Tektronix

NBASE-T and IEEE802.3bz Ethernet Testing

7 MARCH 2016

Agenda

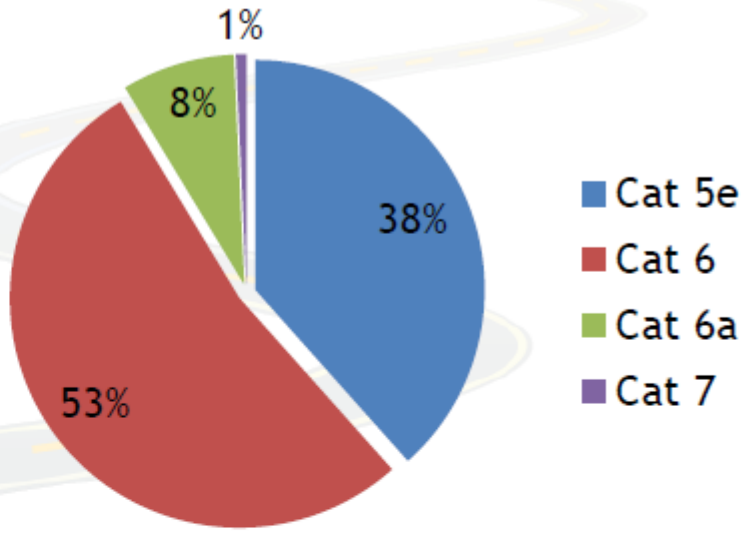
- Market Drivers for 2.5G/5G Ethernet Data Rates
- 2.5G/5G Ethernet Transmitter Test Challenges and Solutions
- Testing Approach for 2.5G/5G Data Rates
- Information/Resources Available

Market Drivers

Enterprise Access Links Today

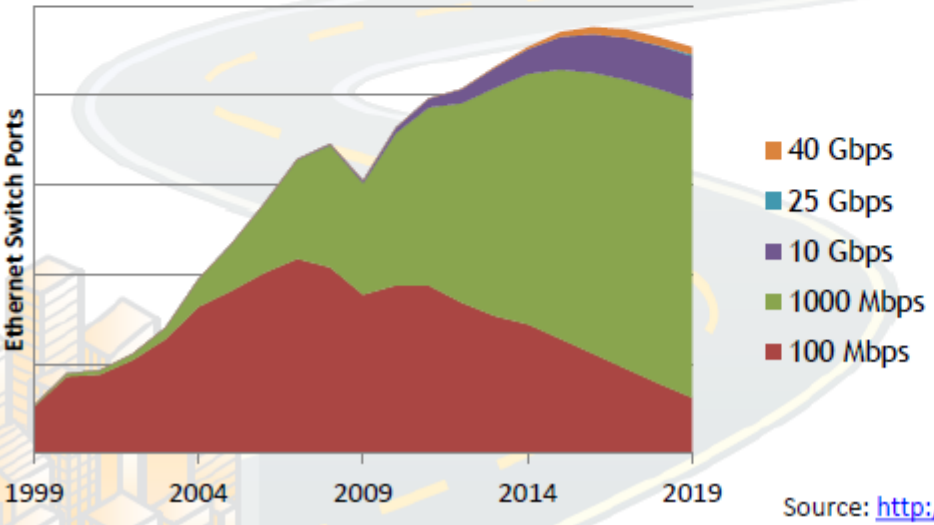
World wide BASE-T cabling is dominated by Cat 5e & Cat 6.

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



Ethernet Switch Ports by Speed

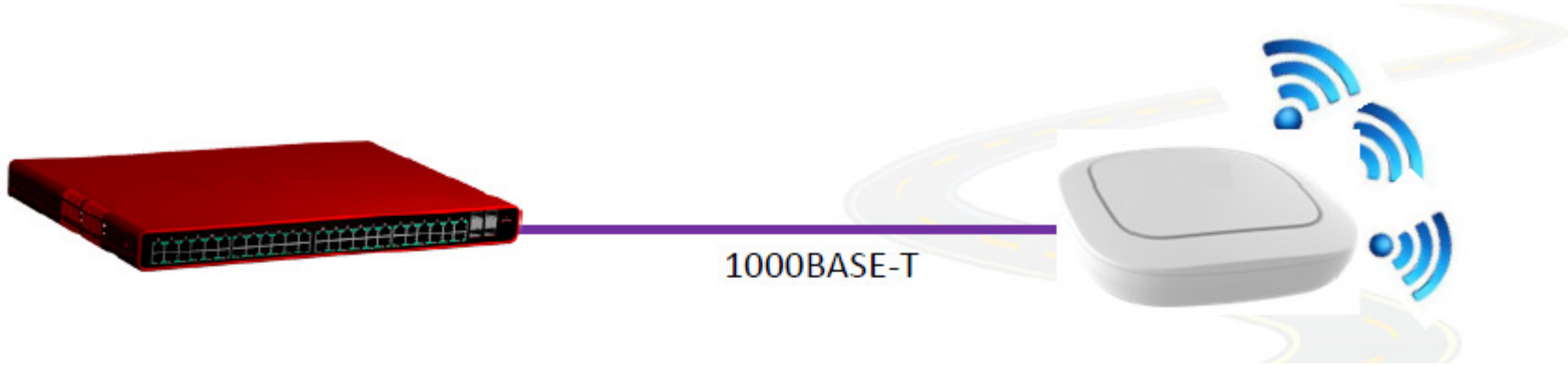
Dell'Oro Group Ethernet Switch 5-year Forecast Jan 2015



