Performance Specification for Miniature Automotive Coaxial Connectors

SAE/USCAR-49
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PERFORMANCE SPECIFICATION FOR MINIATURE AUTOMOTIVE COAXIAL CONNECTORS

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1. SCOPE

This document contains procedures for performance testing of electrical terminals, connectors, and components for coaxial-style cable with an outside cable diameter of 3.6mm and smaller. These are often called “Mini Coax connector systems.” This specification applies to coaxial cable connection systems that operate at frequencies from DC to 9 GHz and are intended for road vehicles. The characteristic impedance of the Mini-Coax connection system described here is 50 ohms, however nothing excludes the use of these connectors in systems with a different characteristic impedance. This specification applies only to connection systems using coaxial cable.

2. RELATED DOCUMENTS

2.1 Normative (Required) References

- SAE/USCAR-2, Performance Specification for Automotive Electrical Connector Systems. USCAR-2 is used for all the mechanical and DC electrical testing. USCAR-49 is for the unique testing for coax only.
- SAE/USCAR-17, Performance Specification for Automotive RF Connector Systems. (Use is optional as an alternate test method for Section 4.3.2, Dielectric Withstanding Voltage).
- SAE/USCAR-21, Performance Specification for Cable-to-Terminal Electrical Crimps.
- IEC 62153-4-7, Metallic cables and other passive components test methods - Part 4-7: EMC -Test method for measuring of transfer impedance and screening attenuation - Triaxial tube in tube method.

2.2 Informative (Not-Required) References

- ISO DIS 19642-11, Dimensions and requirements for coaxial RF cables with a specified analog bandwidth up to 6 GHz.
- IEEE 370, IEEE Standard for Electrical Characterization of Printed Circuit Board and Related Interconnects at Frequencies up to 50 GHz.
- IEC 62153-4-6, Metallic cables and other passive components test methods – Part 4-6: Electromagnetic compatibility (EMC) – Surface transfer impedance – Line injection method.
- Touchstone® File Specification, http://www.ibis.org/connector/touchstone_spec11.pdf.

3. CONNECTOR QUALIFICATION

3.1 General Test Requirements

USCAR-49 is used with other (USCAR and IEC) specifications to form a complete validation test. These test tables are referenced in the applicable testing sections.

- Table 1 lists test requirements for design validation using USCAR-2. These are the basic mechanical and environmental tests that are common with low voltage connectors.
- Table 2 lists the unique tests for coax cables per this document (USCAR-49).
- Table 3 lists additional samples required for environmental testing to evaluate performance at high frequency.

3.1.1 USCAR-2 and USCAR-21 Testing

Use Table 1 as instructed. It provides design validation involving USCAR-2 and USCAR-21. An X indicates a required test.

Table 1 - Low voltage tests from USCAR-2 and USCAR-21

ID [2]	Test Name	Coax Terminal	Mini Coax Connector		Multi-Vendor [3]
		All	Sealed	Unsealed	All
A	Term. - Term. Engage/Disengage	X [4]			
B	Terminal Bend Resistance	X [4]			
C	Current Cycling	X [4]			
D	Term. - Conn. Insertion/Retention		X	X	
E	Misc. Component Engage		X	X	
F	Audible Click		X	X	
G	Conn. Conn Mating/Un-mating		X	X	X
H	Polarization Effectiveness		X	X	
I	Drop		X	X	
J	Cavity Damage		X[3]	X[3]	
K	Header Pin Retention		X	X	
L	Mounting Feature Strength		X	X	
M	Vibration/ Mechanical Shock		X	X	
N	Thermal Shock		X	X	
O	Temp./Humidity		X	X	X
P	High Temp Exposure		X	X	
Q	Fluid Resistance		X		
RSAA	Combined R+S+AA from USCAR-2		X		
TUAB	Combined T+U+AB from USCAR-2		X		
V	Temp/Humidity				X [1]
W	Pressure/Vacuum (Stand Alone)				X [1]
X	Mechanical Assist Integrity		X	X	
Y	Connector Seal Retention – Unmated		X		
Z	Connector Seal Retention – Mated		X		
-	USCAR-21 core conductor crimp	X			

NOTES:

“X” refers to required test sequences for USCAR-49 approval.

[1] Sealed only.

[2] ID and Test Name refer to USCAR-2.

[3] Multi-vendor applies to connectors previously validated that are being tested for interoperability with a different connector maker’s (also previously validated) part.

[4] Check to see if testing is waived by test requester due to not being relevant to specific design of coax connector.

3.1.2 USCAR-49 Testing

Use Table 2 as instructed to apply USCAR-49 test sequences. Validations require test groups AF thru AJ in the table to pass unless otherwise requested by customer. The sequence for testing is shown by number, where the test marked as number “1” is first and the sequence continues in the order listed.

Table 2 - Test sequences

		Test Groups for Unaged Mini Coaxial Connectors				
	Test Name	S Parameters	Shielding Attenuation	Surface Transfer Impedance	Dielectric Withstand Voltage	Header Side Load
Section Reference	Test Sequence ID	AF	AG	AH	AI	AJ
	Connector Sample Size minimum	3 (1)	2	3	3	3
	Applicable Cable Size	Applicable Cable (2)	Applicable Cable (2)	Applicable Cable (2)	Applicable Cable (2)	N/A
5.1 (4)	General	1	1	1	1	1
5.1.8 (4)	Visual Inspection	2	2	2	2	
5.1.7 (4)	Connector Cycling	3	3	3	3	
4.2	S Parameters (IL, RL)	4				
4.3	S Parameters (Impedance)	5				
4.4	S Parameters (Crosstalk)	6				
4.5	Shielding Attenuation		4			
4.6	Shielding Transfer Impedance (STI)			4		
4.7	Dielectric Withstand Voltage				4(5)	
4.8	Mechanical Side Load					2 (3)
5.1.8 (4)	Visual Inspection-Final	7	5	5	5	3

NOTES:

(1) Make complete sample using equipment intended for serial (series) production. Do not hand-build any portion.

(2) Each different cable, including type of shielding, requires separate validation.

(3) Note that procedure for side load requires concurrent Circuit Continuity Monitoring per USCAR-2 #5.1.9.

(4) Test references USCAR-2.

(5) Test may be omitted if USCAR-2 5.5.1 (Insulation resistance test) is run and passed.

3.1.3 RF Testing After Environmental Exposure

Use Table 3 as instructed for testing specially prepared coax terminals after environmental exposure. The samples are specially made in a way that lets them be measured on a network analyzer. Testing per this table is in addition to USCAR-2 environmental testing (test groups N, M, O, and P as called for in USCAR-2 per Table 1). Typically, 28 samples are required beyond what is called for in for USCAR-2 test paths M, N, O, and P.

Table 3 - Additional samples for-environmental sequence

		Additional DUT Samples Req'd for Environmental Sequences			
	Test Name [1]	Vibration / Shock	Thermal Shock	Temp/Humidity Cycling	High Temp. Exposure
	Test Sequence ID	M-RF	N-RF	O-RF	P-RF
	Sample Size min.	7 [3]	7 [3]	7 [3]	7 [3]
	Cable Size to test	Largest Permitted	Largest Permitted	Largest Permitted	Largest Permitted
USCAR-2 5.1	General	1	1	1	1
USCAR-2 5.1.8	Visual Inspection	2,7	2,7	2,7	2,7
USCAR-2 5.1.7	Connector Cycling	3	3	3	3
USCAR-2 5.4.6	Vibration/ Shock	5 [2]			
USCAR-2 5.6.1	Thermal Shock		5		
USCAR-2 5.6.2	Temp. /Humidity Cycling			5	
USCAR-2 5.6.3	High Temp. Exposure				5
4.2 (on 5 samples) 4.5 (on 2 samples)	RL or Shielding Atten-uation (as appropriate)	4, 6 [3]	4, 6 [3]	4, 6 [3]	4, 6 [3]

NOTES:

(1) Test structure mirrors the USCAR-2 test paths M, N, O, and P. Apply environmental conditioning to samples along with the USCAR-2 groups being aged for best use of environmental chambers.

(2) Vibration step does not have fixtures shaken; only DUT goes on the vibration plate.

(3) Test samples to be divided with 5 samples prepped and tested for return loss and two samples prepped and tested for shielding attenuation. Apply applicable measurement (Return loss or Shielding Attenuation) to the prepared sample.

