# Optical specifications updates for 800GBASE-LR1 & 800GBASE-ER1

## Supporting Comments 385, 386, and 388

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# Overview

## 800GBASE-LR1 & ER1 definition methodologies overview

## A noise-based analysis is used for to analyze ETCC in the context of 800GBASE-LR1 & 800GBASE-ER1

## Adding a receiver noise model provides guidance for ETCC limits

*Cl* **185** *SC* **185.6.1** *P* **564** *L* **33** # 385

Maniloff, Eric Ciena

*Comment Type* **TR** *Comment Status* **D** *'Optical) coherent parameters*

The value of 3.4dB ETCC results in an excessively stringent requirement on the receiver. This value needs to be reduces to allow realistic receiver parameters. A supporting contribution will be presented.

*SuggestedRemedy*

Replace the 3.4dB ETCC Max Value with 2.5 dB

*Proposed Response* *Response Status* **W**

PROPOSED ACCEPT IN PRINCIPLE.
Pending review of the following presentation and CRG discussion.
<URL>/maniloff_3dj_xx_2507.pdf.

*Cl* **185** *SC* **185.6.1** *P* **564** *L* **27** # 386

Maniloff, Eric Ciena

*Comment Type* **TR** *Comment Status* **D** *'Optical) coherent parameters*

The average launch power on ETCC should be updated to align with any updates to ETCC Max

*SuggestedRemedy*

Update the maximum ETCC value in Average Power with a value of 2.5dB

*Proposed Response* *Response Status* **W**

PROPOSED ACCEPT IN PRINCIPLE.
Implement suggested remedy. Align with the resolution to comment #385.

*Cl* **187** *SC* **187.6.1** *P* **638** *L* **26** # 388

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*Comment Type* **T** *Comment Status* **D** *Optical) Coherent parameters*

The methodology in 800GBASE-ER1 on defining the Average optical power specifications should be aligned with the coupling to ETCC defined in 800GBASE-LR1. A supporting contribution with details of the values for Tx optical power and ETCC max will be provided

*SuggestedRemedy*

Update the 800GASE-ER1 and 800GBASE-ER1-20 to couple the optical powers to ETCC, to use a methodology aligned with 800GBASE-LR1.

*Proposed Response* *Response Status* **W**

PROPOSED ACCEPT IN PRINCIPLE.
Pending review of the following presentation and CRG discussion.
<URL>/maniloff_3dj_xx_2507.pdf.

# Review: Implementation Noise, Eye Closure, and ETCC

**Implementation Noise and Eye closure are used to model deviations of a practical device from theoretical [1]**

- Implementation noise (IMN) is modeled as AWGN
- Eye closure (EC) representing signal loss

**Both the Rx and Tx have IMN and EC contributions**

- Standards such as OIF 400ZR and 800ZR have ROSNR's specified that can be calculated in terms of IMN and EC, but do not explicitly separate these or the Tx/Rx contributions

**The ROSNR values in OIF 800ZR align with**

- Overall EC/IMN of 0.4dB / 15.1 dB (0.2dB EC and ~18dB IMN each for Tx/Rx)

**ETCC represents a Tx quality metric (analogous to TECQ)**

- ETCC is defined by the SNR penalty of real Transmitter measured by a reference receiver
- ETCC captures only the Tx based SNR penalty

[1] https://www.ieee802.org/3/dj/public/24_05/maniloff_3dj_02_2405.pdf

# 800GBASE-LR1 and 800GBASE-ER1 specification methodologies

**800GBASE-LR1 is defined to have the Tx power related to the ETCC value**

- This is similar to how IMDD couples Tx power to TECQ/TDECQ
- For ETCC > 1dB, Tx power increases dB/dB with ETCC up to $ETCC_{Max}$

**800GBASE-ER1 currently uses a fixed minimum Tx power approach**

**As presented in [2], there are significant performance penalties based on ETCC**

- Although ETCC is a Tx metric, the overall penalty depends on the Rx noise assumptions

