Deliverable 2.1

Motorcyclist Target Specifications

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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. In the year 2017 UTAC CERAM initiated the MUSE-project, aiming to develop protocols and appropriate test equipment taking also into account this kind of road users. Around 15 industry partners, including several OEM's and TIER1s, have joined forces in this project. The following specification defines a motorcyclist target representing a real motorcyclist on a motorbike, taking into account all different types of sensors used in AEB systems.

1.2 Definitions

Throughout this protocol the following terms are used:

Vulnerable Road User (VRU) - pedestrians and users of two-wheeled transport

Autonomous Emergency Braking (AEB) – braking that is applied automatically by the vehicle in response to the detection of a likely collision to reduce the vehicle speed and potentially avoid the collision.

Global Motorcyclist Target (GMT) – means the motorcyclist and motorbike target used in this protocol

Vehicle under test (VUT) – means the vehicle tested according to this protocol with a pre-crash collision mitigation or avoidance system on board.

2 Motorcyclist and Motorcycle Target

Figure 1 motorcyclist and motorbike target

The motorcyclist and motorbike target (GMT) described in this paper, represents an average human adult motorcyclist on a motorbike reflecting two-wheeled vehicles with an engine cylinder capacity in the case of a thermic engine exceeding 50 cm^3, or whatever the means of propulsion a maximum design speed exceeding 50 km/h (Category L3 as applied by UNECE), in relation to the vulnerable road users (VRU) detection sensors used in vehicles. The requirements relate, unless not specified otherwise, to the GMT itself. Target carrier system and resulting motion of the vehicle target should minimally affect target characteristics (radar, optical signature, etc). The GMT is designed to work with the following types of automotive sensors technologies: RADAR, Video, Laser and Near-IR-based systems similar to the definition by ACEA Articulated Pedestrian Target Specifications [1]. The GMT must be a full 3D-dimensional representation of a real motorcyclist and bike.

2.1 Target Dimensions and Posture

The dimensions of the motorbike target are based on mean values of the most registered motorcycles in Europe with a cylinder capacity > 500 ccm (ACEM 2014).

[1] ACEA: Articulated Pedestrian Target Specifications Version 1.0

Typical dimensions are indicated in Figure 2 and Figure 3. The the center point between the wheel centers will be used as reference 0-point in X-direction and the floor level as reference 0-point in Z-direction.

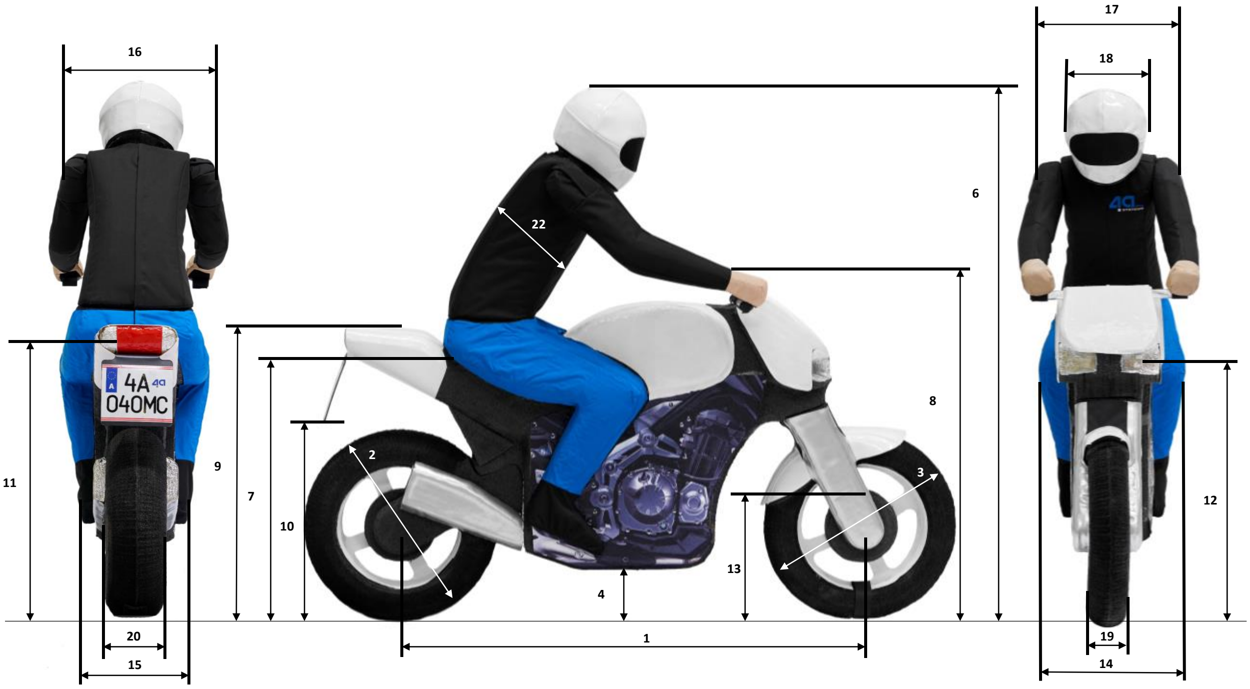

Figure 2 motorbike target dimensions and dummy posture

Table 1 motorcyclist dimensions [mm]

No.	Measurement	Minimum	Maximum	Mean
1	wheel base	1405	1445	1425
2	front wheel diameter	590	610	600
3	rear wheel diameter	590	610	600
4	ground clearance	165	175	170
5	wheel ground clearance	0	20	10
6	total height	1645	1695	1670
7	seat height	835	865	850
8	steering fork height	965	995	980
9	rear height	925	955	940
10	number plate height	660	680	670
11	rear reflector height	875	905	890
12	front light height	790	810	800
13	side reflector height?	385	395	390
14	knee width	510	530	520
15	feed width	355	365	360
16	shoulder width	490	510	500
17	hand width	475	485	480
18	helm width	255	265	260
19	front wheel width	115	125	120
20	rear wheel width	175	185	180
21	number plate width?	195	205	200
22	chest dimension	255	265	260
23	upper body length	570	590	580
24	upper leg length	410	420	415
25	lower leg length	415	425	420
26	foot length	245	255	250
27	back – radius	1115	1145	1130

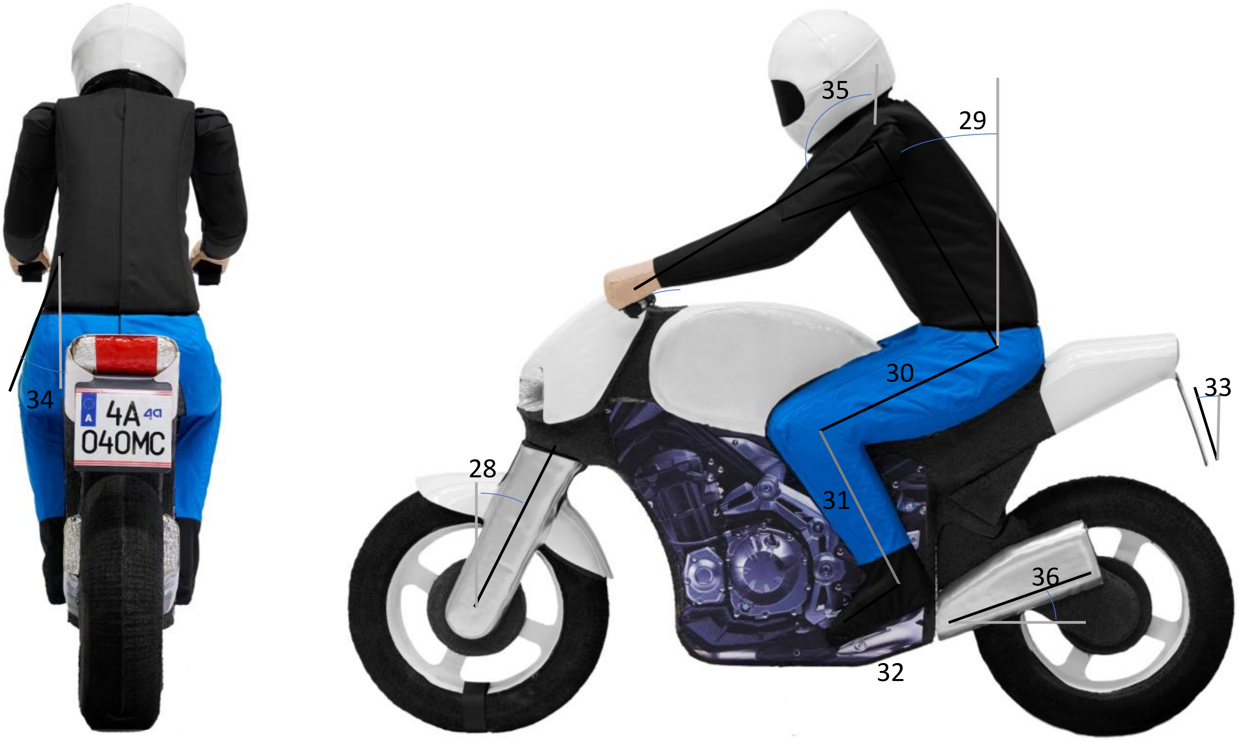

Figure 3 motorbike target dimensions and dummy posture

Table 2 motorcyclist dimensions

No.	Measurement	Minimum	Maximum	Mean
28	steering fork angle	23	28	25
29	upper body angle	25	35	30
30	upper leg angle	60	70	65
31	lower leg angle	25	35	30
32	foot angle	20	30	25
33	number plate angle	25	35	30
34	upper leg front angle	15	25	20
35	arm angle	110	130	120
36	exhaust pipe angle	20	30	25

Dimensions of the motoryclist target are based on an adult pedestrian target, described by ACEA[2], representing average (50th %-ile) male. The shape of the motoryclist target has to comply in its contours with the 50% RAMSIS Bodybuilder based on the RAMSIS version 3.8.30 to a permitted tolerance of ± 2cm. The stature body height of the adult BT is, according to EN ISO 7250-1: 2016-05, 1800mm.

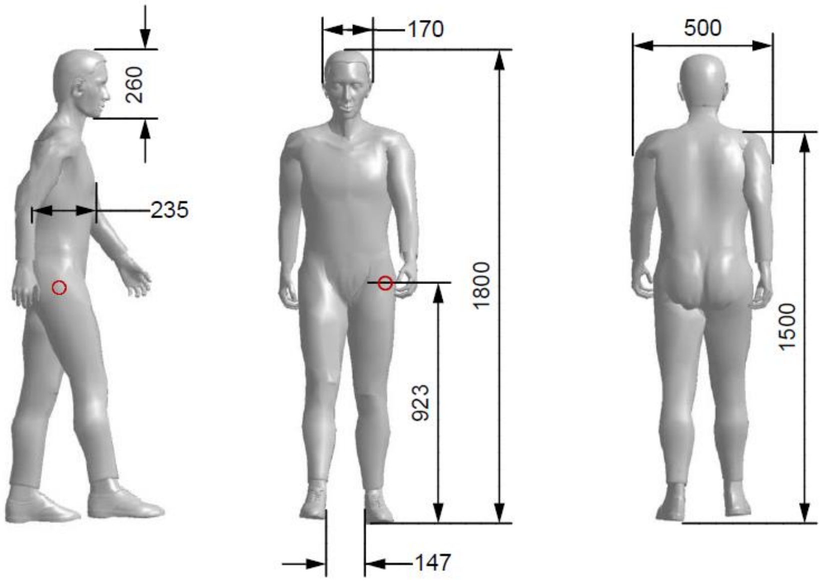

Figure 4: motoryclist target dimensions in standing posture

Table 3: motorcyclist target dimensions in standing posture

Segment	Dimension / Angle	Unit	Tolerance	Unit
Body height (incl. shoes)	1800	mm	± 20	mm
H-Point height	920	mm	± 20	mm
Shoulder width	500	mm	± 20	mm
Shoulder height	1500	mm	± 20	mm
Head width	170	mm	± 10	mm
Head height	260	mm	± 10	mm
Torso depth	240	mm	± 10	mm

[2] ACEA: Articulated Pedestrian Target Specifications Version 1.0

2.2 Visual and Infrared Properties

Similar to the adult pedestrian target specified by ACEA[3], 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 A1 must be in the range described in Table 4 (sRGB 0-255, Observer = 2°, Illuminant = D65).

