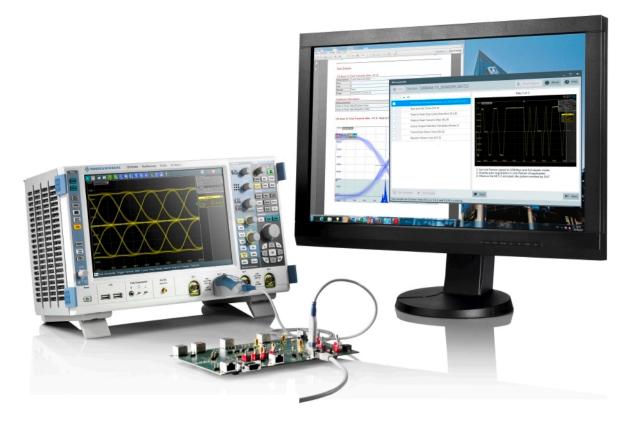
# R&S<sup>®</sup>RTO, R&S<sup>®</sup>RTO6, R&S<sup>®</sup>RTP Ethernet Compliance Tests User Manual







Make ideas real



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

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

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### 1317.7202.02 | Version 19 | R&S®RTO, R&S®RTO6, R&S®RTP

Throughout this manual, products from Rohde & Schwarz are indicated without the ® symbol , e.g. R&S<sup>®</sup>ScopeSuite is indicated as R&S ScopeSuite.

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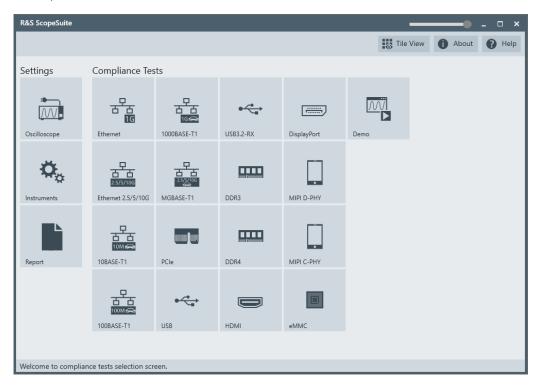
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## 1 R&S ScopeSuite overview

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:

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

- 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
- 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".

R&S ScopeSuite						•	_ 🗆 ×
					Tile	View 1 About	P Help
Settings	Compliance Tes	its					
Oscilloscope	Ethernet	日 日 1000BASE-T1	USB3.2-RX	DisplayPort	Demo		
<b>Ö</b> oo Instruments	Ethernet 2.5/5/10G	2.5/5/10G 2.5/5/10G MGBASE-T1	DDR3	MIPI D-PHY			
Report	10BASE-T1	PCIe	DDR4	MIPI C-PHY			
	100BASE-T1	USB	НДМІ	eMMC			
Welcome to complia	nce tests selection scr	een.					

- 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.

Connecting the arbitrary waveform generator

RSScopeSuite			- 🗆 ×
🕒 Back Oscilloscope	Settings	About	Help
Oscilloscope			
IP address:	10.113.10.30		
	Get Instrument Information		
Device:	RTO		
Serial Number:	400132		
Firmware Version:	2.60.2.7		
Restore Settings On Exit:	Never      Ask      Always		
Connect software to your RTO.			

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.

- 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".
- Select a supported "AWG Type" and enter its IP address.
   For a list of the supported AWGs, see chapter "Test Equipment".

R&S ScopeSuite		_ 🗆 ×
G Back Instruments Settings	1 About	P Help
AWG VNA SA		
Arbitrary Waveform Generator		
Operating Mode Automatic 💌		
AWG Type Scope WaveGen 🔻		
IP Address: 10.10.10.10		
Get Instrument Information		
Device:		
Serial Number:		
Firmware Version:		
Configure default settings for new session		

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 (\*.slp) 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.

RSScopeSuite		- □ >
🕒 Back Instruments Se	iettings 1 Ak	pout 🕐 Help
AWG VNA SA		
Vector Network Analyzer	r	
Operating Mode	Automatic 💌	
VNA Type	ZVL 💌	
IP Address:	10.10.10.10	
	Get Instrument Information	
Device:		
Serial Number:		
Firmware Version:		
Configure default settings for new	w session	

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.

Report configuration

RSScopeSuite		_ 🗆 ×
G Back Instruments Se	ettings 1 About	? Help
AWG VNA SA	—	
Spectrum Analyzer		
Operating Mode	Automatic 🔻	
SA Type	FSV T	
IP Address:	10.10.10.10	
	Get Instrument Information	
Device:		
Serial Number:		
Firmware Version:		
Configure default settings for new	w session	

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.

Report configuration

R&S ScopeSuite			_ 🗆 ×
G Back Report Settings			About 🛛 Help
Content Display Summary 🗸	Format	Icon	
Display Detail 🗹 Display Properties 🗹			
Display Screenshots 🗸	]		
Reports Directory			
Directory		🛟 Change 🗃 Open	
User Input			
Device Under Test (DUT)			
User			
Site			
Temperature			
Comments			
Configure default settings for new s	ession		

## 3 Performing tests

### 3.1 Starting a test session

RSScopeSuite	RSScopeSuite _ 🗆 🗙				
🕒 Back Compliance T	About ? Help				
Select Type  1000BASE-T 100BASE-	-TX 🔿 10BASE-T				
Session Name	Last Accessed	Comment			
1000BASE-T20151126_152947	11/26/2015 3:29:47 PM	DUT Nr. 300			
1000BASE-T20151125_152130	11/25/2015 3:21:34 PM	DUT Nr. 243			
Add 🖬 Open 💼	Remove 🖳 Rename	📮 Comment 🛛 🖹 Show Report	•		
Add new or open existing session	Add new or open existing session to run.				

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 manager", on page 23.
- If you want to use special report settings the "Report Config" tab to define the format and contents of the report. Otherwise the settings defined in "RSScopeSuite" > "Settings" > "Report" are used. See Chapter 2.9, "Report configuration", on page 18.
- Click "Test Checked"/"Test Single" and proceed as described in the relevant test case chapter.

### 3.2.1 General test settings

RSScopeSu	ite						_ 🗆	×
🕒 Back	Session 1000BASE-T_20160205_111728			🖹 Sh	ow Report	About	•	Help
	All	Properties	Limit Manager	Results	Instruments	Report Cont	fig	
	<ul> <li>No Disturber</li> </ul>	Pair						
	Peak Output Voltage (40.6.1.2.1)			вОсО	D			
	Maximum Output Droop (40.6.1.2.2)		● A ●	BOCO	D			
	Differential Output Templates (40.6.1.2.3)	Test Setu	р					
	No TX_TCLK		Average Cour	it 10				
	Transmitter Distortion (40.6.1.2.4)		- Measurement Tim	e 0.1	s			
	▲ With TX_TCLK		weasurement nin	e 0.1	5			
	Transmitter Distortion (40.6.1.2.4)							
	<ul> <li>With Disturber</li> </ul>							
	Peak Output Voltage (40.6.1.2.1)							
	Maximum Output Droop (40.6.1.2.2)							
	Differential Output Templates (40.6.1.2.3)							
	▲ No TX_TCLK							
	Transmitter Distortion (40.6.1.2.4)							
	▲ With TX_TCLK							
	Transmitter Distortion (40.6.1.2.4)							
Test C	Thecked							
Ready to ru	n.					_		

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	В
Peak Voltage Range: Point A	& B	A<=x<=B ▼		V	0.67	0.82
Voltage Difference: Point A 8	LВ	x<=A 💌		%	1	
Voltage Difference: Point C to	o A & B	x<=A 🐨		%	2	
Voltage Difference: Point D to	5 A & B	x<=A 💌		%	2	
Voltage Ratio of Point G to P	oint F	x>=A 💌		%	73.1	
Voltage Ratio of Point J to Po	oint 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 td="" 💌<=""><td></td><td>V</td><td>0.01</td><td></td></a>		V	0.01	
Signal-to-noise Ratio		Ignore 🔻				
Percentage of Eye Opening V	Vithin Limit	x>=A 💌		%	60	
Common-mode Output Volta	age	x<=A ▼		V	0.05	
3 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".
- 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.

### 1000BASE-T tests

Test configuration for Ethernet 1000BASE-T

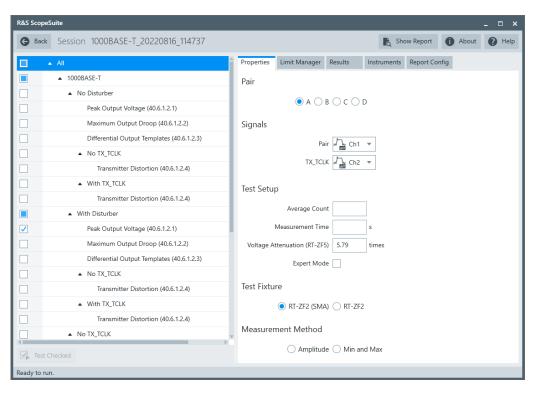


Figure 4-1: Configuration for 1000BASE-T compliance tests

### 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.

	Differential type		Single-	Additional instruments	
	Differen- tial probe	Test fixture	Ended type SMA		
Transmitter Distortion (40.6.1.2.4) No disturber and No TX TCLK	1 at least 1 GHz band- width	R&S RT-ZF2 Section: Resistive Load	-	<b>Optional:</b> 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 band- width	R&S RT-ZF2 Section: Resistive Load	1 at least 1 GHz band- width	<b>Optional:</b> 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 band- width	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	

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

### 1000BASE-T

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

### 1000BASE-T

	Dif	ferential type	Single-	Additional instruments
	Differen- tial probe	Test fixture	Ended type SMA	
Differential Output Tem- plates (40.6.1.2.3) 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
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 band- width	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 band- width	R&S RT-ZF2 Section: Jitter Slave Test 1000BaseT	1 at least 1 GHz band- width	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 band- width	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 band- width	R&S RT-ZF2 Section: Jitter Slave Test 1000BaseT	1 at least 1 GHz band- width	Total of 2 DUTs required
MDI Return Loss (40.8.3.1) Common-mode Output	-	R&S RT-ZF2 Section: Twisted Pair Model R&S RT-ZF2	-	VNA: R&S ZNB or R&S ZNC or R&S ZND or R&S ZVL Optional:
Voltage (40.8.3.3)	at least 1 GHz band- width	Section: Common Mode Volt- age		R&S RTO / R&S RTO6 /R&S RTP-K17

•	Transmitter distortion	30
•	Peak output voltage	. 35
	Maximum output droop	
	Differential output templates	
	Jitter master mode	
	Jitter slave mode	
•	MDI return loss	.56
•	Common-mode output voltage	.58

### 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 Chapter 4.1, "Starting 1000BASE-T tests", on page 25.
- 2. Select the test case:
  - "No TX\_CLK" test: "No Disturber" > "No TX\_CLK" > "Transmitter Distortion (40.6.1.2.4)"

### 1000BASE-T

R&S ScopeSuite						_ 🗆 ×
G Back Session 1000BASE-T_20190917_160216				Show Repor	rt 🚺 About	🕐 Help
All	Properties	Limit Manager	Results	Instruments	Report Config	
▲ 1000BASE-T	Pair					
No Disturber			вОсО	D		
Peak Output Voltage (40.6.1.2.1)		O A O	BOCO	D		
Maximum Output Droop (40.6.1.2.2)	Signals					
Differential Output Templates (40.6.1.2.3)		Pa	ir 🎵 Ch1	Ŧ		
No TX_TCLK			810			
Transmitter Distortion (40.6.1.2.4)	Test Setu	0				
With TX_TCLK		Average Cour	nt 10			
Transmitter Distortion (40.6.1.2.4)		Expert Mod	ie 🗌			
■ No TX_TCLK						
₩ith TX_TCLK						
Common						
Test Checked Test Single						
Ready to run.						

 "With TX\_CLK" test: "No Disturber" > "With TX\_CLK" > "Transmitter Distortion (40.6.1.2.4)"

G Back Session 1000BASE-T_20190917_160216	🖹 Show Report 1 About 1 Help
All	Properties Limit Manager Results Instruments Report Config
▲ 1000BASE-T	Pair
No Disturber	
Peak Output Voltage (40.6.1.2.1)	
Maximum Output Droop (40.6.1.2.2)	Signals
Differential Output Templates (40.6.1.2.3)	Pair 🗸 Ch1 💌
No TX_TCLK	TX_TCLK J ch2 =
Transmitter Distortion (40.6.1.2.4)	
With TX_TCLK	Test Setup
Transmitter Distortion (40.6.1.2.4)	Average Count 10
With Disturber	
▼ No TX_TCLK	Expert Mode
▼ With TX_TCLK	
Common	
▼ 1000BASE-T EEE	
Test Checked Test Single	
Ready to run.	

- 3. Click "Test Single".
- 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.

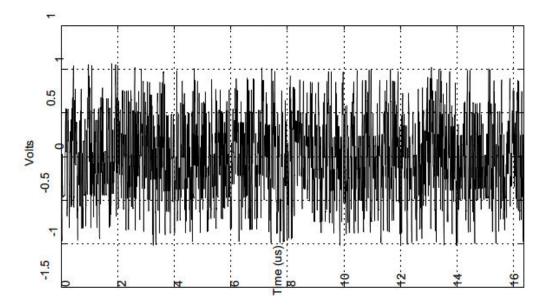


Figure 4-2: Test mode 4 waveform

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 Dis- tortion 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)"

R&S ScopeSuite						_ 🗆 ×
<b>Back</b> Session 1000BASE-T_20190917_160216			1.1	Show Repo	rt 🚺 About	🕐 Help
Differential Output Templates (40.6.1.2.3)	Properties	Limit Manager	Results	Instruments	Report Config	
No TX_TCLK	Pair					
Transmitter Distortion (40.6.1.2.4)			вОсО	D		
With TX_TCLK		● A ●	восо	D		
Transmitter Distortion (40.6.1.2.4)	Signals					
With Disturber		Pa	ir 🎵 Ch1	-		
Peak Output Voltage (40.6.1.2.1)			0.00			
Maximum Output Droop (40.6.1.2.2)	Test Setu	р				
Differential Output Templates (40.6.1.2.3)		Average Cour	nt 10			
No TX_TCLK		Expert Mod	le 🗌	_		
Transmitter Distortion (40.6.1.2.4)						
With TX_TCLK						
Transmitter Distortion (40.6.1.2.4)						
▼ No TX_TCLK						
Common						
□ ▼ 1000BASE-T EEE						
Test Checked Test Single						
Ready to run.						

"With TX\_CLK" test:
 "With Disturber" > "With TX\_CLK" > "Transmitter Distortion (40.6.1.2.4)"

1000BASE-T

#### R&S ScopeSui G Back Session 1000BASE-T\_20190917\_160216 🖹 Show Report 🕕 About 👔 Help Maximum Output Droop (40.6.1.2.2) Properties Limit Manager Results Instruments Report Config Differential Output Templates (40.6.1.2.3) Pair No TX\_TCLK $\bigcirc$ A $\bigcirc$ B $\bigcirc$ C $\bigcirc$ D Transmitter Distortion (40.6.1.2.4) ▲ With TX\_TCLK Signals Transmitter Distortion (40.6.1.2.4) Pair 🛴 Ch1 🔻 With Disturber TX\_TCLK 🕂 Ch2 🔻 Peak Output Voltage (40.6.1.2.1) Maximum Output Droop (40.6.1.2.2) Test Setup Differential Output Templates (40.6.1.2.3) Average Count 10 ▲ No TX\_TCLK Transmitter Distortion (40.6.1.2.4) Expert Mode ▲ With TX\_TCLK ✓ itter Distortion (40.6.1.2.4) No TX TCLK With TX\_TCLK Common ▼ 1000BASE-T EEE 🛃 Test Checked 🕨 🕨 Test Single Ready to run.

- 3. Click "Test Single".
- 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<sub>pp</sub> 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<sub>pp</sub>.

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**

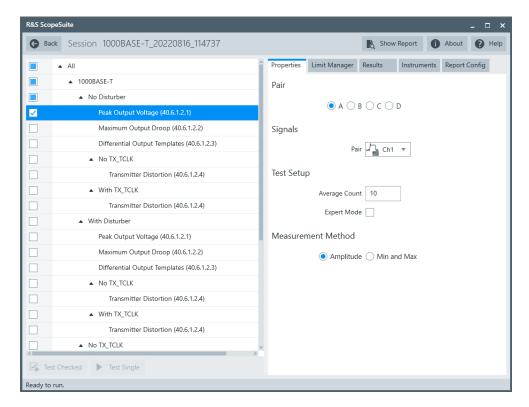
#### Table 4-4: Equipment for Peak Output Voltage test, no disturber

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".

#### 1000BASE-T



- 3. Click "Test Single".
- 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.

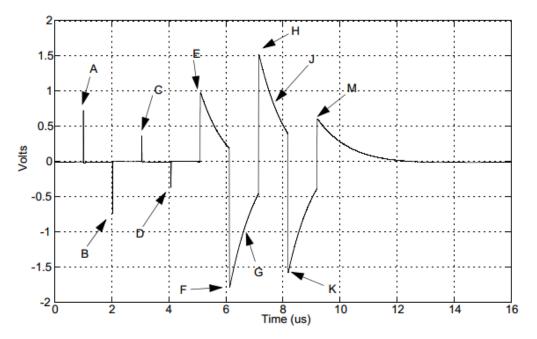


Figure 4-3: Test mode 1 waveform with measurement points

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 Dis- tortion 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".

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All	Properties Limit Manager Results Instruments Report Config
■ 1000BASE-T	Pair
No Disturber	
Peak Output Voltage (40.6.1.2.1)	● A ○ B ○ C ○ D
Maximum Output Droop (40.6.1.2.2)	Signals
Differential Output Templates (40.6.1.2.3)	Pair 🗸 Ch1 💌
► No TX_TCLK	
Transmitter Distortion (40.6.1.2.4)	Test Setup
With TX_TCLK	Average Count 10
Transmitter Distortion (40.6.1.2.4)	Expert Mode
With Disturber	
Peak Output Voltage (40.6.1.2.1)	Measurement Method
Maximum Output Droop (40.6.1.2.2)	Amplitude  Min and Max
Differential Output Templates (40.6.1.2.3)	
► No TX_TCLK	
Transmitter Distortion (40.6.1.2.4)	
With TX_TCLK	
Transmitter Distortion (40.6.1.2.4)	
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Ready to run.	

- 3. Click "Test Single".
- 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**

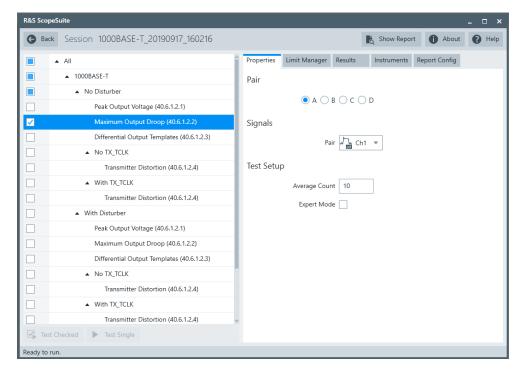
Table 4-6: Equipment for Maximum Output Droop test, no disturber

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".

#### 1000BASE-T



- 3. Click "Test Checked".
- 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 waveform. The same waveform is used for 1000BASE-T "Peak Differential Voltage" test and" Differential Output Template" test.

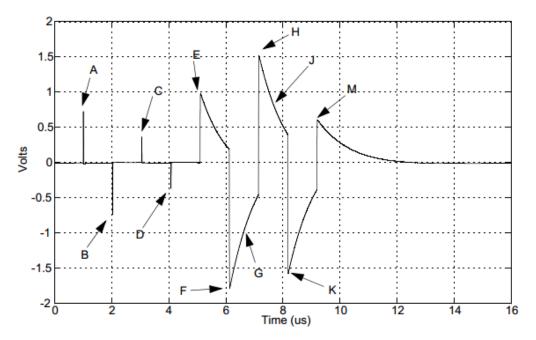


Figure 4-4: Test mode 1 waveform with measurement points

The test consists of two similar measurements:

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

#### 4.3.3.2 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".

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	Maximum Output Droop (40.6.1.2.2)	Signals						
	Differential Output Templates (40.6.1.2.3)		Pa	ir 🞵 Ch1	Ŧ			
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	Transmitter Distortion (40.6.1.2.4)	Test Setu	ıp					
	<ul> <li>With TX_TCLK</li> </ul>		Average Cour	nt 10				
	Transmitter Distortion (40.6.1.2.4)		Expert Mod	e 🗌				
	<ul> <li>With Disturber</li> </ul>							
	Peak Output Voltage (40.6.1.2.1)							
<b>V</b>	Maximum Output Droop (40.6.1.2.2)							
	Differential Output Templates (40.6.1.2.3)							
	No TX_TCLK							
	Transmitter Distortion (40.6.1.2.4)							
	With TX_TCLK							
	Transmitter Distortion (40.6.1.2.4)	*						
🛃 Test (	Checked 🕨 Test Single							
Ready to ru	in							

- 3. Click "Test Checked".
- 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 timedomain 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".

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	⊾ All	Properties	Limit Manager	Results	Instruments	Report Config	
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	<ul> <li>No Disturber</li> </ul>				-		
	Peak Output Voltage (40.6.1.2.1)		• A •	B () C ()	D		
	Maximum Output Droop (40.6.1.2.2)	Signals					
<b>V</b>	Differential Output Templates (40.6.1.2.3)		Pa	ir 🛴 Ch1	-		
	No TX_TCLK						
	Transmitter Distortion (40.6.1.2.4)	Test Setu	р				
	<ul> <li>With TX_TCLK</li> </ul>		Average Cour	nt 10			
	Transmitter Distortion (40.6.1.2.4)		Expert Mod				
	With Disturber		- appert mou				
	Peak Output Voltage (40.6.1.2.1)						
	Maximum Output Droop (40.6.1.2.2)						
	Differential Output Templates (40.6.1.2.3)						
	<ul> <li>No TX_TCLK</li> </ul>						
	Transmitter Distortion (40.6.1.2.4)						
	<ul> <li>With TX_TCLK</li> </ul>						
	Transmitter Distortion (40.6.1.2.4)	-					
⊡ Test C	hecked 🕨 Test Single						
Ready to rur	).						

- 3. Click "Test Checked".
- 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.

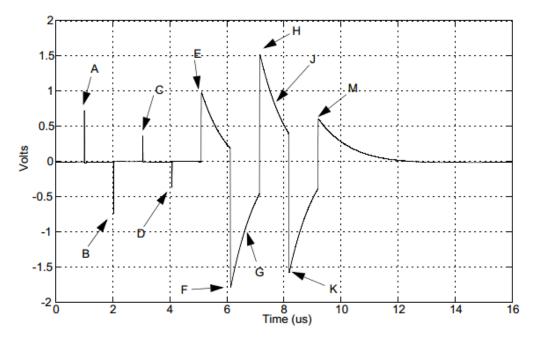


Figure 4-5: Test mode 1 waveform with measurement points

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.

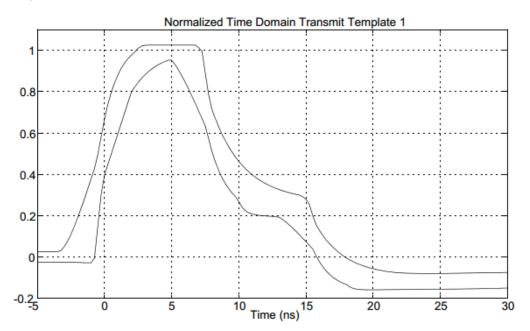


Figure 4-6: Time domain transmit template 1

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.

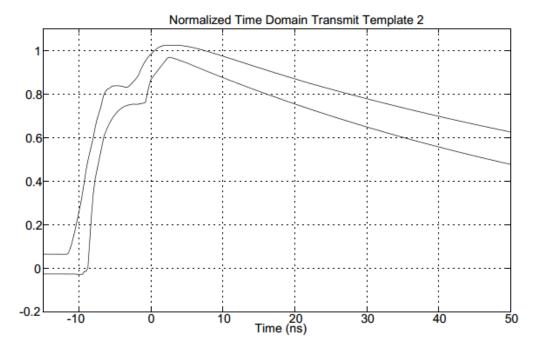


Figure 4-7: Time domain transmit template 2

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**

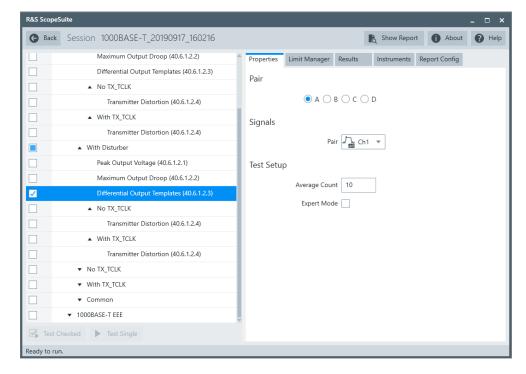
#### Table 4-11: Equipment for Differential Output Templates test with disturber

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".

#### 1000BASE-T



- 3. Click "Test Checked".
- 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 determining the best fit of a sine wave at the fundamental frequency of the disturbing signal and then subtracting that sine wave from the measured waveform.

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

# 4.3.5 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

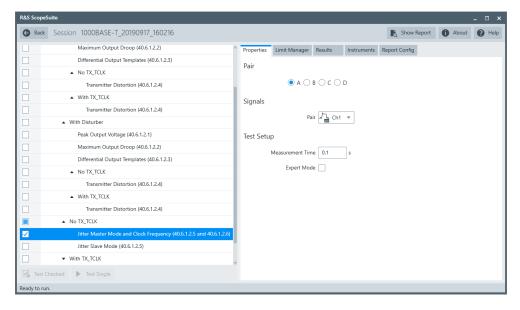
#### **Test equipment**

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.
- Select "Jitter Master Mode (40.6.1.2.5) and Clock Frequency (40.6.1.2.6)" under "No TX\_CLK".

#### 1000BASE-T



- 3. Click "Test Checked".
- 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.

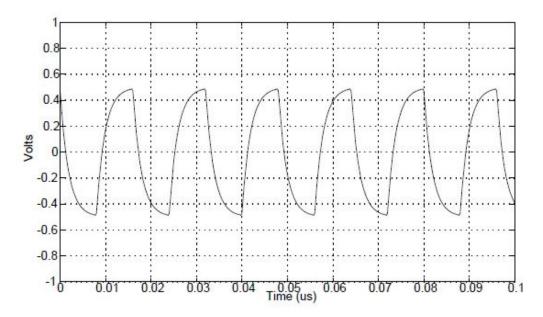


Figure 4-8: Test mode 2 waveform

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 highpass 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.
- 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".

# 1000BASE-T

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	Transmitter Distortion (40.6.1.2.4)							
	▲ With TX_TCLK							
	Transmitter Distortion (40.6.1.2.4)							
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<ul> <li>Image: A start of the start of</li></ul>	Jitter Master Mode Filtered (40.6.1.2.5)							
	Jitter Slave Mode Unfiltered (40.6.1.2.5)							
	Jitter Slave Mode Filtered (40.6.1.2.5)							
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Test Ch	necked							
Ready to run								

- 3. Click "Test Checked".
- 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 highpass 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".

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	▲ 1000BASE-T	Properties	Limit Manager	Results	Instruments	Report Config			
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	Peak Output Voltage (40.6.1.2.1)								
	Maximum Output Droop (40.6.1.2.2)		💿 a 🔾	BOCO	D				
	Differential Output Templates (40.6.1.2.3)	Signals							
	<ul> <li>No TX_TCLK</li> </ul>	- grain		h					
	Transmitter Distortion (40.6.1.2.4)		Pa	iir 🎵 Ch1	Ŧ				
	<ul> <li>With TX_TCLK</li> </ul>	Test Setu	р						
	Transmitter Distortion (40.6.1.2.4)		Measurement Tim	ne 0.1	s				
	▼ With Disturber		weasurement nin	0.1	3				
	▲ No TX_TCLK								
	Jitter Master Mode and Clock Frequency (40.6.1.2.5 and 40.6.1.2.6)								
<b>V</b>	Jitter Slave Mode (40.6.1.2.5)								
	▲ With TX_TCLK								
	Jitter Master Mode Unfiltered (40.6.1.2.5)								
	Jitter Master Mode Filtered (40.6.1.2.5)								
	Jitter Slave Mode Unfiltered (40.6.1.2.5)								
	Jitter Slave Mode Filtered (40.6.1.2.5)								
Test Cl	hecked 🕨 Test Single								
Ready to run									

- 3. Click "Test Single".
- 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**

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.

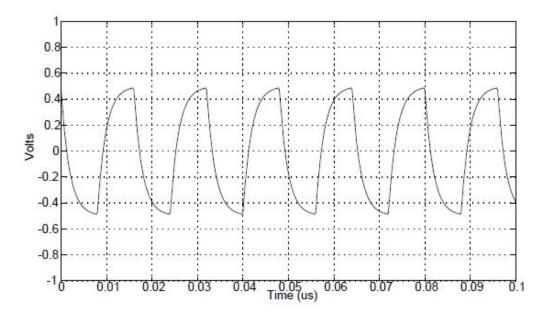


Figure 4-9: Test mode 2 waveform

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-topeak jitter value. The result must be less than 0.4ns.

#### 4.3.6.2 With TX\_CLK

# **Test equipment**

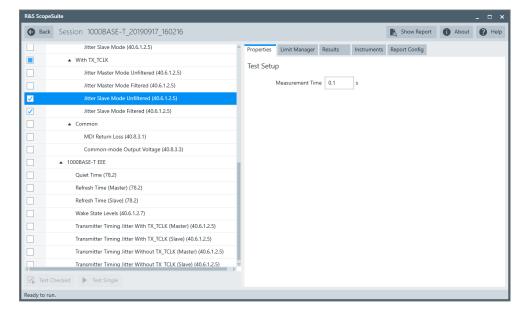
Table 4-15: Equipment for Jitter Slave Mode test, with TX\_CLK

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.
- 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".
- 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.

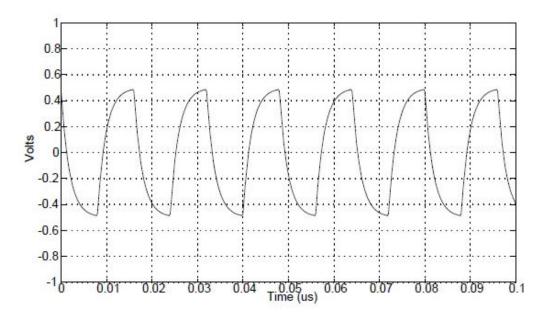


Figure 4-10: Test mode 3 waveform

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 highpass 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 Chapter 4.1, "Starting 1000BASE-T tests", on page 25.
- 2. Select "MDI Return Loss (40.8.3.1)" under "Common".

🕒 Back S	ession 1000BASE-T_20190917_160216					💦 Show Report	About	🕑 Help
	Jitter Slave Mode (40.6.1.2.5)	Properties	Limit Manager	Results	Instruments	Report Config		
	<ul> <li>With TX_TCLK</li> </ul>	Pair						
	Jitter Master Mode Unfiltered (40.6.1.2.5)	Pair						
	Jitter Master Mode Filtered (40.6.1.2.5)		● A ○	B () C ()	D			
	Jitter Slave Mode Unfiltered (40.6.1.2.5)	Signals						
	Jitter Slave Mode Filtered (40.6.1.2.5)	Signals						
	▲ Common	Test Setu	р					
<u>_</u>	MDI Return Loss (40.8.3.1)		Expert Mod	de 🗌				
	Common-mode Output Voltage (40.8.3.3)							
_ <b>^</b>	1000BASE-T EEE							
	Quiet Time (78.2)							
	Refresh Time (Master) (78.2)							
	Refresh Time (Slave) (78.2)							
	Wake State Levels (40.6.1.2.7)							
	Transmitter Timing Jitter With TX_TCLK (Master) (40.6.1.2.5)							
	Transmitter Timing Jitter With TX_TCLK (Slave) (40.6.1.2.5)							
	Transmitter Timing Jitter Without TX_TCLK (Master) (40.6.1.2.5)							
	Transmitter Timing Jitter Without TX TCLK (Slave) (40.6.1.2.5)							

- 3. Click "Test Checked".
- 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

# 4.3.7.3 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 (\*.slp 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

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

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

#### 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".

#### 1000BASE-T

R&S ScopeSu	ite							- 0
🕒 Back	Session 1000BASE-T_20190917_160216					💦 Show Report	About	🕐 He
	Jitter Slave Mode (40.6.1.2.5)	Properties	Limit Manager	Results	Instruments	Report Config		
	<ul> <li>With TX_TCLK</li> </ul>	Pair						
	Jitter Master Mode Unfiltered (40.6.1.2.5)	1 dil						
	Jitter Master Mode Filtered (40.6.1.2.5)		• a •	восо	D			
	Jitter Slave Mode Unfiltered (40.6.1.2.5)	Signals						
	Jitter Slave Mode Filtered (40.6.1.2.5)	<u>j</u>	0	b au				
	▲ Common		Pa	ir 🖵 Ch1	Ŧ			
	MDI Return Loss (40.8.3.1)	Test Setu	р					
<b>V</b>	Common-mode Output Voltage (40.8.3.3)		Measurement Tim	e 0.0002	s			
	▲ 1000BASE-T EEE							
	Quiet Time (78.2)		Expert Mod	e				
	Refresh Time (Master) (78.2)	Test Fixtu	ire					
	Refresh Time (Slave) (78.2)		RT-ZF2 (SM/		2			
	Wake State Levels (40.6.1.2.7)		V KI-ZF2 (SIVI)	V () KI-2F	2			
	Transmitter Timing Jitter With TX_TCLK (Master) (40.6.1.2.5)							
	Transmitter Timing Jitter With TX_TCLK (Slave) (40.6.1.2.5)							
	Transmitter Timing Jitter Without TX_TCLK (Master) (40.6.1.2.5)							
	Transmitter Timing Jitter Without TX TCLK (Slave) (40.6.1.2.5)	*						
Test Ch	ecked 🕨 Test Single							
Ready to run.								

