Coaxial Cable Assembly Test and Validation Procedure

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. The purpose of this specification is to qualify coaxial cable assemblies, and the process that produces them, for use on General Motors vehicles. The list will include, but not necessarily be limited to, the following systems:

- Amplitude Modulation (AM) (530 kHz to 1710 kHz).
- Frequency Modulation (FM) (76.0 MHz to 107.9 MHz).
- OnStar®/Navigation/Mobile Phone/Wi-Fi.
  - Mobile and Wi-Fi (452.5 MHz to 3600 MHz).
  - Global Positioning System (GPS) and Global Navigation Satellite System (GLONASS) (1574.4 MHz to 1607 MHz).
- XM Satellite Radio (2332.5 MHz to 2345.0 MHz).
- Digital Audio Broadcast (DAB).
  - L-Band (1452 MHz to 1492 MHz).
  - DAB III (174 MHz to 240 MHz).
- Vehicle Information and Communication System (VICS).
  - FM Multiplex Broadcast (76 MHz to 90 MHz).
  - Radio Beacon (2.5 GHz and 5.8 GHz).
- Dedicated Short Range Communications (DSRC) (5.850 GHz to 5.930 GHz).

This document specifies requirements and test procedures for verification of coaxial cable assembly performance for all General Motors vehicles marketed and sold around the world. In this document, a coaxial cable assembly is defined as one or more coaxial cables terminated on both ends with Radio Frequency (RF) connectors.

1.2 Applicability. This procedure is applicable to the development and validation of cable assemblies for new vehicle programs as well as design changes for current vehicles. This document applies to passenger vehicles, light duty trucks, and medium duty trucks.

1.3 Remarks. The requirements stated in this document supercede all Component Technical Specifications (CTS), Subsystem Technical Specifications (SSTS), and Vehicle Technical Specifications (VTS) that pertain to coaxial cable assemblies for the systems defined in 1.1. However, the required tests may be increased, reduced or modified to accommodate unique program requirements that may arise.

1.4 Connector and Raw Coax Pre-qualification Requirements. RF connectors constituent to coaxial cable assemblies submitted for scrutiny by this procedure shall be chosen from the most recent GM Approved Connector List and satisfy the requirements of USCAR2, USCAR17, GMW3191 and any other requirements deemed applicable by GM Engineering. Access to the GM Approved Connector List is to be provided by GM Engineering upon request.

Additionally, raw coax constituent to coaxial cable assemblies submitted for scrutiny by this procedure shall have successfully satisfied the test requirements of USCAR29.

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1.4.1 Additional Notes.

1.4.1.1 Connectors and coaxial cables with a history of successful use on GM vehicles, prior to the release of this document, are exempt from proof of compliance to GMW3191 and USCAR29 respectively. However, exemption status shall be requested of, and granted exclusively by GM Engineering.

1.4.1.2 It is the responsibility of the cable assembly supplier to provide proof of compliance to the 1.4.1.1 requirements.

1.4.1.3 Additional information relevant to USCAR29 is contained in Appendix B, Table B1 of this document.

1.4.1.4 Coaxial cable types recommended for the systems referenced in 1.1 are outlined in Appendix C, Table C1.

1.4.1.5 Additional requirements are outlined in Appendix D.

Note: This document is one of a series of antenna and vehicle reception documents, which specify antenna and reception test and validation requirements. The complete series consists of the following documents: GMW15650, GMW15649, GMW16261, GMW16273, GMW15648, GMW17201, and GMW16039.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

DIN 72594-1	MIL-STD-1344A	USCAR17	USCAR29
ISO 17025	USCAR2	USCAR25	

2.2 GM Standards/Specifications.

GMW3172	GMW15649	GMW16261
GMW3191	GMW15650	GMW16273
GMW15648	GMW16039	GMW17201

2.3 Additional References.

- Component Technical Specifications (CTS).
- GM Approved Connector List.
- Subsystem Technical Specifications (SSTS).
- Vehicle Technical Specifications (VTS).

3 Resources

3.1 Facilities. The Component Under Test (CUT) shall be tested at a facility containing the equipment outlined in 3.2.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment. External calibration laboratories that are accredited to ISO 17025 shall be used to calibrate applicable equipment that is used for the testing outlined in this procedure.

3.2.1 Connector Mating/Unmating Forces.

3.2.1.1 Connector mating/unmating testing requires an insertion/extraction force tester capable of 1.0% accuracy, full scale.