3.2 Equipment List

In addition to the equipment listed in USCAR-2 and the other normative references, a 10 GHz network analyzer that is S-Parameter capable, Time Domain capable, along with applicable de-embedding software is required.

4. TEST PROCEDURES

4.1 Required Tests

1. Prepare and test as directed per Table 1. Table 1 tests specify the applicable USCAR-2 (low voltage connector) tests. Note that some USCAR-2 tests were updated in revision 8 to accommodate coax testing so be sure to use the latest version.

2. Prepare and test as directed in Table 2. Table 2 specifies test requirements native to USCAR-49 (except the environmental tests.

3. Prepare and test as directed in 3. Table 3 specifies environmental test requirements native to USCAR-49. Note that Table 3 was separated from Table 2 to make it clear which samples go in the environmental chamber.

4.2 Return Loss and Insertion Loss

4.2.1 Purpose

Return Loss measures the mismatch loss between the connector and the cable at the frequencies of interest. This test is designed to be used for both single vendor and multi-vendor mated pair test samples, using de-embedding.

4.2.2 Sample Preparation

In-Line Connector sample preparation:

1. Prepare one FIX-FIX as shown in Figure 3a. The cable length for the FIX-FIX structure is 470mm ±10. See NOTE 4.2.3.E for cable length details. Make sample using equipment intended for serial production. Do not hand-build.

2. Prepare the number of FIX-DUT-FIX samples as required in the test sequence chart shown in Figure 3b. The two cable segments for the FIX-DUT-FIX structure are 250mm each. See NOTE 4.2.3.E for cable length details. NOTE that Figure 3c is a magnification of Figure 3a.

Board Mount Connector sample preparation:

1. Prepare one FIX-FIX 1 and one FIX-FIX 2 as shown in Figure 4.

2. Calculate the PCB trace length of FIX-FIX 1 (Figure 4a). It is 2 times the trace length of the board mount connector PCB shown in Figure 4c (see NOTE 4.2.3.G for trace length details).

3. The cable length for the FIX-FIX 2 is 470±10mm (Figure 4b), which is the same as FIX-FIX sample (Figure 2a) from the In-Line connector test.

4. The FIX-DUT-FIX structure for the board mount connector is shown in Figure 4c.

5. The PCB trace length should be ½ of the trace length used in FIX-FIX 1 as shown in Figure 4a.

6. The cable length for the FIX-DUT-FIX structure is 250±5mm, identical to the female In-Line test sample depicted in Figure 3b. See NOTE 4.2.3.E for cable length details.

Test port adapters may be used for both the In-Line and board mount connector tests, but they must meet the requirements shown in Table 6. Examples of test port adapters include SMA connectors, adapters, and PCBs. Note that the same test port adapters must be reused for testing all the FIX-FIX and FIX-DUT-FIX structures.

4.2.3 Procedure

Prior to performing this procedure, determine whether the accuracy of the de-embedding tool must be confirmed per Appendix B by customer consultation.

1. Set the VNA to the parameters listed in Table 4.

Table 4 - VNA settings

- Frequency start = 5 MHz
- Frequency stop = 10 GHz
- Frequency step = 5 MHz
- Measurement bandwidth ≤ 1 kHz
- Port output power ≥ -10 dBm

Note: Use De-embedding algorithm of impedance-corrected 2x-thru either internal to VNA or external using software not embedded to VNA.

2. Establish the FIX-FIX structures.

The requirement for FIX-FIX (derived from IEEE 370 specification) is shown in Table 5.

Table 5 - FIX-FIX structure requirements

Test Parameter	Requirement	Applicable Range
S_{11}, S_{22}	≤ -6 dB	$F_{start} \leq f \leq f_{limit}$
S_{21}	≥ -15 dB	$F_{start} \leq f \leq f_{limit}$
$S_{21,\,dB} - S_{11,\,dB}$	≥ 0 dB	$F_{start} \leq f \leq f_{limit}$
unwrap (arg(S_{21}))	≤ -1080 °	@ f_{stop}

NOTE: (f_{limit} = maximum frequency for connector performance specification [e.g. 9 GHz])
(unwrap (arg(S21)) requirement limits minimum PCB fixture length L_{trace} for PCB Header de-embedding)

3. Perform a SOLT or SOLR calibration of the VNA.

NOTE: SOLT and SOLR are the labelling of the Keysight VNA. In a R&S brand VNA, you can choose a TOSM calibration which is the same as SOLT.

4. Measure and save the S-parameter data set(s) as Touchstone file(s). See NOTE 4.2.3.C for Touchstone file details.

- For inline connectors, one cable FIX-FIX structure (Figure 2a) per group of samples.

- For board mount connectors, one PCB FIX-FIX 1 structure (Figure 3a) per group of samples.

5. Provide the FIX-FIX Touchstone file(s) to the de-embedding software tool and perform a self de-embedding of the FIX-FIX structure(s). Use measured file as FIX-FIX and FIX-DUT-FIX input for the tool. Compare the result with the consistency check requirements in Table 6.

Table 6 - Self de-embedding consistency check requirements for 2X THRU (FIX-FIX)

Test Parameter	Requirement
S_{21}	$-0.1\text{ dB} \leq 20\log(\lvert S_{21}\rvert) \leq 0.1\text{ dB}$ $-1° \leq \arg(S_{21}) \leq 1°$

6. Measure the samples and save the S-parameters as Touchstone files.

7. Provide the Touchstone files of the sample measurements and the FIX-FIX file(s) to the de-embedding software tool and perform the de-embedding. For board mount connectors the de-embedding typically is a two-step process, removing one fixture side per step while skipping the other side.

NOTES 4.2.3.A thru 4.2.3.G (for conducting the S Parameter assessment):

- NOTE 4.2.3.A. Always protect the test port adapters during environmental exposure with a mating connector or plug.

- NOTE 4.2.3.B. Make the sample length per Figure 2 and Figure 3. Ensure that all the samples are within ±5mm of these nominal values.

- NOTE 4.2.3.C. Multiple Touchstone file formats exist. It's advisable to save the measurement data in a format that corresponds to the de-embedding software tool used (otherwise, the measurement data has to be converted). In USCAR-49, the generic name "Touchstone file" is used to describe all formats. At the time of publication, most instruments/CAD tools use the Touchstone 1.1 format (file extension .sNp) listed in the reference section.

- NOTE 4.2.3.D. Document the software tool used for de-embedding, including its version, and the settings.

- NOTE 4.2.3.E. Measure the cable length within the cable geometry that is unaffected by the termination, e.g. by possible cable squeezing in the crimp zones or other mechanical support such as sealings and cable ties. This is typically the cable distance between the cable-crimp ferrules. Refer to Figure 1 for measurement details.

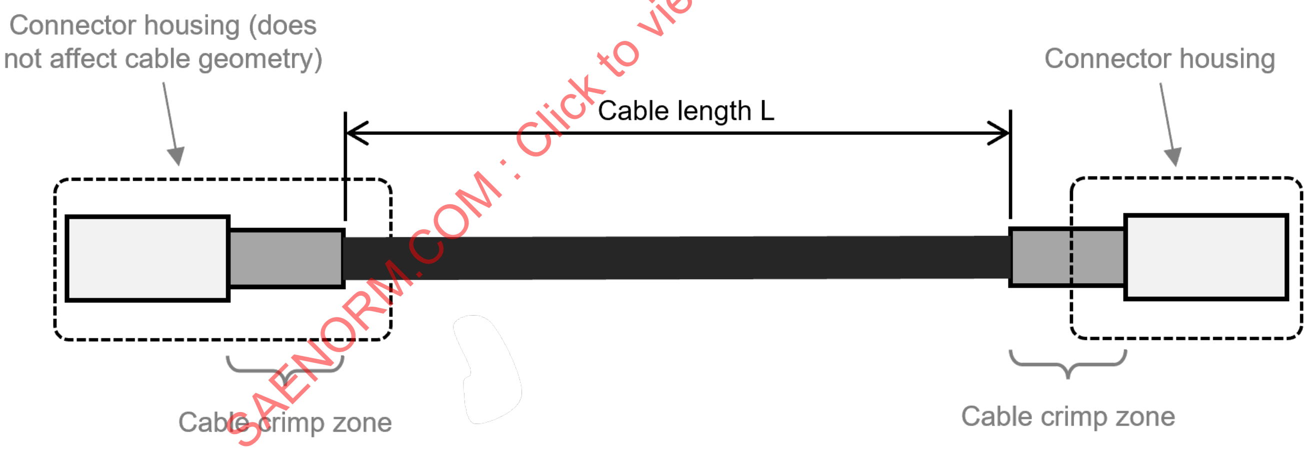


Figure 1 - Measurement location for length on a sample connector

- NOTE 4.2.3.F. Maximize symmetry and similarity of the test fixtures used for the measurements by following these guides as much as possible. Compliance minimizes errors from the de-embedding process.

