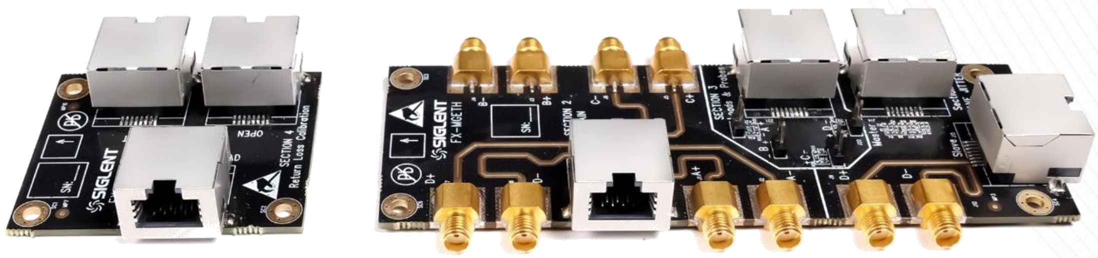
2.5/ 5/ 10G BASE-T Ethernet Compliance Test Application

User Manual

EN01A



SIGLENT TECHNOLOGIES CO., LTD.

Contents

1 Introduction

Siglent provides 2.5/ 5/ 10G Base-T Ethernet Compliance Test application to verify the Ethernet transmitter device under test (DUT) compliance to specifications. The equipment required for Ethernet conformance testing including Oscilloscope, Vector Network Analyzers, Arbitrary Waveform Generator, spectrum analyzer, standard test fixture, balun (option), Power Divider, probe, and cable. This user manual only introduces the test fixture, test methods and Connect for 2.5/ 5/ 10G Base-T Ethernet Compliance Test.

The Ethernet Compliance Test Application:

- Let's you select individual or multiple tests to run.
- Shows you how to connect the oscilloscope to the device under test (DUT).
- Automatically sets up the oscilloscope for every test project.
- Provides detailed information for every test that has been run, and lets you know the thresholds at which marginal or critical warnings appear.
- Creates HTML, XML or PDF test reports of the tests that have been run.

2 Test Items and Standards Reference

2.1 Test Items

2.1.1 2.5G BASE-T Test Items

2.5G BASE-T Ethernet Electrical Compliance Test items:

- Maximum Output Droop
    - Maximum Output Droop Positive
    - Maximum Output Droop Negative
- Transmitter Timing Jitter - Master
- Transmit Clock Frequency
- Transmitter Linearity
    - Tone 1
    - Tone 2
    - Tone 3
    - Tone 4
    - Tone 5
- Transmitter Nonlinear Distortion
    - Tone 1
    - Tone 2
    - Tone 3
    - Tone 4
    - Tone 5
- Power Tests
    - Power Spectral Density (PSD)
    - Power Level
- MDI Return Loss
- Transmitter Timing Jitter - Slave

The IEEE 802.3 specification has clear requirements for every test waveform for the compliance test. The DUT is required to provide corresponding waveforms for compliance test according to the test items. The user can use a software tool that configure the device under test to send out specific test packets according to the requirements.

For all kinds of mainstream NIC chips, you can control the DUT to send out corresponding test waveforms for compliance test by modifying relevant registers or using the packet sending tool provided by the chip manufacturer.

As defined in IEEE 802.3, configuring the registers of a 2.5G BASE-T chip allows the DUT to enter seven different test modes, each corresponding to a specific compliance test item see Figure 2-1. Among these, Test Mode 4 involves register configurations for dual-tone signal generation, as illustrated in Figure 2-2.

Table 126–13—MDIO management register settings for test modes

1.132.15	1.132.14	1.132.13	Mode
0	0	0	Normal operation.
0	0	1	Test mode 1—Setting of MASTER transmitter required by SLAVE for transmit jitter test in SLAVE mode.
0	1	0	Test mode 2—Transmit jitter test in MASTER mode.
0	1	1	Test mode 3—Transmit jitter test in SLAVE mode.
1	0	0	Test mode 4—Transmit distortion test.
1	0	1	Test mode 5—Normal operation with no power backoff. This is for the PSD mask and power level test.
1	1	0	Test mode 6—Transmitter droop test mode.
1	1	1	Test mode 7—Pseudo-random test mode for BER Monitor.

Figure 2-1 2.5/ 5G BASE-T Test mode setting

Table 126–14—MDIO management register settings for transmit frequencies in Test mode 4

1.132.12	1.132.11	1.132.10	Output waveform frequencies in MHz
			Two tone frequency pairs
0	0	0	Reserved
0	1	1	Reserved
1	1	1	Reserved
0	0	1	$S \times (400/1024) \times 47$, $S \times (400/1024) \times 53$
0	1	0	$S \times (400/1024) \times 101$, $S \times (400/1024) \times 103$
1	0	0	$S \times (400/1024) \times 179$, $S \times (400/1024) \times 181$
1	0	1	$S \times (400/1024) \times 277$, $S \times (400/1024) \times 281$
1	1	0	$S \times (400/1024) \times 397$, $S \times (400/1024) \times 401$

Figure 2-2 2.5/ 5G BASE-T Dual-Tone Signal setting

The correspondence between test modes and test items are as follows:

- Test Mode 1: Transmitter Timing Jitter - Slave (Master PHY);
- Test Mode 2: Transmitter Timing Jitter - Master, Transmit Clock Frequency
- Test Mode 3: Transmitter Timing Jitter - Slave (Slave PHY)
- Test Mode 4: Transmitter Linearity, Transmitter Nonlinear Distortion
- Test Mode 5: Power Spectral Density, Power Level, MDI Return Loss
- Test Mode 6: Maximum Output Droop

2.1.2 5G BASE-T Test Items

5G BASE-T Ethernet Electrical Compliance Test items:

- Maximum Output Droop
  - Maximum Output Droop Positive
  - Maximum Output Droop Negative
- Transmitter Timing Jitter - Master
- Transmit Clock Frequency
- Transmitter Linearity
  - Tone 1

  - Tone 2
  - Tone 3
  - Tone 4
  - Tone 5
- Power Tests
  - Power Spectral Density (PSD)
  - Power Level
- MDI Return Loss
- Transmitter Timing Jitter - Slave

The IEEE 802.3 specification has clear requirements for every test waveform for the compliance test. The DUT is required to provide corresponding waveforms for compliance test according to the test items. The user can use a software tool that configure the device under test to send out specific test packets according to the requirements.

For all kinds of mainstream NIC chips, you can control the DUT to send out corresponding test waveforms for compliance test by modifying relevant registers or using the packet sending tool provided by the chip manufacturer.

As defined in IEEE 802.3, configuring the registers of a 5G BASE-T chip allows the DUT to enter seven different test modes, each corresponding to a specific compliance test item see Figure 2-1. Among these, Test Mode 4 involves register configurations for dual-tone signal generation, as illustrated in Figure 2-2.

The correspondence between test modes and test items are as follows:

- Test Mode 1: Transmitter Timing Jitter - Slave (Master PHY);
- Test Mode 2: Transmitter Timing Jitter - Master, Transmit Clock Frequency
- Test Mode 3: Transmitter Timing Jitter - Slave (Slave PHY)
- Test Mode 4: Transmitter Linearity
- Test Mode 5: Power Spectral Density, Power Level, MDI Return Loss
- Test Mode 6: Maximum Output Droop

2.1.3 10G BASE-T Test Items

10G BASE-T Ethernet Electrical Compliance Test items:

- Maximum Output Droop
  - Maximum Output Droop Positive
  - Maximum Output Droop Negative
- Transmitter Timing Jitter - Master
- Transmit Clock Frequency
- Transmitter Linearity
  - Tone 1
  - Tone 2
  - Tone 3
  - Tone 4
  - Tone 5
- Power Test
  - Power Spectral Density (PSD)
  - Power Level
- MDI Return Loss
- Transmitter Timing Jitter - Slave

The IEEE 802.3 standard specifies clear requirements for test waveforms. It mandates that the Device Under Test (DUT) generate corresponding waveforms based on the test items. A packet generation tool is software used to instruct the DUT to transmit specific test packets as required.

For mainstream NIC chips, waveform control can be achieved by modifying relevant registers or utilizing packet generation tools provided by the chip manufacturer. These tools enable the DUT to emit the required waveforms for testing.

As defined in IEEE 802.3, configuring the registers of a 10G BASE-T chip allows the DUT to enter seven different test modes, each corresponding to a specific compliance test item see Figure 2-3. Among these, Test Mode 4 involves register configurations for dual-tone signal generation, as illustrated in Figure 2-4.

Table 55–12—MDIO management register settings for test modes

1.132.15	1.132.14	1.132.13	Mode
0	0	0	Normal operation.
0	0	1	Test mode 1—Setting of MASTER transmitter required by SLAVE for transmit jitter test in SLAVE mode.
0	1	0	Test mode 2—Transmit jitter test in MASTER mode.
0	1	1	Test mode 3—Transmit jitter test in SLAVE mode (if loop timing is supported).
1	0	0	Test mode 4—Transmit distortion test.
1	0	1	Test mode 5—Normal operation with no power backoff. This is for the PSD mask and power level test.
1	1	0	Test mode 6—Transmitter droop test mode.
1	1	1	Test mode 7—Pseudo random test mode for BER Monitor.

Figure 2-3 10G BASE-T Test mode setting

Table 55–13—MDIO management register settings for transmit frequencies in Test mode 4

1.132.12	1.132.11	1.132.10	Output waveform frequencies in MHz
			Two tone frequency pairs
0	0	0	Reserved
0	1	1	Reserved
1	1	1	Reserved
0	0	1	(800/1024) × 47, (800/1024) × 53
0	1	0	(800/1024) × 101, (800/1024) × 103
1	0	0	(800/1024) × 179, (800/1024) × 181
1	0	1	(800/1024) × 277, (800/1024) × 281
1	1	0	(800/1024) × 397, (800/1024) × 401

Figure 2-4 10GBASE-T Dual-Tone Signal setting

The correspondence between test modes and test items are as follows:

- Test Mode 1: Transmitter Timing Jitter - Slave (Master PHY);
- Test Mode 2: Transmitter Timing Jitter - Master, Transmit Clock Frequency
- Test Mode 3: Transmitter Timing Jitter - Slave (Slave PHY)
- Test Mode 4: Transmitter Linearity

- Test Mode 5: Power Spectral Density, Power Level, MDI Return Loss
- Test Mode 6: Maximum Output Droop

2.2 Standards Reference

Siglent provides the 2.5/ 5/ 10G Base-T Ethernet Compliance Test solution which follows the IEEE802.3-2018 section 55 and section 126 standards, and Table 2-1 shows the standard for each test item.

More information for the IEEE802.3 standards, please go to the website: www.ieee802.org.

Table 2-1 2.5/ 5/ 10G Base-T Test by Standard Reference

Standard Reference	Test Mode	Test Items	Test Description
IEEE 802.3-2018, Subclause 126.5.3.1	Test Mode 6	Maximum Output Droop	2.5G BASE-T, Maximum Output Droop
IEEE 802.3-2018, Subclause 126.5.3.3	Test Mode 2	Transmitter Timing Jitter-Master	2.5G BASE-T, Transmitter Timing Jitter-Master
IEEE 802.3-2018, Subclause 126.5.3.5	Test Mode 2	Transmitter Clock Frequency	2.5G BASE-T, Transmitter Clock Frequency
IEEE 802.3-2018, Subclause 126.5.3.2	Test Mode 4	Transmitter Linearity	2.5G BASE-T, Transmitter Linearity
IEEE 802.3-2018, Subclause 126.5.3.2	Test Mode 4	Transmitter Nonlinear Distortion	2.5G BASE-T, Transmitter Nonlinear Distortion
IEEE 802.3-2018, Subclause 126.5.3.4	Test Mode 5	PSD (Power Spectral Density) , Power Level	2.5G BASE-T, PSD (Power Spectral Density), Power Level
IEEE 802.3-2018, Subclause 126.8.2.2	Test Mode 5	MDI Return Loss	2.5G BASE-T, MDI Return Loss
IEEE 802.3-2018, Subclause 126.5.3.3	Test Mode 1 Test Mode 3	Transmitter Timing Jitter-Slave	2.5G BASE-T, Transmitter Timing Jitter-Slave
IEEE 802.3-2018, Subclause 126.5.3.1	Test Mode 6	Maximum Output Droop	5G BASE-T, Maximum Output Droop
IEEE 802.3-2018, Subclause 126.5.3.3	Test Mode 2	Transmitter Timing Jitter-Master	5G BASE-T, Transmitter Timing Jitter-Master
IEEE 802.3-2018, Subclause 126.5.3.5	Test Mode 2	Transmitter Clock Frequency	5G BASE-T, Transmitter Clock Frequency
IEEE 802.3-2018, Subclause 126.5.3.2	Test Mode 4	Transmitter Linearity	5G BASE-T， Transmitter Linearity

IEEE 802.3-2018, Subclause 126.5.3.4	Test Mode 5	PSD (Power Spectral Density) , Power Level	5G BASE-T, PSD (Power Spectral Density) , Power Level
IEEE 802.3-2018, Subclause 126.8.2.2	Test Mode 5	MDI Return Loss	5G BASE-T, MDI Return Loss
IEEE 802.3-2018, Subclause 126.5.3.3	Test Mode 1 Test Mode 3	Transmitter Timing Jitter-Slave	5G BASE-T Transmitter Timing Jitter-Slave
IEEE 802.3-2018, Subclause 55.5.3.1	Test Mode 6	Maximum Output Droop	10G BASE-T, Maximum Output Droop
IEEE 802.3-2018, Subclause 55.5.3.3	Test Mode 2	Transmitter Timing Jitter-Master	10G BASE-T, Transmitter Timing Jitter-Master
IEEE 802.3-2018, Subclause 55.5.3.5	Test Mode 2	Transmitter Clock Frequency	10G BASE-T, Transmitter Clock Frequency
IEEE 802.3-2018, Subclause 55.5.3.2	Test Mode 4	Transmitter Linearity	10G BASE-T, Transmitter Linearity
IEEE 802.3-2018, Subclause 55.5.3.4	Test Mode 5	PSD (Power Spectral Density) , Power Level	10G BASE-T, PSD (Power Spectral Density) , Power Level
IEEE 802.3-2018, Subclause 55.8.2.1	Test Mode 5	MDI Return Loss	10GBASE-T, MDI Return Loss
IEEE 802.3-2018, Subclause 55.5.3.3	Test Mode 1 Test Mode 3	Transmitter Timing Jitter-Slave	10GBASE-T， Transmitter Timing Jitter-Slave

3 Test Equipment

3.1 Required Equipment

2.5/ 5/ 10G Base-T Ethernet electrical compliance test measurements require the following equipment:

- Oscilloscope (SDS7000A): Oscilloscope's bandwidth ≥ 4 GHz, and with the Ethernet Compliance Test Application software that has installed the option key (SDS7000A-CT-2.5/ 5/ 10GBASE-T option).
- FX-MGETH kit: FX-MGETH kit is 2.5/ 5/ 10G Base-T the Ethernet Electrical Compliance Test Fixture from Siglent that provides the physical connection and test points after the DUT enters the test mode.
- Differential probe or SMA cables:
    - Differential probe（e.g., SAP5000D）: Bandwidth greater than 4 GHz for probing signals;
    - SMA cables: connects from the oscilloscope to the test fixture for probing signals.
- Spectrum Analyzer: Used for power spectral density, power level, transmitter linearity, and transmitter nonlinear distortion testing.
- Vector Network Analyzer: VNA is used for MDI return loss test.
- Arbitrary waveform generator: Dual channels arbitrary waveform generator which outputs the required disturbing signals. For 2.5G BASE-T transmitter nonlinear distortion testing.
- USB Cable: Used to connect the oscilloscope's USB Host interface to the USB Device interface of either a network analyzer or spectrum analyzer, enabling the oscilloscope to control these instruments and acquire test data.
- Balun (Optional): A 2:1 impedance ratio balun is used to perform impedance transformation from differential 100 Ω to single-ended 50 Ω. The spectrum analyzer and network analyzer utilize the balun for compliance testing of the device under test (DUT).
- Power Divider: In 2.5G BASE-T transmitter nonlinear distortion testing, the power divider is required to connect the interference source signal to the DUT, route the DUT signal to either an oscilloscope or spectrum analyzer for testing.

3.2 Delivery Checklist

The FX-MGETH kit includes the items are placed inside the black suitcase and the contents of the delivery are shown in the table below. To ensure your rights, please check whether the items in the box are consistent with the list within 48 hours after signing. If you notice any omissions or damage, please contact your nearest Siglent customer service center or distributor as soon as possible. If you fail to contact us immediately in case of omissions or damage, we will not be responsible for replacement. Please understand.

Table 3-1 FX-MGETH Kit Checklist

Item name	Quantities
User Manual	1
Test Fixture Board	1
Calibration fixture Board	1
50 Ω Terminators （SMA）	8
SMA cables （length： 300 mm）	4
SMA cables (length： 300 mm, high performance phase matched cables, Blue)	2
BNC-SMA Adaptors	6
UTP RJ45 Cable （length： 150 mm）	2
Power Divider	2
Balun (Optional)	1

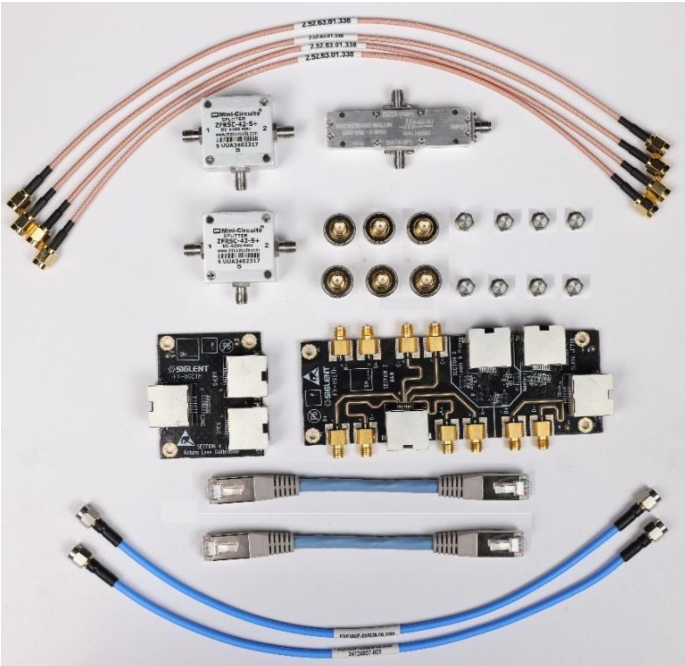


Figure 3-1 FX-MGETH Test Fixture

3.3 Introduction to FX-MGETH Test Fixture

3.3.1 Ethernet Test Fixture Board

FX-MGETH kit is the Ethernet Electrical Compliance Test Fixture which cooperates with software for 2.5/ 5/ 10G BASE-T ethernet compliance validation on SDS7000A. The test fixture board shown in Figure 3-2 which consists of 3 sections, each section has some specific functions, which are clearly marked on the board to help user to use the test fixture.

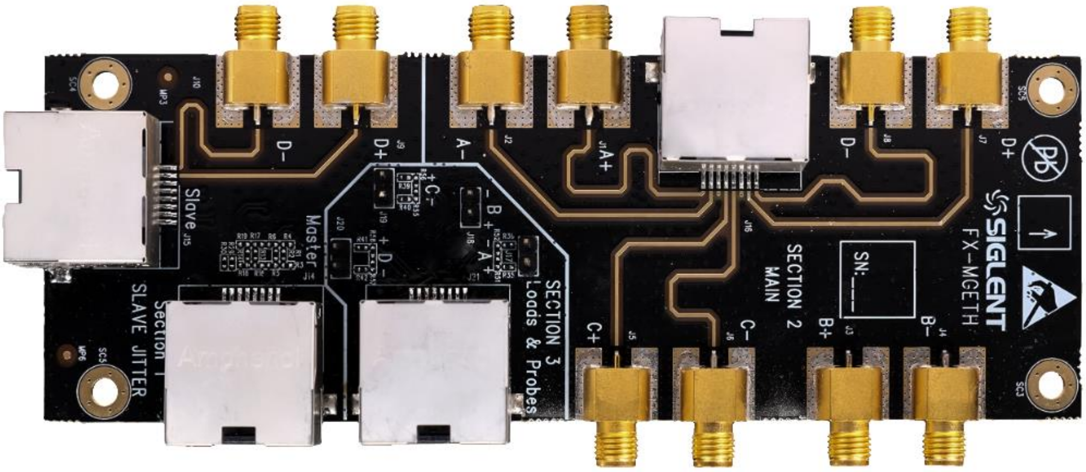


Figure 3-2 Ethernet Electrical Compliance Test Fixture Board

Each section on the board is described as follows:

- Section 1: Supports the Ethernet Compliance test for 2.5/ 5/ 10G BASE-T transmitter timing jitter-slave
- Section 2: Supports most of the Ethernet Compliance tests for 2.5/ 5/ 10G BASE-T by using two SMA cables.
- Section 3: Supports most of the Ethernet Compliance tests for 2.5/ 5/ 10G BASE-T by using a differential probe.

3.3.2 Calibration Fixture Board

Calibration fixture board as shown in the Figure 3-3 .

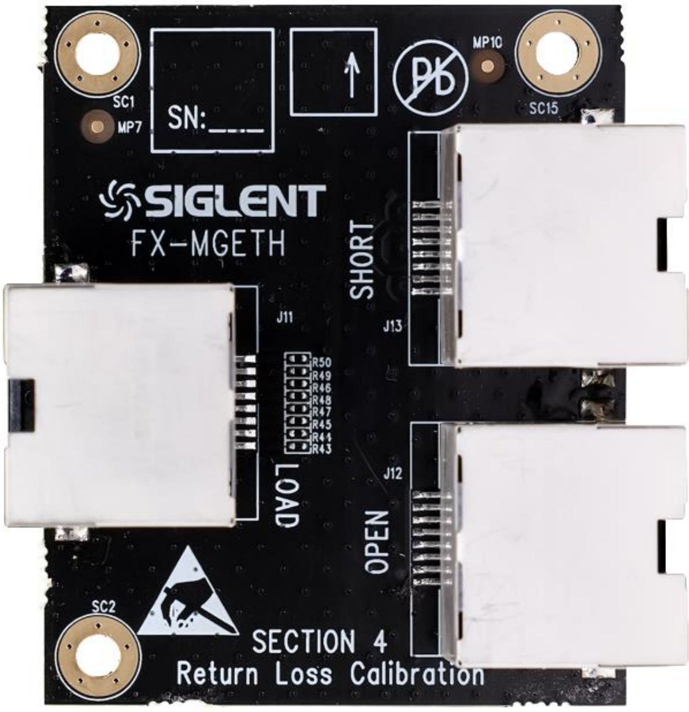


Figure 3-3 Calibration Fixture

The calibration fixture is marked as SECTION 4. Before using the VNA instrument to test the MDI return loss of the device under test, it is necessary to use the calibration fixture to perform Open, Short, and Load calibration on the test environment. After calibration, the MDI return loss test can be performed on the device under test.

4 Compliance Test Software Introduce

Siglent's 2.5/ 5/ 10G BASE-T Ethernet Compliance Test is a solution based on IEEE802.3-2018 specifications. The Ethernet Compliance analysis software controls the oscilloscope to automatically perform the tests. The graphical operation guide simplifies the measurement process, the test items can be flexibly configured, and the test report records the entire measurement results, including the test values and the screenshots of the test waveforms.

SDS7000A provides 2.5/ 5/ 10G Base-T Compliance Test function, according to **Analysis** -> **Compliance Test** -> **Protocol Type** , select **2.5/ 5/ 10G BASE-T** and click **ON** to activate the Compliance Test function, which are shown in Figure 4-1. The Compliance Test function is divided into three main parts: **Test Config** , **Results** , and **Report Setting** .

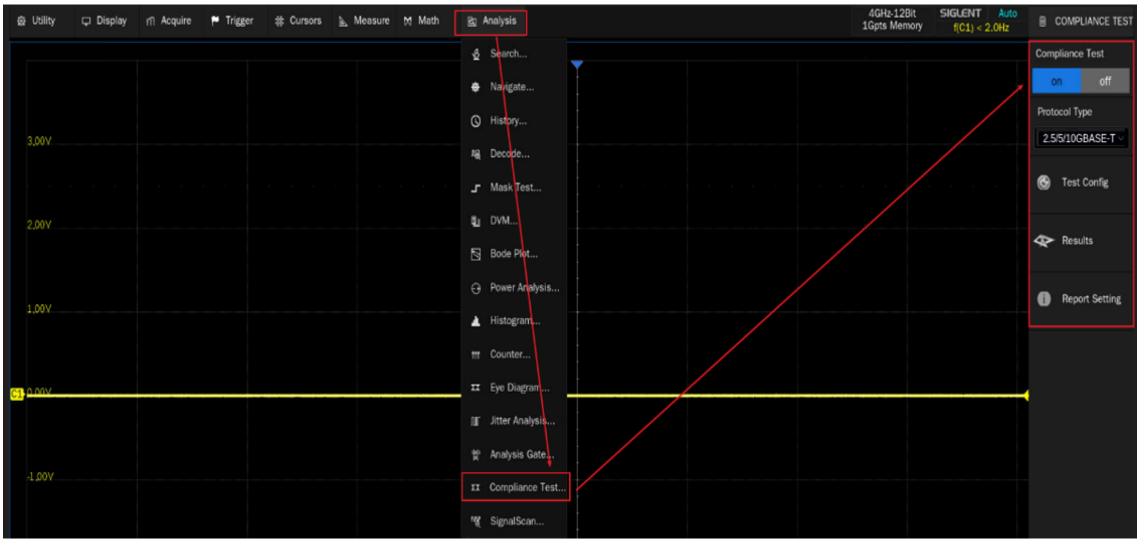


Figure 4-1 Launching 2.5/ 5/ 10G BASE-T Compliance Analysis Software

4.1 Test Configuration

Clicking on Test Config will pop up the specific test configuration window, as shown in Figure 4-2, which is divided into six steps based on the test process: Setup , Test Select , Configure , Connect , Run Test , and Result .

➢ **Setup:**

◆ Provide the functions of Recall , Last and Save for the configuration.

◆ Provide the speed select options: 2.5G Base-T , 5G Base-T , and 10G Base-T .

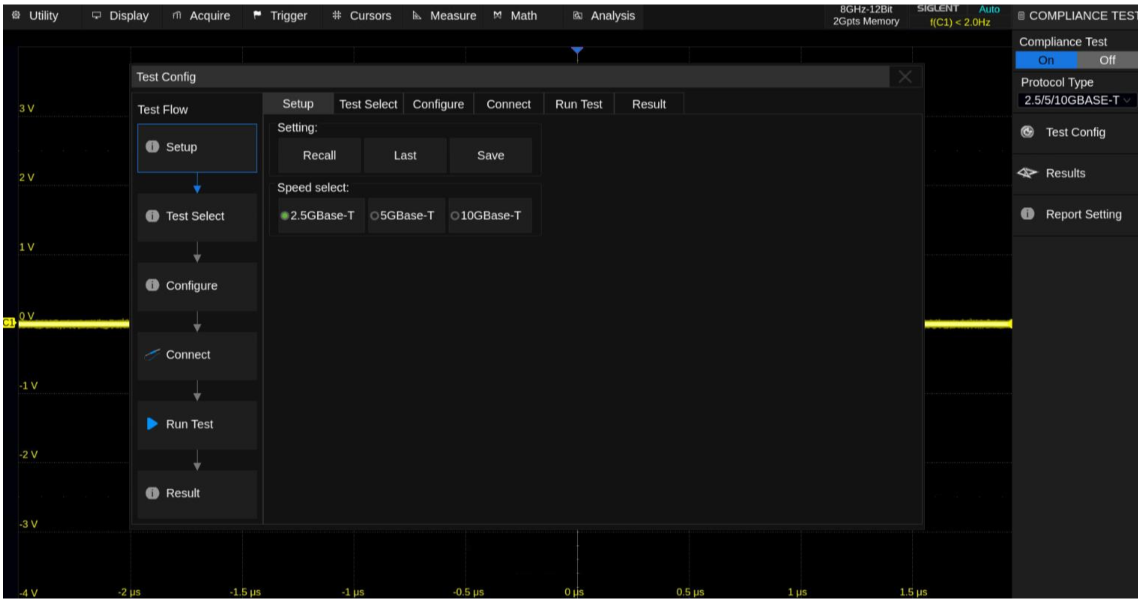


Figure 4-2 Test Configuration Window

➢ **Test Select:** Select the items to be tested in this column, as shown in Figure 4-3

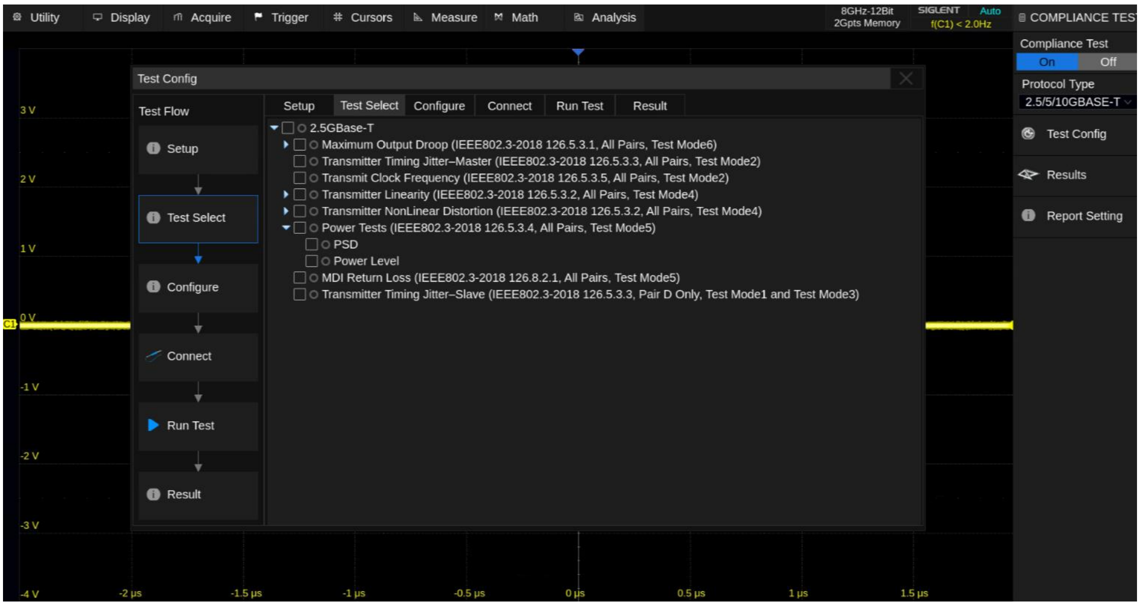


Figure 4-3 Test Item Selection Window

➢ **Configure:** The test items selected in **Test Select** will be highlighted in this column, and you can click the corresponding items to configure. You can set the input channels and probe type, as shown in Figure 4-4.

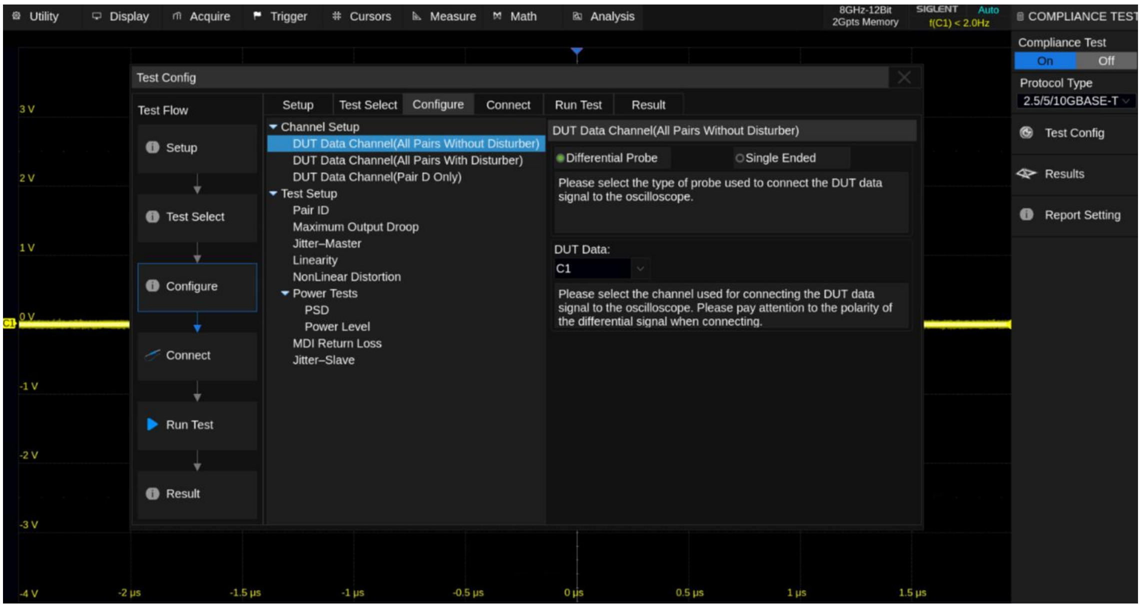


Figure 4-4 Test Item Selection Window

As shown in Figure 4-4, after click **DUT Data Channel (All Pairs Without Disturber)**, the channel setting window for all testable signal pairs and test items whitout disturber will be expanded. The available settings are:

- **Probe type selection (differential probe/single-ended input)**: Set the probe type used by the oscilloscope to connect to the signal to be measured;
- **Channel selection (C1/C2/C3/C4)**: Set the channel used by the oscilloscope to connect to the signal to be measured.

