802.3cu: 400GBASE-LR4 fiber propagation penalty

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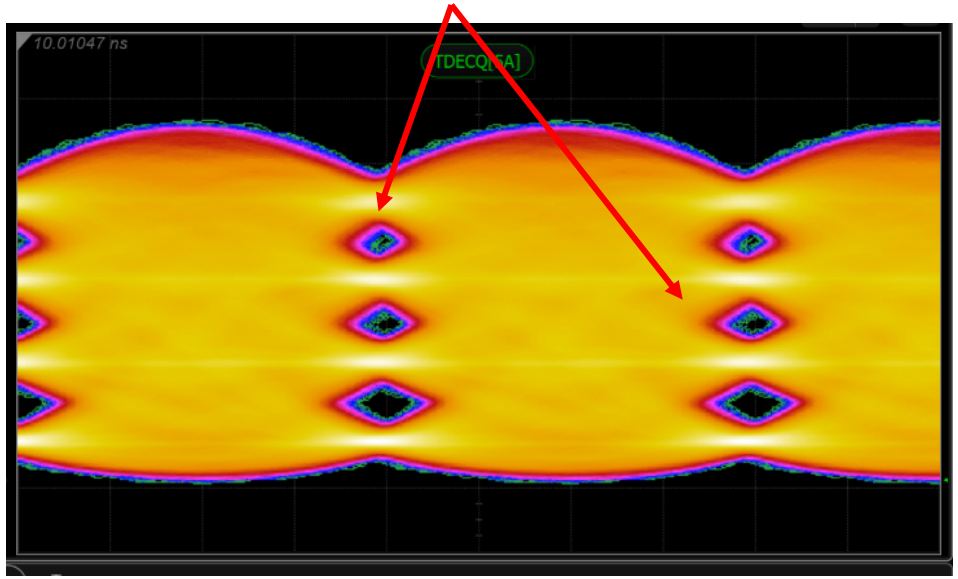
Background and overview.

- Scope of this work is to investigate if 400GBASE-LR4 can be done over CWDM grid.

- Previous investigations into mitigating chromatic dispersion have focused on:
  - Controlling transmitter chirp.
  - Controlling transmitter wavelength or fiber λ_0.

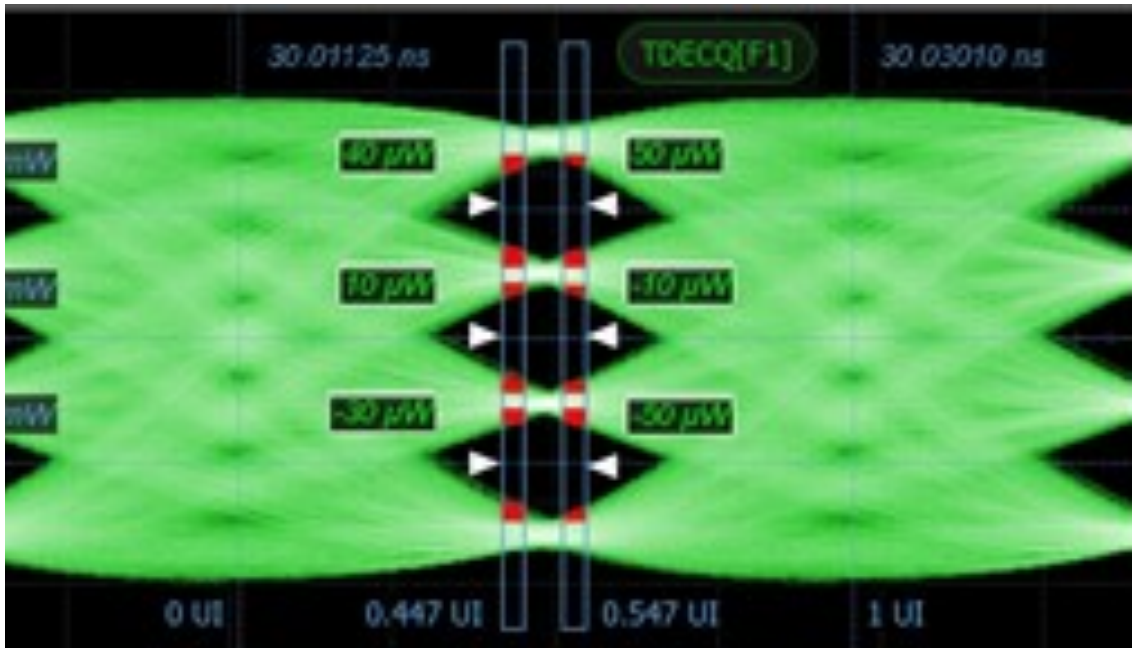
Penalty increases in upper eye(s)



