Agilent Technologies

10GBASE-T Ethernet Cable Test

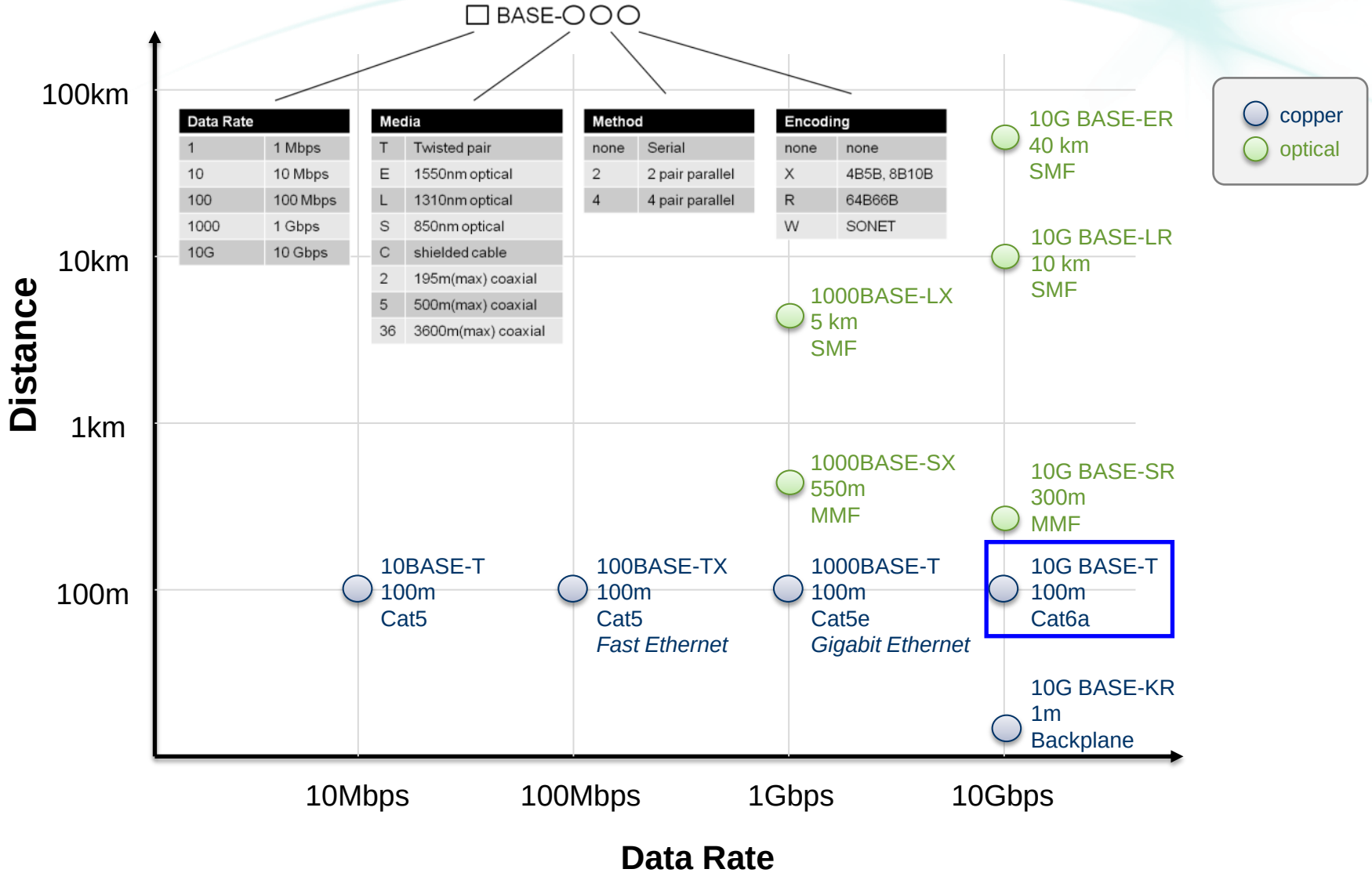
Test Solution Overview Using the Agilent E5071C ENA Option TDR

Last Update 2013/05/21 (TH)

Purpose

- This slide will show how to make measurements of 10GBASE-T Ethernet Cable Tests by using the Agilent E5071C ENA Option TDR.

Ethernet Data Rate and Distance



Ethernet Logo Certification Program

Standard	Standard Body
	USB-IF
	PCI-SIG
	SATA-IO
Ethernet	N/A

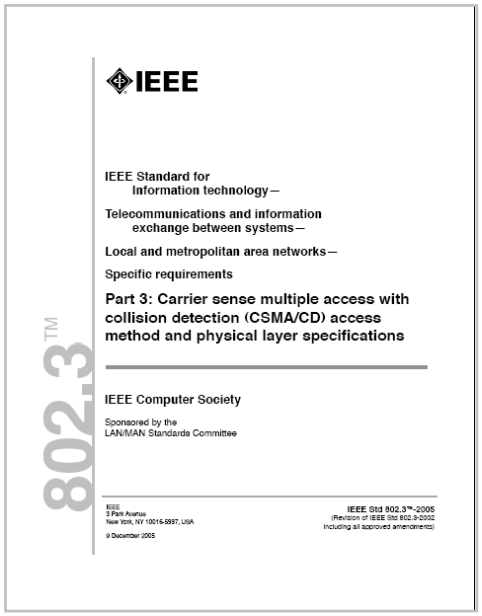
No logo certification program is available for Ethernet (100BASE-TX / 1000BASE-T).

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

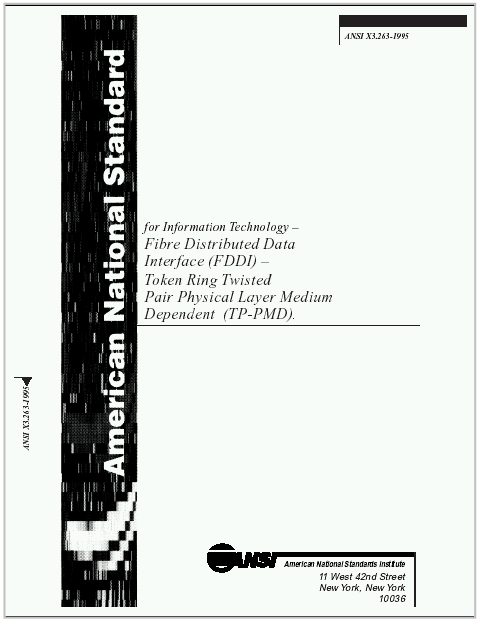
Ethernet Specifications and Electrical Test Procedure

Specifications

IEEE Std 802.3™-2008

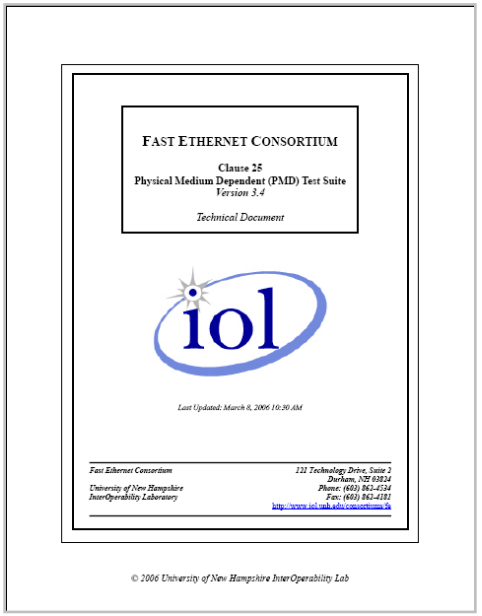


ANSI X3.263-1995
Fiber Distributed Interface -Token Ring Twisted Pair Physical Layer Medium Dependent



