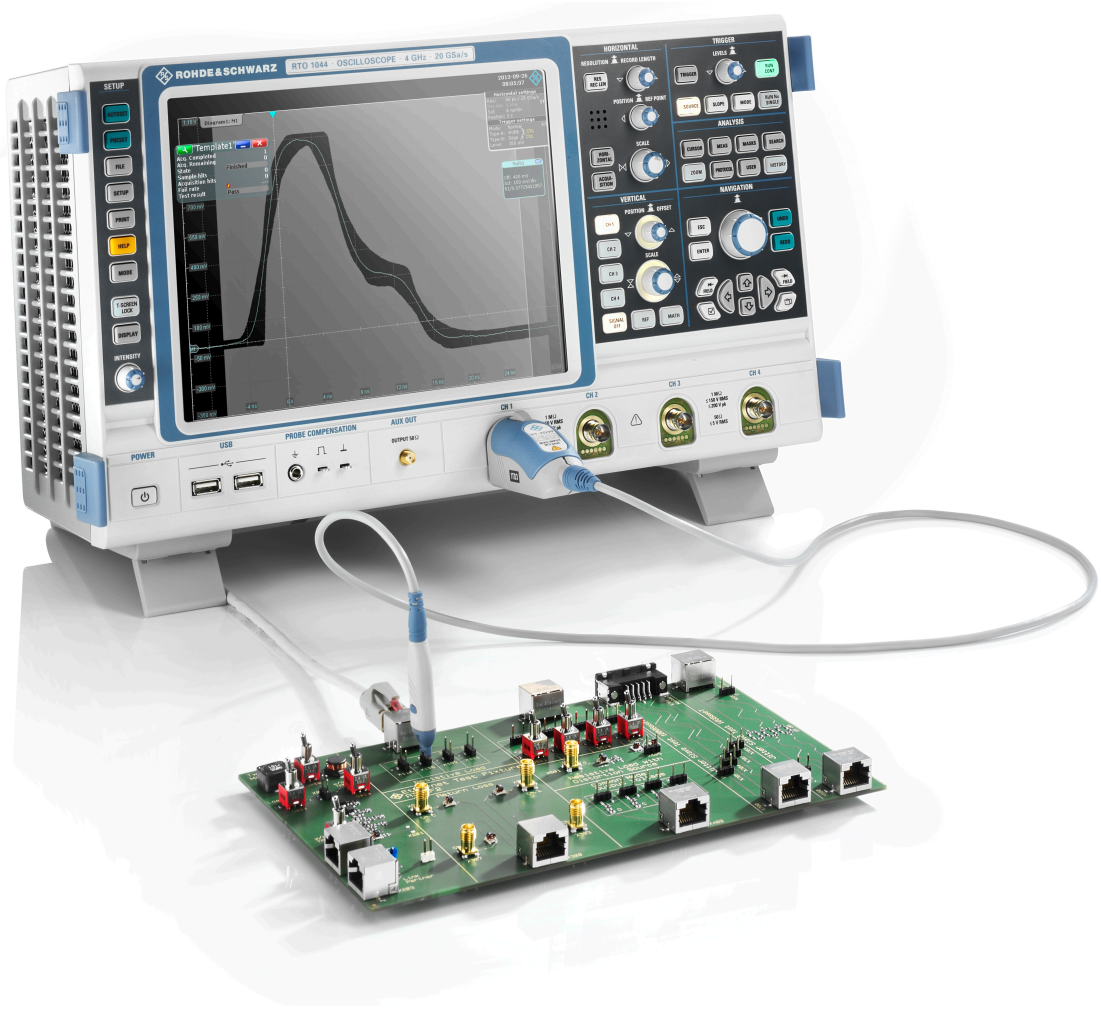
R&S®RTO-K22/K23/K24
Ethernet Compliance Test
Test Procedures



1317.7202.02 ─ 06

Test & Measurement

Test Procedures

ROHDE&SCHWARZ

This manual describes the Ethernet compliance test procedures with the following options:

- R&S®RTO-K22 (1317.4678.02) - 10/100/1000BASE-T
- R&S®RTO-K23 (1320.6261.02) - 10GBASE-T
- R&S®RTO-K24 (1320.6684.02) - BroadR-Reach

The tests require the R&S RT-ZF2 Ethernet Test Fixture (1317.5522.02) and the R&S ScopeSuite software.

The software contained in this product makes use of several valuable open source software packages. For information, see the "Open Source Acknowledgement" document, which is available for download from the R&S RTO product page at http://www.rohde-schwarz.com/product/rto.html > "Software".
Rohde & Schwarz would like to thank the open source community for their valuable contribution to embedded computing.

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The following abbreviations are used throughout this manual: R&S®RTO is abbreviated as R&S RTO, and R&S®ScopeSuite is abbreviated as R&S ScopeSuite.

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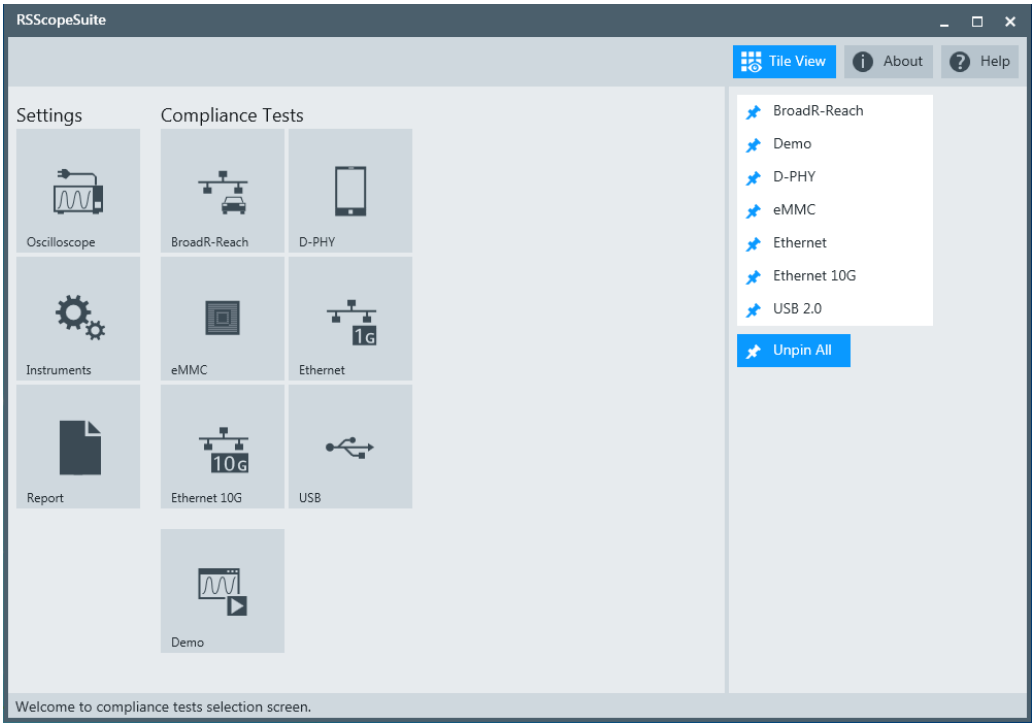
1 R&S ScopeSuite Overview

The R&S ScopeSuite software is used with R&S RTO oscilloscopes. It can be installed on a test computer or directly on the R&S RTO if the instrument has the Windows 7 operating system.



The R&S ScopeSuite main panel has several areas:

- "Settings": connection settings to oscilloscope and other instruments as well as default report settings
- "Compliance Tests": selection of the compliance test
- "Demo": accesses demo test cases that can be used for trying out the software without having a connection to an oscilloscope
- "Help": opens the help file, conatining information about the R&S ScopeSuite configuration
- "About": gives information about the R&S ScopeSuite software
- "Tile View": allows a personalization of the compliance test selection
  You can configure which tests are visible in the compliance test section and which are hidden, so that only the ones you use are displayed.

► To hide a test from the "Compliance Tests" view do one of the following:

a) Right-click on the compliance test you want to hide.
The icon of the test changes, see Figure 1-1. Now with a left click you can hide the test

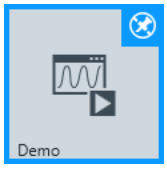


Figure 1-1: Unpin icon

b) Click on "Title View" to show a list of the available test cases. By clicking on a test case in the show list you can pin/unpin it from the main panel.

2 Preparing the Measurements

2.1 Test Equipment

For Ethernet compliance tests, the following test equipment is needed:

- R&S RT-ZF2 Ethernet test fixture set
- **10/100/1000BASE-T Ethernet compliance tests:**
  - R&S RTO oscilloscope with at least 600 MHz bandwidth
  - Differential probe with at least 1 GHz bandwidth
  - R&S RTO-K22 10/100/1000BASE-T Ethernet compliance test option (required option, installed on the R&S RTO)
  - R&S RT-ZF2 Ethernet test fixture set
- **10GBASE-T Ethernet compliance tests:**
  - R&S RTO oscilloscope with at least 2 GHz bandwidth
  - Differential probe with at least 2 GHz bandwidth
  - R&S RTO-K23 10GBASE-T Ethernet compliance test option (required option, installed on the R&S RTO)
  - R&S RT-ZF2 Ethernet test fixture set
- **BroadR-Reach compliance tests:**
  - R&S RTO oscilloscope with at least 600 MHz bandwidth
  - Differential probe with 1 GHz bandwidth
  - R&S RTO-K24 BroadR-Reach compliance test option (required option, installed on the R&S RTO)
  - R&S RT-ZF2 Ethernet test fixture set
- The free-of-charge R&S ScopeSuite software, which can be installed on a computer or directly on the R&S RTO.
- Tabor WX2182B/WX2182C or HAMEG HMF2550 arbitrary waveform generator for disturber tests
- R&S ZVL/R&S ZNB/R&S ZNC/R&S ZND vector network analyzer for return loss measurements

2.2 Installing Software and License

The preparation steps have to be performed only once for each computer and instrument that are used for testing.

NOTICE

Uninstall older versions of the R&S ScopeSuite

If an older version of the R&S ScopeSuite is installed, make sure to uninstall the old version before you install the new one. You can find the version number of the current installation in "Help" menu > "About". To uninstall the R&S ScopeSuite, use the Windows Control Panel > "Programs".

To install the R&S ScopeSuite

1. Download the R&S ScopeSuite software from the "Software" section on the Rohde & Schwarz R&S RTO website: www.rohde-schwarz.com/product/rto.html.
2. Install the R&S ScopeSuite software:
   - Either on the computer that is used for testing,
   - or on the R&S RTO if the instrument has a Windows 7 operating system.

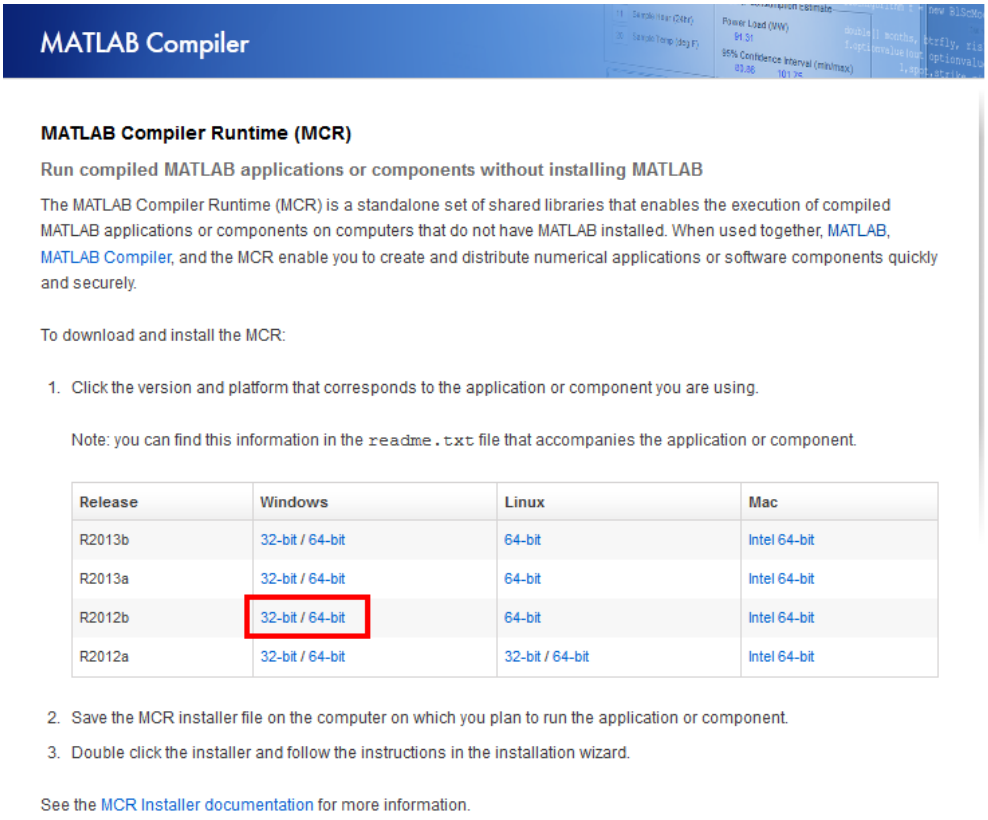
To install the license key on the R&S RTO

► When you got the license key of the compliance test option, enable it on the R&S RTO using SETUP > "SW Options".
For a detailed description, refer to the R&S RTO User Manual, chapter "Installing Options", or to the online help on the instrument.

To install the MATLAB Compiler Runtime on the test computer

For some of the 1000BASE-T test cases you have to install the MATLAB Compiler Runtime (MCR) on the computer that is running the R&S ScopeSuite. The R2012b Windows 32-bit version is required.

1. Download the "R2012b Windows 32-bit" MCR installation file from www.mathworks.com/products/compiler/mcr/ and save it to the test computer.



MATLAB Compiler

MATLAB Compiler Runtime (MCR)

Run compiled MATLAB applications or components without installing MATLAB

The MATLAB Compiler Runtime (MCR) is a standalone set of shared libraries that enables the execution of compiled MATLAB applications or components on computers that do not have MATLAB installed. When used together, MATLAB, MATLAB Compiler, and the MCR enable you to create and distribute numerical applications or software components quickly and securely.

To download and install the MCR:

1. Click the version and platform that corresponds to the application or component you are using.

   Note: you can find this information in the `readme.txt` file that accompanies the application or component.

Release	Windows	Linux	Mac
R2013b	32-bit / 64-bit	64-bit	Intel 64-bit
R2013a	32-bit / 64-bit	64-bit	Intel 64-bit
R2012b	32-bit / 64-bit	64-bit	Intel 64-bit
R2012a	32-bit / 64-bit	32-bit / 64-bit	Intel 64-bit

2. Save the MCR installer file on the computer on which you plan to run the application or component.
3. Double click the installer and follow the instructions in the installation wizard.

See the MCR Installer documentation for more information.

2. Double-click the installation file and follow the instruction in the installation wizard.

2.3 Setting Up the Network

If the R&S ScopeSuite software runs on a test computer, the computer and the testing R&S RTO require a LAN connection.

For some test cases, you need an additional instrument: arbitrary waveform generator (AWG), vector network analyzer (VNA), or spectrum analyzer. These instruments can be used in automatic or manual mode. For automatic testing, a LAN connection to the additional instrument is required.

There are two ways of connection:

- LAN (local area network): It is recommended that you connect to a LAN with DHCP server. This server uses the Dynamic Host Configuration Protocol (DHCP) to assign all address information automatically.
  If no DHCP server is available, or if the Tabor WX2182B is used for automatic testing, assign fixed IP adresses to all devices.
- Direct connection of the instruments and the computer or connection to a switch using LAN cables: Assign fixed IP addresses to the computer and the instruments and reboot all devices.

To set up and test the LAN connection

1. Connect the computer and the instruments to the same LAN.
2. Start all devices.
3. If no DHCP server is available, assign fixed IP addresses to all devices.
4. Ping the instruments to make sure that the connection has been established.
5. If VISA is installed, check if VISA can access the instruments.
   a) Start VISA on the test computer.
   b) Validate the VISA address string of each device.

See also:

- Chapter 2.5, "Connecting the R&S RTO", on page 14
- Chapter 2.6, "Connecting the Arbitrary Waveform Generator", on page 16
- Chapter 2.7, "Connecting the Vector Network Analyzer", on page 17
- Chapter 2.8, "Connecting the Spectrum Analyzer", on page 18

2.4 Starting the R&S ScopeSuite

To start the R&S ScopeSuite on the test computer or on the oscilloscope:

► Double-click the R&S ScopeSuite program icon.

To start the R&S ScopeSuite on the instrument, in the R&S RTO firmware:

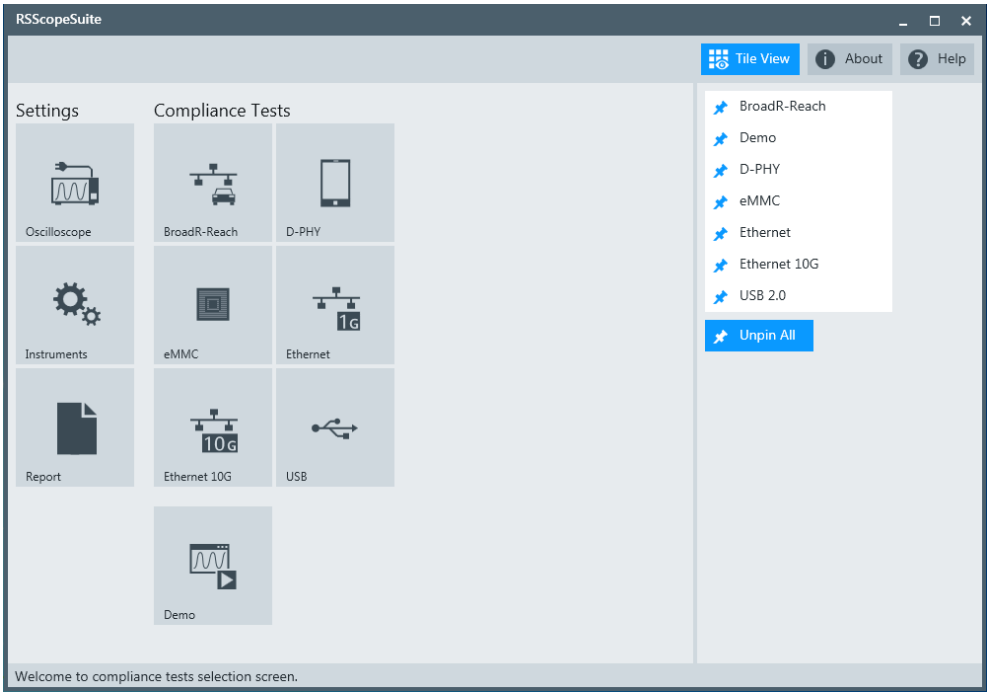
► On the "Analysis" menu, tap "Start Compliance Test".

2.5 Connecting the R&S RTO

If the R&S ScopeSuite is installed directly on the instrument, the software detects the R&S RTO firmware automatically, and the "Oscilloscope" button is not available in the R&S ScopeSuite.

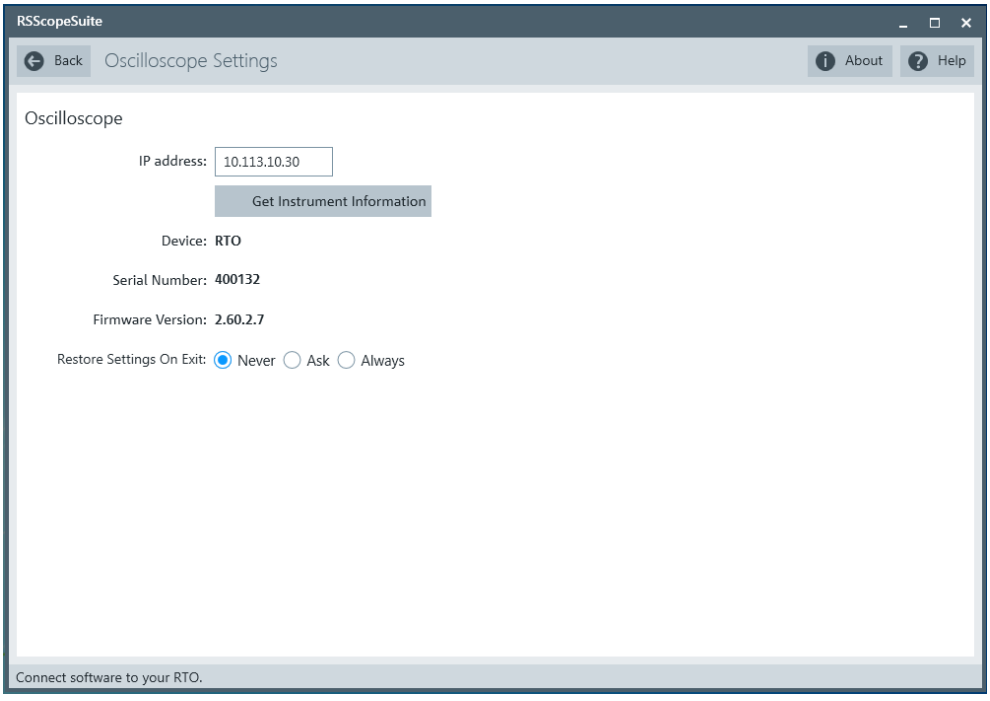
If the R&S ScopeSuite software runs on a test computer, the computer and the testing R&S RTO require a LAN connection, see Chapter 2.3, "Setting Up the Network", on page 13. The R&S ScopeSuite software needs the IP address of the R&S RTO to establish connection.

1. Start the R&S RTO.
2. Start the R&S ScopeSuite software.
3. Click "Settings" > "Osilloscope".



4. Enter the IP address of the R&S RTO.
   To obtain the IP address: Press the SETUP key on the instrument and tap the "System" tab.
5. Click "Get Instrument Information".

   The computer connects with the instrument and gets the instrument data.



If the connection fails, an error message is shown.

2.6 Connecting the Arbitrary Waveform Generator

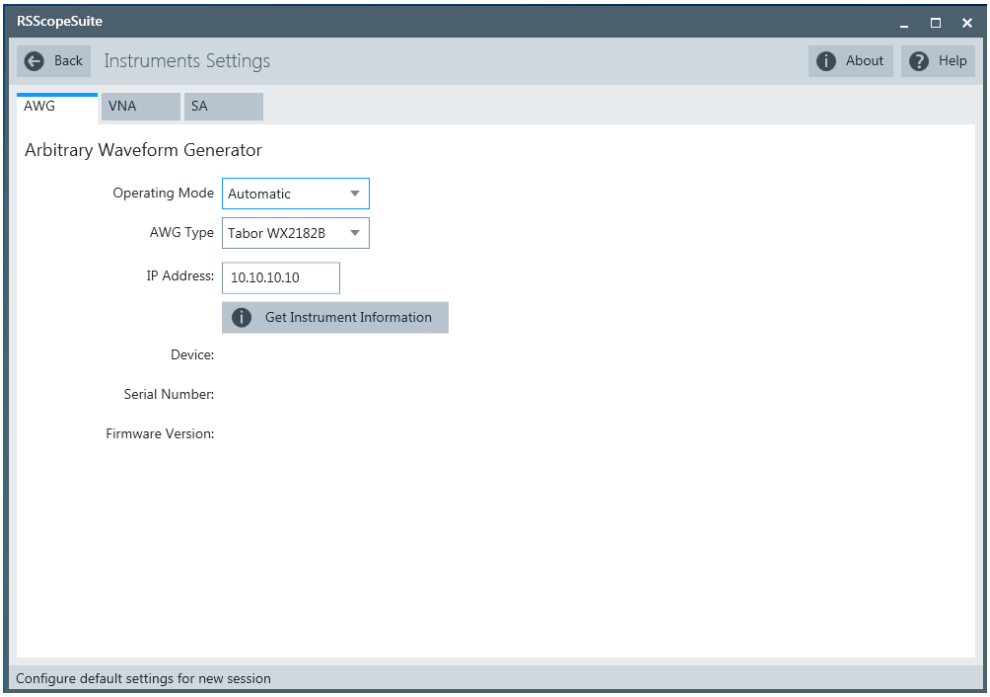
For Ethernet tests using a disturber, an arbitrary waveform generator (AWG) is required. The tests can be performed manually or automatically, depending on the the available AWG.

Automatic test execution is possible with all instruments that are listed in the dialog box. In automatic mode, the R&S ScopeSuite configures the instrument and ensures that the AWG sends the required waveforms. Automatic mode requires a LAN connection and the installation of a VISA implementation (NI-VISA, Agilent-VISA, Tektronic-VISA 4.0 and above) on the computer that is running the R&S ScopeSuite. If the R&S ScopeSuite is installed on the R&S RTO, no installation is needed because VISA is already installed on the instrument. If the Tabor WX2182B is used for automatic testing, fixed IP addresses are required.

For manual test execution it is recommended to use one of the listed AWGs. Moreover, any AWG can be used that has a sampling rate above 1.44 GSa/sec. In manual mode, you connect the AWG to the test board and configure the instrument manually. VISA is not required. The R&S ScopeSuite uses VISA if it is installed, otherwise it uses the VXI-11 protocol.

To configure the arbitrary waveform generator for automatic testing

1. Connect the computer and the AWG and set up the LAN connection, see Chapter 2.3, "Setting Up the Network", on page 13.
2. In the R&S ScopeSuite, click "Instruments".
3. Click the "AWG" tab.
4. Select the "Automatic" operating mode.
5. Select the "AWG Type" and enter its IP address.



6. Click "Get Instrument Information".

   The computer or R&S RTO connects with the instrument and retrieves the instrument data.

7. If the connection to the Tabor arbitrary waveform generator failed, check on the instrument and if the IP address is assigned correctly.

To configure the AWG for manual testing

► In the "AWG" tab, enable the "Manual" operating mode.

2.7 Connecting the Vector Network Analyzer

The vector network analyzer (VNA) is required to perform Ethernet return loss measurements.

Similar to the AWG, the VNA can be used in automatic or manual mode. Automatic mode is supported with R&S ZVL, R&S ZNB and R&S ZNC and requires a LAN connection and a VISA installation on the computer that is running the R&S ScopeSuite. If the R&S ScopeSuite is installed on the R&S RTO, no installation is needed because VISA is already installed on the instrument.

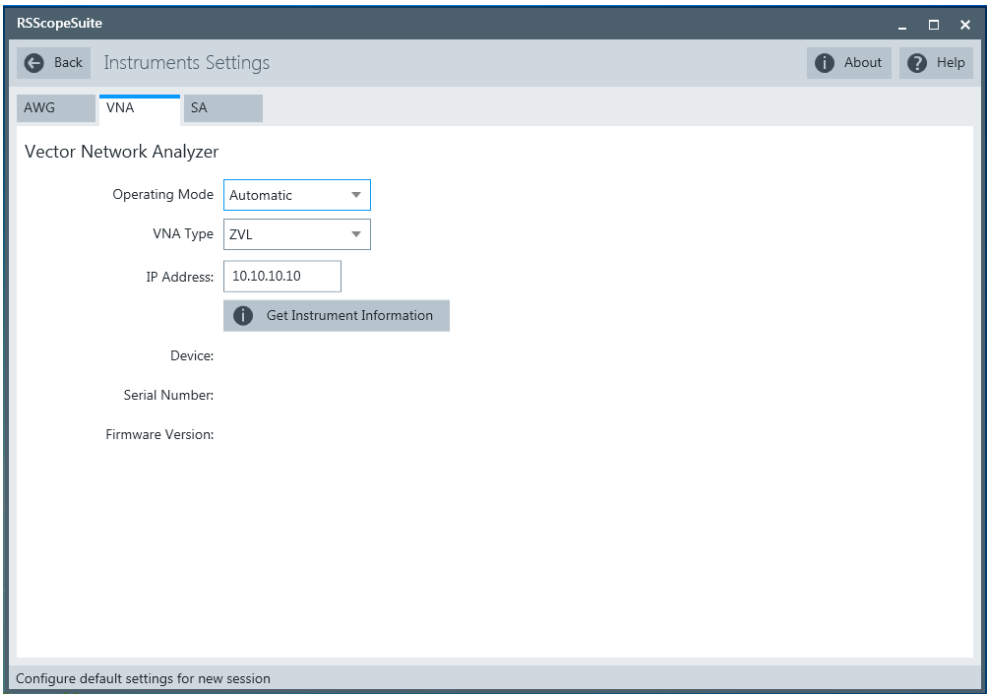
For manual test execution it is recommended to use one of the listed VNAs. Moreover, any VNA can be used that meets the following requirements:

- S11 parameter measurements are possible
- Can export trace data in Touchstone (*.s1p) or *.csv format
- Supports frequency range 1 MHz to 500 MHz

In manual mode, you connect the vector network analyzer to the test board and configure the instrument manually.

To connect the vector network analyzer for automatic testing

1. Connect the computer and the VNA and set up the LAN connection, see Chapter 2.3, "Setting Up the Network", on page 13.
2. In the R&S ScopeSuite, click "Instruments".
3. Click the "VNA" tab.
4. Select the "Automatic" operating mode.
5. Select the "VNA Type" and enter its IP address.



6. Click "Get Instrument Information".

   The computer or R&S RTO connects with the instrument and retrieves the instrument data.

2.8 Connecting the Spectrum Analyzer

A spectrum analyzer is required to perform Ethernet 10GBASE-T transmitter linearity tests.

Similar to the AWG, the spectrum analyzer can be used in automatic or manual mode. Automatic mode is supported with R&S FSV and R&S FSQ. It requires a LAN connection and a VISA installation on the computer that is running the R&S ScopeSuite. If the

R&S ScopeSuite is installed on the R&S RTO, no installation is needed because VISA is already installed on the instrument.

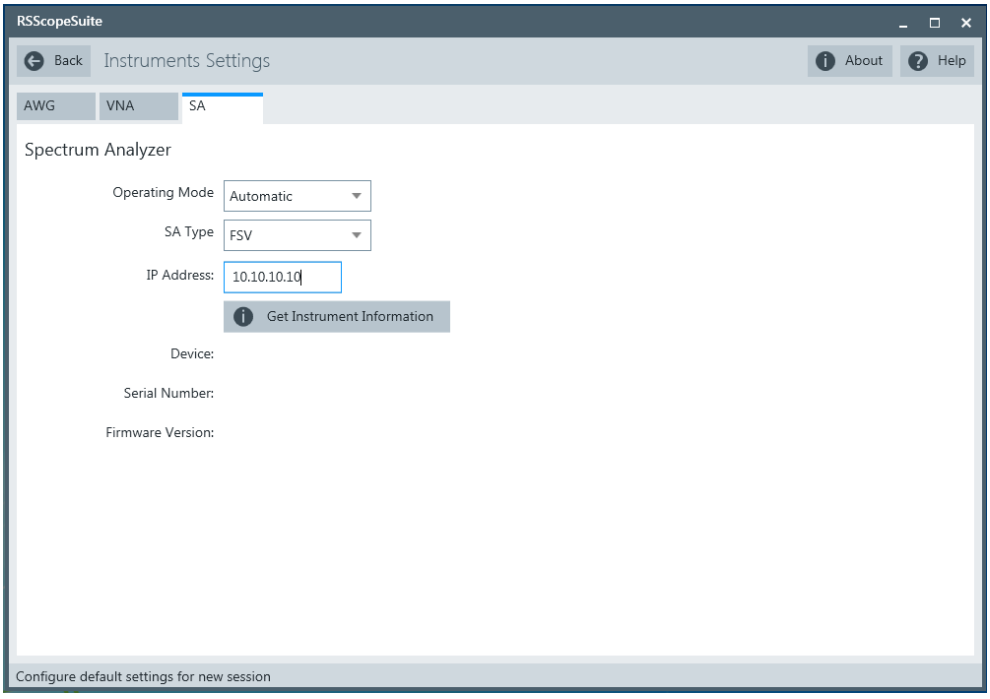
For manual test execution it is recommended to use one of the listed spectrum analyzers. Moreover, any spectrum analyzer can be used that meets the following requirements:

- Frequency range from 1 MHz to 400 MHz
- RF input attenuation greater than 35 dB

In manual mode, you connect the spectrum analyzer to the test board and configure the instrument manually.

To connect the spectrum analyzer for automatic testing

1. Connect the computer and the spectrum analyzer and set up the LAN connection, see Chapter 2.3, "Setting Up the Network", on page 13.
2. In the R&S ScopeSuite, click "Instruments".
3. Click the "SA" tab.
4. Select the "Automatic" operating mode.
5. Select the "SA Type" and enter its IP address.



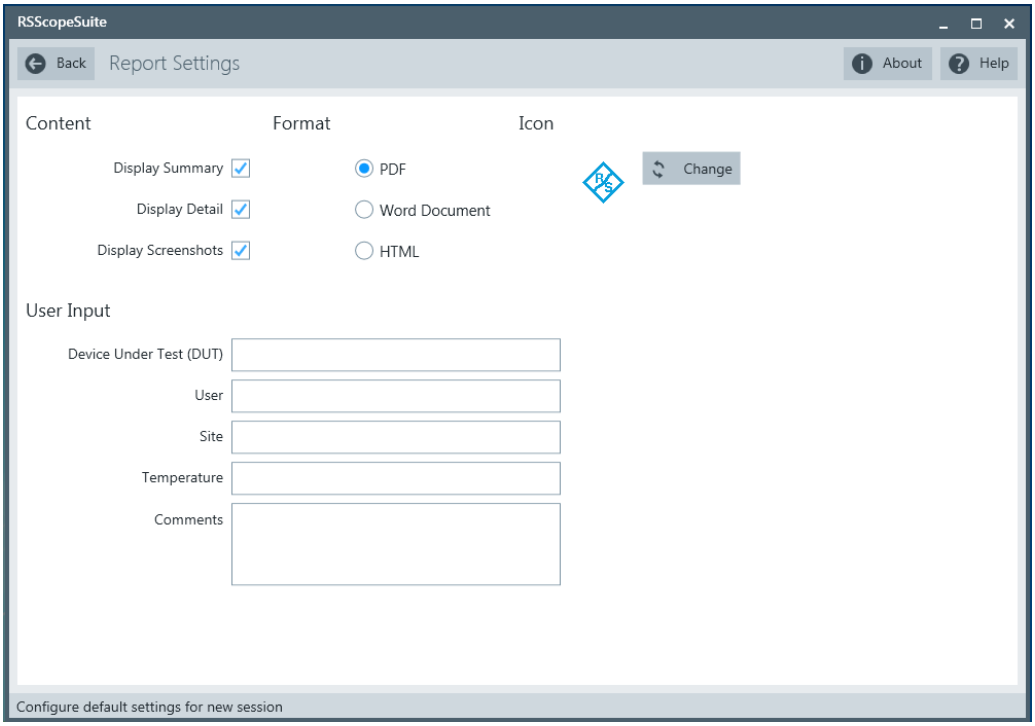
6. Click "Get Instrument Information".

   The computer or R&S RTO connects with the instrument and retrieves the instrument data.

2.9 Report Configuration

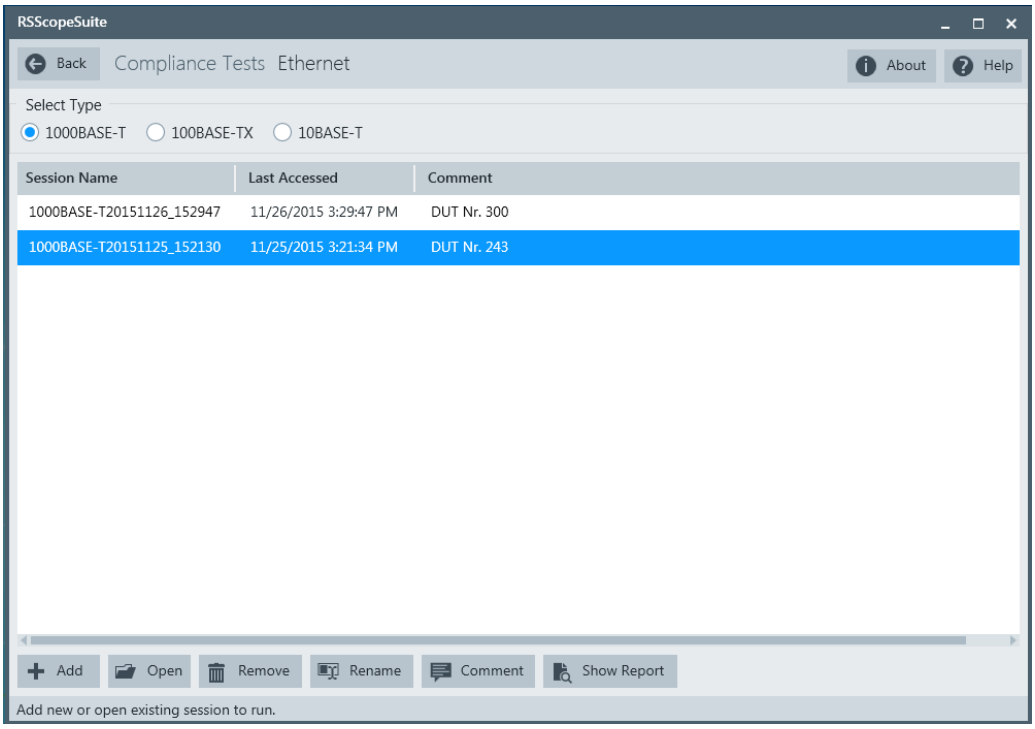
In the "Report Configuration" menu, you can select the format of the report and the details to be included in the report. You can also select an icon that will be displayed in the upper left corner of the report.

Additionally, you can enter common information on the test that will be written in the "General Information" section of the test report.



3 Performing Tests

3.1 Starting a Test Session



After you open a compliance test the "Session Selection" dialog appears. In this dialog you can create new sessions, open or view existing report.

The following functions are available for handling test sessions:

Function	Description
"Add"	Adds a new session
"Open"	Opens the selected session
"Remove"	Removes the selected session
"Rename"	Changes the "Session Name"
"Comment"	Adds a comment
"Show report"	Generates a report for the selected session

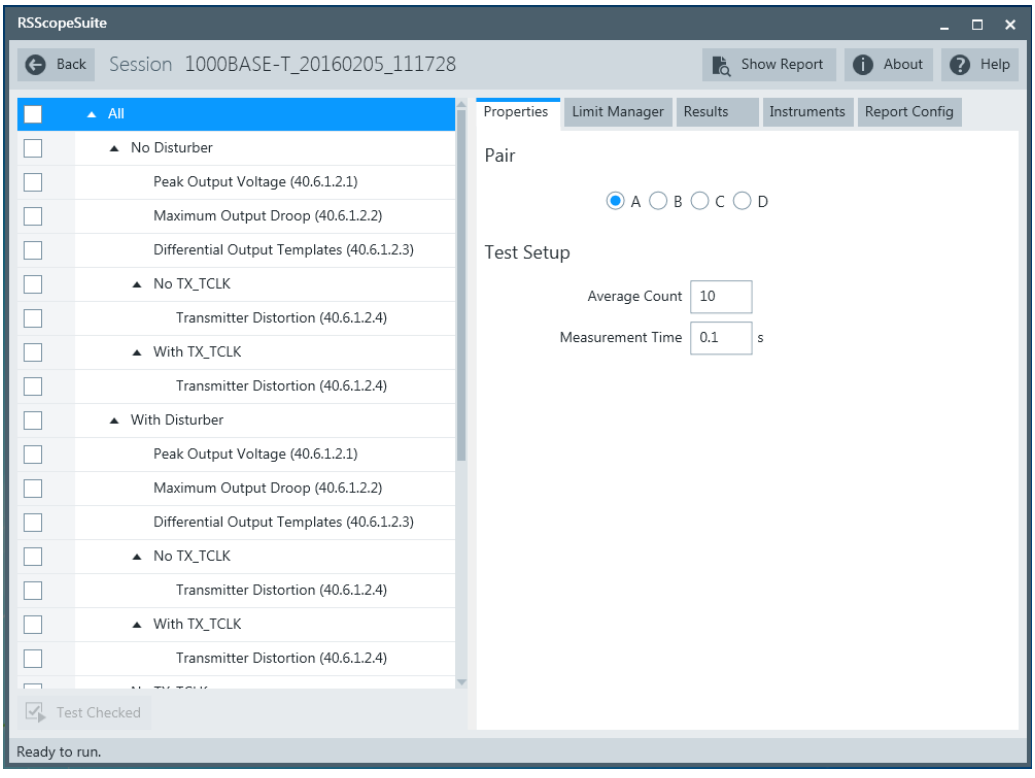
3.2 Configuring the Test

1. In the R&S ScopeSuite window, select the compliance test to be performed:

- "Ethernet"
- "Ethernet 10G"
- "BroadR-Reach"

2. Open a test session, see Chapter 3.1, "Starting a Test Session", on page 21.
3. Adjust the "Properties" settings for the test cases you want to perform.
4. Click "Limit Manager" and edit the limit criterias, see Chapter 3.2.1.1, "Limit Manager", on page 23.
5. If you want to use special report settings the "Report Config" tab to define the format and contents of the report. Otherwise the settings defined in "RSScopeSuite" > "Settings" > "Report" will be used. See Chapter 2.9, "Report Configuration", on page 20.
6. Click "Test Checked"/"Test Single" and proceed as descibed in the relevant test case chapter.

