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The high-frequency pole of the reference CTLE in Annex 120E (comment #r03-12, #r03-45, #r02-21)

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Overview

- A problem to realize stressed input test signal for 120E was reported recently (sekel_062817_3cd_adhoc.pdf and #r02-21)
  - This may be a serious problem as a standard, because nobody can generate a test signal to test Rx devices
  - The bandwidth of reference CTLE seems too low for PAM4, because the 3rd harmonic component is important to widen the upper and low eyes of PAM4, whereas it has been not changed from NRZ (CAUI-4, C2M in Annex 83E)
- #r03-12 proposed to align the high-frequency pole of the reference CTLE of 120E (C2M) to that of 120D, because it is currently much lower in 120E than 120D
- #r03-45 proposed to reduce the 14.2dB channel loss from the output of the pattern generator to TP1a
- My presentations in Elect Ad Hoc on 8/28/17 and 9/7/17 were invalid due to completely wrong simulation
  - Updated P1 and P2 values were incorrectly set to 26.5625 times higher than the intended values in my script. Z1 was calculated on the fly to have unity peak gain. So, results for option 1 thru 4 were completely invalid. Hence, many simulation results were updated since Ad Hoc calls.

Comment #r02-21

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Cl **120E** *SC* **120E.3.3.2** *P* **378** *L* **41** # r02-21

Le Cheminant, Greg

Comment Type **T** *Comment Status* **R**

Test equipment (BERT pattern generators) cannot achieve the specified EW(1E-5) through the specified compliance board channel when measured with the specified reference receiver. The resulting eye is somewhat narrower, which will overstress the DUT

SuggestedRemedy

Relax the specification for the EW in the both the Host and Module input tests to a value which can be obtained in the specified test setup (A presentation on this will be offered on the ad hoc call)

Response *Response Status* **C**

REJECT.

This comment does not apply to the substantive changes between IEEE P802.3bs/D3.2 and IEEE P802.3bs/D3.1 or the unsatisfied negative comments from the previous ballots. Hence it is not within the scope of the recirculation ballot.

A presentation on this subject was made to the Joint Electrical ad hoc call on the 28th June. There was no consensus that there was a problem with the existing EW specification.

No additional information has been provided since the ad hoc call, so there is still no consensus for a change to the draft.

Comment #r03-12

Cl **120E** *SC* **120E.3.1.7** *P* **375** *L* **1** # r03-12

Hidaka, Yasuo Fujitsu Laboratories of

Comment Type **T** *Comment Status* **X**

The CTLE in the reference receiver of 120E.3.1.7 does not provide sufficient bandwidth for PAM4 signals as reported recently in P802.3bs Electrical Ad Hoc conference call on June 28, 2017. The effective bandwidth of CTLE is restricted by the lowest pole which is not associated with any zero, because the effects of poles associated with zeroes may be cancelled by the associated zeroes.

In 120E.3.1.7, the pole of the CTLE effective bandwidth is specified as P1. In D3.3, P1 / 2pi is 15.6GHz (0.5873 fb) or 18.6GHz (0.7 fb) that is too low for PAM4. These values remained unchanged since 83E.3.1.6.1 which were chosen for NRZ. They are OK for NRZ, but not OK for PAM4. PAM4 requires higher effective bandwidth of CTLE than NRZ in order to amplify the third harmonics of the signal component. Otherwise, the top and bottom eyes degrade significantly due to the lack of third harmonics.

In COM, the pole of the CTLE effective bandwidth is specified as f_p2. In 120D (chip-to-chip), f_p2 is specified as 53.125GHz (2 fb), which was doubled since 83D.4. 2 fb is sufficiently high to cover the third harmonics which is 1.5 fb.

The requirement of the bandwidth of CTLE is even higher for C2M than C2C, because the device for C2M may not have a DFE. For C2C, DFE can relax the requirement for CTLE bandwidth. Besides, C2M and C2C will be implemented in the same generation of technology. Therefore, we should align the effective bandwidth of reference CTLE between C2M and C2C.

This comment is related to the comment r02-21 to D3.2.

SuggestedRemedy

Change P1 / 2pi in Table 120E-2 to 53.125GHz.
Adjust other columns to achieve the max gain of 0dB with the same DC gain.
Update Figure 120E-9 accordingly.

The details of the updates to Table 120E-2 will be provided as a presentation.

Reference CTLE in Annex 120E (C2M)

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$$H(f) = \frac{GP_1P_2P_{LF}}{Z_1Z_{LF}} \times \frac{j2\pi f + Z_1}{(j2\pi f + P_1)(j2\pi f + P_2)} \times \frac{j2\pi f + Z_{LF}}{j2\pi f + P_{LF}}$$

Table 120E–2—Reference CTLE coefficients

Peaking (dB)	G	$\frac{P_1}{2\pi}$	$\frac{P_2}{2\pi}$	$\frac{Z_1}{2\pi}$	$\frac{P_{LF}}{2\pi}$	$\frac{Z_{LF}}{2\pi}$
1	0.89125	18.6	14.1	8.359	1.2	1.2
1.5	0.8414	18.6	14.1	8.159	1.2	1.15
2	0.79433	18.6	14.1	7.995	1.2	1.1
2.5	0.74989	18.6	14.1	7.604	1.2	1.075
3	0.70795	15.6	14.1	6.713	1.2	1.05
3.5	0.66834	15.6	14.1	6.421	1.2	1.025
4	0.63096	15.6	14.1	6.155	1.2	1
4.5	0.59566	15.6	14.1	5.733	1.2	1
5	0.56234	15.6	14.1	5.353	1.2	1
5.5	0.53088	15.6	14.1	5.007	1.2	1
6	0.50119	15.6	14.1	4.691	1.2	1
6.5	0.47315	15.6	14.1	4.399	1.2	1
7	0.44668	15.6	14.1	4.13	1.2	1
7.5	0.4217	15.6	14.1	3.88	1.2	1
8	0.39811	15.6	14.1	3.647	1.2	1
8.5	0.37584	15.6	14.1	3.43	1.2	1
9	0.35481	15.6	14.1	3.228	1.2	1

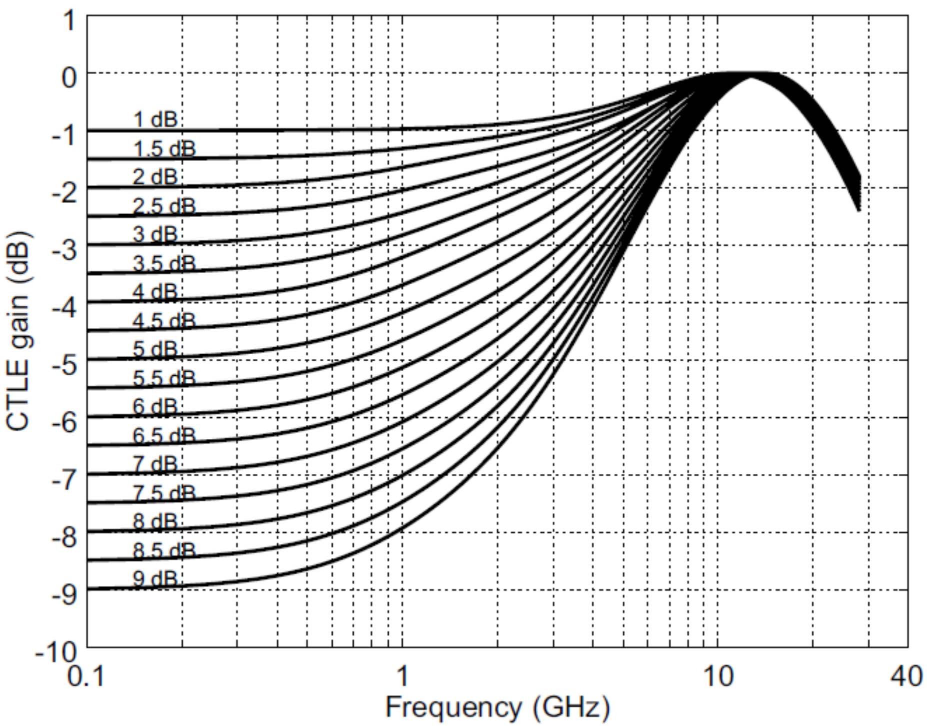


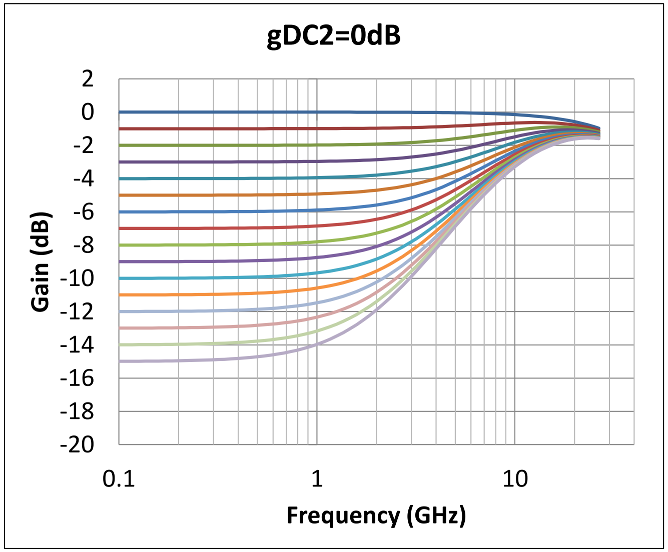
Figure 120E–9—Reference continuous time linear equalizer (CTLE) characteristic

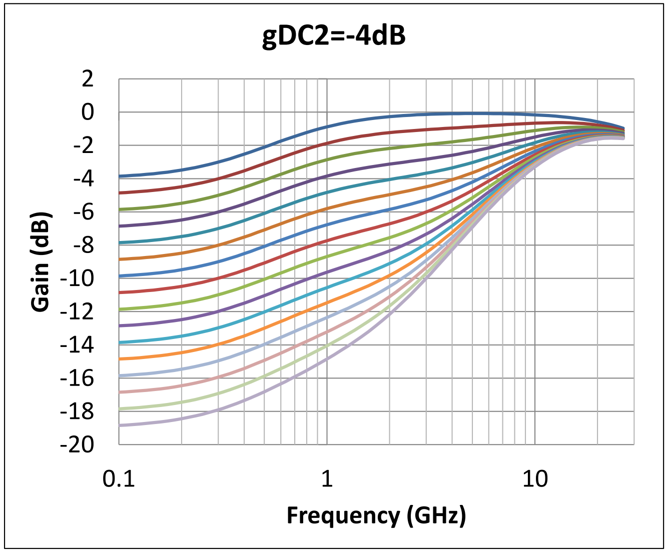
- High pole (P_1) is 15.6GHz (= $0.587f_b$) or 18.6GHz (= $0.7f_b$)
  - Medium pole (P_2) is 14.1GHz (= $0.531f_b$)

Reference CTLE in Annex 120D (C2C)

$$H_{ctf}(f) = \frac{\left(10^{\frac{g_{DC}}{20}} + j\frac{f}{f_z}\right)\left(10^{\frac{g_{DC2}}{20}} + j\frac{f}{f_{LF}}\right)}{\left(1 + j\frac{f}{f_{p1}}\right)\left(1 + j\frac{f}{f_{p2}}\right)\left(1 + j\frac{f}{f_{LF}}\right)}$$

f_b	26.5625	GBd
f_z	$0.4 \times f_b$	GHz
f_{p1}	$0.4 \times f_b$	GHz
f_{p2}	$2 \times f_b$	GHz
f_{LF}	$f_b/40$	GHz





- High pole (f_{p2}) is $2f_b$ (= 53.125GHz), much higher than 120E
  - Medium pole (f_{p1}) is $0.4f_b$ (= 10.625GHz), a little lower than 120E

4 Options Investigated

- Option 1
  - Increase $P_1/2\pi$ to $2 * fb$ (= f_{p2} of Annex 120D)
- Option 2
  - Increase $P_1/2\pi$ to $2 * fb$ (= f_{p2} of Annex 120D)
  - Reduce $P_2/2\pi$ to $0.4 * fb$ (= f_{p1} of Annex 120D)
- Option 3
  - Increase $P_1/2\pi$ to $1 * fb$ (= f_{p2} of CEI-56G-MR-PAM4)
- Option 4
  - Increase $P_1/2\pi$ to $1 * fb$ (= f_{p2} of CEI-56G-MR-PAM4)
  - Reduce $P_2/2\pi$ to $0.4 * fb$ (= f_{p1} of CEI-56G-MR-PAM4)

- Z_1 is also adjusted to force the peak gain always at 0dB
  - Formula of the exact Z_1 values to achieve this is shown in a backup slide

Baseline: P802.3bs D3.3 Annex 120E

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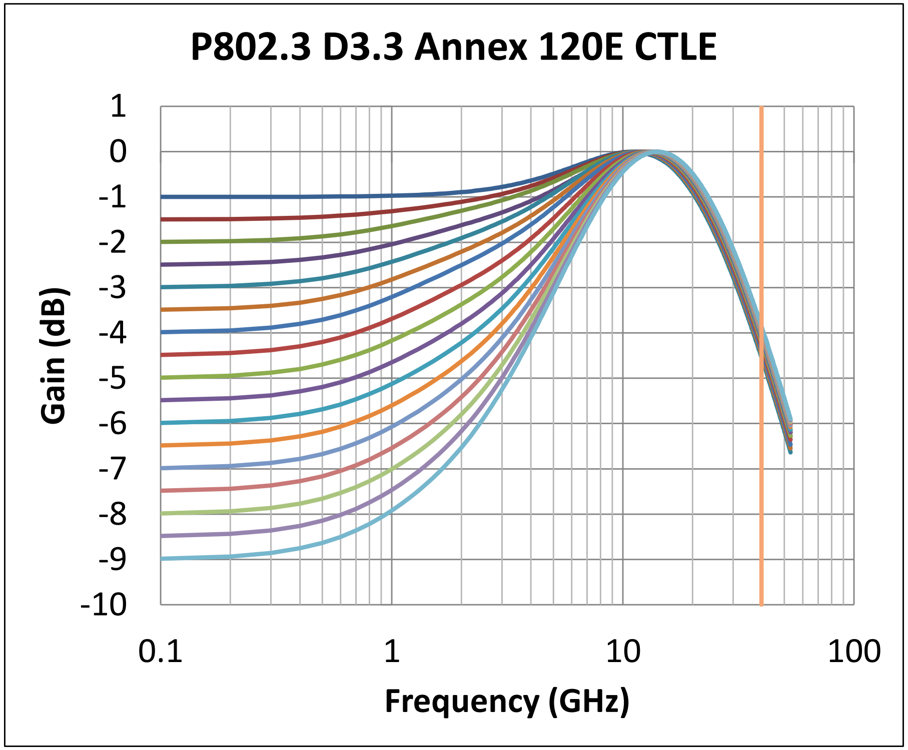
- Current draft
- Gain at $1.5 \times f_b = 39.8GHz$ is -4.3dB ~ -3.9dB

Table 120E-2

Peaking	G	P1/2pi	P2/2pi	Z1/2pi	PLF/2pi	ZLF/2pi
1.0	0.89125	18.6	14.1	8.359	1.2	1.2
1.5	0.8414	18.6	14.1	8.159	1.2	1.15
2.0	0.79433	18.6	14.1	7.995	1.2	1.1
2.5	0.74989	18.6	14.1	7.604	1.2	1.075
3.0	0.70795	15.6	14.1	6.713	1.2	1.05
3.5	0.66834	15.6	14.1	6.421	1.2	1.025
4.0	0.63096	15.6	14.1	6.155	1.2	1
4.5	0.59566	15.6	14.1	5.733	1.2	1
5.0	0.56234	15.6	14.1	5.353	1.2	1
5.5	0.53088	15.6	14.1	5.007	1.2	1
6.0	0.50119	15.6	14.1	4.691	1.2	1
6.5	0.47315	15.6	14.1	4.399	1.2	1
7.0	0.44668	15.6	14.1	4.13	1.2	1
7.5	0.4217	15.6	14.1	3.88	1.2	1
8.0	0.39811	15.6	14.1	3.647	1.2	1
8.5	0.37584	15.6	14.1	3.43	1.2	1
9.0	0.35481	15.6	14.1	3.228	1.2	1

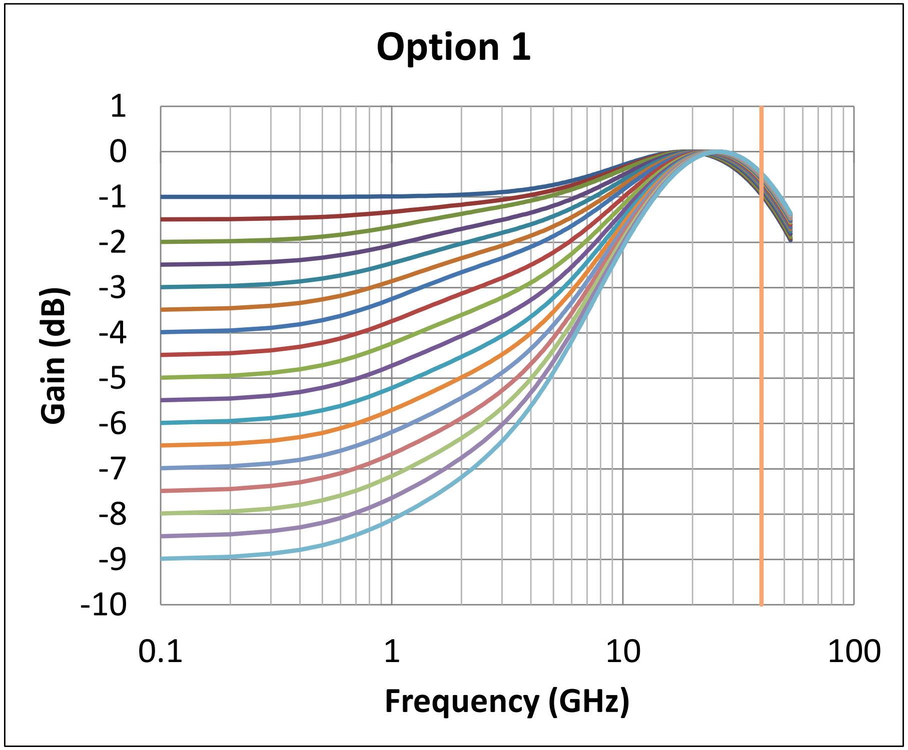
Figure 120E-9 plotted up to $2f_b$



Option 1 (Updated)

