
**Road vehicles — Test devices for
target vehicles, vulnerable road users
and other objects, for assessment of
active safety functions —**

**Part 3:
Requirements for passenger vehicle
3D targets**

*Véhicules routiers — Dispositifs d'essai pour véhicules cibles, usagers
de la route vulnérables et autres objets, pour l'évaluation de fonctions
de sécurité active —*

Partie 3: Exigences pour cibles de véhicules particuliers 3D



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Contents

	Page
Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Abbreviated terms	3
5 Vehicle target specifications	4
5.1 Vehicle classes and target applicability.....	4
5.2 Reference dimensional measurements.....	4
5.3 Safety considerations.....	4
5.4 Repairability and robustness.....	4
5.5 Environmental conditions.....	5
5.6 Reference coordinate system.....	5
5.7 Speed classes.....	5
6 Vehicle target response to sensing technologies	6
6.1 General.....	6
6.2 Optical requirements.....	6
6.2.1 General.....	6
6.2.2 Reference measurements.....	6
6.2.3 Stability of dimensions for optical recognition.....	6
6.2.4 Viewing angles.....	6
6.2.5 Features related to optical requirements.....	7
6.3 Radar requirements.....	7
6.3.1 Reference measurements of radar properties.....	7
6.3.2 Reference measurements.....	7
6.3.3 Radar cross section, static measurements and requirements.....	8
6.3.4 Radar recognition features of vehicle target.....	8
6.3.5 Stability of dimensions for radar recognition.....	8
6.4 Thermal requirements for Far Infrared vision systems.....	8
6.4.1 General.....	8
6.4.2 Reference measurements.....	8
6.4.3 Thermal characteristics.....	8
6.5 Calibration.....	8
6.6 Field verification.....	9
7 Motion and positioning during test for VT including target carrier system	9
7.1 General requirements.....	9
7.2 Longitudinal positioning.....	9
7.2.1 Speed range for operation.....	9
7.2.2 Accelerations.....	9
7.3 Lateral positioning.....	9
7.3.1 General.....	9
7.3.2 Yaw rate.....	9
7.3.3 Lateral position.....	10
7.3.4 Lateral acceleration.....	10
7.3.5 Turning diameter.....	10
7.4 Vertical positioning.....	10
7.4.1 General.....	10
7.4.2 Pitch angle.....	10
7.4.3 Vertical motions.....	10
Annex A (informative) Vehicle classes and dimensions	11

Annex B (normative) Visual and near infrared sensor-specific recognition properties and measurements	16
Annex C (normative) Radar-specific recognition properties and measurements	21
Annex D (informative) Measurement of position, speed and acceleration of the vehicle target	49
Annex E (informative) Field verification of vehicle target properties	50
Bibliography	51

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 33, *Vehicle dynamics and chassis components*.

A list of all parts in the ISO 19206 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

ADAS (advanced driver assistance systems) and active safety systems are designed to support decision-making for the driver, extend the driver's awareness of the traffic situation with advanced warnings, improve the behaviour of the vehicle, and even take over vehicle control in an emergency situation. The goal is to completely avoid an accident or at least reduce the severity of an accident.

The surrogate target is an essential component in the evaluation of ADAS/active safety functions and different levels of automated driving systems, in all situations where a collision with the target may occur.

The characteristics of targets must be trustworthy and a vehicle target must be recognized as a real vehicle by the various sensing technologies.

This document addresses the specification of vehicle 3D test targets.

It is important that a surrogate vehicle target represents a real vehicle in terms of detectability and movement from all directions. It should also provide safety for the subject vehicle and test operators if contact is made between the subject vehicle and the target. Crashworthiness and durability requirements for the vehicle target require that the material and construction of the vehicle target are adapted to fit the purposes.

Test cases usually address both stationary and moving targets and, as such, the physical construction of the target accommodates a target carrier system capable of mimicking realistic motions. This document includes requirements on the target carrier system as applicable.

Targets described in the ISO 19206 series can be used for system development or applied in conjunction with existing standards, or standards under development, for assessment of ADAS and active safety functions of vehicles.

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Road vehicles — Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions —

Part 3: Requirements for passenger vehicle 3D targets

1 Scope

This document specifies performance requirements for surrogate targets used to assess the system detection and performance of active safety systems.

This document specifies the properties of an omni-directional multi-purpose vehicle target for assessment of interaction in a variety of traffic scenarios.

This document specifies the properties of a vehicle target that will allow it to represent a passenger vehicle in terms of size, shape, reflection properties, etc. for testing purposes. This document addresses the detection requirements for a vehicle target in terms of sensing technologies commonly in use at the time of publication of this document, and where possible, anticipates future sensing technologies. It also addresses methodologies to verify the target response properties to these sensors, as well as performance requirements for the target carrier.

The vehicle targets specified in this document reflect passenger cars and, in particular, the smaller and more common B and C segment cars.

This document does not address the test procedures in terms of speeds, positions, or timing of events. Performance criteria for the active safety system are also not addressed.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 8855, *Road vehicles — Vehicle dynamics and road-holding ability — Vocabulary*

ISO 8608, *Mechanical vibration — Road surface profiles — Reporting of measured data*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8855 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

subject vehicle

SV

vehicle with active safety system to be tested

3.2 vehicle target

VT

test device representing a vehicle, whose purpose is to activate sensor systems

Note 1 to entry: Vehicle target consists of a *target structure* (3.2.1) and optionally a *target carrier* (3.2.2).

Note 2 to entry: This document addresses test devices representing a vehicle having the necessary features to be recognised from any direction (3D vehicle target).

3.2.1 target structure

physical structure whose purpose is to maintain the shape and provide the relevant sensor signature representing a vehicle

3.2.2 target carrier

mechanical or electro-mechanical system used to move and/or support the *target structure* (3.2.1) according to a test protocol

Note 1 to entry: Target carrier may be self-contained within, or supporting the target structure or external devices connected with cables, beams, or similar structures. It can also be a self-propelled carrier.

Note 2 to entry: Target structure and target carrier may be integrated.

Note 3 to entry: Target structure fixation is included in the target carrier.

3.3 target axis system

axis system fixed in the reference frame of the target, so that the X_t axis is substantially horizontal and forward (with the target at rest), and is parallel to the target's longitudinal plane of symmetry, and the Y_t axis is perpendicular to the target's longitudinal plane of symmetry and points to the left with the Z_t axis pointing upward

Note 1 to entry: See [Figure 2](#) for further explanation of the target axes X_t , Y_t , Z_t .

3.4 target coordinate system

coordinate system based on the *target axis system* (3.3) with the origin located at the *target reference point* (3.5)

Note 1 to entry: The position of the vehicle in the target coordinate system is described by coordinates x_t, y_t, z_t .

3.5 target reference point

point whose location relative to the external dimensions of the target, in its initial condition, remains constant

Note 1 to entry: to entry:

$x = 0, y = 0$ at the centroid of the area defined by a horizontal projection of the plan view of the target;

$z = 0$ at the ground plane.

3.6 measurement equipment

equipment used to record the position and motions of the *vehicle target* (3.2) relative to the *subject vehicle* (3.1)

Note 1 to entry: The measurement equipment is used to ensure that the test protocol is followed within prescribed tolerances and to record data documenting the function of the active safety system and allowing its performance to be assessed.

3.7**planned path**

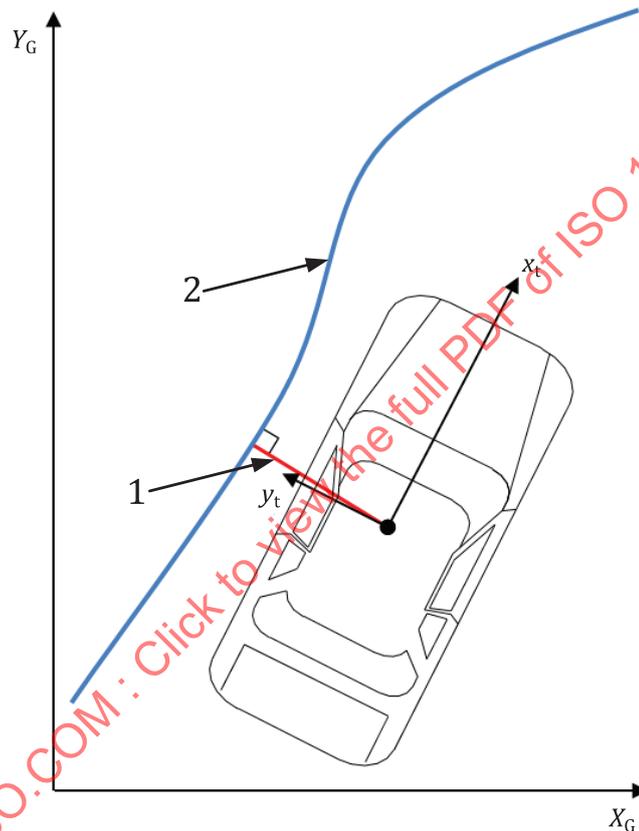
X, Y coordinates that define the desired trajectory of the target vehicle

3.8**lateral path deviation**

position error of the target vehicle relative to the *planned path* (3.7) measured perpendicular from the planned path direction

Note 1 to entry: See illustration in [Figure 1](#).

Note 2 to entry: Y_G and X_G are the ground (fixed) coordinate axes in which the planned path is defined.

**Key**

- 1 lateral path deviation
- 2 planned path

Figure 1 — Lateral path deviation

4 Abbreviated terms

CCD	charge-coupled device
CMOS	complementary metal oxide semiconductor
FIR	far infrared
LIDAR	light detection and ranging
NIR	near infrared

PMD	photonic mixer device
RCS	radar cross section
SV	subject vehicle
VT	vehicle target

5 Vehicle target specifications

5.1 Vehicle classes and target applicability

The vehicle targets specified in this document reflect passenger cars and in particular the smaller and more common B and C segment cars. See [Annex A](#) for more information.

The test devices described in this document are intended for testing of systems designed to mitigate or avoid collisions in which the subject vehicle approaches the target vehicle from any direction.

5.2 Reference dimensional measurements

Reference measurements for the vehicle target should come from a representative sample of vehicles from the B/C segment that were manufactured within five years prior to the publication date of this document.

General dimensions of the vehicle fleet are given in [Annex A](#).

5.3 Safety considerations

Drivers of the subject vehicle shall not be exposed to any substantial risk of personal injury. The vehicle target and its components should not cause more than cosmetic damage to the subject vehicle when struck at a relative velocity of 60 km/h. The conditions specified by the test procedure application shall be taken into consideration.

NOTE Test procedures for specific applications typically indicate what measures are taken to reduce the risk of injury and vehicle damage. These measures can include instructions to disable subject vehicle systems such as supplementary occupant restraints, seatbelt pre-tensioners, vulnerable user protection systems, etc.

5.4 Repairability and robustness

The vehicle target should be easily reassembled or repaired after contacts. Field repairs should be possible to perform with standard hand tools. The sensor-specific characteristics shall be met also after re-assembly and repair. The time for reassembly is affected by the handling efficiency of the users and should be as short as possible. As a guideline the reassembly should be possible with two persons and should take less than 15 minutes. The target requirements should be fulfilled after at least fifty crashes with a relative velocity of 60 km/h with a vehicle of category M1.

NOTE 1 This requirement does not apply to disposable and single impact targets.

NOTE 2 Category M1: vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat. (Source: UN consolidated resolution R.E.3 and Directive 2007/46/EC).

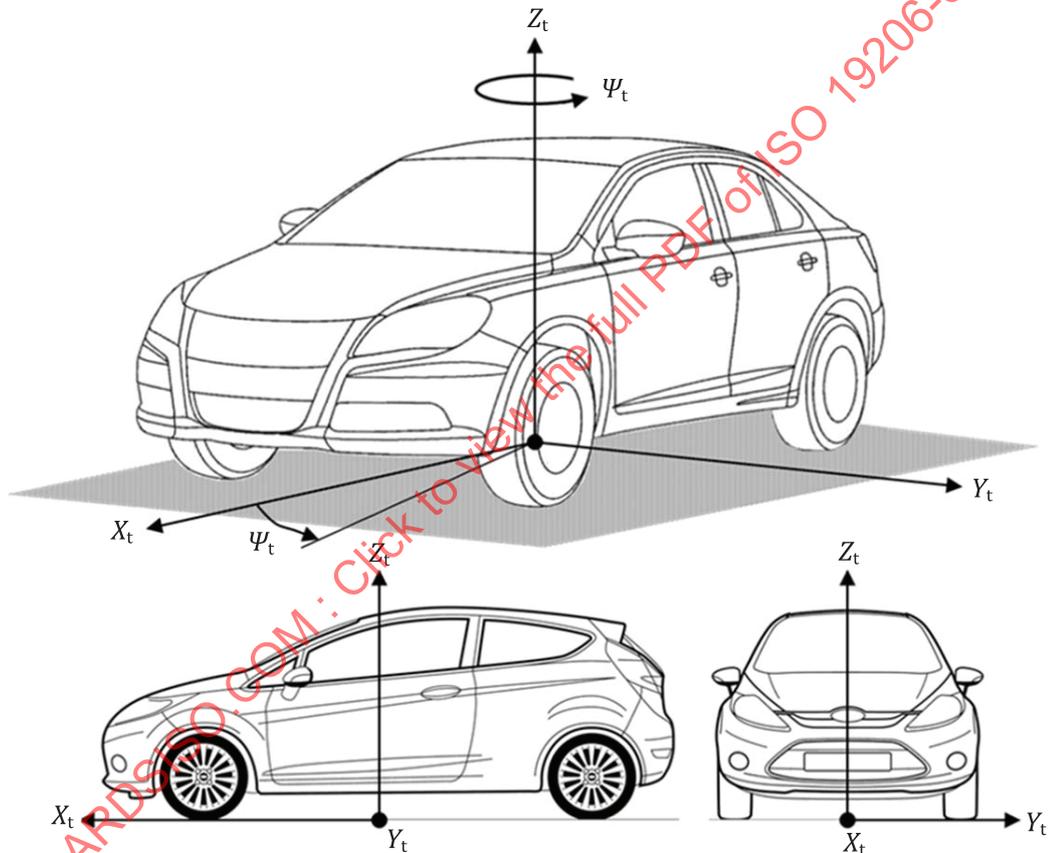
5.5 Environmental conditions

The vehicle target shall fulfil all requirements in an ambient temperature range of -5 °C to $+40\text{ °C}$. The vehicle target shall not deteriorate under storage temperatures in the range of -40 °C to $+80\text{ °C}$ when properly stored.

