InfiniBand Trade Association

Anritsu / Keysight

Method Of Implementation

Active Time Domain Testing For EDR Active Cables

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Acknowledgements

This document would not have been possible if not for contributions made by so many members of the InfiniBand Compliance & Interoperability Working Group and Electromechanical Working Group. Their generous inputs and tireless efforts were instrumental during Plugfest events and the development of this document.

Objective

The objective of the Active Time Domain (ATD) test is verify Active Cable compliance under stressed signal conditions as defined by the InfiniBand Architecture Specifications using test equipment. The performance of the Active Cables is tested in terms of BER and eye parameters. This Method Of Implementation (MOI) contains information relevant to the ATD calibration and testing performed at Plugfest events during which designers of Active Cables participate in the interoperability and compliance testing of their products.

Glossary

This section provides definitions of the terminology used throughout this document. The reference diagram in Figure 1 is a considerably simplified representation of the ATD test system presented in this document, illustrating several terms defined in the glossary.

AOC	Active-Optical Cable assembly. Cable assemblies that use fiber–optic transceivers and fiber-optic interconnects to transmit high-speed serial data such as InfiniBand and Ethernet.
ATD	Active Time-Domain testing. A test methodology for active cable assemblies where time-domain parameters such as jitter, eye-height and eye-width are measured on a stressed victim signal.
Cross-Talk	The phenomena of a signal transmitted on one channel that couples energy onto an adjacent channel, causing an undesirable effect.
Co-Propagating Input Aggressors	Adjacent channels driven from the **input** side of the test system, propagating in the **same** direction as the victim channel; imposing crosstalk energy onto the victim channel at the **input** side of the test system.
Co-Propagating Output Aggressors	Adjacent channels driven from the **input** side of the test system, propagating in the **same** direction as the victim channel; imposing crosstalk energy onto the victim channel at the **output** side of the test system.
Counter-Propagating Input Aggressors	Adjacent channels driven from the **output** side of the test system, propagating in the **opposite** direction of the victim channel; imposing crosstalk energy onto the victim channel at the **input** side of the test system.
Counter-Propagating Output Aggressors	Adjacent channels driven from the **output** side of the test system, propagating in the **opposite** direction of the victim channel; imposing crosstalk energy onto the victim channel at the **output** side of the test system.
FEXT (Far-End Crosstalk)	Cross-Talk occurring at the Far-End of a link. In ATD testing, the location of the Far-End is relative to the location of the victim output measurement. FEXT will normally occur at the input of the ATD test system.
HCB	Host Compliance Board. PCB board or interface with known signal characteristics that allows testing of host or switch specifications. The HCB is used for calibrating signals in the ATD test system. (HCB not shown)
MCB	Module Compliance board. PCB board or interface with known signal characteristics that allows testing of "modules" such as QSFP cable assemblies.
NEXT (Near-End Crosstalk)	Cross-Talk occurring at the Near-End of a link. In ATD testing, the location of the Near-End is relative to the location of the victim output measurement. NEXT will normally occur at the output of the ATD test system.
PPG	Pulse Pattern Generator. Signal generator used to generate pseudo random binary data for traffic.

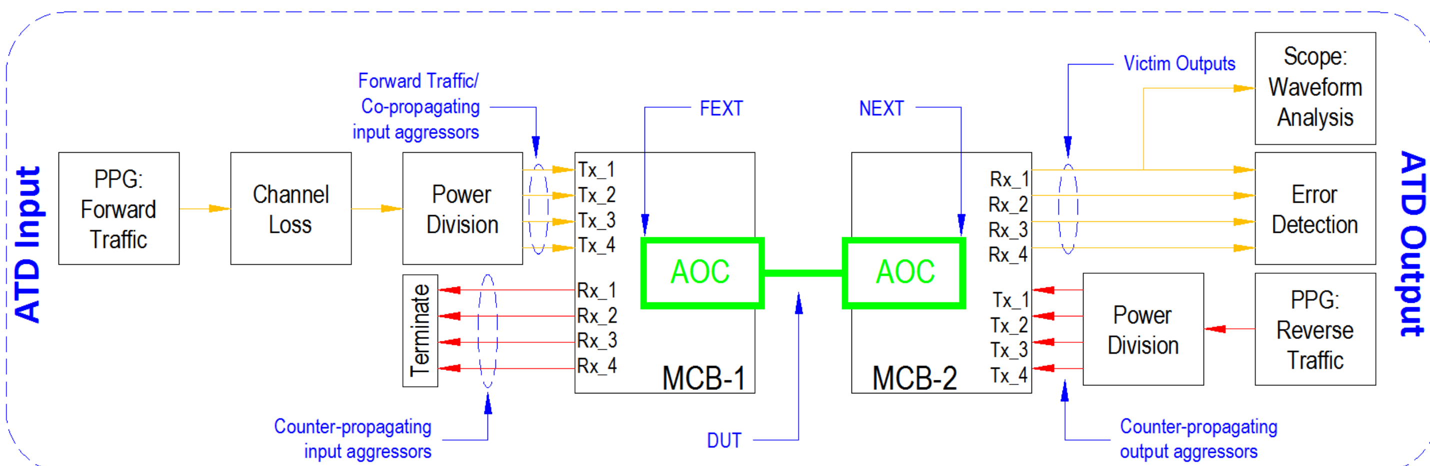


Figure 1. Glossary Reference Diagram

References

- IBTA Volume 2 Physical Specification Draft - Latest Revision
- Anritsu – IB_EDR_AOC_appnote_E_0_00 - MP1800A Series – Active Optical Cable Evaluation Method

Equipment List

Item #	Description	Vendor	Part #	Qty	Function / Details
1	Signal Quality Analyzer	Anritsu	MP1800A	1	Signal Source for traffic and jitter impairments MP1800A SQA - Options 001, 002, 015, 007, 032 MU181000A Synthesizer MU183020A Pattern Generator - Options 023,031 MU183020A Pattern Generator - Options 023,031 MU181500B Jitter Modulation
2	Signal Quality Analyzer	Anritsu	MP1800A	1	BER measurements and reverse traffic clock source MP1800A SQA - Options 001, 002, 015, 007, 032 MU181000A Synthesizer MU183040B Error Detector - Option 020 MU183040B Error Detector - Option 020
3	Sampling Scope Mainframe	Keysight	DCA-X 86100	1	All time domain measurements. Options ETR, 200, 201, 401
4	Sampling Scope Module	Keysight	86108B	1	All time domain measurements. Options 232, HBW
5	Phase Trimmers	Keysight	86108B-PT2	2	Skew adjustment for Scope Inputs, 2.4 mm
6	V Male - K Female Adaptors	Anritsu	34VKF50	2	Conversion for connection of K cables to Phase Trimmers
7	ISI Channel	Artek	CLE-1000-S2	1	Variable ISI channel
8	MCB	Wilder Technologies	QSFP+-TPA100G-MCB-R	2	Module Compliance Board for AOC testing.
9	HCB	Wilder Technologies	QSFP+-TAP100G-HCB-P	1	Host Compliance Board (module) used for ATD calibration.
10	ATD Test Platform	Anritsu	AER-1004	1	Test platform to support for equipment / MCB / DUT connections
11	Power Divider	Anritsu	K240A	4	PPG signal division for driving all AOC lanes. Embedded inside AER-1004
12	Power Splitter	Anritsu	K241A	8	PPG signal division for driving all AOC lanes. Embedded inside AER-1004
13	K Cables, 0.24m	CW Swift	EP7024R-6	21	Interconnect cables for driving AOC lanes. Embedded inside AER-1004
14	K Cables, 0.8m	Anritsu	J1551A	8	Interconnect cables for test equipment. Skew matched pairs.
15	K Cable, 1.3m	Anritsu	J1611A	1	Interconnect cables for MP1800A Clocking and Scope Triggering
16	SMA Cables, 0.3m	Anritsu	J1349A	2	Interconnect cables for MP1800A Clocking and Scope Triggering
17	Pick-Off T	Anritsu	J1510A	2	Signal split between Error Detector and Sampling Scope
18	3dB Passive Equalizer	Anritsu	J1621A	2	Equalization for aggressor signals
19	I2C/SPI Host Adapter	Aardvark	TP240141	2	AOC Programming
20	Clip Lead Set	Aardvark	TP240411	2	Interfaces between DB9 and MCB terminal block for programming
21	3.3V/ 10W Supply	Phihong	PSAA20R-033	2	AOC Power Supplies
22	50 Ohm Terminations	-	-	14	Terminate unused ports during test and calibration
23	Synthesizer	Anritsu	MG3692C	1	Signal source for scope calibration
24	Power Meter	Anritsu	ML2437A	1	Power Meter Control Unit
25	Power Sensor	Anritsu	MA2482D	1	Power Sensor, 10MHz - 18GHz
26	EEPROM Command Center	Software Forge	-	1	Command & Status interface to Active Cables

Table 1. Equipment List

Equipment Connection Diagram

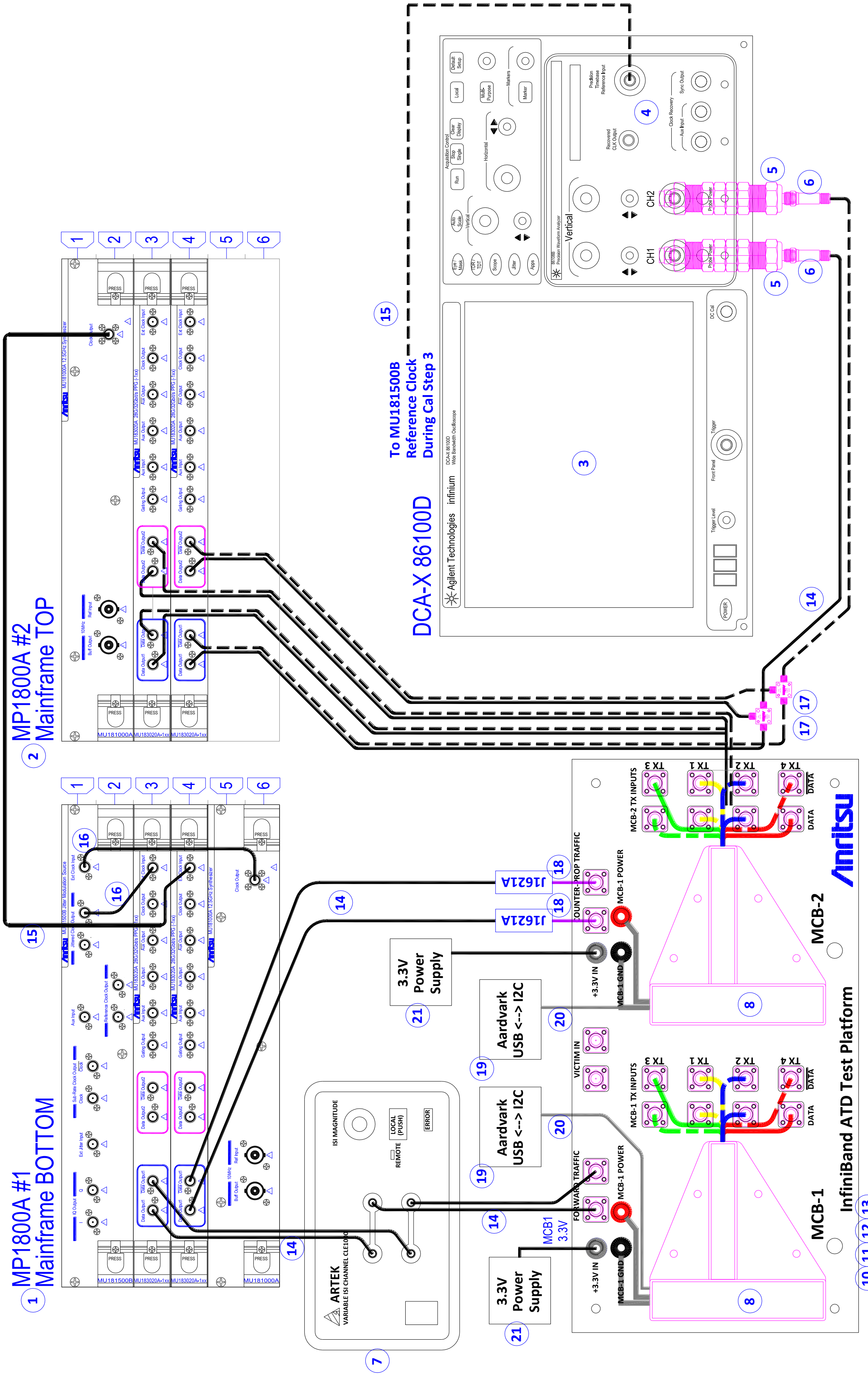


Figure 2. Equipment Connection Diagram

Target Specifications

The table below references source specifications and resources for calibration and DUT test limits.

