



NBASE-T and IEEE802.3bz Ethernet Testing

7 MARCH 2016



Agenda

- Market Drivers for 2.5G/5G Ethernet Data Rates
- 2.5G/5G Ethernet Transmitter Test Challenges and Solutions
- Testing Approach for 2.5G/5G Data Rates
- Information/Resources Available



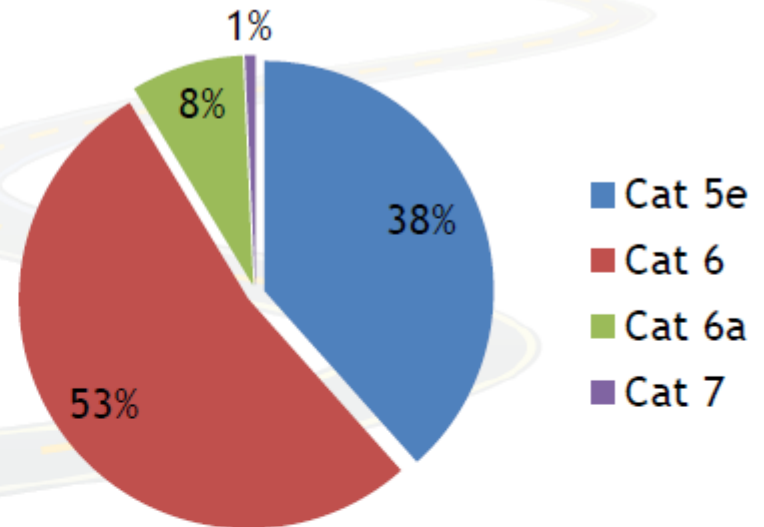
Market Drivers



Enterprise Access Links Today

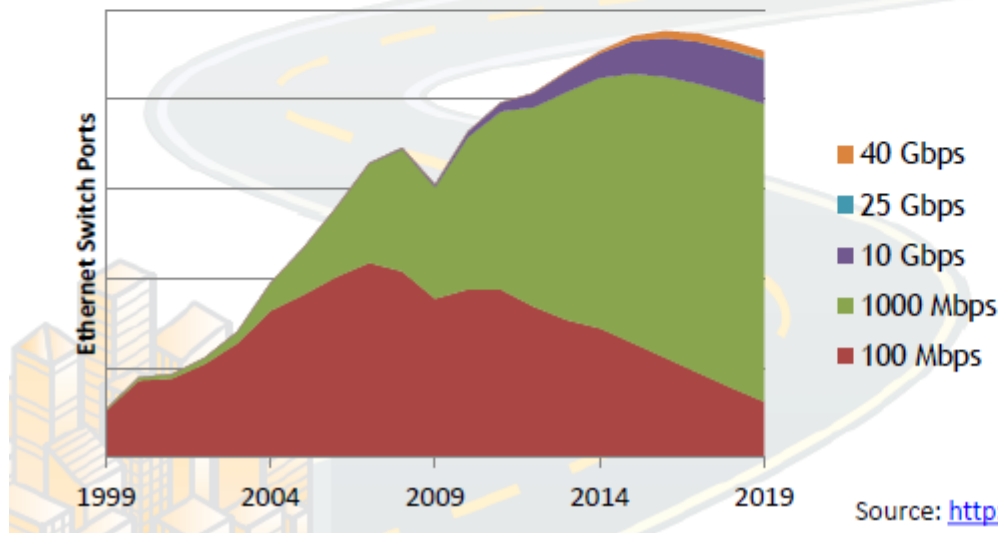
World wide BASE-T cabling is dominated by Cat 5e & Cat 6.

Based on cable sales data, average drop lengths and replacement rates
Source: BSRIA December 14



