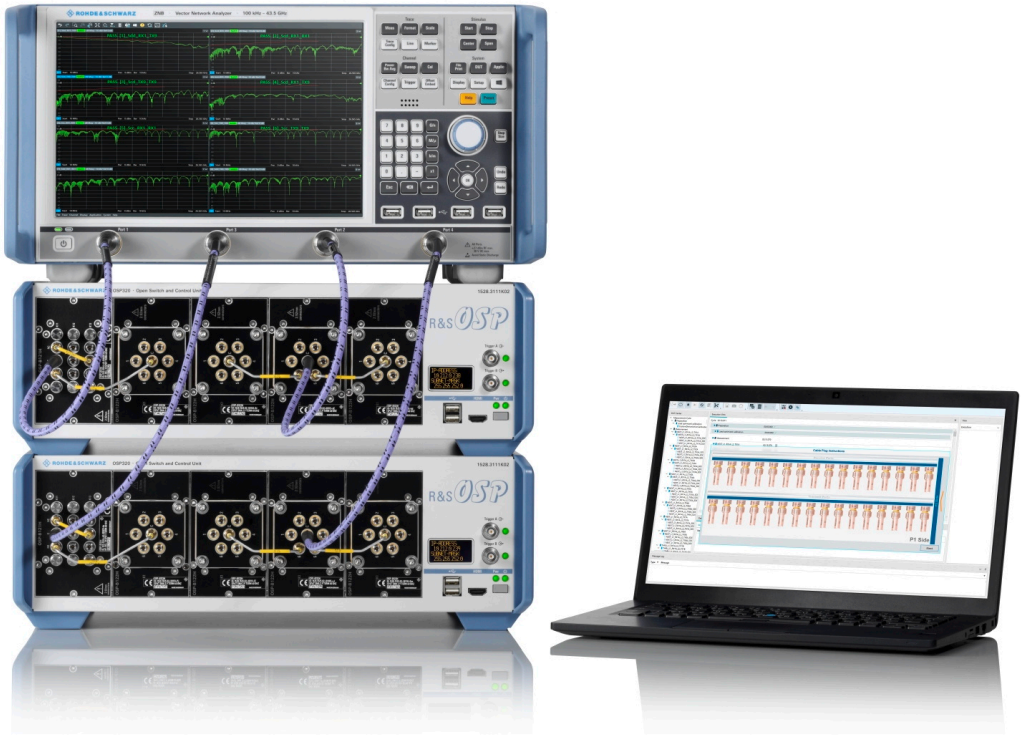
R&S®ZNrun-K4xx
Compliance Test Automation for High Speed Digital Interfaces with R&S®ZNrun V3.10
User Manual



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Version 09

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This document describes the following R&S®ZNRUN-Kxx options:

- R&S®ZNRUN-K400 "Signal integrity base option for ZNrun with R&S®ZNx VNAs" (1354.6041.02)
- R&S®ZNRUN-K410 "Compliance test automation for high-speed Ethernet IEEE 802.3bj/by/cd" (1332.6010.02)
- R&S®ZNRUN-K411 "Compliance test automation for high-speed Ethernet IEEE 802.3ck/df" (1332.6026.02)
- R&S®ZNRUN-K412 "Compliance test automation for high-speed Ethernet IEEE 802.3dj" (1332.6058.02)
- R&S®ZNRUN-K440 "Compliance test automation for PCIe 5.0 and 6.0 cable assemblies" (1332.5965.02)

Options R&S®ZNRUN-K4xx are available as **local licenses** (suffix **.02**, as stated above) and **floating licenses** (suffix **.51**).

Each of these options includes software maintenance for the first year after purchase. Dedicated maintenance options prolong the maintenance period for additional flexibility:

- R&S®ZNRUNMK400 "Software maintenance for R&S®ZNRUN-K400" (1354.6029.81)
- R&S®ZNRUNMK410 "Software maintenance for R&S®ZNRUN-K410" (1332.6061.81)
- R&S®ZNRUNMK411 "Software maintenance for R&S®ZNRUN-K411" (1332.6078.81)
- R&S®ZNRUNMK412 "Software maintenance for R&S®ZNRUN-K412" (1332.6058.81)
- R&S®ZNRUNMK440 "Software maintenance for R&S®ZNRUN-K440" (1332.5965.81)

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1179.6350.02 | Version 09 | R&S®ZNrun-K4xx

Throughout this manual, products from Rohde & Schwarz are indicated without the ® symbol, e.g. R&S®ZNrun is indicated as R&S ZNrun.

1 System overview

Testing high-speed cable assemblies for data centers or consumer electronics, requires high frequencies and a multi-port setup. Characterizing the cable under test with a 4-port vector network analyzers is a time-consuming process: Executing different characterization tests for every lane (or combination of lanes) in a cable assembly, requires many cable reconnections, with many chances for human errors.

Options R&S ZNrun-K4xx enable precise and time-saving compliance tests of high-speed cable assemblies (and connectors), in line with the relevant standards. Each compliance test defines three simple steps for the test procedure: Setup, calibrate and measure. The automated measurement step is time-optimized and ensures measurement reproducibility.

The multi-port setup, based on the R&S OSP Open Switch and Control Platform, allows testing numerous DUT ports without manual reconnection. For automated cable testing, a set of OSP-based switch matrices have been predefined. The ZNrun Server automatically configures the selected matrix when executing one of the generated or predefined compliance test projects.

This setup reduces the typical test time drastically. For example, the test time for a high-speed Ethernet cable with 8 lanes in line with IEEE 802.3cd, is reduced to one hour compared to one day with manual testing.

The implemented calibration algorithms are optimized for maximum speed and minimum number of reconnections, drastically reducing calibration effort and time. For example, the calibration of the 48-port setup for IEEE 802.3cd cables with 8 lanes, takes maximally 45 minutes instead of several hours. User guidance during calibration and measurement minimizes the risk of human error and increases the confidence in the test results.

A full compliance test automatically executes all required measurement steps and post-processes the measured data according to the standard. It exports both raw and processed measurement data and generates a comprehensive test report, including the measurement results and the overall pass/fail verdict. The exported measurement data allow you to do further analysis and custom postprocessing.

For development purposes and precompliance testing, the predefined compliance tests can be customized to a certain extent. With option R&S ZNRUN-K400, you have even more flexibility w.r.t. to hardware setup and tests to be executed.

2 R&S ZNrun

2.1 Introduction

R&S ZNrun is a PC-based software suite for the definition, configuration and execution of automated VNA tests. It controls the involved measurement devices (VNAs, switch matrices, calibration units) and supports many Rohde & Schwarz instruments. A plug-in interface is provided to control additional measurement equipment and devices under test via custom remote control connections.

R&S ZNrun stands for modularity, extensibility, compatibility and optimized speed of measurement execution. Therefore it is ideal for use in high volume production of multiport devices requiring control during test, e.g. for testing the RF properties in various operating states.

Setting up R&S ZNrun for testing is as simple as describing the test setup (test equipment, DUTs) and defining the test sequence. Configurations are modular and reusable and therefore minimize your configuration time. Based on the configuration, R&S ZNrun calculates a connection plan, which is optimized for both quality and measurement speed. It also calculates an initialization sequence, calibration plan and a speed-optimized test plan. At execution time, R&S ZNrun verifies that the measurement can be performed with the connected measurement equipment.

R&S ZNrun comes with the following applications:

- **ZNrun Server**
  The core of the software suite. Runs and manages Measurement Execution Units (MEUs). A plug-in interface enables user-defined extensions, such as custom devices and post processors.
- **ZNrun Workbench**
  The main graphical user interface (GUI) of R&S ZNrun. Allows you to develop, test and tune a MEU, before it is used in the production field. Can deploy the MEU to a ZNrun Server and communicate with the server during MEU execution. Integrates or gives access to the other R&S ZNrun applications (ZNrun Calibration Client, ZNrun Measurement Client, ZNrun Visualization Client).
- **ZNrun Calibration Client**
  The ZNrun Calibration Client guides a technician through all the steps of the calibration process. For laboratory use, it offers a more advanced interface, which allows the definition of user-defined calibration tasks. It is available as a standalone application and integrated in the ZNrun Workbench.
- **ZNrun Measurement Client**
  An application for controlling the execution of a MEU on a ZNrun Server. Provides a graphical and a remote control interface (SCPI commands). A plug-in interface enables user-defined extensions, such as the creation of custom log files and reports.
- **ZNrun Visualization Client**

The ZNrun Visualization Client allows you to visualize and document measurement results. It is available as a stand-alone application and integrated in the ZNrun Workbench.

- **ZNrun Cable Test Client**
  The ZNrun Cable Test Client allows even more streamlined measurements with predefined or user-defined MEUs. This client is particularly useful if the user has to measure a multitude of DUTs (e.g. cables), where standard measurements and appropriate calibrations are requested.

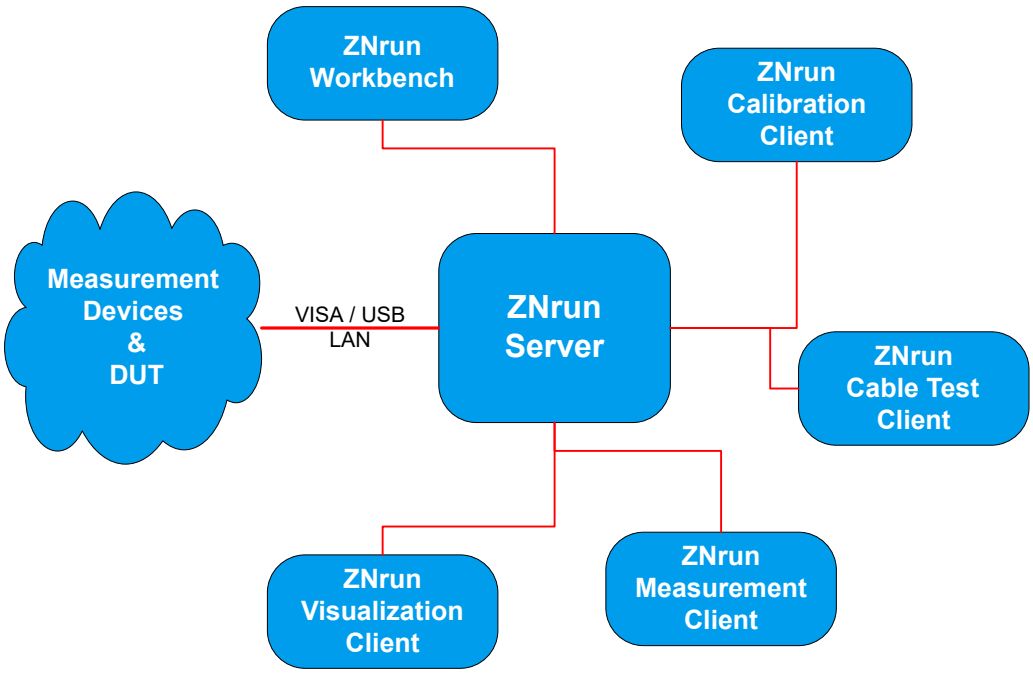


Figure 2-1: R&S ZNrun

2.2 Required software and licenses

Basic requirements

You can download the R&S ZNrun software suite free of charge from the Rohde & Schwarz website. Without purchasing any licenses, you can use the ZNrun Workbench application to:

- Create or modify existing R&S ZNrun measurement projects (defining ports, stimuli, VNA devices etc.)
- Save your work and share it with your colleagues

To execute a measurement project, you need at least license R&S ZNrun-K1 on the ZNrun Server.

Licenses for automated cable tests

Currently, the following licenses are available:

- R&S ZNRUN-K400 "Signal integrity base option for ZNrun with R&S ZNx VNAs" (1354.6041.02)
- R&S ZNRUN-K410 "Compliance test automation for high-speed Ethernet according to IEEE 802.3bj/by/cd"
- R&S ZNRUN-K411 "Compliance test automation for high-speed Ethernet according to IEEE 802.3ck/df"
- R&S ZNRUN-K412 "Compliance test automation for high-speed Ethernet IEEE 802.3dj"
- R&S ZNRUN-K440 "Compliance test automation for PCIe 5.0 and 6.0 cable assemblies"

The specification IEEE 802.3dj is currently in draft state (2024).

The first implementation of the test logic in R&S ZNrun V2.94 was inherited/extrapolated from standards IEEE 802.3ck and IEEE 802.3df. It will be aligned with the ongoing standardization in future R&S ZNrun releases.

3 Test equipment

3.1 Vector network analyzer

At the heart of each test setup, there is a 4-port network analyzer of the R&S ZNB or R&S ZNA family.

3.1.1 R&S ZNB family

With frequency ranges from 9 kHz to 4.5 GHz, 9 GHz, 20 GHz, 26.5 GHz, 32 GHz, 43.5 GHz and 54 GHz the R&S ZNB3000 is ideal for developing, producing and servicing RF components such as cables and connectors, and for high-speed printed circuit board design.

Figure 3-1: 4-port R&S ZNB3000

For more information, see the R&S ZNB3000 product pages at https://www.rohde-schwarz.com/product/znb3000.

The original R&S ZNB, launched in 2012, is the predecessor of the R&S ZNB3000. From the digital interface test perspective, R&S ZNB3000 and R&S ZNB can be used interchangeably in their respective frequency ranges.

Figure 3-2: 4-port R&S ZNB

For more information, see the R&S ZNB product pages at https://www.rohde-schwarz.com/product/znb.

In the remaining sections of this manual, the original R&S ZNB is not mentioned explicitly. However, you can easily replace a R&S ZNB3000 by a R&S ZNB with matching (or larger) frequency range. For example, you can replace a 4-port R&S ZNB3020 with frequency extension option R&S ZNB3-B264 by a 4-port R&S ZNB26. The ZNrun Cable Test Client does not distinguish between them and refers to all family members as "ZNB".

3.1.2 R&S ZNA

The R&S ZNA vector network analyzers are the high-end series of the R&S VNA portfolio: excellent RF performance is combined with a wide range of software features and a unique hardware concept. The touch-only operation makes the R&S ZNA to a powerful, universal and compact measurement system for characterizing both passive and active devices.

For more information, see the R&S ZNA product pages at https://www.rohde-schwarz.com/product/zna.

3.1.3 Recommended/supported models

Both the R&S ZNrun-K400 project generator and the predefined R&S ZNrun-K4xx projects for compliance tests require a 4-port R&S ZNB3000 or R&S ZNA.

The project generator can use any 4-port R&S ZNB3000 or R&S ZNA model that covers the stimulus frequency range of the signal integrity test to be performed. See:

- R&S ZNB3000 models (or R&S ZNB models)
- R&S ZNA models

Some R&S ZNrun-K4xx compliance test projects, however, are optimized for either "ZNB" **or** "ZNA", and require either the one or the other.

The predefined multiport solutions for automated cable testing choose the most cost efficient VNA for certain frequency ranges.

Table 3-1: Recommended VNAs

Stimulus frequencies	Recommended VNA
up to 26.5 GHz	R&S ZNB3020, 4 test ports, 3.5 mm (m) ruggedized • Base unit 9 kHz to 20 GHz, order no. 1351.5050K24 • Frequency extension option R&S ZNB3-B264 "upgrade to 26.5 GHz", order no. 1351.5073.04 Referred to as **R&S ZNB3020+FE**, for short.
up to 40 GHz	R&S®ZNB3032, 4 test ports, 2.92 mm (m) ruggedized • Base unit 9 kHz to 32 GHz, order no. 1351.5050K34 • Frequency extension option R&S ZNB3-B444 "upgrade to 43.5 GHz", order no. 1351.5080.04 Referred to as **R&S ZNB3032+FE**, for short.

Stimulus frequencies	Recommended VNA
up to 50 GHz	**R&S ZNA50**, order no. 1332.4500K54 4 ports 2.4 mm (m), 10 MHz to 50 GHz
up to 67 GHz	**R&S ZNA67**, order no. 1332.4500K64 4 ports 1.85 mm (m), 10 MHz to 67 GHz

When testing 8 lanes or more with a R&S ZNA, set its paging file size to 90 GB or higher. Consider using setup sharing if measurement initialization still takes too long or your R&S ZNA runs out of memory.

For compliance tests, the required frequency range can be derived – to a certain extent – from the applicable standard. According to the PCIe 5.0 and 6.0 standard specification, for example, the compliance tests must cover frequencies up to 24 GHz. In addition, the specification requires an accurate deembedding of the test fixtures, which, from the experience of Rohde & Schwarz and other industry experts, requires frequencies above 26.5 GHz. For this reason, the recommended VNA for PCIe cable compliance tests is a 4-port **R&S ZNB3032+FE**.

(Note, however, that you can prepare the fixture deembedding data on a different VNA than the one that is used for compliance testing.)

3.2 Switch matrices

The predefined switch matrices for automated cable tests are built on one or more open switch and control units R&S OSP320, equipped with certain switch modules at particular front slots. They are remotely operated via LAN.

3.2.1 Base unit R&S OSP320

R&S OSP320 base units (order no. 1528.3111K02) that are used for automated cable tests can accommodate up to 10 switch modules, 5 on the front and 5 on the rear side.

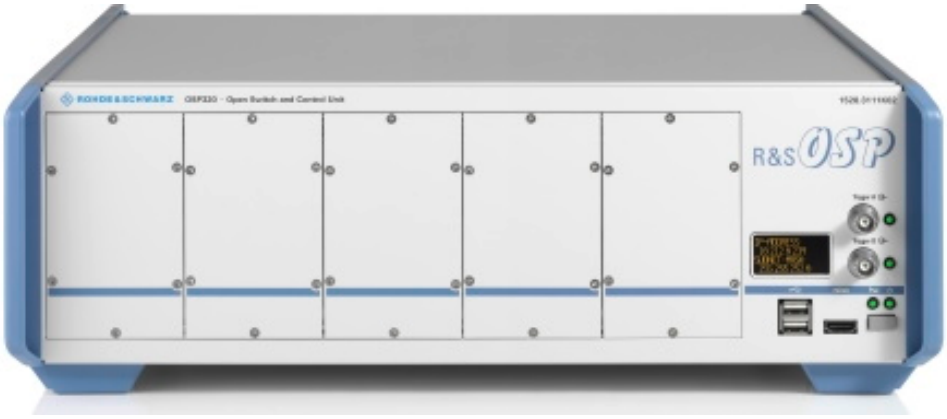


Figure 3-3: R&S OSP320 base unit, front panel

Such a base unit or "frame" can either work standalone or in "interconnection mode", with one or more secondary frames. Some of the multiport solutions for automated cable testing use one or two frames in standalone mode, others use two or three frames in interconnection mode.

- "Interconnection mode" requires the same FW version on all R&S OSP. For information, see the R&S OSP manual.
- The predefined switch matrices for automated cable tests do not use the rear side module slots.

3.2.2 Switch modules

The predefined switch matrices for automated cable tests use the following switch modules:

Frequency range	Module name	Order no.	Switching functionality	Connectors
DC to 40 GHz	R&S OSP-B121H	1515.5504.40	**3 x** SPDT terminated	2.92 mm (f)
	R&S OSP-B122H	1528.1525.02	1 x SP6T	
DC to 50 GHz	R&S OSP-B121U variant 52	1515.5504.52	**2 x** SPDT terminated	2.4 mm (f)
	R&S OSP-B122U	1528.1525.51	1 x SP6T	
DC to 67 GHz	R&S OSP-B121VL variant 62	1528.1654.62	**2 x** SPDT terminated, latching	1.85 mm (f)
	R&S OSP-B122VL	1528.1525.61	1 x SP6T latching	

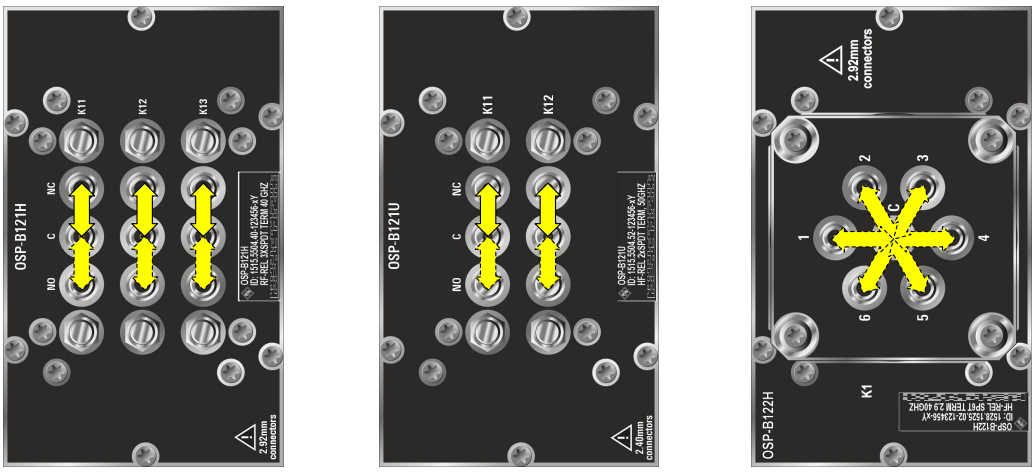


Figure 3-4: R&S OSP modules with connectivity

left = R&S OSP-B121H (3 x SPDT)
middle = R&S OSP-B121U var. 52 (2 x SPDT; same interface as R&S OSP-B121VL var. 62)
right = R&S OSP-B122H (1 x SP6T; same interface as R&S OSP-B122U and R&S OSP-B122VL)

3.2.3 Combined 1:n switches

By combining several switch modules using external cables, it is possible to connect one source port to 8 or more destination ports:

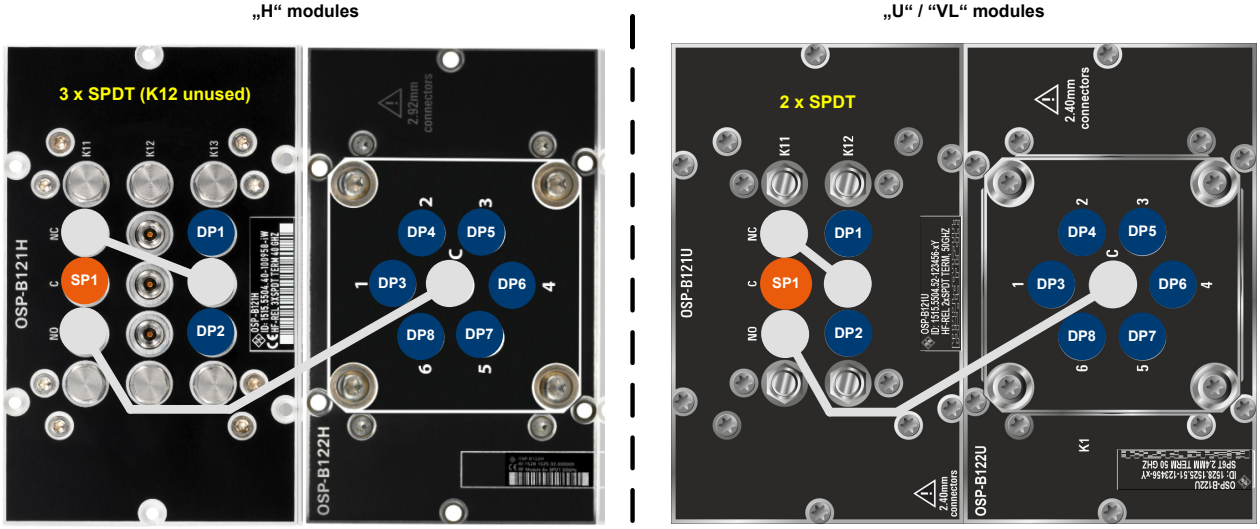


Figure 3-5: Combined 1:8 switch

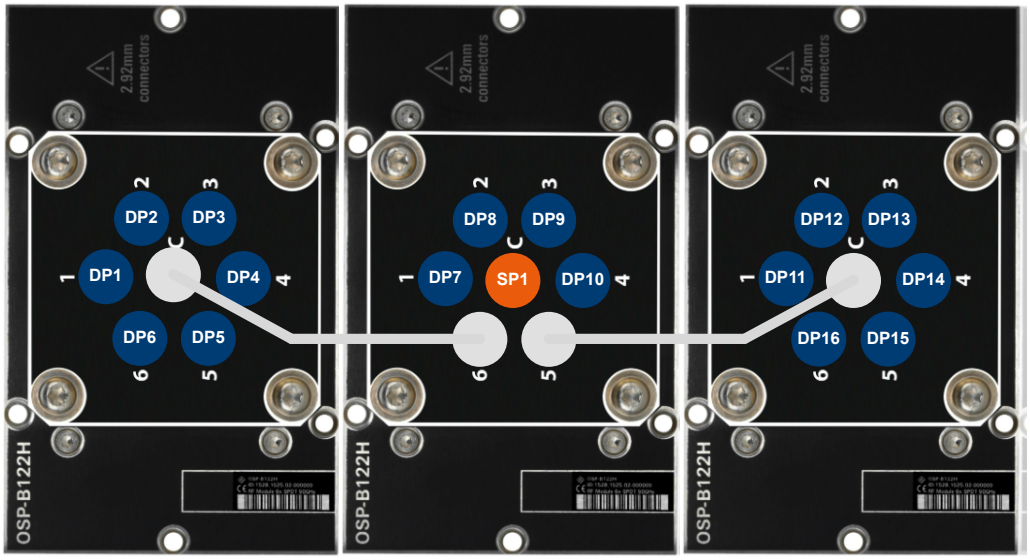


Figure 3-6: Combined 1:16 switch (single R&S OSP320)

R&S OSP "interconnection mode" allows you to build 1:n switches from switch modules residing in different base units:

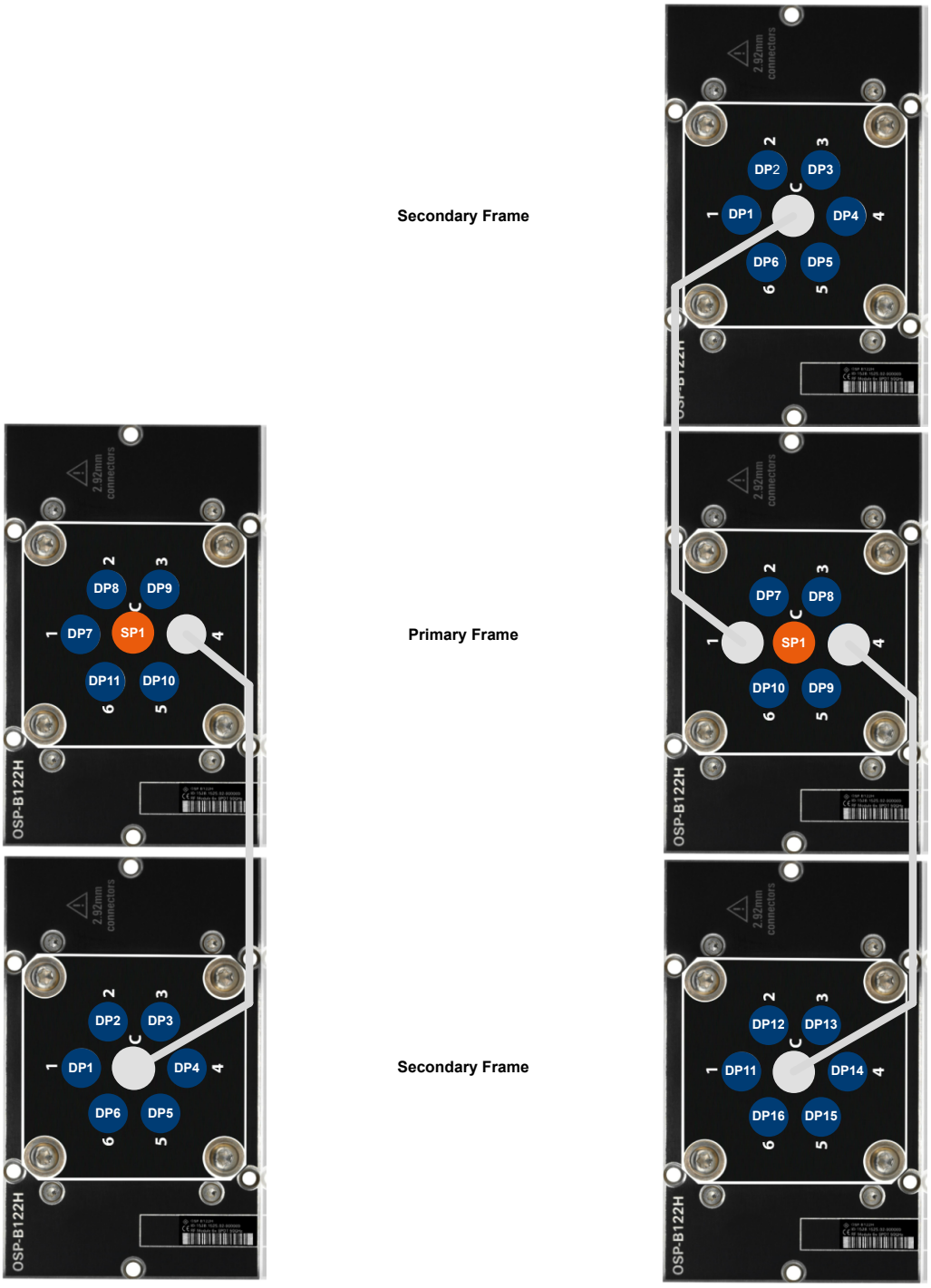


Figure 3-7: Other combined switches (multiple interconnected R&S OSP320)

Left = 1:11 (2 x R&S OSP320)
Right = 1:16 (3 x R&S OSP320)

3.2.4 Predefined switch matrices for automated cable tests

For automated cable tests, Rohde & Schwarz has defined matrices based on 1, 2 or 3 R&S OSP320, each of them equipped with certain switch modules and/or combined 1:n switches at particular front slots.

For easier assembly of RF cables, we recommend using an R&S SMA-WRENCH, order no. 1528.1590.02.

3.2.4.1 OSP320-4-8nc

This 4:8 switch matrix consists of four 1:2 switches (submatrices A to D), implemented via two switch modules R&S OSP-B121x.