Param.	EDR Calibration Parameter	Unit	Tol. (+/-)	Target Min	Target Nominal	Target Max	Window Size	MOI Step	Source
1	Forward Data Rate	Gb/s	0.01%	-	25.78125	-	-	-	v2r1_4.170406.pdf
2	Forward Rate Unit Interval	ps	0.01%	38.78400	38.78788	38.79176	-	-	v2r1_4.170406.pdf
3	Reverse Data Rate	Gb/s	0.01%	-	25.78383	-	-	-	Working Group Discussions
4	Counter FEXT Aggressors Vp-p	mV	5%	428	450	473	45	1	Table 88 v2r1_4.170406.pdf
5	Counter FEXT Aggressors Transition Speed	mV	10%	15.30	17.00	18.70	3.40	1	Table 88 v2r1_4.170406.pdf
6	PPG Cal: Even Odd Jitter	UI p-p	20%	0.028	0.035	0.042	0.014	2	Table 83E-9
		ps p-p	20%	1.09	1.36	1.63	0.54	2	802.3bm, Annex 83
7	PPG Cal: Random Jitter	UI p-p	10%	0.135	0.150	0.165	0.030	2	Table 83E-9
		ps p-p	10%	5.24	5.82	6.40	1.16	2	802.3bm, Annex 83
8	PPG Cal: Total Jitter	UI p-p	10%	0.252	0.280	0.308	0.056	2	Table 83E-9
		ps p-p	10%	9.77	10.86	11.95	2.17	2	802.3bm, Annex 83
9	PPG Cal: SJ Injection	UI p-p	10%	0.045	0.050	0.055	0.010	2	Table 90-13
		ps p-p	10%	1.75	1.94	2.13	0.39	2	802.3ba
10	Forward Traffic Eye Height CDR Enable Condition	mV	5%	114	120	126	12	4	Table 88 v2r1_4.170406.pdf
11	Forward Traffic Eye Width CDR Enable Condition	UI p-p	5%	0.504	0.530	0.557	0.053	4	Table 88 v2r1_4.170406.pdf
12	Forward Traffic Total Jitter CDR Enable Condition	UI p-p	5%	0.444	0.470	0.497	0.05	4	Calculated
13	Counter NEXT Aggressors Vp-p	mV	5%	665	700	735	70	5	Table 90 v2r1_4.170406.pdf
14	Counter NEXT Aggressors Transition Speed	mV	10%	15.30	17.00	18.70	3.40	5	Table 90 v2r1_4.170406.pdf

Param.	EDR DUT Parameter	Unit	Percent (+/-)	Target Min	Target Nominal	Target Max	Window Size	MOI Step	Source
15	Forward Data Rate	Gb/s	0.01%	25.77867	25.78125	25.78383	0.00516	-	v2r1_4.170406.pdf
16	Forward Rate Unit Interval	ps	0.01%	38.78400	38.78788	38.79176	0.00776	-	v2r1_4.170406.pdf
17	Mask Hit Ratio PRBS 31	-	-	-	-	5×10^{-5}	-	-	Table 90 v2r1_4.170406.pdf
18	J2	UI p-p	-	-	-	0.440	-	-	Table 90 v2r1_4.170406.pdf
	PRBS 31	ps p-p	-	-	-	17.07	-	-	Calculated
19	J9	UI p-p	-	-	-	0.690	-	-	Table 90 v2r1_4.170406.pdf
	PRBS 31	ps p-p	-	-	-	26.76	-	-	Calculated
20	Transition Time (20% - 80%)	ps	-	10.00	-	-	-	-	Table 90 v2r1_4.170406.pdf
21	BER 2 minute Gate	-	-	-	-	1.00E-12	-	-	Error Free. All lanes. Working Group Discussions
22	AC common mode output voltage	mV	-	-	-	20	-	-	Table 90 v2r1_4.170406.pdf

Table 2. Specifications

Keysight DCA-X Setup

The Figure 3 diagram shows the DCA-X connections for ATD station calibration and testing. The components are as follows:

- Pick-Off T's used only for DUT Testing. Not for calibration.
- Skew-matched 2.9mm Cable Assemblies for signal measurements
- 2.9mm Female to 2.4mm Male Adaptor for mating cables to the Phase Trimmers
- Phase Trimmers to minimize differential delay within the measurement channels
- 2.4mm Female to 2.4mm Female Adaptors for connecting Phase Trimmers to the scope inputs
- **Use the proper torque wrench while tightening connections to equipment and accessories.**

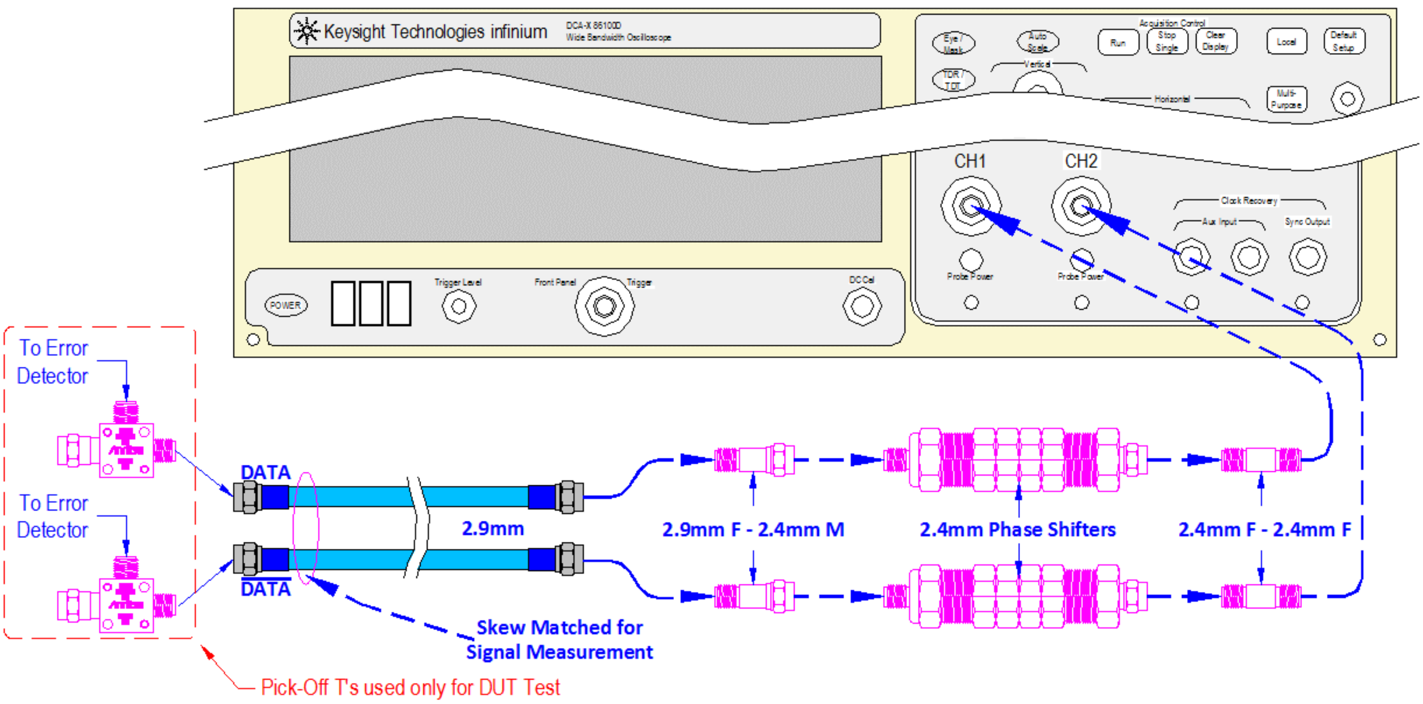


Figure 3.Keysight Equipment Connections

DCA-X De-Skew Procedure

Phase trimmers must be adjusted during initial setup and prior to ATD Calibration. Procedure as follows:

1. Set PPG and Scope to produce a reference eye waveform 25.78125 Gb/s using PRBS9.
2. ***(SCOPE BANDWIDTH MUST BE SET TO 50GHz)***
3. Terminate PPG /DATA output. It will not be used for this adjustment.
4. View PPG DATA output waveform through the cable and accessories using Scope CH1 input.
5. Save waveform to memory, keeping stored waveform displayed.
6. View PPG DATA output waveform through the cable and accessories using Scope CH2 input.
7. Make adjustments to Phase Shifter in Scope CH2, minimizing skew between live CH2 waveform and stored CH1 waveform.
8. Take precautions to ensure that Phase shifter adjustments do not result in misalignment of complementary bits in the pattern sequence. (where the transitions are aligned, but the bits are not)
9. Align crossings to within ±1ps.
10. Lock down Phase Shifter adjustment nuts after channels have been de-skewed.

Phase adjustments must be completed and all cables & components in line with each scope input channel must be present when performing the procedures in ***Appendix 3: Determining Scope Attenuation Factors. Perform this step next. Note that 2 sets of Attenuation Factors will be required. One set for calibration (no pick-off T's) and one set for DUT test (with pick-off T's).***

Keysight DCA-X Settings and Measurement Definitions

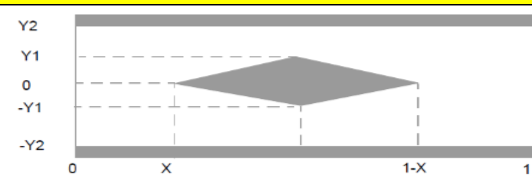
1.0 GENERAL SETTINGS	
Parameter	**Setting**
All Measurements	Differential Mode, DATA → CH1, /DATA → CH2
Trigger	Instructions in each calibration step
Channel 1 Attenuation Factor	Per ***Appendix 3: Determining Scope Attenuation Factors***
Channel 2 Attenuation Factor	Per ***Appendix 3: Determining Scope Attenuation Factors***
2.0 WHEN USING DCA-XCLOCK RECOVERY	
Clock Recovery	ON
Jitter Spectrum Analysis Status	ON: 10kHz, Limit 1: 10kHz, Limit 2: 26.25MHz
Jitter Spectrum Analysis Limits	Limit 1: 10kHz, Limit 2: 26.25MHz
Jitter Spectrum Analysis Averaging	Spectrum Smoothing: 16 Averages
PLL Cut-off	Bit Rate /2578 = 10MHz
PLL Peaking	0dB
PLL Roll-Off	20dB / decade
3.0 WHEN PERFORMING DUT EYE TEST	
Eye Mask	InfiniBand EDR DUT Output Mask AOC Range 0: • X = 0.3UI • Y1 = 50mv, Y2 = 225mV 4M UI Samples per measurement 
Eye Parameters	AOC Range 0: 4M UI Samples per measurement J2, J9, Rise Time, Fall Time
4.0 WHEN PERFORMING DUT AC COMMON MODE NOISE TEST	
AC Common Mode Noise	Scope Mode 200 Waveforms per measurement

Table 3. DCA-X Settings

Definitions

Eye Diagram	A pattern created by an oscilloscope and sourced by a pseudorandom digital signal. This voltage level of this signal is sampled repeatedly while a synchronous clock signal triggers the scope's horizontal sweep. The eye pattern itself represents the superposition of all possible bit sequences in the pattern viewed within a single time interval. Eye patterns are typically used to comprehensively evaluate the effects of noise and inter-symbol interference on data signals.
Eye Mask	An eye mask is a tool that defines the allowable shape of an eye diagram. The mask test is defined by points in both the amplitude and time domains. M***asks required to support the testing described in this document should be loaded into the scope before executing this procedure.***
Mask Hit Ratio	The ratio between the number of mask violations and the number of samples collected. For example 50 violations in 1,000,000 samples results in a hit ratio of 5×10^{-5}.
Eye Vp-p	Peak-to-peak voltage of an eye diagram. The difference between the maximum voltage and minimum voltage with respect to the displayed waveform. This should not be confused with eye amplitude which is a measurement based on statistical analysis of the logical "one" and "zero" level.
Rise / Fall Time	The amount of time required for a pulse to transition between 2 different logic states. The measurements within this document use 20% to 80% reference levels to characterize transition speed.
J2 Jitter	The total jitter that would result in a bit error rate of 2.5×10^{-3}
J9 Jitter	The total jitter that would result in a bit error rate of 2.5×10^{-10}
CTLE	Continuous Time Linear Equalization. During calibration, this mathematical scope function simulates a similar function in the DUT and is used to compensate the eye closure caused by the test system channel loss.