Ethernet Switch Ports by Speed

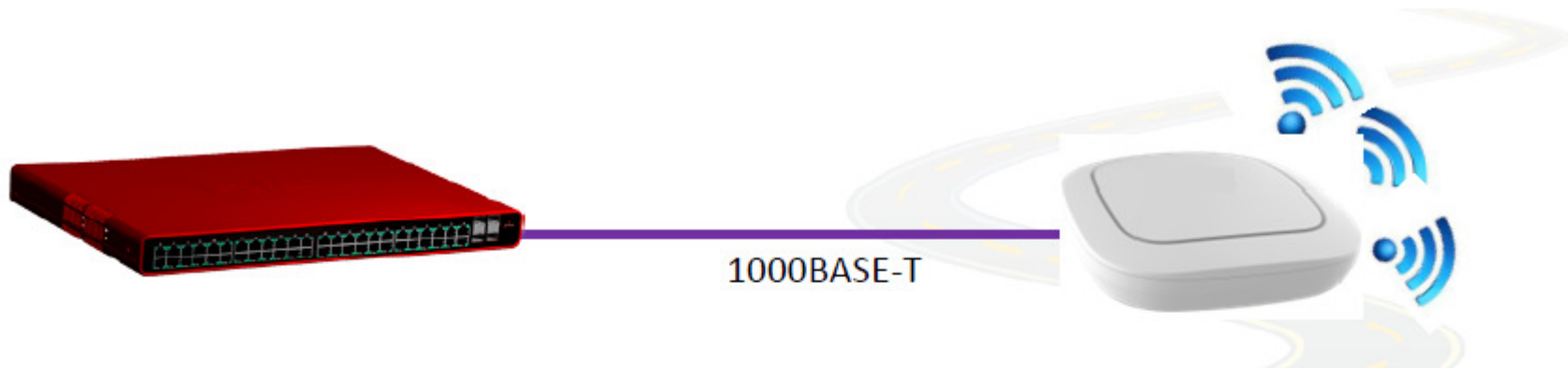
Dell'Oro Group Ethernet Switch 5-year Forecast Jan 2015



Enterprise Access port types are dominated by 1000BASE-T

Source: http://www.ieee802.org/3/NGEBASET/public/jan15/jones_ngeabt_04c_0115.pdf

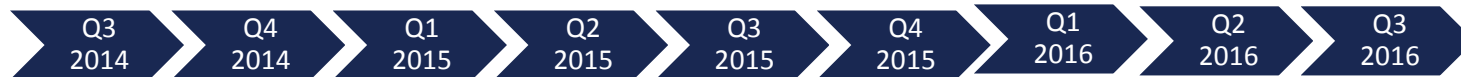
802.3 Ethernet and 802.11 Wireless LAN



The 1Gbps Bottleneck

- Wireless access points driven by IEEE802.11ac Wave1 and Wave2 aggregate bandwidth now greater than 1Gbps
- 90% of installed enterprise access links use Cat5e or Cat6 cabling limiting wired runs to 1GBASE-T
- Upgrading cable to Cat6a (or better) built to 10GBASE-T standards is cost prohibitive
 - \$200 - \$800 per cable run can cost an established campus \$100,000s to upgrade cable

Getting to a 2.5G/5G IEEE Standard



MGBASE-T Alliance

● Alliance Formed

NBASE-T

● Alliance Formed
 ● V1.0 of Specification Released
 ● V 1.1 of Specification Released

Tektronix Supports the NBASE-T Specification and the Emerging IEEE802.3bz standard

IEEE802.3bz

● PAR Approved
 ● 1st Draft of Specification

● Standard Ratification

IEEE 802.3bz Task Force has agreed to baseline proposals for 2.5G/5GBASE-T standard, consistent with the NBASE-T PHY specification