As shown in Figure 4-5, after click **DUT Data Channel (All Pairs With Disturber)**, the channel setting window for all testable signal pairs and test items with disturber will be expanded. The available settings are:

- **Channel selection (C1/C2/C3/C4):** Set the channel used by the oscilloscope to connect to the signal to be measured.

Note: This configuration is only required for the nonlinear distortion test item of 2.5G BASE-T, and the probe type is only support single-ended input.

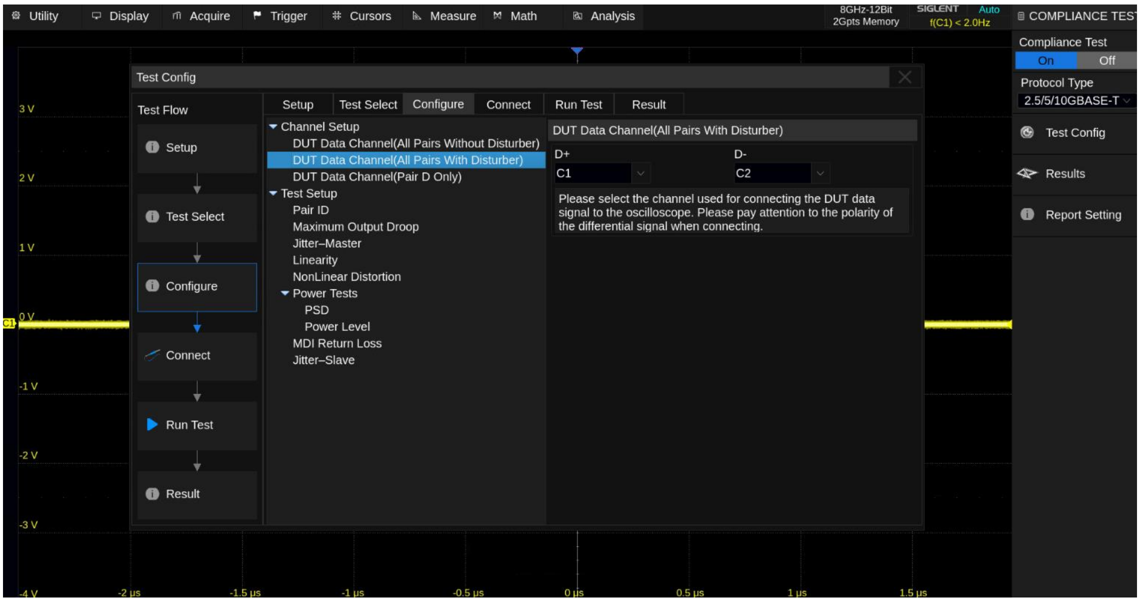


Figure 4-5 DUT Data Channel (All Pairs With Disturber) Configuration Interface

As shown in Figure 4-6, after click **DUT Data Channel (Pair D only)**, the channel setting window for pair D will be expanded, and the available settings are:

- **Channel selection (C1/C2/C3/C4):** Set the channel used by the oscilloscope to connect to the signal to be measured.

Note: Only the transmitter timing jitter-slave item needs to be configured, and the probe type is only support single-ended input.

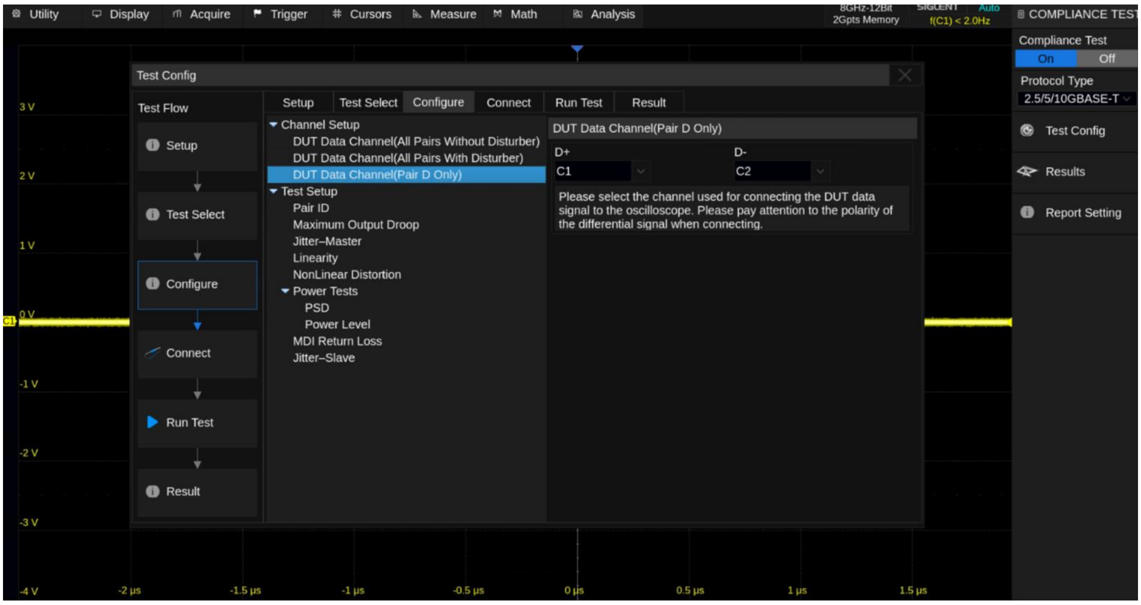


Figure 4-6 DUT Data Channel (Pair D only) Configuration Interface

As shown in Figure 4-7, click **Pair ID** , the configuration window of the test pair ID will be expanded to set the pair ID . The available settings are:

- Test pair ID **(Pair A/ Pair B/ Pair C/ Pair D/ Pair All)**: Select the serial number of the pair being tested.

Note: Transmitter timing jitter-slave item only needs to test Pair D.

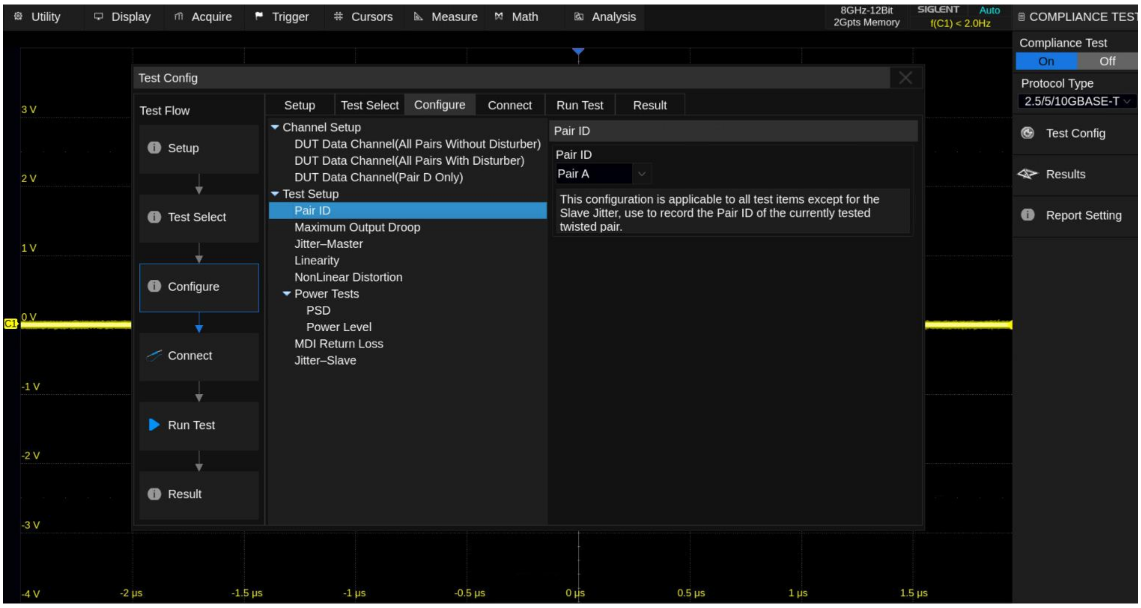


Figure 4-7 Test Pair ID Configuration Interface

As shown in Figure 4-8 , click **Maximum Output Droop** , expand the configuration window for the maximum output droop test, the available settings are:

- Average num (1/ 4/ 16/ 32/ 64/ 128/ 256/ 512): Set the averaging times of the test waveform. The more averaging times, the more stable the test waveform and results.

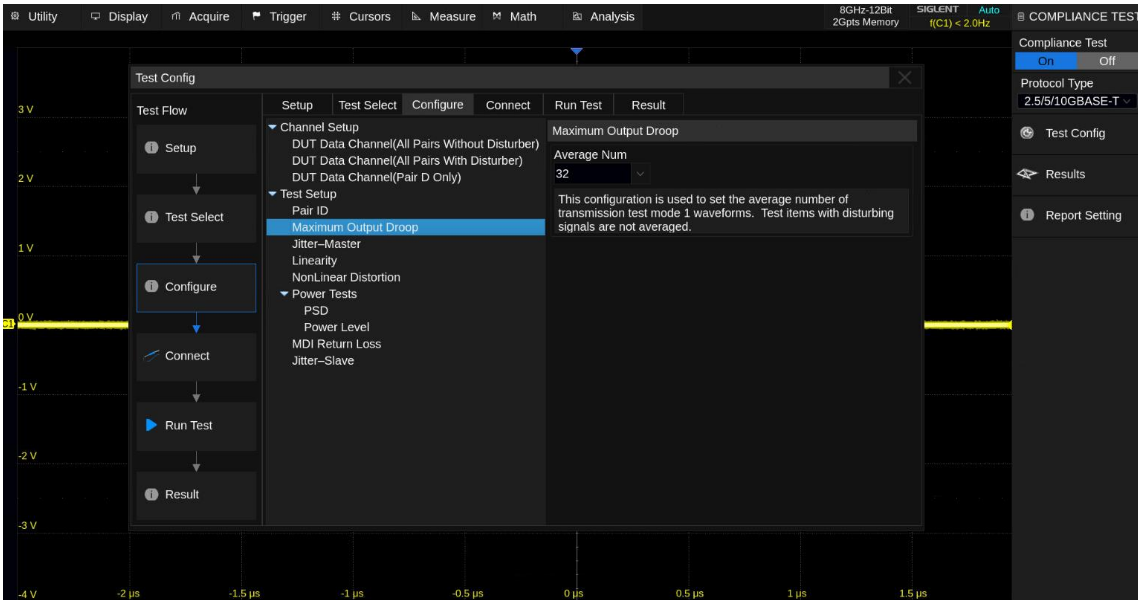


Figure 4-8 Maximum Output Droop Configuration Interface

As shown in Figure 4-9, click **Jitter-Master** , expand the configuration window for the transmitter timing jitter-Master, the available settings are:

- **Jitter type (TIE / Peroid):** Set the jitter type for calculation.
- **Bandpass filter (False / True):** Select whether to filter the waveform before calculating the jitter. Generally, the jitter result after filtering will be better. The center frequency of the bandpass filter used by 2.5G BASE-T is 50 MHz and the bandwidth is 2 MHz; the center frequency of the bandpass filter used by 5G BASE-T is 100 MHz and the bandwidth is 2 MHz; the center frequency of the bandpass filter used by 10G BASE-T is 200 MHz and the bandwidth is 2 MHz.

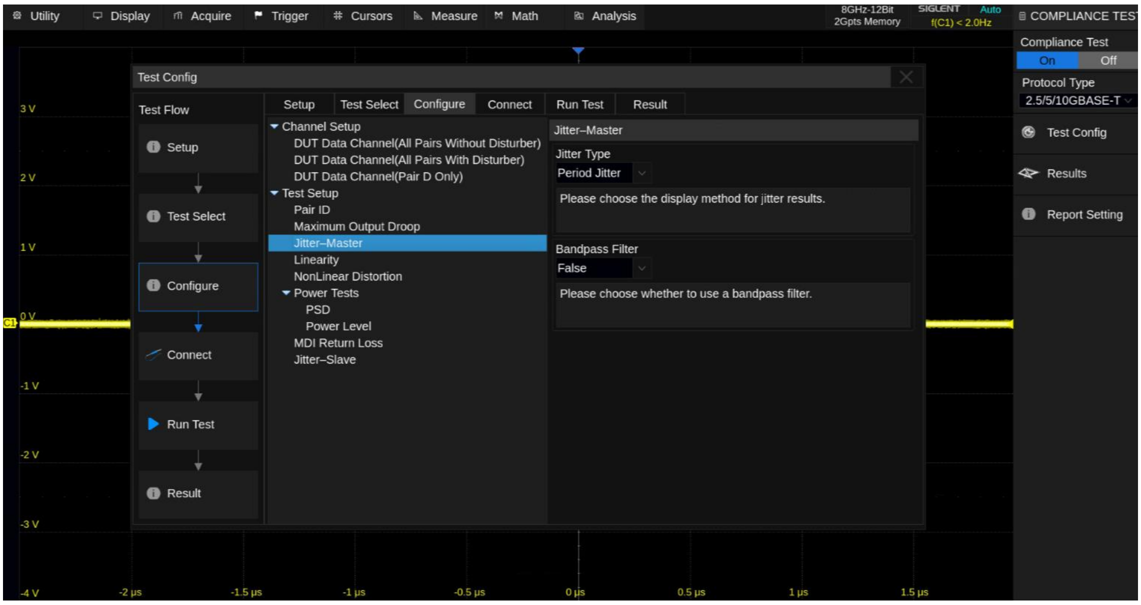


Figure 4-9 Transmitter Timing Jitter-Master Configuration Interface

As shown in Figure 4-10, click **Linearity** , expand the configuration window for the transmitter linearity, the available settings are:

- Test equipment selection (oscilloscope/spectrum analyzer): Select the test instrument used for transmitter linearity.
- Average num (1/ 10/ 20/ 30/ 40/ 50): Set the average number of test results. The more average times, the more stable the results.
- Connect test: Detect the connection status of the spectrum analyzer. The device name will be displayed after the connection is successful.
- Balun compensation (On / Off): Select whether to compensate for the insertion loss of the balun.
- Settings: Click **Configure** to enter the balun compensation interface, as shown in Figure 4-11. You can add/modify/delete insertion loss at different frequencies. Up to 50 points can be added. Because the balun has its own insertion loss and return loss, which will affect the test results, these losses need to be compensated.

Note: Test Connect, balun compensation, and settings are only effective when the test instrument selects the spectrum analyzer, and the settings can only take effect after the balun compensation is turned on.

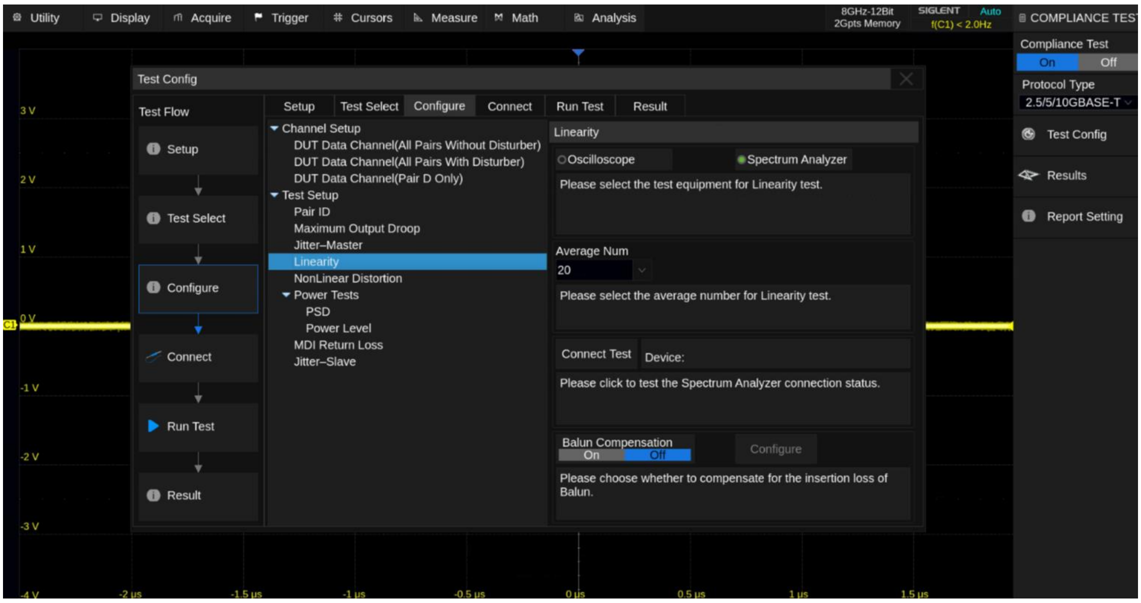


Figure 4-10 Transmitter Linearity Configuration Interface

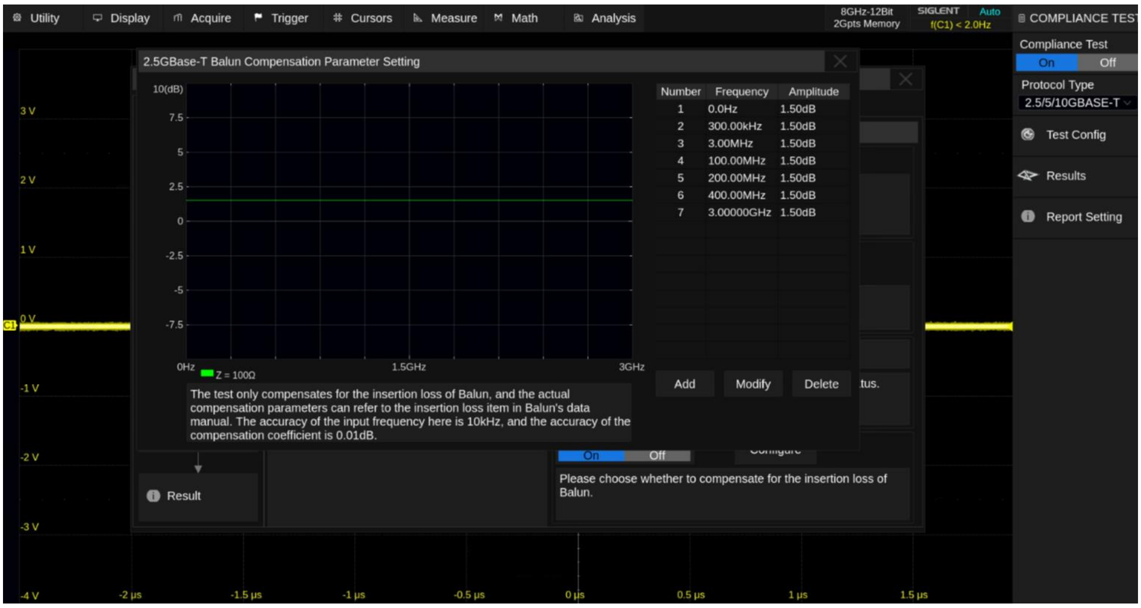


Figure 4-11 Balun Compensation Configuration Interface

As shown in Figure 4-12, click **Nonlinear Distortion**, expand the configuration window for the transmitter nonlinear distortion, the available settings are:

- Test equipment selection (oscilloscope/spectrum analyzer): Select the test instrument used for transmitter nonlinear distortion.
- Average num (1/ 10/ 20/ 30/ 40/ 50): used to set the average number of test results. The more average times, the more stable the results.

◆ Connect test for AWG: Detect the connection status of the arbitrary waveform generator. The device name will be displayed after the connection is successful.

◆ Connect test for SA: Detect the connectionstatus of the spectrum analyzer. The device name will be displayed after the connectionis successful.

◆ Balun compensation (On/ Off): Select whether to compensate for the insertion loss of the balun.

◆ Settings: Click **Configure** to enter the balun compensation interface, as shown in Figure 4-11. You can add/modify/delete insertion loss at different frequencies. A maximum of 50 points can be added.

Note 1: This configuration only exists for 2.5G BASE-T.

Note 2: Test Connect (spectrum analyzer), balun compensation, and settings are only effective when the test instrument selects the spectrum analyzer, and the settings can only take effect after the balun compensation is turned on.

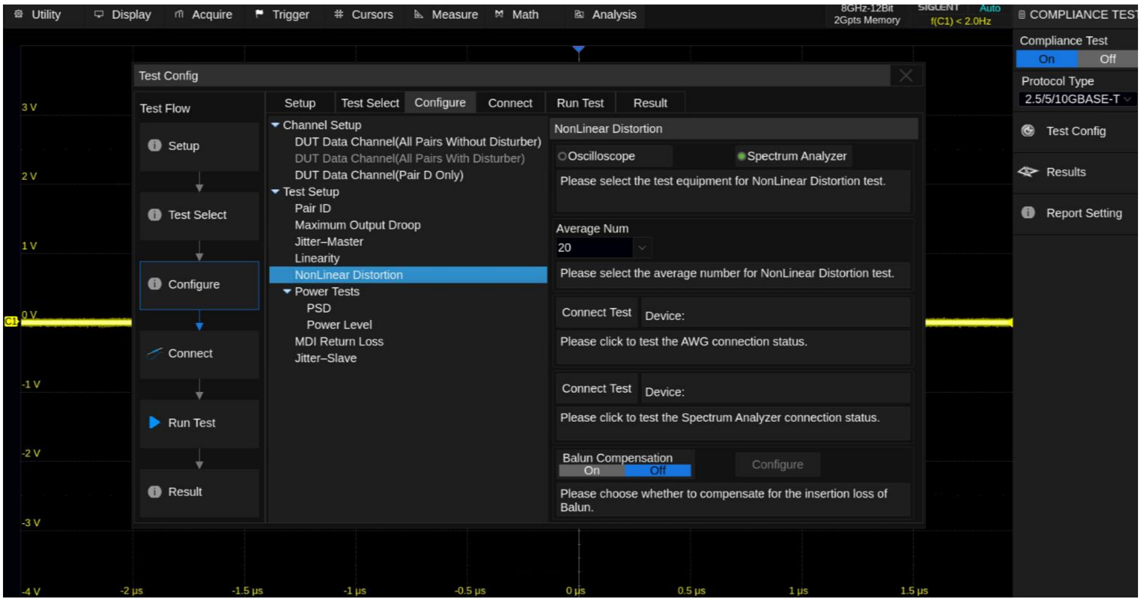


Figure 4-12 Transmitter Nonlinear Distortion Configuration Interface

As shown in Figure 4-13, click **PSD** , expand the configuration window for the power spectral density, the available settings are:

◆ Test equipment selection (oscilloscope/spectrum analyzer): Select the test instrument used for power spectrum density test.

◆ Average num (1/ 10/ 20/ 30/ 40/ 50/ 100): used to set the average number of test results. The more average times, the more stable the results.

- Connect test: used to detect the connectionstatus of the spectrum analyzer. The device name will be displayed after the connectionis successful.
- Balun compensation (On/ Off): used to select whether to compensate for the insertion loss of the balun.
- Settings: Click **Configure** to enter the balun compensation interface, as shown in Figure 4-11. You can add/modify/delete insertion loss at different frequencies. Up to 50 points can be added.

Note: Test Connect, balun compensation, and settings are only effective when the test instrument selects the spectrum analyzer, and the settings can only take effect after the balun compensation is turned on.

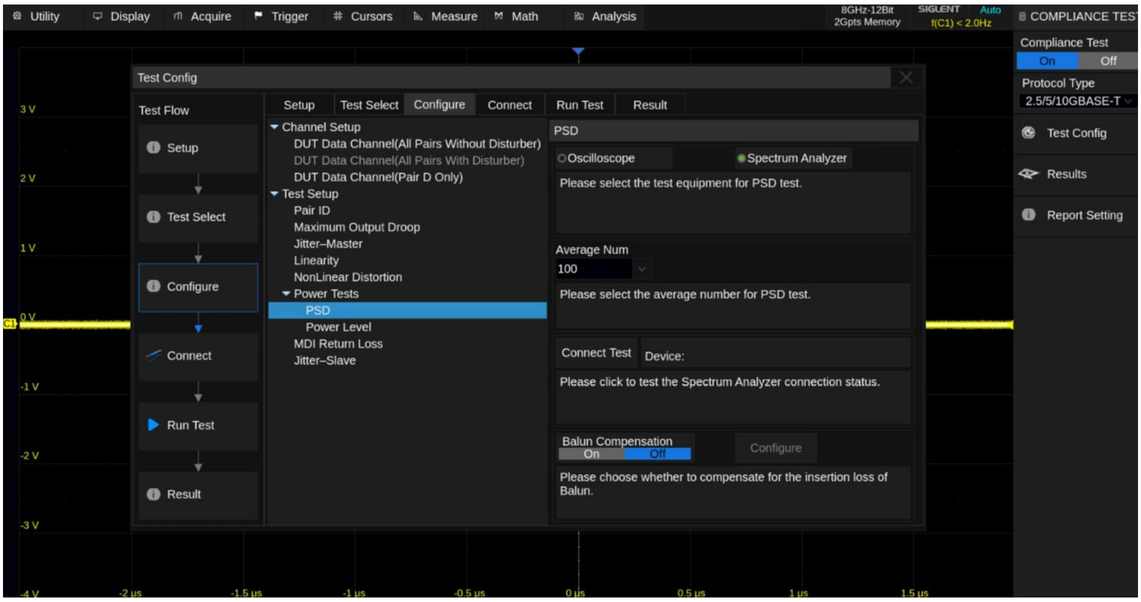


Figure 4-13 PSD Configuration Interface

As shown in Figure 4-14, click **Power Level** , expand the configuration window for the Power Level, the available settings are:

- Test equipment selection (oscilloscope/spectrum analyzer): Select the test instrument used for power spectrum density.
- Average num (1/ 10/ 20/ 30/ 40/ 50/ 100): Set the average number of test results. The more average times, the more stable the results.
- Connect test: Detect the connectionstatus of the spectrum analyzer. The device name will be displayed after the connectionis successful.
- Balun compensation (On/ Off): Select whether to compensate for the insertion loss of the balun.

- Settings: Click **Configure** to enter the balun compensation interface, as shown in Figure 4-11. You can add/modify/delete insertion loss at different frequencies. Up to 50 points can be added.

Note: Test Connect, balun compensation, and settings are only effective when the test instrument selects the spectrum analyzer, and the settings can only take effect after the balun compensation is turned on.

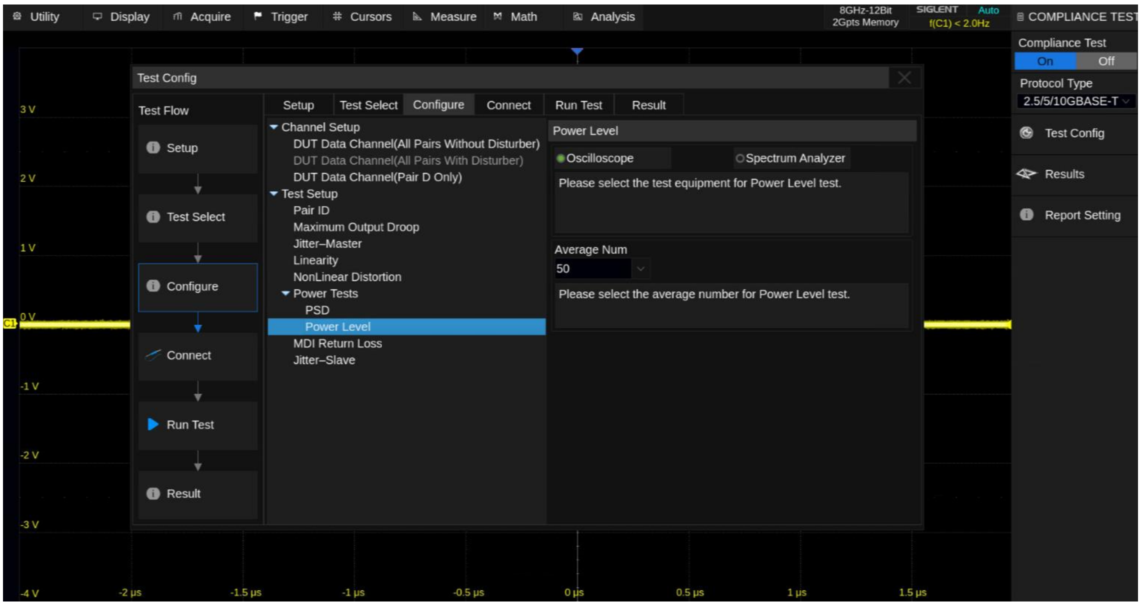


Figure 4-14 Power Level Configuration Interface

As shown in Figure 4-15, click **MDI Return Loss** , expand the configuration window for the MDI Return Loss, the available settings are:

- Connect test: Detect the connectionstatus of the spectrum analyzer. The device name will be displayed after the connectionis successful.
- VNA port selection (Port1/ Port2/ Port3/ Port4): Select the physical port for VNA to measure return loss. The number of available ports will change dynamically according to the VNA model used.
- VNA calibration: After clicking Open/Short/Load, you can perform the corresponding calibration.

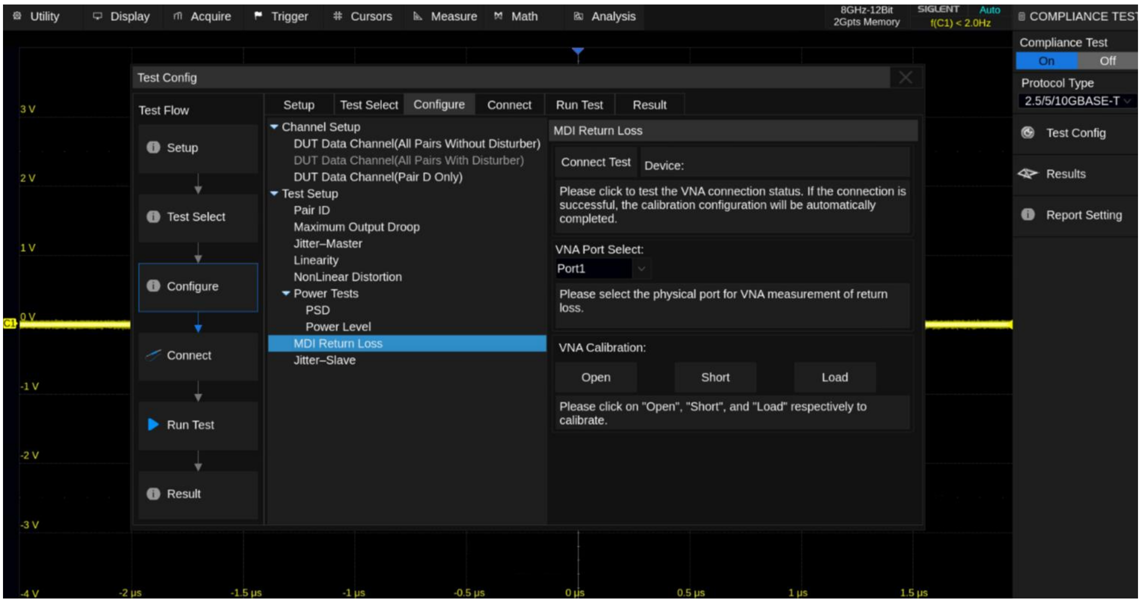


Figure 4-15 MDI Return Loss Configuration Interface

As shown in Figure 4-16, click **Jitter-Slave** , expand the configuration window for the transmitter timing jitter-slave, and the available settings are:

- **Jitter type (TIE / Peroid):** Set the jitter type for calculation.
- **Bandpass filter (False / True):** Select whether to filter the waveform before calculating the jitter. Generally, the jitter result after filtering will be better. The center frequency of the bandpass filter used by 2.5G BASE-T is 50 MHz and the bandwidth is 2 MHz; the center frequency of the bandpass filter used by 5G BASE-T is 100 MHz and the bandwidth is 2 MHz; the center frequency of the bandpass filter used by 10G BASE-T is 200 MHz and the bandwidth is 2 MHz

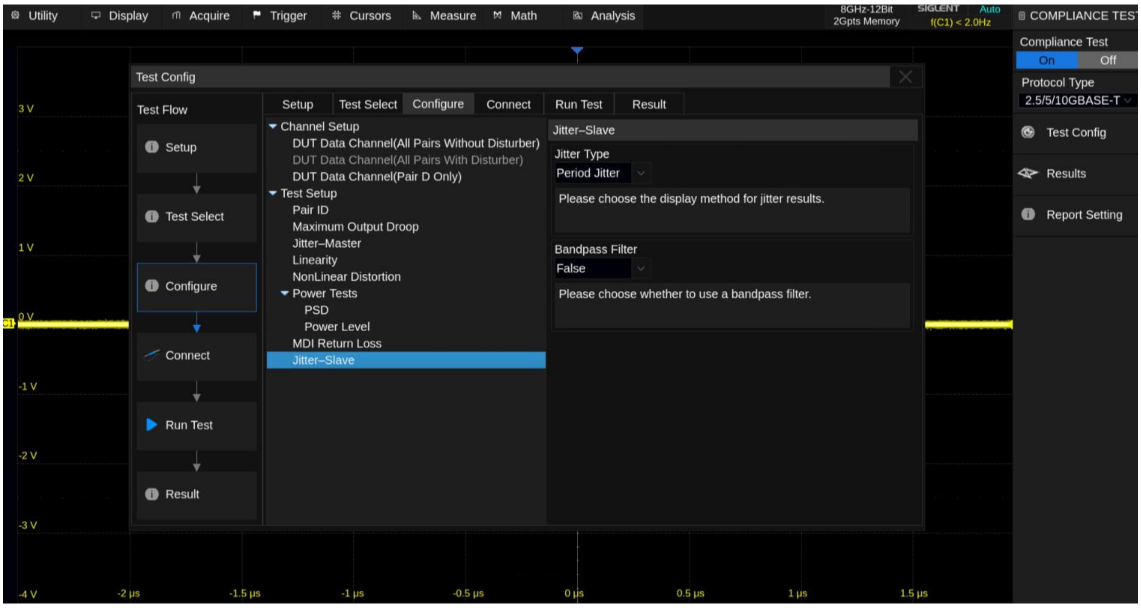


Figure 4-16 Transmitter Timing Jitter-Slave Configuration Interface

- **Connect:** This column displays the connectiondiagram of the compliance test, as shown in Figure 4-17. If more than one item is selected simultaneous, only the connectiondiagram for the first test item will be displayed. For the other test items, if the connectionis different then a new pop-up window will appear at the end of the previous test.