[2] https://www.ieee802.org/3/dj/public/25_05/maniloff_3dj_01a_2505.pdf

# Tx Specs

**Table 185–5—800GBASE-LR1 transmit characteristics**

| Description | Value | Unit |
|---|---|---|
| Signaling rate (range) | 123.6364 ± 50 ppm | GBd |
| Modulation format | DP-16QAM | — |
| Average launch power (max) | –6 | dBm |
| Average launch power (min)<br>for ETCC ≤ 1 dB<br>for 1 < ETCC ≤ 3.4 dB | <br>–11.2<br>–12.2 + ETCC | dBm |
| Carrier frequency (range) | 228.675 ± 20 GHz | THz |
| Power difference between X and Y polarizations (max) | 1.5 | dB |
| Skew between X and Y polarizations (max) | 5 | ps |
| Extended transmit constellation closure (ETCC) (max) | 3.4 | dB |
| Instantaneous I-Q offset per polarization (max) | –20 | dB |
| Mean I-Q offset per polarization (max) | –26 | dB |
| I-Q amplitude imbalance (mean) | 1 | dB |
| I-Q phase error magnitude (max) | 5 | deg |
| I-Q quadrature skew (max) | 0.75 | ps |
| Transmitter OSNR in a 12.5 GHz resolution bandwidth (min) | 40 | dB |
| Average launch power of OFF transmitter (max) | –20 | dBm |
| Transmitter reflectance[a] (max) | –20 | dB |
| RIN average (max) | –145 | dB/Hz |
| RIN peak (max) | –140 | dB/Hz |
| Laser linewidth (max) | 1 | MHz |
| Tx laser frequency slew rate: pre acquisition (max) | 10 | GHz/s |
| Tx laser frequency slew rate: post acquisition (max) | 1 | GHz/s |

**Table 187–5—800GBASE-ER1-20 and 800GBASE-ER1 transmit characteristics**

| Description | 800GBASE-ER1-20 | 800GBASE-ER1 | Unit |
|---|---|---|---|
| Signaling rate (range) | 118.203351 ± 20 ppm | | GBd |
| Modulation format | DP-16QAM | | — |
| Average launch power (max) | –7 | –1 | dBm |
| Average launch power (min) | –11 | –5 | dBm |
| Carrier frequency (range) | 193.7 ± 1.8 GHz | | THz |
| Power difference between X and Y polarizations (max) | 1 | | dB |
| Skew between X and Y polarizations (max) | 5 | | ps |
| ETCC | 2.5 | | dB |
| Instantaneous I-Q offset per polarization (max) | –20 | | dB |
| Mean I-Q offset per polarization (max) | –26 | | dB |
| I-Q amplitude imbalance (mean) | 1 | | dB |
| I-Q phase error magnitude (max) | 5 | | deg |
| I-Q quadrature skew (max) | 0.75 | | ps |
| Transmitter OSNR in a 12.5 GHz bandwidth (min) | 35 | | dB |
| Average launch power of OFF transmitter (max) | –20 | | dBm |
| Transmitter reflectance[a] (max) | –20 | | dB |
| RIN average (max) | –145 | | dB/Hz |
| RIN peak (max) | –140 | | dB/Hz |
| Laser linewidth (max) | 1 | | MHz |

LR1 minimum Average Launch power is coupled to ETCC.

ER1 uses a fixed minimum Tx power approach

# ETCC Analysis

**$RSNR_{FEC}$ represents the theoretical SNR at which the FEC can meet the BER requirements**

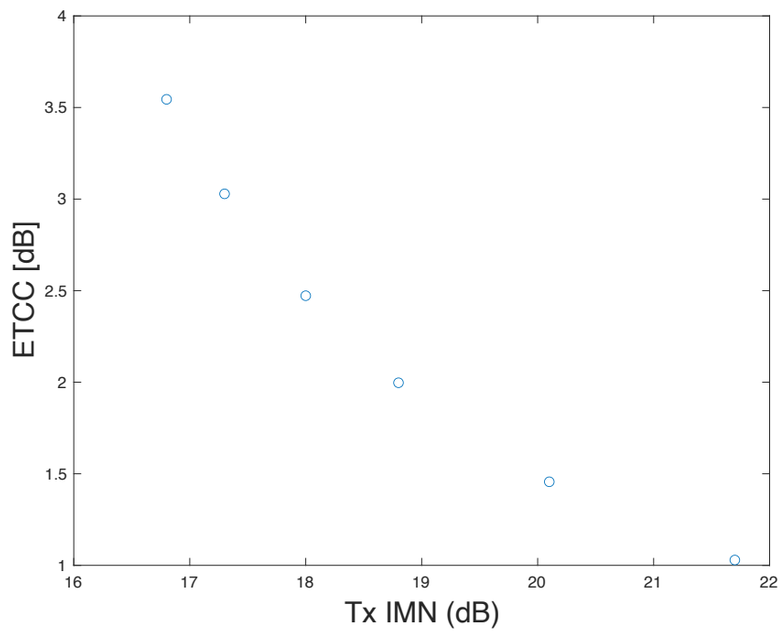
- For 800GBASE-LR1 with BCH FEC, this is ~13.9 dB
- For 800GBASE-ER1 with OFEC, this is ~12.7 dB

