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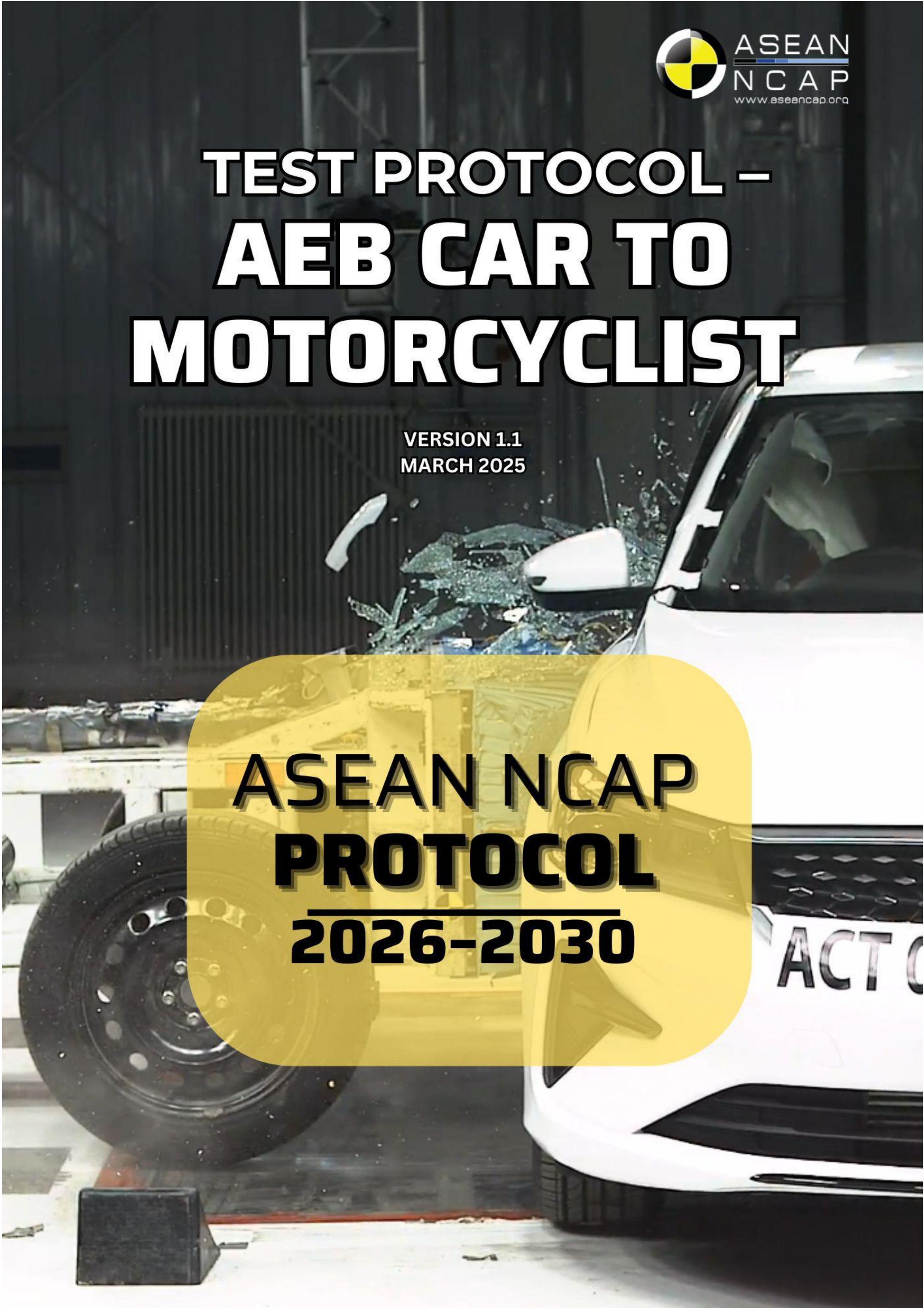

TEST PROTOCOL – AEB CAR TO MOTORCYCLIST

VERSION 1.1
MARCH 2025

ASEAN NCAP
PROTOCOL
2026-2030

Preface

During the test preparation, vehicle manufacturers are encouraged to liaise with the laboratory and to check that they are satisfied with the way cars are set up for testing. Where a manufacturer feels that a particular item should be altered, they should ask the laboratory staff to make any necessary changes. Manufacturers are forbidden from making changes to any required parameter that will influence the test, such as dummy positioning, vehicle setting, test environment, etc.

It is the responsibility of the test laboratory to ensure that any requested changes satisfy the requirements of ASEAN NCAP. Where a disagreement exists between the laboratory and manufacturer, the ASEAN NCAP secretariat should be informed immediately to pass a final judgement. Where the laboratory staff suspects that a manufacturer has interfered with any of the setup, the manufacturer's representatives should be warned that they are not allowed to do so themselves. They should also be informed that if another incident occurs, they will be asked to leave the test site.

Where there is a recurrence of the problem, the manufacturer’s representatives will be told to leave the test site, and the Secretariat should be immediately informed. Any such incident may be reported by the Secretariat to the manufacturer and the persons concerned may not be allowed to attend further ASEAN NCAP tests.

DISCLAIMER: ASEAN NCAP has taken all the necessary steps to ensure that the information published in this protocol is accurate and reflects the technical decisions taken by the organisation. In the unlikely event that this protocol contains a typographical error or any other inaccuracy, ASEAN NCAP reserves the right to make corrections and determine the assessment and subsequent result of the affected requirement(s).

In addition to the settings specified in this protocol, the following information will be required from the manufacturer of the car being tested in order to facilitate vehicle preparation. A vehicle handbook should be provided to the test laboratory prior to the assessment.

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NEW CAR ASSESSMENT PROGRAM FOR SOUTHEAST ASIAN COUNTRIES (ASEAN NCAP)

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1 INTRODUCTION

Since its inception in 2011, the New Car Assessment Program for Southeast Asian Countries (ASEAN NCAP) has aimed to raise vehicle safety standards across the region. With a strong emphasis on motorcyclist protection, ASEAN NCAP is recognized for implementing one of the most challenging safety protocols of its kind. To reinforce this commitment, the Motorcyclist Safety Pillar was introduced in the 2026–2030 Roadmap to encourage the automotive industry to intensify efforts in reducing motorcycle-related fatalities through the adoption of advanced safety technologies.

Autonomous Emergency Braking Car to Motorcyclist (AEB CM) is a technology designed to detect the presence of a motorcycle, enabling the vehicle to avoid a collision with the motorcycle ahead. This technology marks a significant milestone in vehicle safety, as it aims to reduce the number of fatalities involving motorcyclists.

2 DEFINITIONS

Throughout this protocol the following terms are used.

Peak Braking Coefficient (PBC) – the measure of tyre to road surface friction based on the maximum deceleration of a rolling tyre, measured using the American Society for Testing and Materials (ASTM) E1136-10 (2019) standard reference test tyre, in accordance with ASTM Method E 1337-2019, at a speed of 64.4 km/h, without water delivery. Alternatively, the method as specified in UNECE R13-H.

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.

Forward Collision Warning (FCW) – an audiovisual warning that is provided automatically by the vehicle in response to the detection of a likely collision to alert the driver.

Lane Support System (LSS) – a system that corrects the vehicle heading to keep the vehicle within its driving lane and/or warns the driver.

Emergency Lane Keeping (ELK) – default on heading correction that is applied automatically by the vehicle in response to the detection of the vehicle that is about to drift beyond a solid line marking, the edge of the road or into oncoming or overtaking traffic in the adjacent lane.

Car-to-Motorcyclist Rear Moving (CMRm) – a collision in which a vehicle travels forwards towards motorcycle going at a constant lower speed and the frontal structure of the vehicle strikes the rear structure of the motorcycle.

Car-to-Motorcyclist Front Turn Across Path (CMFtap) – a collision in which a vehicle turns across the path of an oncoming motorcyclist travelling at a constant speed, and the frontal structure of the vehicle strikes the front of the motorcycle.

Car-to-Motorcyclist Crossing (CMCrossing) – the situation of crash is represented by the VUT and the AMT driving straight and perpendicularly at an intersection.

Car-to-Motorcyclist Oncoming (CMOncoming) – the scenario represents the passenger car drifting into the lane of the motorcycle which is coming from the opposite direction.

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

ASEAN NCAP Motorcyclist Target (AMT) – refers to the motorcyclist target used in this protocol.

Vehicle Width – the widest point of the vehicle ignoring the rear-view mirrors, side marker lamps, tyre pressure indicators, direction indicator lamps, position lamps, flexible mudguards and the deflected part of the tyre sidewalls immediately above the point of contact with the ground.

Time To Collision (TTC) – the remaining time before the VUT strikes the AMT, assuming that the VUT and AMT would continue to travel with the speed it is travelling.

T_{AEB} – the time where the AEB system activates. Activation time is determined by identifying the last data point where the filtered acceleration signal is below -1 m/s² and then returning to the point in time where the acceleration first crossed -0.3 m/s².

T_{FCW} – the time where the audible warning of the FCW starts. The starting point is determined by audible recognition.

3 REFERENCE SYSTEM

3.1 Convention

3.1.1 For both VUT and AMT, ASEAN NCAP shall use the convention specified in ISO 8855:2011 in which the x-axis points toward the front of the vehicle, the y-axis toward the left and the z-axis upward (right hand system), with the origin at the most forward point on the centreline of the VUT for dynamic data measurements as shown in Figure 1.

3.1.2 Viewed from the origin, roll, pitch, and yaw rotate clockwise around the x, y, and z axes, respectively. Longitudinal refers to the component of the measurement along the x-axis, lateral to the component along the y-axis, and vertical to the component along the z-axis.

3.1.3 This reference system should be used for both left-hand and right-hand drive of the vehicles tested.

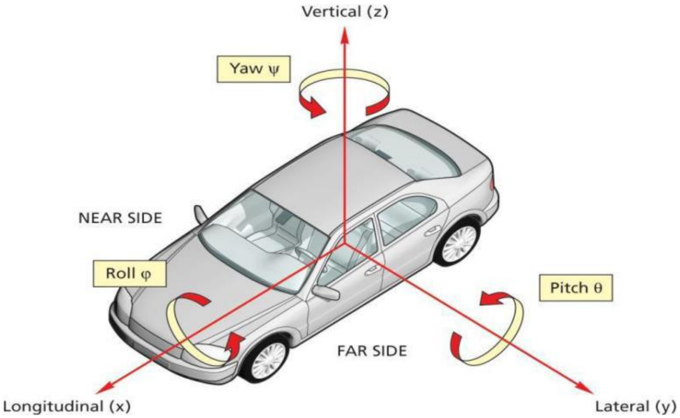


Figure 1: Coordinate system and notation

4 MEASURING EQUIPMENT

4.1 Sample and record

A sample and record of all dynamic data at a frequency of at least 100 Hz are kept. They shall be synchronized using the DGPS time stamp to match the AMT data with that of the VUT.