3.2.1 General Test Settings



Each session dialog is divided into several sections:

- "Properties": shows the settings that can be made for the test case selected on the left side of the dialog. You can differentiate between the "All" and the sub test properties
  In the "All" > "Properties" tab you can configure the settings for all test cases in the current session. Once you change and save a setting in this tab the changes will

be done for all test in the sessions. At the same time there will be a special marking for the functions that have different settings for different sub tests.

- "Limit Manager": sets the measurement limits that are used for compliance testing, see Chapter 3.2.1.1, "Limit Manager", on page 23.
- "Results": shows an overview of the available test results for this session.
- "Instruments": defines instruments settings for connecting to external devices, that are specific for this t est session.
  When a session is first created the global settings ("RSScopeSuite" > "Settings" > "Instruments") are copied to the session. This "Instruments" tab can be used to change those copied defaults.
- "Report Config": defines the format and contents of the report for this session.
  When a session is first created the global settings ("RSScopeSuite" > "Settings" > "Report") are copied to the session. This "Report Config" tab can be used to change those copied defaults.
- "Test Checked"/ "Test Single": starts the selected test group.

3.2.1.1 Limit Manager

The "Limit Manager" shows the measurement limits that are used for compliance testing.

Each limit comprises the comparison criterion, the unit, the limit value A, and a second limit value B if the criterion requires two limits.

You can set the values to defaults, change the values in the table, export the table in xml format, or import xml files with limit settings.

► Check and adjust the measurement limits.

3.3 Getting Test Results

For each Ethernet test, the test data - report, diagrams and waveform files - is saved in the following folder:
`%ProgramData%\Rohde-Schwarz\RSScopeSuite\3.0\Sessions\Ethernet\<Ethernet category>\<Session_Name>`

For each BoradR-Reach test, the test data - report, diagrams and waveform files - is saved in the following folder:
`%ProgramData%\Rohde-Schwarz\RSScopeSuite\3.0\Sessions\BroadRReach\<Session_Name>`

If you resume an existing session, new measurements are appended to the report, new diagrams and waveform files are added to the session folder. Existing files are not deleted or replaced. Sessions data remain until you delete them in the "Results" tab of the session.

The report format can be defined in "RSScopeSuite" > "Settings" > "Report" for all compliance tests (see also Chapter 2.9, "Report Configuration", on page 20). If you want to use special report settings for a session, you can define the format and contents of the report in the "Report Config" tab of the session.

All test results are listed in the "Results" tab. Reports can be provided in PDF, MSWord, or HTML format. To view and print PDF reports, you need a PDF viewer, for example, the Acrobat Reader.

The test report file can be created at the end of the test, or later in the "Session Selection" dialog.

To show a test report

1. In the R&S ScopeSuite window, select the compliance test to be performed.
2. Select the session name in the "Session Selection" dialog and click "Show report".

   The report opens in a separate application window, depending on the file format. You can check the test results and print the report.

To delete the results, diagrams and waveform files of a session

1. In the "Session Selection" dialog select the session and open it.
2. In the "Results" tab, select the result to be deleted.
3. Click "Remove".

4 1000BASE-T Tests

1000BASE-T Ethernet compliance tests require option R&S RTO-K22.

- Starting 1000BASE-T Tests 26
- Test Configuration for Ethernet 1000BASE-T 26
- Transmitter Distortion 28
- Peak Output Voltage 34
- Maximum Output Droop 38
- Differential Output Templates 43
- Jitter Master Mode 49
- Jitter Slave Mode 53
- MDI Return Loss 57
- Common-mode Output Voltage 59

4.1 Starting 1000BASE-T Tests

Before you run the test, complete the following actions:

- Initial setup of the equipment, see Chapter 2.2, "Installing Software and License", on page 11
- LAN connection of the oscilloscope and the computer running the R&S ScopeSuite, see Chapter 2.5, "Connecting the R&S RTO", on page 14
- AWG connection for tests with disturber, see Chapter 2.6, "Connecting the Arbitrary Waveform Generator", on page 16.
- VNA connection for MDI Return Loss and Transmitter Power Spectral Density tests, see Chapter 2.7, "Connecting the Vector Network Analyzer", on page 17.

1. Select "Ethernet" in the R&S ScopeSuite start window.
2. In the "Session Selection" dialog, set "Select Type" > "1000BASE-T".
3. Add a new test session and open it, see Chapter 3.1, "Starting a Test Session", on page 21.
4. Check the test configuration settings and adjust, if neccessary. See:
   - Chapter 4.2, "Test Configuration for Ethernet 1000BASE-T", on page 26
   - Chapter 3.2.1.1, "Limit Manager", on page 23
5. Select/check the test cases you want to run and click "Test Single"/"Test checked".
6. A step-by step guide explains the following individual setup steps. When you have finished all steps of the step-by-step guide, the compliance test runs automatically.

4.2 Test Configuration for Ethernet 1000BASE-T

Open a "1000BASE-T" session.

The test configuration consists of some test-specific configuration settings.

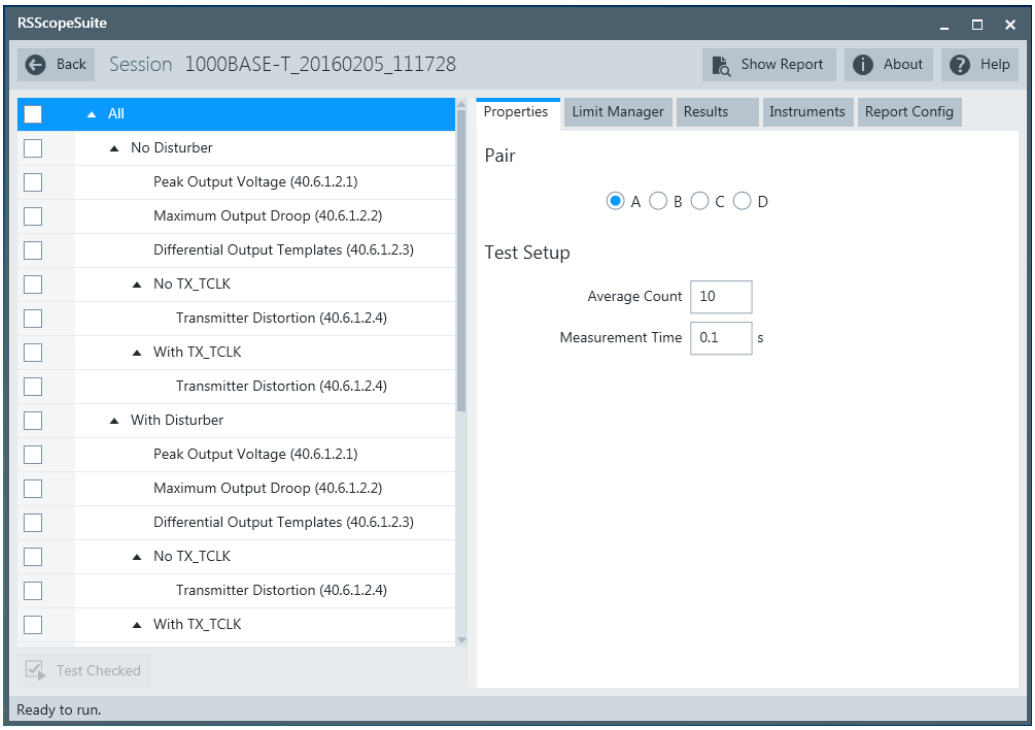


Figure 4-1: Configuration for 1000BASE-T compliance tests

Pair
Select which cable pair is used.

Average Count
Defines the number of waveforms which the oscilloscope acquires to calculate the average waveform (average count). The average waveform is used in the following tests: Peak Output Voltage, Maximum Output Droop, Differential Output Templates, Transmitter Distortion, and Common-mode Output Voltage.

Increasing the number of waveforms results in more accurate measurement results but also in longer test execution time. If you are unsure, use the default values. The valid range is 5 to 200. The default value is 10.

Measurement Time
The measurement time is used in the following test cases: Jitter master mode without TX_TCLK, with TX_TCLK filtered and unfiltered, Jitter slave mode with TX_TCLK, filtered and unfiltered. The valid range is 50E-9 to 100E-3, the default value is 100E-3.

4.3 Transmitter Distortion

The Transmitter Distortion test verifies that the peak distortion of the transmitter is less than 10 mV - without and with a disturbing signal, and with and without a DUT transmit clock TX_CLK.

4.3.1 No Disturber

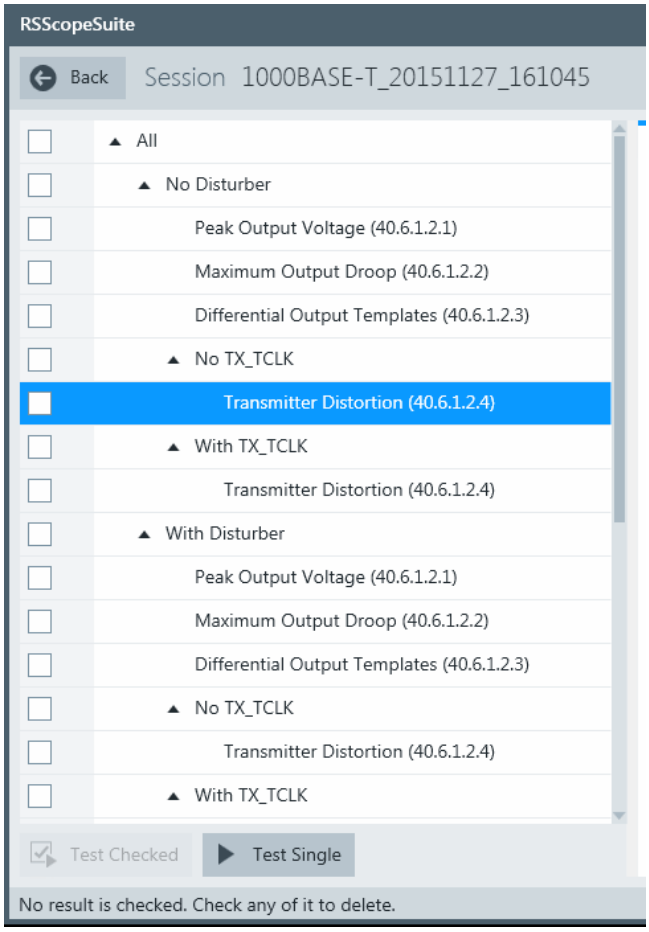
4.3.1.1 Test Equipment

Table 4-1: Equipment for Transmitter Distortion test, no disturber

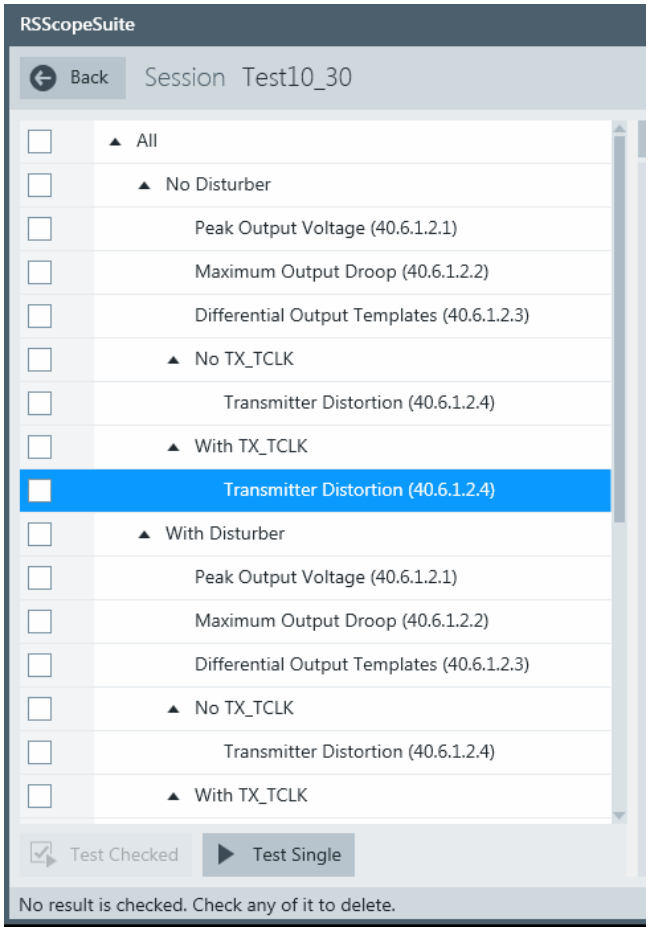
Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Single-ended probe (for test "With TX_CLK")	at least 1 GHz bandwidth	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

4.3.1.2 Performing the Tests

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T Tests", on page 26.
2. Select the test case:
   - "No TX_CLK" test:
     "No Disturber" > "No TX_CLK" > "Transmitter Distortion (40.6.1.2.4)"



- "With TX_CLK" test:
  "No Disturber" > "With TX_CLK" > "Transmitter Distortion (40.6.1.2.4)"



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

4.3.1.3 Measurements

For Transmitter Distortion test, the DUT has to transmit a test mode 4 waveform. The same waveform is used for 1000BASE-T Common Mode Voltage test.

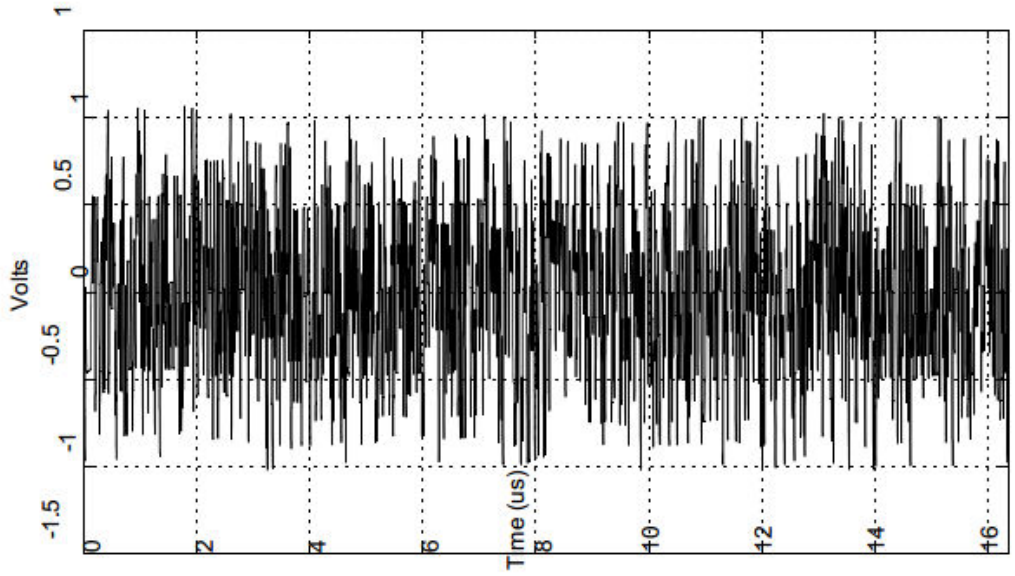


Figure 4-2: Test mode 4 waveform

The test acquires N * 2047 consecutive symbols from the test mode 4 waveform. Each symbol corresponds to approximately 8 ns.

If a DUT transmits clock (TX_TCLK is available), the clock pulses will be extracted directly from the DUT TX_TCLK.

If no DUT transmits clock TX_TCLK, the clock pulses will be extracted from the measured test mode 4 waveform.

Each clock pulse contains one symbol. Each symbol is divided into 40 points, which is averaged over N cycles of 2047 symbols.

After averaging, 2047 symbols with 81880 points are available. One point from each symbol is passed to a MATLAB script to determine the peak distortion. (The MATLAB script can be downloaded from section 40.6.1.2.4 of the IEEE 802.3 specification.) This process is repeated 40 times (once for each point per symbol).

4.3.2 With Disturber

4.3.2.1 Test Equipment

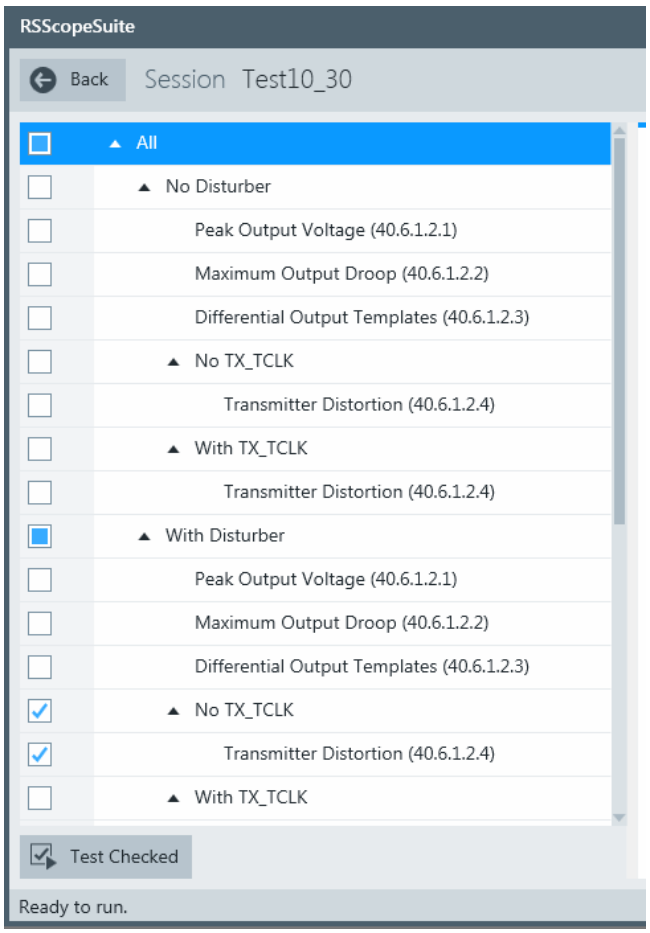
Table 4-2: Equipment for Transmitter Distortion test with disturber

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Arbitrary waveform generator	Tabor WX2182B/WX2182C or HAMEG HMF2550	

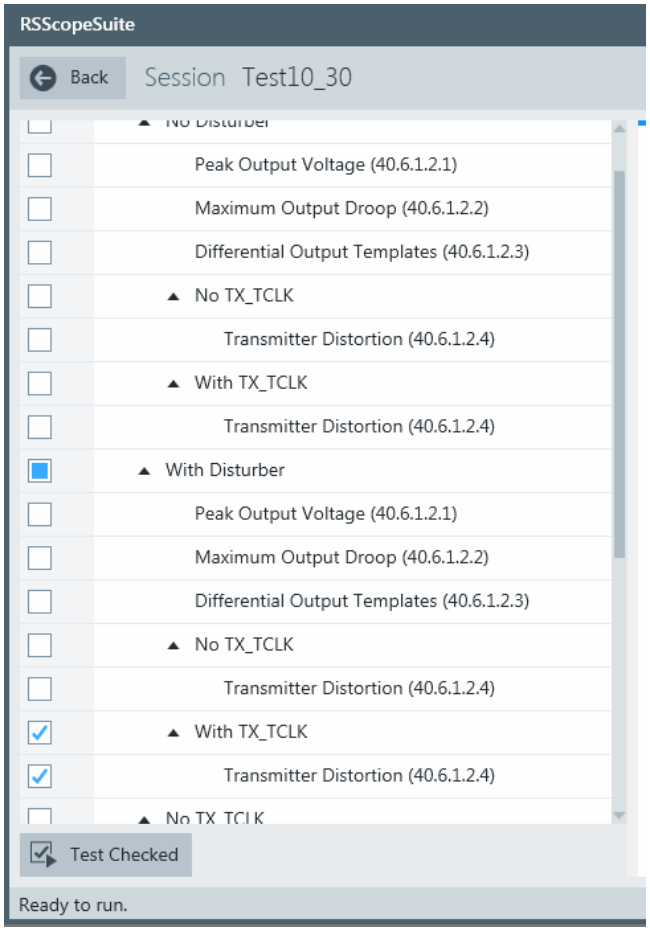
Item	Description, model	Quantity
Ethernet test fixture, "Resistive Load with Distortion source" section	R&S RT-ZF2	1
Single-ended probe (for test "With TX_CLK")	at least 1 GHz bandwidth	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

4.3.2.2 Performing the Test (No TX_CLK)

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T Tests", on page 26.
2. Select the test case:
   - "No TX_CLK" test:
     "With Disturber" > "No TX_CLK" > "Transmitter Distortion (40.6.1.2.4)"



   - "With TX_CLK" test:
     "With Disturber" > "With TX_CLK" > "Transmitter Distortion (40.6.1.2.4)"



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

4.3.2.3 Disturbing Signal

The disturbing signal is a standard 5.4 Vpp 20.833 MHz sine wave. It is recommended to use the indicated HAMEG or Tabor arbitrary waveform generator to create the disturbing signal. If Tabor WX2182B is used, an external amplifier is required because the maximum output voltage of this generator is 4 Vpp.

The disturbing signal is calibrated on the "Resistive Load with Distortion Source" section of the R&S RT-ZF2 Ethernet test fixture. The disturbing signal under calibration is measured at X502 to X505.

The test is also performed on the "Resistive Load with Distortion Source" section of the R&S RT-ZF2 Ethernet test fixture. The output waveform measured at X506 is attenuated by a voltage divider. It is required to compensate for the attenuation. The compen-

sation factor is calculated by measuring the voltage difference between the “Resistive Load” section and the “Resistive Load with Distortion Source” section. Point B of test mode 1 waveform is used for this calibration.

4.3.2.4 Measurements

The measurement is the same as without a disturber (described in Chapter 4.3.1.3, "Measurements", on page 30). However, post-processing requires an additional step to remove the disturbing signal before the interpolated points are calculated.

The disturbing signal is removed in 2 steps:

1. Determine the best fit of a sine wave at the fundamental frequency of the disturbing signal.
2. Subtract the best fit sine wave from the measured waveform.

If a DUT transmit clock TX_CLK is not available, the clock pulses are extracted from the measured waveform after the disturbing signal has been removed.

4.4 Peak Output Voltage

The Peak Output Voltage test that the transmitter output level are within the specified range - without and with disturbing signal. For full compliance testing, the specification requires testing all 4 pairs.

4.4.1 No Disturber

4.4.1.1 Test Equipment

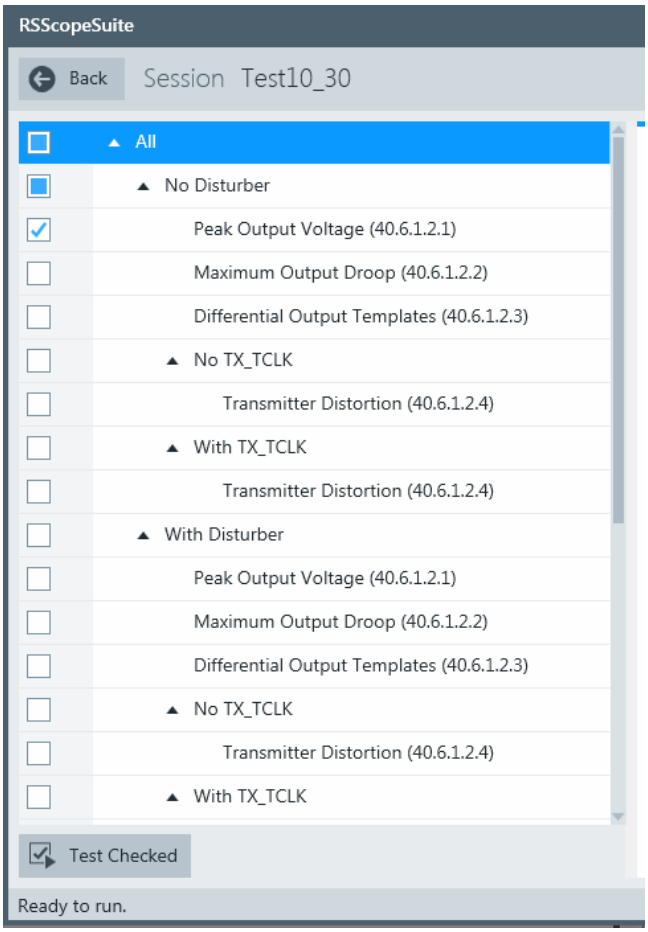
Table 4-3: Equipment for Peak Output Voltage test, no disturber

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

4.4.1.2 Performing the Test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T Tests", on page 26.

2. Select "Peak Output Voltage (40.6.1.2.1)" under "No Disturber".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

4.4.1.3 Measurements

For Peak Output Voltage test, the DUT has to transmit a test mode 1 waveform. The same waveform is used for 1000BASE-T Maximum Output Droop test and Differential Output Template test.

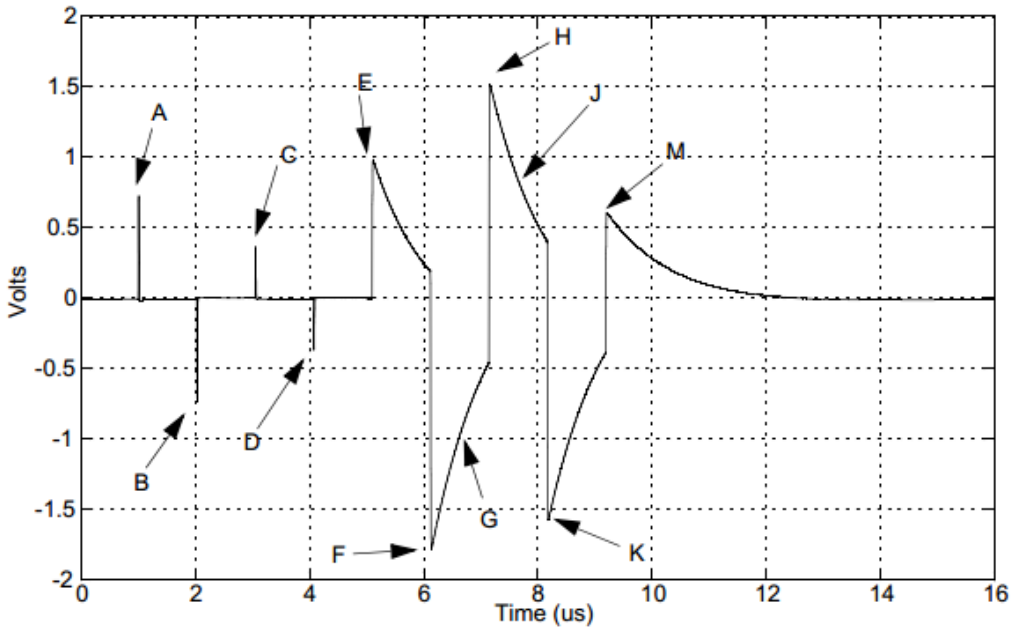


Figure 4-3: Test mode 1 waveform with measurement points

This test consists of five measurements:

- Absolute voltage of point A
- Absolute voltage of point B
- Difference of absolute voltages of point A and B, in percent
- Absolute voltage of point C compared to the average amplitude of points A and B, in percent
- Absolute voltage of point Dcompared to the average amplitude of points A and B, in percent

To locate the waveform, the oscilloscope uses the width trigger to find point A. Then it measures points A, B, C and D with different gates. Each gate is 0.8 µs wide and centered at the corresponding point. All measurements are verified by values that are averaged by multiple measurements.

4.4.2 With Disturber

4.4.2.1 Test Equipment

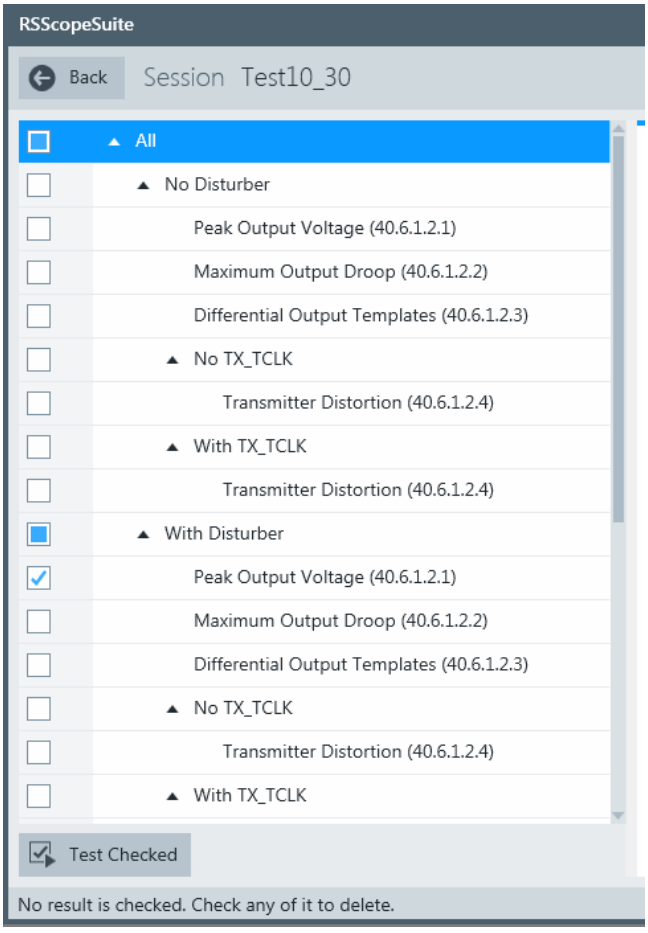
Table 4-4: Equipment for Peak Output Voltage test with disturber

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Arbitrary waveform generator	Tabor WX2182B/WX2182C or HAMEG HMF2550	1

Item	Description, model	Quantity
Ethernet test fixture, "Resistive Load with Distortion source" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

4.4.2.2 Performing the Test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T Tests", on page 26.
2. Select "Peak Output Voltage (40.6.1.2.1)" under "With Disturber".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

4.4.2.3 Disturbing Signal

The disturbing signal is a standard 2.8 Vpp 31.25 MHz sine wave. It is recommended to use the indicated HAMEG or Tabor arbitrary waveform generator to create the disturbing signal.

The disturbing signal is calibrated on the "Resistive Load with Distortion Source" section of the R&S RT-ZF2 Ethernet test fixture. The disturbing signal under calibration is measured at X502 to X505.

The test is also performed on the "Resistive Load with Distortion Source" section of the R&S RT-ZF2 Ethernet test fixture. The output waveform measured at X506 is attenuated by a voltage divider. It is not required to compensate for the attenuation because the attenuation is linear, and the voltage ratio of the output waveform is used in this test.

4.4.2.4 Measurements

For Peak Output Voltage test, the DUT has to transmit a test mode 1 waveform, see Figure 4-3.

After acquiring the waveforms at the measured point, the software uses a MATLAB script to remove the disturbing signal. This is done by removing the best fit of a sine wave at the fundamental frequency of the disturbing signal.

The following measurements are the same as without disturber, but the instrument acquires only one waveform and there is no averaging.

4.5 Maximum Output Droop

The Maximum Output Droop test verifies that the transmitter output level does not decay faster than the maximum specified rate - without and with a disturbing signal.

4.5.1 No Disturber

4.5.1.1 Test Equipment

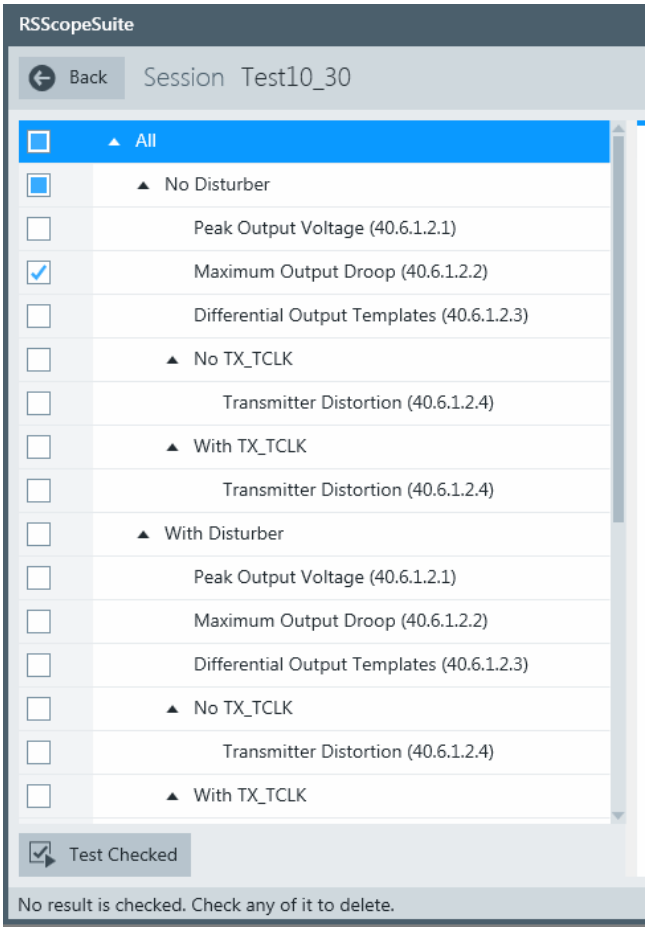
Table 4-5: Equipment for Maximum Output Droop test, no disturber

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1

Item	Description, model	Quantity
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

4.5.1.2 Performing the Test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T Tests", on page 26.
2. Select "Maximum Output Droop (40.6.1.2.2)" under "No Disturber".



3. Click "Test Checked".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

4.5.1.3 Measurements

For the Maximum Output Droop test, the DUT has to transmit a test mode 1 waveform. The same waveform is used for 1000BASE-T Peak Differential Voltage test and Differential Output Template test.

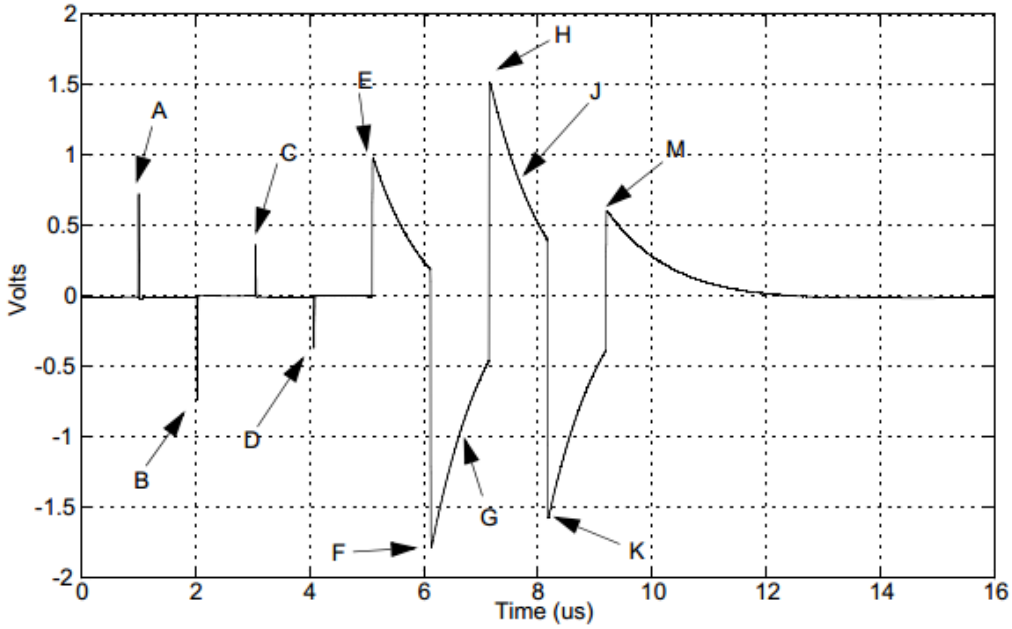


Figure 4-4: Test mode 1 waveform with measurement points

The test consists of two similar measurements:

- The oscilloscope measures the voltage ratio between points F and G of the test mode 1 waveform. Point G is defined as the point exactly 500 ns after point F. The software sets the trigger at point F. The oscilloscope acquires a number N of waveforms and averages them. Then it uses the cursor tracking function to determine the time which corresponds to the minimum value of point F. Point G is 500 ns after point F. The software creates a measurement gate from point F to point G and determines the voltage ratio using the HIGH and LOW measurement functions.
- The oscilloscope measures the voltage ratio between points H and J of the test mode 1 waveform. Point J is defined as the point exactly 500 ns after point H. This measurement is similar to the first one with the following modifications: the trigger is set to point H, and the cursor tracking function determines the time which corresponds to the maximum value of point H.

4.5.2 With Disturber

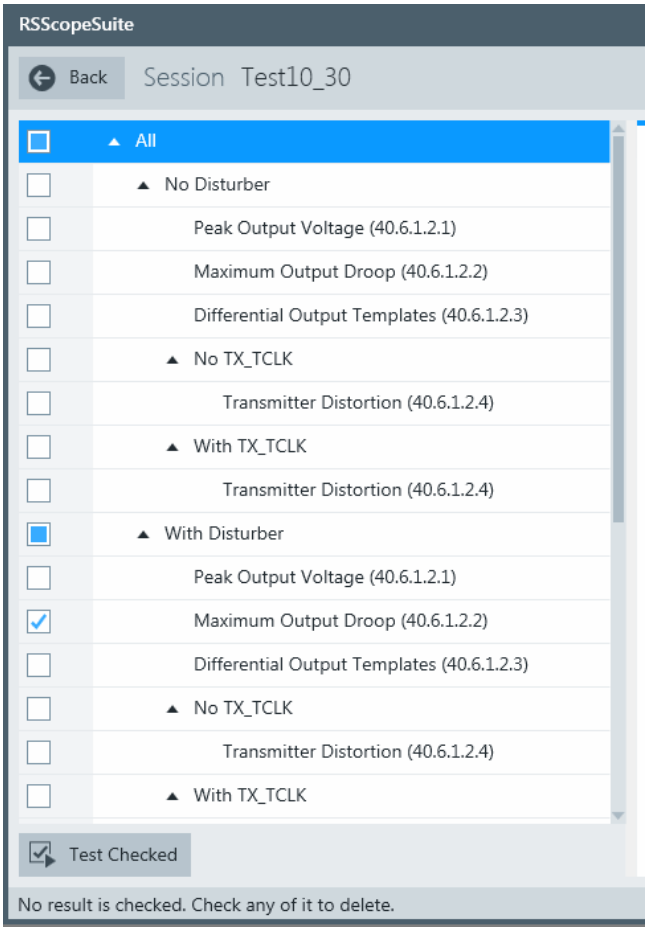
4.5.2.1 Test Equipment

Table 4-6: Equipment for Maximum Output Droop test with disturber

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Arbitrary waveform generator	Tabor WX2182B/WX2182C or HAMEG HMF2550	1
Ethernet test fixture, "Resistive Load with Distortion source" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

4.5.2.2 Performing the Test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T Tests", on page 26.
2. Select "Maximum Output Droop (40.6.1.2.2)" under "With Disturber".



3. Click "Test Checked".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

4.5.2.3 Disturbing Signal

The disturbing signal is a standard 2.8 Vpp 31.25 MHz sine wave. It is recommended to use the indicated HAMEG or Tabor arbitrary waveform generator to create the disturbing signal.

The disturbing signal is calibrated on the "Resistive Load with Distortion Source" section of the R&S RT-ZF2 Ethernet test fixture. The disturbing signal under calibration is measured at X502 to X505.

The test is also performed on the "Resistive Load with Distortion Source" section of the R&S RT-ZF2 Ethernet test fixture. The output waveform measured at X506 is attenuated by a voltage divider. It is not required to compensate for the attenuation because

the attenuation is linear, and the voltage ratio of the output waveform is used in this test.

4.5.2.4 Measurements

For Maximum Output Droop test, the DUT transmits a test mode 1 waveform, see Figure 4-4.

After acquiring the waveforms at the two triggering points (F and H), the software uses a MATLAB script to remove the disturbing signal. This is done by determining the best fit of a sine wave at the fundamental frequency of the disturbing signal and then subtracting that sine wave from the measured waveform.

After removing the disturbing signal, the software downloads the measured waveform from the oscilloscope to perform averaging over N waveforms. The software then uploads the averaged waveform back to the oscilloscope and uses the same method as without a disturber to measure the droop value.

4.6 Differential Output Templates

The Differential Output Templates test verifies that the transmitter output fits the time-domain transmit templates - without and with a disturbing signal.