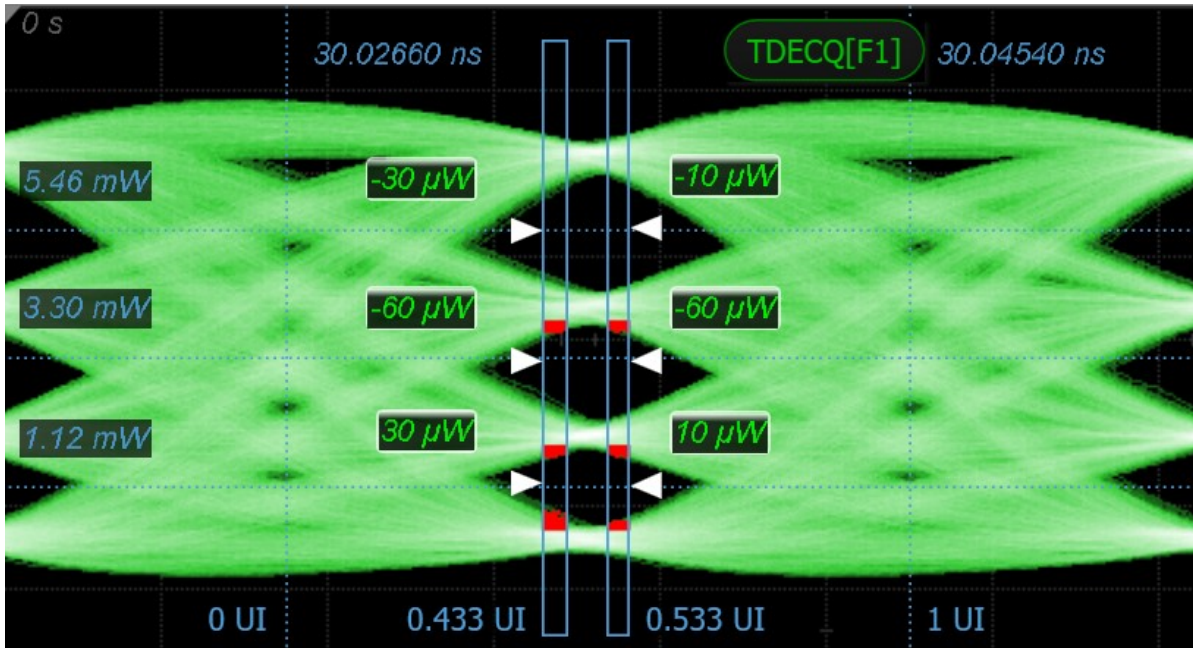
Chromatic dispersion tends to impact levels in a PAM4 transmitter differently, with the upper eye(s) seeing most of the penalty.

We then forced bottom compression to alleviate chromatic dispersion.

Silicon Photonics Experiments.

