

# METHOD OF IMPLEMENTATION (MOI) FOR USB3.2 LEGACY CABLE TEST

## Products:

- ▶ R&S®ZNB

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This document is complemented by configuration files. The configuration files may be updated even if the version of the document remains unchanged.



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# 1 Introduction

The purpose of this document is to provide step-by-step guidance on performing USB-IF compliance testing on a USB legacy cable.

Throughout this Method of Implementation (MOI), procedures will detail how to perform such USB-IF compliance testing using the R&S®ZNB lineup of Network Analyzers.

## References:

This document was written with reference to the [Universal Serial Bus 3.1 Legacy Connectors and Cable Assemblies Compliance Document revision 1.1, 2018](#)

## 2 Required equipment

### 2.1 R&S®ZNB20 configuration

Description	Equipment	Quantity
<b>Network analyzer</b>	R&S®ZNB20 vector network analyzer, 4 ports, 100kHz - 20GHz, PC3.5 connectors with: <ul style="list-style-type: none"> <li>— R&amp;S®ZNB-K2, time domain (TDR) analysis (software license)</li> <li>— R&amp;S®ZNB-K20, extended time domain (TDR) analysis (software license)</li> <li>— R&amp;S®ZNB-K210, easy de-embedding (EZD) (software license)</li> </ul>	1
<b>RF cable</b>	R&S®ZV-Z193 var60, 50 Ohm, DC to 26.5GHz, 3.5mm(f)-3.5mm(m), flexible, phase stable, 60 inch (1520mm)	4
<b>Calibration unit/kit</b>	One of the following: <ul style="list-style-type: none"> <li>— R&amp;S®ZN-Z52 var30 calibration unit, 100kHz to 26.5 GHz, 4 ports, 3.5mm(f)</li> <li>— R&amp;S®ZN-Z53 var32 calibration unit, 100 kHz to 26.5 GHz, 2 ports, 3.5mm(f)</li> <li>— R&amp;S®ZN-Z135 var03 calibration kit, 50 Ohm, 0Hz to 26.5 GHz, 3.5mm(f)</li> </ul>	1
<b>Legacy test fixture</b>	Standard-A test fixture: Luxshare-ICT TFU-12R4R Standard-B test fixture: Luxshare-ICT TFU-19R4R Micro-B test fixture: Luxshare-ICT TFU-14R4R Mini-B test fixture: Luxshare-ICT TFU-26R4R	2*
<b>50 Ohm terminator</b>	One of the following: <ul style="list-style-type: none"> <li>— Hirose HRM-601A(52)</li> <li>— XMA 2003-6110-00</li> <li>— P1dB P1TR-SAM-26G2W</li> </ul>	16

\*2 legacy test fixtures are required to test a cable, but only 1 test fixture of a given connector type is needed for the end of a cable that will be tested. For example, a USB Type-A to USB Type-B cable requires 1 Luxshare-ICT TFU-12R4R fixture and 1 Luxshare-ICT TFU-19R4R

# 3 Test overview and preparation

## 3.1 Measurement scope

This document focusses on how to perform normative compliance measurements for USB legacy passive cables with USB3.1 and USB2.0 capabilities. Test requirements for other types of cables are not described in this document. However, the requirements might be a subset of measurements described in this document.

