RITA Intelligent Transportation Systems Joint Program Office

Cooperative Intersection Collision Avoidance System Limited to Stop Sign and Traffic Signal Violations (CICAS-V)

Task 11

Final Report Objective Tests

(Appendix H-2)

September 30, 2008

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16. Abstract

The objective of the Cooperative Intersection Collision Avoidance System for Violations (CICAS-V) Project is to develop and field-test a comprehensive system to reduce the number of crashes at intersections due to violations of traffic control devices (TCDs; i.e., traffic lights and stop signs). The CICAS-V system provides a salient and timely in-vehicle warning to drivers who are predicted to violate a TCD, with the aim of compelling the driver to stop. This report presents the results of the objective testing of the intersection and vehicle components of the CICAS-V system. This includes the experimental data and the evaluations conducted to determine the FOT readiness of the CICAS-V system. The analysis indicated that the system passed the objective tests and is FOT-ready.

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List of Acronyms

ANSI	American National Standards Institute
ATIS	Advanced Traveler Information System
C2C	Center to Center
CAMP	Crash Avoidance Metrics Partnership
CAN	Controller Area Network. Wired network system common in newer model vehicles.
CICAS	Cooperative Intersection Collision Avoidance System
CICAS-V	Cooperative Intersection Collision Avoidance System for Violations
ConOps	Concept of Operations
DFD	Data Flow Diagrams
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
DVI	Driver-Vehicle Interface
ESS	Environmental Sensor Stations
ETMCC	External Traffic Management Center Communication
FHWA	Federal Highway Administration
FOT	Field Operational Test
GID	Geometric Intersection Description
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HMI	Human-Machine Interface
ID	Identification or Identifier
IEEE	Institute of Electrical and Electronics Engineers
IGN	Ignition
ISO	International Standards Organization
ITS	Intelligent Transportation Systems
LRMS	Location Referencing Message Specification
MS/ETMCC	Message Sets for External Traffic Management Center Communications
NDGPS	Nationwide Differential Global Positioning System
NHTSA	National Highway Traffic Safety Administration
NMEA	National Marine Electronics Association, Inc.
NTCIP	National Transportation Communications for ITS Protocol
OBE	On-board Equipment
OEM	Original Equipment Manufacturer

POC	Proof of Concept
RSE	Roadside Equipment
RTCM	Radio Technical Commission for Maritime Services
SAE	SAE International, an organization formerly known as Society for Automotive Engineers
SPaT	Signal Phase and Timing
SWC	Single Wire CAN
TCIP	Transit Communications Interface Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TIA	Telecommunications Industry Association
TMDD	Traffic Management Data Dictionary
USDOT	United States Department of Transportation
UTC	Coordinated Universal Time
UUID	Universal Unique Identifier
VAN	Vehicle Area Network
VII	Vehicle Infrastructure Integration
VSC2	Vehicle Safety Communications 2
WAAS	Wide Area Augmentation System
WAV/MP3	Audio file formats
WAVE	Wireless Access in Vehicular Environments
WSA	WAVE Service Announcement

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Executive Summary

This report presents the results from the objective tests conducted in Task 11 of the CICAS-V project. The tests were performed at Virginia Tech Transportation Institute's Smart Road test facility during July 15 through July 17, 2008.

The objective tests were developed in Task 7 of the CICAS-V project and were agreed to by the USDOT prior to conducting the objective tests. The purpose of the task was two-fold:

- To test whether the system performed according to the specifications and determine readiness for a large-scale Field Operational Test (FOT). In the Statement of Work (SOW), the go-ahead decision for continuing with an FOT was largely based on the outcome of the objective tests.
- To refine the objective test procedures, incorporating lessons learned from the objective tests.

The objective test consisted of 12 tests and contained multiple runs. The test procedures are listed in the following table.

Table ES-1: Summary of Objective Tests

Name	Purpose	Section	Kind
Signalized Various Speed Approaches Test	Test whether warning distance is as specified for signalized intersections and given vehicle speed	3.1	Objective Requirement Warning
Edge of Approach Testing for Warning	Test whether expected warning is given when vehicle is driven on edge of lane	3.2	Objective Requirement Warning
Edge of Approach Testing for Nuisance Warning	Test whether nuisance warnings are avoided when vehicle is driven on edge of lane	3.3	Objective Requirement Nuisance
Late Lane Shift Test – Warning	Test whether expected warning is given when shifting from green lane into red lane after red lane's warning distance passed	3.4	Objective Requirement Warning
Late Lane Shift Test – Nuisance Warning	Test whether nuisance warning is avoided when shifting from red lane into green lane before red lane's warning distance passed	3.5	Objective Requirement Nuisance
Multiple Intersections within 300m Radius: Warning Case	Test whether warning appropriate warning is given for approaching intersection in presence of multiple nearby intersections	3.6	Objective Requirement Warning
Multiple Intersections within 300m Radius: No Warning Case	Test whether warning is avoided when approaching intersection in presence of multiple nearby intersections	3.7	Objective Requirement Warning
Dynamic Signal Change to Yellow, Too Late to Warn	Test whether warning is avoided on signal change from green to yellow when red arrives after the stop bar	3.8	Objective Requirement Nuisance
Dynamic Signal to Red, In Time for Warning	Test whether expected warning is given on signal change from green to yellow when red occurs before vehicle passes stop bar.	3.9	Objective Requirement Warning
Dynamic Signal to Green, No Warning Case	Test whether warning is avoided when signal change from red to green before the warning distance	3.10	Objective Requirement Nuisance
Stop Sign Various Approach Speeds Test	Test whether warning distance is as specified for stop sign intersections and given vehicle speed	4.1	Objective Requirement Warning
SPaT Reflection and Reception	Tests the system performance / system limits when line of sight between intersection and vehicle is obscured by another vehicle	3.11	Engineering Test

The objective tests were conducted on the Virginia Tech Transportation Institute Smart Road in Blacksburg, VA. The Smart Road includes a signalized intersection with signal phases and timing that can be accurately controlled. The intersection had four approach roads with several approach lanes of which one was used for the tests. The technical team created a GID for the intersection that was used in all the tests. The vehicles utilized for conducting the objective tests were VTTI's Cadillac STS test vehicles which were also used in Task 3.4 for the Pilot FOT. A Tractor-Trailer combination was used as the lead vehicle in the SPaT Reflection and Reception test.

The conditions for the objective tests were:

- A procedure could contain multiple tests
- Each test had to have at least 8 successful runs (intersection approaches)
- A test was judged to have passed if 6 out of 8 runs passed based on the pass/fail criteria for the individual test, e.g., warning came within the expected range
- A test run was judged successful if the validity criteria were fulfilled (e.g., speed was within the allowed range, sufficient packets from the alternate intersection were received at the point where a warning was going to be issued, etc.)

During the objective tests the same set of data was collected as in the Pilot FOT with the addition of the high precision GPS data and the video images of the icon state. The data was used to analyze the test results and to determine whether the system passed or failed the individual test.

The test personnel included:

- A driver, not affiliated with the project
- An observer to protocol the test and observe the outcome
- A government witness from either NHTSA or Volpe
- Additional personnel to perform specific tasks in the vehicle such as changing the signal or determine the distance from a leading vehicle.

The objective tests procedures consisted of 15 individual tests with a pass/fail criteria (120 valid runs) and one engineering test without a pass/fail criteria (8 valid runs).

The CICAS-V system failed one run at the variable speed signalized intersection approach test (55 mph approach speed). During the run, the brake pulse did not engage even though the other DVI modalities performed correctly.

The outcome of the objective tests is that the CICAS-V is performing as well or better than originally specified and that the system is FOT ready.

1 Introduction

1.1 Background

This document presents the Task 11 Final Report for the Cooperative Intersection Collision Avoidance System Limited to Stop Sign and Traffic Signal Violations (CICAS-V) Project. The period covered by the report is from December 1, 2007 through September 30, 2008.

1.1.1 Project Description

The CICAS-V Project's objective was to develop a cooperative intersection collision avoidance system to assist drivers in avoiding crashes in the intersection by warning the driver of an impending violation of a traffic signal or a stop sign. Cooperative means that the system involves both infrastructure and in-vehicle elements working together. The Vehicle Safety Communications 2 Consortium (VSC2) is executing the project under Federal Highway Administration (FHWA) Cooperative Agreement No. DTFH61-01-X-00014, Work Order W-05-001. Members of VSC2 are Ford Motor Company, General Motors Corporation, Honda R & D Americas, Inc., Mercedes-Benz Research & Development North America, Inc. and Toyota Motor Engineering & Manufacturing North America, Inc. Funding for this project is provided from the Joint Program Office of the United States Department of Transportation (U.S. DOT). The project is also supported by Virginia Tech University (Virginia Tech), who plays a major role in the research to define and evaluate the CICAS-V warning system. The work at Virginia Tech is being conducted through its research group at the Virginia Tech Transportation Institute (VTTI).

1.1.2 Purpose for Implementing the System

The purpose of implementing CICAS-V is to reduce crashes due to violation of traffic control devices (both traffic signals and stop signs).

When deployed, this system is intended to:

- Reduce fatalities at controlled intersections
- Reduce the number of injuries at controlled intersections
- Reduce the severity of injuries at controlled intersections
- Reduce property damage associated with collisions at controlled intersections
- Create an enabling environment that additional technologies can leverage to further extend safety benefits

Each year about 5,000 fatal crashes occur in intersections with traffic signals or stop signs (National Highway Traffic Safety Administration, 2005 [1]). About 44% occur at traffic signals and 56% at stop signs. About 400,000 injury crashes occur at those intersections each year. About 600,000 property damage crashes also occur at those intersections annually.

An initial analysis of relevant National Highway Traffic Safety Administration (NHTSA) crash databases shows that violation crashes have a variety of causal factors. The

CICAS-V system is intended to address the causal factors that include driver distraction (a frequent factor cited by Campbell, Smith and Najm, 2004, p. 65 [2]), obstructed/limited visibility due to weather or intersection geometry or other vehicles, the presence of a new control device not previously known to the driver, and driver judgment errors. Driver warnings, such as those planned for CICAS-V, may prevent many violation-related crashes by alerting the distracted driver, thus increasing the likelihood that the driver will stop the vehicle and avoid the crash.

1.1.3 System Goals and Objectives

CICAS-V is intended to provide a cooperative vehicle and infrastructure system that prevents crashes at intersections by warning the vehicle driver that a violation, at an intersection controlled by a stop sign or by traffic signal, is about to occur. The basic concept of CICAS-V is illustrated at a high level in Figure 1 for a signalized intersection. In the figure, a CICAS-V equipped vehicle approaching a CICAS-V equipped intersection receives messages about the intersection geometry and status of the traffic signal. The driver is issued a warning if the equipment in the vehicle determines that, given current operating conditions, the driver is predicted to violate the signal in a manner which is likely to result in the vehicle entering the intersection. While the system may not prevent all crashes through such warnings, it is expected that, with an effective warning, the number of traffic control device violations will decrease, and result in a decrease in the number and severity of crashes at controlled intersections.

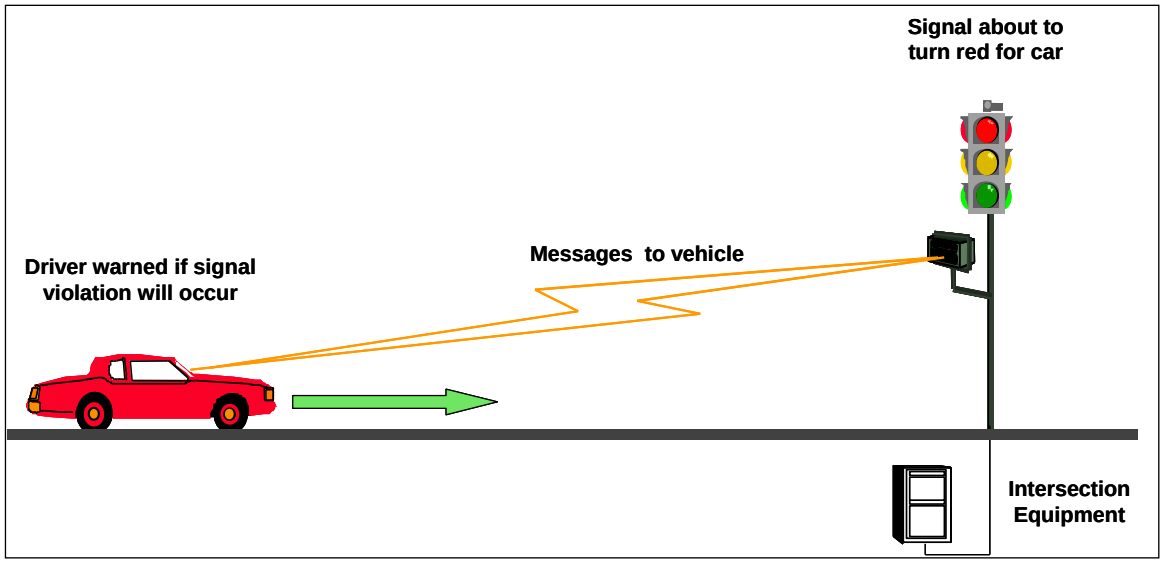

Figure 1: Basic Concept of the CICAS-V System at a Signalized Intersection

Specific goals of CICAS-V include the establishment of:

- A warning system that will be effective at reducing the number of fatal crashes, the severity of injuries and property damage at CICAS-V intersections
- A warning system that is acceptable to users
- A vehicle-infrastructure cooperative system that helps vehicle drivers avoid crashes due to violations of a traffic signal or stop sign
- A system that is deployable throughout the United States

1.2 Purpose

In Task 11 the objective test procedures defined in Task 7 [5] were executed and the results were evaluated. The purpose of the objective tests was to determine if the CICAS-V system is ready for a Field Operational Test (FOT). The observations during the objective tests were also used to improve the test procedures to come to a final set of objective test procedures that can be used to reliably evaluate future CICAS-V systems.

1.3 Scope

The testing is performed according to CICAS-V objective test procedures [5]. The objective test procedures present the test conditions, test results, and the evaluation of those results.

1.4 Organization

Section 2 collects all the test conditions common to all tests. Any deviations from these conditions are noted in the test-specific sections.

Section 3 covers the testing performed at signalized intersections. It is composed of eleven subsections, each of which is devoted to one test of the CICAS-V system operation at signalized intersections. Each subsection briefly summarizes the main intention and the approach of the test (in Subsection 3.x.1), while the test set-up and

procedures are described in detail in [5]. Subsection 3.x.2 notes any deviations in test conditions from Section 2. The validity of the test is analyzed in Subsection 3.x.4. The pass/fail evaluation is performed in Subsection 3.x.5. Any improvements to the test procedure of the subsection's test are detailed in Subsection 3.x.6.

Section 4 covers the testing performed at the stop-sign-controlled intersections. There is only one test in the section covered by Subsection 4.1. The subsection is organized like the subsections of Section 3.

2 General Test Conditions

The test conditions for all tests were recorded by test observers in [6]. That document was transcribed into [7]. The following subsections summarize the recorded conditions and highlights conditions that remained constant throughout testing. Any conditions that differ from those described here are addressed in the sections devoted to specific tests.

2.1 Location and Conditions

All testing reported in this document was performed at the Virginia Tech Transportation Institute's Smart Road test facility [8], [9]. The Smart Road contains a four-way, signalized intersection with multiple approach lanes for the main direction that was used for the tests. The testing started on July 15 and ended on July 17, 2008. All tests were performed during daylight hours. Weather conditions were sunny and dry for all the tests.

2.2 Driver

The same driver was used for all the tests. The driver was not affiliated with the project and was briefed on the operation of the CICAS-V system and instructed to follow the instructions given by [5].

2.3 Difficulties with Test Procedure

2.3.1 GID Inaccuracies

Preparatory testing found that GID maps for the test site were inaccurate. These inaccuracies manifested themselves in the differences between the position data reported relative to GID defined lanes and the vehicle video data, visual observations, and manual measurements of vehicle position relative to the actual painted lane markings. Laterally, inaccuracies were found in the order of 00.65 m where the GID is shifted to the Northeast.. There is also note about this condition in the test procedures [5]. This includes a decision to use visual observations by test observers and cameras instead of the GID-relative position data in tests where the distance to the lane edge is a test validity criteria (as in Subsections 3.2 and 3.3 in this report).

3 Signalized Intersections Tests, Conditions and Results

This subsection details tests performed at the signalized intersection. It consists of one subsection for each test performed. Tests performed at the stop-sign intersection are covered by Section 4.

3.1 Various Speed Approaches Test

3.1.1 Scenario Overview

In this test for each test run, the test vehicle travels down the middle lane at a constant speed toward the intersection which is signaling red to all approaches (Figure 2). The main aim is to test the warning operation of the CICAS-V system in a simple scenario across a range of vehicle speeds. The test set-up and procedure are specified in detail in [5] under the corresponding test heading. It calls for eight test runs at each of 55 mi/h, 35 mi/h, and 25 mi/h. The green area in Figure 2 shows the interval between the yellow flag and the checkered flag where an alert has to be issued for the test to pass. If an alert is issued outside this interval (red area), the system will not pass the test.

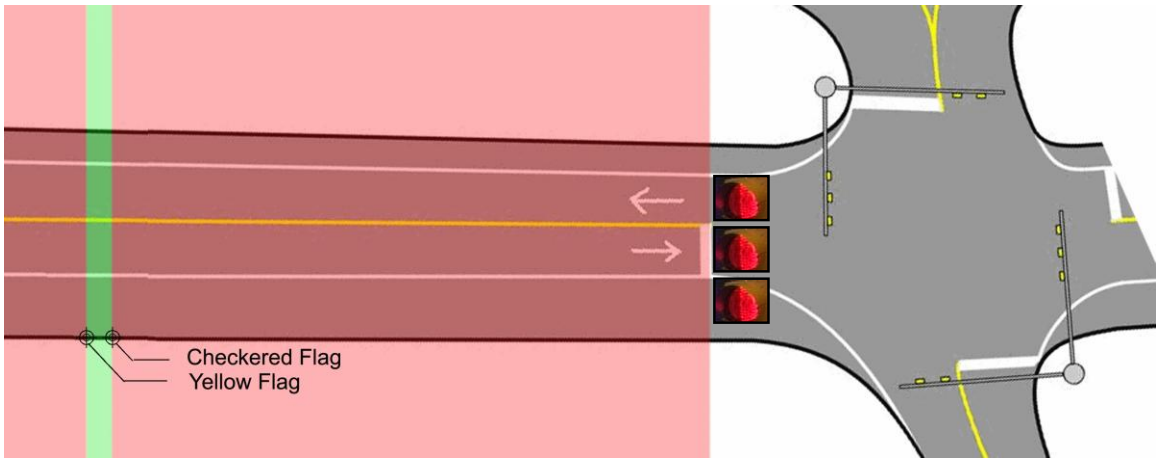

Figure 2: Various Speed Approaches, Test Setup

3.1.2 Conditions

There were no deviations from the general test conditions detailed in Section 2.

Although 8 runs are specified for each test speed in this test, sometimes more than 8 runs were performed per test speed in order to reduce the chance of having to return to this test in case of some invalid test runs. Since none of the test runs in this test were found to be invalid, only the first 8 runs are needed for official pass/fail determination for the overall test and any additional test runs are shown here only for reference.

3.1.3 Results

The data collected during this test was stored in the files listed in Table 1.

Table 1: Test Data Files for Signalized Various Speed Approaches Test

Speed (mi/h)	Result File Name	Description	Created By
55	ACI4_0301_0000_AA_080716_1410.txt	signal values	DAS
	ACI4_0301_0000_AA_080716_1410.avi	video	DAS
35	ACI4_0302_0000_AA_080716_1429.txt	signal values	DAS
	ACI4_0302_0000_AA_080716_1429.avi	video	DAS
25	ACI4_0303_0000_AA_080716_1449.txt	signal values	DAS
	ACI4_0303_0000_AA_080716_1449.avi	video	DAS

This data was analyzed to determine test validity (Subsection 3.1.4) and pass/fail evaluation (Subsection 3.1.5).

3.1.4 Validity

All the values relevant in validity determinations, and the results of those determinations, are presented via Table 2 through Table 4. The validity limits used in those tables (orange columns excluding the first four columns) are taken from [5]. The relevant sections from [5] are noted in the table headings.

Table 2: Validity Check Table, Various Speed Approaches Test, 55 mph

Run	Extents			Speed (2.6.1)								GST_Error_Ellipse (2.6.1)				PDOP (2.6.1)			Satellites (2.6.1)		
	Start (Equip.) frame	(Warn.) frame	End frame	Valid Min. mi/h	Nom. mi/h	Max. mi/h	Min. km/h	Max. km/h	Rec. Min. km/h	Rec. Max. km/h	Eval. Valid?	Valid Max. m	Rec. Min. m	Rec. Max. m	Eval. Valid?	Valid Max. m	Rec. Max. m	Eval. Valid?	Valid Min.	Rec. Min.	Eval. Valid?
1	136182	136338	136338	52.5	55.0	57.5	84.5	92.5	87.6	88.2	valid	1.5	1.1	1.2	valid	5.0	2.4	valid	5	7	valid
2	140034	140193	140193	52.5	55.0	57.5	84.5	92.5	87.8	88.4	valid	1.5	1.1	1.1	valid	5.0	2.3	valid	5	7	valid
3	143733	143892	143892	52.5	55.0	57.5	84.5	92.5	87.0	87.7	valid	1.5	1.1	1.1	valid	5.0	2.3	valid	5	7	valid
4	147054	147210	147210	52.5	55.0	57.5	84.5	92.5	87.7	88.3	valid	1.5	1.1	1.1	valid	5.0	2.3	valid	5	7	valid
5	151707	151872	151872	52.5	55.0	57.5	84.5	92.5	86.0	86.8	valid	1.5	1.1	1.1	valid	5.0	2.2	valid	5	7	valid
6	154809	154962	154962	52.5	55.0	57.5	84.5	92.5	89.1	89.4	valid	1.5	1.1	1.1	valid	5.0	2.2	valid	5	7	valid
7	158370	158529	158529	52.5	55.0	57.5	84.5	92.5	87.6	88.4	valid	1.5	1.1	1.2	valid	5.0	2.1	valid	5	6	valid
8	161511	161670	161670	52.5	55.0	57.5	84.5	92.5	88.3	89.0	valid	1.5	1	1.1	valid	5.0	2.1	valid	5	7	valid
9	164814	164973	164973	52.5	55.0	57.5	84.5	92.5	87.3	88.0	valid	1.5	1	1.1	valid	5.0	2.1	valid	5	6	valid

Table 3: Validity Check Table, Various Speed Approaches Test, 35 mph

Run	Extents			Speed (2.6.1)								GST_Error_Ellipse (2.6.1)				PDOP (2.6.1)			Satellites (2.6.1)		
	Start (Equip.) frame	Mid (Warn.) frame	End (Equip.) frame	Valid Min. mi/h	Nom. mi/h	Max. mi/h	Min. km/h	Max. km/h	Rec. Min. km/h	Rec. Max. km/h	Eval. Valid?	Valid Max. m	Rec. Min. m	Rec. Max. m	Eval. Valid?	Valid Max. m	Rec. Max. m	Eval. Valid?	Valid Min.	Rec. Min.	Eval. Valid?
1	170844	171177	171327	32.5	35.0	37.5	52.3	60.3	59.5	59.9	valid	1.5	0.5	0.5	valid	5.0	2	valid	5	6	valid
2	174282	174645	174795	32.5	35.0	37.5	52.3	60.3	56.1	56.9	valid	1.5	0.4	0.4	valid	5.0	2	valid	5	6	valid
3	177540	177912	178062	32.5	35.0	37.5	52.3	60.3	55.1	55.9	valid	1.5	0.3	0.3	valid	5.0	2	valid	5	6	valid
4	180864	181230	181380	32.5	35.0	37.5	52.3	60.3	55.5	56.3	valid	1.5	0.3	0.3	valid	5.0	2.2	valid	5	6	valid
5	183864	184224	184374	32.5	35.0	37.5	52.3	60.3	56.1	57.0	valid	1.5	0.3	0.3	valid	5.0	2.2	valid	5	6	valid
6	186867	187227	187377	32.5	35.0	37.5	52.3	60.3	56.4	56.8	valid	1.5	0.2	0.2	valid	5.0	2.2	valid	5	6	valid
7	189900	190275	190425	32.5	35.0	37.5	52.3	60.3	54.6	55.4	valid	1.5	0.2	0.2	valid	5.0	2.2	valid	5	6	valid
8	193014	193377	193524	32.5	35.0	37.5	52.3	60.3	55.2	56.6	valid	1.5	0.2	0.2	valid	5.0	2.2	valid	5	6	valid
9	196122	196482	196632	32.5	35.0	37.5	52.3	60.3	55.5	56.8	valid	1.5	0.2	0.2	valid	5.0	2.2	valid	5	6	valid

Table 4: Validity Check Table, Various Speed Approaches Test, 25 mph

Run	Extents			Speed (S. 2.6.1)							GST_Error_Ellipse (2.6.1				PDOP (2.6.1)			Satellites (2.6.1)		
	Start		End	Valid					Rec.		Eval.	Valid	Rec.		Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.
	(Equip.) frame	(Warn.) frame	(Equip.) frame	Min.	Nom. mi/h	Max.	Min.	Max. km/h	Min. km/h	Max.	Valid?	Max. m	Min. m	Max. m	Valid?	Max.	Max.	Valid?	Min.	Min.	Valid?
1	207204	207762	207912	22.5	25.0	27.5	36.2	44.2	40.4	40.9	valid	1.5	0.9	1.1	valid	5.0	2.2	valid	5	6	valid
2	210795	211359	211509	22.5	25.0	27.5	36.2	44.2	39.7	40.5	valid	1.5	0.7	0.7	valid	5.0	2.2	valid	5	6	valid
3	214599	215184	215334	22.5	25.0	27.5	36.2	44.2	38.5	39.3	valid	1.5	0.5	0.5	valid	5.0	2.2	valid	5	6	valid
4	218148	218733	218883	22.5	25.0	27.5	36.2	44.2	38.5	39.3	valid	1.5	0.4	0.4	valid	5.0	2.2	valid	5	6	valid
5	221466	222045	222195	22.5	25.0	27.5	36.2	44.2	39.1	39.8	valid	1.5	0.4	0.4	valid	5.0	2.2	valid	5	6	valid
6	224808	225384	225531	22.5	25.0	27.5	36.2	44.2	38.8	39.6	valid	1.5	0.3	0.3	valid	5.0	2.2	valid	5	6	valid
7	228645	229224	229374	22.5	25.0	27.5	36.2	44.2	39.1	39.7	valid	1.5	0.3	0.3	valid	5.0	2.2	valid	5	6	valid
8	231954	232533	232683	22.5	25.0	27.5	36.2	44.2	39.1	39.7	valid	1.5	0.3	0.3	valid	5.0	1.8	valid	5	6	valid

Parts of those tables are manually entered based on inspecting the test results data while otherwise those tables are automatically filled by scripts running on the test results data. The manual entry is typically marked in this report by orange background and automatic calculation by blue foreground.

In the tables, "Rec." stands for "as recorded during testing" and is to be compared against the valid limits from [5] which appear in the corresponding "Valid" column. The abbreviations "Min.," "Nom.," and "Max." take their usual meaning of "Minimum," "Nominal," and "Maximum." "Eval" stands for "Pass/fail evaluation."

Signals "OBE-Communication.Distance_to_Stop_Bar (meters)" and "OBE-Communication.DVIN_Icon_States (None)," from the DAS .txt results file are used to identify the limits of each test run's extents (the first set of three orange background columns in each table). Figure 3 is a graphical representation containing those signals for an example test run plotted against the video frame number (a larger version of it appears in 8.1.1 along with similar plots for all test runs in this test). At the start of each test run as the test vehicle starts toward the intersection, the vehicle is outside the range of the intersection. During that time Distance_to_Stop_Bar remains 0. When the vehicle enters the DSRC communication range, and the vehicle receives all the necessary messages, Distance_to_Stop_Bar changes from 0 to the current distance to the stop bar. At the same time DVIN_Icon_States changes from 0 (Standby) to 1 (Equipped). This point is considered to be the start of the range in which the test run validity is examined. The minimum extreme of the Figure 3 is determined by video frame at that moment. This frame number for all runs is presented in the second column of Table 2 through Table 4.

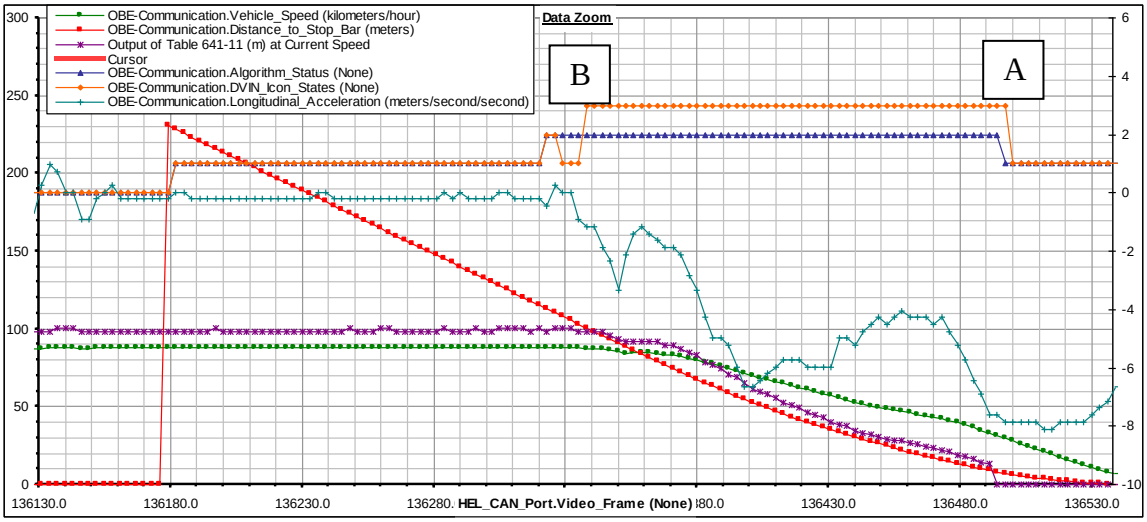

Figure 3: Various Speed Approaches Test, 55 mph, Run 1, Evaluation Plot

The frame at which DVIN_Icon_States changes from 3 (Warning) to 1 (Equipped), marked in Figure 3 as "A," is considered the end of validity checking range for all validity criteria except speed. This is the fourth column in the tables.

Since the speed is expected to change from specified after the warning, the change from 1 (Equipped) to 3 (Warning), marked in Figure 3 as B, is taken as the end of validity checking range for speed. This is the third column in the tables.

In each table, for each of the validity criteria, and for each test run within the validity checking range just described, the minimum and maximum values of the signals corresponding to the validity criteria are found and compared against the specified valid limits. If the signal remains within the limit, then the cell in the corresponding "Eval." column for the criterion, in the row for that particular test run, is marked as "valid," and otherwise as "invalid."

For this test, as Table 2 through Table 4 show, all test runs were found to be valid.

3.1.5 Evaluation

In this test a warning is expected. The pass evaluation for a test run is given for the presence of the warning, in all its modalities, within the expected distance-from-the-intersection interval. The evaluation process and its conclusions are presented via Table 5 through Table 7. Table 5 is accompanied with notes explaining the derivation of columns comprising it. The same notes apply to the other two tables, but are omitted for brevity.

Table 5: Evaluation Table, Various Speed Approaches Test, 55 mph

Run	Warning as Recorded				Speed		Distance								Run
	Icon		Brake[3]	Audio[4]	Recorded	Trunc.[5]	Accept.	Room	Optimum[7]	Tol. (s)[8]	Recorded	Room	Accept.	Eval.	Eval.
	Video[1] (frame)	State[2] (frame)	(yes/ /no)	(yes/ /no)	at Warn. (km/h)	to Table (km/h)	Min.[6] (m)	To Min[9] (m)	from 641-11 (m)	0.200 (m)	at Warn. (m)	To Max[9] (m)	Max.[6] (m)	(pass/ fail)	(pass/ fail)
1	136337	136338	yes	yes	87.56	87.00	93.43	7.32	98.26	4.83	100.75	2.34	103.09	pass	pass
2	140193	140193	yes	yes	87.76	87.00	93.43	4.44	98.26	4.83	97.87	5.22	103.09	pass	pass
3	143893	143892	yes	yes	87.37	87.00	93.43	5.06	98.26	4.83	98.49	4.60	103.09	pass	pass
4	147210	147210	no	yes	87.96	87.00	93.43	7.83	98.26	4.83	101.26	1.83	103.09	pass	fail
5	151871	151872	yes	yes	86.19	86.00	91.21	4.13	95.99	4.78	95.34	5.43	100.77	pass	pass
6	154963	154962	yes	yes	89.11	89.00	97.94	5.55	102.88	4.94	103.49	4.33	107.82	pass	pass
7	158529	158529	yes	yes	87.62	87.00	93.43	6.22	98.26	4.83	99.65	3.44	103.09	pass	pass
8	161669	161670	yes	yes	88.27	88.00	95.67	1.98	100.56	4.89	97.65	7.80	105.45	pass	pass
9	164973	164973	yes	yes	87.62	87.00	93.43	4.66	98.26	4.83	98.09	5.00	103.09	pass	pass

[1]Determined by watching the corresponding DAS video file frame-by-frame. The noted frame is the frame at which the camera pointed at the icon first shows the increase from the equipped level of brightness to the warning level of brightness, for this particular test run.

[2]Determined by analyzing the DAS signal "OBE-Communication.DVIN_Icon_States". The noted frame is the frame at which the signal first reaches the value of 3 ("warning"), for this particular test run.

[3]Determined by analyzing the DAS signal "OBE-Communication.Longitudinal_Acceleration". The value of "yes" is given for presence of two dips in acceleration for this particular test run: one short coinciding with the video warning, and the other longer, after a short reaction delay, which slows the car down to a stop.

[4]Determined by listening to the corresponding DAS video file frame-by-frame. The value of "yes" is given for an audio warning that seems to coincide with the video warning. Analysis of the audio signal to determine exact timing was not performed.

[5]The warning algorithm truncates the fractional part of the vehicle speed before using it to look up the warning distance in the table.

[6]Calculated by adding/subtracting the tolerance distance from the optimum distance.

[7]This is the distance read from the 641-11 table for the truncated speed.

[8]The tolerance distance is determined by multiplying the noted tolerance time by the speed recorded at the warning.

[9]The difference between the recorded distance and the allowable maximum/minimum distance.

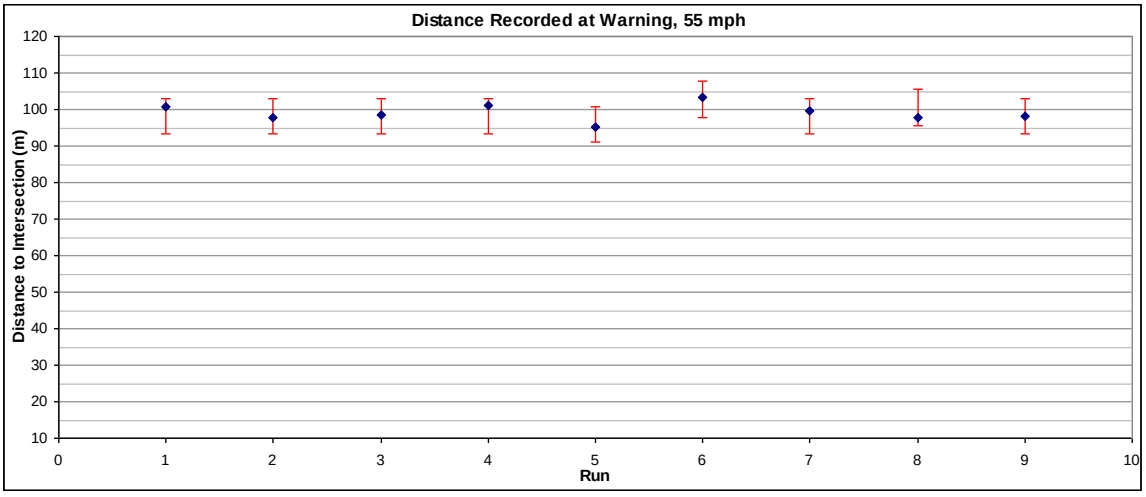

Figure 4: Distance at Warning, Various Speed Approaches Test, 55 mph

There are two columns showing different pass/fail conclusions in each table. The conclusion in the second-to-last column is for the location of the warning only. The location of the warning is the value of "OBE-Communication.Distance_to_Stop_Bar (meters)" when "OBE-Communication.DVIN_Icon_States (None)" becomes 3. These signals, along with other critical signals, are shown in Figure 3 for an example run and for

all runs in "8.1". The columns "Acceptable Min." and "Acceptable Max." are created by adding the 0.200 s tolerance converted to distance based on the actual vehicle speed. If the warning location is within the expected interval defined by values in "Acceptable Min." and "Acceptable Max." columns, then the location of the warning is considered acceptable and the cell in the "Distance Eval." column is marked as "pass," or otherwise marked as "fail." The actual warning distance with respect to the expected range is illustrated in Figure 4 through Figure 6. The conclusion in the last column takes four factors into consideration. The pass in that column requires that: 1) there is a value in "Icon Video" column, which indicates the visual warning modality was verified; 2) there is "yes" in "Brake" column, indicating that the brake warning modality was verified; 3) there is "yes" in the "Audio" column, indicating that the audio warning modality was verified; and 4) the warning distance evaluation, as in "Dist. Eval." column, is "pass." The said columns are determined as described in the aforementioned table notes. There is sometimes a difference between the "Icon Video" and "Icon State" frames, but it is very small, being at most 2 frames across all the runs, which, based on the 30 frames/s video rate, is 66 ms. This difference could be due to sampling mis-synchronization between the video signal and other signals, in conjunction with the delay between the algorithm state change and the corresponding video output change.

Table 5 shows that out of the first 8 valid test runs, 7 runs passed and 1 failed. According to Subsection 2.7 of [5], 6 passing runs out of 8 is sufficient to consider an overall test as passed. Thus, the overall test at this test speed of 55 mi/h passed.

The one test run failure is due to the missing brake modality warning in Run 4. This was determined based on Figure 31 where the double peak typical of the haptic brake functioning is missing. It is not known why the brake modality failed in this case. This is the only recorded failure of the brake modality. The cause behind this failure is to be investigated. It should be noted, though, that the other warning modalities came on at the correct distance from the intersection.

Table 6 and Table 7 show that for the remaining test speeds of 35 and 25 mi/h all test runs passed.

Table 6: Evaluation Table, Various Speed Approaches Test, 35 mph

Run	Warning as Recorded				Speed		Distance								Run
	Icon		Brake[3]	Audio[4]	Recorded	Trunc.[5]	Accept.	Room	Optimum[7]	Tol. (s)[8]	Recorded	Room	Accept.	Eval.	Eval.
	Video[1] (frame)	State[2] (frame)	(yes/ /no)	(yes/ /no)	at Warn. (km/h)	to Table (km/h)	Min.[6] (m)	To Min[6] (m)	from 641-11 (m)	0.200 (m)	at Warn. (m)	To Max[6] (m)	Max.[6] (m)	(pass/ fail)	(pass/ fail)
1	171177	171177	yes	yes	59.47	59.00	41.43	3.92	44.71	3.28	45.35	2.64	47.99	pass	pass
2	174644	174645	yes	yes	56.55	56.00	37.10	3.09	40.21	3.11	40.19	3.13	43.32	pass	pass
3	177912	177912	yes	yes	55.62	55.00	35.70	3.10	38.76	3.06	38.80	3.02	41.82	pass	pass
4	181228	181230	yes	yes	55.89	55.00	35.70	4.34	38.76	3.06	40.04	1.78	41.82	pass	pass
5	184223	184224	yes	yes	56.07	56.00	37.10	3.15	40.21	3.11	40.25	3.07	43.32	pass	pass
6	187226	187227	yes	yes	56.37	56.00	37.10	3.36	40.21	3.11	40.46	2.86	43.32	pass	pass
7	190273	190275	yes	yes	55.03	55.00	35.70	3.10	38.76	3.06	38.80	3.02	41.82	pass	pass
8	193376	193377	yes	yes	56.07	56.00	37.10	3.43	40.21	3.11	40.53	2.79	43.32	pass	pass
9	196484	196482	yes	yes	56.49	56.00	37.10	3.43	40.21	3.11	40.53	2.79	43.32	pass	pass

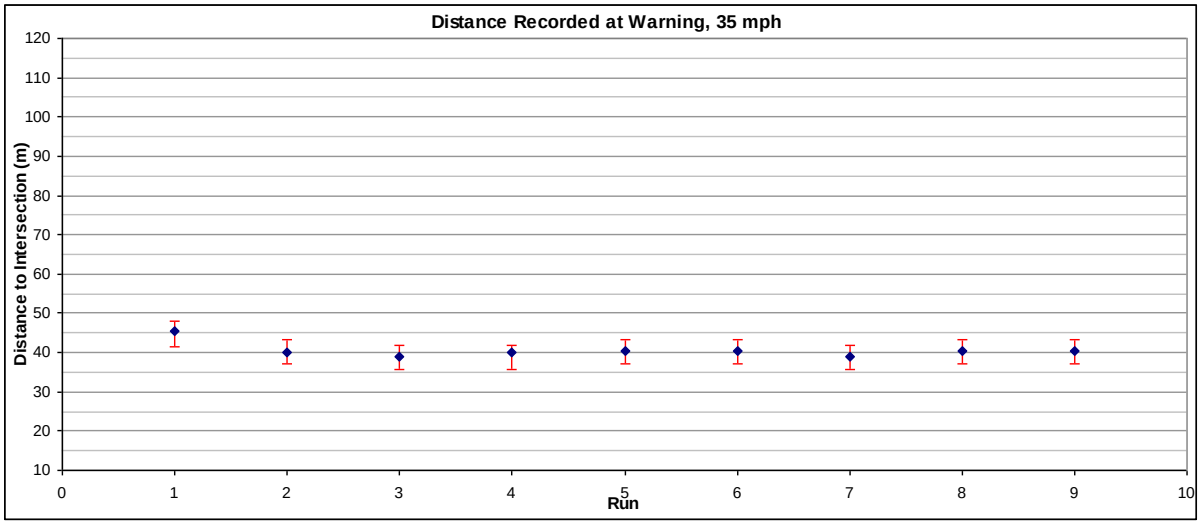

Figure 5: Distance at Warning, Various Speed Approaches Test, 35 mph

Table 7: Evaluation Table, Various Speed Approaches Test, 25 mph

Run	Warning as Recorded				Speed		Distance								Run
	Icon		Brake[3]	Audio[4]	Recorded	Trunc.[5]	Accept.	Room	Optimum[7]	Tol. (s)[8]	Recorded	Room	Accept.	Eval.	Eval.
	Video[1]	State[2]	(yes/	(yes/	at Warn.	to Table	Min.[6]	To Min[6]	from 641-1	0.200	at Warn.	To Max[6]	Max.[6]	(pass/	(pass/
	(frame)	(frame)	/no)	/no)	(km/h)	(km/h)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	fail)	fail)
1	207761	207762	yes	yes	40.46	40.00	17.97	2.05	20.19	2.22	20.02	2.39	22.41	pass	pass
2	211358	211359	yes	yes	40.07	40.00	17.97	2.13	20.19	2.22	20.10	2.31	22.41	pass	pass
3	215183	215184	yes	yes	38.83	38.00	16.05	3.25	18.16	2.11	19.30	0.97	20.27	pass	pass
4	218732	218733	yes	yes	39.02	39.00	16.99	2.44	19.16	2.17	19.43	1.90	21.33	pass	pass
5	222044	222045	yes	yes	39.32	39.00	16.99	1.76	19.16	2.17	18.75	2.58	21.33	pass	pass
6	225382	225384	yes	yes	38.82	38.00	16.05	3.45	18.16	2.11	19.50	0.77	20.27	pass	pass
7	229225	229224	yes	yes	39.14	39.00	16.99	1.90	19.16	2.17	18.89	2.44	21.33	pass	pass
8	232534	232533	yes	yes	39.30	39.00	16.99	2.17	19.16	2.17	19.16	2.17	21.33	pass	pass

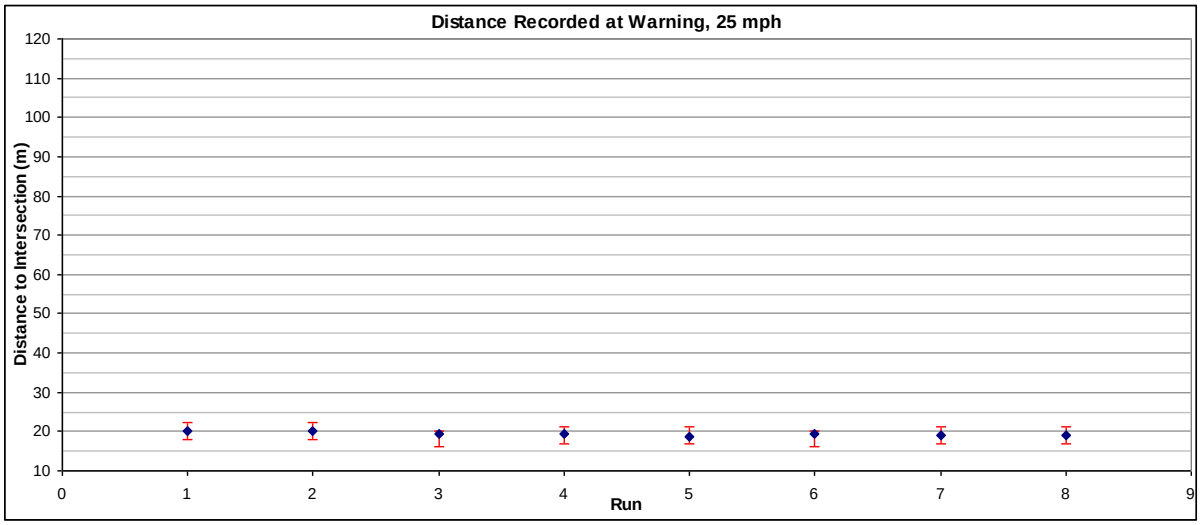

Figure 6: Distance at Warning, Various Speed Approaches Test, 25 mph

Since the test suites for each individual test speed passed, according to Subsection 2.7 of [5], this overall test is also considered passed.

3.1.6 Suggested Improvements

There are no suggestions for test procedure improvements for this test. However, it is desirable to investigate the cause of the brake modality warning failure presented in Subsection 3.1.5.

3.2 Edge of Approach Testing for Warning

3.2.1 Scenario Overview

In this test, the test vehicle is driven down the leftmost lane (Figure 7) toward the intersection, but along the right edge of the lane. The intersection is signaling red to the leftmost lane and green to its neighboring lanes.

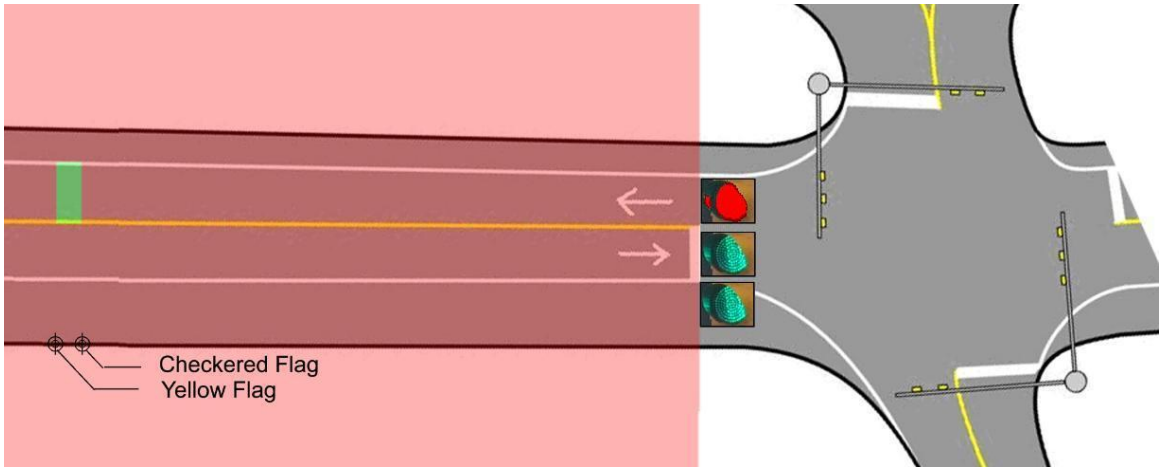

Figure 7: Edge of Approach Testing for Warning, Test Setup

The purpose of this test, and the test described in Subsection 3.3, is to check fidelity of the lane matching algorithm by driving the vehicle along the edge of the lane. In this test, the driven red lane is neighbored by a green lane indicating a warning is expected. While in Subsection 3.3, the signal phasing is reversed and so no warning is expected.

The procedure for this test is fully specified in [5] under the corresponding test heading.

3.2.2 Conditions

There were no deviations from the general test conditions detailed in Section 2.

Although 8 runs are specified for this test, more than 8 runs were performed in order to reduce the chance of having to return to this test in case of some invalid test runs. Since none of the test runs in this test were found to be invalid, only the first 8 runs are needed for official pass/fail determination for the overall test and any additional test runs are shown here only for reference.

3.2.3 Results

The data collected during this test was stored in the files listed in Table 8.

Table 8: Test Data Files for Edge of Approach Testing for Warning

Result File Name	Description	Created By
ACI4_0304_0000_AA_080716_1536.txt	signal values	DAS
ACI4_0304_0000_AA_080716_1536.avi	video	DAS

This data was analyzed to determine test validity (Subsection 3.2.4) and pass/fail evaluation (Subsection 3.2.5).

3.2.4 Validity

The validity of runs for this test is partially analyzed as described earlier in Subsection 3.1.4. The results of this validity analysis are presented in Table 9. There are valid/invalid evaluations for each of the four criteria. Compared to tables in Subsection 3.1.4, Table 9 also has a summary column - the "Overall" column. That column shows "valid" for a particular row when all individual validity criteria for that row also show "valid." As the table shows, all test runs performed for this test were valid with respect to those four criteria. Only the first 8 runs are needed for the official evaluation of this test.

Table 9: Validity Check Table, Edge of Approach Testing for Warning

Run	Extents			Speed (S. 2.6.1)								GST_Error_Ellipse			PDOP			Satellites			Overall
	Start		End	Valid					Rec.		Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	
	Equip. frame	Warn. frame	Equip. frame	Min. mi/h	Nom. mi/h	Max. mi/h	Min. km/h	Max. km/h	Min. km/h	Max. km/h	Valid?	Max. m	Max. m	Valid?	Max.	Max.		Min.	Min.	Valid?	Valid?
1	291693	292053	292203	33	35	38	52.3	60.3	55.1	55.8	valid	1.5	0.1	valid	5.0	1.9	valid	5	6	valid	valid
2	294921	295281	295428	33	35	38	52.3	60.3	55.5	56.1	valid	1.5	0.1	valid	5.0	1.9	valid	5	6	valid	valid
3	297951	298308	298458	33	35	38	52.3	60.3	55.4	55.9	valid	1.5	0.1	valid	5.0	1.7	valid	5	6	valid	valid
4	300978	301335	301485	33	35	38	52.3	60.3	55.3	55.8	valid	1.5	0.1	valid	5.0	1.9	valid	5	6	valid	valid
5	303963	304320	304470	33	35	38	52.3	60.3	55.3	55.9	valid	1.5	0.1	valid	5.0	1.7	valid	5	6	valid	valid
6	306924	307281	307431	33	35	38	52.3	60.3	55.1	55.9	valid	1.5	0.1	valid	5.0	1.6	valid	5	6	valid	valid
7	309912	310269	310419	33	35	38	52.3	60.3	55.3	55.9	valid	1.5	0.1	valid	5.0	1.6	valid	5	6	valid	valid
8	313077	313437	313587	33	35	38	52.3	60.3	55.3	55.8	valid	1.5	0.1	valid	5.0	1.6	valid	5	6	valid	valid
9	316149	316509	316659	33	35	38	52.3	60.3	55.3	56.0	valid	1.5	0.1	valid	5.0	1.9	valid	5	6	valid	valid
10	319146	319509	319659	33	35	38	52.3	60.3	55.2	55.9	valid	1.5	0.1	valid	5.0	1.6	valid	5	6	valid	valid
11	322182	322542	322692	33	35	38	52.3	60.3	55.3	55.9	valid	1.5	0.1	valid	5.0	1.6	valid	5	6	valid	valid
12	325173	325533	325683	33	35	38	52.3	60.3	55.4	55.9	valid	1.5	0.1	valid	5.0	1.6	valid	5	5	valid	valid
13	328164	328524	328674	33	35	38	52.3	60.3	55.3	56.0	valid	1.5	0.1	valid	5.0	1.5	valid	5	5	valid	valid
14	331149	331509	331659	33	35	38	52.3	60.3	55.2	55.9	valid	1.5	0.1	valid	5.0	1.5	valid	5	5	valid	valid
15	334203	334563	334713	33	35	38	52.3	60.3	55.2	55.9	valid	1.5	0.1	valid	5.0	1.5	valid	5	5	valid	valid
16	337347	337707	337857	33	35	38	52.3	60.3	55.1	55.8	valid	1.5	0.1	valid	5.0	1.5	valid	5	5	valid	valid

In addition to validity criteria in Table 9, the test procedures [5] require verification of positioning relative to the lane edge as another validity criterion. As Subsection 2.3.1 already introduced, the originally intended reliance on GID point locations as representations of the lane edge locations proved unreliable and visual observations by test observers and test vehicle cameras were taken as an adequate substitute. The existing video record of the test appears as a difficult source for this judgment, but based on verification by the test observers, one of which was the author of this report, the test vehicle remained sufficiently close (as specified in [5]) to the painted lane edges. Furthermore, the additional number of test runs taken (16 versus the specified 8), all of which evaluated to pass (Subsection 3.2.5), provides additional confidence. Thus, the position relative to the lane edges is also considered valid for this test.

In conclusion, the test runs for this test are considered valid according to criteria specified by [5] and test data analysis presented here.

3.2.5 Evaluation

The runs in this test are evaluated for the location/timing of the warning as earlier described in Subsection 3.2.5. The warning was expected in each run. As Table 10 shows, all runs demonstrated appropriated warnings. The location of the warning within the tolerance window is shown in Figure 8. Only the first 8 runs are needed and considered for the official evaluation of this test. Each of the runs passed thus this test passes also.

Table 10: Evaluation Table, Edge of Approach Testing for Warning

Run	Warning as Recorded				Speed		Distance								Run
	Icon		Brake[3]	Audio[4]	Recorded	Trunc.[5]	Accept.	Room	Optimum[7]	Tol. (s)[8]	Recorded	Room	Accept.	Eval.	Eval.
	Video[1] (frame)	State[2] (frame)	(yes/ /no)	(yes/ /no)	at Warn. (km/h)	to Table (km/h)	Min.[6] (m)	To Min[6] (m)	from 641-11 (m)	0.200 (m)	at Warn. (m)	To Max[8] (m)	Max.[8] (m)	(pass/ fail)	(pass/ fail)
1	292052	292053	yes	yes	55.54	55.00	35.70	3.96	38.76	3.06	39.66	2.16	41.82	pass	pass
2	295279	295281	yes	yes	55.82	55.00	35.70	3.63	38.76	3.06	39.33	2.49	41.82	pass	pass
3	298309	298308	yes	yes	55.60	55.00	35.70	3.90	38.76	3.06	39.60	2.22	41.82	pass	pass
4	301337	301335	yes	yes	55.64	55.00	35.70	3.56	38.76	3.06	39.26	2.56	41.82	pass	pass
5	304321	304320	yes	yes	55.67	55.00	35.70	3.42	38.76	3.06	39.12	2.70	41.82	pass	pass
6	307282	307281	yes	yes	55.59	55.00	35.70	4.25	38.76	3.06	39.95	1.87	41.82	pass	pass
7	310271	310269	yes	yes	55.44	55.00	35.70	4.17	38.76	3.06	39.87	1.95	41.82	pass	pass
8	313436	313437	yes	yes	55.66	55.00	35.70	3.69	38.76	3.06	39.39	2.43	41.82	pass	pass
9	316509	316509	yes	yes	55.59	55.00	35.70	3.69	38.76	3.06	39.39	2.43	41.82	pass	pass
10	319509	319509	yes	yes	55.66	55.00	35.70	3.08	38.76	3.06	38.78	3.04	41.82	pass	pass
11	322541	322542	yes	yes	55.37	55.00	35.70	3.21	38.76	3.06	38.91	2.91	41.82	pass	pass
12	325533	325533	yes	yes	55.62	55.00	35.70	3.21	38.76	3.06	38.91	2.91	41.82	pass	pass
13	328524	328524	yes	yes	55.64	55.00	35.70	3.42	38.76	3.06	39.12	2.70	41.82	pass	pass
14	331508	331509	yes	yes	55.46	55.00	35.70	3.56	38.76	3.06	39.26	2.56	41.82	pass	pass
15	334563	334563	yes	yes	55.75	55.00	35.70	3.98	38.76	3.06	39.68	2.14	41.82	pass	pass
16	337707	337707	yes	yes	55.64	55.00	35.70	3.96	38.76	3.06	39.66	2.16	41.82	pass	pass

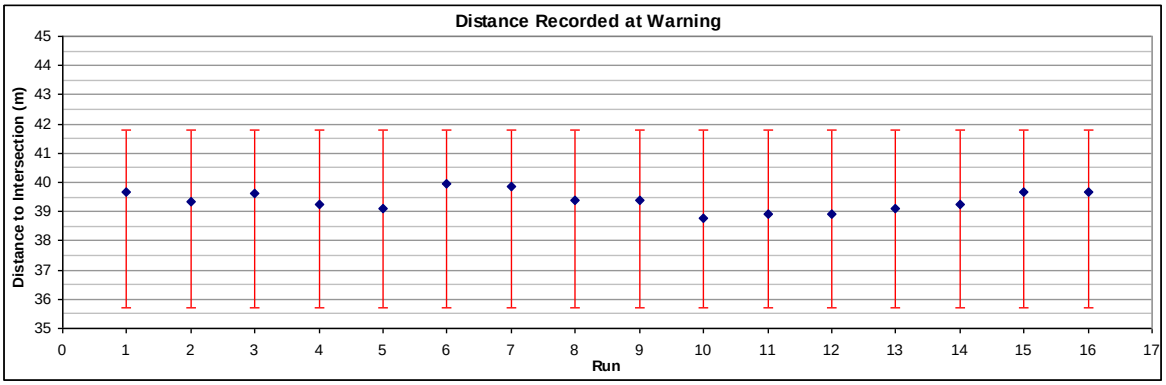

Figure 8: Distance at Warning, Edge of Approach Testing for Warning

3.2.6 Suggested Test Procedure Improvements

Since the reliability of judging the vehicle position with respect to the lane markings is uncertain, it is suggested here that downward facing side cameras be used for this purpose instead. The cameras should have the view of at least both front vehicle wheels and the lane markings to accurately and repeatedly verify distance to the lane edge under all test conditions.

Test procedures indicate that the lane offset to the right is positive and lane offset to the left is negative. This will enhance the data collection procedure and make it easier to determine which side of center the vehicle is deviating.

3.3 Edge of Approach Testing for Nuisance Warning

3.3.1 Scenario Overview

As in the previous test (Subsection 3.2.1), the test vehicle is driven down the middle lane toward the intersection close to left lane boundary (Figure 9). In this case however, the middle lane receives a green signal while its neighboring lanes receive red.

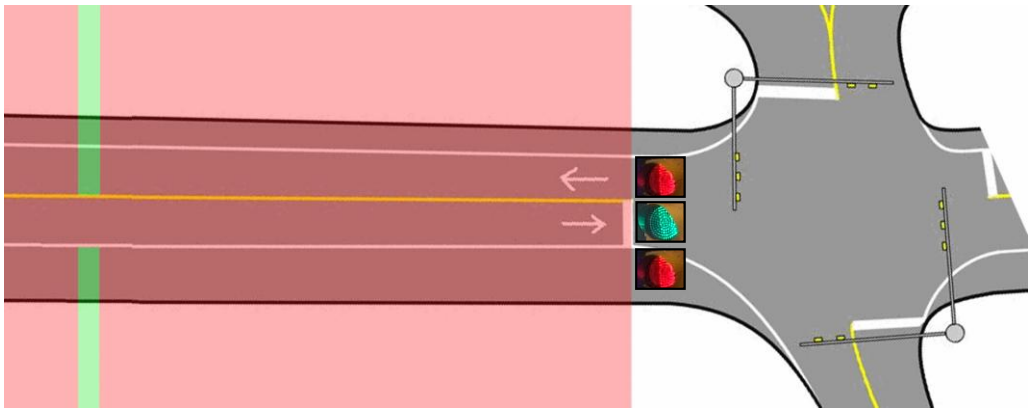

Figure 9: Edge of Approach Testing for Nuisance Warning, Test Setup

The purpose of this test, as for the test described in Subsection 3.2, is to check the fidelity of the lane matching algorithm by driving the vehicle along the edge of a lane with signal phasing different from its neighboring lanes. In this test, the driven lane is green so no warning is expected.

The procedure for this test is fully specified in [5] under the corresponding test heading.

3.3.2 Conditions

There were no deviations from the general test conditions detailed in Section 2.

Although 8 runs are specified for this test, more than 8 runs were performed in order to reduce the chance of having to return to this test in case of some invalid test runs. Since none of the test runs in this test were found to be invalid, only the first 8 runs are needed for official pass/fail determination for the overall test and any additional test runs are shown here only for reference.

3.3.3 Results

The data collected during this test was stored in the files listed in Table 11.

Table 11: Test Data Files for Edge of Approach Testing for Nuisance Warning

Result File Name	Description	Created By
ACI4_0305_0000_AA_080716_1616.txt	signal values	DAS
ACI4_0305_0000_AA_080716_1616.avi	video	DAS

This data was analyzed to determine test validity (Subsection 3.3.4) and pass/fail evaluation (Subsection 3.3.5).

3.3.4 Validity

The validity of the runs in this test is determined as in the related test of Subsection 3.2.4. Table 11 shows that all test runs performed for this test were valid with respect to the four validation criteria. Only the first 8 runs are needed for the official evaluation of this test.

Table 12: Validity Check Table, Edge of Approach Testing for Nuisance Warning

Run	Extents		Speed								GST_Error_Ellipse				PDOP				Satellites				Overall
	Start (Equip.) frame	End (Stand.) frame	Valid Min. mi/h	Valid Nom. mi/h	Valid Max. mi/h	Valid Min. km/h	Valid Max. km/h	Rec. Min. km/h	Rec. Max. km/h	Eval. Valid?	Valid Max. m	Rec. Max. m	Eval. Valid?		Valid Max.	Rec. Max.	Eval. Valid?		Valid Min.	Rec. Min.	Eval. Valid?		Valid? in/valid
1	361839	362304	33	35	38	52.3	60.3	55.1	55.9	valid	1.5	0.05	valid		5.0	1.5	valid		5	6	valid		valid
2	365304	365769	33	35	38	52.3	60.3	54.6	55.7	valid	1.5	0.05	valid		5.0	1.8	valid		5	5	valid		valid
3	368313	368778	33	35	38	52.3	60.3	55.3	55.9	valid	1.5	0.05	valid		5.0	1.8	valid		5	6	valid		valid
4	371535	372000	33	35	38	52.3	60.3	55.3	56.0	valid	1.5	0.05	valid		5.0	1.6	valid		5	7	valid		valid
5	374571	375036	33	35	38	52.3	60.3	55.4	56.0	valid	1.5	0.05	valid		5.0	1.4	valid		5	7	valid		valid
6	377784	378249	33	35	38	52.3	60.3	55.4	55.9	valid	1.5	0.05	valid		5.0	1.6	valid		5	7	valid		valid
7	380826	381288	33	35	38	52.3	60.3	55.3	56.0	valid	1.5	0.05	valid		5.0	1.4	valid		5	7	valid		valid
8	383940	384405	33	35	38	52.3	60.3	55.5	56.1	valid	1.5	0.05	valid		5.0	1.4	valid		5	7	valid		valid
9	387015	387480	33	35	38	52.3	60.3	55.4	56.0	valid	1.5	0.05	valid		5.0	1.4	valid		5	7	valid		valid
10	390123	390585	33	35	38	52.3	60.3	55.4	56.0	valid	1.5	0.05	valid		5.0	1.4	valid		5	7	valid		valid
11	393483	393945	33	35	38	52.3	60.3	55.3	56.0	valid	1.5	0.05	valid		5.0	1.4	valid		5	7	valid		valid
12	396894	397359	33	35	38	52.3	60.3	55.3	56.0	valid	1.5	0.05	valid		5.0	1.4	valid		5	7	valid		valid
13	400110	400569	33	35	38	52.3	60.3	55.4	56.1	valid	1.5	0.05	valid		5.0	1.4	valid		5	7	valid		valid
14	403347	403812	33	35	38	52.3	60.3	55.3	55.9	valid	1.5	0.05	valid		5.0	1.4	valid		5	7	valid		valid
15	406527	406992	33	35	38	52.3	60.3	55.4	56.1	valid	1.5	0.05	valid		5.0	1.4	valid		5	7	valid		valid
16	409707	410169	33	35	38	52.3	60.3	55.5	56.1	valid	1.5	0.05	valid		5.0	1.6	valid		5	7	valid		valid

For this test, as for the other lane edge test (Subsection 3.2.4), test vehicle position relative to the lane edge is an additional validity criteria. As detailed in Subsection 3.2.4, the validation of this criterion was performed visually by test observers. The position relative to the lane edges is considered valid for this test.

In conclusion, the test runs for this test are considered valid according to criteria specified by [5] and test data analysis presented here.

3.3.5 Evaluation

No warnings occurred, as expected. Thus, all test runs passed and this entire test passed.

3.3.6 Suggested Test Procedure Improvements

The suggested test procedure improvements for this test are as the same as those for the related Edge of Approach Testing for Warning. They are described in Subsection 3.2.6.

3.4 Late Lane Shift Test – Warning

3.4.1 Scenario Overview

In this test procedure the test vehicle approaches the intersection in the middle lane (Figure 10). The middle lane is receiving a green signal. The test vehicle shifts into the left lane, which is receiving a red signal. The lane shift occurs after the ideal warning distance for the new lane with the red signal.

The purpose of the test is to verify whether the CICAS-V system still generates a warning for this type of late lane change.

The procedure for this test is fully specified in [5] under the corresponding test heading.

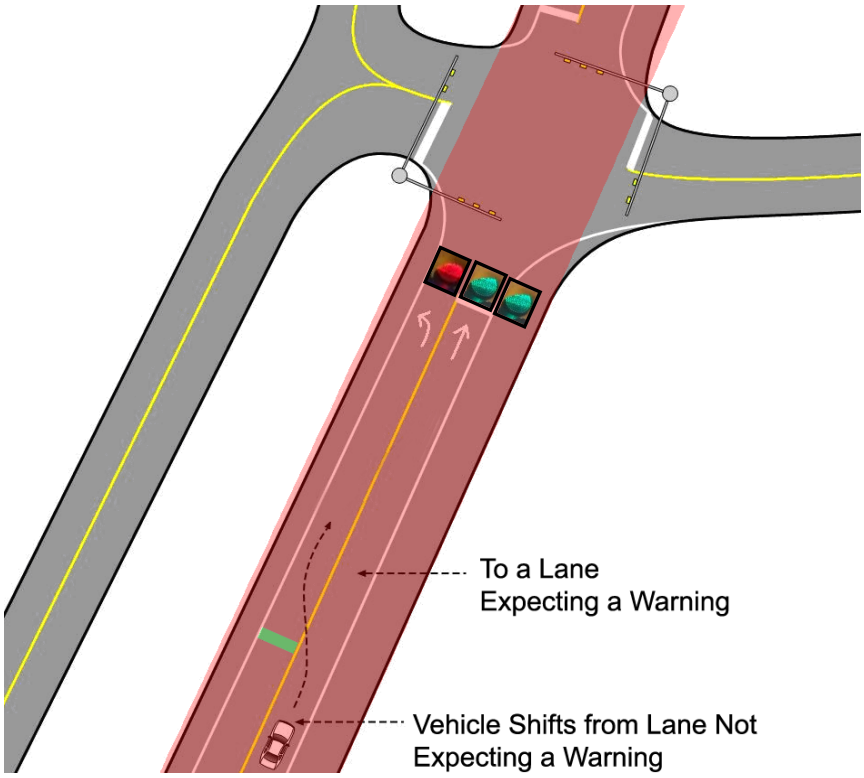

Figure 10: Late Lane Shift Test – Warning, Test Setup

3.4.2 Conditions

There were no deviations from the general test conditions detailed in Section 2.

Although 8 runs are specified for this test, more than 8 runs were performed in order to reduce the chance of having to return to this test in case of some invalid test runs.

3.4.3 Results

The data collected during this test was stored in the files listed in Table 13.

Table 13: Test Data Files for Late Lane Shift Test - Warning

Result File Name	Description	Created By
ACI4_0306_0000_AA_080716_1917.txt	signal values	DAS
ACI4_0306_0000_AA_080716_1917.avi	video	DAS

This data was analyzed to determine test validity (Subsection 3.4.4) and pass/fail evaluation (Subsection 3.4.5).

3.4.4 Validity

The validity analysis for this test is performed using Table 14. In addition to the four already familiar validity criteria from Subsection 3.3.4 (speed, GST error, PDOP, satellites), there is an additional analysis of the lane change maneuver in the "Lane Change, Distance from Stopbar" section of the Table 14. The columns in this section analyze whether the lane change, as indicated by the signal "OBE-Communication.Present_Approach," is within the parameters specified by the test procedures in [5]. The test procedures provide a window of -1.5 s and +2.5 s around the optimum warning distance from Warning Table 641-11. The optimum warning distance based on the specified test speed of 35 mi/h and the Warning Table 641-11 is in the "Warn" column. The advance portion (-1.5 s) of the lane change window is converted from time ("Start Adv. s" column) into distance ("Start Adv. m") column, using the specified test speed. This distance is added to the optimal warning distance to arrive at column "Valid Max. m." Similarly, the delay portion (+ 2.5 s) of the lane change window is converted from time ("End Delay s" column) into distance ("End Delay m" column) and subtracted from the optimum distance to arrive at the "Valid Min. m" column. The recorded distance from the intersection at the moment of change of the "Present_Approach" signal from 6 to 4 (in "Rec. Change m" column) is compared with the said valid maximum and minimum distances. If the recorded distance is within those limits, it is considered and marked "valid" and otherwise as "invalid."

As Table 14 shows, all runs performed for this test were valid. Only the first 8 are needed and considered for the official test evaluation.

Table 14: Validity Check Table, Late Lane Shift Test - Warning

Run	Speed (S. 2.6.1)									Lane Change, Distance from Stopbar (S. 4.5.7)										GST_Error_Ellipse				PDOP				Satellites				Overall
	Valid						Rec.		Eval.	Warn	Start	Start	Valid	Rec.	End	End	Valid	Eval.	Valid	Rec.		Eval.	Valid	Rec.		Eval.	Valid	Rec.		Eval.	
	Min.	Nom.	Max.	Min.	Nom.	Max.	Min.	Max.	Valid?	641-11	Adv.	Adv.	Max.	Change	Del.	Delay	Min.	Valid?	Max.	Max.		Valid?	Max.	Max.		Valid?	Max.	Min.		Valid?	Valid?
	mi/h			km/h			km/h			m	s	m	m	m	s	m	m		m	m										
1	32.5	35	37.5	52.3	56.3	60.3	55.0	56.0	valid	40.21	1.5	23.46	63.67	42.49	2.5	39.11	1.10	valid	1.5	0.10		valid	5.0	1.6		valid	5	8		valid	valid
2	32.5	35	37.5	52.3	56.3	60.3	55.0	56.0	valid	40.21	1.5	23.46	63.67	45.46	2.5	39.11	1.10	valid	1.5	0.10		valid	5	1.6		valid	5	9		valid	valid
3	32.5	35	37.5	52.3	56.3	60.3	55.2	56.0	valid	40.21	1.5	23.46	63.67	43.99	2.5	39.11	1.10	valid	1.5	0.10		valid	5	1.6		valid	5	9		valid	valid
4	32.5	35	37.5	52.3	56.3	60.3	55.1	56.0	valid	40.21	1.5	23.46	63.67	44.42	2.5	39.11	1.10	valid	1.5	0.10		valid	5	1.6		valid	5	9		valid	valid
5	32.5	35	37.5	52.3	56.3	60.3	55.2	56.1	valid	40.21	1.5	23.46	63.67	46.55	2.5	39.11	1.10	valid	1.5	0.10		valid	5	2.1		valid	5	9		valid	valid
6	32.5	35	37.5	52.3	56.3	60.3	55.1	56.1	valid	40.21	1.5	23.46	63.67	44.42	2.5	39.11	1.10	valid	1.5	0.10		valid	5	2.1		valid	5	9		valid	valid
7	32.5	35	37.5	52.3	56.3	60.3	55.3	56.1	valid	40.21	1.5	23.46	63.67	44.42	2.5	39.11	1.10	valid	1.5	0.10		valid	5	2.1		valid	5	9		valid	valid
8	32.5	35	37.5	52.3	56.3	60.3	55.3	55.9	valid	40.21	1.5	23.46	63.67	44.42	2.5	39.11	1.10	valid	1.5	0.10		valid	5	1.9		valid	5	9		valid	valid
9	32.5	35	37.5	52.3	56.3	60.3	55.2	56.0	valid	40.21	1.5	23.46	63.67	44.63	2.5	39.11	1.10	valid	1.5	0.10		valid	5	1.9		valid	5	9		valid	valid
10	32.5	35	37.5	52.3	56.3	60.3	54.9	56.0	valid	40.21	1.5	23.46	63.67	44.42	2.5	39.11	1.10	valid	1.5	0.05		valid	5	1.9		valid	5	9		valid	valid

3.4.5 Evaluation

The pass/fail evaluation for the test runs in this test is presented via Table 15 and Figure 11.

Table 15: Evaluation Table, Late Lane Shift Test - Warning

Run	Warning as Recorded				Speed			Distance											Run
	Icon		Brake[3]	Audio[4]	Nom.	Nom.	Trunc.[5]	Accept.	Room	Optimum[7]	Tol. (s)[8]	Rec. at		Difference		Room	Accept.	Eval.	Eval.
	Video[1]	State[2]	(yes/	(yes/			to Table	Min.[6]	To Min[9]	from 641-11	2.500	Ln. Change	Warning	Ln. To Warn		To Max[9]	Max.[6]	(pass/	(pass/
	(frame)	(frame)	/no)	/no)	(mi/h)	km/h	(km/h)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(s)	(m)	(m)	fail)	fail)
1	56678	56679	yes	yes	35	56.32	56.00	1.10	33.50	40.21	39.11	42.49	34.60	7.89	0.504	5.61	40.21	pass	pass
2	62050	62052	yes	yes	35	56.32	56.00	1.32	36.38	40.21	38.89	45.46	37.70	7.76	0.496	2.51	40.21	pass	pass
3	65281	65283	yes	yes	35	56.32	56.00	1.32	34.86	40.21	38.89	43.99	36.18	7.81	0.499	4.03	40.21	pass	pass
4	68285	68286	yes	yes	35	56.32	56.00	1.32	35.48	40.21	38.89	44.42	36.80	7.62	0.487	3.41	40.21	pass	pass
5	71153	71154	yes	yes	35	56.32	56.00	1.32	35.96	40.21	38.89	46.55	37.28	9.27	0.593	2.93	40.21	pass	pass
6	74296	74298	yes	yes	35	56.32	56.00	1.32	35.34	40.21	38.89	44.42	36.66	7.76	0.496	3.55	40.21	pass	pass
7	77365	77367	yes	yes	35	56.32	56.00	1.32	35.34	40.21	38.89	44.42	36.66	7.76	0.496	3.55	40.21	pass	pass
8	80419	80421	yes	yes	35	56.32	56.00	1.32	35.34	40.21	38.89	44.42	36.66	7.76	0.496	3.55	40.21	pass	pass
9	83440	83442	yes	yes	35	56.32	56.00	1.32	35.48	40.21	38.89	44.63	36.80	7.83	0.501	3.41	40.21	pass	pass
10	86375	86376	yes	yes	35	56.32	56.00	1.32	35.34	40.21	38.89	44.42	36.66	7.76	0.496	3.55	40.21	pass	pass

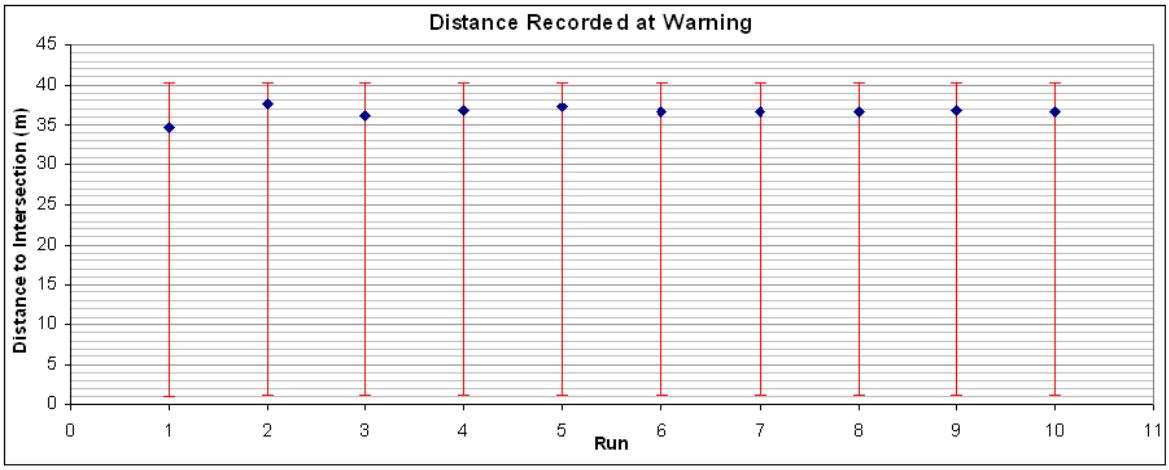

Figure 11: Distance at Warning, Late Lane Shift Test - Warning

The test procedure [5] specifies that the warning in this test is to occur after the lane change is completed, but it does not specify the range of acceptable latencies relative to the completed lane change: "a late warning should be issued up until the stop bar" ([5], page 38). Since no latency is specified, the method of Table 15 was to consider any warning that occurs after the optimum warning ("Optimum" column) and within the 2.5 s lane change delay provision ("Tol" column which gives "Accept. Min" column) as passed.

The other validity considerations in Table 15 are as in previous subsections; for an example, see Subsection 3.1.4.

According to this evaluation of Table 15, all test runs passed. Only 8 are specified to be performed and thus only the first 8 are officially considered.

For reference only, the latency between the lane change completion as recorded by the "Present_Approach" signal and the occurrence of warning is also shown in Table 15 in terms of distance ("Difference Ln. to Warn (s)") and time ("Difference Ln. to Warn (s)"). This latency was consistently around 0.5 s.

3.4.6 Suggested Test Procedure Improvements

The test should specify an allowable latency between a positive lane match and the onset of the warning. Thus, it is suggested here that the test procedure [5] is to be improved for any future use by specifying the allowable maximum latency as in Table 15's column "Difference Ln. to Warn (s)."

3.5 Late Lane Shift Test – Nuisance Warning

In this test, the test vehicle approaches the intersection in the left lane (Figure 12). The left lane is receiving a red signal as shown in Figure 12. The test vehicle shifts into the middle lane, which is receiving a green signal. The lane shift occurs before the ideal warning distance for the new lane with the green signal.

The purpose of the test is to verify whether the CICAS-V system appropriately avoids a warning for this type of late lane change.

The procedure for this test is fully specified in [5] under the corresponding test heading.

3.5.1 Scenario Overview

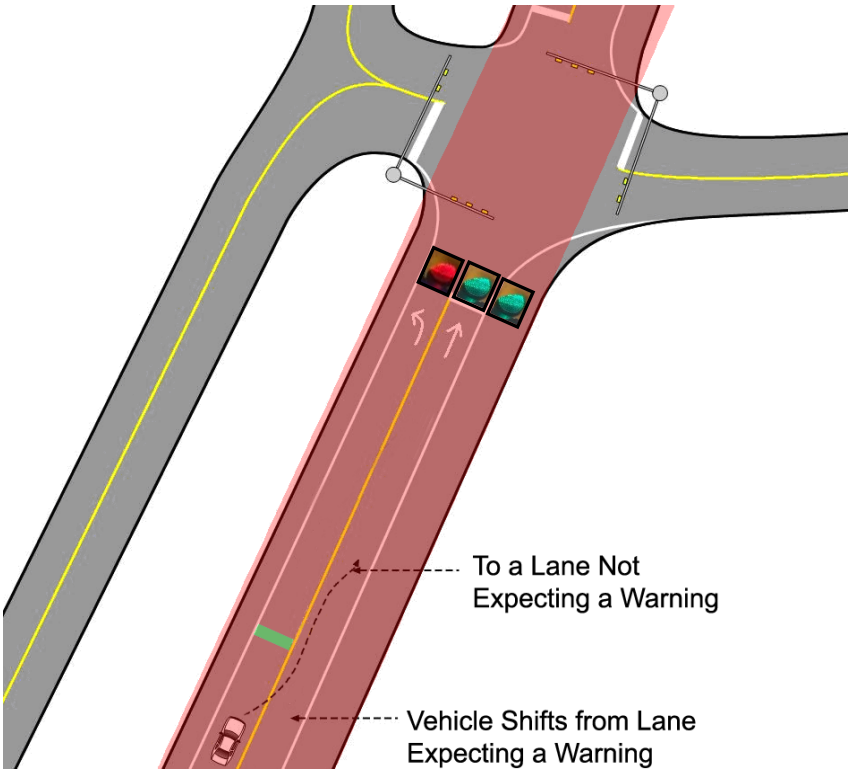

Figure 12: Late Lane Shift Test – Nuisance Warning, Test Setup

3.5.2 Conditions

There were no deviations from the general test conditions detailed in Section 2.

3.5.3 Results

The data collected during this test was stored in the files listed in Table 16.