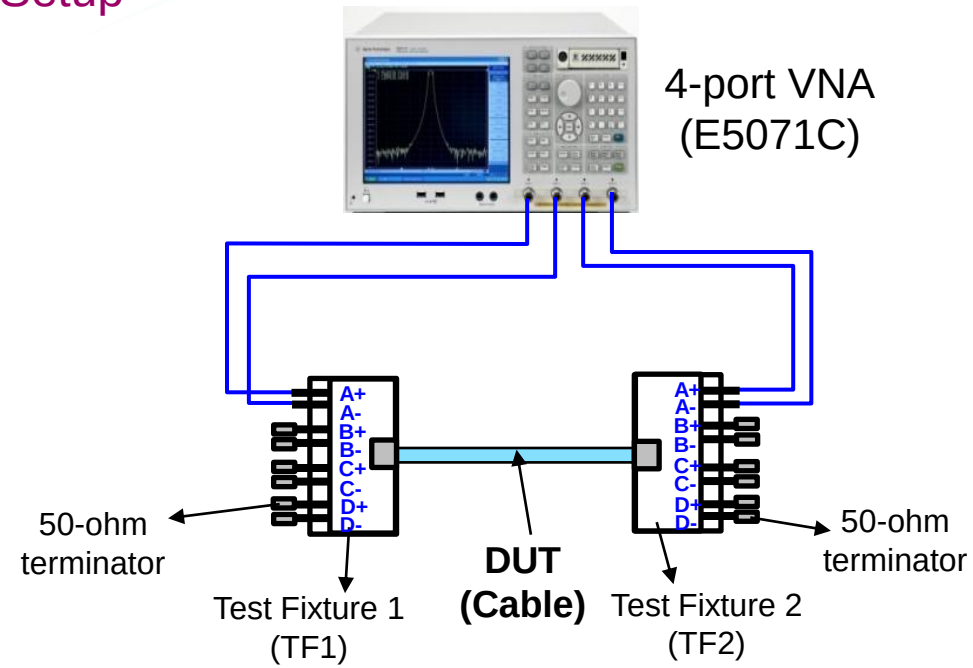
Test Procedure

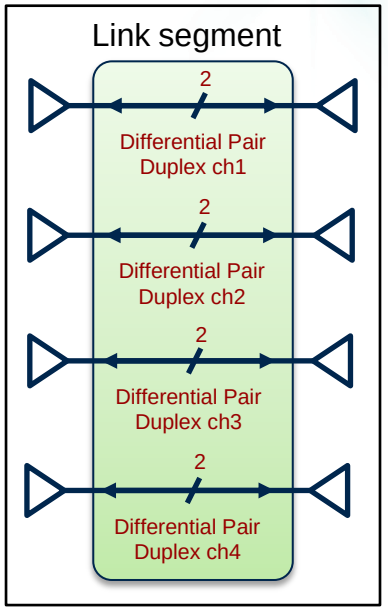
Test Suite for Ethernet
University of New Hampshire InterOperability Laboratory (UNH-IOL)



10GBASE-T Ethernet Cable Test Solution

Test Setup





•10GBASE-T is designed to operate over ISO/IEC 11801 Class E or Class F four-pair balanced cabling.
•Each of the four pairs supports an effective data rate of 2,500 Mbps in each direction simultaneously.
•The term “link segment” refers to four duplex channels. Specifications for a link segment apply equally to each of the four duplex channels.

10GBASE-T Link Segment Electrical Test Item List

Specification	Test Items
IEEE Std 802.3™-2008	[55.7.2.1] Insertion loss
	[55.7.2.2] Differential characteristic impedance
	[55.7.2.3] Return loss
	[55.7.2.4] Coupling parameters between duplex channels comprising one link segment
	[55.7.2.4.1] Differential near-end crosstalk (NEXT)
	[55.7.2.4.2] Multiple disturber near-end crosstalk (MDNEXT) loss
	[55.7.2.4.4] Equal level far-end crosstalk (ELFEXT)
	[55.7.2.4.5] Multiple disturber equal level far-end crosstalk (MDELFEXT)
	[55.7.2.5] Maximum link delay
	[55.7.2.6] Link delay skew

10GBASE-T Ethernet Cable Test Solution

Solution Overview

•10GBASE-T Ethernet cable testing requires parametric measurements in both time and frequency domains.

Time Domain
•Differential Characteristic Impedance

Frequency Domain
•Insertion Loss
•Return Loss
•Near-end Crosstalk (NEXT)
•Multiple Disturber NEXT (MDNEXT)
•Equal Level Far-end Crosstalk (ELFEXT)
•Multiple Disturber ELFEXT (MDELFEXT)
•Maximum Link Delay
•Link Delay Skew

Traditional Solution

TDR Scope

Vector Network Analyzer (VNA)

New Solution

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

One-box Solution !!

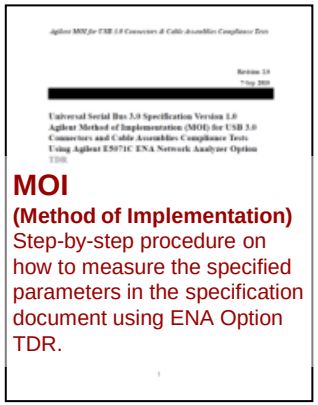
10GBASE-T Ethernet Cable Test Solution

Configuration

- ENA Mainframe (*1)
  - E5071C-440/445: 4-port, 9 kHz/100 kHz to 4.5 GHz
  - E5071C-460/465: 4-port, 9 kHz/100 kHz to 6.5 GHz
  - E5071C-480/485: 4-port, 9 kHz/100 kHz to 8.5 GHz
  - E5071C-4D5: 4-port, 300 kHz to 14 GHz
  - E5071C-4K5: 4-port, 300 kHz to 20 GHz
- Enhanced Time Domain Analysis Option (E5071C-TDR)
- ECal Module (N4431B / N4433A)

*1: Select one of frequency options. Note 10GBASE-T Ethernet cable tests require frequency up to 500 MHz.
*2: The list above includes the major equipment required. Please contact our sales representative for configuration details.

