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Technical Bulletin

Global Vehicle Target Specification

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1 INTRODUCTION

Based on the outcome of the several Global Harmonization workshops organized by Euro NCAP, the National Highway Traffic Safety Administration (NHTSA), and the Insurance Institute for Highway Safety (IIHS), as well as the pre-studies from Dynamic Research, Inc. the following specification defines a 3-dimensional vehicle target called the Global Vehicle Target (GVT).

The Euro NCAP AEB C2C & LSS Test Protocols require the use of the Global Vehicle Target (GVT).

This document provides the technical specification for the GVT, which is designed to be an accurate surrogate for a passenger vehicle from almost any horizontal direction and in almost any conflict scenario while minimizing the potential for damage to the vehicle under test (VUT) and to minimize the risk to the VUT occupants.

All targets used for official Euro NCAP tests will meet these requirements, which are verified by the lab at the start of a test series.

1.1 Abbreviations

GVT	Global Vehicle Target
IR	Infrared
LiDAR	Light Detection And Ranging
LPRV	Low Profile Robotic Vehicle
PMD	Photonic Mixer Device
RADAR	Radio Detection And Ranging
RAM	Radar Absorbing Material
RCS	Radar Cross Section
VUT	Vehicle under test

2 VEHICLE TARGET

The GVT shall be comprised of representative vehicle attributes relevant to the target detection sensors used in the VUT. The required sensor-relevant GVT attributes for a system test are determined by the vehicle manufacturer and must be implemented in the manner specified in this document. The GVT must be detectable by following automotive sensors technologies: RADAR, Video, LiDAR, PMD, and IR.

1.1 Vehicle Target Features

The GVT representing a vehicle, whose purpose is to activate sensor systems, consists of a target structure and optionally a target carrier, representing a vehicle having the necessary features to be recognised from any direction (3D vehicle target).

and shall be lightweight and flexible so as to minimize the load imparted to the VUT body panels in the event of a collision. The GVT should also have radar-reflective and infrared-reflective materials that meet the specifications in sections 1.3 and 0.

The GVT shall provide a safe mounting location for a GPS antenna within the structure such that the radar reflective (i.e., metallic) fabric of the GVT does not interfere with the GPS satellite reception required by the robotic platform responsible for supporting, and moving when appropriate, the GVT during a VUT evaluation.

Figure 1: Global Vehicle Target

1.2 Vehicle Target Dimensions

The dimensions of the GVT provided in Tables 1 and 2 are shown in Figures 2 and 3, respectively. Note that the vertical measurements are based on a typical ground clearance of the motion platform of 20 mm.

Table 1: GVT Longitudinal and Vertical Dimensions

No.	Description	Dimension	Tolerance
1	Overall length	4023 mm	± 50 mm
2	Front ground clearance	173 mm	± 25 mm
3	Front skin height	488 mm	± 25 mm
4*	Hood height	290 mm	± 25 mm
5	Side ground clearance	185 mm	± 25 mm
6	Rear ground clearance	323 mm	± 25 mm
7	Overall height	1427 mm	± 50 mm
8	Tire diameter	607 mm	± 10 mm
9*	Front skin angle	6.4 deg	± 2.0 deg
10*	Rear skin angle	1.0 deg	± 0.5 deg
11	Hood length	792 mm	± 25 mm
12*	Side mirror position	1140 mm	± 25 mm
13	Side mirror length	229 mm	± 10 mm
14	Side mirror clearance	892 mm	± 25 mm
15	Side mirror height	132 mm	± 10 mm
16	Wheelbase	2565 mm	± 50 mm

* Optional reference measurements

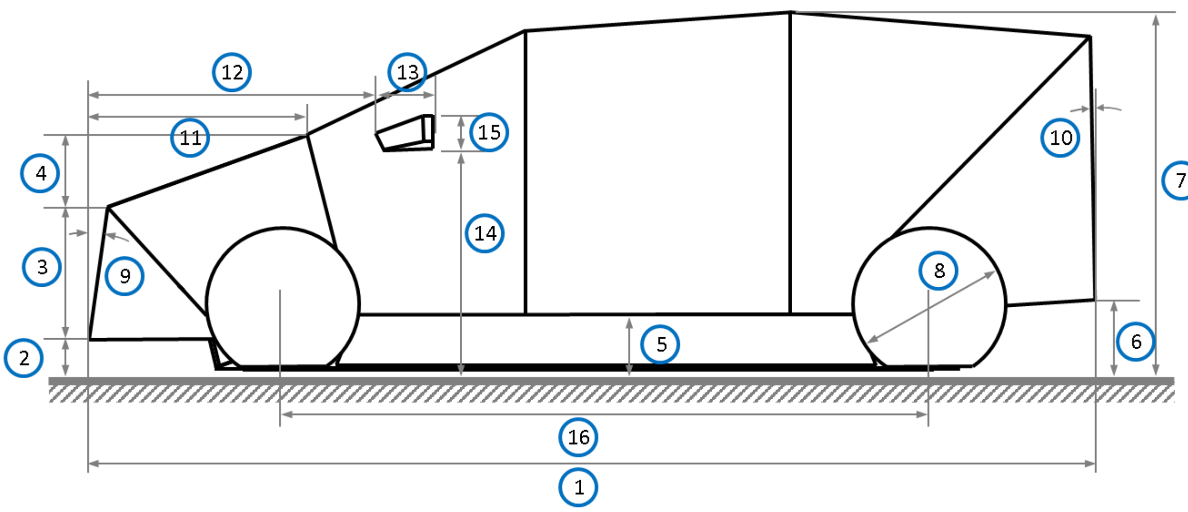

Figure 2: GVT Longitudinal and Vertical Dimensions

Table 2: GVT Lateral Dimensions

No.	Description	Dimension	Tolerance
1	Overall width (excluding mirrors)	1712 mm	± 50 mm
2	Roof width	1128 mm	± 50 mm
3	Overall width (including mirrors)	1798 mm	± 50 mm
4	Tire Width	206 mm	± 10 mm

