Agilent Technologies

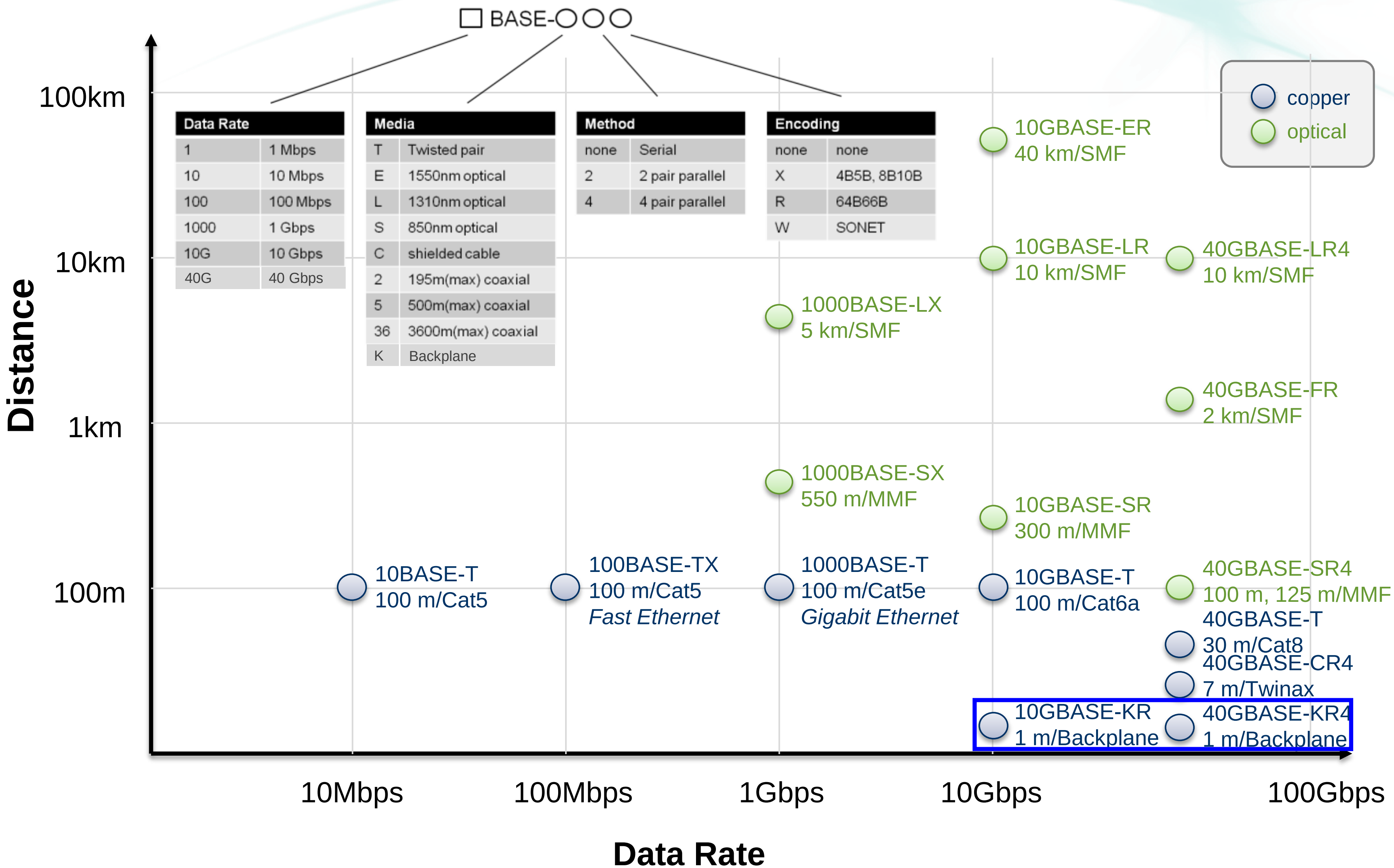
10GBASE-KR/40GBASE-KR4 Backplane Ethernet Interconnect & Transmitter/Receiver (Tx/Rx) Tests

Test Solution Overview Using the Agilent E5071C ENA Option TDR

Purpose

- This slide will show how to make measurements of 10GBASE-KR/40GBASE-KR4 Backplane Ethernet Interconnect & Transmitter/Receiver (Tx/Rx) Tests by using the Agilent E5071C ENA Option TDR.

Ethernet Data Rate and Distance



Data Rate	
1	1 Mbps
10	10 Mbps
100	100 Mbps
1000	1 Gbps
10G	10 Gbps
40G	40 Gbps

Media	
T	Twisted pair
E	1550nm optical
L	1310nm optical
S	850nm optical
C	shielded cable
2	195m(max) coaxial
5	500m(max) coaxial
36	3600m(max) coaxial
K	Backplane

Method	
none	Serial
2	2 pair parallel
4	4 pair parallel

Encoding	
none	none
X	4B5B, 8B10B
R	64B66B
W	SONET

Ethernet Logo Certification Program

Standard	Standard Body
Certified Hi-Speed USB	USB-IF
PCI Express	PCI-SIG
Serial ATA	SATA-IO
Ethernet	N/A

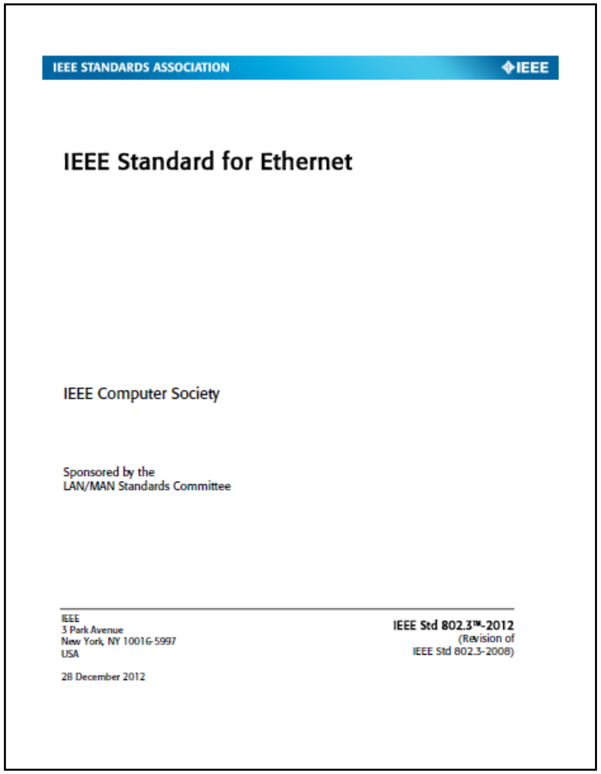
No logo certification program is available for Ethernet.

- PHY tests performed in accordance to test procedure issued by University of New Hampshire InterOperability Laboratory (UNH-IOL).
- Self-compliance.

Ethernet Specification and Electrical Test Procedure

Specification

IEEE Std 802.3™-2012


IEEE STANDARDS ASSOCIATION IEEE

IEEE Standard for Ethernet

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

28 December 2012

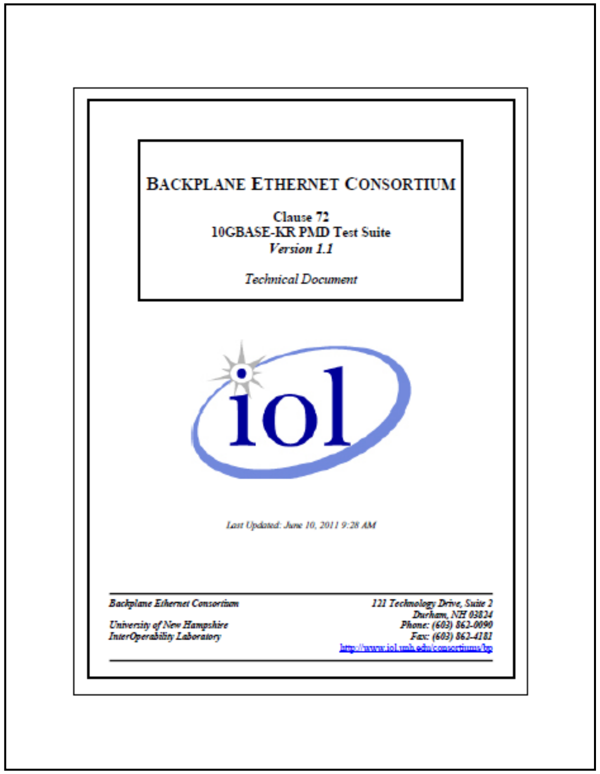
IEEE Std 802.3™-2012
(Revision of
IEEE Std 802.3-2008)

Test Procedure

Test Suite for Ethernet

University of New Hampshire

InterOperability Laboratory (UNH-IOL)


BACKPLANE ETHERNET CONSORTIUM

Clause 72
10GBASE-KR PMD Test Suite
Version 1.1

Technical Document

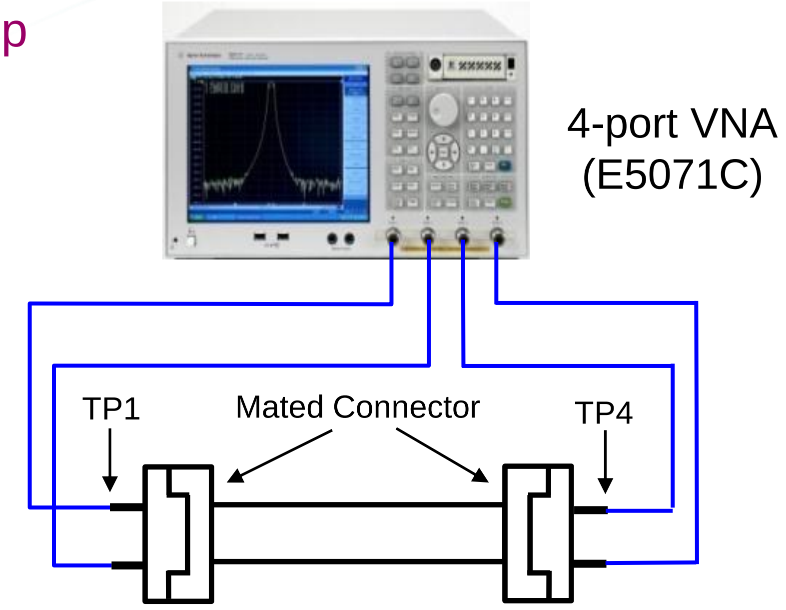
Last Updated: June 10, 2011 9:28 AM

Backplane Ethernet Consortium
University of New Hampshire
InterOperability Laboratory

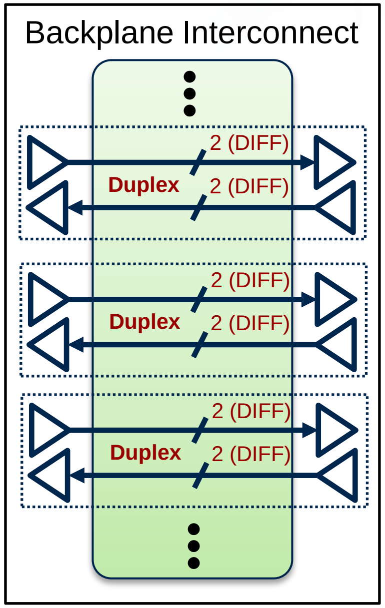
121 Technology Drive, Suite 2
Durham, NH 03824
Phone: (603) 862-0090
Fax: (603) 862-4181
http://www.iol.unh.edu/consortiums/bp

10GBASE-KR/40GBASE-KR4 Interconnect Test Solution

Test Setup



Backplane Channel



- 10GBASE-KR/40GBASE-KR4 backplane Ethernet is primarily intended to operate over differential, controlled impedance traces up to 1 m including two connectors, on printed circuit boards residing in a backplane environment.
- The backplane interconnect is defined between TP1 and TP4.
- It supports an effective data rate of 10 Gbps in each direction simultaneously (full-duplex operation using a single-lane 10 Gbps PHY).

