FUJITSU

shaping tomorrow with you

The high-frequency pole of the reference CTLE in Annex 120E (comment #r03-12, #r03-45) – Additional Simulation Results

Yasuo Hidaka
Fujitsu Laboratories of America, Inc.

IEEE P802.3bs 200GbE and 400GbE Task Force
Electrical Ad Hoc, September 7, 2017

Overview

- In the previous P802.3bs Electrical Ad Hoc on August 28, I proposed to align the high-frequency pole of the reference CTLE of 120E (C2M) to that of 120D (C2C)

- This is an update to my previous presentation reflecting some feedbacks during the previous Ad Hoc call
  - Revised EQ optimization scheme to put higher priority on EW than EH
  - Included results for 14.2dB loss using longer package trace
  - Removed results with 0.04 UI-pp DJ

- This presentation also address comment #r03-45

Comment #r03-45

FUJITSU

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

- 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

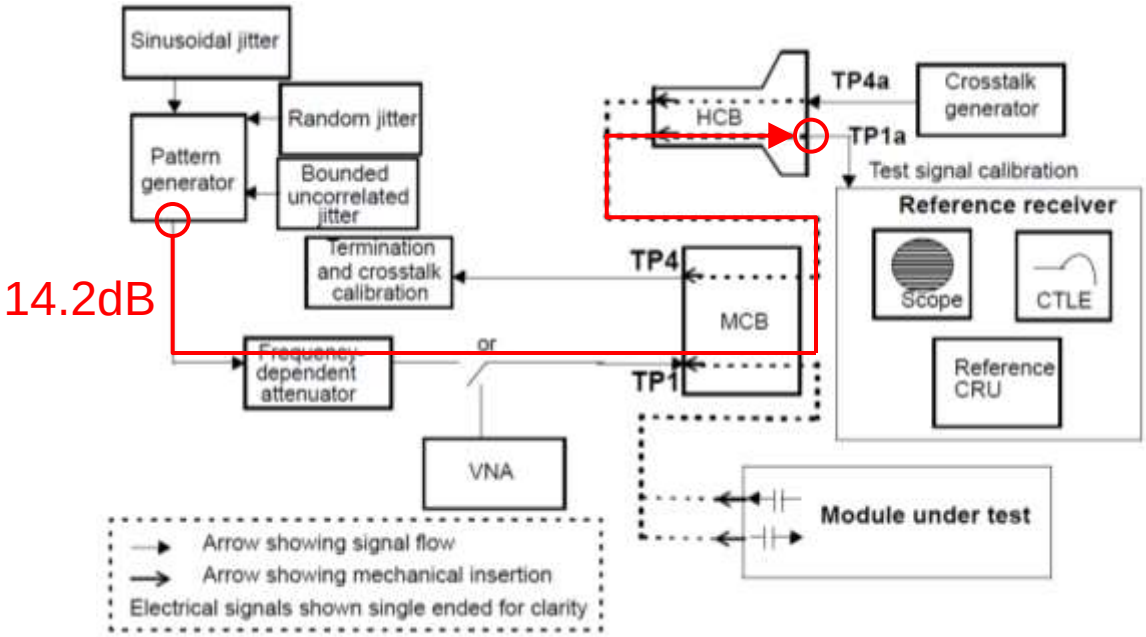
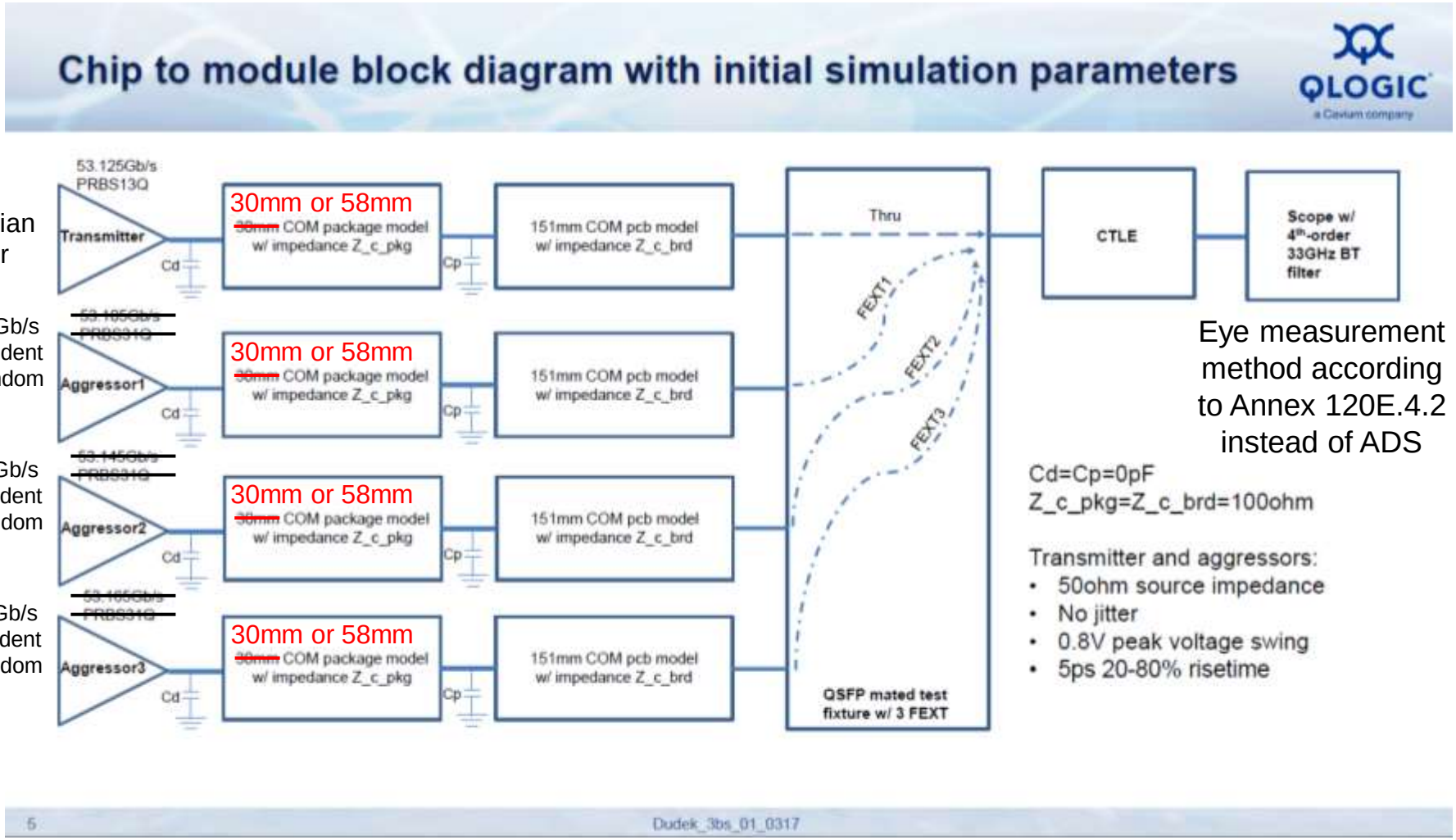


Figure 120E–12—Example module stressed input test

MATLAB Simulation Setup (Revised)

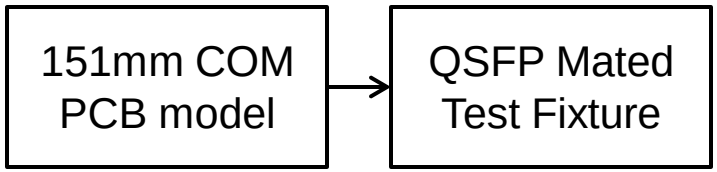
- Similar to dudek_3bs_01_0317.pdf, slide 5

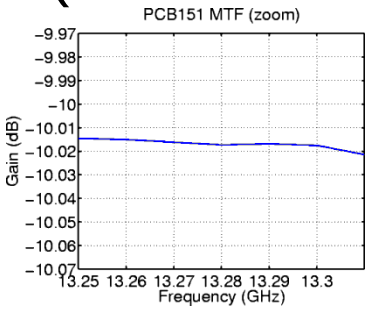


Channel IL with 30mm or 58mm Package

FUJITSU

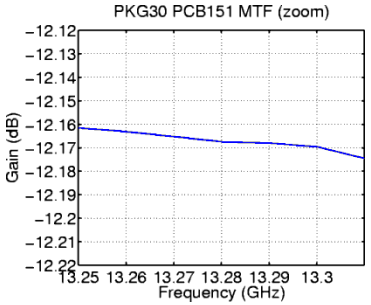
- 151mm PCB trace + Mated Test Fixture (reference w/o PKG)





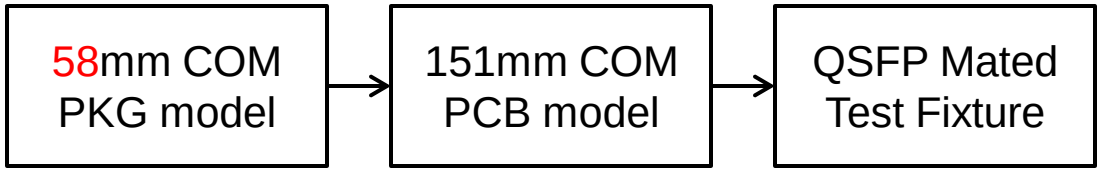
IL = 10.02dB
@ 13.28GHz

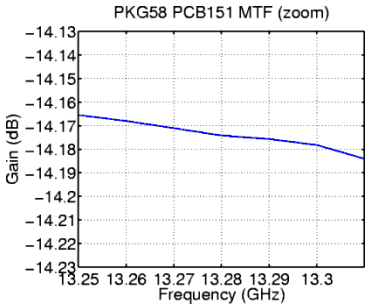
- 30mm PKG trace + 151mm PCB trace + Mated Test Fixture