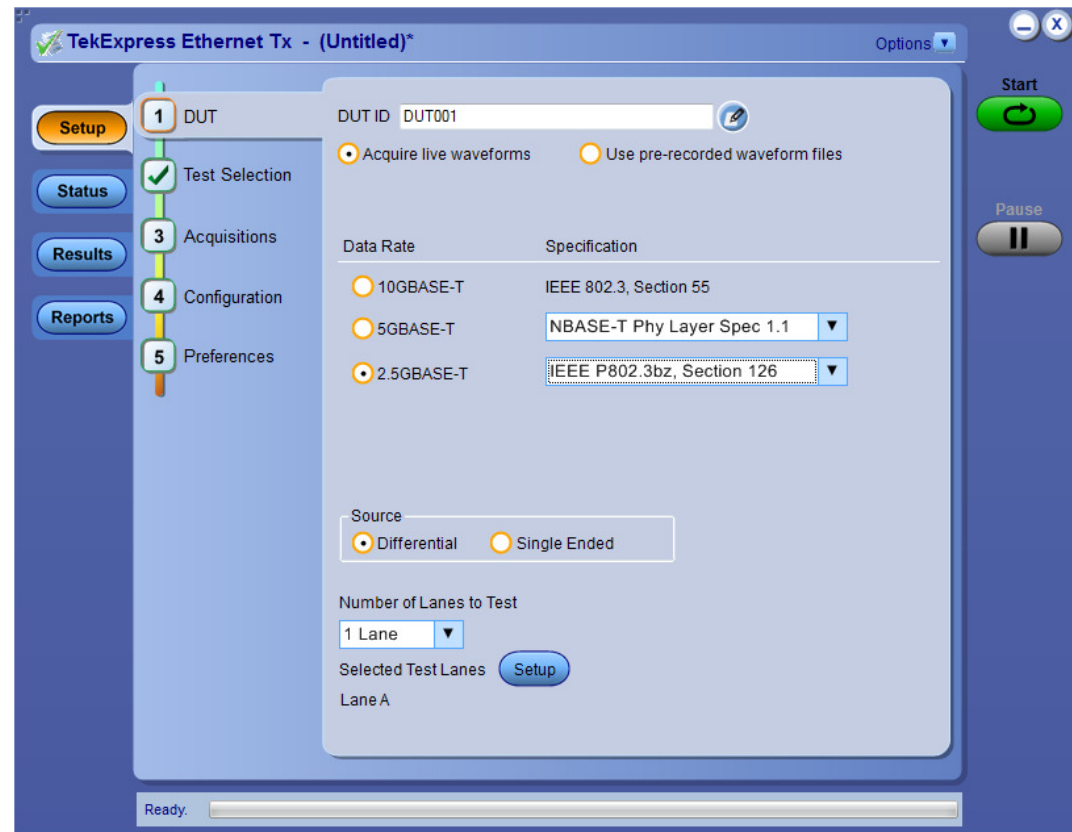


2.5G/5G Ethernet Testing Challenges

- Multiple Specifications/Standards
- Most DUTs need to be tested at multiple data rates(100M/1G/2.5G/5G/10G)
- Multiple measurements need to be performed including spectral measurements
- Test Fixture needed for repeatable and reliable measurements
- Electrical requirements and test procedures are extensions of those defined for 10GBASE-T
- NBASE-T specifications follow the text in section 55.5 of IEEE 802.3-2012 with some minimal changes

Introducing TekExpress for Ethernet Tx

- TekExpress Automation for Ethernet Tx Compliance with unique features including:
 - ✓ Single application supports: 2.5G, 5G, and 10G data rates
 - ✓ Single application supports NBASE-T specification, IEEE802.3bz standard, and 10GBASE-TsStandard
 - ✓ Tests multiple lanes
 - ✓ Automates scope setup
 - ✓ Acquires the data
 - ✓ Provides custom reporting





Automation Simplifies Tx Testing

- While convenient single capture capability is essential, automation makes the testing practical
- Iterate over multiple tests and lanes
- Gather results in a single report

TekExpress for Ethernet Tx - Setup

The screenshot shows the TekExpress Ethernet Tx Setup window. The interface includes a sidebar with navigation buttons: Setup, Status, Results, and Reports. A vertical progress indicator shows five steps: 1 DUT, 2 Test Selection, 3 Acquisitions, 4 Configuration, and 5 Preferences. The main area is divided into several sections:

- DUT ID:** DUT001
- Acquisition Mode:** Acquire live waveforms, Use pre-recorded waveform files
- Data Rate and Specification:**

Data Rate	Specification
<input type="radio"/> 10GBASE-T	IEEE 802.3, Section 55
<input type="radio"/> 5GBASE-T	NBASE-T Phy Layer Spec 1.1
<input checked="" type="radio"/> 2.5GBASE-T	IEEE P802.3bz, Section 126
- Source:** Differential, Single Ended
- Number of Lanes to Test:** 1 Lane
- Selected Test Lanes:** Lane A

On the right side, there are Start and Pause buttons. Four callout boxes point to specific features:

- Run Analysis on Live or Pre-Recorded Data:** Points to the Start button.
- Data rate/ specification selection:** Points to the Data Rate and Specification section.
- Supports Differential or Single-Ended Probes:** Points to the Source section.
- Lane Selection and Setup:** Points to the Number of Lanes to Test and Selected Test Lanes section.

TekExpress for Ethernet Tx – Test

The screenshot shows the TekExpress Ethernet Tx software interface. The main window title is "TekExpress Ethernet Tx - (Untitled)*". On the left, there is a vertical navigation bar with buttons for "Setup", "Status", "Results", and "Reports". A vertical progress indicator shows five steps: 1. DUT, 2. Test Selection (highlighted), 3. Acquisitions, 4. Configuration, and 5. Preferences. The main area displays "Ethernet Tx : 2.5GBASE-T : IEEE P802.3bz, Section 126" with "Deselect All" and "Select All" buttons. A list of test items is shown, all with checked boxes: "2.5GBASE-T Measurements", "Maximum Output Droop", "Power Spectrum Density", "Linearity", "Tone-1", "Tone-2", "Tone-3", "Tone-4", "Tone-5", "Clock Frequency", "Jitter Master", "Jitter Slave", and "Return Loss". Below the list is a "Test Description" section with a text area and a "Schematic" button. On the right side of the interface, there are "Start" and "Pause" buttons. A red box highlights the test selection area, and a blue box labeled "Test Selection" is connected to the "Start" button by a line.