- Take PCBs and board mount connectors for the two fixtures from the same batches.

- Use reproducible soldering processes.

- Take cables used in FIX-FIX and FIX-DUT-FIX structures from one batch.

- Minimize cable bending.

- When applying environmental conditions (heat, cold, and humidity but not vibration) to the fixtures used in the FIX-DUT-FIX measurement, apply the same conditions to the fixtures used in the FIX-FIX measurement.

- NOTE 4.2.3.G. For de-embedding of board mounted connectors, include the complete PCB footprint of the connector in the DUT. Make reference plane that separates FIX and DUT a minimum of 10 mm to any discontinuity (via, matching element etc.). The PCB trace length -- L_{trace} -- is defined up to the reference plane shown in Figure 2.

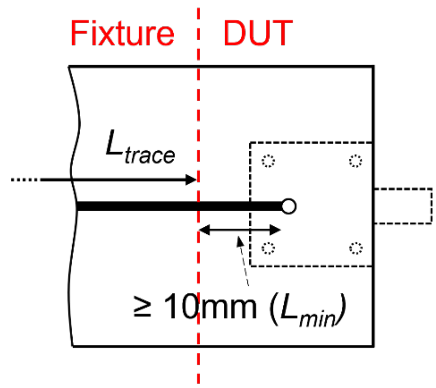


Figure 2 - Structure for de-embedding board-mount connectors

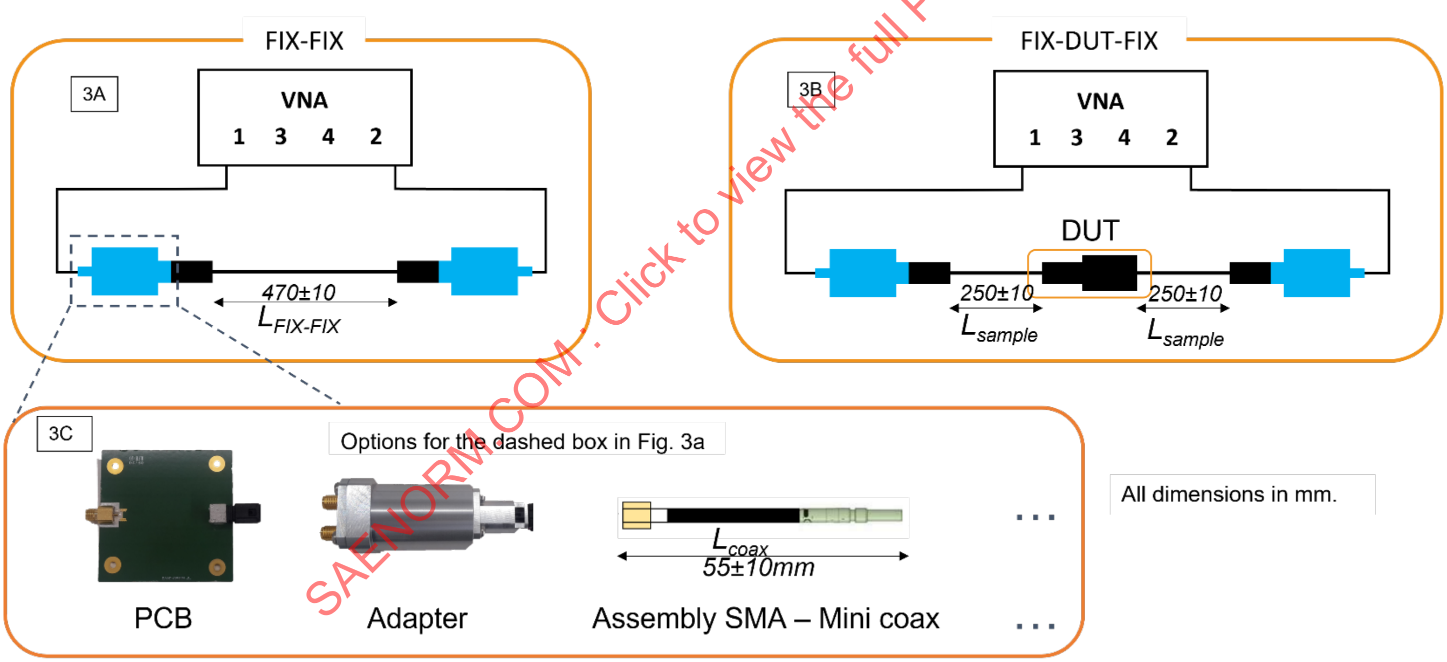
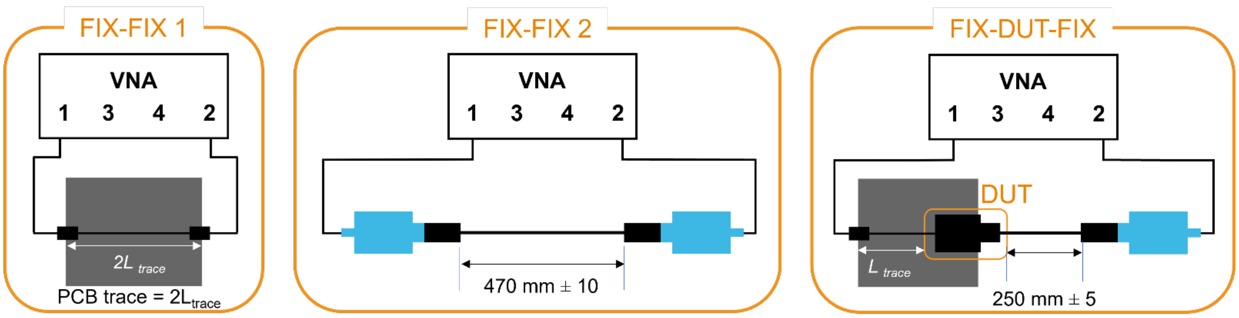


Figure 3 - Structure for de-embedding inline connectors



4a: 2X Thru   4b: Cable length for FIX-FIX 2   4c: Cable length of FIX-DUT-FIX

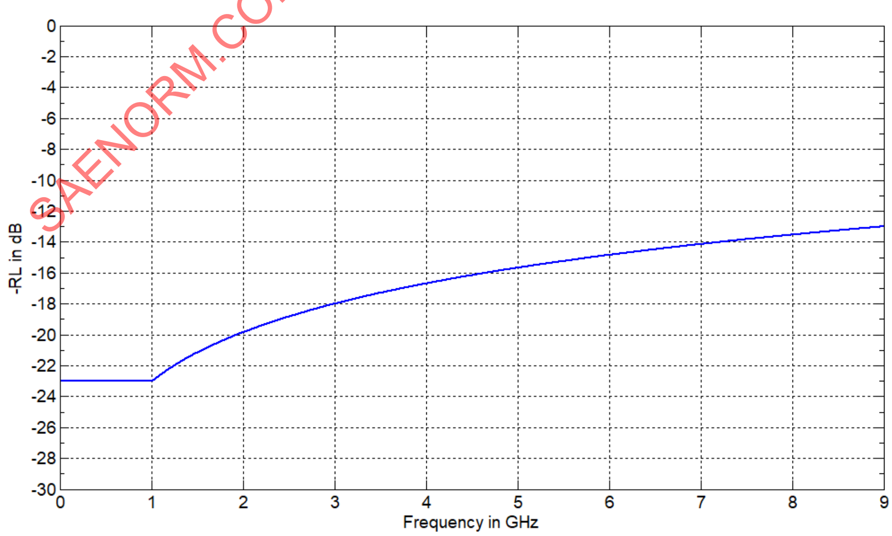
Figure 4 - RF de-embedding configuration for PCB headers

4.2.4 Requirements

Return Loss of the mated connector pair after De-embedding shall satisfy Table 7. NOTE: This specification was released prior to completion of confirmation testing. A revision to relax the RL requirement is possible based on confirmation testing outcomes. Any criteria change in the revision will be applicable to devices tested to this release, with customer approval. There is no requirement for insertion loss (IL). Appendix E has information on considerations when setting customer-specific IL limits.