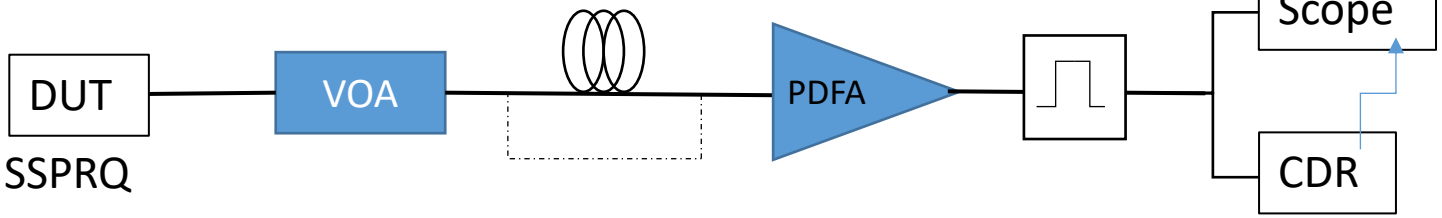


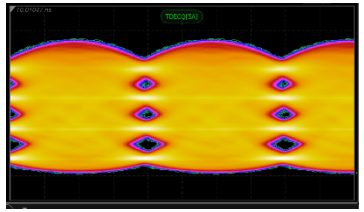
Equivalent PAM4 leveling (RLM = 1)

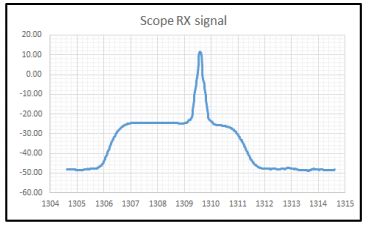


Skewed PAM4 leveling (RLM < 1)

53GBaud PAM 4 CD penalty: TDECQ set-up.