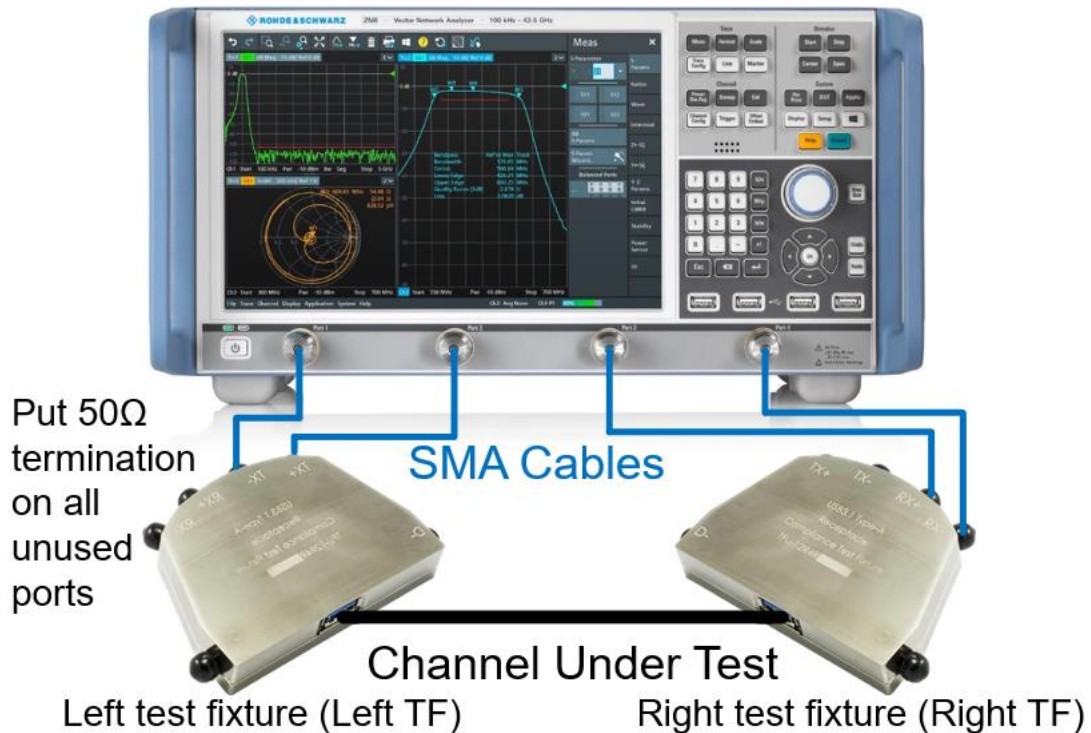
There are two legacy connectors supported by the USB-IF specification. These include USB 3.1 Standard Type-A, USB3.1 Standard Type-B, USB3.1 Micro-B, USB3.1 Micro AB and USB3.1 Micro-A. For simplicity, the diagrams within this document will demonstrate test setups with a Type-A connector, but all test instructions are applicable to all legacy connector types listed above.

Normative compliance requirements are listed below:

- D+/D- Pair Propagation Delay
- D+/D- Pair Propagation Delay Skew
- Differential Near-End Crosstalk Between SuperSpeed Pairs
- Differential Near-End and Far-End Crosstalk Between SuperSpeed and D+/D- Pairs
- Differential Impedance of SuperSpeed Mated Connectors
- D+/D- Pair Attenuation
- Differential Insertion Loss (SuperSpeed) of Mated Cable Assembly
- Differential-to-Common-Mode Conversion (SuperSpeed) of Mated Cable Assembly

## 3.2 Test setup

### 3.2.1 R&S®ZNB20 test setup



Equipment needed for testing is listed in Error! Reference source not found.. Below is an example setup using the R&S®ZNB20.

To avoid confusion, throughout the document the test fixtures are referred to by their orientation in this diagram (left, right).

## 3.3 Recall setup files

There are recall files delivered together with this document which makes it more convenient to perform the required measurements. There is one recall file for each group of measurements, one additional one for the calibration procedure.

### Recalling the setup files

1. On the front panel of the instruments, click the green “PRESET” button.
2. Press “FILE” > “Open Recall...”.
3. Open the recall files (\*.znxml) for the desired tests.

## 3.4 Calibration and de-embedding

Calibration of the VNA and RF cables, as well as de-embedding of the USB test fixtures, is necessary to accurately measure the USB cable characteristics at the proper test points.

This is accomplished by performing a coaxial calibration until the end of the RF cables, extract the test fixture S-parameter files using EAZY De-embedding (EZD) technique, and then import de-embedding files in the VNA which removes the effect of the test fixture. Alternative de-embedding techniques, such as In-Situ De-embedding (ISD), are also supported by R&S®ZNB20.

