RxS Additional Conformance Test Signal Proposal

w/ TFT Illustrations & Examples

IEEE 802.3dj TF Interim Session

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Re: Comments 43, 44

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Outline

- ➢ RxS Conformance Test Signal Proposal (comment #44)
- Appendix 1: TFT VOA Level Illustrations (comment #43)
- Appendix 2: TFT Examples (comment #43)

RxS Conformance Test Signal: 180.9.15 Definition Problem

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.

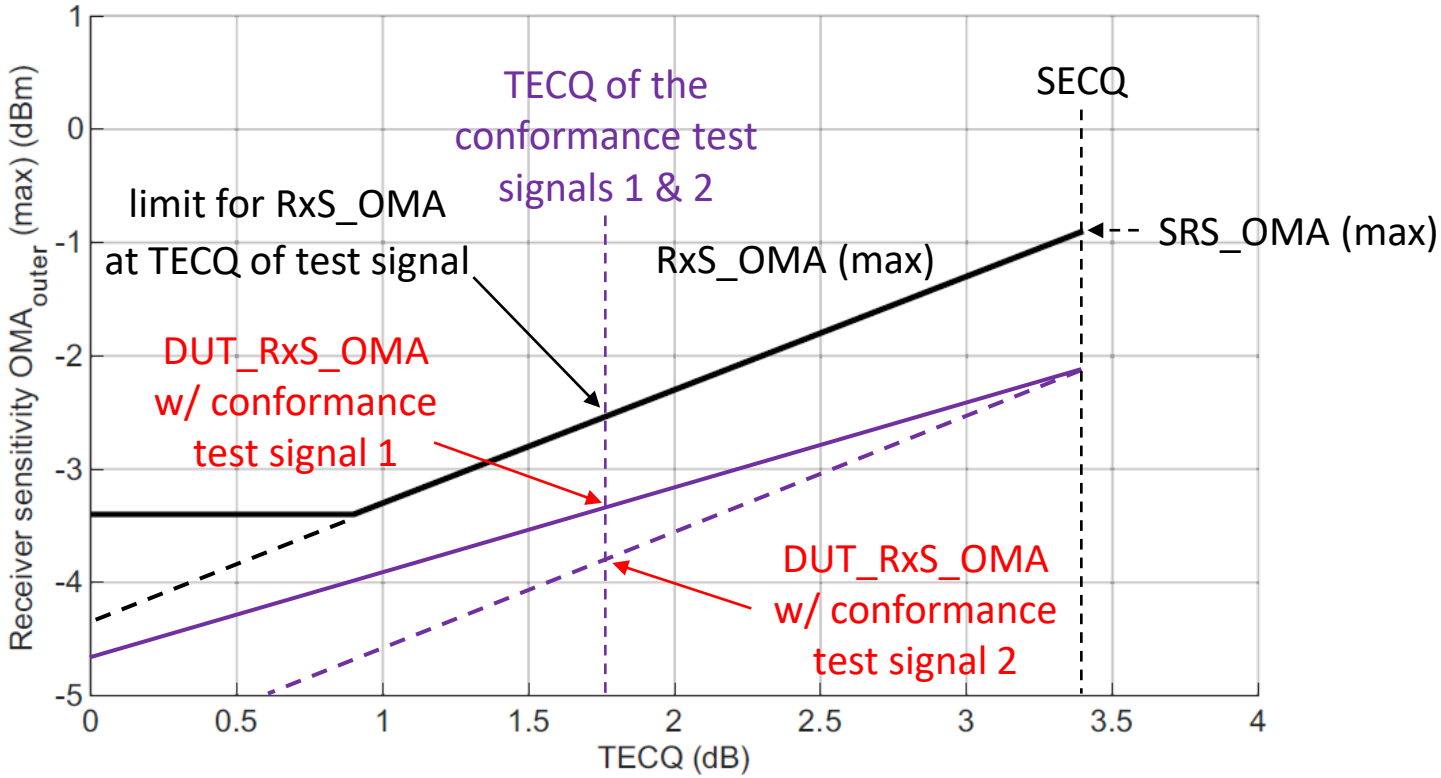


Figure 180–4—Receiver sensitivity (OMA_{outer}), each lane (max)

RxS Additional Conformance Test Signal Proposal

The Low-stressed Receiver Sensitivity (LRS) conformance test signal at TP3 meets the transmit characteristics given in Table 180-7 except for characteristics in Table 180-19.

Table 180-19-Conformance test signal LRS transmit characteristics exceptions to Table 180-7

Parameter	Reference	Value	Unit
TECQ (max)	180.9.8	1.8	dB
TECQ (min)	180.9.8	1.4	dB
Overshoot and undershoot (max)	180.9.10	10	%
Extinction ratio (max)	180.9.12	5.5	dB
Extinction ratio (min)	180.9.12	4.5	dB
Transition time (max)	180.9.13	6.5	ps
Transition time (min)	180.9.13	4.5	ps
ORL tolerance (max)	-	15.5	dB

Supporting data in Christian Reimer, et al., "Reference transmitter data in support of receiver sensitivity specification proposal"

