70th Anniversary

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2016太克科技

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70th Anniversary
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NBASE-T and IEEE802.3bz Technology and Transmitter Test Measurements

MIKE JULIANA

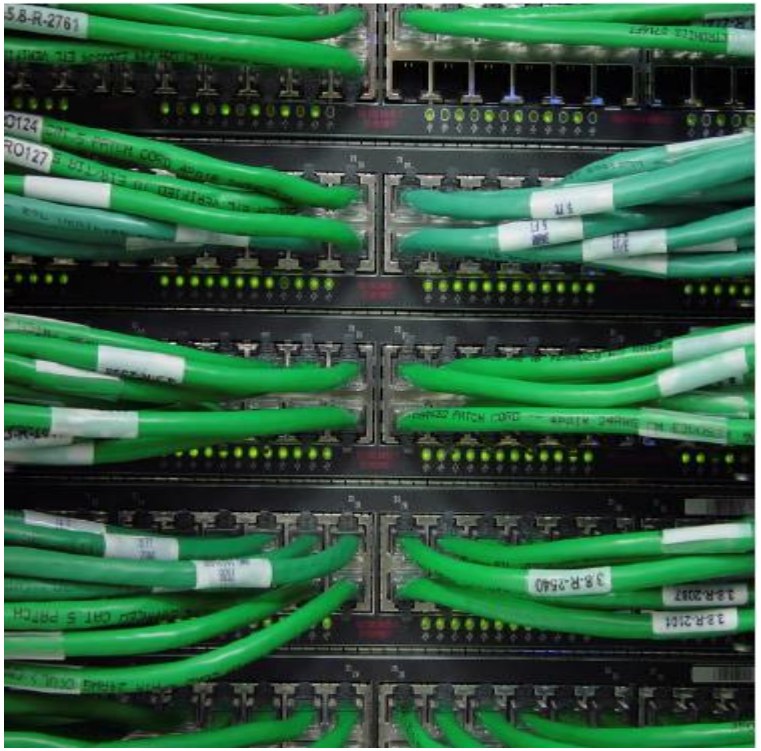
19 MAY 2016

Agenda

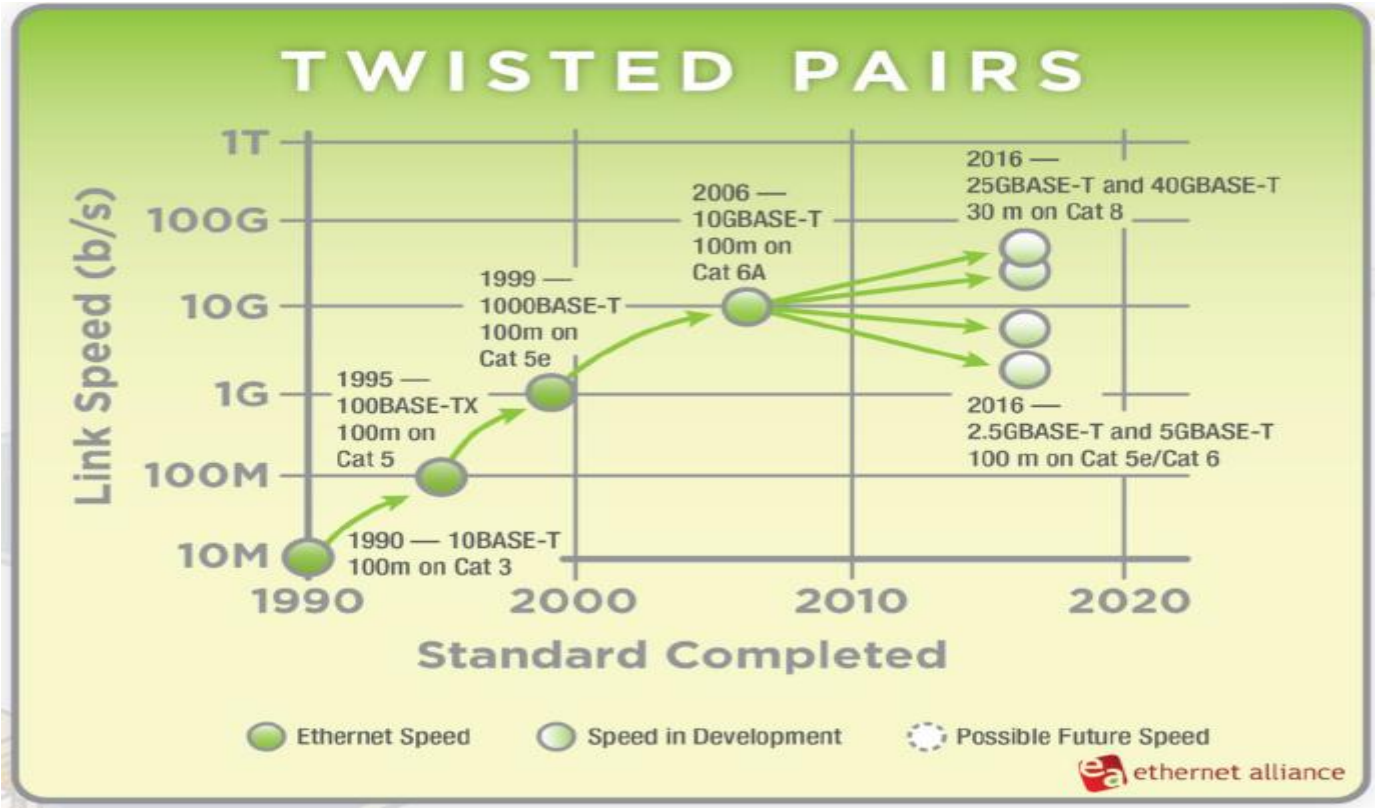
- Market Trends
- 2.5G and 5G Specifications and Standards
- NBASE-T Technology
- Testing Challenges

