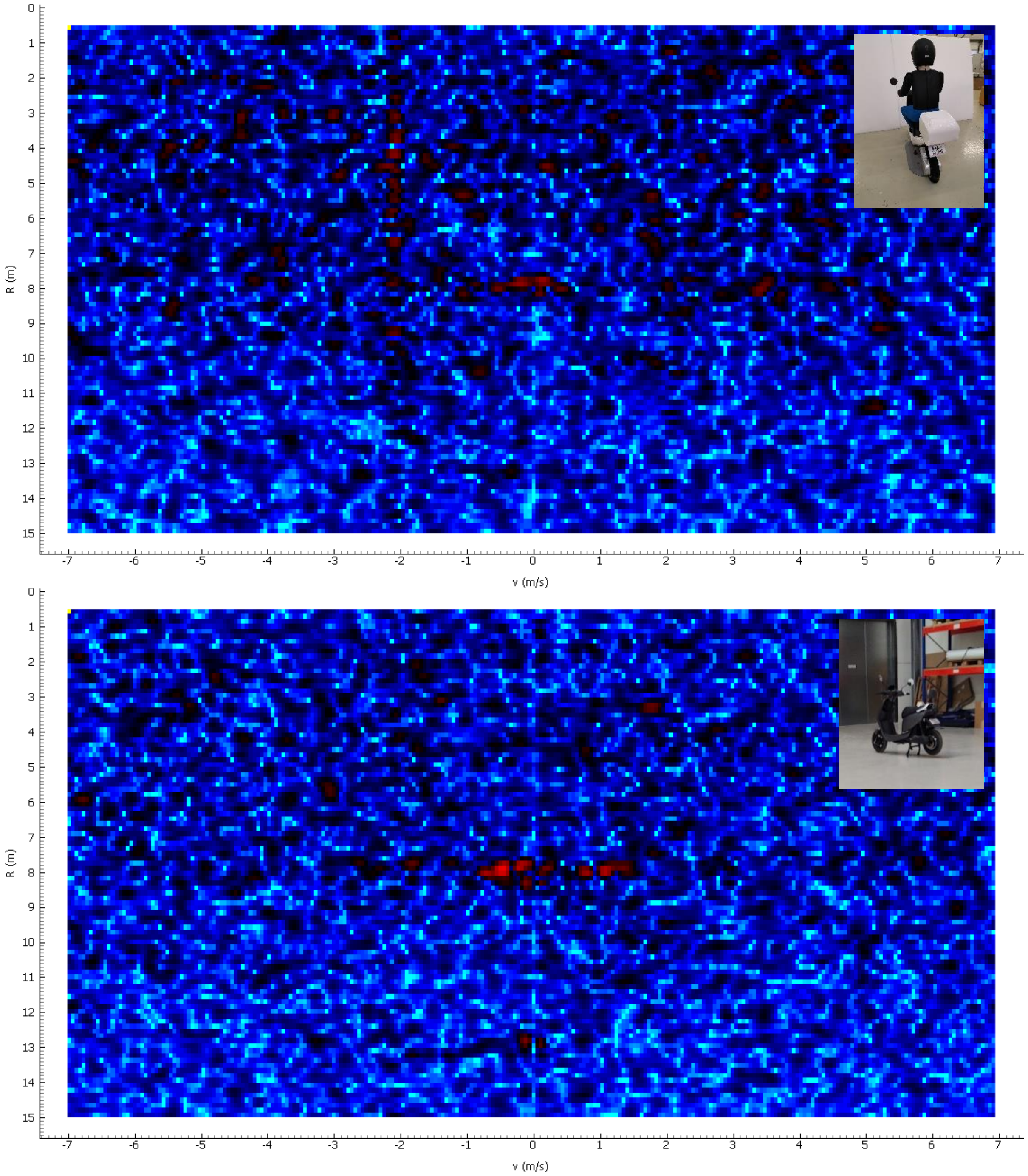