10GBASE-KR/40GBASE-KR4 Interconnect Characteristics Electrical Test Item List (Informative)

IEEE Std 802.3TM-2012 72.8 Interconnect characteristics
Informative interconnect characteristics for 10GBASE-KR/40GBASE-KR4 are provided in Annex 69B.

Specification (IEEE Std 802.3TM-2012)	Test Items
[Annex 69B.3]	Characteristic impedance & differential skew
[Annex 69B.4.2]	Fitted attenuation
[Annex 69B.4.3]	Insertion loss
[Annex 69B.4.4]	Insertion loss deviation
[Annex 69B.4.5]	Return loss
[Annex 69B.4.6.1]	Power sum differential near-end crosstalk (PSNEXT)
[Annex 69B.4.6.2]	Power sum differential far-end crosstalk (PSFEXT)
[Annex 69B.4.6.3]	Power sum differential crosstalk (PSXT)
[Annex 69B.4.6.4]	Insertion loss to crosstalk ratio (ICR)

10GBASE-KR/40GBASE-KR4 Interconnect Test Solution

Solution Overview

•10GBASE-KR/40GBASE-KR4 backplane Ethernet interconnect testing requires parametric measurements in both time and frequency domains.

Time Domain
- •Characteristic impedance
- •Differential skew

Frequency Domain
- •Fitted attenuation
- •Insertion loss
- •Insertion loss deviation
- •Return loss
- •Power sum differential near-end crosstalk (PSNEXT)
- •Power sum differential far-end crosstalk (PSFEXT)
- •Power sum differential crosstalk (PSXT)
- •Insertion loss to crosstalk ratio (ICR)

Traditional Solution

TDR Scope

Vector Network Analyzer (VNA)

New Solution

•**ALL** parameters can be measured with **ENA Option TDR**

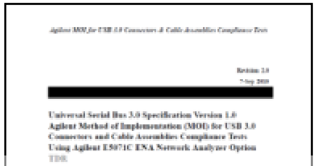
10GBASE-KR/40GBASE-KR4 Interconnect Test Solution

Configuration

- ENA Mainframe (*1)
  - E5071C-4K5: 4-port, 300 kHz to 20 GHz
- Enhanced Time Domain Analysis Option (E5071C-TDR)
- ECal Module (N4433A)

*1: 10GBASE-KR/40GBASE-KR4 interconnect tests require frequency up to 15 GHz.
*2: The list above includes the major equipment required. Please contact our sales representative for configuration details.

- Method of Implementation (MOI) document, state file (4K5), and VBA project file available for download on Agilent.com


Universal Serial Bus 3.0 Specification Version 1.0
Agilent Method of Implementation (MOI) for USB 3.0 Connectors and Cable Assemblies Compliance Tests Using Agilent E5071C ENA Network Analyzer Option TDR

MOI
(Method of Implementation)
Step-by-step procedure on how to measure the specified parameters in the specification document using ENA Option TDR.

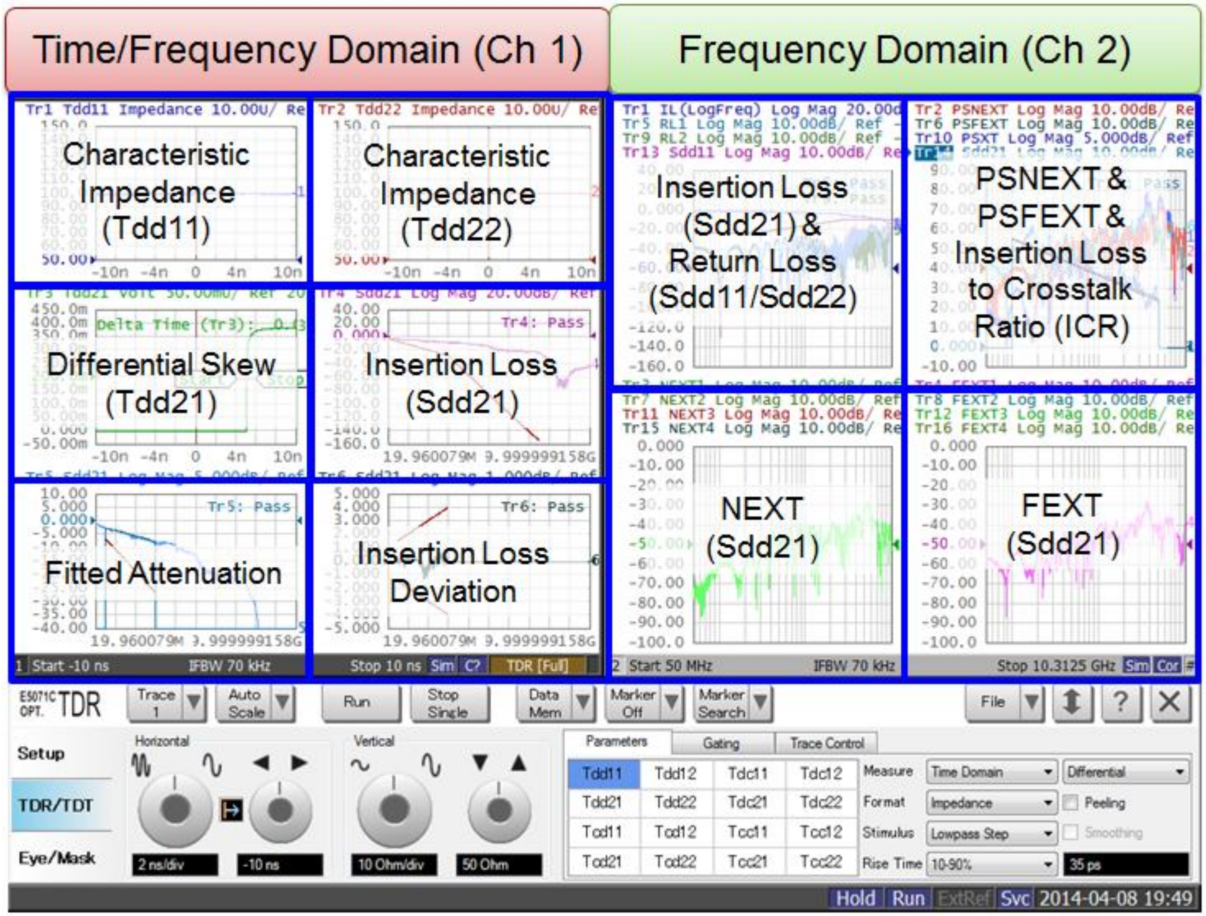
www.agilent.com/find/ena-tdr_compliance
www.agilent.com/find/ena-tdr_ethernet-cabcon

10GBASE-KR/40GBASE-KR4 Interconnect Test Solution

Measurement Parameters

ENA Option TDR Compliance Testing Solution is one-box solution which provides complete characterization of interconnects (time domain, frequency domain)

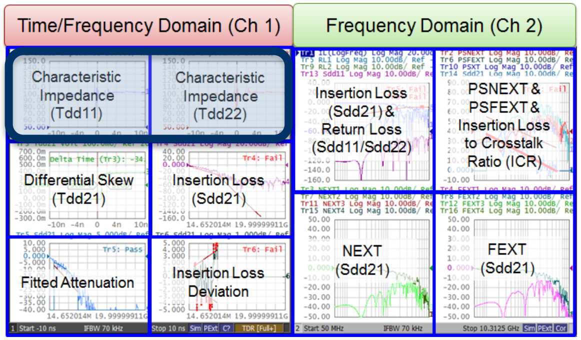
Ch 1 Freq Domain: Linear Freq Sweep



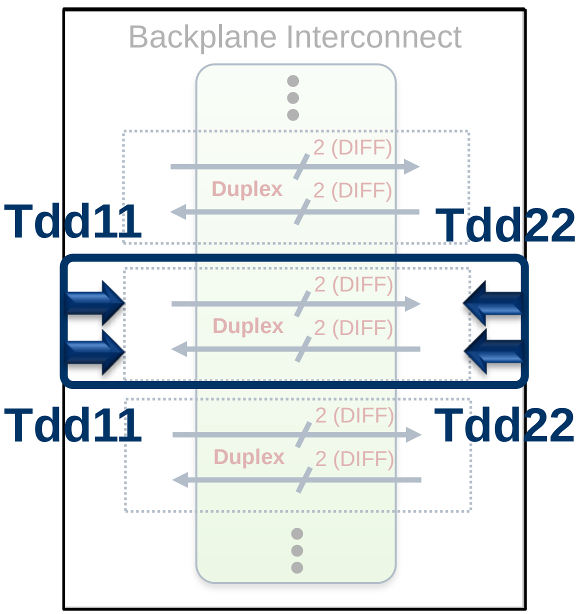
Ch 2 Freq Domain: Log Freq Sweep

IEEE Std 802.3-2012

Annex 69B.3 Characteristic Impedance



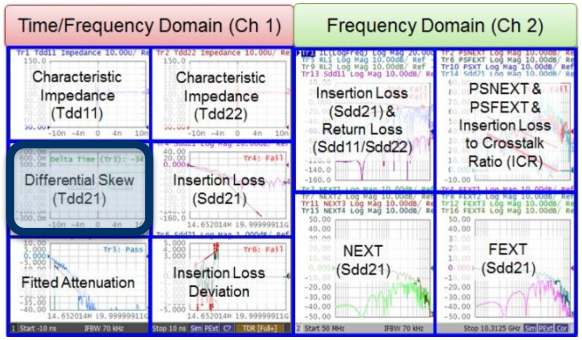
- Multiple reflections from impedance mismatches cause noise at the receiver. Therefore, the impedance profile provides an indication of multiple reflection induced noise.
- Impedance is the most used parameter, but is an indirect measure of the signal arriving at the receiver.



