METHOD OF IMPLEMENTATION (MOI) USB TYPE-C TO LEGACY ADAPTER ASSEMBLY COMPLIANCES TESTS

Products:

► R&S®ZNB

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Contents

1 Introduction

The purpose of this document is to provide a step-by-step guidance on how to perform USB-IF compliance testing on a USB Type-C to legacy adapter assembly.

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.

Throughout this MOI the USB adapter assemblies are referred to by the currently supported performance specification number, USB 3.2. Some of the speed grades included in the USB 3.2 specification were formerly referred to as USB 3.0 or USB 3.1, but this terminology has been deprecated and those speed grades were absorbed into USB 3.2. Specifically, USB 3.0 and USB 3.1 Gen 1 are now USB 3.2 Gen 1x1; USB 3.1 Gen 2 is now USB 3.2 Gen 2x1.

While the adapter assemblies under test will be referred to by the USB 3.2 naming convention, the methodologies listed in this MOI are equally applicable to assemblies created with markings that include USB 3.0 and USB 3.1 conventions.

2 Required equipment

2.1 R&S®ZNB20 configuration

Description	Equipment	Quantity
Network analyzer	R&S®ZNB20 vector network analyzer, 4 ports, 100kHz - 20GHz, PC3.5 connectors with: — R&S®ZNB-K2, time domain (TDR) analysis (software license) — R&S®ZNB-K20, extended time domain (TDR) analysis (software license) — R&S®ZNB-K210, eazy de-embedding (EZD) (software license)	1
RF cable	R&S®ZV-Z193 var60, 50 Ohm, DC to 26.5GHz, 3.5mm(f)-3.5mm(m), flexible, phase stable, 60 inch (1520mm)	4
Calibration unit/kit	One of the following: — R&S®ZN-Z52 var30 calibration unit, 100kHz to 26.5 GHz, 4 ports, 3.5mm(f) — R&S®ZN-Z53 var32 calibration unit, 100 kHz to 26.5 GHz, 2 ports, 3.5mm(f) — R&S®ZN-Z135 var03 calibration kit, 50 Ohm, 0Hz to 26.5 GHz, 3.5mm(f)	1
Type-C receptacle test fixture	Type-C High Speed test fixture: Luxshare-ICT TFU-49R38 (optional) Type-C Low Speed test fixture: Luxshare-ICT TFU-59R18	1
Plug test fixture	Any of the following, dependent on adapter assembly type: - Type-C test fixture: Luxshare-ICT TF21-190G - Type-A test fixture: Luxshare-ICT TFU-12P4R - Micro-B test fixture: Luxshare-ICT TFU-25P4R	1
RFI test fixture	Luxshare-ICT MEU-28R2-041 (100 cm)	1
50 Ohm terminator	One of the following: — Hirose HRM-601A(52) — XMA 2003-6110-00 — P1dB P1TR-SAM-26G2W	16

3 Test overview and preparation

3.1 Measurement scope

This document focusses on how to perform normative compliance measurements for USB Type-C to legacy adapter assemblies with USB3.2 and USB2.0 capabilities. Test requirements for other types of assemblies are not described in this document.

Normative compliance requirements are categorized into three measurement groups:

► High speed – Frequency Domain

    — Insertion Loss Fit at Nyquist Frequencies (ILfitatNq)

    — Integrated Multi-reflection (IMR)

    — Integrated Differential Crosstalk on SuperSpeed (ISSXT)

    — Integrated Differential Crosstalk on D+/D- (IDDXT)

    — Integrated Return Loss (IRL)

    — Differential-to-Common-Mode Conversion (Scd)

► High Speed – Time Domain

    — Differential Impedance

    — Intra-pair Skew

► Low speed – Frequency Domain

    — Differential Insertion Loss (D+/D- attenuation)

► Low Speed – Time Domain

    — Differential impedance

    — Intra-pair skew

► Shielding effectiveness

    — Differential mode

    — Common mode

3.2 Test setup

3.2.1 R&S®ZNB20 test setup

Equipment needed for testing is listed in R&S ZNB20 Configuration. Below is an example setup using the R&S®ZNB20.
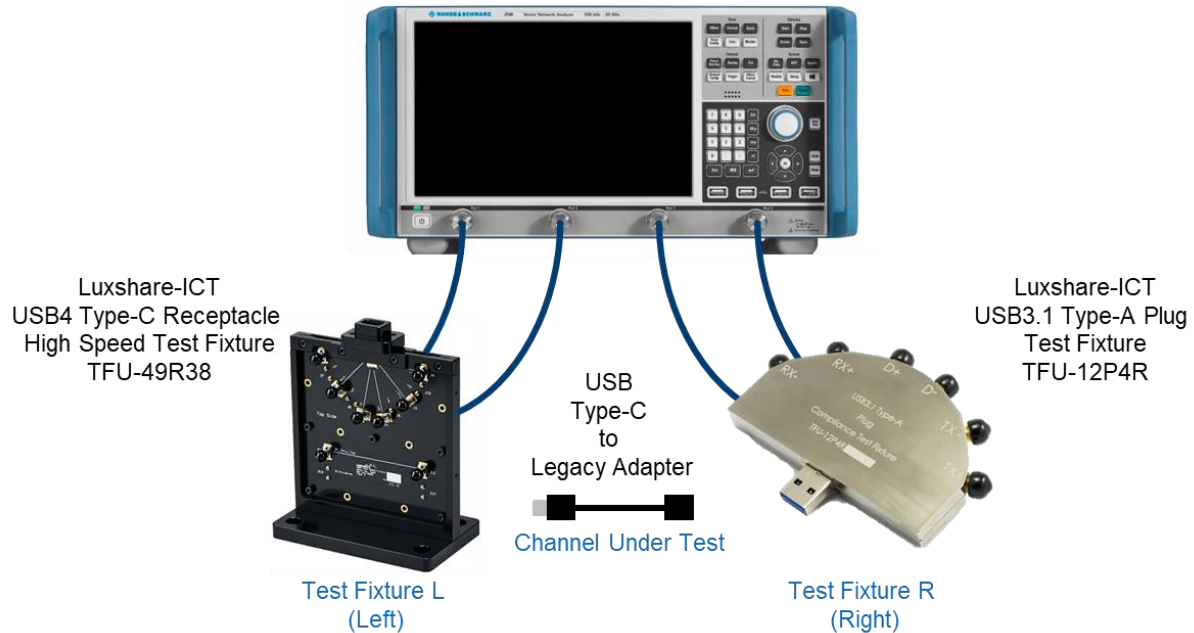
To avoid confusion, throughout the document the test fixtures are referred to by their orientation in this diagram (left, right), or simply by an "L" or "R" subscript when appropriate.

3.3 Necessary software tools

3.3.1 IntePar

The USB-IF provides the IntePar software tool to perform compliance verification for the USB2.0, USB3.2.

The IntePar tool is freely available at https://compliance.usb.org/files/.

1. Download the latest IntePar files.

    At the time of this document's creation, the latest file version is 'IntePar_1p7.zip'.
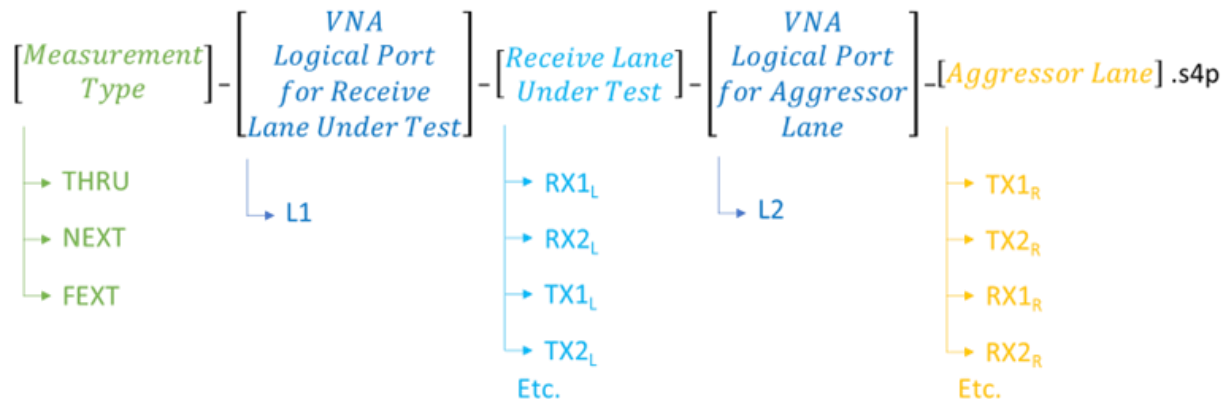
2. Export the contents of the .zip file.

    Examples in this MOI assume the files are exported to the following directory:

    C:\USB-IF_SW\IntePar_1p6\

3.4 Touchstone file naming convention

When saving touchstone files (*.s4p for R&S®ZNB20) to be used with the USB-IF compliance tools, the following naming convention is recommended:

For example, when collecting the touchstone file which includes the differential insertion loss and differential return loss of TX1, or the TX1 "Thru" file, the file name would be:

THRU_L1_ TX1L_L2_RX1R.s4p

3.5 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, and one file for the shielding effectiveness test, e.g., 5 files.

Note: The only normative frequency domain electrical requirement for the D+/D- data lane is differential insertion loss ($S_{dd}21$), also known as 'D+/D- attenuation'. This compliance requirement can actually be observed when using IntePar for process the high speed frequency domain parameters. For this reason, a 'USB3p2_Legacy Adapter_Low_Speed_Frequency_Domain.znx' recall file is unnecessary and does not exist.

3.5.1 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 (*.znx) for the desired tests.

   In total there are 5 recall files for the different test groups and another one dedicated for the calibration procedure:

   – USB3p2_Legacy_Adapter_High_Speed_Frequency_Domain.znx

   – USB3p2_Legacy_Adapter_High_Speed_Time_Domain.znx

   – USB3p2_Legacy_Adapter_Low_Speed_Time_Domain.znx

   – RFI_Type-C_to_Legacy_Adapter.znx

   – Calibration.znx

Overview about the setting in the different recall files:

Recall file	Start	Stop	Step size	IFBW	Power
USB3p2_Legacy_Adapter_High_Speed_Frequency_Domain.znx	10 MHz	20 GHz	10 MHz	1 kHz	-10 dBm
USB3p2_Legacy_Adapter_High_Speed_Time_Domain.znx	10 MHz	16.5 GHz	10 MHz	1 kHz	-10 dBm
USB3p2_Legacy_Adapter_Low_Speed_Time_Domain.znx	10 MHz	1.65 GHz∗	10 MHz	1 kHz	-10 dBm
'RFI_Type-C_to_Legacy_Adapter.znx	10 MHz∗∗	6 GHz	10 MHz	1 kHz	-10 dBm
Calibration.znx	300 kHz	20 GHz	100 KHz	1 kHz	-10 dBm

∗ Stop frequency selected to achieve requested rise time of 40 ps or 400 ps (20% - 80%).

∗ ∗ Start frequency 10 MHz selected; Test requirement start from 500 MHz

3.6 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 assembly 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 In-Situ De-embedding (ISD), are also supported by R&S®ZNB20.