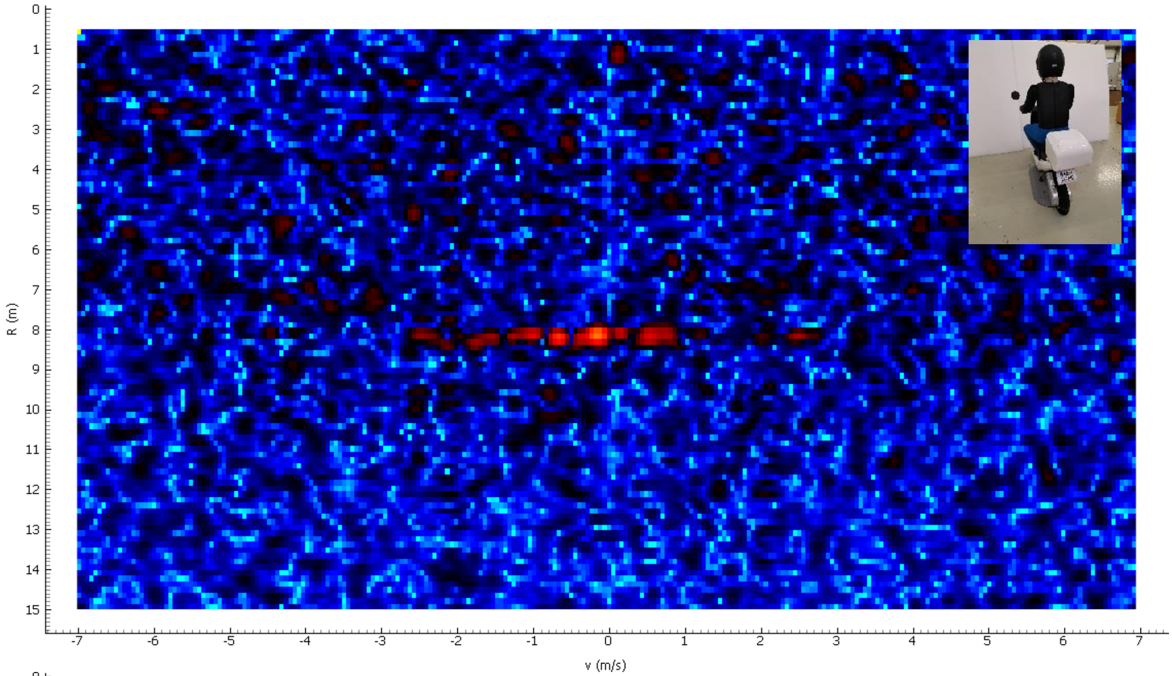