Table 7 - Return loss requirement

Frequency, GHz	Return Loss Requirement, Max.
0.01 < f ≤ 1	≤ -23 dB
1 < f ≤ 9	$\leq 10\frac{\log f(GHz)}{\log 9} - 23$



NOTE to Table 7 and Figure 5:

Customer may require different values for specific applications. Confirmation is recommended.

Figure 5 - Return loss requirement as graphic

4.3 Impedance

4.3.1 Purpose

Impedance testing performs two functions. First, the impedance profile of a mated connector characterizes performance of both male and female connector halves in the mated condition. This measured data illustrates the reflective discontinuity elements of a mated Mini-Coax Connector pair. This information is useful in determining whether the male connector half, female connector half, or the interface may be causing performance issues. The second purpose of the impedance test is to create reference profiles of the different mated Mini-Coax Connector pairs, which help find potential variations or drift in the life of a specific connector program by using this information as a reference.

4.3.2 Procedure

1. Re-use the same samples as used in Section 4.2 (the mated pair samples for the impedance test may be from either a single supplier or multiple suppliers). Set VNA for Impedance measurement per Table 4, with time domain window of Kaiser or Hann. Set rise time to 100 ps for a maximum bandwidth of 10 GHz. Document the following:

- Touchstone file
- Time domain window used
- VNA make and model
- Calibration plane location and calibration method

If DUT is not same as what was used in Section 4.2, ensure the "Electrical Length" between measurement planes is a minimum of 10 times the rise time, with electrical length defined in Equation 1.

$$Electrical\ Length = (c)(t_r)(v_p) \quad \text{(Eq. 1)}$$

where

c = speed of light (299.792 * 10^6) in m/s

t_r = rise time in seconds

v_p = velocity of propagation in cable

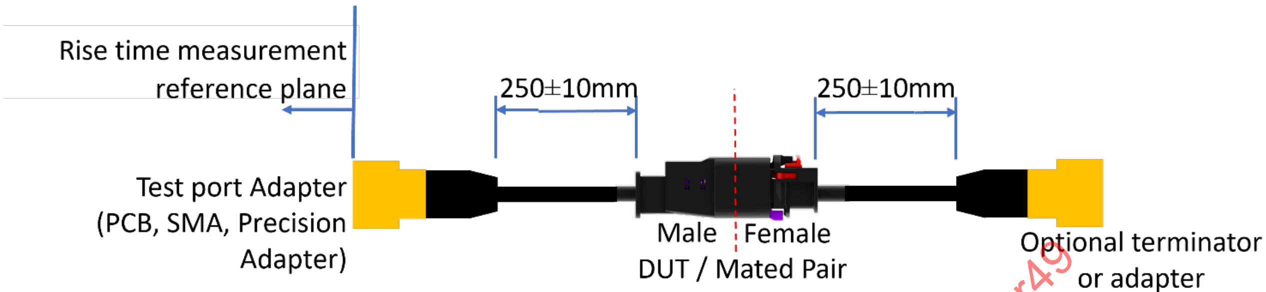
Document:

- Part number of the connector interface (both male and female connector halves)
- Coax cable part # and length (maximum length of wire or PCB trace prior to DUT is 3ns)
- Part # of test port adapter: PCB, SMA, adapter
- Location of DUT interface (in ns)

2. Set-up. Use Figure 6 as an illustration of the impedance test setup for an inline connector. Orientation of the DUT with respect to the mated connector (that is closer to Port 1, i.e. male connector half closer to Port 1) is shown.

3. Create an impedance chart characterizing the mated pair like the impedance template shown in Figure 7.

NOTE: Impedance profile is not intended to overturn the return loss pass/fail limits shown in Figure 5 and Table 7. The time domain view of reflective losses provides a more simplified manner view to find and document potential differences along the physical length of the DUT.



NOTE: The same type of test port adapter or fixture should be used when comparing impedance data.

Figure 6 - Example of impedance test setup

4.3.3 Acceptance Criteria

There are no impedance criteria for impedance performance. Impedance performance, when charted like the template in Figure 7, can be helpful in determining performance drift or relative performance of different connector halves. Customer requirements related to impedance for the above reasons are possible and may be made by the test requester. Save all impedance plots to create reference profiles of the different mated connector pairs, which can be used to help find variations or drift over time.

NOTE: Impedance is not an exact correlation to the return loss pass/fail limits shown in Figure 5 and Table 7. The impedance performance gives a good indication why a specific failing mated pair connector does not meet the required return loss limits. (The problem will be evident from the impedance plot if the male connector, female connector, or the interface between them is disproportionately contributing to high impedance). Note also that the template overlay shown in Figure 7 (blue line) is an example of possible expectations and is neither defined nor required to be shown in the report.

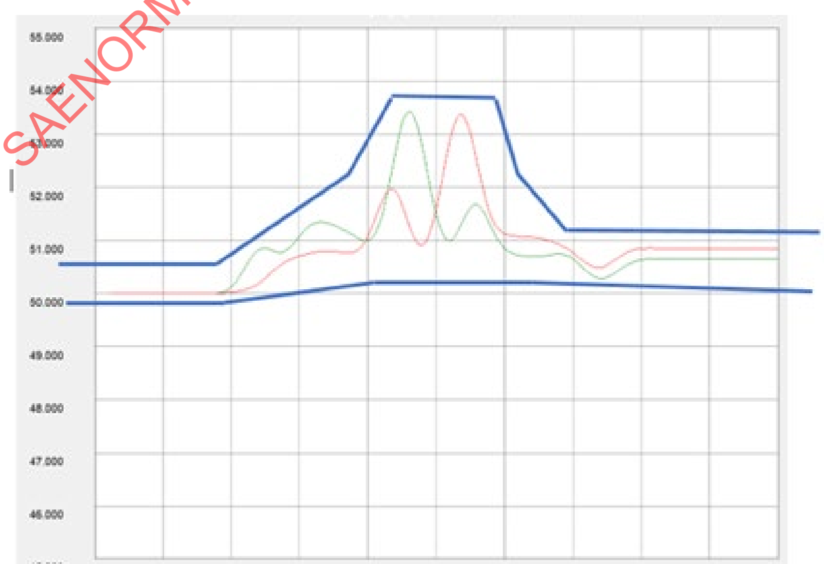


Figure 7 - Example of Impedance of DUT with template overlay

4.4 Near-End Crosstalk

4.4.1 Purpose

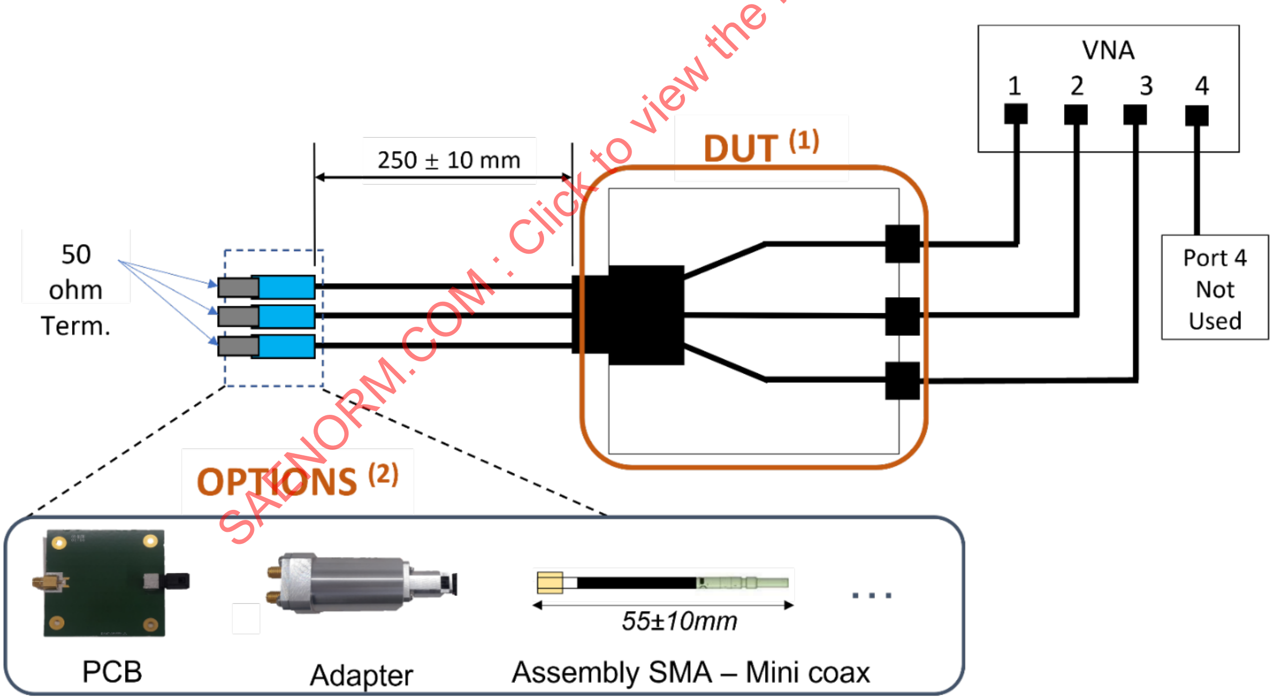
This test determines the amount of signal transmitted on one circuit that is coupled onto another circuit. It applies to multi-position cavity connectors mounted to PCB boards only (and not inline connectors). This section is also used to determine the proper layout of the multi-position connector onto the PCB by measuring the crosstalk of supplier's recommended PCB layout with the mounted connector.