**The overall noise budget needs to be sufficient to accommodate**

- Transmitter Implementation Noise (IMN & Eye Closure) (ETCC)
- Receiver Implementation Noise (IMN & Eye Closure)
- Electrical noise introduced at the receiver

*Example calculation for 800GBASE-LR1*

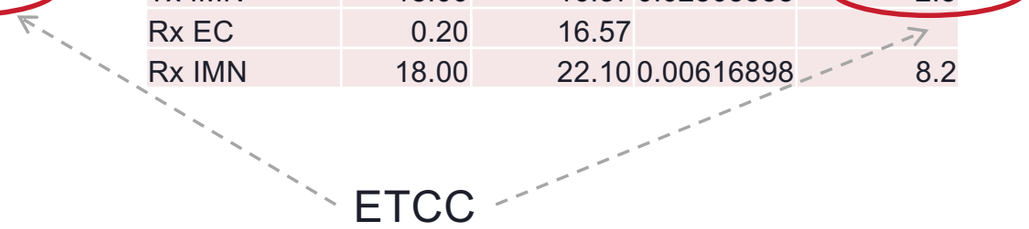
*ETCC is calculated for various IMN values with EC = 0.2dB*



# Examples of Noise stackup

| | | RSNR | NSR | Penalty |
|---|---|---|---|---|
| RSNR_FEC | | 13.90 | 0.04073803 | |
| Tx EC | 0.10 | 14.00 | | |
| Tx IMN | 21.30 | 14.89 | 0.03239761 | 1.0 |
| Rx EC | 0.20 | 15.09 | | |
| Rx IMN | 18.00 | 18.21 | 0.01509055 | 4.3 |

| | | RSNR | NSR | Penalty |
|---|---|---|---|---|
| RSNR_FEC | | 13.90 | 0.04073803 | |
| Tx EC | 0.20 | 14.10 | | |
| Tx IMN | 18.00 | 16.37 | 0.02305558 | 2.5 |
| Rx EC | 0.20 | 16.57 | | |
| Rx IMN | 18.00 | 22.10 | 0.00616898 | 8.2 |




**As Tx Impairments increase, the ETCC noise term uses an increasing proportion of the overall noise budget**

**Allowing higher ETCC puts additional restrictions on Rx design**

# New Analysis

**Calculations of penalty were performed using a noise-based model**

**A receiver model was used to evaluate the change in receiver noise based on power level**

- The model included the following:
  - Responsivity
  - Photodiode noise
  - TIA Noise
  - Crosstalk
  - ADC noise