Enterprise Access port types are dominated by 1000BASE-T

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

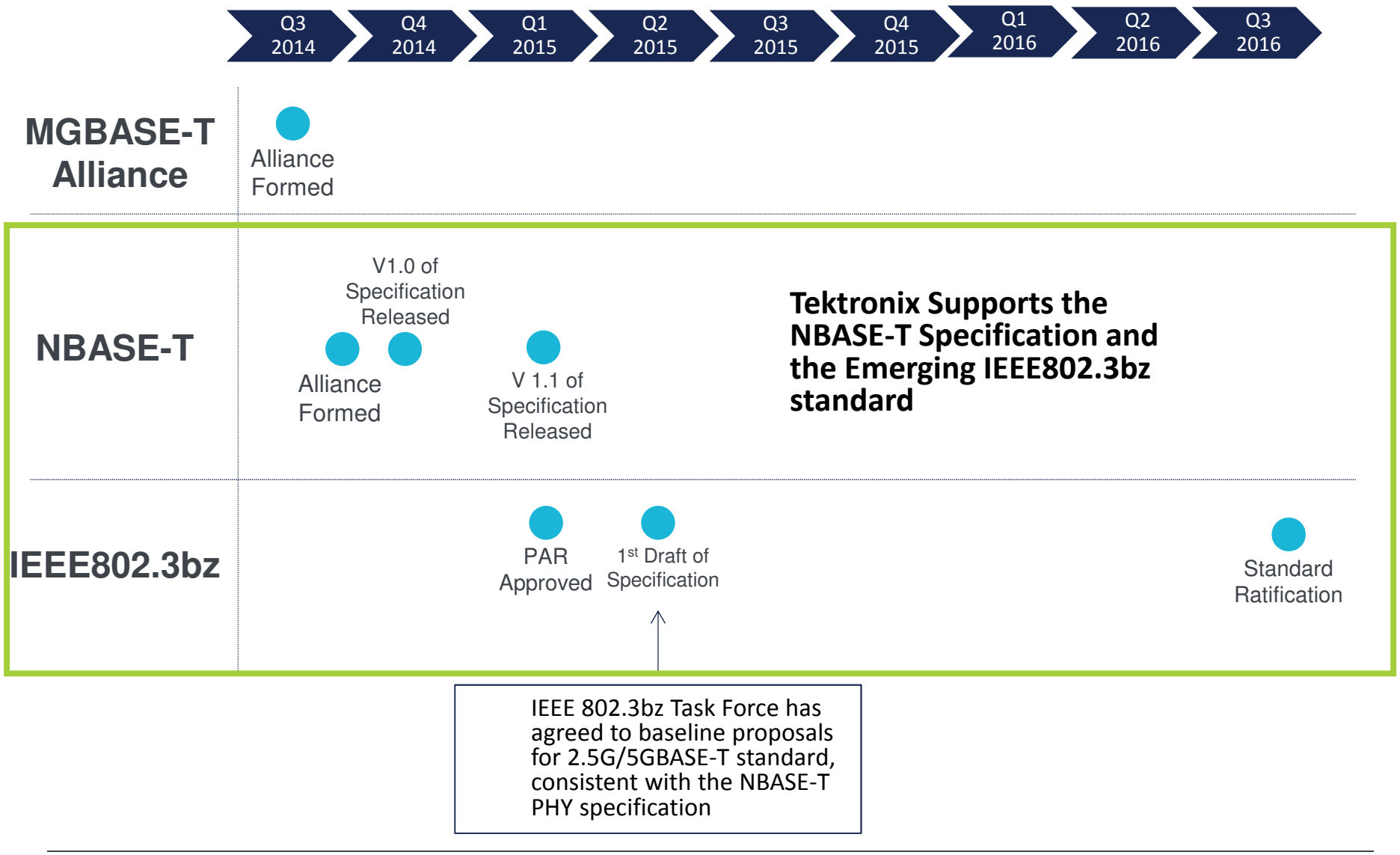
802.3 Ethernet and 802.11 Wireless LAN



The 1Gbps Bottleneck

- Wireless access points driven by IEE802.11ac 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