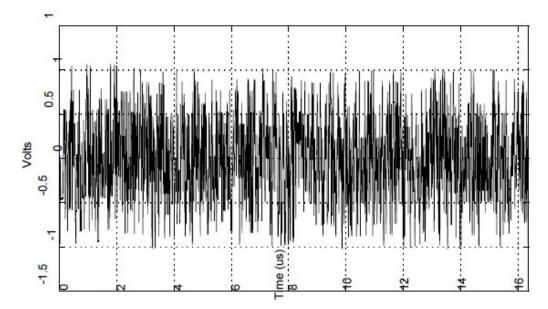
- 3. Click "Test Checked".
- Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

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

# 4.3.8.3 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)

Quiet time	
Refresh time master mode	
Refresh time slave mode	
Wake state levels	
• Transmitter timing jitter with TX_TCLK in master	mode
• Transmitter timing jitter with TX_TCLK in slave m	
• Transmitter timing jitter without TX TCLK in mas	
• Transmitter timing jitter without TX_TCLK in slave	

# 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)"

R&S ScopeS	uite				_ 0	×
🕒 Back	Session 1000BASE-T_20161101_145222		🖹 Show Repor	t 🚺 Abou	it 🕐	Help
	Jitter Master Mode Unfiltered (40.6.1.2.5)	Instruments	Rej	oort Config		
	Jitter Master Mode Filtered (40.6.1.2.5)	Properties	Limit Manage	er Result	s	
	Jitter Slave Mode Unfiltered (40.6.1.2.5)	Pair				
	Jitter Slave Mode Filtered (40.6.1.2.5)		● A ○ B			
	▲ Common		0.000	0000		
	MDI Return Loss (40.8.3.1)	Test Setu	р			
	Common-mode Output Voltage (40.8.3.3)		Average Count	5		
	▲ 1000BASE-T EEE	Voltage At	ttenuation (RT-ZF5)	5.79 ti	nes	
	Quiet Time (78.2)	voltage / l		0.75	neb	
	Refresh Time (Master) (78.2)					
	Refresh Time (Slave) (78.2)					
	Wake State Levels (40.6.1.2.7)					
	Transmitter Timing Jitter With TX_TCLK (Master) (40.6.1.2.5)					
	Transmitter Timing Jitter With TX_TCLK (Slave) (40.6.1.2.5)					
	Transmitter Timing Jitter Without TX_TCLK (Master) (40.6.1.2.5)					
	Transmitter Timing Jitter Without TX_TCLK (Slave) (40.6.1.2.5)	<b>U</b>				
🛃 Test Cł	necked Fast Single					
Ready to run						

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

Further steps:

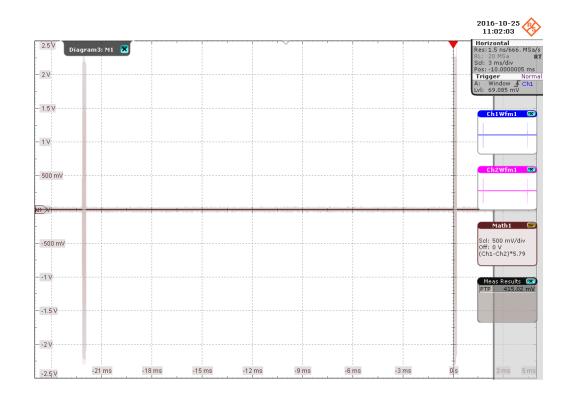
• Chapter 3.3, "Getting test results", on page 23

#### 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:

# 1000BASE-T tests



#### 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)"

R&S ScopeS	luite				-	_ 🗆	×
🕒 Back	Session 1000BASE-T_20161101_145222		Show Re	eport (	About	•	lelp
	Jitter Master Mode Unfiltered (40.6.1.2.5)	Instruments		Report C	onfig		
	Jitter Master Mode Filtered (40.6.1.2.5)	Properties	Limit Mar	nager	Results		
	Jitter Slave Mode Unfiltered (40.6.1.2.5)	Pair					
	Jitter Slave Mode Filtered (40.6.1.2.5)			) в () с	OD		
	▲ Common			000	00		
	MDI Return Loss (40.8.3.1)	Test Setup	)				
	Common-mode Output Voltage (40.8.3.3)		Average Co	unt 5			
	▲ 1000BASE-T EEE	Voltage Att	enuation (RT-Z	(F5) 5.79	times		
	Quiet Time (78.2)	ronage / n			diffes		
<b>V</b>	Refresh Time (Master) (78.2)						
	Refresh Time (Slave) (78.2)						
	Wake State Levels (40.6.1.2.7)						
	Transmitter Timing Jitter With TX_TCLK (Master) (40.6.1.2.5)						
	Transmitter Timing Jitter With TX_TCLK (Slave) (40.6.1.2.5)						
	Transmitter Timing Jitter Without TX_TCLK (Master) (40.6.1.2.5)						
	Transmitter Timing Jitter Without TX_TCLK (Slave) (40.6.1.2.5)						
🔄 Test Cl	hecked 🕨 Test Single						
Ready to run	L.						

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

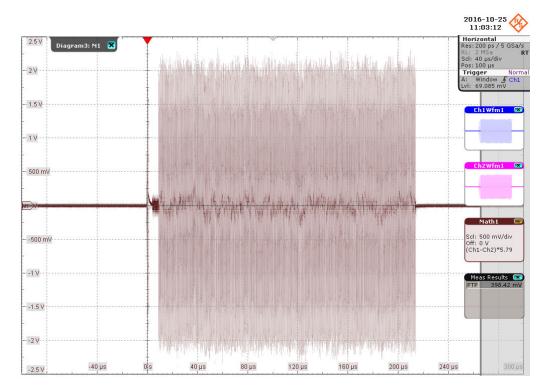
Further steps:

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)"

R&S ScopeS	uite				_ □	×
🖨 Back	Session 1000BASE-T_20161101_145222		🖹 Show Repo	rt 🚺 Abo	out 🕐 H	Help
	Jitter Master Mode Unfiltered (40.6.1.2.5)	Instruments	Re	port Config		
	Jitter Master Mode Filtered (40.6.1.2.5)	Properties	Limit Manag	er Resu	Ilts	
	Jitter Slave Mode Unfiltered (40.6.1.2.5)	Pair				
	Jitter Slave Mode Filtered (40.6.1.2.5)			Oc⊙d		
	▲ Common			0000		
	MDI Return Loss (40.8.3.1)	Test Setup	)			
	Common-mode Output Voltage (40.8.3.3)		Average Count	5		
	▲ 1000BASE-T EEE	Voltage Att	tenuation (RT-ZF5)	5.79	times	
	Quiet Time (78.2)	voluge / la		5.75	lines	
	Refresh Time (Master) (78.2)					
	Refresh Time (Slave) (78.2)					
	Wake State Levels (40.6.1.2.7)					
	Transmitter Timing Jitter With TX_TCLK (Master) (40.6.1.2.5)					
	Transmitter Timing Jitter With TX_TCLK (Slave) (40.6.1.2.5)					
	Transmitter Timing Jitter Without TX_TCLK (Master) (40.6.1.2.5)					
	Transmitter Timing Jitter Without TX_TCLK (Slave) (40.6.1.2.5)	ļ				
💽 Test Cl	hecked Fast Single					
Ready to run						

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

Further steps:

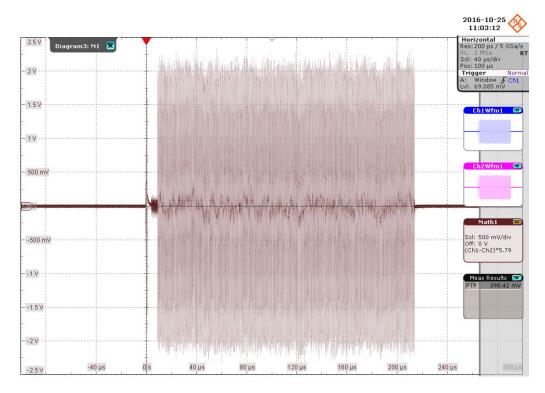
• Chapter 3.3, "Getting test results", on page 23

## 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)"

🕞 Back	Session 1000BASE-T_20161101_145222			👌 Show Re	eport	<b>1</b> AI	bout	) He
	Jitter Master Mode Unfiltered (40.6.1.2.5)	Instru	iments		Report	t Config		
	Jitter Master Mode Filtered (40.6.1.2.5)	Prope	erties	Limit Mar	nager	Re	sults	
	Jitter Slave Mode Unfiltered (40.6.1.2.5)	Pair						
	Jitter Slave Mode Filtered (40.6.1.2.5)			• A (			<u>,</u>	
	▲ Common			● A C			)	
	MDI Return Loss (40.8.3.1)	Test	Setup					
	Common-mode Output Voltage (40.8.3.3)			Average Co	unt 5		]	
	▲ 1000BASE-T EEE	Vol	tago Attop	uation (RT-Z	(5) 5	.79	times	
	Quiet Time (78.2)	101	tage Atten		.F3) 3.	.75	umes	
	Refresh Time (Master) (78.2)							
	Refresh Time (Slave) (78.2)							
2	Wake State Levels (40.6.1.2.7)							
	Transmitter Timing Jitter With TX_TCLK (Master) (40.6.1.2.5)							
	Transmitter Timing Jitter With TX_TCLK (Slave) (40.6.1.2.5)							
	Transmitter Timing Jitter Without TX_TCLK (Master) (40.6.1.2.5)							
	Transmitter Timing Jitter Without TX_TCLK (Slave) (40.6.1.2.5)							
🚺 Test C	hecked 🕨 Test Single							

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

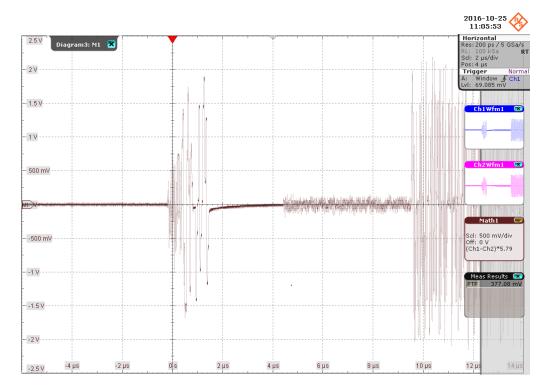
Further steps:

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 Timin	a 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.
- Select the test case: "1000BASE-T-EEE" > "Transmitter Timing Jitter With TX\_TCLK (Master) (40.6.1.2.5) "

#### 1000 BASE-T EEE tests

R&S ScopeS	uite							_ 0	>
🕒 Back	Session 1000BASE-T_20161101_145222			Show Re	eport	0	About	P He	elp
	Jitter Master Mode Unfiltered (40.6.1.2.5)	1	Instruments		Report	t Conf	ig		
	Jitter Master Mode Filtered (40.6.1.2.5)		Properties	Limit Ma	nager		Results		
	Jitter Slave Mode Unfiltered (40.6.1.2.5)		Test Setup						
	Jitter Slave Mode Filtered (40.6.1.2.5)		Mea	surement Ti	ime 0	.001	s		
	▲ Common					.79	_		
	MDI Return Loss (40.8.3.1)		Voltage Atten	times	times				
	Common-mode Output Voltage (40.8.3.3)								
	▲ 1000BASE-T EEE								
	Quiet Time (78.2)								
	Refresh Time (Master) (78.2)	L							
	Refresh Time (Slave) (78.2)	L							
	Wake State Levels (40.6.1.2.7)	L							
<b>V</b>	Transmitter Timing Jitter With TX_TCLK (Master) (40.6.1.2.5)	1							
	Transmitter Timing Jitter With TX_TCLK (Slave) (40.6.1.2.5)								
	Transmitter Timing Jitter Without TX_TCLK (Master) (40.6.1.2.5)	1							
	Transmitter Timing Jitter Without TX_TCLK (Slave) (40.6.1.2.5)								
🛃 Test Cł	hecked F Test Single								
Ready to run									

- 3. Click "Test Single".
- 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

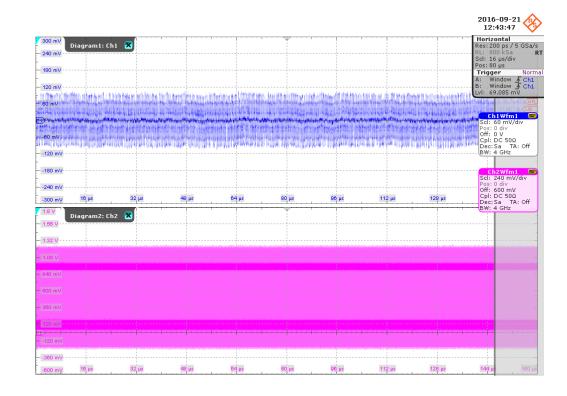
A 1000BASE-T EEE link is set up between the DUT and Link Partner via test fixture R&S RT-ZF5. The DUT must be forced to enter low-power idle mode.

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:

# 1000BASE-T tests

# 1000 BASE-T EEE tests



#### 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.
- Select the test case: "1000BASE-T-EEE" > "Transmitter Timing Jitter With TX\_TCLK (Slave) (40.6.1.2.5) "

R&S ScopeS	uite								_ [	×
🕒 Back	Session 1000BASE-T_20161101_145222			à	Show Repo	ort	<b>()</b> A	bout	0	Help
	Jitter Master Mode Unfiltered (40.6.1.2.5)	1	Instruments		Re	eport (	Config			
	Jitter Master Mode Filtered (40.6.1.2.5)		Properties Limit Manager Resul							
	Jitter Slave Mode Unfiltered (40.6.1.2.5)		Test Setup							
	Jitter Slave Mode Filtered (40.6.1.2.5)		Measurement Time 0.001 s					s		
	▲ Common									
	MDI Return Loss (40.8.3.1)		Voltage Attenuation (RT-ZF5)				79	times		
	Common-mode Output Voltage (40.8.3.3)									
	▲ 1000BASE-T EEE									
	Quiet Time (78.2)									
	Refresh Time (Master) (78.2)	L								
	Refresh Time (Slave) (78.2)	L								
	Wake State Levels (40.6.1.2.7)	L								
	Transmitter Timing Jitter With TX_TCLK (Master) (40.6.1.2.5)	L								
	Transmitter Timing Jitter With TX_TCLK (Slave) (40.6.1.2.5)									
	Transmitter Timing Jitter Without TX_TCLK (Master) (40.6.1.2.5)	1								
	Transmitter Timing Jitter Without TX_TCLK (Slave) (40.6.1.2.5)									
🛃 Test C	hecked Fast Single									
Ready to run	ì.									

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

Further steps:

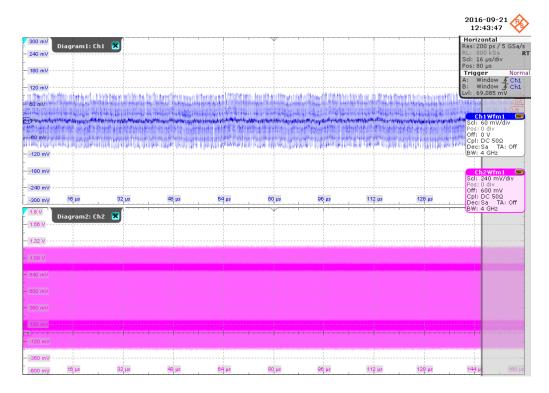
Chapter 3.3, "Getting test results", on page 23

### 4.4.6.3 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	r Timing Jitter with	hout TX_TCLK, Mas	ter 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.
- Select the test case: "1000BASE-T-EEE" > "Transmitter Timing Jitter Without TX\_TCLK (Master) (40.6.1.2.5) "

#### 1000 BASE-T EEE tests

R&S ScopeS	iuite						_ 🗆 ×
🕒 Back	Session 1000BASE-T_20161101_145222		à	Show Repor	t (	About	🕜 Help
	Jitter Master Mode Unfiltered (40.6.1.2.5)	1	Instruments	Rej	port Co	onfig	
	Jitter Master Mode Filtered (40.6.1.2.5)		Properties	Limit Manage	≥r	Results	
	Jitter Slave Mode Unfiltered (40.6.1.2.5)		Pair				
	Jitter Slave Mode Filtered (40.6.1.2.5)			⊙ А ⊖ В	$\bigcirc c$	ΩD	
	▲ Common				00	00	
	MDI Return Loss (40.8.3.1)		Test Setup				
	Common-mode Output Voltage (40.8.3.3)		Measu	irement Time	0.00	1 s	
	▲ 1000BASE-T EEE		Voltage Attenua	tion (RT-ZE5)	5.79	time	5
	Quiet Time (78.2)		ronage / menua		0175		-
	Refresh Time (Master) (78.2)	L					
	Refresh Time (Slave) (78.2)						
	Wake State Levels (40.6.1.2.7)						
	Transmitter Timing Jitter With TX_TCLK (Master) (40.6.1.2.5)						
	Transmitter Timing Jitter With TX_TCLK (Slave) (40.6.1.2.5)						
	Transmitter Timing Jitter Without TX_TCLK (Master) (40.6.1.2.5)						
	Transmitter Timing Jitter Without TX_TCLK (Slave) (40.6.1.2.5)						
🔄 Test Cl	hecked Fast Single						
Ready to run	h.						

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

#### Further steps:

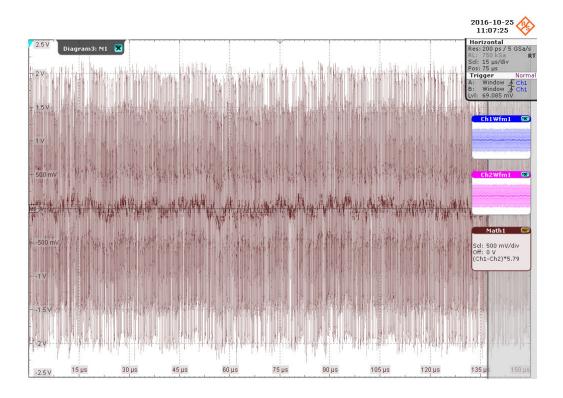
Chapter 3.3, "Getting test results", on page 23

#### 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.
- Select the test case: "1000BASE-T-EEE" > "Transmitter Timing Jitter Without TX\_TCLK (Slave) (40.6.1.2.5) "

R&S ScopeS	uite				_ □	×
🕒 Back	Session 1000BASE-T_20161101_145222		🖹 Show Repor	t 🚺 A	bout	Help
	Jitter Master Mode Unfiltered (40.6.1.2.5)	Instruments	Rej	oort Config		
	Jitter Master Mode Filtered (40.6.1.2.5)	Properties	Limit Manage	er Re	sults	
	Jitter Slave Mode Unfiltered (40.6.1.2.5)	Pair				
	Jitter Slave Mode Filtered (40.6.1.2.5)		💿 а 🔾 в	000	٦.	
	▲ Common		V A U B			
	MDI Return Loss (40.8.3.1)	Test Setup	)			
	Common-mode Output Voltage (40.8.3.3)	N	leasurement Time	0.001	s	
	▲ 1000BASE-T EEE	Voltage Att	enuation (RT-ZF5)	5.79	times	
	Quiet Time (78.2)	voltage Att	endation (k1-21-5)	5.75	umes	
	Refresh Time (Master) (78.2)					
	Refresh Time (Slave) (78.2)					
	Wake State Levels (40.6.1.2.7)					
	Transmitter Timing Jitter With TX_TCLK (Master) (40.6.1.2.5)					
	Transmitter Timing Jitter With TX_TCLK (Slave) (40.6.1.2.5)					
	Transmitter Timing Jitter Without TX_TCLK (Master) (40.6.1.2.5)					
	Transmitter Timing Jitter Without TX_TCLK (Slave) (40.6.1.2.5)					
🛃 Test Cł	necked Fast Single					_
Ready to run						

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

Further steps:

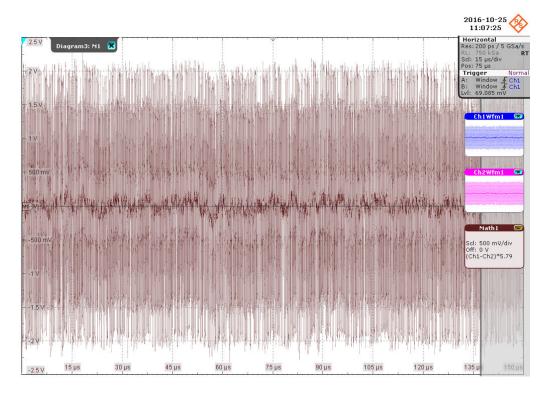
Chapter 3.3, "Getting test results", on page 23

### 4.4.8.3 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".
- 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.

#### 100BASE-TX tests

Test configuration for Ethernet 100BASE-TX

&S ScopeSi	uite						- 0
🕞 Back	Session 100BASE-TX_20190919_160807			là s	Show Report	About	Help
	All	Properties	Limit Manager	Results	Instruments	Report Cor	nfig
	▲ 100BASE-TX	Test Setu	p				
	Amplitude Domain Tests (9.1.2.2, 9.1.3 and 9.1.4)		A				
	Rise and Fall Times (9.1.6)		Average Cour				
	Peak to Peak Duty Cycle Distortion (9.1.8)		Measurement Tim	ie 0.1	S		
	Peak to Peak Transmit Jitter (9.1.9)	# of Ac	cqs for Eye Diagram	m 20000			
	Active Output Interface Template (Annex J)	# of ,	Acqs for Jitter Mea	as 100000	)		
	Transmitter Clock Frequency (24.2.3.4)		Expert Mod	le 🗌			
	Transmitter Return Loss (9.1.5)						
	Receiver Return Loss (9.2.2)		VNA Po	rt 🔘 Ch	1 🔻		
	▲ 100BASE-TX EEE	Test Patte	ern Generation				
	Sleep Time (24.2.3.4 and 78.2)		Link Partne		Software		
	LPI Quiet Time (24.2.3.4 and 78.2)				Soltware		
	LPI Refresh Time (24.2.3.4 and 78.2)	K17 Opti	on				
	LPI Transmitter Timing Jitter (24.2.3.4 and 78.2)		HD Mod	le 🗸			
	Transmit Wake Time (24.2.3.4 and 78.2)			_			
		Measurer	ment Method				
🔥 Test Ch	necked	⊖ HW	CDR (K13 Optior	n) 🔘 SW F	PLL		
ady to run							

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.

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

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

#### 100BASE-TX

•	Amplitude domain tests	82
	Rise and fall times	
•	Peak to peak duty cycle distortion	88
	Peak to peak transmit jitter	
	Active output interface template	
	Transmitter clock frequency	
	Transmitter return loss	
	Receiver return loss.	

# 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)".

#### 100BASE-TX

🕒 Back	Session DemoSession	🖹 Show Report 🚺 About 👔 Hel
	▲ All	Properties Limit Manager Results Instruments Report Config
	▲ 100BASE-TX	Test Setup
✓	Amplitude Domain Tests (9.1.2.2, 9.1.3 and 9.1.4)	Average Count 10
	Rise and Fall Times (9.1.6)	Average Count 10
	Peak to Peak Duty Cycle Distortion (9.1.8)	Test Pattern Generation
	Peak to Peak Transmit Jitter (9.1.9)	Link Partner      DUT Software
	Active Output Interface Template (Annex J)	
	Transmitter Clock Frequency (24.2.3.4)	K17 Option
	Transmitter Return Loss (9.1.5)	HD Mode
	Receiver Return Loss (9.2.2)	
	▲ 100BASE-TX EEE	
	Sleep Time (24.2.3.4 and 78.2)	
	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)	
	Transmit Wake Time (24.2.3.4 and 78.2)	
🖌 Test	Checked 🕨 Test Single	

- 3. Click "Test Single".
- 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:

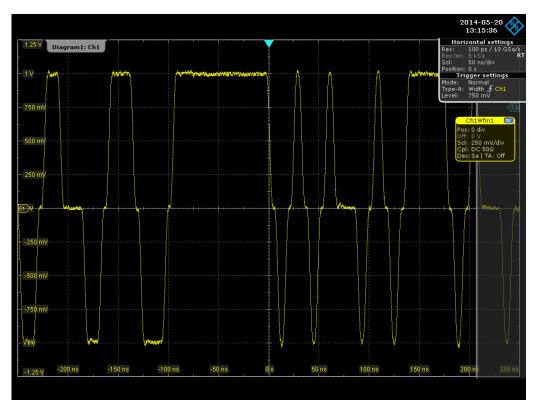


Figure 5-2: Waveform for amplitude domain tests using the TPM section

# 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.

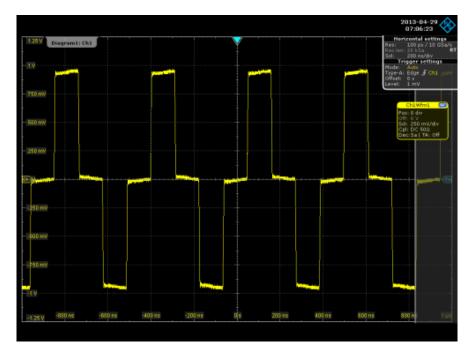


Figure 5-3: Waveform for amplitude domain tests and rise and fall time tests

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 Chapter 5.1, "Starting 100BASE-TX tests", on page 79.
- 2. Select "Rise and Fall Times (9.1.6)".

R&S ScopeSuite	_
General Back Session DemoSession	🖹 Show Report 🚺 About 👔 Help
All	Properties Limit Manager Results Instruments Report Config
▲ 100BASE-TX	Test Setup
Amplitude Domain Tests (9.1.2.2, 9.1.3 and 9.1.4)	Average Count 100
Rise and Fall Times (9.1.6)	Average count 100
Peak to Peak Duty Cycle Distortion (9.1.8)	Test Pattern Generation
Peak to Peak Transmit Jitter (9.1.9)	Link Partner O DUT Software
Active Output Interface Template (Annex J)	
Transmitter Clock Frequency (24.2.3.4)	K17 Option
Transmitter Return Loss (9.1.5)	HD Mode
Receiver Return Loss (9.2.2)	
□ ▲ 100BASE-TX EEE	
Sleep Time (24.2.3.4 and 78.2)	
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)	
Transmit Wake Time (24.2.3.4 and 78.2)	
Test Checked Test Single	
Ready to run.	

- 3. Click "Test Single".
- 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

#### 5.3.2.3 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:

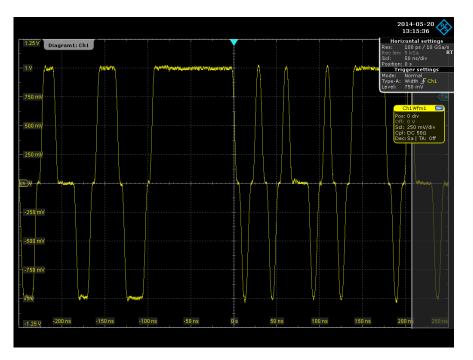


Figure 5-4: Waveform for rise and fall time tests using the TPM section

# 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.

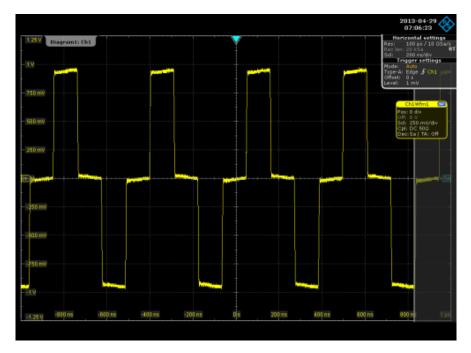


Figure 5-5: Waveform for amplitude domain tests and rise and fall time tests

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

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

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

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)".

R&S ScopeS	uite	×
🕒 Back	Session DemoSession	Reg Show Report 1 About 1 Help
	All	Properties Limit Manager Results Instruments Report Config
	▲ 100BASE-TX	Test Setup
	Amplitude Domain Tests (9.1.2.2, 9.1.3 and 9.1.4)	Average Count 100
	Rise and Fall Times (9.1.6)	Average count 100
	Peak to Peak Duty Cycle Distortion (9.1.8)	Test Pattern Generation
	Peak to Peak Transmit Jitter (9.1.9)	Link Partner O DUT Software
	Active Output Interface Template (Annex J)	0 0
	Transmitter Clock Frequency (24.2.3.4)	K17 Option
	Transmitter Return Loss (9.1.5)	HD Mode
	Receiver Return Loss (9.2.2)	
	▲ 100BASE-TX EEE	
	Sleep Time (24.2.3.4 and 78.2)	
	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)	
	Transmit Wake Time (24.2.3.4 and 78.2)	
🔄 Test C	hecked 🕨 Test Single	
Ready to run		

- 3. Click "Test Single".
- 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:

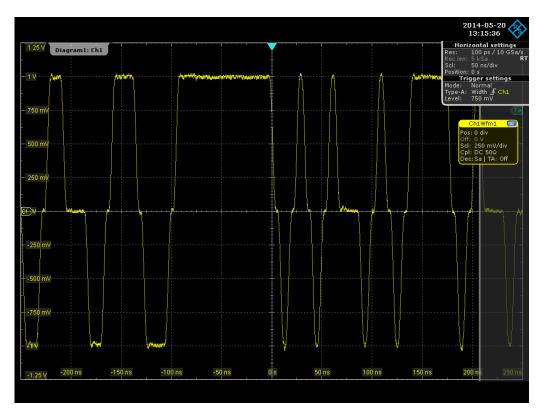


Figure 5-6: Waveform for peak to peak duty cycle distortion tests using the TPM section

#### 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.

# 100BASE-TX tests 100BASE-TX

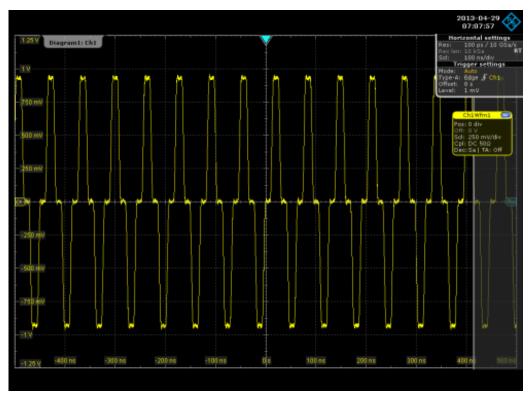
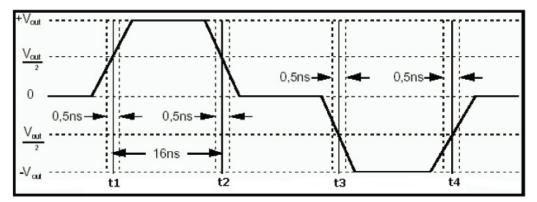


Figure 5-7: MLT-3 encoded clock-like pattern waveform

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 <sub>x</sub> values	$T_1 = t_2 - t_1 - 16 \text{ ns}$
	$T_1 = t_2 - t_1 - 16 \text{ ns}$ $T_2 = t_3 - t_2 - 16 \text{ ns}$
	$T_3 = t_4 - t_3 - 16 \text{ ns}$
	$T_4 = t_3 - t_1 - 16 \text{ ns}$
	$T_5 = t_4 - t_2 - 16 \text{ ns}$ $T_6 = t_4 - t_1 - 16 \text{ ns}$
	$T_6 = t_4 - t_1 - 16 \text{ ns}$
Peak to peak duty cycle distortion	Maximum of T <sub>x</sub> 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

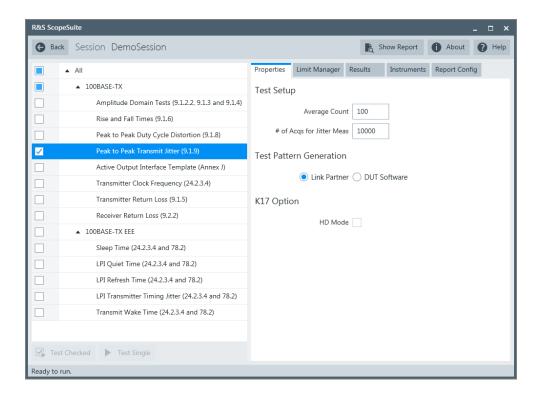
Table 5-5: Equipment for Peak to Peak Transmit Jitter tests

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)".