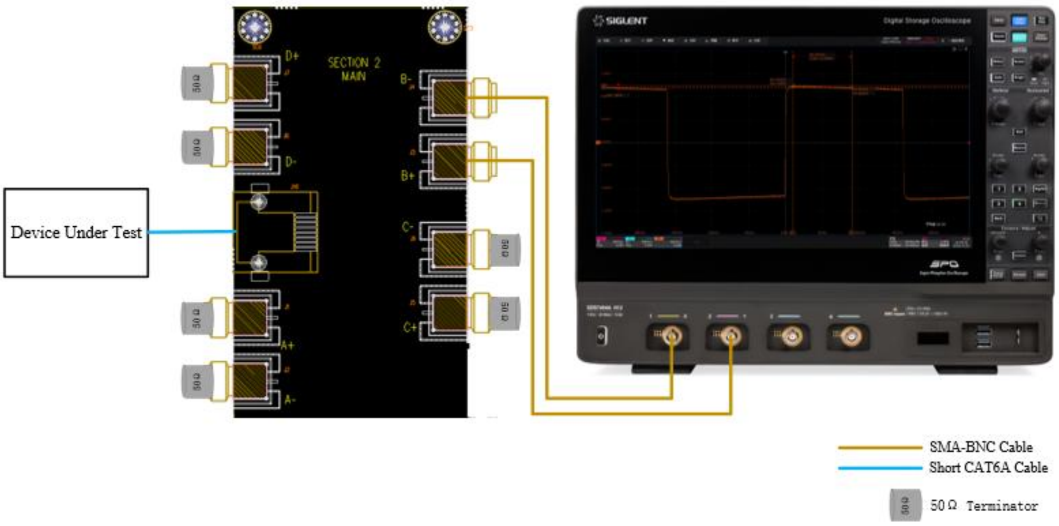


Figure 4-17 Connect Diagram in the Connect Menu

- **Run test:** The Run Test window is shown in Figure 4-18. Both **Continue** and **Stop** options are supported when meets test failures.

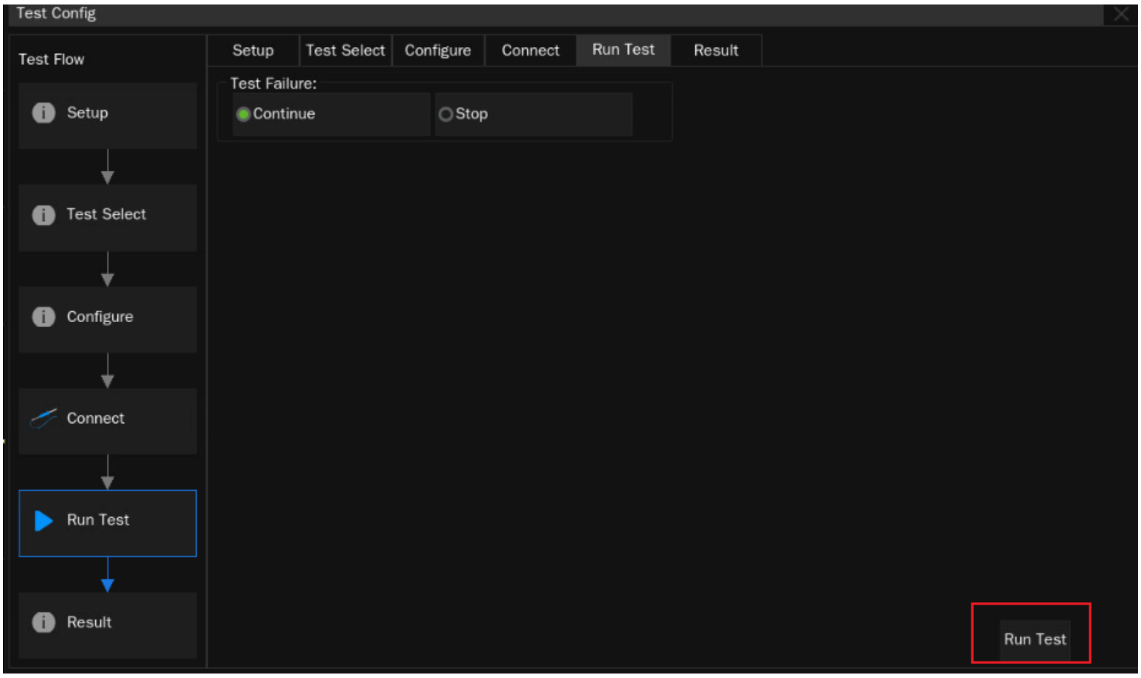


Figure 4-18 Run Test Window

In the following test process, according to the pop-up window prompts to complete the test. After all test items are completed, the test result window will pop up.

4.2 Viewing of Results

Click **Result** to view the corresponding test results.

The upper half of the test results window contains the test items, outlining the results of every test item, as well as the pass thresholds, as shown in Figure 4-19.

The lower half of the test result window displays the corresponding detail picture, click on the item you are concerned about in the upper half of the test results window, and the corresponding details will be displayed in the lower half of the window, click on the picture to view the details of the test waveform in a larger display, as shown in Figure 4-20.

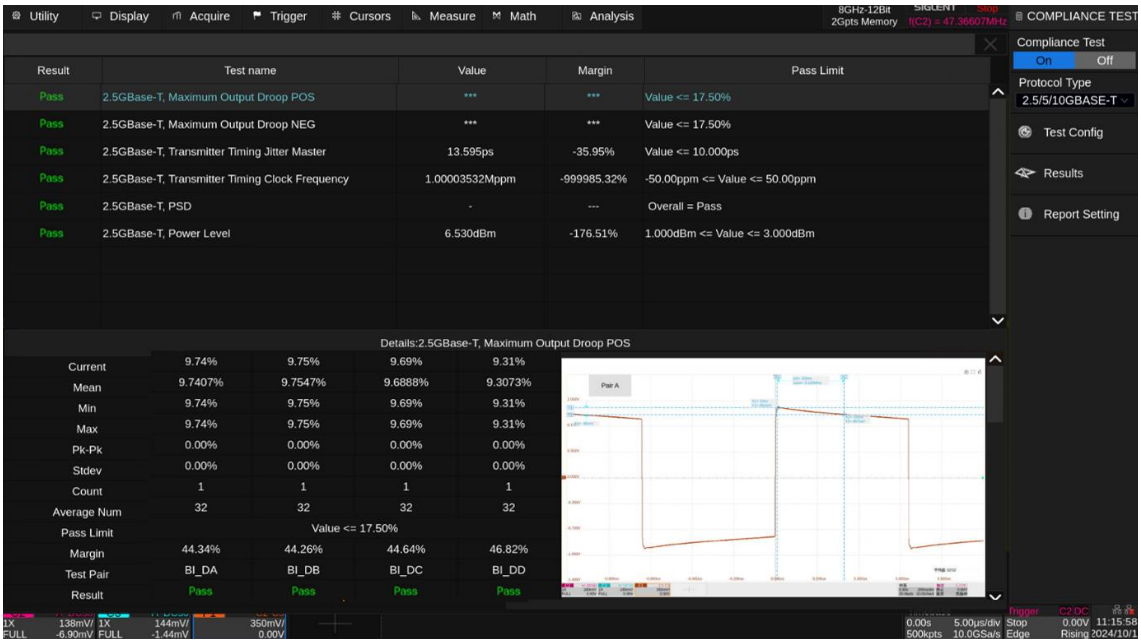


Figure 4-19 List of Test Result Items

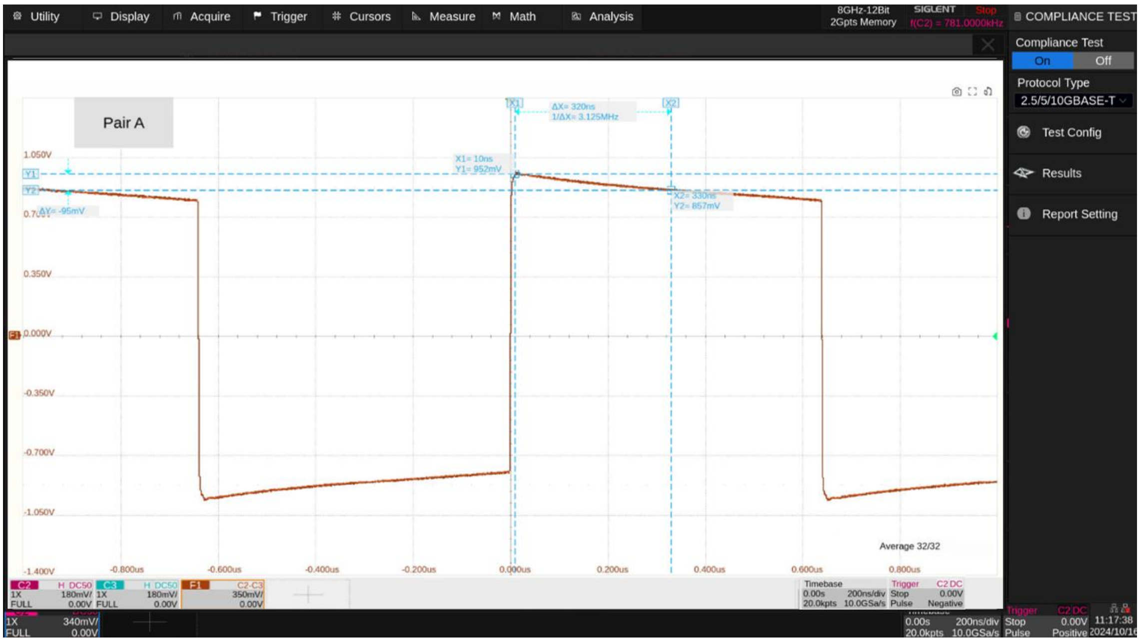


Figure 4-20 Waveform Details

4.3 Report Generation

Click **Report Setting** , fill in the test information, and select the HTML, XML or PDF report type. **Preview Report** can view the generated report in advance. Click **File Management** to select the path to save. Click **Save** to save the test results, as shown in Figure 4-21.

Note: When saved in HTML format, a folder and HTML files will be generated, if you need to copy to a new directory, you need to copy both to the new directory.

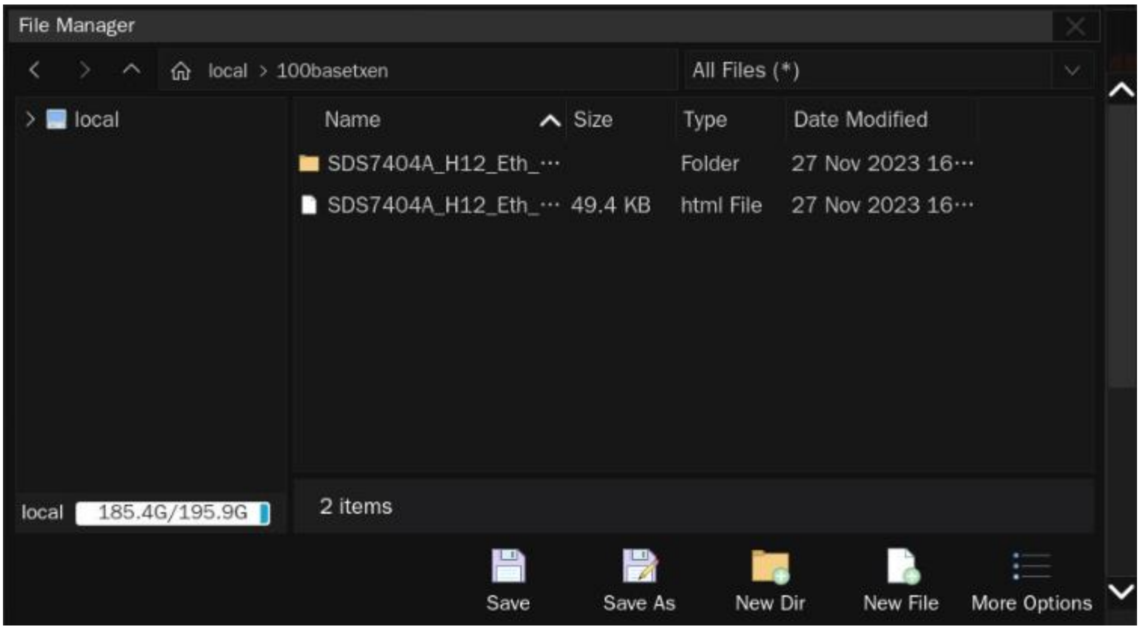


Figure 4-21 Generation of Report Settings

The test report includes a summary table of all test results with hyperlinks to the details page, which includes a screen shot of the associated test waveform, which is shown in Figure 4-22.

2.5/5/10GBase-T Compliance Test Reoprt

Overall Result: Pass

Operator:	
Test Date:	2024-10-16 10:20:40
Device:	
Temperature:	
Remarks:	
Oscilloscope Name:	SDS7404A H12
Oscilloscope Serial Number:	SDS70020230606
Oscilloscope Scope ID:	e709-22fe-5861-2b5b
Oscilloscope Firmware Version:	04.15.05.1.1.8.0 sec00
Test Result:	Total:6,Pass:6,Non Tested:0,Fail:0

Summary

Result	Test name	Value	Value(Min)	Value(Max)	Margin	Pass Limit
PASS	2.5GBase-T, Maximum Output Droop POS	9.75%	9.75%	9.75%	44.26%	Value <= 17.50%
PASS	2.5GBase-T, Maximum Output Droop NEG	9.72%	9.72%	9.72%	44.47%	Value <= 17.50%
PASS	2.5GBase-T, Transmitter Timing Jitter Master	287fs	19.999348ns	20.000701ns	97.13%	Value <= 10.000ps
PASS	2.5GBase-T, Transmitter Timing Clock Frequency	26.03ppm	200.01MHz	200.01MHz	23.97%	-50.00ppm <= Value <= 50.00ppm
PASS	2.5GBase-T, PSD	-	-	-	---	Overall = Pass
PASS	2.5GBase-T, Power Level	1.789dBm	1.789dBm	1.789dBm	39.46%	1.000dBm <= Value <= 3.000dBm

Details

[Top]

2.5GBase-T, Maximum Output Droop POS				
Current	9.74%	9.75%	9.69%	9.31%
Mean	9.7407%	9.7547%	9.6900%	9.3073%
Min	9.74%	9.75%	9.69%	9.31%
Max	9.74%	9.75%	9.69%	9.31%
Pk-Pk	0.00%	0.00%	0.00%	0.00%
Stdev	0.00%	0.00%	0.00%	0.00%
Count	1	1	1	1
Average Num	32	32	32	32
Pass Limit	Value <= 17.50%			
Margin	44.34%	44.26%	44.64%	46.82%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

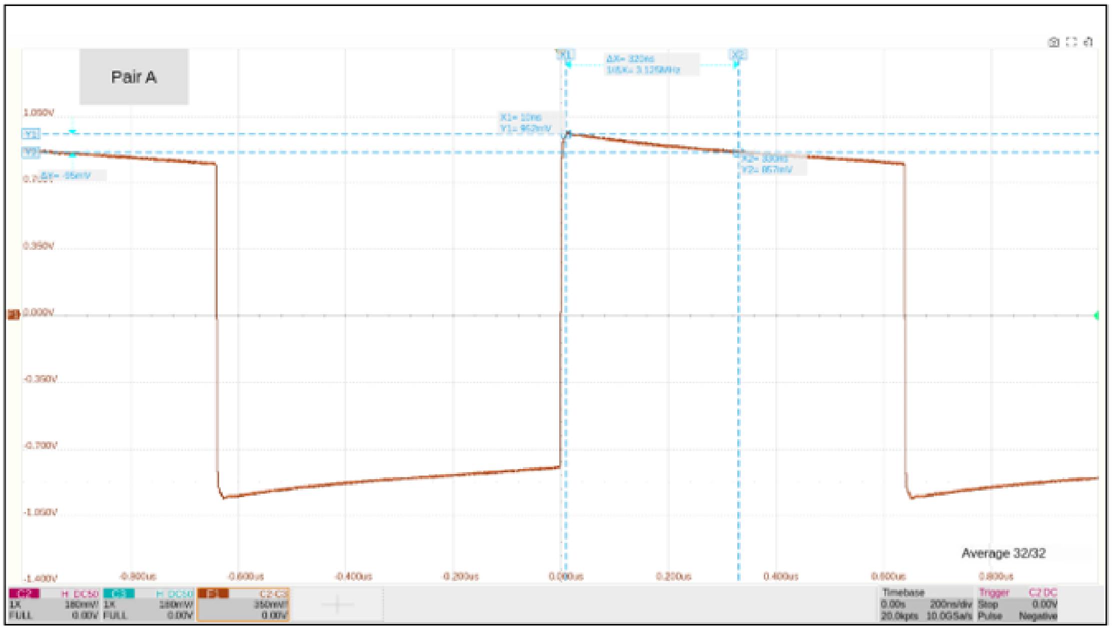


Figure 4-22 Test Report

5 Test Environment Connectivity

For different test items and configurations, the test environment can be categorized into five scenarios: testing with an oscilloscope, testing with a spectrum analyzer, testing with a vector network analyzer, testing for transmitter nonlinear distortion, and testing for slave jitter. The test items for the three rates of 2.5G, 5G, and 10G are similar, and the following descriptions will not differentiate between them.

5.1 Test Environment Using an Oscilloscope

The test environments for maximum output droop, transmitter timing jitter- master, transmitter clock frequency, transmitter linearity (tested with an oscilloscope), power spectral density (tested with an oscilloscope), and power level (tested with an oscilloscope) are the same, utilizing area ② or area ③ of the test fixture. The DUT needs to output waveforms corresponding to the test mode for the respective test item. The FX-MGETH test fixture supports signal detection using differential probes or SMA cables. The connection procedures are as follows:

- Differential Probe: The connect method using an active differential probe is shown in Figure 5-1. The steps are:

1) Connect one end of a short Ethernet cable to connector J21 in area ③ of the test fixture and the other end to the DUT.
2) Based on the DUT's signal pairs under test (DA, DB, DC, DD), connect the active differential probe's detection points to the corresponding test points (J17, J18, J19, J20), and connect the other end to an input channel of the oscilloscope.

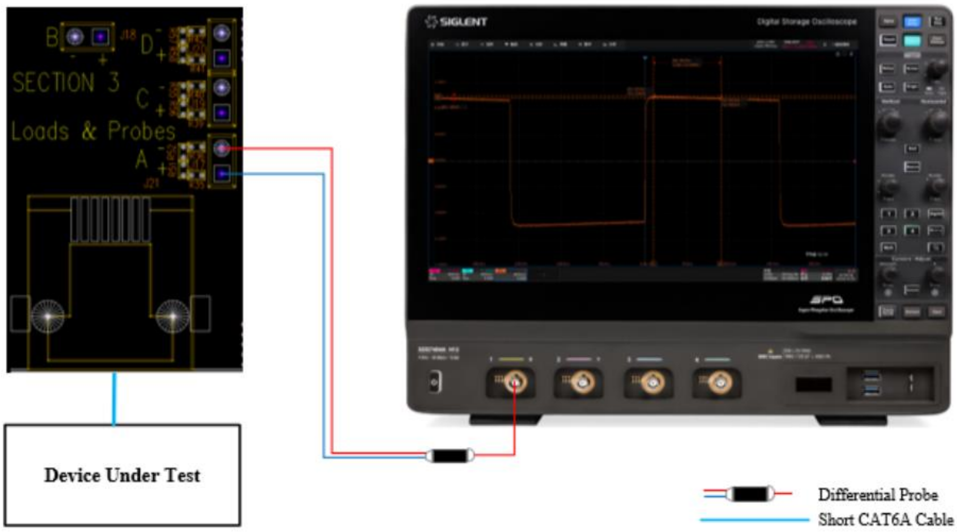


Figure 5-1 Active Differential Probe Environment

- SMA Cable: The connect method using SMA cables is shown in Figure 5-2. The steps are:

1) Connect one end of a short Ethernet cable to connector J16 in area ② of the test fixture and the other end to the DUT.

2) Based on the DUT's signal pairs under test, connect one end of two equal-length SMA cables to the corresponding test points: DA (J1, J2), DB (J3, J4), DC (J5, J6), DD (J7, J8). Connect the other ends of the two SMA cables to two input channels of the oscilloscope.

3) Install 50 Ω termination matchers on the untested signals.

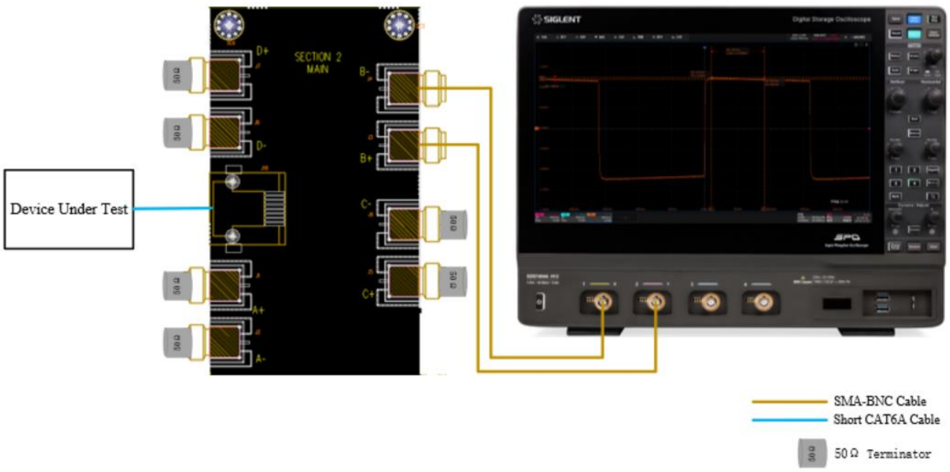


Figure 5-2 Single-ended Input Connect

5.2 Test Environment Using a Spectrum Analyzer

For transmitter linearity, power spectral density, and power level, when selecting a spectrum analyzer for testing, the test environment is the same, utilizing area ② of the test fixture and a balun. The DUT needs to output waveforms corresponding to the test mode for the respective test item. The connection procedures are as follows:

The connect method is shown in Figure 5-3. The steps are:

1) Connect one end of a short Ethernet cable to connector J16 in area ② of the test fixture and the other end to the DUT.
2) Based on the DUT's signal pairs under test, connect one end of two equal-length SMA cables to the corresponding test points: DA (J1, J2), DB (J3, J4), DC (J5, J6), DD (J7, J8). Connect the other ends of the two SMA cables to the input of the balun, and connect the output of the balun to an input channel of the spectrum analyzer.
3) Connect a USB cable between the oscilloscope's USB Host interface and the spectrum analyzer's USB Device interface.
4) Install 50 Ω termination matchers on the untested signals.

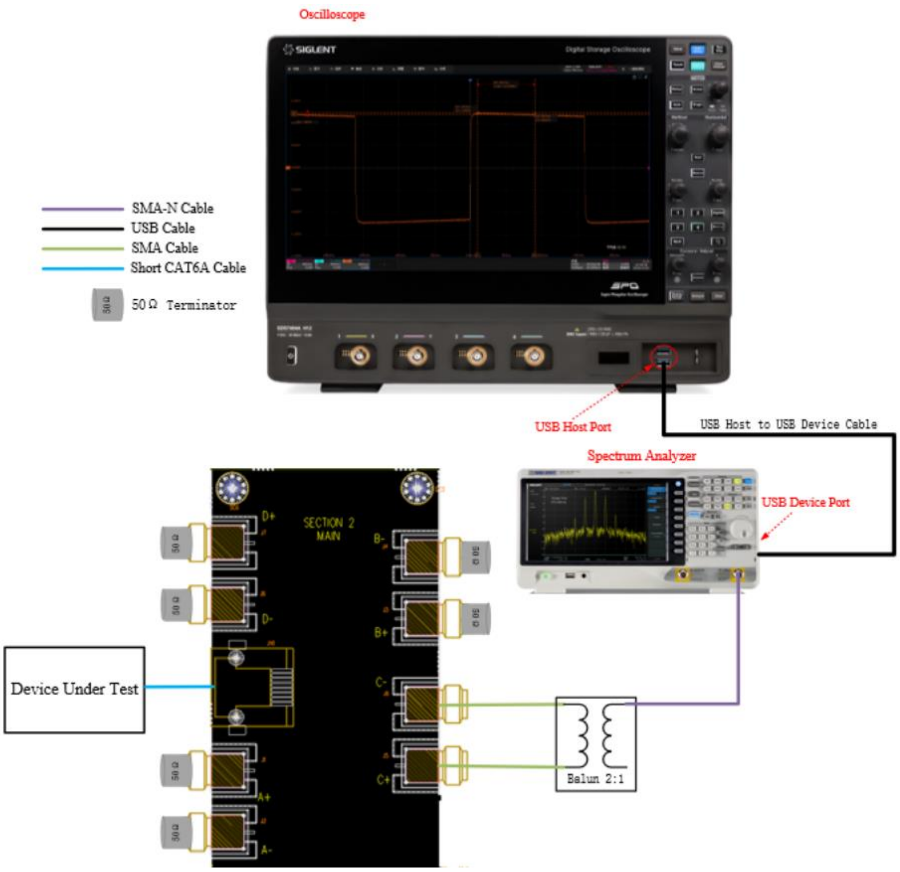


Figure 5-3 Spectrum Analyzer Connect

5.3 Test Environment Using a Vector Network Analyzer

For MDI return loss testing, a vector network analyzer (VNA) is required, utilizing area ② of the test fixture and calibration components. The DUT needs to output waveforms of test mode 5. Additionally, the VNA must be calibrated before MDI return loss testing. The calibration and connection procedures are as follows:

- Calibration Connect: The connect method is shown in Figure 5-4. The steps are:

1) Connect two equal-length SMA cables to the input of the balun and the corresponding test points in area ② of the test fixture: DA (J1, J2), DB (J3, J4), DC (J5, J6), DD (J7, J8).
2) Connect one end of an SMA cable to the VNA port selected under **Configure** > **MDI Return Loss** , and the other end to the output of the balun.
3) Install 50 Ω termination matchers on the untested signals in area ② of the test fixture.
4) Connect a USB cable between the oscilloscope's USB Host interface and the VNA's USB Device interface.
5) Connect one end of a short Ethernet cable to connector J16 in area ② of the test fixture and the other end to the calibration component's J12 for Open calibration.
6) Click Test Connect on the Return Loss Configure page. Once the communication with the VNA is successful, the oscilloscope will display the VNA model information and automatically set the VNA calibration configuration (only supported for Siglent VNAs).
7) Click **Configure** > **MDI Return Loss** > **Open Circuit** to perform Open calibration.
8) For Short and Load calibrations, change the short Ethernet cable Connect and click Short or Load under **Configure** > **MDI Return Loss** , **Short circuit** , **load calibration** to perform the respective calibrations.

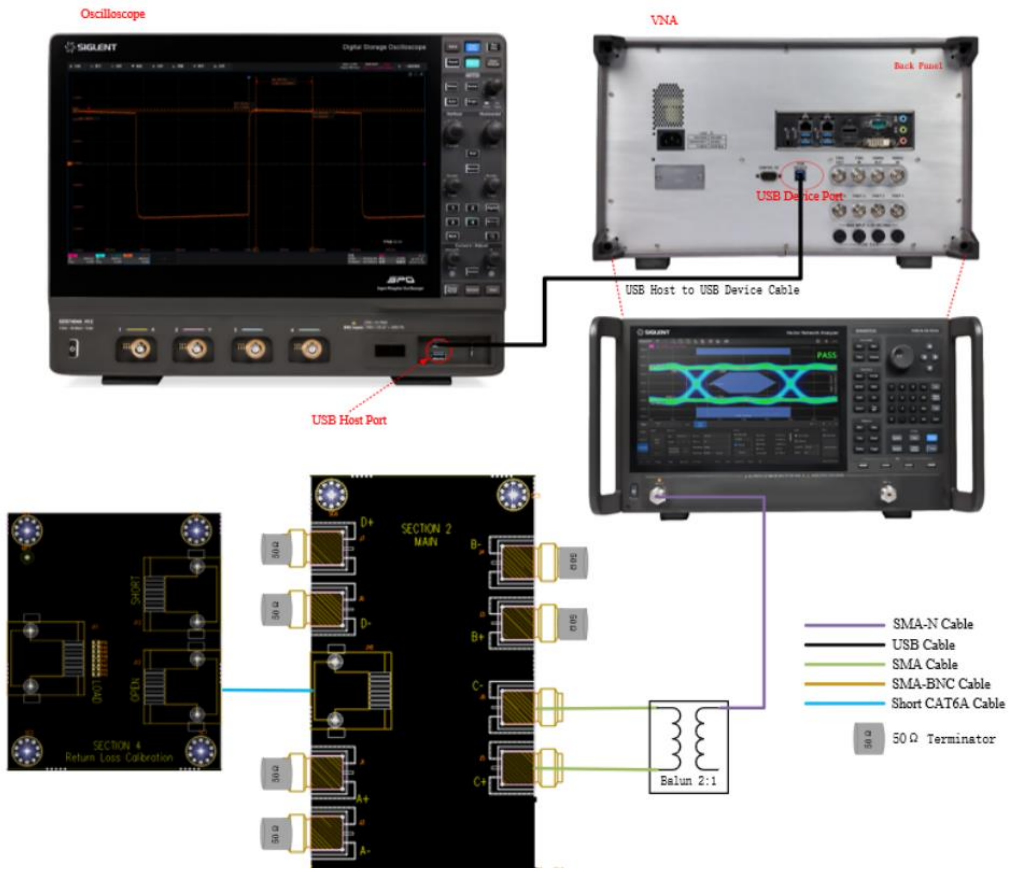


Figure 5-4 MDI Return Loss Calibrations Connect

- Test Connect: The Connect method is shown in Figure 5-5. The steps are:

1) Connect two equal-length SMA cables to the input of the balun and the corresponding test points in area ② of the test fixture: DA (J1, J2), DB (J3, J4), DC (J5, J6), DD (J7, J8).
2) Connect one end of an SMA cable to the VNA port selected under **Configure** > **MDI Return Loss** , and the other end to the output of the balun.
3) Install 50 Ω termination matchers on the untested signals in area ② of the test fixture.
4) Connect a USB cable between the oscilloscope's USB Host interface and the VNA's USB Device interface.
5) Connect one end of a short Ethernet cable to connector J16 in area ② of the test fixture and the other end to the DUT.
6) Configure the DUT to enter test mode 5.
7) Click on the start test in the run test page. When a pop-up window appears with a connection prompt, click **Run Test** , and the oscilloscope will retrieve the S11 data from the VNA, plot the curve, and determine whether the test passes.