Figure 31 Micrdoppler Response Comparison 180 deg



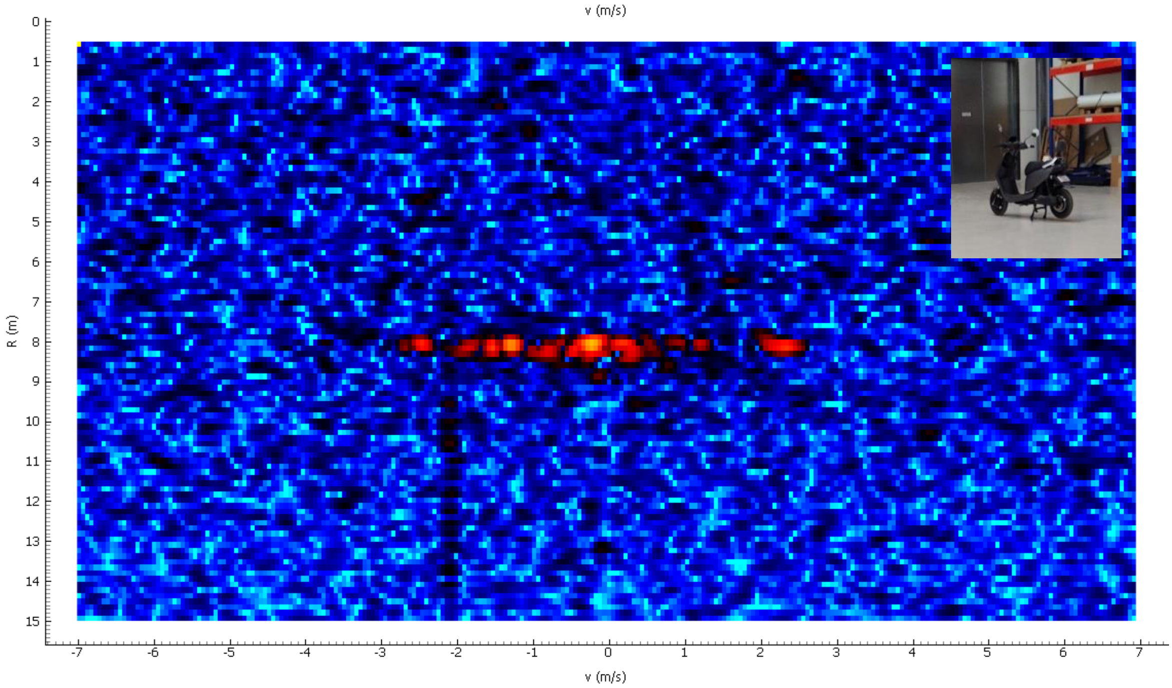


Figure 32 Micrdoppler Response Comparison 135 deg