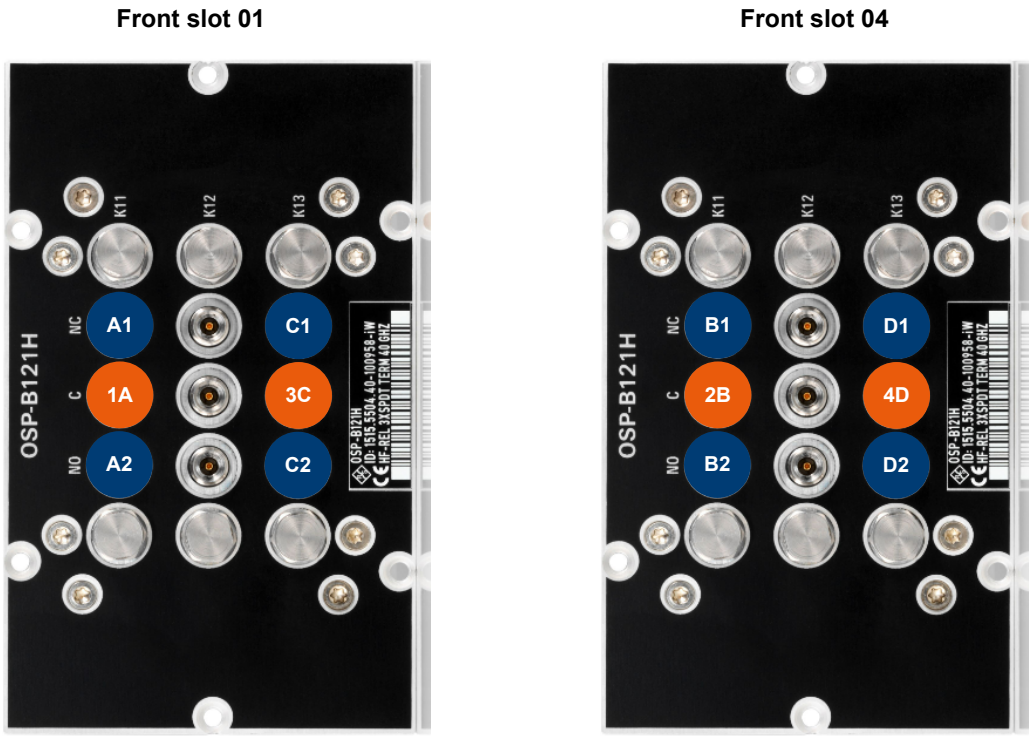


Figure 3-8: OSP320-4-8nc with modules R&S OSP-B121H (3 x SPDT, 1 unused)

Switch modules R&S OSP-B121H (3 x SPDT) are suitable for frequencies up to 40 GHz. Depending on the maximum required stimulus frequency, the matrix can also be equipped with R&S OSP-B121U (up to 50 GHz). The proposed variant 52 of this module only has the 2 SPDTs that are actually needed for this setup.

Table 3-2: Required hardware

Variant	Frequency range	R&S OSP Hardware*	Semi-rigid cable set
H	DC to 40 GHz	1 x R&S OSP320 2 x R&S OSP-B121H	not needed
U	DC to 50 GHz	1 x R&S OSP320 2 x R&S OSP-B121U var. 52	

* see Section 3.2.1, "Base unit R&S OSP320", on page 10 and Section 3.2.2, "Switch modules", on page 11

This matrix is reserved for the predefined R&S ZNRUN-K41x CR1 MOI projects (see Section 4.2, "Test setup for 1-lane copper cables", on page 38). It **cannot** be used to define custom signal integrity tests with the R&S ZNRUN-K400 project generator.

3.2.4.2 OSP320-2-12nc

This 2:12 switch matrix consists of:

- A combined 1:8 switch implementing submatrix 1:8 submatrix A
- A switch module R&S OSP-B122x, implementing 1:4 submatrix B

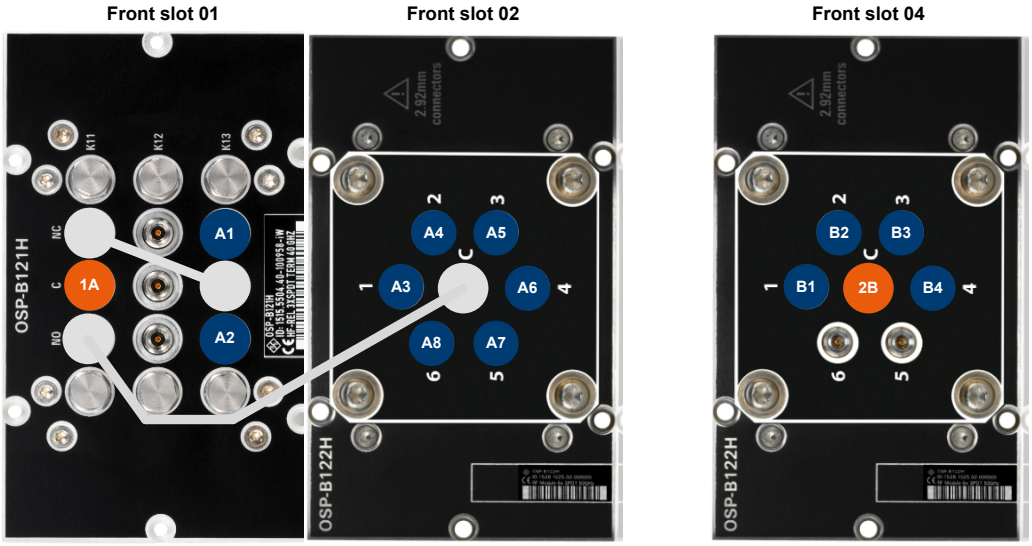


Figure 3-9: OSP320-2-12nc (H variant)

Switch modules R&S OSP-B121H/-B122H can be used for frequencies up to 40 GHz.

Depending on the maximum required stimulus frequency, the matrix can also be equipped with:

- Switch module R&S OSP-B121U (up to 50 GHz) or R&S OSP-B121VL (up to 67 GHz). The proposed variants of these modules (52 and 62, respectively) only have the 2 SPDT that are actually needed for this setup.
- Switch modules R&S OSP-B122U (up to 50 GHz) or R&S OSP-B122VL (up to 67 GHz) with identical interfaces as the "H" variant.

- This matrix is reserved for the predefined R&S ZNRUN-K41x 4-lane tests, which use **two stacked OSP320-2-12nc**.
  It **cannot** be used to define custom signal integrity tests with the R&S ZNRUN-K400 project generator.
- Because they are not needed for the R&S ZNRUN-K41x tests, ports 5 and 6 of the switch module are not part of the OSP320-2-12nc matrix definition.

Table 3-3: Required hardware

Variant	Frequency range	R&S OSP Hardware*	Semi-rigid cable set**
H	DC to 40 GHz	2 x R&S OSP320 2 x R&S OSP-B121H 4 x R&S OSP-B122H	R&S ZV-Z40CR4, order no. 1528.3540.02 4 cables 2.92 mm (m/m)
U	DC to 50 GHz	2 x R&S OSP320 2 x R&S OSP-B121U var. 52 4 x R&S OSP-B122U	R&S ZV-Z50CR4, order no. 1528.3540.04 4 cables 1.85 mm (m/m)
VL	DC to 67 GHz	2 x R&S OSP320 2 x R&S OSP-B121VL var. 62 4 x R&S OSP-B122VL	R&S ZV-Z67CR4, order no. 1528.3540.07 4 cables 1.85 mm (m/m)

* see Section 3.2.1, "Base unit R&S OSP320", on page 10 and Section 3.2.2, "Switch modules", on page 11

** for **2 x** OSP320-2-12nc

3.2.4.3 OSP320-4-24nc

The 4:24 switch matrix OSP320-4-44nc consists of four SP6T switch modules R&S OSP-B122x (= submatrices A to D) in a single R&S OSP320 frame.

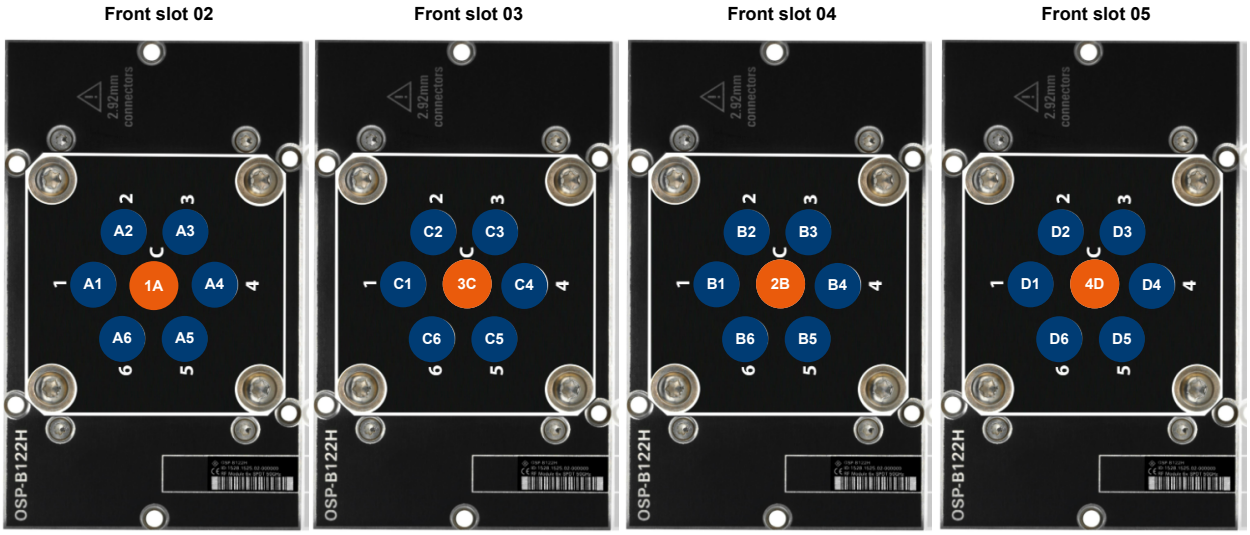


Figure 3-10: OSP320-4-24nc (H variant)

Matrix VNA ports 1A, 2B, 3C, 4D must be connected to VNA ports 1 to 4, respectively.

Switch modules R&S OSP-B122H are suitable for frequencies up to 40 GHz. The matrix can also be equipped with switch modules R&S OSP-B122U (up to 50 GHz) or R&S OSP-B122VL (up to 67 GHz). The interfaces of these modules are identical.

Table 3-4: Required hardware

Variant	Frequency range	R&S OSP Hardware*	Semi-rigid cable set
H	DC to 40 GHz	1 x R&S OSP320 4 x R&S OSP-B122H	not needed
U	DC to 50 GHz	1 x R&S OSP320 4 x R&S OSP-B122U	
VL	DC to 67 GHz	1 x R&S OSP320 4 x R&S OSP-B122VL	

* see Section 3.2.1, "Base unit R&S OSP320", on page 10 and Section 3.2.2, "Switch modules", on page 11

3.2.4.4 OSP320-4-32nc

Same as the 44-port matrix OSP320-4-44nc, but limited to 8 out of 11 test ports used per 1:11 submatrix.

Used by R&S ZNRUN-K440 x4 tests only.

3.2.4.5 OSP320-4-44nc

The 4:44 switch matrix OSP320-4-44nc consists of 4 combined 1:11 switches (= sub-matrices A to D), spanning 2 R&S OSP320 frames in "interconnection mode".

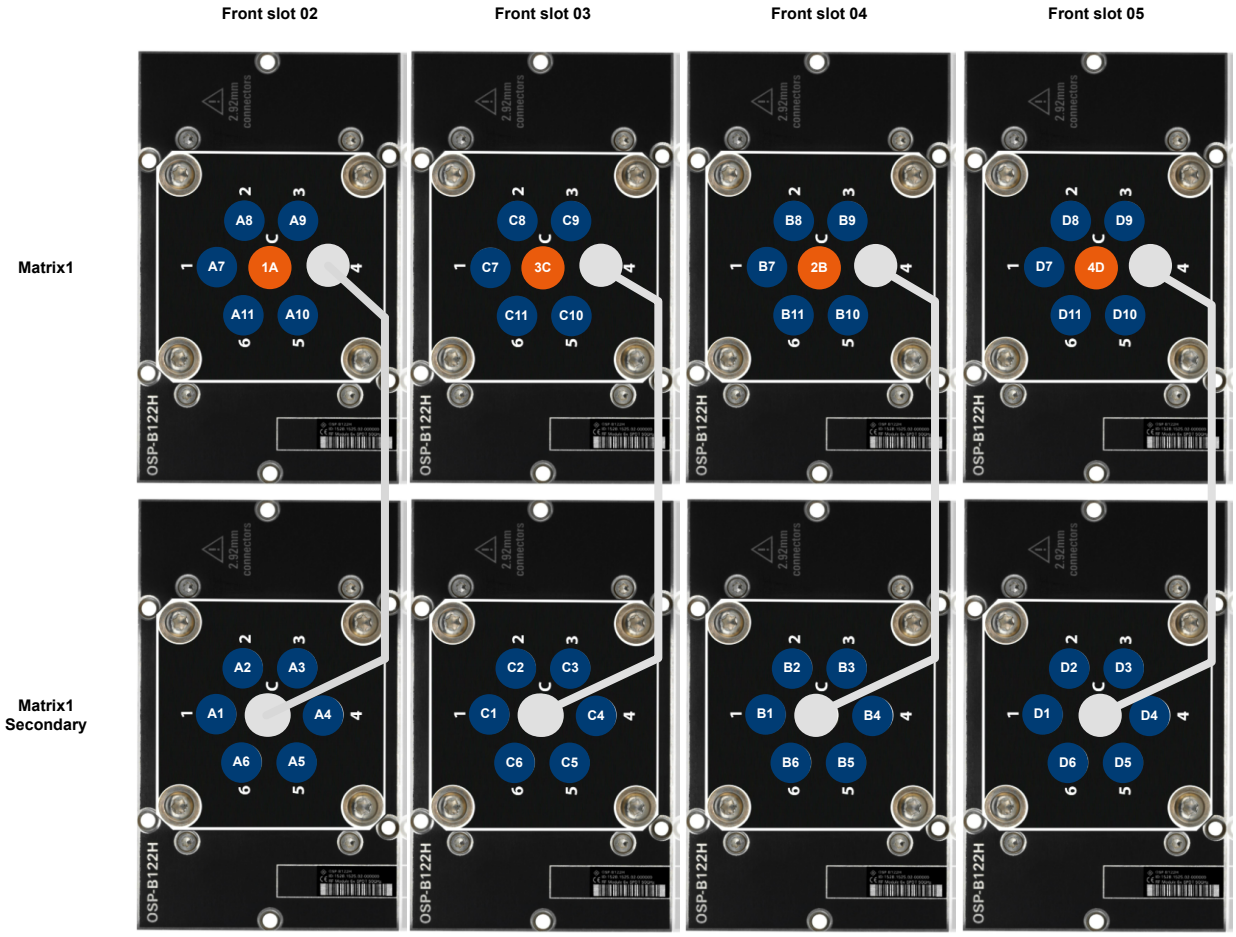


Figure 3-11: OSP320-4-44nc (H variant)

Switch modules R&S OSP-B122H are suitable for frequencies up to 40 GHz. The matrix can also be equipped with switch modules R&S OSP-B122U (up to 50 GHz) or R&S OSP-B122VL (up to 67 GHz) with identical interfaces as the "H" variant.

R&S ZNRUN-K440 x4 test setups also use this matrix, but only with 8 ports per combined 1:11 switch. The "restricted" matrix is called OSP320-4-32nc.

Table 3-5: Required hardware

Variant	Frequency range	R&S OSP Hardware*	Semi-rigid cable set
H	DC to 40 GHz	2 x R&S OSP320 8 x R&S OSP-B122H	R&S ZV-Z40X4, order no. 1528.3557.02 4 cables 2.92 mm (m/m)
U	DC to 50 GHz	2 x R&S OSP320 8 x R&S OSP-B122U	R&S ZV-Z67X4, order no. 1528.3557.04 4 cables 1.85 mm (m/m)
VL	DC to 67 GHz	2 x R&S OSP320 8 x R&S OSP-B122VL	
* see Section 3.2.1, "Base unit R&S OSP320", on page 10 and Section 3.2.2, "Switch modules", on page 11			

3.2.4.6 OSP320-2-24nc

The 2:24 switch matrix OSP320-2-24nc consists of:

- A combined 1:8 switch implementing submatrix A
- A combined 1:16 switch implementing submatrix B

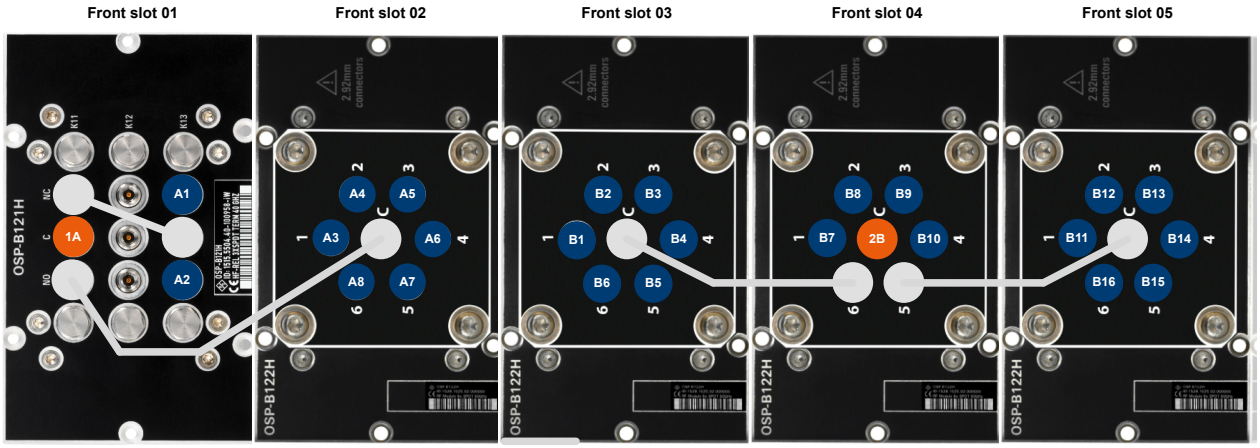


Figure 3-12: OSP320-2-24nc (H variant)

OSP320-4-24nc R&S OSP-B121H/-B122H are suitable for frequencies up to 40 GHz.

Depending on the maximum required stimulus frequency, the matrices can also be equipped with:

- Switch modules R&S OSP-B121U (up to 50 GHz) or R&S OSP-B121VL (up to 67 GHz). The proposed variants of these modules (52 and 62, respectively) only have the 2 SPDTs that are actually needed for this setup.
- Switch modules R&S OSP-B122U (up to 50 GHz) or R&S OSP-B122VL (up to 67 GHz) with identical interfaces as the "H" variant.

Table 3-6: Required hardware

Variant	Frequency range	R&S OSP Hardware*	Semi-rigid cable set**
H	DC to 40 GHz	2 x R&S OSP320 2 x R&S OSP-B121H 8 x R&S OSP-B122H	R&S ZV-Z40CR8, order no. 1528.3540.03 8 cables 2.92 mm (m/m)
U	DC to 50 GHz	2 x R&S OSP320 2 x R&S OSP-B121U var. 52 8 x R&S OSP-B122U	R&S ZV-Z50CR8, order no. 1528.3540.05 8 cables 1.85 mm (m/m)
VL	DC to 67 GHz	2 x R&S OSP320 2 x R&S OSP-B121VL var. 62 8 x R&S OSP-B122VL	R&S ZV-Z67CR8, order no. 1528.3540.06 8 cables 1.85 mm (m/m)

* see Section 3.2.1, "Base unit R&S OSP320", on page 10 and Section 3.2.2, "Switch modules", on page 11

** for **2 x** OSP320-2-24nc

3.2.4.7 OSP320-4-64nc

The 4:64 switch matrix OSP320-4-64nc consists of 4 Figure 3-5combined 1:16 switches (= submatrices A to D), spanning 3 R&S OSP320 frames in "interconnection mode".

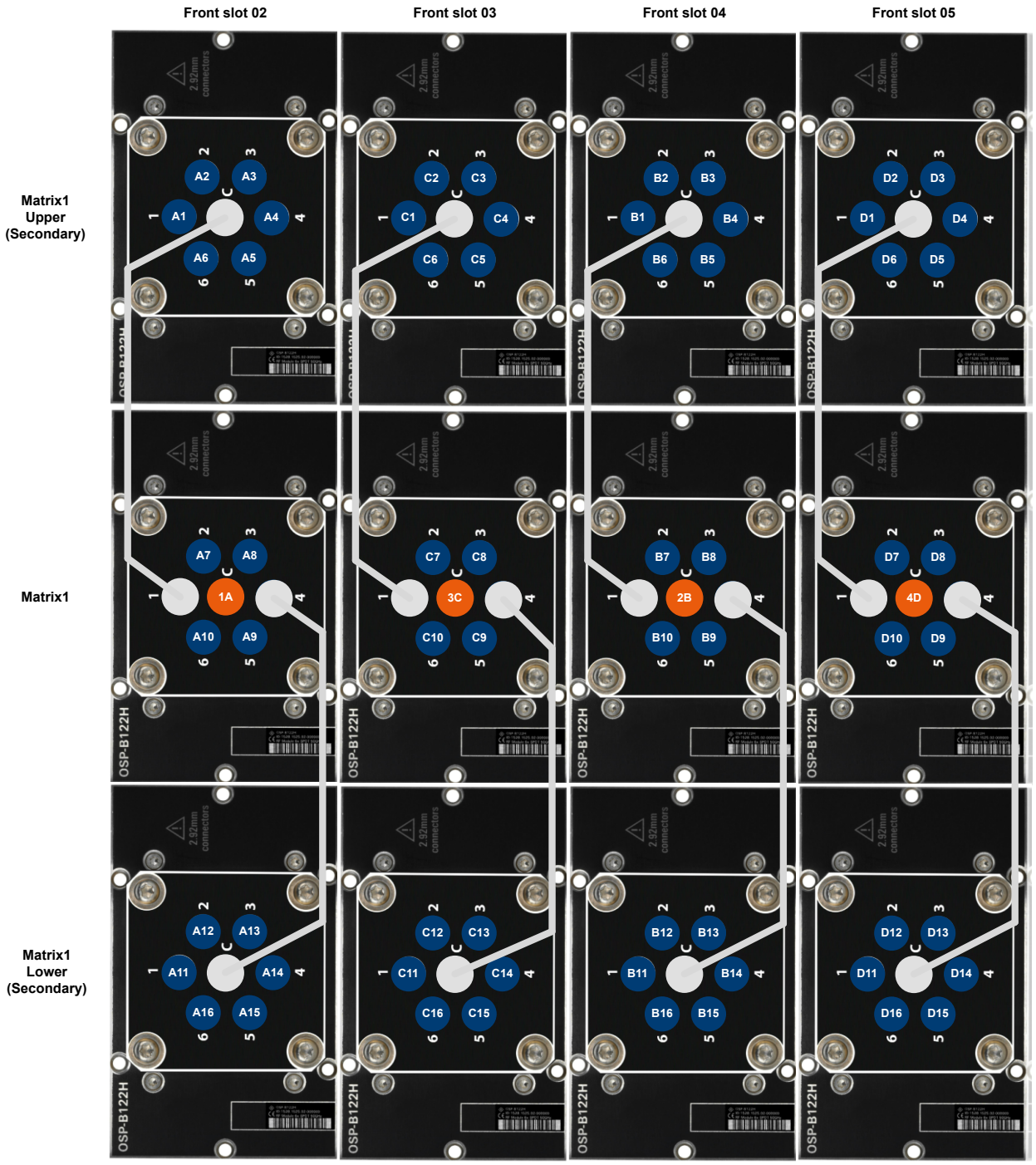


Figure 3-13: OSP320-4-64nc (H variant)

Switch modules R&S OSP-B122H are suitable for frequencies up to 40 GHz. The matrix can also be equipped with switch modules R&S OSP-B122U (up to 50 GHz) or R&S OSP-B122VL (up to 67 GHz) with identical interfaces as the "H" variant.

Table 3-7: Required hardware

Variant	Frequency range	R&S OSP Hardware*	Semi-rigid cable set
H	DC to 40 GHz	3 x R&S OSP320 12 x R&S OSP-B122H	R&S ZV-Z40X8, order no. 1528.3557.03 8 cables 2.92 mm (m/m)
U	DC to 50 GHz	3 x R&S OSP320 12 x R&S OSP-B122U	R&S ZV-Z67X8, order no. 1528.3557.05 8 cables 1.85 mm (m/m)
VL	DC to 67 GHz	3 x R&S OSP320 12 x R&S OSP-B122VL	

* see Section 3.2.1, "Base unit R&S OSP320", on page 10 and Section 3.2.2, "Switch modules", on page 11

3.3 Multiport solutions for automated cable testing

For automated cable tests, Rohde & Schwarz has defined switch matrices with up to 64 ports, based on 1, 2 or 3 R&S OSP320. See Section 3.2.4, "Predefined switch matrices for automated cable tests", on page 15.

Depending on the required stimulus frequency range, these matrices can be equipped with different switch module variants:

- R&S OSP-B121H and R&S OSP-B122H for frequencies up to 40 GHz ("variant H")
- R&S OSP-B121U and R&S OSP-B122U for frequencies up to 50 GHz ("variant U")
- R&S OSP-B121VL and R&S OSP-B122VL for frequencies up to 67 GHz ("variant VL")

In any case, the driving 4-port vector network analyzer you connect to the matrix must support the required stimulus frequencies, as specified in the test setup. The solutions presented in this section recommend the most cost efficient VNA and matrix variant.

Table 3-8: Recommended hardware

Stimulus frequencies	Recommended VNA*	Recommended matrix variant**
up to 26.5 GHz	R&S ZNB3020+FE	H (R&S OSP-B121H/-B122H)
up to 40 GHz	R&S ZNB3032+FE	
up to 50 GHz	R&S ZNA50	U (R&S OSP-B121U/-B122U)
up to 67 GHz	R&S ZNA67	VL (R&S OSP-B121VL/-B122VL)
* see Table 3-1 ** see Section 3.2.4, "Predefined switch matrices for automated cable tests", on page 15		

- For most of these combinations of recommended VNA and matrix variant, Rohde & Schwarz offers semi-rigid cable sets for connecting them in stacked benchtop operation. If you use another R&S ZNB3000 or R&S ZNA, use high-quality Rohde & Schwarz cables (and possibly adapters) to connect it to the matrix.
- For easier assembly of RF cables, we recommend using an R&S SMA-WRENCH, order no. 1528.1590.02.

3.3.1 8-port solution for R&S ZNRUN-K41x

This solution is reserved for the predefined R&S ZNRUN-K41x 1-lane test projects. It **cannot** be used to define custom MOI projects with the R&S ZNRUN-K400 project generator.

The predefined 8-port solution consists of:

- A 4-port Rohde & Schwarz VNA
- A 4:8 switch matrix OSP320-4-8nc based on a single R&S OSP320

Rohde & Schwarz does not offer semi-rigid cable sets to connect the VNA to this matrix. Use high-quality connection cables instead (see Section 3.5, "Connection cables", on page 33).

Figure 3-14: 8-port solution based on switch matrix OSP320-4-8nc

Depending on the required stimulus frequencies, the matrix must be equipped with different switch modules (see Table 3-2).

Table 3-9: Required hardware

Stimulus frequencies	VNA*	OSP320-4-8nc variant**	Semi-rigid cable set VNA ↔ Matrix
up to 26.5 GHz	R&S ZNB3020+FE	H	not available
up to 40 GHz	R&S ZNB3032+FE		
up to 50 GHz	R&S ZNA50	U	

* see Table 3-1

** see Table 3-2

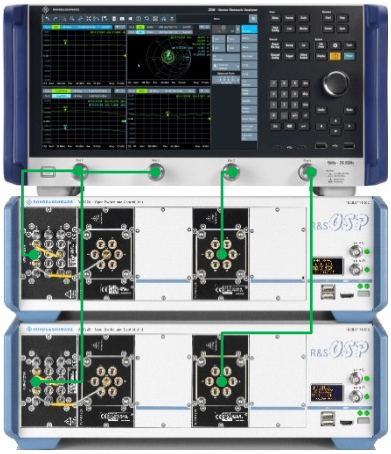
3.3.2 24-port solution for R&S ZNRUN-K41x

This solution is reserved for the predefined R&S ZNRUN-K41x 4-lane test projects. It **cannot** be used to define custom MOI projects with the R&S ZNRUN-K400 project generator.

The predefined 24-port solution consists of:

- A 4-port Rohde & Schwarz VNA
- Two stacked 2:12 switch matrices OSP320-2-12nc
- Semi-rigid cables connecting VNA and switch matrix

Matrix VNA ports 1A and 2B of the upper OSP320-2-12nc are connected to VNA ports 1 and 2. Matrix VNA ports 1A and 2B of the lower OSP320-2-12nc are connected to VNA ports 3 and 4.



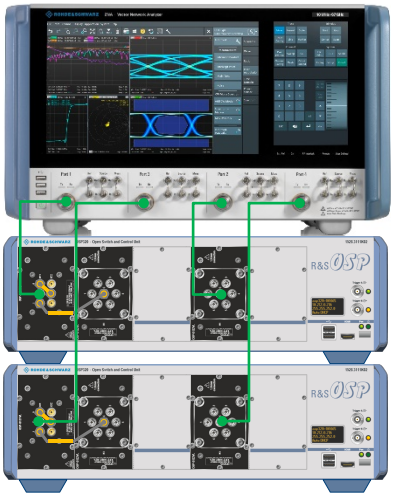


Table 3-10: Required hardware

Stimulus frequencies	VNA*	OSP320-2-12nc variant**	Semi-rigid cable set VNA ↔ Matrix
up to 26.5 GHz	R&S ZNB3020+FE	**2 x** H	R&S ZV-ZB40CR, order no. 1528.3563.06 4 cables 2.92 mm (f/m)
up to 40 GHz	R&S ZNB3032+FE		
up to 50 GHz	R&S ZNA50	**2 x** U	R&S ZV-ZA50CR, order no. 1528.3563.07 4 cables 2.4 mm (f/m)
up to 67 GHz	R&S ZNA67	**2 x** VL	R&S ZV-ZA67CR, order no. 1528.3563.08 4 cables 1.85 mm (f/m)
* see Table 3-1 ** see Table 3-3			

3.3.3 24-port solution

The predefined 24-port solution consists of:

- A 4-port Rohde & Schwarz VNA
- A switch matrix OSP320-4-24nc
- Semi-rigid cables connecting VNA and switch matrix

Matrix VNA ports 1A, 2B, 3C, 4D must be connected to VNA ports 1 to 4, respectively.

This solution is particularly useful for "small" custom cable test projects created with the R&S ZNRUN-K400 project generator.

- The R&S ZNRUN-K400 project generator addresses this solution as **24-port_6RX_6TX** because it allows you to measure the effect of 3 balanced transmitters (aggressors) on 3 balanced receivers (victims) without reconnecting fixtures.
- The non-standard 3-lane compliance test projects for IEEE 802.3 (R&S ZNRUN-K411, R&S ZNRUN-K412) and PCIe (R&S ZNRUN-K440) use this solution for demonstration purposes.

Table 3-11: Required hardware

Stimulus frequencies	VNA*	OSP320-4-24nc variant**	Semi-rigid cable set VNA ↔ Matrix
up to 26.5 GHz	R&S ZNB3020+FE	H	R&S ZV-ZB40, order no. 1528.3563.02 4 cables 2.92 mm (f/m)
up to 40 GHz	R&S ZNB3032+FE		
up to 50 GHz	R&S ZNA50	U	R&S ZV-ZA67, order no. 1528.3563.03 4 cables 1.85 mm (f/m)
up to 67 GHz	R&S ZNA67	VL	

* see Table 3-1

** see Table 3-4

3.3.4 32-port solution

This solution is identical to the 44-port solution for R&S ZNRUN-K400.

Both R&S ZNRUN-K41x IEEE CR4 tests and R&S ZNRUN-K440 PCIe x4 tests only use 8 out of 11 matrix test ports per submatrix. The "restricted" matrix is called OSP320-4-32nc (4·8=32).