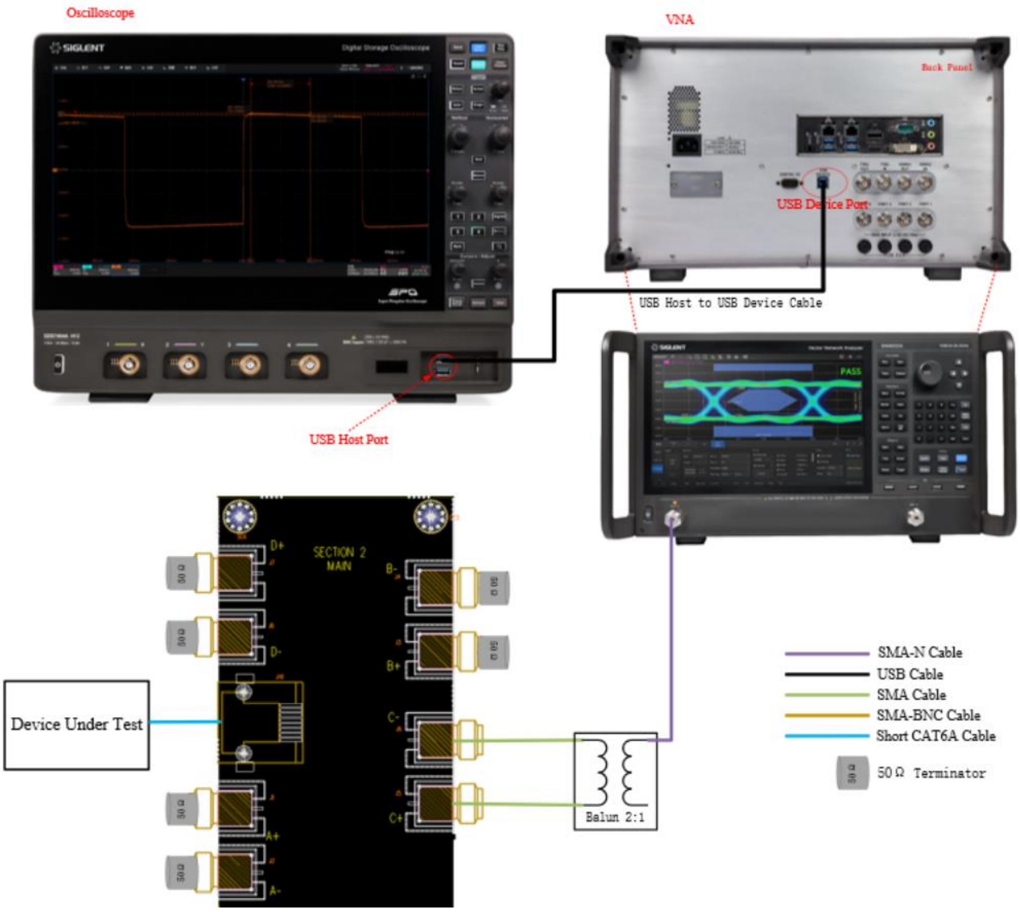


Figure 5-5 MDI Return Loss Test Connect

5.4 Test Environment for Transmitter Nonlinear Distortion

Only 2.5G BASE-T requires transmitter nonlinear distortion testing. This test can be performed using either an oscilloscope or a spectrum analyzer, but both require an arbitrary waveform generator and a power divider, utilizing area ② of the test fixture. The DUT needs to output waveforms of test mode 4. The connection procedures are as follows:

- Oscilloscope Testing: The connect method is shown in Figure 5-6. The steps are:

1) Connect one end of a short Ethernet cable to connector J16 in area ② of the test fixture and the other end to the DUT.

2) Connect one end of two equal-length SMA cables to the corresponding test points: DA (J1, J2), DB (J3, J4), DC (J5, J6), DD (J7, J8). Connect the other ends to the S port of the power divider.

3) Connect two equal-length SMA cables from the arbitrary waveform generator's two output channels to ports 1 of the power divider.

4) Connect two equal-length SMA cables from the oscilloscope's two input channels to ports 2 of

the power divider.

5) Connect a Type A-Type B USB cable between the oscilloscope's USB Host interface and the arbitrary waveform generator's USB Device interface.

6) Install 50 Ω termination matchers on the untested signals.

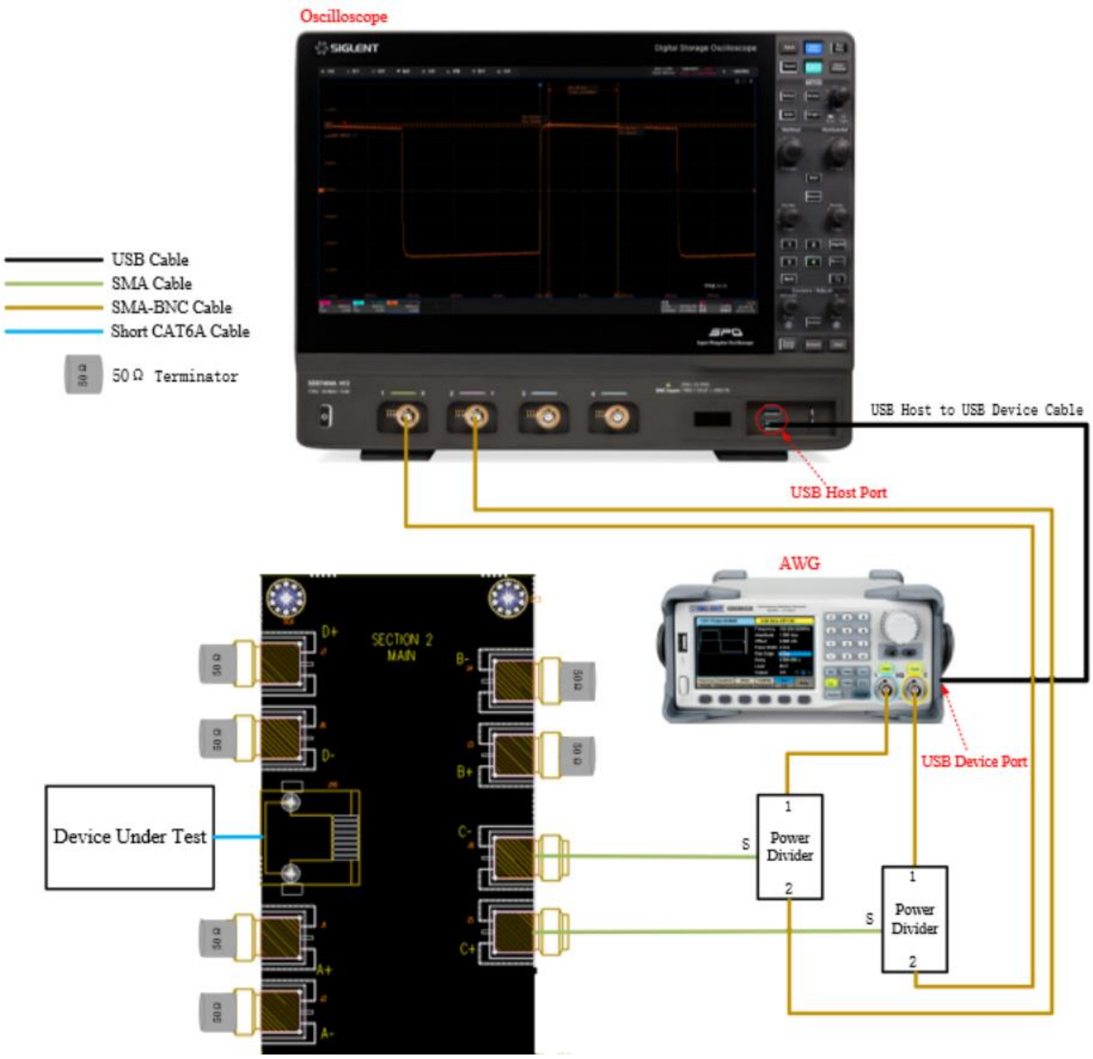


Figure 5-6 Transmitter Nonlinear Distortion Test Using an Oscilloscope

- Spectrum Analyzer Testing: The Connect method is shown in Figure 5-7. The steps are:

1) Connect one end of a short Ethernet cable to connector J16 in area ② of the test fixture and the other end to the DUT.

2) Connect one end of two equal-length SMA cables to the corresponding test points: DA (J1, J2), DB (J3, J4), DC (J5, J6), DD (J7, J8).

3) Connect an SMA cable from the output of the balun to the S port of the power divider.

4) Connect an SMA cable from one output channel of the arbitrary waveform generator to port 1 of the power divider.

5) Connect an SMA cable from one input channel of the spectrum analyzer to port 2 of the power divider.

6) Connect a Type A-Type B USB cable between the oscilloscope's USB Host interface and the arbitrary waveform generator's USB Device interface.

7) Connect a Type A-Type B USB cable between the oscilloscope's USB Host interface and the spectrum analyzer's USB Device interface.

8) Install 50 Ω termination matchers on the untested signals.

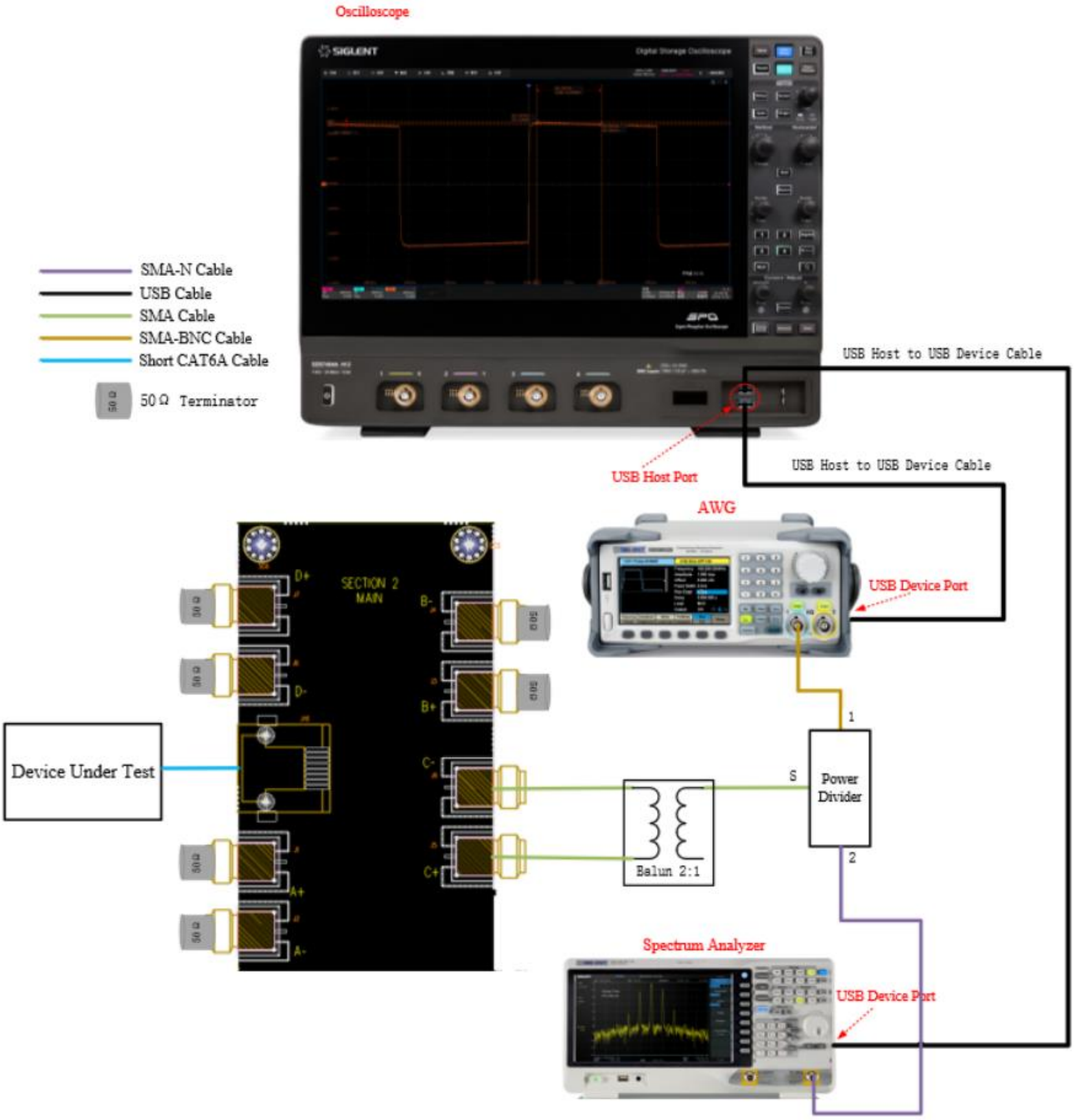


Figure 5-7 Transmitter Nonlinear Distortion Test Using an Spectrum Analyzer

5.5 Test Environment for Slave Jitter Testing

Transmitter timing jitter -slave only requires testing Pair D, utilizing area ① of the test fixture. Two devices are needed: one as the DUT configured for test mode 3 (slave PHY) and one as the Link Partner configured for test mode 1 (master PHY). The connection procedures are as follows:

The Connect method is shown in Figure 5-8. The steps are:

1) Configure the DUT (slave PHY) to enter test mode 3 and the Link Partner (master PHY) to enter test mode 1.
2) Use two short Ethernet cables: one to connect the DUT (slave PHY) to connector J15 in area ① of the test fixture, and the other to connect the Link Partner (master PHY) to connector J14 in area ① of the test fixture.
3) Connect two equal-length SMA cables from test points J9 and J10 in area ① of the test fixture to two channels of the oscilloscope.

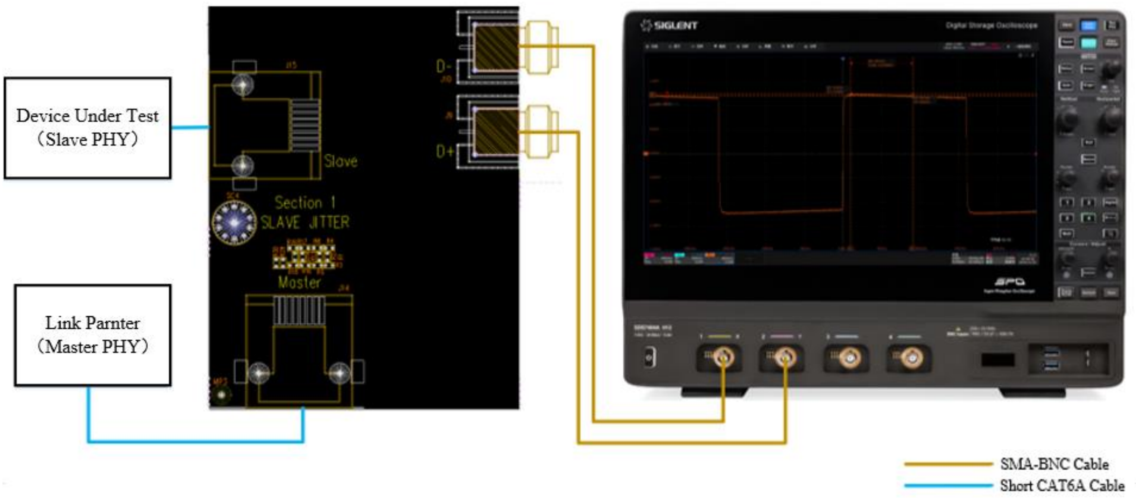


Figure 5-8 Slave Jitter Environment

6 2.5G BASE-T Compliance Testing

6.1 Maximum Output Droop Test

6.1.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.1.

The maximum output droop test verifies whether the attenuation rate of the DUT's output signal complies with the standard. During testing, the DUT must be configured in Test Mode 6, transmitting a periodic signal consisting of 128 consecutive +16-level symbols and 128 consecutive -16-level symbols, which can be regarded as an ideal square wave signal with a period of 1.28 μs.

6.1.2 Test Procedure

1. Select **2.5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Maximum Output Droop** .
3. Set the probe type, signal source, test pair ID (Pair A/B/C/D/All), and averaging number in the **Configure** tab.
4. Set up the test environment refer to the **Connect** tab. Refer to Section 5.1 for connection details.
5. Click **Run Test** . The system will display a test prompt and automatically configure the oscilloscope's channels, triggers, and other settings.
6. After the oscilloscope successfully captures the signal, click **Run Test** on the prompt interface. If the waveform is incorrect, the application will return to the prompt, indicating an environment check is needed.
7. The oscilloscope will complete all configurations automatically and output the results.

6.1.3 Calculation Method and Pass Criteria

According to IEEE 802.3, the test calculates positive and negative maximum output droop:

Positive droop: The voltage at 10 ns (V_{10}) and 330 ns (V_{330}) after the rising edge zero-crossing point.

Negative droop: The voltage at 10 ns (V_{10}) and 330 ns (V_{330}) after the falling edge zero-crossing point.

The formula and pass criteria for both are:

$$\text{Droop} = \frac{(V_{10} - V_{330})}{V_{10}} < 17.5\%$$

6.1.4 Test Result Reference

An example of the Positive droop result is shown in Figure 6-1.

2.5GBase-T, Maximum Output Droop POS				
Current	9.37%	9.79%	9.53%	9.43%
Mean	9.3736%	9.7907%	9.5323%	9.4350%
Min	9.37%	9.79%	9.53%	9.43%
Max	9.37%	9.79%	9.53%	9.43%
Pk-Pk	0.00%	0.00%	0.00%	0.00%
Stdev	0.00%	0.00%	0.00%	0.00%
Count	1	1	1	1
Average Num	64	64	64	64
Pass Limit	Value <= 17.50%			
Margin	46.44%	44.05%	45.53%	46.09%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

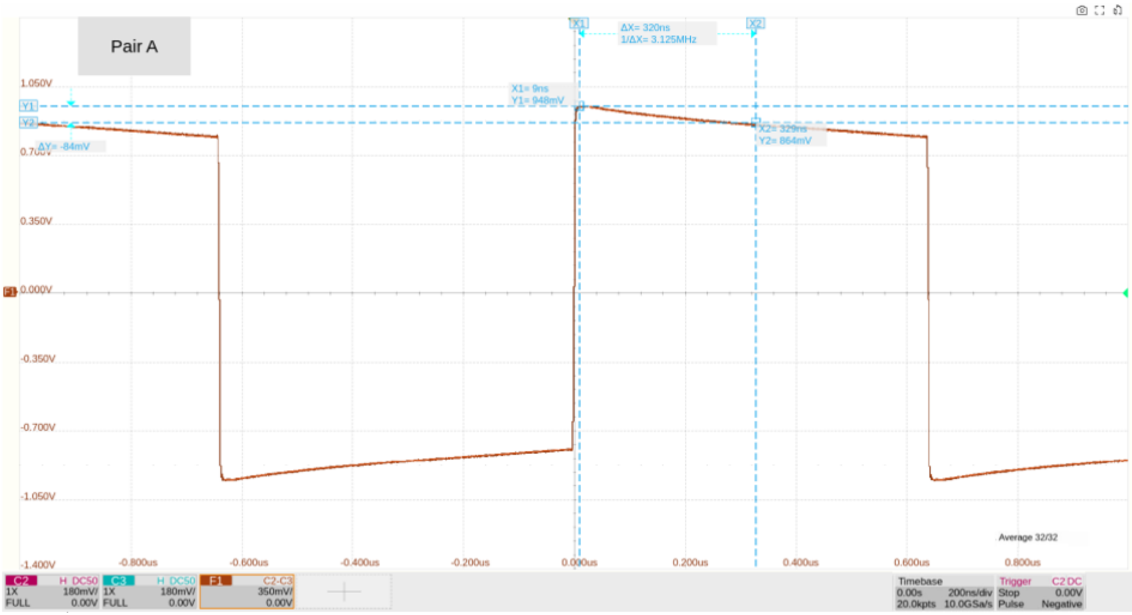


Figure 6-1 Positive Maximum Output Droop Result

An example of the Negative droop result is shown in Figure 6-2.

2.5GBase-T, Maximum Output Droop NEG				
Current	9.74%	9.79%	9.77%	9.70%
Mean	9.7449%	9.7891%	9.7655%	9.7043%
Min	9.74%	9.79%	9.77%	9.70%
Max	9.74%	9.79%	9.77%	9.70%
Pk-Pk	0.00%	0.00%	0.00%	0.00%
Stdev	0.00%	0.00%	0.00%	0.00%
Count	1	1	1	1
Average Num	64	64	64	64
Pass Limit	Value <= 17.50%			
Margin	44.31%	44.06%	44.20%	44.55%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

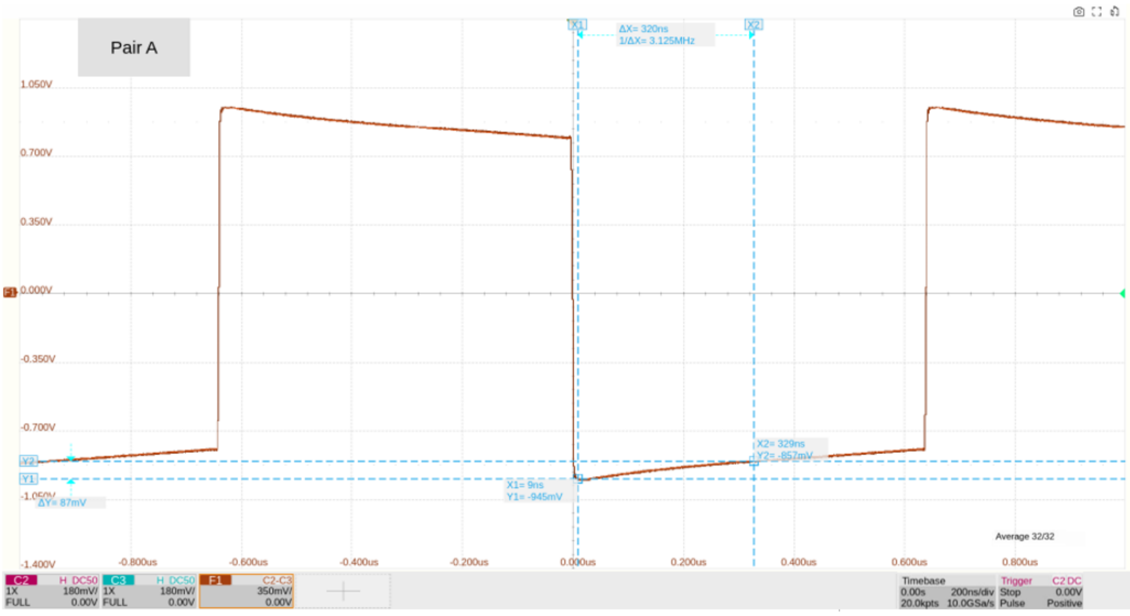


Figure 6-2 Negative Maximum Output Droop Result

6.2 Transmitter Timing Jitter – Master

6.2.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.3.

This transmitter timing jitter-master is used to verify whether the jitter of the DUT output signal complies the requirements of the standard. The DUT must be configured in Test Mode 2, transmitting a periodic signal consisting of 2 consecutive +16-level symbols and 2 consecutive -16-level symbols, which can be regarded as an ideal square wave signal with a period of 20 ns.

6.2.2 Test Procedure

1. Select **2.5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Transmitter Timing Jitter – Master** .
3. Set the probe type, signal source, test pair ID, jitter type (periodic/TIE), and bandpass filter in the **Configure** tab.
4. Set up the test environment refer to the **Connect** tab. Refer to Section 5.1 for connection details
5. Click **Run Test** . The system will display a test prompt and automatically configure the oscilloscope's channels, triggers, and other settings.
6. After the oscilloscope successfully captures the signal, click **Run Test** on the prompt interface. If the waveform is incorrect, the application will return to the prompt, indicating an environment check is needed.
7. The oscilloscope will complete all configurations automatically and output the results.

6.2.3 Calculation Method and Pass Criteria

According to the IEEE802.3 standards, the jitter type calculated by the transmitter timing jitter-master is periodic jitter, and the waveform to be calculated needs to reach 4ms±10%, which is about 200,000±20,000 cycles.

In the compliance test software, users can select the jitter type (periodic jitter/TIE) and whether to use a bandpass filter to filter the waveform with a 50 MHz center frequency and 2 MHz bandwidth before calculation. Generally, the jitter result will be more ideal after using the bandpass filter.

During the calculation, the oscilloscope will collect waveforms that meet the length requirements and calculate the period/TIE of each symbol bit, and finally calculate the RMS of all samples to determine whether the jitter test has passed. The calculation formula and passing standard of the root mean square are:

$$\mathrm{RMS} = \sqrt{\left(\frac{\sum[(T - T_{avg})^2\ ]}{Sample\ \ Size}\right)} < 10ps$$

6.2.4 Test Result Reference

An example of the Transmitter Timing Jitter – Master result is shown in Figure 6-3

2.5GBase-T, Transmitter Timing Jitter Master				
Current	249fs	249fs	247fs	250fs
Mean	19.99956177ns	19.99956208ns	19.99956317ns	19.99956302ns
Min	19.998502ns	19.998500ns	19.998500ns	19.998500ns
Max	20.000691ns	20.000566ns	20.000625ns	20.000624ns
Pk-Pk	2.189ps	2.066ps	2.125ps	2.124ps
Stdev	249fs	249fs	251fs	250fs
Count	200004	200004	200004	200004
Formula	RMS			
Pass Limit	Value <= 10.000ps			
Margin	97.51%	97.51%	97.53%	97.50%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

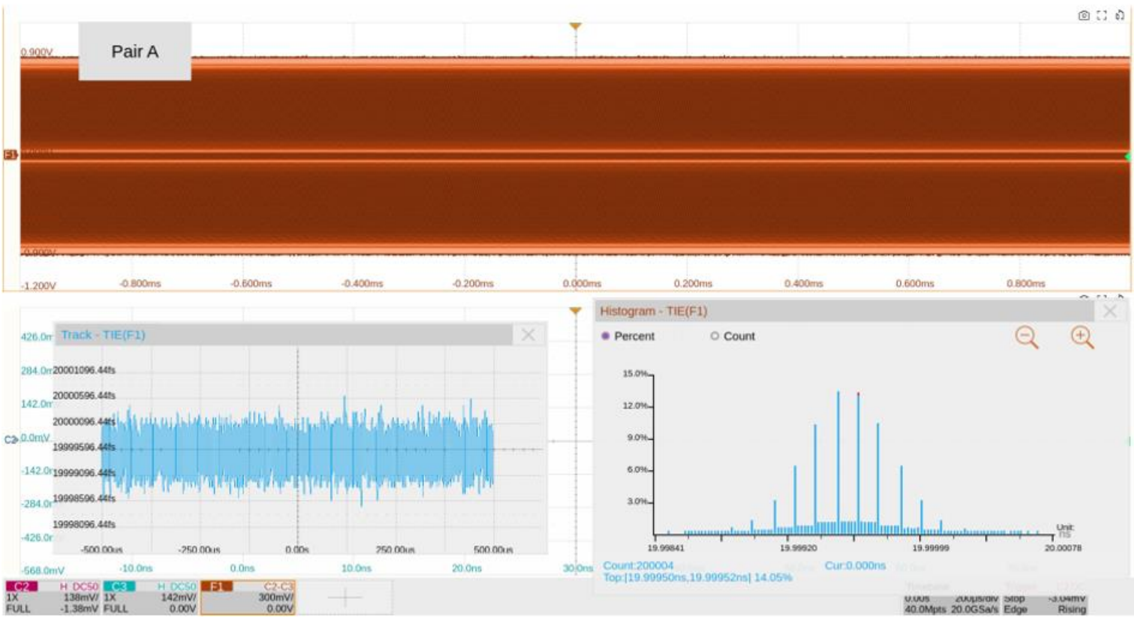


Figure 6-3 Transmitter Timing Jitter-Master Result

6.3 Transmitter Clock Frequency

6.3.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.5.

The transmitter clock frequency test is used to verify whether the clock frequency of the DUT complies with the value specified by the standard to verify the signal quality. The DUT must be configured in Test Mode 2, transmitting a periodic signal consisting of 2 consecutive +16-level symbols and 2 consecutive -16-level symbols, which can be regarded as an ideal square wave signal with a period of 20 ns.

6.3.2 Test Procedure

1. Select **2.5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Transmitter Clock Frequency** .
3. Set the probe type, signal source, and test pair ID (Pair A/B/C/D/All) in the **Configure** tab.
4. Set up the test environment refer to the **Connect** tab. Refer to Section 5.1 for connection details.
5. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other related settings.
6. After the oscilloscope correctly captures the signal under test, click **Run Test** on the test prompt interface to begin the test. If the oscilloscope fails to capture the correct waveform for testing, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the test results.

6.3.3 Calculation Method and Pass Criteria

The IEEE 802.3 standard does not specify the sample size requirement for this test. In actual testing, the actual sample size calculated is the same as the transmitter timing jitter-master sample size, which is about 200,000±20,000 cycles.

The oscilloscope will calculate the length of each cycle of the test mode 2 waveform and divide it by 4 to get the clock frequency. The passing criterion for the clock frequency is 200 MHz±50ppm.

6.3.4 Test Result Reference

An example of the transmitter clock frequency result is shown in Figure 6-4.

2.5GBase-T, Transmitter Timing Clock Frequency				
Current	25.95ppm	25.53ppm	25.57ppm	25.87ppm
Mean	200.0052MHz	200.0051MHz	200.0051MHz	200.0052MHz
Min	200.01MHz	200.01MHz	200.01MHz	200.01MHz
Max	200.01MHz	200.01MHz	200.01MHz	200.01MHz
Pk-Pk	0kHz	0kHz	0kHz	0kHz
Stdev	0kHz	0kHz	0kHz	0kHz
Count	20	20	20	20
Average Num	-	-	-	-
Pass Limit	-50.00ppm <= Value <= 50.00ppm			
Margin	24.05%	24.47%	24.43%	24.13%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

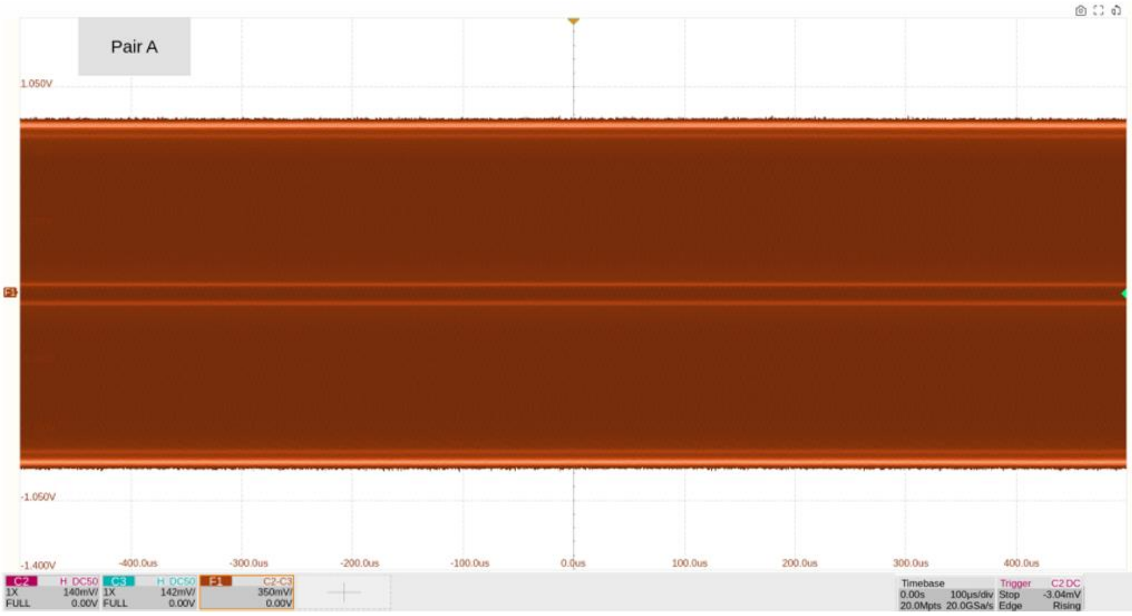


Figure 6-4 Transmitter Clock Frequency Result

6.4 Transmitter Linearity

6.4.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.2.