The IR reflectivity from 850 to 950 nm wavelength of clothes and the motorcycle parts must be within the range defined in Table 5 based on measurement method described in appendix A1. 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 5 infrared and visual properties of GMT

[3] ACEA: Articulated Pedestrian Target Specifications Version 1.0

Table 4 visual properties of GMT

Number	Segment		Colour	Red	Green	Blue	Appearance
1	Helmet, Tank, Mud Guard, Rear Part, Front Plate	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		102	95	72	Matt
		mean		182	165	142	
		max		72	33	0	
5	Steering Fork, Exhaust Pipe	min		231	229	231	Glossy
		mean		241	239	241	
		max		251	249	251	
6	Tires, Rubber Parts	min		35	34	36	Matt
		mean		45	44	46	
		max		55	54	56	
7	Motor Block	min					metal – glossy / rest - matt
		mean					
		max					
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 5 IR properties of GMT

Number	Segment	IR – Reflectivity 850 – 950 nm [%]
1	Helmet, Tank, Mud Guard, Rear Part, Front Plate	≥ 70
2	Black Top, Shoes	40 - 60
3	Trousers	40 - 60
4	Skin, Face, Hands	40 - 60
5	Steering Fork, Exhaust Pipe	10 - 40
6	Tires, Rubber Parts	≤ 15
7	Motor Block	
8	Number Plate	≥ 85
9	Side Mirrors Glass	≤ 30

2.3 Radar Properties

The radar reflectivity characteristics of the motorcyclist and motorcycle target should be equivalent to a human being riding on a motorbike bike with dimensions described in 2.1.

2.3.1 Radar Cross Section (RCS)

The radar cross section of a motorcyclist depends on the observation angle and typically varies significantly. Theoretically there is no RCS variation with the distance. However due to the 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 motorcyclist is not scanned over its complete spatial dimensions. Therefore, in this document RCS is referred to as the measured RCS by radar sensor with its specific parameter set and it does not correspond to the physical RCS. The RCS is also influenced by geometrical effects (i.e. multi path with constructive and destructive interferences).

Therefore, it must be taken into account that the RCS will be reviewed not only constantly, but by a description of the RCS by closing on the GMT. (see example of the RCS distribution at 76GHz of real motorcyclist in appendix xx). It must be ensured that the RCS value is distributed realistically over the whole body of the GMT. This allows achieving the effect of decreasing RCS at a shorter distance by only partial coverage. A more precise definition must be made individually for each frequency and sensor variant.

The radar cross section of the GMT, achieved with a 77GHz Sensor Bosch MRR-SGU (see Appendix A2), should stay within a defined range, depicted from Figure 6 to Figure 12 when approaching the target at fixed angles.

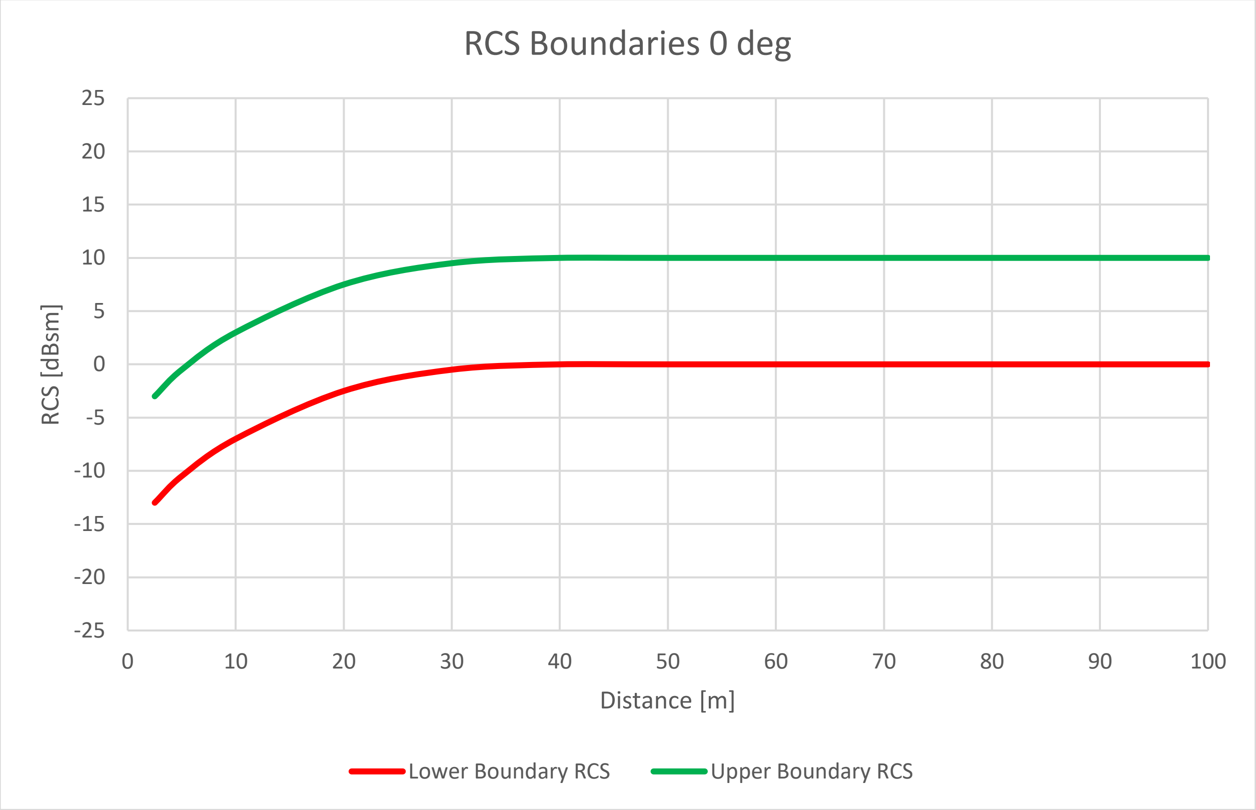

Figure 6 motorcyclist and motorbike target RCS-boundaries (77GHz Sensor Bosch MRR-SGU) 0 deg

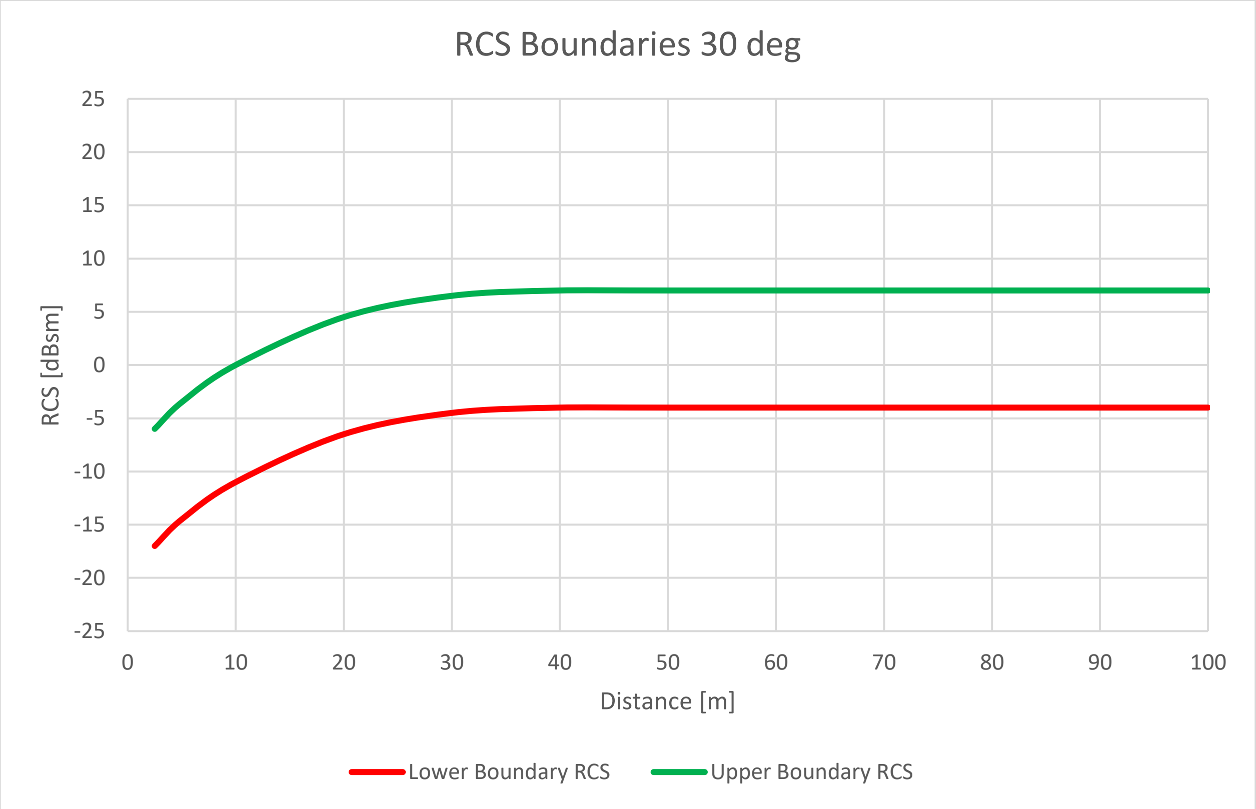

Figure 7 motorcyclist and motorbike target RCS-boundaries (77GHz Sensor Bosch MRR-SGU) 30 deg

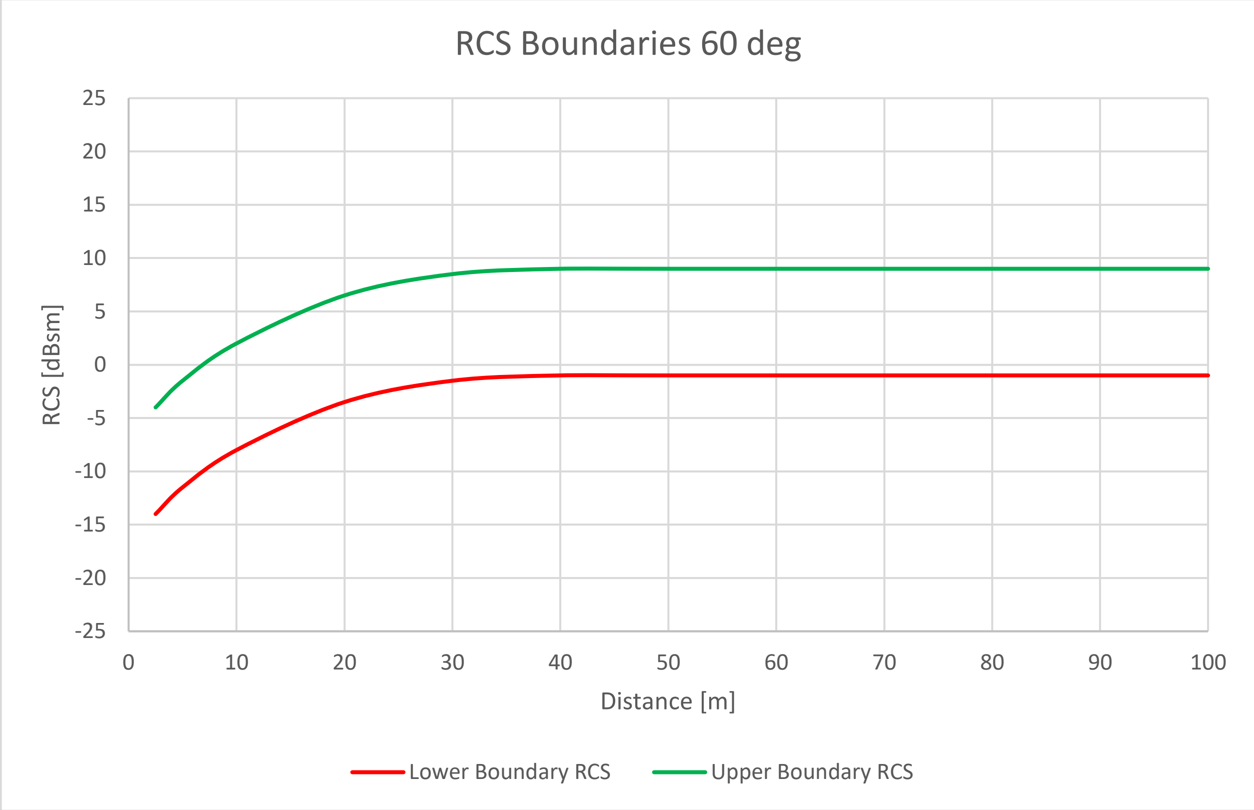

Figure 8 motorcyclist and motorbike target RCS-boundaries (77GHz Sensor Bosch MRR-SGU) 60 deg