IL = 12.17dB
@ 13.28GHz

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





IL = 14.17dB
@ 13.28GHz

Simulated Conditions (Revised)

- 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
~~14~~	~~0.442~~	~~55~~	~~0.18~~	~~0.11~~	~~90~~	~~109.8~~	~~32.5~~	~~0.01~~	~~0.04~~	~~Yes~~	~~13.5~~	~~DJ = 0.04UI~~

- Removed Row 14

4 Options Investigated (Same)

FUJITSU

- 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 for this is shown in a backup slide

Baseline: P802.3bs D3.3 Annex 120E (Same)

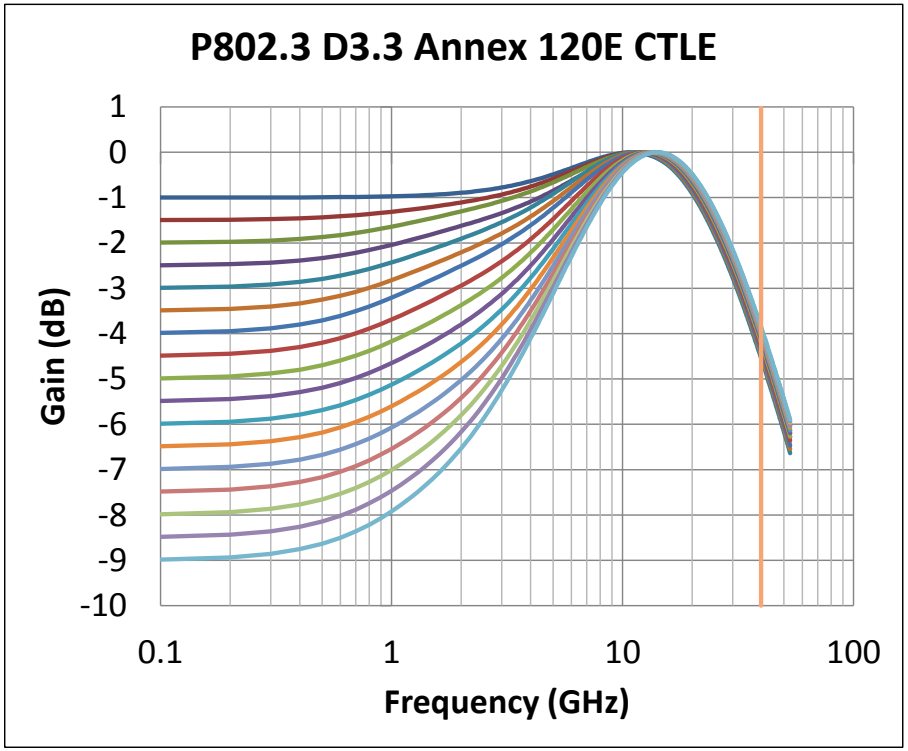
FUJITSU

- 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

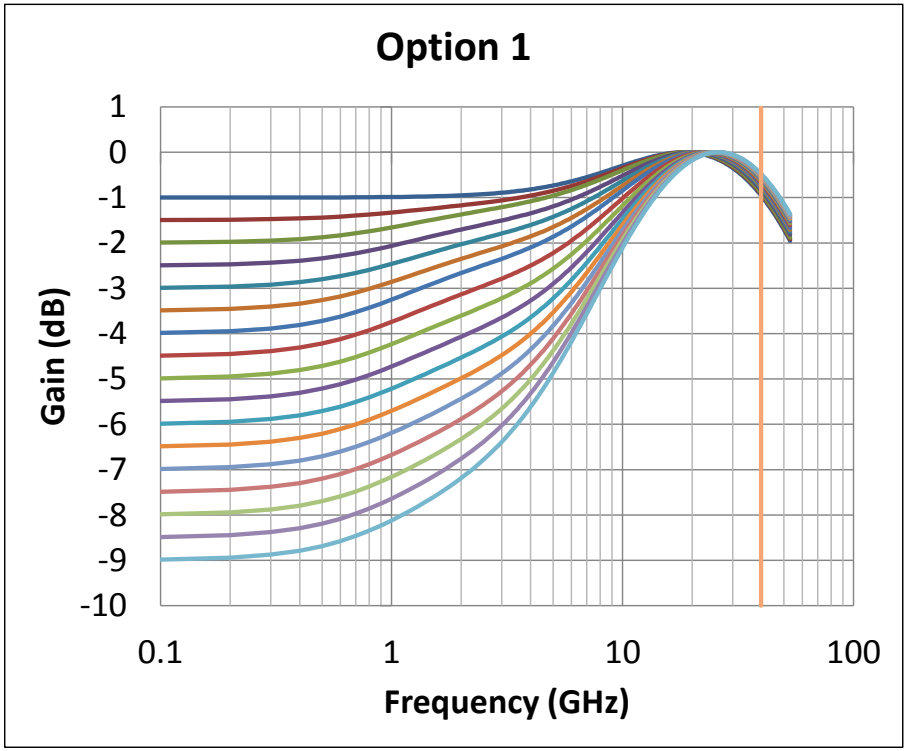
Figure 120E-9 plotted up to $2f_b$



Option 1 (Same)

- 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

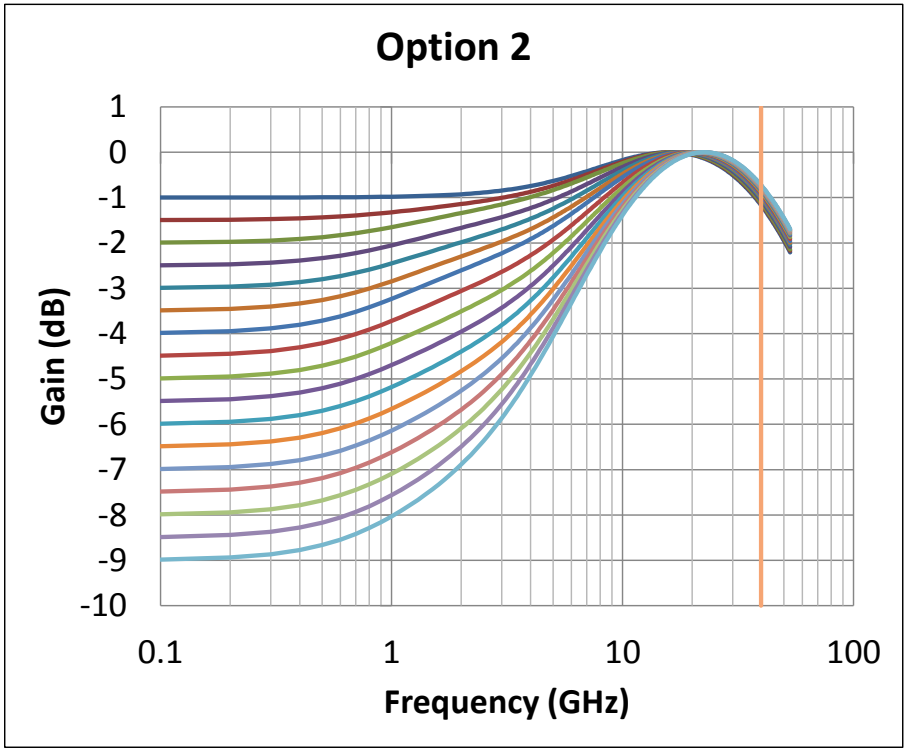
Peaking	G	P1/2pi	P2/2pi	Z1/2pi	PLF/2pi	ZLF/2pi
1.0	0.891251	53.125	14.1	10.974592	1.2	1.200
1.5	0.841395	53.125	14.1	10.756436	1.2	1.150
2.0	0.794328	53.125	14.1	10.573164	1.2	1.100
2.5	0.749894	53.125	14.1	10.117862	1.2	1.075
3.0	0.707946	53.125	14.1	9.702711	1.2	1.050
3.5	0.668344	53.125	14.1	9.320913	1.2	1.025
4.0	0.630957	53.125	14.1	8.967777	1.2	1.000
4.5	0.595662	53.125	14.1	8.393980	1.2	1.000
5.0	0.562341	53.125	14.1	7.868626	1.2	1.000
5.5	0.530884	53.125	14.1	7.384598	1.2	1.000
6.0	0.501187	53.125	14.1	6.936613	1.2	1.000
6.5	0.473151	53.125	14.1	6.520564	1.2	1.000
7.0	0.446684	53.125	14.1	6.133146	1.2	1.000
7.5	0.421697	53.125	14.1	5.771625	1.2	1.000
8.0	0.398107	53.125	14.1	5.433693	1.2	1.000
8.5	0.375837	53.125	14.1	5.117366	1.2	1.000
9.0	0.354813	53.125	14.1	4.820918	1.2	1.000



Option 2 (Same)

