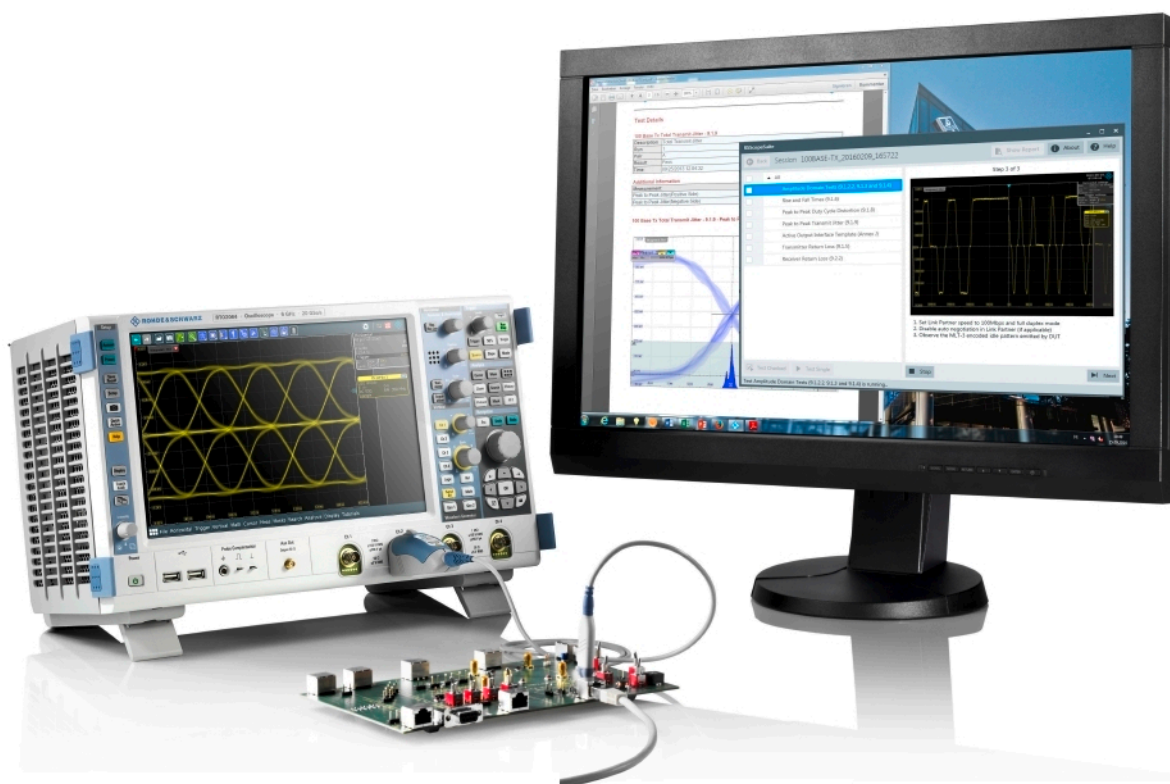# R&S®RTO, R&S®RTO6, R&S®RTP
Ethernet Compliance Tests
User Manual

ROHDE & SCHWARZ

Make ideas real

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

- 10/100/1000BASE-T:
  R&S®RTO-K22 (1329.7460.02), R&S®RTO6-K22 (1801.6929.02), R&S®RTP-K22 (1337.8691.02)
- 2.5/5/10GBASE-T:
  R&S®RTO-K23 (1329.7477.02), R&S®RTO6-K23 (1801.6935.02), R&S®RTP-K23 (1337.8704.02)
- 100BASE-T1:
  R&S®RTO-K24 (1329.7483.02), R&S®RTO6-K24 (1801.6941.02), R&S®RTP-K24 (1800.6531.02)
- 1000BASE-T1:
  R&S®RTO-K87 (1337.8591.02), R&S®RTO6-K87 (1801.6970.02), R&S®RTP-K87 (1800.6554.02)
- MGBASE-T1:
  R&S®RTO-K88 (1801.4526.02), R&S®RTO6-K88 (1801.7890.02), R&S®RTP-K88(1800.6725.02)
- 10BASE-T1:
  R&S®RTO-K89 (1801.4510.02), R&S®RTO6-K89 (1801.6987.02), R&S®RTP-K89 (1800.6719.02)

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

The energy-efficient Ethernet (EEE) 100/1000BASE-T tests require the R&S RT-ZF5 Ethernet probing fixture (1333.0896.02).

The 10BASE-Te tests require the R&S RT-ZF4 10BASE-Te fixture (1333.0880.02).

Contents

1 R&S ScopeSuite overview

The R&S ScopeSuite software is used with R&S RTO/RTO6/RTP oscilloscopes. It can be installed on a test computer or directly on the oscilloscope. For system requirements, refer to the Release Notes.
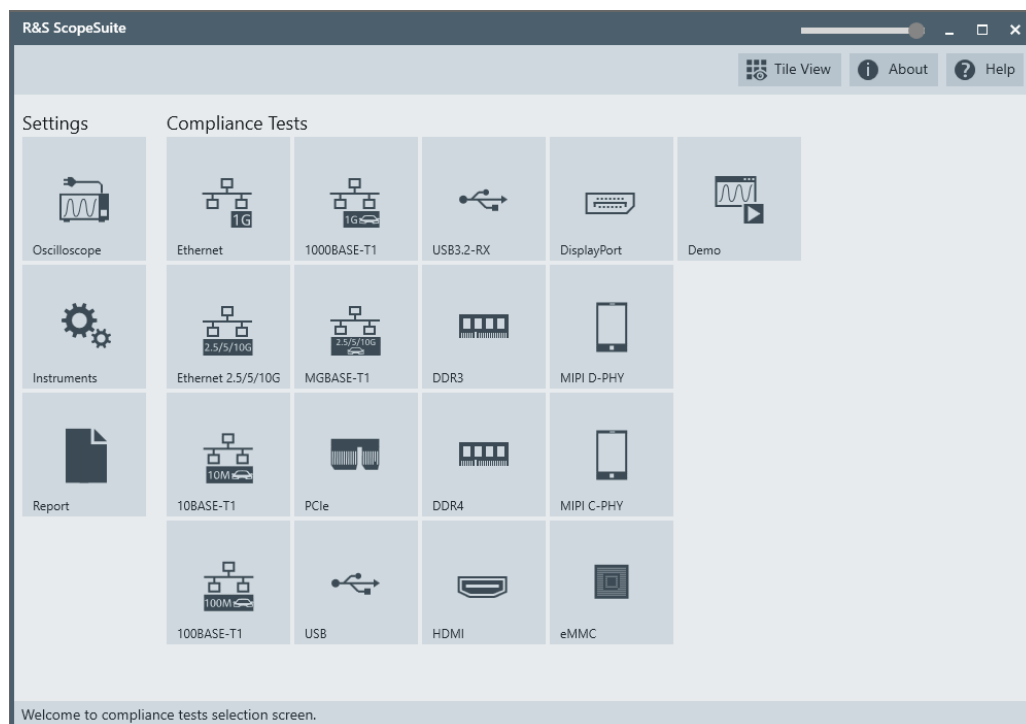
The R&S ScopeSuite main panel has several areas:

- "Settings": connection settings to oscilloscope and other instruments also 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
- ▭▭▭▭: shift sideways to change the transparency of the dialog box
- "Help": opens the help file, containing 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 that you want to hide.
The icon of the test changes, see Figure 1-1. Now with a left click you can hide the test.
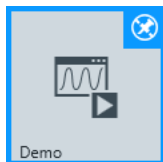
Figure 1-1: Unpin icon

b) Click on "Title View" to show a list of the available test cases. By clicking 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:

- The free-of-charge R&S ScopeSuite software, which can be installed on a computer or directly on the oscilloscope.
- **10/100/1000BASE-T Ethernet compliance tests:**
  - R&S RTO / R&S RTO6 /R&S RTP oscilloscope with at least 600 MHz bandwidth
  - Differential probe with at least 1 GHz bandwidth
  - R&S RTO / R&S RTO6 /R&S RTP-K22 10/100/1000BASE-T Ethernet compliance test option (required option, installed on the oscilloscope)
  - R&S RT-ZF2 Ethernet test fixture set
  - For energy-efficient Ethernet tests, in addition:
    R&S RT-ZF5 Ethernet test fixture set for 100/1000BASE-T EEE tests
    R&S RT-ZF4 test fixture for 10BASE-Te tests
- **2.5GBASE-T Ethernet compliance tests:**
  - R&S RTO / R&S RTO6 /R&S RTP oscilloscope with at least 600 MHz bandwidth
    For precise power spectral density and power level measurements up to
    1 GHz, it is recommended to use an oscilloscope and a differential probe with
    1 GHz bandwidth each.
  - Differential probe with at least 1GHz bandwidth
  - R&S RTO / R&S RTO6 /R&S RTP-K23 GBASE-T Ethernet compliance test option (required option, installed on the R&S RTO/RTO6/RTP)
  - R&S RT-ZF2 Ethernet test fixture set
- **5GBASE-T Ethernet compliance tests:**
  - R&S RTO / R&S RTO6 /R&S RTP oscilloscope with at least 1 GHz bandwidth
    For precise power spectral density and power level measurements up to
    1.5 GHz, it is recommended to use an oscilloscope and a differential probe with
    1.5 GHz bandwidth each.
  - Differential probe with at least 1.5 GHz bandwidth
  - R&S RTO / R&S RTO6 /R&S RTP-K23 GBASE-T Ethernet compliance test option (required option, installed on the R&S RTO/RTO6/RTP)
  - R&S RT-ZF2 Ethernet test fixture set
- **10GBASE-T Ethernet compliance tests:**
  - R&S RTO / R&S RTO6 /R&S RTP oscilloscope with at least 2 GHz bandwidth
    For precise power spectral density and power level measurements up to
    3 GHz, it is recommended to use an oscilloscope and a differential probe with
    3 GHz bandwidth each.

- Differential probe with at least 3 GHz bandwidth
- R&S RTO / R&S RTO6 /R&S RTP-K23 GBASE-T Ethernet compliance test option (required option, installed on the R&S RTO/RTO6/RTP)
- R&S RT-ZF2 Ethernet test fixture set
- **100BASE-T1 compliance tests:**
  - R&S RTO / R&S RTO6 /R&S RTP oscilloscope with at least 600 MHz bandwidth
  - Differential probe with 1 GHz bandwidth
  - R&S RTO / R&S RTO6 /R&S RTP-K24 100BASE-T1 compliance test option (required option, installed on the R&S RTO/RTO6/RTP)
  - R&S RT-ZF2 Ethernet test fixture set
  - R&S RT-ZF3 frequency converter for transmitter distortion tests
- **1000BASE-T1 compliance tests:**
  - R&S RTO / R&S RTO6 /R&S RTP oscilloscope with at least 2 GHz bandwidth
  - Differential probe with 2 GHz bandwidth
  - R&S RTO / R&S RTO6 /R&S RTP-K87 1000BASE-T1 compliance test option (required option, installed on the R&S RTO/RTO6/RTP)
  - R&S RT-ZF2 Ethernet test fixture set
  - R&S RT-ZF6 frequency converter for transmitter distortion tests
- **MGBASE-T1 compliance tests:**
  - R&S RTO / R&S RTO6 /R&S RTP oscilloscope, with a bandwidth of:
    - for 2.5 GBASE-T1 tests: at least 3.5 GHz
    - for 5 GBASE-T1 tests: at least 7 GHz
    - for 10 GBASE-T1 tests: at least 13 GHz
  - 2 BNC/SMA cables
  - R&S RTO / R&S RTO6 /R&S RTP-K88 MGBASE-T1 compliance test option (required option, installed on the R&S RTO/RTO6/RTP)
- **10BASE-T1 compliance tests:**
  - R&S RTO / R&S RTO6 /R&S RTP oscilloscope
  - Optional Differential probe with 1 GHz bandwidth
  - R&S RTO / R&S RTO6 /R&S RTP-K89 10BASE-T1 compliance test option (required option, installed on the R&S RTO/RTO6/RTP)
- R&S RTO-B6/R&S RTP-B6/Tabor WX2182B/Tabor WX2182C arbitrary waveform generator for automatic disturber tests. For some disturber tests, also HMF2550 can be used.
- R&S ZNB/ZNC/ZND/ZVL vector network analyzer for automatic return loss measurements. For manual measurements, also other AWGs and VNAs can be used.

2.2 Installing software and license

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

> **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".

For best operation results, we recommend that the installed firmware versions of the R&S ScopeSuite and the oscilloscope are the same.

To install the R&S ScopeSuite

1. Download the latest R&S ScopeSuite software from the "Software" section on the Rohde & Schwarz R&S RTO/RTO6/RTP website:
   www.rohde-schwarz.com/product/rtp.html
   www.rohde-schwarz.com/product/rto.html

2. Install the R&S ScopeSuite software:
   - On the computer that is used for testing, or
   - On the R&S RTO/RTO6/RTP.

   For system requirements, refer to the Release Notes.

To install the license key on the R&S RTO/RTO6/RTP

► When you got the license key of the compliance test option, enable it on the oscilloscope using [Setup] > "SW Options".
   For a detailed description, refer to the R&S RTO/RTO6/RTP user manual, chapter "Installing Options", or to the online help on the instrument.

2.3 Setting up the network

If the R&S ScopeSuite software runs on a test computer, the computer and the testing oscilloscope 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 or WX2182C is used for automatic testing, assign fixed IP addresses 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 is 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/RTO6/RTP", on page 12
●   Chapter 2.6, "Connecting the arbitrary waveform generator", on page 14
●   Chapter 2.7, "Connecting the vector network analyzer", on page 15
●   Chapter 2.8, "Connecting the spectrum analyzer", on page 17

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/RTO6/RTP firmware:

►   In the "Apps" dialog, open the "Compliance" tab.

2.5   Connecting the R&S RTO/RTO6/RTP

If the R&S ScopeSuite is installed directly on the instrument, the software detects the R&S RTO/RTO6/RTP 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 oscilloscope require a LAN connection, see Chapter 2.3, "Setting up the network", on page 11. The R&S ScopeSuite software needs the IP address of the oscilloscope to establish connection.

1. Start the R&S RTO/RTO6/RTP.

2. Start the R&S ScopeSuite software.

3. Click "Settings" > "Oscilloscope".
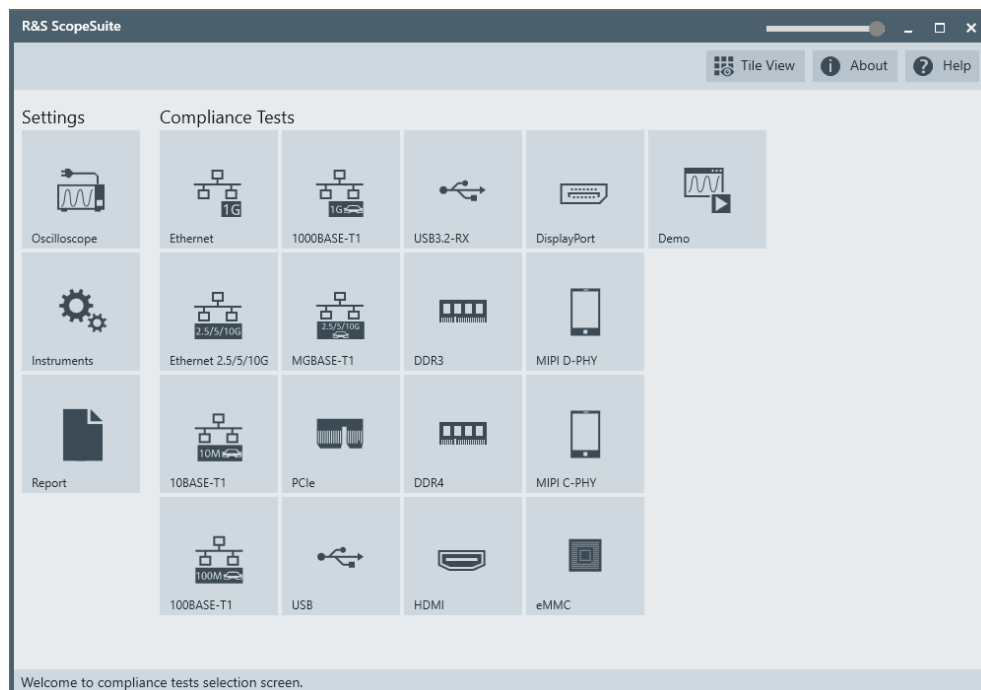
4. Enter the IP address of the oscilloscope.
   To obtain the IP address: press the Rohde & Schwarz logo at the top-right corner of the oscilloscope's display.

5. Click "Get Instrument Information".

   The computer connects with the instrument and gets the instrument data.
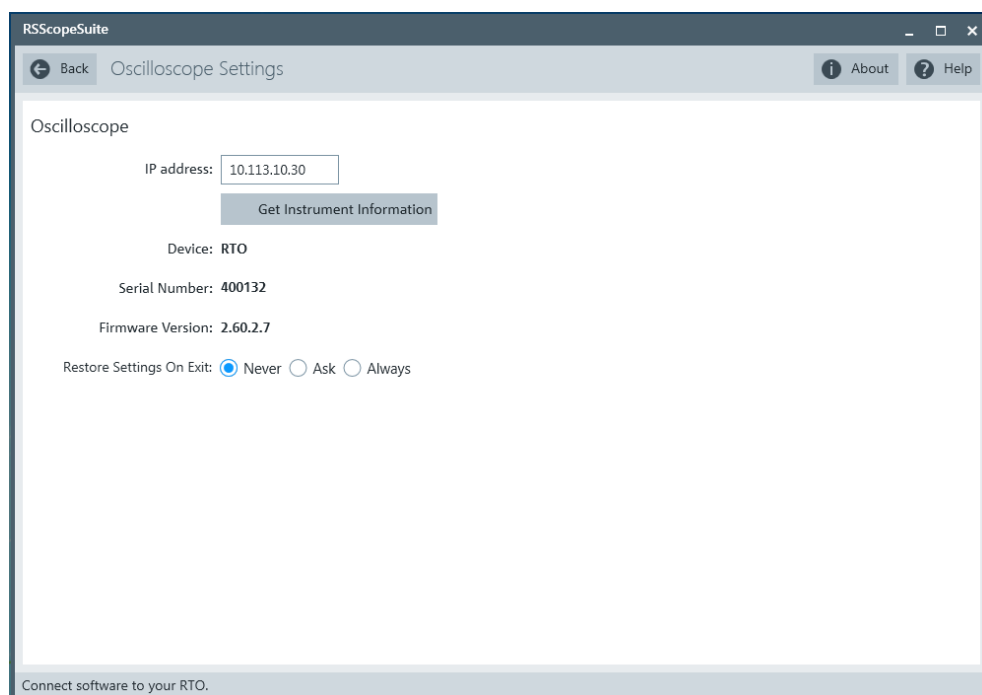
If the connection fails, an error message is shown.

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 available AWG.

Automatic test execution is possible with all instruments that are listed in the R&S ScopeSuite, in the "Instrument Settings" dialog box. In automatic mode, the R&S Scope-Suite 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 (R&S VISA, see www.rohde-schwarz.com/rsvisa) on the computer that is running the R&S ScopeSuite. If the R&S ScopeSuite is installed on the R&S RTO/RTO6/RTP, no installation is needed because VISA is already installed on the instrument. If the Tabor WX2182B / WX2182C or Hameg HMF2550 is used for automatic testing, fixed IP addresses are required.

For manual test execution, it is recommended to use one of the listed AWGs, but you can also use another AWG. 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.

2. Set up the LAN connection. See Chapter 2.3, "Setting up the network", on page 11.

3. In the R&S ScopeSuite, click "Instruments".
   Alternatively, you can select the "Instrument" tab in the test case configuration dialog.

4. Click the "AWG" tab.

5. Select "Operating mode" = "Automatic".

6. Select a supported "AWG Type" and enter its IP address.
   For a list of the supported AWGs, see chapter "Test Equipment".
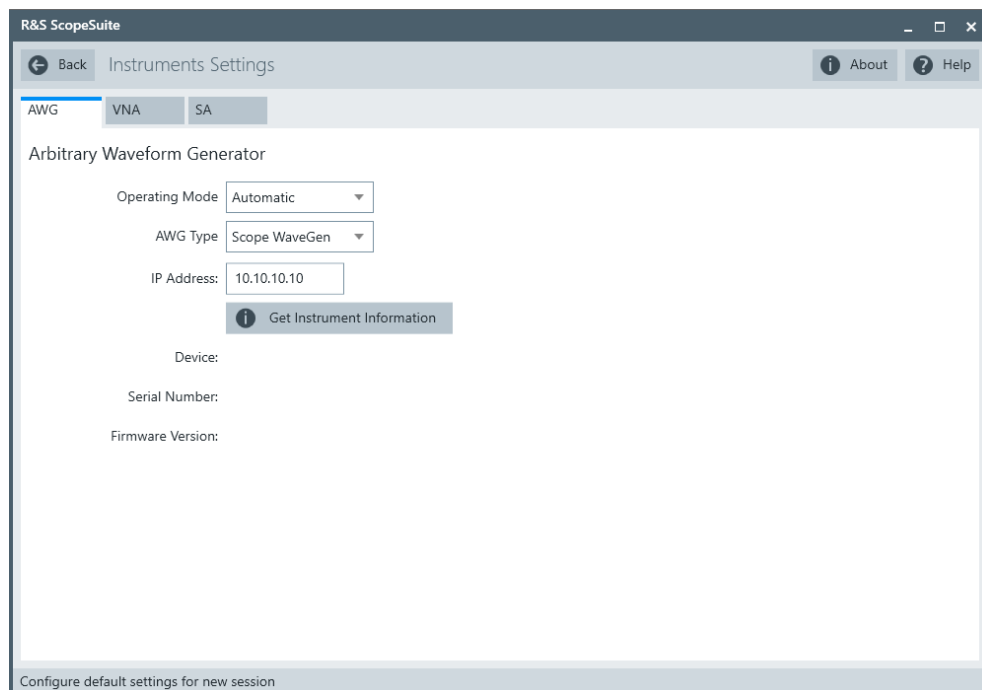
7. Click "Get Instrument Information".

   The computer or R&S RTO/RTO6/RTP connects with the instrument and retrieves the instrument data.

8. If the connection to the arbitrary waveform generator failed, check 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. You can use the automatic mode only with supported instruments. A LAN connection and a VISA

installation on the computer that is running the R&S ScopeSuite is required. If the R&S ScopeSuite is installed on the R&S RTO/RTO6/RTP, 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. Set up the LAN connection, see Chapter 2.3, "Setting up the network", on page 11.

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.
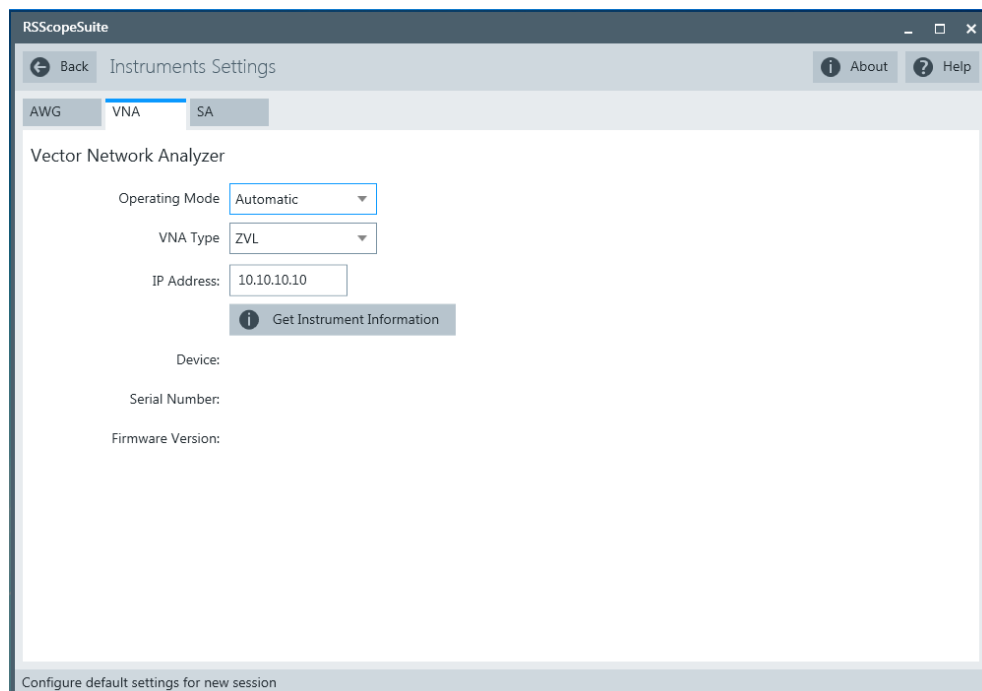
6. Click "Get Instrument Information".

   The computer or R&S RTO/RTO6/RTP 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/FSQ/FSW/ESRP. 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/RTO6/RTP, 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.

2. Set up the LAN connection. See Chapter 2.3, "Setting up the network", on page 11.

3. In the R&S ScopeSuite, click "Instruments".

4. Click the "SA" tab.

5. Select the "Automatic" operating mode.

6. Select the "SA Type" and enter its IP address.
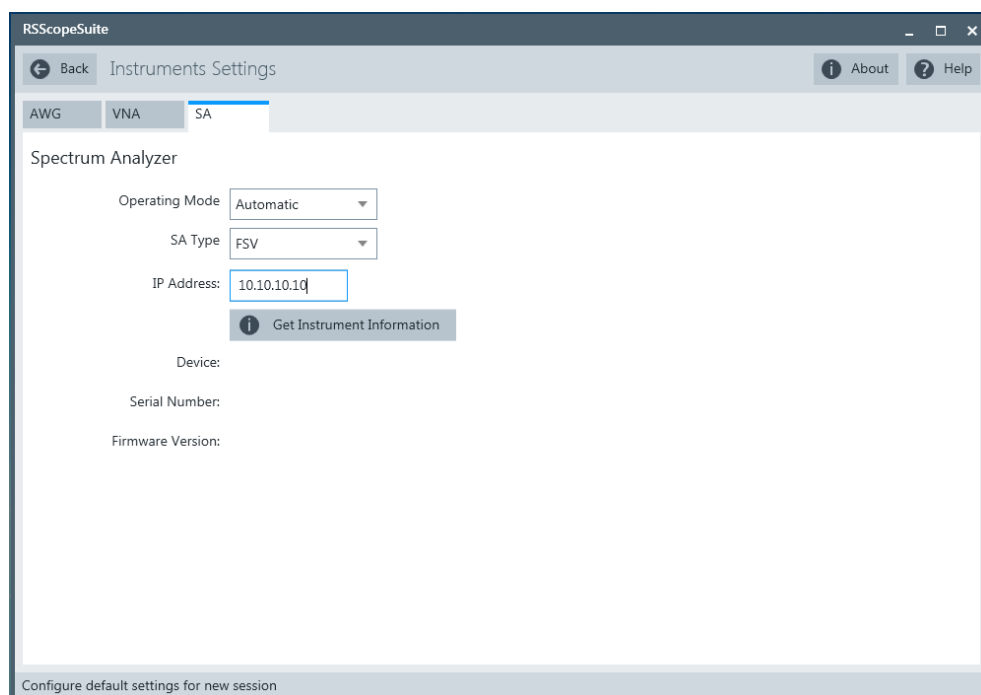
7. Click "Get Instrument Information".

    The computer or R&S RTO/RTO6/RTP 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 is displayed in the upper left corner of the report.

Also, you can enter common information on the test that is written in the "General Information" section of the test report.
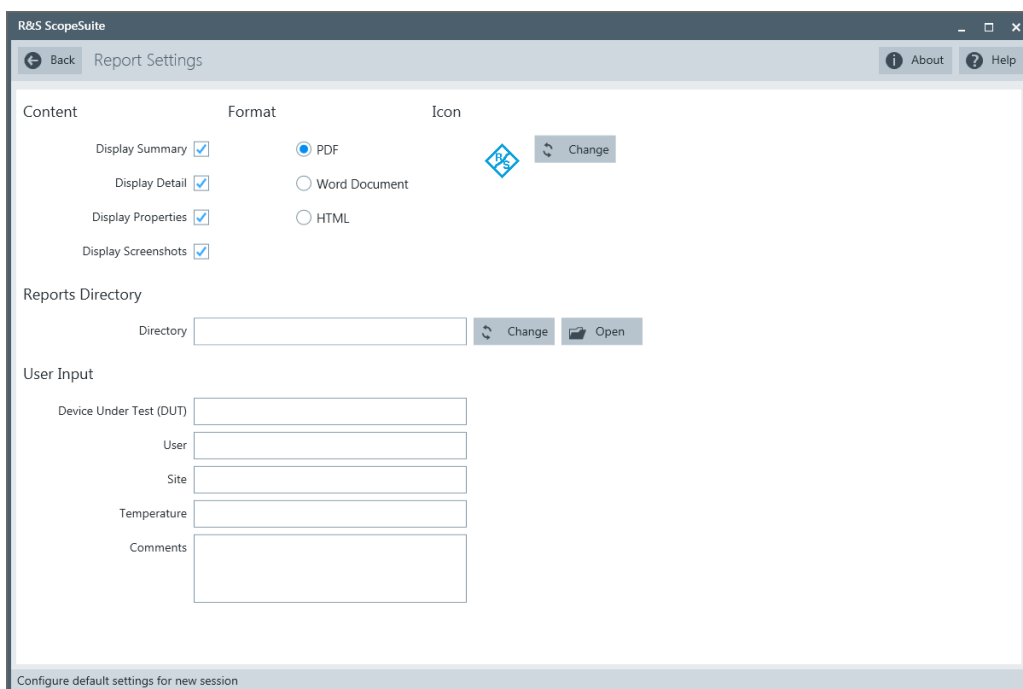
3 Performing tests

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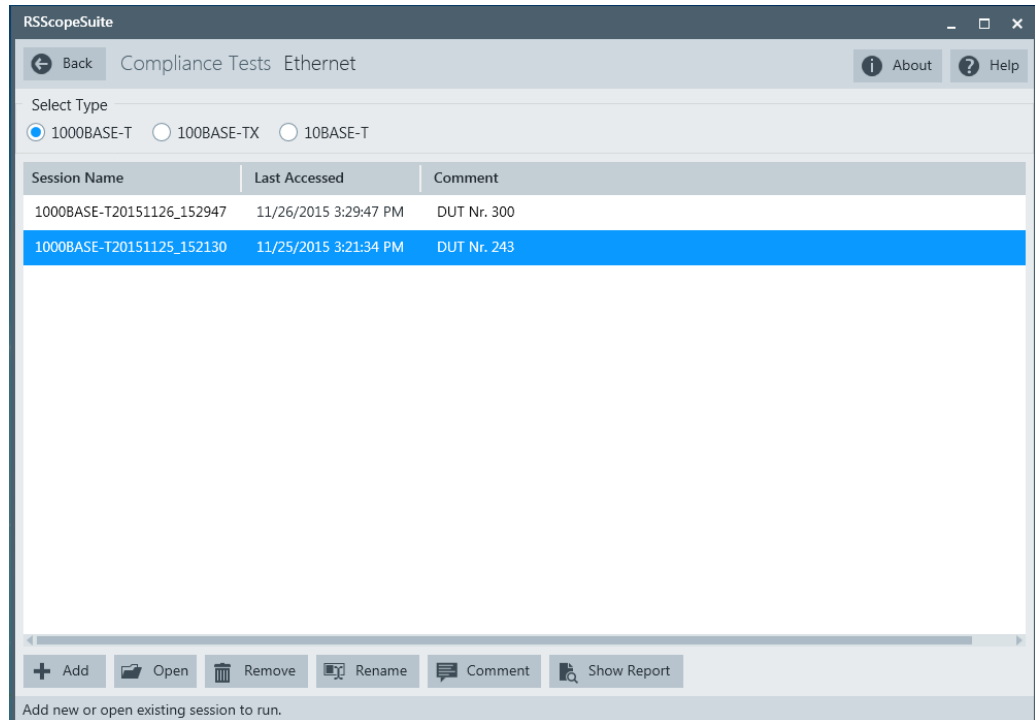
After you open a compliance test, the "Session Selection" dialog appears. In this dialog, you can create new sessions, open or view existing report.

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

To add a test session

1. In the R&S ScopeSuite window, select the compliance test.

2. In the "Session Selection" dialog press "Add".

3. If necessary change the "Session Name"

To open a test session

1. In the R&S ScopeSuite window, select the compliance test.

2. In the "Session Selection" dialog, select the session you want to open and double
   click on it.
   Alternatively, select the session and press "Open".

To show a report for a test session

1. In the R&S ScopeSuite window, select the compliance test.

2. In the "Session Selection" dialog, select the session you want the report for and
   press "Show report".

3.2 Configuring the test

1. In the R&S ScopeSuite window, select the compliance test to be performed:
   - "100BASE-T1"
   - "Ethernet"
   - "MGBASE-T1"
   - "Ethernet 2.5/5G/10G"
   - "1000BASE-T1"
   - "10BASE-T1"

2. Open a test session, see Chapter 3.1, "Starting a test session", on page 20.

3. Adjust the "Properties" settings for the test cases you want to perform.

4. Click "Limit Manager" and edit the limit criteria, see Chapter 3.2.1.1, "Limit man-
   ager", on page 23.

5. If you want to use special report settings the "Report Config" tab to define the for-
   mat and contents of the report. Otherwise the settings defined in "RSScopeSuite" >
   "Settings" > "Report" are used. See Chapter 2.9, "Report configuration",
   on page 18.

6. Click "Test Checked"/"Test Single" and proceed as described in the relevant test
   case chapter.

3.2.1   General test settings
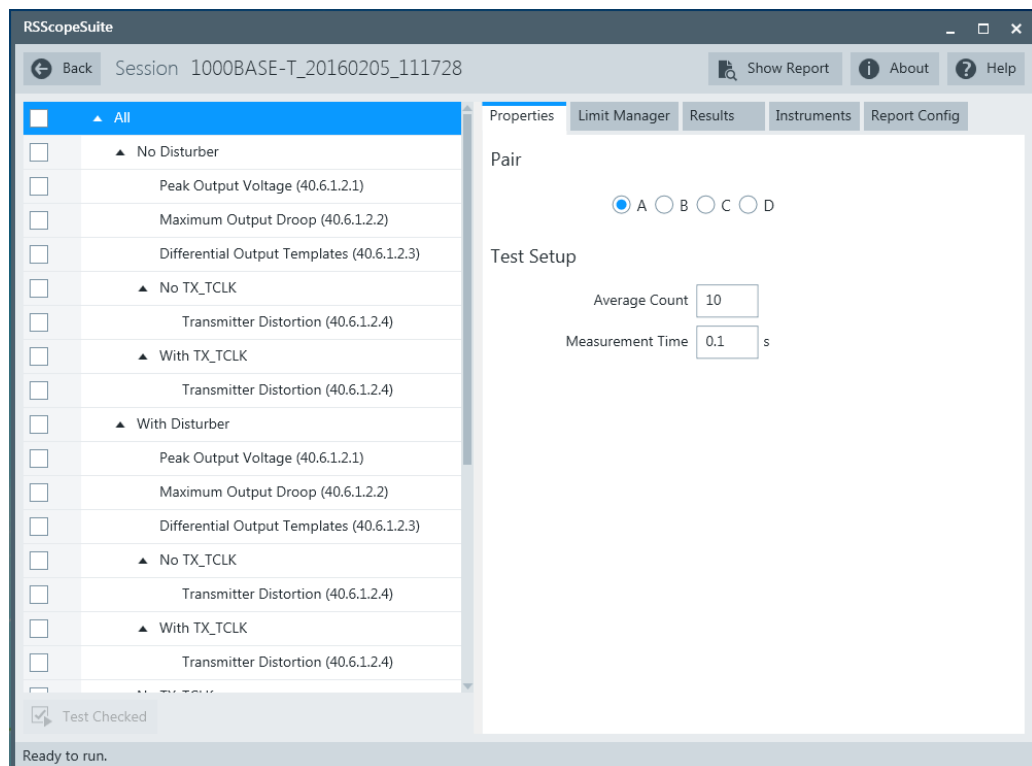
Each session dialog is divided into several sections:

- "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 test 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.

You can also return the values to the original limits with "Reset to default".

► Check and adjust the measurement limits.

Properties	Limit Manager	Results	Instruments	Report Config	

Measurement	Criteria	Unit	A	B
Peak Voltage Range: Point A & B	A<=x<=B ▼	V	0.67	0.82
Voltage Difference: Point A & B	x<=A ▼	%	1	
Voltage Difference: Point C to A & B	x<=A ▼	%	2	
Voltage Difference: Point D to A & B	x<=A ▼	%	2	
Voltage Ratio of Point G to Point F	x>=A ▼	%	73.1	
Voltage Ratio of Point J to Point H	x>=A ▼	%	73.1	
Template 1 Violation Points	x=A ▼	Violation Point	0	
Template 2 Violation Points	x=A ▼	Violation Point	0	
Unfiltered Jitter Mastermode	x<=A ▼	s	1.4E-09	
Filtered Jitter Mastermode	x<=A ▼	s	3E-10	
Unfiltered Jitter Slavemode	x<=A ▼	s	1.4E-09	
Filtered Jitter Slavemode	x<=A ▼	s	4E-10	
Peak Distortion	x<A ▼	V	0.01	
Signal-to-noise Ratio	Ignore ▼			
Percentage of Eye Opening Within Limit	x>=A ▼	%	60	
Common-mode Output Voltage	x<=A ▼	V	0.05	

↻ Reset to Default	🖼 Export	📁 Import

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 100BASE-T1 test, the test data - report, diagrams and waveform files - is saved in the following folder:
`%ProgramData%\Rohde-Schwarz\RSScopeSuite\3.0\Sessions\`
`100BASE-T1\<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 18). 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/RTO6/RTP-K22.

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 Scope-Suite, see Chapter 2.5, "Connecting the R&S RTO/RTO6/RTP", on page 12
- AWG connection for tests with disturber, see Chapter 2.6, "Connecting the arbitrary waveform generator", on page 14.
- VNA connection for MDI Return Loss and Transmitter Power Spectral Density tests, see Chapter 2.7, "Connecting the vector network analyzer", on page 15.

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 20.

4. Check the test configuration settings and adjust, if necessary. See:
   - Chapter 4.2, "Test configuration for Ethernet 1000BASE-T", on page 25
   - 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.
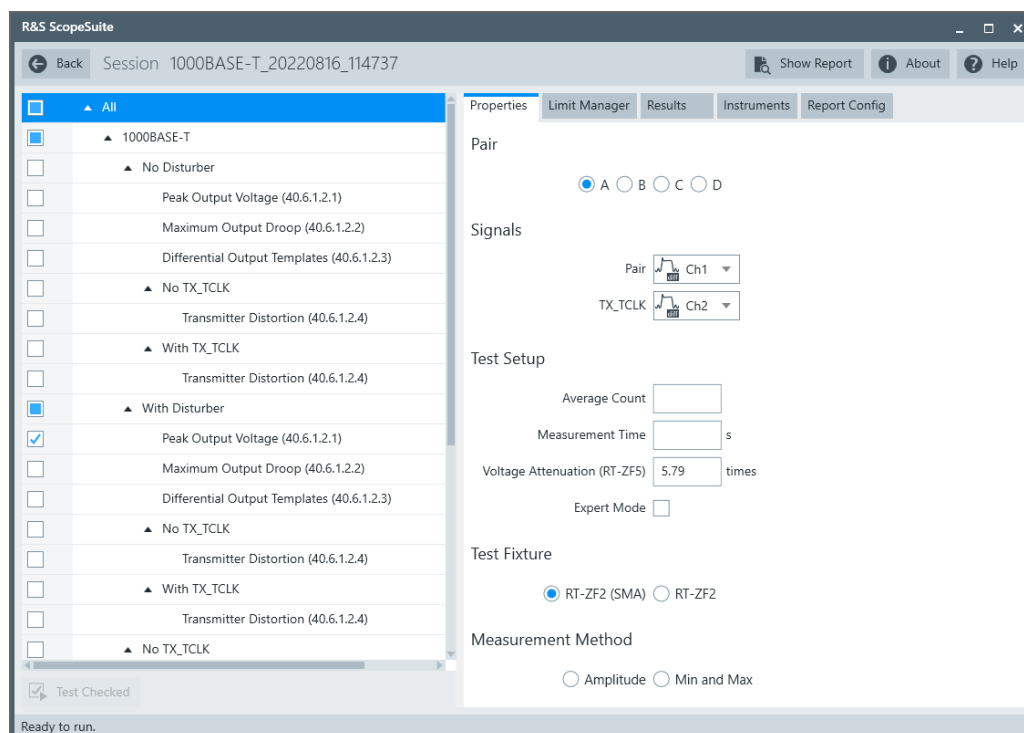
Figure 4-1: Configuration for 1000BASE-T compliance tests

Pair
Select which cable pair is used.

Signals
Selects the oscilloscope channels for the pair testing.

Average Count
Defines the number of waveforms which the oscilloscope acquires to calculate the average waveform (average count).

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
Sets the measurement time. The valid range is 50E-9 to 100E-3, the default value is 100E-3.

Voltage Attenuation
The voltage attenuation is used for all 1000BASE-T EEE test cases.

Voltage attenuation sets how many times the voltage attenuates after going through directional coupler on the test fixture. The default value is a theoretical value and works well for R&S RT-ZF5. It is not suggested to be changed for all time unless a value is confirmed from careful calibration.

Expert Mode

If enabled, the "Expert Mode" allows you to bypass the guided steps of the test case.

Test Fixture

This setting is used for the "Common-mode Output Voltage" test cases.

Selects if the fixture that is used for the measurement has a SMA input or not.

Measurement Method

This setting is used for the "Peak Output Voltage (40.6.1.2.1)" test cases.

For the "Amplitude" measurement mode, the amplitude of the signal is calculated as the difference of high and low signal levels.

For the "Min and Max" measurement mode, the absolute maximum and absolute minimum of the waveform are measured.

4.3 1000BASE-T

The following table shows an overview of the needed equipment for performing the 1000BASE-T test cases. A prerequisite is also a R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth, the R&S ScopeSuite software and a 1000BASE-T DUT.

Table 4-1: Equipment for 1000BASE-T Ethernet compliance tests

	Differential type		Single-Ended type	Additional instruments
	Differential probe	**Test fixture**	**SMA**	
Transmitter Distortion (40.6.1.2.4) No disturber and No TX_TCLK	1 at least 1 GHz bandwidth	R&S RT-ZF2 Section: Resistive Load	-	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Transmitter Distortion (40.6.1.2.4) No disturber and with TX_TCLK	1 at least 1 GHz bandwidth	R&S RT-ZF2 Section: Resistive Load	1 at least 1 GHz bandwidth	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Transmitter Distortion (40.6.1.2.4) With disturber and No TX_TCLK	1 at least 1 GHz bandwidth	R&S RT-ZF2 Section: Resistive Load	-	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17 **ARB:** R&S RTO-B6 or Tabor WX2182B/ WX2182C or HMF2550

	Differential type		Single-Ended type	Additional instruments
	Differen-tial probe	**Test fixture**	**SMA**	
Transmitter Distortion (40.6.1.2.4) With disturber and With TX_TCLK	1 at least 1 GHz band-width	R&S RT-ZF2 Section: Resistive Load	1 at least 1 GHz band-width	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17 **ARB:** R&S RTO-B6 or Tabor WX2182B/ WX2182C or HMF2550
Peak Output Voltage (40.6.1.2.1) No disturber	1 at least 1 GHz band-width	R&S RT-ZF2 Section: Resistive Load	1 at least 1 GHz band-width	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Peak Output Voltage (40.6.1.2.1) With disturber	1 at least 1 GHz band-width	R&S RT-ZF2 Section: Resistive Load	1 at least 1 GHz band-width	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17 **ARB:** R&S RTO-B6 or Tabor WX2182B/ WX2182C or HMF2550
Maximum Output Droop (40.6.1.2.2) No disturber	1 at least 1 GHz band-width	R&S RT-ZF2 Section: Resistive Load	1 at least 1 GHz band-width	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Maximum Output Droop (40.6.1.2.2) With disturber	1 at least 1 GHz band-width	R&S RT-ZF2 Section: Resistive Load	1 at least 1 GHz band-width	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17 **ARB:** R&S RTO-B6 or Tabor WX2182B/ WX2182C or HMF2550
Differential Output Tem-plates (40.6.1.2.3) No disturber	1 at least 1 GHz band-width	R&S RT-ZF2 Section: Resistive Load	1 at least 1 GHz band-width	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17

	Differential type		Single-Ended type	Additional instruments
	Differential probe	**Test fixture**	**SMA**	
Differential Output Templates (40.6.1.2.3) With disturber	1 at least 1 GHz bandwidth	R&S RT-ZF2 Section: Resistive Load	1 at least 1 GHz bandwidth	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17 **ARB:** R&S RTO-B6 or Tabor WX2182B/WX2182C or HMF2550
Jitter Master Mode and Clock Frequency (40.6.1.2.5 and 40.6.1.2.6) No TX_TCLK	1 at least 1 GHz bandwidth	R&S RT-ZF2 Section: Jitter Slave Test 1000BaseT	-	Total of 2 DUTs required
Jitter Master Mode and Clock Frequency (40.6.1.2.5 and 40.6.1.2.6) With TX_TCLK	1 at least 1 GHz bandwidth	R&S RT-ZF2 Section: Jitter Slave Test 1000BaseT	1 at least 1 GHz bandwidth	Total of 2 DUTs required **Gigabit Ethernet jitter cable:** R&S RT-ZF2C
Jitter Slave Mode (40.6.1.2.5) No TX_TCLK	1 at least 1 GHz bandwidth	R&S RT-ZF2 Section: Jitter Slave Test 1000BaseT	-	Total of 2 DUTs required
Jitter Slave Mode (40.6.1.2.5) With TX_TCLK	1 at least 1 GHz bandwidth	R&S RT-ZF2 Section: Jitter Slave Test 1000BaseT	1 at least 1 GHz bandwidth	Total of 2 DUTs required
MDI Return Loss (40.8.3.1)	-	R&S RT-ZF2 Section: Twisted Pair Model	-	**VNA:** R&S ZNB or R&S ZNC or R&S ZND or R&S ZVL
Common-mode Output Voltage (40.8.3.3)	1 at least 1 GHz bandwidth	R&S RT-ZF2 Section: Common Mode Voltage	-	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17

4.3.1 Transmitter distortion

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

4.3.1.1 No disturber

Test equipment

Table 4-2: Equipment for Transmitter Distortion test, no disturber

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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 that you want to test	1

Performing the tests

1. Start the test as described in

2. Select the test case:
   - "No TX_CLK" test:
     "No Disturber" > "No TX_CLK" > "Transmitter Distortion (40.6.1.2.4)"
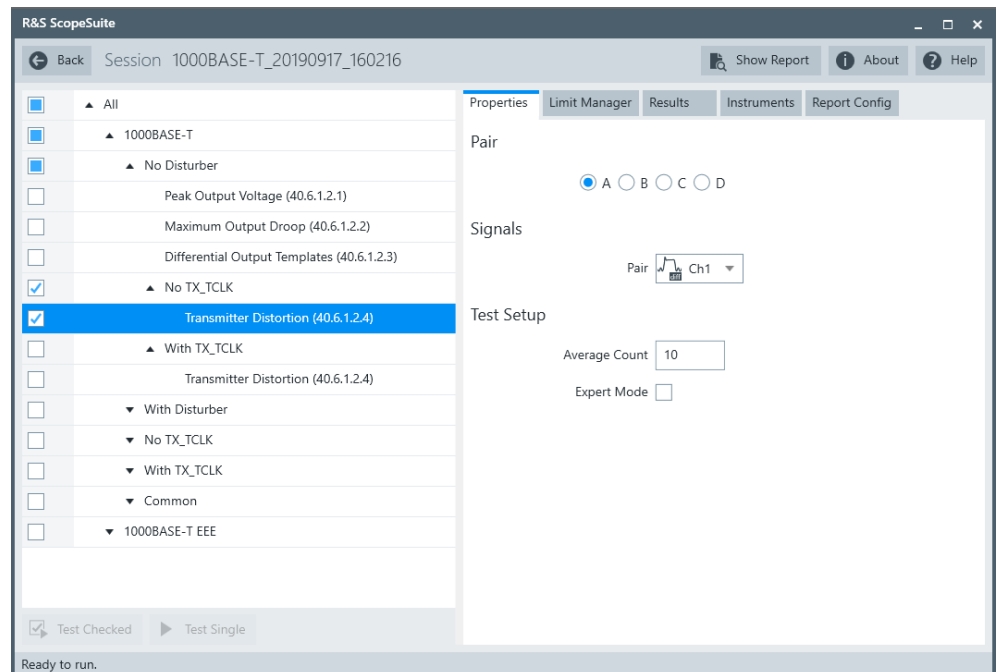
●   "With TX_CLK" test:
    "No Disturber" > "With TX_CLK" > "Transmitter Distortion (40.6.1.2.4)"
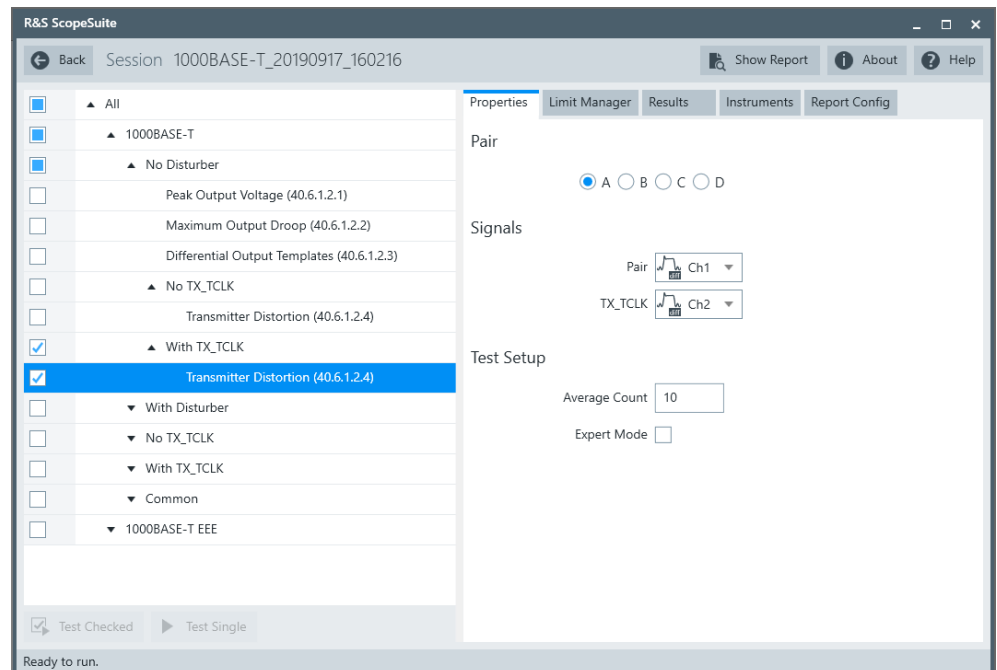
3. Click "Test Single".

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 23

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.
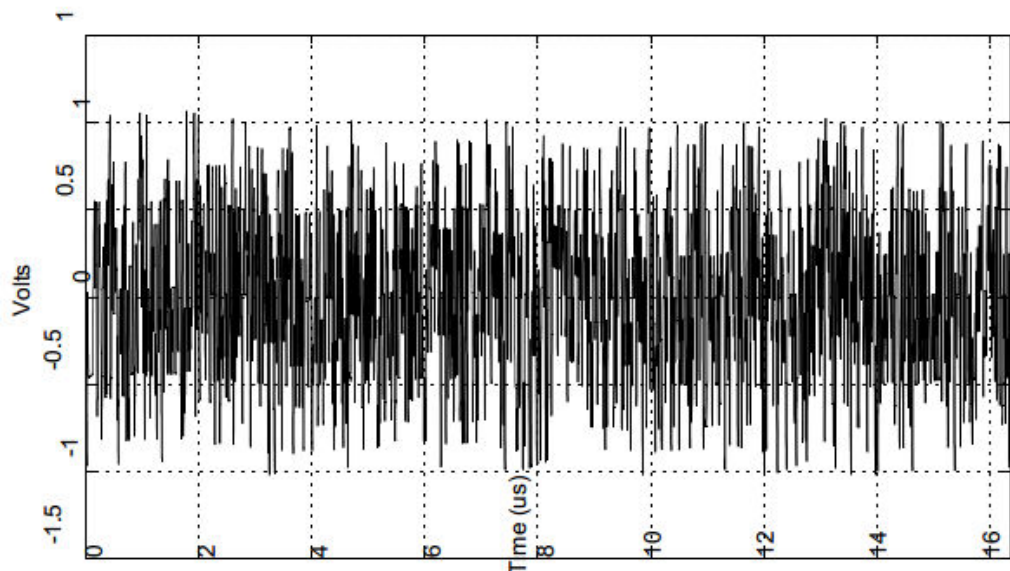
Figure 4-2: Test mode 4 waveform

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 are extracted directly from the DUT TX_TCLK.

If no DUT transmits clock TX_TCLK, the clock pulses are 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).

4.3.1.2 With disturber

Test equipment

Table 4-3: Equipment for Transmitter Distortion test with disturber

| Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Arbitrary waveform generator	R&S RTO-B6/R&S RTP-B6/Tabor WX2182B/Tabor WX2182C	
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 that you want to test	1

Performing master (no TX_CLK)

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

2. Select the test case:

   ● "No TX_CLK" test:
   "With Disturber" > "No TX_CLK" > "Transmitter Distortion (40.6.1.2.4)"
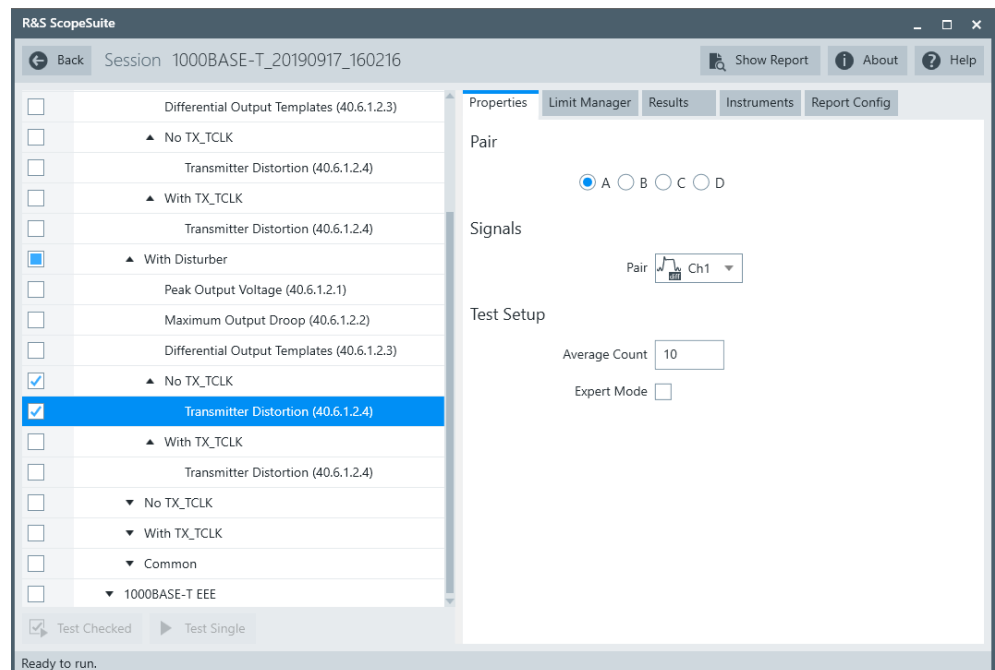
   ● "With TX_CLK" test:
   "With Disturber" > "With TX_CLK" > "Transmitter Distortion (40.6.1.2.4)"
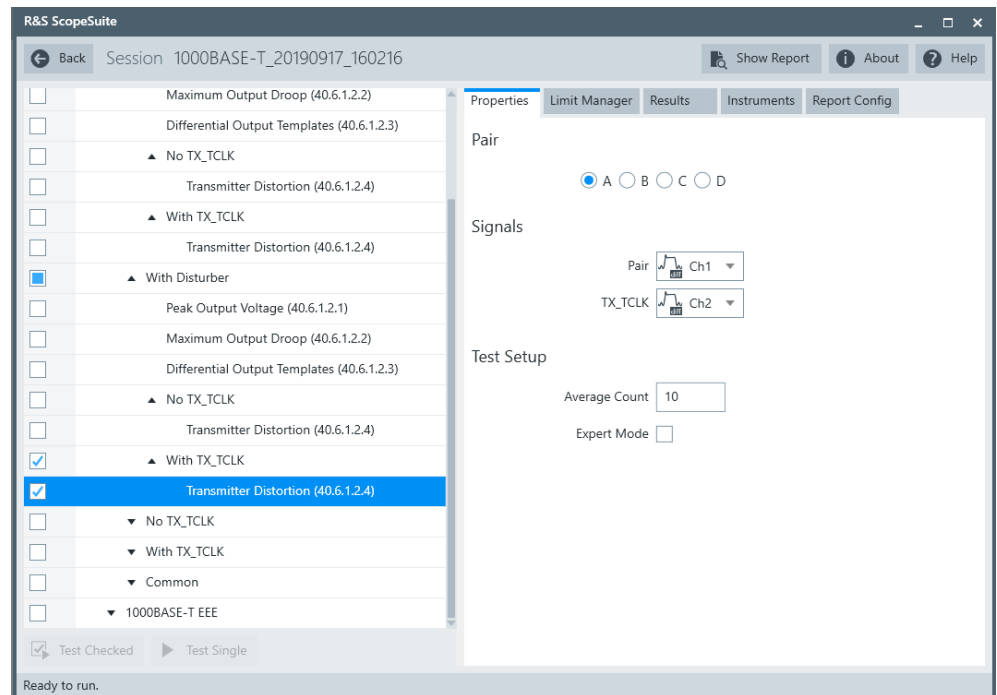
3. Click "Test Single".

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 23

Disturbing signal

The disturbing signal is a standard 5.4 V_{pp} 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 V_{pp}.

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 compensation 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.

Measurements templates

The measurement is the same as without a disturber (described in "Measurements" on page 32). 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.

4.3.2　Peak output voltage

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

4.3.2.1　No disturber

Test equipment

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

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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 that you want to test	1

Performing the test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

2. Select "Peak Output Voltage (40.6.1.2.1)" under "No Disturber".
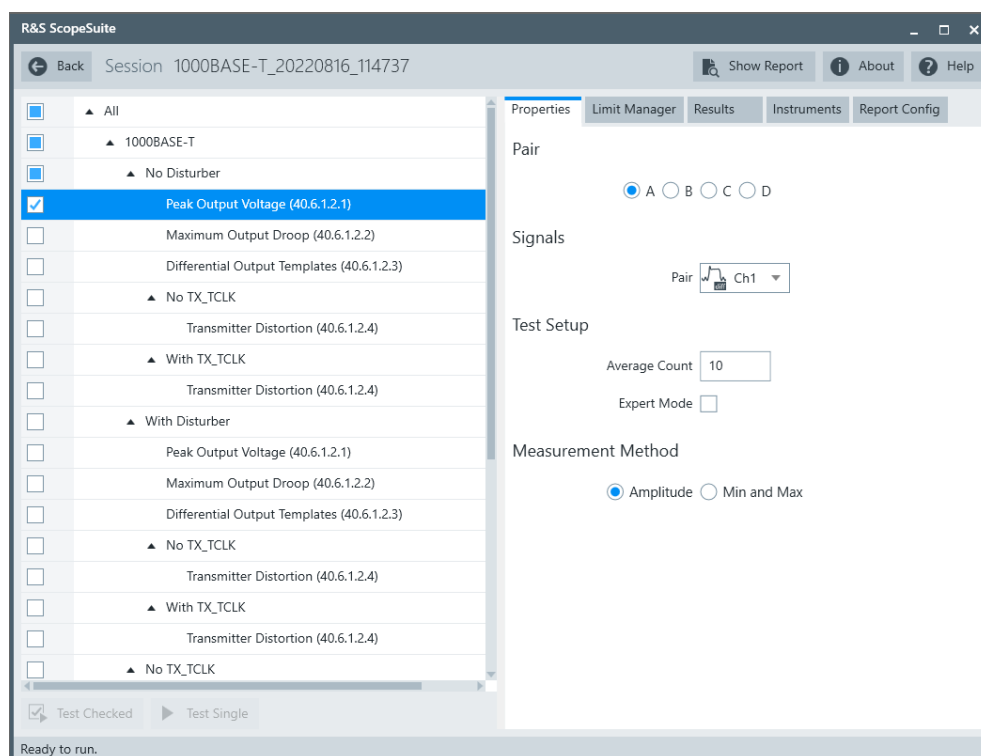
3. Click "Test Single".

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 23

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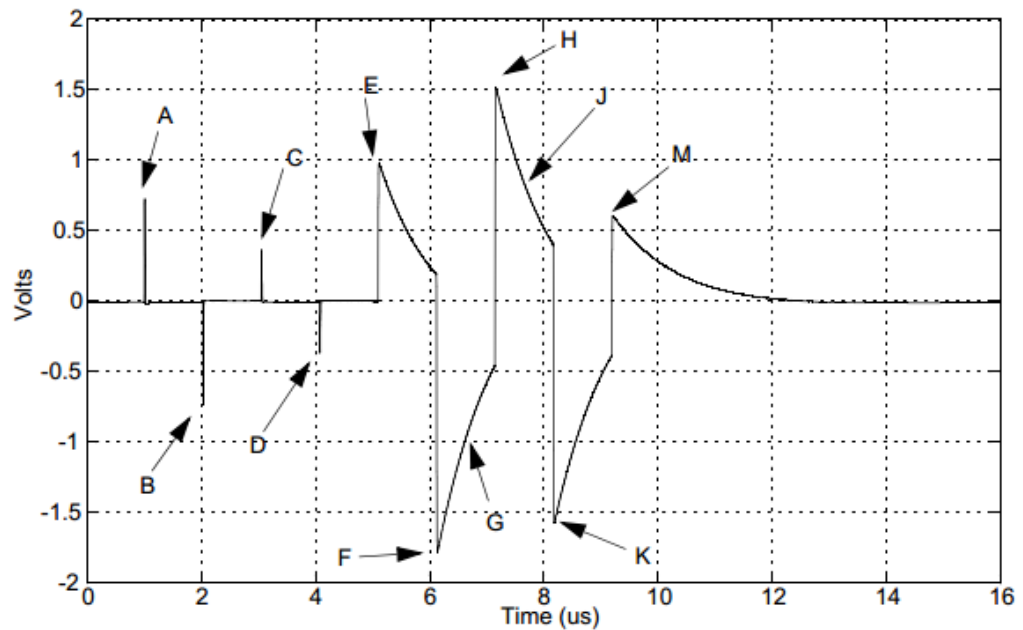
Figure 4-3: Test mode 1 waveform with measurement points

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 D compared 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.

4.3.2.2　With disturber

Test equipment

Table 4-5: Equipment for Peak Output Voltage test with disturber

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Arbitrary waveform generator	R&S RTO-B6/R&S RTP-B6/Tabor WX2182B/Tabor WX2182C	1
Ethernet test fixture, "Resistive Load with Distortion source" section	R&S RT-ZF2	1

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

Performing the test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

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 23

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.

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.

4.3.3 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.

4.3.3.1 No disturber

Test equipment

Table 4-6: Equipment for Maximum Output Droop test, no disturber

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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 that you want to test	1

Performing the test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

2. Select "Maximum Output Droop (40.6.1.2.2)" under "No Disturber".
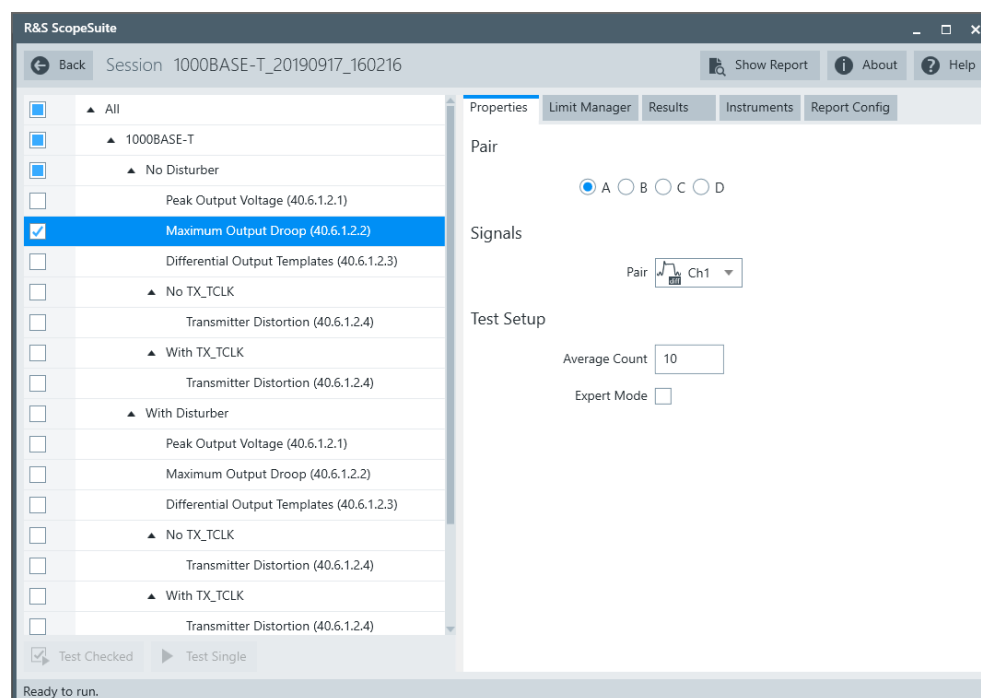
3. Click "Test Checked".

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 23

Measurements

For the "Maximum Output Droop" test, the DUT has to transmit a test mode 1 wave-form. The same waveform is used for 1000BASE-T "Peak Differential Voltage" test and" Differential Output Template" test.
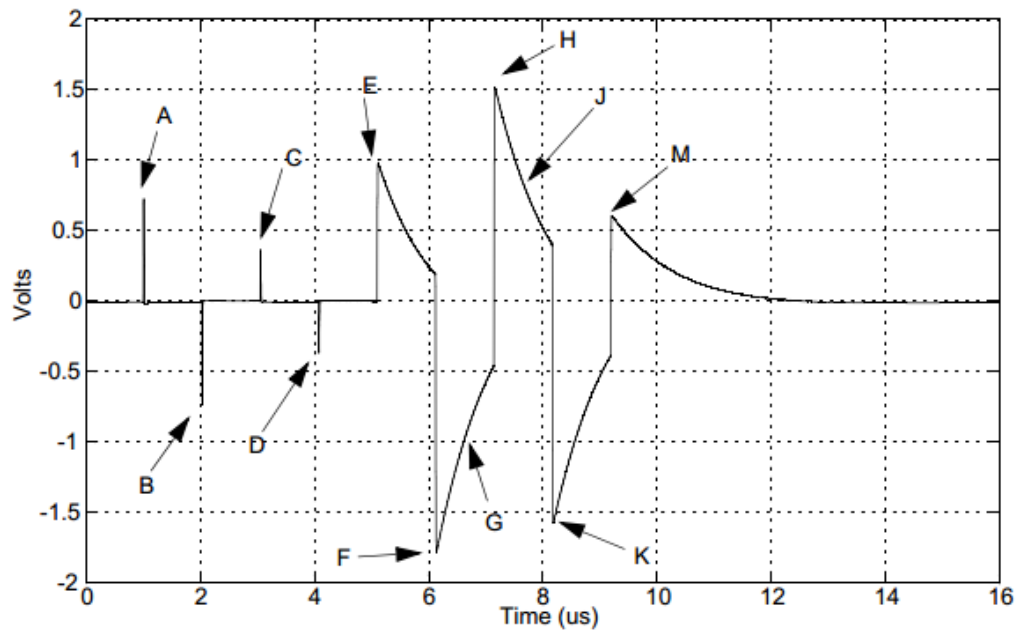
Figure 4-4: Test mode 1 waveform with measurement points

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.

4.3.3.2 With disturber

Test equipment

Table 4-7: Equipment for Maximum Output Droop test with disturber

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Arbitrary waveform generator	R&S RTO-B6/R&S RTP-B6/Tabor WX2182B/Tabor WX2182C	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 that you want to test	1

Performing the test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

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 23

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.

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.

4.3.4 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.

4.3.4.1 No disturber

Test equipment

Table 4-8: Equipment for Differential Output Templates test, no disturber

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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 that you want to test	1

Performing the test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

2. Select "Differential Output Templates (40.6.1.2.3)" under "No Disturber".
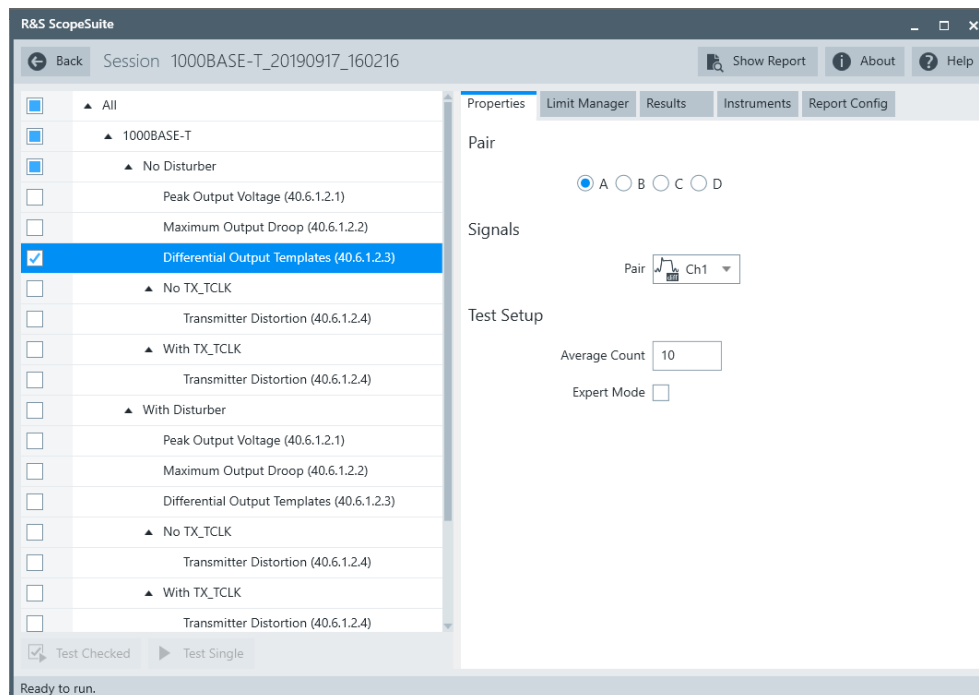
3. Click "Test Checked".

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 23

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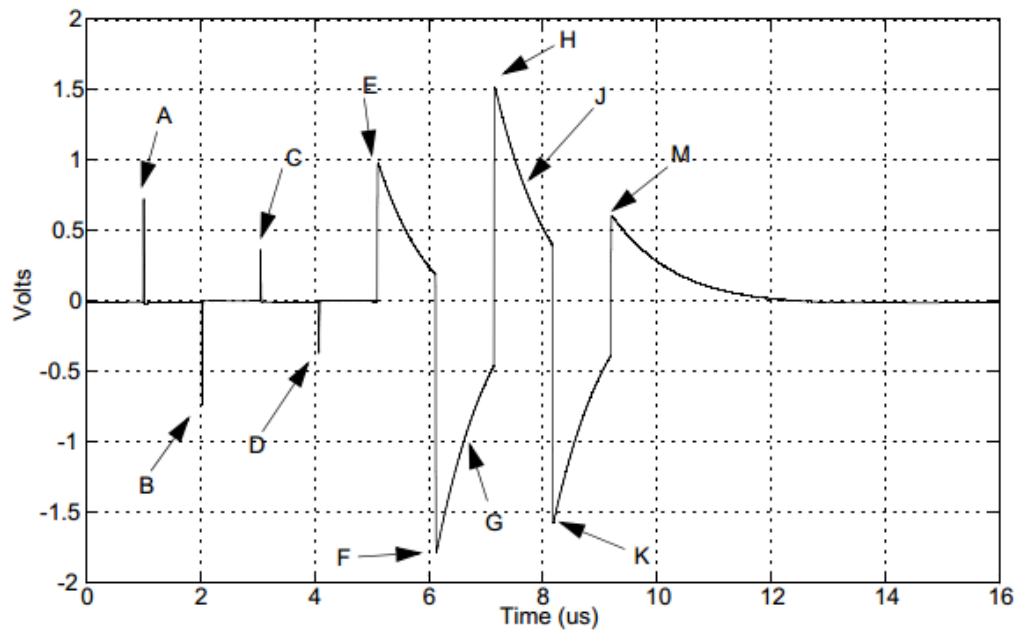
Figure 4-5: Test mode 1 waveform with measurement points

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.
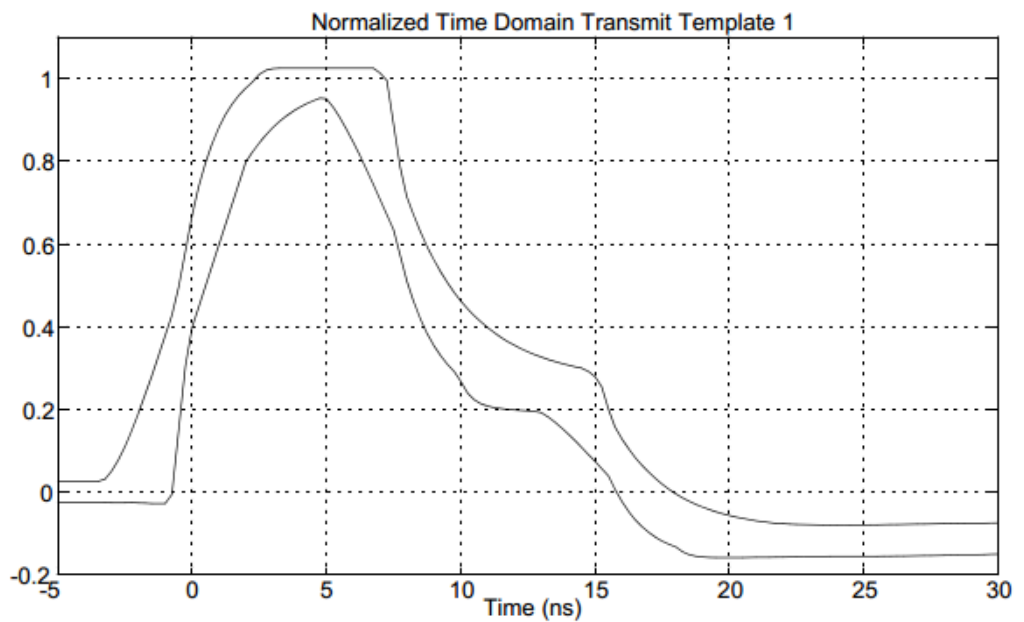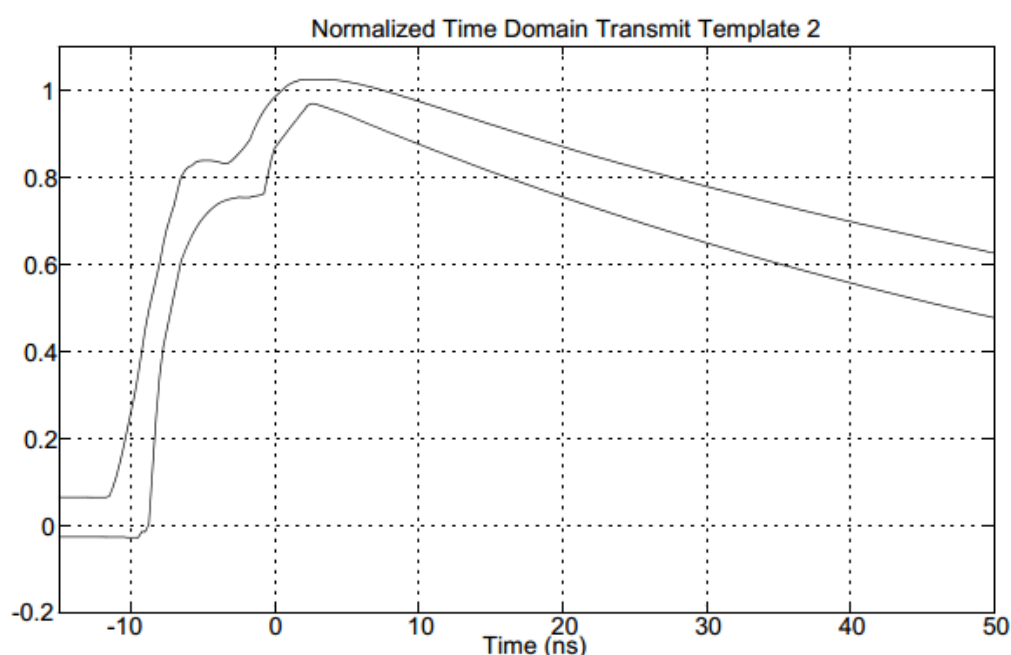

Figure 4-6: Time domain transmit template 1

The waveform is normalized as follows:

Table 4-9: 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 4-10: 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 measurement 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 4-9 and Table 4-10.

5. The waveform shifts in time until the best fit to the specified template (mask) is found.
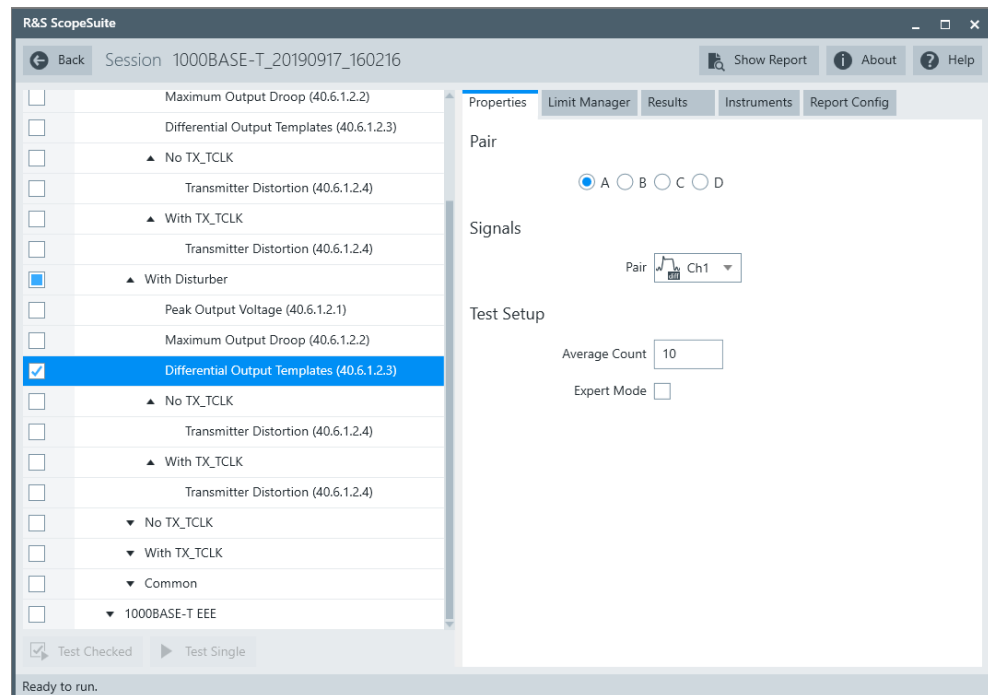
4.3.4.2　With disturber

Test equipment

Table 4-11: Equipment for Differential Output Templates test with disturber

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Arbitrary waveform generator	R&S RTO-B6/R&S RTP-B6/Tabor WX2182B/Tabor WX2182C	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 that you want to test	1

Performing the test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

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 23

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.

Measurements

The test waveform requirements for the "Differential Output Templates" test with disturber are the same as for the no disturber test, see "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 determin-

ing 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.

4.3.5 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.

4.3.5.1 No TX_CLK

Test equipment

Table 4-12: Equipment for Jitter Master Mode and Clock Frequency test, no TX_CLK

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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 that you want to test	2

Performing the test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

2. Select "Jitter Master Mode (40.6.1.2.5) and Clock Frequency (40.6.1.2.6)" under "No TX_CLK".
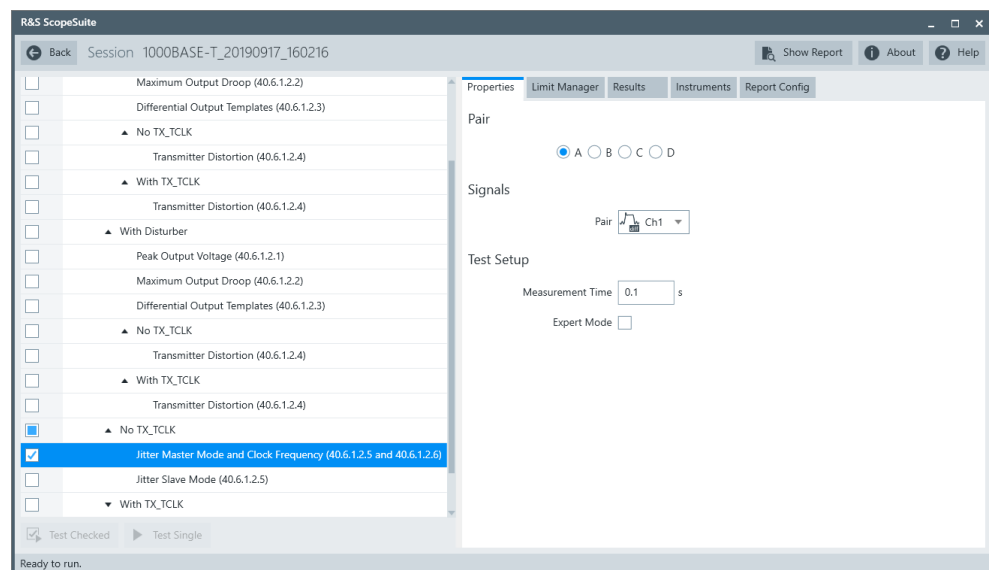
3. Click "Test Checked".

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 23

Measurements

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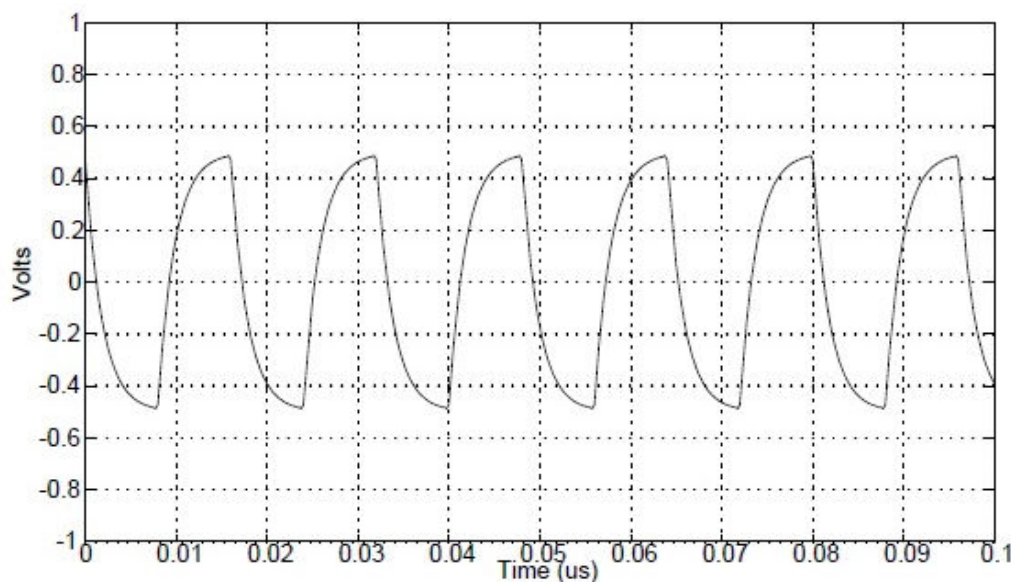

Figure 4-8: Test mode 2 waveform

Jitter is measured at the edge positions. Due to large 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.

- The transmit clock frequency: checks if the quinary symbol transmission rate on each pair of the master PHY is 125.00 MHz ± 0.01%.