RxS Conformance Test Signals Illustration

LRS ≡ Low-stressed Receiver Sensitivity

RxS ≡ Receiver Sensitivity

FnTx ≡ Functional Transmitter

SRS ≡ Stressed Receiver Sensitivity

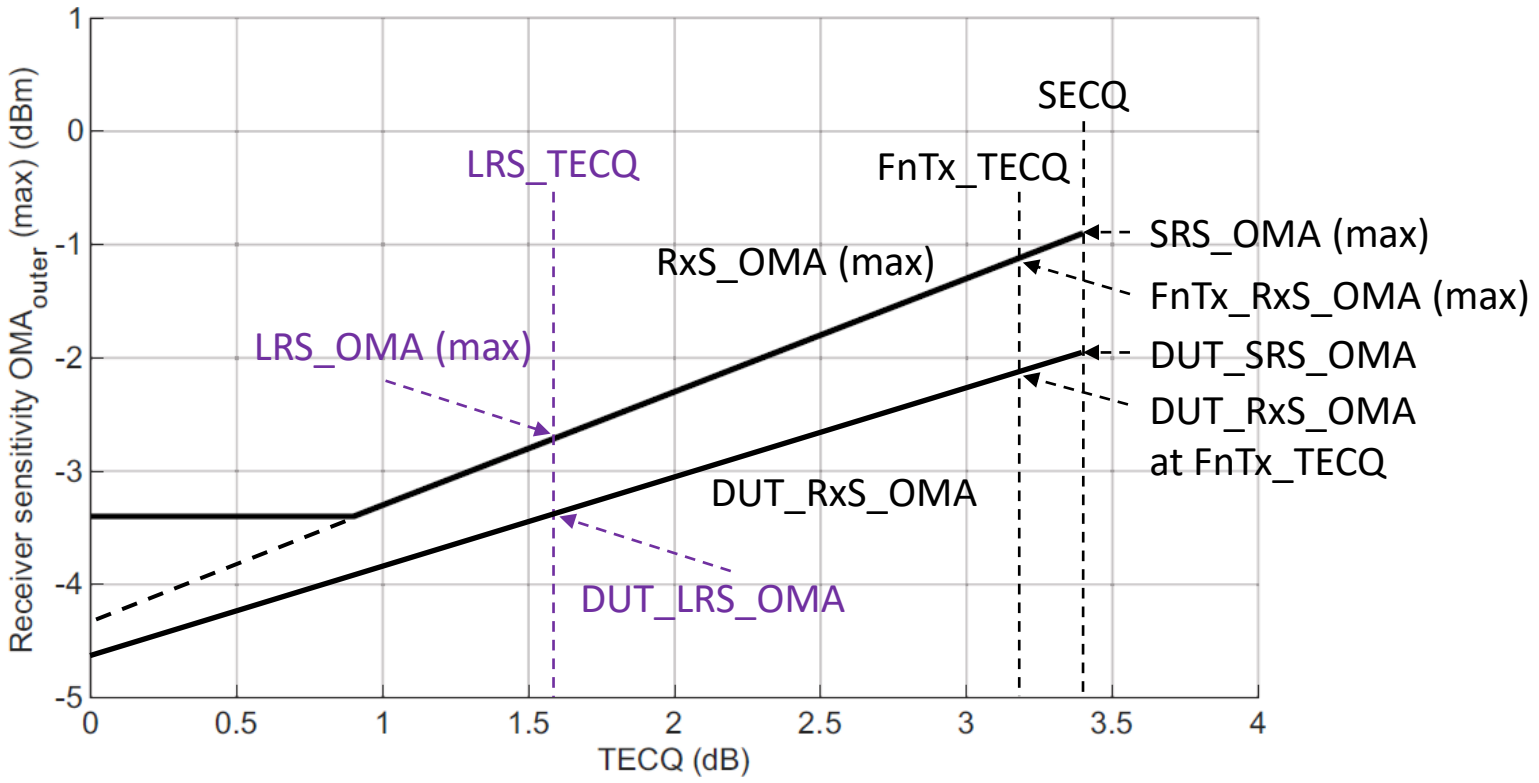


Figure 180–4—Receiver sensitivity (OMA$_{outer}$), each lane (max)

SRS Conformance Test Signal: 180.9.16 Definition Comments

- It is recognized that SRS conformance test signal may not cover every worst-case transmitter that complies with all transmitter characteristics in Table 180-7
- Changes and additions to the SRS conformance test signal have been discussed, ex.
  - SRS Tx, with SRS impairments turned off, constrained to meet LRS Tx characteristics
  - SRS Tx characteristics, ex. transition time, constrained to be worst case
  - Multiple SRS Tx signal sources, each with different maximized impairment
  - Frequency of the SRS sinusoidal interferer required to be greater than 200MHz
- It was decided that there is insufficient time in 802.3dj TF to properly validate a proposal
- Those testing receivers and transmitters may supplement the SRS conformance test signal with functional (worst-case) transmitter(s) (FnTx)
  - It is recommended that such transmitter(s) have their TECQ measured (FnTx_TECQ) so that appropriate OMA (max) limits are used, as illustrated on the previous page.

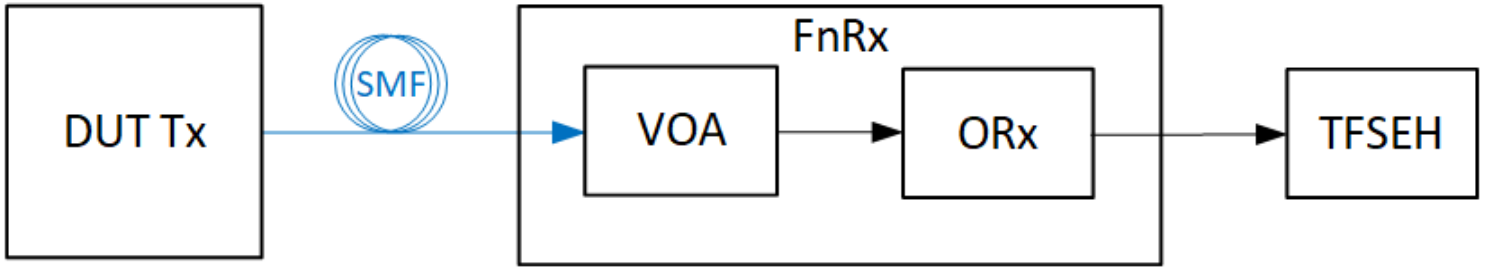
Outline

- RxS Conformance Test Signal Proposal (comment #44)
- ➢ Appendix 1: TFT VOA Level Illustrations (comment #43)
- Appendix 2: TFT Examples (comment #43)

Transmitter Functional Test (TFT) Background

- Not a standalone spec: normative w/ other transmitter characteristics
  - ex. TECQ & TDECQ, OMA (min) & (max), ER (min), over & undershoot (max)
- Uses 802.3 single power penalty optics spec methodology capturing all impairments
- Uses Functional Receiver (FnRx), instead of HW Golden Rx (GRx), normalized by:
  - TECQ & TDECQ measured using scope-based SW GRx
  - RxS & SRS conformance test signals use HW Golden Tx(s) referenced to SW GRx
- Addresses TDECQ corner case problems, ex. Tx Dispersion Penalty spec
- Does not use separate impairment spec methodology, ex. no separate jitter spec
- First proposal, 7/25: patch-cord only
- Proposal update, 9/25: test-fiber added
- Proposal update, 9/25: equations reorganized & full supporters list
- Proposal update, 1/26: equations reorganized
- Proposal update, 3/26: variable names tweaked, functionally same as 7/25 & 9/25 proposals

TFT Block Diagram & VOA_level Equation



VOA_level = Test_fiber_correction + ORx_TECQ_correction - Test_margin (180-28)

Test_fiber_correction normalizes differences in test fibers so that symbol error counts are repeatable across different conditions and is determined by the same algebraic expressions as determine normative transmitter characteristics.