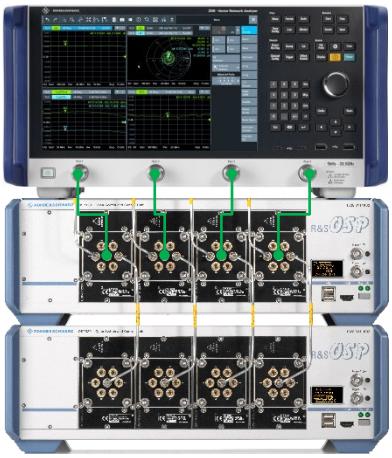
3.3.5 44-port solution for R&S ZNRUN-K400

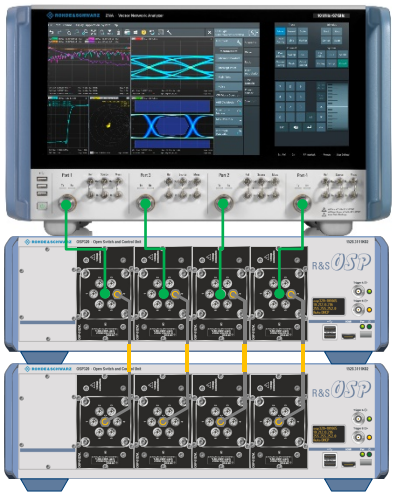
The predefined 44-port solution consists of:

- A 4-port Rohde & Schwarz VNA
- A 4:44 switch matrix OSP320-4-44nc, spanning 2 R&S OSP320 frames in "interconnection mode".
- Semi-rigid cables connecting VNA and switch matrix

The R&S ZNRUN-K400 project generator addresses this interconnected matrix as **44-port_11RX_11TX**, with matrix type OSP320-4-44nc and secondary matrix. It allows you to measure the effect of 11 balanced transmitters on 11 balanced receivers without reconnecting fixtures.

Both R&S ZNRUN-K41x IEEE CR4 "no cable flip" tests and R&S ZNRUN-K440 PCIe x4 tests only use 8 out of 11 matrix test ports per submatrix. The "restricted" matrix is called OSP320-4-32nc (4·8=32).





Matrix VNA ports 1A, 2B, 3C, 4D must be connected to VNA ports 1 to 4, respectively.

Table 3-12: Required hardware

Stimulus frequencies	VNA*	OSP320-4-24nc variant**	Semi-rigid cable set VNA ↔ Matrix
up to 26.5 GHz	R&S ZNB3020+FE	H	R&S ZV-ZB40, order no. 1528.3563.02 4 cables 2.92 mm (f/m)
up to 40 GHz	R&S ZNB3032+FE		
up to 50 GHz	R&S ZNA50	U	R&S ZV-ZA67, order no. 1528.3563.03 4 cables 1.85 mm (f/m)
up to 67 GHz	R&S ZNA67	VL	

* see Table 3-1

** see Section 3.2.4.5, "OSP320-4-44nc", on page 20

3.3.6 48-port solution for R&S ZNRUN-K400 and R&S ZNRUN-41x

The predefined 48-port solution consists of:

- A 4-port Rohde & Schwarz VNA
- Two stacked 2:24 switch matrices OSP320-2-24nc
- Semi-rigid cables connecting the VNA to the switch matrices

Matrix VNA ports 1A and 2B of the upper OSP320-2-24nc are connected to VNA ports 1 and 2. Matrix VNA ports 1A and 2B of the lower OSP320-2-24nc are connected to VNA ports 3 and 4.

The project generator addresses this solution as **48-port_8RX_16TX** because it allows you to measure the effect of 16 balanced transmitters (aggressors) on 8 balanced receivers (victims) without reconnecting fixtures.

Table 3-13: Required hardware

Stimulus frequencies	**VNA***	**OSP320-2-24nc variant****	**Semi-rigid cable set VNA ↔ Matrix**
up to 26.5 GHz	R&S ZNB3020+FE	**2 x** H	R&S ZV-ZB40CR, order no. 1528.3563.06 4 cables 2.92 mm (f/m)
up to 40 GHz	R&S ZNB3032+FE		
up to 50 GHz	R&S ZNA50	**2 x** U	R&S ZV-ZA50CR, order no. 1528.3563.07 4 cables 2.4 mm (f/m)
up to 67 GHz	R&S ZNA67	**2 x** VL	R&S ZV-ZA67CR, order no. 1528.3563.08 4 cables 1.85 mm (f/m)
* see Table 3-1 ** see Table 3-6			

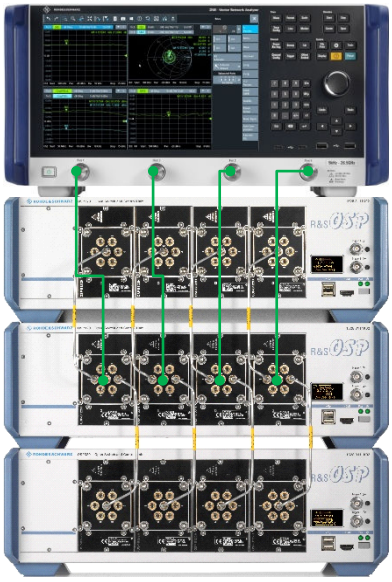
3.3.7 64-port solution

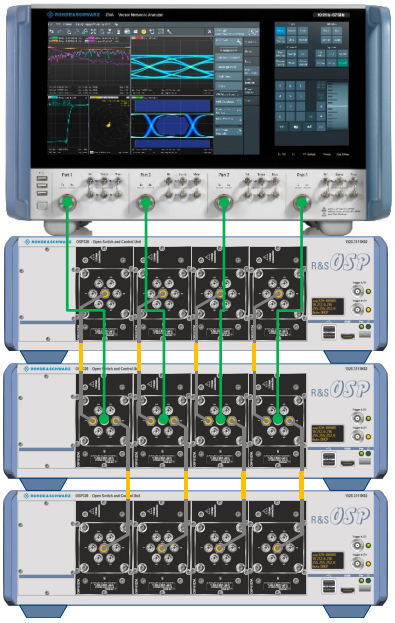
The predefined 64-port solution consists of:

- A 4-port Rohde & Schwarz VNA
- A 4:64 switch matrix OSP320-4-64nc, spanning 3 R&S OSP320 frames in "interconnection mode".
- Semi-rigid cables connecting VNA and switch matrix

The R&S ZNRUN-K400 project generator addresses this solution as **64-port_16RX_16TX**, with matrix type OSP320-4-64nc and two secondary matrices. It allows you to measure the effect of 16 balanced transmitters on 16 balanced receivers without reconnecting fixtures.

R&S ZNRUN-K440 PCIe x8 test setups also use this solution.





Matrix VNA ports 1A, 2B, 3C, 4D must be connected to VNA ports 1 to 4, respectively.

Table 3-14: Required hardware for OSP320-4-64nc / 64-port_16RX_16TX

Stimulus frequencies	**VNA***	**OSP320-4-64nc variant****	**Semi-rigid cable set VNA ↔ Matrix**
up to 26.5 GHz	R&S ZNB3020+FE	H	R&S ZV-ZB40X, order no. 1528.3563.04 4 cables 2.92 mm (f/m)
up to 40 GHz	R&S ZNB3032+FE		
up to 50 GHz	R&S ZNA50	U	R&S ZV-ZA67X, order no. 1528.3563.05 4 cables 1.85 mm (f/m)

Stimulus frequencies	VNA*	OSP320-4-64nc variant**	Semi-rigid cable set VNA ↔ Matrix
up to 67 GHz	R&S ZNA67	VL	
* see Table 3-1 ** see Table 3-7			

3.4 Calibration units

Rohde & Schwarz offers various automatic calibration units, with different connector types and frequency ranges. The following two-port calibration units are recommended for automated cable testing.

Table 3-15: Recommended two-port calibration units

Stimulus frequencies	R&S calibration unit	Connector type	Order no.
up to 26.5 GHz	R&S ZN-Z53 var. 32	3.5 mm (f)	1335.7046.32
up to 40 GHz	R&S ZN-Z54	2.92 mm (f)	1335.7117.92
up to 50 GHz	R&S ZN-Z55	2.4 mm (f)	1335.7181.42
up to 67 GHz	R&S ZN-Z156 Var. 03	1.85 mm (f)	1332.7239.03

3.5 Connection cables

Rohde & Schwarz offers various connection cables and adapters, suitable for different connector types and frequency ranges.

For the predefined switch matrices for automated cable testing, in particular for the connections between R&S OSP modules, we highly recommend using the dedicated semi-rigid cable sets.

If no dedicated semi-rigid cables are available, e.g. for the connections between your VNA and the matrices, the following high-quality cables are recommended.

Table 3-16: Recommended connection cables

Freq. range	R&S cable	Connector types	Order no.*
≤ 26.5 GHz	R&S ZV-Z193	3.5 mm f/m	1306.4520.24
≤ 40 GHz	R&S ZV-Z195	2.92 mm f/m	1306.4536.24
≤ 50 GHz	R&S ZV-Z197	2.4 mm f/m	1306.4571.24
≤ 67 GHz	R&S ZV-Z196	1.85 mm f/m	1306.4559.24
* length 610 mm (24 in)			

For more information and additional cables or cable lengths, see the R&S®ZV-Z9x, ZV-Z19x Test Port Cable Specifications.

4 IEEE 802.3 compliance tests (R&S ZNRUN-K41x)

4.1 Method of implementation

Rohde & Schwarz provides a Method of implementation (MOI) for IEEE up to 100 Gbps interface channel test, which was created in close cooperation with the University of New Hampshire Interoperability Laboratory (UNH-IOL).

The MOI describes precise and error-free compliance testing of high-speed cables and backplanes according to IEEE 802.3 standards, using a VNA from Rohde & Schwarz. The purpose of this document is to provide a step-by-step guideline on how to perform compliance testing for cable assembly and channel characteristics as defined in the following IEEE 802.3 serial interface specifications:

IEEE Specification		PHY Type	Typical Connector Type
Std 802.3bj™-2014	Clause 92	100GBASE-CR4	QSFP28
	Clause 93	100GBASE-KR4	2.92 mm, 2.4 mm connector
Std 802.3by™-2016	Clause 110	25GBASE-CR	SFP28, SFP56
	Clause 111	25GBASE-KR	2.92 mm, 2.4 mm connector
Std 802.3cd™-2018	Clause 136	50GBASE-CR1, 100GBASE-CR2, 200GBASE-CR4	SFP28, SFP56, QSFP28, QSFP56
	Clause 137	50GBASE-KR1, 100GBASE-KR2, 200GBASE-KR4	2.92 mm, 2.4 mm connector
Std 802.3ck™-2022	Clause 162	100GBASE-CR1, 200GBASE-CR2, 400GBASE-CR4	SFP112, QSFP112
	Clause 163	100GBASE-KR1, 200GBASE-KR2, 400GBASE-KR4	2.4 mm, 1.85 mm connector
Std 802.3df™-2024	Clause 162	800GBASE-CR8	QSFP-DD112, OSFP112
	Clause 163	800GBASE-KR8	2.4 mm, 1.85 mm connector
***Draft* P802.3dj™/ D1.2 (2024)**	Clause 178	200GBASE-KR1, 400GBASE-KR2, 800GBASE-KR4, 1.6TBASE-KR8	1.85 mm connector
	Clause 179	200GBASE-CR1, 400GBASE-CR2, 800GBASE-CR4, 1.6TBASE-CR8	SFP224, SFP-DD224, QSFP224, QSFP-DD1600, OSFP1600

The standard IEEE 802.3dj is currently in draft state.

The first implementation of the test logic in R&S ZNrun V2.94 was inherited/extrapolated from IEEE 802.3ck and IEEE 802.3df. It will be aligned with the ongoing standardization in future R&S ZNrun releases.

As described in the MOI, you could do the compliance tests with a single 4-port VNA, successively connecting each balanced TX port to every balanced RX port and measuring the balanced transmission S-parameters. For cables with a single lane (2xTX, 2xRX) this test can be done fast and reliably. With more lanes, however, numerous reconnections must be done, and the procedure becomes time-consuming and error-prone.

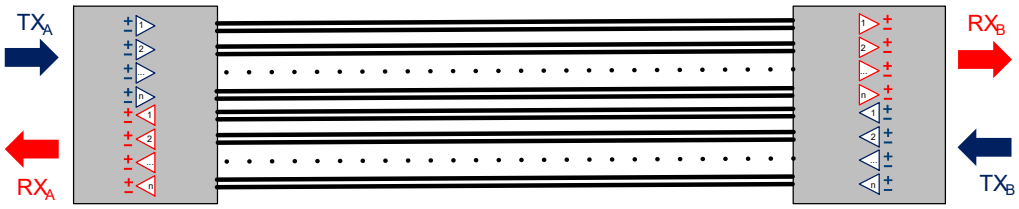


Figure 4-1: N balanced lanes

Multi-port setup

A multiport setup can reduce the measurement time from hours to minutes. The R&S ZNrun compliance test implementation focuses on multi-port setups that require reconnecting test ports and fixture ports during the measurement phase at most once.

With *N* balanced lanes, 4*N* balanced ports = 8*N* test ports would be required to connect all fixture ports. For symmetrical CR*N* cables and *N* > 1, it suffices to connect the *2n* balanced TX ports (on the left and right) to the balanced RX ports on the left, measure, flip the cable under test, and repeat the measurement. This trick limits the number of required test ports to 6*N*.

S-parameter measurements

According to the MOI, for each RX ("victim") and every TX ("aggressor"), the balanced transmission S-parameters from TX to RX must be measured. For associated RX and TX, these parameters are called THRU parameters. For RX and TX on the same cable end, these parameters are called NEXT parameters. For RX and TX on opposite cable ends, these parameters are called FEXT parameters.

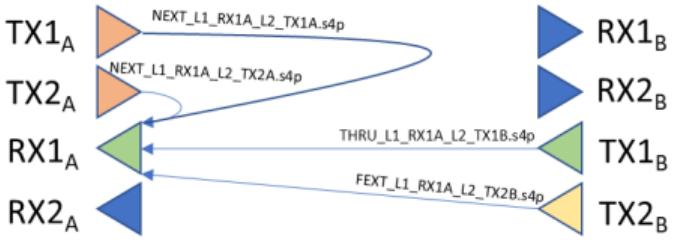


Figure 4-2: Connections to RX1A victim for 2 lanes

In total, $2n \cdot 2n = 4n^2$ `s4p` Touchstone files are generated:

- $2n$ files with THRU parameters
- $2n^2$ files with NEXT parameters
- $2n$ (n-1) files with FEXT parameters

Slightly differing from the MOI, the R&S ZNrun solution uses the following naming convention for the generated `s4p` Touchstone files:

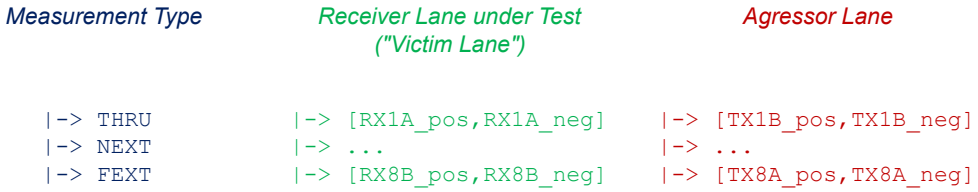


Figure 4-3: Naming convention for measurement result files (8 lanes)

For example, the name of the RX1A THRU touchstone file (i.e. the s4p file containing the differential insertion loss and differential return loss of receiver RX1A) is `THRU_[RX1A_pos,RX1A_neg]_[TX1B_pos,TX1B_neg].s4p`.

S-parameter validation

The IEEE 802.3 standards require the THRU parameters to be within certain masks or limits. The validation can be done by the VNA, directly from the measurement results.

With 2 and 1 denoting the logical port numbers of the RX and TX port, respectively, the following differential S-parameters are covered by the compliance test specifications:

- Differential-mode insertion loss – SDD21
- Differential return loss – SDD11, SDD22
- Differential to common mode return loss – SCD11, SCD22
- Differential to common mode conversion loss – SCD21
- Common mode to common mode return loss – SCC11, SCC22

See the MOI for details.

Additional figures of merit: COM and ERL

In addition to the validation of the THRU parameters, the following metrics are calculated from the s4p Touchstone files using MATLAB® scripts provided by IEEE:

- **Channel operating margin (COM)**
  Basically, COM is the delta (magnitude) between insertion loss and isolation, which can be loosely described as a signal-to-noise ratio or SNR. Isolation is comparable to crosstalk, in the sense that leakage between lanes (NEXT, FEXT) is recorded.
- **Effective return loss (ERL)**
  ERL incorporates an aggregate of mismatches within the channel. Unlike standard return loss, which is only a function of impedance mismatches within the channel, ERL incorporates return loss with the effects of equalization, transmitter noise and receiver frequency response into a signal-to-noise-like figure of merit.

For each receiver RX<i>A or RX<j>B, both COM and ERL can be calculated based from the THRU, NEXT and FEXT s4p files collected for this receiver. See "S-parameter measurements" on page 35. IEEE 802.3 standards require COM and ERL to be within certain limits.

The MATLAB scripts are shipped with the R&S ZNrun installer. However, the MATLAB runtime that is required to run them, has to be installed manually. Download version 9.10 from the MathWorks® internet pages (https://www.mathworks.com/products/compiler/matlab-runtime.html).

4.2 Test setup for 1-lane copper cables

The proposed setup for 1-lane cable tests consists of a 4-port Rohde&Schwarz VNA, a 4:8 switch matrix, and the cables connecting them.

The recommended VNA, matrix equipping and calibration unit depends on the required stimulus frequency range, which can be derived – to a certain extent – from the respective standard.

Compliance tests for 100GBASE-CR1 cables (specified in IEEE 802.3ck) require frequencies above 43.5 GHz, and hence a R&S ZNA50 must be used (see Table 4-1). For precompliance tests, where fast and cost efficient measurements typically overweigh utmost accuracy, you can also use a R&S ZNB3032+FE.

4.2.1 Required equipment

Select the appropriate solution, cal unit and cables according to the required stimulus frequency range.

Table 4-1: Required/recommended equipment for 1-lane cable tests

IEEE specification and cable definition	**8-port solution***	**Calibration unit**
Std 802.3by 25GBASE-CR CA-25G-L/N/S	≤ 26.5 GHz (R&S ZNB3020+FE)	R&S ZN-Z53
Std 802.3cd 50GBASE-CR1		
Std 802.3ck 100GBASE-CR1 **precompliance**	≤ 40 GHz (R&S ZNB3032+FE)	R&S ZN-Z54
Std 802.3ck 100GBASE-CR1 **compliance**	≤ 50 GHz (R&S ZNA50)	R&S ZN-Z55
* See Table 3-9 ** See Table 3-15		

For recommended test fixtures, see Section 4.6, "Test fixtures and connection cables", on page 48.

4.2.2 Connection plan

The following connections must be established:

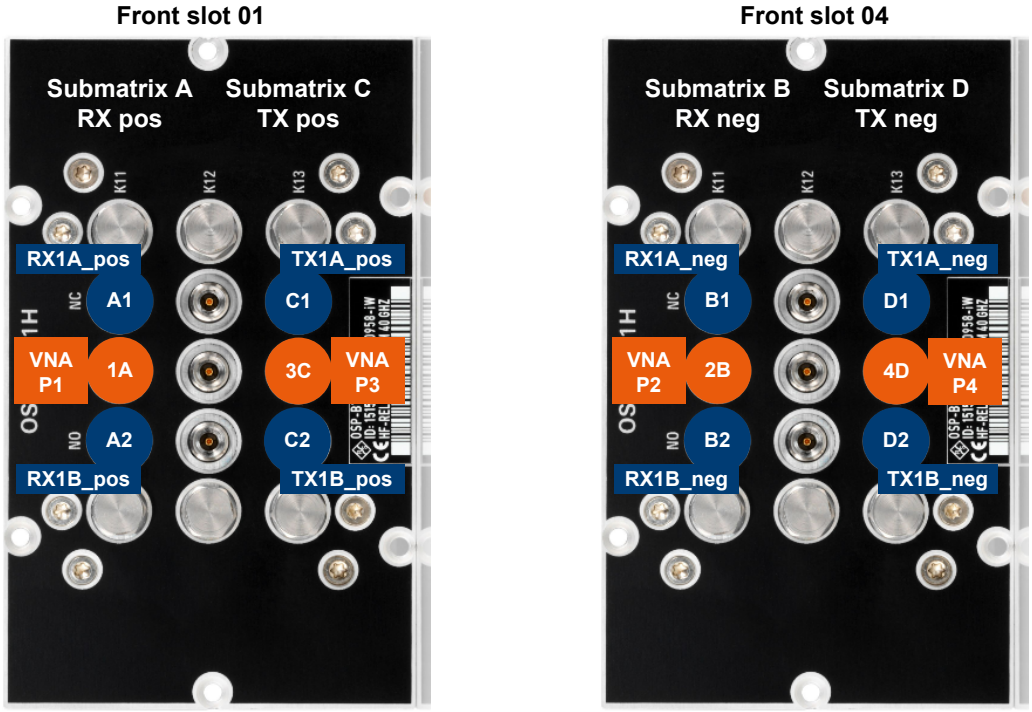


Figure 4-4: Connection plan for 1-lane tests

Front slots 01 and 04	= R&S OSP-B121H/U
1A, ..., 4D	= Matrix VNA port names
P1, ..., P4	= VNA ports to be connected
A1, ..., D8	= Matrix test port names
RX1A_pos, ..., TX1B_neg	= Fixture ports to be connected (MOI naming)

The proposed variant 52 of switch module R&S OSP-B121U only has the 2 x SPDT that are actually needed. SPDT K13 is not available, connect K12 instead.

4.3 Test setup for 3-lane copper cables (demo)

For demonstration purposes.

The proposed setup for non-standard 3-lane cable tests consists of a 4-port Rohde&Schwarz VNA, a 4:24 switch matrix, and the (semi-rigid) cables connecting them.

See Section 3.3.3, "24-port solution", on page 28.

The recommended VNA, matrix equipping and calibration unit depends on the required stimulus frequency range, which can be derived from the respective standard.

4.3.1 Required equipment

Select the appropriate solution and cal unit according to the required stimulus frequency range.

Table 4-2: Required/recommended equipment for 3-lane cable tests

IEEE specification and cable definition	24-port solution*	Calibration unit**
Std 802.3ck 300GBASE-CR3	≤ 43.5 GHz (R&S ZNB3032+FE)	R&S ZN-Z54
Draft P802.3dj 600GBASE-CR6	≤ 67 GHz (R&S ZNA67)	R&S ZN-Z156 Var. 03
* See Table 3-11 ** See Table 3-15		

For recommended test fixtures, see Section 4.6, "Test fixtures and connection cables", on page 48.

4.3.2 Connection plan

The following connections must be established:

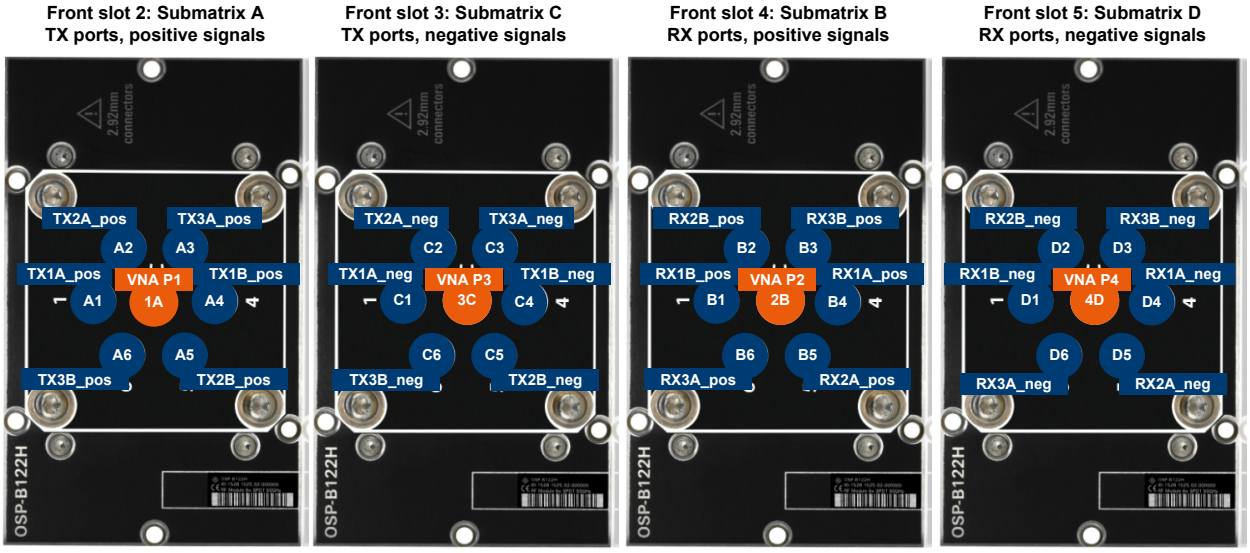


Figure 4-5: Connection plan for 3-lane tests

1A, ..., 4D = Matrix VNA port names
P1, ..., P4 = VNA ports to be connected
A1, ..., D6 = Matrix test port names
RX1A_pos, ..., TX3B_neg = Fixture ports to be connected (MOI naming)

4.4 Test setup for 4-lane copper cables

The proposed setups for 4-lane cable tests consist of a 4-port Rohde&Schwarz VNA, two 2:12 switch matrices or one 4:32 switch matrix, and the (semi-rigid) cables connecting them.

See Section 3.3.2, "24-port solution for R&S ZNRUN-K41x", on page 27 or Section 3.3.4, "32-port solution", on page 29.

- The 24-port solution requires a cable flip during the measurement, the 32-port solution does not.
- The recommended VNA, matrix equipping and calibration unit depends on the required stimulus frequency range, which can be derived from the respective standard.
  - Compliance tests for 400GBASE-CR4 cables (specified in IEEE 802.3ck require frequencies above 43.5 GHz, and hence a R&S ZNA50 must be used (see Table 4-1). For precompliance tests, where fast and cost efficient measurements typically overweigh utmost accuracy, you can also use a R&S ZNB3032+FE.
  - Compliance tests for 800GBASE-CR4 cables (IEEE Draft 802.3dj) require frequencies up to 67 GHz, and hence a R&S ZNA67 must be used (see Table 4-1).

4.4.1 Required equipment

Select the appropriate solution and cal unit according to the required stimulus frequency range..

Table 4-3: Required/recommended equipment for 4-lane cable tests

IEEE specification and cable definition	**24-port solution*** or **32-port solution****	**Calibration unit*****
Std 802.3bj 100GBASE-CR4	≤ 26.5 GHz (R&S ZNB3020+FE)	R&S ZN-Z53
Std 802.3cd 200GBASE-CR4		
Std 802.3ck 400GBASE-CR4 **precompliance**	≤ 40 GHz (R&S ZNB3032+FE)	R&S ZN-Z54
Std 802.3ck 400GBASE-CR4 **compliance**	≤ 50 GHz (R&S ZNA50)	R&S ZN-Z55

IEEE specification and cable definition	24-port solution* or 32-port solution**	Calibration unit***
Draft P802.3dj 800GBASE-CR4 **compliance**	≤ 67 GHz (R&S ZNA67)	R&S ZN-Z156 Var. 03
* See Table 3-10 ** See Section 3.3.4, "32-port solution", on page 29 *** See Table 3-15		

For recommended test fixtures, see Section 4.6, "Test fixtures and connection cables", on page 48.