BASE-T Deployment

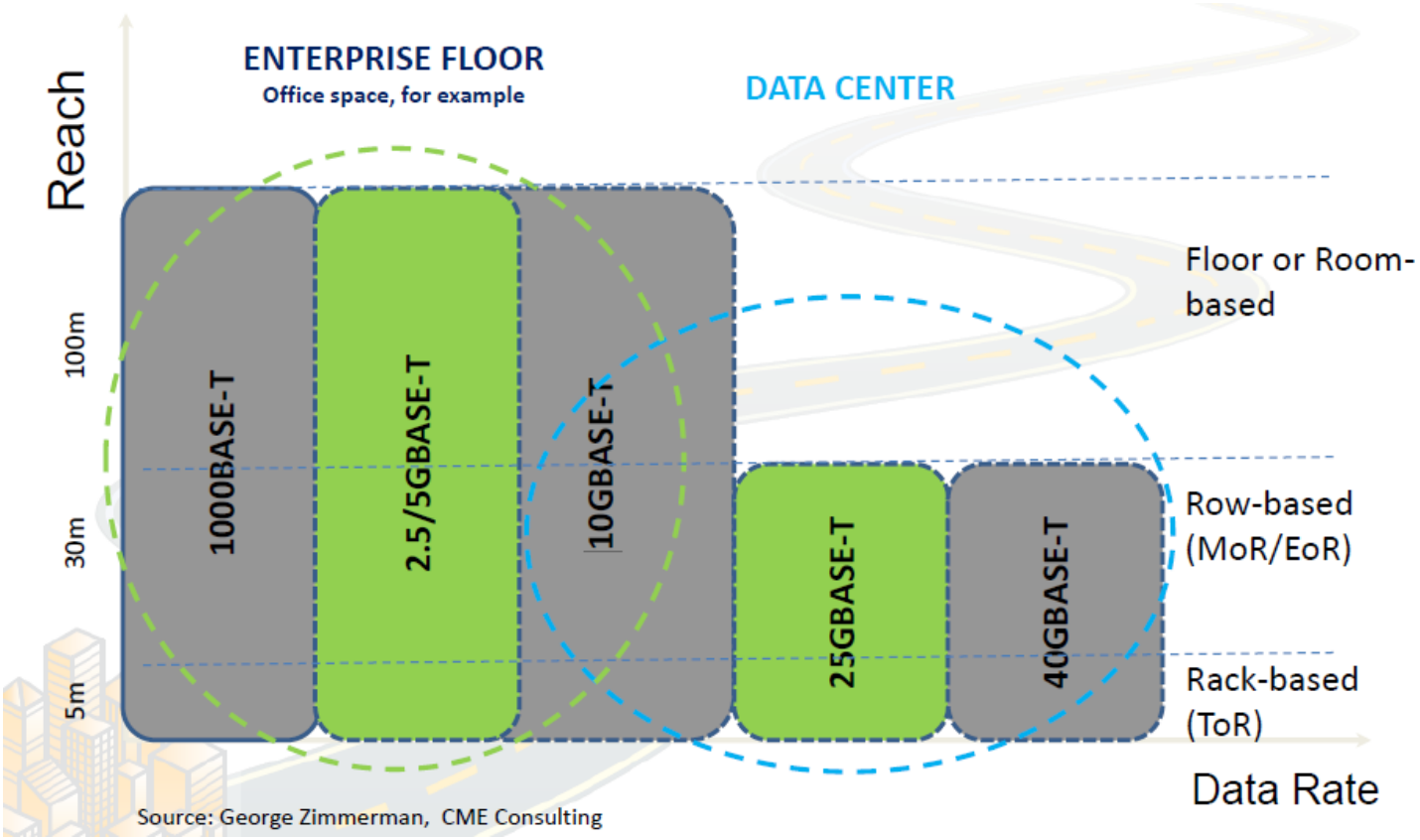
- Major Applications of BASE-T Endpoints
  - Desktops computers, servers,
  - IP Phones, Wireless Access Points
  - Consumer Electronics
- >4 Billion 100BASE-T & 1000BASE-T switch ports shipped in last 20 years.
  - Similar # for end points
  - BASE-T port total is approaching 1B/year
- BASE-T success attributes
  - Ease Of use and backward compatibility
  - Structured cabling
  - Incremental speed upgrades
  - Multi-vendor interoperability
  - Supports Power Over Ethernet
  - Single-cable delivery of power and data to end devices
  - Optimal cost / performance



BASE-T Roadmap



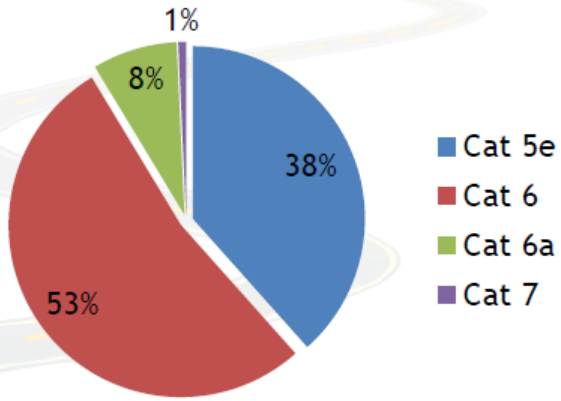
The Application Spaces of BASE-T



Enterprise Access Links Today

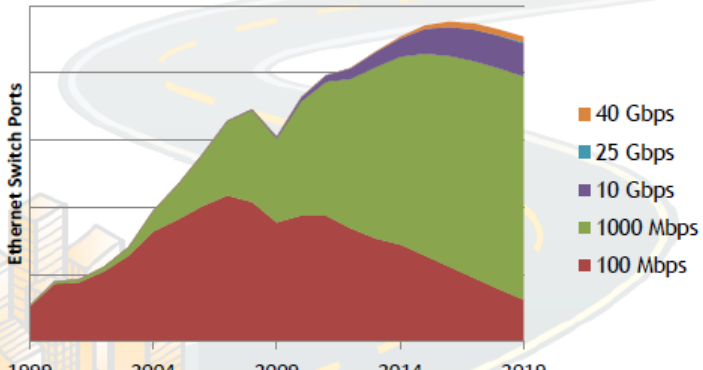
World wide BASE-T cabling is dominated by Cat 5e & Cat 6.