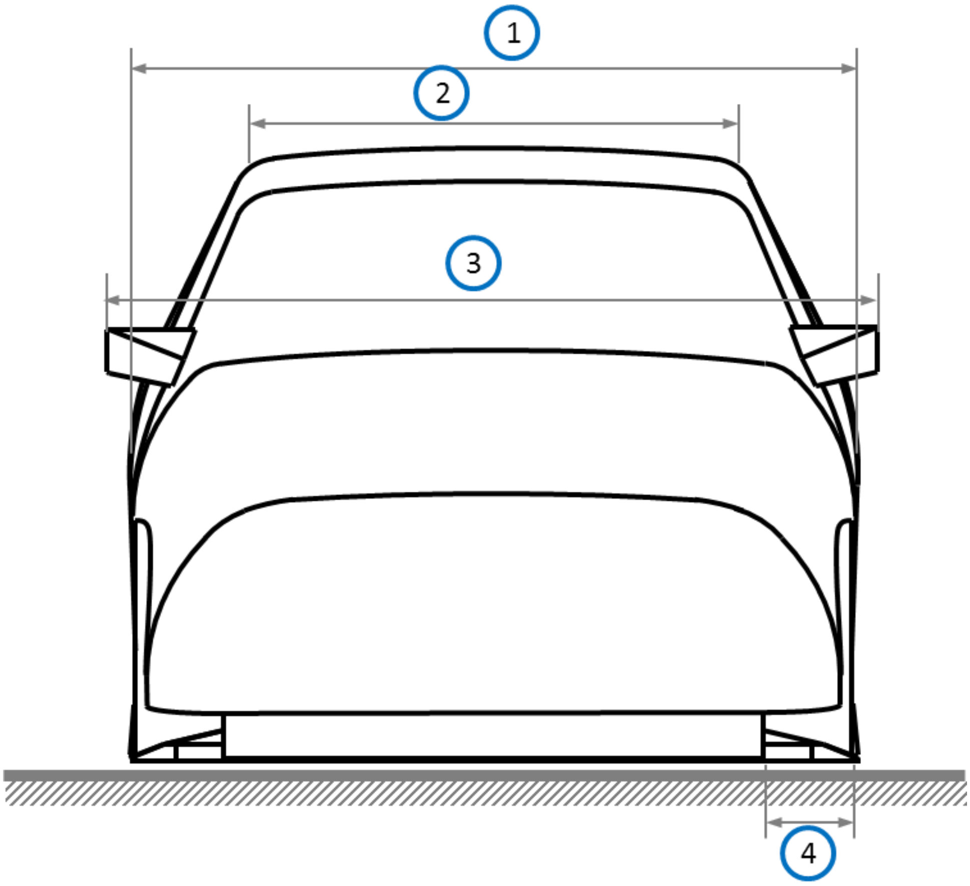

Figure 3: GVT Lateral Dimensions

1.3 Visible and Infrared Properties

Dimensionally, and from the perceptive of the sensors installed in the VUT, the GVT shall be representative of a white hatchback passenger vehicle. The IR reflectivity of the GVT surfaces, specified in Table 3, shall be in the wavelength range of 850 to 910 nm. Each of the visual areas of interest, as indicated in Figure 4, shall be measured in accordance with the procedure outlined in Appendix A1.

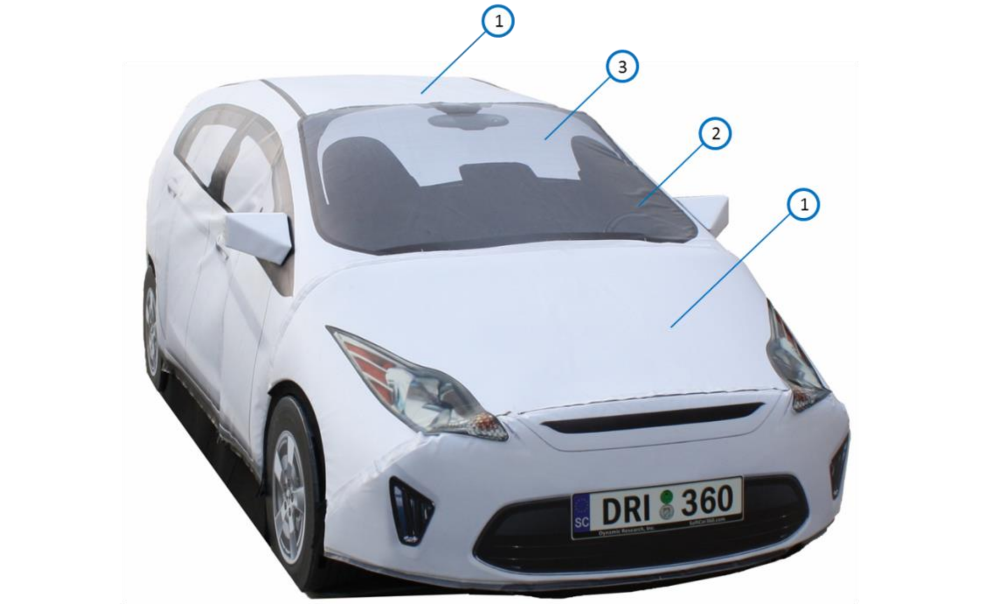

Figure 4: IR Areas of Interest

Table 3: IR Reflectivity

No.	Area of Interest	IR Reflectivity
1	White Vinyl (no graphics)	> 70%
2	Windshield, dark area	40% - 70%
3	Windshield, light area	> 70%
4	Side Mirror Face[(1)]	> 70%
5	Side Panel[(1)]	> 70%
6	Side Windows	> 70%
7	Tire, wall and tread[(1)]	10% - 40%
8	Rear bumper, black	< 10%
9	Rear window, light area	> 70%
10	Black fabric (RAM skirts, wheel wells)	< 10%

Note 1: Most of these objects have large variation in graphics. IR reflectivity should be averaged over many sampled areas.

1.4 Radar Properties

The radar reflectivity characteristics of the GVT shall be similar to a passenger vehicle of the same size.

1.4.1 Radar Cross Section (RCS)

The radar cross section 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. The method of measuring the GVT RCS is described in Appendix A2.

1.5 Mounting and Guidance System

Provisions must be made to ensure the GVT is fully supported and at the correct vertical height. Providing sufficient support is particularly critical for the wheel blocks which are relatively heavy and are located at the corners of the GVT footprint. In general, the following guidelines should be followed.

- All visible parts of the motion platform should be colored in grey.
- It must be ensured that the GVT mounting does not influence radar return. Where needed, RAM skirts shall be used to ensure the radar reflections from the motion platform are minimized.
- Reproducible positioning of the GVT is achieved by aligning the GVT with the motion platform mounting locations to within 2 cm.

1.6 Vehicle Target Weight and Collision Stability

- Maximum relative velocity of the VUT into the GVT: 120 km/h, (to prevent damage to the VUT).
- Maximum GVT weight: approximately 110 kg
- The GVT must continue to meet the specified requirements after repeated collisions.