NOTE The specified temperature range recognises that there are substantial technical challenges achieving a cost-effective target fulfilling the requirements at lower temperatures than -5 °C .

5.6 Reference coordinate system

The reference coordinate system in this document essentially adopts the coordinate system given in ISO 8855, adapting it to the purpose of the target vehicle movement. The target coordinate system, which uses the target axis system located at the target reference point, is shown in [Figure 2](#).



NOTE ψ_t is the rotation about the Z_t axis.

Figure 2 — Reference coordinate system

5.7 Speed classes

The following speed classes are applicable according to this document, see [Table 1](#).

Table 1 — Speed classes

Speed class	Description
SC50	Operational speed up to 50 km/h (13,9 m/s)
SC80	Operational speed up to 80 km/h (22,2 m/s)
SC80+	Operational speed up to and greater than 80 km/h (22,2 m/s)

6 Vehicle target response to sensing technologies

6.1 General

Requirements related to sensing technologies commonly in use at the time of publication of this document are listed in [6.2](#), [6.3](#) and [6.4](#). A vehicle target intended for use with a specific set of sensing technologies only needs to meet the requirements of those technologies.

6.2 Optical requirements

6.2.1 General

Sensors operating on optical principles include CCD and CMOS camera sensors, stereo camera sensors, photonic mixer devices (PMD) and light detection and ranging (LIDAR). These systems cover visible and near infrared light frequency spectra. PMD and LIDAR are more reliant on infrared reflectivity of the target surface.

6.2.2 Reference measurements

When technology-specific measurements are required, information of the type of sensor used, environmental conditions during measurements, and date of measurement shall be provided with the description of the vehicle models. The version of the vehicle target and the target carrier shall be traceable to manufacturing drawings or supplier specifications.

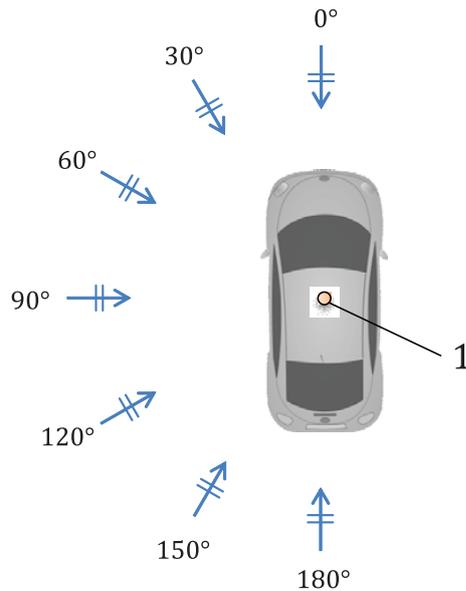
General dimensions of the vehicle fleet are given in [Annex A](#).

6.2.3 Stability of dimensions for optical recognition

Target surface shall not flutter or vibrate unrealistically due to aerodynamic effects for the applicable speed class and a side wind of up to 5 m/s. Local fluttering should not exceed 10 mm perpendicularly from the reference surface. Distortion of the vehicle shape should not exceed 25 mm in any direction.

6.2.4 Viewing angles

Main angles for recognition are shown in [Figure 3](#).

**Key**

1 target reference point

Figure 3 — Viewing angles**6.2.5 Features related to optical requirements**

The visual difference between the VT and a passenger vehicle of the B/C segment size should be as small as possible. The contours of the VT should be representative of a real middle-sized passenger car. It should demonstrate a high level of symmetry about the x-z plane.

The wheels, consisting of tire and rim, shall be round and of realistic dimensions.

The windows (windscreen, side windows, rear window) should give the impression of being transparent. The interior of a real car (seat, steering wheel, rear view mirror, driver) may be indicated.

Features representing the rear lights, reflectors, and registration plate are required.

NOTE General requirements for the size and position of these features are available in 407/2011/EC^[10], UN-ECE Regulation 3^[11], UN-ECE Regulation 48^[12] and FMVSS 108^[9].

Lighter colours of vehicle targets shall be used. High contrast to background should be considered.

Features necessary for the optical recognition as specified in [Annex B](#) shall be followed.

6.3 Radar requirements**6.3.1 Reference measurements of radar properties**

At the time of publication of this document, automotive applications of radar are using 24 GHz and (76 – 81) GHz.

6.3.2 Reference measurements

Reference measurements for the vehicle target should come from a representative sample of vehicles from the B/C segment that were manufactured within five years prior to the publication date of this document.

When technology-specific measurements are required, information of the type of sensor used, environmental conditions during measurements, and date of measurement shall be provided with the description of the vehicle models. The version of the vehicle target and the target carrier shall be traceable to manufacturing drawings or supplier specifications.

6.3.3 Radar cross section, static measurements and requirements

Measurement of radar cross section as described in [Annex C](#) shall be followed.

6.3.4 Radar recognition features of vehicle target

Features necessary for radar recognition as specified in [Annex C](#) shall be followed.

6.3.5 Stability of dimensions for radar recognition

Local fluttering due to aerodynamic effects should not cause radar signature to vary, including micro-Doppler effects, for the applicable speed class and a side wind of up to 5 m/s.

6.4 Thermal requirements for Far Infrared vision systems

6.4.1 General

The vehicle target is defined as possessing the optical characteristics according to [6.2](#) with features added to provide response to thermal sensing. Inclusion of passive thermal sensor requirements is optional.

Far infrared (FIR) vision systems can provide information to active safety systems in conditions of low light or otherwise limited visibility. A thermal camera detects far-infrared electromagnetic radiation with a wavelength in the range of 8 μm to 14 μm . Imaging is provided by means of an appropriate camera.

6.4.2 Reference measurements

When technology-specific measurements are required, information of the type of sensor used, environmental conditions during measurements, and date of measurement shall be provided with the description of the measured subjects and/or target. The version of the target and the target carrier shall be traceable to manufacturing drawings or supplier specifications.

6.4.3 Thermal characteristics

Vehicle targets commonly in use at the time of publication of this document do not feature vehicle-specific FIR characteristics. Developers of vehicle targets that incorporate such characteristics should ensure that the characteristics are comparable to typical vehicles represented by the target.

Characterization of these properties should follow the steps below:

- 1) measurement of typical vehicles,
- 2) establishment of boundaries,
- 3) verification that the vehicle target FIR measurements are within the specified boundaries.

6.5 Calibration

The vehicle target manufacturer shall provide a certificate detailing which test information has been used to verify the product performance and which sensor technologies it conforms to. Target should comply to this document with a certificate.

Calibration shall be based on representative characteristics of the applied detection technology as described in [6.2](#), [6.3](#) and [6.4](#), and the related annexes.

6.6 Field verification

For field verification of vehicle target functionality, see [Annex E](#).

7 Motion and positioning during test for VT including target carrier system

7.1 General requirements

The target carrier system shall be capable of positioning the target within tolerances required by the test procedure application. Repeatable test performance requires that subject and vehicle target relative speed and position be consistent between test repetitions. Unless more stringent requirements are needed by a specific test procedure, the positioning requirements outlined in this section are the minimum requirements for the vehicle target. Recommendations for measurement equipment are given in [Annex D](#).

The following requirements should be fulfilled by the target carrier system.

- All visible parts of the target carrier system should be coloured to minimize the contrast with background, e.g. grey, to approximate the test area road surface. In case of a uniform background the colour shade of the background can be used.
- The target carrier system and resulting motion of the vehicle target shall minimally affect target characteristics (radar, optical signature, etc).
- The target carrier shall accelerate and decelerate in a smooth manner, except for actions intended to avoid impact or damage.

The requirements in this clause are applicable to all speed ranges. The positioning requirements in [7.2](#) and [7.3](#) are with reference to a coordinate system oriented with the vehicle target. The longitudinal axis is parallel with the direction of travel, see [Figure 2](#).

7.2 Longitudinal positioning

7.2.1 Speed range for operation

The steady state speed control accuracy shall be ± 1 km/h ($\pm 0,3$ m/s) for the speed classes in [Table 1](#).

7.2.2 Accelerations

Deceleration/braking of at least 6 m/s^2 is required. Acceleration of at least 1 m/s^2 is recommended.

7.3 Lateral positioning

7.3.1 General

The vehicle target shall be able to meet the lateral positioning requirements in [7.3.2](#) and [7.3.3](#) while operating in the speed range defined in [7.2.1](#) over a smooth road surface no rougher than road class A as defined in ISO 8608.

7.3.2 Yaw rate

When using a self-propelled target carrier, the vehicle target shall be capable of maintaining a straight-line path with a filtered yaw rate of $\pm 1^\circ/\text{s}$.

7.3.3 Lateral position

The vehicle target shall be able to maintain a lateral path deviation of $\pm 0,1$ m during straight line manoeuvres or during a steady-state turning manoeuvre.

7.3.4 Lateral acceleration

The vehicle target shall be able to achieve a lateral acceleration of ± 4 m/s² during turning manoeuvres.

The relative roll angle between the target structure and target carrier should be minimal during manoeuvres performed within the operating capabilities of the target carrier.

7.3.5 Turning diameter

When using a self-propelled target carrier, the vehicle target shall be capable of a minimum turning diameter no greater than 12 m.

7.4 Vertical positioning

7.4.1 General

The vehicle target shall be able to meet the vertical positioning requirements in [7.4.2](#) and [7.4.3](#) while operating in the speed range defined in [7.2.1](#) over a smooth road surface no rougher than road class A as defined in ISO 8608.

7.4.2 Pitch angle

For straight line motions at constant speed, the pitch angle of the VT shall not exceed $\pm 2^\circ$.

7.4.3 Vertical motions

The vehicle target average surface should not vibrate or bounce more than 25 mm when operating in the speed range defined in [7.2.1](#) over a smooth road surface.

Annex A (informative)

Vehicle classes and dimensions

A.1 Overview of vehicle sizes and classes

The vehicle targets specified in this document reflect passenger cars and, in particular, the smaller and more common B and C segment cars. References for requirements in the document are based on a sample of vehicles from the relevant class. The criteria apply to the target structure, connected target carrier system components and installed instrumentation. The vehicle classes referred to in the document are given in [Table A.1](#).

Table A.1 — Vehicle classes

Vehicle class			Example vehicles ^a
EU Segment ^b	US ^c	Euro NCAP	
A - Mini car	Minicompact car	City car	Ford Ka, Smart Fortwo, Toyota Aygo, Volkswagen Up
B - Small car	Subcompact car	Supermini	Ford Fiesta, Volkswagen Polo, Opel Corsa, Peugeot 207
C - Medium car	Compact car	Small family car	Ford Focus, Volkswagen Golf, Opel Astra, Volvo V40
D - Large car	Midsize car	Large family car	Ford Mondeo, Hyundai Sonata, Opel Insignia, Alfa Romeo 159, Mercedes C-Class, BMW 3 Series, Volvo S60
E - Executive car	Full size car	Executive car	Lexus GS, BMW 5 Series, Jaguar XF, Volvo S80
J - Sports utility car	Mid-size SUV Full-size SUV	Small off-road 4x4 Large off-road 4x4	Ford Escape, Honda CR-V, Jeep Liberty, Kia Sportage Jeep Grand Cherokee, Volkswagen Touareg, Volvo XC90
M - Multipurpose car	MPV Minivan Cargo van	Small MPV Large MPV	Citroën C3 Picasso, Ford B-Max, Renault Kangoo VW Touran, Ford C-Max, Renault Scenic Ford Galaxy, Peugeot 807, SEAT Alhambra
^a Vehicle models mentioned are for the convenience of users of this document and does not constitute an endorsement of the products named.			
^b For explanation of the EU vehicle classes, see EU car segment . For EU segment statistics, see ACEA .			
^c The US classes are defined in Reference [6].			

A.2 Measurements on representative vehicles

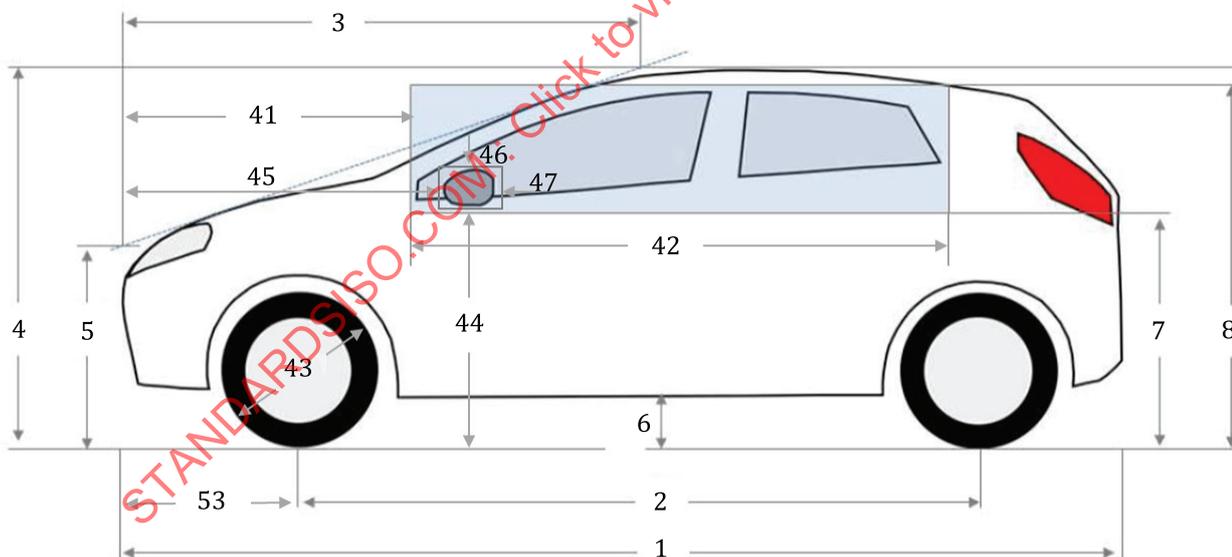
Dimensional data from measurements carried out during the development of this document are shown in [Tables A.2](#) to [A.4](#) below.