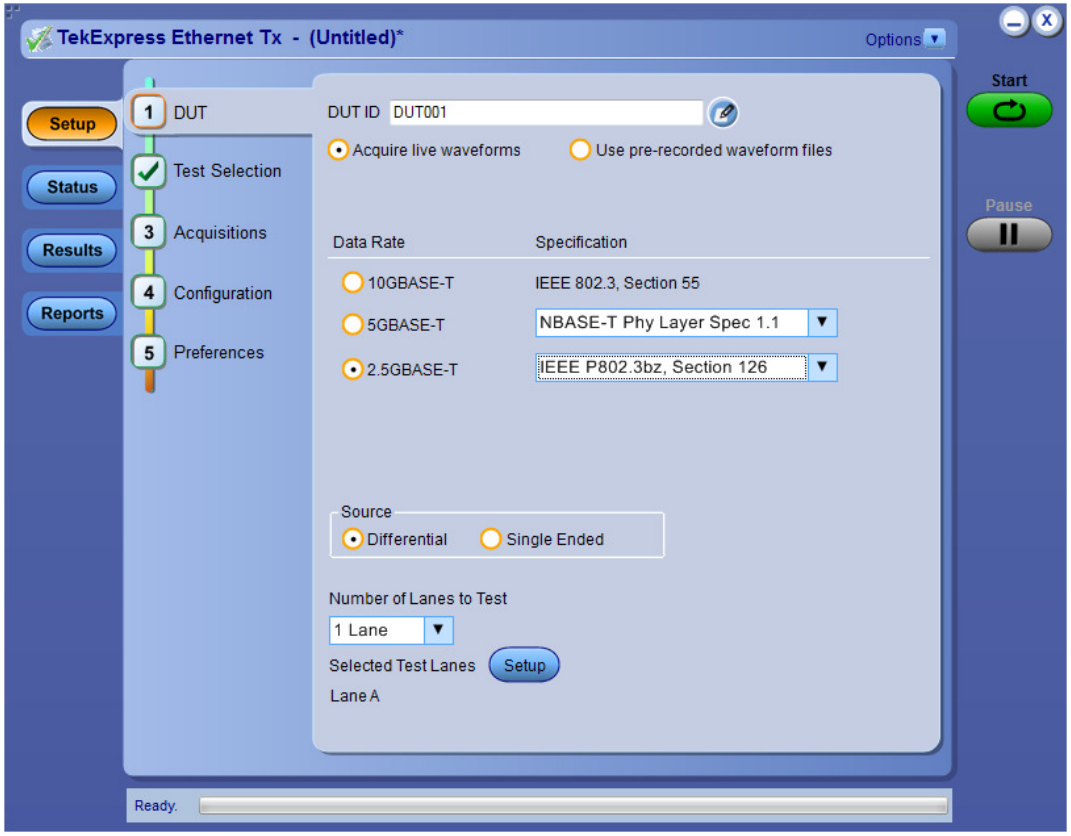


2.5G/5G Ethernet Testing Challenges

- 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

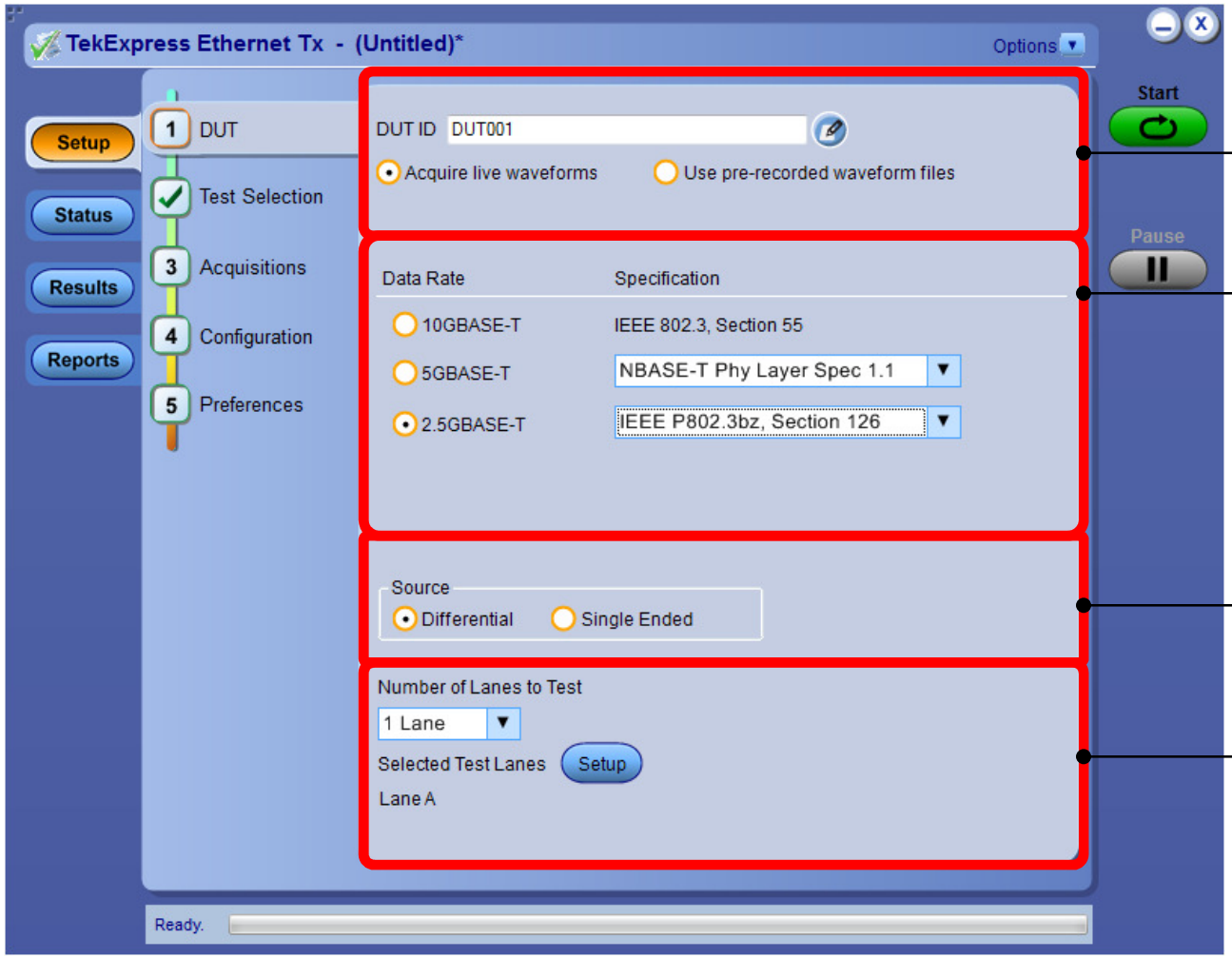
- TekExpress Automation for Ethernet Tx Compliance with unique features including:
  - √ Single application supports: 2.5G, 5G, and 10G data rates