APPENDIX

A1 Measurement of the IR reflectivity

The measurement of the GVT shall be made in accordance with the following procedure.

Required measurement equipment:

- A spectrometer capable of covering wavelengths from 850 to 910 nm, such as the Ocean Optics Flame-S-XR1 spectrometer (shown in Figure A1) or the Jaz Miniaturspektrometer,
- A light source
- A 45-degree probe
- A calibration standard

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

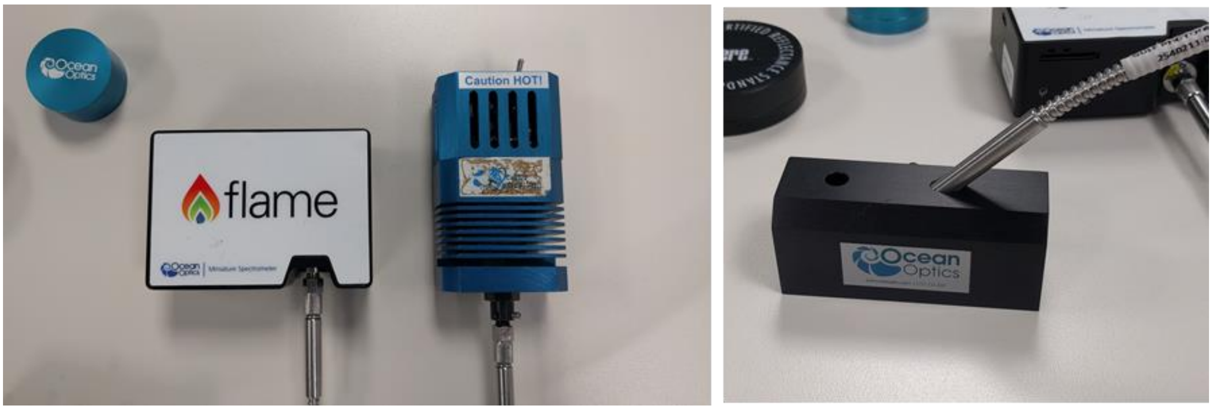

Figure A1. IR Measurement Equipment

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 910 nm.

Figure A2 and Figure A3 show the averaged results for the various areas of interest, which are listed in Table 3 (previously shown in Section 1.3).

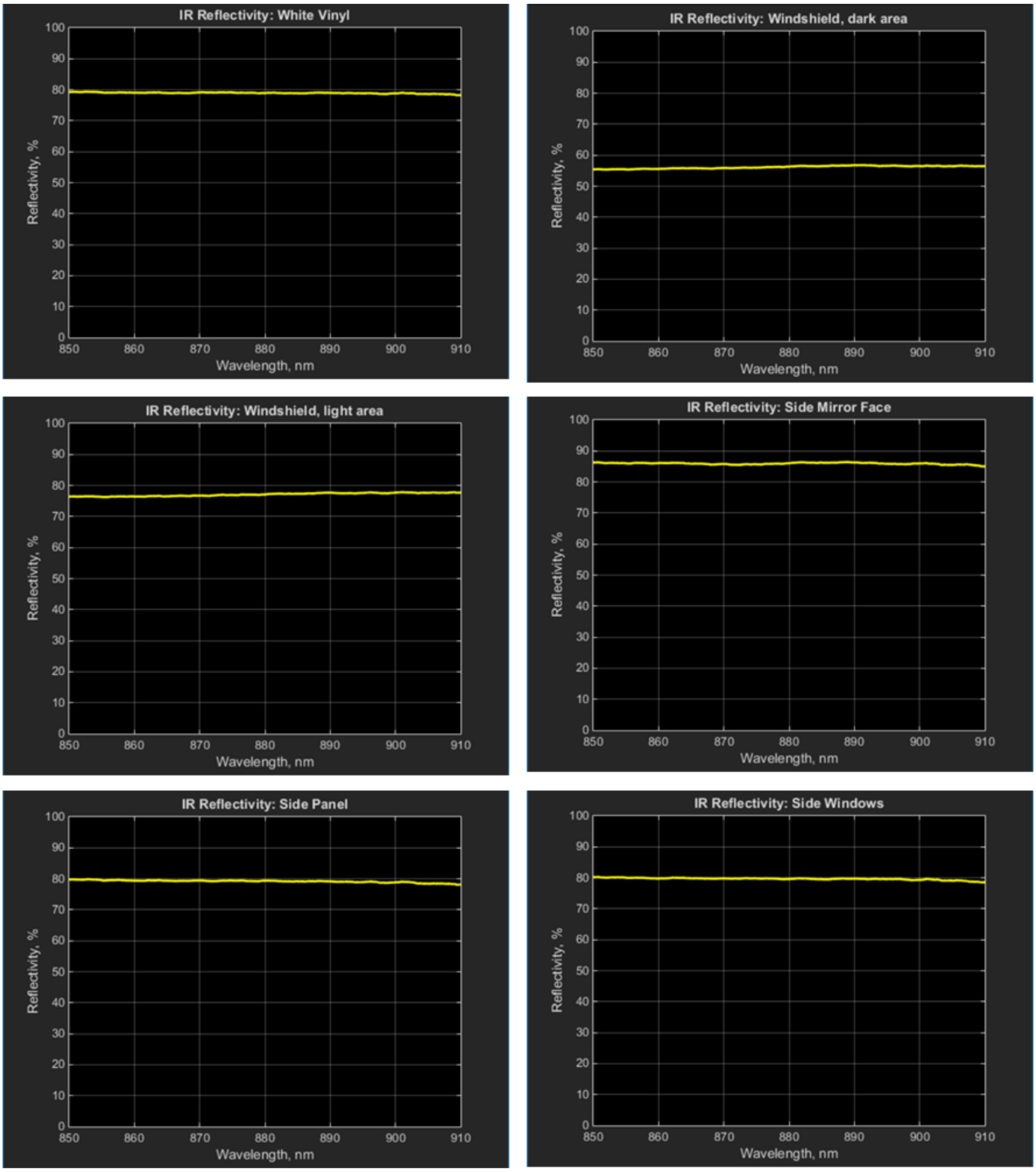

Figure A2. Example IR Measurements (1-6)

