SAE International

SAE/USCAR-17 REVISION 4	
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(R) PERFORMANCE SPECIFICATION FOR AUTOMOTIVE RF CONNECTOR SYSTEMS

SUMMARY OF CONTENTS

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1.0 SCOPE

1. Procedures included within this specification are intended to cover performance testing at all phases of development, production, and field analysis of electrical terminals, connectors and components for coaxial cable connection systems (hereafter referred to as RF connectors) intended for road vehicle applications.

2. The intent of this specification is to qualify RF connectors that operate at frequencies from 70 MHz to 3 GHz. The characteristic impedance of the SMB/FAKRA connection system is 50 ohms however this specification does not exclude the use of these RF connectors on non-50 ohm cables or systems.

3. This specification does not apply to single conductor wire or twisted pair connection systems.

4. This specification (along with SAE/USCAR 18 and SAE/USCAR 19) is designed to provide the mechanical and electrical data required to insure that assemblies from various manufacturers will perform reliably in actual conditions. There is no specific intermateability testing included, however. End users who may be concerned about intermateability are responsible to work directly with their suppliers to address these concerns.

2.0 REFERENCES

SAE/USCAR-2	Performance Specification for Automotive Electrical Connector Systems
SAE/USCAR-25	Electrical Connector Assembly Ergonomic Design Criteria
SAE/USCAR 18	FAKRA SMB RF Connector Supplement
SAE/USCAR 19	Coaxial Cable Connector Interface ï Square Outer Conductor Society Of Automotive Engineering 400 Commonwealth Dr Warrendale, PA 15096-0001 USA http://www.sae.org
IEC 61726	Cable assemblies, cables, connectors and passive microwave components - Screening attenuation measurement by the reverberation chamber method
MIL-PRF-39012	Performance Specification, Connectors, Coaxial, Radiofrequency, General Specification for
IEC 61196-1	Radio-frequency cables - Part 1: Generic specification - General, definitions, requirements and test methods
IEC 60512-23-3	Electromechanical components for electronic equipment - Basic testing procedures and measuring methods - Part 23-3: Test 23c: Shielding effectiveness of connectors and accessories
DIN-72594-1	Road Vehicles ï 50 OHM Radio Frequency Interface (50 q RFI)
EIA-364-30A	Capacitance Test Procedure for Electrical Connectors and Sockets
ISO 20860-1	Road Vehicles ï 50 OHMS Impedance Radio Frequency Connection System Interface

3.0 GENERAL REQUIREMENTS

3.1 SAMPLE SIZE

1. Terminals used for validation testing are applied to cables using the manufacturers recommended tools and processes.

2. The total number of test samples required for each test is listed in tables 6.6.2 and 6.6.3.

3. Number each sample pair of connectors and record crimp dimensions as applicable from a representative group from each set of samples (See tables 6.6.2 and 6.6.3). Document cable information such as type, supplier and supplier part number. All test data, including swept SWR and IL, must be maintained by the supplier for possible review. The supplier must also keep the test samples such that each new customer can visually inspect the samples or confirm SWR and IL.

3.2 CONNECTOR QUALIFICATION

1. The RF connection system will be qualified for a specific coaxial cable per these procedures. The guidelines in Table 3.2 apply for qualifying the product for use on additional cables sizes and constructions.

Connector Construction (dimensions/materials) same as originally validated. Example: connector for RG 174 vs. RG 316 having same cable interface dimensions	Complete Section 4.2.1 (mechanical Pull) and 4.3 (Terminal Electrical Tests) only and other testing as required by end customer
Connector construction differs from originally validated design due to coax cable size/geometry. Example: connector for RG 174 vs. RG 58 and having different cable interface dimensions.	Complete re-qualification is required

Table 3.2: Connector Qualification for Additional Cable Construction

2. Final determination as the level of testing needed for qualification on additional cables shall be determined by agreement between the supplier and the OEM. The qualified coaxial cable(s) and frequency range of interest must be listed on the connector drawing.

3. This specification is a supplement to the SAE/USCAR-2 Performance Specification for Automotive Electrical Connector Systems and all requirements herein must be met in addition to all requirements of the most recent revision of SAE/USCAR-2, unless otherwise specified. Only RF connector related additions and/or subtractions to the SAE/USCAR-2 specification are contained in this document.

3.3 EQUIPMENT

In addition to the equipment listed in the SAE/USCAR-2 Performance Specification, the equipment listed in Table 3.3 is required.

Item	Description	Requirements
1	High Voltage Source	800V AC
2	Network Analyzer	6GHz Minimum S Parameter w/Time Domain Capability

Table 3.3: RF Conn. Additional Equipment

4.0 TEST AND ACCEPTANCE REQUIREMENTS

4.1 GENERAL

Refer to the SAE/USCAR-2 Performance Specification for the majority of RF connector test and acceptance requirements. The exceptions to those tests are listed in the following sections:

1. The Terminal ï Mechanical Tests of SAE/USCAR-2 are not required for RF connector qualification. The Terminal Bend Resistance test is to be considered as optional dependent on the terminal design and as determined by agreement between the supplier and the OEM.

2. The Maximum Test Current Capability test is optional.

4.2 CONNECTOR MECHANICAL TESTS

4.2.1 Mechanical Pull Test and Sideload Test

4.2.1.1 Purpose

This test verifies that the connector latch, terminal retention system, and cable attachment will maintain continuity when subjected to mechanical stress.

For RF connectors, this Mechanical Pull test is in addition to the mechanical connector tests in SAE/USCAR-2 Performance Specification. This is a stand-alone test and requires samples for each cable type qualified.

Note: This test is a destructive design validation test and shall not be used as a production acceptance or quality control test.

4.2.1.2 Procedure

Prepare Connector Under Test (CUT) assemblies for each cable being qualified per Procedure 4.4.2.2, Steps 1 through 7.

Attach a continuity tester so as to check continuity through both the center contact and shield of the mated connector pair.

In-lines, Board Mount, and Panel Mount connectors:

Subject the connection system to a direct pull force parallel with the axis of the connectors (direction A of Figure 4.2.1.2) by gripping on the SMA connectors (or by attaching a mating SMA connector to the assembly and gripping on that). For the optional samples prepared for SWR measurement, (per 4.4.2.2, Note C) it is also acceptable to wrap the cable around a 2-inch diameter mandrel, securing the cable to the mandrel with electrical tape or some other suitable means. Board mount connectors may have the circuit board end firmly attached to a suitable fixture. Increase the pull force at a uniform rate until the full test force is achieved and then hold the force for 5 seconds while monitoring for continuity. Subject SMB connection systems to 110N force and Square Outer Conductor connection systems to 80N force.

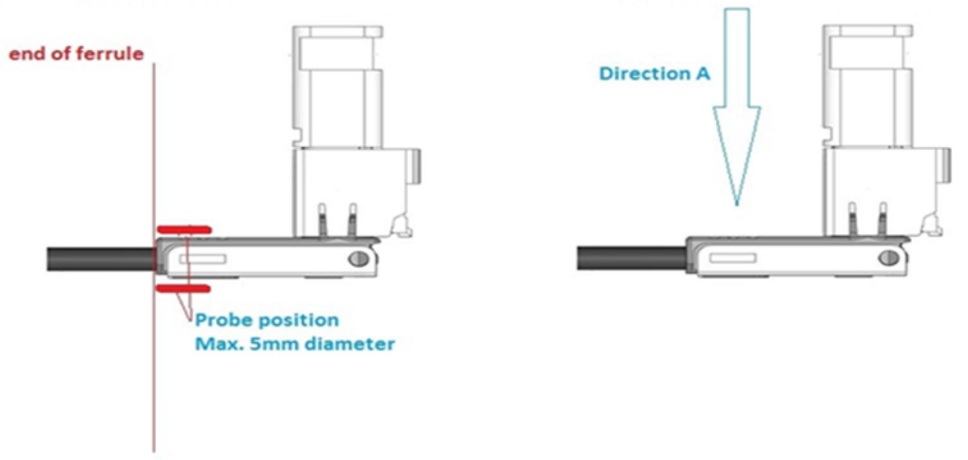
OEM pull test requirements for Square Outer Conductor connector systems may be higher depending on cable size. Prior to conducting this test, always consult with the responsible OEM engineering department for the required acceptance criteria.

