Transmitter Functional Symbol Error Histogram (TFSEH) Updated Proposal

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Proposal in review and edit by Author Team & subject to further changes

TFSEH Functional Receiver (FRx) based Spec Summary

- TFSEH is not a standalone spec, instead it's normative w/ TECQ/TDECQ & RxS/SRS
- Uses established 802.3 optics spec methodology of single power penalty capturing multiple impairments
- FRx is not a HW Golden Receiver (GR), instead uses the following as reference:
  - TECQ/TDECQ scope-based SW GR
  - RxS/SRS conformance test signal, i.e. HW Golden Transmitter (GT)
- Addresses TDECQ corner case problems, ex.
  - TFSEH (p.15 line 4&5) and Tx_DP spec proposals
- Different from spec proposals using individual impairment electrical methodology, ex.
  - Tx jitter generation individual spec (D2.2) (even though TECQ is not a problem)
- Different from spec proposals for standalone interoperability using HW GR, ex.
  - Tx jitter generation individual spec indirectly set by HW GR jitter tolerance mask

TFSEH Update Proposal Background

- Functionally same as previous proposals; tweaks equations to best match 802.3 specs
- 1st proposal: patch-cord only Functional Rx (FRx) based spec

  FRx_OMA = Tx_DUT_OMA - Tx_power_budget - RxS_TECQ_correction + Test_margin
  - uses new term derived from Tx spec; max(DUT_TECQ - DUT_TDECQ, 0)
  - introduces analogy of tasting after cooking an existing recipe transmitter dish
- 2nd proposal: test-fiber & FRx based spec (*Tx_DUT_OMA - FRx_OMA → VOA_level*)

  VOA_level = Test_SMF_correction + RxS_TECQ_correction - Test_margin
- 3rd (in D2.3) proposal: test-fiber & FRx based spec (→ max(DUT_TECQ, DUT_TDECQ))

  VOA_level = Tx_DUT_power_budget - Test_fiber_power_budget
  - ORx_TECQ_allocation - Test_margin
- 4th (this) proposal: back to 2nd proposal except using max(DUT_TECQ, DUT_TDECQ)

  VOA_level = Test_fiber_correction + ORx_TECQ_correction - Test_margin

180.9.9 Transmitter functional symbol error histogram

The error mask is provided in Table 180–18 and is per 200G lane. The limit Hmax(k) is calculated based on 174A.9.5 using BER = 2.4×10^{-5} and p = 1. Test_margin, defined in 180.9.9.1, determines the input BER. Measurement time is 60 seconds.

One or more counts in test symbol errors k per test block with k greater than 8 indicates a probable failure.

Table 180–18—Transmitter functional symbol error mask

Test symbol errors k per test block	Probability Hmax(k)
1	1.15×10^{-1}
2	7.47×10^{-3}
3	3.24×10^{-4}
4	1.05×10^{-5}
5	2.73×10^{-7}
6	5.88×10^{-9}
7	1.08×10^{-10}
8	1.75×10^{-12}

180.9.9.1 Functional receiver (FRx) definition

The functional receiver (FRx) is a variable optical attenuator (VOA) followed by an optical receiver (ORx) that complies with characteristics as given in Table 180–8. The transmitter under test is connected to the FRx by a test fiber, which together with the VOA approximates compliance channel specifications as given in Table 180-15.

VOA level is given by Equation (180–27), in which the first and second term normalize differences in test fibers and optical receivers, respectively, so that symbol errors counts are repeatable across different conditions and are defined by the same algebraic expressions as define normative transmitter and receiver characteristics, respectively.

VOA_level = Test_fiber_correction + ORx_TECQ_correction - Test_margin (180–27)

where:

—Test_fiber_correction is the difference between the power budget used to set the transmitter under test OMA (min) and the estimated power budget of the test fiber, and is given by Equation (180-28)

—ORx_TECQ_correction is difference between receiver sensitivity (max) and ORx receiver sensitivity, both at transmitter under test TECQ, and is given by Equation (180–31)

—Test_margin is additional ORx_OMA which reduces test operating BER and equals 1.5dB

180.9.9.1 Functional receiver (FRx) definition (cont.)

Test_fiber_correction = Tx_DUT_power_budget – Test_fiber_power_budget (180-28)

where:

