Transition time in MMF transmitters

Transmitter transition time in Clauses 193 and 194 — comments #34 and #74 against D1.2

IEEE P802.3ds D1.2, 200 Gb/s per Wavelength MMF PHYs Task Force

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Supporters

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What D1.2 specifies today

Tables 193-5 and 194-5, transmit characteristics, transcribed

Parameter	Ref	Cl 193 (SR)	Cl 194 (MR)	Unit
Signaling rate, each lane	—	106.25 ± 50 ppm	106.25 ± 50 ppm	GBd
TDECQ, each lane (max)	x.9.7	TBD → 4.2	TBD → 4.2	dB
TECQ, each lane (max)	x.9.8	TBD → 4.2	TBD → 4.2	dB
Overshoot and undershoot (max)	x.9.9	27	27	%
Transmitter power excursion (max)	x.9.10	2.3	2.3	dBm
Extinction ratio, each lane (min)	x.9.11	2	2	dB
Transmitter transition time (max)	**x.9.12**	**9**	**9**	**ps**

Both clauses run at 106.25 GBd, so 1 UI is 9.4118 ps and the 9 ps limit is 0.956 UI. TDECQ and TECQ are TBD in draft 1.2; the task force has since adopted 4.2 dB for both [11], which is what this contribution implements. The transition time row was numeric before either was settled. Both clauses measure TDECQ using the methods of 180.9.6 [5], so ds inherits the P802.3dj reference equalizer and its coefficient constraints, restated as Table 193-13 [1].

Comments 34 and 74

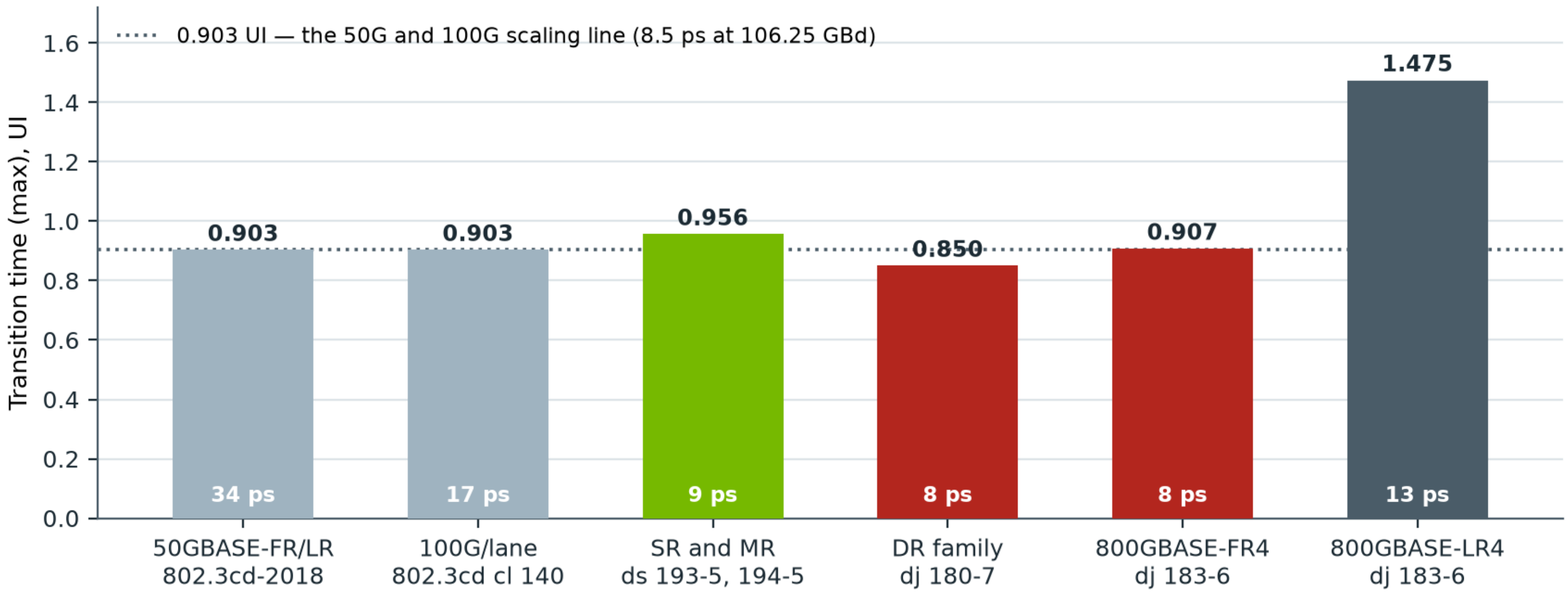
Cl 193, SC 193.7.1, P57 L39 — Pending CRG discussion