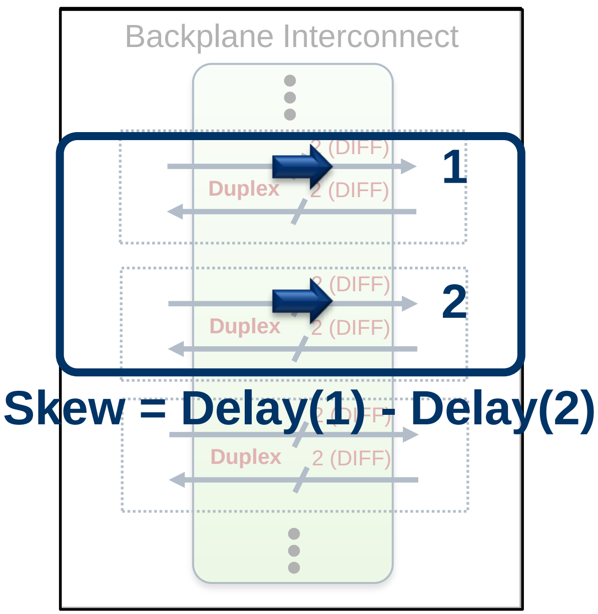
The recommended differential characteristic impedance of circuit board trace pairs is 100 Ω ± 10 %.

IEEE Std 802.3-2012

Annex 69B.3 Differential Skew



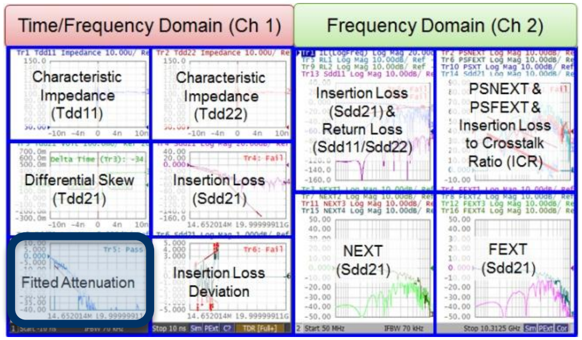
•The skew (propagation delay) between duplex channel pair combinations of a interconnect should meet requirement.



The total differential skew from TP1 to TP4 is recommended to be less than the minimum transition time for port type of interest.

IEEE Std 802.3-2012

Annex 69B.4.2 Fitted Attenuation



•The fitted attenuation is defined to be the least mean squares line fit to the insertion loss computed over the frequency range 1 GHz to 6 GHz.
•The maximum fitted attenuation due to trace skin effect and dielectric properties is defined.

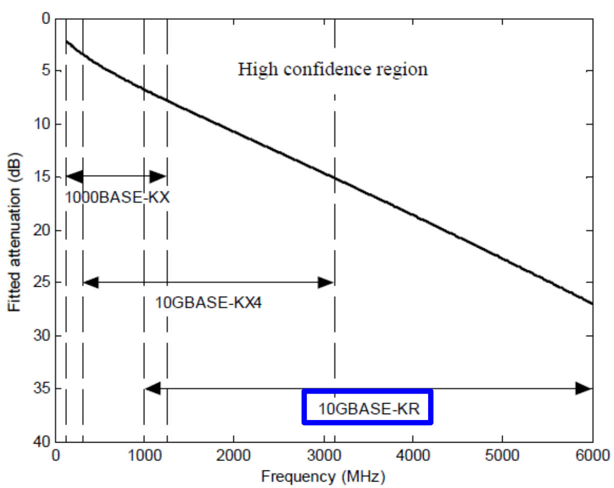


Figure 69B–2—Fitted attenuation limit

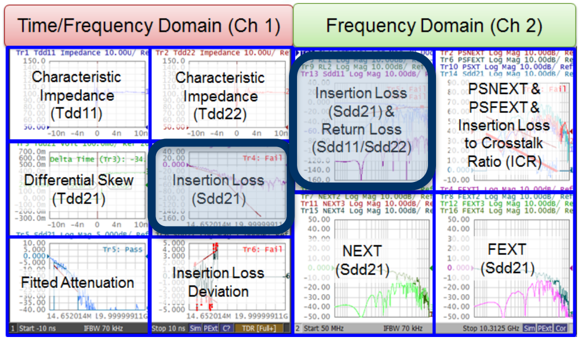
It is recommended that the fitted attenuation of the channel be less than or equal to A_{max} as defined by the equation below, where f is expressed in Hz and coefficient b_1 through b_4 are given in table.

$$A(f) \le A_{max}(f) = 20\log_{10}(e) \times (b_1\sqrt{f} + b_2 f + b_3 f^2 + b_4 f^3)$$

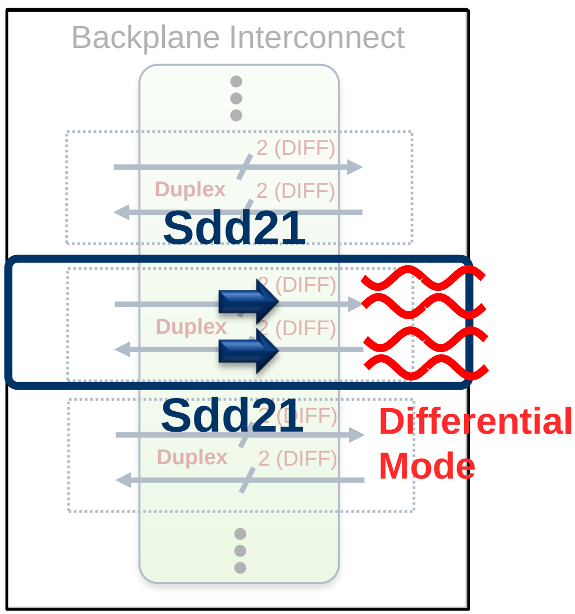
b_1	2.00×10^{-5}
b_2	1.10×10^{-10}
b_3	3.20×10^{-20}
b_4	-1.20×10^{-30}

IEEE Std 802.3-2012

Annex 69B.4.3 Insertion loss



- Insertion loss is defined as the magnitude of the differential response measured from TP1 to TP4.
- Has important consequences for the rise time degradation and the maximum supportable bandwidth.



It is recommended that the insertion loss magnitude be <u>within the high confidence region defined by equations</u>. The values of f_{min}, f_2, and f_{max} are given in tables.

$$IL(f) \le IL_{max}(f) = A_{max}(f) + 0.8 + 2.0\times10^{-10} f$$

for $f_{min} \le f \le f_2$

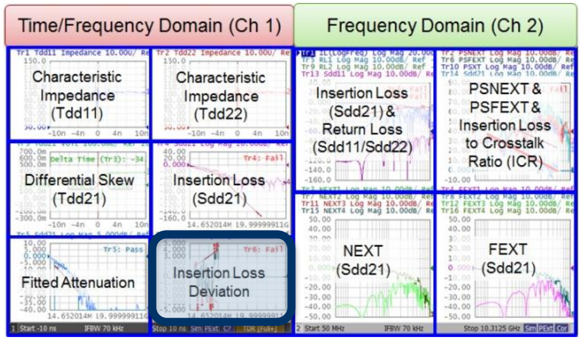
$$IL(f) \le IL_{max}(f) = A_{max}(f) + 0.8 + 2.0\times10^{-10} f_2 + 1\times10^{-8}(f - f_2)$$

for $f_2 < f \le f_{max}$

f_{min}	0.05			GHz
f_{max}	15.00			GHz
f_2	1.250	3.125	6.000	GHz

IEEE Std 802.3-2012

Annex 69B.4.4 Insertion loss Deviation



- Insertion loss deviation is the difference between the insertion loss and the fitted attenuation.

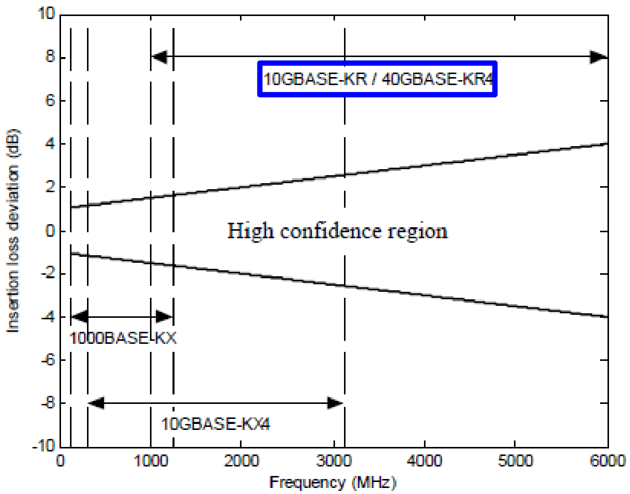


Figure 69B–6—Insertion loss deviation limits

It is recommended that insertion loss deviation be within the high confidence region defined by equations.

$$ILD(f) \geq ILD_{min}(f) = -1.0 - 0.5\times10^{-9}f$$

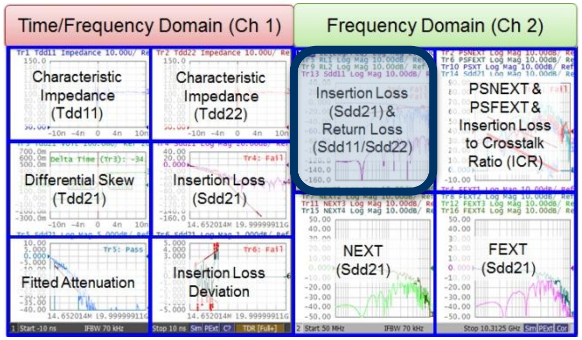
$$ILD(f) \leq ILD_{max}(f) = 1.0 + 0.5\times10^{-9}f$$

for $f_1 \leq f \leq f_2$.

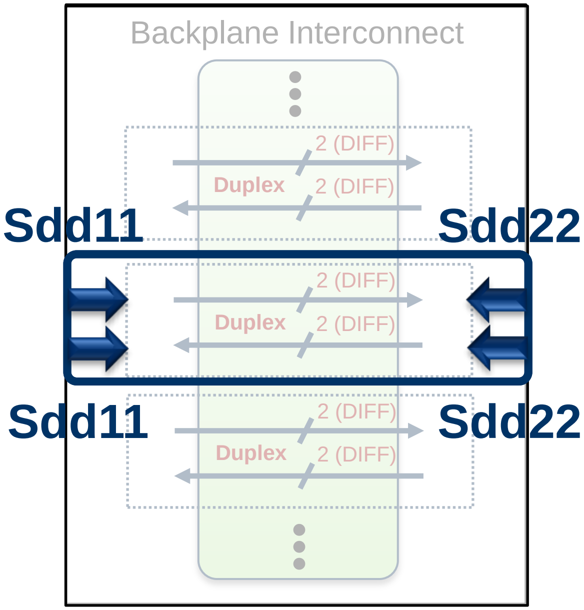
f_1	0.125	0.312	1.000	GHz
f_2	1.250	3.125	6.000	GHz

IEEE Std 802.3-2012

Annex 69B.4.5 Return loss



- Ratio of reflected voltage to incident voltage. Key parameter when evaluating impedance mismatch.
- When impedance match is poor, transmission signal quality is degraded due to multiple-reflection effects, leading to increase in bit error rate.