Table 4. Scope Measurement Definitions

Generating 8 Lanes of Traffic

Forward and reverse traffic are sourced by independent differential PPG channels. Precision power divider networks and skew-matched cables then generate 8 lanes of traffic to drive all lanes of the DUT in both directions. Figure 4 describes the power divider network configuration. Identical networks are used to generate 4 lanes of differential traffic in each direction.

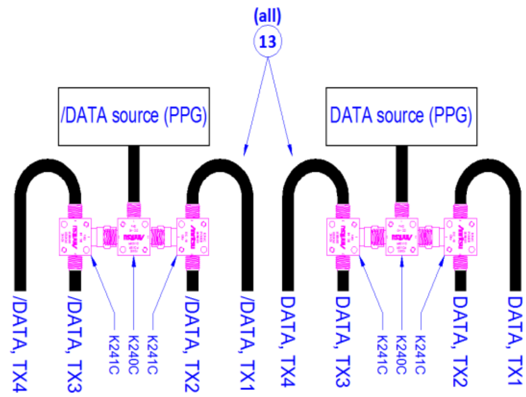


Figure 4. Power Divider Configuration

Maintain a 180° phase shift between alternating lanes of Tx traffic by using the following convention when connecting aggressor traffic to MCB Tx inputs:

- Implement **REVERSE-polarity** connections for odd numbered ports: DATA to **/DATA** and **/DATA** to DATA (TX1, TX3)
- Implement **CORRECT-polarity** connections for even numbered ports: DATA to DATA and **/DATA** to **/DATA** (TX2, TX4)

Wilder Technologies MCBs & HCB

Module Compliance Boards (MCBs) and Host Compliance Boards (HCBs) are provided by Wilder Technologies. These products meet the performance requirements defined by the IBTA spec and provide stable interconnect solutions for station calibration and ATD compliance testing.

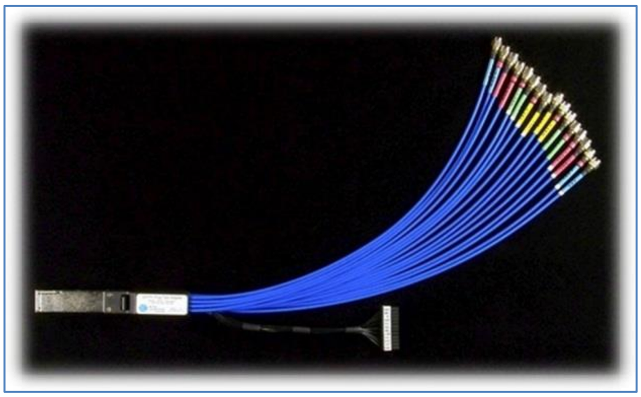


Figure 5. Wilder Technologies HCB

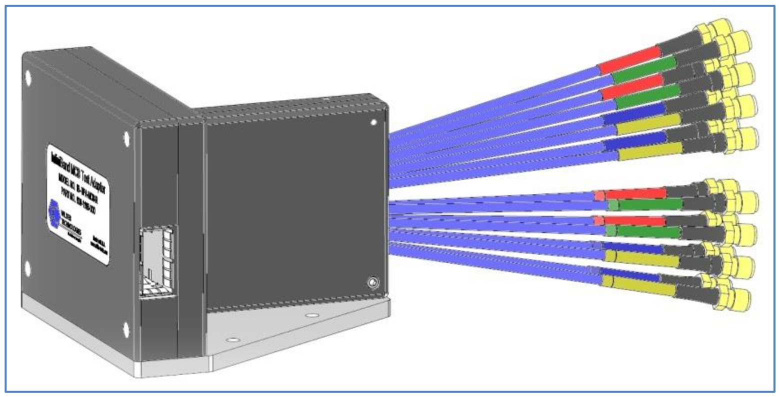


Figure 6. Wilder Technologies MCB

ATD Test Platform

Many components of the ATD station have been integrated into a platform which provides:

- A secure base on which to install the Wilder Technologies MCBs.
- DC power distribution to both MCB's.
- Skew-matched differential signal division for generating traffic (internal cables & power dividers).
- A sealed chassis to protect sensitive connections from disturbances.
- A repeatable test platform using a dedicated set of components for Plugfest events.

Figure 7. Anritsu ATD Test Platform

Input Channel Loss

Channel loss is required to stress the input signal to the DUT. Note that cable, connector, and power dividers contribute to the frequency dependent loss characteristics and must be considered as well. Those accessories will introduce a FIXED amount of frequency-dependent loss at the Nyquist (12.89GHz), and the Artek CLE-1000-S2 Variable ISI channel will make up the difference, targeting 10dB of frequency-dependent channel loss at Nyquist. The entire channel is illustrated in Figure 8. This includes interconnect cables as well as the ATD test platform.

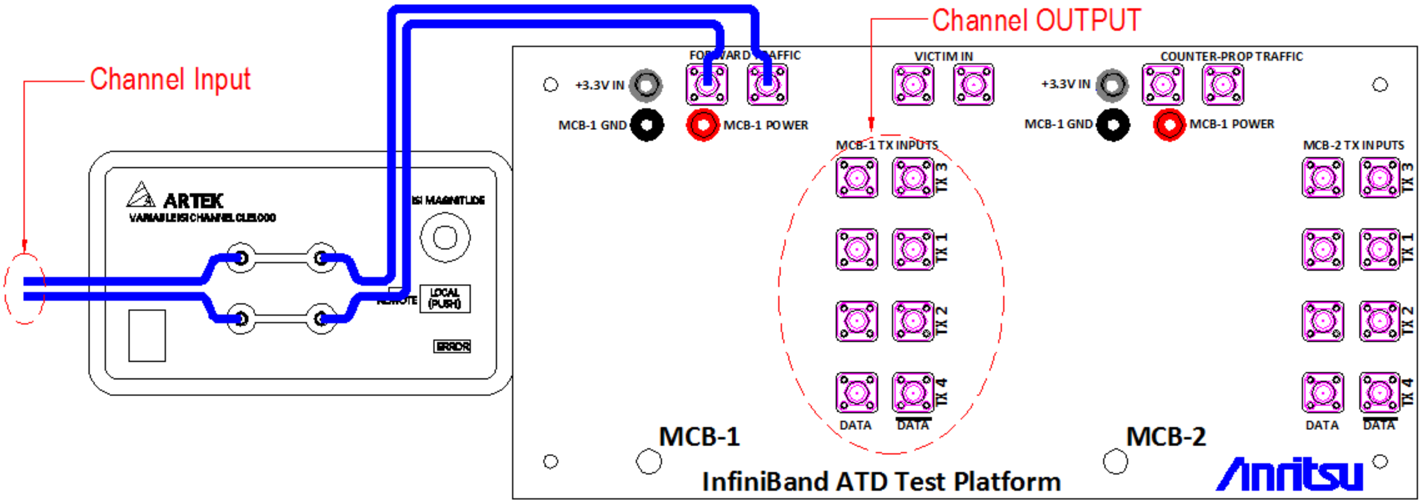


Figure 8. Complete Loss Channel

A network analyzer was used to determine the ideal set point for the CLE-1000-S2 and to measure the uniformity of signal division through the ATD test platform. Test data shown in Figure 9 and Figure 10. Ideal set point for CLE-1000S2 is typically 6.5% as shown in Figure 11, however this value should be verified each time the ATD station is set up for calibration.

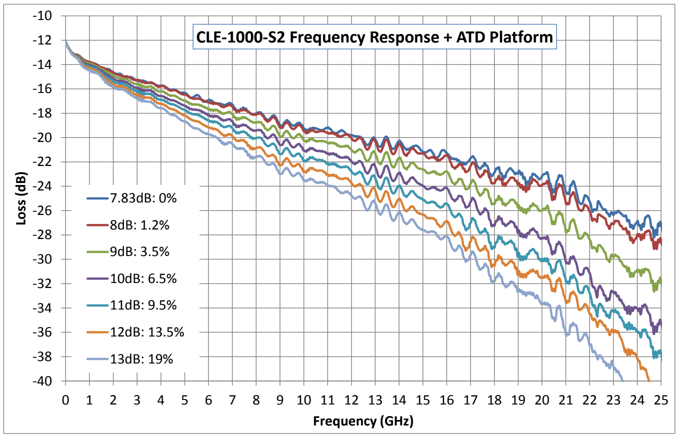


Figure 9. Loss at various set points

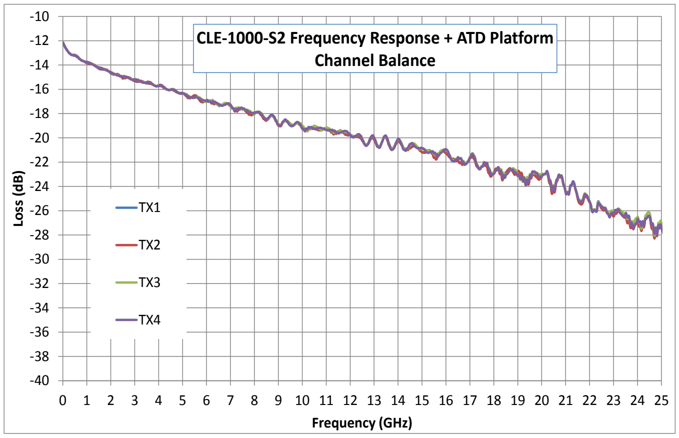


Figure 10. Loss uniformity across channels.

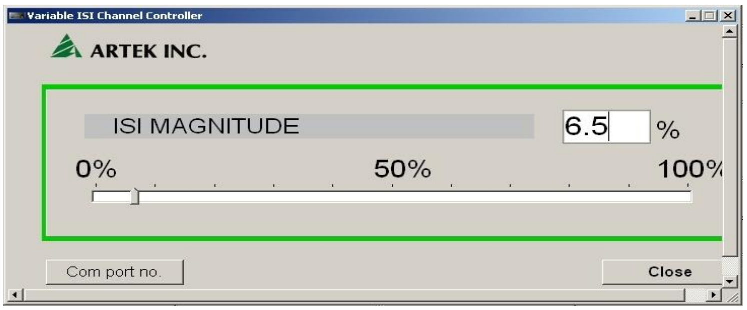


Figure 11. CLE-1000-S2 Control Screen

Important Note:

The resistive power dividers within the ATD Test Platform results in a fixed broadband 12dB insertion loss.

The frequency-dependent insertion loss targeted for this calibration considers the delta between the loss @ 12.89GHz and the loss at 10MHz.

Differential Channel Representation

For the purpose of diagram simplification, signals within a differential pair will not be individually referenced. For example, the differential pair of TX1, DATA and TX1, /DATA will simply be referenced as TX1. All traffic connections described in this document are **differential**. This applies to signal sourcing as well as measurements and terminations.