- 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

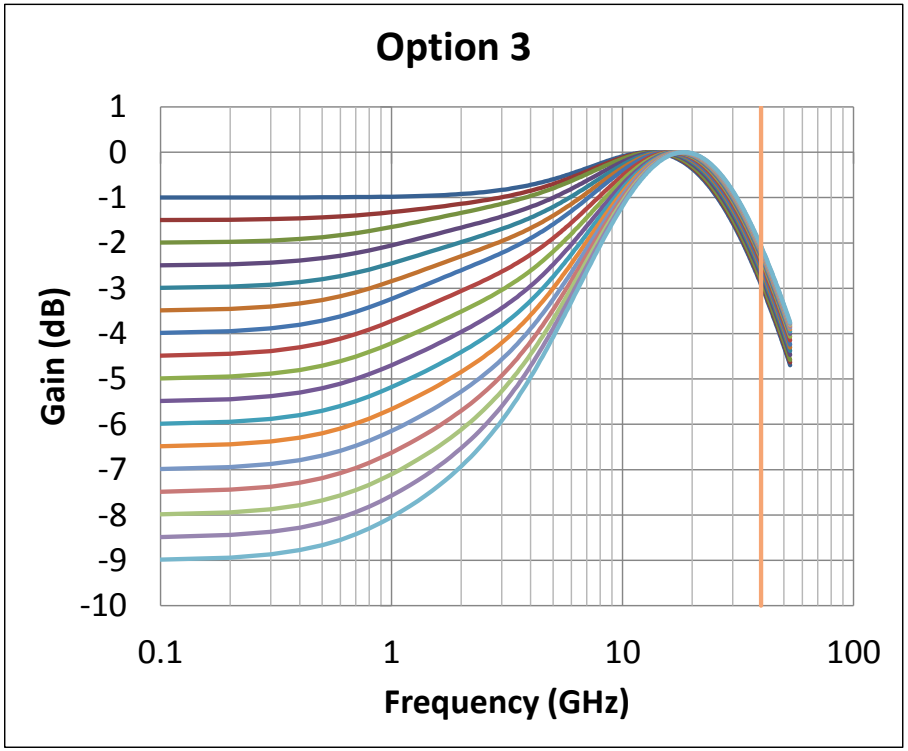
Peaking	G	P1/2pi	P2/2pi	Z1/2pi	PLF/2pi	ZLF/2pi
1.0	0.891251	53.125	10.625	8.568390	1.2	1.200
1.5	0.841395	53.125	10.625	8.406177	1.2	1.150
2.0	0.794328	53.125	10.625	8.269308	1.2	1.100
2.5	0.749894	53.125	10.625	7.927185	1.2	1.075
3.0	0.707946	53.125	10.625	7.612939	1.2	1.050
3.5	0.668344	53.125	10.625	7.322268	1.2	1.025
4.0	0.630957	53.125	10.625	7.052157	1.2	1.000
4.5	0.595662	53.125	10.625	6.610998	1.2	1.000
5.0	0.562341	53.125	10.625	6.204939	1.2	1.000
5.5	0.530884	53.125	10.625	5.829252	1.2	1.000
6.0	0.501187	53.125	10.625	5.480360	1.2	1.000
6.5	0.473151	53.125	10.625	5.155436	1.2	1.000
7.0	0.446684	53.125	10.625	4.852166	1.2	1.000
7.5	0.421697	53.125	10.625	4.568615	1.2	1.000
8.0	0.398107	53.125	10.625	4.303123	1.2	1.000
8.5	0.375837	53.125	10.625	4.054251	1.2	1.000
9.0	0.354813	53.125	10.625	3.820734	1.2	1.000



Option 3 (Same)

- 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

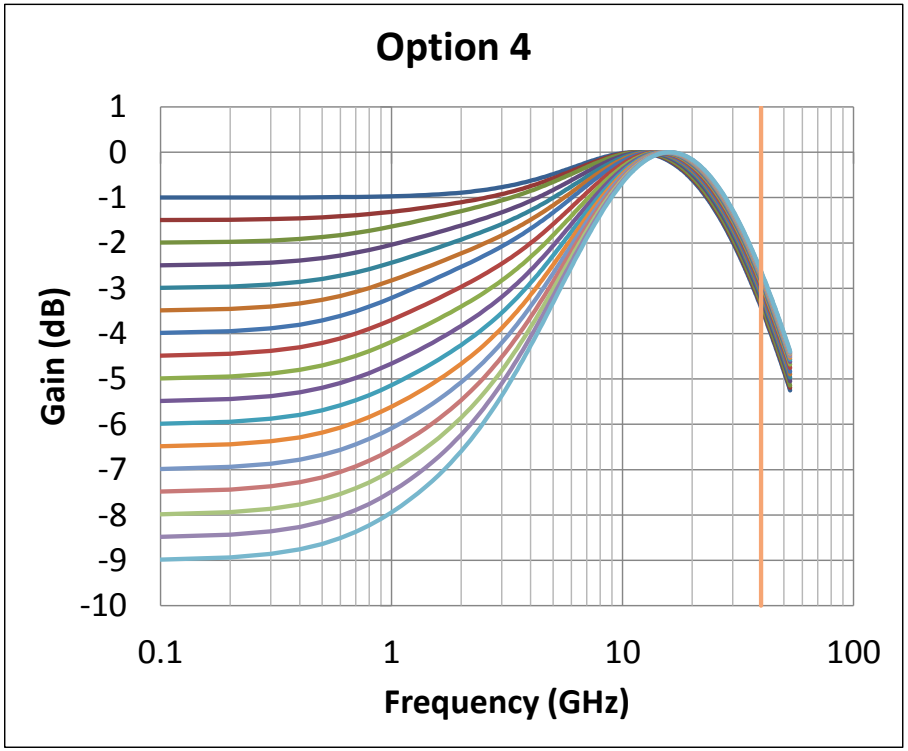
Peaking	G	P1/2pi	P2/2pi	Z1/2pi	PLF/2pi	ZLF/2pi
1.0	0.891251	26.5625	14.1	9.463748	1.2	1.200
1.5	0.841395	26.5625	14.1	9.252896	1.2	1.150
2.0	0.794328	26.5625	14.1	9.077589	1.2	1.100
2.5	0.749894	26.5625	14.1	8.648416	1.2	1.075
3.0	0.707946	26.5625	14.1	8.263874	1.2	1.050
3.5	0.668344	26.5625	14.1	7.915060	1.2	1.025
4.0	0.630957	26.5625	14.1	7.596006	1.2	1.000
4.5	0.595662	26.5625	14.1	7.083885	1.2	1.000
5.0	0.562341	26.5625	14.1	6.620838	1.2	1.000
5.5	0.530884	26.5625	14.1	6.198404	1.2	1.000
6.0	0.501187	26.5625	14.1	5.810522	1.2	1.000
6.5	0.473151	26.5625	14.1	5.452633	1.2	1.000
7.0	0.446684	26.5625	14.1	5.121171	1.2	1.000
7.5	0.421697	26.5625	14.1	4.813269	1.2	1.000
8.0	0.398107	26.5625	14.1	4.526563	1.2	1.000
8.5	0.375837	26.5625	14.1	4.259067	1.2	1.000
9.0	0.354813	26.5625	14.1	4.009088	1.2	1.000



Option 4 (Same)

- 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

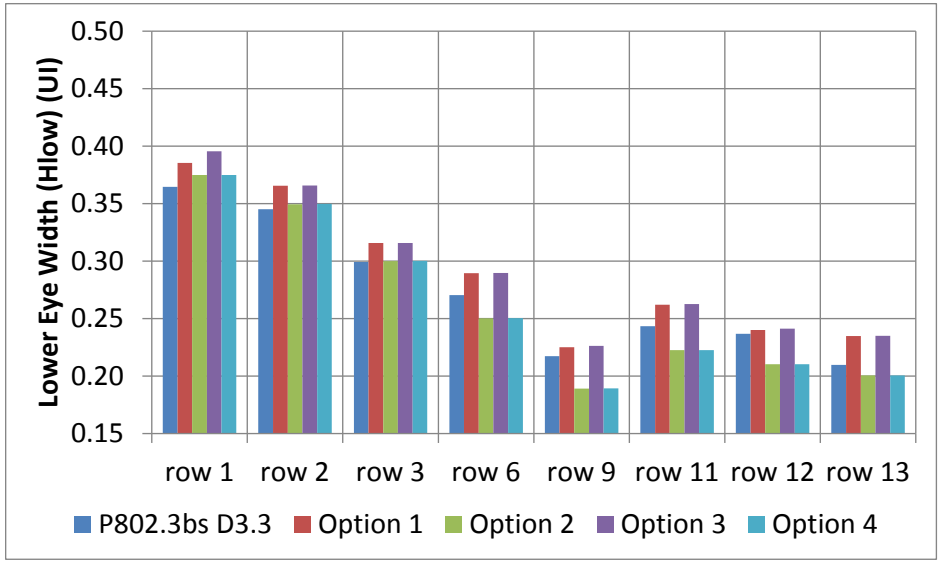
Peaking	G	P1/2pi	P2/2pi	Z1/2pi	PLF/2pi	ZLF/2pi
1.0	0.891251	26.5625	10.625	7.673726	1.2	1.200
1.5	0.841395	26.5625	10.625	7.509911	1.2	1.150
2.0	0.794328	26.5625	10.625	7.373176	1.2	1.100
2.5	0.749894	26.5625	10.625	7.036567	1.2	1.075
3.0	0.707946	26.5625	10.625	6.732960	1.2	1.050
3.5	0.668344	26.5625	10.625	6.456124	1.2	1.025
4.0	0.630957	26.5625	10.625	6.201840	1.2	1.000
4.5	0.595662	26.5625	10.625	5.791795	1.2	1.000
5.0	0.562341	26.5625	10.625	5.419289	1.2	1.000
5.5	0.530884	26.5625	10.625	5.078193	1.2	1.000
6.0	0.501187	26.5625	10.625	4.764061	1.2	1.000
6.5	0.473151	26.5625	10.625	4.473509	1.2	1.000
7.0	0.446684	26.5625	10.625	4.203868	1.2	1.000
7.5	0.421697	26.5625	10.625	3.952967	1.2	1.000
8.0	0.398107	26.5625	10.625	3.719002	1.2	1.000
8.5	0.375837	26.5625	10.625	3.500446	1.2	1.000
9.0	0.354813	26.5625	10.625	3.295987	1.2	1.000