- Method of Implementation (MOI) document and state files (44x/46x/48x or 4D5/4K5) available for download on Agilent.com



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

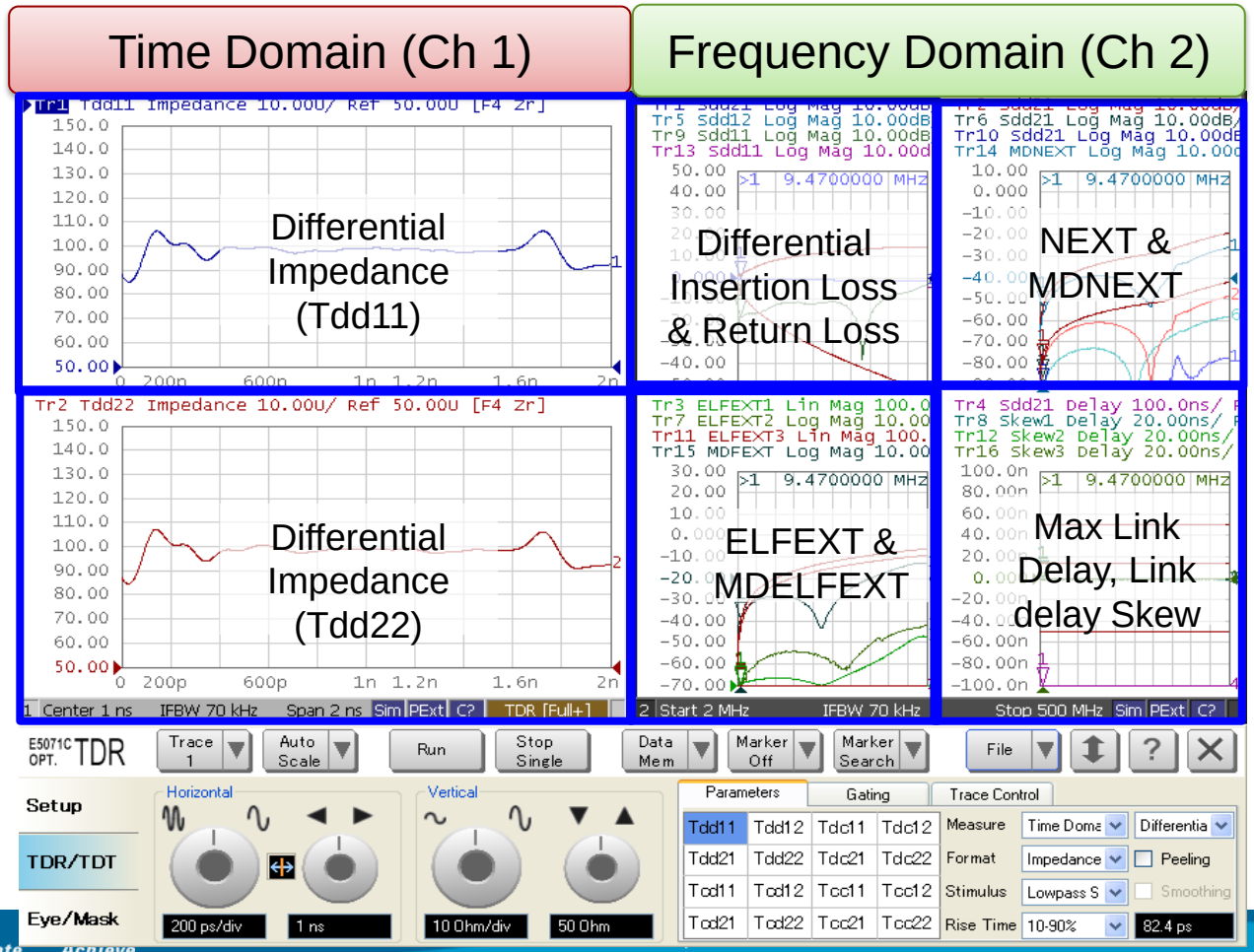
Test Fixtures

U7237A (2/ea)
10GBASE-T Transmitter Electrical Test Fixture

10GBASE-T Ethernet Cable Test Solution

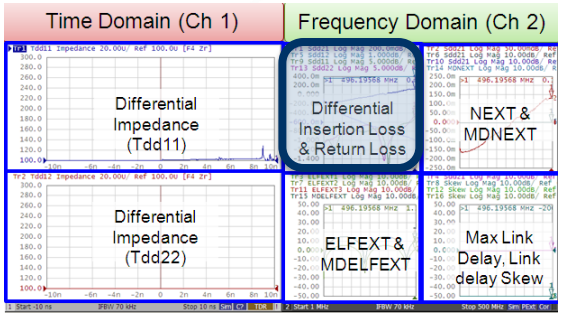
Measurement Parameters

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

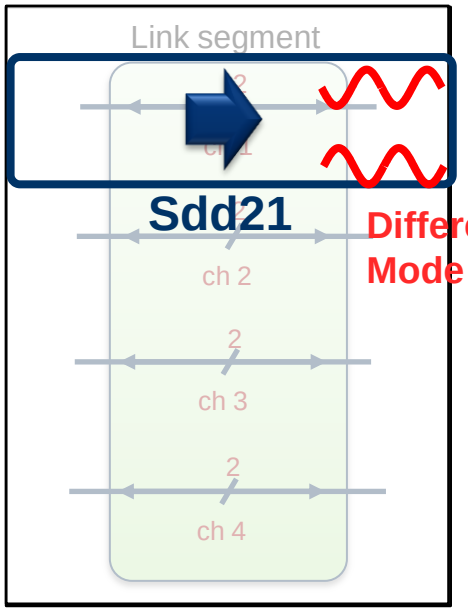


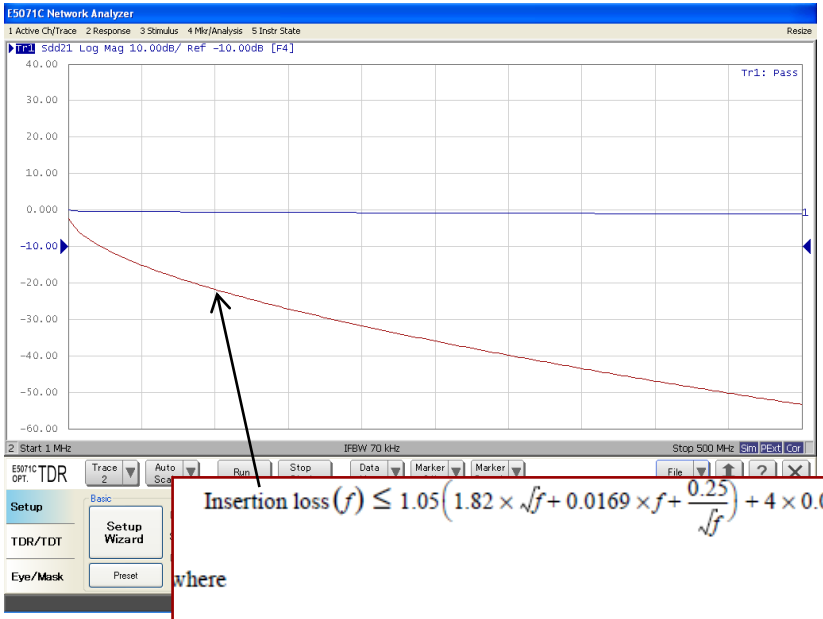
IEEE Std 802.3-2008

55.7.2.1 Insertion Loss



- Insertion loss is the loss through the differential pairs.
- Has important consequences for the rise time degradation and the maximum supportable bandwidth.