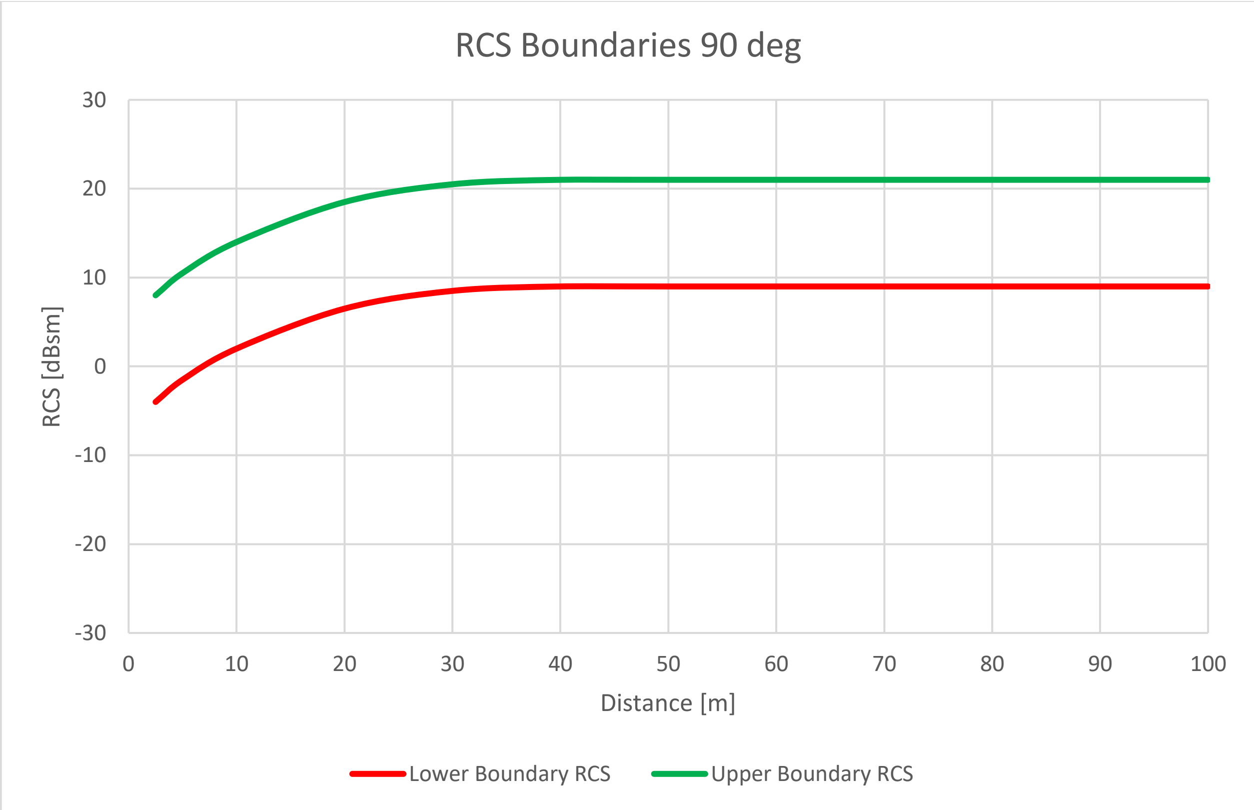

Figure 9 motorcyclist and motorbike target RCS-boundaries (77GHz Sensor Bosch MRR-SGU) 90 deg

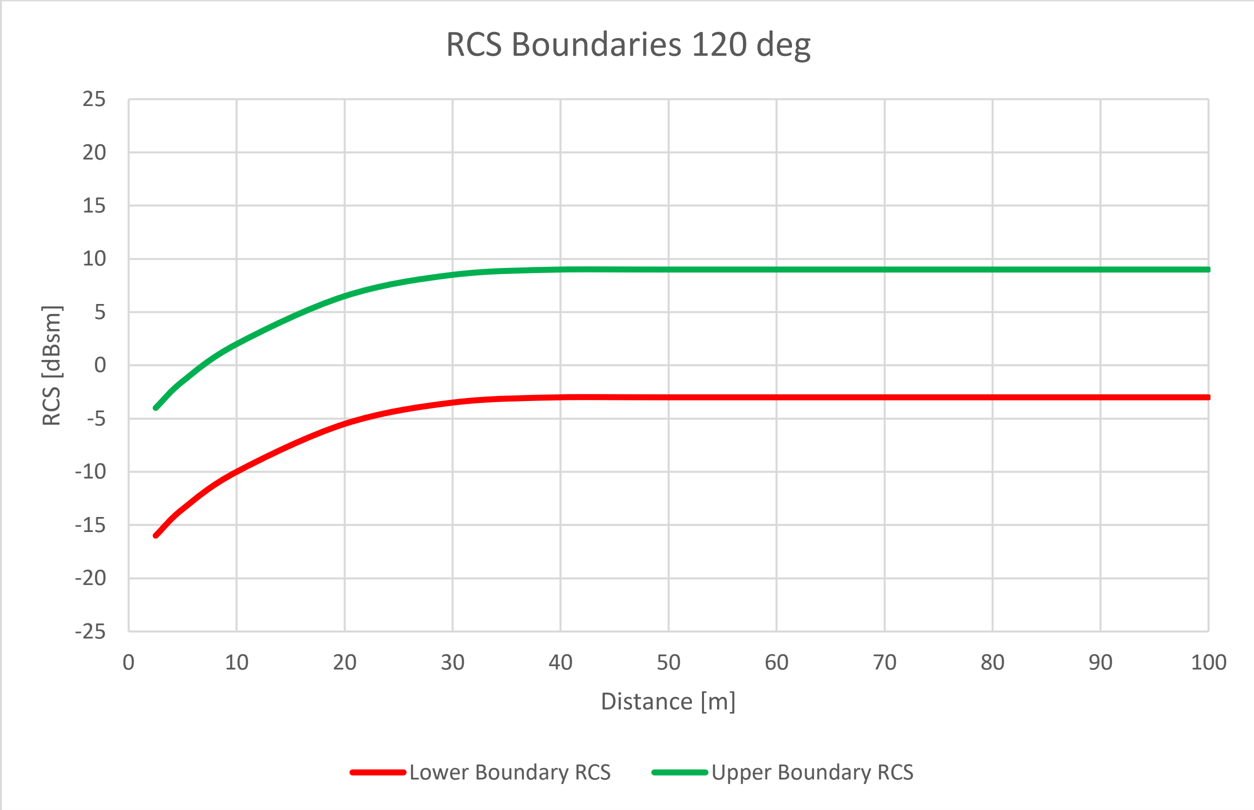

Figure 10 motorcyclist and motorbike target RCS-boundaries (77GHz Sensor Bosch MRR-SGU) 120 deg

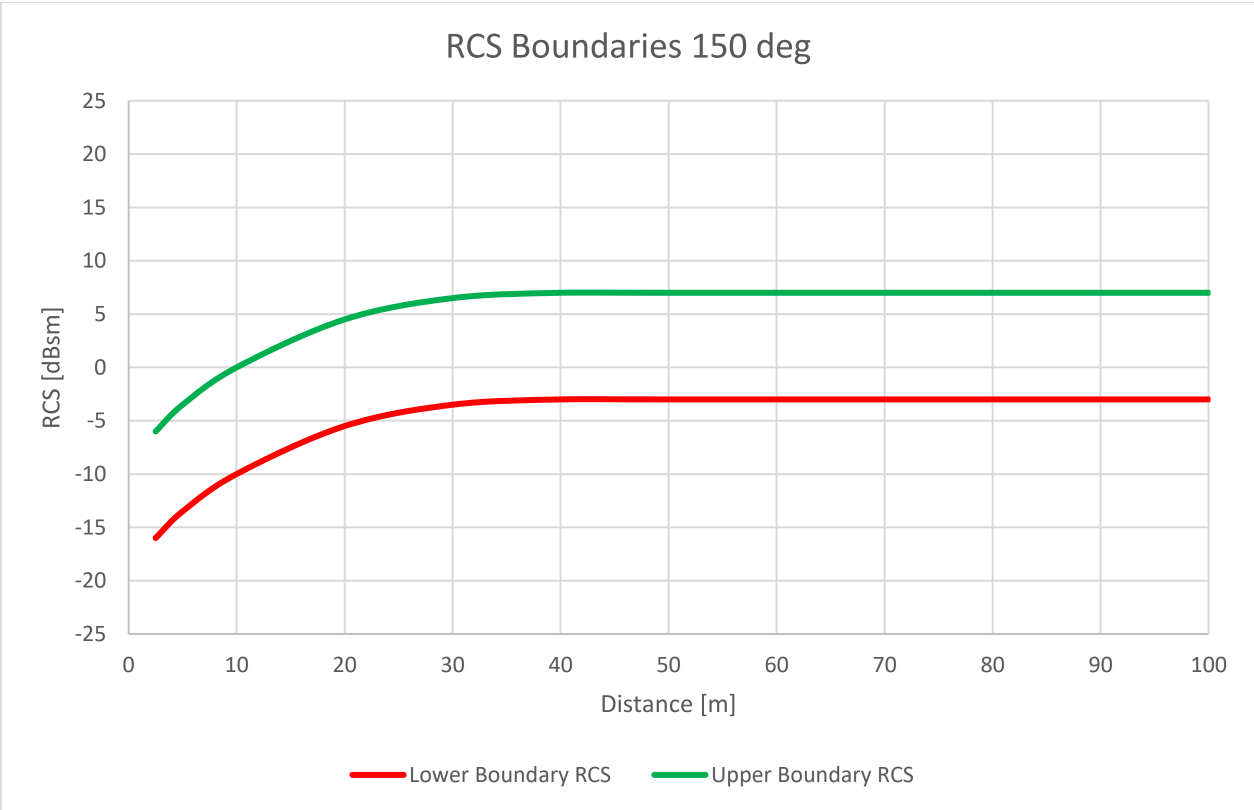

Figure 11 motorcyclist and motorbike target RCS-boundaries (77GHz Sensor Bosch MRR-SGU) 150 deg

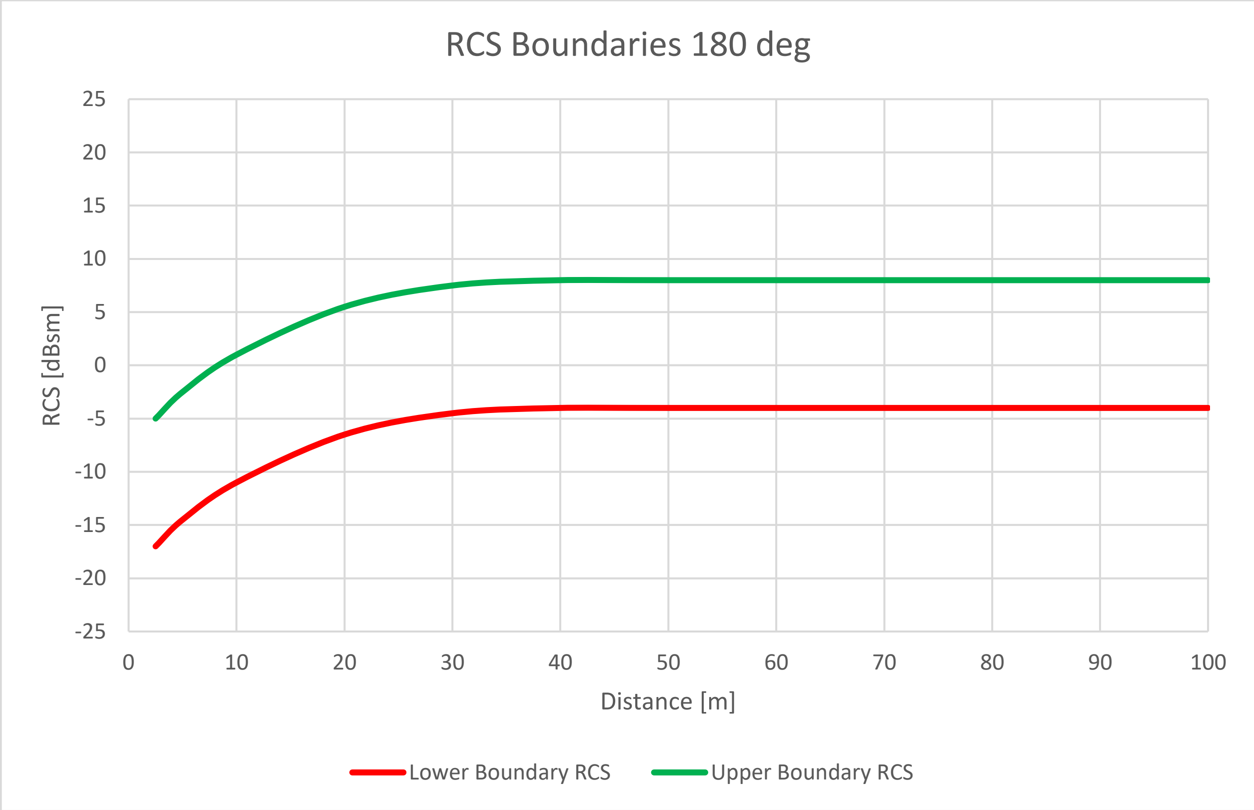

Figure 12 motorcyclist and motorbike target RCS-boundaries (77GHz Sensor Bosch MRR-SGU) 180 deg