4.2 Measurements and Variables

4.2.1 Time	**T**
- T_0, time of test start: T_0 equals TTC = 4s	**T_0**
- T_{AEB}, time where AEB activates	**T_{AEB}**
- T_{FCW}, time where FCW activates	**T_{FCW}**
- T_{impact}, time where VUT impacts EVT	**T_{impact}**

- T_{steer}, time where VUT enters in curve segment	$\mathbf{T}_{steer}$
4.2.2 Time (LSS-related tests)	
- T_0, time where manoeuvre starts with 2s straight path	$\mathbf{T}_0$
- T_{LDW}, time where LDW activates	$\mathbf{T}_{LDW}$
- T_{steer}, time where VUT enters in curve segment	$\mathbf{T}_{steer}$
- $T_{crossing}$, time where VUT crosses the line or road edge	$\mathbf{T}_{crossing}$
4.2.3 Position of the VUT during the entire test	$\mathbf{X}_{VUT}$, $\mathbf{Y}_{VUT}$
4.2.3 Position of the AMT during the entire test	$\mathbf{X}_{AMT}$, $\mathbf{Y}_{AMT}$
4.2.4 Position of the target during the entire test	
- for crossing scenarios	$\mathbf{Y}_{target}$
- for longitudinal scenarios	$\mathbf{X}_{target}$
4.2.5 Speed of the VUT during the entire test	$\mathbf{V}_{VUT}$
- V_{impact}, speed when VUT impacts AMT	$\mathbf{V}_{impact}$
- V_{rel_impact}, relative speed when VUT impacts AMT	$\mathbf{V}_{rel\_impact}$
4.2.6 Speed of the AMT during the entire test	$\mathbf{V}_{AMT}$
4.2.7 Yaw velocity of the VUT during the entire test	$\boldsymbol{\Psi}_{VUT}$

4.2.8 Yaw velocity of the AMT during the entire test $\boldsymbol{\Psi}_{\mathrm{AMT}}$

4.2.9 Yaw angle of the AMT during the entire test $\boldsymbol{\Psi}^{\circ}{}_{\mathrm{AMT}}$

4.2.10 Acceleration of the VUT during the entire test $\mathbf{A}_{\mathrm{VUT}}$

4.2.11 Acceleration of the AMT during the entire test $\mathbf{A}_{\mathrm{AMT}}$

4.2.12 Longitudinal acceleration of the test target during the entire test $\mathbf{A}_{\mathrm{target}}$

4.2.13 Steering wheel velocity of the VUT during the entire test $\boldsymbol{\Omega}_{\mathrm{VUT}}$

4.3 Measuring Equipment

4.3.1 Equip the VUT and AMT with data measurement and acquisition equipment to sample and record data with an accuracy of at least:

- VUT and AMT speed of 0.1 km/h;
- VUT and AMT lateral and longitudinal position to 0.03 m;
- VUT heading angle to 0.1°;
- VUT and AMT yaw rate to 0.1°/s;
- AMT yaw angle to 0.1°;
- VUT and AMT longitudinal acceleration to 0.1 m/s²;
- VUT steering wheel velocity to 1.0°/s.

4.4 Data Filtering

4.4.1 Filter the measured data as follows.

4.4.1.1 Position and speed are not filtered and are used in their raw state.

4.4.1.2 Acceleration with a 12-pole phaseless Butterworth filter with a cut off frequency of 10Hz.

4.4.1.3 Yaw rate with a 12-pole phaseless Butterworth filter with a cut off frequency of 10Hz.

4.4.1.4 VUT steering wheel velocity with a 12-pole phaseless Butterworth filter with a cut off frequency of 10Hz.

5 ASEAN NCAP MOTORCYCLIST TARGET (AMT)

5.1 Specification

5.1.1 The target includes a dummy, representative of the most common motorcycles within the ASEAN market, and a platform as the propulsion system for the dummy (reference in Figure 2). The target requirements are to be cashable and to respect some dynamic parameters to reproduce the test with accuracy. The target replicates the visual, radar reflexion, and LIDAR attributes of an actual motorcycle. Details of the AMT specification can be referred to in ANNEX A.

Figure 2: ASEAN NCAP Motorcyclist Target (AMT)

6 TEST CONDITIONS

6.1 Test Track

6.1.1 Conduct tests on a dry (no visible moisture on the surface), uniform, solid-paved surface with a consistent slope between level and 1%. The test surface shall have a minimal peak braking coefficient (PBC) of 0.9.

6.1.2 The surface must be paved and may not contain any irregularities (e.g., large dips or cracks, manhole covers or reflective studs) that may give rise to abnormal sensor measurements within a lateral distance of 3.0 m to either side of the test path and with a longitudinal distance of 30 m ahead of the VUT when the test ends.

6.1.3 The presence of lane markings is allowed. However, testing may only be conducted in an area where typical road markings depicting a driving lane may not be parallel to the test path within 3.0 m on either side. Lines or markings may cross the test path but may not be present in the area where AEB activation and/or braking after FCW is expected.

6.1.4 Junction and Lane Markings

6.1.4.1 Some scenarios described in this document require the use of a junction, where this is the case, the scenario description will illustrate the scenario on a junction as shown in Figure 3. The main approach lane where the VUT path starts (horizontal lanes in Figure 3) will have a width of 3.5 m. The side lane (vertical lanes in Figure 3) will have a width of 3.25 to 3.5 m. The lane markings on these lanes need to conform to one of the lane markings as defined in UNECE Regulation 130:

i. dashed line starting at the same point where the radius transitions into a straight line with a width between 0.10 and 0.15 m;
ii. solid line with a width between 0.10 and 0.25 m; and
iii. junction without any central markings.

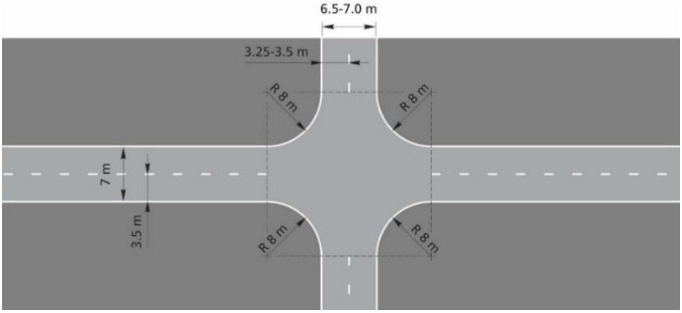


Figure 3: Layout of junction and the connecting lanes (Dimensions reference centre of lane markings)

6.1.5 Lane Markings

6.1.5.1 Some tests described in this document require the use of two different types of lane markings. These lane markings must conform to one of the lane markings as defined in UN Regulation R130 to mark a lane with a width of 3.5 m to 3.7 m when measured from the inside edge of the lane marking:

i. dashed line with a width between 0.10 and 0.25 m (0.10 and 0.15 m for centrelines); and
ii. solid line with a width between 0.10 and 0.25 m.

The lane markings should be sufficiently long to ensure that there is at least 20 m of marking remaining ahead of the vehicle after the test is complete.

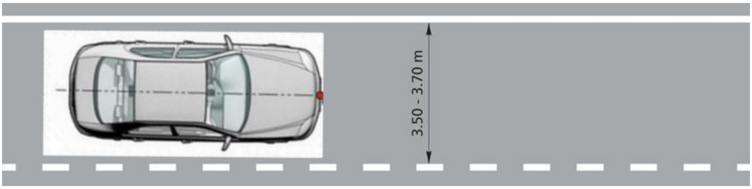


Figure 4: Layout of the lane markings
(Dimensions reference inside edge of lane marking)

6.2 Weather Conditions

6.2.1 Conduct tests in dry conditions with ambient temperatures above 5°C and below 40°C.

6.2.2 No precipitation shall be falling and horizontal visibility at ground level shall be greater than 1 km. Wind speeds shall be below 10 m/s to minimize AMT and VUT disturbances.

6.2.3 The test area's natural ambient illumination must be homogenous and in excess of 2000 lux for daylight testing, with no strong shadows cast across the test area other than those caused by the VUT or AMT. Ensure testing is not performed while driving towards or away from the sun when there is direct sunlight.

6.2.4 Measure and record the following parameters, preferably at the commencement of every single test:

a) ambient temperature in °C;
b) track temperature in °C;
c) wind speed and direction in m/s; and
d) ambient illumination in Lux.

6.3 Surroundings

6.3.1 Conduct testing such that there are no other vehicles, highway furniture, obstructions (except where detailed in the test scenario), other objects or persons protruding above the test surface that may give rise to abnormal sensor measurements within:

- 5 m on either side of the VUT test path during the full duration of the test and within a longitudinal distance of 20 m ahead of the VUT when the test ends;
- a circle of 2 m radius around the AMT; and

- the visual axis between the geometric centre of the VUT and the circle surrounding the AMT.

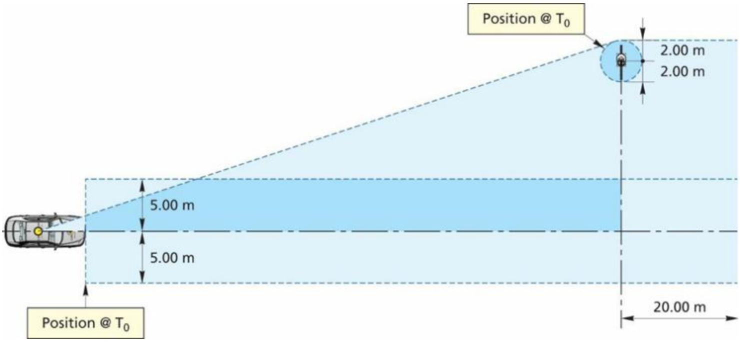


Figure 5: Free space requirements (nearside scenario only)

6.3.2 Test areas where the VUT needs to pass under overhead signs, bridges, gantries or other significant structures are not permitted.

6.3.3 The general view ahead and to either side of the test area shall comprise a wholly plain man-made or natural environment (e.g., further test surface, plain coloured fencing or hoardings, natural vegetation or sky, etc.) and must not comprise any highly reflective surfaces or contain any vehicle-like silhouettes that may give rise to abnormal sensor measurements.

6.4 VUT Preparation

6.4.1 AEB, FCW and LSS System Settings

6.4.1.1 Set any driver-configurable elements of the AEB, FCW and or LSS systems (e.g., the timing of the collision warning or the lane keep assist if present) to the middle setting or midpoint and then the next latest setting, similar to the examples shown in Figure 6 of the AEB and/or FCW system settings for testing.

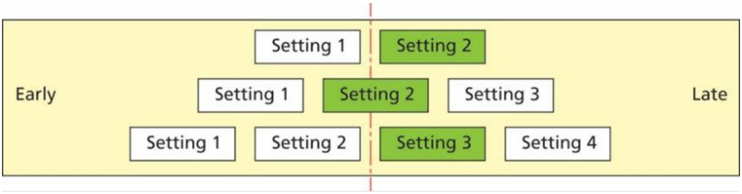


Figure 6: AEB and/or FCW system settings for testing

6.4.2 Tyres

Perform the testing with new original fitment tyres of the make, model, size, speed, and load rating as specified by the vehicle manufacturer. It is permitted to change the tyres that are supplied by the manufacturer or acquired by an official dealer representing the manufacturer if those tyres are identical in make, model, size, speed, and load rating to the original fitment. Inflate the tyres to the vehicle manufacturer's recommended cold tyre inflation pressure(s). Use inflation pressures corresponding to the least-loading normal condition.

Run-in tyres according to the tyre conditioning procedure specified in paragraph 7.1.3. After running-in, maintain the run-in tyres in the same position on the vehicle for the duration of the testing.

6.4.3 Wheel Alignment Measurement

The vehicle should be subject to a vehicle (in-line) geometry check to record the wheel alignment set by the OEM. This should be done with the vehicle's kerb weight.

6.4.4 Unladen Kerb Mass

6.4.4.1 Fill up the tank with fuel to at least 90% of the tank’s capacity.

6.4.4.2 Check the oil level and top it up to its maximum level if necessary. Similarly, top up the levels of all other fluids to their maximum levels if necessary.

6.4.4.3 Ensure that the vehicle has its spare wheel on board, if fitted, along with any tools supplied with the vehicle. Nothing else should be in the car.

6.4.4.4 Ensure that all tyres are inflated according to the manufacturer’s instructions for the appropriate loading condition.