- Always use skew-matched cables at the input of measurement instruments to avoid adding unwanted skew between signals of a differential pair.
- Always terminate both signals of a differential pair with 50Ω. Failure to do so will result in an unbalanced load and an undesirable operating condition.
- Single-ended signaling is only used for external scope triggering (when used).

Calibration Overview

1. Perform scope Channel 1 & Channel 2 de-skew using external phase trimmers.
2. Perform steps outlined in Appendix 3: Determining Scope Attenuation Factors.
3. Load the correct set of Attenuation Factors into the DCA-X for station calibration.
4. Set counter-propagating FEXT aggressors as defined in Table 2, parameters 3 - 5.
5. Set forward traffic PPG amplitude to same setting as FEXT aggressors used in step 4.
6. Set forward traffic baseline jitter conditions as defined in Table 2, parameters 6 – 8 (Even/Odd, RJ, BUJ).
7. Create sinusoidal jitter conditions as defined in Table 2, parameter 9 (SJ).
8. Connect Artek Variable ISI Channel, set to 10dB loss at 12.89GHz
9. Determine optimal CTLE setting for scope.
10. Determine forward traffic settings for Amplitude and RJ for DUT test condition: CDR-Enabled, Table 2, parameters 10 – 12.
11. Set counter propagating NEXT aggressors as defined in Table 2, parameters 13 - 14.
12. Record and save all equipment settings during the calibration process using MP1800A Quick Save function as well as Calibration Worksheet included in this document. See Appendix 4: EDR ATD Calibration Work Sheet

DUT Testing Overview

1. Connect all hardware per Figure 2 (Done only once).
2. Verify that the correct set of Attenuation Factors into the DCA-X for DUT Testing (Done only once).
3. Insert proper cable ends into MCB-1 and MCB-2
4. Perform the following steps for CDR-Enabled AOC mode. (Repeat every cable)
    a. Recall equipment settings for CDR-Enabled condition.
    b. Set MCB-2 cable end for Range 0, CDR On (Fully Re-Timed) AND/OR CDR Off (Semi-Re-Timed)
    c. Set MCB-1 cable end for Range 0, CDR On
    d. Find ideal CTLE Setting for MCB-1 cable end.
    e. Record BER (MCB-2, Rx1 – Rx4) after 2 minute gating time.
    f. Record Eye parameters: Mask Hits, J2, J8, Transition Time (MCB-2, Rx4)
    g. Record AC Common Mode voltage (MCB-2, Rx4)
5. Record data in approved spreadsheets or forms. (Repeat every cable)

Calibration Step 1: Counter-Propagating FEXT Aggressors

Goal: Set the amplitude of the counter-propagating FEXT aggressors for the input side of the ATD test system. This calibration step will set counter-propagating aggressor crosstalk for the victim calibration in later steps. Counter-propagating aggressor signals are applied into the HCB and measured at corresponding points on MCB-1 using the scope. Refer to Figure 12 while executing the following steps.

Equipment Initial Settings

Parameter	Setting
MP1800A Reverse Traffic	MU183020A: PRBS31 pattern
DCA-X 86100 Eye Mode and Scope Mode (per procedure)	Pattern Lock OFF 200 Waveforms per measurement Scope Trigger = CDR or External with Precision Timebase

Procedure

1. Terminate all TX channels on the HCB to 50Ω.
2. Inject counter-propagating traffic into the HCB RX ports.
3. Adjustment and Measurement (IBTA Spec: TP7A) points shown below.
4. Measure each counter-propagating channel (RX1, RX2, RX3, RX4) on MCB-1, while terminating other RX channels to 50Ω.
5. Adjust MU183020A amplitude until Scope Vp-p complies with Table 2, parameter 4. RECORD SETTING.
6. All RX channels must conform to Table 2, parameters 3 - 5.
7. Counter propagating FEXT aggressors are now set.
8. Typical data shown in Figure 13 and Figure 14 must be recorded <u>for each RX channel</u>.

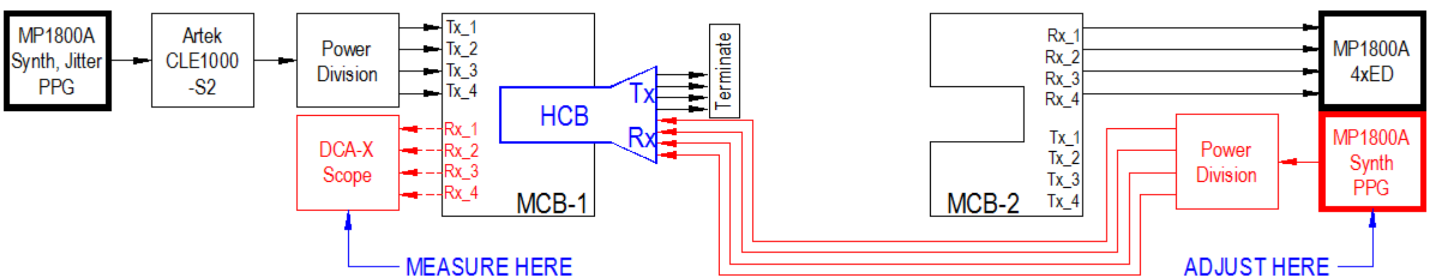


Figure 12. Counter-propagating FEXT aggressor calibration setup

Figure 13. Sample Data: Vp-p, Amplitude

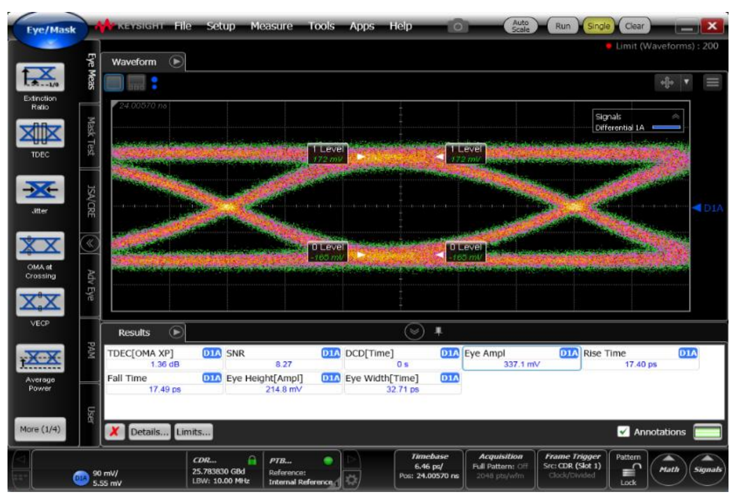


Figure 14. Sample Data: Transition Time + Additional Parameters

Calibration Step 2: Set baseline Forward PPG Jitter

Goal: Set the baseline pattern generator jitter stresses for all forward propagating traffic. Intrinsic jitter characteristics targets for Random Jitter, Bounded Uncorrelated Jitter (BUJ), Odd/Even Jitter and Sinusoidal Jitter (SJ) are adjusted and verified in this calibration step. Forward traffic generator is measured directly at the output of the pattern generator as shown in Figure 15 below. Red entities indicate the relevant signal sources, paths and measurement equipment.

Equipment Initial Settings

Parameter	Setting
MP1800A Forward Traffic	MU183020A: PRBS9 pattern MU181500B BUJ: Bit Rate 2.57Gb/s, PRBS7, 100MHZ LPF MU181500B SJ: Frequency = 91MHz MU181500B RJ: Unfiltered
DCA-X 86100 Jitter / Noise Mode	Pattern Lock ON, 50 Patterns per measurement Scope Trigger = External Trigger Input to Precision Timebase

Procedure

1. Turn on forward traffic MU183020A and set amplitude to same setting as reverse traffic MU183020A from Calibration Step 1.
2. Turn on MU18500B SJ, BUJ, RJ sources and set amplitude to 0UI.
3. Adjust MU183020A Half Period Jitter until DCA-X F/2 complies with Table 2, Param 6. RECORD SETTING.
4. Adjust MU18500B RJ amplitude until DCA-X RJ complies with Table 2, Param 7. RECORD SETTING.
5. Adjust MU18500B BUJ amplitude until DCA-X TJ complies with Table 2, Param 8. RECORD SETTING.
6. Temporarily set MU18500B RJ and BUJ jitter amplitude back to 0UI.
7. Adjust MU18500B SJ amplitude until DCA-X DJ complies with Table 2, Param 9. RECORD SETTING.
8. Reapply all per-determined jitter amplitude settings to MU181500B.
9. Baseline forward PPG jitter is now set. Sample data below.

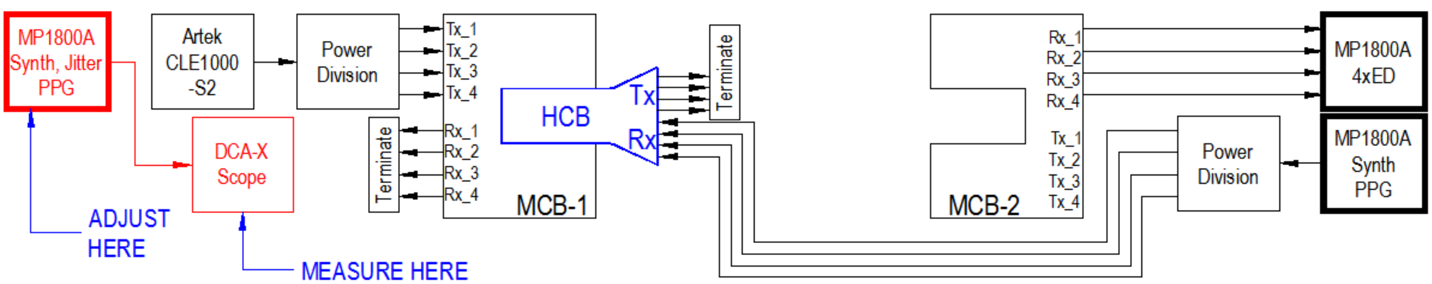


Figure 15. Baseline PPG Jitter setup

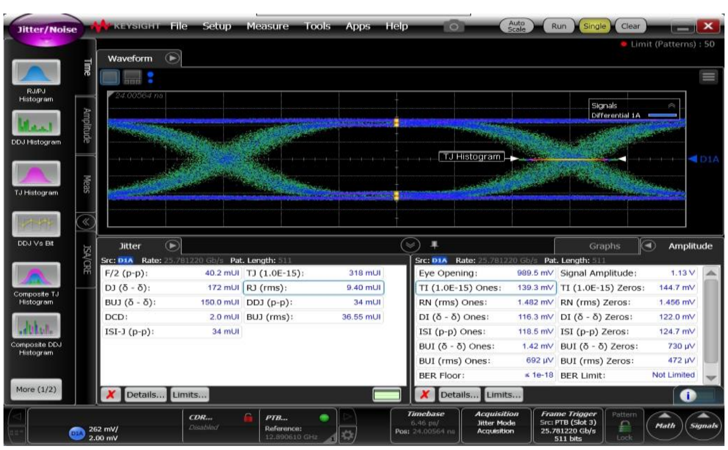


Figure 16. Baseline PPG Jitter without SJ

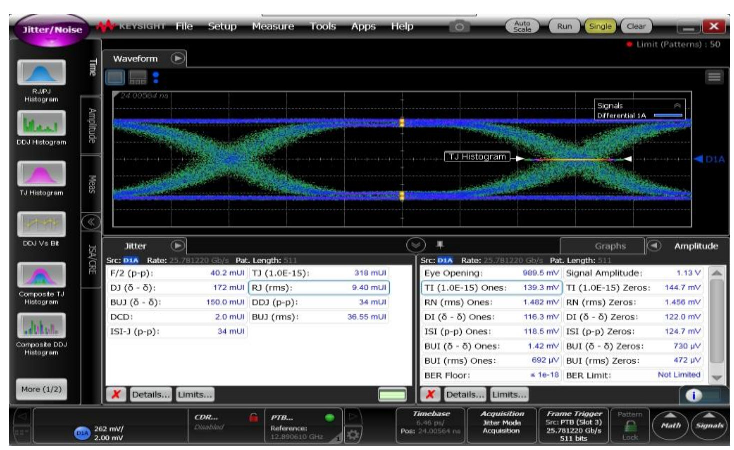


Figure 17. Baseline PPG Jitter with SJ

Calibration Step 3: Scope CTLE Determination

Goal: To determine the DCA-X CTLE setting which will be used for measuring Eye Width and Height parameters through the channel loss during victim calibration. The DCA-X software CTLE function will simulate the effect of the CTLE in the DUT. The specification guidance for determining DCA-X CTLE setting is to cycle through all settings while measuring Eye Height and Width for BER approximation of $1x10^{-15}$. Correct setting is that which results in maximum Height x Width product. It is sufficient to measure only TX1 at the HCB to make this determination as illustrated in Figure 18 connection diagram.