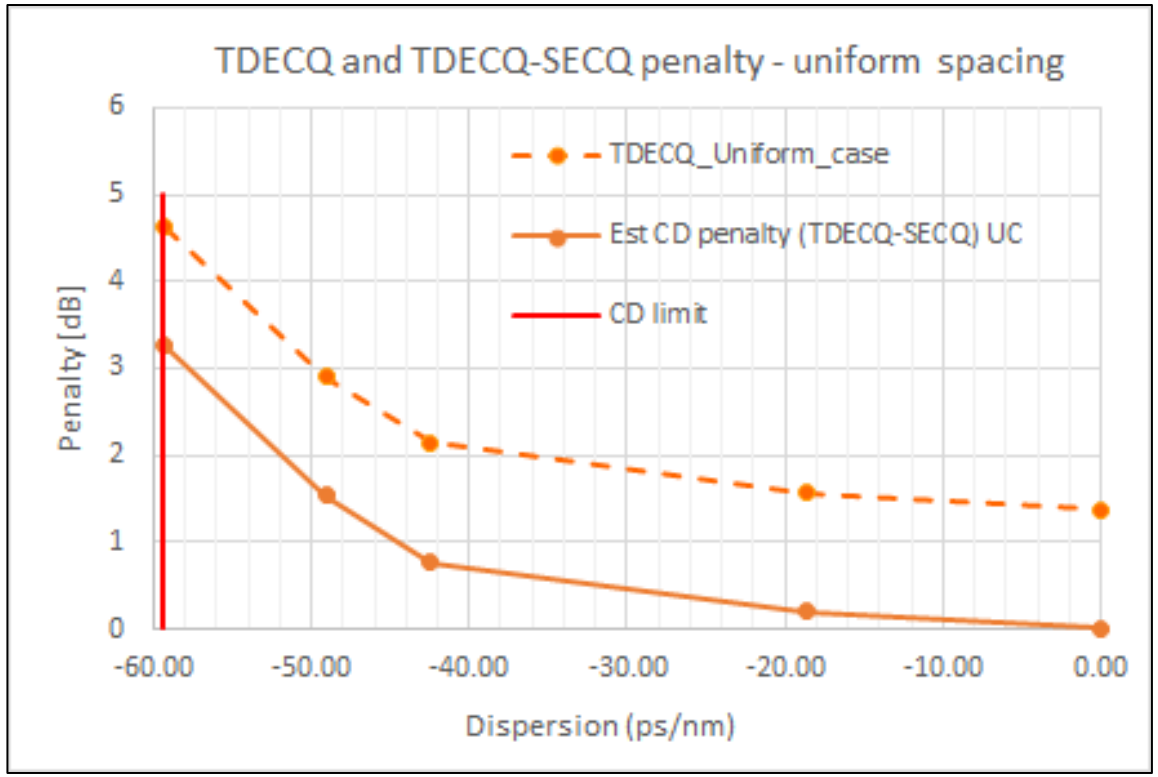


Measured TDECQ, TDECQ-10Log(Ceq) with current IEEE 802.3cd Reference Receiver.

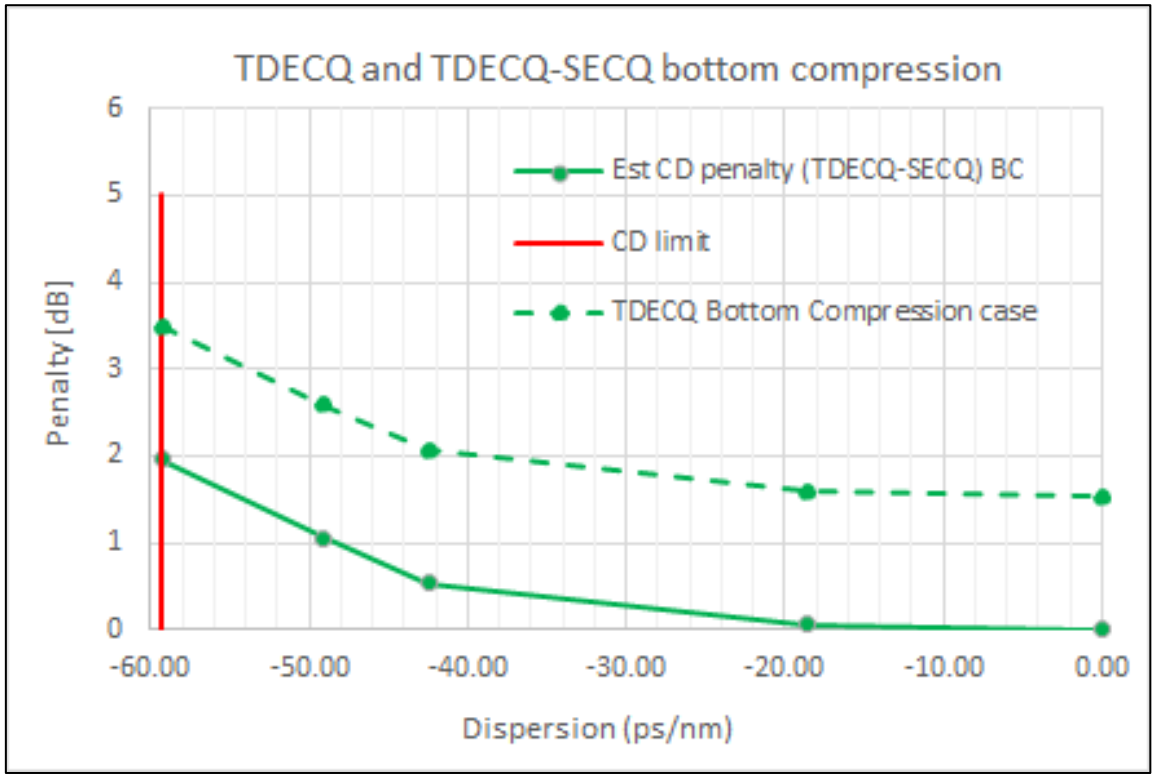
Fiber code	CD22+BZS	CD22+Fiber4	CD22	BZS	Btb	Unit
Total dispersion	-59.28	-49.06	-42.49	-18.57	0.00	ps/nm
Wavelength	1309.56	1309.56	1309.56	1309.56	1309.56	nm
Est PMD	0.36	0.31	0.27	0.24	0	ps
Est DGD (SF=3)	1.08	0.92	0.82	0.71	0	ps
Total lenght	19.539	12.211	1.5	18.039	19.539	km
OSNR	36	36	36	36	36	dB