4.4.2 Connection plan

For the 24-port solution, the following connections must be established:

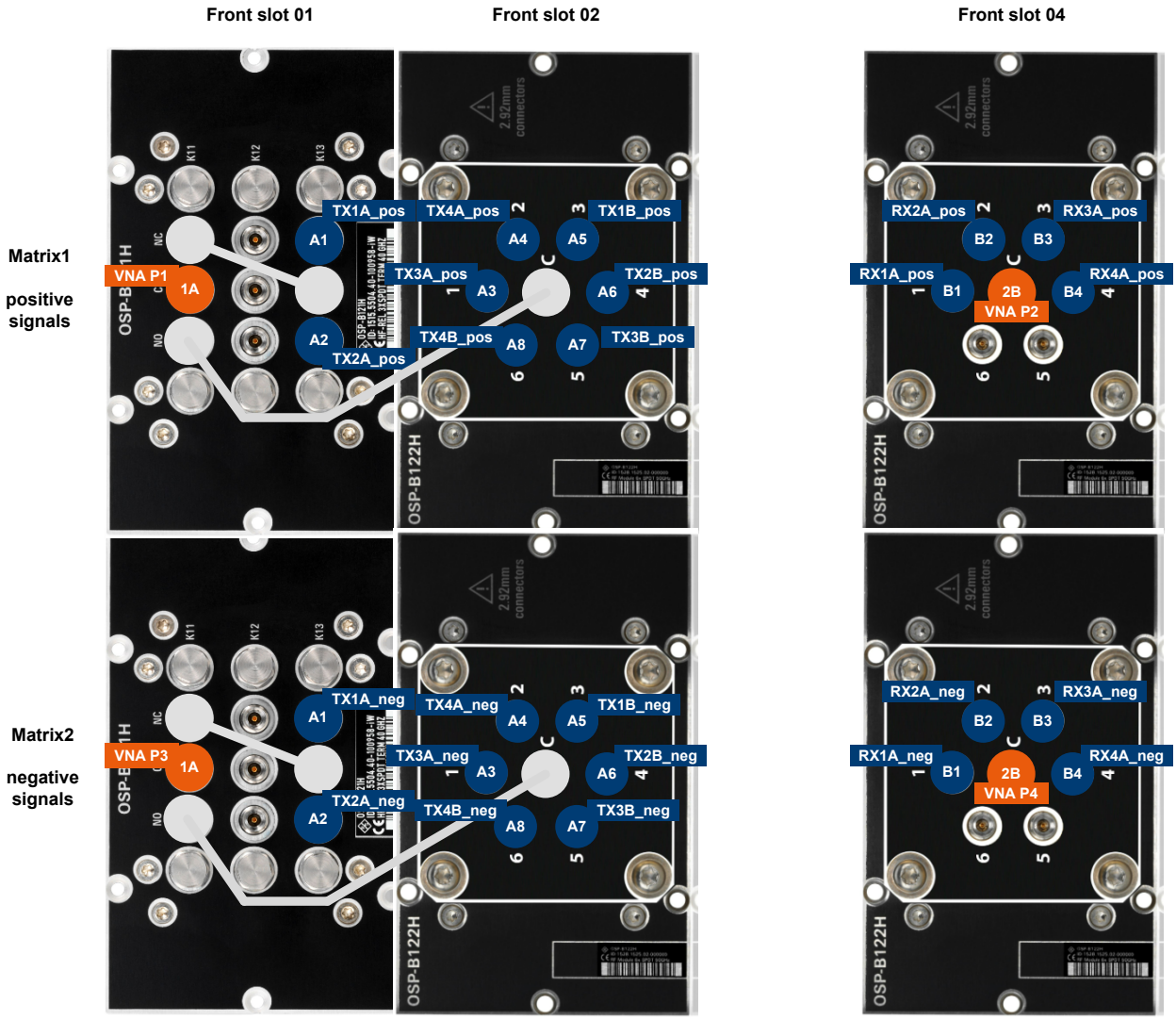


Figure 4-6: Connection plan for 4-lane tests using the 24-port solution

Top R&S OSP	= Matrix 001 ("pos" matrix)
Bottom R&S OSP	= Matrix 002 ("neg" matrix)
Front slot 01	= R&S OSP-B121H/U/VL
Front slots 02 and 04	= R&S OSP-B122H/U/VL
1A, ..., 2B	= Matrix VNA port names
P1, ..., P4	= VNA ports to be connected
A1, ..., A8, B1, ..., B4	= Matrix test port names
RX1A_pos, ..., TX4B_neg	= Fixture ports to be connected (MOI naming)
Grey lines	= Semi-rigid cables

For the 32-port solution, the following connections must be established:

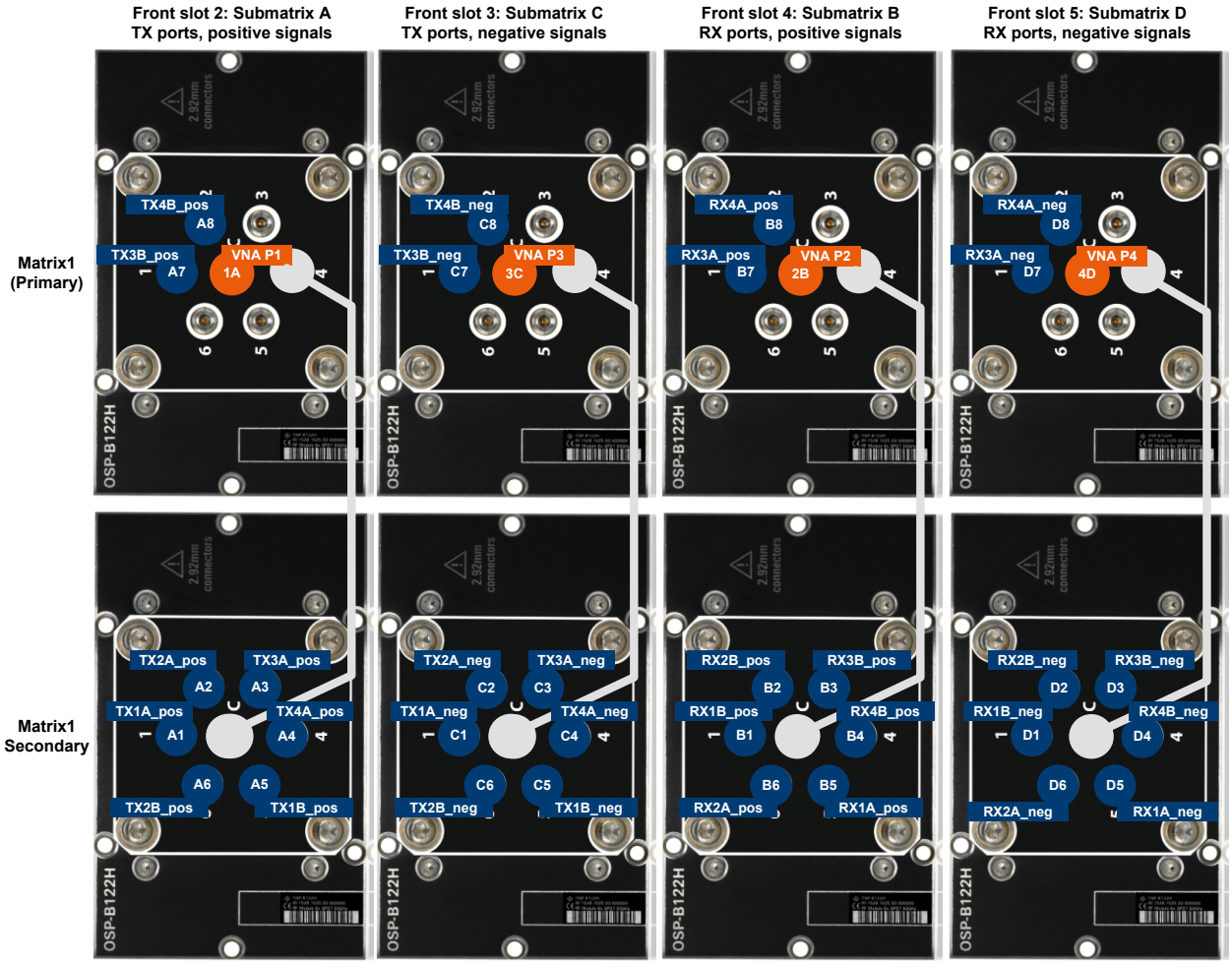


Figure 4-7: Connection plan for 4-lane tests using the 32-port solution

Matrix1	= 2 x R&S OSP320 in interconnection mode
Front slots 2	= "TX pos" submatrix A
Front slots 3	= "TX neg" submatrix C
Front slots 4	= "RX pos" submatrix B
Front slots 5	= "RX neg" submatrix D
1A, ..., 4D	= Matrix VNA ports, to be connected to VNA ports 1 to 4, respectively
A1, ..., D8	= Matrix test ports, submatrix A to D
TX1A_pos, ..., RX4B_neg	= Fixture ports to be connected
Grey lines	= Semi-rigid cables

4.5 Test setup for 8-lane copper cables

The proposed setup for 8-lane cable tests consists of a 4-port Rohde & Schwarz VNA, two 2:24 switch matrices, and the semi-rigid cables connecting them.

See Section 3.3.6, "48-port solution for R&S ZNRUN-K400 and R&S ZNRUN-41x", on page 31.

The recommended VNA, matrix equipping and calibration unit depends on the required stimulus frequency range, which can be derived from the respective standard.

- Compliance tests for 800GBASE-CR8 cables (specified in IEEE 802.3df) require frequencies above 43.5 GHz, and hence a R&S ZNA50 must be used (see Table 4-1). For precompliance tests, where fast and cost efficient measurements typically overweigh utmost accuracy, you can also use a R&S ZNB3032+FE.
- Compliance tests for 1600GBASE-CR8 cables (IEEE **Draft** 802.3dj) require frequencies up to 67 GHz, and hence a R&S ZNA67 must be used (see Table 4-1).

See Section 3.1, "Vector network analyzer", on page 7.

4.5.1 Required equipment

Select the appropriate solution and cal unit according to the required stimulus frequency range.

Table 4-4: Required/recommended equipment for 8-lane cable tests

IEEE specification and cable definition	**48-port solution****	**Calibration unit*****
Std 802.3bj 200GBASE-CR8*	≤ 26.5 GHz (R&S ZNB3020+FE)	R&S ZN-Z53
Std 802.3cd 400GBASE-CR8* **precompliance**	≤ 43.5 GHz (R&S ZNB3032+FE)	R&S ZN-Z54
Std 802.3df-2024 800GBASE-CR8 **compliance**	≤ 50 GHz (R&S ZNA50)	R&S ZN-Z55
Draft 802.3dj 1600GBASE-CR8 preliminary compliance	≤ 67 GHz (R&S ZNA67)	R&S ZN-Z156 Var. 03
* Not part of the standard, but commonly used in industry ** See Table 3-13 *** See Table 3-15		

For recommended test fixtures, see Section 4.6, "Test fixtures and connection cables", on page 48.

4.5.2 Connection plan

The following connections must be established:

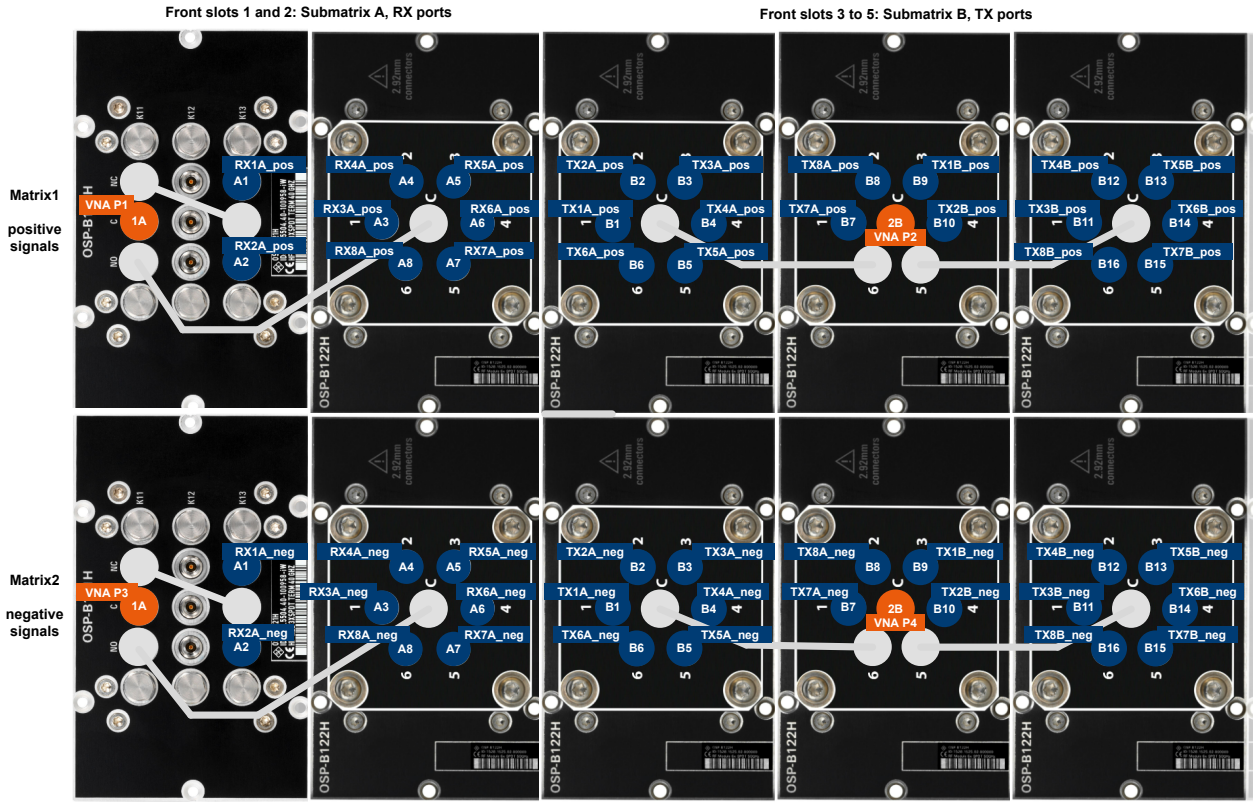


Figure 4-8: Connection plan for 8-lane tests

Top R&S OSP	= Matrix 001 ("plus" matrix)
Bottom R&S OSP	= Matrix 002 ("minus" matrix)
1A, 2B	= Matrix VNA port names
P1, ..., P4	= VNA ports to be connected
A1, ..., A8, B1, ..., B16	= Matrix test port names
RX1A_pos, ..., TX8B_neg	= Fixture ports to be connected (MOI naming)
Grey lines	= Semi-rigid cables

- The proposed variants of switch modules R&S OSP-B121U and R&S OSP-B121VL (52 and 62, respectively) only have the 2 x SPDT that are actually needed. SPDT K13 is not available, connect K12 instead.
- Instead of connecting the RX ports of the B-side fixture to the R&S OSP, which would require a setup with 64 test ports, the cable under test is flipped once during the measurement.
- The (unused) RX ports of the B-side fixture must be terminated during the measurement.

4.6 Test fixtures and connection cables

Leading test fixture makers for IEEE 802.3 high-speed cables:

- Wilder Technologies (https://www.wilder-tech.com/en/products)
- PHY-SI (https://phy-si.com/)

For standard-specific recommendations, see Method of implementation (MOI) for IEEE up to 100 Gbps interface channel test.

As connection cables between OSP and test fixtures we recommend:

- Johnson™ 2.92 mm 40 GHz Test Cable Assemblies
- Mini-Circuits® T50-2FT-VMVM+ (2.4mm, 50GHz)

4.7 R&S ZNrun test projects

Options R&S ZNrun-K41x enable using the predefined R&S ZNrun projects for compliance and precompliance testing.

During installation, these projects are copied to a directory tree below the IEEE-802-3 MOI folder
`C:\ProgramData\Rohde-Schwarz\ZNrun\3.1x\Resources\MOI\IEEE-802-3`
on the ZNrun Server.

Since R&S ZNRUN V2.90, the predefined MOI projects are read-only.
To modify such a project, open it in the ZNrun Workbench, make your changes, and save it to a different location. Or copy the project to a different location and remove the read-only flag before opening it in the ZNrun Workbench.

General remarks

If not stated otherwise:

- CR1 projects must be run on the 8-port solution for R&S ZNRUN-K41x
- CR3 projects must be run on the general-purpose 24-port solution
- CR4 projects must be run on the general-purpose 24-port solution for R&S ZNRUN-K41x
- CR8 projects must be run on the general-purpose 48-port solution for R&S ZNRUN-K400 and R&S ZNRUN-41x

A `ZNB<ff>` or `ZNA<ff>` in the project name indicates that a member of the R&S ZNB or R&S ZNA family must be used. `ZNx` means you can use either the one or the other. <ff> indicates the model, i.e. the (minimum) required stimulus frequency.

`OSP320-<N>port` indicates the multiport solution to be used. `OSP320-24port` is ambiguous: for CR3 it refers to the general purpose solution, for CR4 to the K41x solution.

Option R&S ZNrun-K410

IEEE 802.3bj and IEEE 802.3by

- `<MOI folder>\IEEE8023bj, by\25GBASE-CR1\`
  - `L-ZNB26-OSP320-8port.znrun`
  - `N-ZNB26-OSP320-8port.znrun`
  - `S-ZNB26-OSP320-8port.znrun`
- `<MOI folder>\IEEE8023bj, by\100GBASE-CR4\`
  - `ZNB26-OSP320-24port.znrun`
- `<MOI folder>\IEEE8023bj, by\200GBASE-CR8\`
  - `ZNB26-OSP320-48port.znrun`

IEEE 802.3cd

- `<MOI folder>\IEEE8023cd\50GBASE-CR1`
  - `ZNB26-OSP320-8port.znrun`
- `<MOI folder>\IEEE8023cd\200GBASE-CR4`
  - `ZNB26-OSP320-24port.znrun`
- `<MOI folder>\IEEE8023cd\400GBASE-CR8`
  - `ZNB26-OSP320-48port.znrun`

Option R&S ZNrun-K411

IEEE 802.3ck

- `<MOI folder>\IEEE8023ck\100GBASE-CR1\`
  - `ZNA50-OSP320-8port.znrun`
  - `ZNB43-OSP320-8port.znrun` (precompliance)
- `<MOI folder>\IEEE8023ck\100GBASE-CR3\`
  - `ZNx43-OSP320-24port`
- `<MOI folder>\IEEE8023ck\400GBASE-CR4\`
  - `ZNA50-OSP320-24port.znrun`
  - `ZNA50-OSP320-24port-segm-BW50k`
    Precompliance test: segmented sweep with larger measurement bandwith for "uncritical" segments (faster)
  - `ZNB43-OSP320-24port.znrun` (precompliance)

IEEE 802.3df

- `<MOI folder>\IEEE8023ck\800GBASE-CR8\`
  - `ZNA50-OSP320-48port.znrun`
  - `ZNB43-OSP320-48port.znrun` (precompliance)

Option R&S ZNrun-K412

IEEE Draft 802.3dj

- `<MOI folder>\IEEE8023dj\800GBASE-CR3\` (demo)
  - `ZNA67-OSP320-24port.znrun`

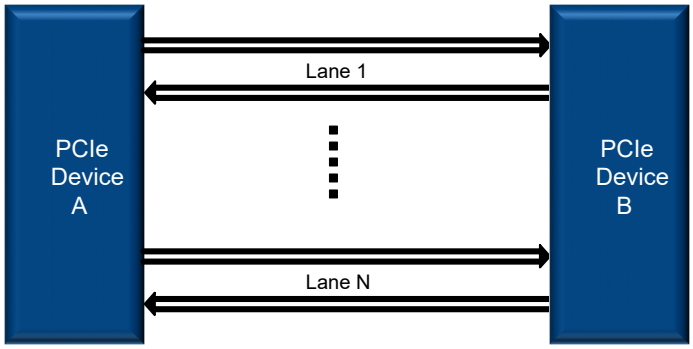
- `<MOI folder>\IEEE8023dj\800GBASE-CR4\`
  - `ZNA67-OSP320-24port.znrun`
    Compliance test, to be run on the 24-port solution for R&S ZNRUN-K41x with cable flip.
  - `ZNA67-OSP320-32port-lin_stim-no_cable_flip.znrun`
    Compliance test, to be run on the 32-port solution without cable flip.
  - `ZNA67-OSP320-32port-segm_stim-no_cable_flip.znrun`
    Precompliance test, also to be run on the 32-port solution. Segmented sweep with larger measurement bandwith for "uncritical" segments (faster)
- `<MOI folder>\IEEE8023dj\1600GBASE-CR8\`
  - `ZNA67-OSP320-48port.znrun`
  - `ZNA67-OSP320-48port-segm-BW50k.znrun`
    Precompliance test: segmented sweep with larger measurement bandwith for "uncritical" segments (faster)

5 PCI Express compliance tests (R&S ZNRUN-K440)

Rohde & Schwarz does not offer its own method of implementation (MOI) for compliance testing of PCI Express (PCIe) cables. However, the automated test solution implemented with software option R&S ZNrun-K440 closely follows the External Cable Specification for PCI Express 5.0 and 6.0, created by PCI-SIG®.

The current implementation is based on version 1.0 of this standard.

A PCIe link is made up of one or more full duplex lanes, each consisting of 1 differential Tx pair and 1 differential Rx pair.



R&S ZNrun-K440 focuses on x4 and x8 mated cable assemblies, i.e. cable assemblies with 4 or 8 lanes.

PCIe Revision	Year	Transfer Rate	Encoding	Modulation	Lanes				
					x1	x2	x4	x8	x16
		GT/s			GB/s	GB/s	GB/s	GB/s	GB/s
1.0	2003	2.5	8b/10b	NRZ	0.25	0.50	1.0	2.0	4.0
2.0	2007	5.0	8b/10b	NRZ	0.50	1.0	2.0	4.0	8.0
3.0	2010	8.0	128b/130b	NRZ	0.98	1.97	3.94	7.88	15.8
4.0	2017	16.0	128b/130b	NRZ	1.97	3.94	7.88	15.8	31.5
5.0	2019	32.0	128b/130b	NRZ	3.94	7.88	15.8	31.5	63.0
6.0	2021	64.0	1b/1b	PAM4	8.0	16.0	32.0	64.0	128.0

In general, you could do the compliance tests with a single 4-port VNA, successively connecting each balanced TX port to every balanced RX port and measuring the differential S-parameters. However, for a cable with multiple lanes numerous reconnections must be done, and the procedure becomes time-consuming and error-prone.

5.1 Measurements and evaluations

To get the full picture, all differential S-parameters between any pair of TX and RX ports must be measured.

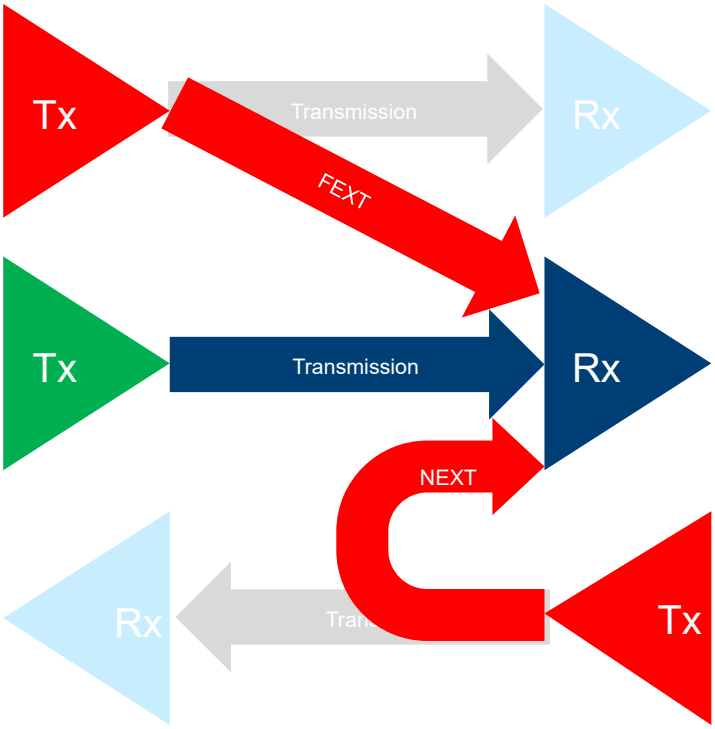


Table 5-1: S-parameter measurements

Measurement	Measured quantity 0 GHz to 24 GHz, 10 MHz grid	Limit 0 GHz to 24 GHz
Differential insertion loss	Sdd_{21} for each lane and both transmission directions	Segmented upper limit line (continuous and piecewise linear)
Differential return loss	Sdd_{11} and Sdd_{22} for each lane and both transmission directions	
Near-end crosstalk NEXT	Sdd between a victim RX port, and an aggressing TX port on the same side of the DUT	Linear upper limit line on PSNEXT curve (see table below)
Far-end crosstalk FEXT	Sdd between a victim RX port, and an aggressing TX port on the other side of the DUT	Linear upper limit line on PSFEXT curve (see table below)

For n lanes, in total $2n \cdot 2n = 4n^2$ `s4p` Touchstone files are generated:

- $2n$ files with THRU parameters
- $2n^2$ files with NEXT parameters
- $2n$ (n-1) files with FEXT parameters

In addition to the measured S-parameter data, the following metrics are calculated and evaluated against specified limits or limit lines.

Table 5-2: Evaluations

Evaluation	Definition	Limit
Integrated return loss (iRL)	Integration of averaged differential return loss after a power weighting filter	If a return loss S-parameter violates its limit line, then the corresponding iRL must be below a specified value.
Differential power sum near-end crosstalk (psNEXT)	Power sum per victim, summed over all NEXT aggressors	Linear limit lines 0 GHz to 24
Differential power sum far-end crosstalk (psFEXT)	Power sum per victim, summed over all NEXT aggressors	
Differential crosstalk (psXT)	Power sum per victim, summed over all NEXT and FEXT aggressors	n.a.
Component contribution to integrated crosstalk noise for NEXT (ccICN-NEXT)	Calculated from PSNEXT values, integrated per victim	If some PSNEXT violates its limit line, then the corresponding ccICN must be below a specified value.
Component contribution to integrated crosstalk noise for FEXT (ccICNFEXT)	Calculated from PSFEXT values, integrated per victim	If some PSFEXT violates its limit line, then the corresponding ccICN must be below a specified value.
Effective intra-pair skew (EIPS)	Calculated from the measured S-parameter data	Must be less than the specified number of picoseconds.

- For the corresponding formulas and limits, see the PCI-SIG® External Cable Specification for PCI Express 5.0 and 6.0.
- The current implementation of the compliance tests is based on version 1.0 of this standard.

Port impedances and deembedding

The specified limit lines are based on 85 Ω differential reference impedance. The impact of test fixtures must be de-embedded from the measured data. All masks are length independent but maximum length of 2 m is assumed for insertion loss.

5.2 Test setup for x3 cables and connectors (demo)

Option R&S ZNrun-K440 enables a set of demo projects `.../x3/<...>-OSP320-24port.znrun` that allow you to test "3 out of *n* lanes" (3 x TX, 3 x RX) of a PCIe x*n* cable. These projects use a single R&S OSP320, equipped and configured as a 4:24 matrix.

See Section 3.3.3, "24-port solution", on page 28.

5.2.1 Required equipment

Select the appropriate solution and cal unit according to the required stimulus frequency range.

Table 5-3: Required/recommended equipment for 3-lane cable tests

PCIe revision	Multiport solution	Calibration unit
5.0	24-port solution for stimulus frequencies ≤ 40 GHz (R&S ZNB3032+FE)	R&S ZN-Z54
6.0		

For recommended test fixtures, see Section 4.6, "Test fixtures and connection cables", on page 48.

5.2.2 Connection plan

Establish the following connections:

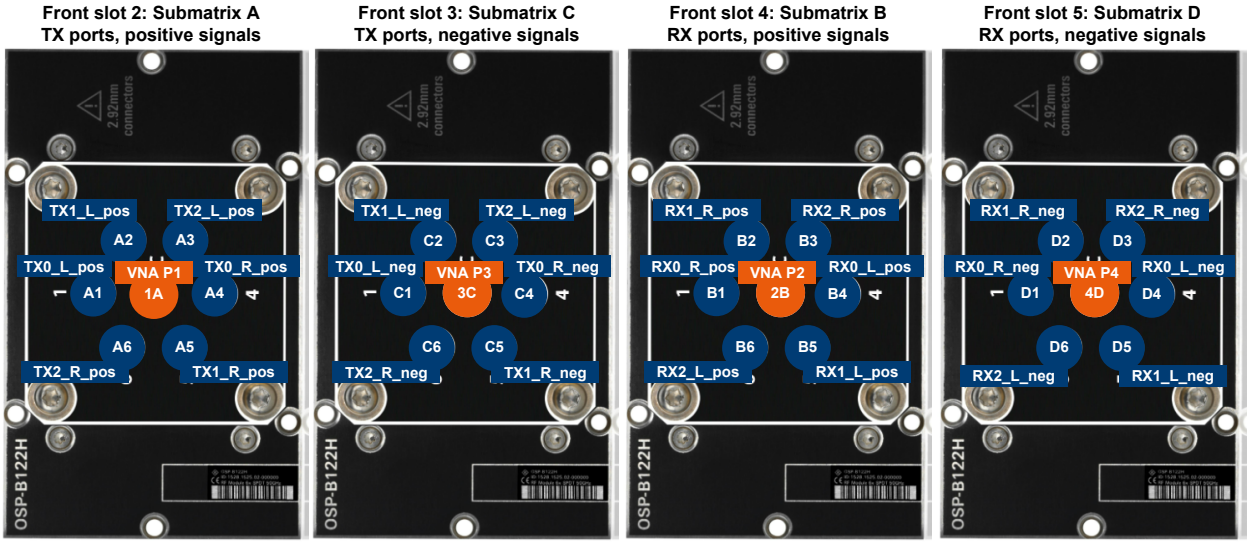


Figure 5-1: Connection plan for 3-lane tests

1A, ..., 4D = Matrix VNA port names
P1, ..., P4 = VNA ports to be connected
A0, ..., D5 = Matrix test port names
RX0A_pos, ..., TX3B_neg = Fixture ports to be connected (MOI naming)

5.3 Test setup for x4 cables and connectors

The proposed setup for 4-lane PCIe 5.0 and 6.0 cable and connector tests consists of a 4-port (seeR&S ZNB43, a 32-port switch matrix OSP320-4-32nc, and the (semi-rigid) cables connecting them.

See Section 3.3.4, "32-port solution", on page 29.

According to the PCIe 5.0 and 6.0 external cable specification, the compliance tests must cover frequencies up to 24 GHz, so a R&S ZNB3020+FE is sufficient. However, the specification requires an accurate deembedding of the test fixtures, which, from the experience of Rohde & Schwarz and other industry experts, requires frequencies above 26.5 GHz. For this reason, the recommended VNA for PCIe cable compliance tests is a 4-port R&S ZNB3032+FE.

5.3.1 Recommended equipment

Table 5-4: Required/recommended equipment for 4-lane cable tests (x4)

PCIe revision	Multiport solution	Calibration unit
5.0	32-port solution for stimulus frequencies ≤ 40 GHz (R&S ZNB3032+FE)	R&S ZN-Z54
6.0		

For recommended test fixtures, see Section 5.5, "Test fixtures and connection cables", on page 61.

5.3.2 Connection plan

The switches at front slot 2 of the two R&S OSP320 are combined to a 1:11 submatrix, with submatrix ports 9 to 11 unused. See Figure 3-7. Same for front slots 3 to 5.

Establish the following connections:

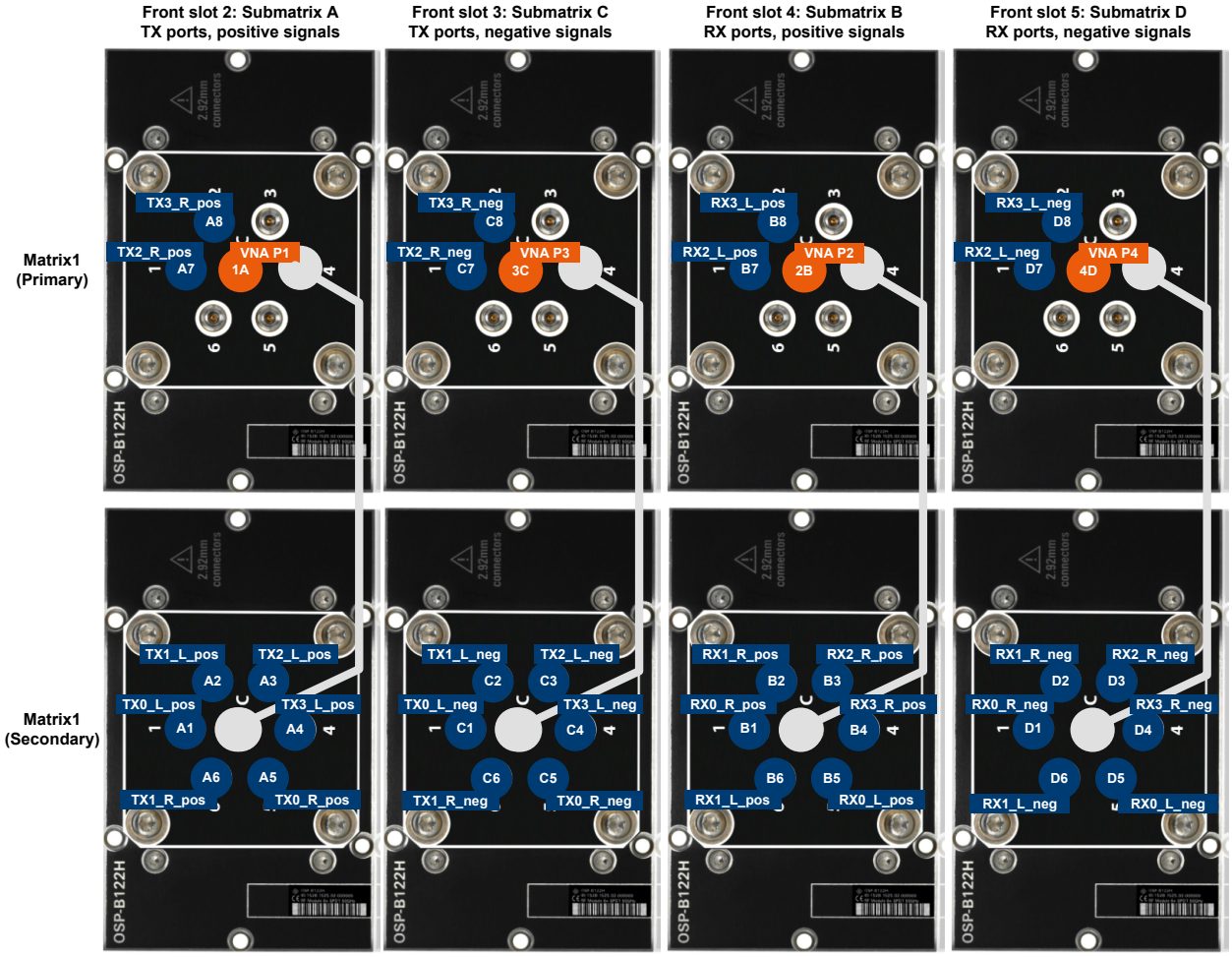


Figure 5-2: Connection plan for x4 cable tests

Front slots 02 to 05 = R&S OSP-B122H
1A, ..., 4D = Matrix VNA port names
P1, ..., P4 = VNA ports to be connected
A1, ..., D8 = Matrix test port names
RX1_L_pos, ..., TX1_R_neg = Fixture ports to be connected (L: left; R: right)
Grey lines = Semi-rigid cables

Legacy connection plan

Up to R&S ZNrun V2.94, matrix setup and connection plan were slightly different:

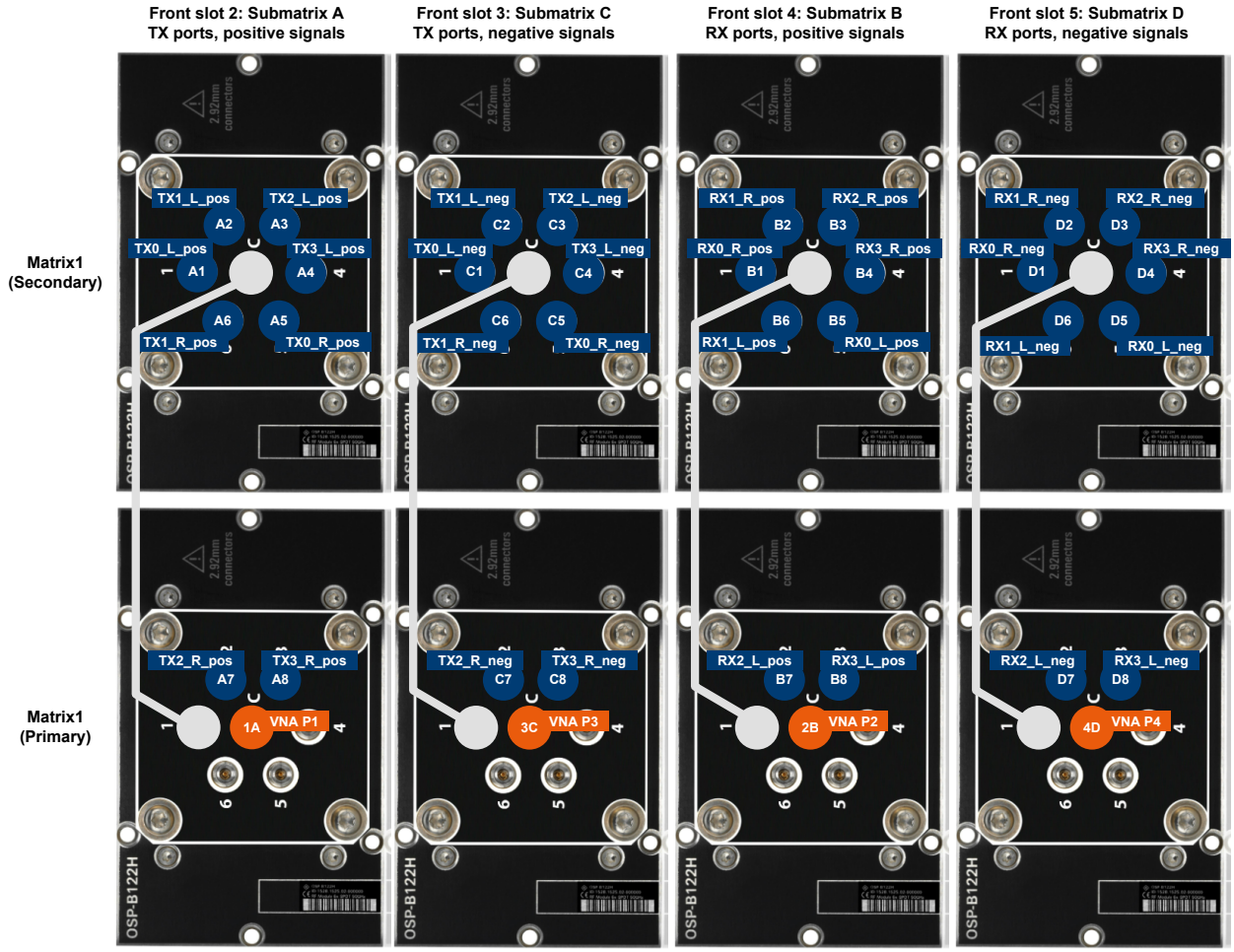


Figure 5-3: Legacy matrix setup and connection plan for x4 cable tests

5.4 Test setup for x8 cables and connectors

The proposed setup for 8-lane PCIe 5.0 and 6.0 cable and connector tests consists of a 4-port R&S ZNB3032+FE, a 64-port switch matrix, and the cables connecting them. See Section 3.3.7, "64-port solution", on page 32.