4.3.5.2　With TX_CLK

Test equipment

Table 4-13: Equipment for Jitter Master Mode test, with TX_CLK

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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	1
DUT	the device that you want to test	2

Performing the test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

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".
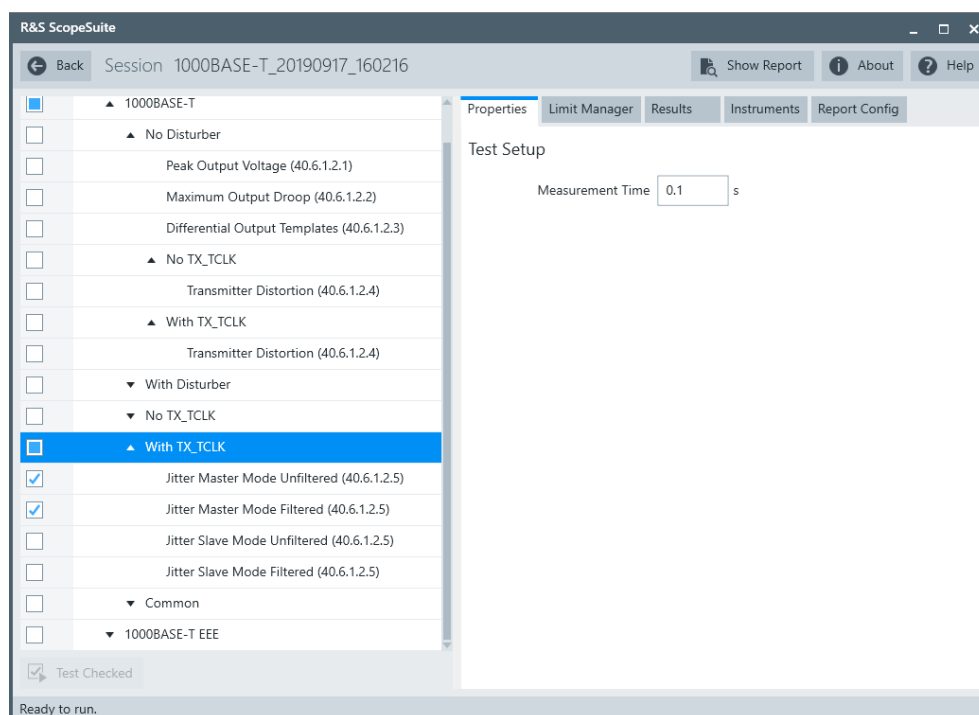
3. Click "Test Checked".

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 23

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 large 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.

4.3.6　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.

4.3.6.1　No TX_CLK

Test equipment

Table 4-14: Equipment for Jitter Slave Mode test, no TX_CLK

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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 that you want to test	2

Performing the test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

2. Select "Jitter Slave Mode (40.6.1.2.5)" under "No TX_CLK".
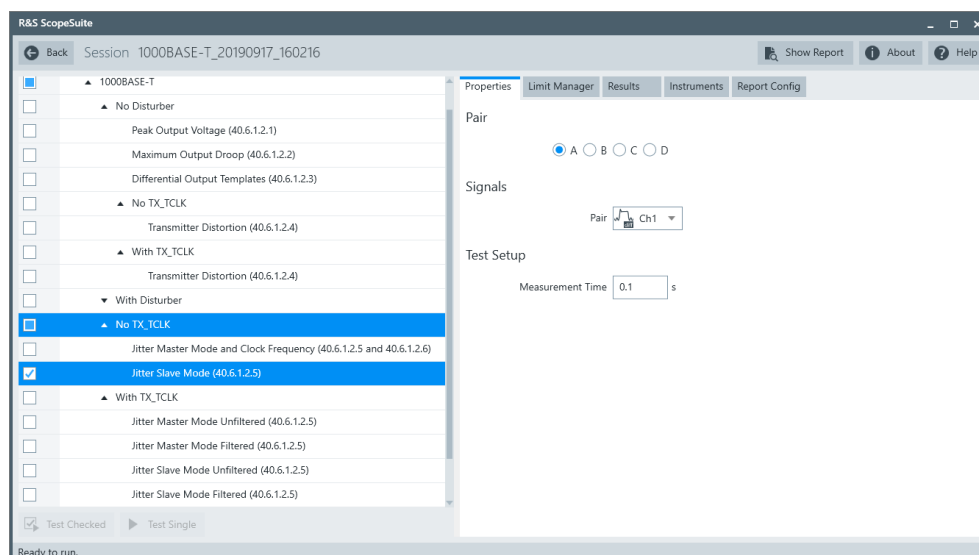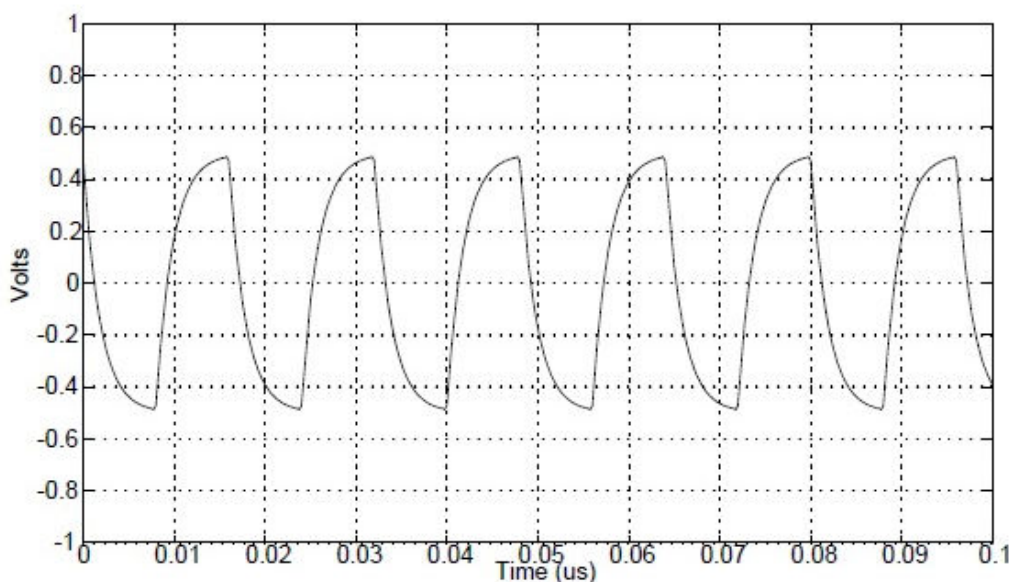

3. Click "Test Single".

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

Further steps:

-

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 large 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.

4.3.6.2　With TX_CLK

Test equipment

Table 4-15: Equipment for Jitter Slave Mode test, with TX_CLK

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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
Single-ended probe	at least 1 GHz bandwidth	2
Gigabit Ethernet jitter cable	R&S RT-ZF2C	1
DUT	the device that you want to test	2

Performing the test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

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".
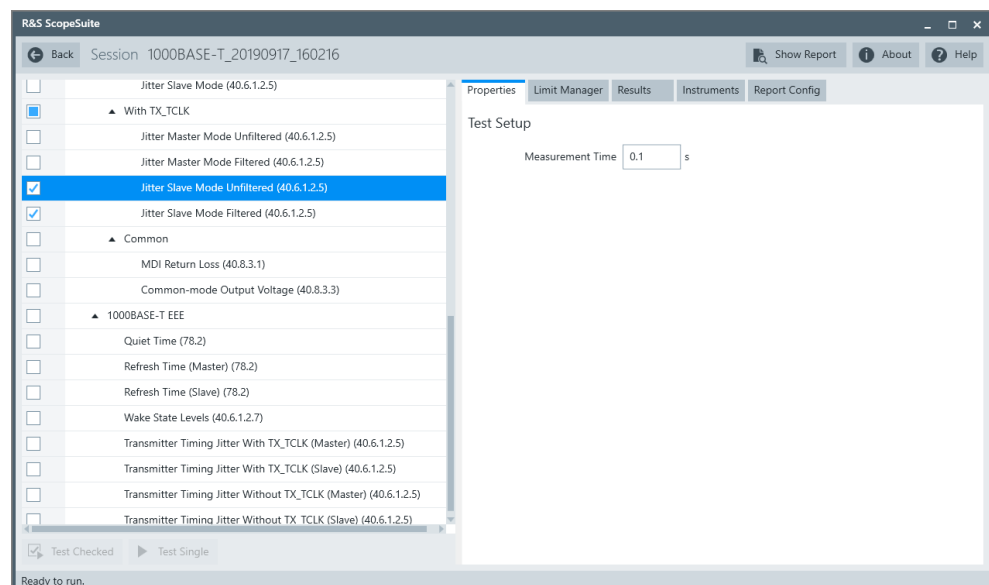
3. Click "Test Checked".

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 23

Measurements

For "Jitter Slave Mode" test, the DUT has to transmit a test mode 3 waveform. Master and slave must be synchronized.
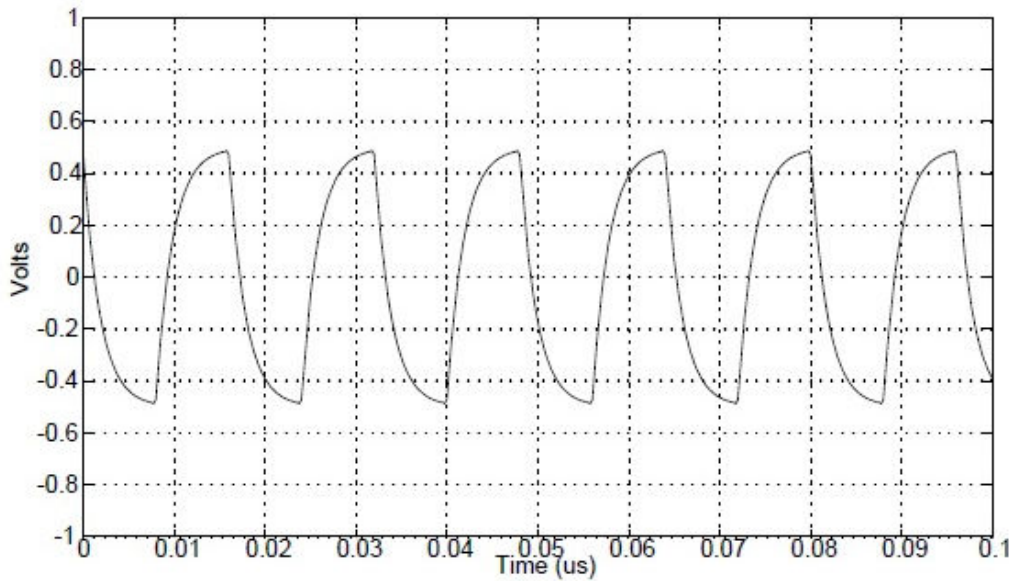
Figure 4-10: Test mode 3 waveform

Jitter is measured at the edge positions. Due to large 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 the peak to peak value of link partner's TX_CLK difference to its averaged reference and filtered by 5KHz HPF, is filtered jitter.

4.3.7 MDI return loss

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

4.3.7.1   Test equipment

Table 4-16: Equipment for MDI Return Loss tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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 auto-matic test	R&S ZNB/ZNC/ZND/ZVL	1
DUT	the device that you want to test	1

4.3.7.2   Performing the test

1. Start the test as described in

2. Select "MDI Return Loss (40.8.3.1)" under "Common".
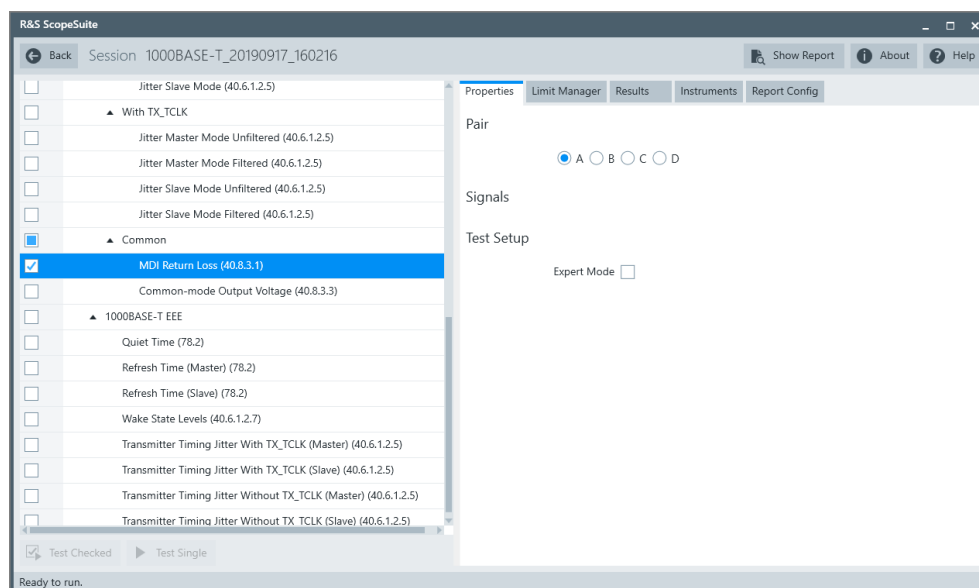
3. Click "Test Checked".

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

Further steps:

●

4.3.7.3   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 should fall below the limit line plotted on the VNA from 1 MHz 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.

4.3.8   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.

4.3.8.1   Test equipment

Table 4-17: Equipment for Common-mode Output Voltage tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Common Mode Volt-age " section	R&S RT-ZF2	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device that you want to test	1

4.3.8.2   Performing the test

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

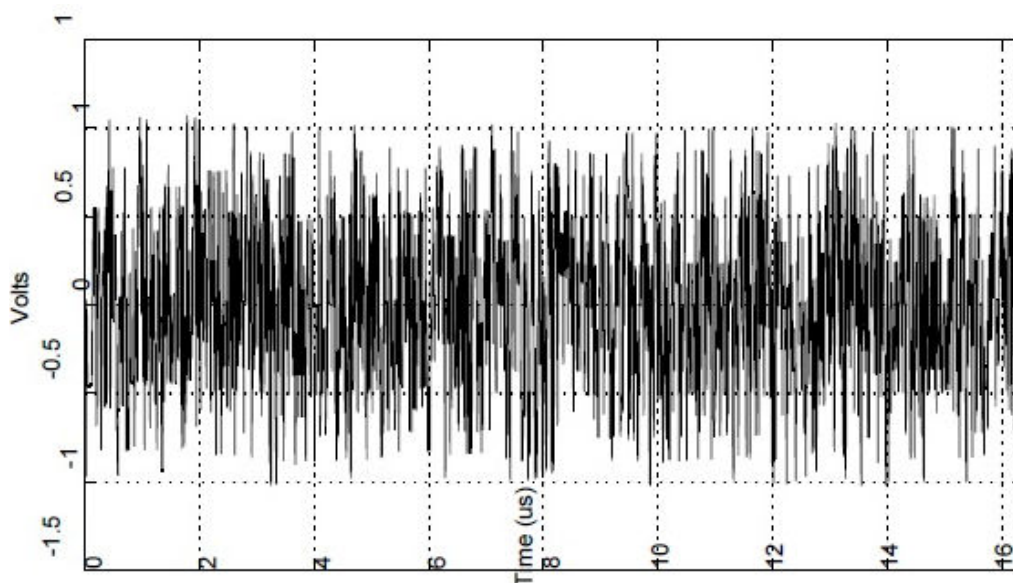2. Select "Common-mode Output Voltage (14.3.1.2.5)" under "Common".
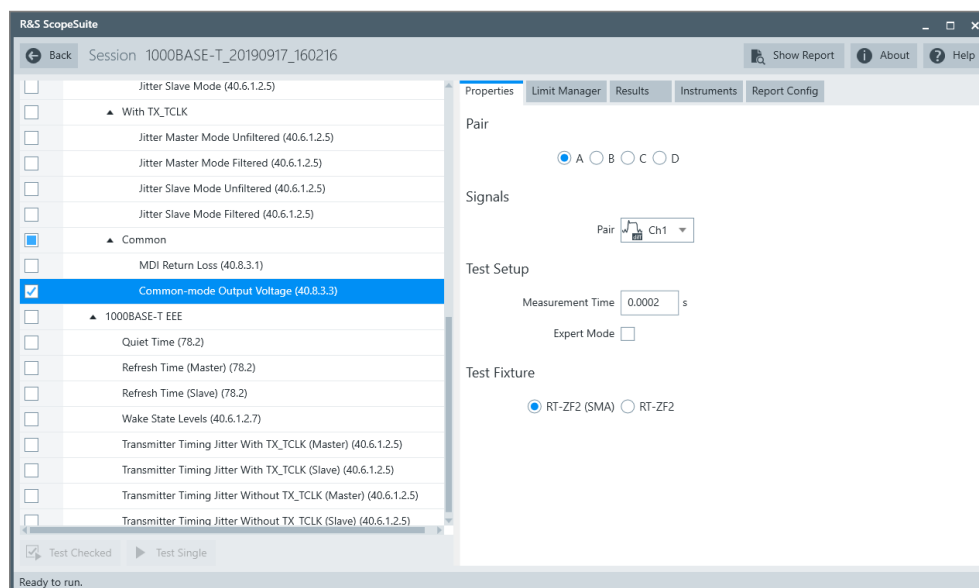
3. Click "Test Checked".

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

Further steps:

-

4.3.8.3 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.

4.4   1000 BASE-T EEE tests

The following list shows an overview of the needed equipment for performing the 1000BASE-T EEE test cases:

- R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth
- R&S ScopeSuite software
- Ethernet test fixture R&S RT-ZF5, "Directional Probe" section
- 1000BASE-T DUT with EEE support (e.g. Intel(R) 82579LM Gigabit Network Adaptor)
- Link partner with EEE support (e.g. Intel(R) 82579LM Gigabit Network Adaptor)

4.4.1   Quiet time

1000BASE-T EEE mode saves power by putting the device into low-Power idle state. The test verifies that the quiet time of the DUT is within its compliance range.

4.4.1.1   Test equipment

Table 4-18: Equipment for Quiet Time test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Directional Probe" section	R&S RT-ZF5	1
DUT with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1
Link partner with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1

4.4.1.2 Performing the tests

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests",
   on page 25.

2. Select the test case: "1000BASE-T-EEE" > "Quiet Time (78.2)"
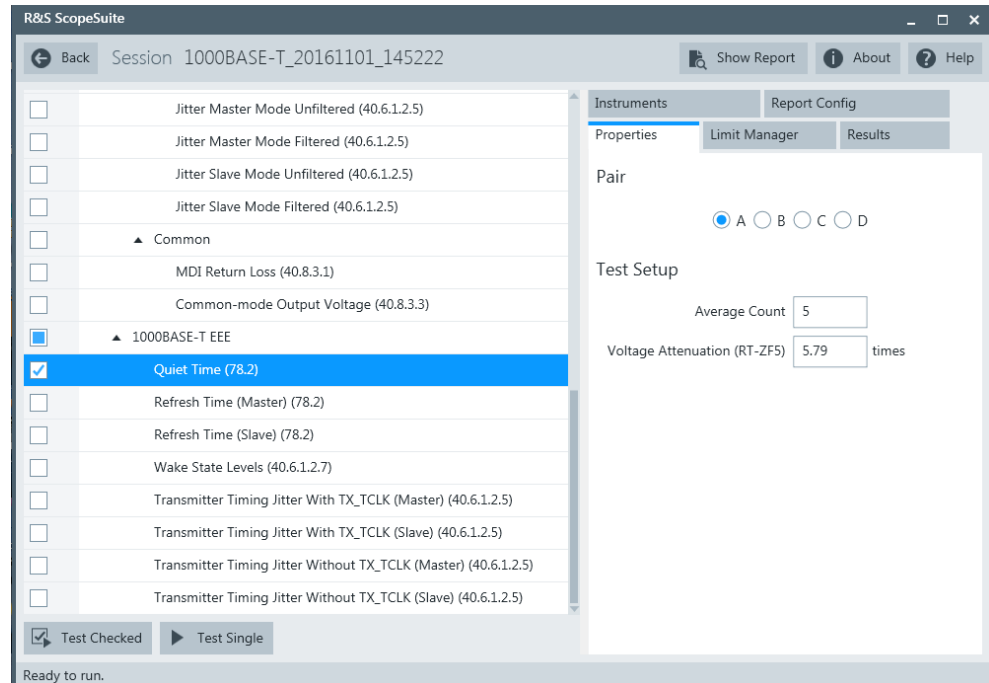
3. Click "Test Single".

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 23

4.4.1.3 Test setup

A 1000BASE-T EEE link is set up between the DUT and link partner via test fixture
R&S RT-ZF5. The DUT must be forced to enter low-power idle mode.

A typical screenshot from R&S RTO / R&S RTO6 /R&S RTP during measurement is
shown in the figure below:
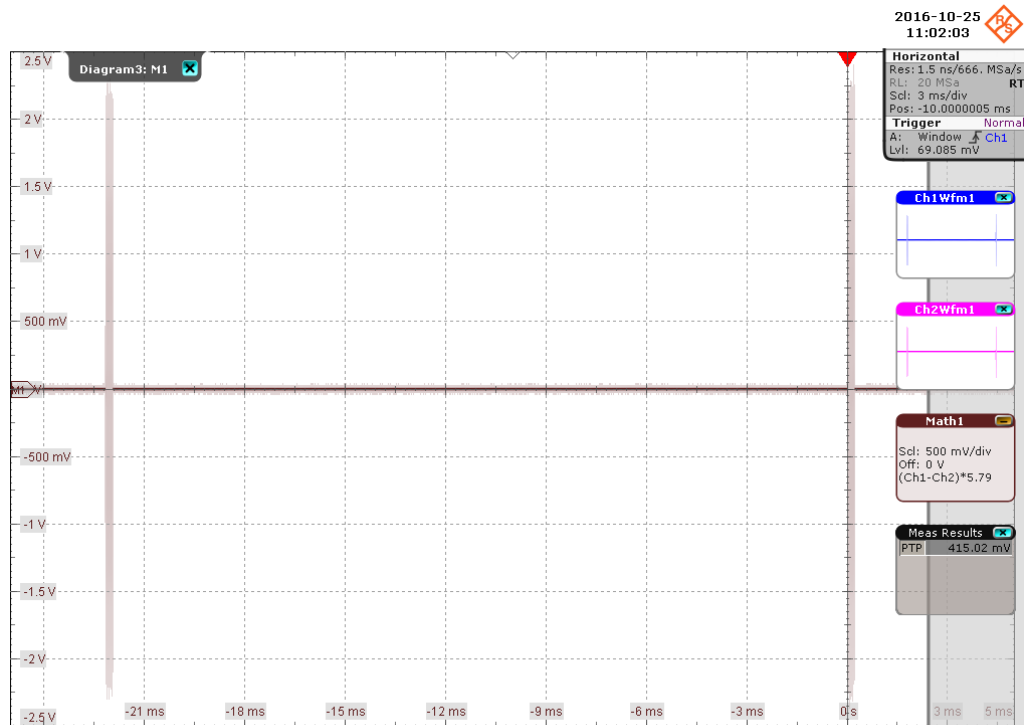
4.4.1.4 Measurement

The quiet time is the duration that the PHY stays in the quiet state.

It is measured as the amount of time in-between the refresh signals. It should be greater than (20ms + 10us) and less than (24ms + 12us).

The final results reported are the maximum and minimum value based on multiple times of measurement.

4.4.2 Refresh time master mode

1000BASE-T EEE mode saves power by putting the device into low-power idle state. The test verifies that the refresh time of the DUT in master mode is within its compliance range.

4.4.2.1 Test equipment

Table 4-19: Equipment for Refresh Time Master Mode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Directional Probe" section	R&S RT-ZF5	1

Item	Description, model	Quantity
DUT with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1
Link partner with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1

4.4.2.2 Performing the tests

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

2. Select the test case: "1000BASE-T-EEE" > "Refresh Time Master(78.2)"
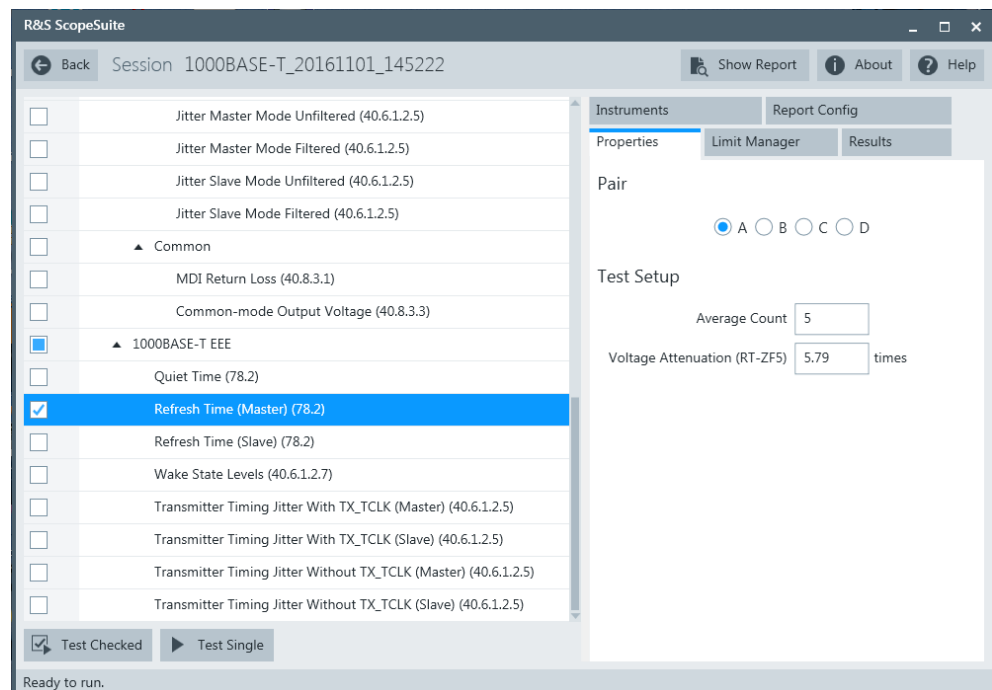
3. Click "Test Single".

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 23

4.4.2.3 Test setup

A 1000BASE-T EEE link is set up between the DUT and link partner via test fixture R&S RT-ZF5. The DUT must be forced to enter low-power idle mode. Ensure that the DUT is operating in master mode.

A typical screenshot from R&S RTO / R&S RTO6 /R&S RTP during measurement is shown as below:
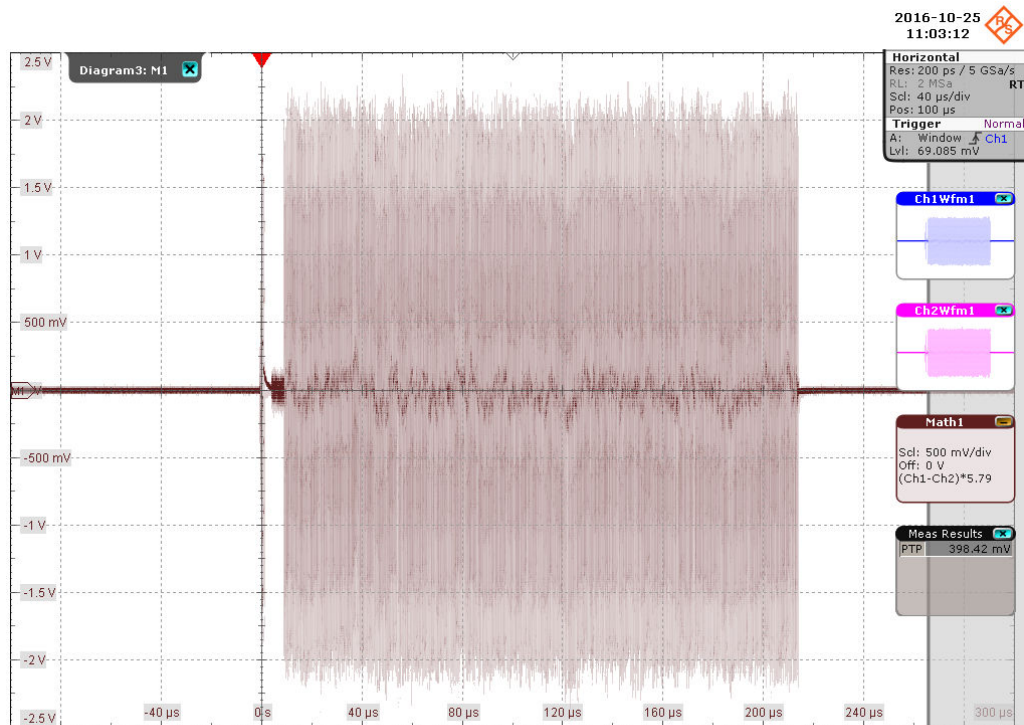
4.4.2.4   Measurement

Refresh time specifies the time that the DUT transmits the refresh signal before entering the quiet state. It is measured from the start of the Wake transient to the entry into the WAIT_QUIET state.

It should be greater than 248.5us and less than 269.7us.

The final results reported are the maximum and minimum value based on multiple times of measurement.

4.4.3   Refresh time slave mode

1000BASE-T EEE mode saves power by putting the device into low-power idle state. The test verifies that the refresh time of the DUT in slave mode is within its compliance range.

4.4.3.1   Test equipment

Table 4-20: Equipment for Refresh Time Slave Mode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Directional Probe" section	R&S RT-ZF5	1
DUT with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1
Link partner with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1

4.4.3.2   Performing the tests

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

2. Select the test case: "1000BASE-T-EEE" > "Refresh Time Slave (78.2)"
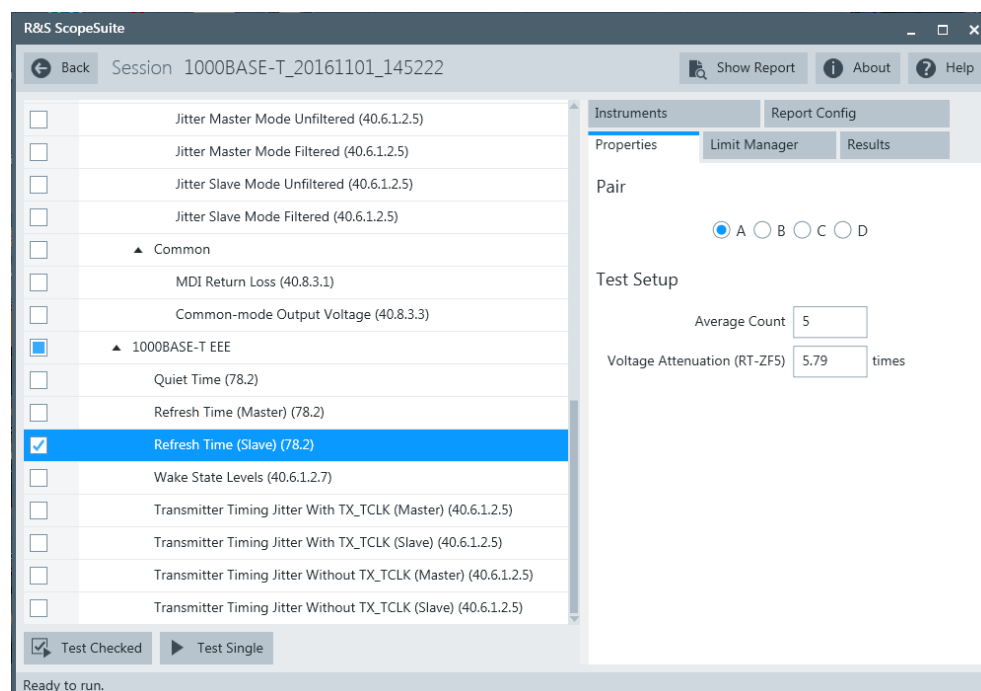
3. Click "Test Single".

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 23

4.4.3.3   Test setup

A 1000BASE-T EEE link is set up between the DUT and link partner via test fixture R&S RT-ZF5. The DUT must be forced to enter low-power idle mode.

Ensure that the DUT is operating in slave mode.

A typical screenshot from R&S RTO / R&S RTO6 /R&S RTP during measurement is shown as below:
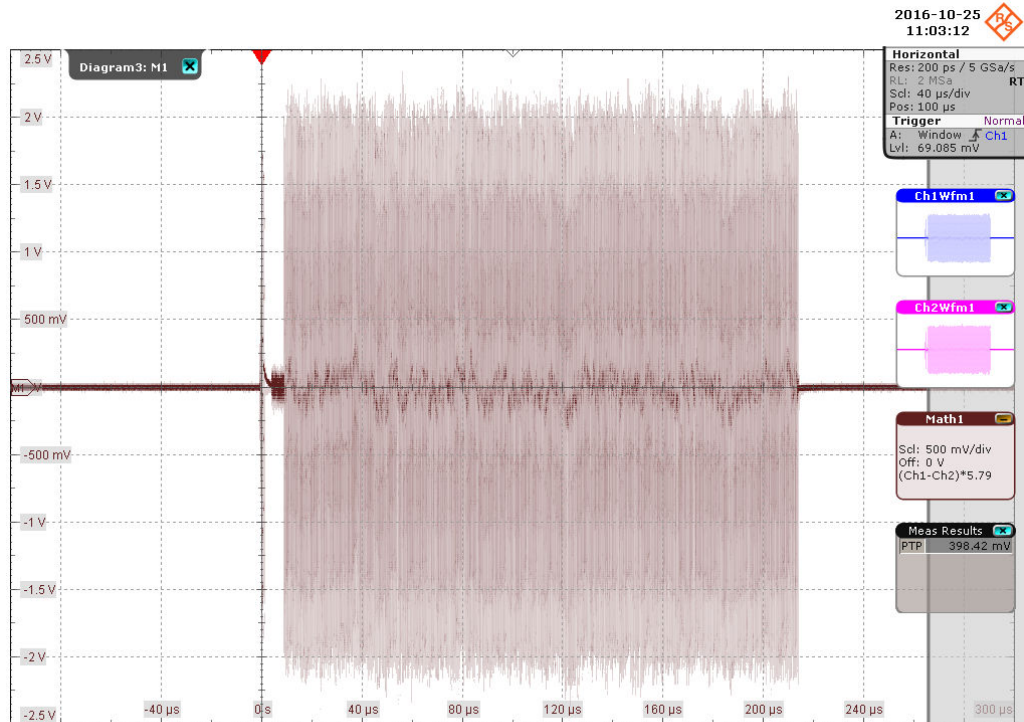
4.4.3.4   Measurement

Refresh time specifies the time that the DUT transmits the refresh signal before entering the quiet state. It is measured from the start of the Wake transient to the entry into the WAIT_QUIET state.

It should be greater than 198.5us and less than 219.7us.

The final results reported are the maximum and minimum value based on multiple times of measurement.

4.4.4   Wake state levels

1000BASE-T EEE mode saves power by putting the device into low-power idle state. The test verifies the wake state levels of the DUT during the wake transient time are within the compliance range.

4.4.4.1 Test equipment

Table 4-21: Equipment for Wake State Levels test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Directional Probe" section	R&S RT-ZF5	1
DUT with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1
Link partner with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1

4.4.4.2 Performing the tests

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

2. Select the test case: "1000BASE-T-EEE" > "Wake State Levels (40.6.1.2.7)"
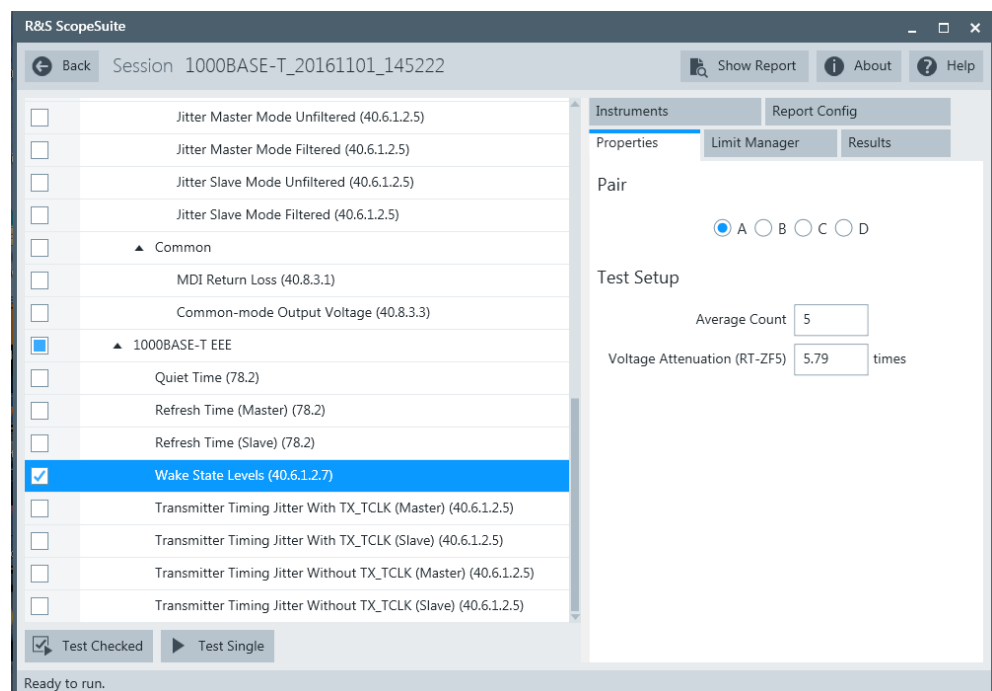
3. Click "Test Single".

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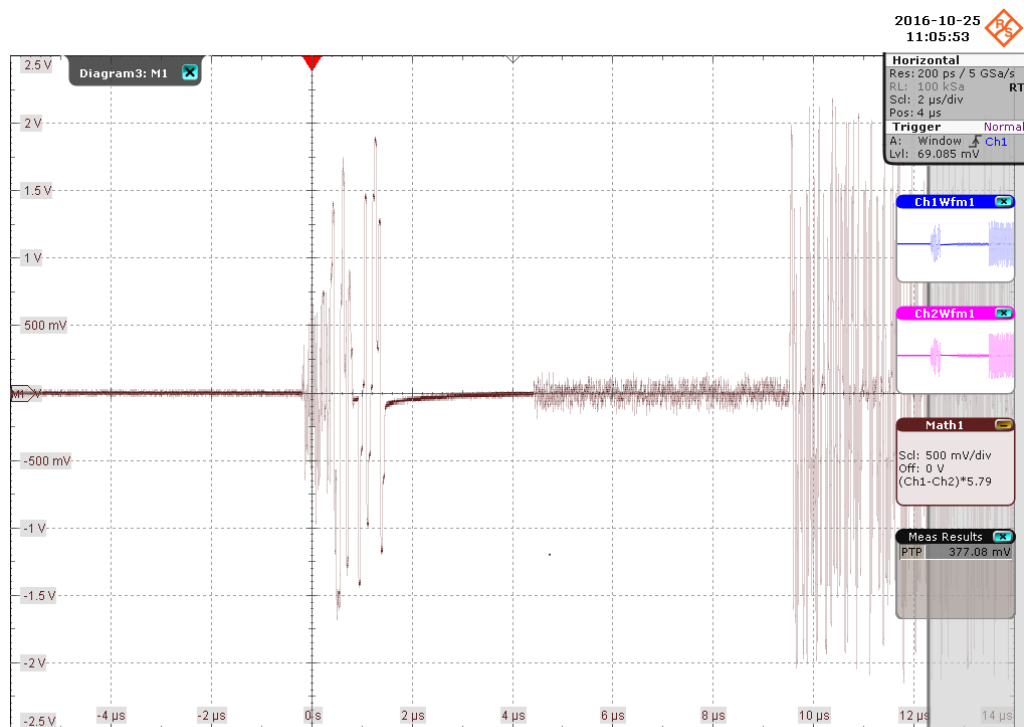
Further steps:

- Chapter 3.3, "Getting test results", on page 23

4.4.4.3 Test setup

A 1000BASE-T EEE link is set up between the DUT and link partner via test fixture R&S RT-ZF5. The DUT must be forced to enter low-power idle mode.

A typical screenshot from R&S RTO / R&S RTO6 /R&S RTP during measurement is shown as below:

4.4.4.4 Measurement

The test verifies the WAKE state idle pattern at the beginning of the WAKE exceeds 65% of the transmit levels of the compliant idle signaling for a minimum of 500ns.

It measures the duration of wake transient which allows the local device to turn the circuitry back on and the remote device to detect a wake event and begin turning circuitry back on.

It should exceed 435.5mV for a minimum of 500ns.

The final results reported are the maximum and minimum value based on multiple times of measurement.

4.4.5　Transmitter timing jitter with TX_TCLK in master mode

1000BASE-T EEE mode saves power by putting the device into low-power idle state. The test verifies the unfiltered jitter on the TX_TCLK of the DUT in master mode during LPI mode shall be within its compliance range.

4.4.5.1　Test equipment

Table 4-22: Equipment for Transmitter Timing Jitter with TX_TCLK, Master Mode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Directional Probe" section	R&S RT-ZF5	1
DUT with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1
Link partner with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1

4.4.5.2　Performing the tests

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

2. Select the test case: "1000BASE-T-EEE" > "Transmitter Timing Jitter With TX_TCLK (Master) (40.6.1.2.5) "
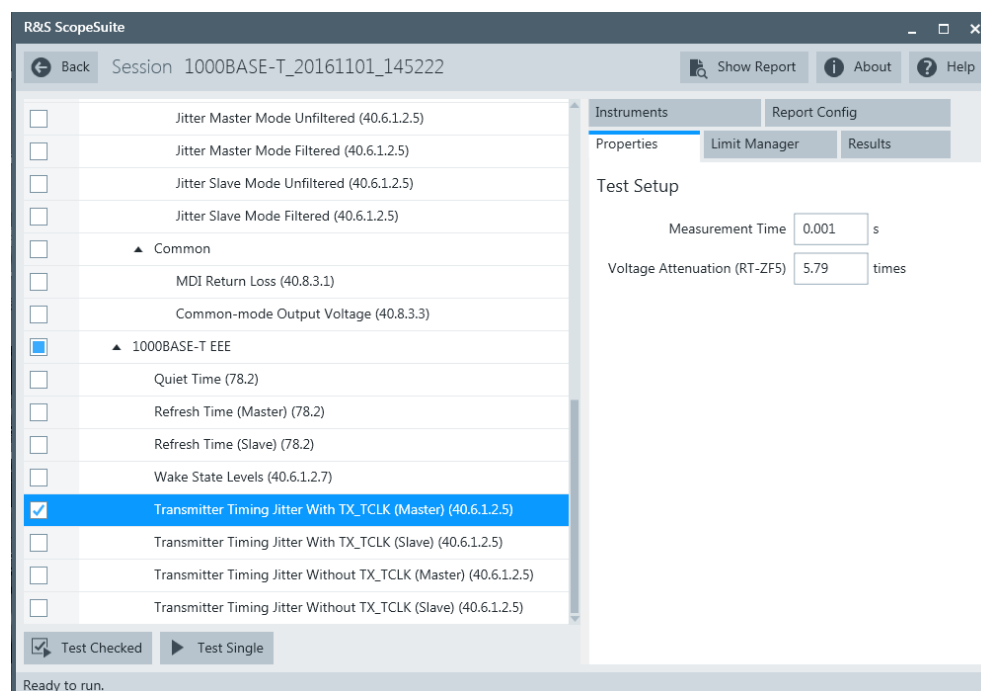
3. Click "Test Single".

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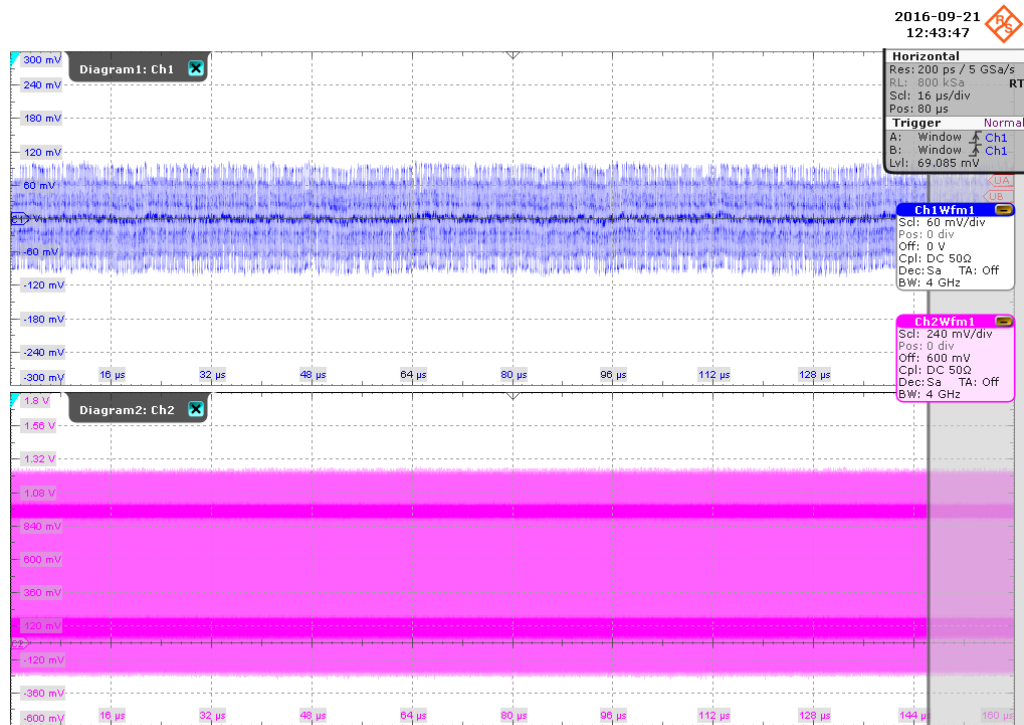
    Further steps:

    *   Chapter 3.3, "Getting test results", on page 23

4.4.5.3   Test setup

A 1000BASE-T EEE link is set up between the DUT and Link Partner via test fixture R&S RT-ZF5. The DUT must be forced to enter low-power idle mode.

Ensure that the DUT is operating in master mode.

A typical screenshot from R&S RTO / R&S RTO6 /R&S RTP during measurement is shown as below:

4.4.5.4 Measurement

It measures the unfiltered jitter on the DUT's TX_TCLK during LPI mode, with the exception that clock edges corresponding to the WAIT_QUIET, QUIET, WAKE and WAKE_SILENT states are not considered in the measurement.

As the jitter may be measured block by block. Max of peak-to-peak jitter is reported as the final result.

It should be less than 1.4ns.

4.4.6 Transmitter timing jitter with TX_TCLK in slave mode

1000BASE-T EEE mode saves power by putting the device into low-power idle state. The test verifies the unfiltered jitter on the TX_TCLK of the DUT in slave mode during LPI mode shall be within its compliance range.

4.4.6.1   Test equipment

Table 4-23: Equipment for Transmitter Timing Jitter with TX_TCLK, Slave Mode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Directional Probe" section	R&S RT-ZF5	1
DUT with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1
Link partner with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1

4.4.6.2   Performing the tests

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

2. Select the test case: "1000BASE-T-EEE" > "Transmitter Timing Jitter With TX_TCLK (Slave) (40.6.1.2.5) "
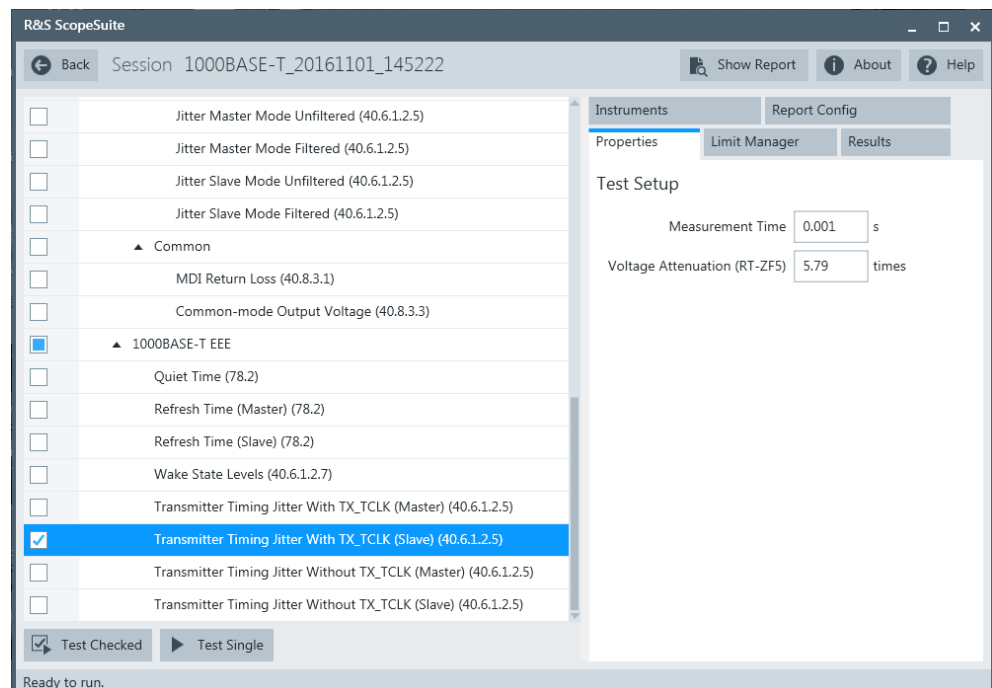
3. Click "Test Single".

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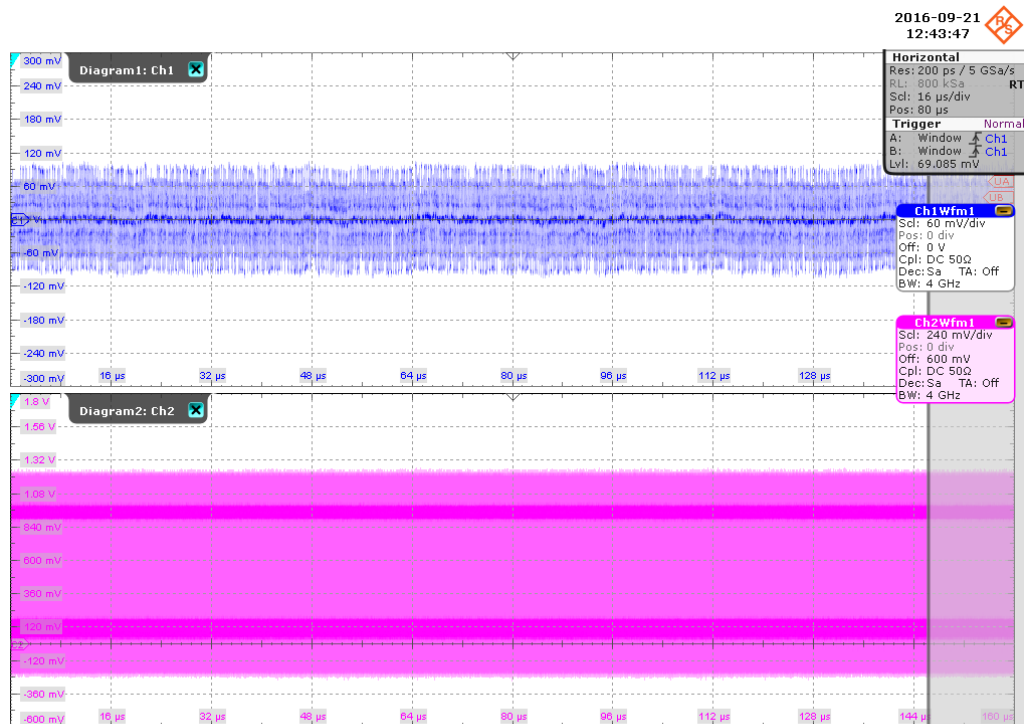   When you have finished all steps, the compliance test runs automatically.

Further steps:

-

4.4.6.3　Test setup

A 1000BASE-T EEE link is set up between the DUT and link partner via test fixture R&S RT-ZF5. The DUT must be forced to enter low-power idle mode.

Ensure that the DUT is operating in slave mode.

A typical screenshot from R&S RTO / R&S RTO6 /R&S RTP during measurement is shown as below:

4.4.6.4　Measurement

It measures the unfiltered jitter on the DUT's TX_TCLK during LPI mode, with the exception that clock edges corresponding to the WAIT_QUIET, QUIET, WAKE and WAKE_SILENT states are not considered in the measurement.

As the jitter may be measured block by block. Max of peak-to-peak jitter is reported as the final result.

It should be less than 1.4ns.

4.4.7 Transmitter timing jitter without TX_TCLK in master mode

1000BASE-T EEE mode saves power by putting the device into low-power idle state. When there is no access to the TX_TCLK, an alternative method is to measure the jitter present on the LPI signaling itself while the DUT is operating in master mode.

4.4.7.1 Test equipment

Table 4-24: Equipment for Timing Jitter without TX_TCLK, Master Mode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Directional Probe" section	R&S RT-ZF5	1
DUT with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1
Link partner with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1

4.4.7.2 Performing the tests

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

2. Select the test case: "1000BASE-T-EEE" > "Transmitter Timing Jitter Without TX_TCLK (Master) (40.6.1.2.5) "
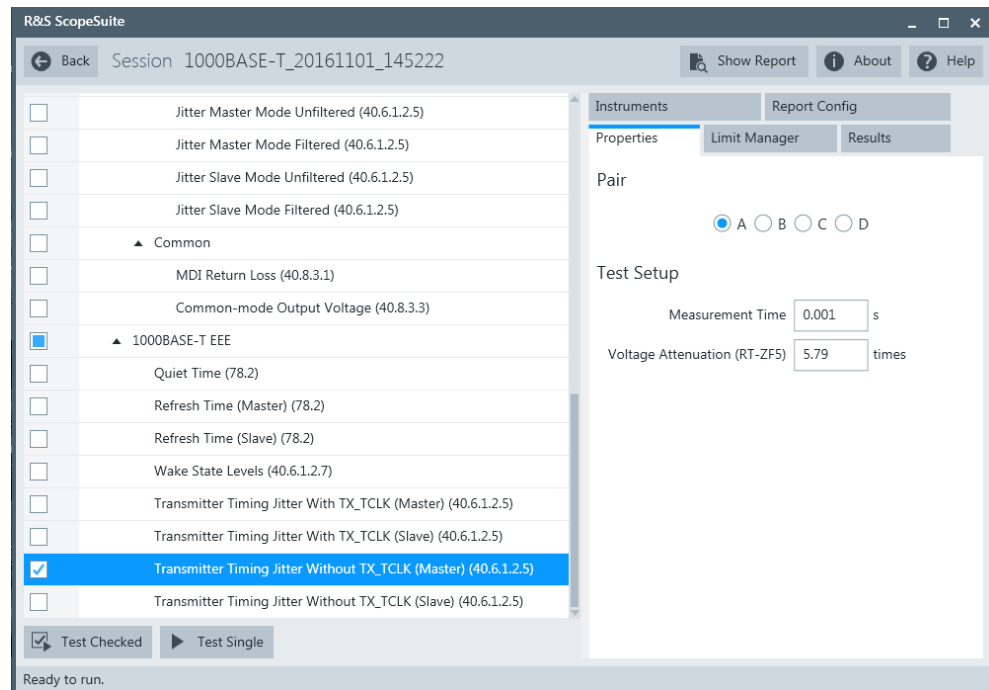
3. Click "Test Single".

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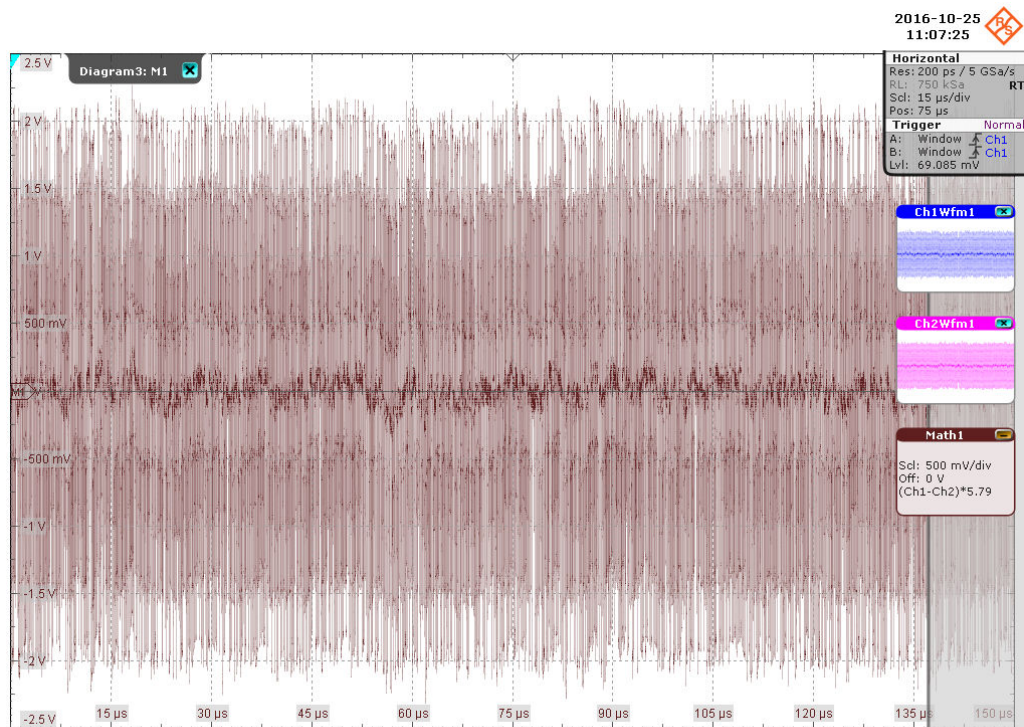
Further steps:

- Chapter 3.3, "Getting test results", on page 23

4.4.7.3 Test setup

A 1000BASE-T EEE link is set up between the DUT and Link Partner via test fixture R&S RT-ZF5. The DUT must be forced to enter low-power idle mode.

Ensure that the DUT is operating in master mode.

A typical screenshot from R&S RTO / R&S RTO6 /R&S RTP during measurement is shown as below:

4.4.7.4　Measurement

It directly measures the jitter based on the timing information extracted from the LPI signaling, with the exception that timing information corresponding to the WAIT_QUIET, QUIET, WAKE and WAKE_SILENT states are not considered in the measurement.

As the jitter may be measured block by block, max of peak-to-peak jitter is reported as the final result.

It should be less than 1.4ns.

4.4.8　Transmitter timing jitter without TX_TCLK in slave mode

1000BASE-T EEE mode saves power by putting the device into low-power idle state. When there is no access to the TX_TCLK, an alternative method is to measure the jitter present on the LPI signaling itself while the DUT is operating in slave mode.

4.4.8.1 Test equipment

Table 4-25: Equipment for Timing Jitter without TX_TCLK, Slave Mode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Directional Probe" section	R&S RT-ZF5	1
DUT with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1
Link partner with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1

4.4.8.2 Performing the tests

1. Start the test as described in Chapter 4.1, "Starting 1000BASE-T tests", on page 25.

2. Select the test case: "1000BASE-T-EEE" > "Transmitter Timing Jitter Without TX_TCLK (Slave) (40.6.1.2.5) "
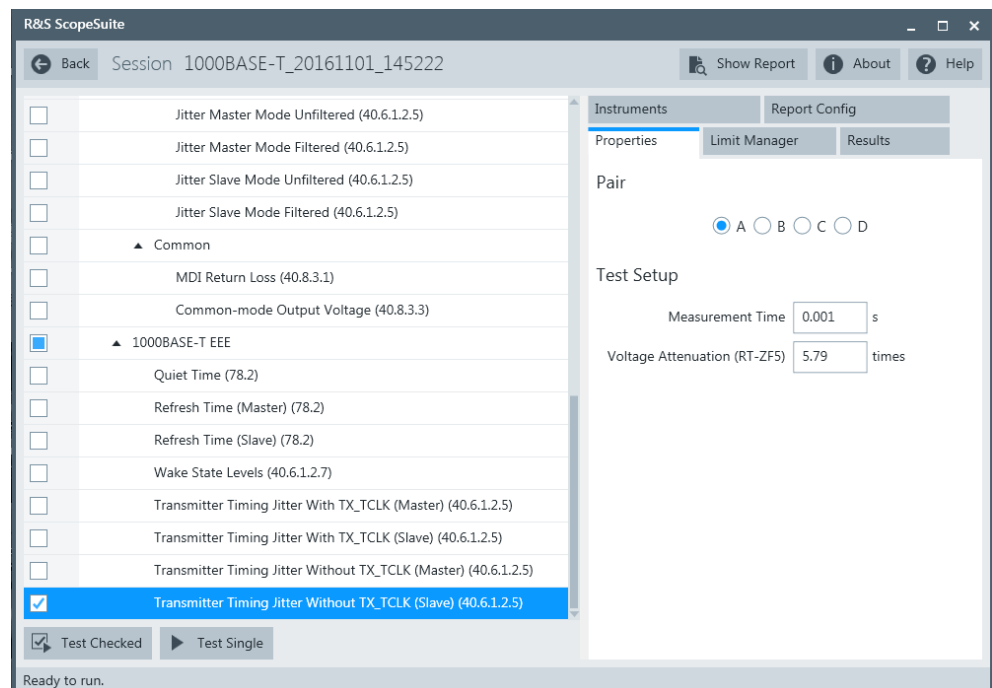
3. Click "Test Single".

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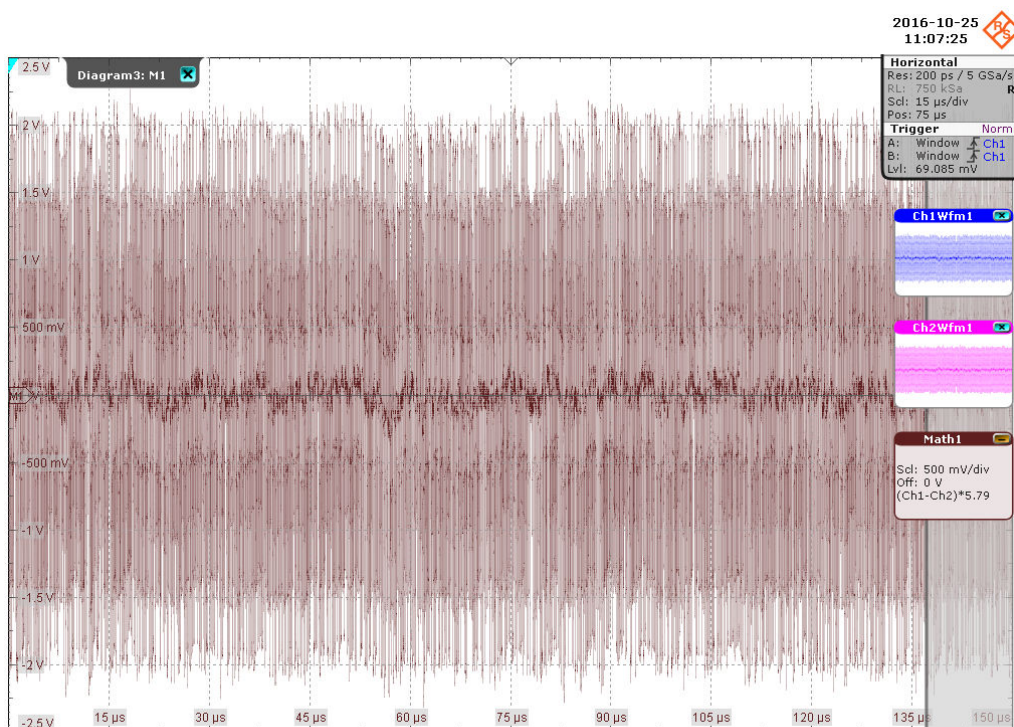
Further steps:

4.4.8.3 Test setup

A 1000BASE-T EEE link is set up between the DUT and link partner via test fixture R&S RT-ZF5. The DUT must be forced to enter low-power idle mode.

Ensure that the DUT is operating in slave mode.

A typical screenshot from R&S RTO / R&S RTO6 /R&S RTP during measurement is shown as below:

4.4.8.4 Measurement

It directly measures the jitter based on the timing information extracted from the LPI signaling, with the exception that timing information corresponding to the WAIT_QUIET, QUIET, WAKE and WAKE_SILENT states are not considered in the measurement.

As the jitter may be measured block by block, max of peak-to-peak jitter is reported as the final result.

It should be less than 1.4ns.

5 100BASE-TX tests

100BASE-TX Ethernet compliance tests require option R&S RTO/RTO6/RTP-K22.

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 Scope-Suite, see Chapter 2.5, "Connecting the R&S RTO/RTO6/RTP", on page 12
- VNA connection for Transmitter and Receiver Return Loss tests, see Chapter 2.7, "Connecting the vector network analyzer", on page 15.

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 20.

4. Check the test configuration settings and adjust them, if necessary. See:
   - Chapter 5.2, "Test configuration for Ethernet 100BASE-TX", on page 79
   - 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.

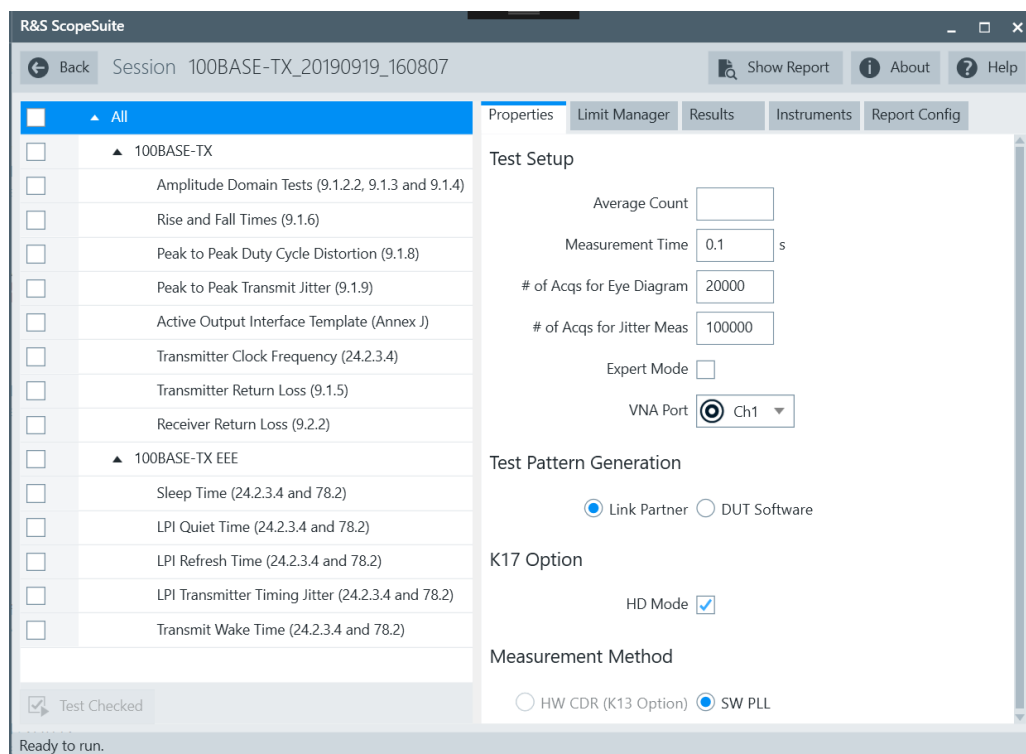The test configuration consists of some test-specific configuration settings.

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).

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.

Expert Mode

If enabled, the "Expert Mode" allows you to bypass the guided steps of the test case.

VNA Port

Selects the VNA channel for return loss testing.

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.

HD Mode

Enables the higher digital resolution mode. Requires option R&S RTO / R&S RTO6 /R&S RTP-K17.

5.3 100BASE-TX

The following table shows an overview of the needed equipment for performing the 100BASE-TX test cases. A prerequisite is also a R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth, the R&S ScopeSuite software and a 1000BASE-TX DUT.

Table 5-1: Equipment for 100BASE-TX Ethernet compliance tests

	Differential probe	Test fixture	Additional instruments
Amplitude Domain Tests (9.1.2.2, 9.1.3 and 9.1.4) Rise and Fall Times (9.1.6) Peak to Peak Duty Cycle Distortion (9.1.8) Peak to Peak Transmit Jitter (9.1.9) Active Output Interface Template (Annex J)	1 at least 2 GHz bandwidth	R&S RT-ZF2	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Transmitter Clock Frequency (24.2.3.4)	1 at least 2 GHz bandwidth	R&S RT-ZF2	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17 R&S RTO / R&S RTO6 /R&S RTP-K13
Transmitter Return Loss (9.1.5) Receiver Return Loss (9.2.2)	-	R&S RT-ZF2 Section: Twisted Pair Model	**VNA:** R&S ZNB or R&S ZNC or R&S ZND or R&S ZVL

5.3.1 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.

5.3.1.1 Test equipment

Table 5-2: Equipment for Amplitude Domain Tests

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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

5.3.1.2 Performing the test

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX tests", on page 79.

2. Select "Amplitude Domain Tests (9.1.2.2, 9.1.3 and 9.1.4)".
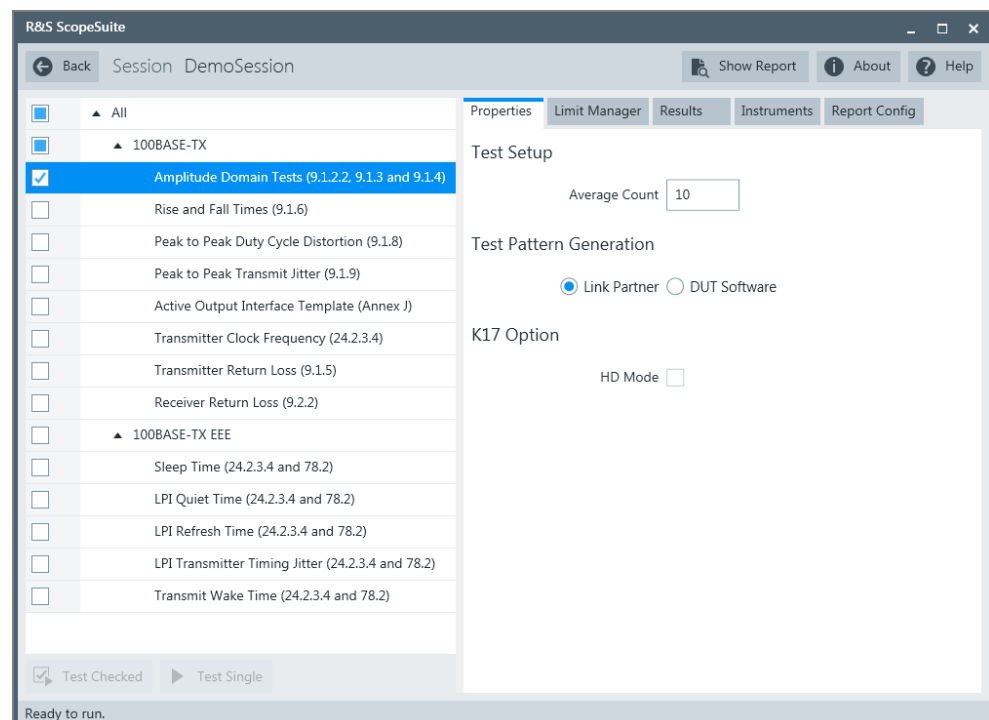
3. Click "Test Single".

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 23

5.3.1.3 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.

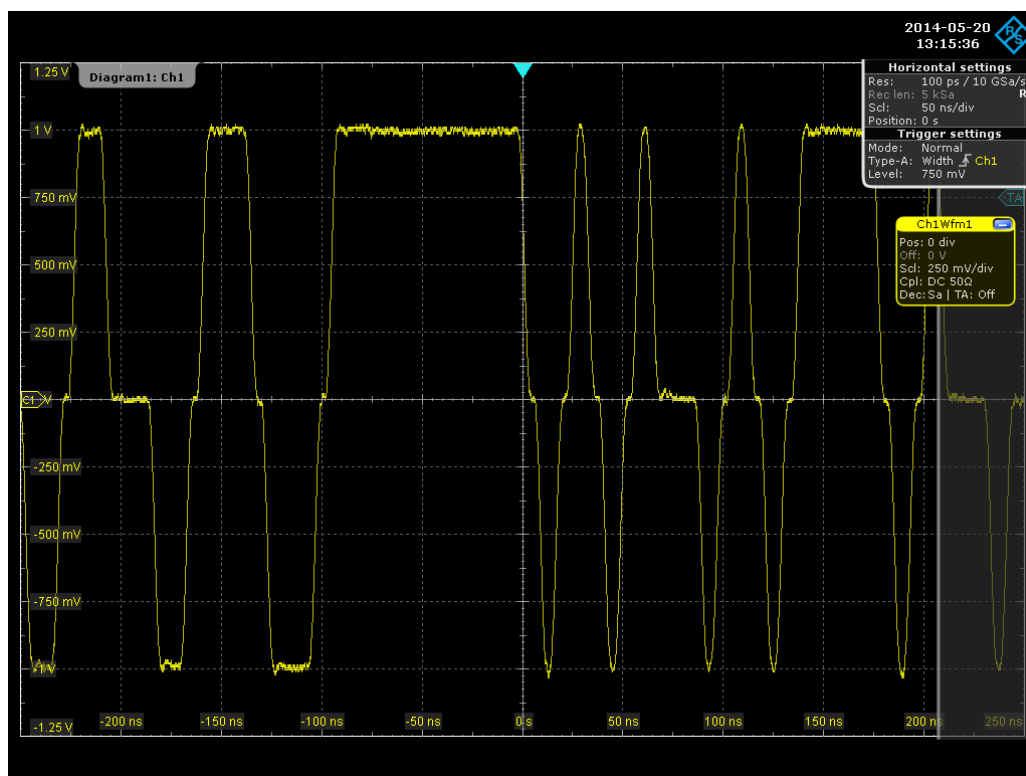   The DUT transmitter should then emit the following waveform, on which the test is performed:

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 bit or 14-bit times of no transition preceded by a 0 V to V_{out} transition.
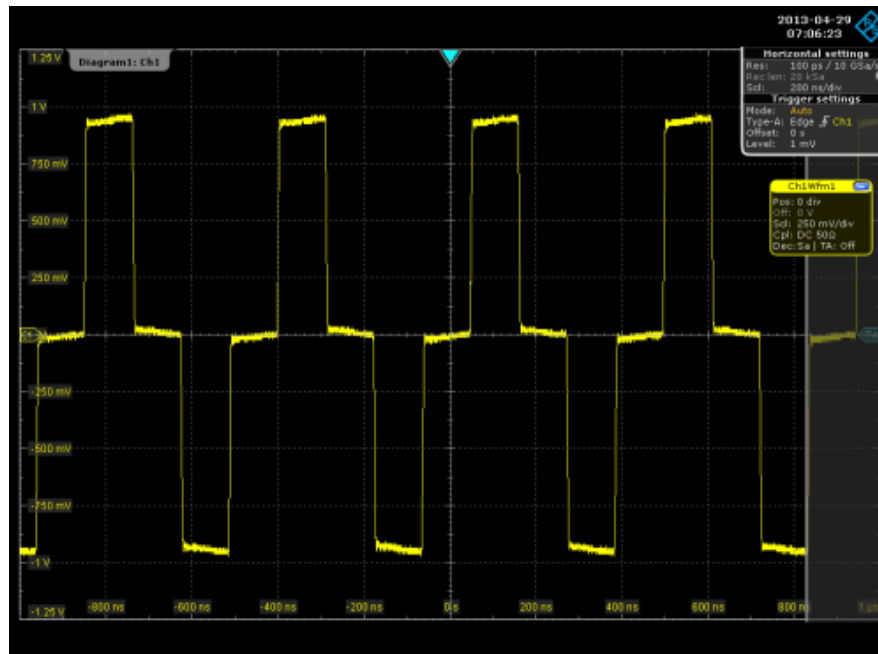
Figure 5-3: Waveform for amplitude domain tests and rise and fall time tests

The test consists of three measurements:

- Differential output voltages
  The mean differential voltage of the positive pulse and that of the negative pulse is 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.

5.3.2 Rise and fall times

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

5.3.2.1 Test equipment

Table 5-3: Equipment for Rise and Fall Time tests

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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

5.3.2.2 Performing the test

1. Start the test as described in

2. Select "Rise and Fall Times (9.1.6)".
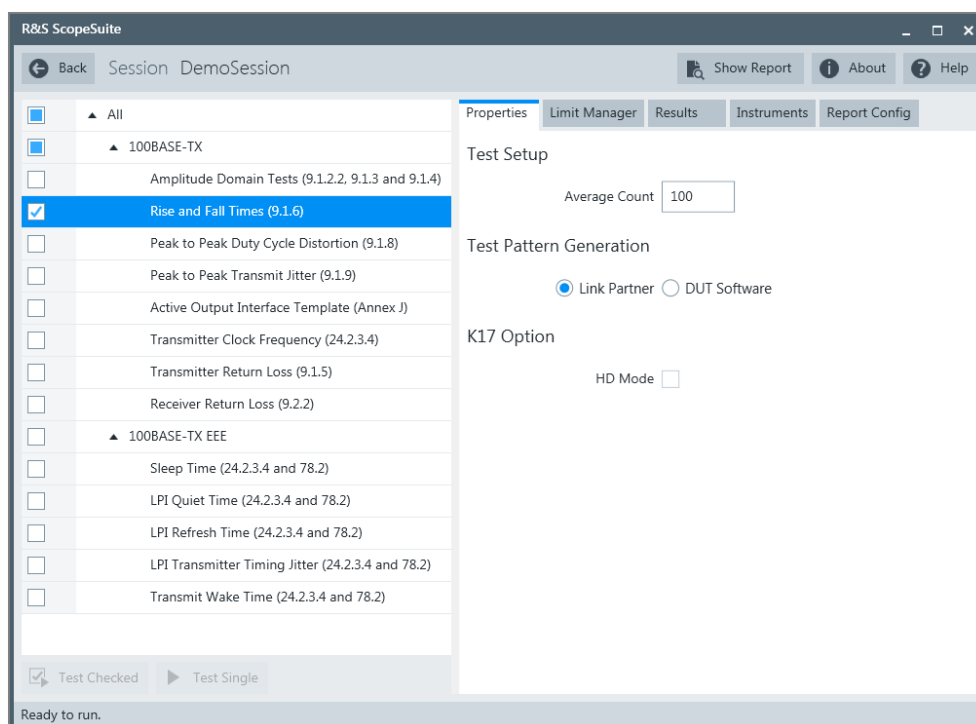
3. Click "Test Single".

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

Further steps:

5.3.2.3 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.

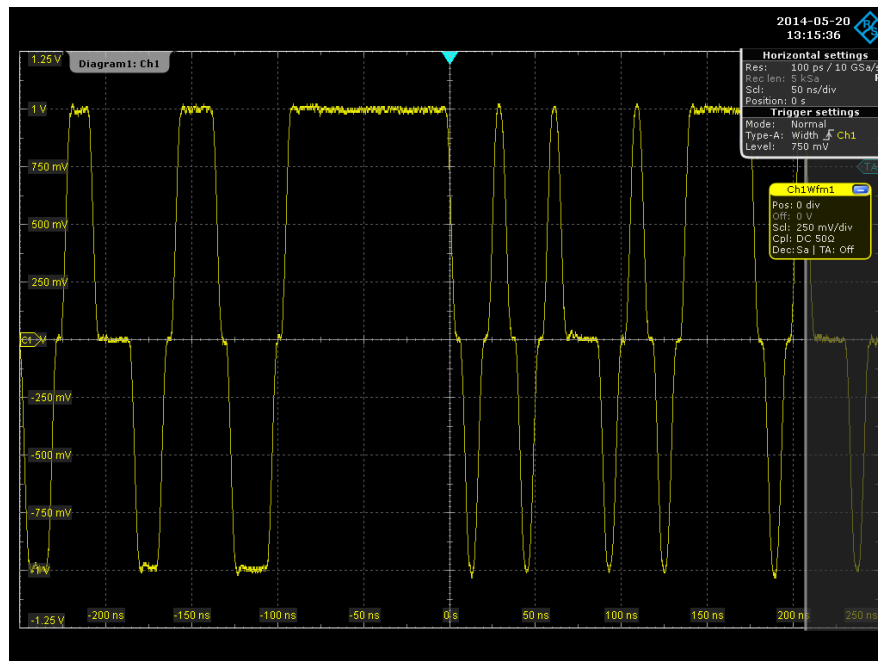   The DUT transmitter should then emit the following waveform, on which the test is performed:

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 bit or 14-bit times of no transition preceded by a 0 V to V_{out} transition.
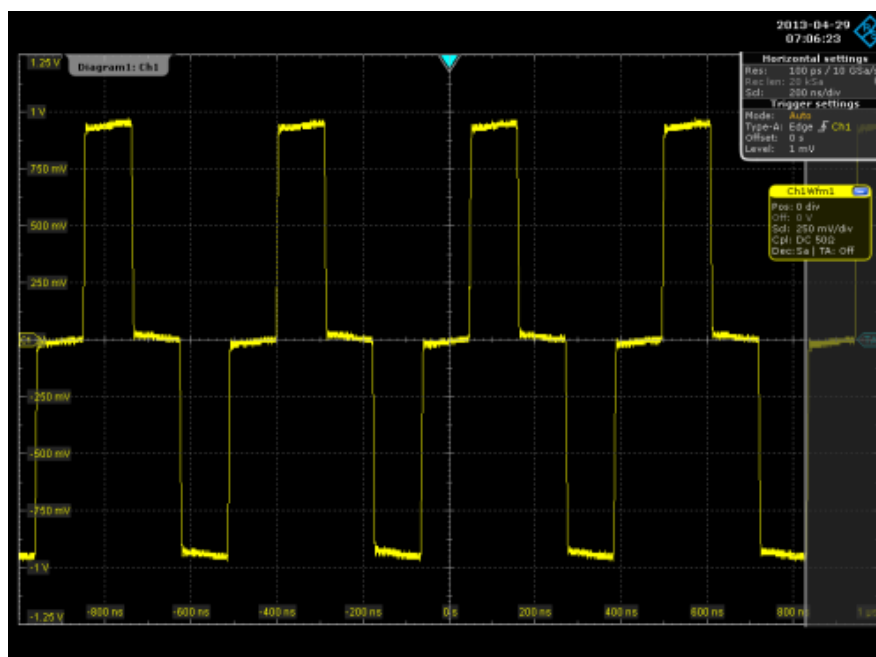
Figure 5-5: Waveform for amplitude domain tests and rise and fall time tests

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.

5.3.3　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.

5.3.3.1　Test equipment

*Table 5-4: Equipment for Peak to Peak Duty Cycle Distortion tests*

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" (TPM) section or "Resistive Load" section	R&S RT-ZF2	1

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

5.3.3.2   Performing the test

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX tests", on page 79.