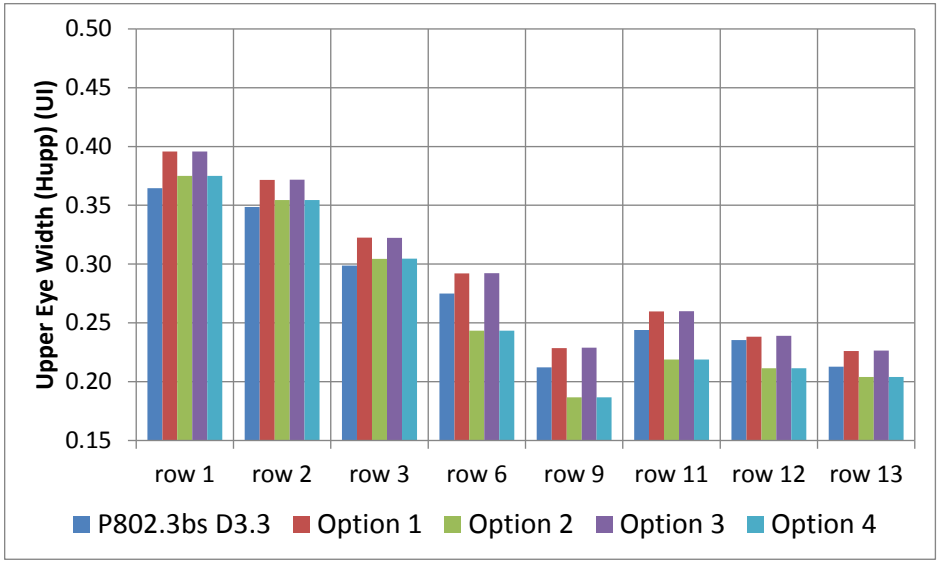


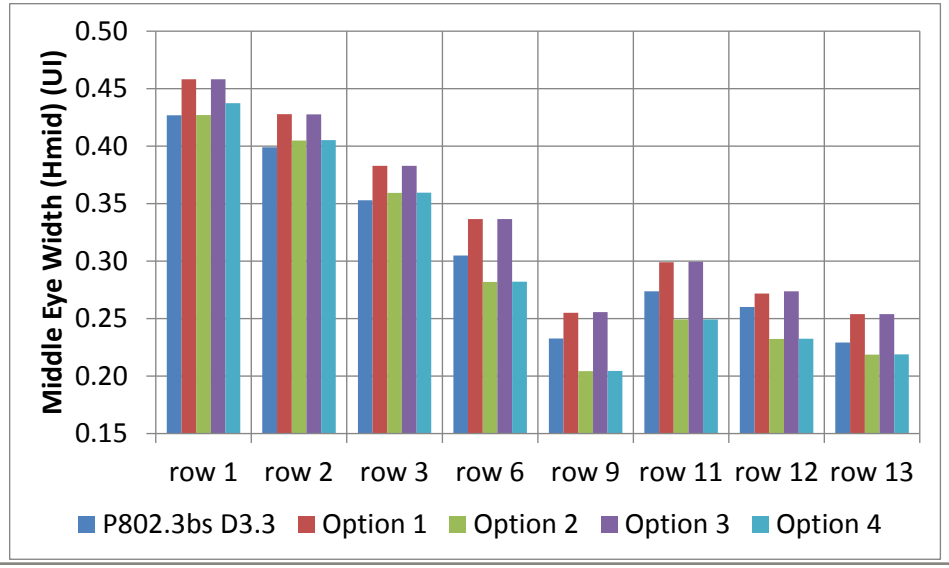
Eye Width with 30mm PKG (Previous Results)

FUJITSU

- Improved with option 1 or 3, but the improvement was small







Lower (ps)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	13.7	14.5	14.1	14.9	14.1
row 2	13.0	13.8	13.2	13.8	13.2
row 3	11.3	11.9	11.3	11.9	11.3
row 6	10.2	10.9	9.4	10.9	9.4
row 9	8.2	8.5	7.1	8.5	7.1
row 11	9.2	9.9	8.4	9.9	8.4
row 12	8.9	9.0	7.9	9.1	7.9
row 13	7.9	8.8	7.6	8.8	7.6

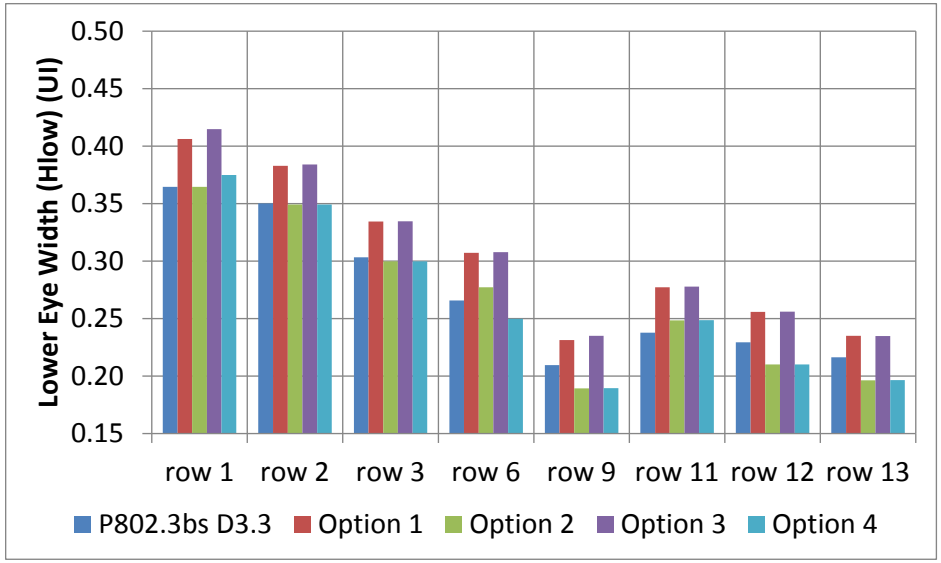
Upper (ps)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	13.7	14.9	14.1	14.9	14.1
row 2	13.1	14.0	13.3	14.0	13.3
row 3	11.2	12.1	11.5	12.1	11.5
row 6	10.4	11.0	9.2	11.0	9.2
row 9	8.0	8.6	7.0	8.6	7.0
row 11	9.2	9.8	8.2	9.8	8.2
row 12	8.9	9.0	8.0	9.0	8.0
row 13	8.0	8.5	7.7	8.5	7.7

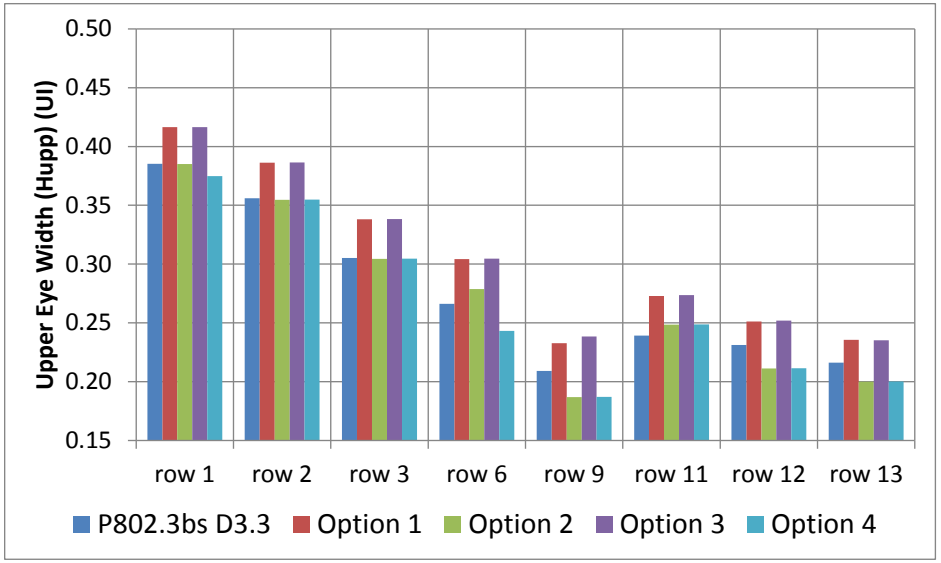
Middle (ps)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	16.1	17.3	16.1	17.3	16.5
row 2	15.0	16.1	15.2	16.1	15.3
row 3	13.3	14.4	13.5	14.4	13.5
row 6	11.5	12.7	10.6	12.7	10.6
row 9	8.8	9.6	7.7	9.6	7.7
row 11	10.3	11.3	9.4	11.3	9.4
row 12	9.8	10.2	8.7	10.3	8.7
row 13	8.6	9.6	8.2	9.6	8.2

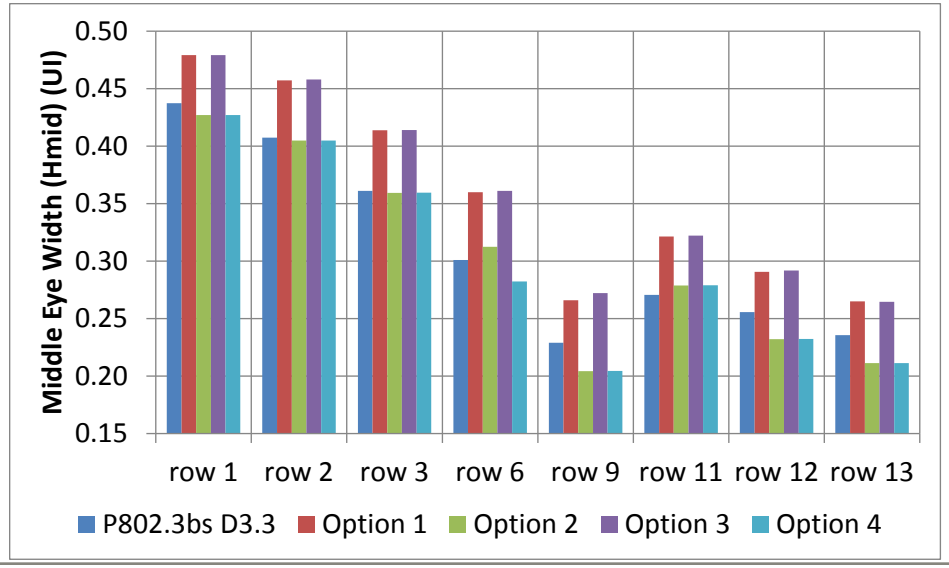
Eye Width with 30mm PKG (New Results)