The five different test groups use different frequency ranges. The calibration recall file includes all the required frequency ranges needed for each test group. This allows for all required frequency ranges to be calibrated in a single step.

3.6.1 Coaxial calibration

3.6.1.1 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.
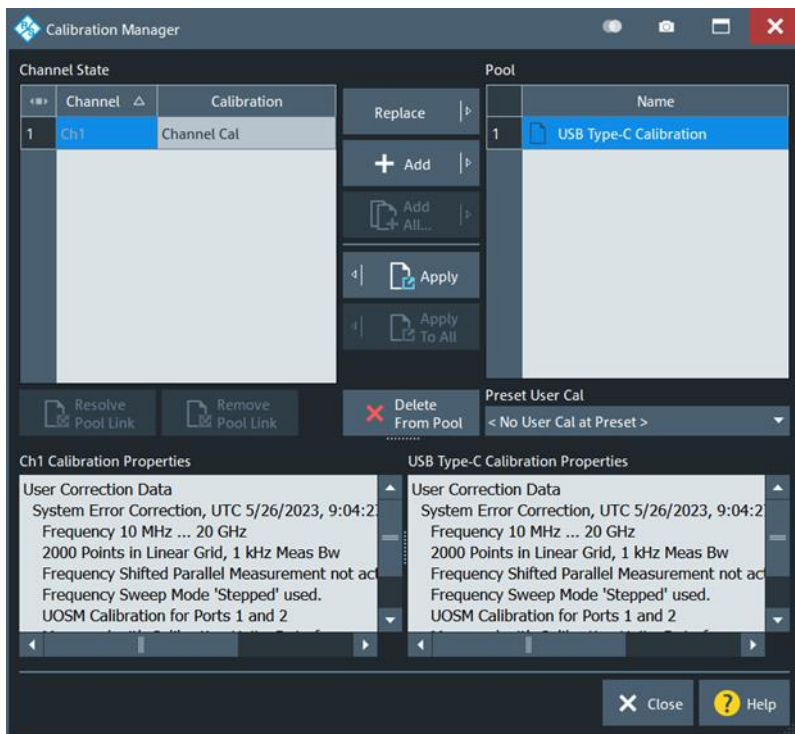
1.   Make sure the active setup is the "Calibration" setup.

2.   On the front panel, press "CAL"

3.   Select "Start… (Cal Unit)"

4. Select Calibration Type UOSM for best accuracy.
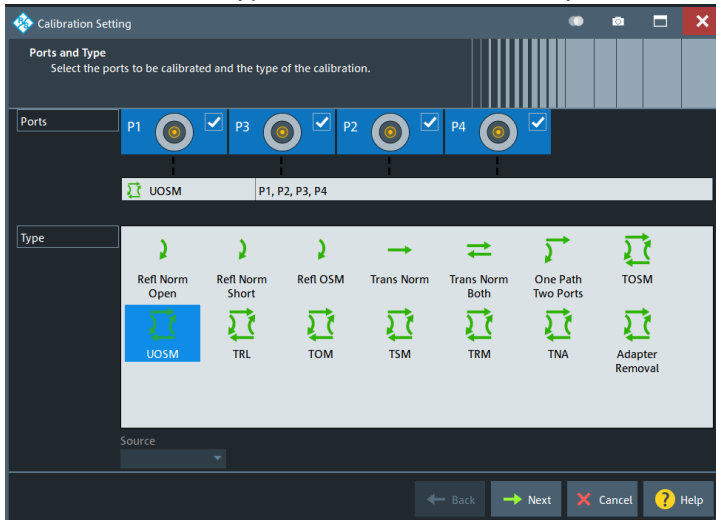
5. Follow the calibration wizard during the whole process.

6. After the calibration is completed, select "Cal" > "Use Cal".

7. Enter the "Cal Manager…".

8. Add the calibration to the Pool and enter a meaningful name for the calibration.

3.6.1.2 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)"

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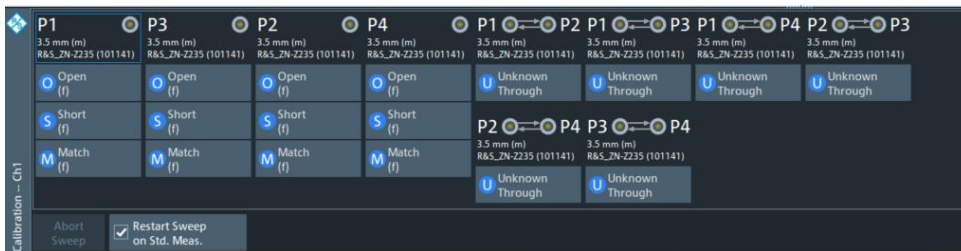
   It is required to measure at least 3 unknown through connections, however further measured connections will increase the accuracy.

6. After the calibration is completed, select "Cal" > "Use Cal".

7. Enter the "Cal Manager…".

8. Add the calibration to the pool and enter a meaningful name for the calibration.
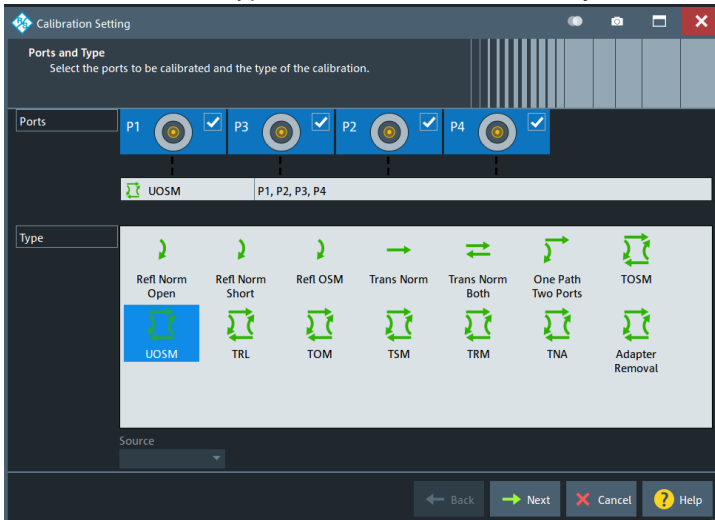
3.6.1.3 Recalling coaxial calibration

After calibrating to the end of the RF cables and storing the calibration data, select the measurement group preset where measurements should be performed. Then recall the calibration in the selected measurement group:

1. On the front panel, press "CAL" > "Use Cal".

2. Open the "Cal manager …".

3. Click "Apply" to make it active for the current measurement group.

   *Note***:** The

Recalling coaxial calibration procedure must be performed on each measurement group and channel after a firmware preset. Otherwise, measurements will be collected without proper calibration applied, resulting in inaccurate results.
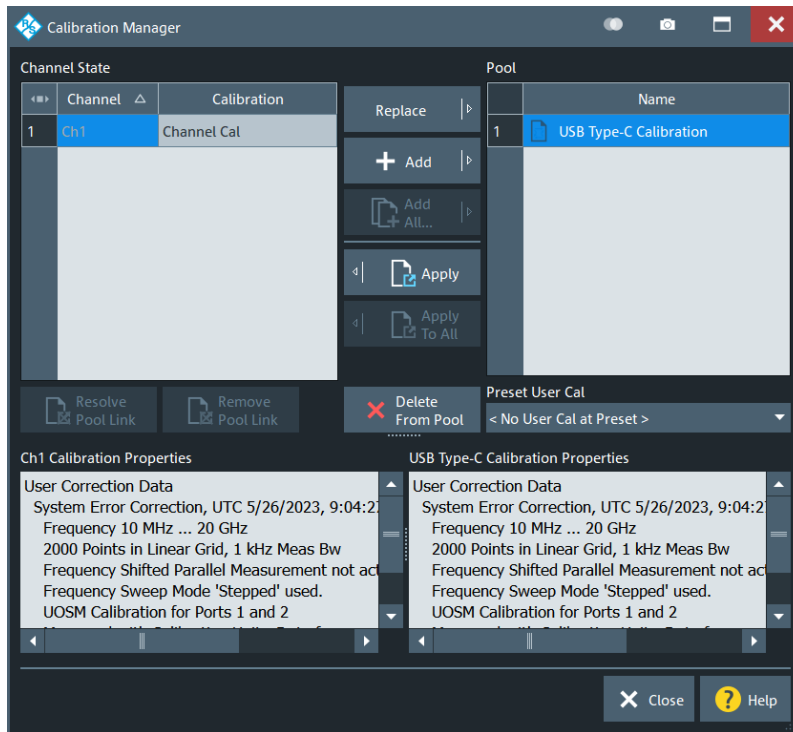
3.6.2 De-embedding USB test fixtures

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.

3.6.2.1 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 (except for RFI test which requires no de-embedding files)

Single Ended			
Deembedding	Active	File Name 1	Swap Gates
P1 ⊙--------⦿ L1	✔	USB4 HS-TFU-49R38-099_POINT2000_10MHZ_TO_20GHZ_CAL_2X_THRU_TOP_1.s2p •••	☐
P2 ⊙--------⦿ L2	✔	USB4 HS-TFU-49R38-099_POINT2000_10MHZ_TO_20GHZ_CAL_2X_THRU_BOTTOM_1.s2p •••	☐
P3 ⊙--------⦿ L3	✔	USB4 HS-TFU-49R38-099_POINT2000_10MHZ_TO_20GHZ_CAL_2X_THRU_TOP_1.s2p •••	☐
P4 ⊙--------⦿ L4	✔	USB4 HS-TFU-49R38-094_POINT2000_10MHZ_TO_20GHZ_CAL_2X_THRU_BOTTOM_1.s2p •••	☐

### 3.6.2.2   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 the EAZY De-embedding (EZD) tool which requires the R&S®ZNB-K210 software option. This De-embedding algorithm is based upon the IEEE 370 specification.

3.6.2.2.1   Performing EZD De-embedding

This section describes how to de-embed the test fixtures from the setup. Since this is for Type-C to Type-C cable testing, Test Fixture L and Test Fixture R will be identical. The following procedure describes how to perform de-embedding of an asymmetrical test setup. For simplicity, test fixture L is assumed to be populated with the Type-C receptacle connector, and test fixture R is assumed to be populated with the legacy plug connector

EZD de-embedding requires the test fixtures to include a "2x Thru" trace, referred to as a "Coupon". When distinguishing between the coupons on the left and right test fixtures, the R&S®ZNB Deembed Assistant refers to the coupons as "Coupon A" and "Coupon B"; where Coupon A is measured from Test Fixture L, and Coupon B is measured from Test Fixture R.