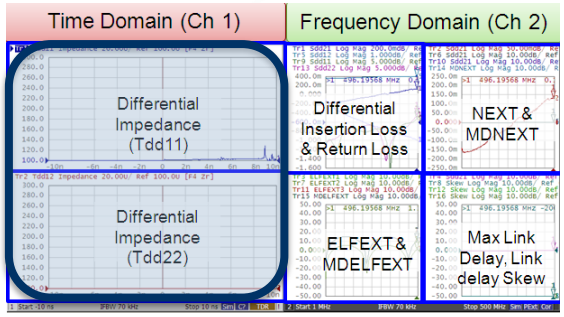
$$\text{Insertion loss}(f) \le 1.05\left(1.82 \times \sqrt{f} + 0.0169 \times f + \frac{0.25}{\sqrt{f}}\right) + 4 \times 0.02 \times \sqrt{f} \quad \text{(dB)}$$

where

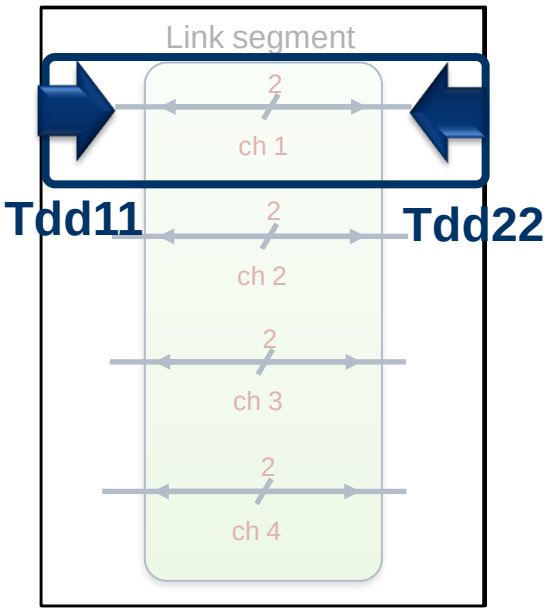
f is the frequency in MHz; $1 \le f \le 500$

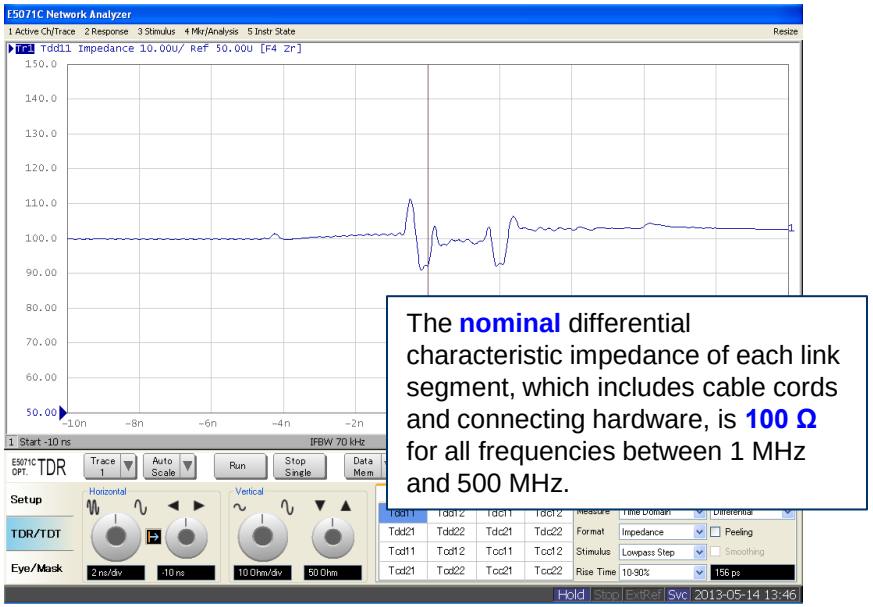
IEEE Std 802.3-2008

55.7.2.2 Differential 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

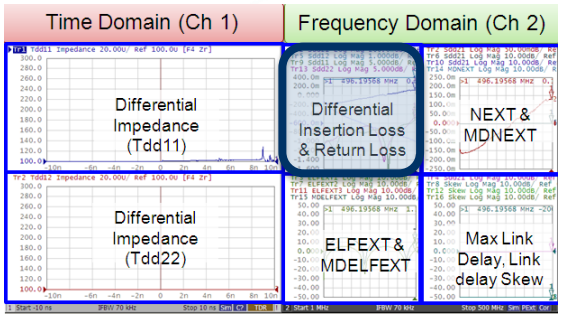




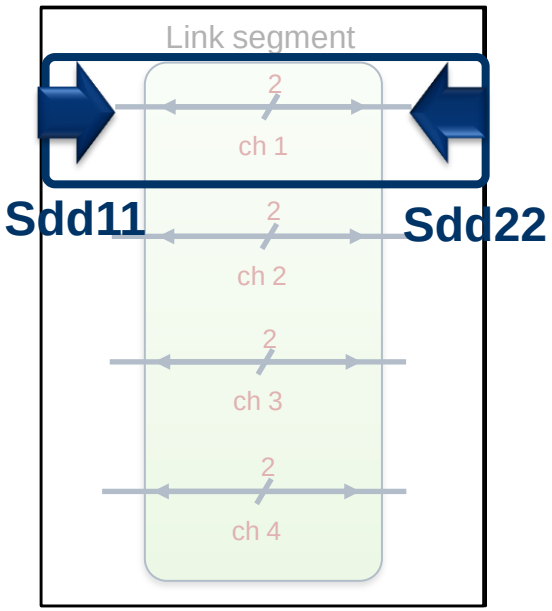
The **nominal** differential characteristic impedance of each link segment, which includes cable cords and connecting hardware, is **100 Ω** for all frequencies between 1 MHz and 500 MHz.