4.6.1 No Disturber

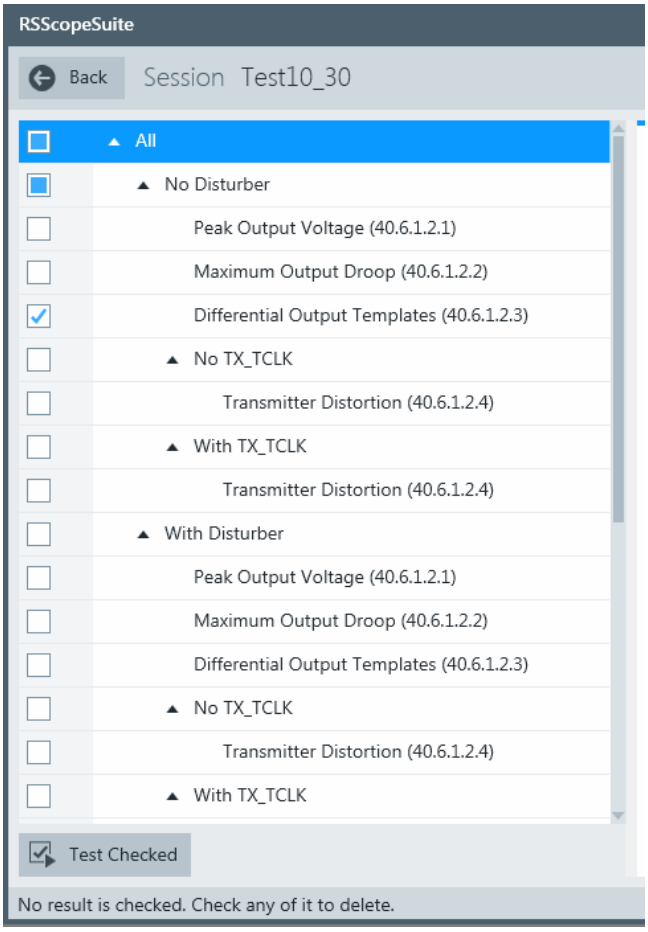
4.6.1.1 Test Equipment

Table 4-7: Equipment for Differential Output Templates test, no disturber

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

4.6.1.2 Performing the Test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T Tests", on page 26.
2. Select "Differential Output Templates (40.6.1.2.3)" under "No Disturber".



3. Click "Test Checked".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

4.6.1.3 Measurements

For Differential Output Templates test, the DUT has to transmit a test mode 1 waveform. The same waveform is used for 1000BASE-T Peak Differential Voltage test and Maximum Output Droop test.

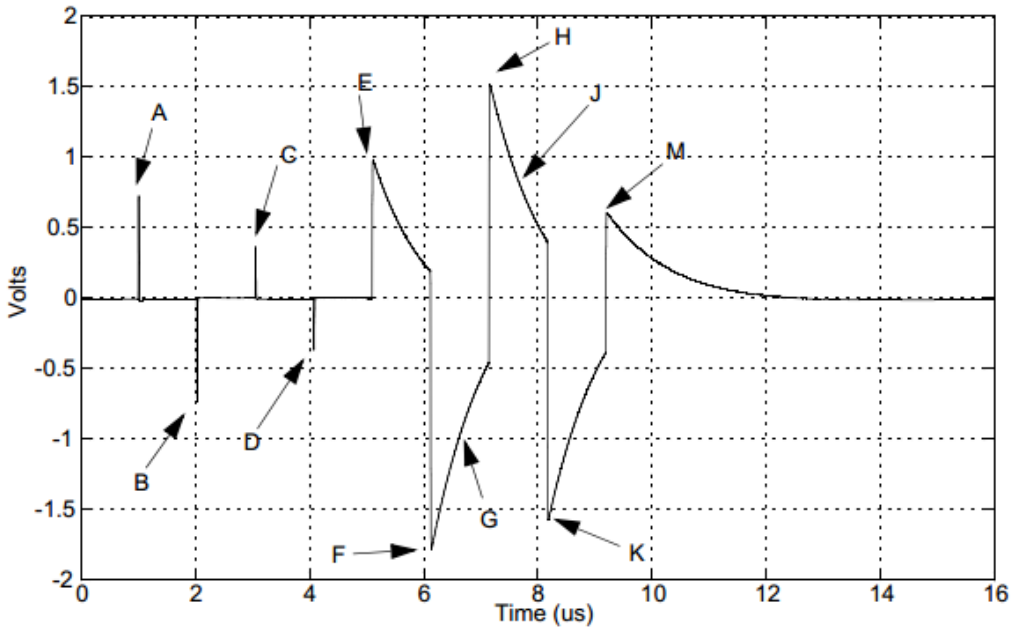


Figure 4-5: Test mode 1 waveform with measurement points

The IEEE 802.3 specification requires that the waveform around points A, B, C and D is normalized and the normalized values lie within the normalized time domain transmit template 1.

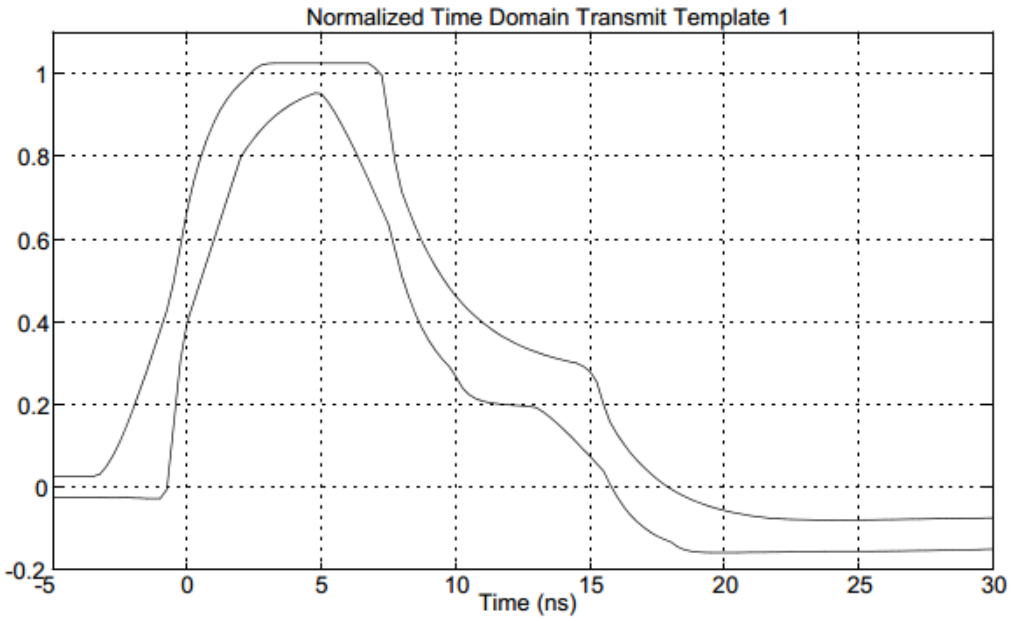


Figure 4-6: Time domain transmit template 1

The waveform is normalized as follows:

Table 4-8: Normalization of waveforms around points A, B, C, and D

Point of test mode1 signal	Normalized by dividing by
Point A	Peak voltage at A
Point B	Negative of the peak voltage at A
Point C	1/2 the peak voltage at A
Point D	Negative of 1/2 the peak voltage at A

The IEEE 802.3 specification requires that the waveform around points F and H is normalized and the normalized values lie within the normalized time domain transmit template 2.

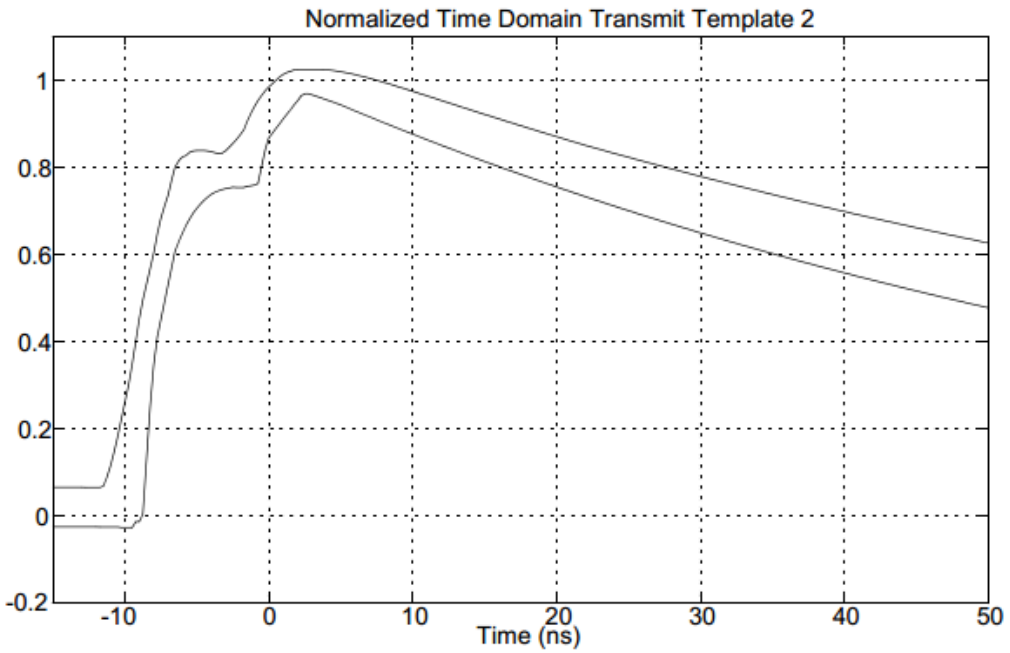


Figure 4-7: Time domain transmit template 2

The waveform is normalized as follows:

Table 4-9: Normalization of waveforms around points F and H

Point of test mode1 signal	Normalized by dividing by
Point F	Peak voltage at F
Point H	Peak voltage at H

The test consists of six measurements, one measurements for each point A, B, C, D, F, and H.

The steps of each measurement are:

1. The software sets the trigger to the measured point A, B, C, D, F, or H, respectively.

2. N waveforms are acquired and averaged into a single waveform.
3. A 2 MHz high-pass filter is applied to the averaged waveform.
4. The waveform is normalized as indicated in Table 4-8 and Table 4-9.
5. The waveform is shifted in time until the best fit to the specified template (mask) is found.

4.6.2 With Disturber

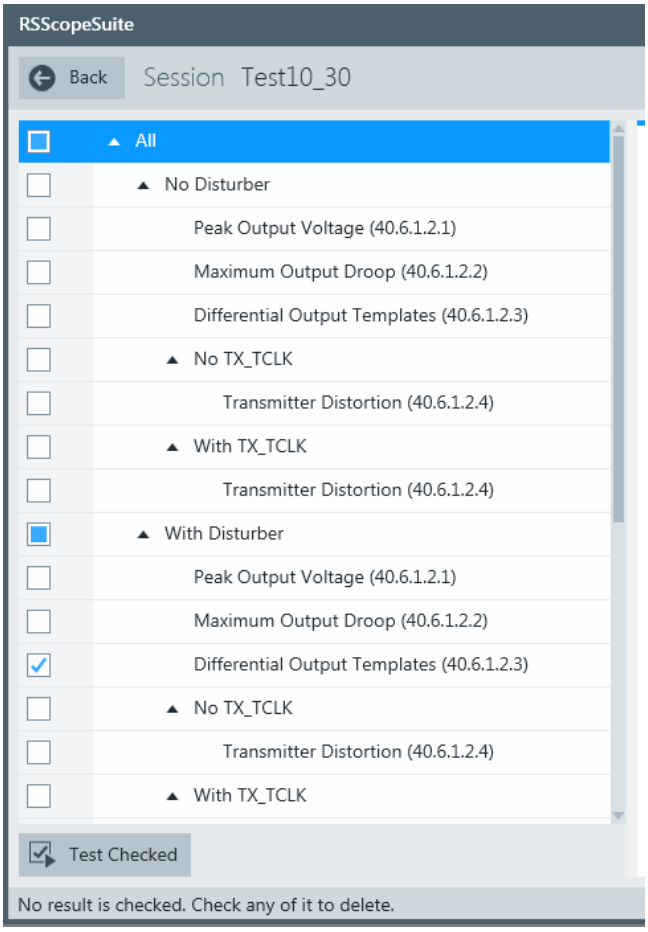
4.6.2.1 Test Equipment

Table 4-10: Equipment for Differential Output Templates test with disturber

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Arbitrary waveform generator	Tabor WX2182B/WX2182C or HAMEG HMF2550	1
Ethernet test fixture, "Resistive Load with Distortion source" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

4.6.2.2 Performing the Test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T Tests", on page 26.
2. Select "Differential Output Templates (40.6.1.2.3)" under "With Disturber".



3. Click "Test Checked".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

4.6.2.3 Disturbing Signal

The disturbing signal is a standard 2.8 Vpp 31.25 MHz sine wave. It is recommended to use the indicated HAMEG or Tabor arbitrary waveform generator to create the disturbing signal.

The disturbing signal is calibrated on the "Resistive Load with Distortion Source" section of the R&S RT-ZF2 Ethernet test fixture. The disturbing signal under calibration is measured at X502 to X505.

The test is also performed on the "Resistive Load with Distortion Source" section of the R&S RT-ZF2 Ethernet test fixture. The output waveform measured at X506 is attenuated by a voltage divider. It is not required to compensate for the attenuation because

the attenuation is linear, and the voltage ratio of the output waveform is used in this test.

4.6.2.4 Measurements

The test waveform requirements for the Differential Output Templates test with disturber are the same as for the No Disturber test, see Chapter 4.6.1.3, "Measurements", on page 44.

After acquiring the waveforms at the six trigger points (A, B, C, D, F and H), the software uses a MATLAB script to remove the disturbing signal. This is done by determining the best fit of a sine wave at the fundamental frequency of the disturbing signal and then subtracting that sine wave from the measured waveform.

After removing the disturbing signal, the software downloads the measured waveform from the oscilloscope to perform averaging over N waveforms. The software then uploads the averaged waveform back to the oscilloscope and uses the same method as without a disturber to find the best fit to the specified template.

4.7 Jitter Master Mode

The Jitter Master Mode tests verify that the jitter of DUT is within the specified range. The DUT is in master mode.

4.7.1 No TX_CLK

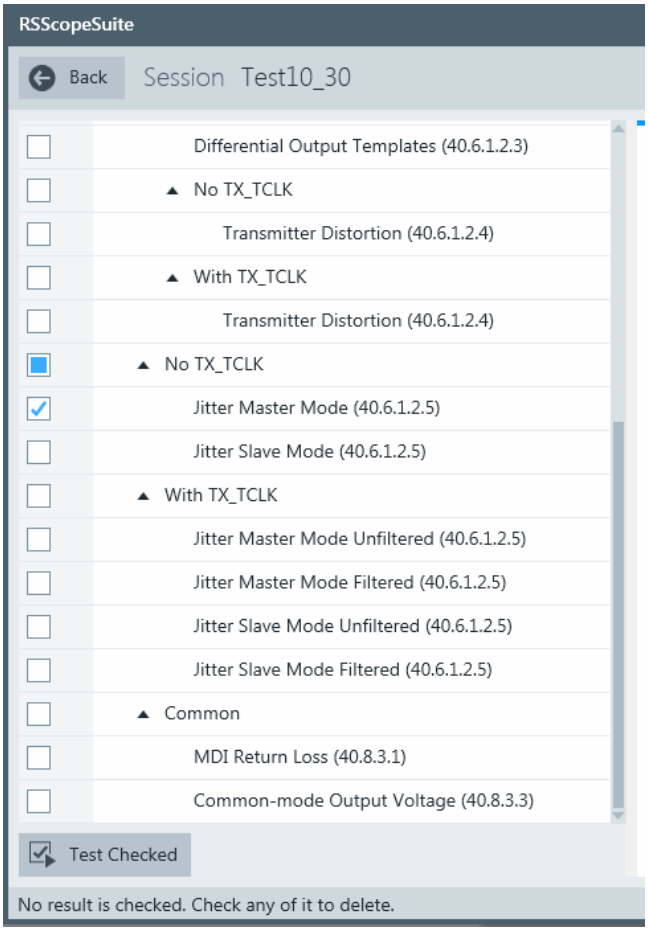
4.7.1.1 Test Equipment

Table 4-11: Equipment for Jitter Master Mode test, no TX_CLK

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Jitter Slave Test 1000BaseT" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	2

4.7.1.2 Performing the Test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T Tests", on page 26.
2. Select "Jitter Master Mode (40.6.1.2.5)" under "No TX_CLK".



3. Click "Test Checked".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

4.7.1.3 Measurements

For Jitter Master Mode test, the DUT has to transmit a test mode 2 waveform. Master and slave must be synchronized.

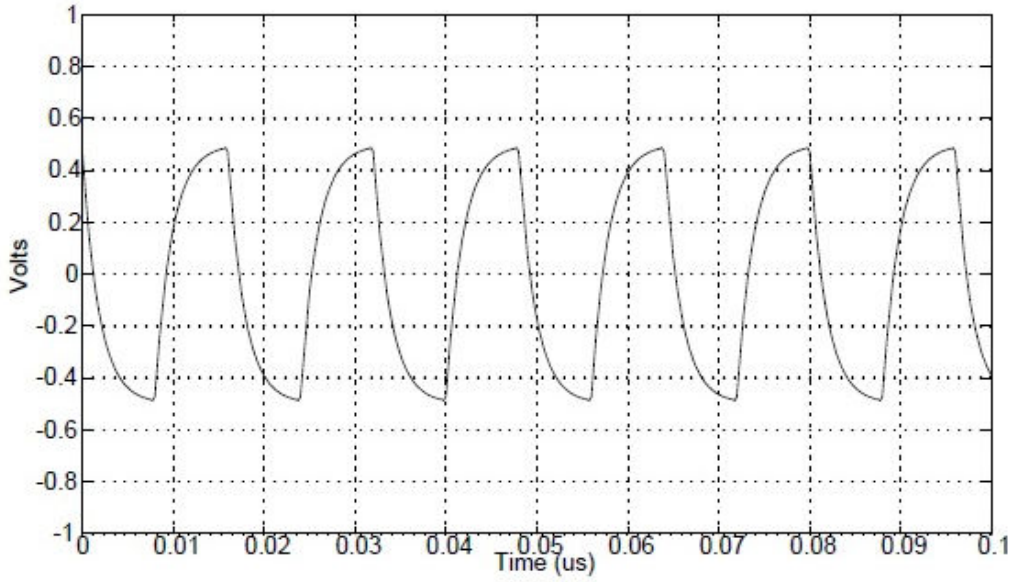


Figure 4-8: Test mode 2 waveform

Jitter is measured at the edge positions. Due to big amount of data, the waveform data is processed segment by segment. One segment comprises 100k samples.

This test consists of the following measurements:

- Unfiltered Jitter for master mode: The difference of the DUT transmit clock (TX_TCLK) to its averaged reference. Peak to peak value is unfiltered jitter. Results within limit are considered pass, results beyond limit are considered inconclusive.
- Filtered Jitter for master mode: waveform from above step filtered by a 5 kHz high-pass filter. Results beyond limit are considered fail, results within limit are considered inconclusive.

4.7.2 With TX_CLK

4.7.2.1 Test Equipment

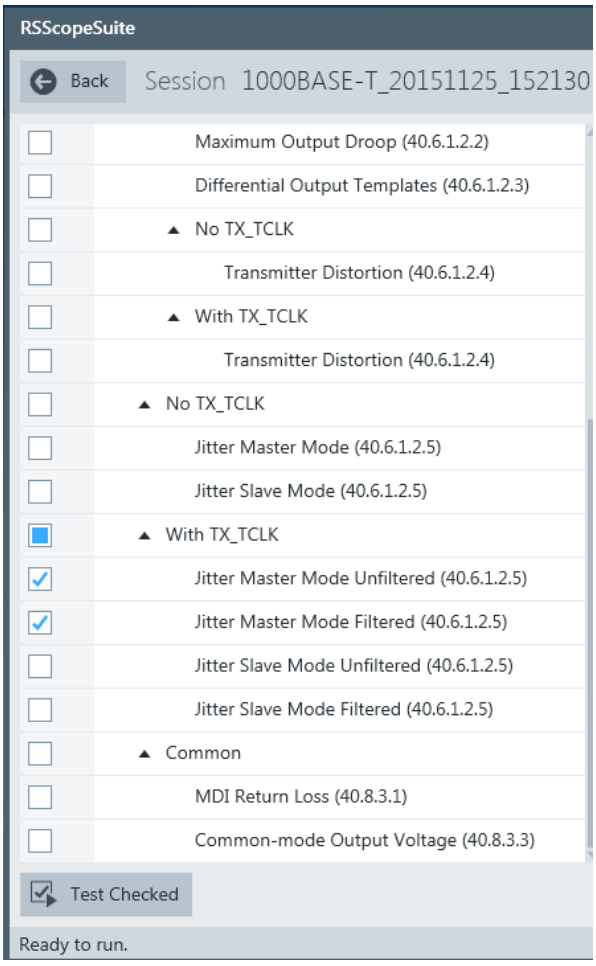
Table 4-12: Equipment for Jitter Master Mode test, with TX_CLK

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1

Item	Description, model	Quantity
Single-ended probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	2

4.7.2.2 Performing the Test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T Tests", on page 26.
2. Select "Jitter Master Mode Unfiltered (40.6.1.2.5)" and/or "Jitter Master Mode Filtered (40.6.1.2.5)" under "With TX_CLK".



3. Click "Test Checked".
4. Follow the instructions of the step-by step guide.
When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

4.7.2.3 Measurements

For Jitter Master Mode test, the DUT has to transmit a test mode 2 waveform, see Figure 4-8. Master and slave must be synchronized.

Jitter is measured at the edge positions. Due to the big amount of data, the waveform data is processed segment by segment. One segment is preset as 100k samples.

This test consists of the following measurements:

- Jtxout: jitter between data and DUT transmit clock (TX_TCLK). Data and clock waveforms are compared. The maximum difference between respective edges is Jtxout.
- Unfiltered Jitter for master mode: The difference of the DUT transmit clock (TX_TCLK) to its averaged reference. Peak to peak value is unfiltered jitter.
- Filtered Jitter for master mode: waveform from above step filtered by a 5 kHz high-pass filter. Peak to peak value plus Jtxout is filtered jitter.

4.8 Jitter Slave Mode

The Jitter Slave Mode tests verify that the jitter of DUT is within the specified range. The DUT is in slave mode.

4.8.1 No TX_CLK

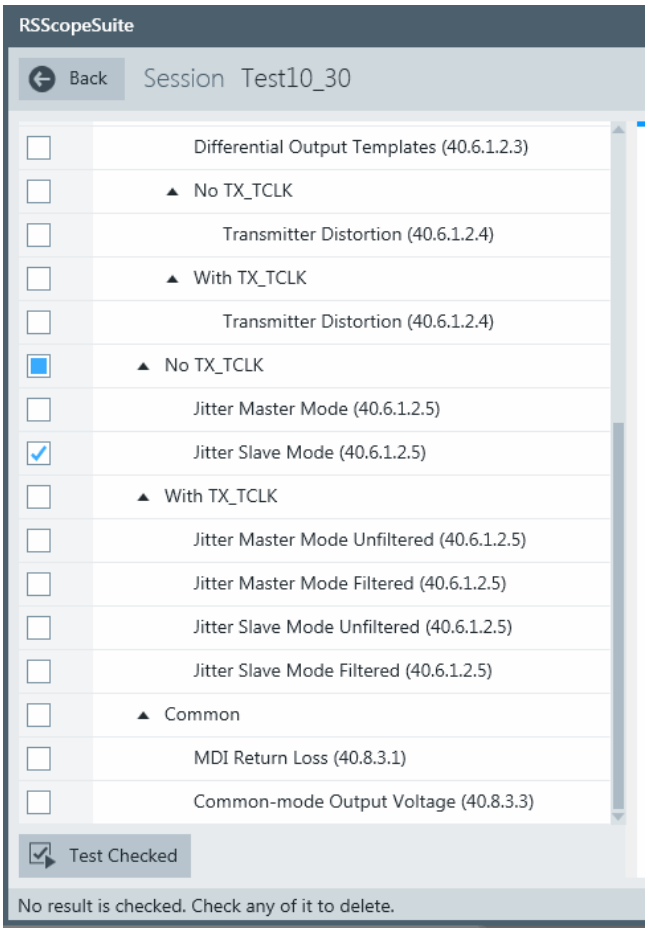
4.8.1.1 Test Equipment

Table 4-13: Equipment for Jitter Slave Mode test, no TX_CLK

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
R&S Ethernet test fixture	R&S RT-ZF2 "Jitter Slave Test 1000BaseT" section	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	2

4.8.1.2 Performing the Test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T Tests", on page 26.
2. Select "Jitter Slave Mode (40.6.1.2.5)" under "No TX_CLK".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

4.8.1.3 Measurements

This test verifies that the jitter of DUT is within a certain range. The test requires the DUT to transmit test mode 2 and 3 waveforms.

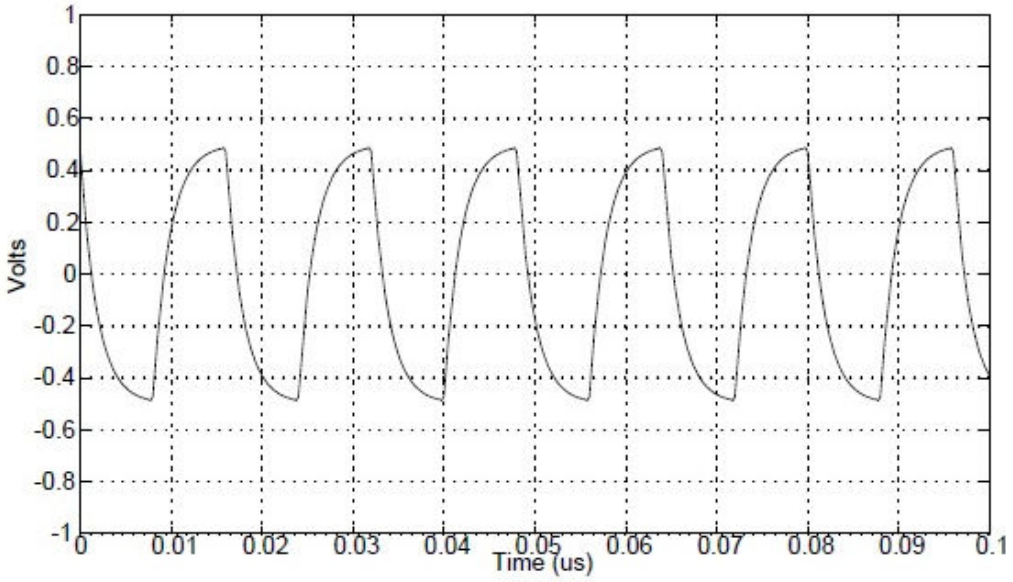


Figure 4-9: Test mode 2 waveform

Jitter is measured at the edge positions. Due to big amount of data, the waveform data is processed segment by segment. One segment comprises 100k samples.

This test consists of the following measurements:

- Measure the DUT's TM2 jitter relative to an unjittered reference, filter with 5KHz high-pass filter, and record both the filtered and unfiltered peak-to-peak values.
- Measure the DUT's TM3 jitter relative to an unjittered reference. Subtract the unfiltered TM2 peak-to-peak jitter value. The result must be less than 1.4ns.
- Filter the TM3 jitter with a 32KHz high-pass filter, subtract the filtered TM2 peak-to-peak jitter value. The result must be less than 0.4ns.

4.8.2 With TX_CLK

4.8.2.1 Test Equipment

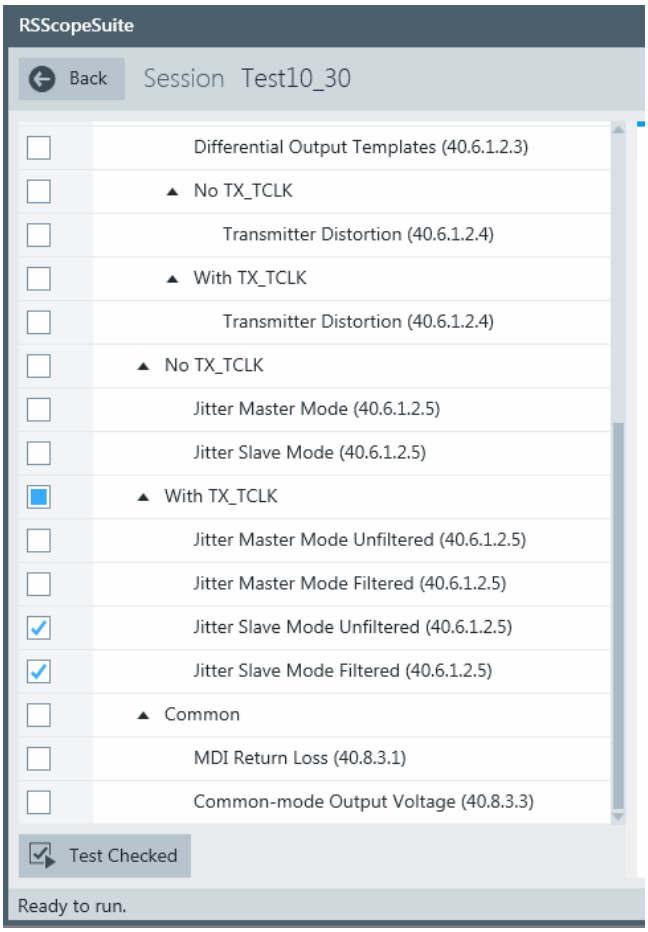
Table 4-14: Equipment for Jitter Slave Mode test, with TX_CLK

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
Single-ended probe	at least 1 GHz bandwidth	2

Item	Description, model	Quantity
Gigabit Ethernet jitter cable	R&S RT-ZF2C	1
DUT	the device you want to test	2

4.8.2.2 Performing the Test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T Tests", on page 26.
2. Select "Jitter Slave Mode Filtered (40.6.1.2.5)" and/or "Jitter Slave Mode Unfiltered (40.6.1.2.5)" under "With TX_CLK".



3. Click "Test Checked".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

4.8.2.3 Measurements

For Jitter Slave Mode test, the DUT has to transmit a test mode 3 waveform. Master and slave must be synchronized.

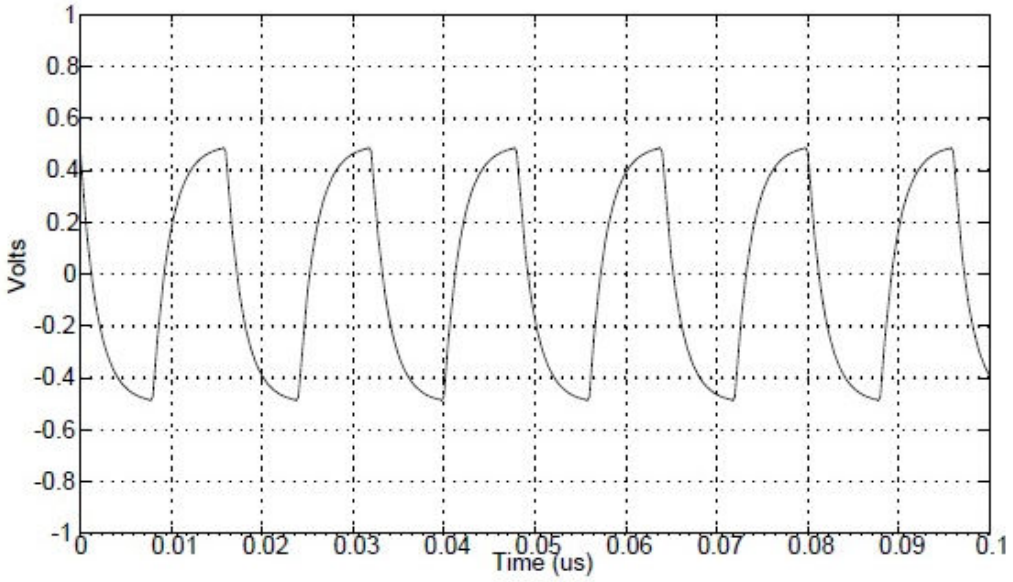


Figure 4-10: Test mode 3 waveform

Jitter is measured at the edge positions. Due to big amount of data, the waveform data is processed segment by segment. One segment is preset as 100k samples.

This test consists of the following measurements:

- Jtxout: jitter between data and DUT transmit clock (TX_TCLK). Data and clock waveforms are compared. The maximum difference between respective edges is Jtxout.
- Unfiltered Jitter for slave mode: The difference of the DUT transmit clock (TX_TCLK) to the TX_CLK of the link partner. Peak to peak value is unfiltered jitter.
- Filtered Jitter for slave mode: waveform from above step filtered by a 32 kHz high-pass filter. Peak to peak value plus Jtxout, minus minus the peak to peak value of link partner's TX_CLK difference to its averaged reference and filtered by 5KHz HPF, is filtered jitter.

4.9 MDI Return Loss

The MDI Return Loss test verifies that the transmitter return loss of the DUT over the frequency range of 1 to 100 MHz is greater than the limits specified in IEEE 802.3-2008, subclause 40.8.3.1.

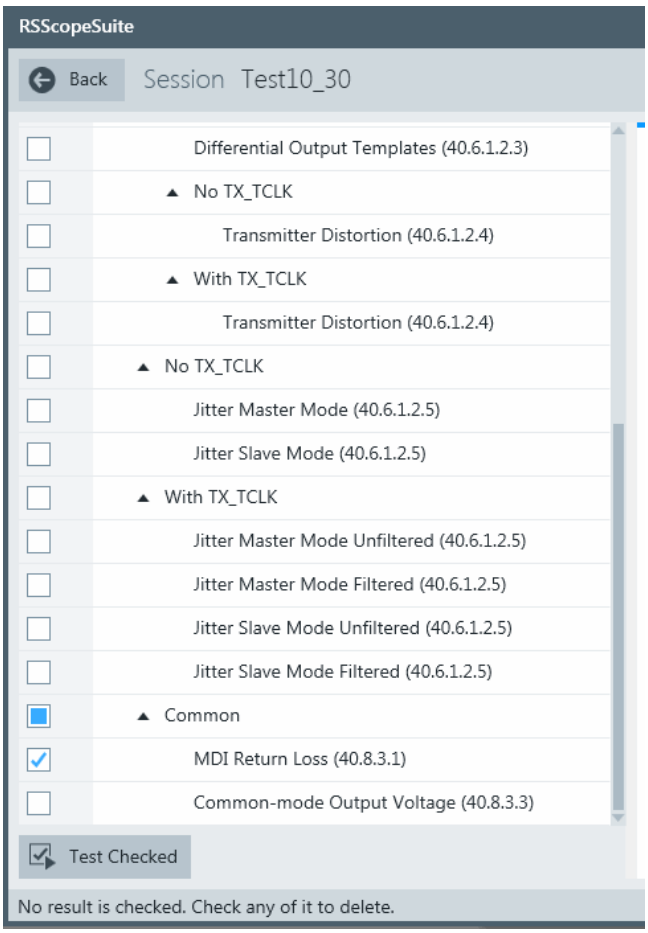
4.9.1 Test Equipment

Table 4-15: Equipment for MDI Return Loss tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Vector Network Analyzer (optional, required only to perform an automatic test	R&S ZVL or R&S ZNB	1
DUT	the device you want to test	1

4.9.2 Performing the Test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T Tests", on page 26.
2. Select "MDI Return Loss (40.8.3.1)" under "Common".



3. Click "Test Checked".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

4.9.3 Measurements

Configure the DUT to "1000BASE-T Test Mode 4 signal (MASTER timing mode) data" output.

During automatic testing, the program measures the S11 parameter on the VNA. It shall fall below the limit line plotted on the VNA from 1 to 100 MHz.

During manual testing, the program checks if every point between 1 MHz and 100 MHz in the result file (*.s1p or *.csv) falls below the limit required by the specification.

4.10 Common-mode Output Voltage

The Common-mode Output Voltage test verifies that the common mode voltage on transmit pair (pair A) is less than 50 mV.

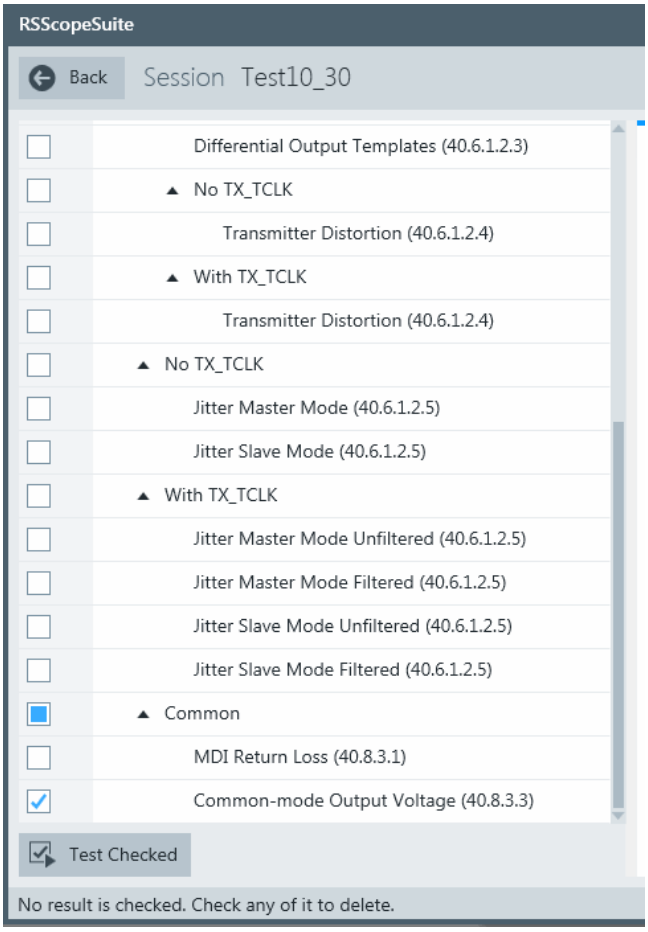
4.10.1 Test Equipment

Table 4-16: Equipment for Common-mode Output Voltage tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Common Mode Voltage " section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

4.10.2 Performing the Test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T Tests", on page 26.
2. Select "Common-mode Output Voltage (14.3.1.2.5)" under "Common".



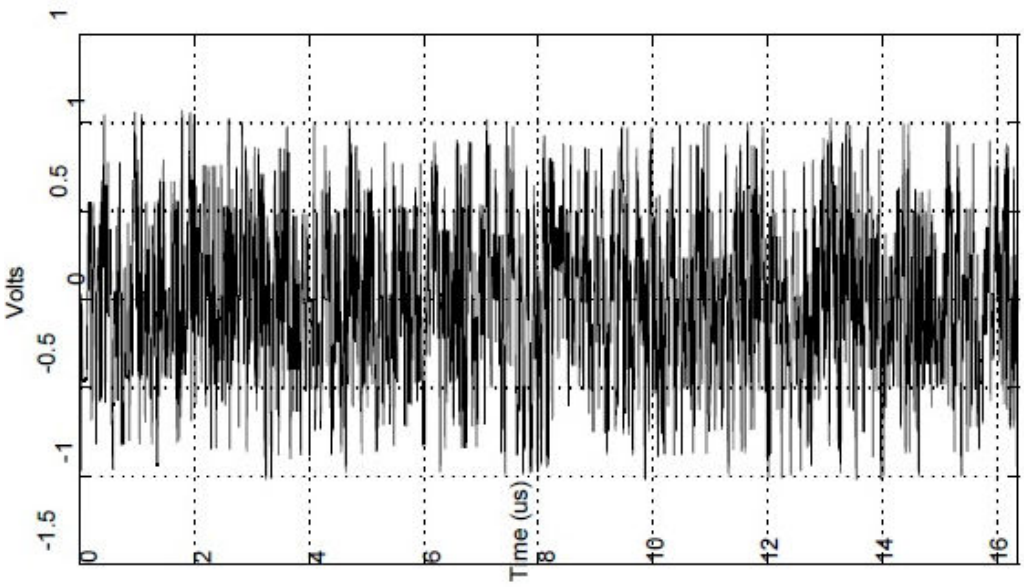
3. Click "Test Checked".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

4.10.3 Measurements

The Common-mode Output Voltage test requires a common mode voltage waveform. This waveform is similar to the test mode 4 waveform of 1000BASE-T tests.



The oscilloscope measures the maximum and minimum voltages of the captured waveform. The highest absolute value is considered as peak common mode voltage.

5 100BASE-TX Tests

100BASE-TX Ethernet compliance tests require option R&S RTO-K22.

- Starting 100BASE-TX Tests....62
- Test Configuration for Ethernet 100BASE-TX....62
- Amplitude Domain Tests....64
- Rise and Fall Times....67
- Peak to Peak Duty Cycle Distortion....70
- Peak to Peak Transmit Jitter....74
- Active Output Interface Template....76
- Transmitter Return Loss....79
- Receiver Return Loss....81

5.1 Starting 100BASE-TX Tests

Before you run the test, complete the following actions:

- Initial setup of the equipment, see Chapter 2.2, "Installing Software and License", on page 11
- LAN connection of the oscilloscope and the computer running the R&S ScopeSuite, see Chapter 2.5, "Connecting the R&S RTO", on page 14
- VNA connection for Transmitter and Receiver Return Loss tests, see Chapter 2.7, "Connecting the Vector Network Analyzer", on page 17.