1. On the front panel, press "Offset Embed".

2. Select "Deembed Assistant".

3. Select "Fixture Tool" > "EZD".

4. In the "Deembed Assistant" dialog, select "Remove Active Deembedding" to remove any residual deembeding files.

5. Use the following configuration:

   a) "Use same coupon Left and Right = Off".

   b) "Left: Model A = Single Ended".

   c) "Right: Model B = Single Ended".

   d) "DUT = 1x1 Single Ended"
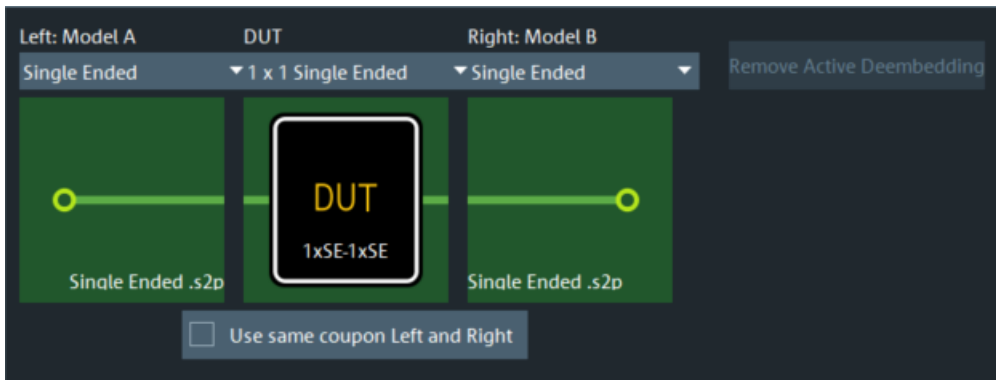
6. Select "Next".

7. Measure the test fixture coupon for the Top Left Fixture:

   a) For "Coupon A", select "Sym 2x Thru". Map the left side to Port 1 and the right side to Port 2.
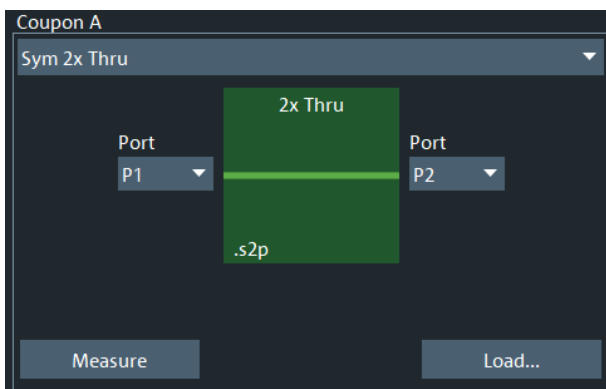
   b) Connect Port 1 and Port 2 of the VNA to each side of the 2x_Thru_Top calibration trace on the left fixture board.

   c) Select "Measure".

8. Measure the test fixture coupon for the Top Right Fixture:

   a) For "Coupon B", select "Sym 2x Thru". Map the left side to Port 3 and the right side to Port 4.
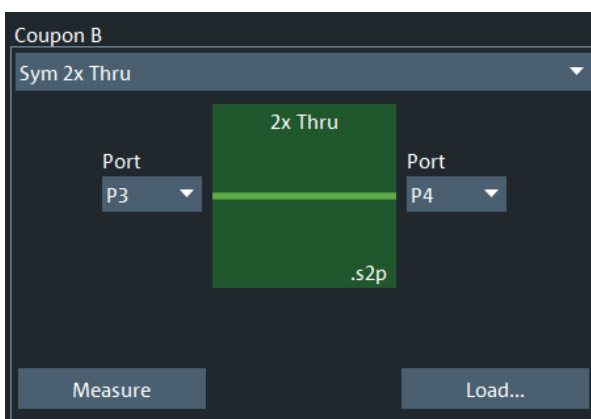
   b) Connect Port 3 and Port 4 of the VNA to each side of the 2x_Thru_Top calibration trace on the right fixture board.

   c) Select "Measure".

9. Generate the de-embedding model for the top layer fixtures for both the left and right sides:

   a) Uncheck the "Impedance Correction" box.

b) Select "Apply".

c) Once completed, close the "Deembed Assistant".

10. The main firmware interface is now present.

The test fixture files for the left-side and right-side, top-layer fixtures have been created.

a) Press the Windows button (⊞) on the tool bar to access the Windows Start Menu and start the Windows File Browser.

b) Navigate to the following directory: "C:\Users\Public\Documents\Rohde-Schwarz\VNA\Embedding\".

c) Verify that the files "A1_left_DUT.s2p" and "B1_right_DUT.s2p" exist, and that the timestamp matches the expected time of the de-embedding operation just completed.

d) Since the EZD de-embedding process will overwrite existing files when performed, rename the fixture files. The preconfigured R&S®ZNB state files are populated with a default file name.

Thus, rename the files as follows:

"A1_left_DUT" to "USBHS_top_left_fixture.s2p" and "B1_right_DUT" to "USBHS_top_right_fixture.s2p".

The left-side and right-side, top layer fixtures have been completed.
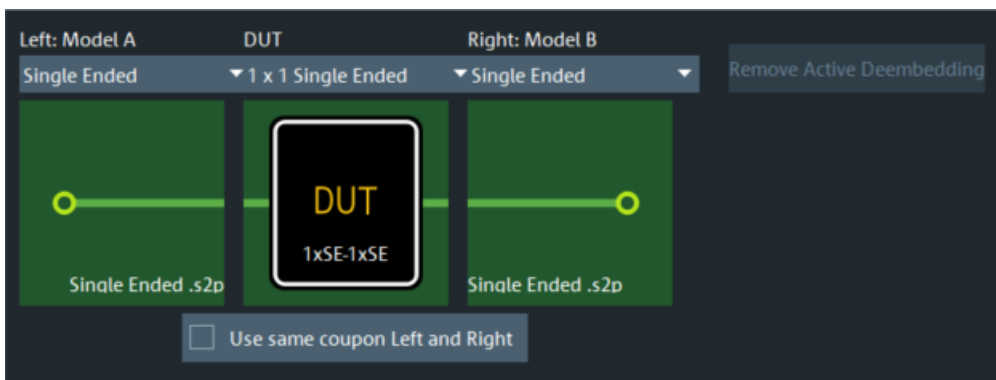
11. De-embed the left-side and right-side bottom layer fixtures:

a) On the front panel, select "Offset Embed".

b) Select "Deembed Assistant".

c) Select "Remove Active Deembedding" to remove any residual deembedding files.

12. Use the following configuration:

a) "Use same coupon Left and Right = Off".

b) "Left: Model A = Single Ended"

c) "Right: Model B = Single Ended"

d) "DUT = 1x1 Sigle Ended"

13. Select "Next".

14. Measure the test fixture coupon for the Bottom Left Fixture:

a) For "Coupon A", select "Sym 2x Thru". Map the left side to Port 1 and the right side to Port 2.
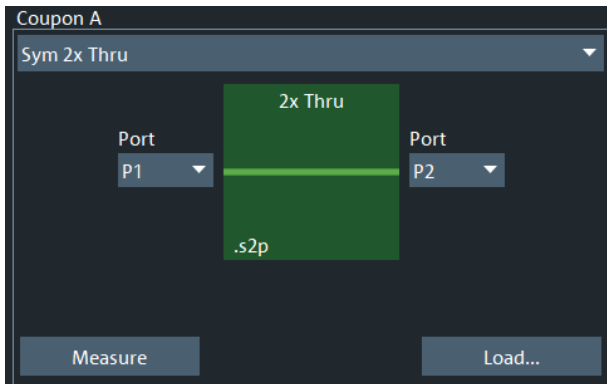
b) Connect Port 1 and Port 2 of the VNA to each side of the 2x_Thru_Bottom calibration trace on the left fixture board.

c) Click the "Measure".

15. Measure the test fixture coupon for the bottom right fixture:

a) For "Coupon B", select "Sym 2x Thru". Map the left side to Port 3 and the right side to Port 4.
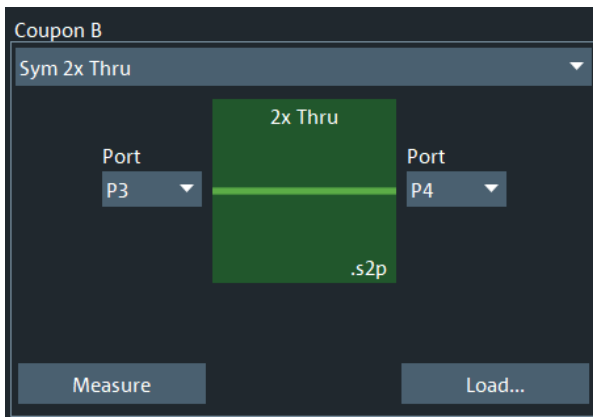
b) Connect Port 3 and Port 4 of the VNA to each side of the 2x_Thru_Bottom calibration trace on the right fixture board.

c) Click the "Measure".

16. Generate the de-embedding model for the bottom layer fixtures for both the left and right sides:

a) Uncheck the "Impedance Correction".

b) Click "Apply".

c) Once completed, close the de-embedding assistant.

17. The main firmware interface is now present.

The test fixture files for the left-side and right-side, bottom-layer fixtures have been created.

a) Press the Windows button (⊞) on the tool bar to access the Windows Start Menu and open the Windows File Browser.

b) Navigate to the following directory: "C:\Users\Public\Documents\Rohde-Schwarz\VNA\Embedding\".

c) Verify that the files "A1_left_DUT.s2p" and "B1_right_DUT.s2p" exist, and that the timestamp matches the expected time of the de-embedding operation just completed.

d) Since the EZD de-embedding process will overwrite existing files when performed, rename the fixture files. The preconfigured R&S®ZNB state files are populated with a default file name.

Thus, rename the files as follows:

"A1_left_DUT" to "USBHS_bottom_left_fixture.s2p" and "B1_right_DUT" to "USBHS_bottom_right_fixture.s2p".

18. Load the 4 fixture files that were created into the single-ended de-embedding dock widget dialog.

Configure as following. Check the "Swap Gates" settings.

Deembedding	Active	File Name 1		Swap Gates
P1	✔	USBHS_top_left_fixture.s2p	•••	☐
P2	✔	USBHS_bottom_right_fixture.s2p	•••	☐
P3	✔	USBHS_top_left_fixture.s2p	•••	☐
P4	✔	USBHS_bottom_right_fixture.s2p	•••	☐

EZD De-embedding is now completed, and the measurements can be started.

3.7 Stimulus rise time adjustment

This section demonstrates how the stimulus rise time 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 rise times 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".
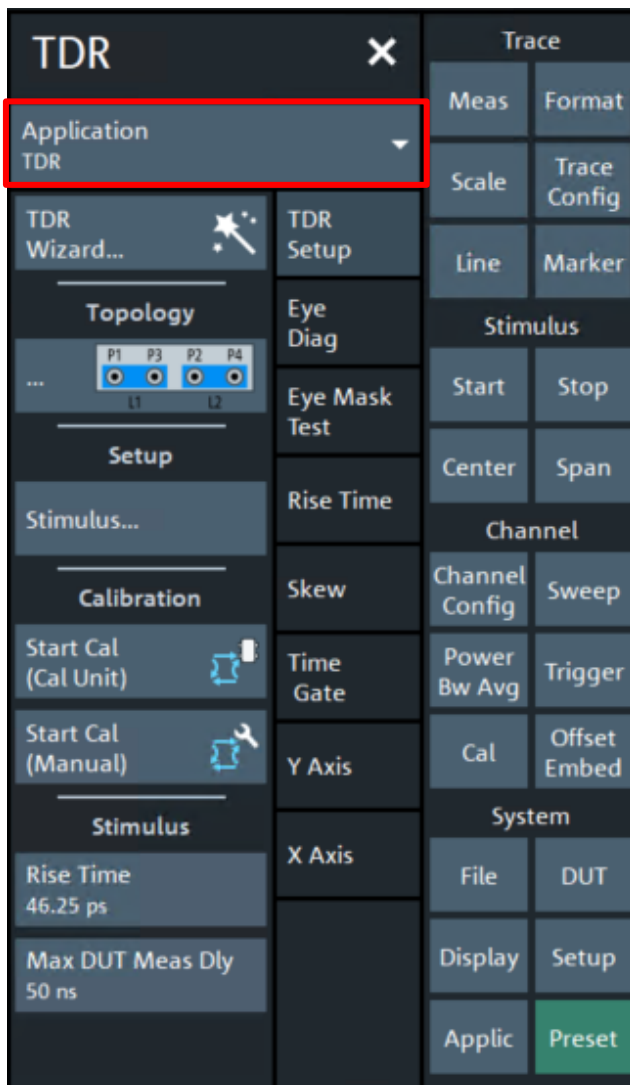
At the bottom of the "TDR" dialog, you find the "Rise Time" button.