This procedure is applicable to near-end crosstalk measurements; far-end crosstalk measurements are not required because of the amount shielding provided by the systems.

4.4.2 Procedure

1. Prepare a sample of a multiport header connector by using a layout for the PCB that is agreed between the customer and supplier. Document the PCB layout in the final report. An example of a 3-port header test setup is shown in Figure 8. For the 3-port header in the figure, for example, the report must include scattering parameters S21 and S23. Other multi-port connector NEXT that need to be reported are listed in Table 8. The results must be listed over the frequency rage measured.

NOTE: Crosstalk measurements of DUT embedded between fixtures do not require post processing.



NOTES:

(1) DUT consists of multi-port header connector and PCB with recommended layout and stack up.

(2) Dotted box can be one of these examples. Each is terminated with 50-ohm RF coaxial termination rated at DC to (a minimum of) 10 GHz, with return loss of < -20 dB over the frequency range.

Figure 8 - Crosstalk test setup example using a 3-port header

2. Set VNA to parameters listed in Table 4.

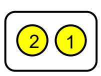
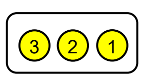
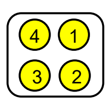
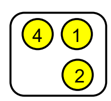
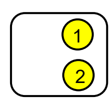
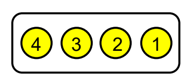
3. Measure Crosstalk between channels listed in Table 8.

4. Record data, including the following in the report (at minimum):

- Plots of the NEXT S-parameters against the limits of Table 9, Figure 10, and Figure 11.
- Pictures of the setups
- List of equipment (with calibration data), cables, connectors, terminations, and adapters
- Specific details of the adapters shown in Figure 9Specific VNA calibration used
- Details of the PCB layout (including):
    - PCB board material /
    - Stackup
    - Transmission line structure /
    - Layout
    - Dimensions of the traces / Copper weight used
    - Dimensions of the pad layout of the multi-port header connector
    - Use of ground planes and stitching of these planes, when used

5. Save all S-parameter files and ensure they are available.

Table 8 - Crosstalk configurations

Assembled channels of the Socket Connector						
Measurement(s) required between channels	1 - 2	1 - 2	1 - 2 1 - 3 1 - 4	1 - 2 1 - 4 2 - 4	1 - 2	1 - 2 1 - 3 2 - 3

NOTE: Illustrations appear reversed since they are the “face view” and not the traditional “back view.” When corrected for the view, circuit numbering shown is consistent with industry standards (USCAR-12) for circuit numbering.

4.4.3 Acceptance Criteria

When applicable, i.e., PCB-mounted multi-wire connectors, NEXT for mated pairs shall satisfy Table 9.

Table 9 - Crosstalk performance requirements for mini coax with foil shielded wire

Frequency	NEXT Limit
0.01 GHz < f ≤ 4 GHz	60 dB
4 GHz < f ≤ 9 GHz	50 dB

4.5 Shielding Attenuation

4.5.1 Purpose

This test determines whether the leakage of RF connectors (sometimes referred to as Screening Attenuation) is sufficient. This is a stand-alone test and requires samples for each cable type being qualified (each inline and header configuration).

4.5.2 Procedure

1. Follow procedure defined in IEC 62153-4-7 (Tube in Tube), using these settings and instructions. Document the PCB description per step 4.4.2 #4, if not already done.

VNA Settings:

- Frequency start = 5 MHz
- Frequency stop = 10 GHz
- Frequency step = 5 MHz
- Measurement bandwidth ≤ 10 Hz
- Port output power ≥ 0 dBm

2. Make samples per Figure 9, Figure 10, and Figure 11.

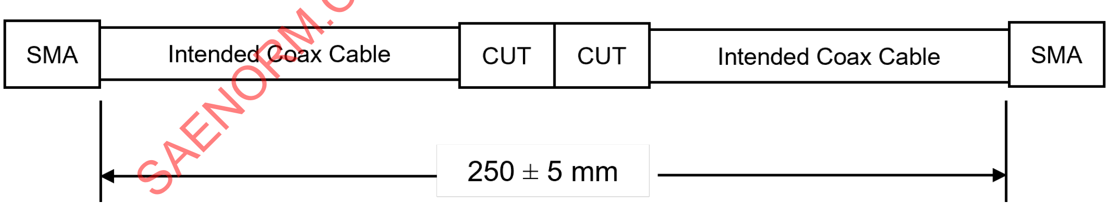


Figure 9 - Dimensions of configuration to be tested

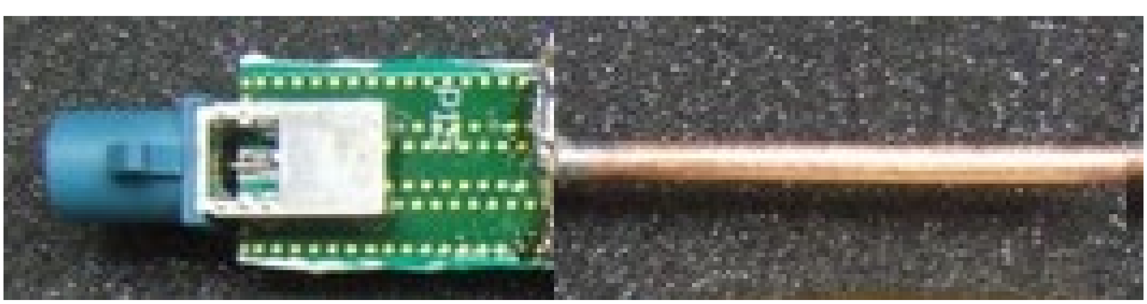


Figure 10 - Sample for shield attenuation (includes some of the intended coax cable)

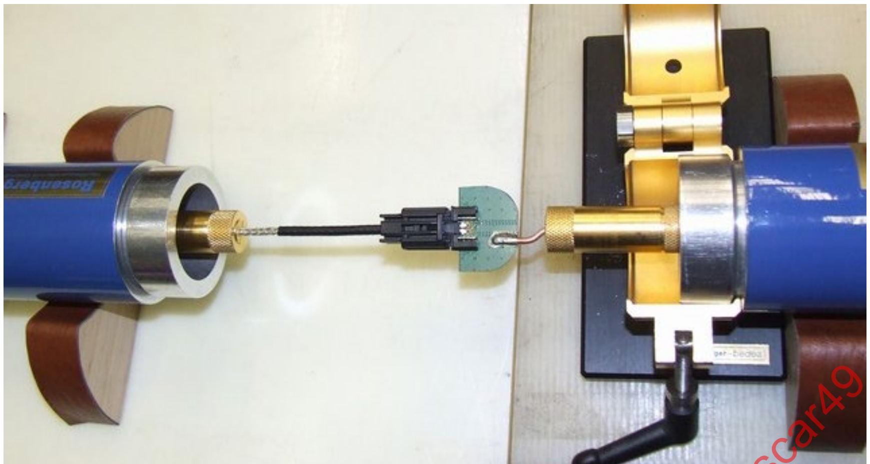


Figure 11 - Additional example shield attenuation for a header

4.5.3 Requirement

The connector under test shall not exceed the limits in Table 10 (also shown graphically as Figure 12).

NOTE: If any DUTs mounted to a PCB fail while the same part in other configurations (such as inlines) pass, the customer and supplier may use the PCB description from step 4.4.2 #4 and an agreed-on assessment tool to determine whether the PCB configuration contributed to the unfavorable result. It is up to the supplier and customer to agree how this analysis should apply.

