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Comment Supporting materials: The Reuse of 10GbE SRS Test for SR4/10, 40G-LR4

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Review 10GbE 802.3ae testing standards

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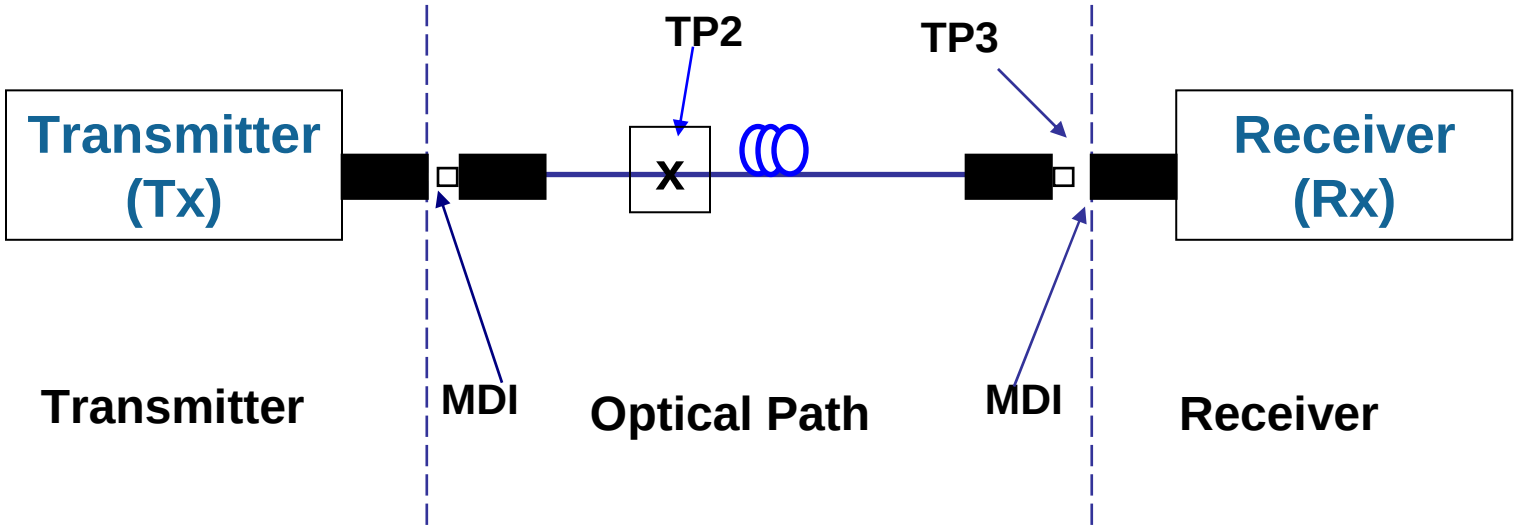
10GbE optical tests and specifications divided into

- Transmitter; measured at **TP2**
- Receiver; signals defined at **TP3**; (with stressed eye conformance)
- Optical path; defined as link power budget.



10GbE 802.3ae link budget based on link model

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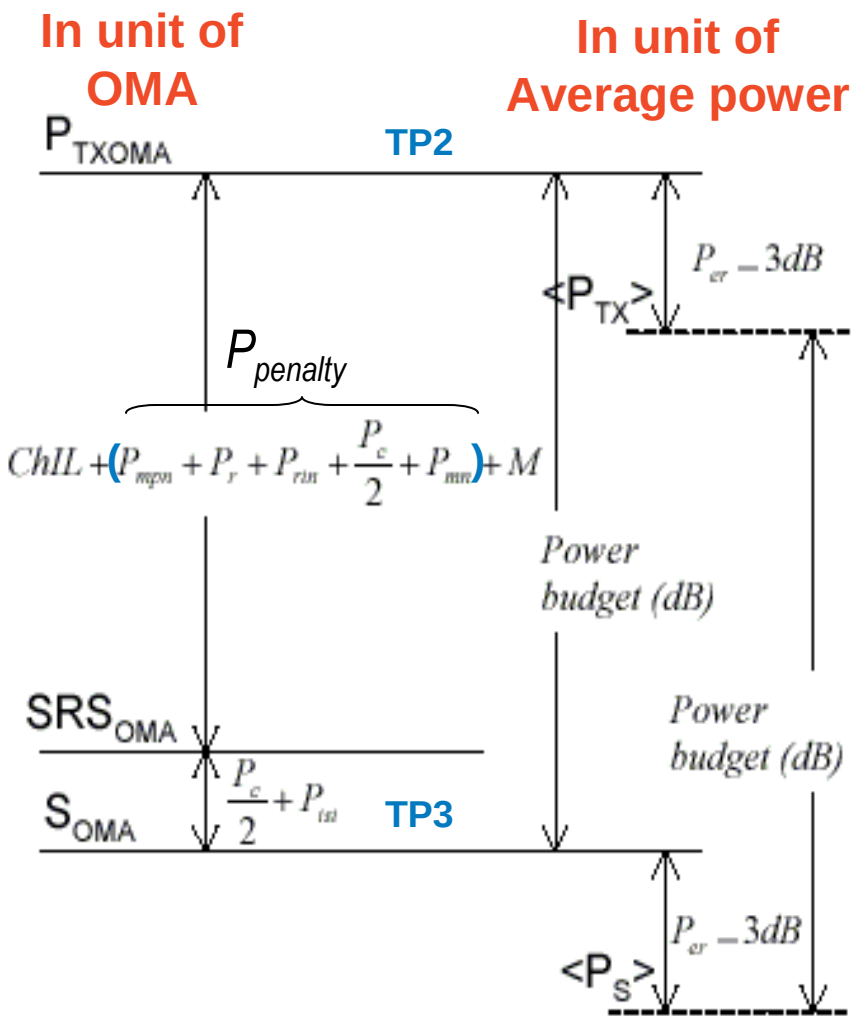

Figure 2. The 10Gigabit Ethernet power budget

- **10GbE link power budget in OMA**

$$SRS_{OMA} = P_{TXOMA} - CHIL - P_{penalty} - M$$

$$S_{OMA} = SRS_{OMA} - P_{ISI} - P_C/2$$

  - SRS_{OMA} : Stressed Rx sensitivity in OMA (dBm)
  - P_{TxOMA} : Transmit power in OMA (dBm)
  - CHIL : Channel loss (dB)
  - M : Link margin (dB)

- **10GbE link power budget in average power**

$$<P_S> = <P_{TX}> - CHIL - P_{penalty} - M$$

  - $<P_S>$: Receiver sensitivity (dBm)
  - $<P_{Tx}>$: Average transmit power (dBm)

- **Correlating OMA with average power**

$$S_{OMA} = <P_S> + P_{ER} - 3dB$$

$$P_{TXOMA} = <P_{TX}> + P_{ER} - 3dB$$

Optical specs of 10GbE standards was developed based on 10GbE link model worst-case analysis.