- Increase $P_1/2\pi$ to $2 * fb$ (align to f_{p2} of Annex 120D)
- Gain at $1.5 \times f_b = 39.8GHz$ is -1.0dB ~ -0.5dB

Peaking	G	P1/2pi	P2/2pi	Z1/2pi	PLF/2pi	ZLF/2pi
1.0	0.891251	53.125	14.1	10.974592	1.2	1.200
1.5	0.841395	53.125	14.1	10.754119	1.2	1.150
2.0	0.794328	53.125	14.1	10.568968	1.2	1.100
2.5	0.749894	53.125	14.1	10.113502	1.2	1.075
3.0	0.707946	53.125	14.1	9.698224	1.2	1.050
3.5	0.668344	53.125	14.1	9.316324	1.2	1.025
4.0	0.630957	53.125	14.1	8.963109	1.2	1.000
4.5	0.595662	53.125	14.1	8.390000	1.2	1.000
5.0	0.562341	53.125	14.1	7.865160	1.2	1.000
5.5	0.530884	53.125	14.1	7.381531	1.2	1.000
6.0	0.501187	53.125	14.1	6.933869	1.2	1.000
6.5	0.473151	53.125	14.1	6.518087	1.2	1.000
7.0	0.446684	53.125	14.1	6.130894	1.2	1.000
7.5	0.421697	53.125	14.1	5.769566	1.2	1.000
8.0	0.398107	53.125	14.1	5.431801	1.2	1.000
8.5	0.375837	53.125	14.1	5.115622	1.2	1.000
9.0	0.354813	53.125	14.1	4.819305	1.2	1.000

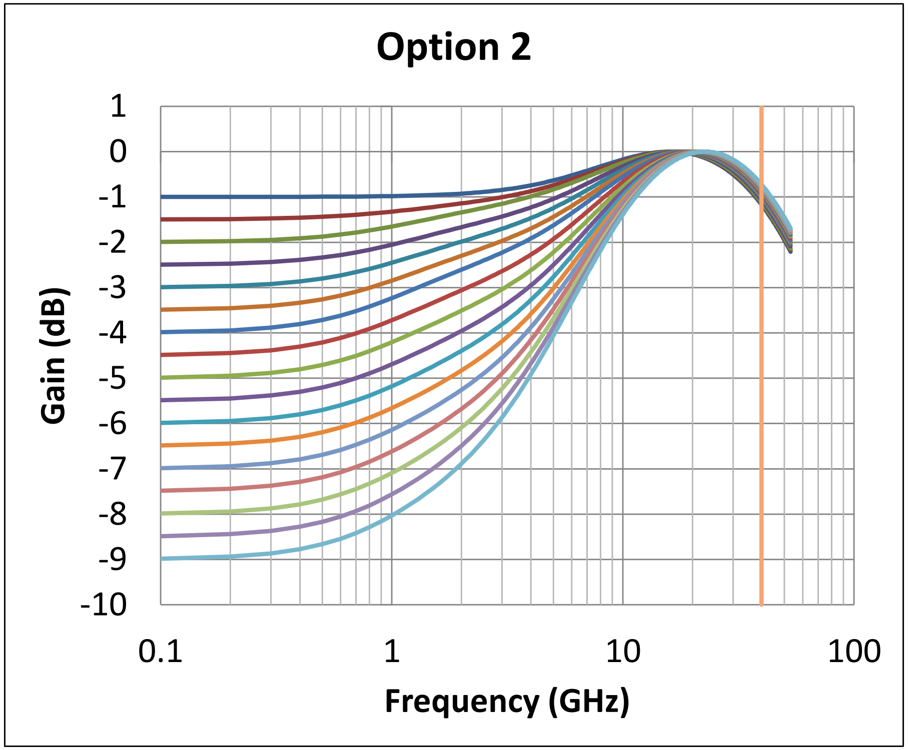


Note: Table is slightly updated since hidaka_3bs_01_082817_elect.pdf and hidaka_3bs_01_90717_elect.pdf.

Option 2 (Updated)

- Increase $P_1/2\pi$ to $2 * fb$ (align to f_{p2} of Annex 120D)
- Reduce $P_2/2\pi$ to $0.4 * fb$ (align to f_{p1} of Annex 120D)
- Gain at $1.5 \times f_b = 39.8GHz$ is -1.2dB ~ -0.7dB

Peaking	G	P1/2pi	P2/2pi	Z1/2pi	PLF/2pi	ZLF/2pi
1.0	0.891251	53.125	10.625	8.568390	1.2	1.200
1.5	0.841395	53.125	10.625	8.403889	1.2	1.150
2.0	0.794328	53.125	10.625	8.265152	1.2	1.100
2.5	0.749894	53.125	10.625	7.922830	1.2	1.075
3.0	0.707946	53.125	10.625	7.608428	1.2	1.050
3.5	0.668344	53.125	10.625	7.317631	1.2	1.025
4.0	0.630957	53.125	10.625	7.047419	1.2	1.000
4.5	0.595662	53.125	10.625	6.606934	1.2	1.000
5.0	0.562341	53.125	10.625	6.201382	1.2	1.000
5.5	0.530884	53.125	10.625	5.826093	1.2	1.000
6.0	0.501187	53.125	10.625	5.477524	1.2	1.000
6.5	0.473151	53.125	10.625	5.152868	1.2	1.000
7.0	0.446684	53.125	10.625	4.849827	1.2	1.000
7.5	0.421697	53.125	10.625	4.566472	1.2	1.000
8.0	0.398107	53.125	10.625	4.301151	1.2	1.000
8.5	0.375837	53.125	10.625	4.052431	1.2	1.000
9.0	0.354813	53.125	10.625	3.819049	1.2	1.000

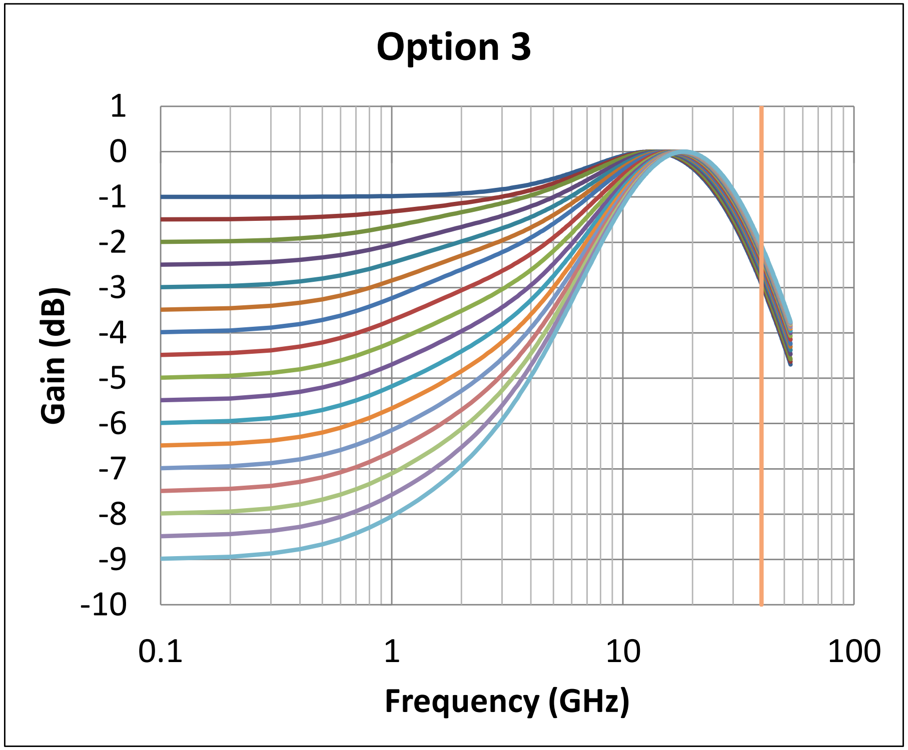


Note: Table is slightly updated since hidaka_3bs_01_082817_elect.pdf and hidaka_3bs_01_90717_elect.pdf.

Option 3 (Updated)

- Increase $P_1/2\pi$ to $1 * fb$ (align to f_{p2} of CEI-56G-MR-PAM4)
- Gain at $1.5 \times f_b = 39.8GHz$ is -2.9dB ~ -2.1dB

Peaking	G	P1/2pi	P2/2pi	Z1/2pi	PLF/2pi	ZLF/2pi
1.0	0.891251	26.5625	14.1	9.463748	1.2	1.200
1.5	0.841395	26.5625	14.1	9.248465	1.2	1.150
2.0	0.794328	26.5625	14.1	9.069645	1.2	1.100
2.5	0.749894	26.5625	14.1	8.640319	1.2	1.075
3.0	0.707946	26.5625	14.1	8.255665	1.2	1.050
3.5	0.668344	26.5625	14.1	7.906766	1.2	1.025
4.0	0.630957	26.5625	14.1	7.587650	1.2	1.000
4.5	0.595662	26.5625	14.1	7.076858	1.2	1.000
5.0	0.562341	26.5625	14.1	6.614781	1.2	1.000
5.5	0.530884	26.5625	14.1	6.193091	1.2	1.000
6.0	0.501187	26.5625	14.1	5.805801	1.2	1.000
6.5	0.473151	26.5625	14.1	5.448395	1.2	1.000
7.0	0.446684	26.5625	14.1	5.117337	1.2	1.000
7.5	0.421697	26.5625	14.1	4.809777	1.2	1.000
8.0	0.398107	26.5625	14.1	4.523367	1.2	1.000
8.5	0.375837	26.5625	14.1	4.256129	1.2	1.000
9.0	0.354813	26.5625	14.1	4.006377	1.2	1.000



Note: Table is slightly updated since hidaka_3bs_01_082817_elect.pdf and hidaka_3bs_01_90717_elect.pdf.

Option 4 (Updated)

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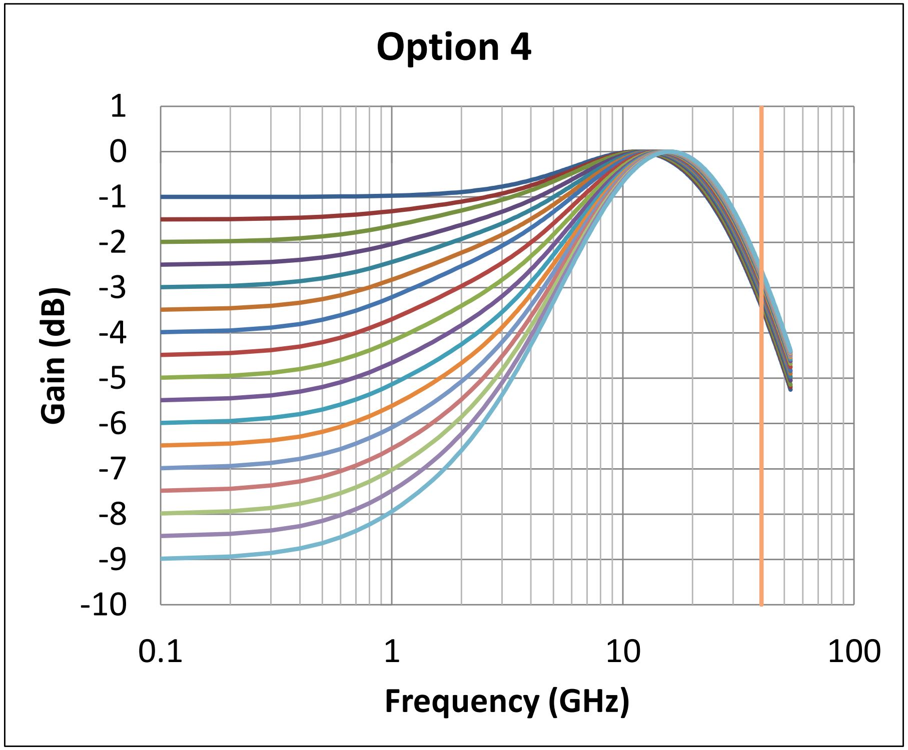
- Increase $P_1/2\pi$ to $1 * fb$ (align to f_{p2} of CEI-56G-MR-PAM4)
- Reduce $P_2/2\pi$ to $0.4 * fb$ (align to f_{p1} of CEI-56G-MR-PAM4)
- Gain at $1.5 \times f_b = 39.8GHz$ is -3.3dB ~ -2.5dB

Peaking	G	P1/2pi	P2/2pi	Z1/2pi	PLF/2pi	ZLF/2pi
1.0	0.891251	26.5625	10.625	7.673726	1.2	1.200
1.5	0.841395	26.5625	10.625	7.505350	1.2	1.150
2.0	0.794328	26.5625	10.625	7.364975	1.2	1.100
2.5	0.749894	26.5625	10.625	7.028143	1.2	1.075
3.0	0.707946	26.5625	10.625	6.724368	1.2	1.050
3.5	0.668344	26.5625	10.625	6.447402	1.2	1.025
4.0	0.630957	26.5625	10.625	6.193017	1.2	1.000
4.5	0.595662	26.5625	10.625	5.784333	1.2	1.000
5.0	0.562341	26.5625	10.625	5.412829	1.2	1.000
5.5	0.530884	26.5625	10.625	5.072507	1.2	1.000
6.0	0.501187	26.5625	10.625	4.758993	1.2	1.000
6.5	0.473151	26.5625	10.625	4.468950	1.2	1.000
7.0	0.446684	26.5625	10.625	4.199734	1.2	1.000
7.5	0.421697	26.5625	10.625	3.949196	1.2	1.000
8.0	0.398107	26.5625	10.625	3.715546	1.2	1.000
8.5	0.375837	26.5625	10.625	3.497265	1.2	1.000
9.0	0.354813	26.5625	10.625	3.293050	1.2	1.000



Note: Table is slightly updated since hidaka_3bs_01_082817_elect.pdf and hidaka_3bs_01_90717_elect.pdf.

Comment #r03-45

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Cl **120E** *SC* **120E.3.4.1.1** *P* **383** *L* **9** # r03-45

Dawe, Piers J G Mellanox Technologie

Comment Type **T** *Comment Status* **X**

The module output is measured with a 10.5 dB channel (part mated compliance boards, part software channel) plus module's own loss with EW, EH 0.2, 30. The module stressed input signal is measured after a 14.2 dB hardware channel, plus pattern generator's own loss, with EW, EH 0.22, 32 - not very different. Although the host and pattern generator are expected to have more sophisticated outputs than the module, it is said that the stressed signal EW is not feasible - this may be because of the extra loss.

SuggestedRemedy

Reduce the 14.2 dB loss because some of the loss is already in the pattern generator and the 14.2 dB represents all the loss including a long host IC package path. We could choose to let the max trace loss, max package loss host look after itself to an extent and target something between 10.5 (no package) and 14.2 (max package). Equivalently, don't connect the longest package trace to the longest PCB trace! Some other metric such as (unequalized) pulse height that takes the pattern generator into account may be better than test channel loss.

Proposed Response *Response Status* **O**

Frequency-dependent attenuator

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- From Pattern Generator Output to TP1a : 14.2dB @ 13.28GHz
- 14.2dB = 10.5dB channel loss + host transmitter package loss

Two levels of frequency-dependent attenuation are used for the module stressed input test: high loss and low loss. For the high loss case, frequency-dependent attenuation is added such that the loss at 13.28 GHz from the output of the pattern generator to TP1a is 14.2 dB. The 14.2 dB loss represents 10.5 dB channel loss with an additional allowance for host transmitter package loss. Eye height and eye width are then measured at