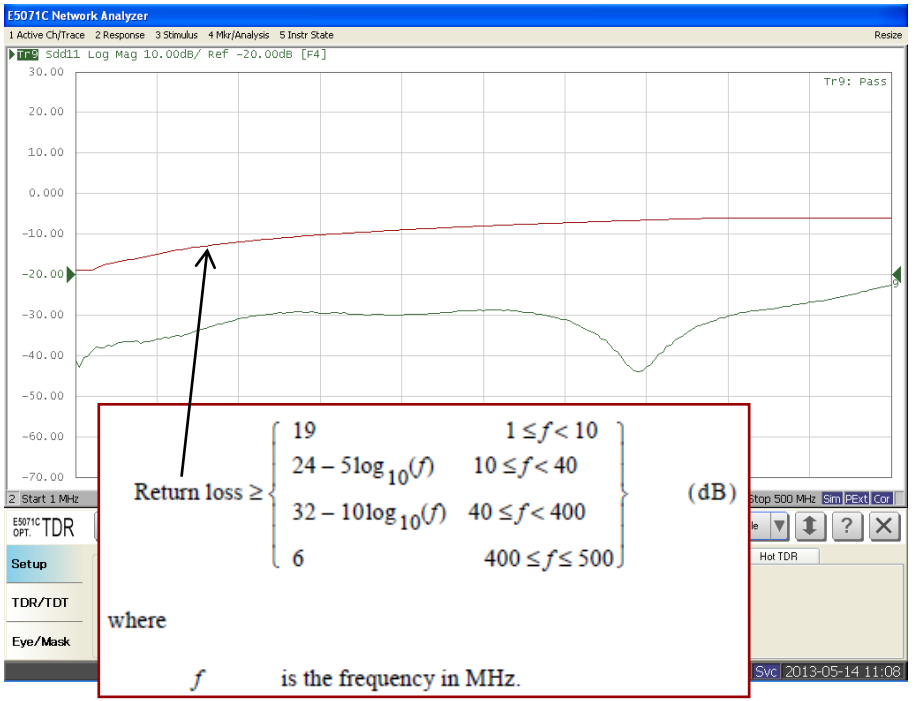
IEEE Std 802.3-2008

55.7.2.3 Return Loss



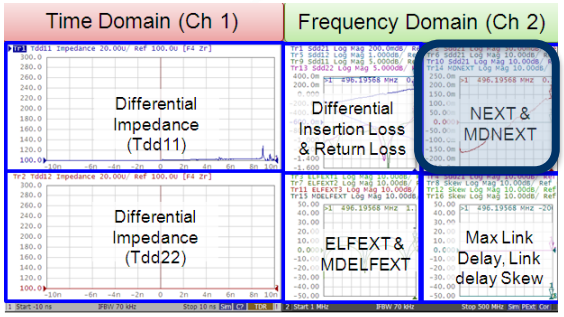
- Ratio of reflected voltage to incident voltage. Key parameter when evaluating impedance mismatch.
- When impedance match is poor, transmission signal quality is degraded due to multiple-reflection effects, leading to increase in bit error rate.



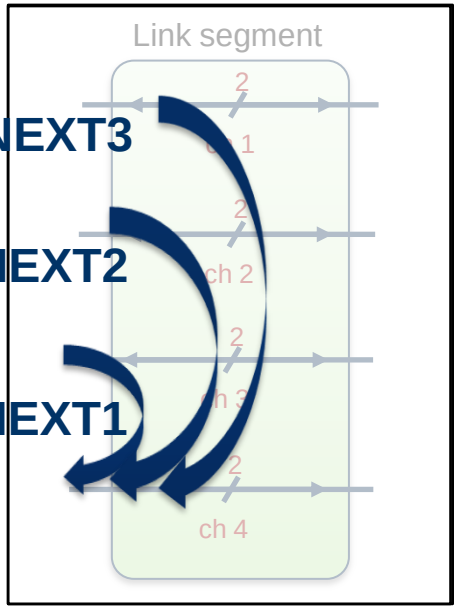


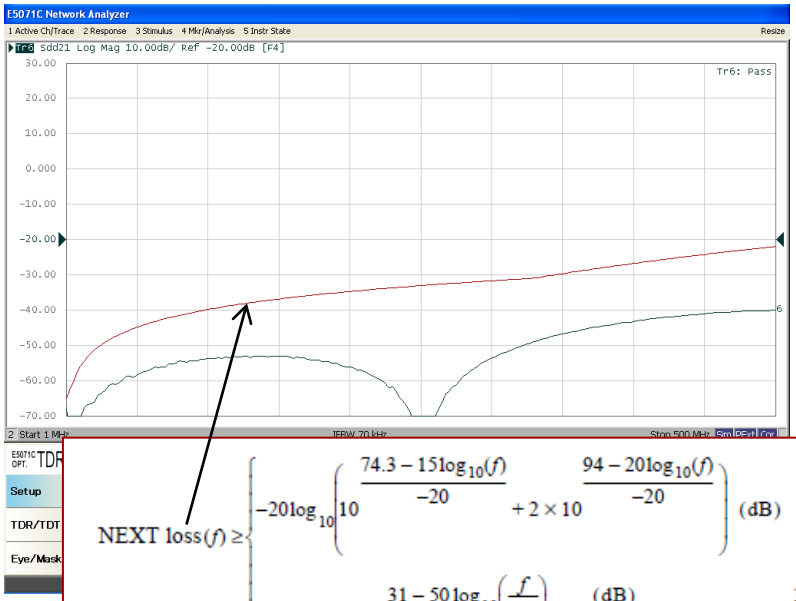
IEEE Std 802.3-2008

55.7.2.4.1 Differential Near-end Crosstalk (NEXT)



- Measure of the coupling between the differential pairs.
- The crosstalk between a duplex channel and the three adjacent disturbers shall meet specification.





$$\text{NEXT loss}(f) \geq \begin{cases} -20\log_{10}\left(10^{\frac{74.3-15\log_{10}(f)}{-20}} + 2\times 10^{\frac{94-20\log_{10}(f)}{-20}}\right) \text{ (dB)} & 1 \leq f < 330 \\ 31 - 50\log_{10}\left(\frac{f}{330}\right) \text{ (dB)} & 330 \leq f \leq 500 \end{cases}$$

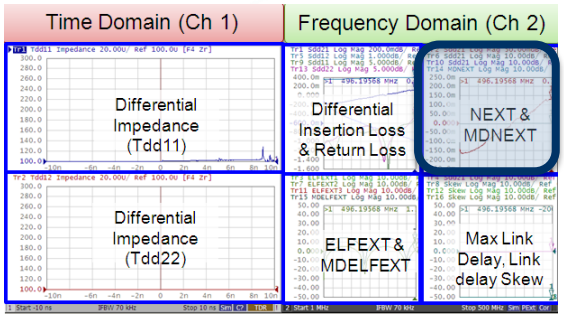
where

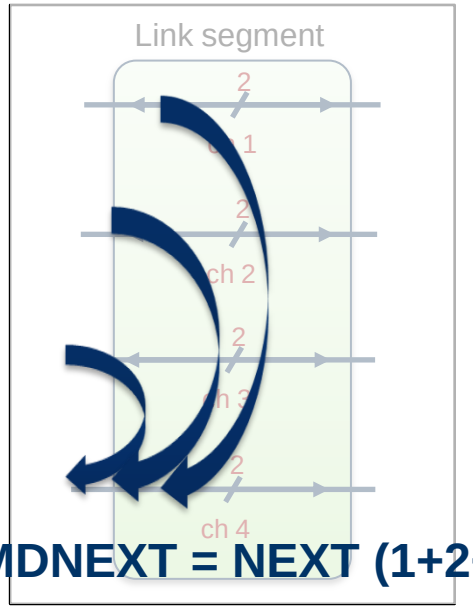
f is the frequency in MHz.

Note: Calculation that result in NEXT loss values greater than 65 dB shall revert to a requirement of 65 dB minimum.

