Optical modeling of 100 GBd PAM4 with relevance to single-wavelength 200 Gb/s per lane PMDs

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IEEE P802.3df 200 Gb/s, 400 Gb/s, 800 Gb/s, and 1.6 Tb/s Ethernet Task Force
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Introduction

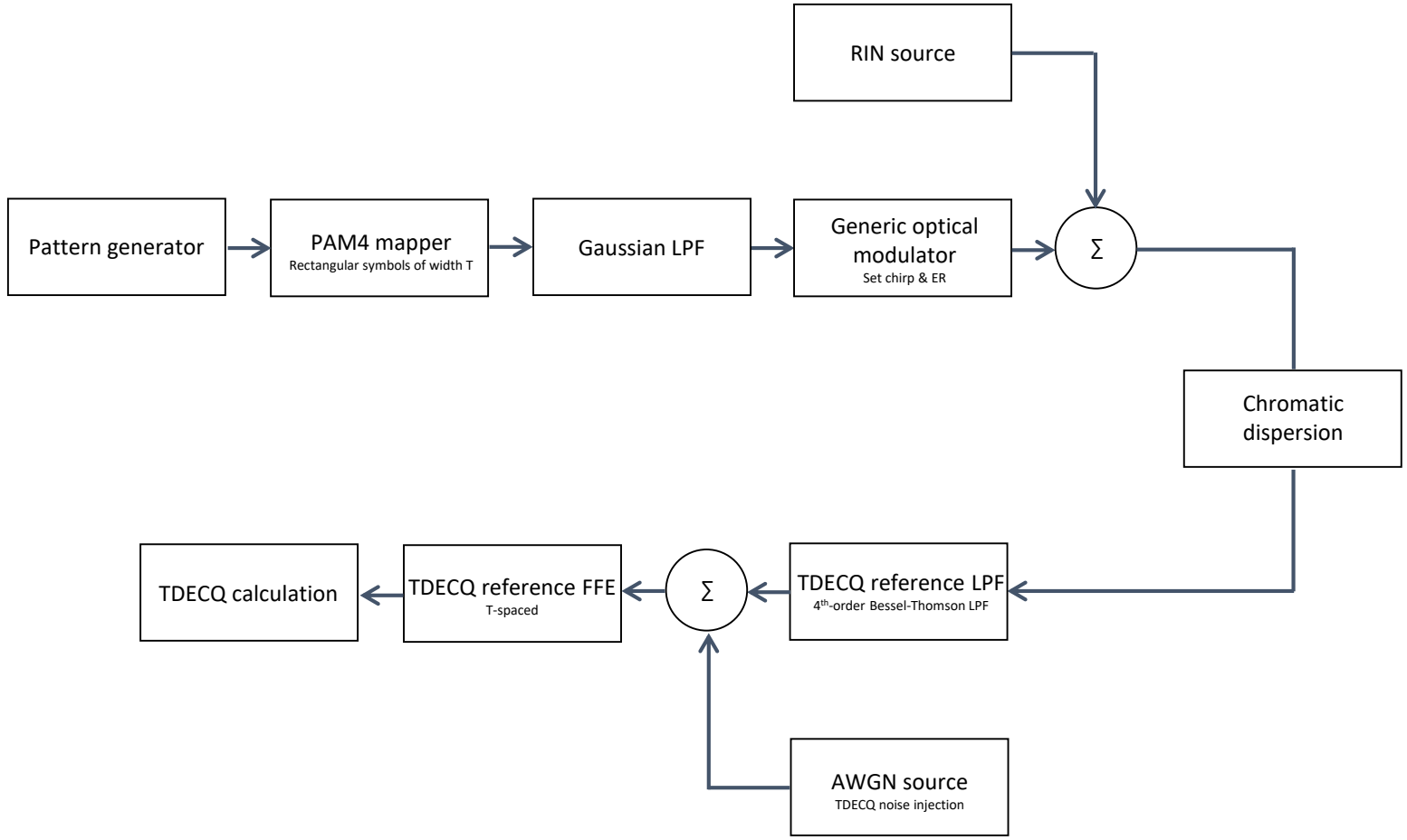
- Initial 100 GBd PAM4 optical modeling
  - Gaussian-filtered Tx pulse shape
  - Single wavelength
  - SMF chromatic dispersion (up to 2 km fiber length)
  - TDECQ reference receiver
- Investigation of TDECQ dependency on TP2 transition time, RIN and TDECQ reference equalizer length
- Aim is to begin to better understand sensitivity of link performance to key parameters