Table 16: Test Data Files for Late Lane Shift Test – Nuisance Warning

Result File Name	Description	Created By
ACI4_0307_0000_AA_080716_1940.txt	signal values	DAS
ACI4_0307_0000_AA_080716_1940.avi	video	DAS

This data was analyzed to determine test validity (Subsection 3.5.4) and pass/fail evaluation (Subsection 3.5.5).

3.5.4 Validity

The validity for this test is judged using Table 17. Similar to Subsection 3.4.4, Table 17 considers the four standard criteria and also examines the lane change validity.

The test procedure [5] specifies the lane change as starting 70 m before the Table 641-11 (Appendix B.1) warning distance for the highest valid speed and ending before this warning distance. In Table 17, the 70 m allowance is in "Start Adv. m" column. It is converted into time domain using maximum valid speed in the column "Start Adv. S."

The Table 641-11 warning distance at maximum valid speed ("Warn" column) is added with 70 m to produce "Valid Max. m" column. The "Valid Min. m" column is simply the Table 641-11 warning distance. The lane change identified in "OBE-Communication.Present_Approach" is presented in column "Rec. Change m." This value is compared with "Valid Min. m" and "Valid Max. m. If within this range, the lane change is considered valid and marked "valid," and, otherwise "invalid."

As Table 17 shows, all 8 runs in this test are considered valid.

Table 17: Validity Check Table, Late Lane Shift Test - Nuisance Warning

Run	Speed (S. 2.6.1)									Lane Change, Distance from Stopbar (S. 4.5.7)								GST_Error_Ellipse			PDOP			Satellites			Overall
	Valid						Rec.		Eval.	Warn	Start	Start	Valid	Rec.	End	Valid	Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	Valid?
	Min.	Nom.	Max.	Min.	Nom.	Max.	Min.	Max.	Valid?	641-11	Adv.	Adv.	Max.	Change	Delay	Min.	Valid?	Max.	Max.	Valid?	Max.	Max.	Valid?	Max.	Min.	Valid?	in/valid
	mi/h			km/h			km/h			m	s	m	m	m	s	m	in/valid	m	m								
1	32.5	35	37.5	52.3	56.3	60.3	55.2	55.9	valid	46.27	4.18	70	116.3	86.5	0	46.27	valid	1.5	0.05	valid	5.0	1.8	valid	5	10	valid	valid
2	32.5	35	37.5	52.3	56.3	60.3	55.3	56.0	valid	46.27	4.18	70	116.3	82.93	0	46.27	valid	1.5	0.05	valid	5	1.8	valid	5	10	valid	valid
3	32.5	35	37.5	52.3	56.3	60.3	55.2	56.1	valid	46.27	4.18	70	116.3	81.41	0	46.27	valid	1.5	0.05	valid	5	2	valid	5	10	valid	valid
4	32.5	35	37.5	52.3	56.3	60.3	55.1	55.9	valid	46.27	4.18	70	116.3	83.54	0	46.27	valid	1.5	0.05	valid	5	2	valid	5	10	valid	valid
5	32.5	35	37.5	52.3	56.3	60.3	55.2	56.0	valid	46.27	4.18	70	116.3	84.15	0	46.27	valid	1.5	0.05	valid	5	2	valid	5	10	valid	valid
6	32.5	35	37.5	52.3	56.3	60.3	55.2	55.9	valid	46.27	4.18	70	116.3	83.41	0	46.27	valid	1.5	0.05	valid	5	1.8	valid	5	10	valid	valid
7	32.5	35	37.5	52.3	56.3	60.3	55.3	56.0	valid	46.27	4.18	70	116.3	84.37	0	46.27	valid	1.5	0.05	valid	5	1.8	valid	5	10	valid	valid
8	32.5	35	37.5	52.3	56.3	60.3	55.2	56.0	valid	46.27	4.18	70	116.3	84.59	0	46.27	valid	1.5	0.05	valid	5	1.8	valid	5	10	valid	valid

3.5.5 Evaluation

The pass/fail evaluation for the test runs in this test is presented in Table 18.

Table 18: Evaluation Table, Late Lane Shift Test - Nuisance Warning

Run	Warning as Recorded				Speed					Distance								Run
	Icon		Brake[3]	Audio[4]	Valid				Trunc.[5]	Accept.	Room	Optimum[7]	Tol. (s)[8]	Recorded	Room	Accept.	Eval.	Eval.
	Video[1]	State[2]	(yes/	(yes/	Nom.		Max.		to Table	Min.[6]	To Min[9]	from 641-11	0.000	at Warn.	To Max[9]	Max.[6]	(pass/	(pass/
	(frame)	(frame)	/no)	/no)	(mi/h)	(km/h)	(mi/h)	(km/h)	(km/h)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	fail)	fail)
1	none	none	no	no	35	56.32	37.50	60.34	60.00	46.27	#N/A	46.27	0.00	#N/A	#N/A	46.27	#N/A	pass
2	none	none	no	no	35	56.32	37.50	60.34	60.00	46.27	#N/A	46.27	0.00	#N/A	#N/A	46.27	#N/A	pass
3	none	none	no	no	35	56.32	37.50	60.34	60.00	46.27	#N/A	46.27	0.00	#N/A	#N/A	46.27	#N/A	pass
4	none	none	no	no	35	56.32	37.50	60.34	60.00	46.27	#N/A	46.27	0.00	#N/A	#N/A	46.27	#N/A	pass
5	none	none	no	no	35	56.32	37.50	60.34	60.00	46.27	#N/A	46.27	0.00	#N/A	#N/A	46.27	#N/A	pass
6	none	none	no	no	35	56.32	37.50	60.34	60.00	46.27	#N/A	46.27	0.00	#N/A	#N/A	46.27	#N/A	pass
7	none	none	no	no	35	56.32	37.50	60.34	60.00	46.27	#N/A	46.27	0.00	#N/A	#N/A	46.27	#N/A	pass
8	none	none	no	no	35	56.32	37.50	60.34	60.00	46.27	#N/A	46.27	0.00	#N/A	#N/A	46.27	#N/A	pass

The second, third, fourth, and fifth columns of Table 18 show that, as desired, no warnings occurred. This makes the other columns irrelevant.

Thus, all runs in this test, and so also the test itself, passed.

3.5.6 Suggested Test Procedure Improvements

None

3.6 Multiple Intersections within 300m Radius: Warning Case

3.6.1 Scenario Overview

This test and the test in Subsection 3.7 feature two intersections within the DSRC transmitting range of 300 m (Figure 13). The purpose of these tests is to verify whether the CICAS-V system uses only the received information that is appropriate for the expected identified intersection, despite the presence of other intersections within the DSRC transmitting range. This test is the warning case where both intersections are all red. The test in Subsection 3.7 is the no warning case. If the vehicle picked the SPaT message from the wrong intersection, a warning would not be given at the correct distance from the stop bar at the main intersection.

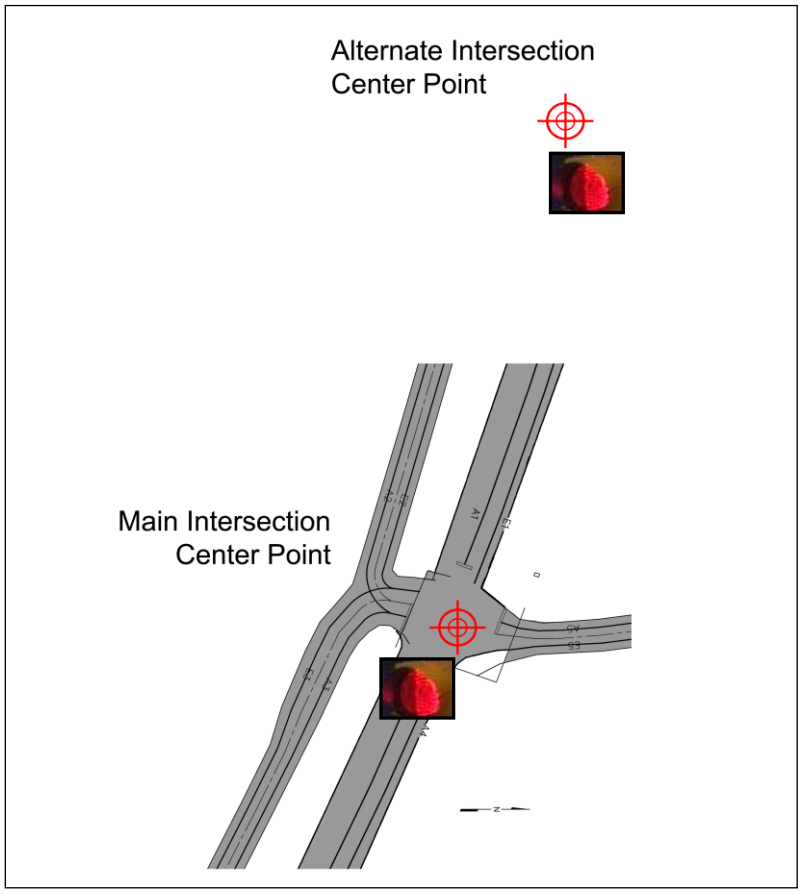

Figure 13: Multiple Intersections: Warning Case, Test Setup

3.6.2 Conditions

There were no deviations from the general test conditions detailed in Section 2.

Although 8 runs are specified for this test, more than 8 runs were performed in order to ensure sufficient number of valid runs. During the test a preliminary evaluation was conducted to see whether DSRC packets from the alternate intersection (SPaT and GID) were present at the warning distance for the main intersection. A second CICAS-V equipped vehicle was used for this purpose. If not enough packets were present at that distance, the run was judged to be not valid.

3.6.3 Results

The data collected during this test was stored in the files listed in Table 16.

Table 19: Test Data Files for Multiple Intersections: Warning Case

Result File Name	Description	Created By
ACI4_0402_0000_AA_080717_1536.txt	signal values	DAS
ACI4_0402_0000_AA_080717_1536.avi	video	DAS
rad_402_20080717_smartrd_1.log	DSRC reception log for Run 1	radiodemux software (logs DSRC communications) running on test observer's laptop in an additional test vehicle located before the earliest valid warning distance (corresponding to the highest valid speed)
rad_402_20080717_smartrd_2.log	DSRC reception log for Run 2	
rad_402_20080717_smartrd_3.log	DSRC reception log for Run 3	
rad_402_20080717_smartrd_4.log	DSRC reception log for Run 4	
rad_402_20080717_smartrd_5.log	DSRC reception log for Run 5	
rad_402_20080717_smartrd_6.log	DSRC reception log for Run 6	
rad_402_20080717_smartrd_7.log	DSRC reception log for Run 7	
rad_402_20080717_smartrd_8.log	DSRC reception log for Run 8	
rad_402_20080717_smartrd_9.log	DSRC reception log for Run 9	
rad_402_20080717_smartrd_10.log	DSRC reception log for Run 10	
rad_402_20080717_smartrd_11.log	DSRC reception log for Run 11	
rad_402_20080717_smartrd_12.log	DSRC reception log for Run 12	

This data was analyzed to determine test validity (Subsection 3.6.4) and pass/fail evaluation (Subsection 3.6.5).

3.6.4 Validity

The validity for this test is judged using Table 20.

In addition to the recurring validity criteria of speed, the error ellipse, PDOP, and the number of satellites, Table 20 also contains an analysis of DSRC reception in its "Alt. Inter. Reception" section. This section counts the sources of DSRC transmissions from the DSRC log files listed in Table 16. During testing the main intersection carried the Intersection Id of 5 and the alternate intersection carried the Intersection Id of 6. Within the "Alt. Inter. Reception" section of the table, the "Main" column contains, for each test run, the count of messages with Intersection Id of 5 and the "Alt." column contains the count of messages with Intersection Id of 6. The "Ratio" column is the alternate intersection count divided by the sum of the main intersection count and the alternate intersection count, expressed as percent. The reception "Eval" column gives a "valid" evaluation when this percentage is greater than or equal to 10 %. The test procedure [5] does not specify 10 % as a validity requirement, but merely requires a "presence" of SPaT receptions, so that the 10 % requirement here is a concrete more stringent expression of that specification. The alternate intersection count was performed while the vehicle was within the warning zone. In future tests, this should be performed throughout the approach of the vehicle, once the icon turns blue until the vehicle reaches the stop bar. There also needs to be a criterion that specifies the allowable gap between alternate intersection message reception. This gap should not be more than 1 sec.

Table 20 shows that there were 8 valid runs in this test: 1, 2, 4, 6, 8, 9, 10, and 12. These are the runs which will be considered for the pass/fail evaluation.

Table 20: Validity Check Table, Multiple Intersections: Warning Case

Run	Extents				Speed (S. 2.6.1)								Alt. Inter. Reception				GST_Error_Ellipse			PDOP			Satellites			Overall
	Start			End	Valid					Rec.		Eval.					Valid	Rec.	Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	
	Equip. frame	Warn. frame	Equip. frame	Stand. frame	Min.	Nom.	Max.	Min.	Max.	Min.	Max.	Valid?	Main	Alt.	Ratio Alt/Main %	Eval. Valid? 10	Max. m	Max. m	Valid?	Max.	Max.	Valid?	Max.	Max.	Valid?	Valid?
					mi/h			km/h		km/h																
1	154421	154790	154940	155306	32.5	35	37.5	52.3	60.3	55.2	56.0	valid	94	14	15	valid	1.5	0.15	valid	5.0	1.9	valid	5	7	valid	valid
2	157952	158321	158471	158678	32.5	35	37.5	52.3	60.3	55.6	56.3	valid	51	80	157	valid	1.5	0.15	valid	5	1.9	valid	5	7	valid	valid
3	160952	161318	161468	161654	32.5	35	37.5	52.3	60.3	55.6	56.2	valid	140	0	0	invalid	1.5	0.15	valid	5	1.9	valid	5	7	valid	valid
4	169442	169808	169958	170162	32.5	35	37.5	52.3	60.3	55.6	56.3	valid	84	52	62	valid	1.5	0.10	valid	5	1.6	valid	5	7	valid	valid
5	173006	173375	173525	173729	32.5	35	37.5	52.3	60.3	55.5	56.2	valid	115	8	7	invalid	1.5	0.10	valid	5	1.9	valid	5	7	valid	valid
6	179075	179444	179594	179846	32.5	35	37.5	52.3	60.3	55.5	56.1	valid	90	47	52	valid	1.5	1.15	valid	5	1.9	valid	5	7	valid	valid
7	182300	182666	182816	183047	32.5	35	37.5	52.3	60.3	55.6	56.3	valid	143	0	0	invalid	1.5	0.70	valid	5	1.9	valid	5	6	valid	valid
8	188030	188393	188543	188897	32.5	35	37.5	52.3	60.3	55.6	56.1	valid	3	111	3700	valid	1.5	0.40	valid	5	1.5	valid	5	6	valid	valid
9	191342	191708	191855	192050	32.5	35	37.5	52.3	60.3	55.7	56.3	valid	88	23	26	valid	1.5	0.35	valid	5	1.8	valid	5	6	valid	valid
10	195278	195647	195797	195992	32.5	35	37.5	52.3	60.3	55.7	56.2	valid	80	33	41	valid	1.5	0.30	valid	5	2.4	valid	5	6	valid	valid
11	198869	199235	199385	200516	32.5	35	37.5	52.3	60.3	55.5	56.1	valid	130	1	1	invalid	1.5	0.25	valid	5	1.8	valid	5	6	valid	valid
12	204482	204854	205004	205643	32.5	35	37.5	52.3	60.3	55.0	55.8	valid	1	127	12700	valid	1.5	0.20	valid	5	2.8	valid	5	6	valid	valid

3.6.5 Evaluation

The pass/fail evaluation for the test runs in this test is presented in Table 21 and Figure 14. Table 21 and Figure 14 are constructed as for previous warnings distance evaluations, such as in Subsection 3.4.5. They show that all runs provided an appropriate warning. However, since only runs 1, 2, 4, 6, 8, 9, 10, and 12 were valid for this test (as determined in Subsection 3.6.4), then only those need to be considered for evaluation here. They all passed and thus this entire test passed.

Table 21: Evaluation Table, Multiple Intersections: Warning Case

Run	Warning as Recorded				Speed		Distance								Run
	Icon		Brake[3]	Audio[4]	Recorded	Trunc.[5]	Accept.	Room	Optimum[7]	Tol. (s)[8]	Recorded	Room	Accept.	Eval.	Eval.
	Video[1]	State[2]	(yes/	(yes/	at Warn.	to Table	Min.[6]	To Min[9]	from 641-11	0.200	at Warn.	To Max[9]	Max.[6]	(pass/	(pass/
	(frame)	(frame)	/no)	/no)	(km/h)	(km/h)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	fail)	fail)
1	154790	154790	yes	yes	55.50	55.00	35.70	3.59	38.76	3.06	39.29	2.53	41.82	pass	pass
2	158320	158321	yes	yes	56.00	56.00	37.10	2.88	40.21	3.11	39.98	3.34	43.32	pass	pass
3	161317	161318	yes	yes	55.66	55.00	35.70	5.05	38.76	3.06	40.75	1.07	41.82	pass	pass
4	169808	169808	yes	yes	55.82	55.00	35.70	5.58	38.76	3.06	41.28	0.54	41.82	pass	pass
5	173374	173375	yes	yes	55.86	55.00	35.70	5.10	38.76	3.06	40.80	1.02	41.82	pass	pass
6	179444	179444	yes	yes	55.86	55.00	35.70	4.85	38.76	3.06	40.55	1.27	41.82	pass	pass
7	182665	182666	yes	yes	55.86	55.00	35.70	5.16	38.76	3.06	40.86	0.96	41.82	pass	pass
8	188393	188393	yes	yes	55.62	55.00	35.70	5.66	38.76	3.06	41.36	0.46	41.82	pass	pass
9	191705	191708	yes	yes	55.66	55.00	35.70	4.62	38.76	3.06	40.32	1.50	41.82	pass	pass
10	195647	195647	yes	yes	55.86	55.00	35.70	4.41	38.76	3.06	40.11	1.71	41.82	pass	pass
11	199233	199235	yes	yes	55.71	55.00	35.70	5.66	38.76	3.06	41.36	0.46	41.82	pass	pass
12	204853	204854	yes	yes	55.40	55.00	35.70	3.05	38.76	3.06	38.75	3.07	41.82	pass	pass

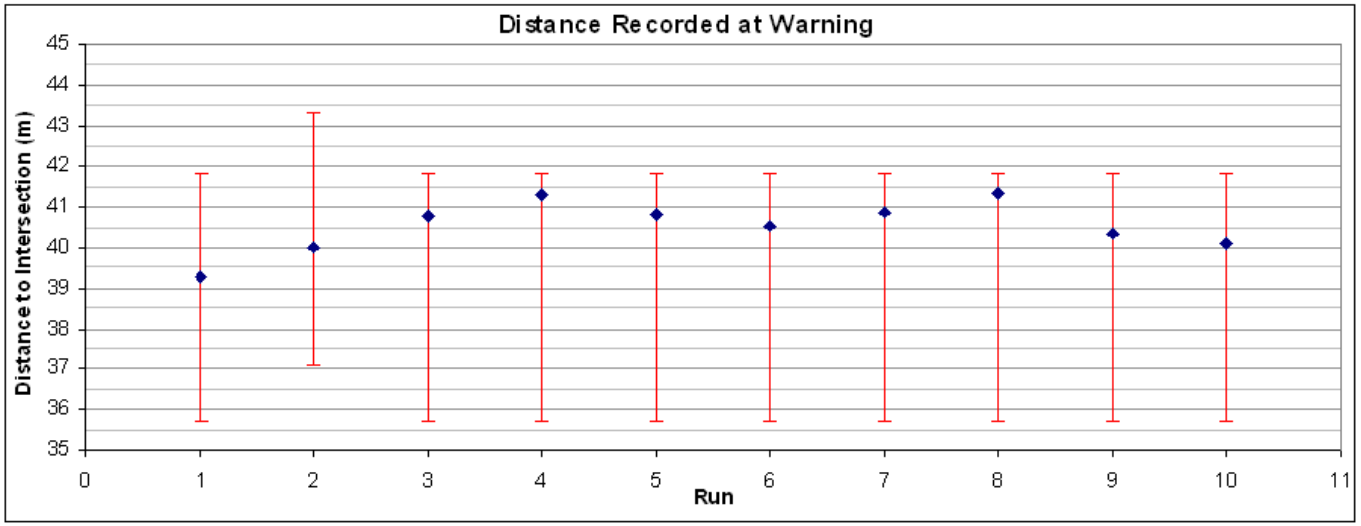

Figure 14: Distance at Warning, Multiple Intersections: Warning Case

3.7 Multiple Intersections within 300m Radius: No Warning Case

3.7.1 Scenario Overview

As the test in Subsection 3.6, this test also verifies whether the CICAS-V system can identify and react to the appropriate intersection in presence of multiple intersections within the DSRC range. However, in contrast to the other test, the test scenario in the main intersection is transmitting green while the alternate intersection is transmitting red (Figure 15). Thus in this case no warning is expected.

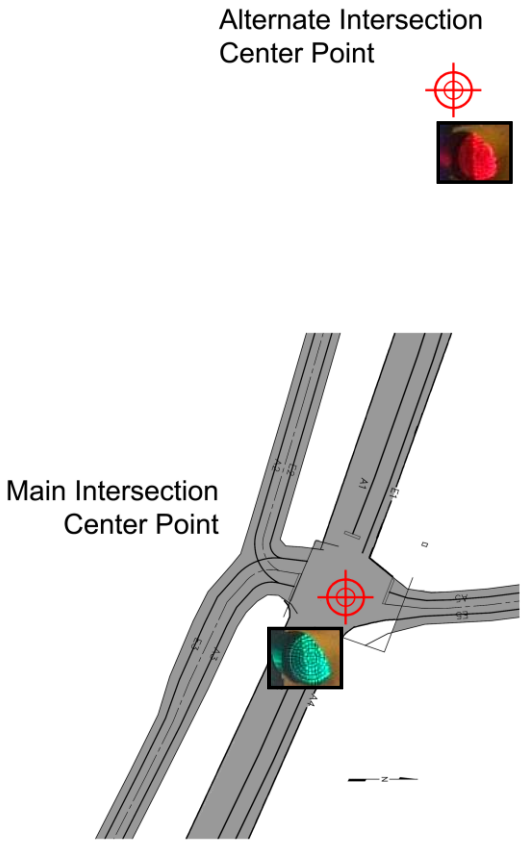

Figure 15: Multiple Intersections: No Warning Case, Test Setup

3.7.2 Conditions

There were no deviations from the general test conditions detailed in Section 2.

Although 8 runs are specified for this test, more than 8 runs were performed in order to ensure sufficient number of valid runs.

3.7.3 Results

The data collected during this test was stored in the files listed in Table 22.

Table 22: Test Data Files for Multiple Intersections: No Warning Case

Result File Name	Description	Created By
ACI4_0404_0000_AA_080717_1859.txt	signal values	DAS
ACI4_0404_0000_AA_080717_1859.avi	video	DAS
rad_404_20080717_smartrd_1.log	DSRC reception log for Run 1	radiodemux software (logs DSRC communications) running on test observer's laptop in an additional test vehicle located before the earliest valid warning distance (corresponding to the highest valid speed)
rad_404_20080717_smartrd_2.log	DSRC reception log for Run 2	
rad_404_20080717_smartrd_3.log	DSRC reception log for Run 3	
rad_404_20080717_smartrd_4.log	DSRC reception log for Run 4	
rad_404_20080717_smartrd_5.log	DSRC reception log for Run 5	
rad_404_20080717_smartrd_6.log	DSRC reception log for Run 6	
rad_404_20080717_smartrd_7.log	DSRC reception log for Run 7	
rad_404_20080717_smartrd_8.log	DSRC reception log for Run 8	
rad_404_20080717_smartrd_9.log	DSRC reception log for Run 9	
rad_404_20080717_smartrd_10.log	DSRC reception log for Run 10	
rad_404_20080717_smartrd_11.log	DSRC reception log for Run 11	
rad_404_20080717_smartrd_12.log	DSRC reception log for Run 12	

This data was analyzed to determine test validity (Subsection 3.7.4) and pass/fail evaluation (Subsection 3.7.5).

3.7.4 Validity

The validity for this test is judged using Table 23. Table 23 is constructed as detailed previously in Subsection 3.6.4 but using the data resulting from this test. According to the table there were 8 valid runs: 1, 2, 3, 5, 8, 9, 10, and 12.

Table 23: Validity Check Table, Multiple Intersections: No Warning Case

Run	Extents				Speed (S. 2.6.1)								Alt. Inter. Reception				GST_Error_Ellipse			PDOP			Satellites			Overall
	Start			End	Valid					Rec.		Eval.	Main	Alt.	Ratio	Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	Valid?
	Equip. frame	Warn. frame	Equip. frame	Stand. frame	Min.	Nom.	Max.	Min.	Max.	Min.	Max.	Valid?			Alt/Main %	Valid? 10	Max. m	Max. m	Valid?	Max.	Max.	Valid?	Max.	Max.	Valid?	
					mi/h			km/h		km/h																
1	154679	none	none	155144	32.5	35	37.5	52.3	60.3	55.6	56.4	valid	72	48	67	valid	1.5	0.15	valid	5.0	1.5	valid	5	9	valid	valid
2	158114	none	none	158576	32.5	35	37.5	52.3	60.3	55.8	56.5	valid	53	58	109	valid	1.5	0.15	valid	5	1.5	valid	5	9	valid	valid
3	161510	none	none	161972	32.5	35	37.5	52.3	60.3	55.8	56.5	valid	44	74	168	valid	1.5	0.10	valid	5	1.5	valid	5	9	valid	valid
4	165011	none	none	165473	32.5	35	37.5	52.3	60.3	55.8	56.5	valid	116	4	3	invalid	1.5	0.10	valid	5	1.6	valid	5	9	valid	valid
5	169814	none	none	170279	32.5	35	37.5	52.3	60.3	55.6	56.5	valid	106	20	19	valid	1.5	0.10	valid	5	1.6	valid	5	9	valid	valid
6	173348	none	none	173810	32.5	35	37.5	52.3	60.3	55.8	56.4	valid	126	0	0	invalid	1.5	0.10	valid	5	1.6	valid	5	9	valid	valid
7	177725	none	none	178187	32.5	35	37.5	52.3	60.3	55.8	56.5	valid	120	2	2	invalid	1.5	0.10	valid	5	1.6	valid	5	9	valid	valid
8	184448	none	none	184937	32.5	35	37.5	52.3	60.3	55.9	56.6	valid	44	83	189	valid	1.5	0.10	valid	5	2.1	valid	5	9	valid	valid
9	187895	none	none	188360	32.5	35	37.5	52.3	60.3	55.4	56.2	valid	60	36	60	valid	1.5	0.10	valid	5	1.6	valid	5	9	valid	valid
10	191126	none	none	191588	32.5	35	37.5	52.3	60.3	55.9	56.5	valid	78	44	56	valid	1.5	0.10	valid	5	2.1	valid	5	9	valid	valid
11	194375	none	none	194834	32.5	35	37.5	52.3	60.3	56.0	56.5	valid	123	0	0	invalid	1.5	0.05	valid	5	2.1	valid	5	9	valid	valid
12	197858	none	none	198314	32.5	35	37.5	52.3	60.3	55.9	56.5	valid	100	32	32	valid	1.5	0.05	valid	5	2.1	valid	5	9	valid	valid

3.7.5 Evaluation

There were no warnings expected in this test, and as the second and third columns of Table 23 demonstrate (automatically generated based on test data), none were received. This means that all the valid runs identified in Subsection 3.7.4 passed and thus this entire test also passed.

3.8 Dynamic Signal Change to Yellow, Too Late to Warn

3.8.1 Scenario Overview

In this test, as the test vehicle drives toward the intersection, the signal changes from green to yellow before the earliest warning distance and stays yellow until after the stop bar when it changes to red. The purpose of the test is to verify whether the CICAS-V system will appropriately avoid issuing a warning for a yellow signal that changes to red only after the stop bar. The test procedure for this test is specified in detail in [5].

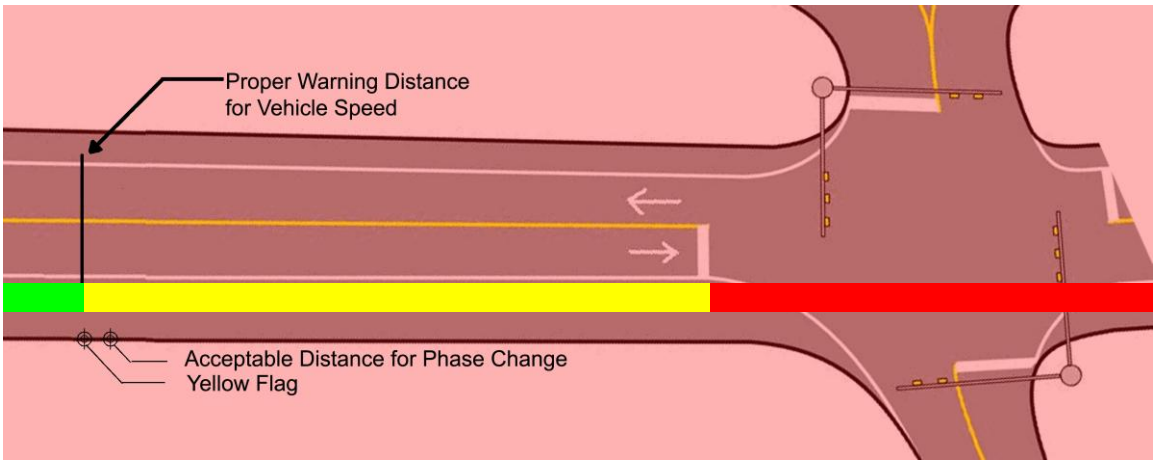

Figure 16: Dynamic Signal Change to Yellow, Too Late to Warn, Test Setup

3.8.2 Conditions

There were no deviations from the general test conditions detailed in Section 2.

Although 8 runs are specified for this test, more than 8 runs were performed in order to ensure sufficient number of valid runs.

3.8.3 Results

The data collected during this test was stored in the files listed in Table 24.

Table 24: Test Data Files for Dynamic Signal Change to Yellow, Too Late to Warn

Result File Name	Description	Created By
ACI4_0308_0000_AA_080716_2053.txt	signal values	DAS
ACI4_0308_0000_AA_080716_2053.avi	video	DAS

This data was analyzed to determine test validity (Subsection 3.8.4) and pass/fail evaluation (Subsection 3.8.5).

3.8.4 Validity

The validity of the runs in this test is analyzed and presented using Table 25.

Table 25 analyzes the validity criteria of speed, GST error ellipse, PDOP, and number of satellites as done in the previously described tests and with methodology detailed in Subsection 3.1.4. In addition, Table 25 also analyzes the validity of the phase change timing in its section “Phase Change.” At that point, the moment of change from green to

yellow is expressed in terms of distance to stop bar (in column “Rec. Yellow Dist. m”) and in terms of time to intersection (in column “Rec. Yellow TTI s”). These were determined based on analyzing the changes in “OBE-Communication.Current_Signal_Phase (None)” signal versus the changes in the distance and time signals. Figures, such as Figure 17, were created for each run and analyzed to identify transitions in the “Current_Signal_Phase” signal. The same was done for the change from yellow to red. The change from green to yellow is considered as valid in the table if it meets the requirements of the corresponding test procedure in [5] expressed in terms of available measurements: the distance at the change (“Rec. Yellow Dist. m“) is greater than earliest warning distance (“Warn 641-11 m”) and the time to intersection (“Rec. Yellow TTI s” is less than the yellow duration of 3.6 s. Similarly, the change from yellow to red is considered as valid in the table if at the time of the change both the distance to intersection (“Rec. Red Dist. m”) is not greater than 0 (vehicle past the stop bar) and the time to intersection (“Rec. Red TTI s”) is not greater than 0. The entire “Phase Change” section of the table is marked as “valid” in its “Eval” column if both the green-to-yellow and yellow-to-red changes are found to be valid.

Table 25 shows that all runs executed for this test were valid.

Table 25: Validity Check Table, Dynamic Signal Change to Yellow, Too Late to Warn

Run	Speed (S. 2.6.1)								Phase Change (S. 4.9.7)						GST_Error_Ellipse			PDOP			Satellites			Overall
	Valid					Rec.		Eval.	Warn	Rec. Yellow		Rec. Red		Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	
	Min.	Nom.	Max.	Min.	Max.	Min.	Max.	Valid?	641-11	Dist.	TTI	Dist.	TTI	Valid?	Max.	Max.	Valid?	Max.	Max.	Valid?	Min.	Min.	Valid?	Valid?
	mi/h			km/h		km/h			m	m	s	m	s		m	m								
1	32.5	35	37.5	52.3	60.3	54.8	55.6	valid	46.3	47.1	3.0	none	none	valid	1.5	0.10	valid	5.0	1.8	valid	5	9	valid	valid
2	32.5	35	37.5	52.3	60.3	55.2	55.7	valid	46.3	48.0	3.1	0.0	0.0	valid	1.5	0.10	valid	5	1.8	valid	5	9	valid	valid
3	32.5	35	37.5	52.3	60.3	55.1	55.8	valid	46.3	51.3	3.3	0.0	0.0	valid	1.5	0.10	valid	5	1.8	valid	5	9	valid	valid
4	32.5	35	37.5	52.3	60.3	55.1	55.7	valid	46.3	48.4	3.1	0.0	0.0	valid	1.5	0.10	valid	5	1.8	valid	5	9	valid	valid
5	32.5	35	37.5	52.3	60.3	55.2	55.9	valid	46.3	48.6	3.1	0.0	0.0	valid	1.5	0.10	valid	5	1.8	valid	5	9	valid	valid
6	32.5	35	37.5	52.3	60.3	55.0	55.8	valid	46.3	48.8	3.1	none	none	valid	1.5	0.05	valid	5	1.8	valid	5	9	valid	valid
7	32.5	35	37.5	52.3	60.3	55.2	55.8	valid	46.3	48.5	3.1	0.0	0.0	valid	1.5	0.05	valid	5	3	valid	5	9	valid	valid
8	32.5	35	37.5	52.3	60.3	55.0	55.9	valid	46.3	49.1	3.2	0.0	0.0	valid	1.5	0.05	valid	5	3	valid	5	9	valid	valid
9	32.5	35	37.5	52.3	60.3	55.2	55.8	valid	46.3	49.5	3.2	0.0	0.0	valid	1.5	0.05	valid	5	3	valid	5	9	valid	valid
10	32.5	35	37.5	52.3	60.3	55.2	55.8	valid	46.3	49.3	3.2	0.0	0.0	valid	1.5	0.05	valid	5	3	valid	5	9	valid	valid

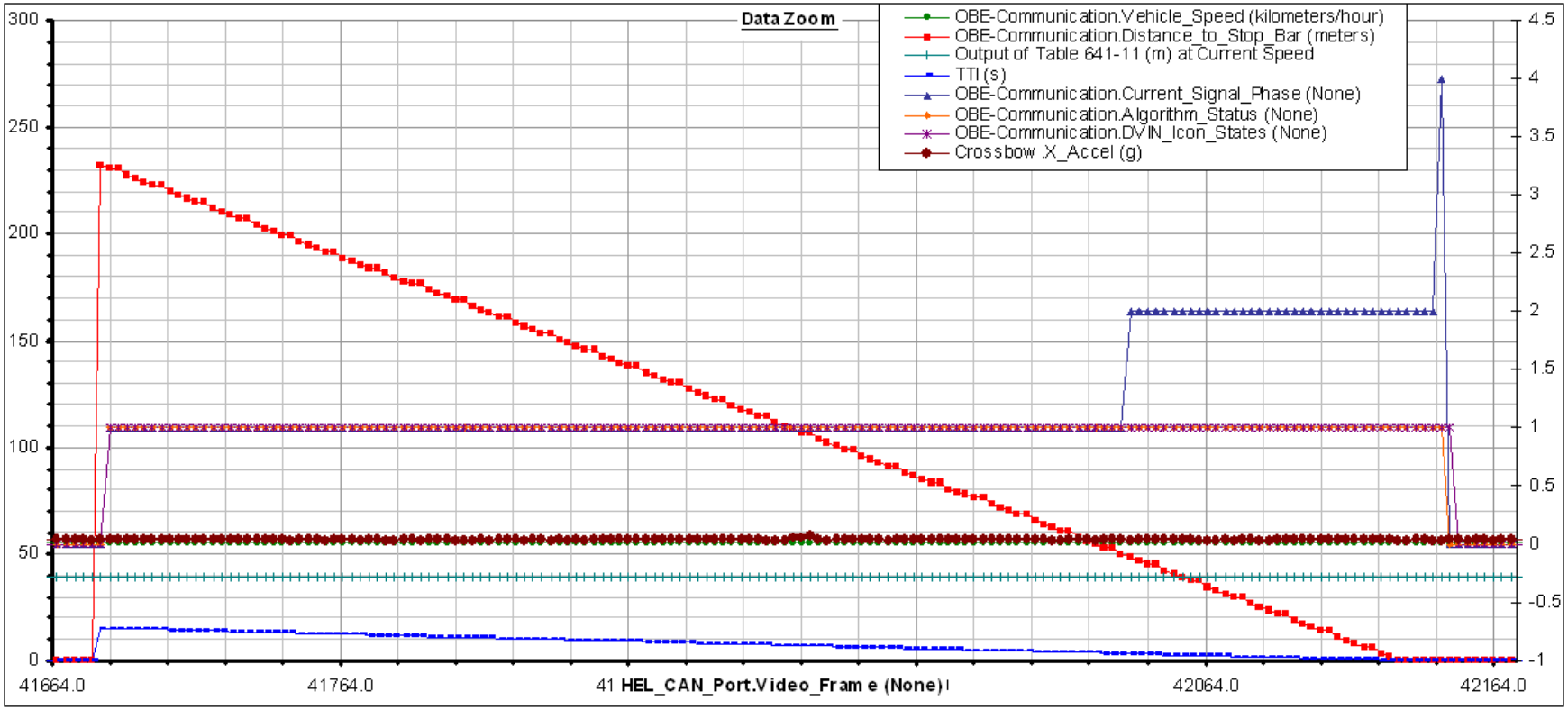

Figure 17: Evaluation Plot, Dynamic Change to Yellow, Too Late to Warn, Run 2

3.8.5 Evaluation

There were no warnings expected in this test. The signal "OBE-Communication.DVIN_Icon_States (None)," as well as video/audio file and the acceleration signal ("Crossbow.X_Accel (g)"), were analyzed to check whether any warning modalities were issued and none were found. Table 26 is the result of analysis of "DVIN_Icon_States" and shows that no warnings were found.

Thus all test runs in this test, out of which only the first 8 are needed, are found to have passed and so the entire test also passed.

Table 26: Warning Analysis, Dynamic Change to Yellow, Too Late to Warn

Run	Extents			
	Start			End
	Equip. frame	Warn. frame	Equip. frame	Stand. frame
1	38681	none	none	39149
2	41684	none	none	42152
3	44543	none	none	45011
4	47543	none	none	48011
5	50558	none	none	51023
6	53711	none	none	54176
7	56744	none	none	57212
8	59729	none	none	60200
9	62807	none	none	63275
10	65966	none	none	66434

3.9 Dynamic Signal to Red, In Time for Warning

3.9.1 Scenario Overview

In this test, as the test vehicle drives toward the intersection, the signal changes from yellow to red after the proper warning distance but before the stop bar. The purpose of the test is to verify whether the CICAS-V system will appropriately issue a warning in this scenario. The test procedure for this test is specified in detail in [5].

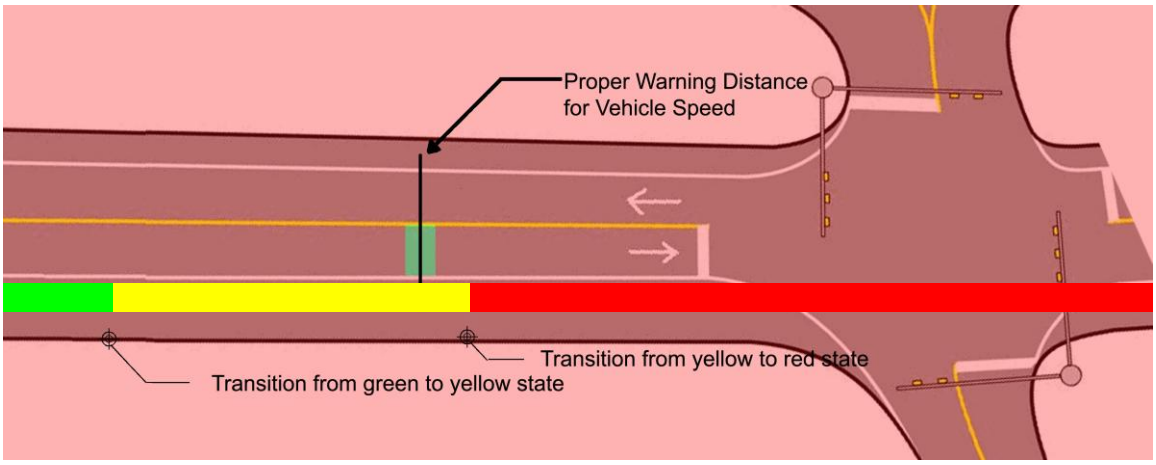

Figure 18: Dynamic Signal to Red, In Time for Warning, Test Setup

3.9.2 Conditions

There were no deviations from the general test conditions detailed in Section 2.

Although 8 runs are specified for this test, more than 8 runs were performed in order to ensure sufficient number of valid runs.

3.9.3 Results

The data collected during this test was stored in the files listed in Table 27.

Table 27: Test Data Files for Dynamic Signal to Red, In Time for Warning

Result File Name	Description	Created By
ACI4_0309_0000_AA_080716_2119.txt	signal values	DAS
ACI4_0309_0000_AA_080716_2119.avi	video	DAS

This data was analyzed to determine test validity (Subsection 3.9.4) and pass/fail evaluation (Subsection 3.9.5).

3.9.4 Validity

The validity for this test was judged using Table 28. This table was constructed similar to the description in Subsection 3.8.4, with the difference being the requirements for the validity of the phase change. In this test, the change to yellow is also expected before the warning distance (yellow "Dist." greater than the warning distance) but the change to red is expected after the warning distance and before the stop bar (yellow "Dist" greater than the yellow duration of 3.6 s, red "Dist" and "TTI" greater than zero).

As Table 28 shows, all runs in this test satisfy all their validity criteria.

Table 28: Validity Check Table, Dynamic Signal to Red, In Time for Warning

Run	Speed (S. 2.6.1)							Phase Change (S. 4.9.7)						GST_Error_Ellipse			PDOP			Satellites			Overall
	Valid					Rec.		Eval.	Warn	Rec. Yellow		Rec. Red		Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	Valid?
	Min.	Nom.	Max.	Min.	Max.	Min.	Max.	Valid?	641-11	Dist.	TTI	Dist.	TTI	Valid?	Max.	Max.	Valid?	Max.	Max.	Valid?	Max.	Max.	Valid?	
	mi/h			km/h		km/h			m	m	s	m	s		m	m								
1	32.5	35	37.5	52.3	60.3	55.1	55.7	valid	46.3	58.1	3.8	8.0	0.9	valid	1.5	0.05	valid	5.0	3	valid	5	9	valid	valid
2	32.5	35	37.5	52.3	60.3	54.9	55.7	valid	46.3	58.0	3.8	7.3	0.7	valid	1.5	0.05	valid	5	2	valid	5	9	valid	valid
3	32.5	35	37.5	52.3	60.3	55.2	55.8	valid	46.3	57.8	3.7	8.6	1.1	valid	1.5	0.05	valid	5	2.9	valid	5	9	valid	valid
4	32.5	35	37.5	52.3	60.3	55.1	55.8	valid	46.3	59.5	3.9	7.9	0.9	valid	1.5	0.05	valid	5	2.8	valid	5	9	valid	valid
5	32.5	35	37.5	52.3	60.3	55.2	55.8	valid	46.3	59.9	3.9	7.8	0.8	valid	1.5	0.05	valid	5	2	valid	5	9	valid	valid
6	32.5	35	37.5	52.3	60.3	55.2	55.9	valid	46.3	57.5	3.7	7.2	0.8	valid	1.5	0.05	valid	5	2	valid	5	9	valid	valid
7	32.5	35	37.5	52.3	60.3	55.0	55.8	valid	46.3	56.9	3.7	7.2	0.7	valid	1.5	0.05	valid	5	2	valid	5	9	valid	valid
8	32.5	35	37.5	52.3	60.3	55.1	55.9	valid	46.3	58.0	3.7	8.7	1.1	valid	1.5	0.05	valid	5	2	valid	5	10	valid	valid
9	32.5	35	37.5	52.3	60.3	55.0	55.8	valid	46.3	58.8	3.8	9.8	1.1	valid	1.5	0.05	valid	5	2	valid	5	10	valid	valid
10	32.5	35	37.5	52.3	60.3	55.1	55.9	valid	46.3	59.4	3.8	8.4	1.0	valid	1.5	0.05	valid	5	1.9	valid	5	10	valid	valid

3.9.5 Evaluation

The pass/fail evaluation for the test runs in this test is presented in Table 29 and Figure 19. Table 29 and Figure 19 are constructed as for previous warnings distance evaluations, such as in Subsection 3.4.5. They show that all runs provided an appropriate warning.

Thus all test runs in this test, out of which only the first 8 are needed, are found to have passed and so the entire test also passed.

Table 29: Evaluation Table, Dynamic Signal to Red, In Time for Warning

Run	Warning as Recorded				Speed		Distance								Run
	Icon		Brake[3]	Audio[4]	Recorded	Trunc.[5]	Accept.	Room	Optimum[7]	Tol. (s)[8]	Recorded	Room	Accept.	Eval.	Eval.
	Video[1]	State[2]	(yes/	(yes/	at Warn.	to Table	Min.[6]	To Min[9]	from 641-11	0.200	at Warn.	To Max[9]	Max.[6]	(pass/	(pass/
	(frame)	(frame)	/no)	/no)	(km/h)	(km/h)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	fail)	fail)
1	84051	84050	yes	yes	55.39	55.00	35.70	2.22	38.76	3.06	37.92	3.90	41.82	pass	pass
2	93746	93746	yes	yes	55.44	55.00	35.70	2.14	38.76	3.06	37.84	3.98	41.82	pass	pass
3	96763	96764	yes	yes	55.46	55.00	35.70	3.45	38.76	3.06	39.15	2.67	41.82	pass	pass
4	99593	99593	yes	yes	55.42	55.00	35.70	3.66	38.76	3.06	39.36	2.46	41.82	pass	pass
5	102424	102425	yes	yes	55.40	55.00	35.70	4.01	38.76	3.06	39.71	2.11	41.82	pass	pass
6	105293	105293	yes	yes	55.57	55.00	35.70	3.18	38.76	3.06	38.88	2.94	41.82	pass	pass
7	108267	108266	yes	yes	55.18	55.00	35.70	2.57	38.76	3.06	38.27	3.55	41.82	pass	pass
8	111105	111104	yes	yes	55.71	55.00	35.70	3.45	38.76	3.06	39.15	2.67	41.82	pass	pass
9	114128	114128	yes	yes	55.53	55.00	35.70	2.91	38.76	3.06	38.61	3.21	41.82	pass	pass
10	117050	117050	yes	yes	55.49	55.00	35.70	3.59	38.76	3.06	39.29	2.53	41.82	pass	pass

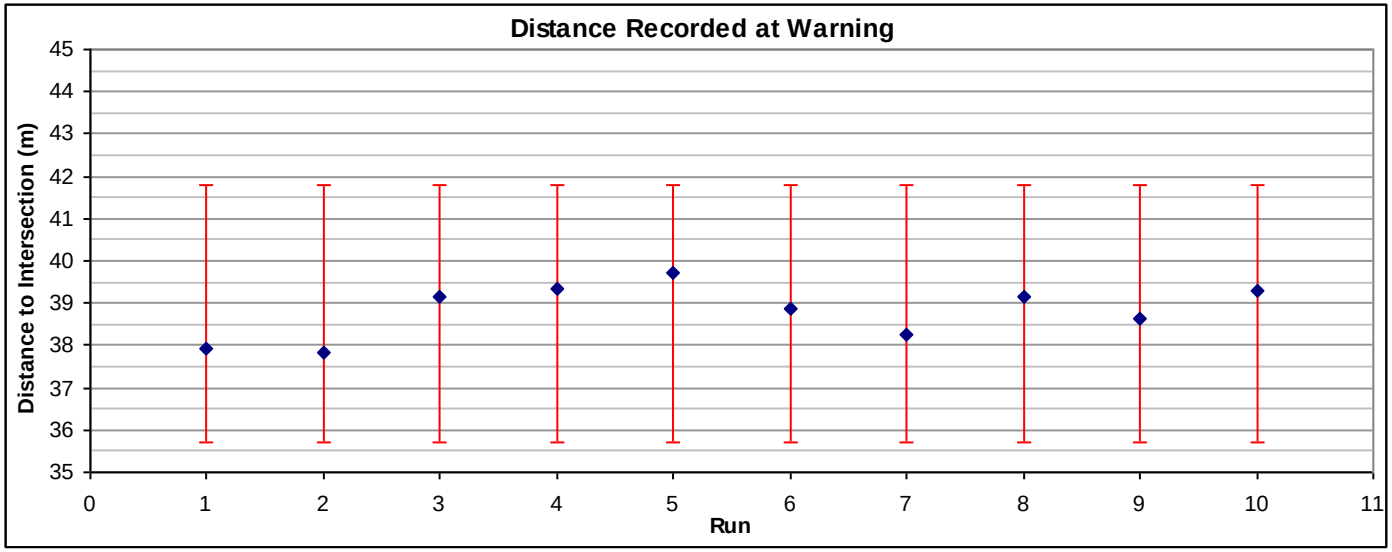

Figure 19: Distance at Warning, Dynamic Signal to Red, In Time for Warning

3.10 Dynamic Signal to Green, No Warning Case

3.10.1 Scenario Overview

Here, for the test vehicle traveling toward the intersection, the light changes from red to green before the earliest warning distance and remains green until the vehicle passes the stop bar. The purpose of this test is to check whether the CICAS-V system will appropriately avoid giving a warning in this scenario. The test procedure for this test is specified in detail in [5].

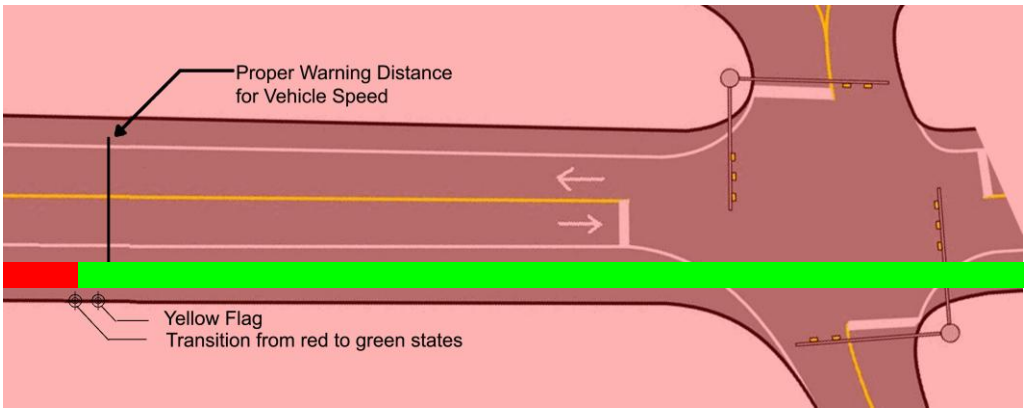

Figure 20: Dynamic Signal to Green, No Warning Case, Test Setup

3.10.2 Conditions

There were no deviations from the general test conditions detailed in Section 2.

3.10.3 Results

The data collected during this test was stored in the files listed in Table 30.

Table 30: Test Data Files for Dynamic Signal to Red, In Time for Warning

Result File Name	Description	Created By
ACI4_0401_0000_AA_080717_1426.txt	signal values	DAS
ACI4_0401_0000_AA_080717_1426.avi	video	DAS

This data was analyzed to determine test validity (Subsection 3.10.4) and pass/fail evaluation (Subsection 3.10.5).

3.10.4 Validity

The validity in this test is analyzed and presented using Table 31. This table is similar to tables described in Subsections 3.8.4 and 3.9.4. The difference is the phase change analysis. Here, in the phase change analysis, only the timing of the change from red to green is relevant and that green remains at least until the vehicle reaches the stop bar. Table 31 shows that the change to green in every case occurs before the warning distance is reached. Additional analysis ensures that the green remains until the stop bar for all runs.

Together, this makes all runs in this test valid.

Table 31: Validity Check Table, Dynamic Signal to Green, No Warning Case

Run	Speed (S. 2.6.1)								Phase Change (S. 4.9.7)				GST_Error_Ellipse			PDOP			Satellites			Overall
	Valid					Rec.		Eval.	Warn	Rec. Green		Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	
	Min.	Nom.	Max.	Min.	Max.	Min.	Max.	Valid?	641-11	Dist.	TTI	Valid?	Max.	Max.	Valid?	Max.	Max.	Valid?	Max.	Max.	Valid?	Valid?
	mi/h			km/h		km/h			m	m	s		m	m								
1	32.5	35	37.5	52.3	60.3	54.6	55.2	valid	46.3	51.2	3.34	valid	1.5	0.10	valid	5.0	2	valid	5	8	valid	valid
2	32.5	35	37.5	52.3	60.3	54.4	55.3	valid	46.3	50.3	3.28	valid	1.5	0.10	valid	5	2	valid	5	8	valid	valid
3	32.5	35	37.5	52.3	60.3	54.4	55.5	valid	46.3	51.1	3.32	valid	1.5	0.10	valid	5	2	valid	5	8	valid	valid
4	32.5	35	37.5	52.3	60.3	54.7	55.5	valid	46.3	49.2	3.20	valid	1.5	0.10	valid	5	1.9	valid	5	8	valid	valid
5	32.5	35	37.5	52.3	60.3	54.6	55.4	valid	46.3	50.5	3.30	valid	1.5	0.10	valid	5	2.2	valid	5	8	valid	valid
6	32.5	35	37.5	52.3	60.3	54.5	55.3	valid	46.3	49.2	3.21	valid	1.5	0.10	valid	5	2.2	valid	5	8	valid	valid
7	32.5	35	37.5	52.3	60.3	54.8	55.4	valid	46.3	51.8	3.38	valid	1.5	0.10	valid	5	2.2	valid	5	8	valid	valid
8	32.5	35	37.5	52.3	60.3	54.6	55.4	valid	46.3	49.1	3.20	valid	1.5	0.10	valid	5	2.2	valid	5	8	valid	valid

3.10.5 Evaluation

In this test no warning is expected. The results of analysis of test data files from Subsection 3.10.3 for occurrences of any warning modalities are presented in Table 32. As Table 32 shows there were no warnings. Thus, all test runs passed and this entire test passed.

Table 32: Warning Analysis, Dynamic Signal to Green, No Warning Case

Run	Warning as Recorded			
	Icon		Brake[3]	Audio[4]
	Video[1] (frame)	State[2] (frame)	(yes/ /no)	(yes/ /no)
1	none	none	no	no
2	none	none	no	no
3	none	none	no	no
4	none	none	no	no
5	none	none	no	no
6	none	none	no	no
7	none	none	no	no
8	none	none	no	no

3.11 SPaT Reflection and Reception – Engineering Test

3.11.1 Scenario Overview

In this scenario, the test vehicle is closely following a large vehicle while driving toward the intersection which is transmitting red (Figure 21). The purpose of this test is to examine the performance of the CICAS-V system when DSRC reception is poor. The large lead vehicle is intended to create an obstruction that reduces DSRC reception. The test procedure for this test is specified in detail in [5].

This test was designed for characterizing CICAS-V system performance under wireless obstructions. It does not evaluate the system's ability to meet a functional requirement. As such, this test does not have pass/fail criteria and does not count in the evaluation of overall objective testing pass/fail conclusion. This document and the test procedures [5] call such tests as "engineering tests."

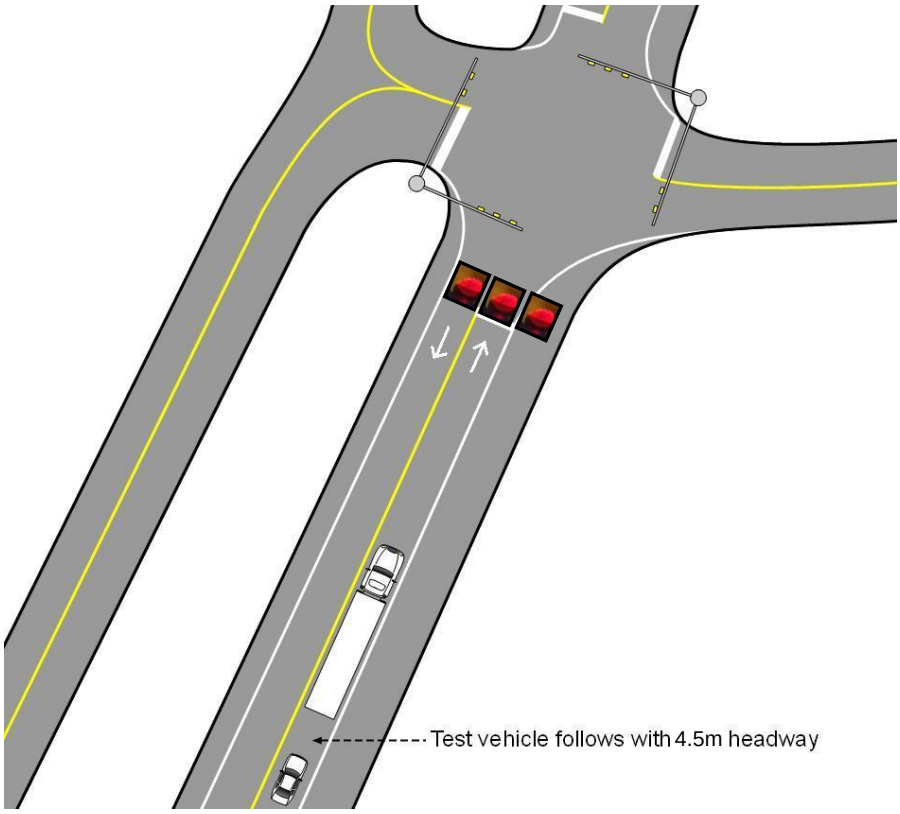

Figure 21: SPaT Reflection and Reception – Engineering Test, Test Setup

3.11.2 Conditions

There were no deviations from the general test conditions detailed in Section 2.

3.11.3 Results

The data collected during this test was stored in the files listed in Table 33.

Table 33: Test Data Files for SPaT Reflection and Reception – Engineering Test

Result File Name	Description	Created By
ACI4_0403_0000_AA_080717_1809.txt	signal values	DAS
ACI4_0403_0000_AA_080717_1809.avi	video	DAS

This data was analyzed to determine test validity in Subsection 3.11.4. The performance of the CICAS-V system under these adverse wireless conditions was analyzed in Subsection 3.11.5.

3.11.4 Validity

Table 34 analyzes the four validity criteria familiar from previous tests (speed, GST error, PDOP, number of satellites) and the validity criteria specific for this test (SPaT reception). The four standard criteria are analyzed and presented as before (for description see Subsection 3.1.4).

The validity criteria specific for this test are analyzed and presented within the "Dropped SPaT Packets" section of the table. This section is based on the analysis of the signal "OBE-Communication.SPAT_Counter (cycles)." The analysis is made under the assumption that the count of SPaT reception is expected to increase by one during every cycle, or conversely, that intervals of constant count are intervals where DSRC reception is absent. The "Total" columns contain counts for each run of the cycles during which DSRC reception was found to be missing, expressed as number of packets dropped and as percentage of packets dropped when compared to the expected number of packets. The "Contiguous" columns are characterizations of blocks of consecutive drop outs. The "Num" column is the number of such blocks within the test run and the "Duration" columns are statistics for the duration of such blocks in cycles, or equivalently, packets.

Since this is an engineering test, there are no valid bounds specified for the reception measures in [5]. The test procedures in [5] only specify that "the number of dropped packets, and especially the number of consecutively dropped packets," be considered, which is done here. They are useful here as an indication of reception quality, in the light of which the performance of the CICAS-V system can be judged in Subsection 3.11.5.

The test procedures [5] also specify the following distance of 3 to 6 m as one of the validity criteria. This distance was ensured using a hand-held laser range-finder and can be considered valid for all test runs.

Table 34 reveals that, using the analysis methodology of previous sections, there are 7 valid runs and one invalid run due to the size of the error ellipse. Since this is only an engineering test, there is no requirement for a number of valid runs. The fact that there is a proper warning issued for this run (as shown in Subsection 3.11.5) in spite of the increased error is a testament to the robustness of the system.

Table 34: Validity Check Table, SPaT Reflection and Reception – Engineering Test

Run	Speed (S. 2.6.1)								Dropped SPaT Packets						GST_Error_Ellipse					PDOP					Satellites					Overall
	Valid			Rec.				Eval.	Total		Contiguous				Valid	Rec.			Eval.	Valid	Rec.			Eval.	Valid	Rec.			Eval.	
	Min.	Nom.	Max.	Min.	Max.	Min.	Max.	Valid?	pkts.	%	Num. blks.	Duration (pkts.) Min.	Avg.	Max.	Max.	Min.	Avg.	Max.	Valid?	Max.	Min.	Avg.	Max.	Valid?	Max.	Min.	Avg.	Max.	Valid?	Valid?
	mi/h			km/h		km/h									m		m													
1	30.0	35	40.0	48.3	64.4	56.7	59.4	valid	38	35	7	2	6	15	1.5	0.95	1.05	1.10	valid	5.0	1.8	1.8	1.8	valid	5	7	7	7	valid	valid
2	30.0	35	40.0	48.3	64.4	56.4	58.6	valid	6	8	4	1	2	3	1.5	1.20	1.37	1.60	invalid	5	1.8	1.8	1.8	valid	5	6	7.6	8	valid	invalid
3	30.0	35	40.0	48.3	64.4	57.4	58.8	valid	46	41	6	1	8	29	1.5	1.05	1.09	1.20	valid	5	1.7	1.7	1.7	valid	5	7	7.5	8	valid	valid
4	30.0	35	40.0	48.3	64.4	56.7	58.6	valid	40	36	5	4	8	19	1.5	0.95	1.00	1.10	valid	5	1.7	1.7	1.7	valid	5	8	8	8	valid	valid
5	30.0	35	40.0	48.3	64.4	55.4	59.1	valid	42	39	7	1	6	27	1.5	1.05	1.11	1.20	valid	5	1.8	1.8	1.8	valid	5	8	8.7	9	valid	valid
6	30.0	35	40.0	48.3	64.4	56.7	59.2	valid	46	39	4	1	12	37	1.5	1.10	1.23	1.35	valid	5	1.4	1.4	1.4	valid	5	7	8.2	9	valid	valid
7	30.0	35	40.0	48.3	64.4	56.9	58.4	valid	18	21	5	1	4	9	1.5	1.00	1.08	1.15	valid	5	1.4	1.4	1.4	valid	5	8	8.8	9	valid	valid
8	30.0	35	40.0	48.3	64.4	57.4	58.2	valid	21	24	5	2	4	7	1.5	1.05	1.17	1.35	valid	5	1.3	1.3	1.4	valid	5	7	7.4	8	valid	valid

3.11.5 Performance

The performance of the CICAS-V system under the conditions of this test is presented in Table 35 and Figure 22.

Table 35: Performance Table, SPaT Reflection and Reception – Engineering Test

Run	Warning as Recorded				Speed		Distance								Run
	Icon		Brake[3]	Audio[4]	Recorded	Trunc.[5]	Accept.	Room	Optimum[7]	Tol. (s)[8]	Recorded	Room	Accept.	Eval.	Eval.
	Video[1] (frame)	State[2] (frame)	(yes/ /no)	(yes/ /no)	at Warn. (km/h)	to Table (km/h)	Min.[6] (m)	To Min[9] (m)	from 641-11 (m)	0.200 (m)	at Warn. (m)	To Max[9] (m)	Max.[6] (m)	(pass/ fail)	(pass/ fail)
1	66909	66908	yes	yes	56.65	56.00	37.10	4.38	40.21	3.11	41.48	1.84	43.32	ok	ok
2	76389	76388	yes	yes	57.41	57.00	38.51	3.52	41.68	3.17	42.03	2.82	44.85	ok	ok
3	85702	85703	yes	yes	57.36	57.00	38.51	4.76	41.68	3.17	43.27	1.58	44.85	ok	ok
4	95275	95276	yes	yes	56.65	56.00	37.10	5.64	40.21	3.11	42.74	0.58	43.32	ok	ok
5	103643	103643	yes	yes	55.44	55.00	35.70	5.64	38.76	3.06	41.34	0.48	41.82	ok	ok
6	112073	112073	yes	yes	57.71	57.00	38.51	3.87	41.68	3.17	42.38	2.47	44.85	ok	ok
7	120781	120782	yes	yes	57.78	57.00	38.51	4.41	41.68	3.17	42.92	1.93	44.85	ok	ok
8	129786	129788	yes	yes	57.58	57.00	38.51	5.24	41.68	3.17	43.75	1.10	44.85	ok	ok

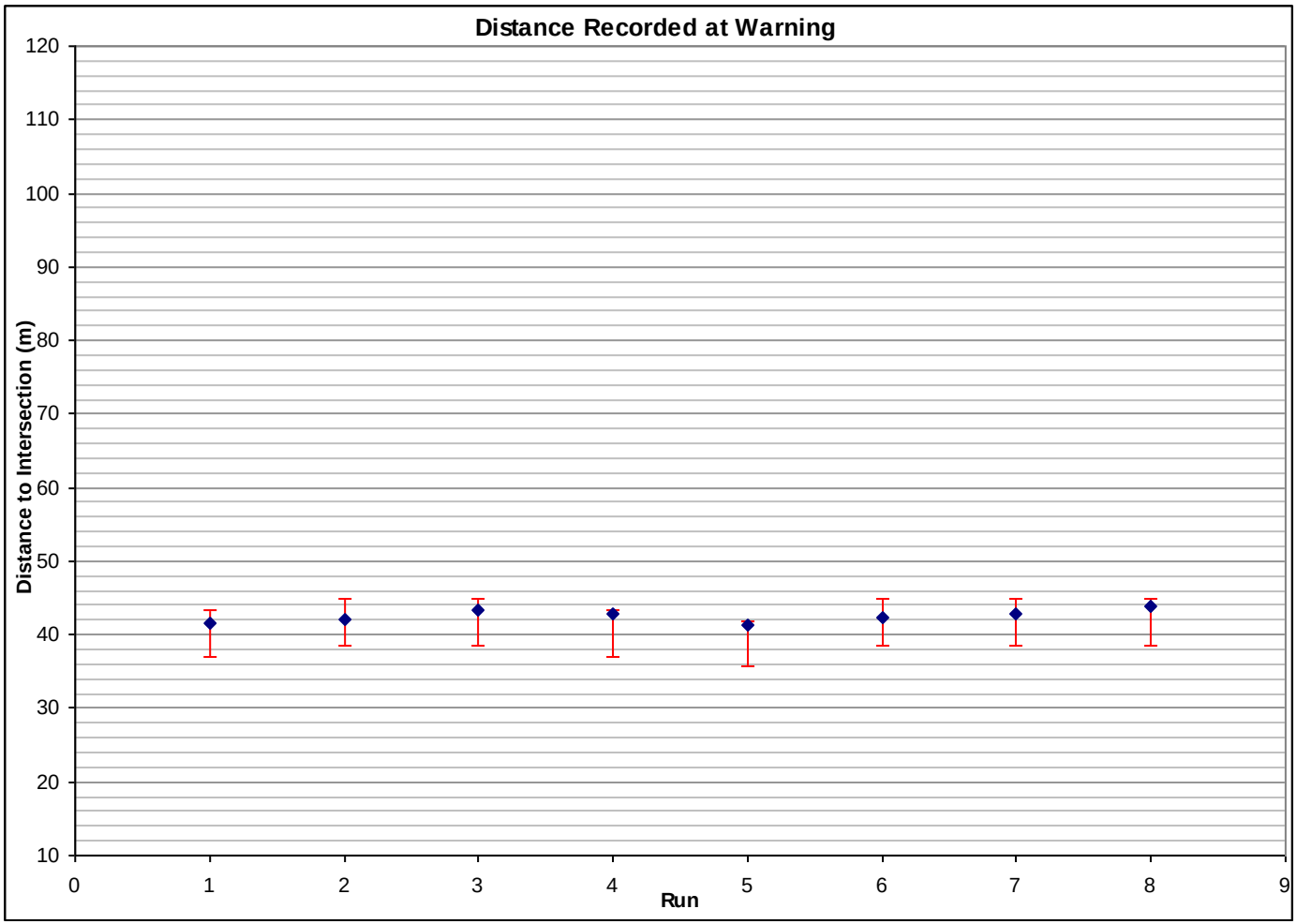

Figure 22: Distance at Warning, SPaT Reflection and Reception – Engineering Test

Table 35 and Figure 22 shows that there was an appropriate warning in all 8 runs, despite the SPaT reception drop-outs ranging from 8 to 41% (Table 34). This is a vote of confidence for the performance of the system in adverse DSRC reception conditions.

3.11.6 Suggested Test Procedure Improvements

The measurements of reception quality and CICAS-V performance can in the future be used to define reception validity bounds and replace this engineering-type test with a pass/fail test.

Measuring the distance between the truck and the vehicle can be improved by placing a reflector on the rear of the truck that the following vehicle's front radar can consistently track. If the radar can consistently track the rear of the truck, the data collected from the radar can be used to verify the distance between the vehicle and the truck and be used to validate each run avoiding the need for methods without record generation capabilities, such as hand-held range-finders.

4 Stop Sign Intersections, Test Conditions and Results

4.1 Various Approach Speeds Test

4.1.1 Test Scenario Overview

In this suite of tests the test vehicle travels toward a stop-sign controlled intersection at one of the test speeds. The warning is expected to be generated at the appropriate distance. This test verifies the operation of the CICAS-V system at the stop-controlled intersections. The test procedure for this test is specified in detail in [5].

4.1.2 Conditions

There were no deviations from the general test conditions detailed in Section 2.

4.1.3 Results

The data collected during this test was stored in the files listed in Table 36.

Table 36: Test Data Files for Stop-Sign Various Speed Approaches Test

Speed (mi/h)	Result File Name	Description	Created By
55	ACI4_0203_0000_AA_080715_2032.txt	signal values	DAS
	ACI4_0203_0000_AA_080715_2032.avi	video	DAS
35	ACI4_0201_0000_AA_080715_1952.txt	signal values	DAS
	ACI4_0201_0000_AA_080715_1952.avi	video	DAS
25	ACI4_0202_0000_AA_080715_2010.txt	signal values	DAS
	ACI4_0202_0000_AA_080715_2010.avi	video	DAS

This data was analyzed to determine test validity (Subsection 4.1.4) and pass/fail evaluation (Subsection 4.1.5).

4.1.4 Validity

The validity for this test is analyzed and presented using Table 37 through Table 39. The analysis method is described in Subsection 3.1.4. The tables show that all runs, across all test speeds, were valid.

Table 37: Validity Check Table, Stop-Sign Various Approach Speeds Test, 25 mph

Run	Speed (S. 2.6.1)								GST_Error_Ellipse			PDOP			Satellites			Overall
	Valid					Rec.		Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	
	Min.	Nom.	Max.	Min.	Max.	Min.	Max.	Valid?	Max.	Max.	Valid?	Max.	Max.	Valid?	Max.	Max.	Valid?	Valid?
	mi/h			km/h		km/h			m	m								
1	22.5	25	27.5	36.2	44.2	39.3	40.1	valid	1.5	0.10	valid	5.0	1.7	valid	5	9	valid	valid
2	22.5	25	27.5	36.2	44.2	39.5	40.3	valid	1.5	0.10	valid	5	1.7	valid	5	9	valid	valid
3	22.5	25	27.5	36.2	44.2	39.0	39.6	valid	1.5	0.10	valid	5	1.5	valid	5	9	valid	valid
4	22.5	25	27.5	36.2	44.2	39.0	39.6	valid	1.5	0.10	valid	5	1.6	valid	5	10	valid	valid
5	22.5	25	27.5	36.2	44.2	40.5	41.0	valid	1.5	0.10	valid	5	1.6	valid	5	10	valid	valid
6	22.5	25	27.5	36.2	44.2	39.8	40.4	valid	1.5	0.05	valid	5	1.7	valid	5	10	valid	valid
7	22.5	25	27.5	36.2	44.2	39.1	39.9	valid	1.5	0.05	valid	5	1.7	valid	5	10	valid	valid
8	22.5	25	27.5	36.2	44.2	38.7	39.8	valid	1.5	0.05	valid	5	1.7	valid	5	10	valid	valid

Table 38: Validity Check Table, Stop-Sign Various Approach Speeds Test, 35 mph

Run	Speed (S. 2.6.1)								GST_Error_Ellipse			PDOP			Satellites			Overall
	Valid					Rec.		Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	
	Min.	Nom.	Max.	Min.	Max.	Min.	Max.	Valid?	Max.	Max.	Valid?	Max.	Max.	Valid?	Max.	Max.	Valid?	Valid?
	mi/h			km/h		km/h			m	m								
1	32.5	35	37.5	52.3	60.3	55.0	55.6	valid	1.5	0.60	valid	5.0	1.8	valid	5	10	valid	valid
2	32.5	35	37.5	52.3	60.3	55.3	56.0	valid	1.5	0.35	valid	5	1.8	valid	5	10	valid	valid
3	32.5	35	37.5	52.3	60.3	57.3	57.6	valid	1.5	0.25	valid	5	1.8	valid	5	10	valid	valid
4	32.5	35	37.5	52.3	60.3	55.3	56.1	valid	1.5	0.20	valid	5	1.8	valid	5	10	valid	valid
5	32.5	35	37.5	52.3	60.3	54.1	54.9	valid	1.5	0.15	valid	5	1.8	valid	5	10	valid	valid
6	32.5	35	37.5	52.3	60.3	56.2	57.0	valid	1.5	0.15	valid	5	1.6	valid	5	10	valid	valid
7	32.5	35	37.5	52.3	60.3	56.0	56.6	valid	1.5	0.15	valid	5	1.6	valid	5	10	valid	valid
8	32.5	35	37.5	52.3	60.3	55.7	56.5	valid	1.5	0.10	valid	5	1.7	valid	5	10	valid	valid

Table 39: Validity Check Table, Stop-Sign Various Approach Speeds Test, 55 mph

Run	Speed (S. 2.6.1)								GST_Error_Ellipse			PDOP			Satellites			Overall
	Valid					Rec.		Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	Valid	Rec.	Eval.	
	Min.	Nom.	Max.	Min.	Max.	Min.	Max.	Valid?	Max.	Max.	Valid?	Max.	Max.	Valid?	Max.	Max.	Valid?	Valid?
	mi/h			km/h		km/h			m	m								
1	52.5	55	57.5	84.5	92.5	86.3	87.0	valid	1.5	0.90	valid	5.0	1.5	valid	5	9	valid	valid
2	52.5	55	57.5	84.5	92.5	86.1	86.6	valid	1.5	0.90	valid	5	1.7	valid	5	9	valid	valid
3	52.5	55	57.5	84.5	92.5	86.3	86.8	valid	1.5	0.95	valid	5	1.7	valid	5	9	valid	valid
4	52.5	55	57.5	84.5	92.5	86.2	86.7	valid	1.5	0.90	valid	5	1.8	valid	5	9	valid	valid
5	52.5	55	57.5	84.5	92.5	87.2	87.8	valid	1.5	0.90	valid	5	1.8	valid	5	9	valid	valid
6	52.5	55	57.5	84.5	92.5	85.9	86.7	valid	1.5	0.90	valid	5	1.8	valid	5	9	valid	valid
7	52.5	55	57.5	84.5	92.5	86.5	87.0	valid	1.5	0.95	valid	5	1.8	valid	5	9	valid	valid
8	52.5	55	57.5	84.5	92.5	87.4	88.0	valid	1.5	0.95	valid	5	1.8	valid	5	9	valid	valid

4.1.5 Evaluation

The pass/fail evaluation for this test is performed using Table 40 through Table 42 and Figure 23 through Figure 25. The analysis method is described in Subsection 3.1.5. The tables show, and figures illustrate, that all test runs passed for this test.