FUJITSU

- More distinctive improvement with option 1 & 3







Lower (ps)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	13.7	15.3	13.7	15.6	14.1
row 2	13.2	14.4	13.1	14.5	13.1
row 3	11.4	12.6	11.3	12.6	11.3
row 6	10.0	11.6	10.4	11.6	9.4
row 9	7.9	8.7	7.1	8.8	7.1
row 11	9.0	10.4	9.4	10.5	9.4
row 12	8.6	9.6	7.9	9.6	7.9
row 13	8.1	8.8	7.4	8.8	7.4

Upper (ps)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	14.5	15.7	14.5	15.7	14.1
row 2	13.4	14.5	13.4	14.5	13.4
row 3	11.5	12.7	11.5	12.7	11.5
row 6	10.0	11.5	10.5	11.5	9.2
row 9	7.9	8.8	7.0	9.0	7.0
row 11	9.0	10.3	9.4	10.3	9.4
row 12	8.7	9.5	8.0	9.5	8.0
row 13	8.1	8.9	7.5	8.9	7.5

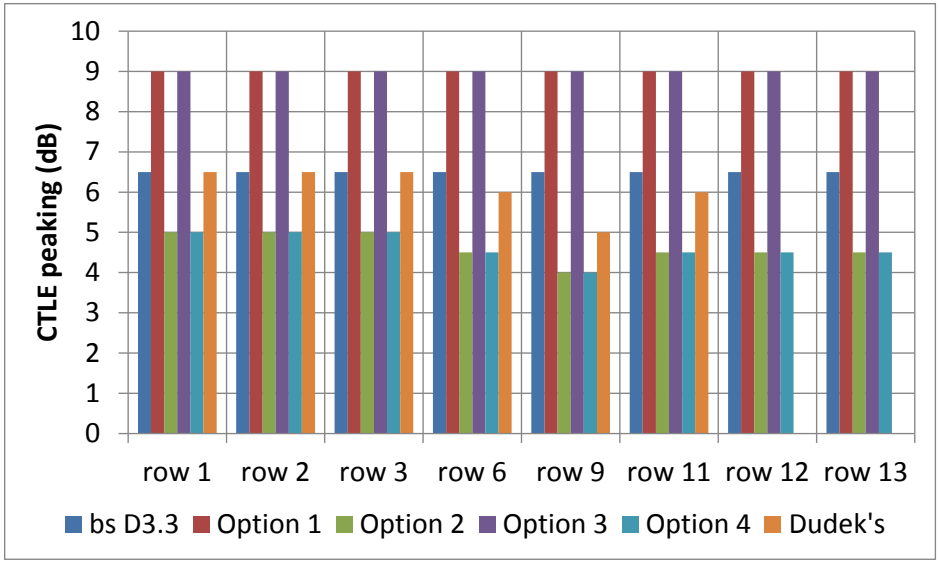
Middle (ps)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	16.5	18.0	16.1	18.0	16.1
row 2	15.3	17.2	15.2	17.2	15.2
row 3	13.6	15.6	13.5	15.6	13.5
row 6	11.3	13.5	11.8	13.6	10.6
row 9	8.6	10.0	7.7	10.2	7.7
row 11	10.2	12.1	10.5	12.1	10.5
row 12	9.6	10.9	8.7	11.0	8.7
row 13	8.9	10.0	8.0	10.0	8.0

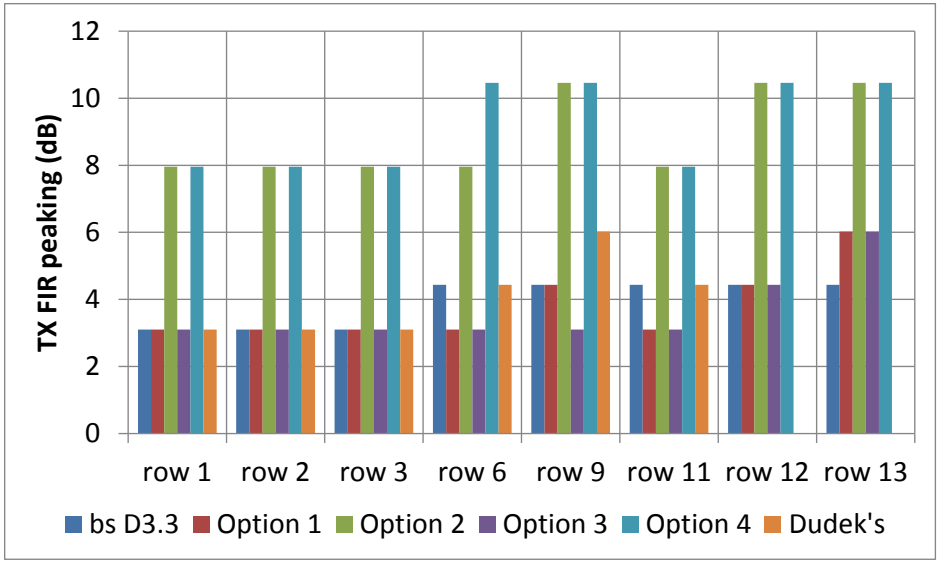
CTLE and TX FIR with 30mm Package

FUJITSU

- Now, put higher priority on EW than EH
  - Results for D3.3 are similar to Dudek's parameters
  - For option 2 and 4, CTLE < TX FIR, for others CTLE > TX FIR

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





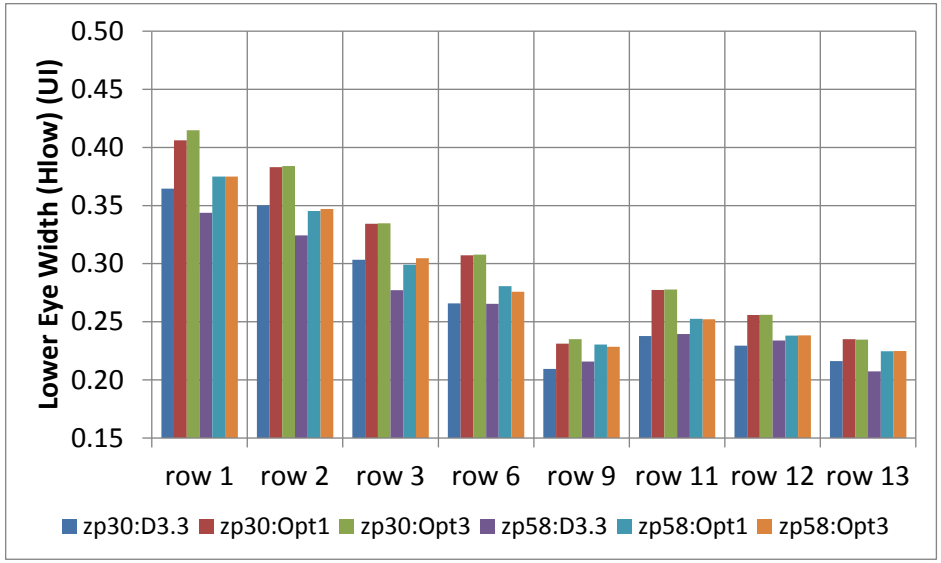
CTLE	bs D3.3	Option 1	Option 2	Option 3	Option 4	Dudek's
row 1	6.5	9.0	5.0	9.0	5.0	6.5
row 2	6.5	9.0	5.0	9.0	5.0	6.5
row 3	6.5	9.0	5.0	9.0	5.0	6.5
row 6	6.5	9.0	4.5	9.0	4.5	6.0
row 9	6.5	9.0	4.0	9.0	4.0	5.0
row 11	6.5	9.0	4.5	9.0	4.5	6.0
row 12	6.5	9.0	4.5	9.0	4.5	
row 13	6.5	9.0	4.5	9.0	4.5	

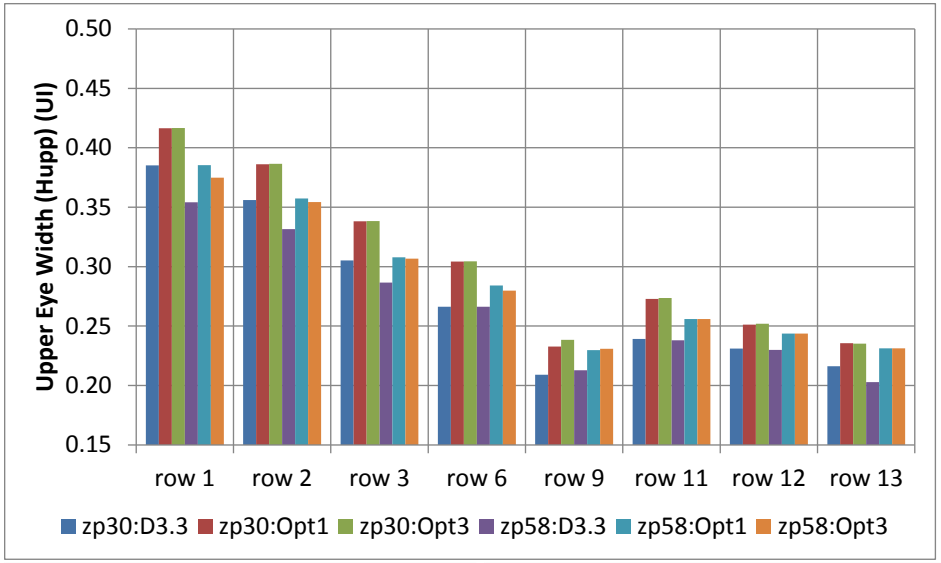
Tx FIR	bs D3.3	Option 1	Option 2	Option 3	Option 4	Dudek's
row 1	[-0.1 0.85 -0.05]	[-0.05 0.85 -0.1]	[-0.05 0.7 -0.25]	[-0.05 0.85 -0.1]	[-0.05 0.7 -0.25]	[-0.1 0.85 -0.05]
row 2	[-0.1 0.85 -0.05]	[-0.05 0.85 -0.1]	[-0.05 0.7 -0.25]	[-0.05 0.85 -0.1]	[-0.05 0.7 -0.25]	[-0.1 0.85 -0.05]
row 3	[-0.1 0.85 -0.05]	[-0.05 0.85 -0.1]	[-0.05 0.7 -0.25]	[-0.05 0.85 -0.1]	[-0.05 0.7 -0.25]	[-0.1 0.85 -0.05]
row 6	[-0.1 0.8 -0.1]	[-0.05 0.85 -0.1]	[-0.05 0.7 -0.25]	[-0.05 0.85 -0.1]	[-0.1 0.65 -0.25]	[-0.1 0.8 -0.1]
row 9	[-0.1 0.8 -0.1]	[-0.05 0.8 -0.15]	[-0.1 0.65 -0.25]	[-0.05 0.85 -0.1]	[-0.1 0.65 -0.25]	[-0.1 0.75 -0.15]
row 11	[-0.1 0.8 -0.1]	[-0.05 0.85 -0.1]	[-0.05 0.7 -0.25]	[-0.05 0.85 -0.1]	[-0.05 0.7 -0.25]	[-0.1 0.8 -0.1]
row 12	[-0.1 0.8 -0.1]	[-0.1 0.8 -0.1]	[-0.1 0.65 -0.25]	[-0.1 0.8 -0.1]	[-0.1 0.65 -0.25]	
row 13	[-0.1 0.8 -0.1]	[-0.1 0.75 -0.15]	[-0.1 0.65 -0.25]	[-0.1 0.75 -0.15]	[-0.1 0.65 -0.25]	