3. Select "Rise Time" to adjust the rise time.

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.

4.1 High speed adapter testing

This section covers the related compliance measurements for High Speed data lanes of the Type-C to legacy adapter assembly.

4.1.1 High speed channel frequency domain requirements

In this group the following normative tests will be performed:

► Insertion Loss Fit at Nyquist Frequencies (ILfitatNq)

► Integrated Multi-reflection (IMR)

► Integrated Differential Crosstalk on SuperSpeed (ISSXT)

► Integrated Differential Crosstalk on D+/D- (IDDXT)

► Integrated Return Loss (IRL)

► Differential-to-Common-Mode Conversion (S_{cd})

These values are calculated or checked based on Touchstone files. This test group requires 15 4-port Touchstone files (*.s4p) to be measured.

4.1.1.1 Test Procedure

For this test the Type-C side of the adapter assembly will be connected to a high-speed Type-C receptacle test fixture.

Note: The Luxshare ICT test fixtures described in this MOI uses 3.5mm ports as the RF interface. For this reason, it's very important that a 8-lb torque wrench is used, when tightening cables or connectors to the fixtures.

Note: Make sure to terminate all unused 3.5mm ports with 50Ω loads/matches.

1. Recall the USB3p2_Legacy_Adapter_High_Speed_Frequency_Domain.znx state file, if not already performed.
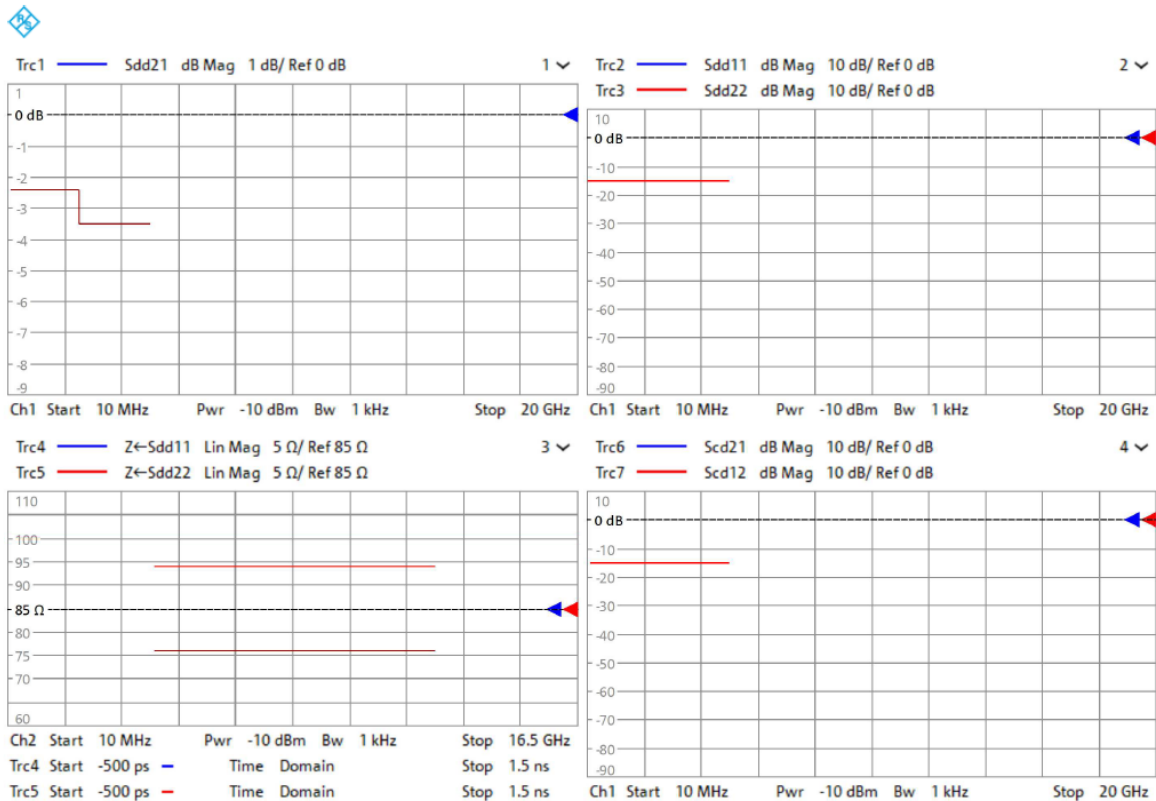
Note: The normative parameters of interest (ILfitatNq, IMR, etc.) cannot be processed natively in the network analyzer firmware. In addition to these normative requirements, the USB-IF also defines informative limits for several common frequency domain S-parameters and time domain impedance parameters. These informative limits are meant to be used as recommended guidelines for cable assembly design only, and not substitute the normative limits listed above. However, since the normative limits are derived from an external software the user can have limited feedback when measuring the necessary Touchstone files, to increase visibility into cable assembly performance the USB3p2_Legacy_Adapter_High_Speed_Frequency_Domain.znx recall file will display the informative limit lines when performing measurements. The displayed S-parameters will be checked against the included informative limit and presented with a 'pass' or 'fail' result; but these are only informative and not indicative of results generated from the normative IntePar results.

Additionally, the displayed limit lines will only be applicable to the high-speed data lanes (TX1/RX1) when measuring the through parameters. When measuring other data lanes, or any respective crosstalk parameters the limit lines should be ignored

2. Verify that the calibration and de-embedding data is recalled and enabled.

3. Perform the measurement and export the Touchstone file.

   a) Using the port mapping defined in the below table, connect Port 1, Port 2, Port 3, and Port 4 to the respective test fixture pins.

   For Insertion Loss (IL) part: Connect the port 1 to 4 to the test fixture according to #1 ~ #3 of the following table:

| #	Test Item	Port 1	Port 3	Port 2	Port 4	Filename
1	Thru, TX1	TX1+ (Left TF)	TX1- (Left TF)	RX1+ (Right TF)	RX1- (Right TF)	Thru_L1_TX1L_L2_RX1R.s4p
2	Thru, RX1	RX1+ (Left TF)	RX1- (Left TF)	TX1+ (Right TF)	TX1- (Right TF)	Thru_L1_RX1L_L2_TX1R.s4p
3	Thru, DD	D+ (Left TF)	D- (Left TF)	D+ (Right TF)	D- (Right TF)	Thru_L1_DDL_L2_DDR.s4p

For crosstalk part: Connect the port 1 to 4 to the test fixture according to #4 ~ #15 of the following table:

#	Test Item	Port 1	Port 3	Port 2	Port 4	Filename
4	Next Tx1(L)-Rx1(L)	TX1+ (Left TF)	TX1- (Left TF)	RX1+ (Left TF)	RX1- (Left TF)	Next_L1_TX1L_L2_RX1L.s4p
5	Next Rx1(R)-Tx1(R)	RX1+ (Right TF)	RX1- (Right TF)	TX1+ (Right TF)	TX1- (Right TF)	Next_L1_RX1R_L2_TX1R.s4p
6	Next Tx1(L)-DD(L)	TX1+ (Left TF)	TX1- (Left TF)	D+ (Left TF)	D- (Left TF)	Next_L1_TX1L_L2_DDL.s4p
7	Next Rx1(L)-DD(L)	RX1+ (Left TF)	RX1- (Left TF)	D+ (Right TF)	D- (Right TF)	Next_L1_RX1L_L2_DDL.s4p
8	Next Rx1(R)-DD(R)	RX1+ (Right TF)	RX1- (Right TF)	D+ (Right TF)	D- (Right TF)	Next_L1_RX1R_L2_DDR.s4p
9	Next Tx1(R)-DD(R)	TX1+ (Right TF)	TX1- (Right TF)	D+ (Right TF)	D- (Right TF)	Next_L1_TX1R_L2_DDR.s4p
10	Fext Tx1(L)-Tx1(R)	TX1+ (Left TF)	TX1- (Left TF)	TX1+ (Right TF)	TX1- (Right TF)	Fext_L1_TX1L_L2_TX1R.s4p
11	Fext Rx1(R)-Rx1(L)	RX1+ (Right TF)	RX1- (Right TF)	RX1+ (Left TF)	RX1- (Left TF)	Fext_L1_RX1R_L2_RX1L.s4p
12	Fext Rx1(R)-DD(L)	RX1+ (Right TF)	RX1- (Right TF)	D+ (Left TF)	D- (Left TF)	Fext_L1_RX1R_L2_DDL.s4p
13	Fext Tx1(R)-DD(L)	TX1+ (Right TF)	TX1- (Right TF)	D+ (Left TF)	D- (Left TF)	Fext_L1_TX1R_L2_DDL.s4p
14	Fext Tx1(L)-DD(R)	TX1+ (Left TF)	TX1- (Left TF)	D+ (Right TF)	D- (Right TF)	Fext_L1_TX1L_L2_DDR.s4p
15	Fext Rx1(L)-DD(R)	RX1+ (Left TF)	RX1- (Left TF)	D+ (Right TF)	D- (Right TF)	Fext_L1_RX1L_L2_DDR.s4p

b) After an acquisition is complete, select "FILE" on the front panel then Select "Trace Data" > "s4p Port 1,2,3,4...".

c) Use the name listed in the 'Filename' column (based on the naming described in 3.4 Touchstone file naming convention) in the above table for the file name of the exported Touchstone file.