—Tx_DUT_power_budget is the transmitter under test power budget as given in Table 180-9, except uses measured instead of max TDECQ value as shown in Fig. 180-5, same as used in calculating transmitter OMA (min) as per Table 180-7, and is given by Equation (180–29)

—Test_fiber_power_budget is the test fiber power budget as given in Table 180-9, except uses estimates of the test fiber channel insertion loss, MPI, DGD and TDECQ penalties instead of their max values, and is given by Equation (180–30)

Tx_DUT_power_budget = Channel_insertion_loss + MPI_DGD_penalty_allocation + max(DUT_TECQ, DUT_TDECQ) (180–29)

where:

—Channel_insertion_loss is “Channel insertion loss” as given in Table 180–9

—MPI_DGD_penalty_allocation is “MPI DGD penalty allocation” as given in Table 180–9

—DUT_TECQ is the TECQ measured for the transmitter under test

—DUT_TDECQ is the TDECQ measured for the transmitter under test

180.9.9.1 Functional receiver (FRx) definition (cont.)

Test_fiber_power_budget = Test_fiber_loss + Test_fiber_MPI+DGD_penalty + Test_fiber_DUT_TDECQ (180–30)

where:

—Test_fiber_loss is an estimate of the actual channel insertion loss of the test fiber

—Test_fiber_MPI+DGD_penalty is an estimate of the actual MPI and DGD penalty of the test fiber

—Test_fiber_DUT_TDECQ is an estimate of the transmitter under test actual TDECQ over the test fiber (equals DUT_TECQ + estimate of the transmitter under test CD penalty over the test fiber)

ORx_TECQ_correction = RxS_OMA@DUT_TECQ - ORx_RxS@DUT_TECQ (180–31)

where:

—RxS_OMA@DUT_TECQ is the receiver sensitivity OMA (max) spec for TECQ >= 0.9 dB, as shown in Figure 180-4, extrapolated to TECQ = 0 dB (-4.3 dBm), at the TECQ measured for the transmitter under test

—ORx_RxS@DUT_TECQ is the actual ORx receiver sensitivity OMA at the TECQ measured for the transmitter under test.

180.9.9.1 Test_fiber_correction ex. using referenced Table 180-9

Test_fiber_correction = Tx_DUT_power_budget – Test_fiber_power_budget (180-28)

—Tx_DUT_power_budget, given by Equation (180–29), uses measured instead of max TDECQ value in link power budget below, same as used in calculating transmitter OMA (min)

—Test_fiber_power_budget, given by Equation (180–30), uses estimates of the test fiber channel insertion loss, MPI, DGD and TDECQ penalties instead of max values in link power budget below

Table 180–9—Illustrative link power budget

Parameter	Value	Unit
Power budget (for max TDECQ)	6.7	dB
Operating distance	500	m
Channel insertion loss[a, b]	3	dB
Maximum discrete reflectance	–35	dB
Allocation for penalties[c] (for max TDECQ)	3.7	dB
Additional insertion loss allowed	0	dB

180.9.9.1 Test_fiber_correction examples

Test_fiber_correction = Tx_DUT_power_budget – Test_fiber_power_budget (180-28)

E1. Short (patch cord) test fiber

- Test_fiber_power_budget = TECQ
- Test_fiber_correction = Tx_DUT_power_budget - TECQ

E2. Max power budget penalty values and channel insertion loss test fiber

- Test_fiber_power_budget = Tx_DUT_power_budget
- Test_fiber_correction = 0

  (results in negative VOA value, i.e. amplification, for positive Test_margin)

E3. Max power budget penalty values and fraction α channel insertion loss (CIL) test fiber

- Test_fiber_power_budget = max_penalty_values + α CIL (α < 1)
- Test_fiber_correction = (1 - α) CIL

180.9.9.1 Test_fiber_correction exs. using referenced Figure 180-5

Test_fiber_correction = Tx_DUT_power_budget – Test_fiber_power_budget (180-28)