For fixed range measurements (procedure depicted in A2) the RCS should be within boundaries shown in Figure 13

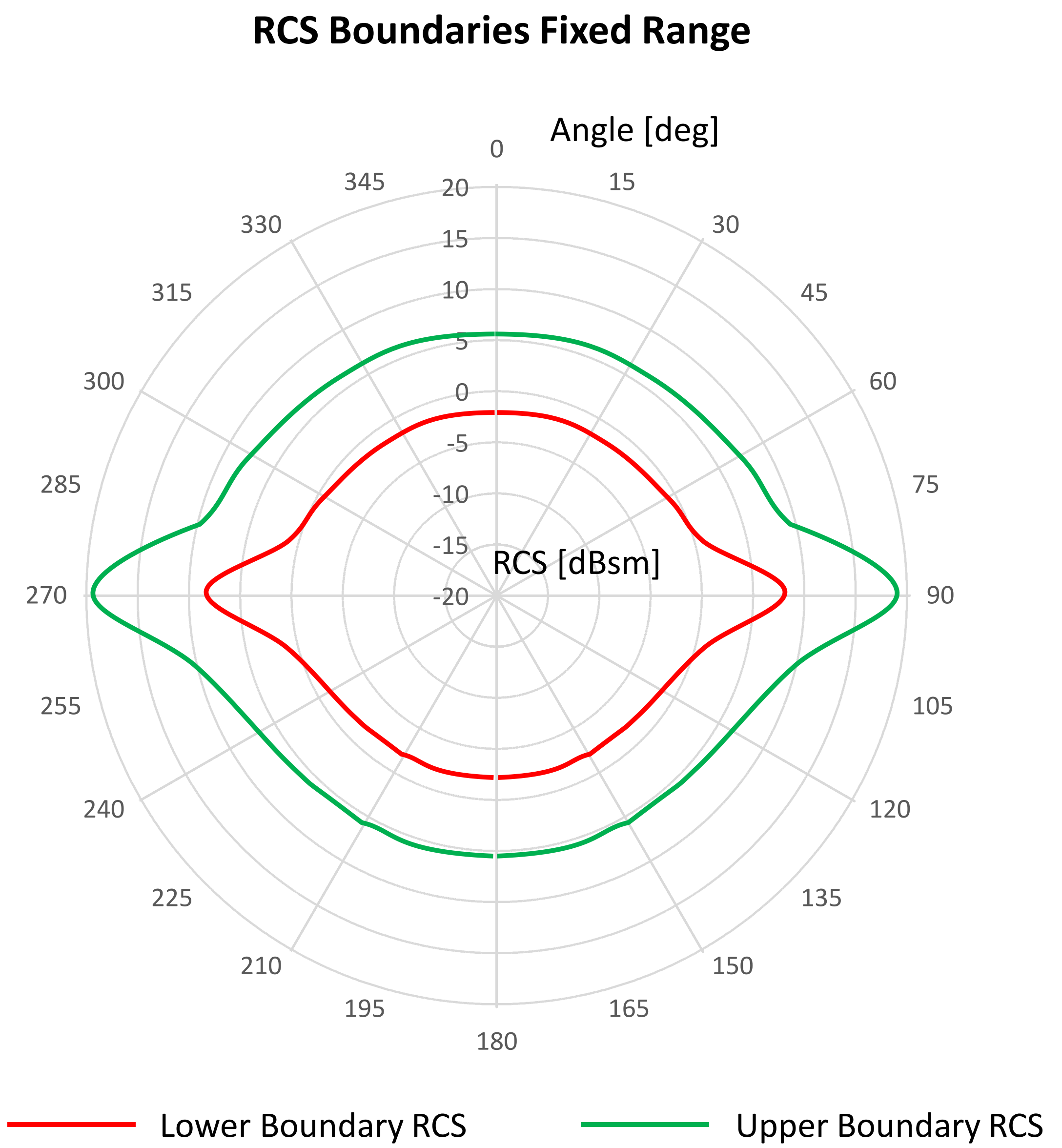

Figure 13 motorcyclist and motorbike target RCS-boundaries (77GHz Sensor Continental ARS400)

2.3.2 Micro-Doppler properties

Optional Micro-Doppler effects generated by the rotating wheels may be an important identification characteristic of PTWs. The PTW 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 PTW target speed. The micro-Doppler spread shall be appropriately distributed referencing to the two rotation centres, i.e. the front and rear axles.

2.4 Mounting and Guidance System

- All visible parts of the GMT 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 GMT 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 GMT 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 GMT posture and dimension has to be checked before starting a new test. The most relevant GMT parameters are defined in Table 1 and Table 2 and are requested during the testing phase (wind, acceleration).

- The GMT must not have any hard impact points to prevent damage of the VUT.
- Max. relative collision velocity of 70km/h (oncoming, crossing) / 60km/h (longitudinal).
- Max BT weight: 15kg

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

3 APPENDIX

A1 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 A1 1) 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 A1 1 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.

A2 Measurement of Radar Reflectivity

The measurement of the radar reflectivity must be carried out by using a measurement setup according to the following specification.

Recommended Measurement Setup

A reference measurement with a corner reflector (calibrated → 10 dBsm) before and after measurements is recommended.

Sensor:

- vertical distance to ground as sensor application height 50cm +/- 15cm
- horizontal alignment +/-1° to centre line
- vertical alignment +/-1° to centre line
- 77 GHz sensor:

  Bosch MRR-SGU

  Continental ARS300/ARS301/ARS400 series

Car:

- angular driving deviation < 2° (driving direction)
- positioning accuracy longitudinal/lateral < 5cm

Motorcyclist and motorbike Target:

- positioning accuracy longitudinal/lateral < 1cm
- angular orientation deviation < 3° (moving direction)

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
- reference measurement with 10dBsm @ 40 m distance, corner reflector mounting height: 1m

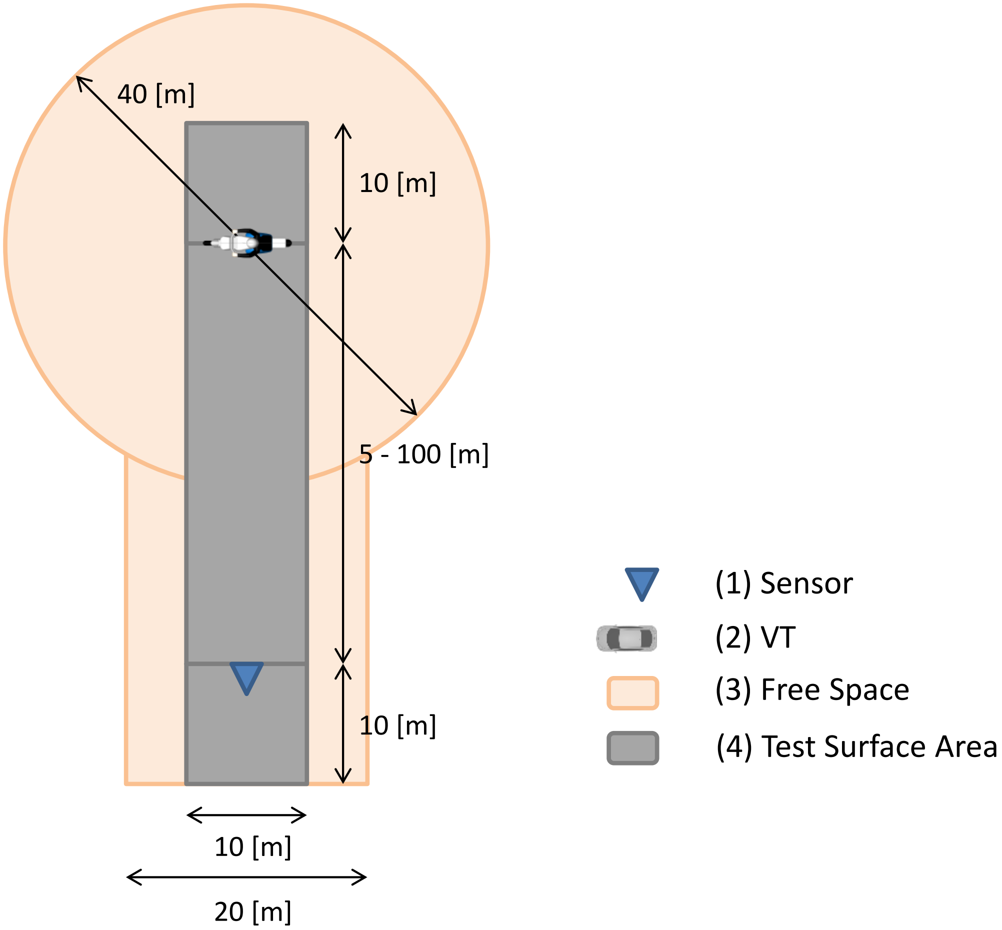

Figure A1 2 test environment

Measurement Scenario

Scenario 1

- static GMT with moving vehicle
- initial distance 100m to 4m
- max. approaching speed 10km/h, no abrupt deceleration
- measurement angles 0°, 30°, 60°, 90°, 120°, 150°, 180° (static GMT facing direction relative to vehicle, assuming symmetry)
- averaging 5 approaches
- low pass filtering using a sliding average window (+/-2.5m)

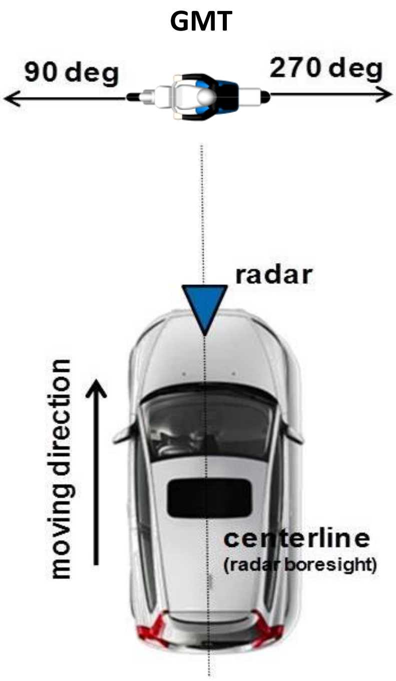

Figure A1 3 radar test scenario 1

Scenario 2

- GMT on 360 degree turntable with static sensor setup
- sensor distance 30 m
- three different sensor heights: 220mm, 480mm 900mm
- averaging 3 measurements per sensor height
- low pass filtering using a sliding average window (2.5 deg)

A3 Measurements of RCS

Following figures provide examples, comparing real motorcycles versus 4a GMT dummy using the evaluation methodology of appendix A2 for different viewing angles.