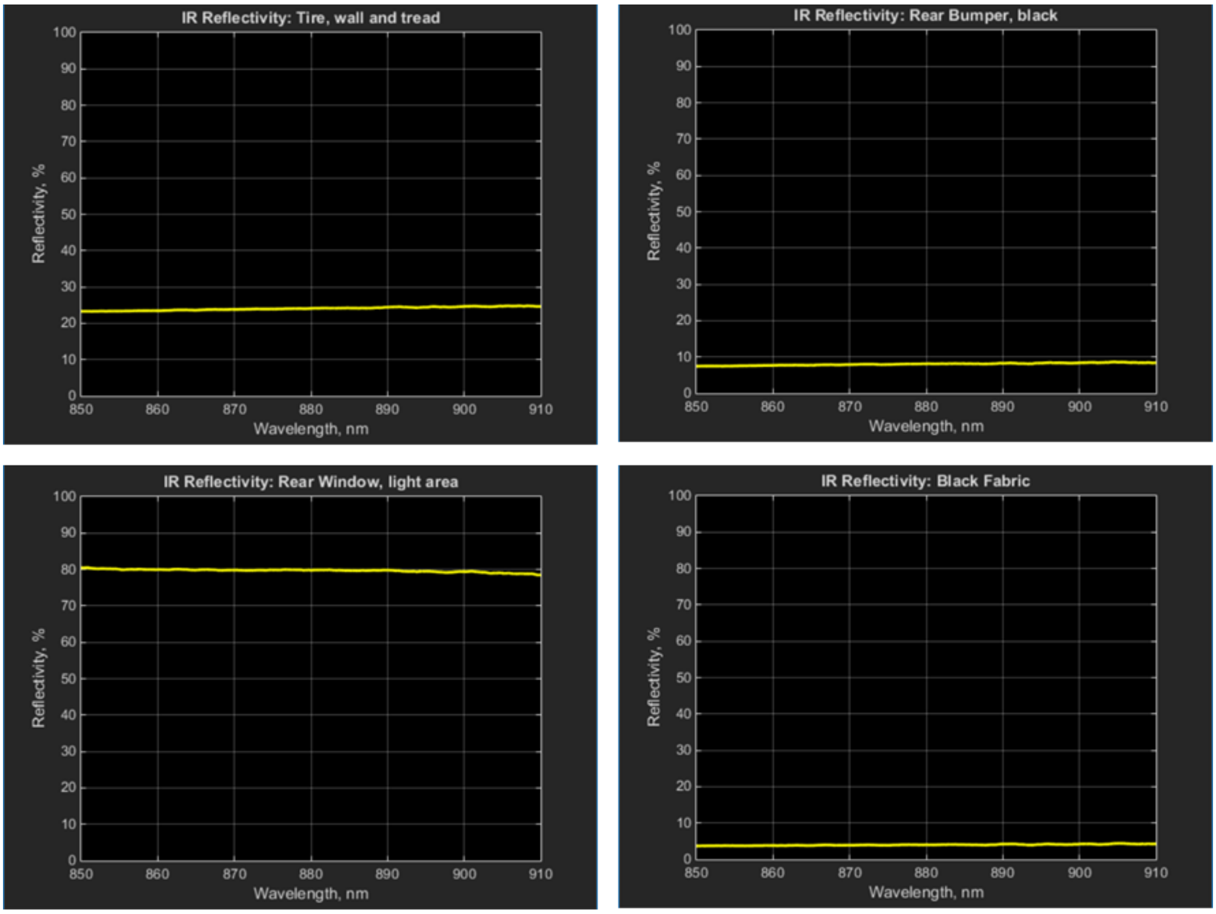

Figure A3. Example IR Measurements (7-10)

A2 Measurement of Radar Reflectivity

Measuring RCS at a fixed distance can produce misleading results because the sensor might be experiencing either cancellation or amplification due to the multi-path effect. Therefore, it is necessary to measure RCS by moving the sensor towards the object, such that the sensor will be moving into and out of the cancellation and amplification regions. Also, to reproduce the effect of decreasing RCS at close range, the radar reflectivity of the GVT must be distributed over the whole body causing the RCS to decrease at shorter distances due to partial visibility of the GVT by the sensor. The method of measuring the GVT RCS is described in Appendix A2.

The instantaneous measured RCS of a vehicle or target can experience cancellation due to the radar multi-path effect at various ranges. These cancellation regions will result in very low RCS relative to the typical RCS at certain distances (see examples in Appendix A3). Reducing the lower RCS boundary to account for these cancellation regions could allow for a target with a low average RCS to be deemed acceptable. Therefore, the RCS of the GVT is specified using a curve fit to the measured RCS data as a function of range, as well as tolerance bounds on the curve fit.

The RCS curve fit characterizes both the far-field RCS and the near-field RCS which, as noted above, decreases with range. The form of the curve fit RCS, as shown in Figure 4, is:

$$RCS_{FIT} = RCS_{FAR} - K_{DEC} \text{ x } \min(R - R_{FAR}, 0)^2 \qquad \text{where } K_{DEC} \geq 0$$

The RCS curve fit is calculated by determining the parameters, RCS_{FAR} and K_{DEC}, such that the sum of the square of errors between the RCS curve fit and the raw RCS data is minimized. The parameter R_{FAR} is dependent on several factors, including the sensor parameters. For this analysis it is assumed to be fixed for a given sensor.

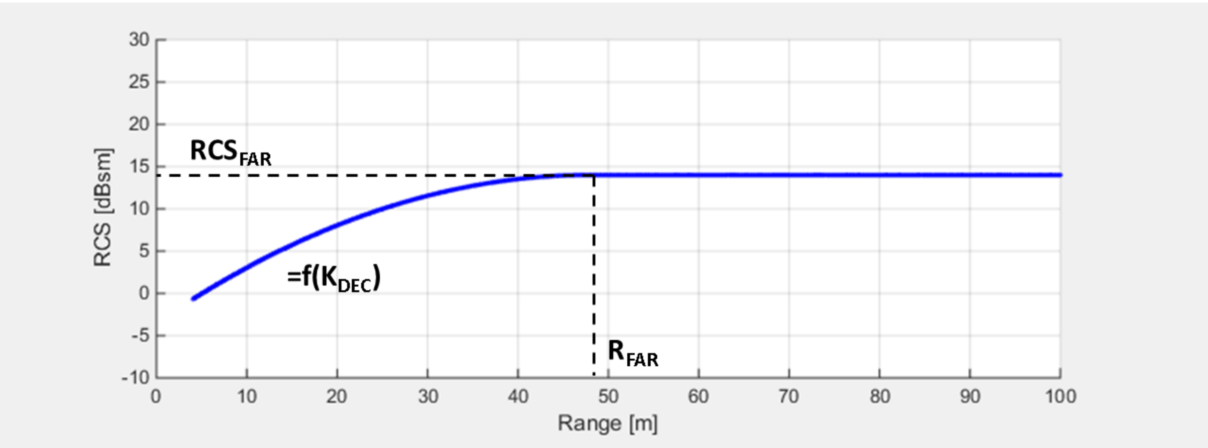

Figure 4: Form of the Average RCS Curve

The RCS curve fit of the GVT should stay within a defined range, defined by upper and lower bounds. For the GVT, the equations defining the bounds are given below for a Bosch LRR3 sensor and a Continental ARS 408-21 sensor, using the calibration and measurement methods described in Appendix A2.