ORx_TECQ_correction normalizes differences in optical receivers so that symbol error counts are repeatable across different conditions and is determined by the same algebraic expressions as determine normative receiver characteristics.

Test_margin is additional ORx_OMA, to improve SNR of transmitter under test measurement. It equals 1.5dB, which decreases the required ORx operating BER to 2.4×10^{-5}.

Test_fiber_correction referencing Table 180-9

Test_fiber_correction = Tx_DUT_power_budget - Test_fiber_power_budget (180-29)

—Tx_DUT_power_budget, given by Eq. (180–30), same as link power budget below, used to determine Tx OMA (min), except instead of max TDECQ uses measured TDECQ over the test fiber

—Test_fiber_power_budget, given by Eq. (180–31), same as link power budget below, except instead of max values uses best estimates of the test fiber insertion loss, MPI, DGD and TDECQ penalties

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

Test_fiber_correction over range of conditions

Test_fiber_correction = Tx_DUT_power_budget - Test_fiber_power_budget (180-29)

CIL ≡ Channel Insertion Loss allocation

- Tx_DUT_power_budget = CIL + MPI_and_DGD_penalties_allocation
  + max(DUT_TECQ, Test_fiber_DUT_TDECQ)

Ex1. Zero CIL & zero penalties patch cord (TECQ test condition)

- Test_fiber_power_budget = DUT_TECQ
- Test_fiber_correction = Tx_DUT_power_budget – DUT_TECQ

Ex2. Max CIL & max penalty values test fiber

- Test_fiber_power_budget = Tx_DUT_power_budget
- Test_fiber_correction = 0

  (If Test_margin is positive, then VOA_level is negative, i.e. gain, see TFT, p.26, Ex. 1)

Ex3. Fraction α CIL (α < 1) & max penalty values test fiber (TDECQ test condition)

- Test_fiber_power_budget = α CIL + Test_fiber_MPI_and_DGD_penalties + Test_fiber_DUT_TDECQ
- Test_fiber_correction = (1 - α) CIL

Test_fiber_correction using Figure 180-5

Test_fiber_correction = Tx_DUT_power_budget - Test_fiber_power_budget (180-29)

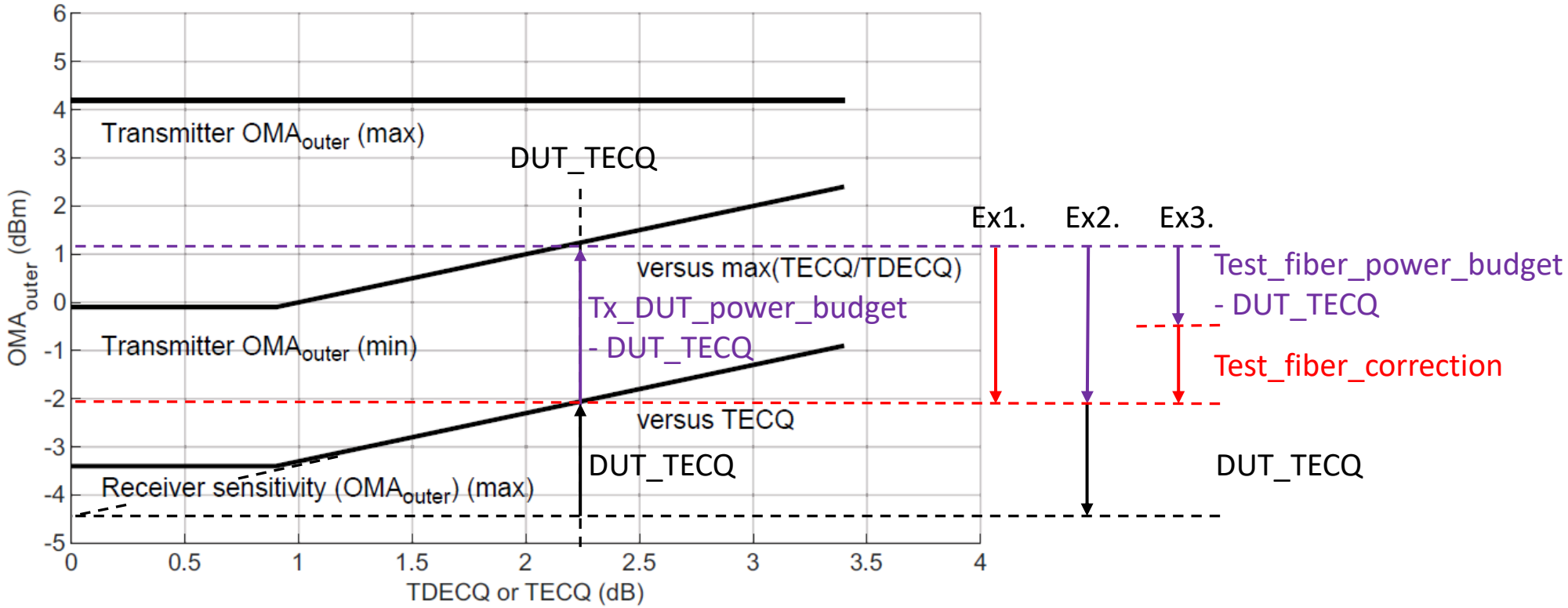


Figure 180–5—Transmitter OMA$_{outer}$ each lane versus max(TECQ, TDECQ) and receiver sensitivity (OMA$_{outer}$) each lane versus TECQ