2. Select "Peak to Peak Duty Cycle Distortion (9.1.8)".
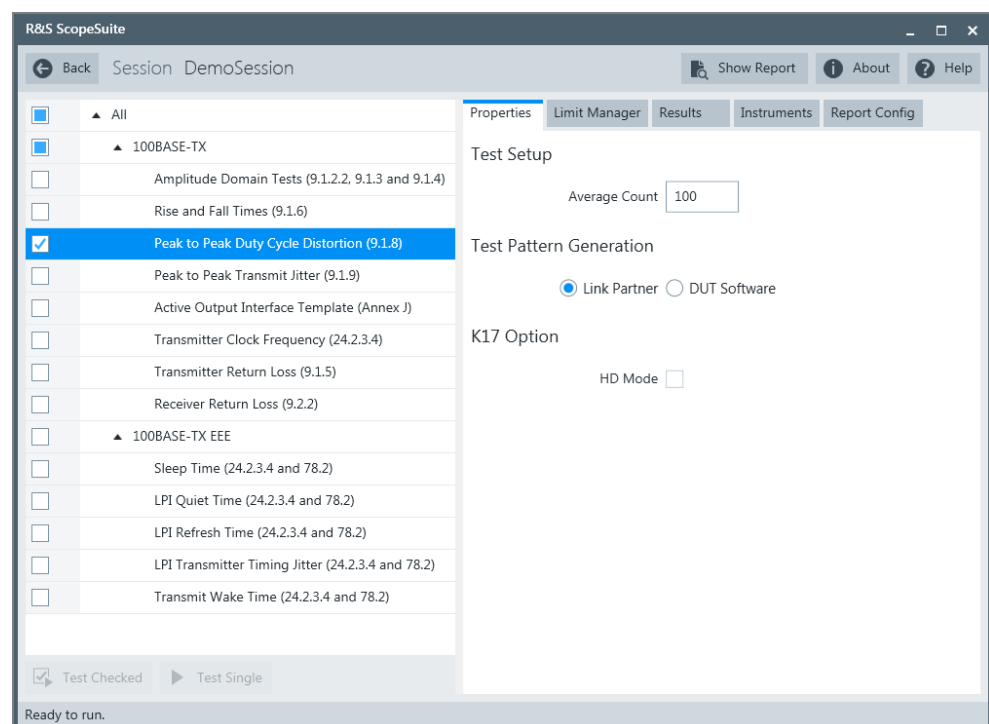
3. Click "Test Single".

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 23

5.3.3.3   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:
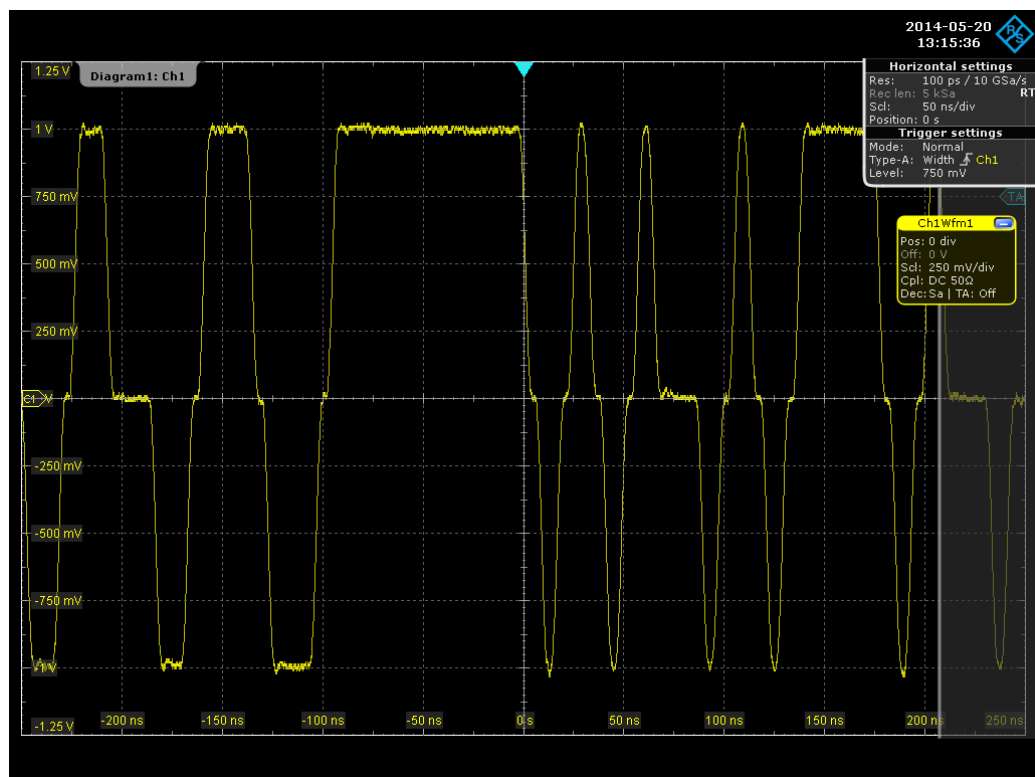

Figure 5-6: Waveform for peak to peak duty cycle distortion tests using the TPM section

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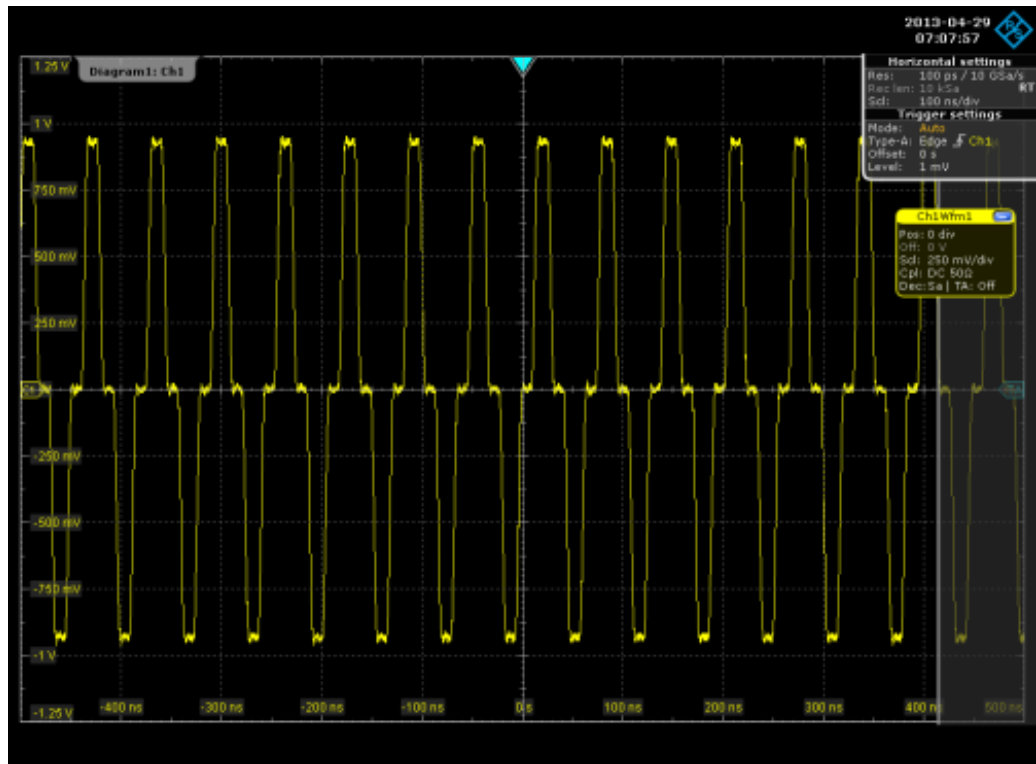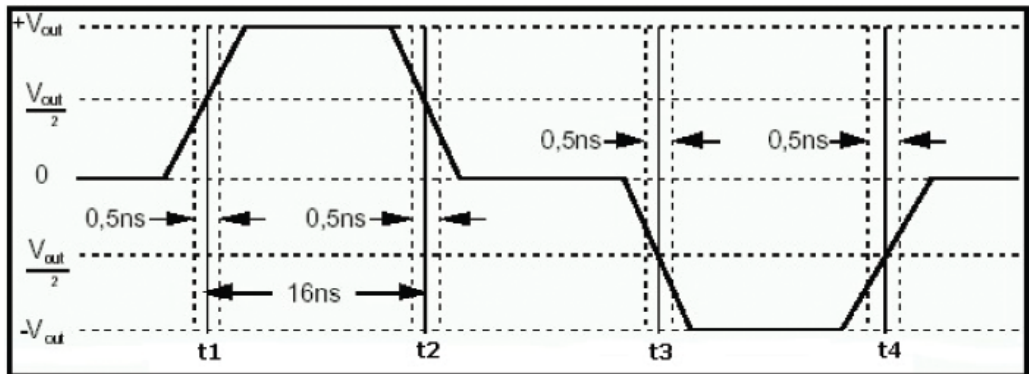
Figure 5-7: MLT-3 encoded clock-like pattern waveform

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.

5.3.4 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.

5.3.4.1 Test equipment

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

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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

5.3.4.2 Performing the test

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX tests", on page 79.

2. Select "Peak to Peak Transmit Jitter (9.1.9)".
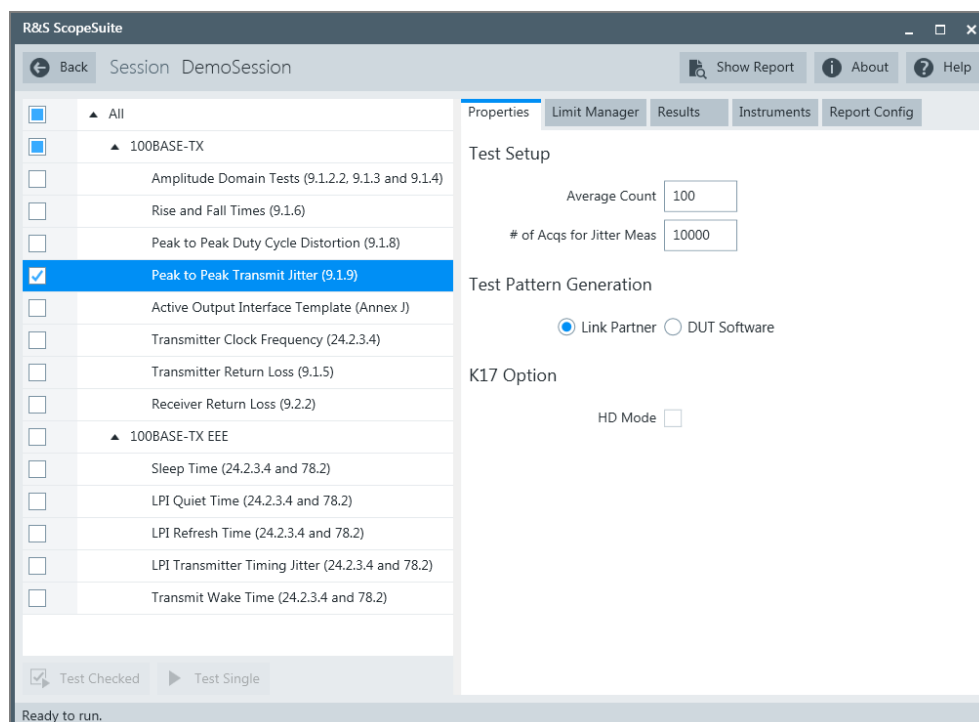
3. Click "Test Single".

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 23

5.3.4.3 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.
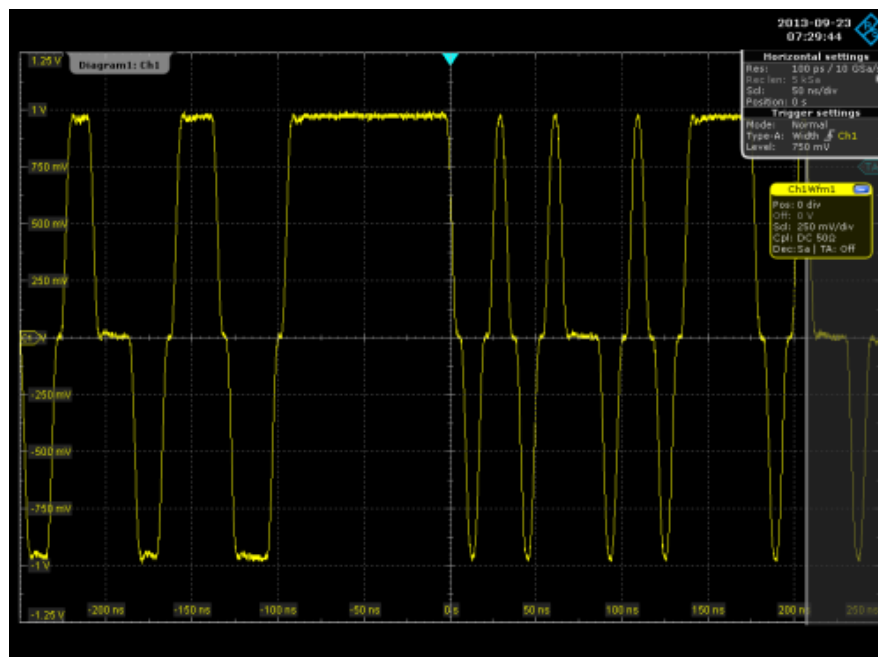
Figure 5-8: Scrambled MLT-3 encoded idle pattern waveform

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. 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.

5.3.5 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.

5.3.5.1 Test equipment

Table 5-6: Equipment for Active Output Interface Template tests

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" (TPM) section or "Resistive Load" section	R&S RT-ZF2	1

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

5.3.5.2 Performing the test

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX tests", on page 79.

2. Select "Active Output Interface Template (Annex J)".
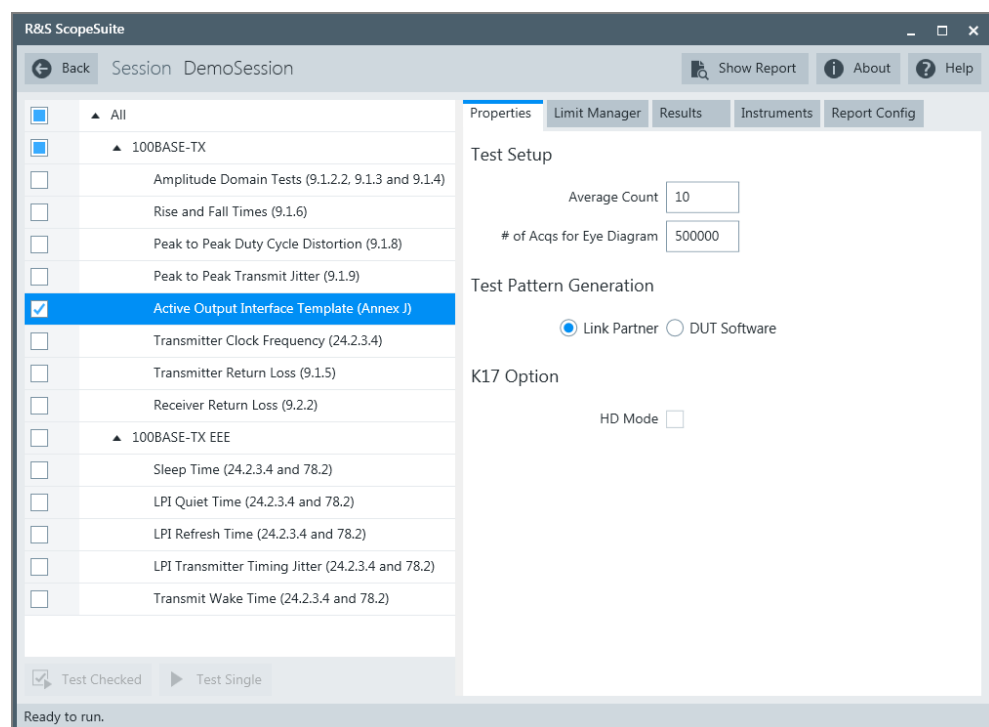
3. Click "Test Single".

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 23

5.3.5.3 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.
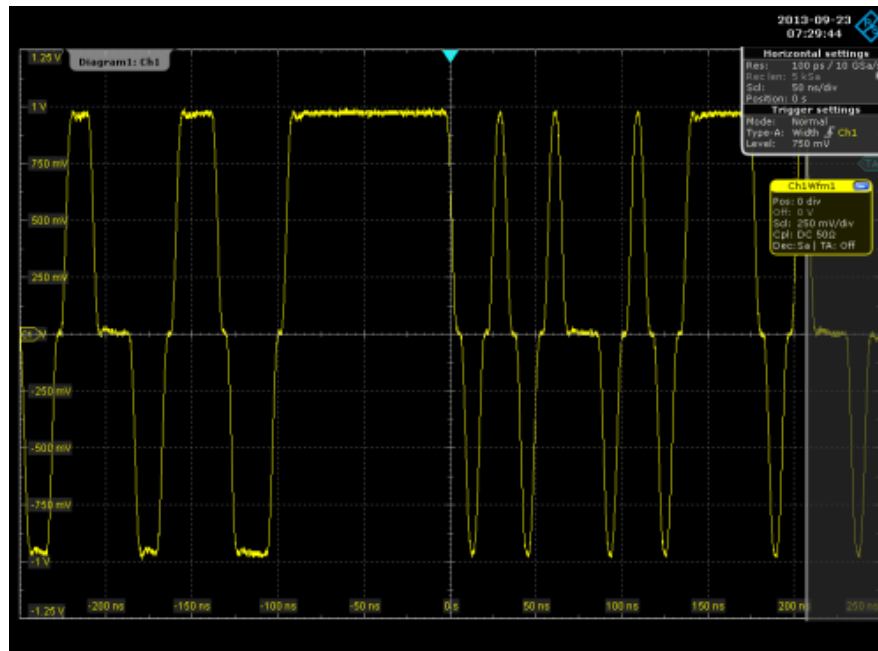

Figure 5-9: Scrambled MLT-3 encoded idle pattern waveform

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.

5.3.6 Transmitter clock frequency

The "Transmitter Clock Frequency (24.2.3.4)" tests verify that the clock frequency is within the conformance limits specified in ANSI X3.263 standards, section 24.2.3.4.

5.3.6.1 Test equipment

Table 5-7: Equipment for Transmitter Clock Frequency tests

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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

5.3.6.2 Performing the test

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX tests", on page 79.

2. Select "Transmitter Clock Frequency (24.2.3.4)".
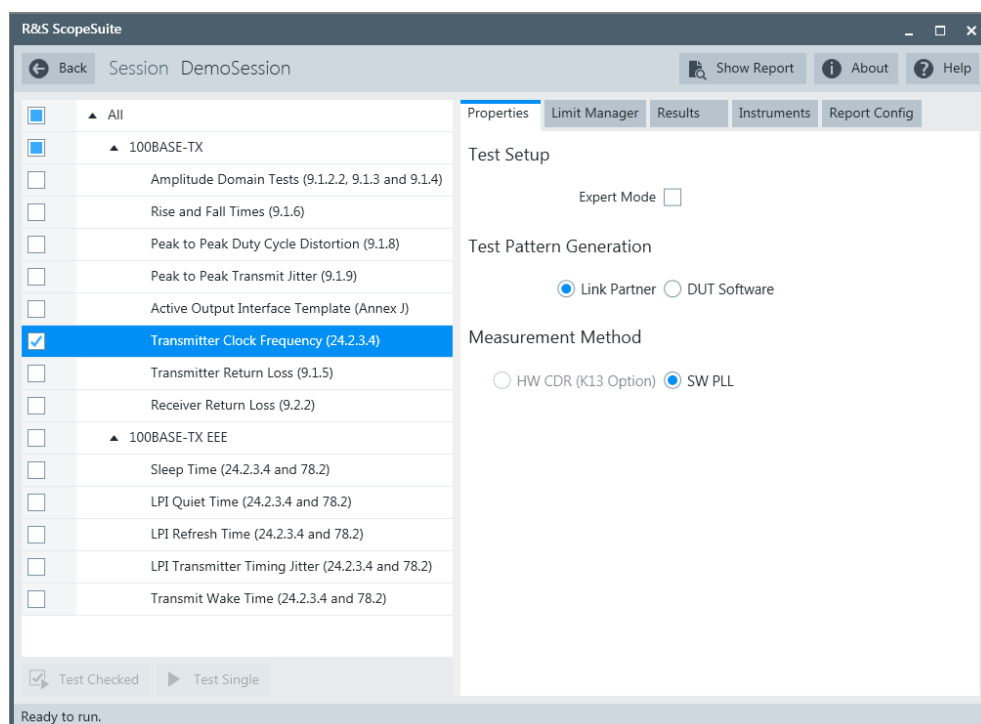
3. Click "Test Single".

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 23

5.3.6.3   Measurements

This test case uses either software PLL (post processing method) or hardware CDR (R&S RTO / R&S RTO6 /R&S RTP-K13 option) method to measure clock frequency.

5.3.7   Transmitter return loss

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

5.3.7.1   Test equipment

Table 5-8: Equipment for Transmitter Return Loss test

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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 ZNB/ZNC/ZND/ZVL	1
DUT	the device you want to test	1

5.3.7.2   Performing the test

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX tests", on page 79.

2. Select "Transmitter Return Loss (9.1.5)".
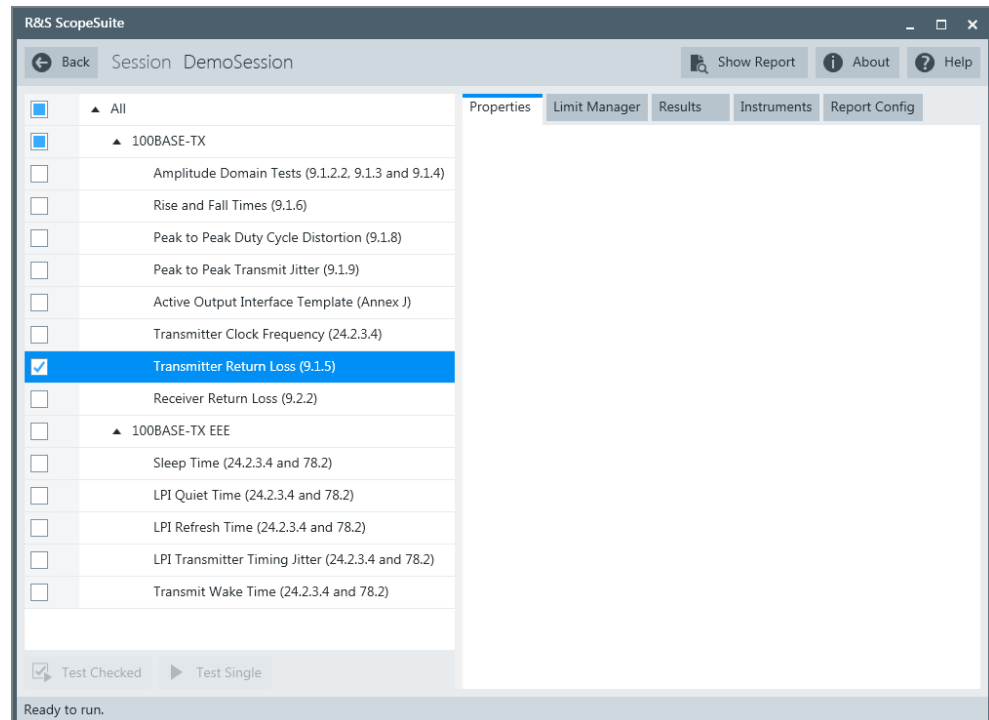
3. Click "Test Single".

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 23

5.3.7.3 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 MHz 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.

5.3.8 Receiver return loss

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

5.3.8.1 Test equipment

Table 5-9: Equipment for Receiver Return Loss test

Item	Recommended model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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 ZNB/ZNC/ZND/ZVL	1
DUT	the device you want to test	1

5.3.8.2 Performing the test

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX tests", on page 79.

2. Select "Receiver Return Loss (9.2.2)".
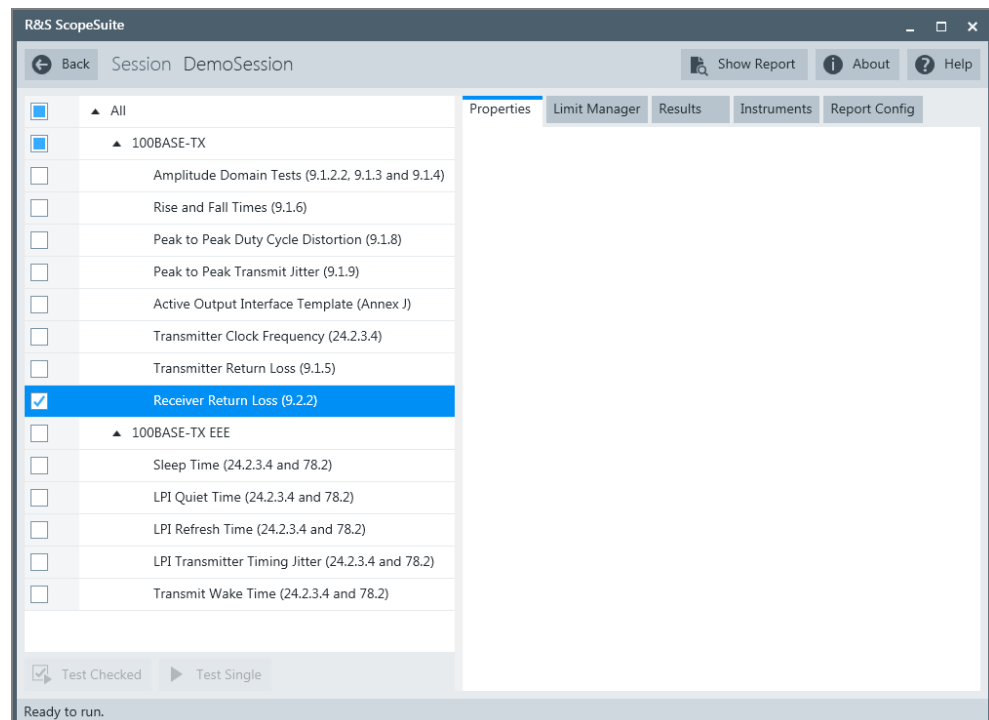
3. Click "Test Single".

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 23

5.3.8.3 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 MHz 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.

5.4 100BASE-TX EEE

The following table shows an overview of the needed equipment for performing the 100BASE-TX EEE test cases. A prerequisite is also a R&S RTO / R&S RTO6 / R&S RTP with at least 600 MHz bandwidth, the R&S ScopeSuite software and a 1000BASE-TX EEE DUT.

Table 5-10: Equipment for 100BASE-TX Ethernet compliance tests

	Differential probe	Test fixture	Additional instruments
Sleep Time (24.2.3.4 and 78.2) Transmit Wake Time (24.2.3.4 and 78.2)	1 at least 2 GHz band-width	R&S RT-ZF5 Section: Link partner section	R&S RTO / R&S RTO6 /R&S RTP-K8
LPI Quiet Time (24.2.3.4 and 78.2)" LPI Refresh Time (24.2.3.4 and 78.2) LPI Transmitter Timing Jitter (24.2.3.4 and 78.2)	at least 2 GHz band-width	R&S RT-ZF5 Section: Link partner section	

5.4.1 Sleep time test

The purpose of the "Sleep Time" test case is to verify that the DUT transmits the SLEEP signal for a time within the conformance limits specified in IEEE802.3az, Section 78.2.

5.4.1.1 Test equipment

Table 5-11: Equipment for Sleep Time test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture Link partner section	R&S RT-ZF5	1
Differential probe	at least 1 GHz bandwidth	
DUT with EEE support	e.g., Intel(R) 82579LM Gigabit Network Controller/Adapter	1
Software option	R&S RTO/RTO6/RTP-K8, Ethernet serial decoding	1

5.4.1.2 Performing the tests

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX tests", on page 79.

2. Select the test case: "100BASE-TX-EEE" > "Sleep Time (24.2.3.4 and 78.2)"
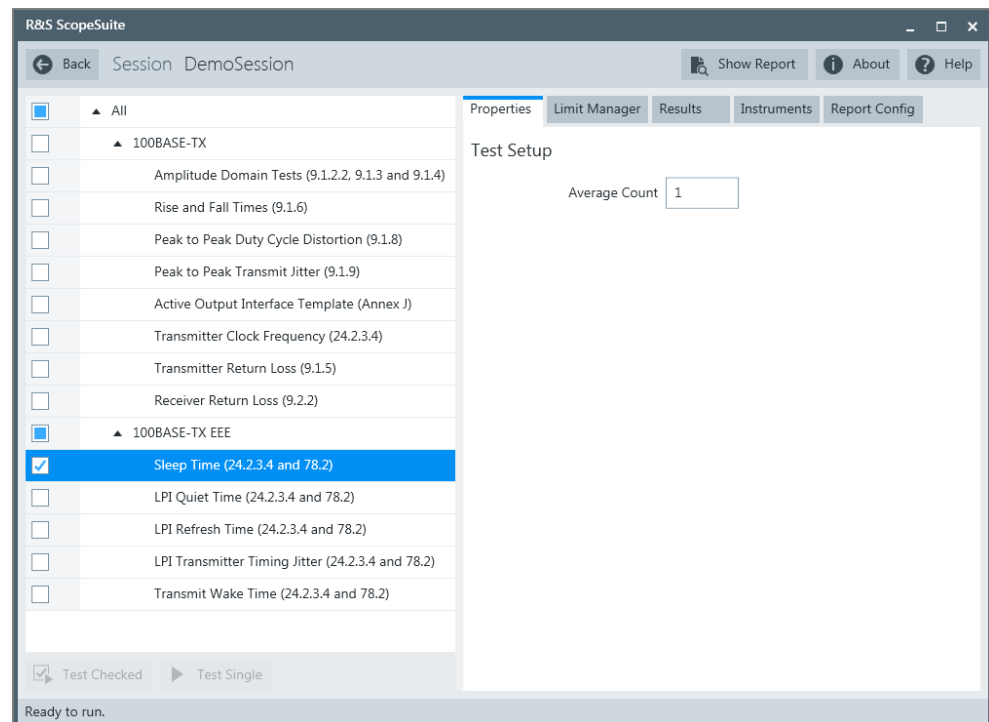
3. Click "Test Single".

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 23

5.4.1.3 Measurement

The software performs a pre-measurement for quiet time and refresh time to trigger on frames since data streams are sent prematurely. Then it applies a width-width sequence trigger to trigger on a wake signal.

The sleep time test case measures the sleep time length which needs 100BaseTx decode option (R&S RTO/RTO6/RTP-K8 option) to support. The sleep time is measured by descrambling the stream just before the quiet state and measuring the continuous stream of the SLEEP sequence, /P/, which is sent as 00000.

The sleep time should be greater than 200us and less than 220us. The software reports the maximum, average and minimum sleep time as results in the report.

5.4.2 LPI quiet time test

The purpose of "LPI Quiet Time" test case is to verify that the DUT transmits the quiet signal for a time within the conformance limits specified in IEEE802.3az, Section 78.2.

5.4.2.1   Test equipment

Table 5-12: Equipment for LPI Quiet Time test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture	R&S RT-ZF5	1
Differential probe	at least 1 GHz bandwidth	
DUT with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1

5.4.2.2   Performing the tests

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX tests", on page 79.

2. Select the test case: "100BASE-TX-EEE" > "LPI Quiet Time (24.2.3.4 and 78.2)"
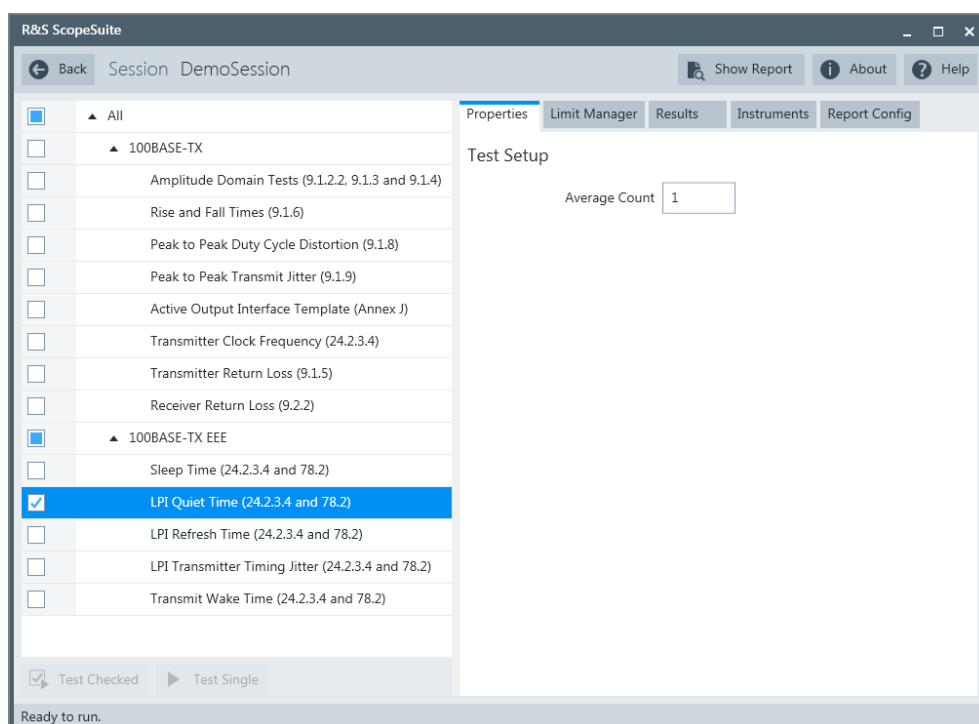
3. Click "Test Single".

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 23

5.4.2.3　Measurement

The software performs a pre-measurement for quiet time and refresh time to trigger on frames since the data streams are sent prematurely. Then apply width-width sequence trigger to trigger on refresh signal.

The quiet time is measured from the time the signal crosses the signal detect de-assertion threshold (200mV) to when the refresh signal crosses the signal detect assertion threshold (400mV).

The quiet time is the amount of time the PHY of DUT stays in the quiet state before it expects a refresh signal. It should be greater than 2 0ms and less than 22 ms. The software reports the maximum, average and minimum quiet time as results in the report.

5.4.3　LPI refresh time test

The purpose of "LPI Refresh Time" test case is to verify that the DUT transmits the refresh signal for a time within the conformance limits specified in IEEE802.3az, Section 78.2.

5.4.3.1　Test equipment

Table 5-13: Equipment for Refresh Time test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture	R&S RT-ZF5	1
Differential probe	at least 1 GHz bandwidth	
DUT with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1

5.4.3.2　Performing the tests

1. Start the test as described in

2. Select the test case: "100BASE-TX-EEE" > "LPI Refresh Time (24.2.3.4 and 78.2)"
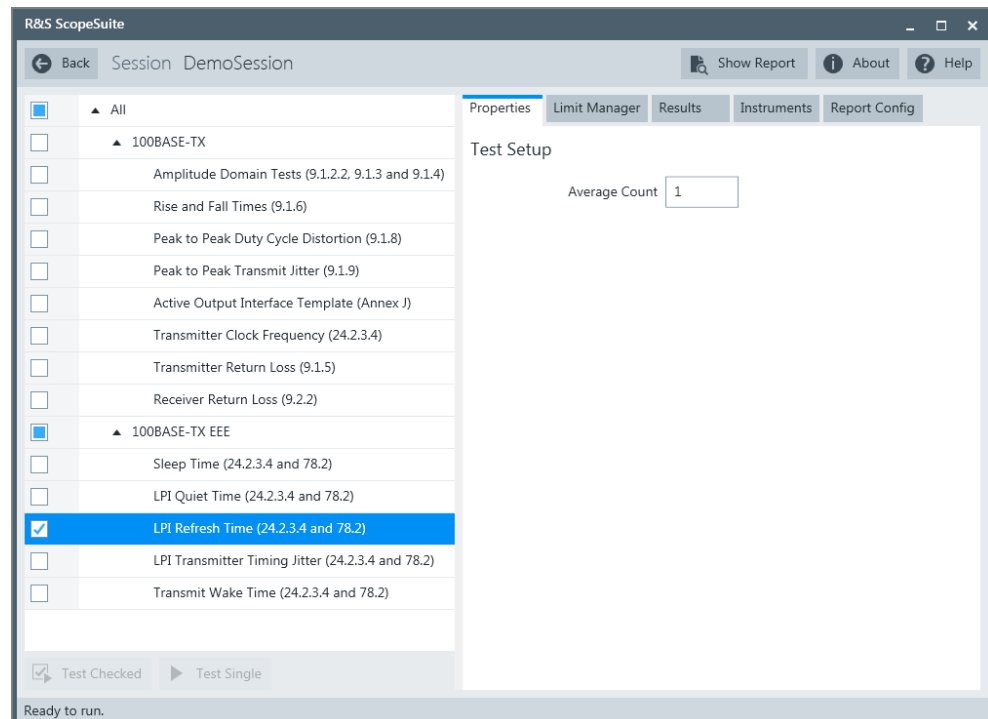
3. Click "Test Single".

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 23

5.4.3.3 Measurement

The software performs a pre-measurement for quiet time and refresh time to trigger on frames since data streams are sent prematurely. Then it applies a width-width sequence trigger to trigger on a refresh signal.

The refresh time is measured from the time the signal detect assertion threshold (200mV) is detected after a quiet period to when the signal detect de-assertion threshold(400mV) is detected before a quiet period.

The refresh time, the amount of time the PHY of DUT transmits the refresh signal before entering the quiet state, should be greater than 200us and less than 220us. The software reports the maximum, average and minimum refresh time as results in the report.

5.4.4 LPI transmitter timing jitter test

The purpose of "Transmitter Timing Jitter" test case is to verify that the total transmit jitter of the device under test is below the conformance limits specified in IEEE802.3az, Section 78.2.

5.4.4.1 Test equipment

Table 5-14: Equipment for LPI Transmitter Timing Jitter test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture	R&S RT-ZF5	1
Differential probe	at least 1 GHz bandwidth	
DUT with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1

5.4.4.2 Performing the tests

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX tests", on page 79.

2. Select the test case: "100BASE-TX-EEE" > "LPI Transmitter Timing Jitter (24.2.3.4 and 78.2)"
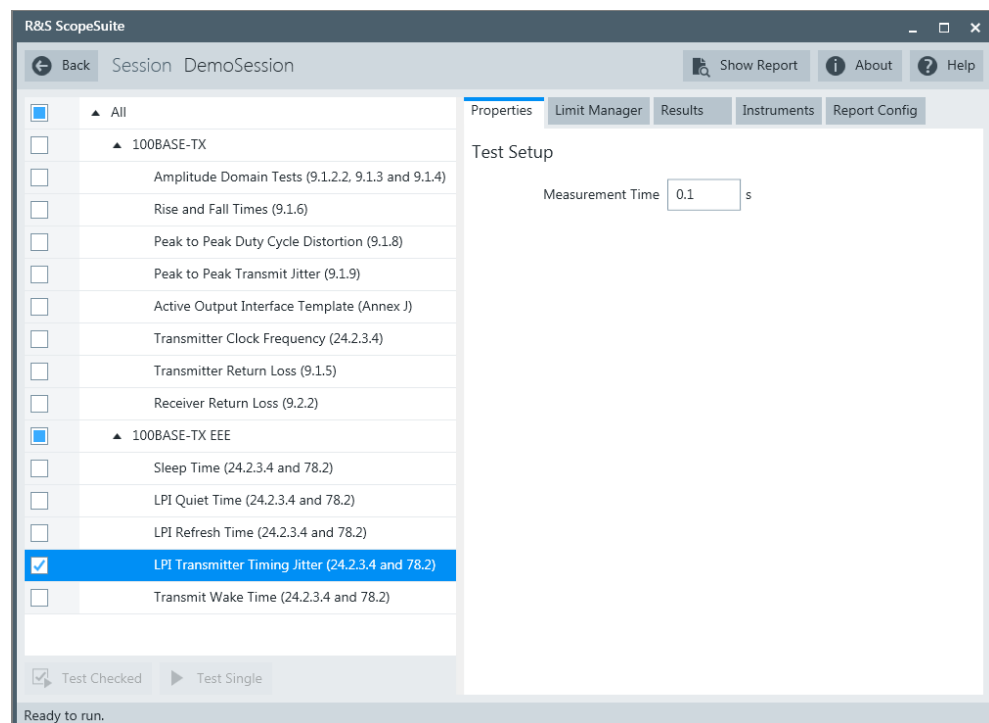
3. Click "Test Single".

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

Further steps:

●

5.4.4.3 Measurement

The software performs a pre-measurement for quiet time and refresh time to trigger on frames since data streams are sent prematurely. Then it applies a width-width sequence trigger to trigger on a refresh signal.

The transmitter timing jitter measurement is done using captured 100ms to 1000ms of data. It excludes the first 5us worth of edge data during the refresh stage and ignores the jitter contributions from clock transition occurring during the quiet stage. After that it performs data processing to find out the jitter.

The peak-to-peak total transmit jitter shall not exceed 1.4ns at a BER of 10^{-8}. The software reports the maximum, average and minimum jitter as results in the report.

5.4.5 Transmit wake time test

The purpose of the "Transmit Wake Time" test case is to verify that the DUT transmits the WEEK signal for a time within the conformance limits specified in IEEE802.3az, section 78.2.

5.4.5.1 Test equipment

Table 5-15: Equipment for Transmit Wake Time Test test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture	R&S RT-ZF5	1
Differential probe	at least 1 GHz bandwidth	
DUT with EEE support	e.g., Intel(R) 82579LM Gigabit Network Adaptor	1
Software option	R&S RTO/RTO6/RTP-K8, Ethernet serial decoding	1

5.4.5.2 Performing the tests

1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX tests", on page 79.

2. Select the test case: "100BASE-TX-EEE" > "Transmit Wake Time (24.2.3.4 and 78.2)"
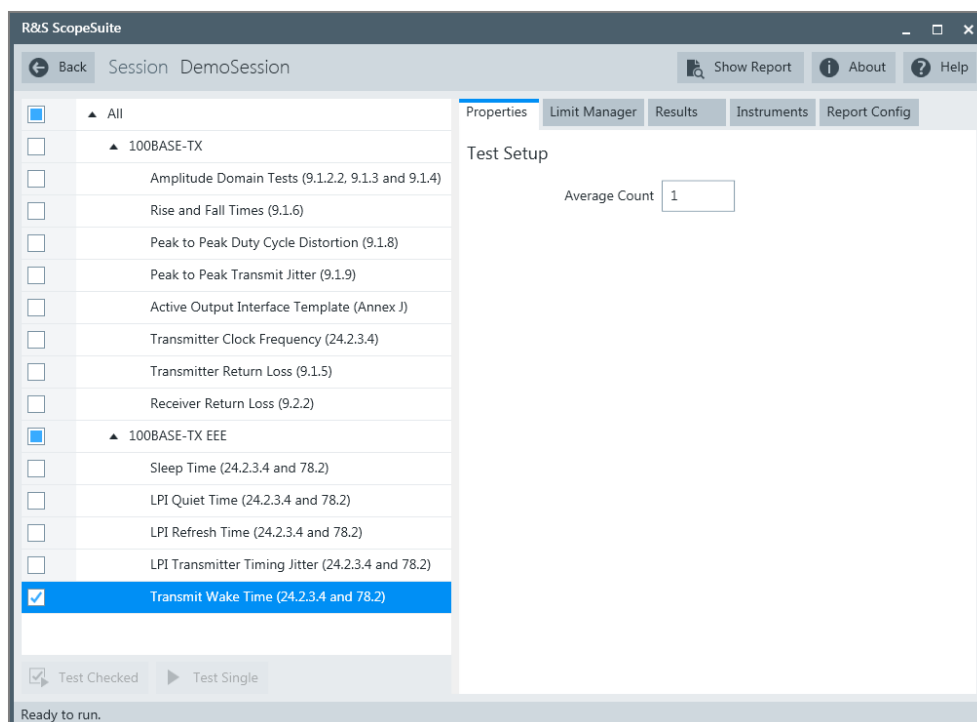
3. Click "Test Single".

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

Further steps:

● , on page 23

5.4.5.3 Measurement

The software performs a pre-measurement for quiet time and refresh time to trigger on frames since data streams are sent prematurely. Then it applies a width-width sequence trigger to trigger on a wake signal.

The wake time test case is to measure the wake time length. Option Ethernet 100BaseTx decode (R&S RTO/RTO6/RTP-K8 option) is needed. The wake time is measured by descrambling the stream just after the quiet state and before a frame. It measures the amount of time the DUT transmit IDLE signaling before the frame.

The wake time, the amount of time the DUT transmit IDLE before a frame, should be greater than 25us. The software reports the maximum, average and minimum wake time as results in the report.

6 10BASE-T tests

10BASE-T Ethernet compliance tests require option R&S RTO/RTO6/RTP-K22.

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 Scope-Suite, see Chapter 2.5, "Connecting the R&S RTO/RTO6/RTP", on page 12
- VNA connection for Transmitter and Receiver Return Loss tests, see Chapter 2.7, "Connecting the vector network analyzer", on page 15.

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 20.

4. Check the test configuration settings and adjust them, if necessary. See:
   - Chapter 6.2, "Test configuration for Ethernet 10BASE-T", on page 110
   - 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.
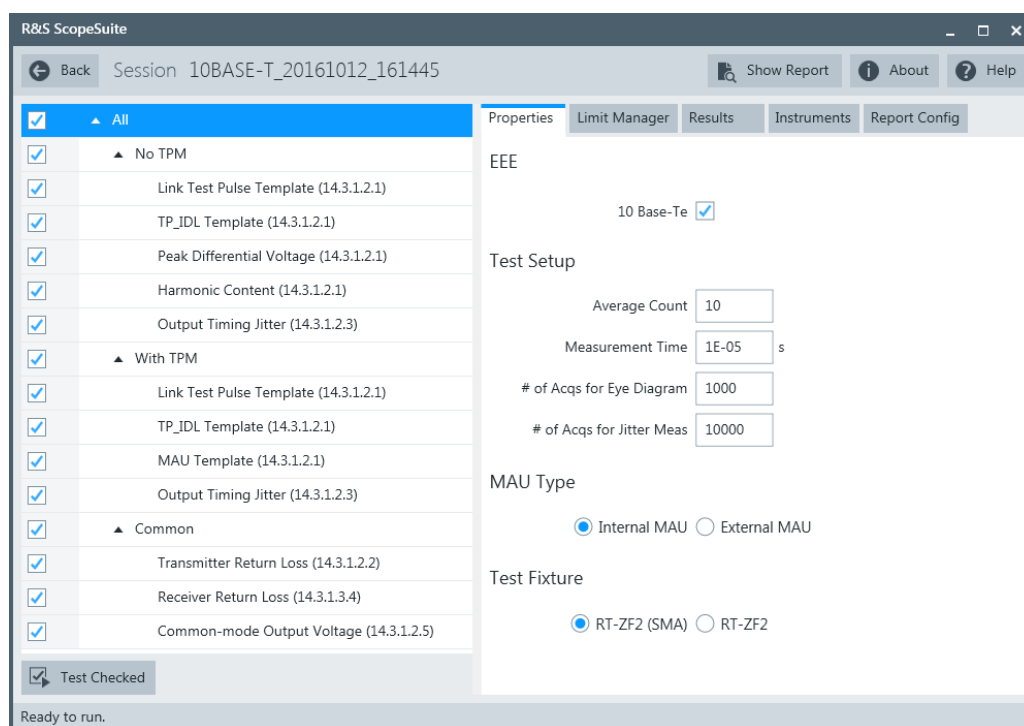
Figure 6-1: Configuration for 10BASE-T compliance tests

10 Base-Te
If enabled, allows test case to be run with 10Base-Te standard.

Average Count
Defines the number of waveforms which the oscilloscope acquires to calculate the average waveform (average count).

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
Sets the total time duration to be measured for. The valid range is 50E-9 to 100E-3, the default value is 100E-3.

# 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".

Test Fixture
Selects which test fixture is used for the tests.

6.3 10BASE-T tests

The following table shows an overview of the needed equipment for performing the 10BASE-T test cases. A prerequisite is also a R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth, the R&S ScopeSuite software and a 10BASE-T DUT.

Table 6-1: Equipment for 10BASE-T Ethernet compliance tests

	Differential probe	Test fixture	Additional instruments
Link Test Pulse Template (14.3.1.2.1)	1 at least 1 GHz band-width	R&S RT-ZF2 Section: Twisted Pair Model	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
TP_IDL Template (14.3.1.2.1)	1	R&S RT-ZF2 Section: Twisted Pair Model	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Output Timing Jitter (14.3.1.2.3)	1	R&S RT-ZF2 Section: Twisted Pair Model	**Optional:** Link partner e.g., Intel PRO/100 GT Desktop Adapter **Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Peak Differential Voltage (14.3.1.2.1)	1	R&S RT-ZF2 Section: Twisted Pair Model	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Harmonic Content (14.3.1.2.1)	1	R&S RT-ZF2 Section: Twisted Pair Model	**Optional:** Link partner e.g., Intel PRO/100 GT Desktop Adapter **Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17

	Differential probe	Test fixture	Additional instruments
MAU Template	1	R&S RT-ZF2 Section: Twisted Pair Model	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Transmitter Return Loss (14.3.1.2.2)	1	R&S RT-ZF2 Section: Twisted Pair Model	**VNA:** R&S ZNB or R&S ZNC or R&S ZND or R&S ZVL
Receiver Return Loss (14.3.1.3.4)	1	R&S RT-ZF2 Section: Twisted Pair Model	**Optional VNA:** R&S ZNB or R&S ZNC or R&S ZND or R&S ZVL
Common-mode Output Voltage (14.3.1.2.5)	1	R&S RT-ZF2 Section: Common Mode Voltage	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17

6.3.1 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 802.3-2012, subclause 14.3.1.2.1. The measurements are made with and without twisted-pair model (TPM), each with three different loads.

6.3.1.1 Test equipment

Table 6-2: Equipment for all Link Test Pulse Template tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" 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

6.3.1.2   No TPM

Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. Under "No TPM", select "Link Test Pulse 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 23

Measurements

Configure the DUT to "10BASE-T random data" mode.
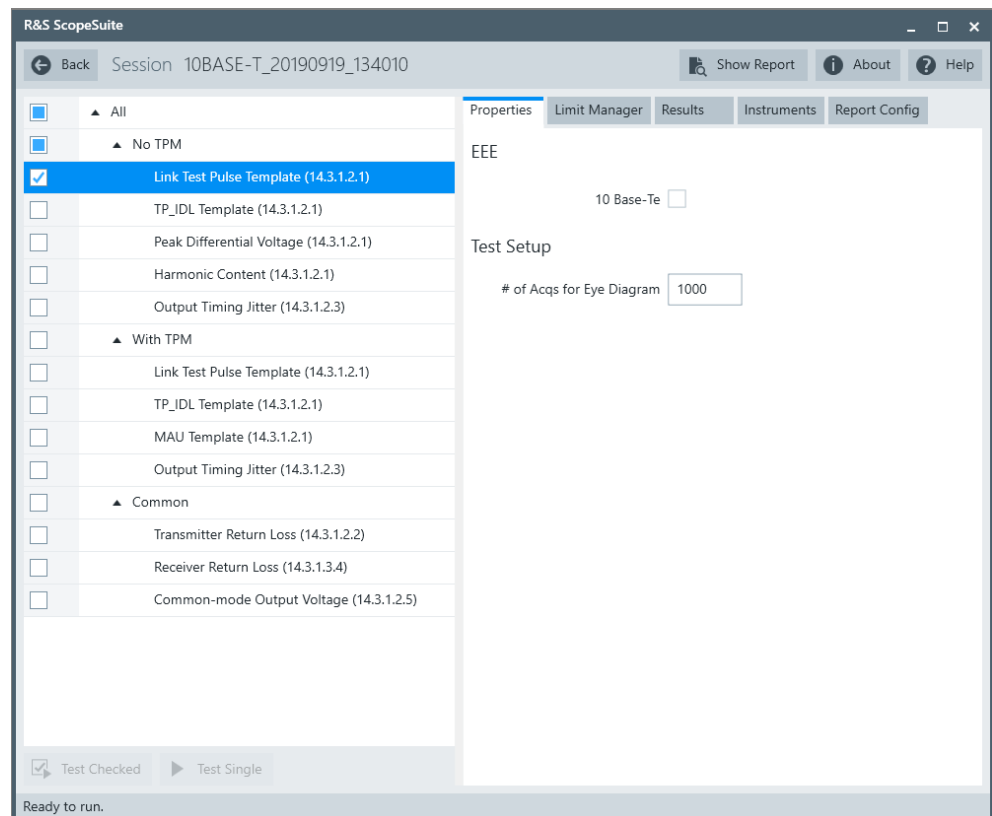
The waveforms displayed on the R&S RTO/RTO6/RTP should look similar to the pictures below.
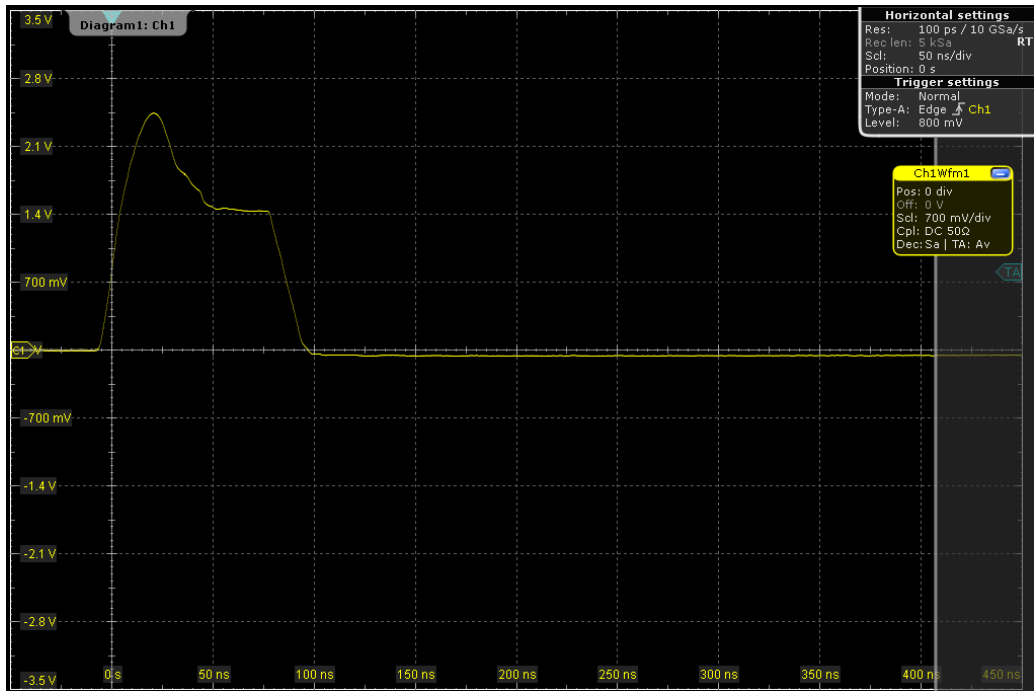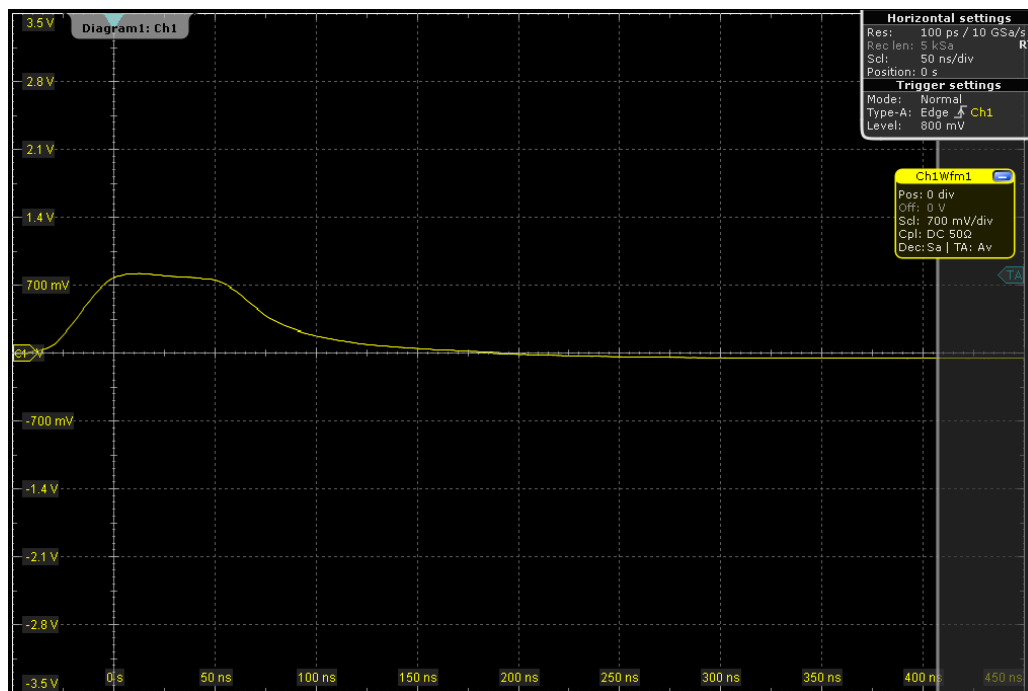

Figure 6-2: Waveform with load 1
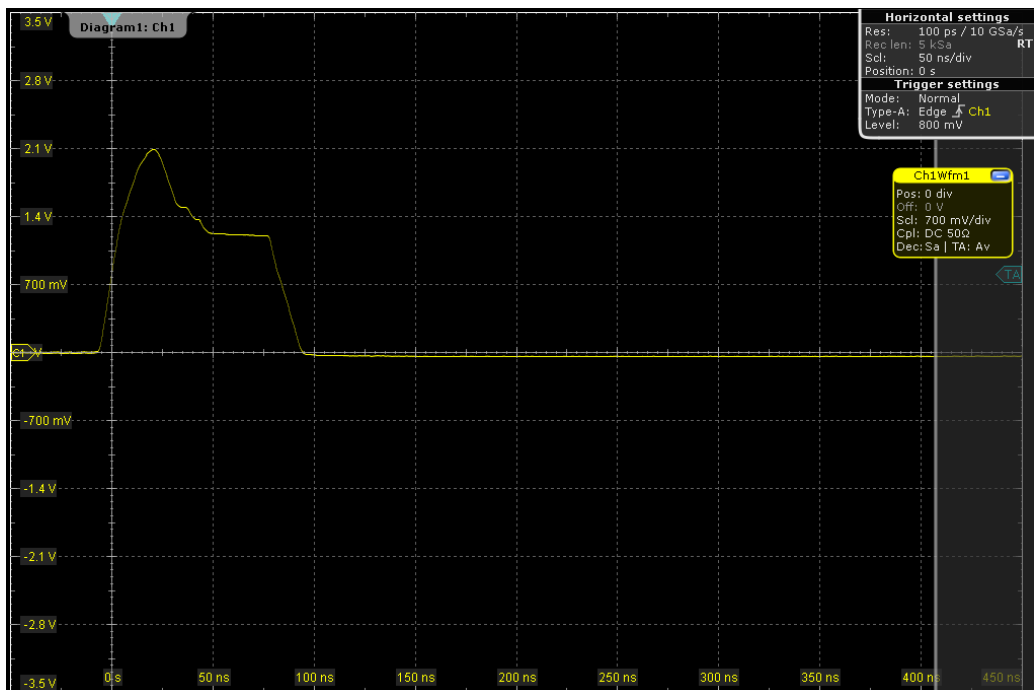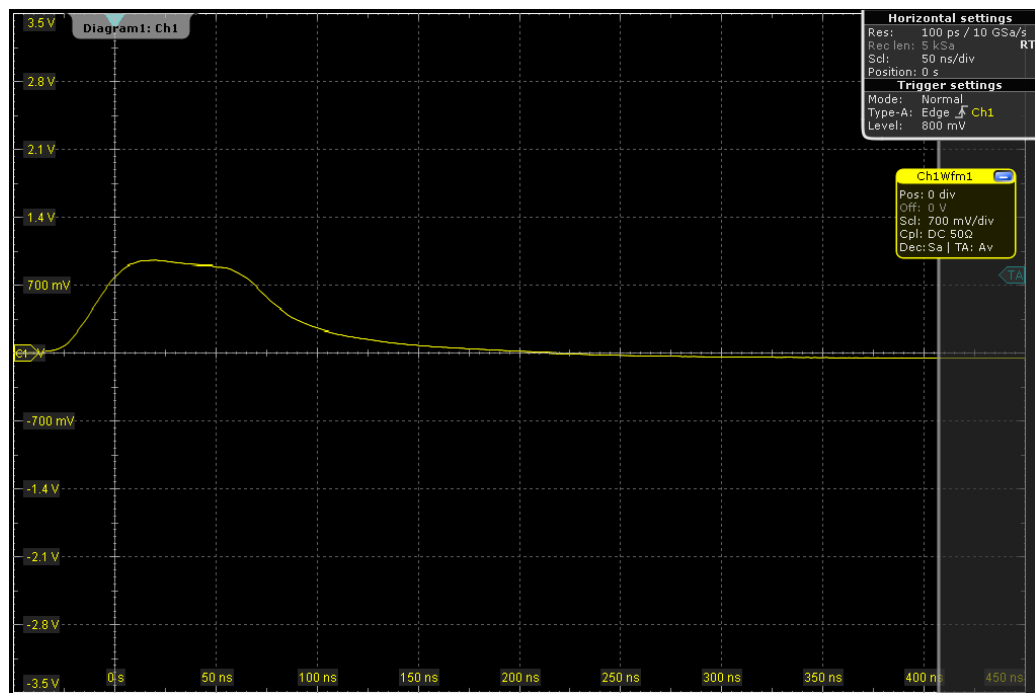

Figure 6-3: Waveform with load 2
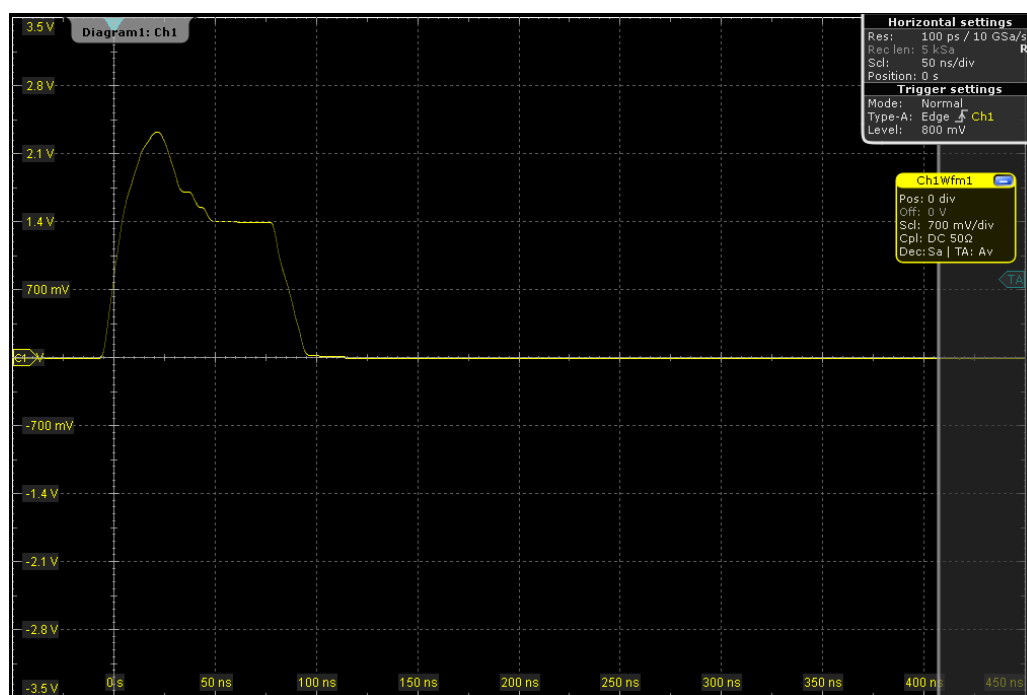
Figure 6-4: Waveform with load 100 Ω

The test procedure is the same for each load. A mask is created according to the template specified in figure 14-12 of IEEE 802.3-2012, subclause 14.3.1.2.1. The test has been passed if the waveform did not violate the mask.

6.3.1.3 With TPM

Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. Under "With TPM", select "Link Test Pulse 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 23

Measurements

Configure the DUT to "10BASE-T random data" mode.
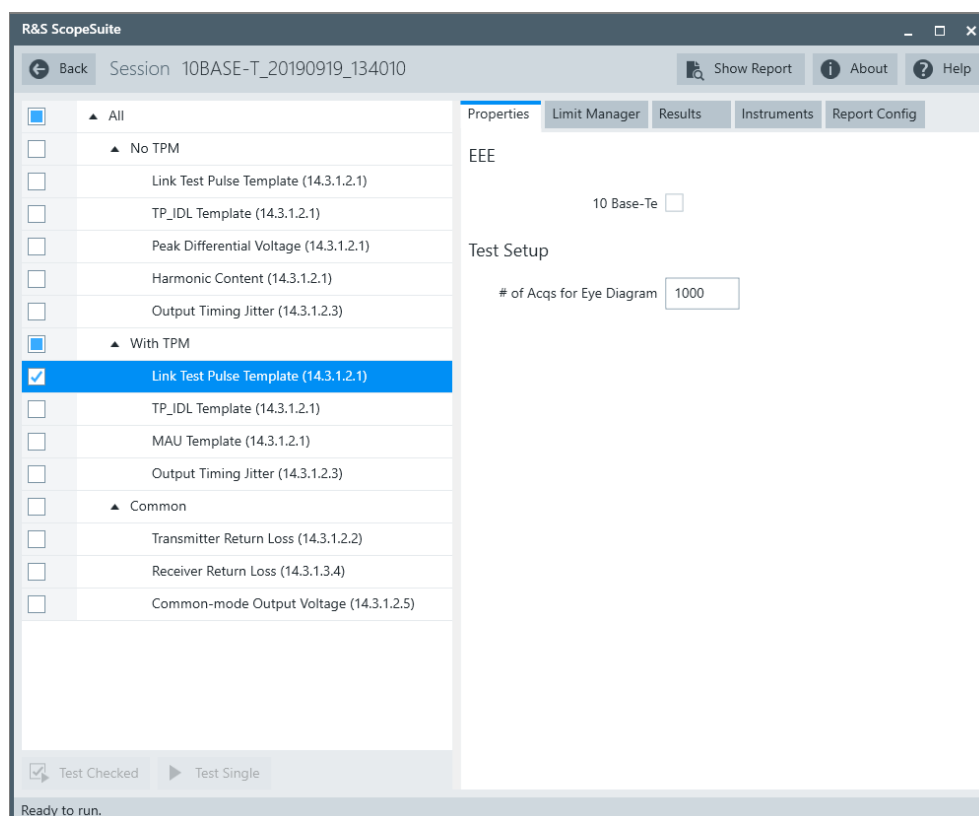
The waveforms displayed on the R&S RTO/RTO6/RTP should look similar to the pictures below.
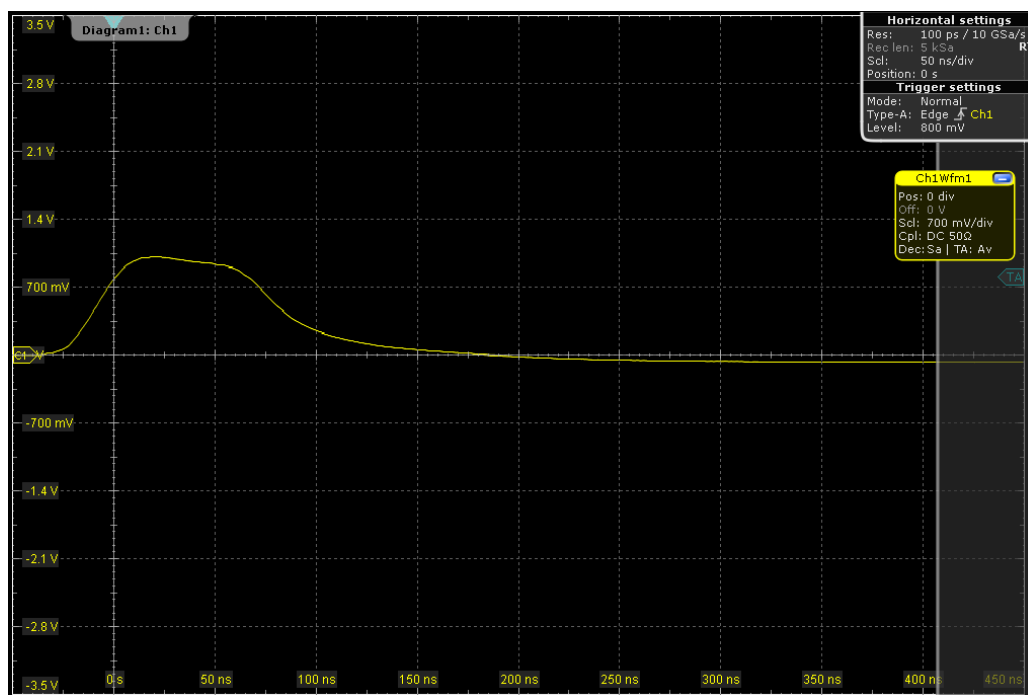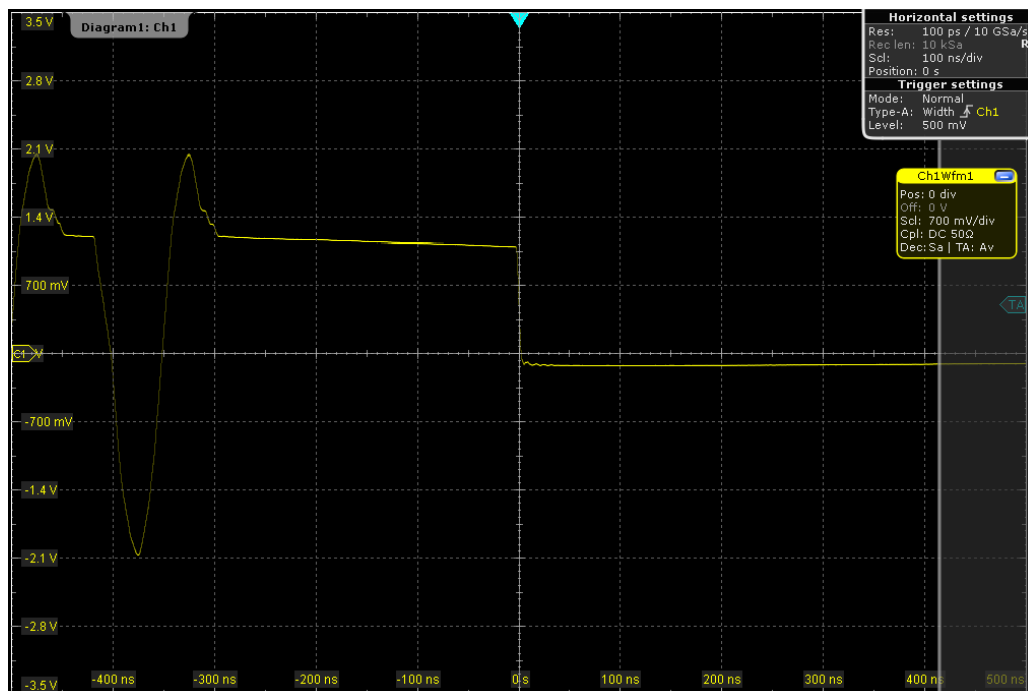
Figure 6-5: Waveform with load 1

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 802.3-2012, subclause 14.3.1.2.1. The test has been passed if the waveform did not violate the mask.

6.3.2 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 802.3-2012, subclause 14.3.1.2.1. The measurements are made with and without twisted-pair model (TPM), each with three different loads.

6.3.2.1 Test equipment

Table 6-3: Equipment for all TP_IDL template tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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

6.3.2.2 No TPM

Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

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 23

Measurements

Configure the DUT to "10BASE-T random data" mode.
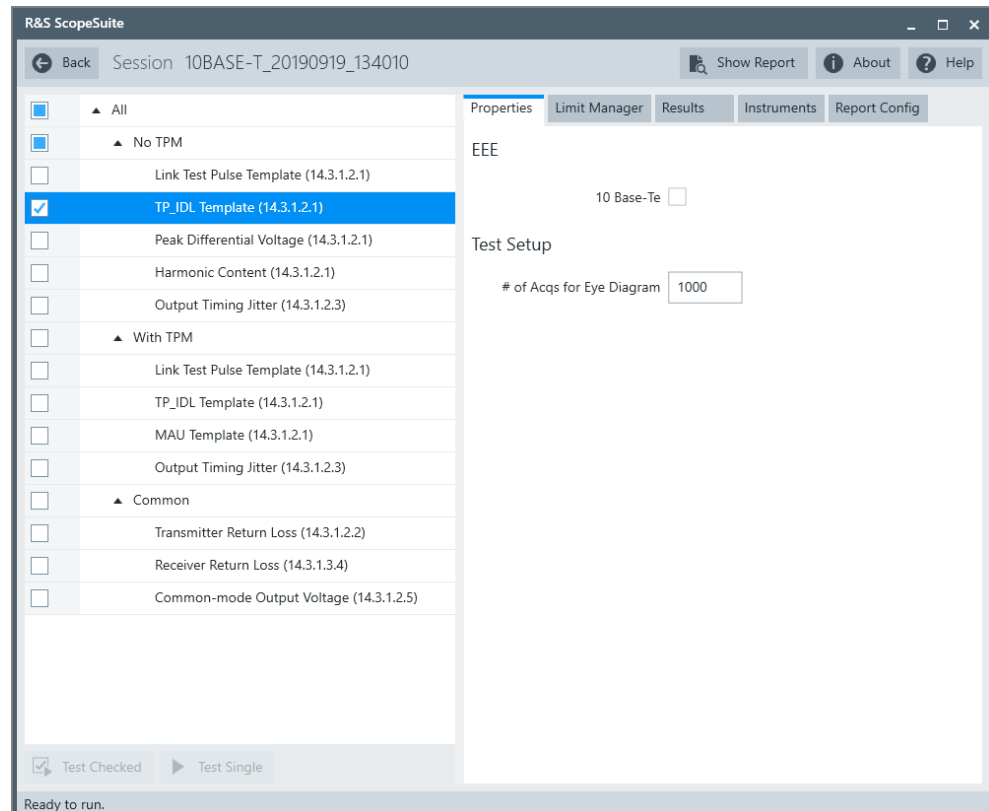
The waveforms displayed on the R&S RTO/RTO6/RTP should look similar to the pictures below.
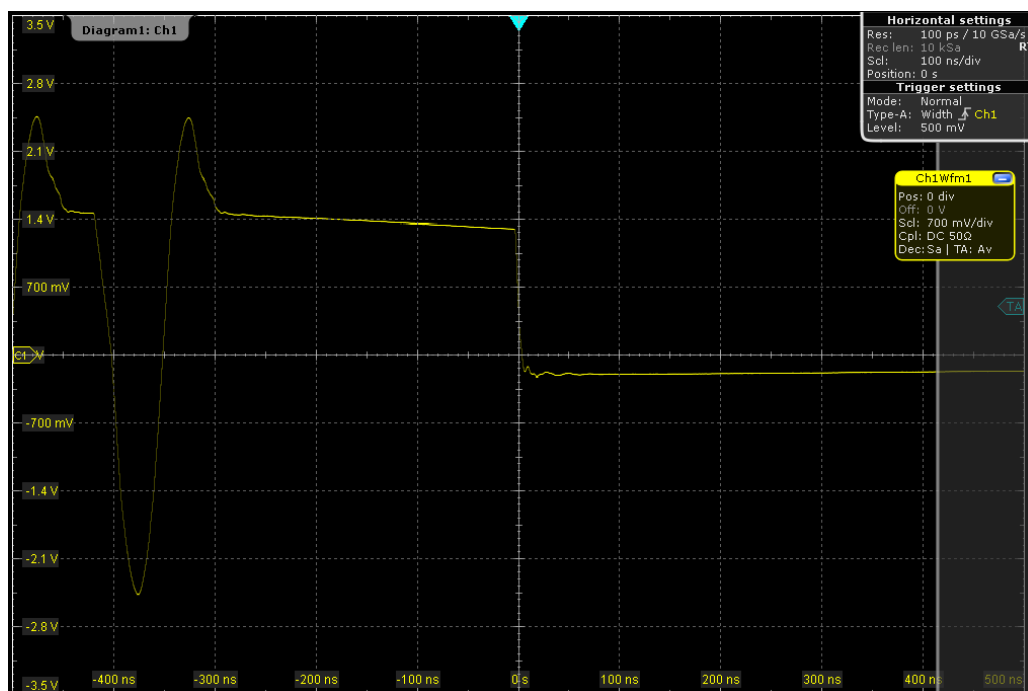
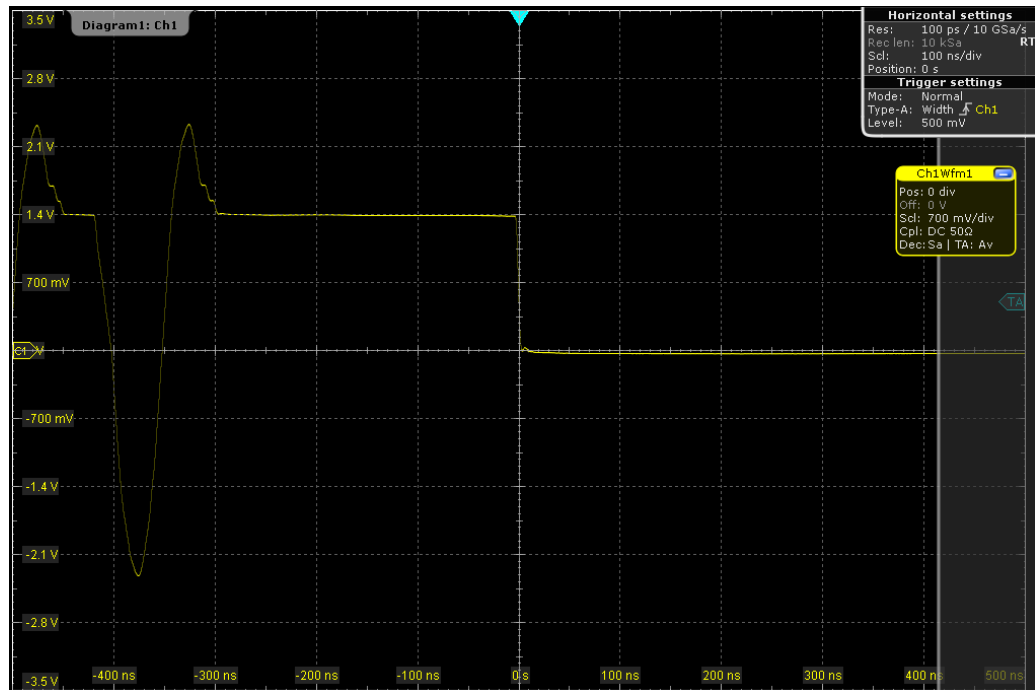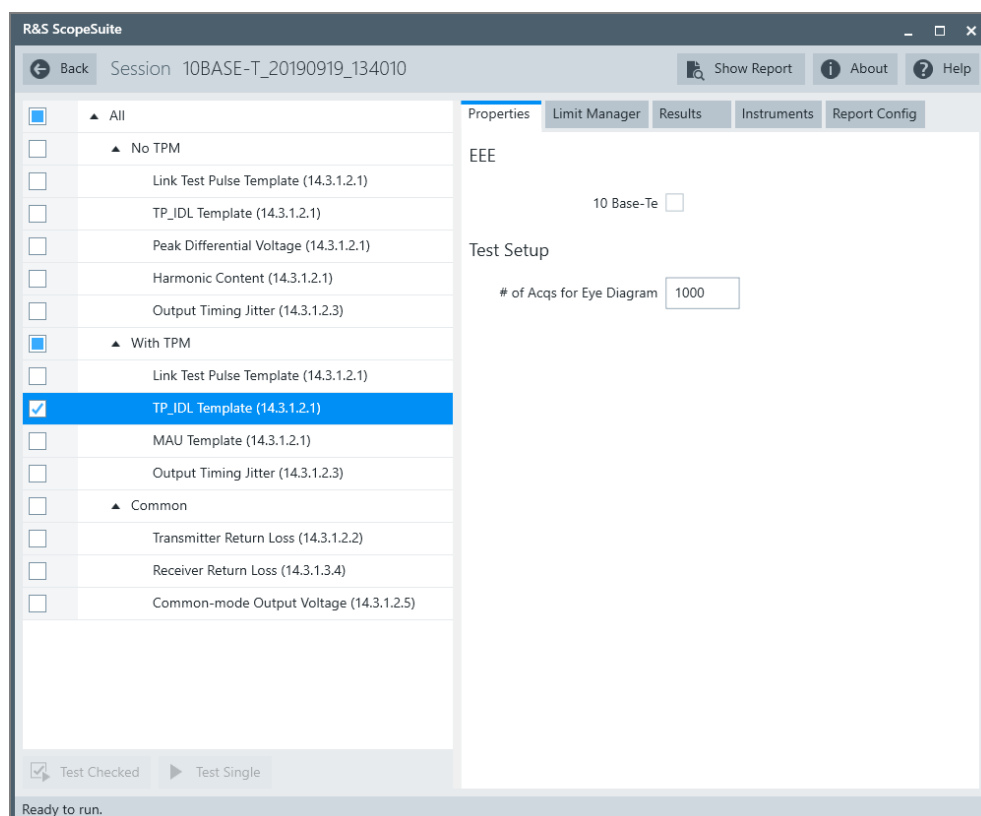*Figure 6-8: Waveform with load 1*

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 802.3-2012, subclause 14.3.1.2.1. The test has been passed if the waveform did not violate the mask.

6.3.2.3　With TPM

Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

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 23

Measurements

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

The waveforms displayed on the R&S RTO/RTO6/RTP should look similar to the pictures below.
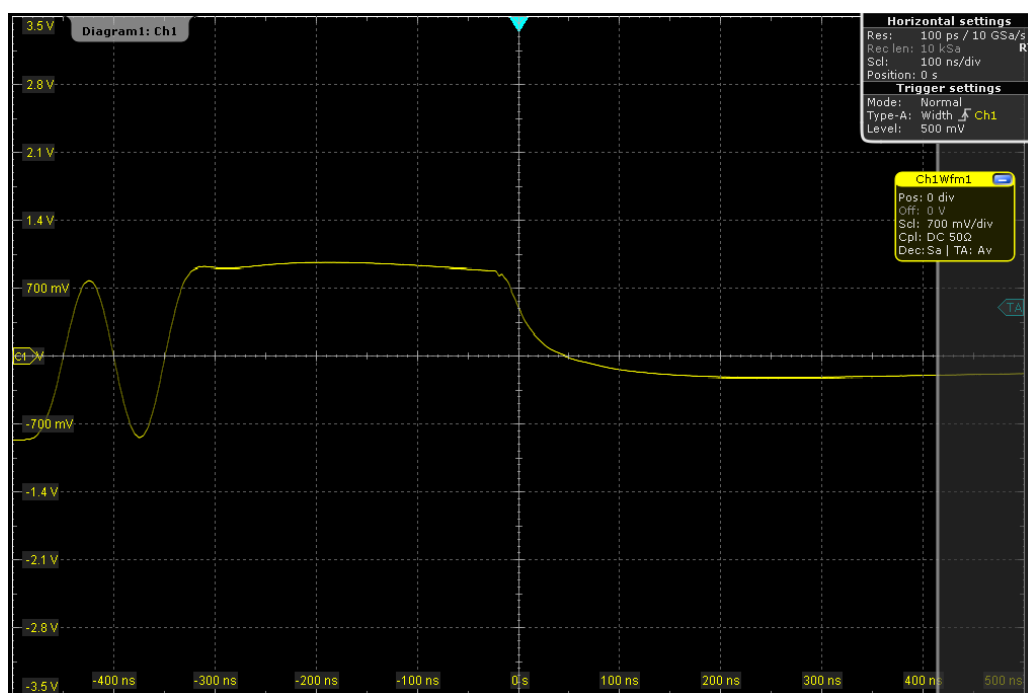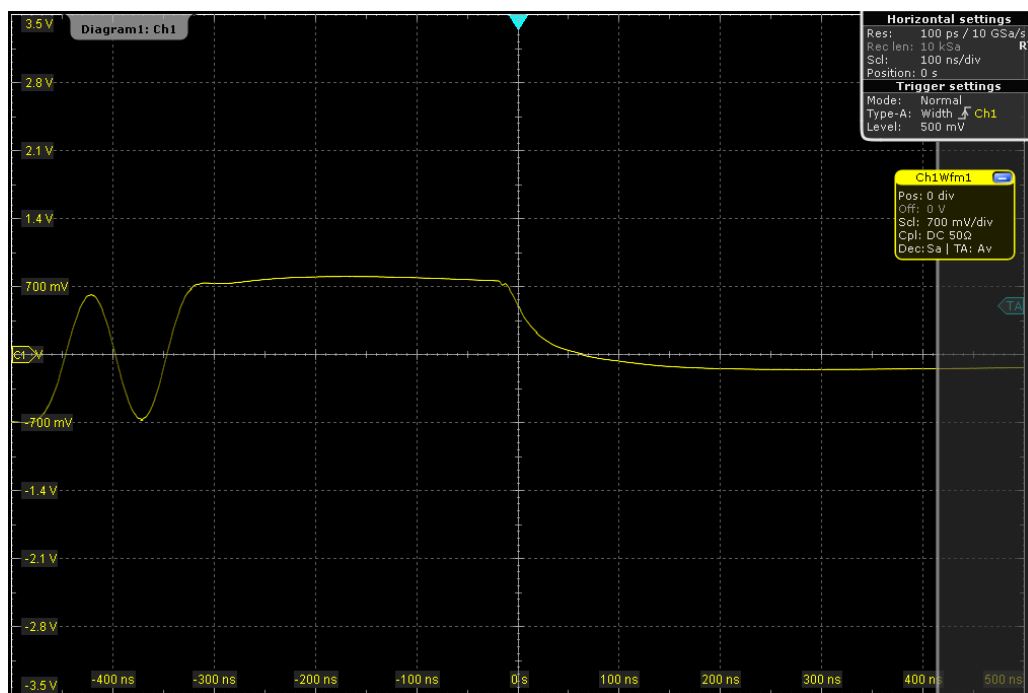
Figure 6-11: Waveform with load 1
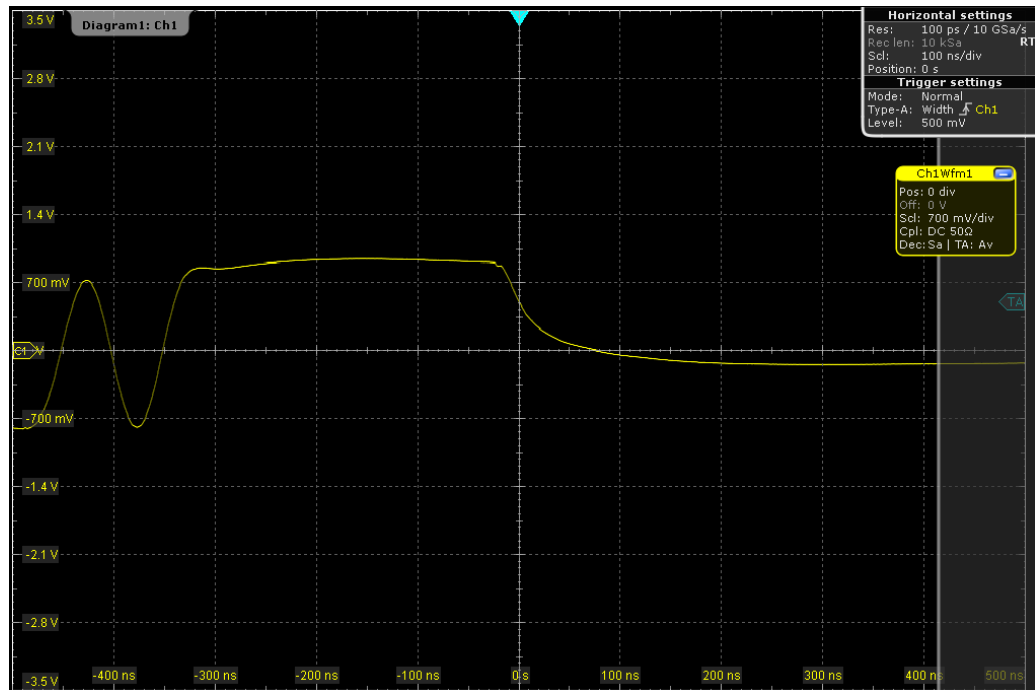

Figure 6-12: Waveform with load 2

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 802.3-2012, subclause 14.3.1.2.1. The test has been passed if the waveform did not violate the mask.