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



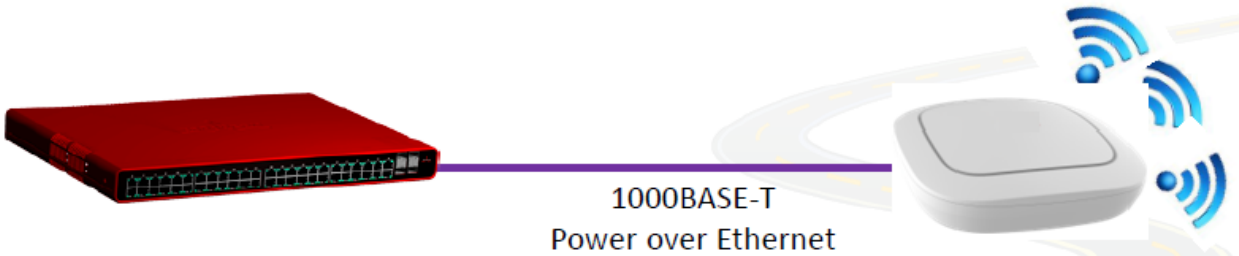
Enterprise Access port types are dominated by 1000BASE-T

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

Cable Infrastructure

- From 2003 to 2014 ~70 billion meters of Cat 5e and Cat 6 cabling have been sold….
  - ~90% of installed base
  - To the moon and back close to 100 times!
- Existing specifications support 1Gb/s over this cable
- Customers demanding more value from this infrastructure.

802.3 Ethernet and 802.11 Wireless LAN



Access Switch

Mostly 1000BASE-T

PoE PSE (15W, 30W, *802.3bt/4PPoE)*

Cabling

Cat 5e/6/6A up to 100M

New installs using Cat 6A for 10+yr life

Access Point

Connects 802.11 to 802.3

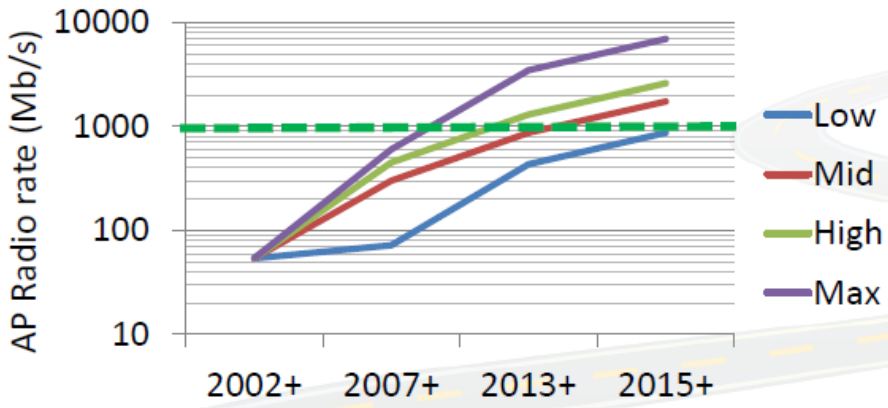
PoE powered

Footprint sensitive (e.g. power, heat, etc.)

802.11ac Wave 2 drives wired traffic > 1 Gb/s.

LinkAgg (Nx1000BASE-T) or 10GBASE-T only options today

Enterprise Access Point Radio Bandwidth



Period	802.11 Standard	Max (Mb/s)
1997-1998	11	2
1999-2001	11b	11
2002-2006	11a/g	54
2007-2011	11n	600
2013-2015	11ac Wave1	3470
2015-2017	11ac Wave2	6930

Graph data: Cisco 802.11ac White Paper (link)