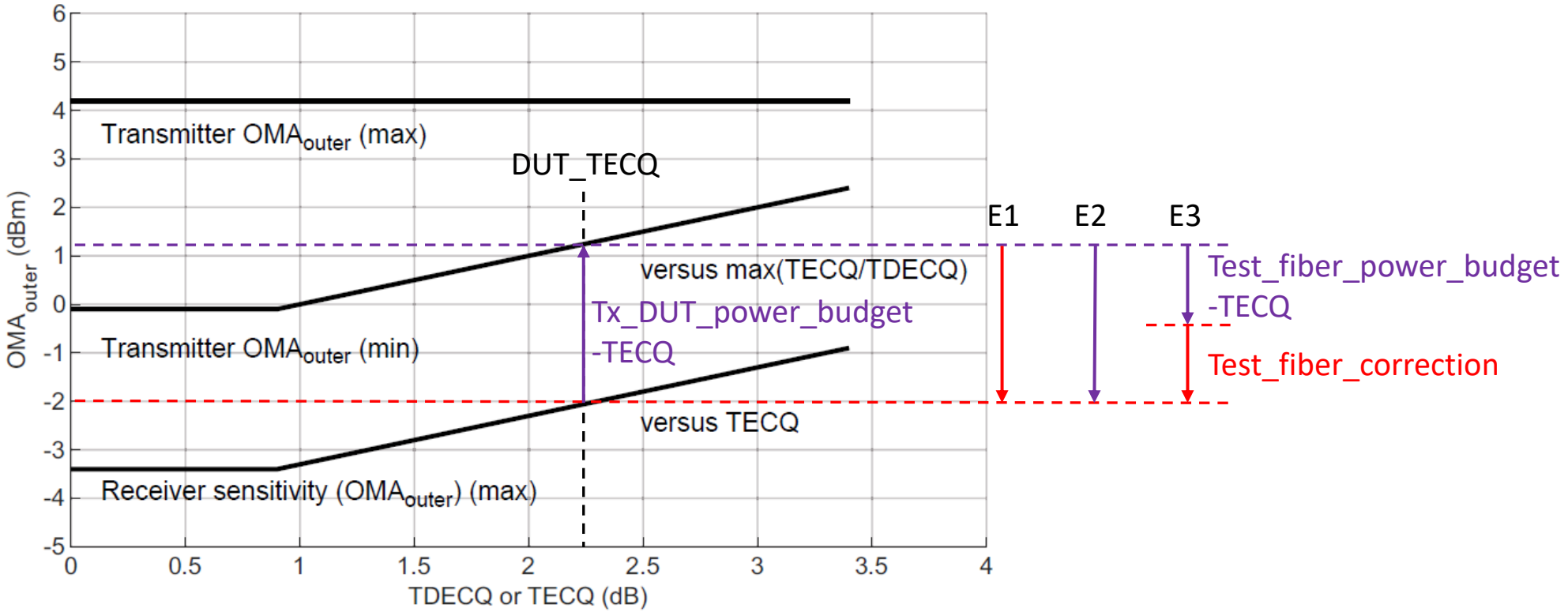

Figure 180–5—Transmitter OMA$_{outer}$ each lane versus max(TECQ, TDECQ) and receiver sensitivity (OMA$_{outer}$) each lane versus TECQ

180.9.9.1 ORx_TECQ_correction ex. using referenced Figure 180-4

ORx_TECQ_correction = RxS_OMA@DUT_TECQ - ORx_RS@DUT_TECQ (180–31)

—RxS_OMA@DUT_TECQ is the receiver sensitivity OMA (max) spec for TECQ >= 0.9 dB, extrapolated to TECQ = 0 dB (-4.3 dBm), at the TECQ measured for the transmitter under test

—ORx_RxS@DUT_TECQ is the actual ORx receiver sensitivity OMA at the TECQ measured for the transmitter under test