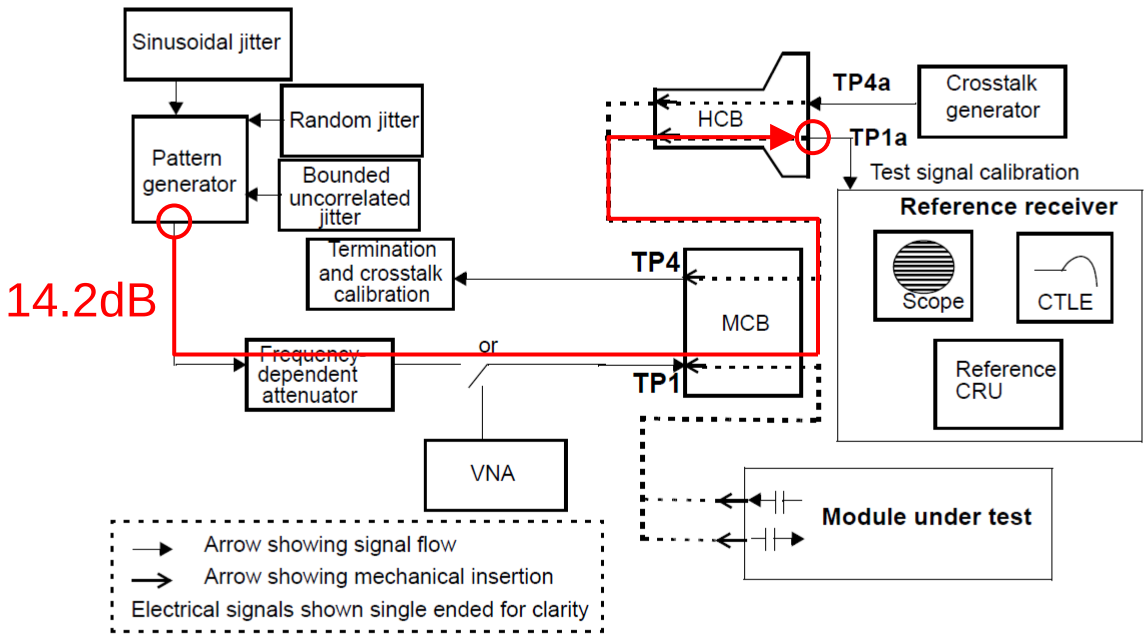
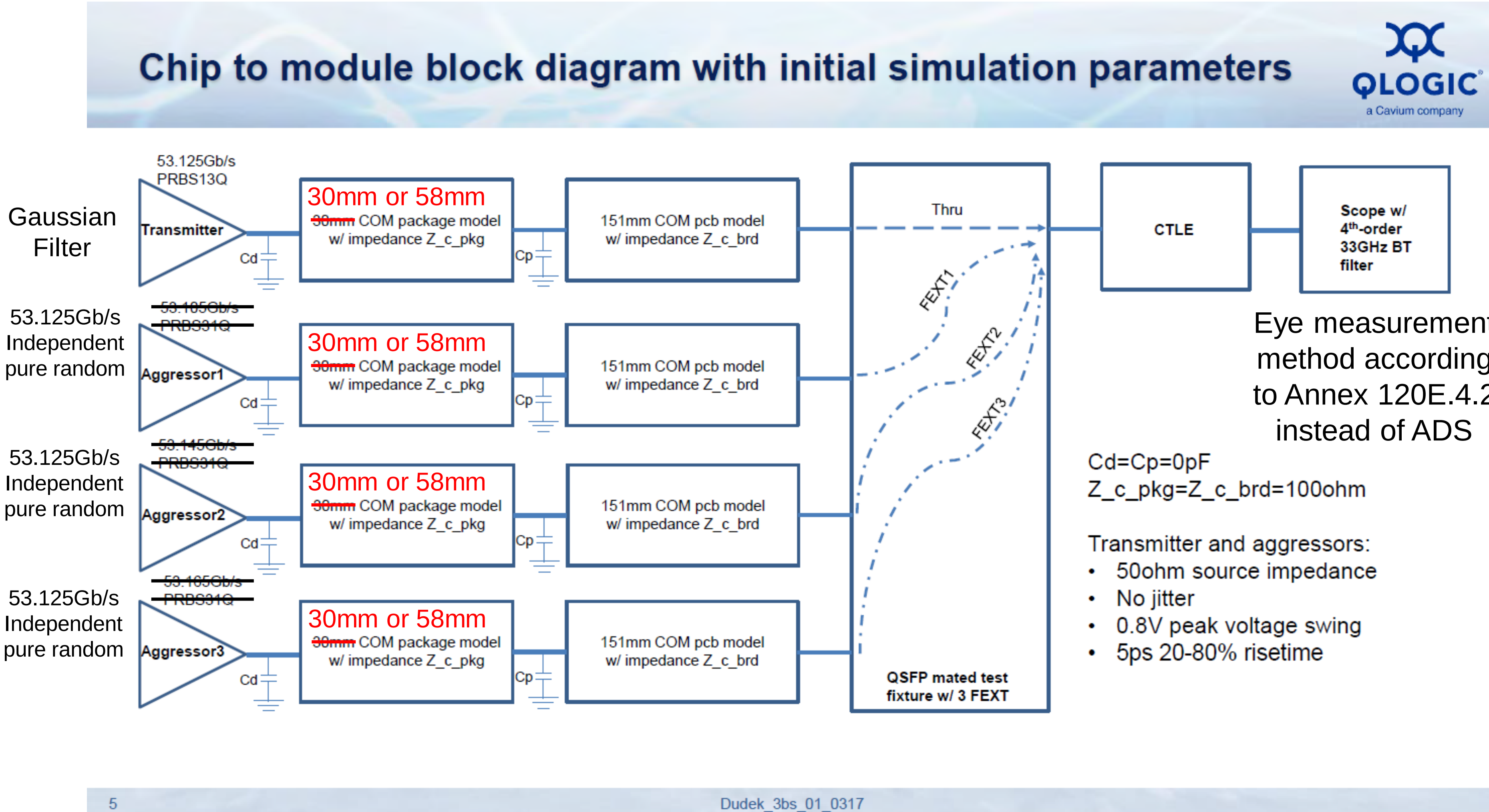


Figure 120E–12—Example module stressed input test

MATLAB Simulation Setup

- Similar to dudek_3bs_01_0317.pdf, slide 5



Channel IL with 30mm or 58mm Package

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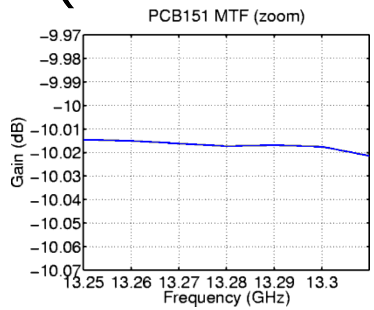
- 151mm PCB trace + Mated Test Fixture (reference w/o PKG)

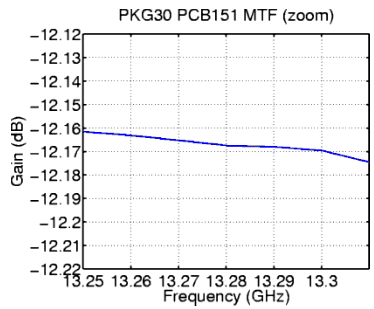
151mm COM PCB model → QSFP Mated Test Fixture



IL = 10.02dB @ 13.28GHz

- 30mm PKG trace + 151mm PCB trace + Mated Test Fixture

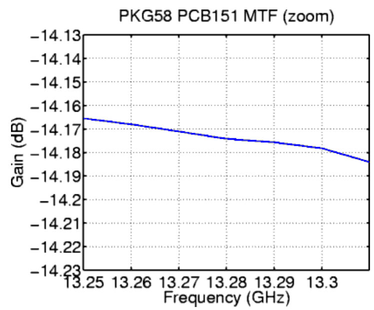
30mm COM PKG model → 151mm COM PCB model → QSFP Mated Test Fixture



IL = 12.17dB @ 13.28GHz

- 58mm PKG trace + 151mm PCB trace + Mated Test Fixture

58mm COM PKG model → 151mm COM PCB model → QSFP Mated Test Fixture



IL = 14.17dB @ 13.28GHz

Simulated Conditions

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- Row 1-11 are same as dudek_3bs_01_0317.pdf, slide 17
- Row 12-13 are Row 11 + slower Tr

Row	Av (V)	Rd (ohm)	Cd (pF)	Cp (pF)	Package Zc (ohm)	Board Zc (ohm)	SNR_TX (dB)	RJ (UI-rms)	DJ (UI-pp)	Xtalk	Tr (ps)	Note
1	0.4	50	0	0	100	100	100	0.00	0.00	No	5.0	Ideal Case
2	0.4	50	0	0	100	100	100	0.00	0.00	Yes	5.0	+ Xtalk
3	0.416	50	0	0	100	100	100	0.01	0.02	Yes	5.0	+ Jitter
6	0.442	55	0.18	0.11	90	109.8	100	0.01	0.02	Yes	5.0	+ Reflection
9	0.445	55	0.28	0.11	85	109.8	31	0.01	0.02	Yes	5.0	bs D3.0 A120D
11	0.442	55	0.18	0.11	90	109.8	32.5	0.01	0.02	Yes	5.0	cd D1.2 CL137
12	0.442	55	0.18	0.11	90	109.8	32.5	0.01	0.02	Yes	9.5	Tr = 9.5ps
13	0.442	55	0.18	0.11	90	109.8	32.5	0.01	0.02	Yes	13.5	Tr = 13.5ps

Eye Width with 30mm Package (Updated)

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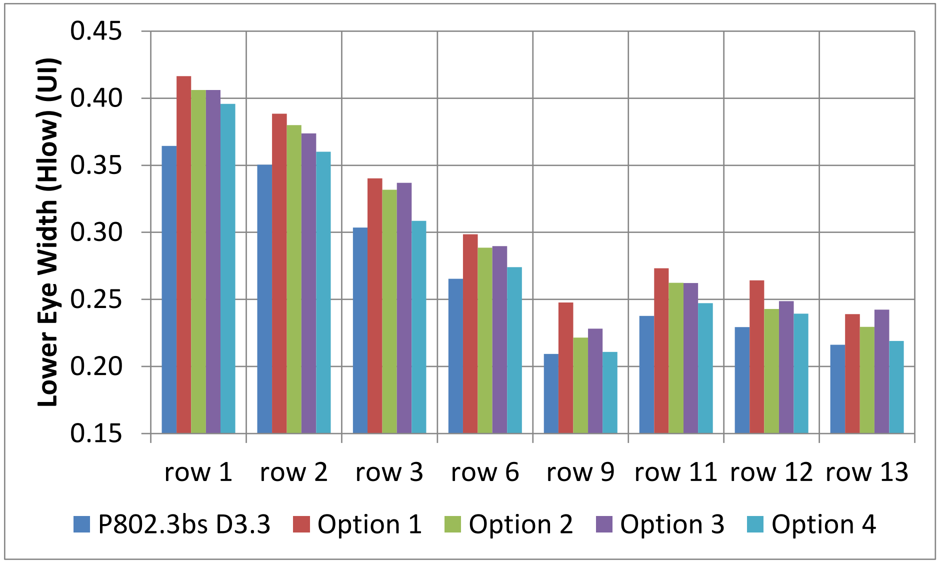
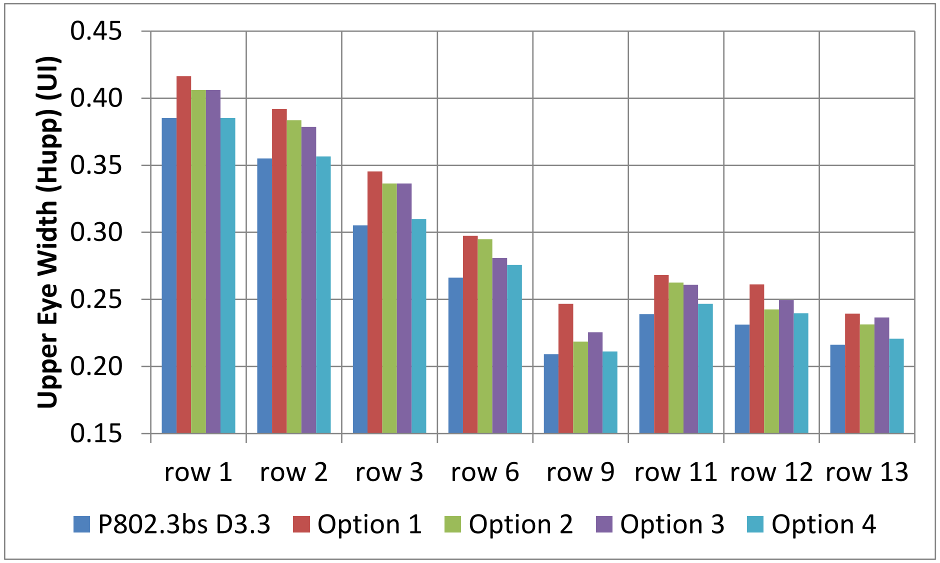
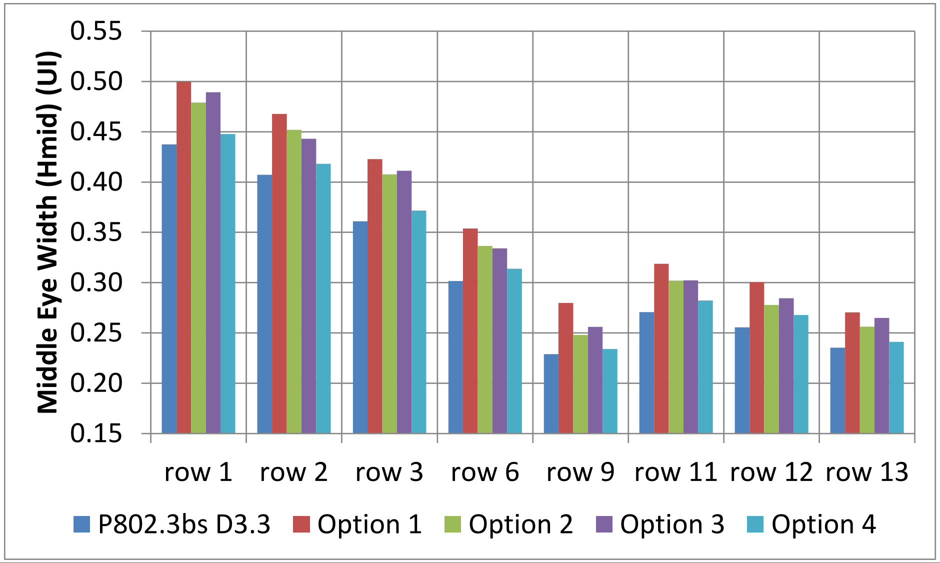
- Improved with all options, best with option 1, followed by 2 or 3







Lower (ps)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	13.7	15.7	15.3	15.3	14.9
row 2	13.2	14.6	14.3	14.1	13.6
row 3	11.4	12.8	12.5	12.7	11.6
row 6	10.0	11.2	10.9	10.9	10.3
row 9	7.9	9.3	8.3	8.6	7.9
row 11	9.0	10.3	9.9	9.9	9.3
row 12	8.6	9.9	9.1	9.4	9.0
row 13	8.1	9.0	8.6	9.1	8.2

Upper (ps)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	14.5	15.7	15.3	15.3	14.5
row 2	13.4	14.8	14.4	14.3	13.4
row 3	11.5	13.0	12.7	12.7	11.7
row 6	10.0	11.2	11.1	10.6	10.4
row 9	7.9	9.3	8.2	8.5	7.9
row 11	9.0	10.1	9.9	9.8	9.3
row 12	8.7	9.8	9.1	9.4	9.0
row 13	8.1	9.0	8.7	8.9	8.3

Middle (ps)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	16.5	18.8	18.0	18.4	16.9
row 2	15.3	17.6	17.0	16.7	15.7
row 3	13.6	15.9	15.3	15.5	14.0
row 6	11.4	13.3	12.7	12.6	11.8
row 9	8.6	10.5	9.3	9.6	8.8
row 11	10.2	12.0	11.4	11.4	10.6
row 12	9.6	11.3	10.5	10.7	10.1
row 13	8.9	10.2	9.6	10.0	9.1

Eye Width with 58mm Package (Updated)

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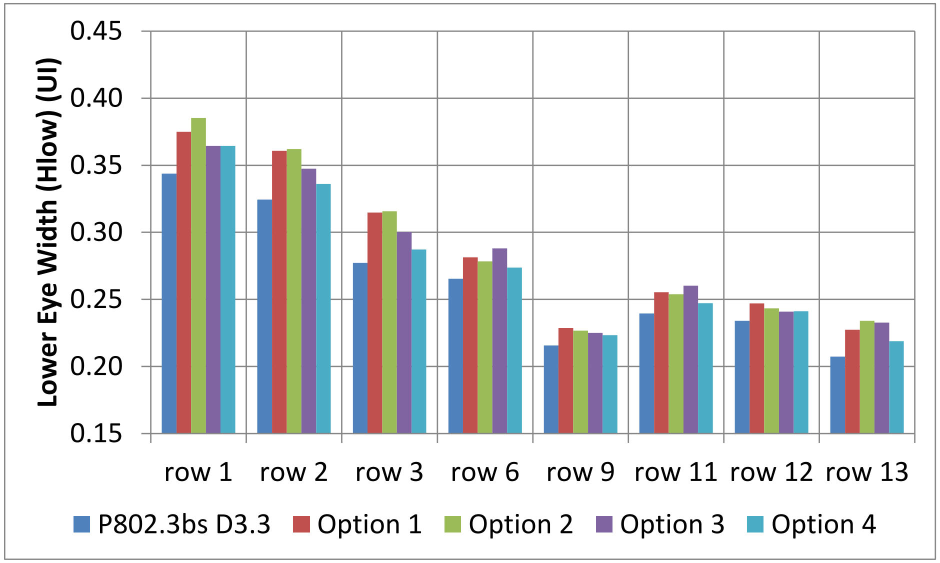
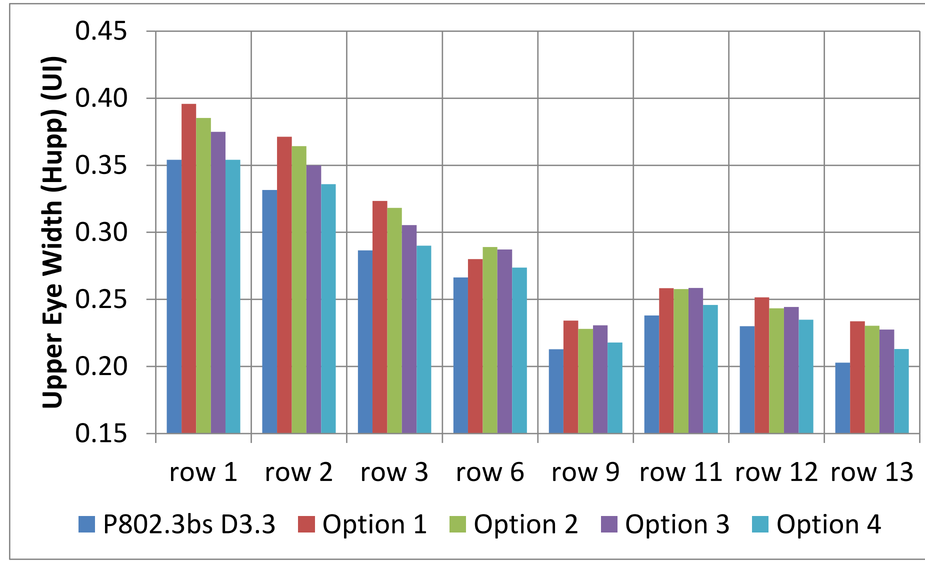
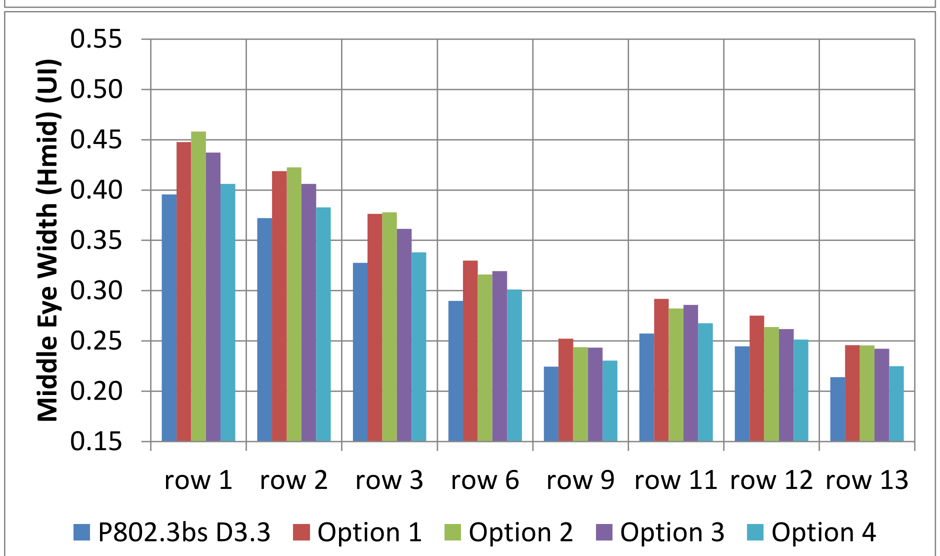
- Improved with all options, best with option 1, followed by 2 or 3