The three different test groups use different frequency ranges. The calibration recall file includes all the required frequency ranges in one setup. This allows the user to do the calibration at once.

### **3.4.1 Coaxial calibration**

#### **3.4.1.1 Calibration with automated calibration unit**

The most convenient method to perform coaxial calibration is to use an automated calibration unit. Doing so will complete calibration faster and more efficiently.

1. Connect E-cal USB cable to the VNA
2. Connect the ports to the e-cal with the cables you will use for testing
3. On the front panel, press Channel > “Cal”
4. Select “Start Auto Cal”, wait a few minutes for Auto Cal to be complete

Now the VNA is successfully calibrated. Optional, save calibration

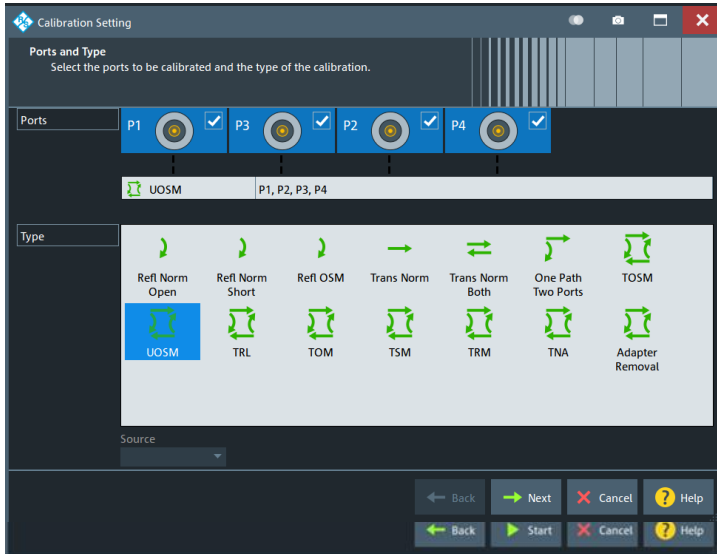
5. Go to File > “Save...”
6. Create file name
7. Save to relevant folder

#### **3.4.1.2 Manual calibration with calibration kit**

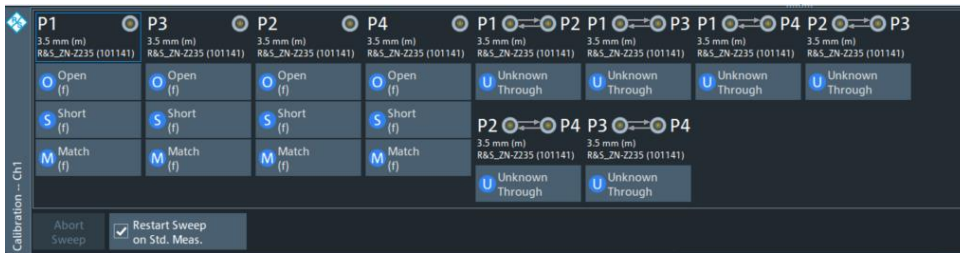
Alternatively, if an automated calibration unit is not available, then a manual calibration kit can be used instead.

1. Make sure the active setup is the “Calibration” setup.
2. On the front panel, press “Cal” > “Start... (Manual)”

3. Select Calibration Type “UOSM” for best accuracy.



4. Open dialog “Calibration Setting”. Check connector (e.g. 3.5 mm), gender (e.g. male) and used CalKit.
5. Start calibration and connect all required calibration standards (open, short, match and unknown through).



- Note: It is required to measure at least 3 unknown through connections, however further measured connections will increase the accuracy.

Optional, save calibration

6. After the calibration is completed, go to File > “Save...”.
7. Create file name
8. Save to relevant folder

### 3.4.2 De-embedding USB test fixtures

After coaxial calibration is completed, the next step is to remove the effect of the test fixtures that will be used during testing. This is accomplished by using files provided by the test fixture supplier or collecting de-embedding files from the fixtures manually. This section describes both methods of de-embedding.



