

Performance Specification for Automotive RF Connector Systems

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1 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 greater than 200 MHz. This does not exclude lower frequency applications; the acceptance criteria may not apply, however (i.e., the AM/FM acceptance criteria is specified on Page 3 of USCAR print 999-U-001-1-A01
3. This specification does not apply to single conductor wire or twisted pair connection systems.

2 REFERENCES

SAE/USCAR-2	Performance Specification for Automotive Electrical Connector Systems
SAE/USCAR-25	Electrical Connector Assembly Ergonomic Design Criteria
	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 – 50 OHM Radio Frequency Interface (50 Ω RFI)

3 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 4.5.2 and 4.5.3.

3. Number each sample pair of connectors and record crimp dimensions as applicable from a representative group from each set of samples (See tables 4.5.2 and 4.5.3). 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 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 – 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

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 and Board 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 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.)

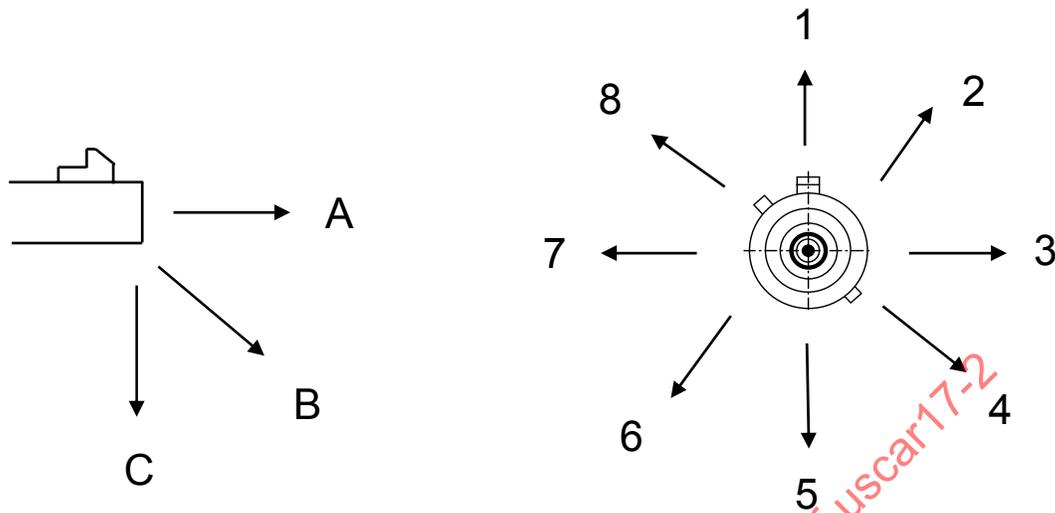


Figure 4.2.1.2: Board Mount Mechanical Pull

1. Measure SWR and I.L. 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.

Note:

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/Un-mating Force

4.2.2.1 Purpose

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

4.2.2.2 Procedure

Follow the procedure for Connector Mating/Un-mating Force found in the latest revision of SAE/USCAR-2.

4.2.2.3 Acceptance Criteria

1. For single contact connectors, the mating force must be less than or equal to 40N; the un-mating force must be less than or equal to 35N with the primary connector lock completely disengaged/disabled.
2. For multiple contact connectors, SAE/USCAR-2 acceptance criteria apply.

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 "Polarization Feature Effectiveness" 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 will not meet this requirement. Each manufacturer must publish the list of tested key code combinations that do not meet this requirement.) For multiple contact SMB connection systems, the minimum mis-mating force to achieve **center contact** electrical continuity is 100N.
2. For Square Outer Conductor connection systems, SAE/USCAR-2 acceptance criteria apply.

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 crimps and corresponding contact interface and the inner conductor crimps and corresponding 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.

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 $\geq 100 \text{ M}\Omega$.

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 replace 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 to the preferred length, as shown in Figure 4.4.2.2-1a. The overall length of the leads shall be 150mm less the length due to insertion of the CUT. (Sample length tolerance is +0/-5 mm)

Board Mount Connectors:

Prepare samples with SMA connectors to the preferred length as shown in Figure 4.4.2.2-1c.