Additional Board Mount and Panel Mount only testing:

Again by gripping on the cable side SMA connector, subject the board mount connection system to at least the following directional forces, all at 75N: 1C, 3C, 5B, 7B, 8C (per Figure 4.2.1.2.)

RIGHT ANGLED CABLED CONNECTORS:

Axial loads are less practical when applied to right angle cabled connectors therefore a sideload shall be applied to the extreme end of the ferrule (furthest from the centerline). The load of 75N shall be applied for 5 seconds while monitoring continuity. SWR measurements and visual inspection for damage shall be done before and after the sideload test. (See drawing below)



Note: Cable to connector retention force to meet 110N, but force value adjusted based on strength of cable type used.

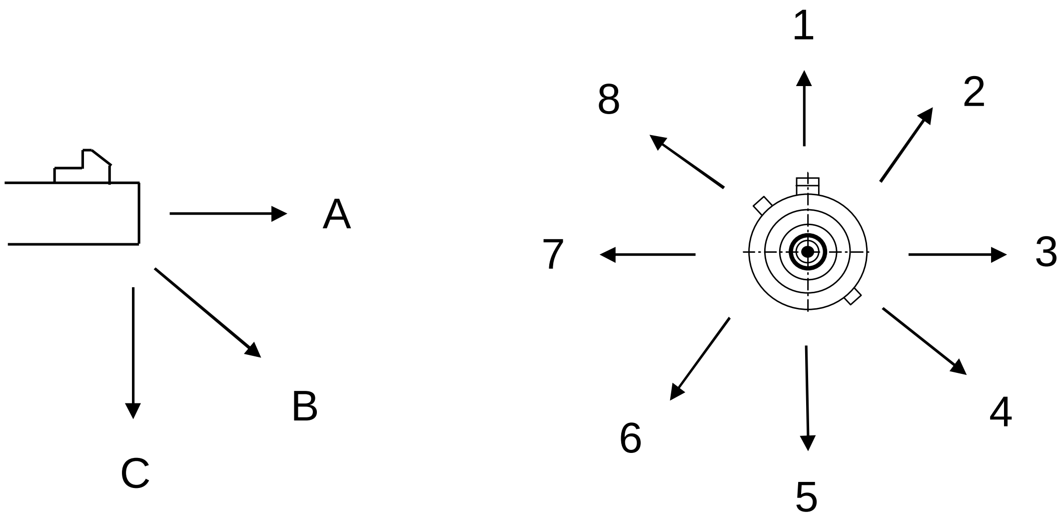


Figure 4.2.1.2: Board Mount Mechanical Pull

1. Measure SWR and IL per Procedure 4.4.2.2, Steps 4, 6, & 7.
2. Disassemble each sample and visually check for damage that could affect the performance of the connection system.

<u>Note</u>:

Optionally, to account for SMA crimp degradation and the corresponding increased insertion loss, a minimum of 10 SMA connector assemblies (same crimp process and length as CUT assembly per Figure 4.4.2.2 1a.) may be subjected to this test (statistical evaluation).

4.2.1.3 Acceptance Criteria

1. There shall be no interruptions in continuity on any sample during the test.
2. The RF connector SWR and Insertion Loss values must be equal to or less than those listed in Tables 4.4.2.3-a and 4.4.2.3-b
3. There shall be no visual damage to any part of the connection system including connector body, metal terminals or cable attachment. Failure of the SMA terminals is not to be interpreted as a failure of the CUT. Samples identified as having SMA failures through failure analysis may be replaced and retested through the entire sequence.

4.2.2 Connector Mating and Un-mating

4.2.2.1 Mating/Un-mating Forces

4.2.2.1.1 Purpose

This test determines the mating/un-mating forces associated with RF connectors.

4.2.2.1.2 Procedure

Follow the procedure for Connector Mating/Un-mating Force found in the latest revision of SAE/USCAR-2. The acceptance criteria are specified in USCAR-25.

4.2.2.1.3 Acceptance Criteria

1. For single contact connectors, the mating force must meet (25N Max.) specified in ISO 20860-1.
2. For multiple contact connectors, USCAR-25 Class 2 acceptance (45N Max.) criteria apply.

4.2.2.2 Mating Under Sideload:

4.2.2.2.1 Purpose

This test is designed to simulate the mating of an 8.0mm centerline dual connector pair when the cables are constrained at an angle perpendicular to the mating direction of the connectors.

4.2.2.2.2 Equipment

Wedge shown in Appendix B

4.2.2.2.3 Procedure

There are two sections to this test. The first section is designed to validate the female connector and the second section validates the male connector. Perform the test on 5 sets of constrained female connectors and 5 sets of constrained male connectors.

Female Connector Constrained

1. Attach the wedge to the Dual Female HD FAKRA Connector in the manner shown in Figure 4.2.2.2.3.A
2. Secure the housing of the Dual Female HD FAKRA using the intended Clip Provision and typical mounting clip.
3. Mate the pair, measure and record the Center & Outer Contact Resistance.
4. Attach a continuity monitoring device to each connection point (both Outer & Inner contacts).
5. Grasp the mating Male connector by the housing only leaving the coaxial leads unrestricted. Mate the Male connector to the stationary Female connector 10 times. Continuity must be detected during each mating cycle.
6. Leave the pair mated, measure and record the Center & Outer Contact Resistance.
7. Visually inspect both interfaces for damage.