1. Select "Ethernet" in the R&S ScopeSuite start window.
2. In the "Session Selection" dialog, set "Select Type" > "100BASE-TX".
3. Add a new test session and open it, see Chapter 3.1, "Starting a Test Session", on page 21.
4. Check the test configuration settings and adjust, if neccessary. See:
   - Chapter 5.2, "Test Configuration for Ethernet 100BASE-TX", on page 62
   - Chapter 3.2.1.1, "Limit Manager", on page 23
5. Select/check the test cases you want to run and click "Test Single"/"Test checked".
6. A step-by step guide explains the following individual setup steps. When you have finished all steps of the step-by-step guide, the compliance test runs automatically.

5.2 Test Configuration for Ethernet 100BASE-TX

Open a "100BASE-TX" session.

The test configuration consists of some test-specific configuration settings.

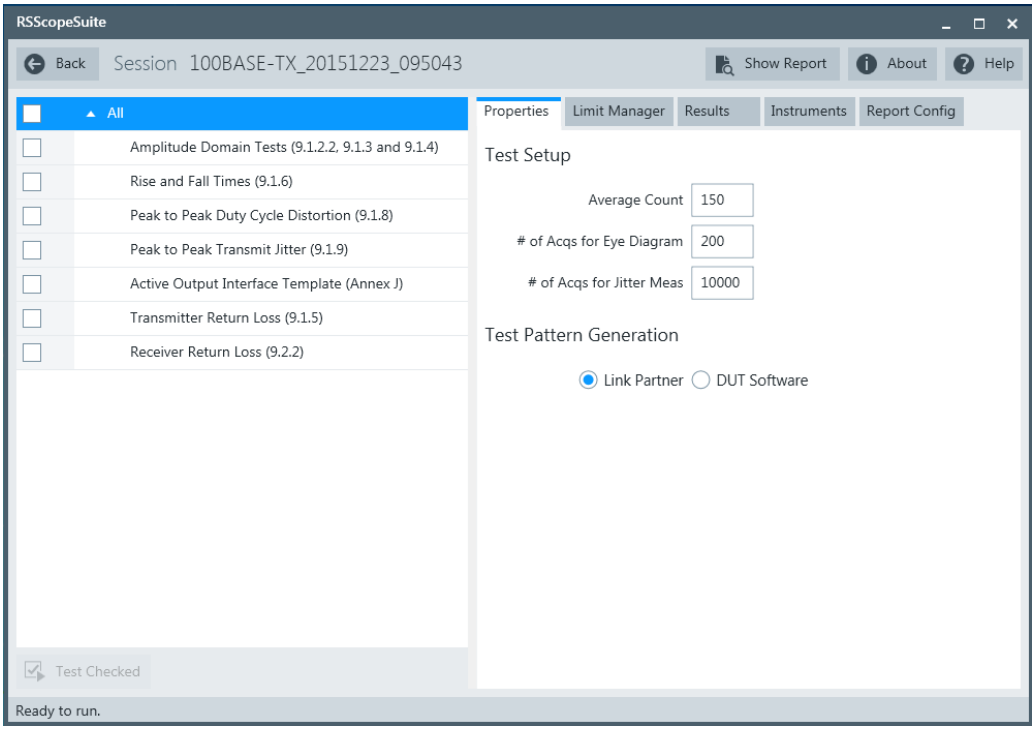


Figure 5-1: Configuration for 100BASE-TX compliance tests

Average Count
Defines the number of waveforms which the oscilloscope acquires to calculate the average waveform (average count). The average waveform is used in the following tests: Amplitude Domain Tests, Time Domain Tests, Duty Cycle Distortion, Total Transmit Jitter and AOI Template.

Increasing the number of waveforms results in more accurate measurement results but also in longer test execution time. If you are unsure, use the default values.

# of Acqs for Eye Diagram
Defines the number of waveforms which the oscilloscope acquires to form an eye diagram. The eye diagram is used to fit the template in the AOI Template test

Increasing the number of waveforms results in more accurate measurement results but also in longer test execution time. If you are unsure, use the default values.

# of Acqs for Jitter Meas
Defines the number of waveforms which the oscilloscope acquires to form a histogram. The histogram is used to measure the jitter in the Total Transmit Jitter test.

Increasing the number of waveforms results in more accurate measurement results but also in longer test execution time. If you are unsure, use the default values.

Test Pattern Generation
Selects the source of the test pattern generation.

Select "Link Partner" if you are using another 100BASE-TX device(link partner) for the pattern generation. The Twisted Pair Model section of the test fixture is used.

Select "DUT Software" if the pattern is generated by a software of your DUT.The Resistive Load section of the test fixture is used.

5.3 Amplitude Domain Tests

The Amplitude Domain tests verify that the differential output voltage, waveform overshoot and amplitude symmetry of the DUT are within the conformance limits specified in ANSI X3.263 standards, section 9.1.2.2, 9.1.3 and 9.1.4.

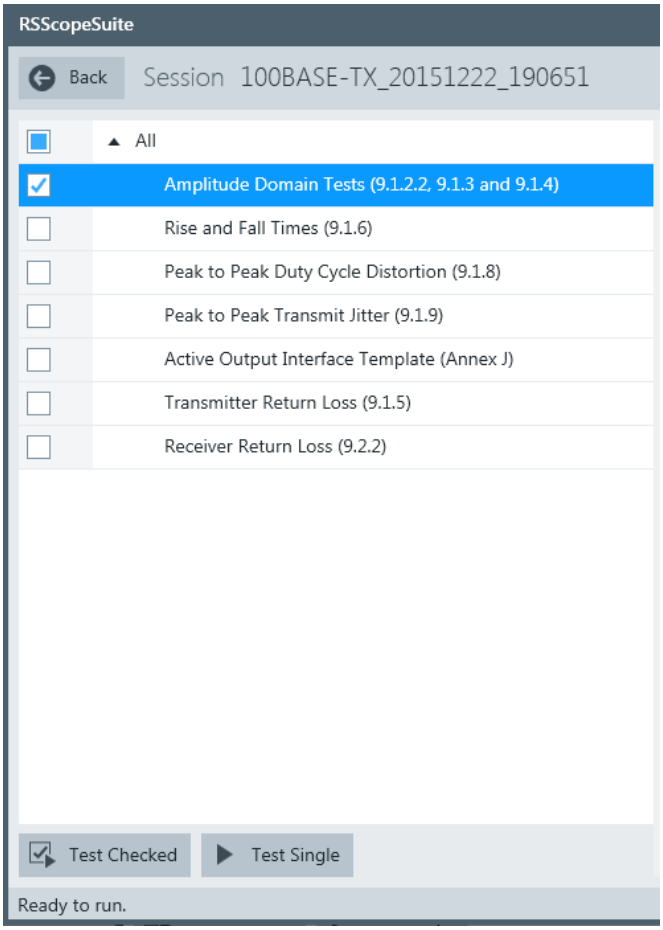
5.3.1 Test Equipment

Table 5-1: Equipment for Amplitude Domain Tests

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" (TPM) section or "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

5.3.2 Performing the Test

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX Tests", on page 62.
2. Select "Amplitude Domain Tests (9.1.2.2, 9.1.3 and 9.1.4)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

5.3.3 Measurements

Using TPM Section

For Amplitude Domain tests using the "Twisted Pair Model" (TPM) section,

1. connect the DUT and Link partner (using the TPM section)
2. configure the Link partner to transmit at 100 Mbps.

   The DUT transmitter should then emit the following waveform, on which the test is performed:

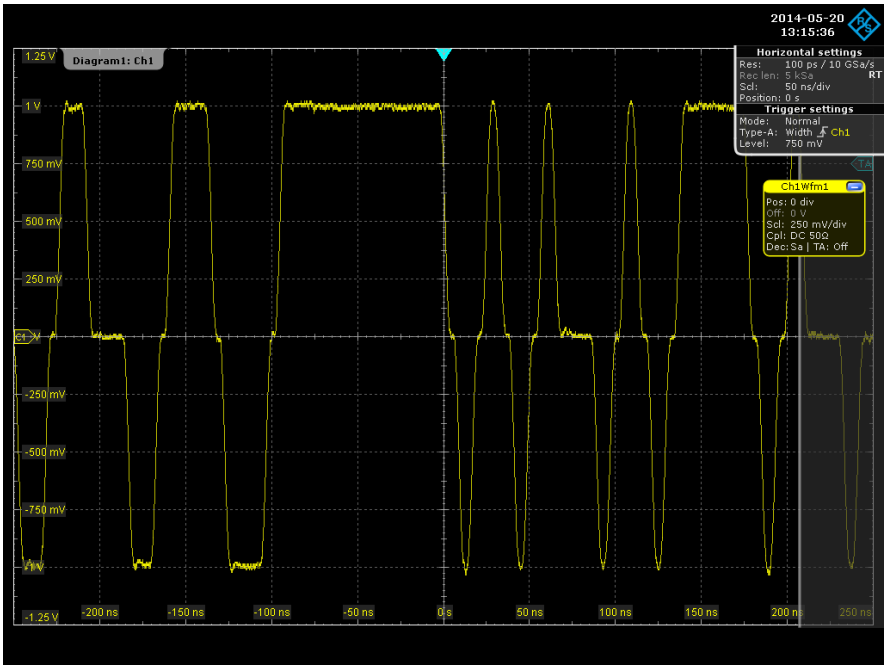


Figure 5-2: Waveform for amplitude domain tests using the TPM section

Using Resistive Load Section

For Amplitude Domain tests using the "Resistive Load" section, the DUT has to emit waveforms having 12 or 14 bit times of no transition preceded by a 0 V to Vout transition.

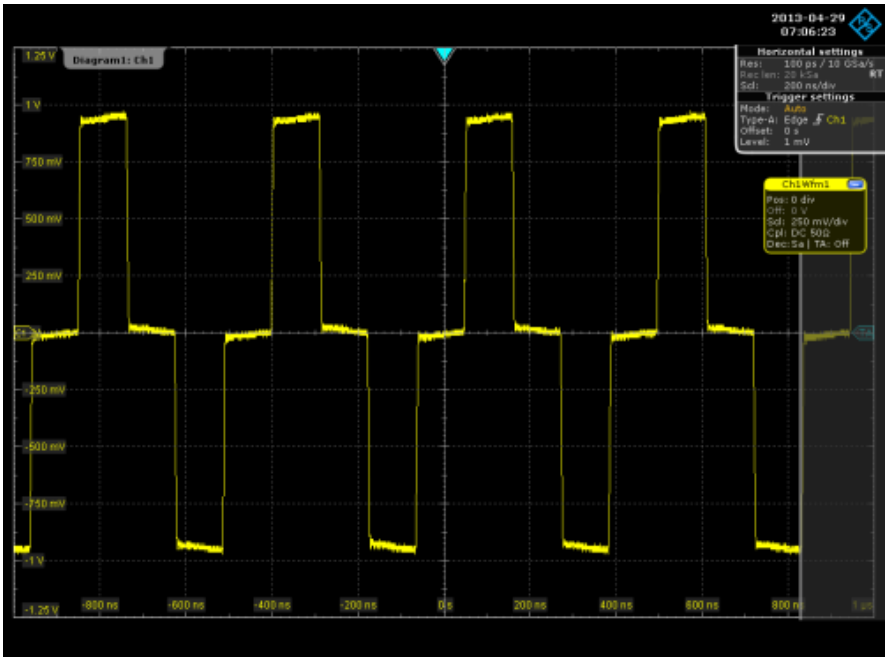


Figure 5-3: Waveform for amplitude domain tests and rise and fall time tests

The test consists of three measurements:

- Differential output voltages
  The mean differential voltage of the positive pulse and that of the negative pulse are measured. The measurements are performed on an averaged waveform. To exclude any overshoots, a measurement gate is defined 8 ns away from transition mid points. The standard defines the following limits for voltage values: 950 mV to 1050 mV.
- Signal amplitude symmetry
  Calculates the ratio of the mean positive and negative voltages measured in "differential output voltages" measurement. This ratio should be between 0.98 and 1.02 as specified in the standard.
- Waveform overshoot
  Overshoot is measured for both positive and negative pulses. The overshoot should be less than 5% of the mean differential output voltage as specified in the standard.

5.4 Rise and Fall Times

The Rise and Fall Times tests verify that the response times of the DUT is within the conformance limits specified in ANSI X3.263 standards, section 9.1.6.

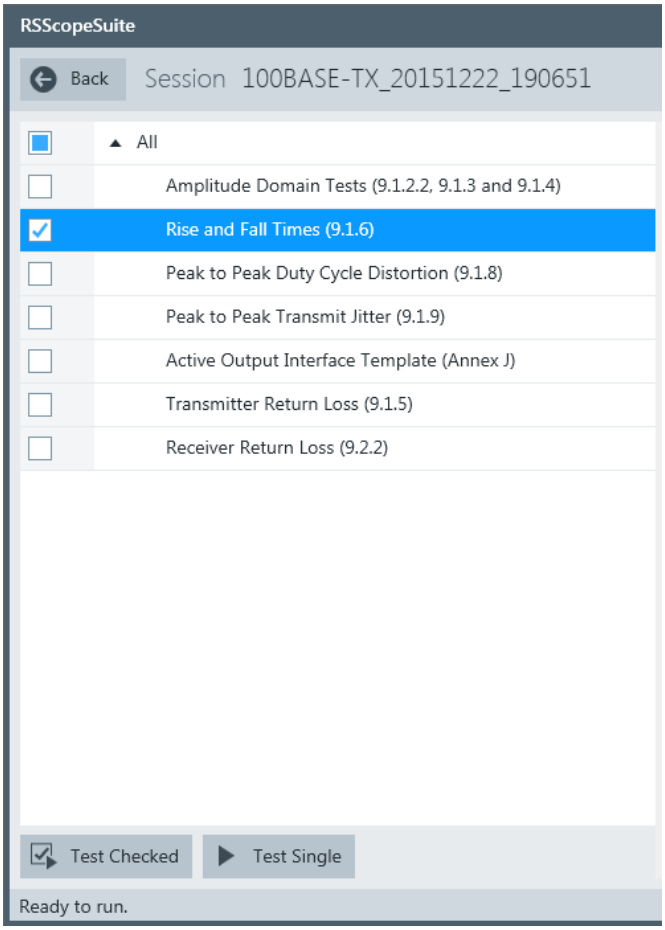
5.4.1 Test Equipment

Table 5-2: Equipment for Rise and fall time tests

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" (TPM) section or "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

5.4.2 Performing the Test

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX Tests", on page 62.
2. Select "Rise and Fall Times (9.1.6)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

5.4.3 Measurements

Using TPM Section

For Rise and Fall Time tests using the "Twisted Pair Model" (TPM) section,

1. connect the DUT and Link partner (using the TPM section)
2. configure the Link partner to transmit at 100 Mbps.

   The DUT transmitter should then emit the following waveform, on which the test is performed:

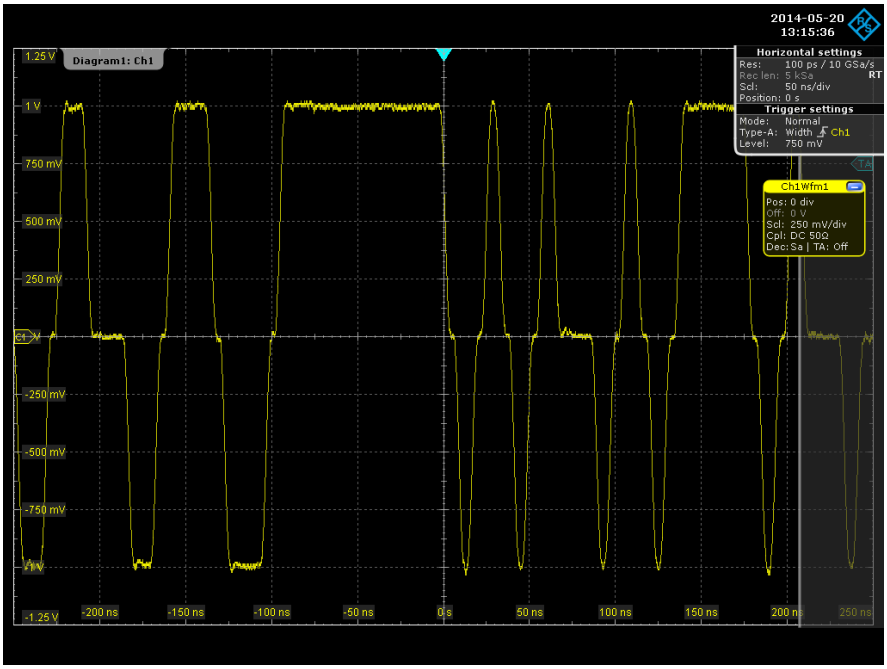


Figure 5-4: Waveform for rise and fall time tests using the TPM section

Using Resistive Load Section

For Rise and Fall Time tests using the "Resistive Load" section, the DUT has to emit waveforms having 12 or 14 bit times of no transition preceded by a 0 V to Vout transition.

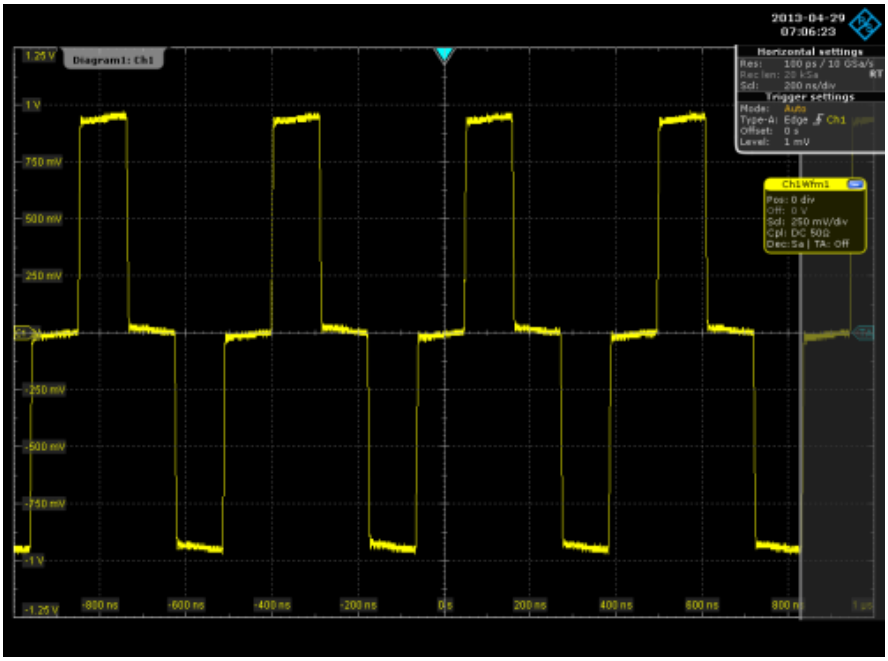


Figure 5-5: Waveform for amplitude domain tests and rise and fall time tests

The test consists of three measurements each of the positive and negative pulses:

- Rise time
  The standard demands a rise time between 3 ns and 5 ns.
- Fall time
  The standard demands a fall time between 3 ns and 5 ns.
- Maximum difference between all rise and fall times
  The standard demands a maximum difference less than 500 ps.

5.5 Peak to Peak Duty Cycle Distortion

The Peak to Peak Duty Cycle Distortion tests verify the peak to peak duty cycle distortion of the DUT is within the conformance limits specified in ANSI X3.263 standards, section 9.1.8.

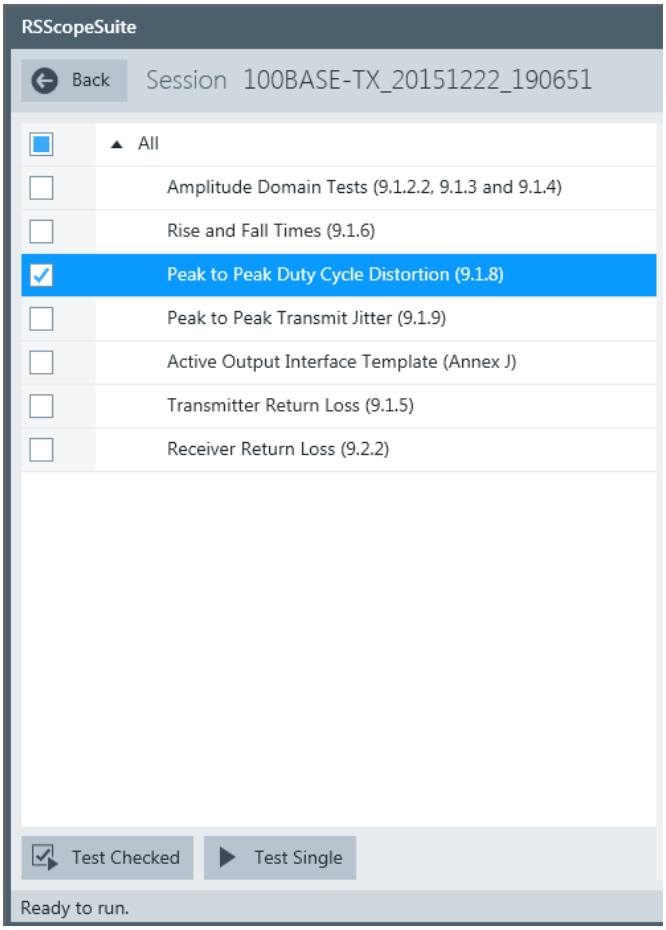
5.5.1 Test Equipment

Table 5-3: Equipment for Peak to Peak Duty Cycle Distortion tests

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" (TPM) section or "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

5.5.2 Performing the Test

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX Tests", on page 62.
2. Select "Peak to Peak Duty Cycle Distortion (9.1.8)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

5.5.3 Measurements

Using TPM Section

For Peak to Peak Duty Cycle Distortion tests using the "Twisted Pair Model" (TPM) section,

1. connect the DUT and Link partner (using the TPM section)
2. configure the Link partner to transmit at 100 Mbps.

   The DUT transmitter should then emit the following waveform, on which the test is performed:

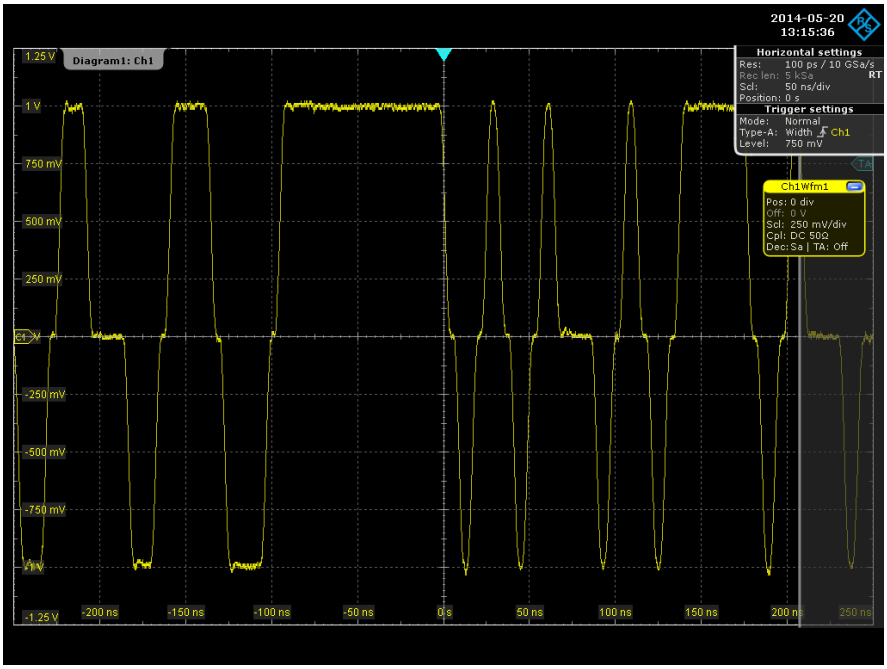


Figure 5-6: Waveform for peak to peak duty cycle distortion tests using the TPM section

Using Resistive Load Section

For Peak to Peak Duty Cycle Distortion tests using the "Resistive Load" section, the DUT has to transmit MLT-3 encoded clock-like pattern waveforms.

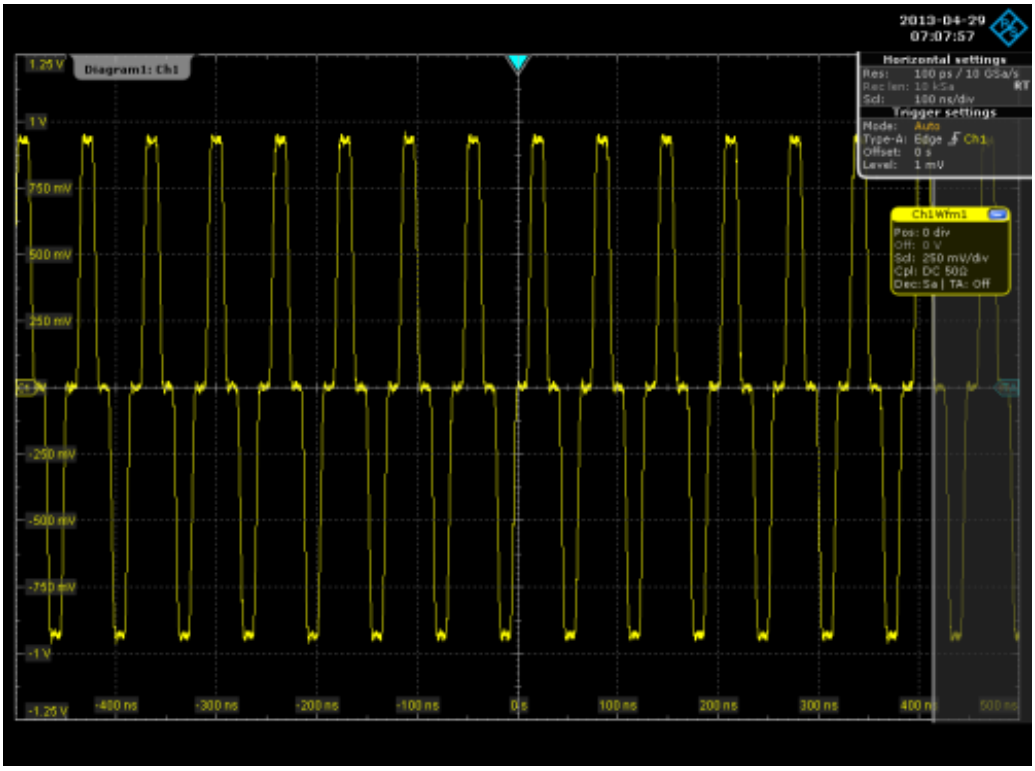
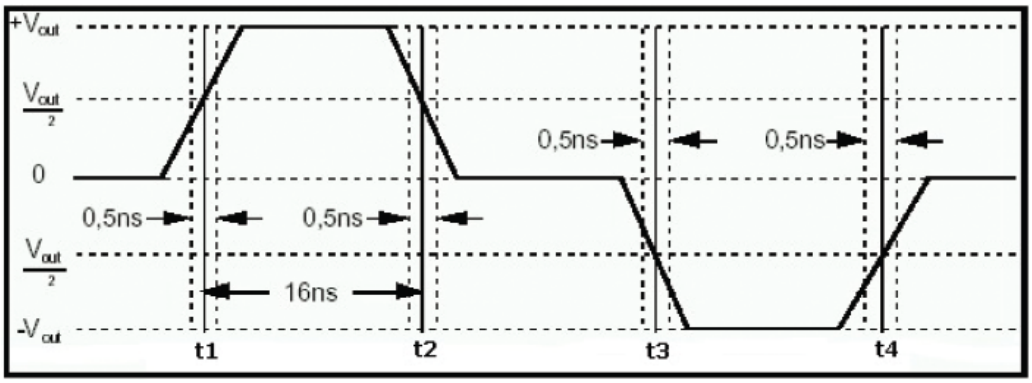


Figure 5-7: MLT-3 encoded clock-like pattern waveform

The test measures the times when the averaged waveform crosses $V_{out}/2$ Volts.

Then the software calculates the peak to peak duty cycle distortion as follows:



Calculation of T_x values	$T_1 = t_2 - t_1 - 16$ ns $T_2 = t_3 - t_2 - 16$ ns $T_3 = t_4 - t_3 - 16$ ns $T_4 = t_3 - t_1 - 16$ ns $T_5 = t_4 - t_2 - 16$ ns $T_6 = t_4 - t_1 - 16$ ns
Peak to peak duty cycle distortion	Maximum of T_x values

The standard defines a maximum Peak to Peak Duty Cycle Distortion of 500 ps.

5.6 Peak to Peak Transmit Jitter

The Peak to Peak Transmit Jitter tests verify that the total transmit jitter of the DUT is within the conformance limits specified in ANSI X3.263 standards, section 9.1.9.

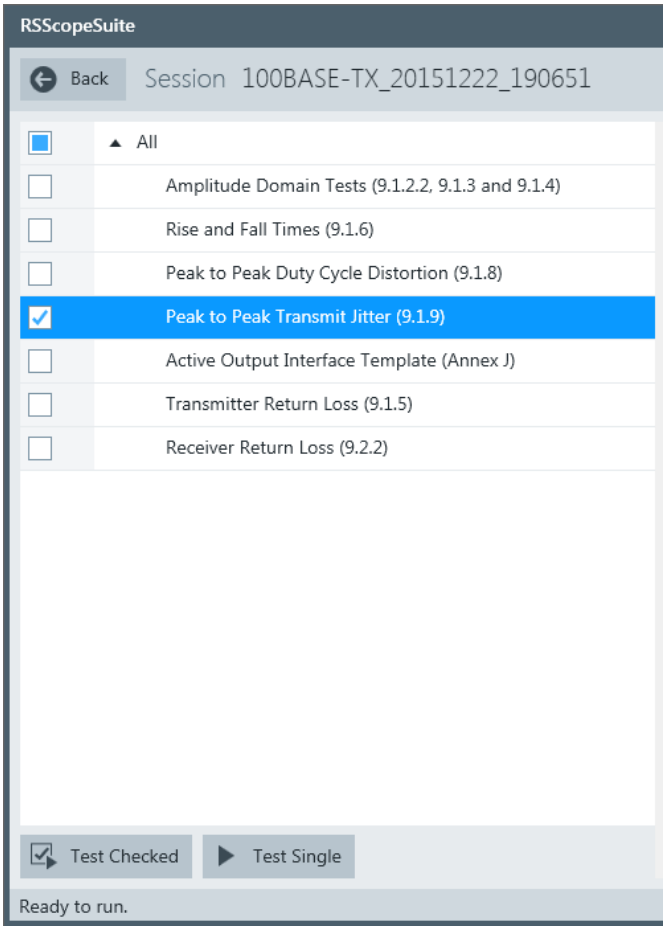
5.6.1 Test Equipment

Table 5-4: Equipment for Peak to Peak Transmit Jitter tests

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" (TPM) section or "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

5.6.2 Performing the Test

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX Tests", on page 62.
2. Select "Peak to Peak Transmit Jitter (9.1.9)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

5.6.3 Measurements

Using TPM Section

For Peak to Peak Transmit Jitter tests using the "Twisted Pair Model" (TPM) section,

1. connect the DUT and Link partner (using the TPM section)
2. configure the Link partner to transmit at 100 Mbps.

   The DUT transmitter should then emit the following waveform, on which the test is performed.

Using Resistive Load Section

For Peak to Peak Transmit Jitter tests using the "Resistive Load" section, the DUT has to transmit scrambled MLT-3 encoded idle pattern waveforms.

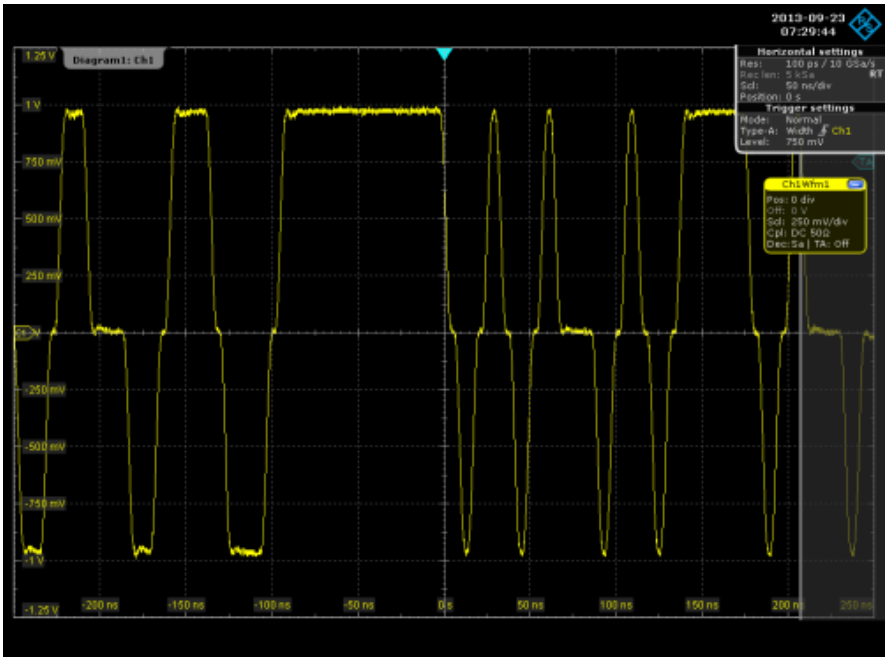


Figure 5-8: Scrambled MLT-3 encoded idle pattern waveform

The test measures the total transmit jitter that is mainly caused by duty cycle distortion and baseline wander. A distribution histogram is constructed with accumulated set of points at waveform crossover, and the peak to peak jitter is inferred from minimum and maximum values in the tails of the histogram. Since the waveform is a three level signal, the jitter is measured at both upper and lower crossovers.

The standard defines a maximum jitter of 1.4 ns.

5.7 Active Output Interface Template

The Active Output Interface (AOI) Template tests verify that the transmitted signal meets industry standards in terms of jitter, overshoot, rise time, fall time etc. ANSI X3.263 standards Annex J defines the mask and also specifies a tolerance of 5% on mask geometries.

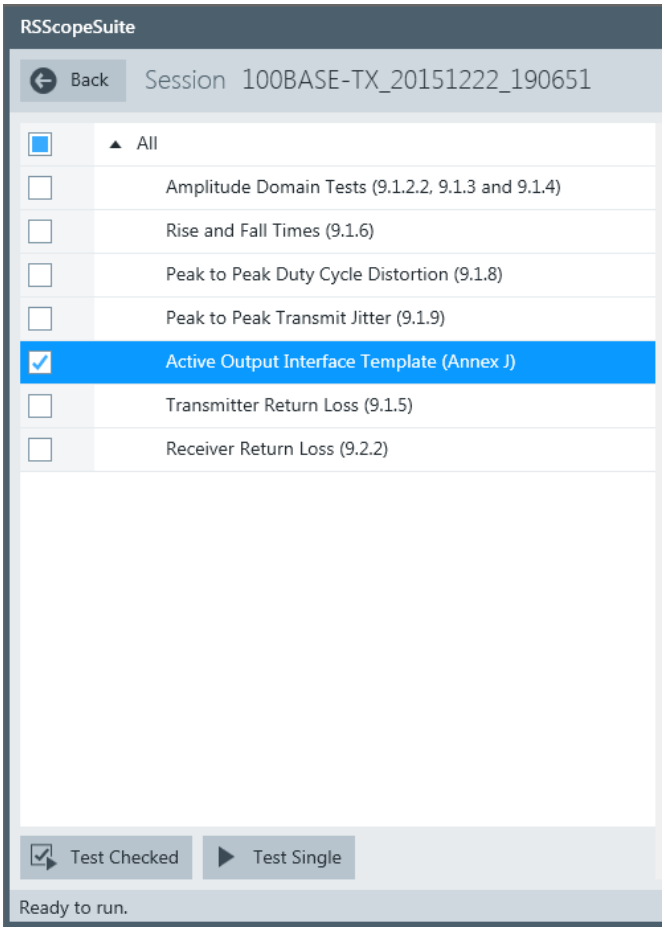
5.7.1 Test Equipment

Table 5-5: Equipment for Active Output Interface Template tests

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" (TPM) section or "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

5.7.2 Performing the Test

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX Tests", on page 62.
2. Select "Active Output Interface Template (Annex J)".



3. Click "Test Single".

4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

5.7.3 Measurements

Using TPM Section

For AOI Template tests using the "Twisted Pair Model" (TPM) section,

1. connect the DUT and Link partner (using the TPM section)
2. configure the Link partner to transmit at 100 Mbps.

   The DUT transmitter should then emit the following waveform, on which the test is performed.

Using Resistive Load Section

For AOI Template tests using the "Resistive Load" section, the DUT has to transmit scrambled MLT-3 encoded idle or halt line pattern waveform.

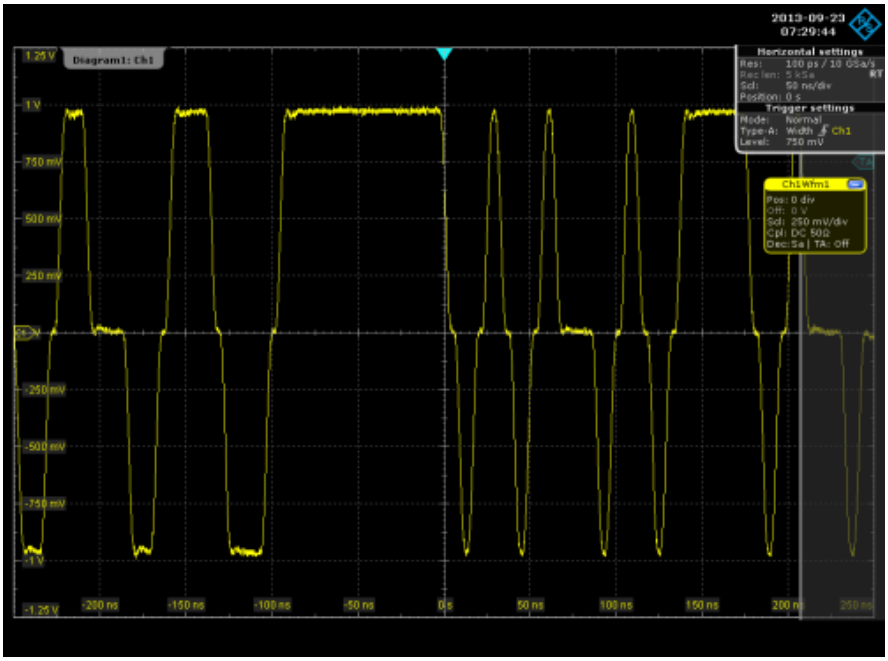


Figure 5-9: Scrambled MLT-3 encoded idle pattern waveform

Both tests adjust the mask up to 5% of originally defined geometries and try to achieve best fit with the waveform. If any violations of the mask occur, the test has failed. Mask test is performed separately for positive and negative sides of the waveform.

5.8 Transmitter Return Loss

The Transmitter Return Loss test verifies that the transmitter return loss of the DUT over the frequency range of 2 to 80 MHz is greater than the limits specified in ANSI X3.263-1995, section 9.1.5.

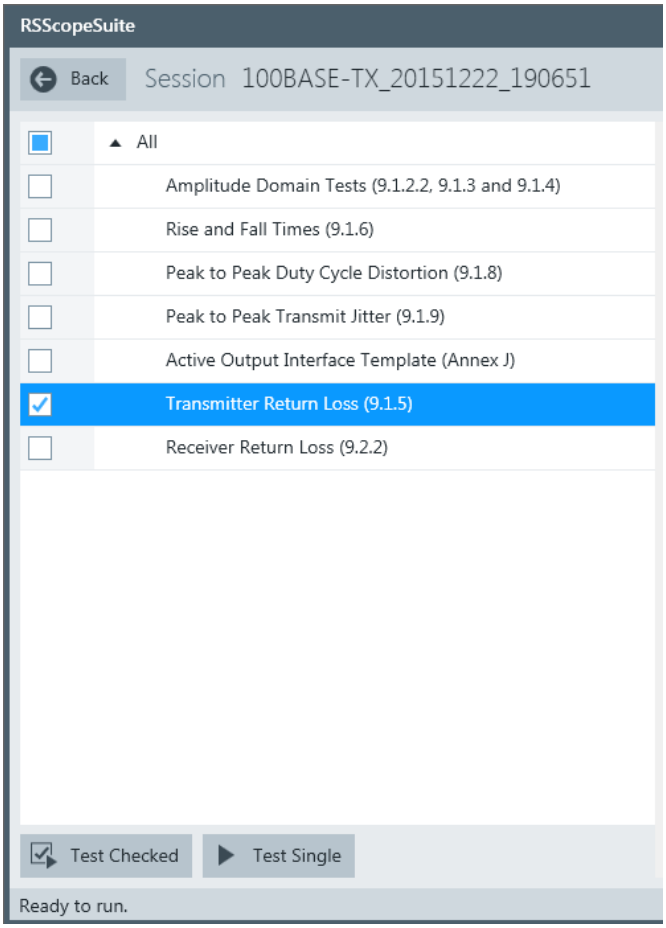
5.8.1 Test Equipment

Table 5-6: Equipment for Transmitter Return Loss test

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Vector Network Analyzer (optional, required only to perform an automatic test)	R&S ZVL or R&S ZNB	1
DUT	the device you want to test	1

5.8.2 Performing the Test

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX Tests", on page 62.
2. Select "Transmitter Return Loss (9.1.5)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

5.8.3 Measurements

Configure the DUT to "100BASE-TX scrambled MLT-3 encoded /I/ code-groups data" output.