Dimensions in millimetres

Table A.2 — Vehicle measurement summary and typical target values, side

No. ^a	Measurement	Minimum	Maximum	Mean	DRI target (typical)	4a target (typical)
1	Length	3 734	4 420	4 075	4 023	4 000
2	Wheelbase	2 464	2 692	2 582	2 565	2 650
3	Roof beginning	1 600	2 134	1 941	1 727	1 950
4	Height	1 422	1 520	1 474	1 427	1 450
5	Height, Engine hood	630	889	710	661	700
6	Ground clearance	160	229	190	185	225
43	Tire diameter	570	635	608	607	620
44	Side mirror, lower edge	880	965	924	892	880
45	Side mirror, front edge	940	1 600	1 245	1 140	1 160
46	Side mirror, height	120	152	143	132	130
47	Side mirror, length	102	270	190	229	205
53	Front overhang	520	940	704	787	608
Graphic features						
7	Side window, lower edge	900	1 080	964	914	860
8	Side window, top edge	1 370	1 461	1 418	1 371	1 385
41	Side window, front edge	965	1 500	1 186	1 294	1 030
42	Side window, length	1 930	2 616	2 313	2 413	2 280

^a See [Figure A.1](#).



NOTE Numbers refer to [Table A.2](#).

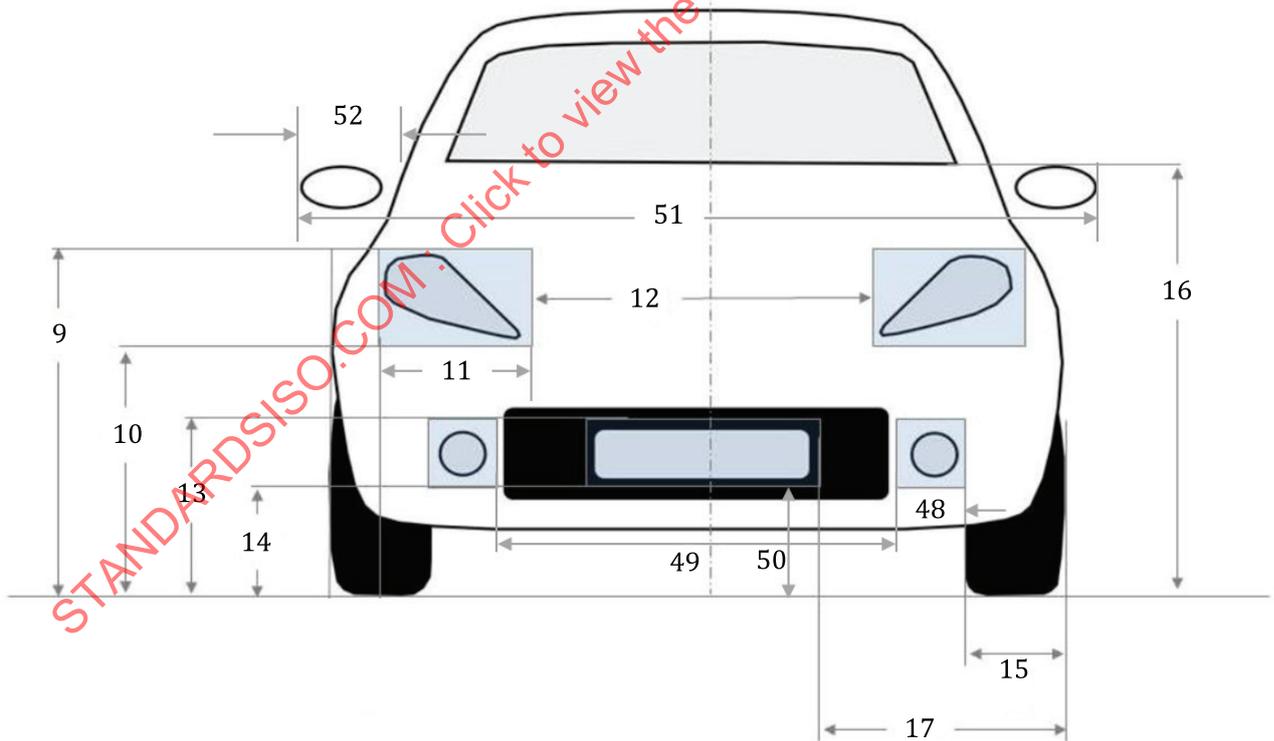
Figure A.1 — Side view measurements

Dimensions in millimetres

Table A.3 — Vehicle measurement summary and typical target values, front

No. ^a	Measurement	Minimum	Maximum	Mean	DRI target (typical)	4a target (typical)
16	Windshield, lower edge	940	1 100	1 009	951	950
50	License plate, lower edge	300	400	347	298	310
15	Tire width	178	280	209	206	160
51	Width, including side mirrors	1 930	2 159	2 048	1 829	2 010
52	Side mirror width	203	305	256	203	240
Graphic features						
9	Headlight, top edge	650	914	797	813	880
10	Headlight, lower edge	550	750	627	572	600
11	Headlight, width	229	770	519	305	600
12	Distance between headlights	810	1 080	928	851	900
13	Fog light, top edge	356	460	397	457	380
14	Fog light, lower edge	260	370	300	267	280
48	Fog light, width	76	400	207	102	110
49	Fog light, distance between	940	1 690	1 161	1 219	1 040

^a See [Figure A.2](#).



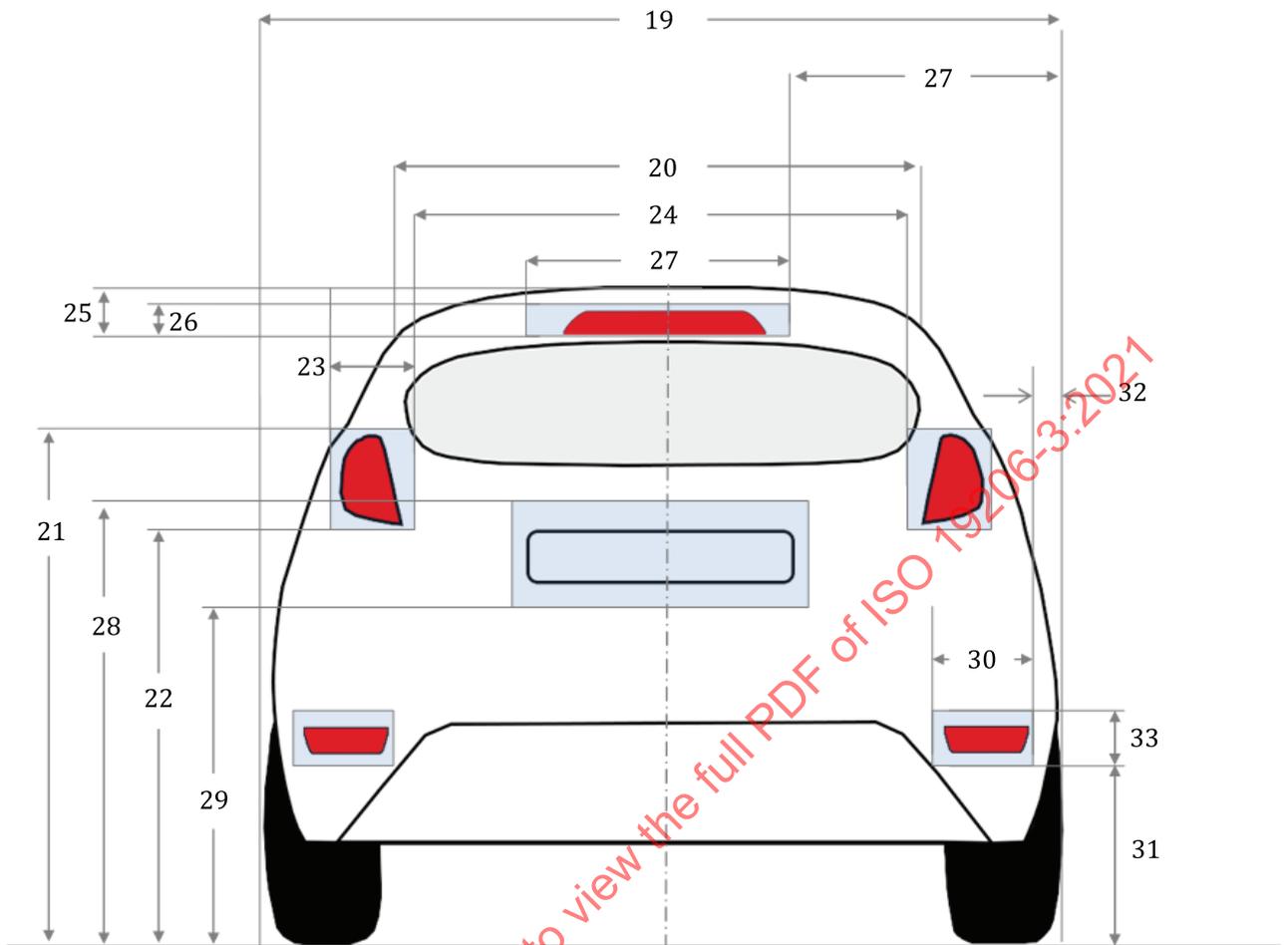
NOTE Numbers refer to [Table A.3](#).

Figure A.2 — Front view measurements

Dimensions in millimetres

Table A.4 — Vehicle measurement summary and typical target values, rear

No. ^a	Measurement	Minimum	Maximum	Mean	DRI target (typical)	4a target (typical)
19	Width	1 575	1 803	1 668	1 712	1 650
20	Roof width	914	1 270	1 104	1 128	1 150
29	License plate, lower edge	370	787	614	775	570
Graphic features						
21	Rear light ^b , top edge	914	1 194	1 048	1 194	1 130
22	Rear light ^b , lower edge and separate retro-reflector upper edge	686	900	781	851	730
23	Rear light ^b , width	178	900	441	229	340
24	Distance between rear lights and distance between retroreflectors	720	1 143	1 000	1 041	1 110
25	High centre taillight, lower edge	23	330	92	102	120
26	High centre taillight, top edge	20	51	31	25	40
27	High centre taillight, width	229	470	341	170	300
30	Separate retro-reflector width	70	300	220	250	180
31	Separate retro-reflector lower edge	350	820	490	500	360
32	Separate retro-reflector side position	N/A	250	80	0	100
33	Reflector area, cm ²	48	120	74	89	81
^a See Figure A.3 . ^b Including retroreflectors (if applicable).						



NOTE Numbers refer to [Table A.4](#).

Figure A.3 — Rear view measurements

Annex B (normative)

Visual and near infrared sensor-specific recognition properties and measurements

B.1 General

The vehicle target (VT) shall be able to represent the attributes of a reference vehicle in relation to the sensors used in the subject vehicle (SV). This also applies after repeated reassemblies. For system testing with a certain detection technology in the SV, the VT shall be equipped with the relevant corresponding features given below.

Since some test procedures refer to a white body colour of the target, this document provides details on the white colour. Other colours are allowed but are not defined in this document.

B.2 Visual and near infrared properties

B.2.1 Overall visual properties

The following requirements and recommendations apply, to enable a proper recognition with regard to visual detection (see also [Figure B.1](#)).

- The visual difference between the passenger car target and a real standard car of the B and C class should be as small as possible.
- The contours of the target should be representative of real standard cars of the B and C class.
- The target should demonstrate a high level of vertical symmetry.
- The body surface texture should be smooth.
- The colour and the texture should not blend in with the background.
- The wheels, consisting of tire and rim, shall be round and of realistic dimensions. They shall be visible from both behind and from each side.
- Tire, rim and wheel casing shall differ in colour to create a visual distinction.
- The target shall give the appearance of a free space between chassis and road. Approximately 200 mm is recommended.
- As the VT shall represent reflections of a real car, the windows (windscreen, side windows, rear window) should give the impression of being transparent. The interior of a real car (seat, steering wheel, rear view mirror) may be indicated.

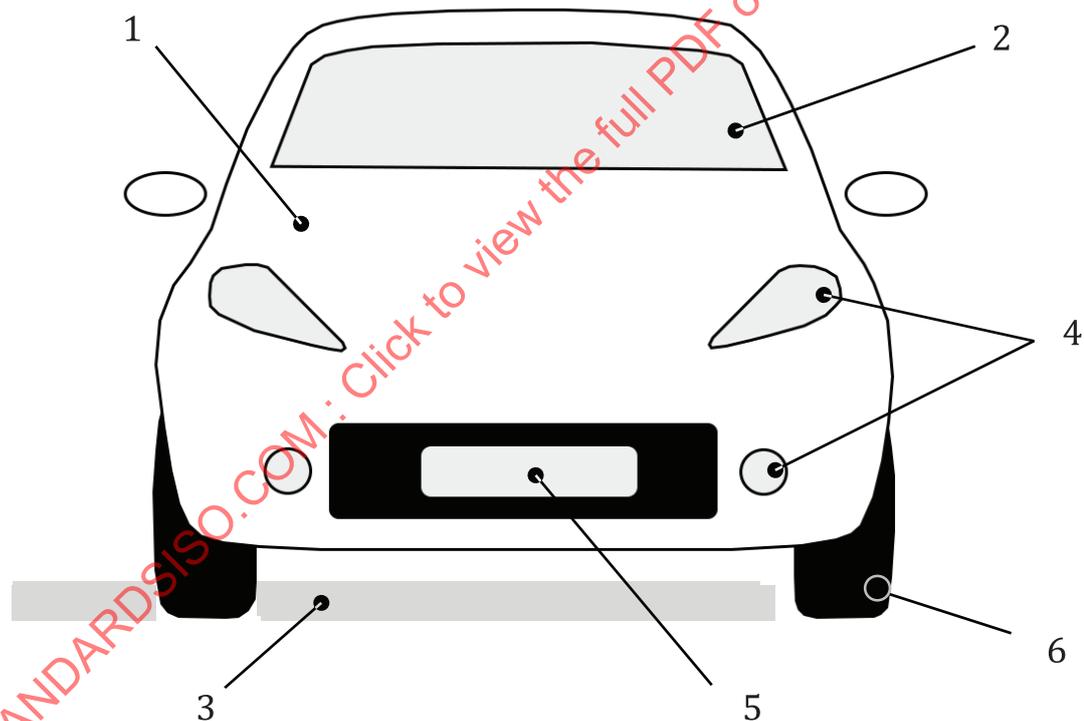
B.2.2 License plate

- The VT shall include a visual representation of a license plate.
- The license plate shall be representative of the region for which the VT is intended, with respect to size, colour, position and reflectivity.
- Where feasible, the VT should be equipped with a real license plate. A license plate shall not be mounted behind a transparent plastic foil.