10GbE testing specifications:

Summary of 10GBASE serial PHY interfaces

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Table 52-1 – 10GBASE serial PHYs*

Name	Description	Technology
10GBASE-SR	850nm Serial LAN PHY	DML-VCSEL; MM; 2-300m
10GBASE-LR	1310nm Serial LAN PHY	DML-FP/DFB; SM; 2-10km
10GBASE-ER	1550nm Serial LAN PHY	EML-DFB; SM; 2-40km
10GBASE-SW	850nm Serial WAN PHY	DML-VCSEL; MM; 2-300m
10GBASE-LW	1310nm Serial WAN PHY	DML-FP/DFB; SM; 2-10km
10GBASE-EW	1550nm Serial WAN PHY	EML-DFB; SM; 2-40km

*: **100GBASE-SR4/10 (850nm Parallel (4/10 Lane) PMD)**

40GBASE-LR4 (1310nm Parallel (4 Lane) PMD)

10GbE testing specifications:

10GBASE-S interfaces (850nm, MMF)

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Table 52-7 – 10GBASE-S transmit characteristics

Description	10GBASE-S	Unit
Signaling speed (nominal) 10GBAS- R 10GBAS- W	10.3125 9.95328	GBd
Signaling speed variation from nominal (max.) 10GBAS- R 10GBAS- W	 ±100 ±20	ppm
Center wavelength (range)	840 – 860	nm
RMS spectral width[a] (max)	See footnote[b]	
Average launch power (max)	See footnote[c]	
Average launch power[d] (min)	-7.3	dBm
Launch power (min) in OMA	See footnote[b]	
Average launch power of OFF transmitter[e] (max)	-30	dBm
Transmitter and dispersion penalty[g] (max)	3.9	dB
Extinction ratio (min)	3	dB
$RIN_{12}OMA$[e] (max)	-128	dB/Hz
Optical Return Loss Tolerance (max)	12	dB
Encircled flux	See footnote[f]	
Transmitter eye mask definition {X1,X2,X3,Y1,Y2,Y3}	{0.25,0.40,0.45,0.25,0.28,0.40}	

[a] RMS spectral width is the standard deviation of the spectrum.

[b] Trade-offs are available between spectral width, center wavelength and minimum optical modulation amplitude. See Figure 52-3 and Table 52-8.

[c] The 10GBASE-S launch power shall be the lesser of the class 1 safety limit as defined by 52.10.2 or the average receive power (max) defined by Table 52-9.

[d] Average launch power (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant, however a value above this does not ensure compliance.

[e] Examples of an OFF transmitter are: no power supplied to the PMD, laser shutdown for safety conditions, activation of a PMD_global_transmit_disable or other optional transmitter shut down conditions.

[f] The encircled flux at 19µm shall be greater than or equal to 86% an dthe encircled flux at 4.5 µm shall be less than or equal to 30% when measured into Type A1a (50/125 µm multimode) fiber per TIA-455-203.

[g] TDP(max) and OMA(min) are at the respective wavelength and spectral width as specified in Table 52-8.

10GbE testing specifications:

10GBASE-S interfaces (850nm, MMF)

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Table 52-9 – 10GBASE-S receive characteristics

Description	10GBASE- S	Unit
Signaling speed (nominal) 10GBAS- R 10GBAS- W	 10.3125 9.95328	GBd
Signaling speed variation from nominal (max.)	±100	ppm
Center wavelength (range)	840 –860	nm
Average receive power [a] (max)	-1.0	dBm
Average receiver power[b] (min)	-9.9	dBm
Receiver sensitivity (max) in OMA [c]	0.077 (-11.1)	mW (dBm)
Receive reflectance (max)	-12	dB
Stressed receiver sensitivity (max) in OMA[d, e]	0.18 (-7.5)	mw (dBm)
Vertical eye closure penalty[f] (min)	3.5	dB
Stressed eye jitter[g] (max)	0.3	UI pk-pk
Receive electrical 3dB upper cutoff frequency	12.3	GHz

[a] The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having a power level equal to the Average Receive Power (max) plus at least 1dB.

[b] Average launch power (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant, however a value above this does not ensure compliance.

[c] Receiver sensitivity is informative.

[d] Measured with conformance test signal at TP3 (see 52.9.10.2) for BER=10^{-12}.

[e] **The stressed sensitivity values in the table are for system level BER measurements which include the effects of CDR circuits**. It is recommended that at least 0.4dB additional margin be allocated if component level measurements are made without the effects of CDR circuits.

[f] Vertical eye closure penalty is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

[g] Stressed eye jitter is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

10GbE testing specifications:

10GBASE-S interfaces (850nm, MMF)

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Table 52-10 – 10GBASE-S link power budgets[a,b]

Parameter	62.5 μm MMF		50 μm MMF			Unit
Modal bandwidth as measured at 850nm	160	200	400	500	2000	MHZ•km
Power budget	7.3					dB
Operating distance	26	33	66	82	300	m
Channel insertion loss[c, d]	1.6		1.7	1.8	2.6	dB
Allocation for penalties	4.7	4.8	5.1	5.0	4.7	dB
Addition insertion loss allowed[e]	1.0	0.8	0.5		0.0	dB

[a] Budget numbers are rounded to nearest 0.1dB.
[b] Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.
[c] Operating distances used to calculate the channel insertion loss are the maximum values specified in Table 52-6.
[d] The specifications for a wavelength of 840nm and a spectral width of 0.29 nm in Table 52-8 is used to calculate channel insertion loss, allocation for penalties, and additional insertion loss allowed.
[e] This portion of the link budget is permitted o be used to overcome insertion loss higher than the “Channel insertion loss” values and in some cases may be less than the value shown.