6.3.3 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.
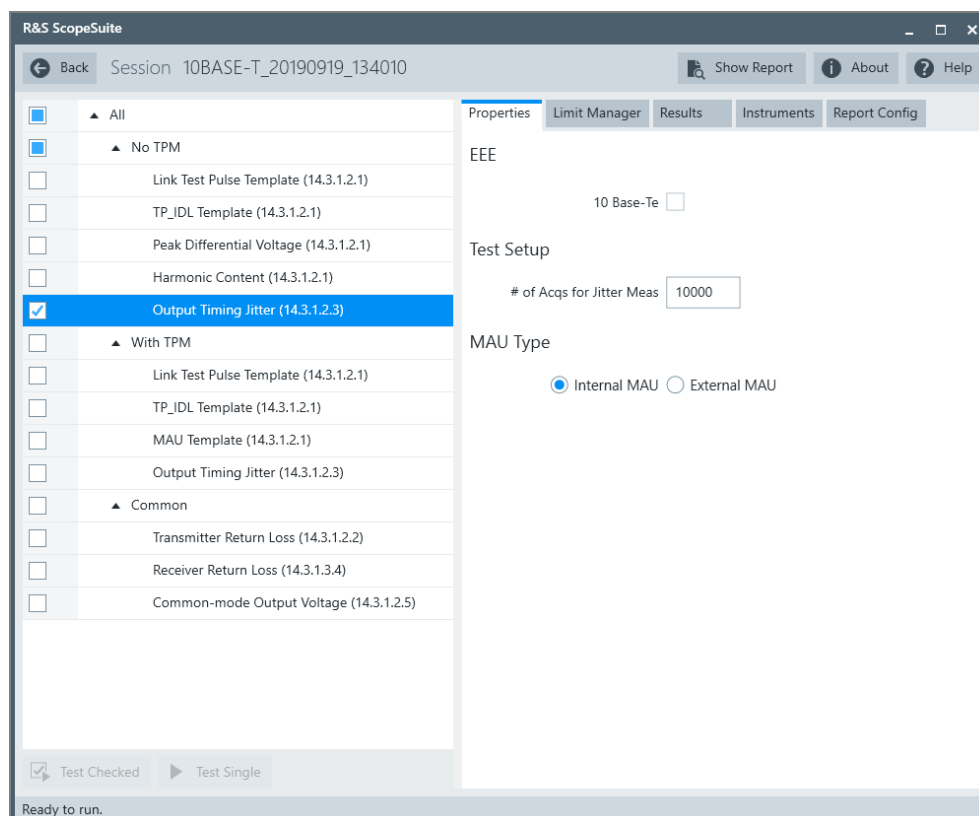
6.3.3.1 Test equipment

Table 6-4: Equipment for all Output Timing Jitter tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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

6.3.3.2 No TPM

Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

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 23

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. Those values are the minimum and maximum deviation from the ideal edge location.

- The oscilloscope measures the jitter at 8.5 BT in the same way.

6.3.3.3 With TPM

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)".
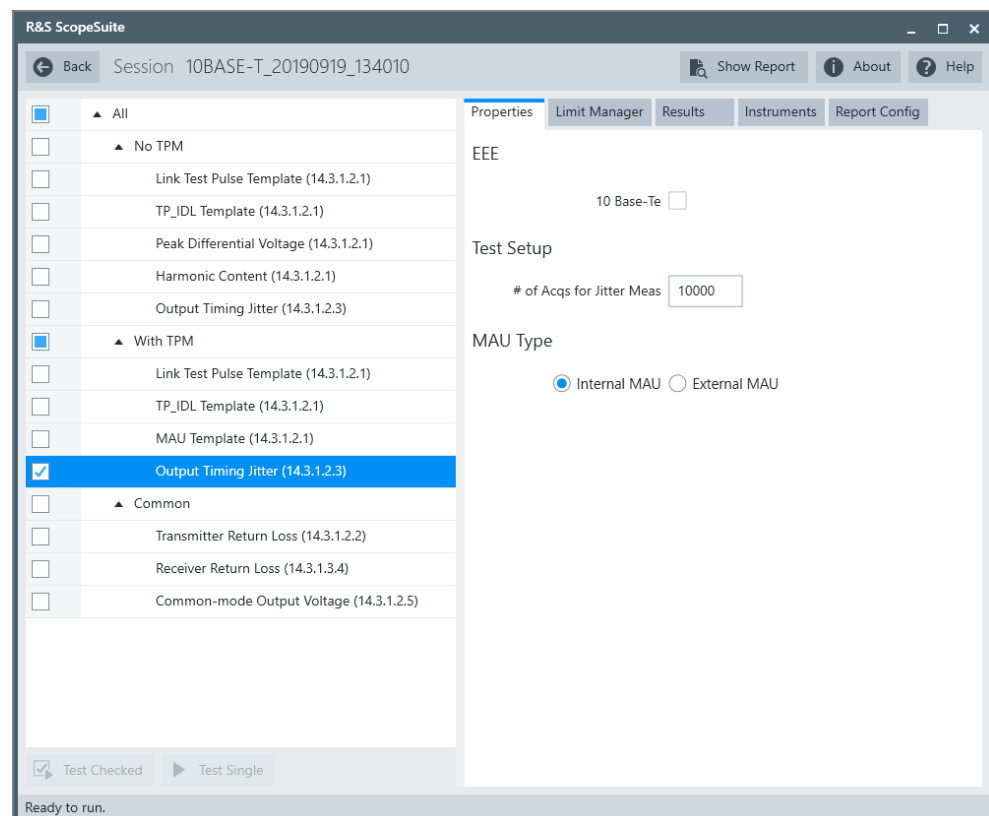
3. Click "Test Single".

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 23

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 measurements are the same as without TPM, see "Measurements" on page 126.

6.3.4 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 802.3-2012, subclause 14.3.1.2.1.

6.3.4.1 Test equipment

Table 6-5: Equipment for Peak Differential Voltage test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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

6.3.4.2 Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. Under "No TPM", select "Peak Differential Voltage (14.3.1.2.1)".
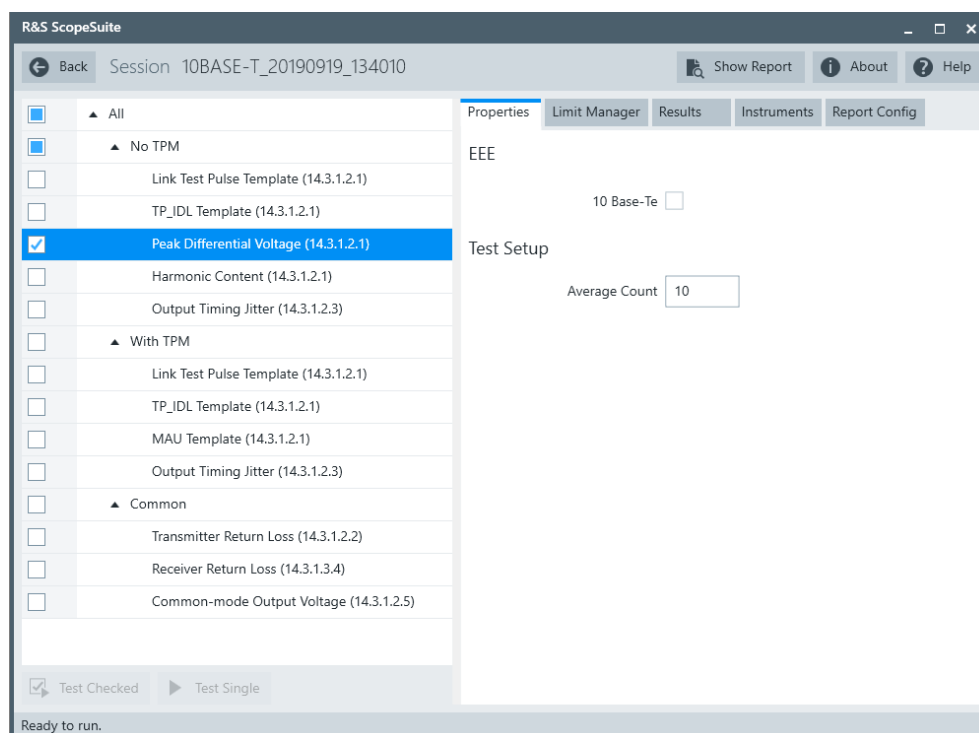
3. Click "Test Single".

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 23

6.3.4.3 Measurements

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

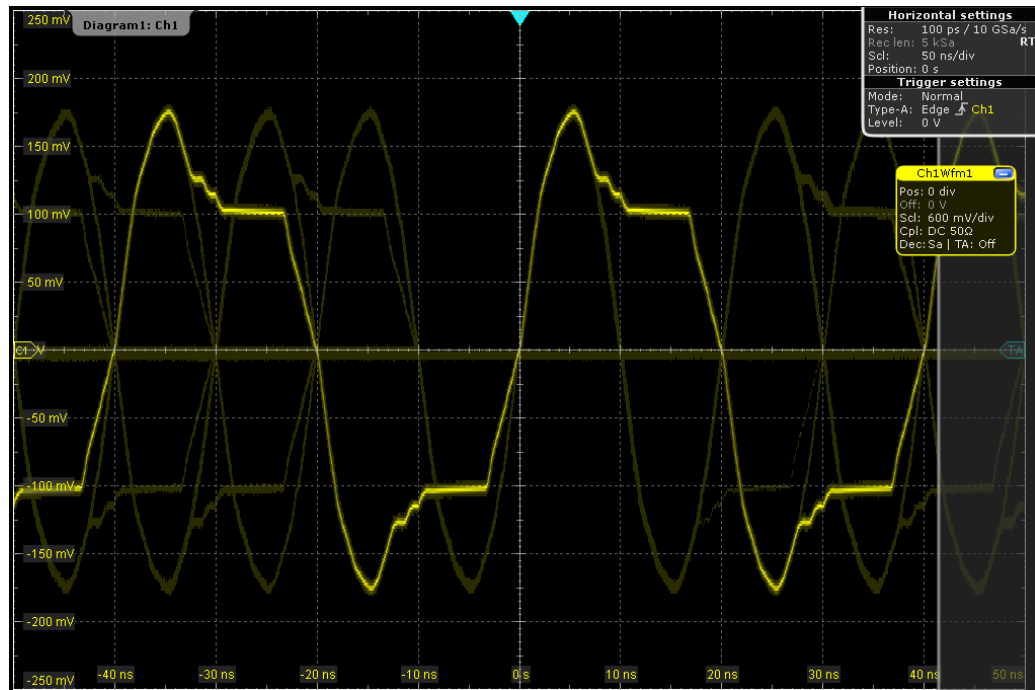The waveform displayed on the R&S RTO/RTO6/RTP should look similar to the picture below.

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).

6.3.5 Harmonic content

The "Harmonic Content" test verifies that any harmonic measured on the TD circuit is at least 27 dB below the fundamental. The harmonic content is measured without twisted-pair model (TPM), optionally with link partner.

6.3.5.1 Test equipment

Table 6-6: Equipment for Harmonic Content test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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

6.3.5.2 Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. Under "No TPM", select "Harmonic Content (14.3.1.2.1)".
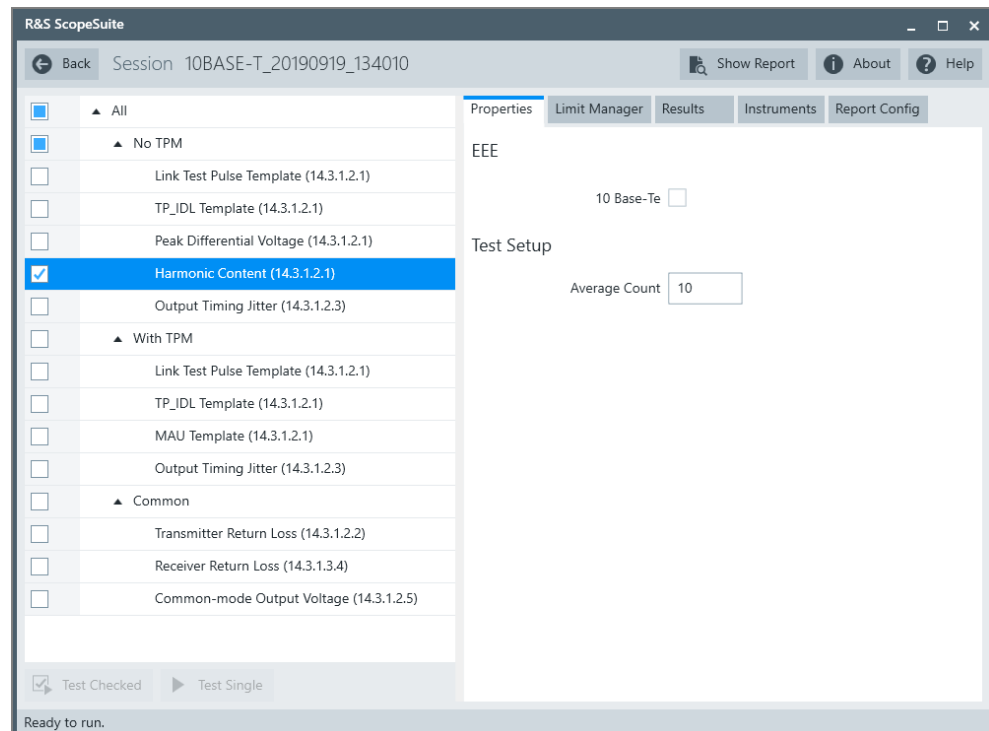
3. Click "Test Single".

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 23

6.3.5.3 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 an 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.

6.3.6 MAU template

The" MAU Template" test verifies that the differential output waveform of the DUT fits into the voltage template specified in IEEE Std 802.3-2012 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).

6.3.6.1 Test equipment

Table 6-7: Equipment for MAU template test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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

6.3.6.2 Performing the test

1. Start the test as described in
2. Under "With TPM", select "MAU Template (14.3.1.2.1)".
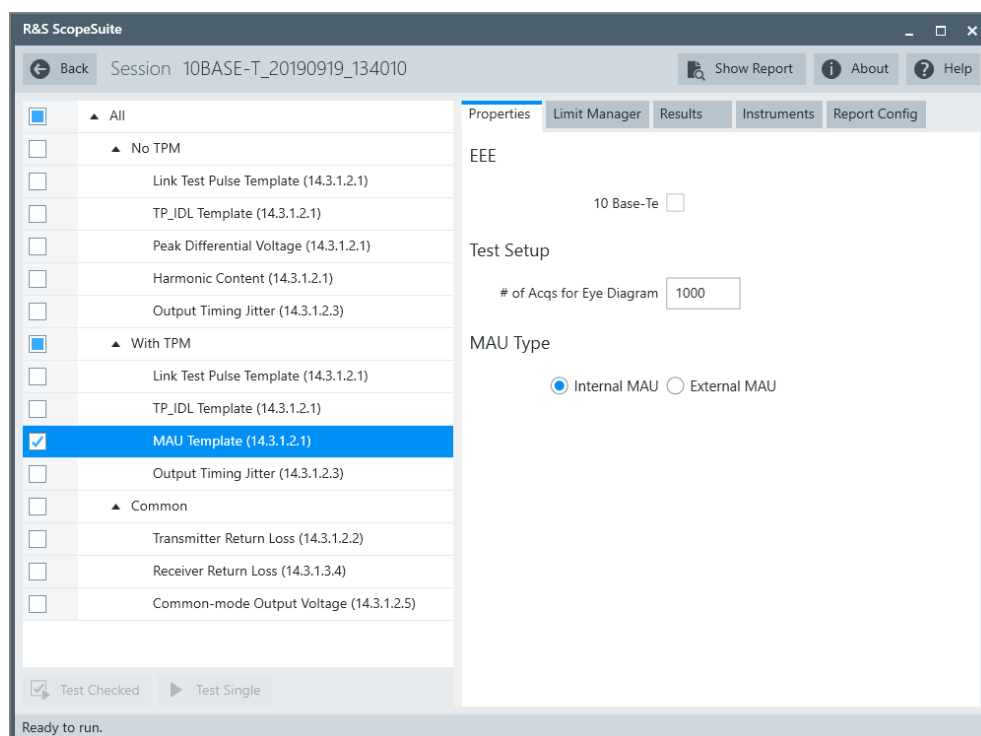
3. Click "Test Single".

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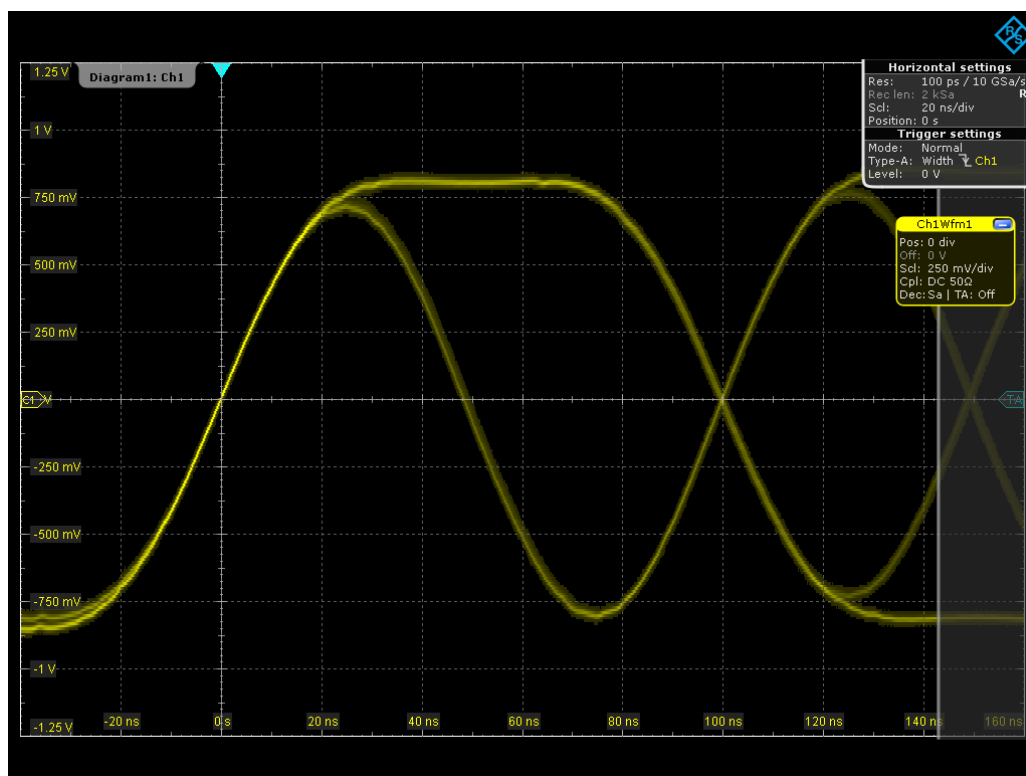   When you have finished all steps, the compliance test runs automatically.

Further steps:

● Chapter 3.3, "Getting test results", on page 23

6.3.6.3 Measurements

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

The waveform displayed on the R&S RTO/RTO6/RTP should look similar to the picture below.

The oscilloscope creates a mask according to the template specified in figure 14-9 of IEEE 802.3-2012, 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.

6.3.7 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 MHz to 10 MHz as specified in IEEE 802.3-2012 subclause 14.3.1.2.2.

6.3.7.1 Test equipment

Table 6-8: Equipment for Transmitter Return Loss

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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 ZNB/ZNC/ZND/ZVL	1
DUT	the device you want to test	1

6.3.7.2 Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. Under "Common", select "Transmitter Return Loss (14.3.1.2.2)".
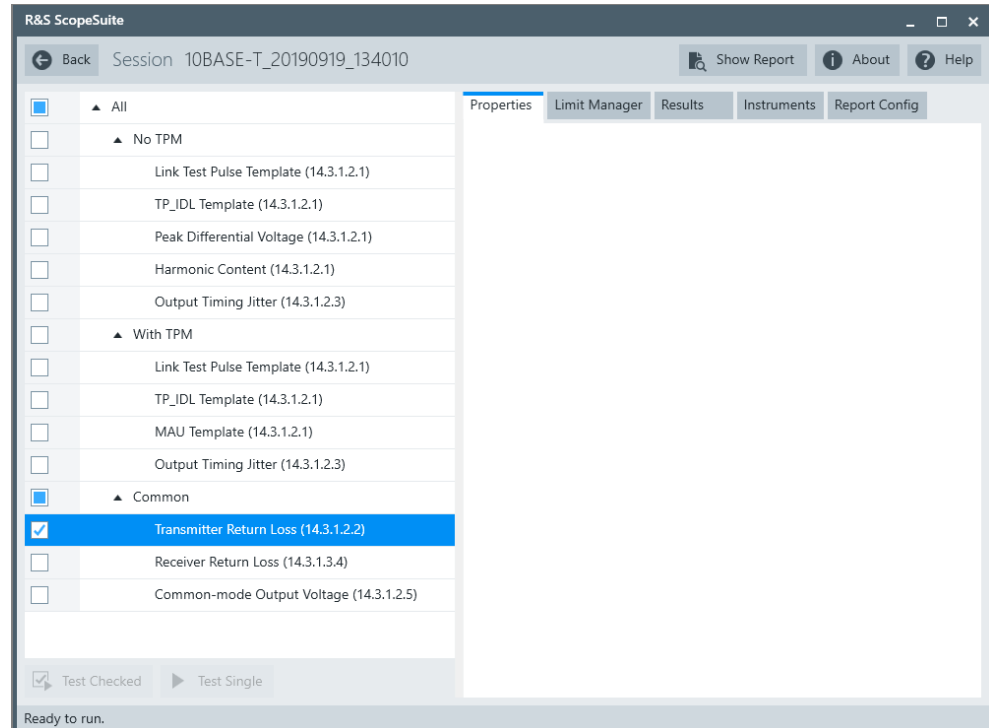
3. Click "Test Single".

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 23

6.3.7.3 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 MHz 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.

6.3.8 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 MHz to 10 MHz as specified in IEEE 802.3-2012 subclause 14.3.1.3.4.

6.3.8.1 Test equipment

Table 6-9: Equipment for Receiver Return Loss tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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 ZNB/ZNC/ZND/ZVL	1
DUT	the device you want to test	1

6.3.8.2 Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. Under "Common", select "Receiver Return Loss (14.3.1.3.4)".
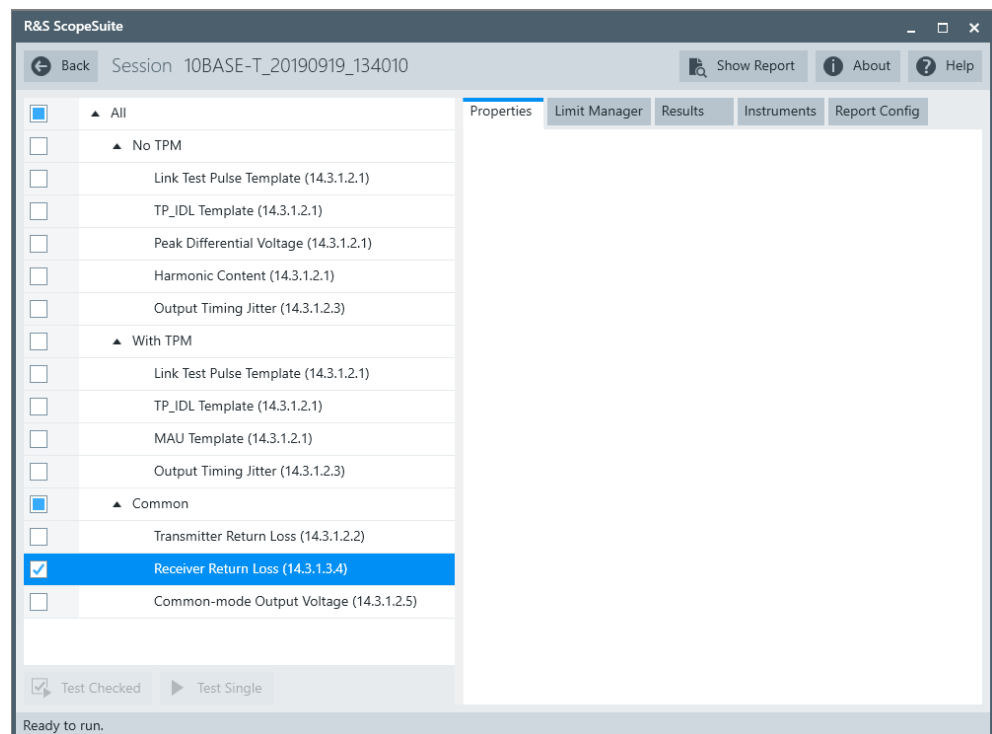
3. Click "Test Single".

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 23

6.3.8.3 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 MHz 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.

6.3.9 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.

6.3.9.1 Test equipment

Table 6-10: Equipment for Common-mode Output Voltage tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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

6.3.9.2 Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. Under "Common", select "Common-mode Output Voltage (14.3.1.2.5)".
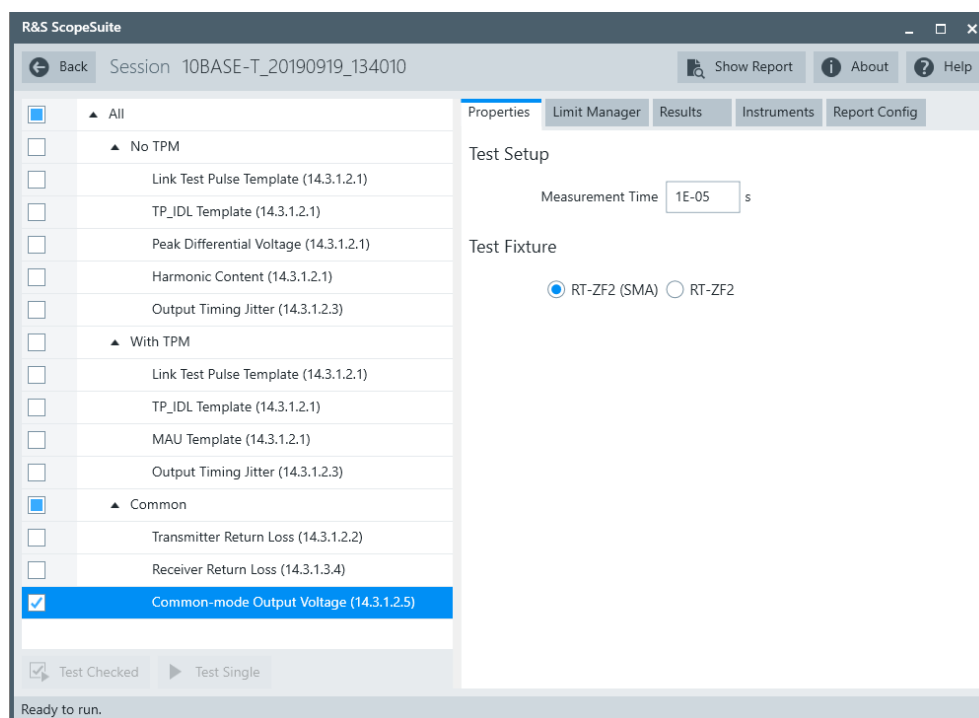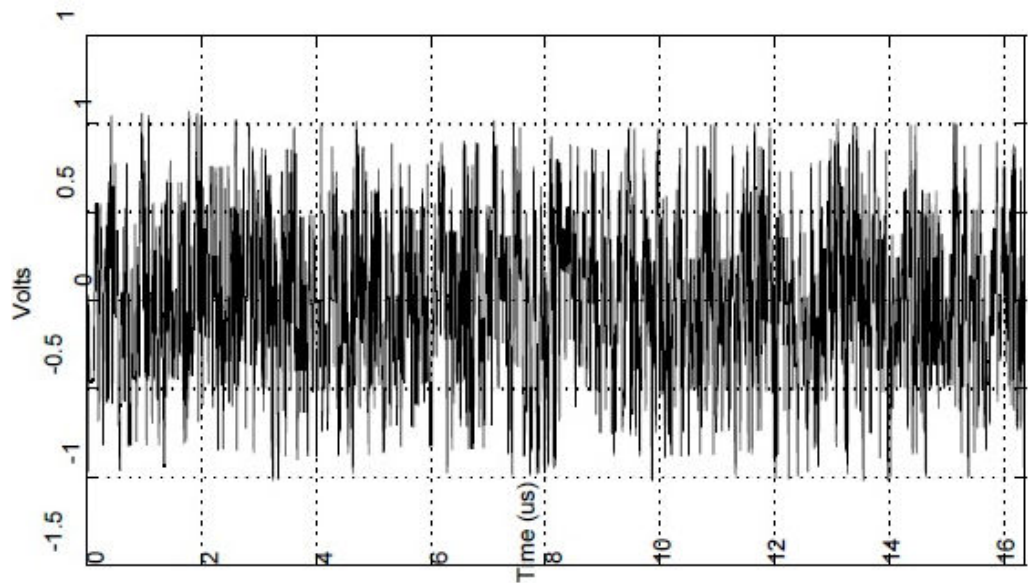
3. Click "Test Single".

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

Further steps:

6.3.9.3 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.

6.4 10BASE-Te tests

The following table shows an overview of the needed equipment for performing the 10BASE-Te test cases. A prerequisite is also a R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth, the R&S ScopeSuite software and a 10BASE-Te DUT.

Table 6-11: Equipment for 10BASE-Te Ethernet compliance tests

	Differential probe	Test fixture	Additional instruments
Link Test Pulse Template (14.3.1.2.1)	1 at least 1 GHz band-width	R&S RT-ZF4 Section: Twisted Pair Model	**Optional:** Link partner e.g., Intel PRO/100 GT Desktop Adapter **Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
TP_IDL Template (14.3.1.2.1)	1	R&S RT-ZF4 Section: Twisted Pair Model	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17

	Differential probe	Test fixture	Additional instruments
Output Timing Jitter (14.3.1.2.3)	1	R&S RT-ZF4 Section: Twisted Pair Model	**Optional:** Link partner e.g., Intel PRO/100 GT Desktop Adapter **Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Peak Differential Voltage (14.3.1.2.1)	1	R&S RT-ZF4 Section: Twisted Pair Model	**Optional:** Link partner e.g., Intel PRO/100 GT Desktop Adapter **Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Harmonic Content (14.3.1.2.1)	1	R&S RT-ZF4 Section: Twisted Pair Model	**Optional:** Link partner e.g., Intel PRO/100 GT Desktop Adapter **Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
MAU Template	1	R&S RT-ZF2 Section: Twisted Pair Model	**Optional:** Link partner e.g., Intel PRO/100 GT Desktop Adapter **Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Transmitter Return Loss (14.3.1.2.2)	1	R&S RT-Z4 Section: Twisted Pair Model	**VNA:** R&S ZNB or R&S ZNC or R&S ZND or R&S ZVL
Receiver Return Loss (14.3.1.3.4)	1	R&S RT-ZF4 Section: Twisted Pair Model	**Optional VNA:** R&S ZNB or R&S ZNC or R&S ZND or R&S ZVL
Common-mode Output Voltage (14.3.1.2.5)	1	R&S RT-ZF4 Section: Common Mode Voltage	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17

6.4.1 Link test pulse template

The "Link Test Pulse Template" tests verify that the link test pulse waveform fits into the template specified in figure 14-13 of IEEE 802.3-2012, subclause 14.3.1.2.1. The measurements are made with and without twisted-pair model (TPM), each with three different loads.
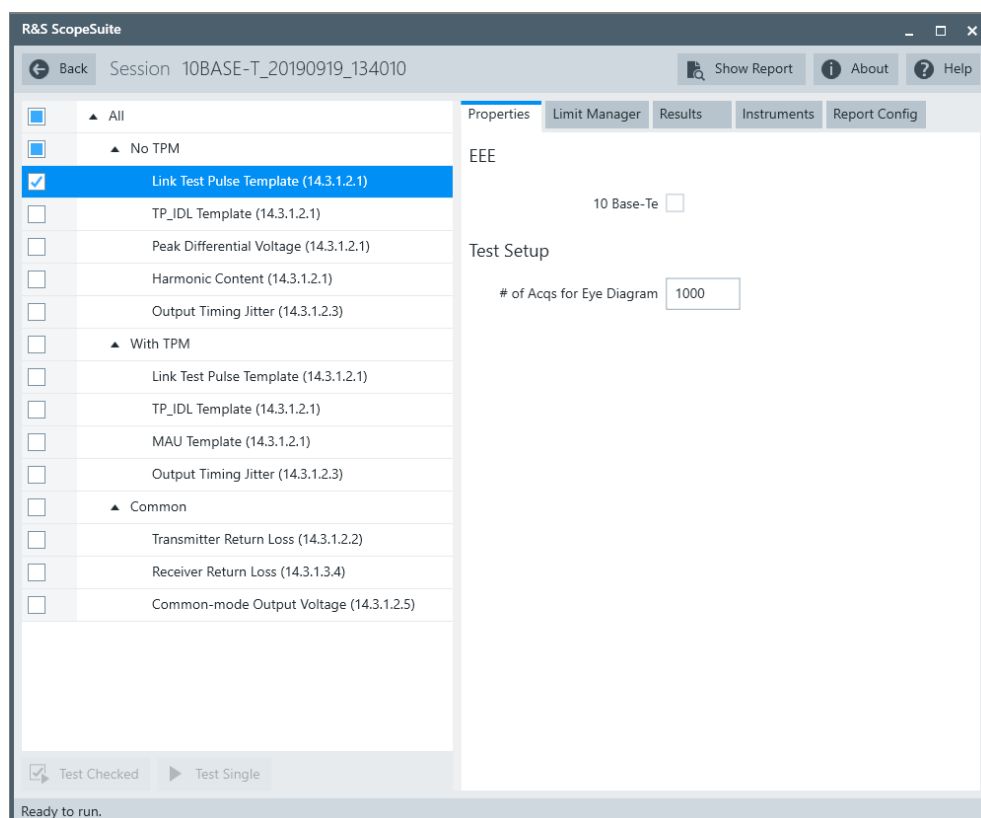
6.4.1.1 Test equipment

Table 6-12: Equipment for all Link Test Pulse Template tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF4	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

6.4.1.2 No TPM

Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. In the "Properties" tab, enable "10 Base-Te".

3. Under "No TPM", select "Link Test Pulse Template (14.3.1.2.1)".

4. Click "Test Single".

5. 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 23

Measurements

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

The waveforms displayed on the R&S RTO/RTO6/RTP should look similar to the pictures below.
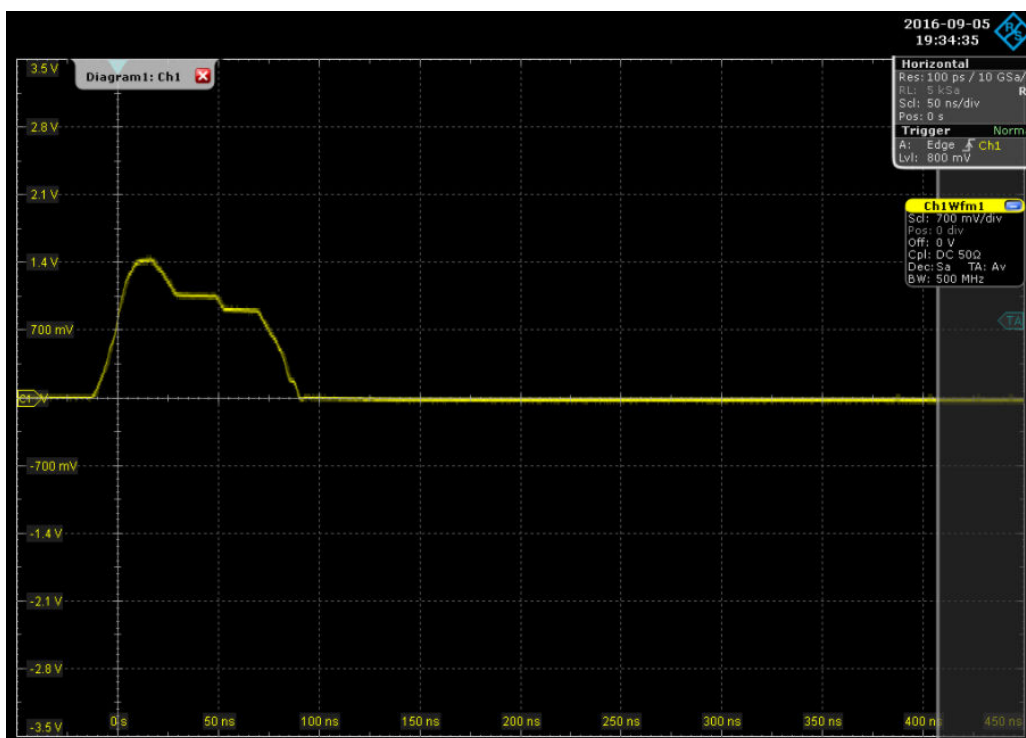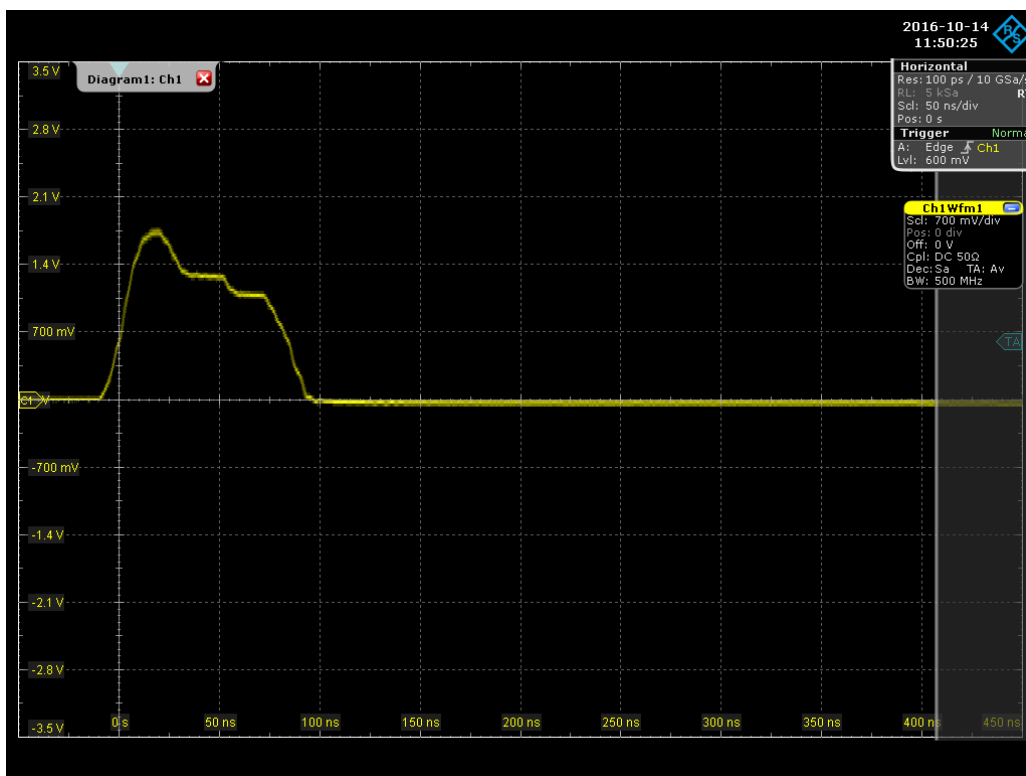
Figure 6-15: Waveform with load 1
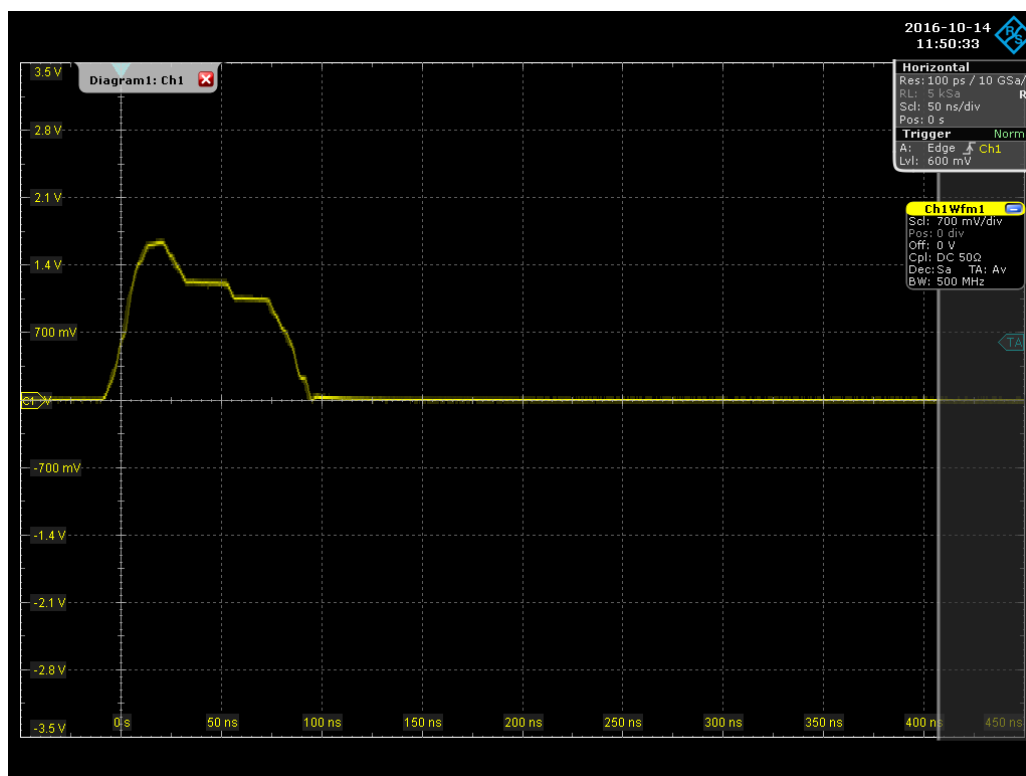

Figure 6-16: Waveform with load 2
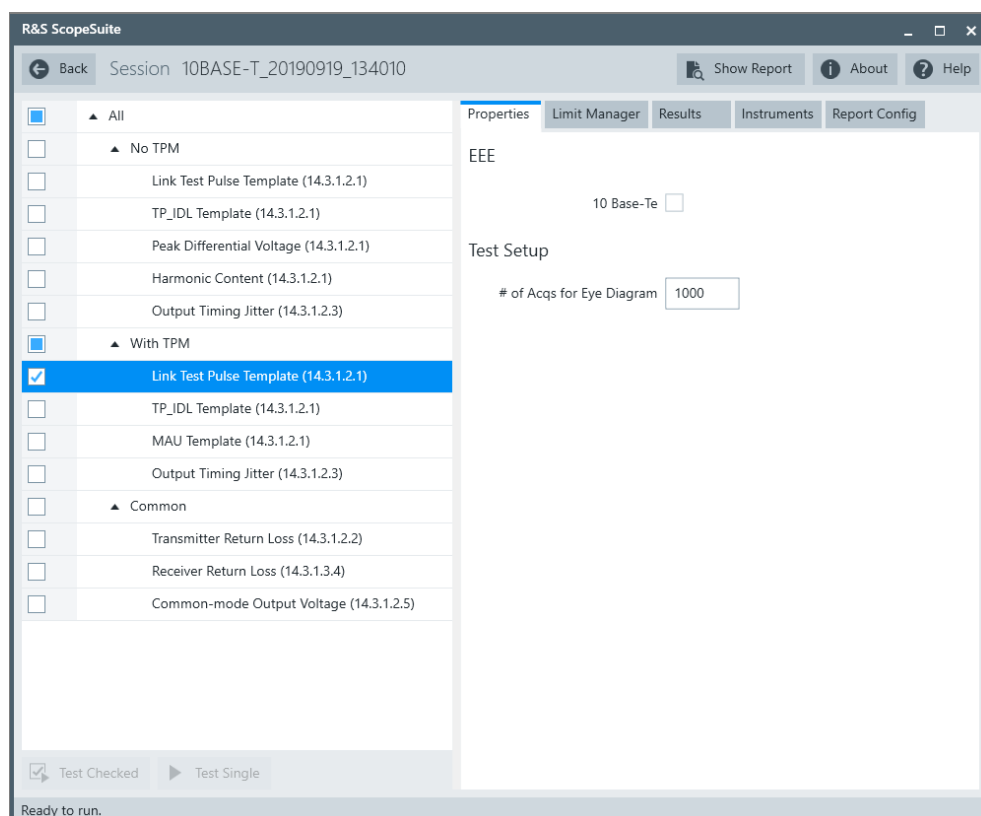
Figure 6-17: Waveform with load 100 Ω

The test procedure is the same for each load. A mask is created according to the template specified in figure 14-13 of IEEE 802.3-2012, section1, subclause 14.3.1.2.1. The test has been passed if the waveform did not violate the mask.

6.4.1.3 With TPM

Performing the test

1. Start the test as described in

2. In the "Properties" tab, enable "10 Base-Te".

3. Under "With TPM", select "Link Test Pulse Template (14.3.1.2.1)".

4. Click "Test Single".

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

Further steps:

●

Measurements

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

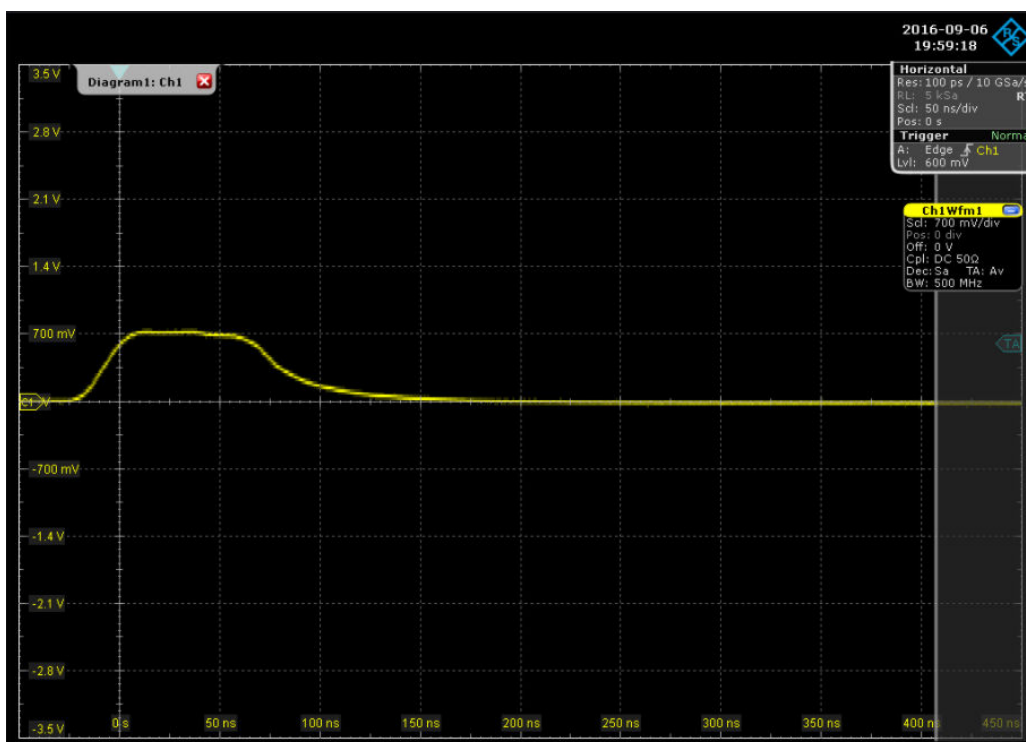The waveforms displayed on the R&S RTO/RTO6/RTP should look similar to the pictures below.
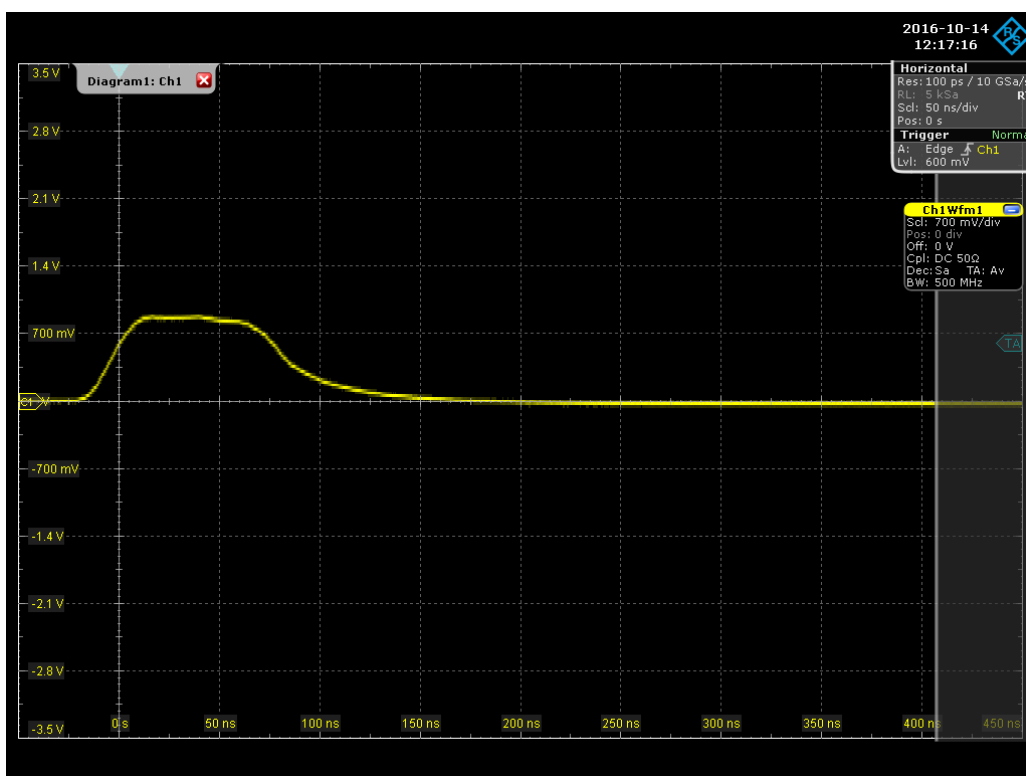
Figure 6-18: Waveform with load 1

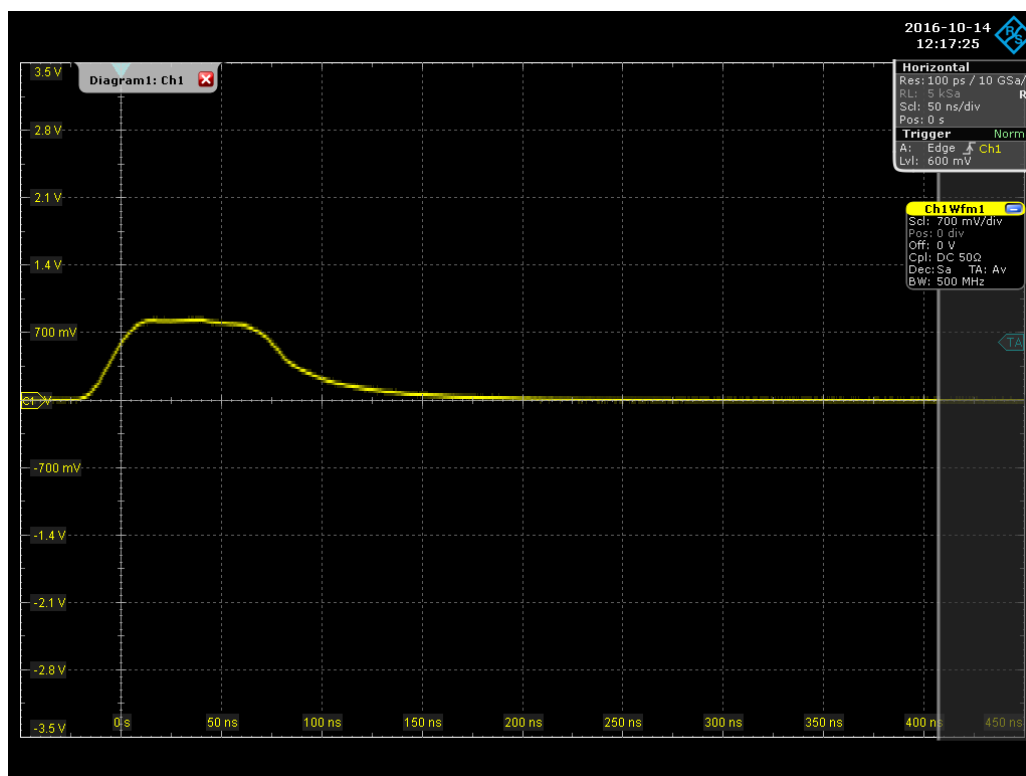

Figure 6-19: Waveform with load 2

Figure 6-20: 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 14-13 of IEEE 802.3-2012, section1, subclause 14.3.1.2.1. The test has been passed if the waveform did not violate the mask.

6.4.2 TP_IDL template

The "TP_IDL Template" tests verify that the TPL_IDL signal fits into the template specified in figure 14-11 of IEEE 802.3-2012, section1, subclause 14.3.1.2.1. The measurements are made with and without twisted-pair model (TPM), each with three different loads.

6.4.2.1 Test equipment

Table 6-13: Equipment for all TP_IDL Template tests
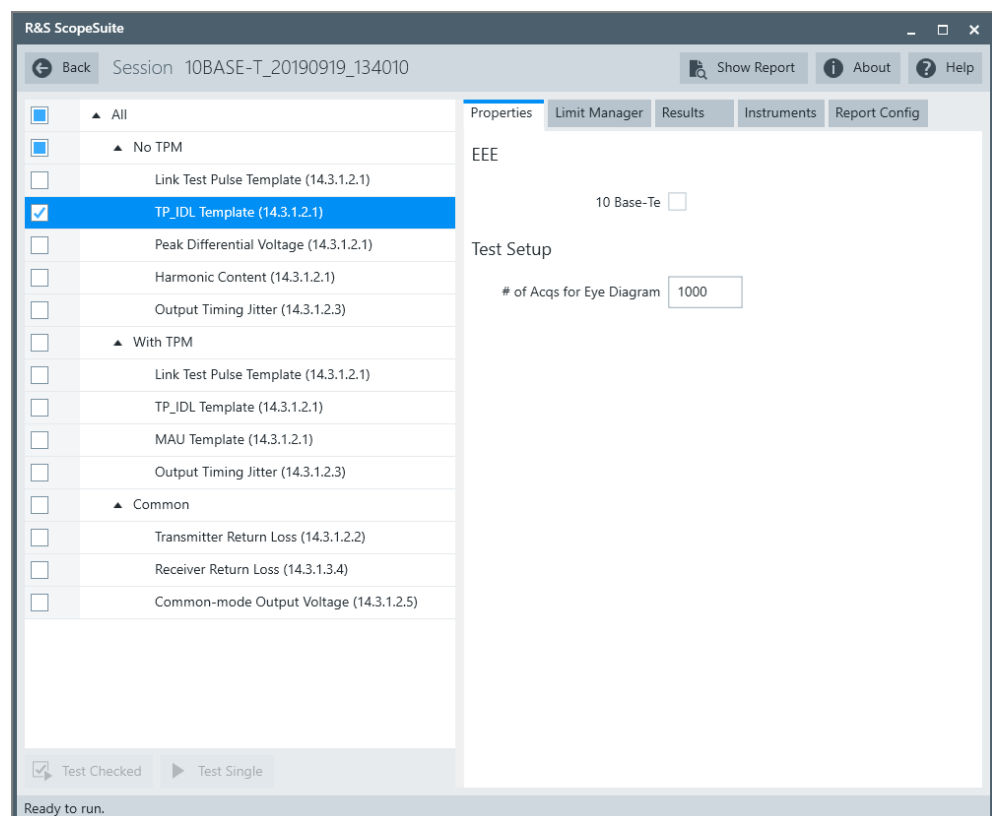
Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF4	1
Differential probe	at least 1 GHz bandwidth	1

Item	Description, model	Quantity
DUT	the device you want to test	1
Link partner (optional)	e.g, Intel PRO/100 GT Desktop Adapter	1

6.4.2.2 No TPM

Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. In the "Properties" tab, enable "10 Base-Te".

3. Under "No TPM", select "TP_IDL Template (14.3.1.2.1)".

4. Click "Test Single".

5. 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 23

Measurements

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

The waveforms displayed on the R&S RTO/RTO6/RTP should look similar to the pictures below.

Figure 6-21: Waveform with load 1

Figure 6-22: Waveform with load 2

Figure 6-23: 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 14-11 of IEEE 802.3-2012, section1, subclause 14.3.1.2.1.The test has been passed if the waveform did not violate the mask.

6.4.2.3 With TPM

Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. In the "Properties" tab, enable "10 Base-Te".

3. Under "With TPM", select "TP_IDL Template (14.3.1.2.1)".

4. Click "Test Single".

5. 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 23

Measurements

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

The waveforms displayed on the R&S RTO/RTO6/RTP should look similar to the pictures below.
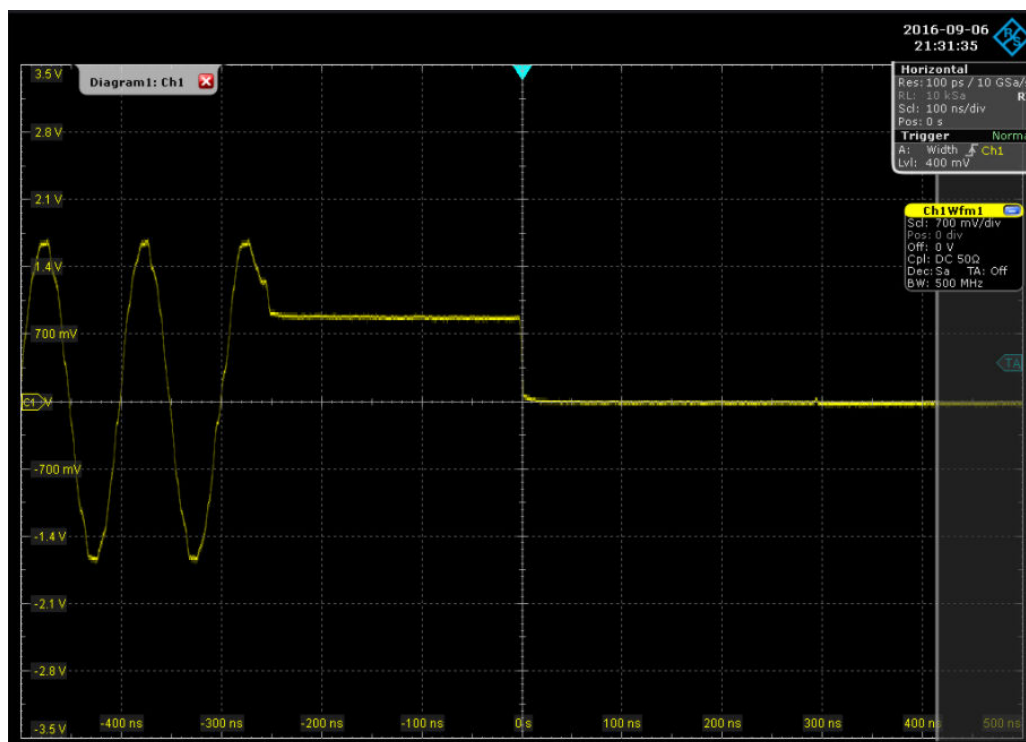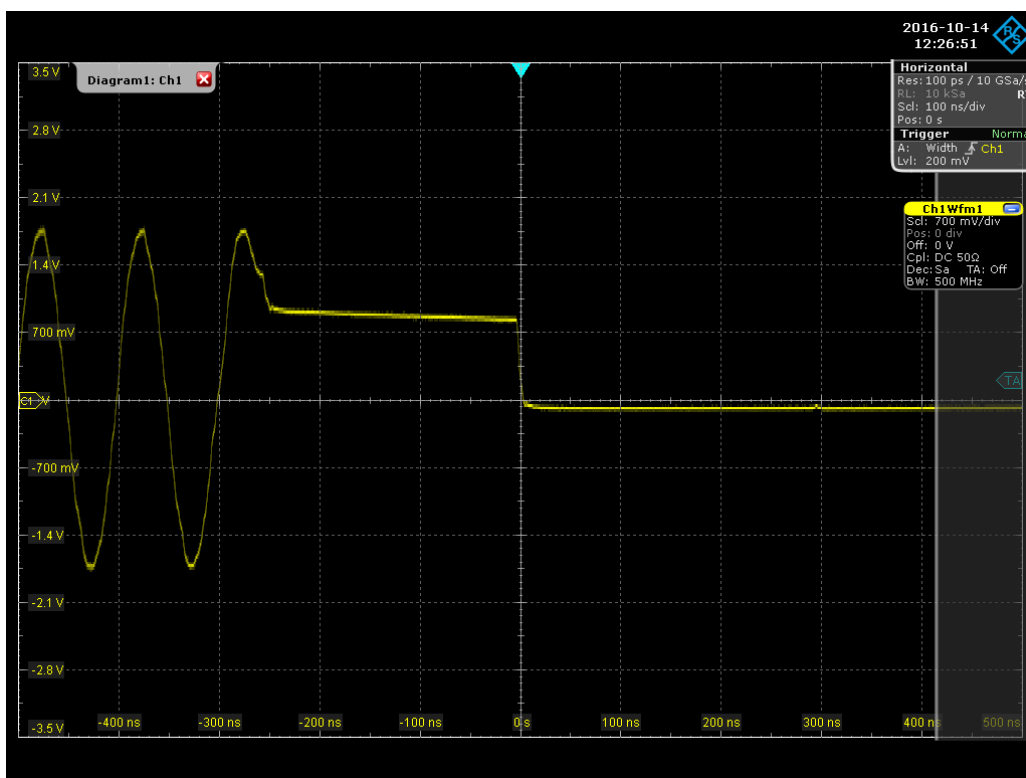

Figure 6-24: Waveform with load 1
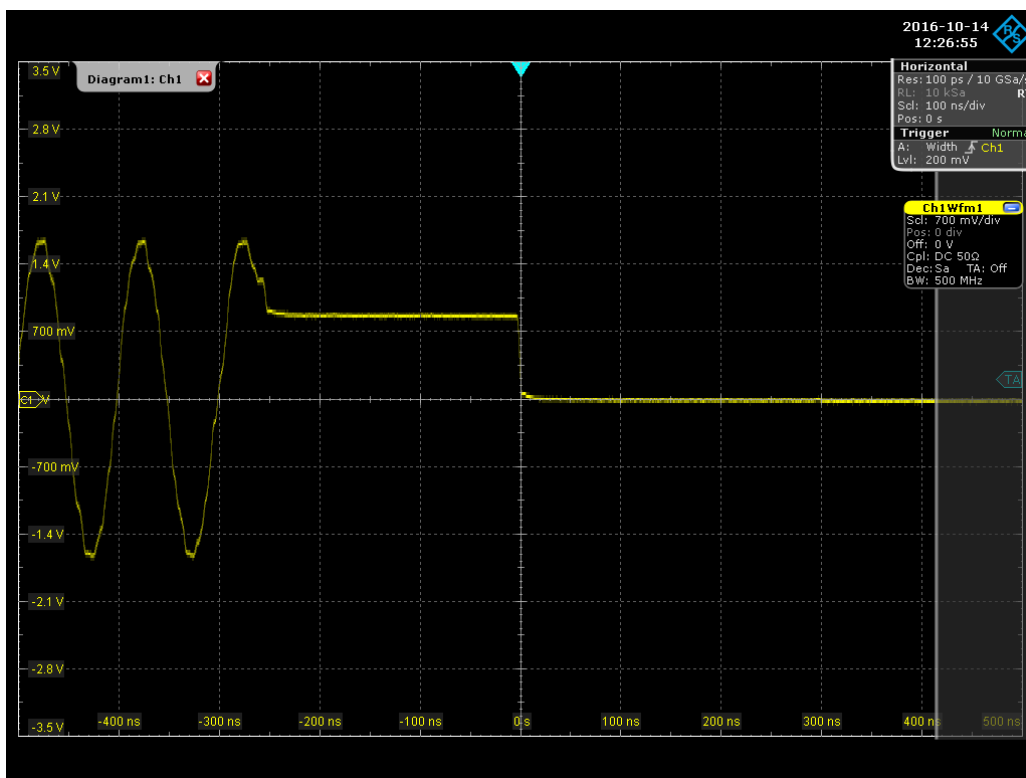
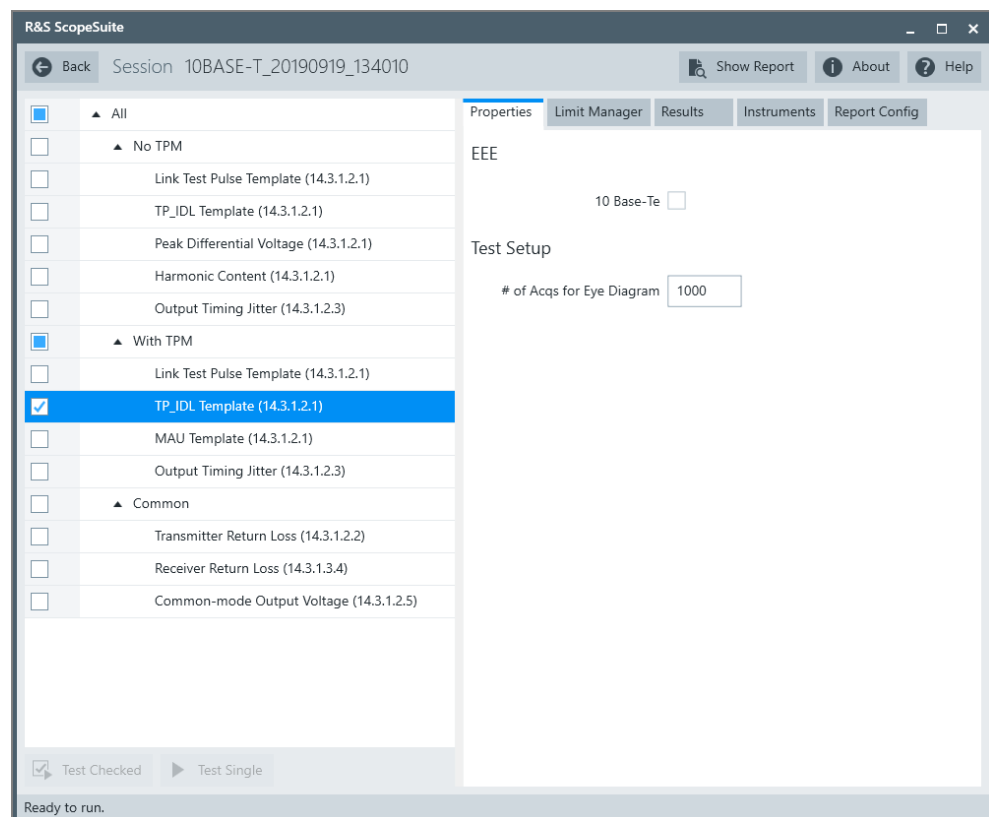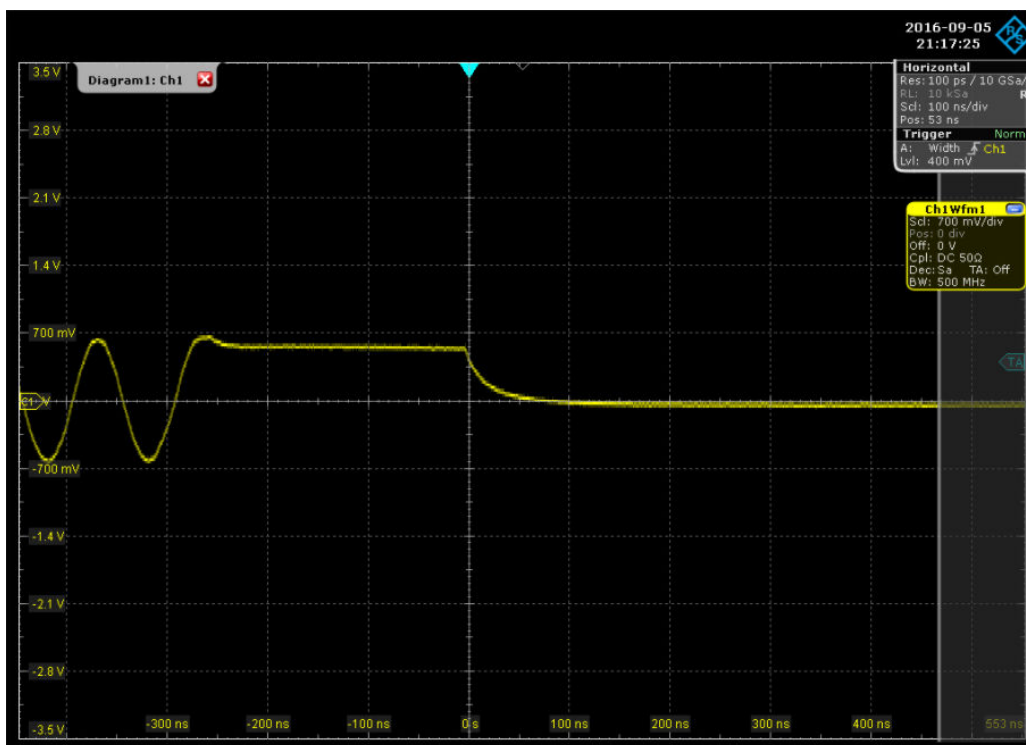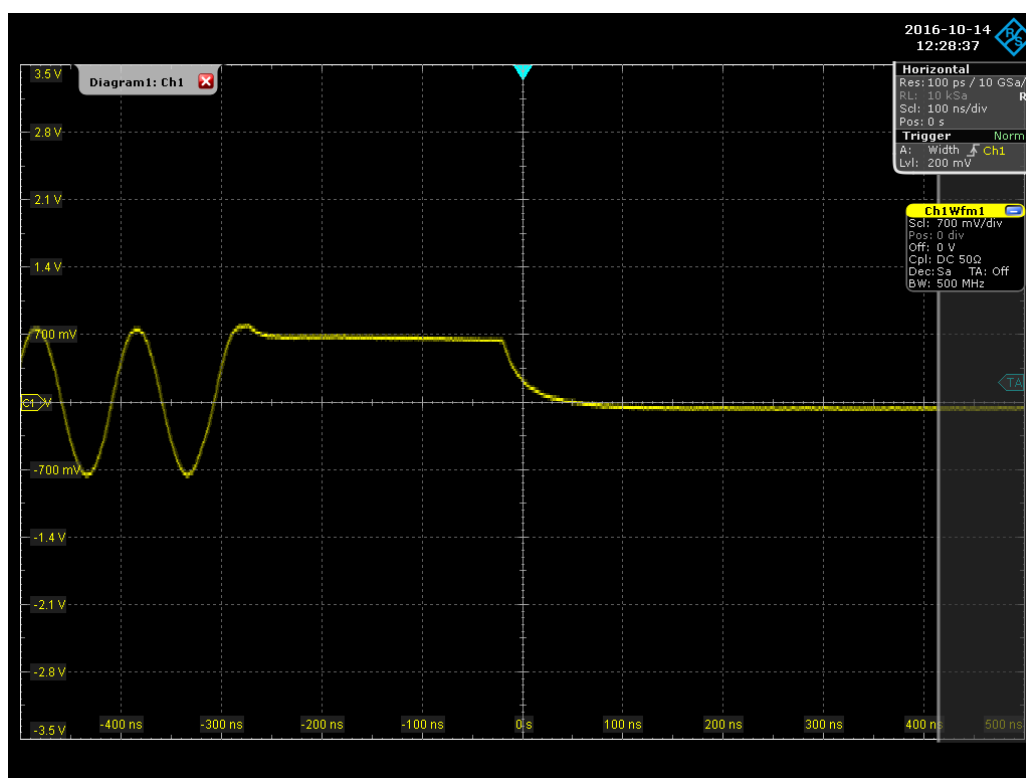*Figure 6-25: Waveform with load 2*
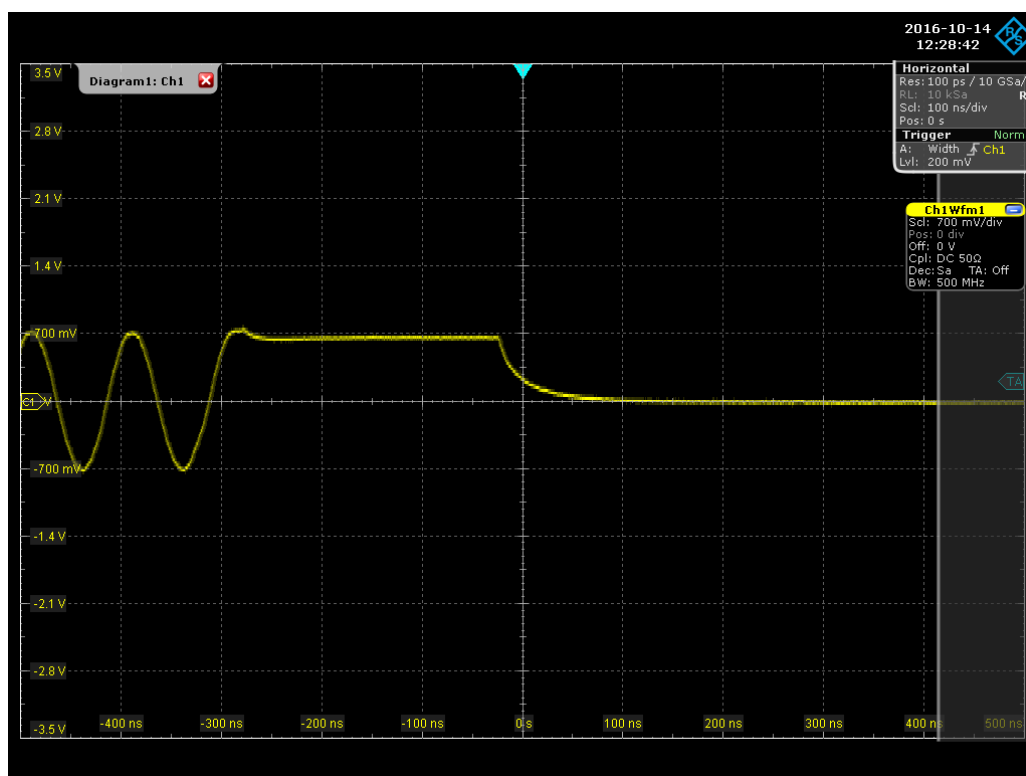
Figure 6-26: Waveform with load 100 Ω

The test procedure is the same for each load. A mask is created according to the template specified in figure 14-10 of IEEE 802.3-2012, subclause 14.3.1.2.1. The test has been passed if the waveform did not violate the mask.

6.4.3 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.

6.4.3.1 Test equipment

Table 6-14: Equipment for all Output Timing Jitter tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF4	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

6.4.3.2 No TPM

Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. In the "Properties" tab, enable "10 Base-Te".

3. Under "No TPM", select "Output Timing Jitter (14.3.1.2.3)".

4.　Click "Test Single".

5.　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 23

Measurements

For "Output Timing Jitter" tests, the DUT has to transmit Manchester-encoded pseu-dorandom 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. Those values are the minimum and maximum devia-tion from the ideal edge location.

● The oscilloscope measures the jitter at 8.5 BT in the same way.

6.4.3.3   With TPM

Performing the test

1. Select "10 Base T" in the "Test Management" dialog box.

2. In the "Properties" tab, enable "10 Base-Te".

3. Under "With TPM", select "Output Timing Jitter (14.3.1.2.3)".

4. Click "Test Single".

5. 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 23

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 measurements are the same as without TPM, see Chapter 6.4.3.2, "No TPM", on page 154.

6.4.4 Peak differential voltage

The "Peak Differential Voltage" test verifies that the peak differential output voltage of the DUT is between 1.54V and 1.96V as specified in IEEE 802.3-2012, section1, sub-clause 14.3.1.2.1.

6.4.4.1 Test equipment

Table 6-15: Equipment for Peak Differential Voltage test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF4	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

6.4.4.2 Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. In the "Properties" tab, enable "10 Base-Te".

3. Under "No TPM", select "Peak Differential Voltage (14.3.1.2.1)".
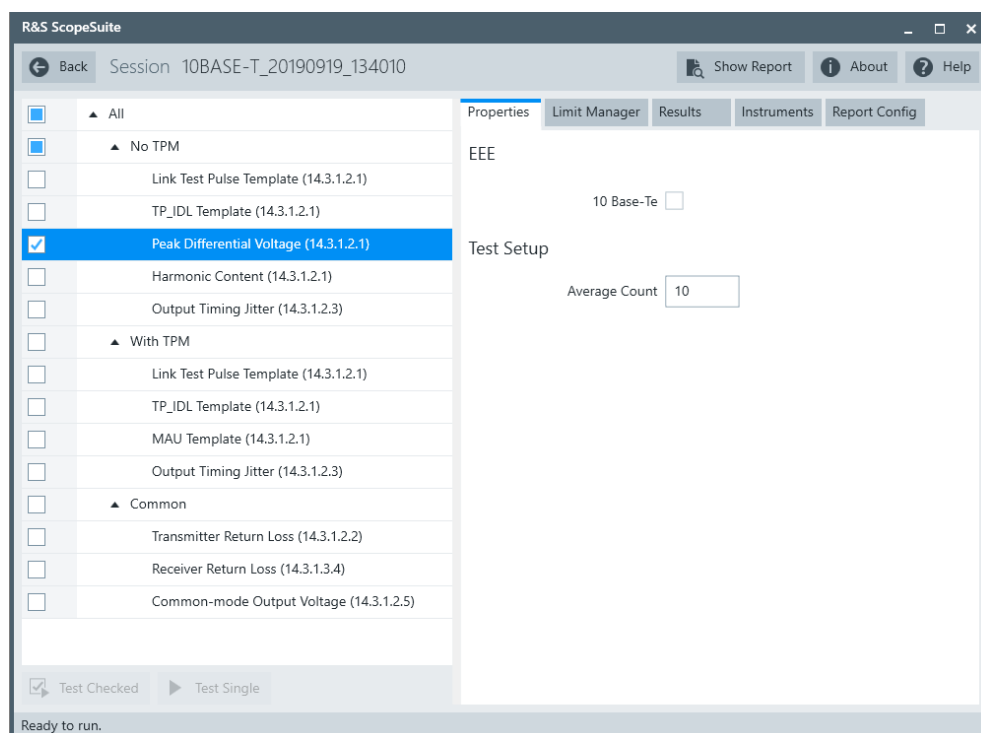
4. Click "Test Single".

5. 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 23

6.4.4.3 Measurements

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

The waveform displayed on the R&S RTO/RTO6/RTP should look similar to the picture below.
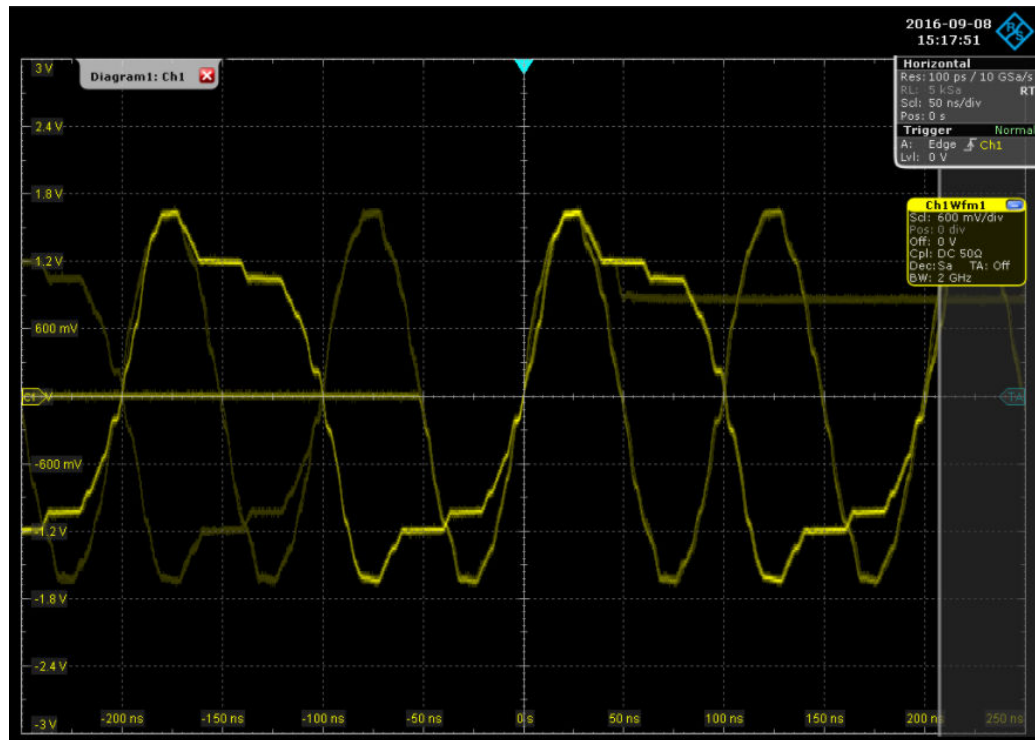
Figure 6-27: Waveform of 10BASE-Te random data

The instrument measures the peak differential output voltage across the transmitter pair of the DUT and compares this value with the specified range (1.54V to 1.96V).

6.4.5 Harmonic content

The "Harmonic Content" test verifies that any harmonic measured on the TD circuit is at least 27 dB below the fundamental. The harmonic content is measured without twisted-pair model (TPM), optionally with link partner.

6.4.5.1 Test equipment

Table 6-16: Equipment for Harmonic Content test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF4	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

6.4.5.2 Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. In the "Properties" tab, enable "10 Base-Te".

3. Under "No TPM", select "Harmonic Content (14.3.1.2.1)".
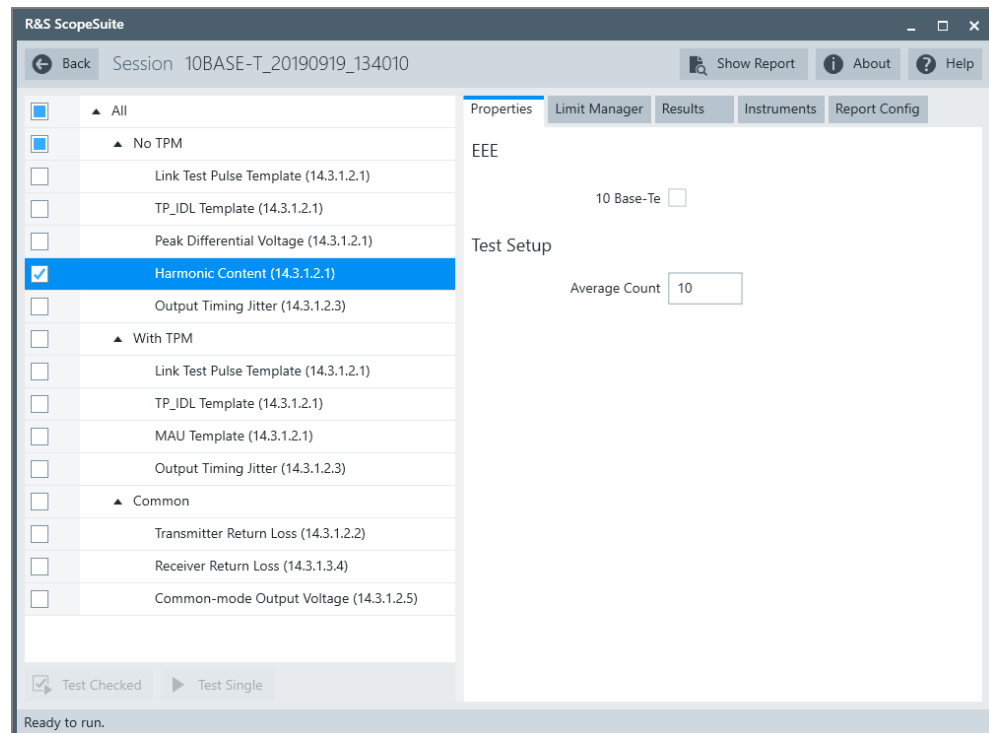
4. Click "Test Single".

5. 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 23

6.4.5.3 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 an 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.

6.4.6 MAU template

The" MAU Template" test verifies that the differential output waveform of the DUT fits into the voltage template specified in IEEE 802.3-2012, section1, figure 14-10, both normal and inverted, with a scaling between 0.9 and 1.1. The test is performed with twisted-pair model (TPM).

6.4.6.1 Test equipment

Table 6-17: Equipment for MAU template test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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

6.4.6.2 Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.
2. In the "Properties" tab, enable "10 Base-Te".
3. Under "With TPM", select "MAU Template (14.3.1.2.1)".
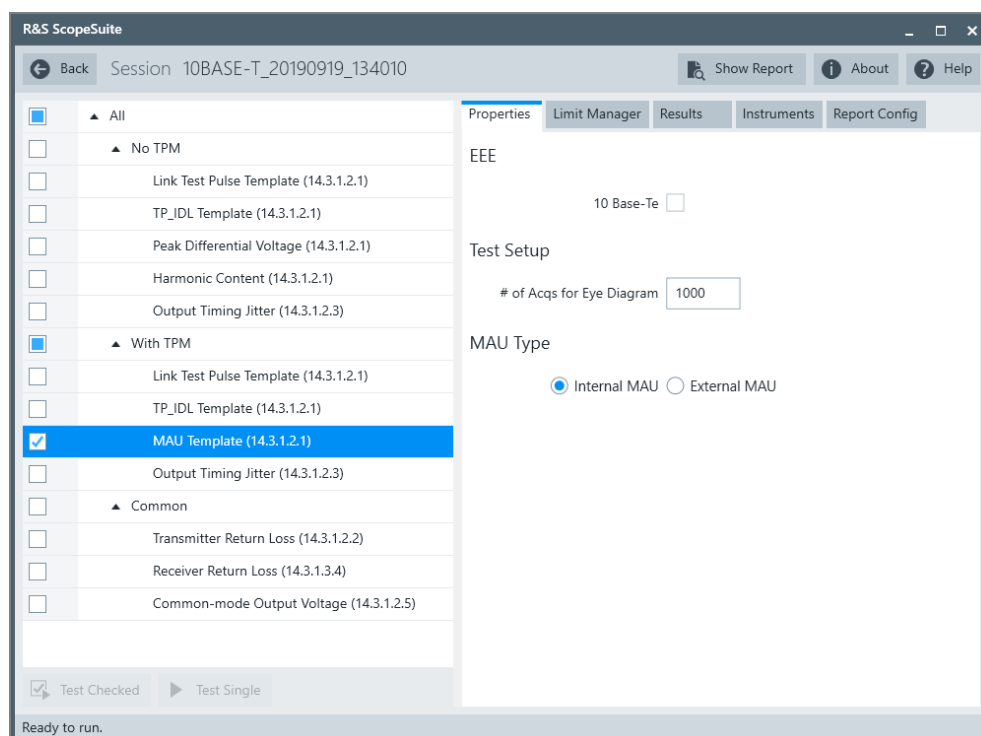
4. Click "Test Single".