Target

Ethernet Rate	Assumed Signaling Rate	AUI	BP	Cu Cable	MMF 50m	MMF 100m	SMF 500m	SMF 2km	SMF 10km	SMF 40km
200 Gb/s	200 Gb/s	Over 1 lane 200GAUI-1		Over 1 pair 200GBASE-CR1			Over 1 Pair	Over 1 Pair		
400 Gb/s	100 Gb/s							Over 4 Pair		
	200 Gb/s	Over 2 lanes 400GAUI-2		Over 2 pairs 400GBASE-CR2			Over 2 Pair			
800 Gb/s	100 Gb/s	Over 8 lanes 800GAUI-8	Over 8 lanes 800GBASE-KR8	Over 8 pairs 800GBASE-CR8	Over 8 pairs 800GBASE-VR8	Over 8 pairs 800GBASE-SR8	Over 8 pairs TBD	Over 8 pairs TBD		
	200 Gb/s	Over 4 lanes 800GAUI-4		Over 4 pairs 800GBASE-CR4			Over 4 pairs	1) Over 4 pairs 2) Over 4 λ's → More work required		
	TBD								Over single SMF in each direction	Over single SMF in each direction
1.6 Tb/s	100 Gb/s	Over 16 lanes 1.6TAUI-16								
	200 Gb/s	Over 8 lanes 1.6TAUI-8		Over 8 pairs 1.6TBASE-CR8			Over 8 pairs	Over 8 pairs		

Depends on the modulation scheme & More work required

Model block diagram



A simple model is best to take into account major trends for performance at the system level.

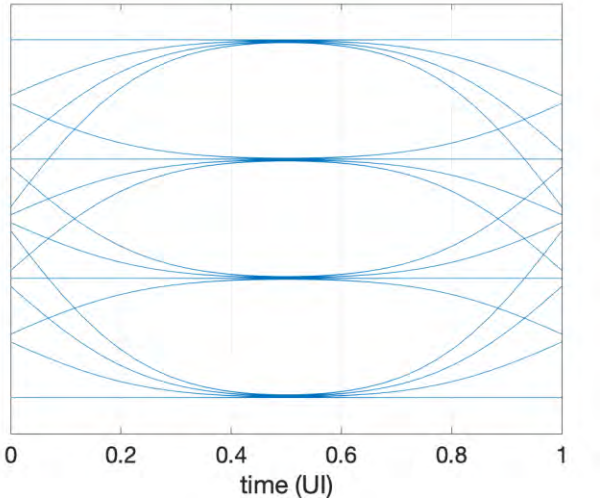
Simulation parameters

Tx
Modulation format: PAM4
Symbol rate: 106.25 GBd
Pattern: PRBS13Q
Pulse shape at TP2: Baud-rate rectangular pulse convolved with Gaussian filter. Variable transition time (20% - 80%) in the filter step response
Center wavelength: 1304.5 nm (for worst-case dispersion)
RIN: variable
Chirp factor: 0
ER: 3.5 dB

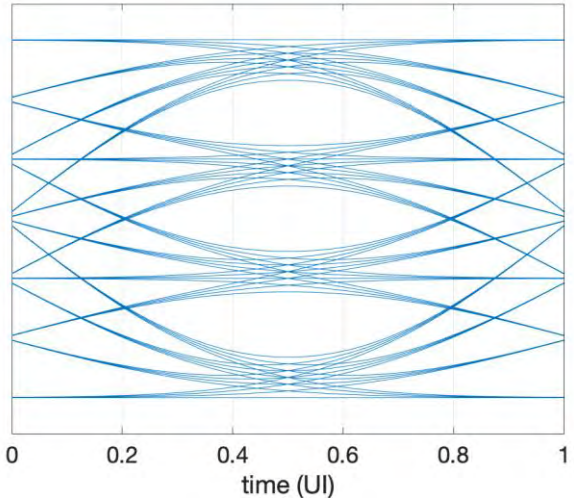
SMF
Length: 2000 m
Zero-dispersion wavelength: 1324 nm
Zero-dispersion slope: 0.093 ps/(nm^2 km)

