Proposed Baseline for 400GPL 500m objectives

Xiaojie Fan, Ping Liao, Yu Xu
Huawei Technologies

Background

1. The pre-baseline for building 400GPL 500m objective has been introduced in welch_400GPL_01_2609.

(1) Based on 200GPL 500m standard, some changes have been proposed for 400GPL 500m objective.

(2) Due to the integrated noise bandwidth increasing, the link budgets need to be shifted up by 1.5dB vs. comparable 200GPL specifications.

(3) Reuse FECo (RS544 only), set TDECQ = 3.75 and enhance reference receiver equalizer while maintaining FFE+DFE architecture.

2. This proposal focuses on the key optical specifications discussion for 400GPL 500m objective such as TX OMA, RX sensitivity and TDECQ.

Theoretical analysis_TX OMA, RX sensitivity

- Assuming the power of the received optical signal at the photodetector(PD) is P_s, the photocurrent after PD can be expressed as:

$$I_s = R * (P_s + \sigma_{tx,n})$$

- RX SNR can be calculated as:

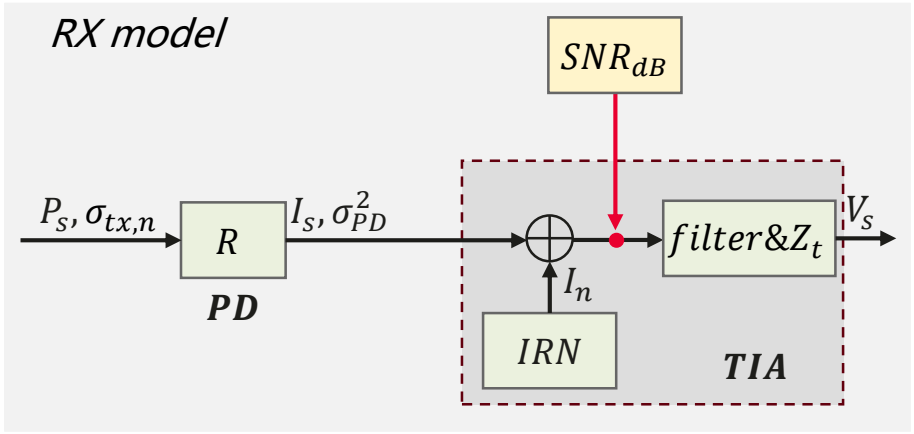
$$SNR = R^2 P_s^2 / ((IRN * \sqrt{BW})^2 + (R * \sigma_{tx,n})^2 + \sigma_{PD}^2)$$

TIA noise *Tx noise (≪ TIA noise)* *PD noise (≪ TIA noise)*

- RX SNR expression can be simplified as:

$$SNR \approx \frac{R^2 P_s^2}{(IRN * \sqrt{BW})^2}$$

$$SNR_{dB} \approx 20 \times log_{10}(\frac{R * P_s}{IRN * \sqrt{BW}})$$



variable	description	unit
P_s	the power of the received optical signal at PD	W
R	the responsivity of PD	A/W
$\sigma_{tx,n}$	the noise power of transmitter(TX)	W
σ_{PD}	the noise power of PD	W
IRN	the input-referred noise spectral density of TIA	$A/\sqrt{Hz}$
BW	the noise bandwidth of TIA	Hz
I_n	the noise current of TIA	A
I_s	the photocurrent after PD	A
V_s	the output voltage	V

Theoretical analysis _TX OMA, RX sensitivity

$$SNR_{dB} \approx 20 \times log_{10}(\frac{R * P_s}{IRN * \sqrt{BW}})$$

From 800GBASE-DR4 to 1.6TBASE-DR4, the noise BW of TIA doubles and the TIA *IRN* will also increase. According to the existing commercial TIA *IRN*, the TIA *IRN* for a 400GPL transceiver is predicted to increase by 1.5 times in the worst case. And the PD responsivity *R* is assumed to reduce by 0.75 times in the worst case.