Lower (ps)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	12.9	14.1	14.5	13.7	13.7
row 2	12.2	13.6	13.6	13.1	12.7
row 3	10.4	11.9	11.9	11.3	10.8
row 6	10.0	10.6	10.5	10.8	10.3
row 9	8.1	8.6	8.5	8.5	8.4
row 11	9.0	9.6	9.6	9.8	9.3
row 12	8.8	9.3	9.2	9.1	9.1
row 13	7.8	8.6	8.8	8.8	8.2

Upper (ps)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	13.3	14.9	14.5	14.1	13.3
row 2	12.5	14.0	13.7	13.2	12.6
row 3	10.8	12.2	12.0	11.5	10.9
row 6	10.0	10.5	10.9	10.8	10.3
row 9	8.0	8.8	8.6	8.7	8.2
row 11	9.0	9.7	9.7	9.7	9.3
row 12	8.7	9.5	9.2	9.2	8.8
row 13	7.6	8.8	8.7	8.6	8.0

Middle (ps)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	14.9	16.9	17.2	16.5	15.3
row 2	14.0	15.8	15.9	15.3	14.4
row 3	12.3	14.2	14.2	13.6	12.7
row 6	10.9	12.4	11.9	12.0	11.3
row 9	8.4	9.5	9.2	9.2	8.7
row 11	9.7	11.0	10.6	10.8	10.1
row 12	9.2	10.4	9.9	9.9	9.5
row 13	8.1	9.2	9.2	9.1	8.5

Eye Width (Option 3 or 4): 30mm vs 58mm

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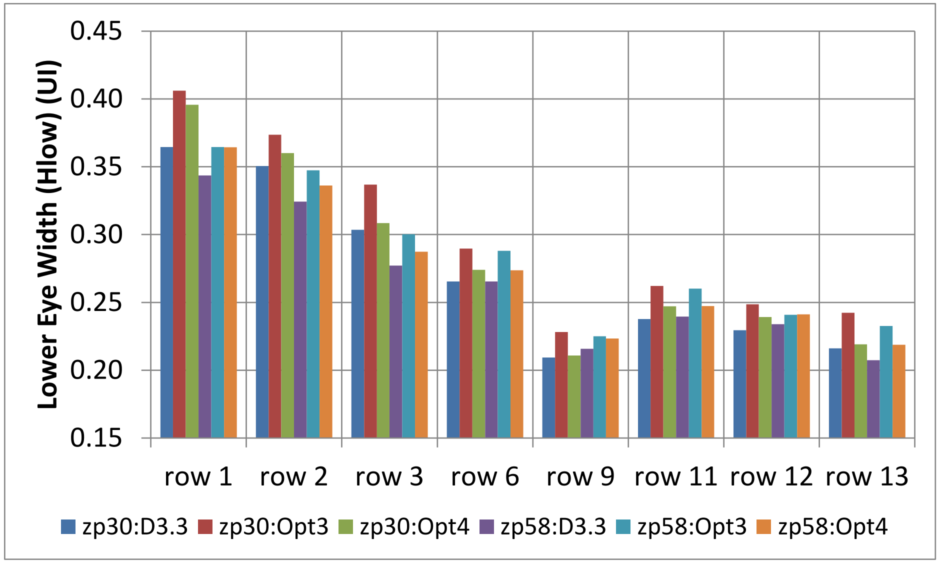
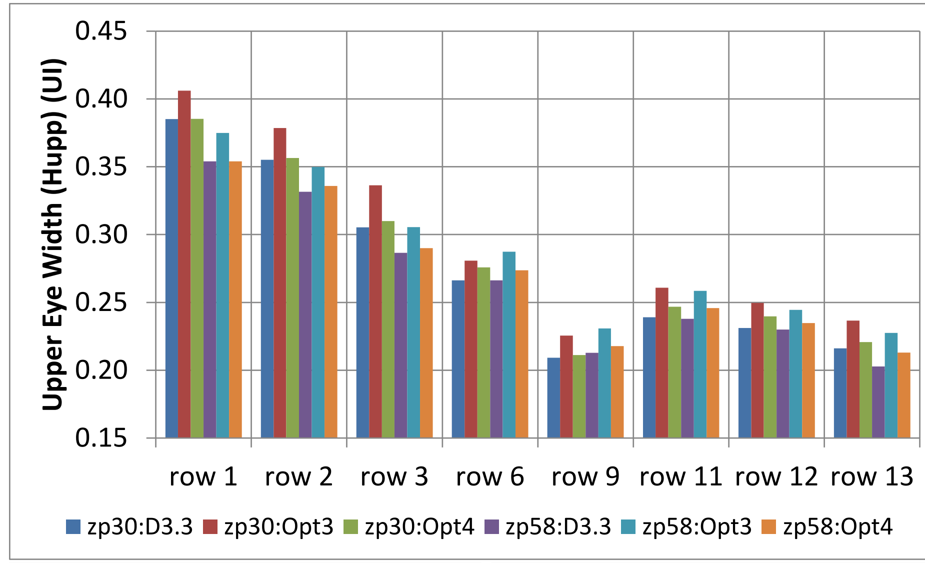
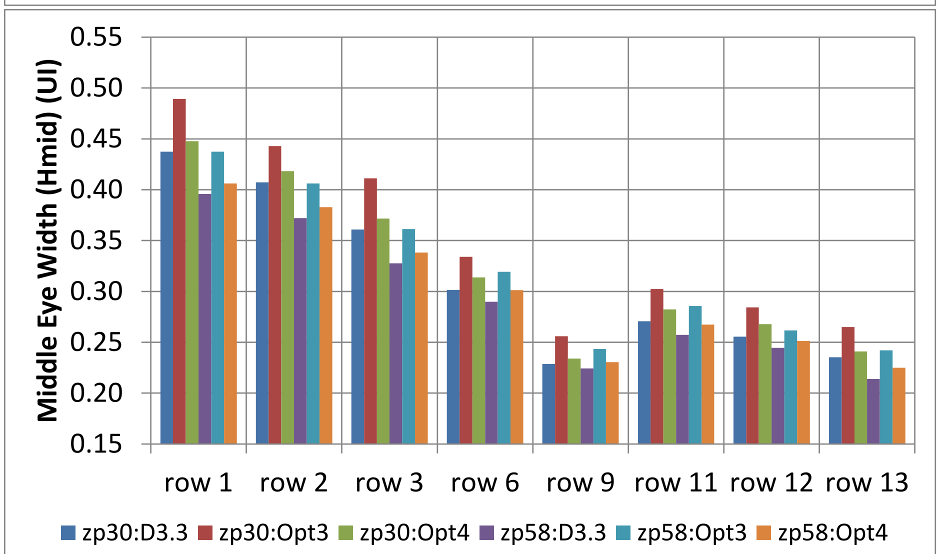
- Effects of D3.3 → Option 3 or 4 > Effects of zp=58 → zp=30







zp (mm)	30			58		
Lower (ps)	D3.3	Opt3	Opt4	D3.3	Opt3	Opt4
row 1	13.7	15.3	14.9	12.9	13.7	13.7
row 2	13.2	14.1	13.6	12.2	13.1	12.7
row 3	11.4	12.7	11.6	10.4	11.3	10.8
row 6	10.0	10.9	10.3	10.0	10.8	10.3
row 9	7.9	8.6	7.9	8.1	8.5	8.4
row 11	9.0	9.9	9.3	9.0	9.8	9.3
row 12	8.6	9.4	9.0	8.8	9.1	9.1
row 13	8.1	9.1	8.2	7.8	8.8	8.2

zp (mm)	30			58		
Upper (ps)	D3.3	Opt3	Opt4	D3.3	Opt3	Opt4
row 1	14.5	15.3	14.5	13.3	14.1	13.3
row 2	13.4	14.3	13.4	12.5	13.2	12.6
row 3	11.5	12.7	11.7	10.8	11.5	10.9
row 6	10.0	10.6	10.4	10.0	10.8	10.3
row 9	7.9	8.5	7.9	8.0	8.7	8.2
row 11	9.0	9.8	9.3	9.0	9.7	9.3
row 12	8.7	9.4	9.0	8.7	9.2	8.8
row 13	8.1	8.9	8.3	7.6	8.6	8.0

zp (mm)	30			58		
Middle (ps)	D3.3	Opt3	Opt4	D3.3	Opt3	Opt4
row 1	16.5	18.4	16.9	14.9	16.5	15.3
row 2	15.3	16.7	15.7	14.0	15.3	14.4
row 3	13.6	15.5	14.0	12.3	13.6	12.7
row 6	11.4	12.6	11.8	10.9	12.0	11.3
row 9	8.6	9.6	8.8	8.4	9.2	8.7
row 11	10.2	11.4	10.6	9.7	10.8	10.1
row 12	9.6	10.7	10.1	9.2	9.9	9.5
row 13	8.9	10.0	9.1	8.1	9.1	8.5

Eye Height (Option 3 or 4): 30mm vs 58mm

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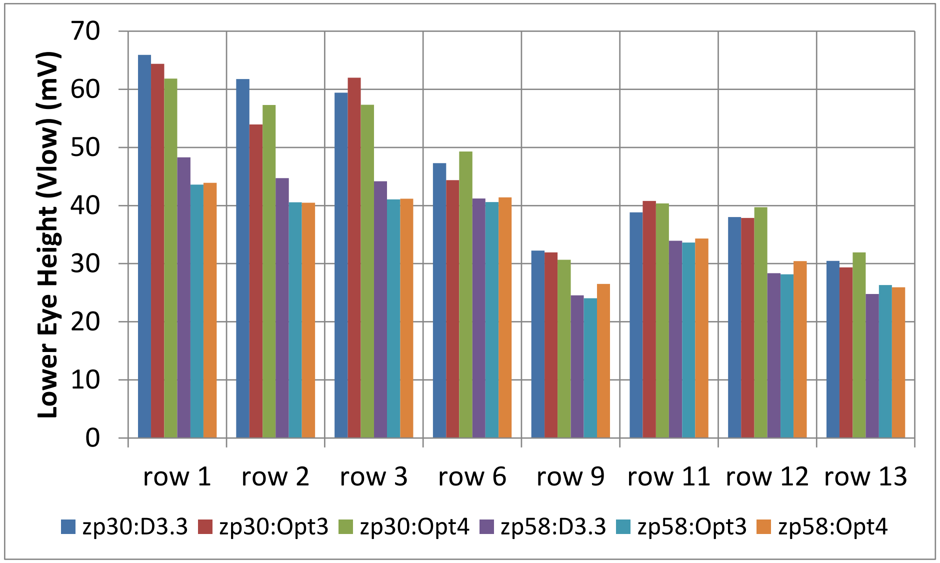
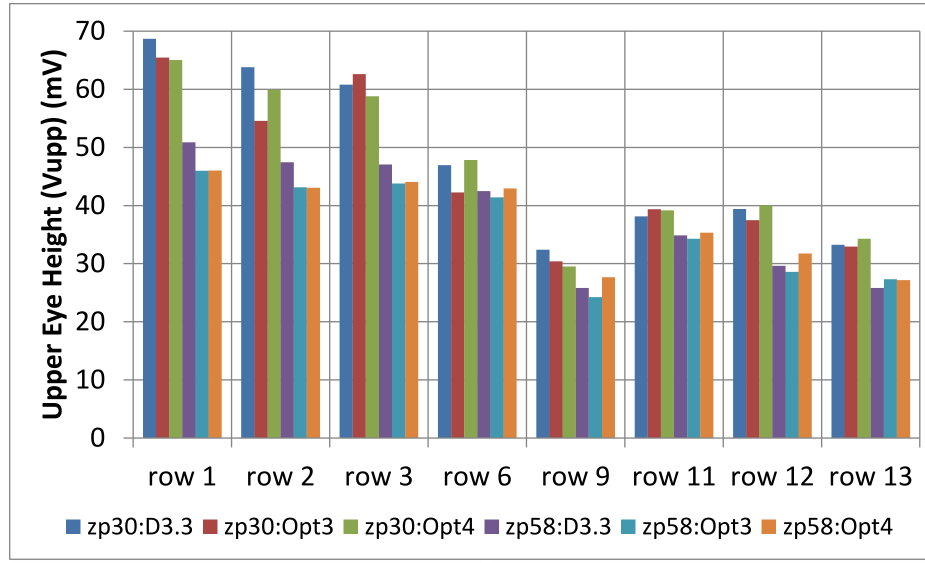
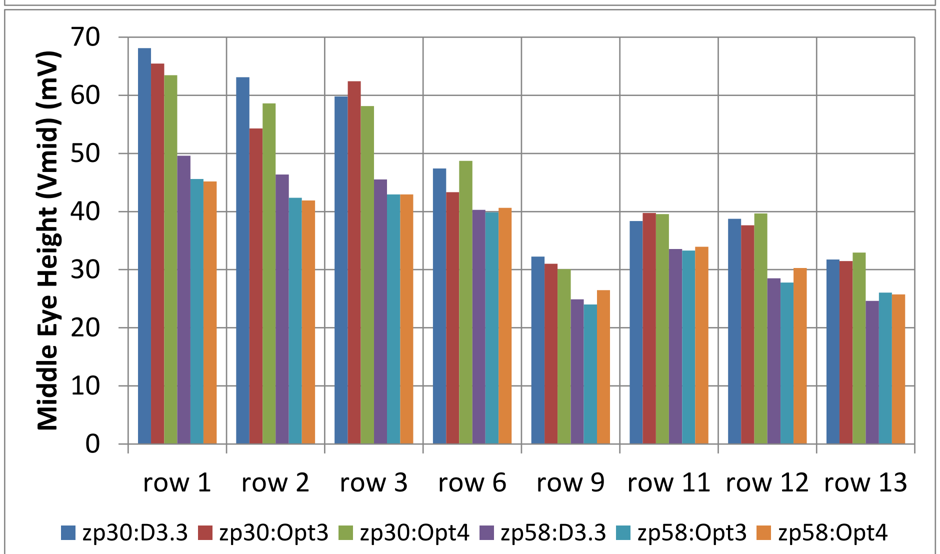
- Hard to meet 32mV with impairments, in particular for 58mm







zp (mm)	30			58		
Lower (mV)	D3.3	Opt3	Opt4	D3.3	Opt3	Opt4
row 1	65.9	64.4	61.8	48.3	43.6	43.9
row 2	61.8	54.0	57.3	44.7	40.6	40.5
row 3	59.4	62.0	57.3	44.2	41.1	41.2
row 6	47.3	44.4	49.3	41.2	40.6	41.4
row 9	32.3	32.0	30.7	24.6	24.0	26.5
row 11	38.8	40.8	40.4	34.0	33.6	34.3
row 12	38.0	37.9	39.7	28.3	28.2	30.4
row 13	30.5	29.4	31.9	24.8	26.3	25.9

zp (mm)	30			58		
Upper (mV)	D3.3	Opt3	Opt4	D3.3	Opt3	Opt4
row 1	68.7	65.5	65.0	50.9	46.0	46.0
row 2	63.8	54.6	59.9	47.5	43.1	43.0
row 3	60.8	62.6	58.8	47.1	43.8	44.0
row 6	46.9	42.3	47.8	42.5	41.4	43.0
row 9	32.4	30.4	29.5	25.8	24.2	27.6
row 11	38.1	39.4	39.2	34.9	34.3	35.3
row 12	39.4	37.5	40.0	29.6	28.6	31.7
row 13	33.3	32.9	34.3	25.8	27.3	27.2

zp (mm)	30			58		
Middle (mV)	D3.3	Opt3	Opt4	D3.3	Opt3	Opt4
row 1	68.1	65.5	63.5	49.6	45.6	45.2
row 2	63.1	54.3	58.6	46.4	42.4	41.9
row 3	59.8	62.4	58.2	45.5	42.9	43.0
row 6	47.4	43.3	48.7	40.3	39.9	40.6
row 9	32.2	31.0	30.1	24.9	24.0	26.5
row 11	38.4	39.7	39.5	33.6	33.3	34.0
row 12	38.7	37.6	39.7	28.5	27.8	30.3
row 13	31.8	31.5	33.0	24.6	26.0	25.8

