Approaching Shannon's Limit

TDFOM normalization factor and corrigendum draft proposal

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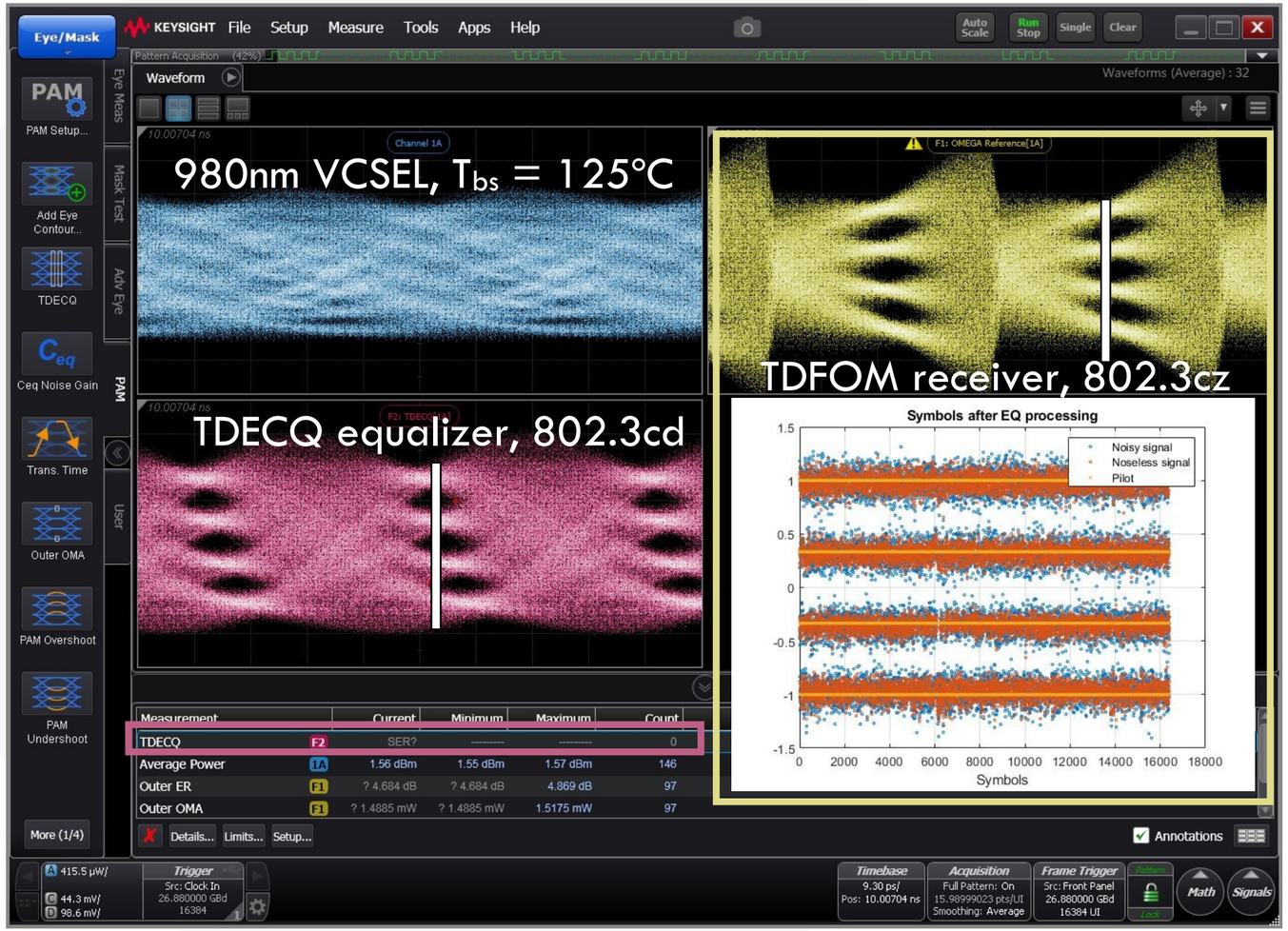
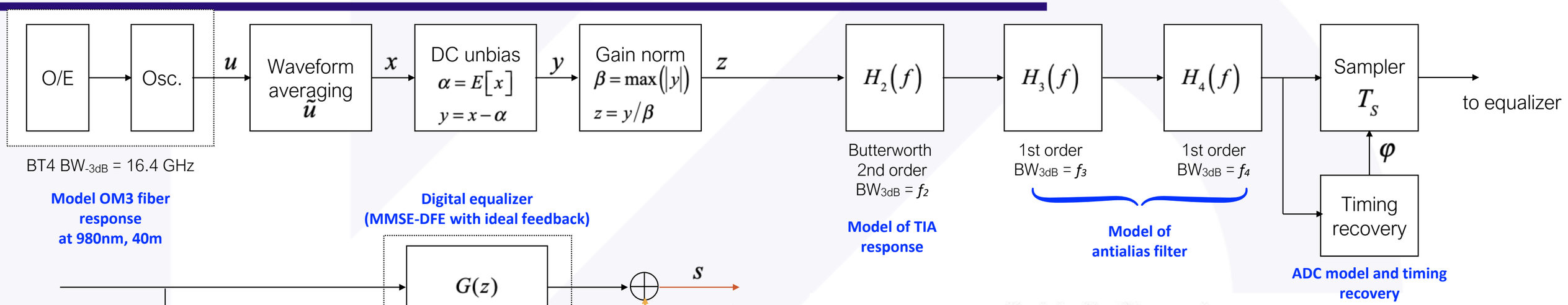
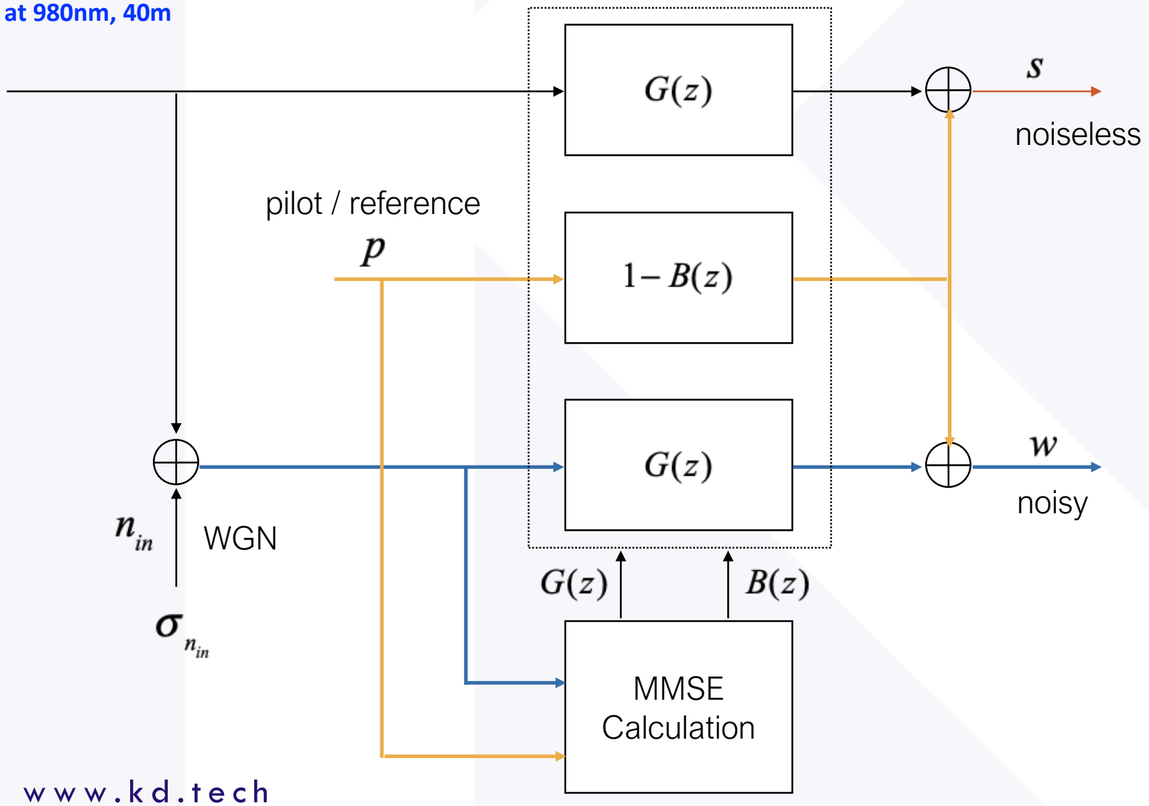
TDFOM motivation: The non-linear ISI issue