#### 100BASE-TX



- 3. Click "Test Single".
- 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.

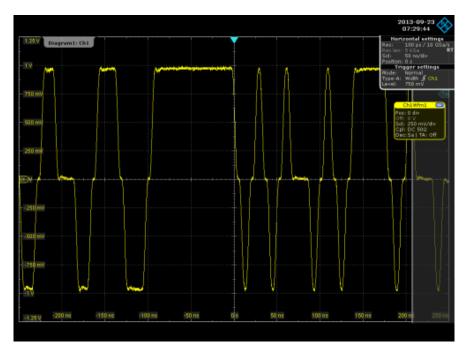


Figure 5-8: Scrambled MLT-3 encoded idle pattern waveform

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

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

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

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)".

R&S ScopeS	uite						_ 🗆 ×
🕒 Back	Session DemoSession			Ŕ	Show Report	About	Help
	All	Properties	Limit Manager	Results	Instruments	Report Cont	fig
	▲ 100BASE-TX	Test Setu	D				
	Amplitude Domain Tests (9.1.2.2, 9.1.3 and 9.1.4)		Average Coun	nt 10			
	Rise and Fall Times (9.1.6)		-				
	Peak to Peak Duty Cycle Distortion (9.1.8)	# of Ac	qs for Eye Diagran	n 50000	0		
	Peak to Peak Transmit Jitter (9.1.9)	Test Patte	rn Generation	1			
	Active Output Interface Template (Annex J)			0.011			
	Transmitter Clock Frequency (24.2.3.4)		Link Partne	r () DUI	Software		
	Transmitter Return Loss (9.1.5)	K17 Optic	n				
	Receiver Return Loss (9.2.2)		HD Mod	e			
	▲ 100BASE-TX EEE			-			
	Sleep Time (24.2.3.4 and 78.2)						
	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)						
	Transmit Wake Time (24.2.3.4 and 78.2)						
🕞 Test Ch	necked Fast Single						
Ready to run							

- 3. Click "Test Single".
- 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.

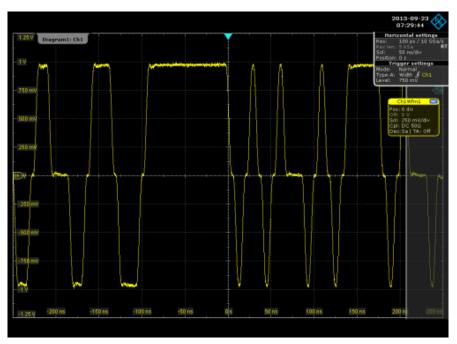


Figure 5-9: Scrambled MLT-3 encoded idle pattern waveform

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)".

🕒 Back	Session DemoSession	💦 Show Report 🚺 About 🕐 He
	All	Properties Limit Manager Results Instruments Report Config
	▲ 100BASE-TX	Test Setup
	Amplitude Domain Tests (9.1.2.2, 9.1.3 and 9.1.4)	Frank Mada
	Rise and Fall Times (9.1.6)	Expert Mode
	Peak to Peak Duty Cycle Distortion (9.1.8)	Test Pattern Generation
	Peak to Peak Transmit Jitter (9.1.9)	Link Partner      DUT Software
	Active Output Interface Template (Annex J)	
<b>V</b>	Transmitter Clock Frequency (24.2.3.4)	Measurement Method
	Transmitter Return Loss (9.1.5)	HW CDR (K13 Option) <b>SW PLL</b>
	Receiver Return Loss (9.2.2)	
	100BASE-TX EEE	
	Sleep Time (24.2.3.4 and 78.2)	
	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)	
	Transmit Wake Time (24.2.3.4 and 78.2)	
Test C	Checked 🕨 Test Single	

- 3. Click "Test Single".
- 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 auto- matic 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)".

#### 100BASE-TX

A All  A	100BASE-TX 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)	Properties	Limit Manager	Results	Instruments	Report Config	
	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)						
	Rise and Fall Times (9.1.6) Peak to Peak Duty Cycle Distortion (9.1.8)						
	Peak to Peak Duty Cycle Distortion (9.1.8)						
	Peak to Peak Transmit Jitter (9.1.9)						
	Active Output Interface Template (Annex J)						
	Transmitter Clock Frequency (24.2.3.4)						
<b>V</b>	Transmitter Return Loss (9.1.5)						
	Receiver Return Loss (9.2.2)						
<b>_</b> ▲	100BASE-TX EEE						
	Sleep Time (24.2.3.4 and 78.2)						
	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)						
	Transmit Wake Time (24.2.3.4 and 78.2)						
Test Check	ed 🕨 Test Single						

- 3. Click "Test Single".
- 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 /l/ 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 (\*.slp 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 auto- matic 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)".

🕒 Back	Session DemoSession			🖹 S	how Report	About	🕐 Hel
	All	Properties	Limit Manager	Results	Instruments	Report Conf	īg
	▲ 100BASE-TX						
	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)						
	Transmitter Clock Frequency (24.2.3.4)						
	Transmitter Return Loss (9.1.5)						
/	Receiver Return Loss (9.2.2)						
	▲ 100BASE-TX EEE						
	Sleep Time (24.2.3.4 and 78.2)						
	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)						
	Transmit Wake Time (24.2.3.4 and 78.2)						
Test	Checked  Test Single						

- 3. Click "Test Single".
- 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 (\*.slp 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.

	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)	at least 2 GHz band- width	R&S RT-ZF5 Section: Link partner section	
LPI Transmitter Timing Jitter (24.2.3.4 and 78.2)	_		

•	Sleep time test	102
	LPI quiet time test	
	LPI refresh time test	
	LPI transmitter timing jitter test	
	Transmit wake time test	

# 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 Control- ler/Adapter	1
Software option	R&S RTO/RTO6/RTP-K8, Ethernet serial decod- ing	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)"

100BASE-TX tests

#### 100BASE-TX EEE

R&S ScopeSi	lite						_ 🗆 ×
🖨 Back	Session DemoSession				Show Report	<b>(</b> ) About	P Help
•	All	Properties	Limit Manager	Results	Instruments	Report Conf	īg
	▲ 100BASE-TX	Test Setu	р				
	Amplitude Domain Tests (9.1.2.2, 9.1.3 and 9.1.4)		Average Coun	. 1			
	Rise and Fall Times (9.1.6)		Average Coun				
	Peak to Peak Duty Cycle Distortion (9.1.8)						
	Peak to Peak Transmit Jitter (9.1.9)						
	Active Output Interface Template (Annex J)						
	Transmitter Clock Frequency (24.2.3.4)						
	Transmitter Return Loss (9.1.5)						
	Receiver Return Loss (9.2.2)						
	▲ 100BASE-TX EEE						
	Sleep Time (24.2.3.4 and 78.2)						
	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)						
	Transmit Wake Time (24.2.3.4 and 78.2)						
🚽 Test Ch	ecked 🕨 Test Single						
Ready to run.							

- 3. Click "Test Single".
- 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 Adap- tor	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)"

AI	l .	Properties	Limit Manager	Results	Instruments	Report Config	
	100BASE-TX	Test Setu	C				
	Amplitude Domain Tests (9.1.2.2, 9.1.3 and 9.1.4)						
	Rise and Fall Times (9.1.6)		Average Coun	t I			
	Peak to Peak Duty Cycle Distortion (9.1.8)						
	Peak to Peak Transmit Jitter (9.1.9)						
	Active Output Interface Template (Annex J)						
	Transmitter Clock Frequency (24.2.3.4)						
	Transmitter Return Loss (9.1.5)						
	Receiver Return Loss (9.2.2)						
•	100BASE-TX EEE						
	Sleep Time (24.2.3.4 and 78.2)						
/	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)						
	Transmit Wake Time (24.2.3.4 and 78.2)						

- 3. Click "Test Single".
- 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 Chapter 5.1, "Starting 100BASE-TX tests", on page 79.
- 2. Select the test case: "100BASE-TX-EEE" > "LPI Refresh Time (24.2.3.4 and 78.2)"

100BASE-TX tests

#### 100BASE-TX EEE

R&S ScopeS	uite						_ 🗆 ×
🕒 Back	Session DemoSession			Ŕ	Show Report	About	🕜 Help
	All	Properties	Limit Manager	Results	Instruments	Report Con	fig
	▲ 100BASE-TX	Test Setup	0				
	Amplitude Domain Tests (9.1.2.2, 9.1.3 and 9.1.4)		Average Cour				
	Rise and Fall Times (9.1.6)		Average Count				
	Peak to Peak Duty Cycle Distortion (9.1.8)						
	Peak to Peak Transmit Jitter (9.1.9)						
	Active Output Interface Template (Annex J)						
	Transmitter Clock Frequency (24.2.3.4)						
	Transmitter Return Loss (9.1.5)						
	Receiver Return Loss (9.2.2)						
	▲ 100BASE-TX EEE						
	Sleep Time (24.2.3.4 and 78.2)						
	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)						
	Transmit Wake Time (24.2.3.4 and 78.2)						
🕞 Test Ch	necked 🕨 Test Single						
Ready to run							

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

🖨 Back	Session DemoSession			ľà,	Show Report	About	0	Help
	All	Properties	Limit Manager	Results	Instruments	Report Con	fig	
	▲ 100BASE-TX	Test Setu	D					
	Amplitude Domain Tests (9.1.2.2, 9.1.3 and 9.1.4)							
	Rise and Fall Times (9.1.6)		Measurement Tim	e 0.1	S			
	Peak to Peak Duty Cycle Distortion (9.1.8)							
	Peak to Peak Transmit Jitter (9.1.9)							
	Active Output Interface Template (Annex J)							
	Transmitter Clock Frequency (24.2.3.4)							
	Transmitter Return Loss (9.1.5)							
	Receiver Return Loss (9.2.2)							
	▲ 100BASE-TX EEE							
	Sleep Time (24.2.3.4 and 78.2)							
	LPI Quiet Time (24.2.3.4 and 78.2)							
	LPI Refresh Time (24.2.3.4 and 78.2)							
<b>V</b>	LPI Transmitter Timing Jitter (24.2.3.4 and 78.2)							
	Transmit Wake Time (24.2.3.4 and 78.2)							
Test Cl	hecked 🕨 Test Single							
Ready to run								

3. Click "Test Single".

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

#### 5.4.4.3 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<sup>-8</sup>. 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

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

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

#### 5.4.5.2 Performing the tests

- 1. Start the test as described in Chapter 5.1, "Starting 100BASE-TX tests", on page 79.
- Select the test case: "100BASE-TX-EEE" > "Transmit Wake Time (24.2.3.4 and 78.2)"

#### 100BASE-TX EEE

R&S ScopeS	ıite						_
🖨 Back	Session DemoSession			R.	Show Report	<b>(</b> ) About	🕜 Help
•	All	Properties	Limit Manager	Results	Instruments	Report Conf	īg
	▲ 100BASE-TX	Test Setu	р				
	Amplitude Domain Tests (9.1.2.2, 9.1.3 and 9.1.4)		Average Coun				
	Rise and Fall Times (9.1.6)		Average Coun	1			
	Peak to Peak Duty Cycle Distortion (9.1.8)						
	Peak to Peak Transmit Jitter (9.1.9)						
	Active Output Interface Template (Annex J)						
	Transmitter Clock Frequency (24.2.3.4)						
	Transmitter Return Loss (9.1.5)						
	Receiver Return Loss (9.2.2)						
	▲ 100BASE-TX EEE						
	Sleep Time (24.2.3.4 and 78.2)						
	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)						
	Transmit Wake Time (24.2.3.4 and 78.2)						
🔄 Test Ch	ecked 🕨 Test Single						
Ready to run.							

- 3. Click "Test Single".
- 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

#### 5.4.5.3 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.

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.
- In the "Session Selection" dialog, set "Select Type" > "10BASE-T".
- 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
- 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.

Test configuration for Ethernet 10BASE-T

🕒 Back	Session 10BASE-T_20161012_161445			🖹 Sh	iow Report	About	🕐 Help
✓ ^	All	Properties	Limit Manager	Results	Instruments	Report Con	fig
<ul> <li>Image: A set of the set of the</li></ul>	▲ No TPM	EEE					
✓	Link Test Pulse Template (14.3.1.2.1)			_			
<ul> <li>Image: A start of the start of</li></ul>	TP_IDL Template (14.3.1.2.1)		10 Base-T	e 🗹			
<ul> <li>Image: A start of the start of</li></ul>	Peak Differential Voltage (14.3.1.2.1)	Test Setu	р				
<ul> <li>Image: A start of the start of</li></ul>	Harmonic Content (14.3.1.2.1)		Average Cour	nt 10			
✓	Output Timing Jitter (14.3.1.2.3)		2				
✓	▲ With TPM		Measurement Tim	e 1E-05	s		
<ul> <li>Image: A start of the start of</li></ul>	Link Test Pulse Template (14.3.1.2.1)	# of Ac	cqs for Eye Diagrar	n 1000			
<ul> <li>Image: A start of the start of</li></ul>	TP_IDL Template (14.3.1.2.1)	# of /	Acqs for Jitter Mea	is 10000			
<ul> <li>Image: A start of the start of</li></ul>	MAU Template (14.3.1.2.1)				_		
✓	Output Timing Jitter (14.3.1.2.3)	MAU Typ	e				
✓	▲ Common		Internal MAI	U 🔘 Extern	al MAU		
<ul> <li>Image: A start of the start of</li></ul>	Transmitter Return Loss (14.3.1.2.2)	Test Fixtu	Iro				
<ul> <li>Image: A start of the start of</li></ul>	Receiver Return Loss (14.3.1.3.4)	restrixtu	iie				
✓	Common-mode Output Voltage (14.3.1.2.5)		RT-ZF2 (SMA)	A) () RT-ZF	2		
Test C	hecked						
eady to run							

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	1	R&S RT-ZF2	Optional:
(14.3.1.2.1)	at least 1 GHz band- width	Section: Twisted Pair Model	R&S RTO / R&S RTO6 /R&S RTP-K17
TP_IDL Template	1	R&S RT-ZF2	Optional:
(14.3.1.2.1)		Section: Twisted Pair Model	R&S RTO / R&S RTO6 /R&S RTP-K17
Output Timing Jitter	1	R&S RT-ZF2	Optional:
(14.3.1.2.3)		Section:	Link partner
		Twisted Pair Model	e.g., Intel PRO/100 GT Desktop Adapter
			Optional:
			R&S RTO / R&S RTO6 /R&S RTP-K17
Peak Differential Voltage	1	R&S RT-ZF2	Optional:
(14.3.1.2.1)		Section:	R&S RTO / R&S
		Twisted Pair Model	RTO6 /R&S RTP-K17
Harmonic Content	1	R&S RT-ZF2	Optional:
(14.3.1.2.1)		Section:	Link partner
		Twisted Pair Model	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	<b>Optional:</b> 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	<b>Optional VNA:</b> R&S ZNB or R&S ZNC or R&S ZND or R&S ZVL
Common-mode Output Volt- age (14.3.1.2.5)	1	R&S RT-ZF2 Section: Common Mode Voltage	<b>Optional:</b> R&S RTO / R&S RTO6 /R&S RTP-K17

•	Link test pulse template	.113
	TP_IDL template	
	Output timing jitter	
	Peak differential voltage	
•	Harmonic content	. 130
•	MAU template	132
•	Transmitter return loss	134
•	Receiver return loss	136
•	Common-mode output voltage	.137

### 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)".

R&S ScopeSuite	×
<b>Back</b> Session 10BASE-T_20190919_134010	R Show Report 1 About 1 Help
All	Properties Limit Manager Results Instruments Report Config
No TPM	EEE
Link Test Pulse Template (14.3.1.2.1)	
TP_IDL Template (14.3.1.2.1)	10 Base-Te
Peak Differential Voltage (14.3.1.2.1)	Test Setup
Harmonic Content (14.3.1.2.1)	# of Acgs for Eye Diagram 1000
Output Timing Jitter (14.3.1.2.3)	
With TPM	
Link Test Pulse Template (14.3.1.2.1)	
TP_IDL Template (14.3.1.2.1)	
MAU Template (14.3.1.2.1)	
Output Timing Jitter (14.3.1.2.3)	
Common	
Transmitter Return Loss (14.3.1.2.2)	
Receiver Return Loss (14.3.1.3.4)	
Common-mode Output Voltage (14.3.1.2.5)	
Test Checked Fest Single	
Ready to run.	

- 3. Click "Test Single".
- 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.

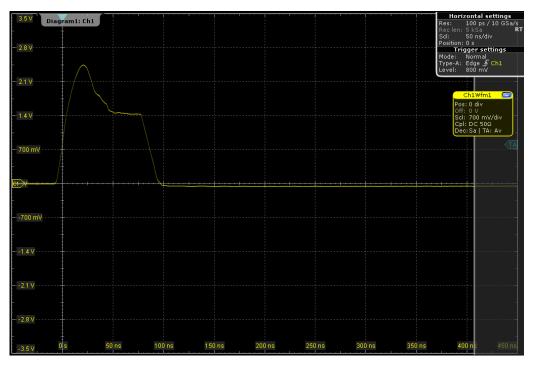


Figure 6-2: Waveform with load 1

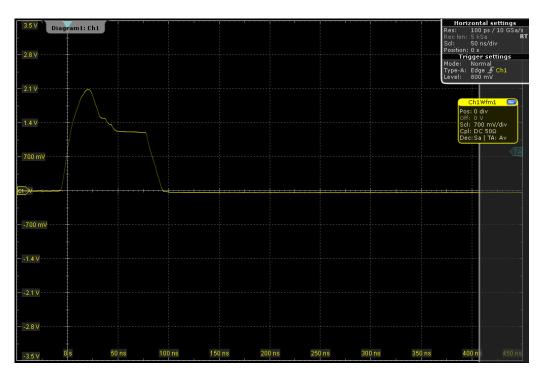


Figure 6-3: Waveform with load 2

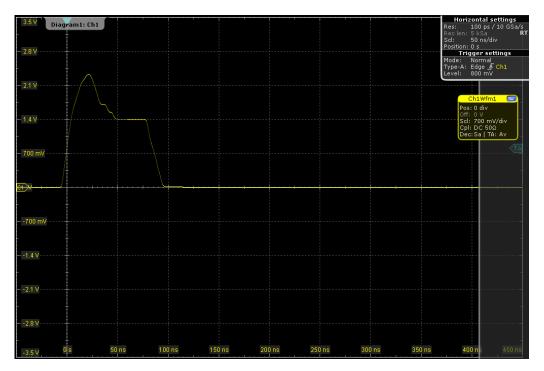


Figure 6-4: Waveform with load 100  $\varOmega$ 

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)".

<ul> <li>All</li> <li>All</li></ul>	🕒 Back	Session 10BASE-T_20190919_134010	🔥 Show Report 🕕 At	oout 🕐 Hel
Image: Common       Image: Common         Image: Common		All	Properties Limit Manager Results Instruments Repo	rt Config
10 Base-Te   10 Peak Differential Voltage (14.3.1.2.1)   110 Peak Differential Voltage (14.3.1.2.1)   110 Peak Differential Voltage (14.3.1.2.1)   110 Dutput Timing Jitter (14.3.1.2.3)   1110 Peak Differential Voltage (14.3.1.2.1)   1110 Peak Differential Voltage (14.3.1.2.1)   1110 Peak Differential Voltage (14.3.1.2.1)   1110 Peak Differential (14.3.1.2.3)   1110 Peak Differential (14.3.1.2.3) <t< td=""><td></td><td>▲ No TPM</td><td>EEE</td><td></td></t<>		▲ No TPM	EEE	
<ul> <li>IP_JDL lemplate (14.3.1.2.1)</li> <li>Peak Differential Voltage (14.3.1.2.1)</li> <li>Harmonic Content (14.3.1.2.1)</li> <li>Output Timing Jitter (14.3.1.2.3)</li> <li>With TPM</li> <li>TP_JDL Template (14.3.1.2.1)</li> <li>MAU Template (14.3.1.2.1)</li> <li>MAU Template (14.3.1.2.1)</li> <li>Output Timing Jitter (14.3.1.2.3)</li> <li>Common</li> <li>Transmitter Return Loss (14.3.1.2.2)</li> <li>Receiver Return Loss (14.3.1.2.3)</li> </ul>		Link Test Pulse Template (14.3.1.2.1)		
Harmonic Content (14.3.1.2.1)   Output Timing Jitter (14.3.1.2.3)   With TPM   Link Test Pulse Template (14.3.1.2.1)   TP_IDL Template (14.3.1.2.1)   MAU Template (14.3.1.2.1)   Output Timing Jitter (14.3.1.2.3)   Output Timing Jitter (14.3.1.2.3)   Output Timing Jitter (14.3.1.2.3)   Common   Transmitter Return Loss (14.3.1.2.2)   Receiver Return Loss (14.3.1.3.4)		TP_IDL Template (14.3.1.2.1)	10 Base-Te	
<pre># of Acqs for Eye Diagram 1000 # of Acqs for Eye Diagram</pre>		Peak Differential Voltage (14.3.1.2.1)	Test Setup	
Output Timing Jitter (14.3.1.2.3)       With TPM       Link Test Pulse Template (14.3.1.2.1)       MAU Template (14.3.1.2.1)       Output Timing Jitter (14.3.1.2.1)       Output Timing Jitter (14.3.1.2.3)       Output Timing Jitter (14.3.1.2.3)       Common       Transmitter Return Loss (14.3.1.2.2)       Receiver Return Loss (14.3.1.3.4)		Harmonic Content (14.3.1.2.1)	# of Acos for Eve Diagram 1000	
Link Test Pulse Template (14.3.1.2.1) TP_IDL Template (14.3.1.2.1) MAU Template (14.3.1.2.1) Output Timing Jitter (14.3.1.2.3) Output Timing Jitter (14.3.1.2.3) Common Transmitter Return Loss (14.3.1.2.2) Receiver Return Loss (14.3.1.3.4)		Output Timing Jitter (14.3.1.2.3)		
TP_JDL Template (14.3.1.2.1)       MAU Template (14.3.1.2.1)       Output Timing Jitter (14.3.1.2.3)       Output Timing Jitter (14.3.1.2.3)       Common       Transmitter Return Loss (14.3.1.2.2)       Receiver Return Loss (14.3.1.3.4)		▲ With TPM		
MAU Template (14.3.1.2.1) Output Timing Jitter (14.3.1.2.3) Common Transmitter Return Loss (14.3.1.2.2) Receiver Return Loss (14.3.1.3.4)		Link Test Pulse Template (14.3.1.2.1)		
Output Timing Jitter (14.3.1.2.3)       Common       Transmitter Return Loss (14.3.1.2.2)       Receiver Return Loss (14.3.1.3.4)		TP_IDL Template (14.3.1.2.1)		
Common Transmitter Return Loss (14.3.1.2.2) Receiver Return Loss (14.3.1.3.4)		MAU Template (14.3.1.2.1)		
Transmitter Return Loss (14.3.1.2.2)       Receiver Return Loss (14.3.1.3.4)		Output Timing Jitter (14.3.1.2.3)		
Receiver Return Loss (14.3.1.3.4)		▲ Common		
		Transmitter Return Loss (14.3.1.2.2)		
Common-mode Output Voltage (14.3.1.2.5)		Receiver Return Loss (14.3.1.3.4)		
		Common-mode Output Voltage (14.3.1.2.5)		
	🔥 Test C	Checked 🕨 Test Single		

- 3. Click "Test Single".
- 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.

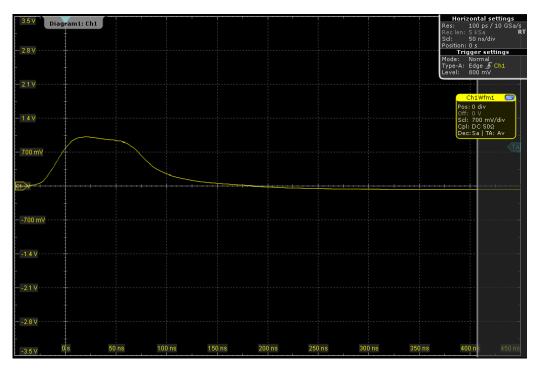


Figure 6-5: Waveform with load 1

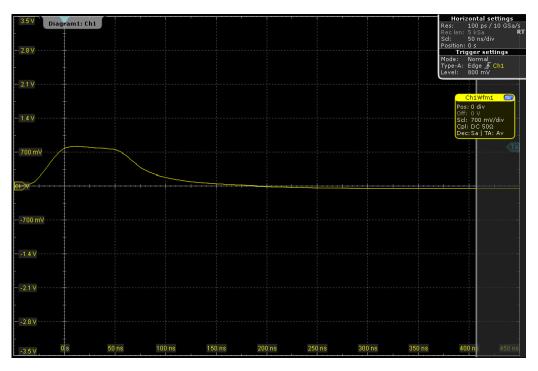


Figure 6-6: Waveform with load 2

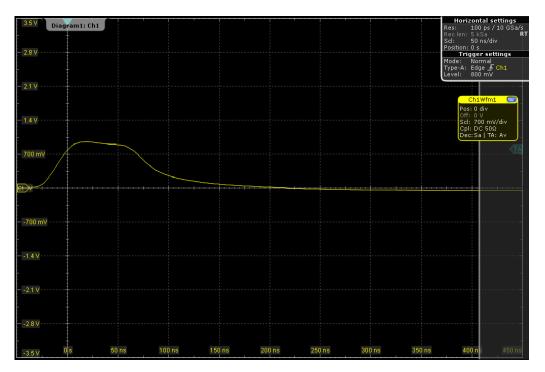


Figure 6-7: Waveform with load 100  $\varOmega$ 

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 Th	P_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)".

R&S ScopeS	uite						-	□ ×
🕒 Back	Session 10BASE-T_20190919_134010			ľà,	Show Report	About	0	Help
	All	Properties	Limit Manager	Results	Instruments	Report Cor	nfig	
	▲ No TPM	EEE						
	Link Test Pulse Template (14.3.1.2.1)							
	TP_IDL Template (14.3.1.2.1)		10 Base-Te	e				
	Peak Differential Voltage (14.3.1.2.1)	Test Setu	р					
	Harmonic Content (14.3.1.2.1)	# of Ac	:qs for Eye Diagran	n 1000				
	Output Timing Jitter (14.3.1.2.3)		iqo tot eye biografi					
	▲ With TPM							
	Link Test Pulse Template (14.3.1.2.1)							
	TP_IDL Template (14.3.1.2.1)							
	MAU Template (14.3.1.2.1)							
	Output Timing Jitter (14.3.1.2.3)							
	▲ Common							
	Transmitter Return Loss (14.3.1.2.2)							
	Receiver Return Loss (14.3.1.3.4)							
	Common-mode Output Voltage (14.3.1.2.5)							
🔄 Test Cl	hecked 🕨 Test Single							
Ready to run	L							

- 3. Click "Test Single".
- 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.

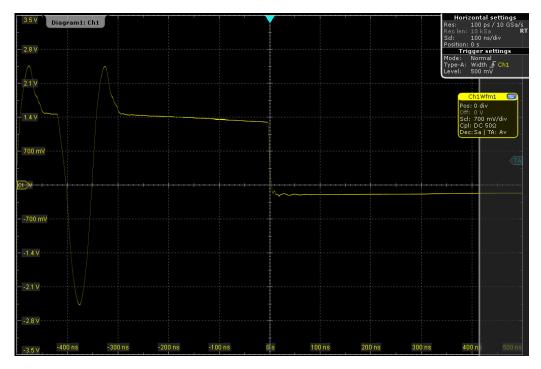


Figure 6-8: Waveform with load 1

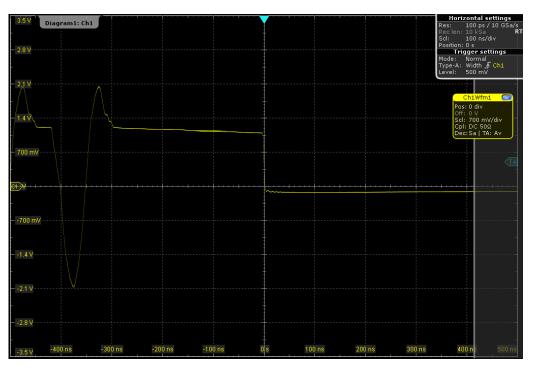


Figure 6-9: Waveform with load 2

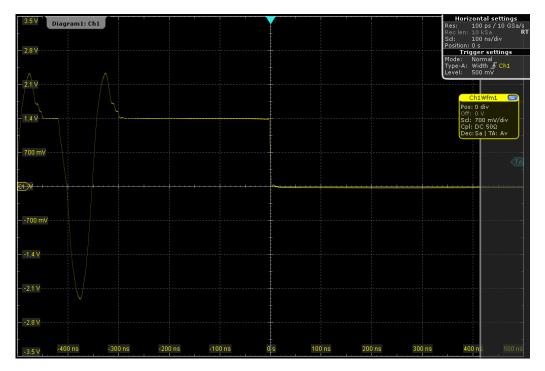


Figure 6-10: Waveform with load 100  $\Omega$ 

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)".

🕒 Back	Session 10BASE-T_20190919_134010	🖹 👌 Show Report 🕕 About 🕐 He
	All	Properties Limit Manager Results Instruments Report Config
	▲ No TPM	EEE
	Link Test Pulse Template (14.3.1.2.1)	
	TP_IDL Template (14.3.1.2.1)	10 Base-Te
	Peak Differential Voltage (14.3.1.2.1)	Test Setup
	Harmonic Content (14.3.1.2.1)	# of Acqs for Eye Diagram 1000
	Output Timing Jitter (14.3.1.2.3)	
	▲ With TPM	
	Link Test Pulse Template (14.3.1.2.1)	
<b>V</b>	TP_IDL Template (14.3.1.2.1)	
	MAU Template (14.3.1.2.1)	
	Output Timing Jitter (14.3.1.2.3)	
	▲ Common	
	Transmitter Return Loss (14.3.1.2.2)	
	Receiver Return Loss (14.3.1.3.4)	
	Common-mode Output Voltage (14.3.1.2.5)	

- 3. Click "Test Single".
- 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.

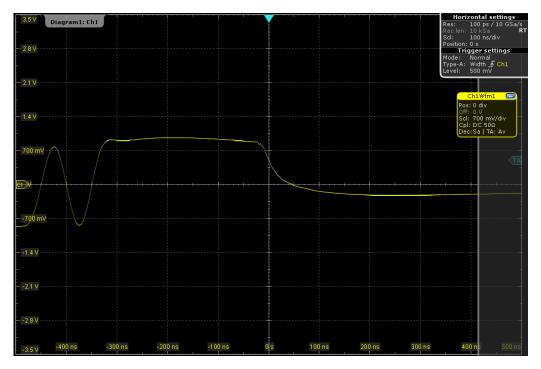


Figure 6-11: Waveform with load 1

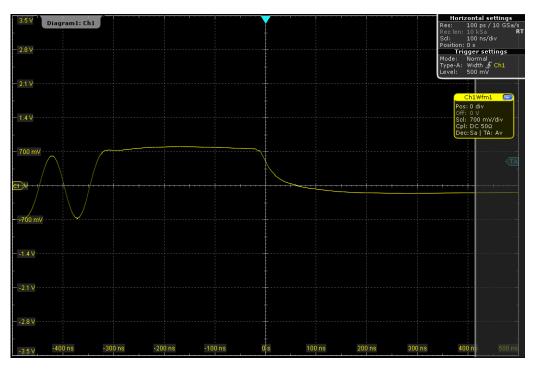


Figure 6-12: Waveform with load 2

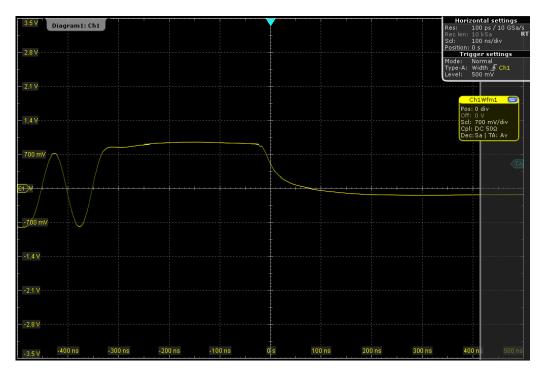


Figure 6-13: Waveform with load 100  $\Omega$ 

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

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)".