6.4.4.5 Measure the front and rear axle masses and determine the total mass of the vehicle. The total mass is the ‘unladen kerb mass’ of the vehicle. Record this mass in the test details.

6.4.4.6 Calculate the required ballast mass by subtracting the mass of the test driver and test equipment from the required 200 kg interior load.

6.4.5 Vehicle Preparation

6.4.5.1 Fit the on-board test equipment and instrumentation in the vehicle. Also fit any associated cables, cabling boxes and power sources.

6.4.5.2 Place weights with a mass of the ballast mass. Any items added should be securely attached to the car.

6.4.5.3 With the driver in the vehicle, weigh the front and rear axle loads of the vehicle.

6.4.5.4 Compare these loads with the “unladen kerb mass”.

6.4.5.5 The total vehicle mass shall be within ±1% of the sum of the unladen kerb mass plus 200 kg. The front/rear axle load distribution needs to be within 5% of the front/rear axle load distribution of the original unladen kerb mass plus full fuel load. If the vehicle differs from the requirements given in this paragraph, items may be removed or added to the vehicle that have no influence on its performance. Any items added to increase the vehicle's mass should be securely attached to the car.

6.4.5.6 Repeat paragraphs 6.4.5.3 and 6.4.5.4 until the front and rear axle loads and the total vehicle mass are within the limits set in paragraph 6.4.5.5. Care needs to be taken when adding or removing weight in order to approximate the original vehicle's inertial properties as closely as possible. Record the final axle loads in the test details. Record the axle weights of the VUT in the ‘as tested’ condition.

7 TEST PROCEDURE

7.1 VUT Pre-test Conditioning

7.1.1 General

7.1.1.1 A new car is delivered to the test laboratory.

7.1.1.2 If requested by the vehicle manufacturer, drive a maximum of 100 km on a mixture of urban and rural roads with other traffic and roadside furniture to ‘calibrate’ the sensor system. Avoid harsh accelerations and braking.

7.1.2 Brakes

7.1.2.1 Condition the vehicle’s brakes in the following manner.

i. Perform ten stops at a speed of 56 km/h with an average deceleration of approximately 0.5 to 0.6 g.
ii. Immediately following the series of 56 km/h stops, perform three additional stops at a speed of 72 km/h, each time applying sufficient force to the pedal to operate the vehicle’s anti-lock braking system (ABS) for the majority of each stop.
iii. Immediately following the series of 72 km/h stops, drive the vehicle at a speed of approximately 72 km/h for five minutes to cool the brakes.

iv. Initiation of the first test shall begin within two hours after the completion of the brake conditioning.

7.1.3 Tyres

7.1.3.1 Condition the vehicle's tyres in the following manner to remove the mould sheen.

i. Drive around a circle of 30 m in diameter at a speed sufficient to generate a lateral acceleration of approximately 0.5 to 0.6 g for three clockwise laps, followed by three anticlockwise laps.
ii. Immediately following the circular driving, drive four passes at 56 km/h, performing ten cycles of a sinusoidal steering input in each pass at a frequency of 1 Hz and amplitude sufficient to generate a peak lateral acceleration of approximately 0.5 to 0.6 g.
iii. During the final cycle of the final pass, double the steering wheel amplitude than that of the previous inputs.

7.1.3.2 In the event of instability in the sinusoidal driving, reduce the amplitude of the steering input to an appropriately safe level and continue the four passes.

7.1.4 AEB/FCW & LSS System Check

7.1.4.1 Before any testing begins, perform a maximum of 10 runs at the lowest test speed the system is supposed to work at to ensure proper functioning of the system.

7.2 Test Scenarios

For AEB/FCW motorcyclist and LSS, the scenarios are considered in these sections; therefore, the test scenarios are:

Table 1: The scenario of AEB/FCW Motorcyclist and LSS

	CMRm		**CMFtap**	**CMCrossing**	**CMOncoming**
Paragraph	7.2.1		7.2.2	7.2.3	7.2.4
Type of test	AEB	FCW	AEB	AEB	LSS
VUT speed [km/h]	40-60	40-80	10,20	20-60	72
VUT direction	Forward		Farside turn	Farside and nearside	Farside
Target speed [km/h]	30,45,60		30,45,60	20	60
Impact location [%]	50	50 and 25	50	50 - 50% motorcycle length	10
Lighting condition	Day		Day	Day	Day

7.2.1 Car to Motorcycle Rear-end Moving (CMRm)

7.2.1.1 CMRm representing the VUT and the AMT going in the same direction, with the VUT impacting the rear of the motorcycle.

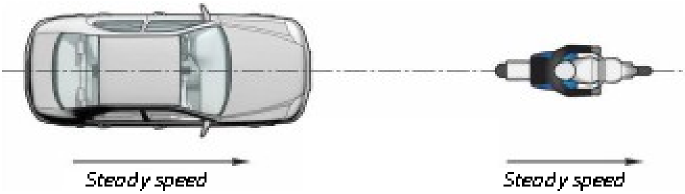


Figure 7: CMRm test scenario

7.2.1.2 The CMRm scenario will be performed with the motorcycle velocity ranging from 30 km/h to 60 km/h and the vehicle speed ranging from 40 km/h to 80 km/h, as shown in Tables 2 and 3.

Table 2: CMRm vehicle scenario paths (50%)

50% impact point				
Speed (km/h)		AMT		
		30	45	60
VUT	40	AEB/FCW	-	-
	45	AEB/FCW	-	-
	50	AEB/FCW	-	-
	55	AEB/FCW	AEB/FCW	-
	60	AEB/FCW	AEB/FCW	-
	65	FCW	FCW	-
	70	FCW	FCW	FCW
	75	FCW	FCW	FCW
	80	FCW	FCW	FCW

Table 3: CMRm vehicle scenario paths (25%)

25% impact point				
Speed (km/h)		AMT		
		30	45	60
VUT	40	FCW	-	-
	45	FCW	-	-
	50	FCW	-	-
	55	FCW	FCW	-
	60	FCW	FCW	-
	65	FCW	FCW	-
	70	FCW	FCW	FCW
	75	FCW	FCW	FCW
	80	FCW	FCW	FCW

7.2.1.3 The vehicle speed should be tested with 10 km/h steps and reduced to 5 km/h steps if there is an impact.

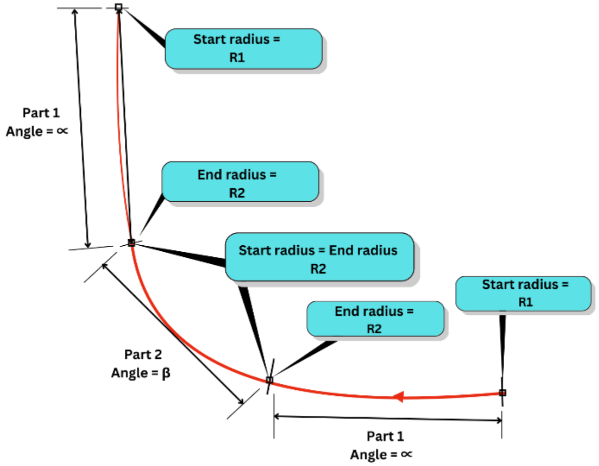
Figure 8: 50% impact point for CMRm scenario (AEB/FCW)

Figure 9: 25% impact point for CMRm scenario (FCW)

7.2.2 Car to Motorcycle Front turn across path (CMFtap)

7.2.2.1 For the CMFtap scenario, for the VUT, assume an initial straight-line path followed by a turn, followed again by a straight line, hereby known as the test path. The direction indicator is applied at 1.0s before T_{steer}.

7.2.2.2 For CMFtap, the following parameters should be used to create the test paths.



<table>
<tr><th rowspan="2">Test speed</th><th colspan="3">Part 1 (clothoid)</th><th colspan="3">Part 2 (constant radius)</th><th colspan="3">Part 3 (clothoid)</th></tr>
<tr><th>Start Radius R1 (m)</th><th>End Radius R2 (m)</th><th>Angle α (deg)</th><th>Start Radius R2 (m)</th><th>End Radius R2 (m)</th><th>Angle β (deg)</th><th>Start Radius R2 (m)</th><th>End Radius R1 (m)</th><th>Angle α (deg)</th></tr>
<tr><td>10 km/h to Far side</td><td>1500</td><td>9.00</td><td>20.62</td><td>9.00</td><td>9.00</td><td>48.76</td><td>9.00</td><td>1500</td><td>20.62</td></tr>
<tr><td>20 km/h to Far side</td><td>1500</td><td>14.75</td><td>21.79</td><td>14.75</td><td>14.75</td><td>46.42</td><td>14.75</td><td>1500</td><td>21.79</td></tr>
</table>

Figure 10: Test path parameter for CMFtap

7.2.2.3 The AMT will follow a straight-line path in the lane adjacent to the VUT’s initial position, in the opposite direction to the VUT. The straight-line path of the VUT and target will be 1.75 m from the centre of the dashed lane marking the VUT lane.

7.2.2.4 The paths of the VUT and AMT will be synchronised so that the front edges of the vehicle meet in a lateral position that gives a 100% overlap (assuming no system reaction) of the width of the VUT. The VUT longitudinal path error shall be within ± [0.5] m.

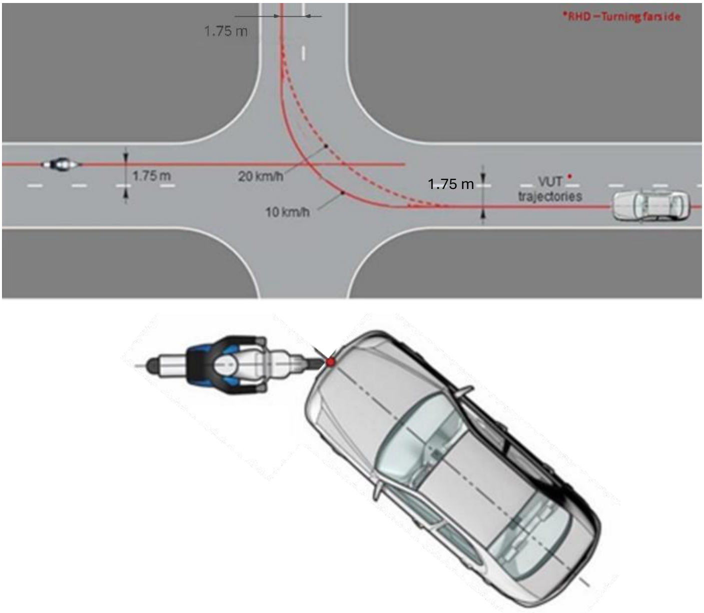


Figure 11: CMFtap scenario VUT and AMT paths

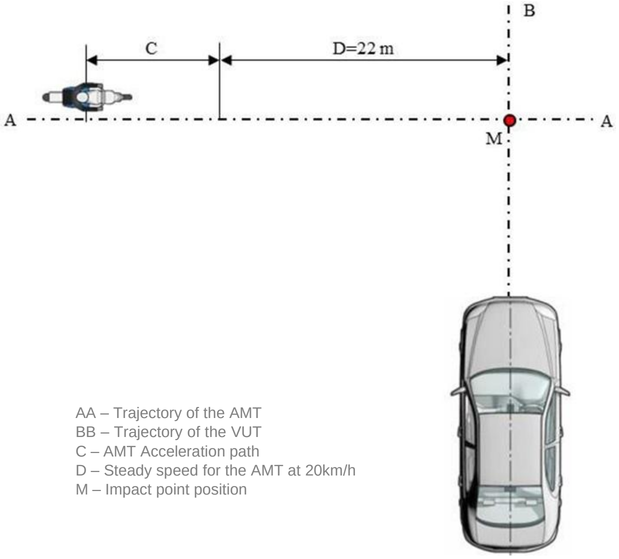
7.2.2.5 The CMFtap scenarios are all combinations of VUT speeds of 10 and 20 km/h combined with AMT speeds of 30, 45 and 60 km/h.