Table 52-52 in 52.14 for optical fiber cabling indicates max. fiber cable attenuation 3.5dB/km at 850nm as well as fiber cabling dispersion and slope.

10GbE testing specifications:

10GBASE-L/E interfaces (1310nm/1550nm, SMF)

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Table 52-12/16 – 10GBASE –L/E transmit characteristics

Description	10GBASE-L	10GBASE-E	Unit
Signaling speed (nominal) 10GBASE- R 10GBASE- W	 10.3125 9.95328	 10.3125 9.95328	GBd
Signaling speed variation from nominal (max.) 10GBASE- R 10GBASE- W	 ±100 ±20	 ±100 ±20	ppm
Center wavelength (range)	1260 –1355	1530-1565	nm
Side Mode Suppression Ratio (min)	30		dB
Average launch power (max)	0.5	4.0	dBm
Average launch power[a] (min)	-8.2	-4.7	dBm
Launch power (min) in OMA minus TDP[b]	-6.2	-2.1	dBm
Average launch power of OFF transmitter[c] (max)	-30		dBm
Optical Modulation Amplitude[d] (min)	-5.2	-1.7	dBm
Transmitter and dispersion penalty (max)	3.2	3.0	dB
Extinction ratio (min)	3.5	3	dB
$RIN_{12}OMA$[e] (max)	-128		dB/Hz
Optical Return Loss Tolerance (max)	12	21	dB
Transmitter Reflectance[f] (max)	-12		dB
Transmitter eye mask definition {X1,X2,X3,Y1,Y2,Y3}	{0.25,0.40,0.45,0.25,0.28,0.40}		

[a] Average launch power (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant, however a value above this does not ensure compliance.
[b] TDP is transmitter and dispersion penalty.
[c] Examples of an OFF transmitter are: no power supplied to the PMD, laser shutdown for safety conditions, activation of a PMD_global_transmit_disable or other optional transmitter shut down conditions.
[d] Even if the TDP < 1dB (-L) or 0.4dB (-E), the OMA(min) must exceed this value.
[e] RIN measurement (-E) is made with return loss at 21dB.
[f] Transmitter reflectance (-L) is defined looking into the transmitter.

10GbE testing specifications:

10GBASE-L/E interfaces (1310nm/1550nm, SMF)

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Table 52-13/17 – 10GBASE–L/E receive characteristics

Description	10GBASE- L	10GBASE- E	Unit
Signaling speed (nominal) 10GBASE- R 10GBASE- W	 10.3125 9.95328	 10.3125 9.95328	GBd
Signaling speed variation from nominal (max.)	±100	±100	ppm
Center wavelength (range)	1260 –1355	1530-1565	nm
Average receive power (max)	0.5[a]	-1.0	dBm
Average receiver power[b] (min)	-14.4	-15.8	dBm
Maximum receive power (for damage)		4.0	dBm
Receiver sensitivity (max)[c] in OMA	0.055 (-12.6)	0.039 (-14.1)	mW (dBm)
Receive reflectance (max)	-12	-26	dB
Stressed receiver sensitivity (max) in OMA[d, e]	0.093 (-10.3)	0.074 (-11.3)	mw (dBm)
Vertical eye closure penalty[f] (min)	2.2	2.7	dB
Stressed eye jitter[g] (max)	0.3		UI pk-pk
Receive electrical 3dB upper cutoff frequency	12.3		GHz

[a] The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having a power level equal to the Average Receive Power (max) plus at least 1dB.

[b] Average launch power (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant, however a value above this does not ensure compliance.

[c] Receiver sensitivity is informative.

[d] **The stressed sensitivity values in the table are for system level BER measurements which include the effects of CDR circuits**. It is recommended that at least 0.4dB additional margin be allocated if component level measurements are made without the effects of CDR circuits.

[e] Measured with conformance test signal at TP3 (see 52.9.10.2) for BER=10^{-12}.

[f] Vertical eye closure penalty is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

[g] Stressed eye jitter is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

10GbE testing specifications:

10GBASE-L/E interfaces (1310nm/1550nm, SMF)

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Table 52-14/18 – 10GBASE-L/E link power budgets[a,b]

Parameter	10GBASE-L	10GBASE-E		Unit
Power budget	9.4	15		dB
Operating distance	10	30	40[c]	km
Channel insertion loss[d]	6.2[e]	10.9[f]		dB
Maximum Discrete Reflectance (max)		-26		dB
Allocation for penalties	3.2	3.6	4.1	dB
Addition insertion loss allowed	0.0	0.5	0.0	dB

[a] Budget numbers are rounded to nearest 0.1dB.

[b] Link penalty are used for link budget calculations, they are not requirements and arenot meant to be tested (-L) Link penalty are built into the transmitter specifications by testing the PMD with a maximum dispersion fiber (-E).

[c] Links longer than 30km are considered engineered links. Attenuation for such links needs to be less than that guaranteed by B1.1 or B1.3 single mode fiber.

[d] Operating distances used to calculate the channel insertion loss are the maximum values specified in Table 52-11 (-L) or 52-15 (-E). And fiber attenuation of 0.4dB/km at 1310 nm plus an allocation for connection and splice loss given in 52.14.2.1.

[e] A transmitter wavelength of 1260 nm with a TDP of 3dB is used to calculate channel insertion loss, and allocation for penalties in this table.

[f] A wavelength of 1565 nm and 3dB transmitter and dispersion penalty (TDP) is used to calculate channel insertion loss, and allocation for penalties.