Test_fiber_correction using Figure 180-5

Test_fiber_correction = Tx_DUT_power_budget - Test_fiber_power_budget (180-29)

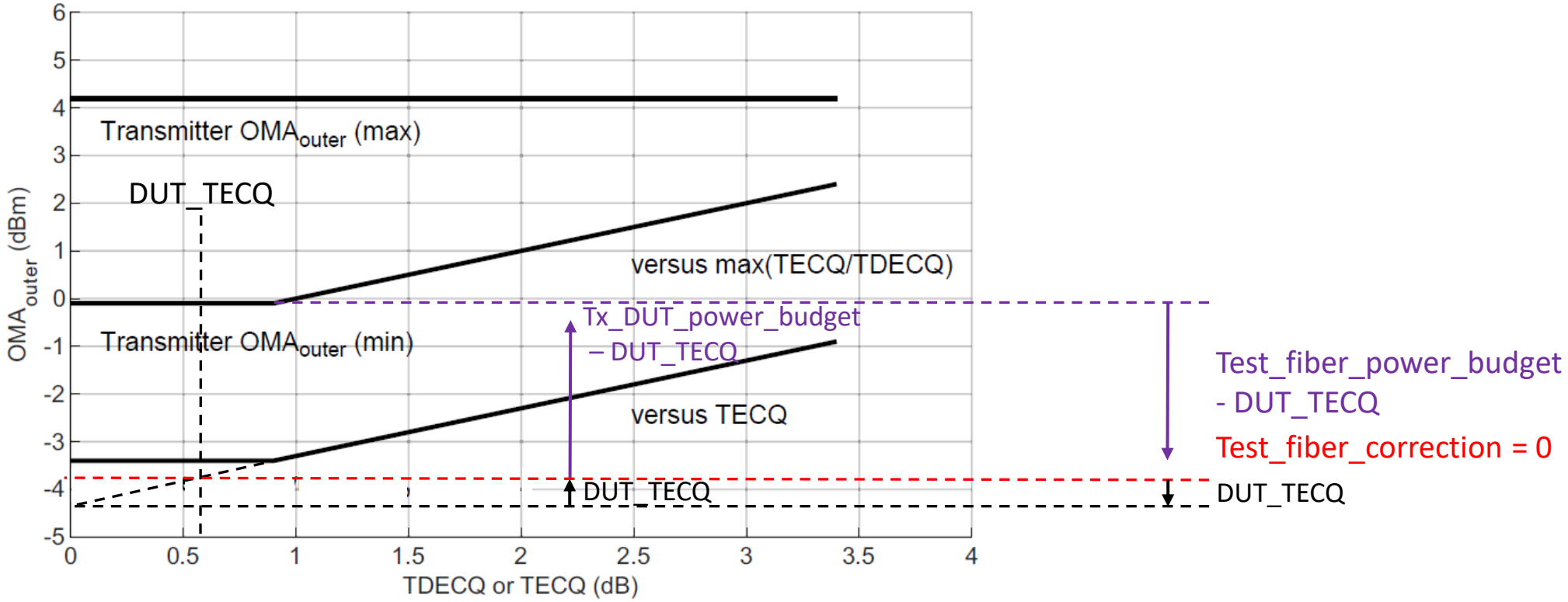


Figure 180–5—Transmitter OMA$_{outer}$ each lane versus max(TECQ, TDECQ) and receiver sensitivity (OMA$_{outer}$) each lane versus TECQ

ORx_TECQ_correction using Figure 180-4

ORx_TECQ_correction = RxS_OMA_max at_DUT_TECQ - ORx_RxS_OMA_at_DUT_TECQ (180–32)

—RxS_OMA_max_at_DUT_TECQ is the receiver sensitivity OMA at the TECQ measured for the transmitter under test

—ORx_RxS_OMA_at_DUT_TECQ is the actual ORx receiver sensitivity OMA at the TECQ measured for the transmitter under test