- In case of using foil/sticker material, its size and position shall be equal to size and position of a standard registration plate for the region of sale for the subject vehicle [e.g. 520 mm x 110 mm in Europe, 305 mm x 152 mm (12 in x 6 in) in North America].

B.2.3 Lighting and retroreflectors

- The passenger car target shall include a visual representation of rear retroreflectors and rear lighting.
- The retroreflectors and lighting shall be representative of the region for which the VT is intended, with respect to size, colour, placement and reflectivity.
- Functional rear lights and brake lights can optionally be implemented.
- Optionally, a reflective foil colour “red” can be used (meeting the specifications of UN R104 or FMVSS 108).
- Retroreflectors shall be implemented in a realistic manner using a retro-reflective element or similar. Retroreflectors may be integrated in the rear lights or separated from the rear lights.



Key

- 1 smooth body surface without texturing
- 2 transparent impression of windows
- 3 characteristic shadow visible
- 4 visual representation of reflective lights
- 5 real/retroreflective license plate
- 6 wheels of realistic dimensions

Figure B.1 — Vehicle target visual properties

B.2.4 Near infrared properties

With regard to near infrared detection (for a wavelength of around 850 nm to 950 nm), the following requirements shall be fulfilled in addition to the ones in B.2.1 to B.2.3:

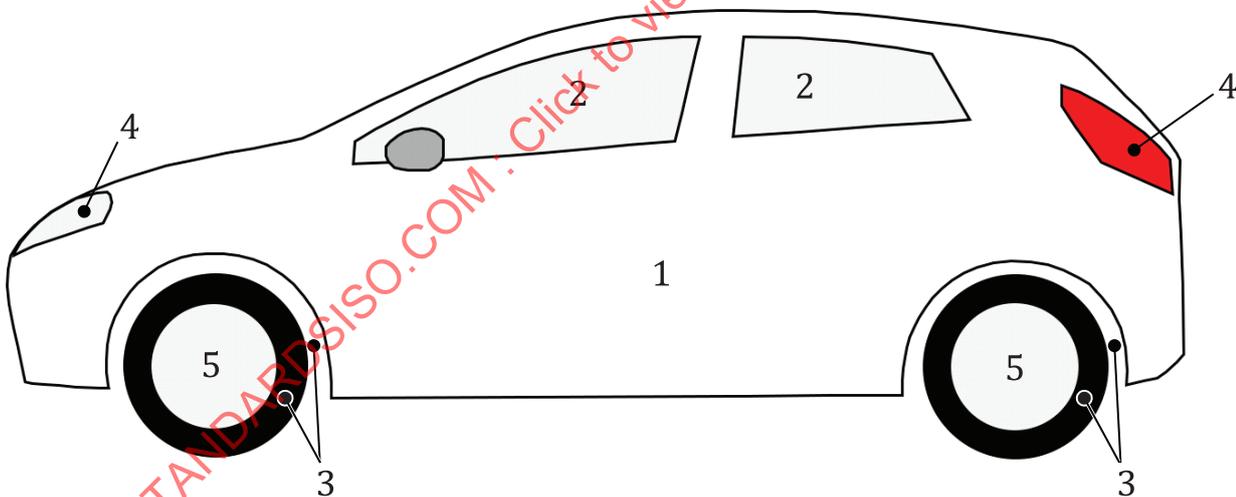
- a homogeneous visible surface without specular reflections is required;
- the target surface shall consist of material with reflectivity in the relevant IR band of at least 50 % (substitute value for real car, based on measurements);
- the VT shall have properties similar to a real car with respect to IR reflectivity of the license plate / tail reflector.

NOTE 1 This section refers to wavelengths in use at the time of publication of this document. Other wavelengths (e.g. 1 400 nm – 1 600 nm) can be taken into account in future revisions.

See Figure B.2 and Tables B.1, B.2 and B.3.

Table B.1 — Vehicle target infrared properties

Segment	IR-Reflectivity 45°
1 outer cover (white)	≥ 50 %
1 outer cover (black)	≤ 10 %
2 windows	≥ 60 %
3 tire, wheel casing	≥ 15 %
4 reflecting lights	≥ 85 %
5 wheel, wheel cover	≥ 60 %



NOTE Numbers refer to Table B.1.

Figure B.2 — Vehicle target infrared properties

Table B.2 — Colour ranges for specific features, sRGB (Observer = 2°, Illuminant = D65)

Segment		Hex	Colour	Red	Green	Blue
Shadow	min	0		0	0	0
	mean	90909		9	9	9
	max	121212		18	18	18

Table B.2 (continued)

Segment		Hex	Colour	Red	Green	Blue
Tyre	min	141414		20	20	20
	mean	262626		38	38	38
	max	383838		56	56	56
Window	min	9FB1A6		159	177	166
	mean	7B8278		123	130	120
	max	575349		87	83	73
Reflector	Min	FF502D		255	80	45
	Mean	D13617		209	54	23
	Max	A21B00		162	27	0

Table B.3 — Recommended colour range for white body, sRGB (Observer = 2°, Illuminant = D65)

Segment		Hex	Colour	Red	Green	Blue
Outer cover (white)	min	EDEDED		237	237	237
	mean	F6F6F6		246	246	246
	max	FFFFFF		255	255	255

NOTE 2 Illuminant D65 is specified in ISO 3668.

B.3 Measurement of IR reflectivity

B.3.1 Equipment and calibration

Measurement of the IR reflectivity is carried out using a spectrometer for wavelength range 850 nm to 950 nm.

Before the start of the measurement the device shall be calibrated with a reflection standard, reflectance 99 %. The calibration should be verified by reflectance standards with reflectivity of, e.g. 50 % or 20 %.

B.3.2 Measurement setup

The measurement of the target should be conducted with a special attachment to the measurement sensor, which ensures a defined distance and angles (90° and 45°) between sensor and target depicted in [Figure B.3](#).

The measurement shall be performed at three different points of the measuring object and shall be recorded.

The resulting IR reflectivity value corresponds to the average of the three reflectivity measurements.



Figure B.3 — Measurement probes, 90° and 45°

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Annex C (normative)

Radar-specific recognition properties and measurements

C.1 General

The vehicle target (VT) shall be able to represent the attributes of a reference vehicle in relation to the sensors used in the subject vehicle (SV). This also applies after repeated reassemblies. For system testing with radar sensor technology in the SV, the VT shall be equipped with the relevant corresponding features described in this annex.

The method for measuring those features is also described in this annex. RCS of the target is measured with the target carrier, when included as part of the test setup.

C.2 Radar properties

C.2.1 General

The difference between the passenger car target and a real standard car concerning radar reflectivity should be as small as possible, as defined by the requirements in the following clause. Moving components to create micro-Doppler effects is not necessary but, if included, should match the micro-Doppler properties of a real vehicle.

C.2.2 Radar cross-section, RCS

C.2.2.1 RCS characteristics

The VT shall appear to be a real vehicle to radar sensors. Thus, the surface of the VT shall not flutter or vibrate due to aerodynamic effects for the applicable speed class, to avoid a variation of radar signature. The VT includes the target and target carrier, when a target carrier is present.

To achieve a realistic distribution of the RCS, it shall not be distributed homogenously. The following features that are characteristic to a real car should contribute to the target RCS:

- wheel casing (4x);
- length and width of front and rear bumper;
- straight side panels and front of the outer cover.

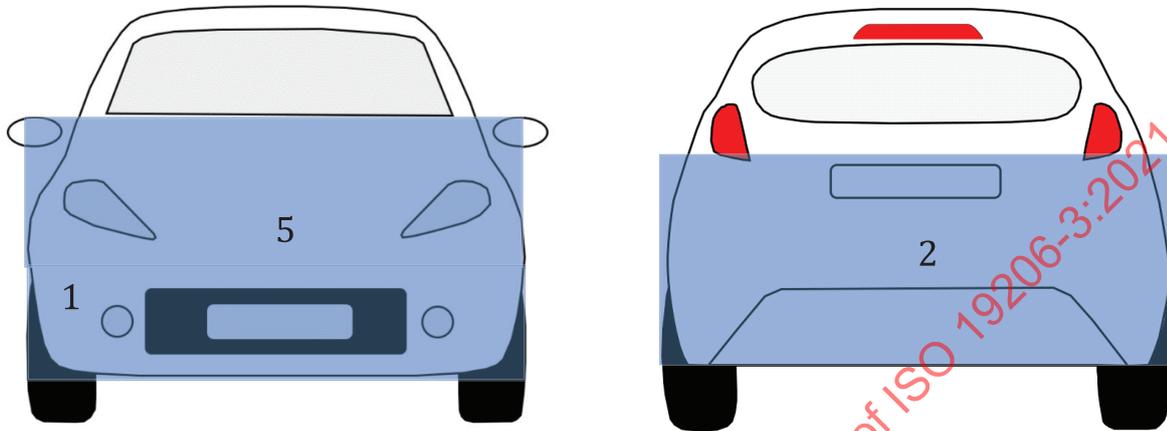
Additionally, the reflection of A- and C-pillars (blind spots) of a real car shall be taken into consideration (see [Figures C.1, C.2](#) and [Table C.1](#)).

Table C.1 — Distribution of RCS according to [Figure C.1](#) and [Figure C.2](#)

Number	Segment
1	front bumper
2	rear bumper
3	side panels
4	wheel casing
5	front

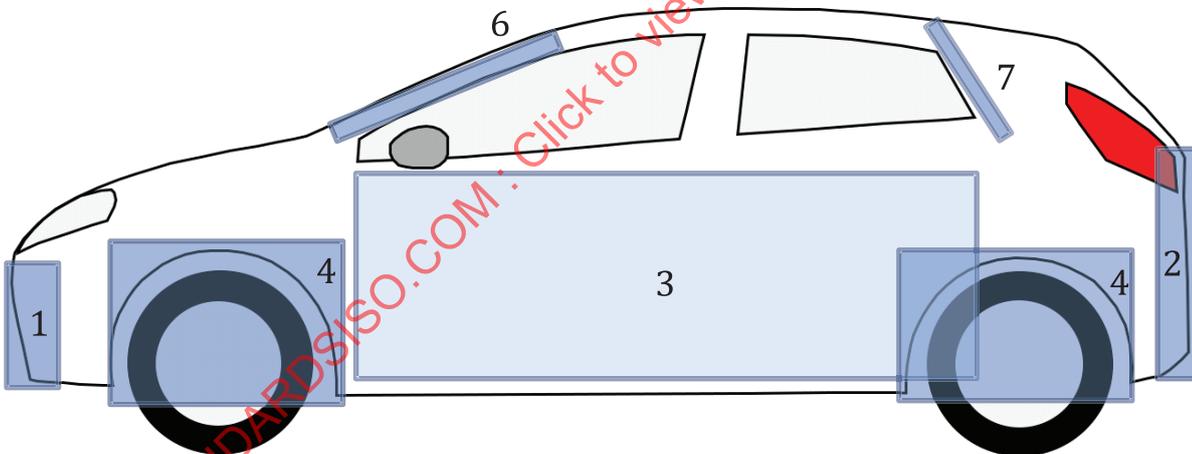
Table C.1 (continued)

Number	Segment
6	A-pillar
7	C-pillar



NOTE Numbers refer to [Table C.1](#).

Figure C.1 — Distribution of RCS, front and rear view



NOTE Numbers refer to [Table C.1](#).

Figure C.2 — Distribution of RCS, side view

The reflections of the interior of the VT shall match the spatial distribution of a real vehicle.

The radar reflectivity of the target carrier shall be at least lower than 0 dBm². This also applies to a metallic target carrier based on a state-of-the-art construction. An adapted ramp (22°) can be used to reduce radar reflectivity.

The radar cross section of the VT 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 VT is not scanned completely. 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 free space RCS in the far field. The RCS is also influenced by geometrical effects and multi-path propagation (i.e. constructive and destructive interferences).

Therefore, it shall be considered that the RCS will be reviewed not only constantly, but by a description of the RCS by closing on the VT (see example of the RCS distribution at 76 GHz of real passenger cars in [Figures C.17](#) and [C.18](#)). A realistic distribution of the RCS over the whole VT area shall be ensured. This allows achieving the effect of decreasing RCS at a shorter distance by only partial coverage.

C.2.2.2 Determination of RCS boundaries

The radar cross section of the VT, achieved by following the procedure defined in [C.3](#) should stay within a defined range, depicted in [Figures C.3, C.4](#) and [C.5](#).

The sensors used to develop these boundaries have a horizontal field of view ranging from 30° to 60° and a vertical field of view ranging from 5° to 20°. If sensors with parameters different than those listed in [C.3.2.1](#), or with a field of view outside the range of what was used in developing the boundaries, are used or the mounting position of the sensor is different, slightly different RCS values may be obtained, especially in the near range when sensor field of view has the greatest effect on the RCS measurement. In that case an additional verification/adaption of the boundaries may be necessary for validation of the VT.

NOTE The boundaries and threshold values are based on the set of vehicles measured and radar sensors used in the development of this document.