According to the PCIe 5.0 and 6.0 external cable specification, the compliance tests must cover frequencies up to 24 GHz, so a R&S ZNB3020+FE is sufficient. However, the specification requires an accurate deembedding of the test fixtures, which, from the experience of Rohde & Schwarz and other industry experts, requires frequencies above 26.5 GHz. For this reason, the recommended VNA for PCIe cable compliance tests is a 4-port R&S ZNB3032+FE.

5.4.1 Recommended equipment

Table 5-5: Multiport VNA/OSP setup for 8-lane cable tests (x8)

PCIe revision	Recommended VNA and calibration unit	Required switch matrix configuration	Recommended connection cables VNA ⇔ Switch matrix
5.0 6.0	R&S ZNB3032+FE and R&S ZN-Z54	• 3 x R&S OSP320 • 12 x R&S OSP-B122H in front slots 2 to 5 of all frames • 1 x R&S ZV-Z40X8 semi-rigid cable set	4 x R&S ZV-Z195

For recommended test fixtures, see Section 4.6, "Test fixtures and connection cables", on page 48.

5.4.2 Connection plan

The switches at front slot 2 of the three R&S OSP320 are combined to a 1:16 submatrix. See Figure 3-7. Same for front slots 3 to 5.

Establish the following connections:

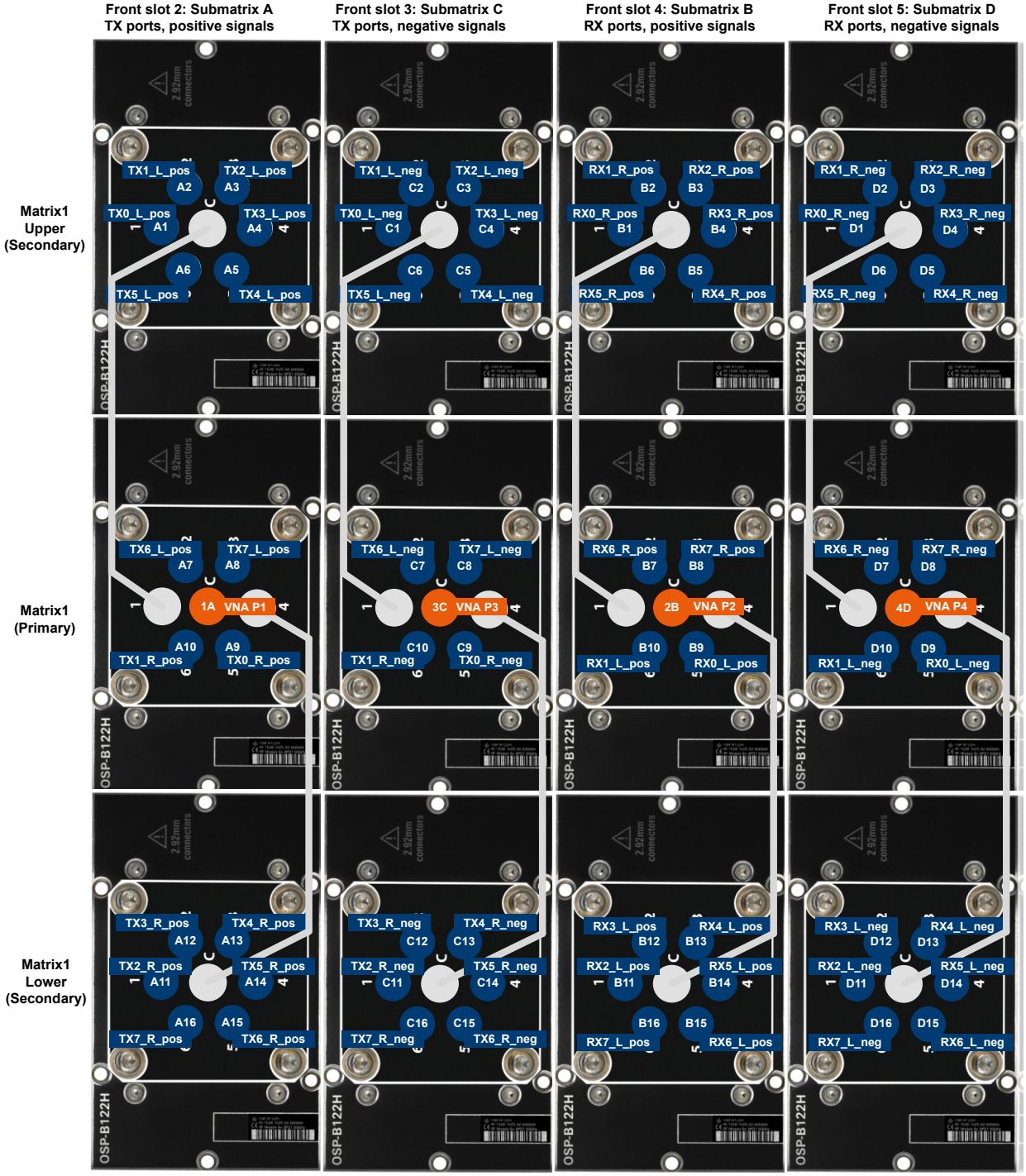


Figure 5-4: Connection plan for x8 cable tests

Front slots 02 to 05 = R&S OSP-B122H
1A, ..., 4D = Matrix VNA port names
P1, ..., P4 = VNA ports to be connected
A1, ..., A16, ..., D1, ..., D16 = Matrix test port names
RX1_L_pos, ..., TX8_R_neg = Fixture ports to be connected (L: left; R: right)
Grey lines = Semi-rigid cable set

5.5 Test fixtures and connection cables

Leading test fixture makers for PCIe 5.0 and 6.0 mated cable assemblies:

- Allion Labs (https://www.allion.com/fixtures/)
- Samtec (https://www.samtec.com/kits/si-eval-cable/si-fly-flyover/)

As connection cables between OSP and test fixtures we recommend:

- Johnson™ 2.92 mm 40 GHz Test Cable Assemblies

5.6 R&S ZNrun compliance test projects

Option R&S ZNrun-K440 enables using the predefined R&S ZNrun projects for compliance tests on PCIe mated cable and connector assemblies.

During installation, these projects are copied to a directory tree below the MOI directory

```
C:\ProgramData\Rohde-Schwarz\ZNrun\3.1x\Resources\MOI\pci-sig\
PCIe 5.0 and 6.0 - CopperLink External Cable
```

on the ZNrun Server.

The predefined projects are read-only. To modify such a project, open it in the ZNrun Workbench, make your changes, and save it to a different location. Or copy the project to a different location and remove the read-only flag before opening it in the ZNrun Workbench.

- All tests projects can be run on members of the R&S ZNB and R&S ZNA family, except for those projects that have a `ZNA` in their name.
- Before R&S ZNrun V3.10, the MOI directory path ended with the standard's revision (`...\Rev 0.9` at the time). This final segment was removed.

`ZNA67` means "R&S ZNA only, preferably R&S ZNA67". These projects require optimizations that are currently not available for the R&S ZNB family.

PCIe rev. 5.0

- Test setup for x3 cables and connectors (demo)

  `<MOI directory>\x3\`
  - `32GTs-matedcable-ZNx-OSP320-24port.znrun`
  - `32GTs-matedconnector-ZNx-OSP320-24port`
- Test setup for x4 cables and connectors

  `<MOI directory>\x4\`
  - `32GTs-matedcable-ZNx-OSP320-32port.znrun`
  - `32GTs-matedcable-ZNx-OSP320-32port-legacyOSPsetup.znrun`
  - `32GTs-matedconnector-ZNx-OSP320-32port`
  - `32GTs-matedconnector-ZNx-OSP320-32port-legacyOSPsetup.znrun`

`legacyOSPsetup` means legacy matrix setup

- Test setup for x8 cables and connectors

  `<MOI directory>\x8\`

  - `32GTs-matedcable-ZNx-OSP320-64port.znrun`
  - `32GTs-matedconnector-ZNx-OSP320-64port`

PCIe rev. 6.0

- Test setup for x3 cables and connectors (demo)

  `<MOI directory>\x3\`

  - `64GTs-matedcable-ZNx-OSP320-24port.znrun`
  - `64GTs-matedconnector-ZNx-OSP320-24port`
  - `64GTs-matedcable-ZNA67-OSP320-24port-67GHz.znrun`
  - `64GTs-matedconnector-ZNA67-OSP320-24port`

- Test setup for x4 cables and connectors

  `<MOI directory>\x4\`

  - `64GTs-matedcable-ZNx-OSP320-32port.znrun`
  - `64GTs-matedcable-ZNx-OSP320-32port-legacyOSPsetup.znrun`
  - `64GTs-matedcable-ZNA67-OSP320-32port-67GHz`
  - `64GTs-matedconnector-ZNx-OSP320-32port`
  - `64GTs-matedconnector-ZNx-OSP320-32port-legacyOSPsetup.znrun`
  - `64GTs-matedconnector-ZNA67-OSP320-32port-67GHz.znrun`

  `legacyOSPsetup` means legacy matrix setup

- Test setup for x8 cables and connectors

  `<MOI directory>\x8\`

  - `64GTs-matedcable-ZNx-OSP320-64port.znrun`
  - `64GTs-matedcable-ZNA67-OSP320-64port-67GHz.znrun`
  - `64GTs-matedconnector-ZNx-OSP320-64port`
  - `64GTs-matedconnector-ZNA67-OSP320-64port-67GHz.znrun`

The 67 GHz projects are for development only. Their stimulus frequency range exceeds the standard's required stimulus frequency range and extrapolates its specified limits.

6 General-purpose balanced signal integrity tests (R&S ZNRUN-K400)

Option R&S ZNRUN-K400 offers a complete and versatile solution for testing high speed cable assemblies.

Its project generator allows you to create compressed cable test projects (`*.znrun`) that can be run in the ZNrun Cable Test Client of every R&S ZNrun instance with software version 3.0 or higher.

The project generator itself does not require a license. However, the generated `*.znrun` files are encrypted and you need option R&S ZNRUN-K400 at runtime (calibration, measurement).

6.1 Project generator

The R&S ZNRUN-K400 project generator is part of the ZNrun Cable Test Client.

Its logic assumes that signals are transmitted between a left and right end and that their integrity can be tested by:

- Connecting the relevant transmitter and receiver fixture ports (aggressors and victims)
- Measuring their balanced transmission S-parameters (THRU, NEXT, FEXT)

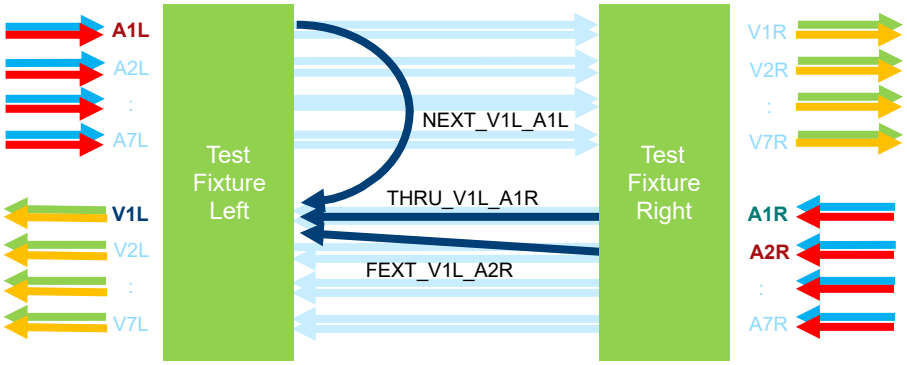


Figure 6-1: Measurements on N balanced lanes

- Doing evaluations (e.g. power sums)
- Applying limits

After the test, the ZNrun Cable Test Client can generate a comprehensive PDF report and/or export the measured results in Touchstone and text format.

Compared to the predefined compliance test projects that are offered with other technology-specific R&S ZNRUN-K4xx options, the project generator provides more flexibility w.r.t. the test stations that you can use and the measurements and evaluations to be performed.

In particular, you can use any vector network analyzer of the R&S ZNB or R&S ZNA family that supports the required stimulus frequencies. And you can use one of the supported multiport solutions.

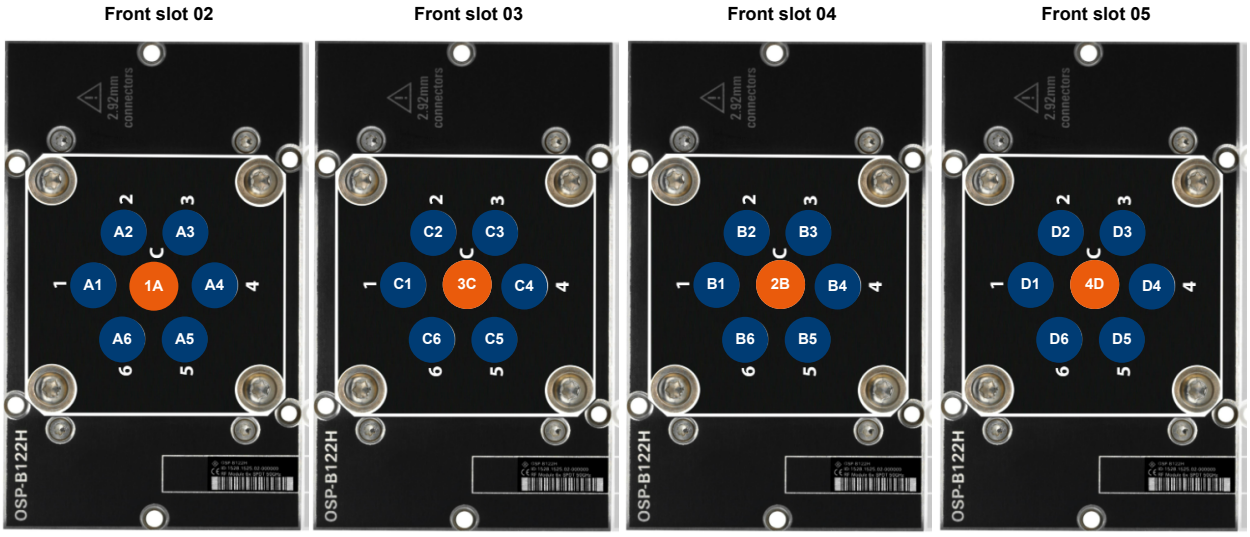
6.2 Supported matrix solutions

In general, you can do any signal integrity test with a single 4-port VNA, successively connecting the relevant TX and RX fixture ports (aggressors and victims) and measuring their balanced transmission S-parameters. For a single lane (2 x TX, 2 x RX) this test can be done fast and reliable. With more lanes, however, numerous reconnections must be done.

The generator allows you to select one of the matrix solutions described below. Based on the selected solution, the ZNrun Cable Test Client automatically calculates the necessary plug connections and indicates them during measurement.

6.2.1 24-port_6RX_6TX

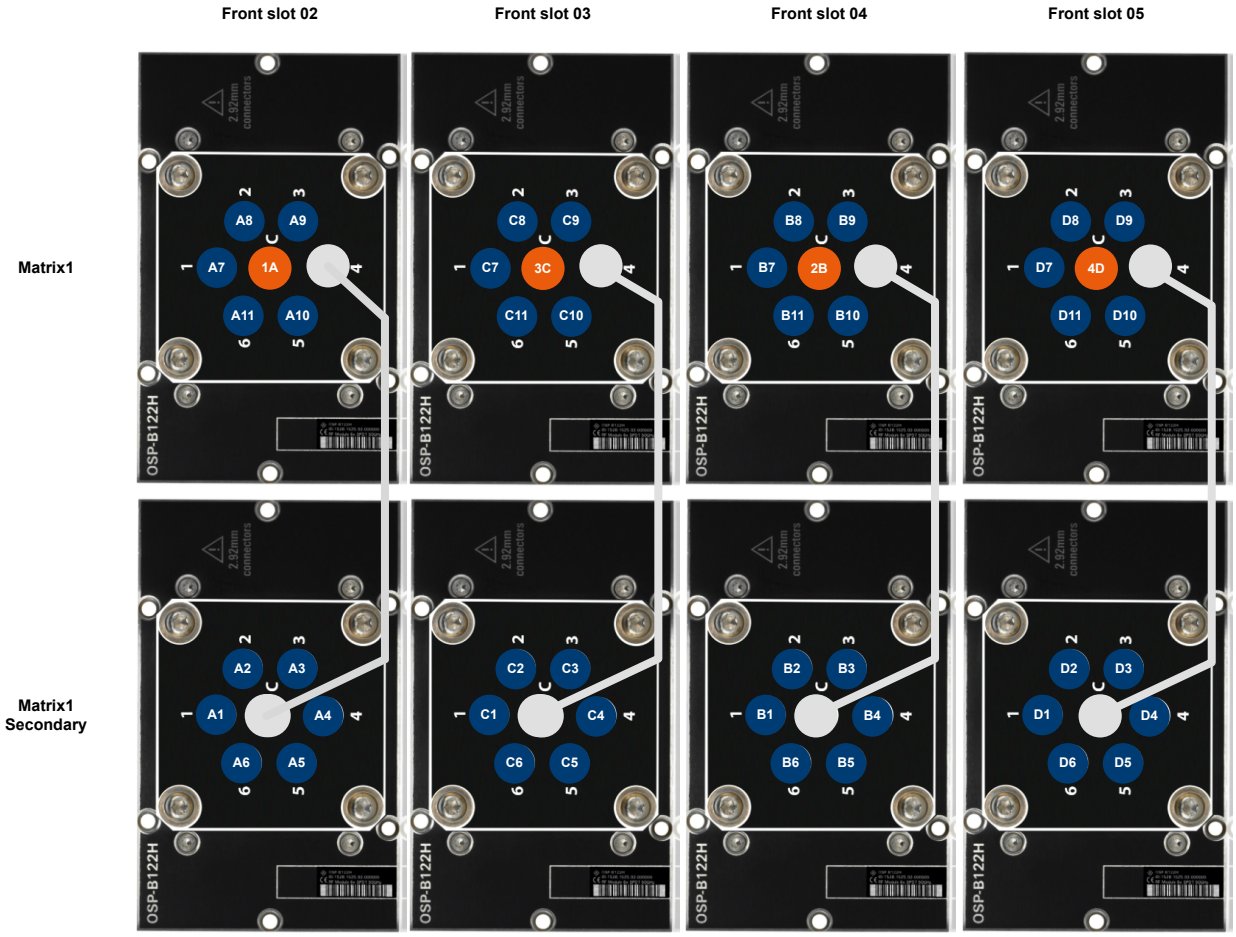
See Section 3.3.3, "24-port solution", on page 28.



Front slots 02 to 05 = R&S OSP-B122H, -B122U, or -B122VL according to required stimulus frequencies
1A, ..., 4D = Matrix VNA ports, to be connected to VNA ports 1 to 4, respectively
A1, ..., D6 = Matrix test ports, submatrices A to D, to be connected according to plug instructions

6.2.2 44-port_11RX_11TX

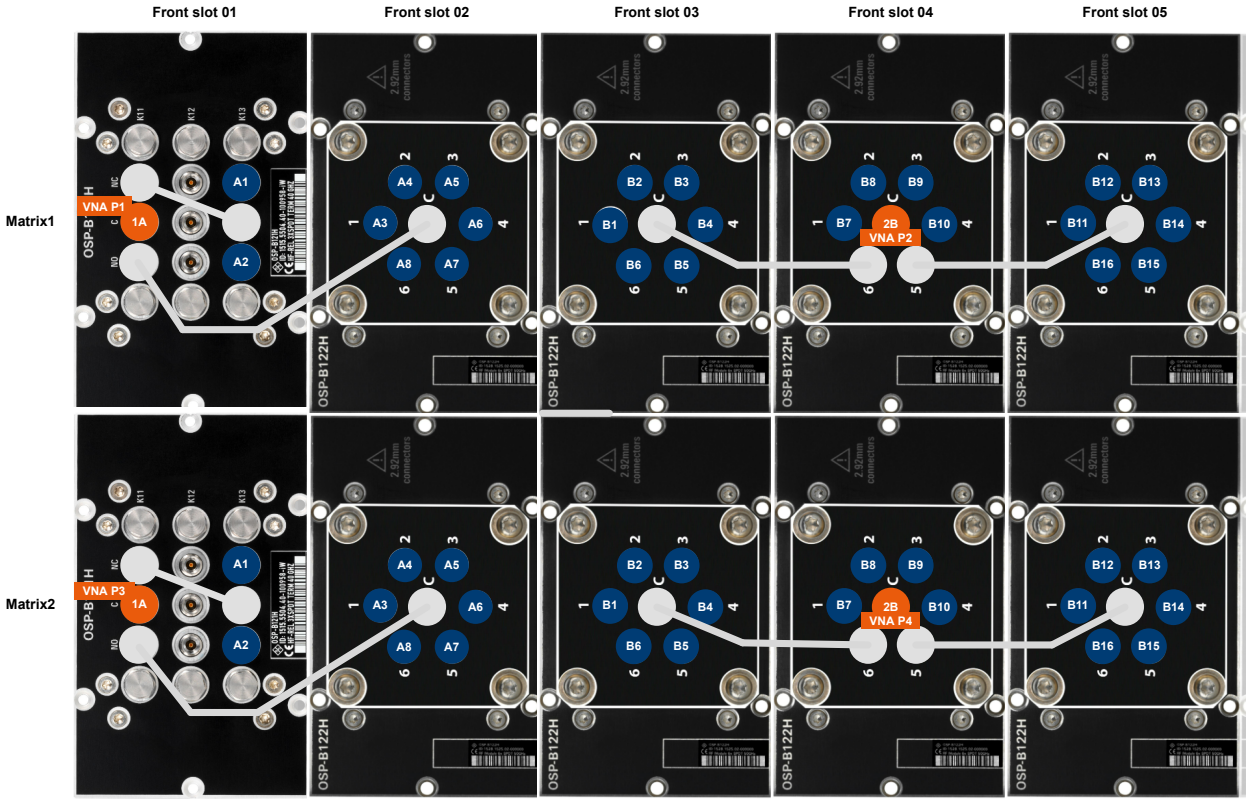
See Section 3.3.6, "48-port solution for R&S ZNRUN-K400 and R&S ZNRUN-41x", on page 31.



Front slots 02 to 05 = R&S OSP-B122H, -B122U, or -B122VL according to required stimulus frequencies
1A, ..., 4D = Matrix VNA ports, to be connected to VNA ports 1 to 4, respectively
A1, ..., D11 = Matrix test ports, submatrices A to D, to be connected according to plug instructions
Grey lines = Semi-rigid cables

6.2.3 48-port_8RX_16TX

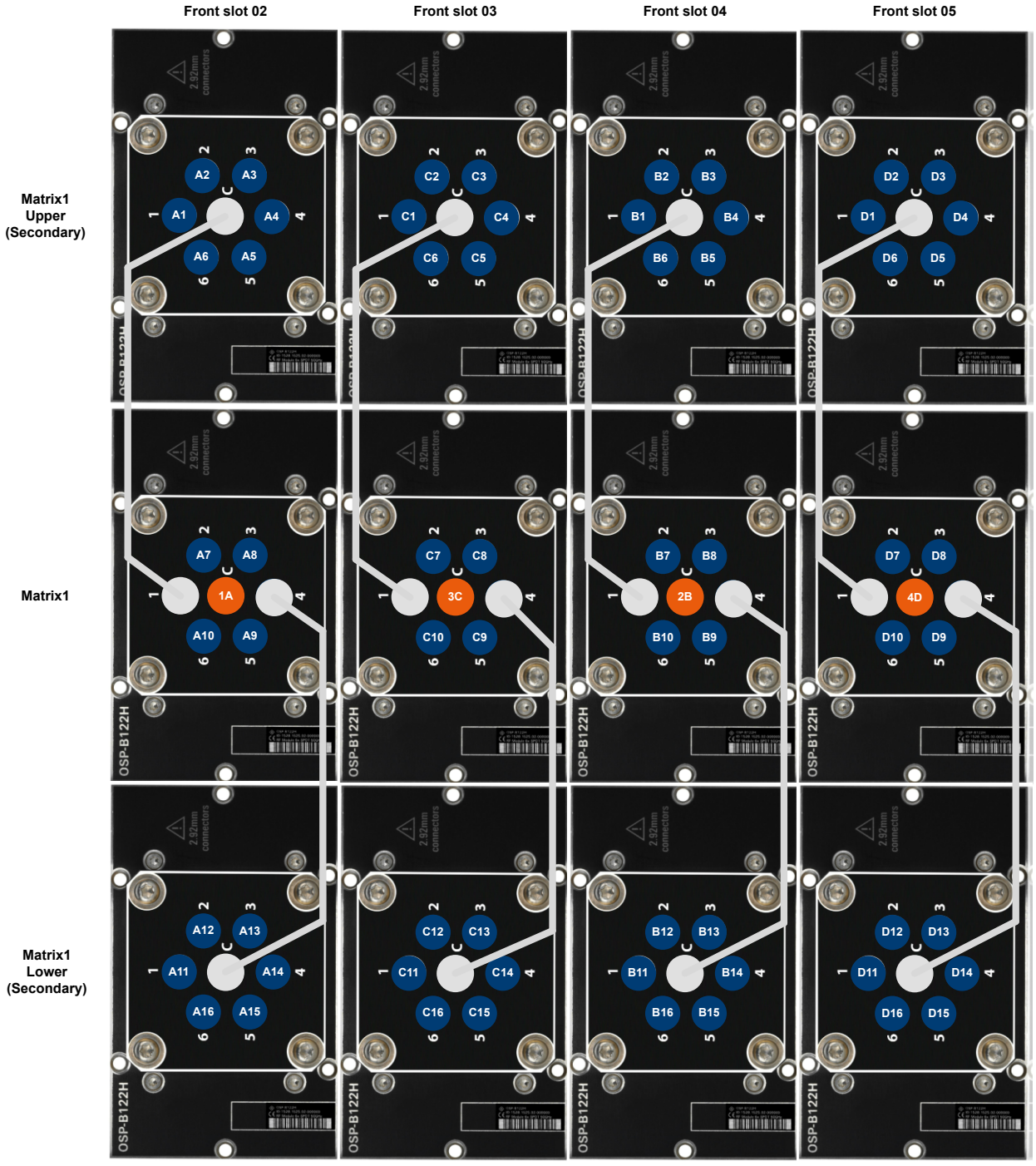
See Section 3.3.6, "48-port solution for R&S ZNRUN-K400 and R&S ZNRUN-41x", on page 31.



Front slots 01 = R&S OSP-B121H (3 x SPDT, 1 unused), -B121U (2 x SPDT), or -B121VL (2 x SPDT) according to required stimulus frequencies
Front slots 02 to 05 = R&S OSP-B122H, -B122U, or -B122VL according to required stimulus frequencies
1A, 2B = Matrix VNA ports, to be connected to VNA ports 1 to 4 as depicted
A1, ..., A8 = Matrix test ports, submatrix A, to be connected according to plug instructions
B1, ..., B16 = Matrix test ports, submatrix B, to be connected according to plug instructions
Grey lines = Semi-rigid cables

6.2.4 64-port_16RX_16TX

See Section 3.3.7, "64-port solution", on page 32.



Front slots 02 to 05 = R&S OSP-B122H, -B122U, or -B122VL according to required stimulus frequencies
1A, ..., 4D = Matrix VNA ports, to be connected to VNA ports 1 to 4, respectively
A1, ..., D16 = Matrix test ports, submatrices A to D, to be connected according to plug instructions
Grey lines = Semi-rigid cables

6.3 Connection plans

In contrast to the predefined compliance tests according to IEEE and PCIe standards, MOI projects created with the project generator can use any of the supported multiport solutions.