Table 4: Speed combination for CMFtap

Speed (km/h)		AMT		
		30	45	60
VUT	10	AEB	AEB	AEB
	20	AEB	AEB	AEB

7.2.3 Car-to-Motorcyclist Crossing (CMCrossing)

7.2.3.1 CMCrossing represents a scenario where the VUT and the AMT approach from perpendicular directions and collide at the centre of the VUT’s front bumper and the midpoint of the AMT.



AA – Trajectory of the AMT
BB – Trajectory of the VUT
C – AMT Acceleration path
D – Steady speed for the AMT at 20km/h
M – Impact point position

Figure 12: CMCrossing scenario (Motorcycle approaching from nearside)

7.2.3.2 The test speeds shall be 20 km/h for the AMT (approaching from both the nearside and far side), and 20 to 60 km/h for the VUT. The VUT speeds shall be increased in 10 km/h increments and reduced to 5 km/h increments if an impact occurs.

Table 5: Speed combination for CMCrossing scenario.

Speed km/h		AMT
		20
VUT	20	AEB
	25	AEB
	30	AEB
	35	AEB
	40	AEB
	45	AEB
	50	AEB
	55	AEB
	60	AEB

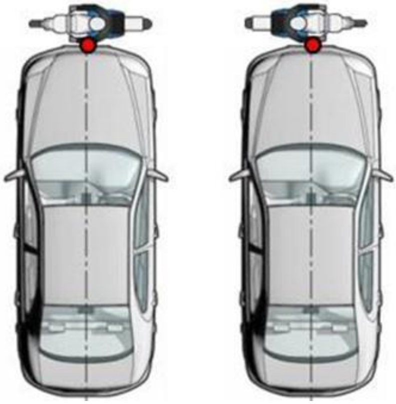


Figure 13: Impact points for CMCrossing test scenario

7.2.4 Car-to-Motorcyclist Oncoming (CMOncoming)

7.2.4.1 For the oncoming scenario, the AMT will follow a straight-line path at 60 km/h in the lane adjacent to the VUT’s initial position, in the opposite direction to the

VUT, which drives at 72 km/h. The straight-line path of the target will be 1 m for the AMT from the centre of the centre dashed lane marking the VUT lane.

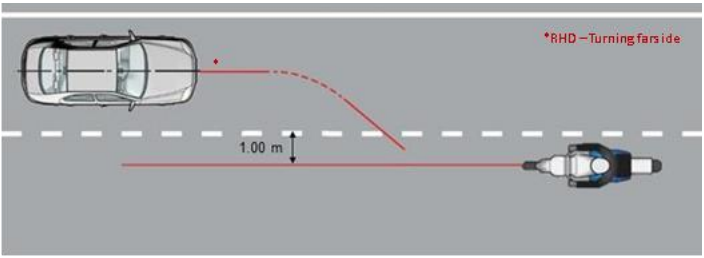


Figure 14: CMOncoming vehicle scenario paths

7.2.4.2 The paths of the VUT and AMT will be synchronised so that the outermost front of the AMT impacts the VUT at 10% of the width of the VUT (assuming no system reaction).

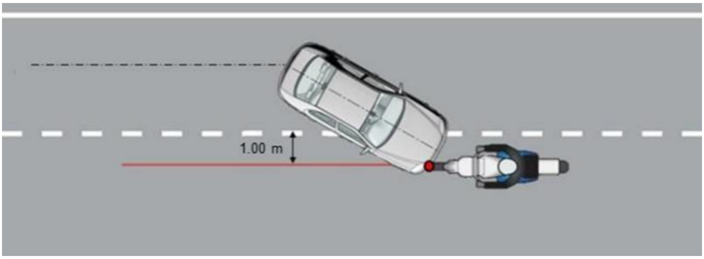


Figure 15: Impact point for CMOncoming test scenario

7.2.4.3 For this scenario, when the vehicle is equipped with an Emergency Lane Keeping (ELK), this system shall be turn on independently before the testing commences.

7.2.4.4 The following parameters should be used to create the test paths for the tests:

Table 6: Test path parameters for CMOncoming

VUT@ 72km/h	**$Vlat_{VUT}$ [m/s]**	**R [m]**	**Ψ_{VUT} [°]**	**d1**	**d2**
Unintentional	0.2	1200	0.57	0.06	0.70
	0.3		0.86	0.14	0.90
	0.4		1.15	0.24	0.80
	0.5		1.43	0.38	0.75
	0.6		1.72	0.54	0.60

Where the lateral offset d from the lane marking:

d = d1 + d2 + Half of the vehicle width (m)

d1: Lateral distance travelled during curve establishing yaw angle (m)

d2: Lateral distance travelled during V_{lat} steady state (m)

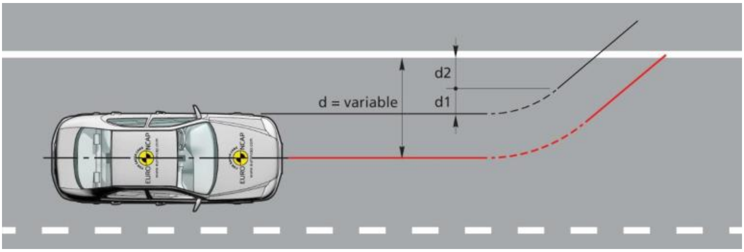


Figure 16: Impact point for CMOncoming test scenario

7.2.4.5 CMOncoming tests will be performed with 0.1 m/s incremental steps within the lateral velocity range of 0.2 to 0.6 m/s for departures at the driver side only.

7.3 Test Conduct

7.3.1 Brake temperature before braking will be measured immediately before the start of each run for braking with the vehicle in a fixed position. Brake temperature before braking refers to the higher of the average temperature of the left wheel or the right wheel of each axle when the temperature of the brake lining or pad of each wheel is measured. The permissible range for brake temperature before braking is 65–100 °C.

7.3.2 Before every test run, drive the VUT around a circle of maximum diameter 30 m at a speed less than 10 km/h for one clockwise lap followed by one anticlockwise lap, and then manoeuvre the VUT into position on the test path. If requested by the OEM, an initialisation run may be included before every test run. Bring the VUT to a halt and push the brake pedal through the full extent of travel and release.

7.3.3 For vehicles with an automatic transmission, select D. For vehicles with a manual transmission, select the highest gear where the RPM will be at least 1500 at the test speed. If fitted, a speed limiting device or cruise control may be used to maintain the VUT speed unless the vehicle manufacturer shows that there are interferences between these devices and the AEB system in the VUT.

Apply only minor steering inputs as necessary to maintain the VUT tracking along the test path.

7.3.4 Perform the first test a minimum of 90 seconds and a maximum of 10 minutes after completing the tyre conditioning, and subsequent tests after the same time period. If the time between consecutive tests exceeds 10 minutes, repeat the tyre conditioning procedures and recommence testing.

7.3.5 Between tests, manoeuvre the VUT at a maximum speed of 50 km/h and avoid riding the brake pedal, harsh acceleration, braking, or turning unless strictly necessary to maintain a safe testing environment.

7.3.6 For FCW systems tests, when the FCW is issued before 1.7s TTC, the subsequent test speed for the next test is incremented with 10km/h.

7.3.7 When the FCW is issued after 1.7s TTC, first perform a test at a test speed 5km/h less than the test speed where this occurred. After this test continue to perform the remainder of the tests with speed increments of 5km/h.

7.3.8 Stop testing when the FCW is not issued before 1.5s TTC.

7.4 Test Execution

7.4.1 AEB tests

7.4.1.1 Accelerate the VUT and AMT (if applicable) to the respective test speeds.

7.4.1.2 The test shall start at T_0 (4 s TTC) and is valid when all boundary conditions are met between T_0 and T_{AEB}/T_{FCW}:

- Speed of VUT (GPS-speed)	Test speed + 1.0 km/h	
- Speed of AMT (GPS-speed)	Test speed ± 1.0 km/h	
- Lateral deviation from test path	0	± 0.1 m
- Yaw velocity	0	± 1.0 °/s
- Steering wheel velocity	0	± 15.0 °/s

7.4.1.3 The end of a test, where the AEB function is assessed, is considered when one of the following occurs:

i. $V_{VUT} = 0$ km/h;
ii. $V_{VUT} < V_{AMT}$; or
iii. contact between VUT and AMT.

7.4.1.4 For AEB system tests, when there is complete avoidance, the subsequent test speed for the next test is increased by 10 km/h. When there is contact, first perform a test at a speed 5 km/h less than the test speed where contact occurred. After this test, continue to perform the remainder of the tests with speed increments of 5 km/h by repeating paragraphs 7.3.1 to 7.4.1.3 Stop testing when the speed reduction seen in the test is less than 5 km/h.

For manual or automatic accelerator control, it needs to be assured that during automatic braking, the accelerator pedal does not result in an override of the system.

7.4.1.5 For tests where the FCW function is assessed, the end of a test is considered when one of the following occurs:

- V_{VUT} = 0km/h (crossing) or $V_{VUT} = V_{target}$ (longitudinal)
- $T_{FCW} <$ 1.5s TTC, after which an evasive action can be started

7.4.1.5 Braking will be applied, which results in a maximum brake level of -4 m/s2 to 0.25 m/s2, when applied in a non-threat situation. The particular brake profile to be applied (pedal application rate applied in 200 ms (maximum 400 mm/s) and pedal force) shall be specified by the manufacturer. When the brake profile provided by the manufacturer results in a higher brake level than allowed, the iteration steps as described in ANNEX B will be applied to scale the brake level from -4 m/s2 to 0.25 m/s2.

7.4.1.6 When no brake profile is provided, the default brake profile as described in ANNEX B will be applied.

7.4.2 LSS tests

7.4.2.1 Accelerate the VUT to 72 km/h depending on the test scenario.

7.4.2.2 Where applicable accelerate the target vehicle to 60 km/h depending on the test scenario.

7.4.2.3 The test shall start at T_0 and is valid when all boundary conditions are met between T_0 and T_{ELK}:

Table 7: Boundy conditions for LSS tests

	VUT	**AMT**
Speed	± 1.0 km/h	
Relative speed (CMovertaking)	± 1.0 km/h	
Lateral deviation	0 ± 0.05 m	0 ± [0.15] m
Steady state lane departure lateral velocity	± 0.05m/s	
Yaw velocity (upto T_{STEER} for VUT)	0 ± 1.0 °/s	
Yaw velocity (upto T_{STEER} for VUT)		0 ± 1.5 °
Steering wheel velocity (upto T_{STEER} for VUT)	0 ± 15.0 °/s	

7.4.2.4 Steer the vehicle as appropriate to achieve the lateral velocity in a smooth controlled manner and with minimal overshoot.

7.4.2.5 The end of an CMOncoming test is considered as when one of the following occurs.

- The system intervenes to prevent a collision between the VUT and target vehicle.
- The system has failed to intervene (sufficiently) to prevent a collision between the VUT and target vehicle. This can be assumed when one of the following occurs:
    - the lateral separation between the VUT and target vehicle equal < 0.3 m in the oncoming scenario; or
    - no intervention is observed at a TTC = 0.8s or a TTC submitted by the OEM.

It is at the labs discretion to select and use one of the options above to ensure a safe testing environment.

7.4.2.6 If the test ends because the vehicle has failed to intervene (sufficiently) or if the AMT has left it's designated path by more than 0.2 m, it is recommended that the VUT and/or AMT are steered away from the impact, either manually or by reactivating the steering control of the driving robot/AMT.