4. Repeat step 3.a through 3.c for all 15 measurements.

5. Import the 15 4-port Touchstone files (*.s4p) to the "IntePar" software.

a) After downloading the latest Intepar files, described in 3.3.1 IntePar, extract the content of the .zip file.

b) In the extracted content, run the executable file called 'Intepar.exe'.

c) In the Select Cable Type dropdown menu, choose
"7. Type-C to Legacy Adapter".

d) Select the '4-port VNA' checkbox.

e) Included with the files associated with the MOI (with the R&S®ZNB20 recall files) there is an xlsx file titled 'R&S_IntePar_USB3p2_Legacy_Adapter_4ports.xlsx' that can be used as a configuration file for IntePar. It is preconfigured with the Touchstone file names discussed in step 4.a. This can be loaded into IntePar by using the "Load config spreadsheet" button in the top left corner of the IntePar user interface.
This template can be used as is, but assumes the Touchstone files are located in the same

directory as the IntePar executable file. The user may need to update the file locations to reflect the proper file location.

f) Run the IntePar tool by clicking the 'Check Compliance' button at the bottom of the IntePar user interface.
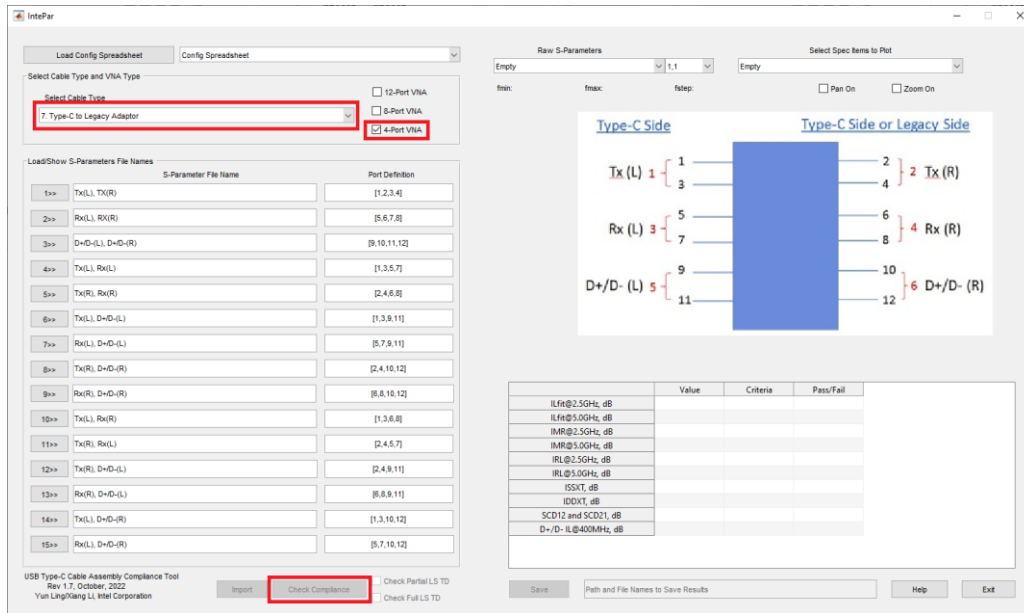
6. Retrieve the analysis results from the table in the bottom right corner IntePar user interface.

4.1.2 High speed channel time domain requirements

Time domain measurements are directly performed on the R&S®ZNB20 vector network analyzer. Only for this section the R&S®ZNB-K2 time domain option is required:

In this group following coupling tests will be performed:

► Intra-pair skew

► Differential impedance

4.1.2.1 Test Procedure

For this test the Type-C side of the adapter assembly can be connected to either the high speed Type-C receptacle test fixture or the low-speed Type-C receptacle test fixture.

Note: The Luxshare ICT test fixtures described in this MOI uses 3.5mm ports as the RF interface. For this reason, it's very important that a 8-lb torque wrench is used, when tightening cables or connectors to the fixtures.

Note: Terminate all unused 3.5mm ports with 50Ω loads/matches.

1. Recall the USB3p2_Legacy_Adapter_High_Speed_Time_Domain.znx state file, if not already performed.
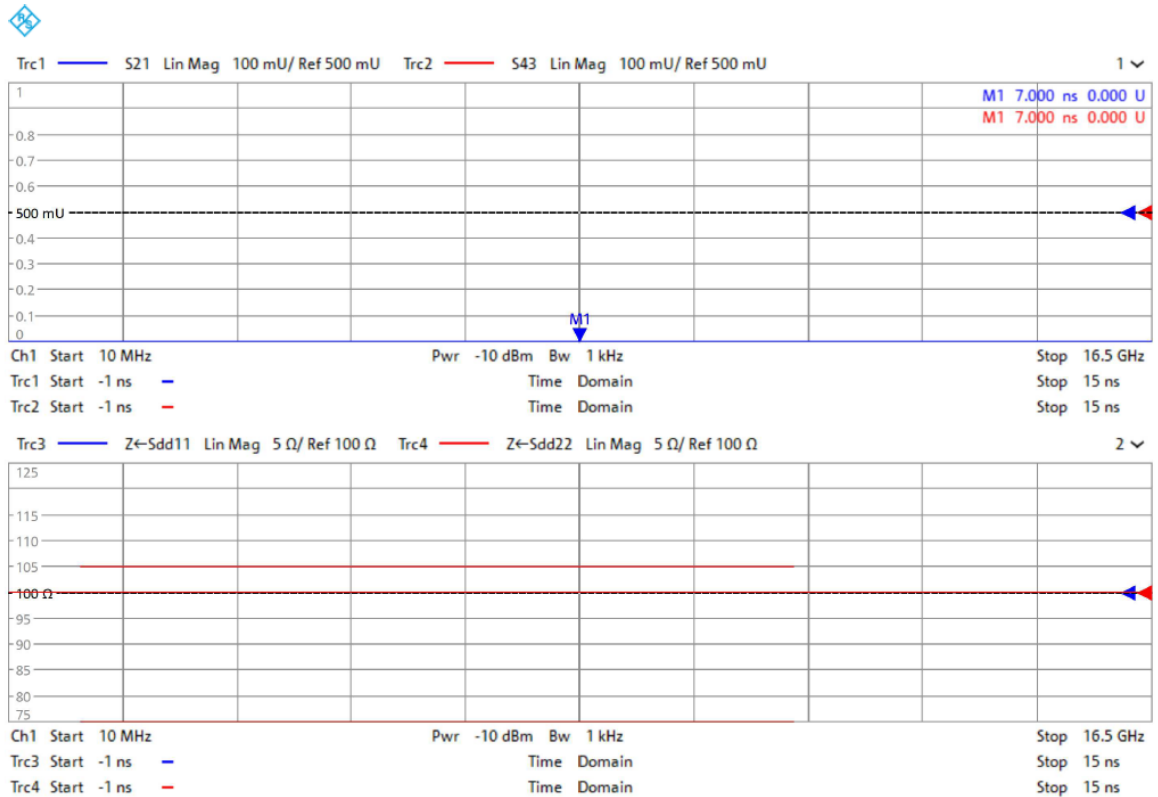
2. Verify that the calibration and de-embedding data is recalled and enabled.

3. Adjust the ZNB20 rise time as needed, using the procedure described in 3.7 Stimulus rise time adjustment, to target 40 ps.

4. Perform the measurements.

   a) Using the port mapping defined in the below table, connect Port 1, Port 2, Port 3, and Port 4 to the respective test fixture pins.

#	Test Item	Port 1	Port 3	Port 2	Port 4
1	TX Time Domain	TX1+ (Left TF)	TX1- (Left TF)	RX1+ (Right TF)	RX1- (Right TF)
2	RX Time Domain	RX1+ (Left TF)	RX1- (Left TF)	TX1+ (Right TF)	TX1- (Right TF)

   b) Intra-pair skew can be verified using trace1 (S21) and trace2 (S43) in the top left window.

   The two marker values are used to measure the difference in skew between positive and negative polarities. To pass, the difference must be ≤ 100 ps.

   c) Differential impedance can be verified using trace3 (Z ← $S_{dd}11$) and trace4 (Z ← $S_{dd}22$) in the bottom window.

   The two red lines in the window are representing the limits defined by USB-IF for differential impedance. Both traces shall be within the limit lines of 75 and 105 Ω.

5. Repeat steps 4.b through 4.c for both measurements.

6. Export the Touchstone file.

a) After an acquisition is complete, select "FILE" on the front panel then Select "Trace Data" > "s4p Port 1,2,3,4...".

4.2 Low speed adapter testing

This section covers the related compliance measurements for Low Speed data lanes of the Type-C to legacy adapter assembly.

4.2.1 Low speed channel frequency domain requirements

For USB 2.0 Type-C to legacy adapter assemblies, the only electrical compliance requirement for the D+/D- data lane is differential insertion loss ($S_{dd}21$), also known as 'D+/D- attenuation'. This parameter is analyzed in the IntePar compliance software, and the pass/fail result can be observed in the procedure described in 4.1.1.1 Test Procedure.

4.2.2 Low speed channel time domain requirements

Time domain measurements are directly performed on the R&S®ZNB20 vector network analyzer. Only for this section the R&S®ZNB-K2 time domain option is required.

In this group following coupling tests will be performed:

► Intra-pair skew

► Differential impedance

4.2.2.1 Test Procedure

For this test the Type-C side of the adapter assembly can be connected to either the low speed Type-C receptacle test fixture or the high-speed Type-C receptacle test fixture.

1. Recall the USB3p2_Legacy_Adapter_Low_Speed_Time_Domain.znx state file, if not already performed.
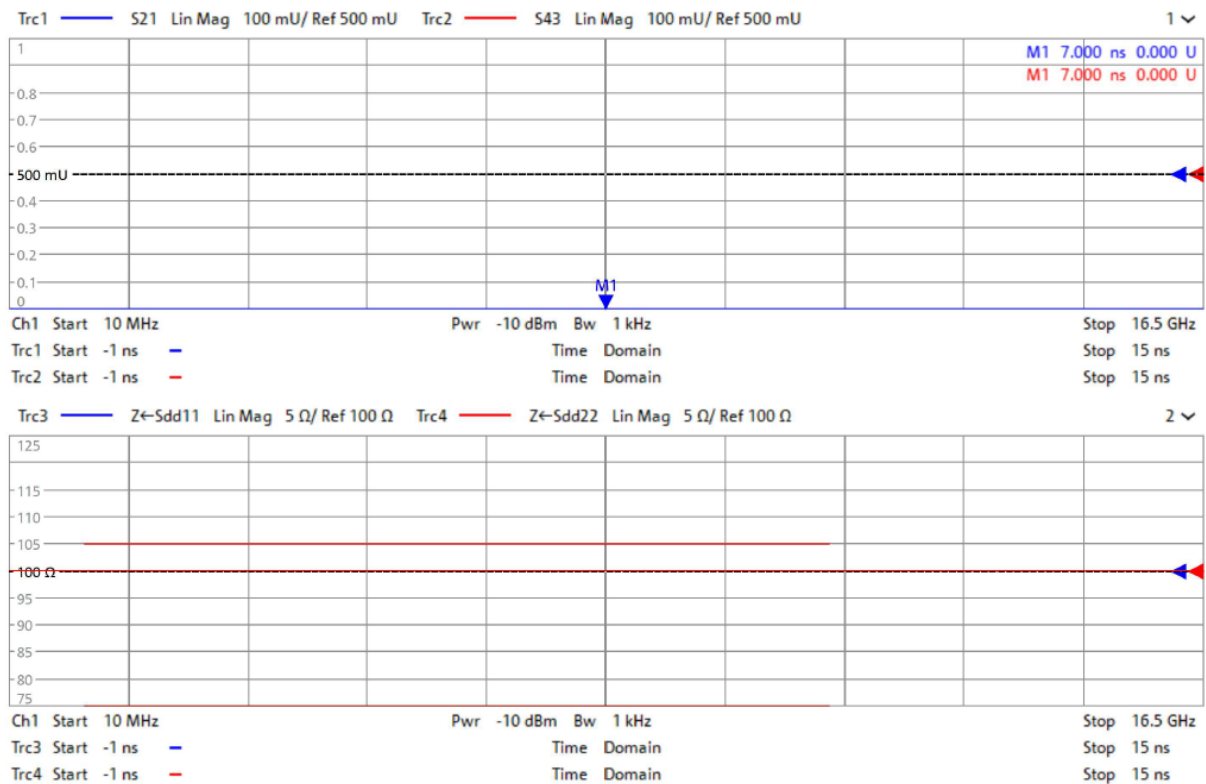
2. Verify that the calibration and de-embedding data is recalled and enabled.

