Infrastructure Connectivity Certification Test Procedures for Infrastructure-Based Connected Automated Vehicle Components

Signal Phase and Timing – SAE J2735

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16. Abstract

The successful deployment and operation of connected vehicle systems will require that devices, systems, and applications developed by different providers are compatible, interoperable, non-interfering, and in some instances, perhaps, interchangeable. Some devices, systems, and applications, such as active safety applications, may be required to meet minimum operational performance standards. A list of questions was distributed to potential stakeholders to gather information on which aspects of the industry should be considered for certification. The results were compiled and consolidated into a list of recommendations that yielded three applications to be addressed under this project. This document contains the test plan for one of the three applications.

The scope of the test cases contained in this document is to evaluate a signal phase and timing (SPaT) generation device output over available technology and test the format, structure, and encoding of the SPaT message. The Society of Automotive Engineers (SAE) J2735 standard governs the SPaT format and structure. The message is represented in the Abstract Syntax Notation One (ASN.1) format, which is UPER Hex encoded for broadcast. The scope for testing includes various mandatory data elements and their corresponding values and verification of the various format conversions.

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List of Acronyms

ASN.1	Abstract Syntax Notation One
CV	connected vehicle
CAV	connected automated vehicle
CTL	certification test lab
CV2X	cellular vehicle-to-everything
FHWA	Federal Highway Administration
GPS	global positioning system
HRDO	Office of Operations Research and Development
IP	internet protocol
NTCIP	National Transportation Communications for Intelligent Transportation Systems Protocol
PC	personal computer
PoE	power-over-Ethernet
RSE	roadside equipment
RSU	roadside unit
SAE	Society of Automotive Engineers
SPaT	signal phase and timing
SSH	secure shell
STOL	Saxton Transportation Operations Laboratory
TFHRC	Turner-Fairbank Highway Research Center
UDP	user datagram protocol
UPER	unaligned packet encoding rules
USDOT	United States Department of Transportation

Test Plan Approvals

Coordination and Approvals

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The signatures below constitute approval of this plan.

Deb Curtis ***Project Manager***	***(Date)***	*(Name)* ***(Title)***	***(Date)***

Chapter 1. Introduction

Background

The United States Department of Transportation's (USDOT) connected vehicle program aims to improve safety, enhance mobility, and reduce the environmental footprint of our transportation systems through connected vehicle technology. In support of that goal, the Federal Highway Administration (FHWA) Office of Operations Research and Development (HRDO) performs transportation operations and research and development (R&D) at the Saxton Transportation Operations Laboratory (STOL), established at the Turner-Fairbank Highway Research Center (TFHRC).

Connected transportation systems use connected vehicle (CV) technology to link vehicles and mobile devices to each other, to transportation infrastructure, and to the larger communication infrastructure requiring trusted communications and interoperability. The USDOT is assessing services and applications that realize the full potential of connected vehicles, travelers, and infrastructure to enhance current operational practices and transform future surface transportation systems. To realize this potential, connected vehicle equipment and applications must meet minimum performance requirements; conform to common technical standards, guidelines, and specifications; and interoperate with one another. Certification testing provides a formal means of verifying that a device, application, or service conforms to these requirements.

The successful deployment and operation of connected vehicle systems will require that devices, systems, and applications developed by different providers are compatible, interoperable, non-interfering, and in some instances, perhaps, interchangeable. Some devices, systems, and applications, such as active safety applications, may be required to meet minimum operational performance standards. A list of questions was distributed to potential stakeholders to gather information on which aspects of the industry should be considered for certification. The results were compiled and consolidated into a list of recommendations that yielded three applications to be addressed under this project. This document contains the test plan and test design for one of the three applications.

Test Scope

The scope of the test cases in this document is to evaluate a signal phase and timing (SPaT) generation device output over available technology and test the format, structure, and encoding of the SPaT message. Society of Automotive Engineers (SAE) J2735 standard governs the SPaT format and structure. The message is represented in the Abstract Syntax Notation One (ASN.1) format, which is UPER Hex encoded for broadcast. The scope for testing includes various mandatory data elements and their corresponding values and verification of the various format conversions.

Items and Features to Be Tested

The test considers three major processes and data structures for effective testing:

1. Input: SPaT data elements (e.g., time stamps and intersection state list).
2. Processing: ASN.1 format.
3. Output: UPER Hex encoded payload.