R&S ScopeS	uite						- [	⊐ ×
🕒 Back	Session 10BASE-T_20190919_134010			📘 Sh	ow Report	() About	0	Help
	All	Properties	Limit Manager	Results	Instruments	Report Cor	ifig	
	▲ No TPM	EEE						
	Link Test Pulse Template (14.3.1.2.1)							
	TP_IDL Template (14.3.1.2.1)		10 Base-T	e				
	Peak Differential Voltage (14.3.1.2.1)	Test Setu	p					
	Harmonic Content (14.3.1.2.1)	# of J	Acqs for Jitter Mea	is 10000				
<b>V</b>	Output Timing Jitter (14.3.1.2.3)	# 017	Acqs for sitter mea	10000				
	▲ With TPM	MAU Typ	e					
	Link Test Pulse Template (14.3.1.2.1)		Internal MAI	U 🔿 Extern	al MAU			
	TP_IDL Template (14.3.1.2.1)		0	0				
	MAU Template (14.3.1.2.1)							
	Output Timing Jitter (14.3.1.2.3)							
	▲ Common							
	Transmitter Return Loss (14.3.1.2.2)							
	Receiver Return Loss (14.3.1.3.4)							
	Common-mode Output Voltage (14.3.1.2.5)							
Test Ch	necked 🕨 Test Single							
Ready to run.								

- 3. Click "Test Single".
- 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 pseudorandom 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)".

Back Session 10BASE-T_20190919_134010			à Sh	iow Report	1 About	- U
All	Properties	Limit Manager	Results	Instruments	Report Con	fig
▲ No TPM	EEE					
Link Test Pulse Template (14.3.1.2.1)						
TP_IDL Template (14.3.1.2.1)		10 Base-T	e			
Peak Differential Voltage (14.3.1.2.1)	Test Setu	D				
Harmonic Content (14.3.1.2.1)			40000			
Output Timing Jitter (14.3.1.2.3)	# of /	Acqs for Jitter Mea	s 10000			
With TPM	MAU Typ	e				
Link Test Pulse Template (14.3.1.2.1)		<ol> <li>Internal MAL</li> </ol>	I O Extern	al MAU		
TP_IDL Template (14.3.1.2.1)						
MAU Template (14.3.1.2.1)						
Output Timing Jitter (14.3.1.2.3)						
▲ Common						
Transmitter Return Loss (14.3.1.2.2)						
Receiver Return Loss (14.3.1.3.4)						
Common-mode Output Voltage (14.3.1.2.5)						
Test Checked 🕨 Test Single						
eady to run.						

- 3. Click "Test Single".
- 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 pseudorandom 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

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

Table 6-5: Equipment for Peak Differential Voltage test

#### 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)".

R&S ScopeSuite	*
G Back Session 10BASE-T_20190919_134010	b Show Report 1 About 1 Help
All	Properties Limit Manager Results Instruments Report Config
No TPM	EEE
Link Test Pulse Template (14.3.1.2.1)	
TP_IDL Template (14.3.1.2.1)	10 Base-Te
Peak Differential Voltage (14.3.1.2.1)	Test Setup
Harmonic Content (14.3.1.2.1)	Average Count 10
Output Timing Jitter (14.3.1.2.3)	
With TPM	
Link Test Pulse Template (14.3.1.2.1)	
TP_IDL Template (14.3.1.2.1)	
MAU Template (14.3.1.2.1)	
Output Timing Jitter (14.3.1.2.3)	
Common	
Transmitter Return Loss (14.3.1.2.2)	
Receiver Return Loss (14.3.1.3.4)	
Common-mode Output Voltage (14.3.1.2.5)	
Test Checked Test Single	
Ready to run.	

- 3. Click "Test Single".
- 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.

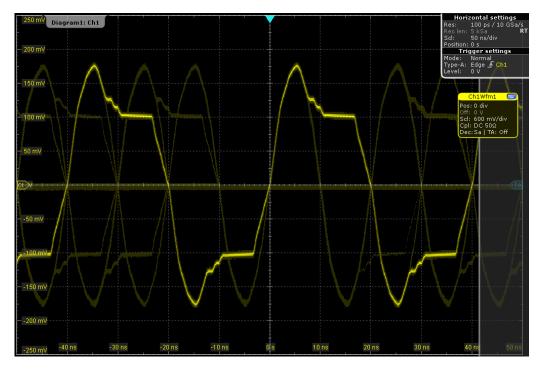


Figure 6-14: Waveform of 10BASE-T random data

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)".

R&S ScopeS	uite						_ 🗆 ×
🖨 Back	Session 10BASE-T_20190919_134010			🖹 Sł	now Report	About	🕐 Help
	All	Properties	Limit Manager	Results	Instruments	Report Con	fig
	▲ No TPM	EEE					
	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)		10 Base-T	e			
	Peak Differential Voltage (14.3.1.2.1)	Test Setu	D				
<b>V</b>	Harmonic Content (14.3.1.2.1)		Average Coun	10			
	Output Timing Jitter (14.3.1.2.3)		, neige cour				
	▲ With TPM						
	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)						
	MAU Template (14.3.1.2.1)						
	Output Timing Jitter (14.3.1.2.3)						
	▲ Common						
	Transmitter Return Loss (14.3.1.2.2)						
	Receiver Return Loss (14.3.1.3.4)						
	Common-mode Output Voltage (14.3.1.2.5)						
Test C	hecked 🕨 Test Single						
Ready to run	L.						

- 3. Click "Test Single".
- 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  $\mu$ s 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).

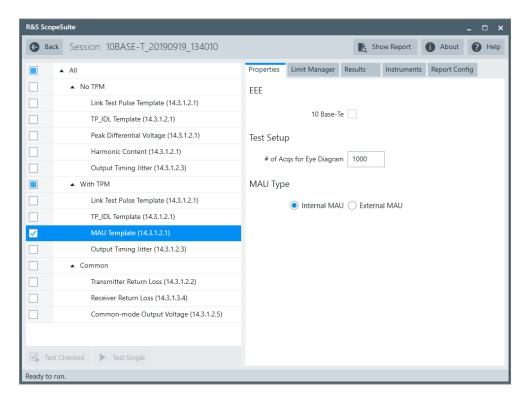
### 6.3.6.1 Test equipment

#### 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 Chapter 6.1, "Starting 10BASE-T tests", on page 110.
- 2. Under "With TPM", select "MAU Template (14.3.1.2.1)".



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

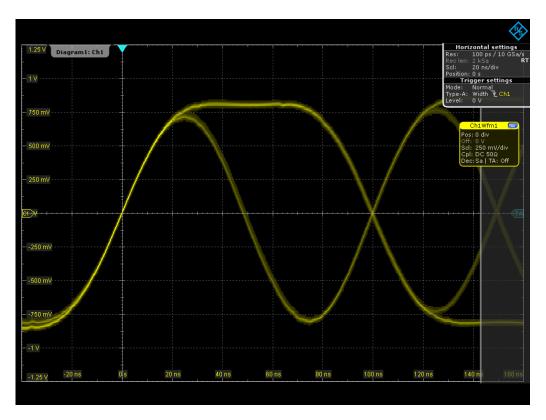
Further steps:

• 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

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 you want to test	1

Table 6-8: Equipment for Transmitter Return Loss

### 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)".

🕒 Back	Session 10BASE-T_20190919_134010			à	Show Report	1 About	🕐 Hel
	▲ All	Properties	Limit Manager	Results	Instruments	Report Con	fig
	▲ No TPM						
	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)						
	Peak Differential Voltage (14.3.1.2.1)						
	Harmonic Content (14.3.1.2.1)						
	Output Timing Jitter (14.3.1.2.3)						
	▲ With TPM						
	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)						
	MAU Template (14.3.1.2.1)						
	Output Timing Jitter (14.3.1.2.3)						
	▲ Common						
<b>V</b>	Transmitter Return Loss (14.3.1.2.2)						
	Receiver Return Loss (14.3.1.3.4)						
	Common-mode Output Voltage (14.3.1.2.5)						
Test C	Checked Test Single						

- 3. Click "Test Single".
- 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 auto- matic 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)".

🕒 Back	Session 10BASE-T_20190919_134010			à	Show Report	About	P He
	▲ All	Properties	Limit Manager	Results	Instruments	Report Conf	ig
	▲ No TPM						
	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)						
	Peak Differential Voltage (14.3.1.2.1)						
	Harmonic Content (14.3.1.2.1)						
	Output Timing Jitter (14.3.1.2.3)						
	With TPM						
	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)						
	MAU Template (14.3.1.2.1)						
	Output Timing Jitter (14.3.1.2.3)						
	▲ Common						
	Transmitter Return Loss (14.3.1.2.2)						
<b>V</b>	Receiver Return Loss (14.3.1.3.4)						
	Common-mode Output Voltage (14.3.1.2.5)						
Test	Checked 🕨 Test Single						
p .cot	, recongre						

- 3. Click "Test Single".
- 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 (\*.slp or \*.csv) falls below the -15 dB limit.

### 6.3.9 Common-mode output voltage

Ethernet test fixture, "Common Mode Volt-

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

Item	Description, model
	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth

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

#### 6.3.9.2 Performing the test

age" section

DUT

Differential probe

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

R&S RT-ZF2

at least 1 GHz bandwidth

the device you want to test

2. Under "Common", select "Common-mode Output Voltage (14.3.1.2.5)".

Quantity

1

1

1

R&S ScopeSuite	
G Back Session 10BASE-T_20190919_134010	🔥 Show Report 🚺 About 👔 Hel
All	Properties Limit Manager Results Instruments Report Config
▲ No TPM	Test Setup
Link Test Pulse Template (14.3.1.2.1)	Measurement Time 1E-05 s
TP_IDL Template (14.3.1.2.1)	Measurement Time 1E-05 s
Peak Differential Voltage (14.3.1.2.1)	Test Fixture
Harmonic Content (14.3.1.2.1)	RT-ZF2 (SMA)      RT-ZF2
Output Timing Jitter (14.3.1.2.3)	
▲ With TPM	
Link Test Pulse Template (14.3.1.2.1)	
TP_IDL Template (14.3.1.2.1)	
MAU Template (14.3.1.2.1)	
Output Timing Jitter (14.3.1.2.3)	
Common	
Transmitter Return Loss (14.3.1.2.2)	
Receiver Return Loss (14.3.1.3.4)	
Common-mode Output Voltage (14.3.1.2.5)	
Test Checked 🕨 Test Single	
eady to run.	

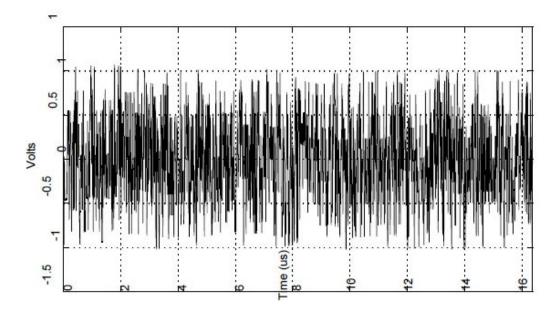
- 3. Click "Test Single".
- Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

Further steps:

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

### 6.3.9.3 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	1	R&S RT-ZF4	Optional:
(14.3.1.2.1)	at least 1	Section:	Link partner
	GHz band- width	Twisted Pair Model	e.g., Intel PRO/100 GT Desktop Adapter
			Optional:
			R&S RTO / R&S RTO6 /R&S RTP-K17
TP_IDL Template	1	R&S RT-ZF4	Optional:
(14.3.1.2.1)		Section:	R&S RTO / R&S
		Twisted Pair Model	RTO6 /R&S RTP-K17

**10BASE-T tests** 10BASE-Te tests

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

•	Link test pulse template	141
•	TP_IDL template	147
•	Output timing jitter	154
	Peak differential voltage	
	Harmonic content	
•	MAU template	161
	Transmitter return loss	
•	Receiver return loss	165
•	Common-mode output voltage	166

### 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)".

10BASE-Te tests

R&S ScopeS	uite						_ 🗆 ×
🕒 Back	Session 10BASE-T_20190919_134010			Ą	Show Report	1 About	Help
	All	Properties	Limit Manager	Results	Instruments	Report Con	fig
	▲ No TPM	EEE					
	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)		10 Base-	le 🔄			
	Peak Differential Voltage (14.3.1.2.1)	Test Setu	р				
	Harmonic Content (14.3.1.2.1)	# of Ac	qs for Eye Diagra	m 1000			
	Output Timing Jitter (14.3.1.2.3)						
	With TPM						
	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)						
	MAU Template (14.3.1.2.1)						
	Output Timing Jitter (14.3.1.2.3)						
	▲ Common						
	Transmitter Return Loss (14.3.1.2.2)						
	Receiver Return Loss (14.3.1.3.4)						
	Common-mode Output Voltage (14.3.1.2.5)						
Test C	necked 🕨 Test Single						
Ready to run							

- 4. Click "Test Single".
- 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.

## **10BASE-T tests** 10BASE-Te tests

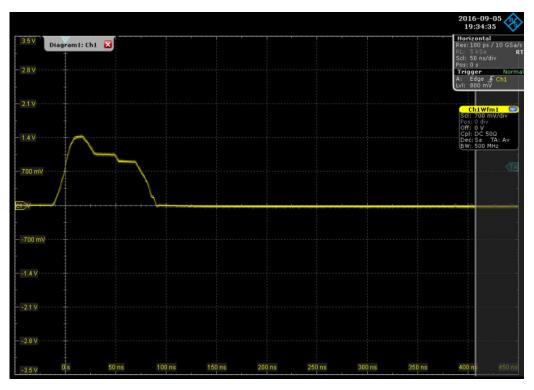


Figure 6-15: Waveform with load 1

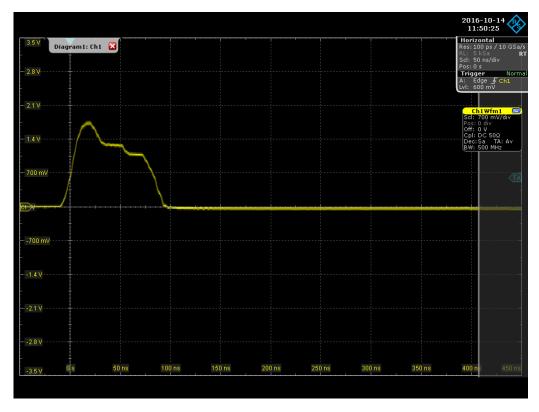


Figure 6-16: Waveform with load 2

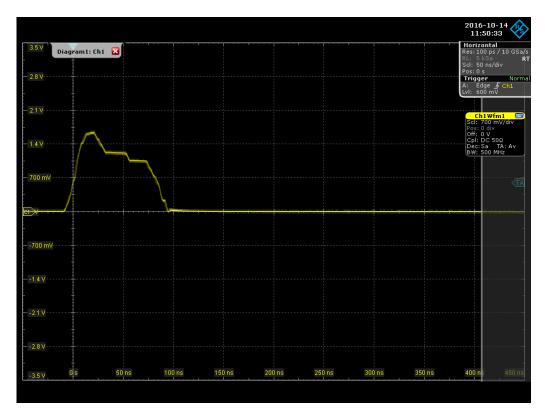


Figure 6-17: Waveform with load 100  $\Omega$ 

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 Chapter 6.1, "Starting 10BASE-T tests", on page 110.
- 2. In the "Properties" tab, enable "10 Base-Te".
- 3. Under "With TPM", select "Link Test Pulse Template (14.3.1.2.1)".

10BASE-Te tests

🕒 Back	Session 10BASE-T_20190919_134010			à	Show Report	About	P Hel
	All	Properties	Limit Manager	Results	Instruments	Report Con	fig
	▲ No TPM	EEE					
	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)		10 Base-T	e			
	Peak Differential Voltage (14.3.1.2.1)	Test Setup	)				
	Harmonic Content (14.3.1.2.1)	# of Ac	qs for Eye Diagrar	n 1000			
	Output Timing Jitter (14.3.1.2.3)		, eye olagidi				
	▲ With TPM						
<u>~</u>	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)						
	MAU Template (14.3.1.2.1)						
	Output Timing Jitter (14.3.1.2.3)						
	▲ Common						
	Transmitter Return Loss (14.3.1.2.2)						
	Receiver Return Loss (14.3.1.3.4)						
	Common-mode Output Voltage (14.3.1.2.5)						
🔨 Test C	hecked 🕨 Test Single						

- 4. Click "Test Single".
- 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.

# **10BASE-T tests** 10BASE-Te tests

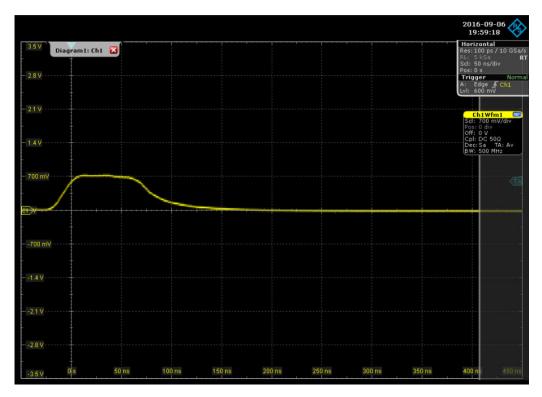


Figure 6-18: Waveform with load 1

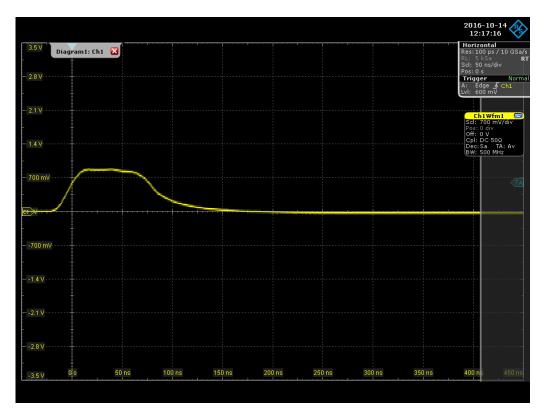


Figure 6-19: Waveform with load 2

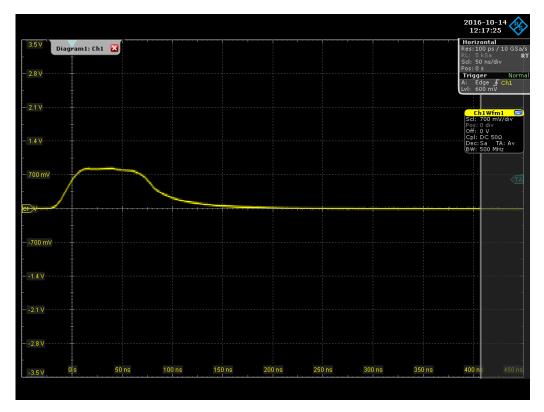


Figure 6-20: Waveform with load 100  $\Omega$ 

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

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

Table 6-13: Equipment for all TP\_IDL Template tests

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)".

R&S ScopeSuite					_ □
G Back Session 10BASE-T_20190919_134010			Ŕ	Show Report	About P He
All	Properties	Limit Manager	Results	Instruments	Report Config
No TPM	EEE				
Link Test Pulse Template (14.3.1.2.1)					
✓ TP_IDL Template (14.3.1.2.1)		10 Base-Te	e		
Peak Differential Voltage (14.3.1.2.1)	Test Setu	0			
Harmonic Content (14.3.1.2.1)	# of Ac	qs for Eye Diagran	n 1000		
Output Timing Jitter (14.3.1.2.3)		qo for eye blagran	1000		
With TPM					
Link Test Pulse Template (14.3.1.2.1)					
TP_IDL Template (14.3.1.2.1)					
MAU Template (14.3.1.2.1)					
Output Timing Jitter (14.3.1.2.3)					
▲ Common					
Transmitter Return Loss (14.3.1.2.2)					
Receiver Return Loss (14.3.1.3.4)					
Common-mode Output Voltage (14.3.1.2.5)					
Test Checked Fast Single					
eady to run.					

- 4. Click "Test Single".
- 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.

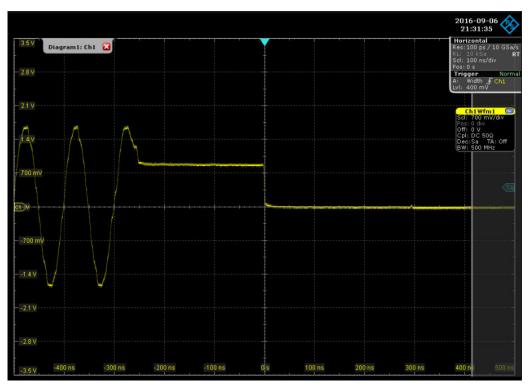


Figure 6-21: Waveform with load 1

# **10BASE-T tests** 10BASE-Te tests

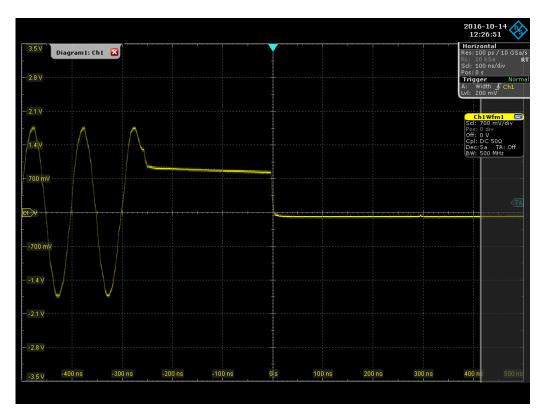


Figure 6-22: Waveform with load 2

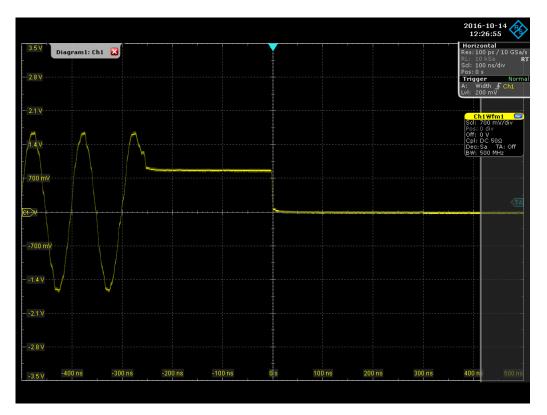


Figure 6-23: Waveform with load 100  $\varOmega$ 

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)".

Back Session 10BASE-T_20190919_134010			à s	Show Report	1 About	0
All	Properties	Limit Manager	Results	Instruments	Report Config	
▲ No TPM	EEE					
Link Test Pulse Template (14.3.1.2.1)						
TP_IDL Template (14.3.1.2.1)		10 Base-T	e			
Peak Differential Voltage (14.3.1.2.1)	Test Setu	р				
Harmonic Content (14.3.1.2.1)	# of Ac	:qs for Eye Diagrar	n 1000			
Output Timing Jitter (14.3.1.2.3)	" OT AC	so or cyc oldyfal				
▲ With TPM						
Link Test Pulse Template (14.3.1.2.1)						
TP_IDL Template (14.3.1.2.1)						
MAU Template (14.3.1.2.1)						
Output Timing Jitter (14.3.1.2.3)						
▲ Common						
Transmitter Return Loss (14.3.1.2.2)						
Receiver Return Loss (14.3.1.3.4)						
Common-mode Output Voltage (14.3.1.2.5)						
Test Checked Test Single						

- 4. Click "Test Single".
- 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 pic-tures below.

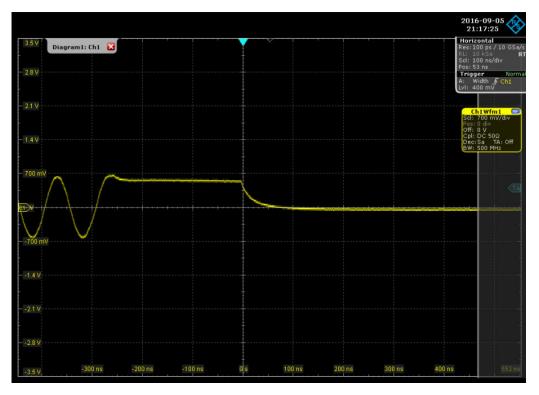


Figure 6-24: Waveform with load 1

# **10BASE-T tests** 10BASE-Te tests

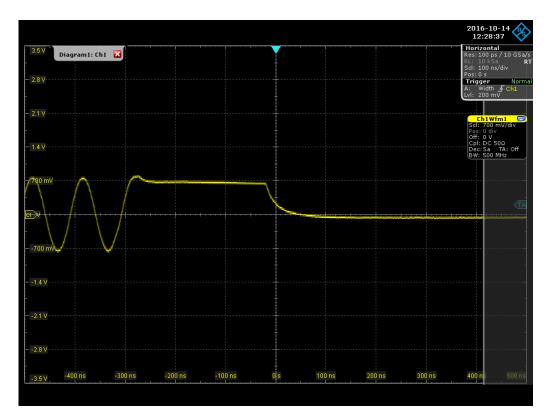


Figure 6-25: Waveform with load 2

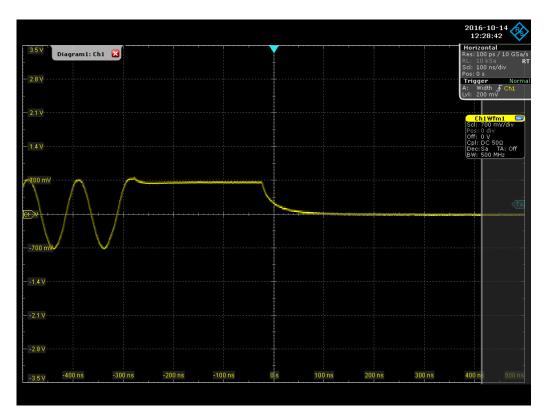


Figure 6-26: Waveform with load 100  $\varOmega$ 

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

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)".

10BASE-Te tests

R&S ScopeSu	ite						_ 🗆 ×
🕒 Back	Session 10BASE-T_20190919_134010			Ŕ	Show Report	About	P Help
•	All	Properties	Limit Manager	Results	Instruments	Report Con	nfig
	▲ No TPM	EEE					
	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)		10 Base-Te	e			
	Peak Differential Voltage (14.3.1.2.1)	Test Setu	р				
	Harmonic Content (14.3.1.2.1)	# of /	Acqs for Jitter Mea	is 10000	)		
	Output Timing Jitter (14.3.1.2.3)	<i>"</i> 017	legs for sitter mea		, 		
	▲ With TPM	MAU Typ	e				
	Link Test Pulse Template (14.3.1.2.1)		Internal MAU	U 🔿 Ext	ernal MAU		
	TP_IDL Template (14.3.1.2.1)						
	MAU Template (14.3.1.2.1)						
	Output Timing Jitter (14.3.1.2.3)						
	▲ Common						
	Transmitter Return Loss (14.3.1.2.2)						
	Receiver Return Loss (14.3.1.3.4)						
	Common-mode Output Voltage (14.3.1.2.5)						
🔄 Test Ch	ecked 🕨 Test Single						
Ready to run.				_			

- 4. Click "Test Single".
- 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 pseudorandom 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.

## 6.4.3.3 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)".

R&S ScopeS	Suite	×
🕒 Back	Session 10BASE-T_20190919_134010	🖹 Show Report 🚺 About 👔 Help
	All	Properties Limit Manager Results Instruments Report Config
	No TPM	EEE
	Link Test Pulse Template (14.3.1.2.1)	
	TP_IDL Template (14.3.1.2.1)	10 Base-Te
	Peak Differential Voltage (14.3.1.2.1)	Test Setup
	Harmonic Content (14.3.1.2.1)	# of Acqs for Jitter Meas 10000
	Output Timing Jitter (14.3.1.2.3)	" of Acqs for fitter meas
	▲ With TPM	MAU Type
	Link Test Pulse Template (14.3.1.2.1)	Internal MAU  External MAU
	TP_IDL Template (14.3.1.2.1)	
	MAU Template (14.3.1.2.1)	
	Output Timing Jitter (14.3.1.2.3)	
	▲ Common	
	Transmitter Return Loss (14.3.1.2.2)	
	Receiver Return Loss (14.3.1.3.4)	
	Common-mode Output Voltage (14.3.1.2.5)	
🛃 Test C	hecked Fast Single	
Ready to run	ı.	

- 4. Click "Test Single".
- 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 pseudorandom 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, subclause 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)".

#### 10BASE-Te tests

🕒 Back	Session 10BASE-T_20190919_134010	Show Report 1 About 1 Help
	▲ All	Properties Limit Manager Results Instruments Report Config
	▲ No TPM	EEE
	Link Test Pulse Template (14.3.1.2.1)	
	TP_IDL Template (14.3.1.2.1)	10 Base-Te
<b>~</b>	Peak Differential Voltage (14.3.1.2.1)	Test Setup
	Harmonic Content (14.3.1.2.1)	Average Count 10
	Output Timing Jitter (14.3.1.2.3)	
	▲ With TPM	
	Link Test Pulse Template (14.3.1.2.1)	
	TP_IDL Template (14.3.1.2.1)	
	MAU Template (14.3.1.2.1)	
	Output Timing Jitter (14.3.1.2.3)	
	▲ Common	
	Transmitter Return Loss (14.3.1.2.2)	
	Receiver Return Loss (14.3.1.3.4)	
	Common-mode Output Voltage (14.3.1.2.5)	
✓ Test	Checked Fast Single	

- 4. Click "Test Single".
- 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.

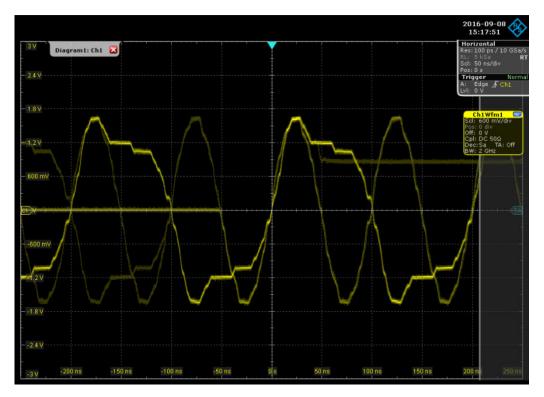


Figure 6-27: Waveform of 10BASE-Te random data

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

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

Table 6-16: Equipment for Harmonic Content test

#### 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)".

R&S ScopeSuite	_ □ ×
<b>Back</b> Session 10BASE-T_20190919_134010	R Show Report 1 About 1 Help
<ul> <li>All</li> </ul>	Properties Limit Manager Results Instruments Report Config
No TPM	EEE
Link Test Pulse Template (14.3.1.2.1)	
TP_IDL Template (14.3.1.2.1)	10 Base-Te
Peak Differential Voltage (14.3.1.2.1)	Test Setup
Harmonic Content (14.3.1.2.1)	Average Count 10
Output Timing Jitter (14.3.1.2.3)	Weldge count in
With TPM	
Link Test Pulse Template (14.3.1.2.1)	
TP_IDL Template (14.3.1.2.1)	
MAU Template (14.3.1.2.1)	
Output Timing Jitter (14.3.1.2.3)	
Common	
Transmitter Return Loss (14.3.1.2.2)	
Receiver Return Loss (14.3.1.3.4)	
Common-mode Output Voltage (14.3.1.2.5)	
Test Checked Test Single	
Ready to run.	

- 4. Click "Test Single".
- 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  $\mu$ s 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

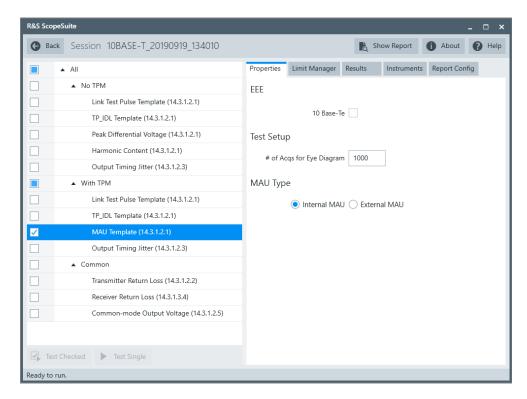
#### Table 6-17: Equipment for MAU template test

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)".