—ORx_TECQ_correction is minimized for best ORx normalization

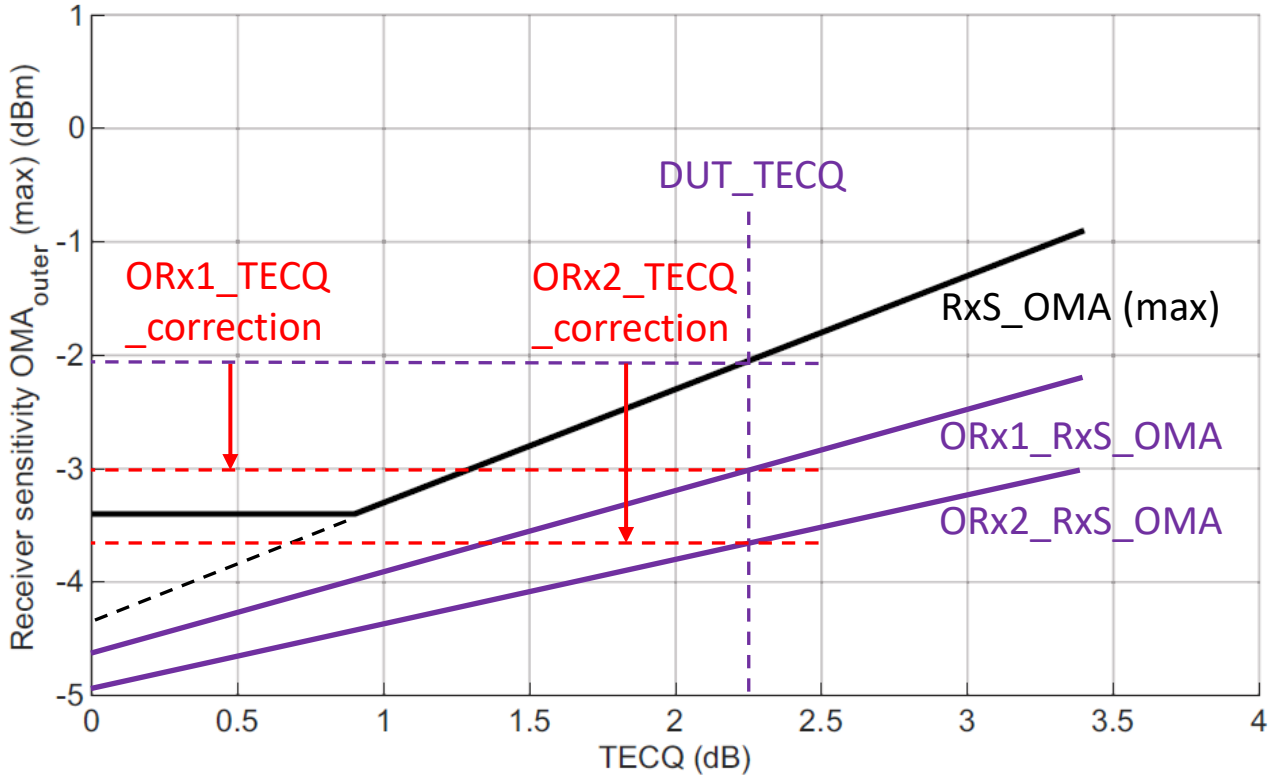


Figure 180–4—Receiver sensitivity (OMA$_{outer}$), each lane (max)

ORx_TECQ_correction using Figure 180-4

ORx_TECQ_correction = RxS_OMA_at_DUT_TECQ - ORx_RxS_OMA_at_DUT_TECQ (180–32)

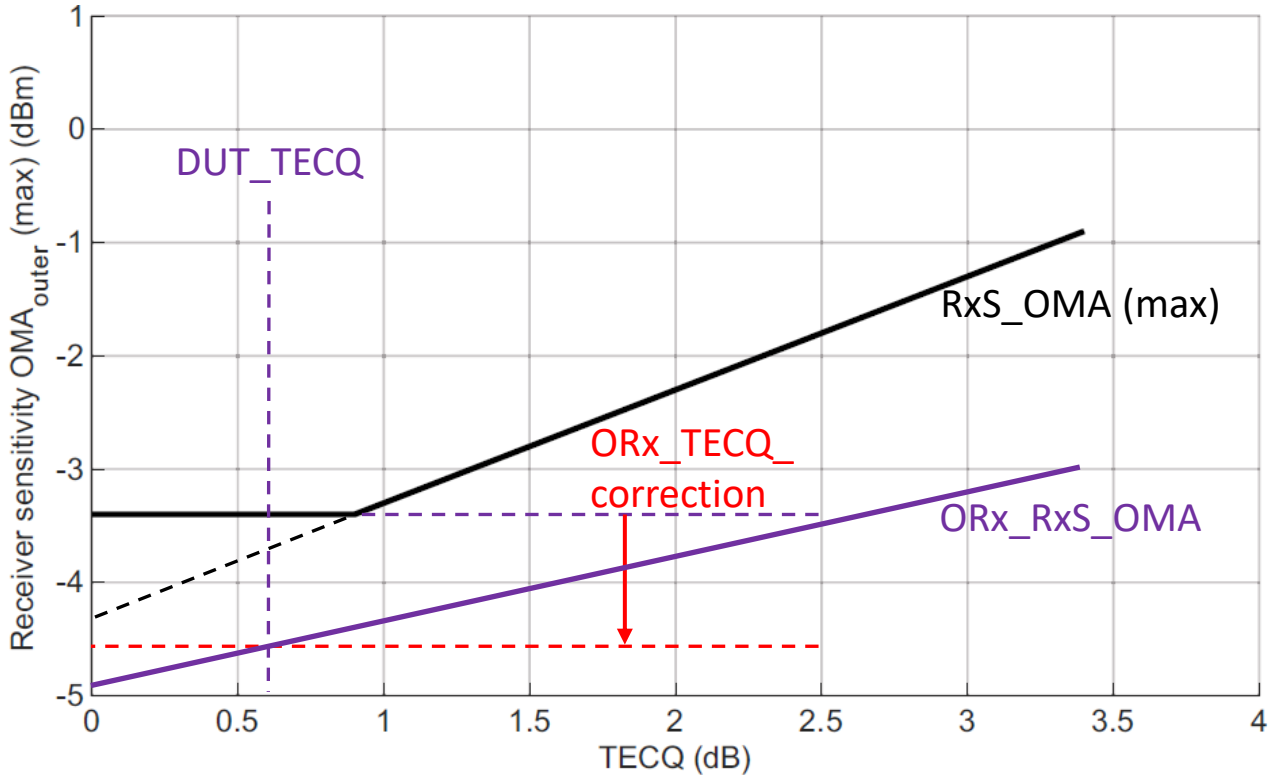


Figure 180–4—Receiver sensitivity (OMA_{outer}), each lane (max)

Test_margin

Test_margin is additional ORx_OMA, to improve SNR of transmitter under test measurement. It equals 1.5dB, which decreases the required ORx operating BER to 2.4×10^{-5}.

- Model: Tx_DUT → Channel → Rx
  - SNR_M ≡ SNR of transmitter under test measurement
  - ch_loss < 1 ≡ Channel insertion loss (linear)
- SNR_M = Tx_DUT_Signal * ch_loss / (Tx_DUT_Noise * ch_loss + Rx_Noise)
  - SNR_M objective: SNR_M ≈ Tx_DUT_Signal / Tx_DUT_Noise → Tx_DUT_Noise * ch_loss > Rx_Noise
  - At receiver sensitivity: Tx_DUT_Noise * ch_loss < Rx_Noise
  - test_margin > 1 ≡ offset gain to reduce effect of ch_loss (linear)
- SNR_M = Tx_DUT_Signal * ch_loss * test_margin / (Tx_DUT_Noise * ch_loss * test_margin + Rx_Noise)
- Transmitter only test operating BER must be decreased from full link (PMD to PMD) BER = 2.28×10^{-4}
- Experimental validation
- Example of common SNR_M improvement: after fiber eye measurement
  - Tx_DUT → Fiber → Gain → DCA

VOA_level w/ no Tx_margin using Figure 180-5

VOA_level = Test_fiber_correction + ORx_TECQ_correction – Test_margin (180–28)