Table 40: Evaluation Table, Stop-Sign Various Approach Speeds Test, 25 mph

Run	Warning as Recorded				Speed		Distance								Run
	Icon		Brake[3]	Audio[4]	Recorded	Trunc.[5]	Accept.	Room	Optimum[7]	Tol. (s)[8]	Recorded	Room	Accept.	Eval.	Eval.
	Video[1]	State[2]	(yes/	(yes/	at Warn.	to Table	Min.[6]	To Min[9]	from 741-9	0.200	at Warn.	To Max[9]	Max.[6]	(pass/	(pass/
	(frame)	(frame)	/no)	/no)	(km/h)	(km/h)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	fail)	fail)
1	147993	147992	yes	yes	39.75	39.00	11.75	2.11	13.92	2.17	13.86	2.23	16.09	pass	pass
2	151861	151862	yes	yes	39.75	39.00	11.75	3.07	13.92	2.17	14.82	1.27	16.09	pass	pass
3	155428	155429	yes	yes	39.08	39.00	11.75	1.97	13.92	2.17	13.72	2.37	16.09	pass	pass
4	158899	158900	yes	yes	39.17	39.00	11.75	1.63	13.92	2.17	13.38	2.71	16.09	pass	pass
5	162444	162443	yes	yes	40.49	40.00	12.60	2.57	14.82	2.22	15.17	1.87	17.04	pass	pass
6	166137	166136	yes	yes	40.10	40.00	12.60	2.57	14.82	2.22	15.17	1.87	17.04	pass	pass
7	169947	169949	yes	yes	39.54	39.00	11.75	2.32	13.92	2.17	14.07	2.02	16.09	pass	pass
8	173463	173465	yes	yes	38.71	38.00	10.95	1.68	13.06	2.11	12.63	2.54	15.17	pass	pass

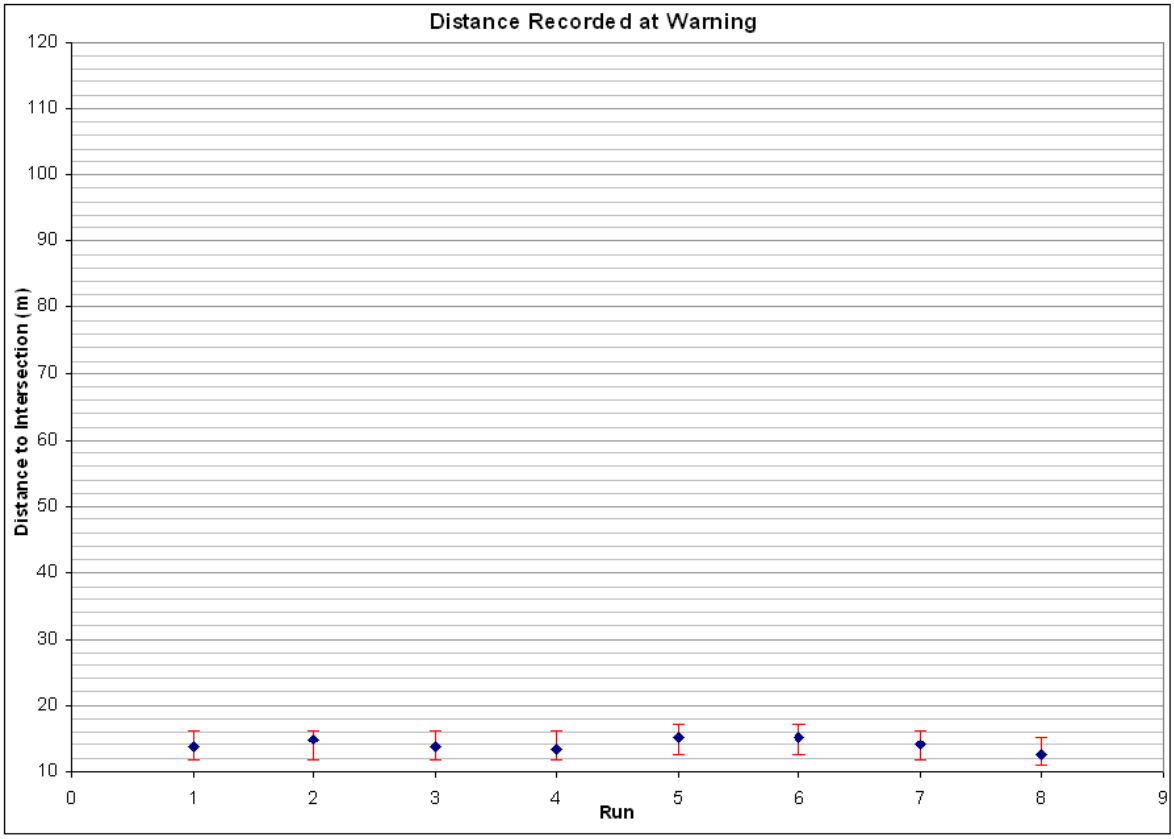

Figure 23: Distance at Warning, Stop-Sign Var. Approach Speeds Test, 25 mph

Table 41: Evaluation Table, Stop-Sign Various Approach Speeds Test, 35 mph

Run	Warning as Recorded				Speed		Distance								Run
	Icon		Brake[3]	Audio[4]	Recorded	Trunc.[5]	Accept.	Room	Optimum[7]	Tol. (s)[8]	Recorded	Room	Accept.	Eval.	Eval.
	Video[1]	State[2]	(yes/	(yes/	at Warn.	to Table	Min.[6]	To Min[9]	from 741-9	0.200	at Warn.	To Max[9]	Max.[6]	(pass/	(pass/
	(frame)	(frame)	/no)	/no)	(km/h)	(km/h)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	fail)	fail)
1	114035	114035	yes	yes	55.12	55.00	30.42	2.82	33.48	3.06	33.24	3.30	36.54	pass	pass
2	117273	117275	yes	yes	55.46	55.00	30.42	4.34	33.48	3.06	34.76	1.78	36.54	pass	pass
3	120441	120443	yes	yes	57.32	57.00	33.60	2.52	36.77	3.17	36.12	3.82	39.94	pass	pass
4	123840	123842	yes	yes	55.69	55.00	30.42	5.84	33.48	3.06	36.26	0.28	36.54	pass	pass
5	127005	127004	yes	yes	54.39	54.00	28.91	2.27	31.91	3.00	31.18	3.73	34.91	pass	pass
6	130195	130193	yes	yes	56.59	56.00	31.99	3.11	35.10	3.11	35.10	3.11	38.21	pass	pass
7	133117	133115	yes	yes	56.45	56.00	31.99	3.80	35.10	3.11	35.79	2.42	38.21	pass	pass
8	136087	136085	yes	yes	56.21	56.00	31.99	3.73	35.10	3.11	35.72	2.49	38.21	pass	pass

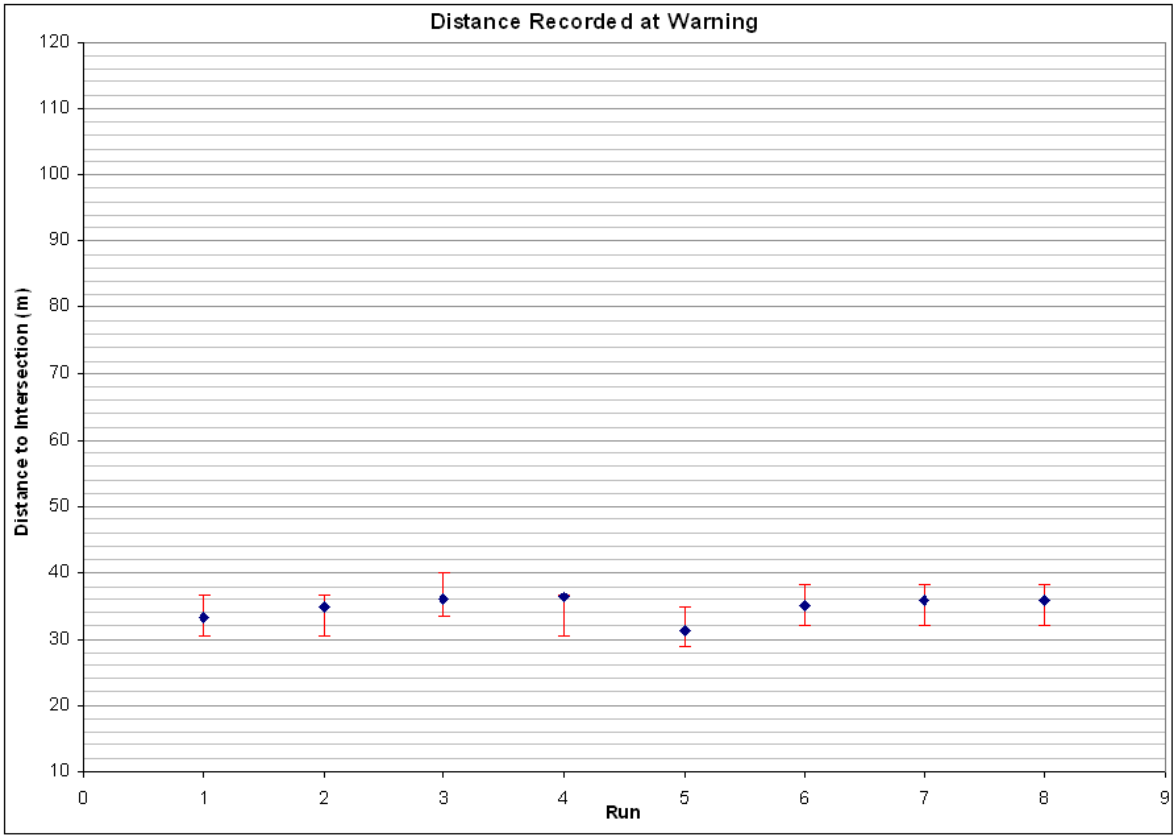

Figure 24: Distance at Warning, Stop-Sign Var. Approach Speeds Test, 35 mph

Table 42: Evaluation Table, Stop-Sign Various Approach Speeds Test, 55 mph

Run	Warning as Recorded				Speed		Distance								Run
	Icon		Brake[3]	Audio[4]	Recorded	Trunc.[5]	Accept.	Room	Optimum[7]	Tol. (s)[8]	Recorded	Room	Accept.	Eval.	Eval.
	Video[1] (frame)	State[2] (frame)	(yes/ /no)	(yes/ /no)	at Warn. (km/h)	to Table (km/h)	Min.[6] (m)	To Min[9] (m)	from 741-9 (m)	0.200 (m)	at Warn. (m)	To Max[9] (m)	Max.[6] (m)	(pass/ fail)	(pass/ fail)
1	186981	186980	yes	yes	86.73	86.00	105.29	4.50	110.07	4.78	109.79	5.06	114.85	pass	pass
2	191018	191018	yes	yes	86.46	86.00	105.29	5.81	110.07	4.78	111.10	3.75	114.85	pass	pass
3	194444	194444	yes	yes	86.70	86.00	105.29	4.32	110.07	4.78	109.61	5.24	114.85	pass	pass
4	197749	197750	yes	yes	86.50	86.00	105.29	4.67	110.07	4.78	109.96	4.89	114.85	pass	pass
5	201040	201041	yes	yes	87.62	87.00	108.73	4.24	113.56	4.83	112.97	5.42	118.39	pass	pass
6	204053	204056	yes	yes	85.85	85.00	101.94	6.15	106.66	4.72	108.09	3.29	111.38	pass	pass
7	206891	206894	yes	yes	86.85	86.00	105.29	4.54	110.07	4.78	109.83	5.02	114.85	pass	pass
8	209795	209795	yes	yes	87.50	87.00	108.73	4.10	113.56	4.83	112.83	5.56	118.39	pass	pass

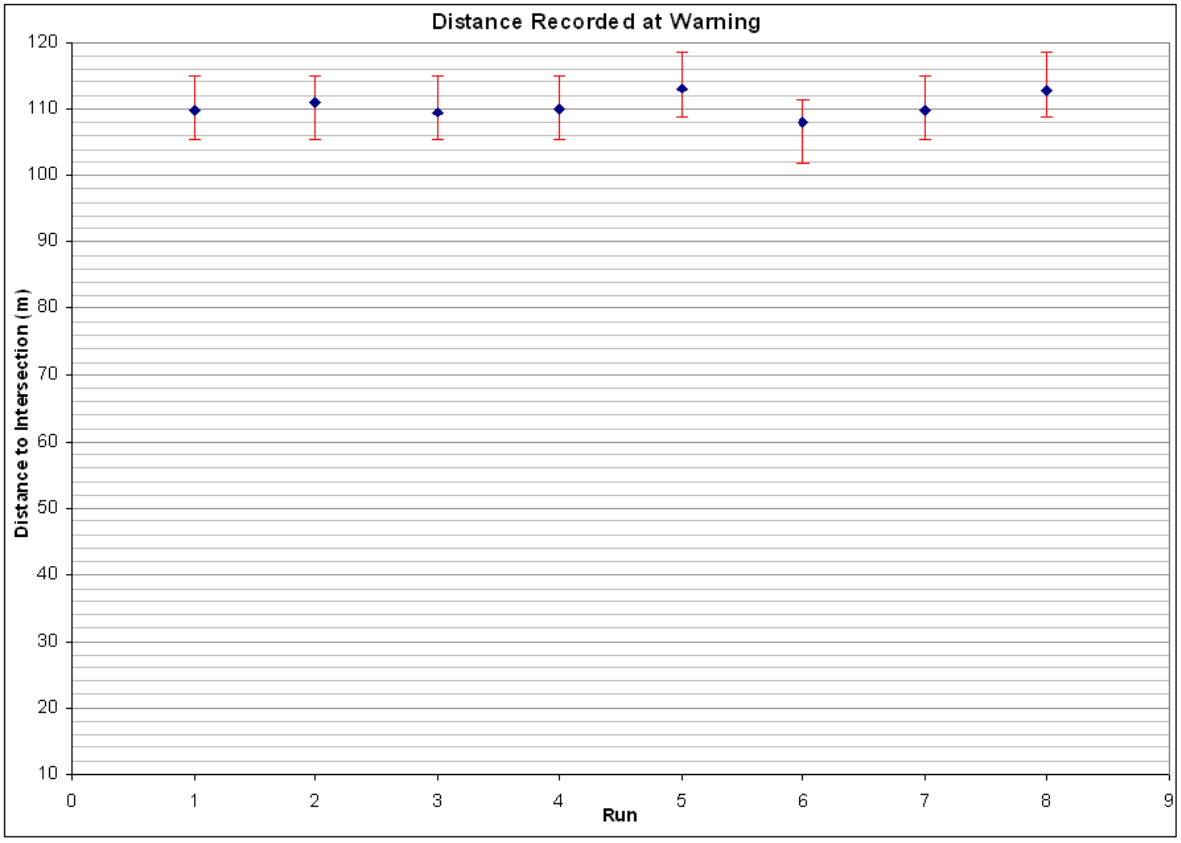

Figure 25: Distance at Warning, Stop-Sign Var. Approach Speeds Test, 55 mph

5 Suggested Test Procedure Improvements

During the execution of some tests specified by [5], as well as during the analysis of the results of those tests, difficulties and unexpected conditions were encountered. Suggestions for improving the procedures to avoid those problems for particular tests are detailed within the sections dealing with those particular tests. This section here instead details overall or general suggested improvements, and suggestions for new tests. A table with the suggested improvements can be found in Appendix D.

5.1 GID Accuracy

A new general requirement procedure needs to be added to test the accuracy of the test GIDs in relation to the markings on the test intersection. Accuracy tests need to be conducted on the placement of the stop bar and the lateral lane markings. The determination of the accuracy of the GID needs to be used to adjust test set-up procedures for the placement of flags and test script that instruct how the drive should position the vehicle for certain tests.

6 Conclusion

This document described objective testing of the CICAS-V system. All 12 tests passed.

7 References

[1] NHTSA. (2005). Traffic Safety Facts 2005. Report No. DOT HS 810 631. Washington, DC: National Highway Traffic Safety Administration. Available on the Web at: http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSFAnn/TSF2005.pdf

[2] Campbell, B., Smith, J., & Najm, W. (2004). Analysis of Fatal Crashes Due to Signal and Stop Sign Violations. Report No. DOT HS 809 779. Washington, DC: National Highway Traffic Safety Administration. Available on the Web at: http://www-nrd.nhtsa.dot.gov/departments/nrd-12/809-779/pages/TOC.htm

[3] CICAS-V Template for USDOT Reports.

[<SVN Repository CICAS-V>\Report Templates\CICAS-V Template for USDOT Reports.doc].

[4] CICAS-V Concept of Operations. Interim release v1.03 on June 29, 2007.

[Task 04 - Concept of Operations &System Requirements\CICAS-V Concept of Operations\ConOps Interim Release v1.03 06-29-07\ CICAS-V_ConOps_v0103.pdf]

[5] *CICAS-V Task 7, Objective Test Procedures*. [v1.2b]. Last changed on August 29, 2008.

[6] various test observers. CICAS-V Objective Testing Observation Forms, Filled by Hand by Test Observers.

[<SVN Repository CICAS-V>Task 11 - Vehicle_Intersection Objective Testing\results\observation form\Objective Testing, Observation Sheets, Original.pdf].

[7] Maile, Michael (Mercedes Benz) (editor and transcriber). CICAS-V Objective Testing Observation Forms, Filled by Test Observers and Transcribed.

[<SVN Repository CICAS-V>Task 11 - Vehicle_Intersection Objective Testing\results\observation form\Objective Testing, Observation Sheets, Typed.pdf].

[8] Virginia Tech Transportation Institute, 3500 Transportation Research Plaza, Blacksburg, VA 24061.

[9] http://www.vtti.vt.edu/virginiasmartroad.html, last accessed September 19, 2008.