#### 10BASE-Te tests



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

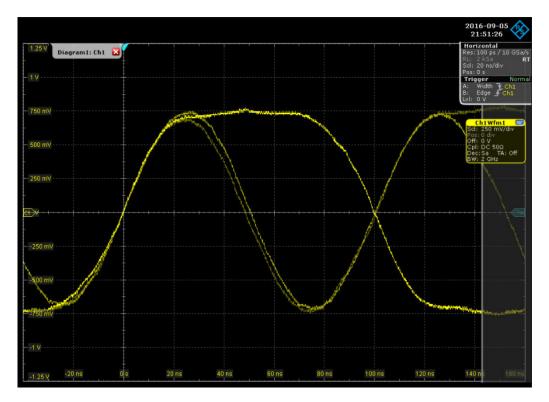
#### Further steps:

• 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

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 auto- matic test)	R&S ZNB/ZNC/ZND/ZVL	1
DUT	the device you want to test	1

Table 6-18: Equipment for Transmitter Return Loss

#### 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)".

R&S ScopeSu	uite						_ 🗆 ×
🖨 Back	Session 10BASE-T_20190919_134010			là s	Show Report	About	🕐 Help
	All	Properties	Limit Manager	Results	Instruments	Report Con	fig
	▲ No TPM						
	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)						
	Peak Differential Voltage (14.3.1.2.1)						
	Harmonic Content (14.3.1.2.1)						
	Output Timing Jitter (14.3.1.2.3)						
	▲ With TPM						
	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)						
	MAU Template (14.3.1.2.1)						
	Output Timing Jitter (14.3.1.2.3)						
	▲ Common						
	Transmitter Return Loss (14.3.1.2.2)						
	Receiver Return Loss (14.3.1.3.4)						
	Common-mode Output Voltage (14.3.1.2.5)						
Test Ch	necked 🕨 Test Single						
Ready to run.							

- 4. Click "Test Single".
- 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 auto- matic 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)".

#### 10BASE-Te tests

R&S ScopeS	uite						>
🕒 Back	Session 10BASE-T_20190919_134010			k	Show Report	1 About	P Help
	All	Properties	Limit Manager	Results	Instruments	Report Cor	ifig
	▲ No TPM						
	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)						
	Peak Differential Voltage (14.3.1.2.1)						
	Harmonic Content (14.3.1.2.1)						
	Output Timing Jitter (14.3.1.2.3)						
	▲ With TPM						
	Link Test Pulse Template (14.3.1.2.1)						
	TP_IDL Template (14.3.1.2.1)						
	MAU Template (14.3.1.2.1)						
	Output Timing Jitter (14.3.1.2.3)						
	▲ Common						
	Transmitter Return Loss (14.3.1.2.2)						
<u> /</u>	Receiver Return Loss (14.3.1.3.4)						
	Common-mode Output Voltage (14.3.1.2.5)						
Test Ch	necked 🕨 Test Single						
eady to run							

- 4. Click "Test Single".
- 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 Volt- age" 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)".

R&S ScopeS	uite	_ □ ×
🕒 Back	Session 10BASE-T_20190919_134010	R Show Report 1 About 1 Help
	All	Properties Limit Manager Results Instruments Report Config
	▲ No TPM	Test Setup
	Link Test Pulse Template (14.3.1.2.1)	Measurement Time 1E-05 s
	TP_IDL Template (14.3.1.2.1)	Measurement Time 1E-05 s
	Peak Differential Voltage (14.3.1.2.1)	Test Fixture
	Harmonic Content (14.3.1.2.1)	RT-ZF2 (SMA)      RT-ZF2
	Output Timing Jitter (14.3.1.2.3)	
	▲ With TPM	
	Link Test Pulse Template (14.3.1.2.1)	
	TP_IDL Template (14.3.1.2.1)	
	MAU Template (14.3.1.2.1)	
	Output Timing Jitter (14.3.1.2.3)	
	▲ Common	
	Transmitter Return Loss (14.3.1.2.2)	
	Receiver Return Loss (14.3.1.3.4)	
	Common-mode Output Voltage (14.3.1.2.5)	
🔄 Test C	hecked 🕨 Test Single	
Ready to run	L.	

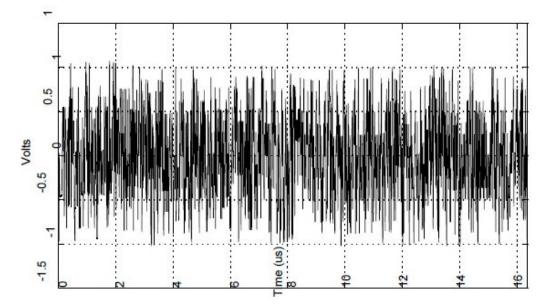
- 4. Click "Test Single".
- Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

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.

	Differential probe	Test fixture	Additional instruments
Maximum Output Droop	1	R&S RT-ZF2	Optional:
(126.5.3.1)	at least 1.5	Section:	R&S RTO / R&S
Transmitter Timing Jitter Mas- ter Mode and Clock Frequency	GHz band- width	Resistive Load	RTO6 /R&S RTP-K17
(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 Dis-	_	R&S RT-ZF2	Spectrum analyzer:
tortion		Section:	R&S FSV/FSQ/FSW/ESRP
(126.5.3.2)		Return Loss	Optional:
			R&S RTO / R&S RTO6 /R&S RTP-K17

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

	Differential probe	Test fixture	Additional instruments
Transmitter Non-Linearity Dis- tortion 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

•	Starting 2.5GBASE-T tests	170
	Test configuration for Ethernet 2.5GBASE-T	
•	Maximum output droop	172
	Transmitter non-linearity distortion	
•	Transmitter non-linearity distortion with disturber	179
•	Transmitter timing jitter master mode and clock frequency	.184
•	Transmitter timing jitter slave mode	186
•	Transmitter power spectral density and power level	189
•	MDI return loss	.190

# 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.

RSScopeSuite						□ ×
<b>G</b> Back Session 2,5GBASE-T_20160509_154425				Show Report	About	B Help
🖌 🔺 All	Properties	Limit Manager	Results	Instruments	Report Config	
Maximum Output Droop (126.5.3.1)	Pair					
Transmitter Non-linear Distortion (126.5.3.2)			вОсО	D		
Transmitter Timing Jitter Master Mode and Clock Frequency			BOCO	D		
Transmitter Timing Jitter Slave Mode (126.5.3.3)	Test Setu	р				
<ul> <li>Transmitter Power Spectral Density and Power Level</li> </ul>		Average Cour	nt 10			
MDI Return Loss (126.8.2.1)		Measurement Tim	e 0.004	s		
				5		
		No. of Acquisition	is 512			
Test Checked						
Ready to run.						

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

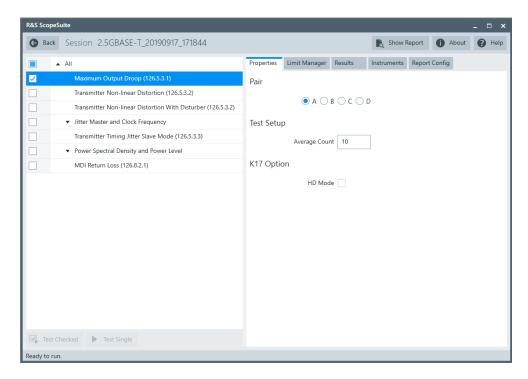
Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 600 MHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 1.5 GHz bandwidth	1
DUT	2.5GBASE-T device to be tested	1

#### 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)".

## 2.5/5/10 G tests

2.5GBASE-T tests



- 3. Click "Test Single".
- 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:

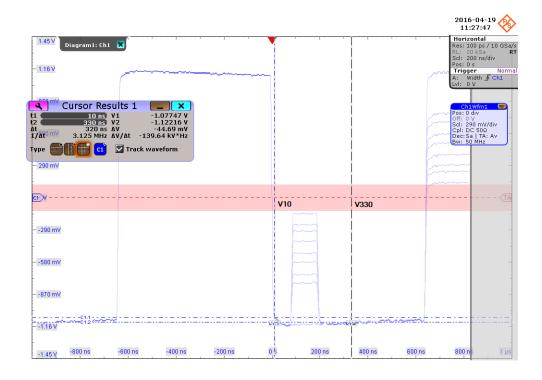
Measure the voltage ratio between V<sub>10</sub> (10 ns after the positive zero crossing) and V<sub>330</sub> (330 ns after the positive zero crossing) of a rising edge.

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  $V_{330}$ .

				2016-04-19 11:27:46
1.45 V         Diagram1: Ch1         X           -1.16 V         -C1.1         -C1.1           -1.16 V         -C1.1         -C1.1           -1.16 V         -C1.1         -C1.1           -1.16 V         -C1.1         -C1.1           -1.12 320         -C1.1         -C1.1           -1.12 320         -C1.1         -C1.1           -1.12 320         -C1.1         -C1.1           -1.12 320         -C1.1         -C1.2           -1.12 320         -C1.1         -C1.1           -1.12	V V IV			Horizontal           Res: 100 ps / 10 GSa/s           R1: 20 Vs30           RT           Sci: 200 ns/div           Pos: 0 s           Normal           A: Width t Chi           Vd: 0 V           ChiWfm1           Pos: 0 div           Ori: 0 0 mV/div           Ori: 0 0 mV/div           Open SJ TA: Av
Type Track waveform				Bw: 50 MHz
				-
€ <b>_</b> ¥		V10	V330	TA
290 mV				
580 mV				
870 mV				_
-1.18V		1.4 01	2	
-1.45 V -800 ns -600 ns -400 r	ns -200 ns 0	200 ns	400 ns 600 ns	800 ns 1 μs

Measure the voltage ratio between V<sub>10</sub> (10 ns after the positive zero crossing) and V<sub>330</sub> (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.

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

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

## 7.1.4.1 Test equipment

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)".

R&S ScopeSuit	te							_ 0	×
🖨 Back	Session 2.5GBASE-T_20190917_171844				Show F	Report 🚺	About	0	Help
	11	Properties	Limit Manager	Results	Instruments	Report Confi	g		
	Maximum Output Droop (126.5.3.1)	Pair							
	Transmitter Non-linear Distortion (126.5.3.2)			вОсО	D				
	Transmitter Non-linear Distortion With Disturber (126.5.3.2)		O A O	BOLO	D				
	<ul> <li>Jitter Master and Clock Frequency</li> </ul>	Test Setu	c						
	Transmitter Timing Jitter Slave Mode (126.5.3.3)		Average Cour	nt 10	7				
	<ul> <li>Power Spectral Density and Power Level</li> </ul>								
	MDI Return Loss (126.8.2.1)								
✓ Test Che	cked 🕨 Test Single								
Ready to run.									

- 3. Click "Test Single".
- 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.

# R&S<sup>®</sup>RTO, R&S<sup>®</sup>RTO6, R&S<sup>®</sup>RTP

# 2.5/5/10 G tests 2.5GBASE-T tests

1AP Clrw		2		2	2			
dBm				-				
LO dBm								
20 d8m		-						
30 dBm		~						
0 dBm		_						
0 dBm		-	-	-				
i0 d8m	-							
ter bitter litte	to the second	in the star	welling the	Lini India	Will still us	todontocia	tilet a bile	all an in

Figure 7-2: First dual tone (9.179688MHz, and 10.35156MHz)

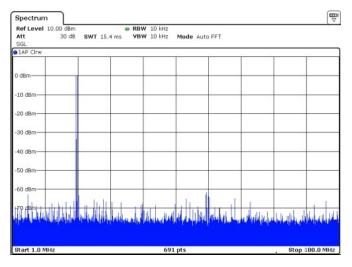


Figure 7-3: Second dual tone (19.72656MHz and 20.11719MHz)

# R&S<sup>®</sup>RTO, R&S<sup>®</sup>RTO6, R&S<sup>®</sup>RTP

# 2.5/5/10 G tests 2.5GBASE-T tests

Spectrum Ref Level 10.00 dBm	e RB	W 10 kHz		
Att 30 dB SGL	SWT 15.4 ms VB	W 10 kHz Mode Aut	O FFT	
1AP Cirw		10 - 10 -	12 17 I	0 - 19312
0 dBm				
-10 dBm				
-20 dBm				
30 dBm				
40 dBm				
50 dBm				
-60 dBm				
		lunellisted at the holes	hillshalls ing the ba	a het statute og statut
Start 1.0 MHz		691 pts		Stop 100.0 MHz

Figure 7-4: Third dual tone (34.96094MHz and 35.35156MHz)

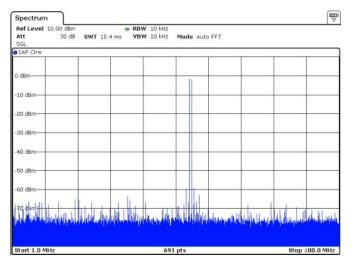


Figure 7-5: Fourth dual tone (54.10156MHz and 54.88281MHz)

Ref Level 10.0 Att			W 10 kHz	Mode Auto	FET			
SGL	JU UD AWI	13.4 115 41	544 10 KHZ	Mode Hoto	FF I			
1AP Clrw	2	12	1			7		
0 dBm			-	-		27	-	-
10 dBm								
10 0011		10						
-20 dBm								+
-30 dBm								
-30 dBm		53-						
40 dBm		50	-				-	
-50 dBm								
-60 dBm			-				-	
1.1.1	100			1	000			
70 630		all sub	dilla dal d	ul . d	ul. I.			and the
Locate and the	an an Andalan	Konse di Manela	diate ministry bird	Mar Burger	n (nasharn) sh	Participation of the		10 - alexandra

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.

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

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 $F_{\rm C}$ = 45 MHz and bandwidth $B_{\rm n}$ = 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 Chapter 7.1.1, "Starting 2.5GBASE-T tests", on page 170.
- 2. Select the test case: "Transmitter Non-linearity Distortion with Disturber (126.5.3.2)".

R&S ScopeSuite							_ 🗆 ×	
<b>G</b> Back Session 2.5GBASE-T_20190917_171844				🖹 Show F	Report	About	🕐 Help	
All	Properties	Limit Manager	Results	Instruments	Report Co	onfig		
Maximum Output Droop (126.5.3.1)	Pair							
Transmitter Non-linear Distortion (126.5.3.2)			вОсО	5				
Transmitter Non-linear Distortion With Disturber (126.5.3.2)		• A •	BOCO	D				
Jitter Master and Clock Frequency	Test Setu	р						
Transmitter Timing Jitter Slave Mode (126.5.3.3)		Average Cour						
Power Spectral Density and Power Level								
MDI Return Loss (126.8.2.1)								
Test Checked Test Single								
Ready to run.								

- 3. Click "Test Single".
- 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.

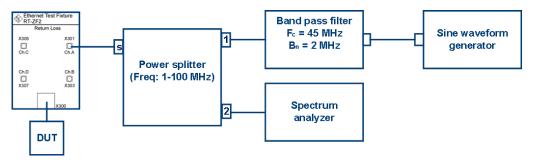


Figure 7-7: Test setup

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.

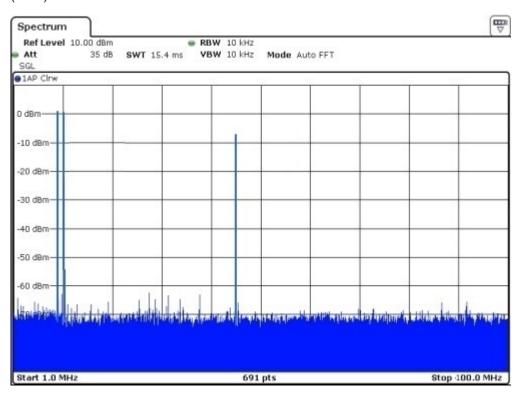


Figure 7-8: First dual tone (9.179688MHz, and 10.35156MHz)

2.5/5/10 G tests

### 2.5GBASE-T tests

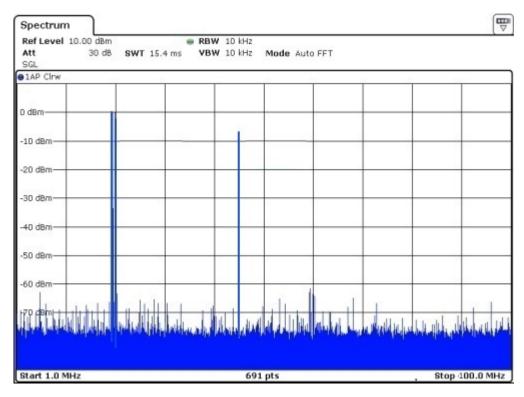


Figure 7-9: Second dual tone (19.72656MHz and 20.11719MHz)

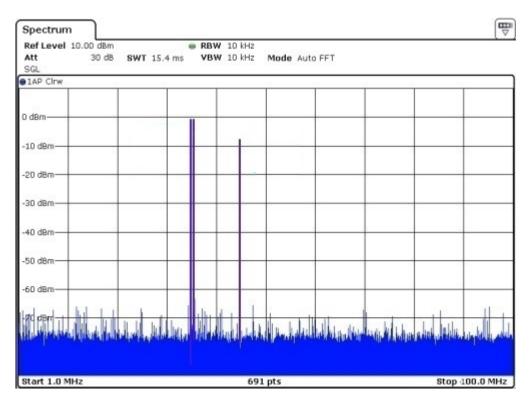


Figure 7-10: Third dual tone (34.96094MHz and 35.35156MHz)

2.5/5/10 G tests

### 2.5GBASE-T tests

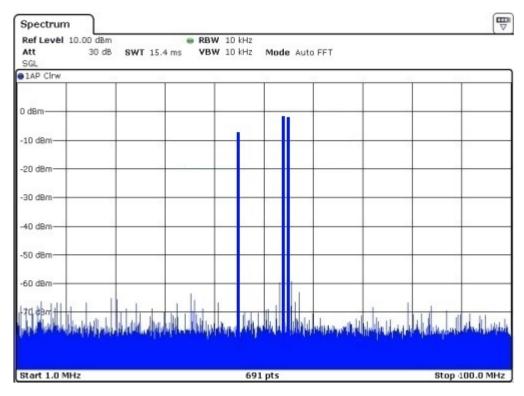


Figure 7-11: Fourth dual tone (54.10156MHz and 54.88281MHz)

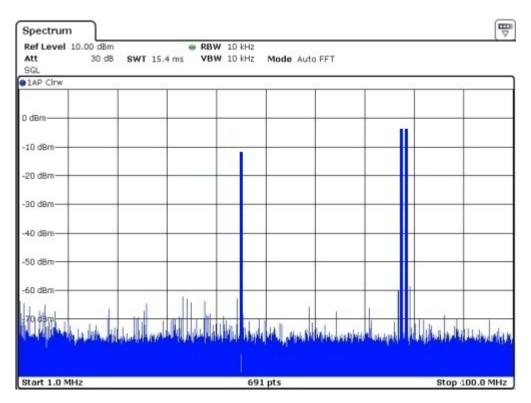


Figure 7-12: Fifth dual tone (77.53906MHz and 78.32031MHz)

### 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

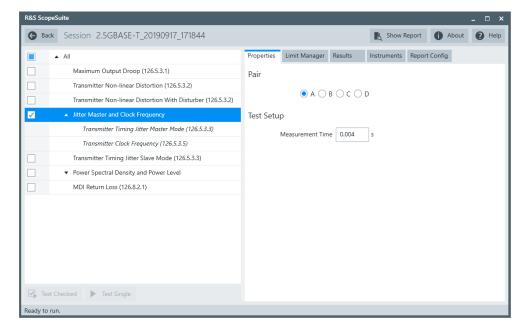
Table 7-5: Equipment for Transmitter Timing Jitter Master Mode and Clock Frequency test

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".

### 2.5GBASE-T tests



- 3. Click "Test Single".
- 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.

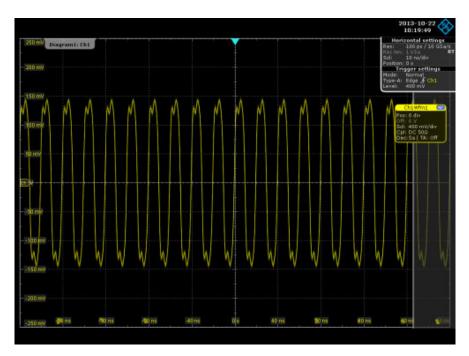


Figure 7-13: Test mode 2 waveform

## 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

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)".

R&S ScopeSuite		_ □ ×
<b>Back</b> Session 2.5GBASE-T_20190917_171844		Show Report 1 About 1 Help
▲ All	Properties Limit Manager Results	Instruments Report Config
Maximum Output Droop (126.5.3.1)	Test Setup	
Transmitter Non-linear Distortion (126.5.3.2)	Measurement Time 0.004	7.
Transmitter Non-linear Distortion With Disturber (126.5.3.2)	Measurement Time 0.004	S
Jitter Master and Clock Frequency		
Transmitter Timing Jitter Slave Mode (126.5.3.3)		
Power Spectral Density and Power Level		
MDI Return Loss (126.8.2.1)		
Test Checked Test Single Ready to run.		

- 3. Click "Test Single".
- 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.

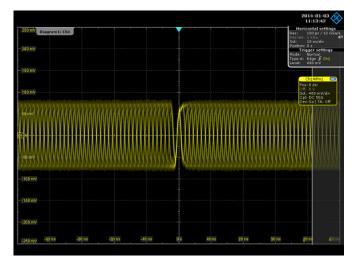


Figure 7-15: Test mode 1 waveform

## 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".

R&S ScopeS	uite							_ 🗆	×
🕒 Back	Session 2.5GBASE-T_20190917_171844				Show R	Report	() About	🕐 He	р
	All	Properties	Limit Manager	Results	Instruments	Report	Config		
	Maximum Output Droop (126.5.3.1)	Pair							
	Transmitter Non-linear Distortion (126.5.3.2)			вОсОг	-				
	Transmitter Non-linear Distortion With Disturber (126.5.3.2)		• A •						
	▼ Jitter Master and Clock Frequency	Test Setu	р						
	Transmitter Timing Jitter Slave Mode (126.5.3.3)		No. of Acquisition	s 512	1				
	Power Spectral Density and Power Level								
	Transmitter Power Spectral Density (126.5.3.4)								
	Transmitter Power Level (126.5.3.4)								
	MDI Return Loss (126.8.2.1)								
Test Cf	recked 🕨 Test Single								
Ready to run									

- 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

### 7.1.8.3 Test setup

Configure the DUT to test mode 5.

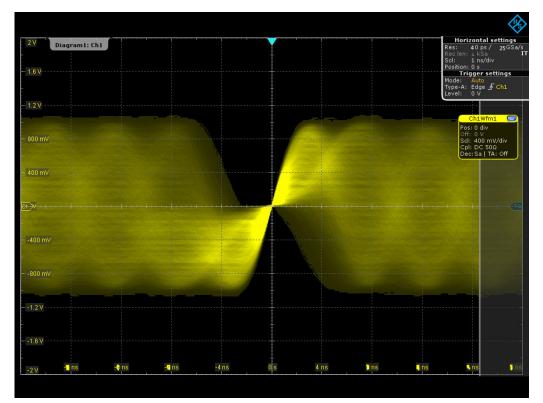


Figure 7-16: Test mode 5 waveform

### 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<sup>TM</sup>/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)".

R&S ScopeSu	iite						_   >
🕒 Back	Session 2.5GBASE-T_20190917_171844				💦 Show F	Report 1 Ab	out 🕐 Help
	All	Properties	Limit Manager	Results	Instruments	Report Config	
	Maximum Output Droop (126.5.3.1)	Pair					
	Transmitter Non-linear Distortion (126.5.3.2)						
	Transmitter Non-linear Distortion With Disturber (126.5.3.2)		• A ()	B () C ()	D		
	<ul> <li>Jitter Master and Clock Frequency</li> </ul>						
	Transmitter Timing Jitter Slave Mode (126.5.3.3)						
	<ul> <li>Power Spectral Density and Power Level</li> </ul>						
	MDI Return Loss (126.8.2.1)						
⊡ Test Ch	ecked 🕨 Test Single						
Ready to run.							

- 3. Click "Test Single".
- 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.

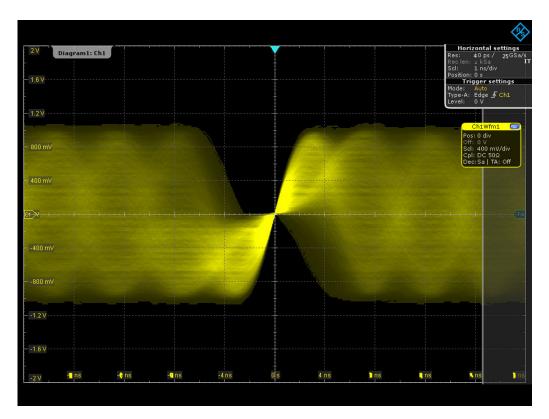


Figure 7-17: Test mode 5 waveform

### 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 (\*.slp 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.

	Differential probe	Test fixture	Additional instruments
Maximum Output Droop	1	R&S RT-ZF2	Optional:
(126.5.3.1)	at least 3 GHz band-	Section:	R&S RTO / R&S
Transmitter Timing Jitter Mas- ter Mode and Clock Frequency	GHZ band- width	Resistive Load	RTO6 /R&S RTP-K17
(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 Dis- tortion	-	R&S RT-ZF2	Spectrum analyzer:
(126.5.3.2)		Section:	R&S FSV/FSQ/FSW/ESRP
(120.0.0.2)		Return Loss	Optional:
			R&S RTO / R&S RTO6 /R&S RTP-K17
MDI Return Loss	-	R&S RT-ZF2	VNA:
(126.8.2.1)		Section:	R&S ZNB or
		Twisted Pair Model	R&S ZNC or
			R&S ZND or
			R&S ZVL

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

•	Starting 5GBASE-T tests	193
•	Test configuration for Ethernet 5GBASE-T	194
•	Maximum output droop	195
•	Transmitter non-linearity distortion	. 198
•	Transmitter timing jitter master mode and clock frequency	.202
•	Transmitter timing jitter slave mode	204
•	Transmitter power spectral density and power level	. 207
•	MDI return loss	.208

# 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".
- 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.

R&S ScopeSuite						□ ×
G Back Session 5GBASE-T_20220607_093234			🖹 Sh	iow Report	About (	P Help
All	Properties	Limit Manager	Results	Instruments	Report Config	
Maximum Output Droop (126.5.3.1)	Pair					
Transmitter Non-linear Distortion (126.5.3.2)			вОсО	D		
Jitter Master and Clock Frequency		● A ●	BOUD	D		
Transmitter Timing Jitter Master Mode (126.5.3.3)	Test Setu	p				
Transmitter Clock Frequency (126.5.3.5)		Average Cour	nt 10	7		
Transmitter Timing Jitter Slave Mode (126.5.3.3)		2				
Power Spectral Density and Power Level	K17 Optio	on				
Transmitter Power Spectral Density (126.5.3.4)		HD Mod	e			
Transmitter Power Level (126.5.3.4)						
MDI Return Loss (126.8.2.1)						
Test Checked Test Single						
Report Generated Successfully.						

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

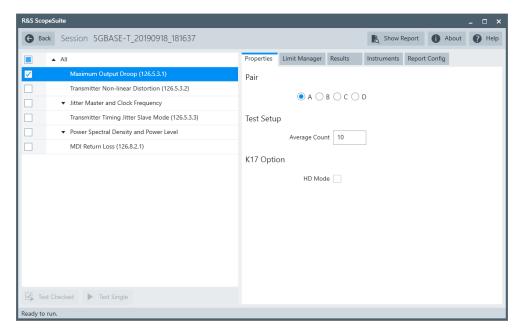
Table 7-10: Equipment for Maximum Output Droop test
---

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)".

5GBASE-T tests



- 3. Click "Test Single".
- 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.

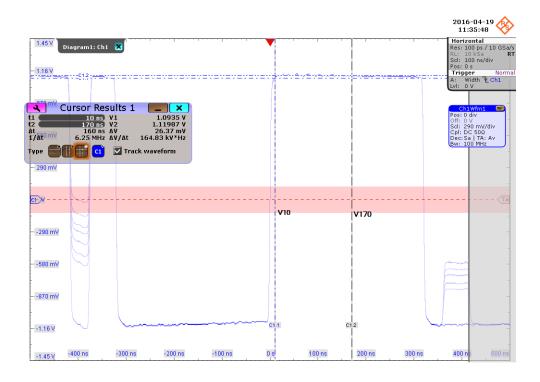
In test mode 6, the DUT transmits 128 +16 symbols followed by 128 -16 symbols continuously on all four transmitters.

### 7.2.3.4 Measurements

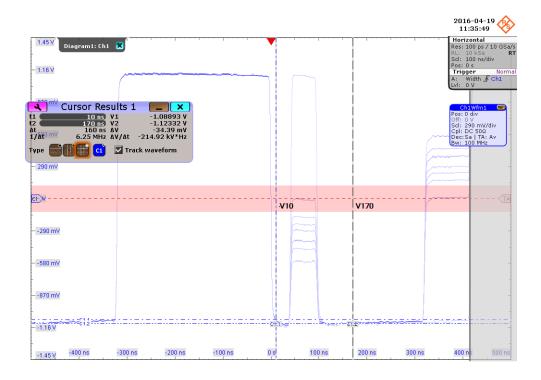
The test makes two measurements:

Measure the voltage ratio between V<sub>10</sub> (10 ns after the zero crossing) and V<sub>170</sub> (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<sub>10</sub> (10 ns after the zero crossing) and V<sub>170</sub> (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<sub>10</sub> and "Cursor 2" at V<sub>170</sub>. The software determines the voltage ratio by measuring the voltage levels at V<sub>10</sub> and V<sub>170</sub>.



# 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.

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

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

### 7.2.4.1 Test equipment

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)".

R&S ScopeSuite	×
G Back Session 5GBASE-T_20190918_181637	C Show Report 1 About 1 Help
All	Properties Limit Manager Results Instruments Report Config
Maximum Output Droop (126.5.3.1)	Pair
Transmitter Non-linear Distortion (126.5.3.2)	
Jitter Master and Clock Frequency	
Transmitter Timing Jitter Slave Mode (126.5.3.3)	Test Setup
Power Spectral Density and Power Level	Average Count 10
MDI Return Loss (126.8.2.1)	
☑ Tect Charked ► Tect Sinole	
✓ Test Checked     ✓ Test Single Ready to run.	

- 3. Click "Test Single".
- 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.

# R&S<sup>®</sup>RTO, R&S<sup>®</sup>RTO6, R&S<sup>®</sup>RTP

# 2.5/5/10 G tests 5GBASE-T tests

1AP Clrw	-				1		1
dBm							
10 dBm	-						
20 dBm						-	
30 dBm							
HD dBm							
50 dBm	-		-				
50 d8m	-						
toutethe Hills	Libra cure hill	it is the state	and the des	Line London and	Wallace Under	In the Hilder of	the sector

Figure 7-19: First dual tone (9.179688MHz, and 10.35156MHz)

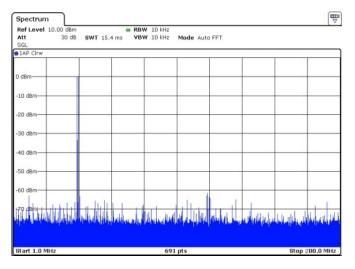


Figure 7-20: Second dual tone (19.72656MHz and 20.11719MHz)

# R&S<sup>®</sup>RTO, R&S<sup>®</sup>RTO6, R&S<sup>®</sup>RTP

# 2.5/5/10 G tests 5GBASE-T tests

Spectrum			
Ref Level 10.00 dBm Att 30 dB SGL	SWT 15.4 ms RBW 10 kHz VBW 10 kHz	Mode Auto FFT	
91AP Clrw			
0 dBm			
-10 dBm			
-20 dBm			
-30 dBm			
-40 dBm			
-50 dBm-			
-60 dBm			
	المعادرا ومساور المحروبين والمرابع	d an hale little and a line below	100 a lieb a billin a sa balla adah
Start 1.0 MHz	691	. pts	Stop 200.0 MHz

Figure 7-21: Third dual tone (34.96094MHz and 35.35156MHz)

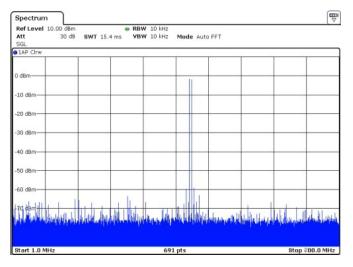


Figure 7-22: Fourth dual tone (54.10156MHz and 54.88281MHz)

Att	30 dB	SWT 15.4	4 ms VB	₩ 10 kHz	Mode Auto	FFT			
1AP Clrw							-	-	
0 dBm									-
10 dBm	-								
-20 dBm									
-30 dBm									
40 dBm	-	5		-					
-50 d8m									
-60 dBm	- 1		lli L						
	uhh.	hullan		A Martine	H. shull	la la contra	a shipe	lighter	Hideorh

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

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".