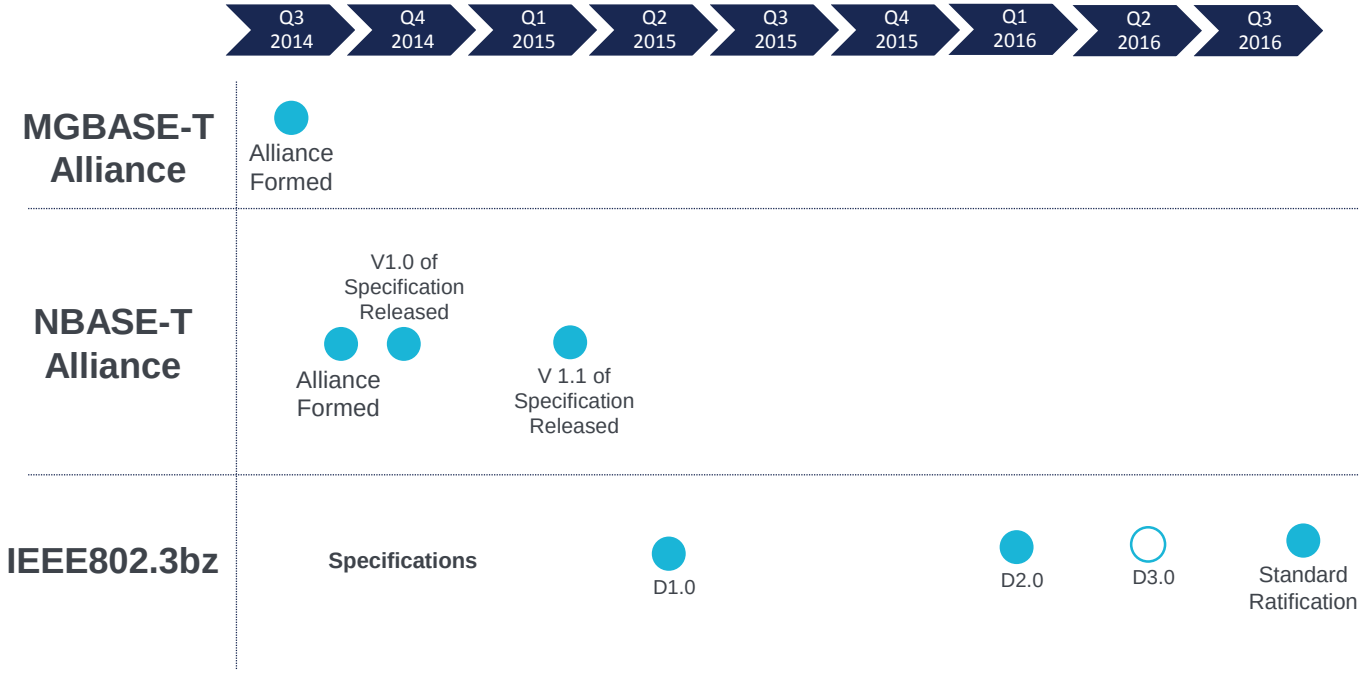
802.11 is clearly outgrowing 1000BASE-T

APs upgraded faster than switches, switches faster than cabling

802.11ax (High Efficiency WLAN) is coming, targets 4x throughput per station.

AP to switch bandwidth should be ~75% of radio bandwidth (to avoid Ethernet link as system bottleneck)

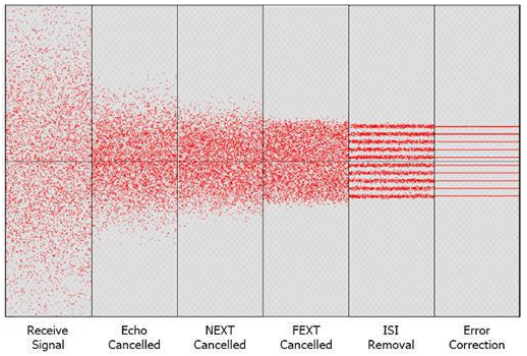
Getting to a 2.5G/5G Standard

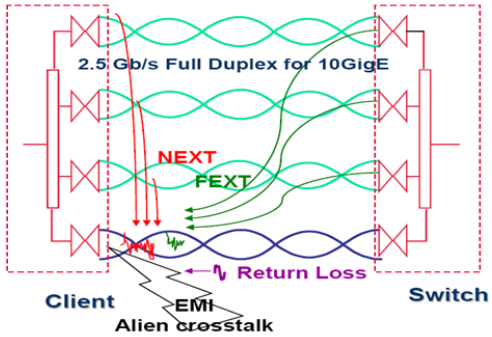


"The technical baselines adopted by the 802.3bz Task Force are consistent with the NBASE-T specification and all NBASE-T products are expected to be compatible with the final standard, which is on track for ratification later this year, the group stated."
Network World; May 4, 2016

2.5G/5G BASE-T Technology

- NBASE-T PHY is similar to 10GBASE-T PHY specified in Clause 55 of IEEE 802.3-2012
  - The clock is scaled by 1/2 and 1/4 in order to accommodate 5Gbps and 2.5Gbps data rates, respectively
- 10GBASE-T technologies used to squeeze usable bandwidth out of installed cabling
- Advanced coding and signal processing allow 2.5G and 5G operation on Cat5e cabling
  - LDPC error correction capability rather than the simple CRC-8 error detection used by 10GBASE-T





2.5GBASE-T and 5GBASE-T PHY Overview

- Full duplex baseband transmission over four pairs of balanced twisted-pair structured cabling
- 2.5 Gb/s or 5 Gb/s data rate achieved by transmitting one-quarter of the aggregate data rate in each direction simultaneously on each wire pair
- Baseband 16-level PAM signaling
  - Modulation rate of 200 Megasymbols per second for 2.5GBASE-T
  - 400 Megasymbols per second for 5GBASE-T is used on each of the wire pairs

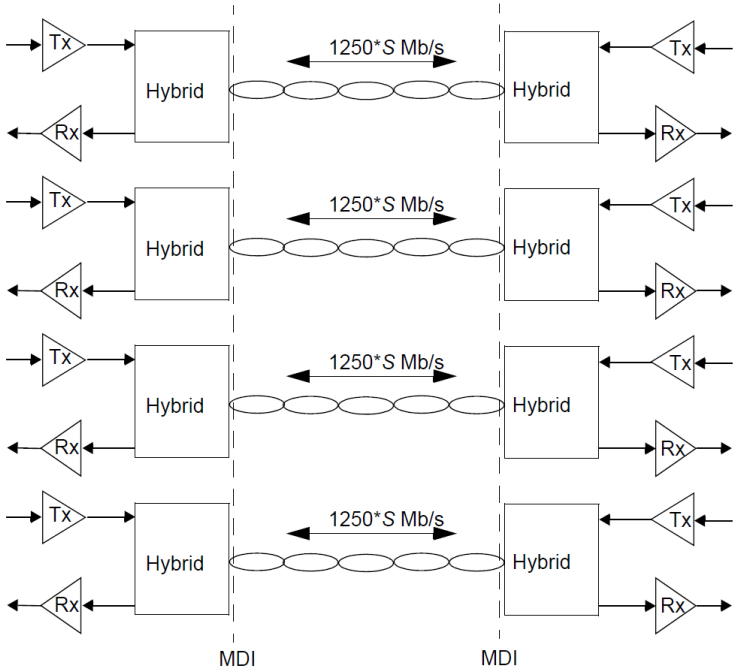


Figure 126–2—2.5GBASE-T and 5GBASE-T topology

2.5G/5G Ethernet Transmitter Test Challenges

- Multiple Specifications/Standards
- Most devices 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