Rx
TDECQ reference LPF: 4th-order Bessel-Thomson with –3 dBe at 53.125 GHz
TDECQ reference FFE: T-spaced with variable number of taps
TDECQ target SER: 4.8 x 10^{-4}

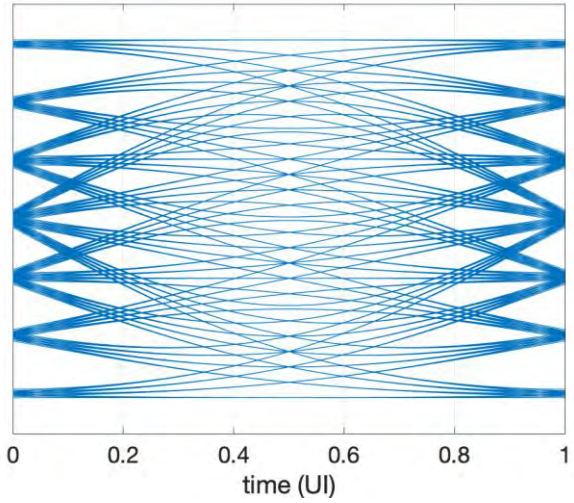
Noise-free eye diagrams at TP2



TP2 transition time: 3 ps

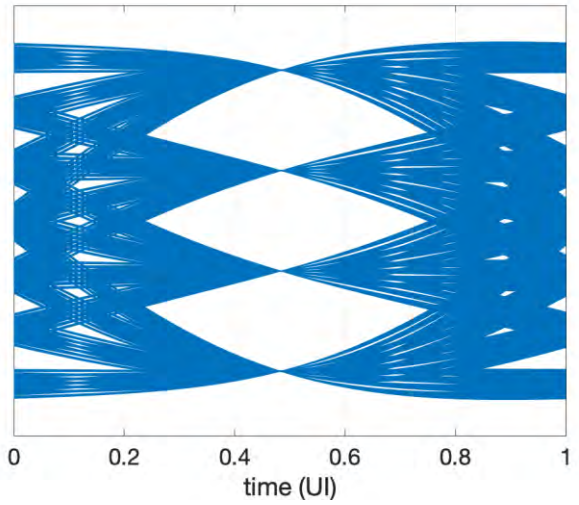


TP2 transition time: 5 ps

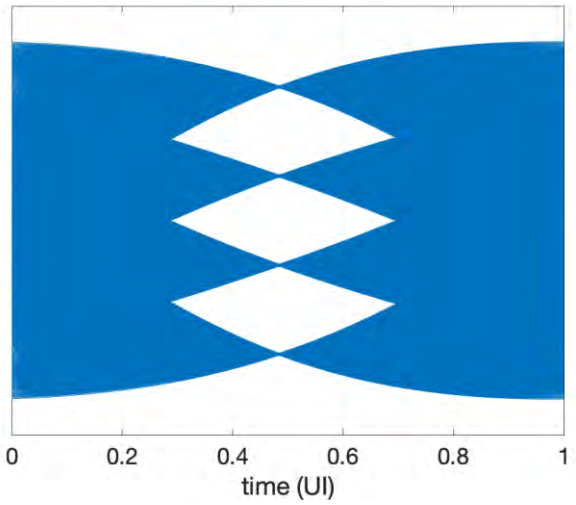


TP2 transition time: 7 ps

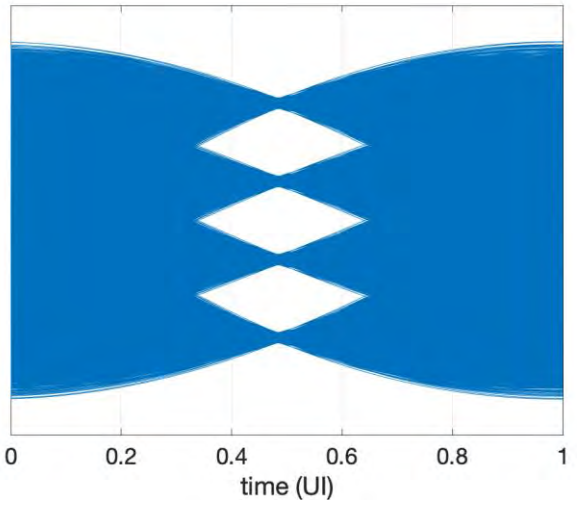
Noise-free eye diagrams after TDECQ reference receiver