$RCS_{BOUNDS,BOSCH} = 16 - 0.004 \times \min(R - 48,0)^2 \pm 6$ for the Bosch sensor

$RCS_{BOUNDS,CONTI} = 16 - 0.015 \times \min(R - 34,0)^2 \pm 6$ for the Continental sensor

A slightly different definition must be made for each frequency and sensor variant since the RCS reduction at close range is a function of the sensor parameters.

Depicted in Figure 6 are the RCS boundaries for measurements with these two commercially available 77 GHz sensors. If other sensors are used or the mounting position deviates from that described in Appendix A2 or the test surface differs from the description in this appendix, other RCS values may be obtained. In that case an additional verification/adaption of the boundaries (Figure 6) may be necessary for validation of the GVT. These boundaries are valid for a rear approach measurement from 180 degrees with 100% overlap.

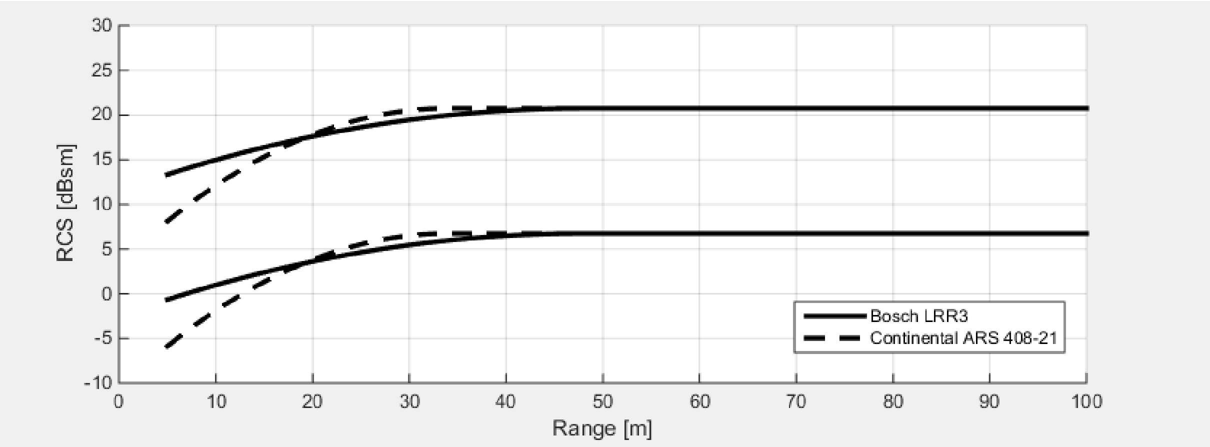

Figure 5: Vehicle target RCS boundaries for measurements at 77GHz

Radar reflectivity measurement of the GVT shall be made in accordance with the following procedure.

Recommended Measurement Setup

A reference measurement with a corner reflector calibrated to 10 dBsm is required. The corner reflector shall be positioned at a vertical height of 500 mm +/- 10mm. The average RCS, calculated as the median RCS in m^2 but reported in decibels per square-meter, shall be used to calculate the correction factor to be applied to the output of the sensor as needed.

Sensor Configuration and Orientation

- 77 GHz wavelength with performance similar to either of the following:
    - Bosch LRR3
    - Continental ARS 408-21
- Vertical height above the ground: 500 mm +/- 25mm
- Horizontal alignment: +/-1 deg to center line
- Vertical alignment: +/-1 deg to center line

Sensor Motion Device

The radar sensor shall be moved towards the object being measured (i.e., the corner reflector reference or GVT). The sensor may be attached to a vehicle or to a specialized measurement cart (e.g., like that shown in Figure A4). Alternatively, the GVT could be moved towards a static sensor, as long as the relative motion between the sensor and GVT is the same as the specified scenario. In any case, the requirements below are applicable:

- Angular deviation (relative to the direction of motion): <0.5 deg
- Positioning measurement accuracy (longitudinal/lateral): < 50 mm

Figure A4. Example Radar Measurement Cart

Vehicle Target

- Positioning accuracy (longitudinal/lateral): < 20 mm
- Angular orientation deviation (relative to direction of sensor motion): < 1 deg

Test Environment

- No additional objects/buildings in the area indicated as "Free space" in Figure A5
- Proving ground surface completely covered with tarmac, asphalt, or concrete and completely flat within 5m of the path of the sensor or GVT
- Ground conditions: flat and dry
- No metallic or other strong radar-reflecting parts within the area indicated as "Free space" in Figure A5