5. 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 23

6.4.6.3 Measurements

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

The waveform displayed on the R&S RTO/RTO6/RTP should look similar to the picture below.
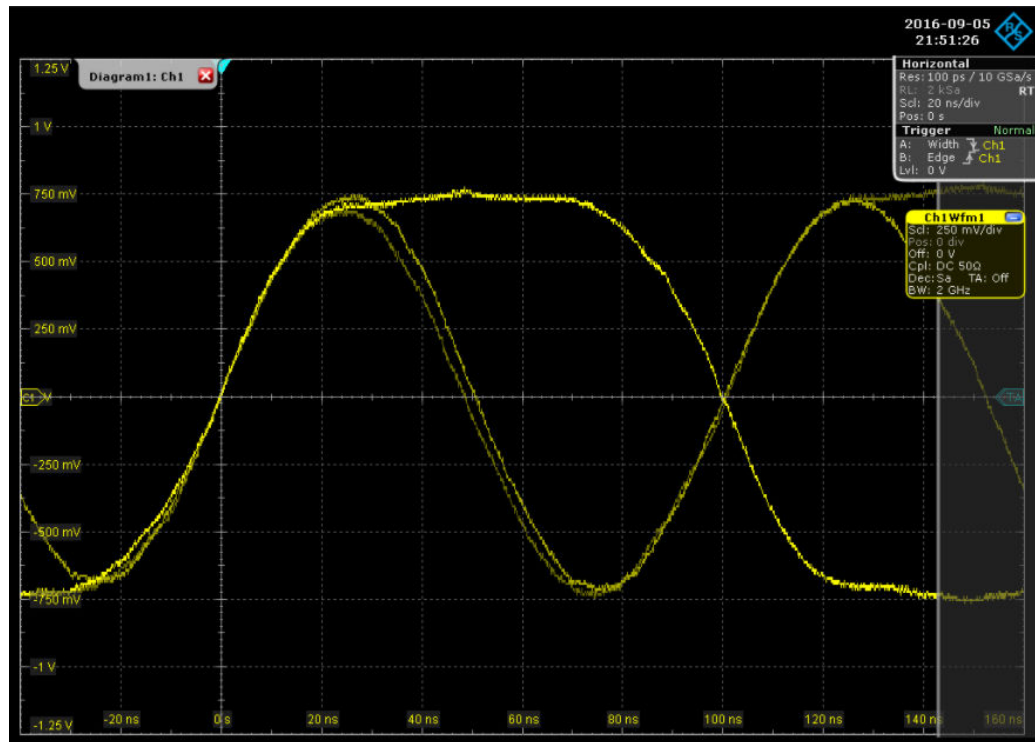
The oscilloscope creates a mask according to the template specified in figure 14-10 of IEEE 802.3-2012, section1, and varies the mask scaling from 0.9 to 1.1. The test has been passed if there is at least one scaling at which the waveform did not violate the mask.

6.4.7 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 MHz to 10 MHz as specified in IEEE 802.3-2012, section1, subclause 14.3.1.2.2.

6.4.7.1 Test equipment

Table 6-18: Equipment for Transmitter Return Loss

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF4	1
Vector network analyzer (optional, required only to perform an automatic test)	R&S ZNB/ZNC/ZND/ZVL	1
DUT	the device you want to test	1

6.4.7.2 Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. In the "Properties" tab, enable "10 Base-Te".

3. Under "Common", select "Transmitter Return Loss (14.3.1.2.2)".
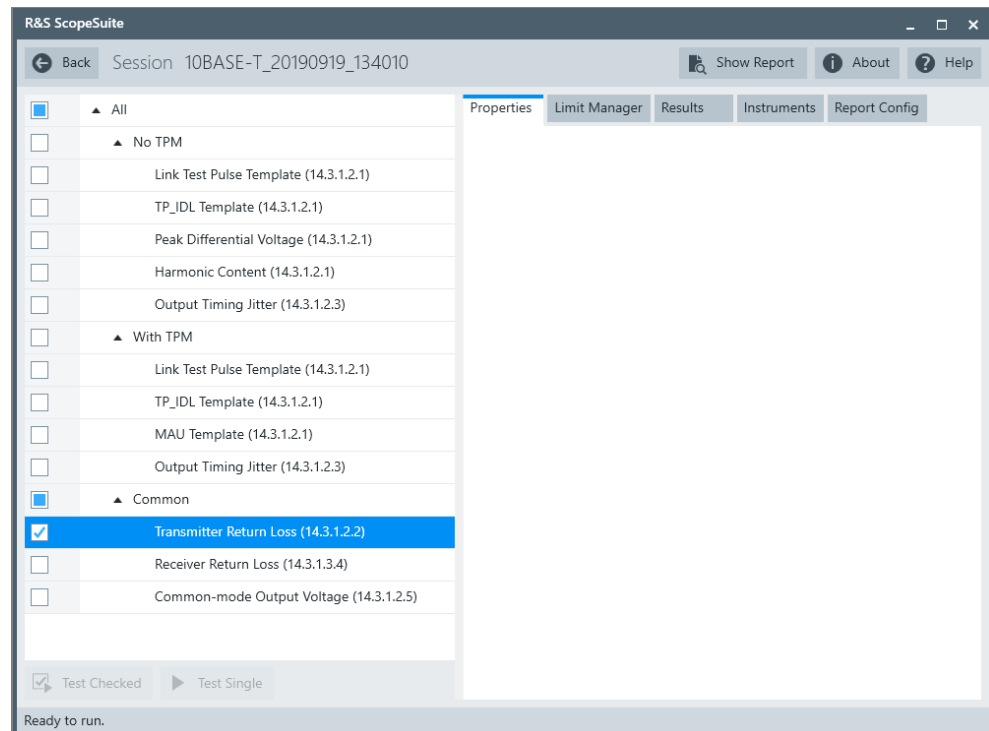
4. Click "Test Single".

5. 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 23

6.4.7.3 Measurements

Configure the DUT to "10BASE-Te 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 MHz 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.

6.4.8 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 MHz to 10 MHz as specified in IEEE 802.3-2012 subclause 14.3.1.3.4.

6.4.8.1 Test equipment

Table 6-19: Equipment for Receiver Return Loss tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Twisted Pair Model" section	R&S RT-ZF4	1
Vector network analyzer (optional, required only to perform an automatic test)	R&S ZNB/ZNC/ZND/ZVL	1
DUT	the device you want to test	1

6.4.8.2 Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. In the "Properties" tab, enable "10 Base-Te".

3. Under "Common", select "Receiver Return Loss (14.3.1.3.4)".
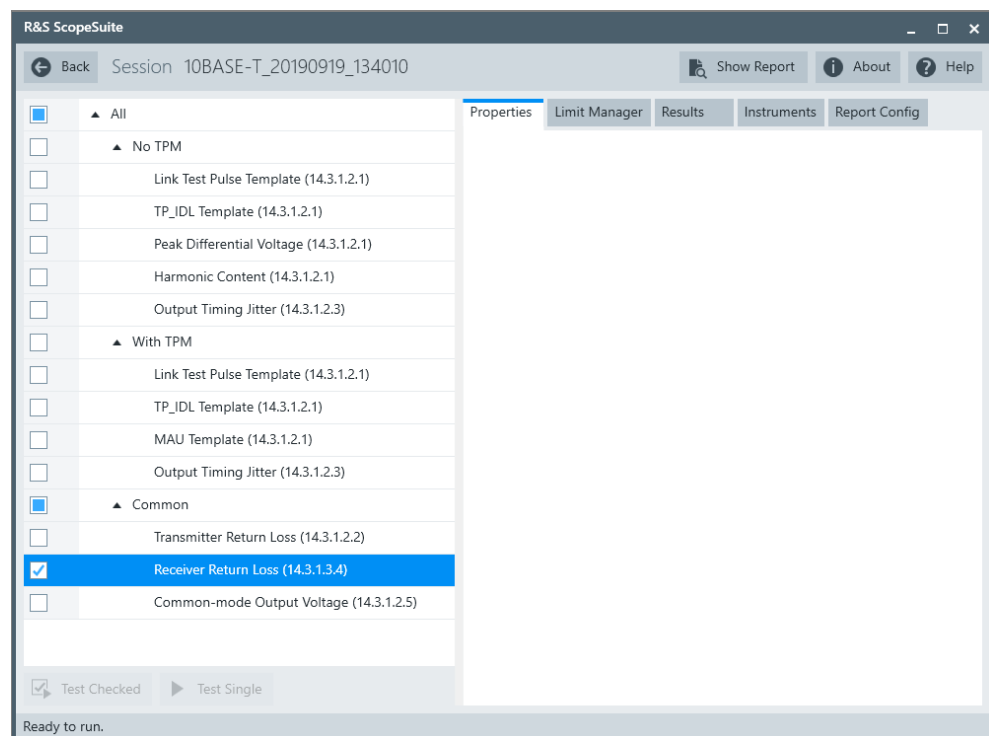
4. Click "Test Single".

5. 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 23

6.4.8.3 Measurements

Configure the DUT to "10BASE-Te 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 MHz 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.

6.4.9 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.

#### 6.4.9.1 Test equipment

Table 6-20: Equipment for Common-mode Output Voltage tests

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Common Mode Voltage" section	R&S RT-ZF4	1
Differential probe	at least 1 GHz bandwidth	1
DUT	the device you want to test	1

6.4.9.2 Performing the test

1. Start the test as described in Chapter 6.1, "Starting 10BASE-T tests", on page 110.

2. In the "Properties" tab, enable "10 Base-Te".

3. Under "Common", select "Common-mode Output Voltage (14.3.1.2.5)".
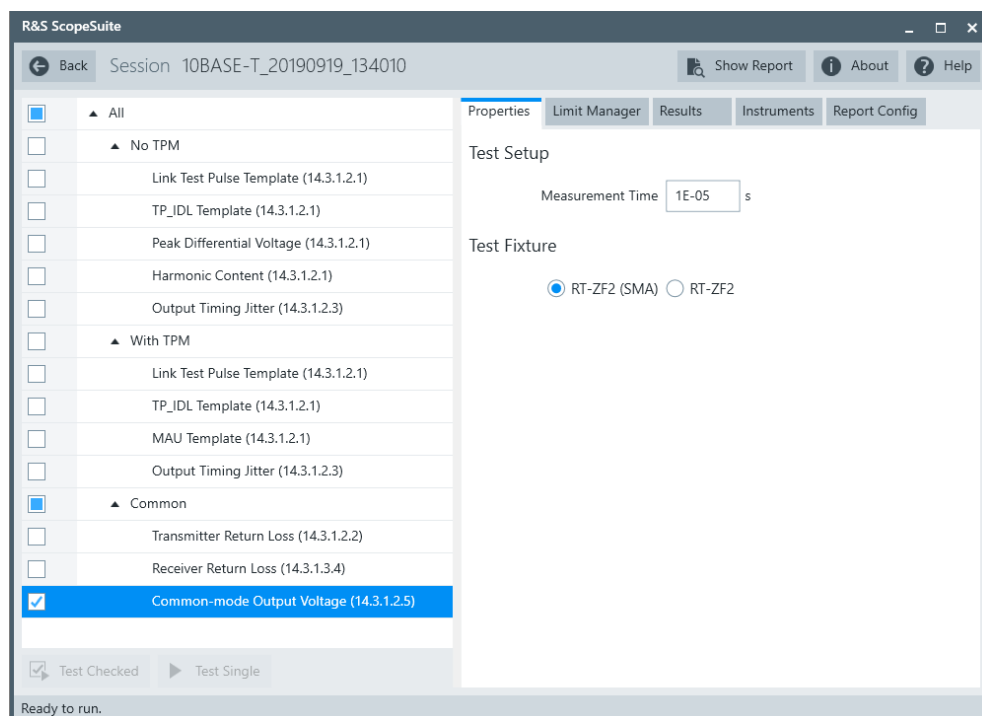
4. Click "Test Single".

5. 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 23

6.4.9.3 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.
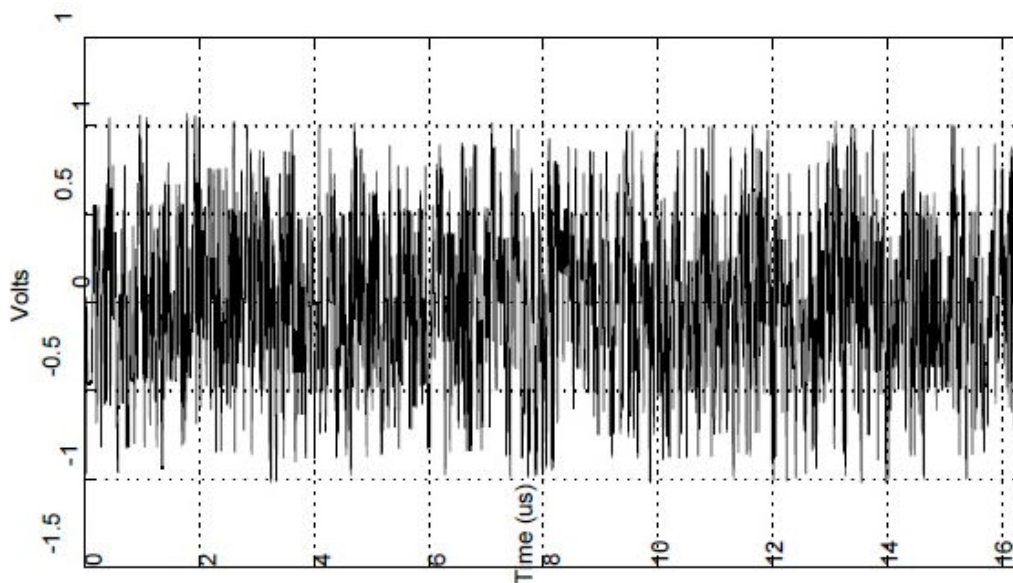
The oscilloscope measures the maximum and minimum voltages of the captured waveform. The highest absolute value is considered as peak common mode voltage.

7 2.5/5/10 G tests

7.1 2.5GBASE-T tests

2.5GBASE-T Ethernet compliance tests require option R&S RTO/RTO6/RTP-K23.

The following table shows an overview of the needed equipment for performing the 2.5GBASE-T test cases. A prerequisite is also a R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth, the R&S ScopeSuite software and a 2.5GBASE-T DUT.

Table 7-1: Equipment for 2.5GBASE-T Ethernet compliance tests

	Differential probe	Test fixture	Additional instruments
Maximum Output Droop (126.5.3.1)	1 at least 1.5 GHz bandwidth	R&S RT-ZF2 Section: Resistive Load	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Transmitter Timing Jitter Master Mode and Clock Frequency (126.5.3.3 and 126.5.3.5)			
Transmitter Timing Jitter Slave Mode (126.5.3.3)			
Transmitter Power Spectral Density and Power Level (126.5.3.4)			
Transmitter Non-Linearity Distortion (126.5.3.2)	-	R&S RT-ZF2 Section: Return Loss	**Spectrum analyzer:** R&S FSV/FSQ/FSW/ESRP **Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17

	Differential probe	Test fixture	Additional instruments
Transmitter Non-Linearity Distortion with Disturber (126.5.3.2)	-	R&S RT-ZF2 Section: Return Loss	**Spectrum analyzer:** R&S FSV/FSQ/FSW/ESRP **Power splitter:** Freq Range1-100 MHz **Band pass filter:** Fc=45MHz, Bn=2MHz **Sine waveform generator:** e.g., HAMEG MHF2550 **Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
MDI Return Loss (126.8.2.1)	-	R&S RT-ZF2 Section: Twisted Pair Model	**VNA:** R&S ZNB or R&S ZNC or R&S ZND or R&S ZVL

7.1.1 Starting 2.5GBASE-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 Scope-Suite, see Chapter 2.5, "Connecting the R&S RTO/RTO6/RTP", on page 12
- VNA connection for MDI Return Loss and Transmitter Power Spectral Density and Power Level tests, see Chapter 2.7, "Connecting the vector network analyzer", on page 15.

1. Select "Ethernet 2.5/5G/10G " in the R&S ScopeSuite start window.

2. In the "Session Selection" dialog, set "Select Type" > "2.5GBASE-T".

3. Add a new test session and open it, see Chapter 3.1, "Starting a test session", on page 20.

4. Check the test configuration settings and adjust, if necessary. See:
   - Chapter 7.1.2, "Test configuration for Ethernet 2.5GBASE-T", on page 171
   - 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.

7.1.2 Test configuration for Ethernet 2.5GBASE-T

The test configuration consists of some test-specific configuration settings.
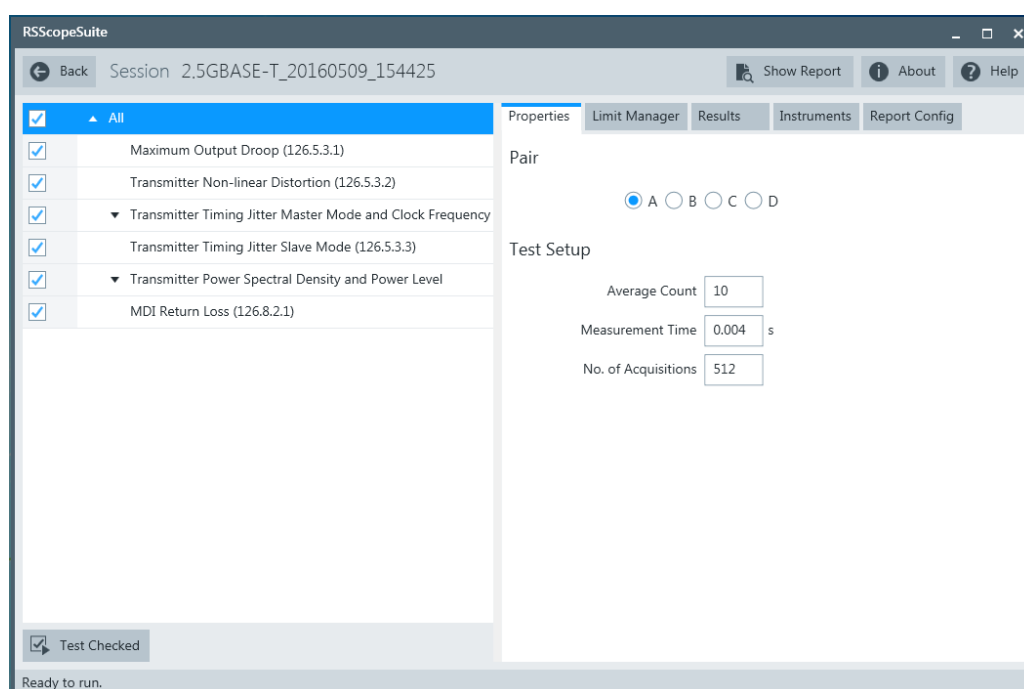
Figure 7-1: Configuration for 2.5GBASE-T compliance tests

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 Clock Frequency and Transmitter Timing Jitter Slave Mode test cases. The valid range is 4E-6 to 4E-3, the default value is 4E-3.

No. of Acquisitions

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

7.1.3 Maximum output droop

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

7.1.3.1 Test equipment

Table 7-2: Equipment for Maximum Output Droop test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 1.5 GHz bandwidth	1
DUT	2.5GBASE-T device to be tested	1

7.1.3.2 Performing the test

1. Start the test as described in Chapter 7.1.1, "Starting 2.5GBASE-T tests", on page 170.

2. Select the test case: "Maximum Output Droop (126.5.3.1)".
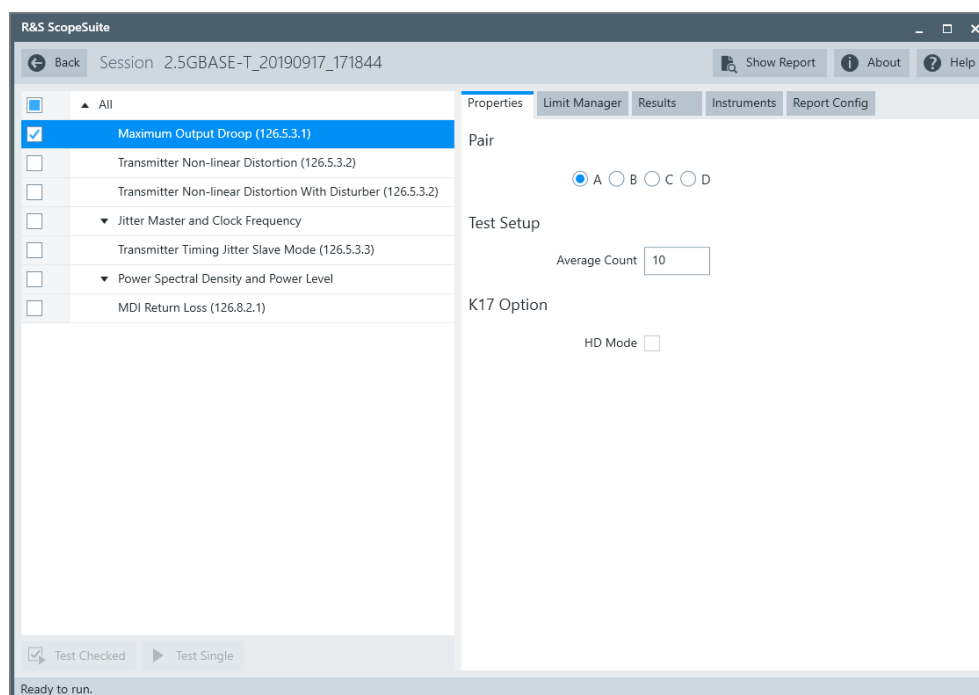
3. Click "Test Single".

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 23
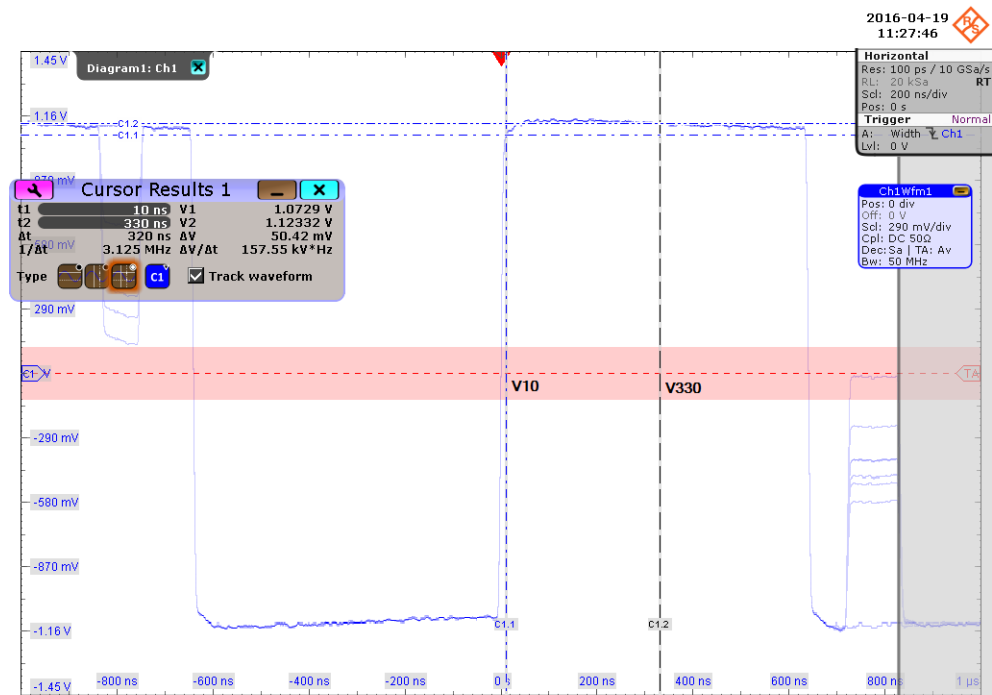
7.1.3.3 Test setup

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.

7.1.3.4 Measurements

The test makes two measurements:

- Measure the voltage ratio between V_{10} (10 ns after the positive zero crossing) and V_{330} (330 ns after the positive zero crossing) of a rising edge.
  The software set a trigger at the zero crossing of a rising edge. After acquiring N number of waveforms, it averages them into a single waveform. The software enables a pair of cursors with "Track waveform". It positions "Cursor 1" at V_{10} and "Cursor 2" at V_{330}. The software determines the voltage ratio by measuring the voltage levels at V_{10} and V_{330}.

- Measure the voltage ratio between V_{10} (10 ns after the positive zero crossing) and V_{330} (330 ns after the positive zero crossing) of a falling edge.
  The software set a trigger at the zero crossing of a falling edge. After acquiring N number of waveforms, it averages them into a single waveform. The software enables a pair of cursors with "Track waveform". It positions "Cursor 1" at V_{10} and "Cursor 2" at V_{330}. The software determines the voltage ratio by measuring the voltage levels at V_{10} and V_{330}.
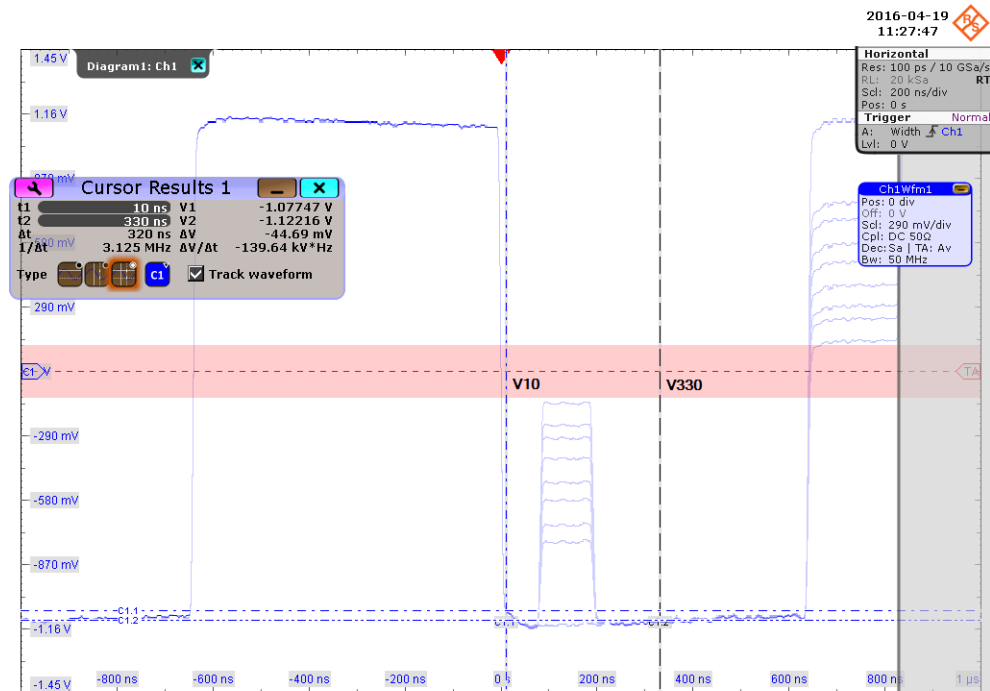
7.1.4 Transmitter non-linearity distortion

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

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

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

7.1.4.1 Test equipment

Table 7-3: Equipment for Transmitter Non-linearity Distortion test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Return Loss" section	R&S RT-ZF2	1
Spectrum analyzer	R&S FSV/FSQ/FSW/ESRP	1
DUT	2.5GBASE-T device to be tested	1

7.1.4.2   Performing the test

1. Start the test as described in Chapter 7.1.1, "Starting 2.5GBASE-T tests", on page 170.

2. Select the test case: "Transmitter Non-linearity Distortion (126.5.3.2)".
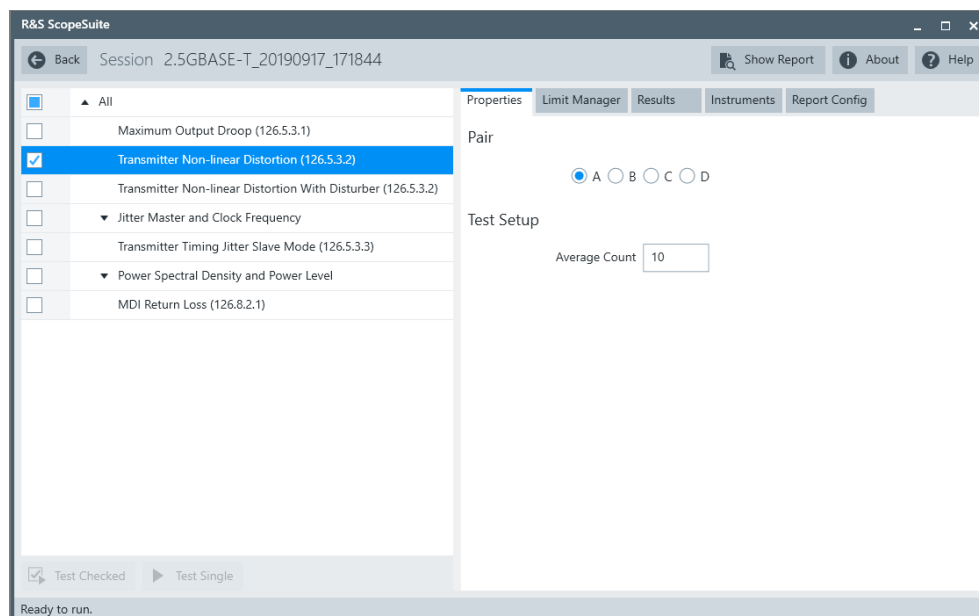
3. Click "Test Single".

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 23

7.1.4.3   Test setup

The test requires the DUT to transmit each of the five dual tones during the test.
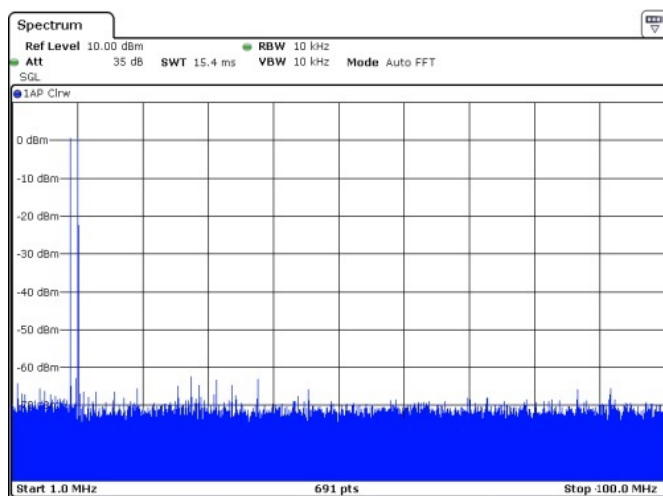
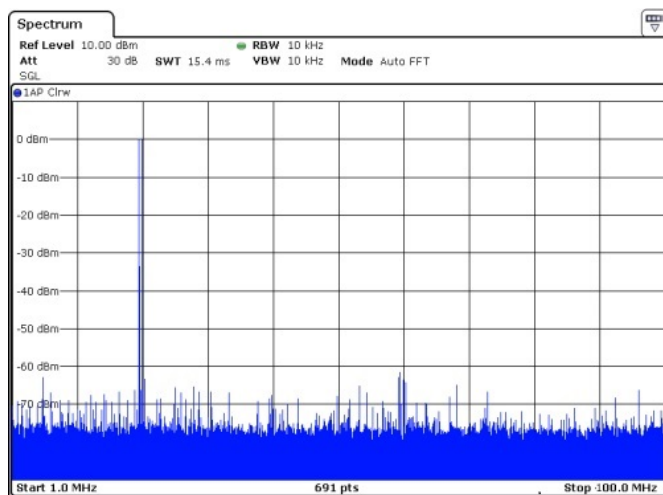*Figure 7-2: First dual tone (9.179688MHz, and 10.35156MHz)*

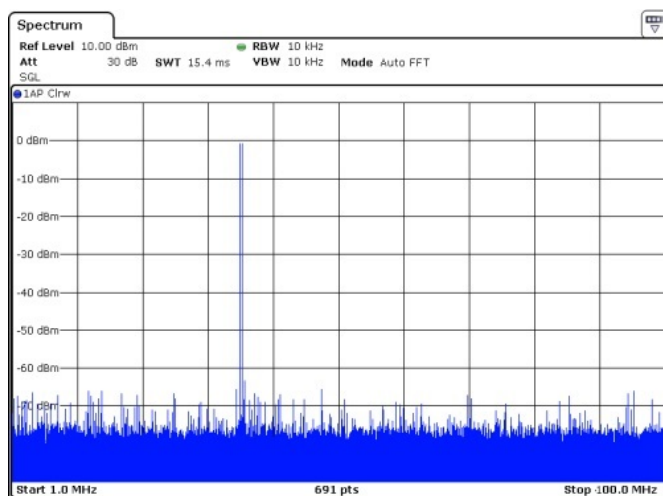

Figure 7-3: Second dual tone (19.72656MHz and 20.11719MHz)

Figure 7-4: Third dual tone (34.96094MHz and 35.35156MHz)
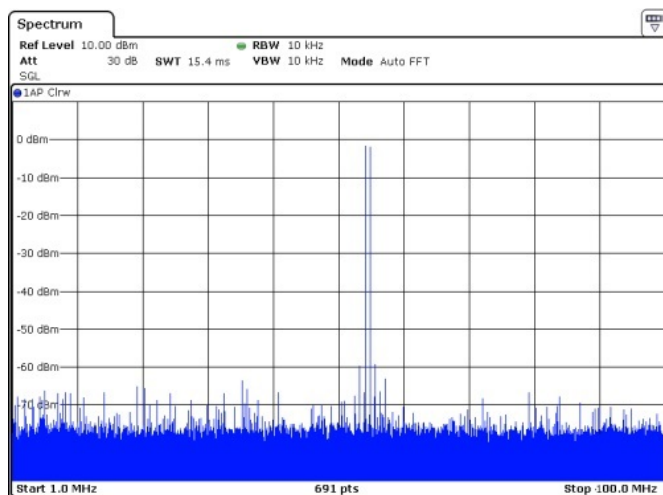
Figure 7-5: Fourth dual tone (54.10156MHz and 54.88281MHz)
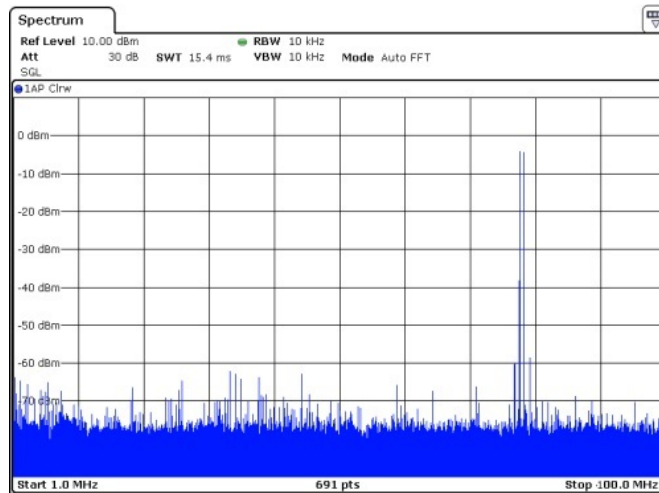
Figure 7-6: Fifth dual tone (77.53906MHz and 78.32031MHz)

7.1.4.4 Measurements

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

In manual testing, you need to provide the frequencies and the magnitudes of the 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 100 MHz.

7.1.5 Transmitter non-linearity distortion with disturber

This test verifies the Spurious Free Dynamic Range (SFDR) of the transmitter despite a disturber. As a disturber, a 45 MHz sine wave signal is used, with an amplitude 7 dB below the minimum dual-tone power at a power offset level (PBO) of 0 dB.

The SFDR is calculated for 5 pairs of different dual tones and should be greater than the value given by the following formula.

$$SFDR \geq -5.5 + min\left\{52.58 - 20log_{10}\left(\frac{f}{25}\right)\right\}$$

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

7.1.5.1 Test equipment

Table 7-4: Equipment for Transmitter Non-linearity Distortion With Disturber test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Return Loss" section	R&S RT-ZF2	1
Sine waveform generator	Sine waveform generator: e.g. HAMEG MHF2550	1
Band pass filter	A bandpass filter with center frequency F_C= 45 MHz and bandwidth B_n = 2MHz	1
Power splitter	Power splitter with frequency range from at least 1 MHz to 100 MHz	1
Spectrum analyzer	R&S FSV/FSQ/FSW/ESRP	1
SMA cables	-	4

7.1.5.2 Performing the test

1. Start the test as described in

2. Select the test case: "Transmitter Non-linearity Distortion with Disturber (126.5.3.2)".
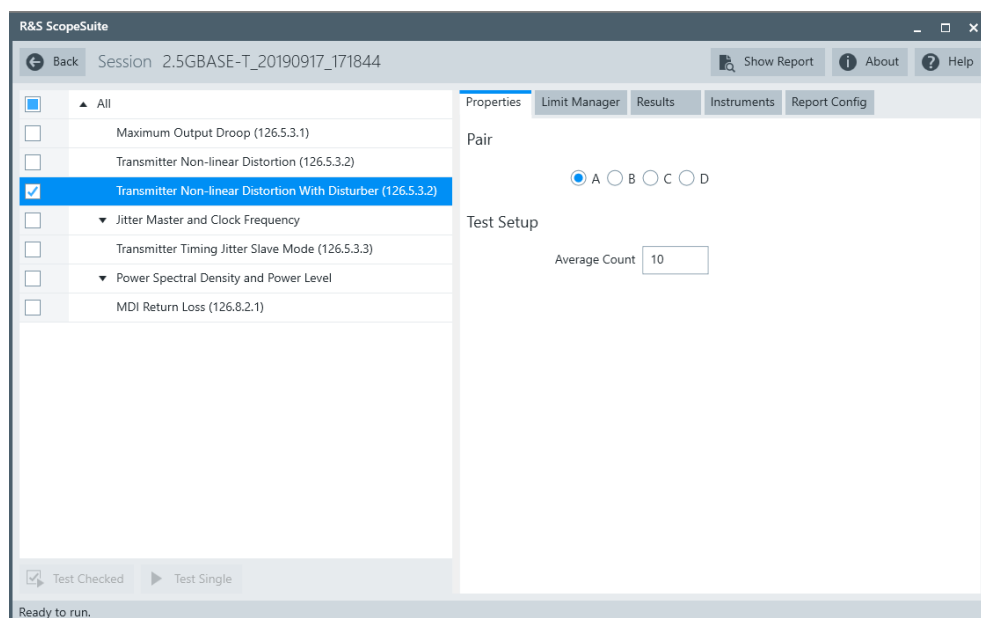
3. Click "Test Single".

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 23

7.1.5.3 Test setup

The test requires the DUT to transmit each of the five dual tones and inject a 45 MHz sine wave disturber signal during the test.

The figure below shows the measurement setup. The step-by step instructions will guide you through the steps needed to complete the setup.
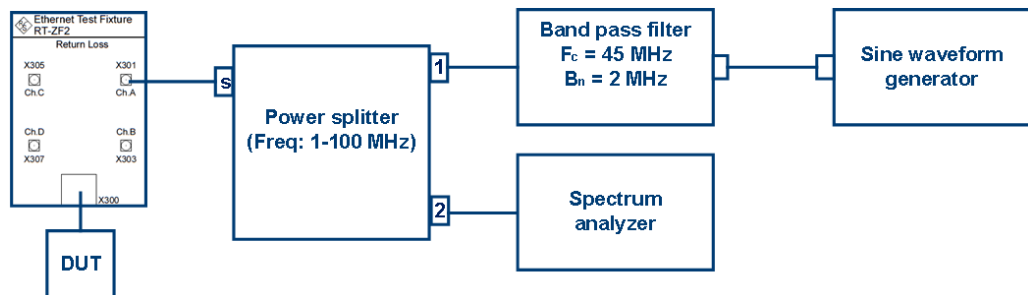
Figure 7-7: Test setup

The amplitude of the disturber signal on the signal generator must be adjusted so that its amplitude is 7 dB below the minimum dual-tone power at a power backoff level (PBO) of 0 dB.
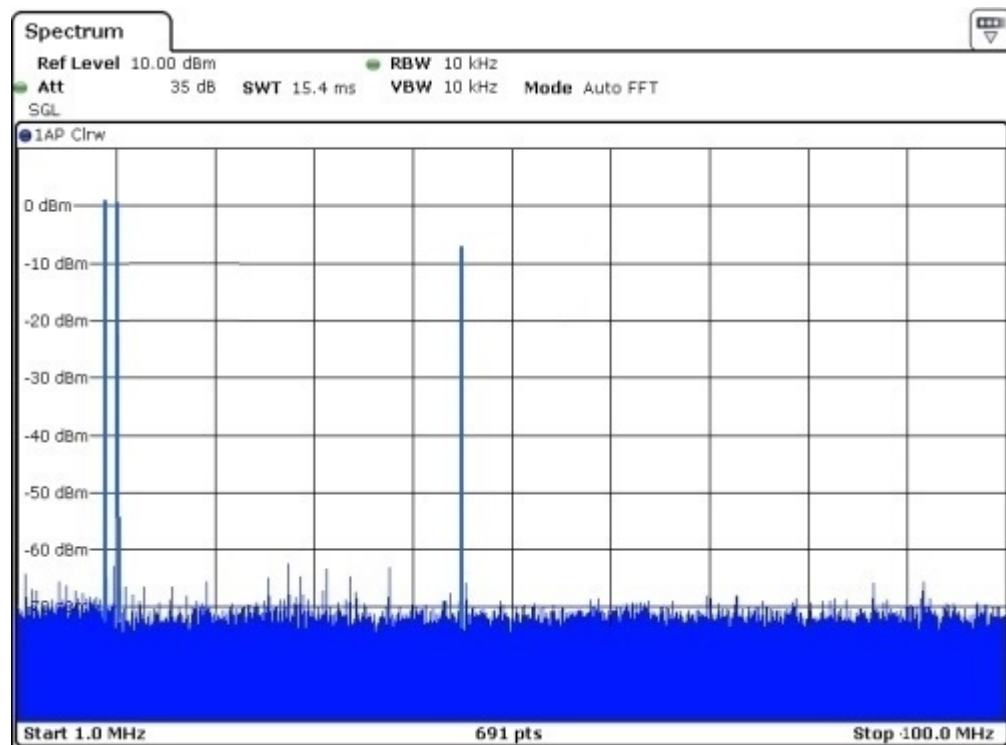
Figure 7-8: First dual tone (9.179688MHz, and 10.35156MHz)
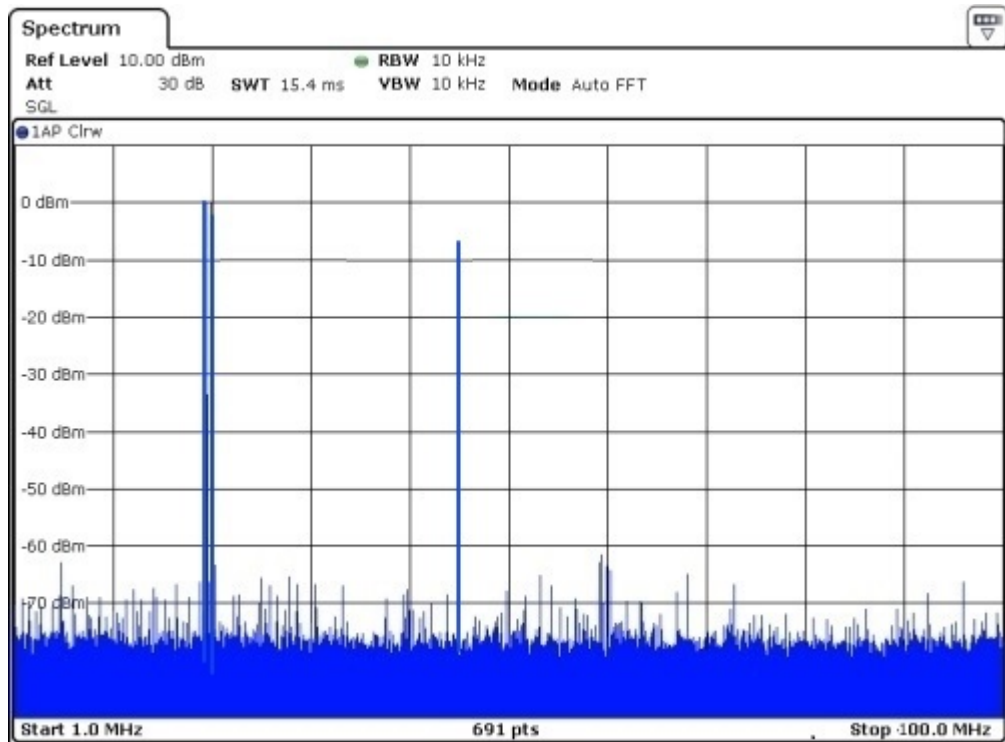
Figure 7-9: Second dual tone (19.72656MHz and 20.11719MHz)
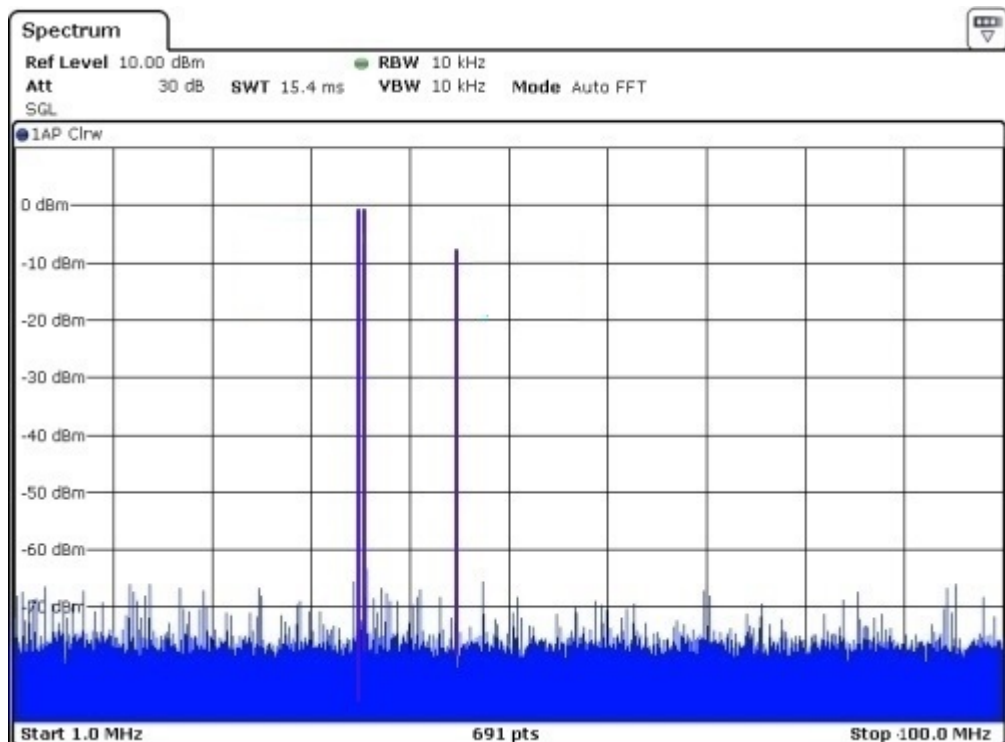
Figure 7-10: Third dual tone (34.96094MHz and 35.35156MHz)
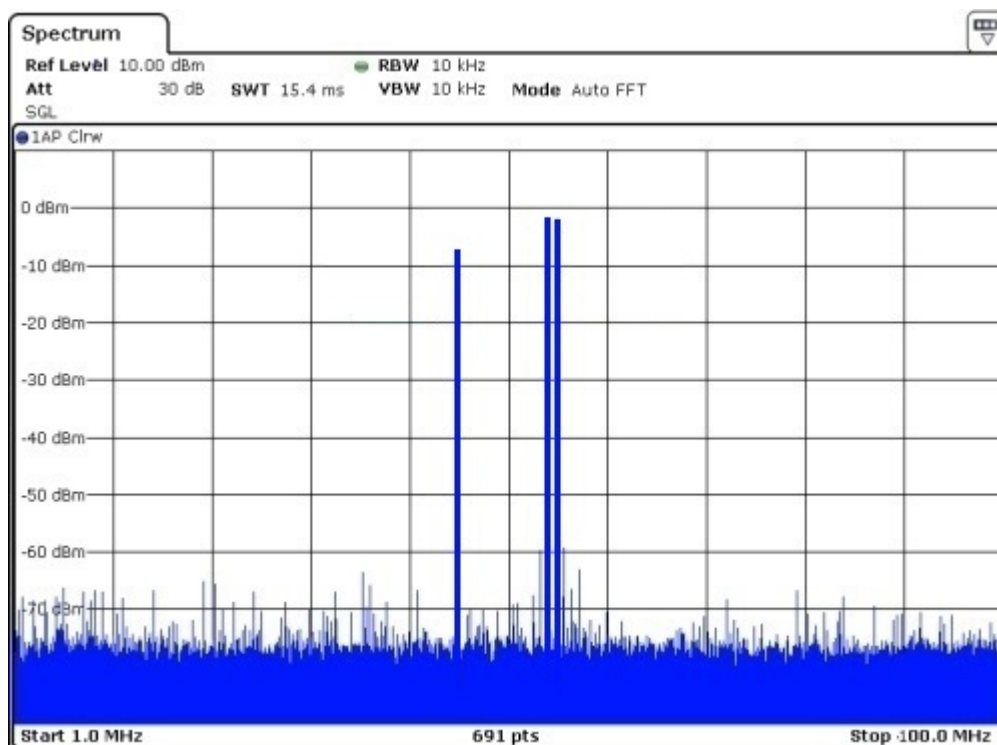
Figure 7-11: Fourth dual tone (54.10156MHz and 54.88281MHz)
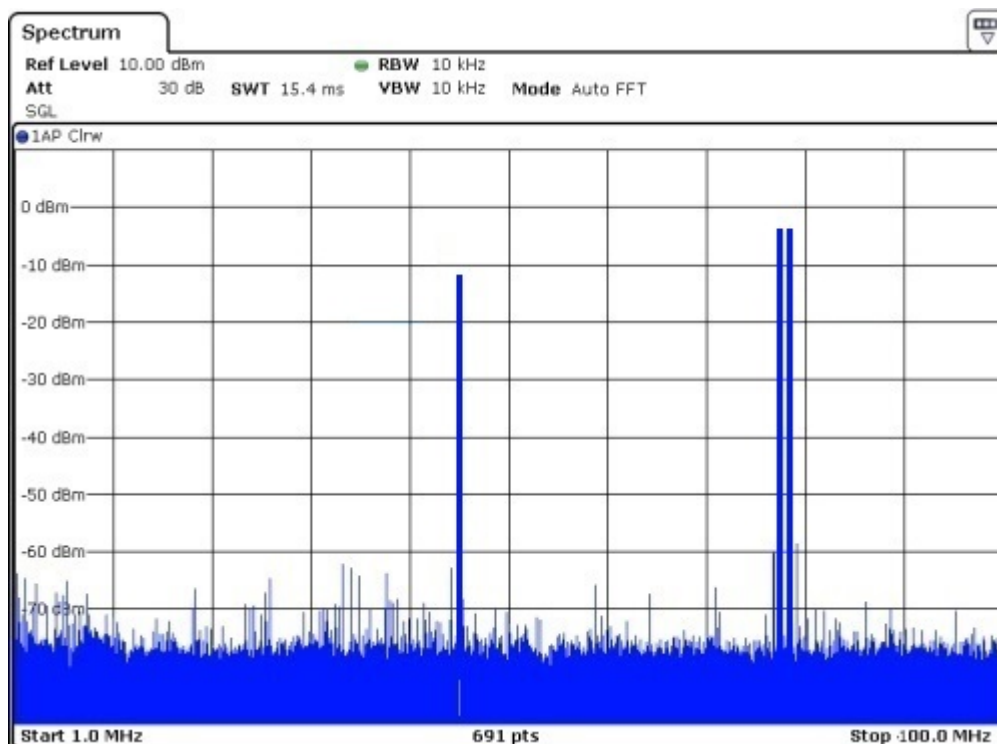
Figure 7-12: Fifth dual tone (77.53906MHz and 78.32031MHz)

7.1.5.4　Measurements

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

In manual testing, you need to provide the frequencies and the magnitudes of the 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 100 MHz.

7.1.6　Transmitter timing jitter master mode and clock frequency

The tests verify that the jitter of the DUT and the transmitter clock is within the specified range. The DUT is in master mode.

7.1.6.1　Test equipment

Table 7-5: Equipment for Transmitter Timing Jitter Master Mode and Clock Frequency test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 1.5 GHz bandwidth	1
DUT	2.5GBASE-T device to be tested	1

7.1.6.2　Performing the test

1. Start the test as described in Chapter 7.1.1, "Starting 2.5GBASE-T tests", on page 170.

2. Select the test case: "Transmitter Timing Jitter Master Mode and Clock Frequency".
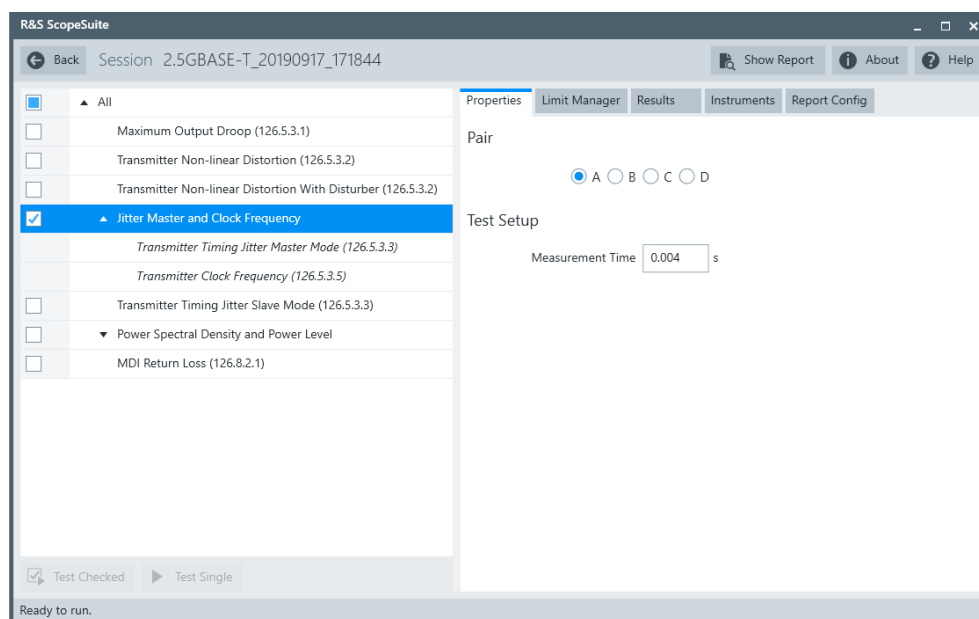
3. Click "Test Single".

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 23

7.1.6.3 Test setup

The DUT has to transmit a test mode 2 waveform.

Figure 7-13: Test mode 2 waveform

7.1.6.4 Measurements

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 10,000 samples. Then RMS period jitter is calculated.

To pass the test, the RMS jitter must be less than 10 ps. Meanwhile, in automated testing the oscilloscope does a frequency measurement and determines if the transmitter clock frequency is within the conformance limits.

7.1.7 Transmitter timing jitter slave mode

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

7.1.7.1 Test equipment

Table 7-6: Equipment for Transmitter Timing Jitter Slave Mode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Jitter Slave Test 10GBASE-T" section	R&S RT-ZF2	1

Item	Description, model	Quantity
Differential probe	at least 1.5 GHz bandwidth	1
DUT	2.5GBASE-T device to be tested	1

7.1.7.2 Performing the test

1. Start the test as described in Chapter 7.1.1, "Starting 2.5GBASE-T tests", on page 170.

2. Select the test case: "Transmitter Timing Jitter Slave Mode (126.5.3.3)".
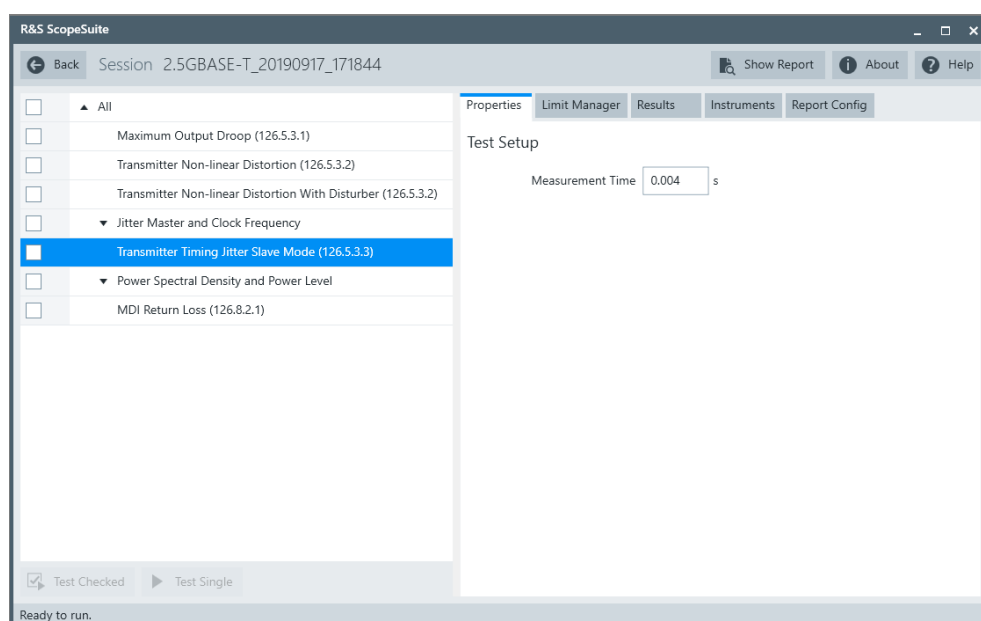
3. Click "Test Single".

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 23

7.1.7.3 Test setup

The test requires the DUT to transmit test 3 mode waveform.
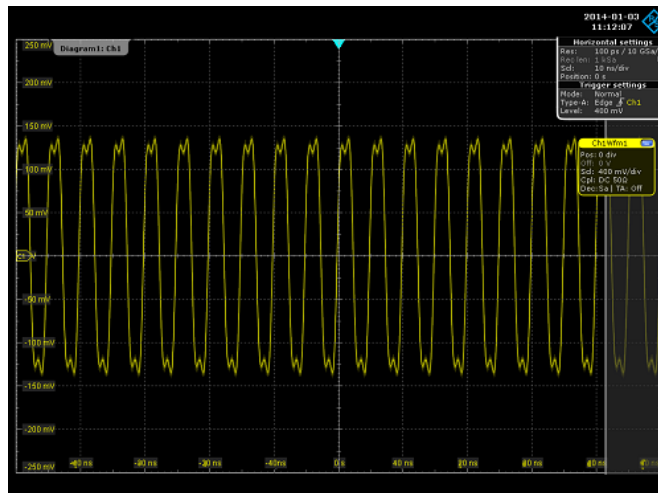
Figure 7-14: Test mode 3 waveform

The test requires the link partner of DUT to transmit test mode 1 waveform.
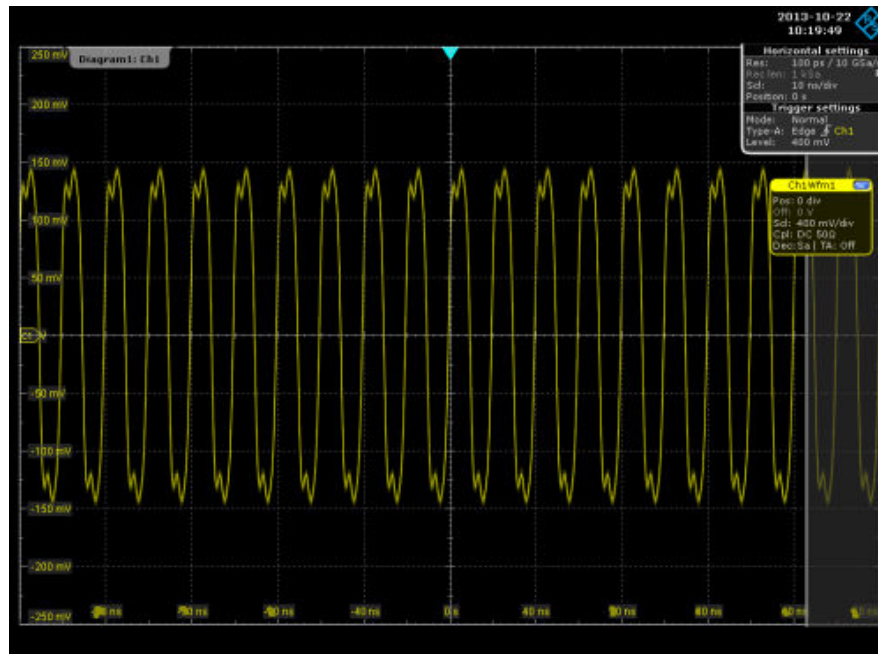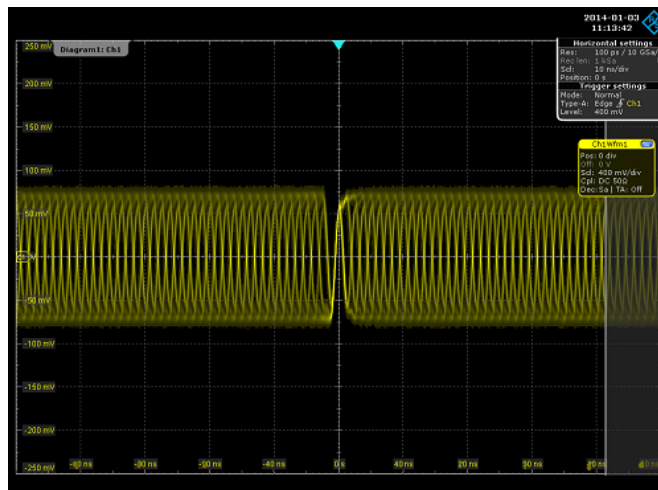

Figure 7-15: Test mode 1 waveform

7.1.7.4 Measurements

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 10 000 samples.

The captured waveform is passed through a band pass filter with a central frequency of 50 MHz and a bandwidth of 2 MHz first. Then the RMS jitter is calculated. To pass the test, the RMS jitter must be less than 10 ps.

7.1.8 Transmitter power spectral density and power level

The test verifies that the transmitter power spectral density of the DUT over the frequency range 0 GHz to 3 GHz falls in between the upper and lower limits specified in specification section 126.5.3.4. It also verifies that the transmitter power level of the DUT is between 1.0 dBm and 3.0 dBm.

7.1.8.1 Test equipment

Table 7-7: Equipment for Transmitter Power Spectral Density and Power Level test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 / R&S RTP with at least 600 MHz bandwidth	1
Ethernet fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Differential probe	at least 1.5 GHz bandwidth	1
DUT	2.5GBASE-T device to be tested	1

7.1.8.2 Performing the test

1. Start the test as described in Chapter 7.1.1, "Starting 2.5GBASE-T tests", on page 170.

2. Select the test case: "Transmitter Power Spectral Density and Power Level".
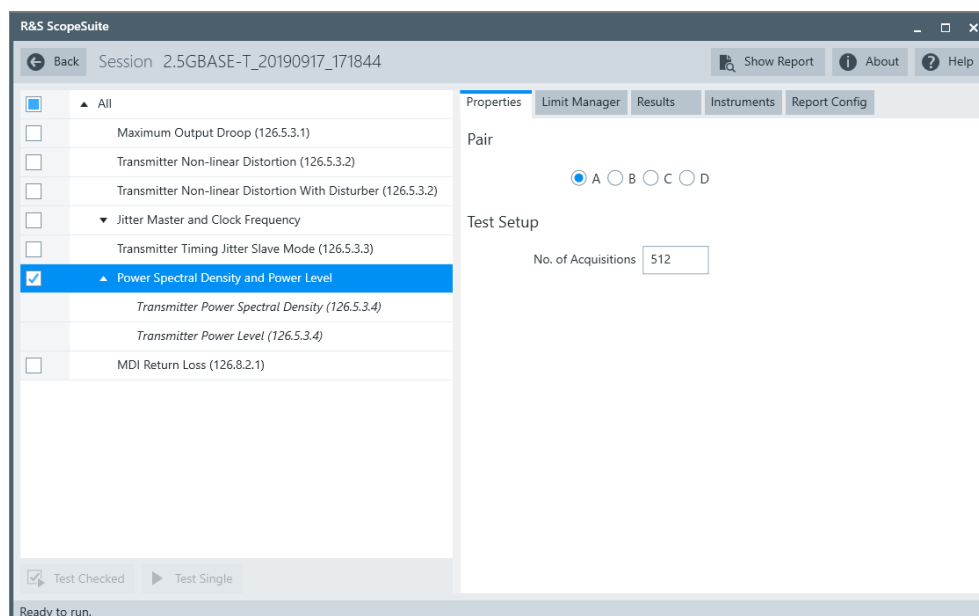
3. Click "Test Single".

4. Follow the instructions of the step-by step guide.

When you have finished all steps, the compliance test runs automatically.

Further steps:

7.1.8.3 Test setup

Configure the DUT to test mode 5.
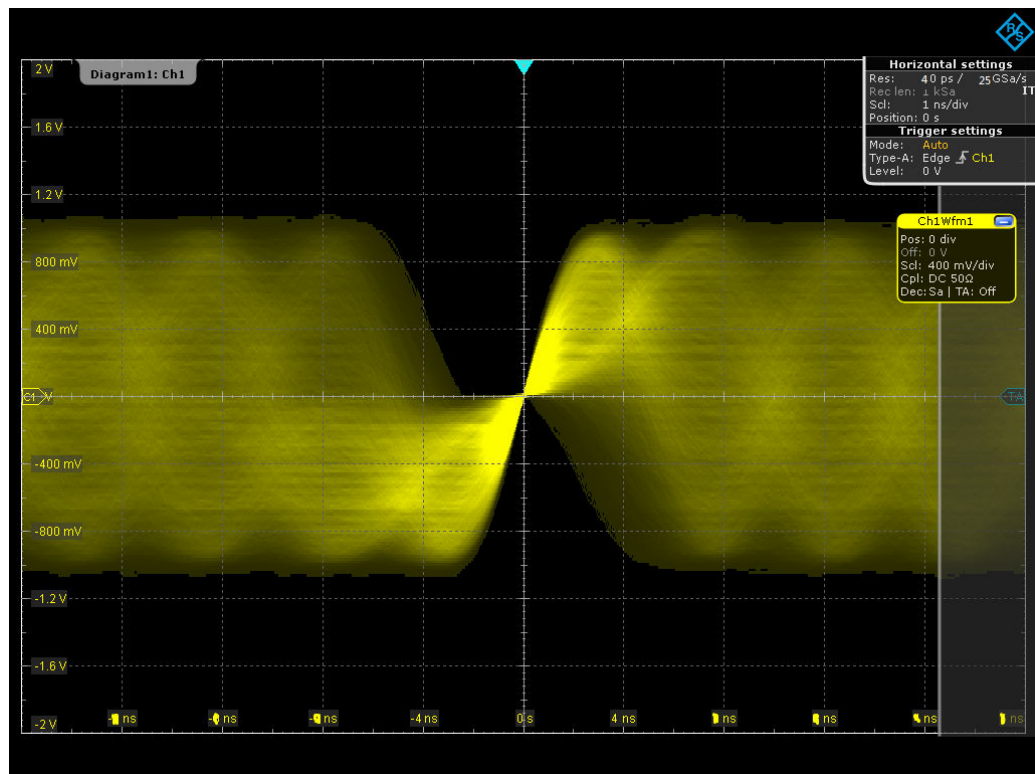
Figure 7-16: Test mode 5 waveform

7.1.8.4 Measurements

First the program measures the power level of the input signal using FFT transform and some mathematics. It also makes an FFT transformation of the input signal over 0 GHz to 3 GHz. Then it performs some averaging and mathematics to plot the PSD curve, and checks whether it falls within the limit mask.

7.1.9 MDI return loss

The test verifies that the differential impedance at the MDI for each transmit/receive channel of the DUT over the frequency range of 1 to 125 MHz is greater than the limits specified in the IEEE P802.3bz[TM]/D2.1 specification, section 126.8.2.1.

7.1.9.1 Test equipment

Table 7-8: Equipment for MDI Return Loss test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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 ZNB/ZNC/ZND/ZVL	1
DUT	2.5GBASE-T device to be tested	1

7.1.9.2 Performing the test

1. Start the test as described in Chapter 7.1.1, "Starting 2.5GBASE-T tests", on page 170.

2. Select the test case: "MDI Return Loss (126.8.2.1)".
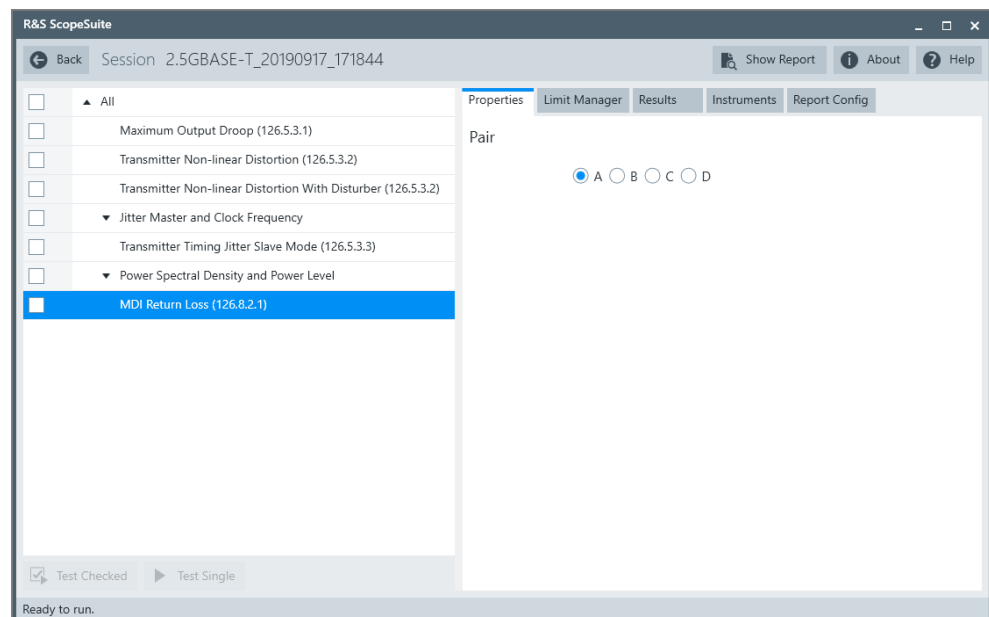
3. Click "Test Single".

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

7.1.9.3 Test setup

Configure the DUT to test mode 5.
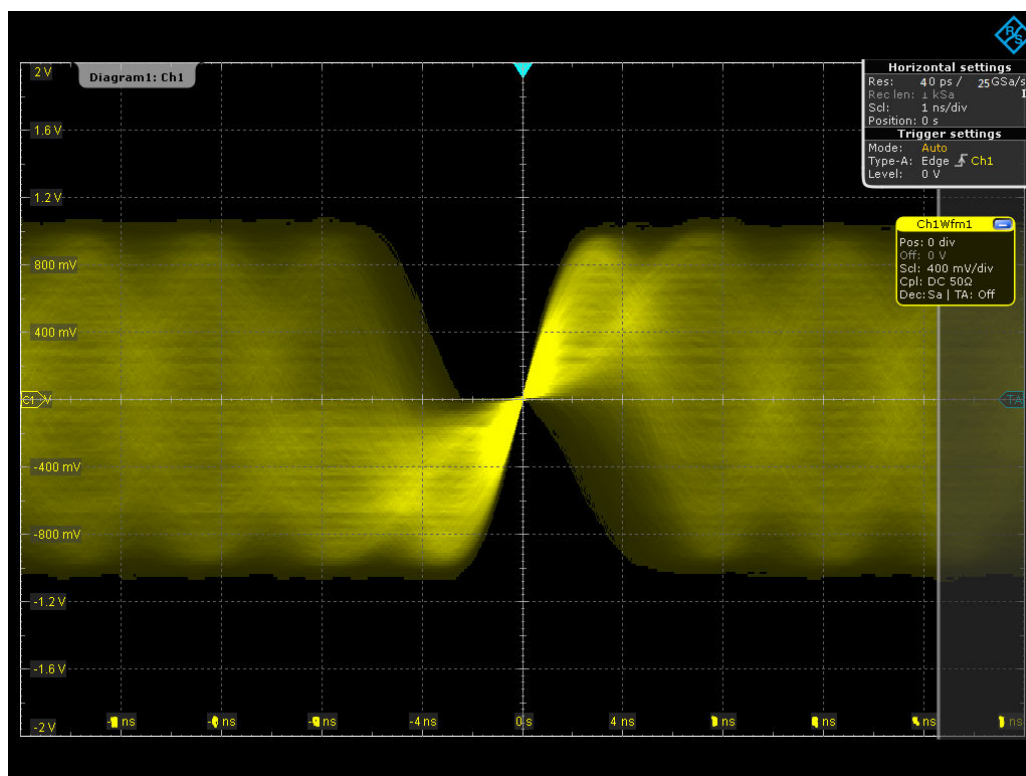
Figure 7-17: Test mode 5 waveform

7.1.9.4 Measurements

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 250 MHz.

During manual testing, the program checks if every point within 1 MHz and 250 MHz in the result file (`*.s1p` or `*.csv`) falls below the limit required by the specification.

7.2 5GBASE-T tests

5GBASE-T Ethernet compliance tests require option R&S RTO/RTO6/RTP-K23.

The following table shows an overview of the needed equipment for performing the 5GBASE-T test cases. A prerequisite is also a R&S RTO / R&S RTO6 /R&S RTP with at least 1 GHz bandwidth, the R&S ScopeSuite software and a 5GBASE-T DUT.

Table 7-9: Equipment for 5GBASE-T Ethernet compliance tests

	Differential probe	Test fixture	Additional instruments
Maximum Output Droop (126.5.3.1) Transmitter Timing Jitter Master Mode and Clock Frequency (126.5.3.3 and 126.5.3.5) Transmitter Timing Jitter Slave Mode (126.5.3.3) Transmitter Power Spectral Density and Power Level (126.5.3.4)	1 at least 3 GHz bandwidth	R&S RT-ZF2 Section: Resistive Load	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Transmitter Non-Linearity Distortion (126.5.3.2)	-	R&S RT-ZF2 Section: Return Loss	**Spectrum analyzer:** R&S FSV/FSQ/FSW/ESRP **Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
MDI Return Loss (126.8.2.1)	-	R&S RT-ZF2 Section: Twisted Pair Model	**VNA:** R&S ZNB or R&S ZNC or R&S ZND or R&S ZVL

7.2.1 Starting 5GBASE-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 Scope-Suite, see Chapter 2.5, "Connecting the R&S RTO/RTO6/RTP", on page 12

● VNA connection for MDI Return Loss and Transmitter Power Spectral Density and Power Level tests, see Chapter 2.7, "Connecting the vector network analyzer", on page 15.

1. Select "Ethernet 2.5/5G/10G " in the R&S ScopeSuite start window.

2. In the "Session Selection" dialog, set "Select Type" > "5GBASE-T".

3. Add a new test session and open it, see Chapter 3.1, "Starting a test session", on page 20.

4. Check the test configuration settings and adjust, if necessary. See:
   - Chapter 7.2.2, "Test configuration for Ethernet 5GBASE-T", on page 194
   - 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.

7.2.2 Test configuration for Ethernet 5GBASE-T

The test configuration consists of some test-specific configuration settings.
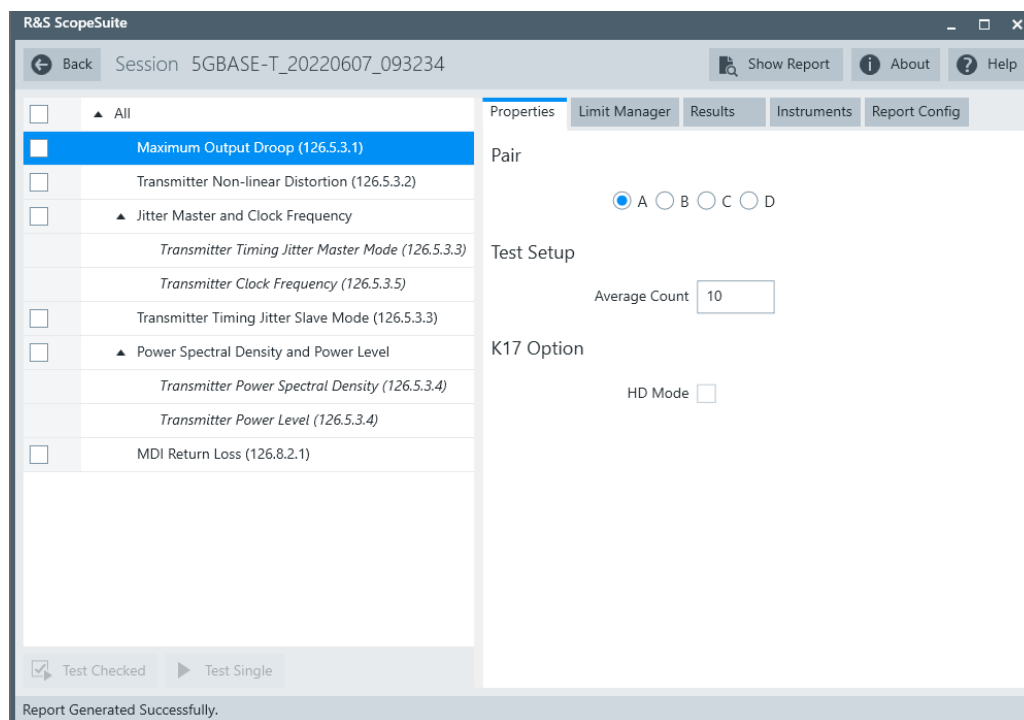
Figure 7-18: Configuration for 5GBASE-T compliance tests

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 Clock Frequency and Transmitter Timing Jitter Slave Mode test cases. The valid range is 2E-6 to 2E-3, the default value is 2E-3.

No. of Acquisitions

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

HD Mode

Enables the higher digital resolution mode. Requires option R&S RTO / R&S RTO6 /R&S RTP-K17.

7.2.3 Maximum output droop

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

7.2.3.1 Test equipment

Table 7-10: Equipment for Maximum Output Droop test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 1 GHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 3 GHz bandwidth	1
DUT	5GBASE-T device to be tested	1

7.2.3.2 Performing non-linearity tests

1. Start the test as described in Chapter 7.2.1, "Starting 5GBASE-T tests", on page 193.

2. Select the test case: "Maximum Output Droop (126.5.3.1)".
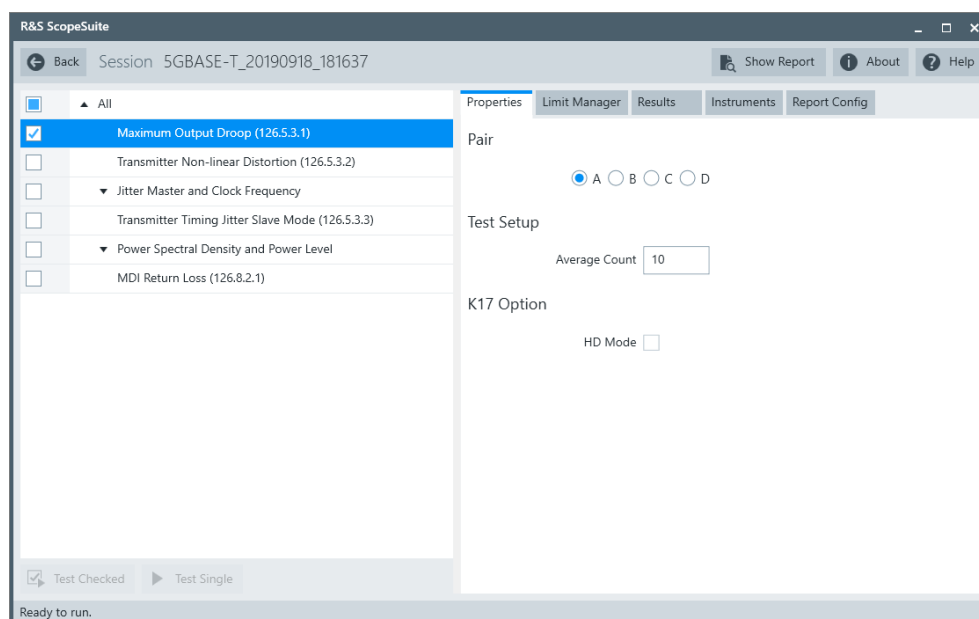
3. Click "Test Single".

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 23

7.2.3.3 Test setup

For "Maximum Output Droop" tests, 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.

7.2.3.4 Measurements

The test makes two measurements:

● Measure the voltage ratio between V_{10} (10 ns after the zero crossing) and V_{170} (170 ns after the zero crossing) of a rising edge.
   The software set a trigger at the zero crossing of a rising edge. After acquiring N number of waveforms, it averages them into a single waveform. The software enables a pair of cursors with "Track waveform". It positions "Cursor 1" at V_{10} and "Cursor 2" at V_{170}. The software determines the voltage ratio by measuring the voltage levels at V_{10} and V_{170}.

- Measure the voltage ratio between V_{10} (10 ns after the zero crossing) and V_{170} (170 ns after the zero crossing) of a falling edge.
  The software set a trigger at the zero crossing of a falling edge. After acquiring N number of waveforms, it averages them into a single waveform. The software enables a pair of cursors with "Track waveform". It positions "Cursor 1" at V_{10} and "Cursor 2" at V_{170}. The software determines the voltage ratio by measuring the voltage levels at V_{10} and V_{170}.
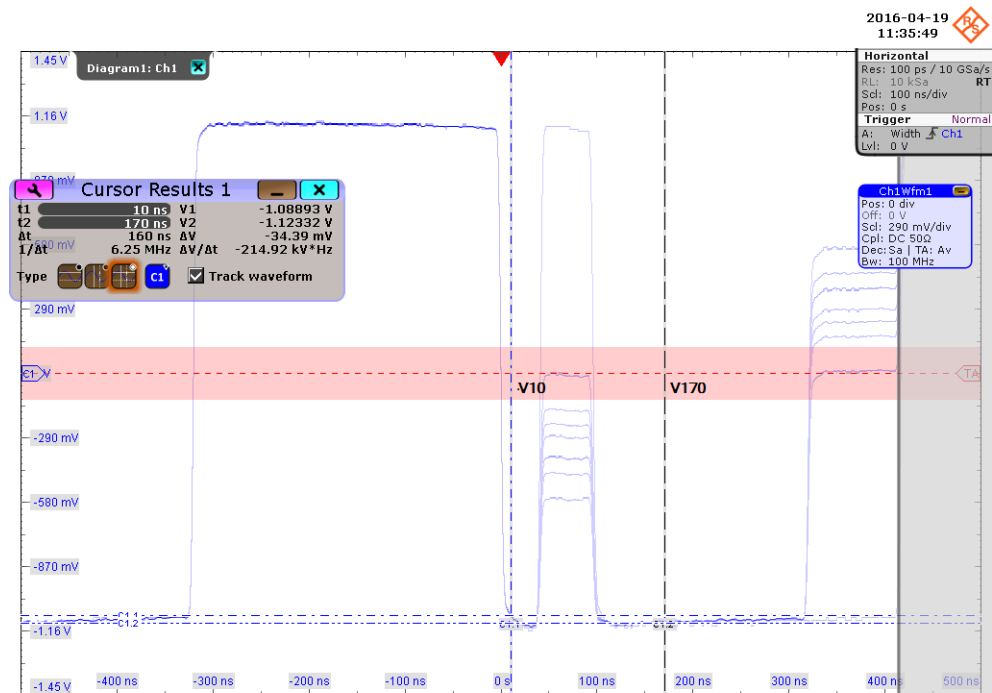
7.2.4 Transmitter non-linearity distortion

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

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

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

7.2.4.1 Test equipment

Table 7-11: Equipment for Transmitter Non-linearity Distortion test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 1 GHz bandwidth	1
Ethernet test fixture, "Return Loss" section	R&S RT-ZF2	1
Spectrum analyzer	R&S FSV/FSQ/FSW/ESRP	1
DUT	5GBASE-T device to be tested	1

7.2.4.2 Performing the test

1. Start the test as described in Chapter 7.2.1, "Starting 5GBASE-T tests", on page 193.

2. Select the test case: "Transmitter Non-linearity Distortion (126.5.3.2)".
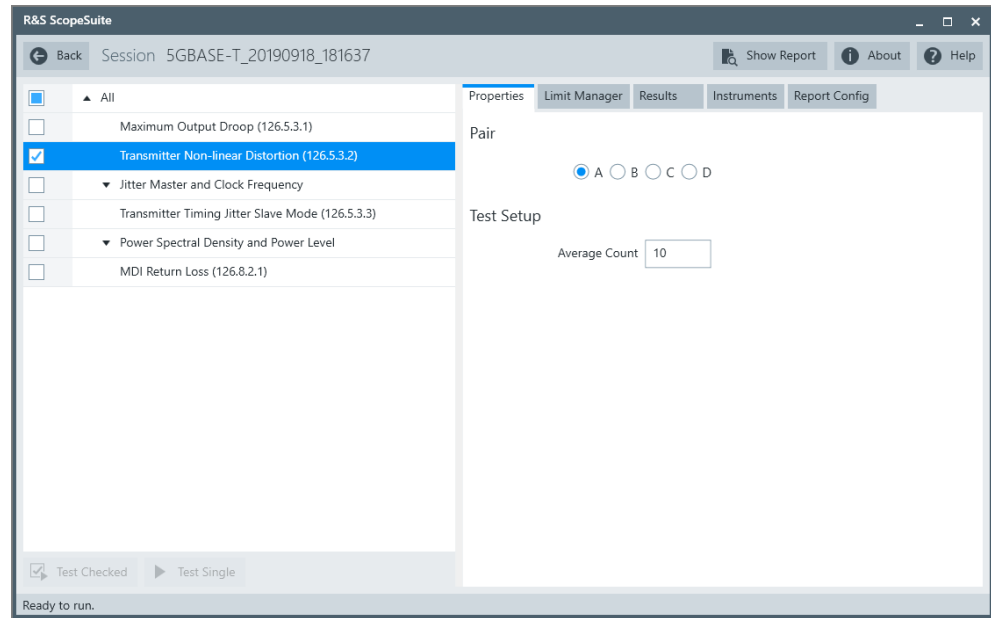
3. Click "Test Single".