Table 10 - Shielding attenuation performance limits

Frequency (MHz)	**Shielding Attenuation (dB)**
100 - 2000	*-62*
2000 - 5000	-55
5000 - 9000	-50

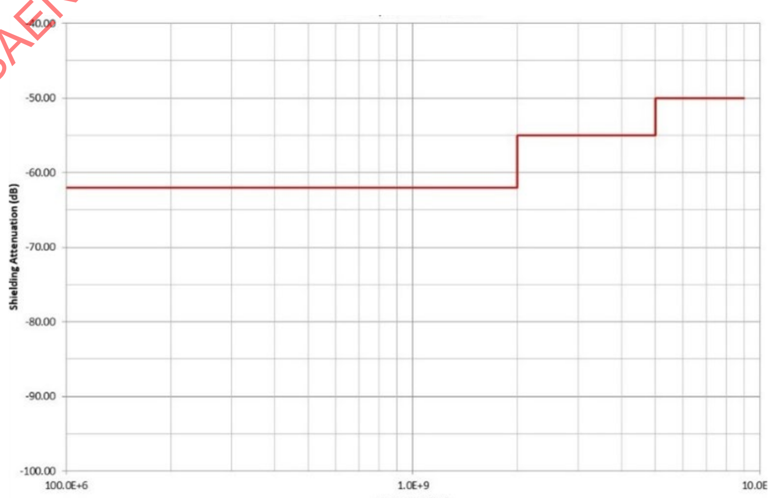


Figure 12 - Shielding attenuation performance limits

4.6 Surface Transfer Impedance

4.6.1 Purpose

The Surface Transfer Impedance (STI) test evaluates RF shielding performance in the frequency range of 10 kHz to 100 MHz.

4.6.2 Procedure

Perform STI test per Appendix C for the “far end” (when needed) for the intended application. Record data per C.3. Document the PCB description per step 4.4.2 #4, if not already done.

4.6.3 Requirement

Coaxial cables and cable assemblies (i.e. including connectors) for far end shall meet the Surface Transfer Impedance requirements per Table 11 and Figure 13, with f being the frequency in MHz. Limits shown are based on sample length as defined in this section. If any DUTs mounted to a PCB fail, while the same part in other configurations (such as inlines) pass, the customer and supplier may use the PCB description from step 4.4.2 #4 and an agreed-on assessment tool to determine whether the PCB configuration contributed to the unfavorable result. It is up to the supplier and customer to agree how this analysis should apply.

Table 11 - Surface transfer impedance limits

f (Frequency in MHz)	Maximum Zt (dB Ohms)
0.01 - 50	-27
50 - 100	-30

NOTE: The limits in table are based on lengths as defined in Appendix C, which differ from what is used in IEC 62153-4-6. If other lengths are used, values must be adjusted accordingly.

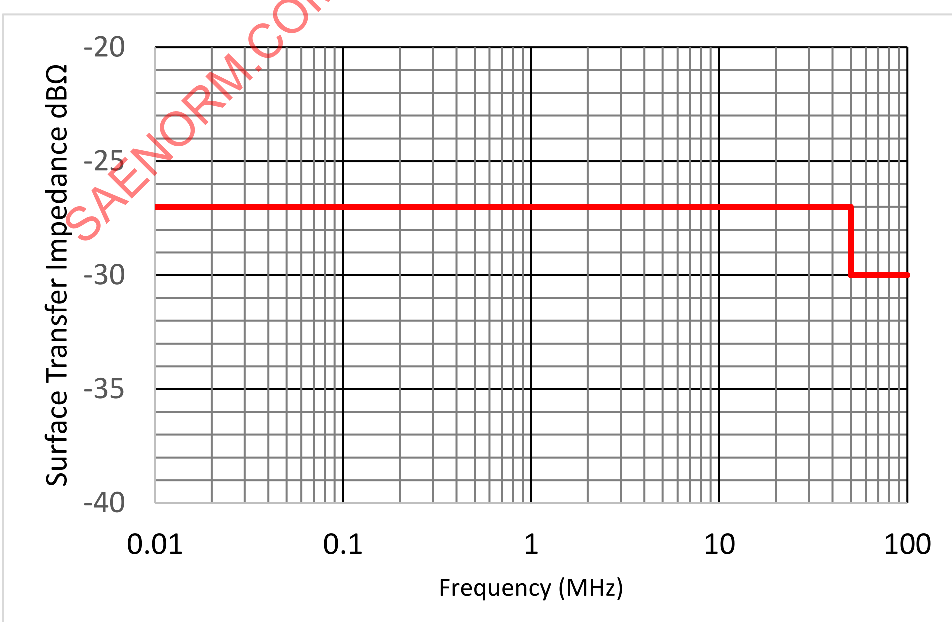


Figure 13 - Maximum allowed far end surface transfer impedance

4.7 Dielectric Withstanding Voltage

4.7.1 Purpose

The dielectric withstanding voltage test is used to determine whether 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.

4.7.2 Procedure

With the connector mated, raise the test voltage from 0 to 500VDC as uniformly as possible between the internal and external conductor terminals. Maintain the 500VDC for 60 seconds and then lower the voltage to 0.

NOTE: USCAR-17 Section 4.3.2 (Dielectric Withstanding Voltage) may be substituted for this procedure if desired.

4.7.3 Acceptance Criteria

The resistance between inner and outer conductors shall exceed 100 MΩ at 500 VDC. If USCAR-17 Section 4.3.2 was used as a substitute test, follow the USCAR-17 criteria.

NOTE: This criterion aligns with USCAR-2 Section 5.5.1 and USCAR-17 Section 4.4.1 for insulation resistance.

4.8 Mechanical Side Load

4.8.1 Purpose

This test verifies that the connector latch, terminal retention system, and cable attachment will maintain continuity when subjected to mechanical stress. This test is in addition to the mechanical connector tests in USCAR-2. This is a stand-alone test and requires samples for each cable type qualified.

4.8.2 Procedure

1. Prepare Connector Under Test (CUT) assemblies to allow for continuity and return loss testing.

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

3. Apply a pull force parallel with the axis of the cable (Direction "A"). For samples prepared for return loss measurement, it is acceptable to wrap the cable around a 2-inch diameter mandrel, securing the cable to the mandrel with electrical tape or other suitable means. Board mount connectors may have the circuit board end rigidly attached to a fixture.

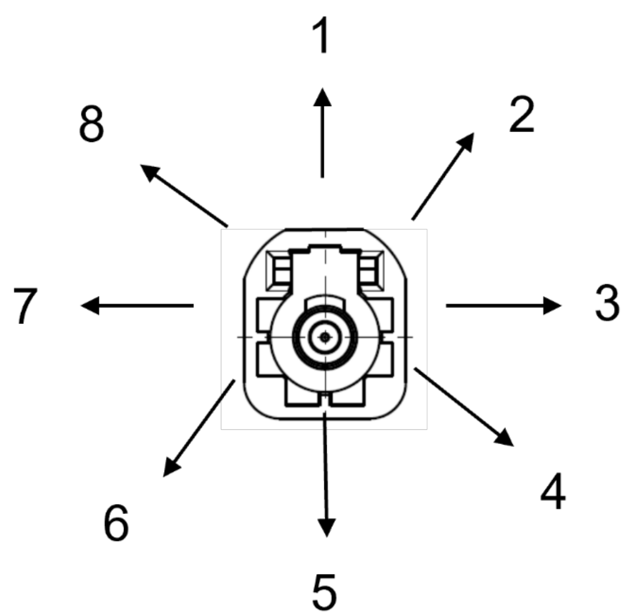
4. Pull at a uniform rate not to exceed 50mm/min until the force reaches 110N.

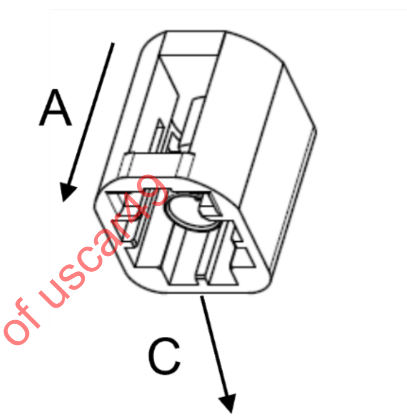
5. Hold the force for 5 seconds while monitoring for continuity.