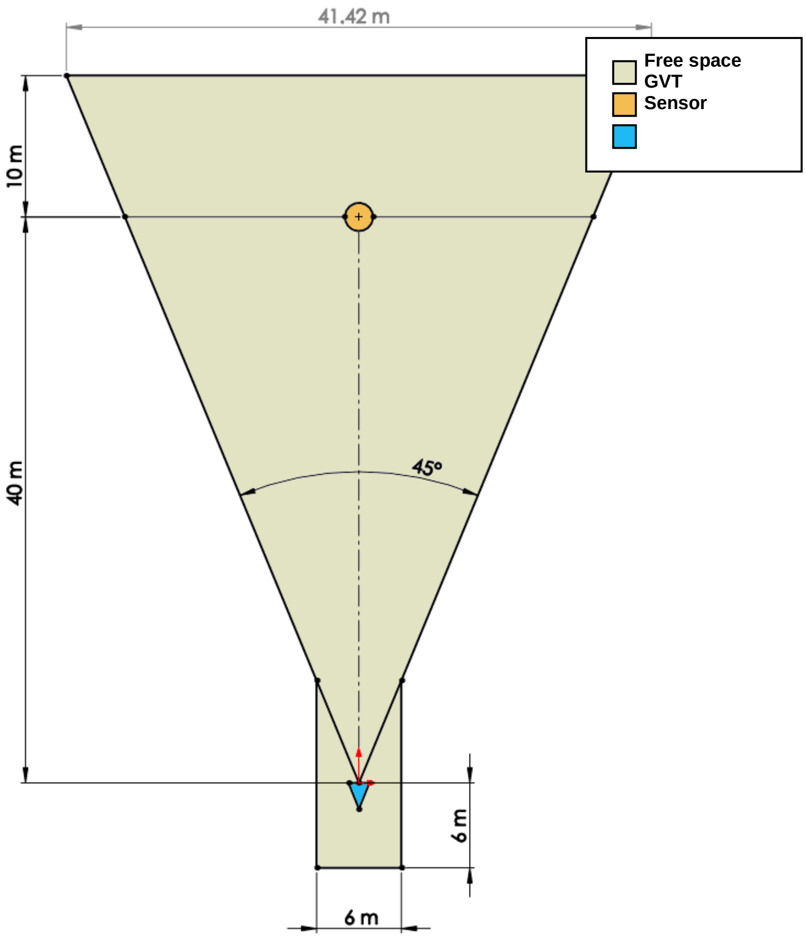

Figure A5: Test Environment

__Measurement Scenario__

- Static GVT with moving measurement device
- Initial distance: 100 m to 5m
- Approaching speed: 3-5 km/h
- Approach aspect: 180 deg (i.e., the sensor faces the rear of a static GVT)
- Perform 3 approaches

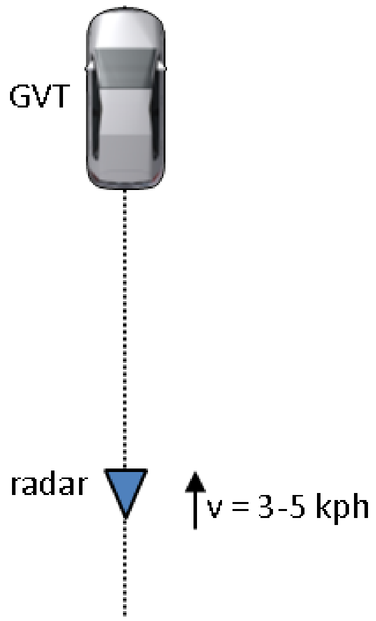

Figure A6: Measurement Scenario

Data Analysis

During each of the three approach measurements, the range and RCS of the GVT shall be recorded. The curve-fit RCS shall then be calculated by minimizing the sum-squared error, E_{SS}, between the raw RCS data and the curve-fit RCS. In other words, the parameters RCS_{FAR} and K_{DEC} shall be optimized to find the solution that minimizes the error term E_{SS}, where

$$E_{SS} = \sum(RCS_{AVG}(R) - RCS_{MEAS}(R))^2$$
$$RCS_{FIT}(R) = RCS_{FAR} - K_{DEC} \text{ x } \min(R - R_{FAR}, 0)^2 \qquad (K_{DEC} \geq 0)$$

Note: As a point of reference, the R_{FAR} values for the sensors previously described in **Sensor Configuration and Orientation** are as follows:

- Bosch LRR3: 48 m
- Continental ARS 408-21 : 34 m

A3 RCS Measurement Examples

The example data in this appendix were measured during the GVT Familiarization event, hosted by Thatcham Research in Upper Heyford, United Kingdom on 12-13 April 2018.

Figure A7 provides an RCS measurement example of the calibration measurement (10 dBsm trihedral) for the Bosch LRR3 and Continental ARS 408-21 sensors. The depicted data has been scaled based on the known RCS of the measured object.

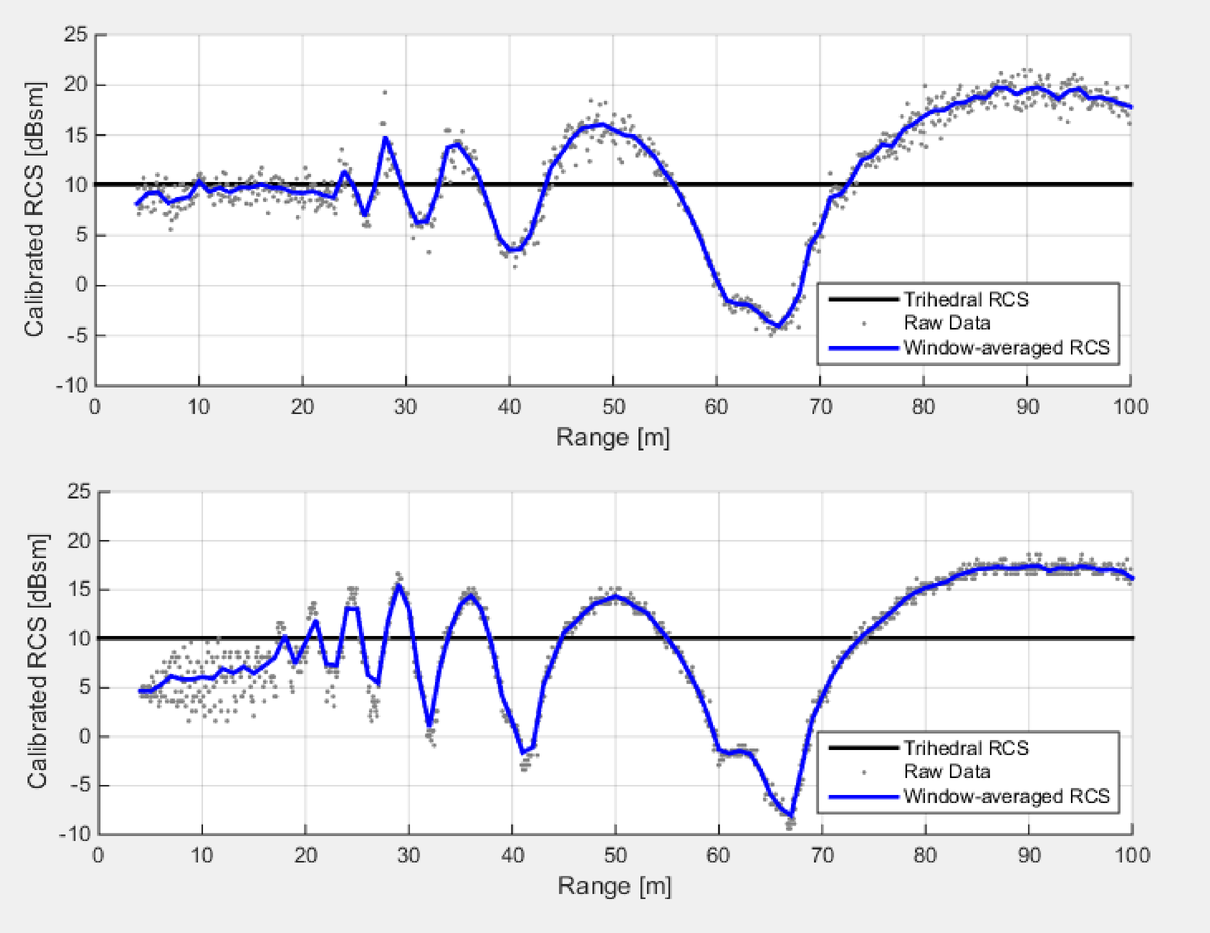

Figure A7: Example RCS measurement of trihedral calibration object using the Bosch (top) and Continental (bottom) sensors