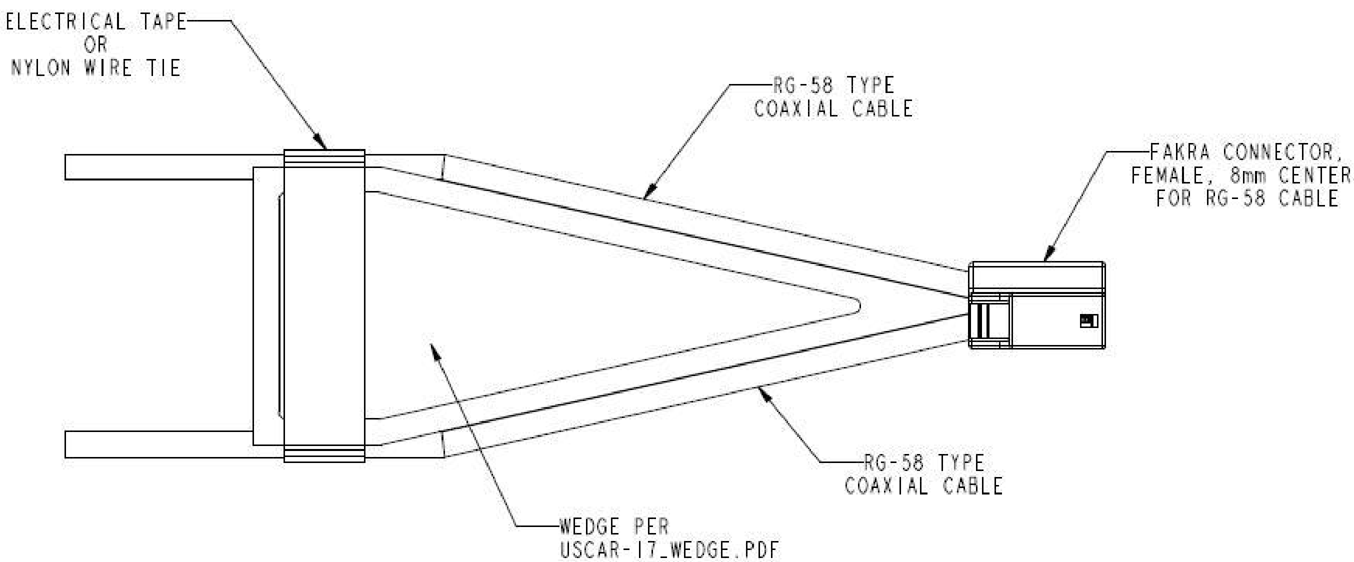


FIGURE 4.2.2.2.3.A Female Connector with Wedge

Male Connector Constrained

1. Attach the Wire Tie around the cables of the Dual Male HD FAKRA Connector approx. 12.7mm from the end of the ferrules in the manner shown in Figure 4.2.2.2.3.B.
2. Secure the housing of the Dual Female HD FAKRA using the intended Clip Provision and typical mounting clip. Leave the coaxial leads of the Female connector unrestricted.
3. Mate the pair, measure and record the Center & Outer Contact Resistance.
4. Attach a continuity monitoring device to each connection point (both Outer & Inner contacts).
5. Grasp the mating Male connector by the housing with the coaxial leads constrained with the Wire Tie. Mate the Male connector to the stationary Female connector 10 times. Continuity must be detected during each mating cycle.
6. Leave the pair mated, measure and record the Center & Outer Contact Resistance.
7. Visually inspect both interfaces for damage.

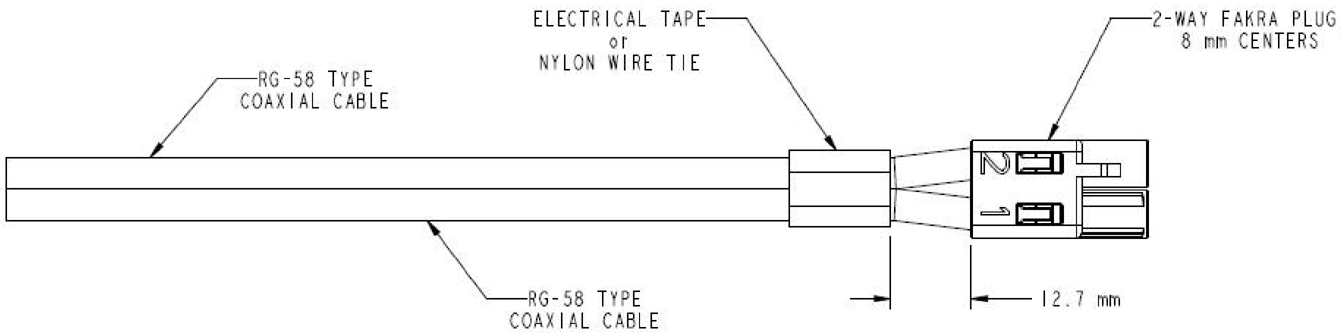


FIGURE 4.2.2.2.3.B Male Connector Constrained

4.2.2.2.4 Acceptance Criteria

The mated connectors must meet the electrical values specified in Section 4.3.1.3.

4.2.3 Polarization Feature Effectiveness

4.2.3.1 Purpose

This test prevents mating of a connector housing with any unintended mate.

4.2.3.2 Procedure

Follow the procedure of SAE/USCAR-2 ñPolarization Feature Effectivenessò with the following exceptions:

1. Test a minimum of 3 sets for each selected mis-orientation or mis-index.
2. Terminals with electrical access to the center conductor are required to be loaded in each connector of each test pair to allow verification of continuity.

4.2.3.3 Acceptance Criteria

1. For single contact SMB connection systems, the minimum mis-mating force to achieve **center contact** electrical continuity is 80N. It is known that certain key code combinations may not meet this requirement. Therefore, the combinations listed below should be avoided.
   a. A & B
   b. I & G
   c. C & N
   d. F & H
   e. K & L
   f. K & M
   g. L & M
2. The ñZò or Neutral Key Code may not mate with L, M, or N Key Codes and should be used solely for developmental or prototype applications.
3. For multiple contact SMB connection systems, the minimum mis-mating force to achieve **center contact** electrical continuity is 100N.
4. For Square Outer Conductor connection systems, SAE/USCAR-2 acceptance criteria apply.

4.2.4 Connector-to-Connector Audible Click Test:

4.2.4.1 Purpose

Studies show that assembly plant technicians depend on audible queues that indicate full seating of electrical connectors regardless of background noise. This test measures the level of noise generated when two connectors are mated. Connectors are mated by hand for this test rather than being clamped into a fixture which could suppress or amplify the sound.

4.2.4.2 Equipment

dB meter

4.2.4.3 Procedure

8 sample pairs are required. Samples are to be production intent. All connector cavities shall be filled with wires and terminals of any size appropriate to the CUT. Include all TPA´s, seals, stuffers and auxiliary pieces as applicable.

1. Measure and record the dB (C) level of the ambient sound within the test environment. The ambient noise level must be 60 dB (C) maximum.

2. Locate the sound measuring device or microphone 600+/-50 mm from the connector.

3. Mate the connectors by hand and measure the dB (C) level of the sound generated as the lock engages. Do not bias the connectors toward or away from the latch as they are engaged.

4. Repeat Steps 1 through 3 using moisture conditioned parts. Parts are brought to their practical limit of moisture content by exposing "dry as molded parts" to 95- 98% Relative Humidity at 40°C for 6 hours (minimum), then completing the test within 30 minutes.

4.2.4.4 Acceptance Criteria

The minimum sound level required shall be 67 dB (C) for un-conditioned parts and 65 dB (C) for conditioned parts.

4.2.5 CENTER CONTACT RETENTION

4.2.5.1 Purpose

The purpose of this test is to assure that the center contact is sufficiently captivated within the insulator to withstand forces exerted by excessive mating forces as well as thermal expansion and contraction of the cable and connector.

4.2.5.2 Equipment

Force Gauge

4.2.5.3 Procedure

Use standard production tooling to terminate 10 male connector samples for each wire size specified.

Allow the samples to stabilize at room temperature (25° C) for a minimum of 24 hours to allow the dielectric materials to cold flow around contact retention features.

Measure the maximum force required to completely extract the center contact from the dielectric material on 5 samples.

Measure the actual force required to push the center contact below the minimum dimensional limits of the manufacturers recommended interface for the other 5 samples.

4.2.5.4 Acceptance Criteria

In both tests, the center contact must withstand an axial load of 10 N minimum.

4.3 TERMINAL ELECTRICAL TESTS

4.3.1 Contact Resistance

4.3.1.1 Purpose

This test determines the electrical resistance of both the outer conductor contact interface and the inner conductor contact interface under low energy conditions.

For RF connectors, this Contact Resistance test replaces the Dry Circuit Resistance testing in the SAE/USCAR-2 Performance Specification.

4.3.1.2 Procedure

Follow the Dry Circuit Resistance procedure in the latest SAE/USCAR-2 Performance Specification. Since gaining access to the inner conductor may damage the outer conductor, the millivolt lead locations need not follow the SAE/USCAR-2 Performance Specification. Subtract the cable resistance portion from the measured value.

4.3.1.3 Acceptance Criteria

The total connection resistance of the inner conductor must not exceed 40 mΩ. Likewise, the total connection resistance of the outer conductor must not exceed 40 mΩ. For AM/FM applications, the center conductor resistance must not exceed 24 mq, the outer conductor resistance must not exceed 5mq initially, and 6mq after environmental testing.