#	Commenter	Type	Remedy asked for	Proposed response
34	Simms, NVIDIA	T	9 ps → 10 ps	pending CRG review with 74
74	Dawe, NVIDIA	TR	Delete the row; or 13 ps, as for 800GBASE-LR4	pending CRG review

- **The two comments approach the problem differently.** Deletion is the cleanest outcome, 13 ps is comfortably safe, and 10 ps is the least disruptive change that still fixes the defect. This contribution supplies the measurement that decides between them [2,3].
- **The shared basis.** The limit “was scaled from 50G (34) then 100G (17) where a product receiver with FFE-based or other linear equalization was considered”, and “this is a specification; we specify outcomes, not possible causes. A signal that the ECQ equaliser finds difficult to equalise, gets a bad rating anyway” [3]. Transition time is a possible cause; TDECQ and TECQ are the outcome.
- **This ground has been covered once already.** The same request was comment #102 against D1.1, rejected because “Tx transition time has been retained as a parameter in 200G per lane DR links”, with “further work on this topic … encouraged” [4]. This is that further work.
- **P802.3dj has voted to make no change at this point in its schedule, and keeps 8 ps.** P802.3ds is not working to that schedule, so there is time here for the discussion and the development the question needs. It is also not the same measurement: Clauses 193 and 194 put a fiber emulation filter ahead of the reference receiver for TDECQ, which the DR PMDs do not have, and ds has adopted 4.2 dB where those PMDs carry 3.4 dB [1,5]. The cases that follow are made on the ds chain with the ds limits.

Where 9 ps comes from

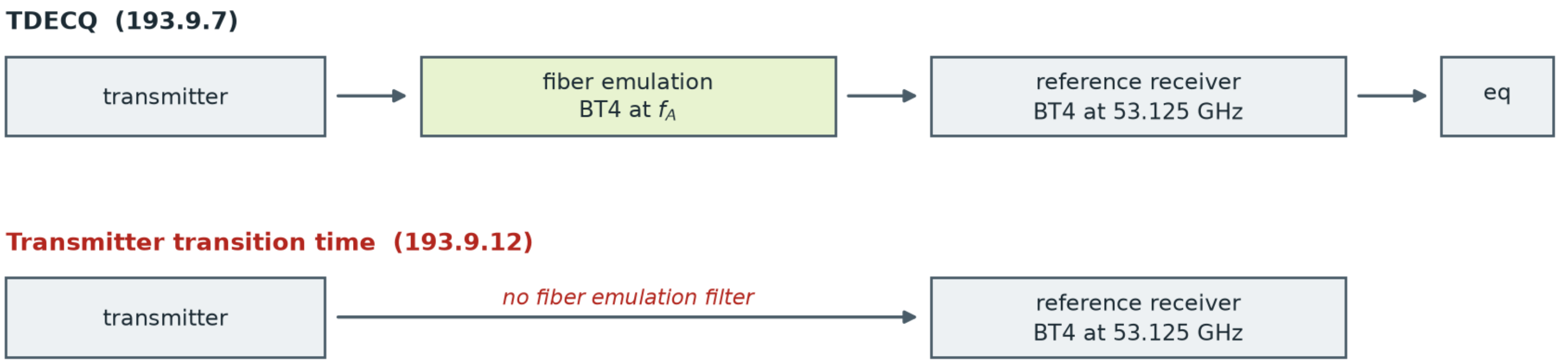
The limit follows the baud rate, not a requirement