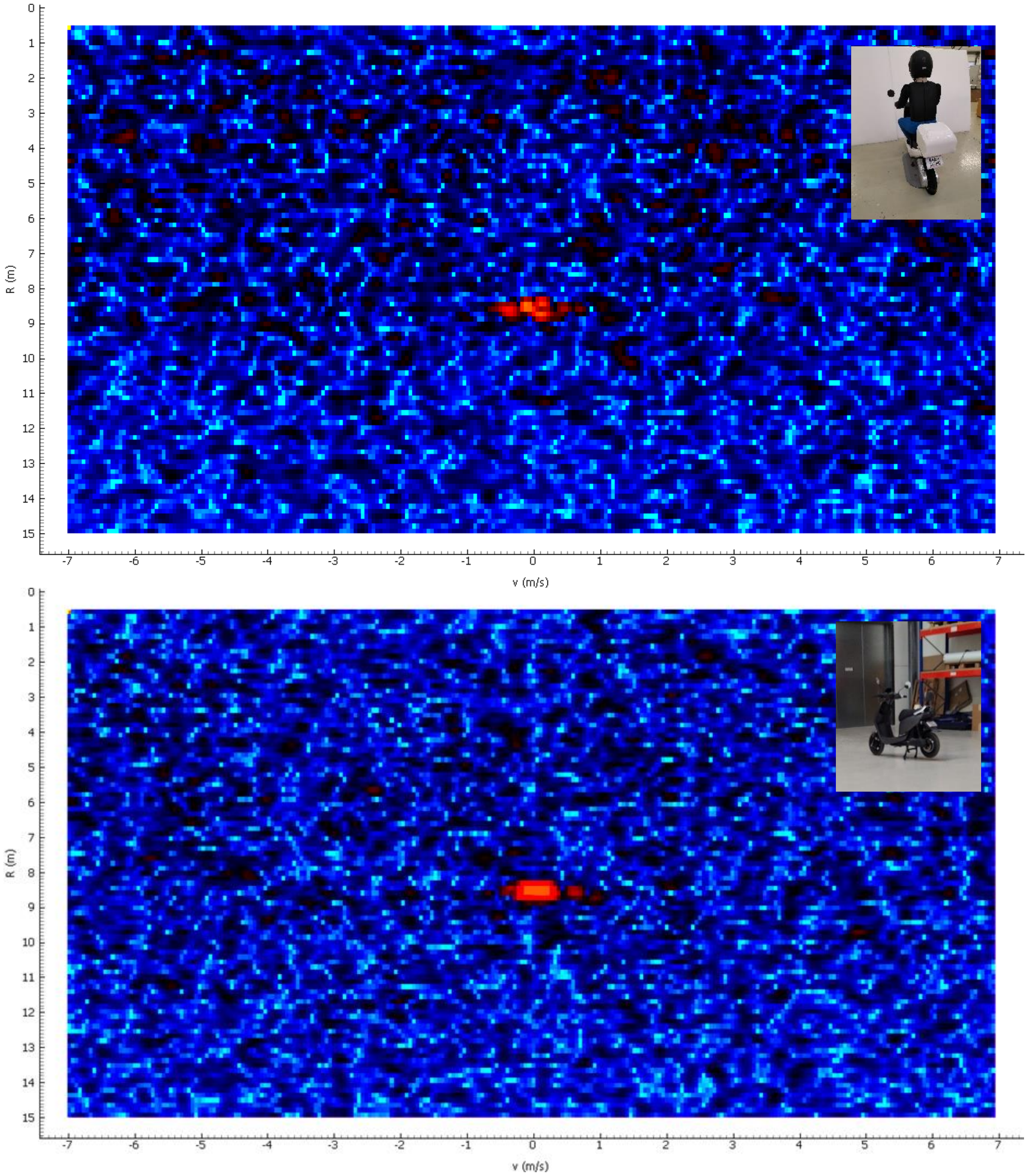


Figure 33 Micrdoppler Response Comparison 90 deg

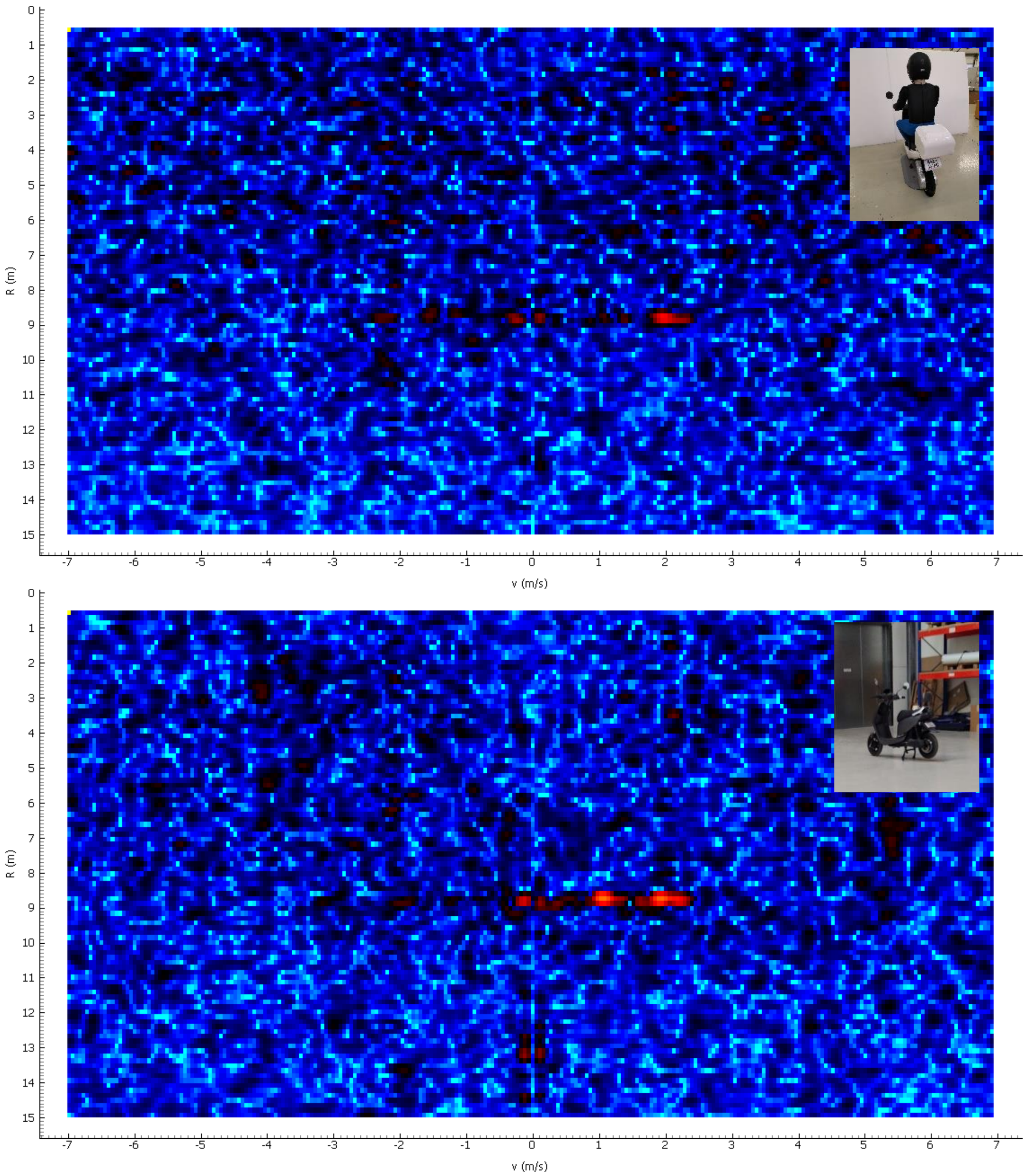


Figure 34 Micrdoppler Response Comparison 45 deg