It is recommended that the channel loss at TP1 and TP4 be greater than or equal to RL_{min} as defined by equations. The recommendation applied from 50 MHz.

$$RL(f) \geq RL_{\min}(f) = 12$$

for 50 MHz $\leq f <$ 275 MHz and

$$RL(f) \geq RL_{\min}(f) = 12 - 6.75\log_{10}\left(\frac{f}{275\text{ MHz}}\right)$$

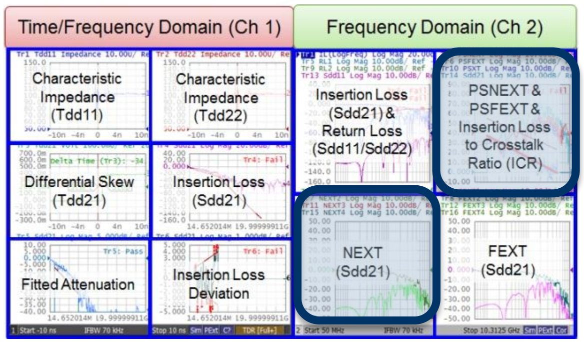
for 275 MHz $\leq f <$ 3000 MHz and

$$RL(f) \geq RL_{\min}(f) = 5$$

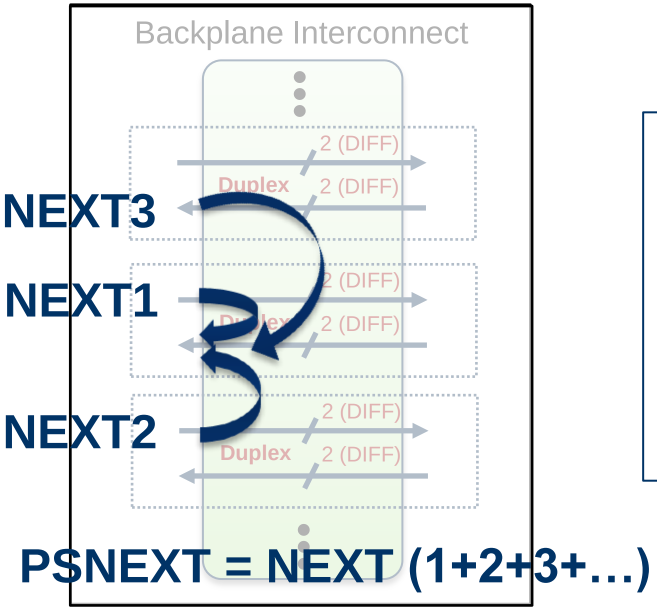
for 3000 MHz $\leq f \leq$ 10312.5 MHz.

IEEE Std 802.3-2012

Annex 69B.4.6.1 Power Sum Differential Near-end Crosstalk (PSNEXT)



- Measure of the coupling between the differential pairs.
- The differential near-end crosstalk at TP4 is calculated as the power sum of the individual NEXT aggressors (PSNEXT).

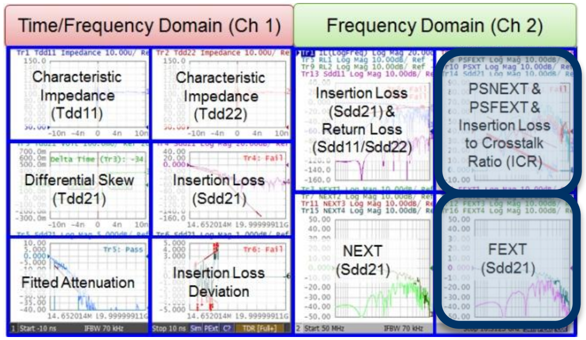


PSNEXT is computed as equation, where $NEXT_n$ is the crosstalk loss (dB) of aggressor n. For the case of a single aggressor, PSNEXT will be the crosstalk loss for that single aggressor.

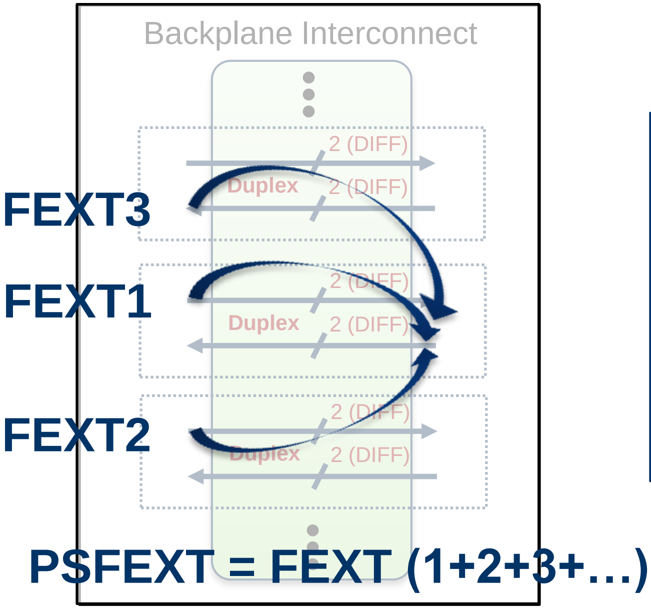
$$PSNEXT(f) = -10\log\left(\sum_{n} 10^{-NEXT_n(f)/10}\right)$$

IEEE Std 802.3-2012

Annex 69B.4.6.2 Power Sum Differential Far-end Crosstalk (PSFEXT)



- Far-end crosstalk (FEXT) is crosstalk that appears at the far end of a duplex channel, which is coupled from another duplex channel.
- The differential far-end crosstalk at TP4 is calculated as the power sum of the individual FEXT aggressors (PSFEXT).

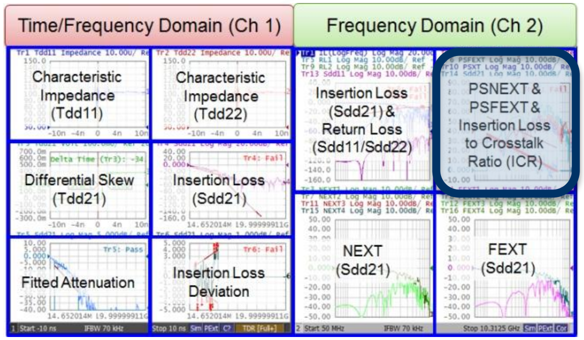


PSFEXT is computed as equation, where $FEXT_n$ is the crosstalk loss (dB) of aggressor n. For the case of a single aggressor, PSFEXT will be the crosstalk loss for that single aggressor.

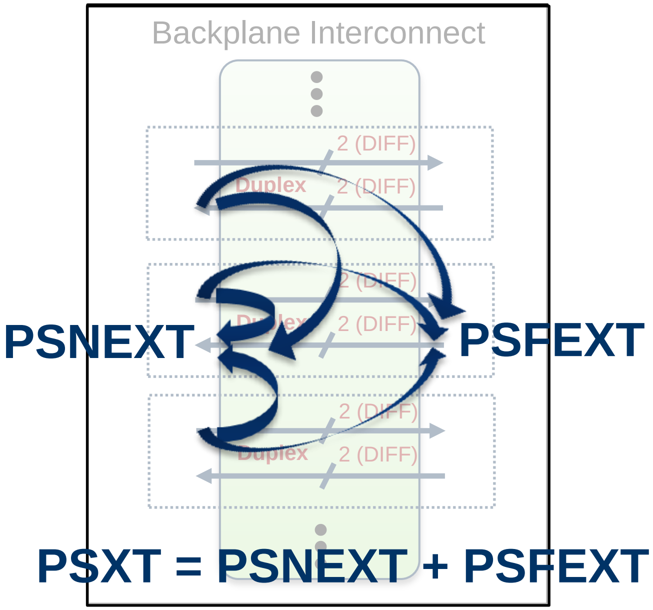
$$PSFEXT(f) = -10\log\left(\sum_n 10^{-FEXT_n(f)/10}\right)$$

IEEE Std 802.3-2012

Annex 69B.4.6.3 Power Sum Differential Crosstalk (PSXT)



•The differential crosstalk at TP4 is calculated as the power sum of the individual NEXT and FEXT aggressors (PSXT).

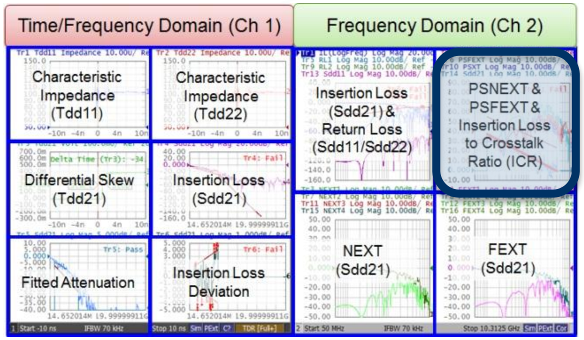


PSXT may be computed as equation.

$$PSXT(f) = -10\log(10^{-PSNEXT(f)/10} + 10^{-PSFEXT(f)/10})$$

IEEE Std 802.3-2012

Annex 69B.4.6.4 Insertion Loss to Crosstalk Ratio (ICR)



- Insertion loss to crosstalk ratio (ICR) is the ratio of the insertion loss, measured from TP1 to TP4, to the total crosstalk measured at TP4.
- ICR_{fit} is defined to be the least mean squares line fit to the ICR computed over the frequency range 100 MHz to 5.15625 GHz.