**This Rx noise is included as an additional contribution to the Rx impairments**

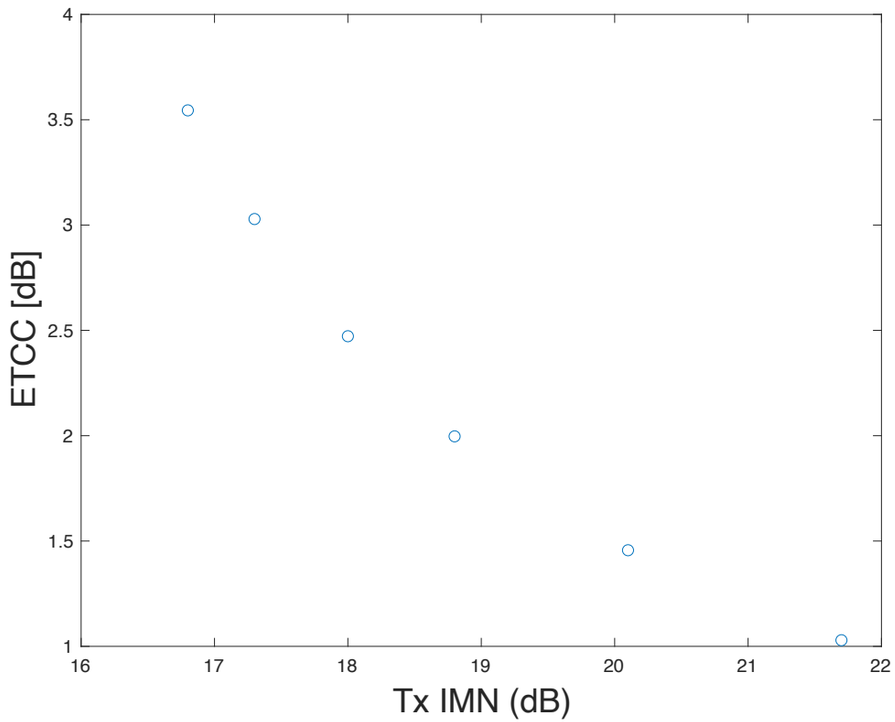
- IMN quoted is for low attenuation

**Performance (margin) was evaluated for ETCC = 1 to 3.5dB in 0.5 dB steps**

# ETCC versus Tx IMN for 800GBASE-LR1

Analysis shows ETCC for an EC of 0.2dB

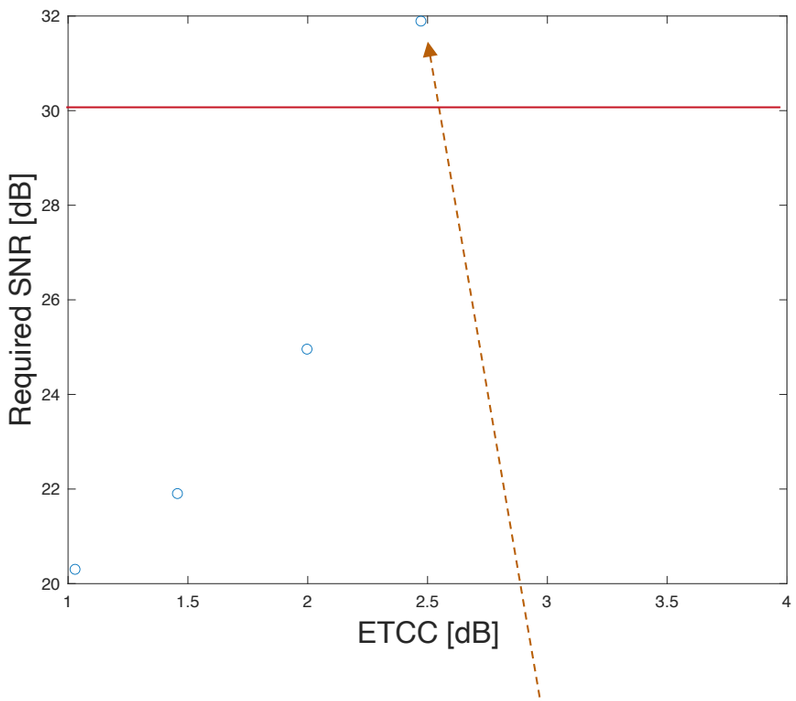
These IMN values for ETCC from 1 to 3.5dB are used to evaluate SNR requirements and penalty in the following slides