Built four fiber link combinations, emulating different negative CD values.
To keep linear region into the fiber a PDFA as pre-amplifier has been inserted - this limits the system OSNR to 36dB.
(Note: PMD calculated as the quadratic sum of the PMD from fiber manufacturer, weighted over length).

Bottom compression vs. uniform levels spacing TDECQ and TDECQ-SECQ behavior.



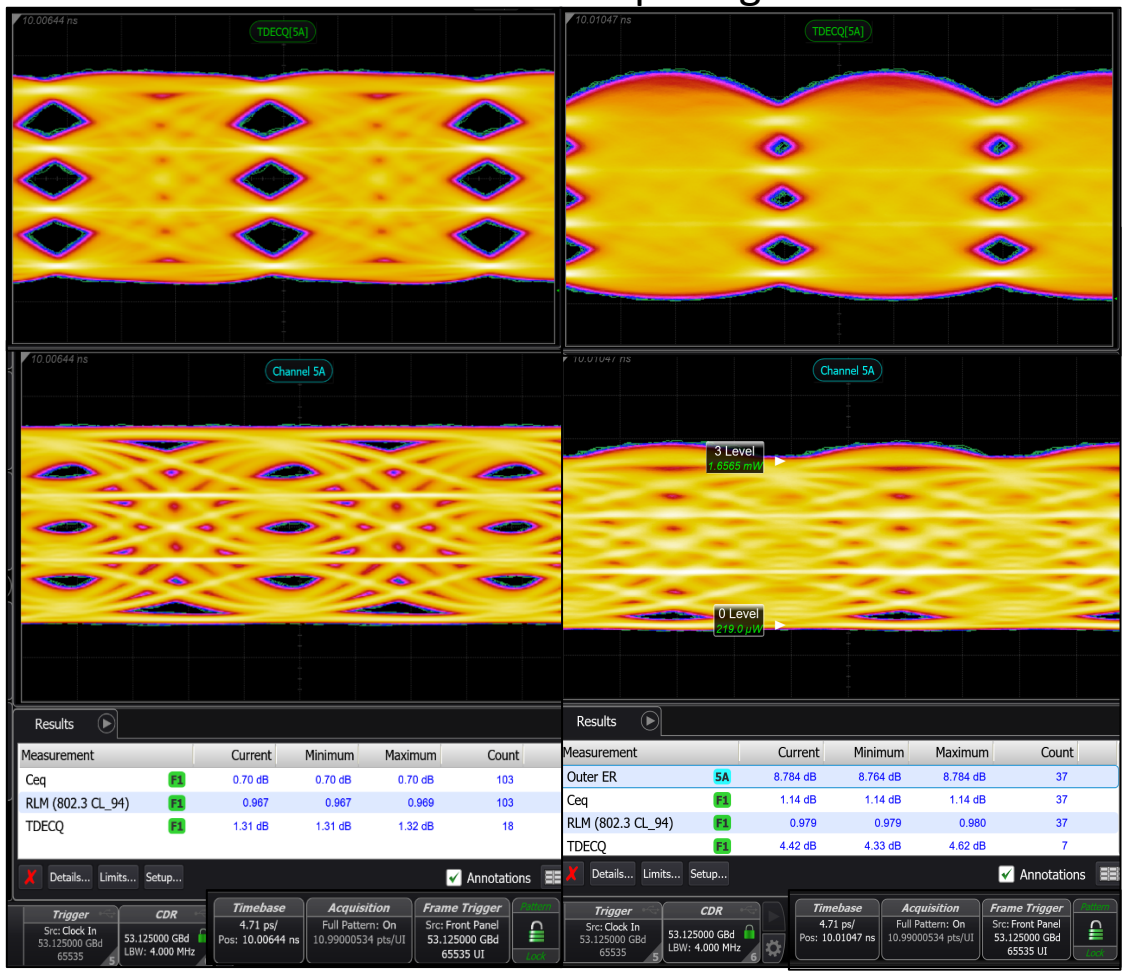
Uniform case:
4.62dB TDECQ at -59.3ps/nm dispersion.
3.25dB CD penalty at minimum dispersion (calculated as TDECQ-SECQ).