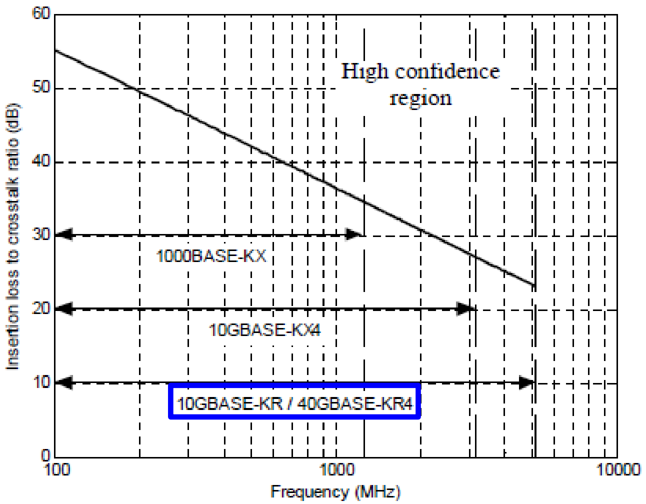


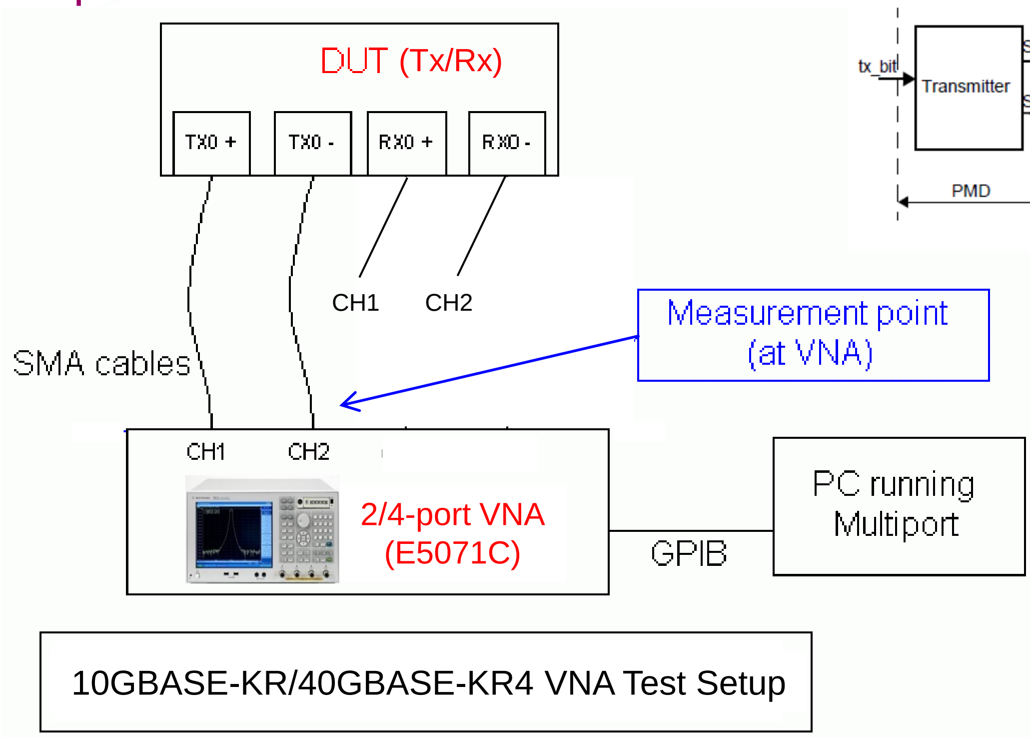
Figure 69B–8—Insertion loss to crosstalk ratio limit

It is recommended that ICR_{fit} be <u>greater than or equal to ICR_{min}</u> as defined by equation.

$$ICR_{fit}(f) \geq ICR_{min}(f) = 23.3 - 18.7\log_{10}\left(\frac{f}{5\ \text{GHz}}\right)$$

10GBASE-KR/40GBASE-KR4 Tx/Rx Test Solution

Test Setup



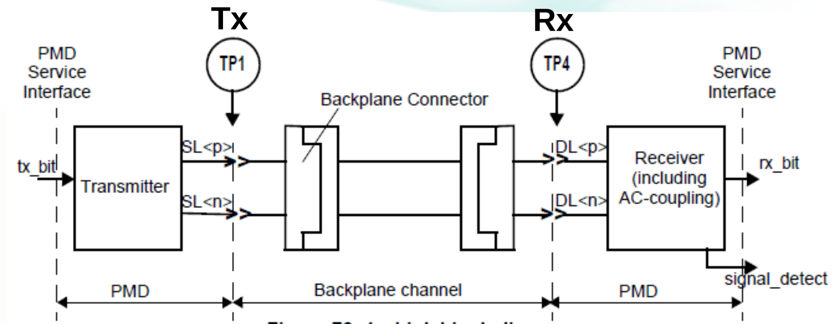


Figure 72–1—Link block diagram

- 10GBASE-KR/40GBASE-KR4 transmitter and receiver are characterized at TP1 and TP4 respectively.
- For the return-loss measurements using VNA, the test fixture is not required for measuring the transmitter specifications.
- Configure the DUT so that it is sourcing normal IDLE signaling then measure the reflection coefficient at the DUT (Hot Return Loss measurement).

10GBASE-KR/40GBASE-KR4 Tx Characteristics Electrical Test Item List (Normative)

IEEE Std 802.3™-2012 72.7.1 Transmitter characteristics
UNH-IOL Clause 72 10GBASE-KR PMD Test Suite Version 1.1 Group 2 Impedance Requirements

Specification (IEEE Std 802.3™-2012)	Test Procedure (UNH-IOL Clause 72)	Test Items
[72.7.1.3]	[72.1.1]	Signaling speed
[72.7.1.4]	[72.1.3]	Differential peak-to-peak output voltage (max.)
[72.6.5]	[72.1.3]	Differential peak-to-peak output voltage (max.) with Tx disabled
[72.7.1.4]	[72.1.2]	Common-mode voltage limits & deviation (max.) during LPI
[72.7.1.5]	[72.2.1]	Differential output return loss (min.)
[72.7.1.6]	[72.2.2]	Common-mode output return loss (min.)
[72.7.1.7]	[72.1.4]	Transition time (20% - 80%)
[72.7.1.9]	[72.1.5]	Max output jitter (peak-to-peak) (random jitter, deterministic jitter, duty cycle distortion, total jitter)
[72.7.1.11]	[72.1.6] [72.1.7]	Transmitter output waveform requirements

Test items measured by VNA

10GBASE-KR/40GBASE-KR4 Rx Characteristics Electrical Test Item List (Normative)

IEEE Std 802.3™-2012 72.7.2 Receiver characteristics
UNH-IOL Clause 72 10GBASE-KR PMD Test Suite Version 1.1 Group 2 Impedance Requirements

Specification (IEEE Std 802.3™-2012)	**Test Procedure** (UNH-IOL Clause 72)	**Test Items**
[72.7.2.1]		Bit error ratio
[72.7.2.2]		Signaling speed
[72.7.2.3]		Receiver coupling
[72.7.2.4]		Differential input peak-to-peak amplitude (max.)
[72.7.2.5]	[72.2.3]	Differential input return loss (min.)

Test items measured by VNA

10GBASE-KR/40GBASE-KR4 Tx/Rx Test Solution

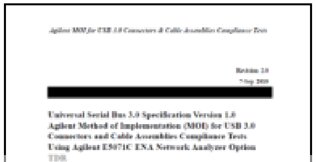
Configuration

- ENA Mainframe (*1)
  - E5071C-280/480: 2/4-port, 9 kHz to 8.5 GHz
  - E5071C-285/485: 2/4-port, 100 kHz to 8.5 GHz
  - E5071C-2D5/4D5: 2/4-port, 300 kHz to 14 GHz
  - E5071C-2K5/4K5: 2/4-port, 300 kHz 20 GHz
- Enhanced Time Domain Analysis Option (E5071C-TDR) (*2)
- ECal Module
  - N4431B for E5071C-280/285/480/485
  - N4433A for E5071C-2D5/4D5/2K5/4K5

*1: Select one of frequency options. 10GBASE-KR/40GBASE-KR4 Tx/Rx tests (return loss) require frequency up to 7.5 GHz.
*2: E5071C-TDR is required to use Avoid Spurious function for Hot Return Loss measurement.
*3: The list above includes the major equipment required. Please contact our sales representative for configuration details.

- Method of Implementation (MOI) document and state file (280, 285, 480, 485, 2D5, 4D5, 2K5, 4K5) available for download on Agilent.com

www.agilent.com/find/ena-tdr_compliance
www.agilent.com/find/ena-tdr_ethernet-txrx


Universal Serial Bus 3.0 Specification Version 1.0
Agilent Method of Implementation (MOI) for USB 3.0 Connectors and Cable Assemblies Compliance Tests
Using Agilent E5071C ENA Network Analyzer Option TDR

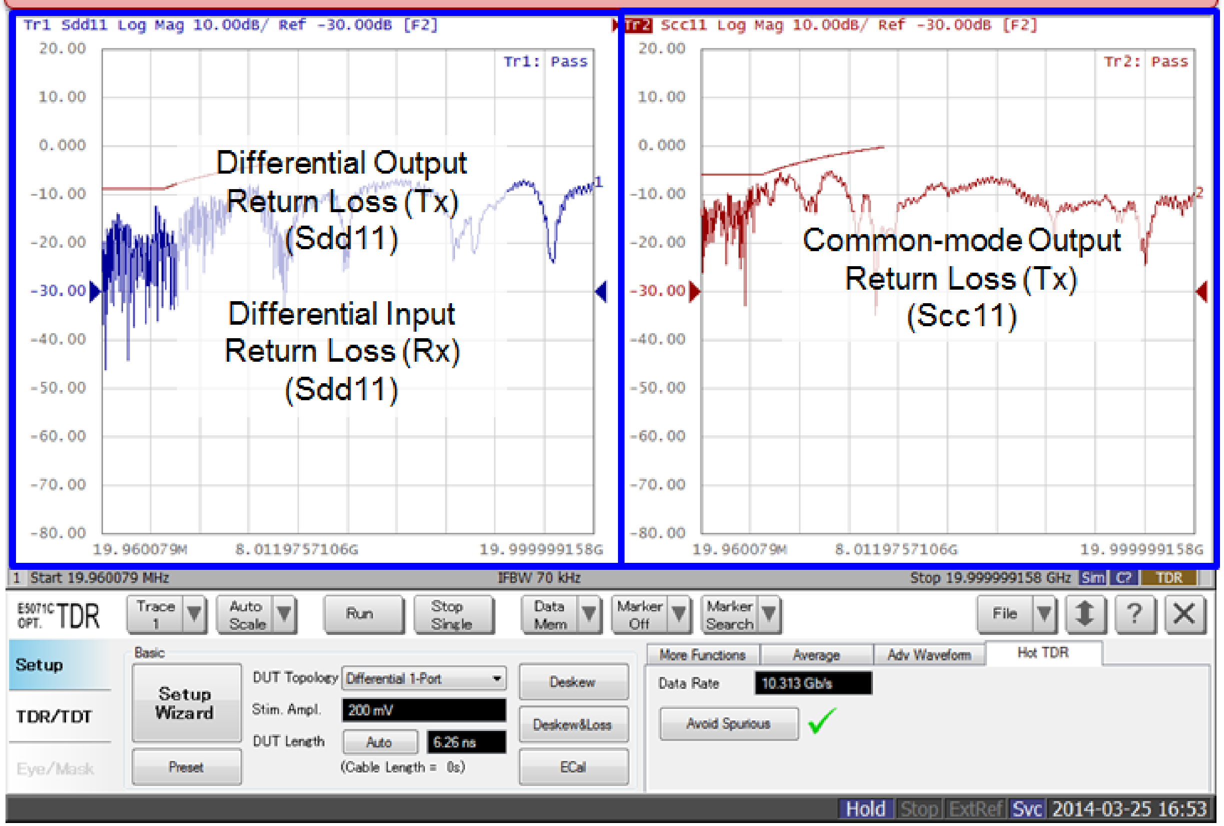
MOI
(Method of Implementation)
Step-by-step procedure on how to measure the specified parameters in the specification document using ENA Option TDR.