The user should verify that the de-embedding files are applied before collecting DUT measurement data. This is especially true after a measurement group preset has been issued. Otherwise, measurements will be collected without proper de-embedding applied, resulting in inaccurate results.

### 3.4.2.1 Using de-embedding files provided by test fixture supplier

The most convenient de-embedding method is to use files provided by the test fixture vendor.

1. On the front panel, press “Offset Embed”.
2. Select “Single Ended”.
3. Import the 2-port Touchstone files (\*.s2p) which are delivered together with the test fixtures of Luxshare-ICT

Single Ended				
Deembedding	Active	File Name 1		Swap Gates
P1	<input checked="" type="checkbox"/>	21_1.s2p	...	<input type="checkbox"/>
P2	<input checked="" type="checkbox"/>	21_2.s2p	...	<input type="checkbox"/>
P3	<input checked="" type="checkbox"/>	43_1.s2p	...	<input type="checkbox"/>
P4	<input checked="" type="checkbox"/>	43_2.s2p	...	<input type="checkbox"/>

### 3.4.2.2 Measuring and generating de-embedding files

In case the test fixture vendor could not supply the necessary files for de-embedding, or there is a concern regarding accuracy of such files (from fixture aging/use due to cable insertion over time), the user creates new de-embedding files by making measurements in the VNA firmware. This procedure will be using Smart fixture deembedding (SFD) tool which requires the R&S®ZNB-K230 software option.

#### Performing ISD De-embedding

1. Go to Channel > Offset Embed
2. Go to Deembed Assistant
3. Connect port 1 to '+' on data lane that is under test and port 3 to '-' on data lane that is under test to the left fixture
4. Connect port 2 to '+' on data lane that is under test and port 4 to '-' on data lane that is under test to the right fixture
5. Select ISD as Fixture Tool
  - 5.1 Select “1 x 1 Balanced” for DUT
  - 5.2 Select “Balanced” for Left: Model A and Right: Model B
  - 5.3 Uncheck “Use same coupon Left and Right”
  - 5.4 Press Next
  - 5.5 On Coupon A select 1x Open
  - 5.6 For Port on Coupon A select “L1”

5.7 Click "Measure" for Coupon A

5.8 On Coupon B select 1x Open

5.9 For Port on Coupon B select "L2"

5.10 Click "Measure" for Coupon B

5.11 On DUT + Fixture select for left side port "L1" and right side port "L2"

5.12 Connect DUT to fixture left and fixture right.

5.13 Click "Measure" DUT + Fixture

5.14 Click "Apply"

Fixture De-embedding is now properly applied.

### 3.5 Stimulus risetime adjustment

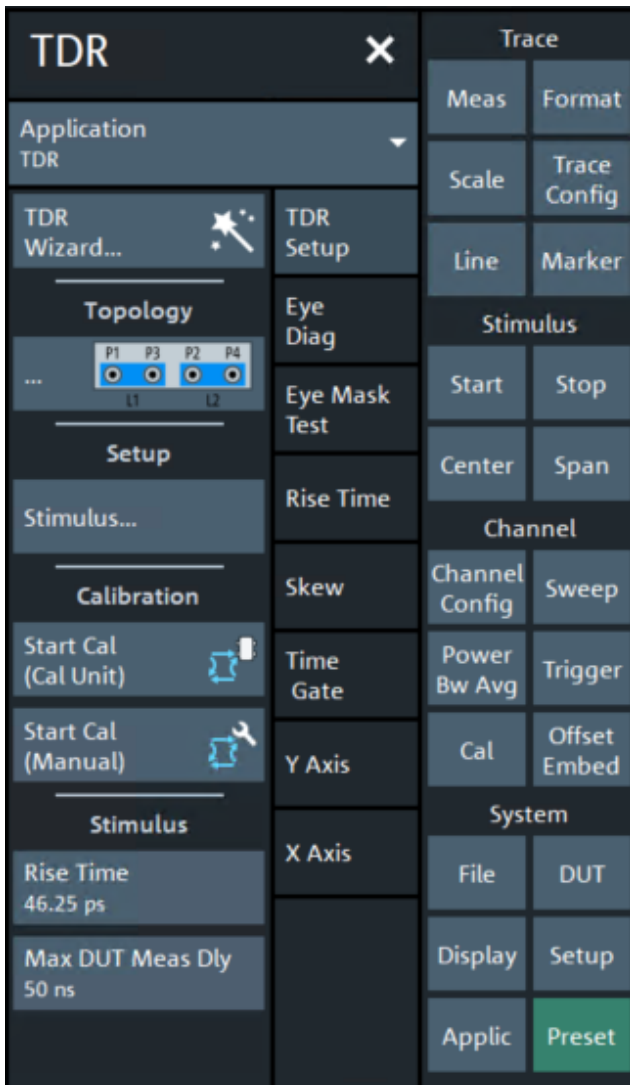
This section demonstrates how the stimulus risetime of the R&S®ZNB is adjusted. This is necessary, when performing the time domain measurements (such as propagation delay), as the USB-IF requires different risetimes be used in each of these scenarios.