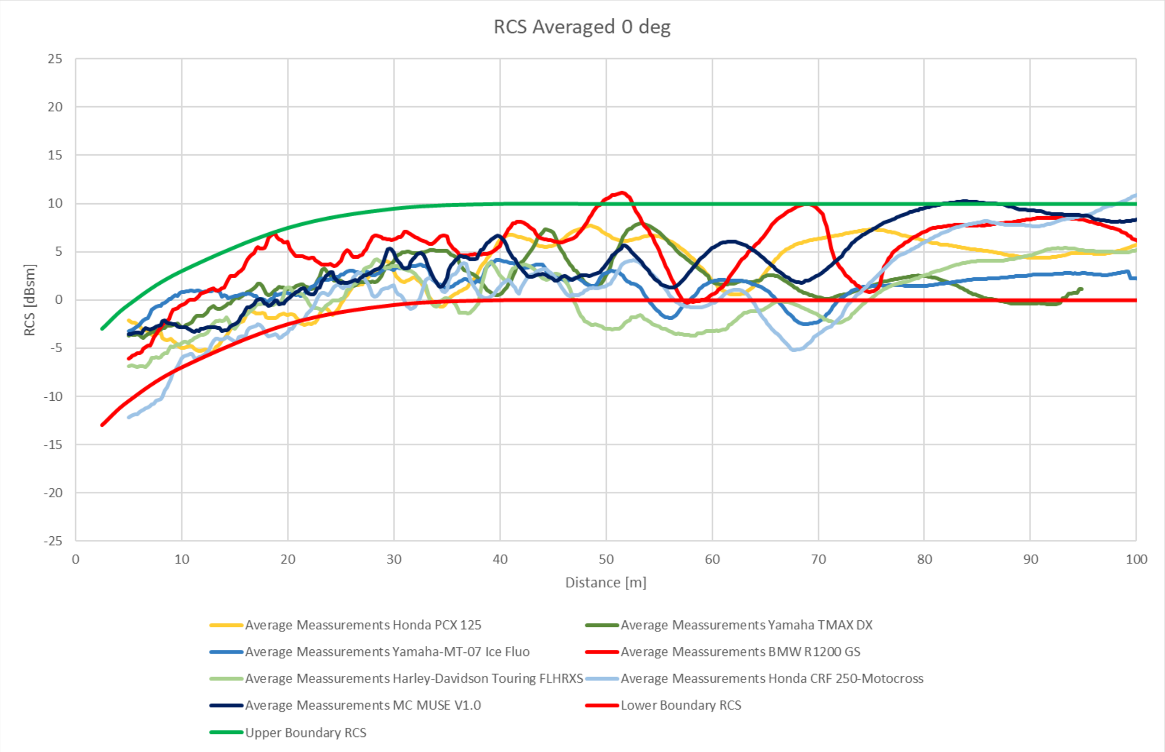

Figure A1 4 Example RCS of 4a GMT versus real motorcycles (77 GHz Sensor Bosch MRR-SGU) 0°

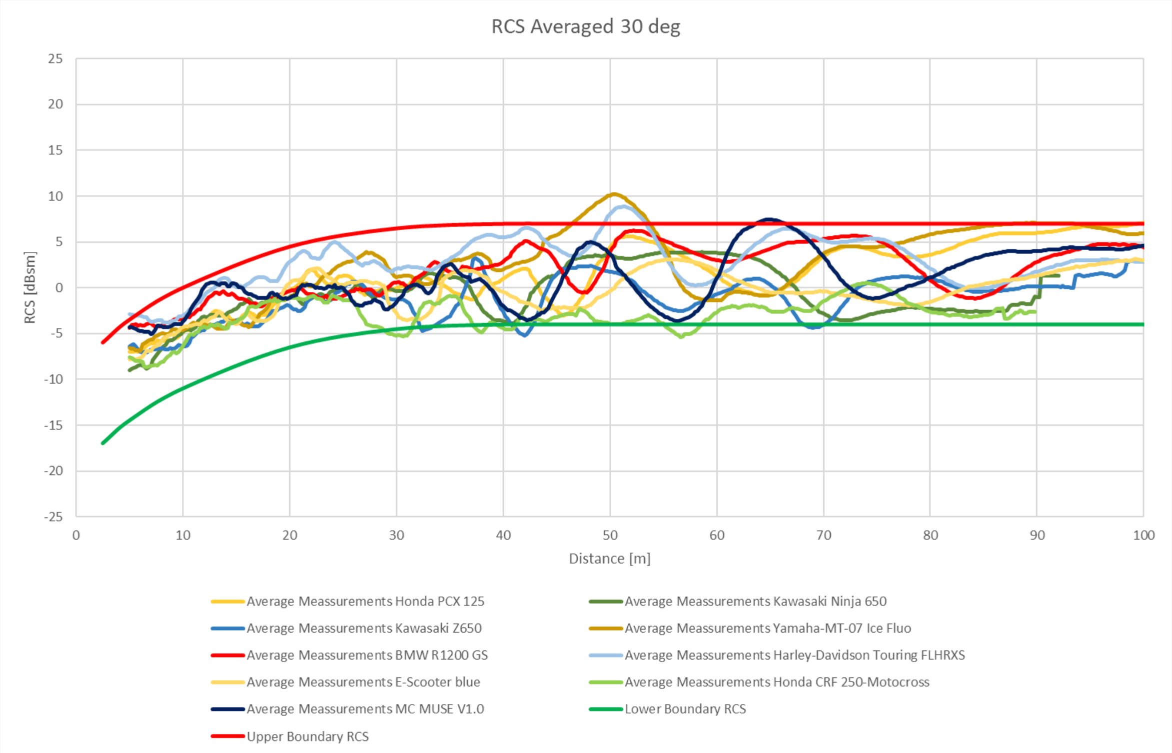

Figure A1 5 Example RCS of 4a GMT versus real motorcycles (77 GHz Sensor Bosch MRR-SGU) 30°

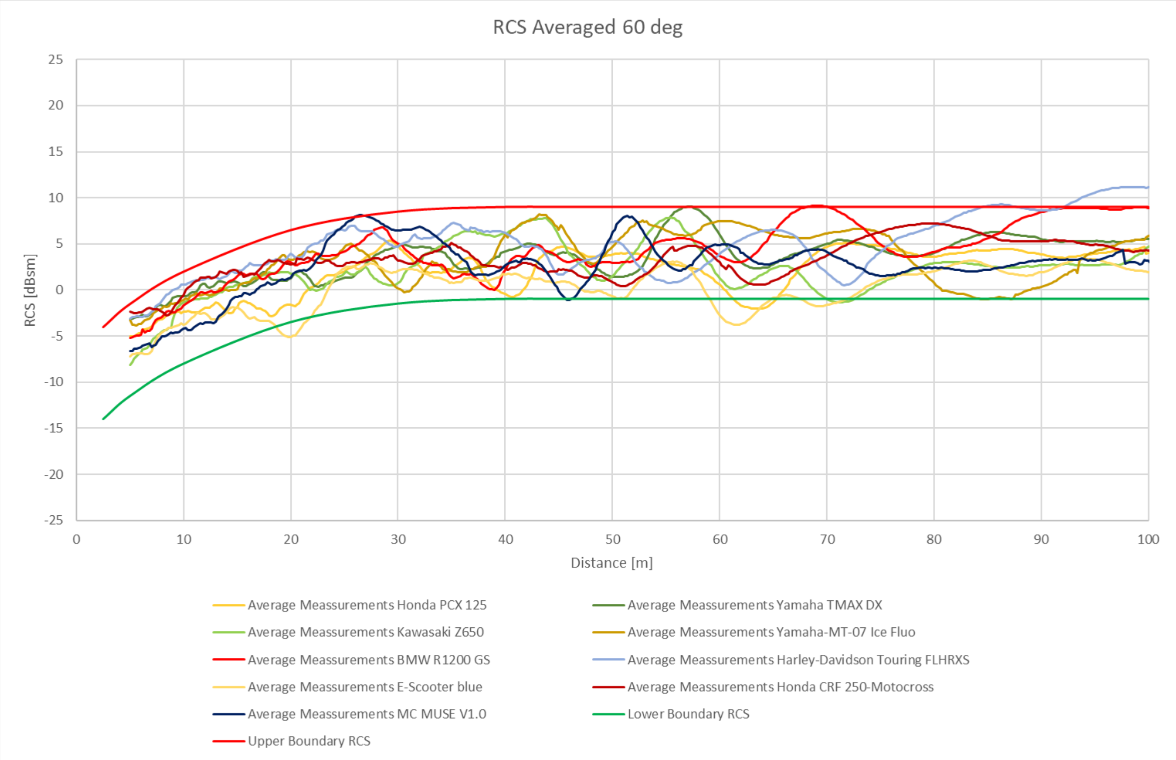

Figure A1 6 Example RCS of 4a GMT versus real motorcycles (77 GHz Sensor Bosch MRR-SGU) 60°

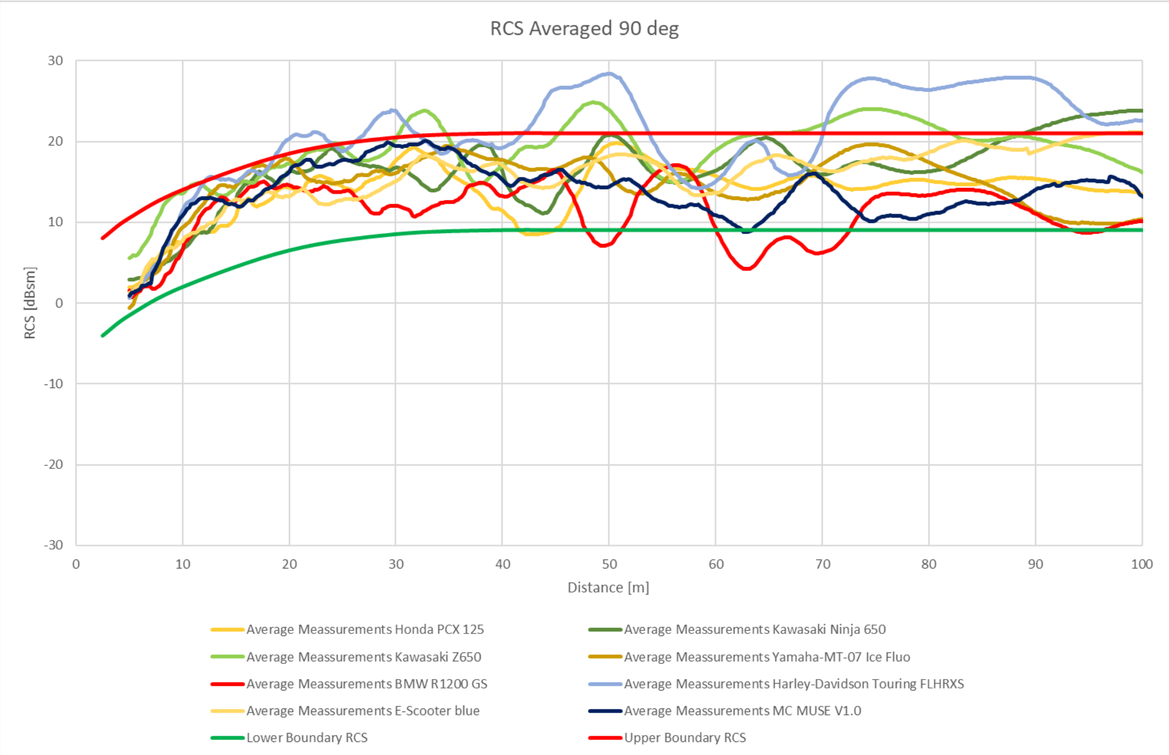

Figure A1 7 Example RCS of 4a GMT versus real motorcycles (77 GHz Sensor Bosch MRR-SGU) 90°