Table 52-23 & 52 for transmitter compliance channel specifications indicates the use of SMF-28 fiber with worst-case dispersion.

$$D(\lambda) = 0.25 \cdot S_o \cdot \lambda \cdot \{1-(\lambda_o/\lambda)^4\}$$

$$1300nm < \lambda_o < 1324nm \text{ and } S_o = 0.093 ps/nm^2 \cdot km$$

10GbE testing standards for transmit:
Transmitter and dispersion penalty (TDP)

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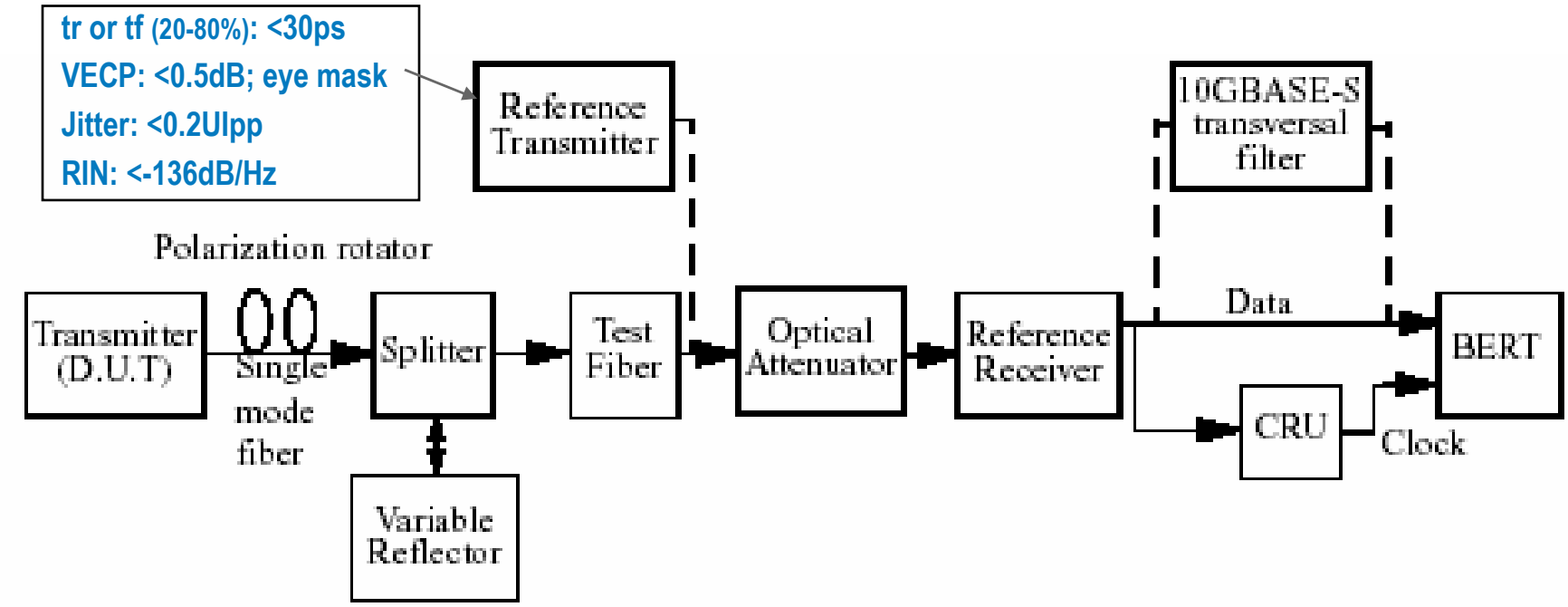

Figure 52–12—Test setup for measurement of transmitter and dispersion penalty

- **52.9.10.2 & 52.9.10.3: TDP is measured as:**
  - **S** = Pin for 10^{-12} BER with Reference Tx
  - **P_DUT** = Pin for 10^{-12} BER with DUT Tx & fiber
  - **TDP = P_DUT - S** <= Spec Value

10GbE testing standards for receive:

Rx stressed eye conformance testing

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52.9.10.2 & 52.9.10.3: "… SJ frequencies must be well within the flat portion of the template…" & "…stepped across freq. & amplitude…"