7.4.2.7 The subsequent lateral velocity for the next test is incremented with 0.1 m/s.

ANNEX A
AMT SPECIFICATIONS

The ASEAN NCAP Motorcyclist Target (AMT) described in this document mimics a real scooter with a rider. It reflects a scooter model with a maximum nominal speed of 120 kph in relation to the vulnerable road users (VRU) detection sensors used in vehicles. The requirements relate, unless specified otherwise, to the STA itself. The 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 sensor technologies: RADAR, video, laser, and near-IR-based systems, as defined by ACEA Articulated Pedestrian Target Specifications[1]. The AMT must be a full 3D-dimensional representation of a real motorcyclist and scooter.

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[1] ACEA: Articulated Pedestrian Target Specifications Version 1.0

Figure A-1: Scooter rider and scooter target

A.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). Typical dimensions are indicated in Table A-1 and Table A-2. The middle point between the wheel centres will be used as a reference 0-point in the X-direction and the floor level as a reference 0-point in the Z-direction.

Figure A-2: Scooter target dimensions and dummy posture

Table A-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 A-3: Scooter target dimensions and dummy posture

Table A-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.

A.2 Visual and Infrared Properties

Like the adult pedestrian target specified by ACEA2, the motorcycle rider shall be clothed with long-sleeved t-shirt and trousers in different colours: a t-shirt in black, jeans in blue, and shoes in black. The clothing has to be made from tear-proof and water-resistant material. Skin surface parts have to be finished with a non-reflective flesh-coloured texture. Colours based on the measurement method described in Appendix A-1 must be in the range described in Table A-3 (sRGB 0-255, observer = 2°, illumination = D65).

The IR reflectivity from the 850 to 950 nm wavelength of clothes and motorcycle parts must be within the range defined in Table A-4 based on the 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 does not differ by more than 20% from the reflectivity measured with the 90° probe.

Figure A-4: Infrared and visual properties of scooter target

Table A-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 A-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

A.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 Appendix A-2.

A.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.

A.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 A-5. The boundaries are defined using cubic spline interpolation of the data breakpoints provided in Table A-5.

Table A-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

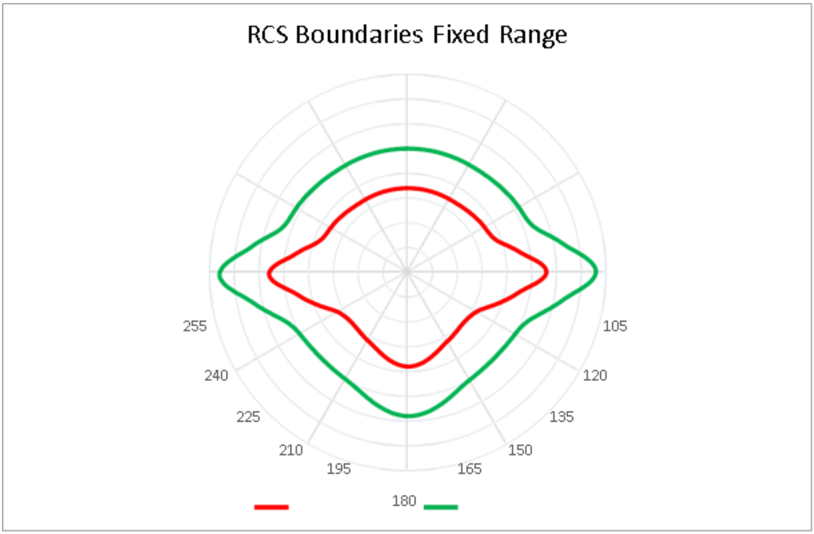

Figure A-5: Scooter Rider and Scooter Target RCS-Boundaries (77GHz Sensor Continental ARS400)

A.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 A-6 to Figure A-12. The boundaries are defined using formulas (1) and (2) and the parameters from Table A-6.

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

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

Table A-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

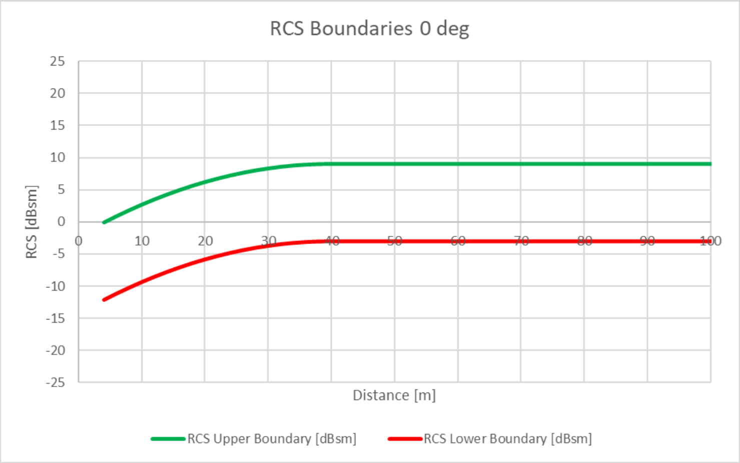

Figure A-6: Scooter Rider and Scooter Target RCS-Boundaries (77GHz Sensor Bosch MRR-SGU) 0 deg

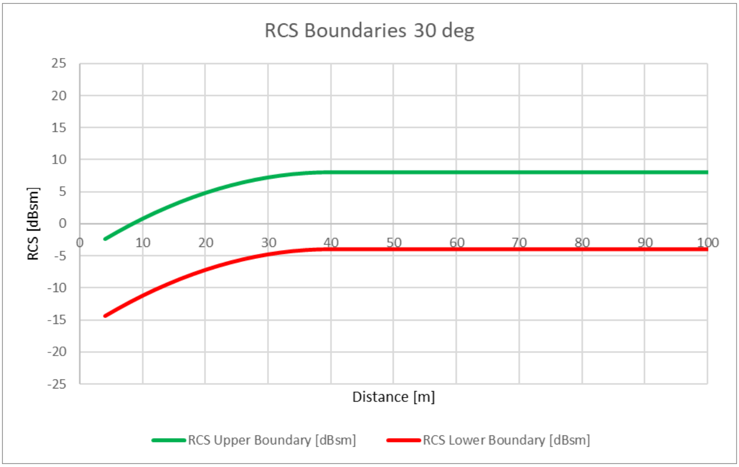

Figure A-7: Scooter Rider and Scooter Target RCS-Boundaries (77GHz Sensor Bosch MRR-SGU) 30 deg

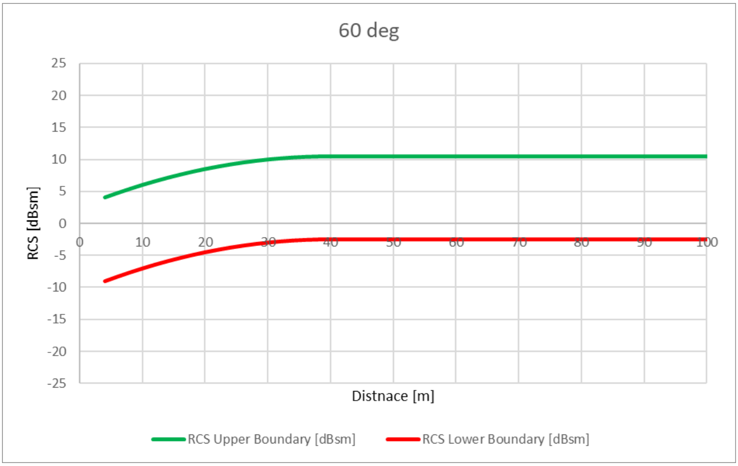

Figure A-8: Scooter Rider and Scooter Target RCS-Boundaries (77GHz Sensor Bosch MRR-SGU) 60 deg

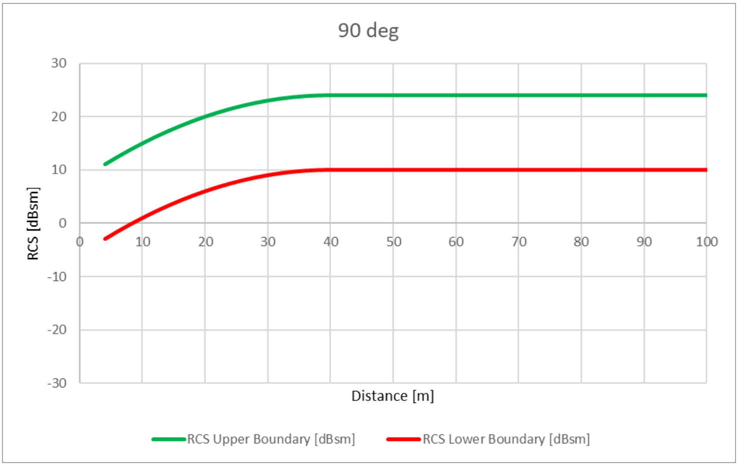

Figure A-9: Scooter Rider and Scooter Target RCS-Boundaries (77GHz Sensor Bosch MRR-SGU) 90 deg

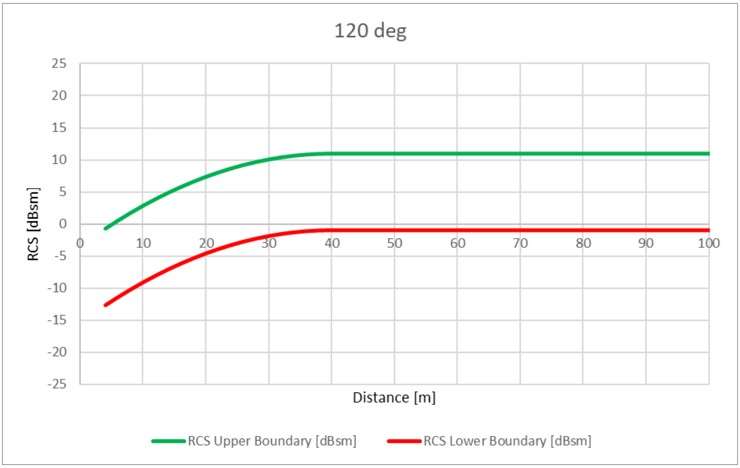

Figure A-10: Scooter Rider and Scooter Target RCS-Boundaries (77GHz Sensor Bosch MRR-SGU) 120 deg

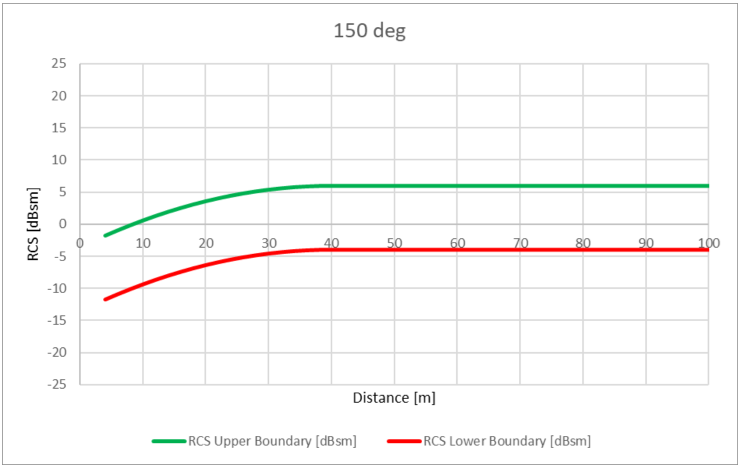

Figure A-11: Scooter Rider and Scooter Target RCS-Boundaries s (77GHz Sensor Bosch MRR-SGU) 150 deg

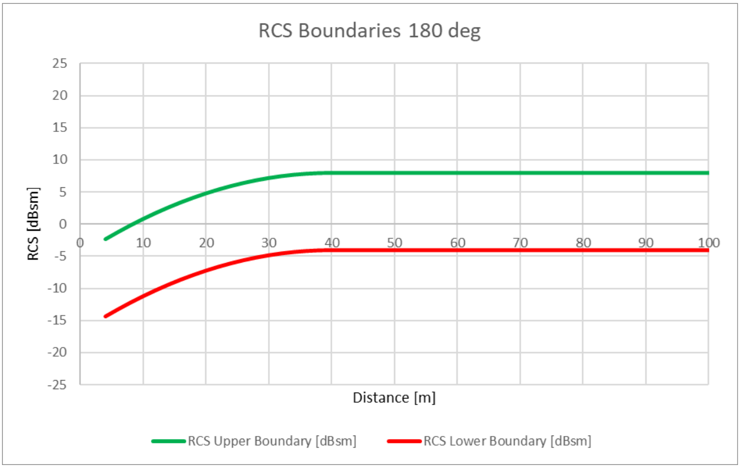

Figure A-12: Scooter Rider and Scooter Target RCS-Boundaries (77GHz Sensor Bosch MRR-SGU) 180 deg

A.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 A-31 to Figure A-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 km/h.