During automatic testing, the program measures the S11 parameter on the VNA. It shall fall below the limit line plotted on the VNA from 2 to 80 MHz.

During manual testing, the program checks if every point between 2 MHz and 80 MHz in the result file (*.s1p or *.csv) falls below the limit required by the specification.

5.9 Receiver Return Loss

The Receiver Return Loss test verifies that the transmitter return loss of the DUT over the frequency range of 2 to 80 MHz is greater than the limits specified in ANSI X3.263-1995, section 9.2.2.

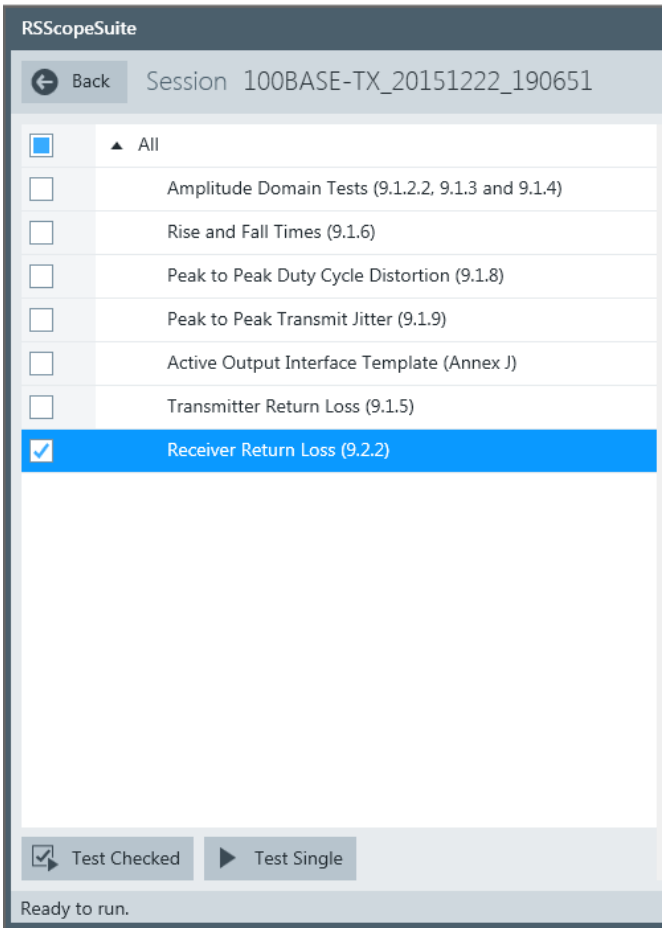
5.9.1 Test Equipment

Table 5-7: Equipment for Receiver Return Loss test

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Vector Network Analyzer (optional, required only to perform an automatic test)	R&S ZVL or R&S ZNB	1
DUT	the device you want to test	1

5.9.2 Performing the Test

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX Tests", on page 62.
2. Select "Receiver Return Loss (9.2.2)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

5.9.3 Measurements

Configure the DUT to "100BASE-TX scrambled MLT-3 encoded /I/ code-groups data" output.

During automatic testing, the program measures the S11 parameter on the VNA. It shall fall below the limit line plotted on the VNA from 2 to 80 MHz.

During manual testing, the program checks if every point between 2 MHz and 80 MHz in the result file (*.s1p or *.csv) falls below the limit required by the specification.

6 10BASE-T Tests

10BASE-T Ethernet compliance tests require option R&S RTO-K22.

- Starting 10BASE-T Tests....83
- Test Configuration for Ethernet 10BASE-T....83
- Link Test Pulse Template....85
- TP_IDL Template....91
- Output Timing Jitter....97
- Peak Differential Voltage....101
- Harmonic Content....103
- MAU Template....105
- Transmitter Return Loss....107
- Receiver Return Loss....109
- Common-mode Output Voltage....111

6.1 Starting 10BASE-T Tests

Before you run the test, complete the following actions:

- Initial setup of the equipment, see Chapter 2.2, "Installing Software and License", on page 11
- LAN connection of the oscilloscope and the computer running the R&S ScopeSuite, see Chapter 2.5, "Connecting the R&S RTO", on page 14
- VNA connection for Transmitter and Receiver Return Loss tests, see Chapter 2.7, "Connecting the Vector Network Analyzer", on page 17.

1. Select "Ethernet" in the R&S ScopeSuite start window.
2. In the "Session Selection" dialog, set "Select Type" > "10BASE-T".
3. Add a new test session and open it, see Chapter 3.1, "Starting a Test Session", on page 21.
4. Check the test configuration settings and adjust, if neccessary. See:
   - Chapter 6.2, "Test Configuration for Ethernet 10BASE-T", on page 83
   - Chapter 3.2.1.1, "Limit Manager", on page 23
5. Select/check the test cases you want to run and click "Test Single"/"Test checked".
6. A step-by step guide explains the following individual setup steps. When you have finished all steps of the step-by-step guide, the compliance test runs automatically.

6.2 Test Configuration for Ethernet 10BASE-T

Open a "10BASE-T" session.

The test configuration consists of some test-specific configuration settings.

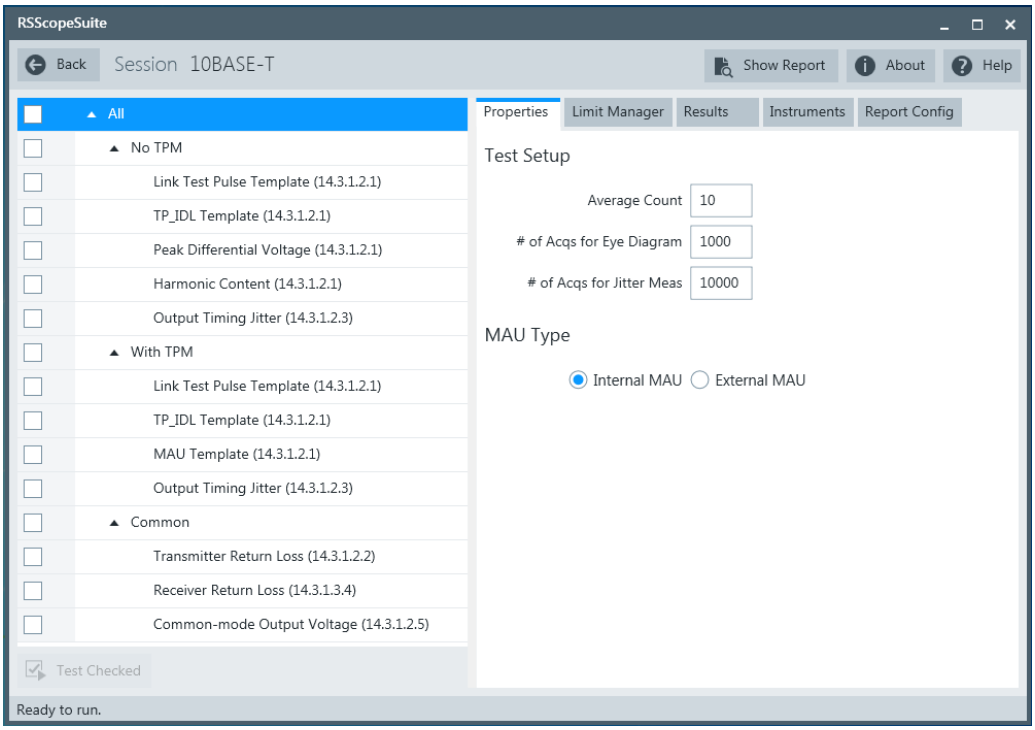


Figure 6-1: Configuration for 10BASE-T compliance tests

Average Count
Defines the number of waveforms which the oscilloscope acquires to calculate the average waveform (average count). The average waveform is used in the following tests: Peak Differential Voltage, Harmonic Content and Common Mode Output Voltage.

Increasing the number of waveforms results in more accurate measurement results but also in longer test execution time. If you are unsure, use the default values.

# of Acqs for Eye Diagram
Defines the number of waveforms which the oscilloscope acquires to form an eye diagram. The eye diagram is used to fit the respective templates in the following tests: Link Test Pulse Template (with and without TPM), TP_IDL Template (with and without TPM) and MAU Template.

Increasing the number of waveforms results in more accurate measurement results but also in longer test execution time. If you are unsure, use the default values.

# of Acqs for Jitter Meas
Defines the number of waveforms which the oscilloscope acquires to form a histogram. The histogram is used to measure the jitters at 8BT and 8.5BT in the following tests: Output Timing Jitter with and without TPM.

Increasing the number of waveforms results in more accurate measurement results but also in longer test execution time. If you are unsure, use the default values.

MAU Type
Select the type of the medium attachment unit (MAU). Usually the MAU is integrated, and the type is "Internal".

6.3 Link Test Pulse Template

The Link test Pulse Template tests verify that the link test pulse waveform fits into the template specified in figure 14-12 of IEEE 802.3-2008, subclause 14.3.1.2.1. The measurements are made with and without Twisted Pair Model (TPM), each with three different loads.

6.3.1 Test Equipment

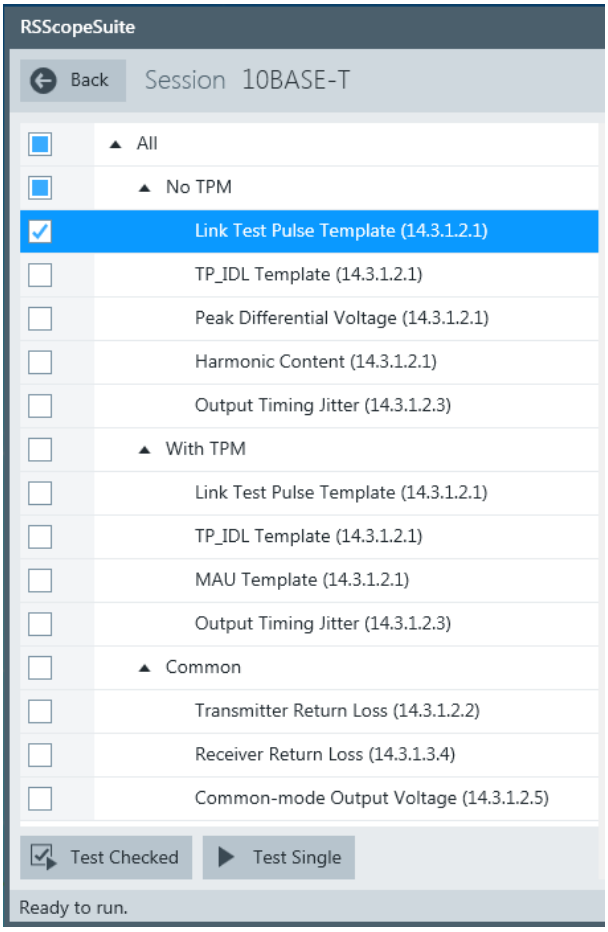
Table 6-1: Equipment for all Link Test Pulse Template tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

6.3.2 No TPM

6.3.2.1 Performing the Test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T Tests", on page 83.
2. Under "No TPM", select "Link Test Puls Template (14.3.1.2.1)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

6.3.2.2 Measurements

Configure the DUT to "10BASE-T random data" mode.

The waveforms displayed on the R&S RTO should look similar to the pictures below.

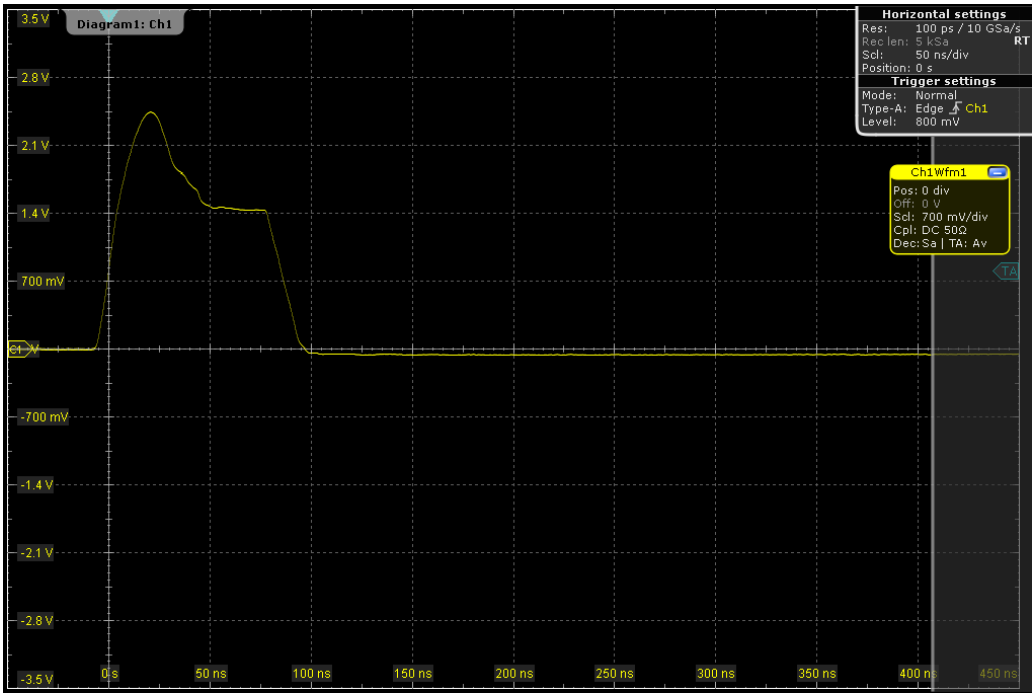


Figure 6-2: Waveform with load 1

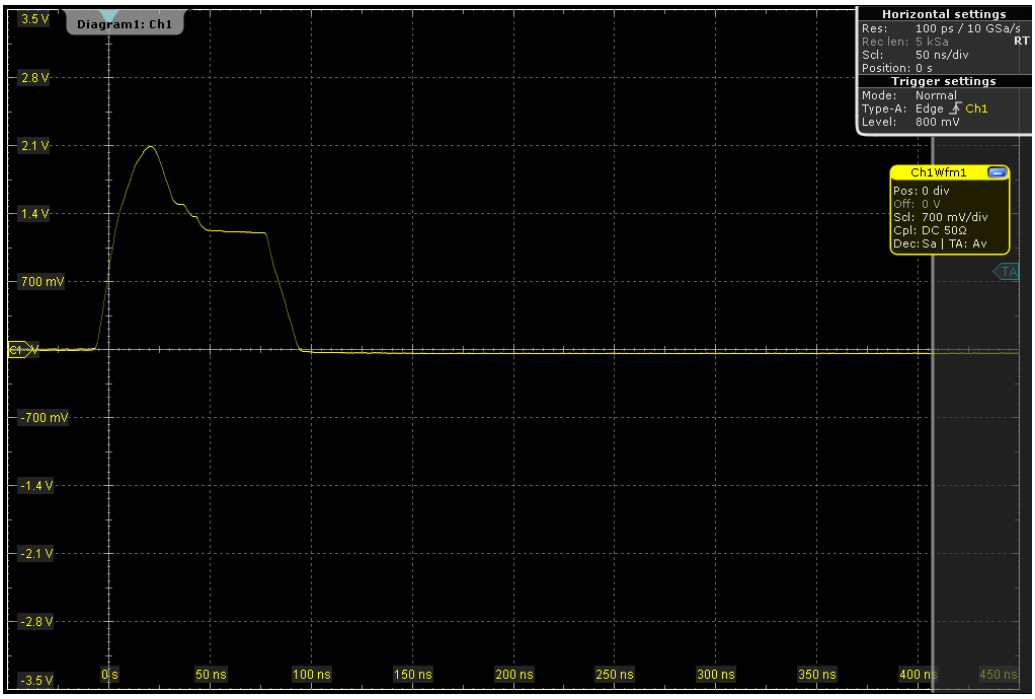


Figure 6-3: Waveform with load 2

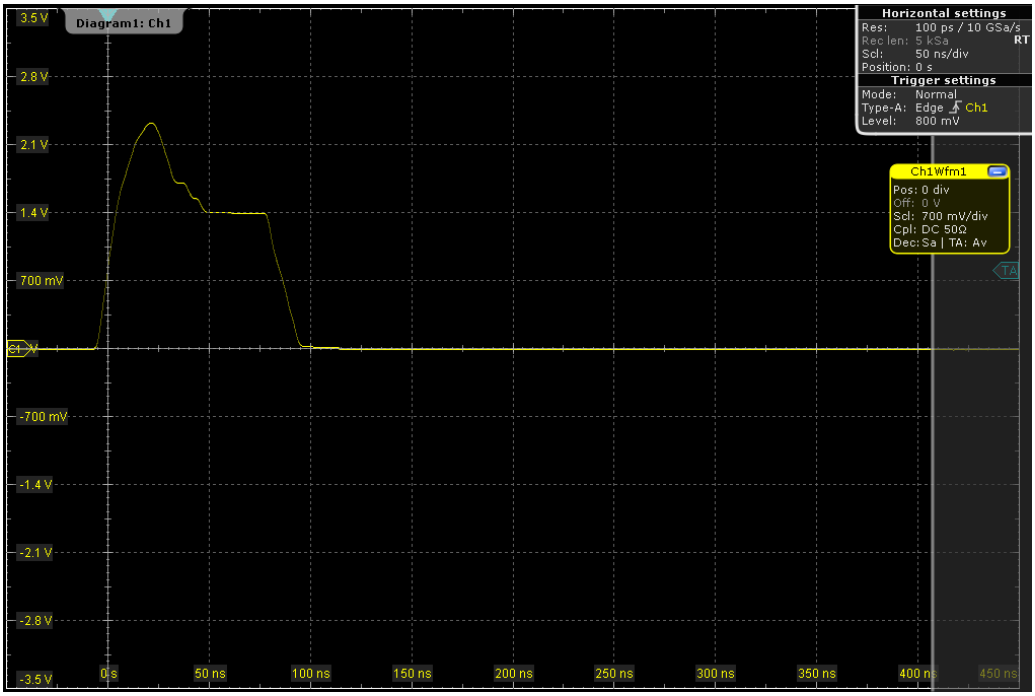


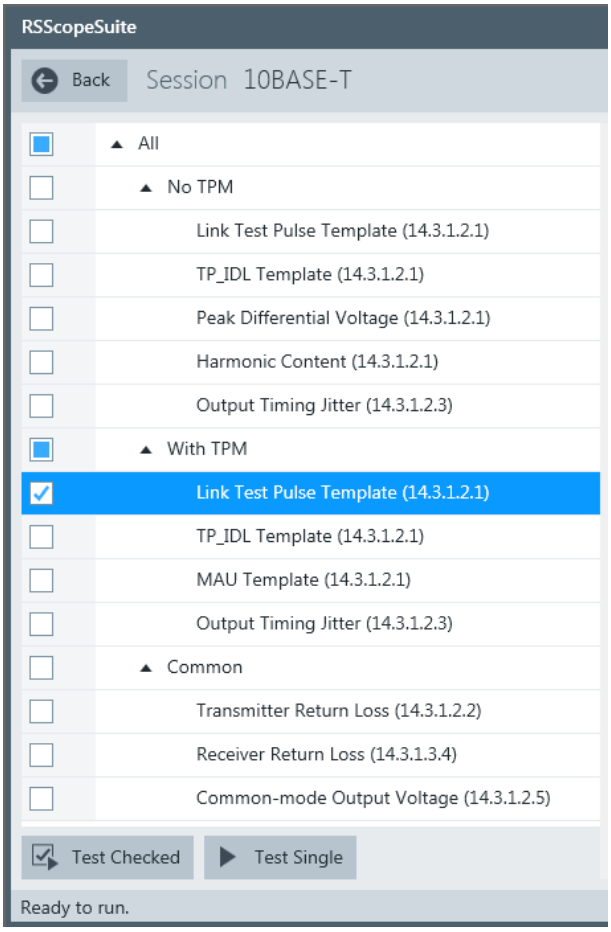
Figure 6-4: Waveform with load 100 Ω

The test procedure is the same for each load. A mask is created according to the template specified in figure 14-12 of IEEE 802.3-2008, subclause 14.3.1.2.1. The test has been passed if the waveform did not violate the mask.

6.3.3 With TPM

6.3.3.1 Performing the Test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T Tests", on page 83.
2. Under "With TPM", select "Link Test Puls Template (14.3.1.2.1)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

6.3.3.2 Measurements

Configure the DUT to "10BASE-T random data" mode.

The waveforms displayed on the R&S RTO should look similar to the pictures below.

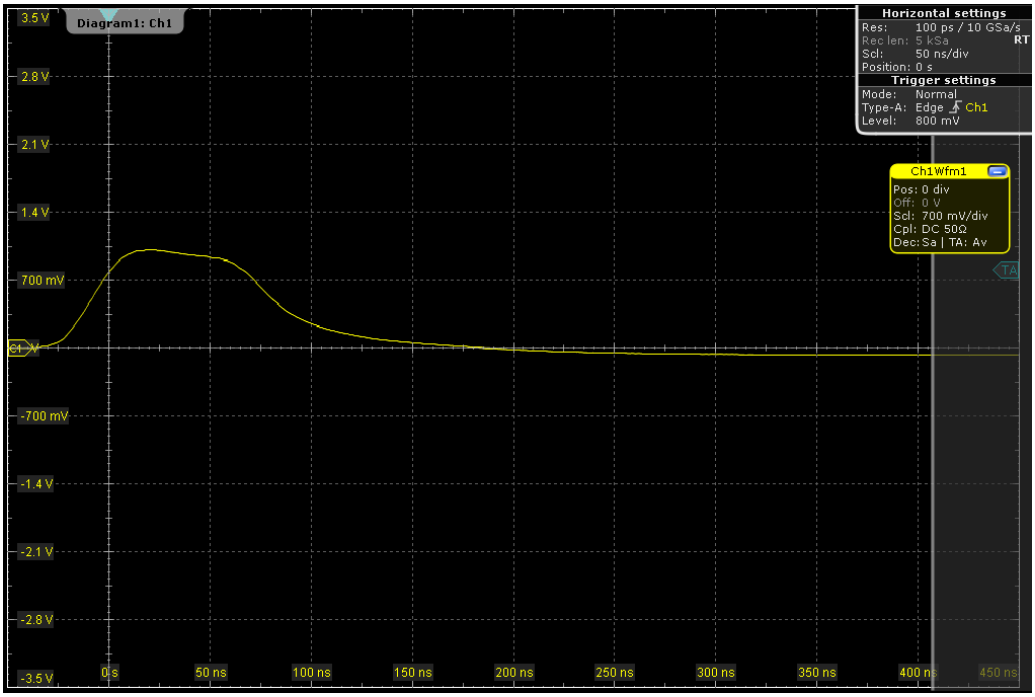


Figure 6-5: Waveform with load 1

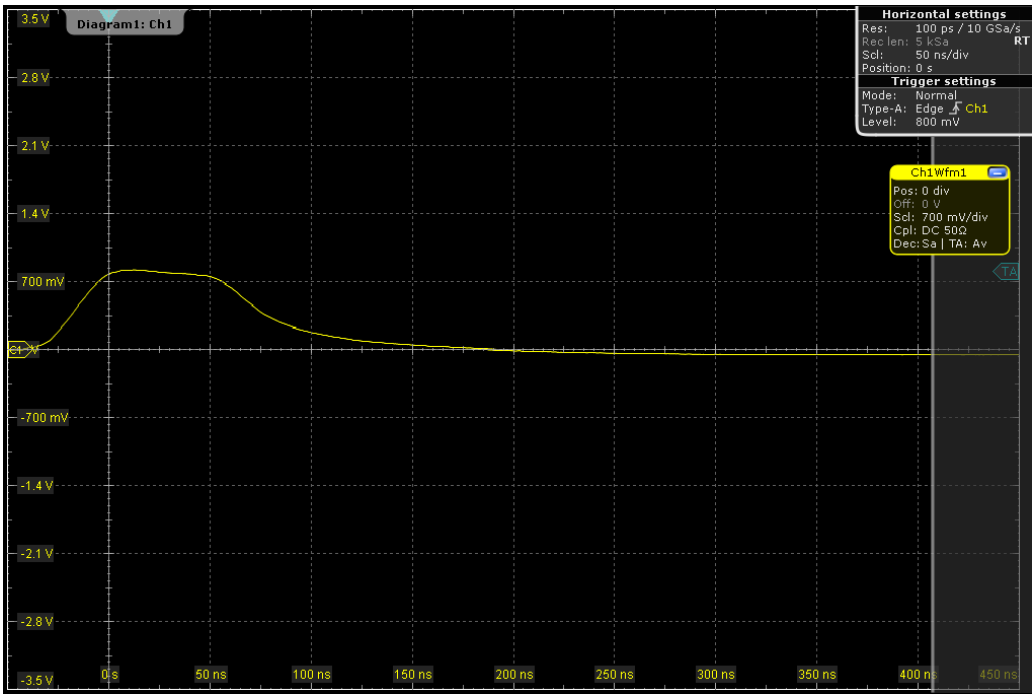


Figure 6-6: Waveform with load 2

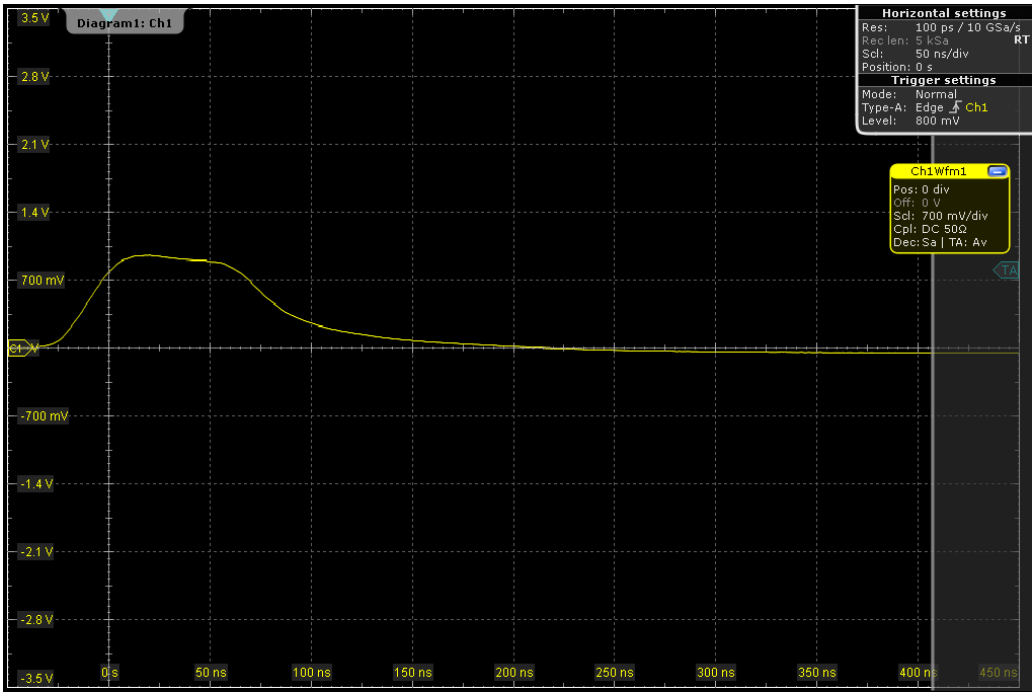


Figure 6-7: Waveform with load 100 Ω

The test procedure is the same for each load. A mask is created according to the template specified in figure 14-12 of IEEE 802.3-2008, subclause 14.3.1.2.1. The test has been passed if the waveform did not violate the mask.

6.4 TP_IDL Template

The TP_IDL Template tests verify that the TPL_IDL signal fits into the template specified in figure 14-10 of IEEE 802.3-2008, subclause 14.3.1.2.1. The measurements are made with and without Twisted Pair Model (TPM), each with three different loads.

6.4.1 Test Equipment

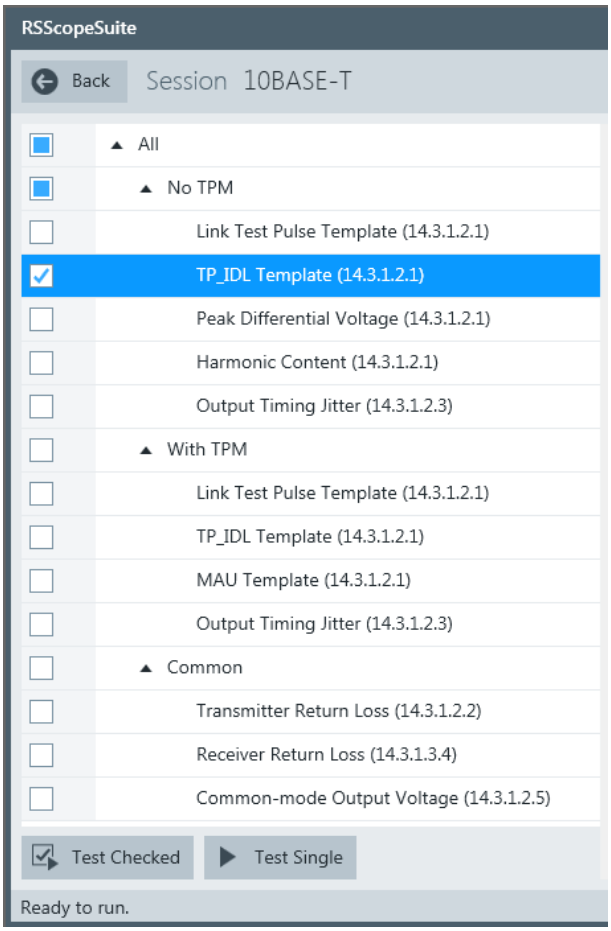
Table 6-2: Equipment for all TP_IDL Template tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

6.4.2 No TPM

6.4.2.1 Performing the Test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T Tests", on page 83.
2. Under "No TPM", select "TP_IDL Template (14.3.1.2.1)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

6.4.2.2 Measurements

Configure the DUT to "10BASE-T random data" mode.

The waveforms displayed on the R&S RTO should look similar to the pictures below.

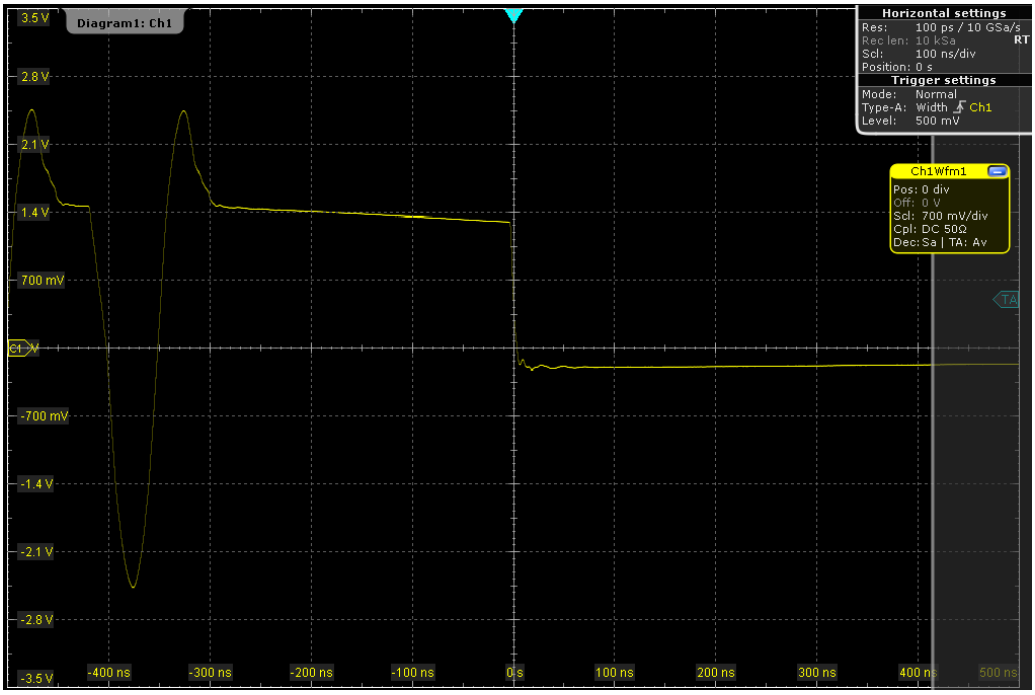


Figure 6-8: Waveform with load 1

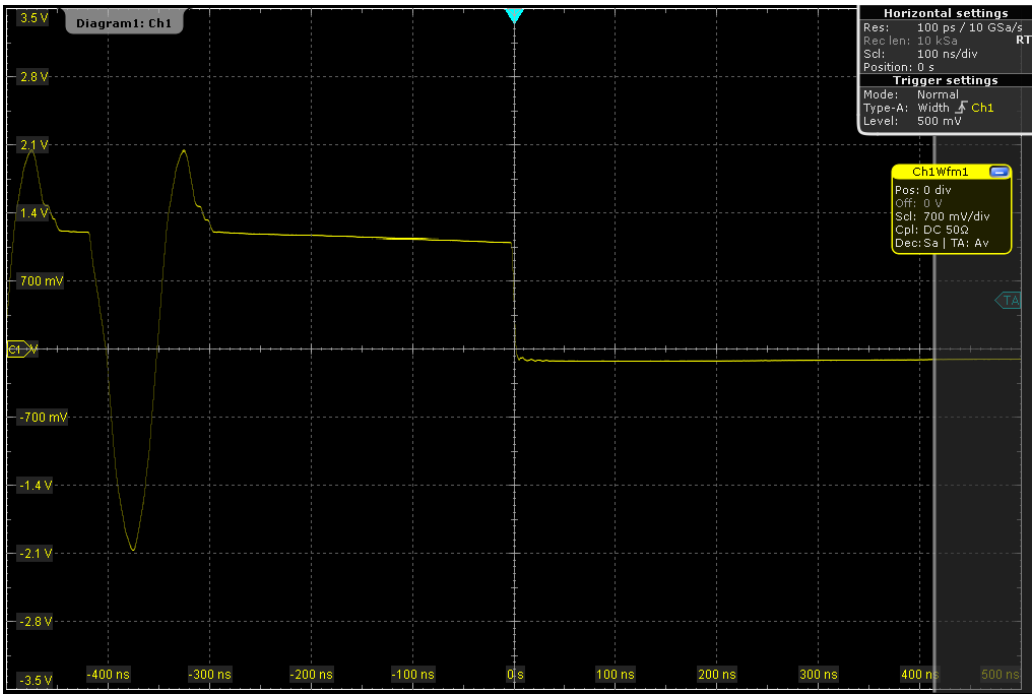


Figure 6-9: Waveform with load 2

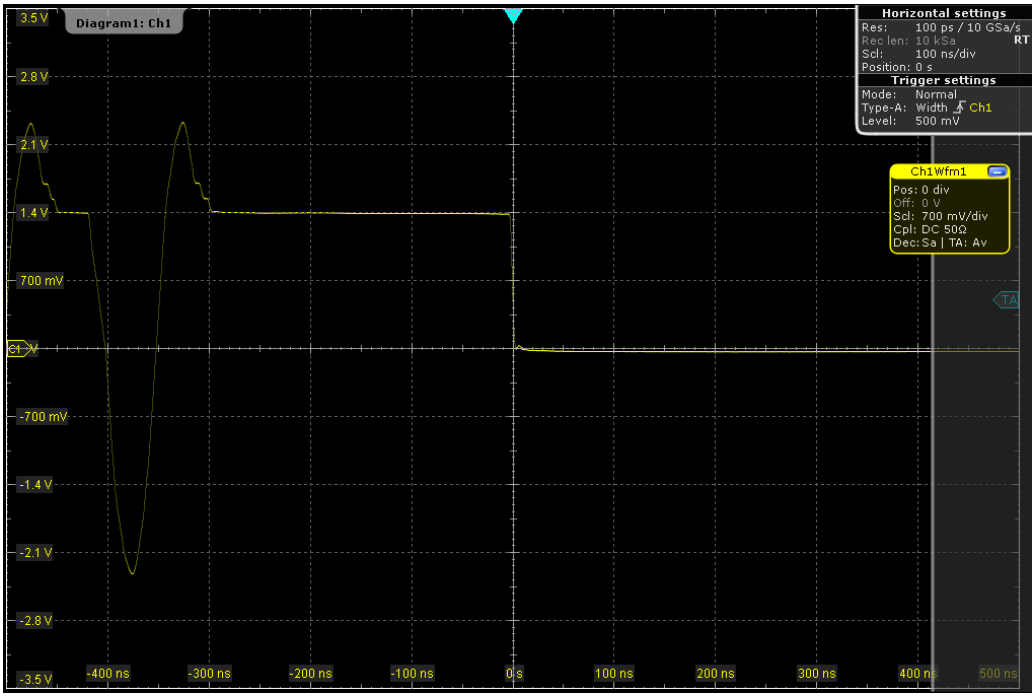


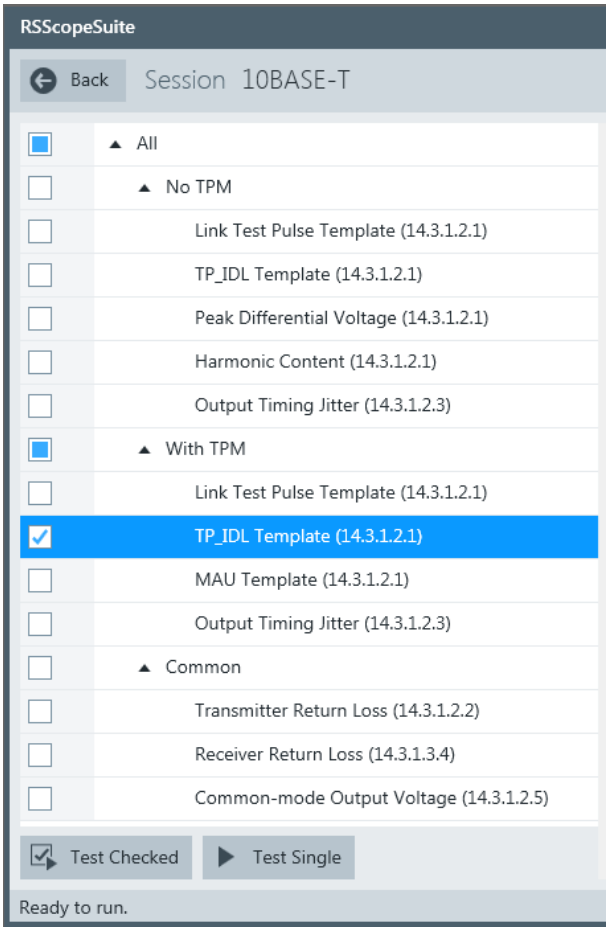
Figure 6-10: Waveform with load 100 Ω

The test procedure is the same for each load. A mask is created according to the template specified in figure 14-10 of IEEE 802.3-2008, subclause 14.3.1.2.1. The test has been passed if the waveform did not violate the mask.

6.4.3 With TPM

6.4.3.1 Performing the Test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T Tests", on page 83.
2. Under "With TPM", select "TP_IDL Template (14.3.1.2.1)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

6.4.3.2 Measurements

Configure the DUT to "10BASE-T random data" mode.

The waveforms displayed on the R&S RTO should look similar to the pictures below.