R&S ScopeS	R&S ScopeSuite _ □ ×							
🕒 Back	Session 5GBASE-T_20190918_181637				💦 Show F	Report	About	🕐 Help
	All	Properties	Limit Manager	Results	Instruments	Report Co	onfig	
	Maximum Output Droop (126.5.3.1)	Pair						
	Transmitter Non-linear Distortion (126.5.3.2)							
	Jitter Master and Clock Frequency		• A •	B () C ()	D			
	Transmitter Timing Jitter Master Mode (126.5.3.3)	Test Setu	p					
	Transmitter Clock Frequency (126.5.3.5)	Measurement Time 0.002 s						
	Transmitter Timing Jitter Slave Mode (126.5.3.3)							
	<ul> <li>Power Spectral Density and Power Level</li> </ul>							
	MDI Return Loss (126.8.2.1)							
Test Ch	necked 🕨 Test Single							
Ready to run.								

- 3. Click "Test Single".
- 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.

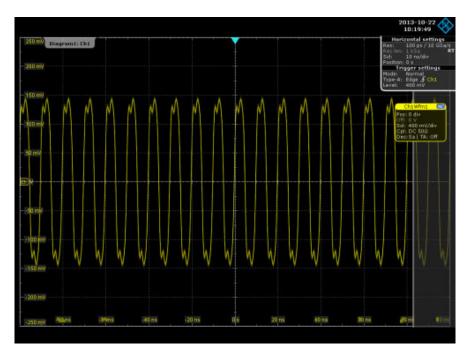


Figure 7-24: Test mode 2 waveform

## 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 Tra	ansmitter 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)".

R&S ScopeSuite			_ 🗆 ×
<b>Back</b> Session 5GBASE-T_20190918_181637		Abo	ut 🕐 Help
<ul> <li>All</li> </ul>	Properties Limit Manager Results	Instruments Report Config	
Maximum Output Droop (126.5.3.1)	Test Setup		
Transmitter Non-linear Distortion (126.5.3.2)		٦.	
□ Jitter Master and Clock Frequency	Measurement Time 0.002	S	
Transmitter Timing Jitter Slave Mode (126.5.3.3)			
Power Spectral Density and Power Level			
MDI Return Loss (126.8.2.1)			
✓ Test Checked ► Test Single			
Ready to run.			

- 3. Click "Test Single".
- 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.

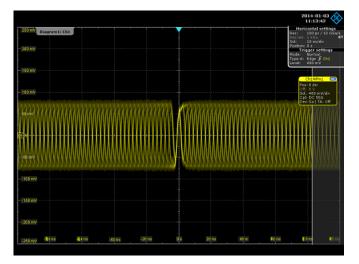


Figure 7-26: Test mode 1 waveform

## 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.

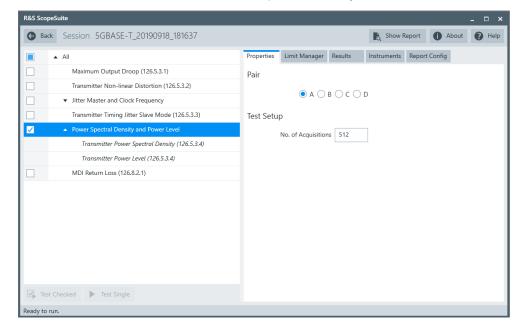
### 7.2.7.1 Test equipment

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.

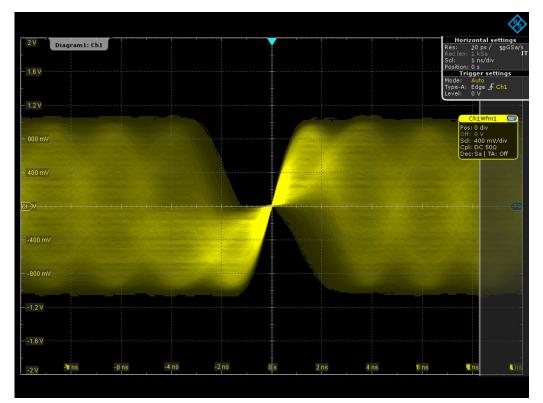


Figure 7-27: Test mode 5 waveform

### 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<sup>TM</sup>/D2.1 specification, section 126.8.2.1.

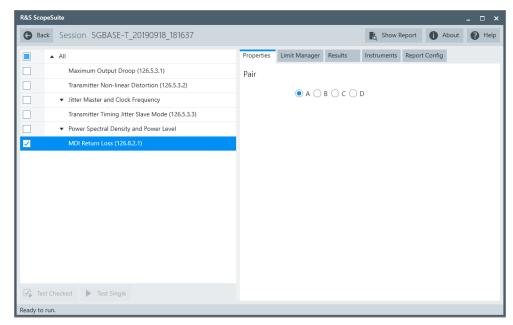
### 7.2.8.1 Test equipment

#### 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".
- 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.

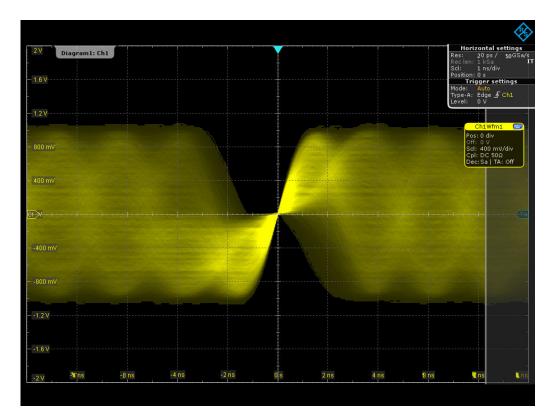


Figure 7-28: Test mode 5 waveform

### 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 (\*.slp 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.

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

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

Starting 10GBASE-T tests	211
Test configuration for Ethernet 10GBASE-T	
Maximum output droop	
Transmitter linearity	
Transmitter timing jitter master mode and clock frequency	
Transmitter timing jitter slave mode	
Transmitter power spectral density and power level	
MDI return loss	
	Starting 10GBASE-T tests Test configuration for Ethernet 10GBASE-T Maximum output droop Transmitter linearity Transmitter timing jitter master mode and clock frequency Transmitter timing jitter slave mode Transmitter power spectral density and power level MDI return loss.

# 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.

RSScopeSuit	e					_ 🗆 ×
🕒 Back	Session Ethernet10G_20160210_104816			Show Repo	ort 🚺 Aba	out 🕐 Help
A 1	All	Properties	Limit Manager	Results	Instruments	Report Config
	Maximum Output Droop (55.5.3.1)	Pair				
	Transmitter Linearity (55.5.3.2)			вОсО	D	
	Transmitter Timing Jitter Master Mode and Clock Frequency		O A O	BOCO	D	
	Transmitter Timing Jitter Master Mode (55.5.3.3)	Test Setu	р			
	Transmitter Clock Frequency (55.5.3.5)		Average Cour	nt 10		
	Transmitter Timing Jitter Slave Mode (55.5.3.3)		Measurement Tim		_	
	Transmitter Power Spectral Density and Power Level				S	
	Transmitter Power Spectral Density (55.5.3.4)		No. of Acquisition	ns 512		
	Transmitter Power Level (55.5.3.4)					
<ul> <li>Image: A start of the start of</li></ul>	MDI Return Loss (55.8.2.1)					
Test Cf						
Ready to run.						

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

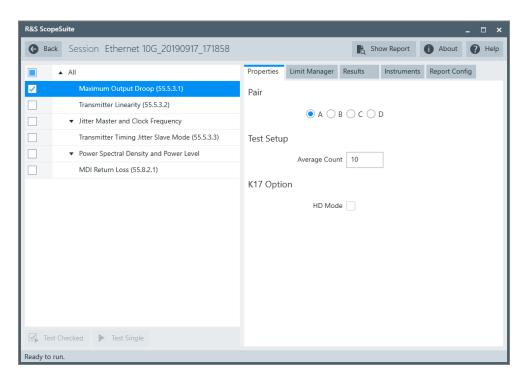
Item	Description, model	Quantity
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
Ethernet test fixture, "Resistive Load" section	R&S RT-ZF2	1
Differential probe	at least 2 GHz bandwidth	1
DUT	10GBASE-T device to be tested	1

Table 7-17: Equipment for Maximum Output Droop test

#### 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)".

10GBASE-T tests



- 3. Click "Test Single".
- 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.

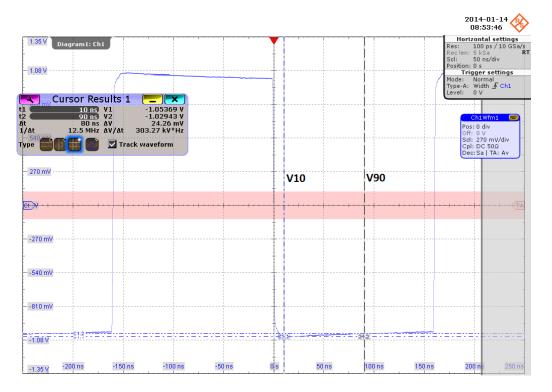
In test mode 6, the DUT transmits 128 +16 symbols followed by 128 -16 symbols continuously on all four transmitters.

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).

# 2.5/5/10 G tests 10GBASE-T tests

1.35 V Diagram 1			 7		Horizontal settings Res: 100 ps / 10 GS. Rec len: 5 kSa Sdl: 50 ns/div Position: 0 s Trigger settings Mode: Normal
10	Results 1 ( ns v1 ns v2	1.05481 V 1.03072 V			Type-A: Width 7 Ch1 Level: 0 V Ch1Wfm1
at 12.5 M	ins AV IHz AV/At -30	-24.1 m¥ 1.19 k¥*Hz			Chilving Pos: 0 div Off: 0 V Sd: 270 mV/div Cpl: DC 500 Dec: Sa   TA: Av
270 mV		-+ + +		···	
270 mV			 V10	V90	
540 mV					
810 mV					

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.

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

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

### 7.3.4.1 Test equipment

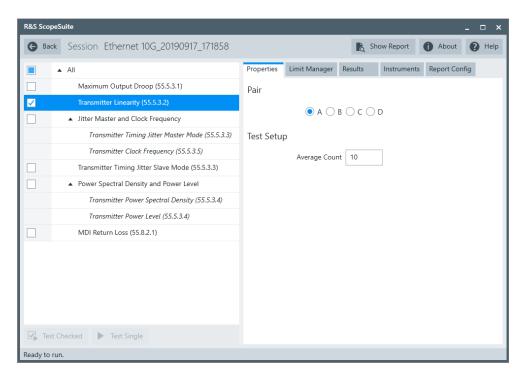
#### Table 7-18: Equipment for Transmitter Linearity test

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 Chapter 7.3.1, "Starting 10GBASE-T tests", on page 211.
- 2. Select the test case: "Transmitter Linearity (55.5.3.2)".

10GBASE-T tests



- 3. Click "Test Single".
- 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.

# R&S<sup>®</sup>RTO, R&S<sup>®</sup>RTO6, R&S<sup>®</sup>RTP

# 2.5/5/10 G tests 10GBASE-T tests

6GL		15.4 ms VB	W 10 kHz M	lode Auto FFT			
1AP Clrw	-	-			1		
dBm					_		
10 dBm			-				
20 dBm							
30 dBm							
10 dBm							
50 dBm							
50 dBm					-		
nu phile	et.line south	Hilling Land	The bill state of the	an production of the second	nellig unimetal	Hider des	-

Figure 7-30: 1st dual tone (36.718 MHz and 41.406 MHz)

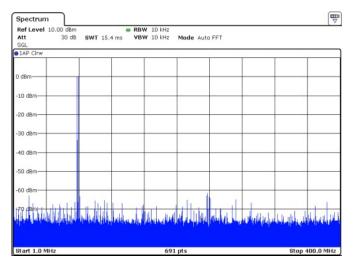


Figure 7-31: 2nd dual tone (78.906 MHz and 80.469 MHz)

# R&S<sup>®</sup>RTO, R&S<sup>®</sup>RTO6, R&S<sup>®</sup>RTP

# 2.5/5/10 G tests 10GBASE-T tests

Spectrum			
Ref Level 10.00 dBm Att 30 dB SGL	<ul> <li>RBW 10 kHz</li> <li>SWT 15.4 ms</li> <li>VBW 10 kHz</li> </ul>	Mode Auto FFT	
1AP Clrw			
0 dBm			
-10 dBm			
-20 dBm			
-30 dBm			
-40 dBm			
-50 dBm			
-60 dBm			
	Juli, Milding, Aller Augusta		
Start 1.0 MHz	69	1 pts	Stop 400.0 MHz

Figure 7-32: 3rd dual tone (139.844 MHz and 141.406 MHz)

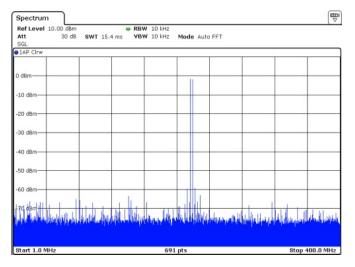


Figure 7-33: 4th dual tone (216.406 MHz and 219.531 MHz)

Ref Level 1			-	/ 10 kHz		0.52			
Att	30 dB SV	NT 15.4	ms VBV	V 10 kHz	Mode Auto	FFT			
1AP Clrw		20					/		
0 dBm		-					-	-	
							L 1		
-10 dBm									
-20 dBm									
-30 dBm		-							
-40 dBm		~							
40 GBIII									
-50 dBm						-			-
-60 dBm			11	1					
70 000									
	La lala de la	lank	a sasal	1 Hilling	14 .4.5.84	يباهيه بالم	a stand	Highing	والمرجولا
	an mar an ann bh dhana.	der with	LAND. Lan	in second of	the self-many		and of	Jacob and a second	na she ane effa
Start 1.0 MH	z			691	pts			Stop	400.0 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".

R&S ScopeS	uite						_ □	×
🕒 Back	Session Ethernet 10G_20190917_171858			Ŕ	Show Report	About	P He	elp
	All	Properties	Limit Manager	Results	Instruments	Report Cor	nfig	
	Maximum Output Droop (55.5.3.1)	Pair						
	Transmitter Linearity (55.5.3.2)				0.5			
	Jitter Master and Clock Frequency		• a •	вОсо	0 D			
	Transmitter Timing Jitter Master Mode (55.5.3.3)	Test Setu	р					
	Transmitter Clock Frequency (55.5.3.5)		Measurement Tim	e 0.001	s			
	Transmitter Timing Jitter Slave Mode (55.5.3.3)							
	Power Spectral Density and Power Level							
	Transmitter Power Spectral Density (55.5.3.4)							
	Transmitter Power Level (55.5.3.4)							
	MDI Return Loss (55.8.2.1)							
Test Ch	necked 🕨 Test Single							
Ready to run								

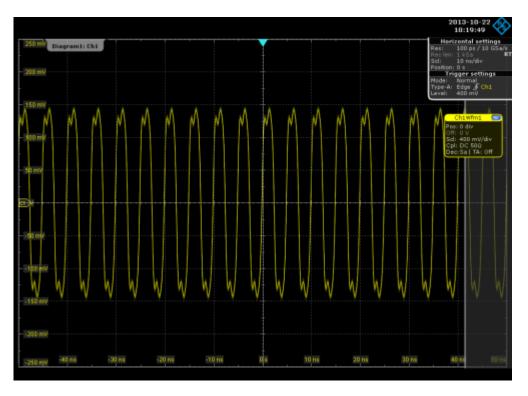
- 3. Click "Test Single".
- Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

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

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

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

### 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)".

R&S ScopeS	uite		_ □ ×
🕒 Back	Session Ethernet 10G_20190917_171858	Show Report	About 🛛 Help
	All	Properties Limit Manager Results Instruments	Report Config
	Maximum Output Droop (55.5.3.1)	Test Setup	
	Transmitter Linearity (55.5.3.2)	-	
	Jitter Master and Clock Frequency	Measurement Time 0.001 s	
	Transmitter Timing Jitter Master Mode (55.5.3.3)		
	Transmitter Clock Frequency (55.5.3.5)		
	Transmitter Timing Jitter Slave Mode (55.5.3.3)		
	<ul> <li>Power Spectral Density and Power Level</li> </ul>		
	Transmitter Power Spectral Density (55.5.3.4)		
	Transmitter Power Level (55.5.3.4)		
	MDI Return Loss (55.8.2.1)		
🔄 Test Cl	necked 🕨 Test Single		
Ready to run			

- 3. Click "Test Single".
- 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.

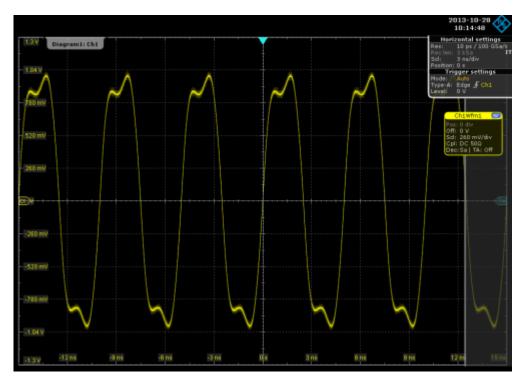


Figure 7-35: Test mode 3 waveform

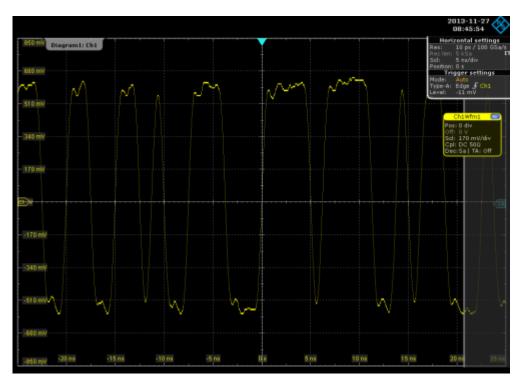


Figure 7-36: Test mode 1 waveform

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

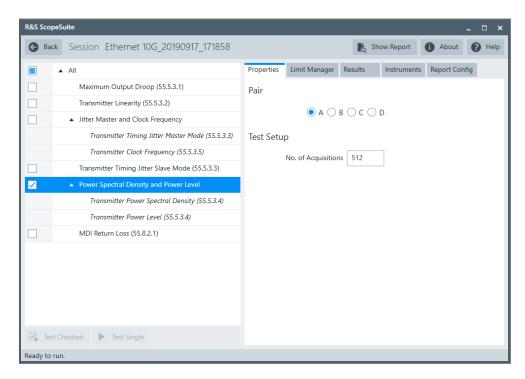
#### Table 7-21: Equipment for Transmitter Power Spectral Density and Power Level test

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 Chapter 7.3.1, "Starting 10GBASE-T tests", on page 211.
- 2. Select the test case: "Transmitter Power Spectral Density and Power Level".

10GBASE-T tests



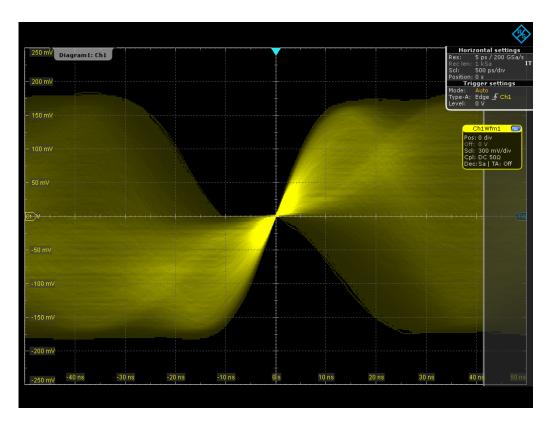
- 3. Click "Test Single".
- Follow the instructions of the step-by step guide.
   When you have finished all steps, the compliance test runs automatically.

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

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

Table 7-22: Equipment for MDI Return Loss test

#### 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)".

R&S ScopeSu	uite						_ 0	×
🕒 Back	Session Ethernet 10G_20190917_171858			à	Show Report	About	0	Help
	All	Properties	Limit Manager	Results	Instruments	Report Cor	nfig	
	Maximum Output Droop (55.5.3.1)	Pair						
	Transmitter Linearity (55.5.3.2)				0.5			
	Jitter Master and Clock Frequency		• A •	BOCO	<u> </u>			
	Transmitter Timing Jitter Master Mode (55.5.3.3)							
	Transmitter Clock Frequency (55.5.3.5)							
	Transmitter Timing Jitter Slave Mode (55.5.3.3)							
	Power Spectral Density and Power Level							
	Transmitter Power Spectral Density (55.5.3.4)							
	Transmitter Power Level (55.5.3.4)							
	MDI Return Loss (55.8.2.1)							
🕞 Test Ch	necked 🕨 Test Single							
Ready to run.								

- 3. Click "Test Single".
- 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.

	Diffe	erential type*	Single	-Ended type <sup>*</sup>	Additional
	Differ- ential probe	Test fixture	SMA	Test fixture (optional)	instruments
Transmitter output droop (96.5.4.1) Transmitter timing jit- ter master mode and clock frequency (96.5.4.3 and 96.5.4.5)	1 at least 1 GHz band- width	R&S RT-ZF2	2	R&S RT-ZF8	<b>Optional:</b> R&S RTO / R&S RTO6 /R&S RTP-K17
Transmitter distortion With disturber (96.5.4.2)	1 at least 1 GHz band- width	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 band- width	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 jit- ter slave mode (96.5.4.3)	1 at least 1 GHz band- width	R&S RT-ZF2	2	R&S RT-ZF8	<b>Optional:</b> R&S RTO / R&S RTO6 /R&S RTP-K17
*The equipment for on	ly either the	e differential type or t	he single-er	nded type is suffic	cient for the test setup

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

	Differential type*		Single	-Ended type <sup>*</sup>	Additional	
	Differ- ential probe	Test fixture	SMA	Test fixture (optional)	instruments	
Transmitter power spectral density and peak differential out- put (96.5.4.4 and 96.5.1.8)	1 at least 1 GHz band- width	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 conver- sion 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 conver- sion 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

	Starting 100BASE-T1 tests	231
•	Test configuration for 100BASE-T1	231
•	Transmitter output droop	234
•	Transmitter distortion	. 237
•	Transmitter timing jitter	241
•	Transmitter power spectral density and peak differential output	244
•	MDI return loss with R&S RT-ZF2	246
•	MDI mode conversion loss and return loss	248
•	MDI mode conversion loss adaptor verification	. 250
•	MDI common mode emission	251

# 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.

100BASE-T1 tests

Test configuration for 100BASE-T1

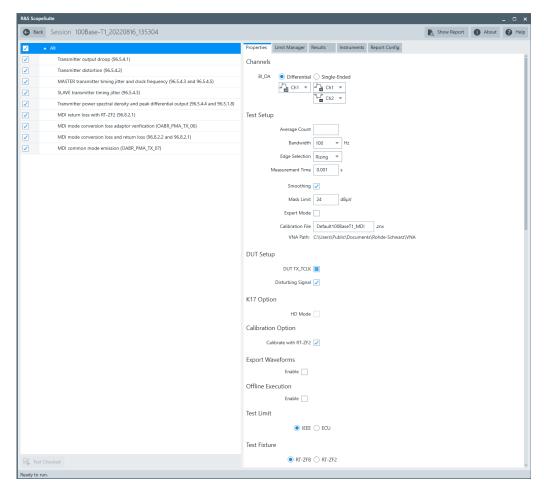


Figure 8-1: Configuration for 100BASE-T1 compliance tests

#### BI\_DA

Selects the channels for testing. You can also select if the connected probe is singleended 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 dB $\mu$ V.

#### **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-Schwa	arz\RS	SscopeSuit	e\4.60.0	\Waveforms\
BroadRReach	\100Base-T1	2133	20190114	144116	

### **Offline Execution**

Offline Execution

Enable	✓		
JitterMaster waveform		<b>F</b> 7	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)".

R&S ScopeSuite		_ 🗆 ×
G Back Session 100Base-T1_20190404_144448	Show Report	About 🕑 Help
All	Properties Limit Manager Results Instruments Report Config	3
✓ Transmitter output droop (96.5.4.1)	Channels	
Transmitter distortion (96.5.4.2)         MASTER transmitter timing jitter and clock frequency (96.5.4.3 and 96.5.4.5)         SLAVE transmitter timing jitter (96.5.4.3)         Transmitter power spectral density and peak differential output (96.5.4.4 and 96.5.1.8)         MDI return loss with RT-ZE2 (96.8.2.1)         MDI mode conversion loss adaptor verification (96.8.2.2)         MDI mode conversion loss and return loss (96.8.2.2 and 96.8.2.1)         MDI common mode emission (96.5.1.2)	BLDA Differential Single-Ended	
Ready to run.		

- 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:

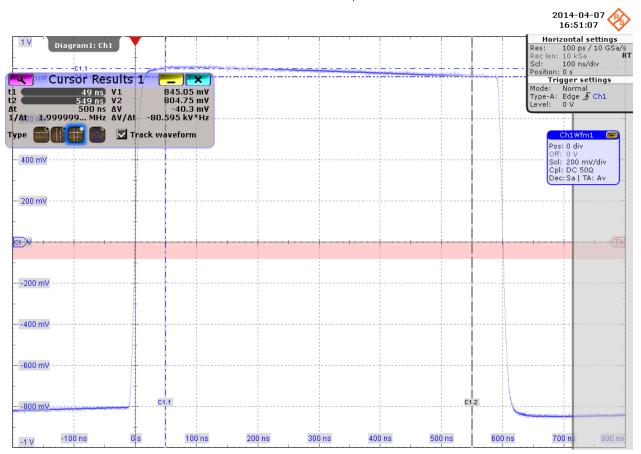
• Chapter 3.3, "Getting test results", on page 23

### 8.3.3 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 <sub>Vpeak</sub> and V<sub>500ns</sub>.



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.

							2014-04-07
1V Diagram1: Ch1	lts 1 ()	X				Res Rec Scl:	len: 10 kSa RT
t1 49 ns V1 t2 549 ns V2 At 500 ns AV 1/Atio 1.999999 MHz AV	1 -845.05 2 -808.7 γ 36.35 γ/Δt 72.69 kv	5 mV 7 mV 5 mV ?*Hz				Тур	e: Normal e-A: Edge Y Ch1 al: 0 V
Type	Track wavefor	n					Ch1Wfm1         End           Pos: 0 div         0ff: 0 V           Off: 0 V         Scl: 200 mV/div           Cpl: DC 50Ω         Dec: Sa   TA: Av
– 200 mV							
<u>e1</u>							•••••
200 mV-							
400 mV							
800 mV	C1.1				C1.2	<u></u>	
-1 V -100 ns	1	00 ns 200 ns	300 ns	400 ns	500 ns	600 ns	700 ns 800 ns

# 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)".

#### Transmitter distortion

R&S ScopeSuite _ 🗆 X					
G Back Session 100Base-T1_20190917_155334	R Show Report 1 About 1 Help				
All	Properties Limit Manager Results Instruments Report Config				
Transmitter output droop (96.5.4.1)	Channels				
Transmitter distortion (96.5.4.2)	BLDA <ul> <li>Differential</li> <li>Single-Ended</li> </ul>				
MASTER transmitter timing jitter and clock frequency (96.5.4.3 and 96.5.4.5)	→ Differential Single-Ended				
SLAVE transmitter timing jitter (96.5.4.3)					
Transmitter power spectral density and peak differential output (96.5.4.4 and 96.5.1.8)					
MDI return loss with RT-ZF2 (96.8.2.1)	Test Setup				
MDI mode conversion loss adaptor verification (OABR_PMA_TX_06)	Expert Mode				
MDI mode conversion loss and return loss (96.8.2.2 and 96.8.2.1)					
MDI common mode emission (96.5.1.2)	DUT Setup				
	DUT TX_TCLK				
	Disturbing Signal 📝				
	Export Waveforms				
	Enable				
	Test Fixture				
	● RT-ZF8 ○ RT-ZF2				
Test Checked Test Single					
Ready to run.					

- 3. Click "Test Single".
- 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.

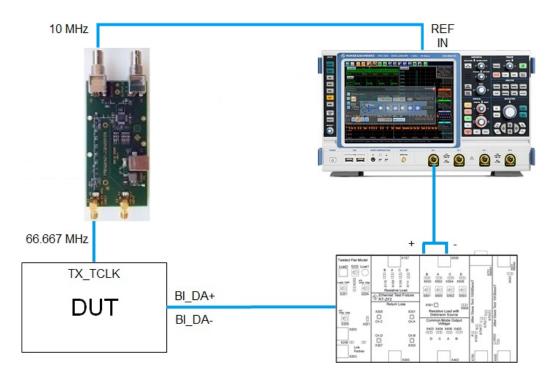
The test is performed on the "Resistive Load" section of the R&S RT-ZF2.

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.

Transmitter distortion



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.

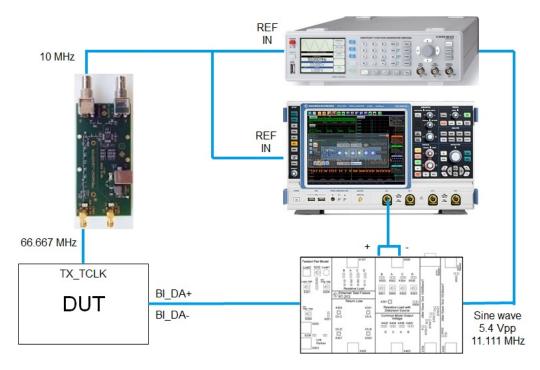
The test is also performed on the "Resistive Load with Distortion Source" section of the R&S RT-ZF2 Ethernet test fixture. This section of the test fixture exposes the DUT to the disturbing signal while allowing little of the disturbing signal to reach the measured point X506.

# 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.

Transmitter timing jitter



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)".

R&S ScopeSu	lite						_ 🗆 ×		
🕒 Back	Session 100Base-T1_20221014_090813			R	Show Report	About	Help		
	All	Properties	Limit Manager	Results	Instruments	Report Config			
	Transmitter output droop (96.5.4.1)	Channels							
	Transmitter distortion (96.5.4.2)	BI_DA	Differenti						
	MASTER transmitter timing jitter and clock frequency (96.5.4.3 and 96.5.4.5)	BI_DA							
	SLAVE transmitter timing jitter (96.5.4.3)			Ch2					
	Transmitter power spectral density and peak differential output (96.5.4.4 and 96.5.1.8)								
	MDI return loss with RT-ZF2 (96.8.2.1)	Test Setu	р						
	MDI mode conversion loss adaptor verification (OABR_PMA_TX_06)	Edge Selection Rising  Measurement Time 0.001 s							
	MDI mode conversion loss and return loss (96.8.2.2 and 96.8.2.1)								
	MDI common mode emission (OABR_PMA_TX_07)								
			Expert Mod	le 🗌					
		K17 Opti	on						
			HD Mod	le					
		Export W	aveforms						
			Enable						
		Offline Ex	ecution						
			Enable						
🔄 Test Ch	ecked 🕨 Test Single								
Ready to run.									

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

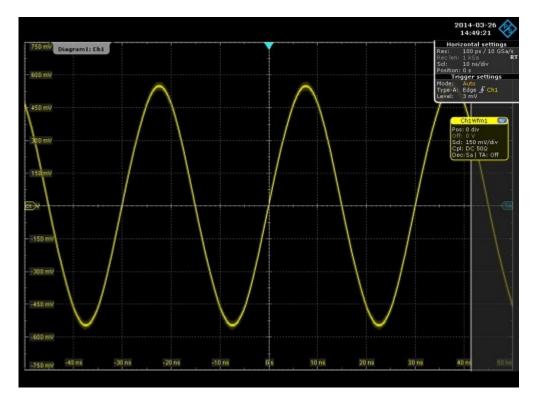
Further steps:

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

### 8.5.1.3 Measurements

The DUT has to transmit a test mode 2 waveform.

#### Transmitter timing jitter



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)".