Equipment Initial Settings

Parameter	Setting
Artek CLE1000	Measured setting for -10dB frequency dependent loss at 12.89GHz
MP1800A Forward Traffic	MU183020A: PRBS31 MU183020A forward traffic set to PRBS9 pattern MU181500B BUJ: Bit Rate 2.5Gb/s, PRBS31, 100MHZ LPF MU181500B SJ: Frequency = 91MHz MU181500B RJ: Unfiltered
DCA-X 86100 Jitter / Noise Mode	CTLE ON: OIF CEI-28G-VSR (x dB) Pattern Lock ON, 50 Patterns per measurement Eye Width and Eye Height Calculations @ BER = $1x10^{-15}$ Scope Trigger = External Trigger Input to Precision Timebase

Procedure

1. Turn on all Forward Traffic and Jitter Sources. Reverse traffic source is off.
2. Record Eye Width and Eye Height as described above at each DCA-X CTLE Setting.
3. Determine product of Eye Width x Eye Height at each CTLE Setting.
4. Desired CTLE Setting is that which maximized the product of Eye Width x Eye Height.
5. Sample calculations shown in Figure 19.

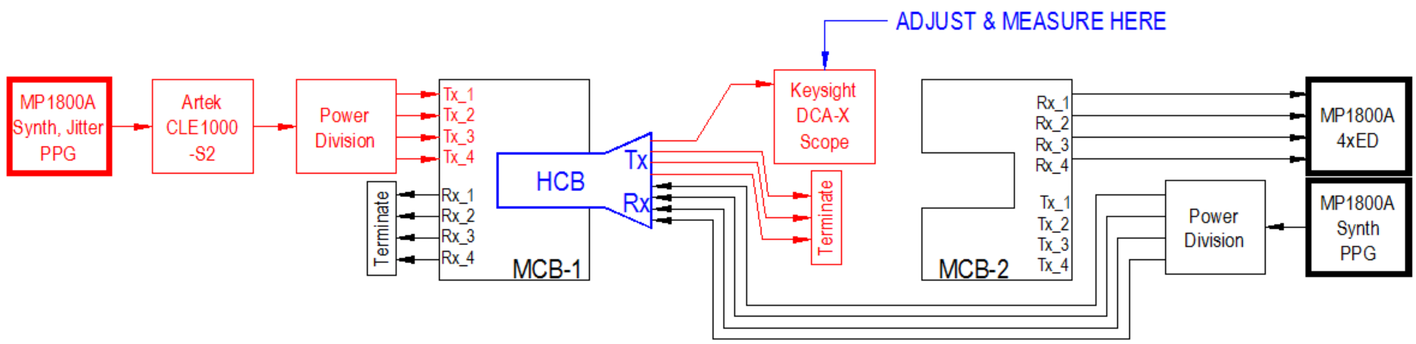
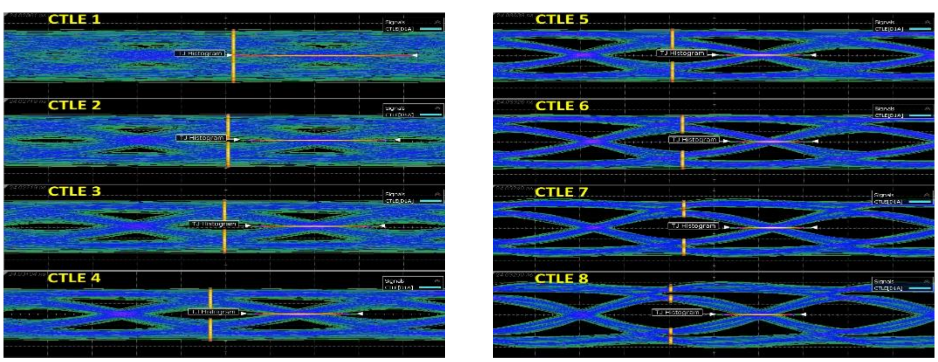


Figure 18. Victim calibration setup



Scope CTLE	Eye Width (UI)	Eye Height (mV)	Product
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	0.418	70	29.26
5	0.512	86	44.03
6	0.536	102	54.67
7	0.54	111	59.94
8	0.512	114	58.37
9	0.51	100	51.00

Figure 19. CTLE Determination

Calibration Step 4: Victim Input Signal Calibration

Goal: To make final adjustments to Forward Traffic Signals, producing target Eye Width and Height for the DUT test. These signals will be calibrated with all stressors and aggressor traffic enabled. Calibration parameters to be determined for **CDR-Enabled** mode of cable testing. Refer to Figure 20 while executing the following steps.

Equipment Initial Settings

Parameter	Setting
MP1800A	All previous traffic generators and stressors enabled Adjustments: MU183020A Forward Traffic Amplitude, MU181500B RJ Amplitude
DCA-X 86100 Jitter / Noise Mode	CTLE ON: OIF CEI-28G-VSR (Setting determined during last calibration step) Pattern Lock ON, 50 Patterns per measurement Eye Height and Eye Width Calculations @ BER = $1x10^{-15}$ Scope Trigger = External Trigger Input to Precision Timebase

Procedure

1. Properly terminate all HCB TX channels which are not being measured.
2. It is acceptable to make adjustments while only measuring TX1 and **verify calibration on TX2, TX3, TX4 afterwards.**
3. Adjustment and Measurement (IBTA Spec: TP6A) points shown below.
4. CDR-Enabled DUT Conditions
    a. Adjust MU183020A Amplitude until DCA-X Eye Height complies with Table 2, Param 10. RECORD SETTING.
    b. Adjust MU181500B RJ Amplitude until DCA-X Eye Width complies with Table 2, Param 11 - 12. RECORD SETTING.
5. Sample calibrated waveforms shown in Figure 21.

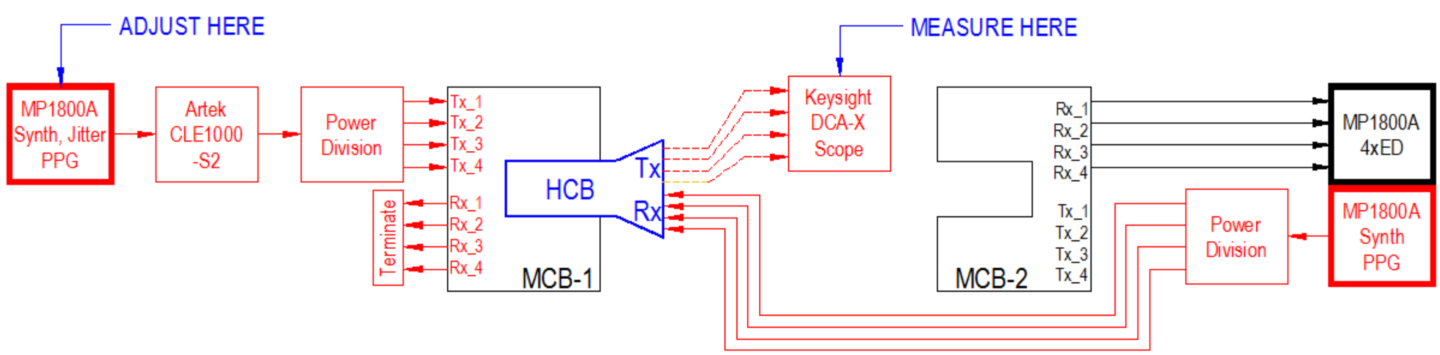


Figure 20. Victim calibration setup

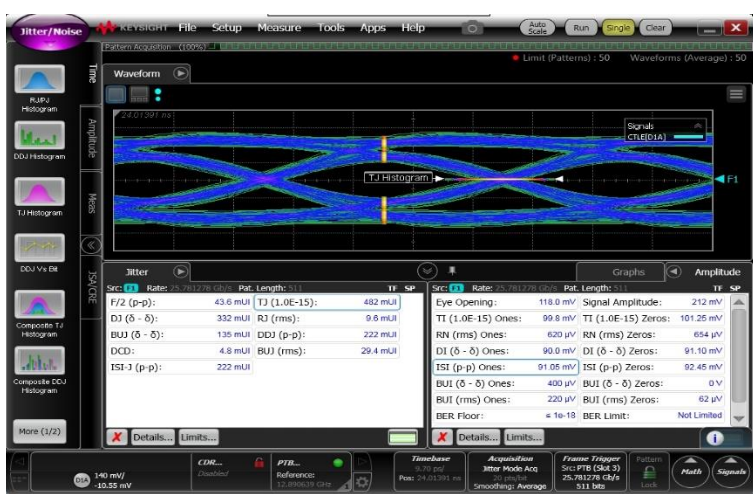


Figure 21. CDR-Enabled Calibration

Calibration Step 5: Counter-Propagating NEXT Aggressors

Goal: Set the amplitude of the counter-propagating NEXT aggressors for the output side of the ATD test system. This calibration step will set up counter-propagating aggressor crosstalk for the DUT during the cable test. Counter-propagating aggressor signals are applied to MCB-2 and measured at corresponding points on the HCB using the DCA-X. Refer to Figure 22 while executing the following steps.

Equipment Initial Settings

Parameter	Setting
MP1800A Reverse Traffic	MU183020A: PRBS31 pattern
DCA-X 86100 Eye Mode and Scope Mode (per procedure)	Pattern Lock OFF 200 Waveforms per measurement Scope Trigger = CDR or External with Precision Timebase

Procedure

1. Terminate all RX channels on the HCB to 50Ω.
2. Inject counter-propagating traffic into MCB-2 TX ports.
3. Adjustment and Measurement (IBTA Spec: TP6A) points shown below.
4. Measure each counter-propagating channel (TX1, TX2, TX3, TX4) on HCB1, while terminating other RX channels to 50Ω.
5. Adjust MU183020A amplitude until Scope Vp-p complies with Table 2, parameters 13 - 14. RECORD SETTING.
6. Typical data shown in Figure 23 and Figure 24 must be recorded <u>for each RX channel</u>.