Test Selection

Transmitter Measurements

Measurement	Purpose	10GBASE-T Standard Reference
Maximum Output Droop	Verify that the transmitter output level does not decay faster than the maximum specified rate.	IEEE 802.3-2012 Subclause 55.5.3.1
Transmit Linearity	Verify that the output of the transmitter conforms to the transmitter linearity limits.	IEEE 802.3-2012 Subclause 55.5.3.2
Transmit Timing Jitter – MASTER	Verify that the transmitter timing jitter of the PMA is within the conformance limits.	IEEE 802.3-2012 Subclause 55.5.3.3
Transmit Timing Jitter – SLAVE	Verify that the transmitter timing jitter of the PMA is within the conformance limits.	IEEE 802.3-2012 Subclause 55.5.3.3
Transmit Power Spectral Density (PSD) and Power Level	Verify the transmitter power level and power spectral density are within the conformance limits	IEEE 802.3-2012 Subclause 55.5.3.14
Transmit Clock Frequency	Verify the frequency of the Transmit Clock is within the conformance limits.	IEEE 802.3-2012 Subclause 55.5.3.5
MDI Return Loss	Measure the return loss at the MDI for all four channels to ensure it is within conformance limits	IEEE 802.3-2012 Subclause 55.8.2.1

TekExpress for Ethernet Tx – Reports

TekExpress Ethernet Tx - (GoldenSession-10G)*

Overall Test Result ✔ Pass

Options v Preferences v

Start ↻

Pause ⏸

Clear ✕

Test Name	Pass/Fail	Value	Margin	Units
[-] Lane A	✔ Pass			
[-] Maximum Output Droop	✔ Pass	0.9277174	L:0.9277 H:9.0723	%
High Limit	✔ Pass	10		
Low Limit	✔ Pass	0		
[-] Maximum Output Droop	✔ Pass	1.0277930	L:1.0278 H:8.9722	%
High Limit	✔ Pass	10		
Low Limit	✔ Pass	0		
[-] Tone-1	✔ Pass	63.0336501	L:8.5337	dBm
High Limit	N.A	N.A		
Low Limit	✔ Pass	54.5		
[+] Tone-2	✔ Pass	61.6429975	L:11.3430	dBm
[-] Tone-3	✔ Pass	61.8778672	L:16.4779	dBm
High Limit	N.A	N.A		
Low Limit	✔ Pass	45.4		
[-] Tone-4	✔ Pass	59.3263199	L:17.7263	dBm
High Limit	N.A	N.A		
Low Limit	✔ Pass	41.6		
[-] Tone-5	✔ Pass	57.1828344	L:18.6828	dBm
High Limit	N.A	N.A		

Completed.

TekExpress for Ethernet Tx – Reports

Tektronix TekExpress Ethernet Tx
10GBASE-T Test Report

Setup Information			
DUT ID	DUT001	Scope Information	DSA73304D, Q100001
Date/Time	2016-02-11 13:53:14	SPC, FactoryCalibration	PASS;PASS
Device Type	Ethernet Tx	Scope F/W Version	7.1.3 Build 1
TekExpress Ethernet Tx Version	0.0.0.60	Probe1 Information	N.A, N.A
TekExpress Framework Version	4.0.4.224	Probe2 Information	N.A, N.A
Execution Mode	Pre-Recorded	Probe3 Information	N.A, N.A
Probing Type	Single-Ended	Probe4 Information	N.A, N.A
Compliance Mode	True		
Overall Test Result	Pass		
Overall Execution Time	0:01:14		
DUT COMMENT:	General comment		

Maximum Output Droop									
Measurement Details	Lane	Iteration	Measured Value	Test Result	Margin	Low Limit	High Limit	Units	Comments
Droop Positive	Lane A	1	0.9277174	Pass	L:0.9277 H:9.0723	0	10	%	Max: 1.6476 Min: 0.1241
Droop Negative	Lane A	1	1.0277930	Pass	L:1.0278 H:8.9722	0	10	%	Max: 1.6545 Min: 0.2289
COMMENTS	Droop Pulse Count: 500Droop Pulse Count: 500								

[Back to Summary Tab](#)

Tone-1									
Measurement Details	Lane	Iteration	Measured Value	Test Result	Margin	Low Limit	High Limit	Units	Comments
Linearity Tone-1	Lane A	1	63.0336501	Pass	L:8.5337	54.5	N.A	dBm	IMD: 0.21% TF1: 36.72 MHz TF2: 41.41 MHz IMF: 17.97 MHz
COMMENTS									

[Back to Summary Tab](#)

Tone-2									
Measurement Details	Lane	Iteration	Measured Value	Test Result	Margin	Low Limit	High Limit	Units	Comments
Linearity Tone-2	Lane A	1	61.6429975	Pass	L:11.3430	50.3	N.A	dBm	IMD: 0.23% TF1: 78.90 MHz TF2: 80.47 MHz IMF: 238.28 MHz
COMMENTS									