  - √ Single application supports NBASE-T specification, IEEE802.3bz standard, and 10GBASE-TsStandard
  - √ Tests multiple lanes
  - √ Automates scope setup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



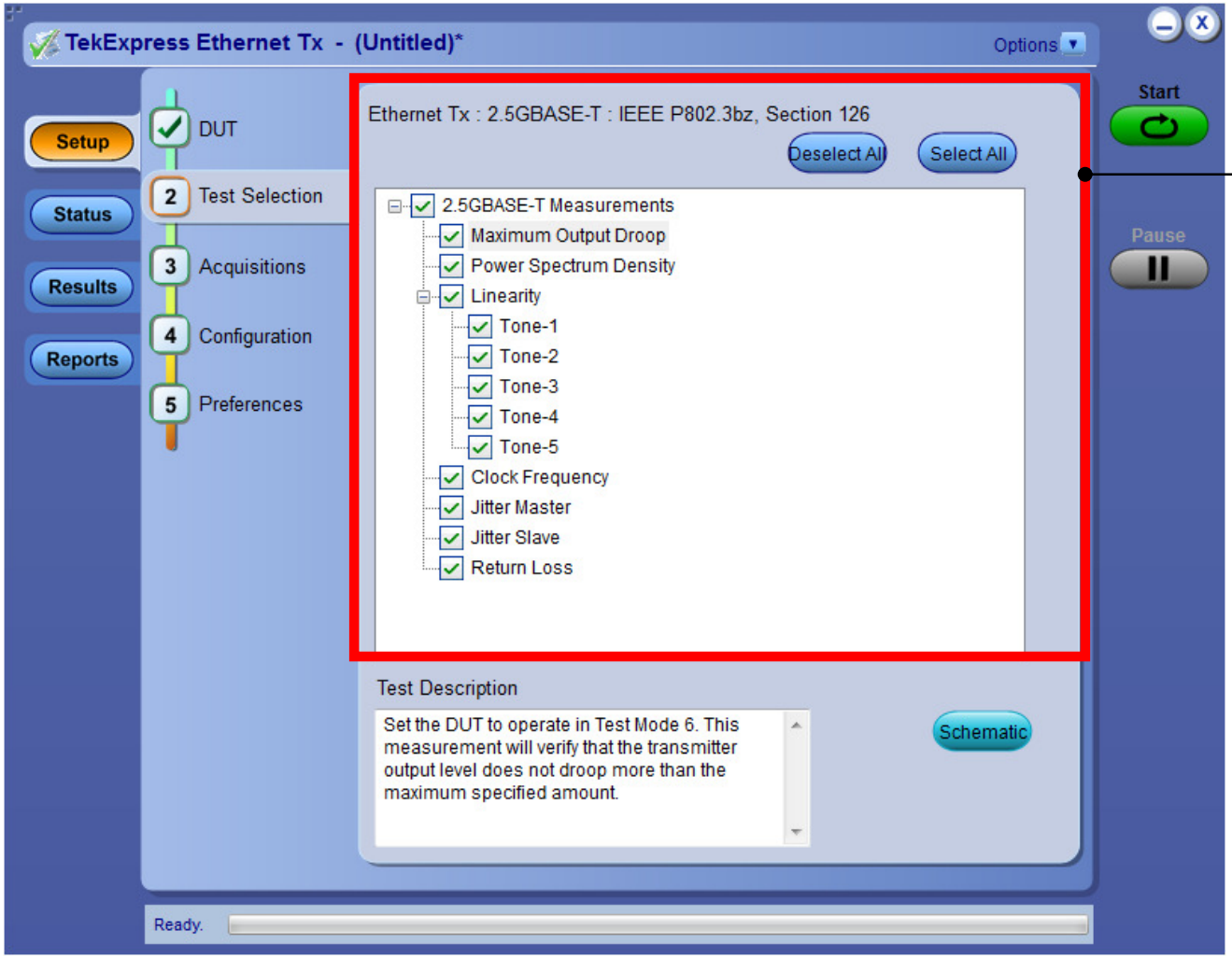
Run Analysis on Live or Pre-Recorded Data