3.2.2 Connector Drop Test.

3.2.2.1 A test fixture and concrete slab drop surface as described in MIL-STD-1344A, Method 2015 are required.

3.2.3 Connector to Connector Audible Click.

3.2.3.1 A decibel meter with a resolution of ± 1.5 dB and the capability of both "A" and "C" scale measurements.

3.2.4 Connector Mechanical Pull.

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3.2.4.1 Connector mechanical pull requires a continuity tester capable of monitoring both inner and outer conductors and an insertion/extraction force tester.

3.2.5 Isolation Resistance (Single Cavity and Multi-Cavity Connectors).

3.2.5.1 Isolation resistance shall be measured with a precision mega-ohmmeter capable of 500 V Direct Current (DC) measurements.

3.2.6 Contact Resistance.

3.2.6.1 Static Measurement. This requirement shall be verified by measurement with a four-wire system using Kelvin clips, operating at 1 kHz, with immunity to ground currents (≤ 5 mΩ difference), and with 1.8 m (minimum) test leads. For example, a Tegam Model 253 Impedance Meter meets these requirements.

3.2.6.2 Dynamic Measurement. Dynamic measurement of contact resistance for connectors requires the following equipment:

- Custom printed circuit boards (PCB) as defined in Appendix A. Although Fachkreis Automobil (Experts Automobile) (FAKRA) connectors are shown, other types of connectors may be substituted.
- A PCB test mount that provides suitable clearance for a mating harness to be connected. In addition, the mount will allow the mated pair to be pulled at the angles and forces outlined in Appendix A.
- A force tester capable of a minimum 45 N pull force, and force versus time measurements with a resolution of 0.1 N and 0.1 s, respectively. This data will be available in graphical and raw data format.
- A milliohm meter as defined in 3.2.6.1.

3.2.7 Dielectric Withstanding Voltage.

3.2.7.1 This test requires a high voltage source capable of providing 800 V Alternating Current (AC).

3.2.8 Standing Wave Ratio (SWR) and Insertion Loss (IL).

3.2.8.1 SWR and IL measurement requires a 6 GHz (minimum) network analyzer capable of time domain based S-Parameter measurements.

3.2.9 Tri-temperature Functional Tests.

3.2.9.1 Tri-temperature testing requires a thermal chamber capable of maintaining temperatures ranging from 40 °C to at least +110 °C, and 0% to 95% Relative Humidity (RH). Additionally, equipment previously referenced will be required, as used for SWR and IL, inner and outer conductor resistance, and isolation resistance.

3.2.10 Visual Inspection.

3.2.10.1 Cameras, video recorders and magnification apparatus are required to perform and document visual inspections.

3.3 Test Vehicle/Test Piece. The CUT shall be in a production ready state, off production tooling. The CUT is comprised of any of the following: A 150 mm test sample, a single coax with single connectors on either end, two (or more) coaxes with single, dual, or tri-connectors on either end, or a combination of those options. In addition to production intent coax and connectors, all production intent clips, tapes, etc., will also be represented on CUTs, where applicable.

3.4 Test Time. Test times are dependent upon GM Validation Engineering assessments of GMW3172 applicability and will be determined on a case-by-case basis.

3.5 Test Required Information. The minimum test information shall contain the cable assembly manufacturer, the type of CUT (coax, clip and connector type(s)), date of manufacture, and date tested. If a GM 8-digit part number has been assigned, it should be used to identify the CUT when applicable.

3.6 Personnel/Skills. Test personnel shall have a working knowledge of spectrum analyzers, network analyzers, test receivers, milliohm meters, coaxial cables, and other RF connectors and equipment. A working knowledge of computers and data spreadsheets is also required.

4 Procedure

4.1 Preparation. All test equipment shall be turned on for a minimum of 15 minutes before any CUT measurements begin. Additionally, connectors shall be conditioned by being mated and unmated ten times prior to testing. Subminiature Version A (SMA) connectors, when utilized, (e.g., for SWR measurements) may be mated and unmated no more than a total of 100 times.

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4.2 Conditions.

4.2.1 Environmental Conditions. Equipment and CUT should be at a room temperature of +23 °C ± 5 °C (+73 °F ± 9 °F), and a relative humidity of 25% to 75%, unless otherwise specified.

4.2.1.1 GMW3172 Code Letter Sequence.

This section (4.2.1.1) establishes the environmental conditions that the vehicle may experience during its intended life within its target market. The commodity and all of its components shall meet the requirements of GMW3172. This requirement indicates the characteristics and requirements for environmental testing including, but not limited to, Temperature, Vibration, and Moisture. See 5.5 for information on validation requirements.

Code descriptions for GMW3172 General Specification for Electrical/Electronic Component Environmental and Durability test are shown in Table 1.