10GBASE-KR/40GBASE-KR4 Tx/Rx Test Solution

Measurement Parameters

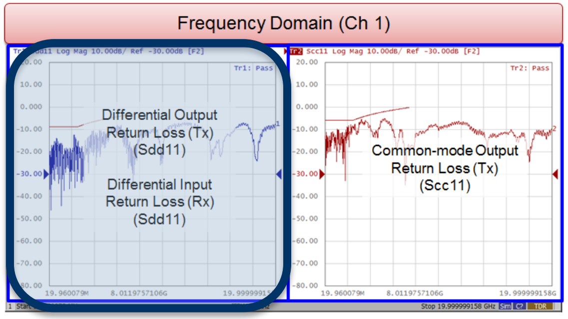
ENA Option TDR Compliance Testing Solution is one-box solution which provides return-loss characterization of Tx/Rx (frequency domain)

Frequency Domain (Ch 1)

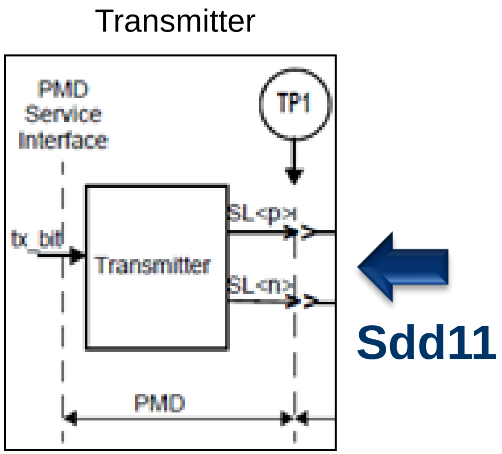


IEEE Std 802.3-2012 / UNH-IOL Clause 72

72.7.1.5 / 72.2.1 Differential Output Return Loss (Tx)



- Ratio of reflected voltage to incident voltage. Key parameter when evaluating impedance mismatch.
- When impedance match is poor, transmission signal quality is degraded due to multiple-reflection effects, leading to increase in bit error rate.



From 50 MHz to 7500 MHz, the differential return loss of the transmitter shall meet the equations. This output impedance requirement applies to all valid output levels. The reference impedance for differential return loss measurement shall be 100 Ώ.

$$ReturnLoss(f) \geq 9$$

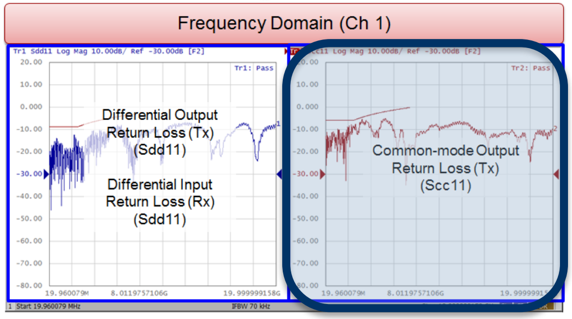
for 50 MHz ≤ f < 2500 MHz

$$ReturnLoss(f) \geq 9 - 12\log_{10}\left(\frac{f}{2500\text{ MHz}}\right)$$

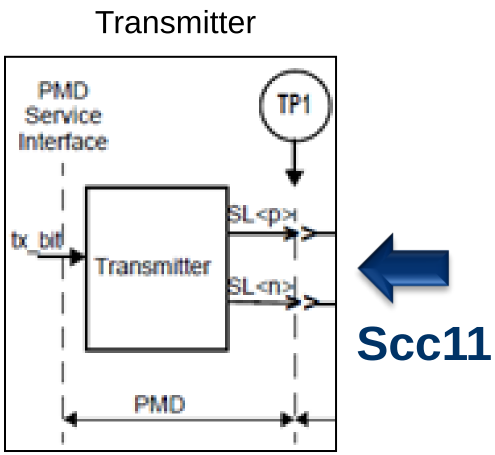
for 2500 MHz ≤ f ≤ 7500 MHz

IEEE Std 802.3-2012 / UNH-IOL Clause 72

72.7.1.6 / 72.2.2 Common-mode Output Return Loss (Tx)



- Ratio of reflected voltage to incident voltage. Key parameter when evaluating impedance mismatch.
- When impedance match is poor, transmission signal quality is degraded due to multiple-reflection effects, leading to increase in bit error rate.



The transmitter common-mode return loss shall meet the equations. The reference impedance for common-mode return loss measurement is 25 Ω.

$$ReturnLoss(f) \geq 6$$

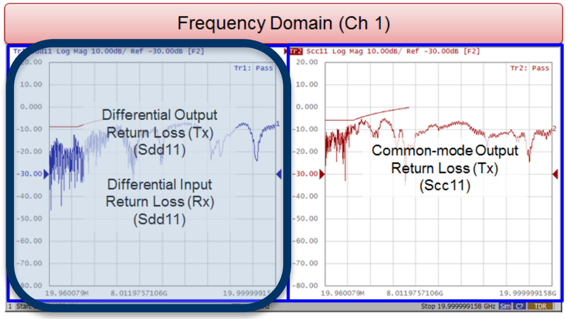
for 50 MHz $\leq f <$ 2500 MHz

$$ReturnLoss(f) \geq 6 - 12\log_{10}\left(\frac{f}{2500\ \text{MHz}}\right)$$

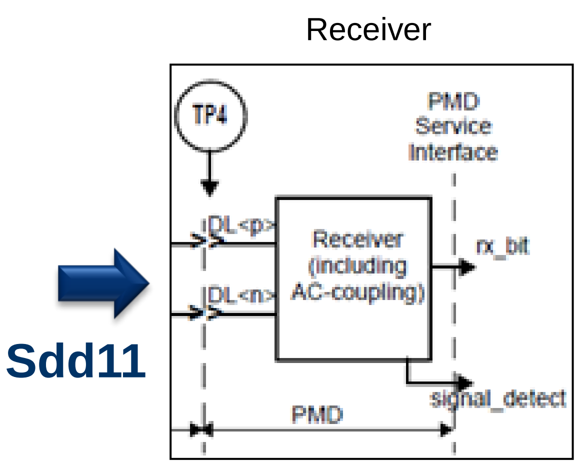
for 2500 MHz $\leq f \leq$ 7500 MHz

IEEE Std 802.3-2012 / UNH-IOL Clause 72

72.7.2.5 / 72.2.3 Differential Input Return Loss (Rx)



- Ratio of reflected voltage to incident voltage. Key parameter when evaluating impedance mismatch.
- When impedance match is poor, transmission signal quality is degraded due to multiple-reflection effects, leading to increase in bit error rate.



From 100 MHz to 7500 MHz, the differential return loss of the receiver shall be greater than or equal to equations. This return loss requirement applies at all valid input levels. The reference impedance for differential return loss measurement is 100 Ώ.

$$ReturnLoss(f) \geq 9$$

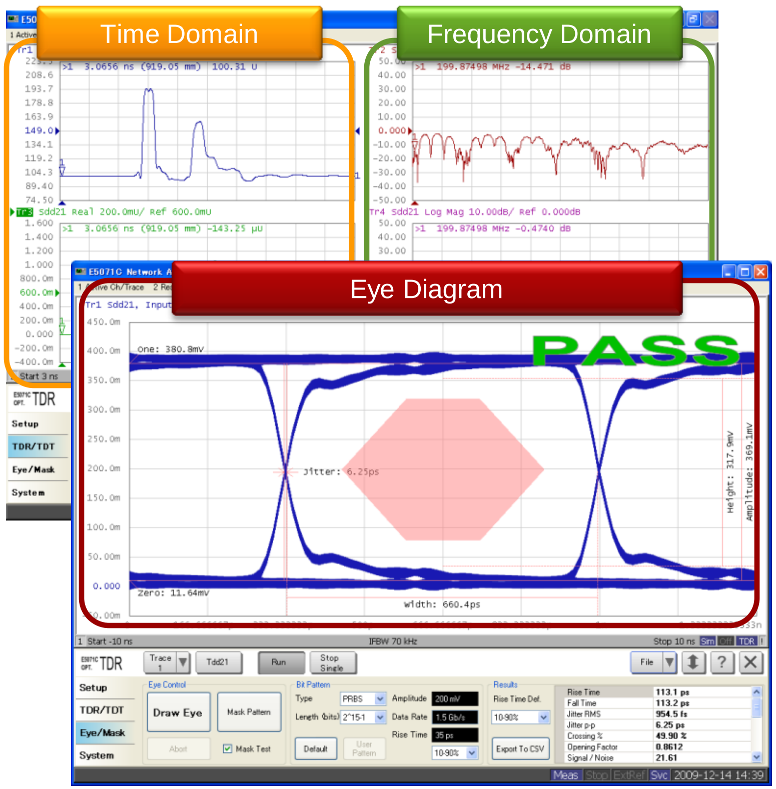
for 50 MHz ≤ f < 2500 MHz

$$ReturnLoss(f) \geq 9 - 12\log_{10}\left(\frac{f}{2500\ \text{MHz}}\right)$$

for 2500 MHz ≤ f ≤ 7500 MHz

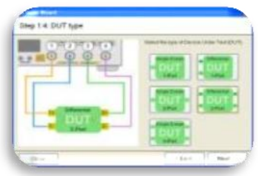
What is ENA Option TDR?

The ENA Option TDR is an application software embedded on the ENA, which provides an **one-box solution** for high speed serial interconnect analysis.