For instance, you can create a complete test on 8 balanced lanes (16 TX, 16 RX) using the 24-port_6RX_6TX solution, if you do not mind reconnecting the text fixtures several times. During the measurement phase, the cable client guides you with the necessary plug instructions.

Whenever you create a custom MOI project, the "Generator" also creates a **connection plan file** (`*.connections`) and stores it in the same directory and with the same name as the generated MOI project file (`*.znrun`). Open it in your favorite text editor to be prepared for the required reconnections.

```
Connection Plan for generated ZNrun CableTestClient Project
<... Path to generated *.znrun file (at creation time) ...>

Plug Step 1
Matrix1, Port: A1  ->  DUT Fixture Port: A1L_p
Matrix1, Port: A2  ->  DUT Fixture Port: A2L_p
Matrix1, Port: A3  ->  DUT Fixture Port: A3L_p
Matrix1, Port: A4  ->  DUT Fixture Port: A4L_p

Matrix1, Port: A5  ->  DUT Fixture Port: A1R_p
Matrix1, Port: A6  ->  DUT Fixture Port: A2R_p

...

Plug Step 2

...


Plug Step 3

...
```

The connection plan is calculated based on:

- The number of lanes *N*
- The R&S OSP matrix solution that is used

When you generate a MOI project, you have to specify both of them.

If *N* is less or equal than **half** the number of TX and RX of the selected matrix solution, then you don't have to reconnect the fixtures during the measurement. I.e., the connection plan consists of a single "Plug Step".

Furthermore, the generated connection plan is compatible to the connection plans of the predefined MOI projects that also use the selected matrix – except for those requiring a cable flip.

If, for example, you create a 3-lane test with 1-based numbering on a 24-port_6RX_6TX solution, then you have to connect the fixtures as follows:

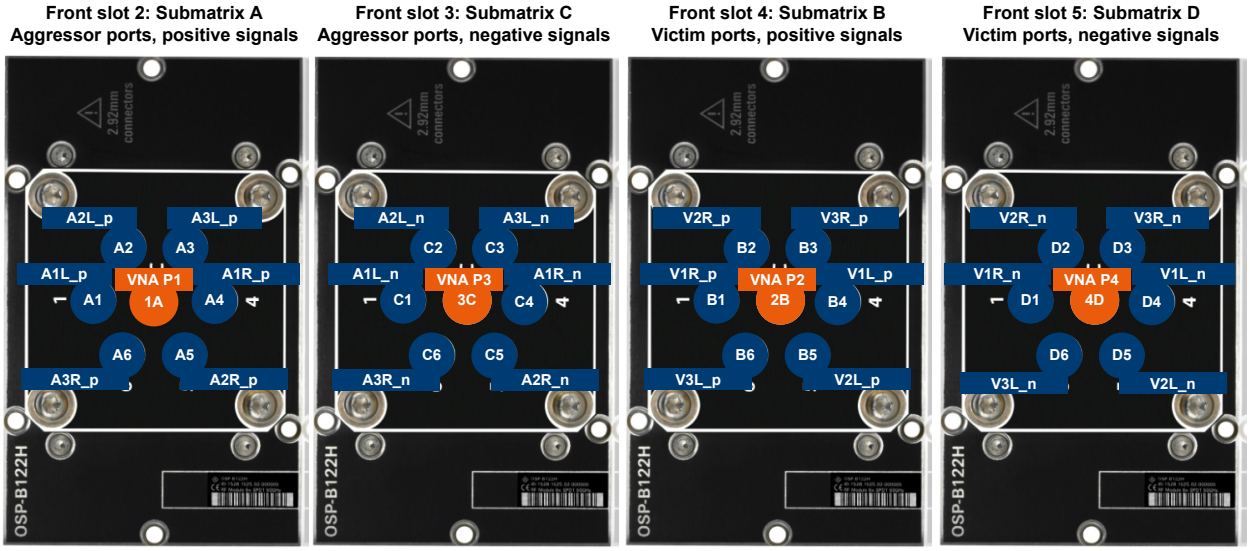


Figure 6-2: Port assignment for 3 lanes on the 24-port_6RX_6TX solution (1-based port numbering)

As you can see, the connections are compatible with the predefined PCIe x3 projects, which also use the 24-port_6RX_6TX solution. Just replace TX by A, RX by V and number the ports starting from 0 instead of 1.

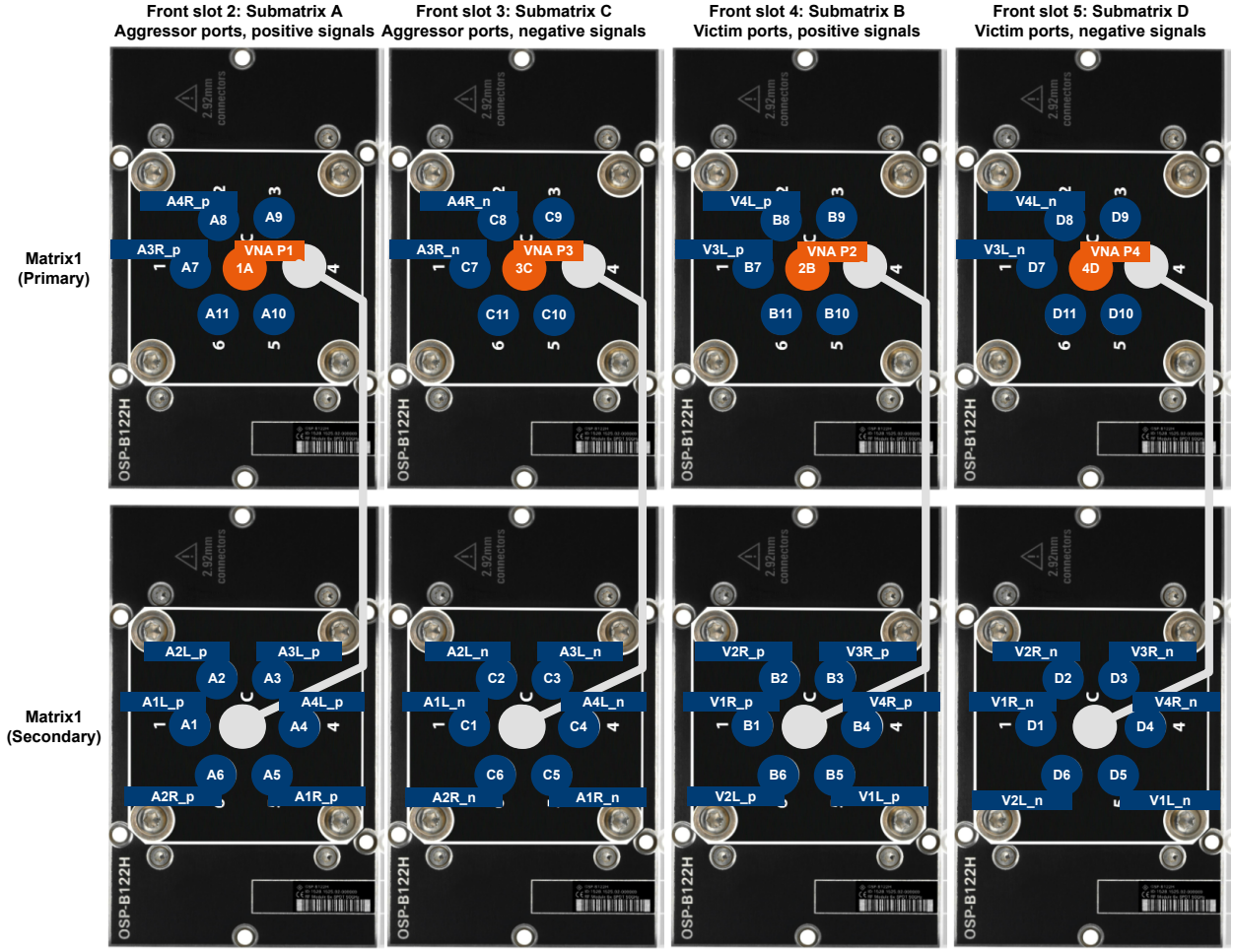


Figure 6-3: Port assignment for 4 lanes on the 44-port_11RX_11TX solution (1-based port numbering)

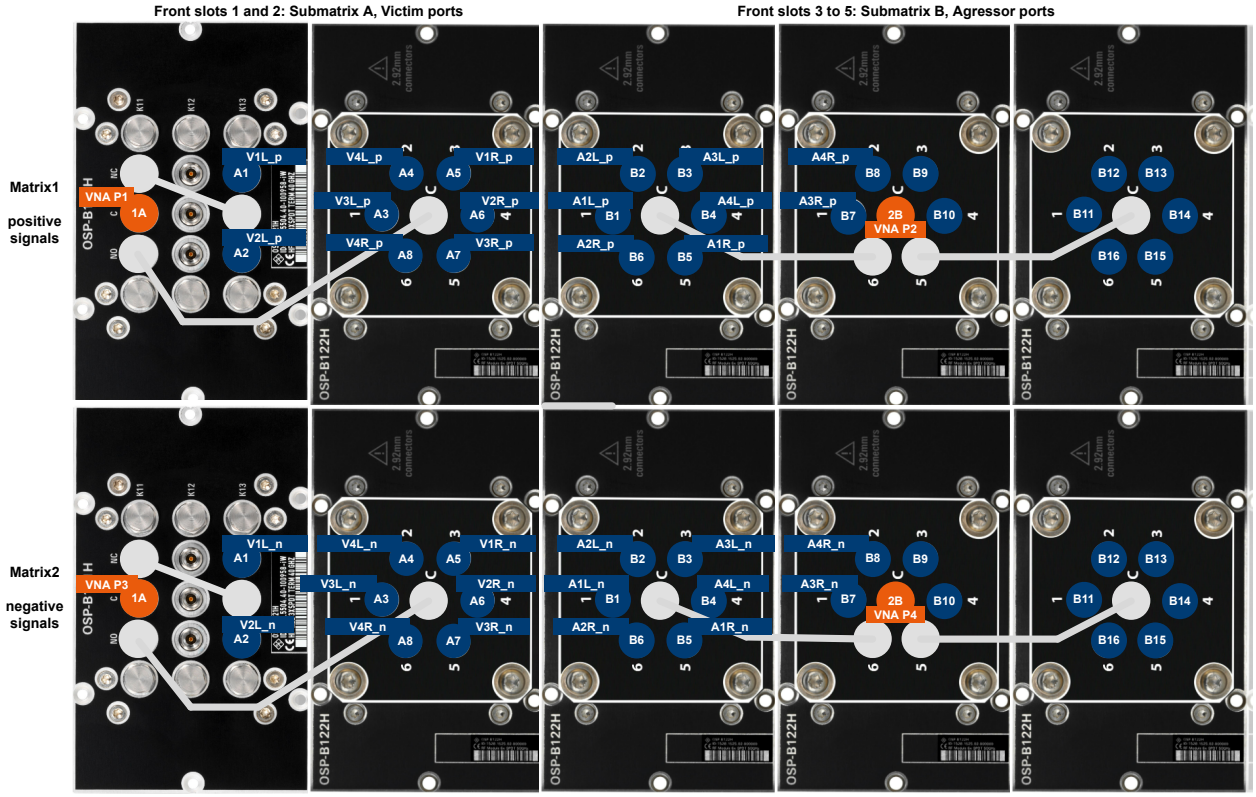


Figure 6-4: Port assignment for 4 lanes on the 48-port_8RX_16TX solution (1-based port numbering)

- The 48-port_**8RX**_16TX matrix solution is not used for any predefined **4**-lane MOI.
- The predefined IEEE CR8 MOIs use it, but require a cable flip.
- The port assignment for user-defined **4**-lane tests is **incompatible** with that of the predefined IEEE CR**8** MOIs.

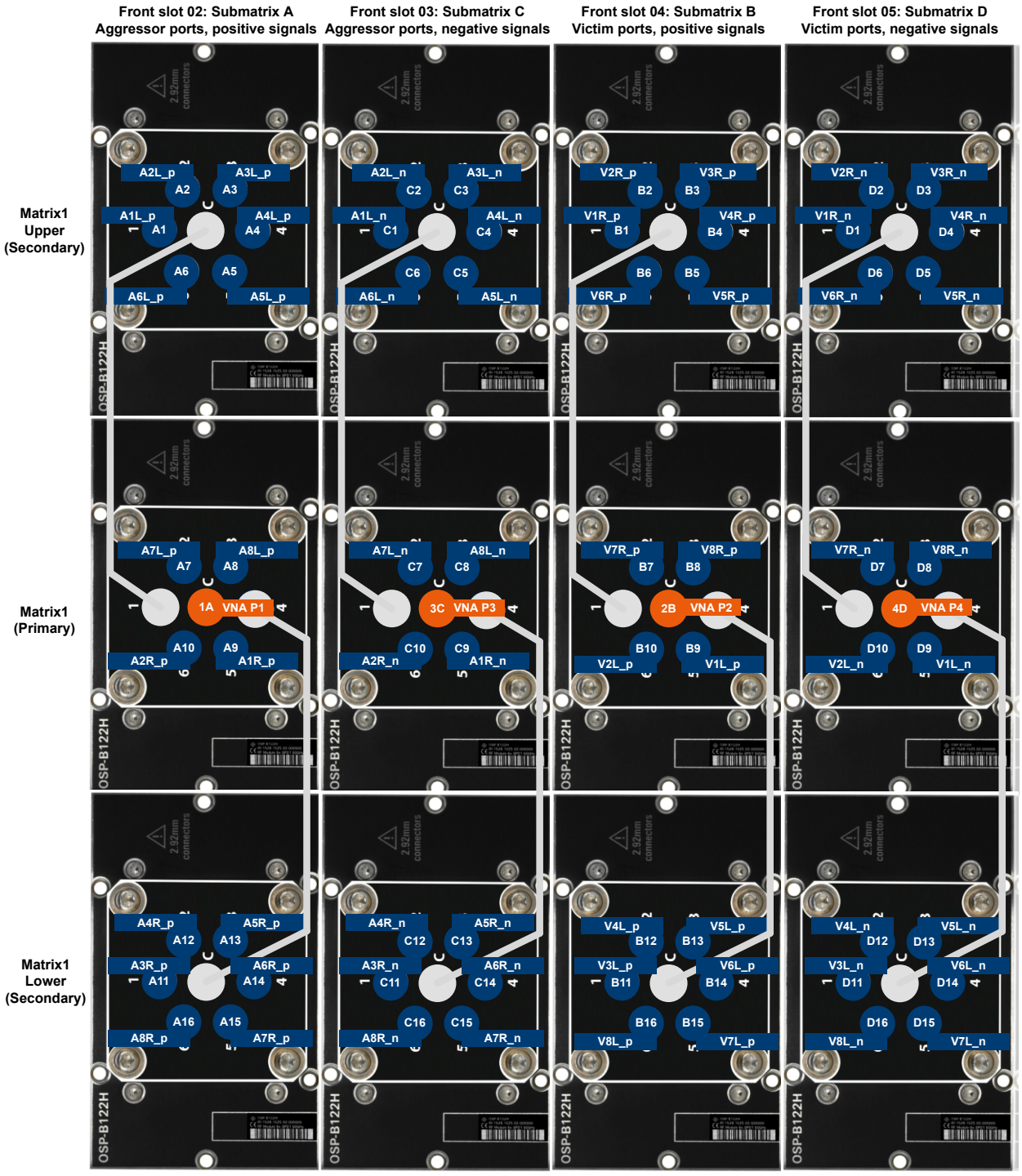


Figure 6-5: Port assignment for 8 lanes on the 64-port_16RX_16TX solution (1-based port numbering)

Port naming schemes

Currently, the naming schemes for the test ports in IEEE 802.3, PCIe and "Generator" projects are slightly different:

- IEEE 802.3 and PCIe projects use the transmitter/reveiver (**TX/RX**) naming convention, the project generator lets you select between the more **generic A**gressor/ **V**ictim and the TX/RX naming scheme
- IEEE 802.3 and "Generator" projects use **L**eft and **R**ight, PCIe projects use **A** and **B**.
- IEEE 802.3 and PCIe projects use terms **pos**itive and **neg**ative polarity, the project generator **p** and **n** for short.
- IEEE 802.3 numbers the ports from 1 to N (1-based numbering), PCIe uses 0-based numbering, the "Generator" can do both.

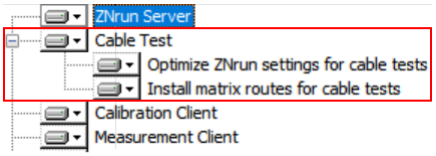
Table 6-1: Test port naming for the nth lane (n = 1, ..., N)

Port type	Side	Polarity	IEEE (1-based)	PCIe (0-based)	Generic 1-based	Generic 0-based
Transmit ≙ Agressor	A ≙ Left	positive	TX<n>A_pos	TX<n-1>_L_pos	A<n>L_p	A<n-1>L_p
		negative	TX<n>A_neg	TX<n-1>_L_pos	A<n>L_n	A<n-1>L_n
	B ≙ Right	positive	TX<n>B_pos	TX<n-1>_R_pos	A<n>R_p	A<n-1>R_p
		negative	TX<n>B_neg	TX<n-1>_R_pos	A<n>R_n	A<n-1>R_n
Receive ≙ Vicitm	A ≙ Left	positive	RX<n>A_pos	RX<n-1>_L_pos	V<n>L_p	V<n-1>L_p
		negative	RX<n>A_neg	RX<n-1>_L_pos	V<n>L_n	V<n-1>L_n
	B ≙ Right	positive	RX<n>B_pos	RX<n-1>_R_pos	V<n>R_p	V<n-1>R_p
		negative	RX<n>B_neg	RX<n-1>_R_pos	V<n>R_n	V<n-1>R_n

7 Operation

The main R&S ZNrun GUI for signal integrity and compliance testing is the **ZNrun Cable Test Client**. Advanced configuration and debugging tasks can be performed in the ZNrun Workbench.

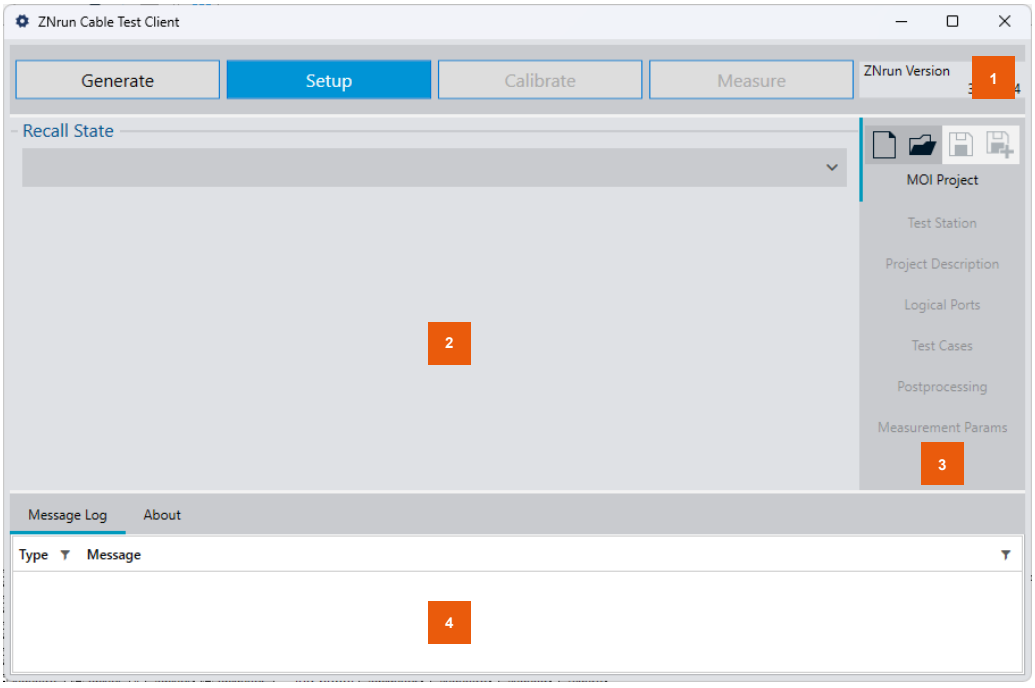
During installation, select "Cable Test" and all its subitems.



You can install and run these applications on any PC to perform configuration tasks. No licenses are required. Calibration and measurement, however, can only be run from the ZNrun Server, with the required licenses installed.

7.1 Working with the ZNrun Cable Test Client

Run the ZNrun Cable Test Client from the "R&S ZNrun <version>" program group of the Windows Start menu. When you start it for the first time, it appears as follows:



1 = Phase selection and version info
2 = Work area (phase dependent)
3 = Menu bar
4 = Log area

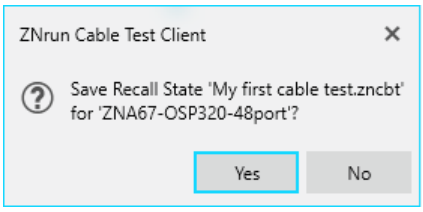
7.1.1 Setup

The ZNrun Cable Test Client always starts in "Setup" mode, which allows you to configure the runtime properties of a cable test based on an existing MOI project. These properties can be persisted to or loaded from a recall state file.

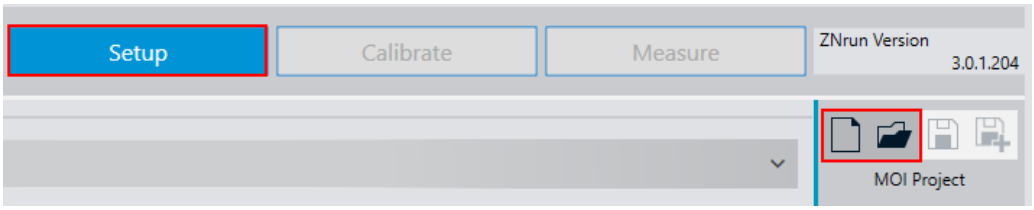
- If you have run the ZNrun Cable Test Client before, it recalls the state (file) of the previous session.
- Only start with Generate if you want to create a custom MOI project (see Section 6, "General-purpose balanced signal integrity tests (R&S ZNRUN-K400)", on page 63).

Recall state files

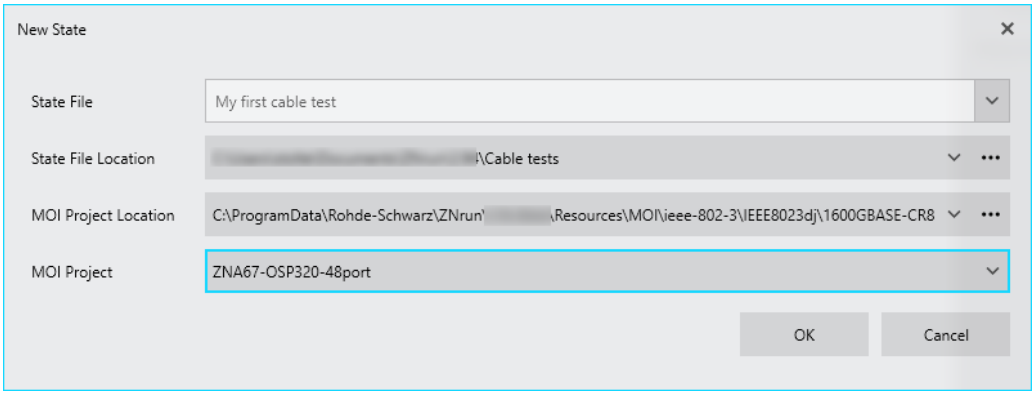
The ZNrun Cable Test Client requires and maintains a "Recall State" file (`*.zncbt`) defining the runtime properties of a cable test based on an existing MOI project. You can recall it in a future cable client session.



When the ZNrun Cable Test Client starts up for the first time, no "Recall State" files are offered for selection. Use the ("Load...") button to browse for an existing `*.zncbt` file, or select the ("New...") button to create one:



The latter opens the "New State" dialog that allows you to create a "Recall State" file.



In the "New State" dialog:

1. Specify the name and select the location of the recall state you want to create.
   If the "State File Location" combo-box does not offer your preferred directory, use the ellipsis button to open a directory explorer and browse to it.
2. Select the location of the cable test project that you want to execute.
   If the "MOI Project Location" combo-box does not offer it, use the ellipsis button to open a directory explorer and browse to it.
   The "MOI Project" combo-box then displays the cable test projects (`*.znrun` files) in this directory.
   At the first start of the ZNrun Cable Test Client, browsing starts at the installation directory of the predefined cable test projects.
3. Select the suitable cable test project.
   For predefined IEEE 802.3 projects, refer to Section 4.7, "R&S ZNrun test projects", on page 48.
   For predefined PCIe 5.0 and 6.0 projects, refer to Section 5.6, "R&S ZNrun compliance test projects", on page 61.
   User-defined cable test projects must be generated beforehand.

You can create multiple recall state files for the same MOI project.

MOI Project

In the "MOI Project" panel, you can select the cable test to be performed.

Once you have loaded a recall state file, the work area displays:

- The path to the recall state file
- The path to the related MOI project
- Other properties of the related MOI project

The displayed properties depend on the type of the related MOI project.

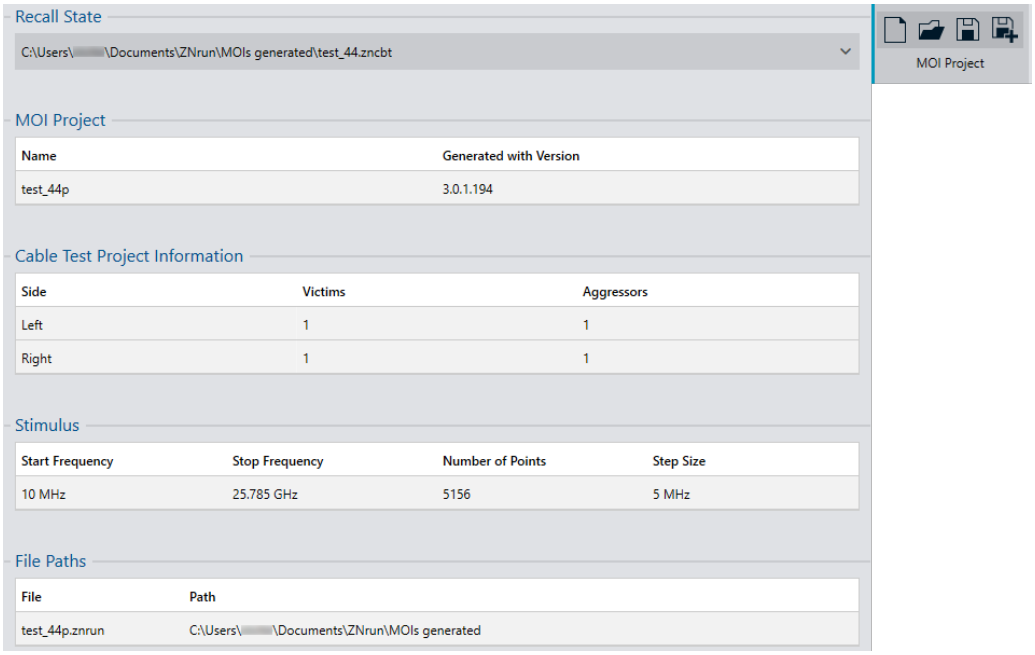


Figure 7-1: Properties of Basic generated MOI projects

"Generated with Version"

This property indicates the R&S ZNrun version that was used to generate the related MOI project. It shows up for all generated MOI projects.

Although backward compatibility is guaranteed, the availability of certain features depends on this generator version. If a feature described in this manual is missing, please re-generate the MOI project.

For predefined R&S ZNRUN-K4xx compliance test projects, and for user-defined MOI projects with Interconnect Technology other than "Basic", the "Supported Communication Standard" is displayed.

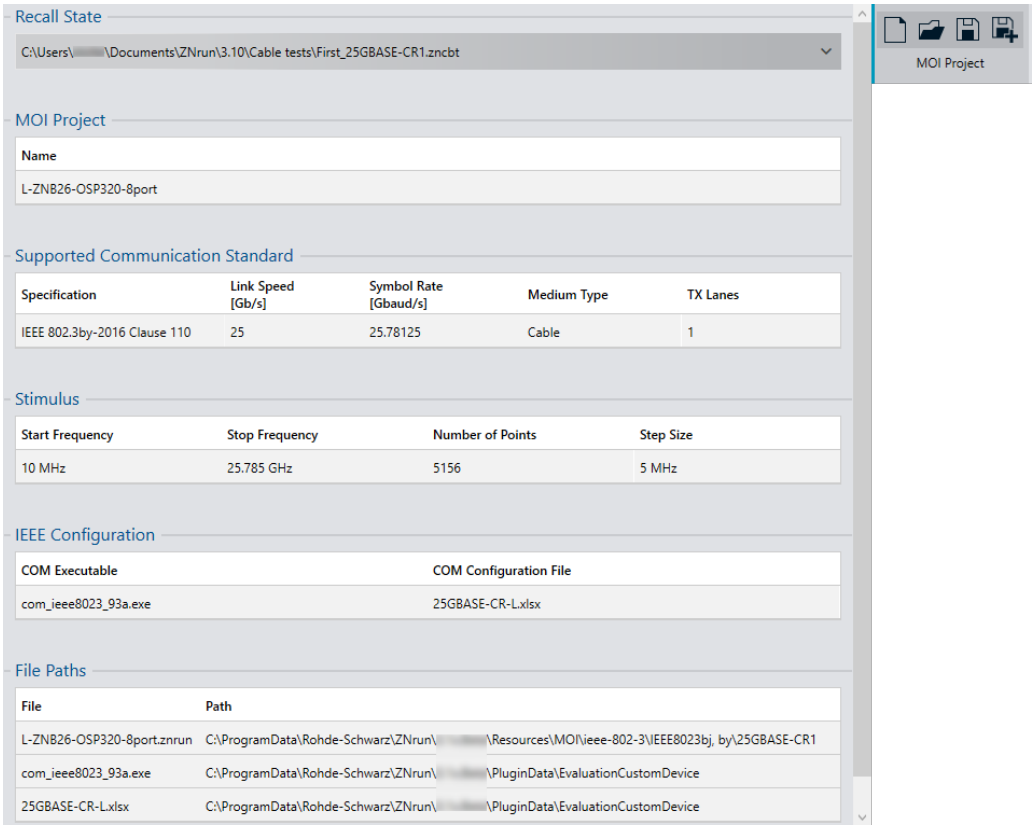


Figure 7-2: Properties of (predefined) IEEE 802.3 MOI projects

For generated IEEE 802.3 projects, "Generated with Version" is displayed to the right of the MOI project name. The "IEEE Configuration" and the related "File Paths" are only visible, if a COM tool and config file were specified during project generation.