TP2 transition time: 3 ps



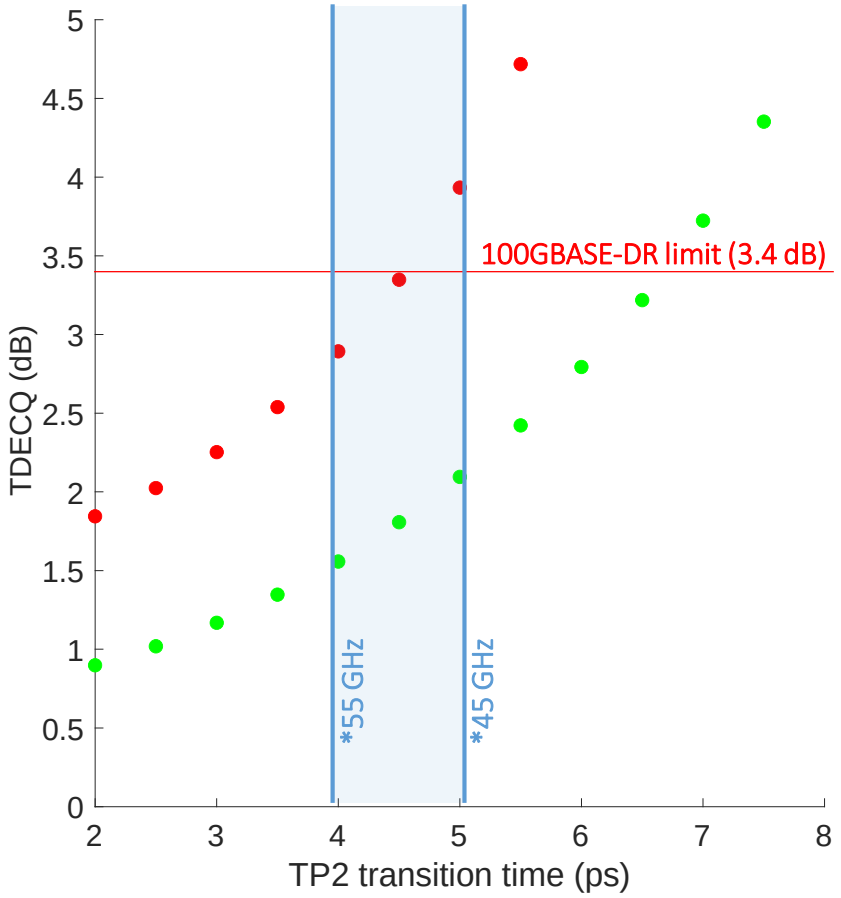
TP2 transition time: 5 ps



TP2 transition time: 7 ps

TDECQ reference FFE: 5 tap

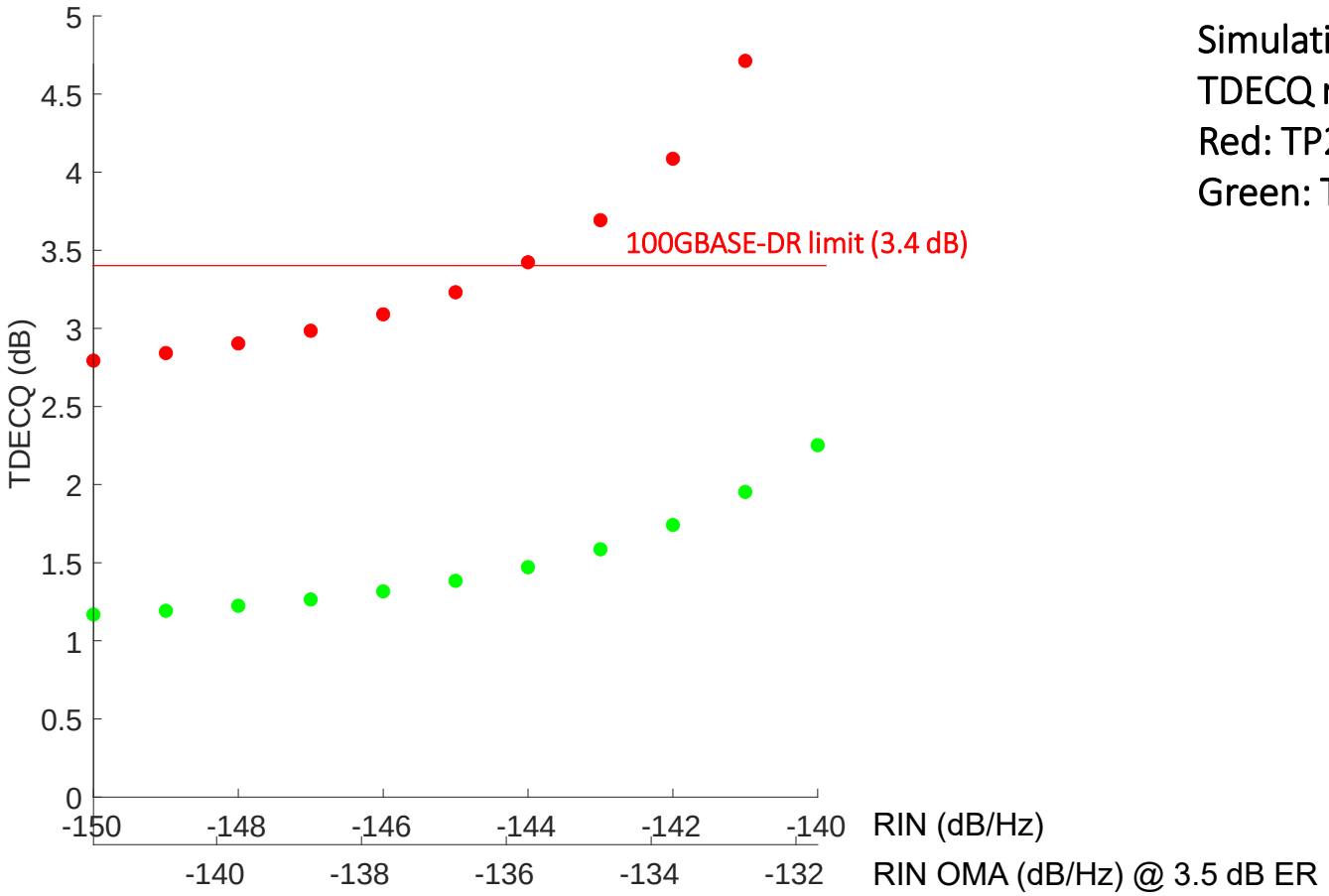
TDECQ vs TP2 transition time



Simulation specific parameters:
TDECQ reference FFE: 5 tap
Red: RIN = –140 dB/Hz
(–131.7 dB/Hz RIN OMA)
Green: RIN = –150 dB/Hz
(–141.7 dB RIN OMA)
*Equivalent aggregate Tx bandwidth

- For equivalent aggregate Tx bandwidth of 45 to 55 GHz, RIN variation from –140 dB/Hz to –150 dB/Hz causes significant TDECQ variation
- Even at RIN of –150 dB/Hz, TP2 transition time must be lower than ≈6 ps for acceptable TDECQ