2.5G/5G Ethernet Test Equipment Overview

- Scopes
 - MSO/DPO70000C
 - MSO/DPO70000DX
 - DPO7354C
 - DPO7254C (only 2.5G/5G data rates)
- Option NBASE-T for 2.5G/5G data rates
 - Supports NBASE-T and IEEE802.3bz
- Option XGBT2 for 10GBASE-T
- Test Fixture
 - TF-XGbT
- Probes
 - Resistance > 10 K ohm and capacitance < 1 pF over the frequency range of (1 MHz to 400 MHz)×S
- AWG7012 (For Return Loss Testing)

Value Proposition & Differentiation

Test Challenge	Tektronix Advantage	Customer Benefits
Long list of required tests	Fully automated TekExpress test solution	Test efficiency, automation capability, and a simple to use solution for the wide range of measurements required
Probing the device under test	Variety of connections methods supported	Option to choose between cost effective SMA cables or scope oscilloscope probes
Need to test 4 lanes	Multiple Lane testing supported	Connections can be made once and all tests can be performed without requiring any new connections.
Cost of Return Loss Testing	Does not require a VNA to do return loss measurements	Lower cost as oscilloscope can be used to perform both time and frequency-domain measurements
Measuring margin beyond compliance	Flexible parameter and limits in user-defined mode	Easily determine how much design margin the system has





Links

- NBASE-T Alliance Website: <http://www.nbase-t.org/>
- Fundamentals of NBASE-T Video: <http://www.nbase-t.org/fundamentals-of-nbase-t/>