Eye Amplitude (Option 3 or 4): 30mm vs 58mm

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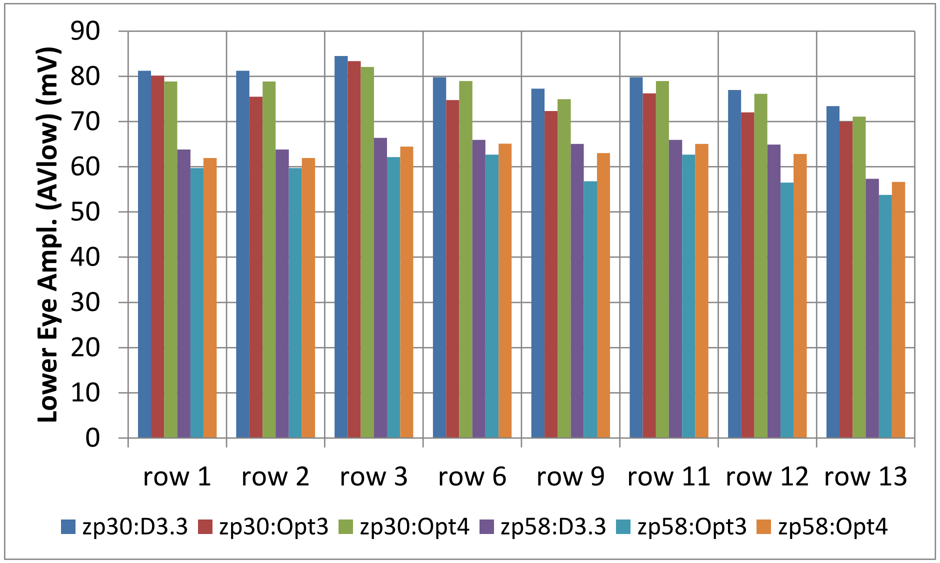
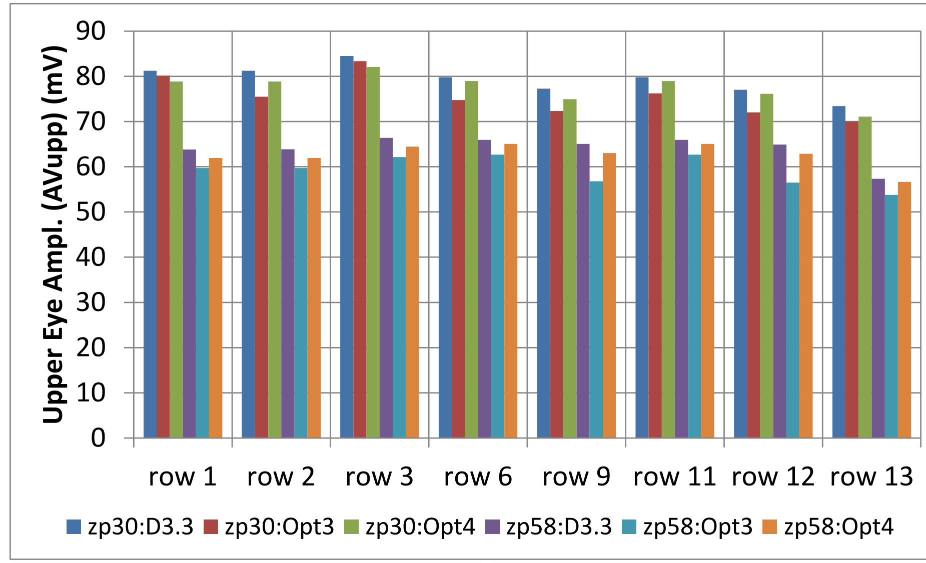
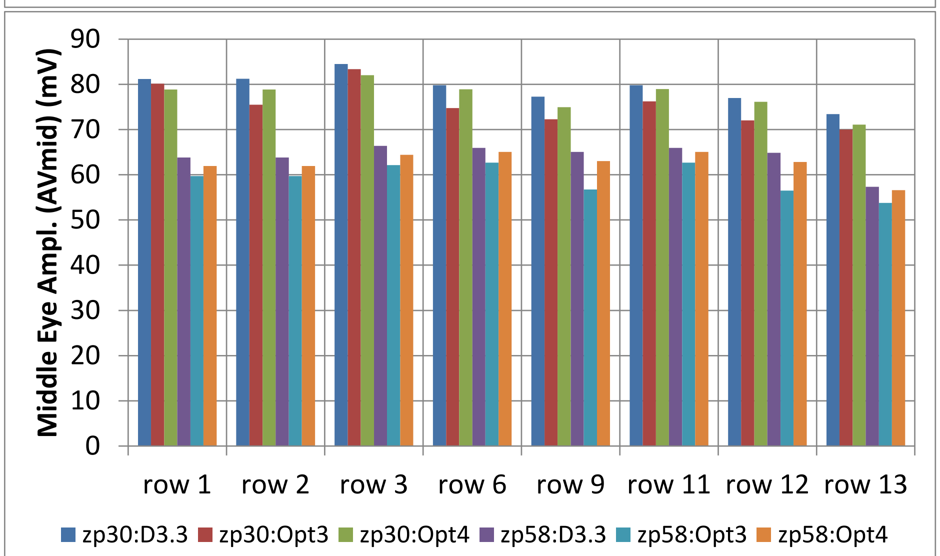
- Significantly drops with 58mm Package







zp (mm)	30			58		
Lower (mV)	D3.3	Opt3	Opt4	D3.3	Opt3	Opt4
row 1	81.2	80.1	78.8	63.8	59.7	62.0
row 2	81.2	75.5	78.9	63.8	59.7	62.0
row 3	84.5	83.4	82.1	66.4	62.1	64.5
row 6	79.8	74.8	78.9	66.0	62.7	65.1
row 9	77.3	72.3	75.0	65.1	56.8	63.0
row 11	79.8	76.3	79.0	66.0	62.7	65.1
row 12	77.0	72.0	76.1	64.9	56.5	62.9
row 13	73.4	70.0	71.1	57.3	53.8	56.6

zp (mm)	30			58		
Upper (mV)	D3.3	Opt3	Opt4	D3.3	Opt3	Opt4
row 1	81.2	80.2	78.9	63.8	59.7	62.0
row 2	81.2	75.5	78.9	63.9	59.7	62.0
row 3	84.5	83.4	82.1	66.4	62.1	64.4
row 6	79.8	74.8	78.9	66.0	62.7	65.1
row 9	77.3	72.3	75.0	65.1	56.8	63.0
row 11	79.8	76.3	79.0	66.0	62.7	65.1
row 12	77.0	72.0	76.1	64.9	56.5	62.9
row 13	73.4	70.0	71.1	57.3	53.8	56.6

zp (mm)	30			58		
Middle (mV)	D3.3	Opt3	Opt4	D3.3	Opt3	Opt4
row 1	81.2	80.2	78.8	63.8	59.7	62.0
row 2	81.2	75.5	78.9	63.8	59.7	62.0
row 3	84.5	83.3	82.1	66.4	62.1	64.4
row 6	79.8	74.8	78.9	66.0	62.7	65.1
row 9	77.3	72.3	75.0	65.1	56.8	63.0
row 11	79.8	76.3	78.9	65.9	62.7	65.1
row 12	77.0	72.0	76.1	64.9	56.5	62.9
row 13	73.4	70.0	71.1	57.3	53.8	56.6

Rx Input Amplitude: 30mm vs 58mm

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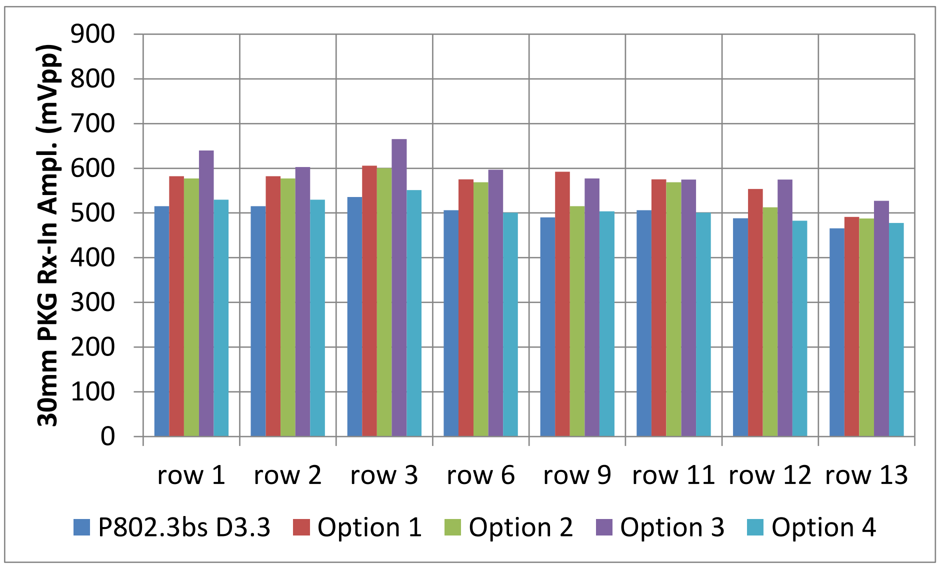
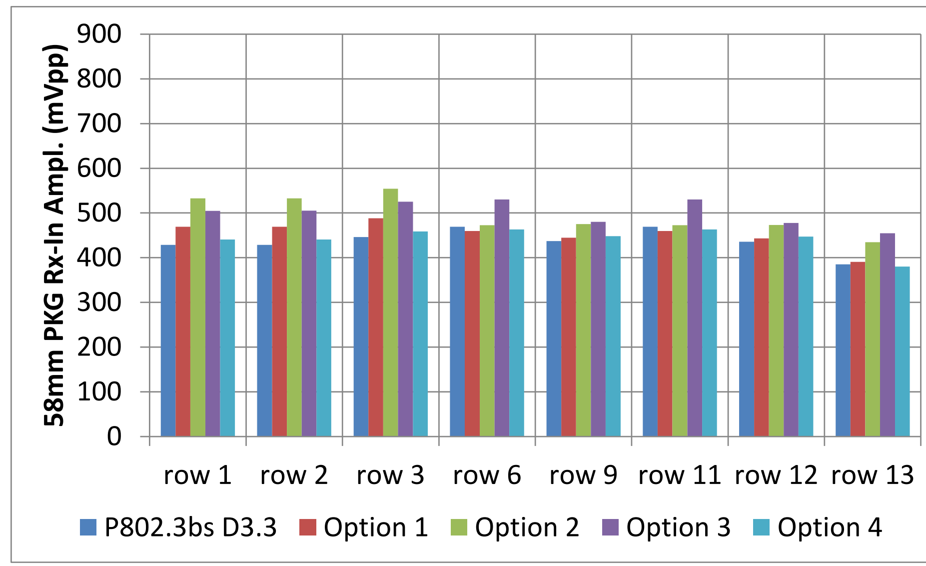
- Estimated from eye amplitudes and CTLE peaking
  - By $\left(AV_{low} + AV_{mid} + AV_{upp}\right) \times 10^{\frac{CTLE_{peaking}}{20}}$
- A lot of headroom to max Rx input of 900mVpp





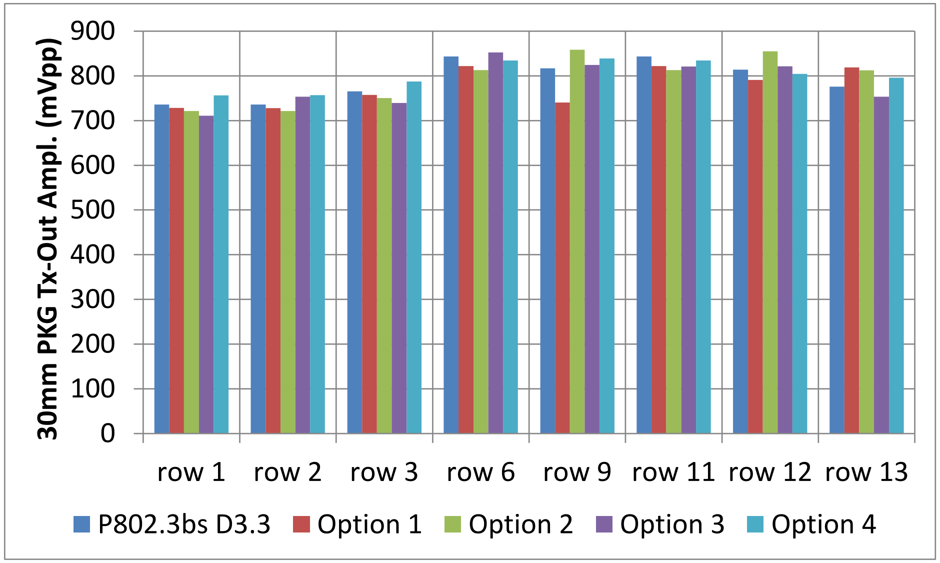
30mm (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	515	583	577	640	530
row 2	515	582	577	603	530
row 3	536	606	600	665	551
row 6	506	575	569	597	501
row 9	490	592	515	577	504
row 11	506	575	569	575	501
row 12	488	554	513	575	483
row 13	466	491	488	527	478

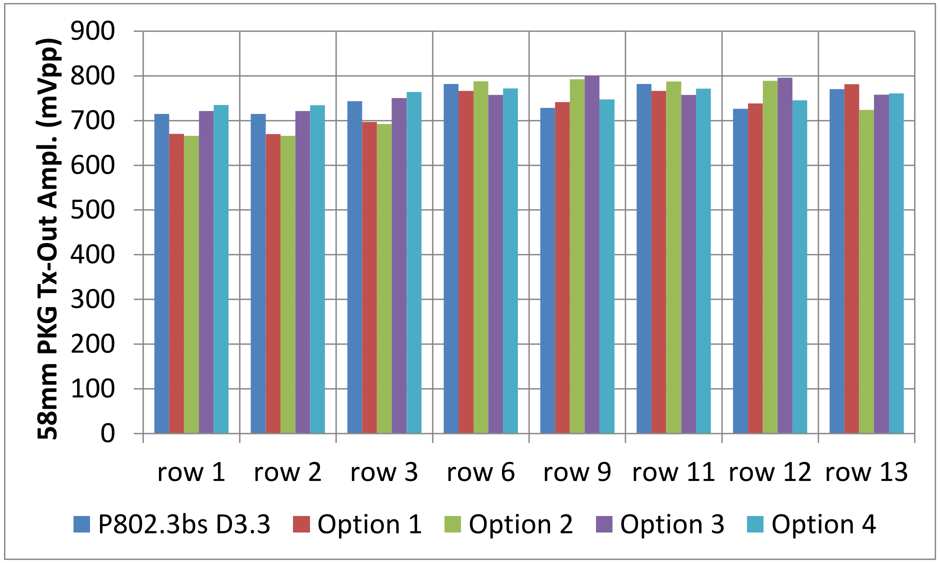
58mm (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	429	469	533	505	441
row 2	429	469	533	505	441
row 3	446	488	554	525	458
row 6	469	460	473	530	463
row 9	437	445	475	480	448
row 11	469	460	473	530	463
row 12	436	443	473	478	447
row 13	385	391	434	455	380

Tx Output Amplitude: 30mm vs 58mm

FUJITSU

- Estimated from eye amplitudes and CTLE and Tx FIR peaking
  - By $(AV_{low} + AV_{mid} + AV_{upp}) \times 10^{\frac{CTLE_{peaking}}{20}} \times \frac{|C_{-1}|+|C_0|+|C_1|}{C_{-1}+C_0+C_1}$
- No much headroom to max Tx output of 900mVpp





Simulation Conditions for Tx Output Amplitude

Sim condition	Av (mV)	2 * Av (mVpp)	Rd (Ω)
row 1	400	800	50
row 2	400	800	50
row 3	416	832	50
row 6	442	884	55
row 9	445	890	55
row 11	442	884	55
row 12	442	884	55
row 13	442	884	55

30mm (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	736	728	722	711	757
row 2	736	728	721	754	757
row 3	765	757	750	739	787
row 6	844	822	813	853	834
row 9	817	740	859	825	839
row 11	844	822	813	821	834
row 12	814	791	855	821	805
row 13	776	819	813	754	796

58mm (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	715	670	666	721	735
row 2	715	670	666	721	735
row 3	743	697	693	750	764
row 6	782	766	788	757	772
row 9	728	741	792	800	747
row 11	782	766	788	757	772
row 12	726	738	789	796	745
row 13	770	781	724	758	761

Discussion

- Option 3 is recommended, because it is best with impairments
    - Align the high-frequency pole P_1 of 120E to f_{p2} of CEI-56G-MR-PAM4
  - We may reduce loss from 14.2dB to 12.2dB for further improvement
  - However, if we just reduce loss, we will not get significant improvement

- PGEN output may exceed 900mV to meet EH >= 32mV
  - I think it is OK, but is it common interpretation and clear with D3.3 text?
  - If we reduce loss from 14.2dB to 12.2dB, no need to exceed 900mV

- With option 3, discrepancy between 120D and 120E remains
- Instead, shall we align poles of 120D to poles of 120E?
  - Not necessary, and it depends
    - Need to check its effects on the COM value for C2C channels
    - Peak gain remains slightly different due to the equations of transfer function
      - The peak gain of reference CTLE for 120D is slightly lower (-1.56dB ~ 0dB)

Simulation of Effects on COM for C2C Channels

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4 Options Investigated

	f_{p1}	f_{p2}	Note
Option 1	$0.531 \times f_b = 14.1GHz$	$2 \times f_b = 53.125GHz$	An option for 120E
Option 2 (baseline)	$0.4 \times f_b = 10.625GHz$	$2 \times f_b = 53.125GHz$	bs D3.3 120D
Option 3	$0.531 \times f_b = 14.1GHz$	$1 \times f_b = 26.5625GHz$	Good for 120E
Option 4	$0.4 \times f_b = 10.625GHz$	$1 \times f_b = 26.5625GHz$	CEI-56G-MR-PAM4

Evaluated Channels

- 10 C2C channels in P802.3bs Task Force channel data area
  - CH1-7: 7 Intel chip-to-chip channels (mellitz_3bs_0[2-8]_0714.zip)
  - CH8-9: 2 improved Intel chip-to-chip channels (mellitz_3bs_0[36]a_0315.zip)
  - CH10: TEC, Medium Reach / C2C with Armor Connector (shanbhag_01_0914.zip)

Channel	1	2	3	4	5	6	7	8	9	10
IL at Nyquist	19.63dB	14.72dB	6.92dB	19.49dB	17.41dB	10.99dB	9.18dB	19.10dB	17.43dB	18.64dB