A.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.

A.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 A-1 and Table A-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 60 km/h (oncoming, crossing) / 60 km/h (longitudinal).
- Max AMT weight: 16 kg
- 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 A-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 A-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

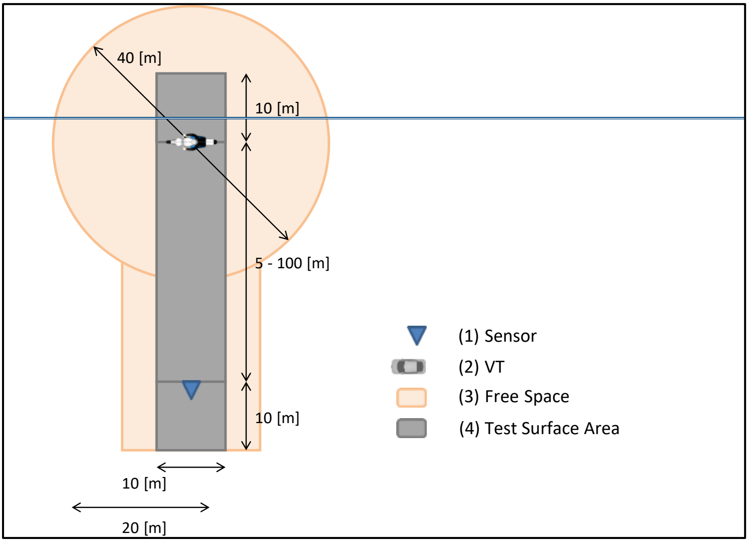

Figure A-14: Test environment

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 10 km/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.

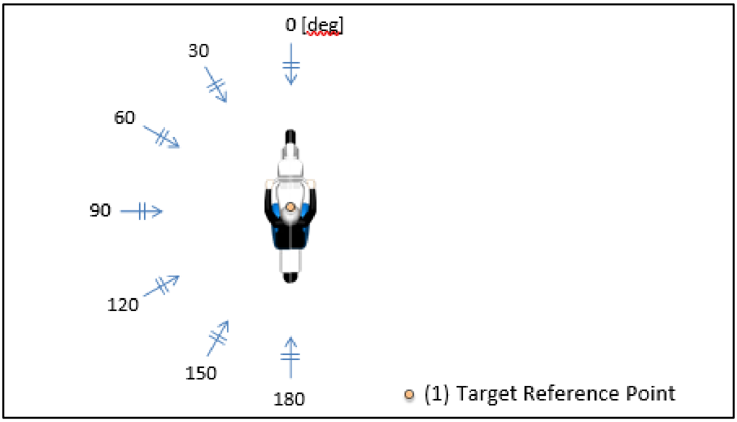

Figure A-15: Fixed angle scan

A-3 RCS Measurement Examples

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

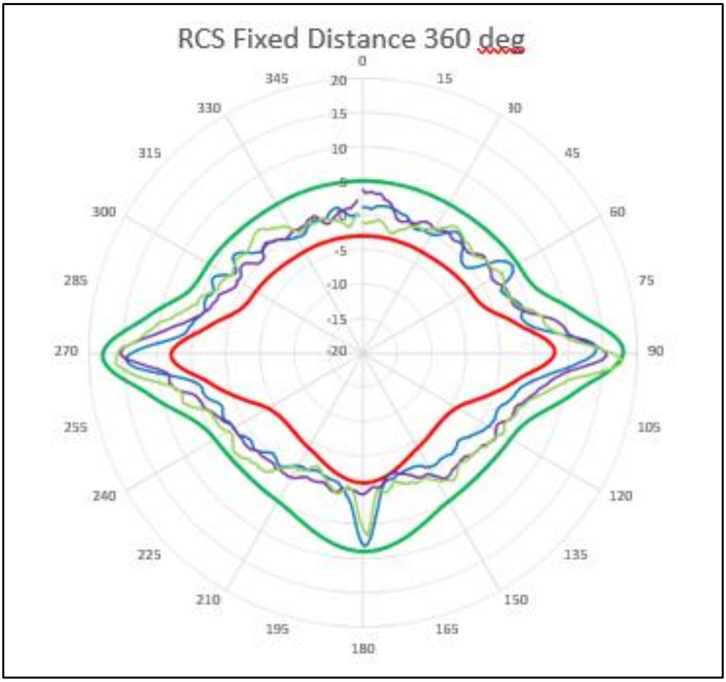

Figure A-16: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS400) 360 deg FD

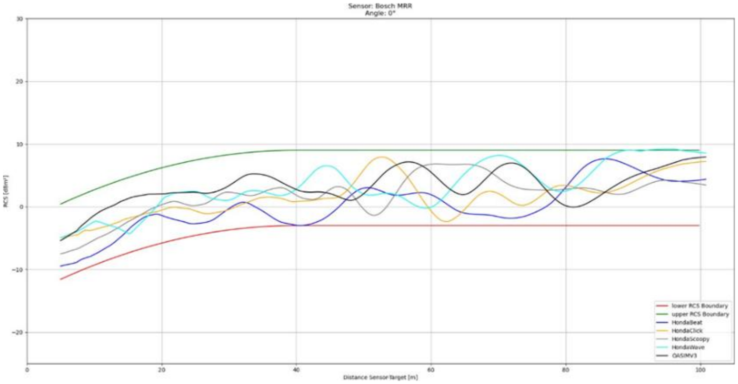

Figure A-17: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Bosch MRR-SGU) 0 deg FA

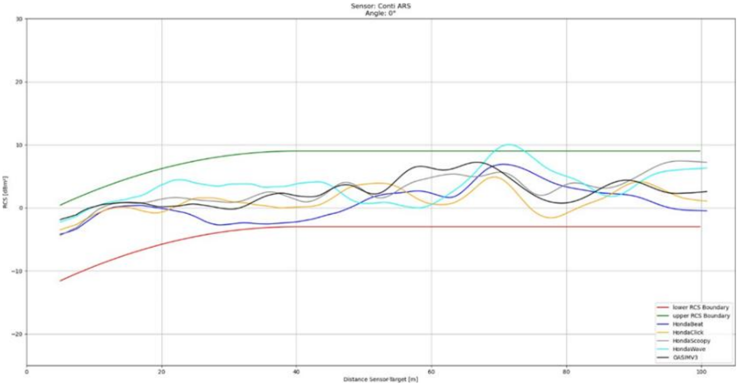

Figure A-18: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS410) 0 deg FA

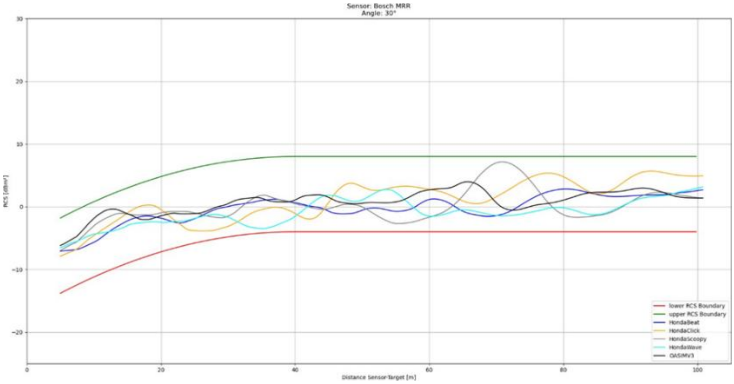

Figure A-19: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Bosch MRR-SGU) 30 deg FA

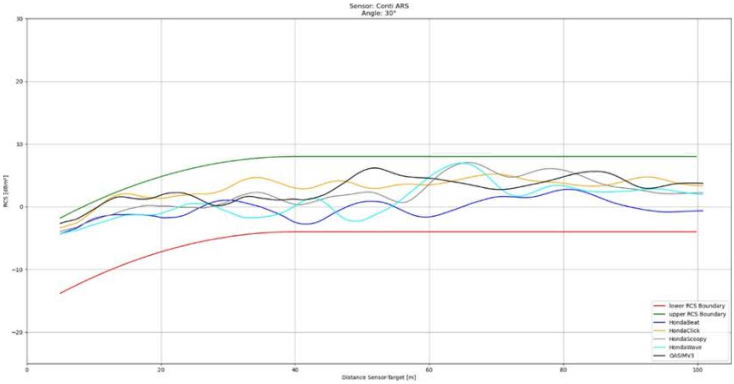

Figure A-20: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS410) 30 deg FA

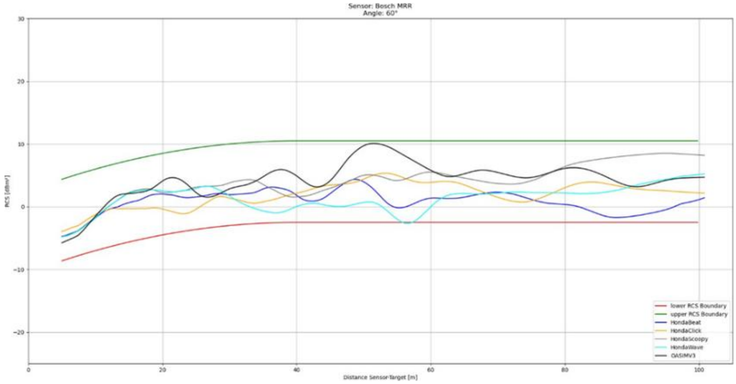

Figure A-21: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Bosch MRR-SGU) 60 deg FA

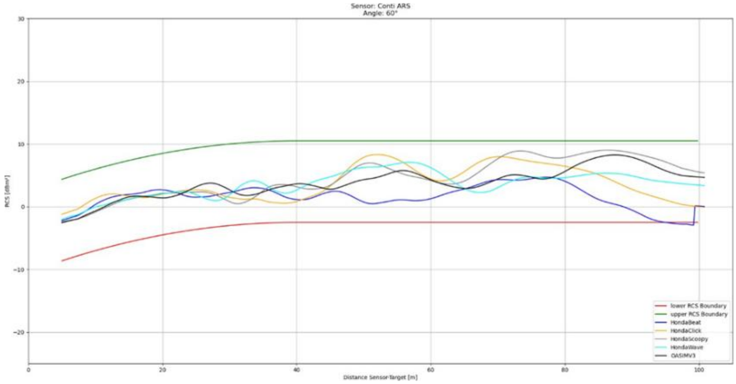

Figure A-22: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS410) 60 deg FA

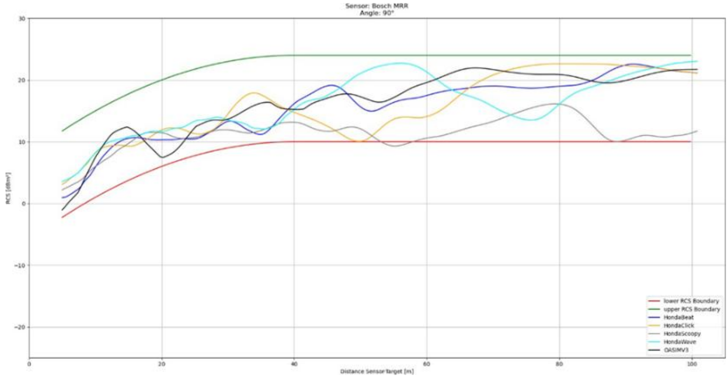

Figure A-23: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Bosch MRR-SGU) 90 deg FA