34 ps at 26.5625 GBd and 17 ps at 53.125 GBd are both 0.903 UI: the limit was halved as the rate doubled. Carrying that same line to 106.25 GBd gives 8.5 ps, and Tables 193-5 and 194-5 carry 9 ps, or 0.956 UI. ***So P802.3ds is consistent with the lineage****, and this contribution does not claim otherwise. The question is whether the lineage was ever derived. 802.3cd adopted 34 ps against supporting simulations that proposed 27 ps to 30 ps [7], so the original anchor was already a rounded ceiling rather than a computed requirement, and every later value inherits it by division.*

The two measurements do not see the same signal

193.9.7 filters the signal before TDECQ; 193.9.12 does not



PMD type	Center wavelength (nm)	fiber emulation fA (GHz)
200/400/800GBASE-SR*-30, 1.6TBASE-SR8-30	844 – 868	60.7
200/400/800GBASE-SR*-50, 1.6TBASE-SR8-50	852 – 868	48.2
200GBASE-MR1 to 1.6TBASE-MR8	1052 – 1068	52.6

Tables 193-12 and 194-12 [1]. Two of the three fiber emulation bandwidths are ***narrower than the 53.125 GHz reference receiver itself****, so TDECQ is evaluated on a signal that has been rolled off twice, while transition time is evaluated after the reference receiver alone. That is worth 0.8 to 1.4 dB of TDECQ at 9 ps [9], and it is what decides whether transition time does any work — quantified two slides on.*

What Table 193-5 already bounds

Transition time is a narrow proxy; these limits are not, and this contribution changes none of them

- **TDECQ and TECQ** bound eye closure through the reference equalizer of 180.9.6 [5], whose Table 193-13 coefficient constraints cap how much equalization may be applied and so already bound slowness from above.
- **Overshoot and undershoot, 27% (max)**, and **transmitter power excursion, 2.3 dBm (max)**, bound the emphasis a transmitter may use.
- **Extinction ratio, 2 dB (min)**, bounds the drive amplitude.
- **The gap this leaves.** Comment #102 makes the sharp point: transition time is specified as a maximum only, so “a transmitter implementer with poor (bandwidth and shape) can get a pass on transition time by cranking up the emphasis, which makes the signal worse but compliant” [4]. The parameter can be satisfied by making the signal worse.
- **It adds no information either way.** Within the simple rolloff shapes, a measured 9 ps pins the 3 dB bandwidth to a narrow 27.2 to 29.1 GHz band [9], so the measurement tells us nothing a bandwidth figure would not. Outside that family, once emphasis is allowed, the same 9 ps admits signals of very different quality — comment #102's point that “the relation between bandwidth and transition time is not 1:1” [4]. Redundant in the easy case, uninformative in the hard one.
- **It also inherits another measurement's uncertainty.** 193.9.12 sets the 0% and 100% levels to P0 and P3 “as defined by the OMAouter measurement procedure (see 193.9.6)” [1], so the transition time reading moves with how OMAouter was extracted.

Redundant against TDECQ, and tighter than TECQ

Both limits now 4.2 dB [11]. Entries are the eye closure, in dB, that a 9 ps VCSEL-like transmitter already produces [9]

Measured through	fA (GHz)	At 9 ps (dB)	Fails at 4.2 dB (ps)	Effect of the 9 ps transition time
TDECQ, SR-30 variants	60.7	4.59 – 4.65	8.59 – 8.62	redundant
TDECQ, MR variants	52.6	4.91 – 4.95	8.26 – 8.34	redundant
TDECQ, SR-50 variants	48.2	5.17 – 5.19	8.01 – 8.12	redundant
TECQ, all PMD groups	—	3.79 – 3.83	9.32 – 9.42	9 ps is tighter