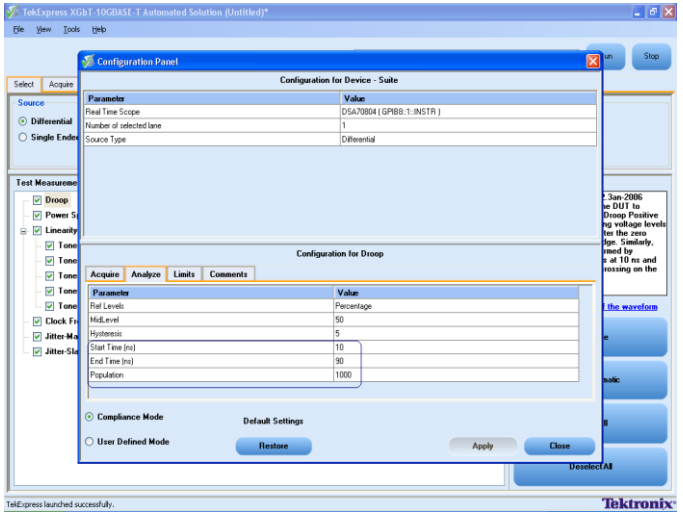
2.5G/5G Technology Transmitter Measurements

Measurement	Purpose	10GBASE-T Standard Reference	IEEE802.3bz Reference
Maximum Output Droop	To verify that the transmitter output level does not droop more than the maximum specified amount.	IEEE 802.3-2012 Subclause 55.5.3.1	IEEE803.bz Subclause 126.5.3.1
Transmit Linearity	Verify that the output of the transmitter conforms to the transmitter linearity limits.	IEEE 802.3-2012 Subclause 55.5.3.2	IEEE803.bz Subclause 126.5.3.2
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	IEEE803.bz Subclause 126.5.3.3
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	IEEE803.bz Subclause 126.5.3.3
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	IEEE803.bz Subclause 126.5.3.4
Transmit Clock Frequency	Verify the frequency of the Transmit Clock is within the conformance limits.	IEEE 802.3-2012 Subclause 55.5.3.5	IEEE803.bz Subclause 126.5.3.5
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	IEEE803.bz Subclause 126.8.2.1

- Test Algorithms for 10GBASE-T, NBASE-T and IEEE802.bz are mostly common
  - IEEE802.3bz linearity measurement for 2.5GBASE-T now requires sine wave to be injected

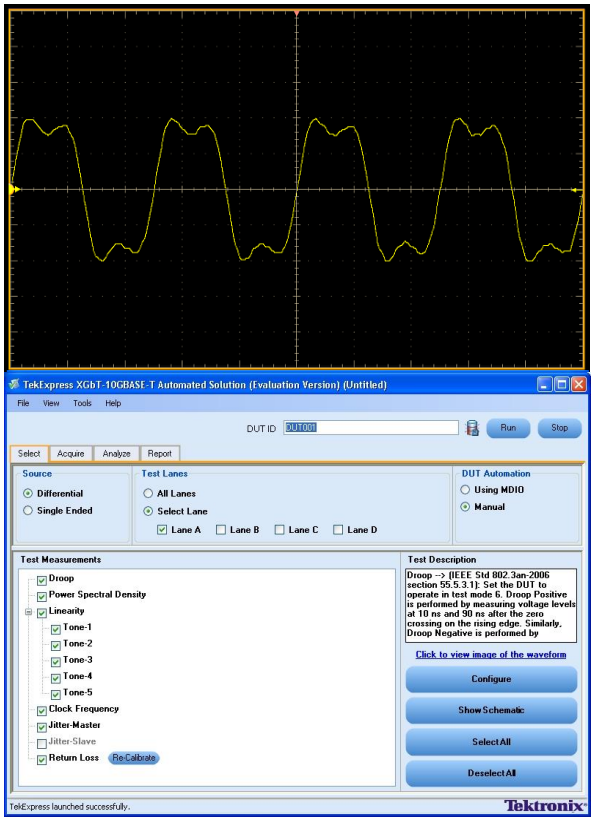
Maximum Output Droop

- **Purpose -** To verify that the transmitter output level does not droop more than the maximum specified amount.
- Configure the DUT for Test Mode 6 operation



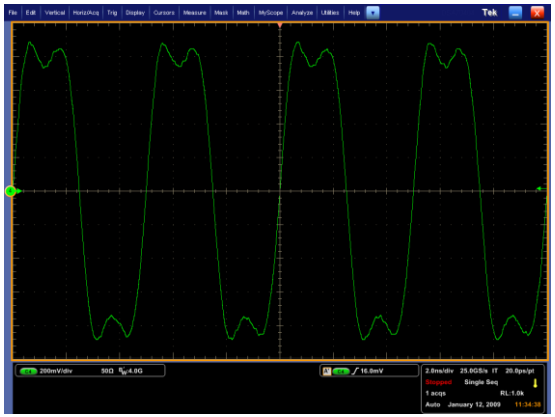
Transmitter Clock Frequency

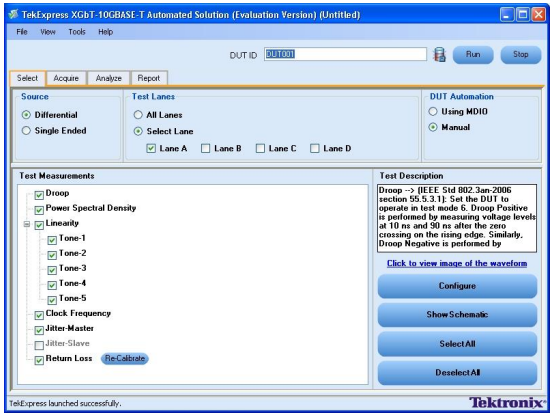
- **Purpose -** To verify the frequency of the Transmit Clock is within the conformance limits.
- Configure the DUT for Test Mode 2 operation
- Exact PPM value for measured clock frequency is shown