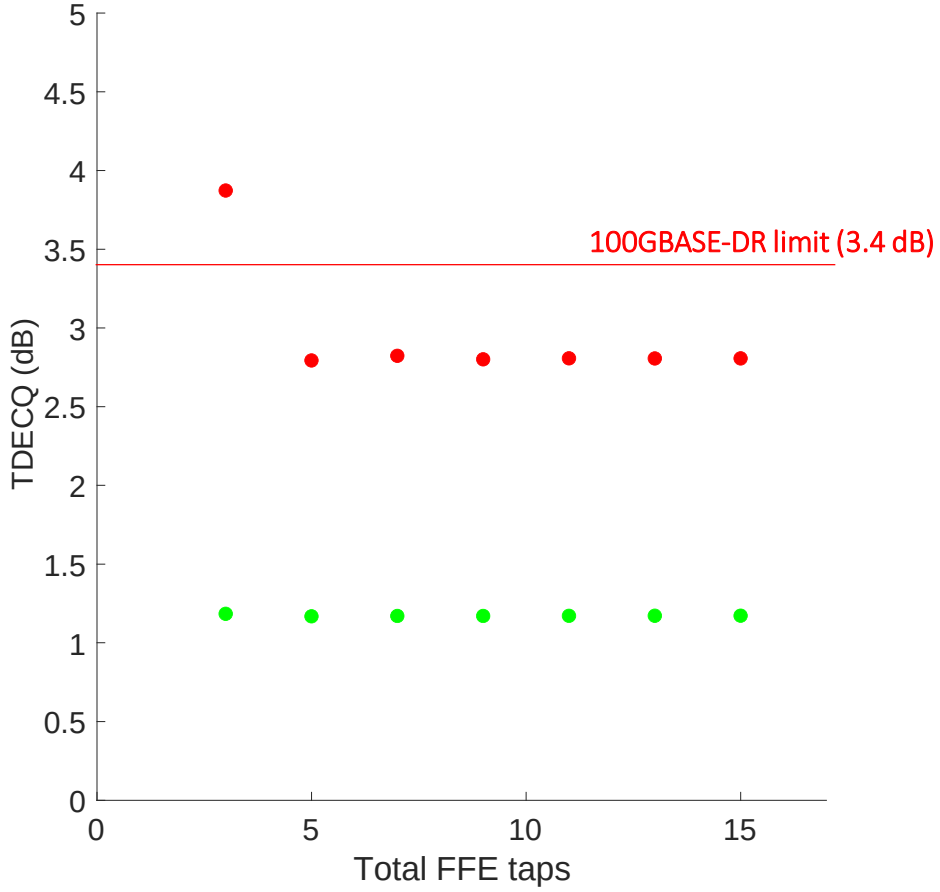
TDECQ vs RIN



Simulation specific parameters:
TDECQ reference FFE: 5 tap
Red: TP2 transition time = 6 ps
Green: TP2 transition time = 3 ps

- Dependency of TDECQ on RIN becomes stronger with increasing TP2 transition time

TDECQ vs reference FFE length



Simulation specific parameters:
TDECQ reference FFE: 5 tap
RIN: --150 dB/Hz
Red: TP2 transition time = 6 ps
Green: TP2 transition time = 3 ps

- Even for the limiting case of a TP2 transition time of 6 ps, there is no benefit from more than 5 FFE taps
- No justification to increase TDECQ reference equalizer length from 5 taps

Conclusions

- For single-wavelength 200 Gb/s per lane PMDs using 100 GBd PAM4:
  - Currently we do not expect need to change TDECQ reference equalizer from 5-tap FFE
  - Currently there is no evidence that DFE is required in the reference equalizer
  - Currently there is evidence that a tighter RIN OMA specification (compared with 50 GBd PAM4 PMDs) is helpful

Next steps

- Investigate other Tx models, including chirp
- Investigate effect of stronger FEC (higher symbol rate and higher pre-FEC BER threshold)
- Include a wider set of industry parameters to the simulation sets

Call for contributions

- Tx performance guidance from Task Force is welcome
- We can compute expected curves given the following:
  - Bandwidth or frequency response (S_{21})
  - RIN
  - Chirp factor