Table 1: GMW3172 Code Letter Sequence

Characteristic	Code Letter
Electrical Load	C
Mechanical Load	G
Operating Temperature Range	C
Climatic Loads	D
Chemical Loads	B
Dust and Water Protection	IP5K2

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.2.3 Test Sequence. The tests defined in the following sections shall be tested per the test matrix outlined in Appendix E, Figure E1.

4.3 Instructions.

4.3.1 Connector Mating/Unmating Forces.

4.3.1.1 The procedure and test sample definition to be utilized for this test is documented in USCAR2 (Connector-Connector Mating/Unmating Force section). Seven samples shall be tested.

4.3.2 Connector Drop Test.

4.3.2.1 The procedure to be utilized for this test is documented in MIL-STD-1344A, Method 2015, utilizing test samples as defined therein. Both male and female connector halves are to be tested. Additionally, samples shall be tested to the moderate service class. Ten samples (five (5) of each gender) of each connector type are required, and each sample will be dropped from 1.219 m (4 ft) and from 2.438 m (8 ft) as defined. However, only four (4) drops shall be performed at each height with a rotation of 90° between successive drops.

Note: One of the four (4) drops at each height shall be oriented such that the surface containing secondary locks, clip slots, etc., contacts the concrete slab.

4.3.3 Connector to Connector Audible Click.

4.3.3.1 Two sets of tests are required for audible click. The first test set shall adhere strictly to the test outlined in USCAR2 (Connector-to-Connector Audible Click section). The supplier may submit the connector supplier's results for this initial test. In addition, an additional test shall be performed per USCAR2 within ambient sound levels of 30 dB (A) to 50 dB (A). However, the test samples will consist of mated pairs on each end of a 1 m length of every type of coax being validated. This test shall be performed for all connector types as well. For example, straight connectors, right angled connectors and two-way connectors are to be combined with every type of coax being validated. Sample sizes shall consist of three (3) of each combination of coax/connector being tested.

4.3.4 Connector Mechanical Pull.

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4.3.4.1 The procedure and test sample definition to be followed for mechanical pull testing is outlined in USCAR17 (Mechanical Pull section). Seven samples are required for testing

4.3.5 Isolation Resistance (Single and Multi-cavity Connectors).

4.3.5.1 Test samples shall consist of a mated pair of connectors (five (5) samples of each connector/coax combination being validated) with equal lengths of coax on each side such that the resultant combination measures 150 m +0/-5 m. This shall apply to single and multi-cavity connectors. Strip the coax jacket, braid and dielectric in a staggered manner such that inner and outer conductor are accessible, but electrically isolated, on both sides of the mated pair. Measure and record resistance(s) between every inner conductor and every other outer (and inner) conductor present in the coax/connector combination being measured. This test shall apply to all coax types; e.g., RG58 LL, RG174 LL, etc.

4.3.6 Contact Resistance.

4.3.6.1 Static Measurement: The test sample description and procedure to be followed to determine inner and outer contact resistance is outlined in USCAR17 (Contact Resistance section). Five samples are required.

4.3.6.2 Dynamic Measurement.

a. **Test Samples.** Ten identical samples as defined in Appendix A, Figure A3 are required. Appendix A shows FAKRA connectors, but other connectors may be substituted. All samples shall utilize RG58 LL coax featuring a solid center conductor. The minimum length of measurement samples shall be 150 mm. The ten samples shall be grouped into five sets (or pairs) of two samples each. During testing, the sample pair shall be mounted to opposite sides of the PCB, as defined in Appendix A. One sample from the pair shall be dynamically manipulated (target sample) while the other sample (measurement sample) simply provides an interface for the measurement equipment on the opposite side of the PCB as shown in Appendix A. It is variation in the target sample's resistance that will be measured during testing. All samples will contain a label identifying the connector manufacturer and type, test position on the PCB, and shall be defined as either target or measurement sample. For example: Amphenol FAKRA Gen 3.0, PCB sample 2, target sample.

b. **Test Sample Mounting.** Each sample pair (measurement and target sample) shall be mated to opposing, electrically common, board mounted connectors on the test PCB. The test PCB shall be properly mounted to withstand the pull forces associated with the testing and also provide clearance sufficient to allow pulls on various angles.

c. **Measurement Connection(s).**
   1. Pull Test Method 1 Connection - The impedance meter's Kelvin clips should be firmly attached to the ferrules of the targeted test pair as shown in Appendix A, Figure A2 for resistance monitoring via the outer conductor crimps.
   2. Pull Test Method 2 Connection - Alternately, the target sample may have its outer and inner conductors mechanically joined (or soldered) so that they are electrically common. The Kelvin clips can then be attached to the inner and outer conductor of the measurement sample such that the total resistance of both samples' coaxes, contacts, and crimps will be monitored.