8 Appendix

8.1 : Test Results, Plots

8.1.1 : Signalized Various Speed Approaches Test, 55 mi/h

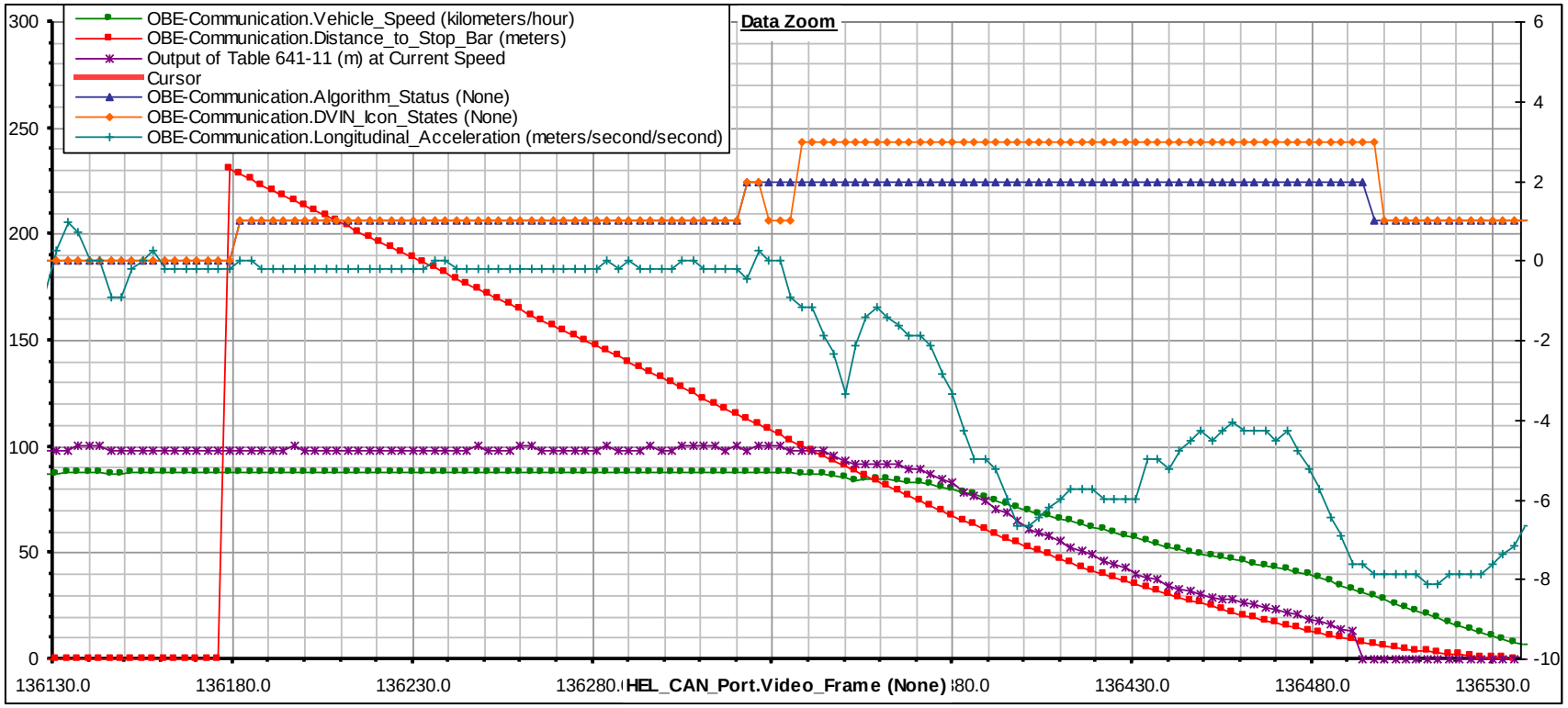

Figure 26: Signalized Various Speed Approaches Test, 55 mi/h, Run 1

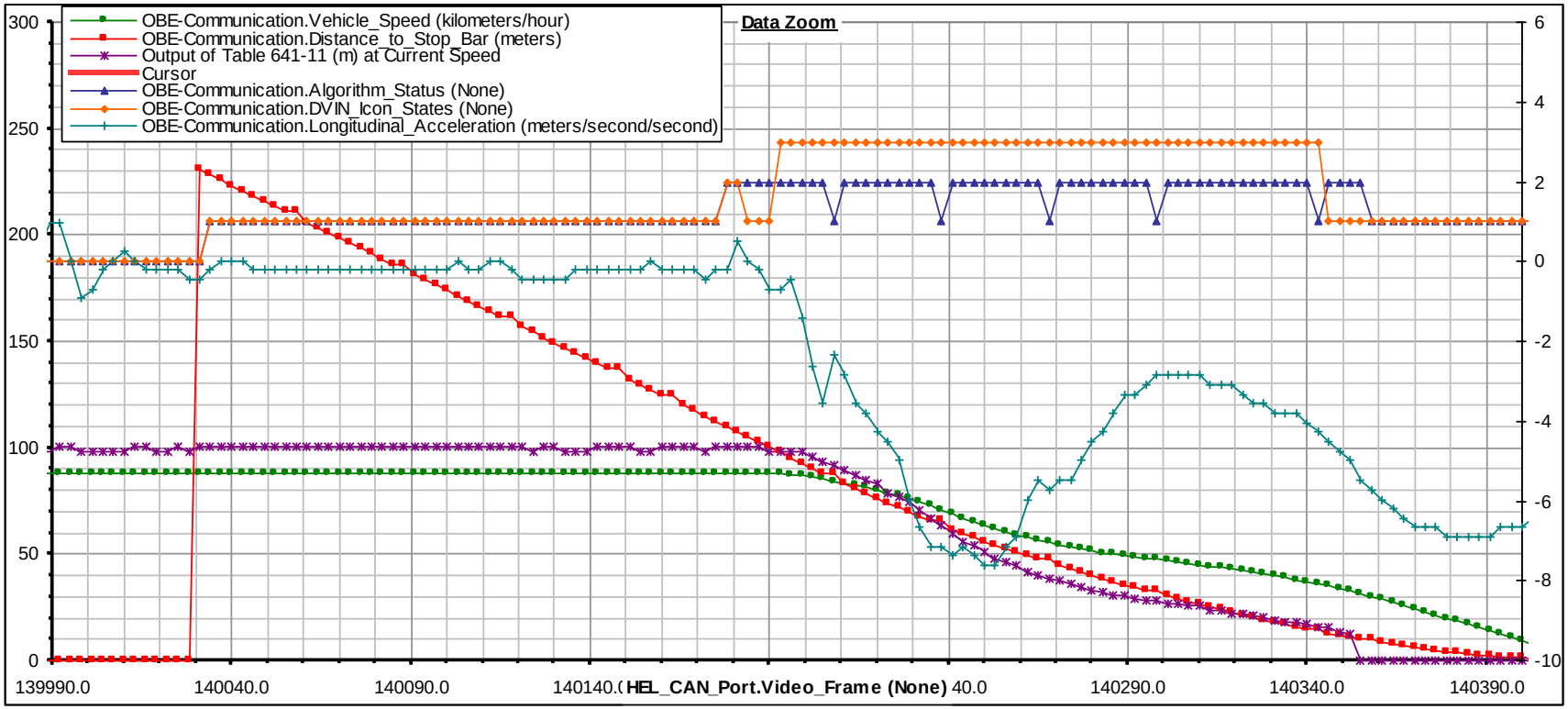

Figure 27: Signalized Various Speed Approaches Test, 55 mi/h, Run 2

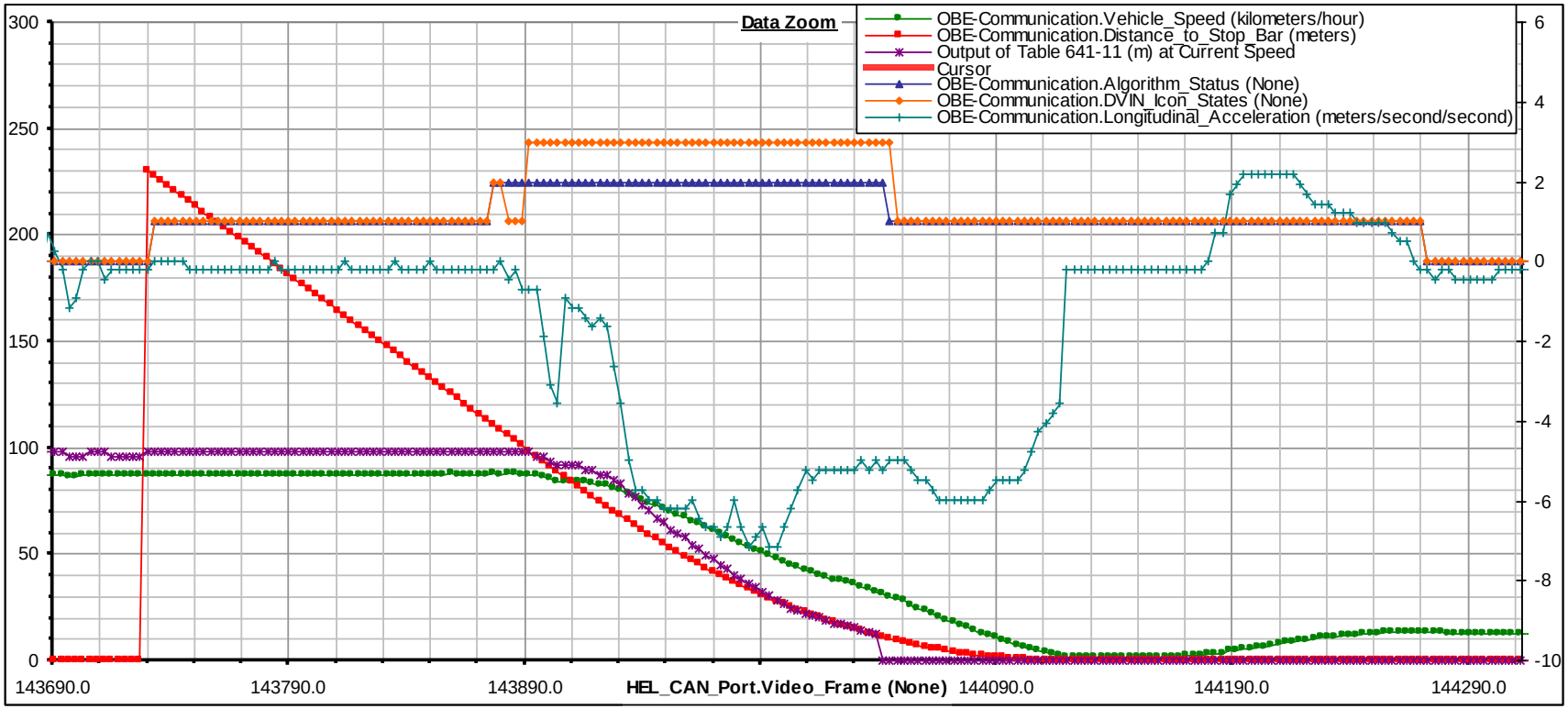

Figure 28: Signalized Various Speed Approaches Test, 55 mi/h, Run 3

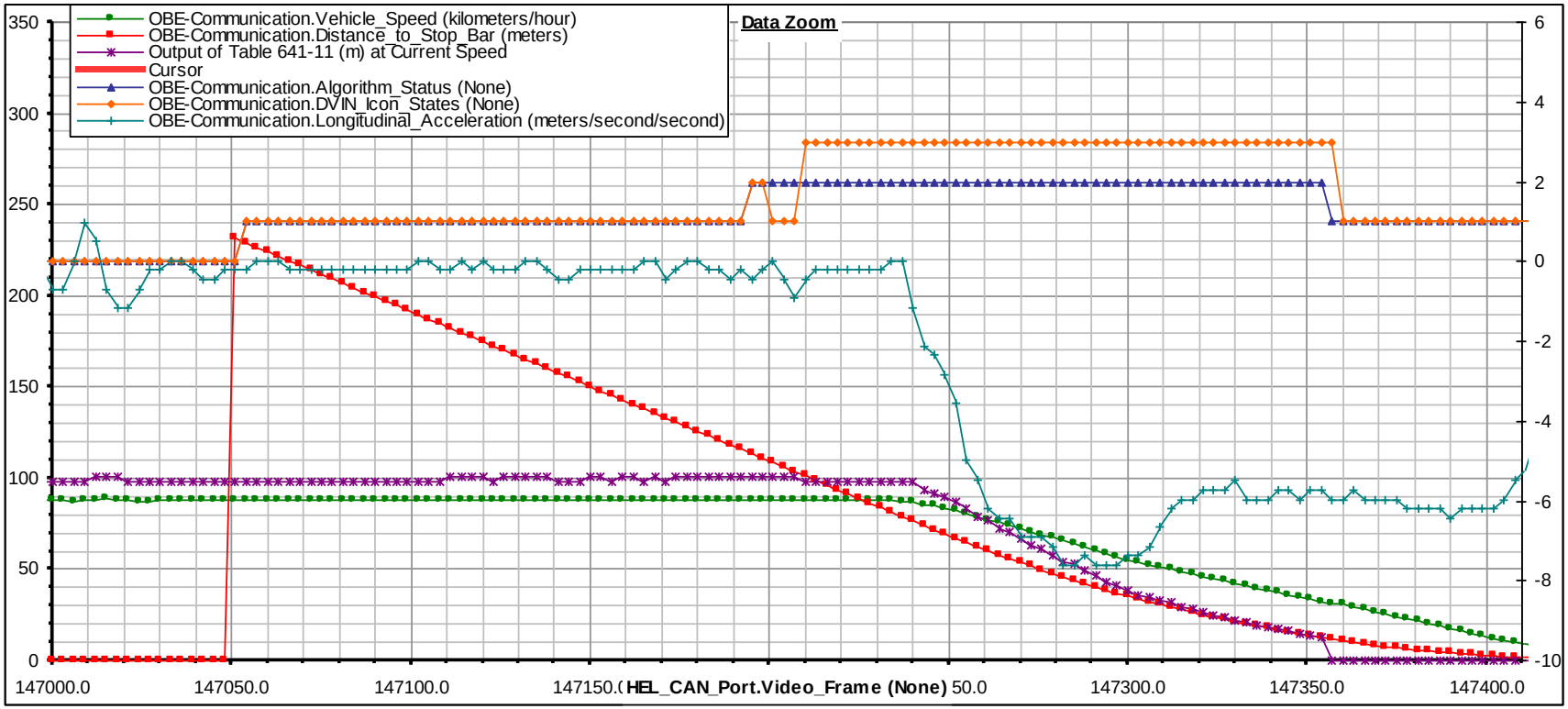

Figure 29: Signalized Various Speed Approaches Test, 55 mph, Run 4

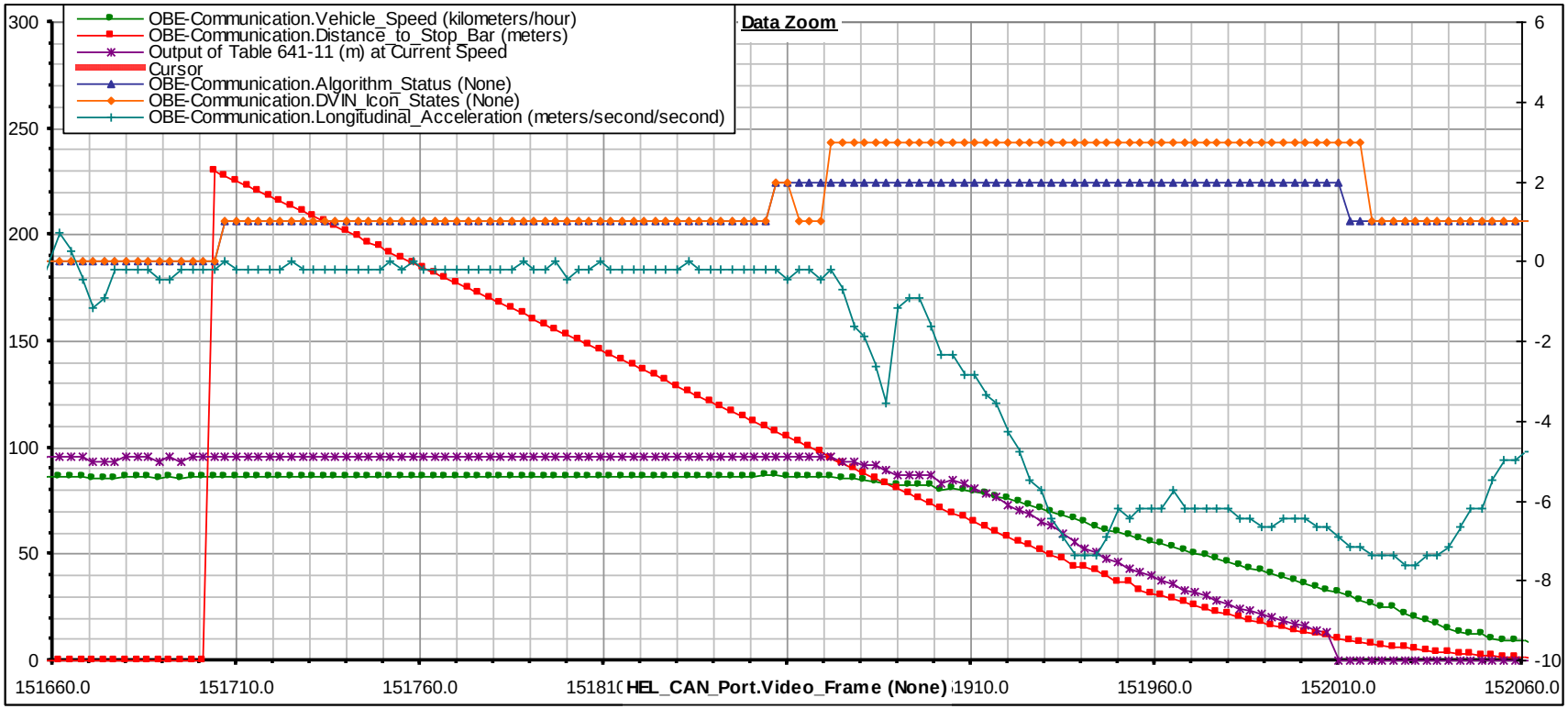

Figure 30: Signalized Various Speed Approaches Test, 55 mph, Run 5

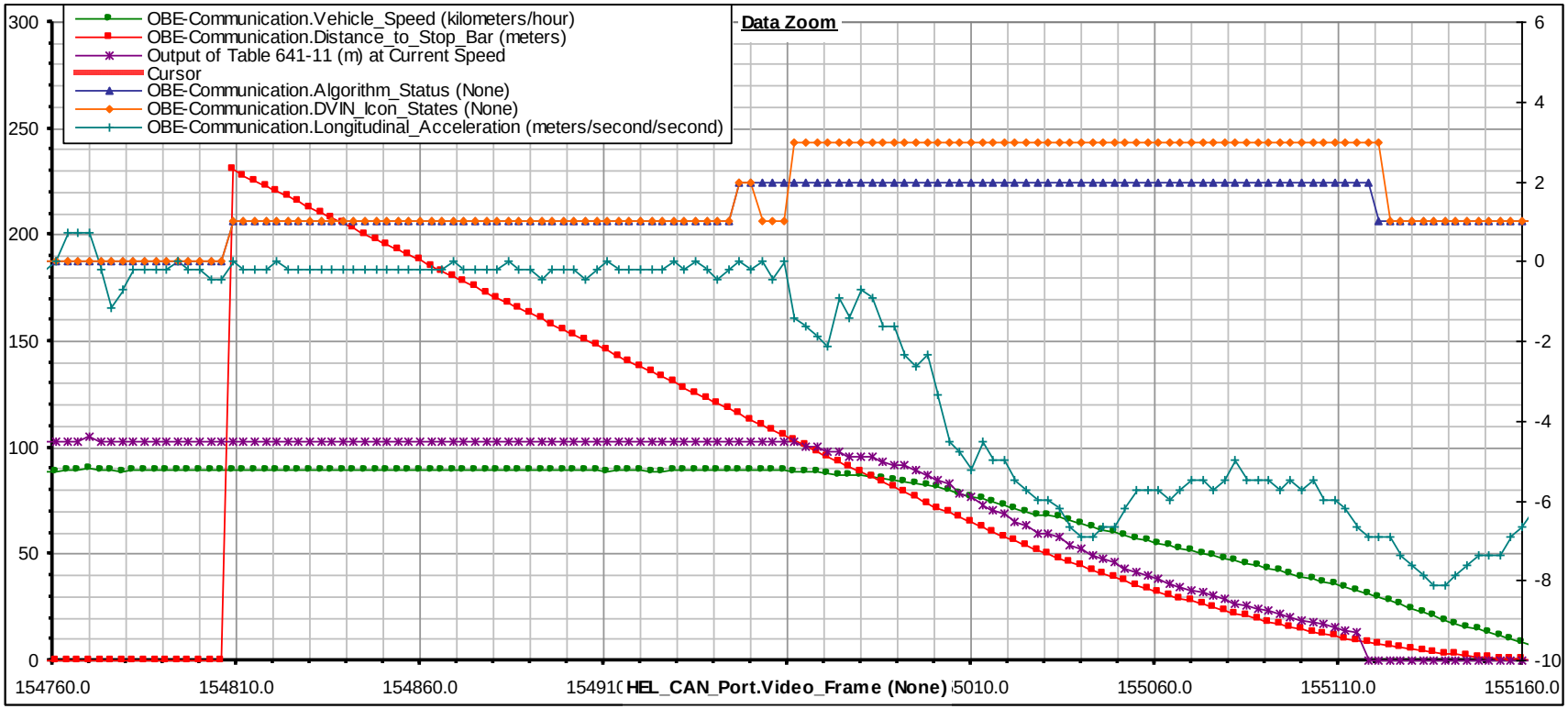

Figure 31: Signalized Various Speed Approaches Test, 55 mph, Run 6

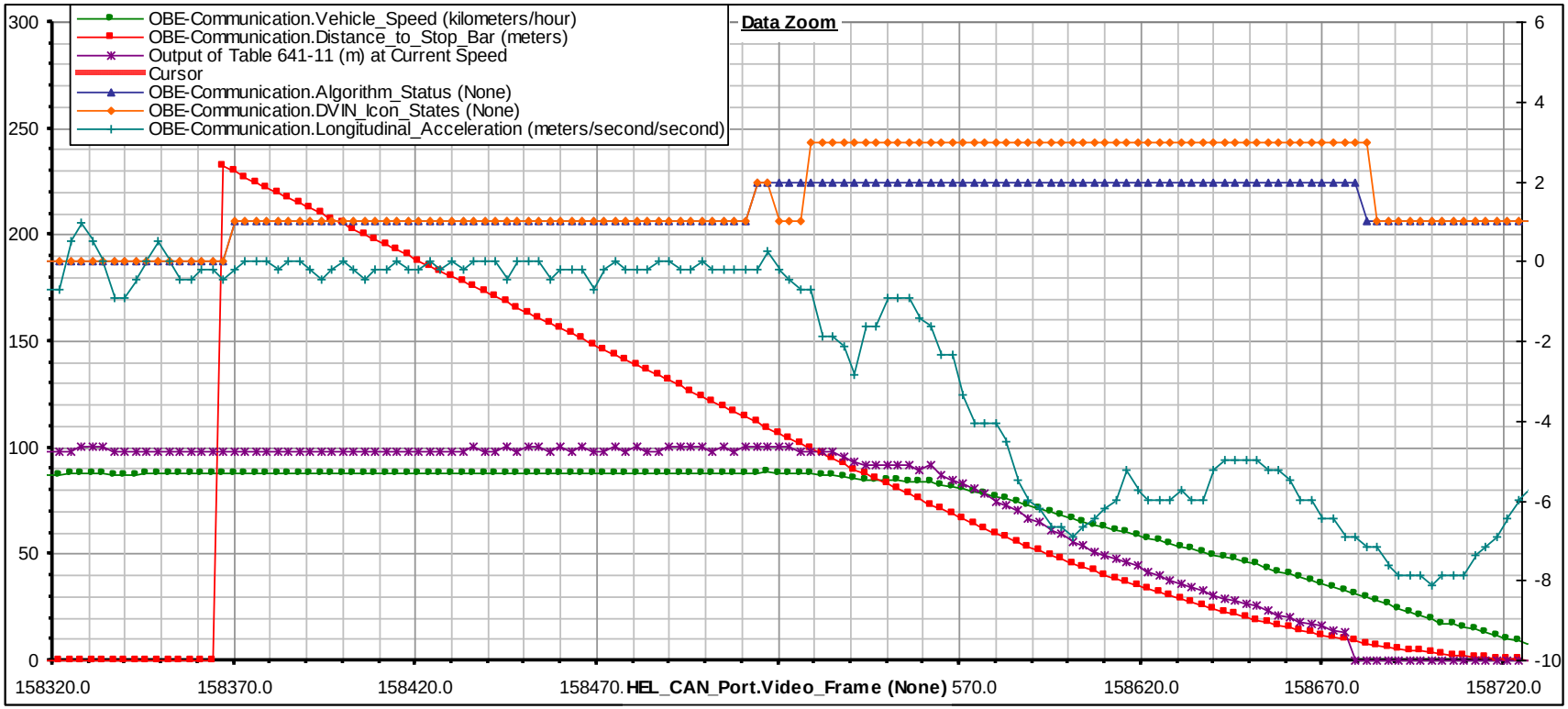

Figure 32: Signalized Various Speed Approaches Test, 55 mph, Run 7

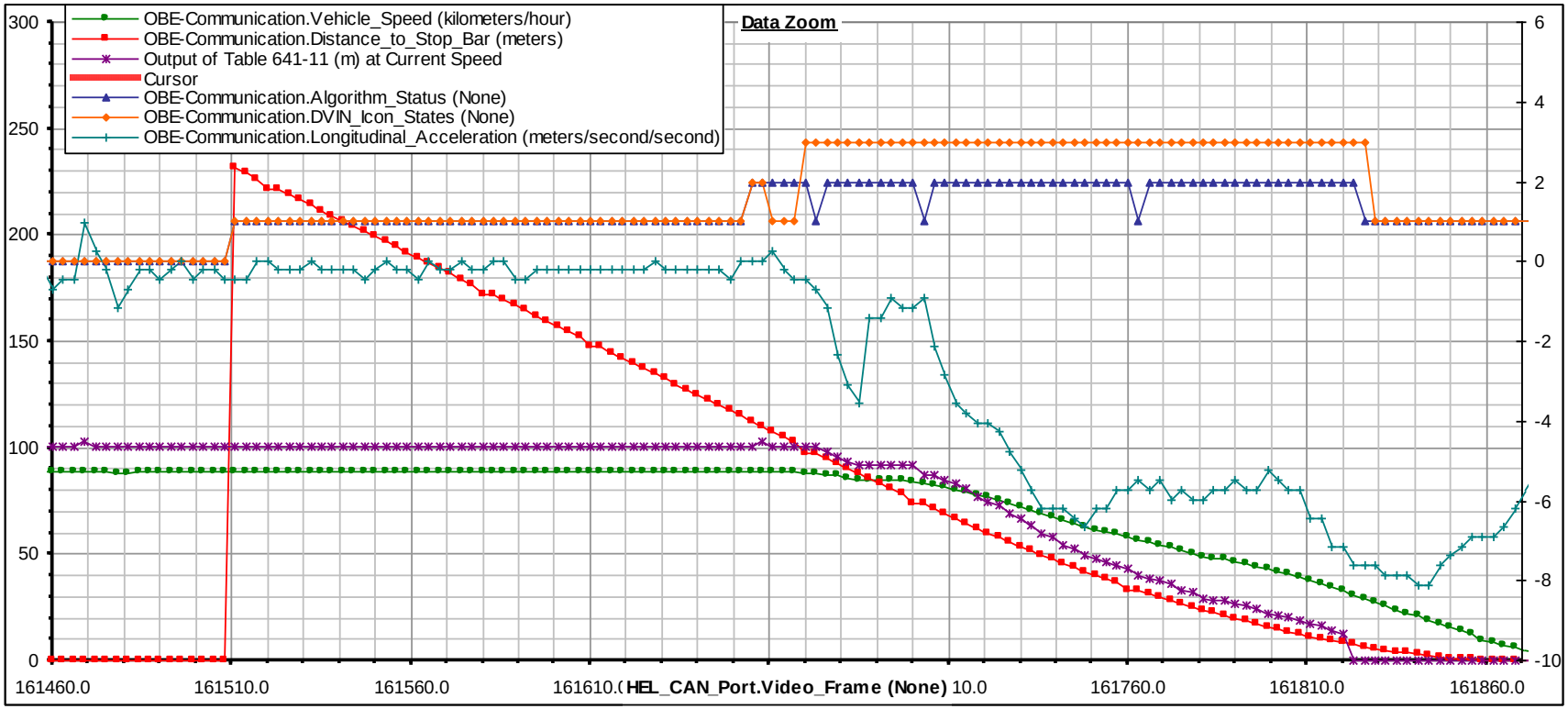

Figure 33: Signalized Various Speed Approaches Test, 55 mph, Run 8

8.1.2 : Signalized Various Speed Approaches Test, 35 mi/h

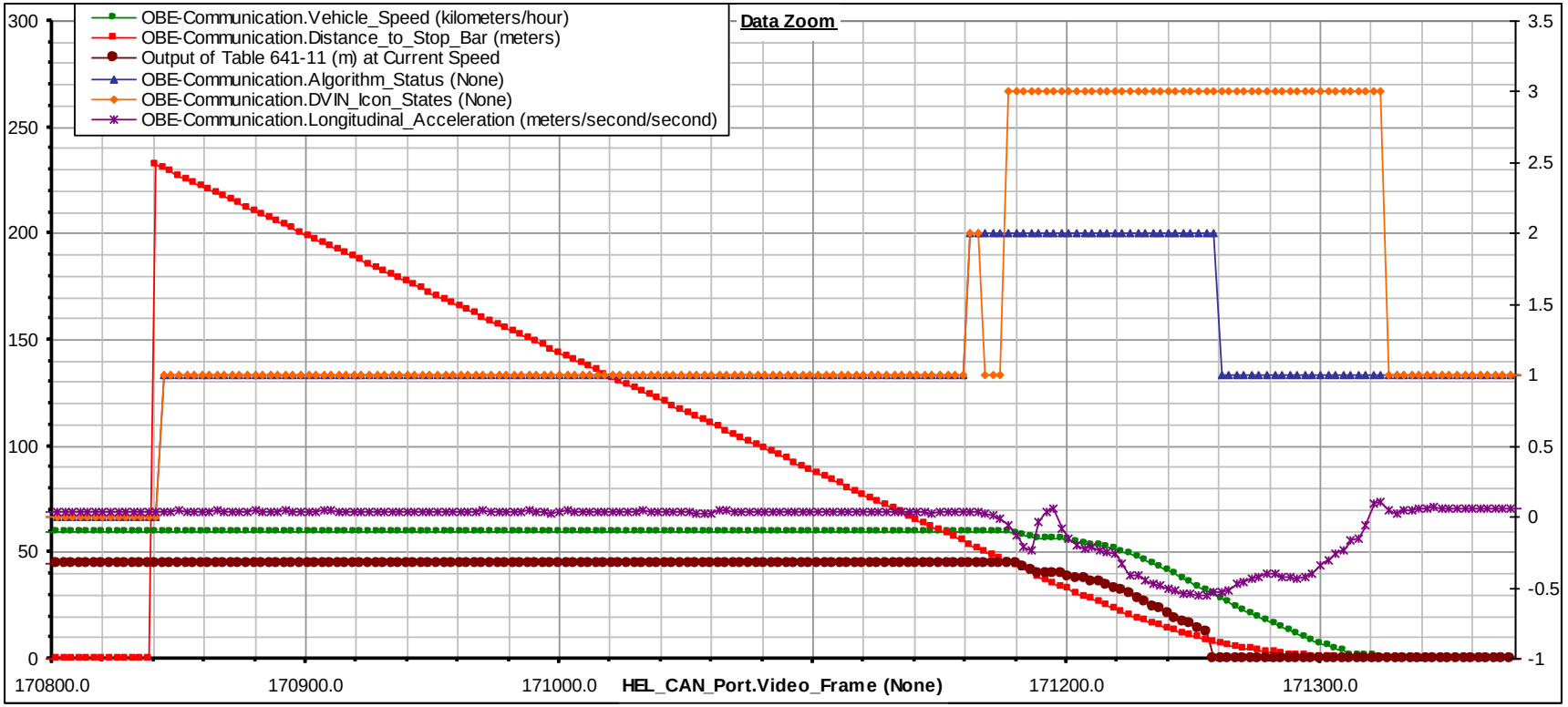

Figure 34: Signalized Various Speed Approaches Test, 35 mi/h, Run 1

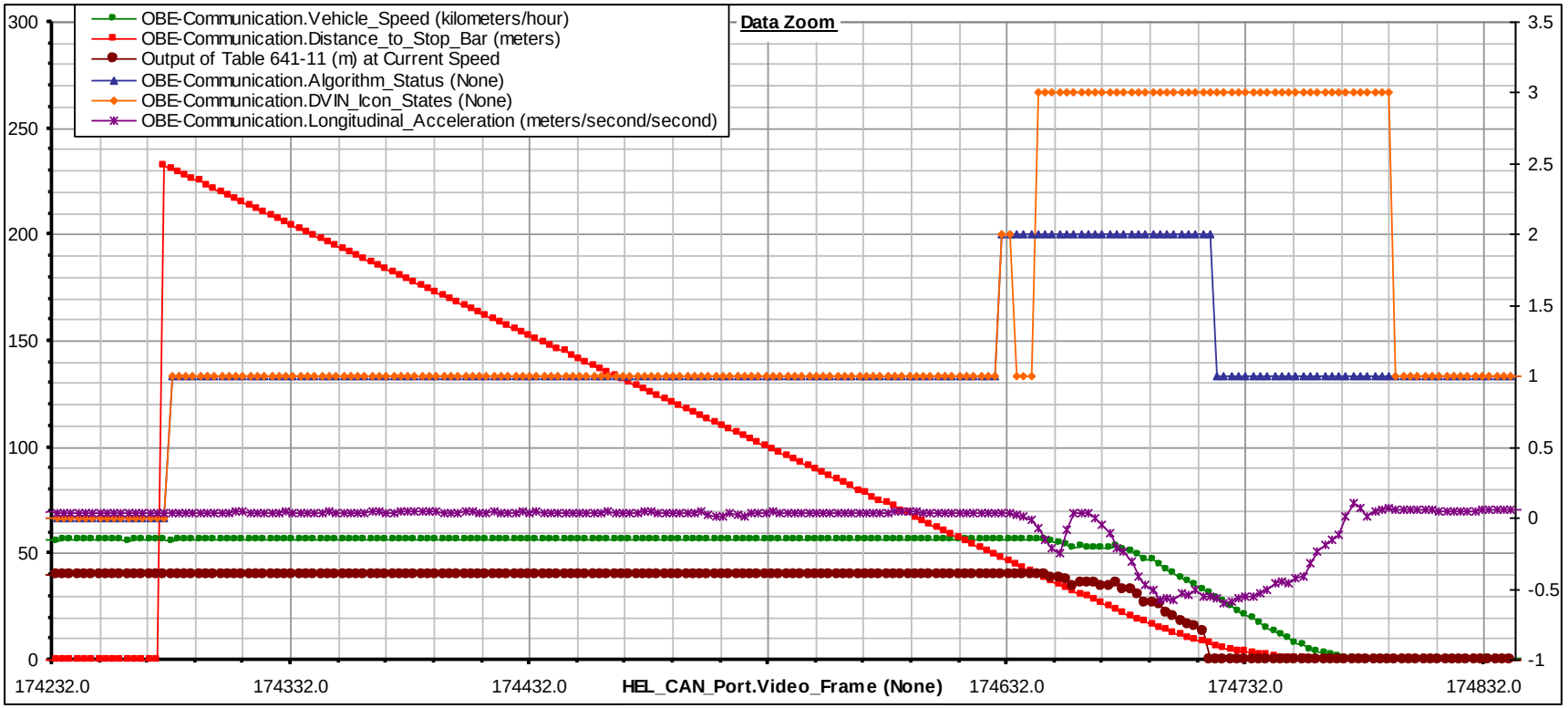

Figure 35: Signalized Various Speed Approaches Test, 35 mi/h, Run 2

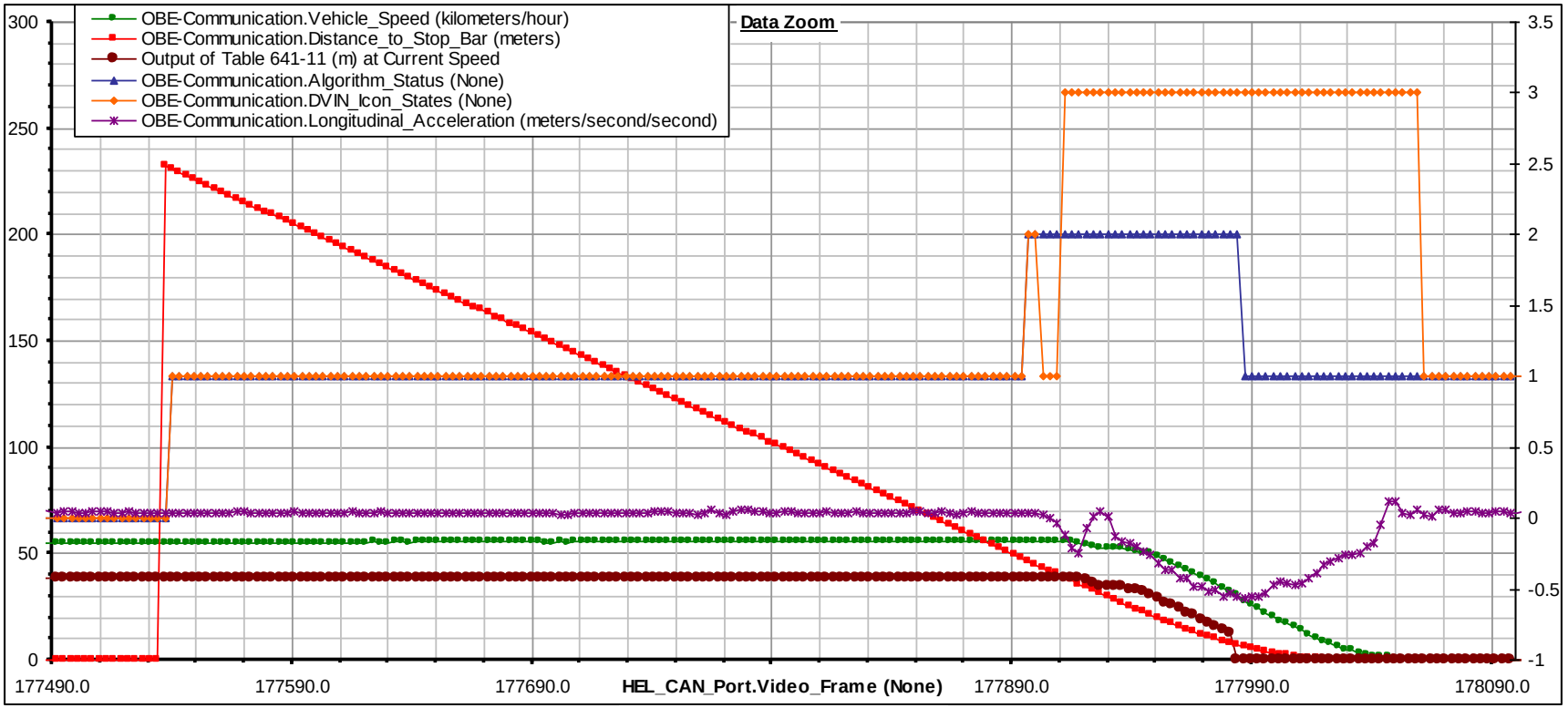

Figure 36: Signalized Various Speed Approaches Test, 35 mi/h, Run 3

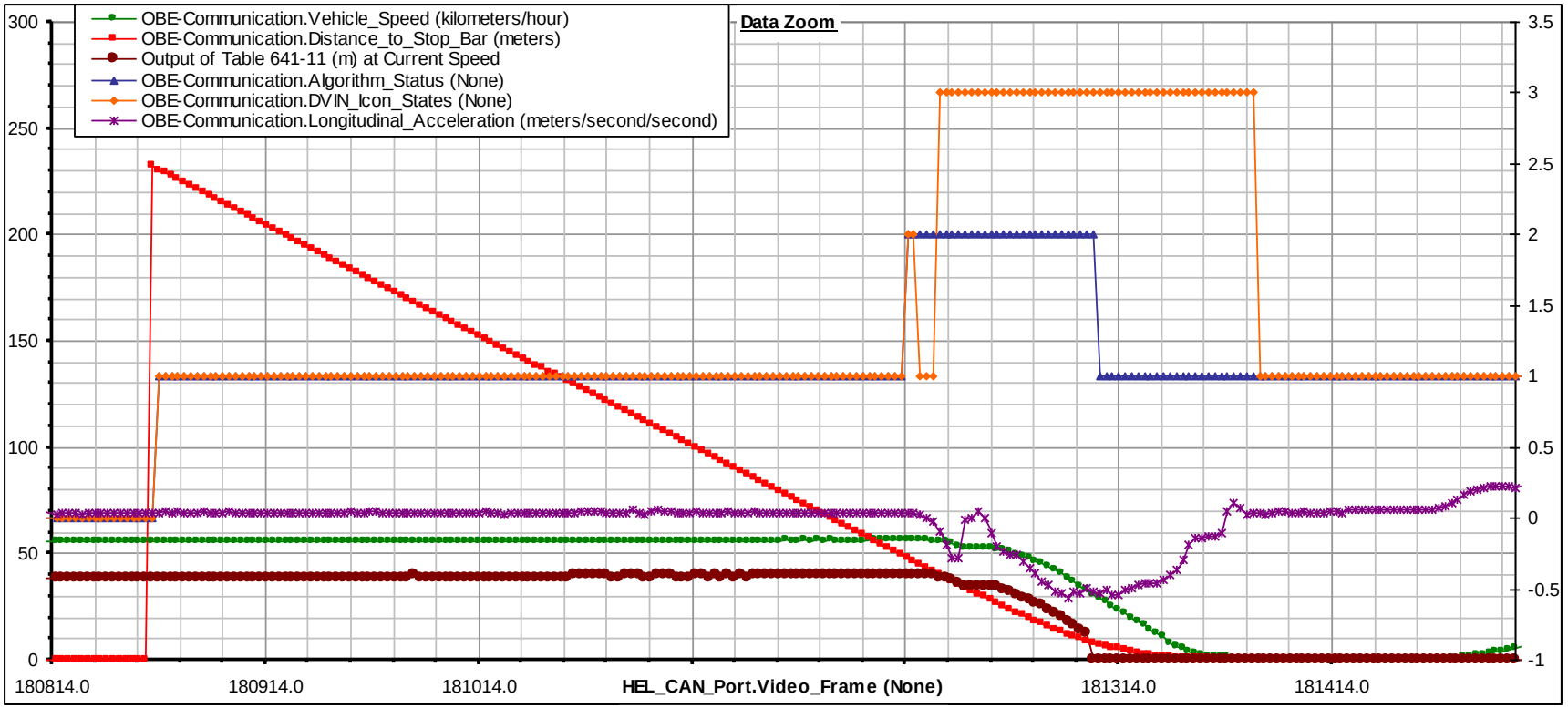

Figure 37: Signalized Various Speed Approaches Test, 35 mi/h, Run 4

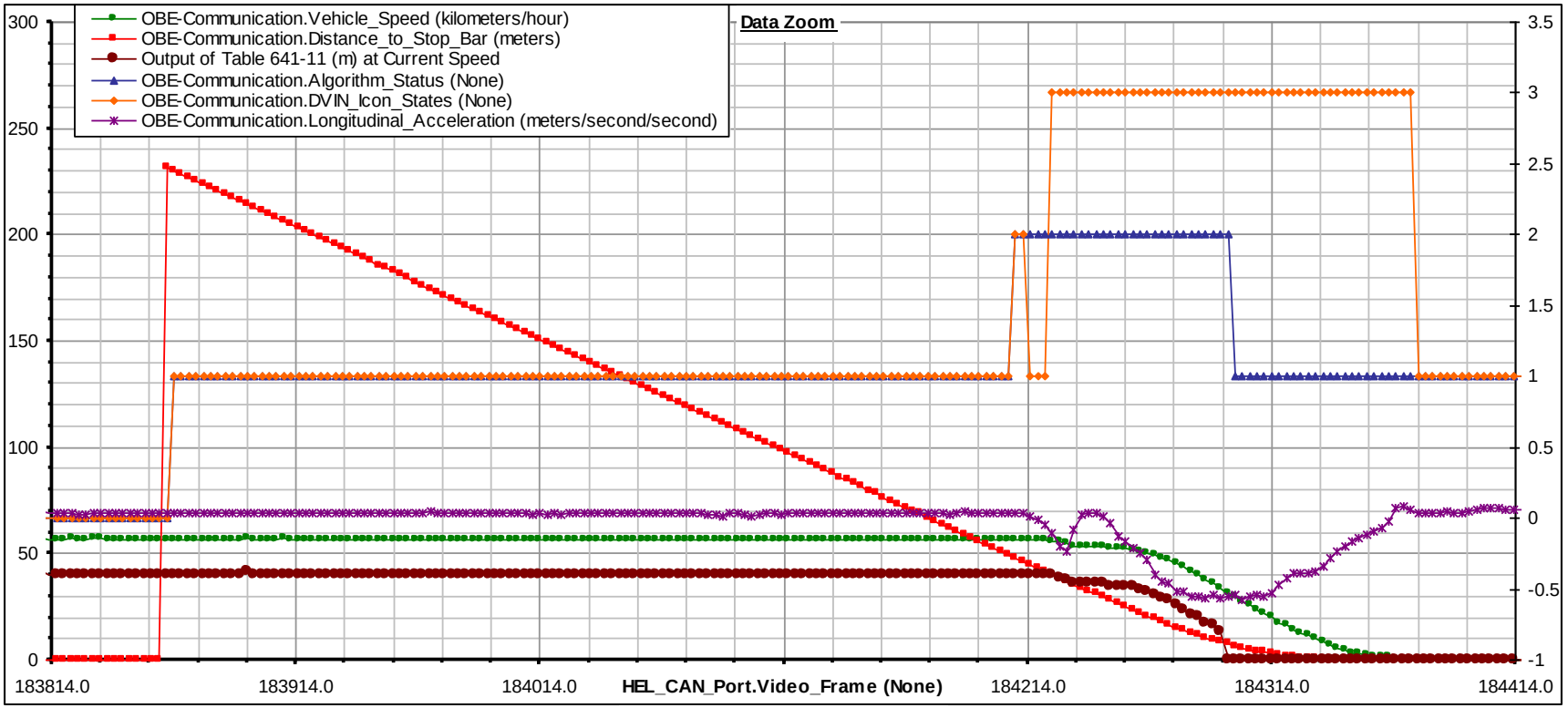

Figure 38: Signalized Various Speed Approaches Test, 35 mi/h, Run 5

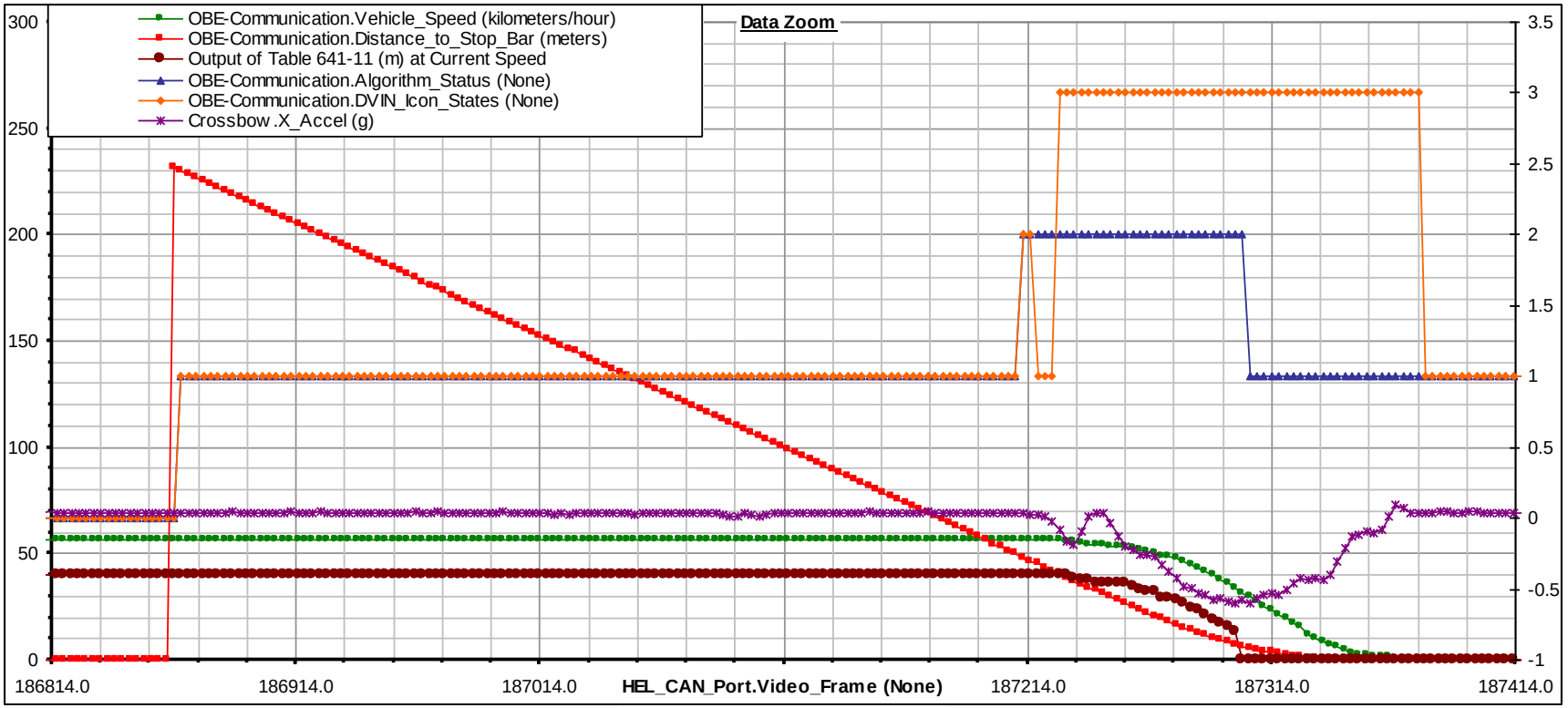

Figure 39: Signalized Various Speed Approaches Test, 35 mi/h, Run 6

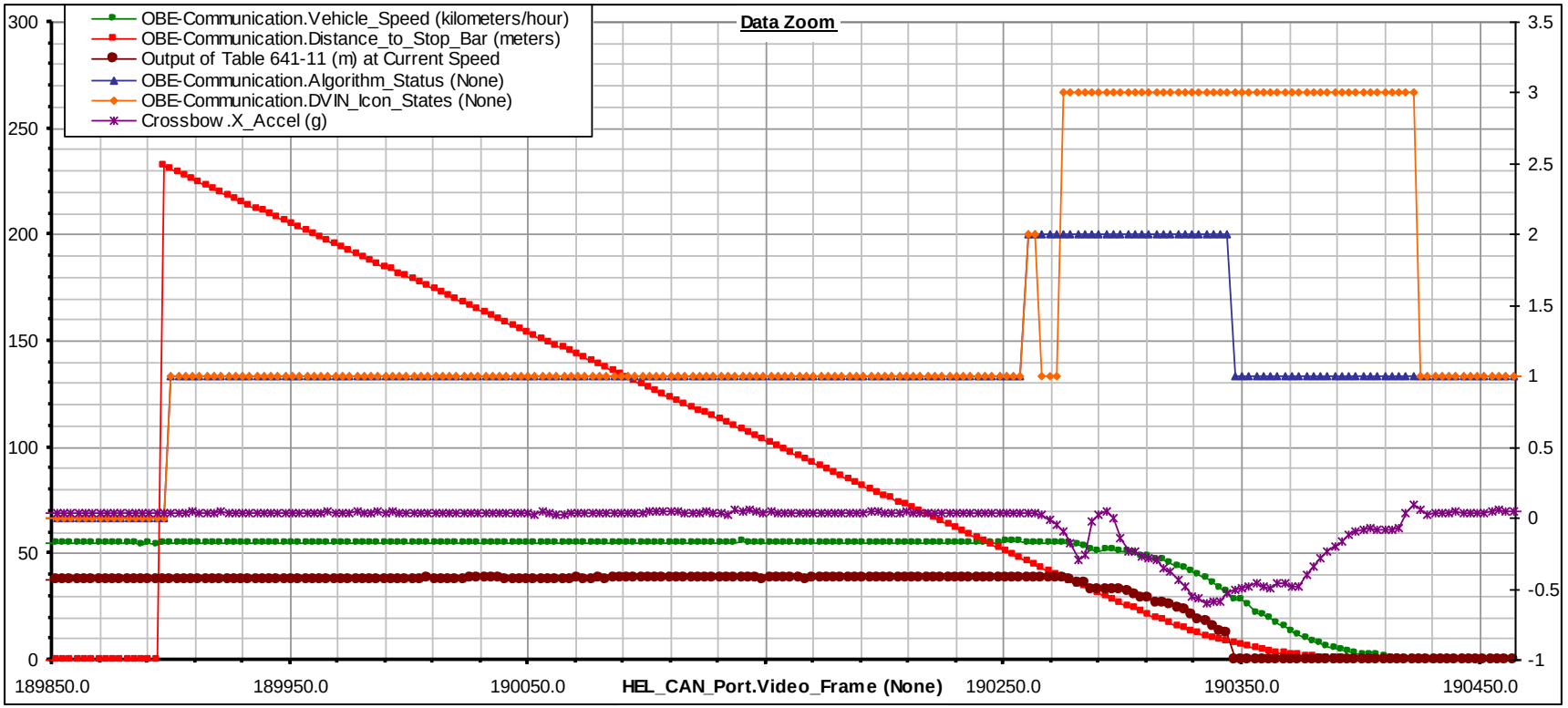

Figure 40: Signalized Various Speed Approaches Test, 35 mi/h, Run 7

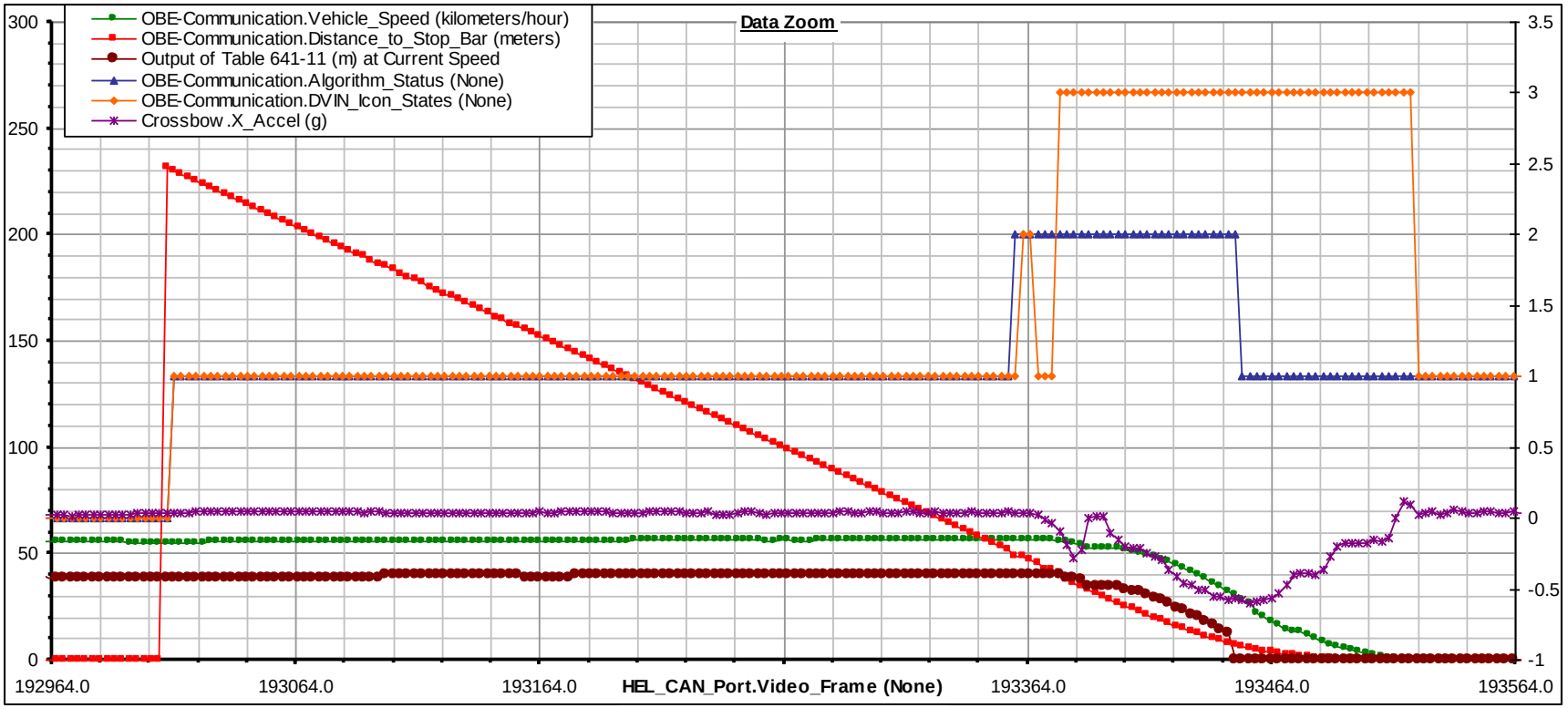

Figure 41: Signalized Various Speed Approaches Test, 35 mi/h, Run 8

8.1.3 : Signalized Various Speed Approaches Test, 25 mi/h

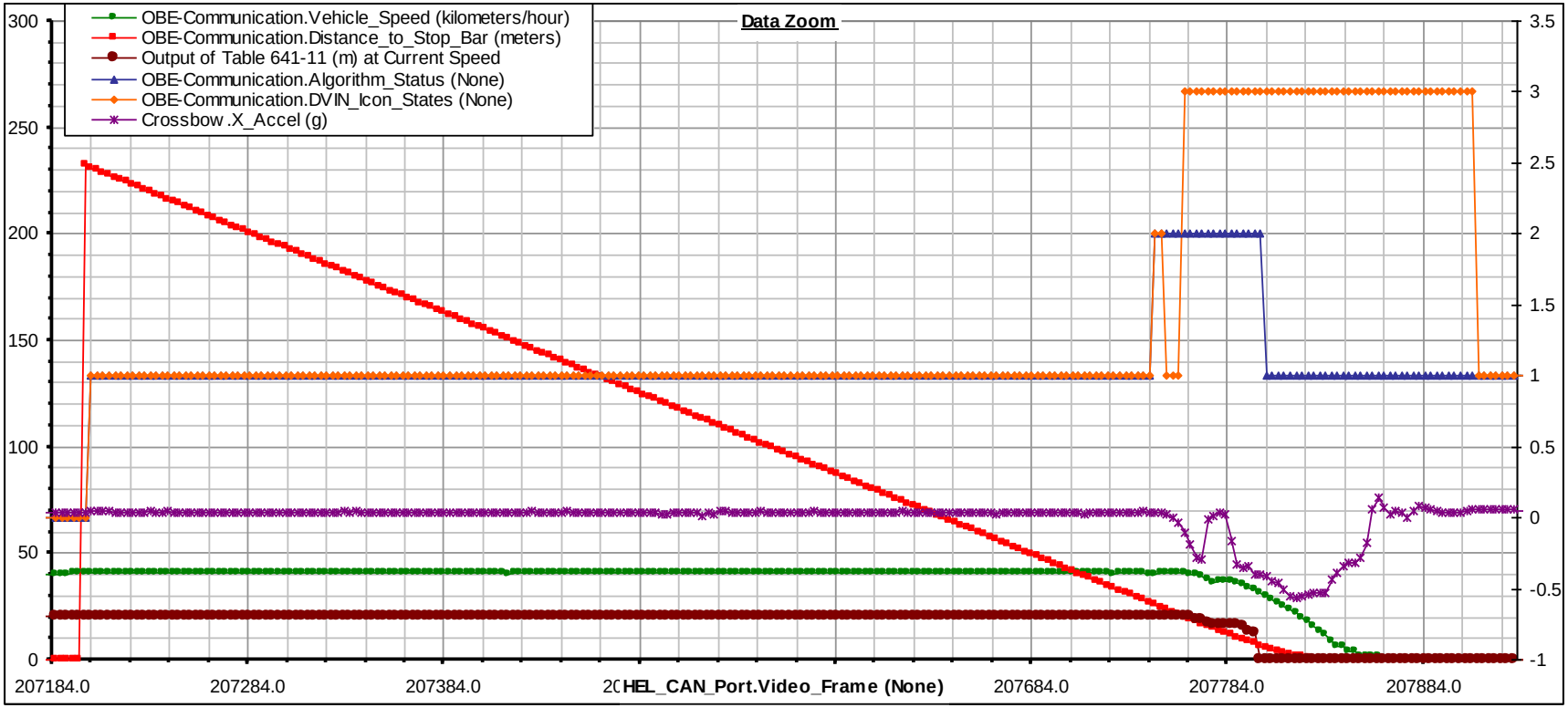

Figure 42: Signalized Various Speed Approaches Test, 25 mi/h, Run 1

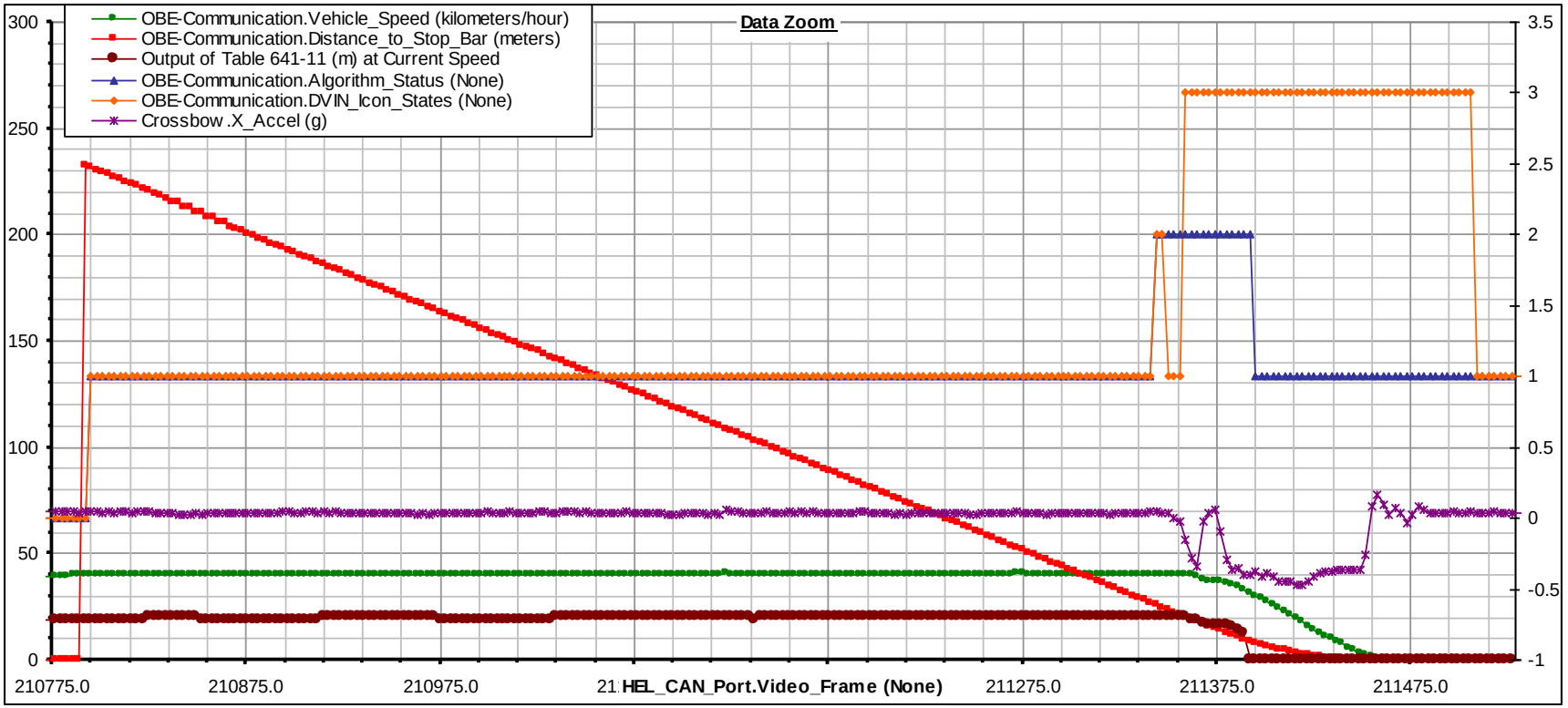

Figure 43: Signalized Various Speed Approaches Test, 25 mi/h, Run 2

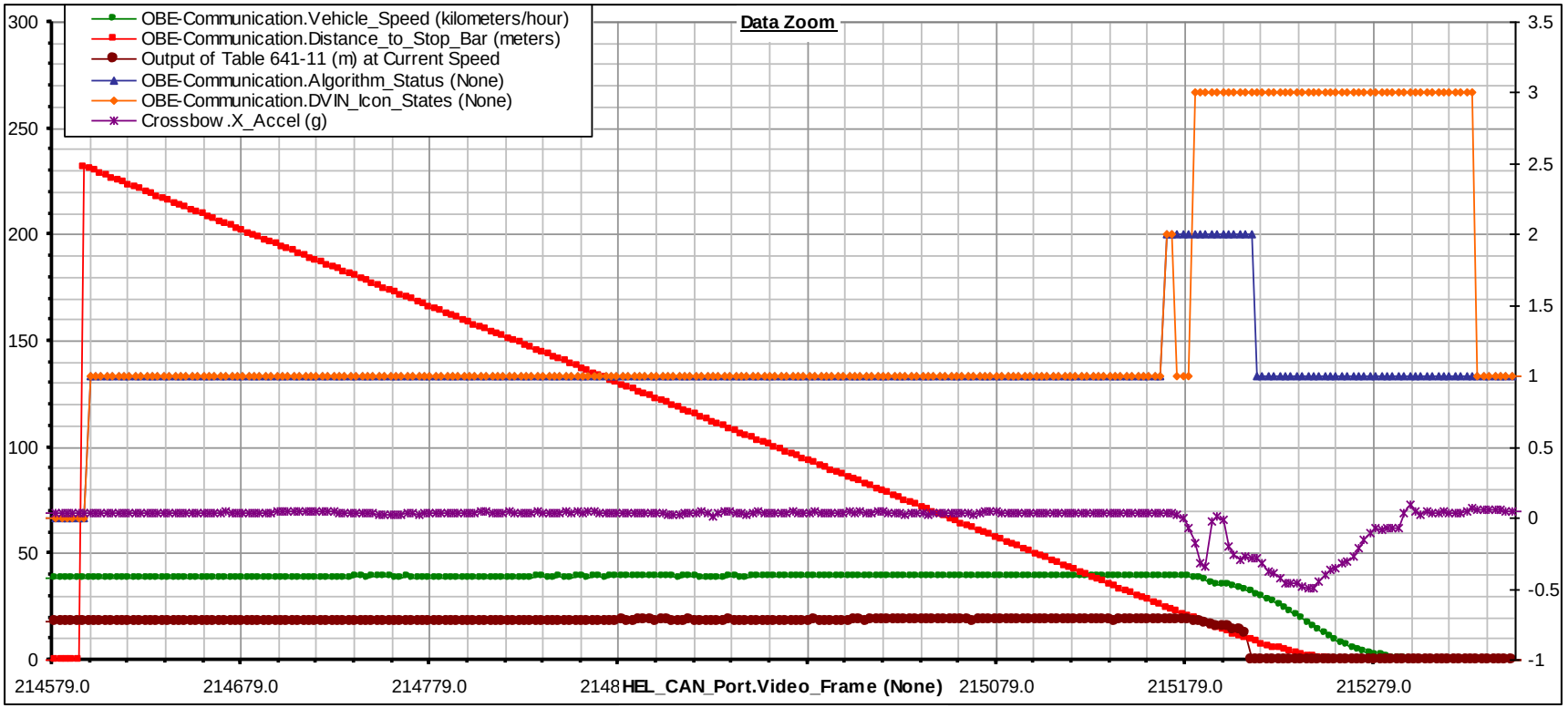

Figure 44: Signalized Various Speed Approaches Test, 25 mi/h, Run 3

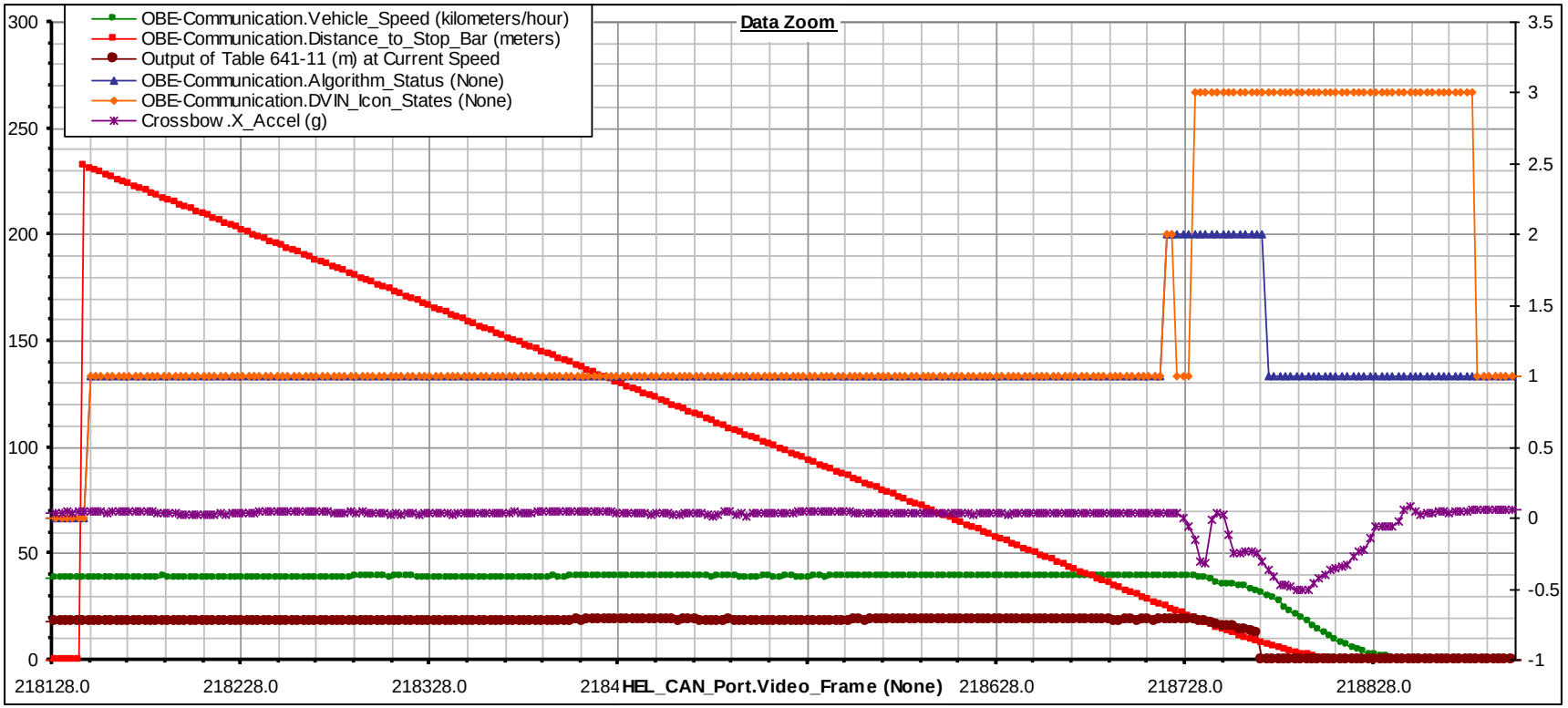

Figure 45: Signalized Various Speed Approaches Test, 25 mi/h, Run 4

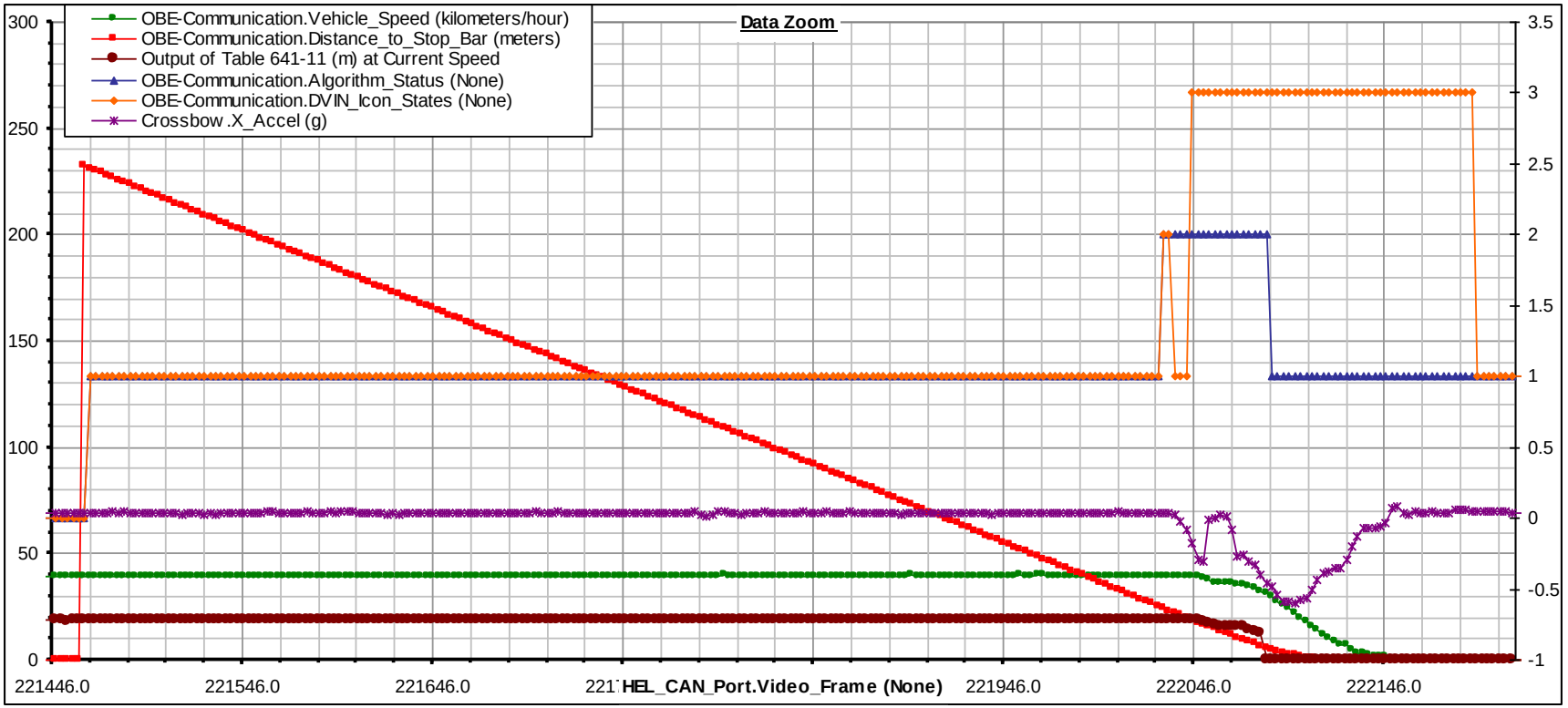

Figure 46: Signalized Various Speed Approaches Test, 25 mi/h, Run 5

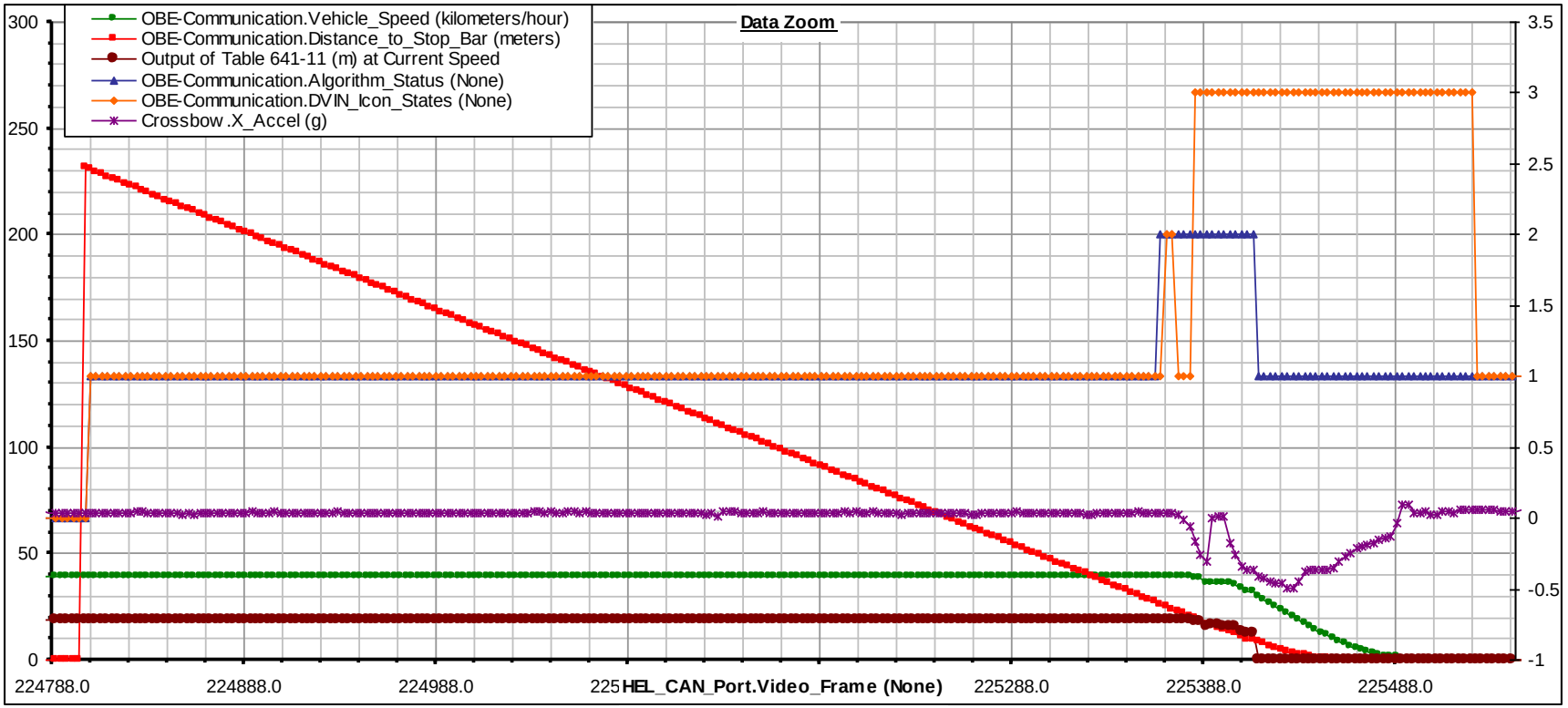

Figure 47: Signalized Various Speed Approaches Test, 25 mi/h, Run 6

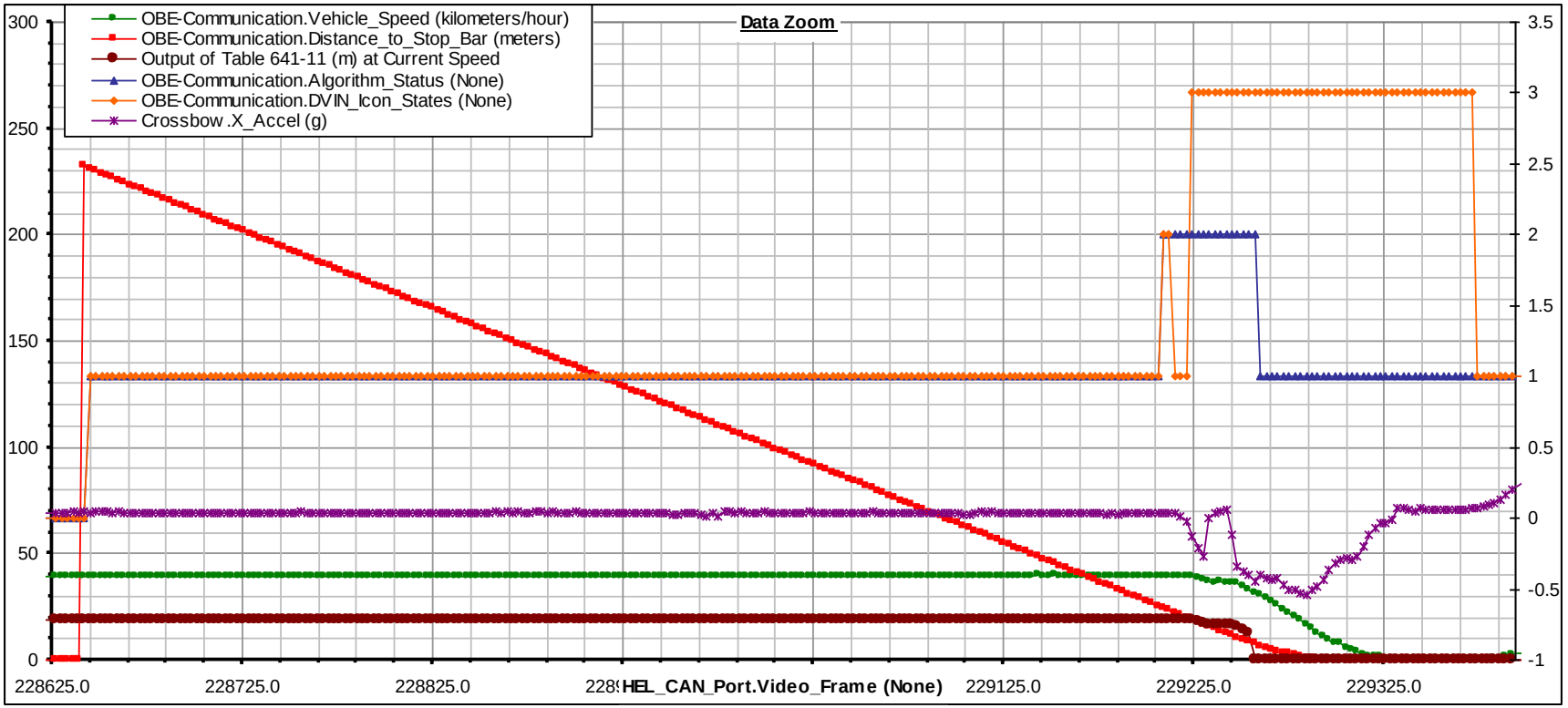

Figure 48: Signalized Various Speed Approaches Test, 25 mi/h, Run 7

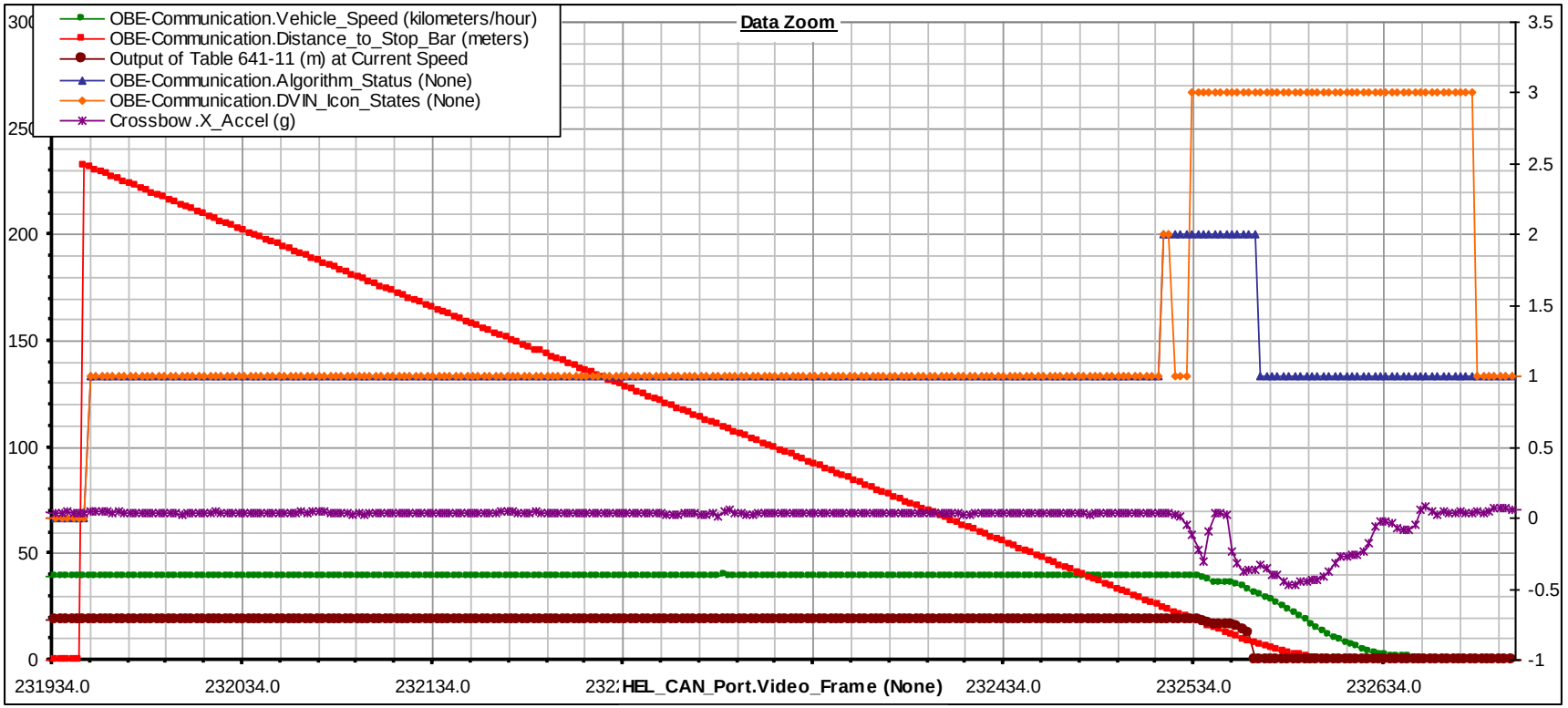

Figure 49: Signalized Various Speed Approaches Test, 25 mi/h, Run 8

8.1.4 : Edge of Approach Testing for Warning

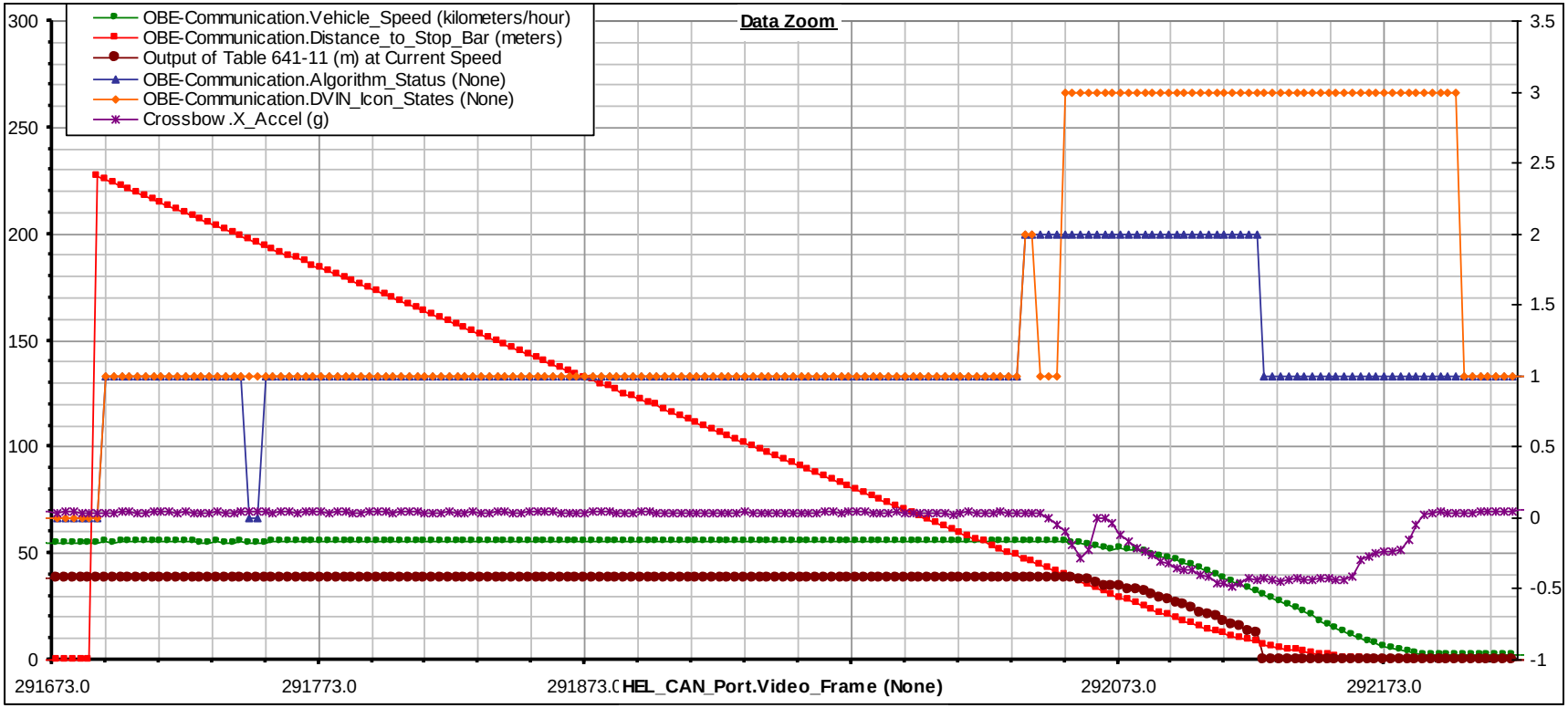

Figure 50: Edge of Approach Testing for Warning, Run 1

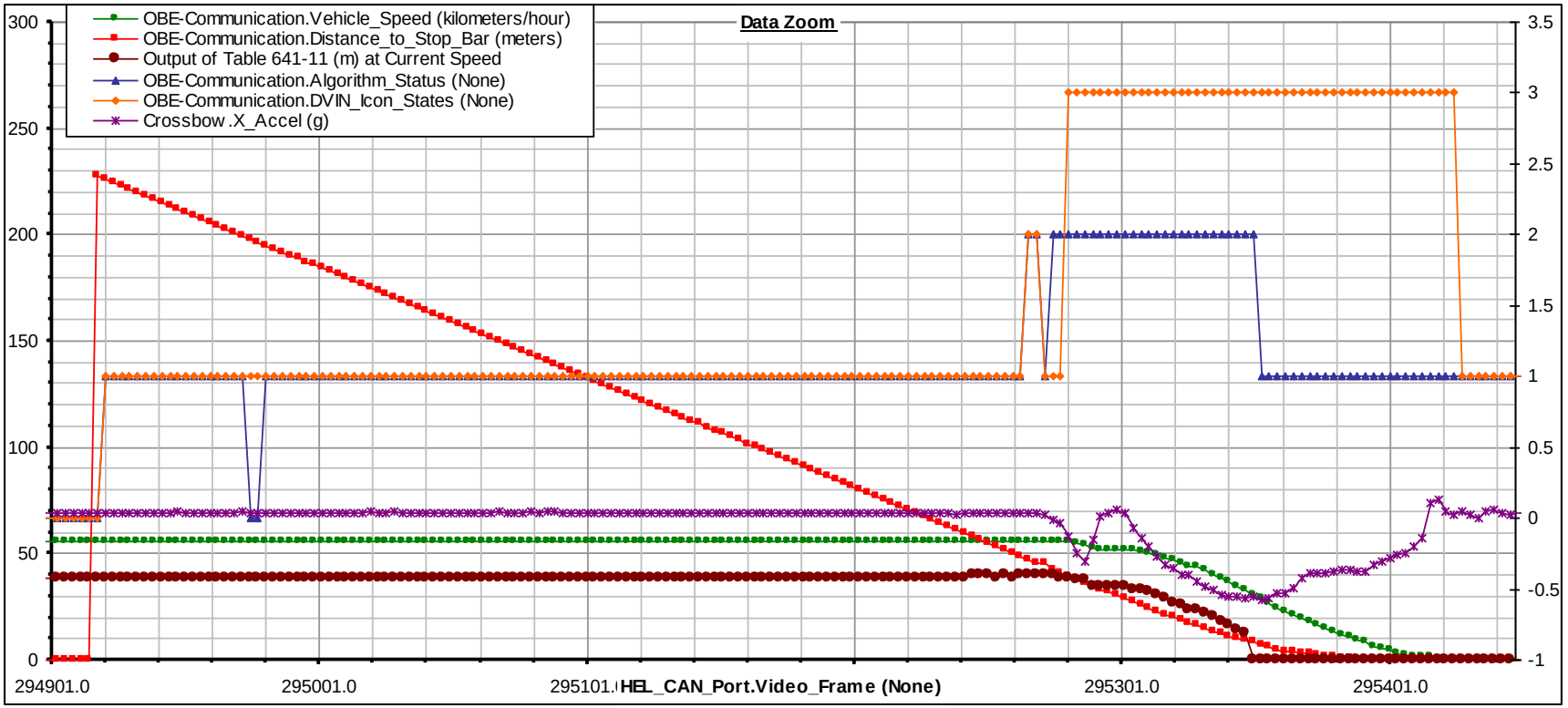

Figure 51: Edge of Approach Testing for Warning, Run 2

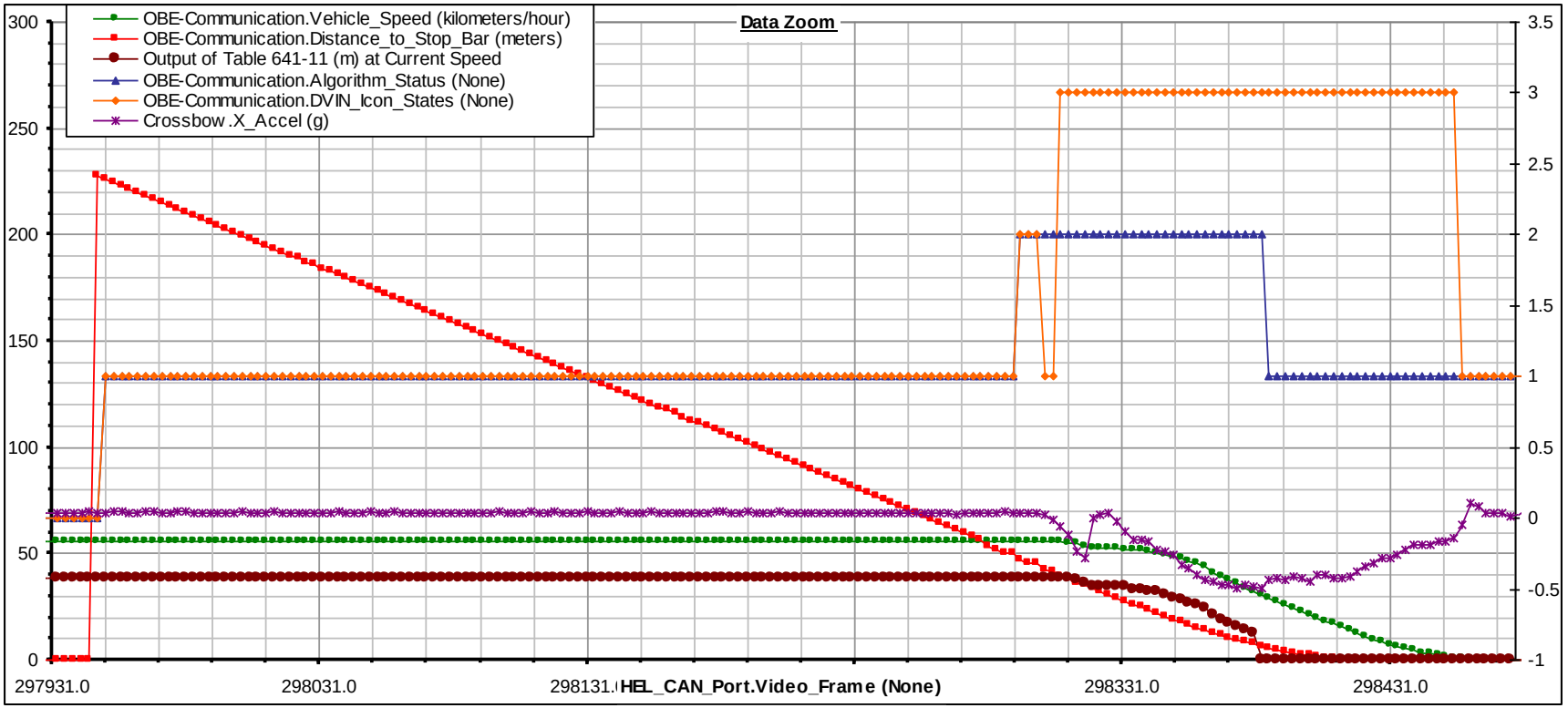

Figure 52: Edge of Approach Testing for Warning, Run 3

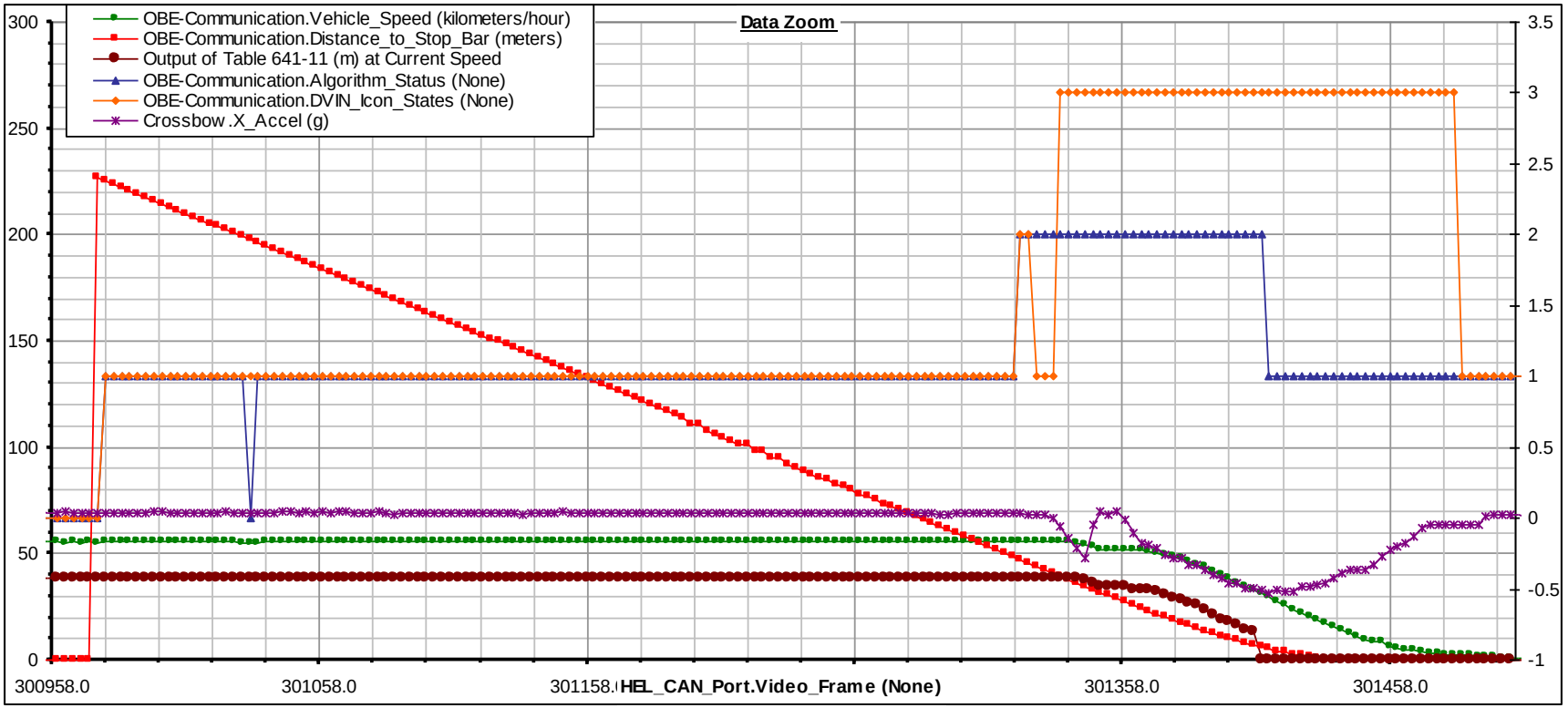

Figure 53: Edge of Approach Testing for Warning, Run 4

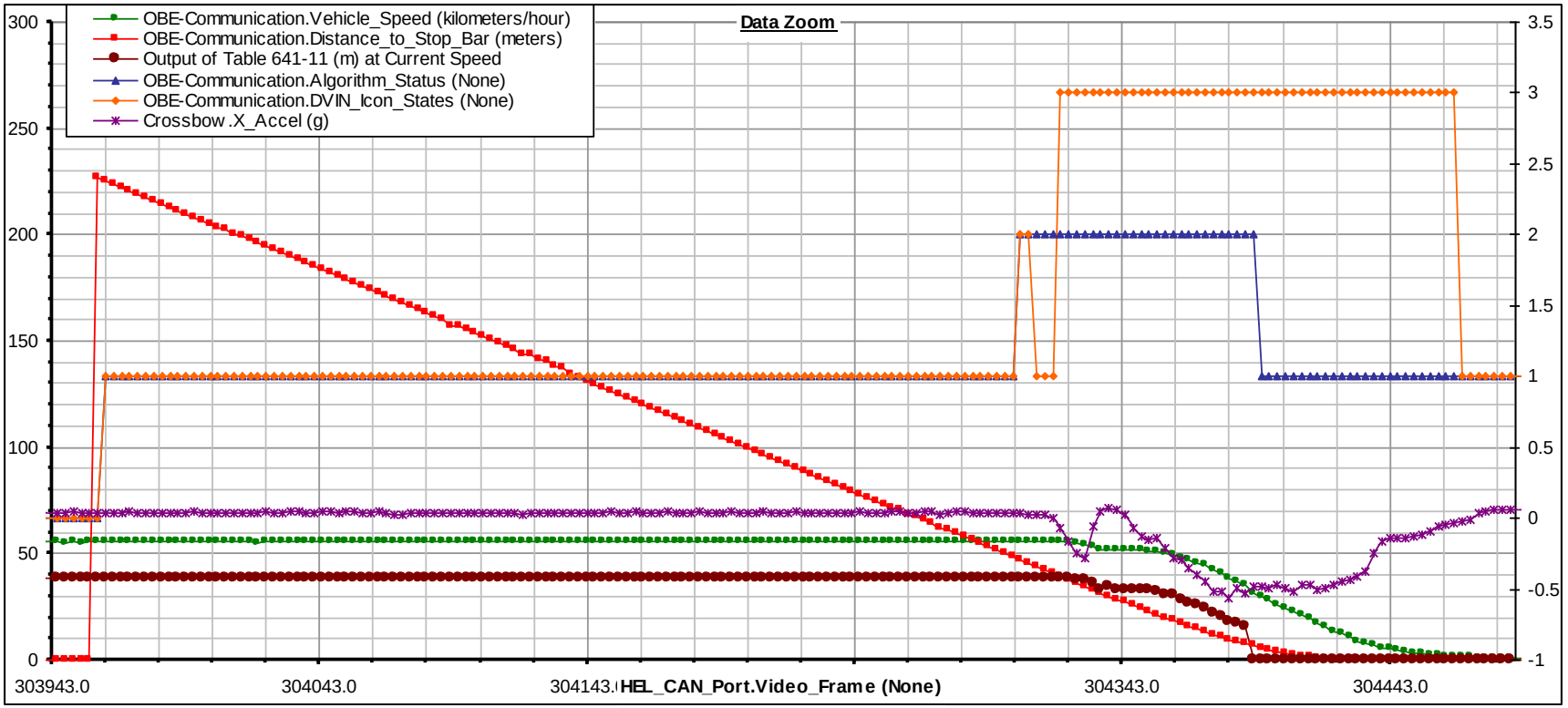

Figure 54: Edge of Approach Testing for Warning, Run 5

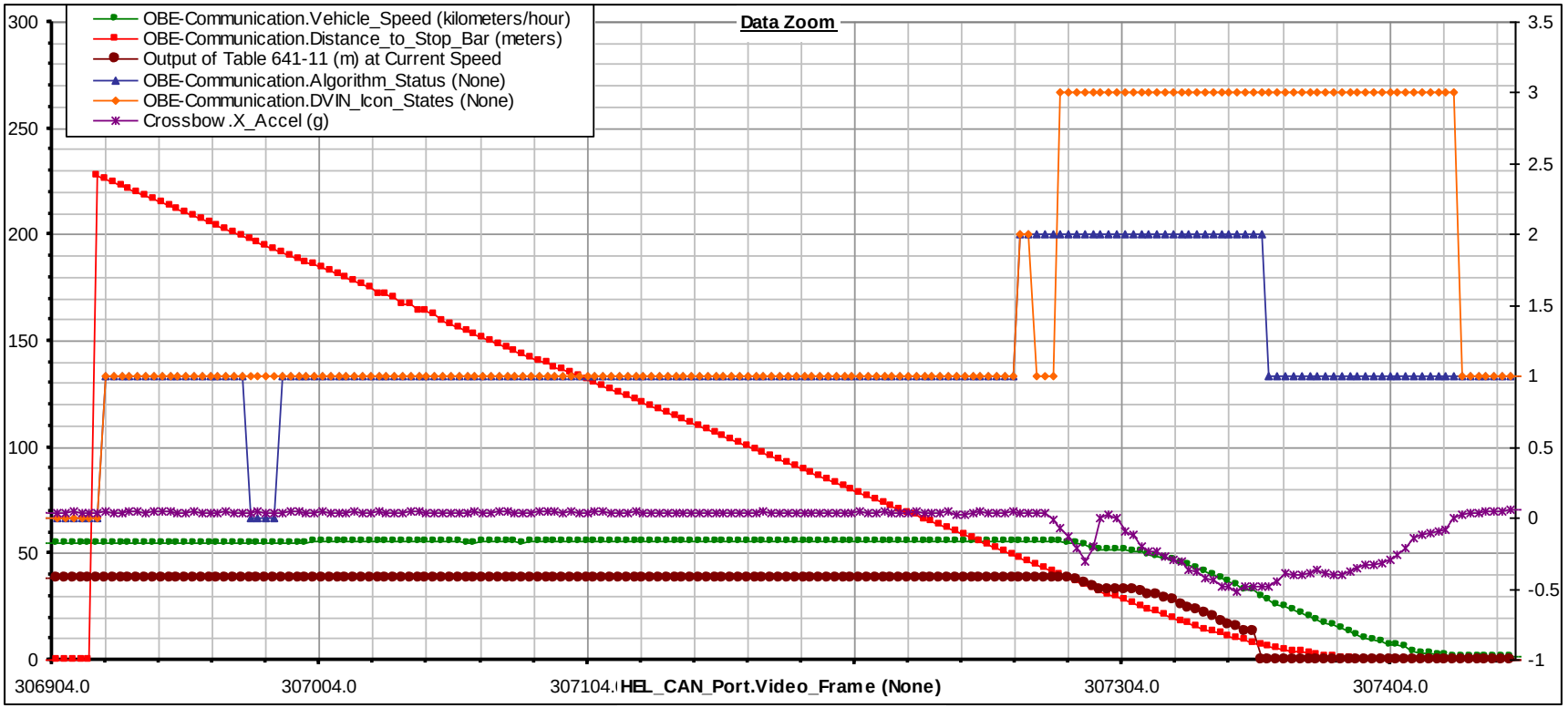

Figure 55: Edge of Approach Testing for Warning, Run 6

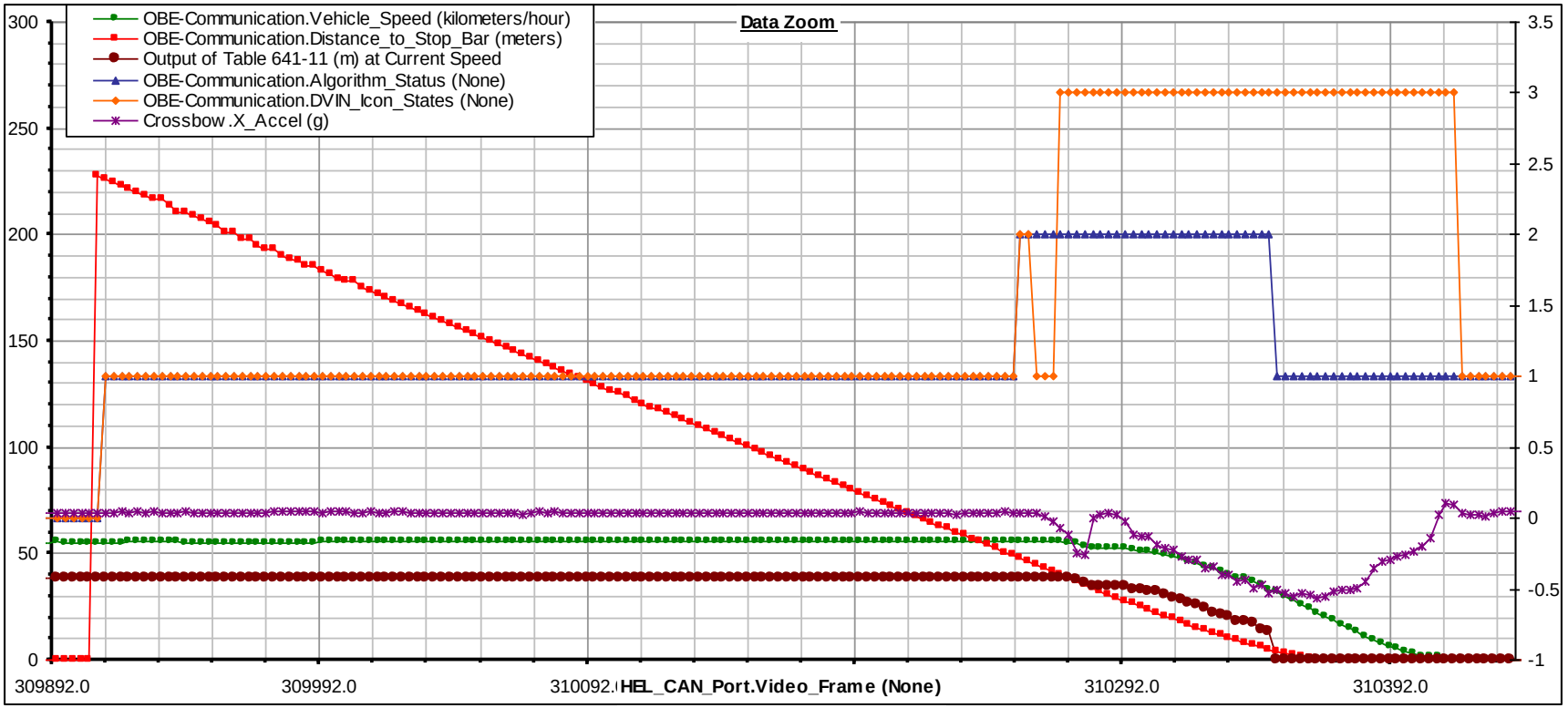

Figure 56: Edge of Approach Testing for Warning, Run 7

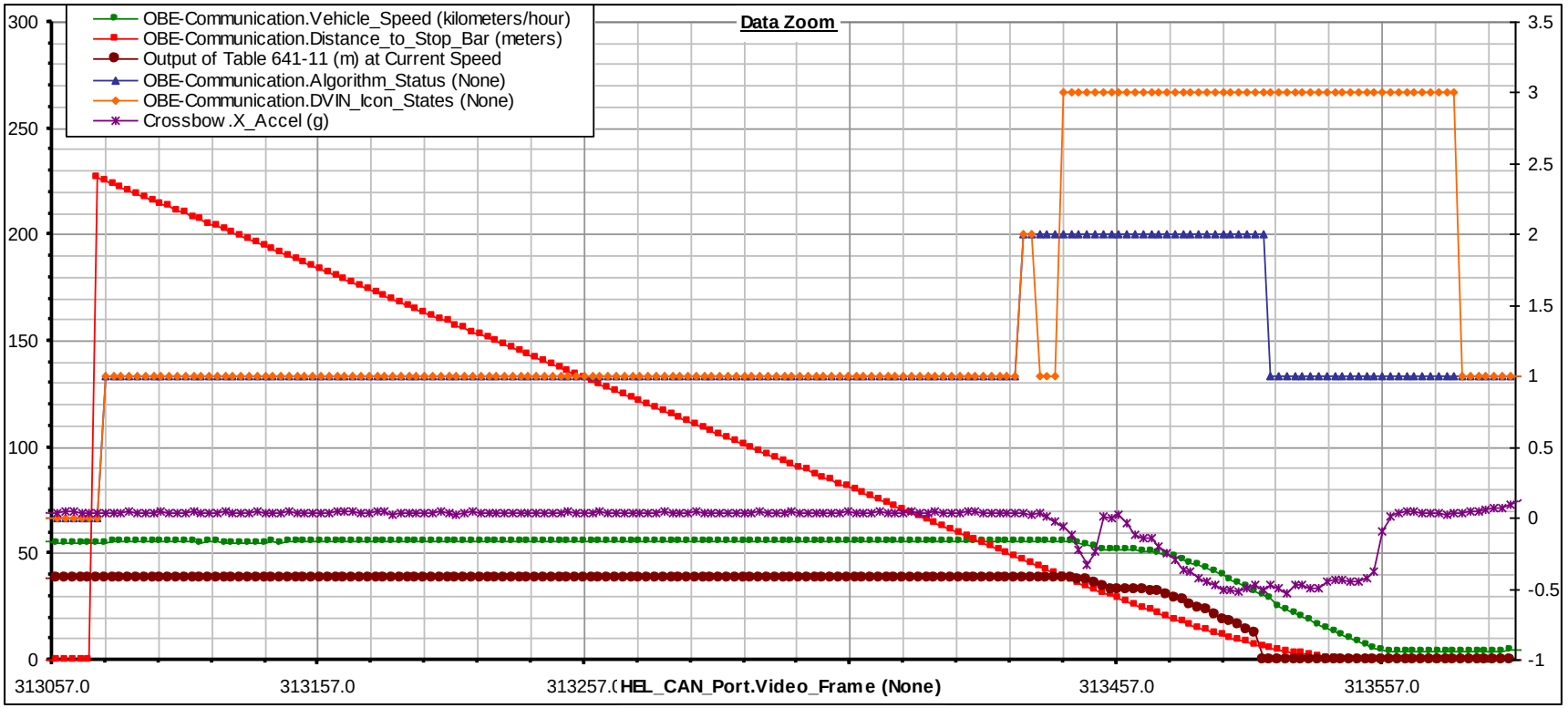

Figure 57: Edge of Approach Testing for Warning, Run 8

8.1.5 : Edge of Approach Testing for Nuisance Warning

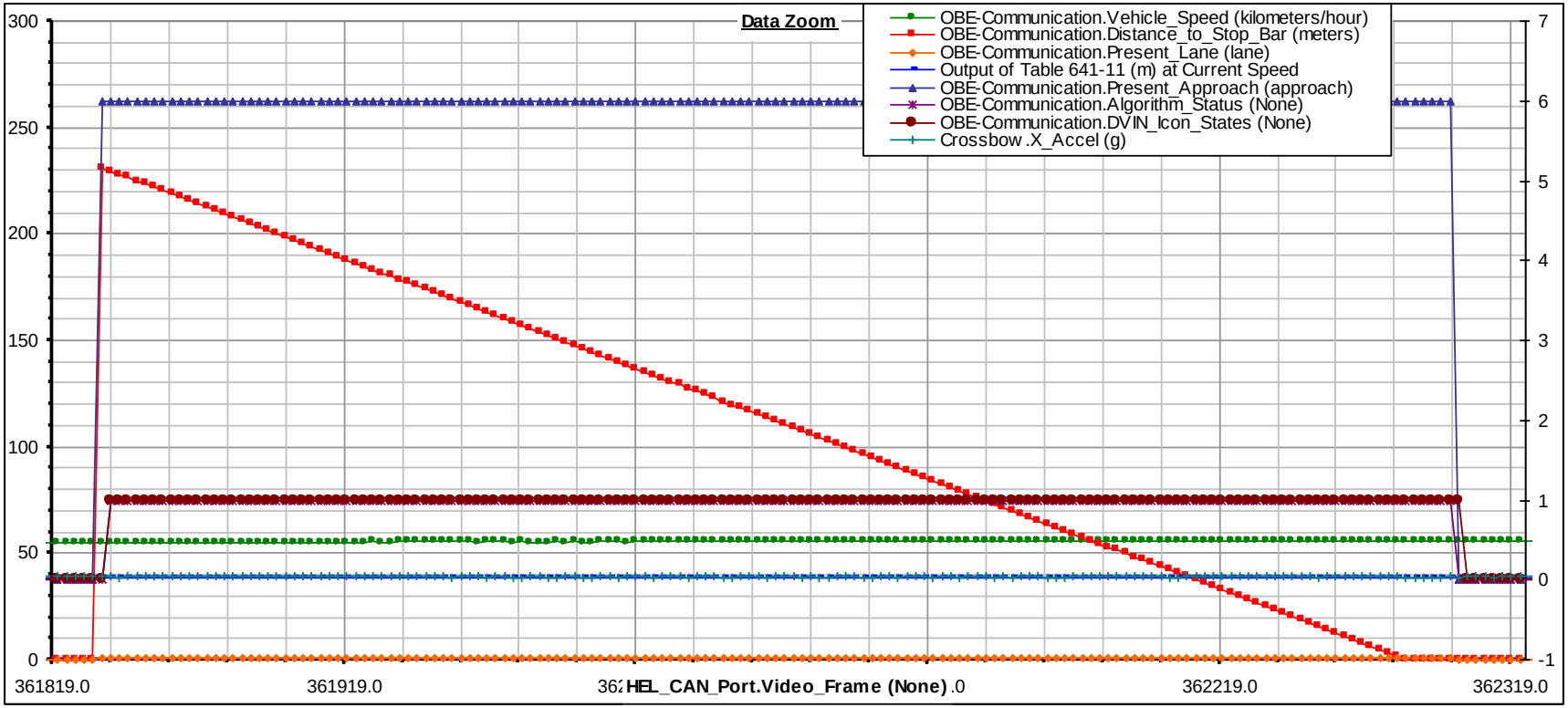

Figure 58: Edge of Approach Testing for Nuisance Warning, Run 1

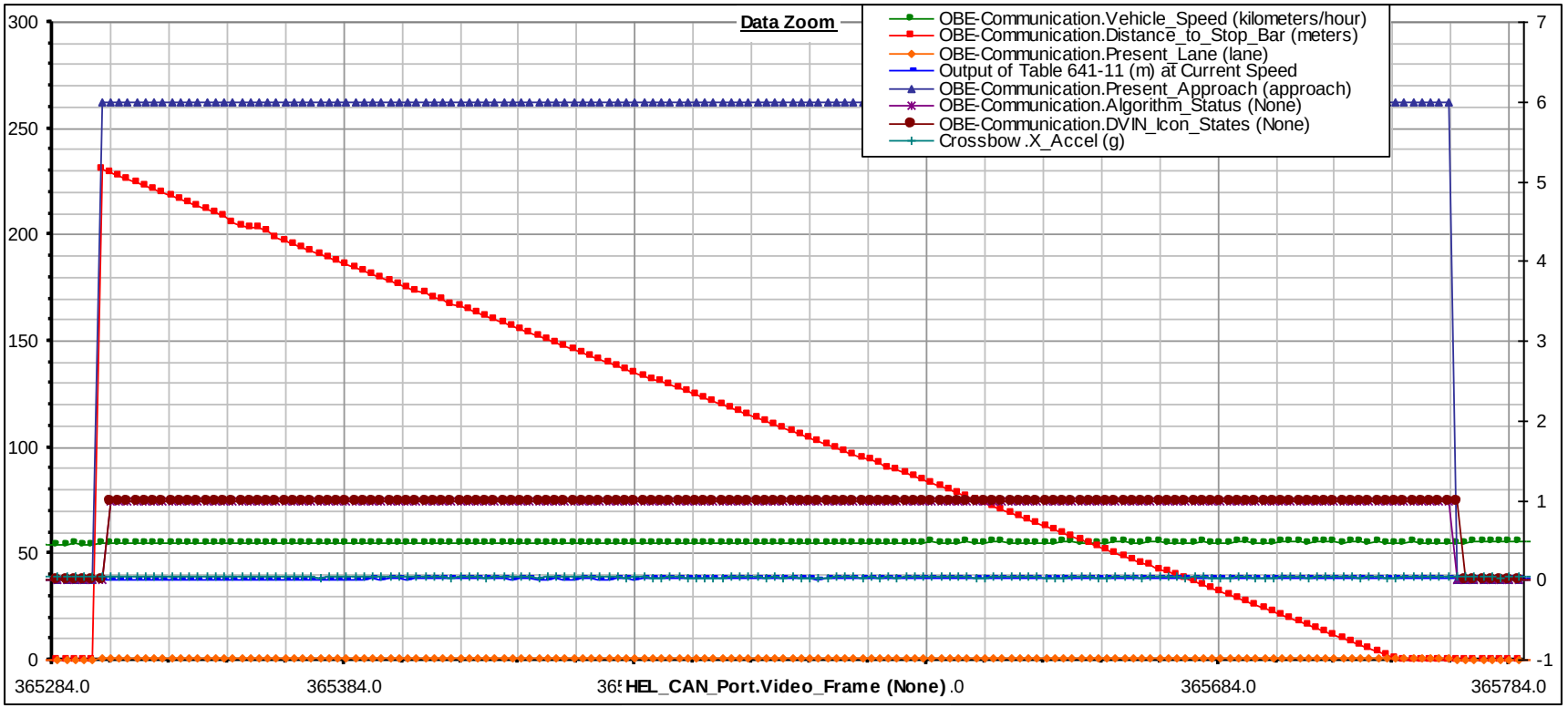

Figure 59: Edge of Approach Testing for Nuisance Warning, Run 2

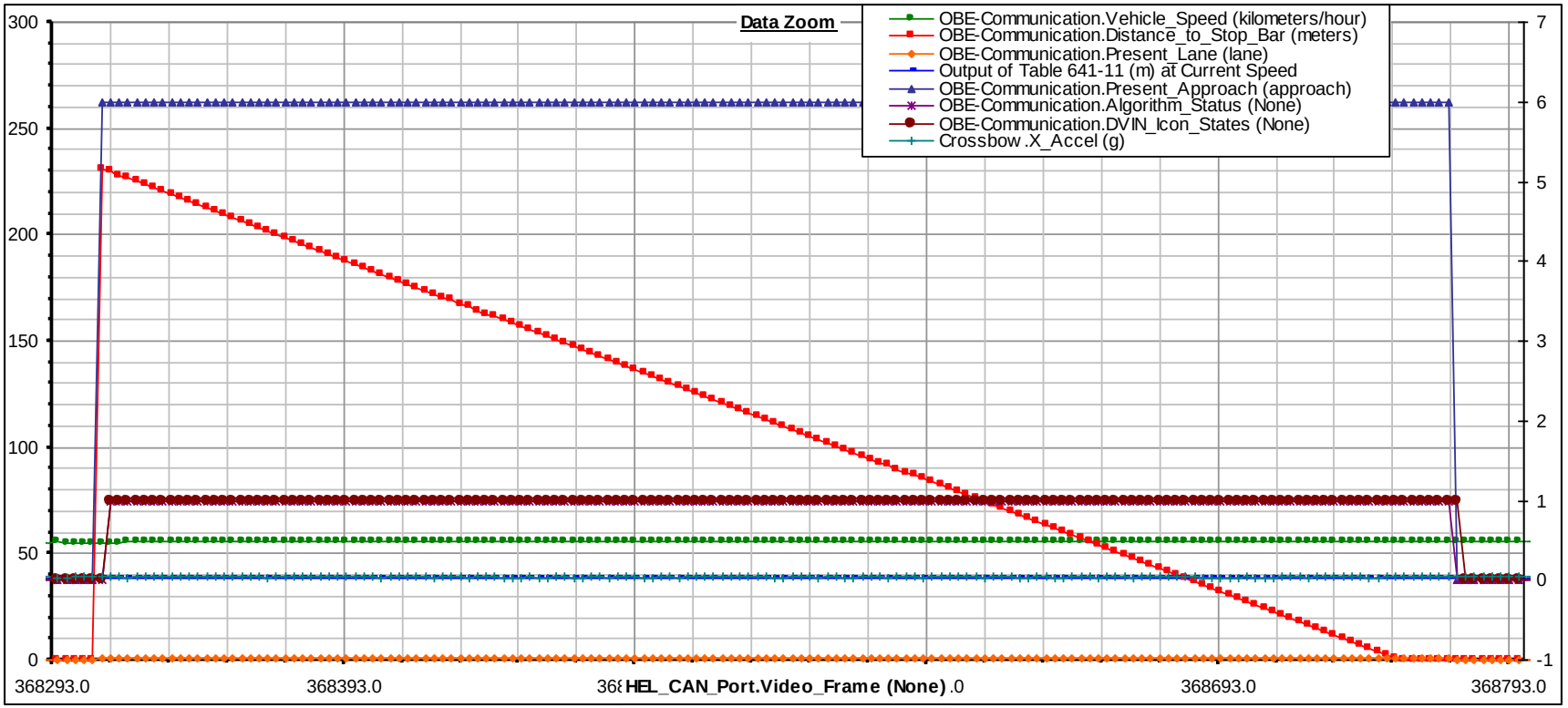

Figure 60: Edge of Approach Testing for Nuisance Warning, Run 3

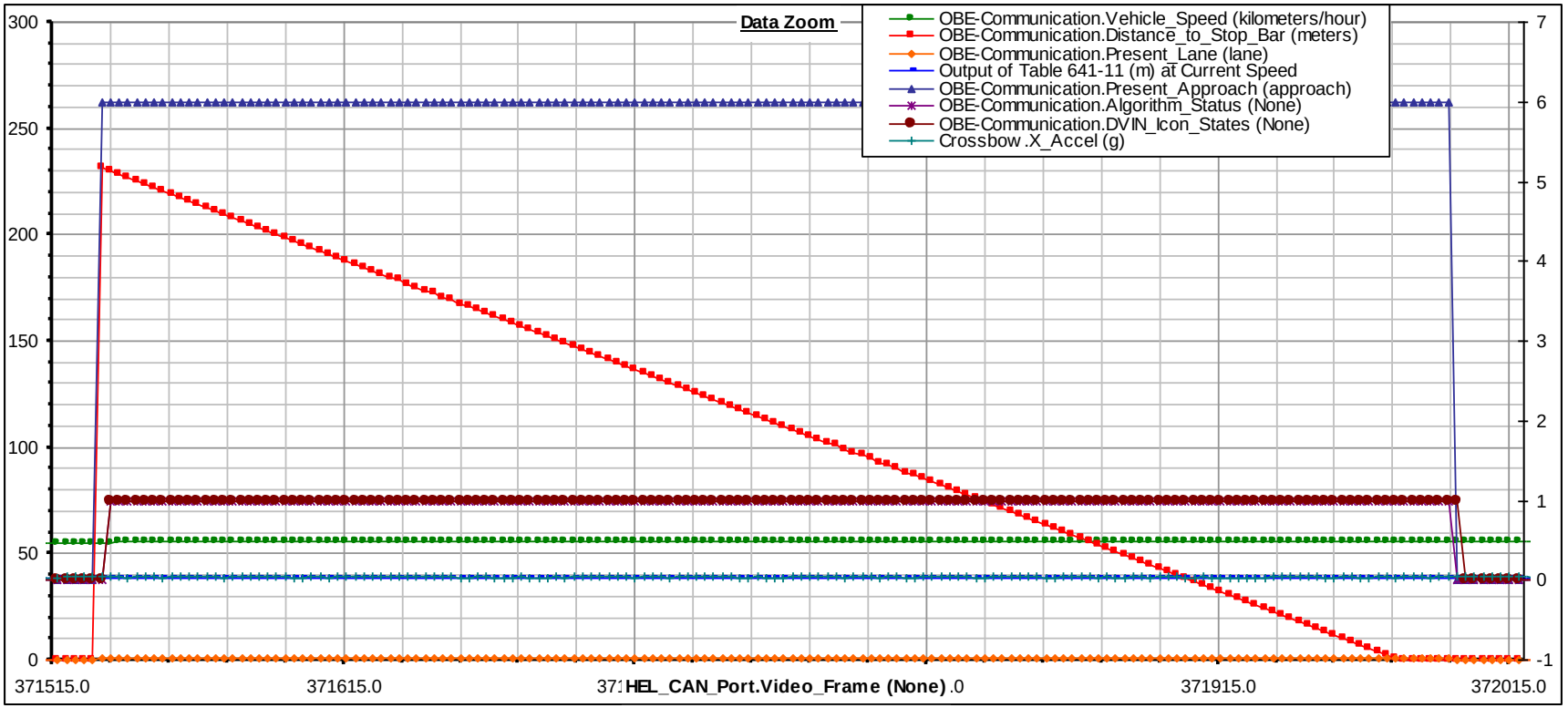

Figure 61: Edge of Approach Testing for Nuisance Warning, Run 4

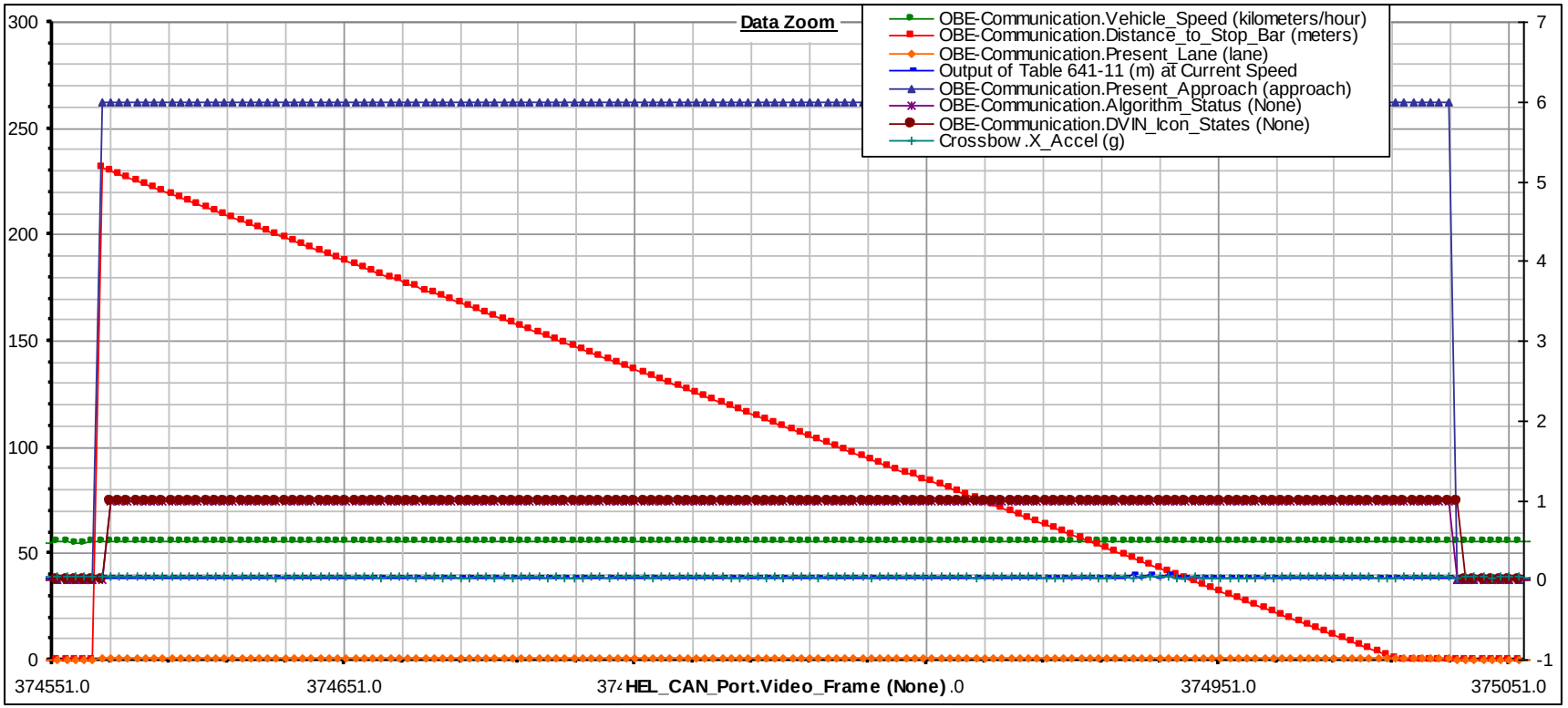

Figure 62: Edge of Approach Testing for Nuisance Warning, Run 5

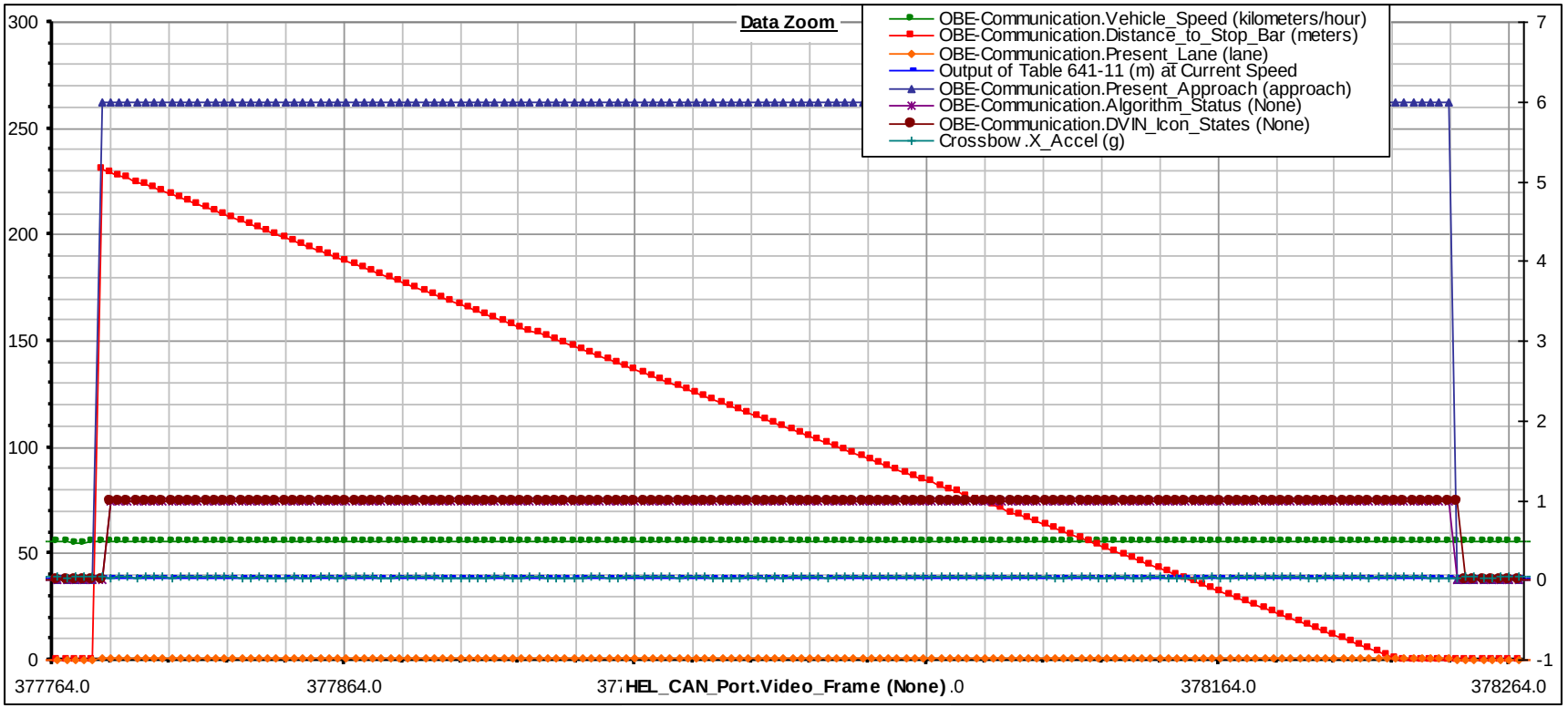

Figure 63: Edge of Approach Testing for Nuisance Warning, Run 6

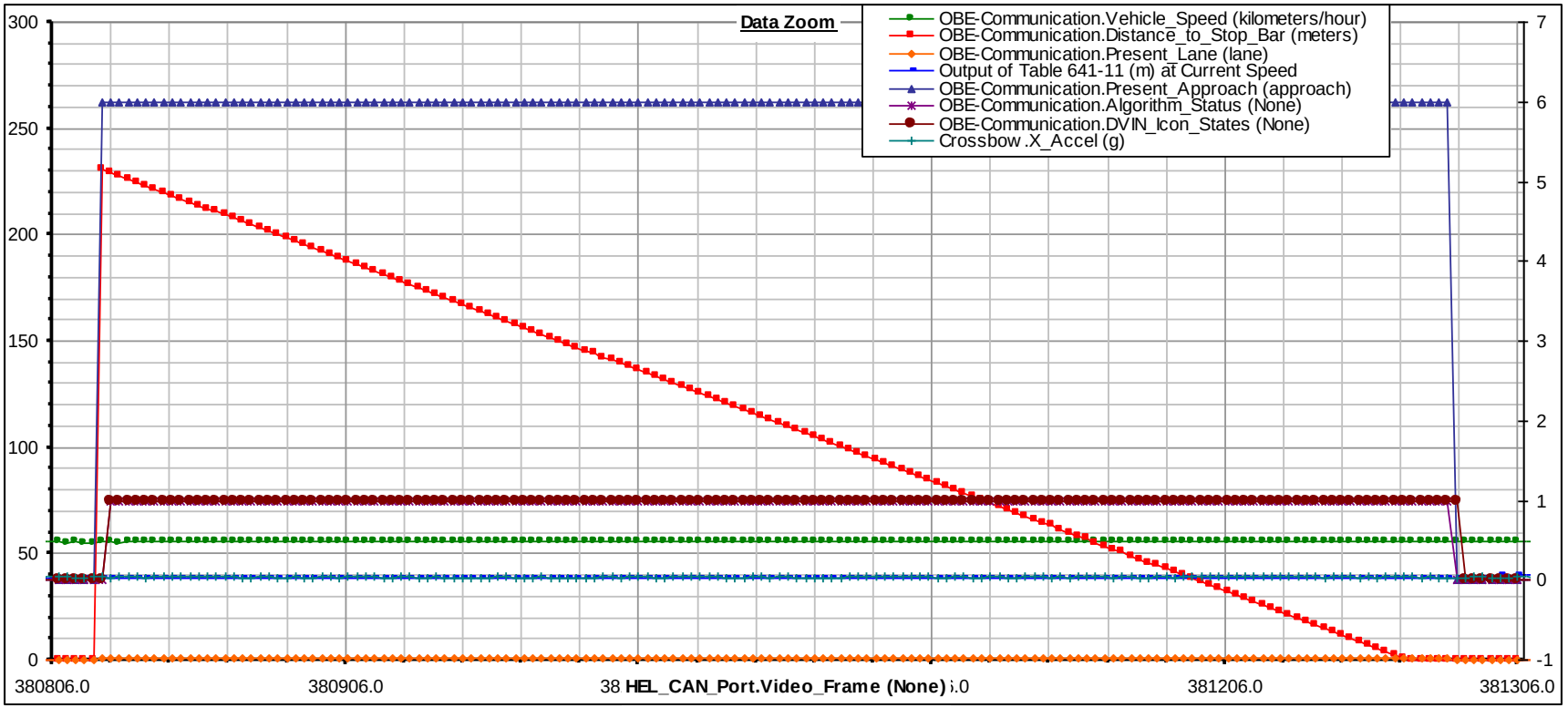

Figure 64: Edge of Approach Testing for Nuisance Warning, Run 7

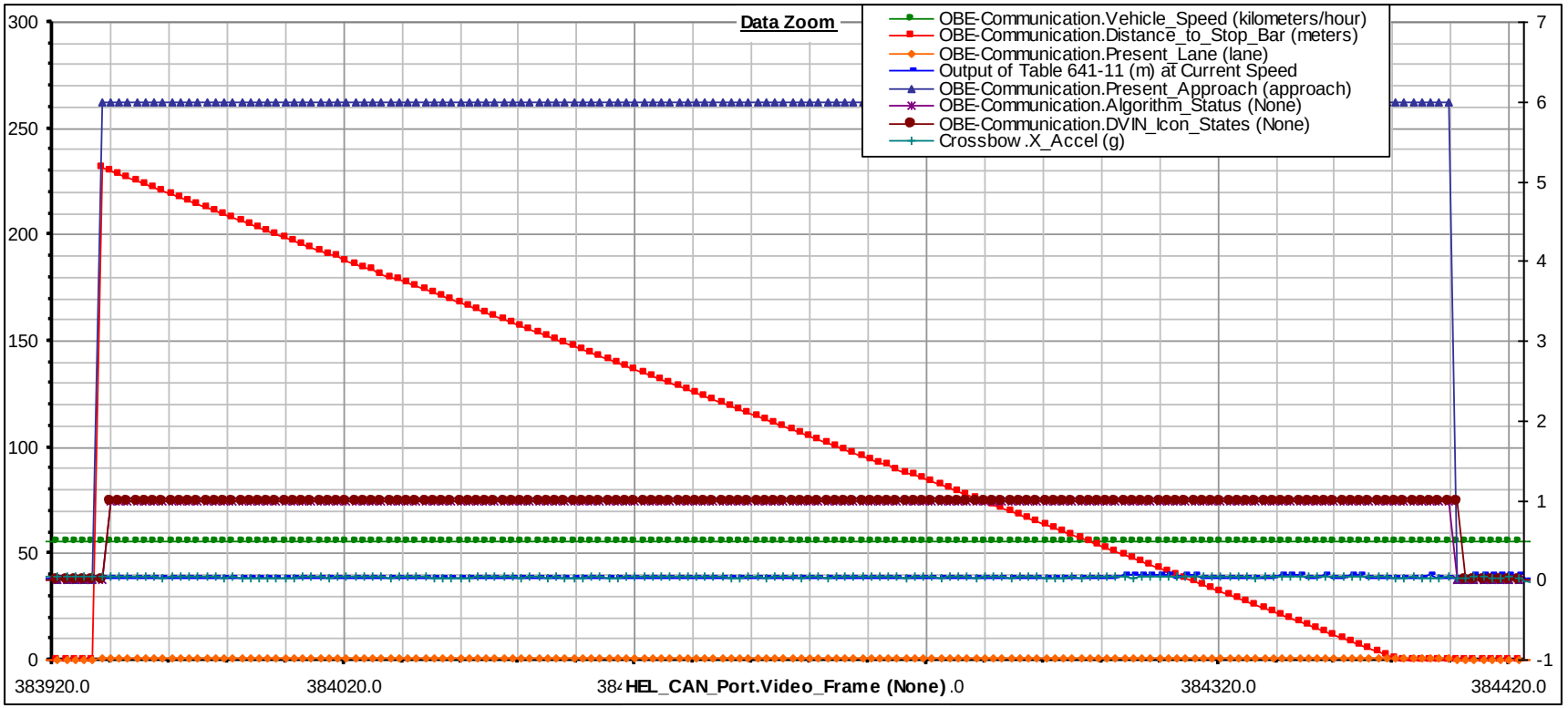

Figure 65: Edge of Approach Testing for Nuisance Warning, Run 8

8.1.6 : Late Lane Shift Test – Warning

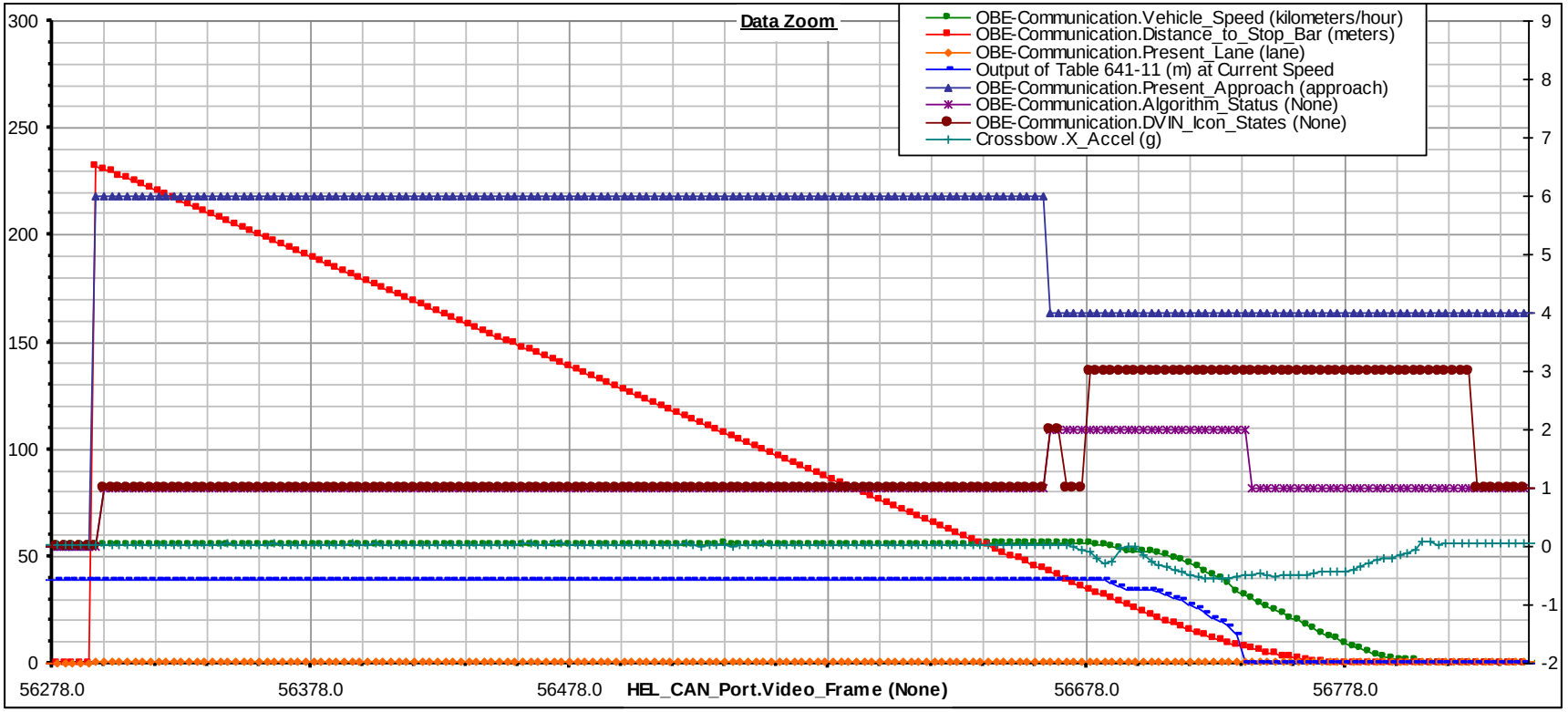

Figure 66: Late Lane Shift Test – Warning, Run 1

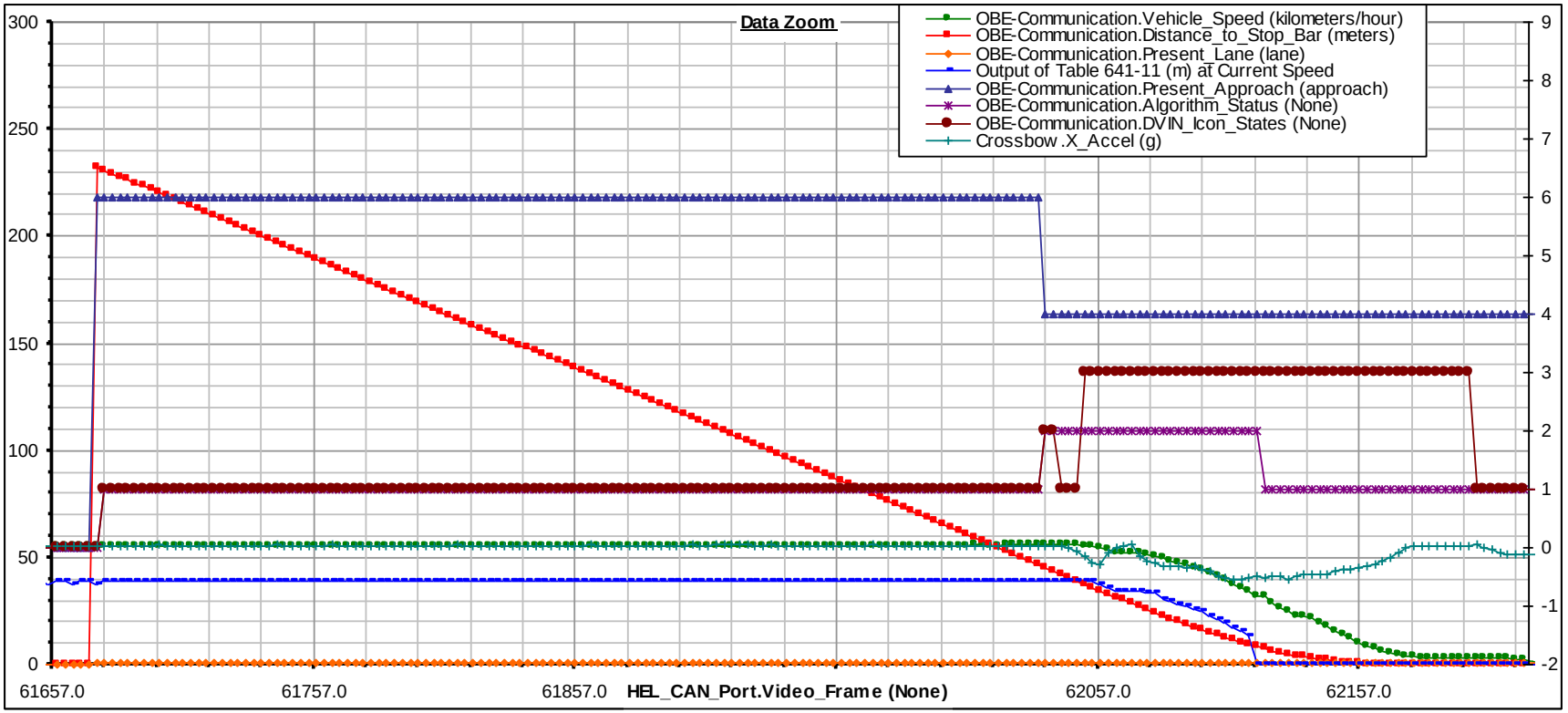

Figure 67: Late Lane Shift Test – Warning, Run 2

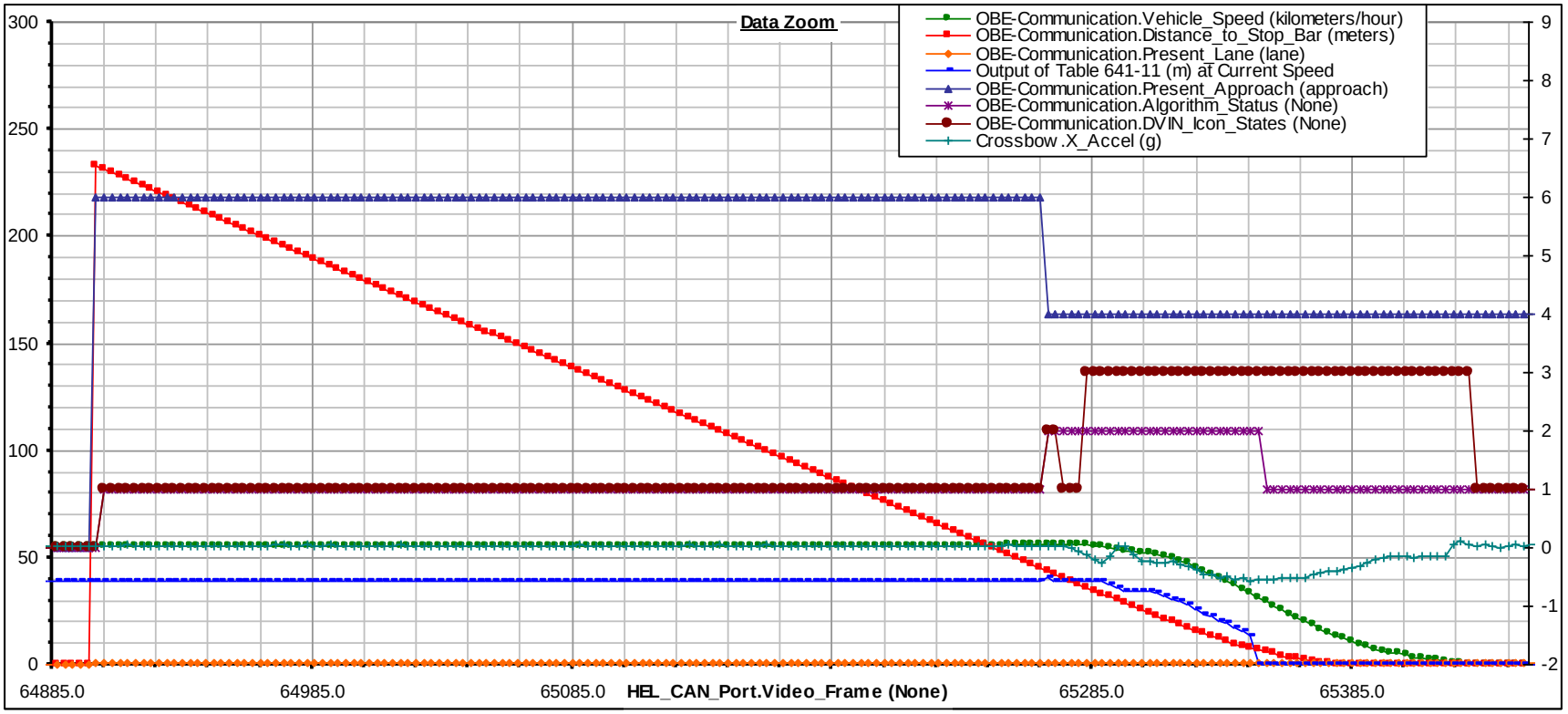

Figure 68: Late Lane Shift Test – Warning, Run 3

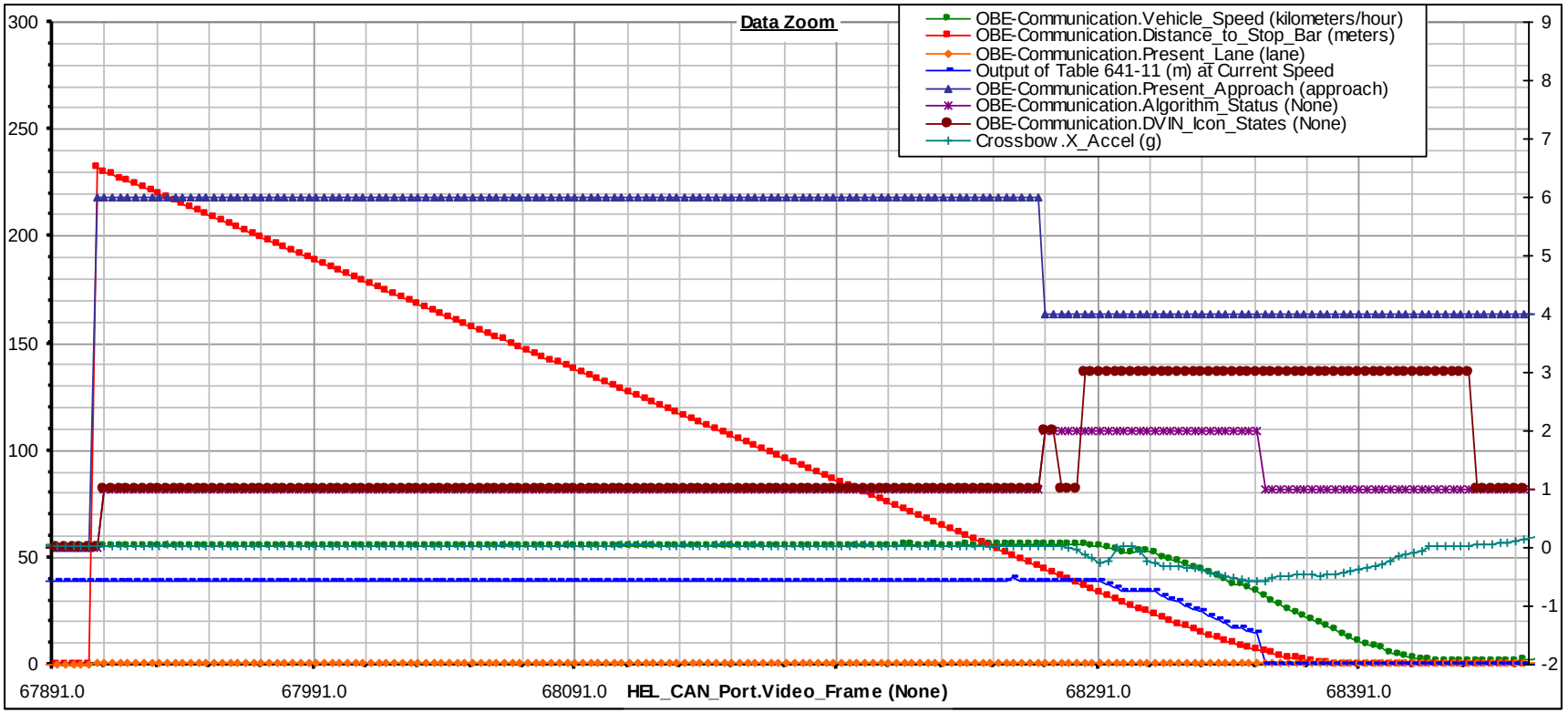

Figure 69: Late Lane Shift Test – Warning, Run 4

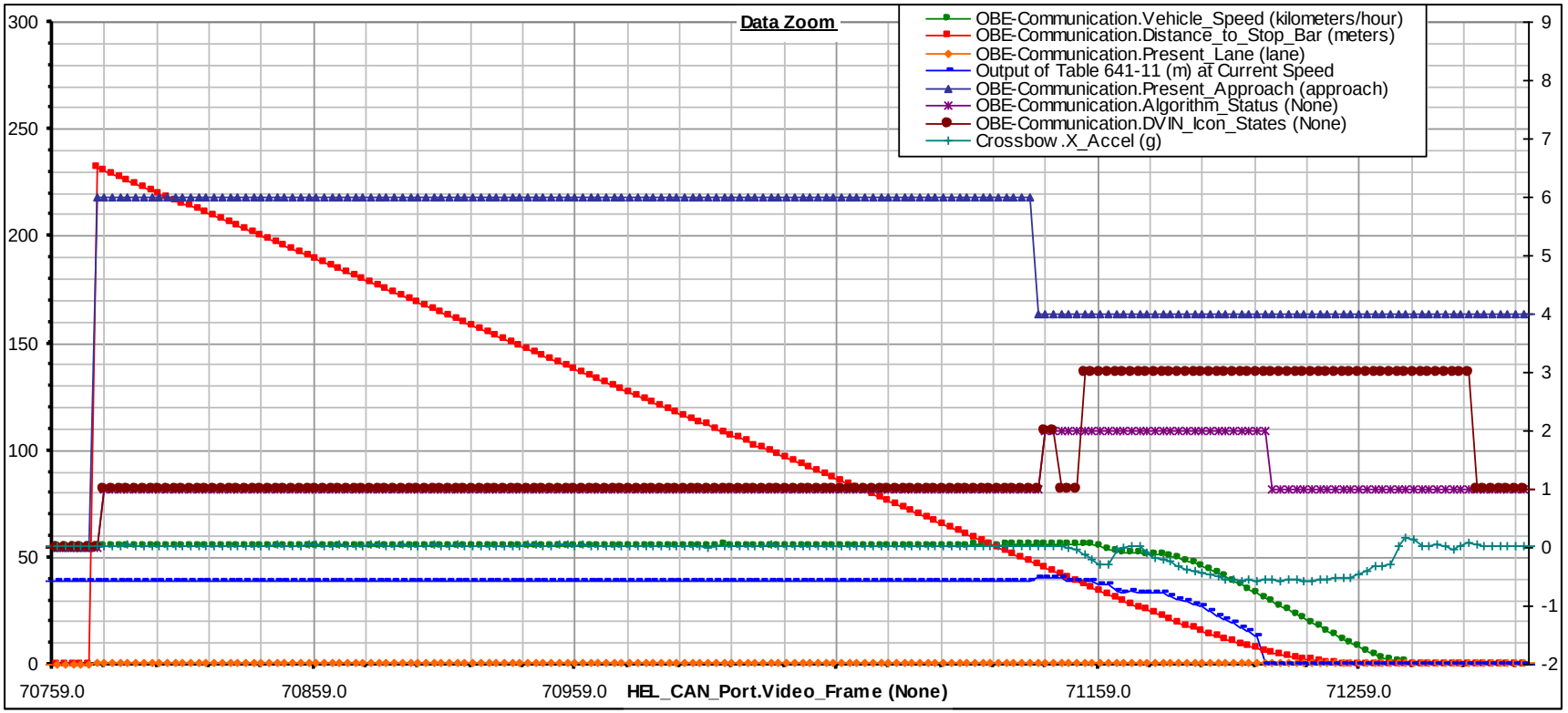