	R	IRN	BW	P_s	$RX\ SNR_{dB}\ penalty(dB)$
baseline	×1	×1	×1	×1	0
①	×0.75	×1	×1	×1	2.5
②	×1	×1.5	×1	×1	3.5
③	×1	×1	×2	×1	3
④	×0.75	×1.5	×2	×1	9

Need to increase the P_s to mitigate the $RX\ SNR_{dB}$ penalty

- If the power P_s of the received optical signal keeps unchanged, the RX SNR shows significant degradation considering the impact of PD responsivity and TIA noise.
- Assuming that *R* and *IRN* are optimized, it is still necessary to increase P_s by 1.5dB to mitigate the RX SNR penalty, like case③.
- 1.5dB shift up is appropriate for TX OMA and RX sensitivity, as mentioned in welch_400GPL_01_2609.

Discussion_TDECQ

- The value of TDECQ needs to effectively provide a reference for the capability of the transceiver and depends on TDECQ reference equalizer functional model.
- In IEEE 802.3dj project, there are multiple discussions on TDECQ value and reference equalizer functional model. TDECQ is set to 3.4. 15-tap FFE and 1-tap DFE constitute the current reference equalizer functional model.
- For 400GPL objective, the reference equalizer needs further enhancement by employing more tap FFE and lager DFE, as mentioned in welch_400GPL_01_2609. However, it needs further evaluation and data support to set the TDECQ value and reference receiver.

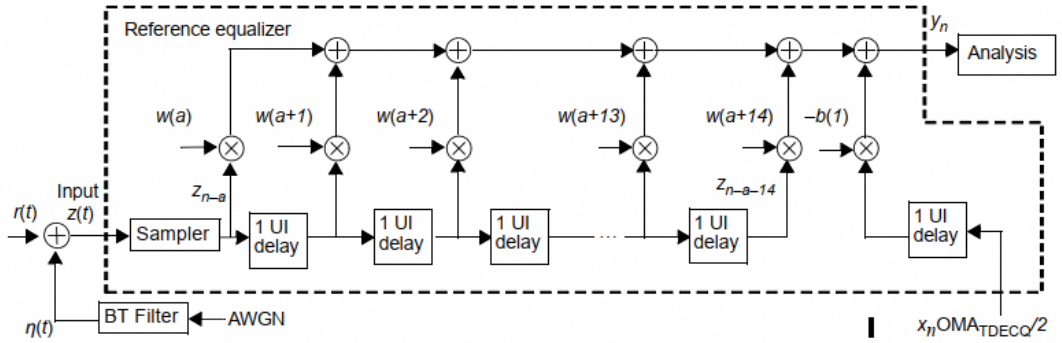
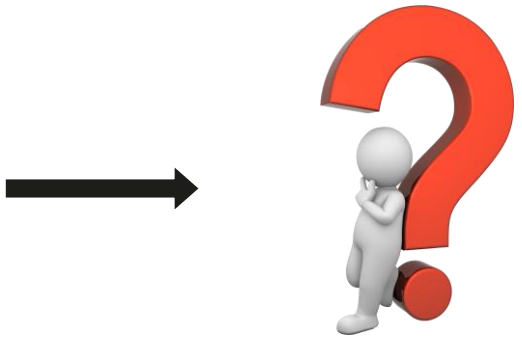