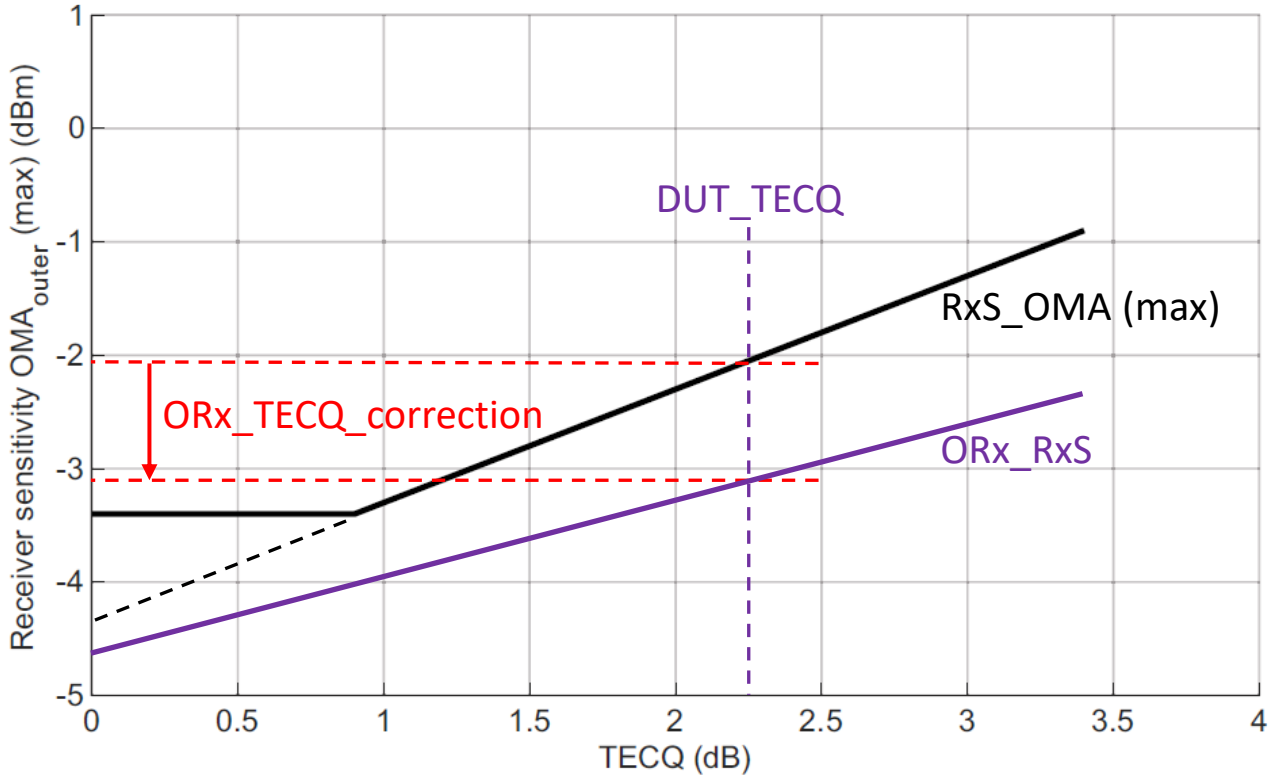

Figure 180–4—Receiver sensitivity (OMA$_{outer}$), each lane (max)

180.9.9.1 VOA_level ex. using referenced Figure 180-5

VOA_level = Test_fiber_correction + ORx_TECQ_correction – Test_margin (180–27)