Data rate/ specification selection

Supports Differential or Single-Ended Probes

Lane Selection and Setup

TekExpress for Ethernet Tx – Test

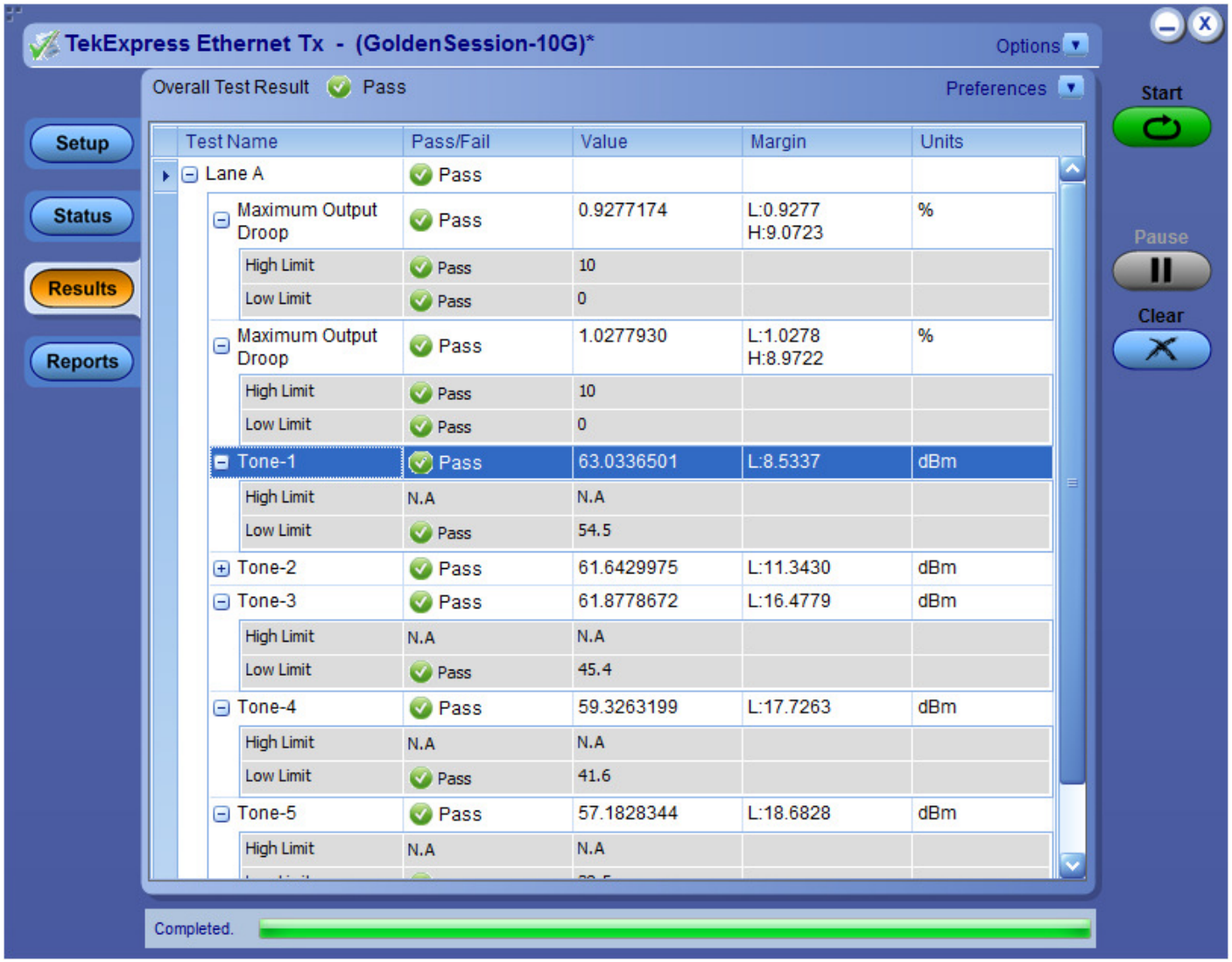


Test Selection

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 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								