Figure 180–10—TDECQ reference equalizer functional model



Need more information

Changes in Transmitter Specifications

Description	200GBASE-DR1 400GBASE-DR2 800GBASE-DR4	400GBASE-DR1 800GBASE-DR2 1.6TBASE-DR4	Unit	Δ
Single rate, each lane(range)	106.25±50ppm	212.5±50ppm	GBd	/
Modulation format	4	4	—	/
Lane wavelength(range)	1304.5 to 1317.5	1304.5 to 1317.5	nm	/
Side-mode suppression ratio(SMSR), each lane(min)	30	30	dB	/
Average launch power, each lane(max)	4	5.5	dBm	+1.5
Average launch power, each lane(min)	-3.1	-1.6	dBm	+1.5
Outer optical modulation amplitude(OMAouter), each lane(max)	4.2	5.7	dBm	+1.5
Outer optical modulation amplitude(OMAouter),each lane(min) for max(TECQ, TDECQ)<0.9dB for 0.9 dB≤max(TECQ, TDECQ) ≤3.4 dB	 -0.1 -1+max(TECQ, TDECQ)	 1.4 0.5+max(TECQ, TDECQ)	 dBm dBm	 +1.5 +1.5
Transmitter and dispersion eye closure for PAM4(TDECQ), each lane(max)	3.4	3.75?	dB	+0.35?
Transmitter eye closure for PAM4(TECQ), each lane(max)	3.4	3.75?	dB	+0.35?
|TDECQ-TECQ|, each lane(max)	2.5	2.5	dB	/
Transmitter functional symbol error histogram, each lane(max)	Table 180-17	TBD	—	
Transmitter overshoot and undershoot, each lane(max)	27	TBD	%	
Transmitter power excursion, each lane(max)	2.9	TBD	dBm	
Extinction ratio, each lane(min)	3.5	3	dB	-0.5
Transmitter transition time, each lane(max)	3.5	TBD	ps	
Average launch power of OFF transmitter, each lane(max)	-15	-15	dBm	/
RINxOMA, each lane(max) x=15.5(DR1)/21.4(DR2,DR4)	-139	TBD	dB/Hz	
Transmitter reflectance, each lane(max)	-26	-26	dB	/

Changes in Receiver Specifications

Description	200GBASE-DR1 400GBASE-DR2 800GBASE-DR4	400GBASE-DR1 800GBASE-DR2 1.6TBASE-DR4	Unit	Δ
Single rate, each lane(range)	106.25±50ppm	212.5±50ppm	GBd	/
Modulation format	4	4	—	/
Lane wavelength(range)	1304.5 to 1317.5	1304.5 to 1317.5	nm	/
Damage threshold, each lane	5	6.5	dBm	+1.5
Average receive power, each lane(max)	4	5.5	dBm	+1.5
Average receive power, each lane(min)	-6.1	-4.6	dBm	+1.5
Receive power(OMAouter), each lane(max)	4.2	5.7	dBm	+1.5
Receiver reflectance	-26	-26	dB	
Receiver sensitivity (OMAouter),each lane(max) for max(TECQ, TDECQ)<0.9dB for 0.9 dB≤max(TECQ, TDECQ) ≤3.4 dB	 -3.4 -4.3+max(TECQ, TDECQ)	 -1.9 -2.8+max(TECQ, TDECQ)	 dBm dBm	 +1.5 +1.5
Stressed receiver sensitivity(OMAouter), each lane(max)	-0.9	0.95	dBm	+1.85?
Conditions of stressed receiver sensitivity test				
Stressed eye closure for PAM4(SECQ), lane under test	3.4	3.75?	dB	+0.35?
OMAouter of each aggressor lane	4.2	5.7	dBm	+1.5

Changes in Illustrative Link Power Budget

Description	200GBASE-DR1 400GBASE-DR2 800GBASE-DR4	400GBASE-DR1 800GBASE-DR2 1.6TBASE-DR4	Unit	Δ
Power budget (for max TDECQ)	6.7	7.05	dB	+0.35?
Operating distance	500	500	m	/
TECQ/TDECQ(max)	3.4	3.75?	dB	+0.35?
Channel insertion loss	3	3	dB	/
Maximum discrete reflectance	-35	TBD	dB	
Allocation for penalties (for max TDECQ)	3.7	4.05?	dB	+0.35?
Additional insertion loss allowed	0	0	dB	/

Summary

This presentation discussed some key optical specifications for 400GPL 500m objective:

- Increasing the TX OMA and RX sensitivity to alleviate the SNR penalty due to TIA noise. 1.5dB shift up is a good reference point, as mentioned welch_400GPL_01_2609.
- The TDECQ is one of the metrics to characterize transceiver performance and is closely related to reference equalizer functional model. It has been suggested to be 3.75 in welch_400GPL_01_2609, which may be suitable. However, more supporting data are needed to ensure its accuracy.
- The reference equalizer model also needs further analyses including the number of FFE taps and the values of FFE and DFE coefficients.

Thanks!