Figure 70: Late Lane Shift Test – Warning, Run 5

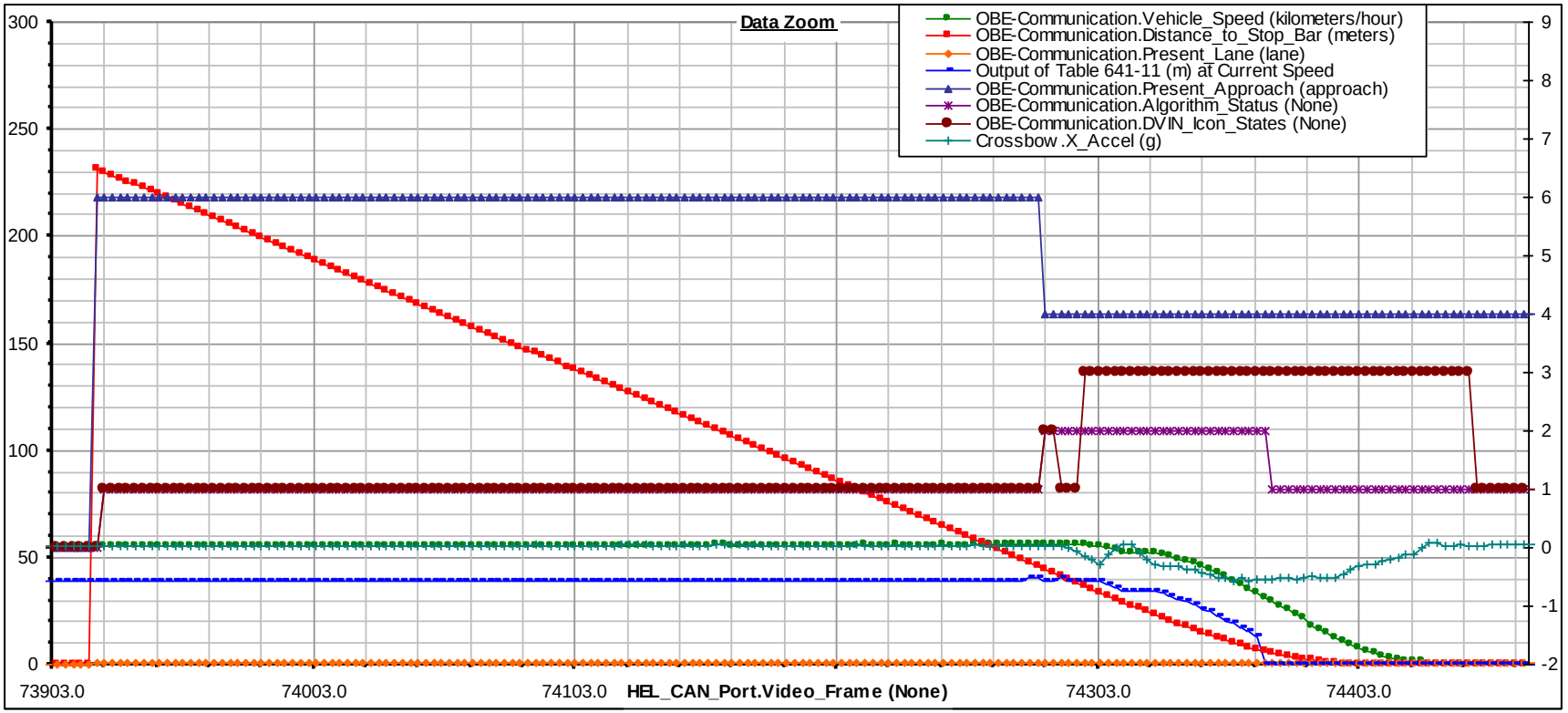

Figure 71: Late Lane Shift Test – Warning, Run 6

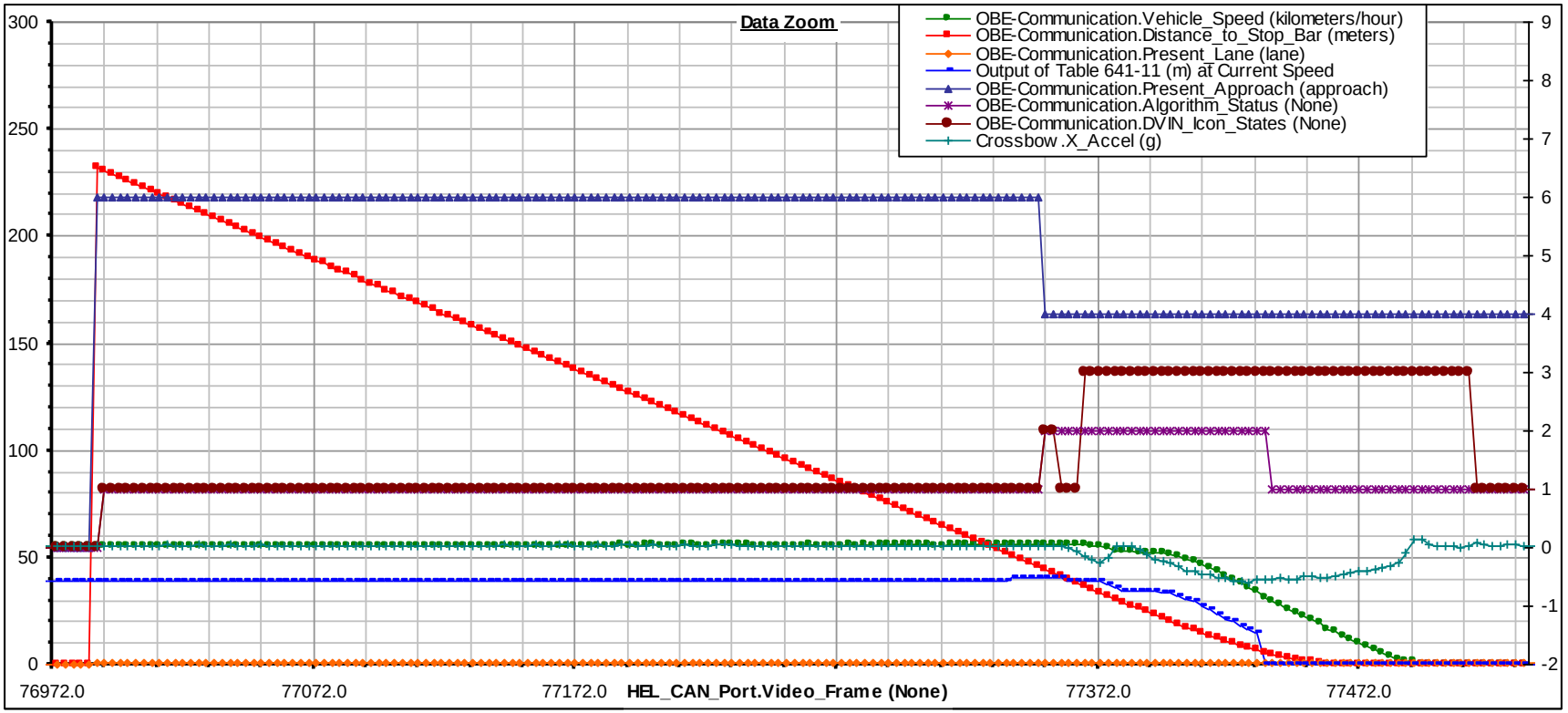

Figure 72: Late Lane Shift Test – Warning, Run 7

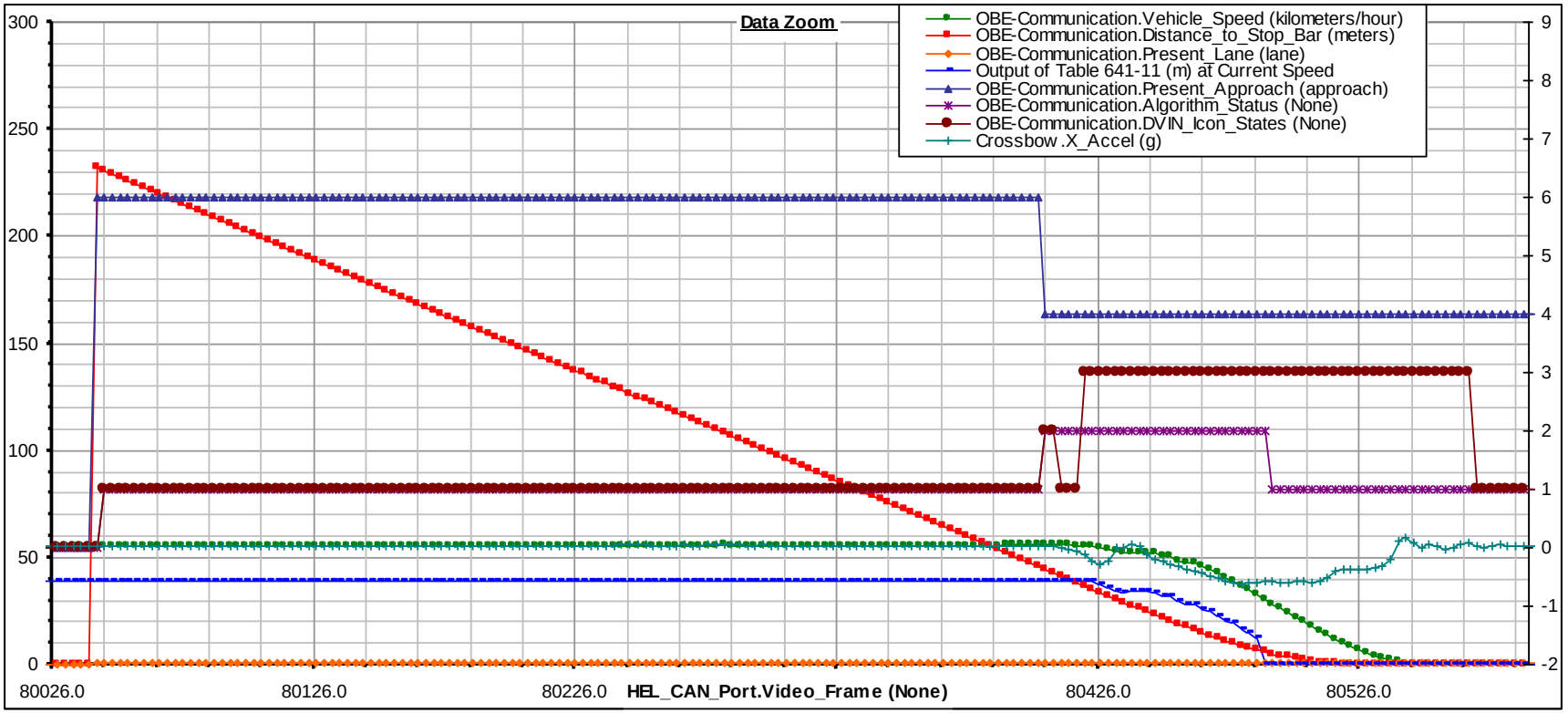

Figure 73: Late Lane Shift Test – Warning, Run 8

8.1.7 : Late Lane Shift Test – Nuisance Warning

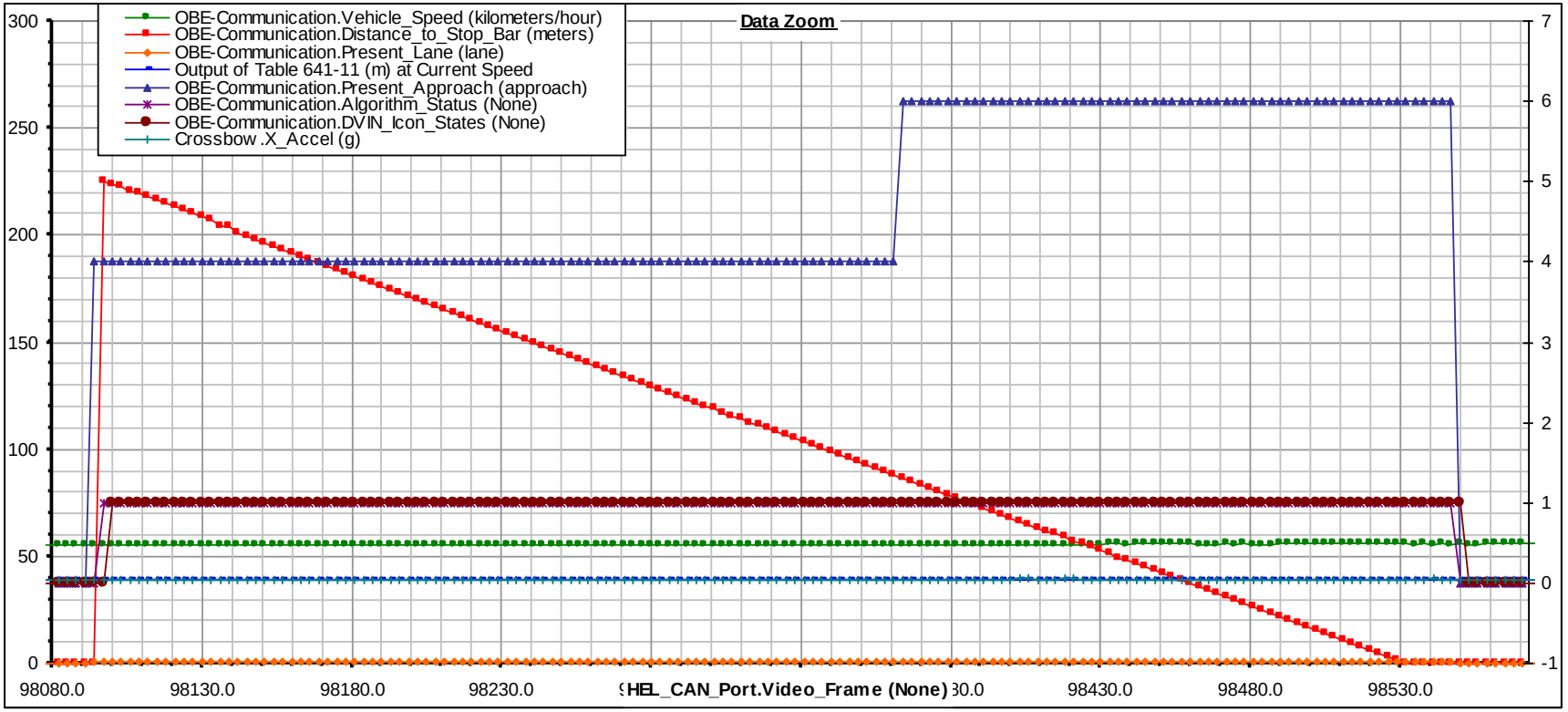

Figure 74: Late Lane Shift Test – Nuisance Warning, Run 1

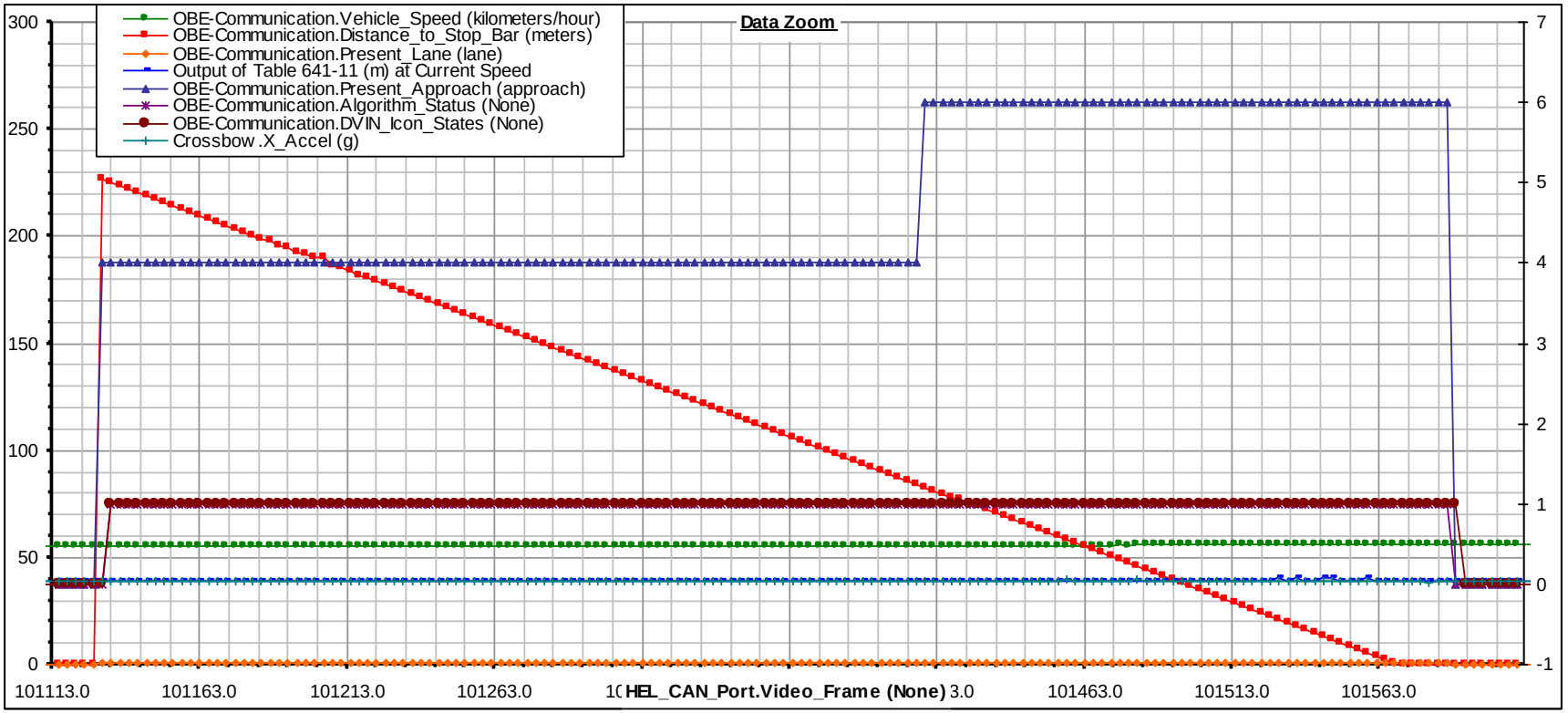

Figure 75: Late Lane Shift Test – Nuisance Warning, Run 2

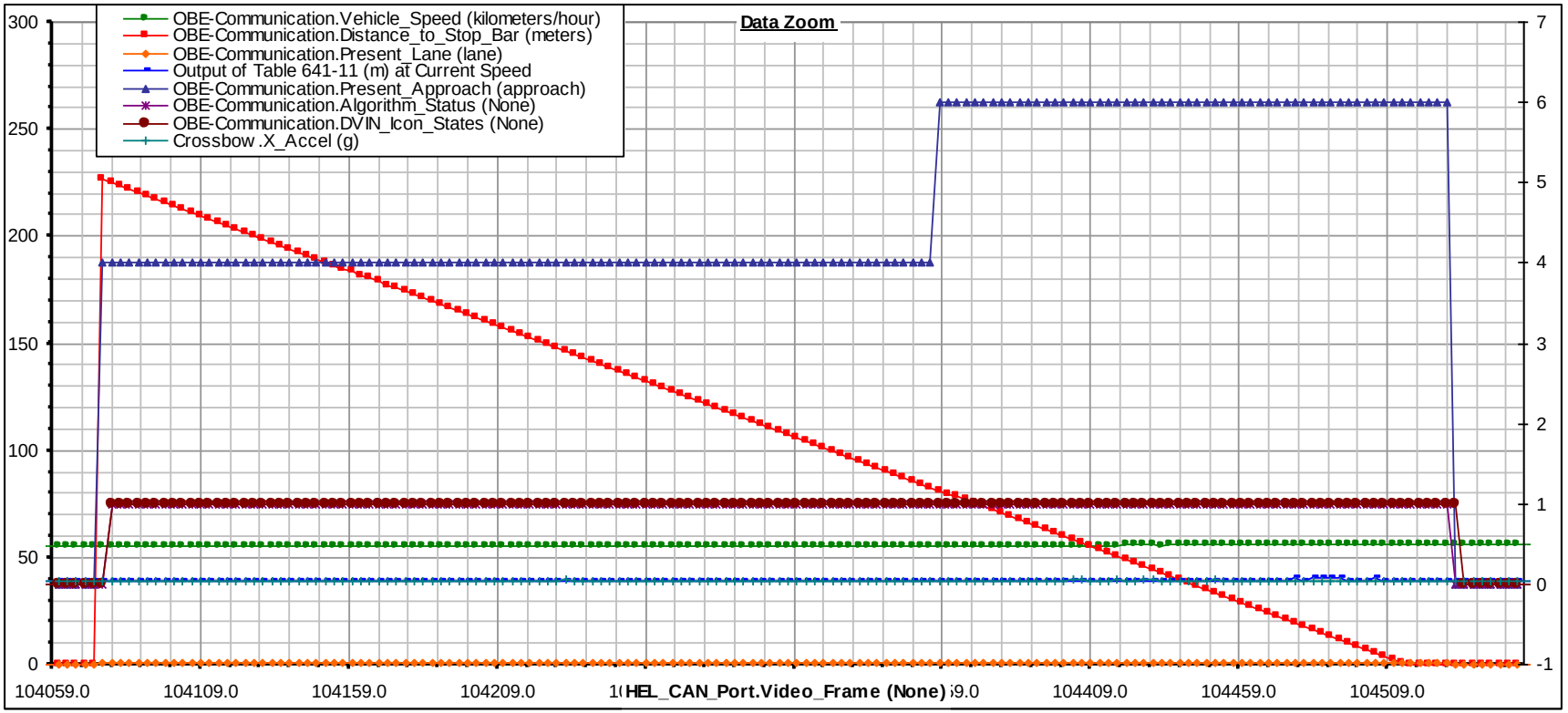

Figure 76: Late Lane Shift Test – Nuisance Warning, Run 3

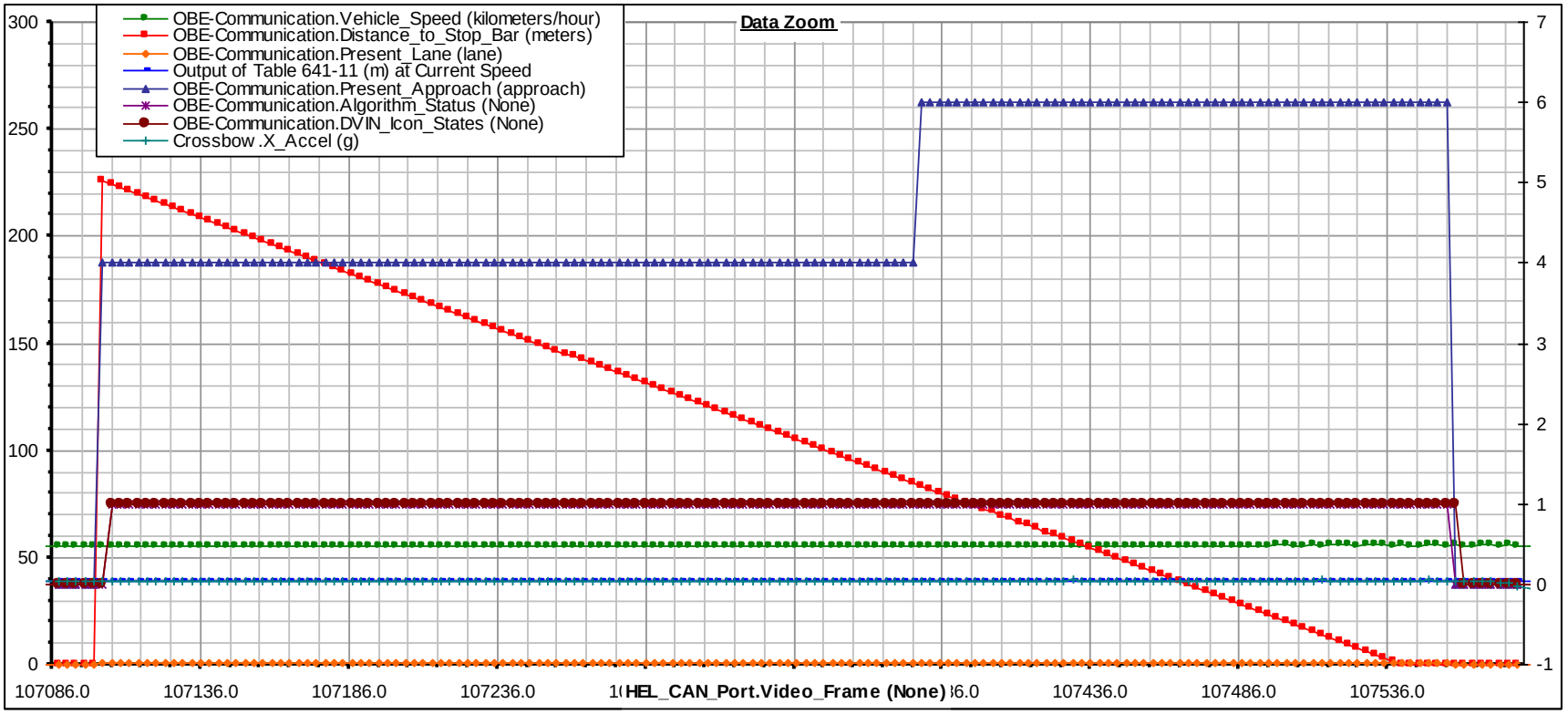

Figure 77: Late Lane Shift Test – Nuisance Warning, Run 4

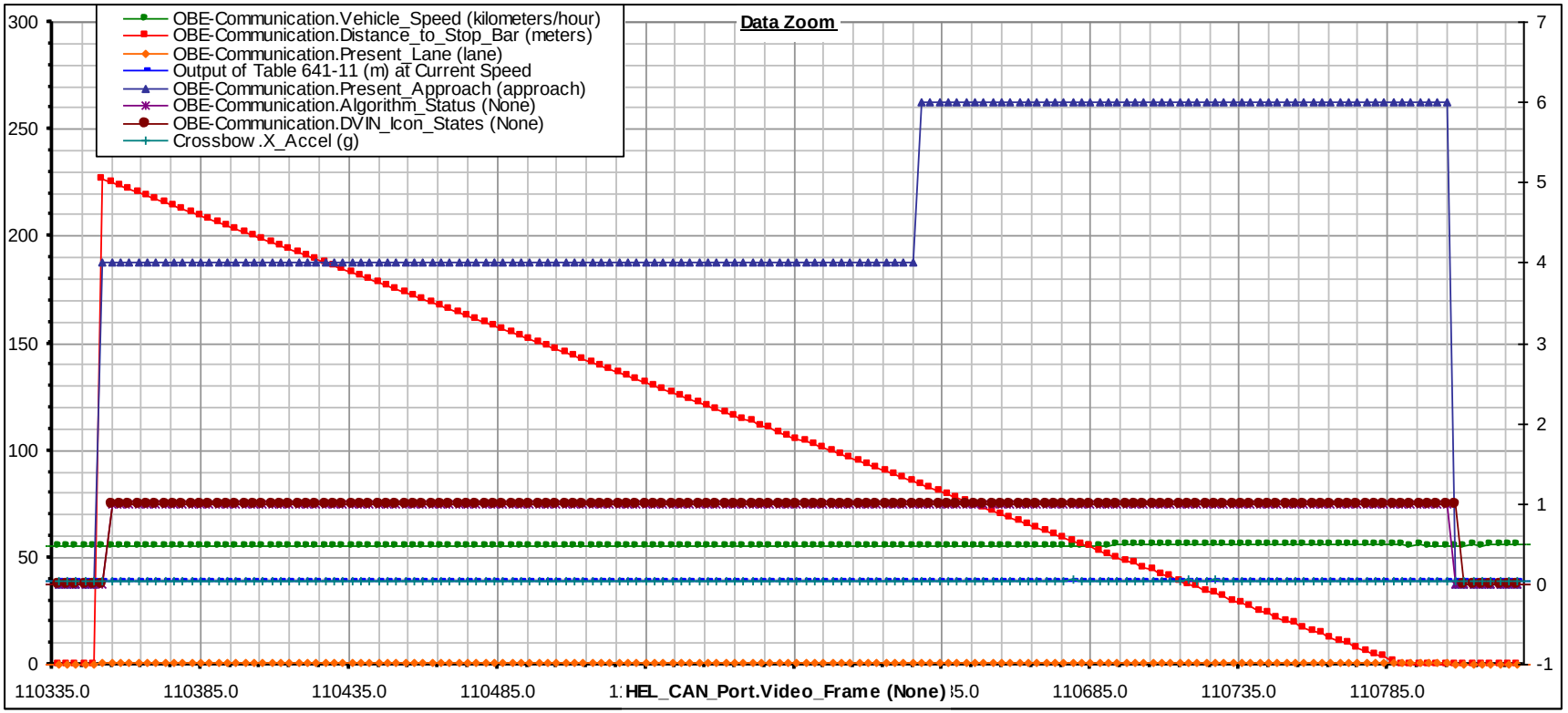

Figure 78: Late Lane Shift Test – Nuisance Warning, Run 5

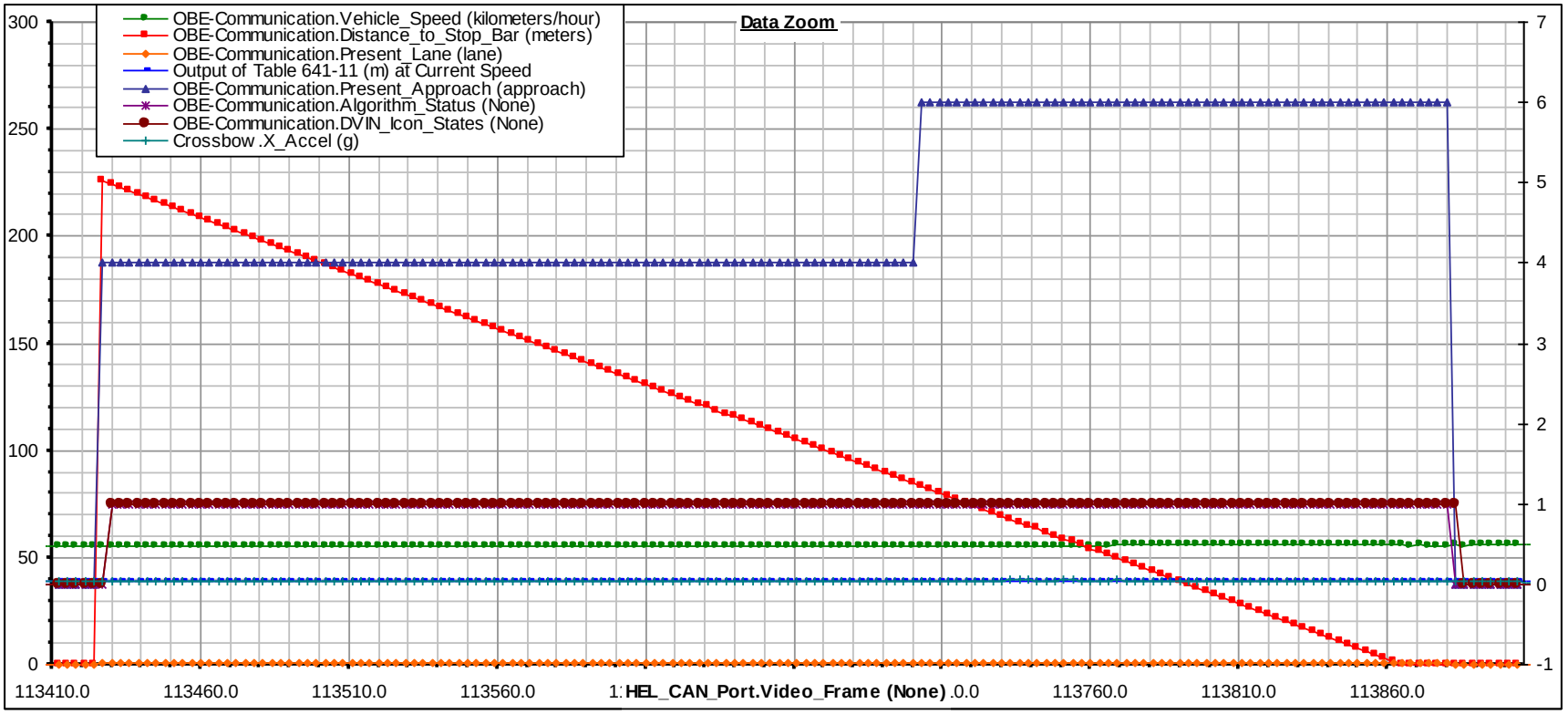

Figure 79: Late Lane Shift Test – Nuisance Warning, Run 6

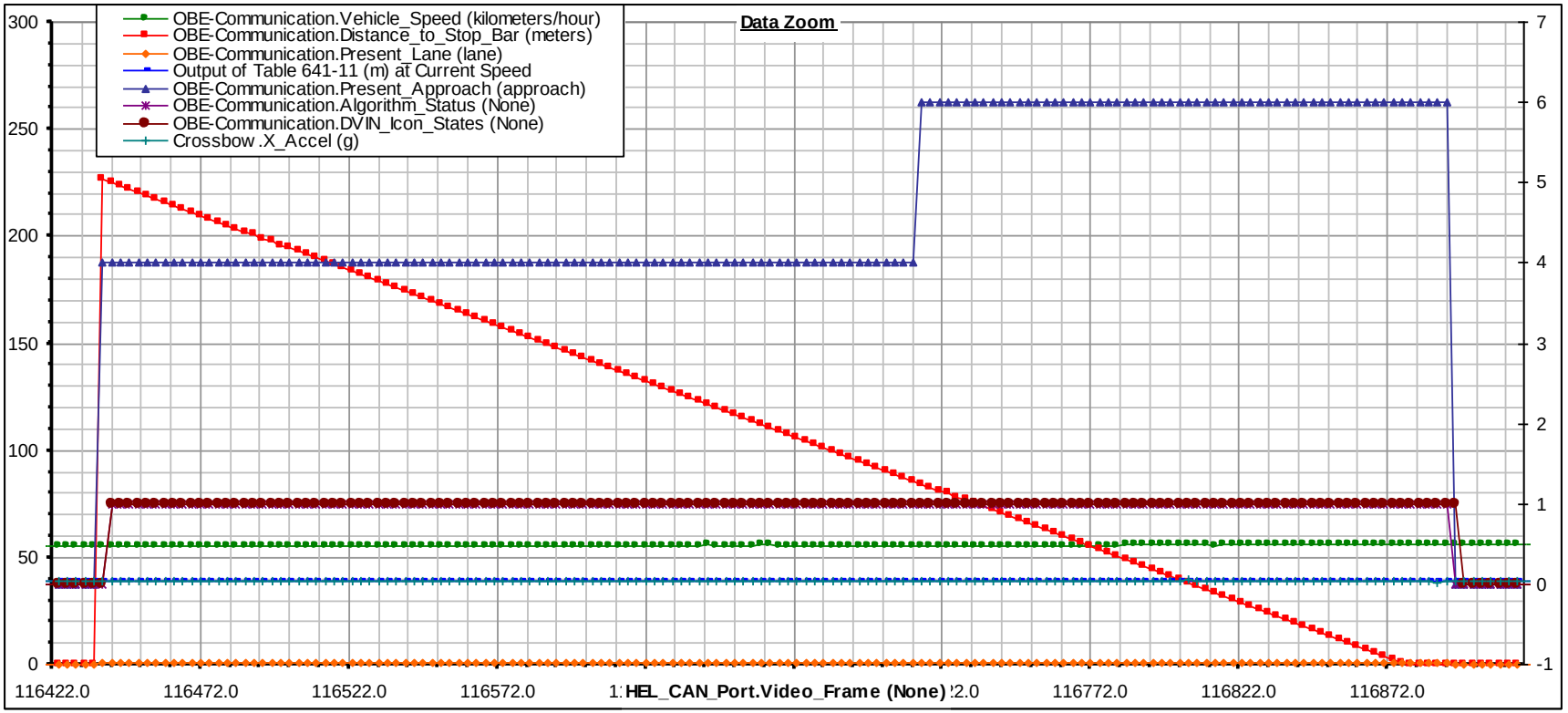

Figure 80: Late Lane Shift Test – Nuisance Warning, Run 7

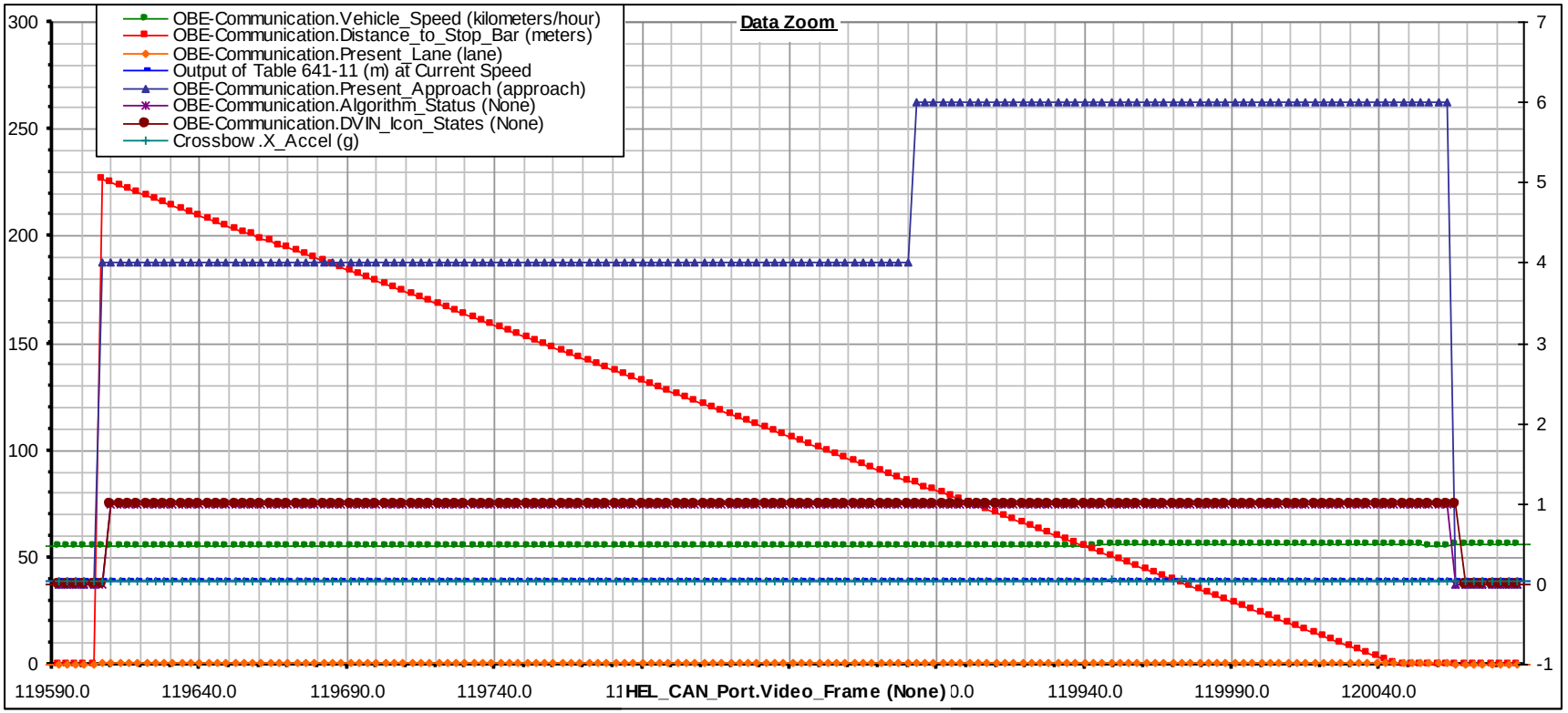

Figure 81: Late Lane Shift Test – Nuisance Warning, Run 8

8.1.8 : Multiple Intersections within 300m Radius: Warning Case

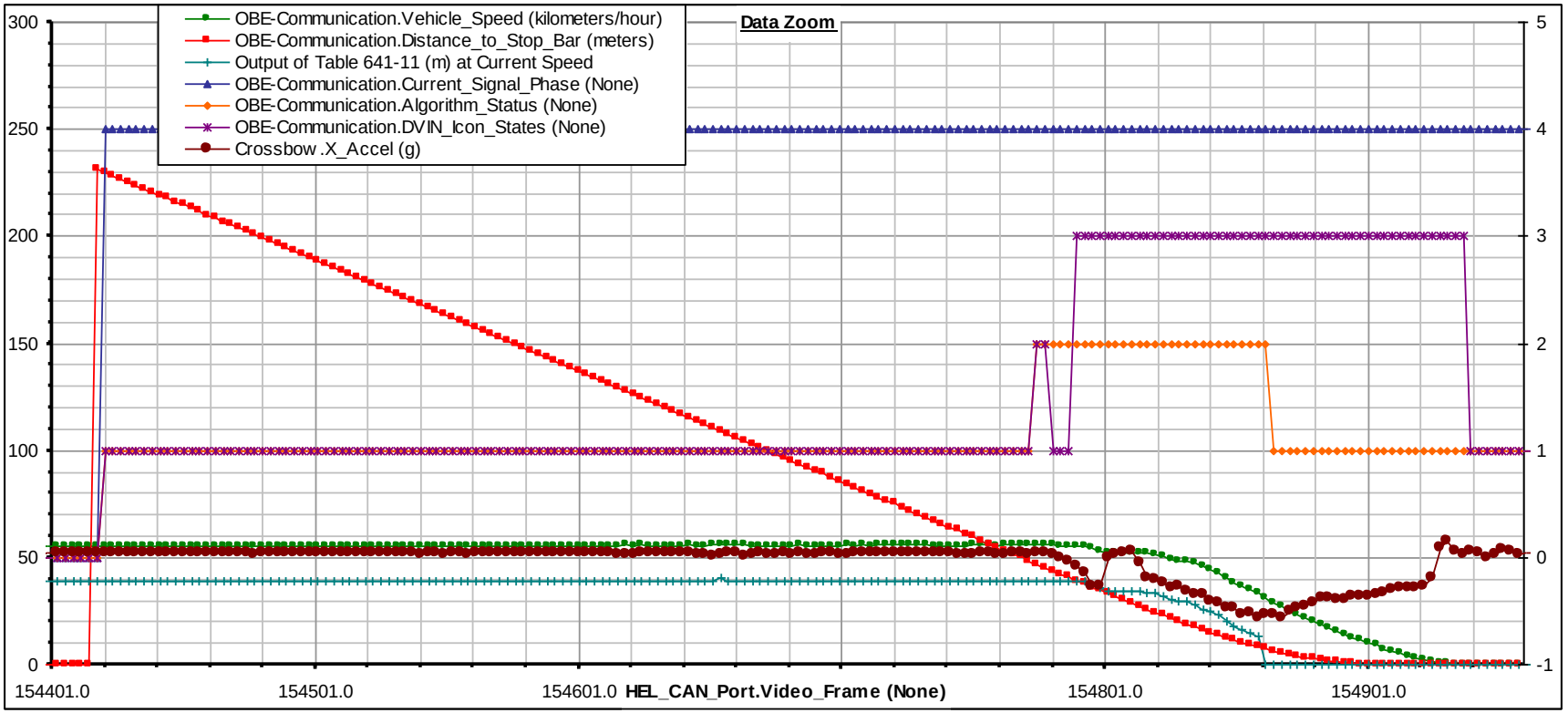

Figure 82: Multiple Intersections within 300m Radius: Warning Case, Run 1

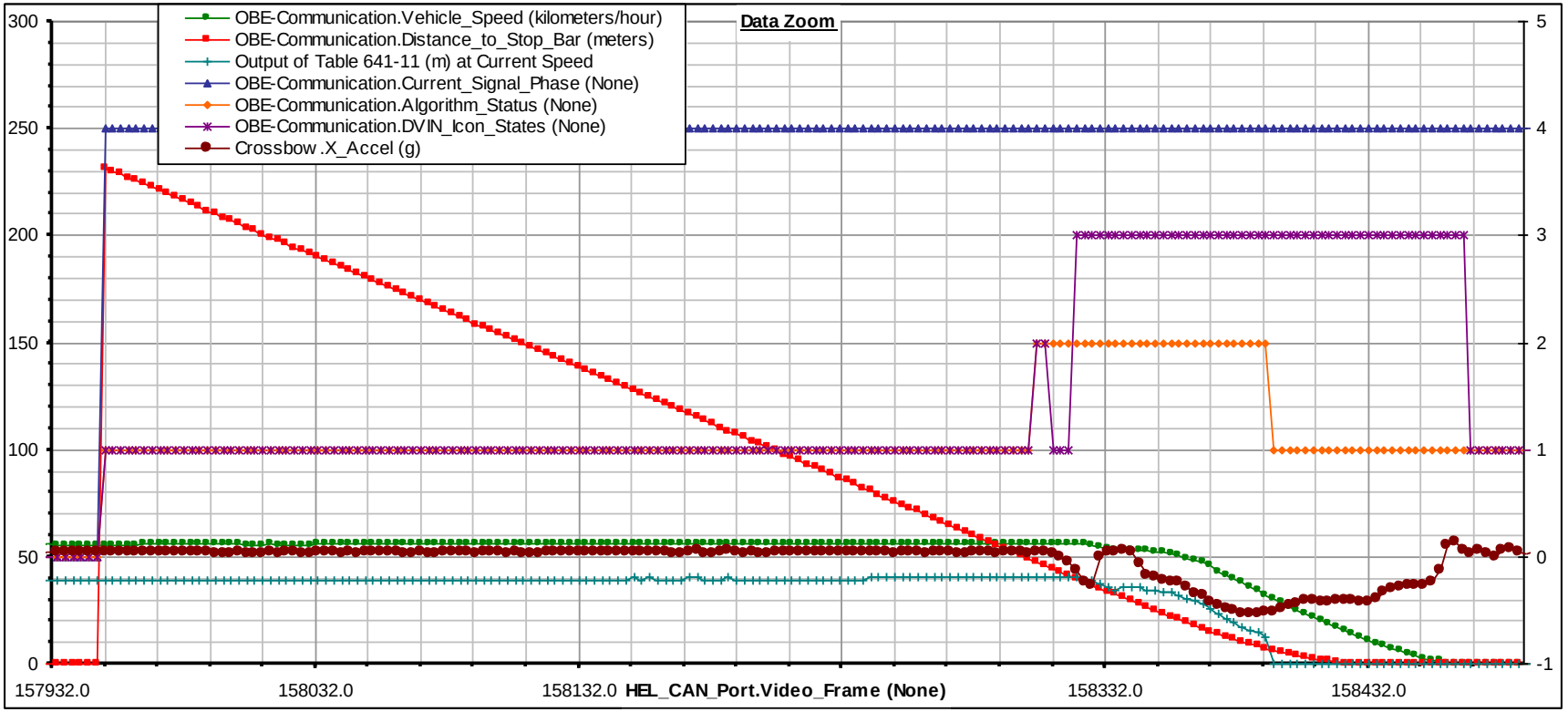

Figure 83: Multiple Intersections within 300m Radius: Warning Case, Run 2

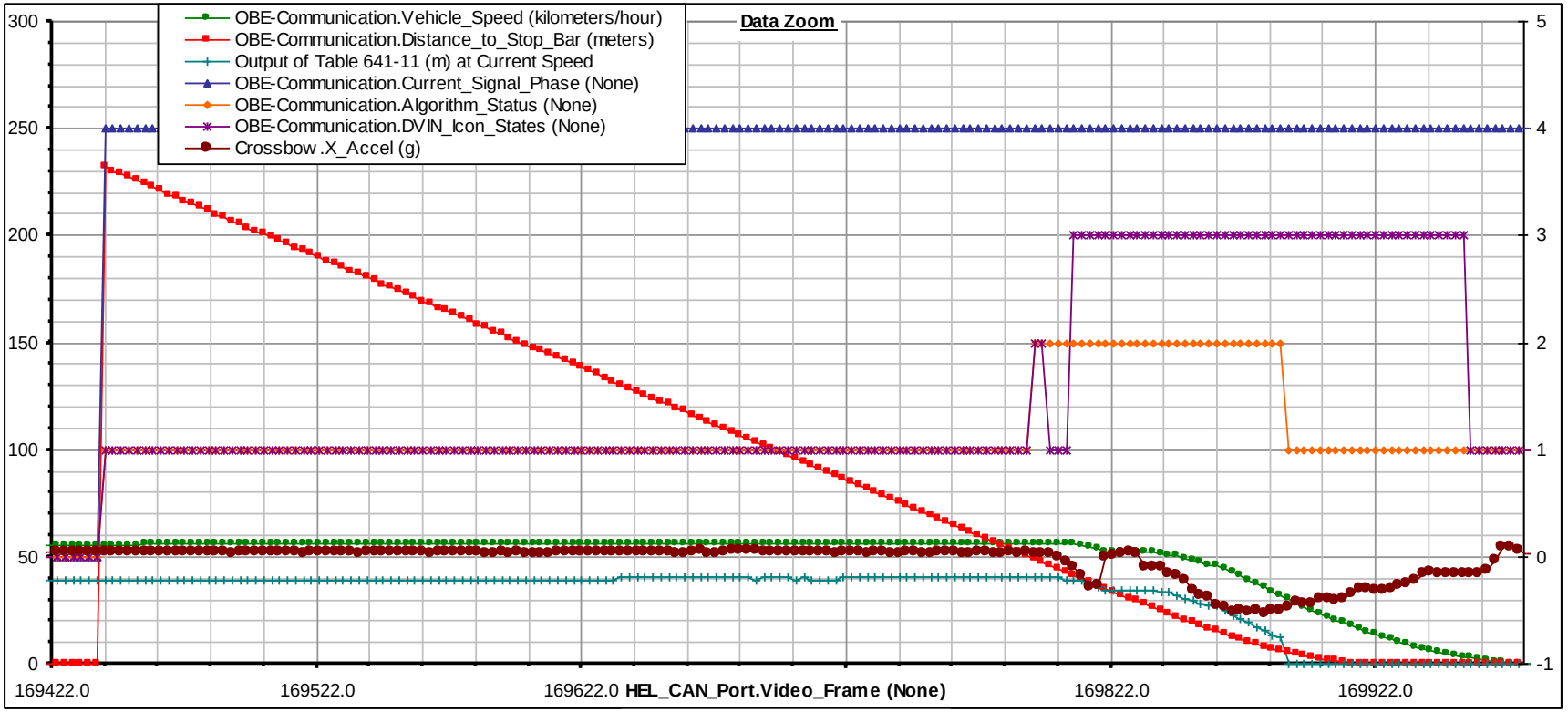

Figure 84: Multiple Intersections within 300m Radius: Warning Case, Run 4

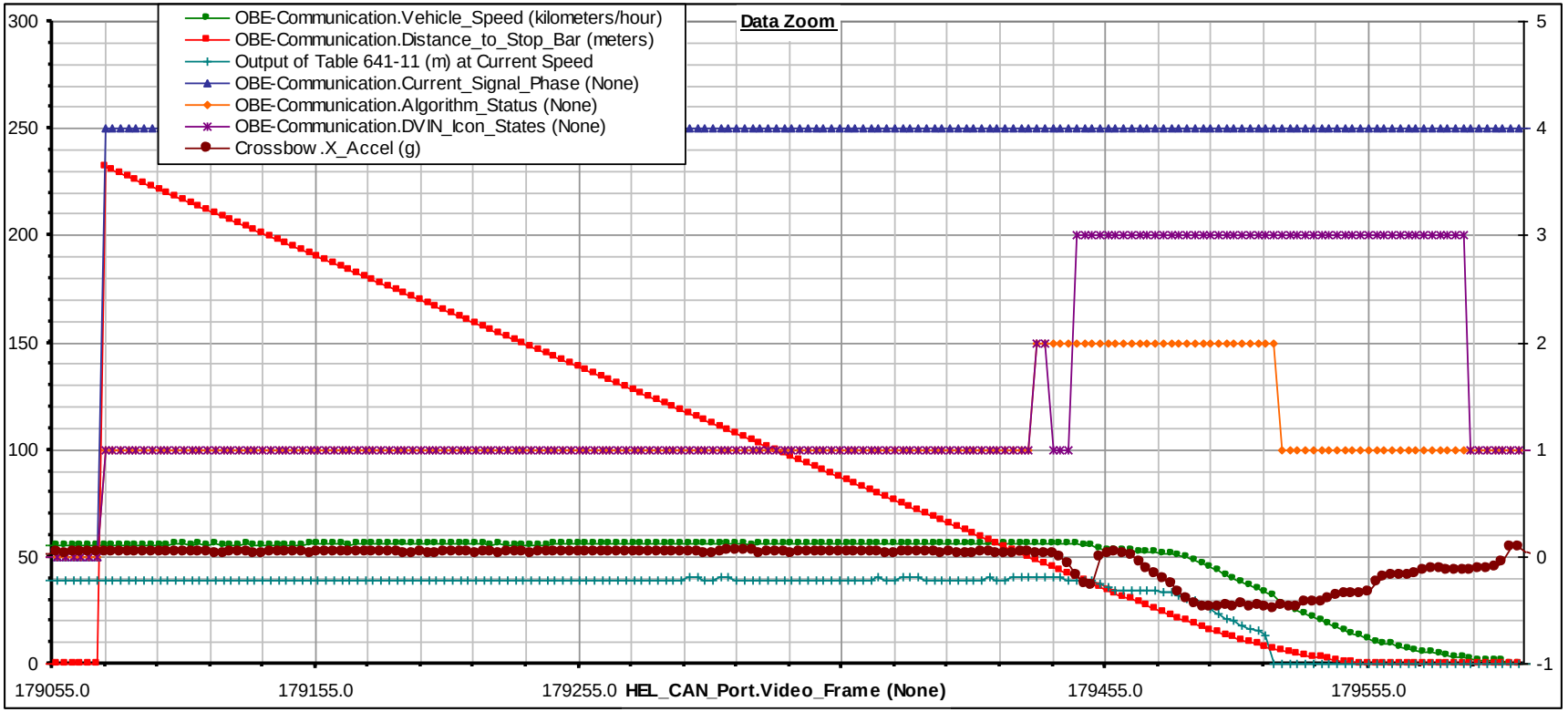

Figure 85: Multiple Intersections within 300m Radius: Warning Case, Run 6

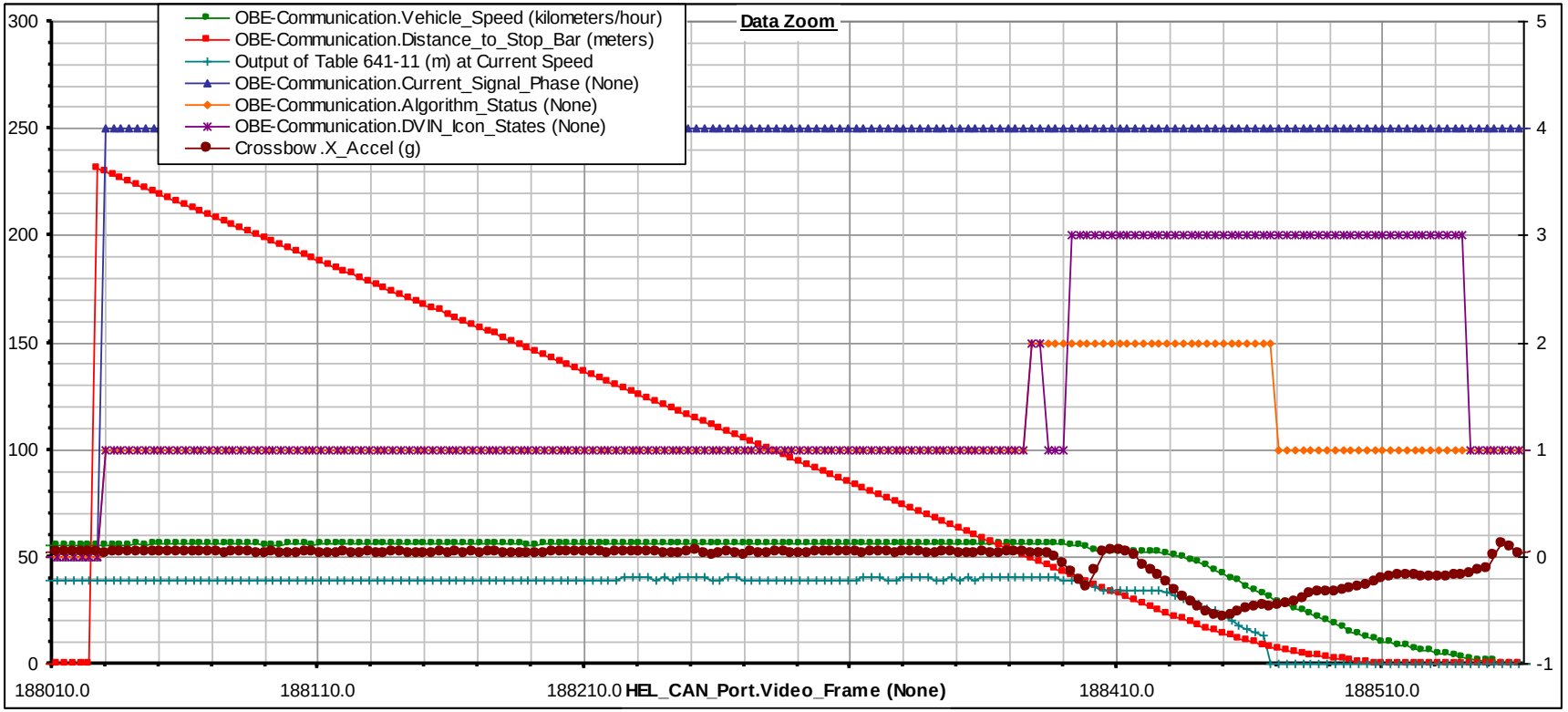

Figure 86: Multiple Intersections within 300m Radius: Warning Case, Run 8

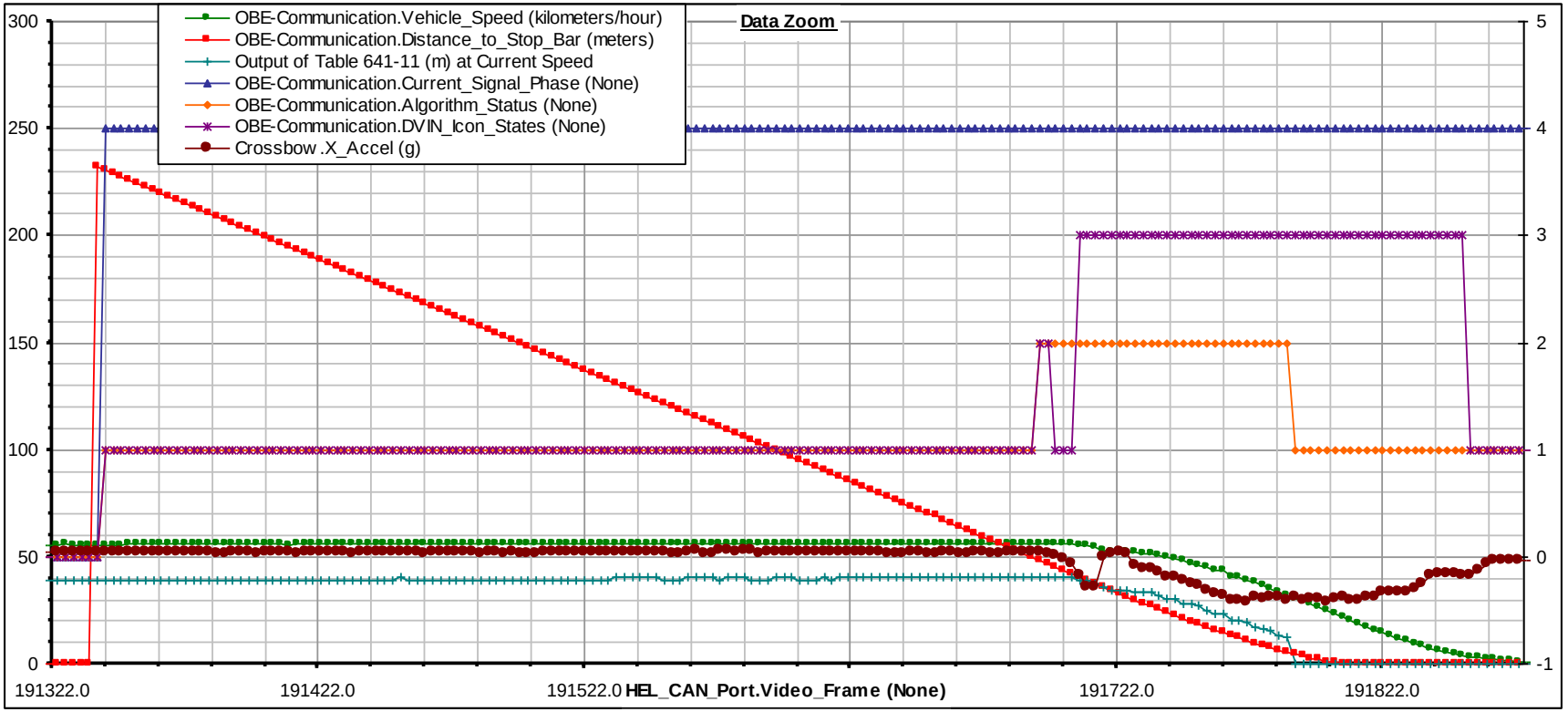

Figure 87: Multiple Intersections within 300m Radius: Warning Case, Run 9

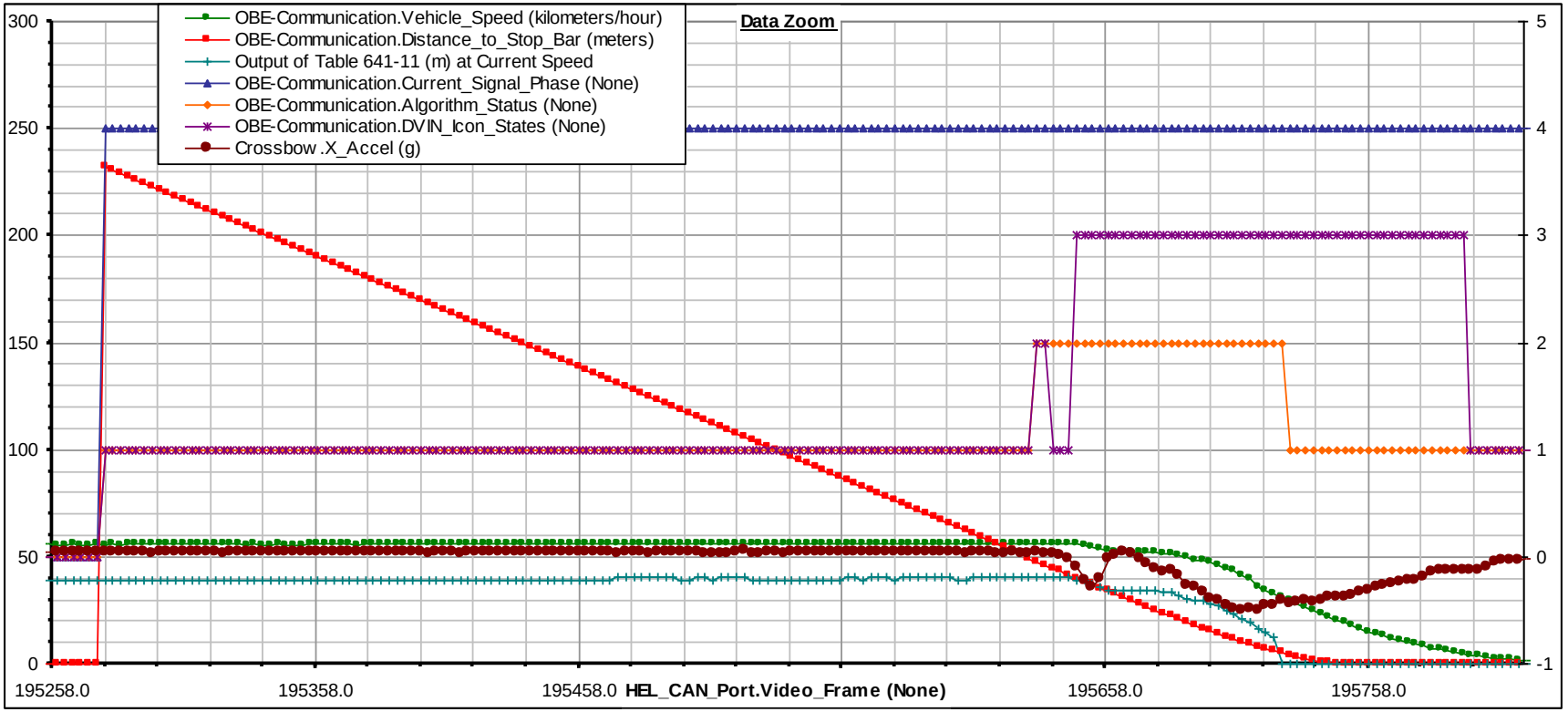

Figure 88: Multiple Intersections within 300m Radius: Warning Case, Run 10

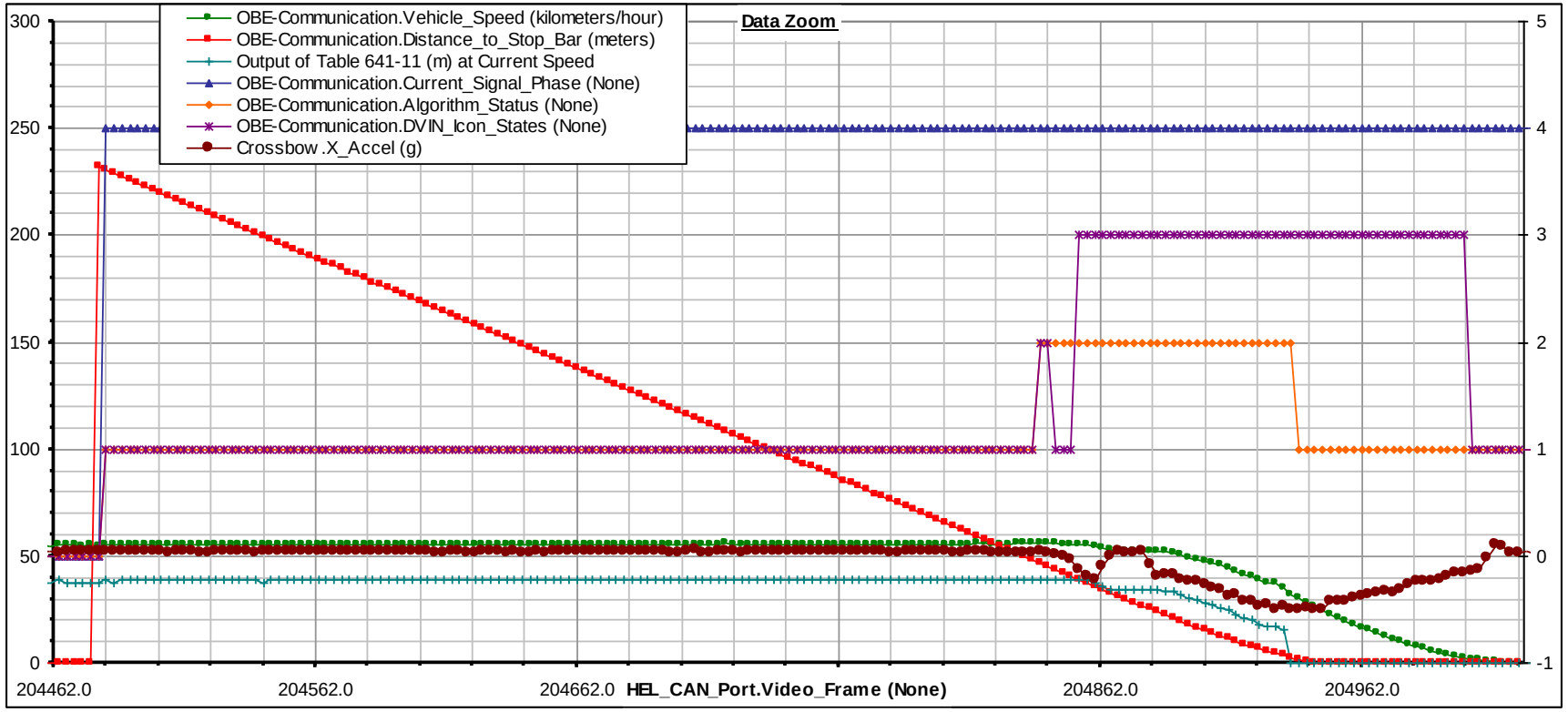

Figure 89: Multiple Intersections within 300m Radius: Warning Case, Run 12

8.1.9 : Multiple Intersections within 300m Radius: No Warning Case

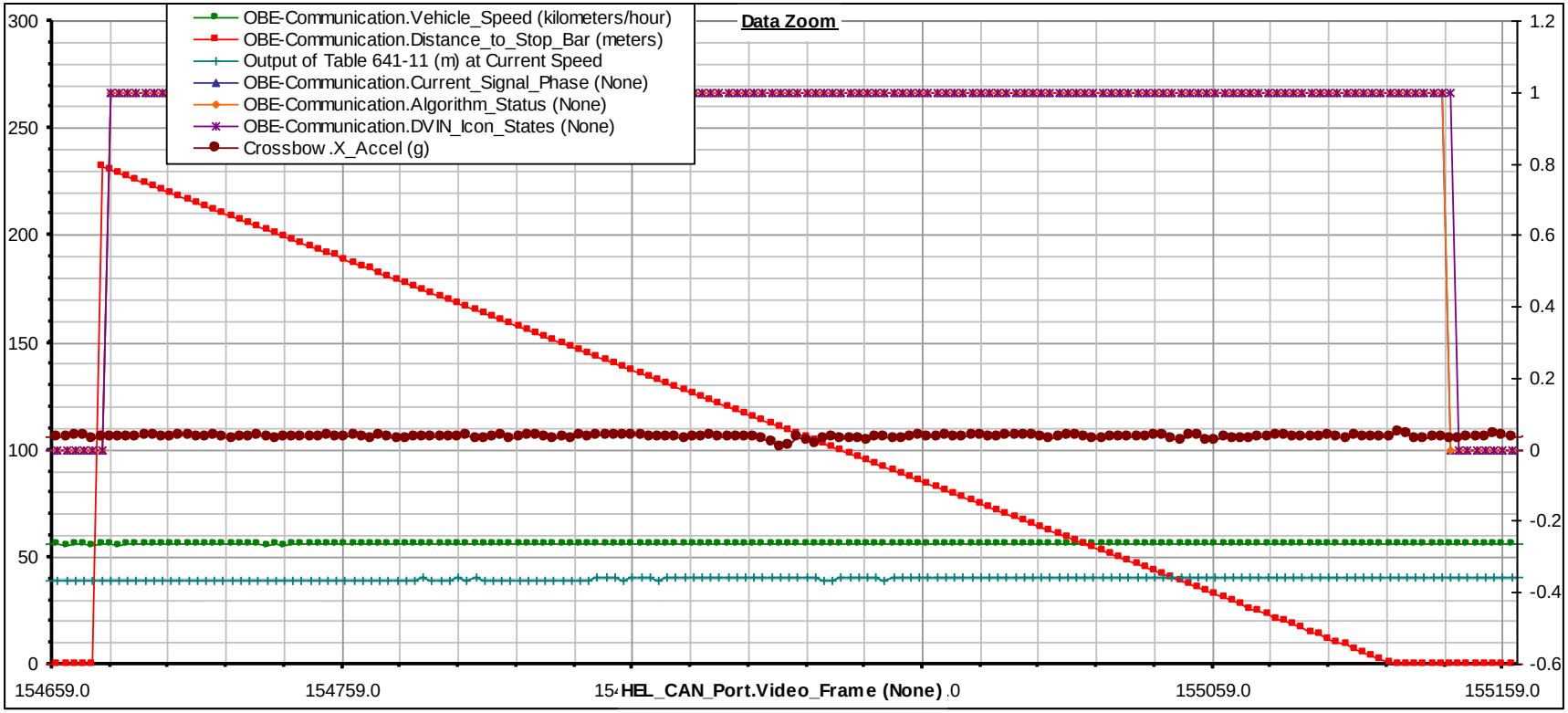

Figure 90: Multiple Intersections within 300m Radius: No Warning Case, Run 1

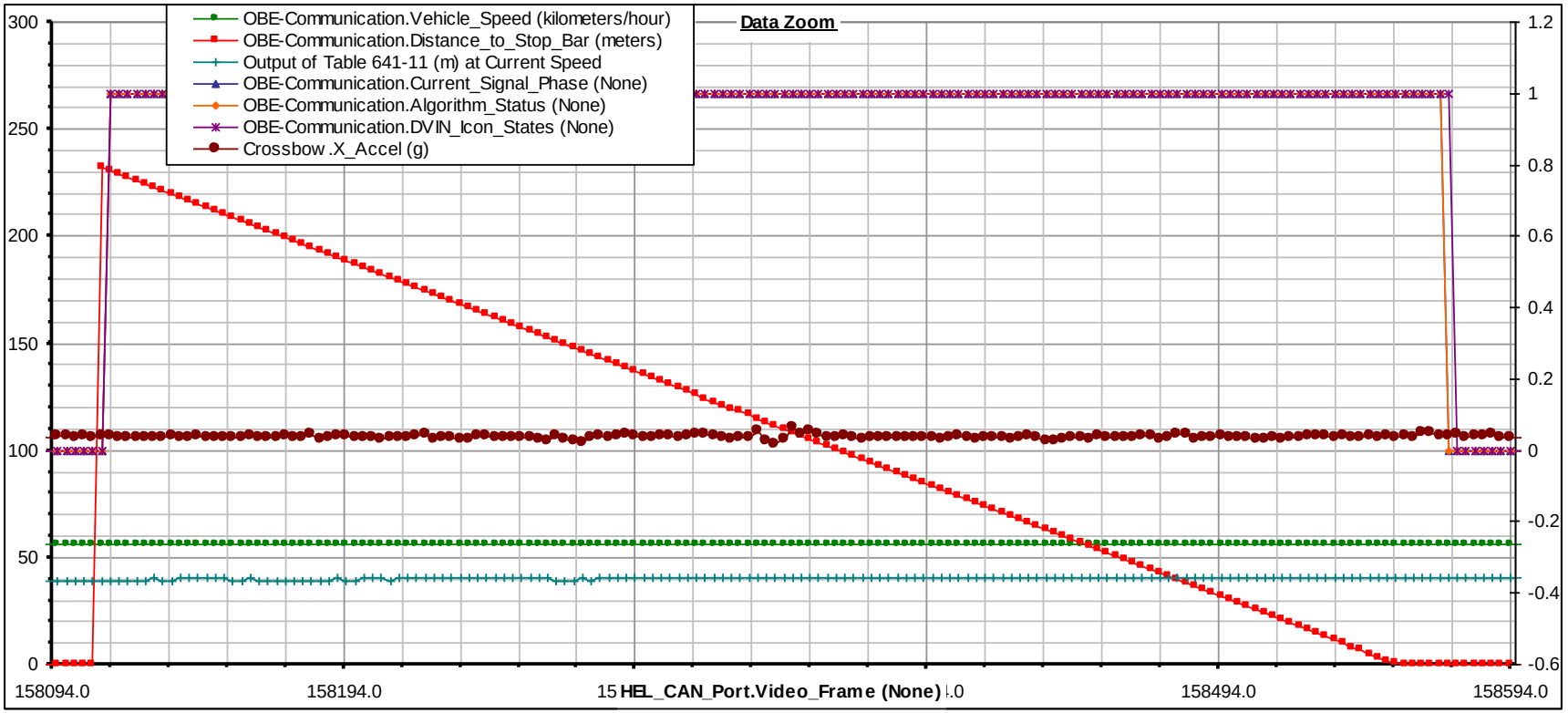

Figure 91: Multiple Intersections within 300m Radius: No Warning Case, Run 2

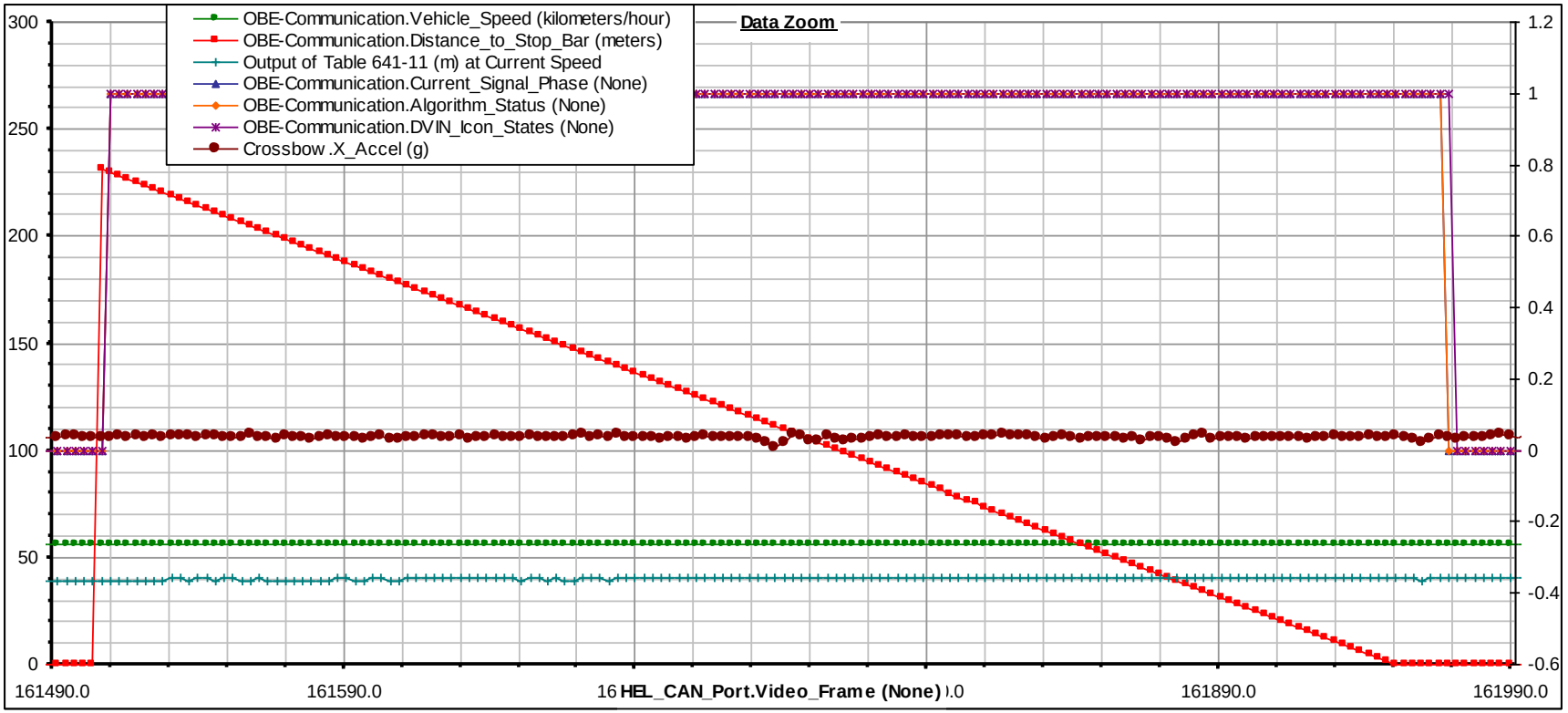

Figure 92: Multiple Intersections within 300m Radius: No Warning Case, Run 3

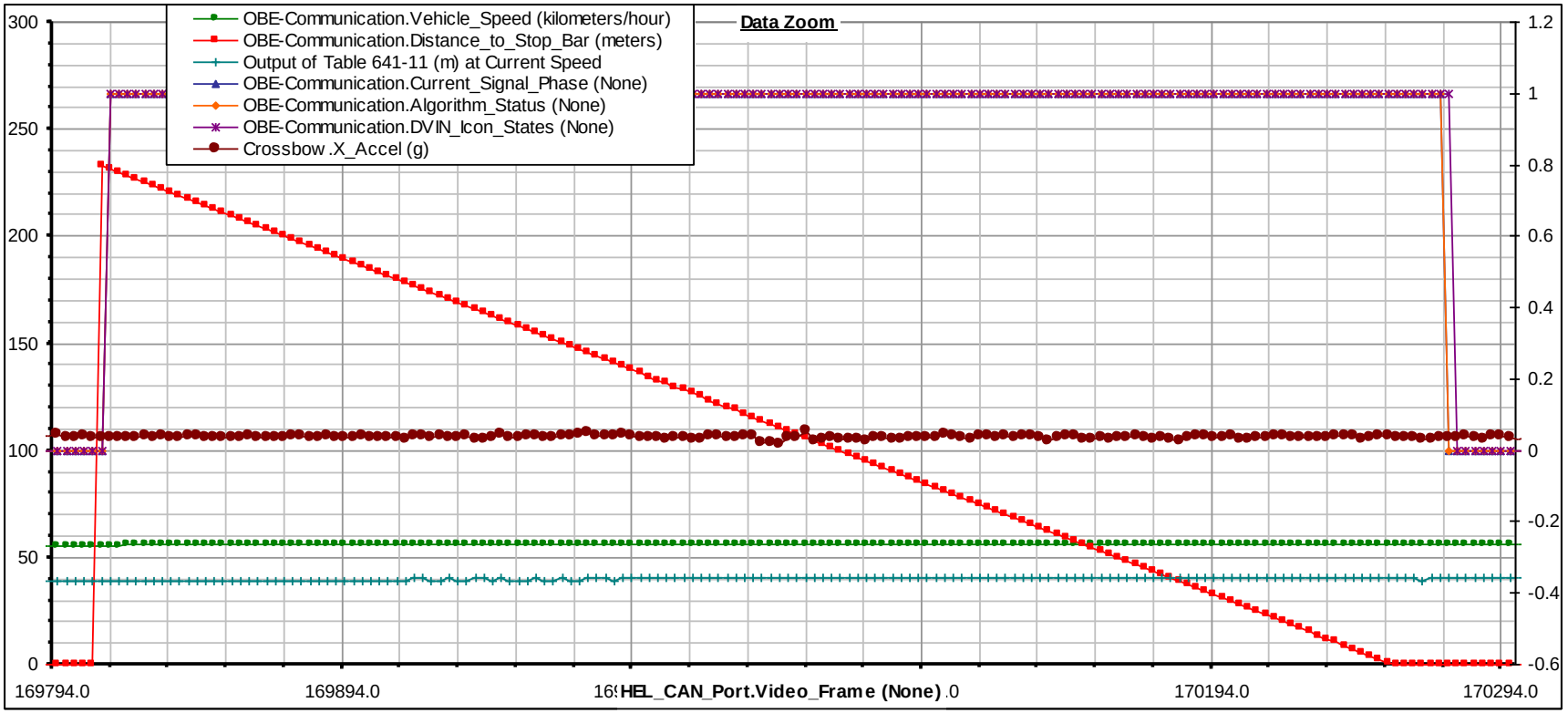

Figure 93: Multiple Intersections within 300m Radius: No Warning Case, Run 5

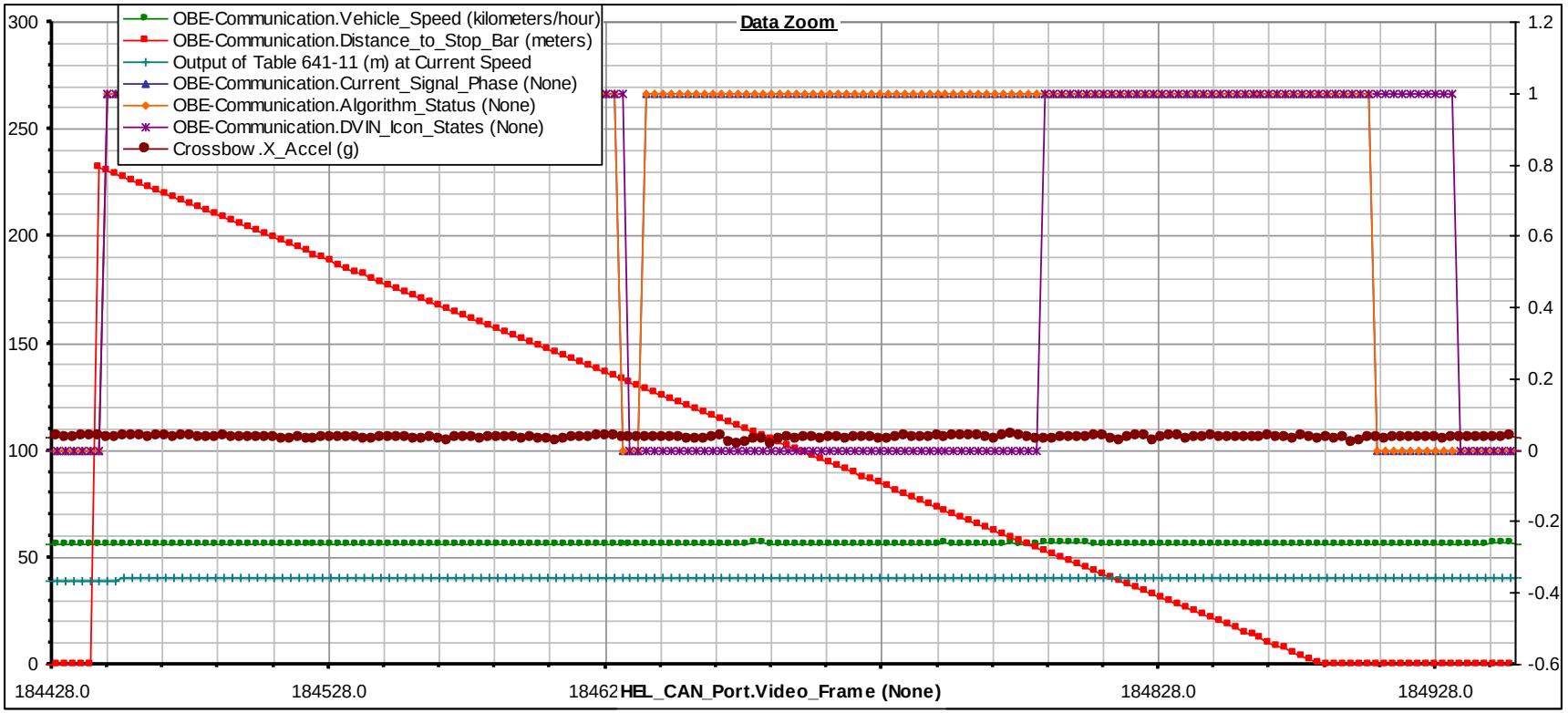

Figure 94: Multiple Intersections within 300m Radius: No Warning Case, Run 8

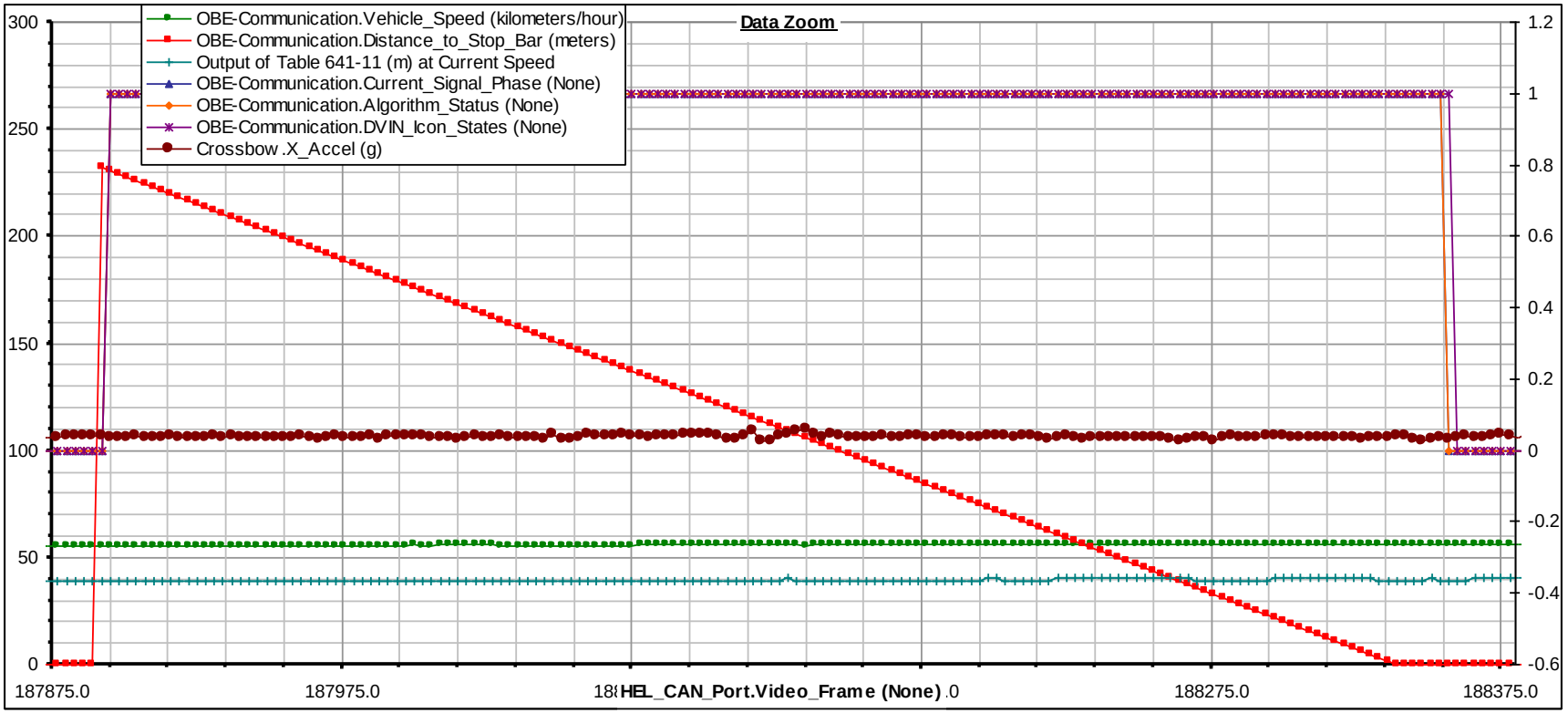

Figure 95: Multiple Intersections within 300m Radius: No Warning Case, Run 9

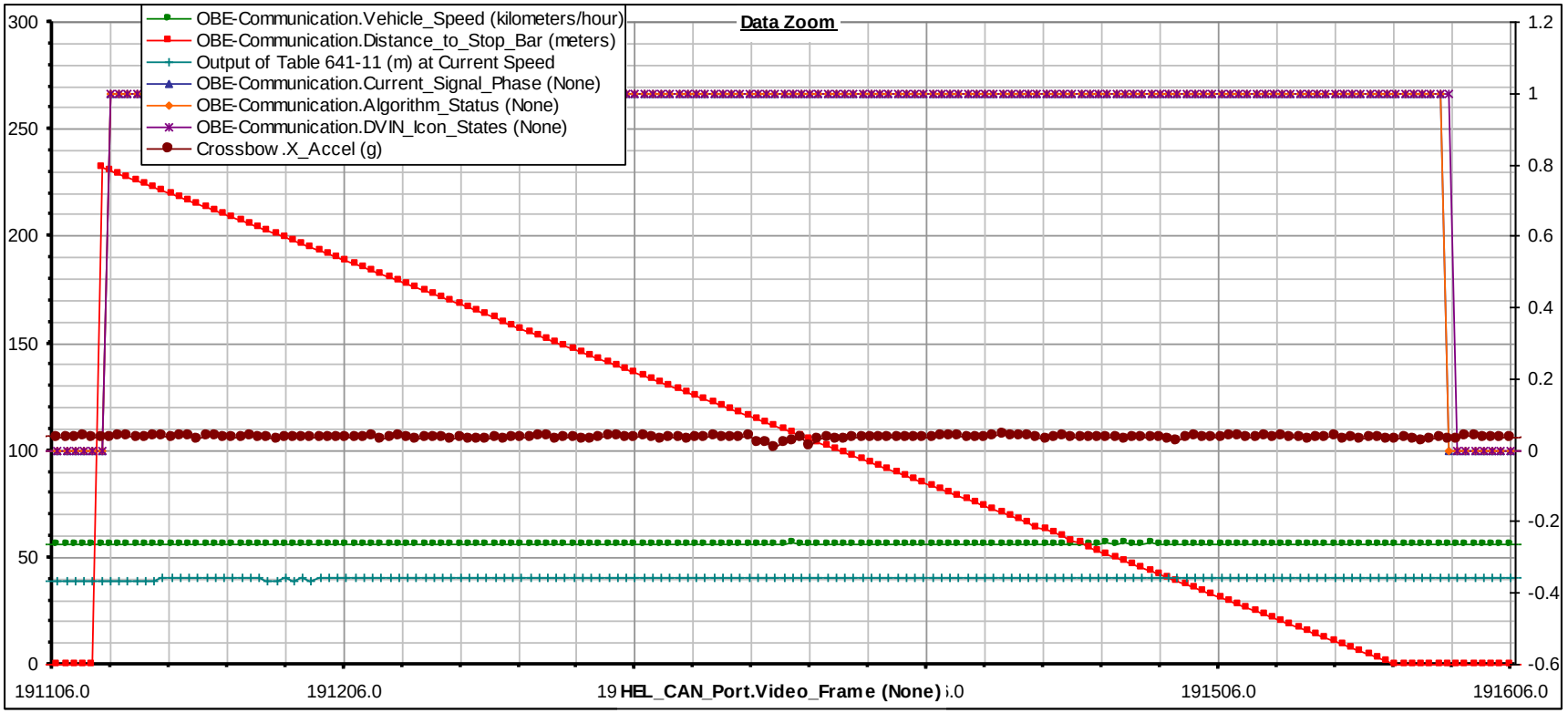

Figure 96: Multiple Intersections within 300m Radius: No Warning Case, Run 10

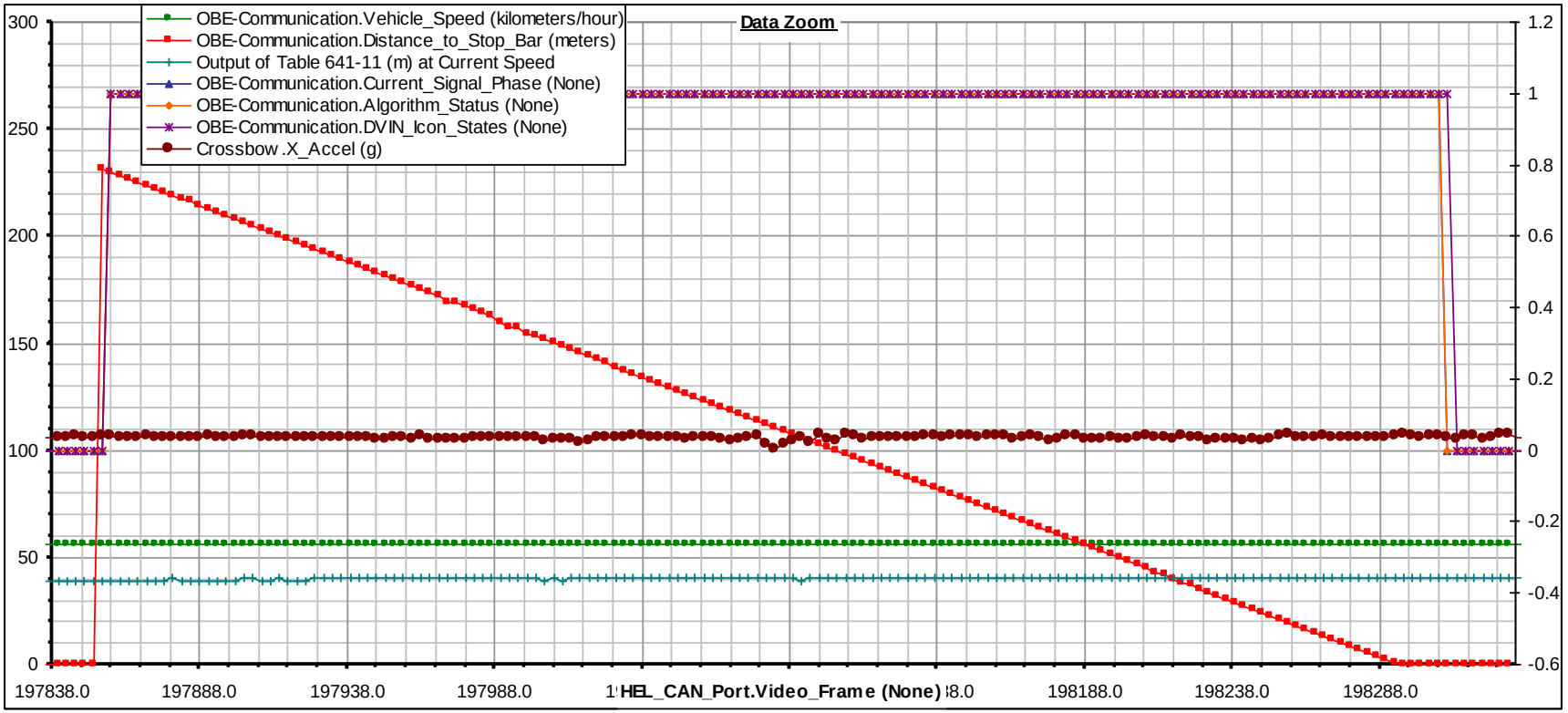

Figure 97: Multiple Intersections within 300m Radius: No Warning Case, Run 12

8.1.10 : Dynamic Signal Change to Yellow, Too Late to Warn

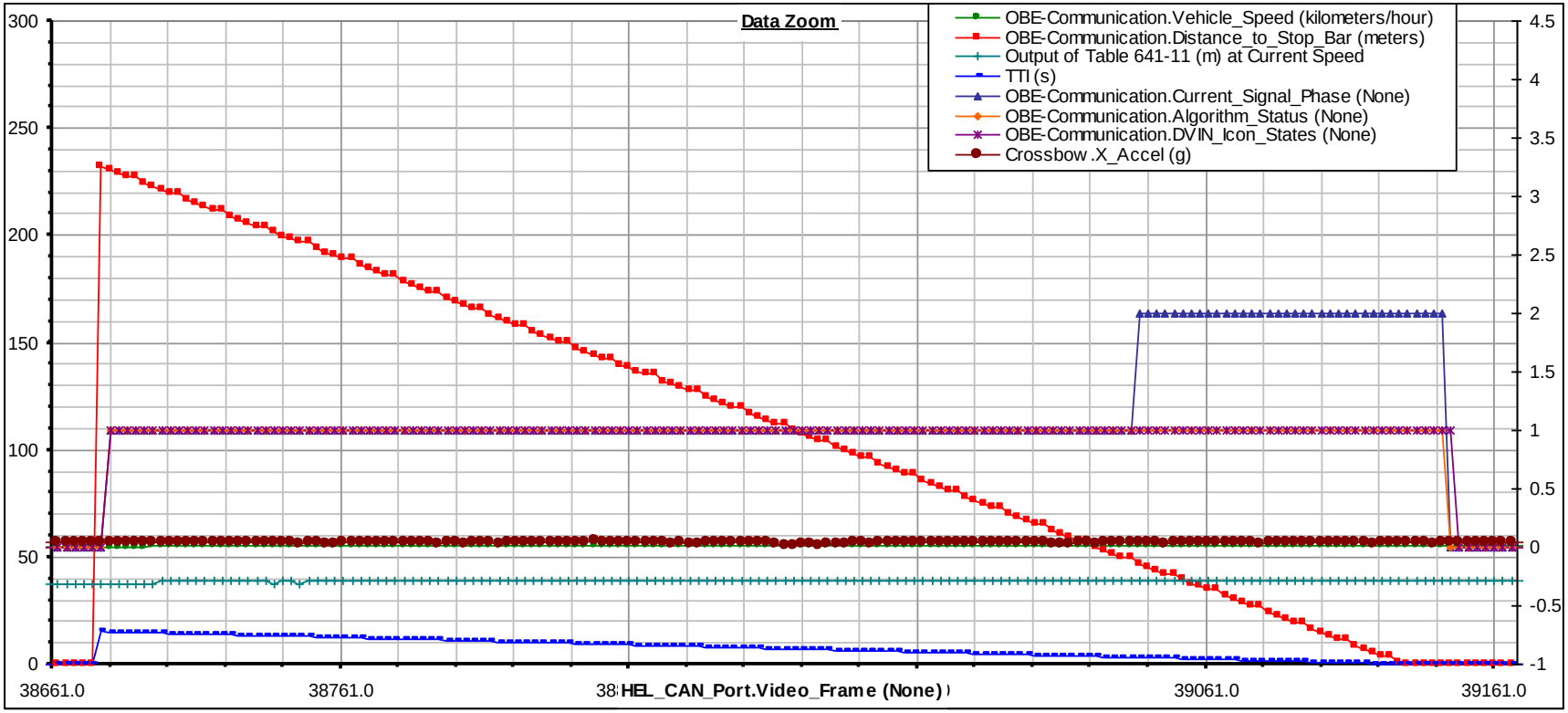

Figure 98: Dynamic Signal Change to Yellow, Too Late to Warn, Run 1

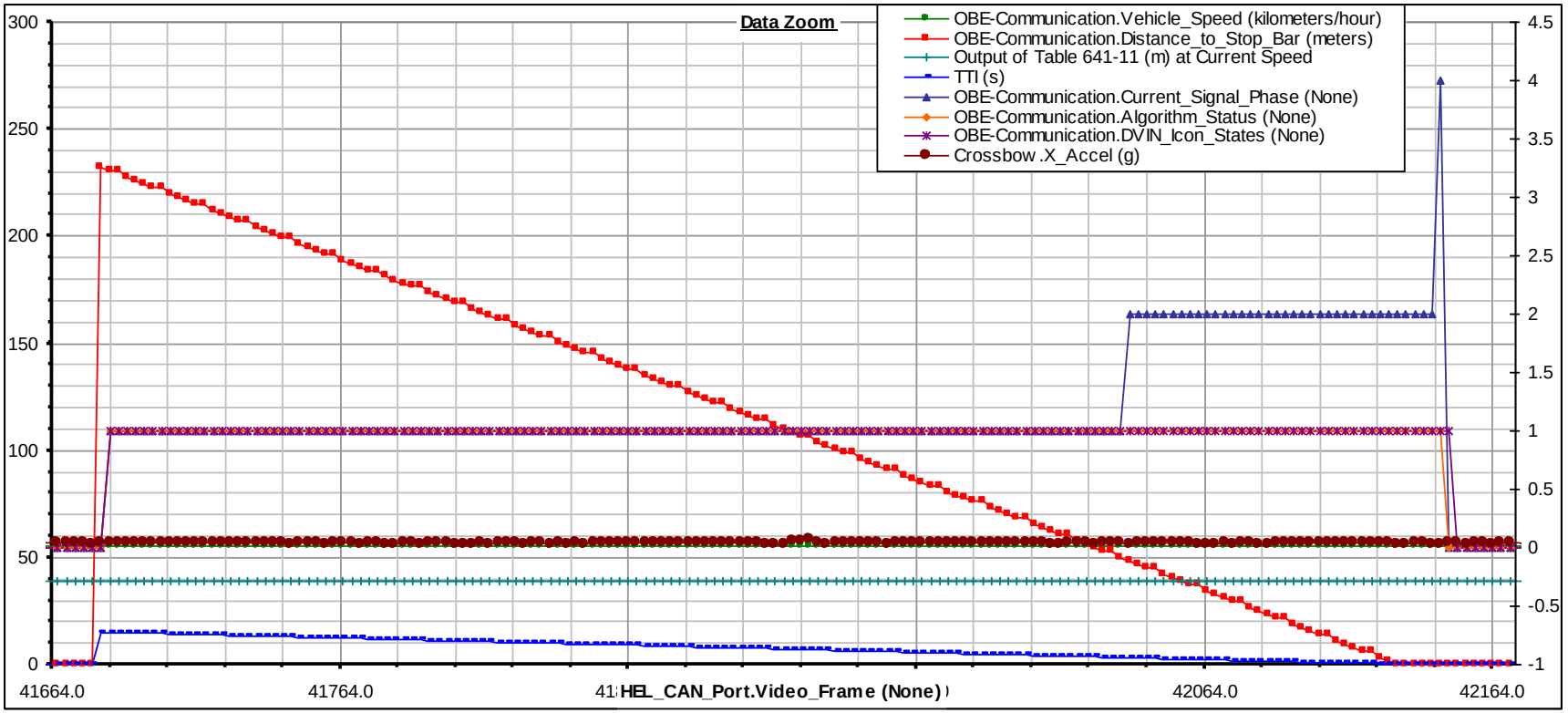

Figure 99: Dynamic Signal Change to Yellow, Too Late to Warn, Run 2

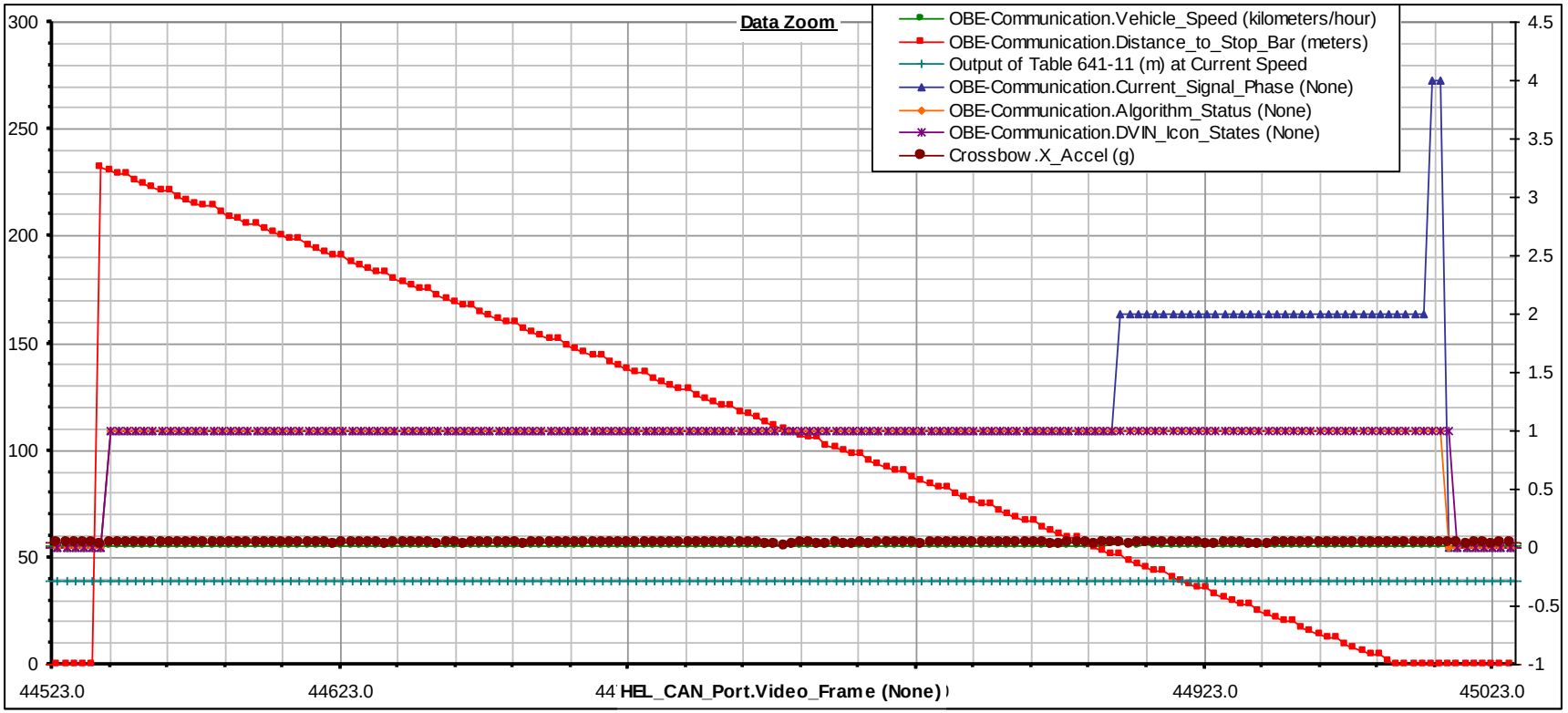

Figure 100: Dynamic Signal Change to Yellow, Too Late to Warn, Run 3

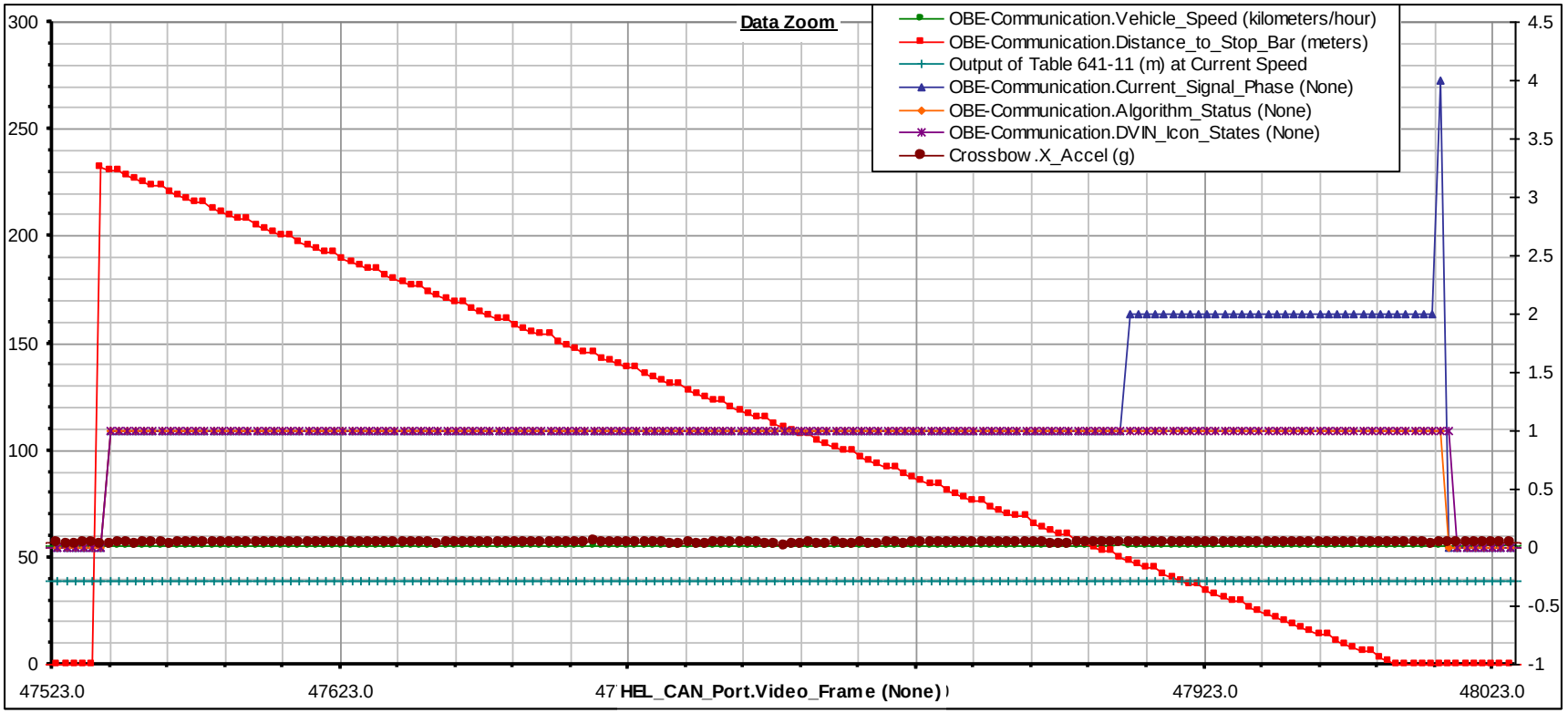

Figure 101: Dynamic Signal Change to Yellow, Too Late to Warn, Run 4

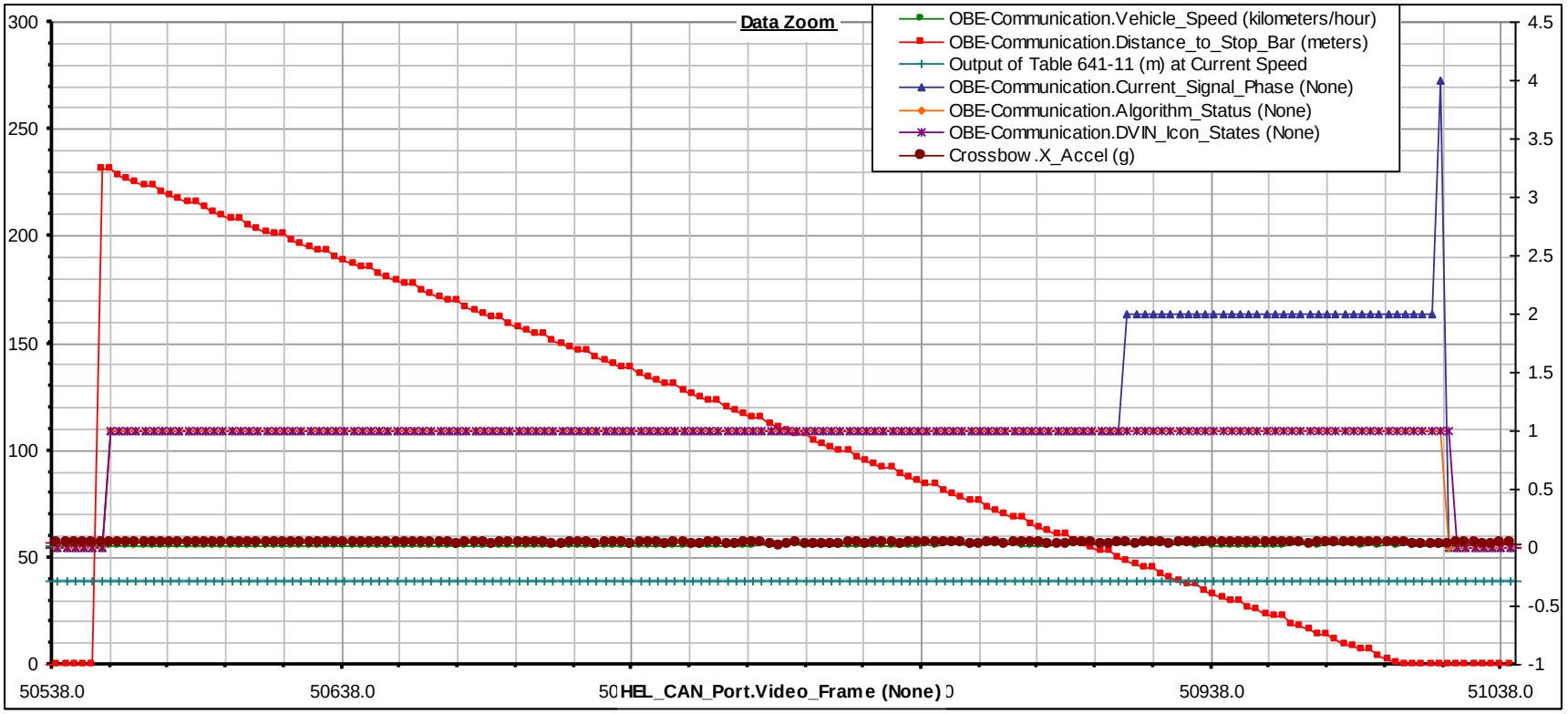

Figure 102: Dynamic Signal Change to Yellow, Too Late to Warn, Run 5

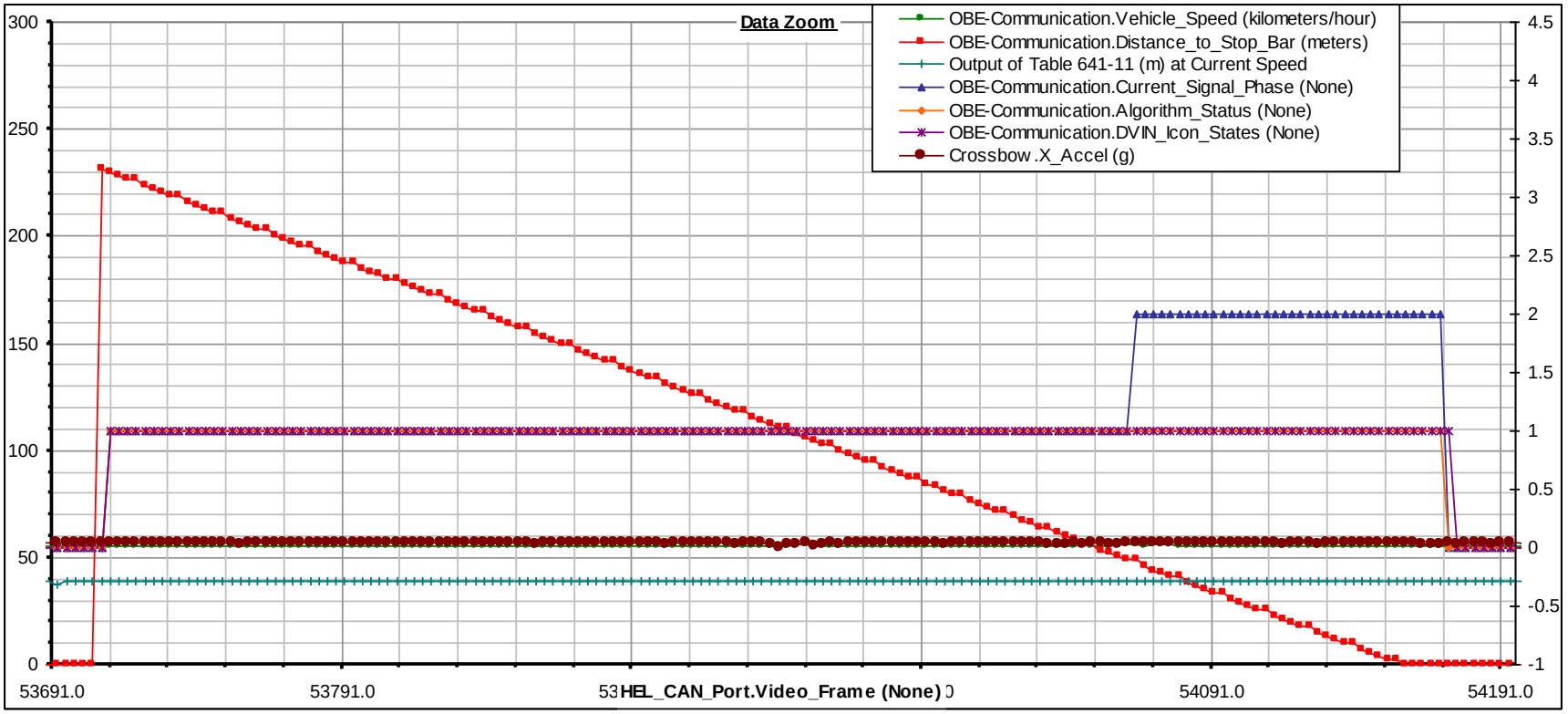

Figure 103: Dynamic Signal Change to Yellow, Too Late to Warn, Run 6

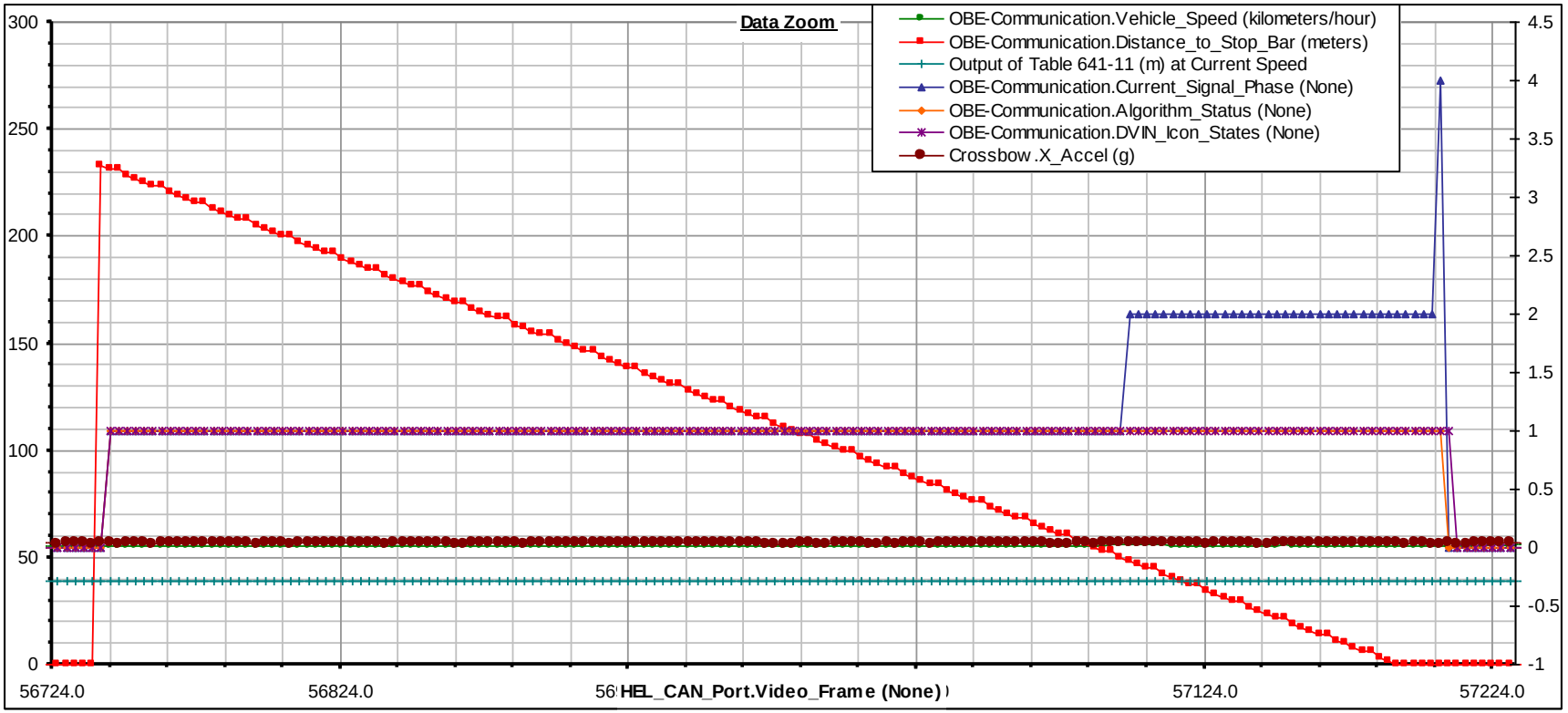

Figure 104: Dynamic Signal Change to Yellow, Too Late to Warn, Run 7

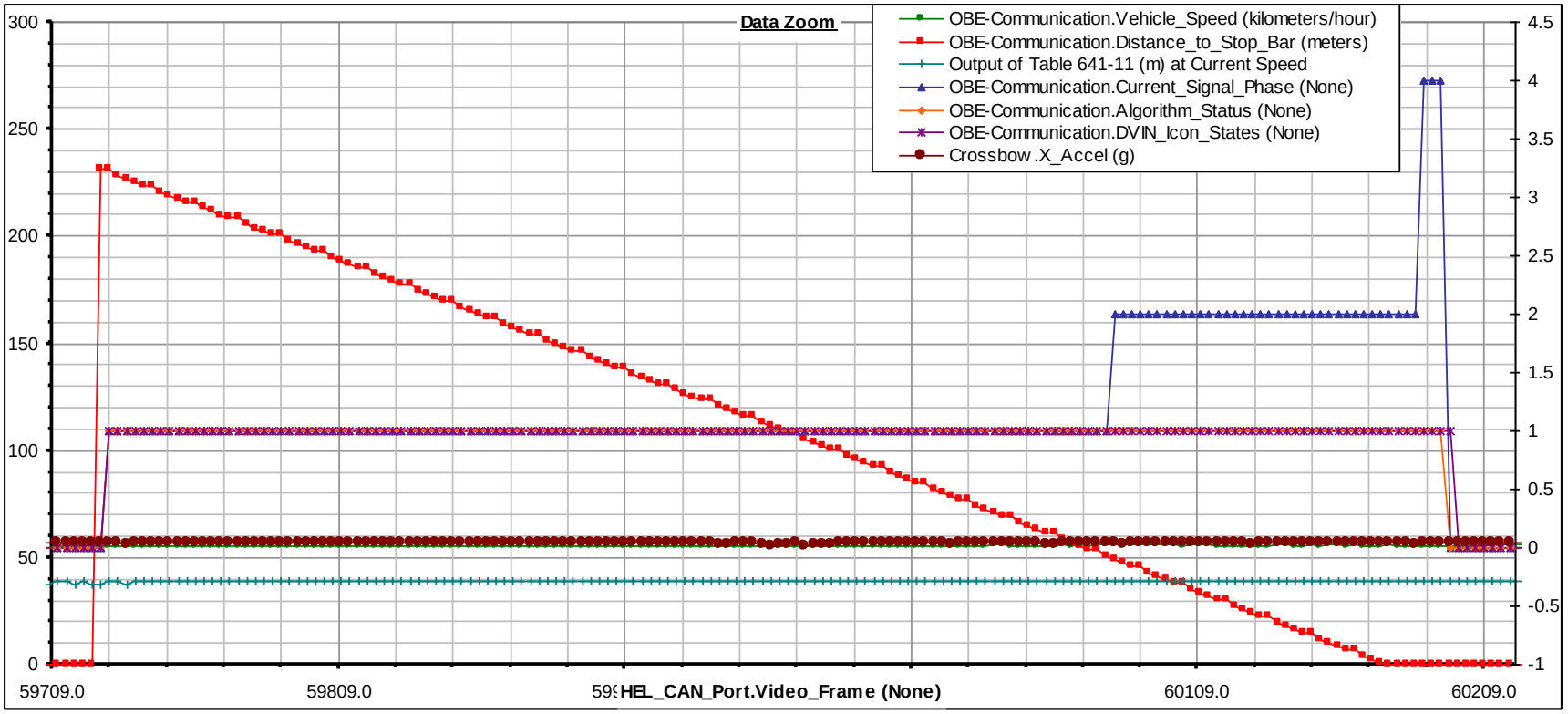

Figure 105: Dynamic Signal Change to Yellow, Too Late to Warn, Run 8

8.1.11 : Dynamic Signal to Red, In Time for Warning

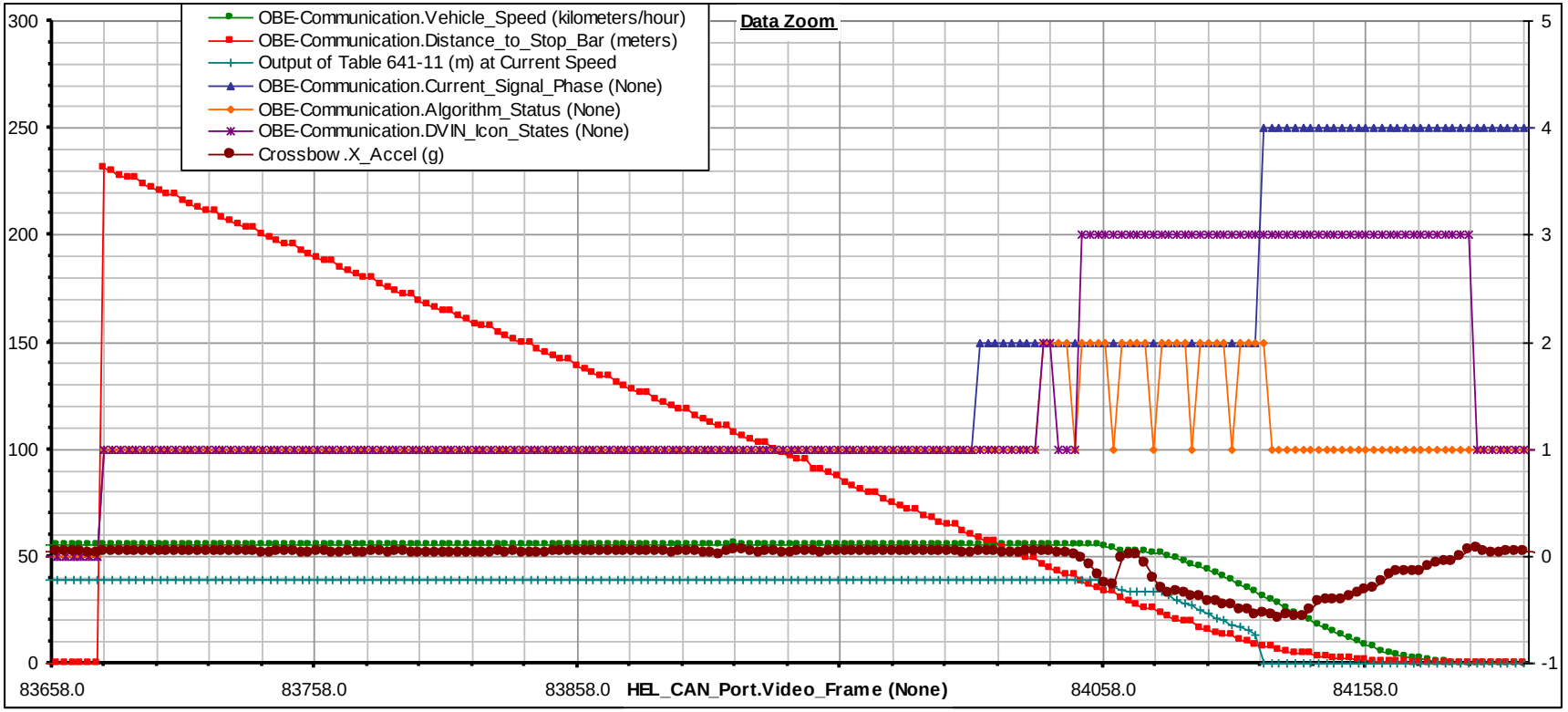

Figure 106: Dynamic Signal to Red, In Time for Warning, Run 1

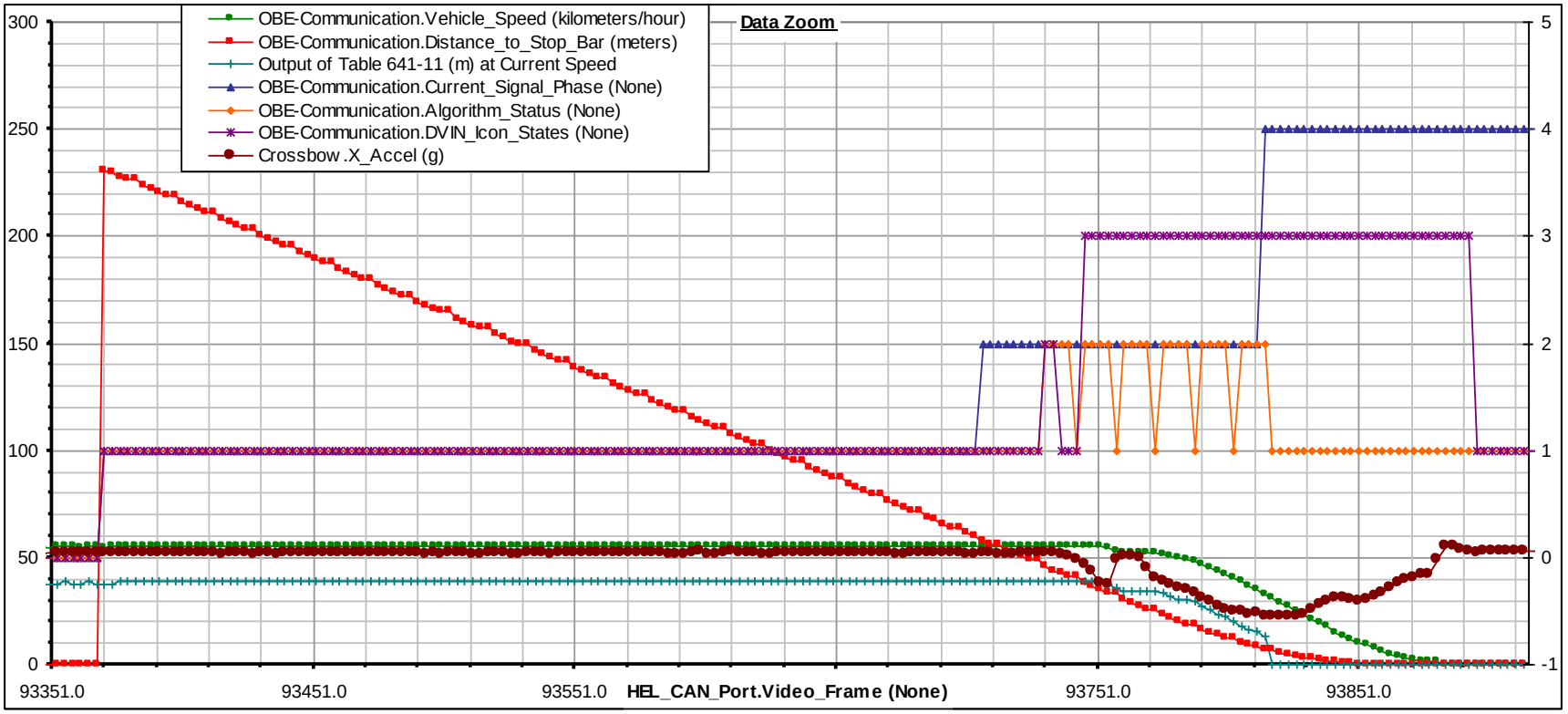

Figure 107: Dynamic Signal to Red, In Time for Warning, Run 2

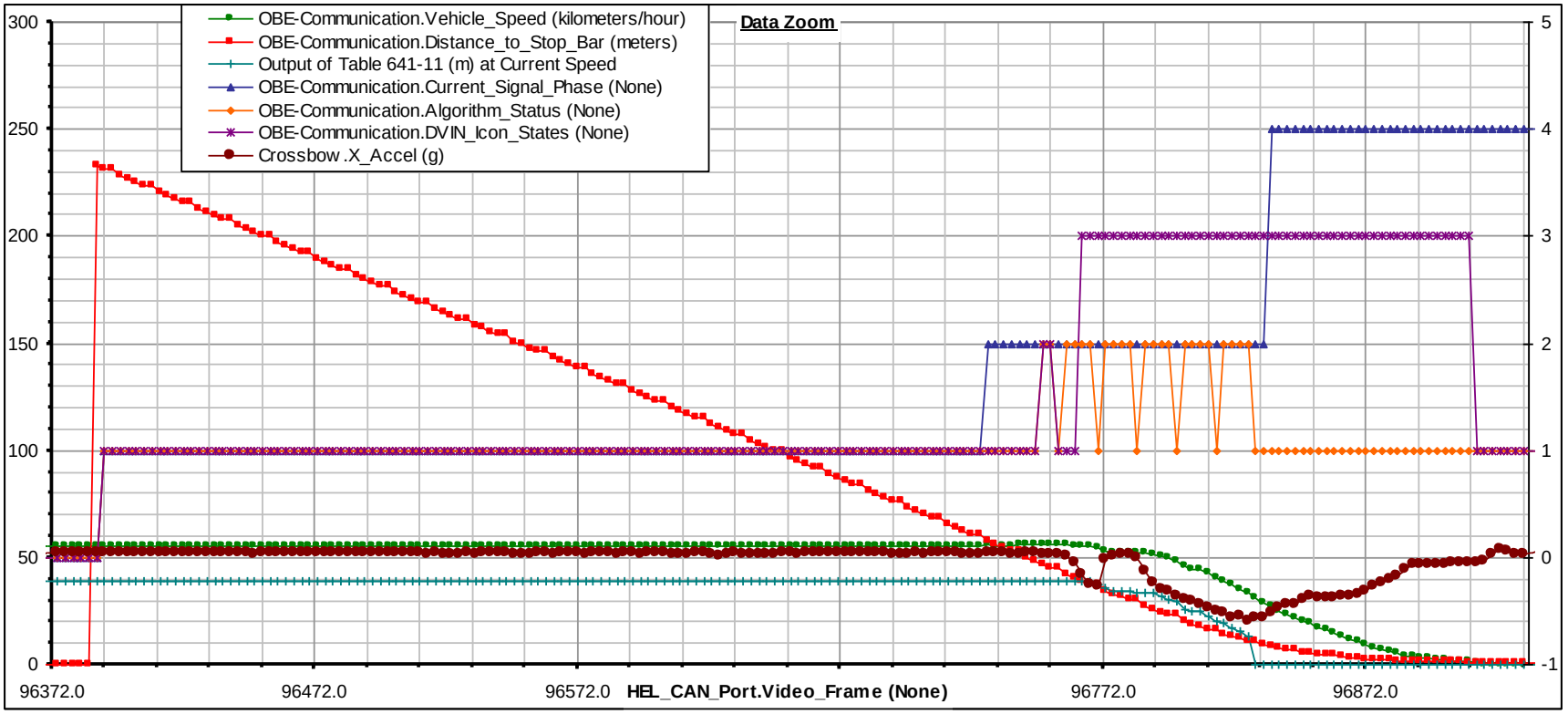

Figure 108: Dynamic Signal to Red, In Time for Warning, Run 3

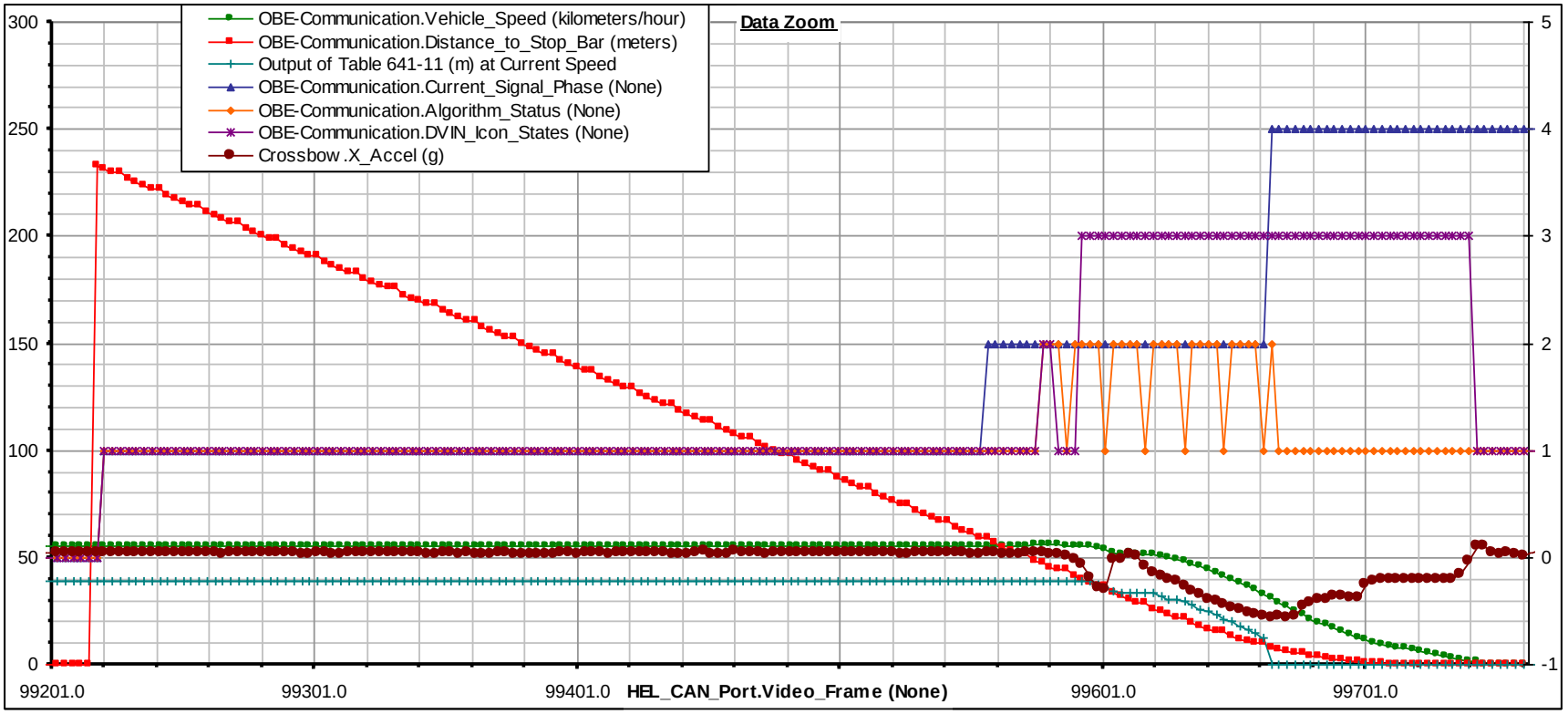

Figure 109: Dynamic Signal to Red, In Time for Warning, Run 4

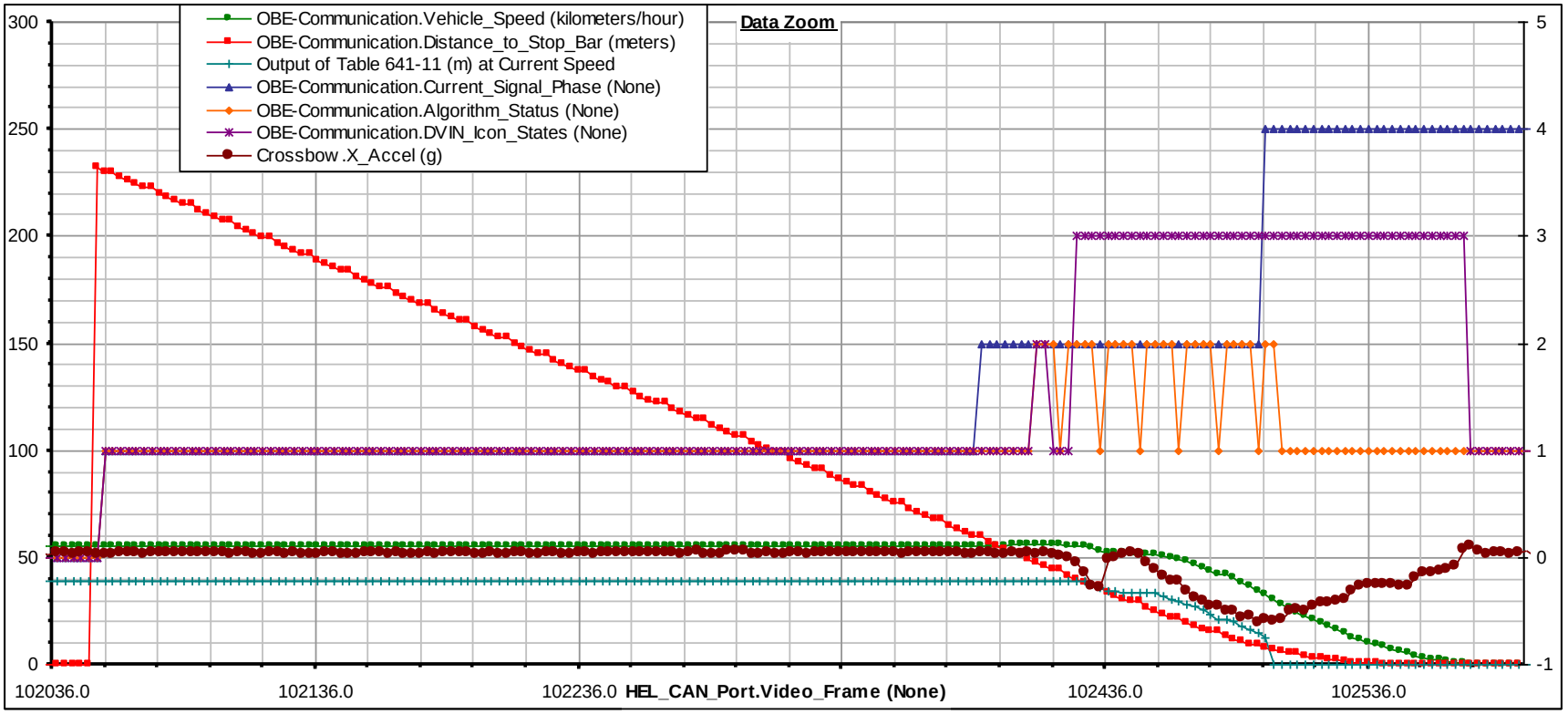

Figure 110: Dynamic Signal to Red, In Time for Warning, Run 5

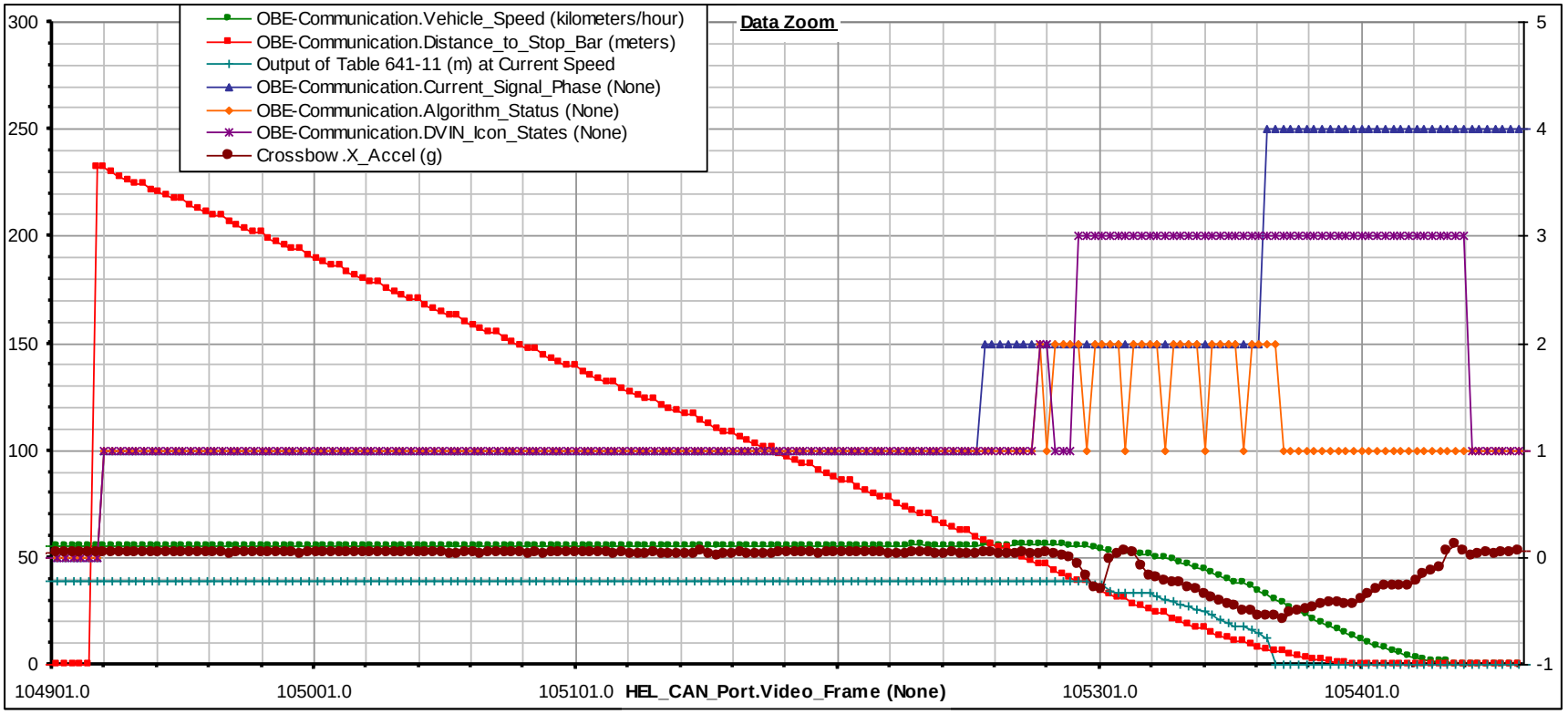

Figure 111: Dynamic Signal to Red, In Time for Warning, Run 6

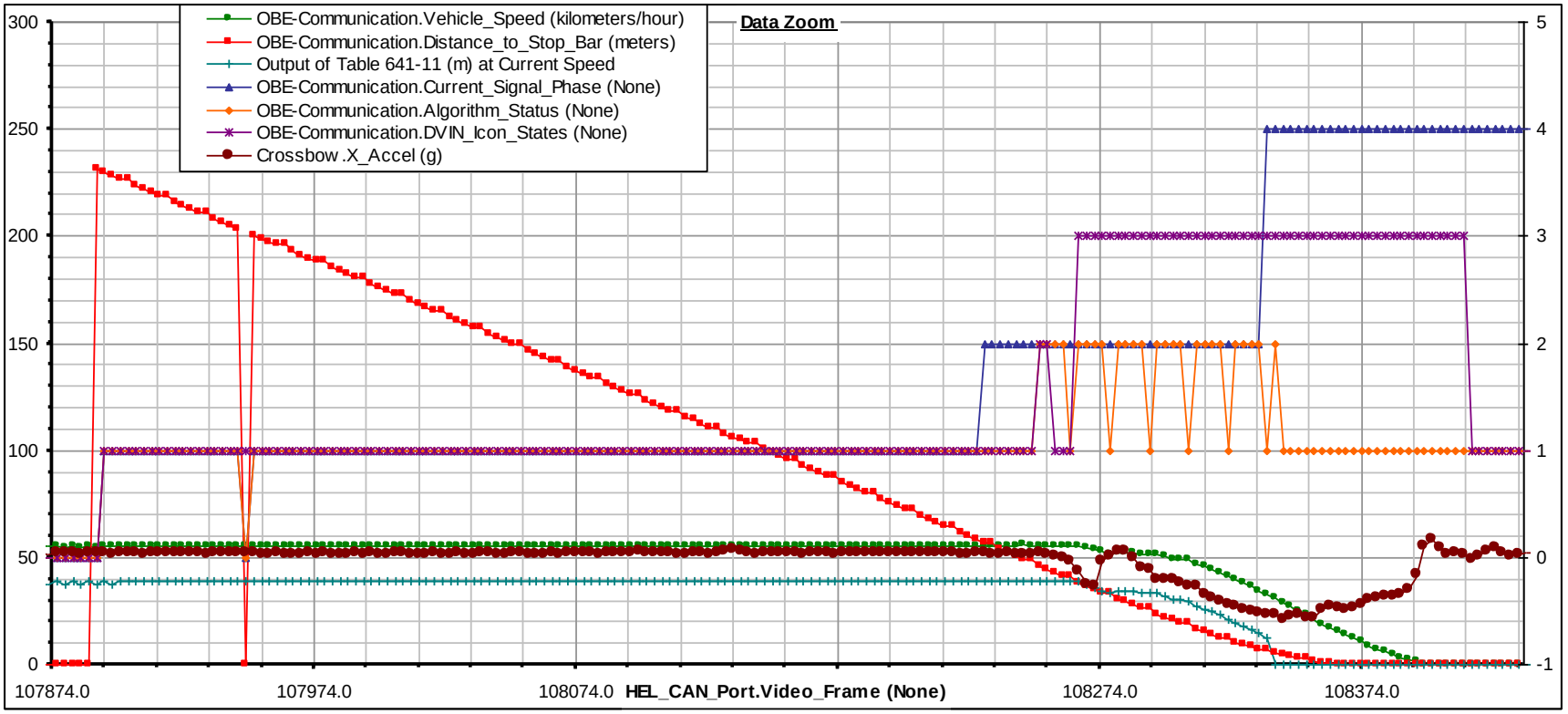

Figure 112: Dynamic Signal to Red, In Time for Warning, Run 7

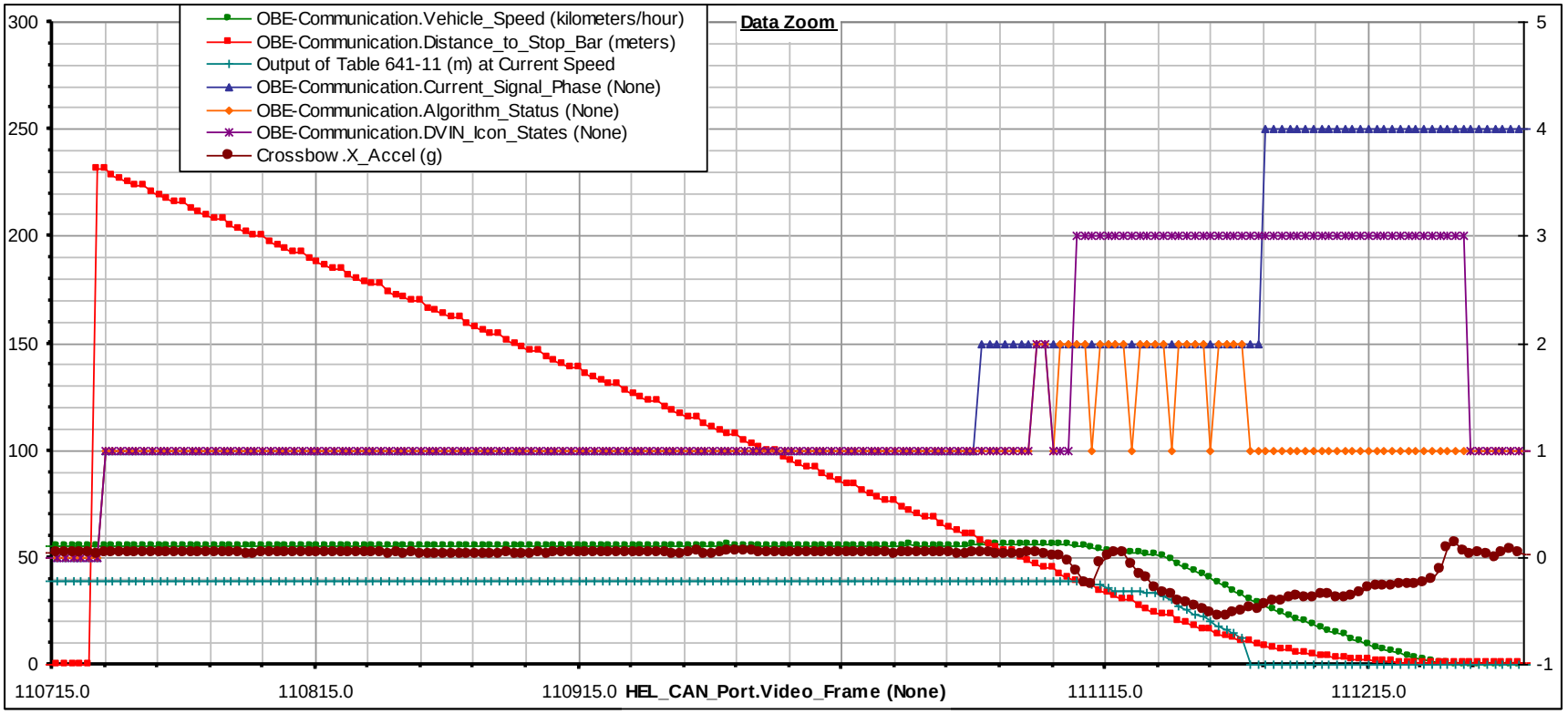

Figure 113: Dynamic Signal to Red, In Time for Warning, Run 8