IEEE Std 802.3-2008

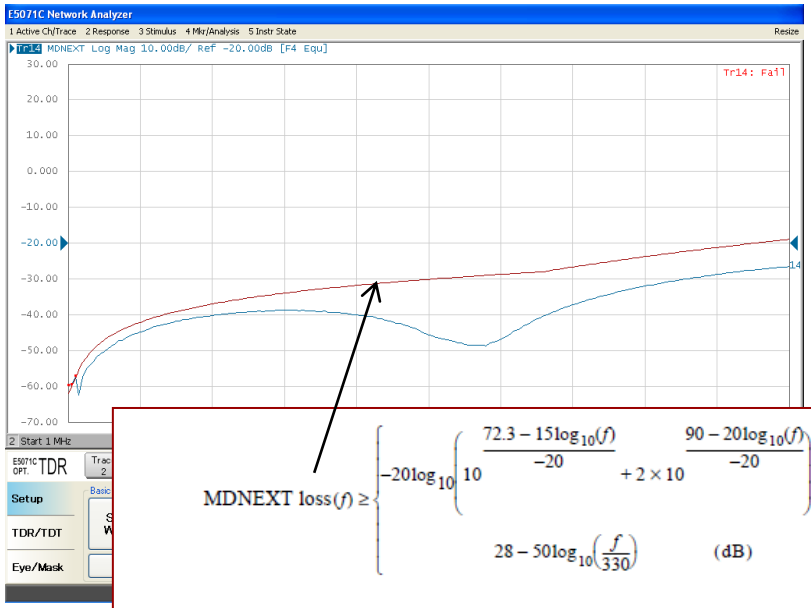
55.7.2.4.2 Multiple Disturber Near-end Crosstalk (MDNEXT)





MDNEXT = NEXT (1+2+3)

- To ensure the total NEXT coupled into a data charring channel is limited.
- MDNEXT loss is specified as the power sum of the individual NEXT losses.



$$\text{MDNEXT loss}(f) \geq \begin{cases} -20\log_{10}\left(10^{\frac{72.3-15\log_{10}(f)}{-20}} + 2\times 10^{\frac{90-20\log_{10}(f)}{-20}}\right) \text{ (dB)} & 1 \leq f < 330 \\ 28 - 50\log_{10}\left(\frac{f}{330}\right) \text{ (dB)} & 330 \leq f \leq 500 \end{cases}$$

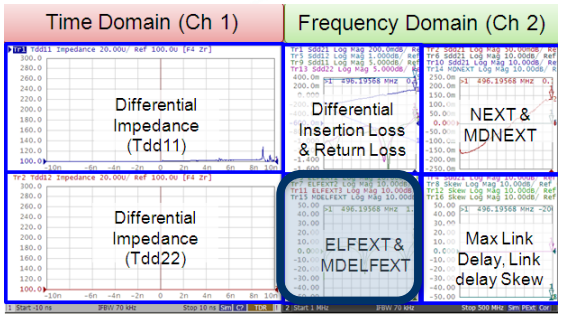
where

f is the frequency in MHz.

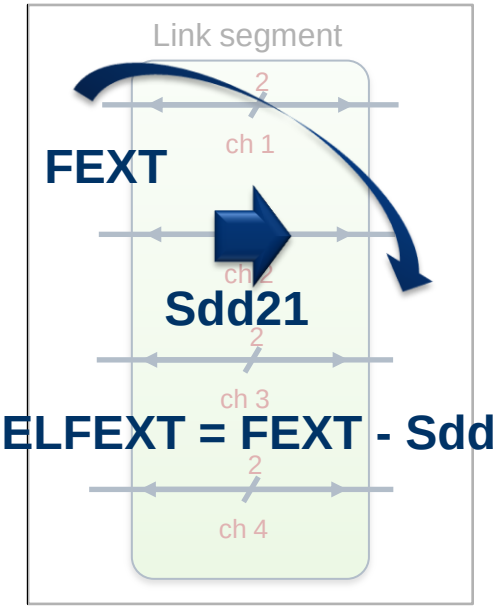
Note: Calculation that result in PS NEXT loss values greater than 62 dB shall revert to a requirement of 62 dB minimum.

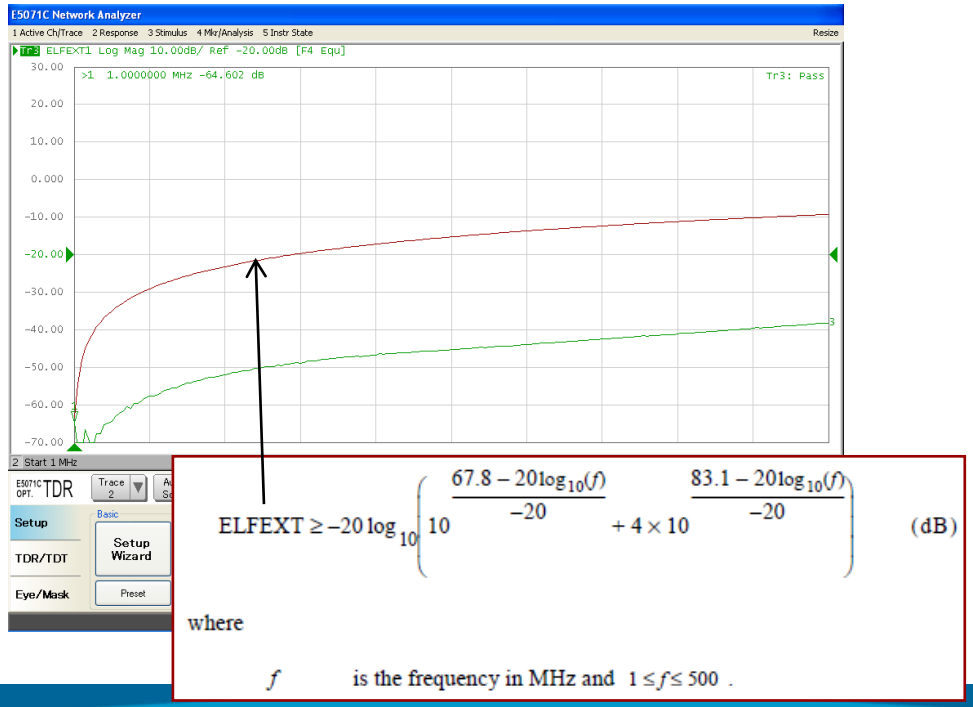
IEEE Std 802.3-2008

55.7.2.4.4 Equal Level Far-end Crosstalk (ELFEXT)



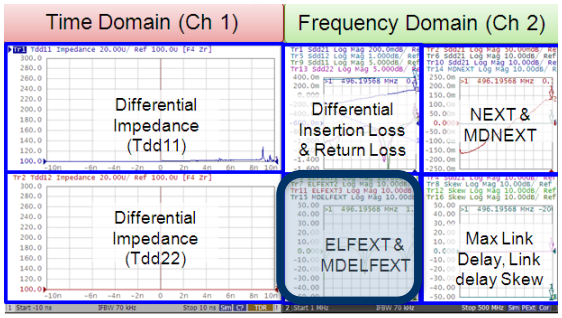
- Far-end crosstalk (FEXT) is crosstalk that appears at the far end of a duplex channel (disturbed channel), which is coupled from another duplex channel (disturbing channel).
- The ELFEXT is equal to FEXT minus the insertion loss of the disturbed line.