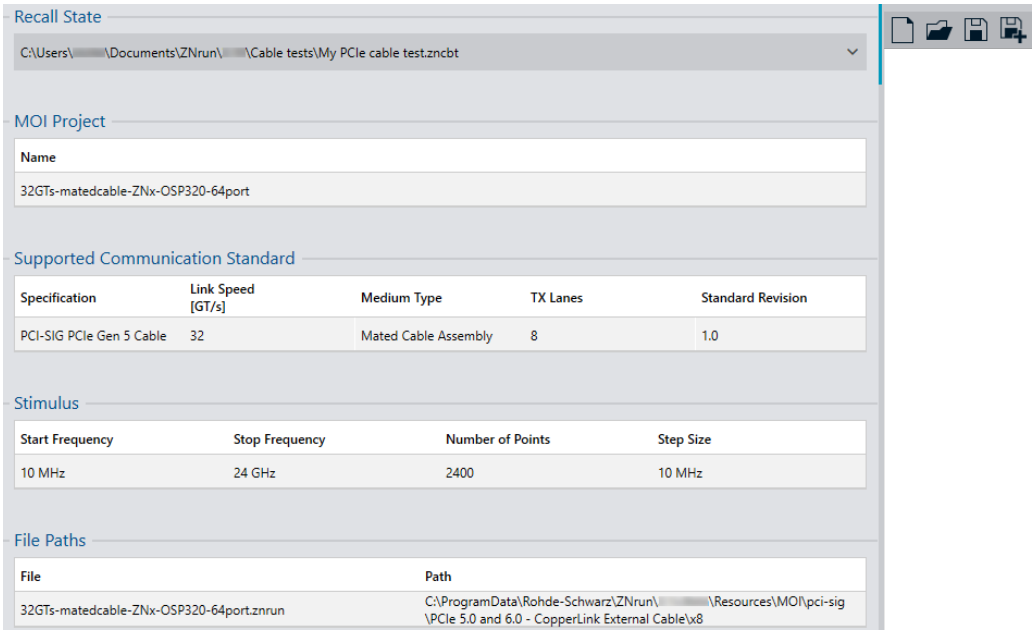


Figure 7-3: Properties of (predefined) PCIe MOI projects

"Standard Revision"

This property indicates the revision of the standard the related MOI project implements. Currently, it is only shown for PCIe projects (either predefined or generated).

The project properties are also part of the PDF report the cable test client can generate for each measurement.

MOI Project

Name
64GTs-matedcable-ZNA43-OSP320-64port-40GHz-4000points

Supported Communication Standard

Specification	Link Speed [GT/s]	Medium Type	TX Lanes
PCI-SIG PCIe Gen 6 Cable with extended frequency range	64	Mated Cable Assembly	8

Stimulus

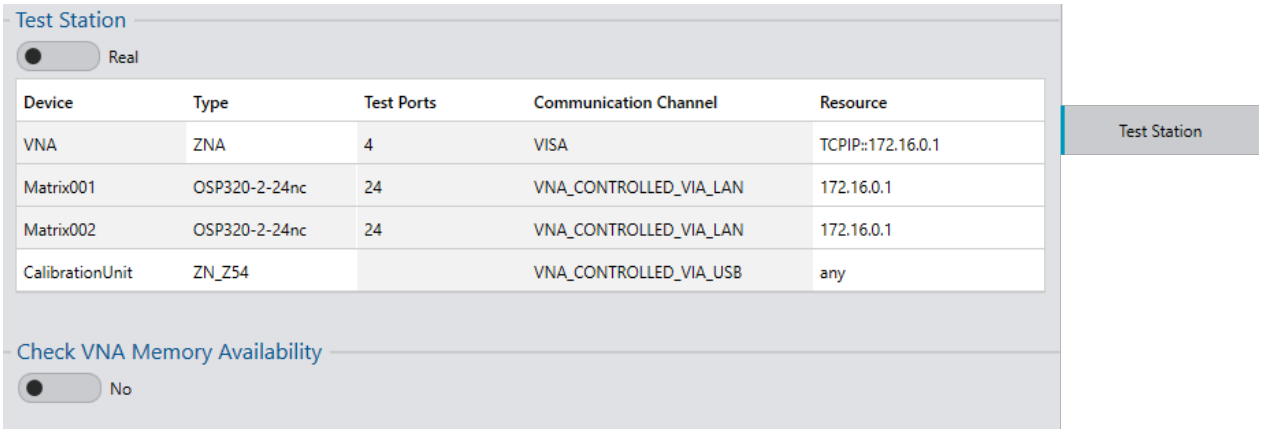
Start Frequency	Stop Frequency	Number of Points	Step Size
10 MHz	40 GHz	4000	10 MHz

Test Station

In the "Test Station" panel, you can configure the test equipment you want to use.

Operation modes

- "Real" (default): Real hardware expected
  When entering the calibration or measurement phase, the ZNrun Cable Test Client checks whether the required HW is available and online(`*IDN` queries). Make sure that IP connections between ZNrun Server, VNA and switch matrices can be established.
  A warning is created if the MOI project's stimulus frequency range is not covered by the selected test station devices.
- "Simulated": Simulation environment expected (R&S ZNXSIM)

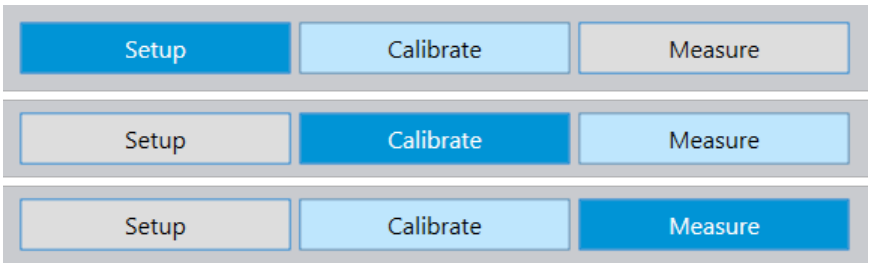


1. Specify the IP address of the VNA that you want to use for this cable test session.
   The selected MOI project defines the supported VNA type. "ZNx" means that you can use any member of the R&S ZNA or R&S ZNB family with a suitable frequency range. All MOI projects require 4-port models.
   The communication channel "VISA" is fixed.
2. Specify the IP addresses of the listed R&S OSP switch matrices.
   (The communication channel "VNA_CONTROLLED_VIA_LAN" is fixed.)
   The selected "MOI Project" defines the required matrix type with its respective number of test ports.
   In "Simulated" mode, there is nothing to configure.
3. If you want to calibrate the test setup:
   a) Choose the "Type" of the calibration unit
   b) Select or specify the appropriate "Communication Channel" and "Resource" ("VNA_CONTROLLED_VIA_USB" and "any" for the recommended calibration units)
   In "Simulated" mode, calibration makes no sense and the "Calibration Unit" configuration is not available.
4. Activate **"Check VNA Memory Availabilty"** to check the VNA for sufficient memory when entering the measurement phase.

   If memory size is insufficient (for the setup to be measured), the ZNrun Cable Test Client displays an error and stops the measurement preparation.

The memory check is particular suitable for R&S ZNA and R&S ZNB3000, whose paging file size can be too small for projects with many lanes. By default it is disabled whenever you enter or re-enter the "Setup" phase.

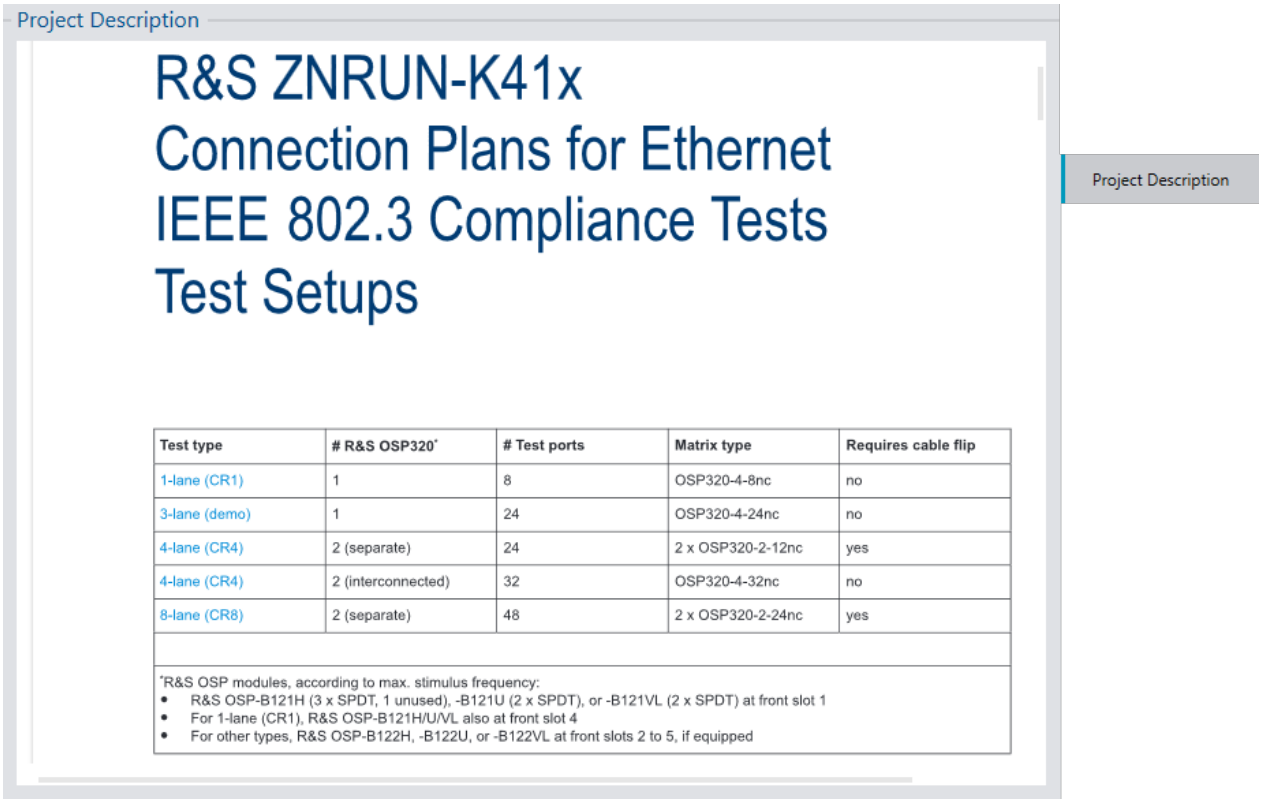
5. To check your setup, try to switch to "Calibrate" and then to "Measure".



Project Description

For predefined MOI projects, this panel displays the connection plans of the related multiport solutions, as described in:

- Section 4, "IEEE 802.3 compliance tests (R&S ZNRUN-K41x)", on page 34
- Section 5, "PCI Express compliance tests (R&S ZNRUN-K440)", on page 51



Test type	# R&S OSP320*	# Test ports	Matrix type	Requires cable flip
1-lane (CR1)	1	8	OSP320-4-8nc	no
3-lane (demo)	1	24	OSP320-4-24nc	no
4-lane (CR4)	2 (separate)	24	2 x OSP320-2-12nc	yes
4-lane (CR4)	2 (interconnected)	32	OSP320-4-32nc	no
8-lane (CR8)	2 (separate)	48	2 x OSP320-2-24nc	yes

*R&S OSP modules, according to max. stimulus frequency:
- R&S OSP-B121H (3 x SPDT, 1 unused), -B121U (2 x SPDT), or -B121VL (2 x SPDT) at front slot 1
- For 1-lane (CR1), R&S OSP-B121H/U/VL also at front slot 4
- For other types, R&S OSP-B122H, -B122U, or -B122VL at front slots 2 to 5, if equipped

For MOI projects created with the project generator, the "Project Description" panel displays all supported Hardware Setups. It helps you to understand the project-specific connection plan, which is created by the generator as a text file `<MOI project name>.connections` together with the MOI project `<MOI project name>.znrun`. See Section 6.3, "Connection plans", on page 68.

Logical Ports

In the "Logical Ports" panel, you can de-embed the test fixtures and specify the balanced reference impedances of the links (cable + test fixtures).

The "Port Defaults" section allows you to specify default settings that are applied to all ports, unless you overwrite them for particular ports in the "Logical Ports Configuration" section.

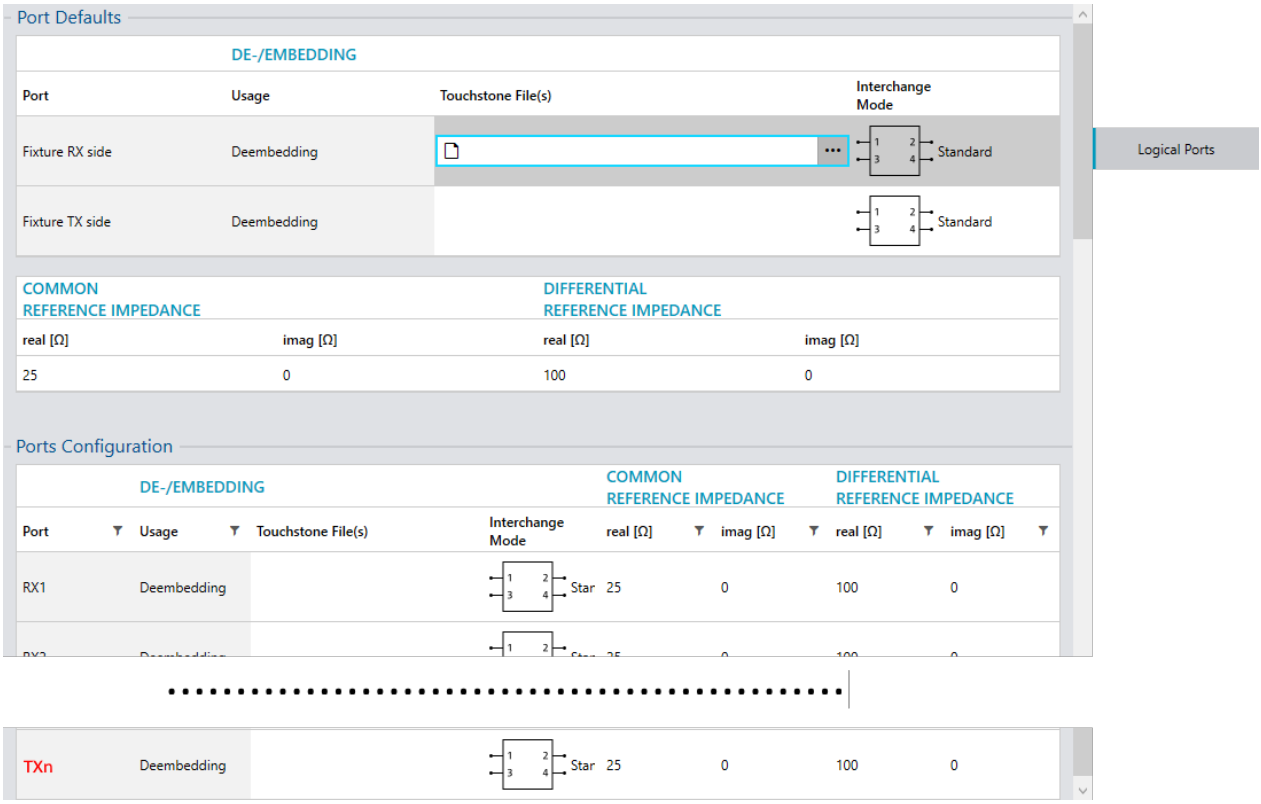


Figure 7-4: Logical ports configuration for predefined IEEE 802.3 projects

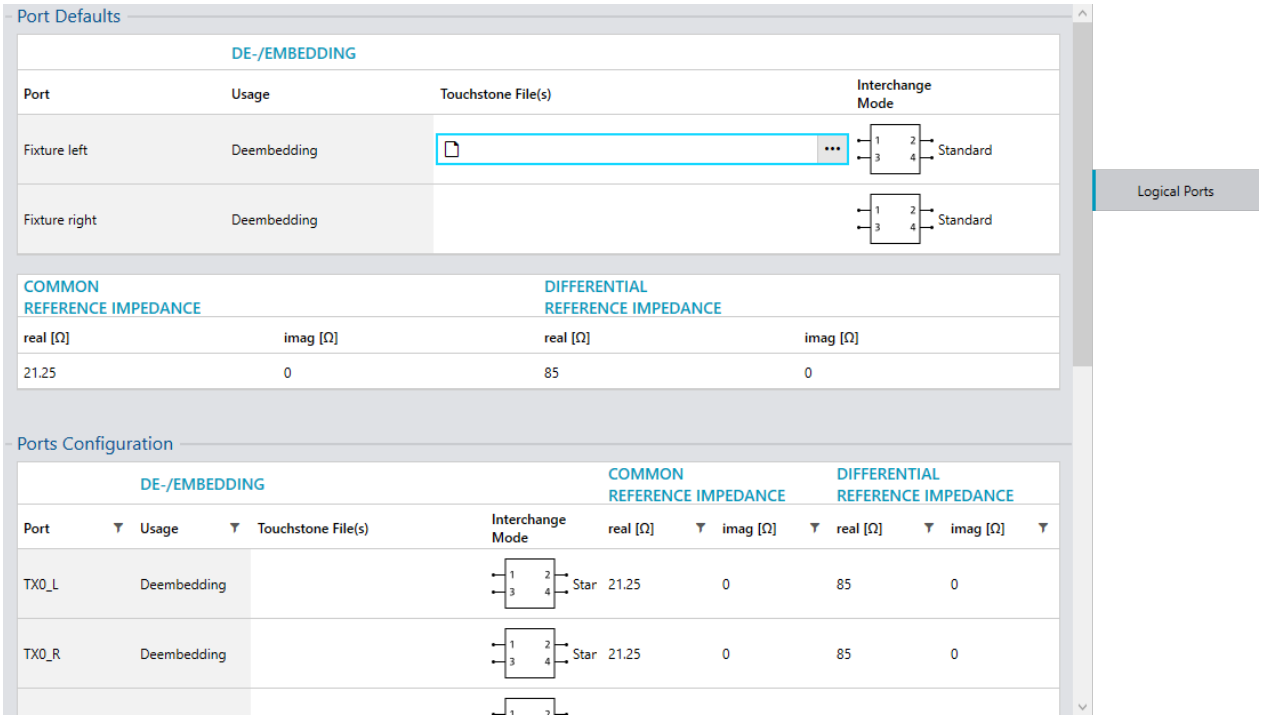


Figure 7-5: Logical ports configuration for predefined PCIe projects

1. Select the "Touchstone Files" you want to use for deembedding the test fixtures. To create these files, we recommend using the deembedding assistant of the R&S ZNA/ZNB firmware.
2. If the port order within a deembedding file is non-standard, select the correct "Interchange Mode".
3. Specify the common and differential reference impedances.

   Your modifications are persisted in the recall state file.

For MOI projects created with the project generator, the logical port configuration is very similar to that of the predefined projects. However:

- The default values of the reference impedances depend on the selected Interconnect Techology.
- The generated projects use a slightly different port naming.

Test Cases

In the "Test Cases" panel, you can select the lanes and directions to be measured, and the subsequent actions (Touchstone export, calculation of additional figures of merit, reporting).

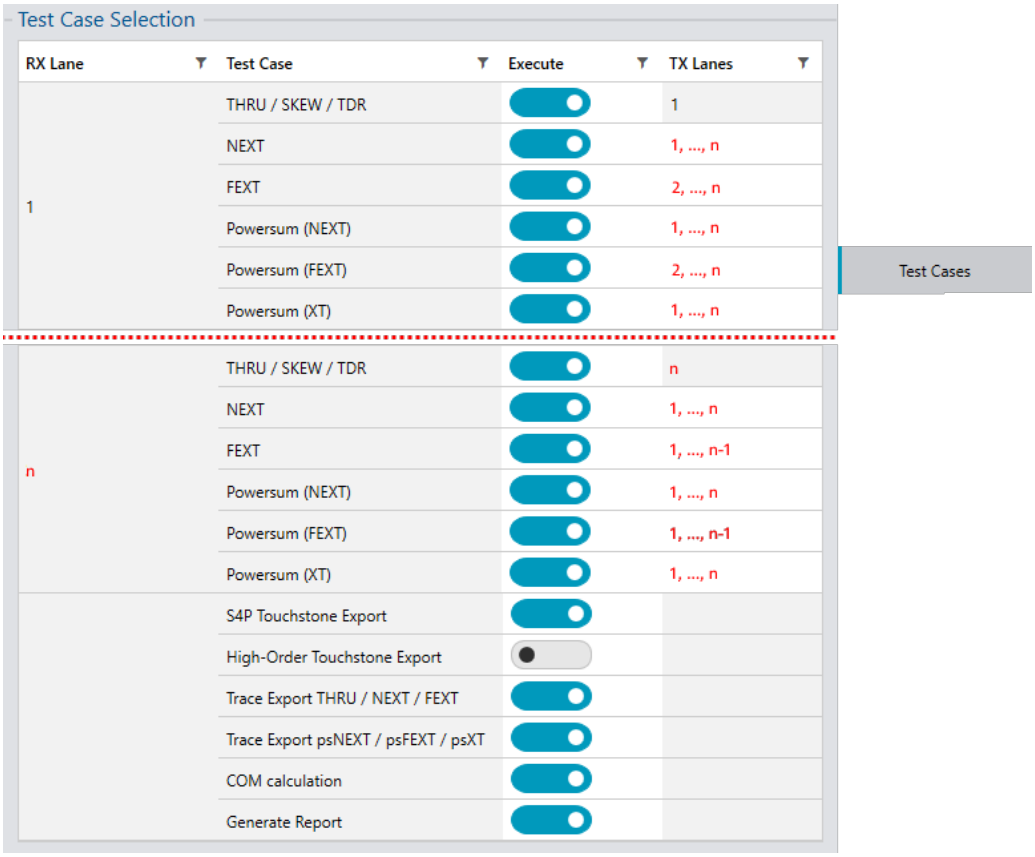


Figure 7-6: Text case selection for generated IEEE 802.3 projects

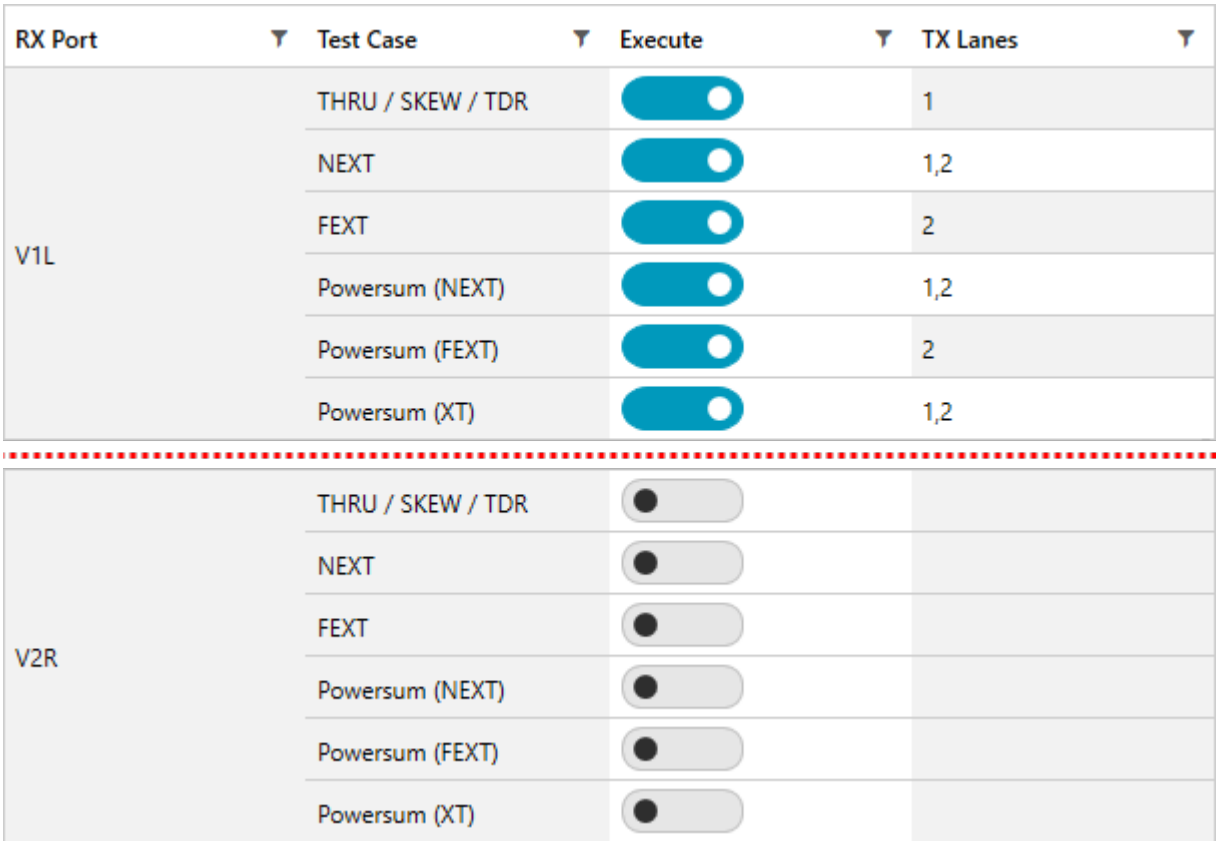
MOI projects for different technologies use different naming conventions w.r.t. port naming, evaluations and postprocessings. For example, user-generated projects use L/R instead of A/B and the generic terms "Powersum NEXT" etc. instead of the IEEE terms "psNEXT" etc.

The offered evaluations and postprocessings are also partly technology-specific. For example, "COM calculation" is only offered for IEEE 802.3 projects – either predefined or user-generated. The latter means that the project was generated with interconnect technology IEEE. Furthermore, a COM tool was selected during project generation.

1. In the "Execute" column, select the test cases to be performed.
2. In the "TX lanes" column of each measurement test case (THRU, NEXT, FEXT lines), select the TX lanes "aggressing" the respective "victim" RX.

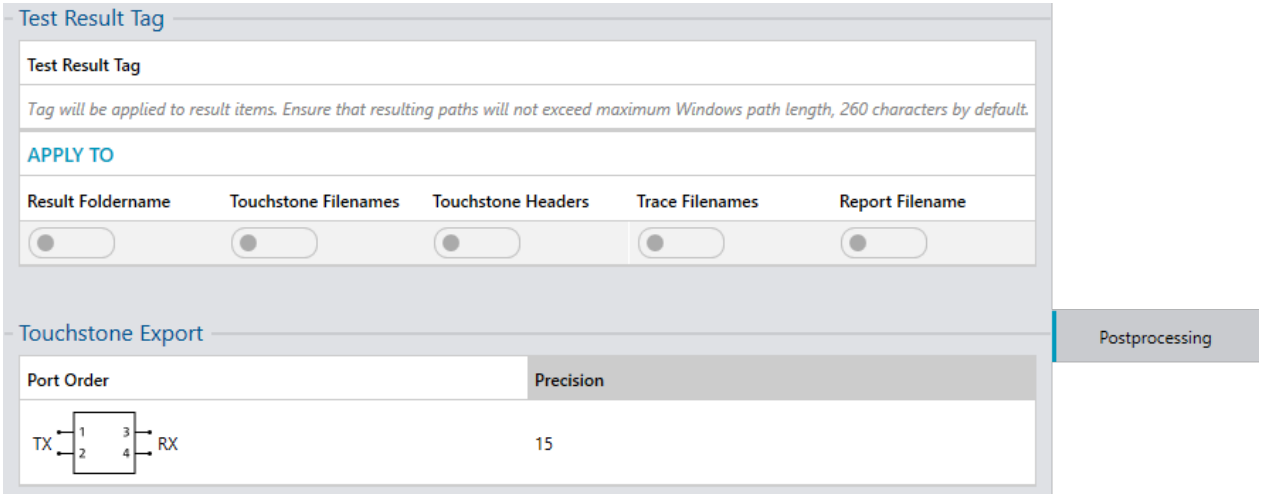
   Your selection is persisted in the recall state file.

- Selecting the TX lanes that contribute to a victim's or RX port's "Powersum" (and ccICN calculations for PCIe) is only possible for generated MOI projects.
- "High-Order Touchstone Export" writes all measured S-parameters to a common `sNp` file, where N is 8 times the number of lanes n.
- For a generated MOI project, the availability of certain test cases and the possibility to customize them depends on the R&S ZNrun version the project was generated with. To get the latest features, re-generate the MOI project with the latest R&S ZNrun version.
- The project generator allows you to create one-sided MOI projects, which means that you can have different measurements on the left and right side of the DUT.



Postprocessing

For both generated an predefined projects, the setup phase offers the same basic postprocessing settings:



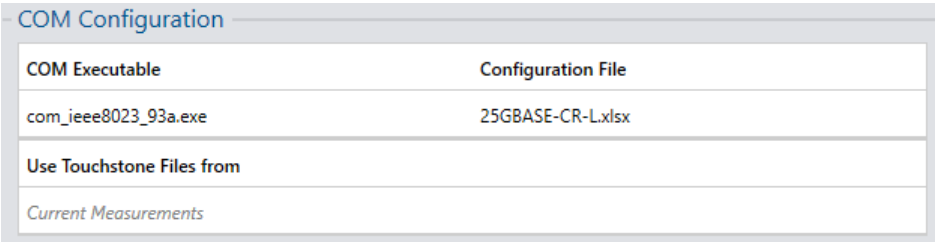
The "Test Result Tag" is a user-defined text that can be added as a prefix to the result folder name, to Touchstone and trace file names (with separator "_"). Furthermore it can be used as the report file name and added to the header of generated Touchstone files.

- Characters `< > : " / \ | ? *` are not allowed.
- In Touchstone headers, the "Test Result Tag" appears as a separate line:
  `! User Input: <Test Result Tag>`
  For maximum compatibility with the Touchstone file format specification, use US-ASCII characters only.

The "Touchstone Export" section is available for all technologies. It allows you to change the port order in the exported Touchstone files. With *N* lanes, either:

- TX ports numbered from 1 to *2N*, RX ports numbered from *2N*+1 to *4N* or
- TX ports even numbers, RX ports odd numbers

The "COM Configuration" section is only available for IEEE 802.3 MOI projects (either predefined or generated). For generated projects, it is only visible if a COM tool was selected during project generation.



You can select (or override for generated projects) the IEEE COM executable and related configuration file to be used for calculating the COM and ERL figures of merit. See "Additional figures of merit: COM and ERL" on page 36.

"Use Touchstone Files from"

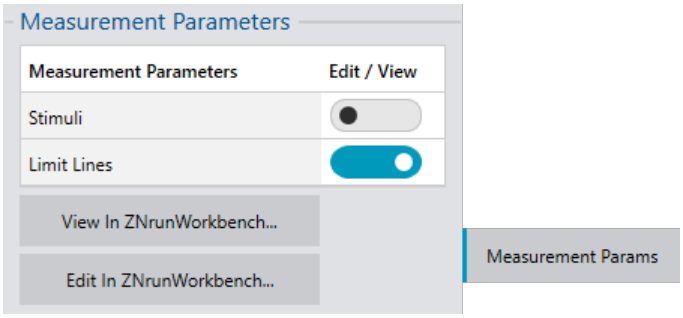
By default, COM and ERL are calculated from the measurement results of the respective measurement cycle ("Current Measurements"). However, you can also calculate them from the results of a previous measurement.

To do so, click the text field and either specify the path to an existing result folder directly, or use the ellipsis button to browse for it. You can unselect all Test Cases except "COM calculation" and immediately go to Measure.

Modified postprocessing settings are persisted in the recall state file.

Measurement Params

Allows you to edit certain measurement parameters. Runs the ZNrun Workbench and opens the appropriate workspaces.



Running the ZNrun Workbench from the ZNrun Cable Test Client is not possible for read-only projects, such as the predefined ones since R&S ZNRUN V2.90.