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

   Further steps:
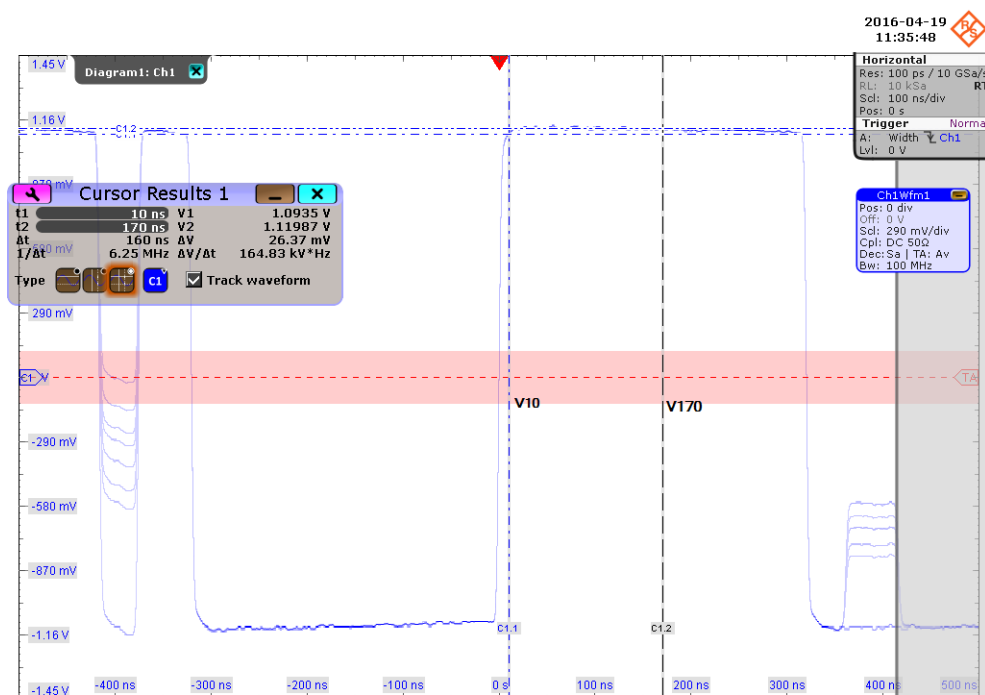   - Chapter 3.3, "Getting test results", on page 23

7.2.4.3 Test setup

The test requires the DUT to transmit each of the five dual tones during the test.
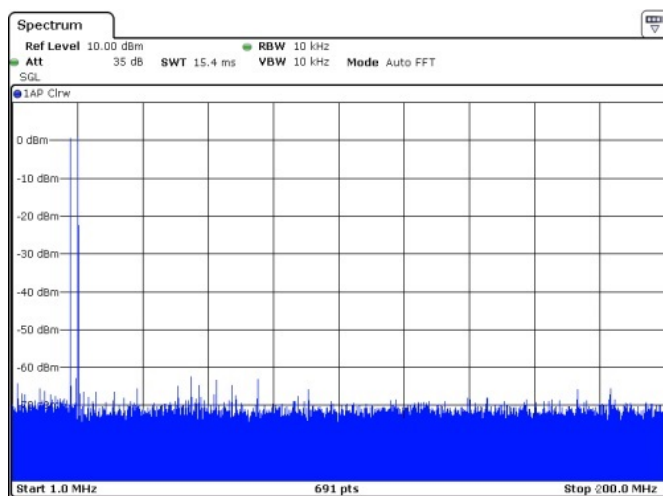
Figure 7-19: First dual tone (9.179688MHz, and 10.35156MHz)
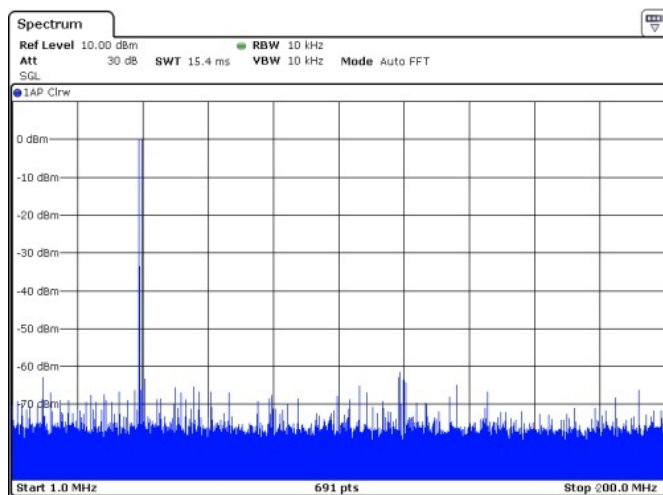
Figure 7-20: Second dual tone (19.72656MHz and 20.11719MHz)
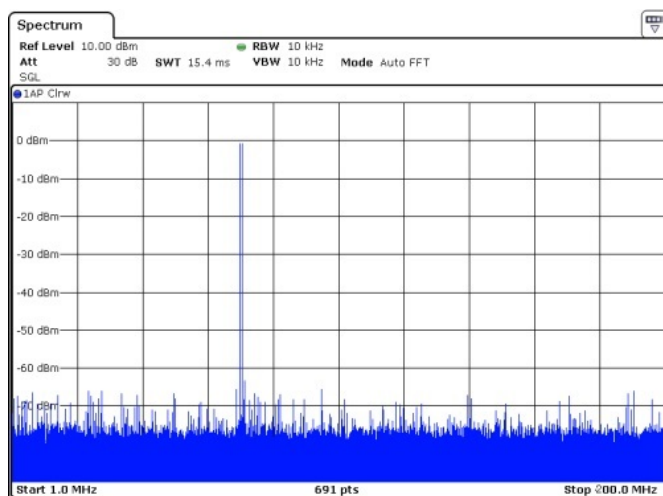
Figure 7-21: Third dual tone (34.96094MHz and 35.35156MHz)
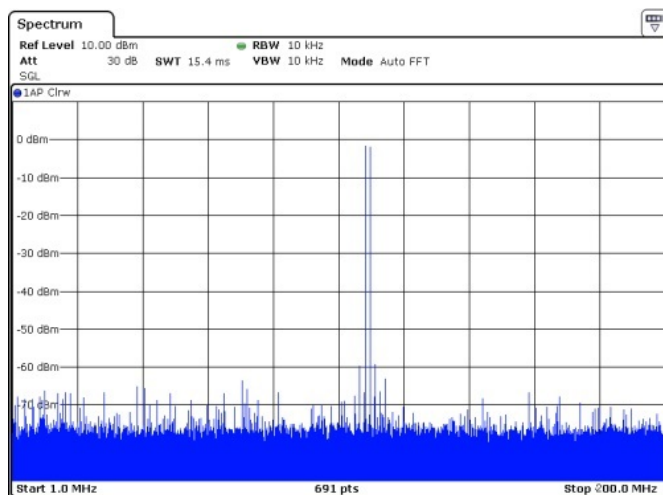
Figure 7-22: Fourth dual tone (54.10156MHz and 54.88281MHz)
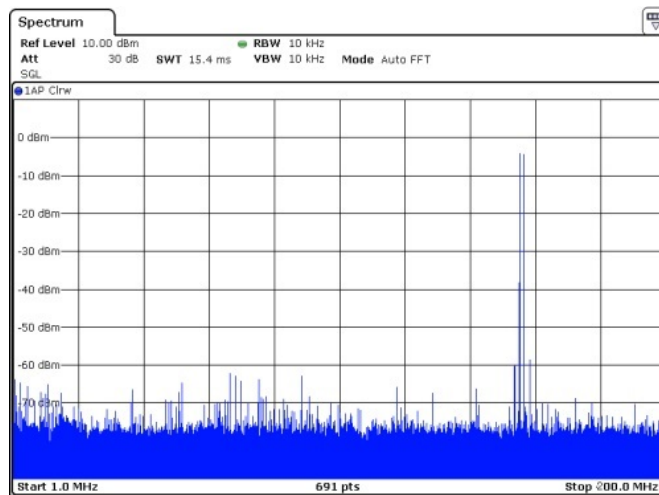
Figure 7-23: Fifth dual tone (77.53906MHz and 78.32031MHz)

7.2.4.4 Measurements

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

In manual testing, you need to provide the frequencies and the magnitudes of the 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 200 MHz.

7.2.5 Transmitter timing jitter master mode and clock frequency

The tests verify that the jitter of the DUT and the transmitter clock is within the specified range. The DUT is in master mode.

7.2.5.1 Test equipment

Table 7-12: Equipment for Transmitter Timing Jitter Master Mode and Clock Frequency test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 1 GHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 3 GHz bandwidth	1
DUT	5GBASE-T device to be tested	1

7.2.5.2　Performing the test

1. Start the test as described in Chapter 7.2.1, "Starting 5GBASE-T tests", on page 193.

2. Select the test case: "Transmitter Timing Jitter Master Mode and Clock Frequency".
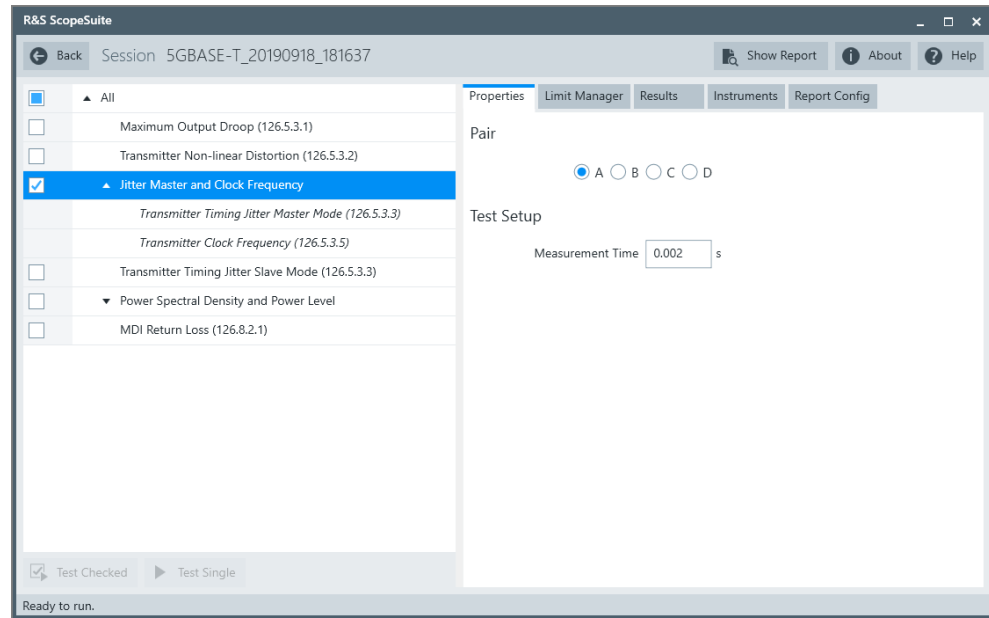
3. Click "Test Single".

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 23

7.2.5.3　Test setup

The DUT has to transmit a test mode 2 waveform.
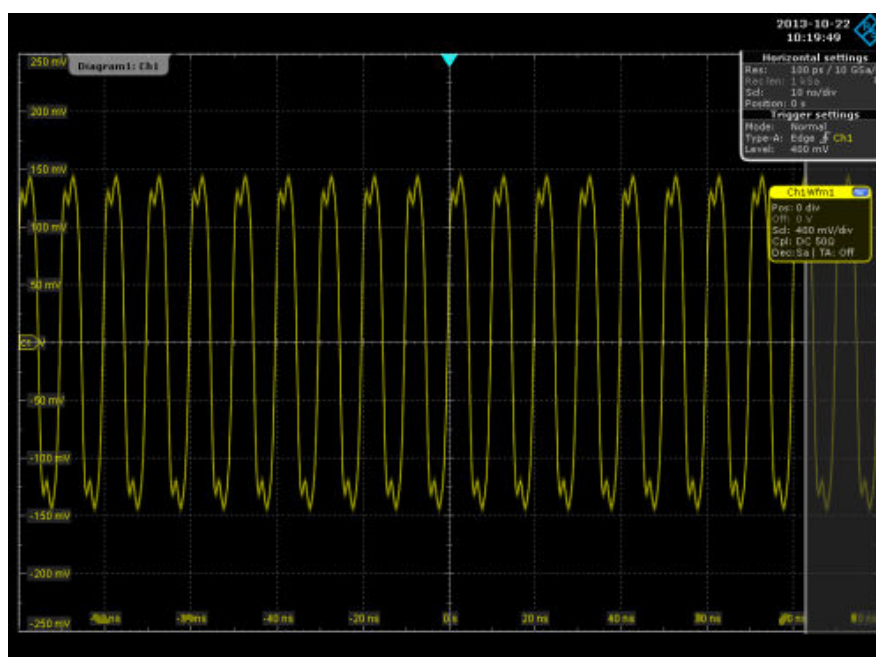
Figure 7-24: Test mode 2 waveform

7.2.5.4 Measurements

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 10,000 samples. Then RMS period jitter is calculated.

To pass the test, the RMS jitter must be less than 7.2 ps. Meanwhile, in automated testing the oscilloscope does a frequency measurement and determines if the transmitter clock frequency is within the conformance limits.

7.2.6 Transmitter timing jitter slave mode

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

7.2.6.1 Test equipment

Table 7-13: Equipment for Transmitter Timing Jitter Slave Mode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 1 GHz bandwidth	1
Ethernet test fixture, "Jitter Slave Test 10GBASE-T" section	R&S RT-ZF2	1

Item	Description, model	Quantity
Differential probe	at least 3 GHz bandwidth	1
DUT	5GBASE-T device to be tested	1

7.2.6.2 Performing the test

1. Start the test as described in Chapter 7.2.1, "Starting 5GBASE-T tests", on page 193.

2. Select the test case: "Transmitter Timing Jitter Slave Mode (126.5.3.3)".
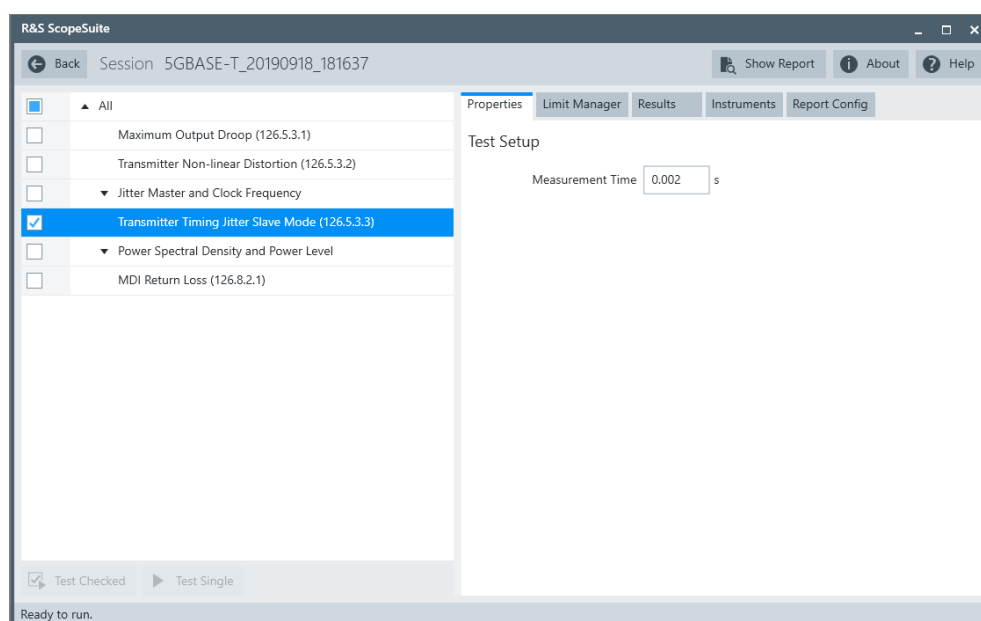
3. Click "Test Single".

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 23

7.2.6.3 Test setup

The test requires the DUT to transmit test 3 mode waveform.
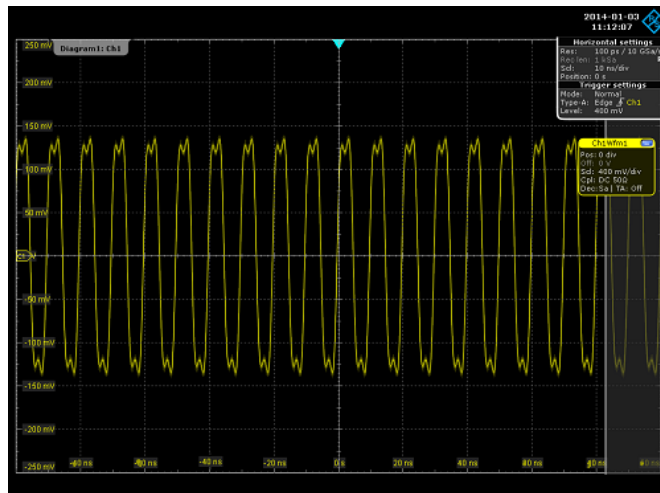
Figure 7-25: Test mode 3 waveform

The test requires the link partner of DUT to transmit test mode 1 waveform.
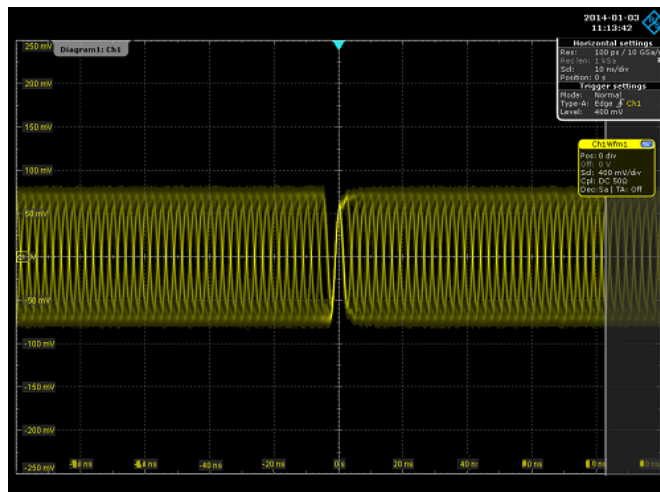
Figure 7-26: Test mode 1 waveform

7.2.6.4 Measurements

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 10 000 samples.

The captured waveform is passed through a band pass filter with a central frequency of 100 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 7.2 ps.

7.2.7 Transmitter power spectral density and power level

The test verifies that the transmitter power spectral density of the DUT over the frequency range 0 GHz to 3 GHz falls in between the limits specified in specification Section 126.5.3.4. It also verifies that the transmitter power level of the DUT is between 1.0 dBm and 3.0 dBm.

7.2.7.1 Test equipment

Table 7-14: Equipment for Transmitter Power Spectral Density and Power Level test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 / R&S RTP with at least 1 GHz bandwidth	1
Ethernet fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Differential probe	at least 3 GHz bandwidth	1
DUT	5GBASE-T device to be tested	1

7.2.7.2 Performing the test

1. Start the test as described in Chapter 7.2.1, "Starting 5GBASE-T tests", on page 193.

2. Select the test case: "Transmitter Power Spectral Density and Power Level".
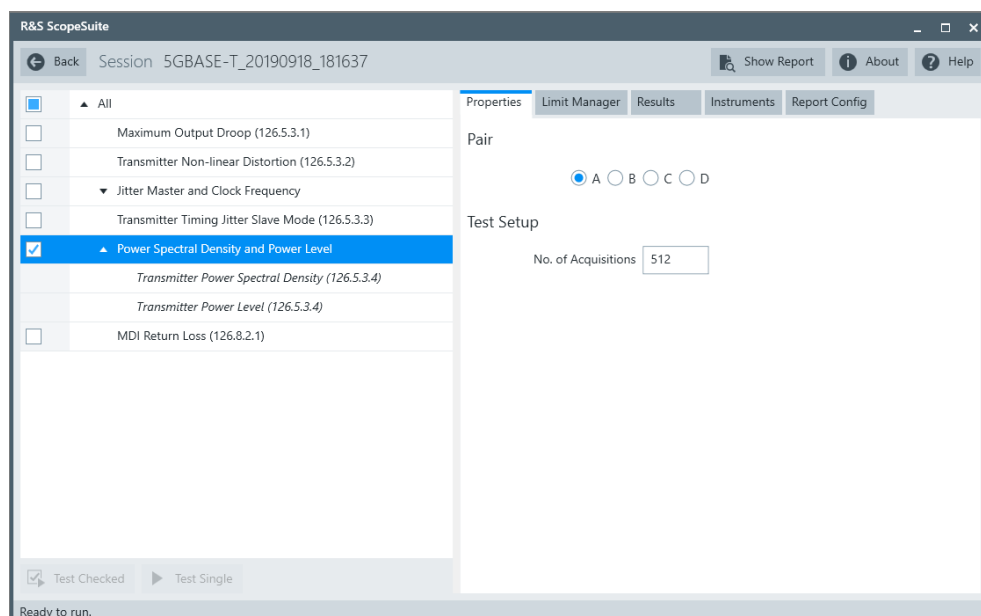
3. Click "Test Single".

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 23

7.2.7.3 Test setup

Configure the DUT to test mode 5.
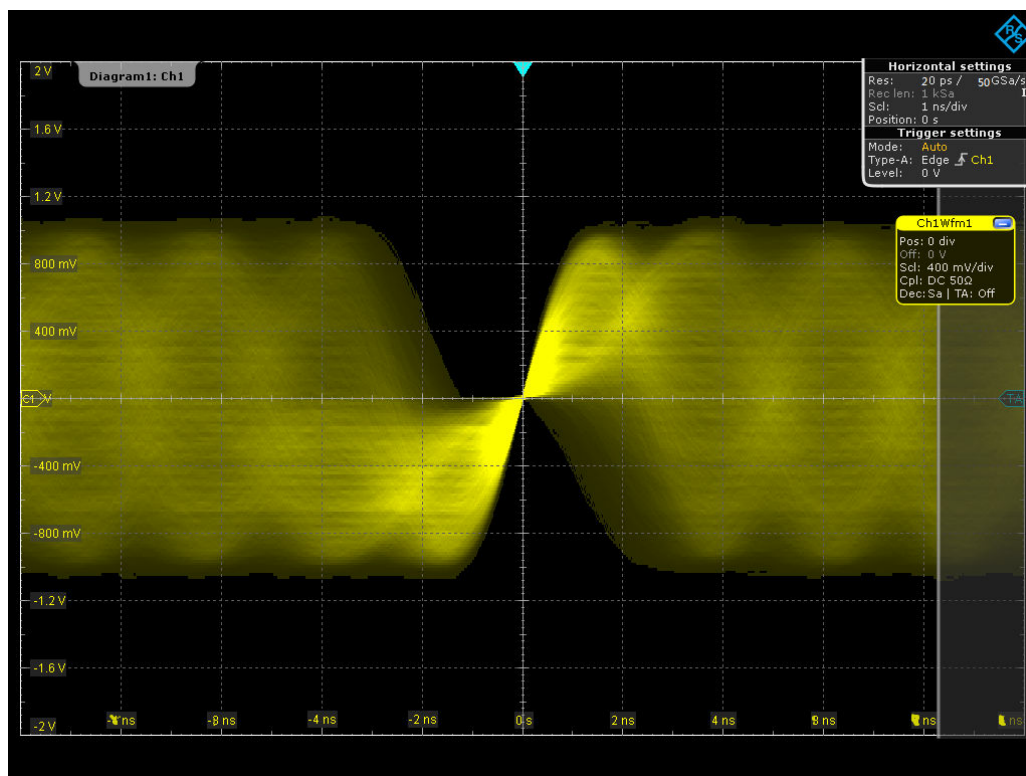
Figure 7-27: Test mode 5 waveform

7.2.7.4 Measurements

First the program measures the power level of the input signal using FFT transform and some mathematics. It also makes an FFT transformation of the input signal over 0 GHz to 3 GHz. Then it performs some averaging and mathematics to plot the PSD curve, and checks whether it falls within the limit mask.

7.2.8 MDI return loss

The test verifies that the differential impedance at the MDI for each transmit/receive channel of the DUT over the frequency range of 1 MHz to 250 MHz is greater than the limits specified in the IEEE P802.3bz[TM]/D2.1 specification, section 126.8.2.1.

7.2.8.1 Test equipment

Table 7-15: Equipment for MDI Return Loss test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 1 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 ZNB/ZNC/ZND/ZVL	1
DUT	5GBASE-T device to be tested	1

7.2.8.2 Performing the test

1. Start the test as described in Chapter 7.2.1, "Starting 5GBASE-T tests", on page 193.

2. Select the test case: "MDI Return Loss (126.8.2.1)".
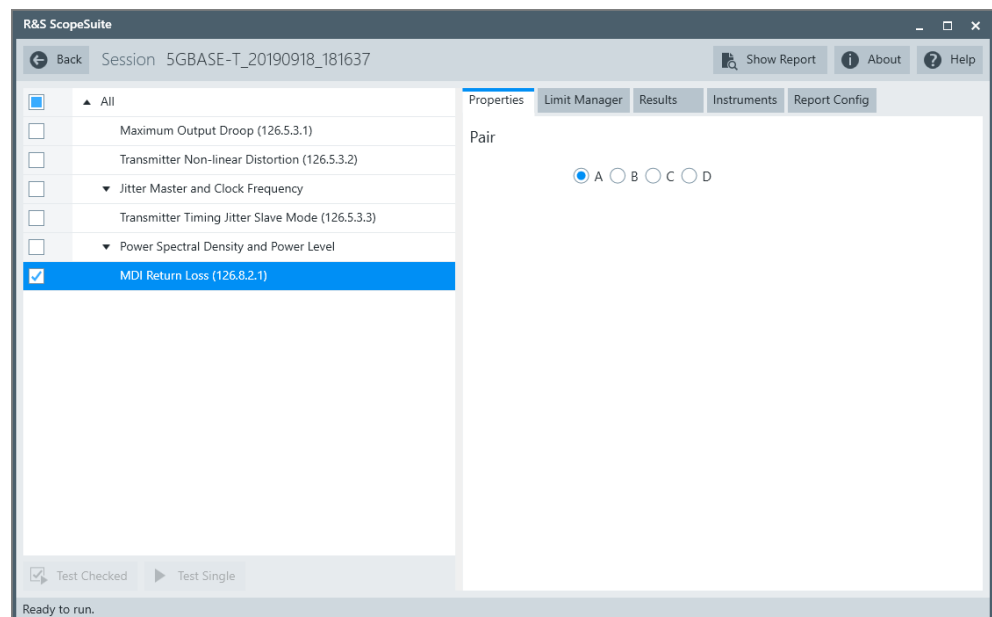
3. Click "Test Single".

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

7.2.8.3 Test setup

Configure the DUT to test mode 5.
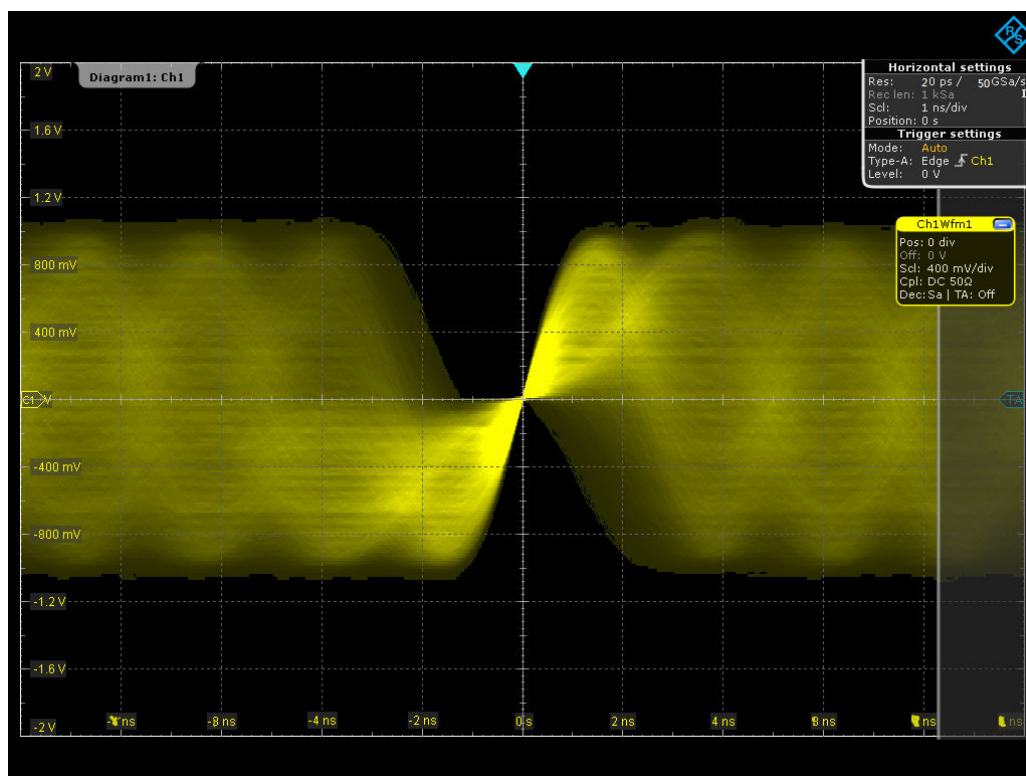
Figure 7-28: Test mode 5 waveform

7.2.8.4 Measurements

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 250 MHz.

During manual testing, the program checks if every point within 1 MHz and 250 MHz in the result file (`*.s1p` or `*.csv`) falls below the limit required by the specification.

7.3 10GBASE-T tests

10GBASE-T Ethernet compliance tests require option R&S RTO/RTO6/RTP-K23.

The following table shows an overview of the needed equipment for performing the 2.5GBASE-T test cases. A prerequisite is also a R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth, the R&S ScopeSuite software and a 10GBASE-T DUT.

Table 7-16: Equipment for 10GBASE-T Ethernet compliance tests

	Differential probe	Test fixture	Additional instruments
Maximum Output Droop (55.5.3.1) Transmitter Timing Jitter Master Mode and Clock Frequency (55.5.3.3 and 55.5.3.5)	1 at least 2 GHz band-width	R&S RT-ZF2 Section: Resistive Load	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Transmitter Power Spectral Density and Power Level (55.5.3.4)	1 at least 2 GHz band-width	R&S RT-ZF2 Section: Twisted Pair Model	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Transmitter Timing Jitter Slave Mode (55.5.3.3)	1 at least 2 GHz band-width	R&S RT-ZF2 Section: Jitter Slave Test 10GBASE-T	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Transmitter Linearity (55.5.3.2)	-	R&S RT-ZF2 Section: Return Loss	**Spectrum analyzer:** R&S FSV/FSQ/FSW/ESRP **Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
MDI Return Loss (55.8.2.1)	-	R&S RT-ZF2 Section: Twisted Pair Model	**VNA:** R&S ZNB or R&S ZNC or R&S ZND or R&S ZVL

7.3.1 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 Scope-Suite, see Chapter 2.5, "Connecting the R&S RTO/RTO6/RTP", on page 12

- VNA connection for MDI Return Loss and Transmitter Power Spectral Density and Power Level tests, see Chapter 2.7, "Connecting the vector network analyzer", on page 15.

1. Select "Ethernet 2.5/5G/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 20.

3. Check the test configuration settings and adjust, if necessary. See:
   - Chapter 7.3.2, "Test configuration for Ethernet 10GBASE-T", on page 212
   - 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.

7.3.2 Test configuration for Ethernet 10GBASE-T

The test configuration consists of some test-specific configuration settings.
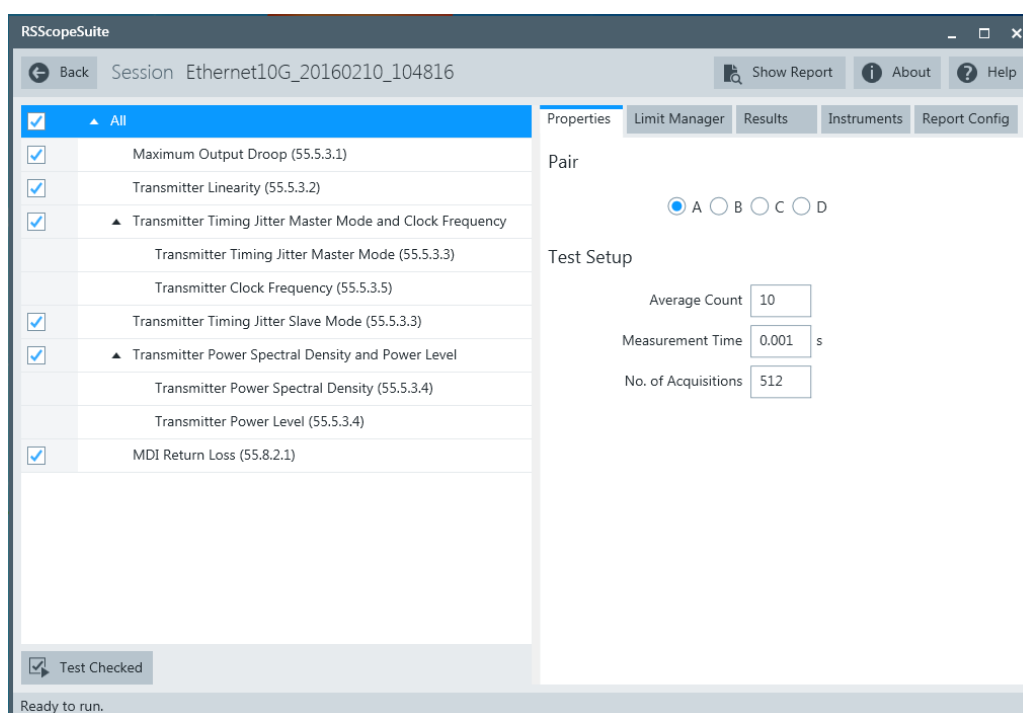
Figure 7-29: Configuration for 10GBASE-T compliance tests

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 Clock Frequency and Transmitter Timing Jitter Slave Mode test cases. The valid range is 1E-6 to 1E-3, the default value is 1E-3.

No. of Acquisitions

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

7.3.3 Maximum output droop

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

7.3.3.1 Test equipment

Table 7-17: Equipment for Maximum Output Droop test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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

7.3.3.2 Performing the test

1. Start the test as described in Chapter 7.3.1, "Starting 10GBASE-T tests", on page 211.

2. Select the test case: "Maximum Output Droop (55.5.3.1)".
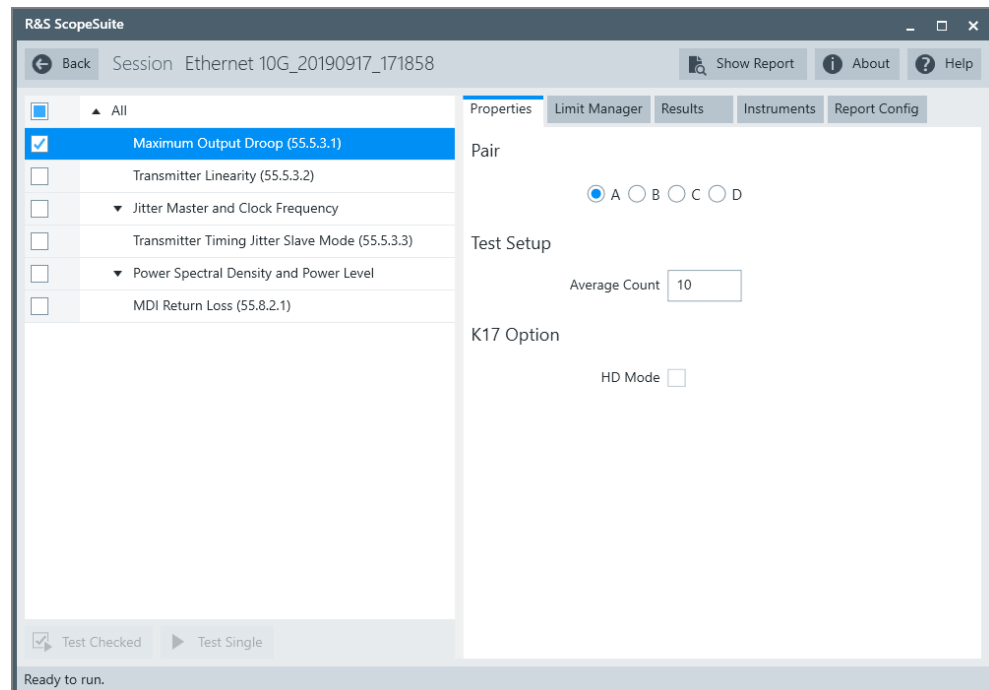
3. Click "Test Single".

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 23

7.3.3.3 Measurements

For the "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).
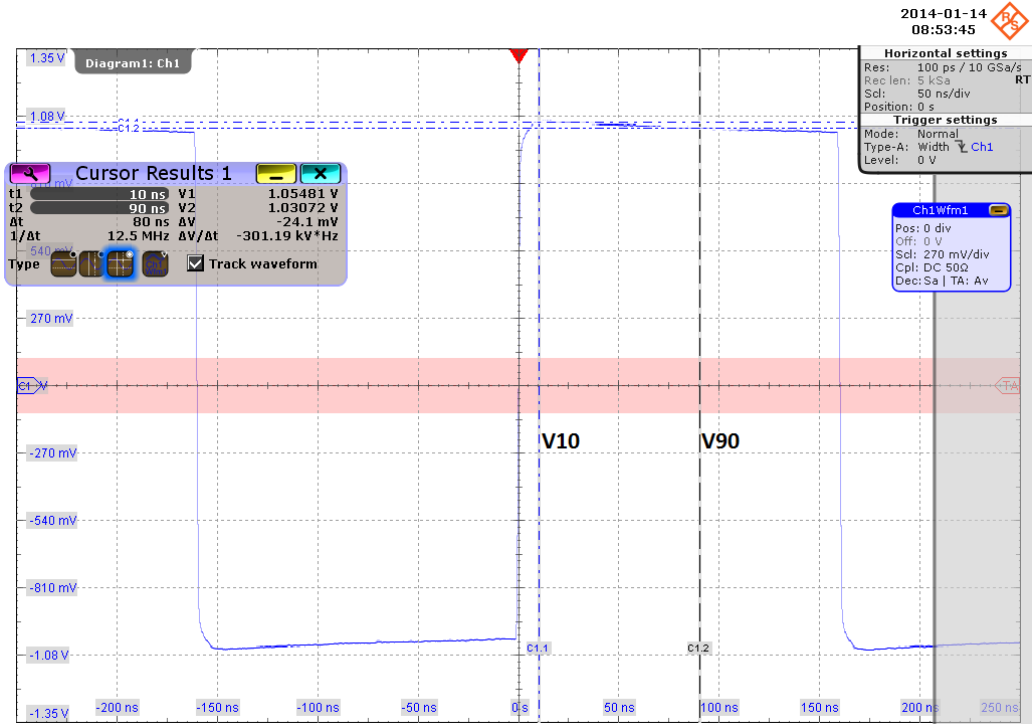
The test is repeated for the negative droop.
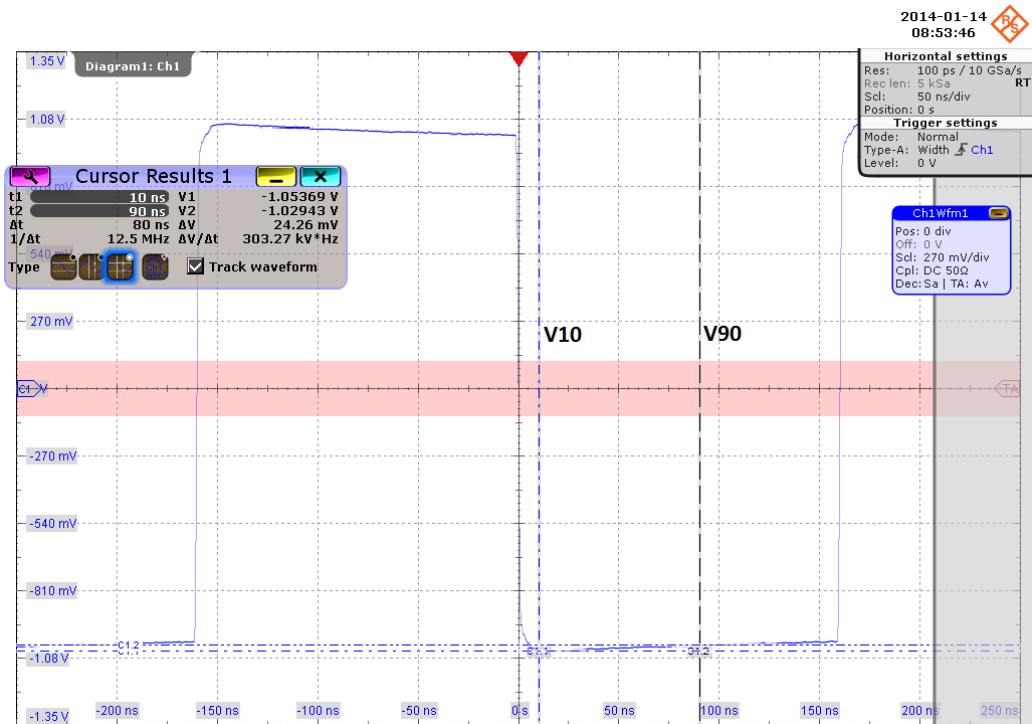
7.3.4 Transmitter linearity

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

7.3.4.1 Test equipment

Table 7-18: Equipment for Transmitter Linearity test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
Ethernet test fixture, "Return Loss" section	R&S RT-ZF2	1
Spectrum analyzer	R&S FSV/FSQ/FSW/ESRP	1
DUT	10GBASE-T device to be tested	1

7.3.4.2 Performing the test

1. Start the test as described in

2. Select the test case: "Transmitter Linearity (55.5.3.2)".
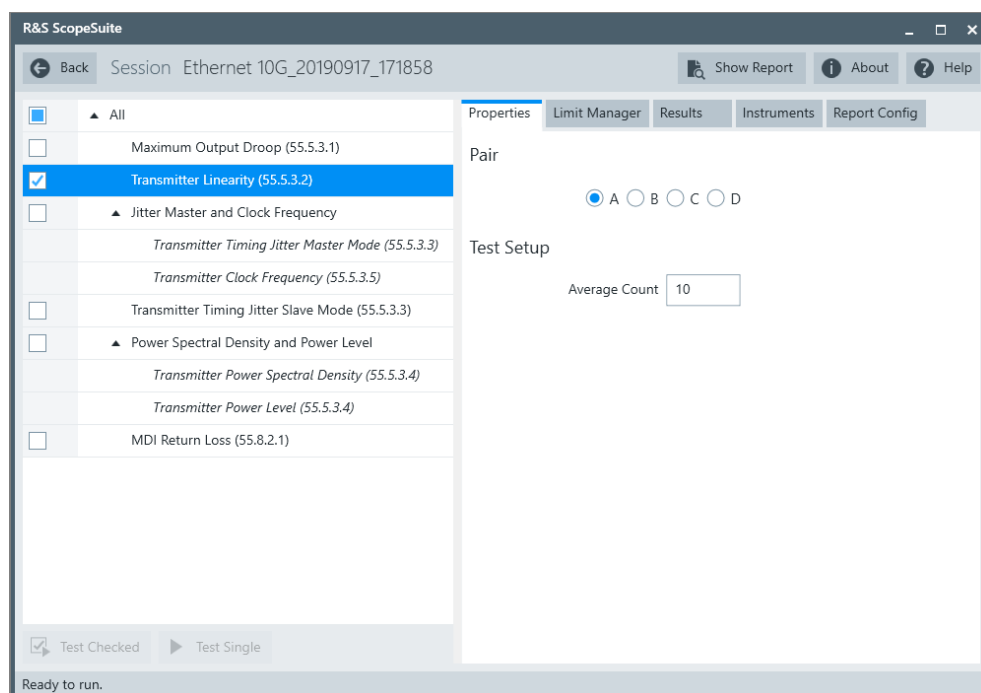
3. Click "Test Single".

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 23

7.3.4.3 Measurements

For transmitter linearity test, the DUT has to transmit each of the five dual tones during the test.
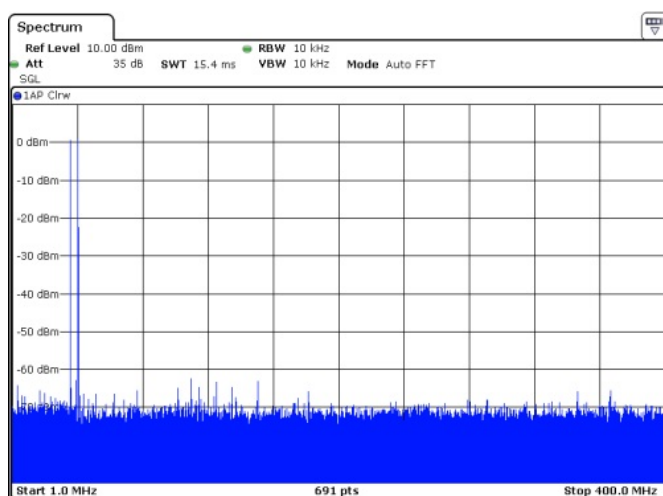
Figure 7-30: 1st dual tone (36.718 MHz and 41.406 MHz)
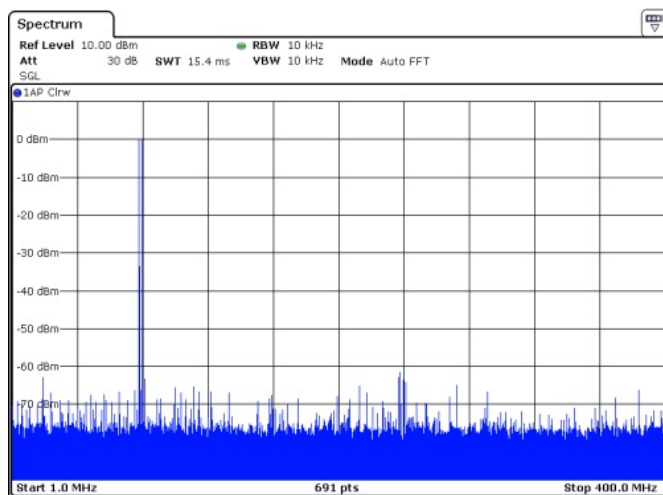
Figure 7-31: 2nd dual tone (78.906 MHz and 80.469 MHz)
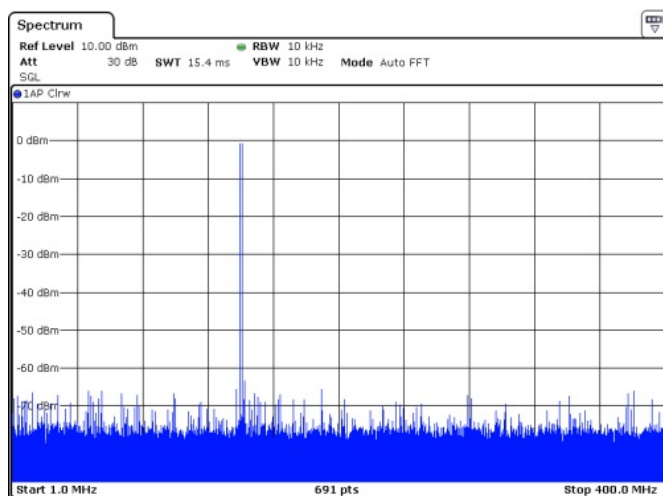
Figure 7-32: 3rd dual tone (139.844 MHz and 141.406 MHz)
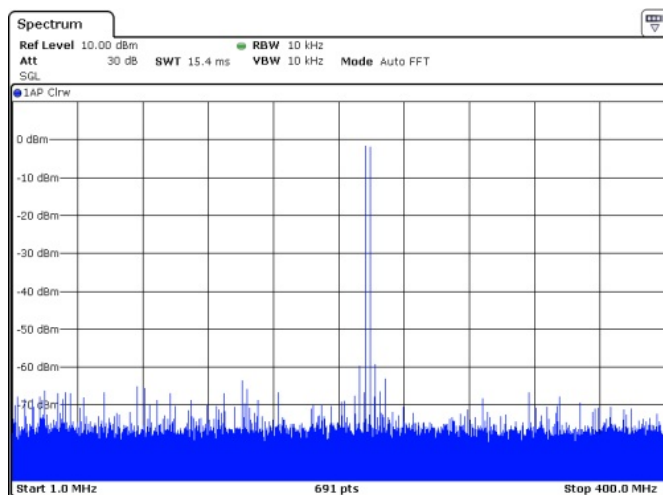
Figure 7-33: 4th dual tone (216.406 MHz and 219.531 MHz)
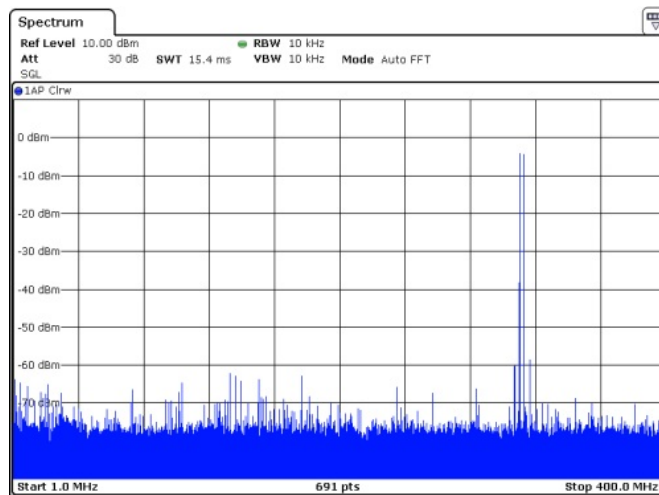
Figure 7-34: 5th Dual tone (310.156 MHz and 313.281 MHz)

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.

7.3.5 Transmitter timing jitter master mode and clock frequency

The tests verify that the jitter of the DUT and the transmitter clock is within the specified range. The DUT is in master mode.

7.3.5.1 Test equipment

Table 7-19: Equipment for Transmitter Timing Jitter Master Mode and Clock Frequency test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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

7.3.5.2 Performing the test

1. Start the test as described in Chapter 7.3.1, "Starting 10GBASE-T tests", on page 211.

2. Select the test case: "Jitter Master Mode and Clock Frequency".
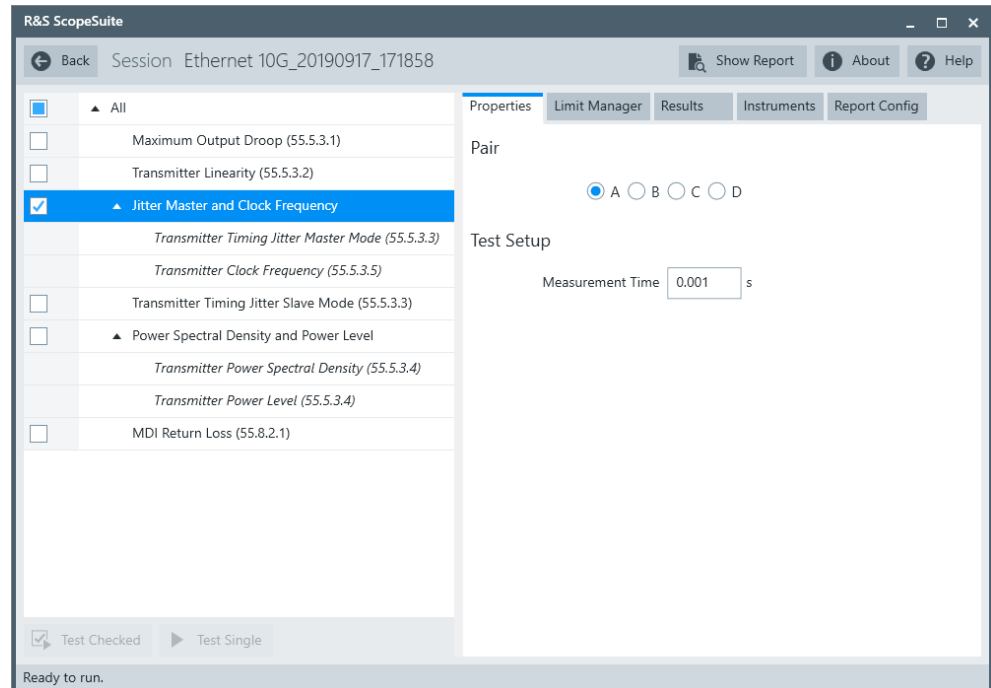
3. Click "Test Single".

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 23

7.3.5.3 Measurements

The DUT has to transmit a test mode 2 waveform.
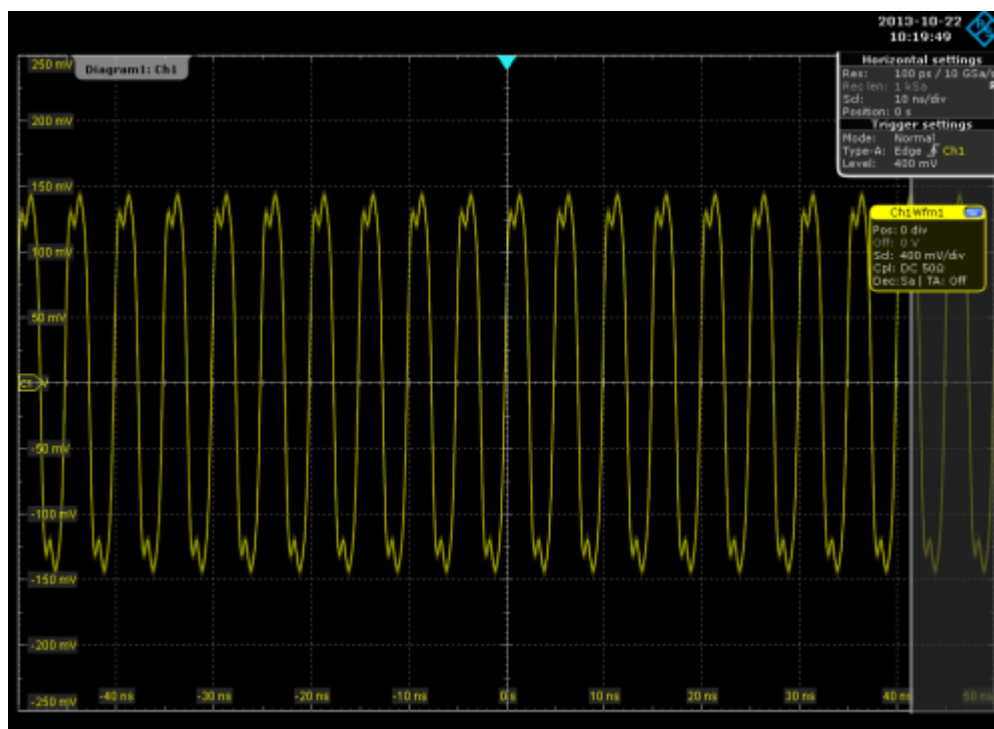
Jitter is calculated by the edge positions. Due to the large amount of data, the waveform data is processed segment by segment. One segment is preset as 10,000 samples. Then RMS period jitter is calculated.

To pass the test, the RMS jitter must be less than 5.5 ps. Meanwhile, in automated testing the oscilloscope does a frequency measurement and determines if the transmitter clock frequency is within the conformance limits.

7.3.6 Transmitter timing jitter slave mode

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

7.3.6.1 Test equipment

Table 7-20: Equipment for Transmitter Timing Jitter Slave Mode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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

7.3.6.2 Performing the test

1. Start the test as described in Chapter 7.3.1, "Starting 10GBASE-T tests", on page 211.

2. Select the test case: "Transmitter Timing Jitter Slave Mode (55.5.3.3)".
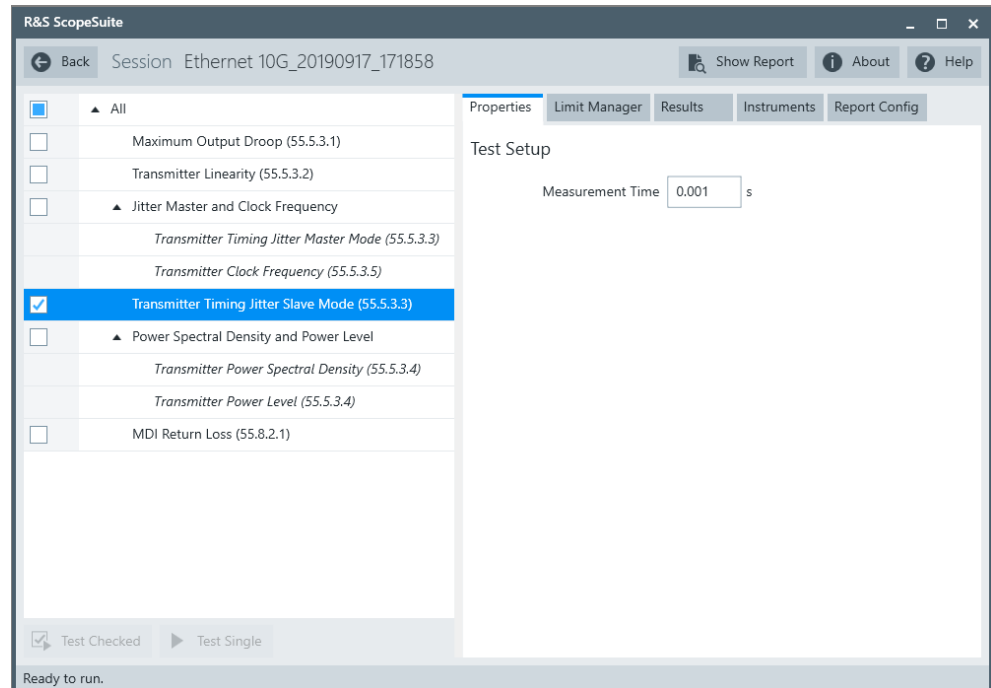
3. Click "Test Single".

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 23

7.3.6.3 Measurements

The DUT has to transmit a test mode 3 waveform and a test mode 1 waveform.
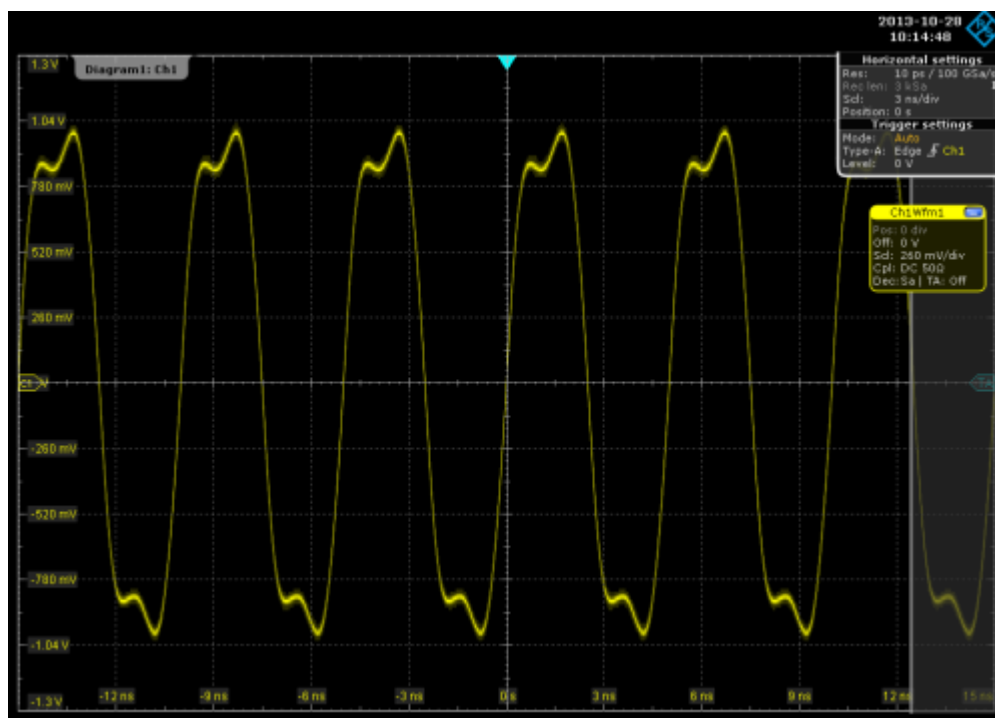
Figure 7-35: Test mode 3 waveform
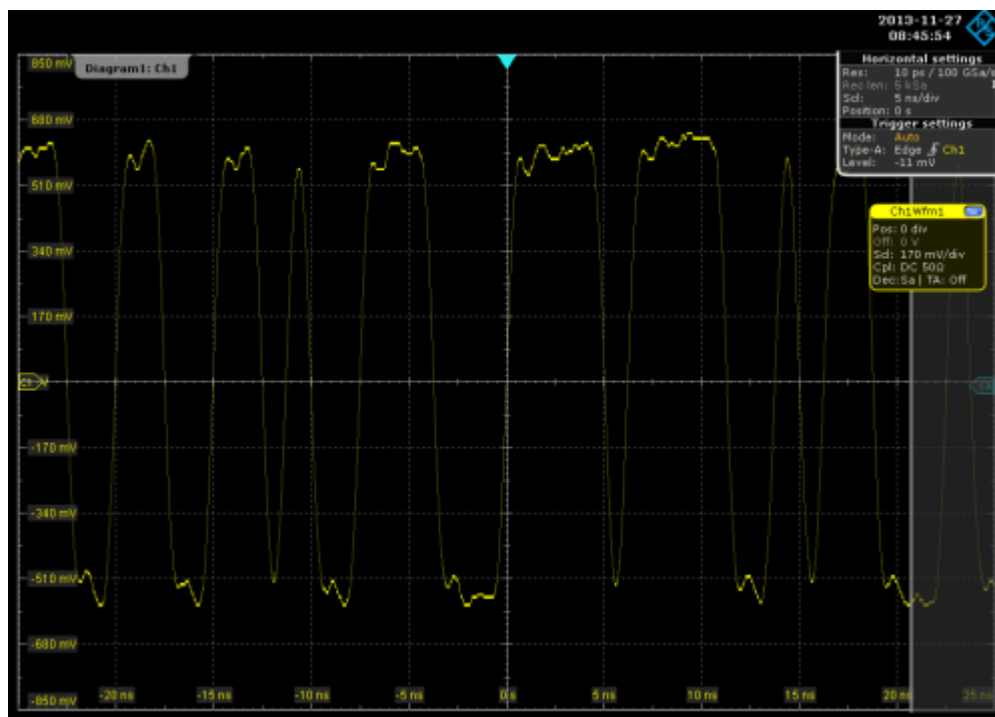
Figure 7-36: Test mode 1 waveform

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. To pass the test, the RMS jitter must be less than 5.5 ps.

7.3.7 Transmitter power spectral density and power level

The test verifies that the transmitter power spectral density of the DUT over the frequency range 0 GHz to 3 GHz falls in between the upper and lower limits specified in specification section 126.5.3.4. It also verifies that the transmitter power level of the DUT is between 3.2 dBm and 5.2 dBm.

7.3.7.1 Test equipment

Table 7-21: Equipment for Transmitter Power Spectral Density and Power Level test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 / R&S RTP with at least 2 GHz bandwidth	1
Ethernet fixture, "Twisted Pair Model" section	R&S RT-ZF2	1
Differential probe	at least 2 GHz bandwidth	1
DUT	10GBASE-T device to be tested	1

7.3.7.2 Performing the test

1. Start the test as described in

2. Select the test case: "Transmitter Power Spectral Density and Power Level".
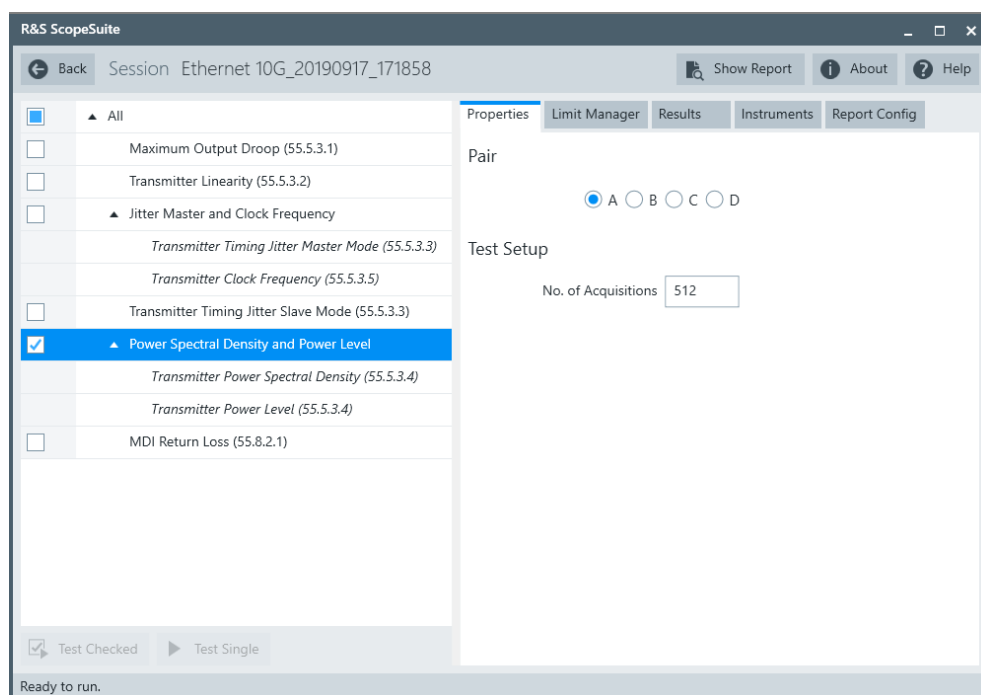
3. Click "Test Single".

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 23

7.3.7.3 Measurements
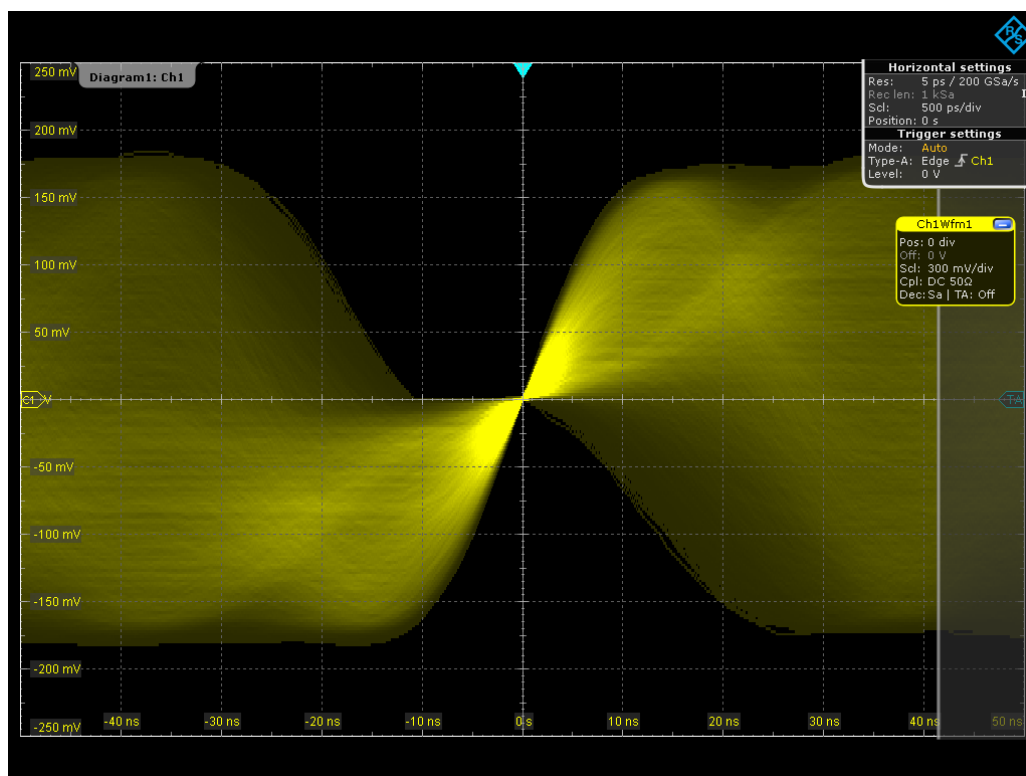
Configure the DUT to test mode 5.

First the program measures the Power Level of the input signal using FFT transform and some mathematics. It also makes a FFT transformation of the input signal over 0 GHz to 3 GHz. Then it performs some averaging and mathematics to plot the PSD curve, and checks whether it falls within the limit mask.

7.3.8 MDI return loss

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

7.3.8.1 Test equipment

Table 7-22: Equipment for MDI Return Loss test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP 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 ZNB/ZNC/ZND/ZVL	1
DUT	10GBASE-T device to be tested	1

7.3.8.2 Performing the test

1. Start the test as described in Chapter 7.3.1, "Starting 10GBASE-T tests", on page 211.

2. Select the test case: "MDI Return Loss (55.8.2.1)".
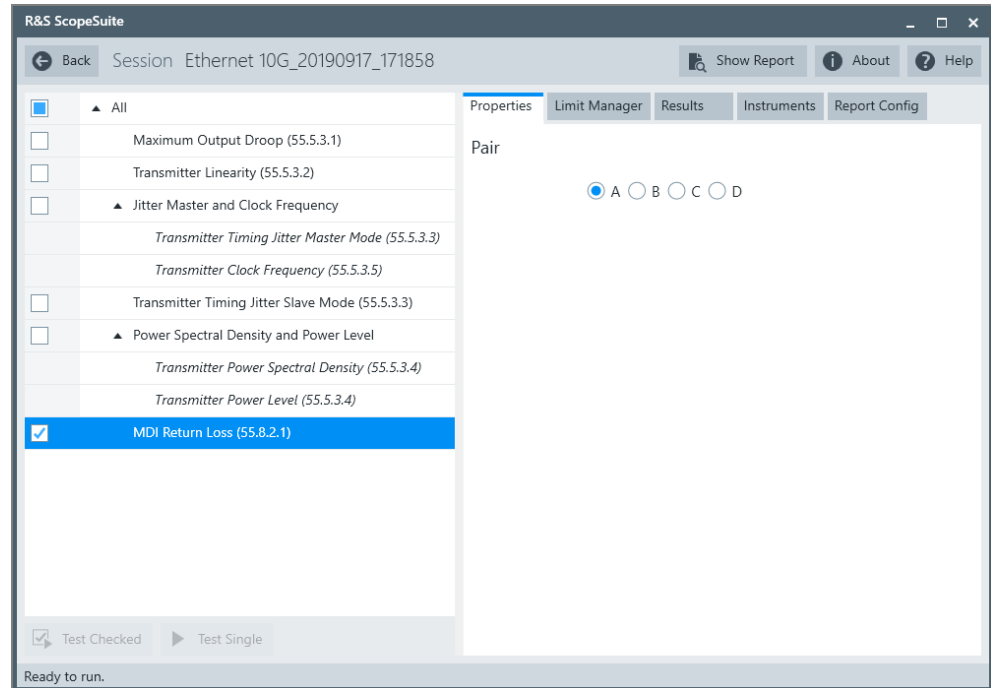
3. Click "Test Single".

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

7.3.8.3 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 100BASE-T1 tests

100BASE-T1 Ethernet compliance tests require option R&S RTO/RTO6/RTP-K24.

The following table shows an overview of the needed equipment for performing the 100BASE-T1 test cases. A prerequisite is also a R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth, the R&S ScopeSuite software and a 100BASE-T1 DUT.

Table 8-1: Equipment for 100BASE-T1 Ethernet compliance tests

	Differential type[*]		Single-Ended type[*]		Additional instruments
	Differential probe	Test fixture	SMA	Test fixture (optional)	
Transmitter output droop (96.5.4.1) Transmitter timing jitter master mode and clock frequency (96.5.4.3 and 96.5.4.5)	1 at least 1 GHz bandwidth	R&S RT-ZF2	2	R&S RT-ZF8	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Transmitter distortion With disturber (96.5.4.2)	1 at least 1 GHz bandwidth	R&S RT-ZF2 or R&S RT-ZF8	up to 6	R&S RT-ZF8	**Frequency converter** R&S RT-ZF3 **For R&S RTO option:** R&S RTO-B4 **ARB:** R&S RTO / R&S RTO6 /R&S RTP-B6 or Hameg HMF2550 or Tabor WX2182B/ WX2182C
Transmitter distortion No disturber (96.5.4.2)	1 at least 1 GHz bandwidth	R&S RT-ZF2 or R&S RT-ZF8	up to 6	R&S RT-ZF8	**Frequency converter** R&S RT-ZF3 **For R&S RTO option:** R&S RTO-B4
Transmitter timing jitter slave mode (96.5.4.3)	1 at least 1 GHz bandwidth	R&S RT-ZF2	2	R&S RT-ZF8	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
[*]The equipment for only either the differential type or the single-ended type is sufficient for the test setup					

	Differential type[*]		Single-Ended type[*]		Additional instruments
	Differential probe	Test fixture	SMA	Test fixture (optional)	
Transmitter power spectral density and peak differential output (96.5.4.4 and 96.5.1.8)	1 at least 1 GHz bandwidth	R&S RT-ZF2	2	R&S RT-ZF8	
MDI Return loss with RT-ZF2 (96.8.2.1)	-	R&S RT-ZF2	-		**VNA:** R&S ZNB or R&S ZNC or R&S ZND or R&S ZVL
MDI mode conversion loss and return loss (96.8.2.2 and 96.8.2.1)	-	R&S RT-ZF8	-		**VNA:** R&S ZNB or R&S ZNC or R&S ZND (option K5 or K6 required)
MDI Mode conversion loss adaptor verification (OABR_PMA_TX_06)	-	R&S RT-ZF8	-		**VNA:** R&S ZNB or R&S ZNC or R&S ZND (option K5 or K6 required)
MDI Common Mode Emission (96.5.1.2)	-	-	3	R&S RT-ZF8	Shielding chamber

[*]The equipment for only either the differential type or the single-ended type is sufficient for the test setup

8.1 Starting 100BASE-T1 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 Scope-Suite, see Chapter 2.5, "Connecting the R&S RTO/RTO6/RTP", on page 12
- AWG connection for tests with disturber, see Chapter 2.6, "Connecting the arbitrary waveform generator", on page 14.
- VNA connection for MDI Return Loss and Transmitter Power Spectral Density tests, see Chapter 2.7, "Connecting the vector network analyzer", on page 15.

1. Select "100BASE-T1" 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 20.

3. Check the test configuration settings and adjust them, if necessary. See:
   - Chapter 8.2, "Test configuration for 100BASE-T1", on page 231
   - 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 100BASE-T1

The test configuration consists of some test-specific configuration settings.
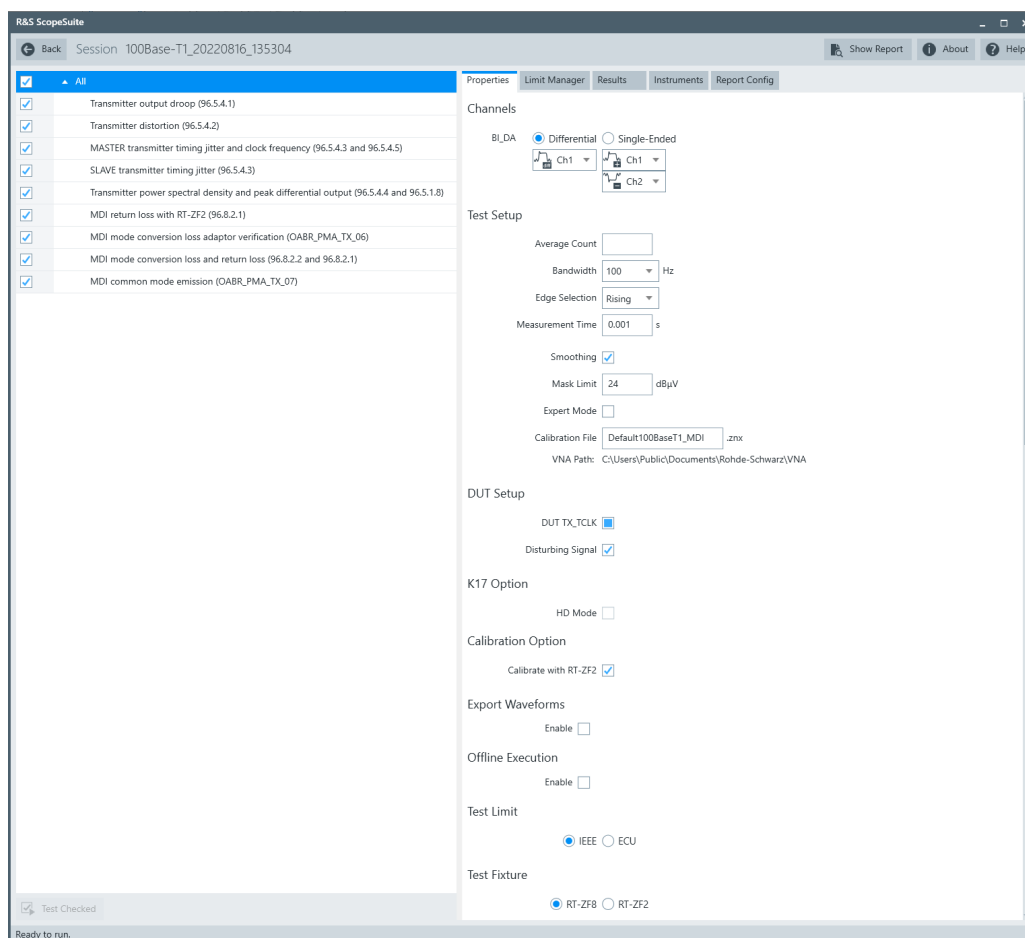
Figure 8-1: Configuration for 100BASE-T1 compliance tests

BI_DA

Selects the channels for testing. You can also select if the connected probe is single-ended or differential type.

If differential type is selected, the Ethernet test fixture R&S RT-ZF2 is needed for performing the measurement.

For the single-ended type, you can use two SMA cables to connect the oscilloscope and the DUT directly. No test fixture is required.

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 1 to 200 and the default value is 10.

For VNA test cases, it defines the number of sweeps used in the measurement. The valid range is 1 to 16. The default value is 16.

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

Bandwidth
Sets the VNA power bandwidth for VNA test cases. Available values are 100Hz, 1KHz or 10KHz.

Edge selection
Selects, if the rising, the falling or both edges are considered for the "Transmitter timing jitter" test cases.

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" test case. The valid range is 1 to 1024, the default value is 512.

Smoothing
Enable if smoothing is required.

Mask Limit
The mask limit is used in the "MDI Common Mode Emission" test case. The valid range is -200 to 200 dBμV.

Expert Mode
If enabled, the "Expert Mode" allows you to bypass the guided steps of the test case.

Calibration File
Specifies the calibration file in the VNA path directory. The file is used for saving and loading data during test execution.

VNA Path
Displays the working directory on the VNA for saving and loading calibration files.

DUT TX_TCLK
Enable when DUT transmit clock(DUT_TX_TCLK) is synchronized with the signal. The DUT_TX_TCLK 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.

HD Mode
Enables the higher digital resolution mode. Requires option R&S RTO / R&S RTO6 /R&S RTP-K17.

Calibration Option
Enable if a calibration with RT-ZF2 is required.

Export Waveforms

Enables you to export a waveform. You can later load the waveforms to run the tests in the offline mode, see Offline Execution.

You can define an export directory, or use the default one:

```
MyDocuments\Rohde-Schwarz\RSScopeSuite\<Version>\Waveforms\
<ComplianceTest>\<SessionName>
```

For example:

```
MyDocuments\Rohde-Schwarz\RSScopeSuite\4.60.0\Waveforms\
BroadRReach\100Base-T1_2133_20190114_144116
```

Offline Execution

Offline Execution

Enable ☑

JitterMaster waveform [   ] 📂 Select

If enabled, allows you to use exported waveforms as a source for the execution of the compliance test.

You can select one waveform for each needed signal.

Test Limit

The test limit is used in the "MDI mode conversion loss and return loss " test case.

Enable "ECU", if you want the value to be tested against the TC8 ECU test specification. If you are unsure, use the default value.

Fixture Compensation

Enable for fixture compensation.

Test Fixture

Selects the fixture that is used for the measurement.

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

You can perform the test either with a test fixture and a differential probe or with SMA cables. The equipment needed for both cases is listed in the tables below.

Table 8-2: Equipment for Transmitter output droop test and test fixture

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture	R&S RT-ZF2 or R&S RT-ZF8	1
Differential probe	at least 1 GHz bandwidth	1
DUT	100BASE-T1 device you want to test	1

Table 8-3: Equipment for Transmitter output droop and no test fixture

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
SMA cables	Connected to DUT	2
Ethernet test fixture	R&S RT-ZF8	2
DUT	100BASE-T1 device you want to test	1

8.3.2 Performing the test

1. Start the test as described in Chapter 8.1, "Starting 100BASE-T1 tests", on page 231.

2. Select the test case: "Transmitter output droop (96.5.4.1)".
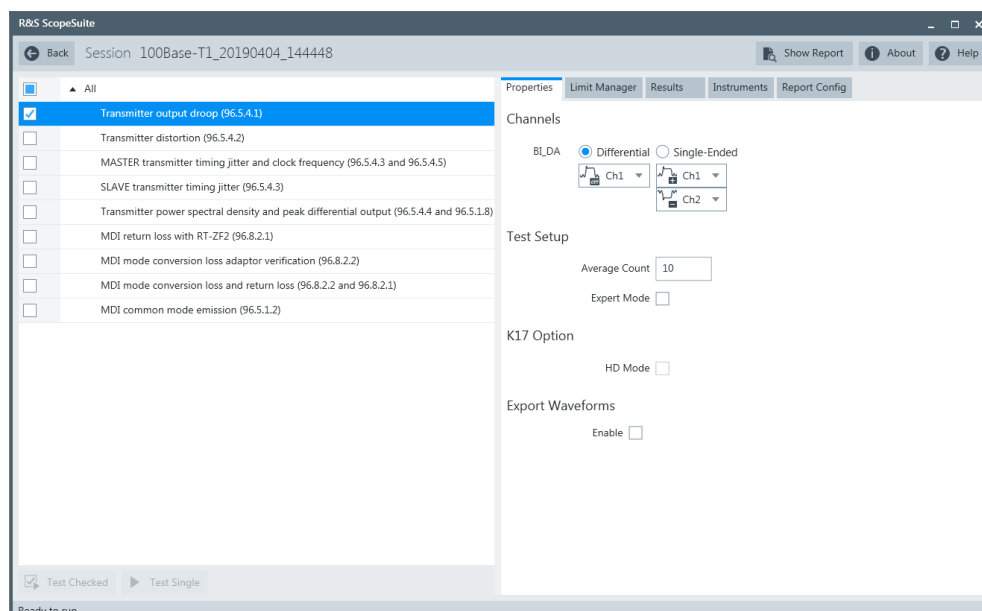
3. Click "Test Single".

4. Follow the instructions of the step-by step guide.

When you have finished all steps, the compliance test runs automatically.