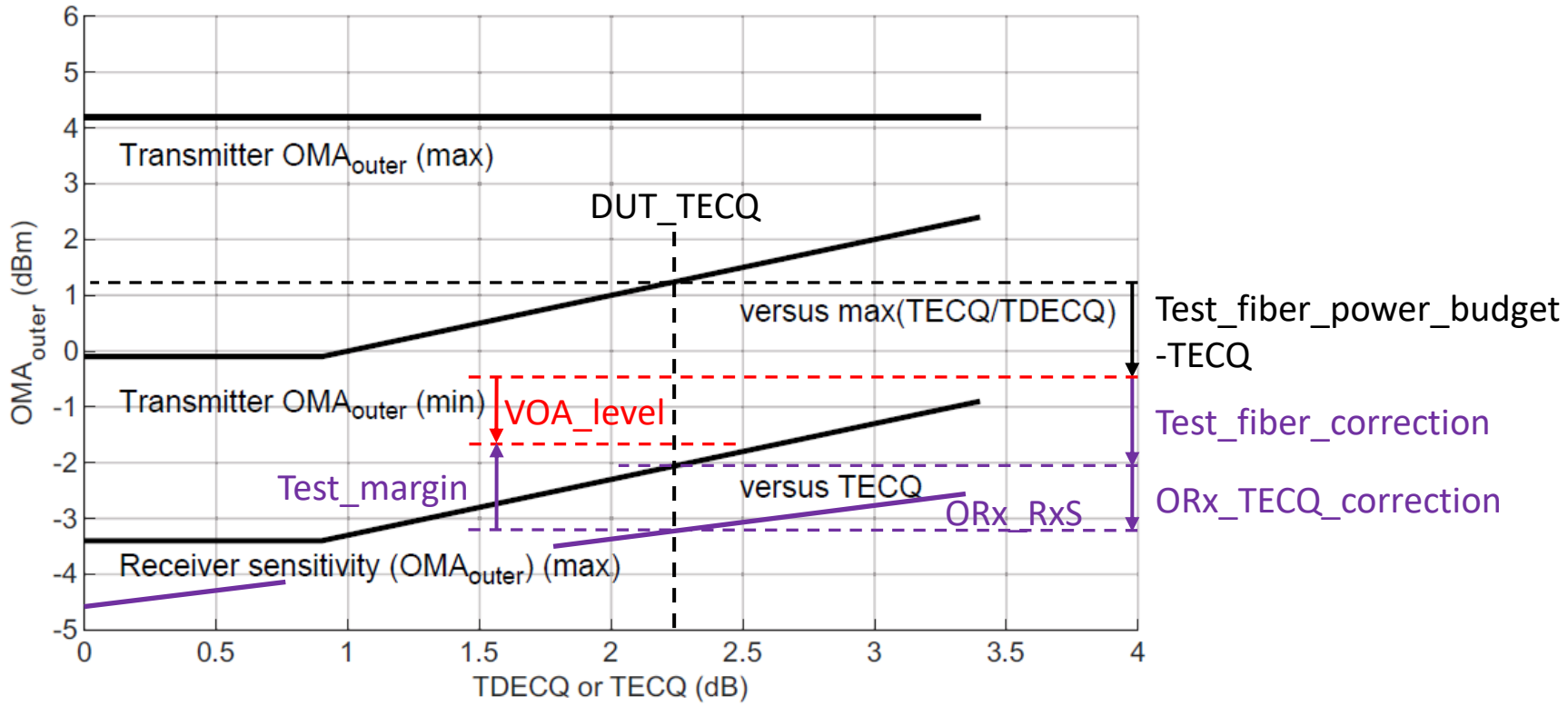

Figure 180–5—Transmitter OMA$_{outer}$ each lane versus max(TECQ, TDECQ) and receiver sensitivity (OMA$_{outer}$) each lane versus TECQ

181.9.9 Transmitter functional symbol error histogram

The transmitter functional symbol error histogram mask for each lane is given in Table 180–18. The transmitter functional symbol error histogram is measured using the method defined in 180.9.9 with the following exceptions:

—The transmitter functional symbol error histogram is measured using the test pattern as given in Table 181–12

—The Functional Receiver (FRx) is a variable optical attenuator (VOA) followed by an Optical Receiver (ORx) that complies with characteristics as given in Table 181–6. The transmitter under test is connected to the FRx by a test fiber, which together with the VOA approximates compliance channel specifications as given in Table 181–13

where in Equation (180-28):

—Tx_DUT_power_budget is the transmitter under test power budget as given in Table 181-7, except uses measured instead of max TDECQ value as shown in Fig. 181-5, same as used in calculating transmitter OMA (min) as per Table 181-5, and is given by Equation (180–29)

—Test_fiber_power_budget is the test fiber power budget as given in Table 181-7, except uses estimates of the test fiber channel insertion loss, MPI, DGD and TDECQ penalties instead of their max values, and is given by Equation (180–30)

181.9.9 Transmitter functional symbol error histogram, cont.

where in Equation (180–29)

—Channel_insertion_loss is “Channel insertion loss” as given in Table 181–7

—MPI_DGD_penalty_allocation is “MPI DGD penalty allocation” as given in Table 181–7

where in Equation (180–31)

—RxS_OMA@DUT_TECQ is the receiver sensitivity OMA (max) spec for TECQ >= 0.9 dB, as shown in Figure 181-4, extrapolated to TECQ = 0 dB (-4.1 dBm), at the TECQ measured for the transmitter under test.

182.9.9 Transmitter functional symbol error histogram

The transmitter functional symbol error histogram mask for each lane is given in Table 180–18. The transmitter functional symbol error histogram is measured using the method defined in 180.9.9 with the following exceptions:

—The transmitter functional symbol error histogram is measured using the test pattern defined in Table 182–14

—The functional receiver (FRx) is a variable optical attenuator (VOA) followed by an optical receiver (ORx) that complies with characteristics as given in Table 182–8. The transmitter under test is connected to the FRx by a test fiber, which together with the VOA approximates compliance channel specifications as given in Table 182–15

where in Equation (180-28):