The following functional areas will be evaluated:

1. Verify completeness of critical elements of SPaT data according to SAE J2735 National Transportation Communications for Intelligent Transportation Systems Protocol (NTCIP) 1202 v03, or another available Signal Status object to ASN.1 {J2735 (SPaT) message format} verification.
2. Verify accuracy of SPaT data (i.e., values of all critical elements of SPaT data that will be encoded to a SPaT message should be identical to the data source, such as SPaT data elements from the traffic signal controller).
3. Verify ASN.1 {J2735 (SPaT) message format} to UPER Hex encoding. The ASN.1 structure will be verified based on the SAE J2735 2016 ASN.1 document. This document includes information about the various message sets, data frames, and data elements. The encoded message is a representation of the ASN.1 message. This message can be back-converted to ASN.1 to compare with the various elements at the previous stage. The UPER message may be obtained as a log on the roadside unit (RSU) or middleware before broadcast. It may also be obtained using a test tool to capture the packets transmitted over the available technology. An UPER to ASN.1 decoder may be used to convert the captured packets to the ASN.1 format for verification.

Analysis and Report Findings

The test conductors will analyze the test results and prepare a test report for each vendor and submit the report to the vendor. These reports provide guidance to vendors regarding implementations that either meet or partially meet the requirements evaluated as part of this test. These reports should not, in any way, serve as official approval, confirmation, or certification by the USDOT.

Upon request, the test conductors may also support briefings with the vendor to explain the results. The test conductors may also support information exchange and collaboration on the recommended next steps.

Test Objective

The primary objective of this document is to describe the process for certifying and evaluating implementations of SAE J2735 SPaT messages. The testing agency will be able to test the messages through various stages of message creation. Certification will be used as a procurement tool for connected vehicle (CV) device deployers.

Chapter 2. Test Environment

Tests will be conducted at a certification test laboratory (CTL), such as OmniAir and its affiliates. This test is designed for the SAE J2735 SPaT message set; it will include testing of various elements starting with the signal status data input used to build the UPER Hex output by linking the various stages to the J2735 message set directory.

Test Environment Requirements

To conduct tests, each test environment must have the following configuration and equipment:

- A power source appropriate to the device under test (DUT).
- An optional global positioning system (GPS) signal to provide location and system time. GPS can be provided by:
    - Access to the open sky.
    - GPS repeater (license may be required).
    - GPS simulator (time synchronization is required across all testing devices for accuracy).
- Network backhaul to allow connection to the hardware that includes the SPaT application.
- Physical or virtual traffic signal controller.
- Laptop with internet protocol (IP) packet sniffer and UPER converter.
- Test tool to log encoded packets over the available wireless technology.

Qualification Criteria

Qualification is determined at the various stages of testing. This will determine that the message is converted in the correct format while maintaining the mandatory standards and fields. Each value will be checked that it is within the acceptable range, as stated in the standards documents. A CTL is expected to have sufficient resources (e.g., equipment; personnel with related expertise) to complete all tests identified in this test plan.

Chapter 3. Test Schedule, Personnel, and Documentation

This section contains a high-level test schedule, required personnel to execute tests, and a description of several documents to record test activities and results.

Test Schedule

Table 1 lists the anticipated activities for the evaluation process after a device is admitted to the certification testing process. These activities are required for each vendor under test.

Table 1. Test activities.

ID	Activity	Estimated Duration
1	Initial hardware inspection	1 day
2	Initial configuration to operate in the applicable test environment	1 day
3	Full evaluation	2 weeks
4	Document results and submit final report	1 week

Personnel

The required number and qualifications of staff to complete testing activities will depend on the organization. Table 2 lists the staff anticipated to complete the activities in the estimated duration shown in table 1.

Table 2. Test personnel.

Title	Minimum Number
Test director/manager	1
Test conductor	1
Test operator	1–2
Roadside equipment technology expert	1
Vendor representative	1 per vendor
Test observers	As desired

Test Director (Quality Assurance Manager)

The test director supervises and controls all tests, reviews and approves test procedures, has authority to direct all test activities, and is responsible for communicating test status to all stakeholders. The test director notifies key stakeholders of the test schedule in advance of the scheduled start.

Test Conductor

The test conductor is responsible for running the daily test activities and remains in contact with vendors, as needed, to communicate which tests are being run and receive support input during testing. The test conductor distributes test scripts, forms, and any other pertinent information, and answers questions.

Throughout the test day, the test conductor verifies that entrance criteria have been met for each test run, verifies readiness of test participants and equipment, and announces the start and end of each testing period. The test conductor also ensures other participants execute tests according to procedures. At all times, the test conductor is responsible for judging how to proceed if incidents or exceptions occur and canceling and rescheduling tests in the event a failure prevents a test from being executed.

At the end of the test period, the test conductor will write up the results of various test runs completed and any incidents or exceptions that occurred. The status report will be provided to relevant stakeholders.

Test Operator

The test operator defines and executes test procedures to evaluate each device and records the outputs and overall results of each test.

Roadside Equipment Technology Expert

The technology expert has extensive knowledge of the technology under test. This includes the use cases, underlying and enabling technologies, communication protocols, data transfer mechanism(s), and security. The technology expert advises the test conductor, as needed.