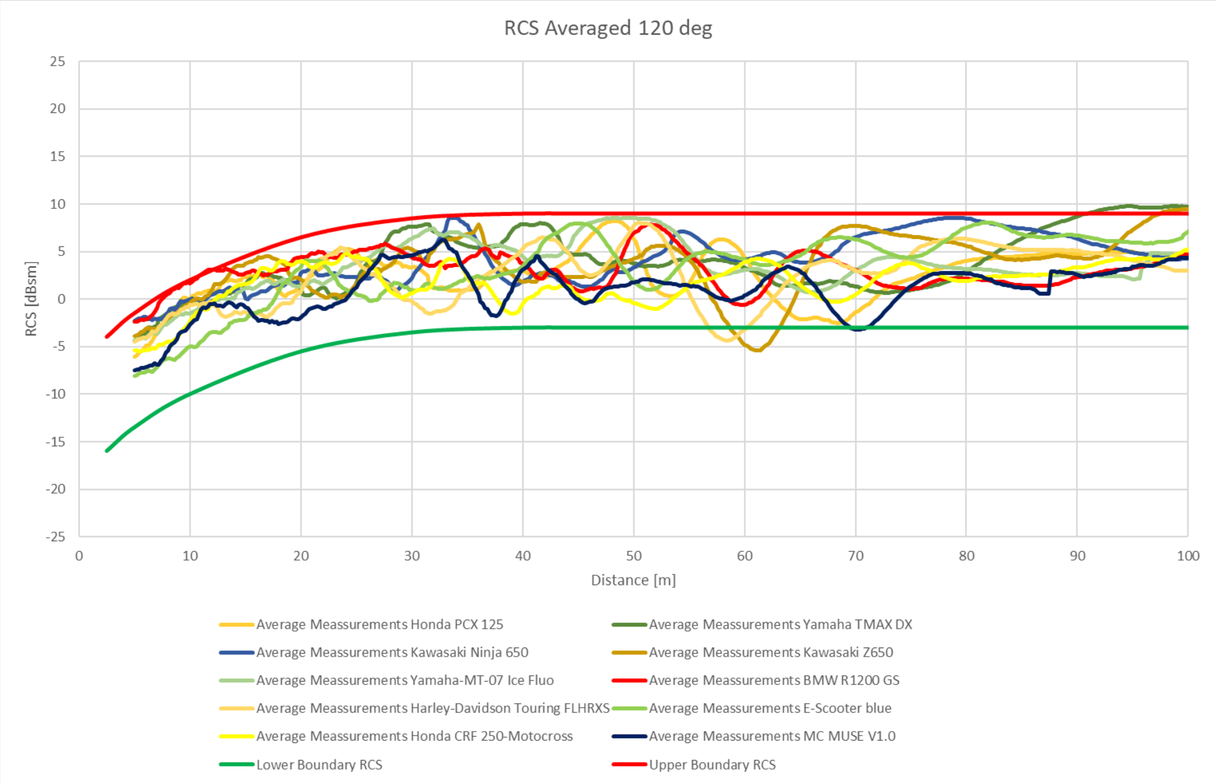

Figure A1 8 Example RCS of 4a GMT versus real motorcycles (77 GHz Sensor Bosch MRR-SGU) 120°

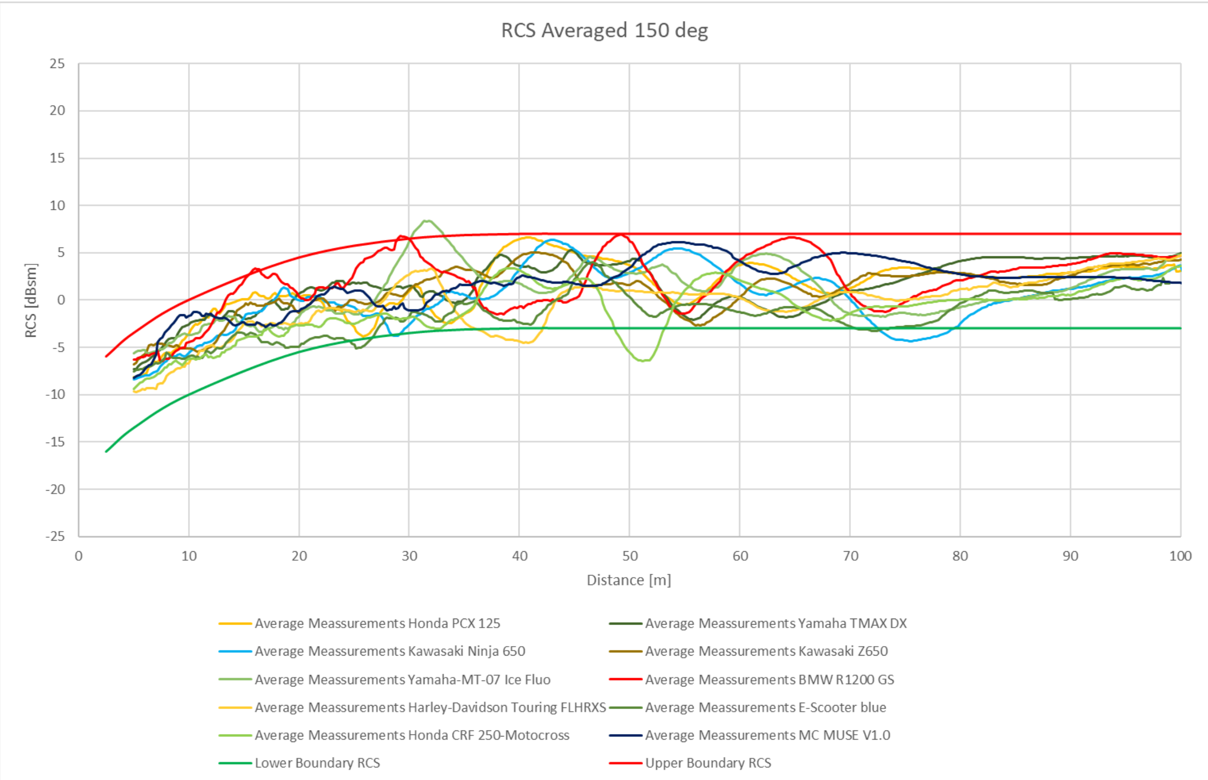

Figure A1 9 Example RCS of 4a GMT versus real motorcycles (77 GHz Sensor Bosch MRR-SGU) 150°

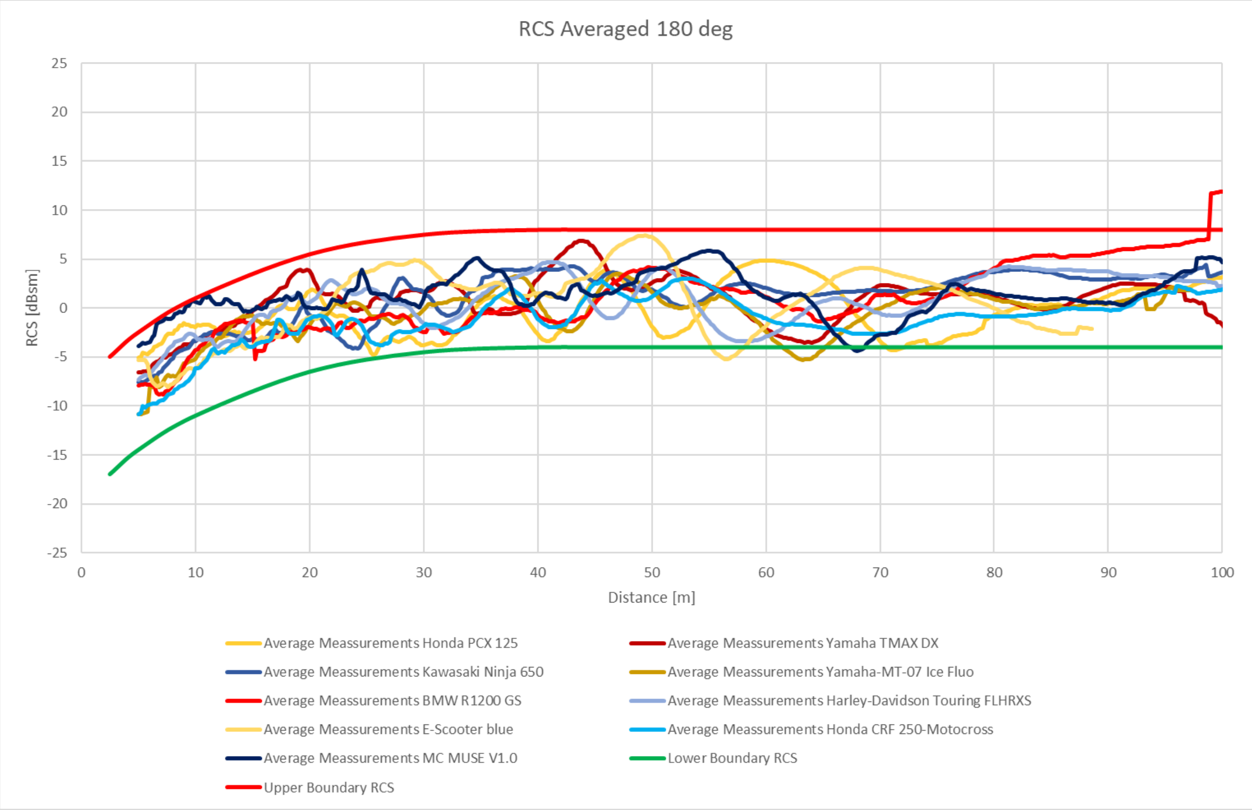

Figure A1 10 Example RCS of 4a GMT versus real motorcycles (77 GHz Sensor Bosch MRR-SGU) 180°

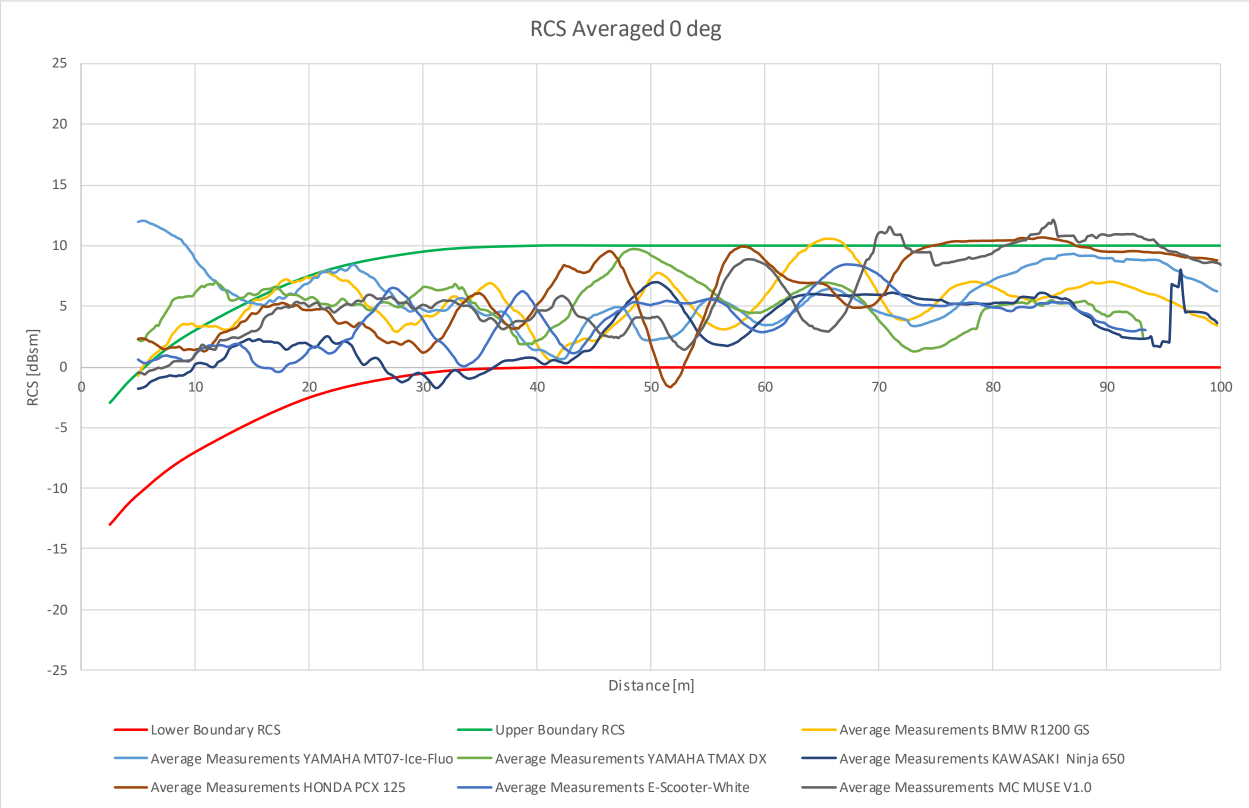

Figure A1 11 Example RCS of 4a GMT versus real motorcycles (77 GHz Sensor Continental ARS 400 Series) 0°