—Tx_DUT_power_budget is the transmitter under test power budget as given in Table 182-9, except uses measured instead of max TDECQ value as shown in Fig. 182-5, same as used in calculating transmitter OMA (min) as per Table Table 182-7, and is given by Equation (180–29)

—Test_fiber_power_budget is the test fiber power budget as given in Table 182-9, except uses estimates of the test fiber channel insertion loss, MPI, DGD and TDECQ penalties instead of their max values, and is given by Equation (180–30)

182.9.9 Transmitter functional symbol error histogram, cont.

where in Equation (180–98)

—Channel_insertion_loss is “Channel insertion loss” given in Table 182–9

—MPI_DGD_penalty_allocation is “MPI DGD penalty allocation” as given in Table 182–9

where in Equation (180–31)

—RxS_OMA@DUT_TECQ is the receiver sensitivity OMA (max) spec for TECQ >= 0.9 dB, as shown in Figure 182-4, extrapolated to TECQ = 0 dB (-5.3 dBm), at the TECQ measured for the transmitter under test.

183.9.9 Transmitter functional symbol error histogram

The transmitter functional symbol error histogram mask for each lane is given in Table 180–18. The transmitter functional symbol error histogram is measured using the method defined in 180.9.9 with the following exceptions:

—The transmitter functional symbol error histogram is measured using the test pattern as given in Table 183–14

—The functional receiver (FRx) is a variable optical attenuator (VOA) followed by an optical receiver (ORx) that complies with characteristics as given in Table 183–7. The transmitter under test is connected to the FRx by a test fiber, which together with the VOA approximates compliance channel specifications as given in Table 183–15

where in Equation (180-28):

—Tx_DUT_power_budget is the transmitter under test power budget as given in Table 183-8, except uses measured instead of max TDECQ value as shown in Fig. 183-5, same as used in calculating transmitter OMA (min) as per Table Table 183-6, and is given by Equation (180–29)

—Test_fiber_power_budget is the test fiber power budget as given in Table 183-8, except uses estimates of the test fiber channel insertion loss, MPI, DGD and TDECQ penalties instead of their max values, and is given by Equation (180–30)

183.9.9 Transmitter functional symbol error histogram, cont.

where in Equation (180–29)

—Channel_insertion_loss is “Channel insertion loss” as given in Table 183–8

—MPI_DGD_penalty_allocation is “MPI DGD penalty allocation” as given in Table 183–8

where in Equation (180–31)

—RxS_OMA@DUT_TECQ is the receiver sensitivity OMA (max) spec for TECQ >= 0.9 dB for 800GBASE-FR4 and TECQ >= 1.4 dB for 800GBASE-LR4, as shown in Figure 183-4, extrapolated to TECQ = 0 dB (-4.6 dBm for 800GBASE-FR4, -6.9 dBm for 800GBASE-LR4), at the TECQ measured for the transmitter under test.

TFSEH FR4-500 (Clause 181) Over-fiber & BtB Test Examples

CL 181		RxS_OMA(max)@TECQ=0 -4.1					Channel_insertion_loss 3.5			MPI+DGD_penalty_allocation 0.6			Tx_OMA(min)@TECQ=0 0.0				
Case		Tx_DUT (per Table 181-5)					Test_SMF (per Table 181-7)						FRx (per 181.9.7)				
No.	Test_SMF actual DUT_CD	TECQ	TDECQ	max(TECQ, TDECQ)	margin	OMA dBm	actual			estimated			ORx_RxS @DUT _TECQ	Test _margin	VOA _level	ORx _OMA dBm	Test _margin _error
							loss	MPI+DGD	DUT_CD	loss	MPI+DGD	TDECQ					
1	max pos penalty	2.0	3.0	3.0	1.0	4.0	3.5	0.6	1.0	3.5	0.6	3.0	-2.1	1.5	-1.5	2.0	0.0
2		2.0	3.0	3.0	0.0	3.0	3.5	0.6	1.0	3.5	0.6	3.0	-2.1	1.5	-1.5	1.0	0.0
3		2.0	3.0	3.0	1.0	4.0	2.0	0.3	1.0	2.0	0.3	3.0	-2.1	1.5	0.3	1.7	0.0
4	typ. pos	2.0	3.0	3.0	0.0	3.0	2.0	0.3	0.7	2.0	0.3	2.7	-2.1	1.2	0.9	0.1	0.0
5	0 penalty	2.0	3.0	3.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	2.0	-2.1	1.5	3.6	-0.6	0.0
6		2.0	2.0	2.0	1.0	3.0	0.0	0.0	0.0	0.0	0.0	2.0	-2.1	1.5	2.6	0.4	0.0
7		3.0	2.0	3.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	3.0	-1.1	1.5	2.6	0.4	0.0
8	min neg penalty	3.0	2.0	3.0	1.0	4.0	2.0	0.3	-1.0	2.0	0.3	2.0	-1.1	1.5	1.3	0.7	0.0
9		3.0	2.0	3.0	0.0	3.0	3.5	0.6	-1.0	3.5	0.6	2.0	-1.1	1.5	-0.5	0.0	0.0
10		3.0	2.0	3.0	1.0	4.0	3.5	0.6	-1.0	3.5	0.6	2.0	-1.1	1.5	-0.5	1.0	0.0