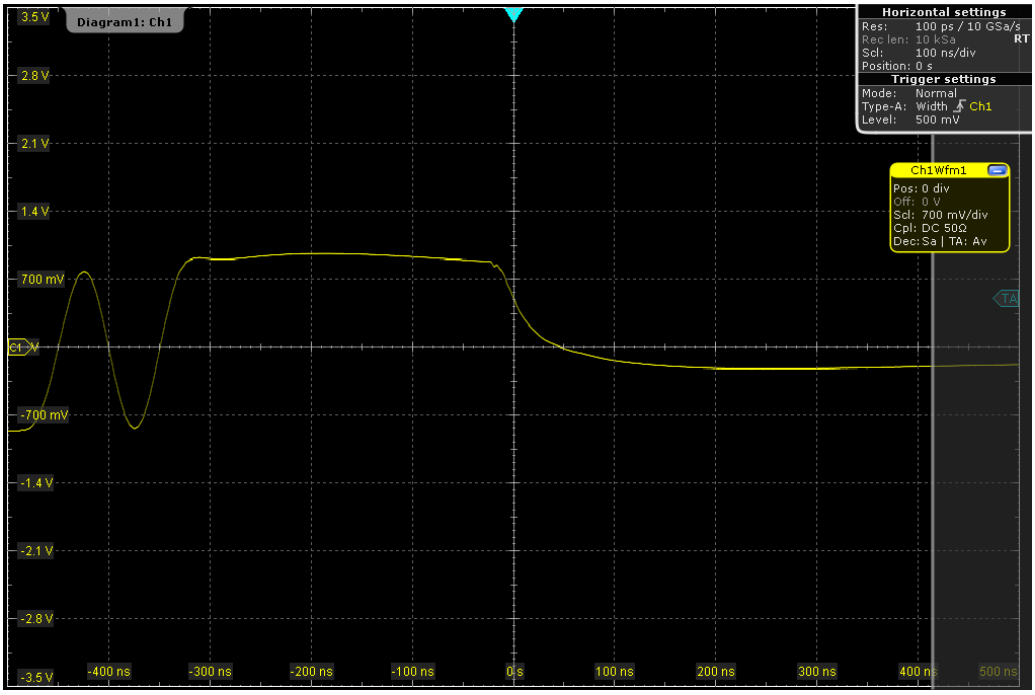


Figure 6-11: Waveform with load 1

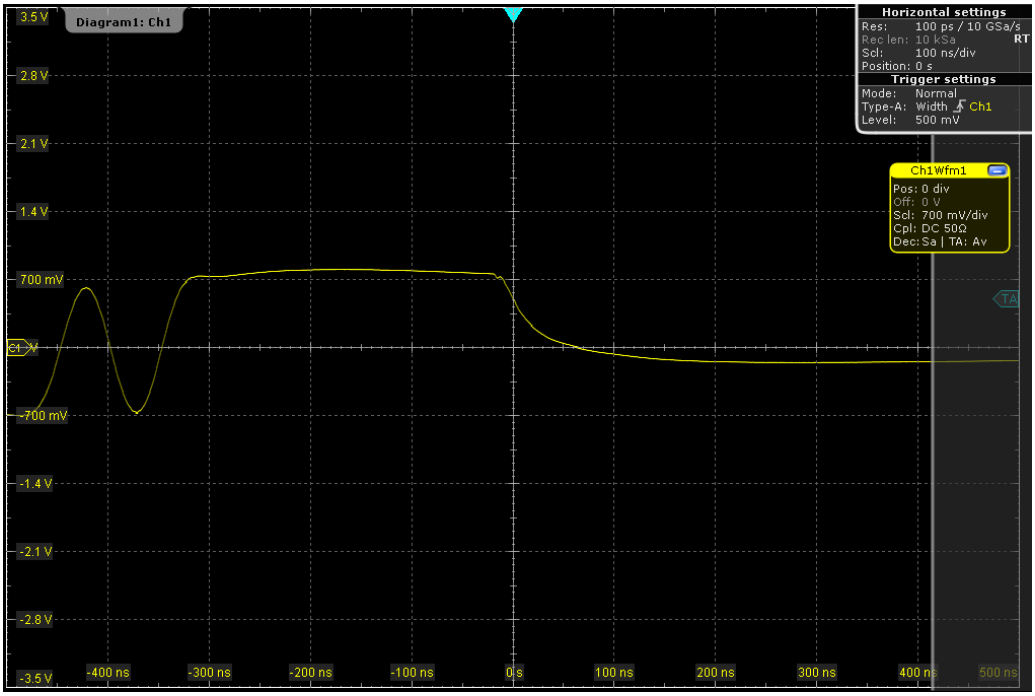


Figure 6-12: Waveform with load 2

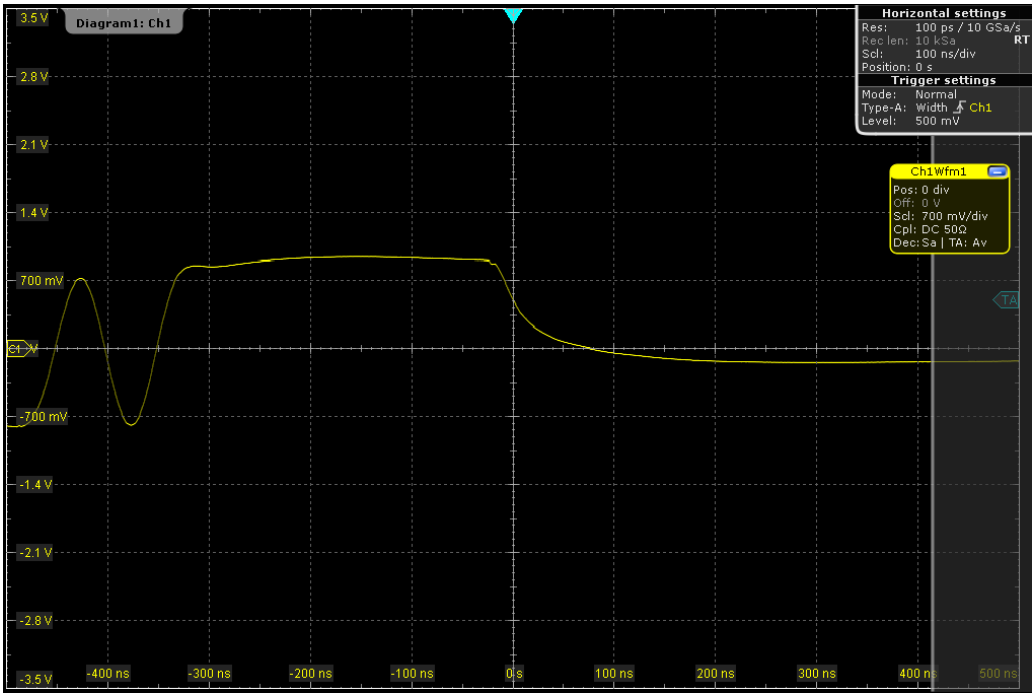


Figure 6-13: Waveform with load 100 Ω

The test procedure is the same for each load. A mask is created according to the template specified in figure 14-10 of IEEE 802.3-2008, subclause 14.3.1.2.1. The test has been passed if the waveform did not violate the mask.

6.5 Output Timing Jitter

The Output Timing Jitter tests verify that the jitter at the zero crossings on the TD circuit is within specification limits. The jitter is measured with and without Twisted Pair Model (TPM), optionally with Link Partner.

6.5.1 Test Equipment

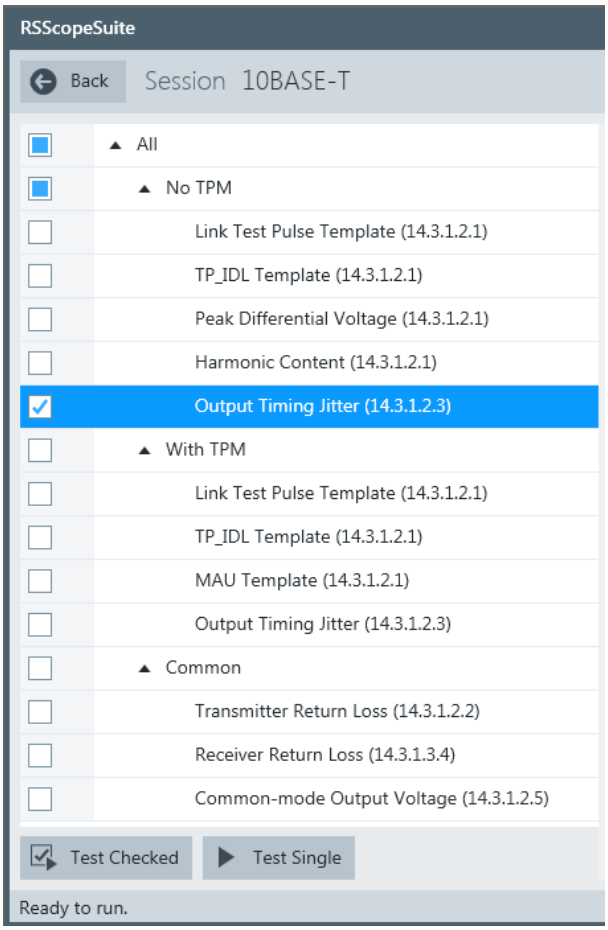
Table 6-3: Equipment for all Output Timing Jitter tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1
Link Partner (optional)	e.g. Intel PRO/100 GT Desktop Adapter	1

6.5.2 No TPM

6.5.2.1 Performing the Test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T Tests", on page 83.
2. Under "No TPM", select "Output Timing Jitter (14.3.1.2.3)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

6.5.2.2 Measurements

For Output Timing Jitter tests, the DUT has to transmit Manchester-encoded pseudo-random sequence with a minimum repetition period of 511 bits. Depending on the

DUT, the test is also known as transmitter output timing jitter without cable model or simply jitter without cable model (1411.10.13).

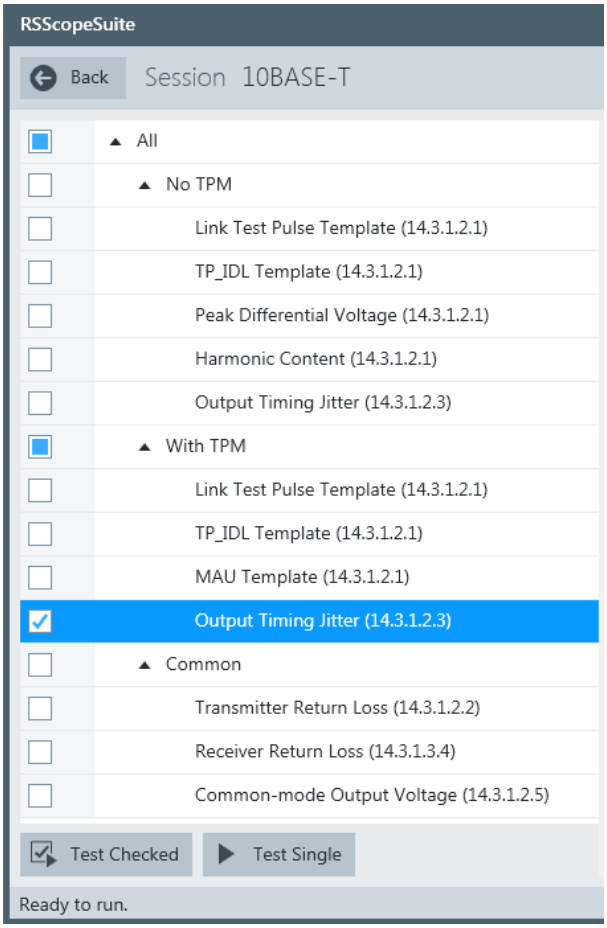
The test consists of two similar measurements:

- The oscilloscope measures the jitter at 8.0 BT.
  The trigger is set at 8 bit times, i.e. 800 ns away from the zero crossings. Then the software creates a horizontal histogram of width 50 ns and height 2 mV, and sets the histogram center at the zero crossings (0 V level). After acquiring N numbers of zero crossings, the software measures the maximum and minimum x values of the waveforms in the histogram - the minimum and maximum deviation from the ideal edge location.
- The oscilloscope measures the jitter at 8.5 BT in the same way.

6.5.3 With TPM

6.5.3.1 Performing the Test

1. Select "10 Base T" in the "Test Management" dialog box.
2. Under "With TPM", select "Output Timing Jitter (14.3.1.2.3)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

6.5.3.2 Measurements

For Output Timing Jitter tests, the DUT has to transmit Manchester-encoded pseudo-random sequence with a minimum repetition period of 511 bits. Some DUT call it transmitter output timing jitter with cable model or simply jitter with cable model (1411.10.13).

The measuments are the same as without TPM, see Chapter 6.5.2.2, "Measurements", on page 98.

6.6 Peak Differential Voltage

The Peak Differential Voltage test verifies that the peak differential output voltage of the DUT is between 2.2V and 2.8V as specified in IEEE 802.3-2008, subclause 14.3.1.2.1.

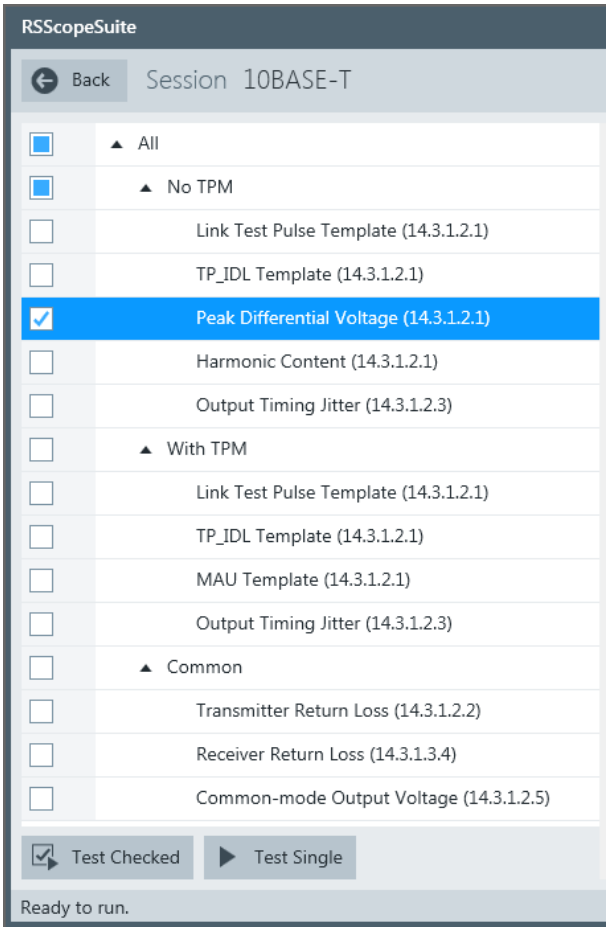
6.6.1 Test Equipment

Table 6-4: Equipment for Peak Differential Voltage test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

6.6.2 Performing the Test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T Tests", on page 83.
2. Under "No TPM", select "Peak Differential Voltage (14.3.1.2.1)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

6.6.3 Measurements

Configure the DUT to "10BASE-T random data" mode, or to output 5MHz peak differential voltage.

The waveform displayed on the R&S RTO should look similar to the picture below.

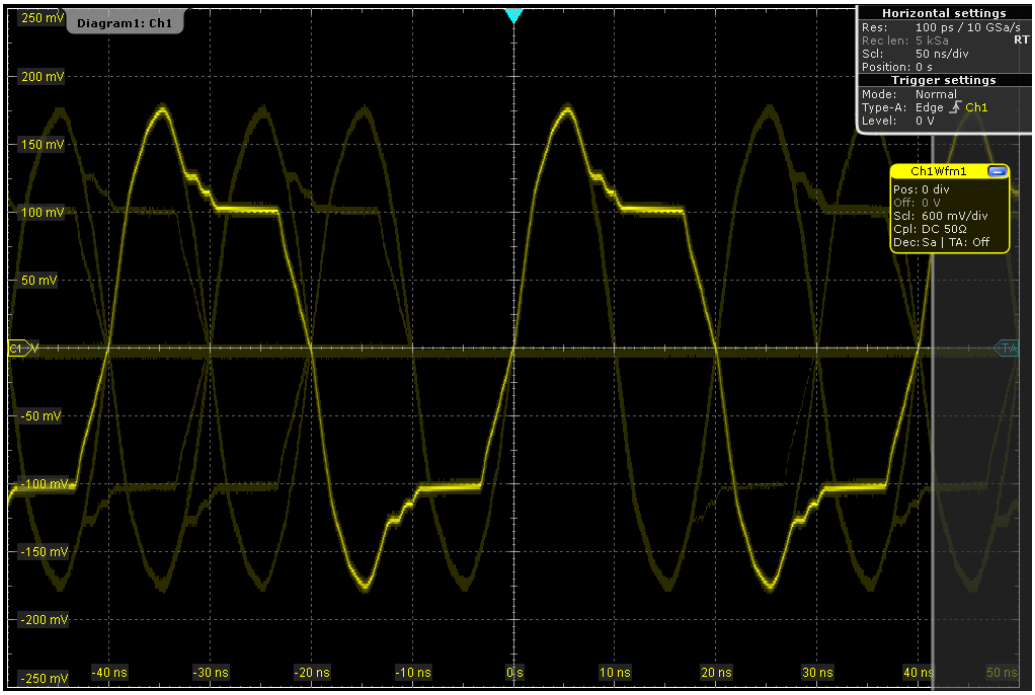


Figure 6-14: Waveform of 10BASE-T random data

The instrument measures the peak differential output voltage across the transmitter pair of the DUT and compares this value with the specified range (2.2V to 2.8V).

6.7 Harmonic Content

The Harmonic Content test verifies that any harmonic measured on the TD circuit is is at least 27 dB below the fundamental. The harmonic content is measured without Twisted Pair Model (TPM), optionally with Link Partner.

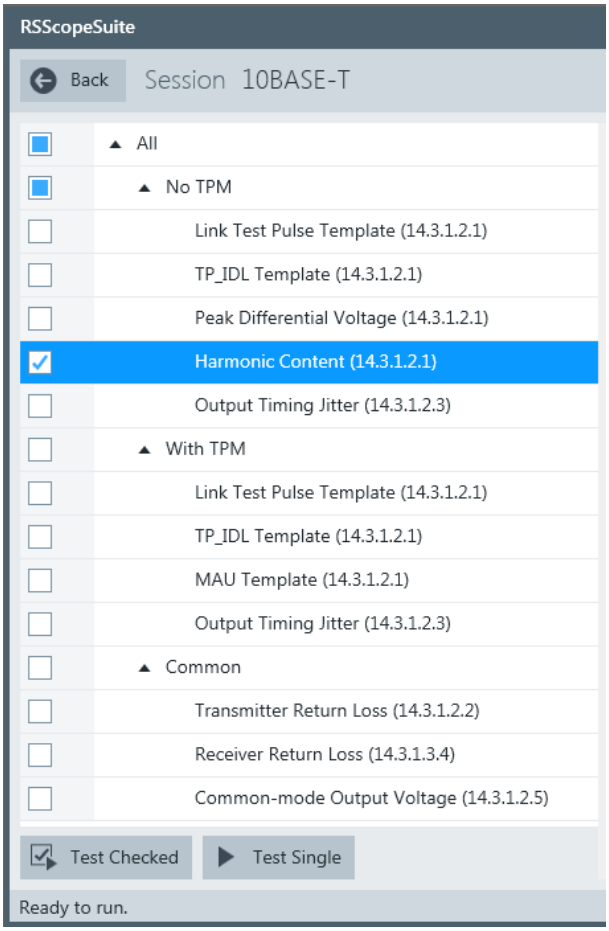
6.7.1 Test Equipment

Table 6-5: Equipment for Harmonic Content test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1
Link Partner (optional)	e.g. Intel PRO/100 GT Desktop Adapter	1

6.7.2 Performing the Test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T Tests", on page 83.
2. Under "No TPM", select "Harmonic Content (14.3.1.2.1)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

6.7.3 Measurements

For Harmonic Content tests, the DUT has to transmit Manchester Encoded all ones or all zeroes data. Some DUT call it harmonic content signal (1411.10.03).

This test captures N acquisitions of 100 µs of all ones or zeroes data and averages them into a single waveform. It performs a FFT on the averaged waveform and takes five measurements:

- Power of the fundament frequency (10 MHz).
- Power of the 2nd harmonic
- Power of the 3rd harmonic
- Power of the 4th harmonic
- Power of the 5th harmonic

The power of each harmonic must be at least 27 dB down from the fundamental.

6.8 MAU Template

The MAU Template test verifies that the differential output waveform of the DUT fits into the voltage template specified in IEEE Std 802.3-2008 figure 14-9, both normal and inverted, with a scaling between 0.9 and 1.1. The test is performed with Twisted Pair Model (TPM).

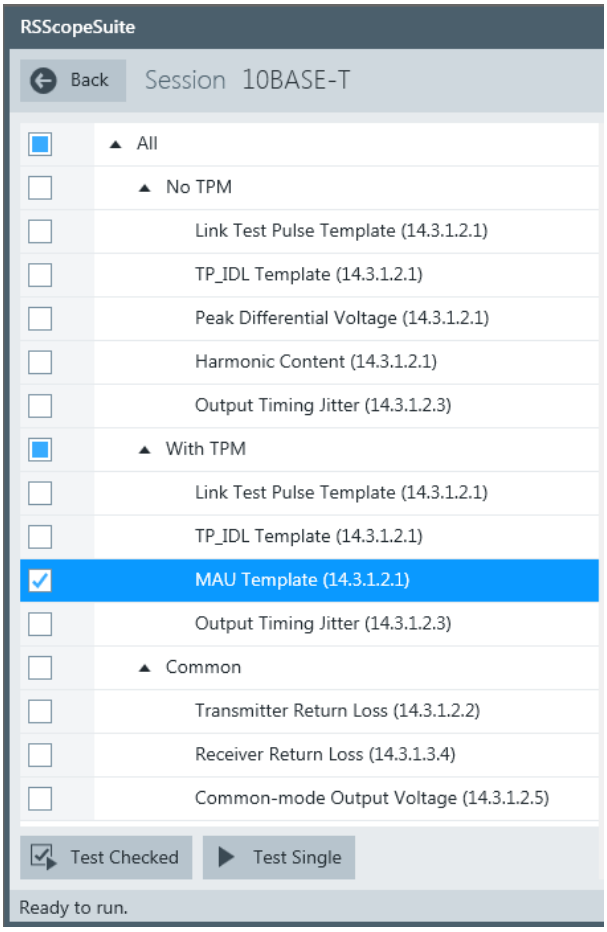
6.8.1 Test Equipment

Table 6-6: Equipment for MAU template test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

6.8.2 Performing the Test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T Tests", on page 83.
2. Under "With TPM", select "MAU Template (14.3.1.2.1)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

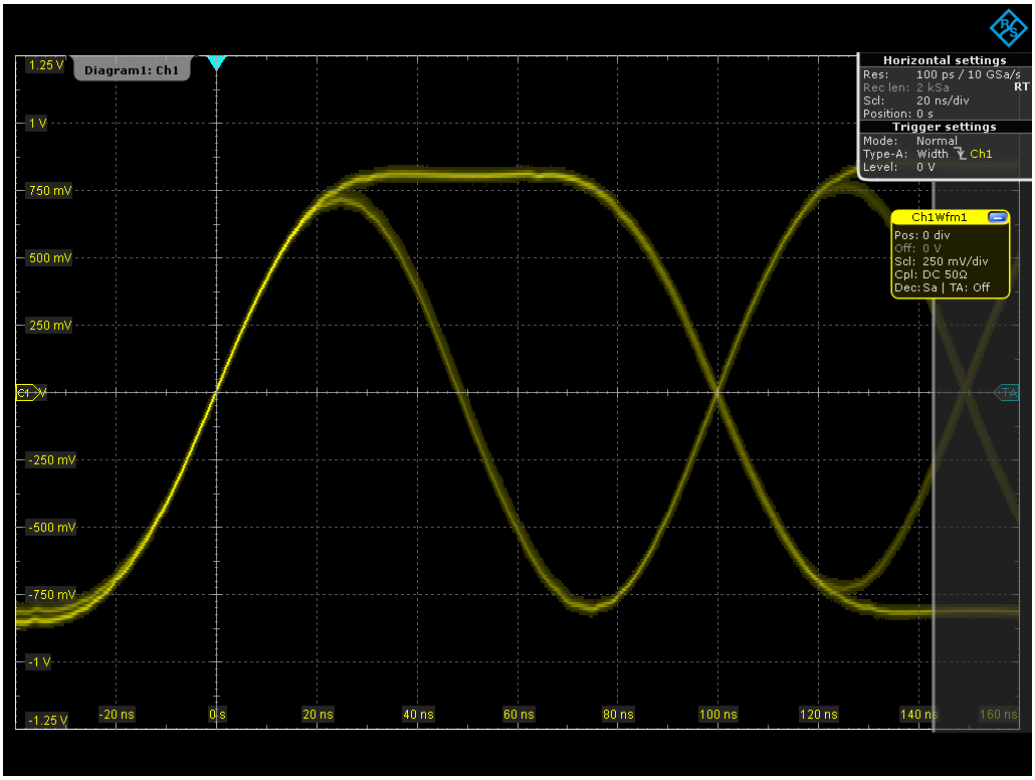
Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

6.8.3 Measurements

Configure the DUT to "10BASE-T random data" mode.

The waveform displayed on the R&S RTO should look similar to the picture below.



The oscilloscope creates a mask according to the template specified in figure 14-9 of IEEE 802.3-2008, and varies the mask scaling from 0.9 to 1.1. The test has been passed if there is at least one scaling at which the waveform did not violate the mask.

6.9 Transmitter Return Loss

The Transmitter Return Loss test verifies that the transmitter return loss of the DUT is at least 15 dB over the frequency range of 5 to 10 MHz as specified in IEEE 802.3-2008 subclause 14.3.1.2.2.

6.9.1 Test Equipment

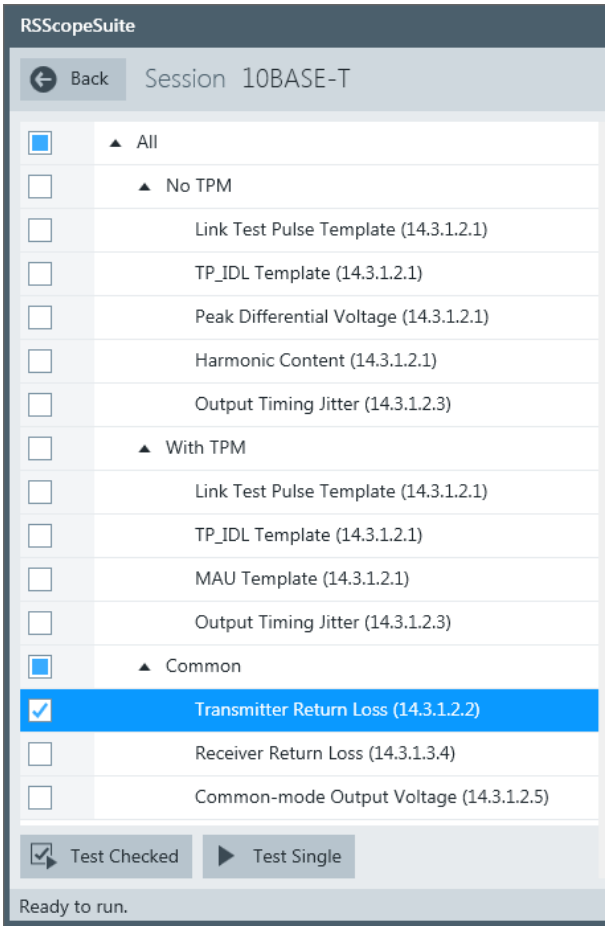
Table 6-7: Equipment for Transmitter Return Loss

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF2	1

Item	Description, model	Quantity
Vector Network Analyzer (optional, required only to perform an automatic test)	R&S ZVL or R&S ZNB	1
DUT	the device you want to test	1

6.9.2 Performing the Test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T Tests", on page 83.
2. Under "Common", select "Transmitter Return Loss (14.3.1.2.2)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

6.9.3 Measurements

Configure the DUT to "10BASE-T random data" mode.

During automatic testing, the program measures the S11 parameter on the VNA. It shall fall below the limit line plotted on the VNA from 5 to 10 MHz.

During manual testing, the program checks if every point between 5 MHz and 10 MHz in the result file (*.s1p or *.csv) falls below the -15 dB limit.

6.10 Receiver Return Loss

The Receiver Return Loss test verifies that the receiver return loss of the DUT is at least 15 dB over the frequency range of 5 to 10 MHz as specified in IEEE 802.3-2008 subclause 14.3.1.3.4.

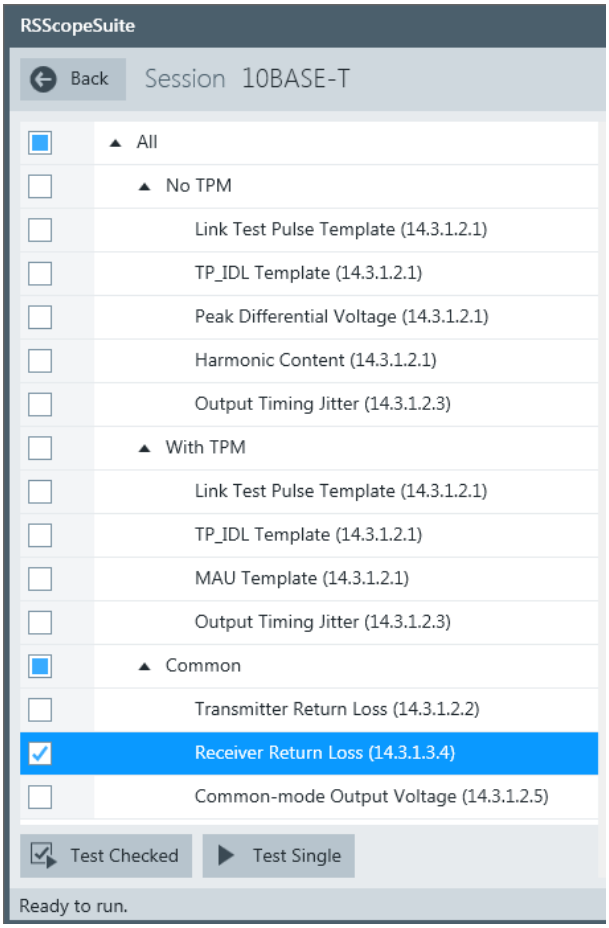
6.10.1 Test Equipment

Table 6-8: Equipment for Receiver Return Loss tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Vector Network Analyzer (optional, required only to perform an automatic test)	R&S ZVL or R&S ZNB	1
DUT	the device you want to test	1

6.10.2 Performing the Test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T Tests", on page 83.
2. Under "Common", select "Receiver Return Loss (14.3.1.3.4)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

6.10.3 Measurements

Configure the DUT to "10BASE-T random data" mode.

During automatic testing, the program measures the S11 parameter on the VNA. It shall fall below the limit line plotted on the VNA from 5 to 10 MHz.

During manual testing, the program checks if every point between 5 MHz and 10 MHz in the result file (*.s1p or *.csv) falls below the -15 dB limit.

6.11 Common-mode Output Voltage

The Common-mode Output Voltage test verifies that the common mode voltage on transmit pair (pair A) is less than 50 mV.

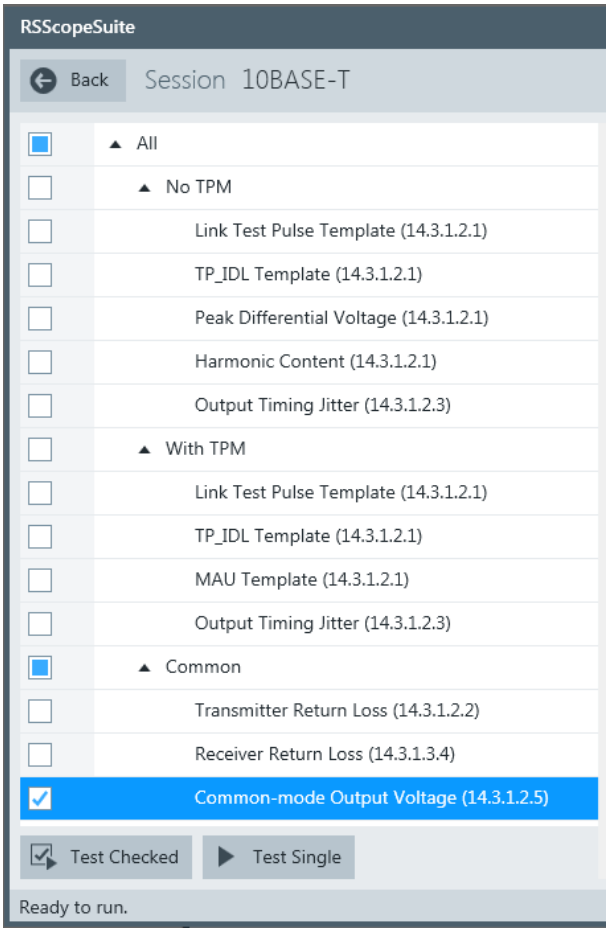
6.11.1 Test Equipment

Table 6-9: Equipment for Common-mode Output Voltage tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Common Mode Voltage" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

6.11.2 Performing the Test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T Tests", on page 83.
2. Under "Common", select"Common-mode Output Voltage (14.3.1.2.5)".



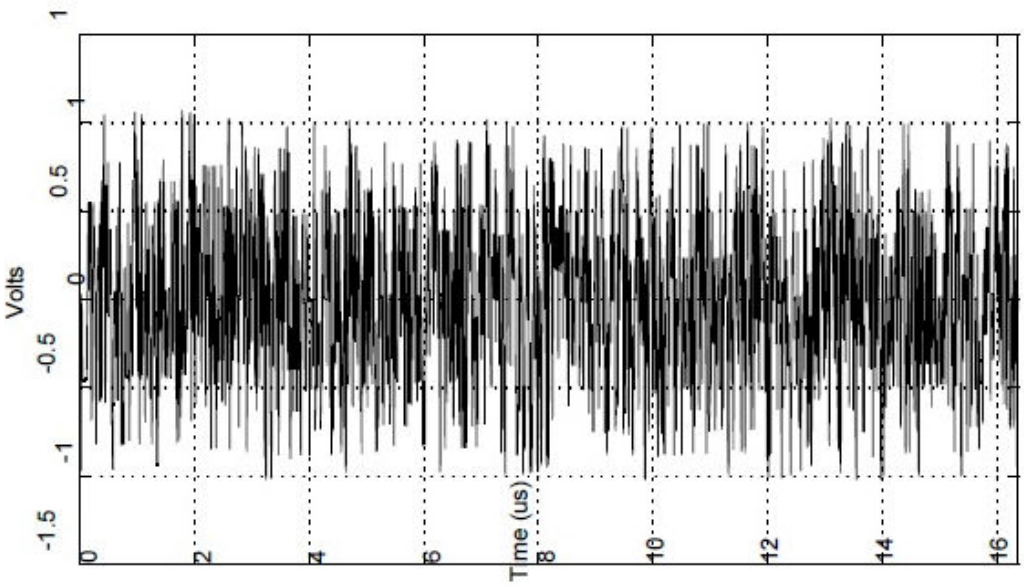
3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

6.11.3 Measurements

The Common-mode Output Voltage test requires a common mode voltage waveform. This waveform is similar to the test mode 4 waveform of 1000BASE-T tests.



The oscilloscope measures the maximum and minimum voltages of the captured waveform. The highest absolute value is considered as peak common mode voltage.

7 10GBASE-T Tests

10GBASE-T Ethernet compliance tests require option R&S RTO-K23.

- Starting 10GBASE-T Tests 114
- Test Configuration for Ethernet 10GBASE-T 114
- Maximum Output Droop 116
- Transmitter Linearity 119
- Transmitter Timing Jitter Master Mode 123
- Transmitter Timing Jitter Slave Mode 125
- Transmitter Power Spectral Density 128
- Transmitter Power Level 130
- Transmitter Clock Frequency 131
- MDI Return Loss 133

7.1 Starting 10GBASE-T Tests

Before you run the test, complete the following actions:

- Initial setup of the equipment, see Chapter 2.2, "Installing Software and License", on page 11
- LAN connection of the oscilloscope and the computer running the R&S ScopeSuite, see Chapter 2.5, "Connecting the R&S RTO", on page 14
- VNA connection for MDI Return Loss, Transmitter Power Level and Transmitter Power Spectral Density tests, see Chapter 2.7, "Connecting the Vector Network Analyzer", on page 17.

1. Select "Ethernet 10G" in the R&S ScopeSuite start window.
2. In the "Session Selection" dialog, add a new test session and open it, see Chapter 3.1, "Starting a Test Session", on page 21.
3. Check the test configuration settings and adjust, if neccessary. See:
   - Chapter 7.2, "Test Configuration for Ethernet 10GBASE-T", on page 114
   - Chapter 3.2.1.1, "Limit Manager", on page 23
4. Select/check the test cases you want to run and click "Test Single"/"Test checked".
5. A step-by step guide explains the following individual setup steps. When you have finished all steps of the step-by-step guide, the compliance test runs automatically.

7.2 Test Configuration for Ethernet 10GBASE-T

The test configuration consists of some test-specific configuration settings.

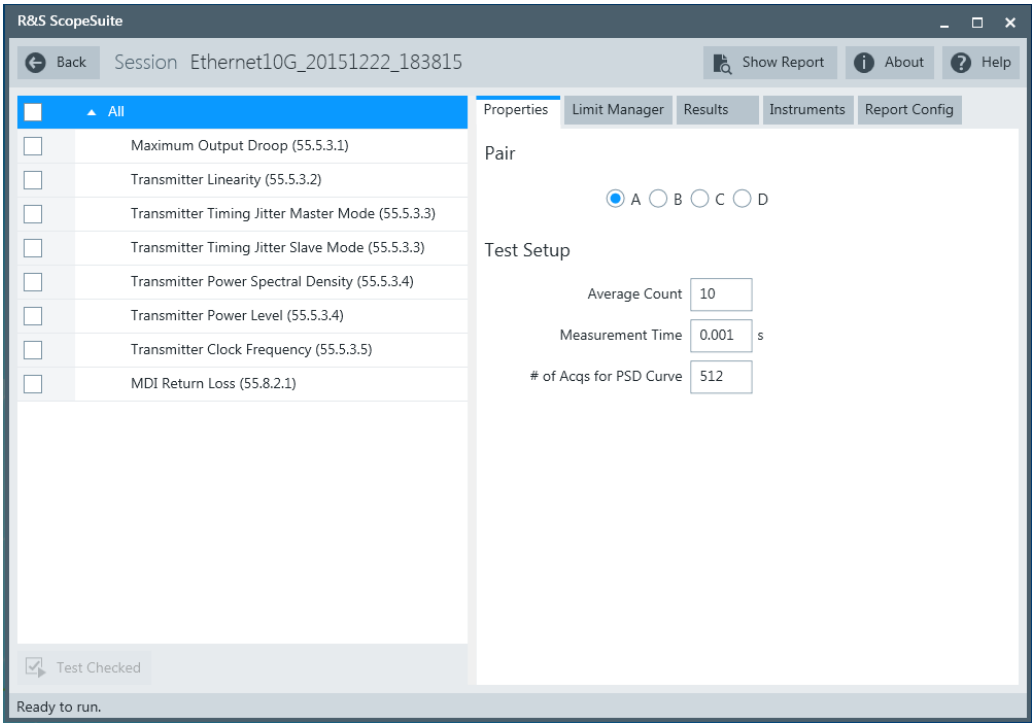


Figure 7-1: Configuration for 10GBASE-T compliance tests

Pair
Select which cable pair is used.

Average Count
Defines the number of waveforms which the oscilloscope acquires to calculate the average waveform (average count). It is used in the Maximum Output Droop test case. The valid range is 5 to 200 and the default value is 10.

Increasing the number of waveforms results in more accurate measurement results but also in longer test execution time. If you are unsure, use the default values.

Measurement Time
Measurement time is used in the Transmitter Timing Jitter Master Mode and Transmitter Timing Jitter Slave Mode test cases. The valid range is 1E-6 to 1E-3, the default value is 1E-3.

# of Acqs for PSD curve
The number of acquisitions for PSD curve is used in the Transmitter Power Spectral Density, and Transmitter Power Level test cases. The valid range is 32 to 1024, the default value is 512.

7.3 Maximum Output Droop

The Maximum Output Droop test verifies that the transmitter output level does not decay faster than the maximum specified rate.