8.1.12 : Dynamic Signal to Green, No Warning Case

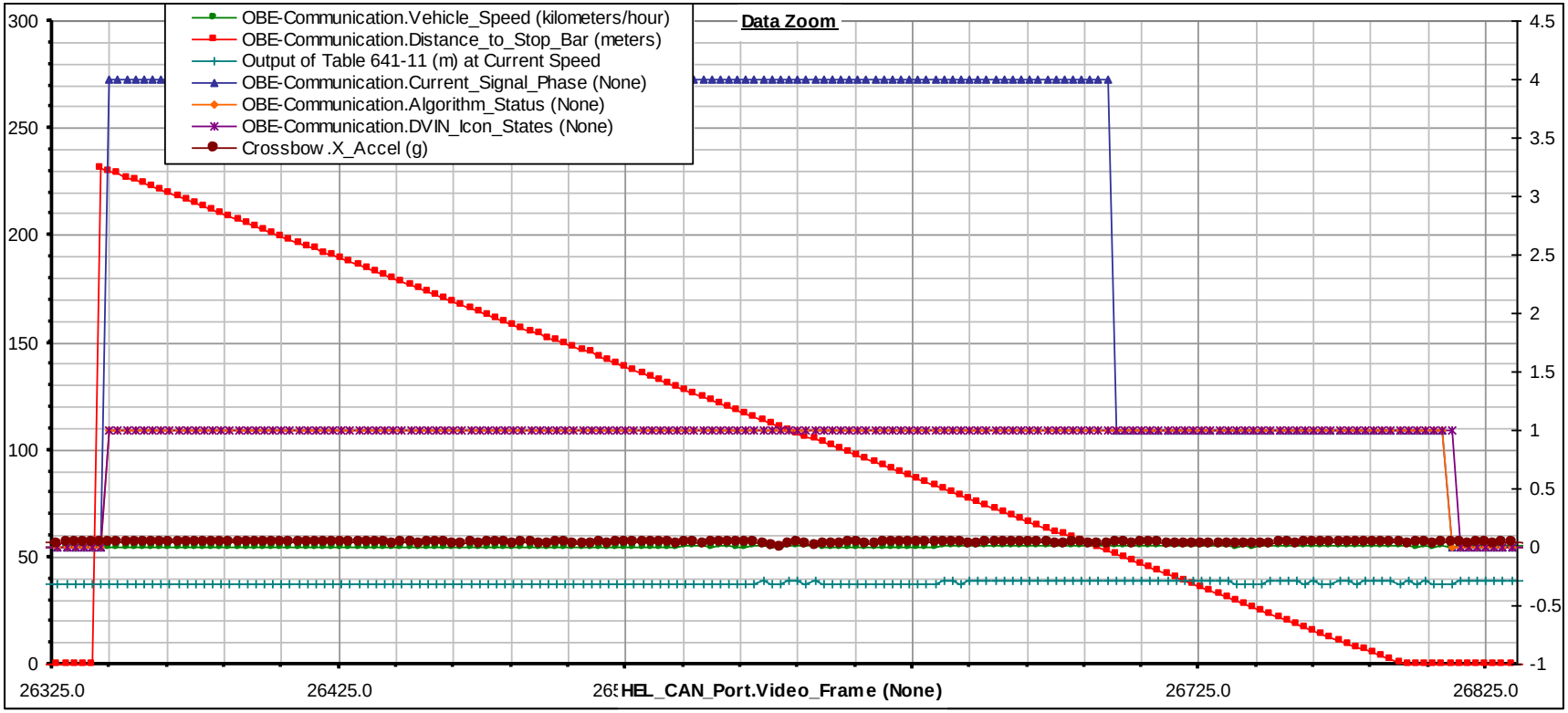

Figure 114: Dynamic Signal to Green, No Warning Case, Run 1

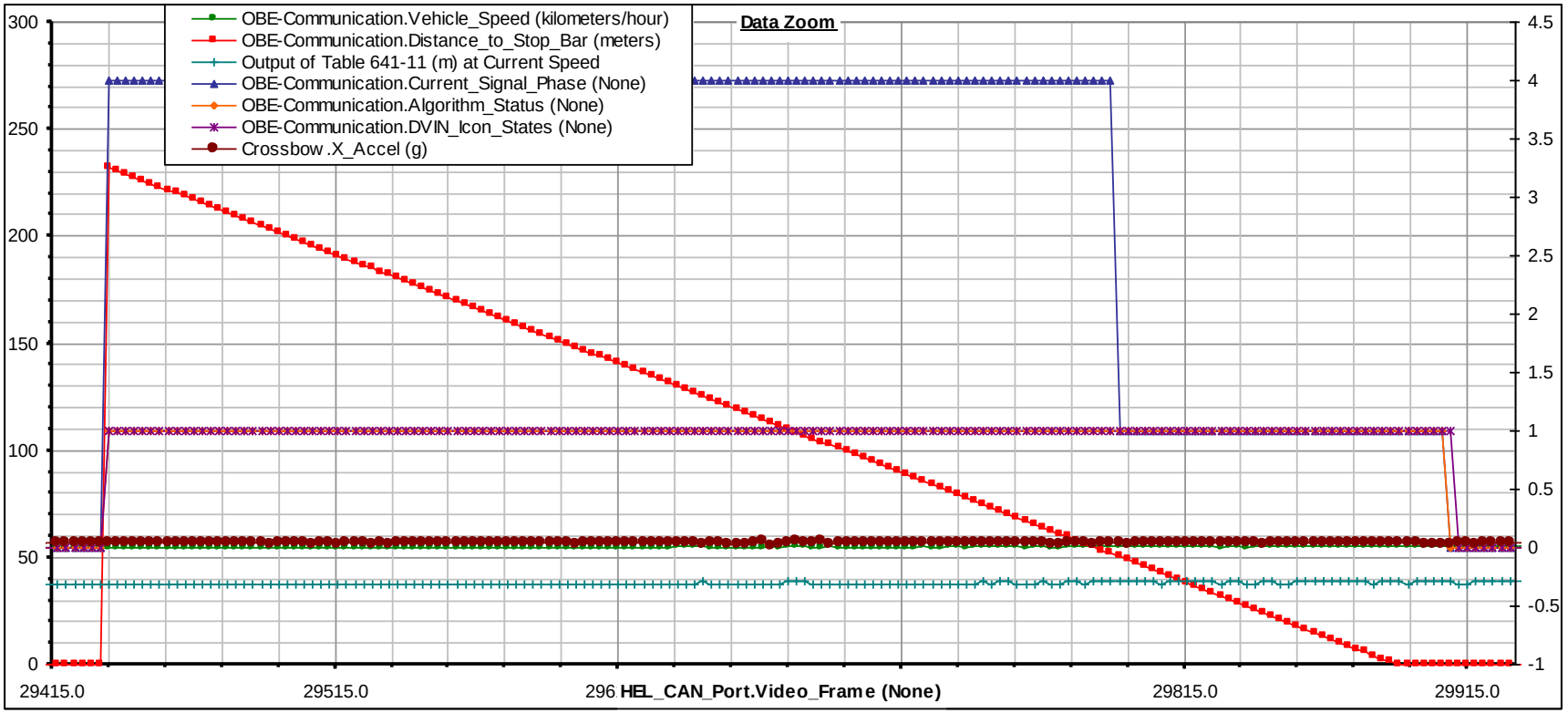

Figure 115: Dynamic Signal to Green, No Warning Case, Run 2

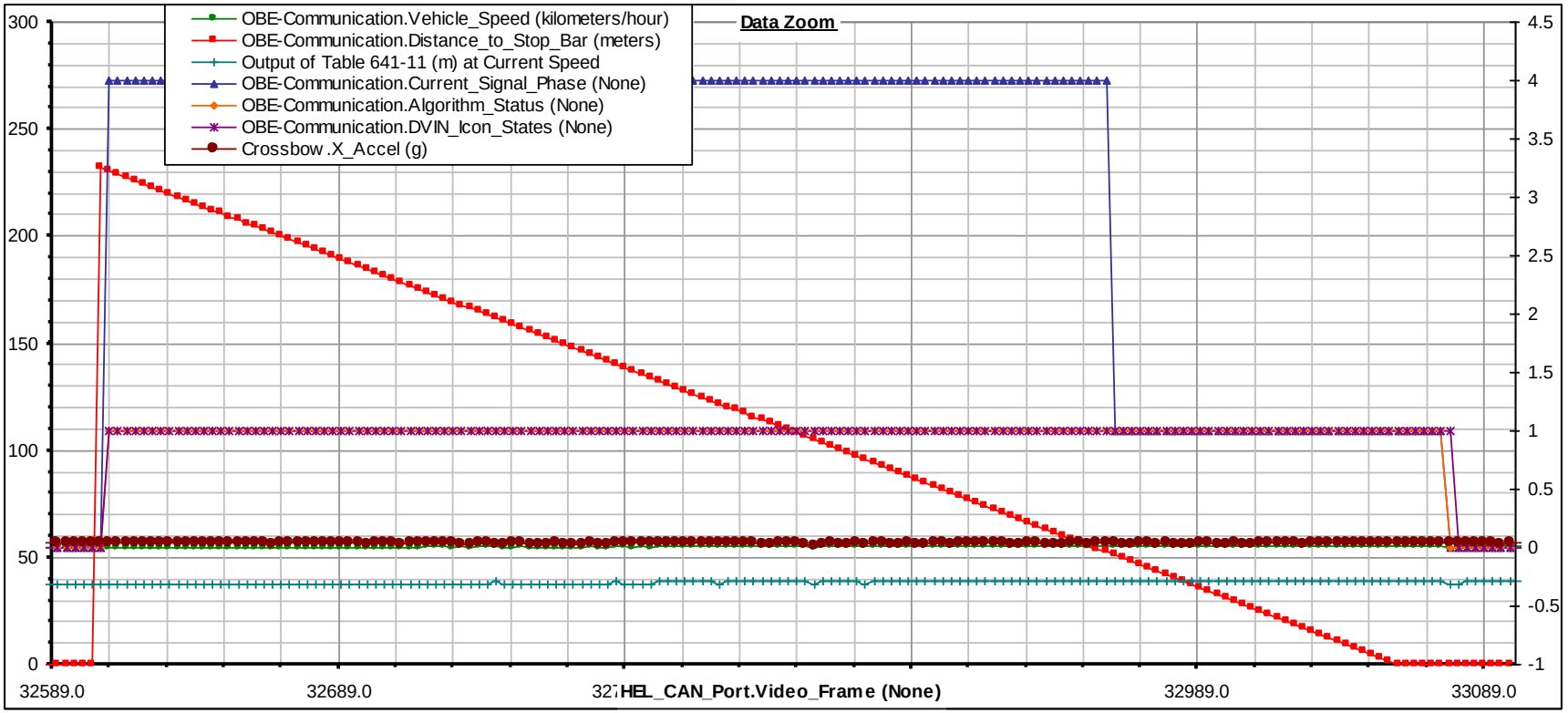

Figure 116: Dynamic Signal to Green, No Warning Case, Run 3

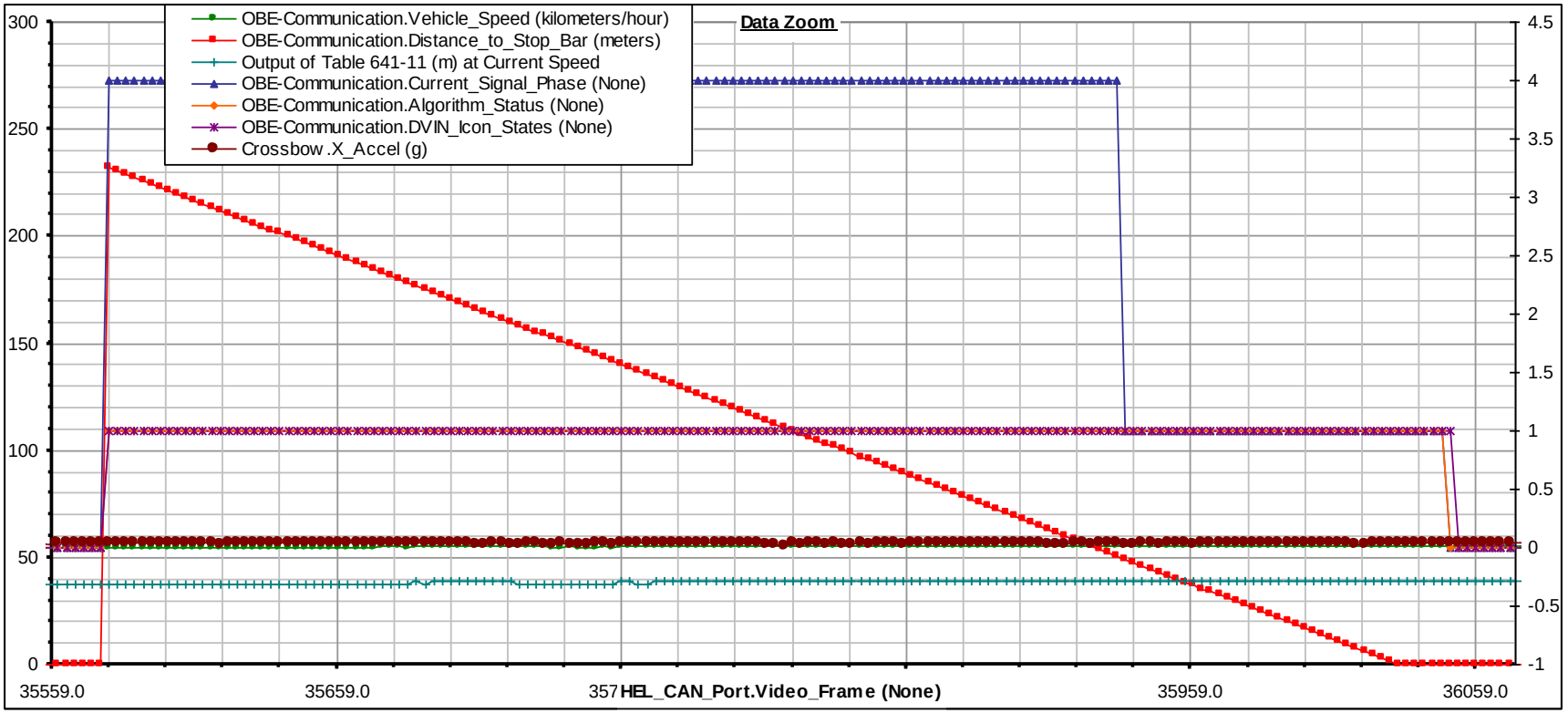

Figure 117: Dynamic Signal to Green, No Warning Case, Run 4

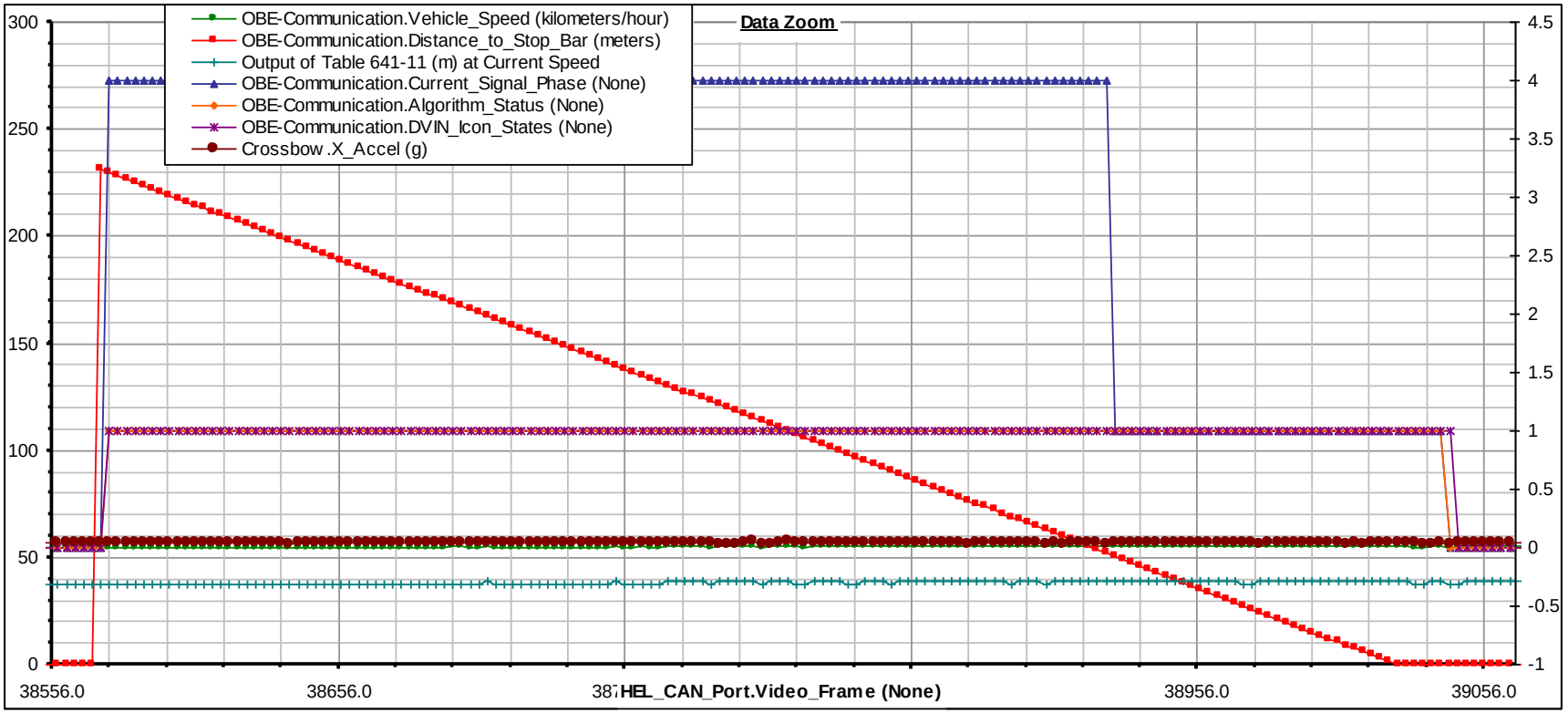

Figure 118: Dynamic Signal to Green, No Warning Case, Run 5

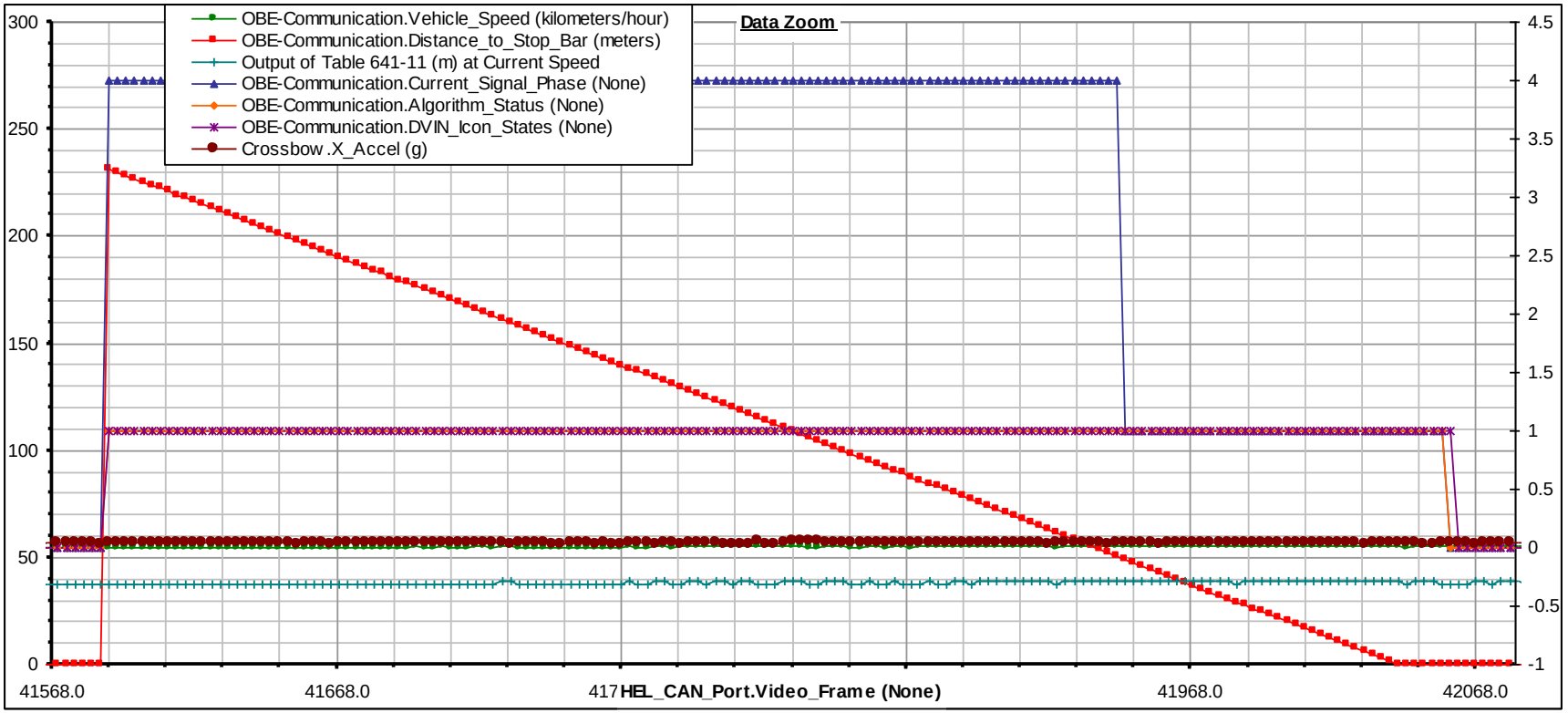

Figure 119: Dynamic Signal to Green, No Warning Case, Run 6

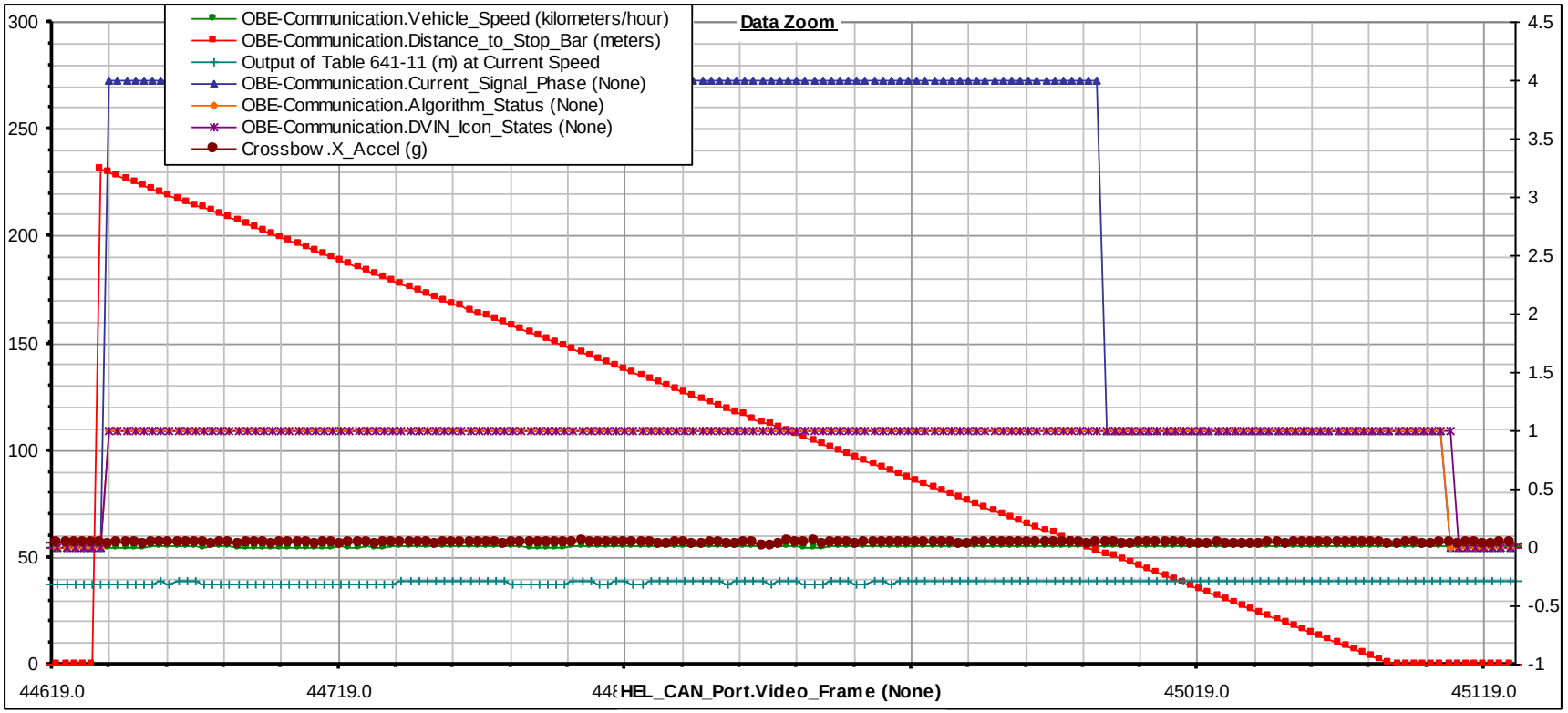

Figure 120: Dynamic Signal to Green, No Warning Case, Run 7

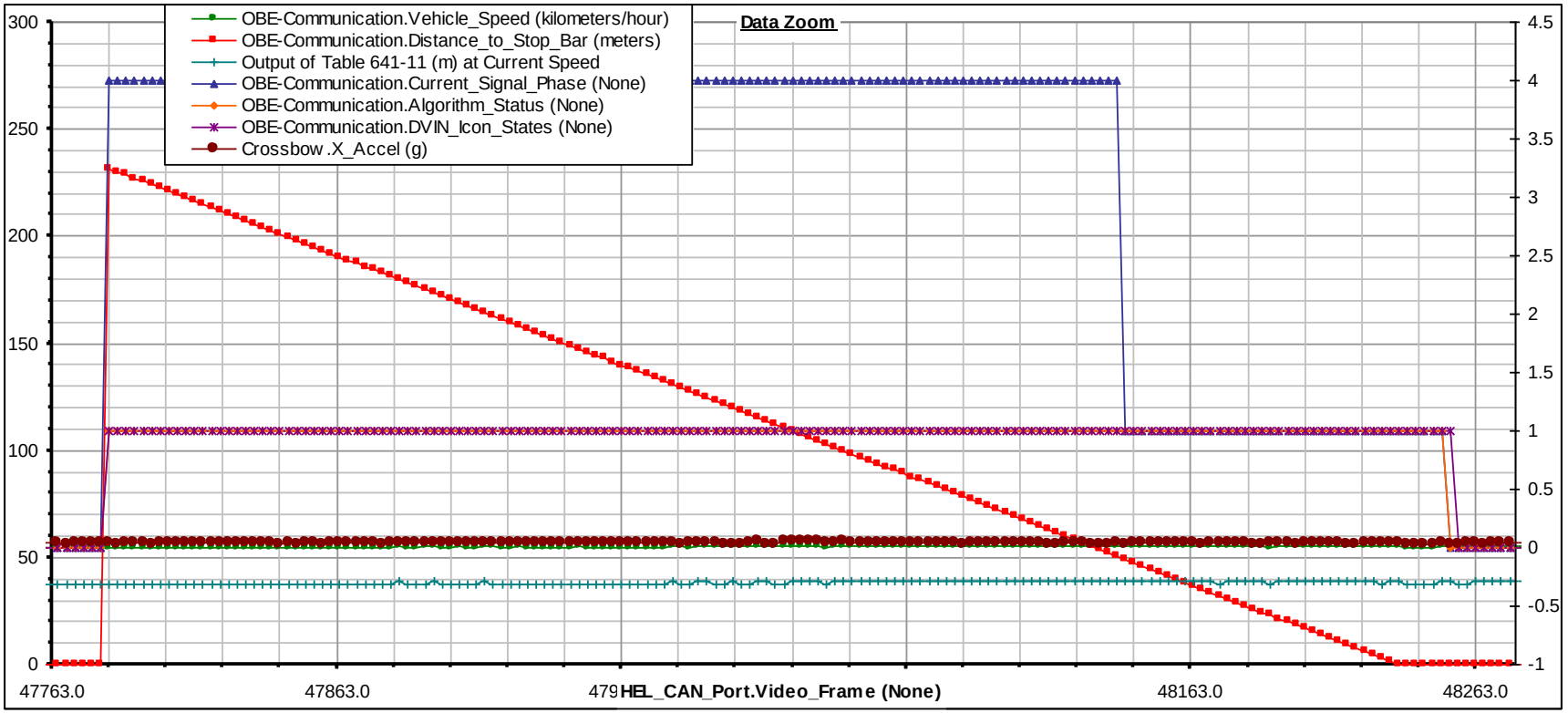

Figure 121: Dynamic Signal to Green, No Warning Case, Run 8

8.1.13 : SPaT Reflection and Reception – Engineering Test

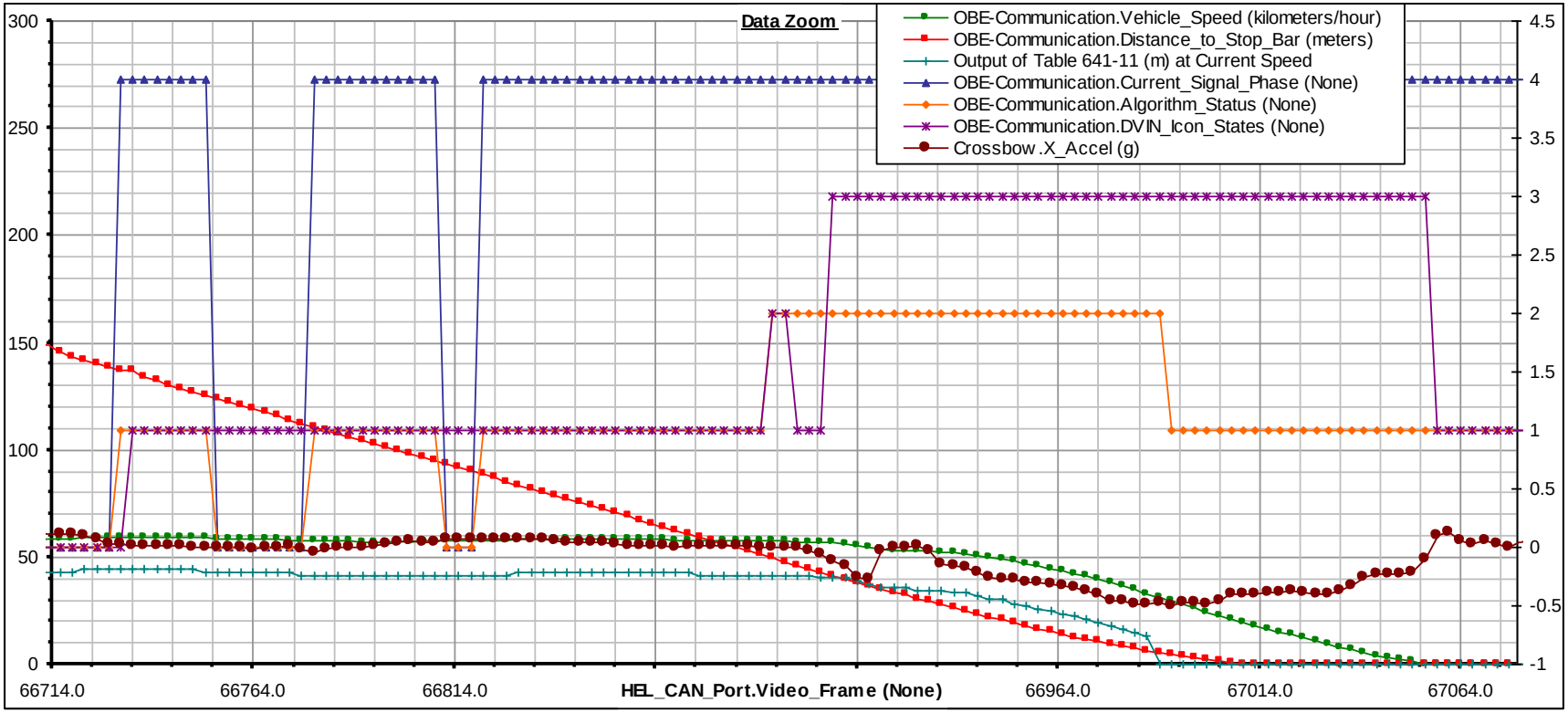

Figure 122: SPaT Reflection and Reception – Engineering Test, Run 1

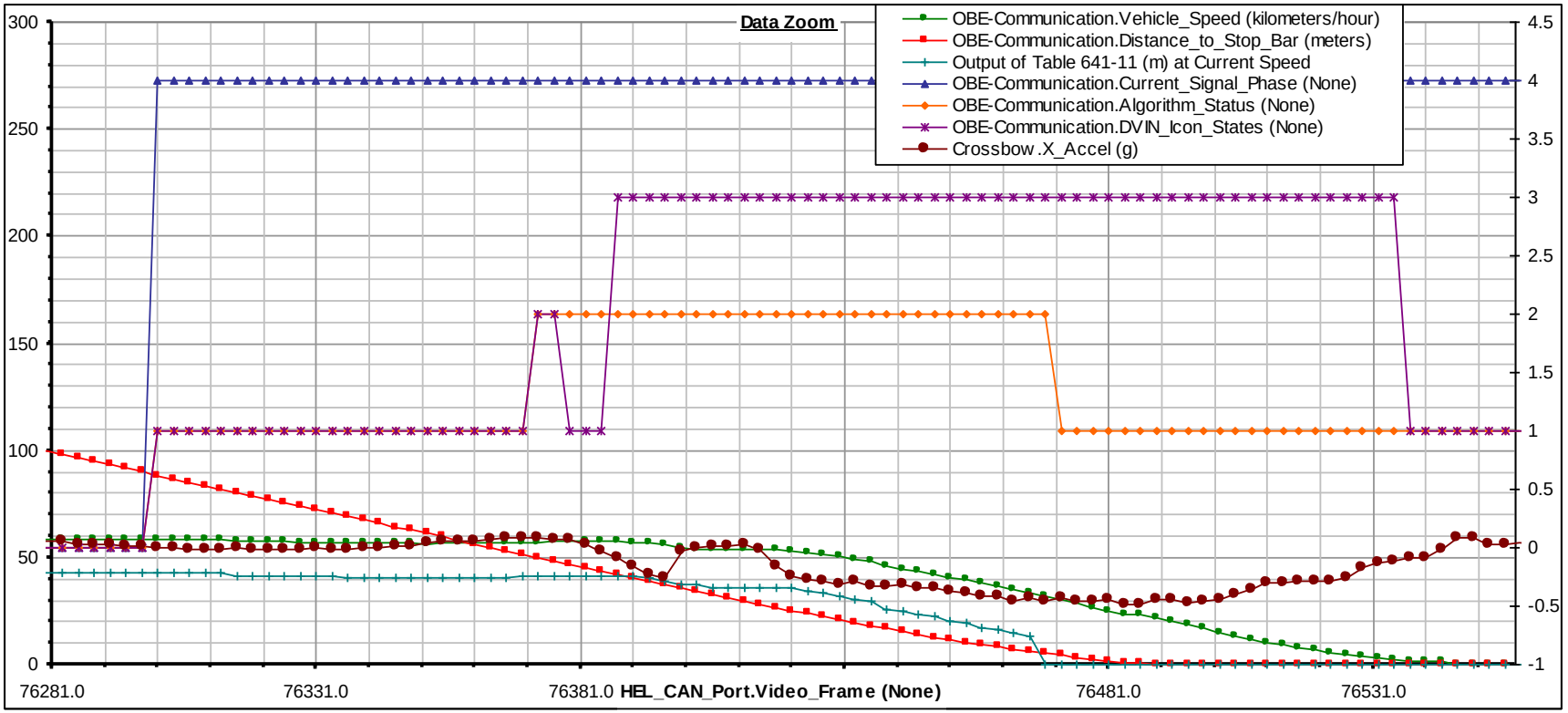

Figure 123: SPaT Reflection and Reception – Engineering Test, Run 2

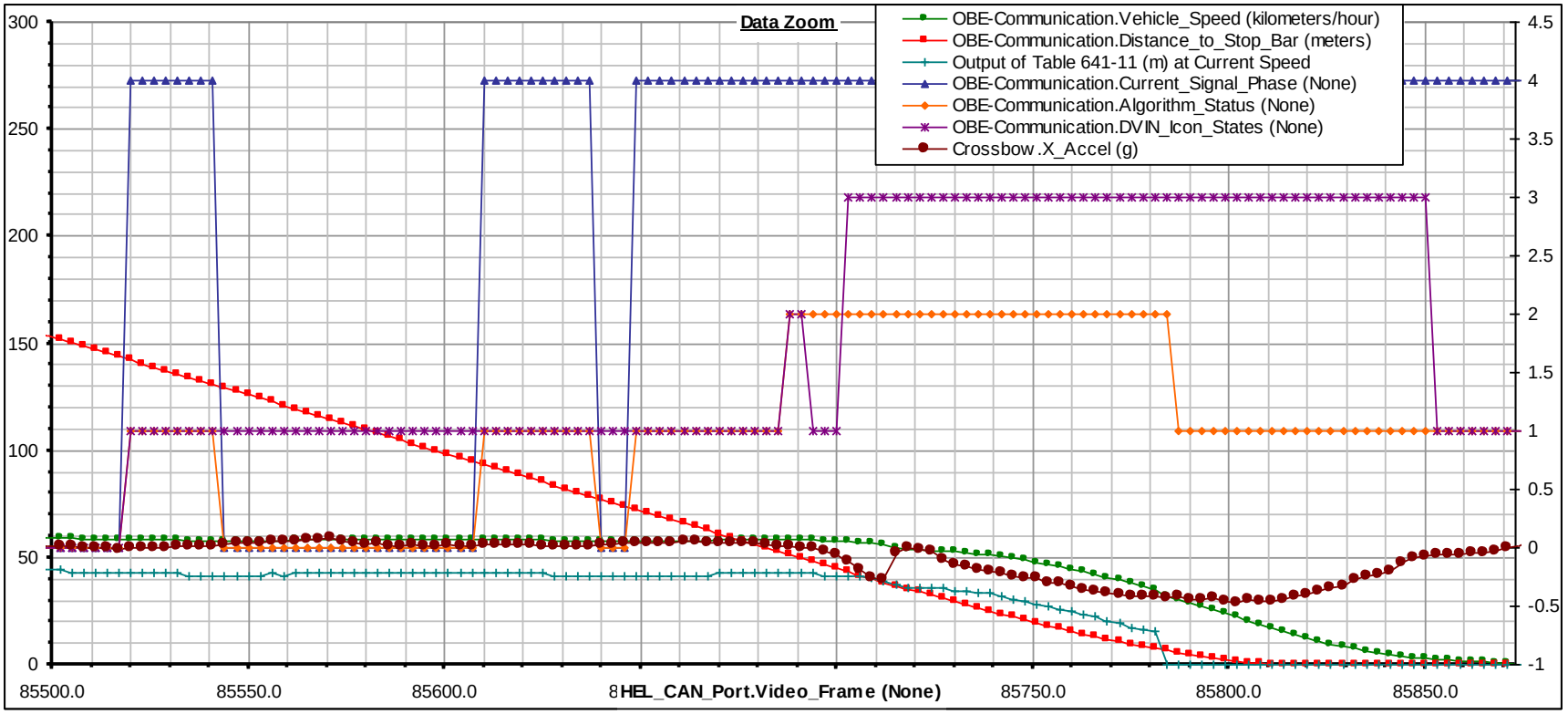

Figure 124: SPaT Reflection and Reception – Engineering Test, Run 3

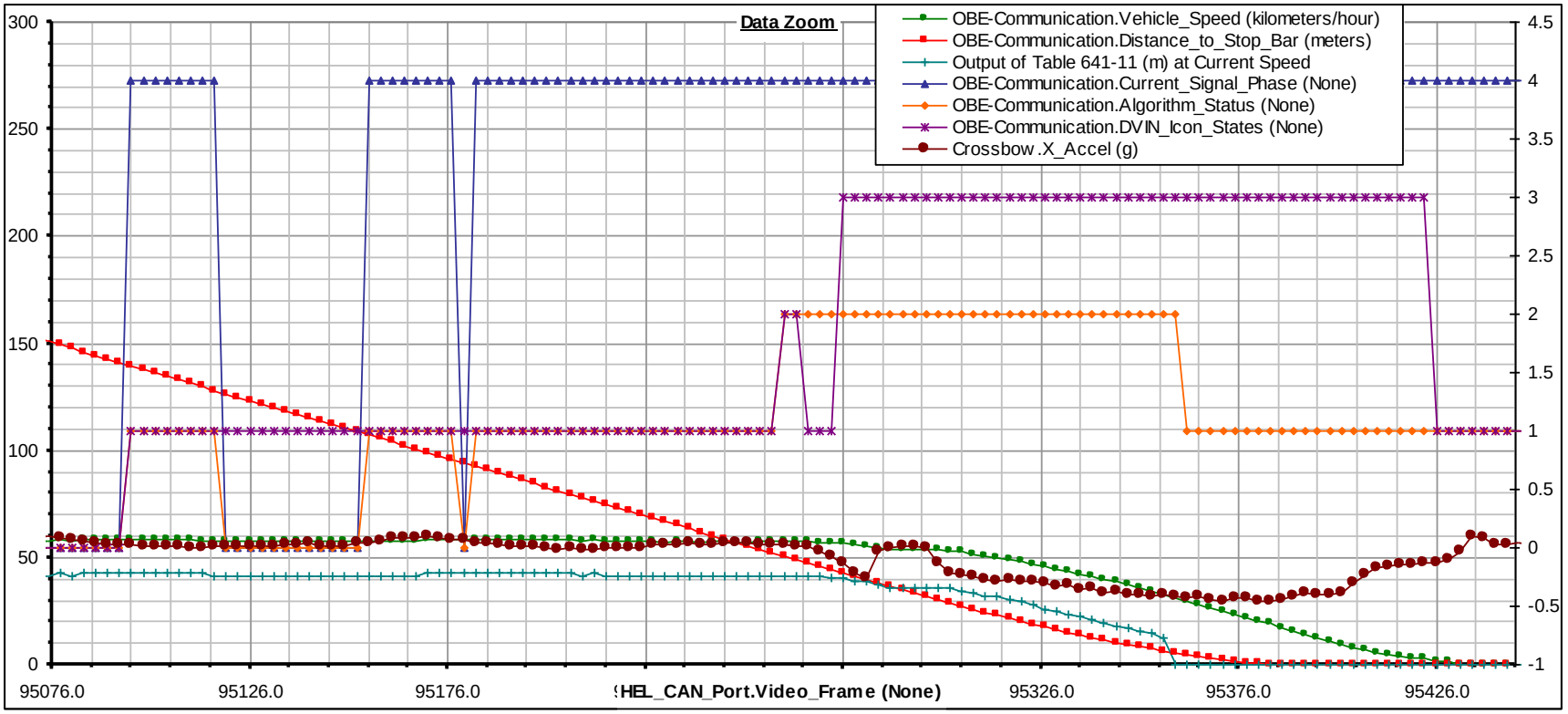

Figure 125: SPaT Reflection and Reception – Engineering Test, Run 4

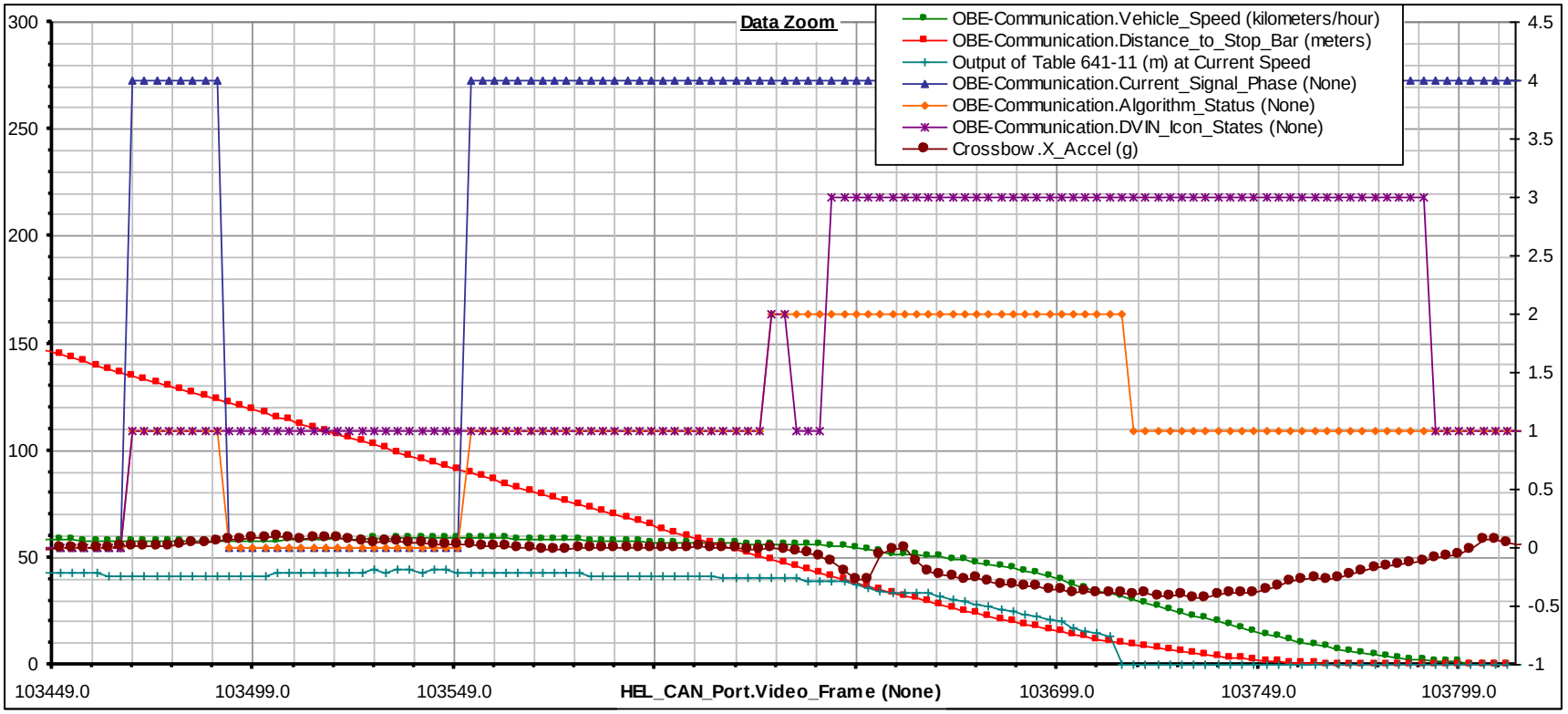

Figure 126: SPaT Reflection and Reception – Engineering Test, Run 5

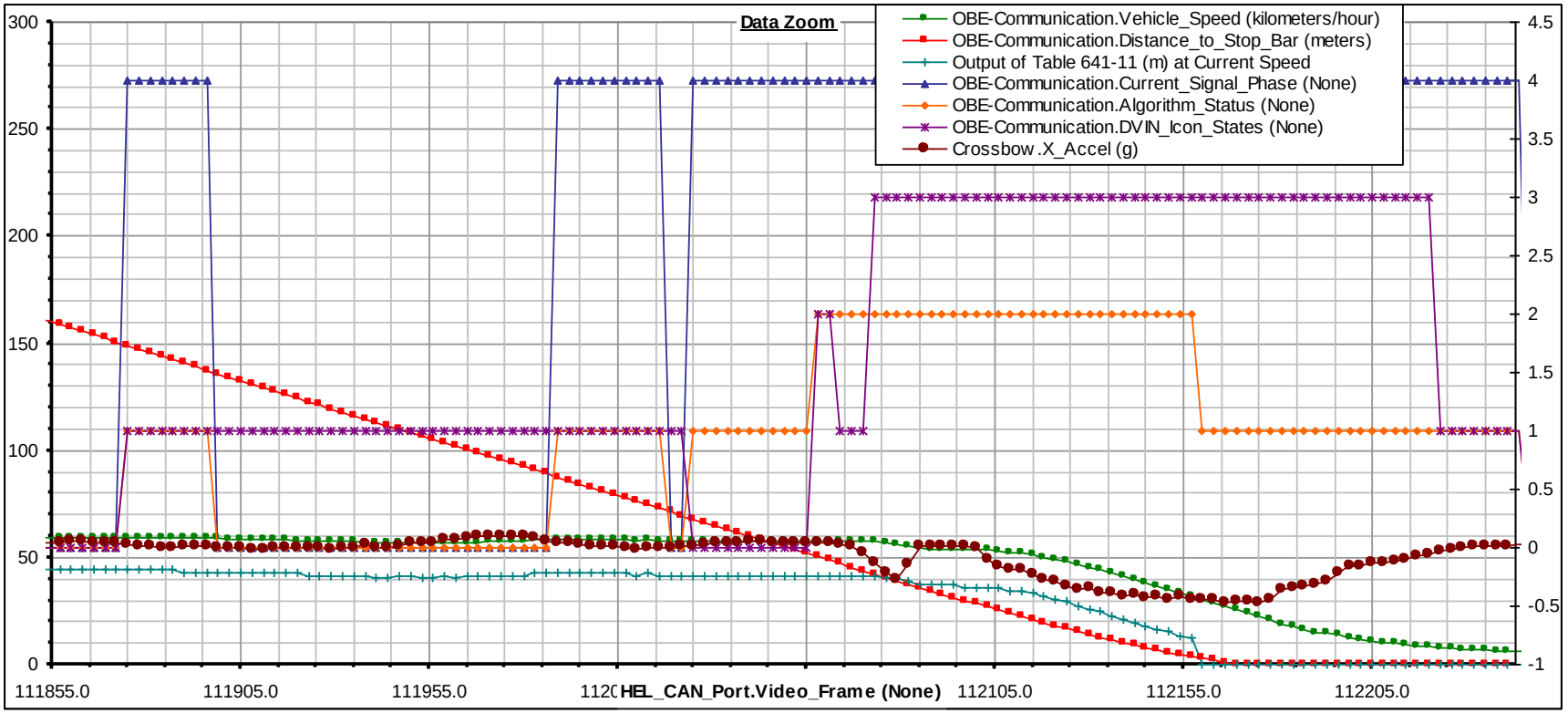

Figure 127: SPaT Reflection and Reception – Engineering Test, Run 6

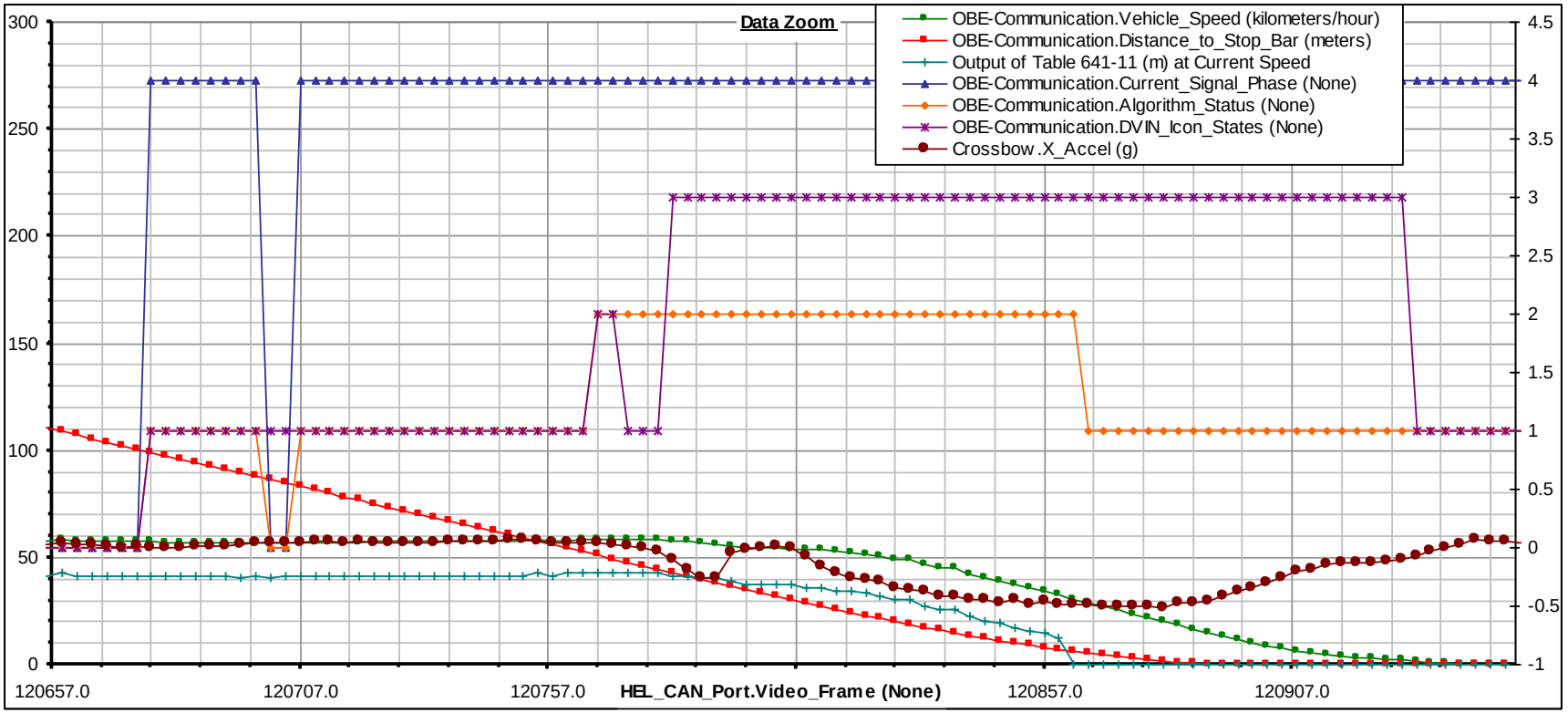

Figure 128: SPaT Reflection and Reception – Engineering Test, Run 7

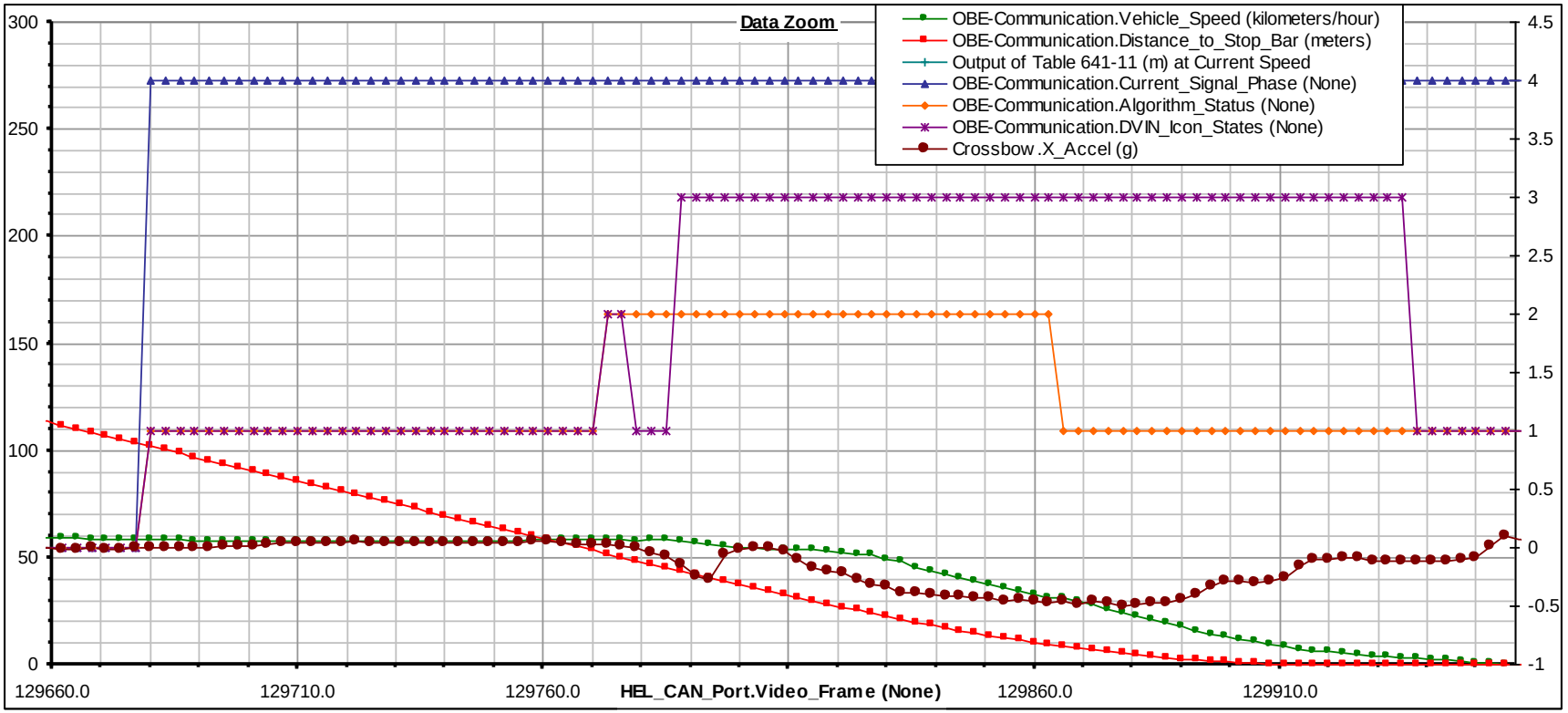

Figure 129: SPaT Reflection and Reception – Engineering Test, Run 8

8.1.14 : Stop-Sign Various Approach Speeds Test, 55 mi/h

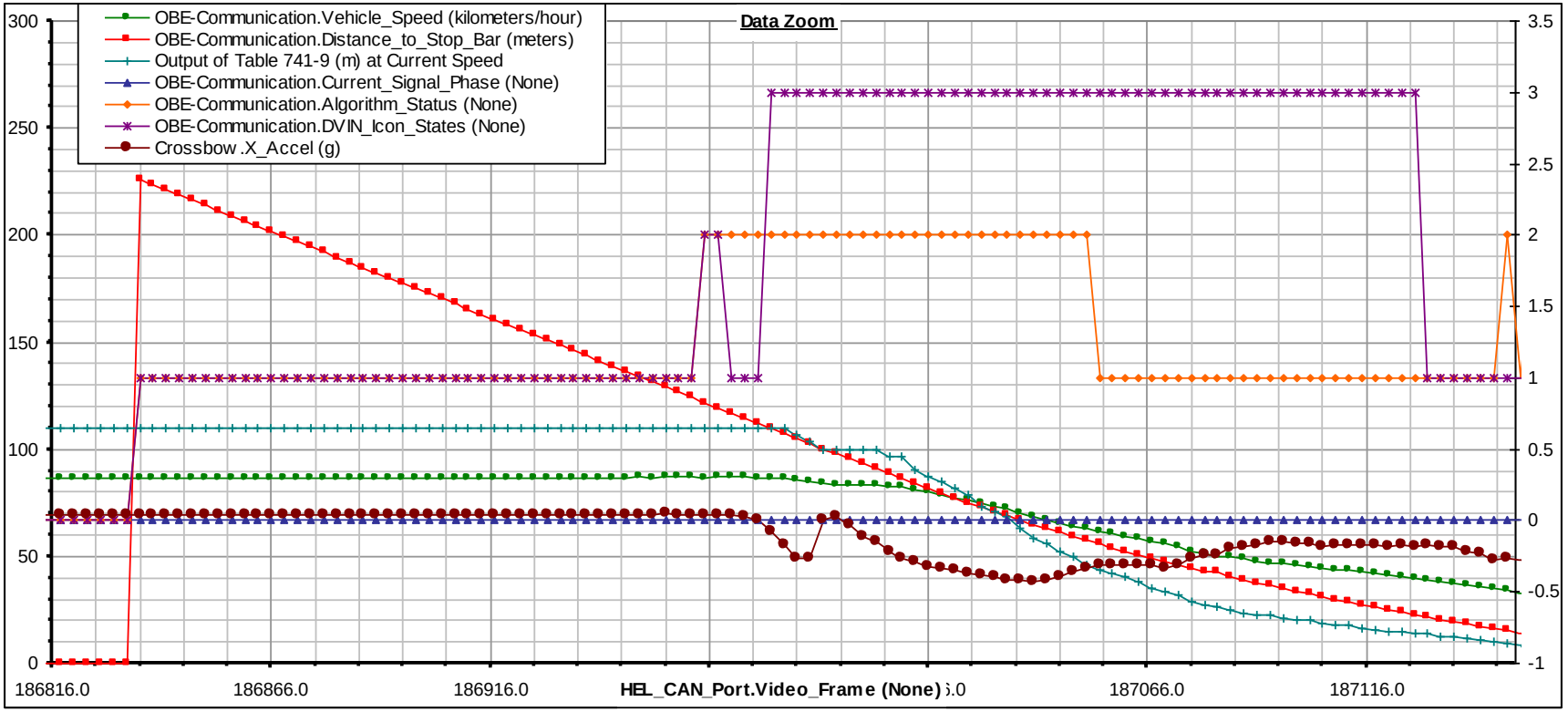

Figure 130: Stop-Sign Various Approach Speeds Test, 55 mi/h, Run 1

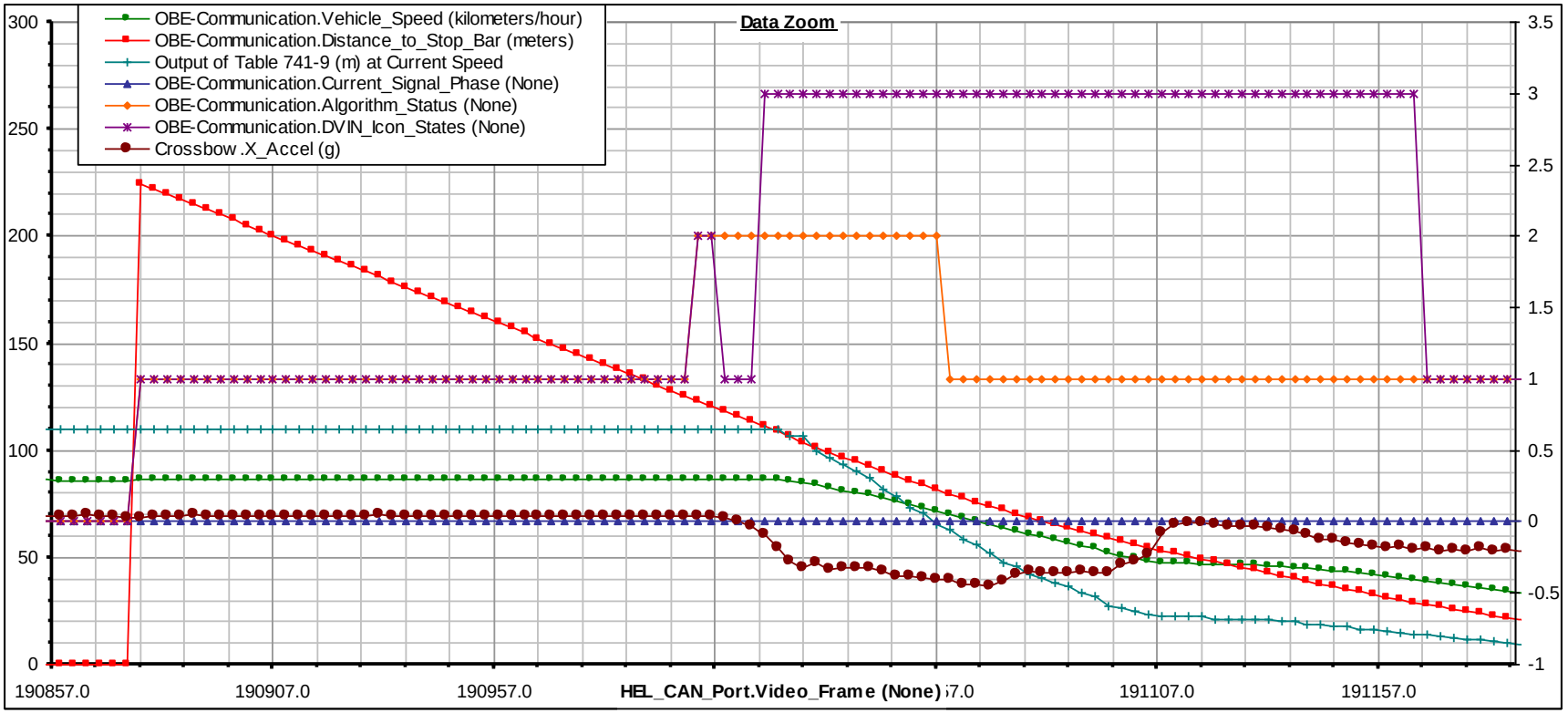

Figure 131: Stop-Sign Various Approach Speeds Test, 55 mi/h, Run 2

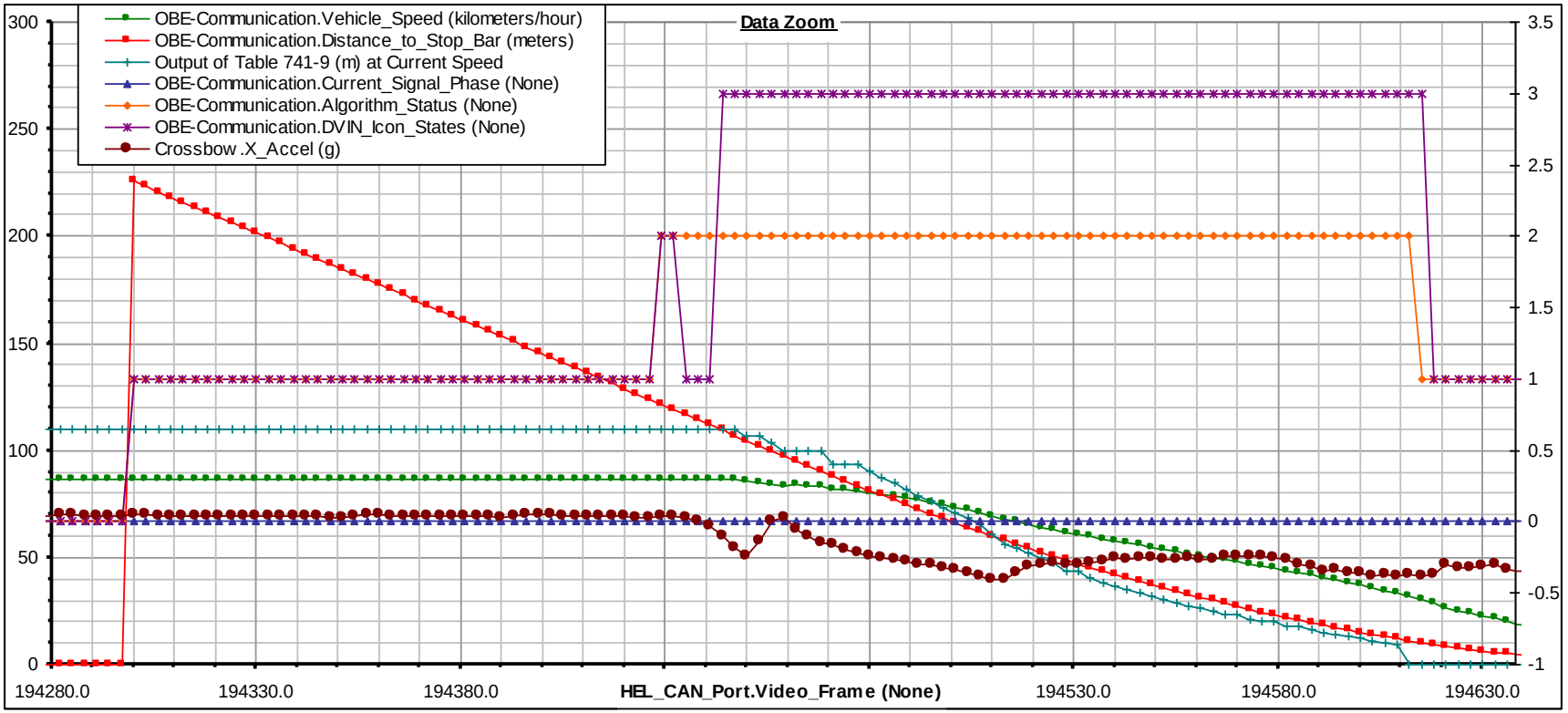

Figure 132: Stop-Sign Various Approach Speeds Test, 55 mi/h, Run 3

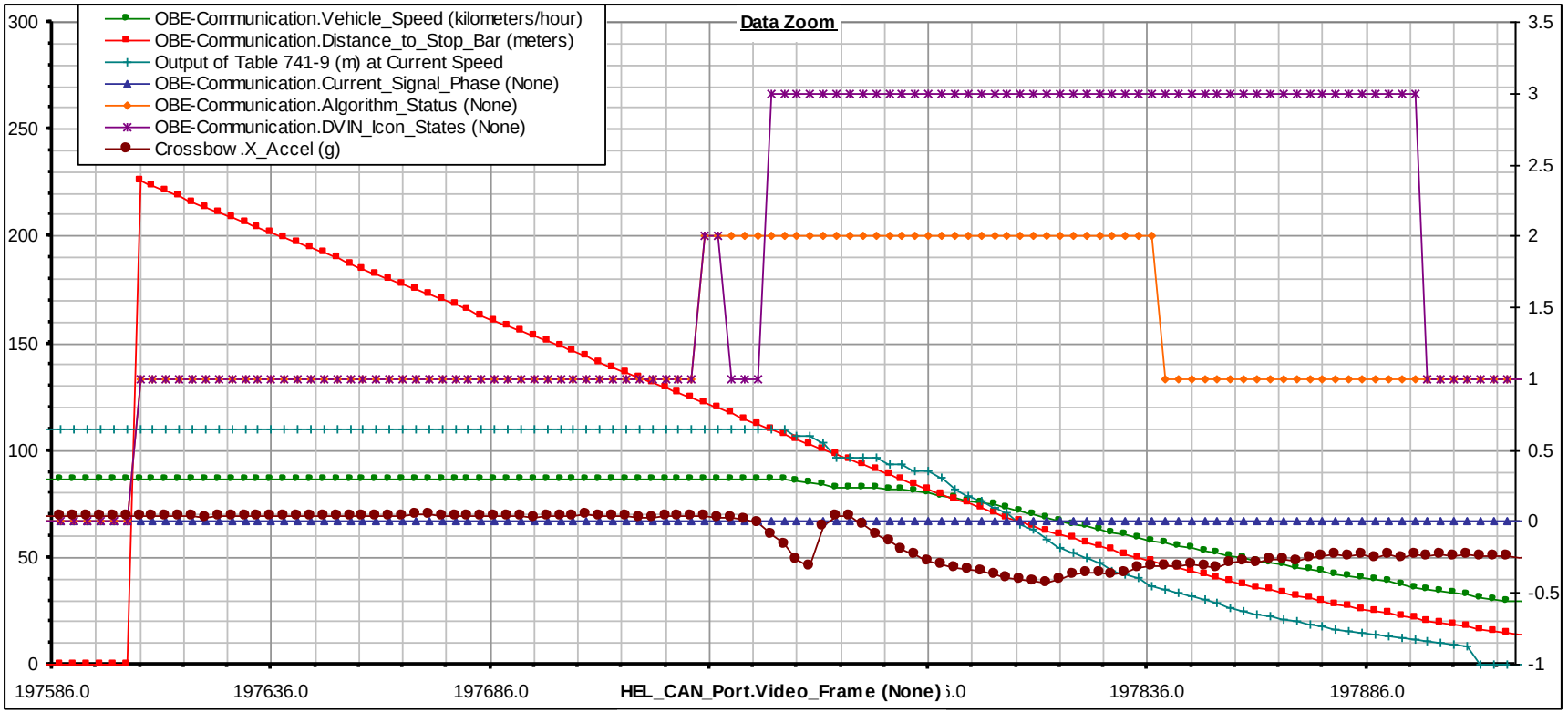

Figure 133: Stop-Sign Various Approach Speeds Test, 55 mi/h, Run 4

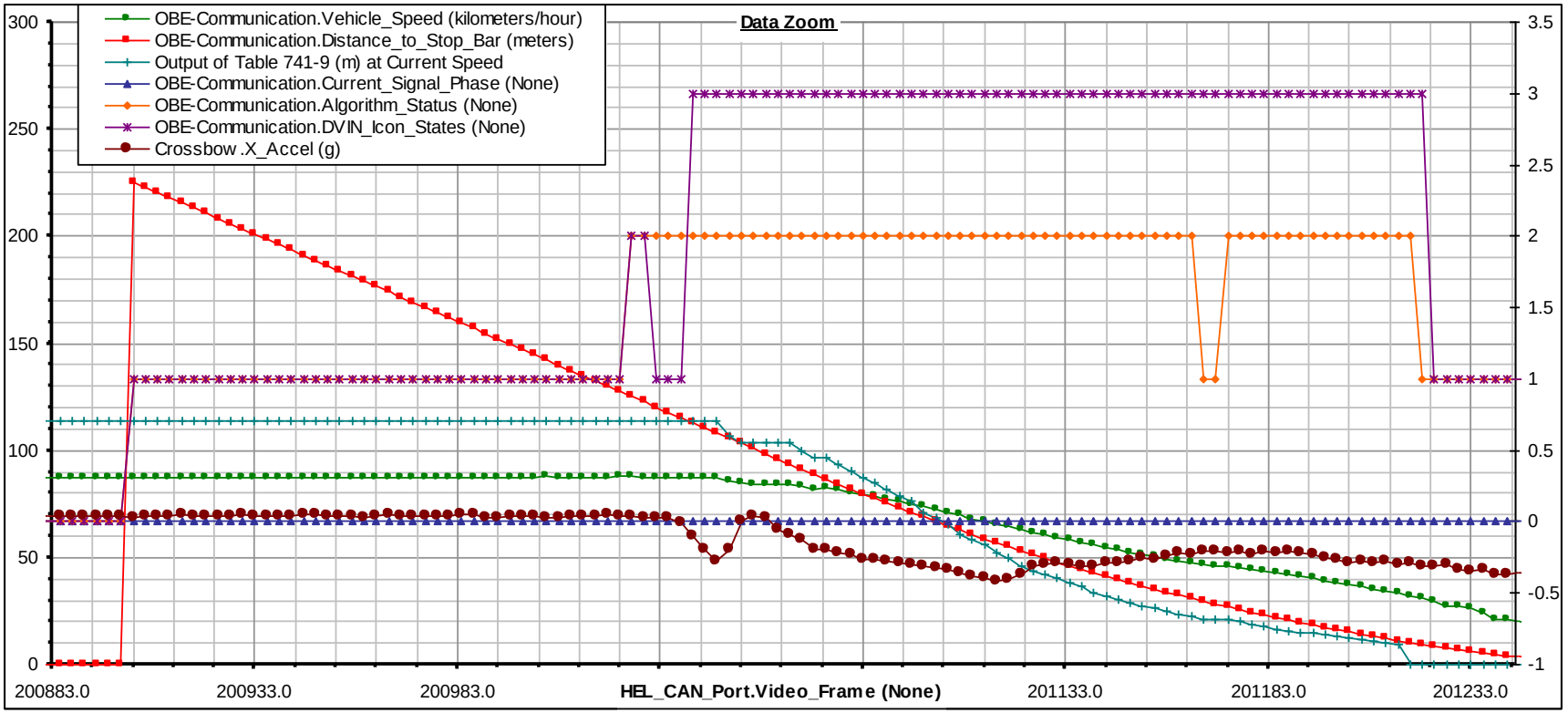

Figure 134: Stop-Sign Various Approach Speeds Test, 55 mi/h, Run 5

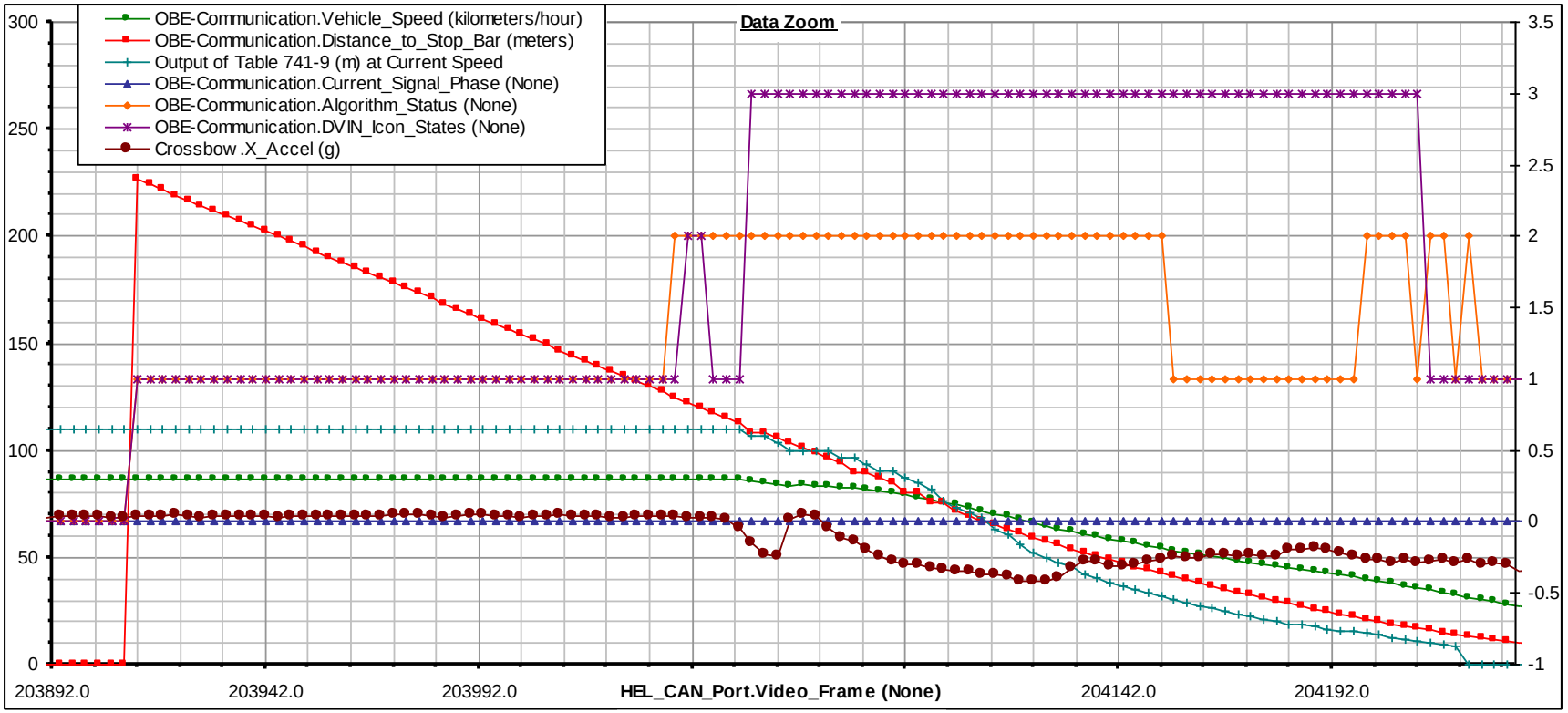

Figure 135: Stop-Sign Various Approach Speeds Test, 55 mi/h, Run 6

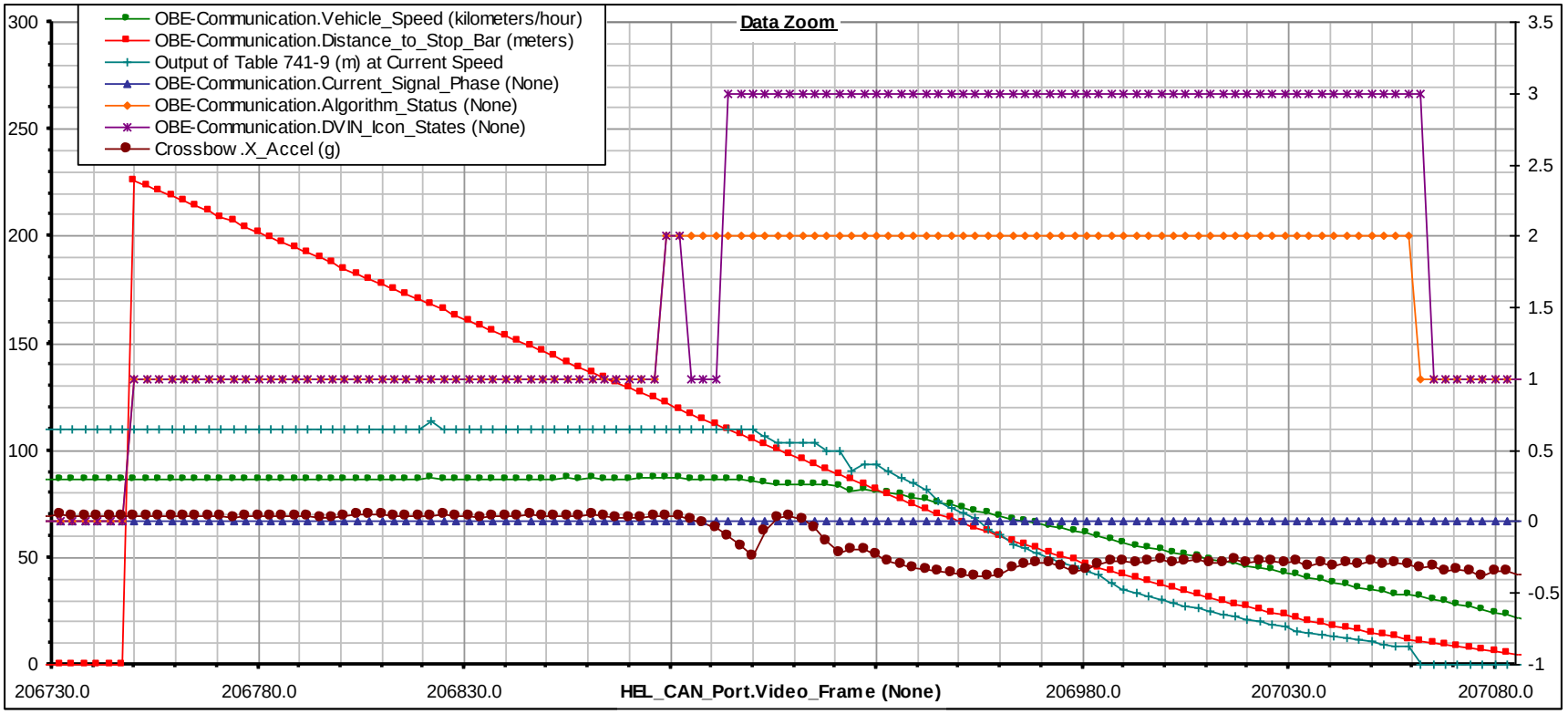

Figure 136: Stop-Sign Various Approach Speeds Test, 55 mi/h, Run 7

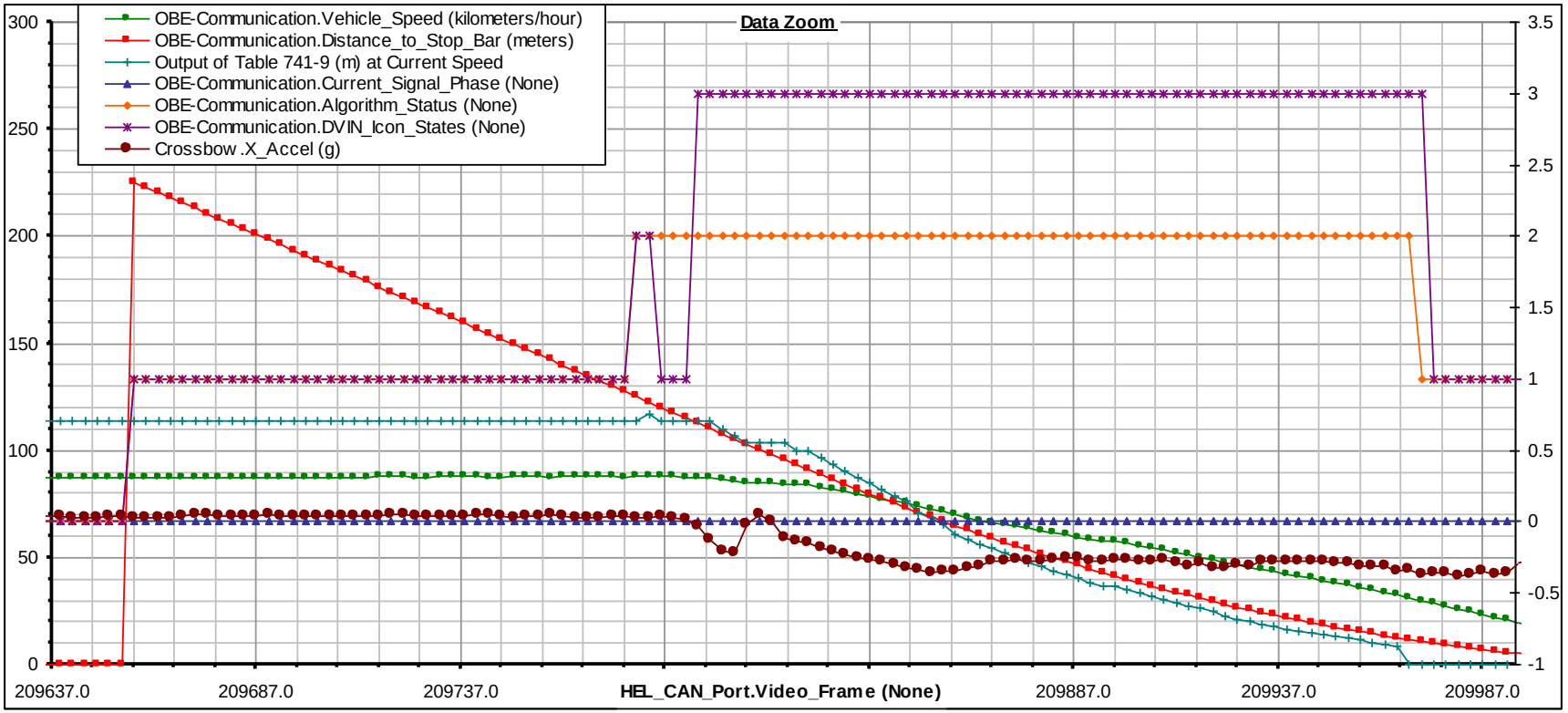

Figure 137: Stop-Sign Various Approach Speeds Test, 55 mi/h, Run 8

8.1.15 : Stop-Sign Various Approach Speeds Test, 35 mi/h

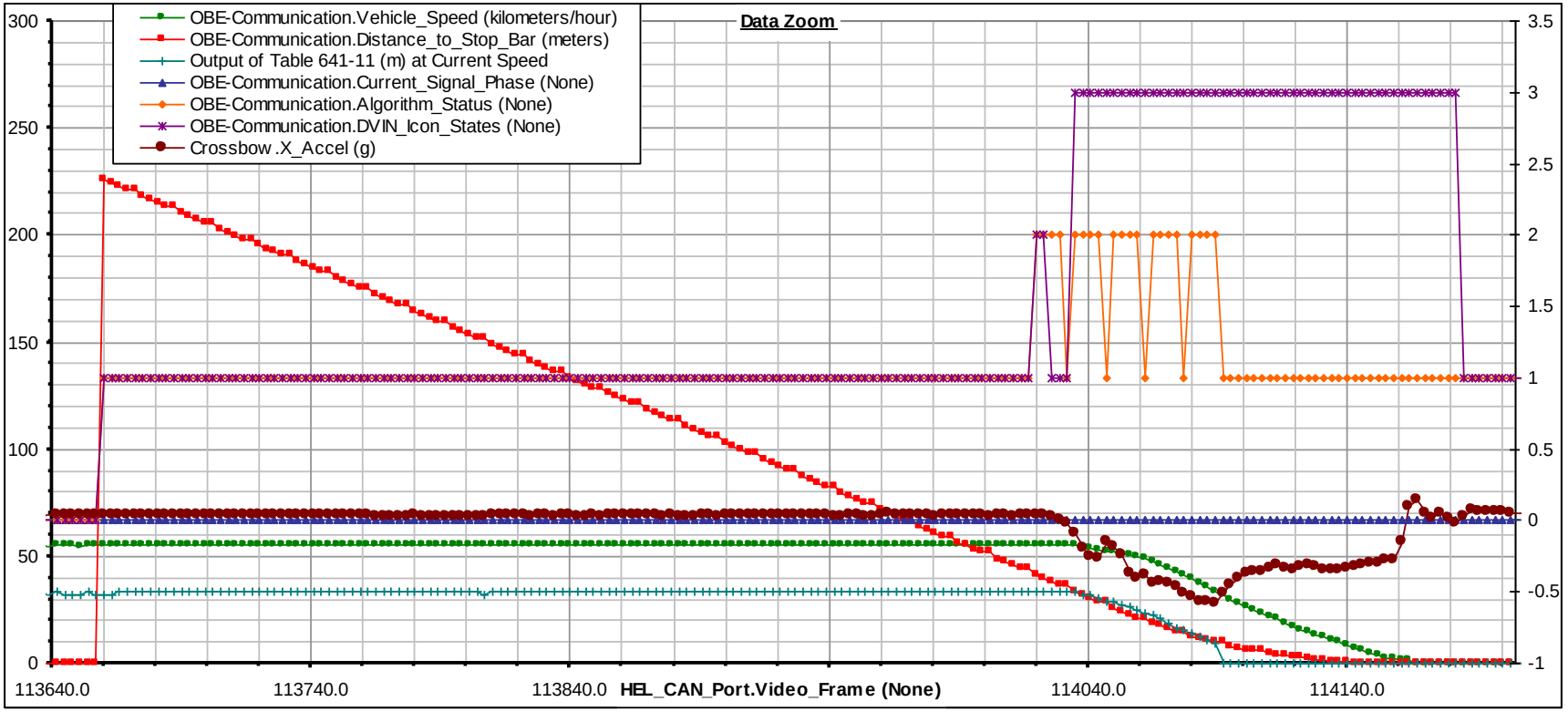

Figure 138: Stop-Sign Various Approach Speeds Test, 35 mi/h, Run 1

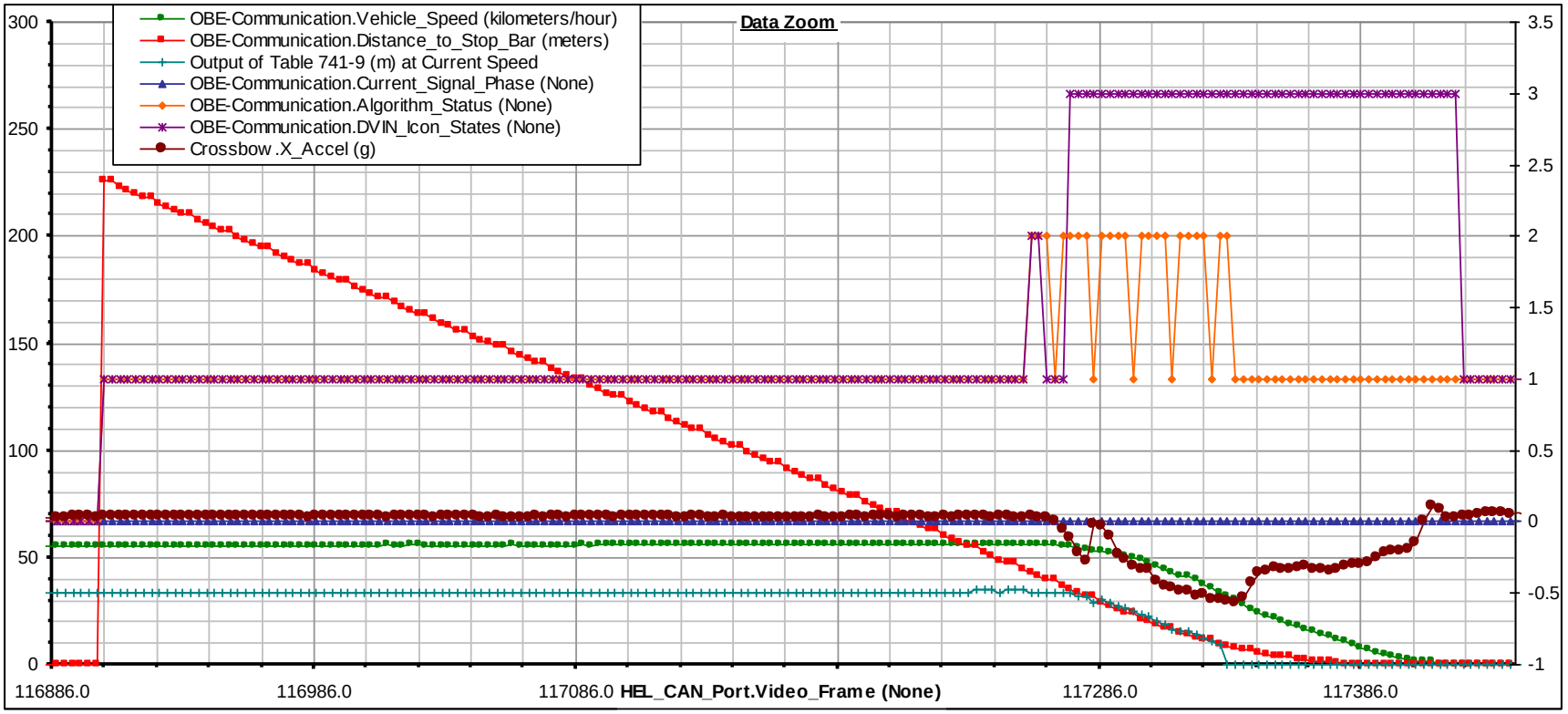

Figure 139: Stop-Sign Various Approach Speeds Test, 35 mi/h, Run 2

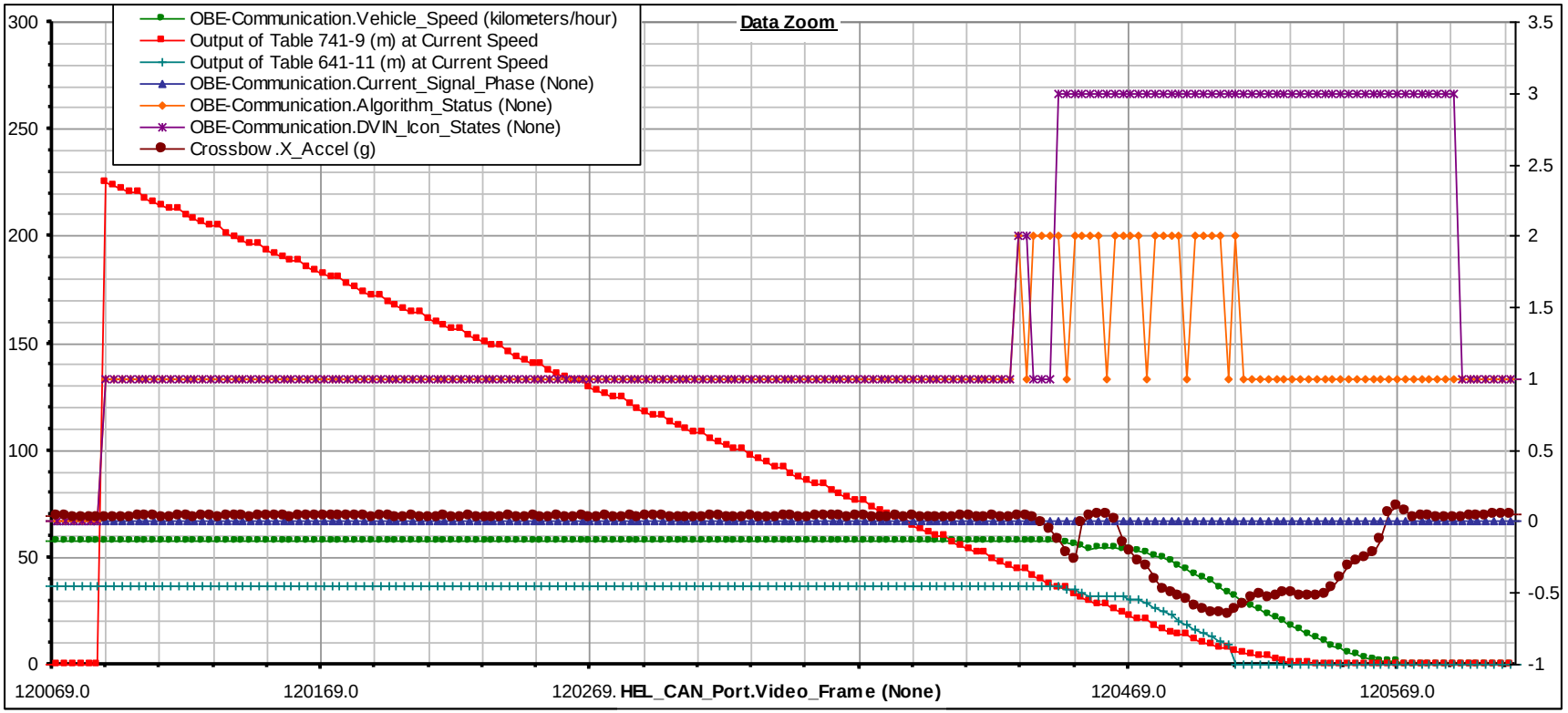

Figure 140: Stop-Sign Various Approach Speeds Test, 35 mi/h, Run 3

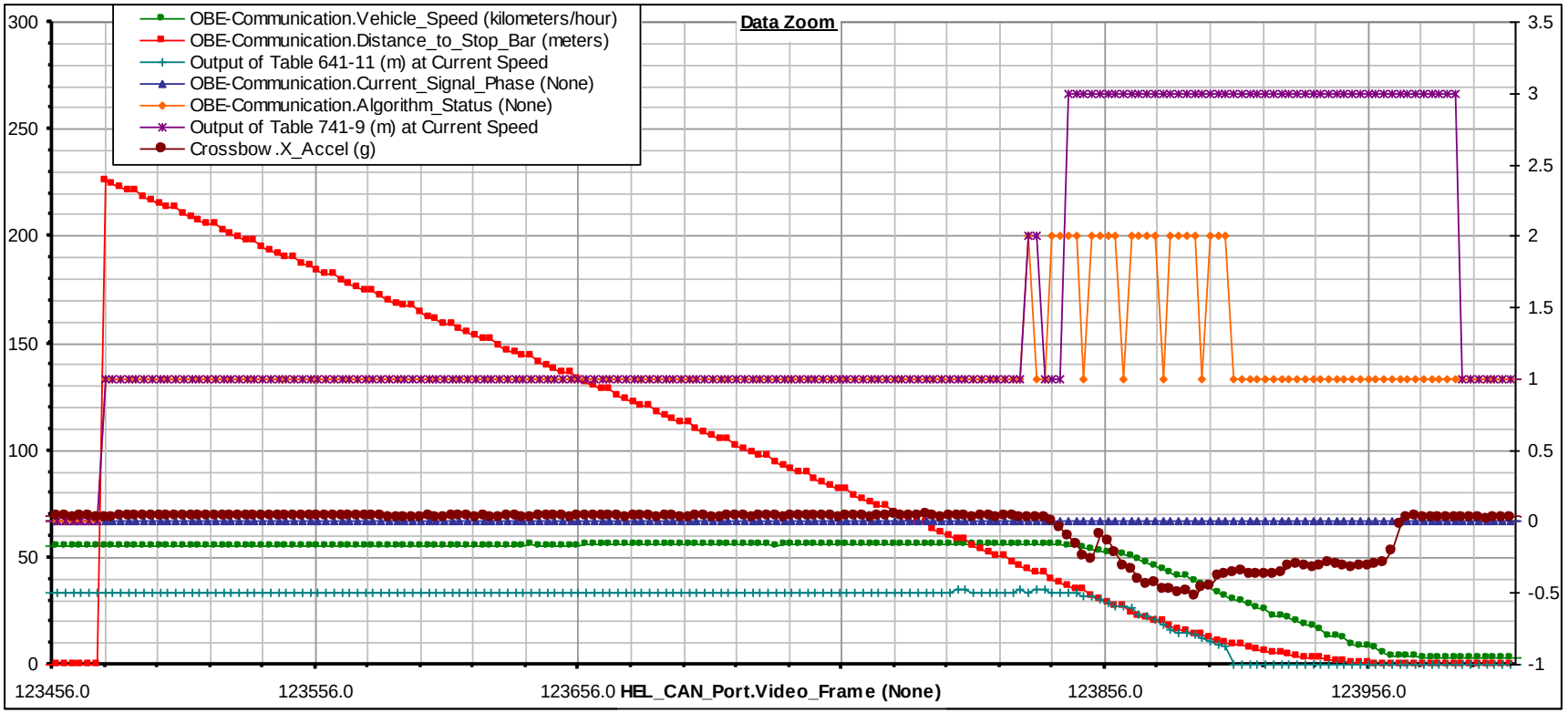

Figure 141: Stop-Sign Various Approach Speeds Test, 35 mi/h, Run 4

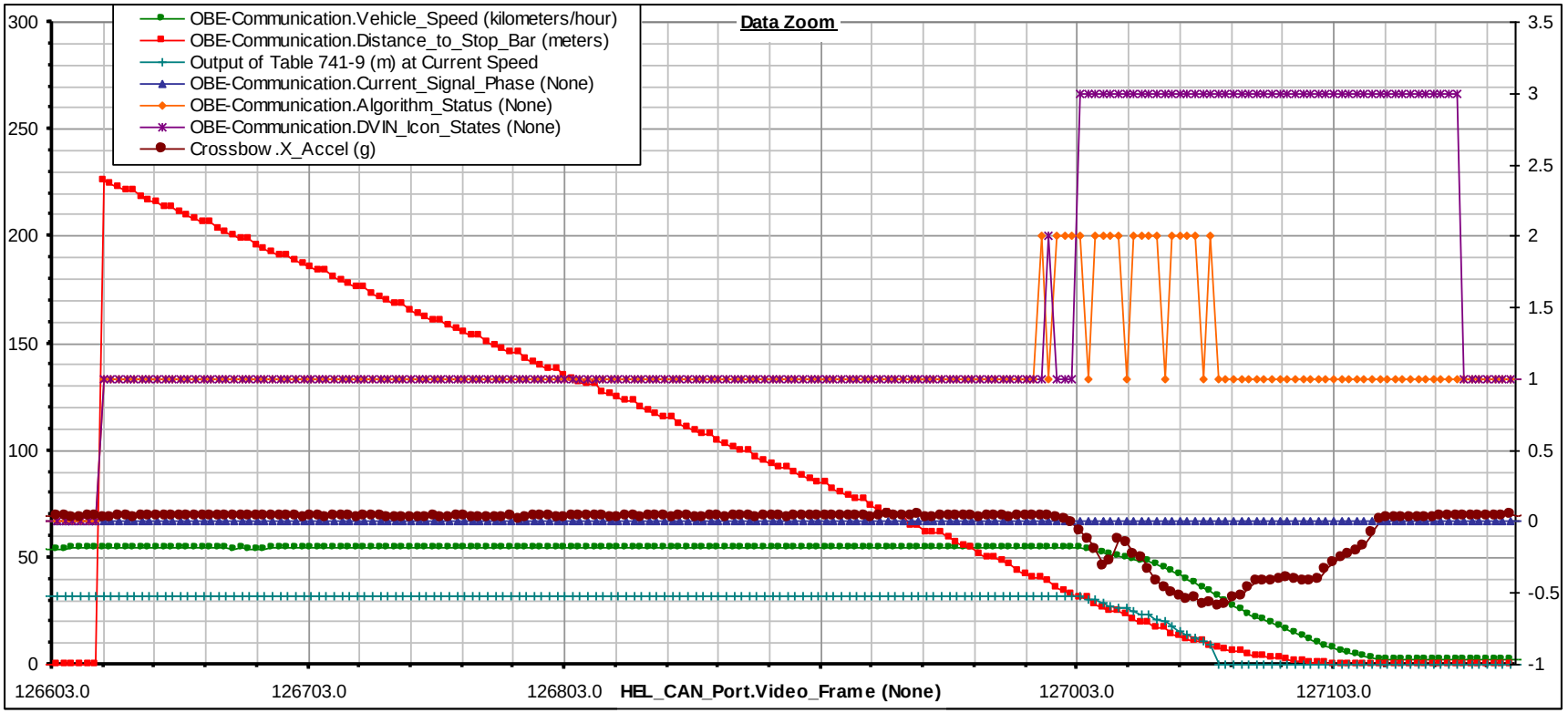

Figure 142: Stop-Sign Various Approach Speeds Test, 35 mi/h, Run 5

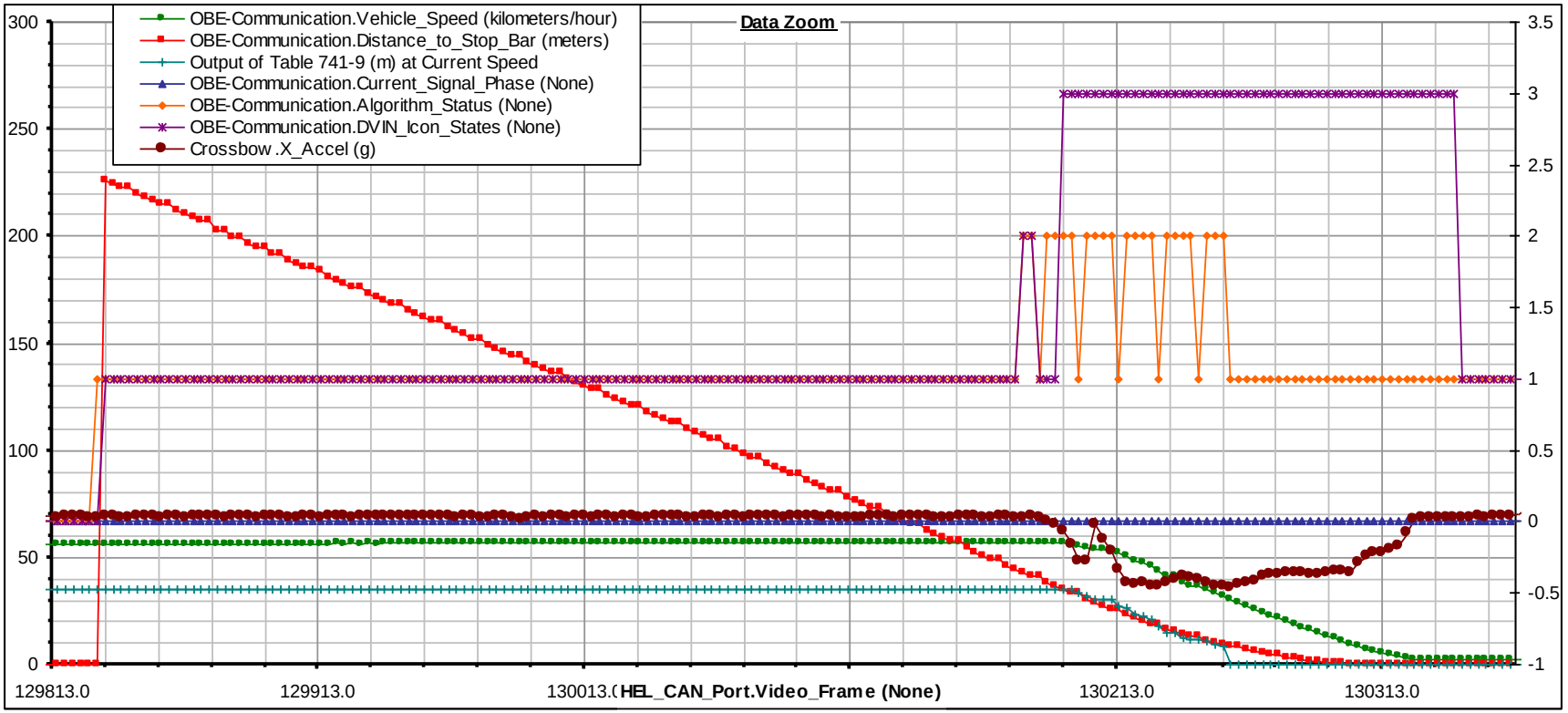

Figure 143: Stop-Sign Various Approach Speeds Test, 35 mi/h, Run 6

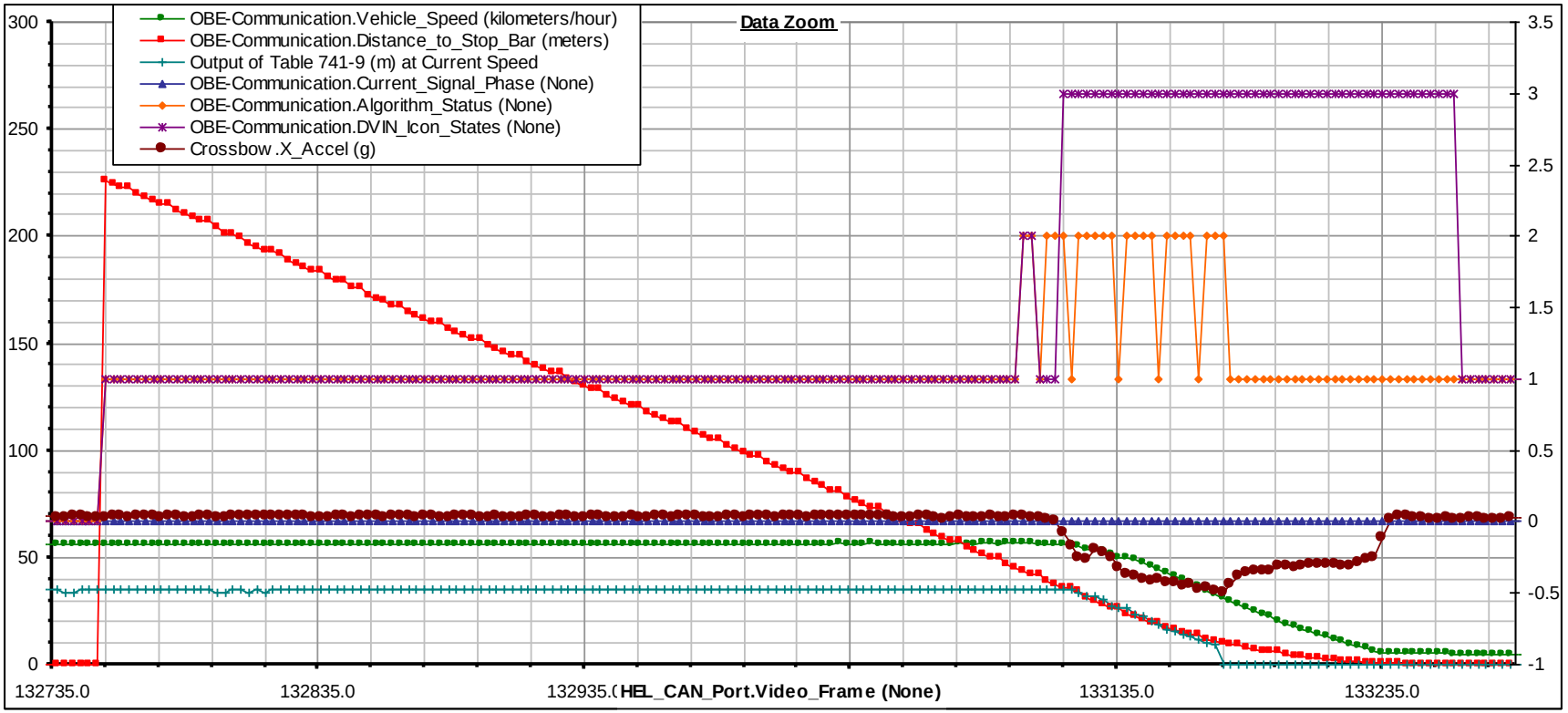

Figure 144: Stop-Sign Various Approach Speeds Test, 35 mi/h, Run 7

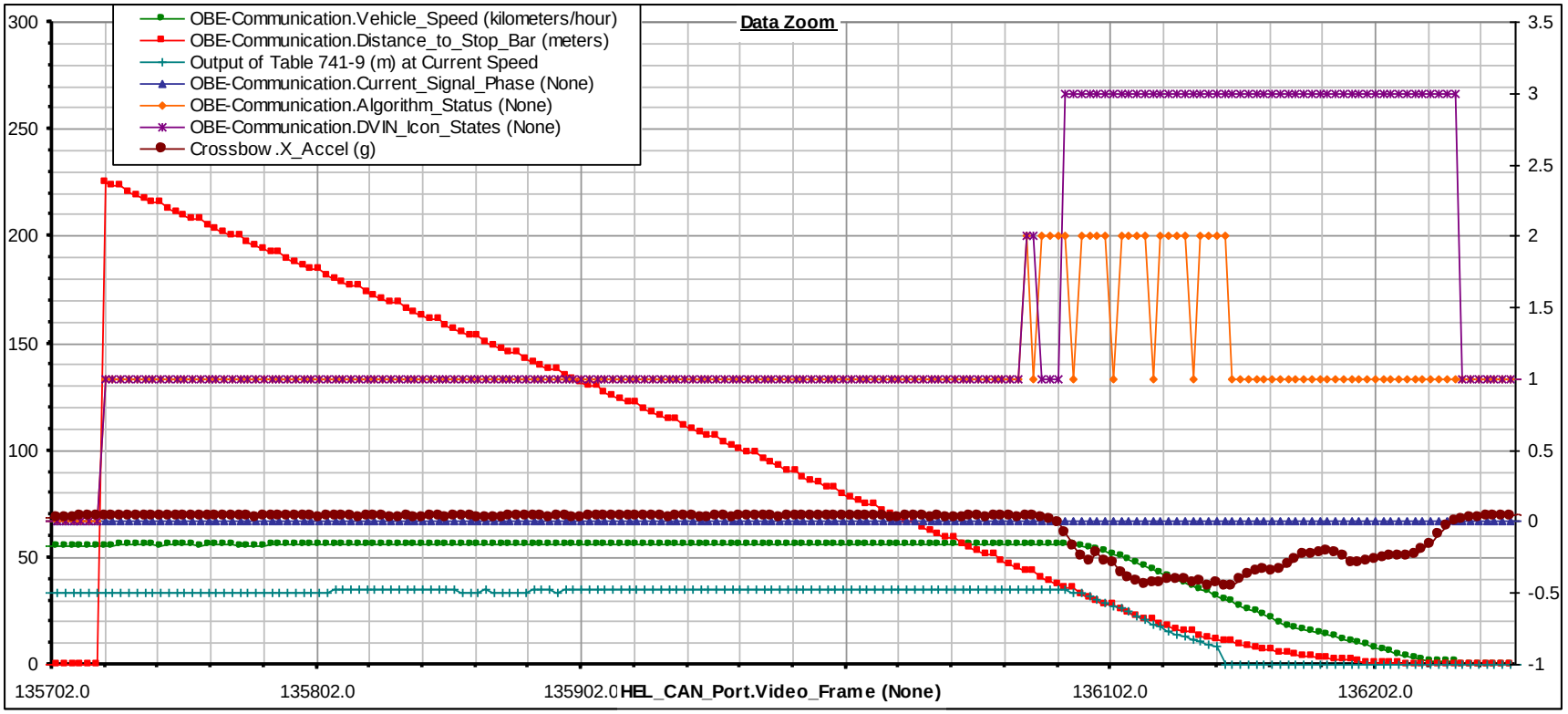

Figure 145: Stop-Sign Various Approach Speeds Test, 35 mi/h, Run 8

8.1.16 : Stop-Sign Various Approach Speeds Test, 25 mi/h

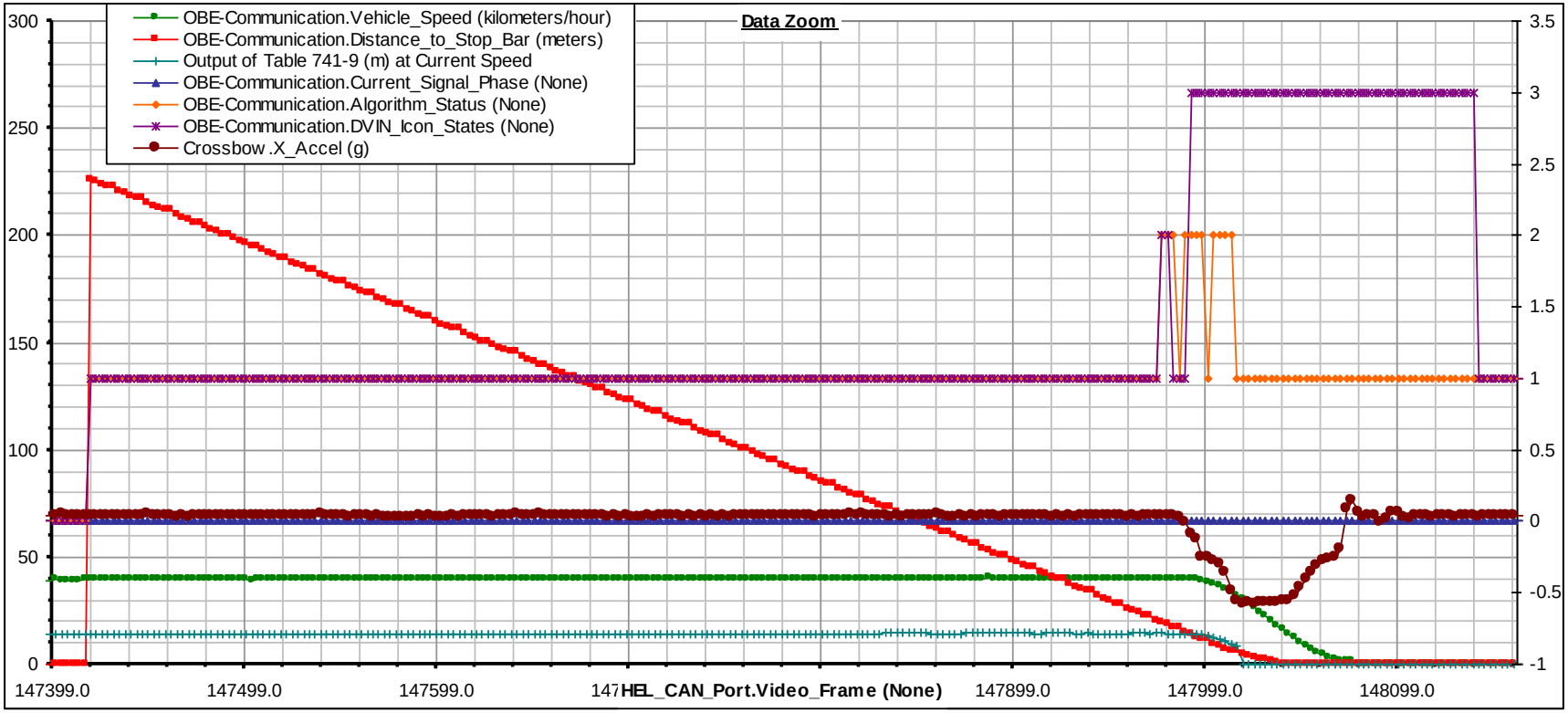

Figure 146: Stop-Sign Various Approach Speeds Test, 25 mi/h, Run 1

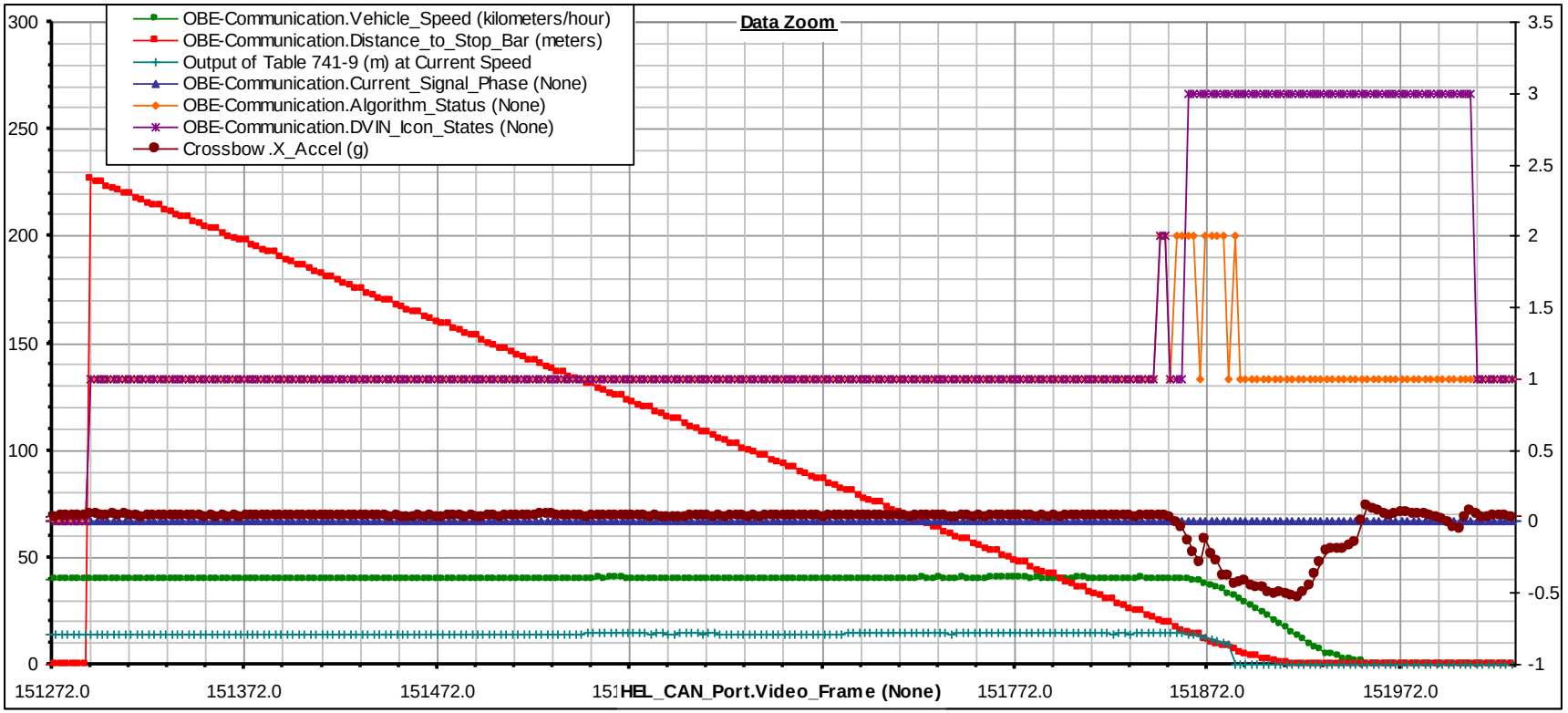

Figure 147: Stop-Sign Various Approach Speeds Test, 25 mi/h, Run 2

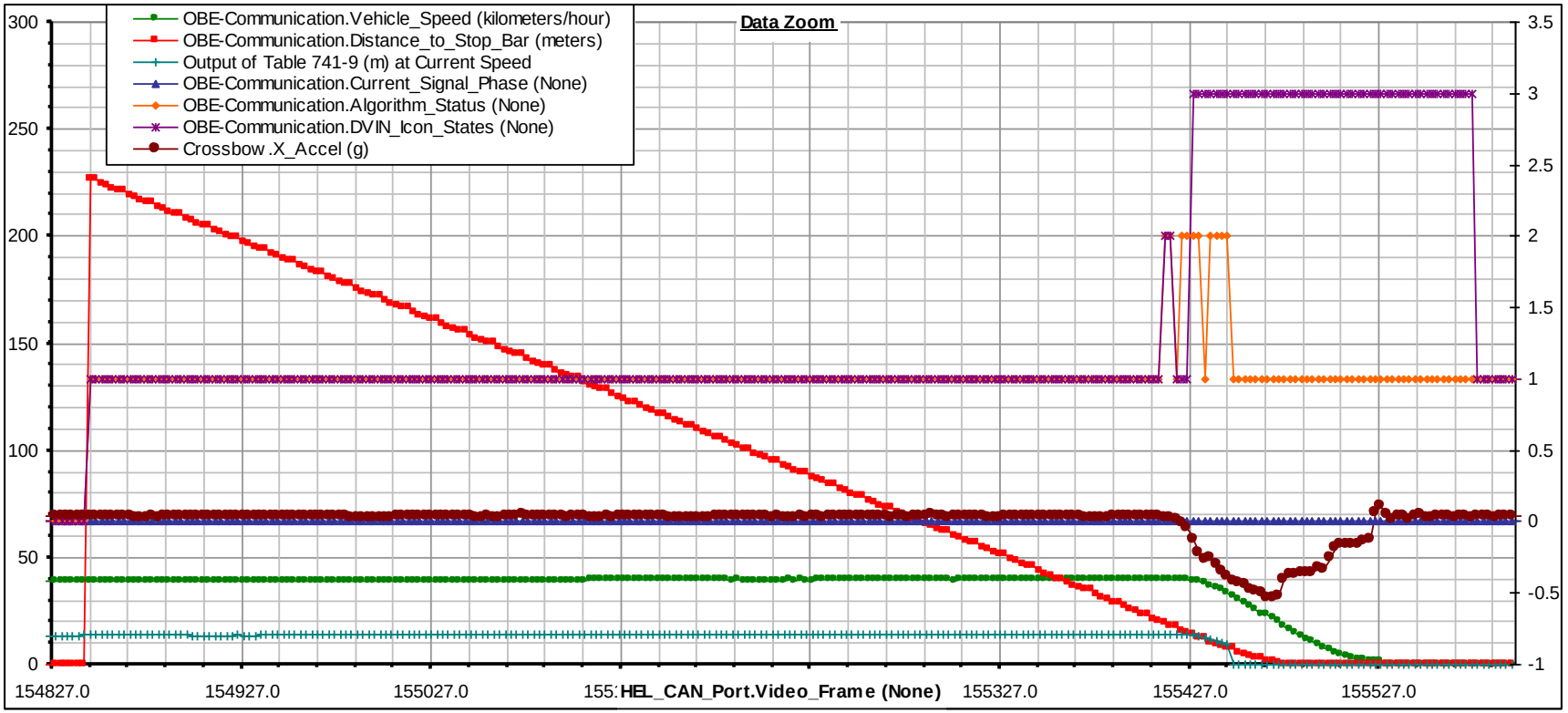

Figure 148: Stop-Sign Various Approach Speeds Test, 25 mi/h, Run 3

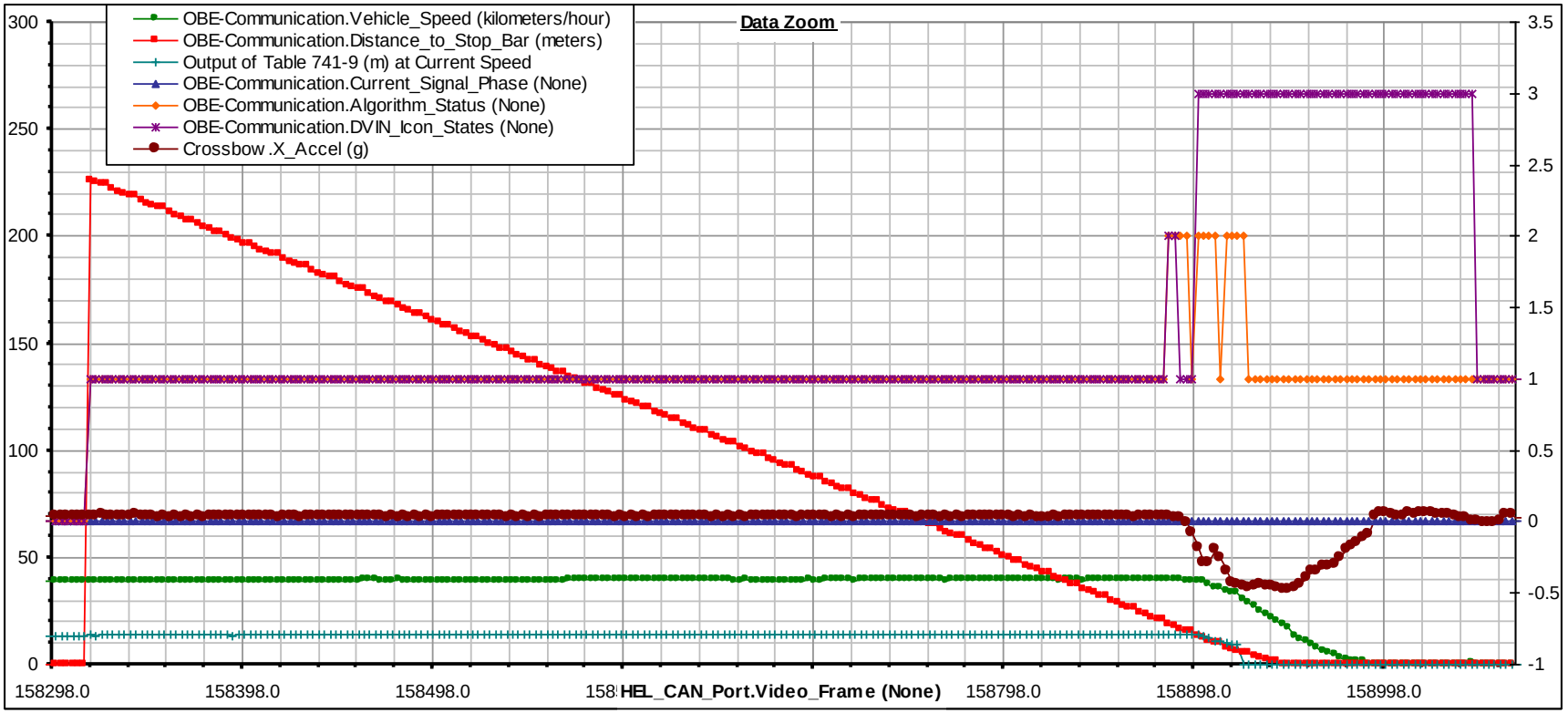

Figure 149: Stop-Sign Various Approach Speeds Test, 25 mi/h, Run 4

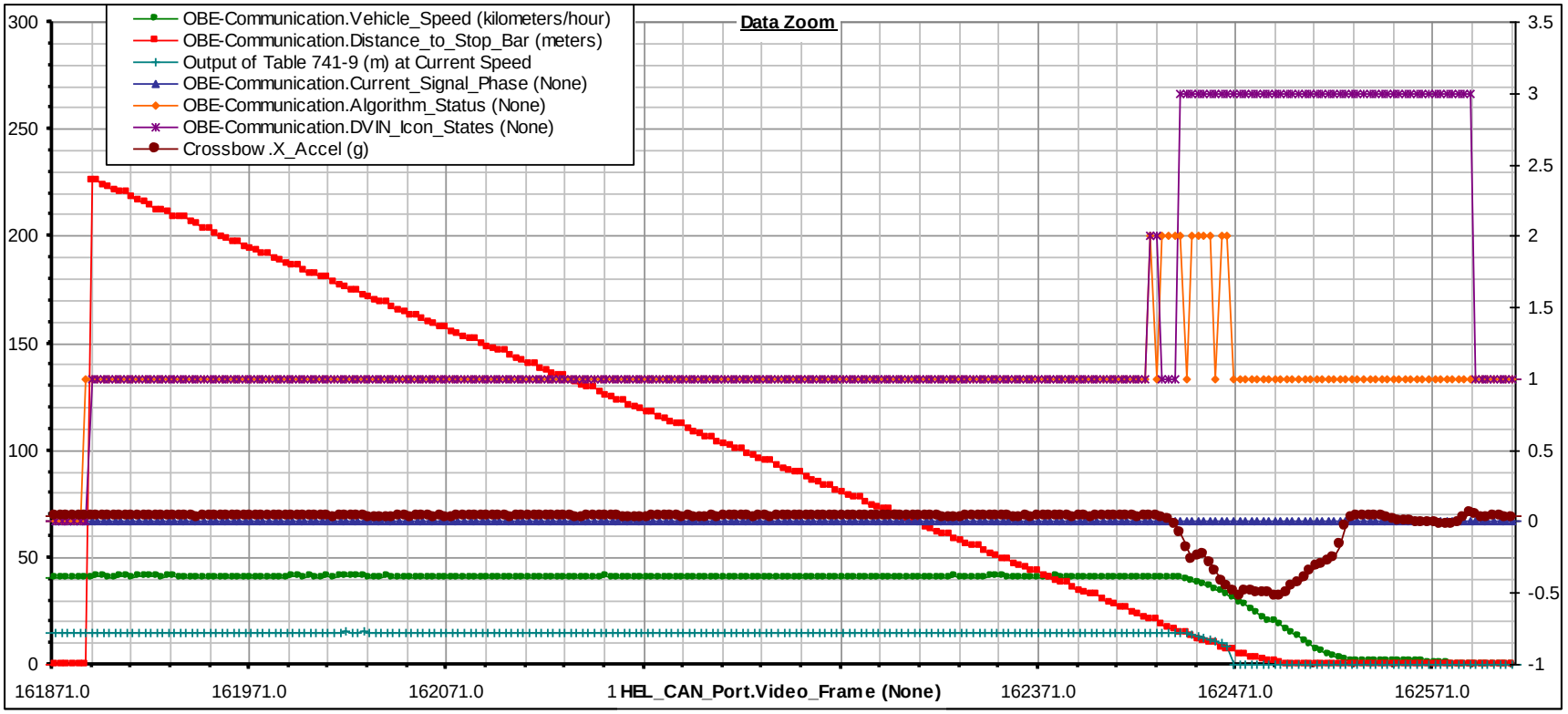

Figure 150: Stop-Sign Various Approach Speeds Test, 25 mi/h, Run 5

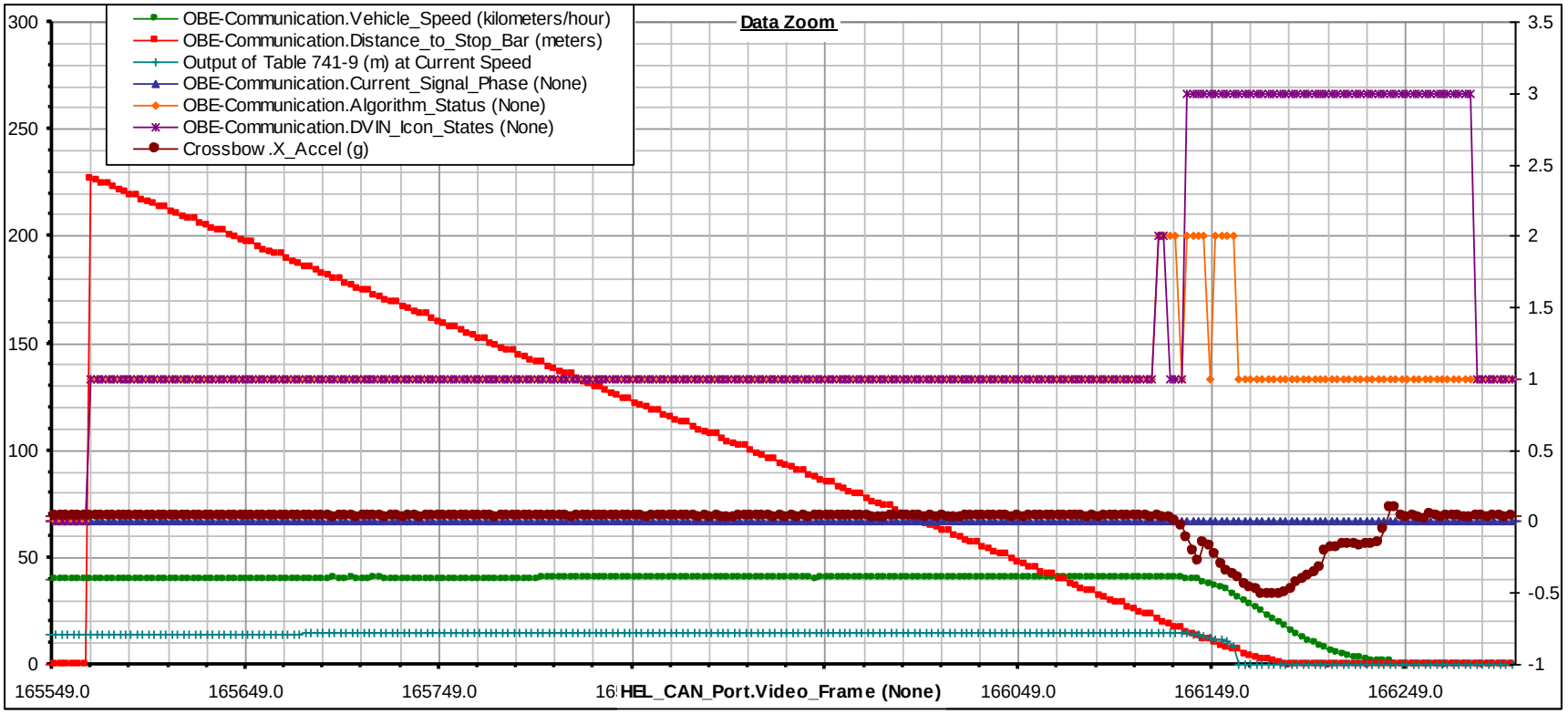

Figure 151: Stop-Sign Various Approach Speeds Test, 25 mi/h, Run 6

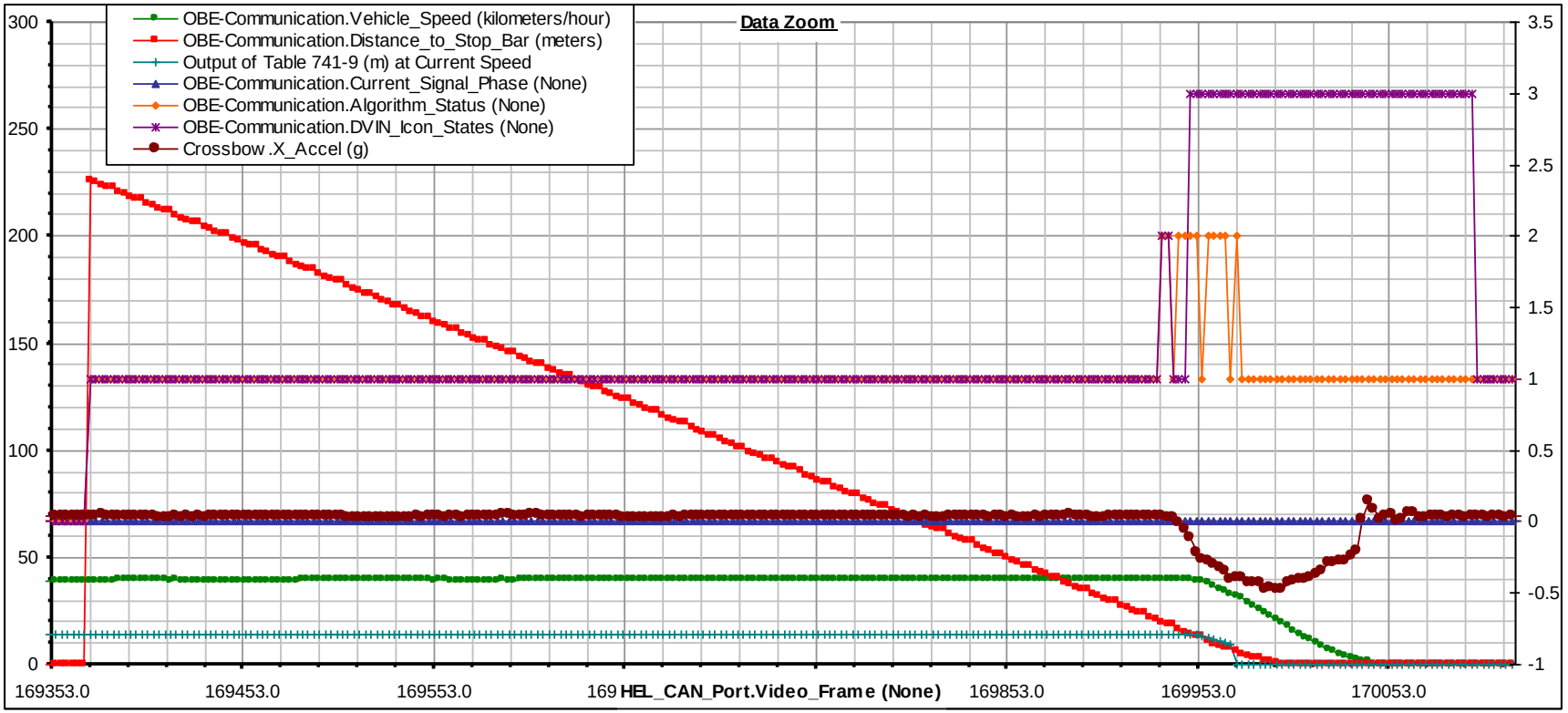

Figure 152: Stop-Sign Various Approach Speeds Test, 25 mi/h, Run 7

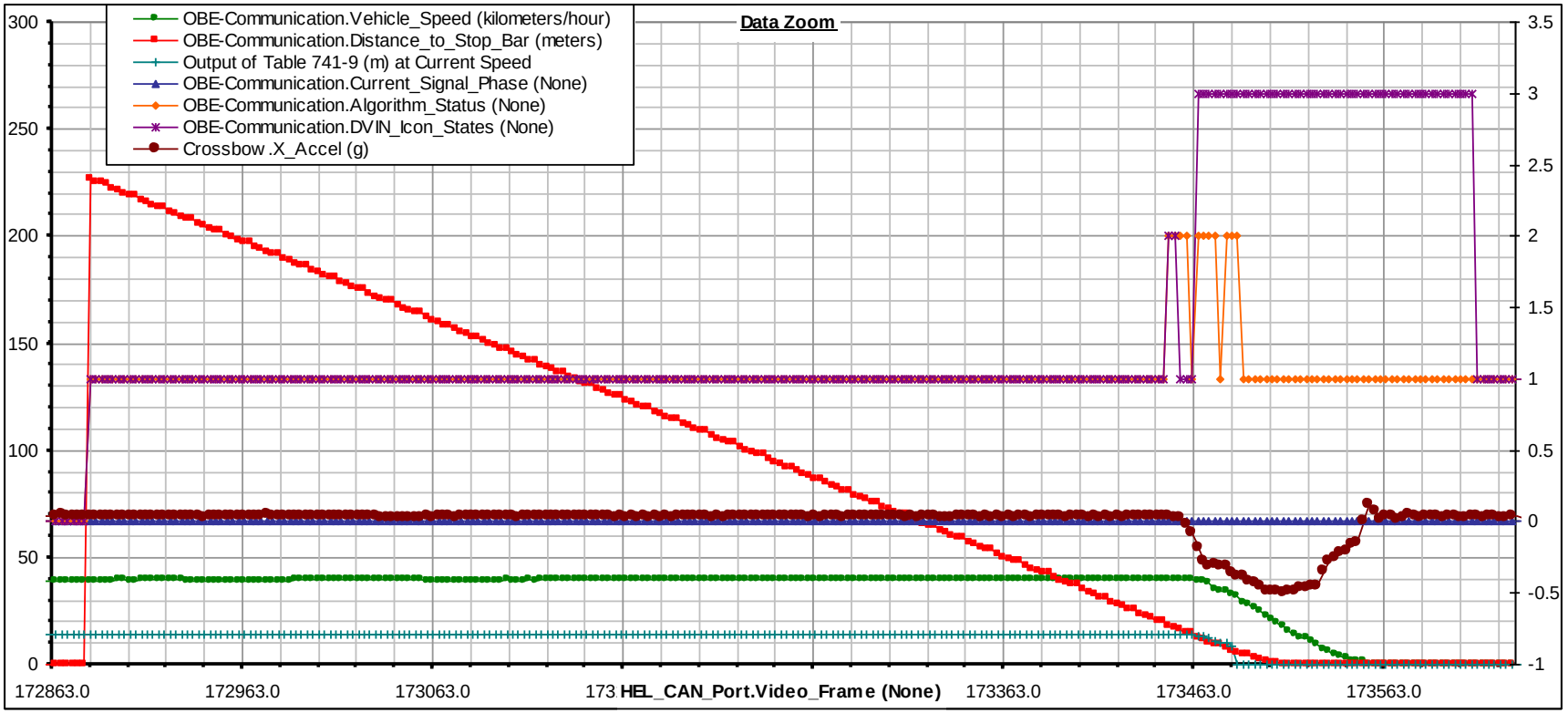

Figure 153: Stop-Sign Various Approach Speeds Test, 25 mi/h, Run 8

8.2 : Warning Tables

8.2.1 : Warning Table 641-11 for Signalized Intersection Approaches

Speed (km/h)	DistanceToWarn (m)
0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	0
19	0
20	0
21	0
22	0
23	0

Speed (km/h)	DistanceToWarn (m)
24	0
25	0
26	0
27	0
28	0
29	0
30	0
31	0
32	12.71
33	13.55
34	14.42
35	15.32
36	16.24
37	17.19
38	18.16
39	19.16
40	20.19
41	21.24
42	22.32
43	23.43
44	24.56
45	25.72