COM Parameters Other than f_{p1} or f_{p2}

FUJITSU

Table 93A-1 parameters			
Parameter	Setting	Units	Information
f_b	26.5625	GBd	
f_min	0.05	GHz	
Delta_f	0.01	GHz	
C_d	[1.8e-4 1.8e-4]	nF	[TX RX]
z_p select	[1 2]		[test cases to run]
z_p (TX)	[12 30]	mm	[test cases]
z_p (NEXT)	[12 12]	mm	[test cases]
z_p (FEXT)	[12 30]	mm	[test cases]
z_p (RX)	[12 30]	mm	[test cases]
C_p	[1.1e-4 1.1e-4]	nF	[TX RX]
R_0	50	Ohm	
R_d	[50 50]	Ohm	[TX RX]
f_r	0.75	*fb	
c(0)	0.6		min
c(-1)	[-0.15:0.05:0]		[min:step:max]
c(1)	[-0.25:0.05:0]		[min:step:max]
g_DC	[-15:1:0]	dB	[min:step:max]
f_z	10.625	GHz	
f_p1	10.625	GHz	
f_p2	53.125	GHz	
A_v	0.418	V	
A_fe	0.418	V	
A_ne	0.63	V	
L	4		
M	32		
N_b	10	UI	
b_max(1)	0.5		
b_max(2..N_b)	0.2		
sigma_RJ	0.01	UI	
A_DD	0.02	UI	
eta_0	2.60E-08	V^2/GHz	
SNR_TX	31	dB	
R_LM	0.95		
DER_0	1.00E-05		
Operational control			
COM Pass threshold	3	dB	
Include PCB	0	Value	0, 1, 2
g_DC_HP	[-4:1:0]		[min:step:max]
f_HP_PZ	0.6640625	GHz	

I/O control		
DIAGNOSTICS	1	logical
DISPLAY_WINDOW	1	logical
Display frequency domain	1	logical
CSV_REPORT	1	logical
RESULT_DIR	\results\D3p3_120D_{date}\	
SAVE_FIGURES	0	logical
Port Order	[1 3 2 4]	
RUNTAG	C2C_	
Receiver testing		
RX_CALIBRATION	0	logical
Sigma BBN step	5.00E-03	V
IDEAL_TX_TERM	0	logical
T_r	1.30E-02	ns
FORCE_TR	1	logical

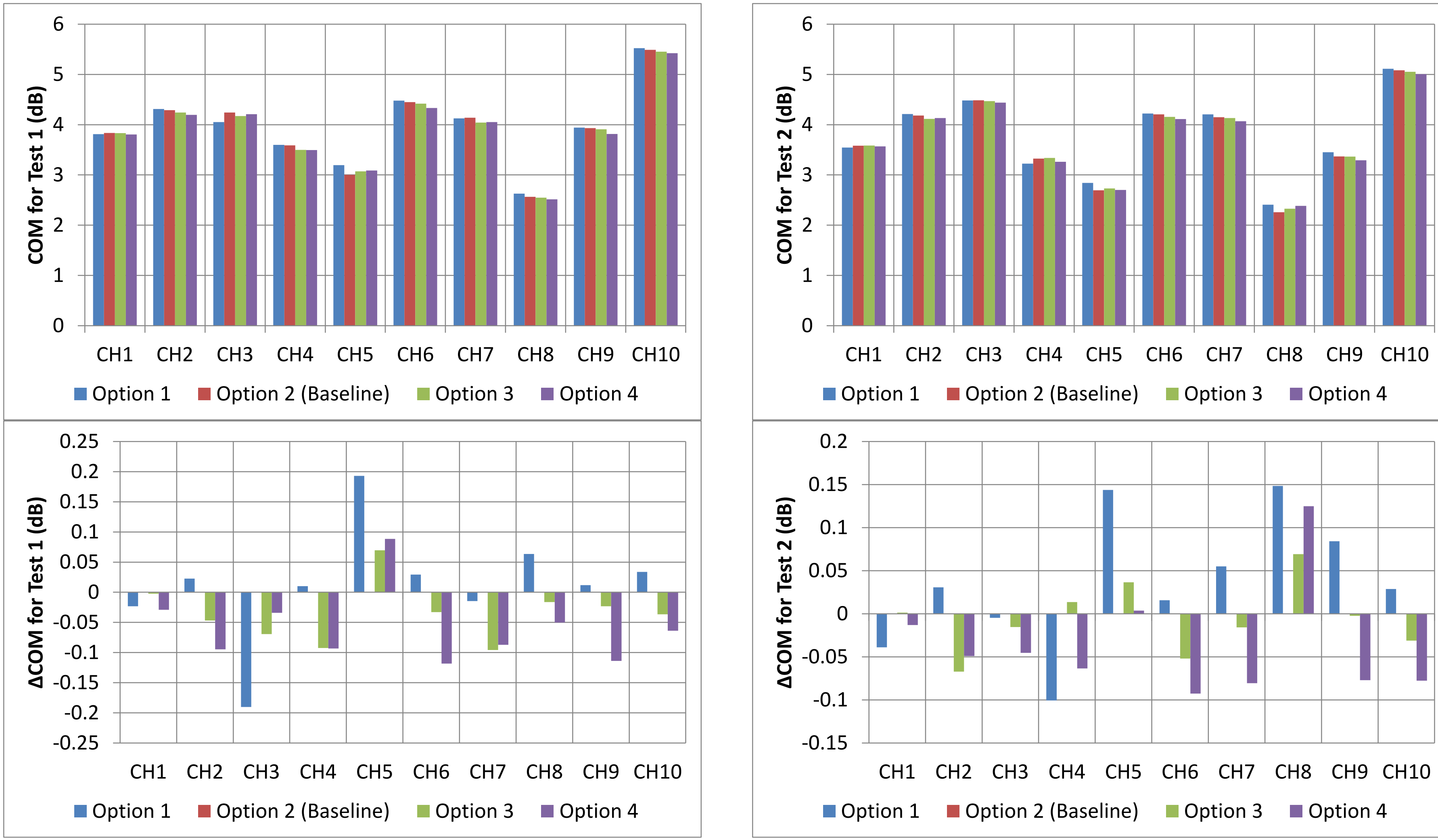
Non standard control options		
COM_CONTRIBUTION	0	logical
TDR	1	logical
ERL	1	logical
Z_t	50	ohms
ERL_ONLY	0	logical
TR_TDR	0.0189	ns
TDR_duration	5	
TDR_f_BT_3db	19.921875	GHz
TDR_Butterworth	1	logical

Table 93A–3 parameters		
Parameter	Setting	Units
package_tl_gamma0_a1_a2	[0 1.734e-3 1.455e-4]	
package_tl_tau	6.141E-03	ns/mm
package_Z_c	95	Ohm

Table 92–12 parameters		
Parameter	Setting	
board_tl_gamma0_a1_a2	[0 4.114e-4 2.547e-4]	
board_tl_tau	6.191E-03	ns/mm
board_Z_c	110	Ohm
z_bp (TX)	151	mm
z_bp (NEXT)	72	mm
z_bp (FEXT)	72	mm
z_bp (RX)	151	mm

Effects of Poles on COM for C2C Channels

- Goes up or down a little, depending on the channel
  - Any option seems acceptable



Distinction of Reference CTLE

- Reference CTLE in 120E
  - Used for observation of Tx output
    - Cancels insertion loss in the measurement path from Tx to scope
  - Does not necessarily model the actual CTLE in Rx
    - If they are matched, we can estimate Rx internal eye, but it is not primary use
  - Bandwidth is critical, and should be sufficiently high
    - CTLE bandwidth should not limit the Tx performance

- Reference CTLE in 120D
  - Used for channel specification (COM) and Rx specification (Rx ITT)
  - Models the actual CTLE in Rx
  - Bandwidth is not critical, because DFE is used together

- Bandwidth of 120E Ref CTLE should be higher than 120D
  - Or, at least same as 120D, but currently it is lower than 120D

Conclusions

- For 120E, I recommend to take option 3
  - Increase $P_1/2\pi$ to $1 * fb$ (= f_{p2} of CEI-56G-MR-PAM4)
  - And reduce insertion loss of attenuator from 14.2dB to 12.2dB
    - Or, clearly write in 120E.3.4.1 that the output of PGEN may exceed 900 mV

- For 120D, I have no strong recommendation
  - No change is required
    - The effect of each option on the performance is rather small, anyway
  - If alignment of reference CTLE pole to 120E is preferred, I recommend to take option 3 (or same option as 120E)
    - Change f_{p1} to $0.531 f_b$ and f_{p2} to $1 f_b$
  - If alignment of reference CTLE pole to OIF CEI-MR-PAM4 is preferred, I recommend to take option 4
    - Change f_{p2} to $1 f_b$

Items to decide and options

- Annex 120E
  - Poles of reference CTLE in Annex 120E (options in slide 7-11)
    - Option 1 (slide 8)
    - Option 2 (slide 9)
    - Option 3 (slide 10)
    - Option 4 (slide 11)
    - No change (slide 7)
  - Insertion loss of attenuator of 120E.3.4.1 module stressed input test
    - 10.5dB (only channel = 151mm PCB trace + MTF, no host package)
    - 12.2dB (10.5dB for channel + host package ~ 30mm)
    - 14.2dB (10.5dB for channel + host package ~ 58mm), add note for PGEN output
    - No change (14.2dB)
- Annex 120D
  - Poles of reference CTLE in Annex 120D (options in slide 25)
    - Option 1
    - Option 3
    - Option 4
    - No change (option 2)

Back up Slides

- Formula of exact Z_1 for unity peak gain of ref CTLE
- CTLE peaking and TX FIR peaking
- Eye Height and Eye Amplitude

Formula of Z_1 for unity peak gain of CTLE

- Transfer function of CTLE in Annex 120E

$$H(f) = \frac{GP_1P_2P_{LF}}{Z_1Z_{LF}} \times \frac{j2\pi f + Z_1}{(j2\pi + P_1)(j2\pi + P_2)} \times \frac{j2\pi f + Z_{LF}}{j2\pi + P_{LF}}$$

- Let $|H_0|$ represents the peak gain at the peak-gain frequency f_0
- Define

$$A \equiv \left(\frac{2\pi}{Z_1}\right)^2, \quad B \equiv \left(\frac{2\pi}{Z_{LF}}\right)^2, \quad C \equiv \left(\frac{2\pi}{P_1}\right)^2, \quad D \equiv \left(\frac{2\pi}{P_2}\right)^2, \quad E \equiv \left(\frac{2\pi}{P_{LF}}\right)^2$$

$$A_0 = A{f_0}^2 + 1, \quad B_0 = B{f_0}^2 + 1, \quad C_0 = C{f_0}^2 + 1, \quad D_0 = D{f_0}^2 + 1, \quad E_0 = E{f_0}^2 + 1$$

- For $\left.\frac{\partial |H|}{\partial f}\right|_{f=f_0} = 0,$

$$A = \frac{-BC_0D_0E_0 + CB_0D_0E_0 + DB_0C_0E_0 + EB_0C_0D_0}{B_0C_0D_0E_0 + {f_0}^2BC_0D_0E_0 - {f_0}^2CB_0D_0E_0 - {f_0}^2DB_0C_0E_0 - {f_0}^2EB_0C_0D_0}$$

- For $|H(f_0)| = |H_0|,$

$$|H(f_0)|^2 = \frac{G^2A_0B_0}{C_0D_0E_0} = \frac{G^2B_0B_0}{B_0\left(2 + (C + D + E){f_0}^2 - CDE{f_0}^6\right) - C_0D_0E_0} = |H_0|^2$$

- For $|H_0| = 1,$

$$\left({f_0}^2\right)^4 + \frac{2}{B}\left({f_0}^2\right)^3 + \frac{B(G^2B - C - D - E) + CD + DE + CE}{BCDE}\left({f_0}^2\right)^2 + \frac{2(G^2 - 1)}{CDE}\left({f_0}^2\right) + \frac{G^2 - 1}{BCDE} = 0$$

- Solve this quartic equation of ${f_0}^2$, and take its positive real root as ${f_0}^2$.
- Take the square root of ${f_0}^2$ as f_0. Calculate A. $Z_1 = 2\pi/\sqrt{A}$.

CTLE and TX FIR with 30mm Package

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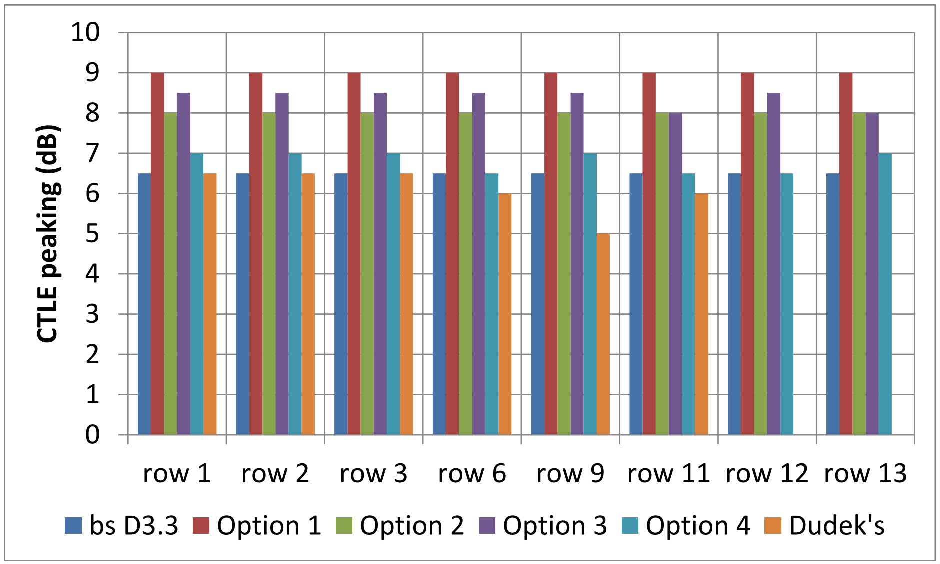
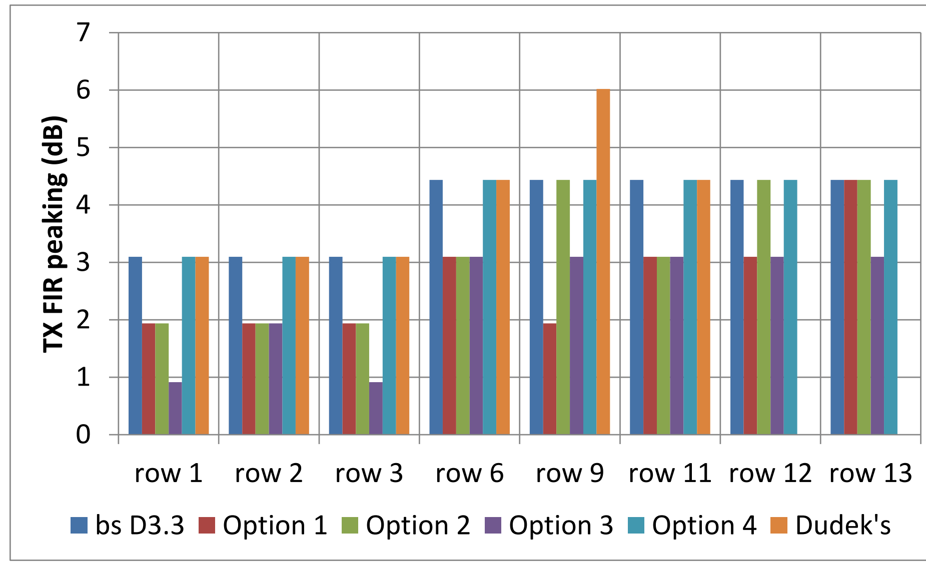
- Put higher priority on EW than EH
  - Results for D3.3 are similar to Dudek's parameters
  - For option 1~3, more CTLE peaking and less TX FIR peaking

$$\text{TX FIR peaking(dB)} = 20\log_{10}\left(\frac{|C_{-1}|+|C_0|+|C_1|}{C_{-1}+C_0+C_1}\right)$$



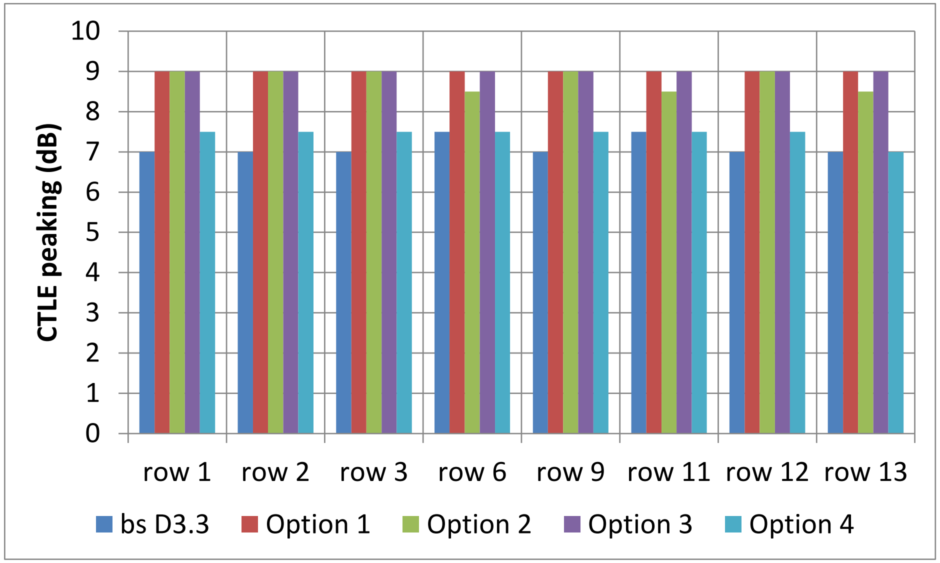


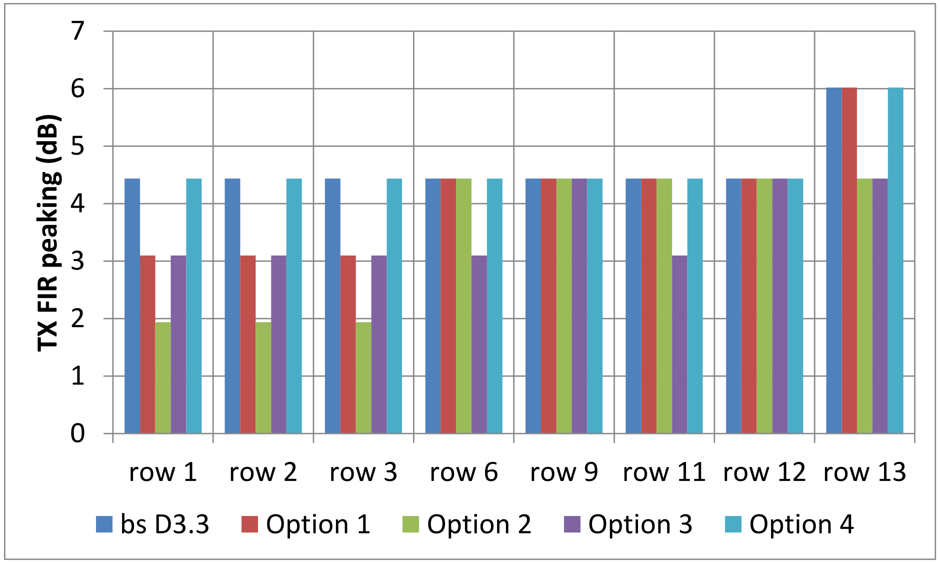
CTLE	bs D3.3	Option 1	Option 2	Option 3	Option 4	Dudek's
row 1	6.5	9.0	8.0	8.5	7.0	6.5
row 2	6.5	9.0	8.0	8.5	7.0	6.5
row 3	6.5	9.0	8.0	8.5	7.0	6.5
row 6	6.5	9.0	8.0	8.5	6.5	6.0
row 9	6.5	9.0	8.0	8.5	7.0	5.0
row 11	6.5	9.0	8.0	8.0	6.5	6.0
row 12	6.5	9.0	8.0	8.5	6.5	
row 13	6.5	9.0	8.0	8.0	7.0	