4.3.2 Dielectric Withstanding Voltage

4.3.2.1 Purpose

The dielectric withstanding voltage test is used to demonstrate that the connection can withstand momentary over-potentials due to switching, surges, and other similar phenomena. It serves to determine whether insulating materials and spacings in the connector are adequate.

For RF connectors, this Dielectric Withstanding Voltage test replaces the Current Cycle testing in the SAE/USCAR-2 Performance Specification

4.3.2.2 Procedure

With the connector engaged, apply 800 volts of commercial frequency alternating voltage between the internal and external conductor terminals for 60 seconds. The test voltage shall be raised from 0 to the 800V (rms) as uniformly as possible.

4.3.2.3 Acceptance Criteria

There must be no dielectric breakdowns.

4.4 CONNECTOR ELECTRICAL TESTS

4.4.1 Isolation Resistance

4.4.1.1 Purpose

This test verifies that the electrical resistance between the center contact and the outer contact will prevent detrimental electrical conductivity.

For RF connectors, this Isolation Resistance test replaces the Isolation Resistance testing in the SAE/USCAR-2 Performance Specification.

4.4.1.2 Procedure

Follow the Isolation Resistance procedure in the latest SAE/USCAR-2 Performance Specification as it pertains to the center conductor and outer conductor of the RF connector.

4.4.1.3 Acceptance Criteria

The center contact to outer contact resistance shall be $\geq$100 MΩ.

4.4.2 Standing Wave Ratio and Insertion Loss

4.4.2.1 Purpose

This test measures both the mismatch loss between the connector and the cable and the insertion loss through the cable test assembly at the frequencies of interest. The SWR is equal to 1 when the cable impedance is perfectly matched to the connector. The insertion loss for an ideal connection system with no loss is 0 dB. Only the SWR will be measured for board mount connectors, however, the Insertion Loss of the corresponding in-line must also meet specification to qualify the board mount connector in question.

For RF connectors, Standing Wave Ratio/Insertion Loss testing replaces the Nominal Current Resistance (Voltage Drop) test in the SAE/USCAR-2 Performance Specification.

4.4.2.2 Procedure

1. The following minimum sample sets should be prepared for each segment of environmental testing per SAE/USCAR-2.

   In-Line Connectors:

      Prepare samples with SMA connectors (See Note E) to the preferred length, as shown in Figure 4.4.2.2-1a. The overall length of the leads shall be 100-150mm (See Note F) less the length due to insertion of the CUT. (Sample length tolerance is +0/-5 mm)

   Board Mount Connectors:

      Prepare samples with SMA connectors (See Note E) to the preferred length as shown in Figure 4.4.2.2-1c.

2. Perform a full 2 port Time Domain Calibration (low pass step response recommended).

3. For in-lines only, measure/record the S_{21} parameter (transmitted power in dB) of each SMA connector assembly (Figure 4.4.2.2-1a) over the frequency range listed in Table 4.4.2.3-b. Affix a CUT in the middle of each of these assemblies allowing the sample length to increase to 100-150 (See Note F) +0/-5 overall. (Figure 4.4.2.2-1b. shows the preferred length).

4. For in-lines only, measure the S_{21} parameter of the CUT assembly and subtract the corresponding SMA connector assembly's S_{21} value. This is the net Insertion Loss of each CUT.

5. For in-lines only, prepare one additional sample with the overall length of 500+0/-5mm when the CUT is engaged. Determine the start gate and stop gate of just the CUT within this additional sample using the S_{11} TDR plot, creating a gate span in pico-seconds.

6. For in-lines only, set the gate span determined in step 5 and place the gate center in the "electrical middle" of each CUT sample (See Note C below for optional SWR sample preparation). Measure the SWR for all samples over the frequency range listed in Table 4.4.2.3-a.

7. For board mount connectors, determine the start gate and stop gate of just the CUT within a sample using the S_{11} TDR plot, creating a gate span in pico-seconds. Measure the gated SWR of the CUT for all samples over the frequency range listed in Table 4.4.2.3-a.

8. Completely un-mate and mate each sample a total of 10 times and leave them mated.

9. Repeat steps 4, 6 and 7.

Note:

Alternative measurement methods are acceptable. Record equipment details, test parameters and test method in the test report.

<u>Notes</u>:

A. The SMA connectors should be protected during environmental exposure with a mating connector or plug.

B. Optionally, to account for SMA insertion loss degradation due to environmental exposure, a minimum of 10 SMA connector assemblies (same crimp process and length as CUT assembly (fig.4.4.2.2-1a)) may be prepared for each segment of environmental exposure (statistical evaluation). The statistical data from these assemblies is to be used as reference for determining the net Insertion Loss of each CUT.

C. Optional in-line SWR samples: To optimize SWR results by improving gating accuracy and providing improved isolation of the SMA test connectors, additional samples may be used solely for SWR measurements. Prepare these samples per 4.4.2.2, Step 5.

D. Optional, a completely separate set of samples may be used for VSWR testing. It is acceptable to build these CUT's at 500 +0/-5mm as shown in Para. 4.4.2.2, Step 5.

E. The VSWR of each SMA connector shall be verified to be less than 1.15:1 to reduce the potential "masking" effects on the VSWR & Insertion Loss measurements of the CUT.

F. The nominal length of the sample shown in Figure 1a can range from 100-150mm however it is imperative that all the samples are within +0/-5mm of the nominal value selected and all the CUT's are held within +0/-5mm of the nominal value selected as shown in Figure 1b.

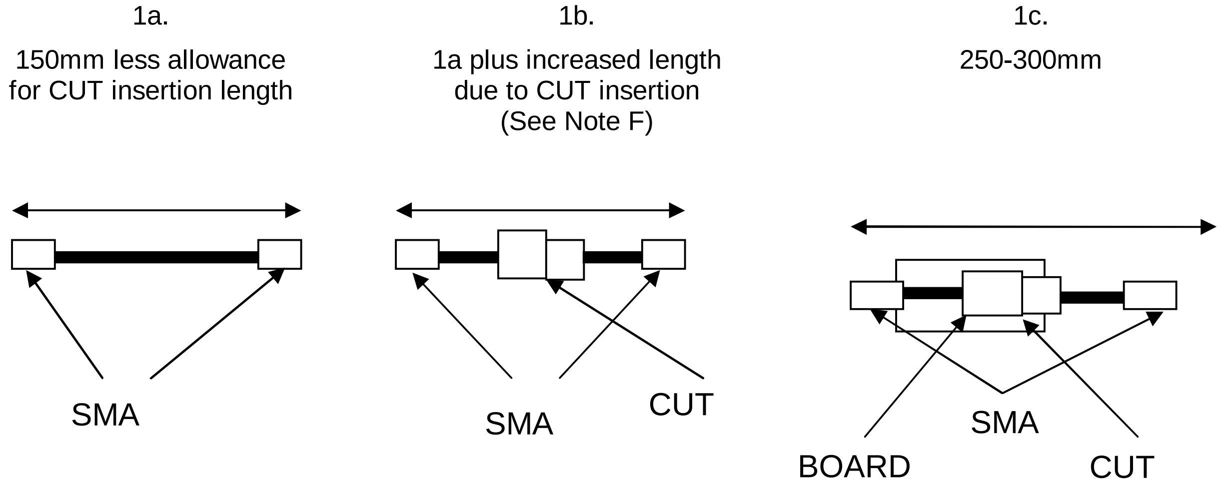


Figure 4.4.2.2: SWR Test Sample

4.4.2.3 Acceptance Criteria

The RF connector maximum SWR and insertion loss values are shown in Tables 4.4.2.3-a and 4.4.2.3-b.