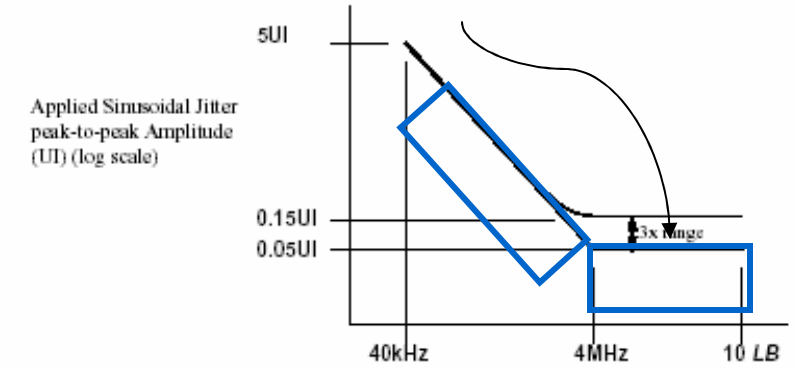
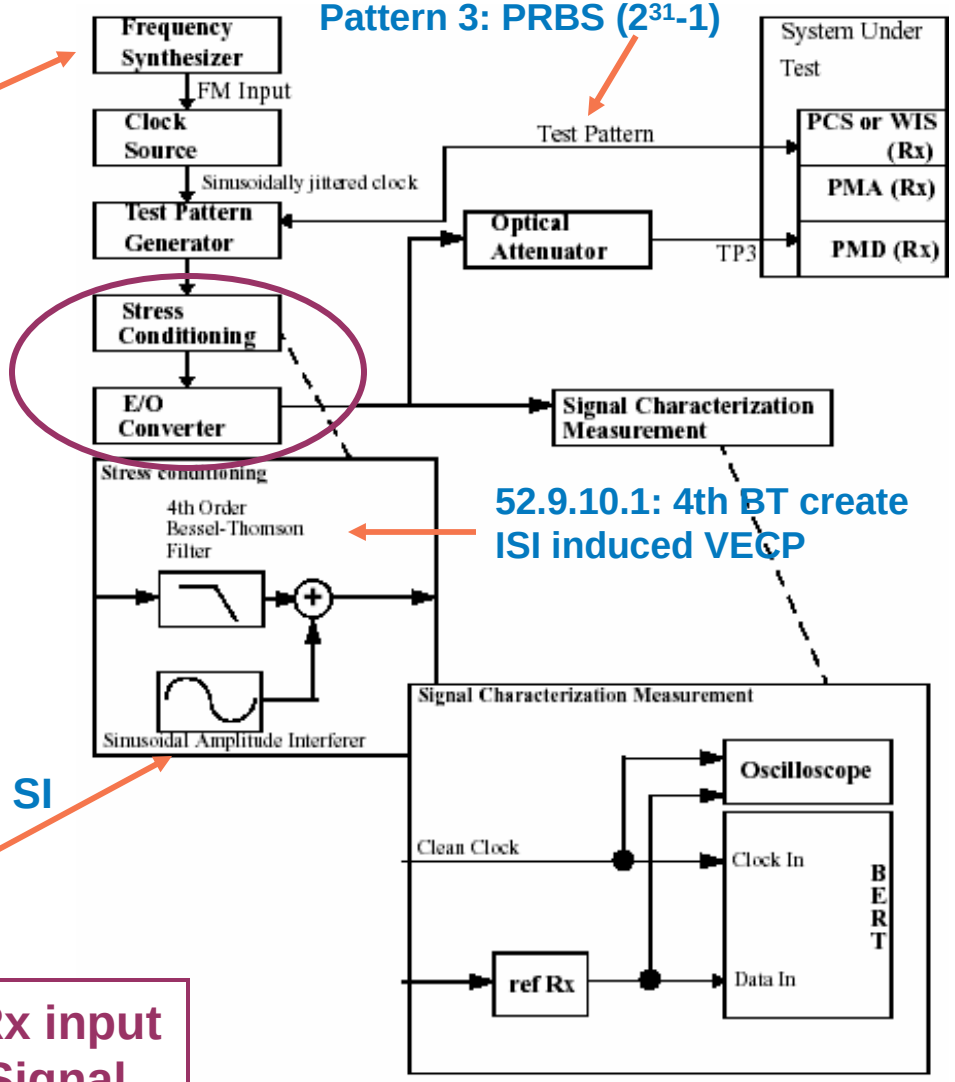


Figure 52–4—Mask of the sinusoidal component of jitter tolerance (informative)

52.9.10.2 : "The frequency of the SI may be set at any frequency between 100 MHz and 2 GHz."

Pattern 2: ($A_nA_iA_nA_i$) or Pattern 3: PRBS (2^{31}-1)



52.9.10.1: 4th BT create ISI induced VECP

Figure 52–10—Stressed receiver conformance test block diagram

Demonstrate 10^{-12} BER at specified Rx input sensitivity with Stressed Transmit Signal

10GbE testing standards for receive:

Rx stressed eye conformance testing

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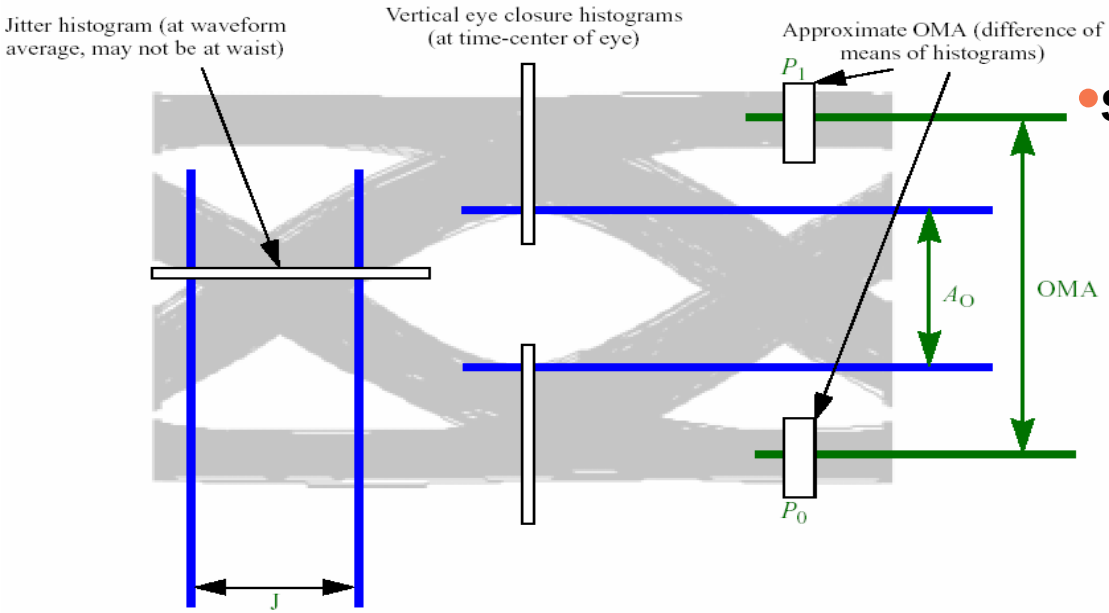


Figure 52–11—Required characteristics of the conformance test signal at TP3

Extinction ratio

$ER_{dB} = 10\log_{10}(P1/P0)$, dB

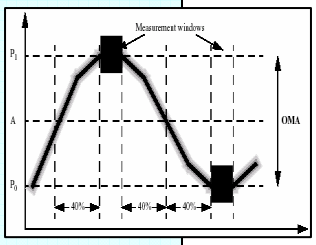
Optical Modulation Amplitude

OMA = P1 – P0, uW

Vertical Eye Closure Penalty

$VECP = 10 \times \log_{10}(OMA/Ao)$, dB

Ao = Amplitude of Eye Opening



- **Stressed eye construction process**
  - **PRBS >= 2^{10}-1 & Square wave**
  - **Set extinction ratio**
  - **Measure Optical Modulation Amplitude (OMA)**
  - **Add ISI induced VECP relative to OMA**
    - **<67% due to filtering**
  - **Add remaining VECP through sinusoidal interferer and sinusoidal jitter**
  - **Iterate (all) to achieve correct VECP & Jitter**
  - **Attenuate signal to required OMA**
  - **Step through complete sinusoidal jitter template**