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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									

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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

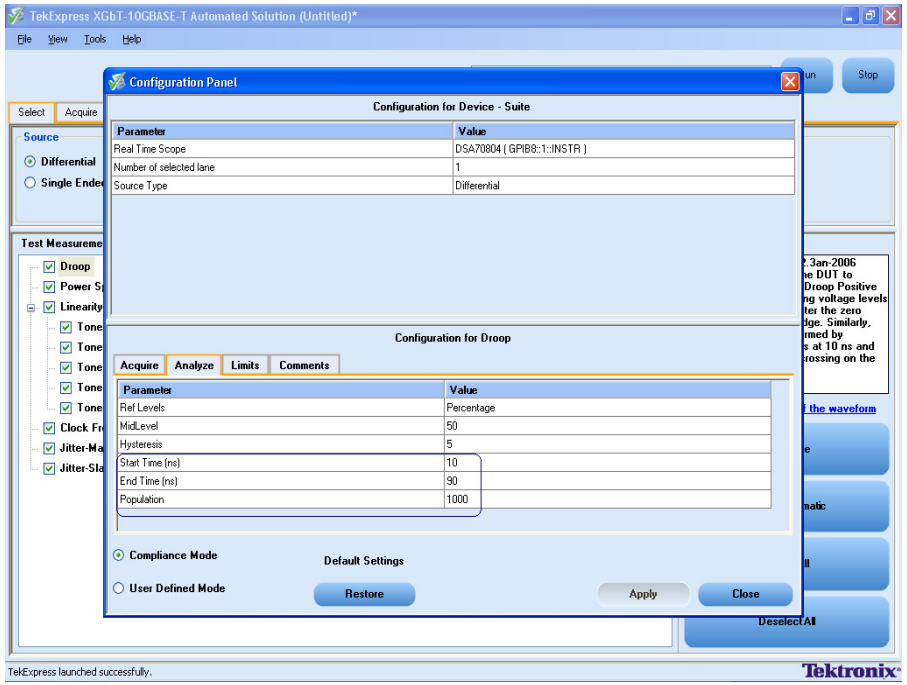
Links

- NBASE-T Alliance Website: http://www.nbaset.org/
- Fundamentals of NBASE-T Video: http://www.nbaset.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