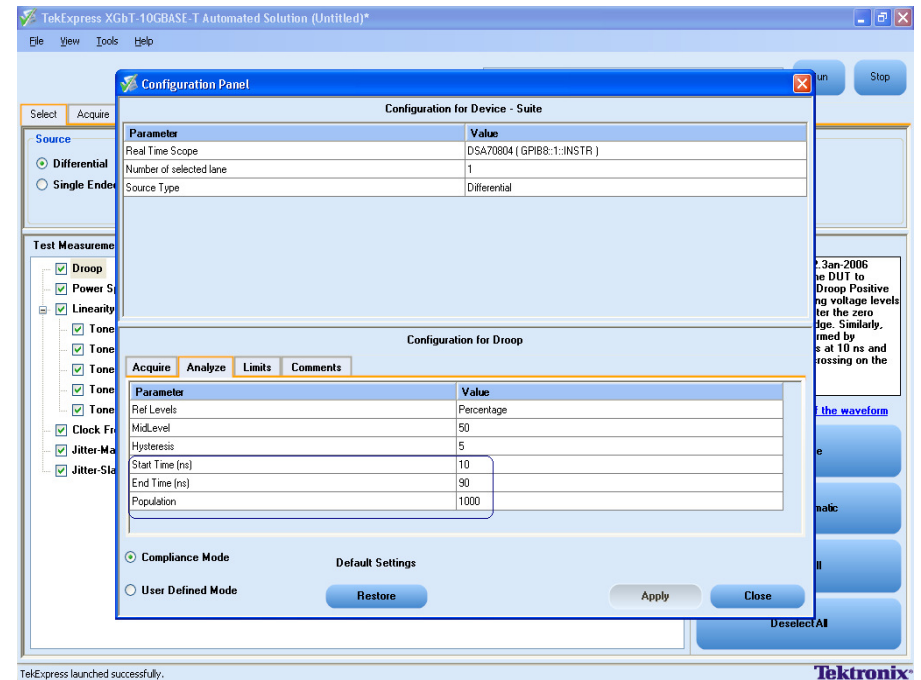


Measurement Details



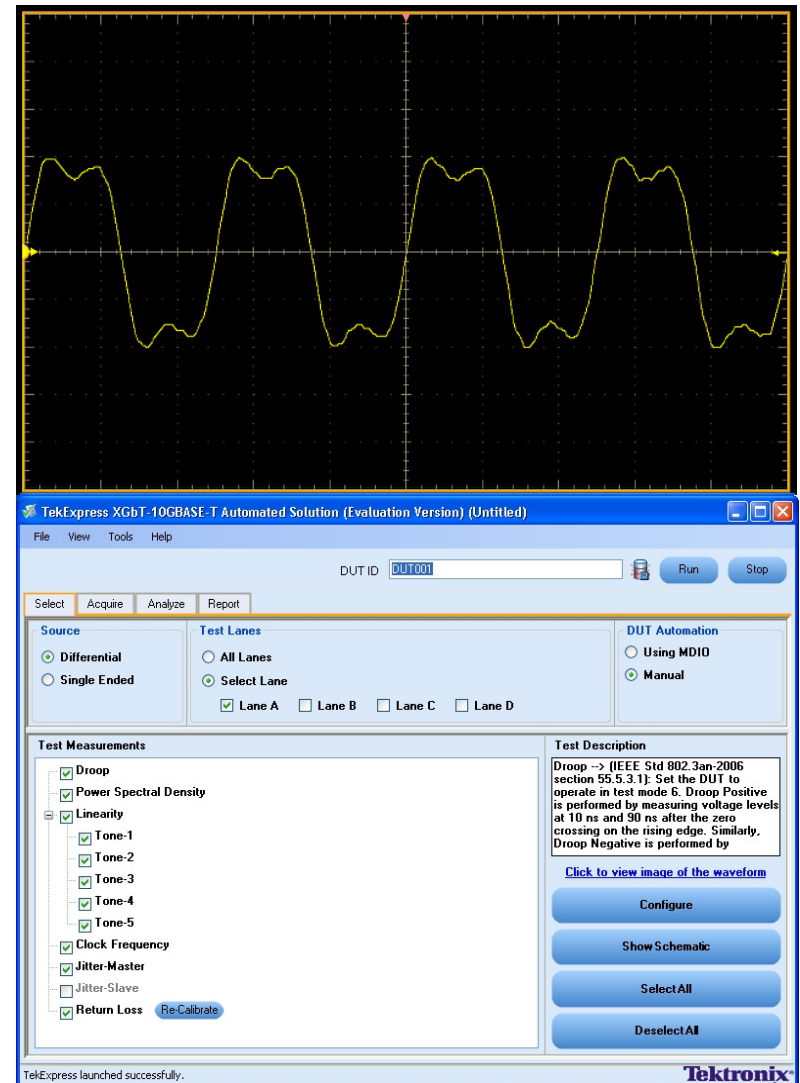
Maximum Output Droop

- **Purpose** - To verify that the transmitter output level does not decay faster than the maximum specified rate.
- The resulting magnitude of both the positive and negative droop shall be less than 10%.
- Flexibility to test beyond compliance – provides the flexibility to perform testing beyond what is specified in standard. It helps users to analyze their PHY in addition to compliance tests.
- Configure the DUT for Test Mode 6 operation



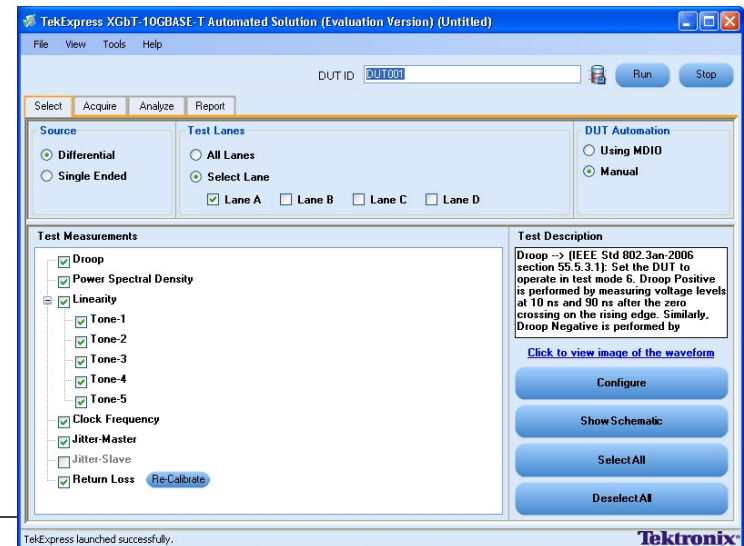
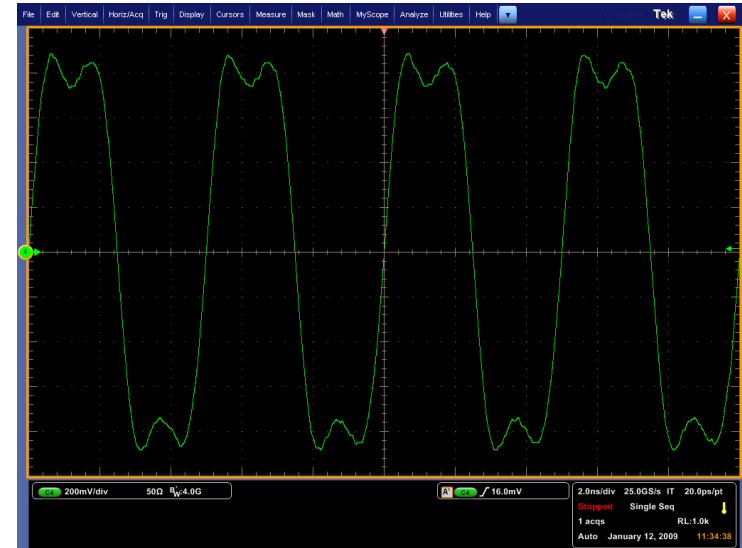
Transmitter Clock Frequency