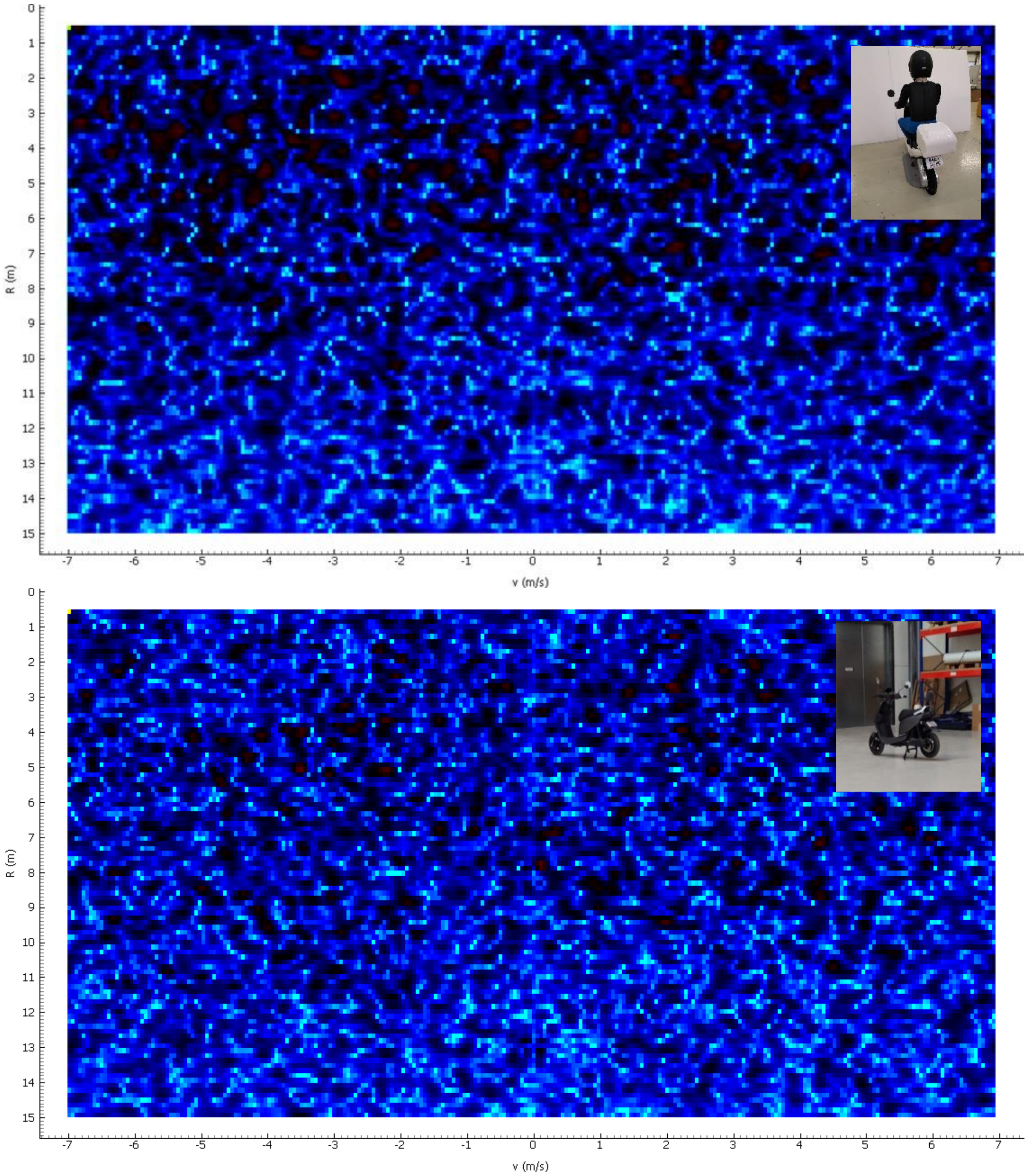


Figure 35 Micrdoppler Response Comparison 0 deg

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