Note:

These are maximum acceptable values. Specific applications may dictate lower values. Actual test data must be available for OEM evaluation against system requirements.

RF Connector Type	Max. SWR [freq.]
Square Outer Conductor, EWCAP	1.35 [0 - 1 GHz] 1.60 [1 - 2 GHz]
SMB 3GHz, FAKRA	1.40 [0 - 2 GHz] 1.50 [2 - 3 GHz]
SMB 0.5GHz	1.35 [0 - 0.5 GHz]
FAKRA AM/FM	1.20 [70-200 MHz]

Table 4.4.2.3-a: Maximum SWR Values

RF Connector Type	Max. Insertion Loss in dB [freq.]
Square Outer Conductor, EWCAP	0.2 [0 - 1 GHz] 0.4 [1 - 2 GHz]
SMB 3GHz FAKRA	0.3 [≤3 GHz]
SMB 0.5GHz	0.25 [≤ 0.5 GHz]
FAKRA, AM-FM	0.15 [70-200 MHz]

Table 4.4.2.3-b: Maximum Insertion loss Values (In-line Connectors only)

4.4.3 RF Leakage

4.4.3.1 Purpose

This test verifies the leakage of RF connectors (sometimes referred to as Shielding Effectiveness), measured in dB.

This is a stand-alone test for in-line connectors only and requires samples for each cable type being qualified. Samples should be made as short as possible to minimize the effects of RF leakage from the coax cable.

4.4.3.2 Procedure

The following procedures are acceptable:

1. IEC 61726 (mode stirrer)
2. MIL-PRF-39012, paragraph 4.7.23 (triax chamber)
3. IEC 61196-1, paragraph 12.6 (matched tri-axial)
4. IEC 60512-23-3 (line injection)
5. IEC 62153-4-7 (Tube in Tube)

4.4.3.3 Acceptance Criteria

SMB connection systems must not exceed -45 dB throughout frequency range. Square Outer Conductor connection systems must not exceed -25 dB throughout frequency range.

4.4.4. Capacitance

4.4.4.1 Purpose:

This procedure is designed to assure a low capacitance interconnect system specifically for AM/FM applications.

4.4.4.2 Procedure:

The capacitance of each connector shall be measured per EIA-364-30A

4.4.4.3 Acceptance Criteria

The capacitance shall not exceed 6.0 pF for in-line devices and 4.0 pF for PCB devices. It is acceptable to subtract the capacitance of a short length of cable (100mm or less) for in-line devices.

4.5 ENVIRONMENTAL TESTS

4.5.1. Thermal Shock Environmental Conditioning

4.5.1.1 Purpose

This conditioning process exposes electrical components to high and low temperature environments. Rapid transfer between the two environments tests the component's ability to withstand drastic temperature changes.

4.5.1.2 Samples:

1. A minimum of 10 samples of each crimp height shall be submitted for test. Data shall be obtained and recorded for minimum, maximum and nominal production crimp heights. Prepare at least 1 additional sample of each crimp height to be used to determine the deduct value as described in steps 4 and 5.

2. A sample length of 150 mm is recommended. However, any sample length ≥75 mm is acceptable as long as there is no effect on the crimped interface during processing and handling of samples. The same dimensions shall be used for all samples under test as well as for the deduct sample.

3. Prepare resistance measurement points on the test samples at a point on the cable 75 ± 3 mm from the rear edge of the terminal conductor grip.

4. Prepare one additional sample with solder applied to the crimped interface. Except for the soldered interface, this sample must be the same in all characteristics as the samples under test. This resistance value of this reference sample will be deducted from the values measured on the samples under test.
   Note: The samples prepared with the soldered interface shall be exposed to the same environmental conditioning as the samples under test.

5. Measure and record the crimped interface resistance on all samples under test:
   The crimped interface resistance is equal to the overall resistance measured in the samples under test less the resistance value measured in soldered deduct sample.

Note: The groups of samples shall be consecutively exposed to the Thermal Shock and Temp/Humidity exposure and the resistance shall be measured by the dry circuit procedure detailed in section 4.3.1.

4.5.1.3 Equipment recommendations

Thermal shock chamber or separate hot and cold chambers.

4.5.1.4 Procedure

1. Set controls to the necessary temperatures, dwell times, and number of cycles.

2. Allow the chambers sufficient time to achieve the programmed temperature.

3. Place the samples in the Thermal Shock conditioning environment.

4. Start the test program per figure 4.5.1.4.

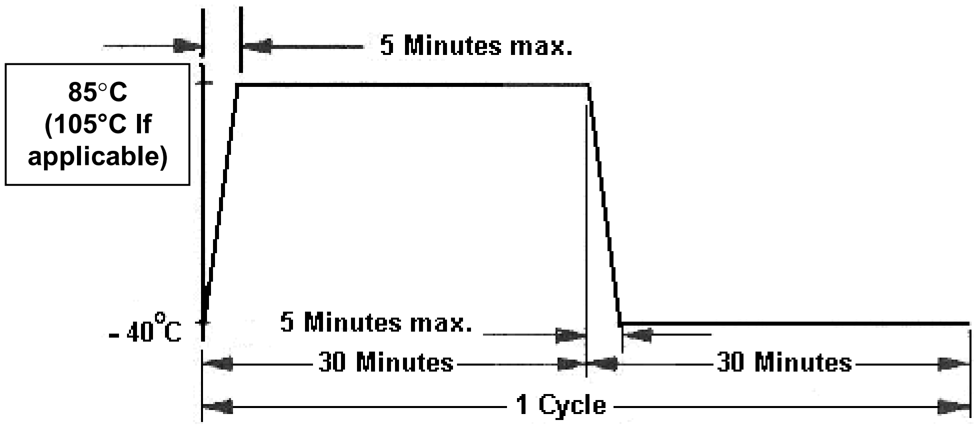


Figure 4.5.1.4: Thermal Shock Programming and Operation

5. When test program is complete, shut off the thermal shock chamber(s) and remove samples.

6. Document environmental exposure.

   Include in the report:
   Operating temperatures, dwell times, and number of cycles tested

4.5.1.5 Acceptance Criteria

The samples shall meet Contact Resistance, VSWR, and Insertion Loss values as shown in Section 4.3 and Section 4.4. These temperature extremes apply to the connector only. Cables are covered as Class 1 or Class 2 per USCAR-2.

4.5.2 Temperature / Humidity Cycle Environmental Conditioning

4.5.2.1 Purpose

1. This conditioning process exposes electrical components to temperature/humidity cycle conditioning.
2. Temperature/humidity cycle conditioning is used to determine the effect of sequential exposure to high humidity and high and low temperature environments on electrical and electronic components. High and low temperature and high humidity environments may promote corrosion of metals, degrade properties of other materials, and establish electrical bridging between circuits.

4.5.2.2 Samples

1. Prepare samples per section 4.5.1.2.

   Note: The groups of samples shall be consecutively exposed to the Thermal Shock and Temp/Humidity exposure and the resistance shall be measured by the dry circuit procedure detailed in section 4.3.1.

4.5.2.3 Equipment recommendations

1. Humidity chamber.

2. Forced air oven.

3. Temperature chamber.

4. Automatic temperature/humidity cycling chamber. This equipment may be used as an alternative to that listed in 1, 2, and 3 above.

4.5.2.4 Procedure

1. Expose samples under test to temperature/humidity cycling as follows:

    a. 0.5 hours @ ï 40 ± 3 °C.

    b. 4.5 hours @ 80-100 percent relative humidity at +80 to 90 °C. This is the only step where humidity is controlled.

    c. 2 hours @ +85 ± 3 °C (+105 °C if applicable).