Transmitter Timing Jitter – Master

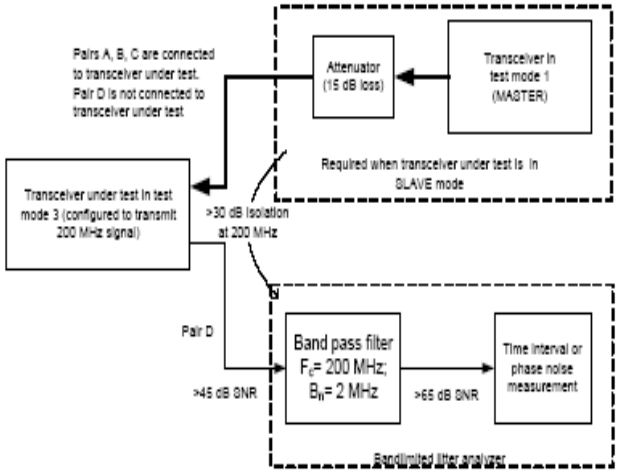
- **Purpose -** To verify that the transmitter timing jitter of the PMA is within the conformance limits.
- Configure the DUT for Test Mode 2 operation
- An appropriate software filter is applied to the input waveform.

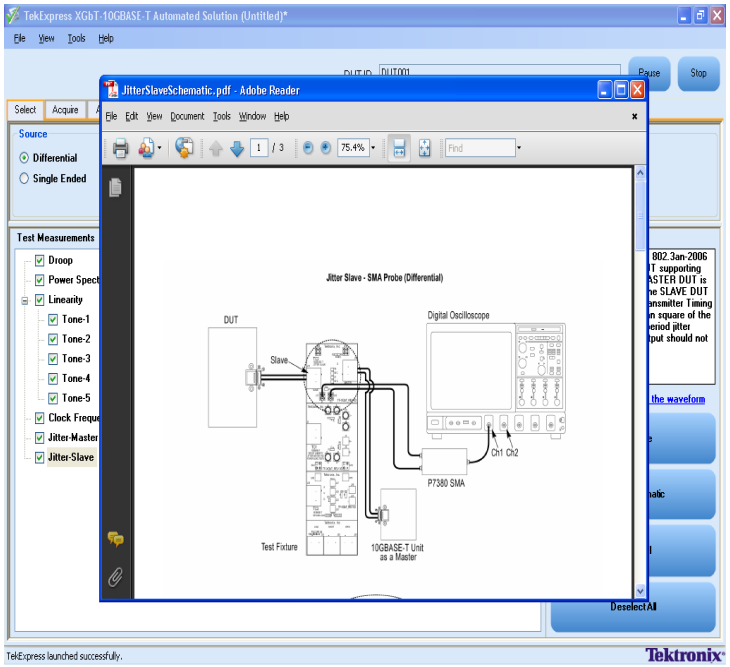




Transmitter Timing Jitter –Slave

- **Purpose -** To verify that the transmitter timing jitter of the PMA is within the conformance limits.
- Configure the Master PHY for Test Mode 1 and Slave PHY for Test Mode 3 operation
- An appropriate software filter is applied to the input waveform.

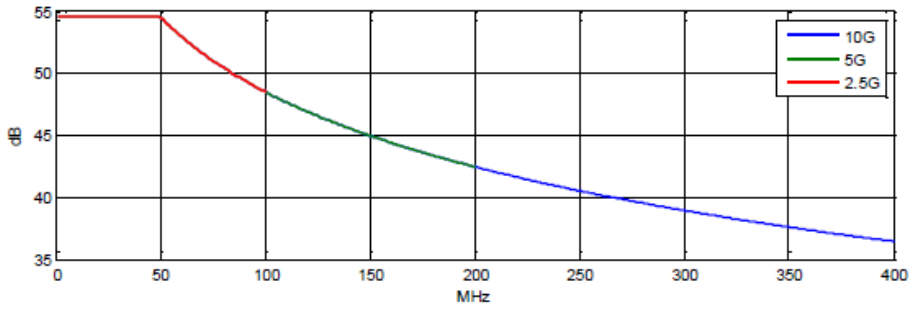




Transmitter Linearity

- **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×log10(f/25)} dB



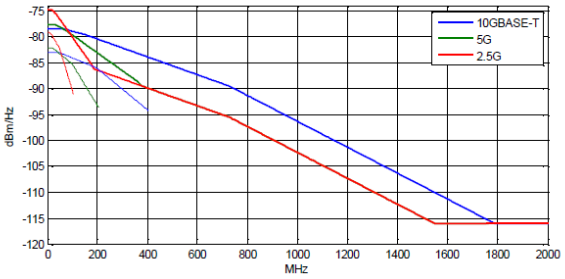
Transmitter Power Spectral Density (PSD) and Power Level

- **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

Media Dependent Interface (MDI) Return Loss

- For reliable signal transmission, the DUT must adhere to a return loss limit curve

Figure 5: NBASE-T Tx PSD



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

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

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

2.5G/5GBASE-T Recommended Equipment

Test Equipment Requirements are similar to 10GBASE-T so most labs should consider the need for 10GBASE-T as well

- Real-Time Scope
  - 4 GHz recommended for 10GBASE-T (3.5 GHz is minimum)
  - 2.5 GHz bandwidth recommended for 2.5G and 5G testing
- Test Fixture
  - Tektronix TF-XGbT supports differential and SMA probes
- Probes
  - Resistance > 10 K ohm and capacitance < 1 pF over the frequency range of (1 MHz to 400 MHz)×S
    - P6330 – 3.5GHz Differential Probe
- Automation Software
- Arbitrary Waveform Generator(For Return Loss Testing)

Test Fixture

- Provides easy access to the 10GBASE-T Electrical signals to perform conformance testing and device characterization