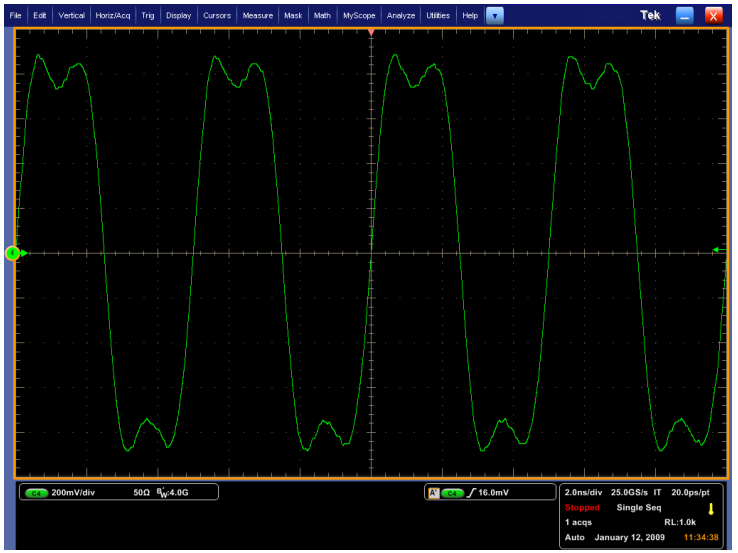


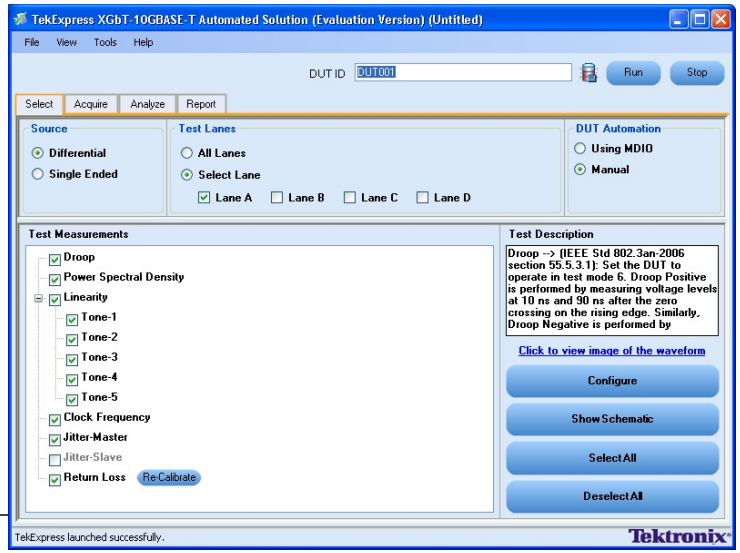
Transmitter Clock Frequency

- **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

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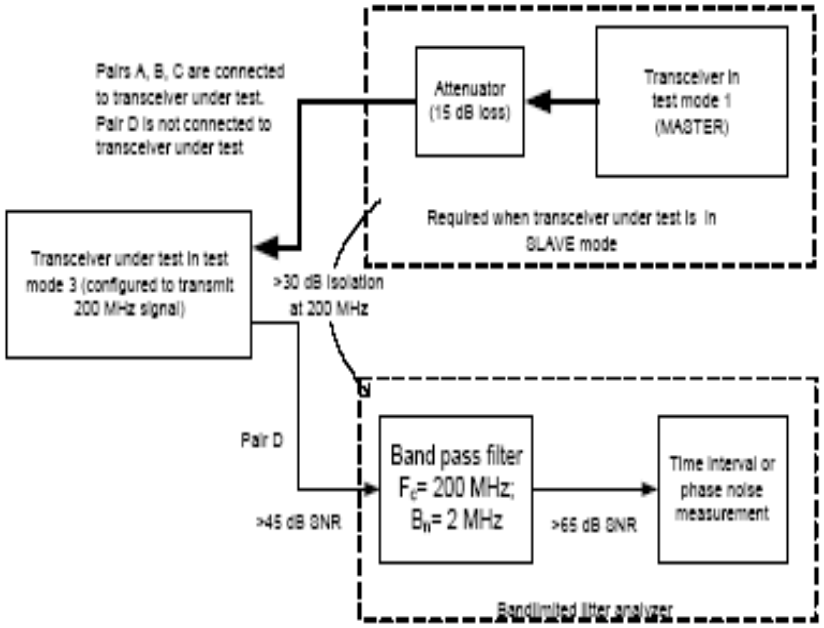
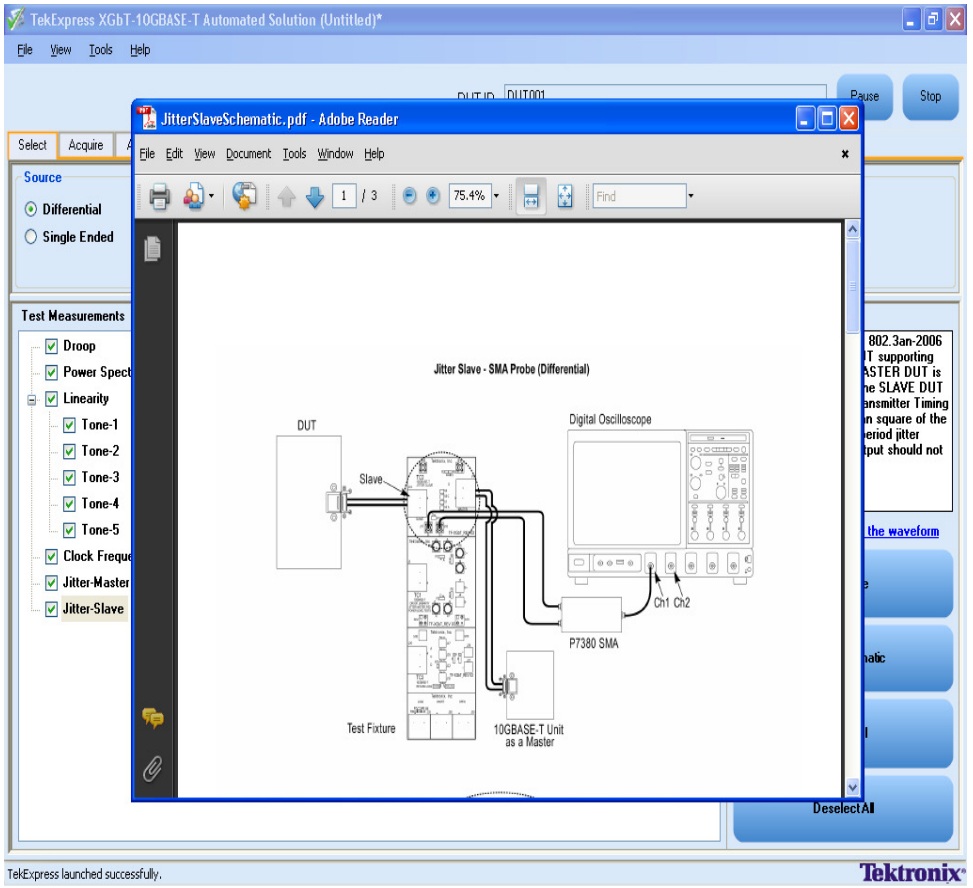
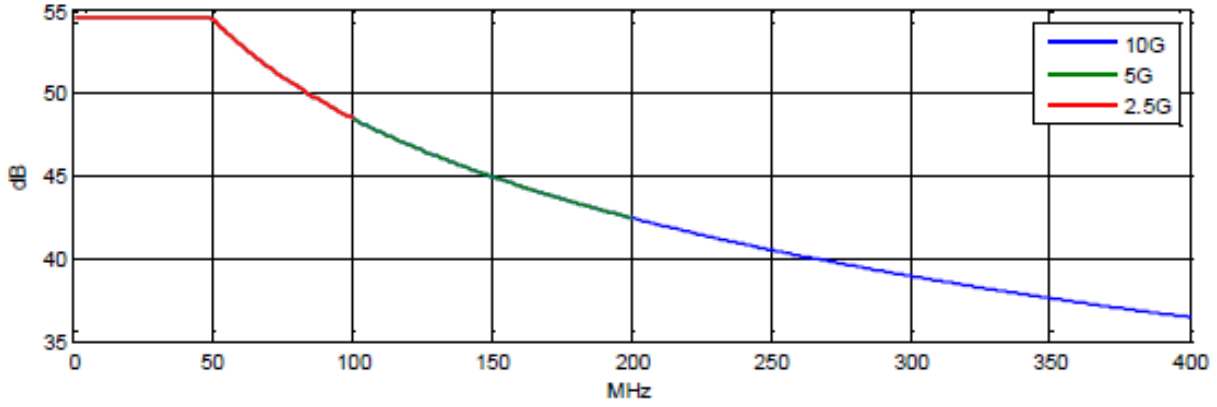