Tx_margin
= Tx_DUT_OMA
- max(TECQ, TDECQ)
- Tx_OMA(min) extra-
polated to TECQ=0

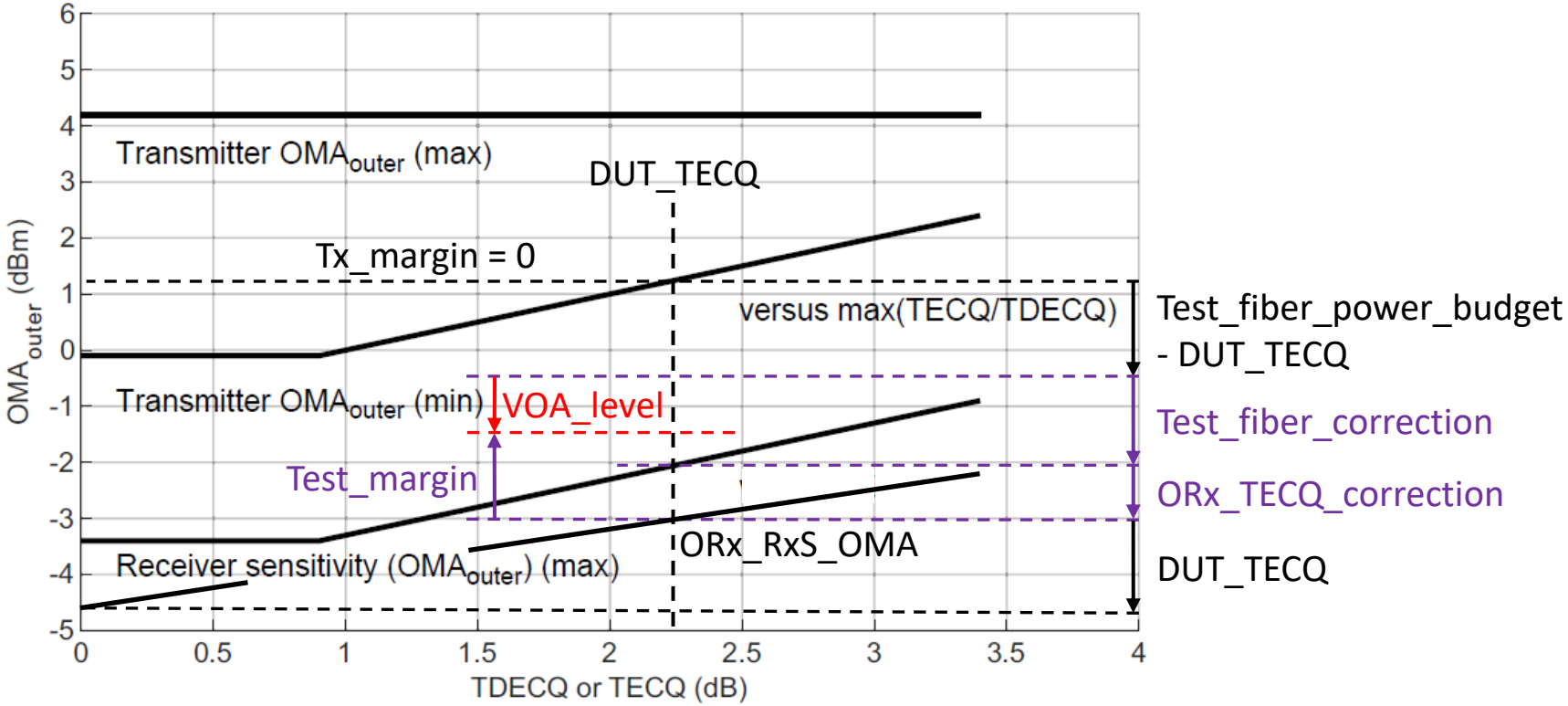


Figure 180–5—Transmitter OMA$_{outer}$ each lane versus max(TECQ, TDECQ) and receiver sensitivity (OMA$_{outer}$) each lane versus TECQ

VOA_level w/ Tx_margin using Figure 180-5

VOA_level = Test_fiber_correction + ORx_TECQ_correction - Test_margin (180–28)