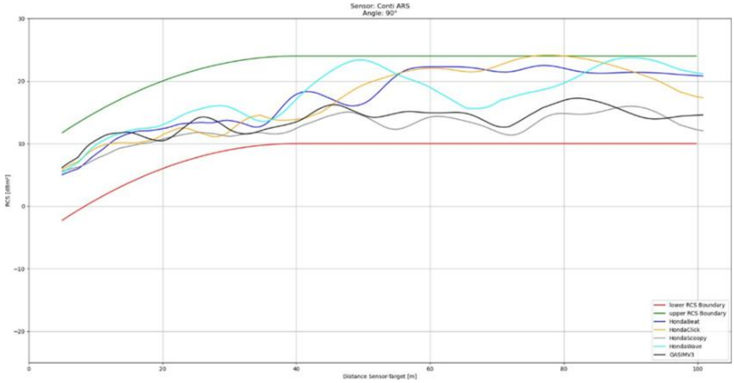

Figure A-24: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS410) 90 deg FA

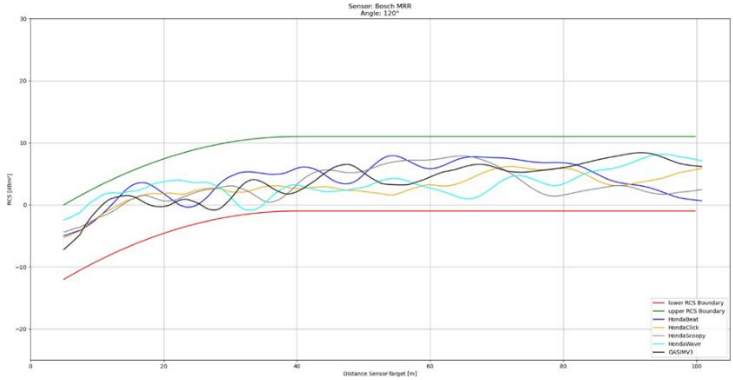

Figure A-25: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Bosch MRR-SGU) 120 deg FA

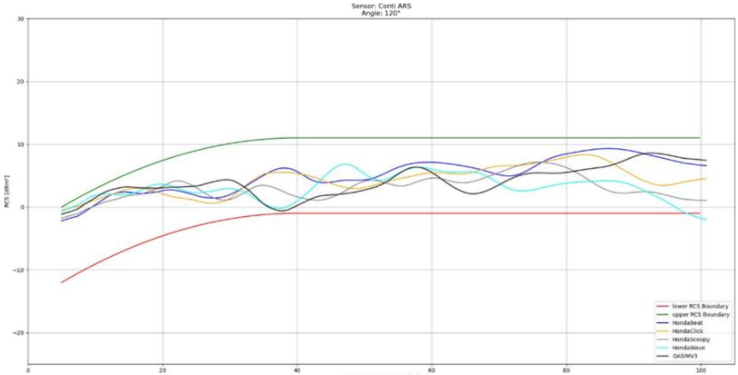

Figure A-26: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS410) 120 deg FA

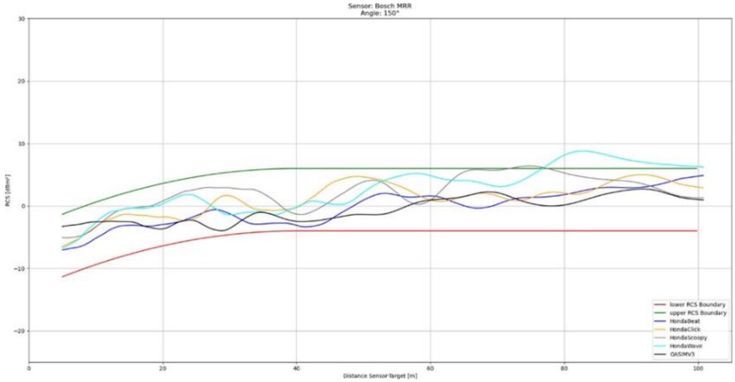

Figure A-27: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Bosch MRR-SGU) 150 deg FA

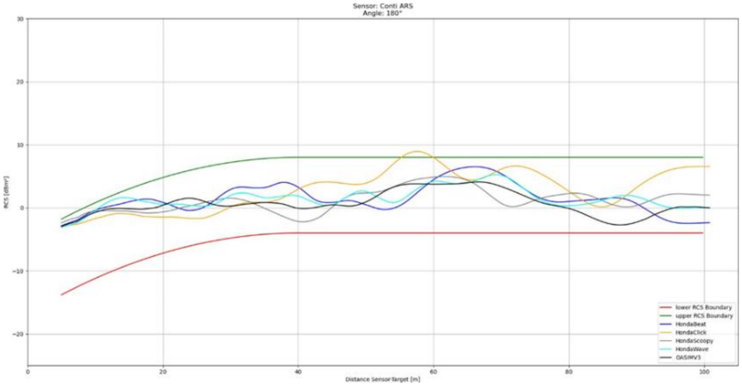

Figure A-28: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS410) 150 deg FA

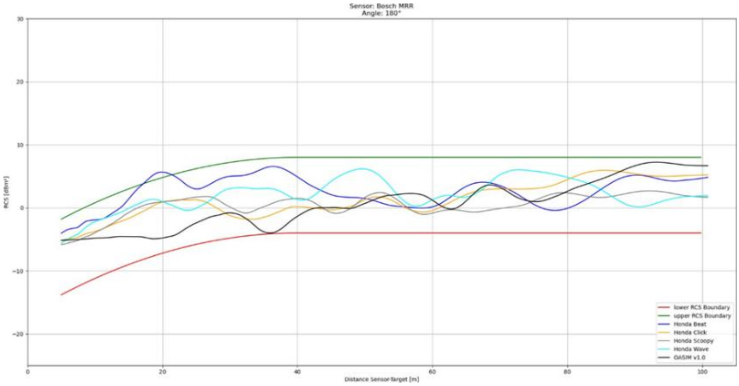

Figure A-29: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Bosch MRR-SGU) 180 deg FA

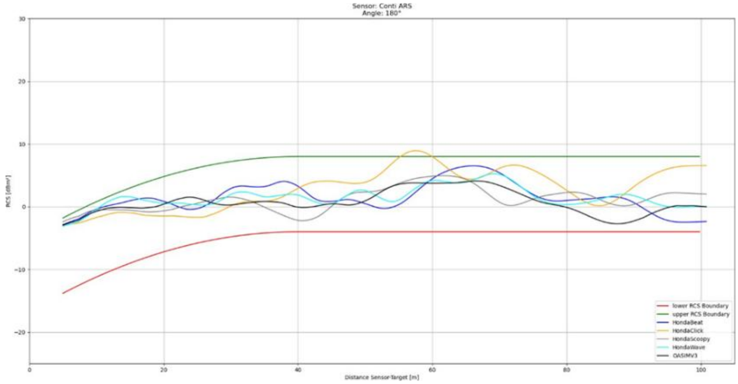

Figure A-30: Scooter Rider and Scooter RCS-Comparison (77GHz Sensor Continental ARS410) 180 deg FA