Further steps:

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 wave-forms 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 V_{peak} and V_{500ns}.
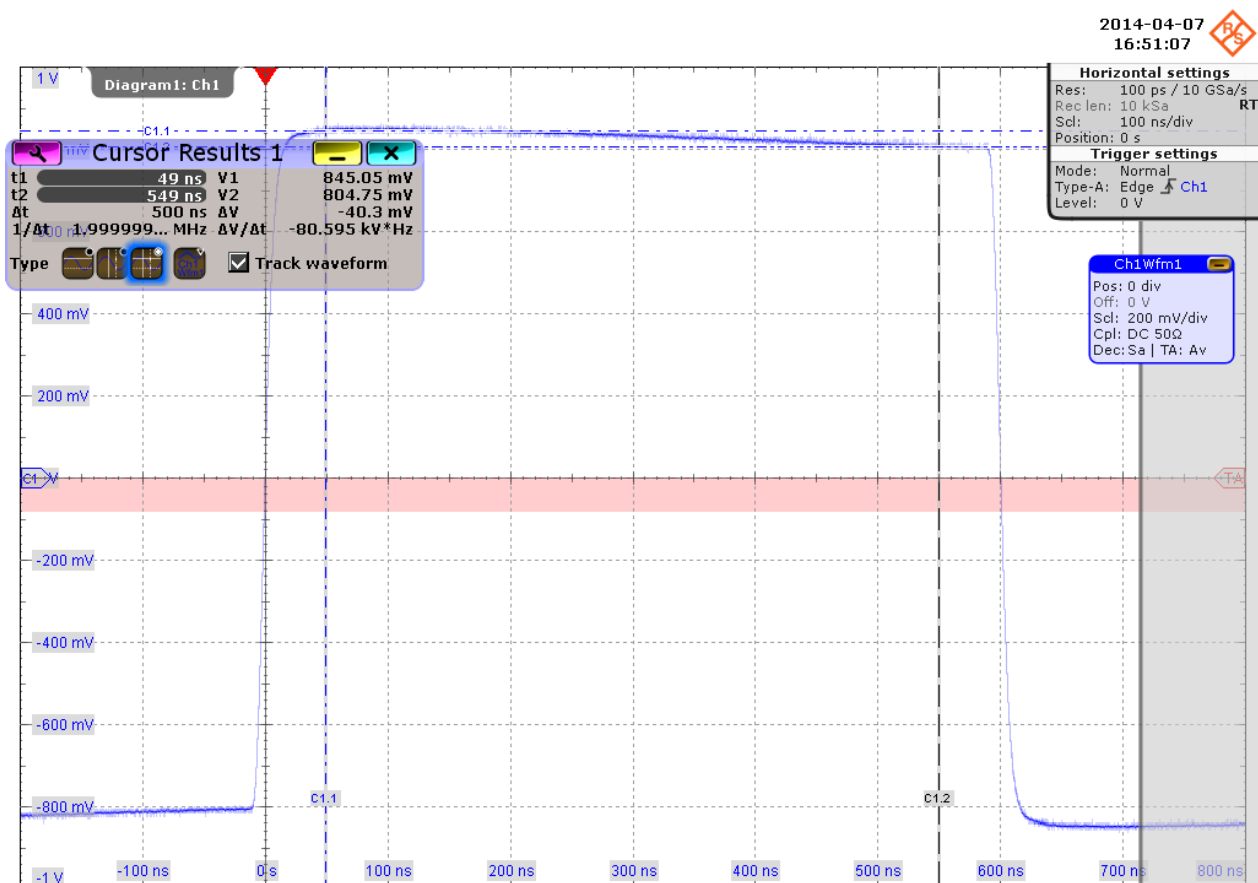
- For the negative side of the waveform

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.
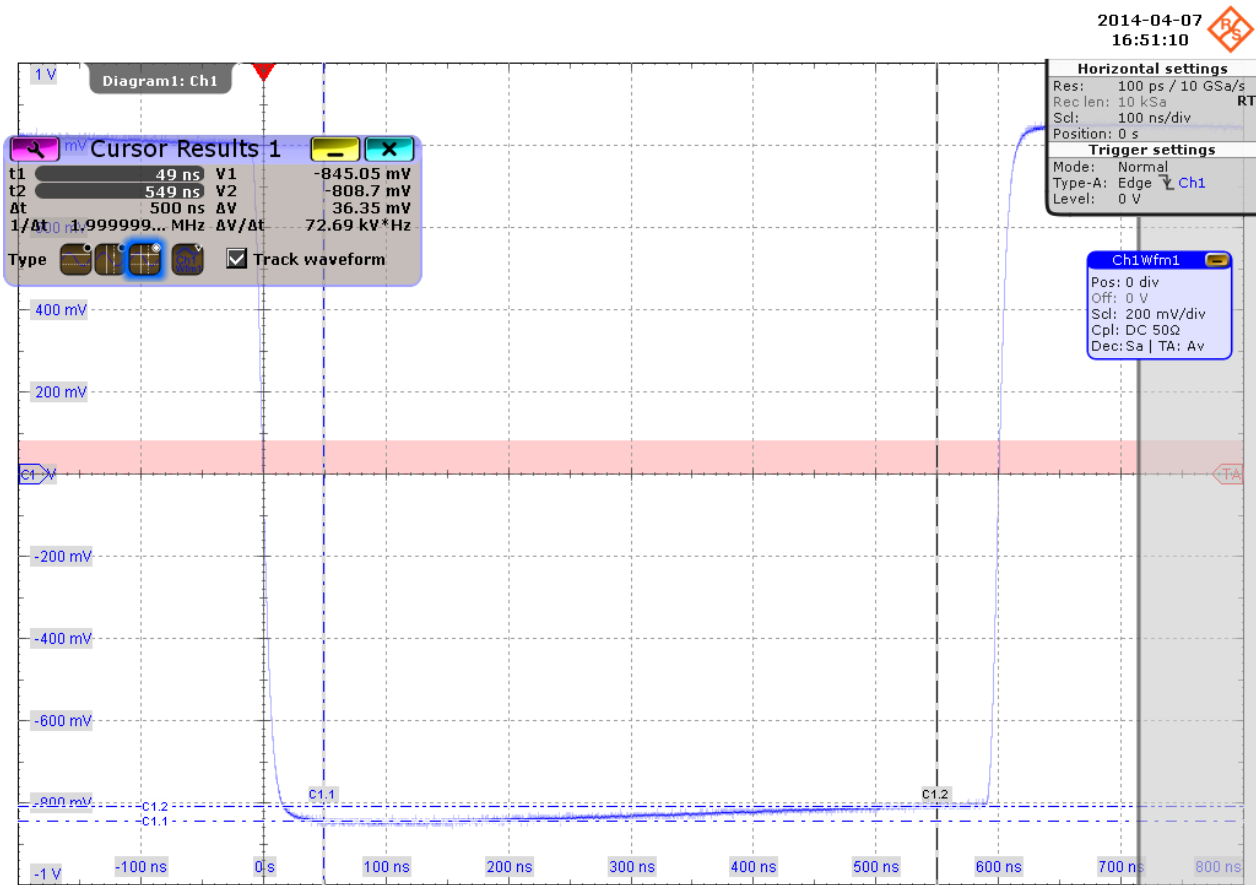
8.4 Transmitter distortion

The "Transmitter distortion" 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 8-4: Equipment for Transmitter distortion (no disturber) test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Oven Controlled Crystal Oscillator Clock (OCXO, 10 MHz)	R&S RTO-B4 for R&S RTO	1

Item	Description, model	Quantity
Ethernet test fixture	R&S RT-ZF2 or R&S RT-ZF8	1
Frequency converter	R&S RT-ZF3	1
Differential probe	at least 1 GHz bandwidth	1
DUT	100BASE-T1 device you want to test	1

Table 8-5: Equipment for Transmitter distortion (with disturber) test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Oven Controlled Crystal Oscillator Clock (OCXO, 10 MHz)	R&S RTO-B4 for R&S RTO	1
Arbitrary waveform generator	R&S RTO-B6/R&S RTP-B6/Tabor WX2182B/Tabor WX2182C or HMF2550	1
Ethernet test fixture	R&S RT-ZF2 or R&S RT-ZF8	1
Frequency converter	R&S RT-ZF3	1
Differential probe	at least 1 GHz bandwidth	1
DUT	100BASE-T1 device you want to test	1

8.4.2 Performing the test

1. Start the test as described in Chapter 8.1, "Starting 100BASE-T1 tests", on page 231.

2. Select the test case: "Transmitter distortion (96.5.4.2)".
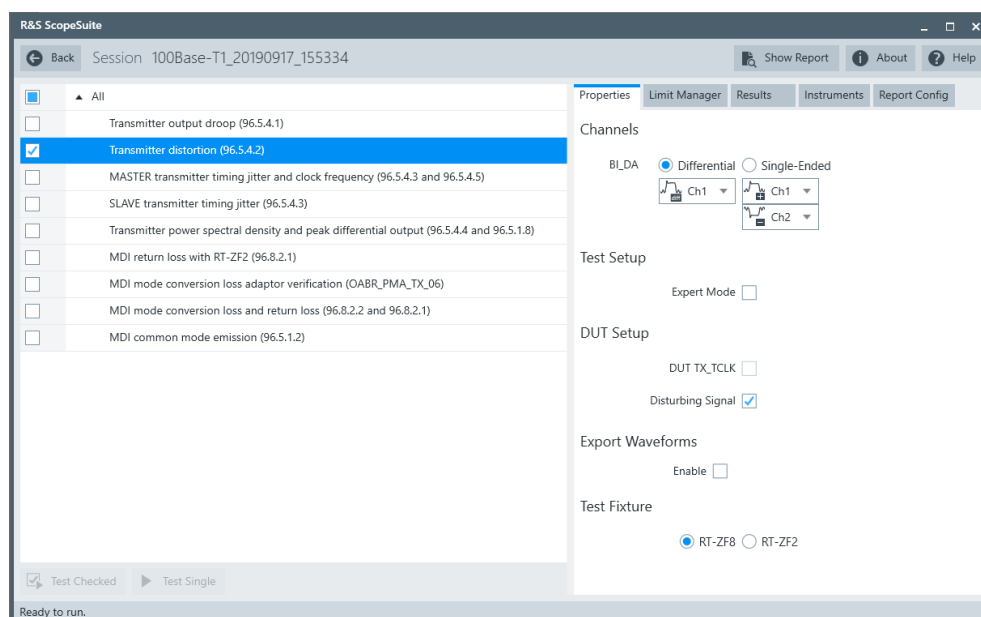
3. Click "Test Single".

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 23

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 100BASE-T1specification.

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 test acquires 200 µs of data at a sampling rate of 2 GSa/s and uses a MATLAB script provided in the 100BASE-T1 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 that 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.
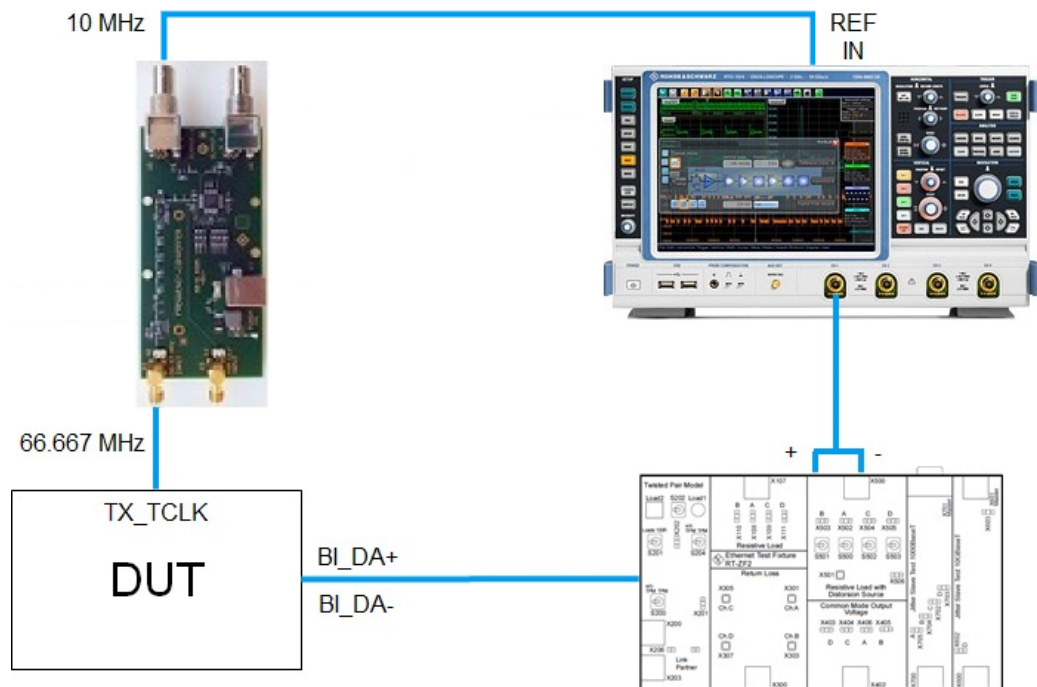
Note: "REF IN" is only available on R&S RTO/RTO6/RTP with R&S RTO/RTO6/RTP-B4 OCXO option.

8.4.4 Disturbing signal

The disturbing signal is a standard 5.4 Vpp 11.111 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 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 239). 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 of how this can be achieved using RT-ZF3.
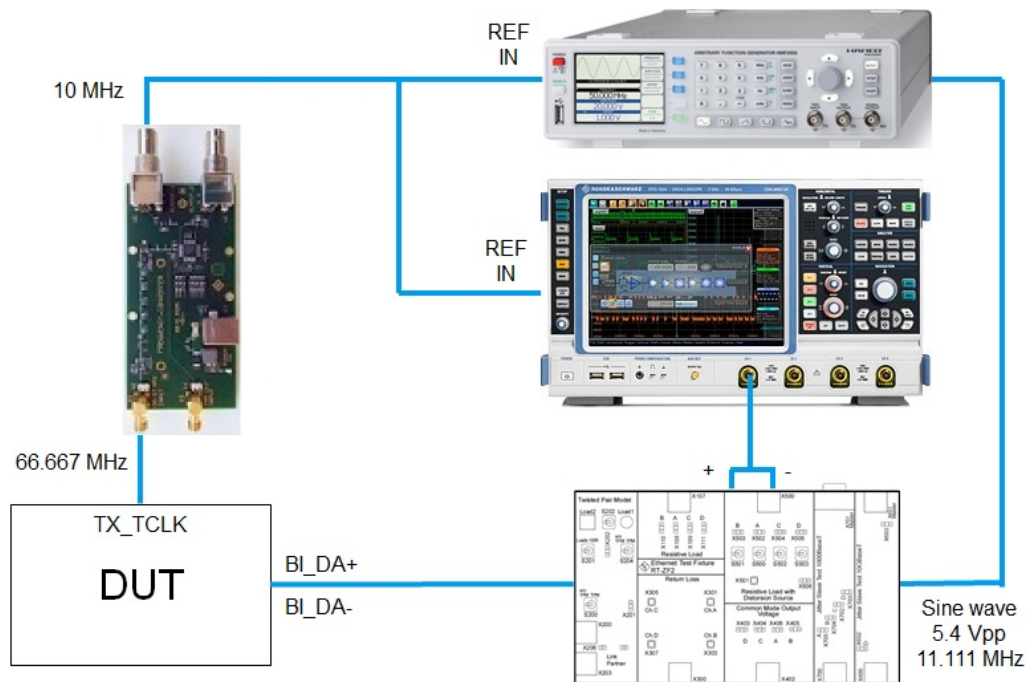
Note: "REF IN" is only available on R&S RTO/RTO6/RTP with R&S RTO/RTO6/RTP-B4 OCXO option.

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 transmitter timing jitter and clock frequency

8.5.1.1 Test equipment

Table 8-6: Equipment for Master transmitter timing jitter and clock frequency test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture	R&S RT-ZF2 or R&S RT-ZF8	1
Differential probe	at least 1 GHz bandwidth	1
DUT	100BASE-T1 device you want to test	1

8.5.1.2 Performing the test

1. Start the test as described in Chapter 8.1, "Starting 100BASE-T1 tests", on page 231.

2. Select the test case: "Master transmitter timing jitter and clock frequency (96.5.4.3 and 96.5.4.5)".
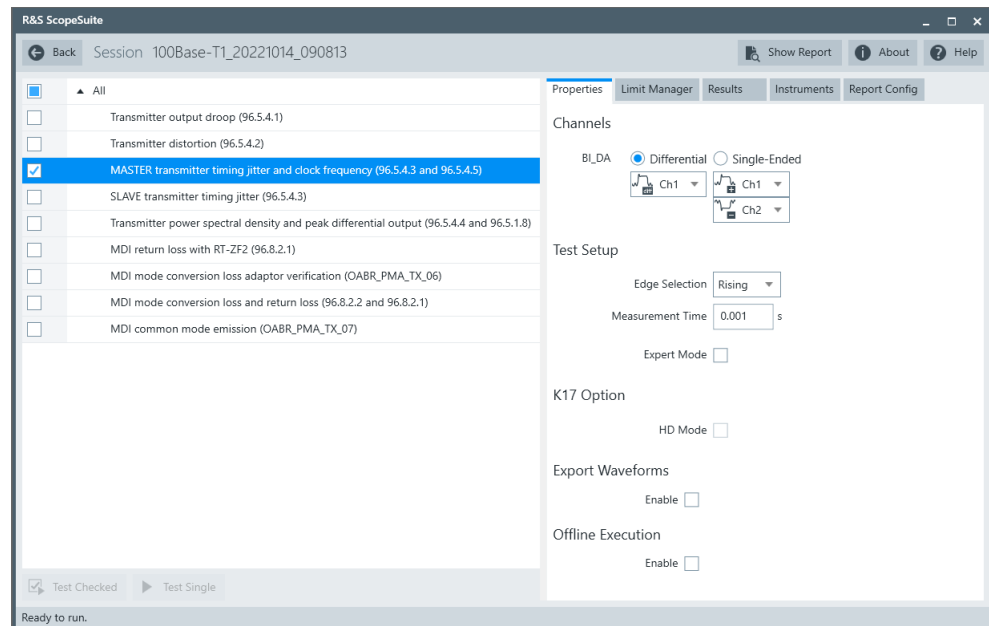
3. Click "Test Single".

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 23

8.5.1.3 Measurements

The DUT has to transmit a test mode 2 waveform.
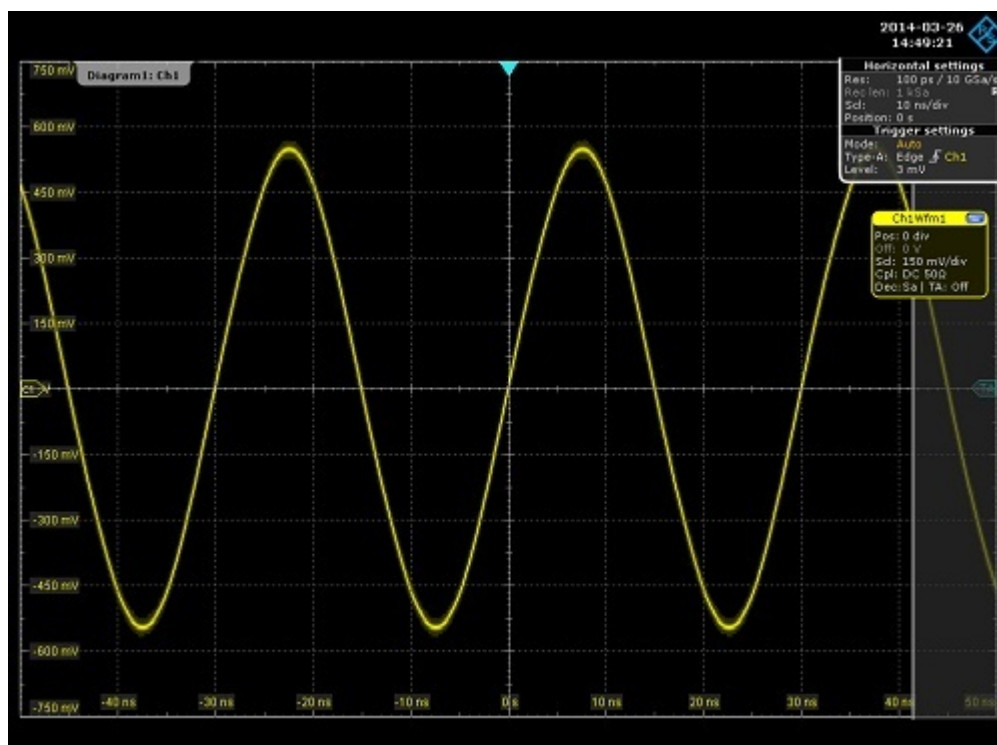
Connect the data port to the R&S RTO/RTO6/RTP for measurement.

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

8.5.2 Slave mode

8.5.2.1 Test equipment

Table 8-7: Equipment for SLAVE transmitter timing jitter test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Differential probe	at least 1 GHz bandwidth	1
DUT	100BASE-T1 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 100BASE-T1 tests", on page 231.

2. Select the test case: "SLAVE transmitter timing jitter (96.5.4.3)".
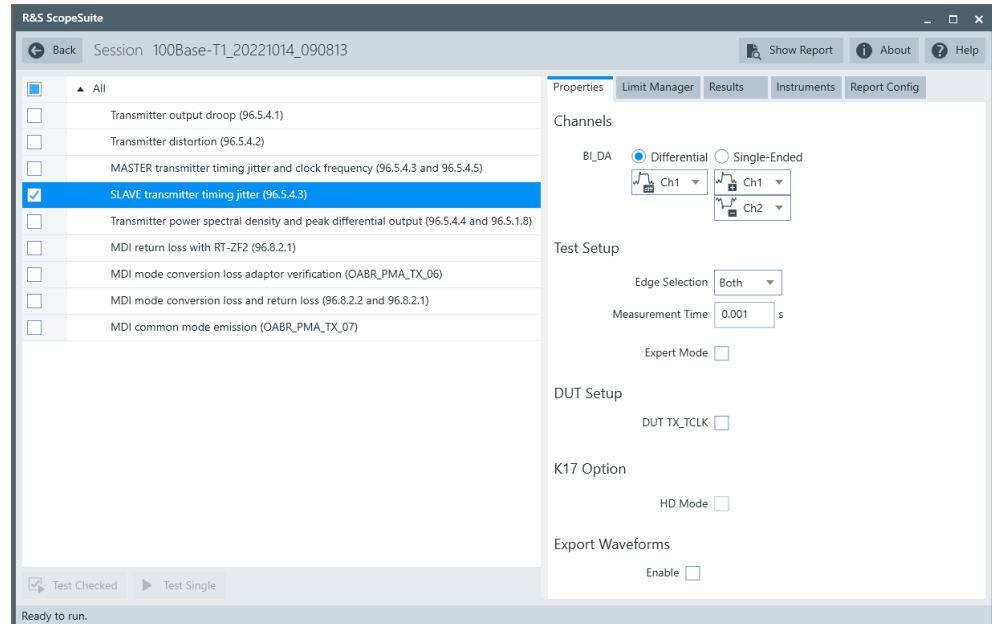
3. Click "Test Single".

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 23

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/RTO6/RTP for measurement.

8.6 Transmitter power spectral density and peak differential output

The test verifies that the transmitter power spectral density of the DUT over the frequency range 1 MHz to 200 MHz falls in-between the upper and lower limits specified in IEEE Std. 802.3bw, section 96.5.4.4:

$$
Lower\ PSD(f) \geq \begin{cases} -70.9 - 4.9 \times \dfrac{f-1}{19} & dBm/Hz & for\ 1MHz \leq f \leq 20MHz \\[2ex] -75.8 - 13.4\ \times \dfrac{f-20}{20} & dBm/Hz & for\ 20MHz \leq f \leq 200MHz \end{cases}
$$

$$Upper\ PSD(f) \geq \begin{cases} -63.3 - 1.5 \times \dfrac{f-1}{19} & dBm/Hz & for\ 1MHz \leq f \leq 20MHz \\ -64.8 - 3.7 \times \dfrac{f-20}{20} & dBm/Hz & for\ 20MHz \leq f \leq 40MHz \\ -68.5 - 8.0 \times \dfrac{f-40}{17} & dBm/Hz & for\ 40MHz \leq f \leq 57MHz \\ -76.5\ \ dBm/Hz & & for\ 57MHz \leq f \leq 20MHz \end{cases}$$

8.6.1 Test equipment

Table 8-8: Equipment for Transmitter power spectral density and peak differential output test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture	R&S RT-ZF2 or R&S RT-ZF8	1
DUT	100BASE-T1 device you want to test	1

8.6.2 Performing the test

1. Start the test as described in Chapter 8.1, "Starting 100BASE-T1 tests", on page 231.

2. Select the test case: "Transmitter power spectral density and peak differential output (96.5.4.4 and 96.5.1.8)".
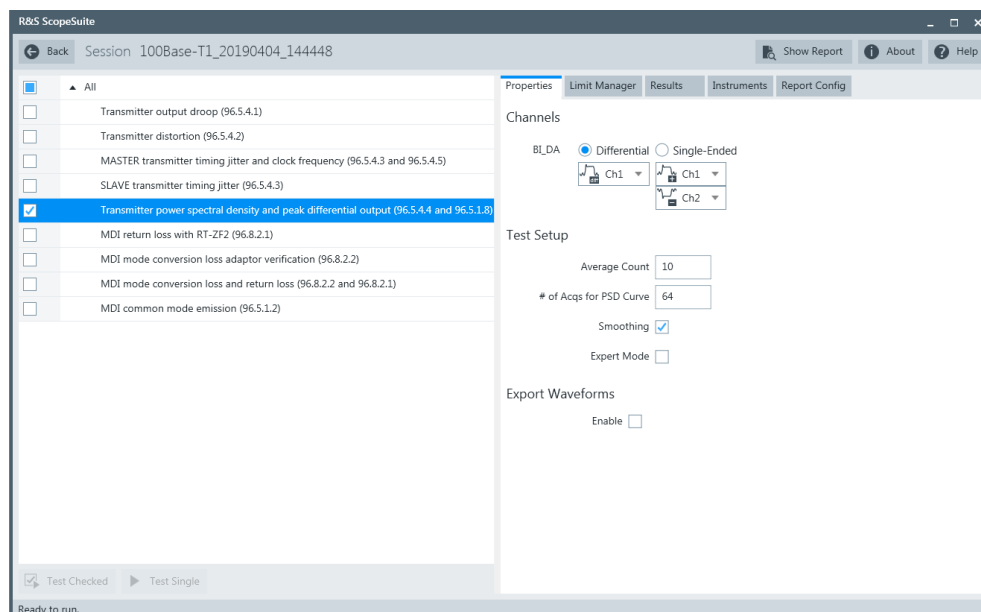

3. Click "Test Single".

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 23

8.6.3 Measurements

Configure the DUT to test mode 5.

The oscilloscope performs an FFT transformation of the input signal over 1 MHz to 200 MHz. Then it performs some averaging and mathematics to plot the PSD curve, and checks whether it falls within the limit mask.

If "Differential" channel is selected, but you do not use a differential probe, a compensation factor is applied to the final peak-to-peak output voltage calculation to account for the losses in the test fixture R&S RT-ZF2.

8.7 MDI return loss with R&S RT-ZF2

The "MDI return loss" test verifies that the transmitter return loss of the DUT meets or exceeds the limit defined in the following equation for all frequencies from 1MHz to 66 MHz:

$$MDI \ return \ loss \ (f) \geq \begin{cases} 20 \ dB & for \ 1MHz \leq f \leq 30MHz \\ 20 - 20 \times log_{10} \left(f/30 \right) dB & for \ 30MHz \leq f \leq 66MHz \end{cases}$$

8.7.1 Test equipment

Table 8-9: Equipment for MDI return loss test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture	R&S RT-ZF2	1
Vector network analyzer (optional, required only to perform an automatic test)	R&S ZNB/ZNC/ZND/ZVL	1
DUT	100BASE-T1 device you want to test	1

8.7.2 Performing the test

1. Start the test as described in Chapter 8.1, "Starting 100BASE-T1 tests", on page 231.

2. Select the test case: "MDI return loss (96.8.2.2)".
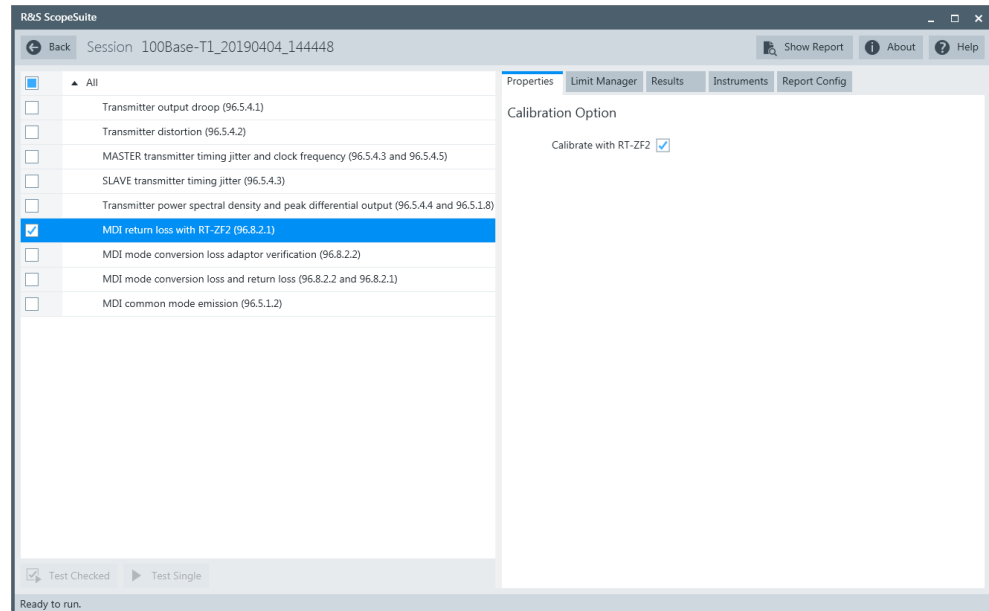
3. Click "Test Single".

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 23

8.7.3 Measurements

Configure the DUT to slave 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 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.

8.8 MDI mode conversion loss and return loss

The "MDI mode conversion loss" test case performs two measurements, for the transmitter return loss and the MDI common mode to differential-mode conversion (LCL) of the PHY.

Transmitter return loss of the DUT shall meet or exceed the limit defined in the following equation for all frequencies from 1MHz to 66MHz (IEEE Std 802.3bw):

$$MDI\ return\ loss(f) \geq \begin{cases} 20\,dB & for\ 1MHz \leq f \leq 30MHz \\ 20 - 20 \times log_{10}\left(\frac{f}{30}\right) dB & for\ 30MHz \leq f \leq 66MHz \end{cases}$$

For th the MDI common mode to differential mode conversion (LCL) of the PHY you can choose different specifications from the menu:

- For "ECU Limit > Disabled"
  IEEE Std 802.3bw

$$MDI\ mode\ conversion\ loss(f) \geq \begin{cases} 50\,dB & for\ 1\,MHz \leq f \leq 33\,MHz \\ 50 - 20 \times log_{10}\left(\frac{f}{30}\right) dB & for\ 33\,MHz \leq f \leq 66\,MHz \end{cases}$$

- For "ECU Limit > Enabled"
  OPEN Alliance TC8 Automotive Ethernet ECU Test Specification

$$MDI\ MC(f) \geq \begin{cases} 60\,dB & for\ 1\,MHz \leq f \leq 22\,MHz \\ 60 - 20 \times log_{10}\left(\frac{f}{22}\right) dB & for\ 22\,MHz \leq f \leq 100\,MHz \\ 47 - 30 \times log_{10}\left(\frac{f}{100}\right) dB & for\ 100\,MHz \leq f \leq 200\,MHz \end{cases}$$

8.8.1 Test equipment

Table 8-10: Equipment for MDI mode conversion loss test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture	R&S RT-ZF8	1
Vector network analyzer (optional, required only to perform an automatic test)	R&S ZNB, R&S ZNC or R&S ZND (option K5 or K6 required)	1
DUT	100BASE-T1 device you want to test	1

8.8.2 Performing the test

1. Start the test as described in

2. Select the test case: "MDI mode conversion loss and return loss (96.8.2.2 and 96.8.2.1)".

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.

Further steps:

-
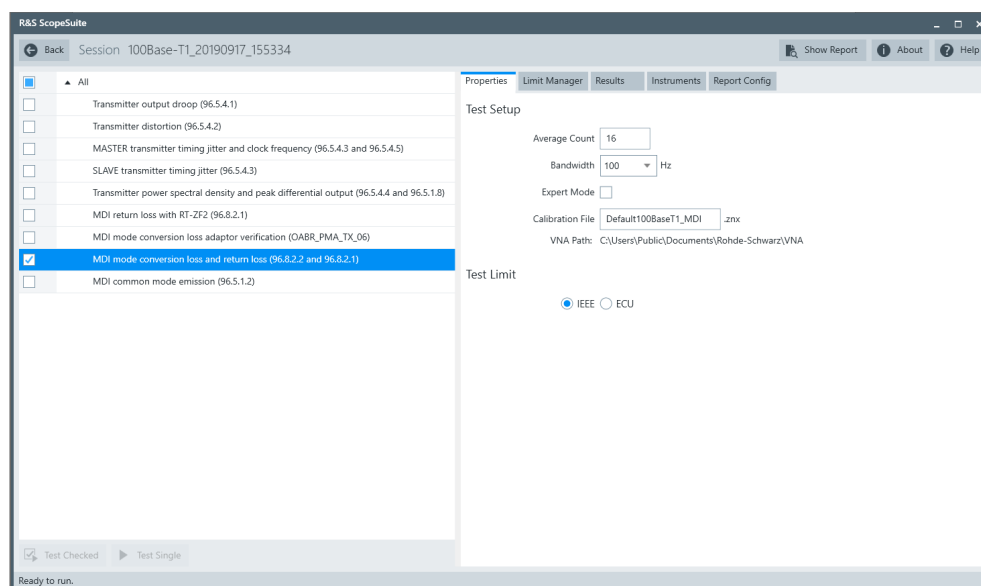
8.8.3 Test setup

The DUT should be configured to be in slave mode.

Test property "Fixture Compensation" is unchecked by default. You can enable it, to perform fixture compensation automatically.

8.8.4 Measurements

For automatic test, the mode conversion loss is measured as "Sdc11" parameter on VNA. It shall fall below the limit line plotted on the VNA from 1 MHz to 200 MHz required by the specification. The return loss is measured as "Sdc11" parameter on VNA, It shall fall below the limit line plotted on the VNA from 1 MHz to 66 MHz.

For manual test, the program checks if every point within 1 MHz and 200 MHz in the result file (`*.s1p` or `*.csv`) falls below the limit required by the specification for mode conversion loss. It also checks if every point within 1 MHz and 66 MHz in the result file (`*.s1p`) falls below the limit required by the specification for return loss.

8.9 MDI mode conversion loss adaptor verification

The test case verifies that the adaptor used for the MDI mode conversion loss measurement is symmetrical. Measurement of the open adaptor shall meet or exceed the limit for all frequencies from 1MHz to 200MHz.

$$MDI\ MC\ test\ jig(f) \geq \begin{cases} 70\ dB & for\ 1MHz \leq f \leq 20MHz \\ 70 - 20 \times log_{10}\left(f/20\right)\ dB & for\ 20MHz \leq f \leq 200MHz \end{cases}$$

8.9.1 Test equipment

Table 8-11: Equipment for MDI mode conversion loss adaptor verification test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture	R&S RT-ZF8	1
Vector network analyzer (optional, required only to perform an automatic test)	R&S ZNB, R&S ZNC or R&S ZND (option K5 or K6 required)	1

8.9.2 Performing the test

1. Start the test as described in Chapter 8.1, "Starting 100BASE-T1 tests", on page 231.

2. Select the test case: "MDI mode conversion loss adaptor verification (96.8.2.2)".
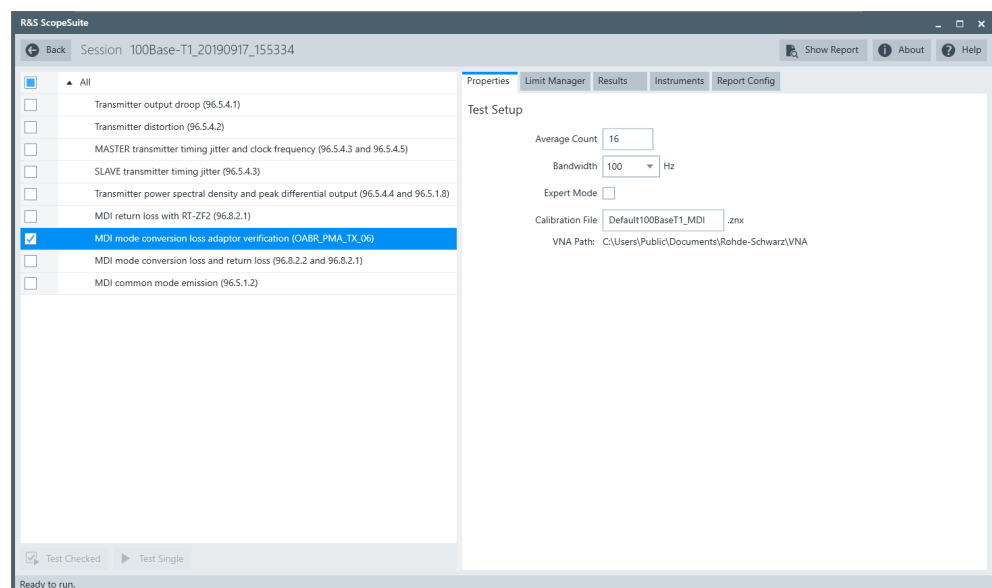
3. Click "Test Single".

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 23

8.9.3 Measurements

For automatic test, the mode conversion loss is measured as "Sdc11" parameter in VNA. It shall fall below the limit line plotted on the VNA from 1 MHz to 200 MHz required by the specification.

For manual test, the program checks if every point within 1 MHz and 200 MHz in the result file (`*.s1p` or `*.csv`) falls below the limit required by the specification.

8.10 MDI common mode emission

The "MDI common mode emission" test verifies the emission of the DUT's PMA transmitter to its electrical environment. It shall not exceed the limit of 24dBuV from 1MHz to 200MHz. It may need to comply with more stringent requirements as agreed between customers and suppliers.

8.10.1 Test equipment

Table 8-12: Equipment for MDI common mode emission test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Shielding chamber	For example, R&S TS7124M	1
Ethernet test fixture	R&S RT-ZF8	1
DUT	100BASE-T1 device you want to test	

8.10.2 Performing the test

1. Start the test as described in Chapter 8.1, "Starting 100BASE-T1 tests", on page 231.

2. Select the test case: "MDI common mode emission (96.5.1.2)".
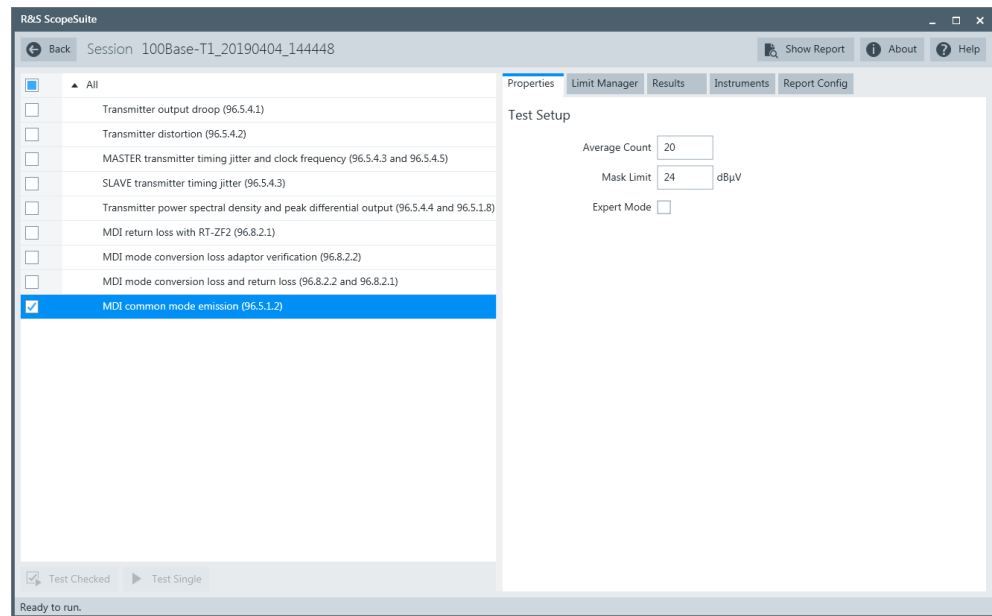
3. Click "Test Single".

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

Further steps:

-

8.10.3 Test setup

To achieve correct results, the usage of a shielded chamber is essential for this test.

A typical setup is shown in the figure below:
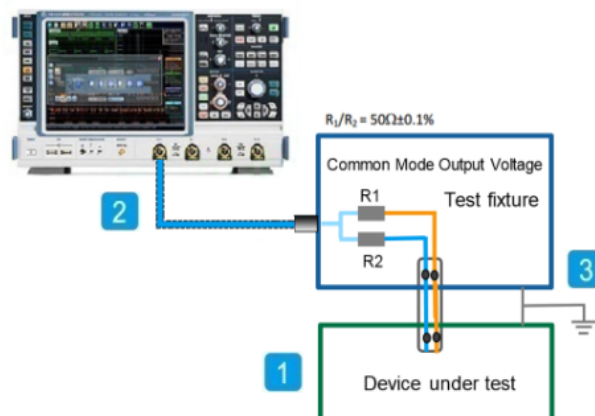
Also, a shielding chamber should be used. An overview is shown in the figure below:

DUT + Test Fixture
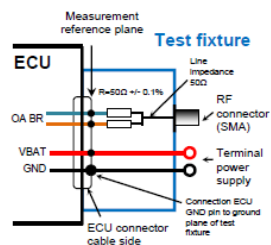
Shielding chamber TS7124M

8.10.4 Measurements

Configure the DUT to test mode 5.

Test property "Mask Limit" is used to define the limit for the mask test. It is 24dBµV by default. You can adjust the limit based on the requirements to comply.

The test case makes an FFT transformation of the input signal over 1 MHz to 200 MHz. It then performs a mask test to check whether the measurement falls within the limit.

If option R&S RTO/RTO6/RTP-K18 is available on your oscilloscope, the frequency axis is displayed logarithmically. Otherwise, a linear frequency axis scale is displayed.

9 1000BASE-T1 tests

1000BASE-T1 Ethernet compliance tests require option R&S RTO/RTO6/RTP-K87.

The following test cases meet the specifications defined in the IEEE Std. 802.3bp. The numbers before the name (for example 97.5.3.3), refer to the relevant subclause of the specification.

The following table shows an overview of the needed equipment for performing the 1000BASE-T1 test cases. A prerequisite is also a R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth, the R&S ScopeSuite software and a 1000BASE-T1 DUT.

Table 9-1: Equipment for 1000BASE-T1 Ethernet compliance tests

	Differential type[*]		Single-Ended type[*]		Additional instruments
	Differential probe	Test fixture	SMA	Test fixture	
Transmitter timing jitter(test mode 1) (97.5.3.3)	-	-	1		**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
MDI jitter and clock frequency (test mode 2) (97.5.3.3/ 97.5.3.6)	1	R&S RT-ZF2	2	R&S RT-ZF8	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
Transmitter distortion (test mode 4) (97.5.3.3) With disturber	1	R&S RT-ZF2 or R&S RT-ZF8	up to 6	R&S RT-ZF8	**For R&S RTO option:** R&S RTO-B4 **Frequency converter:** R&S RT-ZF6 **ARB:** R&S RTO / R&S RTO6 /R&S RTP-B6 (with low pass filter) or Tabor WX2182B/ WX2182C
Transmitter distortion (test mode 4) (97.5.3.3) No disturber	1	R&S RT-ZF2 or R&S RT-ZF8	up to 6	R&S RT-ZF8	**For R&S RTO option:** R&S RTO-B4 **Frequency converter:** R&S RT-ZF6
[*]The equipment for only either the differential type or the single-ended type is sufficient for the Test setup					

	Differential type[*]		Single-Ended type[*]		Additional instruments
	Differ- ential probe	Test fixture	SMA	Test fixture	
PSD power level and output voltage (test mode 5) (97.5.3.4/ 97.5.3.5)	1	R&S RT-ZF2	2	R&S RT-ZF8	-
Maximum output droop (test mode 6) (97.5.3.1)	1	R&S RT-ZF2	2	R&S RT-ZF8	**Optional:** R&S RTO / R&S RTO6 /R&S RTP-K17
MDI return loss with RT-ZF2 (97.7.2.1)	-	R&S RT-ZF2	-		**VNA:** R&S ZNB or R&S ZNC or R&S ZND or R&S ZVL
MDI mode conversion loss test head verfication (OA ECU)	-	R&S RT-ZF8	-	R&S RT-ZF8	**VNA:** R&S ZNB or R&S ZNC or R&S ZND (option K5 or K6 required)
MDI mode conversion loss and return loss (97.7.2.2 and 97.7.2.1)	-	R&S RT-ZF8	-		**VNA:** R&S ZNB or R&S ZNC or R&S ZND (option K5 or K6 required)

[*]The equipment for only either the differential type or the single-ended type is sufficient for the Test setup

9.1 Starting 1000BASE-T1 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 Scope-Suite, see Chapter 2.5, "Connecting the R&S RTO/RTO6/RTP", on page 12

1. Select "1000BASE-T1" 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 20.

3. Check the test configuration settings and adjust them, if necessary. See:
   - Chapter 9.2, "Test configuration for 1000BASE-T1", on page 256
   - 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.

9.2 Test configuration for 1000BASE-T1

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

Figure 9-1: Configuration for 1000BASE-T1 compliance tests

BI_DA

Selects the channels for testing. You can also select if the connected probe is single-ended or differential type.

If differential type is selected, the Ethernet test fixture R&S RT-ZF2 is needed for performing the measurement.

For the single-ended type, you can use two SMA cables to connect the oscilloscope and the DUT directly. No test fixture is required.

TX_TCLK125
Selects the channel for the reduced 125 MHz symbol clock. It is used in the "Transmitter Timing Jitter Master Mode (test mode 1)" and "Transmitter Timing Jitter Slave Mode (test mode 1)" test cases.

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 1 to 200 and the default value is 10.

For VNA test cases, it defines the number of sweeps used in the measurement. The valid range is 1 to 16. The default value is 16.

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

Edge selection
Selects, if the rising, the falling or both edges are considered for the "Transmitter timing jitter" test cases.

Measurement Time
Measurement time is used in the "Transmitter Timing Jitter Master Mode (test mode 1)", "Transmitter Timing Jitter Slave Mode (test mode 1)" and "MDI jitter and clock frequency (test mode 2)" test cases. The valid range is 1E-6 to 1E-3, the default value is 1E-3.

5MHz Bandpass filter
Enables the usage of the 5MHz bandpass filter.

# of Acqs for PSD Curve
The number of acquisitions for PSD curve is used in the "PSD, power level and output voltage (test mode 5)" test case. The valid range is 1 to 1024, the default value is 512.

Bandwidth
Sets the VNA power bandwidth for VNA test cases. Available values are 100Hz, 1KHz or 10KHz.

Smoothing
Enable if smoothing is required.

Digital filter
Sets the digital filter of the oscilloscope for "97.5.3.2 Transmitter distortion test (test mode 4)". The valid range is 0.0001 to 8, the default value is 8.

Available only for R&S RTP with bandwidth of 8 GHz or higher.

Expert Mode
If enabled, the "Expert Mode" allows you to bypass the guided steps of the test case.

Calibration File

Specifies the calibration file in the VNA path directory. The file is used for saving and loading data during test execution.

VNA Path

Displays the working directory on the VNA for saving and loading calibration files.

DUT TX_TCLK

Enable when DUT transmit clock (DUT_TX_TCLK) is synchronized with the signal. The DUT_TX_TCLK 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.

HD Mode

Enables the higher digital resolution mode. Requires option R&S RTO / R&S RTO6 /R&S RTP-K17.

Export Waveforms

Enables you to export a waveform. You can later load the waveforms to run the tests in the offline mode, see "Offline Execution" on page 259.

You can define an export directory, or use the default one:

```
MyDocuments\Rohde-Schwarz\RSScopeSuite\<Version>\Waveforms\
<ComplianceTest>\<SessionName>
```
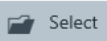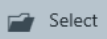
For example:

```
MyDocuments\Rohde-Schwarz\RSScopeSuite\4.60.0\Waveforms\
1000BASE-T1\1000BASE-T1_2133_20190114_144116
```

Offline Execution

If enabled, allows you to use exported waveforms as a source for the execution of the compliance test.

You can select one waveform for each needed signal.

Test Limit

The test limit is used in the "MDI mode conversion loss and return loss " test case.

Enable "ECU", if you want the value to be tested against the TC8 ECU test specification. If you are unsure, use the default value.

Fixture Compensation

The fixture compensation is used in the "MDI mode conversion loss " test case.

Enable for fixture compensation.

Test Fixture

Selects the fixture that is used for the measurement.

9.3 Transmitter timing jitter (97.5.3.3)

9.3.1 Master mode

9.3.1.1 Test equipment

Table 9-2: Equipment for Transmitter timing jitter master mode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
BNC/SMA cable	Cable for connecting the DUT	1
DUT	1000BASE-T1 device you want to test	1

9.3.1.2 Performing the test

1. Start the test as described in Chapter 9.1, "Starting 1000BASE-T1 tests", on page 255.

2. Select the test case: "97.5.3.3 Transmitter timing jitter master mode (test mode 1)".
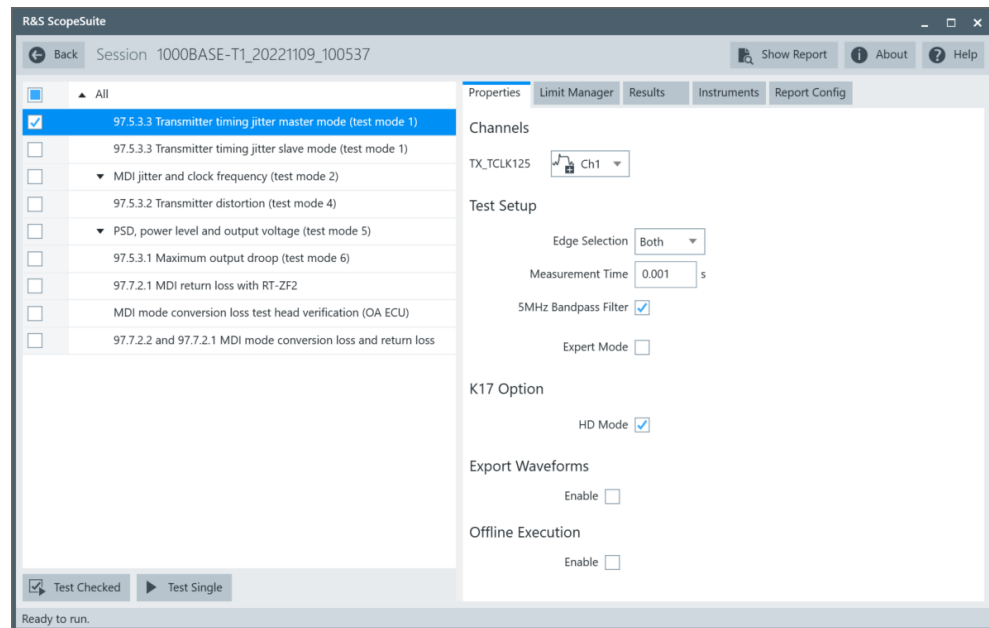
3. Click "Test Single".

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 23

9.3.1.3   Test setup

The setup of this test is as in the following figure.

Make sure the DUT and the LP are connected and are configured for test mode 1. In test mode 1, the PHY is in normal operation but exposes a reduced symbol clock (TX_TCLK 125). This clock has to be connected to the scope.
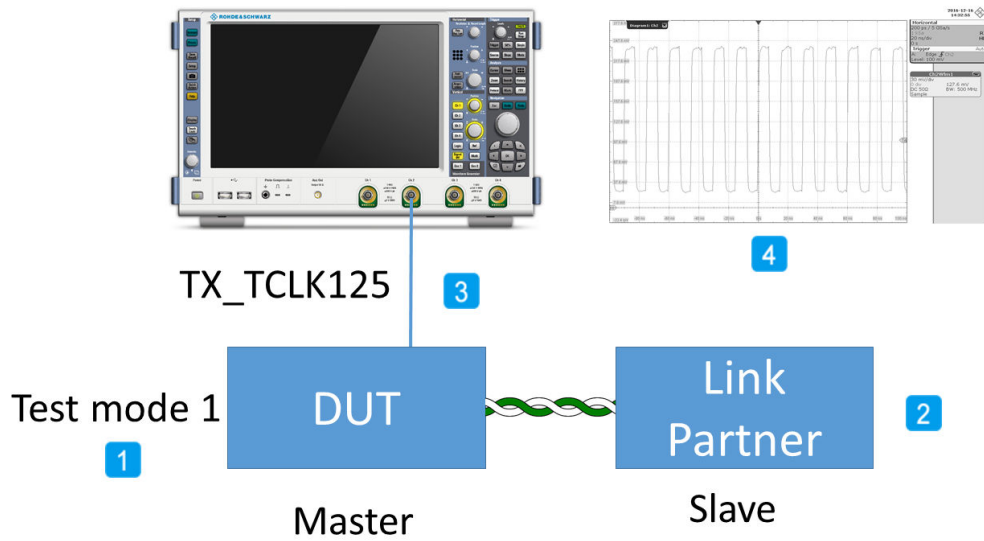
A clock signal can look like in the figure below. If your clock has a large offset compared to the clock amplitude, the R&S ScopeSuite could have problems to scale the signal correctly.
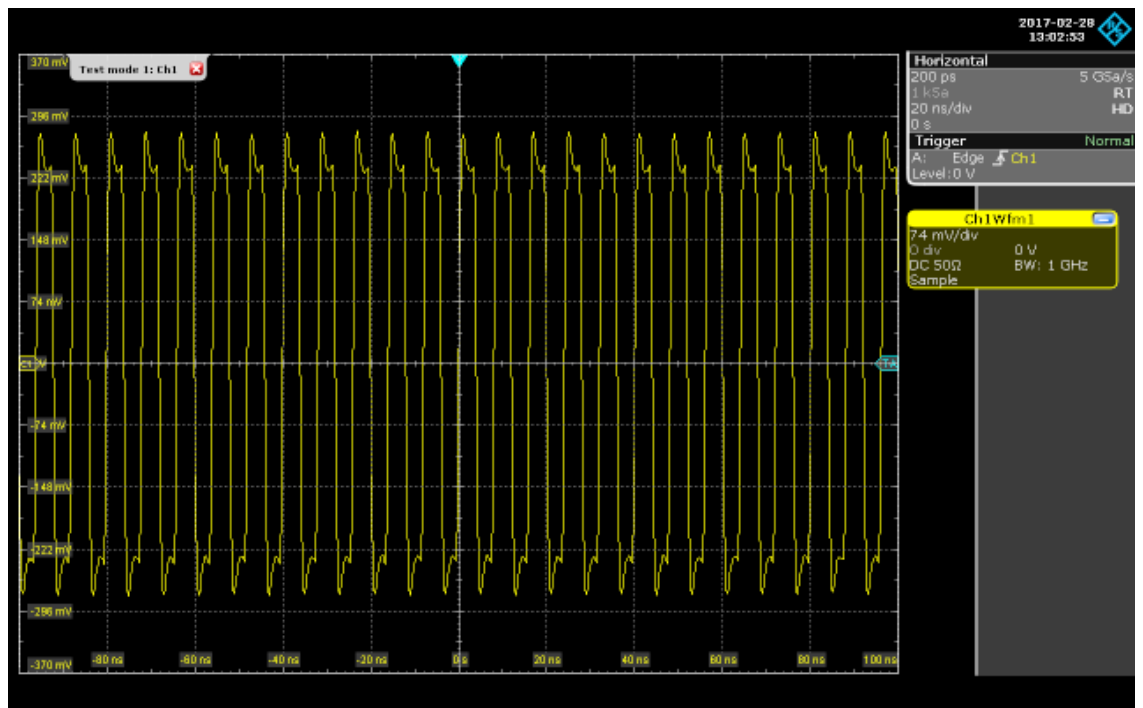
9.3.1.4 Measurements

The test verifies that the transmitter timing jitter of the PMA is within the conformance limits. The jitter is measured over a time interval of at least 1ms. The RMS TIE jitter shall be less than 5ps and the Peak-to-Peak TIE jitter shall be less than 50ps.

You can expect a greater jitter if measuring with an active probe compared to when measuring directly with the BNC plugs.

9.3.2 Slave mode

9.3.2.1 Test equipment

Table 9-3: Equipment for Transmitter timing jitter slave mode test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
BNC/SMA cable	Cable for connecting the DUT	1
DUT	1000BASE-T1 device you want to test	1

9.3.2.2 Performing the test

1. Start the test as described in Chapter 9.1, "Starting 1000BASE-T1 tests", on page 255.

2. Select the test case: "97.5.3.3 Transmitter timing jitter slave mode (test mode 1)".
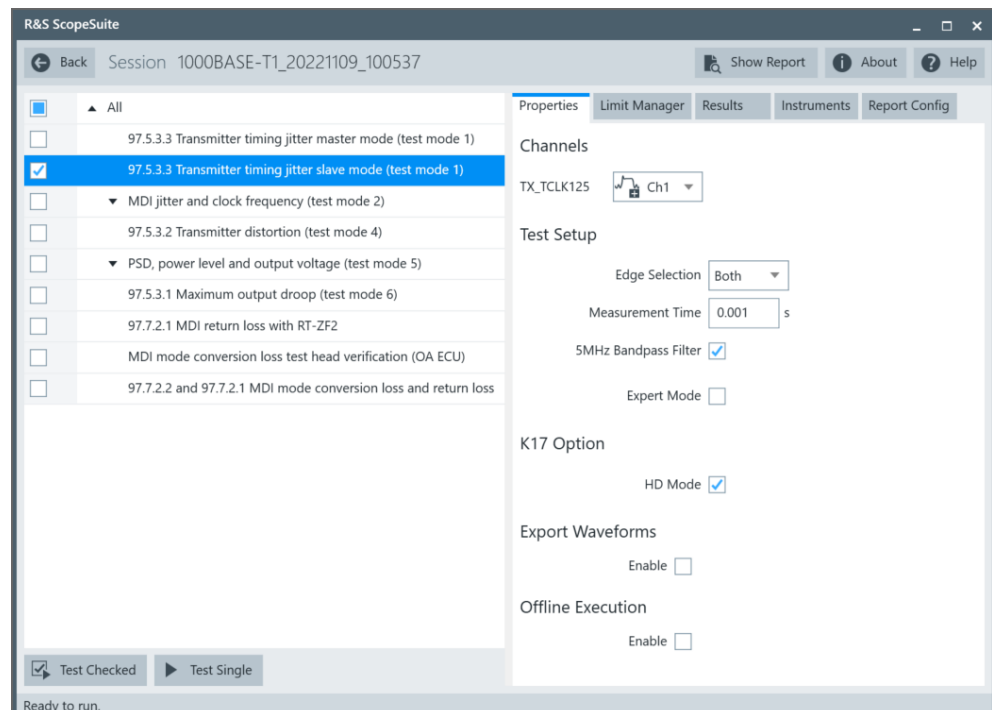
3. Click "Test Single".

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 23

9.3.2.3 Test setup

The setup of this test is as in the following figure.

Make sure the DUT and the LP are connected and are configured for test mode 1. In test mode 1, the PHY is in normal operation but exposes a reduced symbol clock (TX_TCLK 125). This clock has to be connected to the scope.
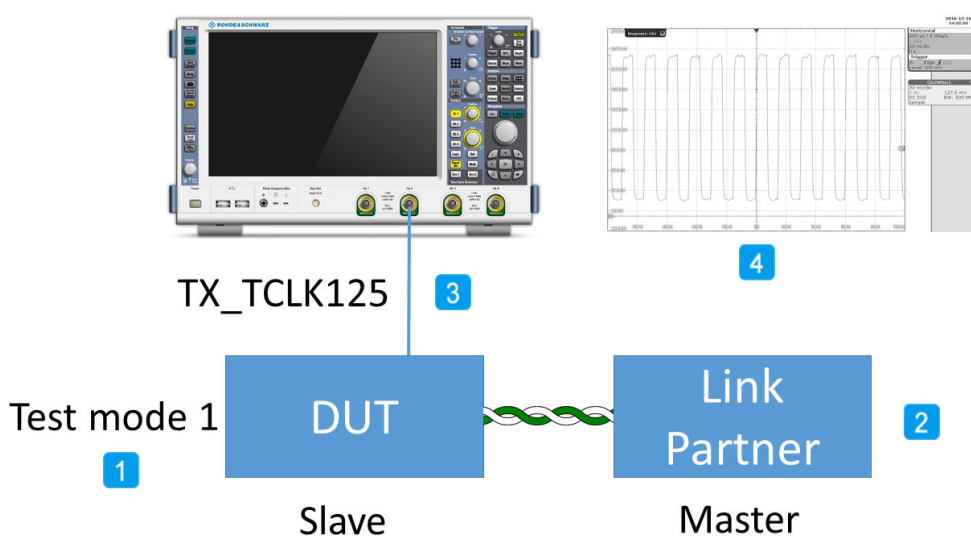
A clock signal can look like in the figure below. If your clock has a large offset compared to the clock amplitude, the R&S ScopeSuite could have problems to scale the signal correctly.
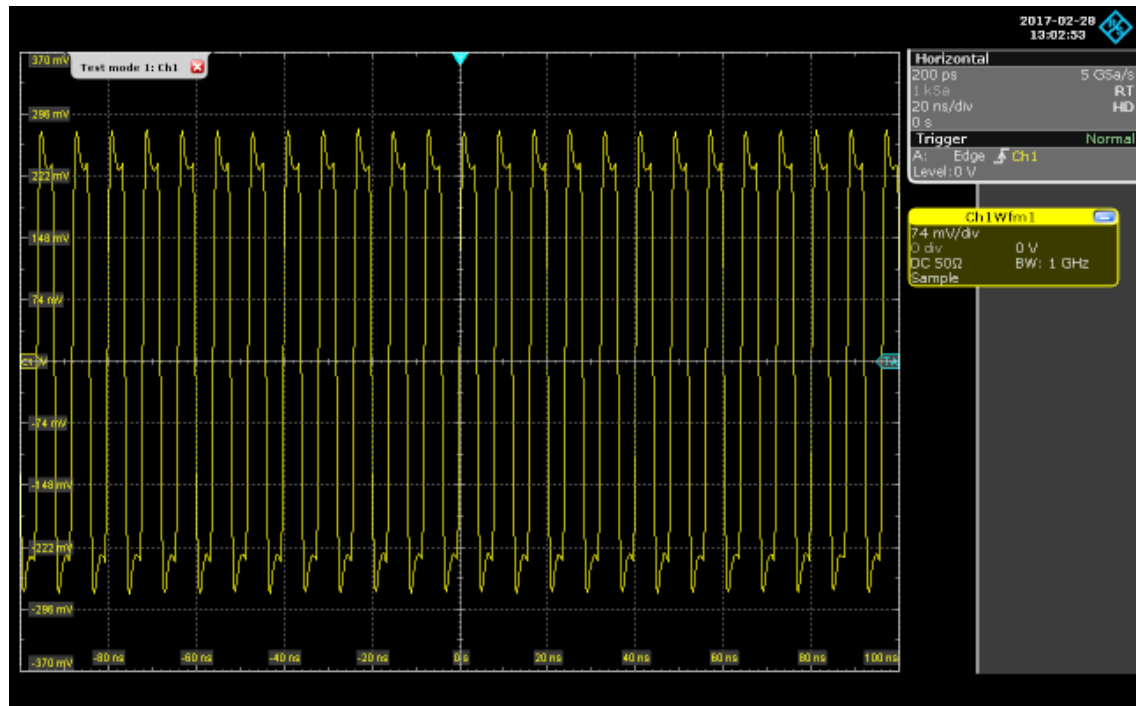
9.3.2.4 Measurements

The test verifies that the transmitter timing jitter of the PMA is within the conformance limits. The jitter is measured over a time interval of at least 1ms. The RMS TIE jitter shall be less than 10ps and the Peak-to-Peak TIE jitter shall be less than 100ps.

You can expect a greater jitter if measuring with an active probe compared to when measuring directly with the BNC plugs.

9.4 MDI jitter and clock frequency (97.5.3.3/97.5.3.6)

9.4.1 Test equipment

Table 9-4: Equipment for MDI jitter and clock frequency (test mode 2) and differential BI_DA

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
Ethernet test fixture	R&S RT-ZF2	1
Differential probe	at least 2 GHz bandwidth	1
DUT	1000BASE-T1 device you want to test	1

Table 9-5: Equipment for MDI jitter and clock frequency (test mode 2) and single-ended BI_DA

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
Ethernet test fixture	R&S RT-ZF8	1
SMA cables	Connected to DUT	2
DUT	1000BASE-T1 device you want to test	1

9.4.2   Performing the test

1. Start the test as described in Chapter 9.1, "Starting 1000BASE-T1 tests", on page 255.

2. Select the test case: "MDI jitter and clock frequency (test mode 2)". Click on the triangle of the test case to expand the subtests ("97.5.3.3 Transmitter timing MDI jitter" and "97.5.3.6 Transmitter clock frequency").
   Select the tests you want to platform. When you select a subtest, a tick appears in the checkbox next to it.
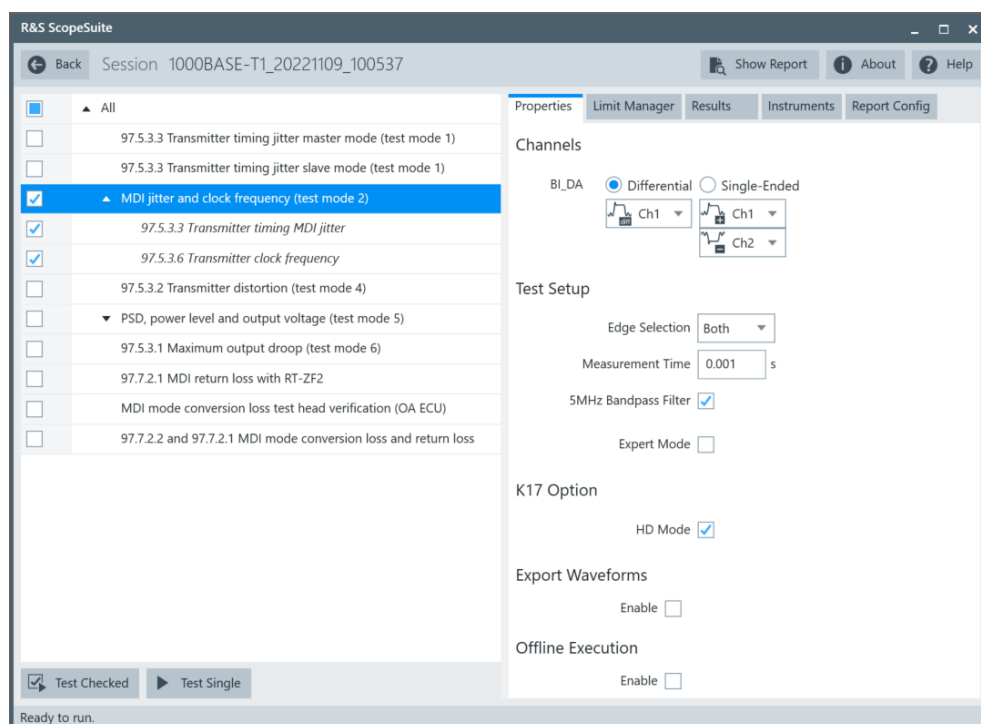
3. Click "Test Single".

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 23

9.4.3 Transmitter timing MDI jitter (97.5.3.3)

The 1000BASE-T1 PHY shall transmit a continuous pattern of three {+1} symbols fol-lowed by three {-1} symbols with the transmitted symbols timed from its local clock source of 750 MHz. In this mode, the transmitter output should be a 125 MHz signal.

For " 97.5.3.3 Transmitter timing MDI jitter" test, the RMS TIE jitter measured at the PHY MDI output shall be less than 5 ps. Also, the Peak-to-Peak TIE jitter measured at the PHY MDI output shall be less than 50 ps. The jitter is measured over an integration time interval of at least 1 ms.

9.4.4 Transmitter clock frequency (97.5.3.6)

For "97.5.3.6 Transmitter clock frequency" test, when the transmitter is in the LPI trans-mit mode, the transmitter clock short-term rate of frequency variation shall be less than 0.1 ppm/second.

The symbol transmission rate of the MASTER PHY shall be within the range 750 MHz ± 100 ppm.

9.5 Transmitter distortion (97.5.3.2)

This test case is to verify the peak distortion values, measured at a minimum of 10 equally spaced phases of a single symbol period, shall be less than 15mV.

9.5.1 Test equipment

Table 9-6: Equipment for Transmitter distortion (test mode 4) and differential BI_DA

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
Oven Controlled Crystal Oscillator Clock (OCXO, 10 MHz)	R&S RTO-B4 for R&S RTO	1
For tests with disturber: Arbitrary waveform generator	R&S RTO / R&S RTO6 /R&S RTP-B6 (with low pass filter)* or Tabor WX2182B/WX2182C	1
Ethernet test fixture	R&S RT-ZF2 or R&S RT-ZF8	1
Frequency converter	R&S RT-ZF6	1
* Use a low pass filter so that all harmonics are -40dB below the fundamental frequency as defined in the IEEE Std 802.3TM-2018 Table 40-9-Vd charasteristics		

Item	Description, model	Quantity
Differential probe	at least 2 GHz bandwidth	1
DUT	1000ASE-T1 device you want to test	1
* Use a low pass filter so that all harmonics are -40dB below the fundamental frequency as defined in the IEEE Std 802.3™-2018 Table 40-9-Vd charasteristics		

Table 9-7: Equipment for Transmitter distortion (test mode 4) without disturber and single-ended BI_DA

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
Oven Controlled Crystal Oscillator Clock (OCXO, 10 MHz)	R&S RTO-B4 for R&S RTO	1
Ethernet test fixture	R&S RT-ZF2 or R&S RT-ZF8	1
Frequency converter	R&S RT-ZF6	1
SMA cables	Connected to DUT	2
DUT	1000BASE-T1 device you want to test	1

9.5.2 Performing the test

1. Start the test as described in Chapter 9.1, "Starting 1000BASE-T1 tests", on page 255.

2. Select the test case: "97.5.3.2 Transmitter disortion (test mode 4) ".
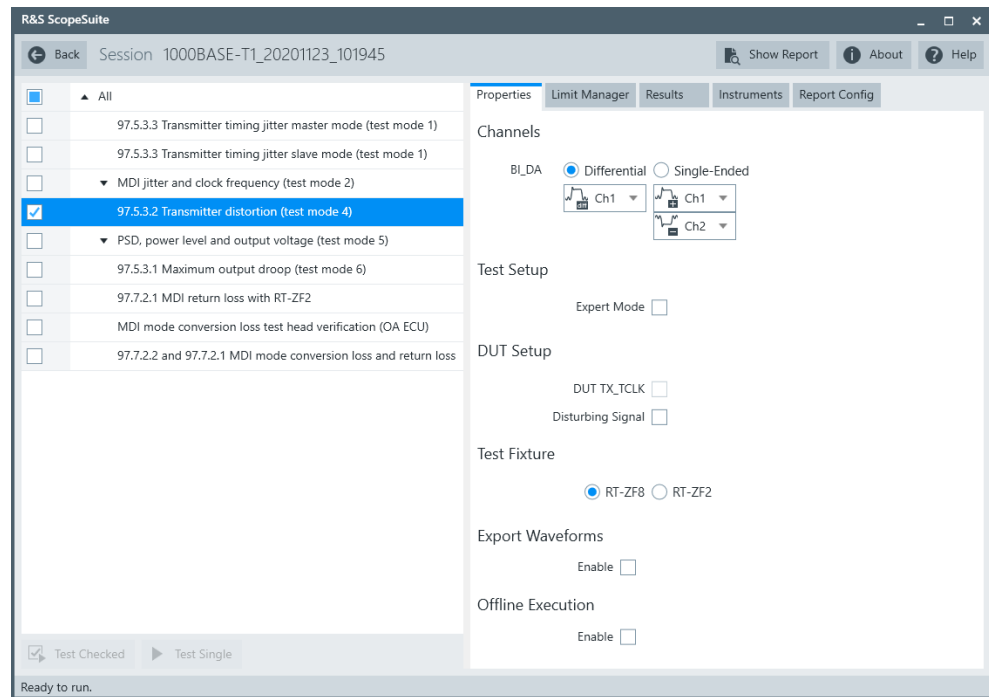
3.　Click "Test Single".

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

Further steps:

●

9.5.3　Test setup

The picture below shows the test fixture design used for this test case. V_d is the sinus-oidal disturbing signal which has amplitude of 3.6 volts peak-to-peak differential with frequency of 125MHz. This corresponds to a 1.8 V peak to peak disturber terminated with 50Ohms.

Ensure that the DUT is operating in test mode 4.

The test case assumes the disturber signal and the data acquisition clock are fre-quency locked to the DUT transmit clock.
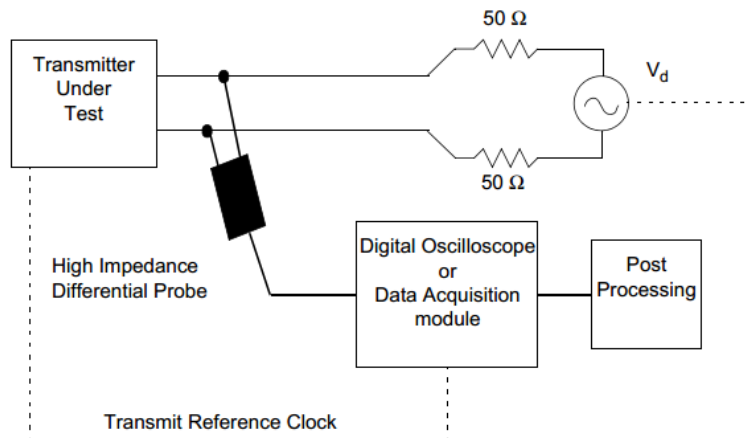
9.5.4 Measurements

The test case captures 42.5776us of consecutive symbols in the test mode 4 waveform at sampling rate of 10Gs/s. It is resampled to 7.5Gs/s and then the peak distortion is calculated at 10 uniformly spaced phase offsets over 1UI using the Matlab scripts stated in the test case specification.

The peak transmitter distortion should be less than 15mV for all the sampled phase offsets over 1UI.

9.6 PSD power level and output voltage (97.5.3.4/ 97.5.3.5)

9.6.1 Test equipment

Table 9-8: Equipment for PSD, power level and output voltage (test mode 5) and differential BI_DA

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
Ethernet test fixture	R&S RT-ZF2	1
Differential probe	at least 2 GHz bandwidth	1
DUT	1000BASE-T1 device you want to test	1

Table 9-9: Equipment for PSD, power level and output voltage (test mode 5) and single-ended BI_DA

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
SMA cables	Connected to DUT	2
Ethernet test fixture (optional)	R&S RT-ZF8	
DUT	1000BASE-T1 device you want to test	1

9.6.2 Performing the test

1. Start the test as described in Chapter 9.1, "Starting 1000BASE-T1 tests", on page 255.

2. Select the test case: "PSD, power level and output voltage (test mode 5)".
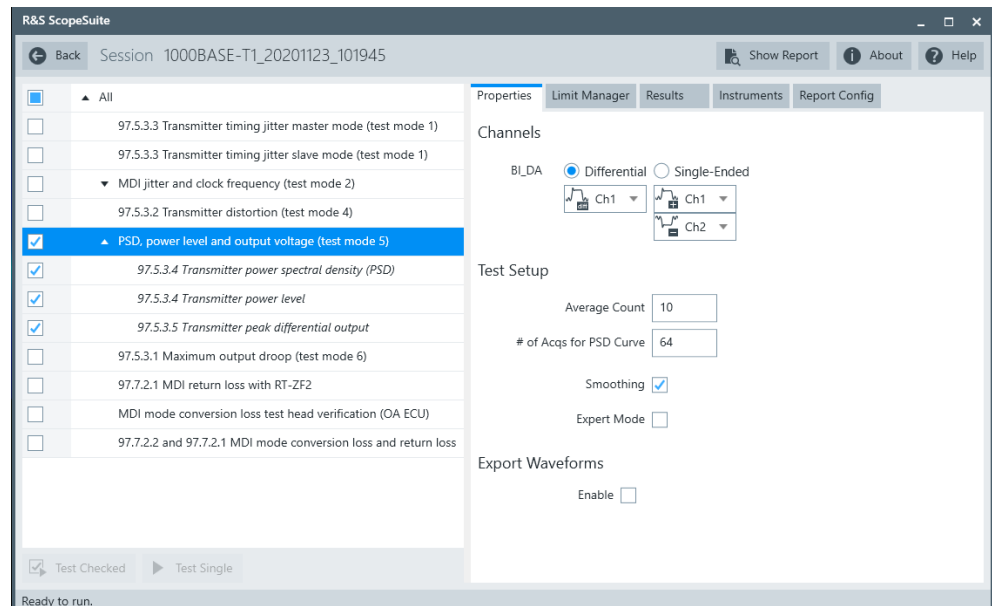
3. Click "Test Single".

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 23

9.6.3 Transmitter power spectra density (PSD) and power level

The test verifies that the transmitter power spectral density of the DUT over the frequency range 0 MHz to 1000 MHz falls in-between the upper and lower limits as specified in IEEE Std. 802.3bp, section 97.5.3.4:

$$
Lower\ PSD(f) \geq
\begin{cases}
-86 & dBm/Hz & for\ 40 \leq f \leq 100 \\
-82 - \dfrac{f}{25} & dBm/Hz & for\ 100 < f \leq 400
\end{cases}
$$

$$
Upper\ PSD(f) \geq
\begin{cases}
-80 & dBm/Hz & for\ 0 \leq f \leq 100 \\
-76 - \dfrac{f}{25} & dBm/Hz & for\ 100 < f \leq 400 \\
-85.6 - \dfrac{f}{62.5} & dBm/Hz & for\ 400 < f \leq 600
\end{cases}
$$

9.6.3.1 Measurements

Capture the spectrum of the transmitter while in test mode 5. Compute the transmitter PSD and power level.

The resulting PSD curve shall fit in the limits mentioned above. The transmit power level shall be less than 5 dBm.

9.6.4 Peak differential output voltage

This test verifies that the peak-to-peak value of the differential signal terminated with 100 Ohm is less than 1.3V. This limit applies to all transmit modes including SEND_S, SEND_T, SEND_I, and SEND_N modes. Test mode 5 is fulfilling these requirements.

9.6.4.1 Measurements

Measure the peak-to-peak amplitude of the differential signal. Increase "Average Count" to increase the number of acquisitions included in this measurement.

9.7 Maximum output droop (97.5.3.1)

9.7.1 Test equipment

You can perform the test either with a test fixture and a differential probe or with SMA cables. The equipment needed for both cases is listed in the tables below.

Table 9-10: Equipment for Maximum output droop (test mode 6) and differential BI_DA

| Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
Ethernet test fixture	R&S RT-ZF2	1
Differential probe	at least 2 GHz bandwidth	1
DUT	1000BASE-T1 device you want to test	1

Table 9-11: Equipment for Maximum output droop (test mode 6) and single-ended BI_DA

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
Ethernet test fixture (optional)	R&S RT-ZF8	1
SMA cables	Connected to DUT	2
DUT	1000BASE-T1 device you want to test	1

9.7.2 Performing the test

1. Start the test as described in Chapter 9.1, "Starting 1000BASE-T1 tests", on page 255.

2. Select the test case: "Maximum output droop (test mode 6)".
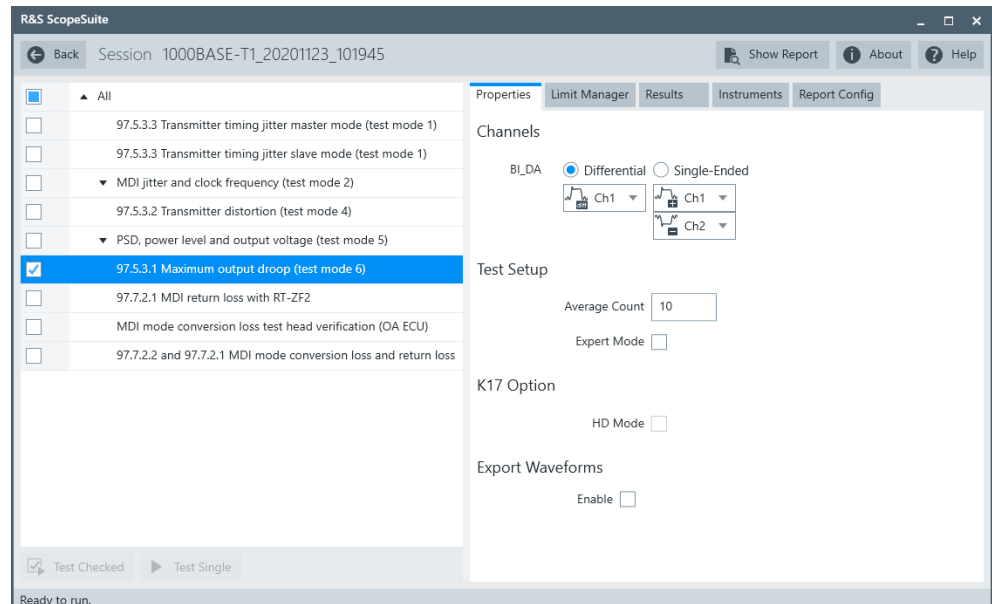
3. Click "Test Single".

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 23

9.7.3 Measurements

This test measures the voltage of the waveform of test mode 6, 4ns after a zero crossing V_{4ns} and 16ns after the zero crossing V_{16ns}. A droop is calculated according to this formula.

$$\text{Droop} = \left(\frac{V_{4ns} - V_{16ns}}{V_{4ns}}\right) * 100\%$$

This is performed on the positive and the negative peaks. The droop should be less than 10.0%.

9.7.4 References

The following references are relevant for this test case:

- IEEE Std. 802.3bp, subclause 97.5.2- Test modes
- IEEE Std. 802.3bp, subclause 97.5.3.1- Maximum output droop

9.8 MDI return loss with R&S RT-ZF2 (97.7.2.1)

This test case verifies that the transmitter return loss of the DUT meets or exceeds the limit defined in the equation for all frequencies from 2 MHz to 600 MHz:

$$Return\ Loss(f) \geq \begin{cases} 18 - 18 \times log_{10}\left(20/f\right)\ dB & for\ 2MHz \leq f \leq 20MHz \\ 18 & for\ 20MHz \leq f \leq 100MHz \\ 18 - 16.7 \times log_{10}\left(f/100\right)\ dB & for\ 100MHz \leq f \leq 600MHz \end{cases}$$

9.8.1 Test equipment

Table 9-12: Equipment for MDI return loss test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
Ethernet test fixture	R&S RT-ZF2	1

Item	Description, model	Quantity
Vector network analyzer	R&S ZNB/ZNC/ZND/ZVL	1
DUT	1000BASE-T1 device you want to test	1

9.8.2 Performing the test

1. Start the test as described in Chapter 9.1, "Starting 1000BASE-T1 tests", on page 255.

2. Select the test case: "MDI return loss".
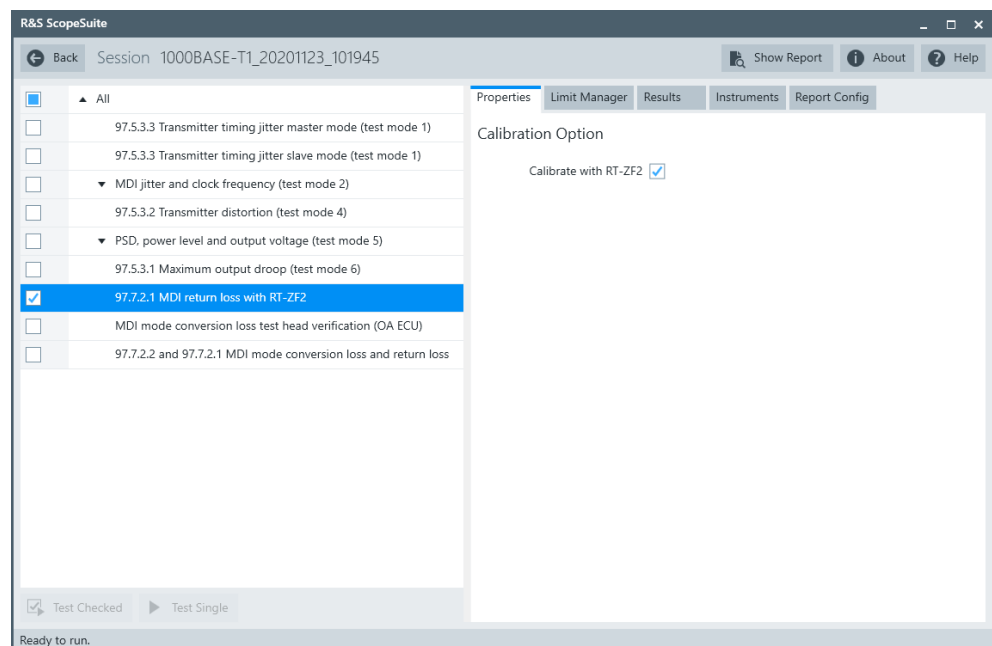
3. Click "Test Single".

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 23

9.8.3 Test setup

The DUT should be configured to operate in slave mode.