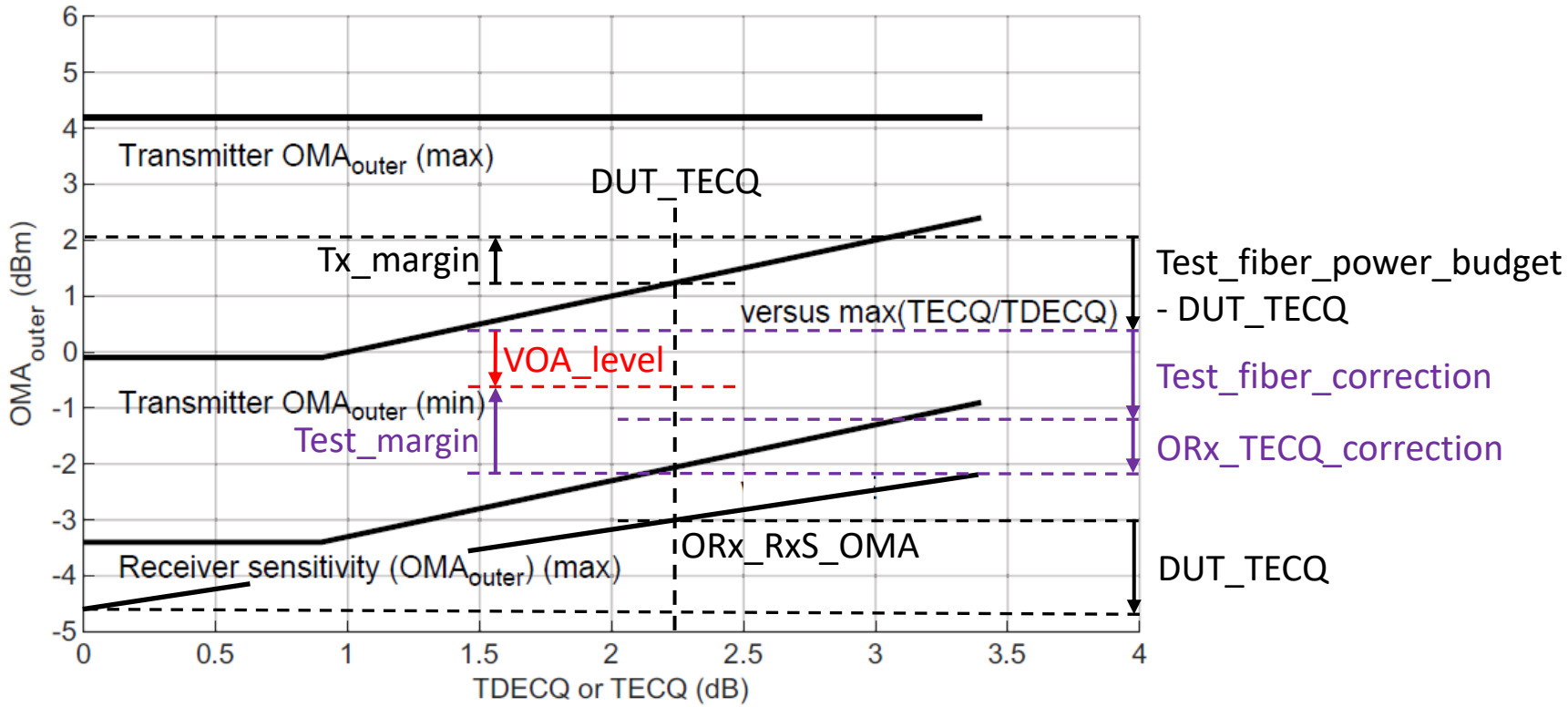


Figure 180–5—Transmitter OMA$_{outer}$ each lane versus max(TECQ, TDECQ) and receiver sensitivity (OMA$_{outer}$) each lane versus TECQ

VOA_level w/ no Tx_margin & low TECQ using Figure 180-5

VOA_level = Test_fiber_correction + ORx_TECQ_correction - Test_margin (180–28)

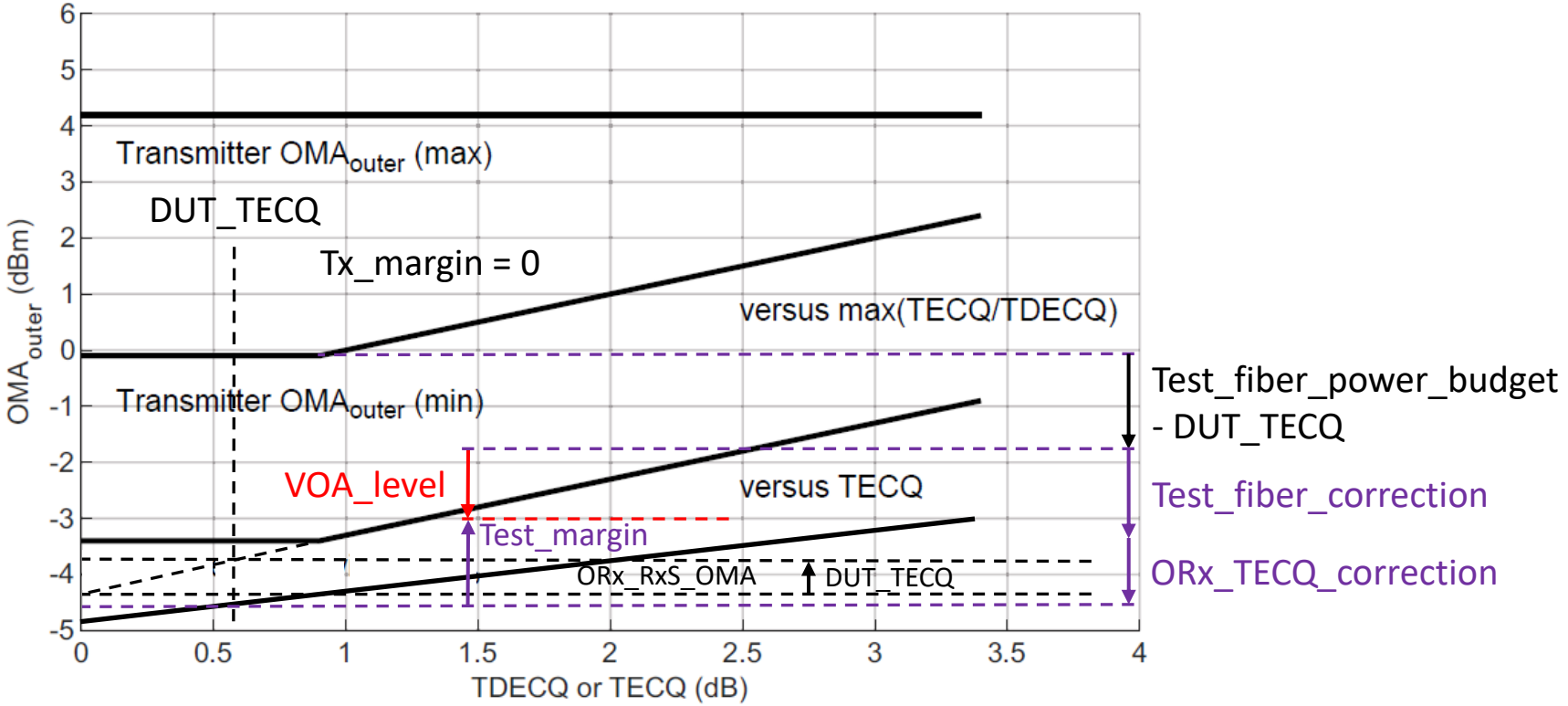


Figure 180–5—Transmitter OMA$_{outer}$ each lane versus max(TECQ, TDECQ) and receiver sensitivity (OMA$_{outer}$) each lane versus TECQ

Outline

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- ➢ Appendix 2: TFT Examples (comment #43)

Transmitter Functional Test (TFT) Setup

- Equipment
  - DCA, Power Meter, other
  - FnRx = VOA → ORx (w/ RxS_OMA_max & ORx_RxS_OMA vs. TECQ data)
  - Test fiber (w/ insertion loss, MPI and DGD penalties, and Chromatic Dispersion best estimates)
- VOA level equation, Test margin, and error criteria
  - VOA_level = Test_fiber_correction + ORx_TECQ_correction - Test_margin
  - Test_margin = 1.5dB
  - Error criteria: Test Functional Symbol Error Histogram (TFSEH) mask (next page)

Test functional symbol error histogram 180.9.9.2 Definition

The transmitter functional symbol error histogram mask for each lane is given in Table180–18 and is measured using the test pattern as given in Table180–14. Minimum measurement time is 60 seconds.