Vendor Representative

The vendor representative supports the test conductors and test operators during all testing phases, as required. Support is provided in person or remotely. A representative of the vendor of each device being certified should be involved in the testing.

Test Observers

Test observers witness test runs at the certification test lab's (CTL) discretion.

Note: Some roles can be combined such that a single person assumes up to two roles (i.e., the test conductor can also be the test operator).

Documentation

Test Records

Specific test information, including test environment, test execution, and attendees/participants/observers, are captured for each individual test. Each requirement evaluated will be marked with a P or an F, indicating success (pass) or failure (fail). All failures, work-arounds, and deviations from procedure are recorded in a comments section of the form. These entries are entered electronically during test execution.

Risks and Mitigation

Risks include product risks and project risks. Product risks include possible misunderstandings or errors in implementation; these may be expected since the standard is newly released. These risks may be mitigated by accepting from reputable manufacturers devices whose primary functionalities have gone through other qualification testing or have been used in the field. Project risks include a lack of trained staff due to new and evolving test tools, rigid deadlines, and changing industry standards and requirements. This may be mitigated by using test tools, and other equipment, that has good documentation for beginners.

Chapter 4. Test Case Specification

This section contains information about individual test case specifications used to certify and evaluate if a roadside equipment (RSE) can provide critical and necessary Society of Automotive Engineers (SAE) J2735 signal phase and timing (SPaT) message objects for the target connected vehicle (CV) applications.

General Test Environment Setup

Chapter 2 presented the minimum device requirements for executing the below test cases. Figure 1 shows a general test environment setup. A physical or virtual wireless broadcasting device under test (DUT) must be compatible with the SAE J2735 standard messages. A personal computer (PC) is needed to conduct all test cases. A user-preferred packet capture (.pcap decoder) tool, like Wireshark, is expected to be installed on this PC. (Note: this document uses Wireshark as an example to illustrate test procedures. This does not indicate the authors endorse Wireshark.)

The following steps are necessary to configure the wireless broadcasting device and logging computer before conducting test cases described in this document:

- Configure DUT:
  - Power on the device using Power-over-Ethernet (PoE) or other available power source.
  - Connect to the device under test using an Ethernet/Wi-Fi connection.
  - Use one of the following methods for data capture based on the functions available for the DUT:
    i. Configure the device to log the encoded SAE J2735 SPaT messages on the DUT, to be accessed by the logging device.
    ii. Forward the SPaT messages to the Ethernet interface pointing to the internet protocol (IP) address of the logging device.
    iii. Use a packet capture tool over the available wireless technology to be able to capture and log the packets for further analysis on the device.
- Configure PC:
  - Power on the PC.
  - Configure the DUT using secure shell (SSH) or other available communication method to enable logging of encoded SAE J2735 SPaT Message packets using any of the three methods mentioned in the section above.
  - Configure a software package that can monitor and collect data on the target communication layer, or decode logged .pcap files for analysis (e.g., Wireshark).
- Configure time source:
  - Ensure that the DUT and the control/logging device are synchronized using a common time source. This may be done by synchronizing one with the other, or by synchronizing to a third source, such as a global positioning system (GPS).
- Decode message:

- Decode the encoded SAE J2735 SPaT message before checking for mandatory fields.
- Use any of the below methods to decode the message:
    i. Configure the packet capture device to decode the SAE J2735 user datagram protocol (UDP) packet to unpack the various layers and decode the payload.
    ii. Use an available Abstract Syntax Notation One (ASN.1) or other convertor, to convert the encoded payload to an object value defining output for analysis.