# Impact of Rx Power adjustment, 800GBASE-LR1

Calculation for Rx IMN = 18.5dB/Rx EC = 0.2dB

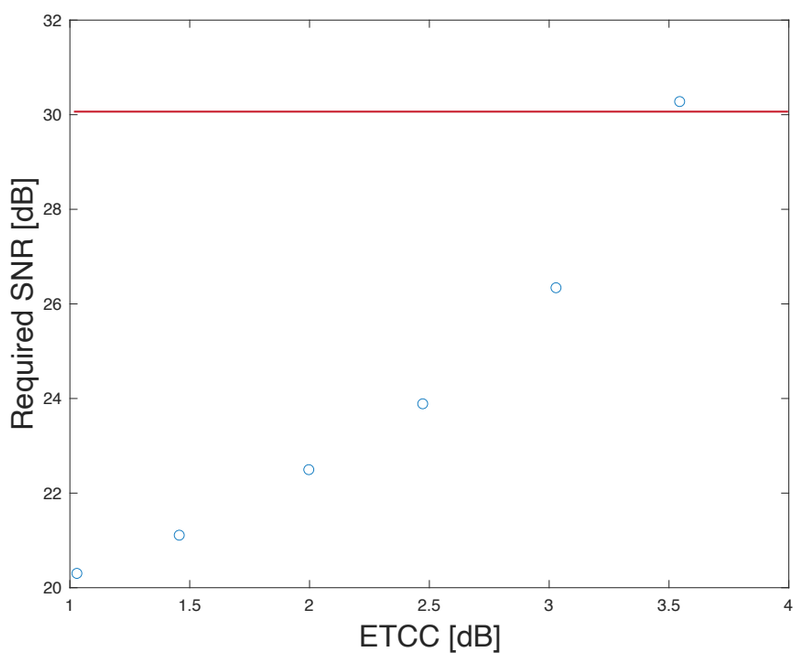
Rx Power fixed at -18dBm



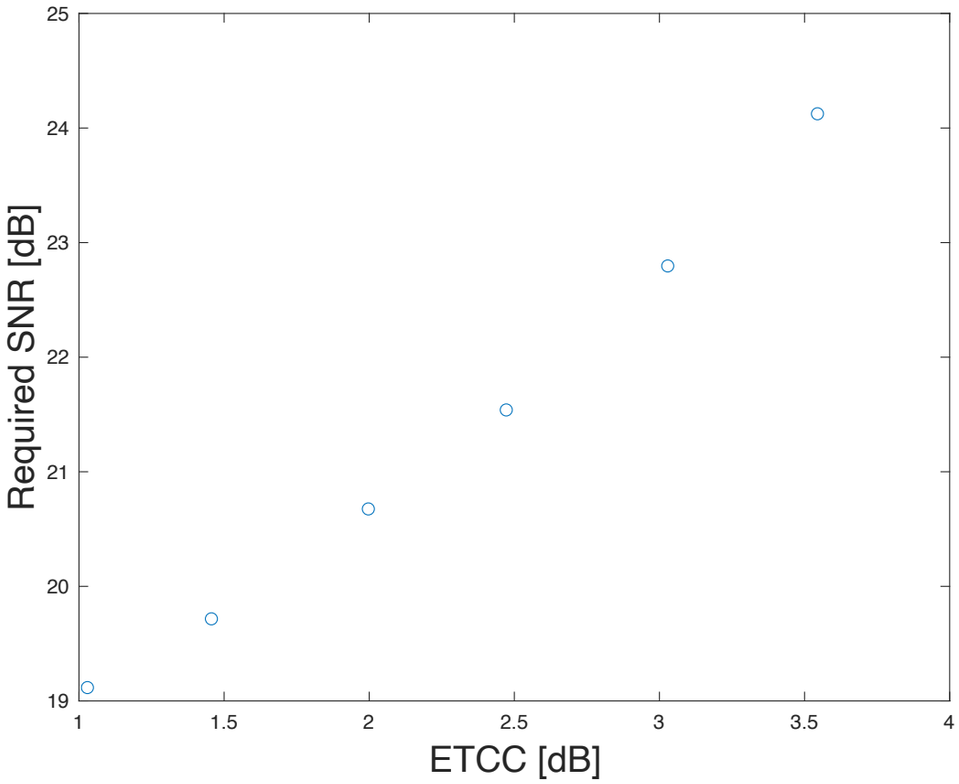

RSNR → Approaching Infinite

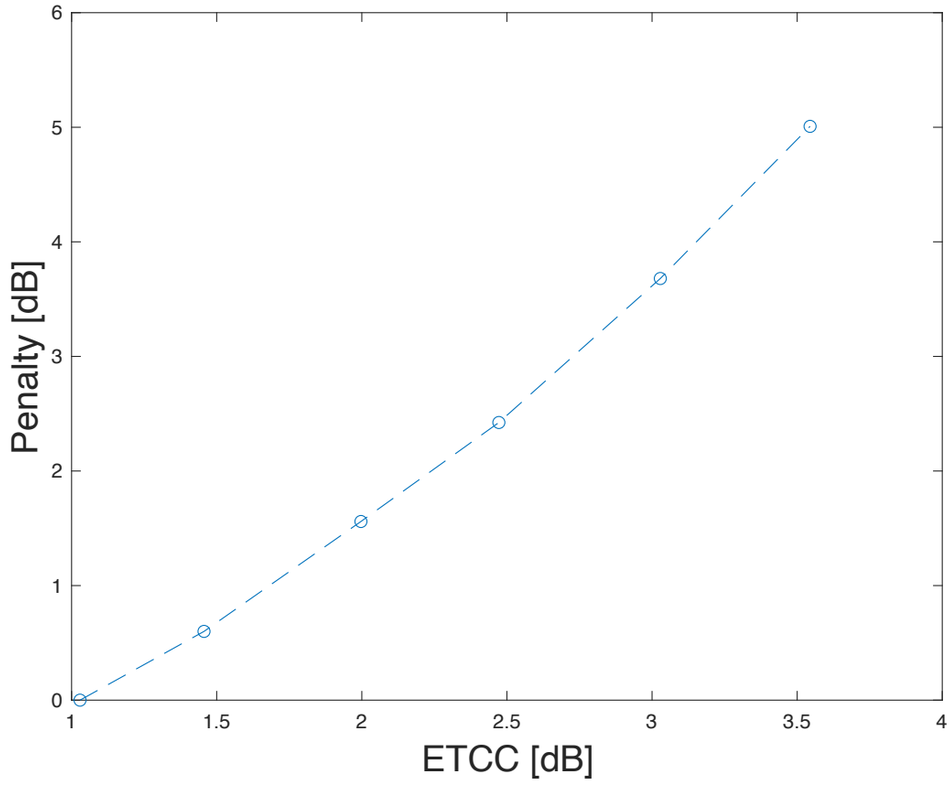
Tx $OSNR_{Min}$

Rx Power = -19dBm + ETCC for ETCC> 1dB