46	26.91
47	28.12
48	29.35
49	30.62
50	31.91
51	33.23

Speed (km/h)	DistanceToWarn (m)
52	34.57
53	35.94
54	37.34
55	38.76
56	40.21
57	41.68
58	43.19
59	44.71
60	46.27
61	47.85
62	49.46
63	51.09
64	52.75
65	54.44
66	56.15
67	57.89
68	59.66
69	61.45
70	63.27
71	65.12
72	66.99
73	68.89
74	70.82
75	72.77
76	74.75
77	76.75
78	78.78
79	80.84

Speed (km/h)	DistanceToWarn (m)
80	82.93
81	85.04
82	87.18
83	89.34
84	91.53
85	93.75
86	95.99
87	98.26
88	100.56
89	102.88
90	105.24
91	107.61
92	110.02
93	112.45
94	114.9
95	117.39
96	119.9
97	122.43
98	125
99	127.59
100	130.2
101	132.84
102	135.51
103	138.21
104	140.93
105	143.68
106	146.46
107	149.26

Speed (km/h)	DistanceToWarn (m)
108	152.09
109	154.95
110	157.83
111	160.74
112	163.68
113	166.64
114	169.63
115	172.64
116	175.69
117	178.75
118	181.85
119	184.97
120	188.12
121	191.3
122	194.5
123	197.73
124	200.99
125	204.27
126	207.58
127	210.91
128	214.28
129	217.67
130	221.08
131	224.53
132	227.99
133	231.49
134	235.01
135	238.56

Speed (km/h)	DistanceToWarn (m)
136	242.14
137	245.74
138	249.37
139	253.03
140	256.71
141	260.42
142	264.16
143	267.92
144	271.71
145	275.53
146	279.37
147	283.24
148	287.14
149	291.06
150	295.01
151	298.99
152	303
153	307.03
154	311.08
155	315.17
156	319.28
157	323.42
158	327.58
159	331.77
160	335.99
161	340.24
162	344.51
163	348.81

Speed (km/h)	DistanceToWarn (m)
164	353.13
165	357.48
166	361.86
167	366.27
168	370.7
169	375.16
170	379.64
171	384.16
172	388.7
173	393.26
174	397.86
175	402.48
176	407.12
177	411.8
178	416.5
179	421.22
180	425.98
181	430.76
182	435.56
183	440.4
184	445.26
185	450.15
186	455.06
187	460
188	464.97
189	469.97
190	474.99
191	480.04

Speed (km/h)	DistanceToWarn (m)
192	485.11
193	490.22
194	495.34
195	500.5
196	505.68
197	510.89
198	516.13
199	521.39
200	526.68

8.2.2 : Warning Table 741-9 for Stop-Controlled Intersection Approaches

Speed (km/h)	DistanceToWarn (m)
0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	0
12	0

Speed (km/h)	DistanceToWarn (m)
13	0
14	0
15	0
16	0
17	0
18	0
19	0
20	0
21	0
22	0
23	0
24	0
25	0
26	0
27	0
28	0
29	0
30	0
31	0
32	8.67
33	9.31
34	9.99
35	10.7
36	11.45
37	12.23
38	13.06
39	13.92
40	14.82

Speed (km/h)	DistanceToWarn (m)
41	15.76
42	16.74
43	17.76
44	18.82
45	19.93
46	21.08
47	22.27
48	23.51
49	24.79
50	26.12
51	27.5
52	28.92
53	30.39
54	31.91
55	33.48
56	35.1
57	36.77
58	38.49
59	40.26
60	42.08
61	43.96
62	45.9
63	47.88
64	49.93
65	52.02
66	54.18
67	56.39
68	58.66

Speed (km/h)	DistanceToWarn (m)
69	60.99
70	63.37
71	65.82
72	68.33
73	70.89
74	73.52
75	76.21
76	78.97
77	81.78
78	84.66
79	87.61
80	90.62
81	93.69
82	96.83
83	100.04
84	103.32
85	106.66
86	110.07
87	113.56
88	117.11
89	120.73
90	124.42
91	128.19
92	132.02
93	135.93
94	139.91
95	143.97
96	148.1

Speed (km/h)	DistanceToWarn (m)
97	152.3
98	156.59
99	160.94
100	165.38
101	169.89
102	174.47
103	179.14
104	183.89
105	188.71
106	193.62
107	198.6
108	203.67
109	208.81
110	214.04
111	219.36
112	224.75
113	230.23
114	235.8
115	241.45
116	247.18
117	253
118	258.91
119	264.9
120	270.98
121	277.15
122	283.41
123	289.76
124	296.2

Speed (km/h)	DistanceToWarn (m)
125	302.72
126	309.34
127	316.05
128	322.85
129	329.74
130	336.73
131	343.81
132	350.98
133	358.25
134	365.61
135	373.07
136	380.63
137	388.28
138	396.02
139	403.87
140	411.81
141	419.85
142	428
143	436.24
144	444.58
145	453.02
146	461.56
147	470.2
148	478.95
149	487.8
150	496.75
151	505.8
152	514.96

Speed (km/h)	DistanceToWarn (m)
153	524.22
154	533.59
155	543.07
156	552.65
157	562.33
158	572.13
159	582.03
160	592.04
161	602.16
162	612.38
163	622.72
164	633.17
165	643.72
166	654.39
167	665.17
168	676.06
169	687.07
170	698.18
171	709.41
172	720.76
173	732.22
174	743.79
175	755.48
176	767.28
177	779.21
178	791.24
179	803.4
180	815.67

Speed (km/h)	DistanceToWarn (m)
181	828.06
182	840.57
183	853.2
184	865.95
185	878.82
186	891.81
187	904.92
188	918.15
189	931.51
190	944.98
191	958.58
192	972.3
193	986.15
194	1000.1
195	1014.2
196	1028.4
197	1042.8
198	1057.3
199	1071.9
200	1086.6

9 Appendix C: Analysis of GID Error

During the Edge of Lane approach tests it was found that the GID had errors but the exact magnitude of the errors was not known at the time of testing. For this test, the lateral offset is the most important to determine the validity of the test. To evaluate the amount of lateral offset in the GID relative to the lane boundaries, the collected GPS traces from the objective tests were analyzed. For the analysis, the data collected from the edge of approach test was used, since the position of the car relative to the lane edge was the most consistent due to the test design. Lanes A3 and A4 were used for the Edge of Lane Approach Tests, see Figure 154.

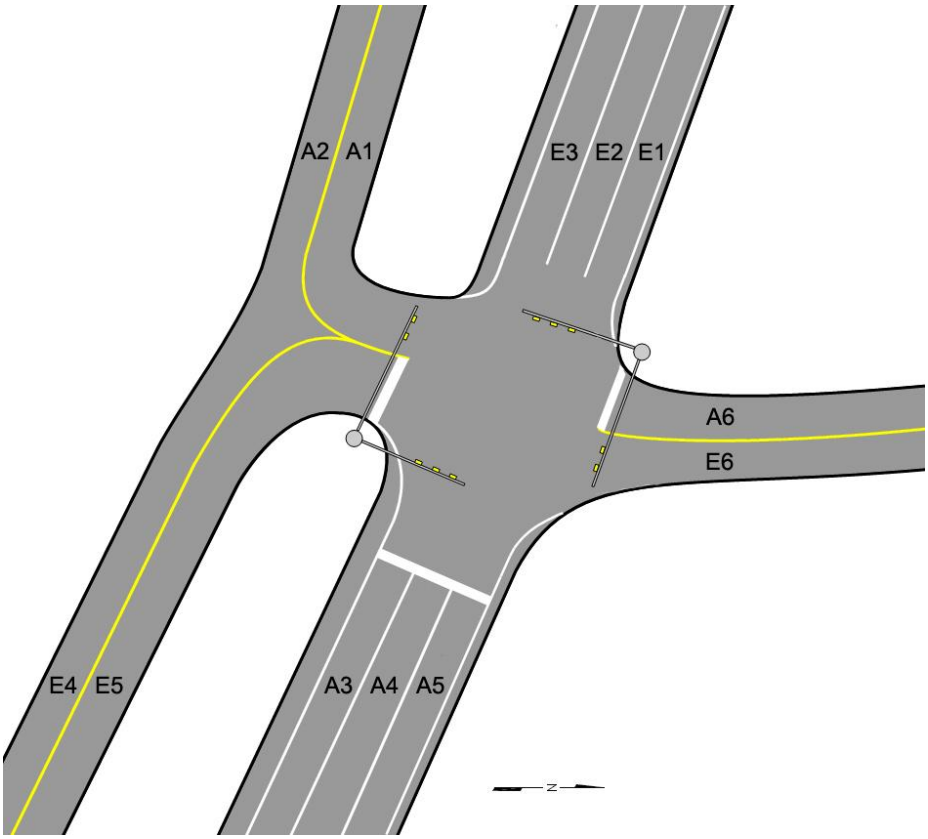

Figure 154: Smart Road GID with Lane Labels

In this analysis the distance of the vehicle from the GPS points used for developing the GID were used. Those points can be seen in Figure 155. The two lanes in question are Lane A3 and Lane A4. The intersection is at the upper left corner of the plot. As can be seen, there is a slight curve in the roadway.