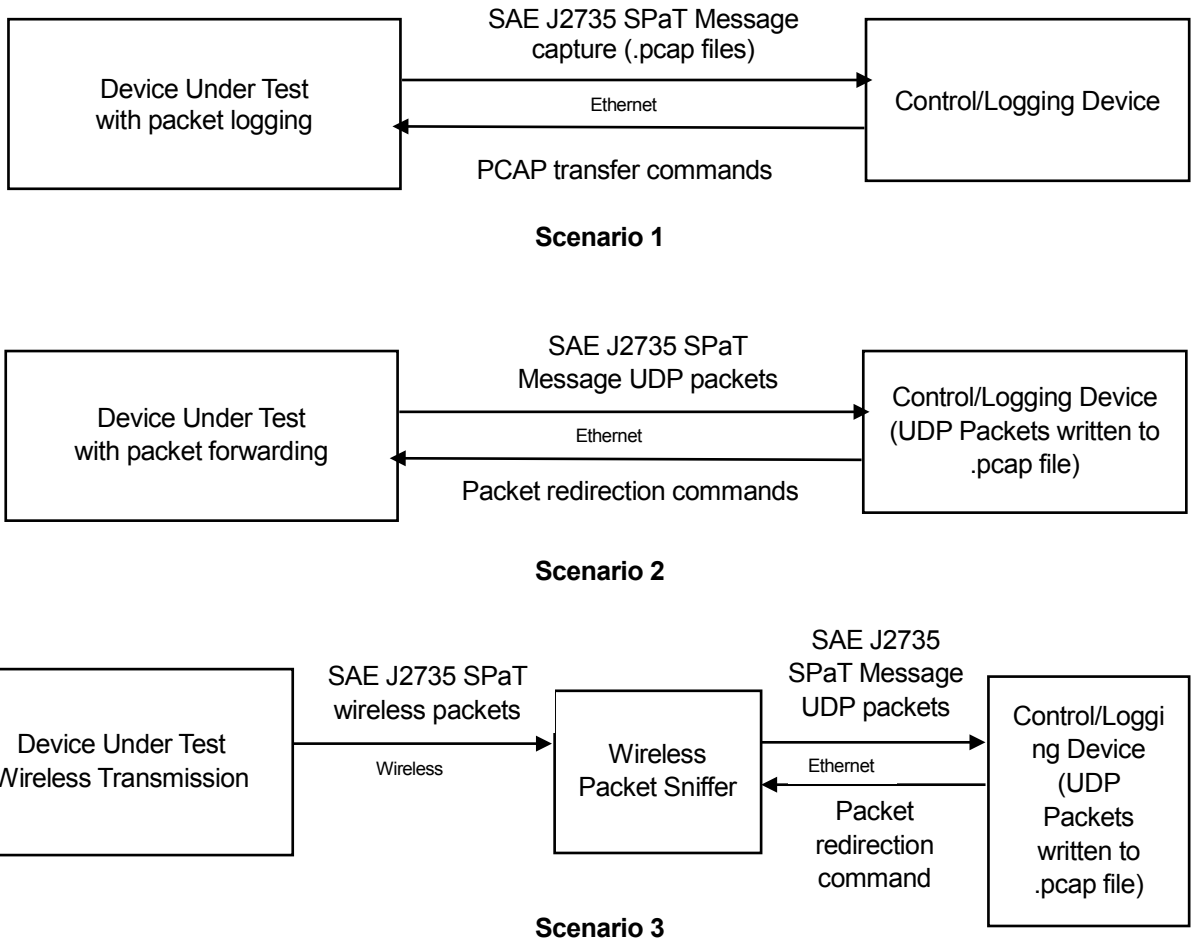

Figure 1. Diagram. Typical test environment setup.

Source: *Federal Highway Administration*

DUT can be any physical or virtual device that builds SPaT messages according to the J2735 standard. After configuring the DUT, logging computer, and, alternatively, the wireless packet capture device, any two devices communicating through the Ethernet interface must be connected within a subnet by using an Ethernet cable or a network switch. The test operator must ensure communication between two devices are properly set up. The wireless interface of the device under test is the preferred method for collecting the output data.

Timestamp Verification

The test cases in this section evaluate if the timestamp in the SPaT message broadcast from the RSE matches the RSE system timestamp.

Table 3. Timestamp agrees with system time.

Test Case #	**TIMING-01**
Test Case	**Timestamp Agrees with System Time**
Reference	*SAE J2735 2016: Section 5.13*
Objective	Users can verify whether the timestamp embedded in the SPaT message broadcast from the RSE agrees with the timestamp on the system
Entrance Criteria	The RSE under test complies with SAE J2735 2016
Data Inputs	SPaT message logging device IP address with listening port configured by the user
Data Outputs	SPaT messages contained in the .pcap file on the user's computer after conversion from the encoded SPaT message logs
Exit Criteria	Timestamp is within 50 milliseconds of the system time and the results are documented
Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message. • The test operator configures the test PC to receive the encoded SPaT messages. • The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to check the presence of a timestamp in the J2735 SPaT message. • The test operator then logs the SPaT message in the logging computer along with the timestamp from a GPS source. • The time from the decoded SPaT message is then compared with the GPS time at logging.

Signal Groups Verification

The test cases in this section evaluates if the correct number of signal groups are included in the SPaT message broadcast from the RSE.

Table 4. Signal groups verification.

Test Case #	**SIGNALS-01**
Test Case	**Signal Groups Verification**
Reference	*SAE J2735 2016: Section 7.171*
Objective	Users can verify the correct number of signal groups are included in the SPaT message broadcast from the RSE

Test Case #	SIGNALS-01
Test Case	**Signal Groups Verification**
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	SPaT message logging device IP address with listening port configured by the user along with the user SPaT application input configuration for cross-existence
Data Outputs	SPaT messages contained in the .pcap file on the user's computer after conversion from the encoded SPaT message logs
Exit Criteria	Number of signal groups in the SPaT message broadcast is verified and the results are documented
Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message. • The test operator configures the test PC to receive the encoded SPaT messages. • The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to check the presence of signal groups in the SPaT message. The number of signal groups should be equivalent to the number of phases set up in the physical or virtual traffic signal controller. • The acceptable values for the number of signal groups are: • Integer (0..255). • The test operator repeats the test with an invalid input, and verifies that an invalid output is not produced.