6. For Board and Panel Mount testing only: Apply 75N of force in the following directions using the same test sample: 1C, 3C, 5C, 7C, 8C per Figure 14. The sequence of force application is at the lab's discretion. Direction vector C revolves 360° around the connector axis.

7. Additional test for right angle cabled connectors: Apply a side load shall to the extreme end of the ferrule (furthest from the centerline). Apply 75N for 5 seconds. Monitor continuity of center conductor. (This is needed since axial loads are less practical when applied to right angle connectors)

8. Disassemble each sample and visually check for damage that could affect the performance of the connection system.





NOTE: Direction vector C revolves 360° around the connector axis.

Figure 14 - Mechanical side load forces

4.8.3 Acceptance Criteria

1. No interruptions in continuity shall occur during the force test.

2. The Return Loss taken after the test shall fulfil Table 7.

3. No visual damage to the connection system, including connector body, metal terminals or cable attachment shall be noted.

4. Mechanical requirements:

a. Pull force in direction A shall satisfy USCAR-2, Table 5.4.1.4, using the “Retention after Moisture Conditioning” column. (Table 5.4.1.4 is also documented in Appendix D as Table 12).

b. Side load shall be 75N minimum in direction C. (Applies for board and panel mount connectors only).

APPENDIX A - DEFINITIONS

BOARD MOUNT CONNECTOR: A Connector with electrical connections soldered directly to a printed circuit board.

CUT: Connector Under Test

DE-EMBEDDING: The mathematical process by which electrical reference planes can be set to desired locations. Its importance originates from the fact that electrical characteristics are not always directly measurable at the reference planes of interest.

DUT: Device Under Test

DWV: Dielectric Withstanding Voltage, also known as dielectric strength testing

HEADER CONNECTOR: A connector system that utilizes one or more fixed male terminals inserted into a housing. The non-mating ends of the terminals are usually soldered to a printed circuit board or connect internally to the device.

INLINE CONNECTOR: A connector that is terminated with coax cable on both sides (opposed to a header connector, that is that is terminated with coax cable on one side only.

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

MALE CONNECTOR: A connector where the center conductor is a pin contact.

NEXT: Near-end Crosstalk

SOLR: A method of VNA calibration using “Short, Open, Load, and Reflection.

SOLT: A method of VNA calibration using “Short, Open, Load, and Through.

TOSM: A method of VNA calibration using “Through, Open, Short, and Match.”

TDR: Time Domain Reflectometry

APPENDIX B - CONFIRMATION OF DE-EMBEDDING TOOL ACCURACY (INFORMATIVE)

B.1 INSTRUCTIONS

Perform this assessment, if requested by customer, prior to testing parts. Confirm the de-embedding tool meets the requirement before performing USCAR-49 testing. The confirmation is performed only one time for a given configuration.

B.1.1 Sample Preparation

Prepare FIX-FIX, DUT, and FIX-DUT-FIX samples as shown in Figure 15 and test on VNA. Samples may be hand-made.

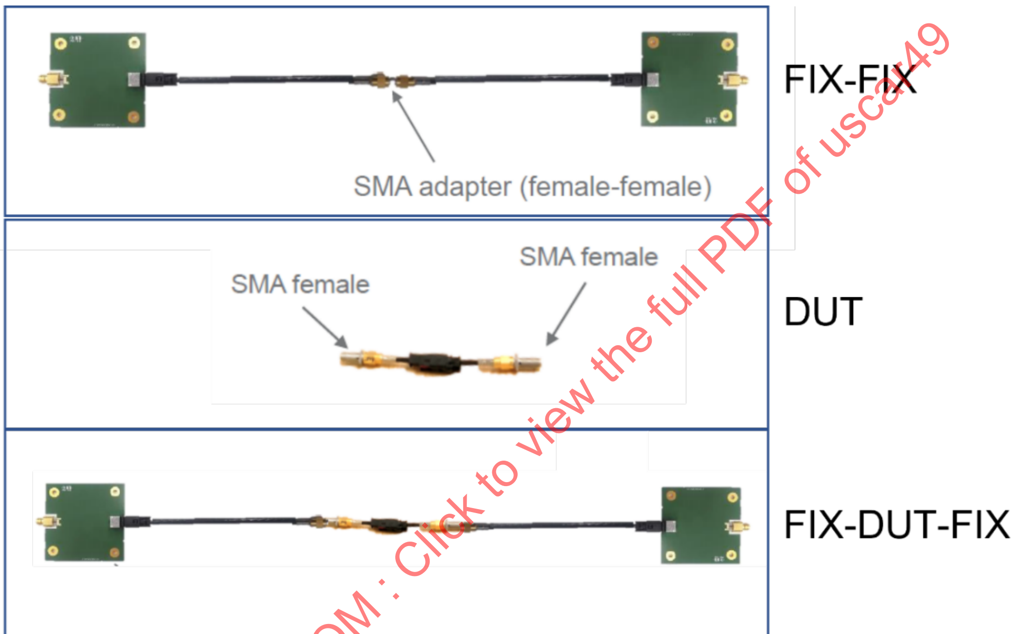


Figure 15 - Sample preparation example for de-embedding tool verification

B.1.2 Procedure

1. Compare complex S-parameter data for direct measurement using fixtures in Figure 15 vs. de-embedded results.

2. Calculate error metrics for absolute error for reflection parameters and relative error for transmission parameters per Equation 2 and Equation 3.

$$Absolute\ error = \left| S_{11}^{A} - S_{11}^{B} \right| \quad \text{(Eq. 2)}$$

$$Relative\ error = \frac{\left| S_{12}^{A} - S_{12}^{B} \right|}{0.5 \cdot \left(\left| S_{12}^{A} \right| + \left| S_{12}^{B} \right| \right)} \quad \text{(Eq. 3)}$$

B.1.3 Acceptance Criteria

This is an informative section with no requirement. A typical customer requirement for this section, when requested, is: "The de-embedding tool error shall be smaller than -20 dB."

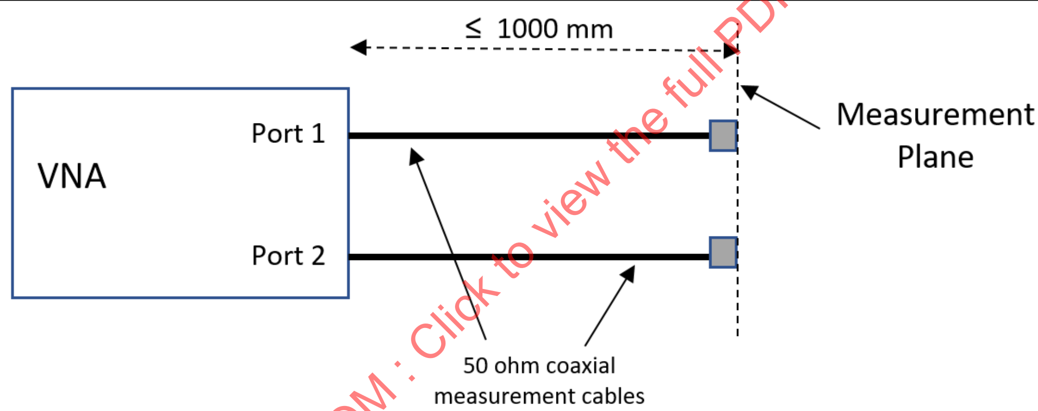
APPENDIX C - TEST METHOD FOR SURFACE TRANSFER IMPEDANCE (NORMATIVE)

C.1 TEST VERIFICATION AND TEST SETUP

Verification testing for inline connectors is based on IEC 62153-4-6 (Line Injection) and IEC 62153-4-4 except where delineated. Details presented are currently limit testing of individual connectors including those used on the PCB. IEC 62153-4-7 may be used if agreed upon between customer and supplier.

C.1.1 Measurement Equipment Procedure

Perform all measurements using a Vector Network Analyzer (VNA) with S-parameter measurement capability. (The VNA, when properly calibrated must be capable of making loss measurements with an accuracy of less than 0.1 dB.) Calibrate the VNA using the SOLT (Short, Open, Load, Through) or equivalent method via high quality reference (traceable) standards). Cable connections between the VNA and sample shall consist of low loss cables of sufficient length to facilitate connection. Cable length shall not exceed 1000 mm. Include cables in the VNA calibration per Figure 16. Adaptors should be avoided but must be included in the VNA calibration, if used. Do not use time-gating or de-embedding to remove the effects of using adaptors, unless approved by customer.



S parameters relate to voltages of an N-port network. VNA measurements of these parameters may be reported in the formats shown in Figure 16. Example given is for reporting of S_{21}.