d. **Measurement Procedures.** Before the application of any force, (for either test method), a static measurement shall be taken and recorded for use as a baseline comparison.
   1. Pull Test Procedure - The target sample shall have forces applied in the direction, rate of application and maximum force defined in Appendix A, Figure A2. In each pull direction, the cable's direction of orientation should be perpendicular to the ferrule during the entirety of the 5 s hold period at maximum force. Each measurement test sample will generate three (3) data sets.
   2. Wiggle Test - A second test shall be performed after completion of pull testing. The PCB will be removed from the fixture and the appropriate pigtails reconnected, if unmated, to the corresponding PCB mounted connectors. The milliohm meter will be reconnected and a subjective "wiggle" shall be performed on the target sample while looking for variation in resistance by moving the free end of the coax cable relative to the PCB. The PCB should be held as steady as possible while the coax is moved in an attempt to induce an open circuit or resistance deviation. Testers should earnestly and honestly try to find areas of deviation and should also expect to repeat this test with the assistance of GM Engineering.

4.3.7 Dielectric Withstanding Voltage.

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4.3.7.1 Utilize a mated pair of connectors (five (5) samples of each for all connector types being validated) with equal lengths of coax on each side such that the resulting coax/connector combination shall be 150 mm +0/-5 mm per test sample preparation for SWR and IL in USCAR17. SMA connectors will not be required. Strip jacket, braid and dielectric such that the inner conductor is accessible on one side and the outer conductor is accessible on the opposite side. With the connector engaged, apply 800 V of commercial frequency alternating voltage between the internal and external conductor terminals for 60 s. The test voltage shall be raised from 0 V to the 800 V_{rms} level as uniformly as possible. This test shall apply to all coax types; e.g., RG58 LL, RG174 LL, etc.

4.3.8 Standing Wave Ratio and Insertion Loss.

4.3.8.1 SWR and IL tests are to be performed per USCAR17 (Standing Wave Ratio and Insertion Loss section), utilizing the test samples described therein, over the operating frequency range 0 GHz to 3 GHz looking in to both ports. Cable/connector combinations intended for use in DSRC systems, or other systems operational in the 3 GHz to 6 GHz range, shall also be tested from 3 GHz to 6 GHz. Seven samples shall be tested and the requirement shall be verified by performing 2 port S-parameter measurements using a vector network analyzer (VNA), Agilent E5071C or equivalent. The VNA must be calibrated by performing a 2 port short-open-load-through (SOLT) calibration procedure to correct for any internal error sources. The reference plane of the measurement must be at the connector interface of the test sample.

4.3.9 Tri-temperature Functional Tests.

4.3.9.1 The tests outlined in the following list shall be performed at three (3) different ambient temperatures: Low temperature (-40 °C (-40 °F)), room temperature (+23 °C ± 5 °C (+73 °F ± 9 °F)), and high temperature (+85 °C (185 °F)). Test samples will consist of both CUTs as defined previously in this document and parts as they will appear on GM vehicles. Testing shall begin with room temperature measurements. These initial results are to be recorded and used as baselines for subsequent measurements at extreme temperatures. Samples shall soak a minimum of 30 minutes at extreme temperatures before testing. It is acceptable to remove the test samples from the test chamber to perform the tests at the temperature extremes. However, all attempts should be made to test the samples as soon as possible after removal from the chamber to minimize the sample's temperature deviation from the extreme(s).

a. SWR.
b. Insertion Loss.
c. Inner Conductor DC Resistance.
d. Outer Conductor DC Resistance.
e. Isolation Resistance.
f. Visual Inspection.

Note: Tri-temperature testing when conducted on production intent assemblies, versus connectors with coax stubs terminated with SMA connectors, will require a deviation from the measurement method(s) previously outlined. Testers may have to use adapters (Subminiature Version B (SMB) to SMA) to attach to the connectors on each end of the assembly. As a result, measured values may not mirror the results from strict USCAR17 based testing. Testers are expected to document and explain their test setups in these cases to GM Engineering.

5 Data

5.1 Calculations. Not applicable.

5.2 Interpretation of Results. Not applicable.

5.3 Test Documentation. Not applicable.

5.4 Requirements.

5.4.1 Connector Mating/Unmating Force.

5.4.1.1 Connector mating force requirements are dependent upon the number of contacts included in the connector.

5.4.1.1.1 Single Contact Connectors. The mating force must be ≤ 40 N; the unmating force must be ≤ 35 N with the connector lock disengaged.

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