3. Adjust the ZNB20 rise time as needed, using the procedure described in 3.7 Stimulus rise time adjustment, to target 400 ps.

4. Perform the measurements.

   a) Using the port mapping defined in the below table, connect Port 1, Port 2, Port 3, and Port 4 to the respective test fixture pins.

#	Test Item	Port 1	Port 3	Port 2	Port 4
1	D+/D- Time Domain	D+ (Left TF)	D- (Left TF)	D+ (Right TF)	D- (Right TF)

   b) Intra-pair skew can be verified using trace1 (S21) and trace2 (S43) in the top left window.

   The two marker values are used to measure the difference in skew between positive and negative polarities. To pass, the difference must be ≤ 100 ps.

   c) Differential impedance can be verified using trace3 (Z ← $S_{dd}11$) and trace4 (Z ← $S_{dd}22$) in the bottom window.

   The two red lines in the window are representing the limits defined by USB-IF for differential impedance. Both traces shall be within the limit lines of 75 and 105 Ω.

5. Export the Touchstone file.

   a) After an acquisition is complete, select "FILE" on the front panel then Select "Trace Data" > "s4p Port 1,2,3,4...".

4.3 Shielding Effectiveness Test

In the shielding effectiveness test, the RFI and EMI levels from the adapter are measured. This test group requires four 4-port Touchstone files (*.s4p) to be measured.

For this measurement a coaxial calibration is mandatory, but de-embedding of the test fixture is not required.

A specialized test fixture is used for the shielding effectiveness test. The test setup is demonstrated on the following figure.
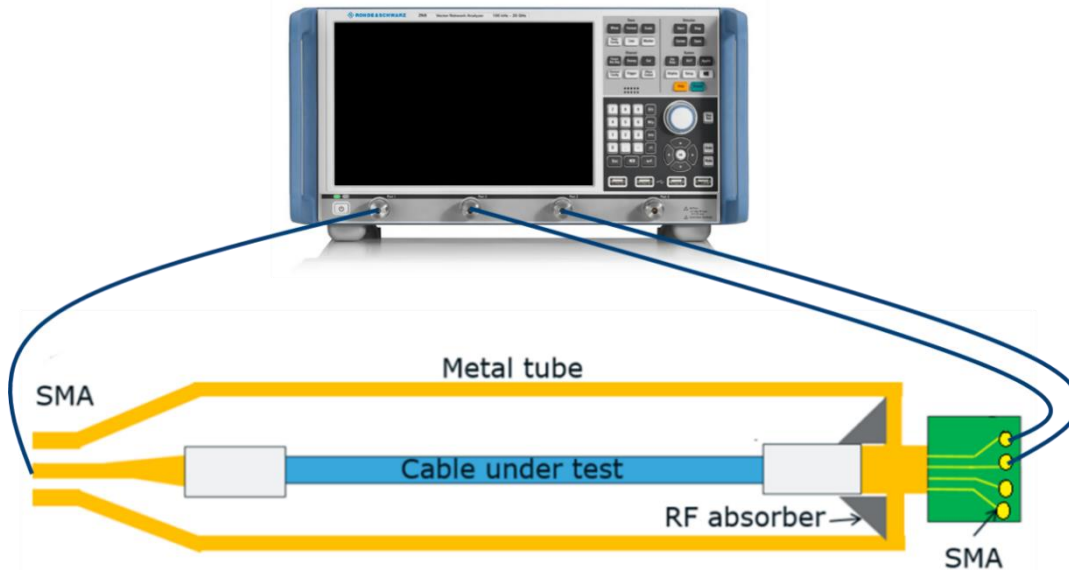
4.3.1 Test Procedure

1. Recall the state file 'RFI_Type-C_to_Legacy_Adapter.znx', if not already performed..

    This will configure the R&S®ZNB with limit lines respective to the RFI compliance limits for Type-C to legacy adapter assemblies. Below is a description of the RFI limit.
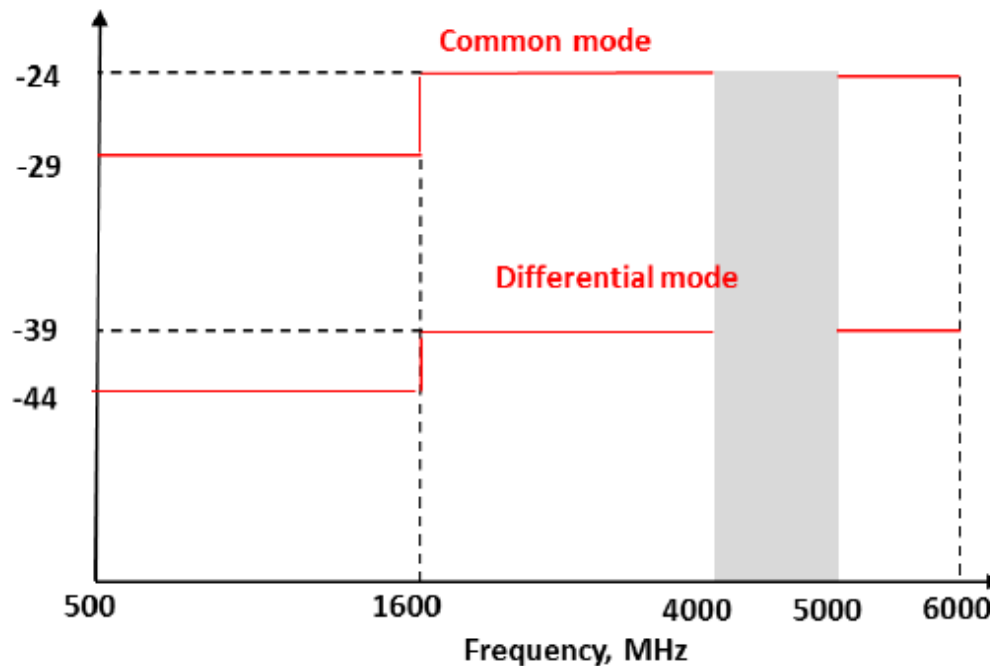
Measurement	Start Frequency (MHz)	Stop Frequency (MHz)	Start Limit (dB)	Stop Limit (dB)
Differential Mode (Sds21)	500	1600	-44.0	-44.0
	1600	4000	-39.0	-39.0
	5000	6000	-39.0	-39.0
Common Mode (Scs21)	500	1600	-29.0	-29.0
	1600	4000	-24.0	-24.0
	5000	6000	-24.0	-24.0

2. Verify that the calibration data is recalled. De-embedding is not required for this test and therefore should be disabled.

3. Perform the measurement and export the Touchstone file.

   a) Using the port mapping defined in the below table, connect Port 1, Port 2, and Port 3 to the respective test fixture pins. Port 4 is unused, and can be left terminated with 50 Ω load.

#	Test Item	Port 1	Port 3	Port 2	Port 4
1a	RFI TX1	Driver Side (Left)	TX1+ (Right TF)	TX1- (Right TF)	Terminated with 50 Ω
1b	RFI RX1	Driver Side (Left)	RX1+ (Right TF)	RX1- (Right TF)	Terminated with 50 Ω
1c	RFI TX2	Driver Side (Left)	TX2+ (Right TF)	TX2- (Right TF)	Terminated with 50 Ω
1d	RFI RX2	Driver Side (Left)	RX2+ (Right TF)	RX2- (Right TF)	Terminated with 50 Ω

   b) After an acquisition is complete, select "FILE" on the front panel then Select "Trace Data" > "s4p Port 1,2,3,4...".

   c) Use the test # in the above table for the file name of the exported Touchstone file.

4. Repeat step 3.a through 3.c for all 4 measurements.

5 Literature

[1] "Universal Serial Bus Type-C Connectors and Cable Assemblies Compliance Document," Revision 2.1b (June 2021).

[2] Universal Serial Bus Type-C Cable and Connector Specification, Revision 2.1 (May 2021).

6 Appendix

A De-embedding USB test fixtures with older R&S®ZNB firmware versions

The process described in 3.6.2 De-embedding USB test fixtures assumes the R&S®ZNB20 is updated and running firmware version 3.45 or newer. This section describes how to perform de-embedding with firmware versions older than 3.45.

A.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, select "OFFSET EMBED".

2. Select "Offset Embed" > "Single Ended".

3. Import the 2-port Touchstone files (*.s2p) which are delivered together with the test fixtures of Luxshare-ICT (except for RFI test which requires no de-embedding files).
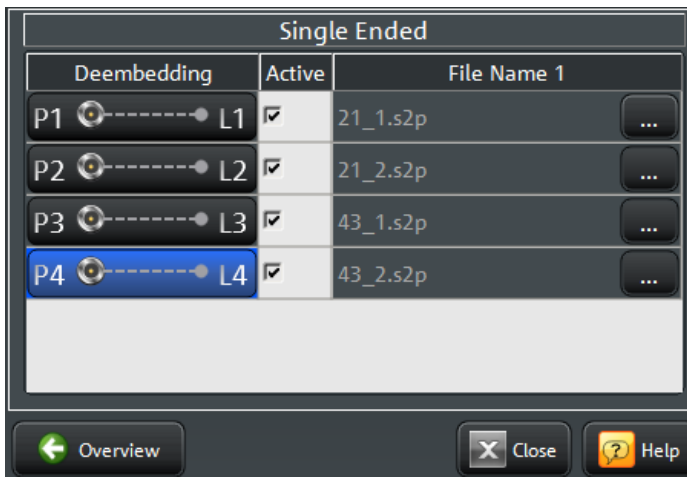
A.2 Measuring and generating de-embedding files

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 can create new de-embedding files by making measurements in the VNA firmware. This procedure will be using the EAZY De-embedding (EZD) tool which requires the R&S®ZNB-K210 software option. This De-embedding algorithm is based upon the IEEE 370 document.

Performing EZD de-embedding

This section describes how to de-embed *symmetrical test setups*.

1. On the front panel, select "OFFSET EMBED".

2. Select "Offset Embed" > "Single Ended".

3. In the single-ended de-embedding dialog, check the "Active" checkboxes for all ports.

   This enables the ability to launch the fixture tools. By default, "Through" is loaded.

   See below for example:

4. Select "Fixture Tool" > "EZD".

5. Click the "Run Tool…" button.

   The dialog "EZD Single Ended Ports" appears.