The transmitter linearity test is used to verify whether the spurious-free dynamic range (SFDR) of the DUT's output signal complies with the value specified by the standard. During the test, the DUT must be configured to test mode 4, which can be further divided into 5 sub-modes to send five sets of dual-tone signals with different frequencies.

6.4.2 Test Procedure

6.4.2.1 Using an Oscilloscope

1. Select **2.5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Transmitter Linearity** .
3. Set the probe type, signal source, test pair ID (Pair A/B/C/D/All), test instrument (select oscilloscope), and averaging number in the **Configure** tab.
4. Set up the test environment refer to the **Connect** tab. Refer to Section 5.1 for connection details.
5. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other related settings.
6. After the oscilloscope correctly captures the signal under test, click **Run Test** on the test prompt interface to begin the test. If the oscilloscope fails to capture the correct waveform for testing, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the test results.

6.4.2.2 Using a Spectrum Analyzer

1. In the Settings, select the rate as **2.5G BASE-T** .
2. Select the test item: **Test Select** > **Transmitter Linearity** .
3. In the **Configure** , set the test pair ID (Pair A/B/C/D/All), test instrument (select spectrum analyzer), averaging count, balun compensation (On/Off), etc.

4. In the **Configure**, click **Connect Test** to confirm whether the spectrum analyzer is connected to the oscilloscope. If the connection is successful, the model of the spectrum analyzer will be displayed. If balun compensation is required, click settings to enter the balun compensation interface and configure the relevant parameters.
5. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to Section 5.2.
6. Click **Run Test**. The system will pop up a test prompt interface and automatically configure the oscilloscope and spectrum analyzer.
7. After confirming that the spectrum analyzer has captured the signal under test, click **Run Test** on the oscilloscope's test prompt interface to begin the test. If the oscilloscope does not receive data from the spectrum analyzer for an extended period, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
8. During the test, the spectrum analyzer will measure the signal under test and transmit the results back to the oscilloscope. The oscilloscope will process the received data and output the test results.

6.4.3 Calculation Method and Pass Criteria

According to the IEEE 802.3 standard, the transmitter linearity test requires testing five sets of dual tone signals. The frequencies and pass criteria for these signals are listed in the table below.

Dual Tone Signal	Frequency（MHz)	Pass Criteria (dBc)
Dual Tone 1	9.1796 & 10.3515	SFDR ≥ 54.5
Dual Tone 2	19.7265 & 20.11725	SFDR ≥ 54.5
Dual Tone 3	34.961 & 35.3515	SFDR ≥ 54.5
Dual Tone 4	54.1015 & 54.88281	SFDR ≥ 53.67
Dual Tone 5	77.539 & 78.32031	SFDR ≥ 50.581

When using an oscilloscope for calculation, the oscilloscope will compute the amplitude spectrum of the dual tone signals using the FFT algorithm. When using a spectrum analyzer, the oscilloscope will directly read the amplitude spectrum measured by the spectrum analyzer.

The basic settings for calculating the amplitude spectrum are:

- Start frequency: 0.3 MHz;

- End frequency: 100 MHz;
- Resolution bandwidth: 30 kHz.

After obtaining the amplitude spectrum, the oscilloscope will record the amplitude values corresponding to the two frequency points of the dual-tone signals and select the highest value, denoted as the Highest Peak. Next, the oscilloscope will record the amplitude values corresponding to the harmonic and intermodulation components of the dual-tone signals and select the highest value among them, denoted as the Third Highest Peak. The formula for calculating the spurious-free dynamic range (SFDR) is:

SFDR = Highest Peak - Third Highest Peak

6.4.4 Test Result Reference

Examples of the transmitter linearity test results for the five sets of dual-tone signals are shown in the following five figures.

2.5GBase-T, Linearity Tone-1				
Current	54.741dBm	55.819dBm	55.388dBm	55.172dBm
Mean	54.74138dBm	55.81897dBm	55.38793dBm	55.17241dBm
Min	54.741dBm	55.819dBm	55.388dBm	55.172dBm
Max	54.741dBm	55.819dBm	55.388dBm	55.172dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 46.500dBm			
Margin	17.72%	20.04%	19.11%	18.65%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

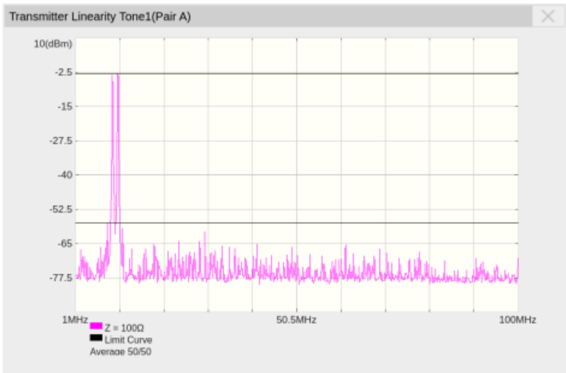


Figure 6-5 Tone1 Example of Transmitter Linearity Results

2.5GBase-T, Linearity Tone-2				
Current	59.483dBm	58.836dBm	59.052dBm	58.836dBm
Mean	59.48276dBm	58.83621dBm	59.05172dBm	58.83621dBm
Min	59.483dBm	58.836dBm	59.052dBm	58.836dBm
Max	59.483dBm	58.836dBm	59.052dBm	58.836dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 46.500dBm			
Margin	27.92%	26.53%	26.99%	26.53%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

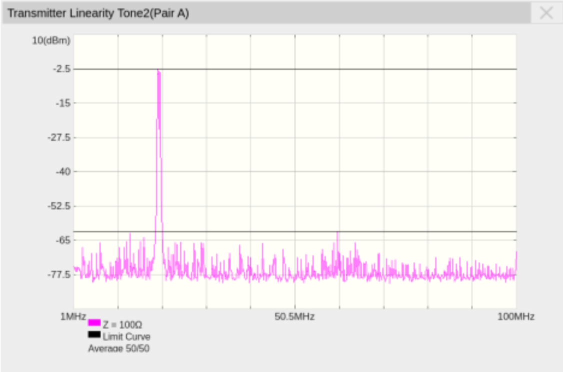


Figure 6-6 Tone2 Example of Transmitter Linearity Results

2.5GBase-T, Linearity Tone-3				
Current	61.422dBm	61.422dBm	61.638dBm	61.853dBm
Mean	61.42241dBm	61.42241dBm	61.63793dBm	61.85344dBm
Min	61.422dBm	61.422dBm	61.638dBm	61.853dBm
Max	61.422dBm	61.422dBm	61.638dBm	61.853dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 46.500dBm			
Margin	32.09%	32.09%	32.55%	33.02%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

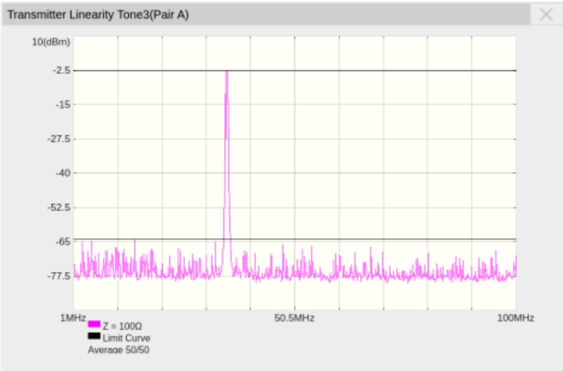


Figure 6-7 Tone3 Example of Transmitter Linearity Results

2.5GBase-T, Linearity Tone-4				
Current	58.621dBm	58.621dBm	59.267dBm	58.190dBm
Mean	58.62069dBm	58.62069dBm	59.26724dBm	58.18965dBm
Min	58.621dBm	58.621dBm	59.267dBm	58.190dBm
Max	58.621dBm	58.621dBm	59.267dBm	58.190dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 45.670dBm			
Margin	28.36%	28.36%	29.77%	27.41%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

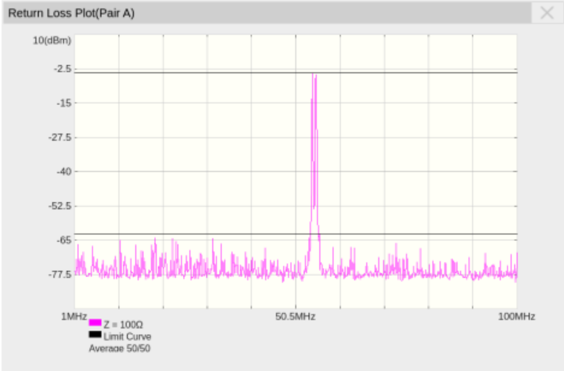


Figure 6-8 Tone4 Example of Transmitter Linearity Results

2.5GBase-T, Linearity Tone-5				
Current	56.034dBm	56.250dBm	56.681dBm	56.034dBm
Mean	56.03448dBm	56.25000dBm	56.68103dBm	56.03448dBm
Min	56.034dBm	56.250dBm	56.681dBm	56.034dBm
Max	56.034dBm	56.250dBm	56.681dBm	56.034dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 42.580dBm			
Margin	31.60%	32.10%	33.12%	31.60%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

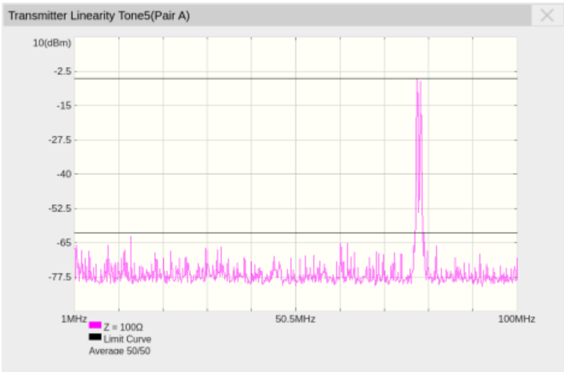


Figure 6-9 Tone5 Example of Transmitter Linearity Results

6.5 Transmitter Nonlinear Distortion

6.5.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.2.

The transmitter nonlinear distortion test verifies whether the spurious-free dynamic range (SFDR) of the DUT's output signal meets the specified standard value under signal interference conditions. During the test, the DUT must be configured in Test Mode 4, which is further divided into five sub-modes to send five sets of dual-tone signals with different frequencies. Additionally, the test also requires a power divider to couple the 45 MHz sinusoidal signal generated by the arbitrary waveform generator to add interference.

6.5.2 Test Procedure

6.5.2.1 Using an Oscilloscope

1. Select **2.5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Transmitter Nonlinear Distortion** .
3. In the **Configure** set the signal source, test pair ID (Pair A/B/C/D/All), test instrument (select oscilloscope), and averaging count.
4. In the **Configure** click **Connect Test** for the signal source to confirm its Connect to the oscilloscope. A successful Connect will display the signal source model.
5. Set up the test environment refer to the **Connect** tab. Refer to Section 5.4 for specific connection methods.
6. Click **Run Test** . The system will display a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other settings.
7. After the oscilloscope successfully captures the test signal, click **Run Test** on the prompt interface to begin testing. If the oscilloscope fails to capture the correct waveform, the application will return to the prompt interface, prompting you to check the test environment.
8. During the test, the oscilloscope will automatically complete all configurations and adjust the signal source settings, then output the test results.

6.5.2.2 Using a Spectrum Analyzer

1. Select **2.5G BASE-T** in the **Setup** tab.

2. Select the test item: **Connect Test** > **Transmitter Nonlinear Distortion** .
3. In the **Configure** set the test pair ID (Pair A/B/C/D/All), test instrument (select spectrum analyzer), averaging count, balun compensation (On/Off), etc.
4. In the **Configure** , click **Test Connect** for the signal source to confirm its Connect to the oscilloscope. A successful connect will display the signal source model.
5. In the **Configure** , click **Test Connect** for the spectrum analyzer to confirm its Connect to the oscilloscope. A successful connect will display the spectrum analyzer model. If balun compensation is required, click setting to enter the compensation interface and configure the parameters.
6. Set up the test environment refer to the **Connect** tab. Refer to Section 5.4 for specific connection methods.
7. Click **Run Test** . The system will display a test prompt interface and automatically configure the oscilloscope and spectrum analyzer settings.
8. After confirming that the spectrum analyzer has captured the test signal, click **Run Test** on the oscilloscope prompt interface. If the oscilloscope does not receive data from the spectrum analyzer, the application will return to the prompt interface, prompting you to check the test environment.
9. During the test, the spectrum analyzer will measure the signal and transmit the results to the oscilloscope, which processes the data and outputs the final results.

6.5.3 Calculation Method and Pass Criteria

According to IEEE 802.3, the transmitter nonlinear distortion test requires testing five sets of dual tone signals. The frequencies and pass criteria are as follows:

Dual Tone Signals	Frequency (MHz)	Pass Criteria (dBc)
Dual Tone 1	9.1796 & 10.3515	SFDR ≥ 46.5
Dual Tone 2	19.7265 & 20.11725	SFDR ≥ 46.5
Dual Tone 3	34.961 & 35.3515	SFDR ≥ 46.5
Dual Tone 4	54.1015 & 54.88281	SFDR ≥ 45.67
Dual Tone 5	77.539 & 78.32031	SFDR ≥ 42.58

When using an oscilloscope for calculation, the oscilloscope obtains the dual tone signal amplitude spectrum through FFT algorithm; when using a spectrum analyzer, the oscilloscope directly reads the amplitude spectrum measured by the spectrum analyzer.

The basic settings for calculating the amplitude spectrum are:

- Start frequency: 0.3 MHz;
- End frequency: 100 MHz;
- Resolution bandwidth: 30 kHz.

After obtaining the amplitude spectrum, the oscilloscope records the amplitude values corresponding to the two frequency points of the dual-tone signal and selects the maximum value, referred to as the Highest Peak. Next, the oscilloscope records the amplitude value corresponding to the interference signal (45 MHz sine wave), referred to as the Third Highest Peak. The oscilloscope then automatically adjusts the amplitude of the interference signal from the arbitrary waveform generator to ensure:

Highest Peak - Third Highest Peak = 7dB

After adjustment, the oscilloscope records the amplitude values corresponding to the harmonic and intermodulation components of the dual-tone signal and selects the maximum value, referred to as the Fourth Highest Peak. Finally, the spurious-free dynamic range (SFDR) is calculated using the formula:

SFDR = Highest Peak - Fourth Highest Peak

6.5.4 Test Result Reference

Examples of nonlinear distortion test results for five sets of dual tone signals are shown in the following five figures.

2.5GBase-T, Nonlinear Distortion Tone-1				
Current	56.765dBm	56.358dBm	56.929dBm	56.548dBm
Mean	56.76536dBm	56.35762dBm	56.92873dBm	56.54762dBm
Min	56.765dBm	56.358dBm	56.929dBm	56.548dBm
Max	56.765dBm	56.358dBm	56.929dBm	56.548dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	20	20	20	20
Average Num	-	-	-	-
Pass Limit	Value >= 46.500dBm			
Margin	---	---	---	---
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

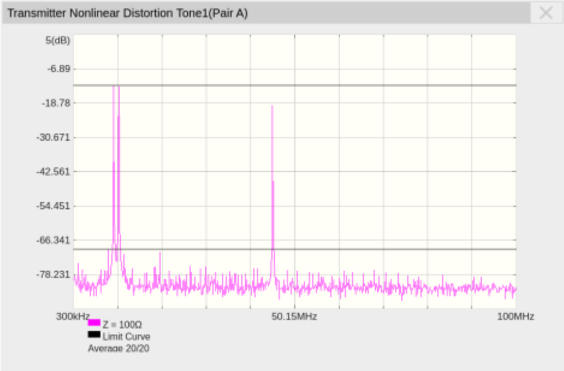


Figure 6-10 Tone1 Example of Nonlinear Distortion Results

2.5GBase-T, Nonlinear Distortion Tone-2				
Current	52.673dBm	55.313dBm	60.197dBm	54.226dBm
Mean	52.67258dBm	55.31268dBm	60.19663dBm	54.22553dBm
Min	52.673dBm	55.313dBm	60.197dBm	54.226dBm
Max	52.673dBm	55.313dBm	60.197dBm	54.226dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	20	20	20	20
Average Num	-	-	-	-
Pass Limit	Value >= 46.500dBm			
Margin	---	---	---	---
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

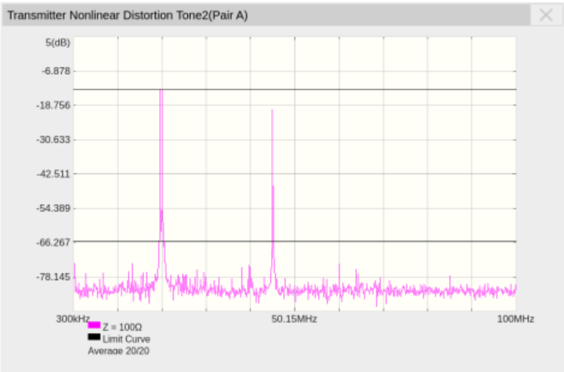


Figure 6-11 Tone2 Example of Nonlinear Distortion Results

2.5GBase-T, Nonlinear Distortion Tone-3				
Current	54.628dBm	52.762dBm	52.449dBm	60.995dBm
Mean	54.62799dBm	52.76171dBm	52.44900dBm	60.99540dBm
Min	54.628dBm	52.762dBm	52.449dBm	60.995dBm
Max	54.628dBm	52.762dBm	52.449dBm	60.995dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	20	20	20	20
Average Num	-	-	-	-
Pass Limit	Value >= 46.500dBm			
Margin	---	---	---	---
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

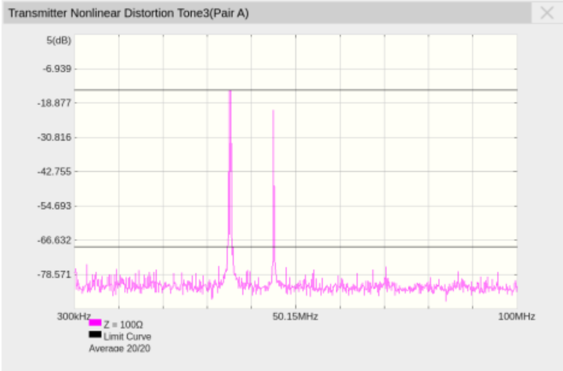


Figure 6-12 Tone3 Example of Nonlinear Distortion Results

2.5GBase-T, Nonlinear Distortion Tone-4				
Current	56.325dBm	55.202dBm	55.268dBm	***
Mean	56.32532dBm	55.20156dBm	55.26844dBm	***
Min	56.325dBm	55.202dBm	55.268dBm	***
Max	56.325dBm	55.202dBm	55.268dBm	***
Pk-Pk	0mdBm	0mdBm	0mdBm	***
Stdev	0mdBm	0mdBm	0mdBm	***
Count	20	20	20	0
Average Num	-	-	-	***
Pass Limit	Value >= 45.670dBm			
Margin	---	---	---	***
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	SKIP

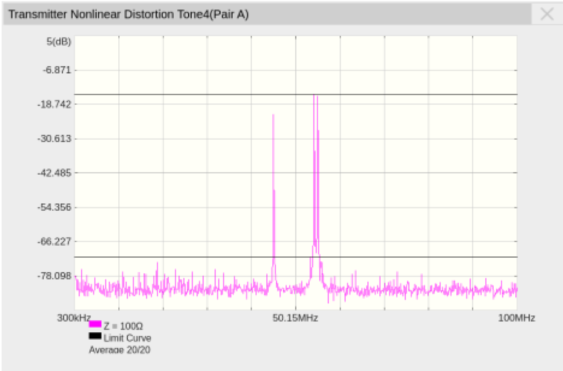


Figure 6-13 Tone4 Example of Nonlinear Distortion Results

2.5GBase-T, Nonlinear Distortion Tone-5				
Current	54.136dBm	53.349dBm	53.717dBm	***
Mean	54.13565dBm	53.34863dBm	53.71689dBm	***
Min	54.136dBm	53.349dBm	53.717dBm	***
Max	54.136dBm	53.349dBm	53.717dBm	***
Pk-Pk	0mdBm	0mdBm	0mdBm	***
Stdev	0mdBm	0mdBm	0mdBm	***
Count	20	20	20	0
Average Num	-	-	-	***
Pass Limit	Value >= 42.580dBm			
Margin	---	---	---	***
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	SKIP

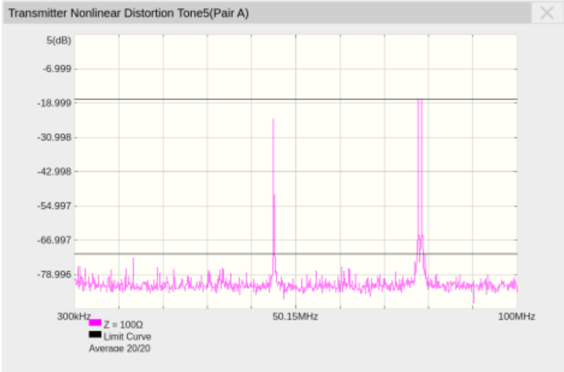


Figure 6-14 Tone5 Example of Nonlinear Distortion Results

6.6 Power Spectral Density

6.6.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.4.

This test verifies whether the power spectral density (PSD) complies with the standard. The DUT must be configured in Test Mode 5.

6.6.2 Test Procedure

6.6.2.1 Using an Oscilloscope

1. Select **2.5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Power Test** > **Power Spectral Density** .
3. In the **Configure** , set the probe type, signal source, test pair ID (Pair A/B/C/D/All), test instrument (select oscilloscope), and averaging count.
4. Set up the test environment refer to the **Connect** tab. Refer to section 5.1 for specific connection methods.
5. Click **Run Test** . The system will display a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other settings.
6. After the oscilloscope successfully captures the test signal, click **Run Test** on the prompt interface. If the oscilloscope fails to capture the correct waveform, the application will return to the prompt interface, prompting you to check the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the results.

6.6.2.2 Using a Spectrum Analyzer

1. Select **2.5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Power Test** > **Power Spectral Density** .
3. In the **Configure** , set the test pair ID (Pair A/B/C/D/All), test instrument (select spectrum analyzer), averaging count, balun compensation (On/Off), etc.
4. In the **Configure** , click **Connect Test** to confirm the spectrum analyzer's Connect to the oscilloscope. A successful Connect will display the spectrum analyzer model. If balun

compensation is required, click Settings to configure the parameters.

5. Set up the test environment refer to the **Connect** tab. Refer to Section 5.2 for specific connection methods.
6. Click **Run Test** . The system will display a test prompt interface and automatically configure the oscilloscope and spectrum analyzer settings.
7. After confirming that the spectrum analyzer has captured the test signal, click **Run Test** on the oscilloscope prompt interface. If the oscilloscope does not receive data from the spectrum analyzer, the application will return to the prompt interface, prompting you to check the test environment.
8. During the test, the spectrum analyzer will measure the signal and transmit the results to the oscilloscope, which processes the data and outputs the final results.

6.6.3 Calculation Method and Pass Criteria

According to IEEE 802.3, the power spectral density judgment criteria for 2.5GBASE-T are shown in Figure 6-15, where S=0.25 (One-quarter of the 10GBASE-T rate). Equation 55-9 refers to the upper limit of the 10GBASE-T power spectral density, as shown in Figure 8-10. Based on these criteria, the power spectral density template is derived, as shown in Figure 6-16.

$$\mathrm{PSD1}(f) \le \begin{cases} -77.7 - 10 \times \log_{10}(S) & \mathrm{dBm/Hz} \quad 0 < 2\frac{f}{S} \le 70 \\ -77.7 - 10 \times \log_{10} S - \frac{\left(2\frac{f}{S} - 70\right)}{80} & \mathrm{dBm/Hz} \quad 70 < 2\frac{f}{S} \le 150 \\ -78.7 - 10 \times \log_{10} S - \frac{\left(2\frac{f}{S} - 150\right)}{58} & \mathrm{dBm/Hz} \quad 150 < 2\frac{f}{S} \le 730 \\ -78.7 - 10 \times \log_{10} S - \frac{\left(2\frac{f}{S} - 330\right)}{40} & \mathrm{dBm/Hz} \quad 730 < 2\frac{f}{S} \le 1822 - 400 \times \log_{10}(S) \\ -116 & \mathrm{dBm/Hz} \quad S \times (911 - 200 \times \log_{10}(S)) < f \le 3000 \end{cases}$$

$$\mathrm{UpperPSD}(f) \le \max(\mathrm{PSD1}(f), (\text{Equation 55-9}) - 6\ \mathrm{dB}) \qquad (126\text{–}9)$$

and

$$\mathrm{Lower\ PSD}\ (f) \ge \begin{cases} -82.2 - 10 \times \log_{10}(S) & \mathrm{dBm/Hz} \quad 5 < 2\frac{f}{S} \le 50 \\ -82.2 - 10 \times \log_{10} S - \frac{\left(2\frac{f}{S} - 50\right)}{50} & \mathrm{dBm/Hz} \quad 50 < 2\frac{f}{S} \le 200 \\ -85.2 - 10 \times \log_{10} S - \frac{\left(2\frac{f}{S} - 200\right)}{25} & \mathrm{dBm/Hz} \quad 200 < 2\frac{f}{S} \le 400 \end{cases} \qquad (126\text{–}10)$$

where

f is in MHz

Figure 6-15 2.5/5G BASE-T Power Spectral Density Judgment Standard

$$\text{Upper PSD}(f) \le \begin{cases} -78.5 \text{ dBm/Hz} & 0 < f \le 70 \\ -78.5 - \left(\dfrac{f-70}{80}\right) \text{dBm/Hz} & 70 < f \le 150 \\ -79.5 - \left(\dfrac{f-150}{58}\right) \text{dBm/Hz} & 150 < f \le 730 \\ -79.5 - \left(\dfrac{f-330}{40}\right) \text{dBm/Hz} & 730 < f \le 1790 \\ -116 \text{ dBm/Hz} & 1790 < f \le 3000 \end{cases} \quad (55\text{–}9)$$

$$\text{Lower PSD}(f) \ge \begin{cases} -83 \text{ dBm/Hz} & 5 \le f \le 50 \\ -83 - \left(\dfrac{f-50}{50}\right) \text{dBm/Hz} & 50 < f \le 200 \\ -86 - \left(\dfrac{f-200}{25}\right) \text{dBm/Hz} & 200 < f \le 400 \end{cases} \quad (55\text{–}10)$$

Figure 23 Equations for PSD Masks applicable to 10GBase-T DUT

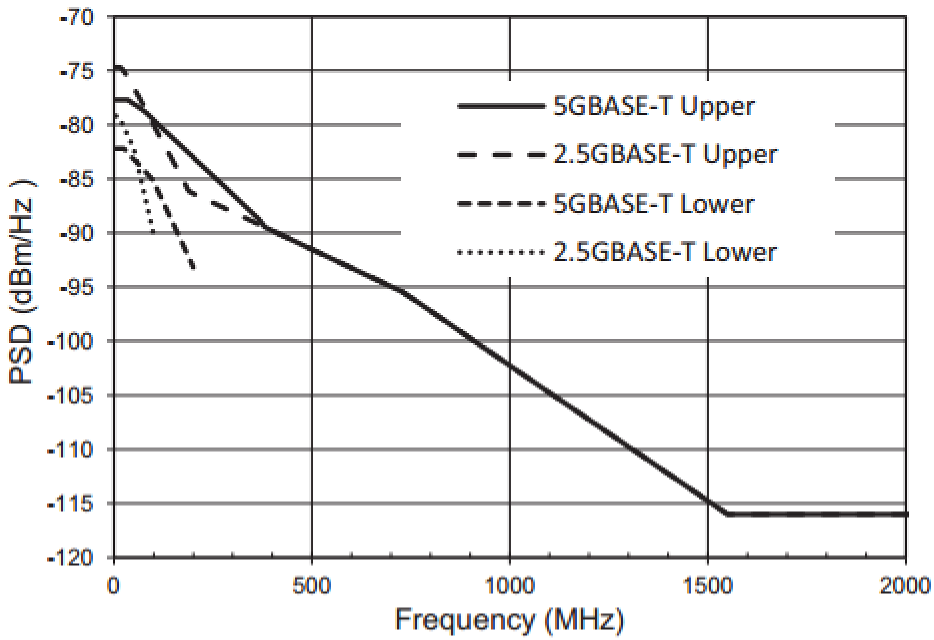


Figure 126–36—Transmitter power spectral density mask

Figure 6-16 2.5/5G BASE-T Power Spectral Density Stencil

When using an oscilloscope for calculation, the oscilloscope obtains the amplitude spectrum through FFT algorithm; when using a spectrum analyzer, the oscilloscope directly reads the amplitude spectrum measured by the spectrum analyzer.

The basic settings for calculating the amplitude spectrum are:

- Start frequency: 3 MHz;
- End frequency: 3 GHz;
- Resolution bandwidth: 300 kHz.

After obtaining the amplitude spectrum, the oscilloscope normalizes it based on the resolution bandwidth to derive the power spectral density, which is then compared with the template to determine the result.

6.6.4 Test Result Reference

An example of the power spectral density test result is shown in Figure 6-17.

2.5GBase-T, PSD				
Current	-	-	-	-
Mean	-	-	-	-
Min	-	-	-	-
Max	-	-	-	-
Pk-Pk	-	-	-	-
Stdev	-	-	-	-
Count	1	1	1	1
Average Num	50	50	50	50
Pass Limit	Overall = Pass			
Margin	---	---	---	---
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

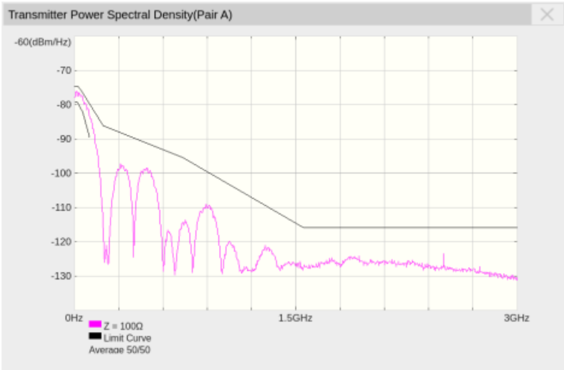


Figure 6-17 Power Spectral Density Test Result

6.7 Power Level

6.7.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.4.

This test is used to verify whether the power level complies with the standard specifications. During the test, the device under test (DUT) must be configured to test mode 5.

6.7.2 Test Procedure

6.7.2.1 Using an Oscilloscope

1. Select **2.5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Power Test** > **Power Level** .
3. In the **Configure** , set the probe type, signal source, test pair ID (Pair A/B/C/D/All), test instrument (select oscilloscope), and averaging count.
4. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section 5.1.
5. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other related settings.
6. After the oscilloscope correctly captures the signal under test, click **Run Test** on the test prompt interface to begin the test. If the oscilloscope fails to capture the correct waveform for testing, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the test results.

6.7.2.2 Using a Spectrum Analyzer

1. Select **2.5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Power Test** > **Power Level** .
3. In the **Configure** , set the test pair ID (Pair A/B/C/D/All), test instrument (select spectrum analyzer), averaging count, balun compensation (On/Off), etc.
4. In the **Configure** , click **Connect Test** to confirm whether the spectrum analyzer is

connected to the oscilloscope. If the connection is successful, the model of the spectrum analyzer will be displayed. If balun compensation is required, click settings to enter the balun compensation interface and configure the relevant parameters.

5. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to Section 5.2.
6. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope and spectrum analyzer.
7. After confirming that the spectrum analyzer has captured the signal under test, click **Run Test** on the oscilloscope's test prompt interface to begin the test. If the oscilloscope does not receive data from the spectrum analyzer for an extended period, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
8. During the test, the spectrum analyzer will measure the signal under test and transmit the results back to the oscilloscope. The oscilloscope will process the received data and output the test results.

6.7.3 Calculation Method and Pass Criteria

According to the IEEE 802.3 standard, the power level is calculated within the frequency range of 3 MHz to 400 MHz, and the result must be between 1 dBm and 3 dBm.

When using an oscilloscope for calculation, the oscilloscope computes the amplitude spectrum of the signal under test using the FFT algorithm. When using a spectrum analyzer, the oscilloscope directly reads the amplitude spectrum measured by the spectrum analyzer.

The basic settings for calculating the amplitude spectrum are:

- Start frequency: 3 MHz;
- End frequency: 400 MHz;
- Resolution bandwidth: 300 kHz.

After obtaining the amplitude spectrum, the oscilloscope calculates the power within the 3 MHz to 400 MHz bandwidth and converts it to the power level.

6.7.4 Test Result Reference

The power level test result is shown in Figure 6-18.