10GbE SRS Testing Configuration

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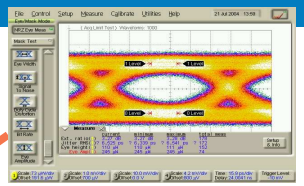


Tx
(stressed)

10GbE Stressed RX optical Test Systems

SR: 850nm; 9.95/10.3Gb/s

LR: 1310nm; 9.95/10.3Gb/s

ER: 1550nm; 9.95/10.3Gb/s

Rx
(for BER)

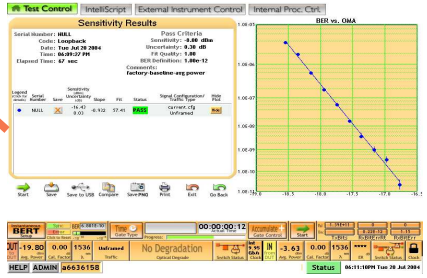
10G Rx

10G Serdes or CDR

Optional O/E module

PMA loopback

(PMA loopback is pretty useful for both physical layer BIST and SRS test)



(Source from Circadiant box)

Other two h/w configurations:

1) Rx-path only, Tx path terminated.
2) Rx path directly loopback to Tx path with external cable for xtalk check.

Systems Configurations:

SRS = Stressed RX Sensitivity

802.3ae 10.3GBASE-R, 10.3125Gb/s, BER=10^{-12}

9.95/10.3GBASE-E stressed eye diagram from Commercial testers

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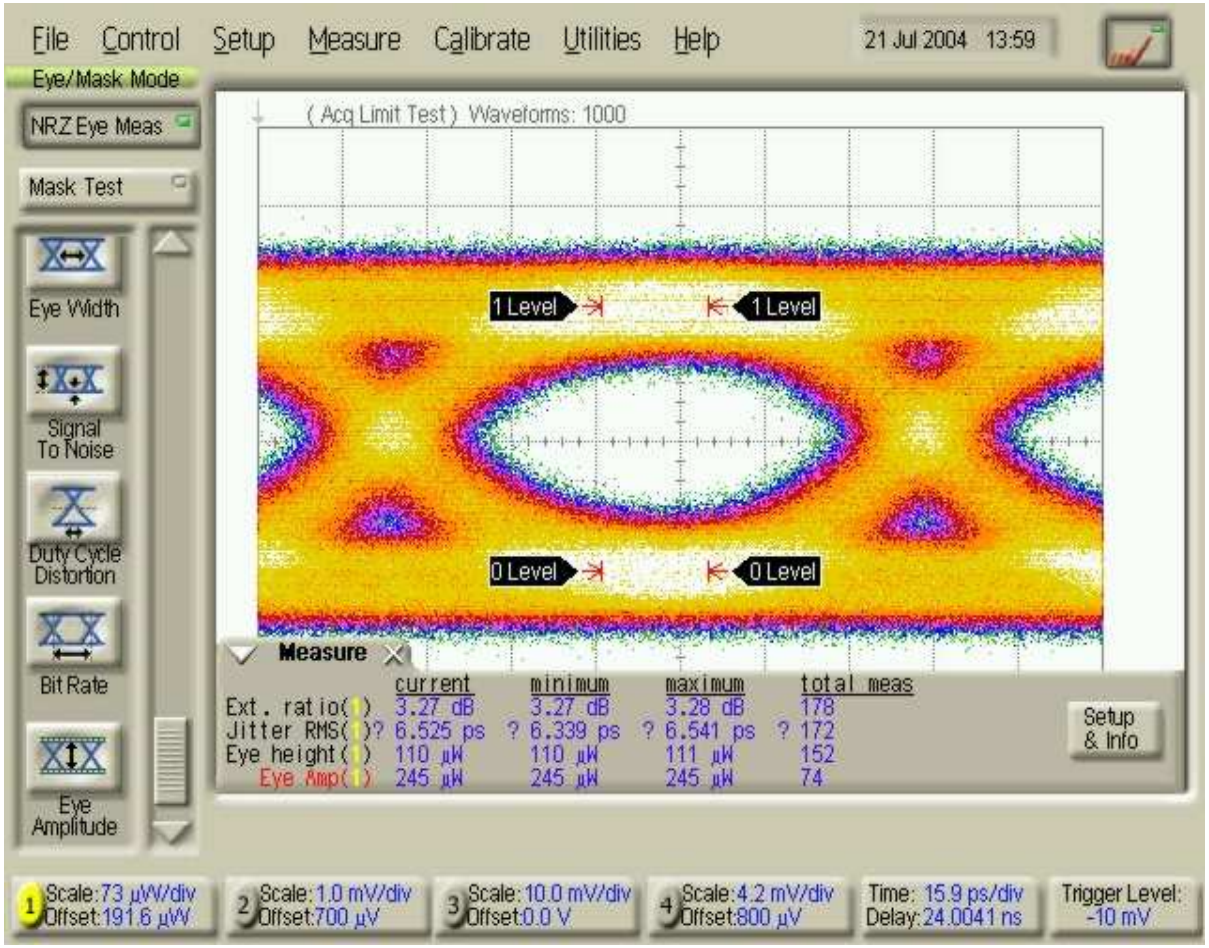
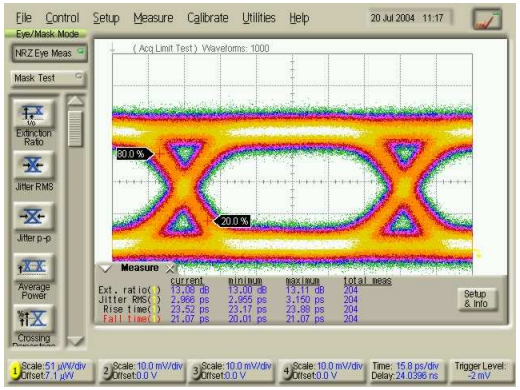
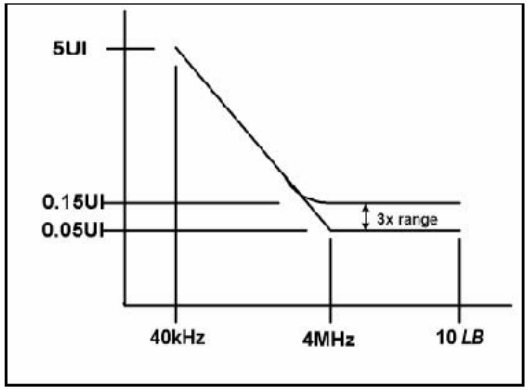