Fig 1: XGbT Test Fixture main board

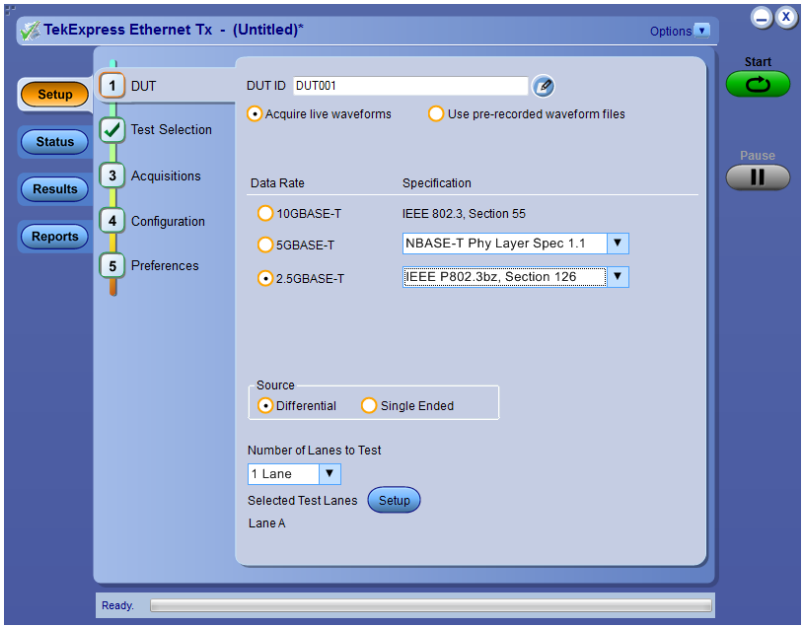
Fig 2: Calibration Board

Figure 3: RJ45 Shielded Patch cord

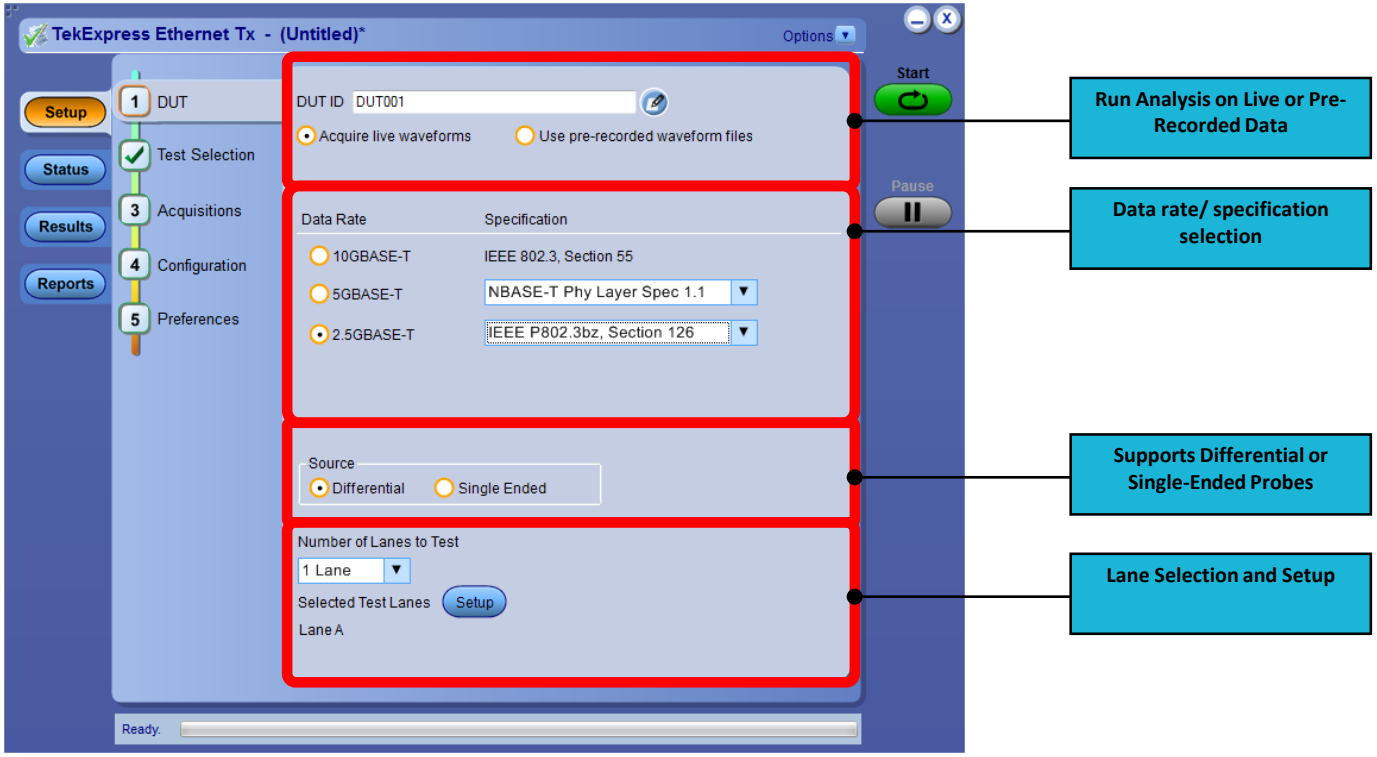
Automation Software

- TekExpress Automation for Ethernet Tx Compliance

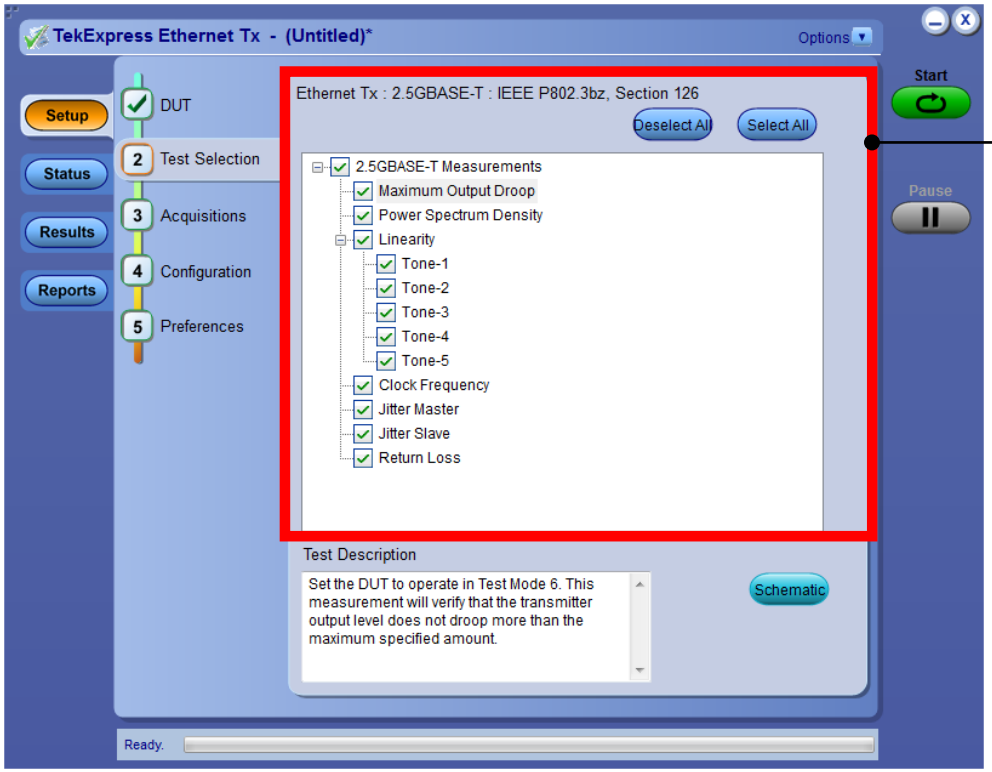
  - √ Single application supports: 2.5G, 5G, and 10G data rates
  - √ Single application supports NBASE-T specification, IEEE802.3bz standard, and 10GBASE-T Standard
  - √ Tests multiple lanes
  - √ Automates scope setup
  - √ Acquires the data
  - √ Provides custom reporting



TekExpress for Ethernet Tx - Setup

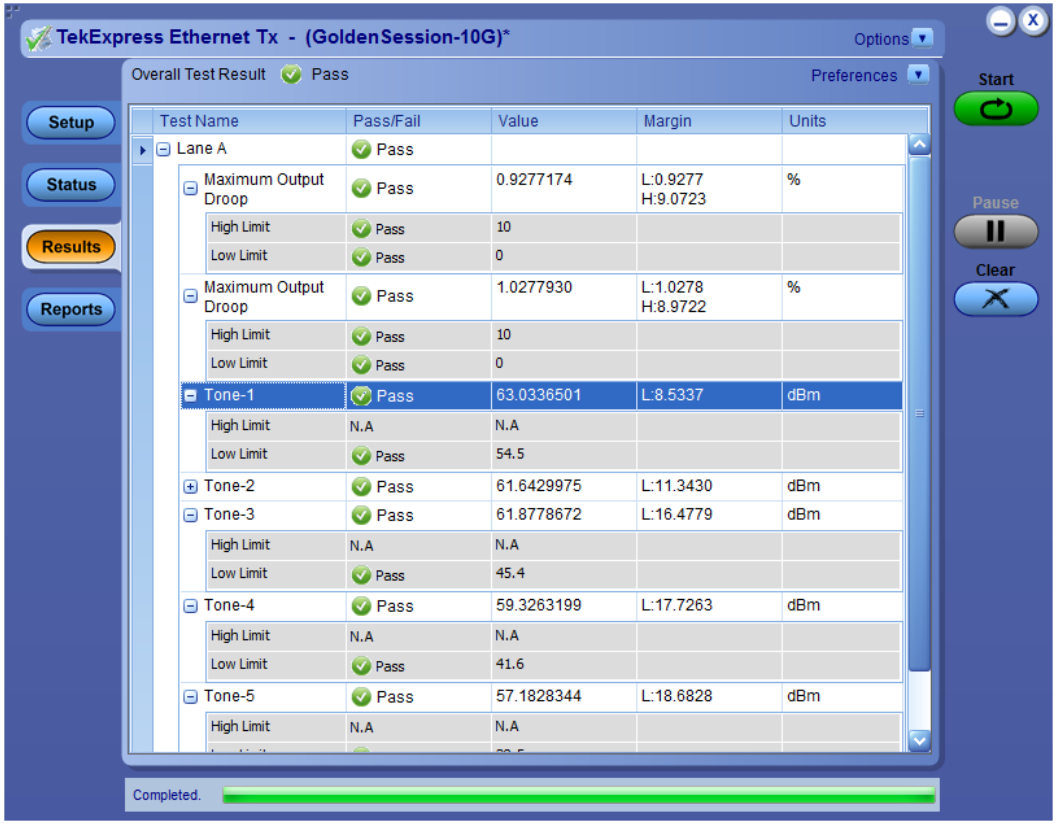


TekExpress for Ethernet Tx – Test Selection



Test Selection

TekExpress for Ethernet Tx – Results Table



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		

20 MAY 2016

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									

Back to Summary Tabl

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									

Summary

- Increases in wireless bandwidth outpacing current wired capability
- Massive installed-based of Cat 5e and Cat 6 cable is expensive to upgrade so jump to 10GBASE-T is not cost-effective
- IEEE currently working on 2.5GBASE-T and 5GBASE-T standards (IEEE802.3bz)
- Similar testing challenges as for 10GBASE-T
- Automation of testing is key to productivity
- Testing needs to support multiple speeds

Links

- Tektronix Ethernet Solutions: http://www.tek.com/ethernet-test
- TekExpress Ethernet Tx Datasheet: http://www.tek.com/datasheet/tekexpress-10gbase-t-and-nbase-t-datasheet
- NBASE-T Alliance Website: http://www.nbaset.org/
- Fundamentals of NBASE-T Video: http://www.nbaset.org/fundamentals-of-nbase-t/

Thank You!