    (Steps a–c, bracketed: Humidity not controlled)

    d. 1 hour @ +23 ± 3 °C.

    e. This constitutes one complete temperature/humidity cycle (8 hours).

    f. Maximum transfer time of samples from one environment to the next during the defined temperature/ humidity cycle is 1 hour.

    g. All time periods listed in the defined cycle have a tolerance of ± 5 minutes

    h. 40 cycles (320 hours) of the environmental exposure described above constitutes a complete temperature/humidity cycling test.

4.4.4.5 Acceptance criteria:

1. All samples within 3 consecutive crimp heights representing the lower, nominal, and upper specification limits per the stated* conductor crimp height tolerances must satisfy one of the following two acceptance criteria upon completion of environmental conditioning exposure.

    a. <u>Maximum</u> allowable resistance = 0.011 x $(\rho_1+\rho_2)/(2d)$ milliohms.
    (Allows 11 times the initial calculated crimp resistance)

    b. Allowable resistance <u>Change</u> = 0.0099 x $(\rho1+\rho2)/(2d)$ milliohms.
    (Allows 9.9 times the initial calculated crimp resistance)
    Note: The maximum allowable resistance or allowable resistance change requirement must be met before between and after all environmental conditioning and resistance measurement steps.

Where ρ_1 = The resistivity of the conductor in micro-ohm-mm²/mm

Note: For copper conductor, ρ_1 = 17.2 micro-ohm-mm²/mm per the International Annealed Copper Standard)

ρ_2 = The resistivity of the base terminal material in micro-ohm-mm²/mm

d = The diameter of a circle with the same area as the total cross sectional area of the conductor in mm.
$(\rho_1+\rho_2)/2d$ = Theoretical Crimp Resistance based upon geometry and resistivity of terminal and cable.

*Specification established by the supplier and documented in the test plan

4.6 TEST SEQUENCE

Follow the Test Sequence paragraph specified in the SAE/USCAR-2 Performance Specification, replacing all occurrences of those tests listed in Table 4.6.

RF Connector Spec.	SAE/USCAR-2
Section 4.3.1, Contact Resistance	Dry Circuit Resistance
Section 4.3.2, Dielectric Withstanding Voltage	Current Cycling
Section 4.4.1, Isolation Resistance	Isolation Resistance
Section 4.4.2, SWR and Insertion Loss	Nom. Current Resistance (Voltage Drop)

Table 4.6: Test Sequence Replacements

4.6.1 Test Sequence General Notes

1. The sequential test tables in this section are base sequences and may be altered as determined by the Authorized Person.

2. Test sequence is the order in which tests are performed. The sequence should be logical and interrelated in order to accurately establish the performance characteristics of the component or assembly.

3. Numbers in the body of Tables 4.6.2 and 4.6.3 indicate the order in which the tests or conditioning procedures are performed. Where there are duplicate numbers in the same column, the procedures are performed concurrently.

4. Destructive tests should be performed only on samples that are not intended for use in further test sequences.

5. The minimum number of test samples needed for sequential tests is shown at the top of each column. Samples may be re-used for more than one test sequence, but the acceptance requirements remain the same as if separate samples were used.

6. Tables 4.6.2 and 4.6.3 contain test procedures from this document as well as from SAE/USCAR-2, Performance Specification for Automotive Electrical Connector Systems. Paragraph numbers from SAE/USCAR-2 are given for reference only and are listed in their own column. Use the appropriately titled procedure in the event that paragraph numbers do not correspond. Always use the latest revision level of SAE/USCAR-2.

4.6.2 Connector System Mechanical Test Sequences

Per USCAR-2 Reference Paragraph	USCAR-17 Reference Paragraph	Test	Terminal Bend Resistance	Terminal to Connector Engage (w/o TPA)	Terminal to Connector Disengage (w/o TPA)	Terminal to Connector Retention (w/ TPA)	Terminal to Connector Retention (Moisture Conditioned)	Terminal to Connector Retention (After Temp Humidity)	Connector Mating/Unmating	Polarization Effectiveness	Misc. Component Engage/Disengage	Connector-to-Connector Audible Click	Center Contact Retention	Connector Drop Test	Cavity Damage	Connector Mounting Feature Mechanical Strength	Mechanical Pull and Sideload
		Sequence ID	**A**[(1)]	**B**[(2)]	**C**[(2)]	**D**[(2)]	**E**[(2)]	**F**	**G**	**H**	**I**	**J**	**Z**	**K**	**L**[(5)]	**M**	**N**
		Sample Size for tests listed below (minimum)	15	10	10	10	10	[(3)]	10	[(4)]	40	8	10	3	5	20	10[(6)]
	3.1	Crimp Height Measurement	1		1	1	1	1					1				1
5.1.8		Visual Inspection	2,4	1,4	2,4	2,4	2,4	2,5	1,4	1,3	1,3	1,3	2,4	1,3	1,3	1,3	2,6
5.2.2		Terminal Bend Resistance [(1)]	3														
5.4.1		Terminal - Connector Engage / Disengage Force															
		Terminal to Connector Engage (w/o TPA)		2													
		Forward Stop, Push-through Force		3													
		Terminal to Connector Disengage (w/o TPA)			3												
		Terminal to Connector Retention (w/ TPA)				3		4									
		Terminal to Connector Retention (Moisture Conditioned)					3										
5.4.2	4.2.2.1	Connector-Mating/Unmating Forces															
		Connector Engagement Force							2								
		Connector Disengage Force with Lock enabled (5 of the 10 samples)							3								
		Force to disengage Lock (Other 5 of 10 samples)							3								
		Connector Disengage Force with Lock disabled (same 5 of 10 samples as disengage lock)							3								
	4.2.2.2	Mating Under Sideload															
	4.2.2.2.3	Female with Wedge							2								
	4.2.2.2.3	Male with wire tie							3								
5.4.4	4.2.3	Polarization Feature Effectiveness [(4)]								2							
5.1.9		Circuit Continuity Monitoring								2[(7)]							4
5.4.5		Miscellaneous Component Engage/Disengage Force															
		Insert to Lock (assembly) (10 of 40)									2						
		Pre-set to Full Install (10 of 40)									2						
		Full Install to Pre-set (10 of 40)									2						
		Removal (Disengage from mating part)(10/40)									2						
	4.2.4	Connector-to-Connector Audible Click										2					
	4.2.5	Center Contact Retention											3				
5.4.8		Connector Drop Test												2			
5.4.9		Cavity Damage [(5)]													2		
5.6.2		Temperature/Humidity Cycling						3									
5.7.2		Connector Mounting Feature Mechanical Strength														2	
	4.4.2	SWR and Insertion Loss [(6)]															3[(6)],5
	4.2.1	Mechanical Pull Test and Sideload															4

Table 4.6.2: Connector System Mechanical Tests
(See following page for notes)

NOTES:

(1) For center contacts only. This test is optional dependant on the Terminal design and as determined by agreement between the supplier and the OEM. For example Screw Machined designs do not require testing.
(2) All Terminal to Connector tests are to be performed with respect to the terminated coaxial terminals and the housings.
(3) Use Insertion Loss samples from sequence Q for this group.
(4) Sample size (number of each key code required) for Polarization Effectiveness is determined by the following equations:
K = Number of different Key codes to be tested.
S = Number of sample sets tested, (3 is the minimum per 4.2.3.2)
N = Number of each Key code required of each male and female housings.
C = Number of test combinations required.
T = Total number of force measurements to be taken.
N = K*S
C = K*K
T = K*K*S
(5)

Value:	Example 1	Example 2	Comment
K	2	13	Different key codes to be tested
S	3	5	Sets of samples to be tested of each test combination
N	2*3 = 6	13*5 = 65	# of Male and # of Female housings of each of the key codes is required
C	2*2 = 4	13*13 = 169	Combinations are to be tested
T	2*2*3 = 12	13*13*5 = 845	Total test measurements to be made

(6) This test is required only if the connector design provides for the functionality identified by this test.
(7) If the separate optional SWR samples are made (per 4.4.2.2, Note C), then an additional 10 samples are required, 10 IL samples and 10 SWR samples. Note also 10 each SMA ï SMA reference samples are also optional for each of the above.
(8) Only the center contact need be monitored for Polarization Effectiveness testing.