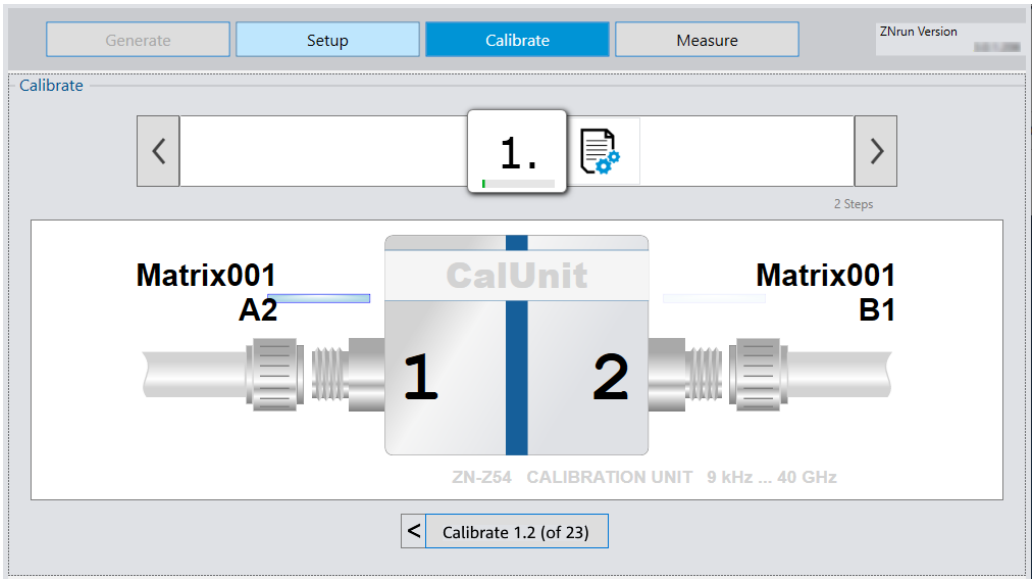
To modify a predefined project, open it directly in the ZNrun Workbench (not via the ZNrun Cable Test Client), make your changes, and save it to a different location. Or copy the project to a different location and remove the read-only flag before opening it in the ZNrun Workbench or ZNrun Cable Test Client.

Proceed with Calibrate or Measure.

7.1.2 Calibrate

After you have completed the Setup, you can enter the calibration phase.

- The calibration is performed using the graphical ZNrun Calibration Client, embedded in the ZNrun Cable Test Client.
- The ZNrun Cable Test Client selects the ports to be calibrated according to the current test case setup.
- A completed calibration is added to the calibration pool of the VNA and to the calibration database of the ZNrun Server.
- In "Simulated" mode (see "Operation modes" on page 80), calibration makes no sense and is not supported.



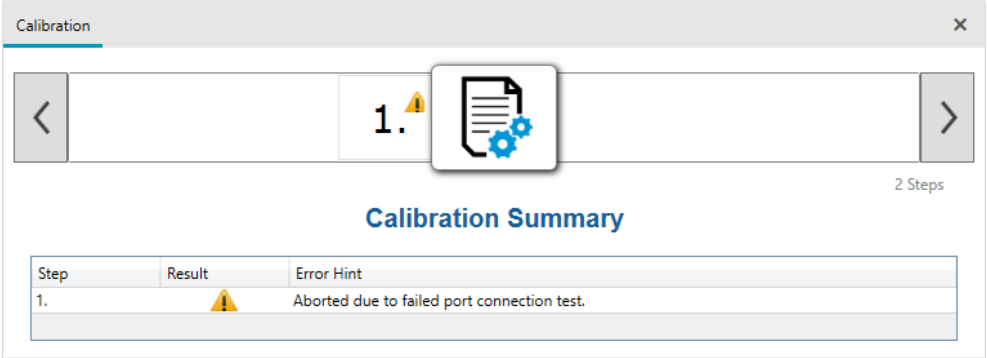
1. In the ZNrun Cable Test Client, click "Calibrate" to run the ZNrun Calibration Client.

   It proceeds in two steps.

2. Step 1 comprises multiple substeps, corresponding to the required cal unit connections. It executes the necessary calibration sweeps, collects the acquired data, calculates the calibration and – if plausible – applies it.
   For substeps *n* from 1 to *N*:

   a) Connect the calibration unit as depicted in the graphical area of the ZNrun Calibration Client.
      Ports that have to be reconnected are marked with a blue bar. The matrix port naming is explained in Section 3.2.4, "Predefined switch matrices for automated cable tests", on page 15.
   b) Click "Calibrate (n/N)" to proceed.
      For substeps 2 to *N*-1, you can always go back to repeat previous substeps.

   In the final substep, "Calibrate (N/N)" starts the calibration sweeps and, subsequently, calculates the calibration result, which can take some time. The ZNrun Calibration Client immediatedely proceeds to the "Calibration Summary":



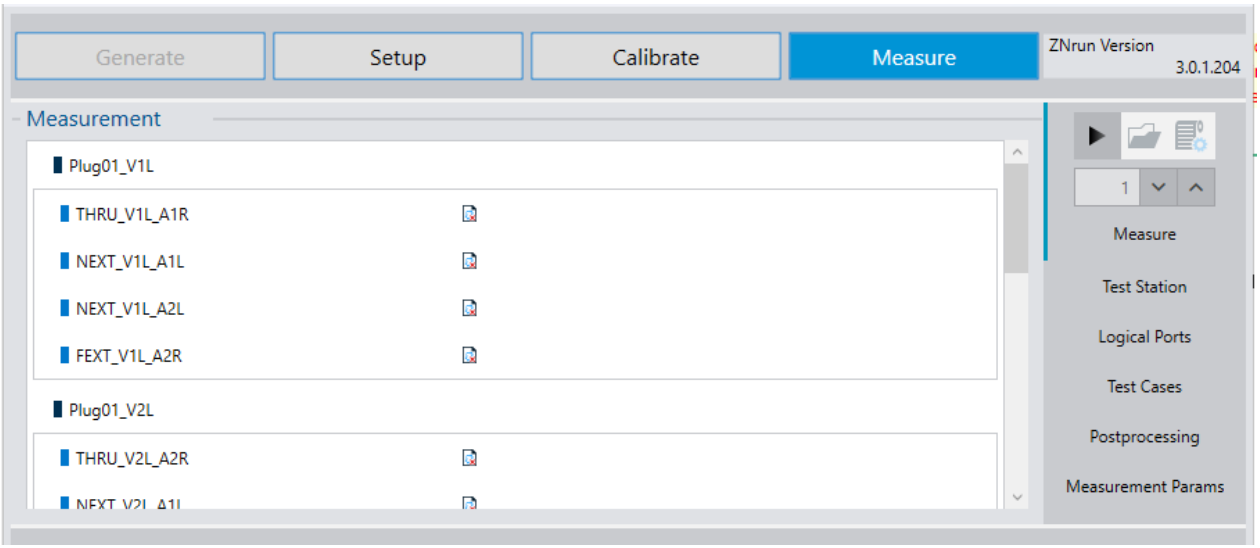
Note: Once you have clicked "Calibrate (N/N)", you cannot go back to repeat previous substeps, but have to repeat the entire step 1.

7.1.3 Measure

After you have completed the setup, you can click "Measure" to enter the measurement phase.

Calibration is optional: If the ZNrun Server finds applicable calibrations in its calibration database and in the cal pool of the selected VNA, it automatically selects the one to be used according to its calibration settings (ZNrun Settings app).

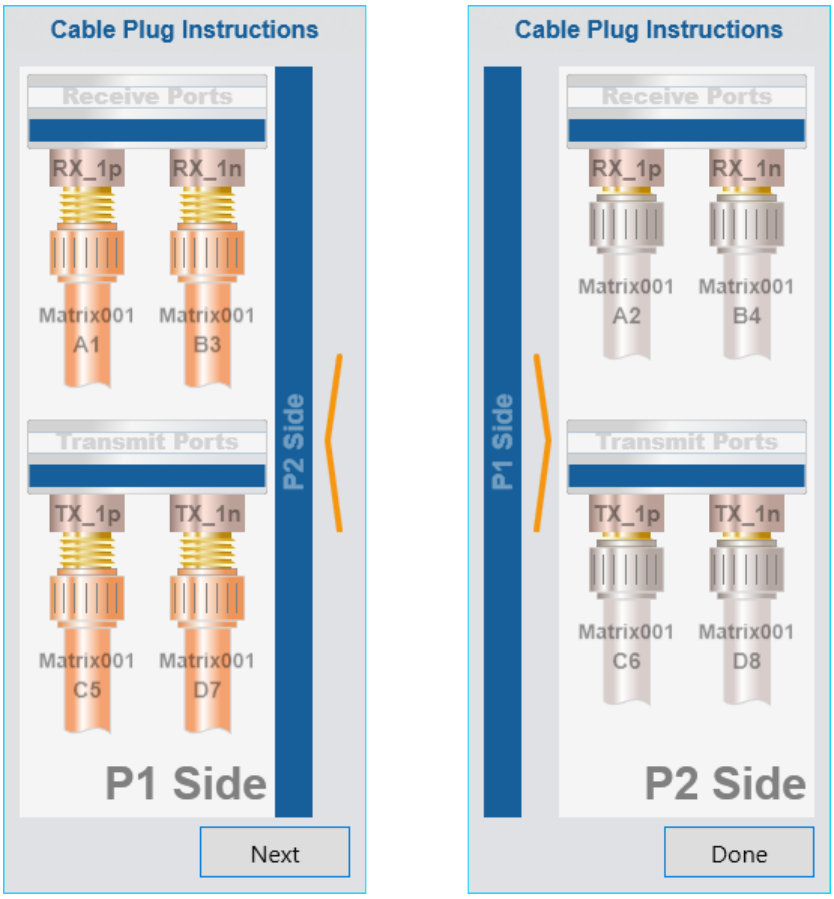
- To speed up measurement on a R&S ZNA with option R&S ZNA-K66, enable fast sweep mode in the ZNrun Settings client.
- When measuring 8 lanes or more with a R&S ZNA, its paging file size of must be set to 90 GB or higher.



For informational purposes, the measurement GUI replicates the configuration tabs of the Setup phase. During measurement, however, most of the settings are read-only.

Since R&S ZNrun V3.10 the "Test Cases" tab allows you to deselect some of the test cases you have selected during the setup phase.

1. For recap:
   a) Go through the other tabs to review the current setup.
   b) If you need to change something other than the test cases, go back to "Setup".
2. Use the (Iterations) control to run the cable test multiple times – and populate multiple output directories – without having to restart the measurement again and again.
3. Click ("Start") to run the measurement.
4. Follow the cable plug instructions for both sides of the DUT ("P1 Side", "P2 Side"), to set up the connections between (VNA or) switch matrix and cable fixtures correctly. The matrix port naming is explained in Section 3.2.4, "Predefined switch matrices for automated cable tests", on page 15.



5. If prompted to do so, flip the cable under test.

   The ZNrun Server executes the selected Test Cases.

After the VNA has finished the THRU, NEXT and FEXT measurements, the ZNrun Server enters the "Data collection and processing phase", i.e.

- It saves the selected measurement results and exports to a directory `ZNrun\<MOI name>\<Timestamp>` of your user documents directory (typically `C:\Users\<username>\Documents\`).
- It performs the selected evaluations.
- If selected, it generates a PDF report summarizing the test results.
- It saves the measurement results, other selected exports and the report to a directory `ZNrun\<MOI name>\<Timestamp>` of your user documents directory (typically `C:\Users\<username>\Documents\`).

Setup sharing

Setup sharing was introduced in R&S ZNrun version 3.0, and was initially referred to as "Delta initialization".

If enabled for a synchronous measurement context (SMC), then during measurement initialization a **single "shared" setup** is created on the VNA, instead of one setup per port group (default). This speeds up the initialization and reduces the memory footprint on the VNA, which is particularly useful for R&S ZNA. However, measurement times slightly increase.

Because for muti-lane cable tests, setup sharing can yield substantial time and memory savings, it is enabled for each SMC of the predefined and generated cable test projects. To take effect, however, setup sharing must be **globally** enabled in the ZNrun Settings client ("Use Setup Sharing Mode"). By default it is globally **disabled**.

7.1.4 Generate

The R&S ZNRUN-K400 MOI project generator allows you to create custom MOI projects.

- The project generator creates encrypted ZNrun project files (`*.znrun`).
- You don't need option R&S ZNRUN-K400 to *generate* custom projects. To *run* them, however, you need the option on the target ZNrun Server.

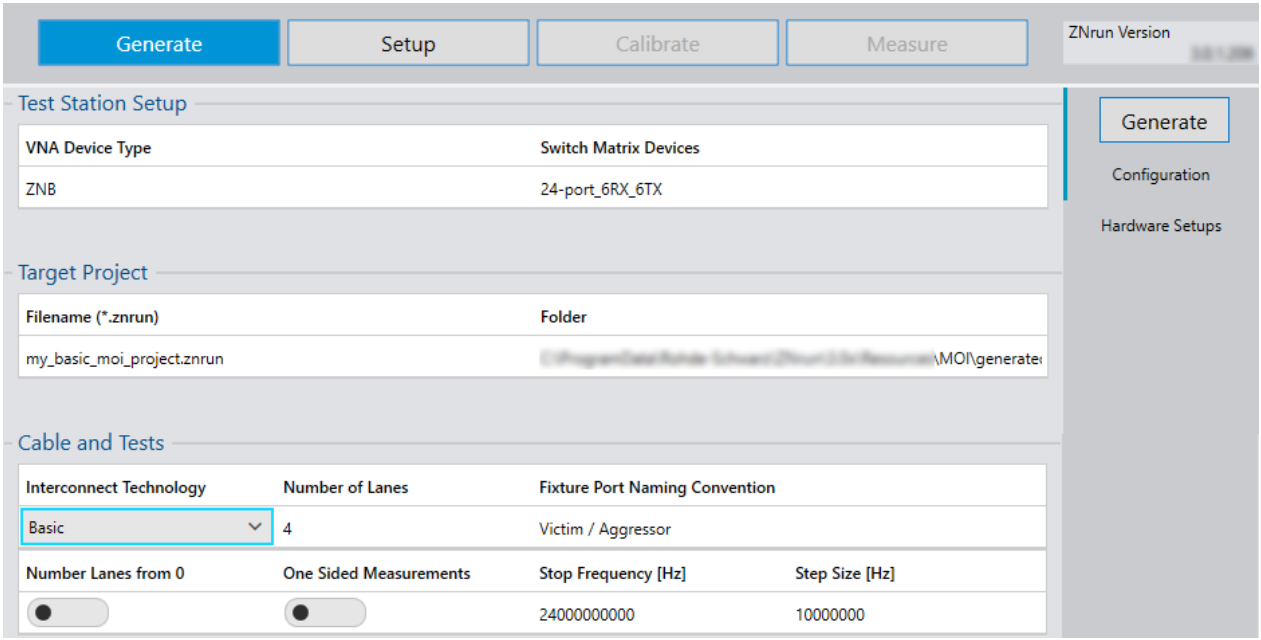


Figure 7-7: Project generator, Configuration panel, Interconnect Technology: Basic

Click "Generate" in the phase selection area, to run the project generator and display its "Configuration" view.

Configuration

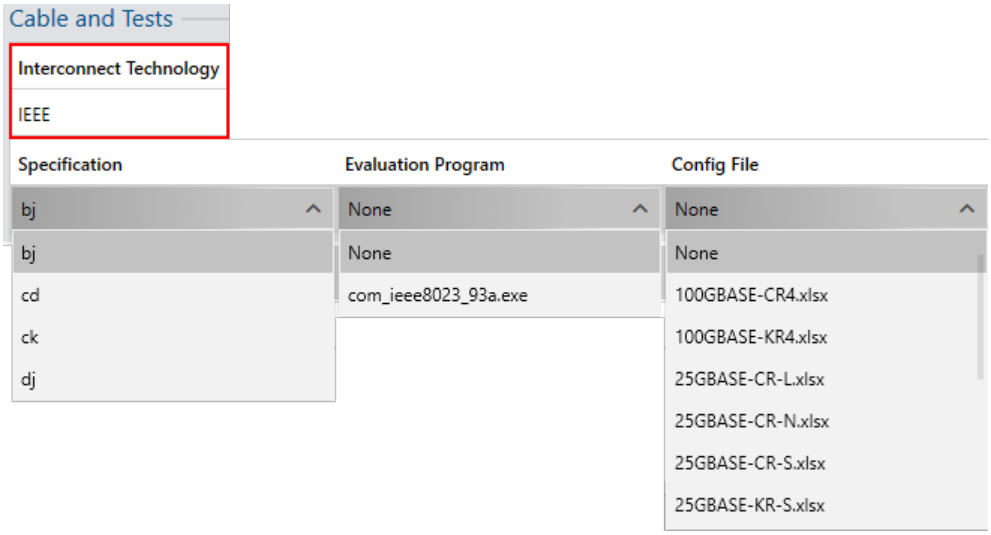
Before you generate a custom MOI project, consider the test station equipment that is available at the target site.

- If the selected "VNA Device Type" is not available, certain optimizations cannot be performed.
- The selected "Switch Matrix Devices" cannot be changed at runtime, i.e. without re-generating the project.

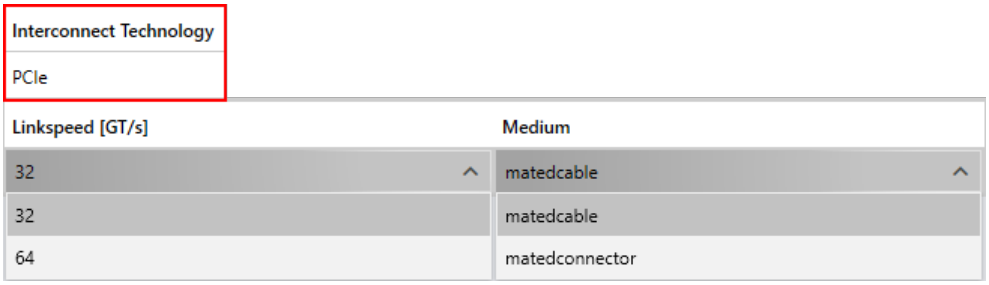
1. "Test Station Setup":
   a) Select the suitable "VNA Device Type". See Section 3.1.3, "Recommended/ supported models", on page 9.
   b) Select suitable "Switch Matrix Devices", i.e. one of the matrix solutions described in section Section 6.2, "Supported matrix solutions", on page 64.
   Open the Hardware Setups panel to display these solutions in the ZNrun Cable Test Client.
2. "Target Project":
   Specify filename and folder of the encrypted MOI project (`*.znrun` file) to be generated.
3. "Cable and Tests" > "Interconnect Technology"

The fundamental decision regarding the generated project. You can select between "Basic" and one of the interconnect technologies that R&S ZNrun supports with dedicated R&S ZNRUN-K4xx options.
If you select one of the standard bodies, then additional settings appear below the "Interconnect Technology" combo-box. These settings allow you to tailor the test according to a cable or connector type defined in the related standards. Similar to the predefined R&S ZNRUN-K4xx projects that are delivered with the R&S ZNrun installer. The related standard(s) impose certain postprocessings, evaluations and limits.

- "IEEE"
  For "Inerconnect Type" IEEE, you can specify the target specification and the COM tool to be used, along with its config file. See Section 4, "IEEE 802.3 compliance tests (R&S ZNRUN-K41x)", on page 34.

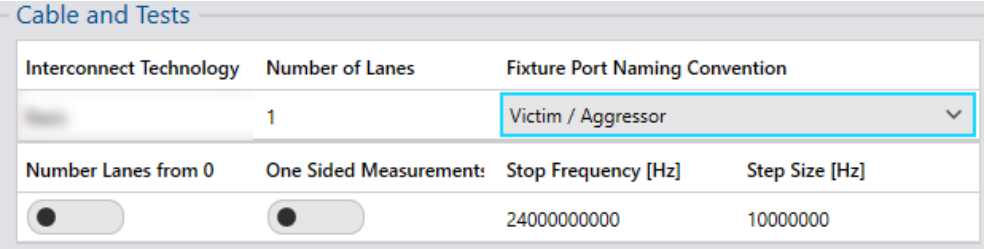


- "PCIE":
  For "Inerconnect Type" PCIe, you can specify the link speed in Gigatransfers per second, and whether cables or connectors shall be measured. The latter determines the applicable limits. See Section 5, "PCI Express compliance tests (R&S ZNRUN-K440)", on page 51.



- "Basic":
  With this selection, you only have the basic settings described below.

4. "Cable and Tests" > Basic settings



These settings are available for all interconnect technologies.

a) Select the "Number of Lanes" *N* you want to measure.

b) Choose your preferred port naming scheme by selecting the suitable "Fixture Port Naming Convention" and by deciding whether to "Number Lanes from 0" or from 1.
"Number of Lanes", "Fixture Port Naming Convention", "Number Lanes from 0", and the "Switch Matrix Devices" determine the connection plan (see Section 6.3, "Connection plans", on page 68).

c) The "One Sided Measurement" toggle defines whether the test cases for victim (RX) ports are "vertically symmetrical", or if you can have different test cases for the left and right side.
With "One Sided Measurement" enabled, you can toggle and configure the V<n>R measurements in the Test Cases step of the "Setup" phase.

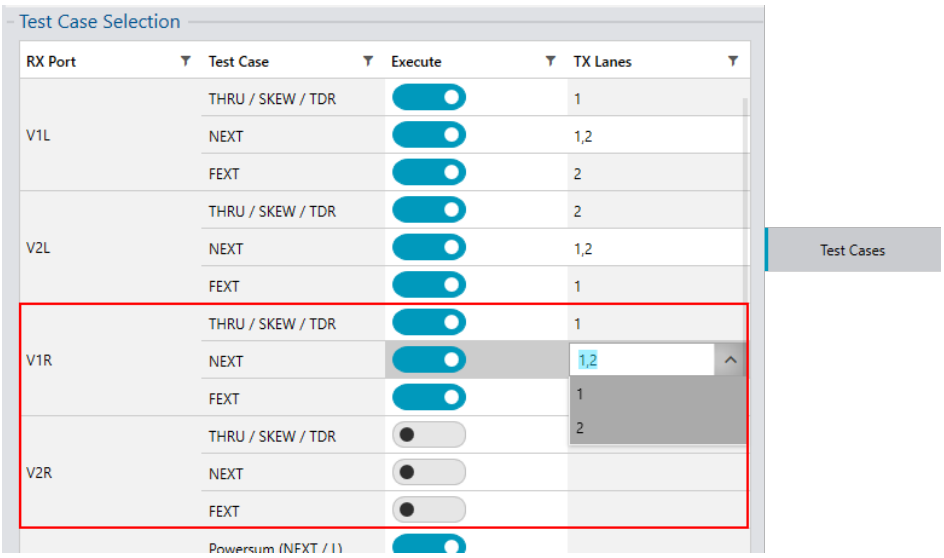


Figure 7-8: One Sided Measurements: "R" victim ports visible & configurable

Note that for predefined MOI projects, "One Sided Measurement" is not available.

d) "Stop Frequency [Hz]" and "Step Size [Hz]" determine the frequency sweep that the VNA performs.

5. "Generate"

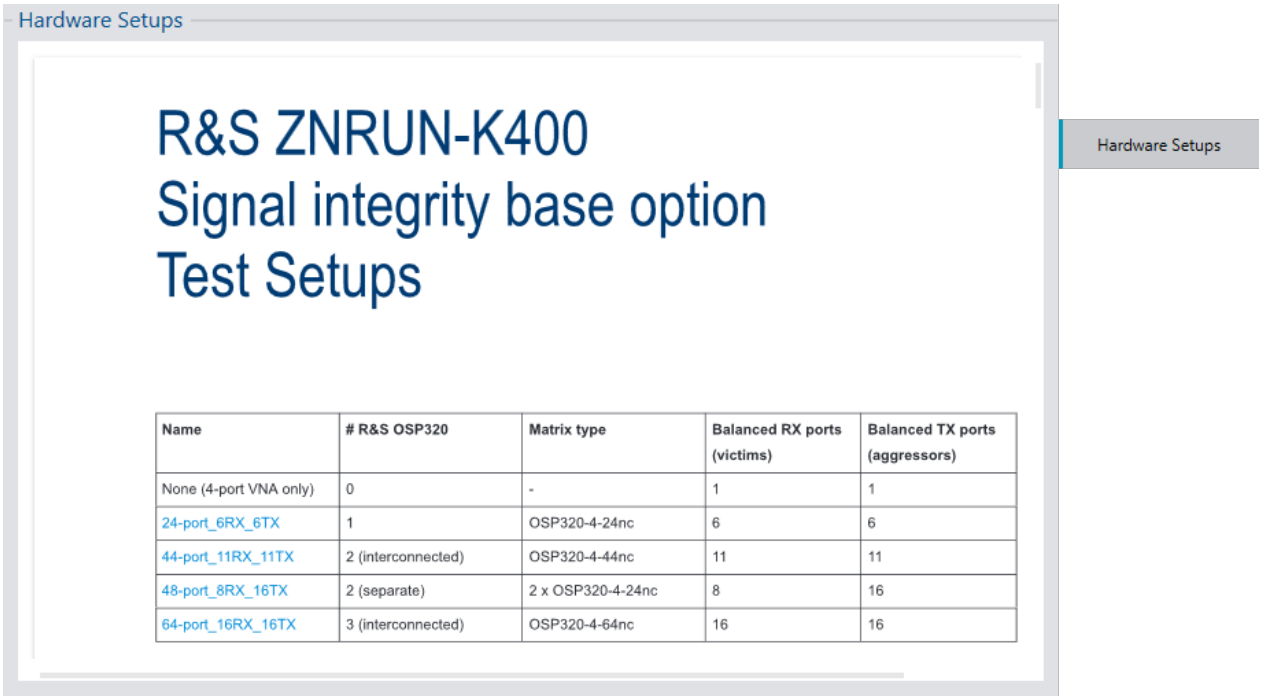
Finally click the right-hand "Generate" button to create the MOI project file (`*.znrun`) and a connection plan file (`*.connections`) in the same directory ("Folder").

In this manual, screenshots of *generated* MOI projects always show the default port naming scheme, i.e. fixture ports are classified as **V**ictim or **A**ggressor, and lane numbers start from 1.

If you select IEEE (or PCIe) as "Interconnect Technology", then **at runtime** you need option R&S ZNRUN-K400 plus the related technology option R&S ZNRUN-K41x (or K440).

Hardware Setups

The "Hardware Setups" panel displays the matrix solutions described in section Section 6.2, "Supported matrix solutions", on page 64.



Name	# R&S OSP320	Matrix type	Balanced RX ports (victims)	Balanced TX ports (aggressors)
None (4-port VNA only)	0	-	1	1
24-port_6RX_6TX	1	OSP320-4-24nc	6	6
44-port_11RX_11TX	2 (interconnected)	OSP320-4-44nc	11	11
48-port_8RX_16TX	2 (separate)	2 x OSP320-4-24nc	8	16
64-port_16RX_16TX	3 (interconnected)	OSP320-4-64nc	16	16

Click one of the links in the "Name" column of the overview table to jump to the corresponding matrix solution.

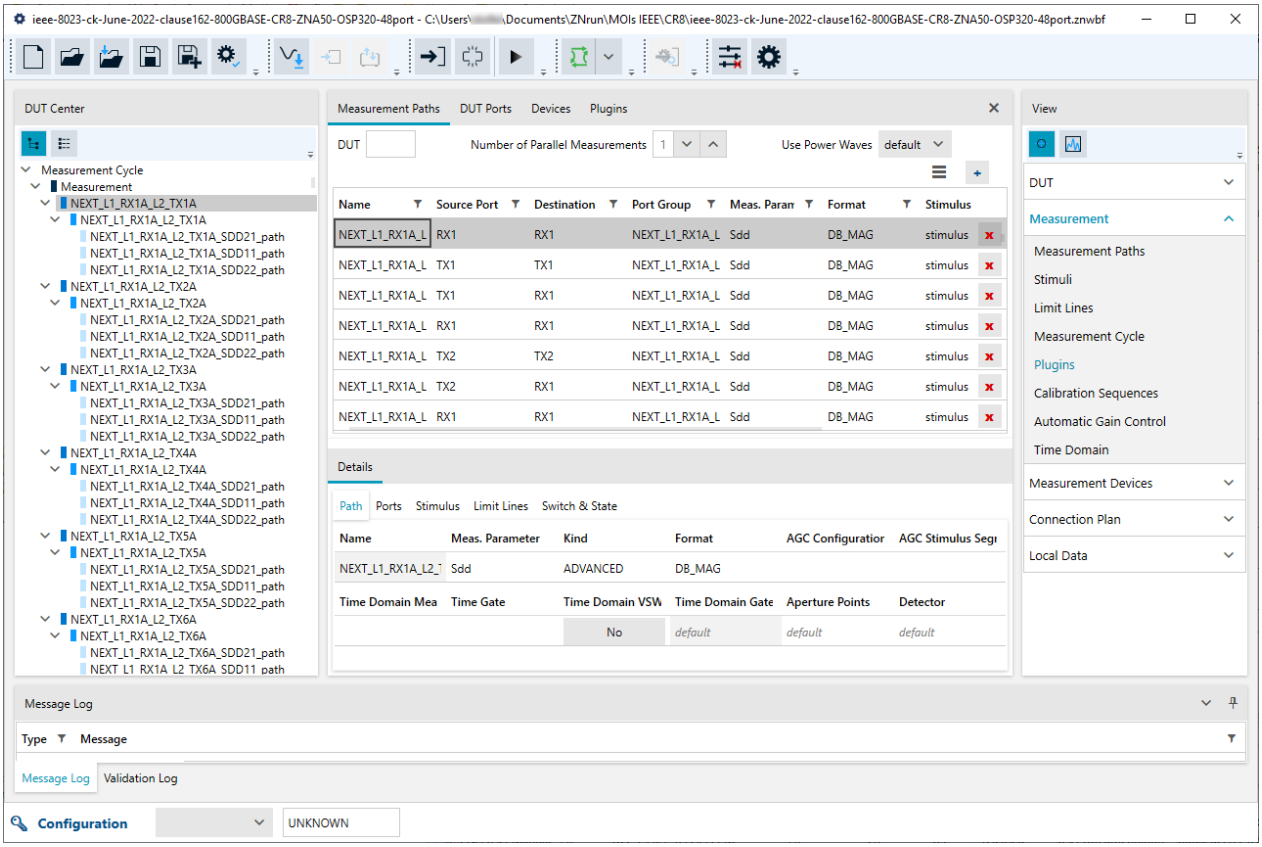
7.2 Working with the ZNrun Workbench

The ZNrun Workbench allows you to:

- Edit existing MOI projects.

By modifying the test parameters of a compliance test project (stimuli, limits, etc.), you can execute first plausibility measurements before starting the full compliance test.

- Debug existing MOI projects.
  If you run a MOI project from the ZNrun Workbench, you can set breakpoints or use step-by-step execution to analyze non-passing measurements.



Protected R&S ZNrun-K4xx projects remain protected when edited and saved. They can be executed on a ZNrun Server with suitable K4xx option, but cannot be rolled out. Furthermore, the ZNrun Server runs them exclusively (see "Exclusive measurement execution" on page 96).

Exclusive measurement execution

The ZNrun Server runs the protected R&S ZNrun-K4xx projects as exclusive measurement execution units, i.e.:

- Only the executing client (ZNrun Cable Test Client or ZNrun Workbench) has access to the MEU. Other clients cannot connect to it.
- During execution, the MEU and registered plugins have only limited access to the properties of the ZNrun project.
- The ZNrun Server unloads the MEU when execution stops.