- **fA is the fiber emulation filter bandwidth**, set by PMD type and center wavelength in Tables 193-12 and 194-12. 193.9.7 places a fourth-order Bessel-Thomson at fA ahead of the reference receiver for TDECQ; TECQ and transition time see no such filter [1].
- **TECQ and transition time are measured through the same chain.** 193.9.8 defines TECQ as the TDECQ method of 193.9.7 “except that the first filter representing the dispersion of the fiber is omitted”, with the reference equalizer of 193.9.7.1; 193.9.12 reads transition time at the output of that same reference receiver [1]. Two parameters, one signal path — so they can be compared directly, and now that both limits are numeric they can be compared as adopted.
- **Against TDECQ transition time is redundant.** With the fiber emulation filter in the path, 4.2 dB puts the wall at 8.0 to 8.6 ps for all three PMD groups — faster than 9 ps, so TDECQ removes every transmitter that transition time would have removed, and more.
- **Against TECQ transition time is the tighter of the two.** On the identical chain, 4.2 dB of TECQ admits a transmitter out to 9.32 – 9.42 ps. The 9 ps transition time cuts it off first, taking 0.37 to 0.41 dB out of the TECQ budget the task force has just set.

Figures are for simple rolloffs — 4th-order Bessel-Thomson, Gaussian and 2nd-order Butterworth — which is the family a VCSEL's damped carrier-photon resonance falls into. ***The conclusion strengthens for slower responses****: a single-pole transmitter loses 1.67 dB of TECQ budget to the 9 ps transition time rather than 0.41 dB. The modeled transmitter's only impairment is low-pass rolloff, so a real part with emphasis, reflections or nonlinearity sits above these curves. Full shape sweep in backup, and the model and its calibration are described there [9].*

What next

Comments #34 and #74 are to be reviewed together; the measurement decides between them

- **The ask: accept comment #34 and set the limit to 10 ps**, in Tables 193-5 and 194-5 [2]. On the chain transition time is actually measured through, 4.2 dB of TECQ admits a transmitter out to 9.32 – 9.42 ps. 10 ps is the smallest round value that clears that wall, so it is the least disruptive change that stops transition time removing transmitters the adopted eye-closure limits accept.
- **Deletion remains the cleaner outcome**, and is the preferred remedy of comment #74 [3]. Delete the row from Tables 193-5 and 194-5, delete 193.9.12 and 194.9.12, and delete the corresponding rows in Tables 193-11 and 194-11. TDECQ, TECQ, the Table 193-13 tap constraints and the overshoot limit already bound the signal, in a balanced way that emphasis cannot game. #74's 13 ps fallback clears every wall as well.
- **Whatever value is chosen, express it in UI.** Stated in UI it does not need rescaling at the next rate, which is how 9 ps came to be carried here without a requirement behind it.

A drafting consequence that separates the two remedies. 193.9.15 and 194.9.15 require the stressed receiver conformance test signal to have “a transition time that is no greater than the value specified in Table 193-5” [1]. Changing the value to 10 ps needs no further edit, because that requirement is by reference and follows automatically. Deleting the row instead leaves it pointing at a value that no longer exists, and #74's remedy does not cover it [3]; a complete deletion also strikes that exception or states the calibration value in 193.9.15 directly. The stressed signal stays bounded either way: the same subclause already sets its SECQ equal to the TECQ measured per 193.9.8, and holds its overshoot, undershoot and power excursion to Table 193-5.