Field Existence

The test cases in this section evaluates if the mandatory fields exist in the SPaT message generated by the RSE.

Table 5. Name (DescriptiveName) existence (optional field).

Test Case #	EXIST-01
Test Case	**Name (DescriptiveName) Existence**
Reference	*SAE J2735 2016: Section 6.37, 7.29*
Objective	Users can verify the name field exists in the SPaT message broadcast from the RSE
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	SPaT message logging device IP address with listening port configured by the user
Data Outputs	SPaT messages contained in the .pcap file on the user's computer after conversion from the encoded SPaT message logs
Exit Criteria	Each SPaT message contains an intersection name field (optional)

Test Case #	EXIST-01
Test Case	**Name (DescriptiveName) Existence**
Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message. • The test operator configures the test PC to receive the encoded SPaT messages. • The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to check the presence of a name value.

Table 6. RegionId existence.

Test Case #	EXIST-02
Test Case	**RegionId Existence**
Reference	*SAE J2735 2016: Section 5.1, 7.151*
Objective	Users can verify the RegionId exists in the SPaT message broadcast from the RSE
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	SPaT message logging device IP address with listening port configured by the user
Data Outputs	SPaT messages contained in the .pcap file on the user's computer after conversion from the encoded SPaT message logs
Exit Criteria	Each SPaT message contains a RegionId
Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message. • The test operator configures the test PC to receive the encoded SPaT messages. • The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to check the presence of a RegionId value.

Table 7. id (IntersectionID) existence.

Test Case #	EXIST-03
Test Case	**id (IntersectionID) Existence**
Reference	*SAE J2735 2016: Section 6.36, 7.56*
Objective	Users can verify the id field exists in the SPaT message broadcast from the RSE
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	SPaT message logging device IP address with listening port configured by the user
Data Outputs	SPaT messages contained in the .pcap file on the user's computer after conversion from the encoded SPaT message logs
Exit Criteria	Each SPaT message contains an id

Test Case #	EXIST-03
Test Case	**id (IntersectionID) Existence**
Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message. • The test operator configures the test PC to receive the encoded SPaT messages. • The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to check the presence of an id value.

Table 8. revision (MsgCount) existence.

Test Case #	EXIST-04
Test Case	**revision (MsgCount) Existence**
Reference	*SAE J2735 2016: Section 6.37, 7.104*
Objective	Users can verify the revision field exists in the SPaT message generated by the RSE
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	SPaT message logging device IP address with listening port configured by the user
Data Outputs	SPaT messages contained in the .pcap file on the user's computer after conversion from the encoded SPaT message logs
Exit Criteria	Each SPaT message contains a revision field
Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message. • The test operator configures the test PC to receive the encoded SPaT messages. • The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to check the presence of a revision value.

Table 9. status (IntersectionStatusObject) existence.

Test Case #	EXIST-05
Test Case	**status (IntersectionStatusObject) Existence**
Reference	*SAE J2735 2016: Section 6.37, 7.57*
Objective	Users can verify the status exists in the SPaT message broadcast from the RSE
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	SPaT message logging device IP address with listening port configured by the user
Data Outputs	SPaT messages contained in the .pcap file on the user's computer after conversion from the encoded SPaT message logs

Test Case #	EXIST-05
Test Case	**status (IntersectionStatusObject) Existence**
Exit Criteria	Each SPaT message contains a status field
Test Procedures	• The test operator configures DUT to produce and transmit the encoded SPaT message. • The test operator configures the test PC to receive the encoded SPaT messages. • The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to check the presence of a status value.

Table 10. signalGroup existence.

Test Case #	EXIST-06
Test Case	**signalGroup Existence**
Reference	*SAE J2735 2016: Section 6.53, 7.171*
Objective	Users can verify the signalGroup exists for each lane in the SPaT message broadcast from the RSE
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	SPaT message logging device IP address with listening port configured by the user
Data Outputs	SPaT messages contained in the .pcap file on the user's computer after conversion from the encoded SPaT message logs
Exit Criteria	Each lane of the SPaT message contains a signalGroup
Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message. • The test operator configures the test PC to receive the encoded SPaT messages. • The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to check the presence of a signalGroup value for each lane in the SPaT message.

Table 11. eventState (MovementPhaseState) existence.