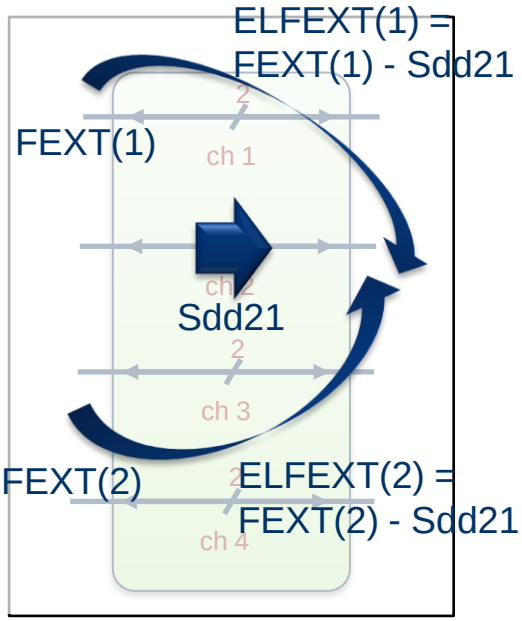


IEEE Std 802.3-2008

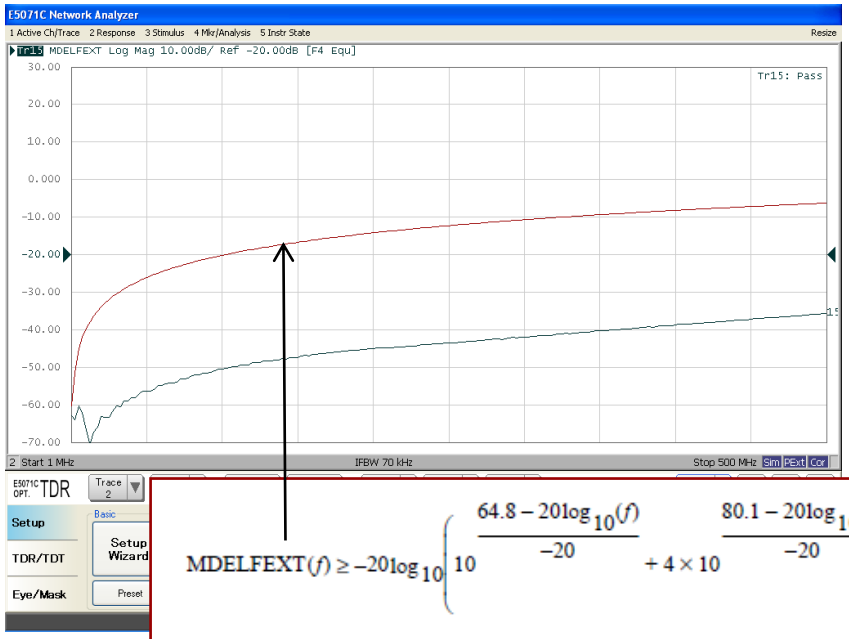
55.7.2.4.5 Multiple Disturber Equal Level Far-end Crosstalk (MDELFEXT)



- To ensure the total FEXT coupled into a data charring channel is limited.
- MDELFEXT loss is specified as the power sum of the individual ELFEXT disturbers.



MDELFEXT = ELFEXT(1+2+3)



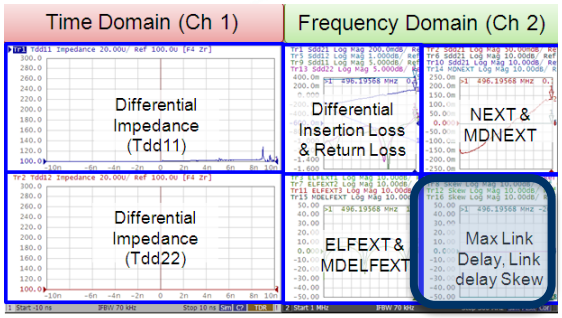
$$MDELFEXT(f) \geq -20\log_{10}\left(10^{\frac{64.8-20\log_{10}(f)}{-20}} + 4\times 10^{\frac{80.1-20\log_{10}(f)}{-20}}\right) \quad (dB)$$

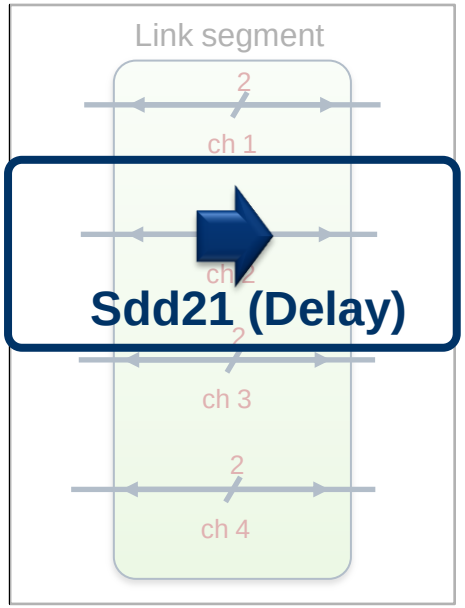
where

f is the frequency $1 \leq f \leq 500$.