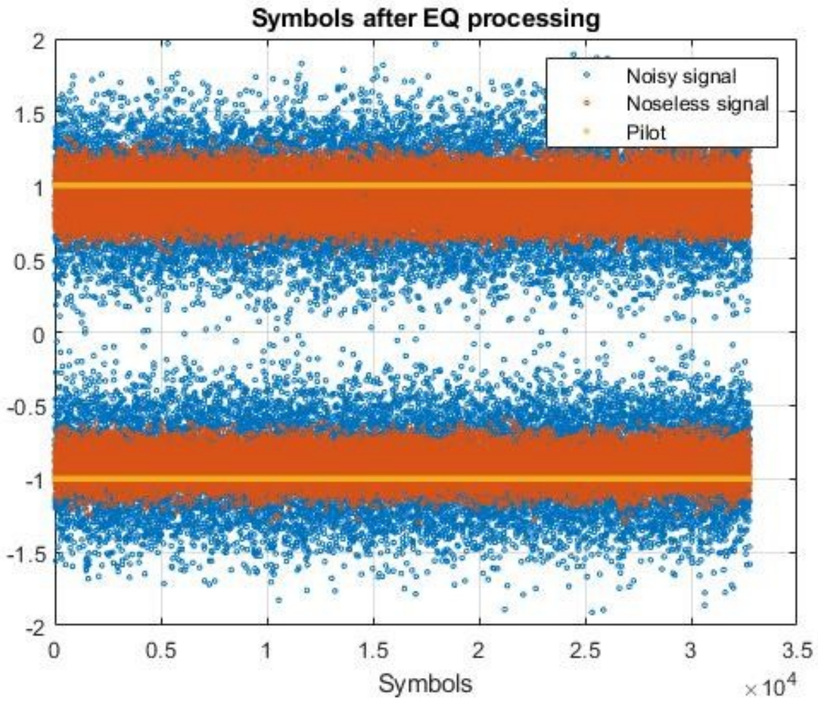
- IEEE 802.3cz includes non-linear light source (VCSEL) and in-line connectors which generate non-linear ISI
- TDECQ reference receiver and equalizer cannot find a valid sampling point in certain circumstances
  - VCSEL operating at TBS = 125°C, 26.88 GBd, PAM4
- A new Figure of Merit and reference receiver is needed: TDFOM [1][2]
- Other TDECQ limitations reported at IEEE 802.3cd TF by Tamura et al. [3]



TDFOM calculation







BER = 0.00017

TDFOM normalization

- TDFOM implies optimization of not only F(z) and B(z), but also sampler delay ϕ and F(z) delay per 166.6.4.8.2

> Additionally, the selected sampler delay ϕ and $F(z)$ delay are optimized for minimum BER after equalization, calculated as specified in 166.6.4.8.4, at each value of σ_{in}.