Test Case #	EXIST-07
Test Case	**eventState (MovementPhaseState) Existence**
Reference	*SAE J2735 2016: Section 6.51, 7.103*
Objective	Users can verify the eventState field exists for each lane in the SPaT message broadcast from the RSE
Entrance Criteria	RSE under test complies with SAE J2735 2016

Test Case #	EXIST-07
Test Case	**eventState (MovementPhaseState) Existence**
Data Inputs	SPaT message logging device IP address with listening port configured by the user
Data Outputs	SPaT messages contained in the .pcap file on the user's computer after conversion from the encoded SPaT message logs
Exit Criteria	Each lane of the SPaT message contains an eventState
Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message. • The test operator configures the test PC to receive the encoded SPaT messages. • The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to check the presence of an eventState value for each lane in the SPaT message.

Table 12. minEndTime existence.

Test Case #	EXIST-08
Test Case	**minEndTime Existence**
Reference	*SAE J2735 2016: Section 6.134, 7.194*
Objective	Users can verify the minEndTime exists for each lane in the SPaT message broadcast from the RSE
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	SPaT message logging device IP address with listening port configured by the user
Data Outputs	SPaT messages contained in the .pcap file on the user's computer after conversion from the encoded SPaT message logs
Exit Criteria	Each lane of the SPaT message contains a minEndTime
Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message. • The test operator configures the test PC to receive the encoded SPaT messages. • The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to check the presence of a minEndTime value for each lane in the SPaT message.

Table 13. maxEndTime existence.

Test Case #	EXIST-09
Test Case	**maxEndTime Existence**
Reference	*SAE J2735 2016: Section 6.134, 7.194*

Test Case #	EXIST-09
Test Case	**maxEndTime Existence**
Objective	Users can verify the maxEndTime exists for each lane in the SPaT message broadcast from the RSE
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	SPaT message logging device IP address with listening port configured by the user
Data Outputs	SPaT messages contained in the .pcap file on the user's computer after conversion from the encoded SPaT message logs
Exit Criteria	Each lane of the SPaT message contains a maxEndTime
Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message. • The test operator configures the test PC to receive the encoded SPaT messages. • The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to check the presence of a maxEndTime value for each lane in the SPaT message.

Input Verification

The test case specifications in this section evaluate whether mandatory fields in the SPaT message broadcast from the RSE match with the input.

Table 14. name (DescriptiveName) input verification.

Test Case #	VERIFY-01
Test Case	**name (DescriptiveName) Input Verification**
Reference	*SAE J2735 2016: Section 6.37, 7.29*
Objective	Users can verify the name field in the SPaT message broadcast from the RSE matches with the input
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	Encoded SPaT message and parallel listening port configured by the user for the SPaT-message-generating device
Data Outputs	Data received from the SPaT-message-generating device and a report verifying the value associated with the name field by comparing the encoded SPaT message logs to the SPaT data obtained on the listening port
Exit Criteria	Intersection name in the SPaT message broadcast is verified with the input and the results are documented

Test Case #	VERIFY-01
Test Case	**name (DescriptiveName) Input Verification**

Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message.
	• The test operator configures the test PC to receive the encoded SPaT messages.
	• The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to compare the name value with the SPaT configuration file.
	• The acceptable values are:
	  • DescriptiveName: <String> of length 1..63.
	• The test operator repeats the test with the following values:
	  • Lowest acceptable value.
	  • Highest acceptable value.
	  • Value within acceptable range.
	  • Value outside of range.
	A list of recommended values to be tested is available in appendix A.

Table 15. RegionId input verification.

Test Case #	VERIFY-02
Test Case	**RegionId Input Verification**
Reference	*SAE J2735 2016: Section 5.1, 7.151*
Objective	Users can verify the RegionId in the SPaT message broadcast from the RSE matches with the input
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	Encoded SPaT message and parallel listening port configured by the user for the SPaT-message-generating device
Data Outputs	Data received from the SPaT-message-generating device and a report verifying the value associated with RegionId by comparing the encoded SPaT message logs to the SPaT data obtained on the listening port
Exit Criteria	RegionId in the SPaT message broadcast is verified with the input and the results are documented
Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message. • The test operator configures the test PC to receive the encoded SPaT messages. • The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to compare the RegionId value with the SPaT configuration file. • The acceptable values are:

Test Case #	VERIFY-02
Test Case	**RegionId Input Verification**

	• RegionId: integer (0..255).
	• The test operator repeats the test with the following values:
	  • Lowest acceptable value.
	  • Highest acceptable value.
	  • Value within acceptable range.
	  • Value outside of range.
	A list of recommended values to be tested is available in appendix A.

Table 16. id (IntersectionID) input verification.