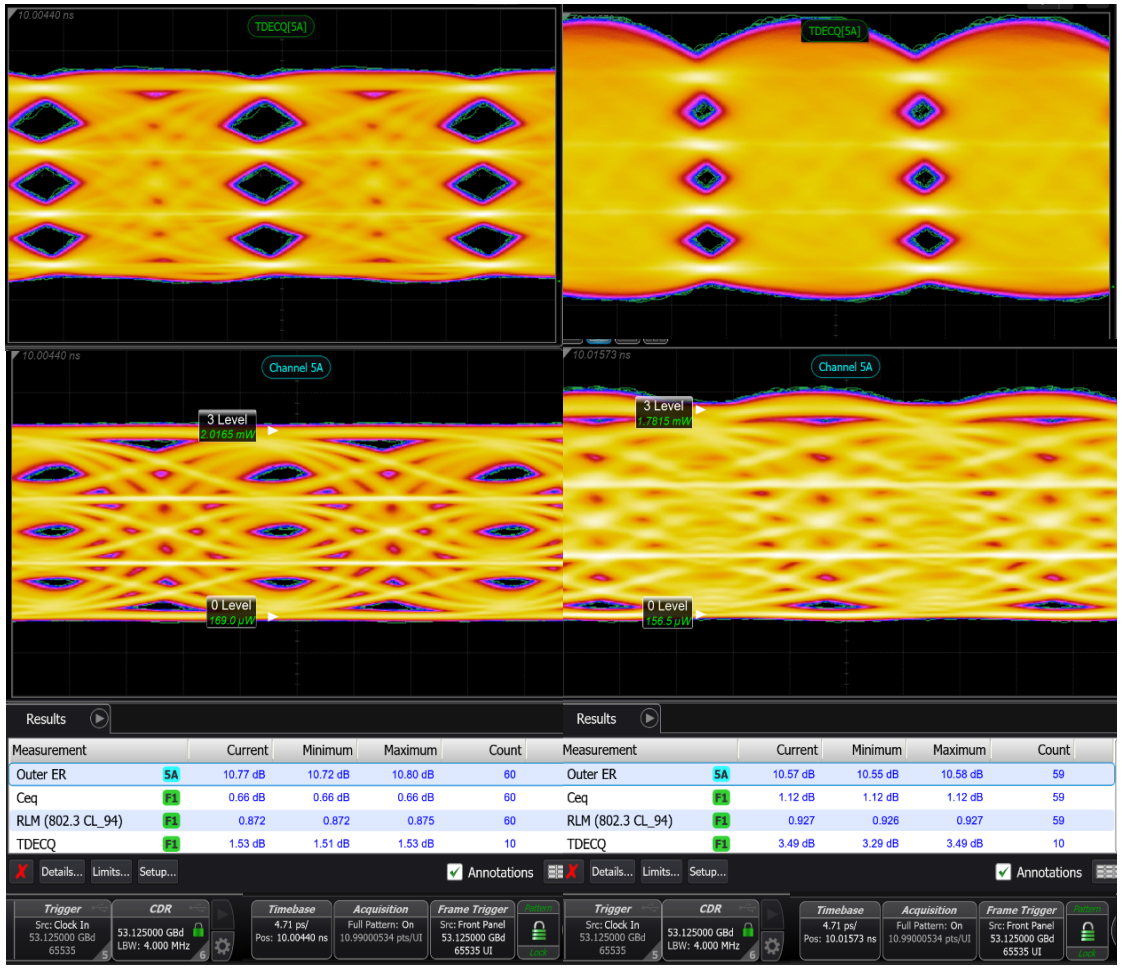
Bottom compression case:
3.49dB TDECQ at -59.3ps/nm dispersion.
2dB CD penalty at minimum dispersion (calculated as TDECQ-SECQ).