*Note:* Licenses for the additional R&S®ZNB-K2 and R&S®ZNB-K20 options will be required for this functionality.

1. On the front panel, select “APPLIC”.



2. In the “Application” dialog, select “TDR”.



At the bottom of the “TDR” dialog, you find the “Rise Time” button.

3. Select “Rise Time” to adjust the risetime.

The rise time value can be defined to 10%/90% or 20%/80%.

# 4 Compliance Measurements with R&S®ZNB20

This section describes how to perform the compliance measurements with the R&S®ZNB20 4-port vector network analyzer. Tests are broken into Time Domain and Frequency Domain measurements.

Tests covered in this section:

- D+/D- Pair Propagation Delay
- D+/D- Pair Propagation Delay Skew
- Differential Near-End Crosstalk Between SuperSpeed Pairs
- Differential Near-End and Far-End Crosstalk Between SuperSpeed and D+/D- Pairs
- Differential Impedance of SuperSpeed Mated Connectors

Test Case	Rise Time %	Target Stimulus Rise Time	Pass Criteria
D+/D- Pair Propagation Delay	10 – 90 %	200 ps	Standard connector: 16 ns maximum Micro connector family: 10 ns maximum
D+/D- Pair Propagation Delay Skew	10 – 90 %	200 ps	100 ps maximum
Differential Impedance of SuperSpeed Mated Connectors	20 – 80 %	50 ps	Minimum: 75Ω Maximum: 105Ω
Differential Near-End Crosstalk Between SuperSpeed Pairs of Mated Cable Assembly	20 – 80 %	50 ps	Must not exceed: Standard-A connector: ± 0.81Ω normalized to 90Ω (0.9%) Standard-B connector: ± 1.62Ω normalized to 90Ω (1.8%) Micro connector family: ± 1.08Ω normalized to 90Ω (1.2%)
Differential Near-End and Far-End Crosstalk Between SuperSpeed and D+/D- Pairs	10 – 90 %	50 ps	Must not exceed: Standard-A connector, Standard-B connector, and Micro connector family: ± 1.8Ω normalized to 90Ω (2%)

## 4.1.1 D+/D- Pair Propagation Delay

1. Recall the “Dpair\_Propagation\_Delay.znxml” state file
2. Verify that the calibration and de-embedding data is recalled and enabled.
3. Connect ports 1 to 4 to the test fixture according to the table below:

VNA Port	Port 1	Port 3	Port 2	Port 4
Test Fixture	D+ (Left TF)	D- (Left TF)	D+ (Right TF)	D- (Right TF)

4. Analyze results, fail if the result is greater than the value below for your given connector type.

Connector Type	Allowable propagation delay
Standard A to Standard B	<26 nanoseconds

Connector Type	Allowable propagation delay
Standard to Micro or Micro to Micro	<10 nanoseconds

#### 4.1.2 D+/D- Pair Propagation Delay Skew

1. Recall the “Dpair\_Propagation\_Delay\_Skew.znxml” state file
2. Verify that the calibration and de-embedding data is recalled and enabled.
3. Connect ports 1 to 4 to the test fixture according to the table below:

VNA Port	Port 1	Port 3	Port 2	Port 4
Test Fixture	D+ (Left TF)	D- (Left TF)	D+ (Right TF)	D- (Right TF)

4. Analyze skew result, the difference in time between the two marker values is the Propagation Delay Skew. If measured value is less than 100 ps then pass, otherwise fail.