2.5GBase-T, Power Level				
Current	1.867dBm	2.005dBm	1.891dBm	1.846dBm
Mean	1.86678dBm	2.00495dBm	1.89055dBm	1.84650dBm
Min	1.867dBm	2.005dBm	1.891dBm	1.846dBm
Max	1.867dBm	2.005dBm	1.891dBm	1.846dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	1	1	1	1
Average Num	50	50	50	50
Pass Limit	1.000dBm <= Value <= 3.000dBm			
Margin	43.34%	49.75%	44.53%	42.32%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

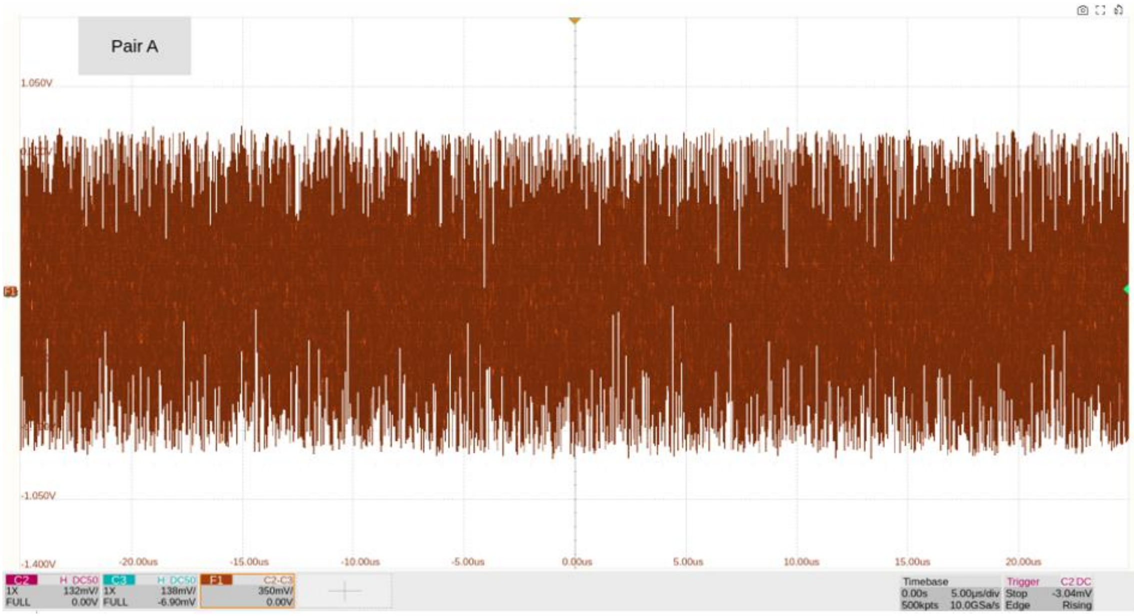


Figure 6-18 Example of Power Level Test Results

6.8 MDI Return Loss

6.8.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.8.2.2.

The MDI return loss test is used to verify whether the return loss of the DUT's interface complies with the value specified by the standard. During the test, the DUT must be configured to test mode 5.

6.8.2 Test Procedure

1. Select **2.5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **MDI Return Loss** .
3. In the **Configure** , set the VNA port and confirm the VNA connection is successful.
4. In the **Configure** , click **Open** , **Short** , and **Load** to calibrate the VNA. A calibration prompt interface will appear. Follow the instructions to verify the calibration environment setup, then click start calibration to begin calibration. For calibration wiring methods, refer to section 5.3.
5. After confirming successful calibration, set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section 5.3.
6. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope and VNA.
7. After confirming that the VNA has captured the signal under test, click **Run Test** on the test prompt interface.
8. After the VNA test completes, the oscilloscope will read the VNA results and output them.

6.8.3 Calculation Method and Pass Criteria

This test is performed using the VNA, and the oscilloscope reads the data and compares it with the standard to output the results.

According to the IEEE 802.3 standard, the pass criteria for return loss are shown in Figure 6-19.

$$\text{Return loss} \geq \begin{cases} 16 & 1 \leq f \leq 40 \quad (\text{dB}) \\ 16 - 10\log_{10}(f/40) & 40 < f \leq f_{max} \quad (\text{dB}) \end{cases} \qquad (126\text{–}38)$$

where

f is in MHz
f_{max} is 125 MHz for 2.5GBASE-T and 250 MHz for 5GBASE-T

Figure 6-19 MDI return loss passes the standard

6.8.4 Test Result Reference

Examples of the MDI return loss test results are shown in Figure 6-19 and Figure 6-20.

2.5GBase-T, MDI Return Loss				
Current	-	-	-	-
Mean	-	-	-	-
Min	-	-	-	-
Max	-	-	-	-
Pk-Pk	-	-	-	-
Stdev	-	-	-	-
Count	1	1	1	1
Average Num	-	-	-	-
Pass Limit	Info only, ref return loss plot			
Margin	-	-	-	-
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

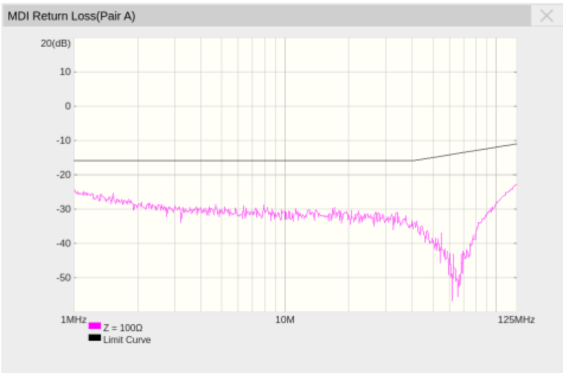


Figure 6-20 Examples of the MDI Return Loss Test Results

6.9 Transmitter Timing Jitter - Slave Test

6.9.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.3.

The transmitter timing jitter - slave mode test is used to verify whether the jitter of the DUT's output signal complies with the value specified by the standard, thereby validating signal quality. During the test, the DUT must be configured to test mode 3 (slave mode), and the Link Partner must be configured to test mode 1 (master mode). The DUT will transmit a periodic signal consisting of 2 consecutive +16-level symbols and 2 consecutive -16-level symbols, which can be regarded as an ideal square wave signal with a period of 20 ns.

Additionally, due to the connection method between the master PHY and slave PHY, only Pair D is tested for slave jitter.

6.9.2 Test Procedure

1. Select **2.5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Transmitter Timing Jitter - Slave**
3. In the **Configure** , set the signal source, jitter type, and bandpass filter.
4. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section5.5.
5. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other related settings.
6. After the oscilloscope correctly captures the signal under test, click **Run Test** on the test prompt interface to begin the test. If the oscilloscope fails to capture the correct waveform for testing, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the test results.

6.9.3 Calculation Method and Pass Criteria

According to the IEEE 802.3 standard, the jitter type calculated for the transmitter timing jitter - slave mode is periodic jitter. The sample size must cover a waveform length of 4 ms ±10%, i.e., 200,000

±20,000 cycles. Before calculation, the waveform must be filtered using a bandpass filter with a center frequency of 50 MHz and a bandwidth of 2 MHz.

In practice, on the Siglent compliance test software, users can select the jitter type (periodic jitter/TIE) and choose whether to apply the bandpass filter. Generally, using the bandpass filter yields more ideal jitter results.

During calculation, the oscilloscope captures a waveform of 4 ms ±10% lengths, measures the period/TIE for each symbol, and calculates the root mean square (RMS) of all samples to determine whether the jitter test passes.

The RMS calculation formula and pass criteria are:

$$\mathrm{RMS} = \sqrt{(\frac{\sum[(T - T_{avg})^2\ ]}{Sample\ \ Size})} < 10ps$$

6.9.4 Test Result Reference

An example of the transmitter timing jitter – slave test result is shown in Figure 6-21.

2.5GBase-T, Transmitter Timing Jitter Slave	
Current	476fs
Mean	19.99719811ns
Min	19.995244ns
Max	19.999113ns
Pk-Pk	3.869ps
Stdev	476fs
Count	200028
Formula	RMS
Pass Limit	Value <= 10.000ps
Margin	95.24%
Test Pair	BI_DD
Result	PASS

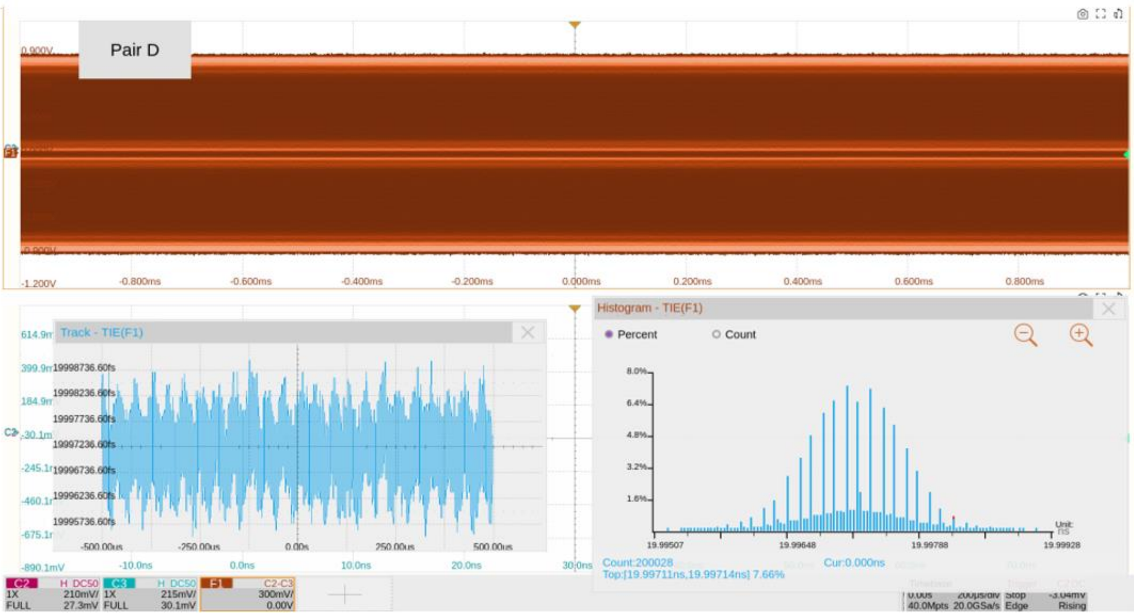


Figure 6-21 Transmitter Timing Jitter – Slave Test Result

7 5G BASE-T Compliance Testing

7.1 Maximum Output Droop Test

7.1.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.1.

The maximum output droop test verifies whether the attenuation rate of the DUT's output signal complies with the standard. During testing, the DUT must be configured in Test Mode 6, transmitting a periodic signal consisting of 128 consecutive +16-level symbols and 128 consecutive -16-level symbols, which can be regarded as an ideal square wave signal with a period of 0.64 μs.

7.1.2 Test Procedure

1. Select **5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Maximum Output Droop** .
3. In the **Configure** , set the probe type, signal source, test pair ID (Pair A/B/C/D/All), and averaging count.
4. Set up the test environment refer to the **Connect** tab. Refer to section 5.1 for connection details.
5. Click **Run Test** . The system will display a test prompt and automatically configure the oscilloscope's channels, triggers, and other settings.
6. After the oscilloscope successfully captures the signal, click **Run Test** on the prompt interface. If the waveform is incorrect, the application will return to the prompt, indicating an environment check is needed.
7. The oscilloscope will complete all configurations automatically and output the results.

7.1.3 Calculation Method and Pass Criteria

Per IEEE 802.3, the test calculates positive and negative maximum output droop:

Positive droop: The voltage at 10 ns (V_{10}) and 170 ns (V_{170}) after the rising edge zero-crossing point.

Negative droop: The voltage at 10 ns (V_{10}) and 170 ns (V_{170}) after the falling edge zero-crossing point.

The formula and pass criteria for both are:

$$\text{Droop} = \frac{(V_{10} - \ V_{170})}{V_{10}} < 12.5\%$$

7.1.4 Test Result Reference

An example of the positive maximum output droop result is shown in Figure 7-1

5GBase-T, Maximum Output Droop POS				
Current	5.92%	5.96%	5.82%	5.94%
Mean	5.9245%	5.9613%	5.8224%	5.9406%
Min	5.92%	5.96%	5.82%	5.94%
Max	5.92%	5.96%	5.82%	5.94%
Pk-Pk	0.00%	0.00%	0.00%	0.00%
Stdev	0.00%	0.00%	0.00%	0.00%
Count	1	1	1	1
Average Num	64	64	64	64
Pass Limit	Value <= 12.50%			
Margin	52.60%	52.31%	53.42%	52.48%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

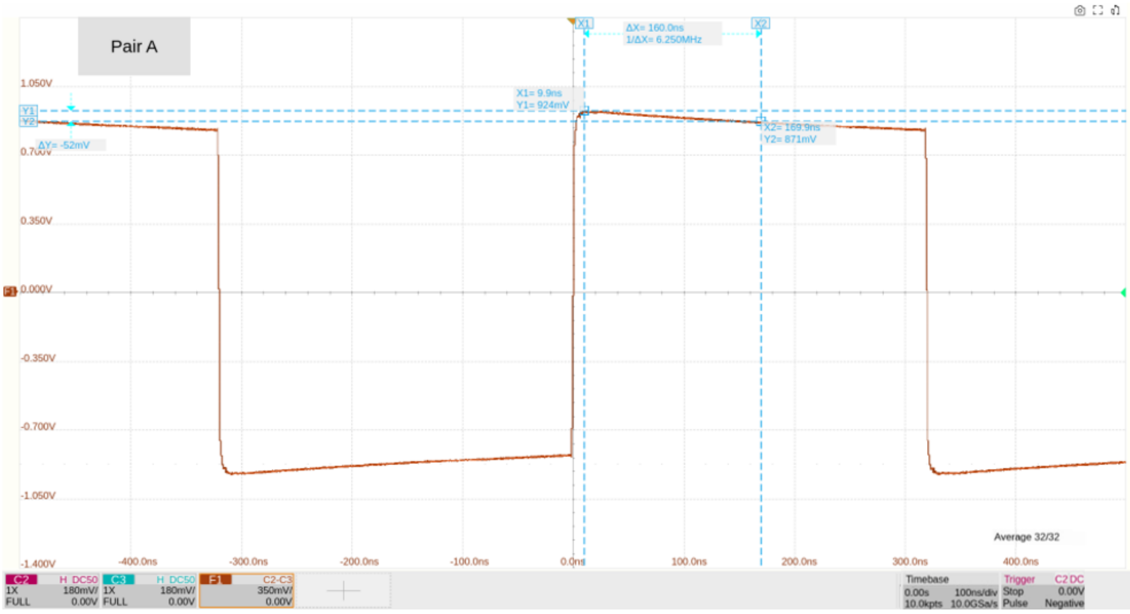


Figure 7-1 Positive Maximum Output Droop

An example of the negative maximum output droop result is shown in Figure 7-2.

5GBase-T, Maximum Output Droop NEG				
Current	5.92%	5.95%	5.94%	5.89%
Mean	5.9192%	5.9466%	5.9388%	5.8905%
Min	5.92%	5.95%	5.94%	5.89%
Max	5.92%	5.95%	5.94%	5.89%
Pk-Pk	0.00%	0.00%	0.00%	0.00%
Stdev	0.00%	0.00%	0.00%	0.00%
Count	1	1	1	1
Average Num	64	64	64	64
Pass Limit	Value <= 12.50%			
Margin	52.65%	52.43%	52.49%	52.88%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

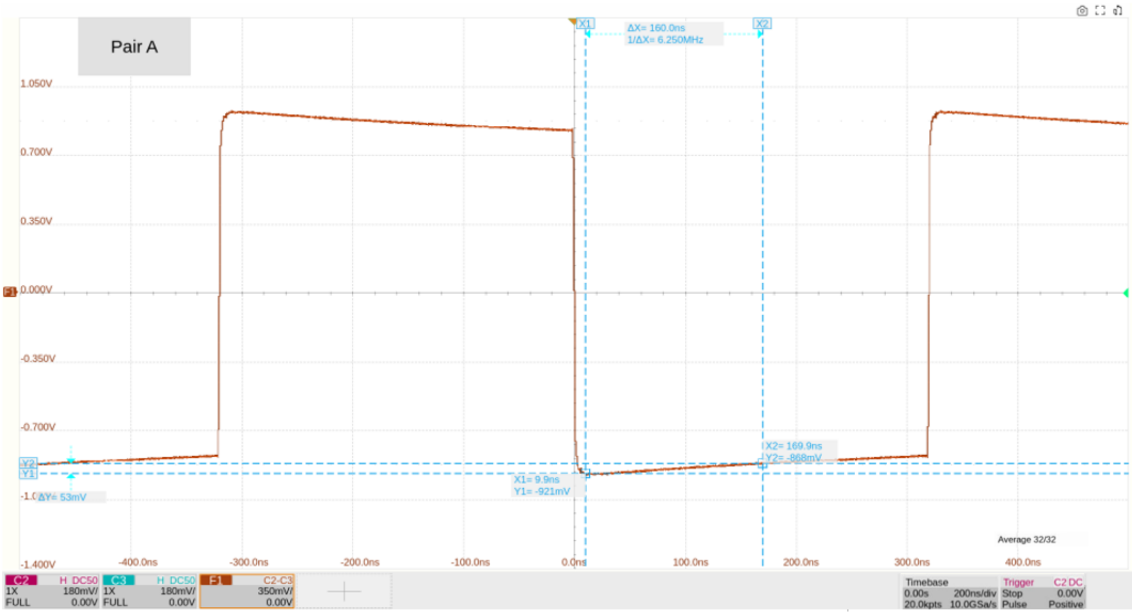


Figure 7-2 Negative Maximum Output Droop

7.2 Transmitter Timing Jitter – Master Test

7.2.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.3.

This transmitter timing jitter - master test validates the DUT's output signal jitter compliance. The DUT must be configured in Test Mode 2, transmitting a periodic signal consisting of 2 consecutive +16-level symbols and 2 consecutive -16-level symbols, which can be regarded as an ideal square wave signal with a period of 10 ns.

7.2.2 Test Procedure

1. Select **5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Transmitter Timing Jitter – Master** .
3. In the **Configure** set the probe type, signal source, test pair ID, jitter type (periodic/TIE), and bandpass filter.
4. Set up the test environment refer to the **Connect** tab. Refer to section 5.1 for specific connection methods.
5. Click **Run Test** . The oscilloscope will auto-configure.
6. After signal capture, click **Run Test** . If the waveform is invalid, the system will prompt an environment check.
7. Results are output automatically.

7.2.3 Calculation Method and Pass Criteria

According to the IEEE802.3 standards, the jitter type calculated by the transmitter timing jitter-main mode is periodic jitter, and the sample size needs to reach 2ms±10% of the waveform length, that is, 200000±20000 cycles. At the same time, the waveform needs to be filtered using a bandpass filter with a 100 MHz center frequency and a 2 MHz bandwidth before calculation.

In fact, on the consistency test software, users can select the jitter type (periodic jitter/TIE) and whether to use a bandpass filter to filter the waveform. In general, the jitter result will be more ideal after using a bandpass filter.

During the calculation, the oscilloscope will collect a waveform with a length of 2ms±10%, calculate the period/TIE of each symbol bit, and finally calculate the root mean square of all samples to determine whether the jitter test has passed.

The calculation formula and passing standard of the root mean square are:

$$\mathrm{RMS} = \sqrt{\left(\frac{\sum[(T - T_{avg})^2\ ]}{Sample\ \ Size}\right)} < 7.2ps$$

7.2.4 Test Result Reference

An example of the Transmitter Timing Jitter – Master result is shown in Figure 7-3

5GBase-T, Transmitter Timing Jitter Master				
Current	94fs	93fs	94fs	95fs
Mean	9.99978011ns	9.99978008ns	9.99978022ns	9.99978020ns
Min	9.999364ns	9.999412ns	9.999412ns	9.999411ns
Max	10.000186ns	10.000131ns	10.000196ns	10.000196ns
Pk-Pk	823fs	719fs	784fs	785fs
Stdev	94fs	93fs	94fs	95fs
Count	200006	200006	200006	200006
Formula	RMS			
Pass Limit	Value <= 7.200ps			
Margin	98.70%	98.71%	98.69%	98.67%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

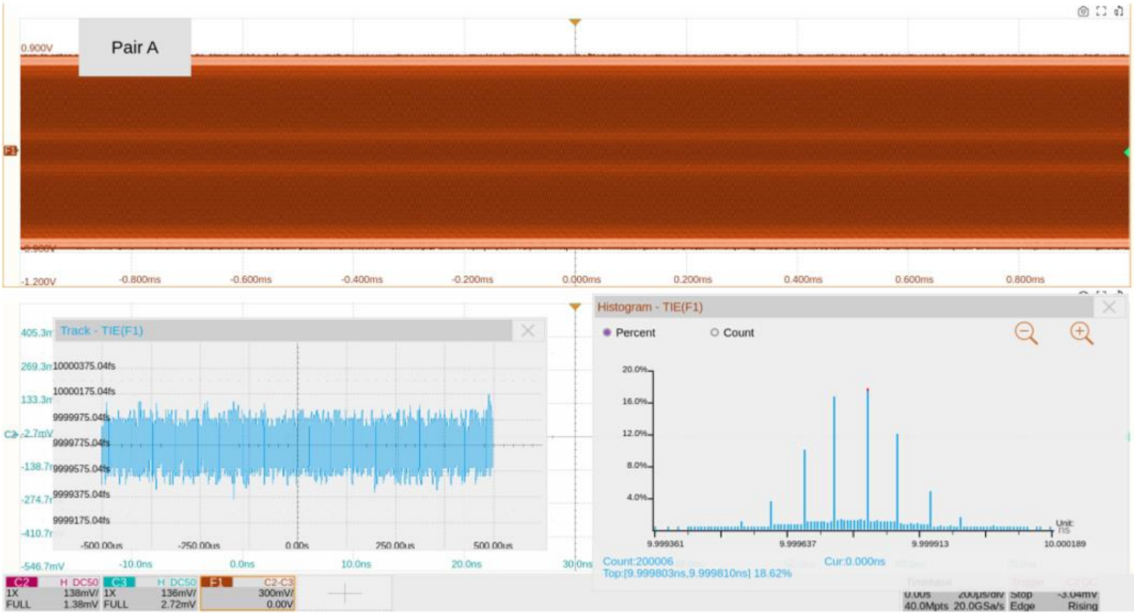


Figure 7-3 Transmitter Timing Jitter – Master Result

7.3 Transmitter Clock Frequency

7.3.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.5.

The transmitter clock frequency test is used to verify whether the clock frequency of the DUT complies with the value specified by the standard, thereby validating signal quality. During the test, the device under test (DUT) must be configured to test mode 2, where it transmits a periodic signal composed of two consecutive +16-level symbols followed by two consecutive -16-level symbols, i.e., an ideal square wave signal with a period of 10 ns.

7.3.2 Test Procedure

1. Select **5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Transmitter Clock Frequency** .
3. In the **Configure** , set the probe type, signal source, and test pair ID (Pair A/B/C/D/All).
4. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to Section 5.1.
5. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other related settings.
6. After the oscilloscope correctly captures the signal under test, click **Run Test** on the test prompt interface to begin the test. If the oscilloscope fails to capture the correct waveform for testing, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the test results.

7.3.3 Calculation Method and Pass Criteria

The IEEE 802.3 standard does not specify the sample size requirement for this test. Therefore, during actual testing, the sample size for the transmitter timing jitter—master mode test is referenced for collection and calculation, i.e., capturing a waveform length of 2 ms ±10%, which corresponds to 200,000 ±20,000 cycles.

During calculation, the oscilloscope measures the length of each cycle in the test mode 2 waveform and divides it by 4 to obtain the clock frequency. The pass criterion for the clock frequency is: 400 MHz ±50 ppm.

7.3.4 Test Result Reference

An example of the transmitter clock frequency result is shown in Figure 7-4

5GBase-T, Transmitter Timing Clock Frequency				
Current	28.24ppm	28.13ppm	28.49ppm	28.15ppm
Mean	400.0113MHz	400.0113MHz	400.0114MHz	400.0113MHz
Min	400.01MHz	400.01MHz	400.01MHz	400.01MHz
Max	400.01MHz	400.01MHz	400.01MHz	400.01MHz
Pk-Pk	0kHz	0kHz	0kHz	0kHz
Stdev	0kHz	0kHz	0kHz	0kHz
Count	20	20	20	20
Average Num	-	-	-	-
Pass Limit	-50.00ppm <= Value <= 50.00ppm			
Margin	21.76%	21.87%	21.51%	21.85%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

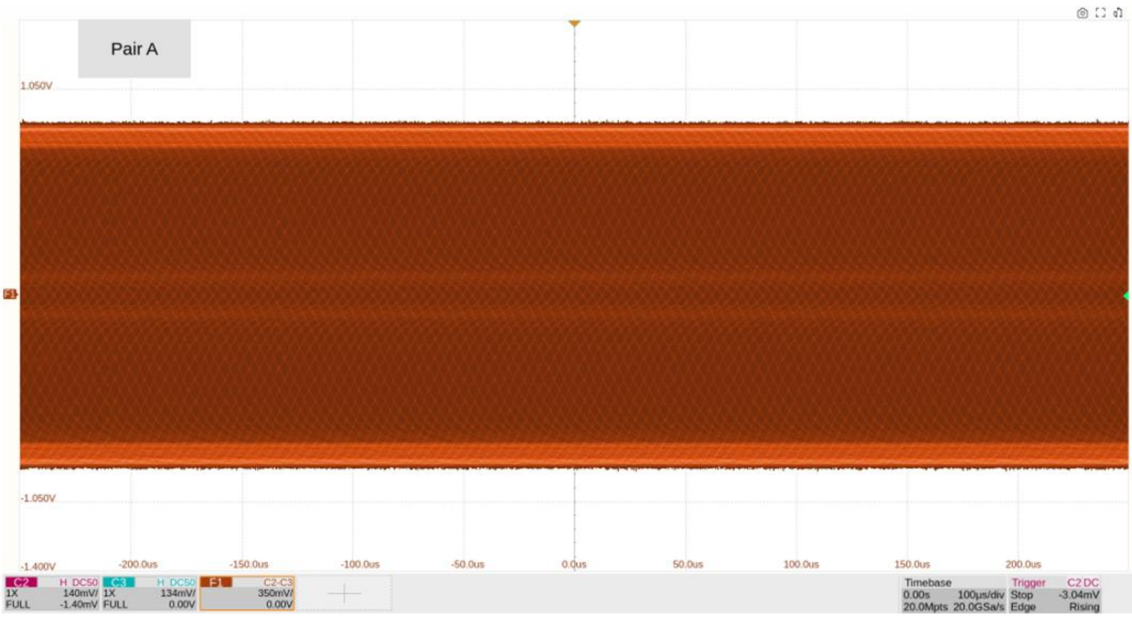


Figure 7-4 Transmitter Clock Frequency Result

7.4 Transmitter Linearity

7.4.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.2.

The transmitter linearity test is used to verify whether the spurious-free dynamic range (SFDR) of the DUT's output signal complies with the value specified by the standard. During the test, the DUT must be configured to test mode 4, which can be further divided into 5 modes, each transmitting a set of dual-tone signals with different frequencies.

7.4.2 Test Procedure

7.4.2.1 Using an Oscilloscope

1. Select **5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Transmitter Linearity** .
3. In the **Configure** , set the probe type, signal source, test pair ID (Pair A/B/C/D/All), test instrument (select oscilloscope), and averaging count.
4. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section 5.1.
5. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other related settings.
6. After the oscilloscope correctly captures the signal under test, click **Run Test** on the test prompt interface to begin the test. If the oscilloscope fails to capture the correct waveform for testing, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the test results.

7.4.2.2 Using a Spectrum Analyzer

1. Select **5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Item Selection** > **Transmitter Linearity** .
3. In the **Configure** , set the test pair ID (Pair A/B/C/D/All), test instrument (select spectrum analyzer), averaging count, balun compensation (On/Off), etc.

4. In the **Configure** , click **Connect Test** to confirm whether the spectrum analyzer is connected to the oscilloscope. If the connection is successful, the model of the spectrum analyzer will be displayed. If balun compensation is required, click settings to enter the balun compensation interface and configure the relevant parameters.

5. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section 5.2.

6. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope and spectrum analyzer.

7. After confirming that the spectrum analyzer has captured the signal under test, click **Run Test** on the oscilloscope's test prompt interface to begin the test. If the oscilloscope does not receive data from the spectrum analyzer for an extended period, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.

8. During the test, the spectrum analyzer will measure the signal under test and transmit the results back to the oscilloscope. The oscilloscope will process the received data and output the test results.

7.4.3 Calculation Method and Pass Criteria

According to the IEEE 802.3 standard, the transmitter linearity test requires testing five sets of dual tone signals. The frequencies and pass criteria for these signals are listed in the table below.

Dual Tone Signal	Frequency（MHz)	Pass Criteria (dBc)
Dual Tone 1	18.359 & 20.703	SFDR ≥ 54.5
Dual Tone 2	39.453 & 40.2343	SFDR ≥ 54.5
Dual Tone 3	69.922 & 70.703	SFDR ≥ 51.47
Dual Tone 4	108.203 & 109.7656	SFDR ≥ 47.649
Dual Tone 5	155.078 & 156.6406	SFDR ≥ 44.561

When using an oscilloscope for calculation, the oscilloscope will compute the amplitude spectrum of the dual tone signals using the FFT algorithm. When using a spectrum analyzer, the oscilloscope will directly read the amplitude spectrum measured by the spectrum analyzer.

The basic settings for calculating the amplitude spectrum are:

- Start frequency: 0.3 MHz;
- End frequency: 200 MHz;

- Resolution bandwidth: 30 kHz.

After obtaining the amplitude spectrum, the oscilloscope will record the amplitude values corresponding to the two frequency points of the dual-tone signals and select the highest value, denoted as the Highest Peak. Next, the oscilloscope will record the amplitude values corresponding to the harmonic and intermodulation components of the dual-tone signals and select the highest value among them, denoted as the Third Highest Peak. The formula for calculating the spurious-free dynamic range (SFDR) is:

SFDR = Highest Peak - Third Highest Peak

7.4.4 Test Result Reference

Examples of the transmitter linearity test results for the five sets of dual-tone signals are shown in the following five figures.