- **Purpose** - To verify the frequency of the Transmit Clock is within the conformance limits.
- Configure the DUT for Test Mode 2 operation
- Exact PPM value for measured clock frequency is shown



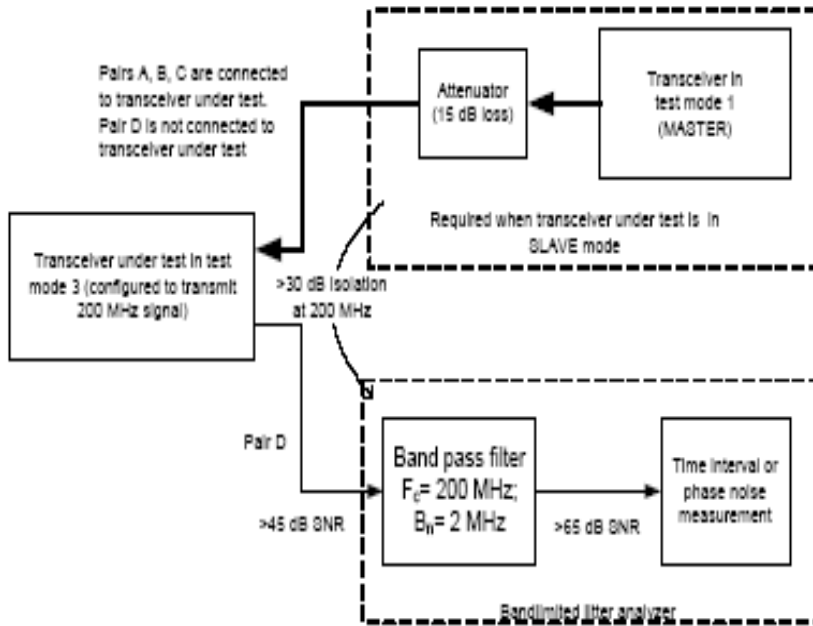
Transmitter Timing Jitter – Master & Slave

- **Purpose** - To verify that the transmitter timing jitter of the PMA is within the conformance limits.
- Configure the DUT for Test Mode 2 operation
- An appropriate software filter available on each oscilloscope is applied to the input waveform.



Transmitter Timing Jitter – Master & Slave

...



The screenshot shows the TekExpress XGbT-10GBASE-T Automated Solution interface. A window titled "JitterSlaveSchematic.pdf - Adobe Reader" is open, displaying a schematic diagram of a "Jitter Slave - SMA Probe (Differential)".

The schematic shows a DUT (Device Under Test) connected to a Slave transceiver, which is connected to a Test Fixture. The Test Fixture is connected to a 10GBASE-T Unit acting as a Master. The Slave transceiver is connected to a Digital Oscilloscope via a PT380 SMA probe. The oscilloscope is configured to measure jitter on Ch1 and Ch2.

The software interface includes a "Test Measurements" panel with the following settings:

- Droop
- Power Spect
- Linearity
- Tone-1
- Tone-2
- Tone-3
- Tone-4
- Tone-5
- Clock Freq
- Jitter-Master
- Jitter-Slave

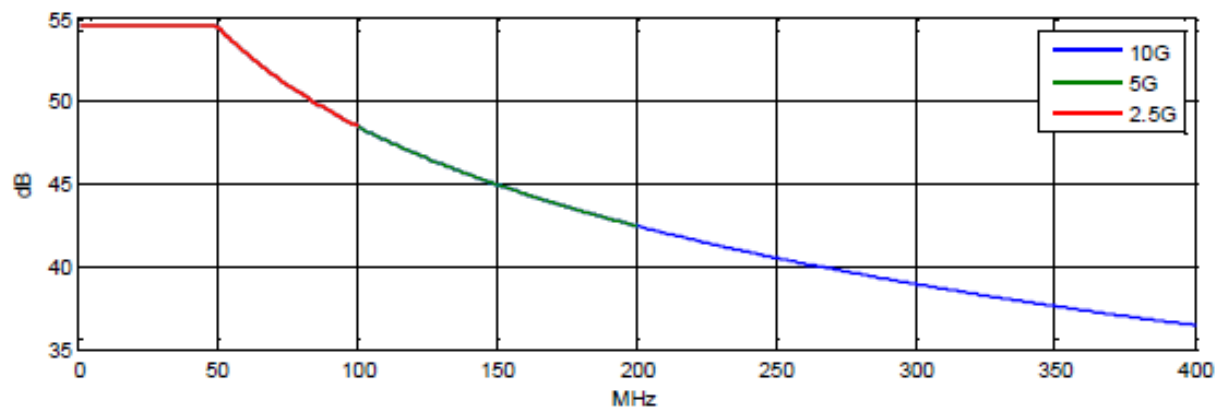
At the bottom right of the schematic window, there is a note: "802.3an-2006 IT supporting MASTER DUT is the SLAVE DUT transmitter Timing in square of the period jitter input should not".