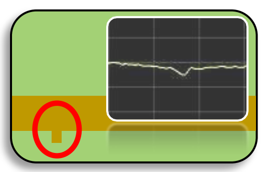


3 Breakthroughs

for Signal Integrity Design and Verification



Simple and Intuitive Operation



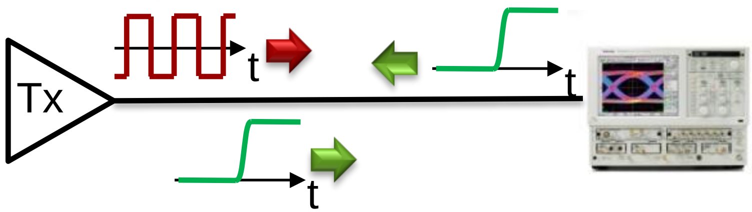
Fast and Accurate Measurements

ESD Robustness

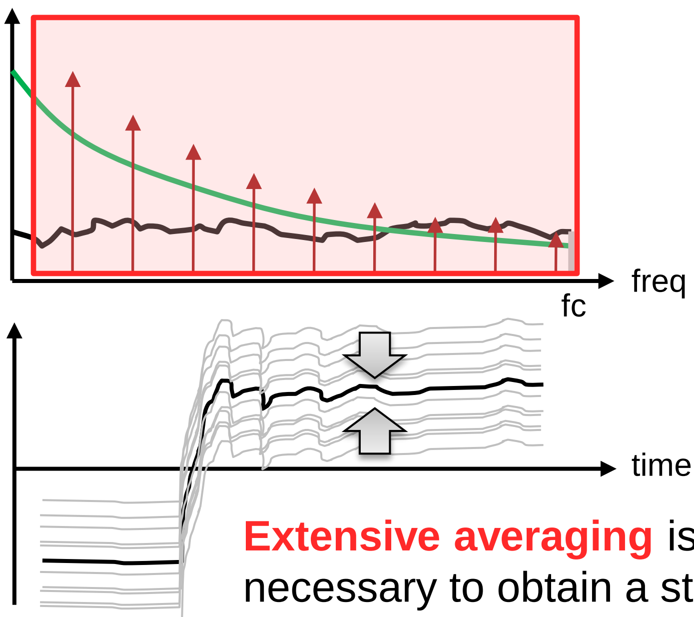
Advantage of ENA Option TDR for Hot TDR

Fast and Accurate Measurements

TDR Scopes

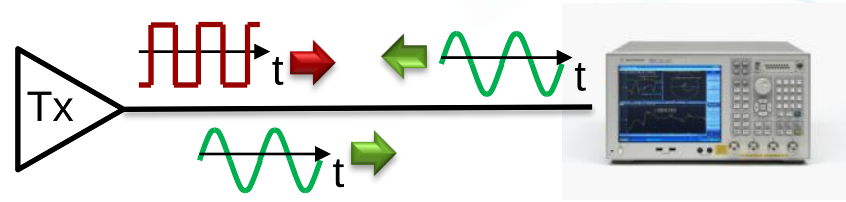


•**wideband receiver** captures all of the signal energy from the transmitter

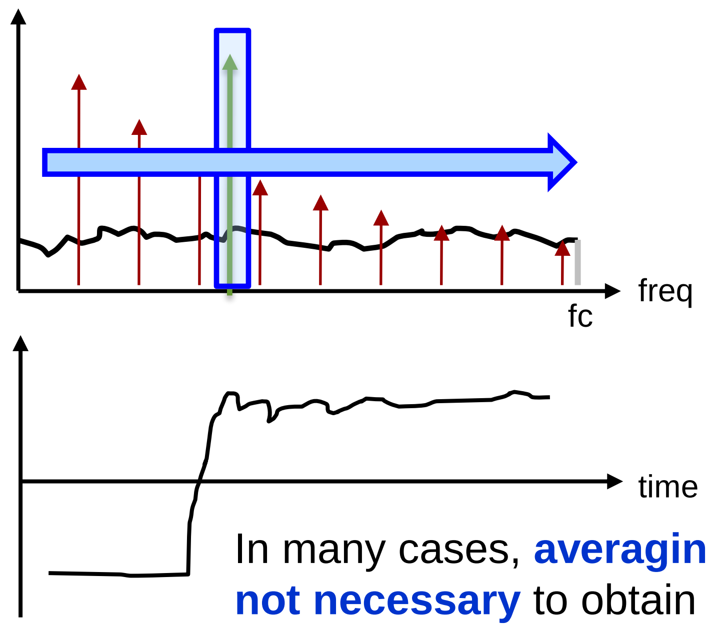


Extensive averaging is necessary to obtain a stable waveform.

ENA Option TDR



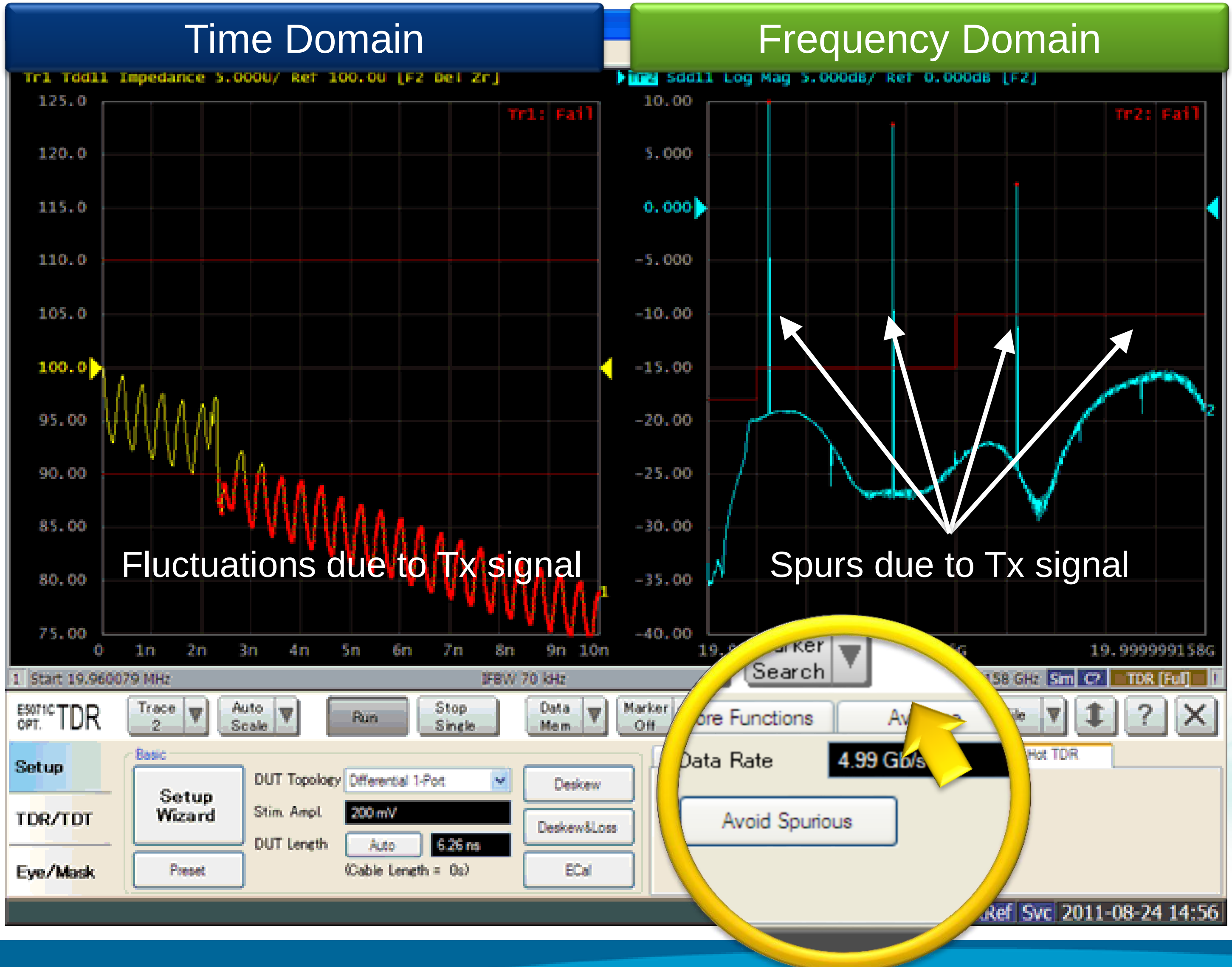
•**narrowband receiver** minimizes the effects of the data signal from the transmitter



In many cases, **averaging is not necessary** to obtain a stable waveform.

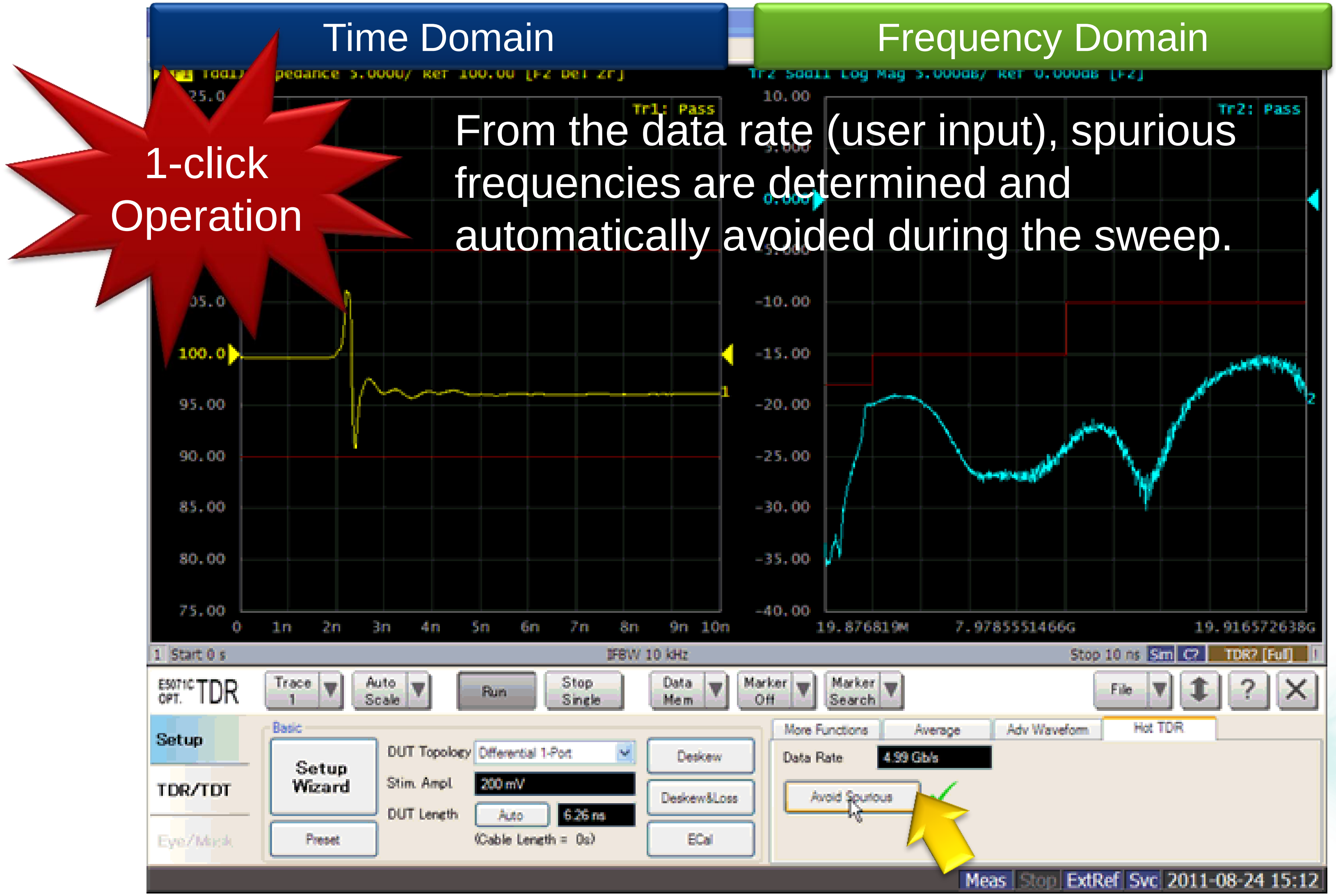
Hot TDR Measurements

Avoiding Errors from the Transmitter Signal



Hot TDR Measurements

Avoiding Errors from the Transmitter Signal



Advantages of ENA Option TDR for Hot TDR

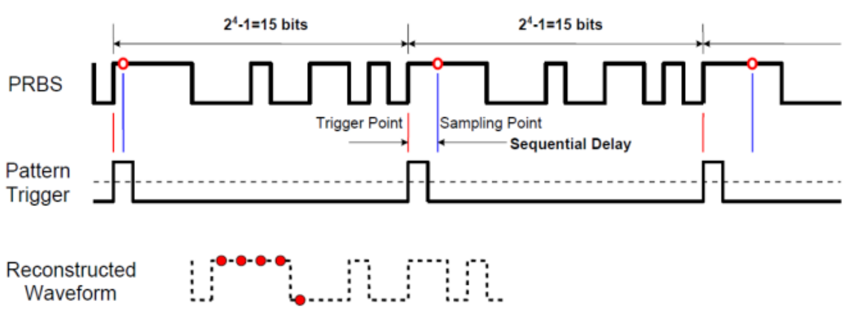
Simple and Intuitive Operation

TDR Scopes

The **TDR repetition rate** setting is utilized to avoid the effects of the Tx signal.