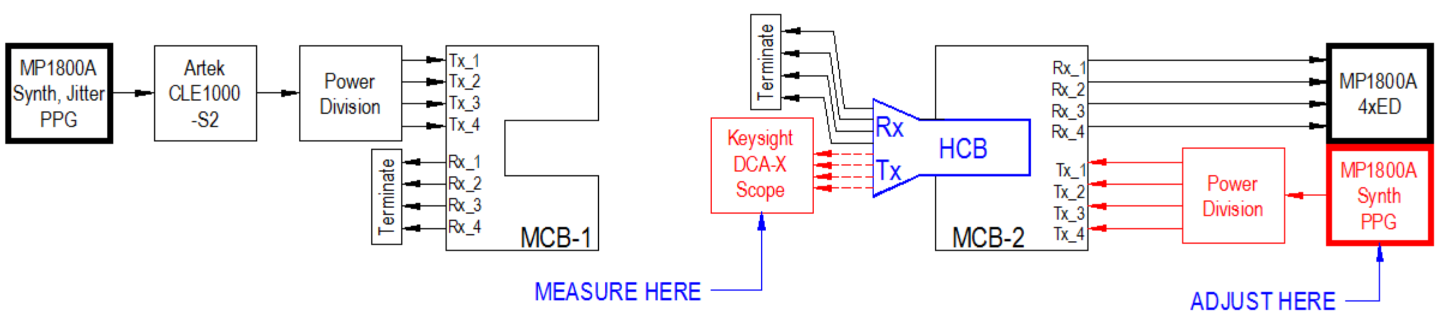


Figure 22. Counter-propagating NEXT aggressor calibration setup

Figure 23. Sample Data: Vp-p, Amplitude

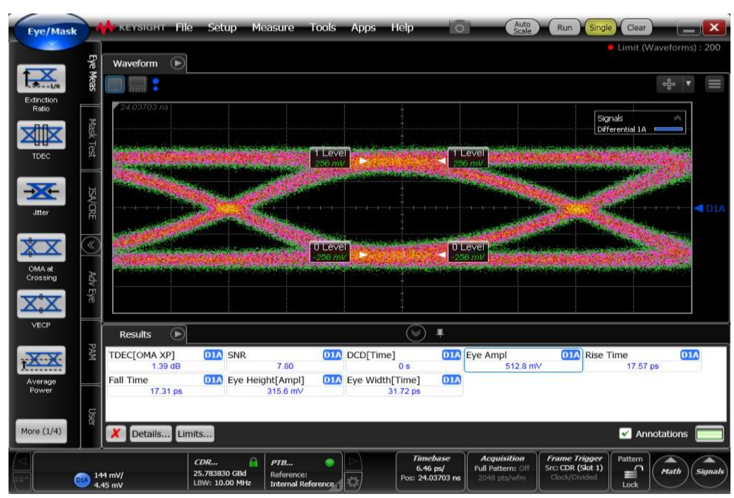


Figure 24. Sample Data: Transition Time + Additional Parameters

Test System Configuration Overview

The system is ready for the ATD measurements after completing the multi-step calibration process described in previous sections. Test system must now be configured as shown in Figure 25 (signal flow) and Figure 2 (detailed).

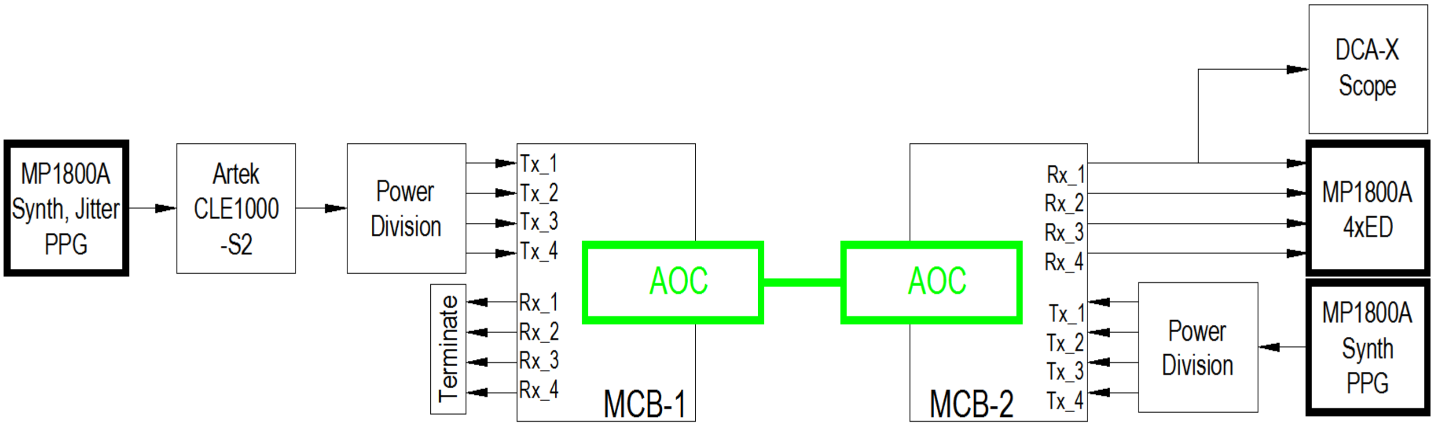


Figure 25. DUT Test Configuration

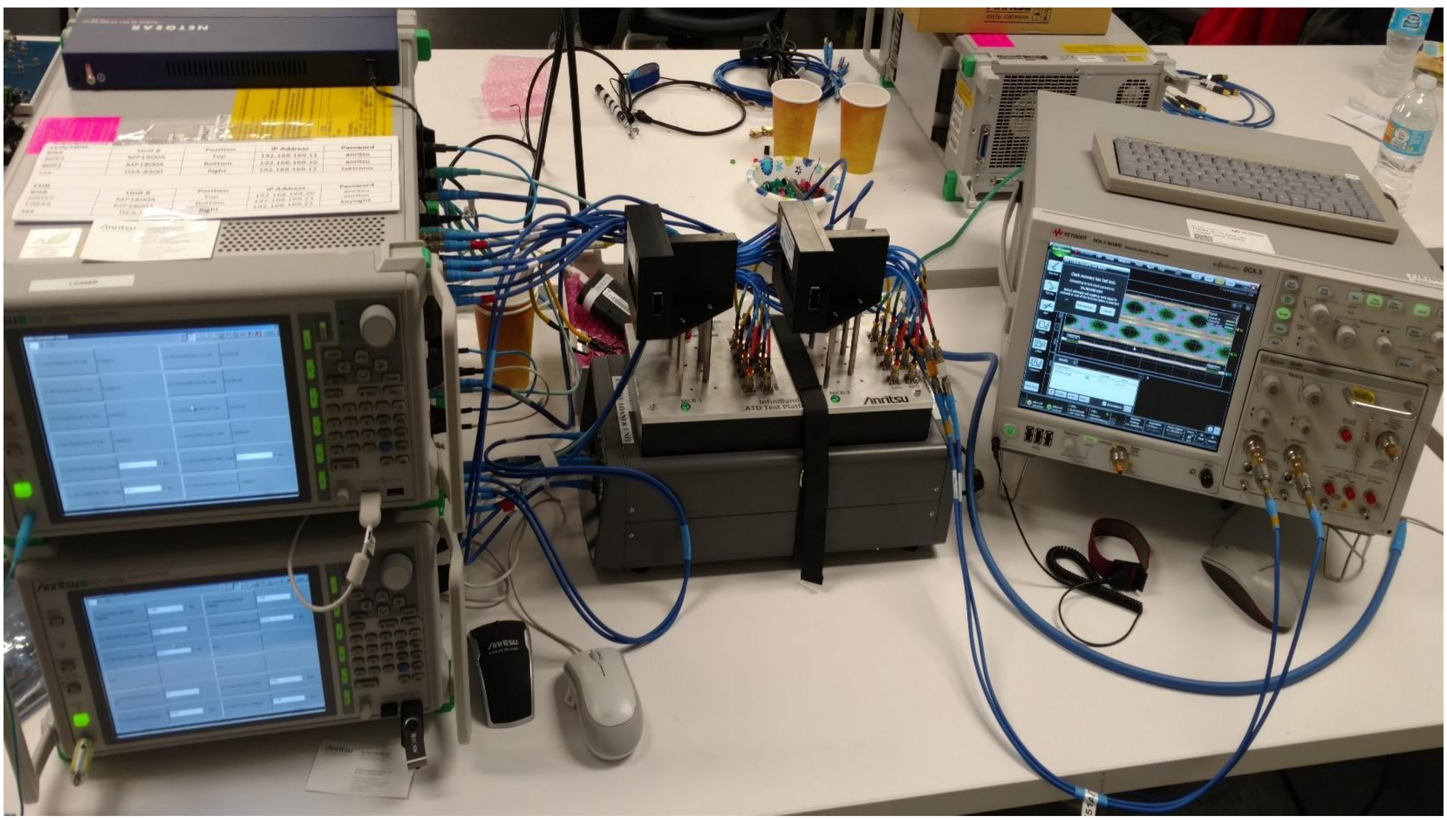


Figure 26. ATD Station Photograph

DUT Data Collection

Compliance measurements and DUT management will require specific applications and user interfaces across several pieces of equipment. To maximize testing efficiency, all equipment may be networked and managed from a single access point via VNC or Remote Desktop interface. The screen captures and figures below shows the typical control interface as well as the test equipment results which are required to test for spec compliance.