Summary

- P802.3ds carries 9 ps in Tables 193-5 and 194-5, which is 0.956 UI and sits on the 50G/100G scaling line of 0.903 UI. **The value is consistent; the lineage was never derived.**
- Two comments against D1.2 sit on this row and are to be reviewed together: #34 asks for 10 ps and #74 asks for deletion, or 13 ps if that is too bold. Both are proposed REJECT pending CRG discussion [2,3]. The same request was rejected against D1.1 on the grounds that another project retains the parameter, with further work invited [4]. **That project measures TDECQ without a fiber emulation filter and at 3.4 dB; this one does neither** [1,5].
- TDECQ, TECQ, the inherited tap constraints and the 27% overshoot limit already bound slow and over-emphasized transmitters. Transition time adds a maximum-only proxy that can be passed by making the signal worse.
- TDECQ is measured through a fiber emulation filter that transition time does not see, and two of the three fA values are narrower than the reference receiver, so TDECQ is the harder constraint on slowness. **TECQ is measured through exactly the chain that transition time does see** [1], so those two are directly comparable.
- **With TDECQ (max) and TECQ (max) both adopted at 4.2 dB [11], transition time is redundant against one and tighter than the other.** Against TDECQ the wall is 8.0 to 8.6 ps, faster than 9 ps. Against TECQ — measured through the identical chain — 9 ps bites first and removes 0.37 to 0.41 dB of the TECQ budget just set [9].

References

[1] IEEE P802.3ds D1.2 (14 August 2026) — Tables 193-5, 193-11, 193-12, 193-13, 194-5, 194-12; subclauses 193.9.3, 193.9.7, 193.9.12, 193.9.15, 194.9.3, 194.9.12

[2] Comment #34 (Simms, NVIDIA), P802.3ds D1.2 3rd Task Force review, Cl 193 SC 193.7.1 P57 L39, type T — “change the value here to 10ps or note that this number may need to change. Same values shared with table 194-5 S194.7.1 P92 L38”. Proposed response: REJECT, pending CRG discussion, “Review together with comment 74” — 8023ds_D1p2_Proposed_Responses_by_Clause.pdf

[3] Comment #74 (Dawe, NVIDIA), P802.3ds D1.2 3rd Task Force review, Cl 193 SC 193.7.1 P57 L39, type TR — “Preferably: Delete the row. Delete 193.9.12 … If that is too bold at this stage, change the limit to 13 ps, same as for 800GBASE-LR4. Similarly in Clause 194”. Proposed response: REJECT, pending CRG discussion. Re-files and expands comment #102 against D1.1

[4] Comment #102 (Dawe, NVIDIA), P802.3ds D1.1 2nd Task Force review, Cl 193 SC 193.7.1 P59 L39, type TR — rejected: “Tx transition time has been retained as a parameter in 200G per lane DR links. Further work on this topic is encouraged.” 8023ds_D1p1_Final_Responses_by_Clause.pdf

[5] IEEE P802.3dj D3.2 — Tables 180-7, 180-16, 183-6; subclauses 180.9.2, 180.9.6, 180.9.6.4, 180.9.12

[6] IEEE Std 802.3cd-2018 — Tables 139-6 and 140-6; subclause 139.7.5, the 5-tap feed-forward reference equalizer with no DFE

[7] king_3cd_02a_0518, Max rise fall time for PAM4 transmitters — the 0.8 UI and 0.9 UI anchors behind the 34 ps limit

[8] dawe_3cd_01b_0518, TDECQ and SRS — the bounded TDECQ map and its right-hand bound

[9] TDECQ map study, this contribution — 106.25 GBd, Table 180-16 / 193-13 reference equalizer, MMSE taps per 180.9.6.4, SSPRQ at 64 samples/UI; TDECQ through the 193.9.7 cascade including the fiber emulation filter, T20-80 through the 193.9.3 reference receiver alone. Four VCSEL-family response shapes — 4th-order Bessel-Thomson, Gaussian, 2nd-order Butterworth and single-pole RC. The underlying TDECQ map was calibrated against the published 802.3cd right-hand bound of dawe_3cd_01b_0518

[10] Comments #74 and #83 (Ghiasi), P802.3ds **D1.1** — propose 4.4 dB for TECQ and TDECQ, with TDECQ(k) = TDECQ – 10log10(Ceq) limited to 3.4 dB. Rejected; the straw poll on adding the TDECQ(k) specification ran 7 yes to 11 no, and the response records that “Data supporting limit on TDECQ is encouraged”