Tx FIR	bs D3.3	Option 1	Option 2	Option 3	Option 4	Dudek's
row 1	[-0.1 0.85 -0.05]	[-0.05 0.9 -0.05]	[-0.05 0.9 -0.05]	[-0.05 0.95 0]	[-0.1 0.85 -0.05]	[-0.1 0.85 -0.05]
row 2	[-0.1 0.85 -0.05]	[-0.05 0.9 -0.05]	[-0.05 0.9 -0.05]	[-0.05 0.9 -0.05]	[-0.1 0.85 -0.05]	[-0.1 0.85 -0.05]
row 3	[-0.1 0.85 -0.05]	[-0.05 0.9 -0.05]	[-0.05 0.9 -0.05]	[-0.05 0.95 0]	[-0.1 0.85 -0.05]	[-0.1 0.85 -0.05]
row 6	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.85 -0.05]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]
row 9	[-0.1 0.8 -0.1]	[-0.05 0.9 -0.05]	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]	[-0.1 0.75 -0.15]
row 11	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.85 -0.05]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]
row 12	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]	
row 13	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]	

CTLE and TX FIR with 58mm Package

- Put higher priority on EW than EH
  - For option 1~3, more CTLE peaking and less TX FIR peaking



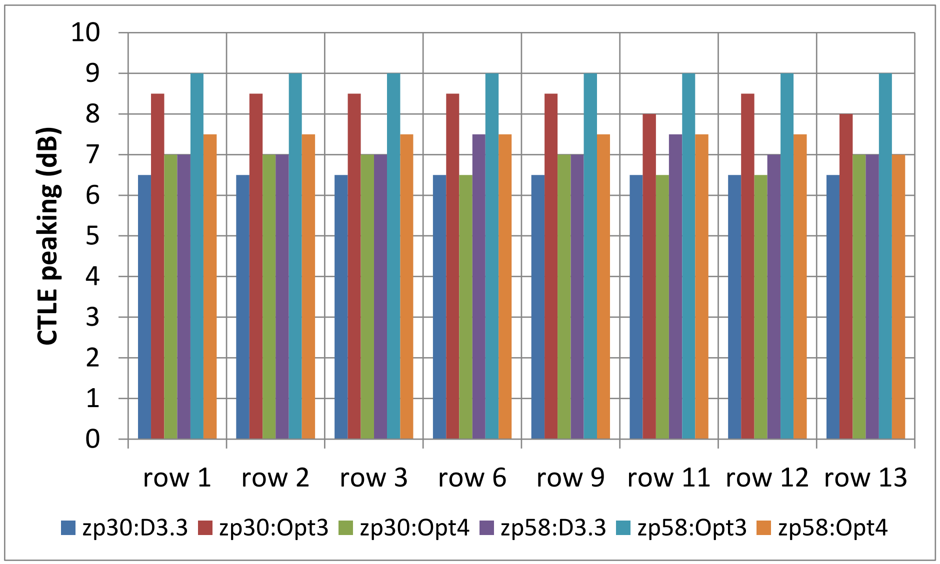


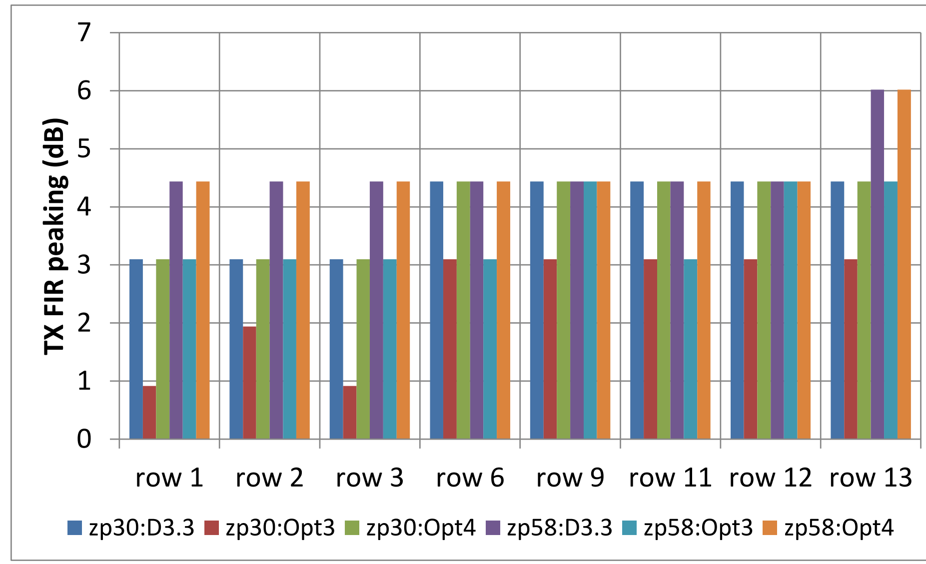
CTLE	bs D3.3	Option 1	Option 2	Option 3	Option 4
row 1	7.0	9.0	9.0	9.0	7.5
row 2	7.0	9.0	9.0	9.0	7.5
row 3	7.0	9.0	9.0	9.0	7.5
row 6	7.5	9.0	8.5	9.0	7.5
row 9	7.0	9.0	9.0	9.0	7.5
row 11	7.5	9.0	8.5	9.0	7.5
row 12	7.0	9.0	9.0	9.0	7.5
row 13	7.0	9.0	8.5	9.0	7.0

Tx FIR	bs D3.3	Option 1	Option 2	Option 3	Option 4
row 1	[-0.1 0.8 -0.1]	[-0.05 0.85 -0.1]	[-0.05 0.9 -0.05]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]
row 2	[-0.1 0.8 -0.1]	[-0.05 0.85 -0.1]	[-0.05 0.9 -0.05]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]
row 3	[-0.1 0.8 -0.1]	[-0.05 0.85 -0.1]	[-0.05 0.9 -0.05]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]
row 6	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]
row 9	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]
row 11	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]
row 12	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]
row 13	[-0.1 0.75 -0.15]	[-0.1 0.75 -0.15]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.75 -0.15]

CTLE & TX FIR with 30mm or 58mm Package

- With option 3, more CTLE peaking, less TX FIR peaking





zp (mm)	30			58		
CTLE (dB)	bs D3.3	Option 3	Option 4	bs D3.3	Option 3	Option 4
row 1	6.5	8.5	7.0	7.0	9.0	7.5
row 2	6.5	8.5	7.0	7.0	9.0	7.5
row 3	6.5	8.5	7.0	7.0	9.0	7.5
row 6	6.5	8.5	6.5	7.5	9.0	7.5
row 9	6.5	8.5	7.0	7.0	9.0	7.5
row 11	6.5	8.0	6.5	7.5	9.0	7.5
row 12	6.5	8.5	6.5	7.0	9.0	7.5
row 13	6.5	8.0	7.0	7.0	9.0	7.0

zp (mm)	30			58		
TXFIR(dB)	bs D3.3	Option 3	Option 4	bs D3.3	Option 3	Option 4
row 1	[-0.1 0.85 -0.05]	[-0.05 0.95 0]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]
row 2	[-0.1 0.85 -0.05]	[-0.05 0.9 -0.05]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]
row 3	[-0.1 0.85 -0.05]	[-0.05 0.95 0]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]
row 6	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]
row 9	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]
row 11	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]
row 12	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]
row 13	[-0.1 0.8 -0.1]	[-0.1 0.85 -0.05]	[-0.1 0.8 -0.1]	[-0.1 0.75 -0.15]	[-0.1 0.8 -0.1]	[-0.1 0.75 -0.15]

Eye Height with 30mm Package

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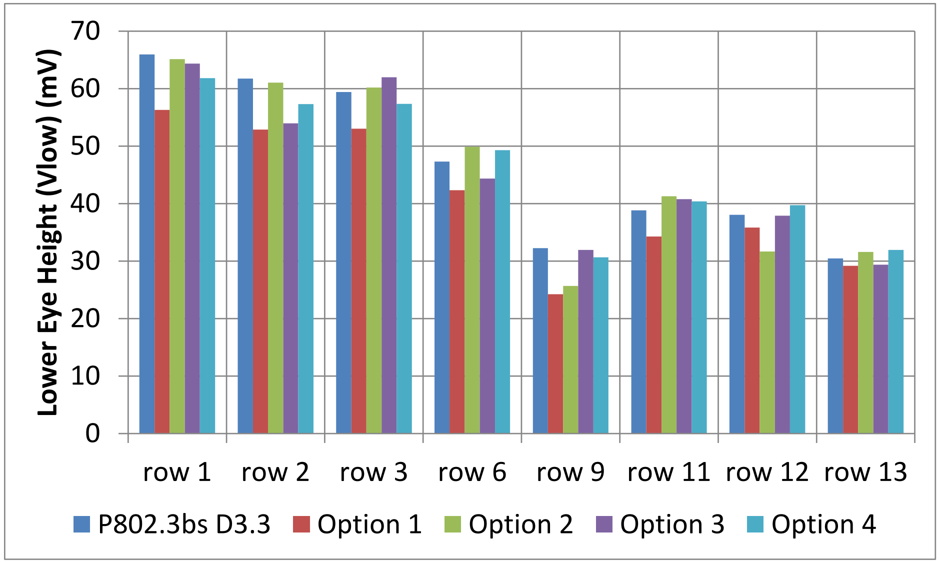
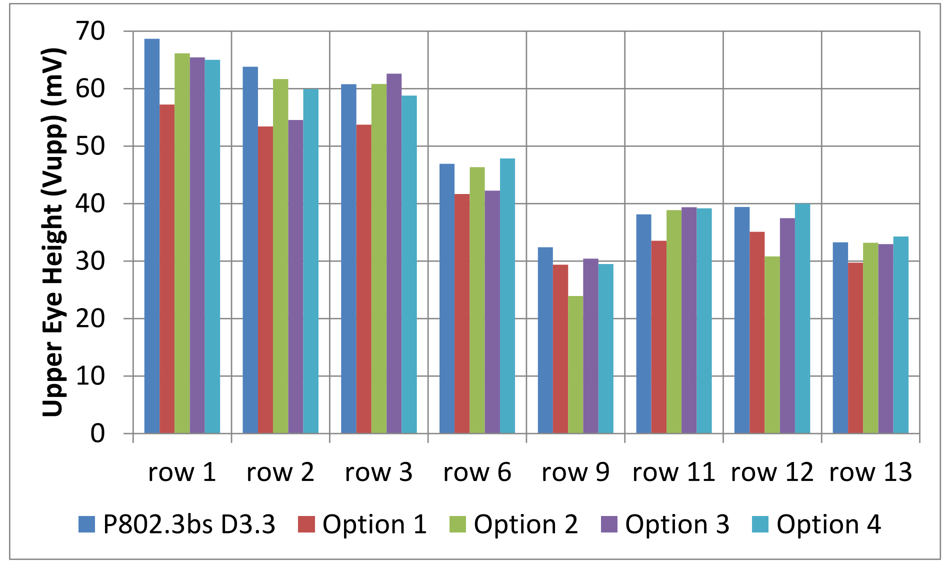
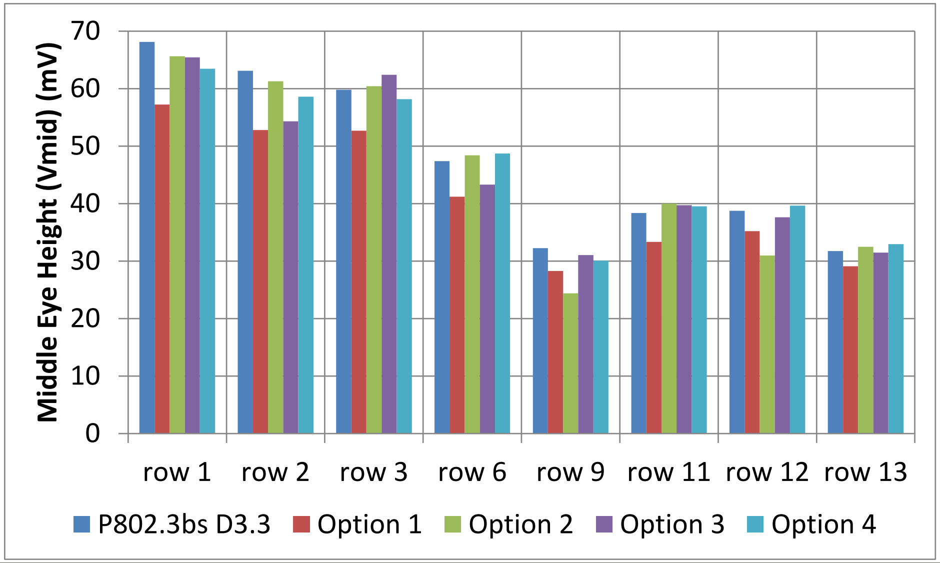
- Drops for all options, most significantly for option 1







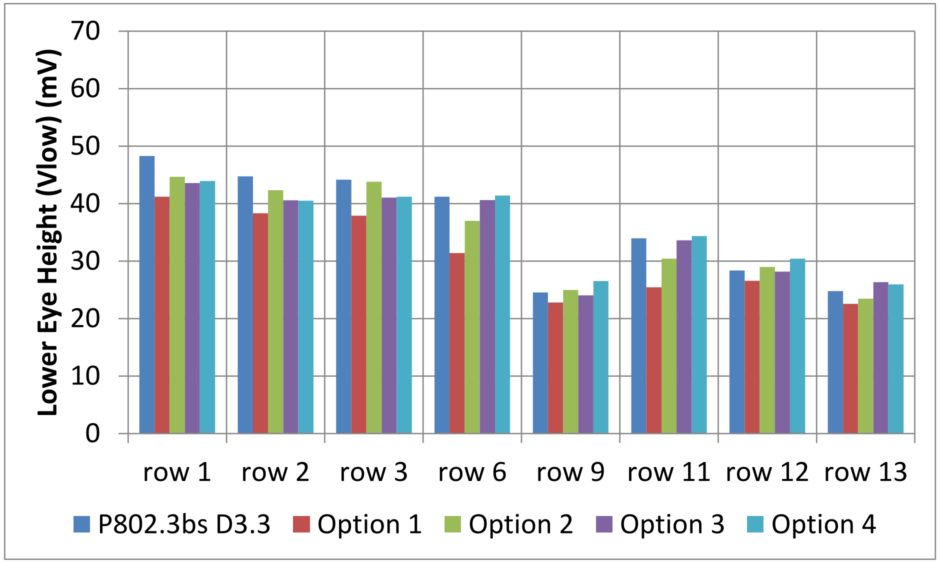
Lower (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	65.9	56.3	65.1	64.4	61.8
row 2	61.8	52.9	61.1	54.0	57.3
row 3	59.4	53.0	60.2	62.0	57.3
row 6	47.3	42.3	49.9	44.4	49.3
row 9	32.3	24.3	25.7	32.0	30.7
row 11	38.8	34.3	41.3	40.8	40.4
row 12	38.0	35.9	31.7	37.9	39.7
row 13	30.5	29.2	31.6	29.4	31.9

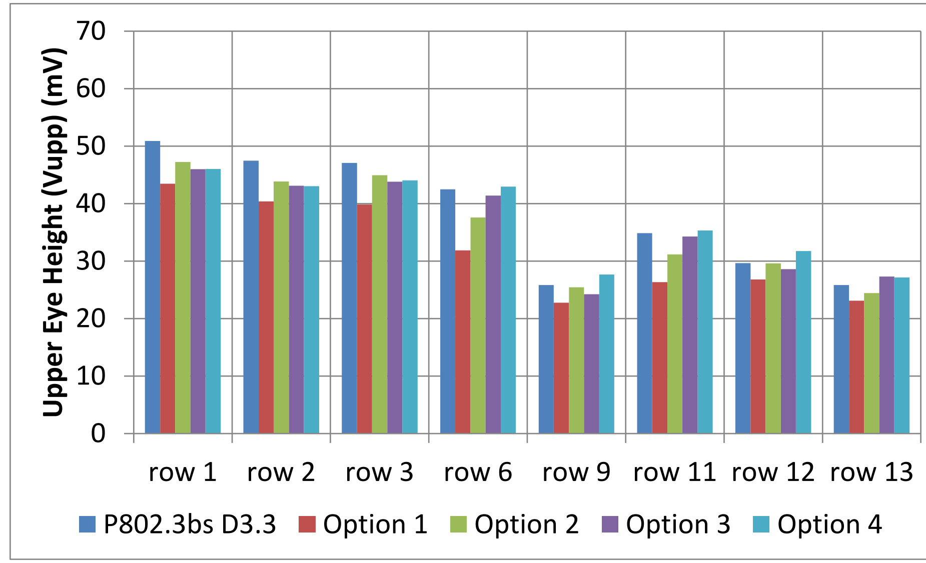
Upper (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	68.7	57.2	66.2	65.5	65.0
row 2	63.8	53.4	61.7	54.6	59.9
row 3	60.8	53.7	60.8	62.6	58.8
row 6	46.9	41.7	46.3	42.3	47.8
row 9	32.4	29.4	23.9	30.4	29.5
row 11	38.1	33.6	38.9	39.4	39.2
row 12	39.4	35.1	30.8	37.5	40.0
row 13	33.3	29.7	33.2	32.9	34.3