The TekExpress interface also shows a "Source" panel with "Differential" selected and "Single Ended" unselected. The "TekExpress launched successfully." message is visible at the bottom.

Transmitter Linearity

- **Purpose** : To verify that the output of the transmitter conforms to the transmitter linearity limits.
- Measured on all four lanes: A, B, C & D
- While in Test Mode 4, the SFDR of the transmitter when subject to dual tone inputs producing output peak-to-peak transmit amplitude shall meet the specification
- Frequency scaling is performed to keep the minimum SFDR as in 10GBASE-T but over the relevant frequency range.

$$\text{SFDR} > 2.5 + \min\{52, 58 - 20 \times \log_{10}(f/25)\} \text{ dB}$$



Transmitter Power Spectral Density (PSD) and Power Level

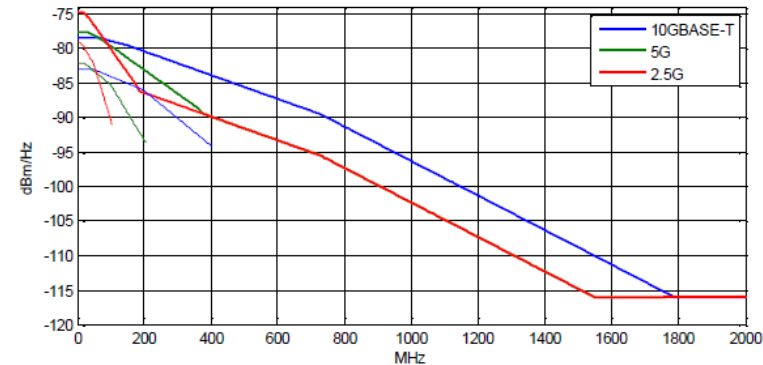
- **Purpose** : To verify the transmitter power level and power spectral density are within the conformance limits.
- Measured on all four lanes: A, B, C & D
- Total transmit power: 1.0 to 3.0 dBm. This is 2.2 dB below 10GBASE-T bounds to limit emission on CAT5e while still allows reasonable SNR



Media Dependent Interface (MDI) Return Loss

- For reliable signal transmission, the DUT must adhere to a return loss limit curve
- In-band PSD limits are similar to the 10GBASET-T mask but scaled in frequency according to the baud-rate

Figure 5: NBASE-T Tx PSD



$$P_u(f) = \begin{cases} -80.7 - 10 \times \log_{10}(S) \frac{\text{dBm}}{\text{Hz}} & 0 < \frac{f}{S} \leq 70 \\ -80.7 - 10 \times \log_{10}(S) - \left(\frac{f}{S} - 70\right) \frac{\text{dBm}}{\text{Hz}} & 70 < \frac{f}{S} \leq 150 \\ -81.7 - 10 \times \log_{10}(S) - \left(\frac{f}{S} - 150\right) \frac{\text{dBm}}{\text{Hz}} & 150 < \frac{f}{S} \leq 730 \\ -81.7 - 10 \times \log_{10}(S) - \left(\frac{f}{S} - 330\right) \frac{\text{dBm}}{\text{Hz}} & 730 < \frac{f}{S} \leq 1790 - 400 \times \log_{10}(S) \\ -116 \frac{\text{dBm}}{\text{Hz}} & 1790 - 400 \times \log_{10}(S) < \frac{f}{S} \leq 3000 \end{cases}$$

$$\text{Upper PSD}(f) = \text{Max}(P_u(f), \text{Upper PSD}_{10\text{GBASE-T}}(f) - 6)$$

$$\text{Lower PSD}(f) = \begin{cases} -85.2 - 10 \times \log_{10}(S) \frac{\text{dBm}}{\text{Hz}} & 5 < f \leq 50 \times S \\ -85.2 - 10 \times \log_{10}(S) - \left(\frac{f}{S} - 50\right) \frac{\text{dBm}}{\text{Hz}} & 50 < \frac{f}{S} \leq 200 \\ -88.2 - 10 \times \log_{10}(S) - \left(\frac{f}{S} - 200\right) \frac{\text{dBm}}{\text{Hz}} & 200 < \frac{f}{S} \leq 400 \end{cases}$$