From 802.3ae SR: ER=3dB, VECP=2.7dB, SJ sweep, ISI on, AM on

Clean eye w/o SJ, AM, ISI



SJ sweep template



802.3ae 10GbE testing specifications:
Pass/fail criteria for -L/E (1310nm/1550nm, SMF)

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- One example: 10GBASE-L/E standard for clean and stressed receiver sensitivity requirement

Description	10GBASE- L	10GBASE- E	Unit
Signaling speed (nominal) 10GBASE- R 10GBASE- W	 10.3125 9.95328	 10.3125 9.95328	GBd
Signaling speed variation from nominal (max.)	±100	±100	ppm
Center wavelength (range)	1260 –1355	1530-1565	nm
Average receive power (max)	0.5[a]	-1.0	dBm
Average receiver power[b] (min)	-14.4	-15.8	dBm
Maximum receive power (for damage)		4.0	dBm
Receiver sensitivity (max)[c] in OMA	0.055 (-12.6)	0.039 (-14.1)	mW (dBm)
Receive reflectance (max)	-12	26	dB
Stressed receiver sensitivity (max) in OMA[d,e]	0.093 (-10.3)	0.074 (-11.3)	mw (dBm)
Vertical eye closure penalty[f] (min)	2.2	2.7	dB
Stressed eye jitter[g] (max)	0.3		UI pk-pk
Receive electrical 3dB upper cutoff frequency	12.3		GHz

-14.1dBm for clean eye (informative)

-11.3dBm for stressed eye (mandatory)

Note: SRS (max) in OMA is -7.5dBm for SR

Review off-the-shelf RX chain (BER=10^{-12}):

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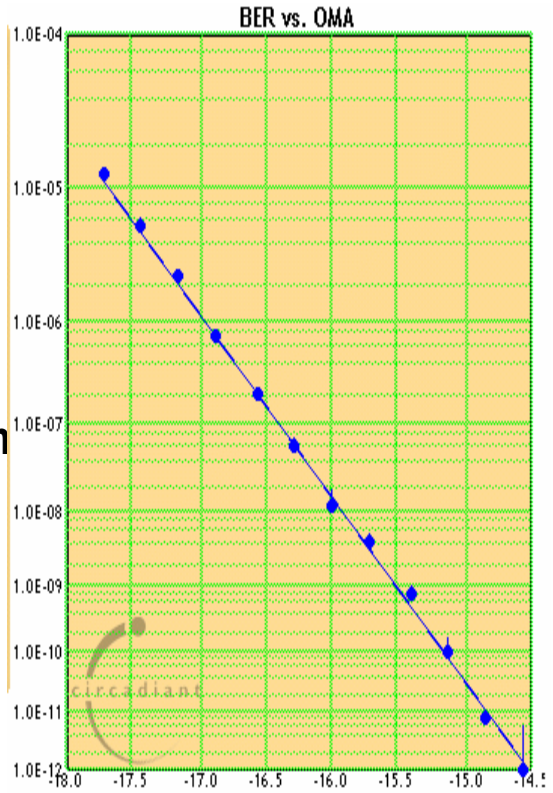
- **SRS values are for system level BER measurements which include the effects of CDR circuits.**
- **Measured SRS in OMA for Off-the-shelf parts .**
  - **10GBASE-SR:**
    - **Normally show better than -11dBm in OMA against -7.5dBm**
    - **Typically >3.5dB margin.**
  - **10GBASE-LR:**
    - **Normally show better than -13dBm in OMA against -10.3dBm**
    - **Typically >2.5dB margin (slightly less)**
  - **10GBASE-ER:**
    - **Normally show SRS < -14.5dBm in OMA against -11.3dBm**
    - **RX sens. for Clean eye is about -17dBm against -14.1dBm.**
    - **Typically over 3dB margin**



Estimating Multi-channel Xtalk

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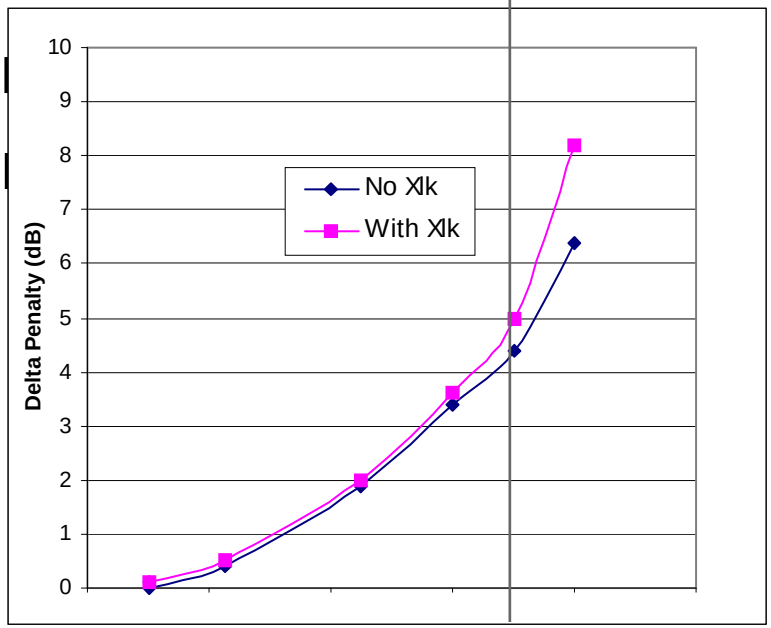
- The Xtalk for SR4/10 and 40G-LR4 are budgeted by reduced RX sens.
- Multi-channel Xtalk mainly come from adjacent channels, estimated from prototyped QSFP 850nm transceiver.
- Measured Xtalk is ~1dB at operati
  (Sound reasonable to defined wo
  case Xtalk at ~2dB.)