[11] TDECQ (max) = TECQ (max) = 4.2 dB, adopted by the task force at the comment resolution meeting of 8 September 2026, resolving P802.3ds D1.2 comments #2, #13, #24 and #61 — the group the proposed responses identify as setting TDECQ (max). Supersedes the 4.4 dB of D1.2 comment #2 and D1.1 comments #74 and #83, and the 4.0 dB of D1.2 comments #13 and #24

[12] murty_3ds_01_2609, Supporting Information for Comments Related to TDECQ (max) — parameterizes the power budget, penalty allocation, receiver sensitivity, stressed receiver sensitivity and SECQ by T = TDECQ (max)

Backup

Material to answer objections, not part of the main case

Backup: the edge limit does not track the eye-closure limit

Every 200G per lane IMDD PMD, one reference equalizer family, sorted by permitted edge

PMD group	Transition time (max)	in UI	TDECQ (max)	TECQ (max)
200GBASE-DR1 and similar, Table 180-7	8 ps	0.850	3.4 dB	3.4 dB
800GBASE-FR4, Table 183-6	8 ps	0.907	3.4 dB	3.4 dB
SR and MR, Tables 193-5 and 194-5	9 ps	0.956	4.2 dB	4.2 dB
800GBASE-LR4, Table 183-6	13 ps	1.475	3.9 dB	3.2 dB

- **If the edge limit were protecting against slowness, it would tighten where eye closure is tight.** It does not. Across these four groups the permitted edge spans 0.850 to 1.475 UI while TDECQ spans 3.4 to 4.2 dB, and the two orderings do not match [1,5].
- **Against TECQ they run the wrong way.** TECQ is the like-for-like comparison, since 193.9.8 and its equivalents define it on the same no-fiber chain that transition time is measured through. The group given the slowest permitted edge, 1.475 UI, is held to the *tightest* TECQ of all, 3.2 dB; the groups held to the fastest edges get 3.4 dB. The edge limit and the eye-closure limit anti-correlate.
- **SR and MR are the clearest case.** They carry the most permissive eye closure of any group here, 4.2 dB on both metrics, and still an edge limit tight enough to bind before TECQ does. That is the combination the front of this deck measures: at 4.2 dB the TECQ wall is 9.32 – 9.42 ps and transition time is set at 9 ps.

No claim is made here about what any other project should specify. The point is only that these values were not set in any consistent relationship to one another, so the edge limit cannot be said to be carrying a requirement that the eye-closure limits leave uncovered.

Backup: how much of the measurement is the instrument

De-embedding the 53.125 GHz reference receiver of 193.9.3 from a measured 9 ps

Transmitter shape	Tx 3 dB BW (GHz)	Tx-only T20-80 (ps)	in UI	Instrument share
Bessel-Thomson 4th order	29.08	8.12	0.863	10%
Gaussian	27.92	7.99	0.849	11%
Single-pole RC	27.22	8.11	0.862	10%
Butterworth 2nd order	28.63	8.26	0.878	8%

The reference receiver alone has a T20-80 of 4.446 ps, which is 0.472 UI at any rate because its bandwidth is defined as half the signaling rate. That looks like half of a 9 ps budget, but transition times cascade approximately in quadrature rather than linearly, so the instrument inflates the reading by only about 10%: a transmitter that measures 9 ps is about 8.1 ps on its own. ***We therefore do not argue that the specification mostly measures the instrument.*** *The relevant point is narrower: root-sum-square de-embedding is exact only for a Gaussian response and under-reads by up to 0.3 ps here, so a de-embedded number is shape-dependent and two labs can legitimately disagree [9].*

Backup: does the limit protect the receiver's clock recovery?