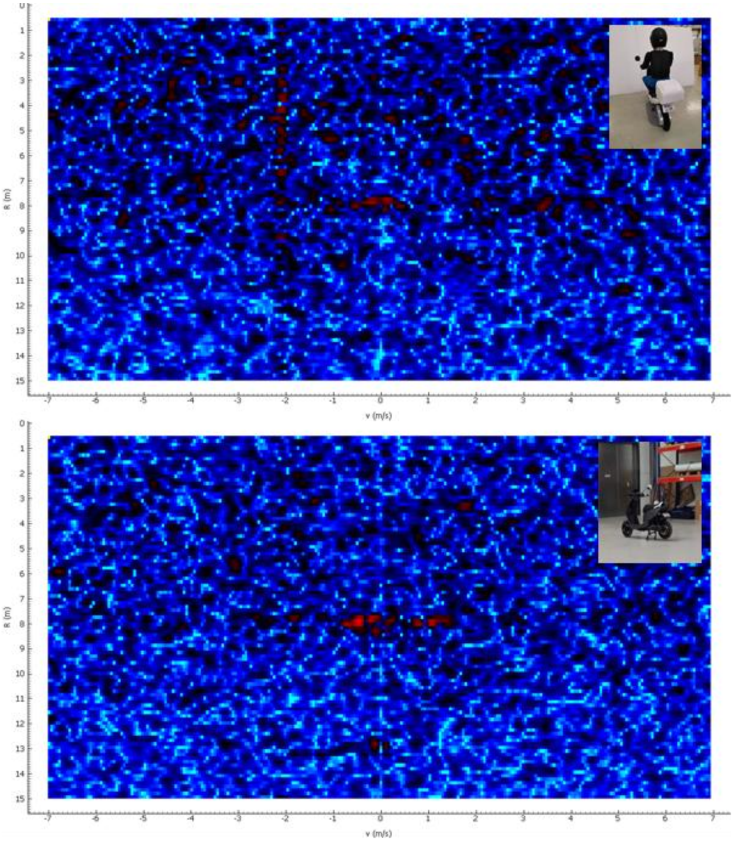

Figure A-31: Micrdoppler response comparison 180 deg

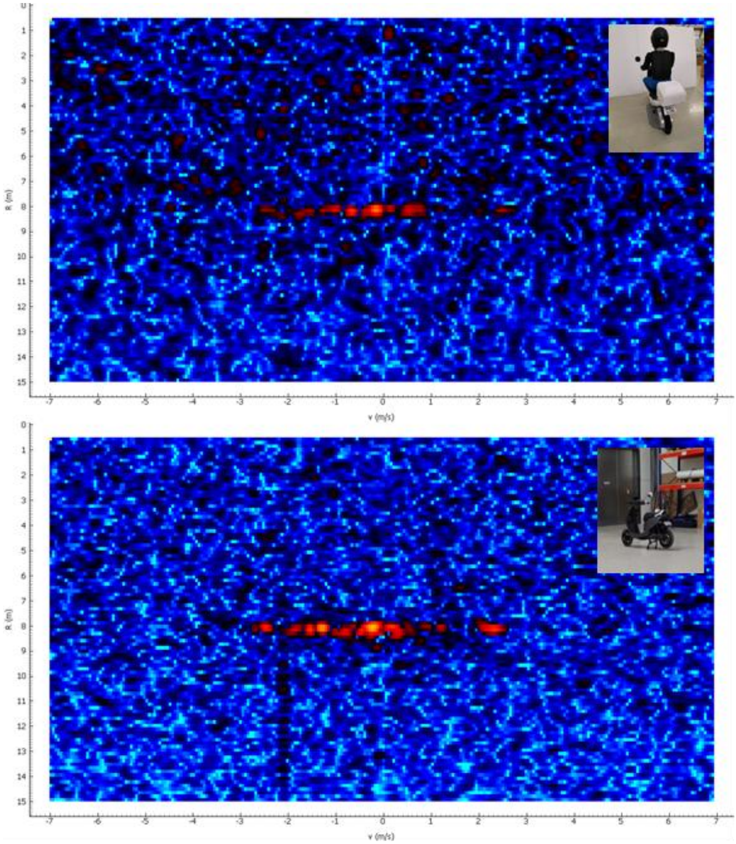

Figure A-32: Micrdoppler response comparison 135 deg

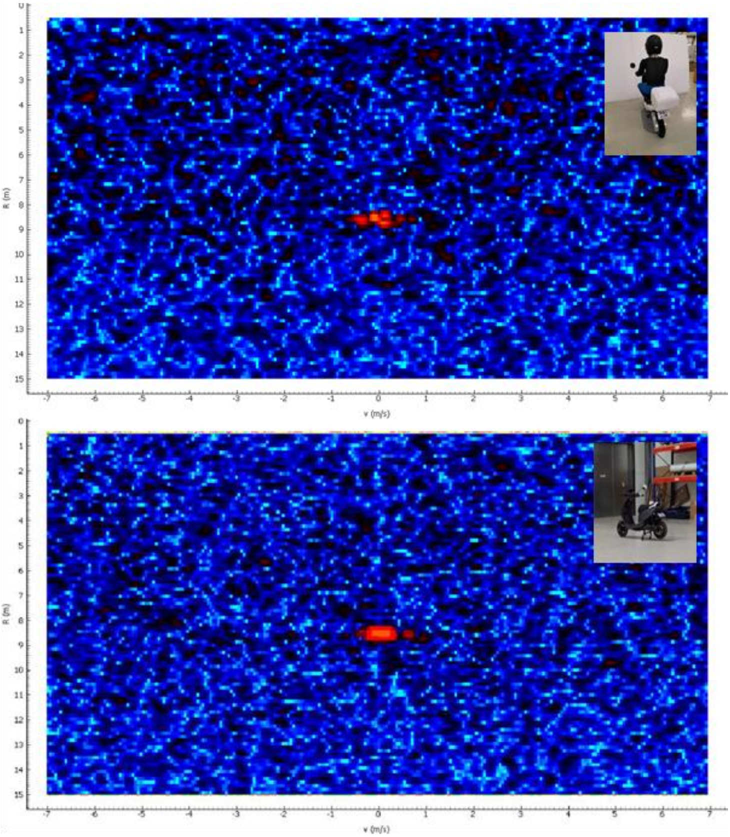

Figure A-33: Micrdoppler response comparison 90 deg

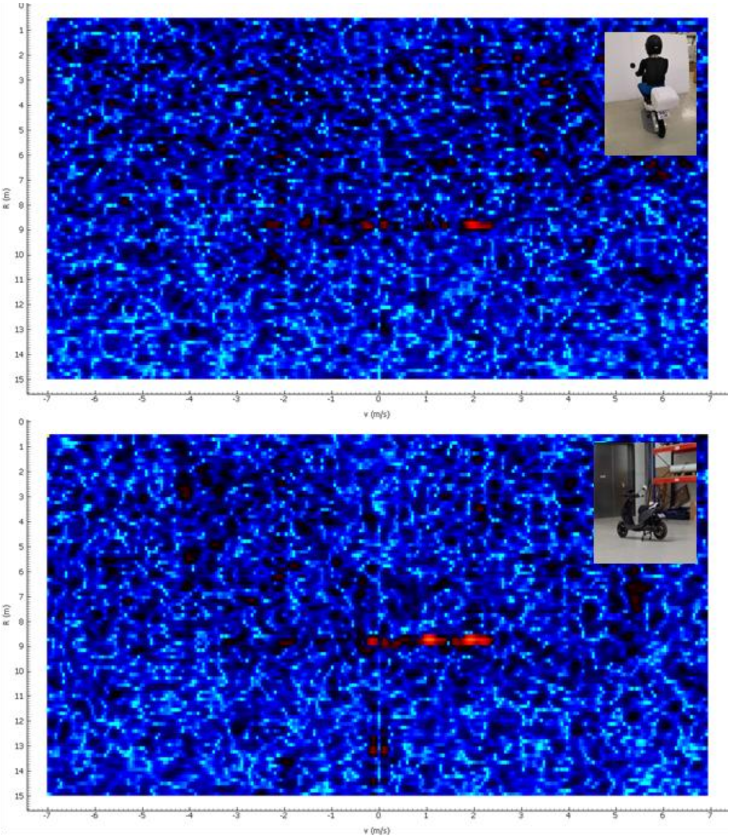

Figure A-34: Micrdoppler response comparison 45 deg

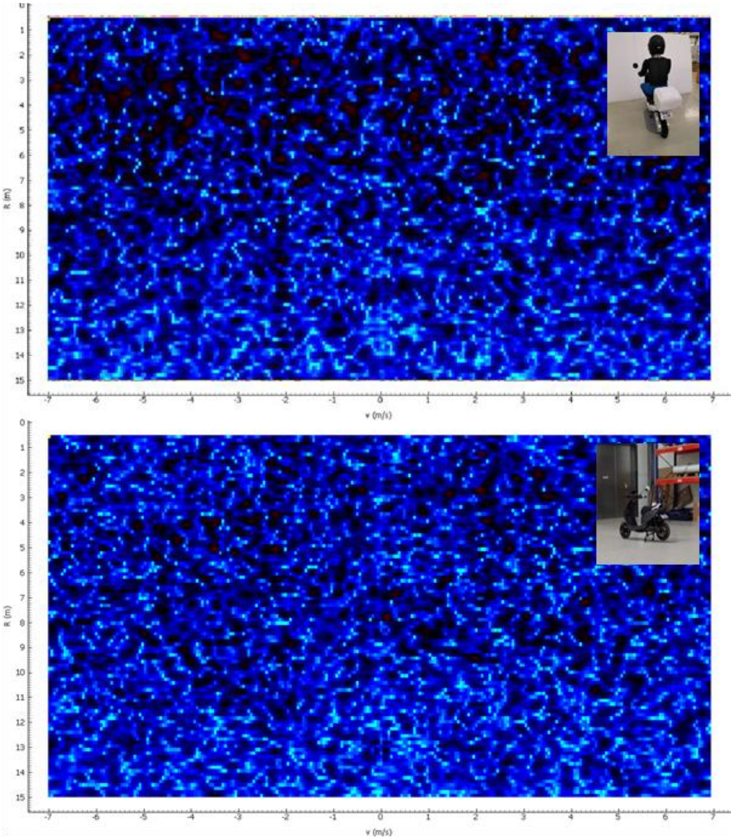

Figure A-35: Micrdoppler response comparison 0 deg

ANNEX B
BRAKE APPLICATION PROCEDURE

The braking input characterisation test determines the brake pedal displacement and force necessary to achieve a vehicle deceleration typical of that produced by a typical real-world driver in emergency situations.

B.1 Definitions

T_{BRAKE} - The point in time where the brake pedal displacement exceeds 5 mm.

T_{-6m/s^2} - The point in time is defined as the first data point where filtered, zeroed and corrected longitudinal acceleration data is less than -6 m/s^2.

T_{-2m/s^2}, T_{-4m/s^2} - similar to T_{-6m/s^2}.

B.2 Measurements

Measurements and filters to be applied as described in Section 4 of this protocol.

B.3 Brake Characterization Procedure

First perform the brake and tyre conditioning tests as described in paragraphs 7.1.2 and 7.1.3. The brake input characterisation tests shall be undertaken within 10 minutes after conditioning the brakes and tyres.

B.3.1 <u>Brake Displacement Characterisation Tests</u>

- Push the brake pedal through the full extent of travel and release.

- Accelerate the VUT to a speed in excess of 85 km/h. Vehicles with an automatic transmission will be driven in D. For vehicles with a manual transmission select the highest gear where the RPM will be at least 1500 at the 85 km/h.

- Release the accelerator and allow the vehicle to coast. At a speed of 80 ± 1.0 km/h initiate a ramp braking input with a pedal application rate of 20±5 mm/s and apply the brake until a longitudinal acceleration of -7 m/s2 is achieved. For manual transmission vehicles, press the clutch as soon as the RPM drops below 1500. The test ends when a longitudinal acceleration of -7 m/s2 is achieved.

- Measure the pedal displacement and applied force normal to the direction of travel of the initial stroke of the brake pedal, or as close as possible to normal as can be repeatedly achieved.

- Perform three consecutive test runs. A minimum time of 90 seconds and a maximum time of 10 minutes shall be allowed between consecutive tests. If the maximum time of 10 minutes is exceeded, the tyre and brake conditioning procedures shall be repeated before restarting the brake pedal force characterisation tests.

- Using second order curve fit and the least squares method between T_{-2m/s^2}, T_{-6m/s^2}, calculate the pedal travel value corresponding to a longitudinal acceleration of -4 m/s^2 (=D4, unit is m). Use data of at least three valid test runs for the curve fitting.

□ This brake pedal displacement is referred to as D4 in the next chapters.

□ Using second order curve fit and the least squares method between T_{-2m/s^2}, T_{-6m/s^2}, calculate the pedal force value corresponding to a longitudinal acceleration of -4 m/s^2 (=F4, unit is N). Use data of at least three valid test runs for the curve fitting.

□ This brake pedal force is referred to as F4 in the next chapters.

B.3.3 Brake Force Confirmation and Iteration Procedure

□ Accelerate the VUT to a speed of 80+1 km/h. Vehicles with an automatic transmission will be driven in D. For vehicles with a manual transmission select the highest gear where the RPM will be at least 1500 at the 80 km/h.

□ Apply the brake force profile as specified in B.4, triggering the input manually rather than in response to the FCW. Determine the mean acceleration achieved during the window from T_{BRAKE} +1s T_{BRAKE} +3s. If a mean acceleration outside the range of -4-0.25 m/s^2 results, apply the following method to ratio the pedal force applied.

F4new = F4original * (-4/mean acceleration), i.e. if F4original results in a mean acceleration of -5 m/s^2, F4new = F4original * -4 / -5

- Repeat the brake force profile with this newly calculated F4, determine the mean acceleration achieved and repeat the method as necessary until a mean acceleration within the range of -4-0.25 m/s^2 is achieved.

- Three valid pedal force characteristic tests (with the acceleration level being in the range as specified) are required. A minimum time of 90 seconds and a maximum time of 10 minutes shall be allowed between consecutive tests. If the maximum time of 10 minutes is exceeded, the tyre and brake conditioning procedures shall be repeated before restarting the brake pedal force characterisation tests. This brake pedal force is referred as F4 in the next chapters.

B.4 Brake Application Profile

- Detect T_{FCW} during the experiment in real-time.

- Release the accelerator at T_{FCW} + 1 s.

- Perform displacement control for the brake pedal, starting at T_{FCW} + 1.2 s with a gradient of the lesser of 5 x D4 or 400 mm/s (meaning the gradient to reach pedal position D4 within 200 ms, but capped to a maximum application rate of 400 mm/s).

- Monitor brake force during displacement control and use second-order filtering with a cutoff frequency between 20 and 100 Hz (online) as appropriate.

- Switch to force control with a desired value of F4 when:
  i. the value D4 as defined in B.3 is exceeded for the first time,
  ii. the force F4 as defined in B.3 is exceeded for the first time, whichever is reached first.

- The point in time where position control is switched to force control is noted as T_{switch}.

- Maintain the force within boundaries of F4 ± 25% F4. A stable force level should be achieved within a period of 200ms maximum after the start of force control. Additional disturbances of the force over ± 25% F4 due to further AEB interventions are allowed, as long as they have a duration of less than 200ms.

- The average value of the force between T_{FCW} + 1.4s and the end of the test should be in the range of F4 ± 10 N.

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