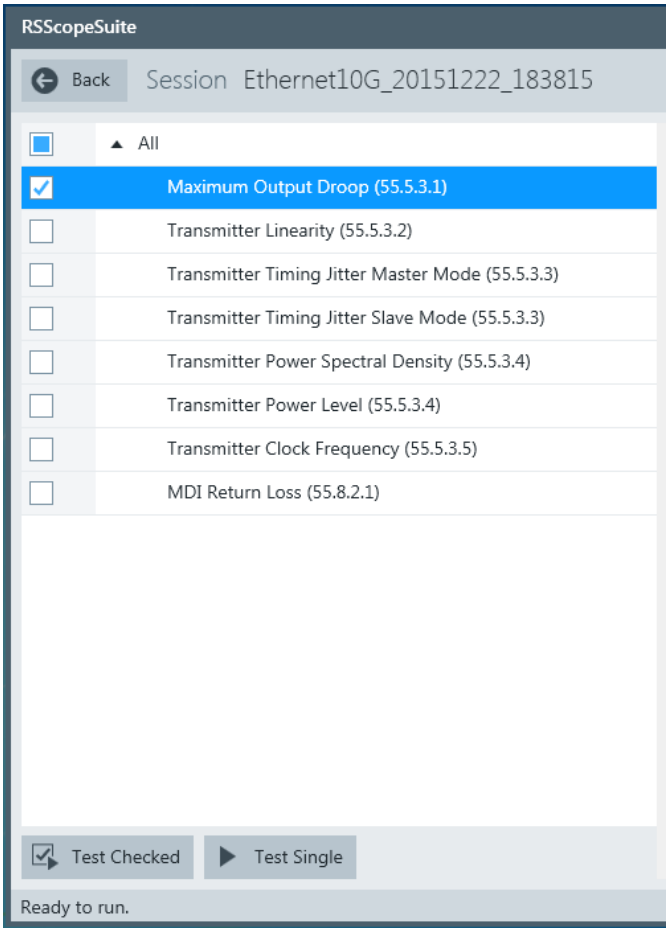
7.3.1 Test Equipment

Table 7-1: Equipment for Maximum Output Droop test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 2 GHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 2 GHz bandwidth	1
DUT	10GBASE-T device to be tested	1

7.3.2 Performing the Test

1. Start the test as described in Chapter 7.1, "Starting 10GBASE-T Tests", on page 114.
2. Select the test case: "Maximum Output Droop (55.5.3.1)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

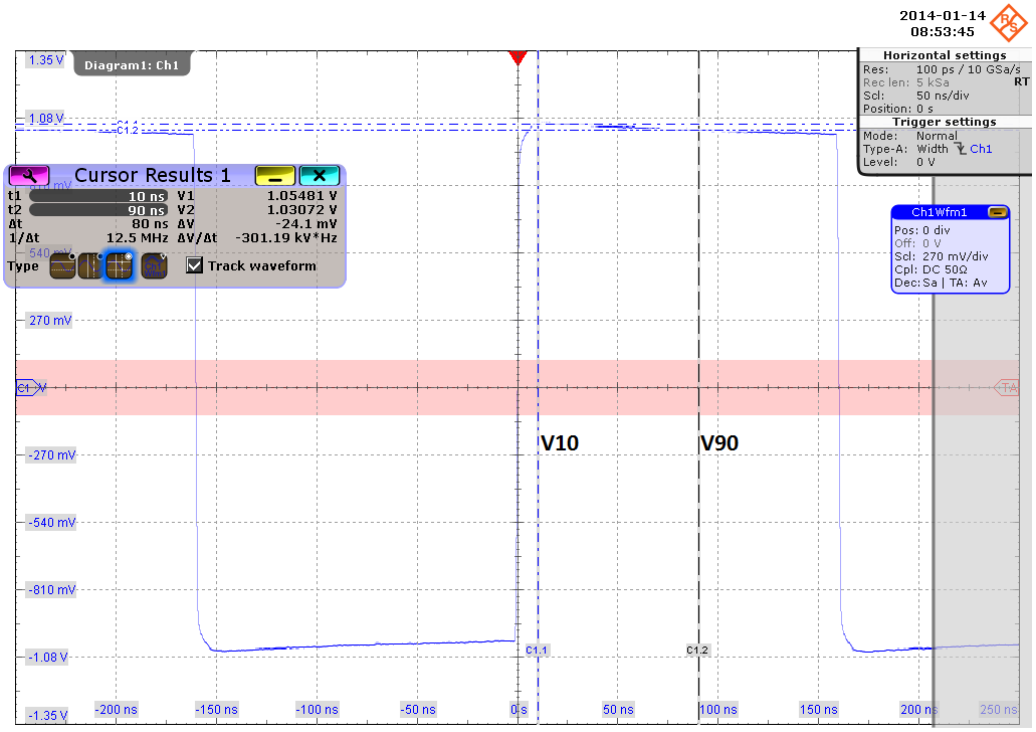
- Chapter 3.3, "Getting Test Results", on page 24

7.3.3 Measurements

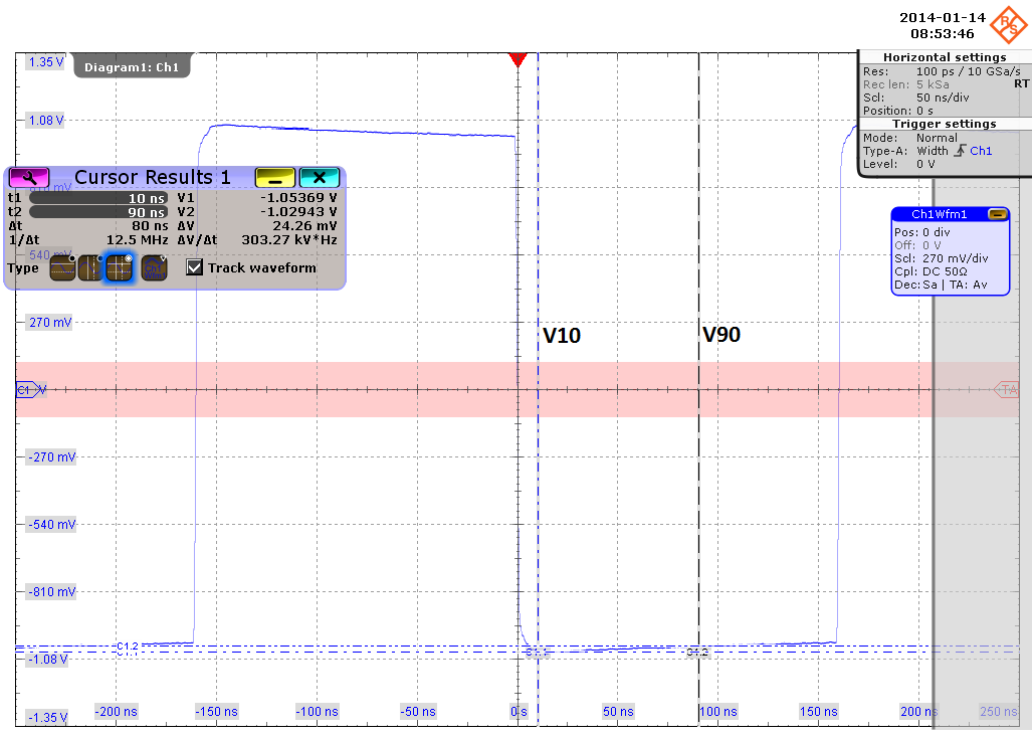
For Maximum Output Droop test, the DUT has to transmit a test mode 6 waveform.

In test mode 6, the DUT transmits 128 +16 symbols followed by 128 -16 symbols continuously on all four transmitters.

In this test, the software instructs the oscilloscope to measure the voltage ratio between V_{10} (10 ns after the positive zero crossing) and V_{90} (90 ns after the positive zero crossing). The oscilloscope acquires a number N of waveforms and averages them into a single waveform before measuring the voltages at V_{10} and V_{90} with a pair of cursors ("Track waveform" function enabled).



The test is repeated for the negative droop.



7.4 Transmitter Linearity

This test verifies that the Spurious Free Dynamic Range (SFDR) of the transmitter is greater than the value given by following formula. SFDR is calculated for 5 pairs of different dual tones.

$$SFDR \geq 2.5 + min\left\{52.58 - 20\,log_{10}\left(\frac{f}{25}\right)\right\}$$

where *f* is the maximum frequency of the two test tones in MHz

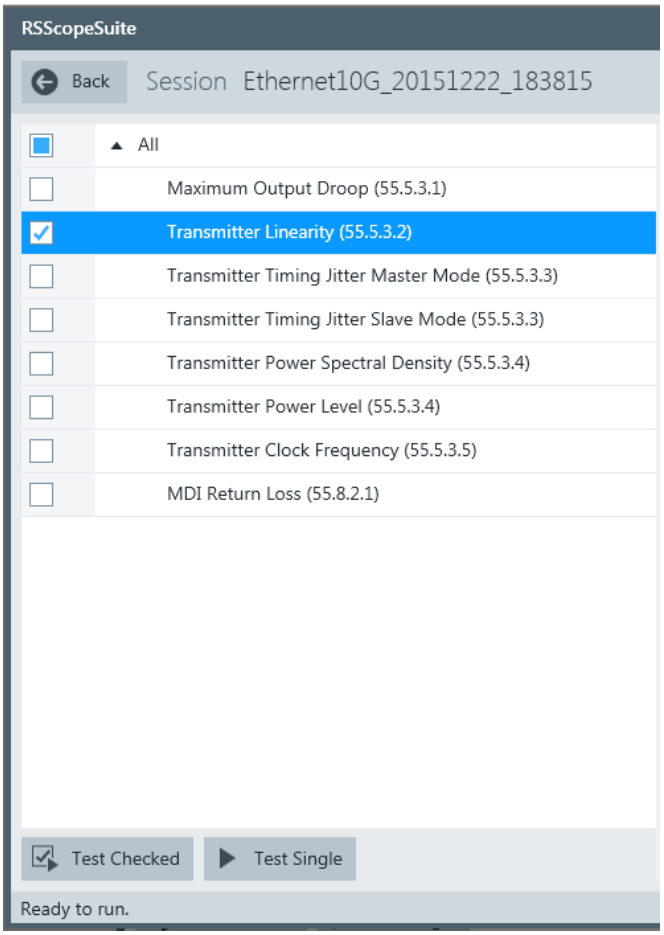
7.4.1 Test Equipment

Table 7-2: Equipment for Transmitter Linearity test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 2 GHz bandwidth	1
Ethernet test fixture, "Return Loss" section	R&S RT-ZF2	1
Spectrum analyzer	R&S FSV, R&S FSQ26 or any other	1
DUT	10GBASE-T device to be tested	1

7.4.2 Performing the Test

1. Start the test as described in Chapter 7.1, "Starting 10GBASE-T Tests", on page 114.
2. Select the test case: "Transmitter Linearity (55.5.3.2)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

7.4.3 Measurements

For transmitter linearity test, the DUT has to transmit each of the five dual tones during the test.

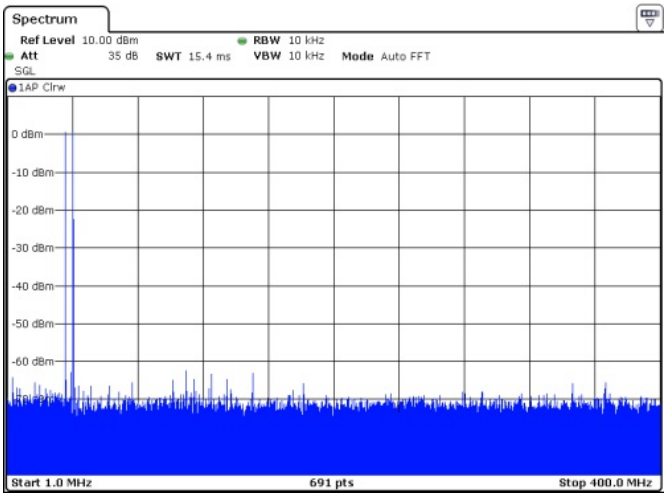


Figure 7-2: 1st Dual tone (36.718 MHz and 41.406 MHz)

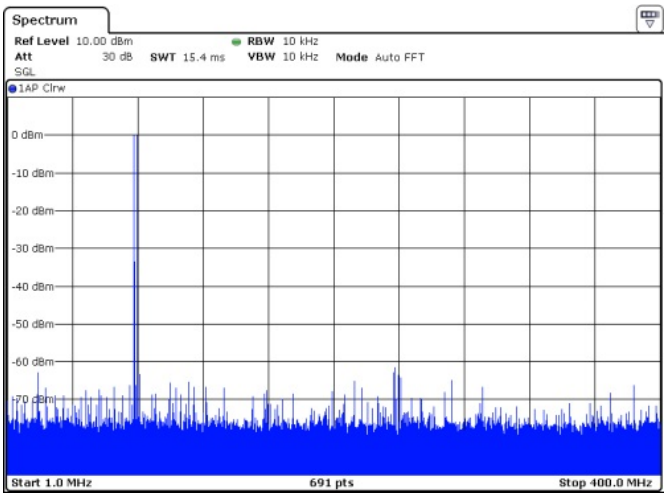


Figure 7-3: 2nd Dual tone (78.906 MHz and 80.469 MHz)

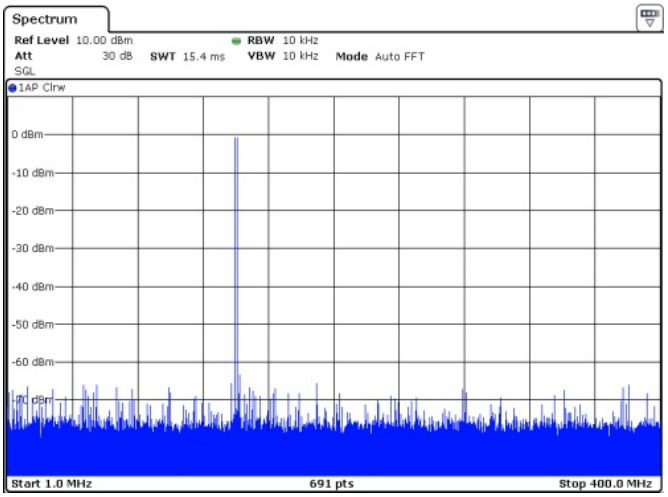


Figure 7-4: 3rd Dual tone (139.844 MHz and 141.406 MHz)

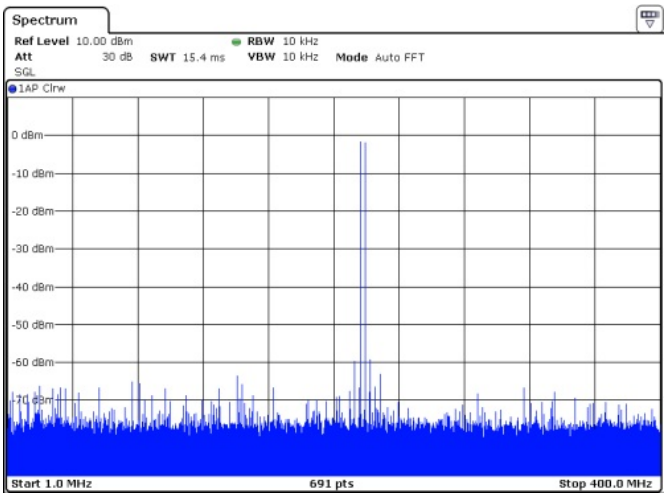


Figure 7-5: 4th Dual tone (216.406 MHz and 219.531 MHz)

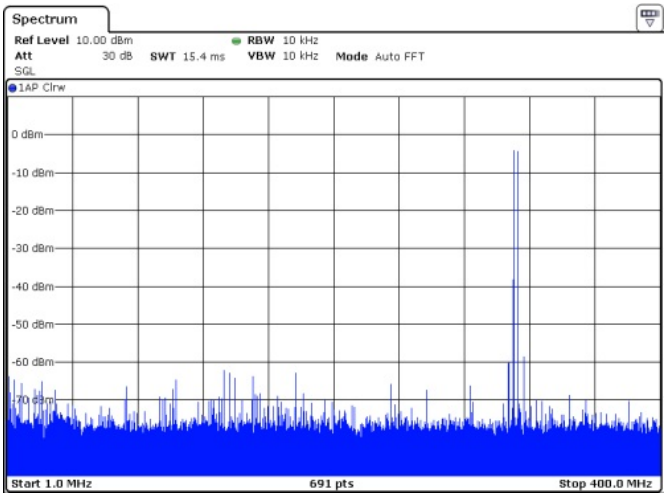


Figure 7-6: 5th Dual tone (310.156 MHz and 313.281 MHz)

In automated testing the spectrum analyzer measures the magnitudes of each tone and few intermodulation frequencies. Then it calculates SFDR. This is done for each of the dual tones.

In manual testing you have to provide frequencies and magnitudes of 10 highest signals.

SFDR is the ratio in dB of the minimum RMS value of either input tone to the RMS value of the worst intermodulation product in the frequency range of 1 MHz to 400 MHz.

7.5 Transmitter Timing Jitter Master Mode

The Transmitter Timing Jitter Master Mode tests verify that the jitter of the DUT is within the specified range. The DUT is in master mode.

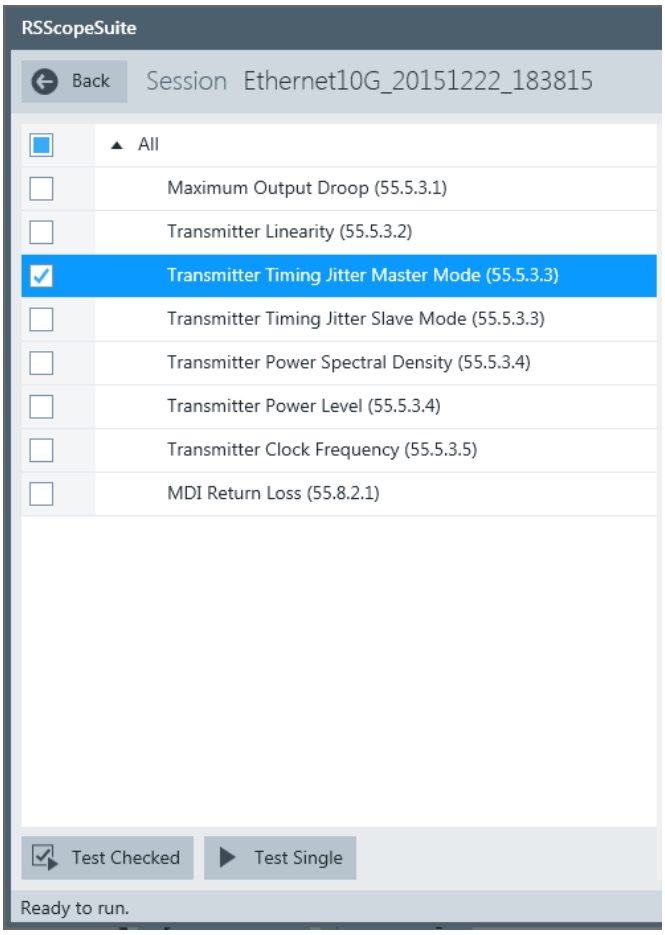
7.5.1 Test Equipment

Table 7-3: Equipment for Transmitter Timing Jitter Master Mode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 2 GHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 2 GHz bandwidth	1
DUT	10GBASE-T device to be tested	1

7.5.2 Performing the Test

1. Start the test as described in Chapter 7.1, "Starting 10GBASE-T Tests", on page 114.
2. Select the test case: "Transmitter Timing Jitter Master Mode (55.5.3.3)".



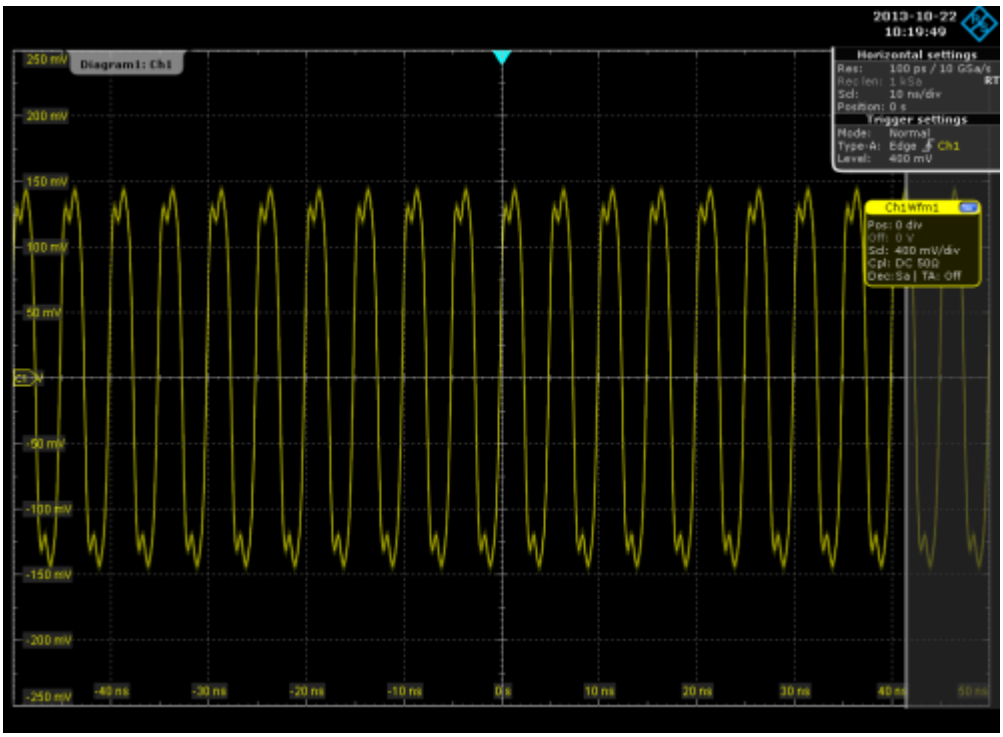
3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

7.5.3 Measurements

The DUT has to transmit a test mode 2 waveform.



Jitter is calculated by the edge positions. Due to the large amount of data, the waveform data is processed segment by segment. One segment is preset as 1E4.

The captured waveform is passed through a band pass filter with a central frequency of 200 MHz and a bandwidth of 2 MHz first. Then the RMS jitter is calculated. In order to pass the test, the RMS jitter must be less than 5.5 ps.

7.6 Transmitter Timing Jitter Slave Mode

The Transmitter Timing Jitter Slave Mode tests verify that the jitter of DUT is within the specified range. The DUT is in slave mode.

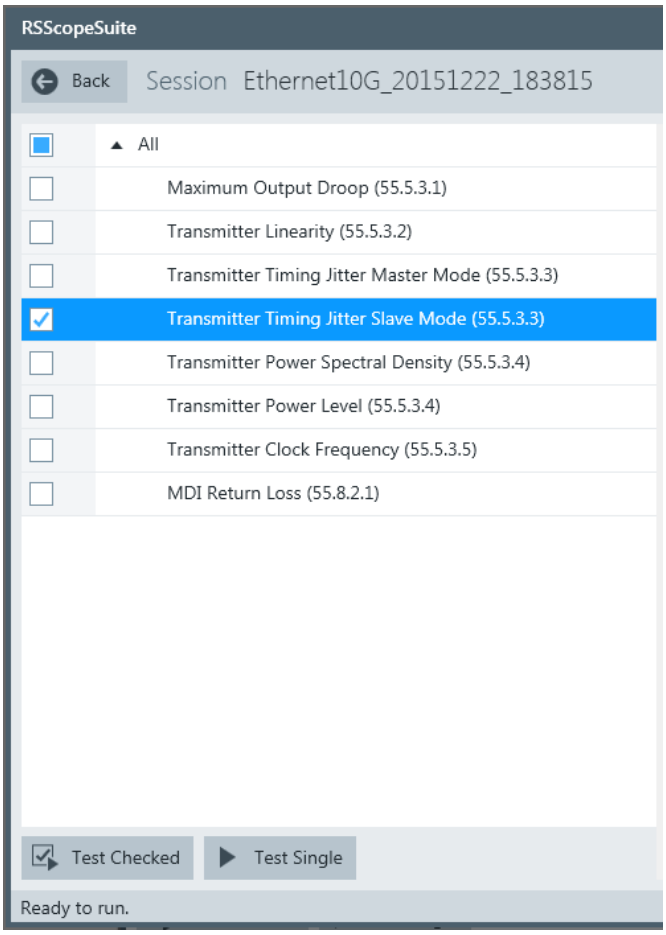
7.6.1 Test Equipment

Table 7-4: Equipment for Transmitter Timing Jitter Slave Mode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 2 GHz bandwidth	1
Ethernet test fixture, "Jitter Slave Test 10GBASE-T" section	R&S RT-ZF2	1
Differential probe	at least 2 GHz bandwidth	1
DUT	10GBASE-T device to be tested	1

7.6.2 Performing the Test

1. Start the test as described in Chapter 7.1, "Starting 10GBASE-T Tests", on page 114.
2. Select the test case: "Transmitter Timing Jitter Slave Mode (55.5.3.3)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

7.6.3 Measurements

The DUT has to transmit a test mode 3 waveform and a test mode 1 waveform.

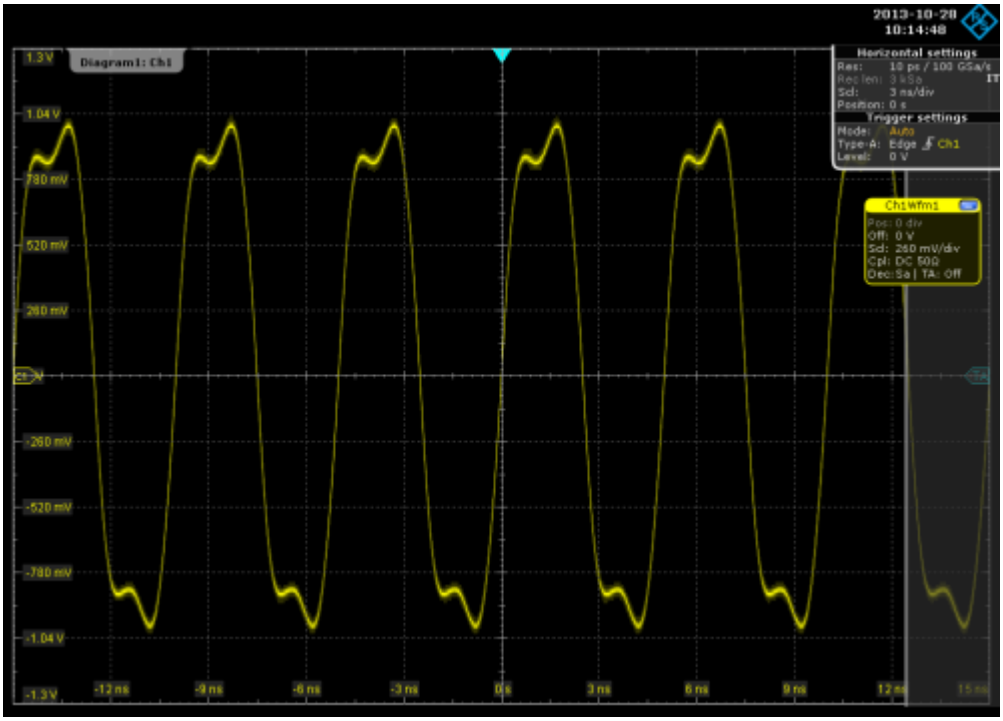


Figure 7-7: Test mode 3 waveform

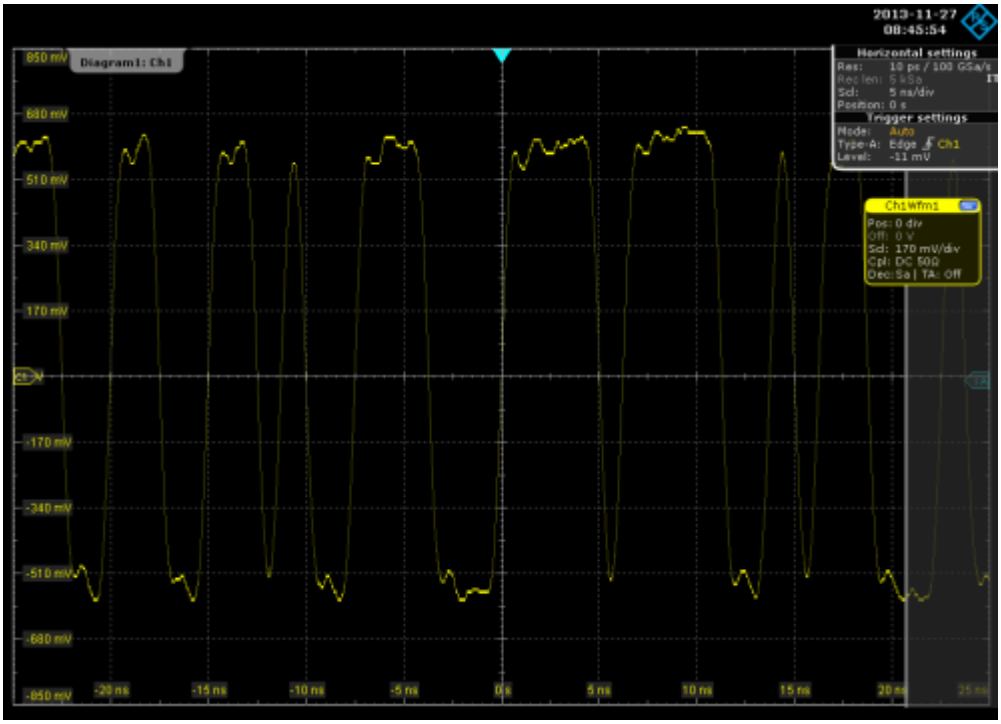


Figure 7-8: Test mode 1 waveform

Jitter is calculated by the edge positions. Due to the large amount of data, the waveform data is processed segment by segment. One segment is preset as 1E4.

The captured waveform is passed through a band pass filter with a central frequency of 200 MHz and a bandwidth of 2 MHz first. Then the RMS jitter is calculated. In order to pass the test, the RMS jitter must be less than 5.5 ps.

7.7 Transmitter Power Spectral Density

The Transmitter Power Spectral Density test verifies that the transmitter power spectral density of the DUT over the frequency range 0 to 3 GHz falls in-between the upper and lower limits specified in IEEE Std. 802.3, Section 55.5.3.4.

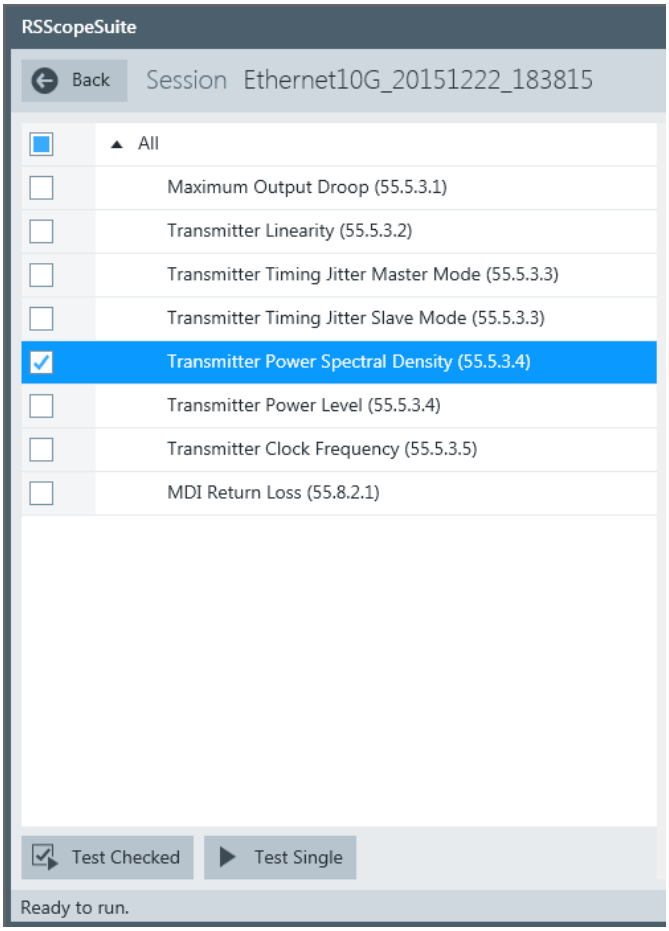
7.7.1 Test Equipment

Table 7-5: Equipment for Transmitter Power Spectral Density test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 2 GHz bandwidth	1
Ethernet fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
DUT	10GBASE-T device to be tested	1

7.7.2 Performing the Test

1. Start the test as described in Chapter 7.1, "Starting 10GBASE-T Tests", on page 114.
2. Select the test case: "Transmitter Power Spectral Density (55.5.3.4)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

7.7.3 Measurements

Configure the DUT to test mode 5.

First, the oscilloscope performs an FFT transformation of the input signal over 0 – 3 GHz. Then it performs some averaging and mathematics to plot the PSD curve, and checks whether it falls within the limit mask.

7.8 Transmitter Power Level

The Transmitter Power Level test verifies that the transmitter power level of the DUT is between 3.2 dBm and 5.2 dBm as specified in IEEE Std. 802.3-2008, Section 55.5.3.4.

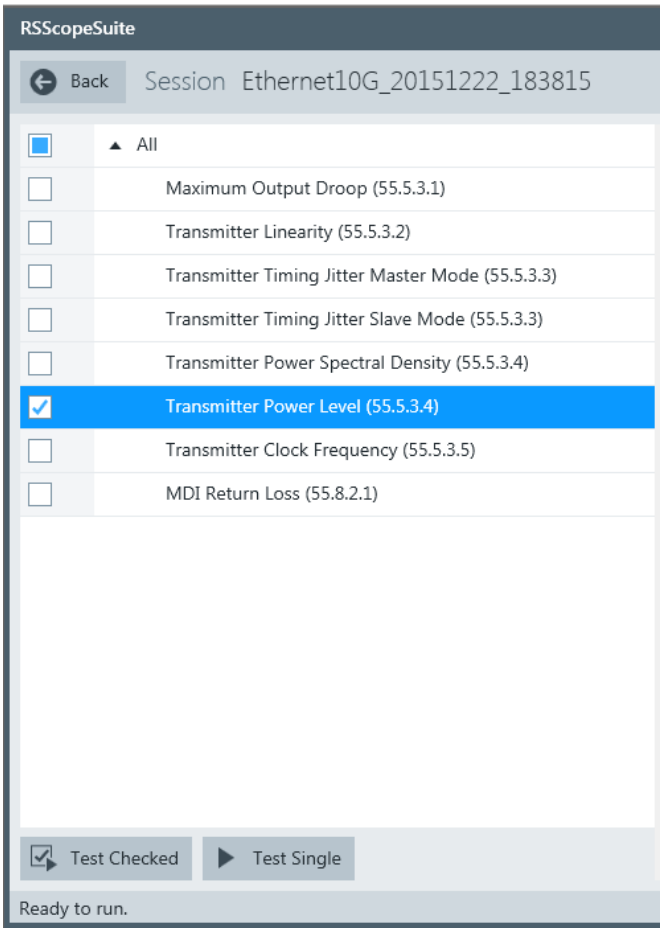
7.8.1 Test Equipment

Table 7-6: Equipment for Transmitter Power Level test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 2 GHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Vector Network Analyzer (optional, required only to perform an automatic test)	R&S ZVL or R&S ZNB	1
DUT	10GBASE-T device to be tested	1

7.8.2 Performing the Test

1. Start the test as described in Chapter 7.1, "Starting 10GBASE-T Tests", on page 114.
2. Select the test case: "Transmitter Power Level (55.5.3.4)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

7.8.3 Measurements

Configure the DUT to test mode 5.

The software measures the power level of the input signal using FFT transformation and some mathematics.

7.9 Transmitter Clock Frequency

The Transmitter Clock Frequency test verifies that the frequency of the transmitter clock is within the conformance limits.

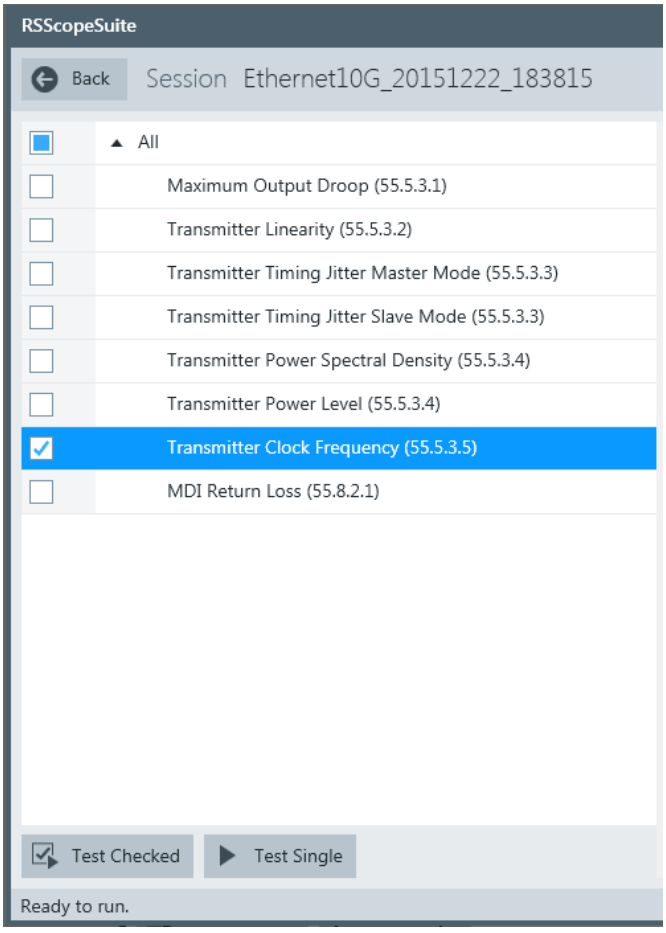
7.9.1 Test Equipment

Table 7-7: Equipment for Transmitter Clock Frequency test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 2 GHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
DUT	10GBASE-T device to be tested	1

7.9.2 Performing the Test

1. Start the test as described in Chapter 7.1, "Starting 10GBASE-T Tests", on page 114.
2. Select the test case: "Transmitter Clock Frequency (55.5.3.5)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

7.9.3 Measurements

The DUT has to transmit test mode 2 waveform.

In automated testing the oscilloscope measures the frequency and determines if the transmitter clock frequency is within the conformance limits.

7.10 MDI Return Loss

The MDI Return Loss test verifies that the differential impedance at the MDI for each transmit/receive channel of the DUT over the frequency range of 1 to 500 MHz is greater than the limits specified in IEEE Std. 802.3-2008, Section 55.8.2.1.

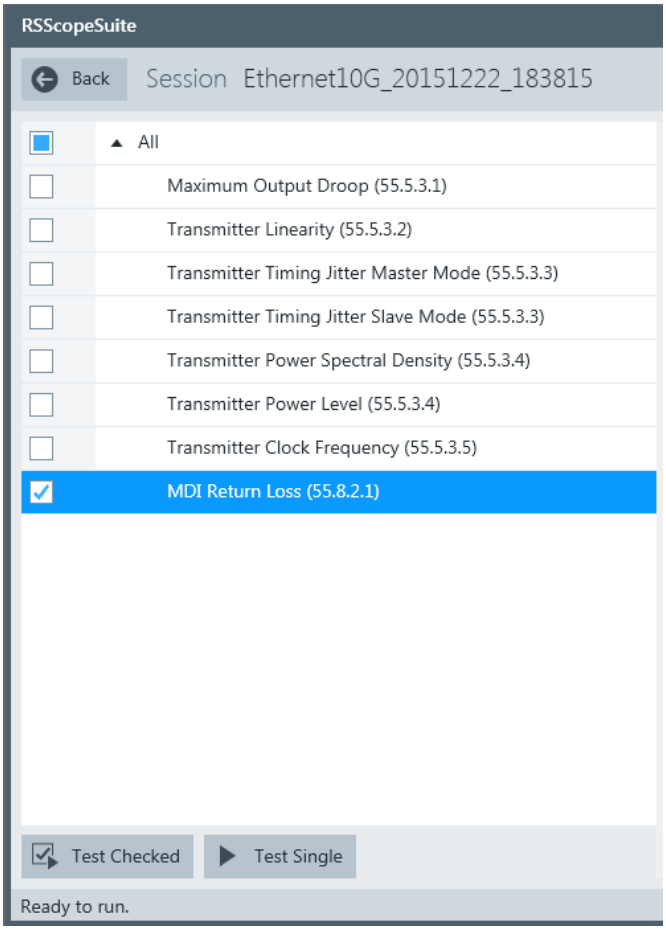
7.10.1 Test Equipment

Table 7-8: Equipment for MDI Return Loss test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 2 GHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Vector Network Analyzer (optional, required only to perform an automatic test)	R&S ZVL or R&S ZNB	1
DUT	10GBASE-T device to be tested	1

7.10.2 Performing the Test

1. Start the test as described in Chapter 7.1, "Starting 10GBASE-T Tests", on page 114.
2. Select the test case: "MDI Return Loss (55.8.2.1)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

7.10.3 Measurements

Configure the DUT to test mode 5.

During automatic testing, the program measures the S11 parameter on the VNA. It shall fall below the limit line plotted on the VNA from 1 MHz to 500 MHz.

During manual testing, the program checks if every point within 1 MHz and 500 MHz in the result file (`*.s1p` or `*.csv`) falls below the limit required by the specification.

8 BroadR-Reach Tests

BroadR-Reach Ethernet compliance tests require option R&S RTO-K24.

- Starting BroadR-Reach Tests 135
- Test Configuration for BroadR-Reach 135
- Transmitter Output Droop 137
- Transmitter Distortion 140
- Transmitter Timing Jitter 144
- Transmitter Power Spectral Density 148
- Transmitter Clock Frequency 150
- MDI Return Loss 152

8.1 Starting BroadR-Reach Tests

Before you run the test, complete the following setups:

- Initial setup of the equipment, see Chapter 2.2, "Installing Software and License", on page 11
- LAN connection of the oscilloscope and the computer running the R&S ScopeSuite, see Chapter 2.5, "Connecting the R&S RTO", on page 14
- AWG connection for tests with disturber, see Chapter 2.6, "Connecting the Arbitrary Waveform Generator", on page 16.
- VNA connection for MDI Return Loss and Transmitter Power Spectral Density tests, see Chapter 2.7, "Connecting the Vector Network Analyzer", on page 17.