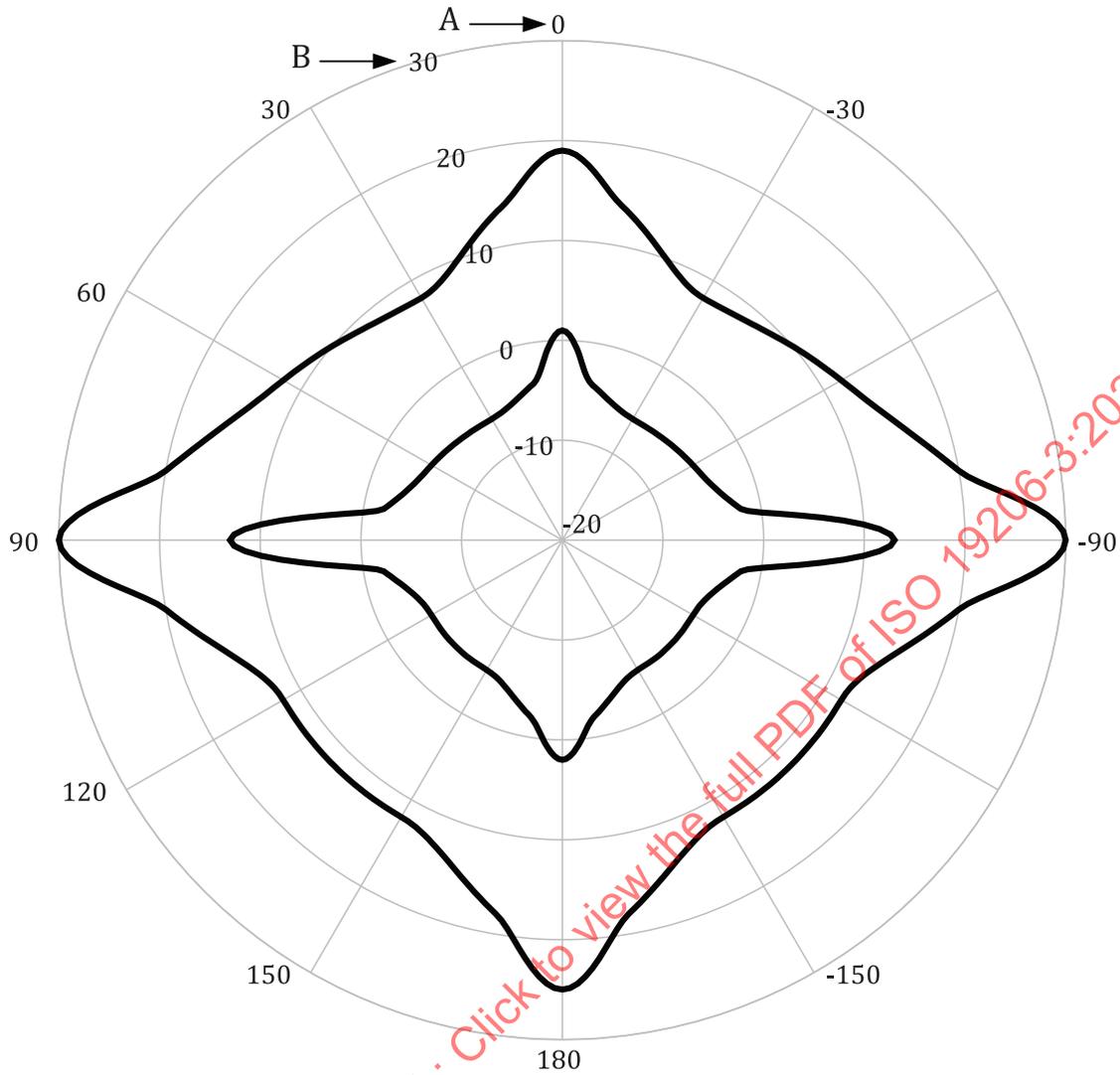
C.2.2.3 RCS boundaries for fixed-range, variable viewing angle measurement

For fixed-range RCS boundaries shown in [Figure C.3](#), at least 95 % of the filtered data points should lie within the boundary. The boundaries are defined using cubic spline interpolation of the data breakpoints provided in [Table C.2](#).

NOTE In this context, range refers to the distance between the radar sensor and the vehicle target reference point as defined in term [3.5](#).

Table C.2 — Fixed-range RCS boundary breakpoints

Angle (°)	Lower boundary (dBm ²)	Upper boundary (dBm ²)
0	1	19
10	-4	14
30	-6	8
60	-5	12
80	-2	20
90	13	30
100	-2	20
120	-5	12
150	-5	12
170	-2	18
180	2	25



Key
 A viewing angle (°)
 B RCS (dBm²)

NOTE RCS boundary breakpoints are given in [Table C.2](#).

Figure C.3 — Fixed-range RCS boundaries for a passenger vehicle target

C.2.2.4 RCS boundaries for fixed viewing angle, variable range measurement

For the fixed-angle RCS boundaries shown in [Figure C.4](#), at least 92 % of the filtered data points should lie within the boundary. This accounts for the fact that multi-path interference may cause the RCS at some distances to fall outside of the specified boundaries. The boundaries are defined using [Formulae \(C.1\)](#) and [\(C.2\)](#) and the parameters from [Table C.3](#).

$$B_U = P_{FAR} - K_{DEC} \times \min(D - D_{FAR}, 0)^2 + \Delta_P \tag{C.1}$$

$$B_L = P_{FAR} - K_{DEC} \times \min(D - D_{FAR}, 0)^2 - \Delta_P \tag{C.2}$$

where

B_U is the upper boundary (dBm²);

B_L is the lower boundary (dBm²);

D is the range (m);

P_{FAR} is the average RCS at far distances (dBm²);

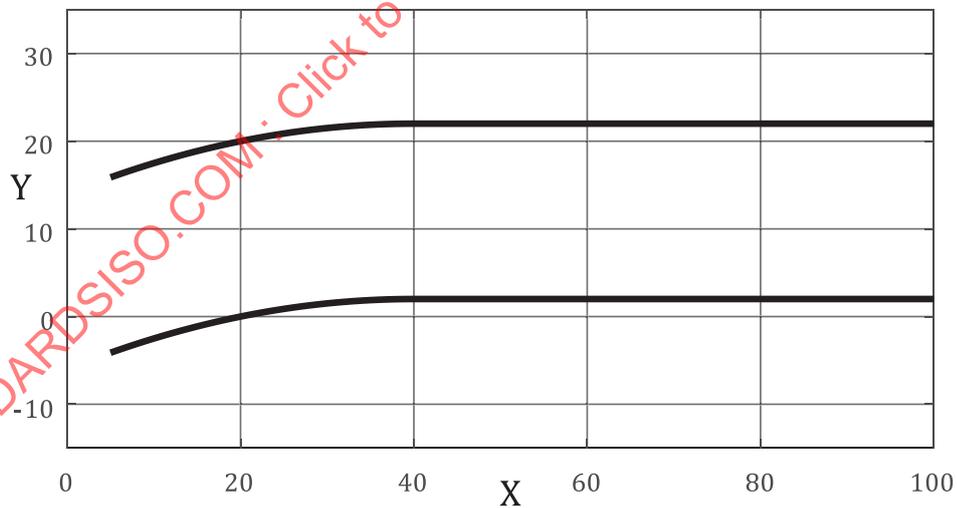
D_{FAR} is the range beyond which the average RCS is P_{FAR} (m);

K_{DEC} is the factor of decreasing RCS as a function of distance (dBm²/ m²);

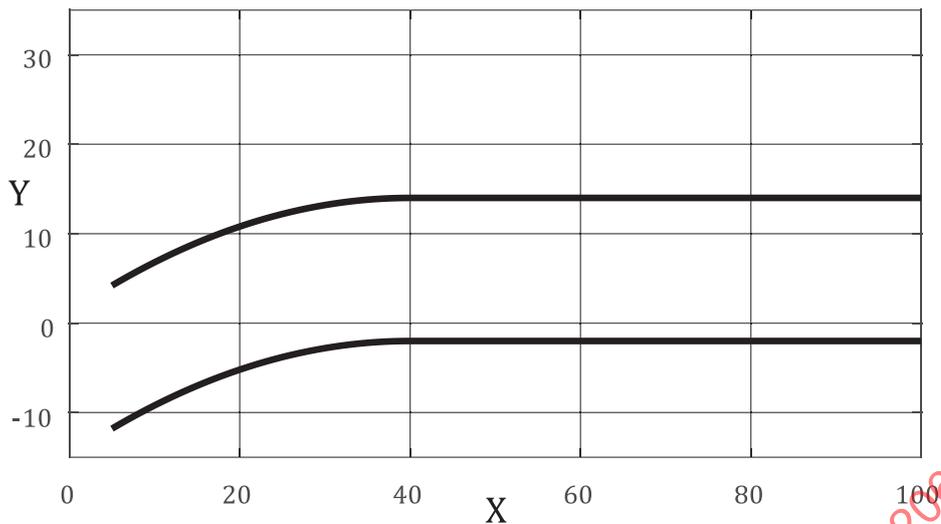
Δ_P is the half width of the RCS boundary (dBm²).

Table C.3 — Fixed viewing angle RCS boundary parameters

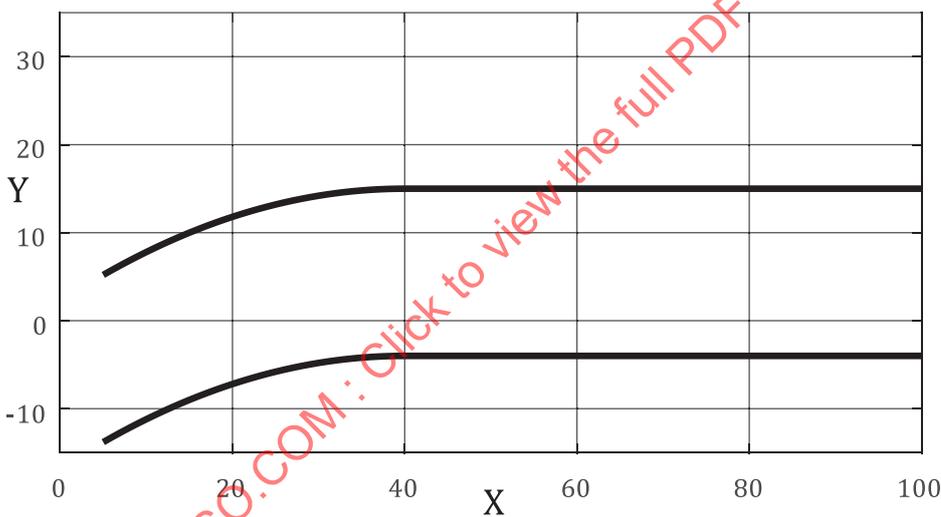
Angle (°)	K_{DEC} (dBm ² /m ²)	D_{FAR} (m)	P_{FAR} (dBm ²)	Δ_P (dBm ²)
0	0,005	40	12,0	10,0
30	0,008	40	6,0	8,0
60	0,008	40	5,5	9,5
90	0,013	40	24,5	9,5
120	0,008	40	8,0	9,0
150	0,008	40	8,0	10,0
180	0,013	40	20,0	10,0



a) 0° viewing angle

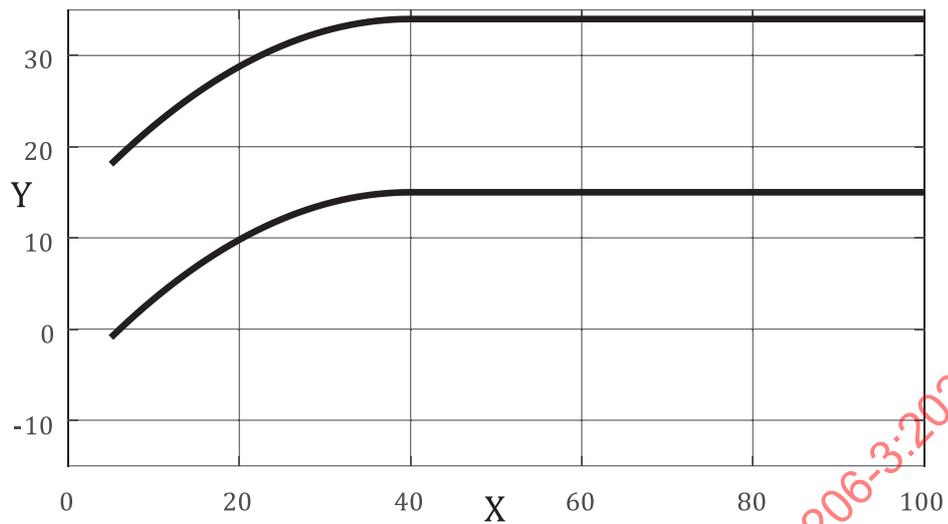


b) 30° viewing angle

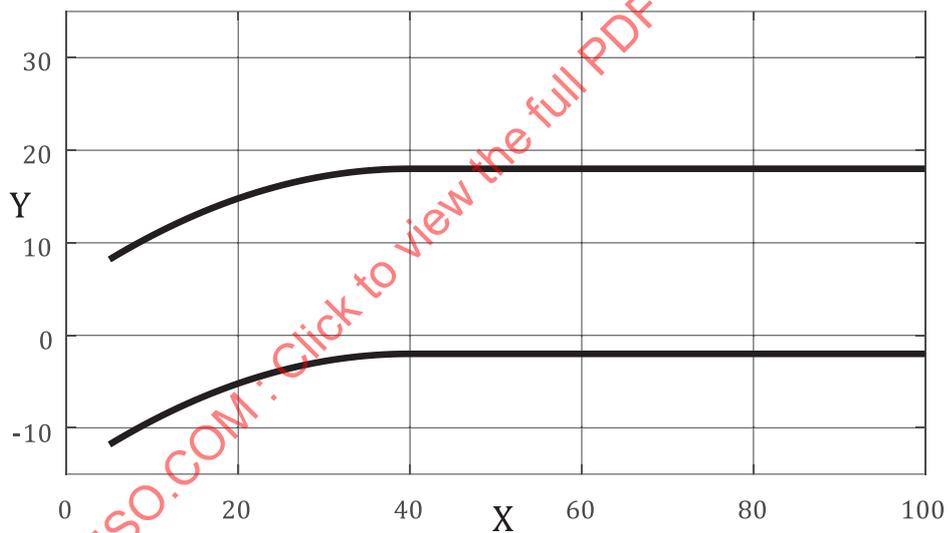


c) 60° viewing angle

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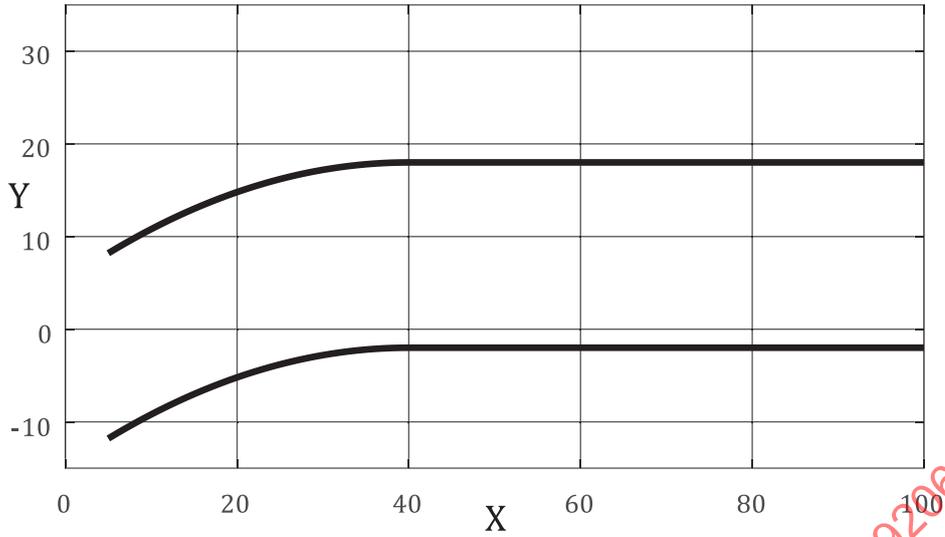