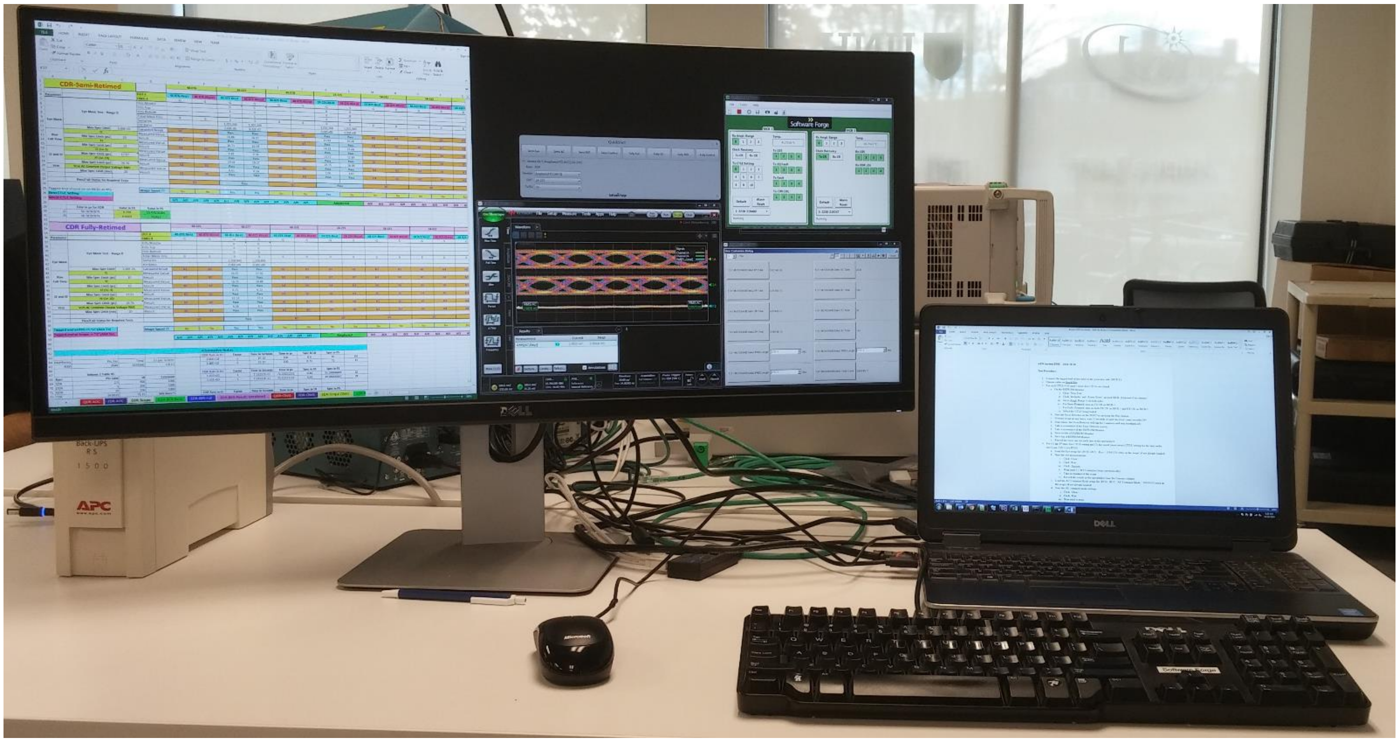


Figure 27. ATD Testing Pilot Seat View

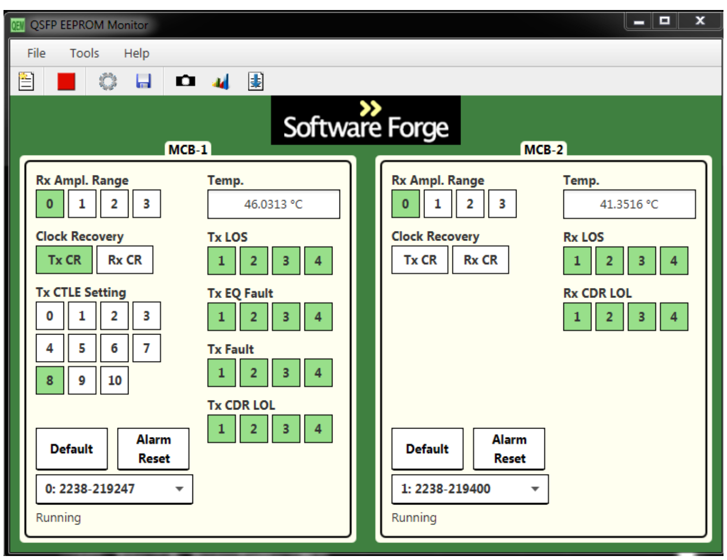


Figure 28. Software Forge ECC for DUT control

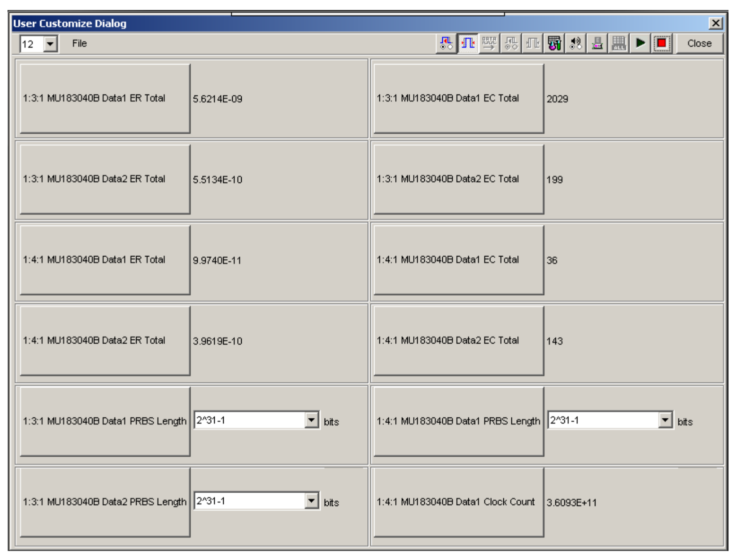


Figure 29. Anritsu MP1800A BER Measurements

Figure 30. Keysight DCA-X for Eye Parameters

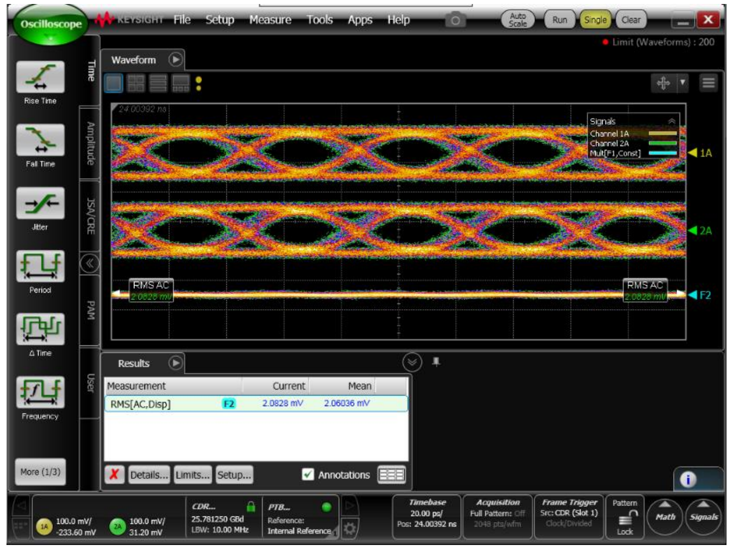


Figure 31. Keysight DCA-X for AC Common Mode Noise

Usage Notes:

DUT Power

Power is applied to the DUT via the Wilder Technologies MCBs and cable assemblies through the ATD Evaluation fixture, sourced by the power supplies specified in the BOM.

I2C Control

The Software Forge EEPROM Command Center (ECC) will interface with the DUT connectors via Aardvark I2C to USB adaptors.

- The ECC provides control over DUT amplitude range, CDR, CTLE, and monitors temperature and alarms.
- One Aardvard is required for each cable end.
- Both Aardvards are controlled by a single session of the ECC if they are connected to a common computer.
- Properly associate the specific Aardvard serial numbers with the correct MCB location for the DUT test.

BER Testing

The Anritsu MP1800A will simultaneously monitor DUT BER on all 4 channels at the MCB-2 Rx outputs.

- Clock Recovery must be enabled for both MU183040B modules.
- Auto-Adjust must be turned on for all 4 error detector channels.
- Measurement cycle must be set for a single acquisition with 2 minute gating period.
- User-configurable menu screen may be used to conveniently display results for all channels.

Time Domain Testing

The Keysight DCA-X will measure Eye Parameters as well as AC common-mode noise.

- Individual scope setups can be stored and recalled to quickly switch between the two measurement types.
- Eye Parameters: Mask hits, J2, J9, transition speed. (4M samples)
- AC Common-Mode: Math function of (CH1 + CH2)/2. (200 Waveforms)

Appendix 1: Low Speed Interface

The Aardvark I2C to USB adaptor is used to interface with the cable to perform the following functions.

- Set cable Rx amplitude range
- Enable / Disable clock recovery function.
- Control CTLE setting at cable input
- Read temperature, alarm and error status as reported by the cable.

The diagram shown below describes the connection of power and the low-speed interface for communicating with the DUT. Each MCB requires an interface as shown below.

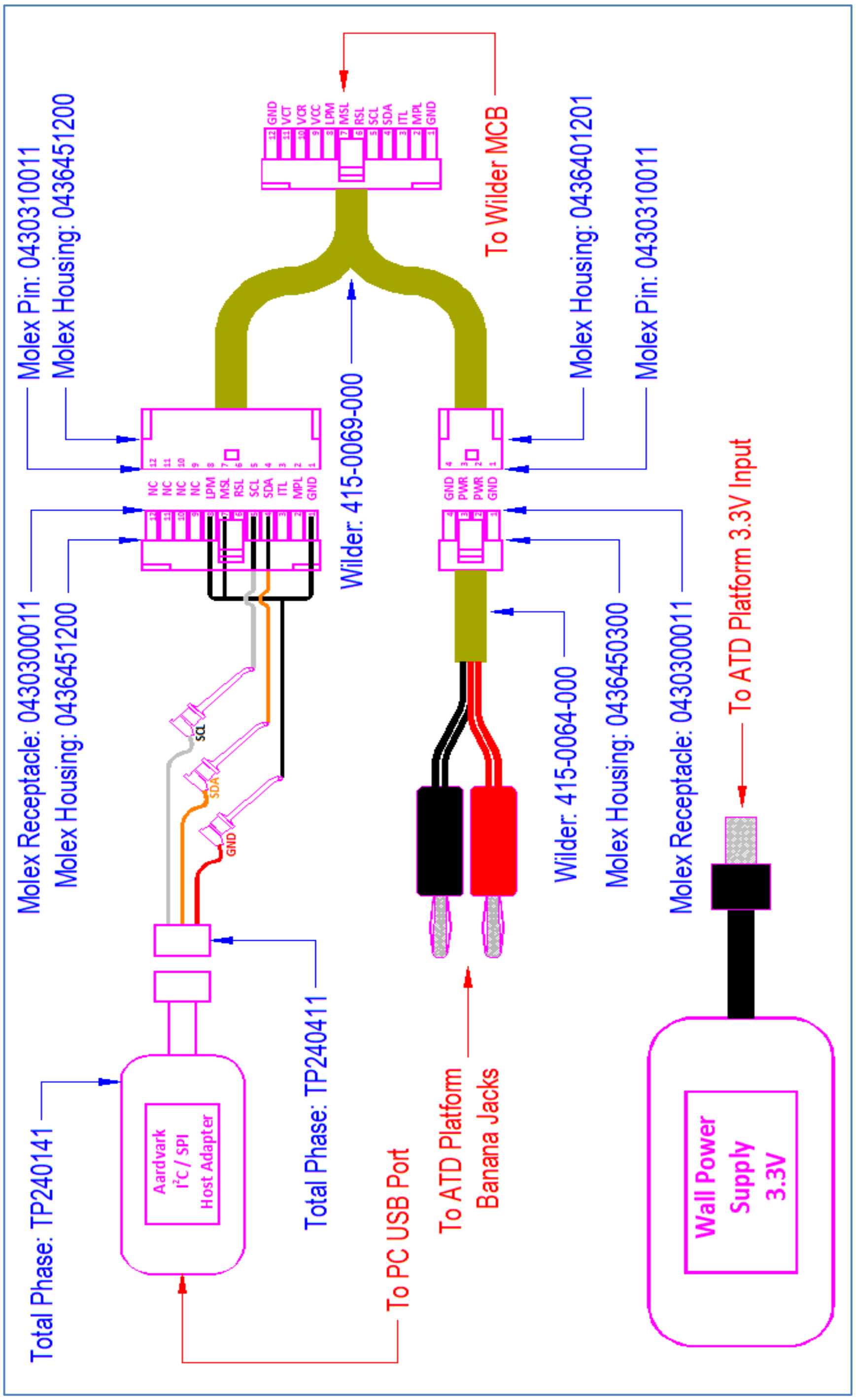


Figure 32. DUT Test Physical Connections

Appendix 2: Relevant InfiniBand Specification Tables

The following tables are excerpts from InfiniBand Architecture Specification Volume 2, Release 1.4
Figure 211, Table 89, Table 85 are references within the Specification.

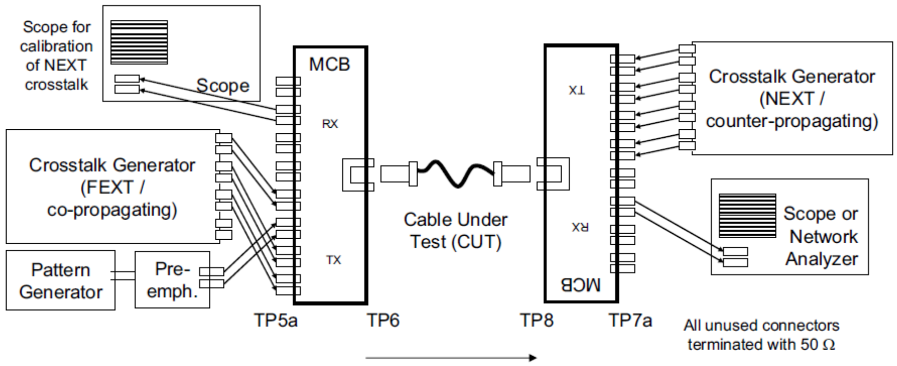


Figure 211 Cable characterization setup using MCB

Figure 33. InfiniBand Spec ATD Diagram

Table 89 EDR limiting active cable input electrical specifications

Symbol	Parameter	Specification value(s)	Unit	Conditions
	Crosstalk signal Vpk-pk	+/- 5% (See Conditions)	mV	At TP6a. Co-propagating aggressors. Crosstalk signal Vpk-pk to match lane under test, to within +/- 20%.
	Crosstalk signal transition time, 20%-80%	17	ps	
	Crosstalk calibration signal Vpk-pk, each aggressor	450 +/- 10%	mV	At TP7a. Counter-propagating aggressors. Apply during crosstalk calibration only[a]
	Crosstalk calibration signal transition time, 20%-80%	17 +/- 3	ps	

Symbol	Parameter	Max	Min	Unit	Conditions
	Single-ended input voltage	3.3	-0.3	V	At TP6a
V_{CM-AC}	AC common mode input voltage tolerance (RMS)	20		mV	At TP6a
V_{CM-DC}	DC common mode input voltage tolerance	2850	-350	mV	At TP6a
S_{DD11}	Differential input return loss	Eq. 5 on page 309		dB	At TP5a, 50 MHz to 26 GHz
S_{DC11}	Common mode to differential reflection	Eq. 6 on page 309		dB	At TP5a, 50 MHz to 26 GHz
EH15	Eye Height tolerance, at 1E-15	120		mV	
EW15	Eye Width tolerance, at 1E-15	0.53		UI	At TP6a, with TX CDR enabled
		0.71		UI	At TP6a, with TX CDR bypassed (i.e., disabled)

a. Please refer to CIWG Method of Implementation (MOI) document Active Time Domain Testing for detailed specification of testing methodology and parameters.