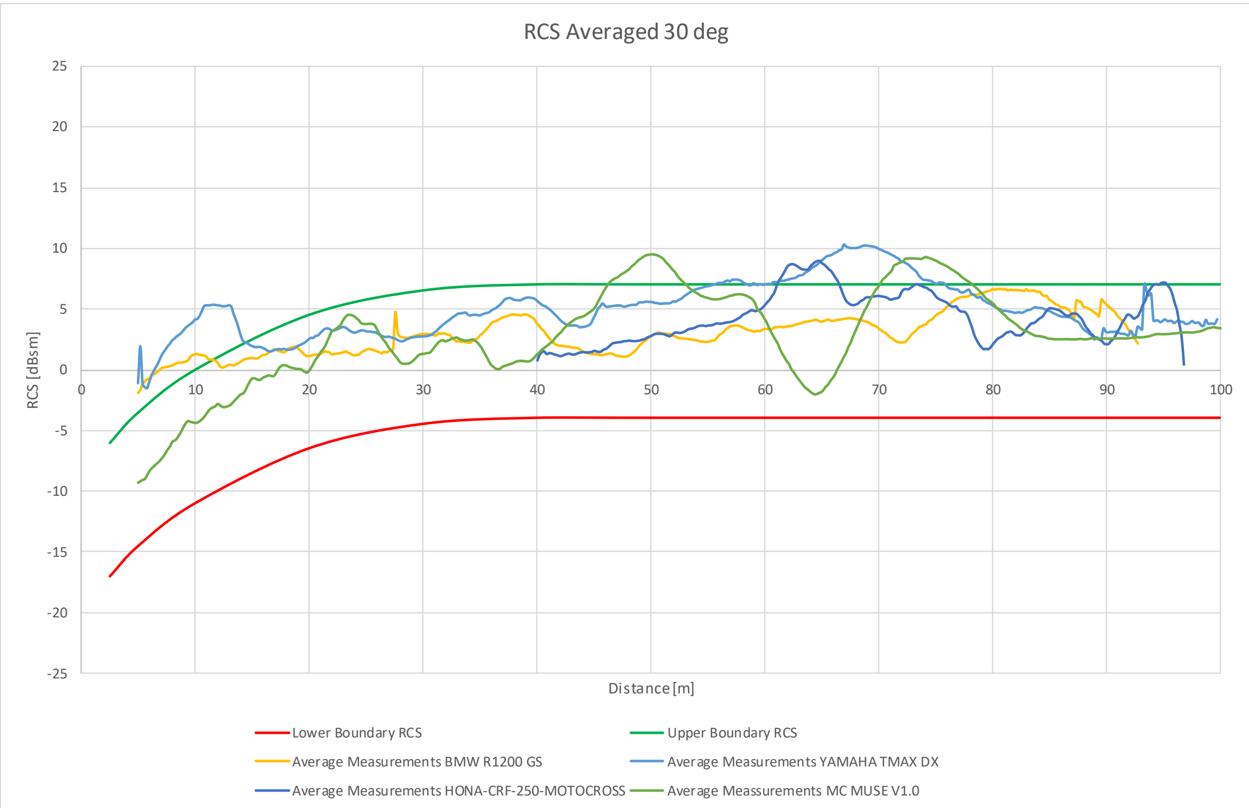

Figure A1 12 Example RCS of 4a GMT versus real motorcycles (77 GHz Sensor Continental ARS 400 Series) 30°

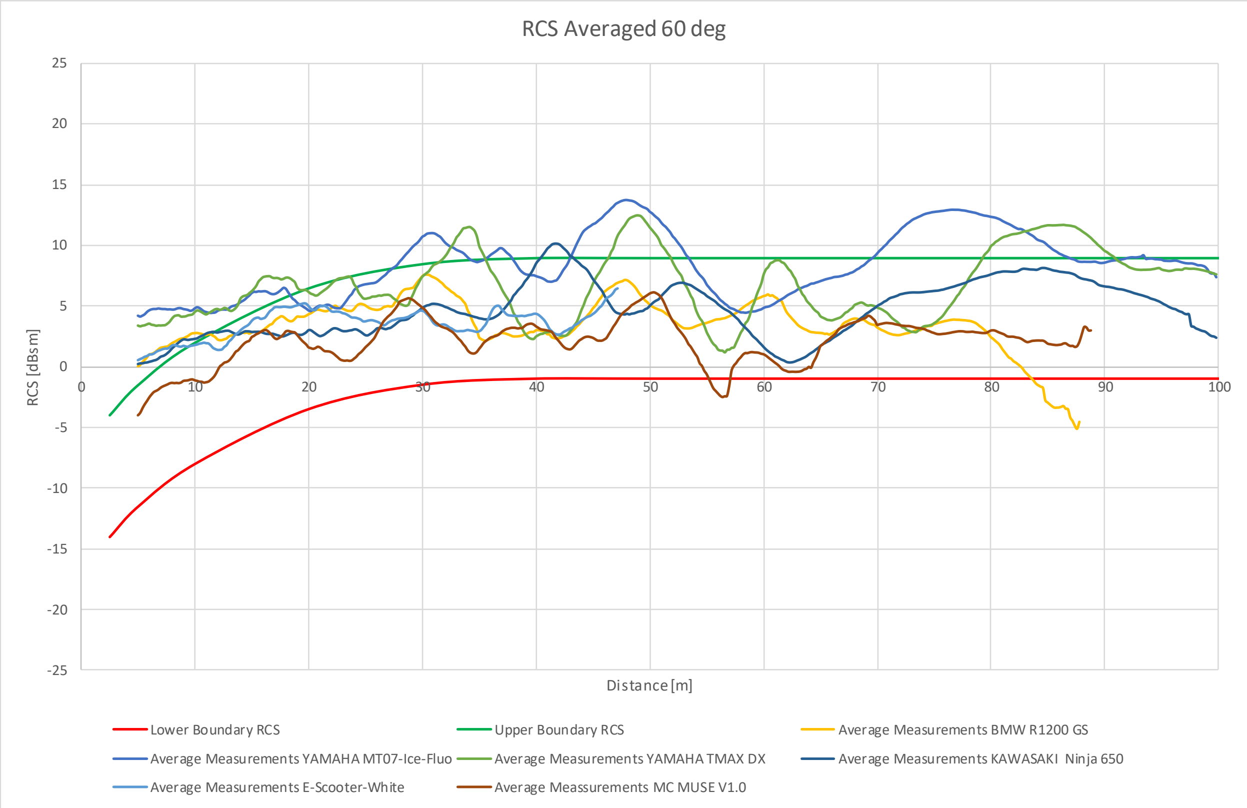

Figure A1 13 Example RCS of 4a GMT versus real motorcycles (77 GHz Sensor Continental ARS 400 Series) 60°

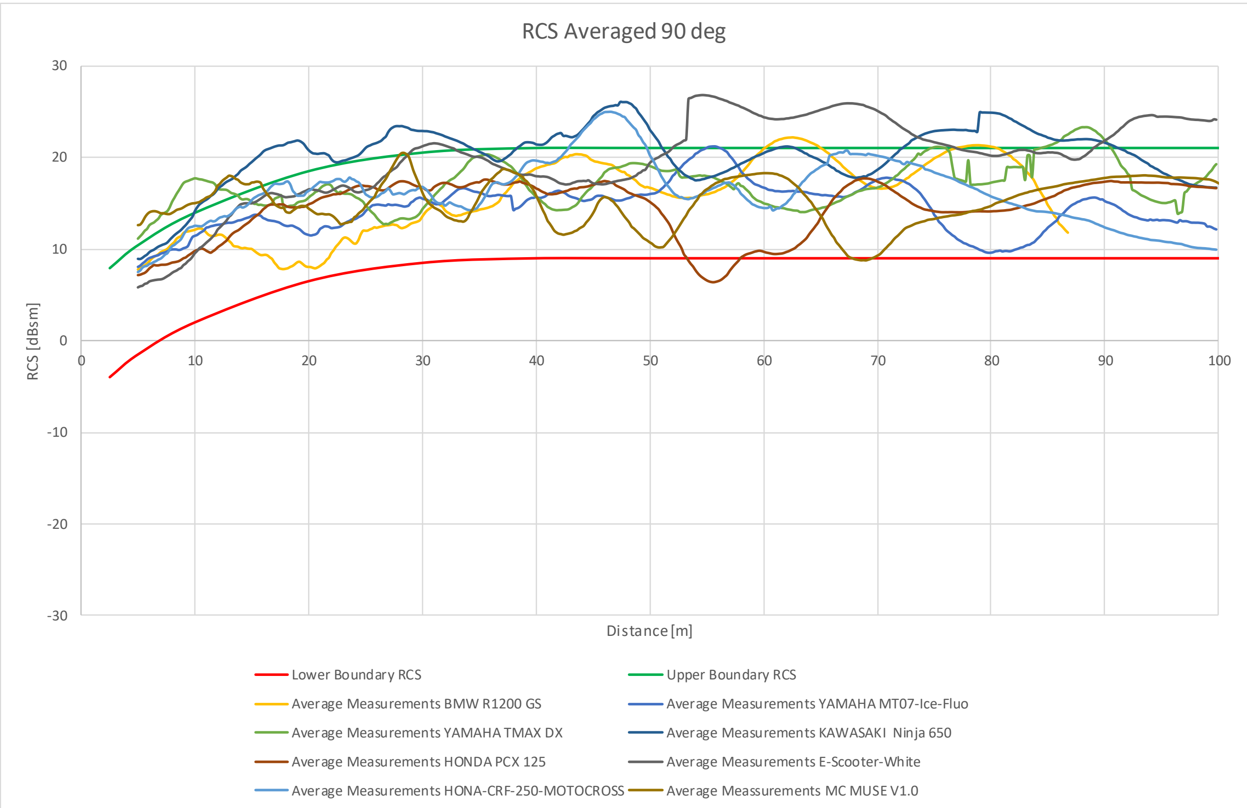

Figure A1 14 Example RCS of 4a GMT versus real motorcycles (77 GHz Sensor Continental ARS 400 Series) 90°

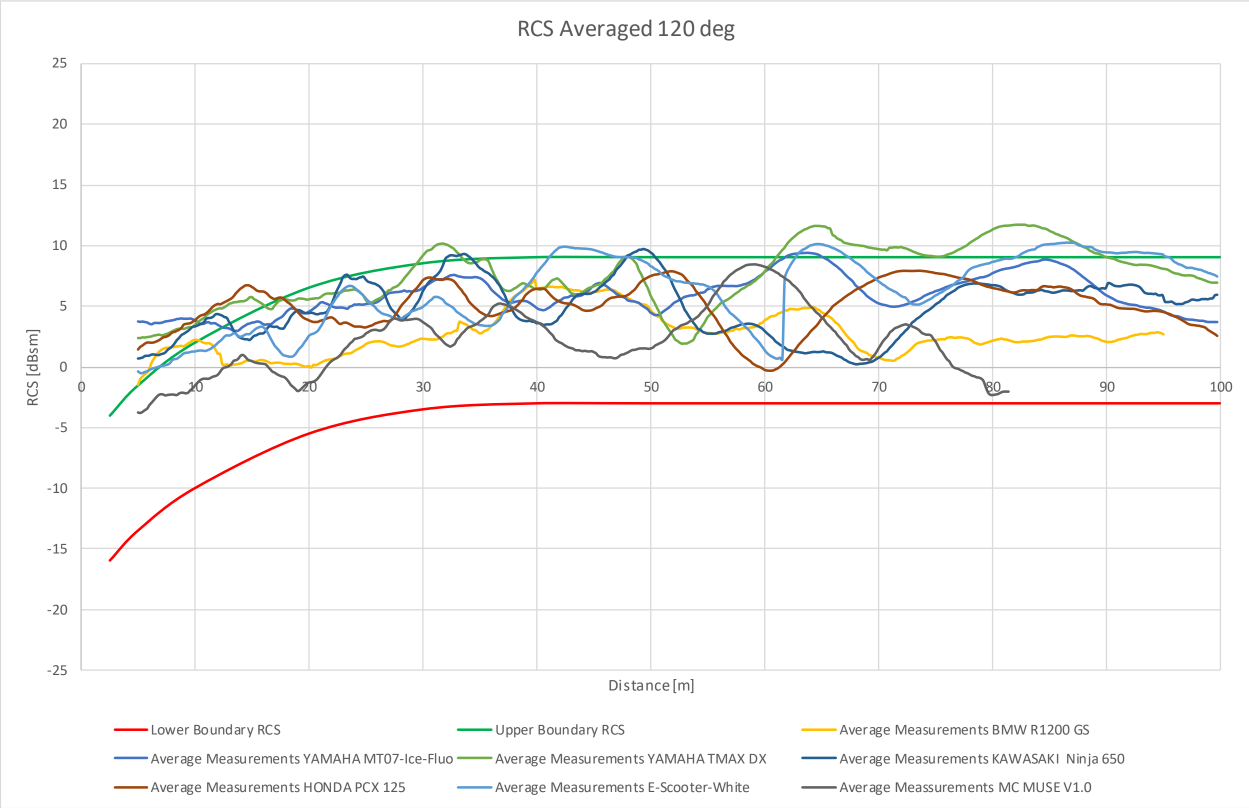

Figure A1 15 Example RCS of 4a GMT versus real motorcycles (77 GHz Sensor Continental ARS 400 Series) 120°