A probable failure is indicated by exceeding the transmitter functional symbol error histogram mask defined in Table180–18, or by one or more counts in test symbol errors k per test block with k > 8.

Table 180–18—Transmitter functional symbol error mask

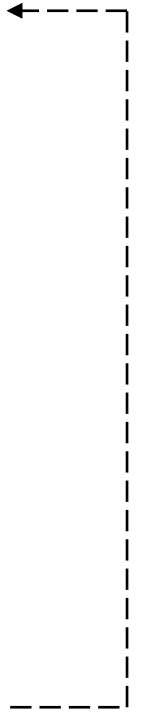
Test symbol errors per test block, k	Probability $H_{max}(k)$
1	1.15×10^{-1}
2	7.47×10^{-3}
3	3.24×10^{-4}
4	1.05×10^{-5}
5	2.73×10^{-7}
6	5.88×10^{-9}
7	1.08×10^{-10}
8	1.75×10^{-12}

TFT VOA Level Pre-calculation

- Tx DUT OMA programming as part of transceiver standard setup
  - Measure DUT TECQ and TDECQ, w/ Patch Cord and Test Fiber, respectively
  - Tx_DUT_OMA = Tx_OMA(min) extrapolated to TECQ=0 + max(TECQ, TDECQ) + Tx_margin
- VOA level equation first and second term pre-calculation
  - Test_fiber_correction1 = Tx_DUT_power_budget - Test_fiber_power_budget
  - Test_fiber_correction2 = Tx_DUT_power_budget - DUT_TECQ (w/ Patch Cord)
  - ORx_TECQ_correction = RxS_OMA_max_at_DUT_TECQ - ORx_RxS_OMA_at_DUT_TECQ
- VOA level pre-calculation
  - VOA_level1 = Test_fiber_correction1 + ORx_TECQ_correction - Test_margin
  - VOA_level2 = Test_fiber_correction2 + ORx_TECQ_correction - Test_margin

TFT

- w/ Test Fiber & optional TDECQ check
  - Tx DUT → Test Fiber → (FnRx = VOA → ORx)
  - VOA_level = VOA_level1
  - Spec. compliant if TFSEH mask not exceeded
  - Optionally adjust TDECQ by mask margin to *TDP* (see TFT, p.26, Ex. 2 & 3)
- w/ Patch Cord & optional TECQ check
  - Tx DUT → Patch Cord → (FnRx = VOA → ORx)
  - VOA_level = VOA_level2
  - Spec. compliant if TFSEH mask not exceeded
  - Optionally adjust TECQ by mask margin to *TP* (see TFT, p.26, Ex. 4 & 5)



CL 183 LR4 Test Fiber & Patch Cord TFT Examples

LR4	RxS_OMA(max) at TECQ=0: -6.9					Channel_insertion_loss: 6.3				MPI+DGD_penalty_allocation: 1.1				ORx_RxS_OMA at TECQ=0: -7.9			
Ex.	**Tx DUT** Tx (min): 0.5		Tx_margin: 1.0			**Test Fiber**								**FnRx**	Test_margin: 1.5		
no.	actual	estimated		max (TECQ, TDECQ)	Tx _OMA	actual				estimated			Test _fiber_ correction	ORx _TECQ_ correction	VOA _level	ORx _OMA	Mask _margin
	TECQ	TECQ *(TP)*	TDECQ *(TDP)*		dBm	loss	MPI+DGD	CD penalty	TDECQ	loss	MPI+DGD	TDECQ				dBm	
1	2.0	2.0	3.5	3.5	5.0	6.3	1.1	1.5	3.5	6.3	1.1	3.5	0.0	1.0	-0.5	-0.8	0.0
	2.0	2.0	3.5	3.5	5.0	5.3	0.5	1.5	3.5	5.3	0.5	3.5	1.6	1.0	1.1	-1.4	0.0
2	2.0	2.0	2.5	2.5	4.0	5.3	0.5	1.5	3.5	5.3	0.5	2.5	1.6	1.0	1.1	-2.4	-1.0
	2.0	2.0	*3.5*	3.5	5.0	5.3	0.5	1.5	3.5	5.3	0.5	3.5	1.6	1.0	1.1	-1.4	0.0
3	2.0	2.0	5.5	5.5	7.0	5.3	0.5	1.5	3.5	5.3	0.5	5.5	1.6	1.0	1.1	0.6	2.0
	2.0	2.0	*3.5*	3.5	5.0	5.3	0.5	1.5	3.5	5.3	0.5	3.5	1.6	1.0	1.1	-1.4	0.0
4	2.0	1.5	3.5	3.5	5.0	0.0	0.0	0.0	2.0	0.0	0.0	1.5	9.4	1.0	8.9	-3.9	-0.5
	2.0	*2.0*	3.5	3.5	5.0	0.0	0.0	0.0	2.0	0.0	0.0	2.0	8.9	1.0	8.4	-3.4	0.0
5	2.0	3.0	5.5	5.5	7.0	0.0	0.0	0.0	2.0	0.0	0.0	3.0	9.9	1.0	9.4	-2.4	1.0
	2.0	*2.0*	5.5	5.5	7.0	0.0	0.0	0.0	2.0	0.0	0.0	2.0	10.9	1.0	10.4	-3.4	0.0

Mask_margin = (ORx_OMA = Tx_OMA - Test_SMF_actual_loss - VOA_level) - (ORx_RxS_OMA at TECQ=0 + Test_SMF_actual_MPI+DGD+TDECQ_penalties + Tx_margin + Test_margin)

RxS Additional Conformance Test Signal Proposal

Thank you