Figures A8 through A10 provide RCS measurement examples for the GVT using the evaluation methodology defined in Appendix A2 for the Bosch LRR3 and Continental ARS 408-21 sensors, respectively. The raw data depicted in the figures below were captured during three measurement scenarios.

Figure A8 provides an example RCS measurement of the GVT on a robotic platform. Figure A9 provides an example RCS measurement of the GVT on a foam stand used for static test scenarios. Figure A10 provides an example RCS measurement of the previous version (Revision E) GVT with a Retrofit Kit. The Retrofit Kit is designed to ensure the radar characteristics of the Revision E GVT are similar to the latest GVT.

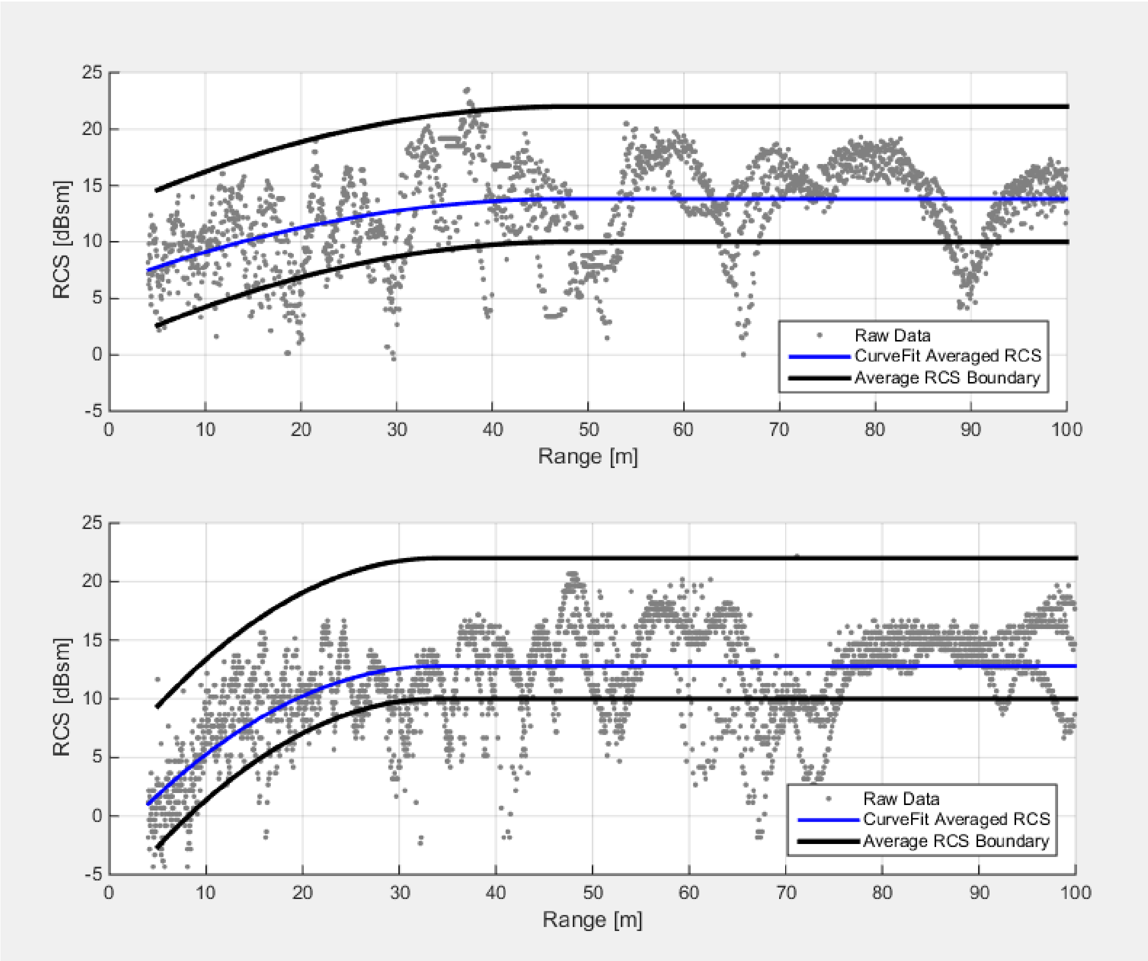

Figure A8: Example RCS measurement of GVT on Platform using the Bosch (top) and Continental (bottom) sensors