BTB and -59.3ps/nm CD eye diagrams.

Uniform levels spacing

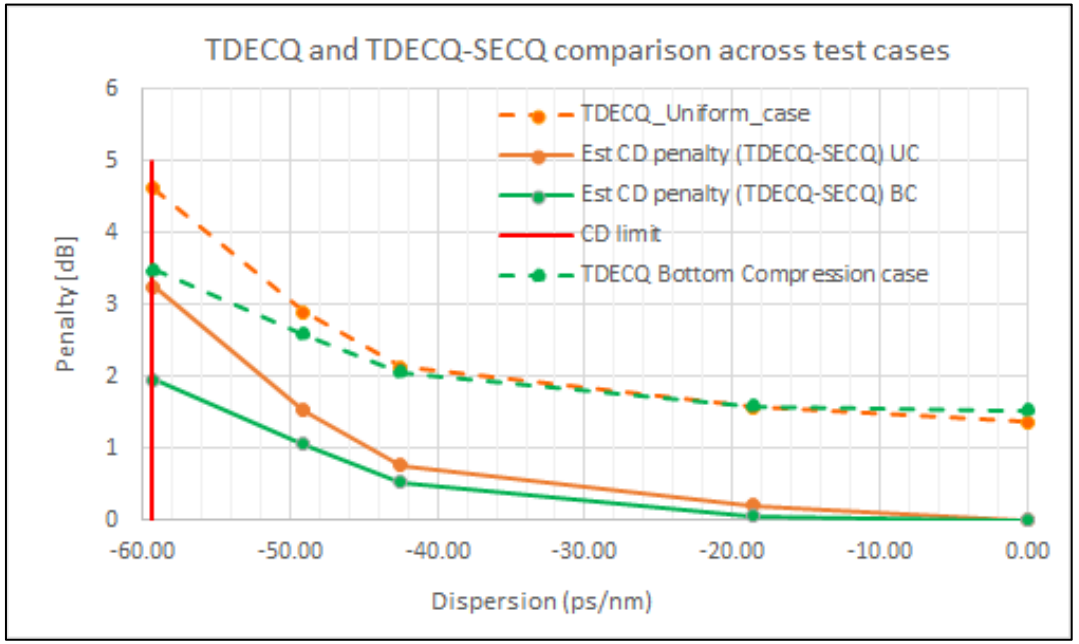


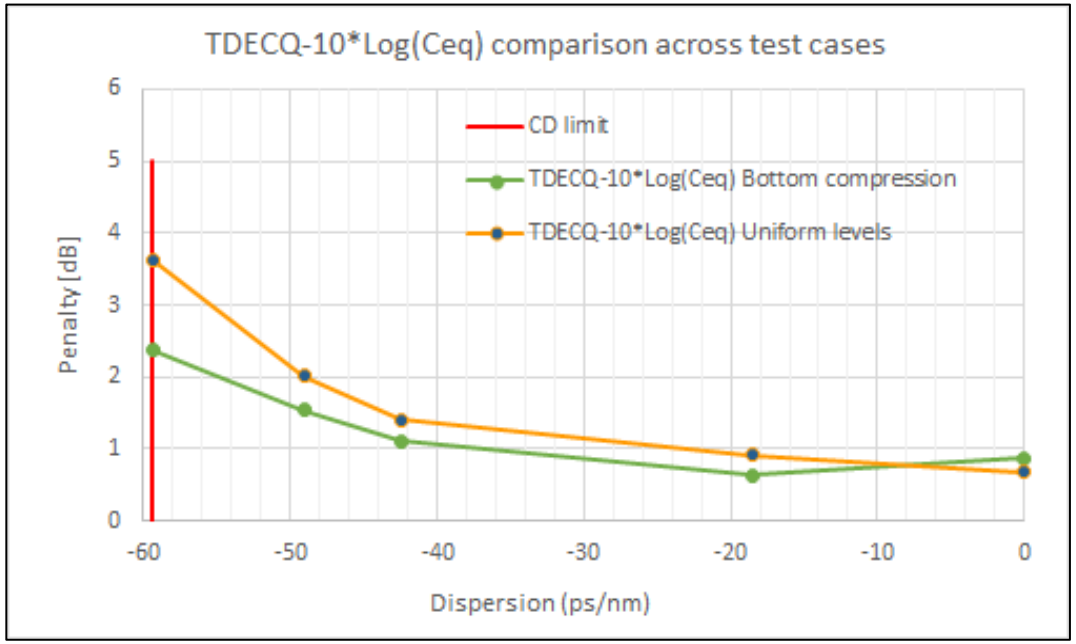
Bottom compression



- Bottom compression is an effective way to compensate CD penalty.
- Minimal TDECQ penalty at zero dispersion (details in next slide).

Uniform/bottom levels spacing TDECQ/TDECQ-SECQ and TDECQ-10Log(Ceq) comparison.





- Both TDECQ and TDECQ-10*Log(Ceq) < 3.5dB for bottom compression case.
- Around 0.2dB TDECQ and TDECQ-10*Log(Ceq) at zero dispersion for bottom compression case versus uniform spaced levels.
- *Bottom compression does NOT violate any of current IEEE transmitter requirements.*

Summary of experiments.

- Assuming 3.9dB as maximum TDECQ value (proposed in lewis_3cu_adhoc_061919_v2).
- Bottom compression allows to achieve this limit with no changes in current IEEE TDECQ reference receiver and methodology, neither limiting foreseen link characteristics.

Parameter	-59.28	-49.06	-42.49	-18.57	0.00	Unit	
TDECQ/SECQ	3.49	2.59	2.06	1.59	1.53	dB	Bottom compression case