5GBase-T, Linearity Tone-1				
Current	58.190dBm	58.621dBm	58.621dBm	59.052dBm
Mean	58.18965dBm	58.62069dBm	58.62069dBm	59.05172dBm
Min	58.190dBm	58.621dBm	58.621dBm	59.052dBm
Max	58.190dBm	58.621dBm	58.621dBm	59.052dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 54.500dBm			
Margin	6.77%	7.56%	7.56%	8.35%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

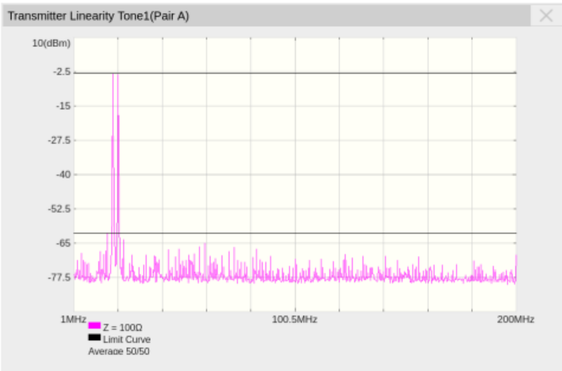


Figure 7-5 Tone1 Example of Transmitter Linearity Results

5GBase-T, Linearity Tone-2				
Current	57.543dBm	57.328dBm	56.897dBm	57.328dBm
Mean	57.54310dBm	57.32759dBm	56.89655dBm	57.32759dBm
Min	57.543dBm	57.328dBm	56.897dBm	57.328dBm
Max	57.543dBm	57.328dBm	56.897dBm	57.328dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 54.500dBm			
Margin	5.58%	5.19%	4.40%	5.19%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

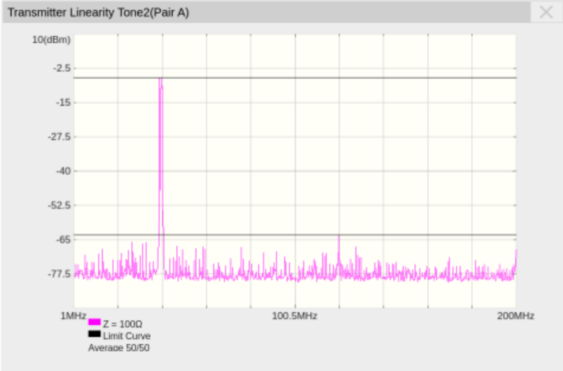


Figure 7-6 Tone2 Example of Transmitter Linearity Results

5GBase-T, Linearity Tone-3				
Current	61.207dBm	61.422dBm	61.422dBm	61.207dBm
Mean	61.20689dBm	61.42242dBm	61.42242dBm	61.20689dBm
Min	61.207dBm	61.422dBm	61.422dBm	61.207dBm
Max	61.207dBm	61.422dBm	61.422dBm	61.207dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 51.470dBm			
Margin	18.92%	19.34%	19.34%	18.92%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

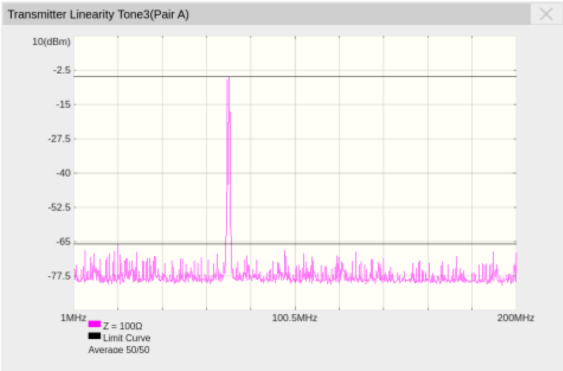


Figure 7-7 Tone3 Example of Transmitter Linearity Results

5GBase-T, Linearity Tone-4				
Current	56.897dBm	56.897dBm	57.112dBm	57.112dBm
Mean	56.89655dBm	56.89655dBm	57.11207dBm	57.11207dBm
Min	56.897dBm	56.897dBm	57.112dBm	57.112dBm
Max	56.897dBm	56.897dBm	57.112dBm	57.112dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 47.649dBm			
Margin	19.41%	19.41%	19.86%	19.86%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

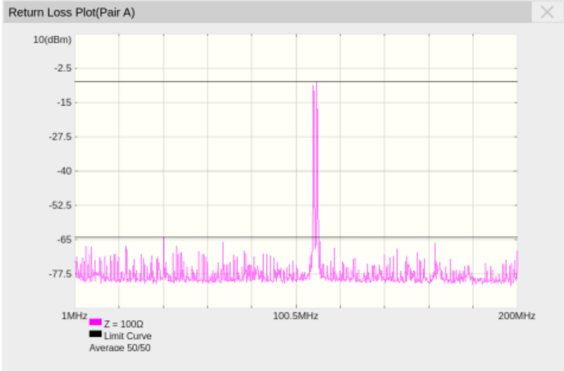


Figure 7-8 Tone4 Example of Transmitter Linearity Results

5GBase-T, Linearity Tone-5				
Current	54.310dBm	53.664dBm	54.095dBm	53.664dBm
Mean	54.31034dBm	53.66379dBm	54.09483dBm	53.66379dBm
Min	54.310dBm	53.664dBm	54.095dBm	53.664dBm
Max	54.310dBm	53.664dBm	54.095dBm	53.664dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 44.561dBm			
Margin	21.88%	20.43%	21.39%	20.43%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

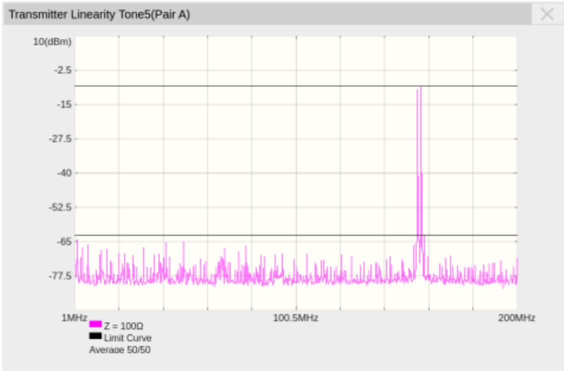


Figure 7-9 Tone1 Example of Transmitter Linearity Results

7.5 Power Spectral Density

7.5.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.4.

This test verifies whether the power spectral density (PSD) complies with the standard. The DUT must be configured in Test Mode 5.

7.5.2 Test Procedure

7.5.2.1 Using an Oscilloscope

1. Select 5G BASE-T in the Setup tab.
2. Select the test item: Test Select > Power Test > Power Spectral Density .
3. In the Configure , set the probe type, signal source, test pair ID (Pair A/B/C/D/All), test instrument (select oscilloscope), and averaging count.
4. Set up the test environment refer to the Connect tab. Refer to section 5.1 for specific connection methods.
5. Click Run Test . The system will display a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other settings.
6. After the oscilloscope successfully captures the test signal, click Run Test on the prompt interface. If the oscilloscope fails to capture the correct waveform, the application will return to the prompt interface, prompting you to check the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the results.

7.5.2.2 Using a Spectrum Analyzer

1. Select 5G BASE-T in the Setup tab.
2. Select the test item: Test Select > Power Test > Power Spectral Density .
3. In the Configure , set the test pair ID (Pair A/B/C/D/All), test instrument (select spectrum analyzer), averaging count, balun compensation (On/Off), etc.
4. In the Configure , click Connect Test to confirm the spectrum analyzer's Connect to the oscilloscope. A successful connect will display the spectrum analyzer model. If balun

compensation is required, click settings to configure the parameters.

5. Set up the test environment refer to the **Connect** tab. Refer to section 5.2 for specific connection methods.
6. Click **Run Test** . The system will display a test prompt interface and automatically configure the oscilloscope and spectrum analyzer settings.
7. After confirming that the spectrum analyzer has captured the test signal, click **Run Test** on the oscilloscope prompt interface. If the oscilloscope does not receive data from the spectrum analyzer, the application will return to the prompt interface, prompting you to check the test environment.
8. During the test, the spectrum analyzer will measure the signal and transmit the results to the oscilloscope, which processes the data and outputs the final results.

7.5.3 Calculation Method and Pass Criteria

According to IEEE 802.3, the power spectral density judgment criteria for 5GBASE-T are shown in Figure 6-15, where S=0.5 (One-half of the 10GBASE-T rate). Equation 55-9 refers to the upper limit of the 10GBASE-T power spectral density, as shown in Figure 8-10. Based on these criteria, the power spectral density template is derived, as shown in Figure 6-16.

When using an oscilloscope for calculation, the oscilloscope obtains the amplitude spectrum through FFT algorithm; when using a spectrum analyzer, the oscilloscope directly reads the amplitude spectrum measured by the spectrum analyzer.

The basic settings for calculating the amplitude spectrum are:

- Start frequency: 3 MHz;
- End frequency: 3 GHz;
- Resolution bandwidth: 300 kHz.

After obtaining the amplitude spectrum, the oscilloscope normalizes it based on the resolution bandwidth to derive the power spectral density, which is then compared with the template to determine the result.

7.5.4 Test Result Reference

An example of the power spectral density test result is shown in Figure 7-10

5GBase-T, PSD				
Current	-	-	-	-
Mean	-	-	-	-
Min	-	-	-	-
Max	-	-	-	-
Pk-Pk	-	-	-	-
Stdev	-	-	-	-
Count	1	1	1	1
Average Num	50	50	50	50
Pass Limit	Overall = Pass			
Margin	---	---	---	---
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

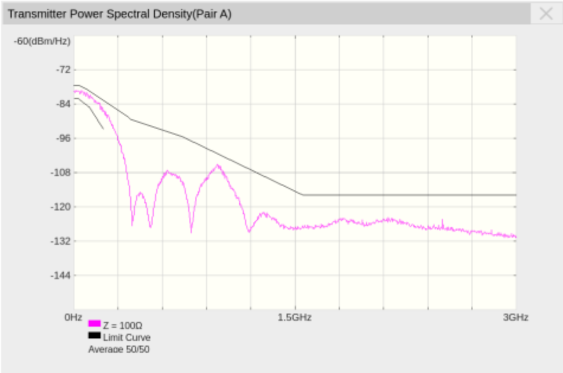


Figure 7-10 Power Spectral Density Test Result

7.6 Power Level

7.6.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.4.

This test is used to verify whether the power level complies with the standard specifications. During the test, the device under test (DUT) must be configured to test mode 5.

7.6.2 Test Procedure

7.6.2.1 Using an Oscilloscope

1. Select **5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Power Test** > **Power Level** .
3. In the **Configure** , set the probe type, signal source, test pair ID (Pair A/B/C/D/All), test instrument (select oscilloscope), and averaging count.
4. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section 5.1.
5. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other related settings.
6. After the oscilloscope correctly captures the signal under test, click **Run Test** on the test prompt interface to begin the test. If the oscilloscope fails to capture the correct waveform for testing, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the test results.

7.6.2.2 Using a Spectrum Analyzer

1. Select **5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Power Test** > **Power Level** .
3. In the **Configure** , set the test pair ID (Pair A/B/C/D/All), test instrument (select spectrum analyzer), averaging count, balun compensation (On/Off), etc.
4. In the **Configure** , click **Connect Test** to confirm whether the spectrum analyzer is

connected to the oscilloscope. If the connection is successful, the model of the spectrum analyzer will be displayed. If balun compensation is required, click settings to enter the balun compensation interface and configure the relevant parameters.

5. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section 5.2.
6. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope and spectrum analyzer.
7. After confirming that the spectrum analyzer has captured the signal under test, click **Run Test** on the oscilloscope's test prompt interface to begin the test. If the oscilloscope does not receive data from the spectrum analyzer for an extended period, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
8. During the test, the spectrum analyzer will measure the signal under test and transmit the results back to the oscilloscope. The oscilloscope will process the received data and output the test results.

7.6.3 Calculation Method and Pass Criteria

According to the IEEE 802.3 standard, the power level is calculated within the frequency range of 3 MHz to 400 MHz, and the result must be between 1 dBm and 3 dBm.

When using an oscilloscope for calculation, the oscilloscope computes the amplitude spectrum of the signal under test using the FFT algorithm. When using a spectrum analyzer, the oscilloscope directly reads the amplitude spectrum measured by the spectrum analyzer.

The basic settings for calculating the amplitude spectrum are:

- Start frequency: 3 MHz;
- End frequency: 400 MHz;
- Resolution bandwidth: 300 kHz.

After obtaining the amplitude spectrum, the oscilloscope calculates the power within the 3 MHz to 400 MHz bandwidth and converts it to the power level.

7.6.4 Test Result Reference

The power level test result is shown in Figure 7-11

5GBase-T, Power Level				
Current	1.929dBm	1.964dBm	1.861dBm	1.896dBm
Mean	1.92857dBm	1.96395dBm	1.86143dBm	1.89613dBm
Min	1.929dBm	1.964dBm	1.861dBm	1.896dBm
Max	1.929dBm	1.964dBm	1.861dBm	1.896dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	1	1	1	1
Average Num	50	50	50	50
Pass Limit	1.000dBm <= Value <= 3.000dBm			
Margin	46.43%	48.20%	43.07%	44.81%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

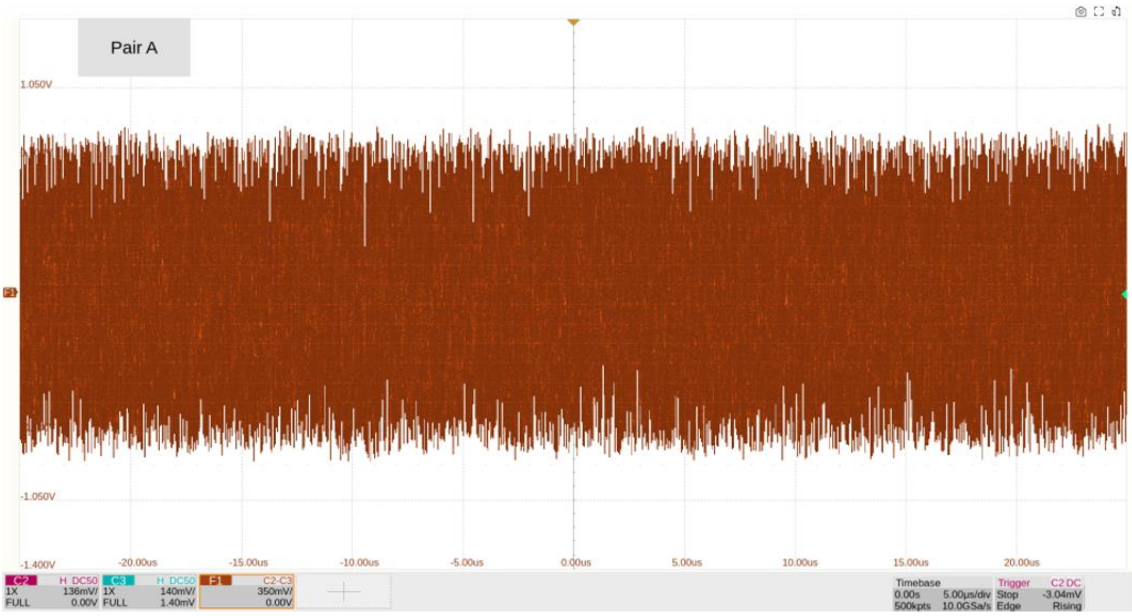


Figure 7-11 Power Level Test Result

7.7 MDI Return Loss

7.7.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.8.2.2.

The MDI return loss test is used to verify whether the return loss of the DUT's interface complies with the value specified by the standard. During the test, the DUT must be configured to test mode 5.

7.7.2 Test Procedure

1. Select **5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **MDI Return Loss** .
3. In the **Configure** , set the VNA port and confirm the VNA connection is successful.
4. In the **Configure** , click **Open** , **Short** , and **Load** to calibrate the VNA. A calibration prompt interface will appear. Follow the instructions to verify the calibration environment setup, then click start calibration to begin calibration. For calibration wiring methods, refer to section 5.3.
5. After confirming successful calibration, Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section 5.3.
6. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope and VNA.
7. After confirming that the VNA has captured the signal under test, click **Run Test** on the test prompt interface.
8. After the VNA test completes, the oscilloscope will read the VNA results and output them.

7.7.3 Calculation Method and Pass Criteria

This test is performed using the VNA, and the oscilloscope reads the data and compares it with the standard to output the results.

According to the IEEE 802.3 standard, the pass criteria for return loss are shown in Figure 6-19.

7.7.4 Test Result Reference

The MDI return loss test results are shown in Figure 7-12.

5GBase-T, MDI Return Loss				
Current	-	-	-	-
Mean	-	-	-	-
Min	-	-	-	-
Max	-	-	-	-
Pk-Pk	-	-	-	-
Stdev	-	-	-	-
Count	1	1	1	1
Average Num	-	-	-	-
Pass Limit	Info only, ref return loss plot			
Margin	-	-	-	-
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

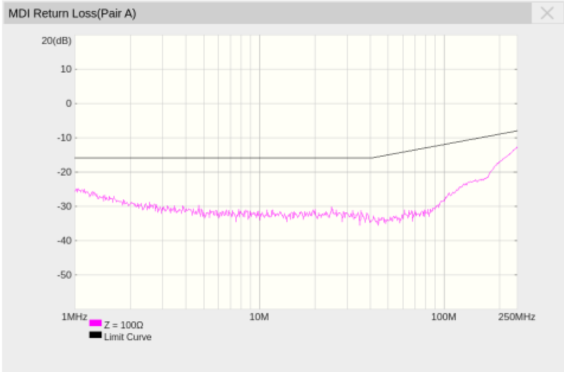


Figure 7-12 MDI Return Loss Test Results

7.8 Transmitter Timing Jitter - Slave Test

7.8.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 126.5.3.3.

The transmitter timing jitter - slave mode test is used to verify whether the jitter of the DUT's output signal complies with the value specified by the standard, thereby validating signal quality. During the test, the DUT must be configured to test mode 3 (slave mode), and the Link Partner must be configured to test mode 1 (master mode). The DUT will transmit a periodic signal consisting of 2 consecutive +16-level symbols and 2 consecutive -16-level symbols, which can be regarded as an ideal square wave signal with a period of 10 ns.

Additionally, due to the connection method between the master PHY and slave PHY, only Pair D is tested for slave jitter.

7.8.2 Test Procedure

1. Select **5G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Transmitter Timing Jitter - Slave**
3. In the **Configure** , set the signal source, jitter type, and bandpass filter.
4. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section5.5.
5. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other related settings.
6. After the oscilloscope correctly captures the signal under test, click **Run Test** on the test prompt interface to begin the test. If the oscilloscope fails to capture the correct waveform for testing, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the test results.

7.8.3 Calculation Method and Pass Criteria

According to the IEEE 802.3 standard, the jitter type calculated for the transmitter timing jitter - slave mode is periodic jitter. The sample size must cover a waveform length of 2 ms ±10%, i.e., 200,000

±20,000 cycles. Before calculation, the waveform must be filtered using a bandpass filter with a center frequency of 100 MHz and a bandwidth of 2 MHz.

In practice, on the Siglent compliance test software, users can select the jitter type (periodic jitter/TIE) and choose whether to apply the bandpass filter. Generally, using the bandpass filter yields more ideal jitter results.

During calculation, the oscilloscope captures a waveform of 2 ms ±10% lengths, measures the period/TIE for each symbol, and calculates the root mean square (RMS) of all samples to determine whether the jitter test passes.

The RMS calculation formula and pass criteria are:

$$\mathrm{RMS} = \sqrt{\left(\frac{\sum[(T - T_{avg})^2\ ]}{Sample\ \ Size}\right)} < 10ps$$

7.8.4 Test Result Reference

An example of the transmitter timing jitter – slave test result is shown in Figure 7-13

5GBase-T, Transmitter Timing Jitter Slave	
Current	922fs
Mean	9.99637228ns
Min	9.994308ns
Max	9.998449ns
Pk-Pk	4.141ps
Stdev	921fs
Count	200072
Formula	RMS
Pass Limit	Value <= 7.200ps
Margin	87.19%
Test Pair	BI_DD
Result	PASS

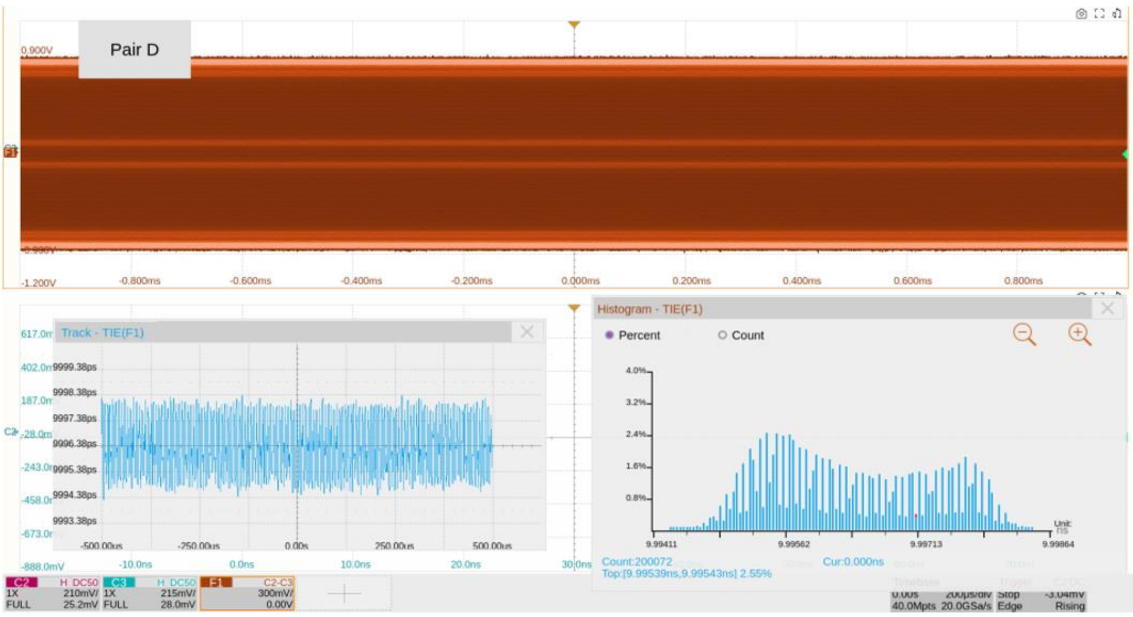


Figure 7-13 Transmitter Timing Jitter – Slave Test Result

8 10GBASE-T Compliance Testing

8.1 Maximum Output Droop Test

8.1.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 55.5.3.1.

The maximum output droop test verifies whether the attenuation rate of the DUT's output signal complies with the standard. During testing, the DUT must be configured in Test Mode 6, transmitting a periodic signal consisting of 128 consecutive +16-level symbols and 128 consecutive -16-level symbols, which can be regarded as an ideal square wave signal with a period of 0.32 µs.

8.1.2 Test Procedure

1. Select **10G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Maximum Output Droop** .
3. In the **Configure** , set the probe type, signal source, test pair ID (Pair A/B/C/D/All), and averaging count.
4. Set up the test environment refer to the **Connect** tab. Refer to section 5.1 for connect details.
5. Click **Run Test** . The system will display a test prompt and automatically configure the oscilloscope's channels, triggers, and other settings.
6. After the oscilloscope successfully captures the signal, click **Run Test** on the prompt interface. If the waveform is incorrect, the application will return to the prompt, indicating an environment check is needed.
7. The oscilloscope will complete all configurations automatically and output the results.

8.1.3 Calculation Method and Pass Criteria

Per IEEE 802.3, the test calculates positive and negative maximum output droop:

Positive droop: The voltage at 10 ns (V_{10}) and 90 ns (V_{90}) after the rising edge zero-crossing point.

Negative droop: The voltage at 10 ns (V_{10}) and 90 ns (V_{90}) after the falling edge zero-crossing point.

The formula and pass criteria for both are:

$$\text{Droop} = \frac{(V_{10} - \ V_{90})}{V_{10}} < 10\%$$

8.1.4 Test Result Reference

An example of the positive maximum output droop result is shown in Figure 8-1.

10GBase-T, Maximum Output Droop POS				
Current	2.99%	2.97%	2.91%	2.96%
Mean	2.9864%	2.9721%	2.9128%	2.9643%
Min	2.99%	2.97%	2.91%	2.96%
Max	2.99%	2.97%	2.91%	2.96%
Pk-Pk	0.00%	0.00%	0.00%	0.00%
Stdev	0.00%	0.00%	0.00%	0.00%
Count	1	1	1	1
Average Num	64	64	64	64
Pass Limit	Value <= 10.00%			
Margin	70.14%	70.28%	70.87%	70.36%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

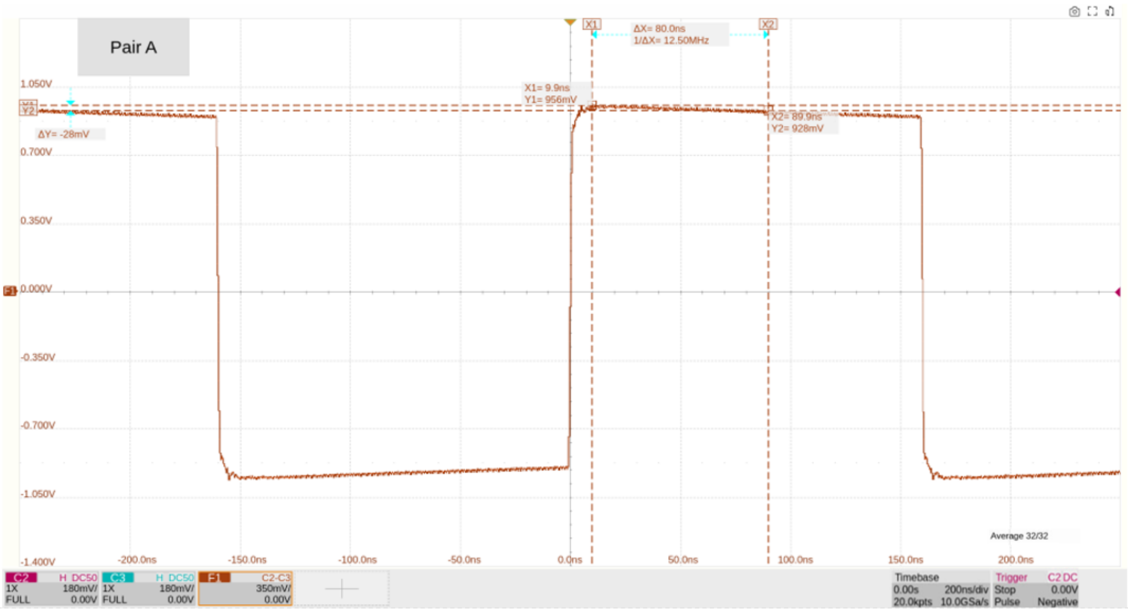


Figure 8-1 Positive Maximum Output Droop Result

An example of the negative maximum output droop result is shown in Figure 8-2.

10GBase-T, Maximum Output Droop NEG				
Current	2.97%	2.96%	2.85%	2.79%
Mean	2.9722%	2.9556%	2.8542%	2.7940%
Min	2.97%	2.96%	2.85%	2.79%
Max	2.97%	2.96%	2.85%	2.79%
Pk-Pk	0.00%	0.00%	0.00%	0.00%
Stdev	0.00%	0.00%	0.00%	0.00%
Count	1	1	1	1
Average Num	64	64	64	64
Pass Limit	Value <= 10.00%			
Margin	70.28%	70.44%	71.46%	72.06%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

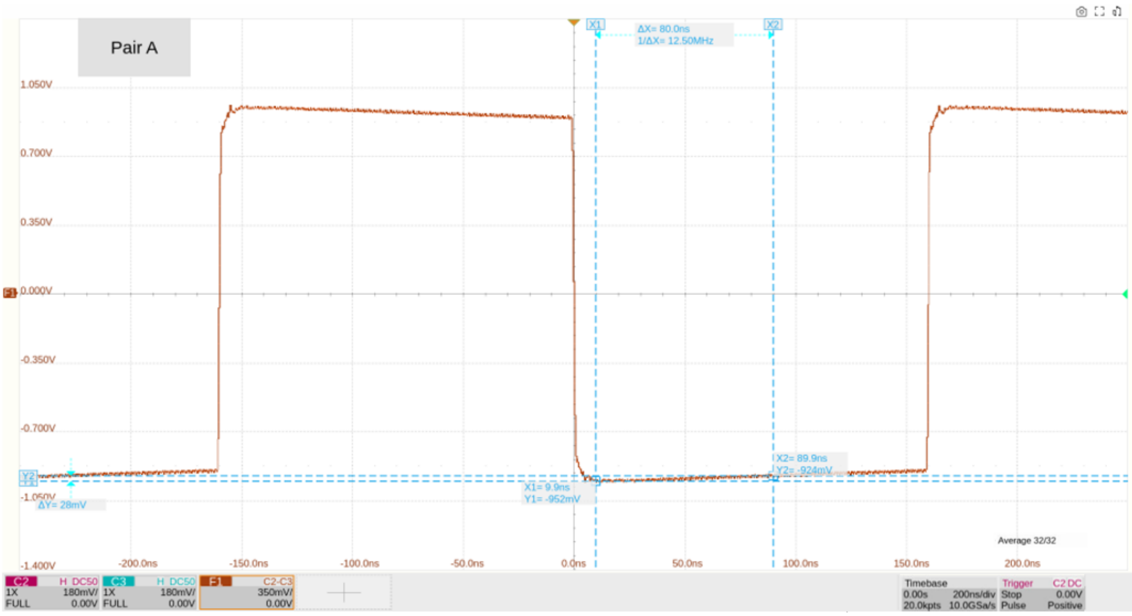


Figure 8-2 Negative Maximum Output Droop Result

8.2 Transmitter Timing Jitter – Master Test

8.2.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 55.5.3.3.

This transmitter timing jitter – master test validates the DUT's output signal jitter compliance. The DUT must be configured in Test Mode 2, transmitting a periodic signal consisting of 2 consecutive +16-level symbols and 2 consecutive -16-level symbols, which can be regarded as an ideal square wave signal with a period of 50 ns.

8.2.2 Test Procedure

1. Select **10G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Transmitter Timing Jitter – Master** .
3. In the **Configure** set the probe type, signal source, test pair ID, jitter type (periodic/TIE), and bandpass filter.
4. Set up the test environment refer to the **Connect** tab. Refer to section 5.1 for specific connection methods.
5. Click **Run Test** . The oscilloscope will auto-configure.
6. After signal capture, click **Run Test** . If the waveform is invalid, the system will prompt an environment check.
7. Results are output automatically.

8.2.3 Calculation Method and Pass Criteria

According to the IEEE802.3 standards, the jitter type calculated by the transmitter timing jitter-main mode is periodic jitter, and the sample size needs to reach 1ms±10% of the waveform length, that is, 200000±20000 cycles. At the same time, the waveform needs to be filtered using a bandpass filter with a 200 MHz center frequency and a 2 MHz bandwidth before calculation.

In fact, on the consistency test software, users can select the jitter type (periodic jitter/TIE) and whether to use a bandpass filter to filter the waveform. In general, the jitter result will be more ideal after using a bandpass filter.

During the calculation, the oscilloscope will collect a waveform with a length of 1ms±10%, calculate the period/TIE of each symbol bit, and finally calculate the root mean square of all samples to determine whether the jitter test has passed.

The calculation formula and passing standard of the root mean square are:

$$\mathrm{RMS} = \sqrt{\left(\frac{\sum[(T - T_{avg})^2\ ]}{Sample\ \ Size}\right)} < 5.5ps$$

8.2.4 Test Result Reference

An example of the Transmitter Timing Jitter – Master result is shown in Figure 8-3.

10GBase-T, Transmitter Timing Jitter Master				
Current	37fs	37fs	37fs	37fs
Mean	4.99988944ns	4.99988937ns	4.99988922ns	4.99988927ns
Min	4.999737ns	4.999742ns	4.999738ns	4.999707ns
Max	5.000066ns	5.000033ns	5.000066ns	5.000033ns
Pk-Pk	328fs	291fs	328fs	326fs
Stdev	37fs	37fs	37fs	37fs
Count	200005	200005	200005	200005
Formula	RMS			
Pass Limit	Value <= 5.500ps			
Margin	99.32%	99.32%	99.33%	99.32%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

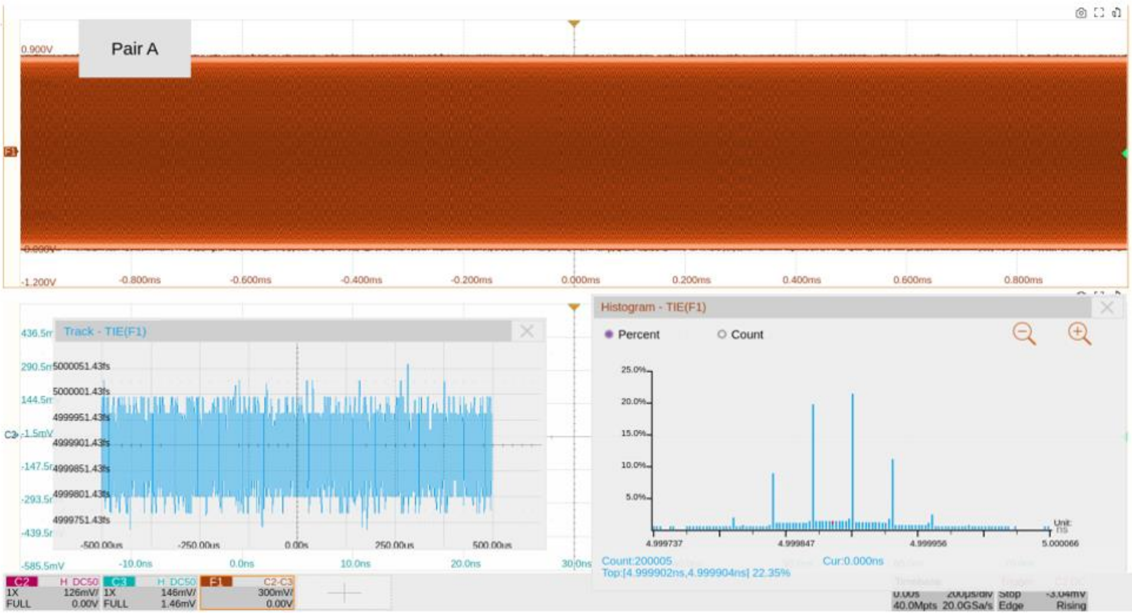


Figure 8-3 Transmitter Timing Jitter – Master Result

8.3 Transmitter Clock Frequency

8.3.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 55.5.3.5.

The transmitter clock frequency test is used to verify whether the clock frequency of the DUT complies with the value specified by the standard, thereby validating signal quality. During the test, the device under test (DUT) must be configured to test mode 2, where it transmits a periodic signal composed of two consecutive +16-level symbols followed by two consecutive -16-level symbols, i.e., an ideal square wave signal with a period of 5 ns.