Test_margin_error = (ORx_OMA = Tx_DUT_OMA - Test_SMF_actual_loss - VOA_level) - (ORx_RxS@actual_TECQ + Test_SMF_actual_MPI+DGD+DUT_CD_penalty + Tx_margin + Test_margin)

TFSEH LR4 (Clause 183) Over-fiber & BtB Test Examples

CL 183		RxS_OMA(max)@TECQ=0 -6.9					Channel_insertion_loss 6.3			MPI+DGD_penalty_allocation 1.1			Tx_OMA(min)@TECQ=0 0.5				
Case		Tx_DUT (per Table 183-5)					Test_SMF (per Table 183-7)						FRx (per 183.9.7)				
No.	Test_SMF actual DUT_CD	TECQ	TDECQ	max(TECQ, TDECQ)	margin	OMA dBm	actual			estimated			ORx_RxS @DUT _TECQ	Test _margin	VOA _level	ORx _OMA dBm	Test _margin _error
							loss	MPI+DGD	DUT_CD	loss	MPI+DGD	TDECQ					
1	max pos penalty	2.0	3.5	3.5	1.0	5.0	6.3	1.1	1.5	6.3	1.1	3.5	-4.9	1.5	-1.5	0.2	0.0
2		2.0	3.5	3.5	0.0	4.0	6.3	1.1	1.5	6.3	1.1	3.5	-4.9	1.5	-1.5	-0.8	0.0
3		2.0	3.5	3.5	0.0	4.0	5.3	0.5	1.5	5.3	0.5	3.5	-4.9	1.5	0.1	-1.4	0.0
4		2.0	5.5	5.5	1.0	7.0	5.3	0.5	1.5	5.3	0.5	5.5	-4.9	1.5	0.1	1.6	2.0
5		2.0	3.5	3.5	1.0	5.0	5.3	0.5	1.5	5.3	0.5	3.5	-4.9	1.5	0.1	-0.4	0.0
6	typ. pos	2.0	3.5	3.5	1.0	5.0	5.3	0.5	1.0	5.3	0.5	3.0	-4.9	0.5	1.6	-1.9	0.0
7	0 penalty	2.0	3.5	3.5	0.0	4.0	0.0	0.0	0.0	0.0	0.0	2.0	-4.9	1.5	7.4	-3.4	0.0
8		2.0	2.5	2.5	0.0	3.0	0.0	0.0	0.0	0.0	0.0	2.0	-4.9	1.5	6.4	-3.4	0.0
9		1.0	1.5	1.5	1.0	3.0	0.0	0.0	0.0	0.0	0.0	1.0	-5.9	1.5	6.4	-3.4	-1.0
10		2.0	2.5	2.5	1.0	4.0	0.0	0.0	0.0	0.0	0.0	2.0	-4.9	1.5	6.4	-2.4	0.0

Test_margin_error = (ORx_OMA = Tx_DUT_OMA - Test_SMF_actual_loss - VOA_level) - (ORx_RxS@actual_TECQ + Test_SMF_actual_MPI+DGD+DUT_CD_penalty + Tx_margin + Test_margin)

Appendix: Incomplete 180.9.15 RxS Spec found in FRx Testing

The receiver sensitivity (OMA_{outer}) of each lane shall be within the limits given in Table 180–8 if measured using a test pattern for receiver sensitivity in Table 180–14. The conformance test signal at TP3 meets the requirements for a transmitter followed by an attenuator.