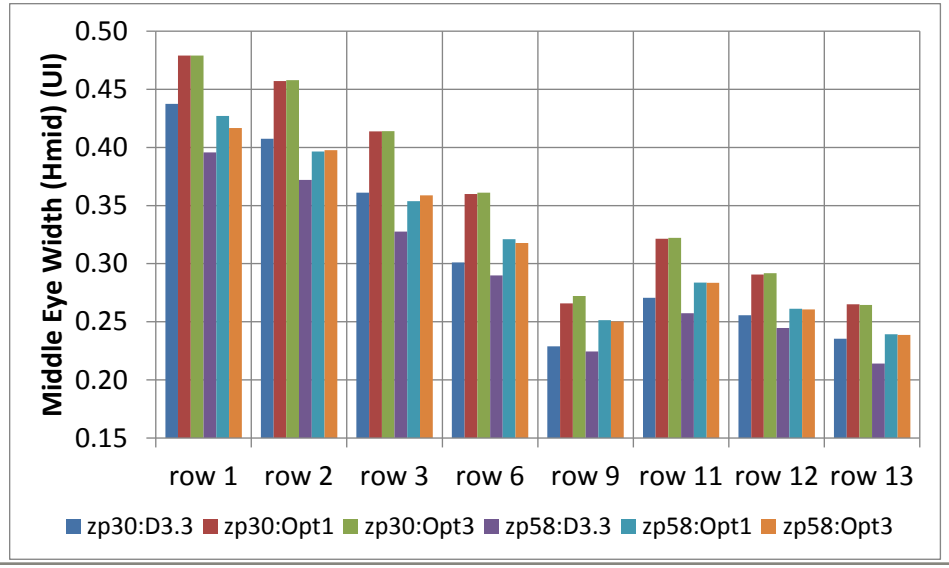
Eye Width with 30 or 58mm Package

FUJITSU

- (Effects of zp=58 → zp=30) < (Effects of D3.3 → Option 1 or 3)







zp (mm)	30			58		
Lower (ps)	D3.3	Opt1	Opt3	D3.3	Opt1	Opt3
row 1	13.7	15.3	15.6	12.9	14.1	14.1
row 2	13.2	14.4	14.5	12.2	13.0	13.1
row 3	11.4	12.6	12.6	10.4	11.3	11.5
row 6	10.0	11.6	11.6	10.0	10.6	10.4
row 9	7.9	8.7	8.8	8.1	8.7	8.6
row 11	9.0	10.4	10.5	9.0	9.5	9.5
row 12	8.6	9.6	9.6	8.8	9.0	9.0
row 13	8.1	8.8	8.8	7.8	8.5	8.5

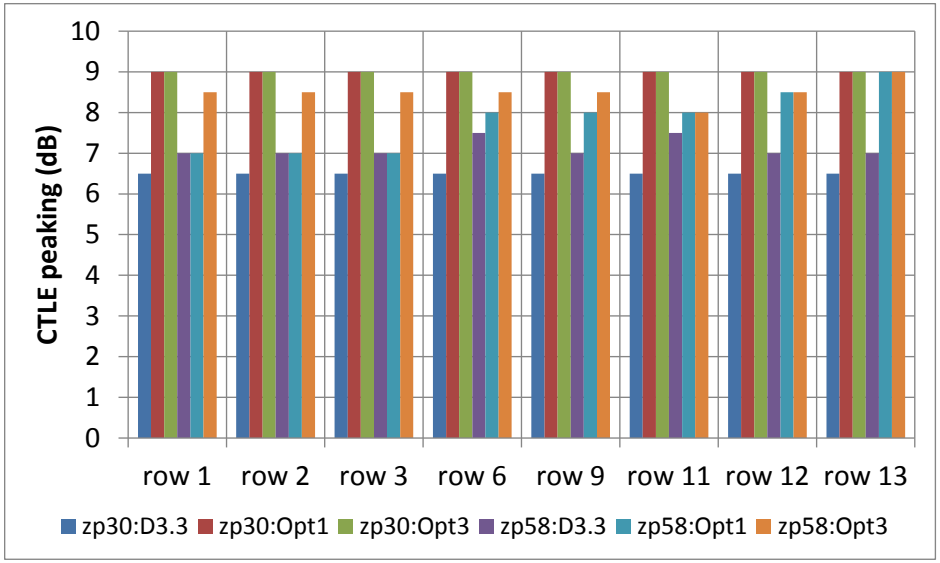
zp (mm)	30			58		
Upper (ps)	D3.3	Opt1	Opt3	D3.3	Opt1	Opt3
row 1	14.5	15.7	15.7	13.3	14.5	14.1
row 2	13.4	14.5	14.5	12.5	13.5	13.3
row 3	11.5	12.7	12.7	10.8	11.6	11.5
row 6	10.0	11.5	11.5	10.0	10.7	10.5
row 9	7.9	8.8	9.0	8.0	8.6	8.7
row 11	9.0	10.3	10.3	9.0	9.6	9.6
row 12	8.7	9.5	9.5	8.7	9.2	9.2
row 13	8.1	8.9	8.9	7.6	8.7	8.7

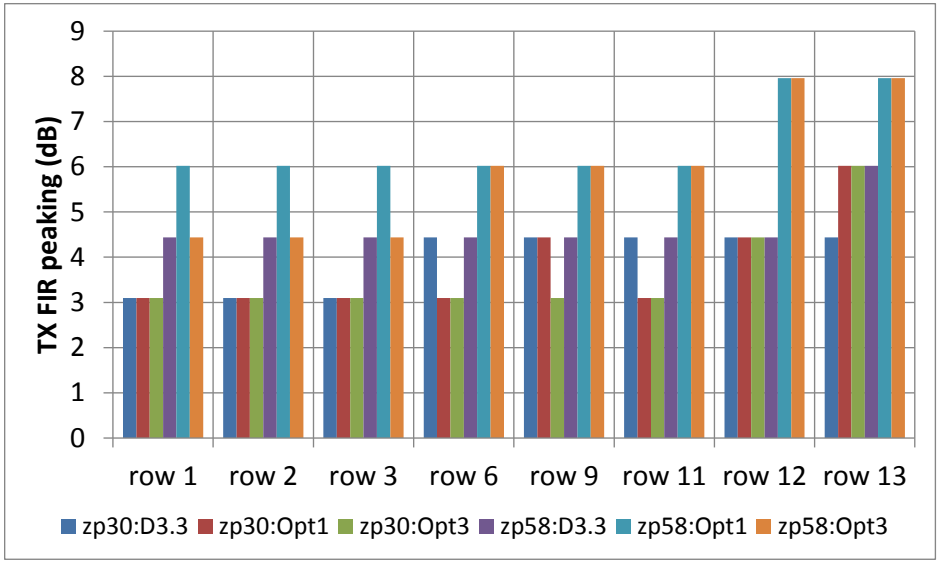
zp (mm)	30			58		
Middle (ps)	D3.3	Opt1	Opt3	D3.3	Opt1	Opt3
row 1	16.5	18.0	18.0	14.9	16.1	15.7
row 2	15.3	17.2	17.2	14.0	14.9	15.0
row 3	13.6	15.6	15.6	12.3	13.3	13.5
row 6	11.3	13.5	13.6	10.9	12.1	12.0
row 9	8.6	10.0	10.2	8.4	9.5	9.4
row 11	10.2	12.1	12.1	9.7	10.7	10.7
row 12	9.6	10.9	11.0	9.2	9.8	9.8
row 13	8.9	10.0	10.0	8.1	9.0	9.0

CTLE & TX FIR with 30mm or 58mm Package

FUJITSU

- With Option 1 or 3
  - CTLE maxed out (=9dB) for 30mm package, but not for 58mm package
  - 58mm may be tough even for high-bandwidth CTLE (i.e. option 1 or 3)