R&S ScopeSuite	_
G Back Session 100Base-T1_20221014_090813	🖹 Show Report 🚺 About 👔 Help
All	Properties Limit Manager Results Instruments Report Config
Transmitter output droop (96.5.4.1)	Channels
Transmitter distortion (96.5.4.2)	BLDA   Differential  Single-Ended
MASTER transmitter timing jitter and clock frequency (96.5.4.3 and 96.5.4.5)	0
SLAVE transmitter timing jitter (96.5.4.3)	<u>רו ד</u> Ch1 ד ווידעם Ch1 ד ווידעם Ch1 ד ווידעם Ch2 ד וו
Transmitter power spectral density and peak differential output (96.5.4.4 and 96.5.1.8)	
MDI return loss with RT-ZF2 (96.8.2.1)	Test Setup
MDI mode conversion loss adaptor verification (OABR_PMA_TX_06)	Edge Selection Both 💌
MDI mode conversion loss and return loss (96.8.2.2 and 96.8.2.1)	Measurement Time 0.001 s
MDI common mode emission (OABR_PMA_TX_07)	
	Expert Mode
	DUT Setup
	K17 Option
	HD Mode
	Export Waveforms
Test Checked Test Single	Enable
Ready to run.	

- 3. Click "Test Single".
- 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:

$$Lower \ PSD(f) \ge \begin{cases} -70.9 - 4.9 \times \frac{f-1}{19} & dBm/Hz & for \ 1MHz \le f \le 20MHz \\ -75.8 - 13.4 \times \frac{f-20}{20} & dBm/Hz & for \ 20MHz \le f \le 200MHz \end{cases}$$

Transmitter power spectral density and peak differential output

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

# 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)".

R85 ScopeSuite				_ 0 ×
G Back Session 100Base-T1_20190404_144448		Report Show Report	About	🕐 Help
All	Properties Limit Manager Results Instru	ments Report Config		
Transmitter output droop (96.5.4.1)	Channels			
Transmitter distortion (96.5.4.2)	BL DA			
MASTER transmitter timing jitter and clock frequency (96.5.4.3 and 96.5.4.5)				
SLAVE transmitter timing jitter (96.5.4.3)	Ch1 ▼ ↓ Ch1 ▼ ↓ Ch1 ▼ ↓ Ch1 ▼			
Transmitter power spectral density and peak differential output (96.5.4.4 and 96.5.1	8)			
MDI return loss with RT-ZF2 (96.8.2.1)	Test Setup			
MDI mode conversion loss adaptor verification (96.8.2.2)	Average Count 10			
MDI mode conversion loss and return loss (96.8.2.2 and 96.8.2.1)	# of Acgs for PSD Curve 64			
MDI common mode emission (96.5.1.2)	·			
	Smoothing 🖌			
	Expert Mode			
	Export Waveforms			
	Enable			
	Liable			
Test Checked Test Single				
Ready to run.				

3. Click "Test Single".

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:

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

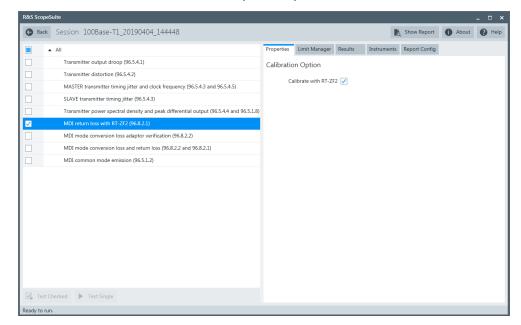
# 8.7.1 Test equipment

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".
- 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

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

# 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 Chapter 8.1, "Starting 100BASE-T1 tests", on page 231.
- Select the test case: "MDI mode conversion loss and return loss (96.8.2.2 and 96.8.2.1)".

### 100BASE-T1 tests

MDI mode conversion loss and return loss

R&S Scope	Suite								_ 0 ×
G Back	Session 100Base-T1_20190917_155334						💫 Show Report	About	🕜 Help
	▲ All	Properties	Limit Manager	Results	Instruments	Report Config			
	Transmitter output droop (96.5.4.1)	Test Setu	p						
	Transmitter distortion (96.5.4.2)		Average Coun						
	MASTER transmitter timing jitter and clock frequency (96.5.4.3 and 96.5.4.5)		-		_				
	SLAVE transmitter timing jitter (96.5.4.3)		Bandwidth	100	₩ Hz				
	Transmitter power spectral density and peak differential output (96.5.4.4 and 96.5.1.8)		Expert Mode	e 🗌					
	MDI return loss with RT-ZF2 (96.8.2.1)		Calibration File	e Default10	00BaseT1_MDI	.znx			
	MDI mode conversion loss adaptor verification (OABR_PMA_TX_06)		VNA Path:	C:\Users\P	ublic\Document	s\Rohde-Schwa	rz\VNA		
	MDI mode conversion loss and return loss (96.8.2.2 and 96.8.2.1)	*							
	MDI common mode emission (96.5.1.2)	Test Limit							
			IEEE	e 🔿 ecu					
🛃 Test	Checked Fast Single								
Ready to ru	in.								

- 3. Click "Test Single".
- 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

## 8.8.3 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 (\*.slp 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 (\*.slp) 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.

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

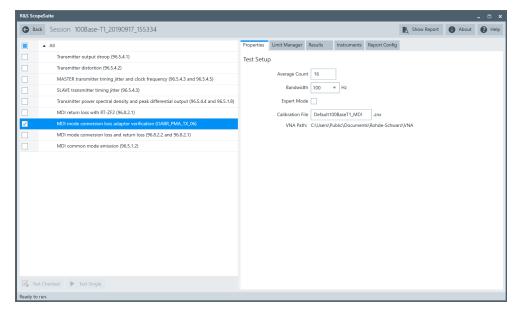
### 8.9.1 Test equipment

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".
- 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 (\*.slp 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

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	

Table 8-12: Equipment for MDI common mode emission 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)".

100BASE-T1 tests

R&S ScopeSuite			_ 🗆 ×
G Back Session 100Base-T1_20190404_144448		💦 Show Report	About Pelp
All	Properties Limit Manager Results	Instruments Report Config	
Transmitter output droop (96.5.4.1)	Test Setup		
Transmitter distortion (96.5.4.2)	Average Count 20		
MASTER transmitter timing jitter and clock frequency (96.5.4.3 and 96.5.4.5)			
SLAVE transmitter timing jitter (96.5.4.3)	Mask Limit 24	dBµV	
Transmitter power spectral density and peak differential output (96.5.4.4 and 96.5.1.8)	Expert Mode		
MDI return loss with RT-ZF2 (96.8.2.1)			
MDI mode conversion loss adaptor verification (96.8.2.2)			
MDI mode conversion loss and return loss (96.8.2.2 and 96.8.2.1)			
MDI common mode emission (96.5.1.2)			
Test Checked Test Single			
Ready to run.			

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

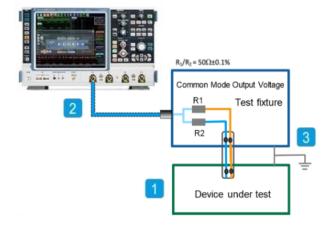
Further steps:

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

### 8.10.3 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:



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  $24dB\mu V$  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.

	Diff	erential type <sup>*</sup>	Single	e-Ended type <sup>*</sup>	Additional instru-		
	Differ- ential probe	Test fixture	SMA	Test fixture			
Transmitter timing jit- ter(test mode 1) (97.5.3.3)	-	-	1		<b>Optional:</b> 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	<b>Optional:</b> 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 con- verter: 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 con- verter: R&S RT-ZF6		
*The equipment for onl	The equipment for only either the differential type or the single-ended type is sufficient for the Test setup						

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

#### Starting 1000BASE-T1 tests

	Differential type*		Sing	le-Ended type <sup>*</sup>	Additional instru-	
	Differ- ential probe	Test fixture	SMA	Test fixture	— ments	
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 conver- sion 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 conver- sion 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

Starting 1000BASE-T1 tests	255
Test configuration for 1000BASE-T1	
Transmitter timing jitter (97.5.3.3)	
• MDI jitter and clock frequency (97.5.3.3/97.5.3.6)	
Transmitter distortion (97.5.3.2)	
<ul> <li>PSD power level and output voltage (97.5.3.4/ 97.5.3.5 )</li> </ul>	270
Maximum output droop (97.5.3.1)	
MDI return loss with R&S RT-ZF2 (97.7.2.1)	
MDI mode conversion loss test head verification (OA ECU)	276
MDI mode conversion loss and return loss(97.7.2.2)	277

# 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.

#### R&S®RTO, R&S®RTO6, R&S®RTP

#### 1000BASE-T1 tests

Test configuration for 1000BASE-T1

R&S ScopeS	suite							_ 🗆 🗙
🕒 Back	Session 1000BASE-T1_20221109_100537					Show Report	1 About	🕐 Help
A 1	. All	Properties	Limit Manager	Results	Instruments	Report Config		
	97.5.3.3 Transmitter timing jitter master mode (test mode 1)	Channels						Î
	97.5.3.3 Transmitter timing jitter slave mode (test mode 1)	BI_DA	0.0:11					
	<ul> <li>MDI jitter and clock frequency (test mode 2)</li> </ul>	DI_DA	Ch1	ial 🔵 Single r 🗸 🖓 Ch1				
	97.5.3.2 Transmitter distortion (test mode 4)			° ∎ Chi ∿_ Ch2				
	<ul> <li>PSD, power level and output voltage (test mode 5)</li> </ul>			-				
	97.5.3.1 Maximum output droop (test mode 6)	TX_TCLK125	🖓 Ch1 🧃	7				
	97.7.2.1 MDI return loss with RT-ZF2	Test Setup	)					
	MDI mode conversion loss test head verification (OA ECU)		Edge Selectio	on Both	•			
	97.7.2.2 and 97.7.2.1 MDI mode conversion loss and return loss		Average Cou		7			
			-					
		N	Aeasurement Tin	ne 0.001	S			
		5M	Hz Bandpass Filt	er 🗸				
		# of A	Acqs for PSD Cur	ve 64				
			Bandwid	th 100	▼ Hz			
			Smoothir	ng 🗸				
			Digital Filt	er 8	GHz			
			Expert Mod	de				
			Calibration Fi	ile Default10	000BaseT1_MDI	.znx		
			VNA Pat	h: C:\Users\P	ublic\Documen	ts\Rohde-Schwar	z\VNA	
		DUT Setup	D					
			DUT TX_TC	LK				
			Disturbing Sign	al				
		K17 Optio	n					
			HD Mod	de 🗸				
		Calibration	n Option					
		Cal	ibrate with RT-Z	F2 🗸				
		Test Limit						
				EE 🔵 ECU (P	Preliminary)			
		Test Fixtur	e					
			● RT-ZI	F8 🔿 RT-ZF2	2			
		Export Wa	veforms					I
			Enable	]				
		Offline Exe	ecution					
Test C	hecked		Enable	]				
Ready to run	h.							

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 singleended 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**

Offline Execution

Enable	✓		
TM1 waveform		<b>F7</b>	Select
TM2 waveform		-7	Select
Distortion 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**

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)".

#### Transmitter timing jitter (97.5.3.3)

R&S ScopeSuite	×
G Back Session 1000BASE-T1_20221109_100537	R Show Report 1 About 1 Help
All	Properties Limit Manager Results Instruments Report Config
97.5.3.3 Transmitter timing jitter master mode (test mode 1)	Channels
97.5.3.3 Transmitter timing jitter slave mode (test mode 1)	TX_TCLK125
MDI jitter and clock frequency (test mode 2)	TX_TCLK125 Via Ch1 🔻
97.5.3.2 Transmitter distortion (test mode 4)	Test Setup
PSD, power level and output voltage (test mode 5)	Edge Selection Both 💌
97.5.3.1 Maximum output droop (test mode 6)	
97.7.2.1 MDI return loss with RT-ZF2	
MDI mode conversion loss test head verification (OA ECU)	5MHz Bandpass Filter 🖌
97.7.2.2 and 97.7.2.1 MDI mode conversion loss and return loss	Expert Mode
	K17 Option
	HD Mode 🗸
	Export Waveforms
	Enable
	Offline Execution
	Enable
Test Checked Test Single	
Ready to run.	

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

Further steps:

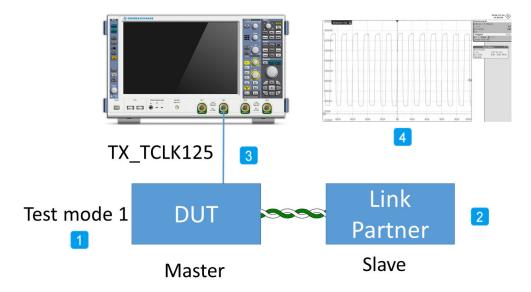
• Chapter 3.3, "Getting test results", on page 23

#### 9.3.1.3 Test setup

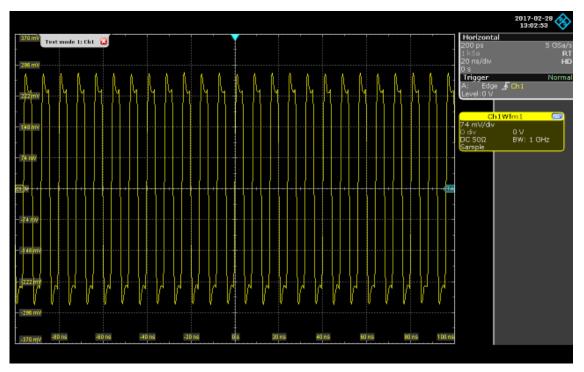
The setup of this test is as in the following figure.

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.

Transmitter timing jitter (97.5.3.3)



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)".

R&S ScopeS	uite	_	_	_		_ 0	
🕒 Back	Session 1000BASE-T1_20221109_100537			Show I	Report	About	Hel
	All	Properties	Limit Manager	Results	Instruments	Report Config	l
	97.5.3.3 Transmitter timing jitter master mode (test mode 1)	Channels					
<b>V</b>	97.5.3.3 Transmitter timing jitter slave mode (test mode 1)	TX_TCLK125	√ Ch1 -				
	<ul> <li>MDI jitter and clock frequency (test mode 2)</li> </ul>	TA_TOLKT25					
	97.5.3.2 Transmitter distortion (test mode 4)	Test Setup	D				
	<ul> <li>PSD, power level and output voltage (test mode 5)</li> </ul>		Edge Selectio	n Both	•		
	97.5.3.1 Maximum output droop (test mode 6)	,	Measurement Tim	e 0.001	s		
	97.7.2.1 MDI return loss with RT-ZF2						
	MDI mode conversion loss test head verification (OA ECU)	510	1Hz Bandpass Filte	er 🗸			
	97.7.2.2 and 97.7.2.1 MDI mode conversion loss and return loss		Expert Mod	e 🗌			
		K17 Optic	on				
			HD Mod	e 🗸			
		Export Wa	aveforms				
			Enable				
		Offline Ex	ecution				
			Enable				
🖌 Test Cl	hecked 🕨 Test Single						
eady to run							

- 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.

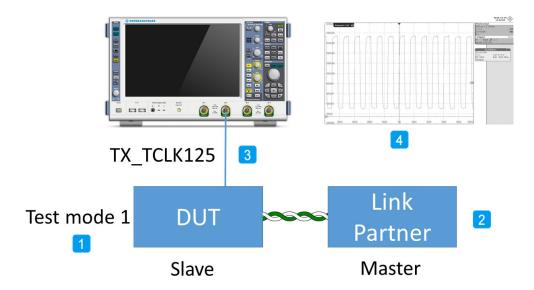
Further steps:

• 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.

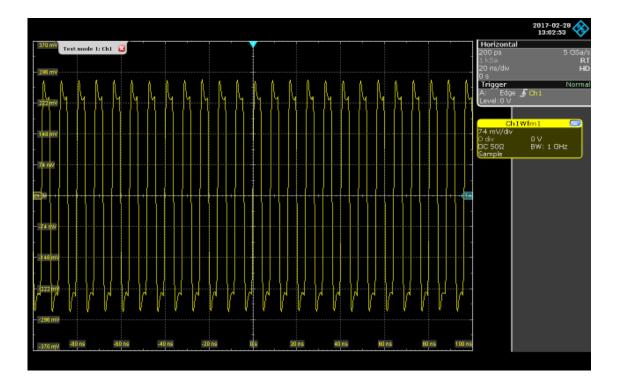
Make sure the DUT and the LP are connected and are configured for test mode 1. In test mode 1, the PHY is in normal operation but exposes a reduced symbol clock (TX\_TCLK 125). This clock has to be connected to the scope.



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.

#### 1000BASE-T1 tests

#### MDI jitter and clock frequency (97.5.3.3/97.5.3.6)



#### 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

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 9-4: Equipment for MDI jitter and clock frequency (test mode 2) and differential BI\_DA

MDI jitter and clock frequency (97.5.3.3/97.5.3.6)

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

Table 9-5: Equipment for MDI jitter and clock frequency (test mode 2) and single-ended BI\_DA

#### 9.4.2 Performing the test

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

R&S ScopeSuite	_ □ ×
G Back Session 1000BASE-T1_20221109_100537	K Show Report 1 About 1 Help
II AII	Properties Limit Manager Results Instruments Report Config
97.5.3.3 Transmitter timing jitter master mode (test mode 1)	Channels
97.5.3.3 Transmitter timing jitter slave mode (test mode 1)	BI_DA <ul> <li>Differential</li> <li>Single-Ended</li> </ul>
MDI jitter and clock frequency (test mode 2)      97.5.3.3 Transmitter timing MDI jitter	BI_DA  Differential O Single-Ended       Image: Chi mage:
97.5.3.3 Transmitter timing MDI jitter	™≝ cm t ™≝ ch2 ▼
97.5.3.6 Transmitter clock frequency	Citte -
97.5.3.2 Transmitter distortion (test mode 4)	Test Setup
▼ PSD, power level and output voltage (test mode 5)	Edge Selection Both 💌
97.5.3.1 Maximum output droop (test mode 6)	Measurement Time 0.001 s
97.7.2.1 MDI return loss with RT-ZF2	
MDI mode conversion loss test head verification (OA ECU)	5MHz Bandpass Filter 🗹
97.7.2.2 and 97.7.2.1 MDI mode conversion loss and return loss	Expert Mode
	K17 Option
	HD Mode 🖌
	Export Waveforms
	Enable
	Offline Execution
Test Checked Fest Single	Enable
Ready to run.	

- 3. Click "Test Single".
- 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 followed 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 transmit 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  $\pm$  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) <sup>*</sup> 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 802.3 <sup>TM</sup> -2018 Table 40-9-Vd charasteristics		

#### Transmitter distortion (97.5.3.2)

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 <sup>™</sup> -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) ".

#### Transmitter distortion (97.5.3.2)

R&S ScopeSuite	×
G Back Session 1000BASE-T1_20201123_101945	R Show Report 1 About 1 Help
All	Properties Limit Manager Results Instruments Report Config
97.5.3.3 Transmitter timing jitter master mode (test mode 1)	Channels
97.5.3.3 Transmitter timing jitter slave mode (test mode 1)	BI_DA 💿 Differential 🔿 Single-Ended
MDI jitter and clock frequency (test mode 2)	
✓ 97.5.3.2 Transmitter distortion (test mode 4)	<u>씨놃 Ch1 ▼ </u> 가슬 Ch2 ▼
PSD, power level and output voltage (test mode 5)	Cut fac
97.5.3.1 Maximum output droop (test mode 6)	Test Setup
97.7.2.1 MDI return loss with RT-ZF2	Expert Mode
MDI mode conversion loss test head verification (OA ECU)	
97.7.2.2 and 97.7.2.1 MDI mode conversion loss and return loss	DUT Setup
	DUT TX_TCLK
	Disturbing Signal
	Test Fixture
	RT-ZF8      RT-ZF2
	Export Waveforms
	Enable
	Offline Execution
	Enable
Test Checked Test Single	
Ready to run.	

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

Further steps:

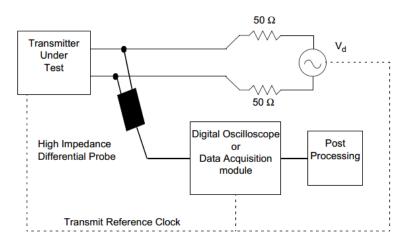
• Chapter 3.3, "Getting test results", on page 23

#### 9.5.3 Test setup

The picture below shows the test fixture design used for this test case.  $V_d$  is the sinusoidal 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 frequency locked to the DUT transmit clock. PSD power level and output voltage (97.5.3.4/97.5.3.5)



## 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

PSD power level and output voltage (97.5.3.4/97.5.3.5)

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)".

R&S ScopeSuite	_ □ ×
G Back Session 1000BASE-T1_20201123_101945	Kan Show Report 1 About 1 Help
All     97.5.3.3 Transmitter timing jitter master mode (test mode 1)     97.5.3.3 Transmitter timing jitter slave mode (test mode 1)     97.5.3.2 Transmitter distortion (test mode 2)     97.5.3.2 Transmitter distortion (test mode 4)     97.5.3.4 Transmitter power spectral density (PSD)     97.5.3.4 Transmitter power level	Properties     Limit Manager     Results     Instruments     Report Config       Channels     BL_DA <ul> <li>Differential</li> <li>Single-Ended</li> <li>Image: Ch1</li> <li>I</li></ul>
97.5.3.5 Transmitter peak differential output     97.5.3.1 Maximum output droop (test mode 6)     97.7.2.1 MDI return loss with RT-ZF2     MDI mode conversion loss test head verification (OA ECU)     97.7.2.2 and 97.7.2.1 MDI mode conversion loss and return loss      Test Checked      Test Single	# of Acqs for PSD Curve 64 Smoothing Expert Mode Export Waveforms Enable _
Ready to run.	

- 3. Click "Test Single".
- 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:

$$Lower PSD(f) \ge \begin{cases} -86 & dBm/Hz & for \ 40 \le f \le 100 \\ -82 - \frac{f}{25} & dBm/Hz & for \ 100 < f \le 400 \end{cases}$$
$$Upper PSD(f) \ge \begin{cases} -80 & dBm/Hz & for \ 0 \le f \le 100 \\ -76 - \frac{f}{25} & dBm/Hz & for \ 100 < f \le 400 \\ -85.6 - \frac{f}{62.5} & dBm/Hz & for \ 400 < f \le 600 \end{cases}$$

#### 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)".

	- 0
<b>Back</b> Session 1000BASE-T1_20201123_101945	R Show Report 1 About 1 Hel
All      97.5.3.3 Transmitter timing jitter master mode (test mode 1)      97.5.3.3 Transmitter timing jitter slave mode (test mode 1)      97.5.3.3 Transmitter timing jitter slave mode (test mode 1)      97.5.3.2 Transmitter distortion (test mode 2)      97.5.3.2 Transmitter distortion (test mode 4)      97.5.3.1 Maximum output voltage (test mode 5)      97.5.3.1 Maximum output droop (test mode 6)      97.7.2.1 MDI return loss with RT-ZF2      MDI mode conversion loss test head verification (OA ECU)      97.7.2.2 and 97.7.2.1 MDI mode conversion loss and return loss      Test Checked  Test Single	Properties     Limit Manager     Results     Instruments     Report Config       Channels     BLDA     Differential     Single-Ended       Image: Ch1 m     Image: Ch1 m     Image: Ch2 m       Test Setup     Average Count     10       Expert Mode     Image: Ch1 m     Image: Ch2 m       K17 Option     HD Mode     Image: Ch2 m       Export Waveforms     Enable     Image: Ch2 m
Ready to run.	

- 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.

$$\mathsf{Droop} = \left(\frac{V_{4ns} - V_{16ns}}{V_{4ns}}\right) * 100\%$$

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:

	$\left( 18 - 18 \times \log_{10} \left( \frac{20}{f} \right) dB \right)$	for $2MHz \le f \le 20MHz$
$Return \ Loss(f) \ge \langle$		for $20MHz \le f \le 100MHz$
	$\left(18 - 16.7 \times \log_{10} \left(\frac{f}{100}\right) dB\right)$	for $100MHz \le f \le 600MHz$

#### 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

#### MDI return loss with R&S RT-ZF2 (97.7.2.1)

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".

R&S ScopeSuite							- 🗆 ×
G Back Session 1000BASE-T1_20201123_101945				👌 Show	Report	About	🕐 Help
All	Properties	Limit Manager	Results	Instruments	Report 0	Config	
97.5.3.3 Transmitter timing jitter master mode (test mode 1)	Calibratio	on Option					
97.5.3.3 Transmitter timing jitter slave mode (test mode 1)		alibrate with RT-ZF	2 🔽				
■ MDI jitter and clock frequency (test mode 2)	G	ilibrate with KI-ZF	2 🔽				
97.5.3.2 Transmitter distortion (test mode 4)							
<ul> <li>PSD, power level and output voltage (test mode 5)</li> </ul>							
97.5.3.1 Maximum output droop (test mode 6)							
97.7.2.1 MDI return loss with RT-ZF2							
MDI mode conversion loss test head verification (OA ECU)							
97.7.2.2 and 97.7.2.1 MDI mode conversion loss and return loss							
Test Checked Fest Single							
Ready to run.							

- 3. Click "Test Single".
- 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 (\*.slp 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.

 $Conversion \ Loss(f) \ge \begin{cases} 61 & 10 \le f \le 80 \\ 83 - 11.51 \times \log_{10}(f) & 80 < f \le 600 \end{cases} dB$ 

#### 9.9.1 Test equipment

Table 9-13: Equipment for MDI mode conversion loss test head verification (OA ECU) test

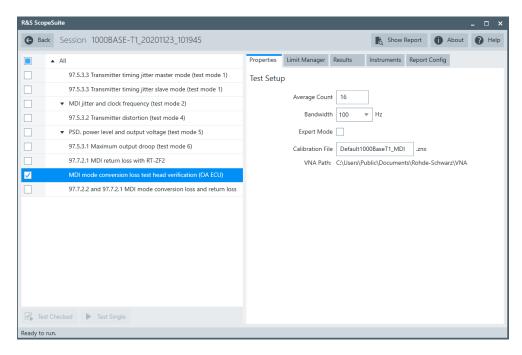
Item	Description, model	Quantity
	S	
Rohde & Schwarz oscilloscope	R&S RTO / R&S RTO6 /R&S RTP with at least 2 GHz bandwidth	1
Ethernet test fixture	R&S RT-ZF8	1
Vector network analyzer (optional, required only to perform an automatic test)	R&S ZNB, R&S ZNC or R&S ZND (option K5 or K6 required)	1

#### 9.9.2 Performing the test

- 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 test head verification (OA ECU)".

#### 1000BASE-T1 tests

MDI mode conversion loss and return loss(97.7.2.2)



- 3. Click "Test Single".
- 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

#### 9.9.3 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:

MDI mode conversion loss and return loss(97.7.2.2)

$$Conversion \ Loss \ (f) \ge \begin{cases} 55 \ dB & for \ 10MHz \le f \le 80MHz \\ 77 - 11.51 \times \log_{10}(f) \ dB & for \ 80MHz < f \le 600MHz \end{cases}$$

## 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".

R&S ScopeSuite	_ 🗆 ×
G Back Session 1000BASE-T1_20201123_101945	R Show Report 1 About 1 Help
All	Properties Limit Manager Results Instruments Report Config
97.5.3.3 Transmitter timing jitter master mode (test mode 1)	Test Setup
97.5.3.3 Transmitter timing jitter slave mode (test mode 1)	Average Count 16
<ul> <li>MDI jitter and clock frequency (test mode 2)</li> </ul>	
97.5.3.2 Transmitter distortion (test mode 4)	Bandwidth 100 v Hz
<ul> <li>PSD, power level and output voltage (test mode 5)</li> </ul>	Expert Mode
97.5.3.1 Maximum output droop (test mode 6)	Calibration File Default1000BaseT1_MDI .znx
97.7.2.1 MDI return loss with RT-ZF2	VNA Path: C:\Users\Public\Documents\Rohde-Schwarz\VNA
MDI mode conversion loss test head verification (OA ECU)	Test Limit
97.7.2.2 and 97.7.2.1 MDI mode conversion loss and return loss	lest Limit
	IEEE ECU (Preliminary)
R Test Charlest N. Test Charles	
Test Checked Fest Single	
Ready to run.	

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

MDI mode conversion loss and return loss(97.7.2.2)

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 perform 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 (\*.slp 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.
- 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.

Test configuration for Ethernet 10BASE-T1

R&S ScopeSuite	×
G Back Session 10BASE-T1S_20220726_090037	R Show Report 1 About 1 Help
▲ All	Properties Limit Manager Results Instruments Report Config
Output voltage and timing jitter (test mode 1)	Channels
147.5.4.1 Transmitter output voltage	<ul> <li>Single-Ended O Differential</li> </ul>
147.5.4.3 Transmitter timing jitter	
147.5.4.2 Transmitter output droop (test mode 2)	Data+ $\bigvee_{\underline{k}} Ch1 =$ $\bigvee_{\underline{k}} Ch1 =$ Data- $\bigvee_{\underline{k}} Ch2 =$
147.5.4.4 Transmitter Power Spectral Density (PSD) (test mode 3)	
147.9.2 MDI return loss	Test Setup
	Average Count 10 Measurement Count 10 • Aquisition Time 0.001 s Multidrop Expert Mode Expert Mode Export Waveforms Enable D Offline Execution
Test Checked Fast Single	Enable
Ready to run.	

#### 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  $\Omega$  resistive differential load is connected to the transmitter output. Otherwise 100  $\Omega$  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	Offline Execution			
Enable	✓			
TM2 waveform		-7	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<sup>™</sup>, 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<sup>™</sup>, 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)".

Back Session 10BASE-TIS_20220726_090037   All     Output voltage and timing jitter (test mode 1)     147.5.4.1 Transmitter output voltage     147.5.4.3 Transmitter output dotoge (test mode 2)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     147.5.4.1 Transmitter output droop (test mode 2)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     147.5.4.3 Transmitter output droop (test mode 2)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 3)     15.1 Expert Mode     147.5.4.1 Transmitter Power Spectral Density (PSD) (test mode 4) </th <th>R&amp;S ScopeSuite</th> <th>_ □ ×</th>	R&S ScopeSuite	_ □ ×
Channels   Id7.5.4.1 Transmitter output voltage Id7.5.4.1 Transmitter output voltage Id7.5.4.2 Transmitter output droop (test mode 2) Id7.5.4.2 Transmitter output droop (test mode 2) Id7.5.4.4 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Id7.5.4.2 Transmitter Power Spectral Density (PSD) (test mode 3) Expert Mode	G Back Session 10BASE-T15_20220726_090037	Ka Show Report 1 About 1 Help
Intrastruction output voltage       Intrastruction output voltage         Intrastruction output voltage       Intrastruction output voltage         Intrastruction output droop (test mode 2)       Intrastruction output droop (test mode 2)         Intrastruction output droop (test mode 2)       Intrastruction output droop (test mode 2)         Intrastruction output droop (test mode 2)       Intrastruction output droop (test mode 2)         Intrastruction output droop (test mode 2)       Intrastruction output droop (test mode 3)         Intrastruction output droop (test mode 2)       Intrastruction output droop (test mode 3)         Intrastruction output droop (test mode 2)       Intrastruction output droop (test mode 3)         Intrastruction output droop (test mode 2)       Intrastruction output droop (test mode 3)         Intrastruction output droop (test mode 2)       Intrastruction output droop (test mode 3)         Intrastruction output droop (test mode 3)       Intrastruction output droop (test mode 3)         Intrastruction output droop (test mode 3)       Intrastruction output droop (test mode 3)         Intrastruction output droop (test mode 3)       Intrastruction output droop (test mode 3)         Intrastruction output droop (test mode 3)       Intrastruction output droop (test mode 3)         Intrastruction output droop (test mode 3)       Intrastruction output droop (test mode 3)         Intrastruction output droop (test mode 3)       Intrastruc	All	Properties Limit Manager Results Instruments Report Config
Intractal Transmitter timing jitter   Intractal Transmitter output droop (test mode 2)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (PSD) (test mode 3)   Intractal Transmitter Power Spectral Density (test mode 3)   Intractal Transmitter Power Spectral Density	<ul> <li>Output voltage and timing jitter (test mode 1)</li> </ul>	Channels
Idf.5.4.3 Transmitter timing jitter         147.5.4.2 Transmitter output droop (test mode 2)         147.5.4.4 Transmitter Power Spectral Density (PSD) (test mode 3)         147.5.2 MDI return loss         Test Setup         Average Count         Aquisition Time       0.001         Setupert Mode         Expert Mode	✓ 147.5.4.1 Transmitter output voltage	Single Federal O Differential
□ 147.5.4.4 Transmitter Power Spectral Density (PSD) (test mode 3)   □ 147.9.2 MDI return loss     ✓ Est Setup   Average Count Aquisition Time 0.001 s Multidrop Expert Mode Ison Point Po	✓ 147.5.4.3 Transmitter timing jitter	
147.5.4.4 Transmitter Power Spectral Density (PSD) (test mode 3)     147.9.2 MDI return loss     Test Setup     Average Count        Aquisition Time     0.001        Multidrop        Expert Mode	147.5.4.2 Transmitter output droop (test mode 2)	
Average Count     Aquisition Time     0.001 s     Multidrop     Expert Mode	147.5.4.4 Transmitter Power Spectral Density (PSD) (test mode 3)	
Aquisition Time 0.001 s Multidrop Expert Mode Vert Checked	147.9.2 MDI return loss	Test Setup
	₩. Test Checked	Aquisition Time 0.001 s Multidrop
Ready to run.	Ready to run.	