  - *But first implementations of the algorithm had a fixed ϕ and F(z) delay*

- $TDFOM_0$ is defined to obtain TDFOM = 0 dB when measuring a transmitter generating a perfect squared signal ("perfect transmitter")

> **166.6.4.8.6 TDFOM calculation**
>
> TDFOM is calculated as specified in Equation (166–16), where M, Q_0, and $TDFOM_0$ depend on the BASE-AU under test as specified in Table 166–16.
>
> $$TDFOM = 10\log_{10}\left(\frac{OMA_{in}}{2(M-1)\sigma_{in}Q_0}\right) - TDFOM_0 \quad \text{(dB)} \quad (166\text{–}16)$$

  - *But first implementations of the algorithm had a fixed ϕ and F(z) delay. Existing $TDFOM_0$ values in current IEEE Std 802.3 are based on this assumption*

Proposal of Corrigendum to IEEE Std 802.3: TDFOM normalization

- Current values without optimization of sampler delay ϕ

Table 166–16— BASE-AU TDFOM parameters

Parameter	2.5GBASE-AU	5GBASE-AU	10GBASE-AU	25GBASE-AU	50GBASE-AU	Units
M	2				4	—
Q_0	3.5741[a]				3.4981[a]	—
$TDFOM_0$	3.59	3.61	3.63	3.92	2.83	dB

[a] Consistent with BER = 1.757×10^{-4}.

- Proposed values with optimization of sampler delay ϕ

Table 166–16— BASE-AU TDFOM parameters

Parameter	2.5GBASE-AU	5GBASE-AU	10GBASE-AU	25GBASE-AU	50GBASE-AU	Units
M	2				4	—
Q_0	3.5741[a]				3.4981[a]	—
$TDFOM_0$	3.72	3.74	3.77	3.90	2.83	dB

[a] Consistent with BER = 1.757×10^{-4}.

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THANKS!

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References

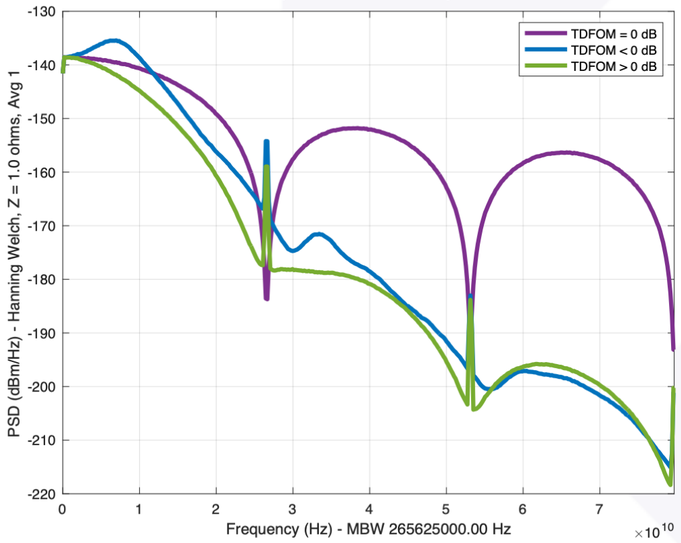
[1] Rubén receiver and transmitter and distortion figure of merit," February 2022, [Online], Available: https://www.ieee802.org/3/cz/public/8_feb_2022/perezaranda_3cz_01c_080222_TDFOM.pdf

[2] Rubén Pérez-Aranda, "TDFOM simplification proposal," February 2022, [Online], Available: https://www.ieee802.org/3/cz/public/may_2022/perezaranda_3cz_01a_0522_TDFOM_Simpler.pdf

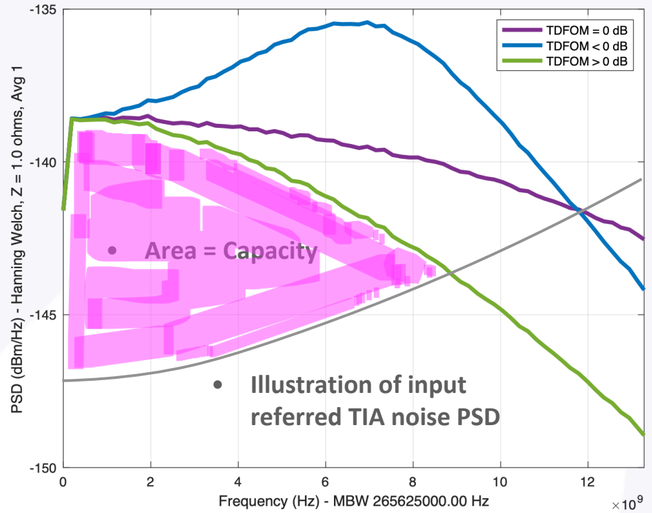
[3] Tamura et al, "Concerning Comments r03-21, -22, -42, -43 On TDECQ," July 2018, [Online], Available: https://grouper.ieee.org/groups/802/3/cd/public/July18/tamura_3cd_01c_0718.pdf