6. Select "Advanced Settings…".

   g) Uncheck the "Impedance Corrected" box.

   h) Uncheck the "Generate Side 2" box.

   i) Select "Close".
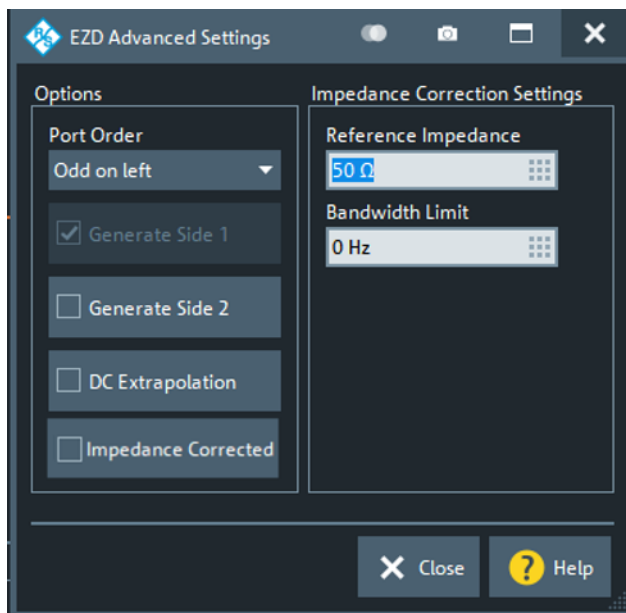
7. Configure the "EZD – Single Ended Ports" settings as follows:

8. Measure the test fixture coupon:

    j) Connect Port 1 and Port 2 of the VNA to each side of the 2x_Thru_Top calibration trace on the left fixture board.

    k) Enable that the checkboxes next to Port 1 and Port 2.

    l) Select "Measure Coupon" > "Measure".

9. Select "Save Fixture Model" > "Run EZD" to start the EZD process.

    The EZD de-embedding process is completed, and the appropriate de-embedding file can be saved.

10. In the "EZD – Single Ended Ports" dialog, select "Apply".
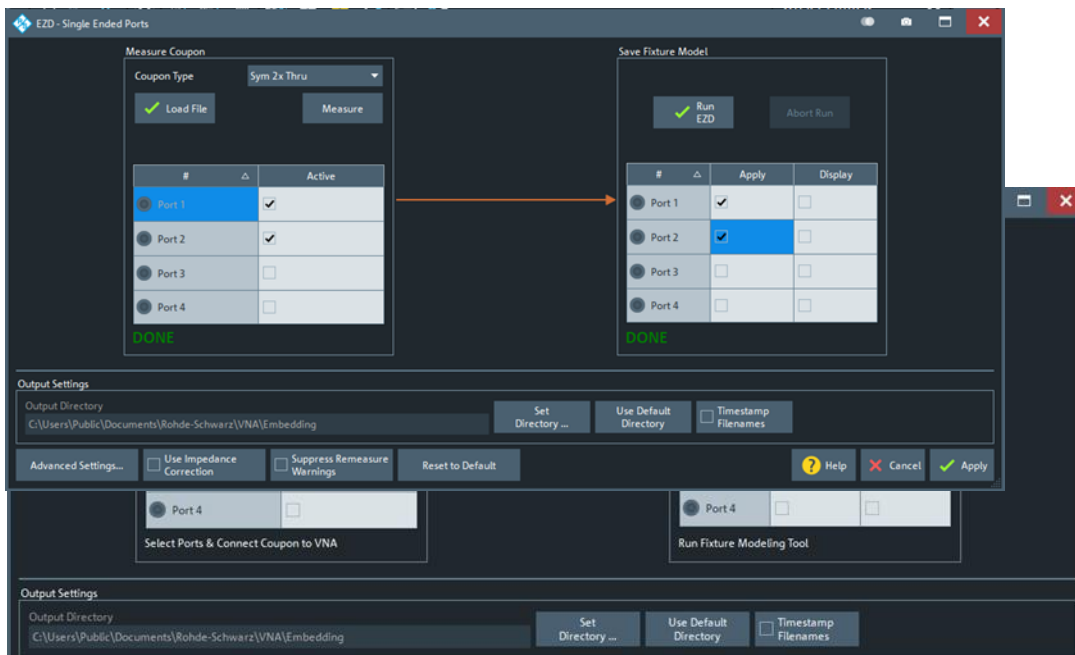
All pop-up dialogs should be closed, and the main firmware interface is present. The test fixture file for the left-side, top-layer fixture has been created.

11. Click the Windows button (⊞) on the tool bar to access the Windows Start menu and open the Windows file browser.

    a) Navigate to the directory "C:\Users\Public\Documents\Rohde-Schwarz\VNA\Embedding\".

    b) Verify that the file "dut_plus_fixtures.s2p_LEFT_DUT.s2p" exists, and that the timestamp matches the expected time of the de-embedding operation just completed.

    c) Since the EZD de-embedding process will overwrite existing files when performed, rename the file "dut_plus_fixtures.s2p_LEFT_DUT.s2p".

    The preconfigured R&S®ZNB state files are populated with a default file name.

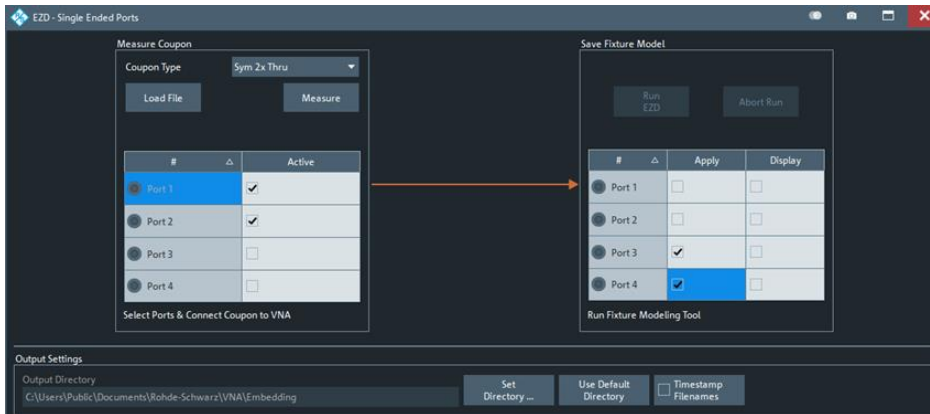   Rename "dut_plus_fixtures.s2p_LEFT_DUT.s2p" to "USBHS_top_left_fixture.s2p".

    The left-side, top layer fixture has been de-embedded.

12. De-embed *the left-side bottom layer fixture*:

    a) On the front panel, select "OFFSET EMBED".

    b) Select "Offset Embed" > "Single Ended".

c) Select "Run Tool…"

The dialog "EZD Single Ended Ports" opens.

d) Configure the "EZD – Single Ended Ports" settings as follows:

13. Measure the test fixture coupon:

a) Connect Port 1 and Port 2 of the VNA to each side of the 2x_Thru_Bottom calibration trace for the left fixture board.

b) Enable the checkboxes next to Port 1 and Port 2.

c) Select "Measure Coupon" > "Measure".

14. Select "Save Fixture Model" > "Run EZD" to start the EZD process.

The EZD de-embedding process is completed, and the appropriate de-embedding file can be saved.

15. In the "EZD – Single Ended Ports" dialog, select "Apply".
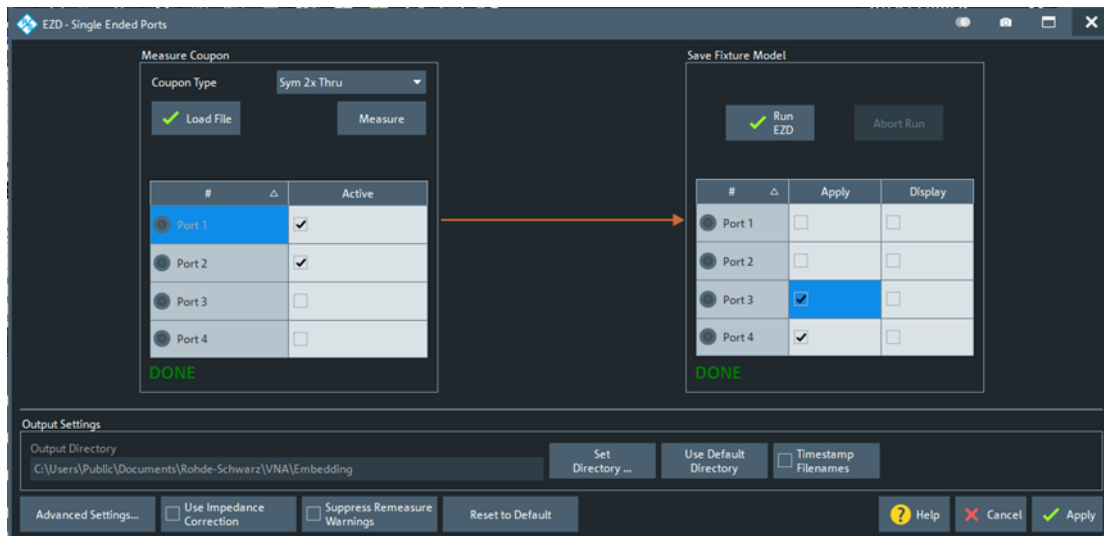
All pop-up dialogue boxes should be closed, and the main firmware interface is present. The test fixture file for the left-side, bottom-layer fixture has been created.

16. Click the Windows button (⊞) on the tool bar to access the Windows Start menu and open the Windows file browser.

a) Navigate to the directory "C:\Users\Public\Documents\Rohde-Schwarz\VNA\Embedding\".

b) Verify that the file "dut_plus_fixtures.s2p_LEFT_DUT.s2p" exists, and that the timestamp matches the expected time of the de-embedding operation just completed.

c) Since the EZD de-embedding process will overwrite existing files when performed, rename the file "dut_plus_fixtures.s2p_LEFT_DUT.s2p".

The preconfigured R&S®ZNB state files are populated with a default file name.

Rename "dut_plus_fixtures.s2p_LEFT_DUT.s2p" to "USBHS_bottom_left_fixture.s2p".