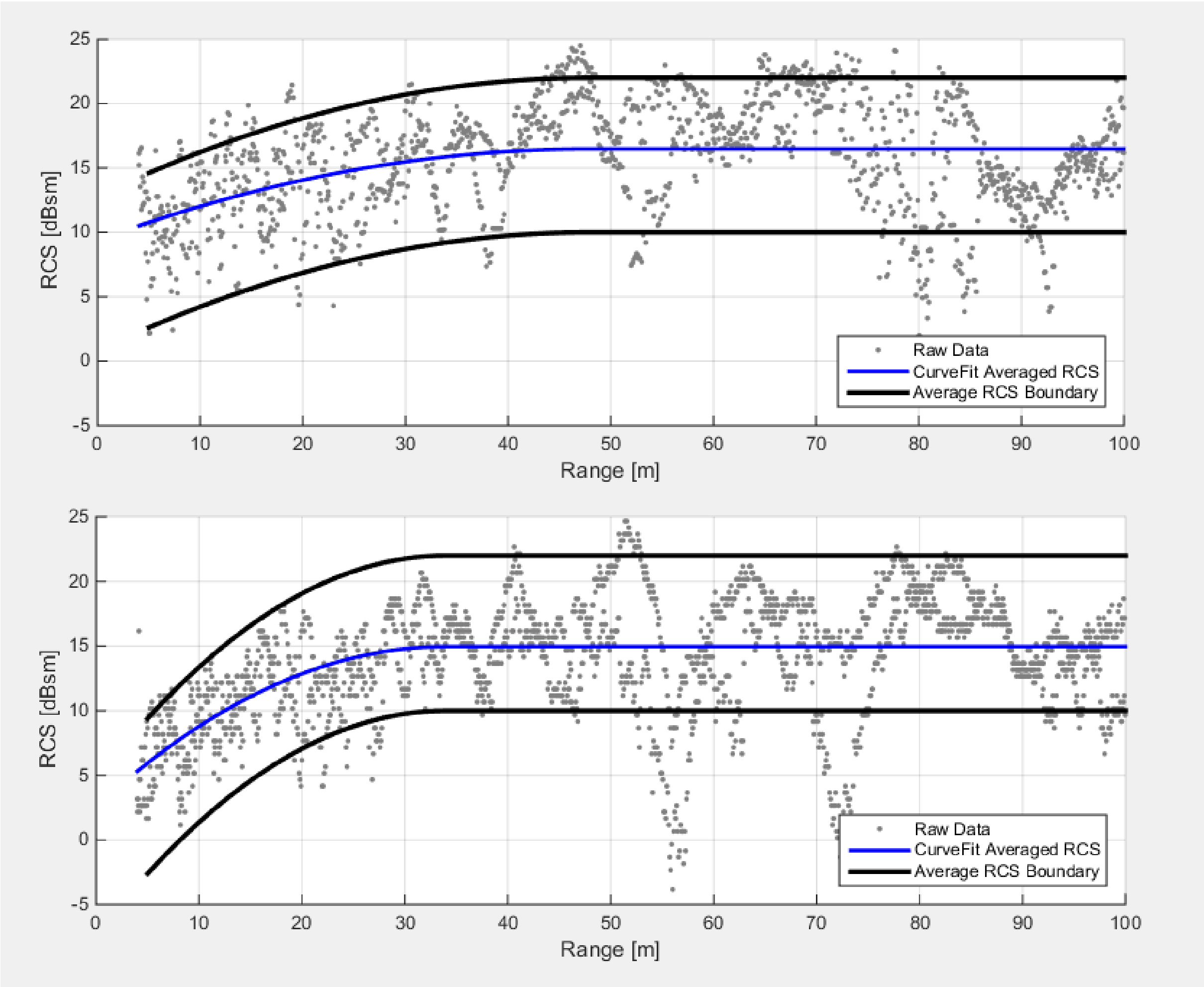

Figure A9: Example RCS measurement of GVT on Foam Stand using the Bosch (top) and Continental (bottom) sensors

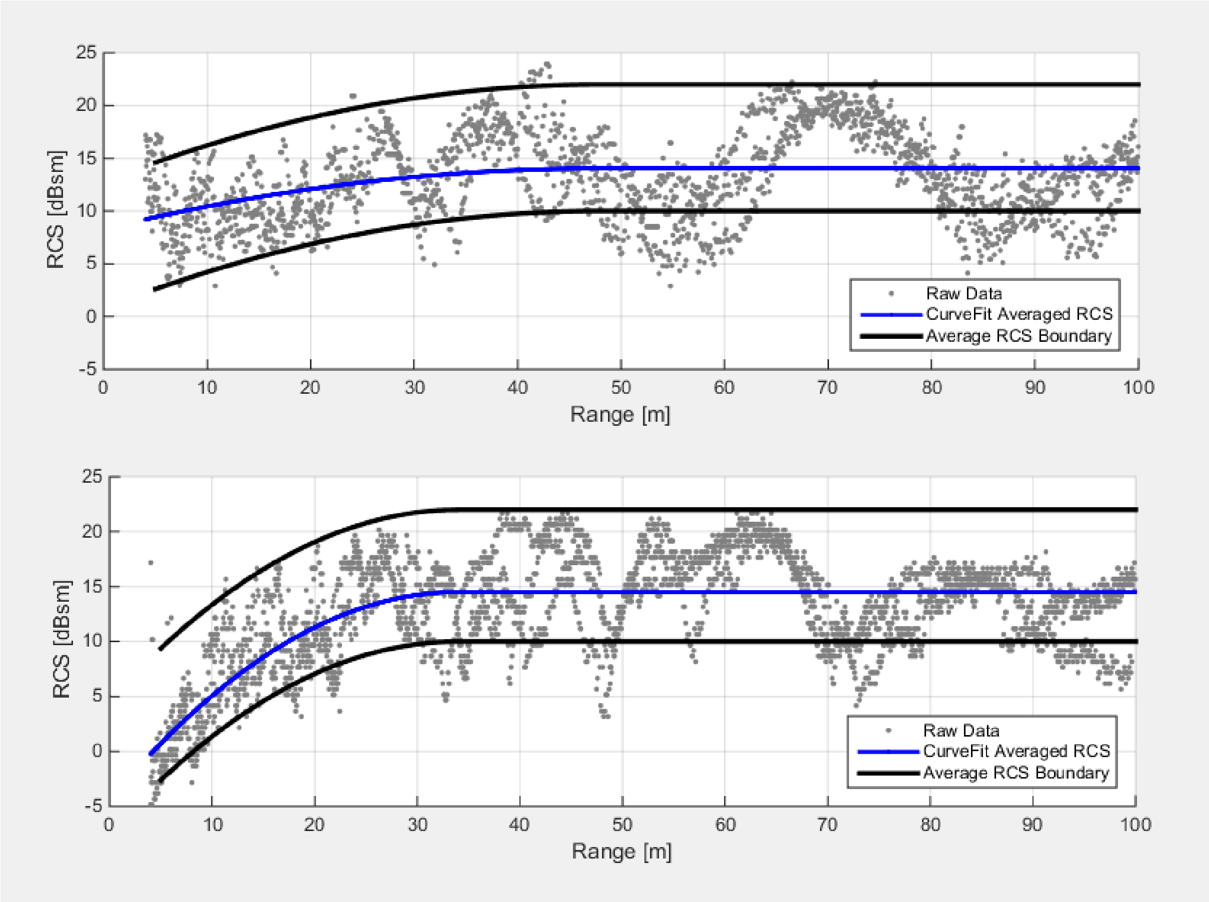

Figure A10: Example RCS measurement of GVT (Revision E with Retrofit Kit) on Platform using the Bosch (top) and Continental (bottom) sensors