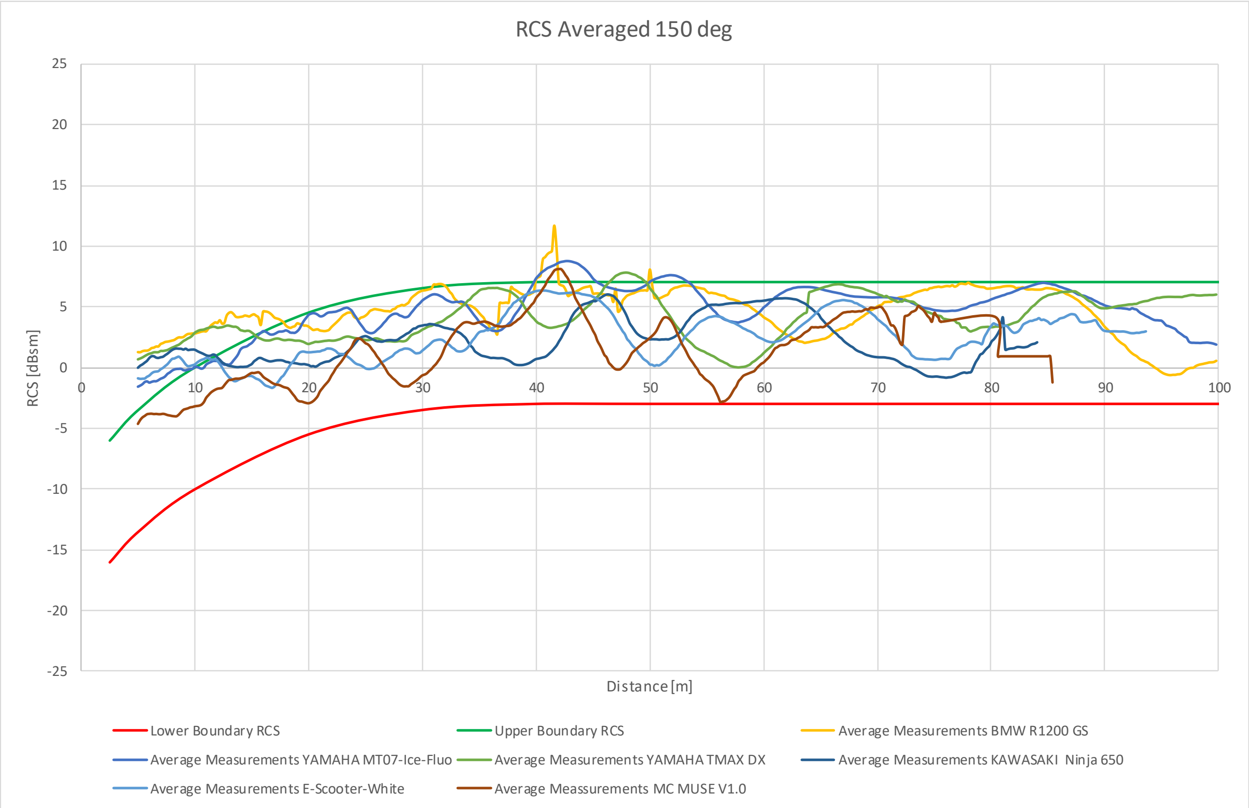

Figure A1 16 Example RCS of 4a GMT versus real motorcycles (77 GHz Sensor Continental ARS 400 Series) 150°

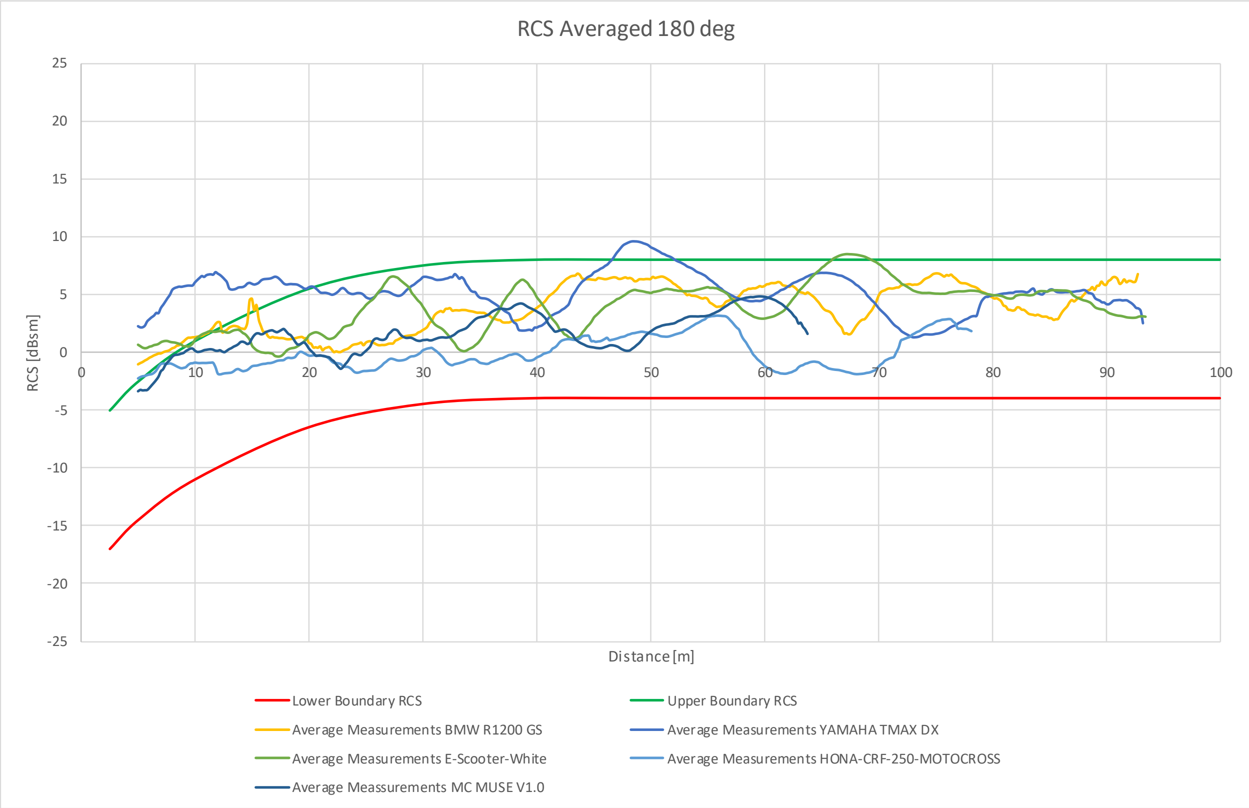

Figure A1 17 Example RCS of 4a GMT versus real motorcycles (77 GHz Sensor Continental ARS 400 Series) 180°

Following figure provides an example, comparing real motorcycles versus 4a GMT dummy using the evaluation methodology of appendix A2 for fixed range measurement.

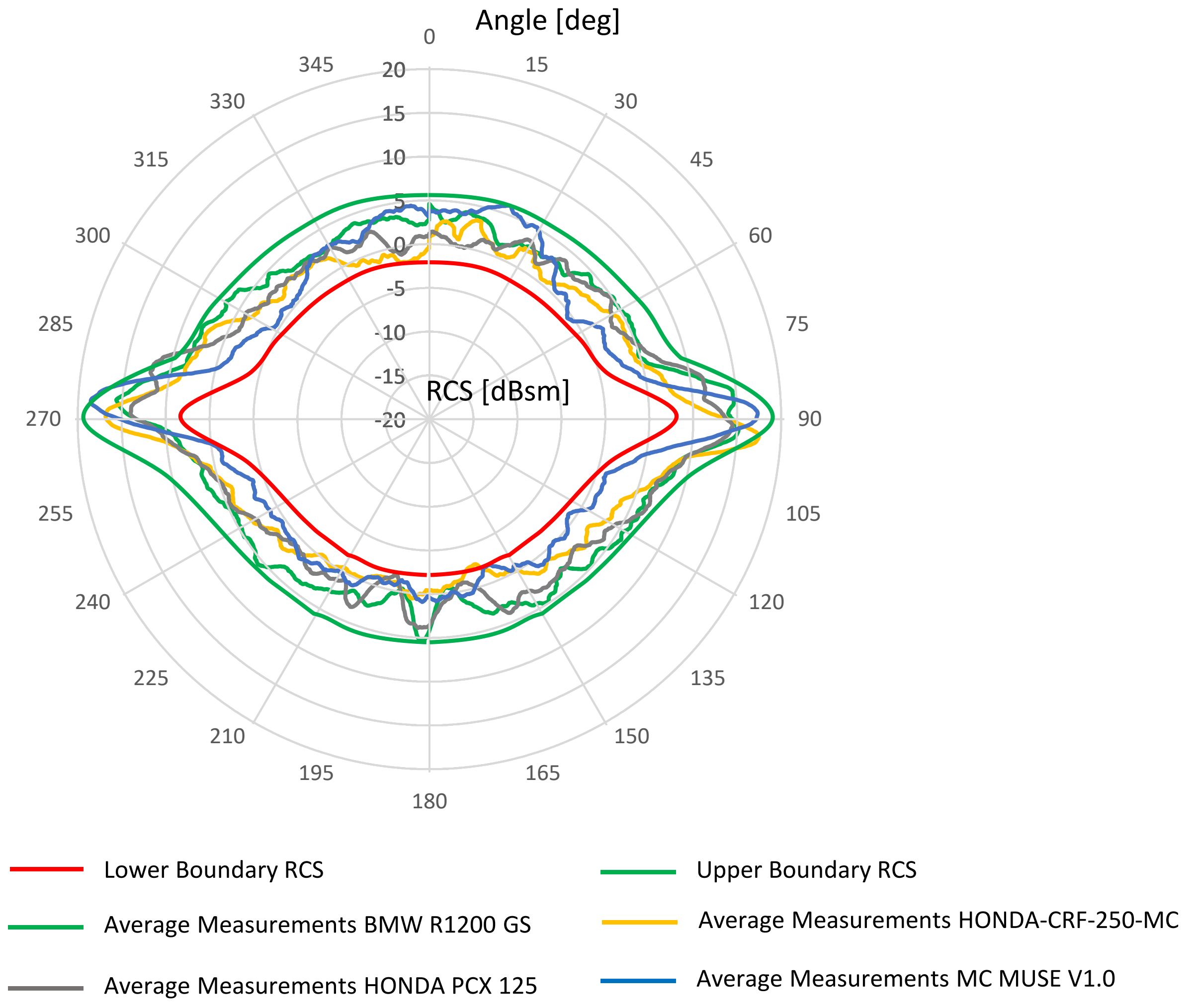

Figure 14 Example RCS of 4a GMT versus real motorcycles fixed range (77 GHz Sensor Continental ARS 400 Series)

4 Acknowledgements:

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