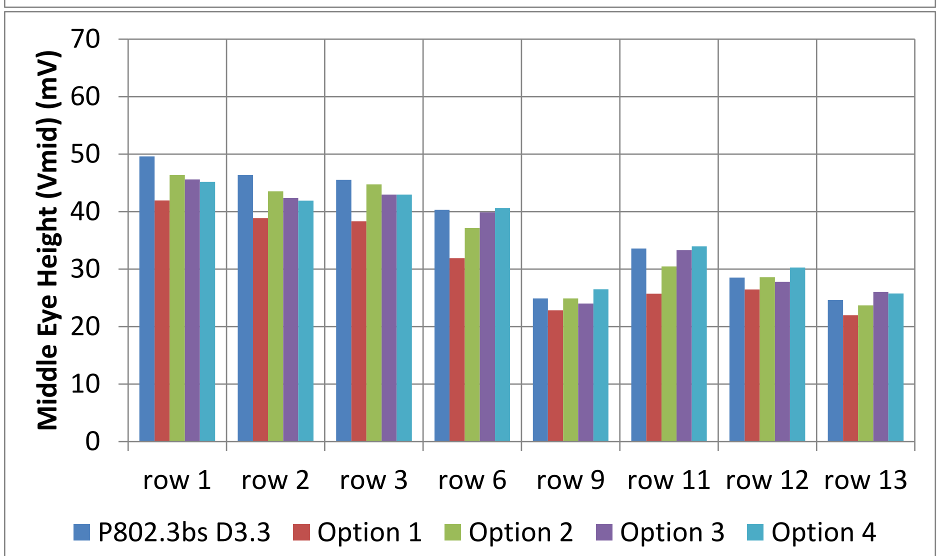
Middle (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	68.1	57.2	65.7	65.5	63.5
row 2	63.1	52.8	61.3	54.3	58.6
row 3	59.8	52.7	60.4	62.4	58.2
row 6	47.4	41.2	48.4	43.3	48.7
row 9	32.2	28.3	24.4	31.0	30.1
row 11	38.4	33.3	40.0	39.7	39.5
row 12	38.7	35.2	31.0	37.6	39.7
row 13	31.8	29.1	32.5	31.5	33.0

Eye Height with 58mm Package

- Drops for all options, most significantly for option 1







Lower (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	48.3	41.2	44.7	43.6	43.9
row 2	44.7	38.3	42.3	40.6	40.5
row 3	44.2	37.9	43.8	41.1	41.2
row 6	41.2	31.4	37.0	40.6	41.4
row 9	24.6	22.8	25.0	24.0	26.5
row 11	34.0	25.4	30.4	33.6	34.3
row 12	28.3	26.6	29.0	28.2	30.4
row 13	24.8	22.6	23.4	26.3	25.9

Upper (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	50.9	43.5	47.2	46.0	46.0
row 2	47.5	40.4	43.8	43.1	43.0
row 3	47.1	39.8	44.9	43.8	44.0
row 6	42.5	31.9	37.6	41.4	43.0
row 9	25.8	22.8	25.4	24.2	27.6
row 11	34.9	26.3	31.2	34.3	35.3
row 12	29.6	26.8	29.6	28.6	31.7
row 13	25.8	23.1	24.4	27.3	27.2

Middle (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	49.6	42.0	46.4	45.6	45.2
row 2	46.4	38.9	43.5	42.4	41.9
row 3	45.5	38.3	44.8	42.9	43.0
row 6	40.3	31.9	37.2	39.9	40.6
row 9	24.9	22.9	24.9	24.0	26.5
row 11	33.6	25.7	30.5	33.3	34.0
row 12	28.5	26.4	28.6	27.8	30.3
row 13	24.6	22.0	23.7	26.0	25.8

Eye Amplitude with 30mm Package

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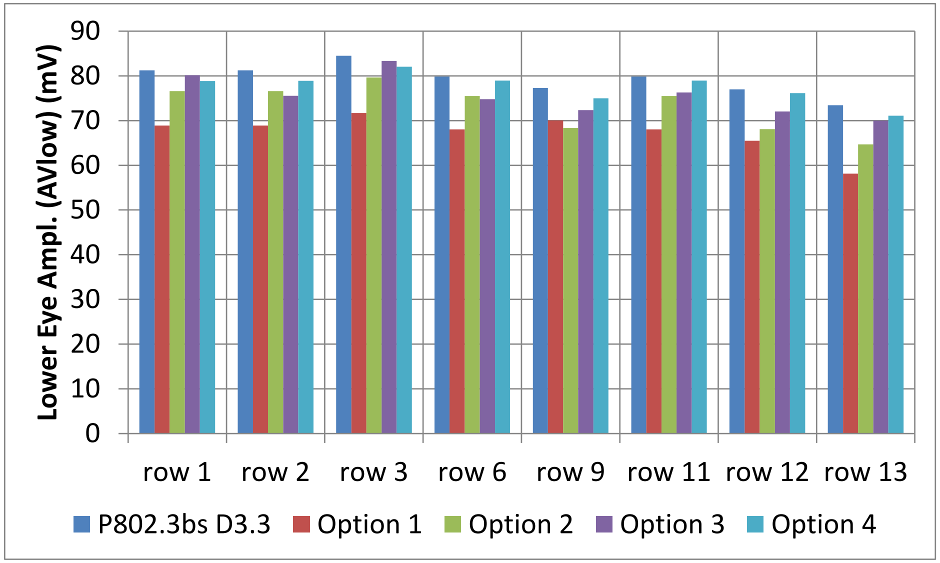
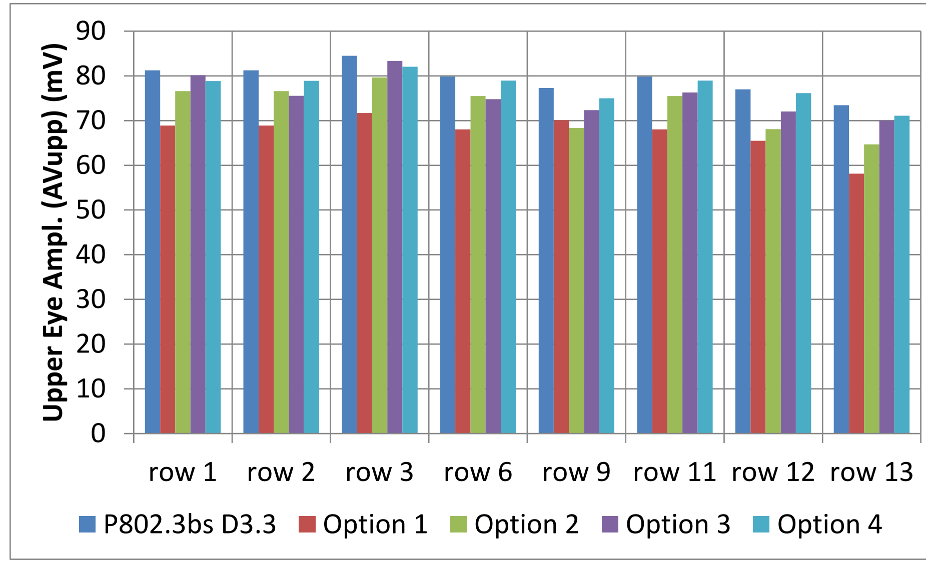
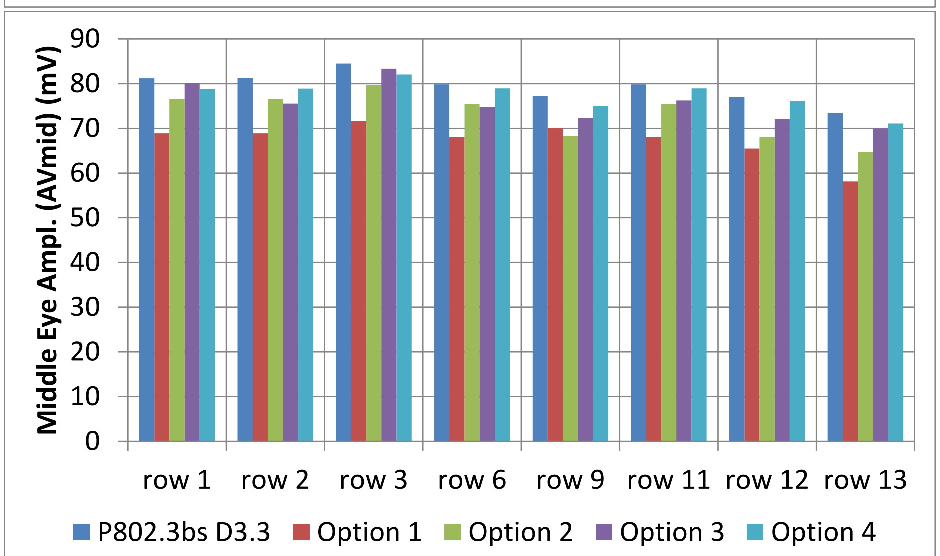
- Drops for all options, most significantly for option 1







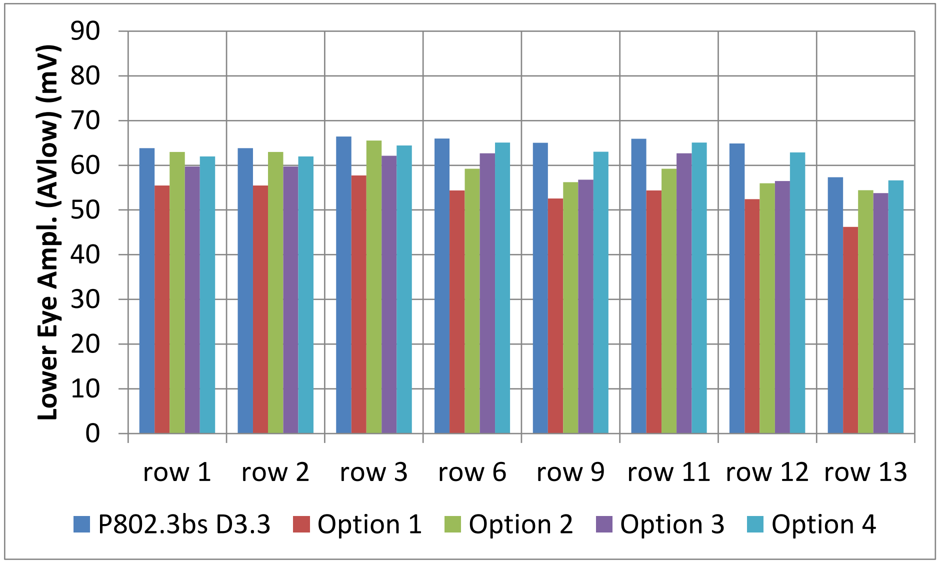
Lower (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	81.2	68.9	76.6	80.1	78.8
row 2	81.2	68.9	76.6	75.5	78.9
row 3	84.5	71.7	79.7	83.4	82.1
row 6	79.8	68.0	75.5	74.8	78.9
row 9	77.3	70.1	68.4	72.3	75.0
row 11	79.8	68.0	75.5	76.3	79.0
row 12	77.0	65.5	68.1	72.0	76.1
row 13	73.4	58.1	64.7	70.0	71.1

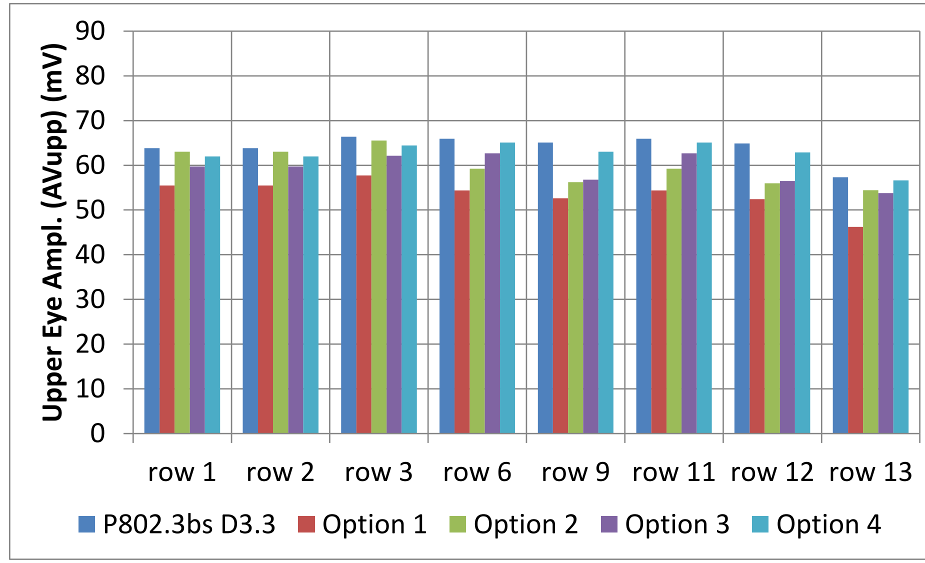
Upper (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	81.2	68.9	76.6	80.2	78.9
row 2	81.2	68.9	76.6	75.5	78.9
row 3	84.5	71.7	79.7	83.4	82.1
row 6	79.8	68.0	75.5	74.8	78.9
row 9	77.3	70.1	68.4	72.3	75.0
row 11	79.8	68.0	75.5	76.3	79.0
row 12	77.0	65.5	68.1	72.0	76.1
row 13	73.4	58.1	64.7	70.0	71.1

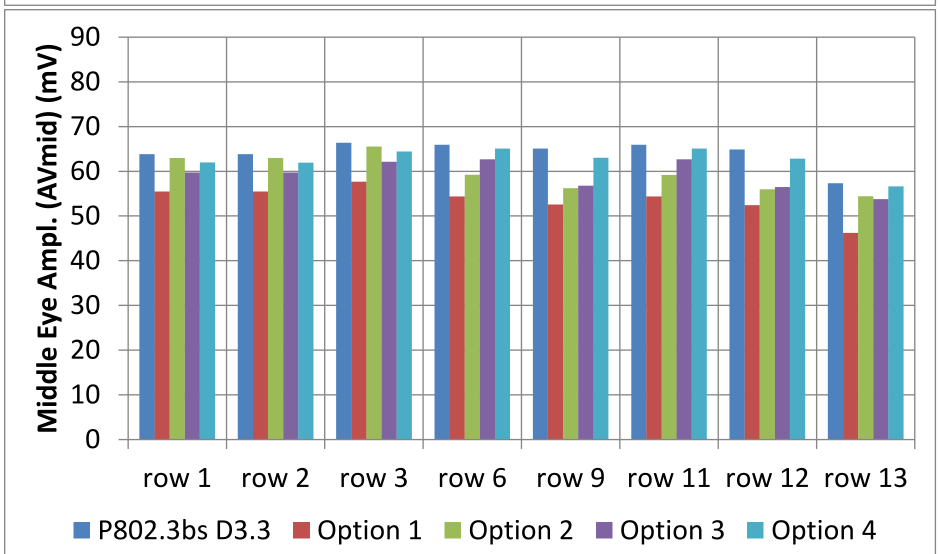
Middle (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	81.2	68.9	76.6	80.2	78.8
row 2	81.2	68.9	76.6	75.5	78.9
row 3	84.5	71.7	79.6	83.3	82.1
row 6	79.8	68.0	75.5	74.8	78.9
row 9	77.3	70.1	68.4	72.3	75.0
row 11	79.8	68.0	75.5	76.3	78.9
row 12	77.0	65.5	68.1	72.0	76.1
row 13	73.4	58.1	64.7	70.0	71.1

Eye Amplitude with 58mm Package

- Drops for all options, most significantly for option 1







Lower (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	63.8	55.5	63.0	59.7	62.0
row 2	63.8	55.5	63.0	59.7	62.0
row 3	66.4	57.7	65.5	62.1	64.5
row 6	66.0	54.4	59.2	62.7	65.1
row 9	65.1	52.6	56.2	56.8	63.0
row 11	66.0	54.4	59.2	62.7	65.1
row 12	64.9	52.4	56.0	56.5	62.9
row 13	57.3	46.2	54.4	53.8	56.6

Upper (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	63.8	55.5	63.0	59.7	62.0
row 2	63.9	55.5	63.0	59.7	62.0
row 3	66.4	57.7	65.5	62.1	64.4
row 6	66.0	54.4	59.2	62.7	65.1
row 9	65.1	52.6	56.2	56.8	63.0
row 11	66.0	54.4	59.2	62.7	65.1
row 12	64.9	52.4	56.0	56.5	62.9
row 13	57.3	46.2	54.4	53.8	56.6

Middle (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	63.8	55.5	63.0	59.7	62.0
row 2	63.8	55.5	63.0	59.7	62.0
row 3	66.4	57.7	65.5	62.1	64.4
row 6	66.0	54.4	59.2	62.7	65.1
row 9	65.1	52.6	56.2	56.8	63.0
row 11	65.9	54.4	59.2	62.7	65.1
row 12	64.9	52.4	56.0	56.5	62.9
row 13	57.3	46.2	54.4	53.8	56.6

Thank you