# Analysis: Rx ~19.5dB Rx internal noise

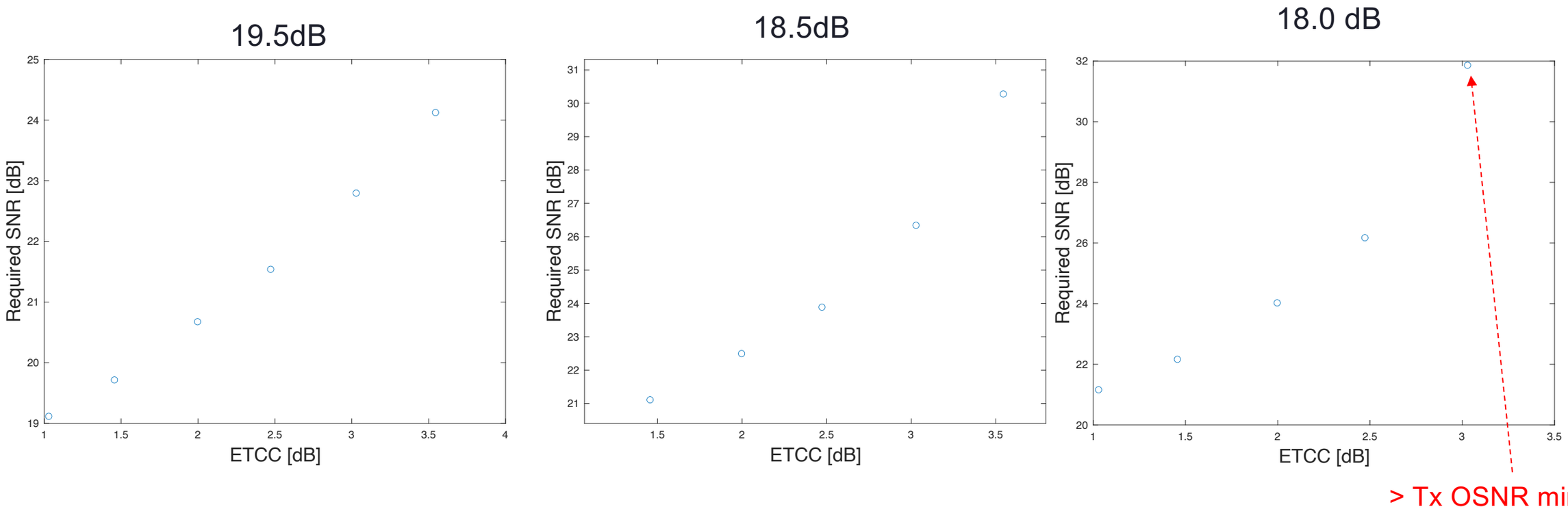



Penalty is calculated relative to RSNR at $P_{input}$ = -18dBm, ETCC = 1dB

Although power increases with ETCC, a penalty with increasing ETCC is observed

# SNR requirement vs Rx IMN




For an 18dB Rx IMN, even with power adjustment, ETCC > 2.5dB results in an unrealistic OSNR requirement