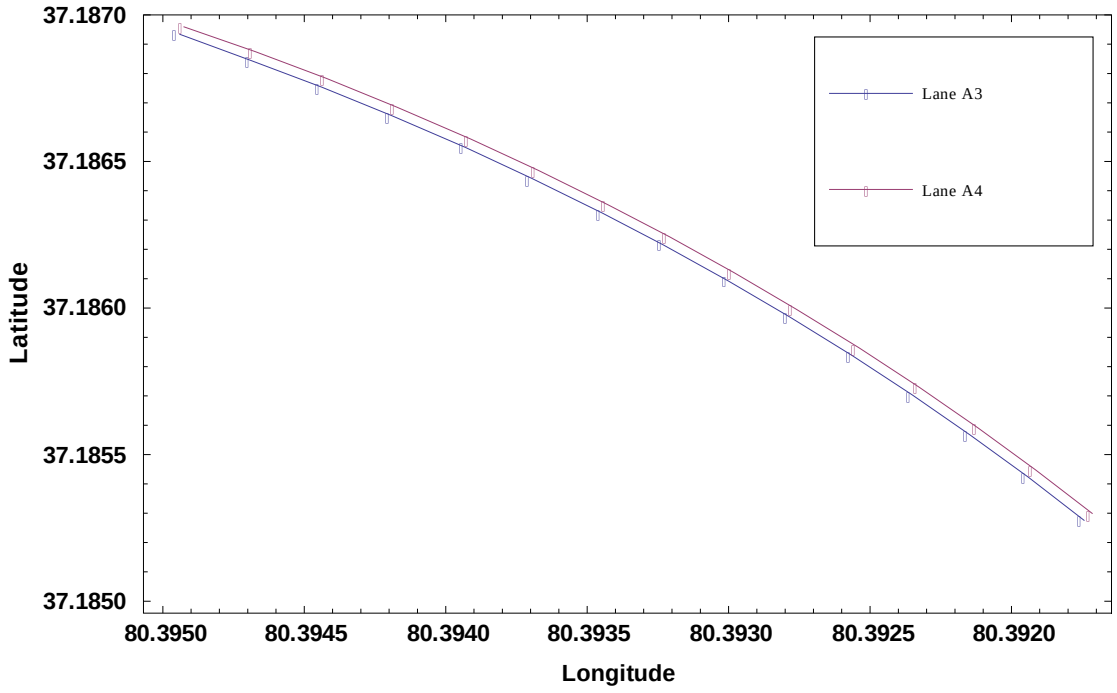

Figure 155: GPS points for Lanes A3 and A4 in GID 003

Figure 156 shows the GPS traces that were collected with the GPS system that was used for the CICAS-V system.

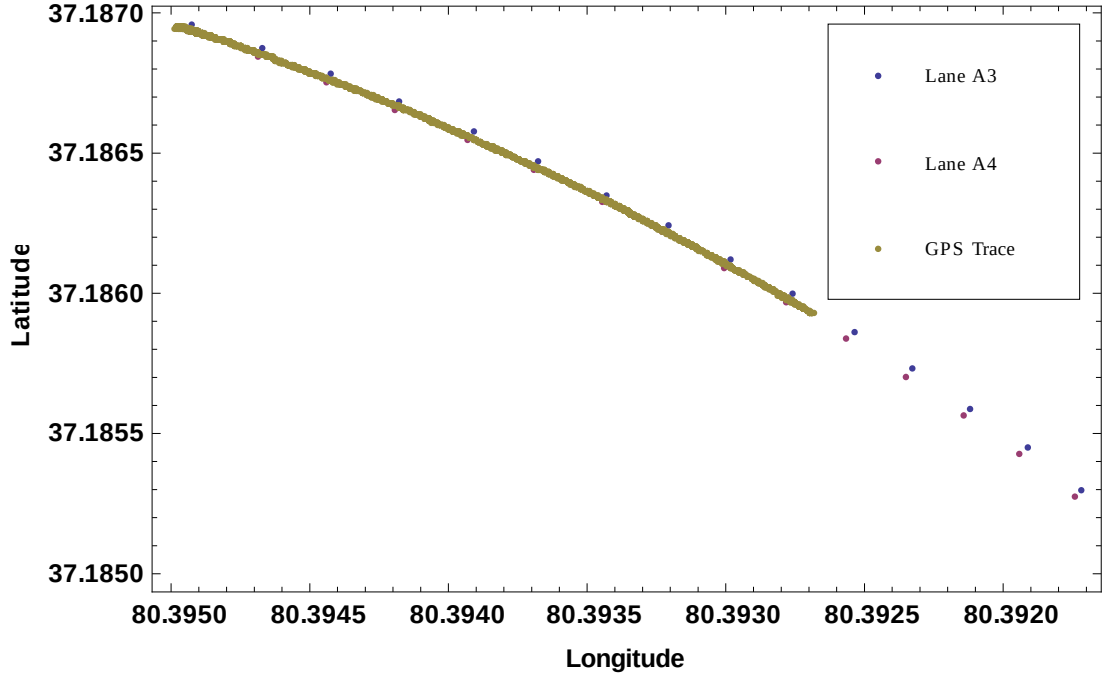

Figure 156: GPS traces for the Edge of Approach – Warning test

For all eight runs, the minimum distance from the GID points of Lane A3 and Lane A4 was calculated and then the numerical average was taken, For Lane A3 those distances were 1.26201, 1.3008, 1.35862, 1.21279, 1.28267, 1.29729, 1.20574, 1.27084, 1.28328 [m]. The average over these values is 1.28 m, The distances for Lane A4 were 2.39798, 2.37792, 2.33717, 2.22415, 2.27204, 2.32373, 2.42539, 2.38988, 2.42999, 2.33261 [m] with an average of 2.35 m.

The design of the test called for the vehicle to be driven within 50 cm of the lane edge and from observation, the distance between the outer edge of the tire and the lane was around 30 cm. Since the GPS antenna was placed on the long axis of the vehicle and the vehicle width was 1.8 m, the distance of the antenna from the outer edge of the tire was 90 cm.

The geometry of the test is shown in Figure 157.

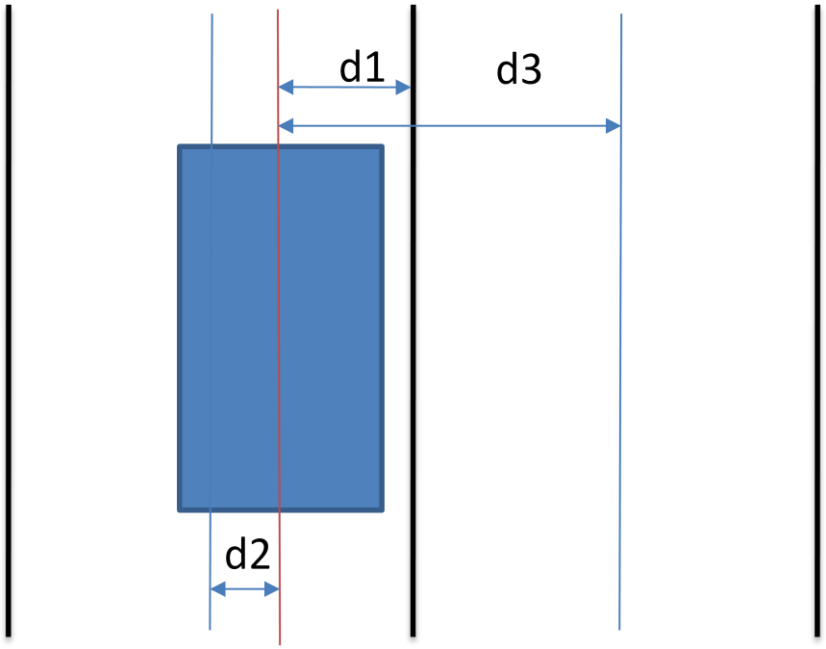

Figure 157: Geometry of the Test

As can be seen from Figure 157, the vehicle center is a distance d1 from the lane boundary. The distance between the lane center and the center axis of the vehicle is d2. The distance between the center axis of the vehicle and the lane center of the neighboring lane (Lane A4) is d3The lane width of the smart road is 3.6 m. Assuming 30 cm distance between the tire and the lane boundary, d1 = 120 cm, d2 = 60 cm and d3 = 300 cm. As can be seen from the data above, d1= 128 cm and d2 = 235cm. This means that the GID is shifted to the left in Figure XZ by approximately 60-70 cm.

This means that in the Edge of Lane Approach Test - Warning, the vehicle was driving approx. 30 cm over the lane boundary of the GID and in the Edge of Lane Approach Test – Nuisance, the vehicle was driven approx. 90 cm from the lane boundary.

10 Appendix D: Test Procedure Improvements

Test Procedure	Improvement
Edge of Lane Approach Test - Warning	Since the reliability of judging the vehicle position with respect to the lane markings is uncertain, it is suggested here that downward facing side cameras be used for this purpose instead. The cameras should have the view of at least both front vehicle wheels and the lane markings to accurately and repeatedly verify distance to the lane edge under all test conditions. Test procedures indicate that the lane offset to the right is positive and lane offset to the left is negative. This will enhance the data collection procedure and make it easier to determine which side of center the vehicle is deviating.
Edge of Lane Approach Test - Nuisance	Since the reliability of judging the vehicle position with respect to the lane markings is uncertain, it is suggested here that downward facing side cameras be used for this purpose instead. The cameras should have the view of at least both front vehicle wheels and the lane markings to accurately and repeatedly verify distance to the lane edge under all test conditions. Test procedures indicate that the lane offset to the right is positive and lane offset to the left is negative. This will enhance the data collection procedure and make it easier to determine which side of center the vehicle is deviating.
Late Lane Shift Test - Warning	The test should specify an allowable latency between a positive lane match and the onset of the warning. Thus, it is suggested here that the test procedure is to be improved for any future use by specifying the allowable maximum latency

Test Procedure	Improvement
	as in Table 15's column "Difference Ln. to Warn (s)."
Multiple Intersections within 300 m Radius – Warning Case	The alternate intersection count was performed while the vehicle was within the warning zone. In future tests, this should be performed throughout the approach of the vehicle, once the icon turns blue until the vehicle reaches the stop bar. There also needs to be a criterion that specifies the allowable gap between alternate intersection message reception. This gap should not be more than 1 sec.
SPaT Reflection and Reception – Engineering test	The measurements of reception quality and CICAS-V performance can in the future be used to define reception validity bounds and replace this engineering-type test with a pass/fail test. Measuring the distance between the truck and the vehicle can be improved by placing a reflector on the rear of the truck that the following vehicle's front radar can consistently track. If the radar can consistently track the rear of the truck, the data collected from the radar can be used to verify the distance between the vehicle and the truck and be used to validate each run avoiding the need for methods without record generation capabilities, such as hand-held range-finders.

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