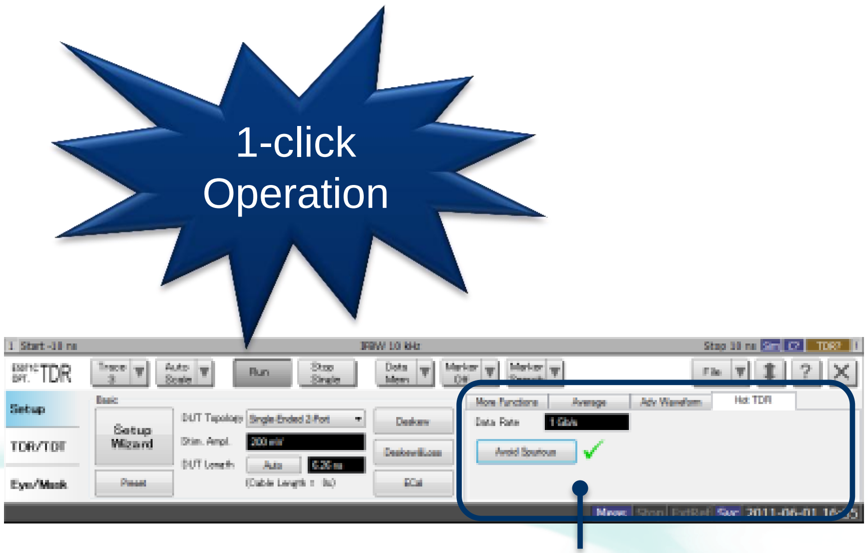
The ideal TDR repetition rate setting is unique to each DUT (as the ideal setting is related to the harmonic relationship of the rep rate and the Tx signaling rate).

The process for finding the ideal setting is usually best determined by **trial and error**.



ENA Option TDR

From the data rate (user input), spurious frequencies are determined and **automatically** avoided during the sweep.



1. Enter data rate
2. Click **[Avoid Spurious]**

ENA Option TDR Compliance Test Solution

Certified MOIs available at **www.agilent.com/find/ena-tdr_compliance**

Cable/Connector/Interconnect

- SuperSpeed USB: Time & Frequency
- HDMI: Frequency
- Serial ATA: Time & Frequency
- DisplayPort: Time & Frequency
- 100BASE-TX: Time & Frequency
- 10GBASE-T: Time & Frequency
- 10GBASE-KR/40GBASE-KR4: Time & Frequency
- MHL: Time & Frequency
- PCI Express
- BroadR-Reach*: Time & Frequency

Transmitter/Receiver (Hot TDR/Hot Return Loss)

- Serial ATA: Time & Frequency
- mipi alliance: Time & Frequency
- 10GBASE-KR/40GBASE-KR4: Frequency
- MHL: Time & Frequency
- Thunderbolt*: Time & Frequency

More Standards Currently Under Investigation

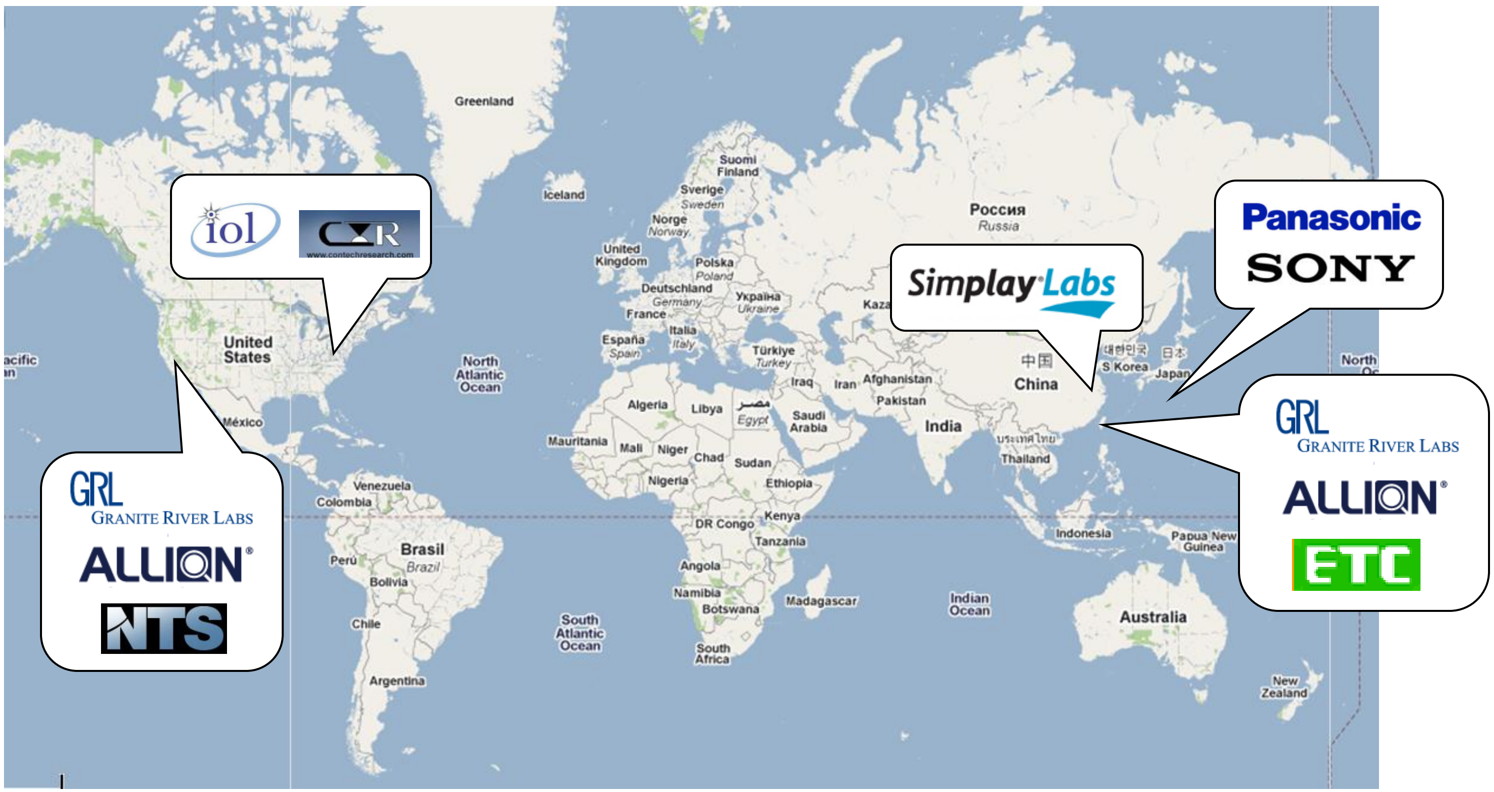
* For more detail about Thunderbolt and BroadR-Reach compliance test solution using the ENA Option TDR, contact Agilent sales representative.

ENA Option TDR Compliance Test Solution

Certified Test Centers using ENA Option TDR

Test Centers Support ENA Option TDR

ENA Option TDR is used world wide by certified test centers of USB, HDMI, DisplayPort, MHL, Thunderbolt and SATA.



Agilent Technologies

Ethernet Cable Compliance Test Solution

Summary

ENA Option TDR Compliance Testing Solution is ….

- ***One-box solution*** which provides complete characterization of high speed digital interconnects (time domain, frequency domain, eye diagram)
- Similar look-and-feel to traditional TDR scopes, providing ***simple and intuitive operation*** even for users unfamiliar to VNAs and S-parameters
- ***Fast and Accurate*** output/input impedance measurements of transmitter/receiver under operating condition **(Hot TDR / Hot Return Loss)**
- Adopted by test labs worldwide

Questions?

Agilent VNA Solutions

Performance

PNA-X, NVNA

Industry-leading performance
10 M to 13.5/26.5/43.5/50/67 GHz
Banded mm-wave to 2 THz

PNA

Performance VNA
10 M to 20, 40, 50, 67, 110 GHz
Banded mm-wave to 2 THz

PNA-L

World's most capable value VNA
300 kHz to 6, 13.5, 20 GHz
10 MHz to 40, 50 GHz

Mm-wave solutions

Up to 2 THz

PNA-X receiver

8530A replacement

PNA Series

E5072A

Best performance ENA
30 kHz to 4.5, 8.5 GHz

E5071C

World's most popular economy VNA
9 kHz to 4.5, 8.5 GHz
300 kHz to 20.0 GHz

E5061B

NA + ZA in one-box
5 Hz to 3 GHz
Low cost RF VNA
100 k to 1.5/3.0 GHz

ENA Series

FieldFox

Handheld RF Analyzer
5 Hz to 4/6 GHz

What is ENA Option TDR?

[Video]

Agilent ENA Option TDR

Changing the world of Time Domain Reflectometry (TDR) Measurements

- www.youtube.com/watch?v=hwQNlyyJ5hI&list=UUAJAjd97CfnCehC4jZAfkxQ&index=20&feature=plcp
- www.agilent.com/find/ena-tdr

Additional Resources

- **ENA Option TDR Reference Material**

www.agilent.com/find/ena-tdr

- Technical Overview (5990-5237EN)
- Application Notes
  - Correlation between TDR oscilloscope and VNA generated time domain waveform (5990-5238EN)
  - Comparison of Measurement Performance between Vector Network Analyzer and TDR Oscilloscope (5990-5446EN)
  - Effective Hot TDR Measurements of Active Devices Using ENA Option TDR (5990-9676EN)
  - Measurement Uncertainty of VNA Based TDR/TDT Measurement (5990-8406EN)
  - Accuracy Verification of Agilent's ENA Option TDR Time Domain Measurement using a NIST Traceable Standard (5990-5728EN)
- **Method of Implementation (MOI) for High Speed Digital Standards**

www.agilent.com/find/ena-tdr_compliance