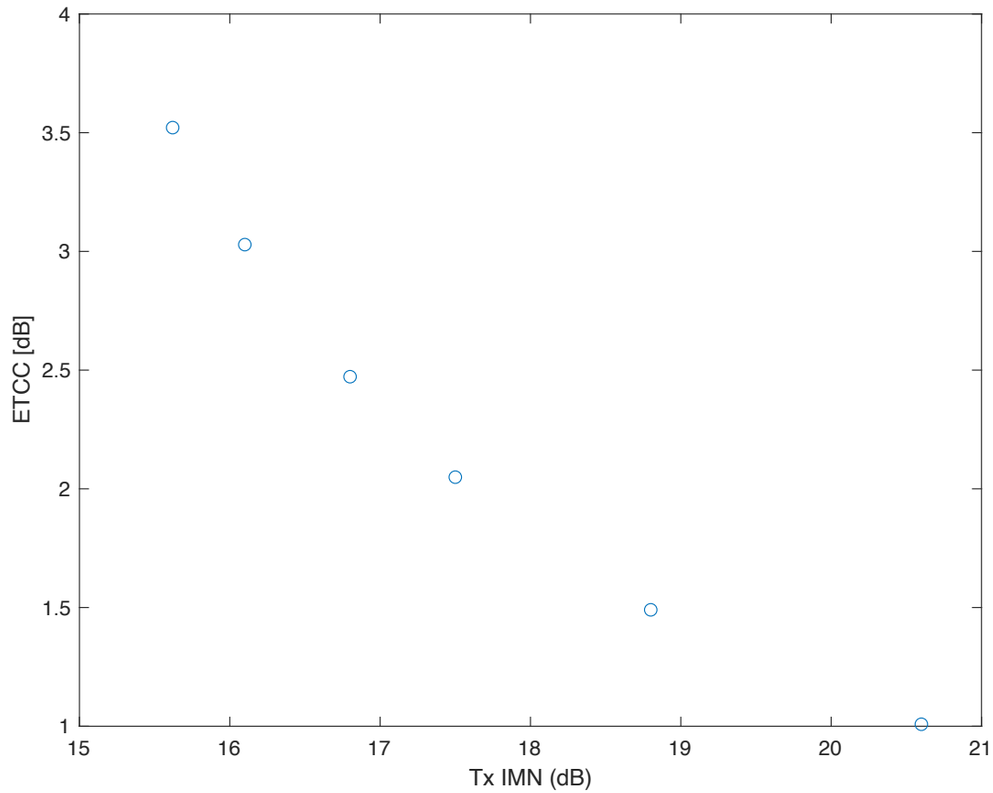
At this limit, internal noise sources account for the entire SNR budget