#### 4.1.3 Differential Near-End Crosstalk Between SuperSpeed Pairs

1. Recall the “Differential\_Near-End\_Crosstalk\_SuperSpeed\_Pairs.znxml” state file
2. Verify that the calibration and de-embedding data is recalled and enabled.
3. Connect ports 1 to 4 to the test fixture according to the table below:

VNA Port	Port 1	Port 3	Port 2	Port 4
Test Fixture	D+ (Left TF)	D- (Left TF)	Tx+ (Left TF)	Tx- (Left TF)

4. Analyze normalized results, fail if the result is greater than the value below for your given connector type.

Connector Type	Allowable near-end crosstalk
Standard A	$\pm 0.81\Omega$ normalized to $90\Omega$ (0.9%)
Standard B	$\pm 1.62\Omega$ normalized to $90\Omega$ (1.8%)
Micro connector family	$\pm 1.08\Omega$ normalized to $90\Omega$ (1.2%)

5. Repeat steps 3 and 4 with new test fixture connections shown in the table below:

VNA Port	Port 1	Port 3	Port 2	Port 4
Test Fixture	D+ (Left TF)	D- (Left TF)	Rx+ (Left TF)	Rx- (Left TF)
	D+ (Left TF)	D- (Left TF)	Tx+ (Right TF)	Tx- (Right TF)
	D+ (Left TF)	D- (Left TF)	Rx+ (Right TF)	Rx- (Right TF)
	D+ (Right TF)	D- (Right TF)	Tx+ (Right TF)	Tx- (Right TF)
	D+ (Right TF)	D- (Right TF)	Rx+ (Right TF)	Rx- (Right TF)
	D+ (Right TF)	D- (Right TF)	Tx+ (Left TF)	Tx- (Left TF)

VNA Port	Port 1	Port 3	Port 2	Port 4
	D+ (Right TF)	D- (Right TF)	Rx+ (Left TF)	Rx- (Left TF)

#### 4.1.4 Differential Near-End and Far-End Crosstalk Between SuperSpeed and D+/D- Pairs

1. Recall the “Differential\_Near-End\_Far-End\_Crosstalk\_SuperSpeedPair\_DPair.znxml” state file
2. Verify that the calibration and de-embedding data is recalled and enabled.
3. Connect ports 1 to 4 to the test fixture according to the table below:

VNA Port	Port 1	Port 3	Port 2	Port 4
Test Fixture	D+ (Left TF)	D- (Left TF)	Tx+ (Right TF)	Tx- (Right TF)

4. Analyze normalized results, fail if the result is greater than the value below for your given connector type.

Connector Type	Allowable near-end crosstalk
Standard A	$\pm 1.8\Omega$ normalized to $90\Omega$ (2%)
Standard B	$\pm 1.8\Omega$ normalized to $90\Omega$ (2%)
Micro connector family	$\pm 1.8\Omega$ normalized to $90\Omega$ (2%)

5. Repeat steps 3 and 4 for the following connections:

VNA Port	Port 1	Port 3	Port 2	Port 4
Test Fixture	D+ (Left TF)	D- (Left TF)	Tx+ (Right TF)	Tx- (Right TF)
	D+ (Left TF)	D- (Left TF)	Rx+ (Left TF)	Tx- (Left TF)
	D+ (Left TF)	D- (Left TF)	Rx+ (Right TF)	Rx- (Right TF)
	D+ (Right TF)	D- (Right TF)	Tx+ (Right TF)	Tx- (Right TF)
	D+ (Right TF)	D- (Right TF)	Rx+ (Right TF)	Rx- (Right TF)
	D+ (Right TF)	D- (Right TF)	Tx+ (Left TF)	Tx- (Left TF)
	D+ (Right TF)	D- (Right TF)	Rx+ (Left TF)	Rx- (Left TF)