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

zp (mm)	30			58		
TXFIR(dB)	bs D3.3	Option 1	Option 3	bs D3.3	Option 1	Option 3
row 1	[-0.1 0.85 -0.05]	[-0.05 0.85 -0.1]	[-0.05 0.85 -0.1]	[-0.1 0.8 -0.1]	[-0.05 0.75 -0.2]	[-0.05 0.8 -0.15]
row 2	[-0.1 0.85 -0.05]	[-0.05 0.85 -0.1]	[-0.05 0.85 -0.1]	[-0.1 0.8 -0.1]	[-0.05 0.75 -0.2]	[-0.05 0.8 -0.15]
row 3	[-0.1 0.85 -0.05]	[-0.05 0.85 -0.1]	[-0.05 0.85 -0.1]	[-0.1 0.8 -0.1]	[-0.05 0.75 -0.2]	[-0.05 0.8 -0.15]
row 6	[-0.1 0.8 -0.1]	[-0.05 0.85 -0.1]	[-0.05 0.85 -0.1]	[-0.1 0.8 -0.1]	[-0.05 0.75 -0.2]	[-0.05 0.75 -0.2]
row 9	[-0.1 0.8 -0.1]	[-0.05 0.8 -0.15]	[-0.05 0.85 -0.1]	[-0.1 0.8 -0.1]	[-0.05 0.75 -0.2]	[-0.05 0.75 -0.2]
row 11	[-0.1 0.8 -0.1]	[-0.05 0.85 -0.1]	[-0.05 0.85 -0.1]	[-0.1 0.8 -0.1]	[-0.05 0.75 -0.2]	[-0.05 0.75 -0.2]
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 0.7 -0.2]	[-0.1 0.7 -0.2]
row 13	[-0.1 0.8 -0.1]	[-0.1 0.75 -0.15]	[-0.1 0.75 -0.15]	[-0.1 0.75 -0.15]	[-0.1 0.7 -0.2]	[-0.1 0.7 -0.2]

Summary

FUJITSU

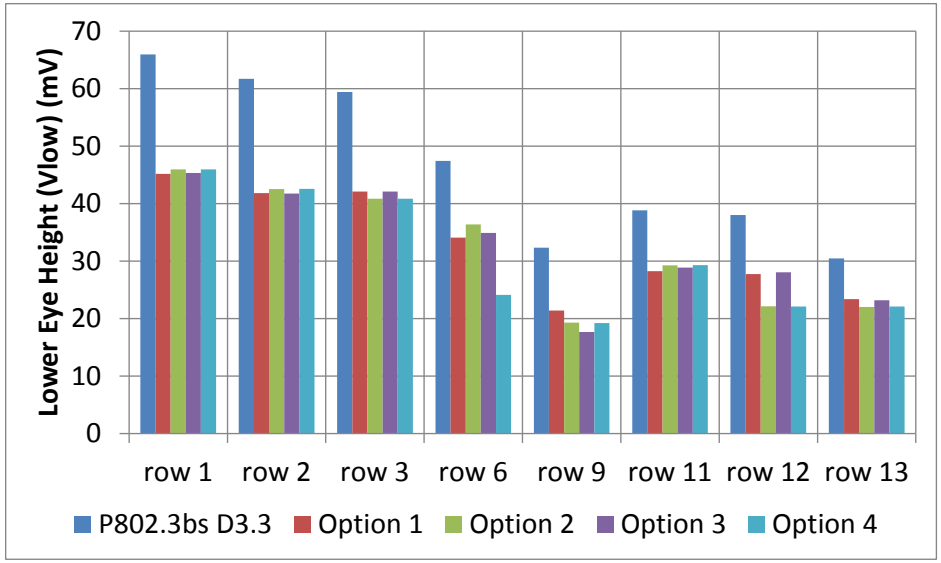
- If we optimize EQ with higher priority on EW than EH, EW is clearly improved by option 1 and 3 compared with D3.3
- Reducing channel loss from 14.2dB (58mm PKG) to 12.2dB (30mm PKG) is effective with option 1 and 3, but not so effective without option 1 or 3
- I recommend to take option 3
  - Increase $P_1/2\pi$ to $1 * fb$ (= f_{p2} of CEI-56G-MR-PAM4)
  - And optionally, reduce channel loss from 14.2dB to 12.2dB

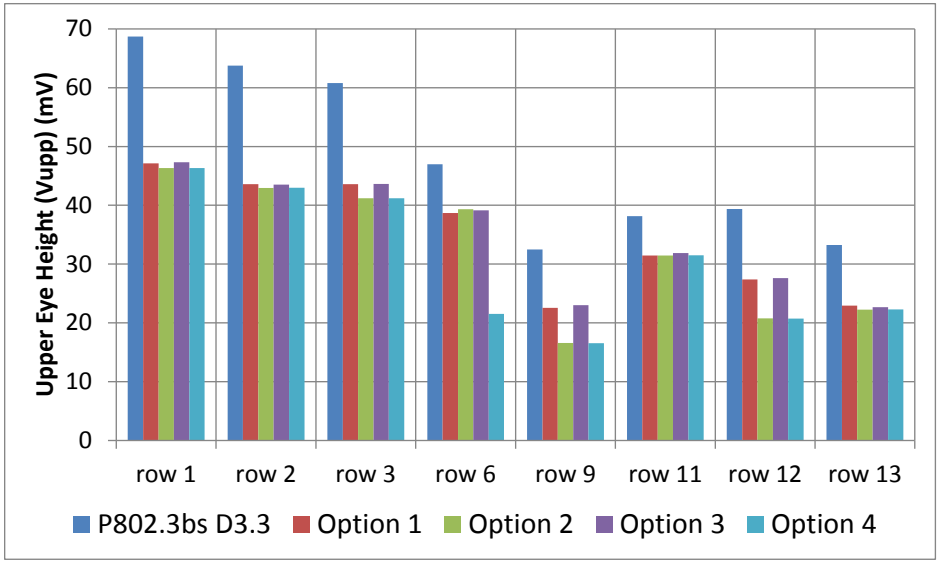
Back up Slides

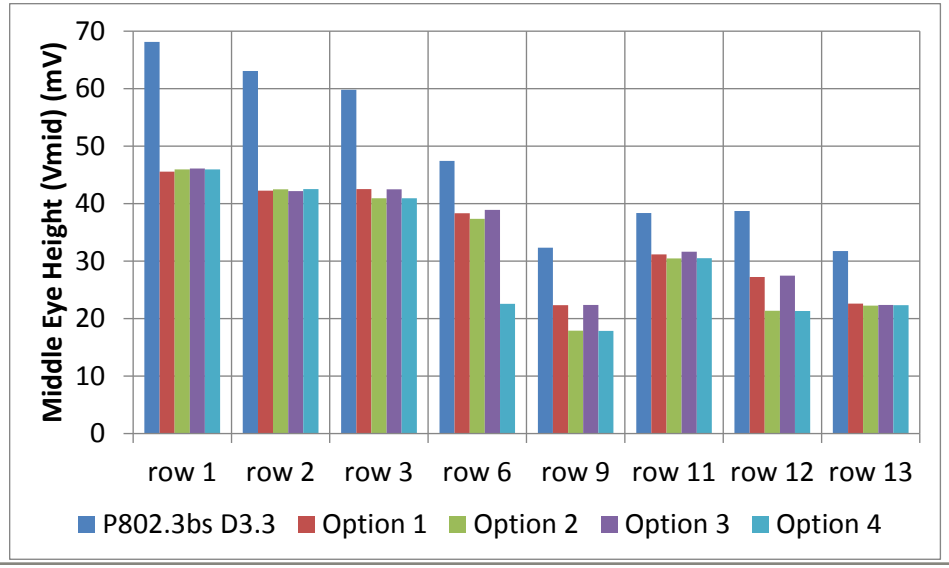
- Eye Height
- Eye Amplitude

Eye Height with 30mm Package

- Drops for any option due to more peaking, i.e. lower DC gain







Lower (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	65.9	45.2	45.9	45.3	46.0
row 2	61.7	41.8	42.5	41.8	42.6
row 3	59.4	42.1	40.8	42.1	40.9
row 6	47.4	34.1	36.4	34.9	24.1
row 9	32.3	21.4	19.3	17.6	19.2
row 11	38.8	28.2	29.2	28.9	29.3
row 12	38.0	27.7	22.1	28.0	22.1
row 13	30.5	23.4	22.0	23.2	22.1

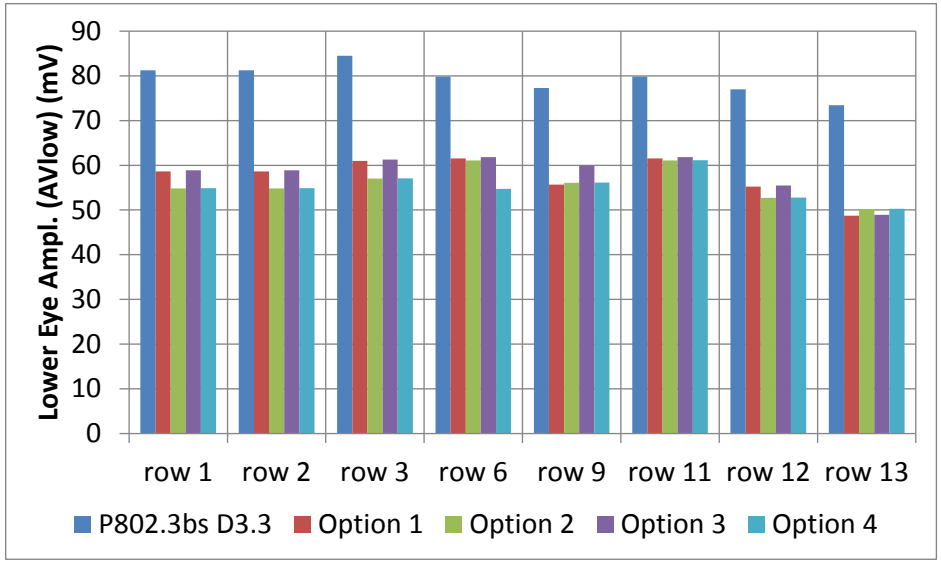
Upper (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	68.7	47.1	46.3	47.3	46.3
row 2	63.8	43.6	43.0	43.5	43.0
row 3	60.8	43.6	41.2	43.6	41.2
row 6	47.0	38.7	39.3	39.1	21.5
row 9	32.5	22.5	16.6	23.0	16.5
row 11	38.1	31.5	31.5	31.9	31.5
row 12	39.4	27.4	20.8	27.6	20.7
row 13	33.2	22.9	22.2	22.7	22.3