The one quantity TDECQ cannot see, and why it does not carry the argument

- **The mechanism is real.** TDECQ is an eye-closure penalty measured through a reference equalizer, so it does not directly bound the signal power near Nyquist that a receiver's timing loop extracts. A transition time limit does bound that, indirectly.
- **But no such requirement exists.** D1.2 specifies only the CRU corner frequency, 4 MHz with a 20 dB/decade slope, in 193.9.3 and 194.9.3 [1]. There is no timing-energy requirement anywhere to budget against.
- **And the limits in force are not consistent in it.** Modeled across the transition time limits specified for 200G per lane IMDD PMDs, normalized Nyquist-band power runs from 0.160 at an 8 ps edge to 0.0037 at a 13 ps edge, a factor of 43 [9]. A quantity left to vary by 43x across PMDs sharing one reference equalizer was not budgeted.
- **Historically the concern was the other bound.** The 2018 material ties the right-hand bound of the TDECQ map to equalizer tap weights, not to clock recovery [8].

Backup: the TDECQ map, and what a transition time limit removes

C is the equalizable axis; K = TDECQ – C is the rest

- **The decomposition.** TDECQ splits into C, the part an equalizer can recover, and K, the part it cannot [8]. A transition time limit of T removes everything to the right of C(T), so C(T) is the position of the right-hand wall.
- **Why the wall is not the whole story.** The compliant region is already bounded by TDECQ = C + K ≤ the table limit. A transition time limit only removes something if it bites at a faster transition time than the TDECQ limit does.
- **What the model covers.** Transmitter and reference receiver at 106.25 GBd, the Table 180-16 reference equalizer, restated for ds as Table 193-13, with its coefficient constraints applied, MMSE taps per 180.9.6.4, SSPRQ at 64 samples per UI [9]. Its calibration is against the published 802.3cd right-hand bound, computed there on the 5-tap equalizer with no DFE [6,8].
- **The ds extension.** The 193.9.7 fiber emulation filter is applied to the TDECQ path only, as an ideal fourth-order Bessel-Thomson at fA, while T20-80 stays on 193.9.12's chain. N(f) excludes fA, because 193.9.7 requires the fiber emulation's effect on noise to be compensated so that “the correct magnitude of noise is present at the output of the equalizer” [1]. Setting fA aside returns the sweep to this study's own no-filter baseline to within 1e-9 dB, which is the check that adding the fiber emulation filter disturbed nothing else in the chain.

Backup: the full shape sweep, and the transmitter each wall needs

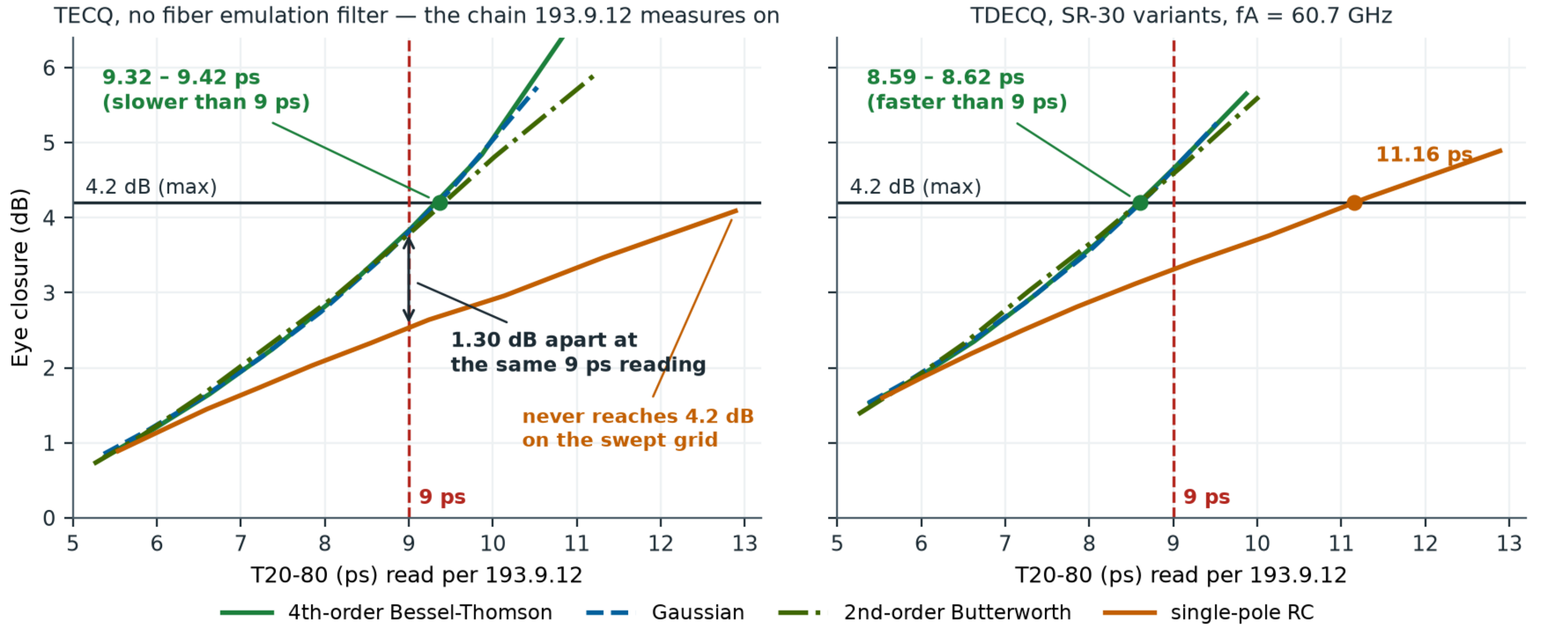
Wall in ps at the adopted 4.2 dB, with the transmitter 3 dB bandwidth that reaches it [9]