Linear-Complex: $S_{21} = Re + jIm$

Linear-Magnitude: $|S_{21}| = |Re + jIm| = \sqrt{Re^2 + Im^2}$ where: $|S_{21}| < 1$

dB: $S_{21}(dB) = 20 \cdot Log|S_{21}|$

Figure 16 - STI equipment set-up

C.1.2 Test Sample Preparation

1. Figure 17 and Figure 18 illustrate initial sample preparation for cables and cable assemblies (dimensions are in millimeters). To facilitate line injection measurement, the jacket of the cable must be window stripped. Care must be exercised to avoid damage of the braid; a thermal cable stripper (e.g., Teledyne TWC 6) is recommended.

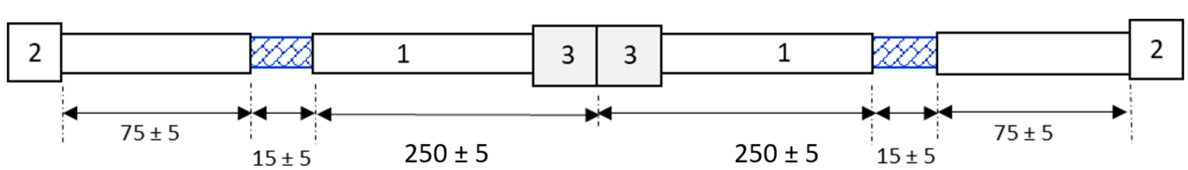
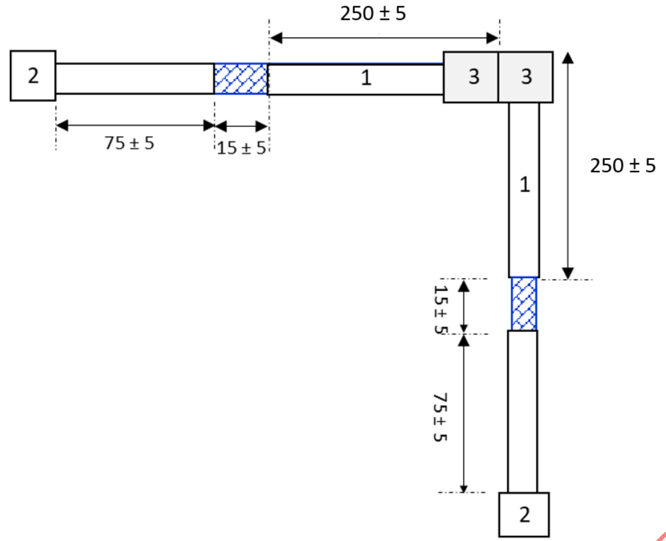


Figure 17 - Sample preparation for straight inline connector (initial)



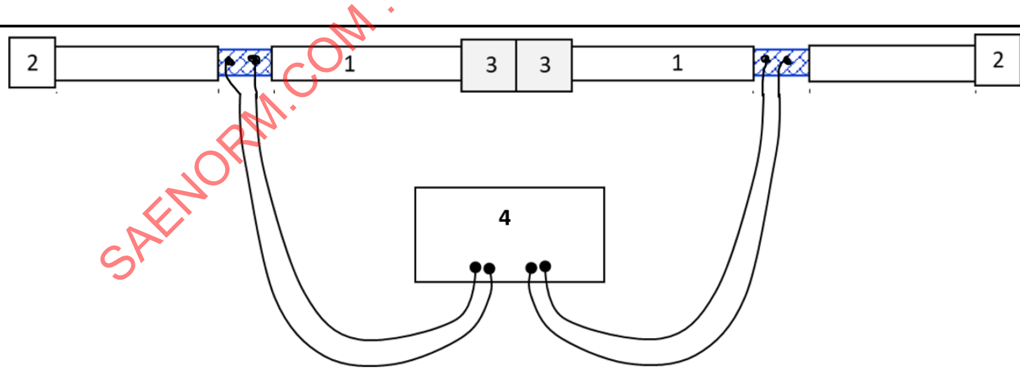
All dimensions in mm.

Where:

1.Coaxial cable
2.SMA connector (under consideration to be other connections)
3.Connector Under Test (CUT)

Figure 18 - Sample preparation for right angle inline connector (initial)

2. Measure the DC resistance of the cable/cable assembly shield before assembly of the line Injection test sample by using a 4-wire milliohm meter capable of measuring DC resistance less than 1 milliohm. Connect the meter the exposed braid sections of the cable/cable sample per in Figure 19. Record the DC resistance measured.



Where:

1.Coaxial cable
2.SMA connector (under consideration to be other connections as well)
3.Connector Under Test (CUT)
4.Four (4)-wire DC ohmmeter

Figure 19 - Setup for shield DC resistance measurement

3. Prepare samples for Line Injection testing per Figure 20 and Figure 21. Testing requires use of semi ridged coaxial cable (RG402) used for the launch assembly for the Line Injection. Cut cable to 100± 5 mm with an SMA (male) connector affixed to one end. The other end is open to allow soldering of the injection wire. The cable may be bent slightly to allow ease in connection to the VNA. When soldering the outer conductor (shield) of the cable take care to limit the solder temperature to avoid damage to the dielectric material in the CUT.

4. To avoid measurement errors particularly at lower test frequencies, place ferrite beads on both the launch assemblies and CUT (“Snap-It” beads may be use for ease of installation.) Figure 22 provides information on the typical mechanical and electrical characteristics. The bead should be selected to get the maximum impedance below 10 MHz.

NOTE: A commercially available material for the bead is “Type 75” from Fair-Rite Products Corp p/n 0475164281.

5. The injection line must consist of an uninsulated, tin-plated stranded copper wire bundled with the cable or cable assembly. It is critical that the injection line lie tightly against the insulation of the cable jacket and connector shell. It is recommended to use a non-adhesive vinyl tape to facilitate injection line movement around the connector. Shrinkable tubing may also be used around the cable. (Use of adhesive electrical tape should be avoided due to the difficulty it presents for repositioning of the injection line.) Solder the injection line to the center conductor of each RG402 coaxial launch point.

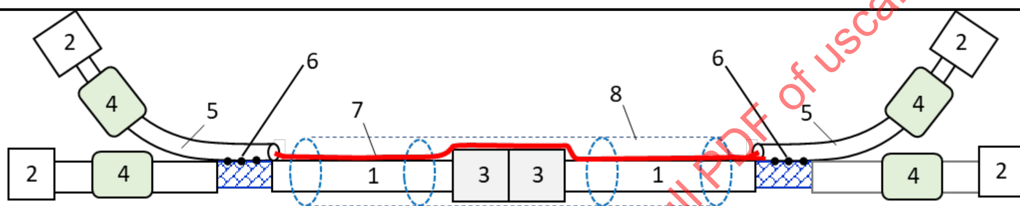
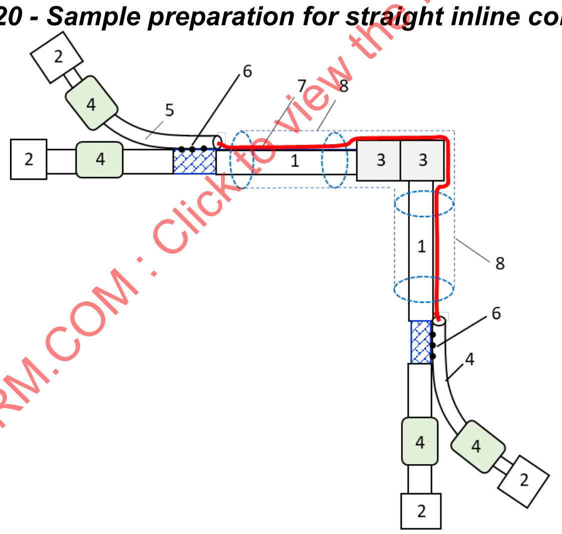


Figure 20 - Sample preparation for straight inline connector



Key:

1. Cable Under Test (CUT)
2. 50-ohm SMA (male) coaxial connector
3. In-line connector (e.g., SMB or USCAR-18 style). Includes right angle connectors (see 1.3.2)
4. Ferrite Bead (as described above)
5. RG402 semi ridged cable
6. Solder connection between RG402 and braid of CUT
7. Injection Line (1mm or 18 AWG un-insulated)
8. Non-adhesive vinyl tape wrap

Figure 21 - Sample preparation for right angle connector