d) 90° viewing angle

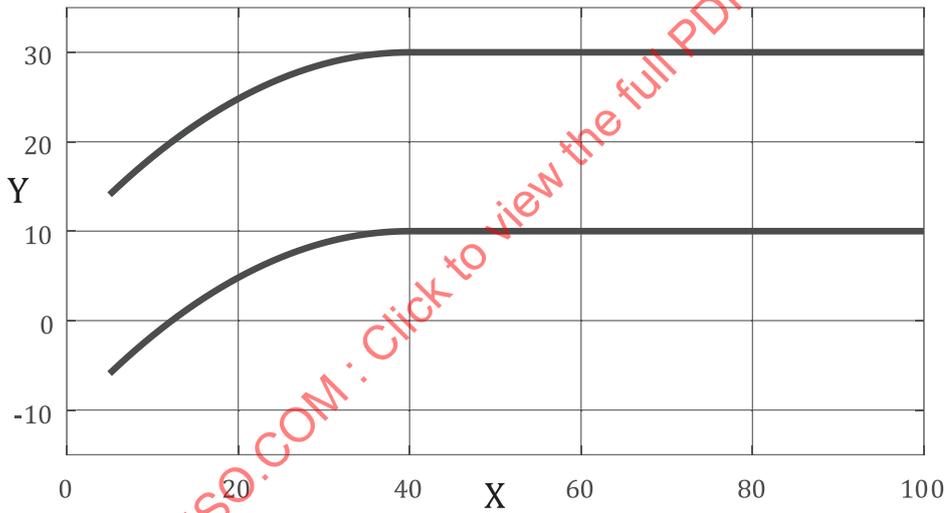


e) 120° viewing angle

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f) 150° viewing angle



g) 180° viewing angle

Key

X range (m)

Y RCS (dBm²)

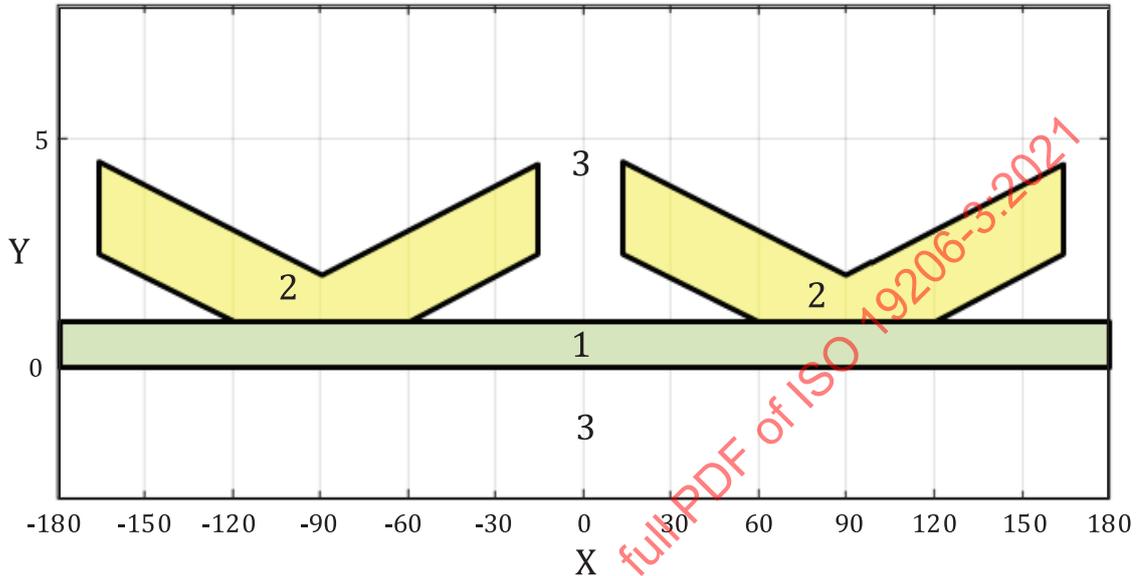
Figure C.4 — Fixed viewing angle RCS boundaries for a passenger vehicle target

C.2.2.5 Spatial RCS boundaries using the angle-penetration method

Based on the viewing angle and penetration distance, as described in [C.3.3.1.1](#), each reflection is allocated to be within one of the three regions shown in [Figure C.5](#). The total power within each region is calculated by summing the RCS, in m², of all reflections. The percentage range of radar power being reflected from with each region is provided in [Table C.4](#). The results for six representative passenger vehicles are shown in [Figures C.14](#) and [C.15](#).

Table C.4 — Radar power reflection from each vehicle region

Region	Description	Reflection power percentage
1	Primary reflections	86 % - 95 %
2	Internal reflections	2 % - 14 %
3	Extraneous reflections	0 % - 4 %

**Key**

X viewing angle (°)

Y penetration distance (m)

NOTE Numbers refer to [Table C.4](#).**Figure C.5 — Spatial RCS regions for angle-penetration method****C.3 Radar measurements****C.3.1 General**

Measurement of the radar reflectivity is carried out using a measurement setup according to the specification in [C.3.2](#). RCS of the vehicle target is measured with the target carrier if the vehicle target includes a target carrier.

C.3.2 Measurement setup**C.3.2.1 Radar sensor and fixture**

The measurements shall be taken using an automotive-grade sensor that operates at (76-81) GHz and can operate at ranges of 5 m to 100 m. The range gate length should be smaller than 0,6 m. In order to best match the data in this document, the sensor should have the following parameter values:

- field of view, horizontal: 10° minimum (-3dB amplitude limit);
- field of view, elevation: 5° minimum (-3dB amplitude limit);
- sensor range: > 100 m; and
- frequency bandwidth: (76-81) GHz.

The sensor shall be mounted on a fixture which can be on a host vehicle or other measurement fixture as long as the required motion can be achieved. The sensor shall be capable of being mounted between 230 mm and 900 mm above the ground and should be aligned parallel to the ground to within $\pm 1^\circ$.

The relative motion (distance and viewing angle) between the sensor and VT may be achieved either by moving the fixture (such as a vehicle or mobile measurement cart) or by moving the VT (such as using a turn table as used in Reference [13]) as shown in Figure C.6 assuming the turntable RCS is confirmed to be neutral. The viewing angle shall be measured with an accuracy of $0,25^\circ$ and the range shall be measured with an accuracy of 100 mm.



Figure C.6 — Example measurement cart (top), turntable (bottom)

C.3.2.2 Sensor calibration equipment

The radar sensor should be calibrated by performing reference measurements with two objects of the same shape and known RCS (see Figure C.7). It is recommended but not necessary that dihedral or trihedral corner reflectors be used as calibration objects. Dihedral corner reflectors have the benefit

of reducing the multipath interference when performing calibration measurements. Trihedral corner reflectors have the benefits of minimizing the effects of sensor/object misalignment. The effective areas of the calibration object should be large compared to the radar wavelength.

One object should have a known RCS that is within the range of 5 dBm² to 20 dBm² and the second object should have a much lower RCS (-20 dBm² to 0 dBm²). Using two objects with RCS values on either end of the expected RCS range of interest will ensure the sensors are not saturated and provide linear results within that range. It should be ensured that consistent results are provided within a sensor field of view of $\pm 10^\circ$. Acceptable variations are typically within ± 3 dB.

Both calibration objects should be mounted with their centres at 480 mm \pm 10 mm above the ground and the reflectivity of the mounting fixture should be reduced either using non-reflective material or, preferably, using radar absorbers.

Calibration should be performed at distances ranging from 5 m to 100 m.

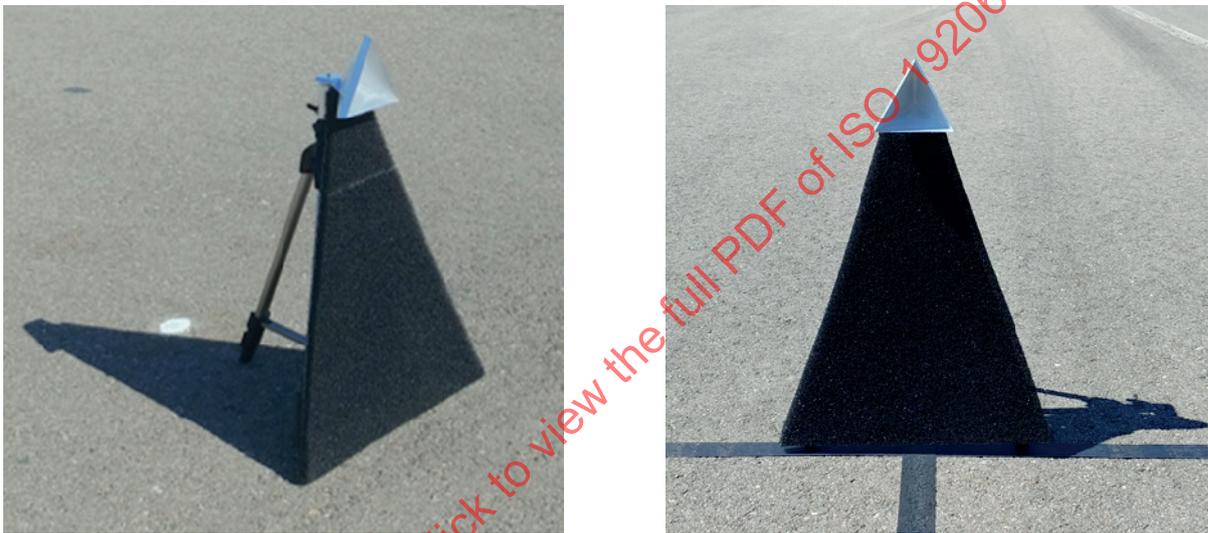
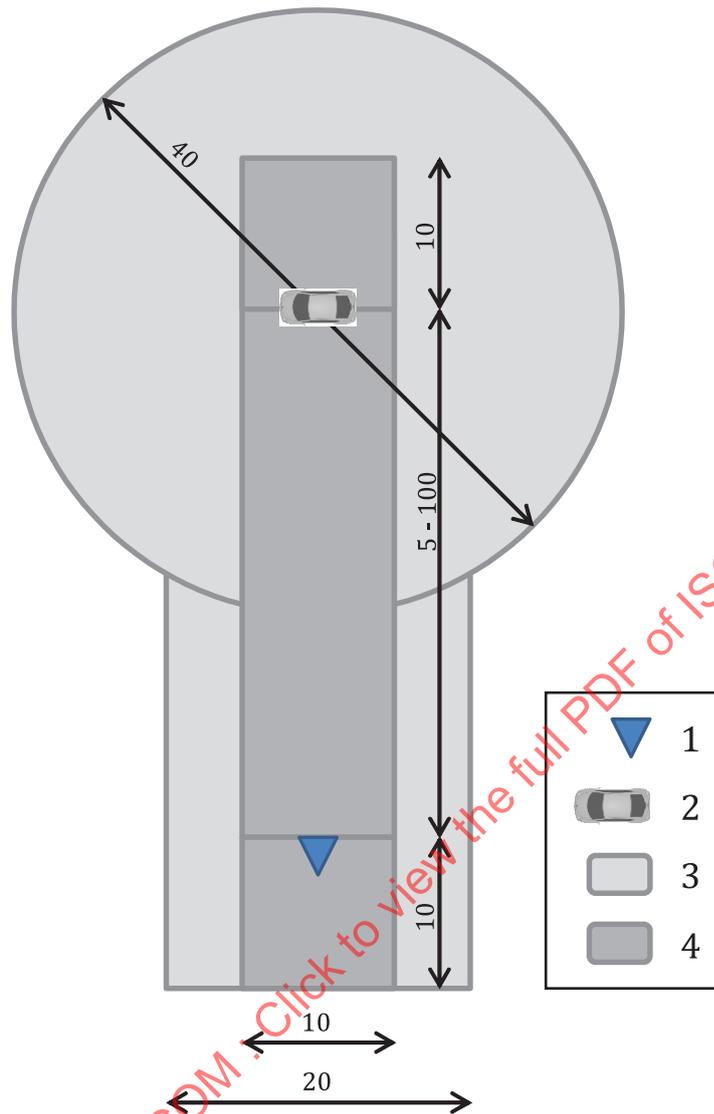


Figure C.7 — Example dihedral calibration object

C.3.2.3 Test environment

The following requirements apply:

- no additional objects/buildings in the observation area that could lead to multipath propagation;
- test surface area to be dry and completely covered with tarmac or concrete filling the test surface area shown in [Figure C.8](#), having a consistent surface; and
- no metallic or other strong radar reflecting parts in ground or other surrounding area in the free space shown in [Figure C.8](#).



Key

- 1 sensor
- 2 VT
- 3 free space
- 4 test surface area

Figure C.8 — Test environment

C.3.3 Measurement scenarios

C.3.3.1 Scenario 1 — Fixed-range measurement or viewing angle scan

The purpose of the fixed-range measurement is to characterize the radar reflectivity of the VT from all angles. It is important to perform a full sweep of the viewing angles because the reflectivity of an object can be very sensitive to viewing angle such that a feature that very reflective at one angle may be much less reflective at a slightly different angle. To capture all features, a high-resolution scan of the VT shall be performed.

The fixed-range measurements shall be performed based on the following guidelines:

- VT shall be measured with static vehicle or measurement fixture;
- in order to reduce the multi-path effect, the measurements shall be taken at three sensor heights of 230 mm ± 10 mm, 480 mm ± 10 mm, and 900 mm ± 10 mm at a nominal range of 30 m (distance from VT reference point to sensor);
- the sensor shall maintain the range with ± 0,3 m;
- continuous measurements should be taken from viewing angles of 0° to 180° and preferably from 0° to 360°.

The sensor should move at a speed such that there are at least 5 measurement samples per angular degree.