Measured through	fA (GHz)	Simple rolloffs	Single-pole RC
TDECQ, SR-30 variants	60.7	8.59 – 8.62	11.16 (20 GHz)
TDECQ, MR variants	52.6	8.26 – 8.34	10.44 (22 GHz)
TDECQ, SR-50 variants	48.2	8.01 – 8.12	9.86 (24 GHz)
TECQ, all PMD groups	—	9.32 – 9.42	off grid

- **The shapes.** Simple rolloffs are 4th-order Bessel-Thomson, Gaussian and 2nd-order Butterworth, the family a VCSEL's damped carrier-photon resonance falls into. The single pole is carried separately because it is the slowest response these clauses plausibly need to cover, and it is the unfavorable case for the argument made here.
- **The last row is the TECQ chain, not a spare baseline.** 193.9.8 specifies TECQ as the TDECQ method with the fiber emulation filter omitted [1], so it is the fA = none row, and it is where the 9 ps limit turns out to be the tighter constraint. It is also the row that carries the map's calibration, since that was established with no fiber emulation filter in the path.
- **The result does not depend on which shape is believed.** The slower the response, the *more* of the adopted TECQ budget the 9 ps transition time removes, not less — 1.67 dB for a single pole against 0.41 dB for the simple rolloffs. Every shape in the family these clauses cover points the same way.
- **Scope.** Only VCSEL-family responses are carried. Sub-first-order tails — diffusive rolloffs and traveling-wave Mach-Zehnder electrodes — are the signature of single-mode modulators, and are excluded as outside what Clauses 193 and 194 are written for.

Backup: the same reading, different signals

Eye closure against the transition time a conformance test would read, by transmitter shape



- **The three simple rolloffs are one curve.** Bessel-Thomson, Gaussian and 2nd-order Butterworth are indistinguishable here, which is why the tables quote them as a narrow range rather than three cases. The single pole is a different line: at the same 9 ps reading it sits 1.30 dB lower in TECQ [9].
- **The crossings fall on opposite sides of 9 ps.** Without the fiber emulation filter the adopted 4.2 dB is not reached until 9.32 – 9.42 ps, so transition time binds first; with it the same limit is reached at 8.59 – 8.62 ps, so TDECQ binds first. SR-30 is drawn because its fA is the widest of the three, and so the weakest case for that second point; MR and SR-50 move the crossing to 8.01 ps.
- **The single pole is the exception, and it is disclosed.** With the filter in the path it does not reach 4.2 dB until 11.16 ps, so for that shape the 9 ps limit is what binds. The table on the previous slide gives the transmitter bandwidth such a part needs, and it is 20 GHz.