Figure 34. Infiniband Spec for input signal conditions

Table 90 EDR limiting active cable output electrical specifications

Symbol	Parameter	Specification value(s)	Unit	Conditions
X	eye mask parameter, time; see Figure 90 on page 289	0.30	UI	Hit ratio=5E-5 with 100 Ohm load at TP7a (Note [a])
Y1, Y2	Diff. unsigned output voltage range 0 (required) range 1 (optional) range 2 (optional)	50, 225 100, 350 150, 450	mV	
	Crosstalk signal Vpk-pk, each aggressor	700 +/- 10%	mV	At TP6a. Counter-propagating aggressors.[b] Transition time measured at this PRBS9 test pattern transition: 1111111**10**000011...
	Crosstalk signal transition time, 20%-80%	17 +/- 3	ps	

Symbol	Parameter	Max	Min	Unit	Conditions
Vout	Single-ended output voltage	4.0	-0.3	V	Referred to Signal Ground; measured at TP7a
V_{CM}	AC common mode output voltage	20		mV	(RMS); at TP7a
	Termination mismatch	5		%	1 MHz; at TP7a
S_{DD22}	Differential output return loss	Eq. 5 on page 309		dB	At TP7a, 50 MHz to 26 GHz
S_{CC22}	Common mode output return loss	-2		dB	At TP7a, 200 MHz to 26 GHz
S_{DC22}	Common mode to differential reflection	Eq. 6 on page 309		dB	At TP7a, 50 MHz to 26 GHz
t_r, t_f	Output transition time		10	ps	20-80%, Transition time measured at these PRBS9 test pattern transitions: 1111111**10**000**01**11101...
J2	J2 Jitter	0.44		UI	At TP7a
J9	J9 jitter	0.69		UI	At TP7a

a. Output range is set for QSFP+ interfaces using page 03, addresses 238 & 239; see Section 8.5.
For CXP interfaces, output range is set using Rx Addresses 62-67; see Section 8.7.2.
b. Please refer to CIWG Method of Implementation (MOI) document Active Time Domain Testing for detailed specification of testing methodology and parameters.

Figure 35. InfiniBand Spec for output signal conditions

Appendix 3: Determining Scope Attenuation Factors

All sampling scopes provide a means of compensating for fixed external path losses between the test signal's source and the scope input. This compensation will allow accurate measurements as the test signal experiences path loss which causes the scope to measure a lower voltage than actual as illustrated in Figure 36. This loss must be considered in order for reported scope voltage measurements to be correct. This section describes the procedure to determine the compensation value for each of the scope input channels used in this MOI's differential signal measurements.

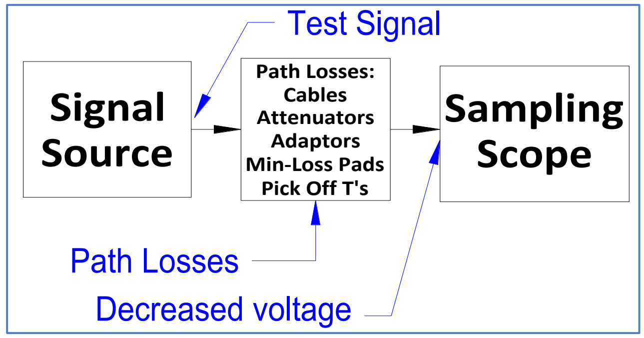


Figure 36. Loss Compensation

Equipment Required

Equivalent substitutions may be made for the equipment listed below. It is critical when two independent stations must be correlated for a test event, that the same exact equipment be used to determine attenuation factors for both stations.

Item #	Description	Vendor	Part #	Qty	Notes
1	Synthesizer	Anritsu	MG3692C	1	Source for 6.445GHz CW calibration signal (or equivalent)
2	Power Meter	Anritsu	ML2437A	1	Power Meter Control Unit (or equivalent)
3	Power Sensor	Anritsu	MA2482D	1	Power Sensor, 10MHz - 18GHz (or equivalent)
4	Measurement Cables	Per MOI	-	2	The exact same skew-matched cables that will be used for all sampling scope measurements while executing this MOI
5	Inline RF Components	Per MOI	-	As Required	All components, accessories, adaptors and connectors that will be present at the sampling scope inputs while executing this MOI
6	Sampling Scope	Per MOI	-	1	The same sampling scope used while executing this MOI

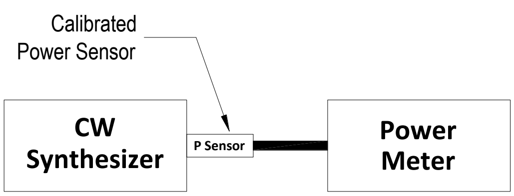
Table 5. Scope Calibration Equipment

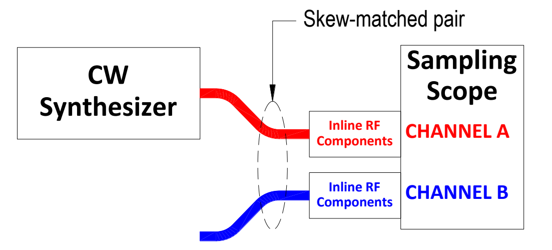
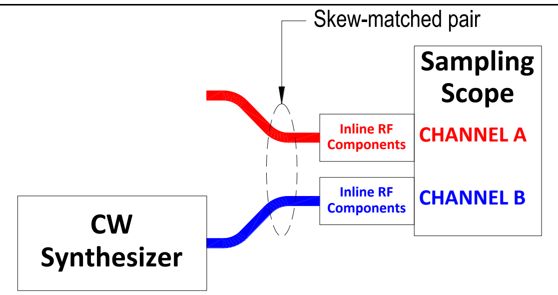
Procedure Overview

This process determines, through actual measurements, the attenuation factors that will be used for each channel of the sampling scope inputs that will be used to measure differential signals during the execution of this document.
The general steps include:

- Generating a reference signal (≈ bit rate /4)
- Measuring that reference signal amplitude using calibrated NIST-traceable equipment
- Applying the reference signal to the measurement equipment used for ATD testing
- Determining the difference between the NIST-traceable measurement and the ATD measurement equipment
- Using that difference as the basis for calculating the scope attenuation factor.

Procedure Steps

Step	Description	Connection Diagram
1	a. Set synthesizer frequency to 6.445GHz, CW / Non-Modulated b. Set synthesizer output power to -3.0dBm c. Connect power sensor directly to synthesizer output port d. Turn synthesizer power on e. Record measured power meter level (P_{REF}) f. Turn synthesizer power off.	

2	a. Connect scope Channel A cable to synthesizer output port b. All inline accessories for ATD testing must be present c. Turn on synthesizer d. Record mV p-p on Channel A using scope (V_A) e. Turn synthesizer power off.	
3	a. Connect scope Channel B cable to synthesizer output port b. All inline accessories for ATD testing must be present c. Turn on synthesizer d. Record mV p-p on Channel B using scope (V_B) e. Turn synthesizer power off.	

Calculations

- To convert power meter ***dBm*** reading to ***mVp-p***:
  mV_{REF} =SQRT(10^(P_{REF} / 10)*0.05)*1.414*2000
- Scope Channel A Attenuation Factor = 20 * LOG (mV_{REF} / V_A)
- Scope Channel B Attenuation Factor = 20 * LOG (mV_{REF} / V_B)

Apply the attenuation factors determined above into each sampling scope channel. Doing so will improve the accuracy of the voltage measurements across different test stations. This procedure will also improve the repeatability of test data spanning different Plugfest events.

Important Note:

The EDR ATD test station requires 2 sets of attenuation factors for the 2 different accessory scenarios described below.

1. Skew-Matched Cables → Phase Trimmers
2. Pick-Off T's → Skew Matched Cables → Phase Trimmers

This procedure should be conducted once for each accessory scenario. The proper attenuation factor must be loaded into the DCA-X during calibration steps and during DUT testing steps.

Sample Values (Taken from Anritsu Calibration Worksheet)

	Freq (GHz)	Synthesizer Setting (dBm)	Power Meter (dBm)	Power Meter (mV)	Scope CH A Vp-p (mV)	Scope CH B Vp-p (mV)	Atten Factor A (dB)	Atten Factor B (dB)
EDR-CAL	6.445	2	-7.84	256	199.5	197.3	2.18	2.28
EDR-DUT	6.445	2	-7.84	256	142.7	138.6	5.09	5.34

Appendix 4: EDR ATD Calibration Work Sheet

COUNTER-FEXT AGGRESSORS

Parameter	Unit	Module	Setting	Unit
Reverse Bit Rate	MP1800A #2	MU181000A	25.78383	Gb/s
Aggressor PRBS	MP1800A #1	MU183020A #2, CH1	PRBS31	-
Aggressor PPG Ampliude	MP1800A #1	MU183020A #2, CH1		V

PPG BASELINE PERFORMANCE

Parameter	Unit	Module	Setting	Unit
Forward Bit Rate	MP1800A #1	MU181000A	25.78125	Gb/s
Forward Traffic PRBS	MP1800A #1	MU183020A #1, CH1	PRBS9	
Forward Traffic PPG Amplitude	MP1800A #1	MU183020A #1, CH1		V
Even-Odd Jitter	MP1800A #1	MU183020A #1, CH1		-
Random Jitter	MP1800A #1	MU181500B		UI
Bounded Uncorrelated Jitter	MP1800A #1	MU181500B		UI
Sinusoidal Jitter	MP1800A #1	MU181500B		UI

FORWARD TRAFFIC

Parameter	Unit	Module	Setting	Unit
Forward Bit Rate	MP1800A #1	MU181000A	25.78125	Gb/s
Forward Traffic PRBS	MP1800A #1	MU183020A #1, CH1	PRBS9	
Artek ISI Magnitude	CLE1000-S2	-		%
Forward Traffic Amplitude	MP1800A #1	MU183020A #1, CH1		V
Random Jitter	MP1800A #1	MU18500B		UI

COUNTER-NEXT AGGRESSORS

Parameter	Unit	Module	Setting	Unit
Reverse Bit Rate	MP1800A #2	MU181000A	25.78383	Gb/s
Aggressor PRBS	MP1800A #1	MU183020A #2, CH1	PRBS31	-
Aggressor PPG Ampliude	MP1800A #1	MU183020A #2, CH1		V

Revision History

Revision	Release Date	Rev Notes
2.00	5/17/2017	Significant re-write to reflect conversion to IEEE calibration method.
1.04	3/14/2015	Changed document revision format to single decimal. Removed trigger cable. Not needed for scope measurements. Added worksheet for recording equipment settings during ATD calibration. Added notation about alternating reverse-polarity connections for aggressors. Changed reverse traffic rate to 25.78383 Gb/s. Expanded calibration Step 3 to include Tx CDR Enabled condition. Test point corrections in calibration figures and document. Updated I2C cable interface. MSL pin must be grounded. Add transition speed measurements during calibration steps. Reversed order of Revision History table.
1.0.03	10/6/2014	Added Complete DUT Test Connection Diagram (Figure 22) Corrected frequency used in Appendix 7 (6.445GHz) Changed reverse traffic rate to 25.00Gb/s.
1.0.02	9/25/2014	Replaced “Agilent” with “Keysight” in document file name. Corrected part number for ATD Platform in Table 1 Updated Table of Contents. Reference to Appendix 8 now points to Appendix 7. General clean-up.
1.0.01	9/17/52014	Replaced “Agilent” with “Keysight” throughout. Corrected part numbers. General clean-up.
1.0.00	9/11/2014	Initial Release

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