The necessary sensor speed (v) to achieve this can be calculated according to [Formula \(C.3\)](#):

$$v \leq \frac{2\pi R}{(360 \times n) \times \tau} \quad (\text{C.3})$$

where

R is the range radius (i.e. 30 m);

n is the number of samples per degree (i.e. 5), such that $360 n$ is the number of samples per revolution;

τ is the time (seconds) between sensor measurements.

The sensor outputs with the largest RCS should be filtered using a 2,5° viewing angle moving average window.

The filtered RCS at each angle should be averaged across the three sensor height measurements.

[Figures C.9](#) and [C.10](#) show the results of the fixed-range measurements for six-passenger vehicles using two different vehicle radar sensors.

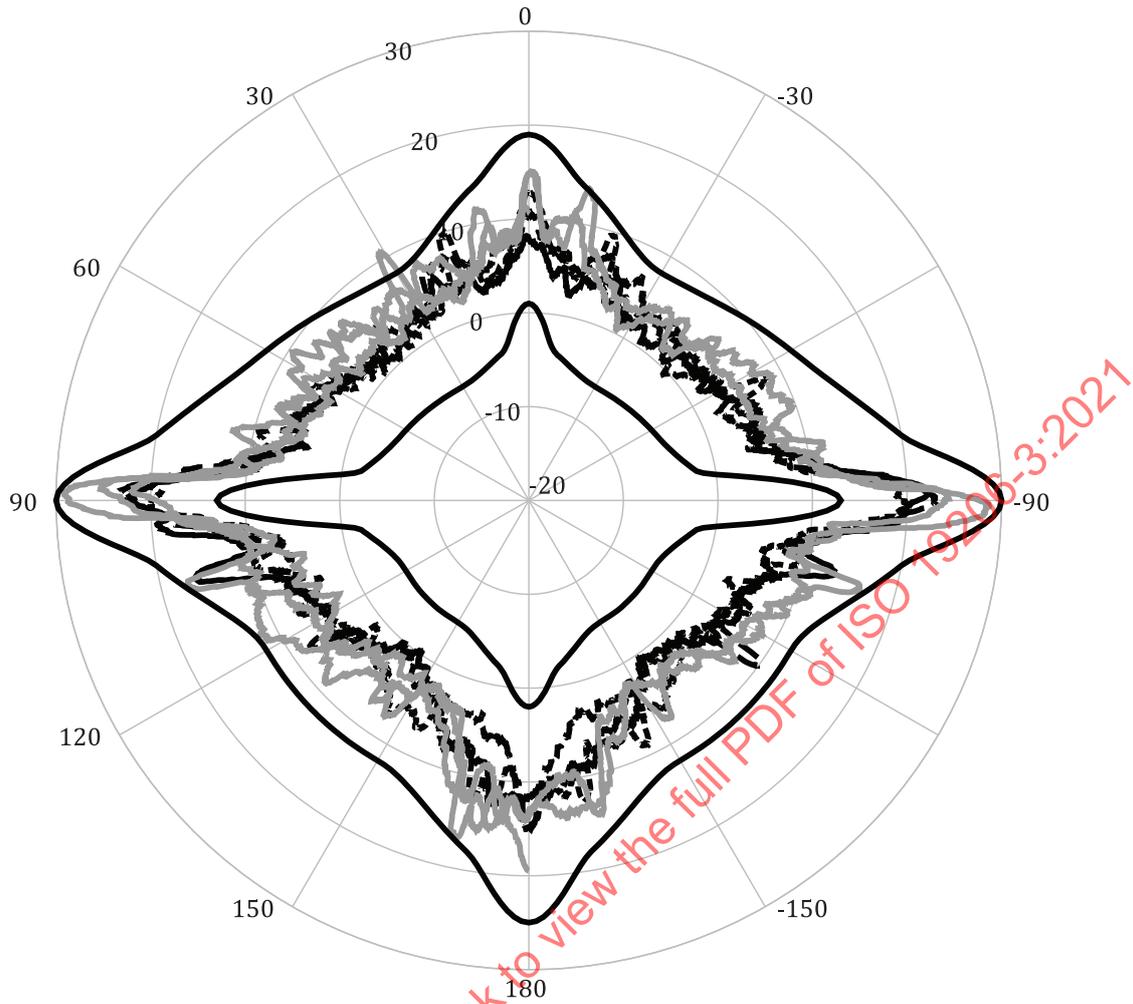


Figure C.9 — Fixed-range RCS measurement of six passenger vehicles, sensor 1

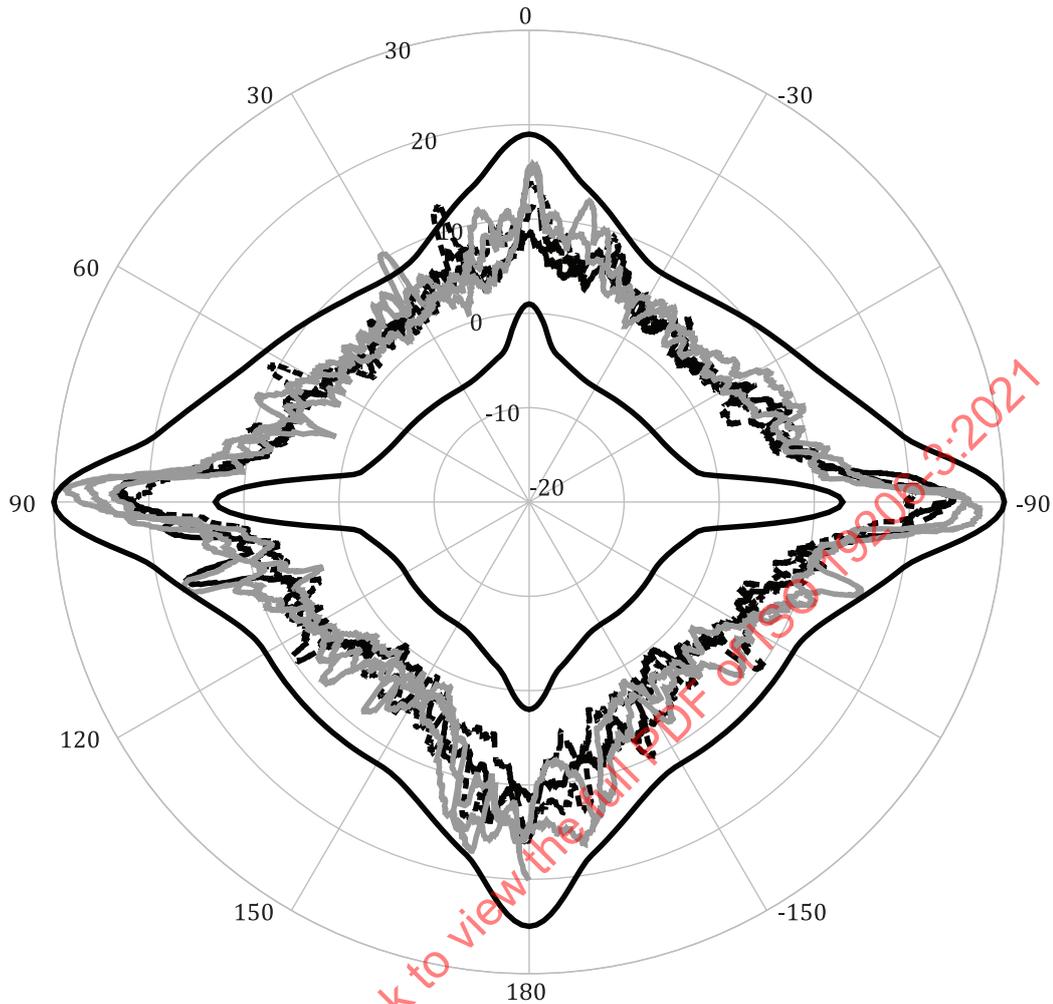


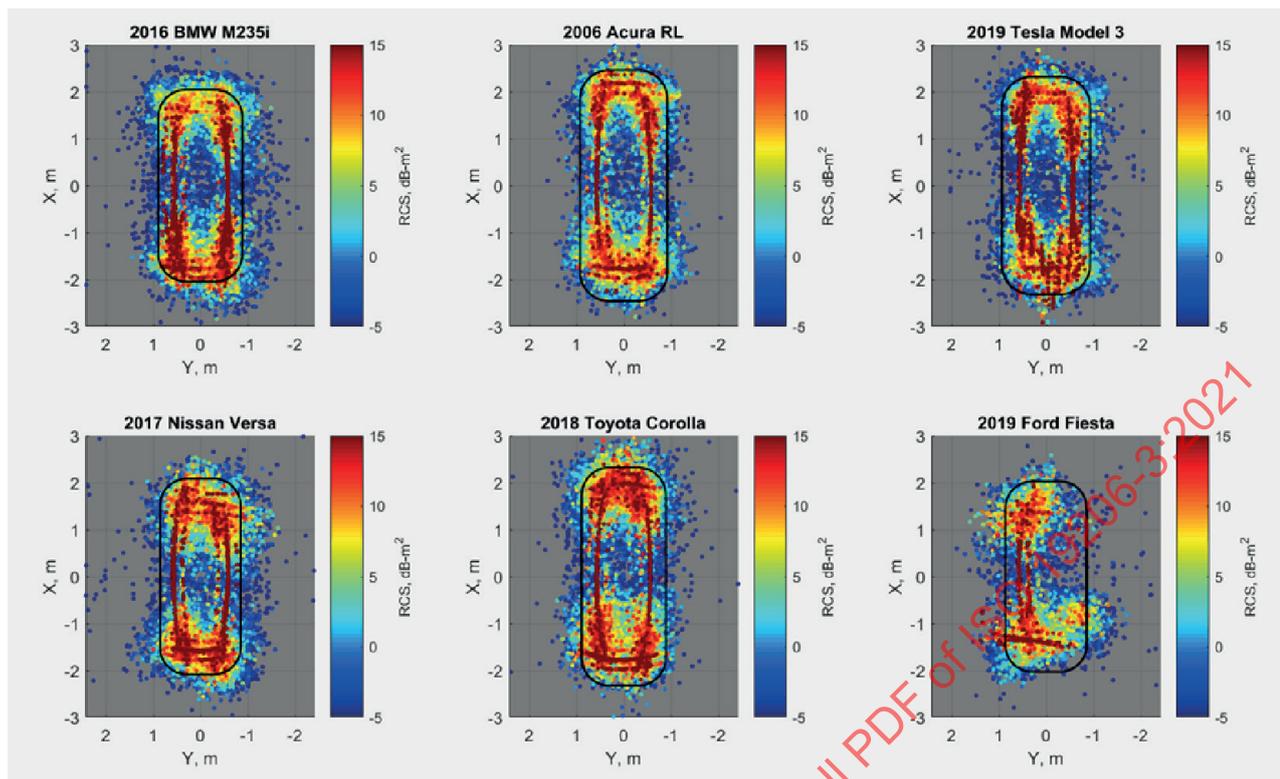
Figure C.10 — Fixed-range RCS measurement of six passenger vehicles, sensor 2

C.3.3.1.1 Spatial RCS calculation using fixed-range measurement data

The data from the fixed-range measurements are used to calculate the spatial distribution of the object.

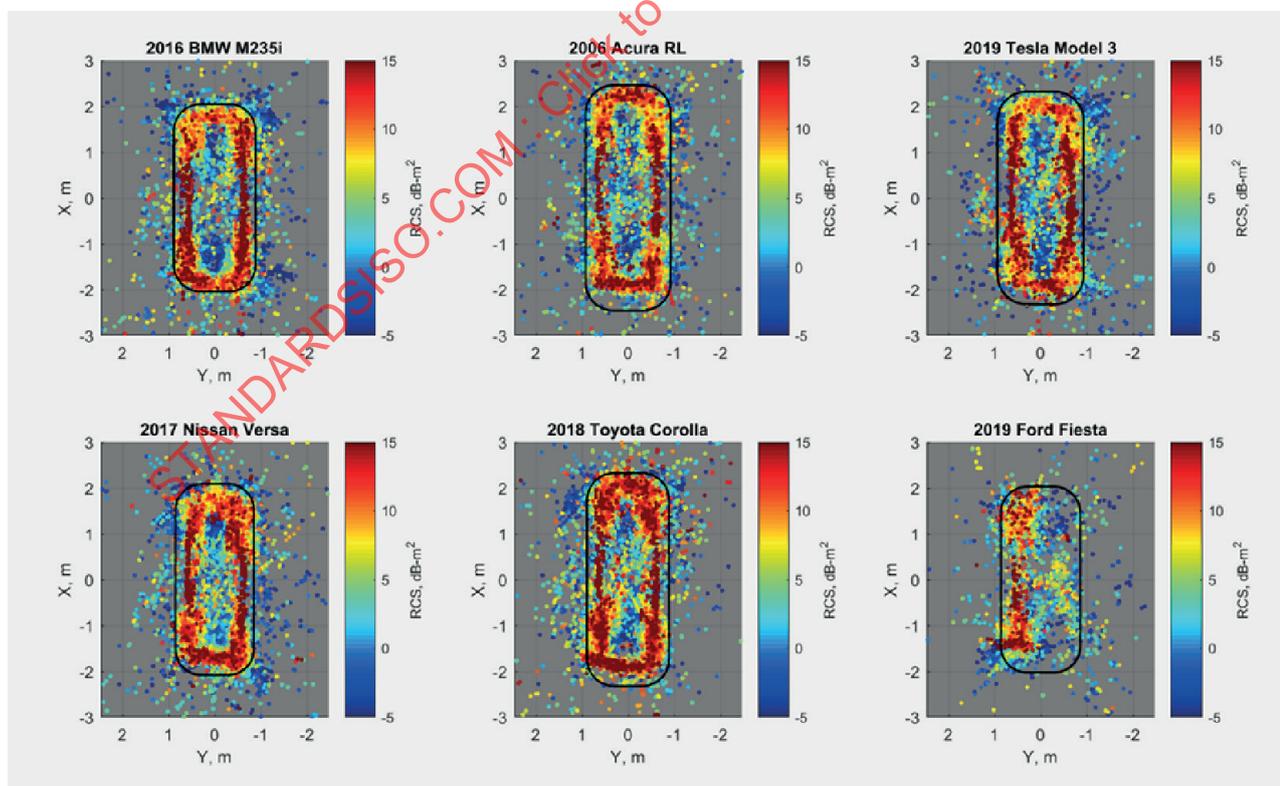
The absolute position of each reflection is calculated using the absolute position and heading of the sensor as well as the relative position of the reflection with respect to the sensor. The spatial locations of the reflections are calculated in the vehicle reference frame, where the origin (0,0) is the centre of the object being measured.