Est CD penalty (TDECQ-SECQ)	1.96	1.06	0.53	0.06	0	dB	
Ceq	1.12	1.05	0.95	0.95	0.66	dB	
TDECQ-10*Log(Ceq)	2.37	1.54	1.11	0.64	0.87	dB	
TDECQ/SECQ	4.62	2.9	2.14	1.57	1.37	dB	Uniform level case
Est CD penalty (TDECQ-SECQ)	3.25	1.53	0.77	0.2	0	dB	
Ceq	1	0.88	0.74	0.65	0.69	dB	
TDECQ-10*Log(Ceq)	3.62	2.02	1.4	0.92	0.68	dB	

Comments.

- Presented SiP transmitter chromatic dispersion penalty results against standard SMF negative limits for 400GBASE-LR4 in CWDM grid.

- The proposed 3.9dB TDECQ value proposed in lewis_3cu_adhoc_061919_v2 appears adequate considering SiP transmitters technology (next step will be to investigate positive dispersion penalties and mitigations).

- Bottom compression does not violate any of current standards requirements.
  - It is a simple setting that can be applied for just outer wavelengths of the CWDM grid.
  - Should be a viable tuning method for different transmitter technologies (ie, EML and SiP).

- Bottom compression is just one knob available on SiP transmitter (besides chirp management, transmitter BW control or any combination of these).

THANK YOU