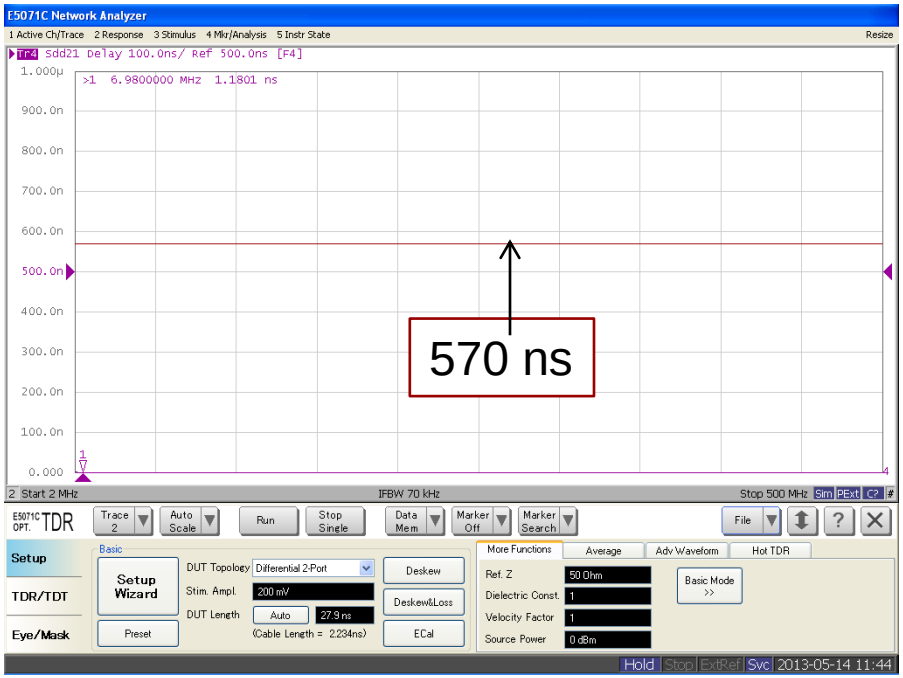
IEEE Std 802.3-2008

55.7.2.5 Maximum Link Delay



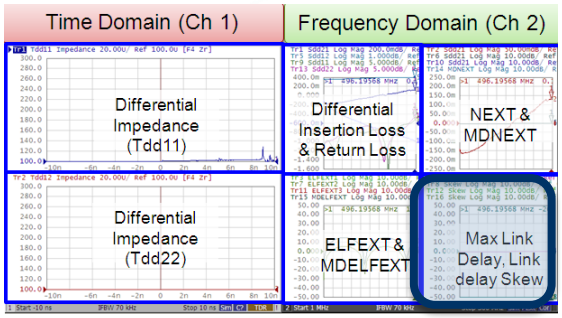


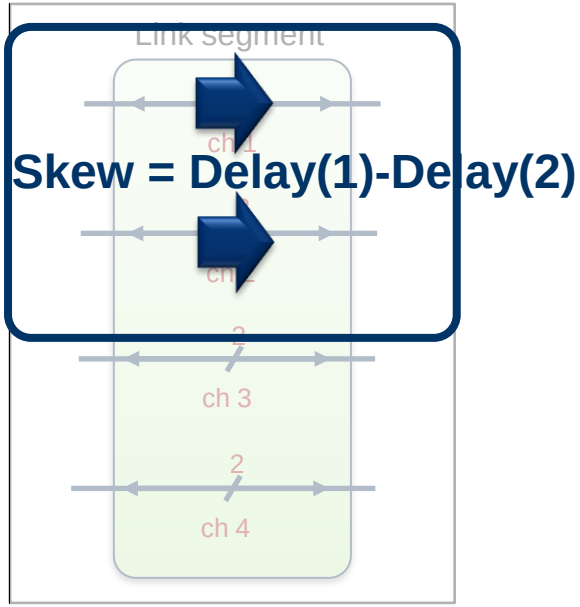
- The propagation delay of a link segment shall not exceed 570 ns at all frequencies between 2 MHz and 500 MHz.



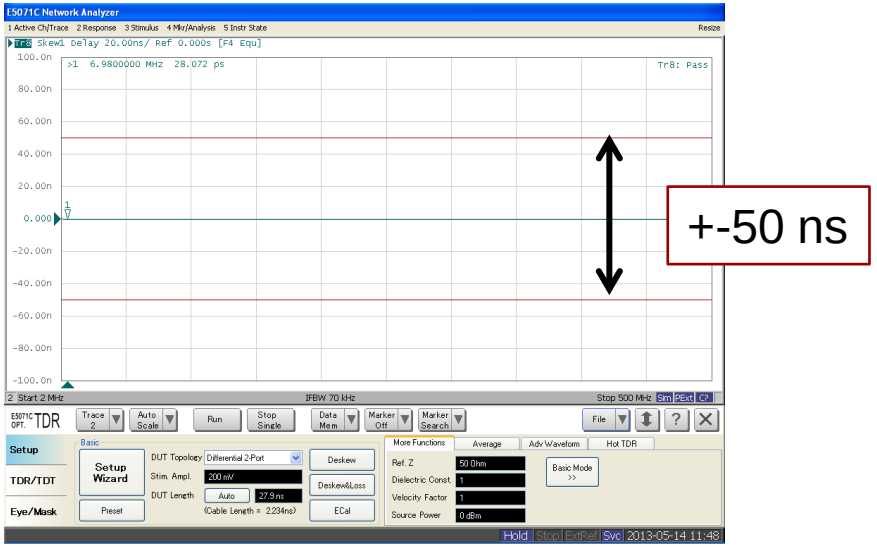
IEEE Std 802.3-2008

55.7.2.6 Link Delay Skew





- The difference in propagation delay (or skew) between all duplex channel pair combinations of a link segment shall meet requirements within 50 ns for 2 MHz to 500 MHz.
- Pair to pair skew can lead to a multilane signal to arrive at the receiver at different times, this degrades the ability of a receiver.



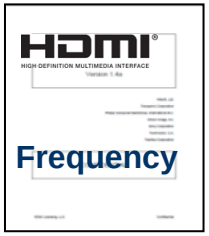
- If is a further functional requirement that, once installed, the skew between any two of the four duplex channels due to environmental conditions shall not vary more than 10 ns.

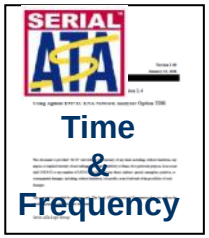
ENA Option TDR Compliance Test Solution

Certified MOIs

Compliance test solutions (i.e. Certified MOIs) with the ENA Option TDR are available at:
www.agilent.com/find/ena-tdr_compliance

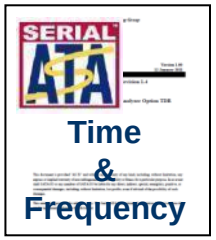
Cable / Connector





More Standards Currently Under Investigation

Transmitter/Receiver (Hot TDR)



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, and SATA

Ethernet Cable Compliance Test Solution
Summary

ENA Option TDR Cable/Connector 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

•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

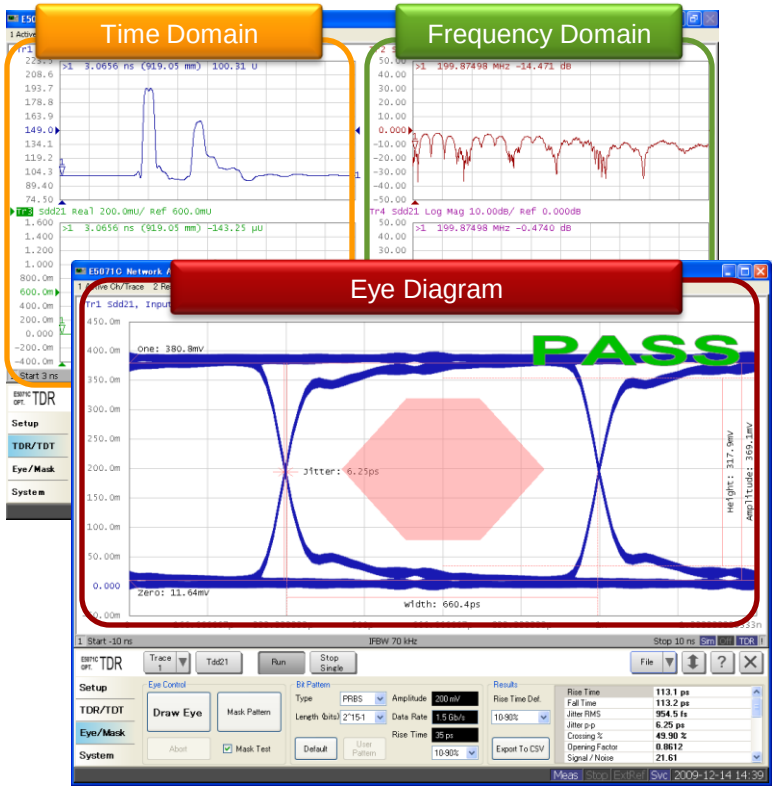
E5061B
NA + ZA in one-box
5 Hz to 3 GHz
Low cost RF VNA
100 k to 1.5/3.0 GHz

ENA Series

FieldFox
Handheld RF Analyzer
5 Hz to 4/6 GHz

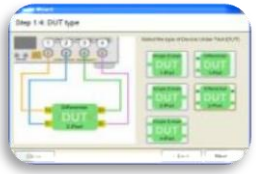
What is ENA Option TDR?

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

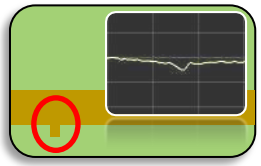


3 Breakthroughs

for Signal Integrity Design and Verification



Simple and Intuitive Operation



Fast and Accurate Measurements

ESD Robustness

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