#### 4.1.5 Differential Impedance of SuperSpeed Mated Connector

1. Recall the “Differential\_Impedance\_SuperSpeedMated\_Connector.znxml” state file
2. Verify that the calibration and de-embedding data is recalled and enabled.
3. Connect ports 1 to 4 to the test fixture according to the table below:

VNA Port	Port 1	Port 3	Port 2	Port 4
Test Fixture	Tx+ (Left TF)	Tx- (Left TF)	Tx+ (Right TF)	Tx- (Right TF)

- Analyze results, fail if the resulting impedance is below 75Ω or above 105Ω for the duration of measurement
- Make reconnections in the table below and repeat steps 15 and 16

VNA Port	Port 1	Port 3	Port 2	Port 4
Test Fixture	Rx+ (Left TF)	Rx- (Left TF)	Rx+ (Right TF)	Rx- (Right TF)

Tests covered in this section:

D+/D- Pair Attenuation

Differential Insertion Loss (SuperSpeed) of Mated Cable Assembly

Differential-to-Common-Mode Conversion (SuperSpeed) of Mated Cable Assembly

#### 4.2.1 D+/D- Pair Attenuation

- Recall the “Dplus\_Dminus\_Pair\_Attenuation.znxml” state file
- Verify that the calibration and de-embedding data is recalled and enabled.
- Connect ports 1 to 4 to the test fixture according to the table below:

VNA Port	Port 1	Port 3	Port 2	Port 4
Test Fixture	D+ (Left TF)	D- (Right TF)	D+ (Right TF)	D- (Left TF)

- Analyze results, pass if the resulting trace is within the limit line defined in the table below:

All connector test points	
Frequency	Max
12 MHz	-0.67 dB
24 MHz	-0.95 dB
48 MHz	-1.35 dB
96 MHz	-1.90 dB
200 MHz	-3.20 dB
400 MHz	-5.80 dB

#### 4.2.2 Differential Insertion Loss

- Recall the “Differential\_Insertion\_Loss.znxml” state file
- Verify that the calibration and de-embedding data is recalled and enabled.



- Connect ports 1 to 4 to the test fixture according to the table below:

VNA Port	Port 1	Port 3	Port 2	Port 4
Test Fixture	Tx+ (Left TF)	Tx- (Left TF)	Rx+ (Right TF)	Rx- (Right TF)

- Analyze results, pass if the resulting trace is within the limit line defined in the table below:

Standard	
Frequency	Limit
100 MHz	-1.50 dB
1.25 GHz	-5.0 dB
2.5 GHz	-7.5 dB
7.5 GHz	-25 dB

Micro connector Family	
Frequency	Limit
100 MHz	-0.6 dB
1.25 GHz	-2.33 dB
2.5 GHz	-3.5 dB
7.5 GHz	-11.67 dB

### 4.2.3 Differential-to-Common-Mode Conversion

- Recall the “Differential-to-Common-Mode\_Conversion.znxml” state file
- Verify that the calibration and de-embedding data is recalled and enabled.
- Connect ports 1 to 4 to the test fixture according to the table below:

VNA Port	Port 1	Port 3	Port 2	Port 4
Test Fixture	Tx+ (Left TF)	Tx- (Left TF)	Rx+ (Left TF)	Rx- (Right TF)

- Analyze results, pass if the resulting trace is less than or equal to -20 dB from 100 MHz to 7.5 GHz
- Repeat steps 3 and 4 for the following connection

VNA Port	Port 1	Port 3	Port 2	Port 4
Test Fixture	Rx+ (Left TF)	Rx- (Right TF)	Tx+ (Right TF)	Tx- (Right TF)

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