Test property "Calibrate with RT-ZF2" is checked by default. You can disable it to skip the calibration procedure.

9.8.4 Measurements

For automatic test, the program measures the S11 parameter on the VNA, it shall fall below the limit line plotted on the VNA from 2 MHz to 600 MHz.

For manual test, the program checks if every point within 2 MHz and 600 MHz in the result file (`*.s1p` or `*.csv`) falls below the limit required by the specification.

9.9 MDI mode conversion loss test head verification (OA ECU)

The test case verifies that the adaptor used for the MDI mode conversion loss measurement is symmetrical. Measurement of the open adaptor shall meet or exceed the limit for all frequencies from 10 MHz to 600 MHz.

$$Conversion\ Loss(f) \geq \left\{ \begin{array}{ll} 61 & 10 \leq f \leq 80 \\ 83 - 11.51 \times log_{10}(f) & 80 < f \leq 600 \end{array} \right\} dB$$

9.9.1 Test equipment

Table 9-13: Equipment for MDI mode conversion loss test head verification (OA ECU) test

Item	Description, model s	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
Ethernet test fixture	R&S RT-ZF8	1
Vector network analyzer (optional, required only to perform an automatic test)	R&S ZNB, R&S ZNC or R&S ZND (option K5 or K6 required)	1

9.9.2 Performing the test

1. Start the test as described in

2. Select the test case: "MDI mode conversion loss test head verification (OA ECU)".

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:

-
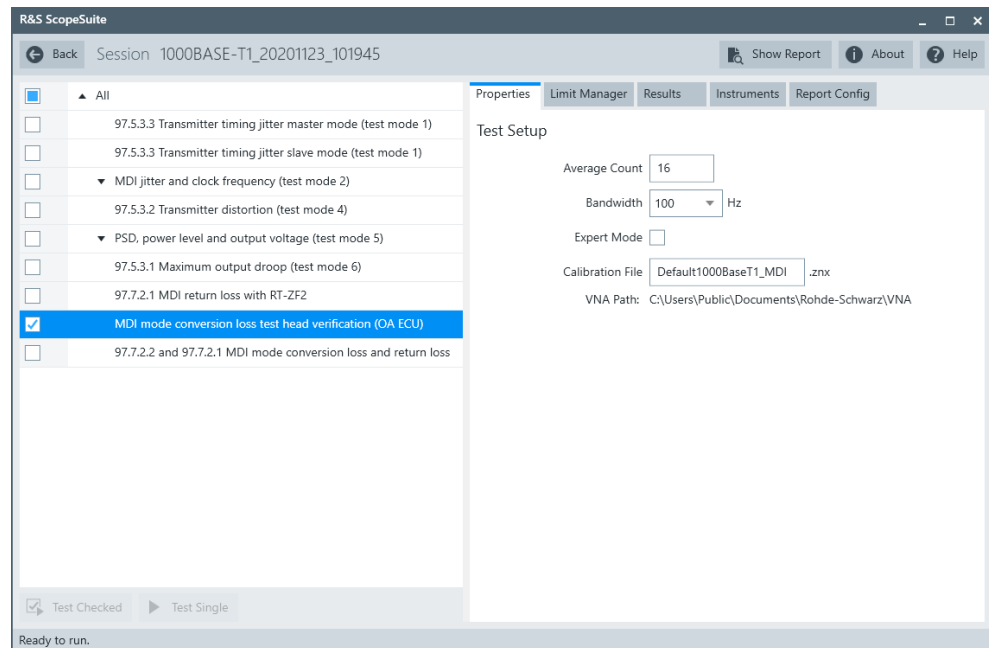
9.9.3 Measurements

For automatic test, the mode conversion loss is measured as "Sdc11" parameter in VNA. It shall fall below the limit line plotted on the VNA from 10 MHz to 600 MHz required by the specification.

For manual test, the program checks if every point within 10 MHz and 600 MHz in the result file (`*.s1p` or `*.csv`) falls below the limit required by the specification.

9.10 MDI mode conversion loss and return loss(97.7.2.2)

The MDI common mode to differential mode conversion (LCL) of the PHY shall meet or exceed the limit defined in the following equation for all frequencies from 10 MHz to 600 MHz:

$$Conversion\ Loss\ (f) \geq \begin{cases} 55\ dB & for\ 10MHz \leq f \leq 80MHz \\ 77 - 11.51 \times log_{10}(f)\ dB & for\ 80MHz < f \leq 600MHz \end{cases}$$

9.10.1　Test equipment

Table 9-14: Equipment for MDI mode conversion loss test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
Vector network analyzer	R&S ZNB, R&S ZNC or R&S ZND (option K5 or K6 required)	
DUT	1000BASE-T1 device under test	

9.10.2　Performing the test

1. Start the test as described in Chapter 9.1, "Starting 1000BASE-T1 tests", on page 255.

2. Select the test case: "MDI mode conversion loss and return loss".
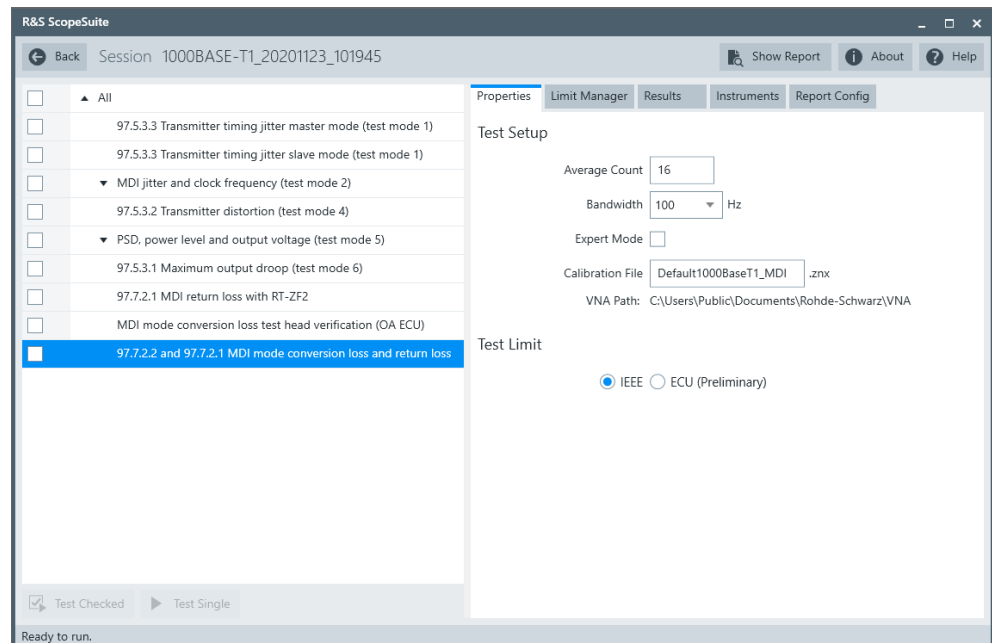
3. Click "Test Single".

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 23

9.10.3　Test setup

The DUT should be configured to operate in slave mode.

Test property "Fixture Compensation" is disabled by default. You can enable it to per-
form fixture compensation automatically.

9.10.4　Measurements

For automatic test, the mode conversion loss is measured as "Sdc11" parameter in
VNA. It shall fall below the limit line plotted on the VNA from 10 MHz to 600 MHz
required by the specification.

For manual test, the program checks if every point within 10 MHz and 600 MHz in the
result file (`*.s1p` or `*.csv`) falls below the limit required by the specification.

10   10BASE-T1 tests

10BASE-T1 Ethernet compliance tests require option R&S RTO/RTO6/RTP-K89.

10.1   Starting 10BASE-T1 tests

1. Select "10BASE-T1" in the R&S ScopeSuite start window.

2. Select "10BASE-T1S" or "10BASE-T1L" type.

3. Add a new test session and open it. See Chapter 3.1, "Starting a test session", on page 20.

4. Check the test configuration settings. Adjust them, if necessary. See:
   - Chapter 10.2, "Test configuration for Ethernet 10BASE-T1", on page 280
   - 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.

10.2   Test configuration for Ethernet 10BASE-T1

Open a "10BASE-T1S"/"10BASE-T1L" session.

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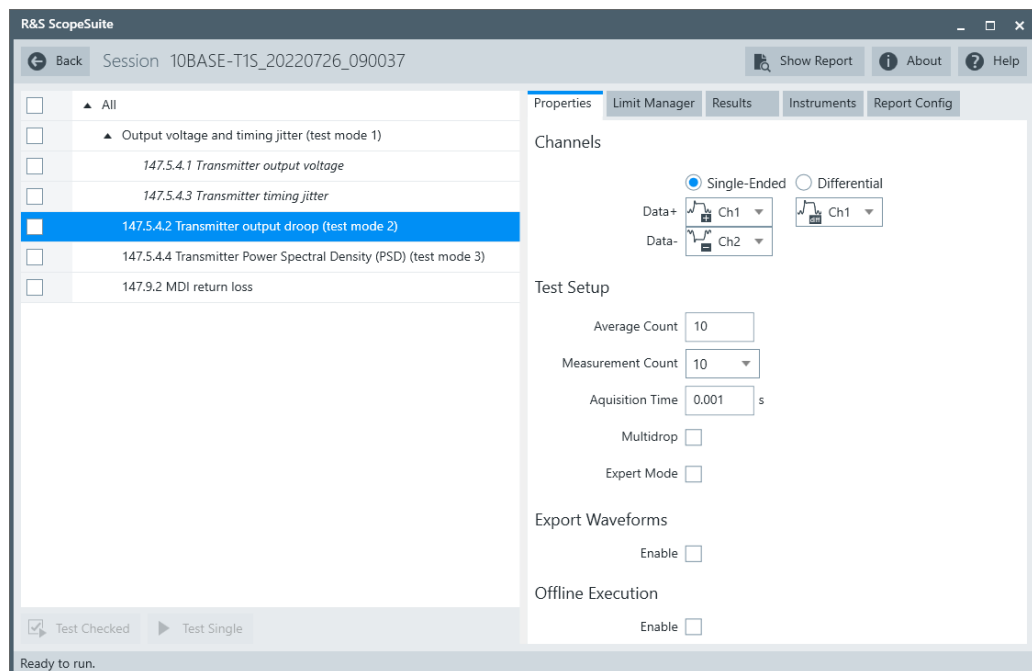
Channels

Selects the channels for testing. You can also select if the connection is single-ended (connected through BNC cables) or through differential probe type.

Average Count

Defines the number of acquisitions which the oscilloscope acquires to calculate the average waveform (average count).

For VNA test cases, it defines the number of sweeps used in the measurement. The valid range is 1 to 16. The default value is 5.

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 Count

Sets the count of how many measurements are performed for this acquisition.

Aquisition Time

Sets the total time duration that measurement data is collected for.

Bandwidth

Sets the VNA power bandwidth for VNA test cases. Available values are 100Hz, 1KHz or 10KHz.

Multidrop

Enable this function for DUTs operating in multidrop mode.

The multidrop mode is a half-duplex shared-medium mode, where multiple stations connected to a mixing segment can operate simultaneously. A mixing segment is a single balanced pair of conductors.

For operation in multidrop mode, 50 Ω resistive differential load is connected to the transmitter output. Otherwise 100 Ω resistive differential load is connected to the transmitter output.

Expert Mode

If enabled, the "Expert Mode" allows you to bypass the guided steps of the test case.

Calibration File

Specifies the calibration file in the VNA path directory. The file is used for saving and loading data during test execution.

VNA Path

Displays the working directory on the VNA for saving and loading calibration files.

Export Waveforms

Enables you to export a waveform. You can later load the waveforms to run the tests in the offline mode, see Offline Execution.

You can define an export directory, or use the default one:

```
MyDocuments\Rohde-Schwarz\RSScopeSuite\<Version>\Waveforms\
<ComplianceTest>\<SessionType>\<SessionName>
```

For example:

```
MyDocuments\Rohde-Schwarz\RSScopeSuite\4.70.0\Waveforms\
10BASE-T1\10BASE-T1L\10Base-T1_2133_20200430_144116
```

Offline Execution

Offline Execution

Enable	✓
TM2 waveform	[_____] 📁 Select

If enabled, allows you to use exported waveforms as a source for the execution of the compliance test.

You can select one waveform for each needed signal.

10.3 10BASE-T1S tests

10.3.1 Output voltage and timing jitter

The "Output Voltage and Timing Jitter" tests verify that :

- Transmitter output voltage is 1V ±20% peak-to-peak differential, for the test conditions as specified in IEEE Std. P802.3cg^{TM}, section 147.5.4.1
- The maximum jitter at the transmitter side is less than 5 ns symbol-to-symbol, for the test conditions as specified in IEEE Std. P802.3cg^{TM}, section 147.5.4.3.

10.3.1.1 Test equipment

Table 10-1: Equipment for Output voltage and timing jitter

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP	1
Ethernet test fixture (optional)	R&S RT-ZF8	1
DUT	10BASE-T1S device you want to test	1

10.3.1.2 Performing the test

1. Start the test as described in Chapter 10.1, "Starting 10BASE-T1 tests", on page 280.

2. Select the test case: "Output voltage and timing jitter (test mode 1)".
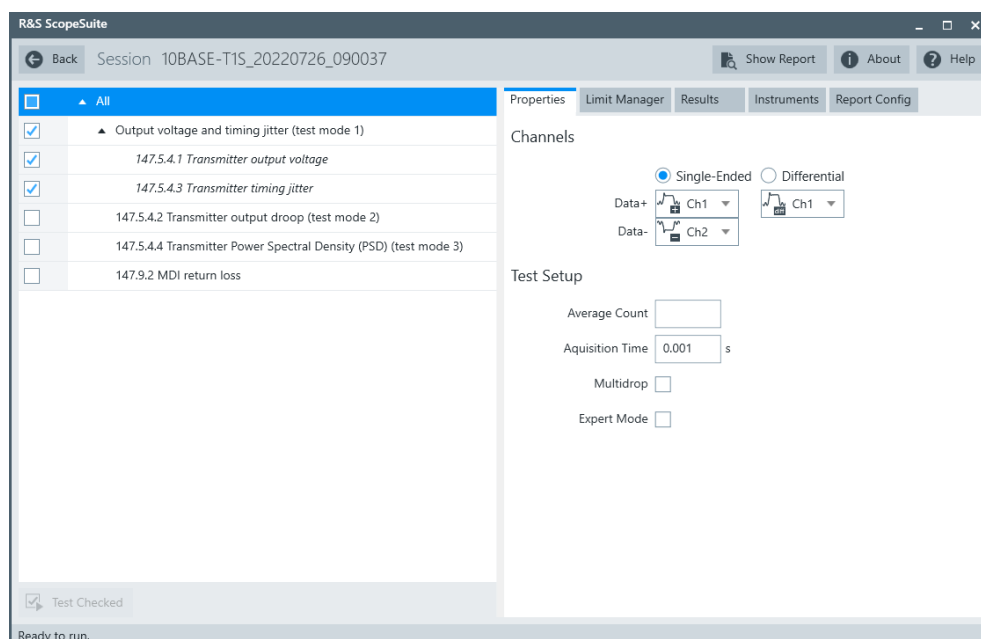
3. Click "Test Single".

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 23

10.3.1.3 Measurements

The DUT has to transmit test mode 1, as specified in IEEE Std. P802.3cg^TM, section 147.5.2.

10.3.2 Transmitter output droop

The "Transmitter output droop" test verifies that the transmitter output level does not decay faster than the maximum rate, as specified in IEEE Std. P802.3cg™, section 147.5.4.2 .

10.3.2.1 Test equipment

Table 10-2: Equipment for Transmitter output droop test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP	1
Ethernet test fixture (optional)	R&S RT-ZF8	1
DUT	10BASE-T1S device you want to test	1

10.3.2.2 Performing the test

1. Start the test as described in Chapter 10.1, "Starting 10BASE-T1 tests", on page 280.

2. Select the test case: "Transmitter output droop (test mode 2)".
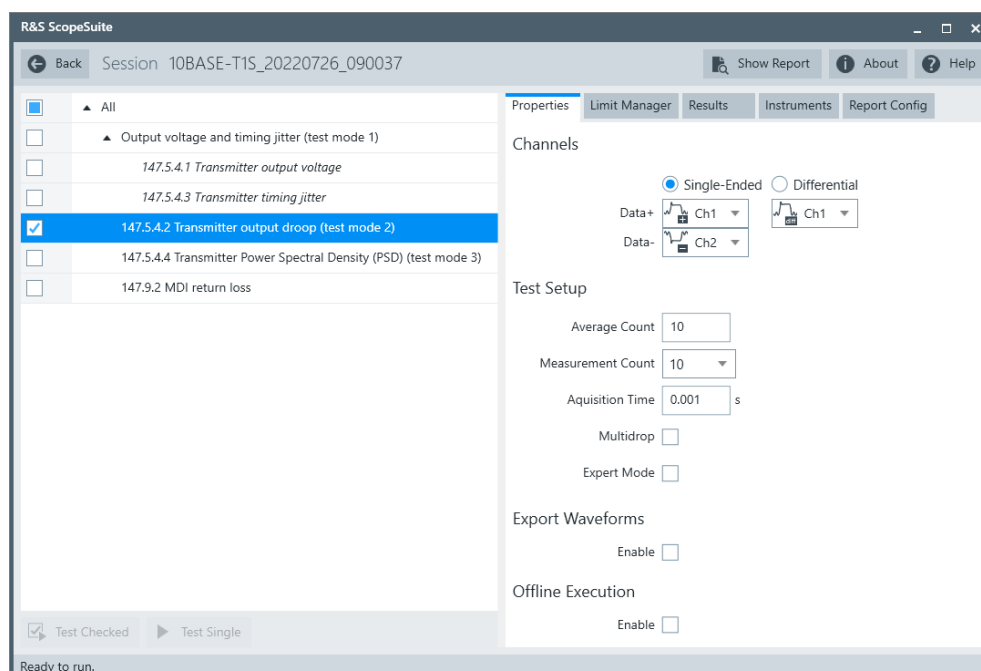
3. Click "Test Single".

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 23

10.3.2.3 Measurements

For "Transmitter output droop" test, the DUT has to transmit a test mode 2 waveform.

It measures the droop after 800ns regarding max and min of a pulse which is a sequence of 1.6us of positive and negative pulses. The magnitude of the negative and the positive droop should be less than 30%, where the droop is defined as:

Droop = 100 x (V_d x V_{pk})[%]

V_{pk} is the magnitude at peak and V_d is the magnitude after 800ns as shown in Figure 10-1
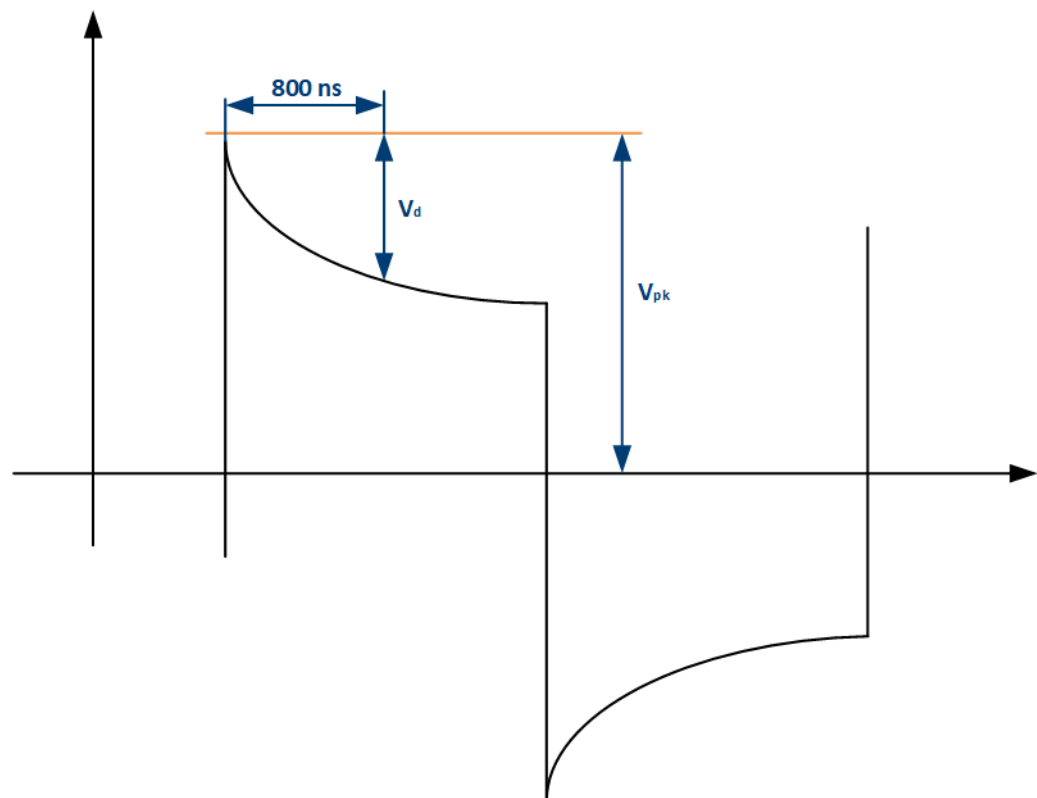

Figure 10-1: 10BASE-T1S transmitter output droop

10.3.3 Transmitter power spectral density

The test verifies that the transmitter power spectral density of the DUT over the frequency range falls in-between the upper and lower masks specified in IEEE Std. P802.3cg[TM], section 147.5.4.4:

● Upper PSD for the frequency f 0.3 MHz ≤f ≤ 40 MHz

$$UpperPSD(f) \begin{cases} -61 & 0.3 \leqslant f < 15 \\ -40 - 1.4f & 15 \leqslant f < 25 \\ -75 & 25 \leqslant f \leqslant 40 \end{cases} dBm/Hz$$

- Lower PSD for the frequency f 5 MHz ≤f ≤ 15 MHz

$$LowerPSD(f) \begin{cases} -87 + 2f & 5 \leqslant f < 10 \\ -47 - 2f & 10 \leqslant f < 15 \end{cases} dBm/Hz$$
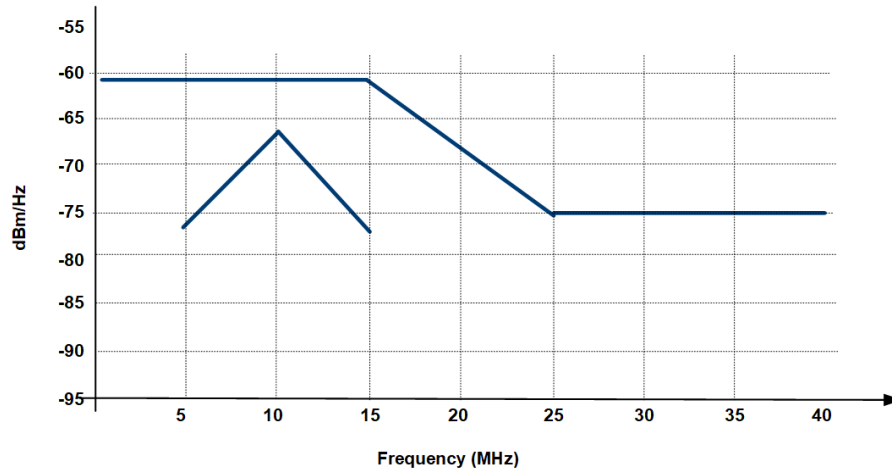
Figure 10-2: PSD limits (as defined in IEEE Std. P802.3cg^{TM}, section 147.5.4.4.3)

10.3.3.1 Test equipment

Table 10-3: Equipment for Transmitter power spectral density test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP	1
Ethernet test fixture (optional)	R&S RT-ZF8	1
DUT	10BASE-T1S device you want to test	1

10.3.3.2 Performing the test

1. Start the test as described in Chapter 10.1, "Starting 10BASE-T1 tests", on page 280.

2. Select the test case: "147.5.4.4 Transmitter power spectral density (PSD) (test mode 3)".
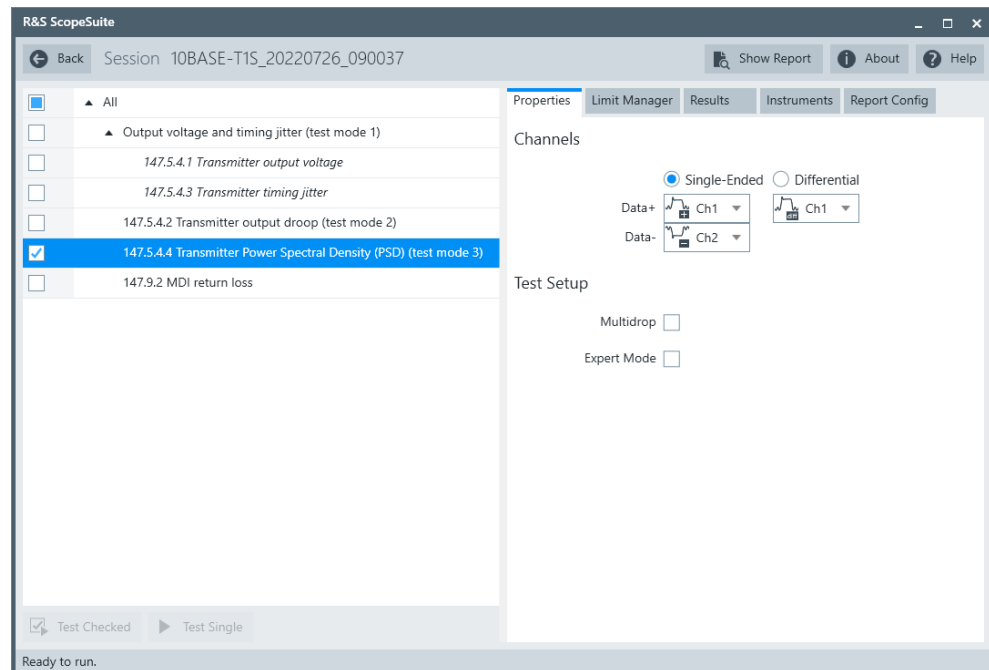
3. Click "Test Single".

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 23

10.3.3.3 Measurements

Configure the DUT to test mode 3.

10.3.4 MDI mode return loss

The "MDI mode return loss" test case measures the transmitter return loss.

Transmitter return loss of the DUT shall meet or exceed the limit defined in the following equation for all frequencies from 1 MHz to 66 MHz (IEEE Std. P802.3cg[TM]):

$$
MDI\ Return\ Loss(f) \begin{cases} 20\ dB & 1 \leqslant f \leqslant 30\ MHz \\ 20 - 20 \times log_{10}\left(\frac{f}{30}\right) dB & 30 \leqslant f < 66\ MHz \end{cases}
$$

10.3.4.1 Test equipment

Table 10-4: Equipment for MDI mode conversion loss and return loss test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP	1
Ethernet test fixture (optional)	R&S RT-ZF8	1
Vector network analyzer (optional, required only to perform an automatic test)	R&S ZNB, R&S ZNC or R&S ZND (option K5 or K6 required)	1
DUT	10BASE-T1S device you want to test	1

10.3.4.2 Performing the test

1. Start the test as described in Chapter 10.1, "Starting 10BASE-T1 tests", on page 280.

2. Select the test case: "MDI return loss".
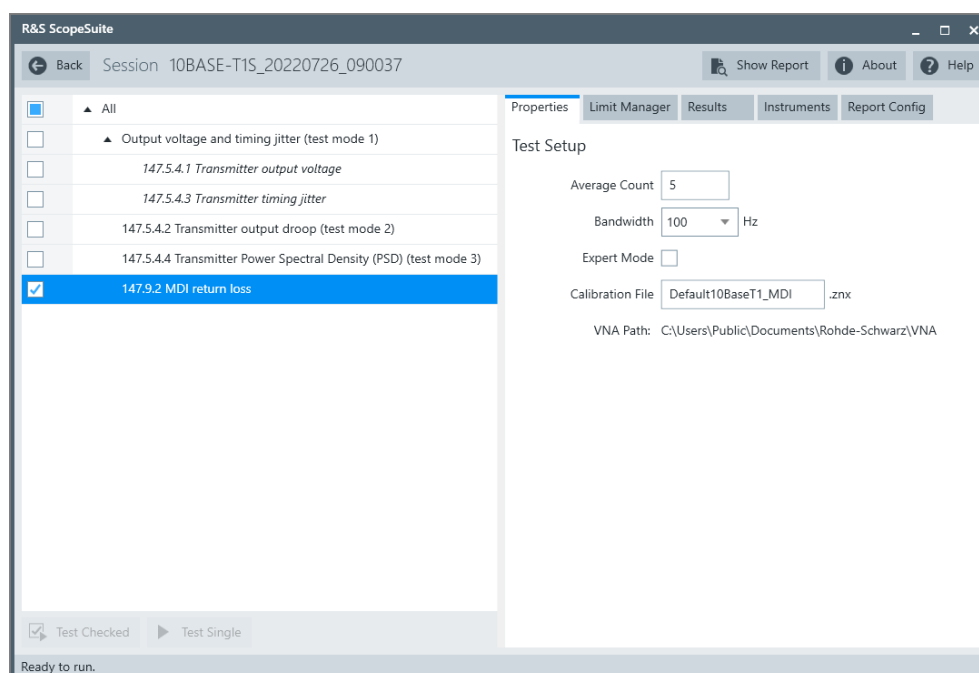
3. Click "Test Single".

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 23

10.3.4.3 Test Setup

The DUT should be in slave mode.

Test property "Fixture Compensation" is disabled by default. You can enable it to per-form fixture compensation automatically.

10.3.4.4 Measurements

For automatic test, the return loss is measured as "S11" parameter on VNA. It shall fall below the limit line plotted on the VNA from 1 MHz to 66 MHz.

For manual test, the program checks if every point within 1 MHz to 66 MHz in the result file (`*.s1p`) falls below the limit required by the specification for return loss.

10.4 10BASE-T1L tests

10.4.1 Output voltage and timing jitter

The "Output Voltage and Timing Jitter" tests verify that :

- Transmitter output voltage, as specified in IEEE Std. P802.3cg^{TM}, section 146.5.4.1, is:
  - For the 2.4 V_{pp} operating mode: 2.4 V + 5%/– 15% peak-to-peak
  - For the 1.0 V_{pp} operating mode: 1.0 V + 5%/– 15% peak-to-peak
- The maximum jitter at the transmitter side is less than 10 ns symbol-to-symbol, for the test conditions as specified in IEEE Std. P802.3cg^{TM}, section 146.5.4.3.
- The symbol transmission rate of the MASTER PHY is within the range 7.5 MBd ± 50 ppm, as specified in IEEE Std. P802.3cg^{TM}, section 146.5.4.5.

10.4.1.1 Test equipment

Table 10-5: Equipment for Output voltage and timing jitter

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP	1
Ethernet test fixture (optional)	R&S RT-ZF8	1
DUT	10BASE-T1L device you want to test	1

10.4.1.2 Performing the test

1. Start the test as described in Chapter 10.1, "Starting 10BASE-T1 tests", on page 280.

2. Select the test case: "Output voltage and timing jitter (test mode 1)".
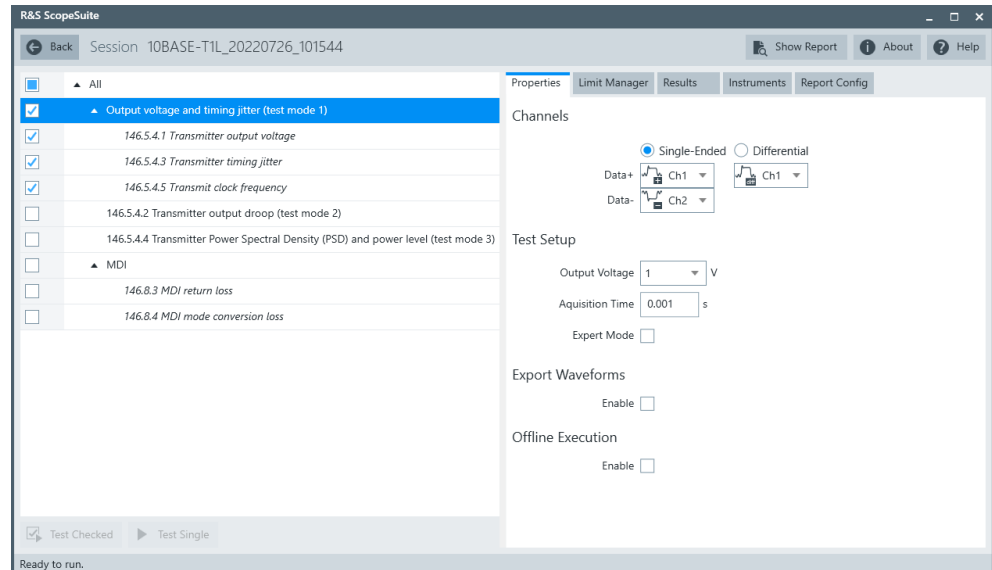
3. Click "Test Single".

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 23

10.4.1.3 Measurements

The DUT has to transmit a test mode 1 waveform.

10.4.2 Transmitter output droop

The "Transmitter output droop" test verifies that the transmitter output level does not decay faster than the maximum rate, as specified in IEEE Std. P802.3cg^{TM}, section 146.5.4.2 .

10.4.2.1 Test equipment

Table 10-6: Equipment for Transmitter output droop test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP	1
Ethernet test fixture (optional)	R&S RT-ZF8	1
DUT	10BASE-T1L device you want to test	1

10.4.2.2 Performing the test

1. Start the test as described in Chapter 10.1, "Starting 10BASE-T1 tests", on page 280.

2. Select the test case: "Transmitter output droop (test mode 2)".
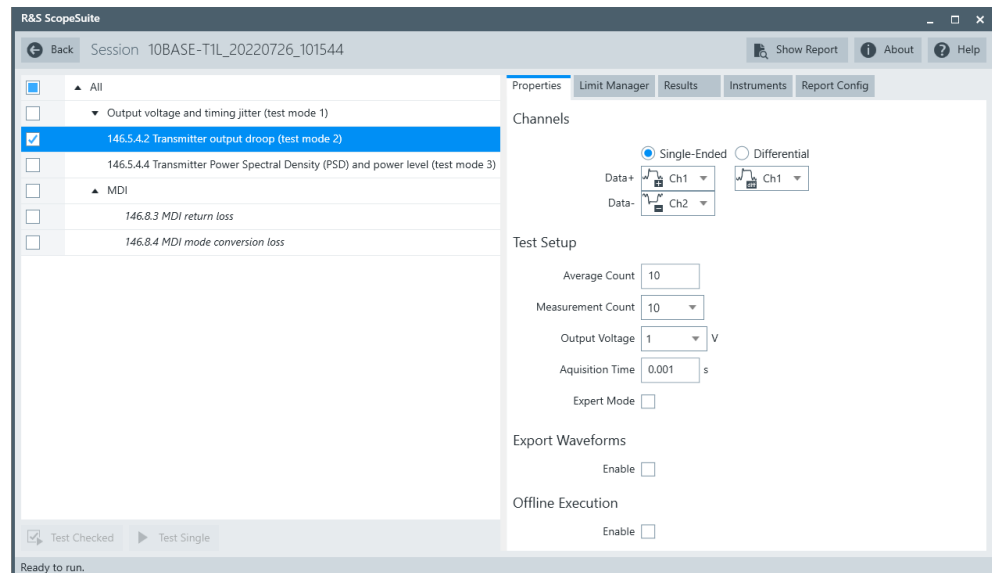
3. Click "Test Single".

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 23

10.4.2.3 Measurements

The DUT has to transmit at test mode 2, as specified in IEEE Std. P802.3cg^{TM}, section 146.5.2.

It measures the droop after 800ns regarding max and min of a pulse which is a sequence of 1.6us of positive and negative pulses. The magnitude of the negative and the positive droop should be less than 10%, where the droop is defined as:

Droop = 100 x (V_d x V_{pk})[%]

V_{pk} is the magnitude at peak and V_d is the magnitude after 800ns as shown in Figure 10-1
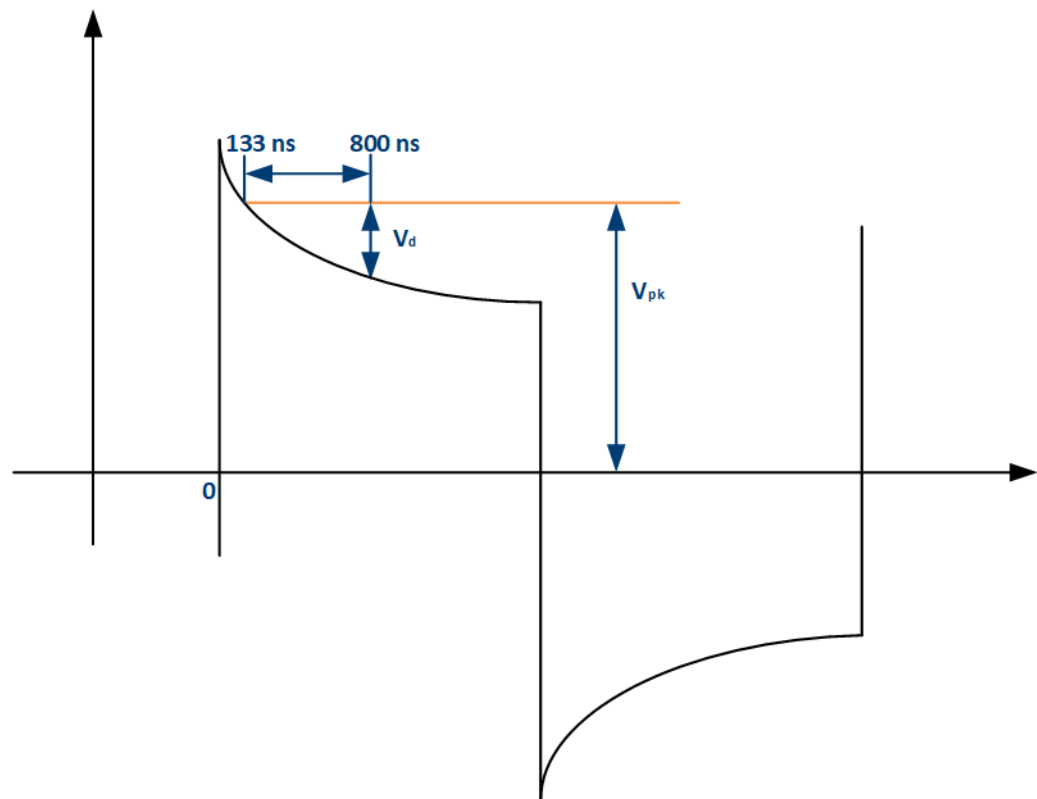
Figure 10-3: 10BASE-T1L transmitter output droop

10.4.3 Transmitter power spectral density

The test verifies that the transmitter power spectral density of the DUT over the frequency range falls in-between the upper and lower masks specified in IEEE Std. P802.3cg[TM], section 146.5.4.4:

- For the 2.4 V_{pp} transmit signal amplitude:
  - Upper PSD for the frequency f

$$Upper\ PSD\ Limit(f) \geq \begin{cases} -54\ dBm/Hz & 0 \leq f \leq 2.5 \\ -54 - 1.6 \times (f - 2.5)\ dBm/Hz & 2.5 < f < 12.5 \\ -70\ dBm/Hz & 12.5 \leq f \leq 20 \end{cases}$$

  - Lower PSD for the frequency f

$$Lower\ PSD\ Limit(f) \geq \begin{cases} -60\ dBm/Hz & 0.625 \leq f \leq 2.5 \\ -60 - 4 \times (f - 2.5)\ dBm/Hz & 2.5 < f \leq 5 \end{cases}$$

- For the 1.0 V$_{pp}$ transmit signal amplitude:
  - Upper PSD for the frequency f

$$Upper\ PSD\ Limit(f) \geq \begin{cases} -61.6\ dBm/Hz & 0 \leq f \leq 2.5 \\ -61.6 - 1.6 \times (f - 2.5)\ dBm/Hz & 2.5 < f < 12.5 \\ -77.6\ dBm/Hz & 12.5 \leq f \leq 20 \end{cases}$$

  - Lower PSD for the frequency f

$$Lower\ PSD\ Limit(f) \geq \begin{cases} -67.6\ dBm/Hz & 0.625 \leq f \leq 2.5 \\ -67.6 - 4 \times (f - 2.5)\ dBm/Hz & 2.5 < f \leq 5 \end{cases}$$
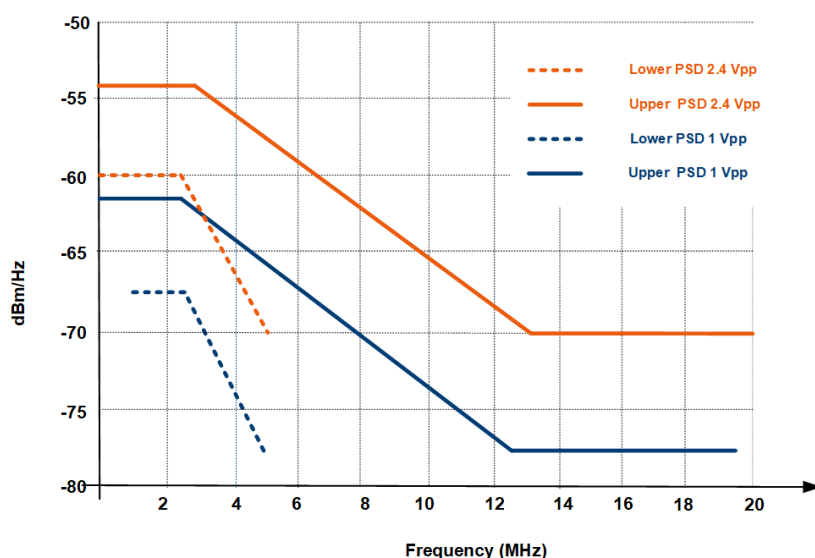
Figure 10-4: Transmitter PSD limits (as defined in IEEE Std. P802.3cg^{TM}, section 146.5.4.4)

10.4.3.1 Test equipment

Table 10-7: Equipment for Transmitter power spectral density test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP	1
Ethernet test fixture (optional)	R&S RT-ZF8	1
DUT	10BASE-T1 device you want to test	1

10.4.3.2 Performing the test

1. Start the test as described in

2. Select the test case: "146.5.4.4 Transmitter power spectral density (PSD) (test mode 3)".
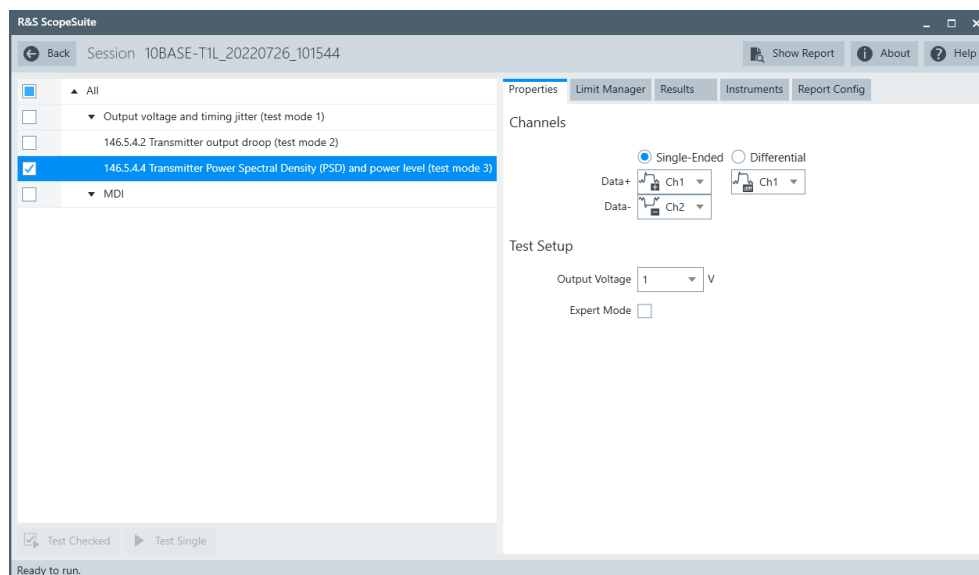
3. Click "Test Single".

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 23

10.4.3.3 Measurements

Configure the DUT to test mode 3.

10.4.4 MDI mode conversion loss and return loss

The "MDI mode conversion loss and return loss" test case performs two measurements, for the transmitter return loss and the MDI common mode to differential mode conversion (LCL) of the PHY.

Transmitter return loss of the DUT shall meet or exceed the limit defined in the following equation for all frequencies from 0.1 MHz to 20 MHz (IEEE Std. P802.3cg™):

$$
Return\ Loss(f) \geq \begin{cases}
20 - 18 \times log_{10}\left(\frac{0.2}{f}\right) dB & 0.1 \leq f < 0.2\ MHz \\
20\ dB & 0.2 \leq f \leq 1\ MHz \\
20 - 16.7 \times log_{10}\left(f\right) dB & 1 < f \leq 10\ MHz \\
3.3 - 7.6 \times log_{10}\left(\frac{f}{10}\right) dB & 10 < f \leq 20\ MHz
\end{cases}
$$

The MDI common mode to differential mode conversion (LCL) of the PHY shall meet or exceed the limit defined in the following equation for all frequencies from 0.1 MHz to 20 MHz (IEEE Std. P802.3cg™):

$$Conversion\ Loss(f) \geq \left\{ \begin{array}{ll} 25\ dB & 0.1 \leq f \leq 10\ MHz \\ 25 - 20 \times log_{10}\left(\frac{f}{10}\right)\ dB & 10 < f \leq 20\ MHz \end{array} \right\}$$

10.4.4.1 Test equipment

Table 10-8: Equipment for MDI mode conversion loss and return loss test

Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP	1
Ethernet test fixture (optional)	R&S RT-ZF8	1
Vector network analyzer (optional, required only to perform an automatic test)	R&S ZNB, R&S ZNC or R&S ZND (option K5 or K6 required)	1
DUT	10BASE-T1L device you want to test	1

10.4.4.2 Performing the test

1. Start the test as described in Chapter 10.1, "Starting 10BASE-T1 tests", on page 280.

2. Select the test case: "146.8.3 and 146.8.4 MDI mode conversion loss and return loss".
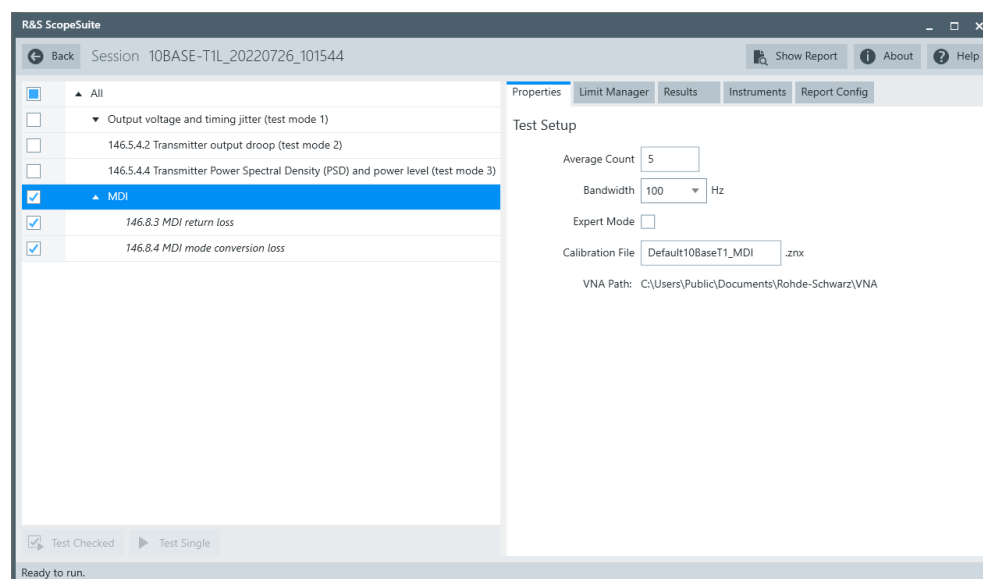
3. Click "Test Single".

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 23

10.4.4.3 Test setup

The DUT should be in slave mode.

Test property "Fixture Compensation" is disabled by default. You can enable it to per-form fixture compensation automatically.

10.4.4.4 Measurements

For automatic test, the mode conversion loss is measured as "Sdc11" parameter on VNA. It shall fall below the limit line plotted on the VNA from 0.1MHz to 20 MHz required by the specification. The return loss is measured as "Sdc11" parameter on a VNA. It shall fall below the limit line plotted on the VNA from 0.1 MHz to 20 MHz.

For manual test, the program checks if every point within 0.1 MHz to 20 MHz in the result file (`*.s1p`) falls below the limit required by the specification for mode conver-sion loss. It also checks if every point within 0.1 MHz and 20 MHz in the result file (`*.s1p`) falls below the limit required by the specification for return loss.

11 MGBASE-T1 tests

MGBASE-T1 Ethernet compliance tests require option R&S RTO/RTO6/RTP-K88.

The following MGBASE-T1 tests, check the limits for the respective parameters as specified in IEEE P802.3ch™/D1.3.

11.1 Starting MGBASE-T1 tests

1. Perform a self-alignment of the oscilloscope.

   The detailed procedure is described in the oscilloscope's user manual.

2. Connect the measurement setup.

   Note: Always use matched SMA cables to ensure precise measurements.

3. Measure the deskew of the signal path of each channel. You need the values for the test configuration.
   You can use the pulse source option R&S RTO/RTO6/RTP-B7 for deskew measurement.

4. Select "MGBASE-T1" in the R&S ScopeSuite start window.

5. Select "2.5 G" or "5G" or "10G" type.

6. Add a new test session.

7. Open the test session, see Chapter 3.1, "Starting a test session", on page 20.

8. Select the test cases that you want to run.

9. Check the test configuration settings. Adjust them, if necessary. See:
   - Chapter 11.2, "Test configuration for MGBASE-T1", on page 297
   - Chapter 3.2.1.1, "Limit manager", on page 23

10. Click "Test Single" or "Test checked".

11. 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.

11.2 Test configuration for MGBASE-T1

The test configuration consists of some test-specific configuration settings. If "All" is selected in the test case list, you can see all settings that are used in at least two test cases. Settings that are specific to one dedicated test case are only shown if that test case is selected.

All settings are explained in this section.
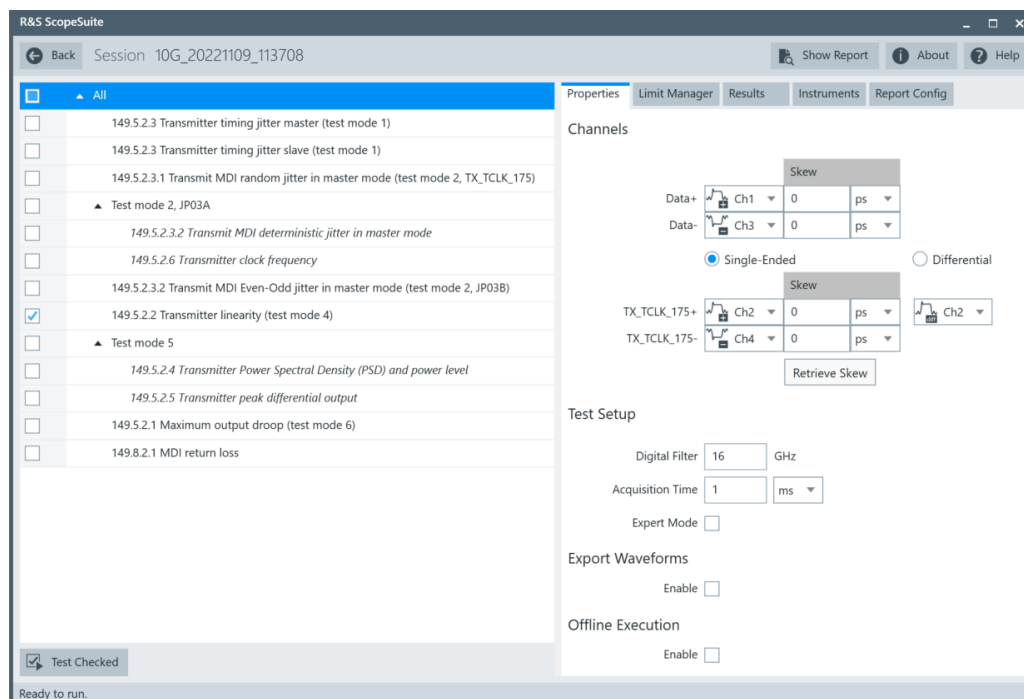
Data+/Data-, TX_TCLK+/TX_TCLK-
Select the channels to which the data and clock lines are connected. To measure with maximum sampling rate, combine Ch1 with Ch3, or Ch2 with Ch4.

Skew
When creating a new session, the skew values are read from the oscilloscope and the skew fields are updated.

You can also enter the skew value for each channel. Measure the deskew of each channel before you start the compliance test, for example, using the pulse source option R&S RTO/RTO6/RTP-B7.

Retrieve skew
The skew values are read from the oscilloscope and updated.

Average Count
Defines the number of waveforms which the oscilloscope acquires to calculate the average waveform. The valid range is 1 to 30 and the default value is 10.

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

Measurement Count
Defines the Number of measurements performed on one waveform. Select a value from the list, or enter another integer value.

Digital Filter

Enables the digital filter for the "Transmitter linearity (test mode 4)" test case. It only applies to 10G speed linearity test using oscilloscopes with bandwidth of 8 GHz of higher.

Acquisition Time

Time of one acquisition that is the time across all horizontal divisions of the diagram. The valid range is 200 µs to 1.2 ms, the default value is 1 ms.

JP03A Acquisition Time

Time of one acquisition that is the time across all horizontal divisions of the diagram. This property is used in test mode 2, JP03A. The limits depend on the selected MGBASE type ("2.5 G" or "5G" or "10G"). The limit values are:

- 2.5G: 200 µs to 7.2 ms
- 5G: 200 µs to 3.6 ms
- 10G: 200 µs to 1.8 ms

Fixture Compensation

The fixture compensation is used in the "MDI return loss " test case.

Enable for fixture compensation.

Expert Mode

If enabled, the "Expert Mode" allows you to bypass the guided steps of the test case.

Export Waveforms

Enables you to export a waveform. You can later load the waveforms to run the tests in the offline mode, see Offline Execution.

You can define an export directory, or use the default one:

```
MyDocuments\Rohde-Schwarz\RSScopeSuite\<Version>\Waveforms\
<ComplianceTest>\<SessionName>
```

For example:

```
MyDocuments\Rohde-Schwarz\RSScopeSuite\4.90.0\Waveforms\
MGBase-T1\MGBase-T1__20210114_144116
```

Offline Execution

If enabled, allows you to use exported waveforms as a source for the execution of the compliance test.

You can select one waveform for each needed signal.

VNA average count

Only relevant for measurements with VNA. It defines the number of sweeps of the VNA used in the measurement.

Bandwidth

Only relevant for measurements with VNA. Enter the resolution bandwidth of the VNA.

Calibration File

Only relevant for measurements with VNA. Specifies the calibration file in the VNA path directory. The file is used for saving and loading data during test execution.

VNA Path

Only relevant for measurements with VNA. Displays the working directory on the VNA for saving and loading calibration files.

11.3 Test equipment

The following table shows an overview of the needed equipment for performing the MGBASE-T1 test cases. A prerequisite is also the R&S ScopeSuite software, an MGBASE-T1 DUT and a R&S RTO / R&S RTO6 /R&S RTP with a bandwidth of:

●   For 2.5 GBASE-T1 tests: at least 3.5 GHz

●   For 5 GBASE-T1 tests: at least 7 GHz

●   For 10 GBASE-T1 tests: at least 13 GHz

Table 11-1: MGBASE-T1 test equipment

Test	Cables (SMA or BNC)	Additional instruments
Transmitter timing jitter master (test mode 1)	2	Link partner
Transmitter timing jitter slave mode (test mode 1)	2	Link partner
Transmitter MDI random jitter in master mode (test mode 2, TX_TCLK_175)	2	
Test mode 2	2	
Transmit MDI even-odd jitter in master mode (test mode 2, JP03B)	2	
Transmitter linearity (test mode 4)	2	
Test mode 5	2	
Maximum output droop (test mode 6)	2	
MDI return loss	2	Cal kit
		Vector network analyzer: (optional, required only to perform an automatic test) R&S ZNB/ZNC/ZND/ZVL

11.4 Common parameters

The IEEE P802.3ch™/D1.3 defines three different PHY types. Fro some parameters there is a parameter S used for scaling of the results.

Scaling parameter

S is a scaling parameter defined in table IEEE P802.3ch™/D1.3 of the specification. Its value depends on the PHY type:

- For 10GBASE-T1: S=1
- For 5GBASE-T1: S=0.5
- For 2.5GBASE-T1: S=0.25

11.5 Transmitter timing jitter master

The test verifies, that the transmitter timing jitter in master mode is within the limits specified in the IEEE P802.3ch™/D1.3 specification, section 149.5.2.3.

11.5.1 Performing the test

For an overview of the needed equipment, see Chapter 11.3, "Test equipment", on page 300.

1. Start the test as described in Chapter 11.1, "Starting MGBASE-T1 tests", on page 297.

2. Select the test case: "149.5.2.3 Transmitter timing jitter master (test mode 1)".
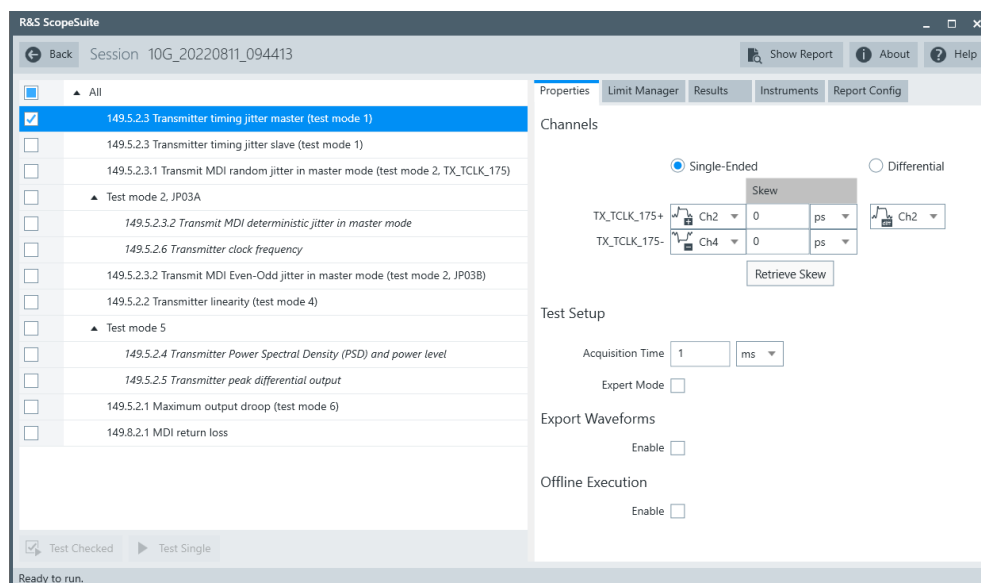
3. Click "Test Single".

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 23

11.5.2 Measurements

The DUT has to transmit a test mode 1 waveform.

For this test, the transmitter timing jitter is measured by capturing the TX_TCLK_175 square waveform, while in master mode.

To pass the test, the RMS jitter value of the MASTER TX_TCLK_175 jitter relative to an unjittered reference must be less than 1/S ps. The peak-to-peak value of the MASTER TX_TCLK_175 jitter relative to an unjittered reference must be less than 10/S ps.

S is a scaling parameter, which value depends on the PHY type, see Scaling parameter.

11.6 Transmitter timing jitter slave mode

The test verifies, that the transmitter timing jitter in slave mode is within the limits specified in the IEEE P802.3ch^TM/D1.3 specification, section 149.5.2.3.

11.6.1 Performing the test

For an overview of the needed equipment, see Chapter 11.3, "Test equipment", on page 300.

1. Start the test as described in Chapter 11.1, "Starting MGBASE-T1 tests", on page 297.

2. Select the test case: "149.5.2.3 Transmitter timing jitter slave (test mode 1)".
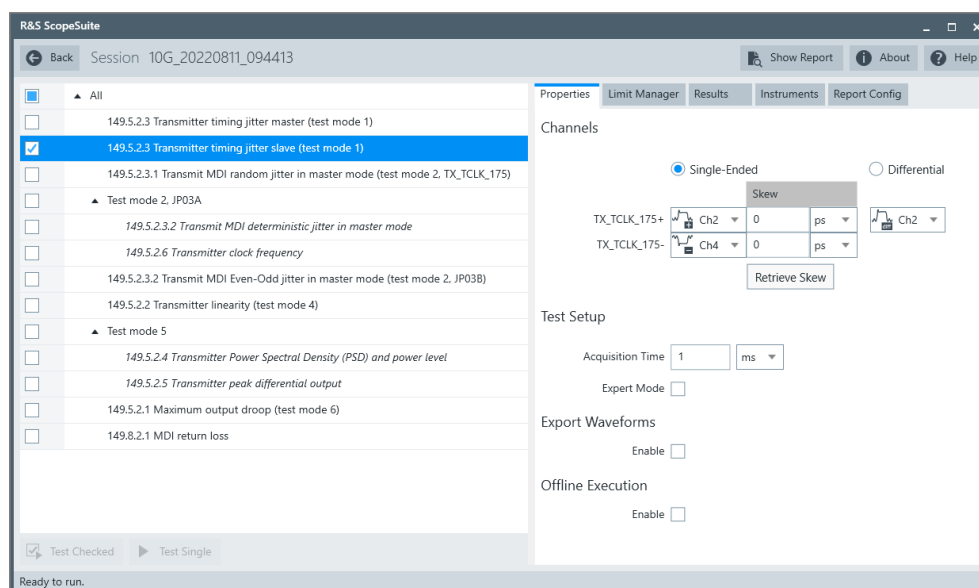
3. Click "Test Single".

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 23

11.6.2 Measurements

The DUT has to transmit a test mode 1 waveform.

For this test, the transmitter timing jitter is measured by capturing the TX_TCLK_175 square waveform, while in slave mode.

To pass the test, the RMS jitter value of the SLAVE TX_TCLK_175 jitter relative to an unjittered reference must be less than 2/S ps. The peak-to-peak value of the SLAVE TX_TCLK_175 jitter relative to an unjittered reference must be less than 20/S ps.

S is a scaling parameter, which value depends on the PHY type, see Scaling parameter.

11.7 Transmitter MDI random jitter in master mode

The test verifies, that the transmitter MDI random jitter in master mode is within the limits specified in the IEEE P802.3ch™/D1.3 specification, section 149.5.2.3.1.

11.7.1 Performing the test

For an overview of the needed equipment, see Chapter 11.3, "Test equipment", on page 300.

1. Start the test as described in Chapter 11.1, "Starting MGBASE-T1 tests", on page 297.

2. Select the test case: "149.5.2.3.1 Transmitter MDI random jitter in master mode (test mode2, TX_TCLK_175)".
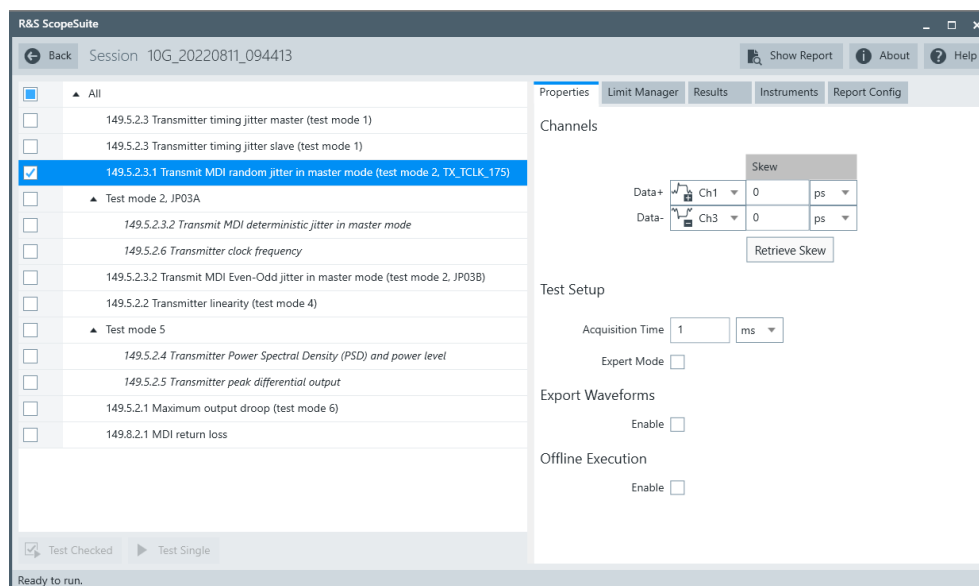
3. Click "Test Single".

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 23

11.7.2 Measurements

The DUT has to transmit a test mode 2 waveform.

For this test, the transmitter timing jitter is measured by capturing the TX_TCLK_175 square waveform.

To pass the test, the RMS jitter value of the MDI output jitter relative to an unjittered reference must be less than 1/S ps. The peak-to-peak value of the MDI output jitter relative to an unjittered reference must be less than 10/S ps.

S is a scaling parameter, which value depends on the PHY type, see Scaling parameter.

11.8   Test mode 2, JP03A

Two tests are performed in test mode 2 and with a JP03A test pattern :

- "Transmit MDI deterministic jitter in master mode": verifies that the measurement is within the limits specified in the IEEE P802.3ch™/D1.3 specification, section 149.5.2.3.2.
- "Transmitter clock frequency": verifies that the measurement is within the limits specified in the IEEE P802.3ch™/D1.3 specification, section 149.5.2.6.

11.8.1   Performing the test

For an overview of the needed equipment, see Chapter 11.3, "Test equipment", on page 300.

1. Start the test as described in Chapter 11.1, "Starting MGBASE-T1 tests", on page 297.

2. Select the test case: "Test mode 2, JP03A".
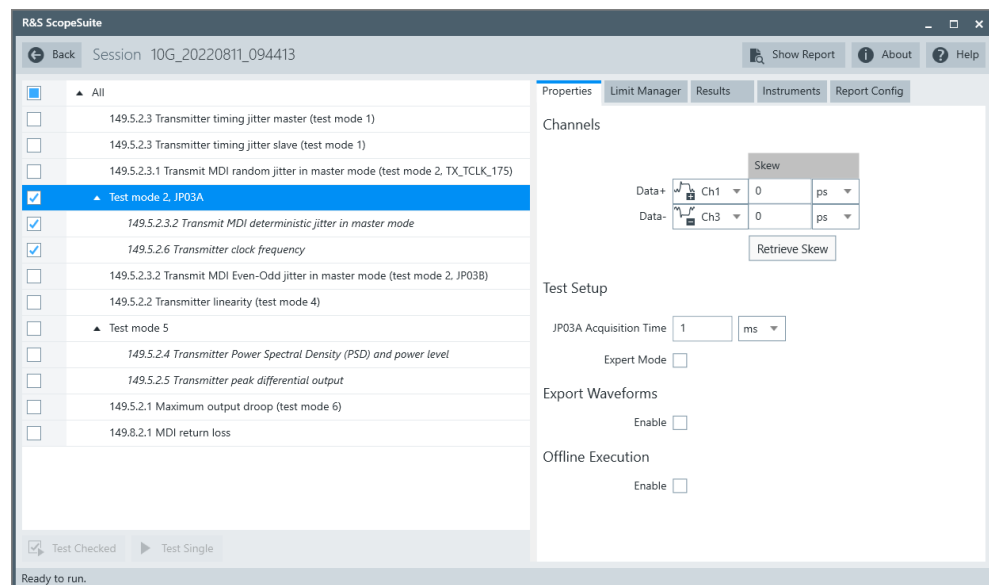
3. Click "Test Single".

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 23

11.8.2 Measurements

For these test cases, the transmitter is set to test mode 2. The test pattern is JP03A as defined in section 94.2.9.1 of the specification.

To pass the transmit MDI deterministic jitter in master mode test, the transmit MDI deterministic jitter (DJ_{pk-pk}) in master mode must be less than 9/S ps.

For transmitter clock frequency test, the MASTER PHY must be within the range of 5625×S MHz ± 50 ppm.

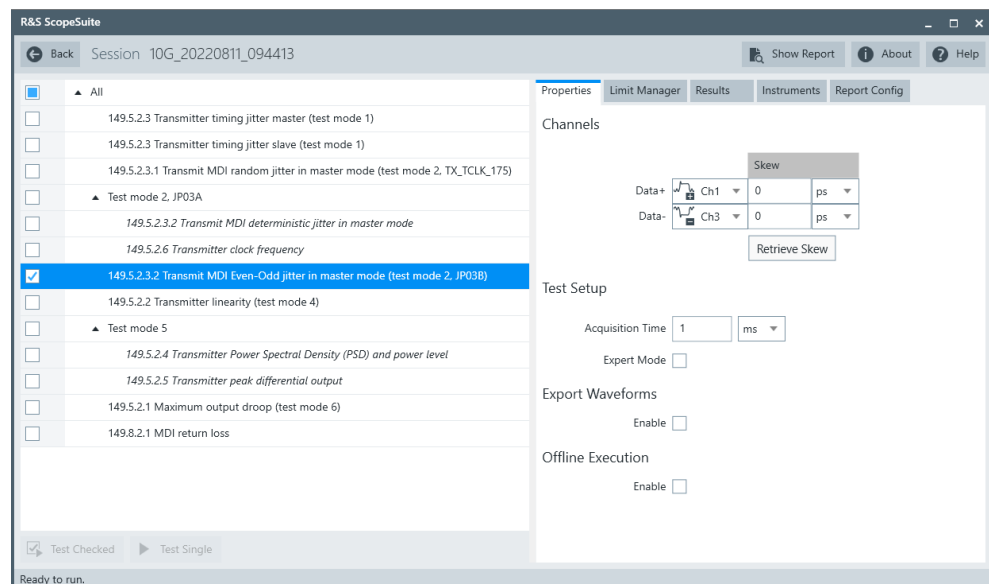S is a scaling parameter, which value depends on the PHY type, see Scaling parameter.

11.9 Transmit MDI even-odd jitter in master mode

The test verifies, that the transmit MDI even-odd jitter in master mode is within the limits specified in the IEEE P802.3ch™/D1.3 specification, section 149.5.2.3.2.

11.9.1 Performing the test

For an overview of the needed equipment, see Chapter 11.3, "Test equipment", on page 300.

1. Start the test as described in Chapter 11.1, "Starting MGBASE-T1 tests", on page 297.

2. Select the test case: "149.5.2.3.2 Transmit MDI Even-Odd jitter in master mode (test mode 2, JP03B)".

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 23

11.9.2 Measurements

The DUT has to transmit a test mode 2 waveform. The test pattern is JP03B as defined in section 94.2.9.1 of the specification.

To pass the test, the transmit MDI even-odd jitter (EOJ_{pk-pk}) in master mode must be less than 4 /S ps.

S is a scaling parameter, which value depends on the PHY type, see Scaling parameter.

11.10 Transmitter linearity

The test verifies, that the transmitter linearity is within the limits specified in the IEEE P802.3ch[TM]/D1.3 specification, section 149.5.2.2.

11.10.1 Performing the test

For an overview of the needed equipment, see Chapter 11.3, "Test equipment", on page 300.

1. Start the test as described in Chapter 11.1, "Starting MGBASE-T1 tests", on page 297.

2. Select the test case: "149.5.2.2 Transmitter linearity (test mode 4)".
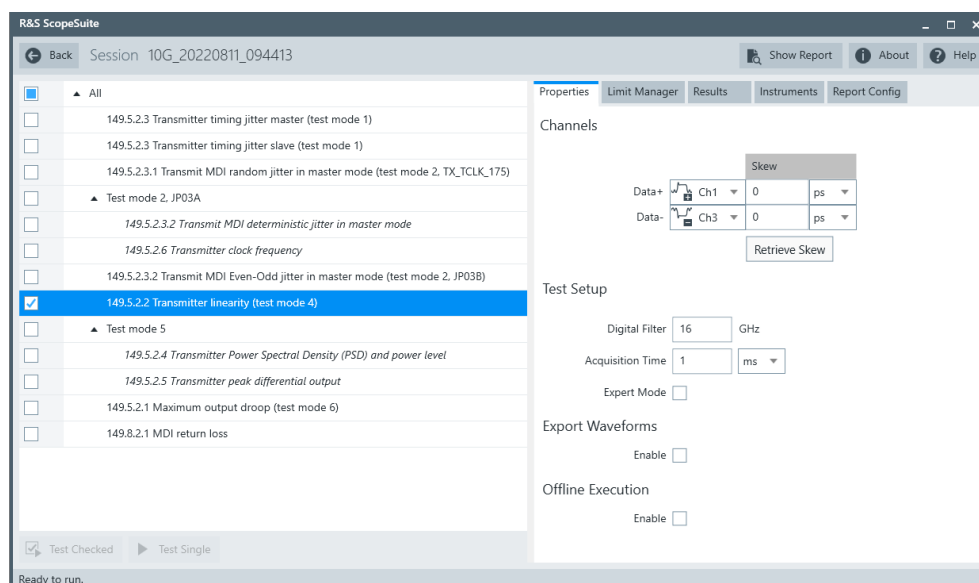
3. Click "Test Single".

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 23

11.10.2 Measurements

The DUT has to transmit a test mode 4 waveform.

The transmitter signal-to-noise distortion ratio (SNDR) is measured. The reference value depends on the selected test:

● For 10GBASE-T1, it must be higher than 38 dB
● For 5GBASE-T1, it must be higher than 36 dB
● For 2.5GBASE-T1, it must be higher than 35 dB

11.11 Test mode 5

Two tests are performed in test mode 5:

● "Transmitter power spectral density (PSD) and power level": verifies that the measurement is within the limits specified in the IEEE P802.3ch™/D1.3 specification, section 149.5.2.4.
● "Transmitter peak differential output": verifies that the measurement is within the limits specified in the IEEE P802.3ch™/D1.3 specification, section 149.5.2.5.

11.11.1 Performing the test

For an overview of the needed equipment, see Chapter 11.3, "Test equipment", on page 300.

1. Start the test as described in Chapter 11.1, "Starting MGBASE-T1 tests", on page 297.

2. Select the test case: "Test mode 5".
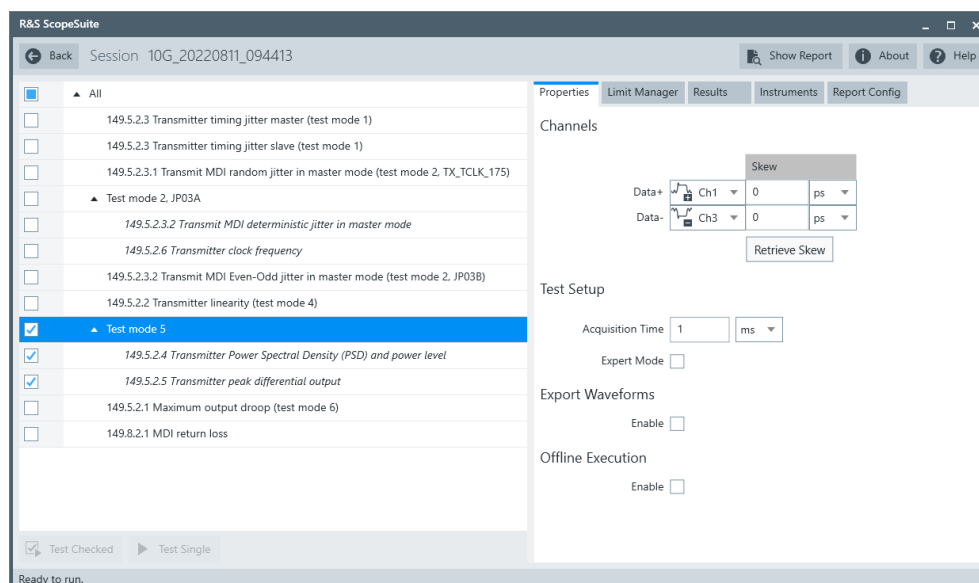
3. Click "Test Single".

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 23

11.11.2 Measurements

The DUT has to transmit a test mode 5 waveform.

Transmitter power spectral density (PSD) and power level

To pass the test, the transmit power must be in the range of –1 dBm to 2 dBm. The power spectral density of the transmitter must be within the following limits:

$$LSPD(f) = \begin{cases} -96 - K \ \ dBm/Hz & 5 < f \leqslant 400 \times S \\ -95 - K - \frac{f}{400 \times S} \ \ dBm/Hz & 400 \times S < f \leqslant 2000 \times S \\ -90 - K - \frac{f}{200 \times S} \ \ dBm/Hz & 2000 \times S < f \leqslant 3000 \times S \end{cases}$$

$$USPD(f) = \begin{cases} -90 - K \;\; dBm/Hz & 0 < f \leqslant 600 \times S \\ -89 - K - \frac{f}{600 \times S} \;\; dBm/Hz & 600 \times S < f \leqslant 3000 \times S \\ -82 - K - \frac{f}{250 \times S} \;\; dBm/Hz & 3000 \times S < f \leqslant 5500 \times S \end{cases}$$

where f is the frequency in MHz and K=101log$_{10}$ (S). S is the scaling factor, see Scaling parameter.

Transmitter peak differential output

To pass the test, the transmit differential signal at MDI must be less than 1.3 V peak-to-peak. It must be measured with 100 Ω termination.
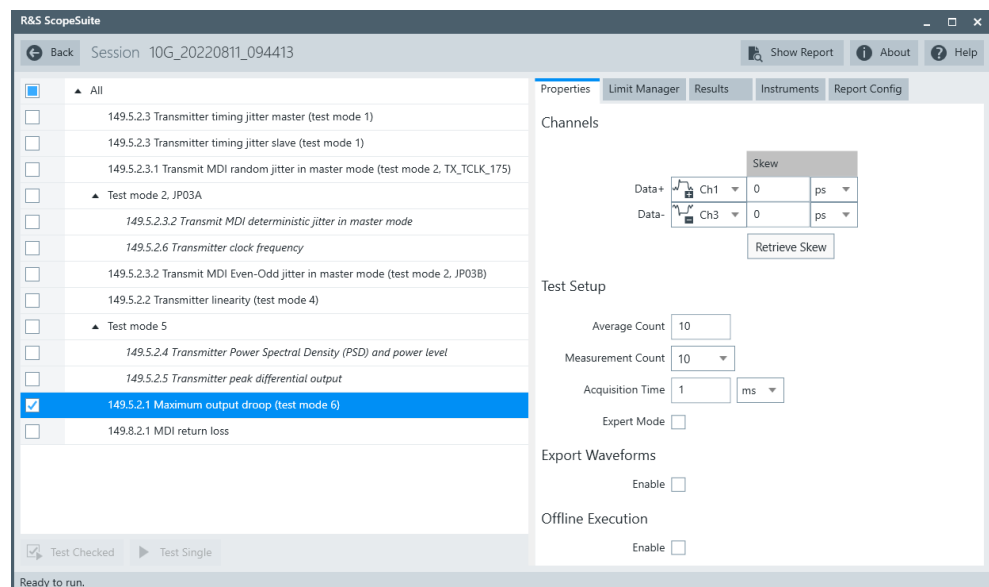
11.12   Maximum output droop

The test verifies, that the maximum output droop is within the limits specified in the IEEE P802.3ch^{TM}/D1.3 specification, section 149.5.2.1.

11.12.1   Performing the test

For an overview of the needed equipment, see Chapter 11.3, "Test equipment", on page 300.

1. Start the test as described in Chapter 11.1, "Starting MGBASE-T1 tests", on page 297.

2. Select the test case: "149.5.2.1 Maximum output droop (test mode 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 23

11.12.2 Measurements

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

In test mode 6, the DUT transmits 128 xS {+1} symbols followed by 128 xS {-1} symbols with a timing done by the local clock source.

S is a scaling parameter, which value depends on the PHY type, see Scaling parameter.

The magnitude of the positive and negative droop is measured regarding V_{init} (at 4ns after the zero crossing) and V_{Delay} (at 16 ns after the zero crossing). The magnitude must be less than 15%.

Worst positive droop

$V_{Init} = 0.6v, t = 4ns$

$V_{Delay} = 0.4v, t = 16ns$

$V_{zero} = 0V, t = 0ns$

0V
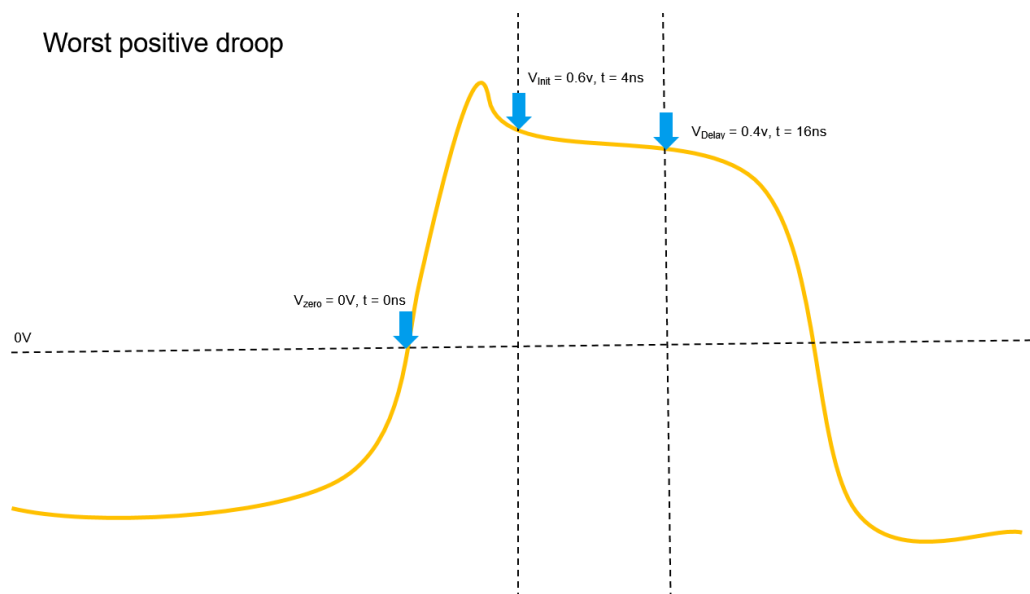
11.13 MDI return loss

The test verifies, that the MDI return loss is within the limits specified in the IEEE P802.3ch[TM]/D1.3 specification, section 149.8.2.1.

11.13.1 Performing the test

For an overview of the needed equipment, see Chapter 11.3, "Test equipment", on page 300.

1. Start the test as described in Chapter 11.1, "Starting MGBASE-T1 tests", on page 297.

2. Select the test case: "149.8.2.1 MDI return loss".
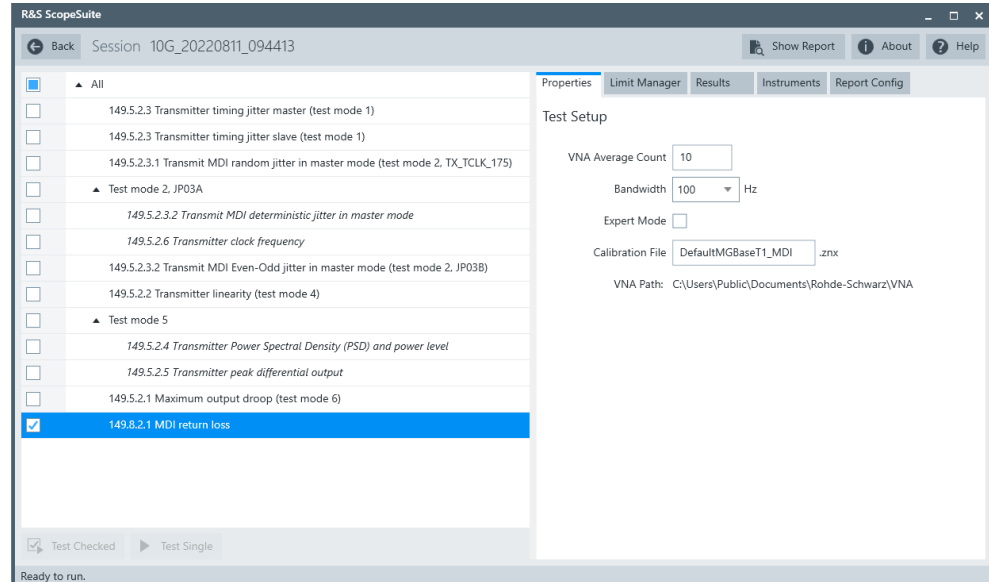
3. Click "Test Single".

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 23

11.13.2 Measurements

The DUT has to transmit a test mode 5 waveform.

The MDUI return loss, must be within the following limits:

$$MDIReturnLoss(f) \leq \begin{Bmatrix} 20 - 20\left(log_{10}\frac{10}{f}\right) & 1 \leq f < 10 \\ 20 & 10 \leq f < 280S \\ 20 - 10log_{10}(f/(280S)) & 280S \leq f < 2800S \\ 10 - 16log_{10}(f/(2800S)) & 2800S \leq f \leq Fmax \end{Bmatrix} dB$$

where f is the frequency in MHz and S is the scaling factor, see Scaling parameter.

During automatic testing, the program measures the S11 parameter on the VNA. It must fall below the limit line plotted on the VNA from 1 MHz to 4000 MHz.

During manual testing, the program checks if every point within 1 MHz and 4000 MHz in the result file (`*.s1p` or `*.csv`) falls below the limit required by the specification.