Test Case #	VERIFY-03
Test Case	**id (IntersectionID) Input Verification**
Reference	*SAE J2735 2016: Section 6.36, 7.56*
Objective	Users can verify the id value in the SPaT message broadcast from the RSE matches with the input
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	Encoded SPaT message and parallel listening port configured by the user for the SPaT-message-generating device
Data Outputs	Data received from the SPaT-message-generating device and a report verifying the value associated with the id field by comparing the encoded SPaT message logs to the SPaT data obtained on the listening port
Exit Criteria	id in the SPaT message broadcast is verified with the input and the results are documented

Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message.
	• The test operator configures the test PC to receive the encoded SPaT messages.
	• The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to compare the id value with the SPaT configuration file.
	• The acceptable values are:
	  • IntersectionID: integer (0..65535).
	• The test operator repeats the test with the following values:
	  • Lowest acceptable value.
	  • Highest acceptable value.
	  • Value within acceptable range.
	  • Value outside of range.
	A list of recommended values to be tested is available in appendix A.

Table 17. revision (MsgCount) verification.

Test Case #	**VERIFY-04**
Test Case	**revision (MsgCount) Verification**
Reference	*SAE J2735 2016: Section 6.37, 7.104*
Objective	Users can verify the revision field in the SPaT message broadcast from the RSE matches with the input
Entrance Criteria	RSE under test complies with SAE J2735 2016 standard and the revision field exists
Data Inputs	Encoded SPaT message and parallel listening port configured by the user for the SPaT-message-generating device
Data Outputs	Data received from the SPaT-message-generating-device and a report verifying the value associated with message count by comparing the encoded SPaT message logs to the SPaT data obtained on the listening port
Exit Criteria	revision in the SPaT message broadcast is verified with the input and the results are documented
Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message. • The test operator configures the test PC to receive at least 257 encoded SPaT messages. • The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to verify the value contained in the revision field is monotonically increasing, except when the value rolls over, and within the acceptable range. • The acceptable values are: • MsgCount: integer (0..127).

Table 18. status (IntersectionStatusObject) input verification.

Test Case #	**VERIFY-05**
Test Case	**status (IntersectionStatusObject) Input Verification**
Reference	*SAE J2735 2016: Section 6.37, 7.57; NTCIP 1202 v03*
Objective	Users can verify the status field in the SPaT message broadcast from the RSE matches with the input
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	Encoded SPaT message and parallel listening port configured by the user for the SPaT-message-generating device

Test Case #	VERIFY-05
Test Case	**status (IntersectionStatusObject) Input Verification**
Data Outputs	Data received from the SPaT-message-generating device and a report verifying the value associated with status by comparing the encoded SPaT message logs to the SPaT data obtained on the listening port
Exit Criteria	status in the SPaT message broadcast is verified with the input and the results are documented

Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message.
	• The test operator configures the test PC to receive the encoded SPaT messages.
	• The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to compare the status value with the SPaT configuration file.
	• The acceptable values are:
	  • IntersectionStatusObject: Bitstring (SIZE(16)).
	• The test operator repeats the test with the following values:
	  • Lowest acceptable value.
	  • Highest acceptable value.
	  • Value within acceptable range.
	  • Value outside of range.
	A list of recommended values to be tested is available in appendix A.

Table 19. signalGroup input verification.

Test Case #	VERIFY-06
Test Case	**signalGroup Input Verification**
Reference	*SAE J2735 2016: Section 6.53, 7.171; NTCIP 1202 v03*
Objective	Users can verify the signalGroup for each lane in the SPaT message broadcast from the RSE matches with the input
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	Encoded SPaT message and parallel listening port configured by the user for the signal-status-generating device
Data Outputs	Data received from the SPaT-message-generating device and a report verifying the value associated with signalGroup by comparing the encoded SPaT message logs to the SPaT data obtained on the listening port
Exit Criteria	signalGroup for each lane in the SPaT message broadcast is verified with the input and the results are documented
Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message.

Test Case #	VERIFY-06
Test Case	**signalGroup Input Verification**

	• The test operator configures the test PC to receive the encoded SPaT messages.
	• The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to compare the signalGroup value for each lane with the SPaT configuration file.
	• The acceptable values are:
	  • SignalGroupID: integer (0..255).
	• The test operator repeats the test with the following values:
	  • Lowest acceptable value.
	  • Highest acceptable value.
	  • Value within acceptable range.
	  • Value outside of range.
	A list of recommended values to be tested is available in appendix A.

Table 20. eventState (MovementPhaseState) input verification.