4.6.3 Connector System Electrical / Environmental Test Sequences

USCAR-2 Reference Paragraph	USCAR-17 Reference Paragraph	Test	Vibration/Mechanical Shock	RF Leakage	Thermal Shock	Temp./Humidity Cycling	High Temp Exposure	Maximum Test Current /Dielectric Withstand Voltage	Capacitance
		Sequence ID	**O**	**P**	**Q**	**R[7]**	**S**	**T[1]**	**U**
		Sample Size for tests listed below (min)	20[2]	3	20[2]	20[2]	10[2]	20[2]	10
	3.1	Crimp Height Measurement	1	1	1	1	1	1	1
5.1.8		Visual Inspection	2, 9	2,4	2,8	2,9	2,8	2,8	2,4
5.1.7		Connector Cycling	4		4	4	4	4	
5.1.9		Circuit Continuity Monitoring [3]	5[3,4]		5[3,4]				
	4.3.1	Contact Resistance	3[4], 6[4]		3[4], 6[4]	3[4], 6[4]		3[4], 6[4]	
5.5.1	4.4.1	Isolation Resistance				3[5,6], 6[5,6]			
	4.4.2	SWR and Insertion Loss	3[6], 6[6]		3[6], 6[6]	3[6], 6[6]	3[6], 6[6]	3[6], 6[6]	
	4.4.3	RF Leakage		3[8]					
	4.5.1	Thermal Shock			5				
5.6.2		Temperature/Humidity Cycling				5			
5.6.3		High Temperature Exposure					5		
5.3.3		Maximum Test Current [1]						5	
	4.3.2	Dielectric Withstand Voltage	7		7	7	7	7	
	4.4.4	Capacitance							3
5.4.6		Vibration/Mechanical Shock	5						
5.4.1		Terminal to Connector Retention (w/ TPA)	8			8[7]			

Table 4.6.3: Connector System Electrical / Environmental Test Sequences

(1) Optional
(2) Sample quantities do not account for differences in sample preparation based on individual company requirements for taking measurements. If the same samples cannot be used for all of the measurements in the test sequence, then additional samples are required.
(3) Monitor both the center and outer contacts.
(4) Contact Resistance requires 10 separate samples since the Continuity Monitoring, SWR and Insertion Loss test equipment may cause the potential across the circuit to exceed 20mvolts. The 10 separate samples utilized for SWR and Insertion Loss are to be tested in parallel to the Contact Resistance samples, Continuity Monitoring is to be performed only on these separate samples.
(5) Isolation Resistance **cannot** be performed on the same samples as used for Contact Resistance due to the 500V required for the Isolation Resistance measurement. Isolation Resistance is to be performed on the SWR and Insertion Loss samples.
(6) If the separate optional SWR samples are made (per 4.4.2.2, Note C), then an additional 10 samples are required, 10 IL samples and 10 SWR samples. Note also, 10 each SMA ï SMA reference samples are also optional for both of these groups of samples. Isolation Resistance is required only on the Insertion Loss samples.
(7) Use Insertion Loss samples from this group for the group E test. All previous tests must be completed within the 6 hr limit.
(8) It is not necessary to perform the RF leakage test on connectors with identical cables with identical interfaces (e.g. right angle jacks, 2-way or 3 way systems.) Surrogate data is acceptable.

4.7 TEST REPORT

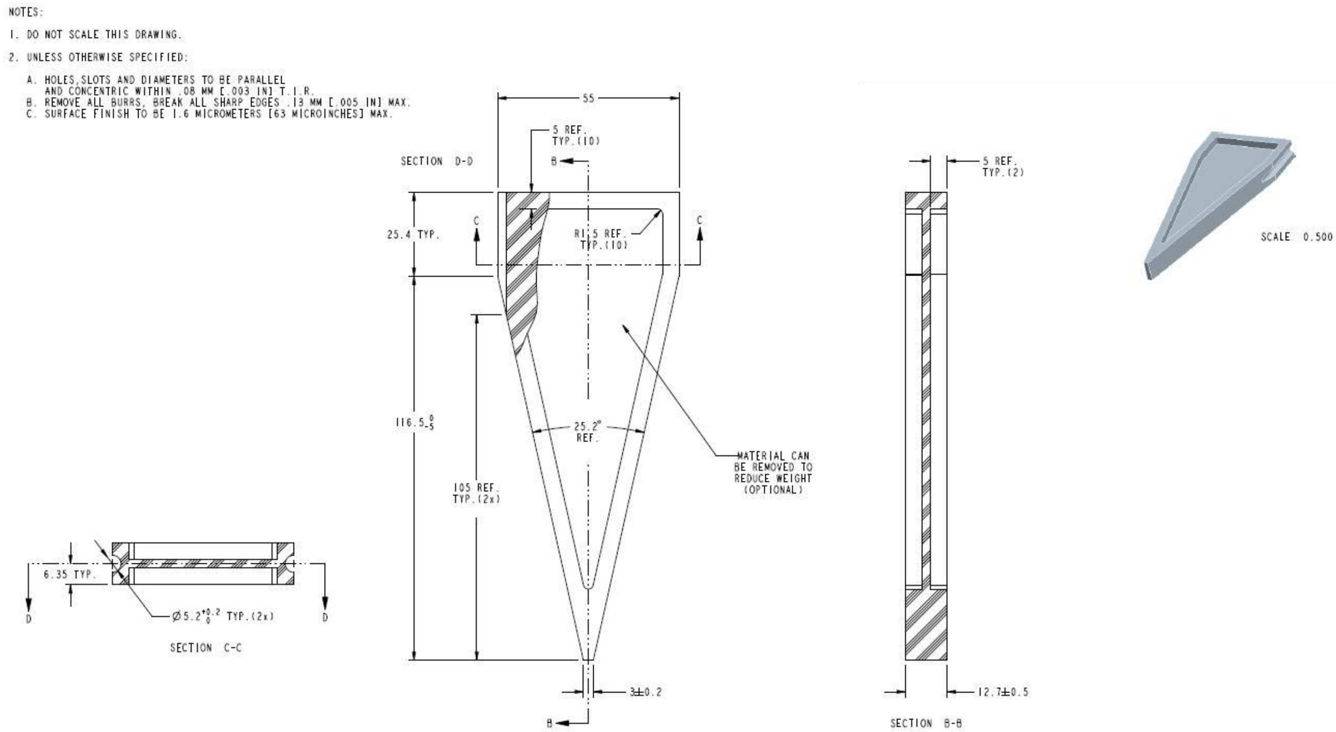
Along with the data required in the acceptance criteria section of each test, record the following additional items as a minimum in the test report:

- Type of cable used
- Sample lengths
- Frequency span
- Gate span
- Gate shape
- Network analyzer description
- Number of points measured

APPENDIX A - DEFINITIONS

CUT	Component under test
DWV	Dielectric Withstanding Voltage, also known as dielectric strength testing, it is an application of voltage higher than the working voltage. This test is used to determine if the connector can operate safely at its working voltage requirement and still take momentary over-potentials due to switching, surges, and other similar phenomena. Typically the DWV requirement is 3 times the working voltage.
FAKRA	Fachkreis Automobil (German equivalent of USCAR)
FEMALE CONNECTOR	A connector where the center conductor is a socket contact.
MALE CONNECTOR	A connector where the center conductor is a pin contact.
SMA	Threaded RF connectors that are widely used on instrumentation
SMB	Small RF connector with snap coupling for fast connection and excellent performance even in moderate vibration
SWR	Standing Wave Ratio - The ratio of the amplitude of a standing wave at an anti-node to the amplitude of a node. Note: The standing wave ratio in a uniform transmission line is (1+p)/(1-p) where p = the reflection coefficient. It is a measure of the impedance mismatch between the connector and the cable. SWR is 1 when the system is perfectly matched. SWR greater than 1 indicates reduced signal at the output due to reflections at impedance boundaries.
TDR	Time Domain Reflectometry
WORKING VOLTAGE	Sometimes called service rating, this is the voltage that the connector will withstand continuously (100% duty cycle).
IL	Insertion Loss The loss of load power due to the insertion of a connector at some point in a transmission system. Generally expressed in decibels as the ratio of the power received at the load before insertion of the connector, to the power received after insertion.