The TECQ of the conformance test signal is measured according to 180.9.6, except that the test fiber is not used. The measured value of TECQ is then used to calculate the limit for receiver sensitivity (OMA_{outer}) as specified in Table 180–8.

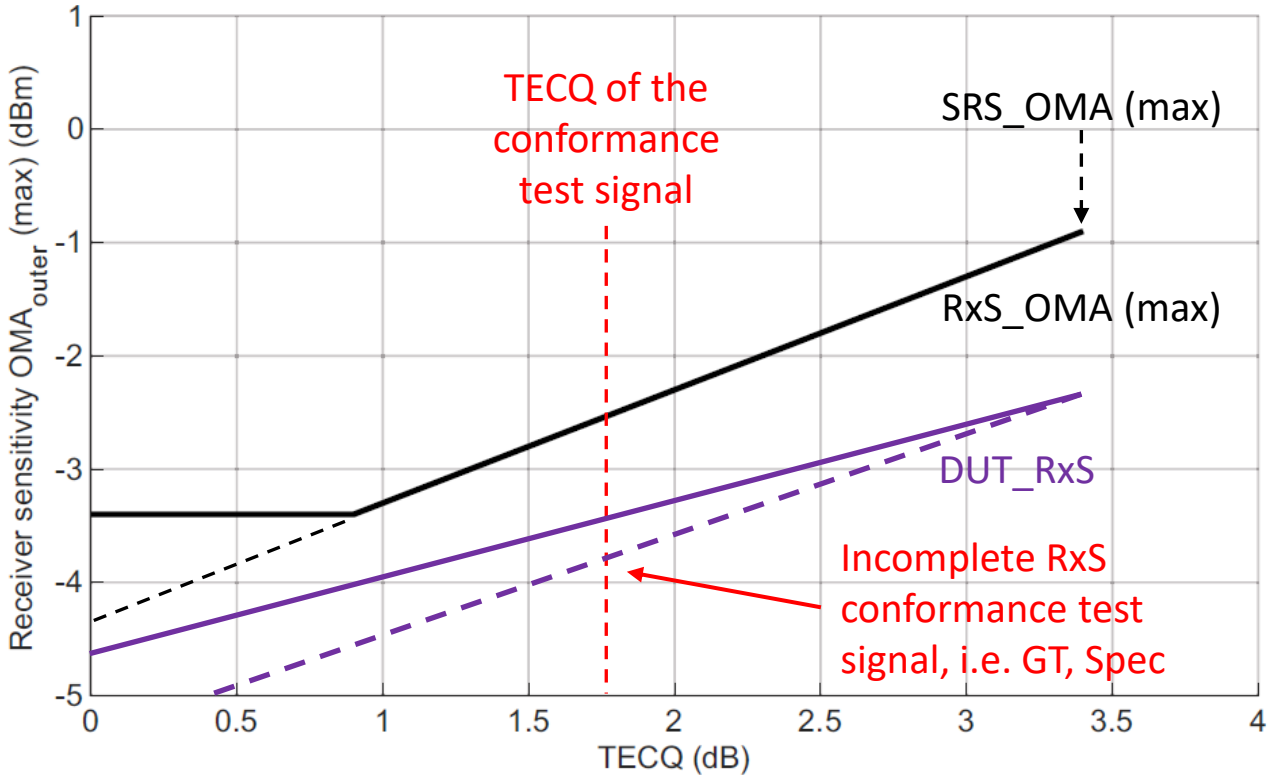

Figure 180–4—Receiver sensitivity (OMA_{outer}), each lane (max)

Appendix: Incomplete 180.9.15 RxS Spec Proposed Remedy

180.9.15 Receiver sensitivity

The receiver sensitivity (OMA_{outer}) of each lane shall be within the limits given in Table 180–8 if measured using a test pattern for receiver sensitivity in Table 180–14. ~~The conformance test signal at TP3 meets the requirements for a transmitter followed by an attenuator.~~

The conformance test signal at TP3 is the stressed receiver sensitivity test signal, specified in 180.9.16, except that the Gaussian noise generator and sinusoidal interferer are both turned off (the sinusoidal jitter remains on).

The stressed receiver sensitivity conformance test signal, specified in 180.9.16, needs additional review to confirm it is worst-case stress. For example, the sinusoidal jitter specification is incomplete. The above receiver sensitivity conformance test signal would be benefit from this.

TFSEH Updated Proposal

Thank you