Note:

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

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 150 +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.

Notes:

- 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.

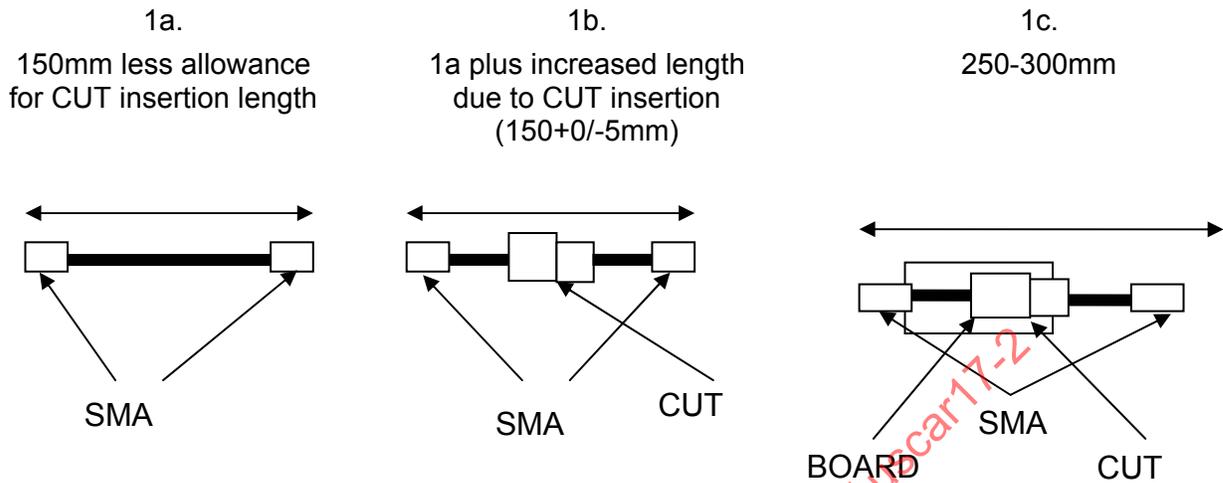


Figure 4.4.2.2: SWR Test Sample

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]

Table 4.4.2.3-a: Maximum SWR Values

RF Connector Type	Max. Insertion Loss [freq.]
Square Outer Conductor, EWCAP	0.2 [0 - 1 GHz] 0.4 [1 - 2 GHz]
SMB 3GHz FAKRA	0.3 [\leq 3 GHz]
SMB 0.5GHz	0.25 [\leq 0.5 GHz]

**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)

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.

4.5 TEST SEQUENCE

Follow the Test Sequence paragraph specified in the SAE/USCAR-2 Performance Specification, replacing all occurrences of those tests listed in Table 4.5.

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 4.5: Test Sequence Replacements

4.5.1 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 4.5.2 and 4.5.3 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 4.5.2 and 4.5.3 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.

4.5.2 Connector System Mechanical Test Sequences

Per USCAR-2 Revision 4 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 Engagement/Disengagement Force	Polarization Effectiveness	Misc. Component Engage/Disengage	Connector-to-Connector Audible Click	Connector Drop Test	Cavity Damage	Connector Mounting Feature Mechanical Strength	Mechanical Pull
		Sequence ID	A ⁽¹⁾	B ⁽²⁾	C ⁽²⁾	D ⁽²⁾	E ⁽²⁾	F	G	H	I	J	K	L ⁽⁵⁾	M	N
		Sample Size for tests listed below (minimum)	15	10	10	10	10	⁽³⁾	10	⁽⁴⁾	40	8	3	5	20	10 ⁽⁶⁾
	3.1	Crimp Height Measurement	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	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	Connector-Connector Engage / Disengage Force														
		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							
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					
5.4.7		Connector-to-Connector Audible Click										2				
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														4

Table 4.5.2: 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.
 $N = K * S$
 $C = K * K$
 $T = K * K * S$

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

- (5) This test is required only if the connector design provides for the functionality identified by this test.
- (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 – SMA reference samples are also optional for each of the above.
- (7) Only the center contact need be monitored for Polarization Effectiveness testing.

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