Transmitter Linearity

- **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.

$$SFDR > 2.5+\min\{52, 58-20\times\log10(f/25)\} \quad dB$$



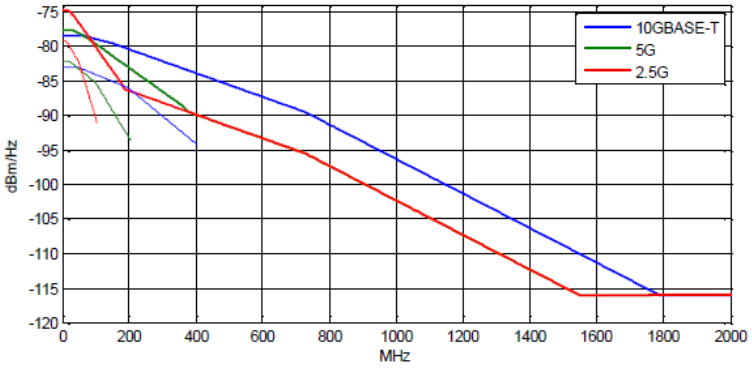
Transmitter Power Spectral Density (PSD) and Power Level

- **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



$$\text{Pu}(f) = \begin{cases} -80.7 - 10\times log_{10}(S)\ \frac{\text{dBm}}{\text{Hz}} & 0 < \frac{f}{S} \le 70 \\ -80.7 - 10\times log_{10}(S) - \left(\frac{\frac{f}{S}-70}{80}\right)\frac{\text{dBm}}{\text{Hz}} & 70 < \frac{f}{S} \le 150 \\ -81.7 - 10\times log_{10}(S) - \left(\frac{\frac{f}{S}-150}{58}\right)\frac{\text{dBm}}{\text{Hz}} & 150 < \frac{f}{S} \le 730 \\ -81.7 - 10\times log_{10}(S) - \left(\frac{\frac{f}{S}-330}{40}\right)\frac{\text{dBm}}{\text{Hz}} & 730 < \frac{f}{S} \le 1790 - 400\times log_{10}(S) \\ -116\ \frac{\text{dBm}}{\text{Hz}} & 1790 - 400\times log_{10}(S) < \frac{f}{S} \le 3000 \end{cases}$$

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

$$\text{Lower PSD}\,(f) = \begin{cases} -85.2 - 10\times log_{10}(S)\ \text{dBm/Hz} & 5 < f \le 50\times S \\ -85.2 - 10\times log_{10}(S) - \left(\frac{\frac{f}{S}-50}{50}\right)\ \text{dBm/Hz} & 50 < \frac{f}{S} \le 200 \\ -88.2 - 10\times log_{10}(S) - \left(\frac{\frac{f}{S}-200}{25}\right)\ \text{dBm/Hz} & 200 < \frac{f}{S} \le 400 \end{cases}$$