# ETCC versus Tx IMN for 800GBASE-ER1

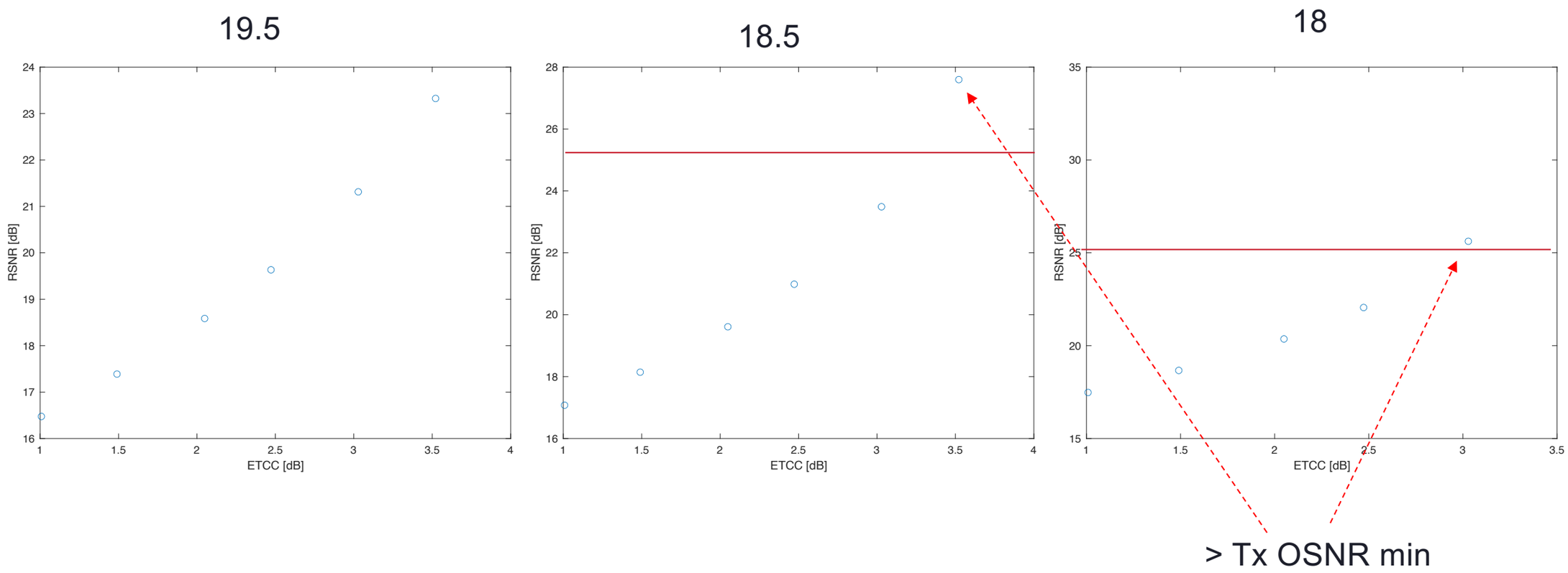
800GBASE-ER1 tolerates more noise for comparable ETCC

The preceding analysis is run for 800GBASE-ER1 using similar ETCC values

Rx noise is evaluated in the C band, at 800GBASE-ER1 Rx power levels



# 800GBASE-ER1 SNR vs Rx IMN




Conclusions from 800GBASE-LR1 hold for 800GBASE-ER1: 2.5dB ETCC Max is appropriate for 800GBASE-ER1

# 800GBASE-LR1 update

**Make the following changes to Table 185-5**

- Update ETCC (max) to 2.5 dB
- Update Tx power range to align with ETCC (max) of 2.5 dB

**Make the following changes to Table 185-6**

- Update the ETCC range for Average receive power tolerance (min) and Receiver sensitivity (max) to align with ETCC max = 2.5dB

# 800GBASE-ER1 Updates

**Make the following changes to Table 187-5**

- Update the 800GBASE-ER1-20 Average launch power (min) to
  - -11 dBm for ETCC  ≤ 1 dB
  - -12 + ETCC dBm for 1 < ETCC ≤ 2.5 dB
- Update the 800GBASE-ER1 Average launch power (min) to
  - -5 dBm for ETCC ≤ 1 dB
  - -6 + ETCC dBm for 1 < ETCC ≤ 2.5 dB

**Make the following changes to Table 187-6**

- Average receive power tolerance (min)
  - -18 dBm for ETCC ≤ 1 dB
  - -19 + ETCC dBm for 1 < ETCC ≤ 2.5 dB
- Receiver sensitivity (max) for [ER1-20 / ER1]
  - [-18.5 / -19] dBm for ETCC ≤ 1 dB
  - [-19.5 / -20] + ETCC dBm for 1 < ETCC ≤ 2.5 dB

# Summary

**A noise based analysis for 800GBASE-LR1 & 800GBASE-ER1 provides guidance for ETCC limits**

**Using an Rx model, the dependence of the SNR requirements on ETCC are shown**

**Recommend setting ETCC max value to 2.5dB for 800GBASE-LR1 & 800GBASE-ER1**

**800GBASE-ER1 and 800GBASE-ER1-20 Optical power specifications can be coupled to ETCC, using a similar approach as 800GBASE-LR1**

# Thanks!