APPENDIX B
Wedge for Mating Under Sideload Test



APPENDIX C - REVISIONS

This specification was approved by USCAR/EWCAP on (12-7-01).

Any revisions since that date have been incorporated into the specification. Revisions that altered the content of the specification are recorded below:

DATE	SECTION	SUMMARY OF CHANGES MADE *	NOTES
12-7-01	ALL	Released	
8-02-02	All	Revised pull test, Added RF Leakage Test, revised polarization feature effectiveness acceptance criteria	
8-25-04	Table 3.2	Table added	
	1	Re-worded to clarify requirement for re-testing on various cables	
	2	Added SAE web site, IEC, MIL, & DIN references	
	3.1	Re-worded to clarify sample quantities	
	3.2	Network analyzer was 3GHz, added ñw/Time Domain Capabilityò	
	4.1	Added bend resistance	
	4.2.1.2	Allowed use of mandrel for pull test	
	4.2.1.3	Added exception for SMA failures	
	4.2.3.2	Added exceptions 1 & 2	
	4.2.3.3	3rd sentence re-worded & added provisions for exceptions	
	Figure 4.4.2.2	Revised sample lengths	
	4.4.2.2	Revised sample lengths & procedure, revised note C	
	4.5.1, 4.5.2, 4.5.3	Added test sequence tables	
	Various	SWR was VSWR	
	4.4.3.1	Revised sample length to ñshort as possibleò	
	4.4.3.2	IEC 60512-23 was 360069-1	
	4.6	Added test report requirements	
	Appendix B	Removed definitions for ñJackò and ñPlugò. Added definitions for ñmaleò and ñfemaleò from ISO	
8/16/10	4.4.2.2	Add: (See Note D) to Para. 4.4.2.2 after "SMA connectors"	
		D. The VSWR of each SMA connector shall be verified to be less than 1.15:1 to reduce the potential "masking" effects on the VSWR & Insertion Loss measurements of the CUT.	
10/16/10	4.3.1.3	Added resistance values for AM/FM applications	
	4.2.4	Added connector to connector audible click section.	
11/23/10	4.2.2.3	Added USCAR 25 ergonomic requirements	
	1.4	Added Intermateability paragraph	
2/1/11	4.2.3.3	Added note for non-recommended mating styles	
	4.4.4 to 4.4.6	Added test sequences for crimp validation	
3/10/11	4.2.2.2	Added Mating Under sideload test	
	Appendix C	Added drawing	
3/21/11	4.2.5,4.4.5, Table 4.5.2 and Table 4.6.2	Added Center Contact Retention section, added capacitance procedure for AM/FM applications, modified applicable tables.	
2/22/2012	Please see next sheet with list of changes.		

APPENDIX C (continued)

Date	Section	Summary of Changes Made
2/22/2012	3.1	Corrected table # reference.
	4.2.1	Added "& Sideload Test"
	4.2.1.2	Added paragraph:"R/A Cabled Connectorsé .".
	4.2.2.1.3	Changed Force Values.
	Fig. 4.2.2.2.3.A	Corrected view.
	Fig. 4.2.2.2.3.B	Corrected view.
	4.4.4.2	Line 4, corrected fig. reference.
	Fig. 4.4.4.4-a	Corrected view.
	Fig. 4.4.4.4-b	Corrected view.
	Fig. 2.4	Changed temperature.
	6.6.1	Corrected table # reference, lines #3 and #6.
	Table 6.6.2	Table # corrected, added sideload to last table item.
	Table 6.6.3	Table # corrected.
	Appendix A	Definitions re-typed to line up items. Added IL definition.
	Appendix B	Removed foreign figure, upper right hand corner.
	Appendix C	Added 2/22/2012 changes.
10/16/2012	Page 1	Added Section ñTitlesò, Modified Page References.
	Sec. 4.2.1.2	R/A Changes to ñRight Angledò
	Fig. 4.2.2.2.3.A	Improved Picture
	Fig. 4.2.2.2.3.B	Improved Picture
	Sec. 4.4.3.2	Add 5. IEC 62153-4-7 (bubble test)
	Fig. 2.4	85°C Changed back to 85°C (105°C if Applicable)
	Sec. 4.5.1.5	Table 4.6.3 Ref. changed to Sec. 4.3 & Sec. 4.4
	Sec. 4.6	Changed Sec. from 5.6 to 4.6
	Sec. 4.6.1	Changed Sec. from 5.6.1 to 4.6.1
	Sec. 4.6.2	Changed Sec. from 5.6.2 to 4.6.2
	Sec. 4.6.3	Changed Sec. from 5.6.3 to 4.6.3
	Sec. 5.7	Changed Sec. from 5.7 to 4.7
	Appendix A	Added Acronym IL
	Table 4.5	Changed to Table 4.6
	Table 6.6.2	Changed to Table 4.6.2
	Table 6.6.3	Changed to Table 4.6.3
2/14/2013	Page 2	1., 2., 3. Became 1.0, 2.0, 3.0
		Added ISO 20860-1
	Page 3	4. now 4.0
	Sec. 4.2.1.2	Added words (See drawing below)
	Page 5	Added drawing and note
	Sec. 4.2.2.1.3	22N changed to 25N, removed reference to USCAR-25 & added ISO 20860-1
	Page 13	C., D., E., F., to line up with A. and B.
	Sec. 4.4.3.2	5. (Bubble Test) changed to (Tube in Tube)

APPENDIX C (continued)

Date	Section	Summary of Changes Made
	Sec. 4.4.4	ñDry Circuit Termination Resistance Measurement of Static Contactsò, replaced with ñCapacitanceò
	Sec. 4.4.4.2	Changed to Sec. 4.5.1.2, removed words ñsec. 1.4ò and step 3 changed to step 4. In item 5 under samples, T/S changed to Temp/Humidity. Sec. 1 ref. changed to 4.3.1
	Sec. 4.5.1.4	Item 4 ref. to fig. 2.4 changed to fig. 4.5.1.4
	Page 16	Fig. 2.4 changed to fig. 4.5.1.4
	Sec. 4.5.2.2	Ref. to paragraph 4.4.4.2 changed to section 4.5.1.2, T/S changed to Thermal Shock, and T/H changed to Temp/Humidity, Sec. 1 ref. changed to 4.3.1
	Table 4.6.2	Removed Rev. 5 from USCAR-2 ref., and in column ñNò added words: (and sideload).
	Table 4.6.3	2nd column: 4.5.5 Thermal Shock changed to 4.5.1 Thermal Shock
		4.45 Capacitance changed to 4.4.4 Capacitance