1. Select "BroadR-Reach" in the R&S ScopeSuite start window.
2. In the "Session Selection" dialog, add a new test session and open it, see Chapter 3.1, "Starting a Test Session", on page 21.
3. Check the test configuration settings and adjust, if necessary. See:
   - Chapter 8.2, "Test Configuration for BroadR-Reach", on page 135
   - Chapter 3.2.1.1, "Limit Manager", on page 23
4. Select/check the test cases you want to run and click "Test Single"/"Test checked".
5. A step-by step guide explains the following individual setup steps. When you have finished all steps of the step-by-step guide, the compliance test runs automatically.

8.2 Test Configuration for BroadR-Reach

The test configuration consists of some test-specific configuration settings.

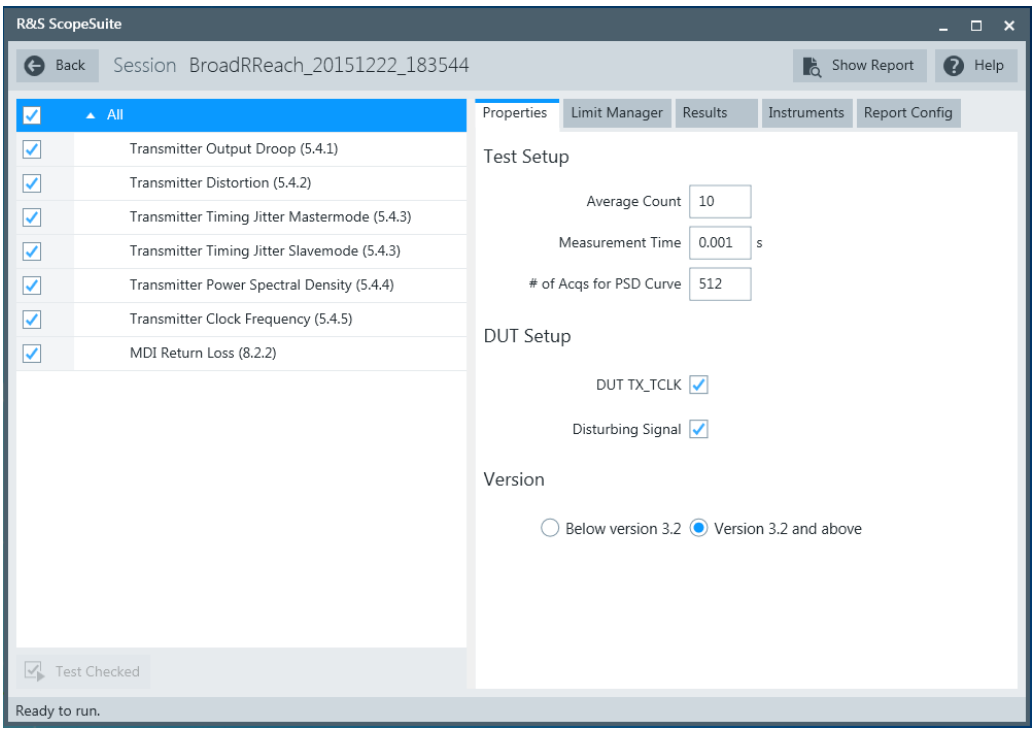


Figure 8-1: Configuration for BroadR-Reach compliance tests

Average Count
Defines the number of waveforms which the oscilloscope acquires to calculate the average waveform (average count). It is used in the following test cases: Transmitter Output Droop, Transmitter Timing Jitter Mastermode, and Transmitter Timing Jitter Slavemode. The valid range is 5 to 200 and the default value is 10.

Increasing the number of waveforms results in more accurate measurement results but also in longer test execution time. If you are unsure, use the default values.

Measurement Time
Measurement time is used in the Transmitter Timing Jitter Master Mode and Transmitter Timing Jitter Slave Mode test cases. The valid range is 1E-6 to 1E-3, the default value is 1E-4.

# of Acqs for PSD Curve
The number of acquisitions for psd curve is used in the Transmitter Power Spectral Density test case. The valid range is 32 to 1024, the default value is 512.

DUT TX_CLX
Enable when DUT transmit clock(DUT_TX_CLX) is synchronized with the signal. The DUT_TX_CLX is used in the Transmitter Disortion test case.

Disturbing Signal
Enable when a disturbing signal is used for the testing. The disturbing signal is used in the Transmitter Disortion test case.

Version
Selects which BroadR-Reach specification version you want to consider for the testing. If you are testing the device according to a version lower than 3.2, select "Below version 3.2". Otherwise select "Version 3.2 and above".

8.3 Transmitter Output Droop

The Transmitter Output Droop test verifies that the transmitter output level does not decay faster than the maximum specified rate.

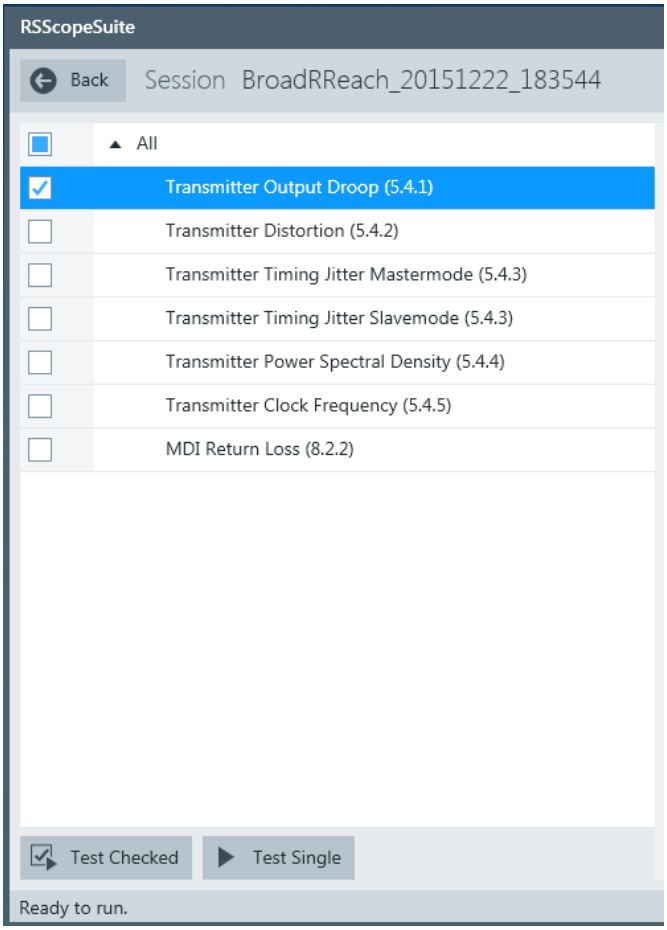
8.3.1 Test Equipment

Table 8-1: Equipment for Transmitter Output Droop test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	BroadR-Reach device you want to test	1

8.3.2 Performing the Test

1. Start the test as described in Chapter 8.1, "Starting BroadR-Reach Tests", on page 135.
2. Select the test case: "Transmitter Output Droop (5.4.1)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

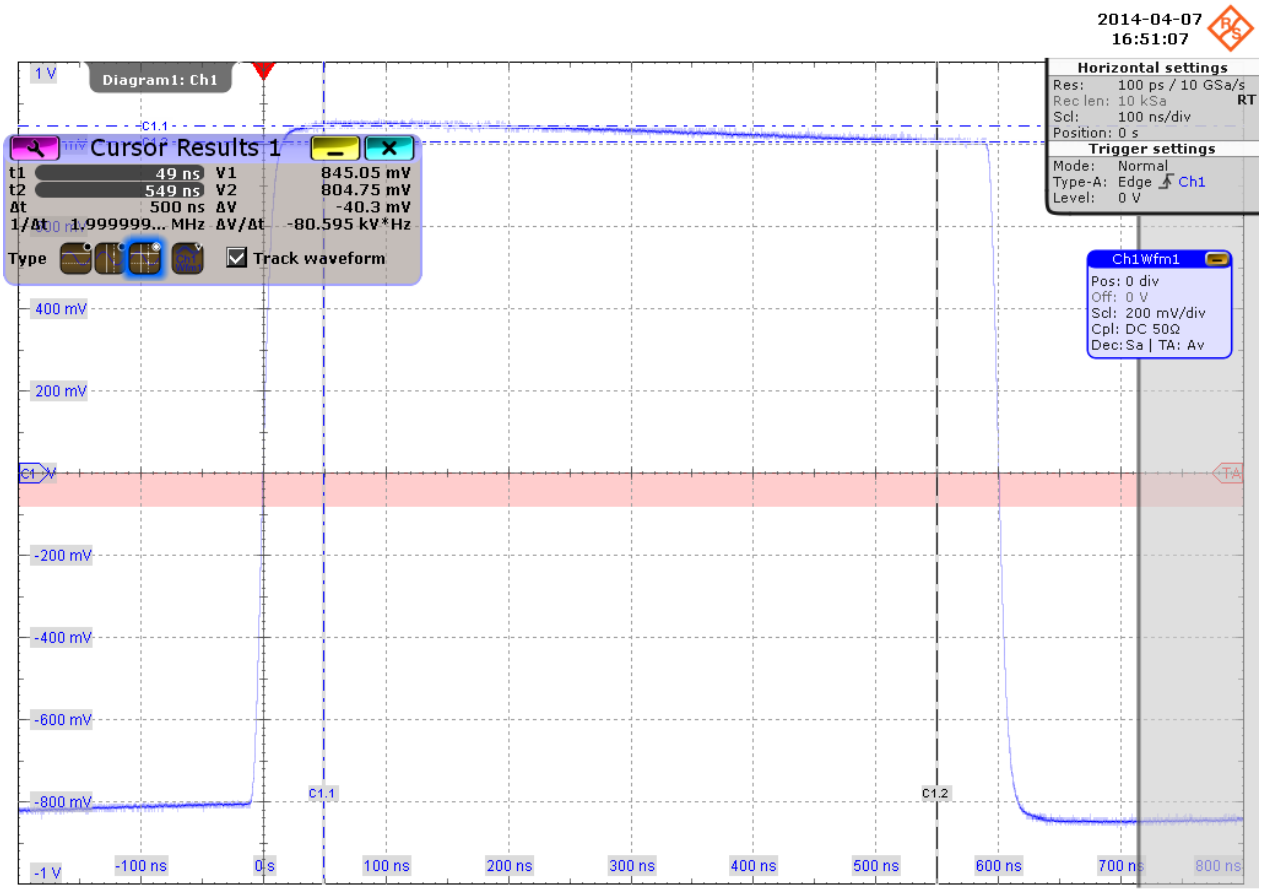
- Chapter 3.3, "Getting Test Results", on page 24

8.3.3 Measurements

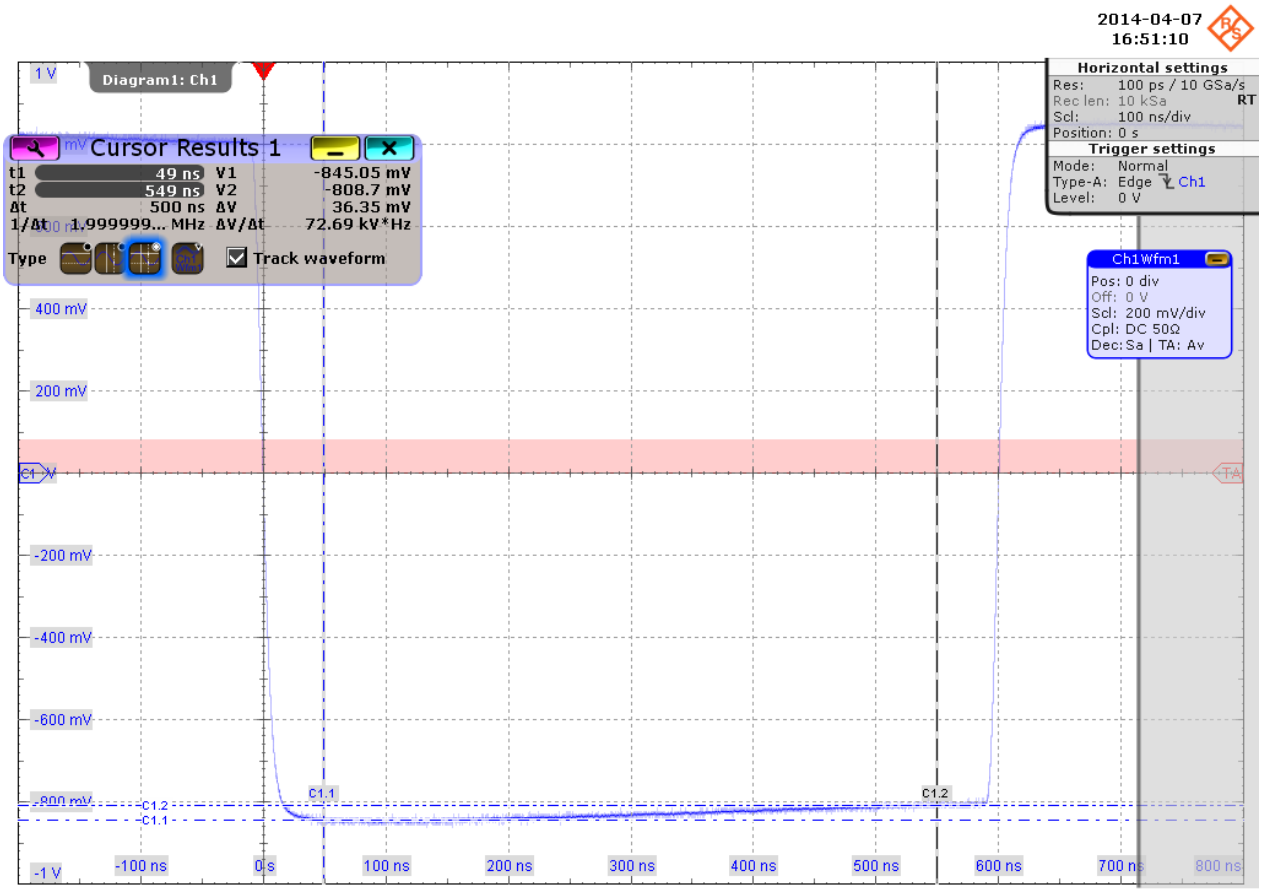
For Transmitter Output Droop test, the DUT has to transmit a test mode 1 waveform.

The test consists of two similar measurements:

- For the positive side of the waveform
  The oscilloscope measures the ratio between the peak positive voltage after zero crossing and voltage 500 ns after the peak position. The software set a trigger at the zero crossing of a rising edge. The oscilloscope acquires a number N of waveforms and averages them into a single waveform. The software enables a pair of cursors with “Track waveform”. It positions cursor 1 at positive peak position and cursor 2 at 500ns after the peak position. The software determines the voltage ratio by measuring the voltage levels at $_{Vpeak}$ and V_{500ns}.



- For the negative side of the waveform
  The oscilloscope measures the ratio between the peak negative voltage after zero crossing and voltage 500 ns after the peak position in the same way, with a trigger at the zero crossing of a falling edge.



8.4 Transmitter Distortion

The Transmitter Distorion test verifies that the peak distortion of the transmitter is less than 15 mV - without and with a disturbing signal.

8.4.1 Test Equipment

Table 8-2: Equipment for Transmitter Distortion (no disturber) test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Oven Controlled Crystal Oscillator Clock (OCXO, 10 MHz)	R&S RTO-B4	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Frequency Converter	R&S RT-ZF3	1

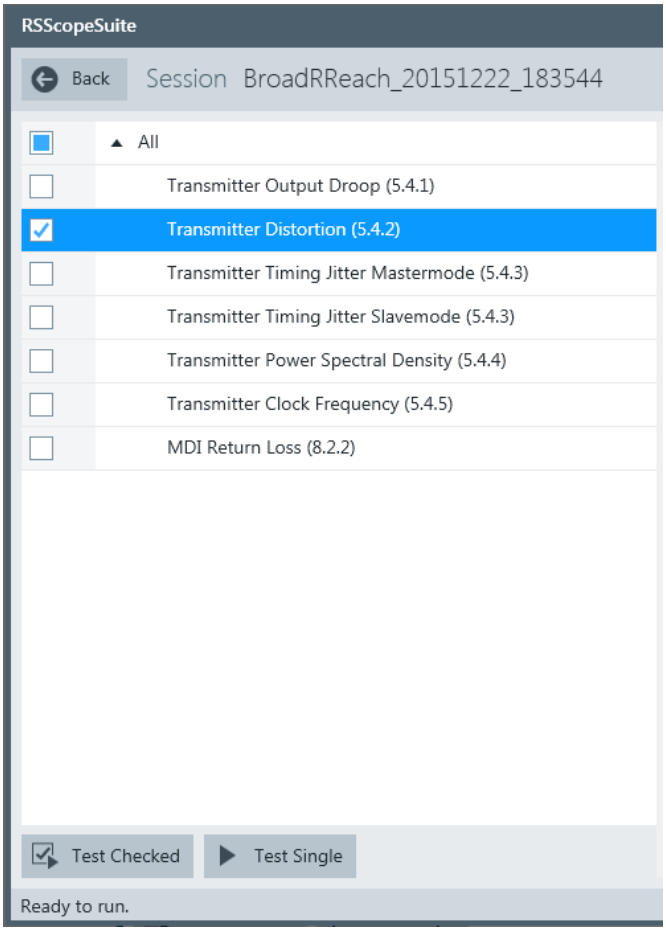
Item	Description, model	Quantity
Differential probe	at least 1 GHz bandwidth	1
DUT	BroadR-Reach device you want to test	1

Table 8-3: Equipment for Transmitter Distortion (with disturber) test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Oven Controlled Crystal Oscillator Clock (OCXO, 10 MHz)	R&S RTO-B4	1
Arbitrary waveform generator	Tabor WX2182B/WX2182C or HAMEG HMF2550	1
Ethernet test fixture, "Resistive Load with Distortion source" section	R&S RT-ZF2	1
Frequency Converter	R&S RT-ZF3	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the BroadR-Reach device you want to test	1

8.4.2 Performing the Test

1. Start the test as described in Chapter 8.1, "Starting BroadR-Reach Tests", on page 135.
2. Select the test case: "Transmitter Distortion (5.4.2)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

8.4.3 No Disturber Measurements

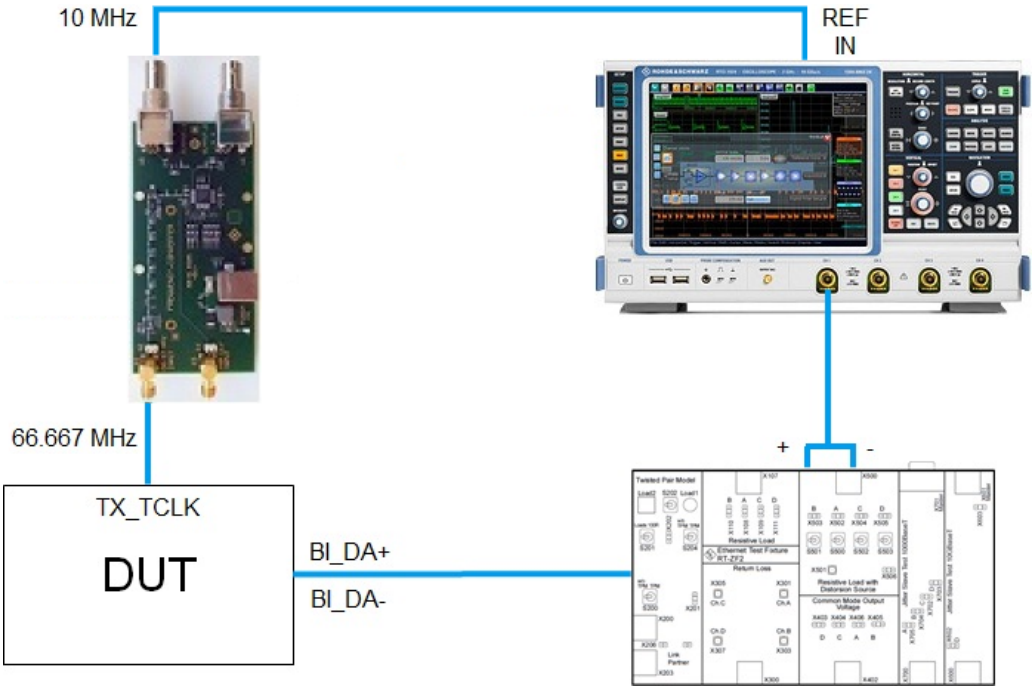
The DUT has to transmit a test mode 4 waveform. In test mode 4, the DUT transmits the sequence of symbols generated by the scrambler generator. Polynomial, bit generation and level mappings described in section 5.2 of the BroadR-Reach specification.

The test is performed on the "Resistive Load" section of the R&S RT-ZF2

Although there is an option to test without a disturber, the test result shall not be used for compliance.

The Transmiiter Distortion test acquires 200 µs of data at a sampling rate of 2 GSa/s and uses a MATLAB script provided in the BroadR-Reach specification to determine the transmitter peak distortion. Out of the 200 µs of data, six periods of 2047 consecutive symbols are used. A symbol period is 15 ns. The MATLAB script assumes the oscilloscope data acquisition clock is frequency locked to the DUT transmit clock TX_TCLK.

Figure below shows an example on how this can be achieved using RT-ZF3.



Note: “REF IN” is only available on R&S RTO with R&S RTO-B4 OCXO option.

8.4.4 Disturbing Signal

The disturbing signal is a standard 5.4 Vpp 20.833 MHz sine wave. It is recommended to use the indicated HAMEG or Tabor arbitrary waveform generator to create the disturbing signal. If Tabor WX2182B is used, an external amplifier is required because the maximum output voltage of this generator is 4 Vpp.

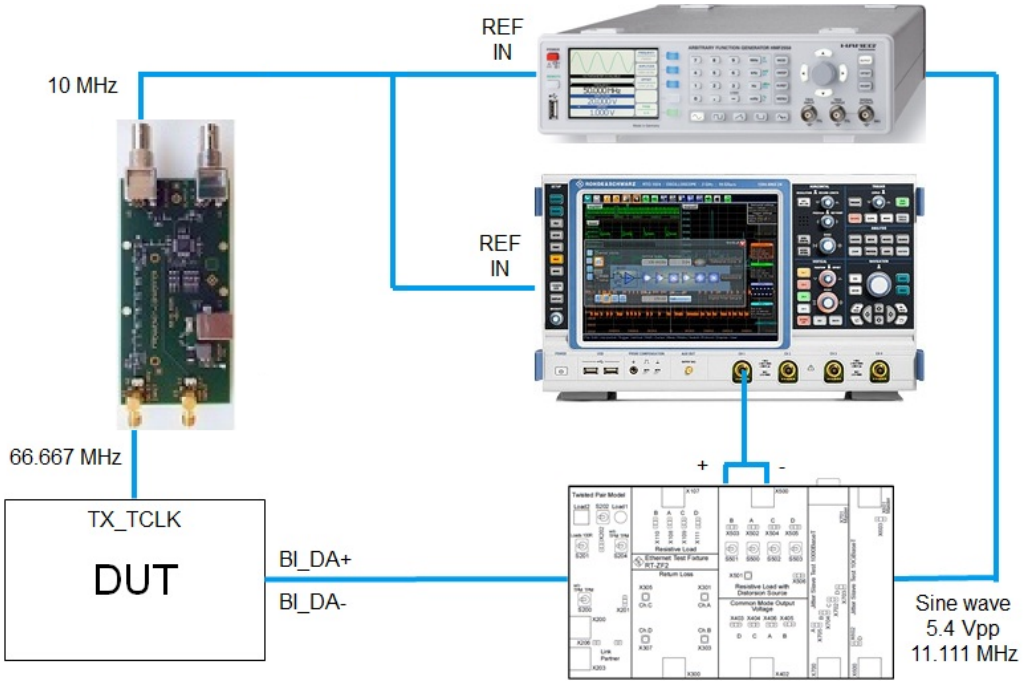
The disturbing signal is calibrated on the "Resistive Load with Distortion Source" section of the R&S RT-ZF2 Ethernet test fixture. The disturbing signal under calibration is measured at point X502.

The test is also performed on the "Resistive Load with Distortion Source" section of the R&S RT-ZF2 Ethernet test fixture. This section of the test fixture exposes the DUT to the disturbing signal while allowing very little of the disturbing signal to reach the measured point X506.

8.4.5 With Disturber Measurements

The measurement is the same as without a disturber (described in Chapter 8.4.3, "No Disturber Measurements", on page 142). However, if this test is run with a disturber, it also requires the disturbing signal source to be synchronized with the DUT TX_TCLK.

Figure below shows an example on how this can be achieved using RT-ZF3.



Note: “REF IN” is only available on R&S RTO with R&S RTO-B4 OCXO option.

8.5 Transmitter Timing Jitter

The Transmitter Timing Jitter test verifies that the transmitter timing jitter is less than 50 ps for master mode or 150 ps for slave mode.

8.5.1 Master Mode

8.5.1.1 Test Equipment

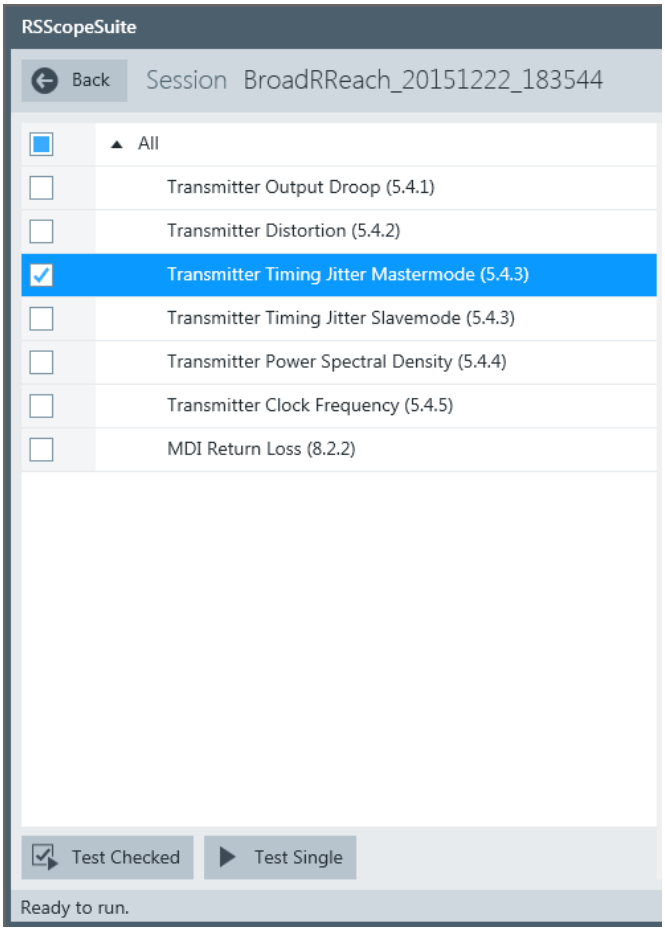
Table 8-4: Equipment for Transmitter Timing Jitter Mastermode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1

Item	Description, model	Quantity
Differential probe	at least 1 GHz bandwidth	1
DUT	BroadR-Reach device you want to test	1

8.5.1.2 Performing the Test

1. Start the test as described in Chapter 8.1, "Starting BroadR-Reach Tests", on page 135.
2. Select the test case: "Transmitter Timing Jitter Mastermode (5.4.3)".



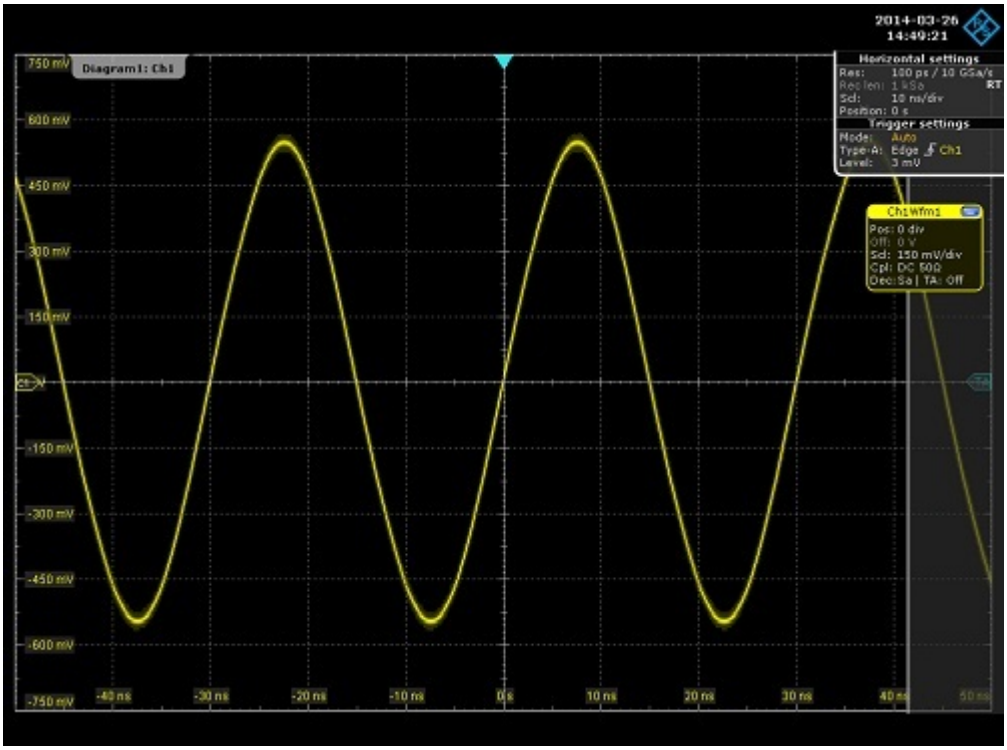
3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

8.5.1.3 Measurements

The DUT has to transmit a test mode 2 waveform.



Connect the data port to the R&S RTO for measurement.

8.5.2 Slave Mode

8.5.2.1 Test Equipment

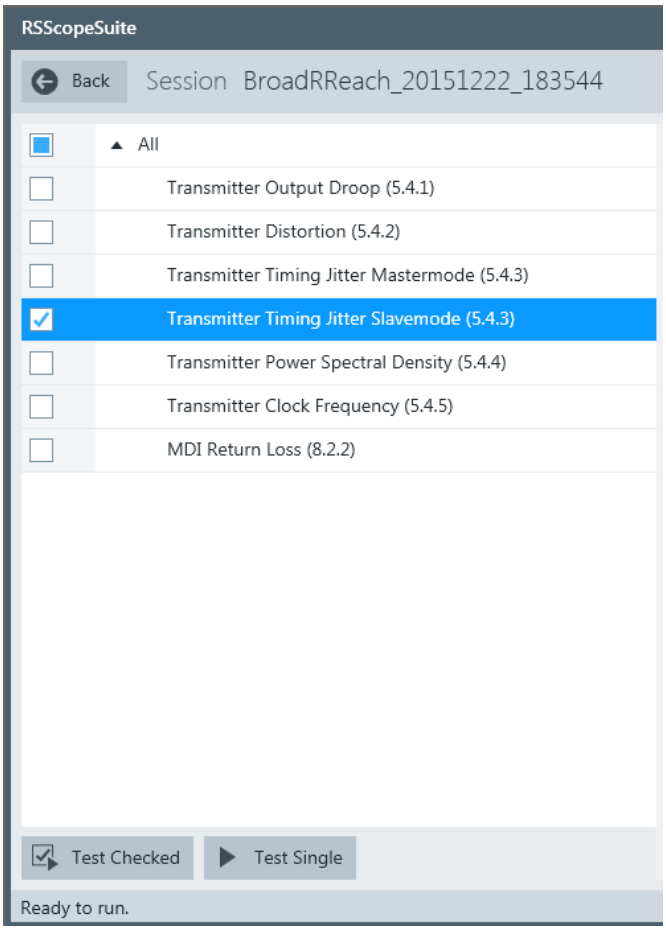
Table 8-5: Equipment for Transmitter Timing Jitter Mastermode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Differential probe	at least 1 GHz bandwidth	1
DUT	BroadR-Reach device you want to test	1
Link Partner	Additional DUT	1

8.5.2.2 Performing the Test

1. Start the test as described in Chapter 8.1, "Starting BroadR-Reach Tests", on page 135.

2. Select the test case: "Transmitter Timing Jitter Slavemode (5.4.3)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

8.5.2.3 Measurements

The DUT has to be in test mode, and the Link Partner works as master.

Connect the DUT's TX_TCLK to the R&S RTO for measurement.

8.6 Transmitter Power Spectral Density

The Transmitter Power Spectral Density test verifies that the transmitter power spectral density of the DUT over the frequency range 0 to 3 GHz falls inbetween the upper and lower limits specified in IEEE Std. 802.3-2012, Section 55.5.3.4.

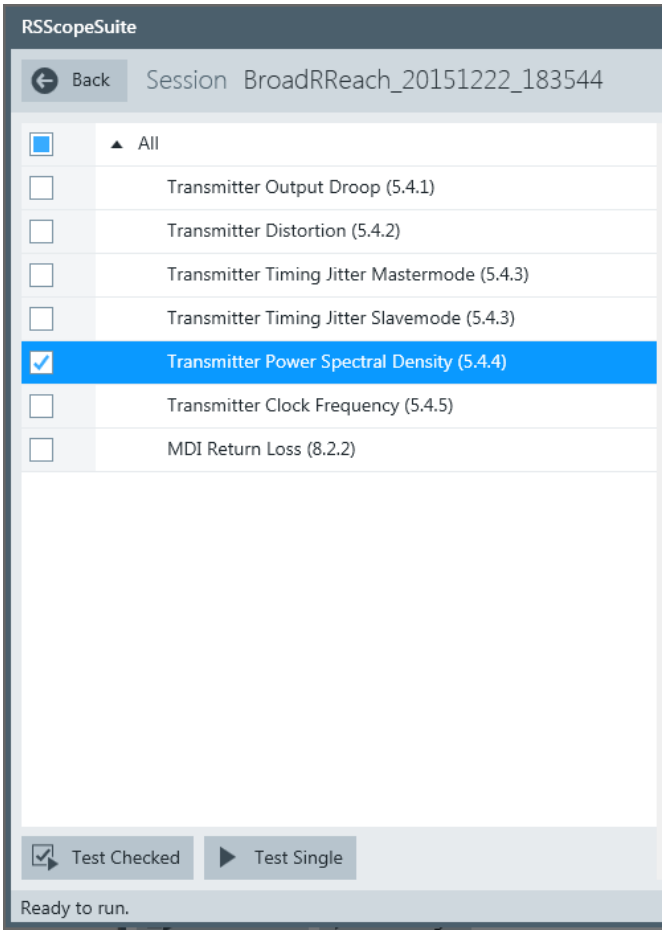
8.6.1 Test Equipment

Table 8-6: Equipment for TransmitterPower Spectral Density

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Vector Network Analyzer (optional, required only to perform an automatic test)	R&S ZVL or R&S ZNB	1
DUT	BroadR-Reach device you want to test	1

8.6.2 Performing the Test

1. Start the test as described in Chapter 8.1, "Starting BroadR-Reach Tests", on page 135.
2. Select the test case: "Transmitter Power Spectral Density (55.5.3.4)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

8.6.3 Measurements

Configure the DUT to test mode 5.

First, the oscilloscope performs an FFT transformation of the input signal over 0 – 3 GHz. Then it performs some averaging and mathematics to plot the PSD curve, and checks whether it falls within the limit mask.

8.7 Transmitter Clock Frequency

The Transmitter Clock Frequency test verifies that the frequency of the transmitter clock is within the conformance limits.

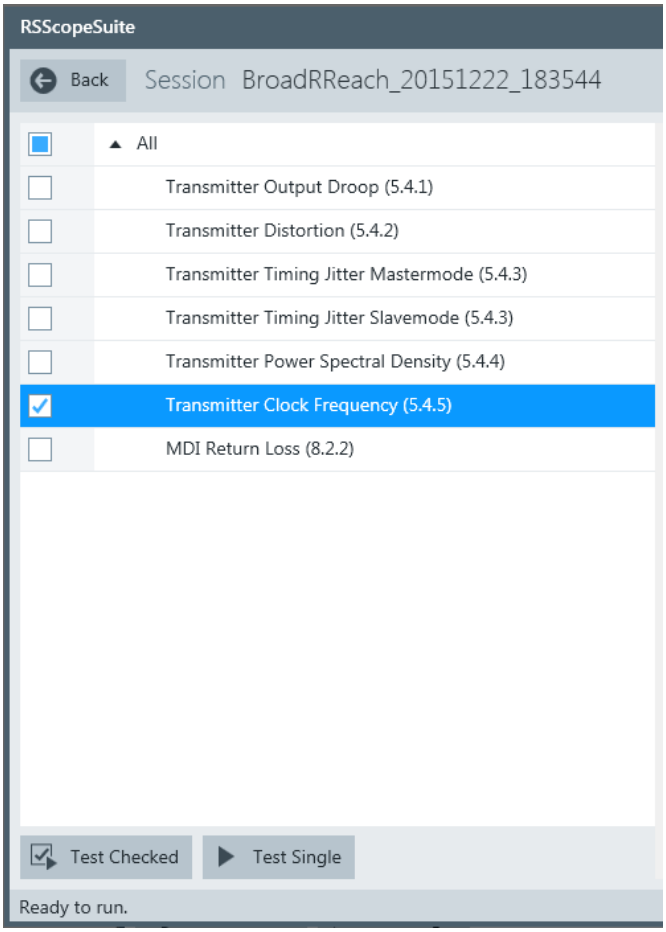
8.7.1 Test Equipment

Table 8-7: Equipment for Transmitter Clock Frequency test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the BroadR-Reach device you want to test	1

8.7.2 Performing the Test

1. Start the test as described in Chapter 8.1, "Starting BroadR-Reach Tests", on page 135.
2. Select the test case "Transmitter Clock Frequency (5.4.5)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

8.7.3 Measurements

The DUT has to transmit test mode 2 waveform.

In automated testing the oscilloscope measures the frequency and determines if the transmitter clock frequency is within the conformance limits.

8.8 MDI Return Loss

The MDI Return Loss test verifies that the transmitter return loss of the DUT is at least 20 dB from 1 to 40 MHz, and at least *26 - 0.15*f dB* from 40 to 66 MHz when referenced to a characteristic impedance of 100 Ω.

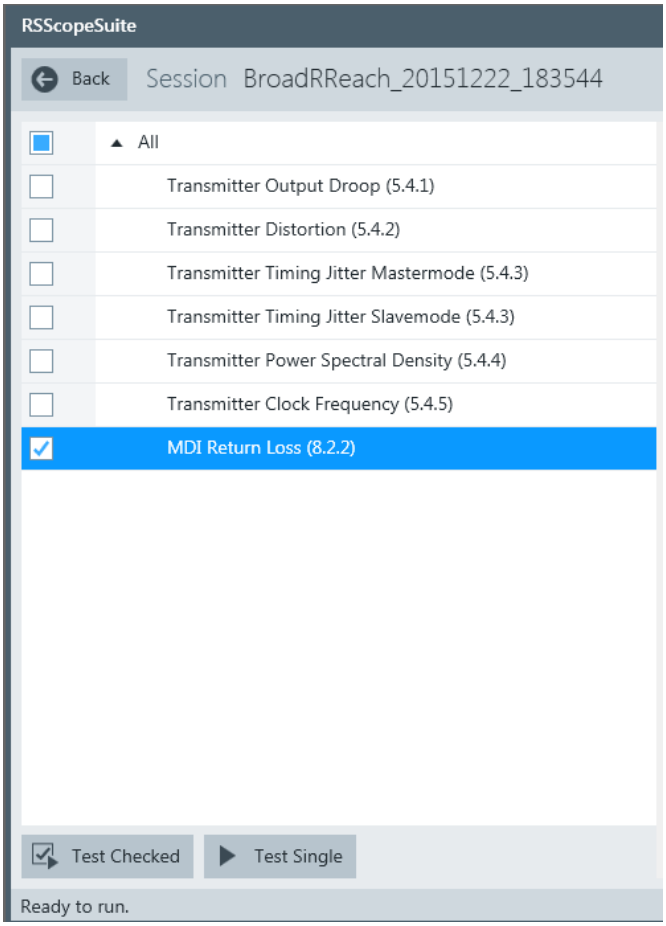
8.8.1 Test Equipment

Table 8-8: Equipment for MDI Return Loss test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Vector Network Analyzer (optional, required only to perform an automatic test)	R&S ZVL or R&S ZNB	1
DUT	BroadR-Reach device you want to test	1

8.8.2 Performing the Test

1. Start the test as described in Chapter 8.1, "Starting BroadR-Reach Tests", on page 135.
2. Select the test case: "MDI Return Loss (8.2.2)".



3. Click "Test Single".
4. Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

- Chapter 3.3, "Getting Test Results", on page 24

8.8.3 Measurements

Configure the DUT to test mode 4.

During automatic testing, the program measures the S11 parameter on the VNA. It shall fall below the limit line plotted on the VNA from 1 MHz to 66 MHz.

During manual testing, the program checks if every point within 1 MHz and 66 MHz in the result file (`*.s1p` or `*.csv`) falls below the limit required by the specification.