Test Case #	VERIFY-07
Test Case	**eventState (MovementPhaseState) Input Verification**
Reference	*SAE J2735 2016, section 6.51, 7.103; NTCIP 1202 v03*
Objective	Users can verify the eventState value for each lane in the SPaT message broadcast from the RSE matches with the input
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	Encoded SPaT message and parallel listening port configured by the user for the signal-status-generating device
Data Outputs	Data received from the SPaT-message-generating device and a report verifying the value associated with eventState by comparing the encoded SPaT message logs to the SPaT data obtained on the listening port
Exit Criteria	eventState for each lane in the SPaT message broadcast is verified with the input and the results are documented
Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message. • The test operator configures the test PC to receive the encoded SPaT messages. • The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to compare the eventState value for each lane with the SPaT input from the physical or virtual traffic signal controller. • The acceptable values are: • MovementPhaseState: integer (0..9). • The test operator repeats the test with the following values:

Test Case #	VERIFY-07
Test Case	**eventState (MovementPhaseState) Input Verification**
	• Lowest acceptable value. • Highest acceptable value. • Value within acceptable range. • Value outside of range. A list of recommended values to be tested is available in appendix A.

Table 21. minEndTime input verification.

Test Case #	VERIFY-08
Test Case	**minEndTime Input Verification**
Reference	*SAE J2735 2016: Section 6.134, 7.194; NTCIP 1202 v03*
Objective	Users can verify the minEndTime for each lane in the SPaT message broadcast from the RSE matches with the input
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	Encoded SPaT message and parallel listening port configured by the user for the signal-status-generating device
Data Outputs	Data received from the SPaT-message-generating device and a report verifying the value associated with minEndTime by comparing the encoded SPaT message logs to the SPaT data obtained on the listening port
Exit Criteria	minEndTime for each lane in the SPaT message broadcast is verified with the input and the results are documented

Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message.
	• The test operator configures the test PC to receive the encoded SPaT messages.
	• The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to compare the minEndTime value for each lane with the SPaT input from the physical or virtual traffic signal controller.
	• The acceptable values are:
	  • TimeMark: integer (0..36000).
	  • Invalid value: integer (36001).
	• The test operator repeats the test with the following values:
	  • Lowest acceptable value.
	  • Highest acceptable value.
	  • Value within acceptable range.
	  • Value outside of range.
	A list of recommended values to be tested is available in appendix A.

Test Case #	VERIFY-08
Test Case	**minEndTime Input Verification**
	Note: This value indicates the one-tenth of a second within the current hour or next hour at which the phase will change. For example, a value of 7200 represents 12 minutes past the hour. If the current time were 11:10, it would convert to 11:12. If the current time were 11:15, it would convert to 12:12.

Table 22. maxEndTime input verification.

Test Case #	VERIFY-09
Test Case	**maxEndTime Input Verification**
Reference	*SAE J2735 2016: Section 6.134 & 7.194; NTCIP 1202 v03*
Objective	Users can verify the maxEndTime for each lane in the SPaT message broadcast from the RSE matches with the input
Entrance Criteria	RSE under test complies with SAE J2735 2016
Data Inputs	Encoded SPaT message and parallel listening port configured by the user for the signal-status-generating device
Data Outputs	Data received from the SPaT-message-generating device and a report verifying the value associated with maxEndTime by comparing the encoded SPaT message logs to the SPaT data obtained on the listening port
Exit Criteria	maxEndTime for each lane in the SPaT message broadcast is verified with the input and the results are documented

Test Procedures	• The test operator configures the DUT to produce and transmit the encoded SPaT message.
	• The test operator configures the test PC to receive the encoded SPaT messages.
	• The test operator uses the converted SAE J2735 SPaT message in the ASN.1 or other human readable format to compare the maxEndTime value for each lane with the SPaT input from the physical or virtual traffic signal controller.
	• The acceptable values are:
	  • TimeMark: integer (0..36000).
	  • Invalid value: integer (36001).
	• The test operator repeats the test with the following values:
	  • Lowest acceptable value.
	  • Highest acceptable value.
	  • Value within acceptable range.
	  • Value outside of range.
	A list of recommended values to be tested is available in appendix A.
	Note: This value indicates the one-tenth of a second within the current hour or next hour at which the phase will change. For example, a value of 7200 represents 12 minutes past

Test Case #	VERIFY-09
Test Case	**maxEndTime Input Verification**
	the hour. If the current time were 11:10, it would convert to 11:12. If the current time were 11:15, it would convert to 12:12.

Appendix A. Test Values for SPaT Fields

Field Under Test	Lowest Acceptable Value	Highest Acceptable Value	Within Acceptable Range	Outside Range/Invalid Value	Negative Invalid Value
name (DescriptiveName)*	0	127	64	129	-1
RegionId	0	255	128	256	-1
id (IntersectionID)	0	65535	32768	65536	-1
revision (MsgCount)	0	127	64	129	-1
status (IntersectionStatusObject)	0b0000000000000000 (0)	0b0011111111111111 (16383)	0b0000000100000000 (256)	0b0100000000000000 (16384)	0b1000000000000000 (32768)
signalGroup	0	255	128	256	-1
eventState (MovementPhaseState)	0	9	5	10	-1
minEndTime	0	36001	18000	36002	-1
maxEndTime*	0	36001	18000	36002	-1

*Indicates field is optional

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