8.3.2 Test Procedure

1. Select **10G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Transmitter Clock Frequency** .
3. In the **Configure** , set the probe type, signal source, and test pair ID (Pair A/B/C/D/All).
4. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section 5.1.
5. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other related settings.
6. After the oscilloscope correctly captures the signal under test, click **Run Test** on the test prompt interface to begin the test. If the oscilloscope fails to capture the correct waveform for testing, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the test results.

8.3.3 Calculation Method and Pass Criteria

The IEEE 802.3 standard does not specify the sample size requirement for this test. Therefore, during actual testing, the sample size for the transmitter timing jitter—master mode test is referenced for collection and calculation, i.e., capturing a waveform length of 1 ms ±10%, which corresponds to 200,000 ±20,000 cycles.

During calculation, the oscilloscope measures the length of each cycle in the test mode 2 waveform and divides it by 4 to obtain the clock frequency. The pass criterion for the clock frequency is: 800 MHz ±50 ppm.

8.3.4 Test Result Reference

An example of the transmitter clock frequency result is shown in Figure 8-4.

10GBase-T, Transmitter Timing Clock Frequency				
Current	26.58ppm	26.60ppm	26.57ppm	26.61ppm
Mean	800.0213MHz	800.0213MHz	800.0213MHz	800.0213MHz
Min	800.02MHz	800.02MHz	800.02MHz	800.02MHz
Max	800.02MHz	800.02MHz	800.02MHz	800.02MHz
Pk-Pk	0kHz	0kHz	0kHz	0kHz
Stdev	0kHz	0kHz	0kHz	0kHz
Count	20	20	20	20
Average Num	-	-	-	-
Pass Limit	-50.00ppm <= Value <= 50.00ppm			
Margin	23.42%	23.40%	23.43%	23.39%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

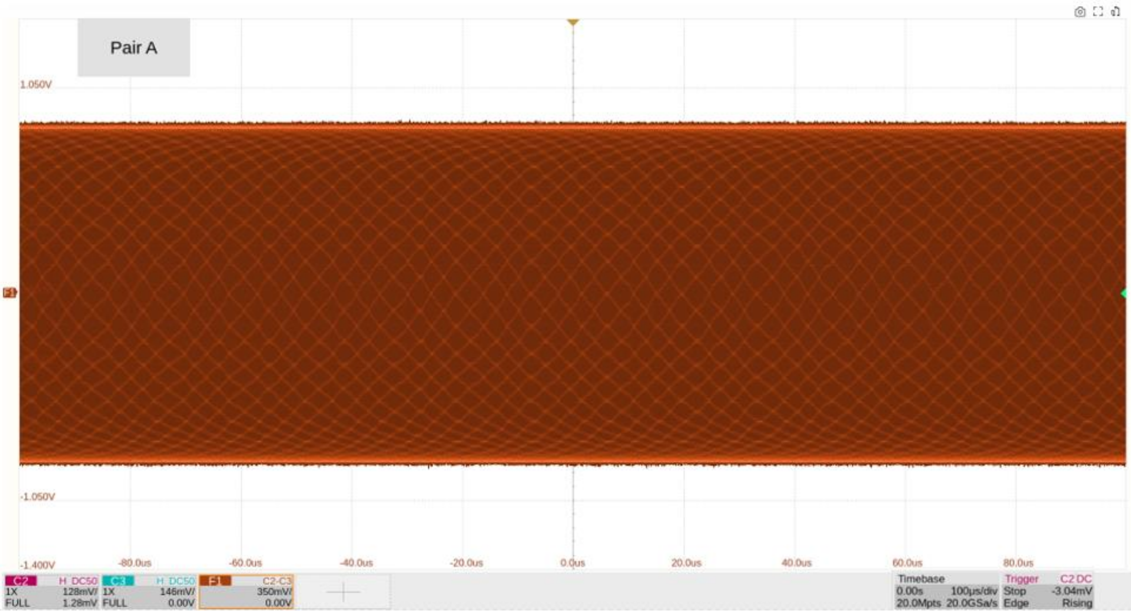


Figure 8-4 Transmitter Clock Frequency Result

8.4 Transmitter Linearity

8.4.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 55.5.3.2.

The transmitter linearity test is used to verify whether the spurious-free dynamic range (SFDR) of the DUT's output signal complies with the value specified by the standard. During the test, the DUT must be configured to test mode 4, which can be further divided into 5 modes, each transmitting a set of dual-tone signals with different frequencies.

8.4.2 Test Procedure

8.4.2.1 Using an Oscilloscope

1. Select **10G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Transmitter Linearity** .
3. In the **Configure** , set the probe type, signal source, test pair ID (Pair A/B/C/D/All), test instrument (select oscilloscope), and averaging count.
4. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section 5.1.
5. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other related settings.
6. After the oscilloscope correctly captures the signal under test, click **Run Test** on the test prompt interface to begin the test. If the oscilloscope fails to capture the correct waveform for testing, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the test results.

8.4.2.2 Using a Spectrum Analyzer

1. Select **10G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Transmitter Linearity** .
3. In the **Configure** , set the test pair ID (Pair A/B/C/D/All), test instrument (select spectrum analyzer), averaging count, balun compensation (On/Off), etc.

4. In the **Configure**, click **Connect Test** to confirm whether the spectrum analyzer is connected to the oscilloscope. If the connection is successful, the model of the spectrum analyzer will be displayed. If balun compensation is required, click settings to enter the balun compensation interface and configure the relevant parameters.
5. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section 5.2.
6. Click **Run Test**. The system will pop up a test prompt interface and automatically configure the oscilloscope and spectrum analyzer.
7. After confirming that the spectrum analyzer has captured the signal under test, click **Run Test** on the oscilloscope's test prompt interface to begin the test. If the oscilloscope does not receive data from the spectrum analyzer for an extended period, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
8. During the test, the spectrum analyzer will measure the signal under test and transmit the results back to the oscilloscope. The oscilloscope will process the received data and output the test results.

8.4.3 Calculation Method and Pass Criteria

According to the IEEE 802.3 standard, the transmitter linearity test requires testing five sets of dual tone signals. The frequencies and pass criteria for these signals are listed in the table below.

Dual Tone Signal	Frequency（MHz)	Pass Criteria (dBc)
Dual Tone 1	36.718 & 41.406	SFDR ≥ 54.5
Dual Tone 2	78.906 & 80.469	SFDR ≥ 50.346
Dual Tone 3	139.844 & 141.406	SFDR ≥ 45.449
Dual Tone 4	216.406 & 219.531	SFDR ≥ 41.629
Dual Tone 5	310.156 & 313.281	SFDR ≥ 38.540

When using an oscilloscope for calculation, the oscilloscope will compute the amplitude spectrum of the dual tone signals using the FFT algorithm. When using a spectrum analyzer, the oscilloscope will directly read the amplitude spectrum measured by the spectrum analyzer.

The basic settings for calculating the amplitude spectrum are:

- Start frequency: 0.3 MHz;

- End frequency: 400 MHz;
- Resolution bandwidth: 100 kHz.

After obtaining the amplitude spectrum, the oscilloscope will record the amplitude values corresponding to the two frequency points of the dual-tone signals and select the highest value, denoted as the Highest Peak. Next, the oscilloscope will record the amplitude values corresponding to the harmonic and intermodulation components of the dual-tone signals and select the highest value among them, denoted as the Third Highest Peak. The formula for calculating the spurious-free dynamic range (SFDR) is:

SFDR = Highest Peak - Third Highest Peak

8.4.4 Test Result Reference

Examples of the transmitter linearity test results for the five sets of dual-tone signals are shown in the following five figures.

10GBase-T, Linearity Tone-1				
Current	61.422dBm	61.422dBm	61.422dBm	61.422dBm
Mean	61.42242dBm	61.42242dBm	61.42242dBm	61.42242dBm
Min	61.422dBm	61.422dBm	61.422dBm	61.422dBm
Max	61.422dBm	61.422dBm	61.422dBm	61.422dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 54.500dBm			
Margin	12.70%	12.70%	12.70%	12.70%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

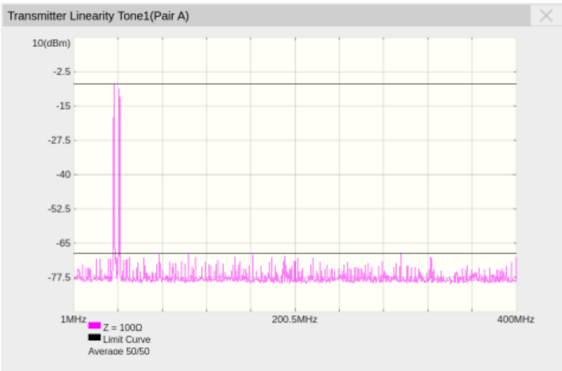


Figure 8-5 Tone1 Example of Transmitter Linearity Results

10GBase-T, Linearity Tone-2				
Current	59.267dBm	57.328dBm	57.543dBm	58.190dBm
Mean	59.26724dBm	57.32759dBm	57.54310dBm	58.18966dBm
Min	59.267dBm	57.328dBm	57.543dBm	58.190dBm
Max	59.267dBm	57.328dBm	57.543dBm	58.190dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 50.346dBm			
Margin	17.72%	13.87%	14.30%	15.58%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

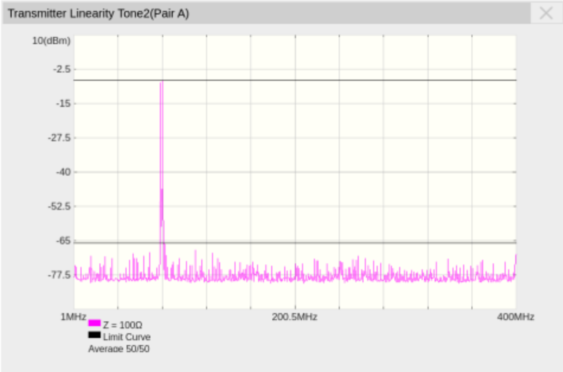


Figure 8-6 Tone2 Example of Transmitter Linearity Results

10GBase-T, Linearity Tone-3				
Current	55.172dBm	54.957dBm	55.388dBm	55.388dBm
Mean	55.17241dBm	54.95690dBm	55.38793dBm	55.38793dBm
Min	55.172dBm	54.957dBm	55.388dBm	55.388dBm
Max	55.172dBm	54.957dBm	55.388dBm	55.388dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 45.449dBm			
Margin	21.39%	20.92%	21.87%	21.87%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

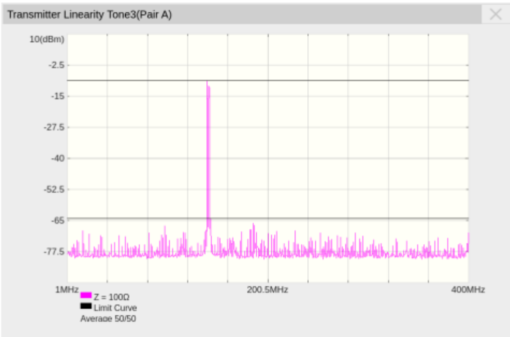


Figure 8-7 Tone3 Example of Transmitter Linearity Results

10GBase-T, Linearity Tone-4				
Current	56.466dBm	56.466dBm	56.250dBm	56.466dBm
Mean	56.46552dBm	56.46552dBm	56.25000dBm	56.46552dBm
Min	56.466dBm	56.466dBm	56.250dBm	56.466dBm
Max	56.466dBm	56.466dBm	56.250dBm	56.466dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 41.629dBm			
Margin	35.64%	35.64%	35.12%	35.64%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

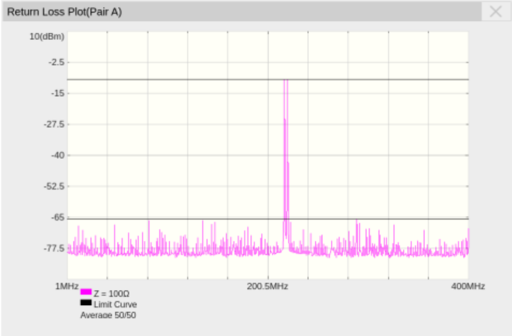


Figure 8-8 Tone4 Example of Transmitter Linearity Results

10GBase-T, Linearity Tone-5				
Current	51.940dBm	51.940dBm	51.940dBm	51.940dBm
Mean	51.93965dBm	51.93965dBm	51.93965dBm	51.93965dBm
Min	51.940dBm	51.940dBm	51.940dBm	51.940dBm
Max	51.940dBm	51.940dBm	51.940dBm	51.940dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	50	50	50	50
Average Num	-	-	-	-
Pass Limit	Value >= 38.540dBm			
Margin	34.77%	34.77%	34.77%	34.77%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

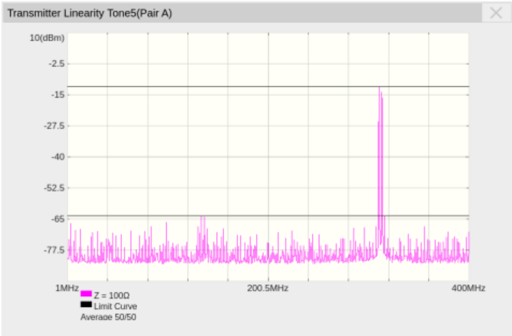


Figure 8-9 Tone5 Example of Transmitter Linearity Results

8.5 Power Spectral Density

8.5.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 55.5.3.4.

This test verifies whether the power spectral density (PSD) complies with the standard. The DUT must be configured in Test Mode 5.

8.5.2 Test Procedure

8.5.2.1 Using an Oscilloscope

1. Select **10G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Power Test** > **Power Spectral Density** .
3. In the **Configure** , set the probe type, signal source, test pair ID (Pair A/B/C/D/All), test instrument (select oscilloscope), and averaging count.
4. Set up the test environment refer to the **Connect** tab. Refer to section 5.1 for specific connection methods.
5. Click **Run Test** . The system will display a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other settings.
6. After the oscilloscope successfully captures the test signal, click **Run Test** on the prompt interface. If the oscilloscope fails to capture the correct waveform, the application will return to the prompt interface, prompting you to check the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the results.

8.5.2.2 Using a Spectrum Analyzer

1. Select **10G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Power Test** > **Power Spectral Density** .
3. In the **Configure** , set the test pair ID (Pair A/B/C/D/All), test instrument (select spectrum analyzer), averaging count, balun compensation (On/Off), etc.
4. In the **Configure** , click **Connect Test** to confirm the spectrum analyzer's connect to the oscilloscope. A successful connect will display the spectrum analyzer model. If balun

compensation is required, click Settings to configure the parameters.

5. Set up the test environment refer to the **Connect** tab. Refer to section 5.2 for specific connection methods.
6. Click **Run Test** . The system will display a test prompt interface and automatically configure the oscilloscope and spectrum analyzer settings.
7. After confirming that the spectrum analyzer has captured the test signal, click **Run Test** on the oscilloscope prompt interface. If the oscilloscope does not receive data from the spectrum analyzer, the application will return to the prompt interface, prompting you to check the test environment.
8. During the test, the spectrum analyzer will measure the signal and transmit the results to the oscilloscope, which processes the data and outputs the final results.

8.5.3 Calculation Method and Pass Criteria

According to IEEE 802.3, the power spectral density judgment criteria for 10GBASE-T are shown in Figure 8-10. Based on these criteria, the power spectral density template is derived, as shown in Figure 8-11.

$$\text{Upper PSD }(f) \le \begin{cases} -78.5 \text{ dBm/Hz} & 0 < f \le 70 \\ -78.5 - \left(\frac{f-70}{80}\right) \text{dBm/Hz} & 70 < f \le 150 \\ -79.5 - \left(\frac{f-150}{58}\right) \text{dBm/Hz} & 150 < f \le 730 \\ -79.5 - \left(\frac{f-330}{40}\right) \text{dBm/Hz} & 730 < f \le 1790 \\ -116 \text{ dBm/Hz} & 1790 < f \le 3000 \end{cases} \qquad (55\text{–}9)$$

$$\text{Lower PSD }(f) \ge \begin{cases} -83 \text{ dBm/Hz} & 5 \le f \le 50 \\ -83 - \left(\frac{f-50}{50}\right) \text{dBm/Hz} & 50 < f \le 200 \\ -86 - \left(\frac{f-200}{25}\right) \text{dBm/Hz} & 200 < f \le 400 \end{cases} \qquad (55\text{–}10)$$

Figure 23 Equations for PSD Masks applicable to 10GBase-T DUT

Figure 8-10 10G Base-T Power Spectral Density Judgment Criteria

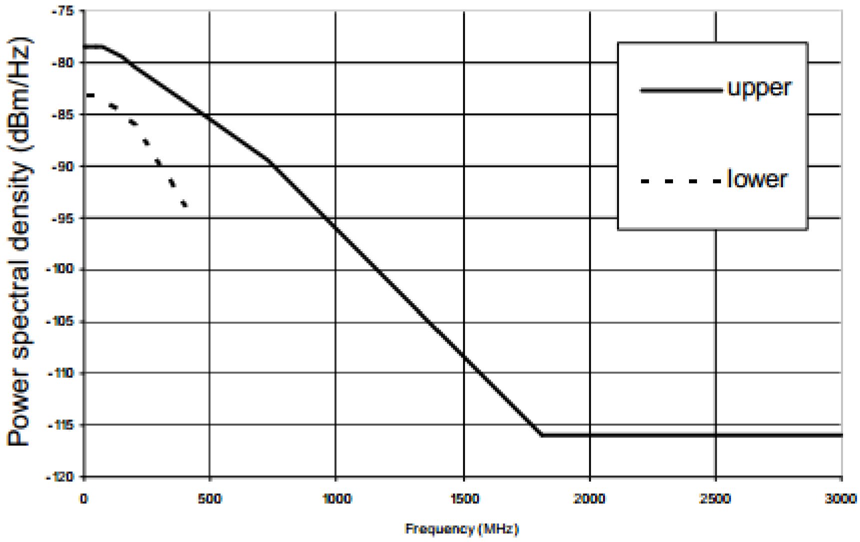


Figure 55–37—Transmitter power spectral density mask

Figure 8-11 10G Base-T Power Spectral Density Template

When using an oscilloscope for calculation, the oscilloscope obtains the amplitude spectrum through FFT algorithm; when using a spectrum analyzer, the oscilloscope directly reads the amplitude spectrum measured by the spectrum analyzer.

The basic settings for calculating the amplitude spectrum are:

- Start frequency: 3 MHz;
- End frequency: 3 GHz;
- Resolution bandwidth: 300 kHz.

After obtaining the amplitude spectrum, the oscilloscope normalizes it based on the resolution bandwidth to derive the power spectral density, which is then compared with the template to determine the result.

8.5.4 Test Result Reference

An example of the power spectral density test result is shown in Figure 8-12.

10GBase-T, PSD				
Current	-	-	-	-
Mean	-	-	-	-
Min	-	-	-	-
Max	-	-	-	-
Pk-Pk	-	-	-	-
Stdev	-	-	-	-
Count	1	1	1	1
Average Num	50	50	50	50
Pass Limit	Overall = Pass			
Margin	---	---	---	---
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

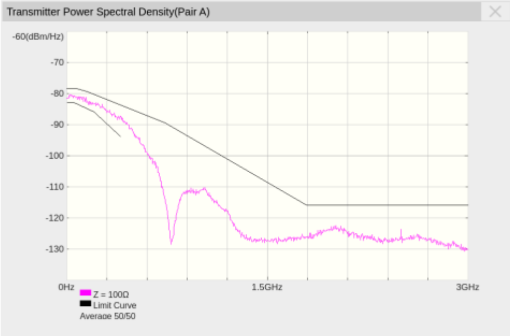


Figure 8-12 Power Spectral Density Test Result

8.6 Power Level

8.6.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 55.5.3.4.

This test is used to verify whether the power level complies with the standard specifications. During the test, the device under test (DUT) must be configured to test mode 5.

8.6.2 Test Procedure

8.6.2.1 Using an Oscilloscope

1. Select **10G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Power Test** > **Power Level** .
3. In the **Configure** , set the probe type, signal source, test pair ID (Pair A/B/C/D/All), test instrument (select oscilloscope), and averaging count.
4. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section 5.1.
5. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other related settings.
6. After the oscilloscope correctly captures the signal under test, click **Run Test** on the test prompt interface to begin the test. If the oscilloscope fails to capture the correct waveform for testing, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the test results.

8.6.2.2 Using a Spectrum Analyzer

1. Select **10G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Power Test** > **Power Level** .
3. In the **Configure** , set the test pair ID (Pair A/B/C/D/All), test instrument (select spectrum analyzer), averaging count, balun compensation (On/Off), etc.
4. In the **Configure** , click **Connect Test** to confirm whether the spectrum analyzer is

connected to the oscilloscope. If the connection is successful, the model of the spectrum analyzer will be displayed. If balun compensation is required, click settings to enter the balun compensation interface and configure the relevant parameters.

5. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section 5.2.
6. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope and spectrum analyzer.
7. After confirming that the spectrum analyzer has captured the signal under test, click **Run Test** on the oscilloscope's test prompt interface to begin the test. If the oscilloscope does not receive data from the spectrum analyzer for an extended period, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
8. During the test, the spectrum analyzer will measure the signal under test and transmit the results back to the oscilloscope. The oscilloscope will process the received data and output the test results.

8.6.3 Calculation Method and Pass Criteria

According to the IEEE 802.3 standard, the power level is calculated within the frequency range of 3 MHz to 400 MHz, and the result must be between 3.2 dBm and 5.2 dBm.

When using an oscilloscope for calculation, the oscilloscope computes the amplitude spectrum of the signal under test using the FFT algorithm. When using a spectrum analyzer, the oscilloscope directly reads the amplitude spectrum measured by the spectrum analyzer.

The basic settings for calculating the amplitude spectrum are:

- Start frequency: 3 MHz;
- End frequency: 400 MHz;
- Resolution bandwidth: 300 kHz.

After obtaining the amplitude spectrum, the oscilloscope calculates the power within the 3 MHz to 400 MHz bandwidth and converts it to the power level.

8.6.4 Test Result Reference

The power level test result is shown in Figure 8-13

10GBase-T, Power Level				
Current	2.822dBm	2.843dBm	2.814dBm	2.797dBm
Mean	2.82222dBm	2.84332dBm	2.81437dBm	2.79656dBm
Min	2.822dBm	2.843dBm	2.814dBm	2.797dBm
Max	2.822dBm	2.843dBm	2.814dBm	2.797dBm
Pk-Pk	0mdBm	0mdBm	0mdBm	0mdBm
Stdev	0mdBm	0mdBm	0mdBm	0mdBm
Count	1	1	1	1
Average Num	50	50	50	50
Pass Limit	3.200dBm <= Value <= 5.200dBm			
Margin	-18.89%	-17.83%	-19.28%	-20.17%
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	FAIL	FAIL	FAIL	FAIL

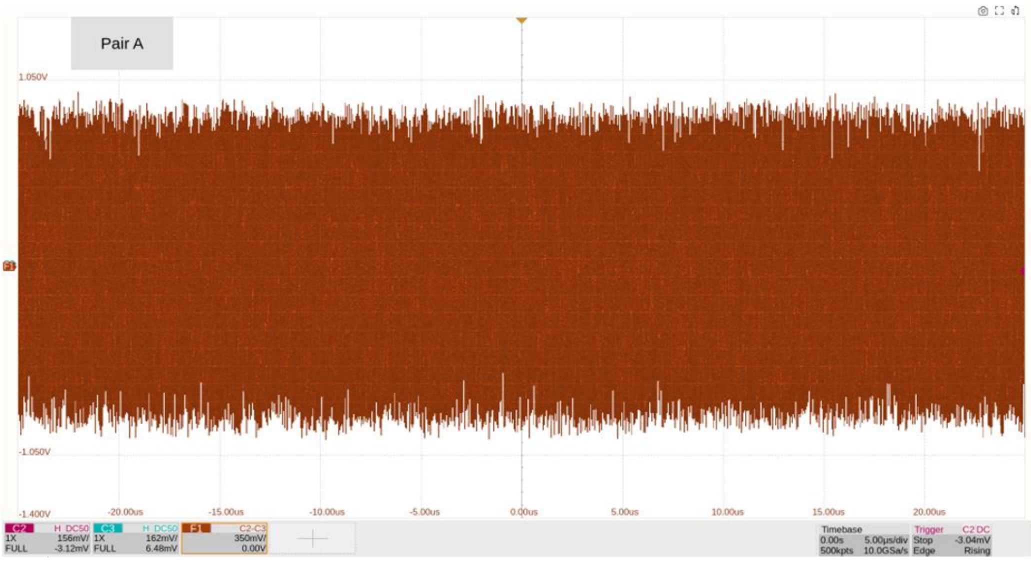


Figure 8-13 Power Level Test Result

8.7 MDI Return Loss

8.7.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 55.8.2.2.

The MDI return loss test is used to verify whether the return loss of the DUT's interface complies with the value specified by the standard. During the test, the DUT must be configured to test mode 5.

8.7.2 Test Procedure

1. Select **10G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **MDI Return Loss** .
3. In the **Configure** , set the VNA port and confirm the VNA connection is successful.
4. In the **Configure** , click **Open** , **Short** , and **Load** to calibrate the VNA. A calibration prompt interface will appear. Follow the instructions to verify the calibration environment setup, then click start calibration to begin calibration. For calibration wiring methods, refer to section 5.3.
5. After confirming successful calibration, set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section 5.3.
6. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope and VNA.
7. After confirming that the VNA has captured the signal under test, click **Run Test** on the test prompt interface.
8. After the VNA test completes, the oscilloscope will read the VNA results and output them.

8.7.3 Calculation Method and Pass Criteria

This test is performed using the VNA, and the oscilloscope reads the data and compares it with the standard to output the results.

According to the IEEE 802.3 standard, the pass criteria for return loss are shown in Figure 8-14.

$$\text{Return loss} \geq \begin{cases} 16 & 1 \leq f \leq 40 \quad (\text{dB}) \\ 16 - 10\log_{10}(f/40) & 40 < f \leq 400 \quad (\text{dB}) \\ 6 - 30\log_{10}(f/400) & 400 < f \leq 500 \quad (\text{dB}) \end{cases} \qquad (55\text{–}54)$$

Figure 8-14 Pass Criteria for MDI Return Loss

8.7.4 Test Result Reference

The MDI return loss test results are shown in Figure 8-15

10GBase-T, MDI Return Loss				
Current	-	-	-	-
Mean	-	-	-	-
Min	-	-	-	-
Max	-	-	-	-
Pk-Pk	-	-	-	-
Stdev	-	-	-	-
Count	1	1	1	1
Average Num	-	-	-	-
Pass Limit	Info only, ref return loss plot			
Margin	-	-	-	-
Test Pair	BI_DA	BI_DB	BI_DC	BI_DD
Result	PASS	PASS	PASS	PASS

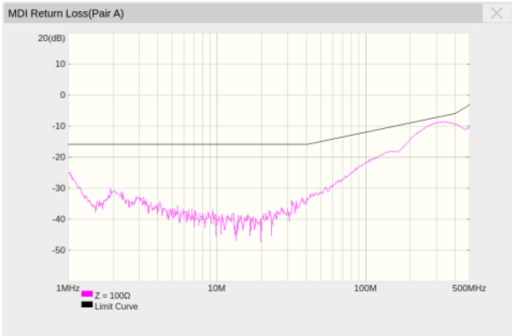


Figure 8-15 MDI Return Loss Test Results

8.8 Transmitter Timing Jitter - Slave Test

8.8.1 Test Introduction

Reference standard: IEEE 802.3-2018, Subclause 55.5.3.3.

The transmitter timing jitter - slave mode test is used to verify whether the jitter of the DUT's output signal complies with the value specified by the standard, thereby validating signal quality. During the test, the DUT must be configured to test mode 3 (slave mode), and the Link Partner must be configured to test mode 1 (master mode). The DUT will transmit a periodic signal consisting of 2 consecutive +16-level symbols and 2 consecutive -16-level symbols, which can be regarded as an ideal square wave signal with a period of 5 ns.

Additionally, due to the connection method between the master PHY and slave PHY, only Pair D is tested for slave jitter.

8.8.2 Test Procedure

1. Select **10G BASE-T** in the **Setup** tab.
2. Select the test item: **Test Select** > **Transmitter Timing Jitter - Slave**
3. In the **Configure** , set the signal source, jitter type, and bandpass filter.
4. Set up the test environment refer to the **Connect** tab. For specific test connection methods, refer to section 5.5.
5. Click **Run Test** . The system will pop up a test prompt interface and automatically configure the oscilloscope's channels, triggers, and other related settings.
6. After the oscilloscope correctly captures the signal under test, click **Run Test** on the test prompt interface to begin the test. If the oscilloscope fails to capture the correct waveform for testing, the application will return to the test prompt interface, prompting you to check the accuracy of the test environment.
7. During the test, the oscilloscope will automatically complete all configurations and output the test results.

8.8.3 Calculation Method and Pass Criteria

According to the IEEE 802.3 standard, the jitter type calculated for the transmitter timing jitter - slave mode is periodic jitter. The sample size must cover a waveform length of 1 ms ±10%, i.e., 200,000

±20,000 cycles. Before calculation, the waveform must be filtered using a bandpass filter with a center frequency of 200 MHz and a bandwidth of 2 MHz.

In practice, on the Siglent compliance test software, users can select the jitter type (periodic jitter/TIE) and choose whether to apply the bandpass filter. Generally, using the bandpass filter yields more ideal jitter results.

During calculation, the oscilloscope captures a waveform of 1 ms ±10% length, measures the period/TIE for each symbol, and calculates the root mean square (RMS) of all samples to determine whether the jitter test passes.

The RMS calculation formula and pass criteria are:

$$\mathrm{RMS} = \sqrt{\left(\frac{\sum[(T - T_{avg})^2\ ]}{Sample\ \ Size}\right)} < 5.5ps$$

8.8.4 Test Result Reference

An example of the transmitter timing jitter – slave mode test result is shown in

10GBase-T, Transmitter Timing Jitter Slave	
Current	62fs
Mean	4.99989493ns
Min	4.999670ns
Max	5.000126ns
Pk-Pk	457fs
Stdev	62fs
Count	200005
Formula	RMS
Pass Limit	Value <= 5.500ps
Margin	98.88%
Test Pair	BI_DD
Result	PASS

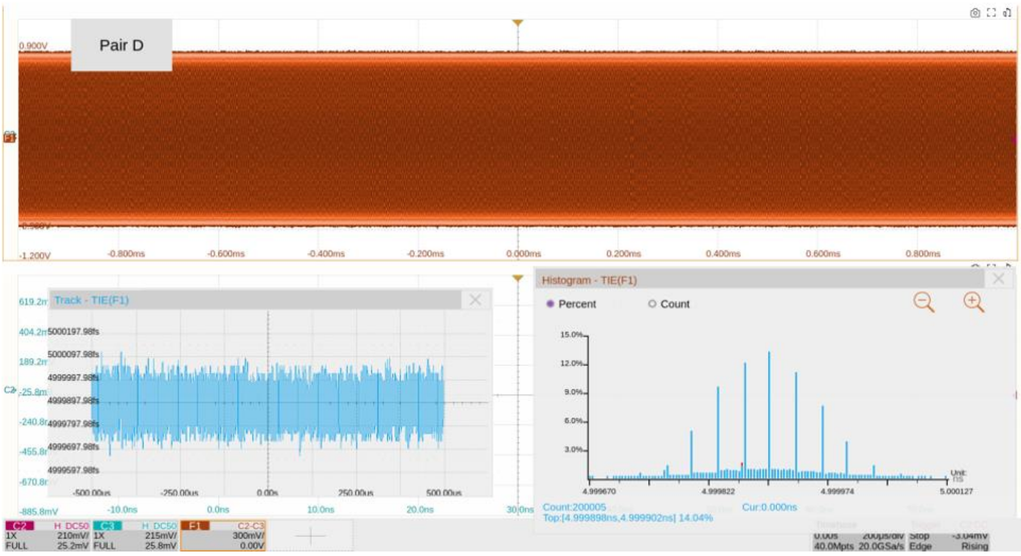


Figure 8-16 Transmitter Timing Jitter – Slave Test Result

About SIGLENT

SIGLENT is an international high-tech company, concentrating on R&D, sales, production and services of electronic test & measurement instruments.

SIGLENT first began developing digital oscilloscopes independently in 2002. After more than a decade of continuous development, SIGLENT has extended its product line to include digital oscilloscopes, isolated handheld oscilloscopes, function/arbitrary waveform generators, RF/MW signal generators, spectrum analyzers, vector network analyzers, digital multimeters, DC power supplies, electronic loads and other general purpose test instrumentation. Since its first oscilloscope was launched in 2005, SIGLENT has become the fastest growing manufacturer of digital oscilloscopes. We firmly believe that today SIGLENT is the best value in electronic test & measurement.

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