TDFOM examples for 25 Gb/s

AC PSD, from 0 to 3/T_s

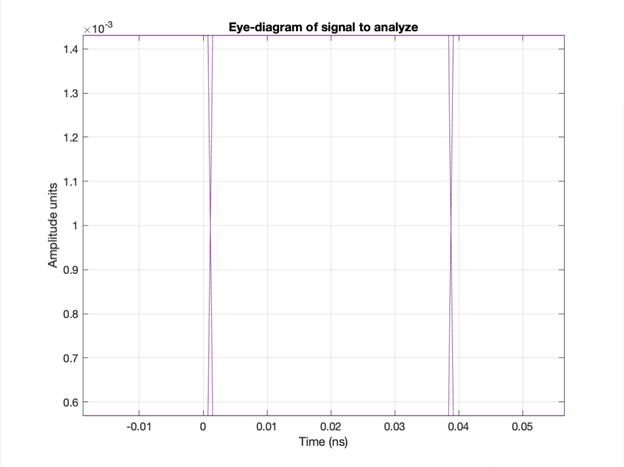


AC PSD, from 0 to Nyquist



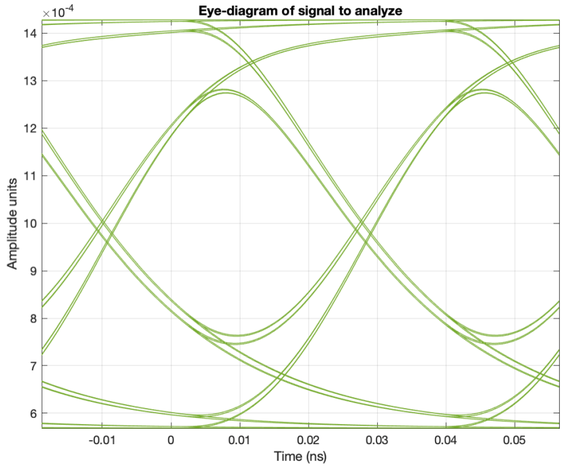
Area between signal and noise PSDs define the channel capacity, hence the sensitivity of the receiver

TDFOM = 0 dB (reference)



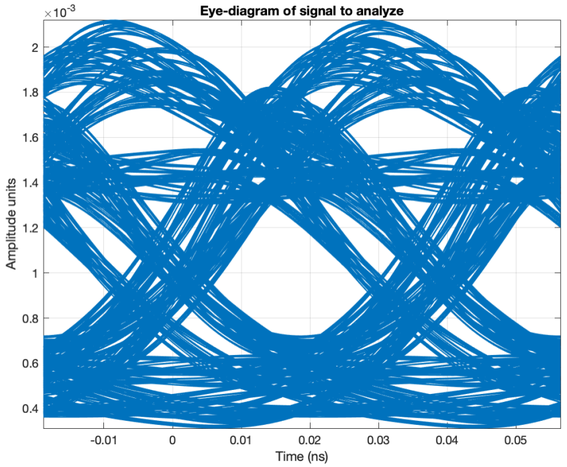
"Perfect transmitter" eye diagram

TDFOM = 1.2 dB (will produce worse sensitivity)



VCSEL @ -40 ºC, Driver 3, eye diagram

TDFOM = -0.7 dB (will produce better RX sensitivity)



VCSEL @ +125 ºC, Driver 1, eye diagram

- (Note: the OMA_{tx} has been normalised in these examples for comparison)