Xtalk is estimated with all other channels having ~300mVpp (diff) sync and async data input.

Consider SR4/10 SRS in Table 86-10 (#331)

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- **Suggest to reuse 802.3ae 10GBASESR SRS for TP3 specs by taking into account Xtalk impacts.**

Table 86–10—40GBASE–SR4 and 100GBASE–SR10 optical receiver characteristics

Description	Type	Value	Unit
Center wavelength, each lane	Range	840 to 860	nm
Damage threshold[a]	Min	+2	dBm
Average power at receiver input, each lane	Max	+1[b]	dBm
	Min	–7.9 [b c]	dBm
Receiver reflectance	Max	–12	dB
Stressed receiver sensitivity in OMA, each lane[d e]	Max	TBD	dBm
Conditions of stressed receiver sensitivity test:			
Vertical eye closure penalty[f], each lane	–	TBD	dB
Stressed eye jitter J[g], each lane	–	TBD	UI

Consistent with -9.9 dBm single-ch specs

-5.5dBm (consider 2dB xtalk)

1.7dB (relaxed)

0.3UIpp (no change)

[a] The receiver shall be able to tolerate, without damage, continuous exposure to a modulated optical input signal having this power level on one lane. The receiver does not have to operate correctly at this input power. *[Editor's note (to be removed prior to publication) - 1 dB above average receive power maximum, to allow headroom for receiver testing.]*

[b] *[Editor's note (to be removed prior to publication) - For further study]*

[c] *[Editor's note (to be removed prior to publication) - Depends on connector loss]*

[d] Measured with conformance test signal at TP3 (see 86.7.5.9) for BER = 10^{-12}.

[e] *[Editor's note (to be removed prior to publication) - Values of -5.4 dBm for Stressed receiver sensitivity in OMA, 1.67 dB for Vertical eye closure penalty and 0.37 UI Stressed eye jitter J have been proposed. Further information is invited.]*

[f] Vertical eye closure penalty is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

[g] Stressed eye jitter is a test condition for measuring stressed receiver sensitivity. It is not a required characteristic of the receiver.

Note: SRS values are for system level BER measurements which include the effects of CDR circuits.

SR4/10 link budget in Table 86-13 (#330)

VITESSE

- The penalty due to crosstalk in RX is budgeted by RX sensitivity. So it's not rational to have significantly larger . Xtalk in TX is part of the penalty, during the RX-TX loopback test.
- The baseline proposal pepeljugoski_01_0508 (Slide#13) indicate PMA as a CDR, possibly with simple EDC (similar to existing SFP+ implementation), thus help further reduce the penalty.

Table 86–13—40GBASE–SR4 and 40GBASE–SR10 link power budget (informative)

Parameter	Value	Unit
Effective modal bandwidth at 850 nm	2000[a]	MHz•km
Power budget	8.3[b]	dB
Operating distance	0.5 to 100	m
Channel insertion loss[c]	1.9[d]	dB
Allocation for penalties[e]	6.4	dB
Additional insertion loss allowed	0	dB

[a] Per IEC 60793-2-10
[b] *[Editor's note (to be removed prior to publication) - For further study]*
[c] The channel insertion loss is calculated using the maximum distance specified in Table 86–1 and fiber attenuation of 3.5 dB/km at 850 nm plus an allocation for connection and splice loss given in 86.10.2.2.1.
[d] *[Editor's note (to be removed prior to publication) - Connector loss under study]*
[e] Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

-6.9dBm

5.0dB (equivalent to signal channel link budget)

SR4/10 RX jitter tolerance Table 86-17 (#333)

VITESSE

- **RX jitter tolerance is tested against sinusoidal jitter mask.**
- **Adopt 10GbE-R SRS test specs as well-established test methodology with commercial testset available.**

86.7.5.9 Stressed receiver sensitivity

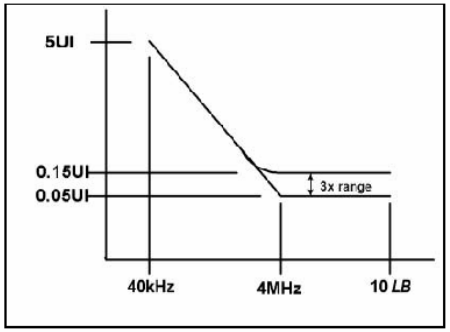
Stressed receiver sensitivity shall be within the limits given in Table 86–10 if measured using the method defined by 52.9.9 with the conformance test signal at TP3 with jitter J and vertical eye closure penalty as given in Table 86–10 and added sinusoidal jitter as specified in Table 86–17.

Table 86–17—Applied sinusoidal jitter

Frequency range	Sinusoidal jitter (UI_{pk-pk})
$f < 40$ kHz	Not specified
40 kHz $< f \leq 4$ MHz	TBD
4 MHz $< f < 10$ *LB*[a]	TBD

[a] *LB* = loop bandwidth; upper frequency bound for added sine jitter should be at least 10 times the loop bandwidth of the receiver being tested.

For each lane, the stressed receiver sensitivity is defined with the transmit section in operation on all lanes and with the receive lanes not under test in operation. The pattern for the received compliance signal is specified in Table 86–16. TBD, or a valid 40GBASE–R4 or 100GBASE–R10 signal is sent from the transmit section of the receiver under test. The data being transmitted is asynchronous to the received data.



$2x10^5/f+S-0.05$

$0.05 \leq S \leq 0.15$

Note: S is the sine jitter value used actually for calibration of the stressed eye.

Same for 40G-LR4 in Table 87-13.