[Figures C.11](#) and [C.12](#) show example RCS spatial reflections in the vehicle coordinate system. The figures also show the vehicle extents, assuming a rectangle with rounded corners as defined in [Figure C.13](#).



NOTE The lower right case was measured only from 0° to 180° (left side).

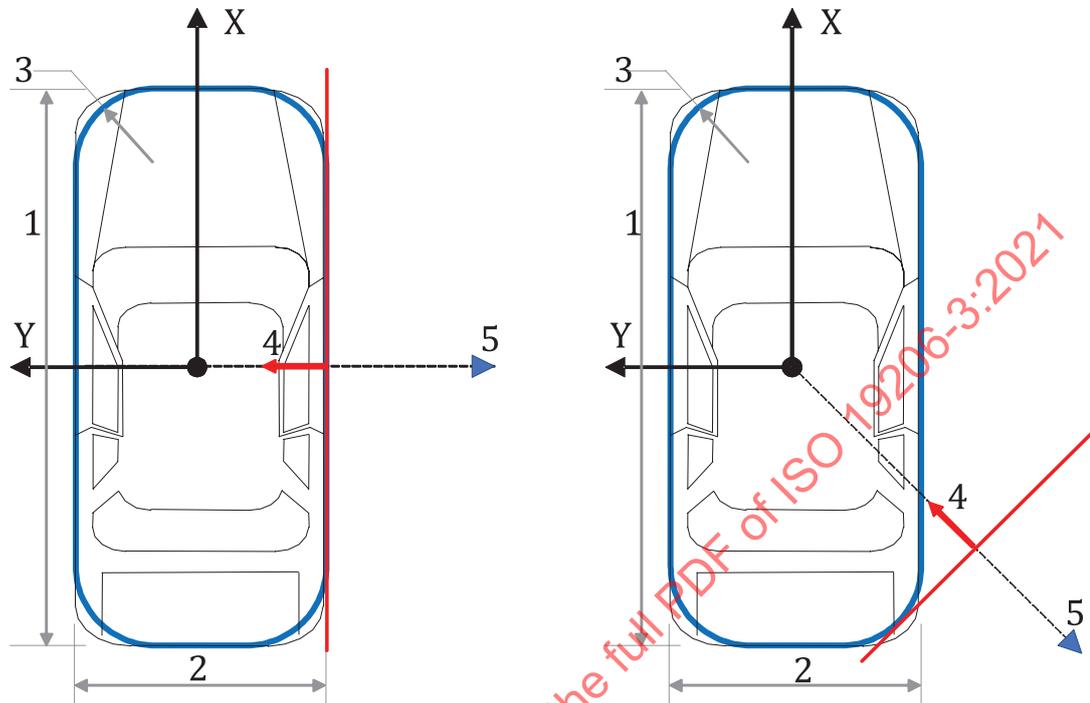
Figure C.11 — Example spatial RCS in vehicle coordinate system, sensor 1



NOTE The lower right case was measured only from 0° to 180° (left side).

Figure C.12 — Example spatial RCS in vehicle coordinate system, sensor 2

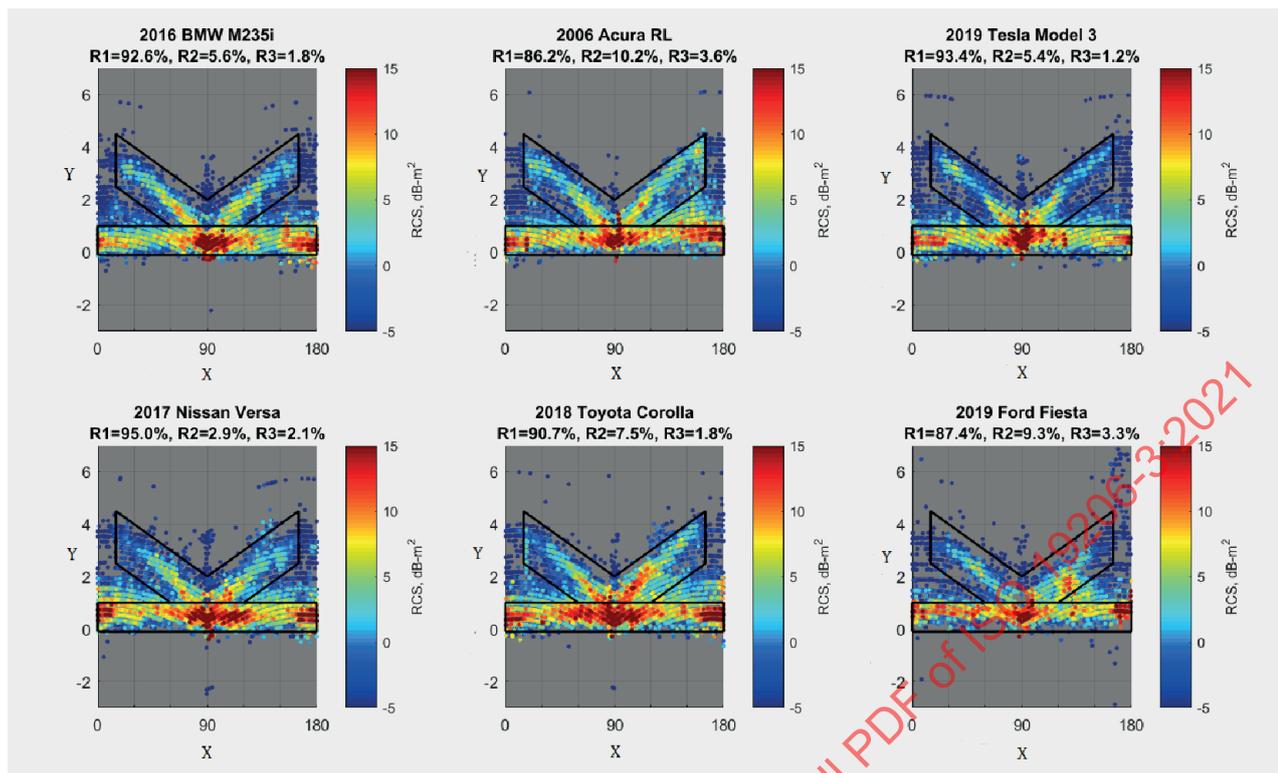
The penetration distance of each reflection into the vehicle is then calculated to be the distance beyond the orthogonal plane that intersects the nearest point on the vehicle, assuming a two-dimensional rectangular vehicle shape with rounded corners ($R = W/3$). Examples of the penetration distance, D_p , are shown in [Figure C.13](#).



Key

- 1 vehicle length, L_V
- 2 vehicle width, W_V
- 3 vehicle corner radius, $R_V (= W_V/3)$
- 4 penetration distance, D_p
- 5 radar sensor

Figure C.13 — Penetration distance example for viewing angle of -90° (left) and -135° (right)

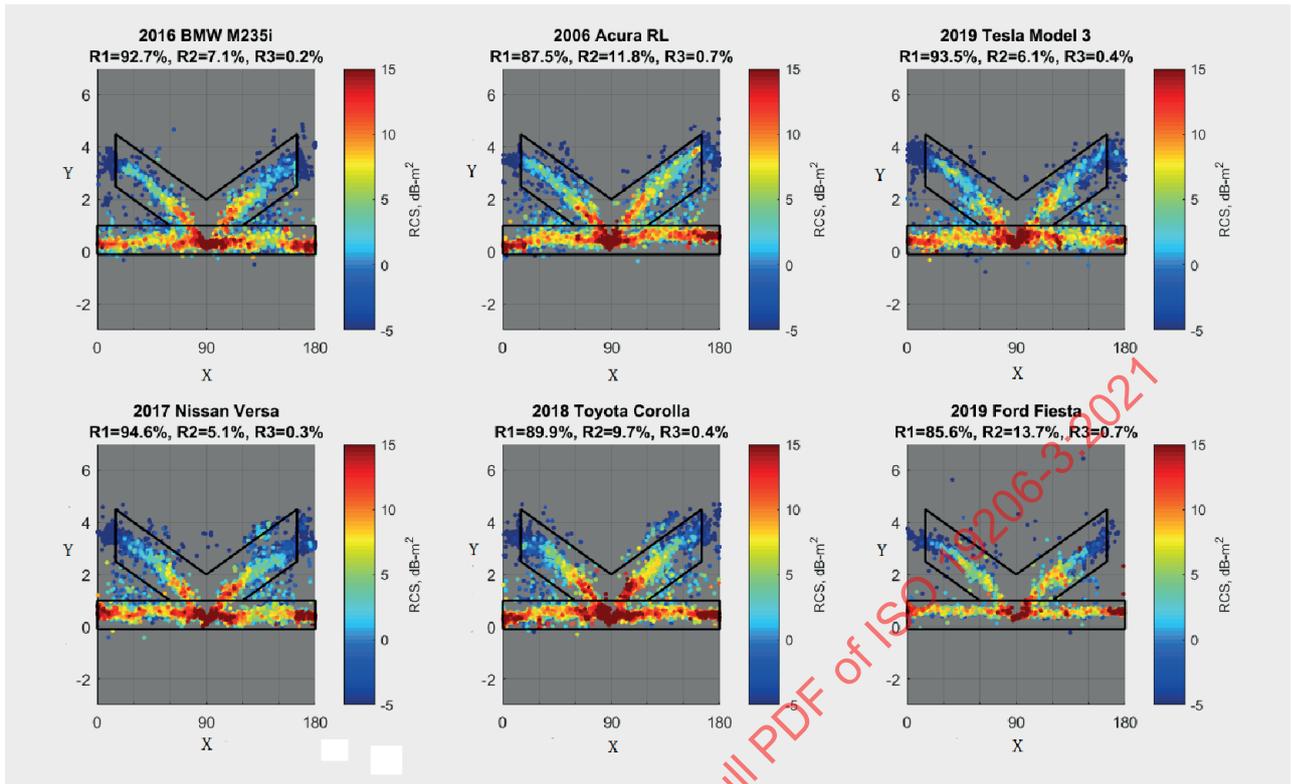


Key

- X viewing angle (°)
- Y penetration distance (m)

NOTE For explanation of vehicle regions (R1 to R3) and recommended values, see [Table C.4](#) and [Figure C.5](#).

Figure C.14 — Spatial RCS using angle-penetration method for six passenger vehicles, sensor 1



Key

X viewing angle (°)

Y penetration distance (m)

NOTE For explanation of vehicle regions (R1 to R3) and recommended values, see [Table C.4](#) and [Figure C.5](#).

Figure C.15 — Spatial RCS using angle-penetration method for six passenger vehicles, sensor 2

C.3.3.2 Scenario 2 — Fixed-angle scans

The purpose of the fixed-angle scan is primarily to characterize the overall magnitude reduction in reflectivity that occurs as a sensor approaches an object (i.e. not local interference). This reduction is caused by a combination of factors that include VT reflectivity distribution and sensor field of view.

Since the reflectivity magnitude has already been characterized by the fixed-range measurements, the fixed-angle measurement only needs to be performed at specific viewing angles.

The fixed-angle measurements shall be performed based on the following guidelines:

- static VT with moving vehicle or measurement fixture;
- measurement range: 5 m to 100 m;
- maximum sensor speed is determined such that there are at least 5 measurement samples per meter.

The necessary sensor speed (v) to achieve this can be calculated according to [Formula \(C.4\)](#):

$$v \leq 1/n\tau$$

(C.4)

where

ISO 19206-3:2021(E)

n is the number of samples per meter (i.e. 5 samples/meter);

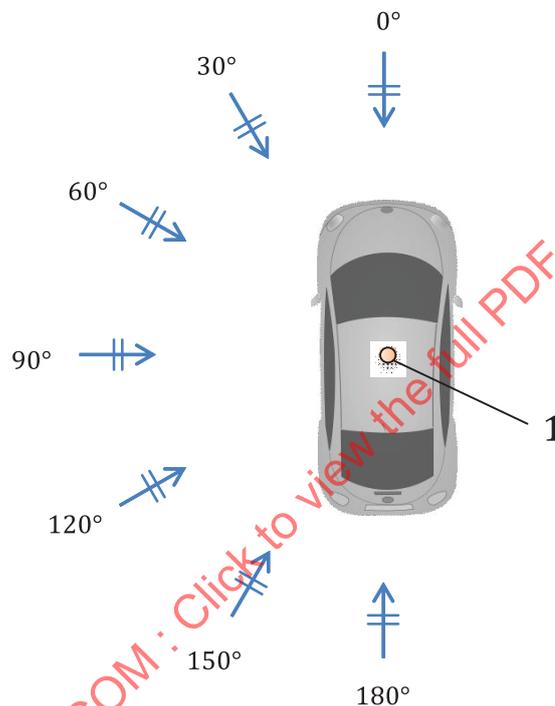
τ is the time (seconds) between sensor measurements.

Measurement viewing angle of 0°, 30°, 60°, 90°, 120°, 150°, and 180° shall be used (VT facing direction relative to sensor, see [Figure C.16](#)).

Perform three measurements for each viewing angle.

In order to reduce the multi-path effect, each measurement shall be taken at a different sensor height of 230 mm ± 10 mm, 480 mm ± 10 mm, and 900 mm ± 10 mm.

The sensor outputs with the largest RCS should be filtered using a low pass averaging window (± 2,5 m) across the approaches.



Key

1 target reference point

Figure C.16 — Fixed-angle measurement viewing angles

Objects that are above ground level will experience some level of multi-path interference. To ensure the target does not look like a ground-level object, the following procedure should be used to ensure there is some level of variability in the RCS measurement of the target, indicating that there are reflections coming from above ground level.

For each of the three fixed-angle measurements, a linear regression model in the least-square sense of the RCS depending on the distance shall be calculated based on unfiltered sensor output data between 50 and 100 m. The root mean squared error of the RCS values to this model should be between 2 dBm² and 6 dBm² for each viewing angle.

[Figures C.17](#) and [C.18](#) show the results of the fixed-angle measurements for six passenger vehicles using two different vehicle radar sensors.