- 3. Click "Test Single".
- 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<sup>™</sup>, 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<sup>TM</sup>, 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)".

R&S ScopeSuite _ 🗆 🗙		
G Back Session 10BASE-T15_20220726_090037	R Show Report 1 About 1 Help	
All	Properties Limit Manager Results Instruments Report Config	
Output voltage and timing jitter (test mode 1)	Channels	
147.5.4.1 Transmitter output voltage	● Single-Ended ○ Differential	
147.5.4.3 Transmitter timing jitter	Data+	
147.5.4.2 Transmitter output droop (test mode 2)	Data- 1 Ch2 V	
147.5.4.4 Transmitter Power Spectral Density (PSD) (test mode 3)		
147.9.2 MDI return loss	Test Setup	
	Average Count 10	
	Measurement Count 10 💌	
	Aquisition Time 0.001 s	
	Multidrop	
	Expert Mode	
	Export Waveforms	
	Enable	
	Offline Execution	
Test Checked Test Single	Enable	
Ready to run.		

- 3. Click "Test Single".
- 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 =  $100 \times (V_d \times V_{pk})[\%]$ 

 $V_{\rm pk}$  is the magnitude at peak and  $V_{\rm d}$  is the magnitude after 800ns as shown in Figure 10-1

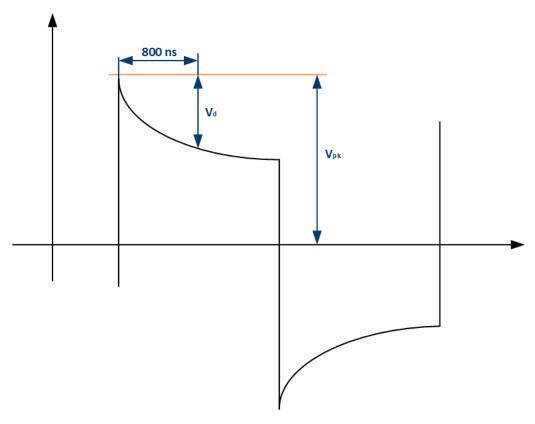


Figure 10-1: 10BASE-T1S transmitter output droop

#### **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<sup>™</sup>, section 147.5.4.4:

• Upper PSD for the frequency f 0.3 MHz ≤f ≤ 40 MHz

#### R&S<sup>®</sup>RTO, R&S<sup>®</sup>RTO6, R&S<sup>®</sup>RTP

# $UpperPSD(f) \begin{cases} -61 & 0.3 \leqslant f < 15 \\ -40 - 1.4f & 15 \leqslant f < 25 \\ -75 & 25 \leqslant f \leqslant 40 \end{cases} dBm/Hz$

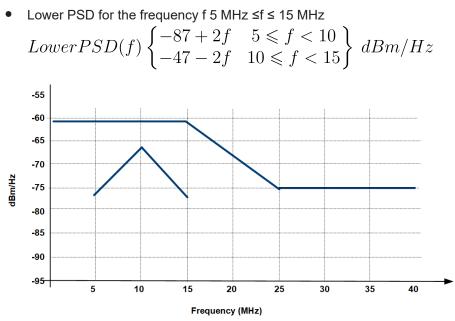


Figure 10-2: PSD limits (as defined in IEEE Std. P802.3cg<sup>™</sup>, section 147.5.4.4.3)

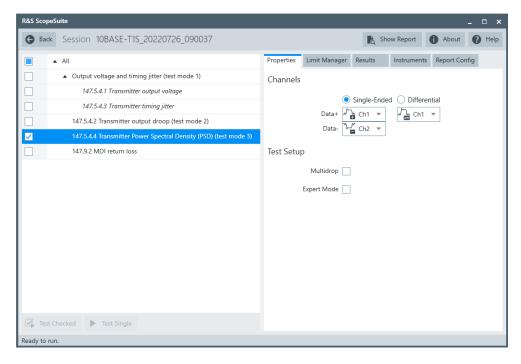
#### 10.3.3.1 Test equipment

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.
- Select the test case: "147.5.4.4 Transmitter power spectral density (PSD) (test mode 3)".

#### 10BASE-T1S tests



- 3. Click "Test Single".
- 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<sup>™</sup>):

$$MDI \ Return \ Loss(f) \begin{cases} 20 \ dB & 1 \le f \le 30 \ MHz \\ 20 - 20 \times \log_{10}\left(\frac{f}{30}\right) dB & 30 \le f < 66 \ MHz \end{cases}$$

#### 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".

R&S ScopeSuite	×
G Back Session 10BASE-T1S_20220726_090037	Kan Show Report 1 About 1 Help
All	Properties Limit Manager Results Instruments Report Config
Output voltage and timing jitter (test mode 1)	Test Setup
147.5.4.1 Transmitter output voltage	Average Count 5
147.5.4.3 Transmitter timing jitter	
147.5.4.2 Transmitter output droop (test mode 2)	Bandwidth 100 THZ
147.5.4.4 Transmitter Power Spectral Density (PSD) (test mode 3)	Expert Mode
✓ 147.9.2 MDI return loss	Calibration File Default10BaseT1_MDI .znx
✓ Test Checked     ✓ Test Single	VNA Path: C:\Users\Public\Documents\Rohde-Schwarz\VNA
Ready to run.	

- 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 perform 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<sup>™</sup>, section 146.5.4.1, is:
  - For the 2.4 V<sub>pp</sub> operating mode: 2.4 V + 5%/– 15% peak-to-peak
  - For the 1.0 V<sub>pp</sub> 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<sup>™</sup>, 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<sup>™</sup>, 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)".

R&S ScopeSuite	_ □ ×			
G Back Session 10BASE-T1L_20220726_101544	R Show Report 1 About 1 Help			
All	Properties Limit Manager Results Instruments Report Config			
Output voltage and timing jitter (test mode 1)	Channels			
✓ 146.5.4.1 Transmitter output voltage	Single-Ended      Differential			
✓ 146.5.4.3 Transmitter timing jitter				
✓ 146.5.4.5 Transmit clock frequency	Data+ $\bigvee_{\underline{h}} Ch1 = \bigvee_{\underline{h}} Ch1 =$ Data- $\bigvee_{\underline{h}} Ch2 =$			
146.5.4.2 Transmitter output droop (test mode 2)				
146.5.4.4 Transmitter Power Spectral Density (PSD) and power level (test mode 3)	Test Setup			
MDI	Output Voltage 1 v			
146.8.3 MDI return loss	Aquisition Time 0.001 s			
146.8.4 MDI mode conversion loss				
	Expert Mode			
	Export Waveforms			
	Enable			
	Offline Execution			
	Enable			
Test Checked Test Single				
Ready to run.				

- 3. Click "Test Single".
- 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<sup>™</sup>, 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)".

R&S ScopeSuite	_ 🗆 ×			
G Back Session 10BASE-T1L_20220726_101544	🖹 Show Report 🚺 About 👔 Help			
All	Properties Limit Manager Results Instruments Report Config			
Output voltage and timing jitter (test mode 1)	Channels			
V 146.5.4.2 Transmitter output droop (test mode 2)	Single-Ended O Differential			
146.5.4.4 Transmitter Power Spectral Density (PSD) and power level (test mode 3)	Data+			
MDI	Data-			
146.8.3 MDI return loss				
146.8.4 MDI mode conversion loss	Test Setup			
	Average Count 10			
	Measurement Count 10 💌			
	Output Voltage 1 👻 V			
	Aquisition Time 0.001 s			
	Expert Mode			
	Export Waveforms			
	Enable			
	Offline Execution			
Test Checked Fest Single	Enable			
Ready to run.				

- 3. Click "Test Single".
- 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<sup>™</sup>, 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 =  $100 \times (V_d \times V_{pk})[\%]$ 

 $V_{pk}$  is the magnitude at peak and  $V_d$  is the magnitude after 800ns as shown in Figure 10-1

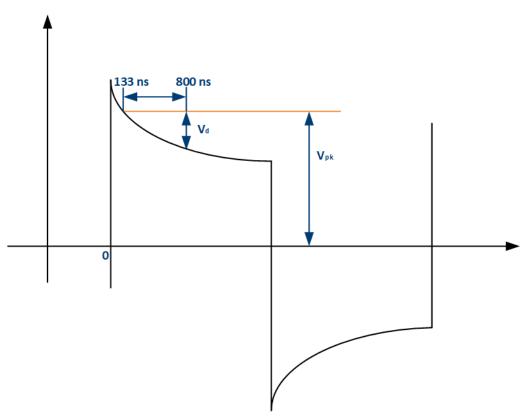


Figure 10-3: 10BASE-T1L transmitter output droop

# **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<sup>™</sup>, section 146.5.4.4:

- For the 2.4 V<sub>pp</sub> transmit signal amplitude:
  - Upper PSD for the frequency f

$$Upper PSD Limit(f) \ge \begin{cases} -54 \ dBm/Hz & 0 \le f \le 2.5\\ -54 - 1.6 \times (f - 2.5) \ dBm/Hz & 2.5 < f < 12.5\\ -70 \ dBm/Hz & 12.5 \le f \le 20 \end{cases}$$

- Lower PSD for the frequency f

# R&S<sup>®</sup>RTO, R&S<sup>®</sup>RTO6, R&S<sup>®</sup>RTP

# 10BASE-T1 tests

10BASE-T1L tests

$$Lower PSD \ Limit(f) \ge \begin{cases} -60 \ dBm/Hz & 0.625 \le f \le 2.5 \\ -60 - 4 \times (f - 2.5) \ dBm/Hz & 2.5 < f \le 5 \end{cases}$$
• For the 1.0 V<sub>pp</sub> transmit signal amplitude:
- Upper PSD for the frequency f
$$Upper PSD \ Limit(f) \ge \begin{cases} -61.6 \ dBm/Hz & 0 \le f \le 2.5 \\ -61.6 \ -1.6 \times (f - 2.5) \ dBm/Hz & 2.5 < f < 12.5 \\ -77.6 \ dBm/Hz & 12.5 \le f \le 20 \end{cases}$$
- Lower PSD for the frequency f
$$Lower \ PSD \ Limit(f) \ge \begin{cases} -67.6 \ dBm/Hz & 0.625 \le f \le 2.5 \\ -77.6 \ dBm/Hz & 2.5 < f \le 5 \end{cases}$$
• Lower PSD Limit(f) 
$$\ge \begin{cases} -67.6 \ dBm/Hz & 0.625 \le f \le 2.5 \\ -67.6 \ -4 \times (f - 2.5) \ dBm/Hz & 2.5 < f \le 5 \end{cases}$$
• Cover PSD Limit(f) 
$$\ge \begin{cases} -67.6 \ dBm/Hz & 0.625 \le f \le 2.5 \\ -67.6 \ -4 \times (f - 2.5) \ dBm/Hz & 2.5 < f \le 5 \end{cases}$$
• Frequency (MHz)

Figure 10-4: Transmitter PSD limits (as defined in IEEE Std. P802.3cg<sup>™</sup>, 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 Chapter 10.1, "Starting 10BASE-T1 tests", on page 280.

2. Select the test case: "146.5.4.4 Transmitter power spectral density (PSD) (test mode 3)".

R&S ScopeSuite	- 🗆	×
G Back Session 10BASE-T1L_20220726_101544	R Show Report 1 About 1 He	р
All	Properties Limit Manager Results Instruments Report Config	
Output voltage and timing jitter (test mode 1)	Channels	
146.5.4.2 Transmitter output droop (test mode 2)	<ul> <li>Single-Ended O Differential</li> </ul>	
146.5.44 Transmitter Power Spectral Density (PSD) and power level (test mode 3)     v MDI	Data+ Data- Data-	
	Test Setup	
	Output Voltage 1 v	
	Expert Mode	
Test Checked Test Single		
Ready to run.		

- 3. Click "Test Single".
- 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<sup>™</sup>):

$$Return \ Loss(f) \ge \begin{cases} 20 - 18 \times \log_{10}\left(\frac{0.2}{f}\right) dB & 0.1 \le f < 0.2 \ MHz \\ 20 \ dB & 0.2 \le f \le 1 \ MHz \\ 20 - 16.7 \times \log_{10}\left(f\right) dB & 1 < f \le 10 \ MHz \\ 3.3 - 7.6 \times \log_{10}\left(\frac{f}{10}\right) dB & 10 < f \le 20 \ MHz \end{cases}$$

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<sup>™</sup>):

$$Conversion \ Loss(f) \ge \begin{cases} 25 \ dB & 0.1 \le f \le 10 \ MHz \\ 25 - 20 \times \log_{10} \left(\frac{f}{10}\right) \ dB & 10 < f \le 20 \ MHz \end{cases}$$

#### 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.
- Select the test case: "146.8.3 and 146.8.4 MDI mode conversion loss and return loss".

R&S ScopeSuite	_ 🗆 ×
G Back Session 10BASE-T1L_20220726_101544	K Show Report 1 About 1 Help
All	Properties Limit Manager Results Instruments Report Config
Output voltage and timing jitter (test mode 1)	Test Setup
146.5.4.2 Transmitter output droop (test mode 2)	Average Count 5
146.5.4.4 Transmitter Power Spectral Density (PSD) and power level (test mode 3)	
MDI	Bandwidth 100 v Hz
146.8.3 MDI return loss	Expert Mode
✓ 146.8.4 MDI mode conversion loss	Calibration File Default10BaseT1_MDI .znx
	VNA Path: C:\Users\Public\Documents\Rohde-Schwarz\VNA
Test Checked Test Single	
Ready to run.	

3. Click "Test Single".

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 perform 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 (\*.slp) falls below the limit required by the specification for mode conversion loss. It also checks if every point within 0.1 MHz and 20 MHz in the result file (\*.slp) 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<sup>™</sup>/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.

- 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.

R&S ScopeSuite	×
<b>G</b> Back Session 10G_20221109_113708	Show Report         About         Help
All	Properties Limit Manager Results Instruments Report Config
149.5.2.3 Transmitter timing jitter master (test mode 1)	Channels
149.5.2.3 Transmitter timing jitter slave (test mode 1)	
149.5.2.3.1 Transmit MDI random jitter in master mode (test mode 2, TX_TCLK_175)	Skew
Test mode 2, JP03A	Data+
149.5.2.3.2 Transmit MDI deterministic jitter in master mode	Data- Ch3 V 0 ps V
149.5.2.6 Transmitter clock frequency	Single-Ended     Differential
149.5.2.3.2 Transmit MDI Even-Odd jitter in master mode (test mode 2, JP03B)	Skew
✓ 149.5.2.2 Transmitter linearity (test mode 4)	TX_TCLK_175+
Test mode 5	TX_TCLK_175- "→" Ch4 ▼ 0 ps ▼
149.5.2.4 Transmitter Power Spectral Density (PSD) and power level	Retrieve Skew
149.5.2.5 Transmitter peak differential output	Test Colum
149.5.2.1 Maximum output droop (test mode 6)	Test Setup
149.8.2.1 MDI return loss	Digital Filter 16 GHz
	Acquisition Time 1 ms 💌
	Expert Mode
	Export Waveforms
	Enable
	Liane
	Offline Execution
☑ Test Checked	Enable
Ready to run.	

#### 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  $\mu$ s 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<sup>TM</sup>/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<sup>™</sup>/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<sup>™</sup>/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)".

R&S ScopeSuite								- 0	×
G Back Se	ssion 10G_20220811_094413				🖹 Show Rep	ort	About	🕐 н	lelp
All		Properties	Limit Manage	er Results	Instruments	Rep	oort Config		
<b>V</b>	149.5.2.3 Transmitter timing jitter master (test mode 1)	Channels							
	149.5.2.3 Transmitter timing jitter slave (test mode 1)								
	149.5.2.3.1 Transmit MDI random jitter in master mode (test mode 2, TX_TCLK_175)		(	Single-End		_	<ul> <li>Differ</li> </ul>	ential	
□ ▲	Test mode 2, JP03A		г	ha	Skew		h		
	149.5.2.3.2 Transmit MDI deterministic jitter in master mode		X_TCLK_175+			os 🔻	Ch2	•	
	149.5.2.6 Transmitter clock frequency		TX_TCLK_175-	Ch4 V	0 1	os 🔻			
	149.5.2.3.2 Transmit MDI Even-Odd jitter in master mode (test mode 2, JP03B)				Retrieve Ske	w			
	149.5.2.2 Transmitter linearity (test mode 4)	Test Setu	n						
□ ▲	Test mode 5	iest setu							
	149.5.2.4 Transmitter Power Spectral Density (PSD) and power level	Aco	uisition Time	1	ms 🔻				
	149.5.2.5 Transmitter peak differential output		Expert Mode [						
	149.5.2.1 Maximum output droop (test mode 6)	Export W	aveforms						
	149.8.2.1 MDI return loss	Export W	Enable [	_					
		Offline Ex	ecution						
			Enable [						
Test Checke	d 🕨 Test Single								
Ready to run.									
neugy to run.						_			

3. Click "Test Single".

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 MAS-TER 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<sup>™</sup>/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.

- 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)".

Transmitter MDI random jitter in master mode

R&S ScopeSuite	×
G Back Session 10G_20220811_094413	the show Report
All	Properties Limit Manager Results Instruments Report Config
149.5.2.3 Transmitter timing jitter master (test mode 1)	Channels
✓ 149.5.2.3 Transmitter timing jitter slave (test mode 1)	
149.5.2.3.1 Transmit MDI random jitter in master mode (test mode 2, TX_TCLK_175)	Single-Ended     Differential
Test mode 2, JP03A	Skew
149.5.2.3.2 Transmit MDI deterministic jitter in master mode	TX_TCLK_175+
149.5.2.6 Transmitter clock frequency	TX_TCLK_175- <sup>™</sup> L <sup>™</sup> Ch4 ▼ 0 ps ▼
149.5.2.3.2 Transmit MDI Even-Odd jitter in master mode (test mode 2, JP03B)	Retrieve Skew
149.5.2.2 Transmitter linearity (test mode 4)	Test Setup
Test mode 5	iest setup
149.5.2.4 Transmitter Power Spectral Density (PSD) and power level	Acquisition Time 1 ms 🔻
149.5.2.5 Transmitter peak differential output	Expert Mode
149.5.2.1 Maximum output droop (test mode 6)	Export Waveforms
149.8.2.1 MDI return loss	Enable
	chable
	Offline Execution
	Enable
Test Checked Test Single	
Ready to run.	

- 3. Click "Test Single".
- 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<sup>TM</sup>/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.
- Select the test case: "149.5.2.3.1 Transmitter MDI random jitter in master mode (test mode2, TX\_TCLK\_175)".

R&S ScopeSuite	
G Back Session 10G_20220811_094413	R Show Report 1 About 1 Help
All	Properties Limit Manager Results Instruments Report Config
149.5.2.3 Transmitter timing jitter master (test mode 1)	Channels
149.5.2.3 Transmitter timing jitter slave (test mode 1)	
149.5.2.3.1 Transmit MDI random jitter in master mode (test mode 2, T	
Test mode 2, JP03A	Data+ Ch1 v 0 ps v
149.5.2.3.2 Transmit MDI deterministic jitter in master mode	Data- 🎦 Ch3 🔻 0 ps 🔻
149.5.2.6 Transmitter clock frequency	Retrieve Skew
149.5.2.3.2 Transmit MDI Even-Odd jitter in master mode (test mode 2	, JP03B) Test Setup
149.5.2.2 Transmitter linearity (test mode 4)	lest setup
Test mode 5	Acquisition Time 1 ms 💌
149.5.2.4 Transmitter Power Spectral Density (PSD) and power level	Expert Mode
149.5.2.5 Transmitter peak differential output	Export Waveforms
149.5.2.1 Maximum output droop (test mode 6)	
149.8.2.1 MDI return loss	Enable
	Offline Execution
	Enable
Test Checked Test Single	
Ready to run.	

- 3. Click "Test Single".
- 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<sup>™</sup>/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<sup>™</sup>/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".

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G Back Session 10G_20220811_094413	R Show Report 1 About 1 Help
All	Properties Limit Manager Results Instruments Report Config
149.5.2.3 Transmitter timing jitter master (test mode 1)	Channels
149.5.2.3 Transmitter timing jitter slave (test mode 1)	
149.5.2.3.1 Transmit MDI random jitter in master mode (test mode 2, TX_TCLK_175)	Skew
Test mode 2, JP03A	Data+ V Ch1 v 0 ps v
✓ 149.5.2.3.2 Transmit MDI deterministic jitter in master mode	Data- 🖓 🚰 Ch3 🔻 0 🌐 ps 💌
✓ 149.5.2.6 Transmitter clock frequency	Retrieve Skew
149.5.2.3.2 Transmit MDI Even-Odd jitter in master mode (test mode 2. JP03B)	Test Setup
149.5.2.2 Transmitter linearity (test mode 4)	its setup
Test mode 5	JP03A Acquisition Time 1 ms 🔻
149.5.2.4 Transmitter Power Spectral Density (PSD) and power level	Expert Mode
149.5.2.5 Transmitter peak differential output	Export Waveforms
149.5.2.1 Maximum output droop (test mode 6)	Enable
149.8.2.1 MDI return loss	
	Offline Execution
	Enable
Test Checked F Test Single	
Ready to run.	

- 3. Click "Test Single".
- 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  $5625 \times S$  MHz  $\pm 50$  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<sup>TM</sup>/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.
- Select the test case: "149.5.2.3.2 Transmit MDI Even-Odd jitter in master mode (test mode 2, JP03B)".

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G Back Session 10G_20220811_094413	K Show Report 1 About 1 Help
All	Properties Limit Manager Results Instruments Report Config
149.5.2.3 Transmitter timing jitter master (test mode 1)	Channels
149.5.2.3 Transmitter timing jitter slave (test mode 1)	
149.5.2.3.1 Transmit MDI random jitter in master mode (test mode 2, TX_TCLK_175)	Skew
Test mode 2, JP03A	Data+
149.5.2.3.2 Transmit MDI deterministic jitter in master mode	Data- Ch3 V 0 ps V
149.5.2.6 Transmitter clock frequency	Retrieve Skew
✓ 149.5.2.3.2 Transmit MDI Even-Odd jitter in master mode (test mode 2, JP03B)	Test Setup
149.5.2.2 Transmitter linearity (test mode 4)	
Test mode 5	Acquisition Time 1 ms 💌
149.5.2.4 Transmitter Power Spectral Density (PSD) and power level	Expert Mode
149.5.2.5 Transmitter peak differential output	Export Waveforms
149.5.2.1 Maximum output droop (test mode 6)	
149.8.2.1 MDI return loss	
	Offline Execution
	Enable
Test Checked 🕨 Test Single	
Ready to run.	

3. Click "Test Single".

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<sub>pk-pk</sub>) 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<sup>™</sup>/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)".

Back Session 10G_2022081_094413            Show Report         Market             All            Hais Show Report            Market           Properties            Instantiate timing jitter ansater (test mode 1)            Market           Properties            Instantiater timing jitter ansater (test mode 1)                 Hatter Statuments              Channels                   Hatter Statuments              Stow Report                    Hatter            Data-                Data-            Data-            Data-            Data-            Data-            Data-            Data-               Data-               Data-                 IndepSSL2S Transmitter finantial Output            Data- <th>R&amp;S ScopeS</th> <th colspan="7">R&amp;S ScopeSuite &gt;</th>	R&S ScopeS	R&S ScopeSuite >										
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<ul> <li>149.5.2.3 Z Transmit MDI Even-Odd jitter in master mode (test mode 2. JP038)</li> <li>149.5.2.2 Transmitter Invarity (test mode 4.)</li> <li>149.5.2.4 Transmitter Power Spectral Density (PSD) and power level</li> <li>149.5.2.5 Transmitter powd differential output</li> <li>149.5.2.1 Maximum output droop (test mode 6)</li> <li>149.5.2.1 MDI return loss</li> <li>149.5.2.1 MDI return loss</li> <li>Export Waveforms</li> <li>Enable</li> <li>Offline Execution</li> <li>Enable</li> </ul>		149.5.2.3.2 Transmit MDI deterministic jitter in master mode		Data-	Ch3 ▼	0 ps	*					
143.5.22 Transmitter linearity (test mode 4)       Test Setup         143.5.24 Transmitter Power Spectral Density (PSD) and power level       Digital Filter 16 GHz         143.5.25 Transmitter power differential output       Expert Mode _         143.5.2.1 Maximum output droop (test mode 6)       Expert Mode _         143.5.2.1 MDI return loss       Export Waveforms         Continue       Enable _         Offline Execution       Enable _		149.5.2.6 Transmitter clock frequency				Retrieve Skew						
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Image: 149.5.24 Transmitter Power Spectral Density (PSD) and power level       Acquisition Time 1 ms ▼         Image: 149.5.25 Transmitter peak differential output       Expert Mode □         Image: 149.5.21 Maximum output droop (test mode 6)       Expert Mode □         Image: 149.5.2.1 MDI return loss       Export Waveforms         Image: 149.5.21 MDI return loss       Enable □         Image: 149.5.21 MDI return loss       Offline Execution         Image: 149.5.21 MDI return loss       Enable □		149.5.2.2 Transmitter linearity (test mode 4)	lest Setu	ιP								
Image: Mage:		▲ Test mode 5		Digital Filter 1	6	GHz						
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Enable				Enable 🗌								
			Offline E	xecution								
				Enable								
	Test Ch	necked Fast Single										

- 3. Click "Test Single".
- 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<sup>™</sup>/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<sup>TM</sup>/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".

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	149.5.2.3 Transmitter timing jitter master (test mode 1)	Channels								
	149.5.2.3 Transmitter timing jitter slave (test mode 1)							_		
	149.5.2.3.1 Transmit MDI random jitter in master mode (test mode 2, TX_TCLK_175)					Skew				
	<ul> <li>Test mode 2, JP03A</li> </ul>			_	Ch1 🔻		ps 1	v		
	149.5.2.3.2 Transmit MDI deterministic jitter in master mode		Data-		Ch3 🔻	0	ps '	Ŧ		
	149.5.2.6 Transmitter clock frequency					Retrieve S	<ew< td=""><td></td><td></td><td></td></ew<>			
	149.5.2.3.2 Transmit MDI Even-Odd jitter in master mode (test mode 2, JP03B)	Test Setu	-							
	149.5.2.2 Transmitter linearity (test mode 4)	lest Setu	5							
	▲ Test mode 5	Acc	uisition Time	1		ms 🔻				
<ul> <li>Image: A set of the set of the</li></ul>	149.5.2.4 Transmitter Power Spectral Density (PSD) and power level		Expert Mode							
	149.5.2.5 Transmitter peak differential output	Export W	aveforms							
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	149.8.2.1 MDI return loss		chable							
		Offline Ex	ecution							
			Enable							
Test Ch	hecked 🕨 Test Single									
Ready to run	h.									

- 3. Click "Test Single".
- 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:

$$LSPD(f) = \begin{cases} -96 - K \ dBm/Hz & 5 < f \le 400 \times S \\ -95 - K - \frac{f}{400 \times S} \ dBm/Hz & 400 \times S < f \le 2000 \times S \\ -90 - K - \frac{f}{200 \times S} \ dBm/Hz & 2000 \times S < f \le 3000 \times S \end{cases}$$

$$USPD(f) = \begin{cases} -90 - K \ dBm/Hz & 0 < f \le 600 \times S \\ -89 - K - \frac{f}{600 \times S} \ dBm/Hz & 600 \times S < f \le 3000 \times S \\ -82 - K - \frac{f}{250 \times S} \ dBm/Hz & 3000 \times S < f \le 5500 \times S \end{cases}$$

where f is the frequency in MHz and  $K=101\log_{10}$  (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-topeak. It must be measured with 100  $\Omega$  termination.

# 11.12 Maximum output droop

The test verifies, that the maximum output droop is within the limits specified in the IEEE P802.3ch<sup>™</sup>/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)".

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All	Properties Limit Manager Results Instruments Report Config
149.5.2.3 Transmitter timing jitter master (test mode 1)	Channels
149.5.2.3 Transmitter timing jitter slave (test mode 1)	
149.5.2.3.1 Transmit MDI random jitter in master mode (test mode 2, TX_TCLK_175)	Skew
▲ Test mode 2, JP03A	Data+
149.5.2.3.2 Transmit MDI deterministic jitter in master mode	Data- 📜 Ch3 💌 0 ps 💌
149.5.2.6 Transmitter clock frequency	Retrieve Skew
149.5.2.3.2 Transmit MDI Even-Odd jitter in master mode (test mode 2, JP03B)	Test Setup
149.5.2.2 Transmitter linearity (test mode 4)	lest Setup
▲ Test mode 5	Average Count 10
149.5.2.4 Transmitter Power Spectral Density (PSD) and power level	Measurement Count 10 -
149.5.2.5 Transmitter peak differential output	Acquisition Time 1 ms 💌
149.5.2.1 Maximum output droop (test mode 6)	Expert Mode
149.8.2.1 MDI return loss	Expert Mode
	Export Waveforms
	Enable
	Offline Execution
Test Checked Test Single	Enable
eady to run.	

- 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

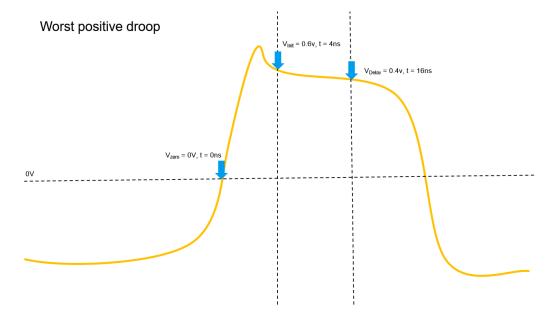
### 11.12.2 Measurements

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

In test mode 6, the DUT transmits  $128 \text{ xS} \{+1\}$  symbols followed by  $128 \text{ xS} \{-1\}$  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%.



# 11.13 MDI return loss

The test verifies, that the MDI return loss is within the limits specified in the IEEE P802.3ch<sup>™</sup>/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".

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	▲ All	Properties Limit Manager Results Instruments Report Config
	149.5.2.3 Transmitter timing jitter master (test mode 1)	Test Setup
	149.5.2.3 Transmitter timing jitter slave (test mode 1)	
	149.5.2.3.1 Transmit MDI random jitter in master mode (test mode 2, TX_TCLK_175)	VNA Average Count 10
	<ul> <li>Test mode 2, JP03A</li> </ul>	Bandwidth 100 💌 Hz
	149.5.2.3.2 Transmit MDI deterministic jitter in master mode	Expert Mode
	149.5.2.6 Transmitter clock frequency	Calibration File DefaultMGBaseT1 MDI .znx
	149.5.2.3.2 Transmit MDI Even-Odd jitter in master mode (test mode 2, JP03B)	
	149.5.2.2 Transmitter linearity (test mode 4)	VNA Path: C:\Users\Public\Documents\Rohde-Schwarz\VNA
	▲ Test mode 5	
	149.5.2.4 Transmitter Power Spectral Density (PSD) and power level	
	149.5.2.5 Transmitter peak differential output	
	149.5.2.1 Maximum output droop (test mode 6)	
	149.8.2.1 MDI return loss	
🛃 Test (	Checked Frest Single	
Ready to ru	n.	

- 3. Click "Test Single".
- 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:

$$MDIReturnLoss(f) \leq \begin{cases} 20 - 20\left(log_{10}\frac{10}{f}\right) & 1 \leq f < 10\\ 20 & 10 \leq f < 280S\\ 20 - 10log_{10}(f/(280S)) & 280S \leq f < 2800S\\ 10 - 16log_{10}(f/(2800S)) & 2800S \leq f \leq Fmax \end{cases} dB$$

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 (\*.slp or \*.csv) falls below the limit required by the specification.