The left-side, bottom layer fixture has been de-embedded.
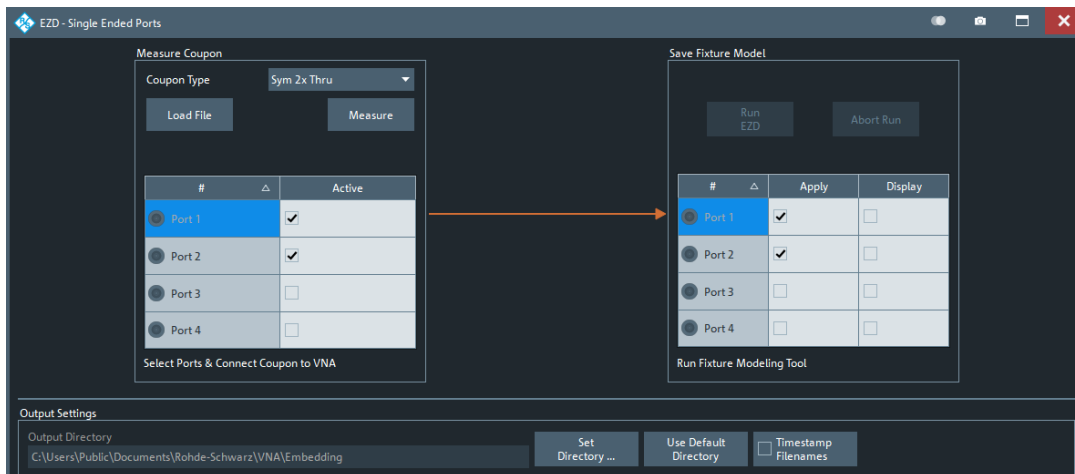
17. De-embed the *right-side top layer fixture*.

d) On the front panel, select "OFFSET EMBED".

e) Select "Offset Embed" > "Single Ended".

f) Select "Run Tool…"

The dialog "EZD Single Ended Ports" opens.

g) Select "Advanced Settings…".

h) Check the Generate Side 2 box. Uncheck the Generate Side 1 box. Select "Close".
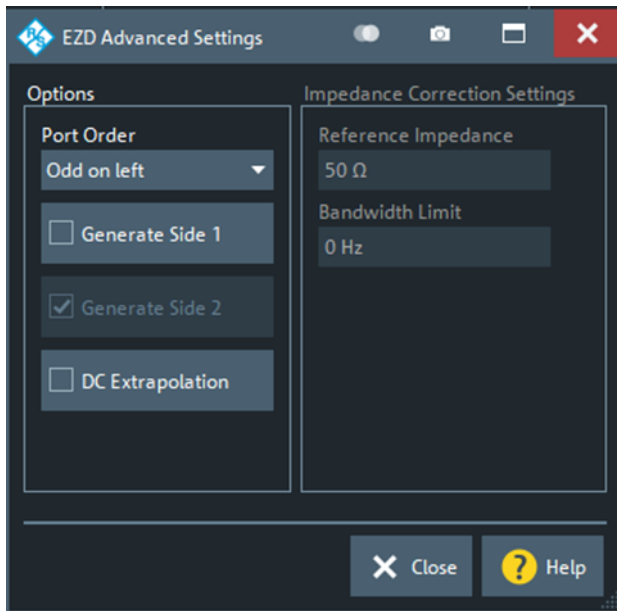
18. Configure the "EZD – Single Ended Ports" settings as follows:

19. Measure the test fixture coupon:

   a) Connect Port 1 and Port 2 of the VNA to each side of the 2x_Thru_Top calibration trace for the right fixture board.

   b) Enable the checkboxes next to Port 1 and Port 2.

   c) Select "Measure Coupon" > "Measure".

20. In the "Save Fixture Model" dialog, select "Run EZD" to start the EZD process.

   The EZD de-embedding process is completed, and the appropriate de-embedding file can be saved.

21. In the "EZD – Single Ended Ports" dialog, select "Apply".
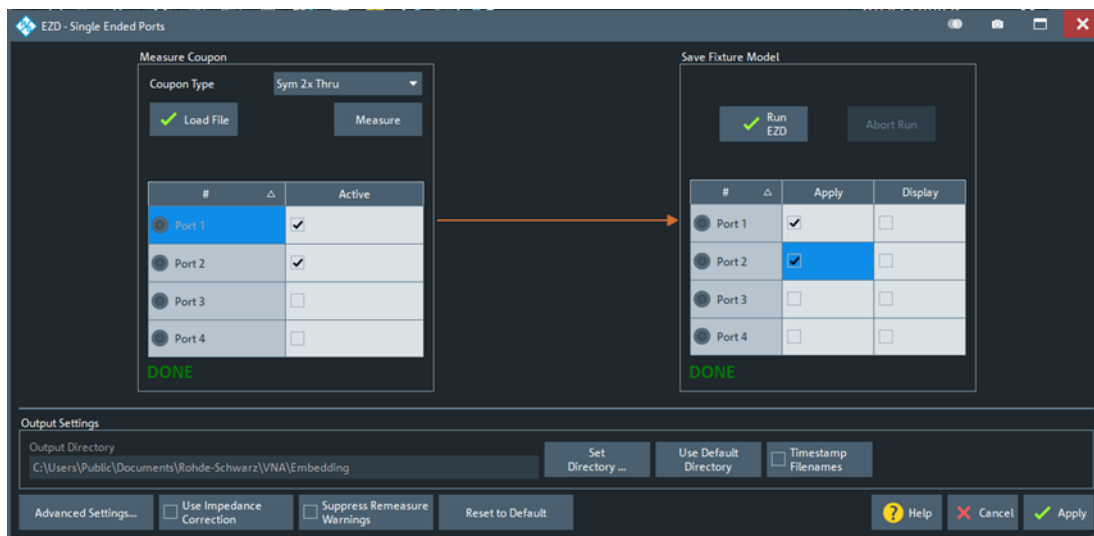
All pop-up dialogue boxes should be closed, and the main firmware interface is present. The test fixture file for the left-side, bottom-layer fixture has been created.

22. Click the Windows button (⊞) on the tool bar to access the Windows Start menu and open the Windows file browser.

   d) Navigate to the directory "C:\Users\Public\Documents\Rohde-Schwarz\VNA\Embedding\".

   e) Verify that the file "dut_plus_fixtures.s2p_RIGHT_DUT.s2p" exists, and that the timestamp matches the expected time of the de-embedding operation just completed.

   f) Since the EZD de-embedding process will overwrite existing files when performed, rename the file "dut_plus_fixtures.s2p_RIGHT_DUT.s2p".

      The preconfigured R&S®ZNB state files are populated with a default file name, thus rename "dut_plus_fixtures.s2p_RIGHT_DUT.s2p" to "USBHS_top_right_fixture.s2p".

   The right-side, top layer fixture has been de-embedded.

23. De-embed *the right-side bottom layer fixture*:

   a) On the front panel, select "OFFSET EMBED".

   b) Select "Offset Embed" > "Single Ended".

   c) Select "Run Tool…"

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d) The dialog "EZD Single Ended Ports" opens.

e) Select "Advanced Settings…".

f) Configure the "EZD – Single Ended Ports" settings as follows:
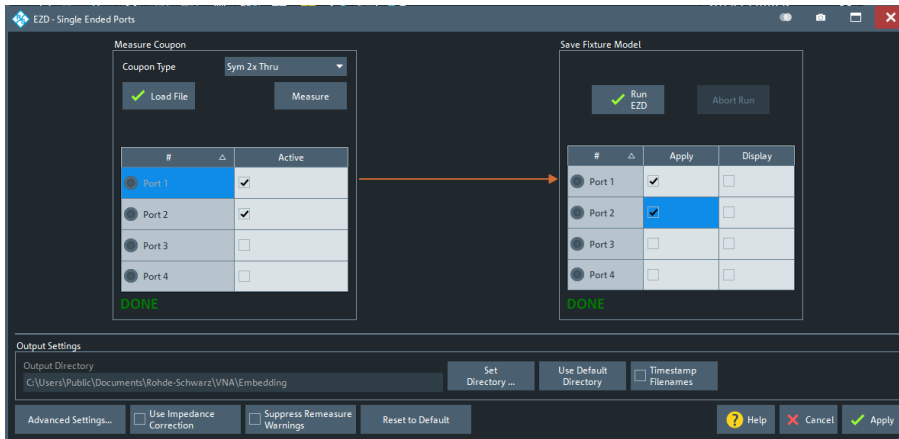
24. Measure the test fixture coupon:

a) Connect Port 1 and Port 2 of the VNA to each side of the 2x_Thru_Bottom calibration trace for the right fixture board.

b) Enable the checkboxes next to Port 1 and Port 2.

c) Select "Measure Coupon" > "Measure".

25. In the "Save Fixture Model" dialog, select "Run EZD" to start the EZD process.

The EZD de-embedding process is completed, and the appropriate de-embedding file can be saved.

26. In the "EZD – Single Ended Ports" dialog, select "Apply".
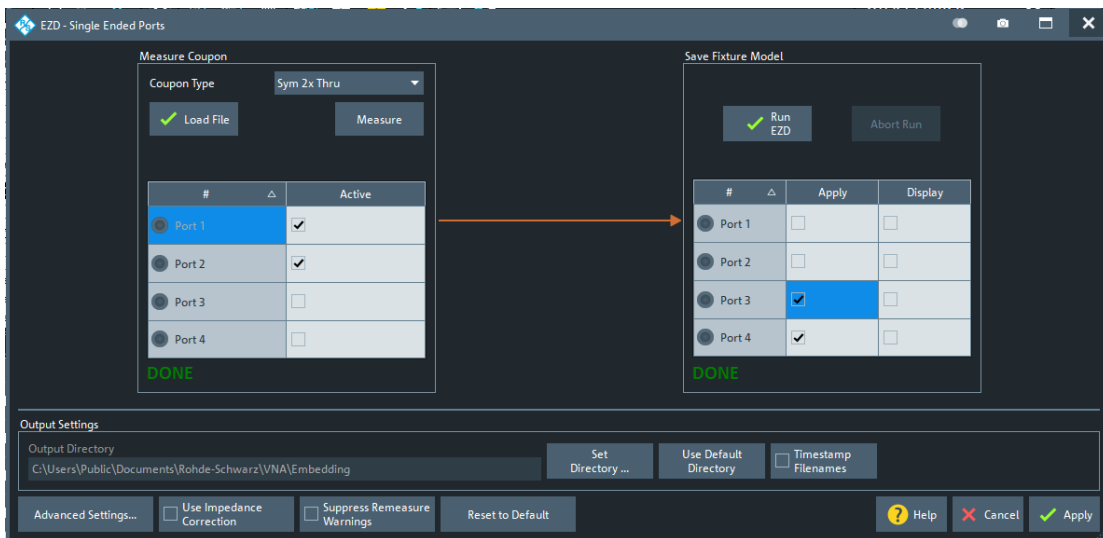
All pop-up dialogue boxes should be closed, and the main firmware interface is present. The test fixture file for the left-side, bottom-layer fixture has been created.

27. Click the Windows button (⊞) on the tool bar to access the Windows Start menu and open the Windows file browser.

a) Navigate to the directory "C:\Users\Public\Documents\Rohde-Schwarz\VNA\Embedding\".

b) Verify that the file "dut_plus_fixtures.s2p_RIGHT_DUT.s2p" exists, and that the timestamp matches the expected time of the de-embedding operation just completed.

c) Since the EZD de-embedding process will overwrite existing files when performed, rename the file "dut_plus_fixtures.s2p_RIGHT_DUT.s2p".

The preconfigured R&S®ZNB state files are populated with a default file name, thus rename "dut_plus_fixtures.s2p_RIGHT_DUT.s2p" to "USBHS_top_right_fixture.s2p".

The right-side, bottom layer fixture has been de-embedded.

28. Load the 4 fixture files that were created into the single-ended de-embedding dialogs.

29. Configure as follow:

Deembedding	Active	File Name 1		Swap Gates
P1	✔	USBHS_top_left_fixture.s2p	•••	☐
P2	✔	USBHS_bottom_right_fixture.s2p	•••	☐
P3	✔	USBHS_top_left_fixture.s2p	•••	☐
P4	✔	USBHS_bottom_right_fixture.s2p	•••	☐

EZD De-embedding is now completed. You can start the measurements.

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