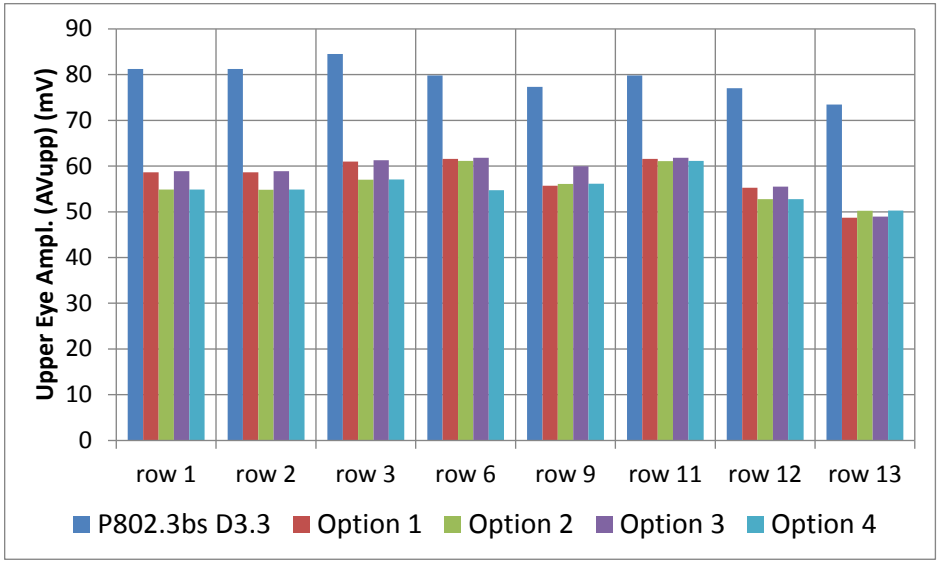
Middle (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	68.1	45.6	45.9	46.1	46.0
row 2	63.1	42.3	42.5	42.2	42.5
row 3	59.8	42.5	40.9	42.5	40.9
row 6	47.4	38.3	37.3	38.9	22.6
row 9	32.3	22.3	17.9	22.4	17.9
row 11	38.4	31.2	30.5	31.6	30.5
row 12	38.7	27.2	21.4	27.5	21.3
row 13	31.7	22.6	22.3	22.4	22.3

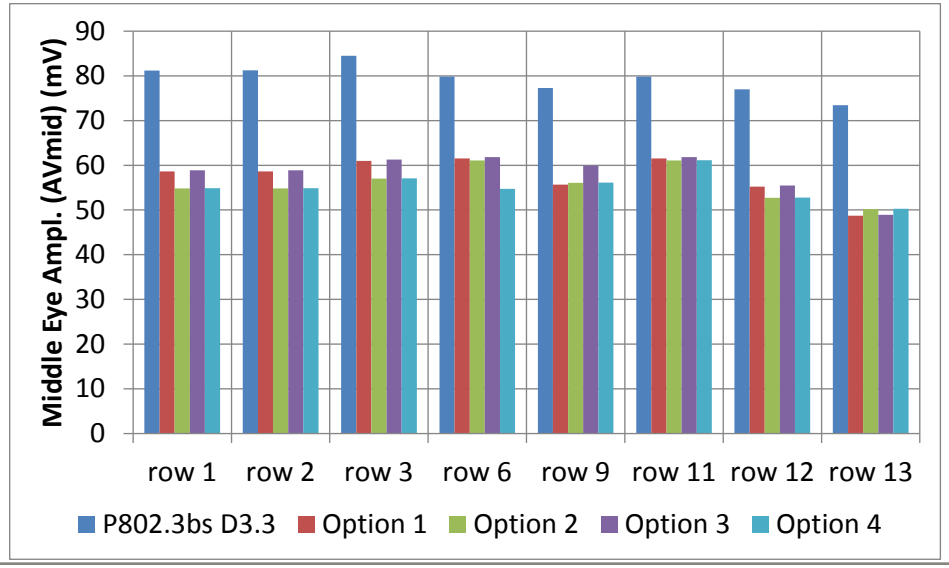
Eye Amplitude with 30mm Package

FUJITSU

- Drops for any option due to more peaking, i.e. lower DC gain







Lower (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	81.2	58.6	54.8	58.9	54.9
row 2	81.2	58.6	54.8	58.9	54.9
row 3	84.5	61.0	57.0	61.3	57.1
row 6	79.8	61.6	61.1	61.8	54.7
row 9	77.3	55.7	56.1	59.9	56.1
row 11	79.8	61.6	61.1	61.8	61.1
row 12	77.0	55.2	52.7	55.5	52.8
row 13	73.4	48.7	50.2	48.9	50.3

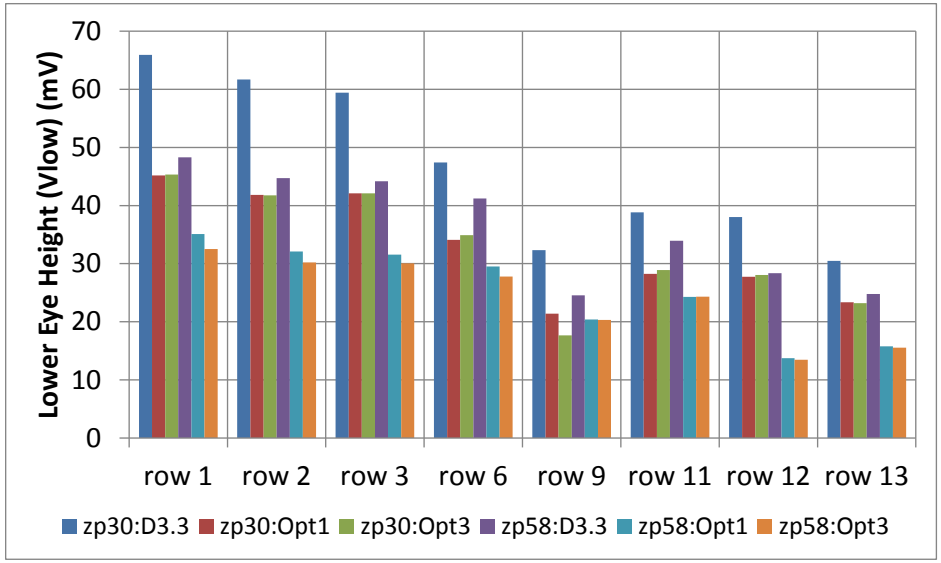
Upper (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	81.2	58.6	54.8	58.9	54.9
row 2	81.3	58.6	54.8	58.9	54.9
row 3	84.5	61.0	57.0	61.3	57.1
row 6	79.8	61.6	61.1	61.8	54.7
row 9	77.3	55.7	56.1	59.9	56.1
row 11	79.8	61.6	61.1	61.8	61.1
row 12	77.0	55.2	52.7	55.5	52.8
row 13	73.4	48.7	50.2	48.9	50.3

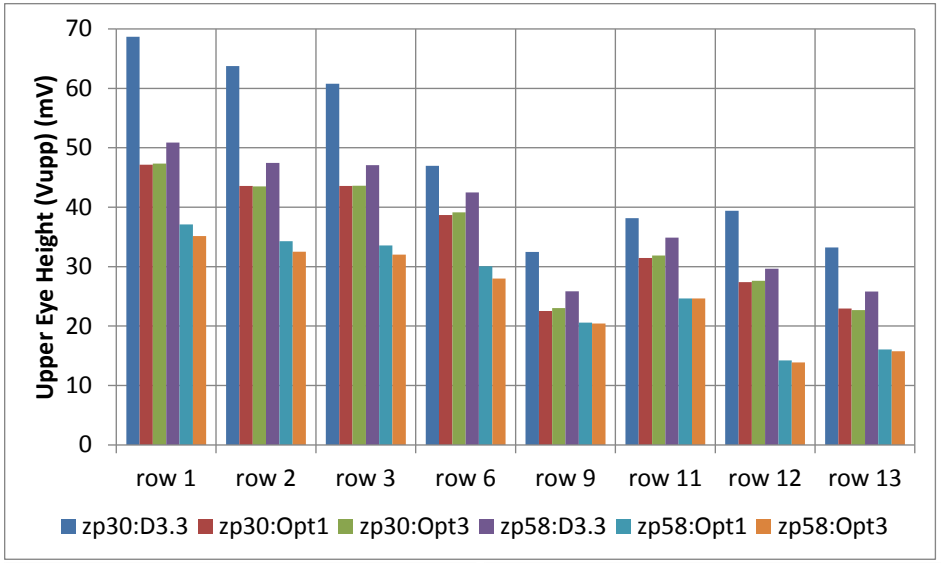
Middle (mV)	D3.3	Opt1	Opt2	Opt3	Opt4
row 1	81.2	58.6	54.8	58.9	54.9
row 2	81.2	58.6	54.8	58.9	54.9
row 3	84.5	61.0	57.0	61.3	57.1
row 6	79.8	61.6	61.1	61.8	54.7
row 9	77.3	55.7	56.1	59.9	56.1
row 11	79.8	61.6	61.1	61.8	61.1
row 12	77.0	55.2	52.7	55.5	52.8
row 13	73.4	48.7	50.2	48.9	50.3

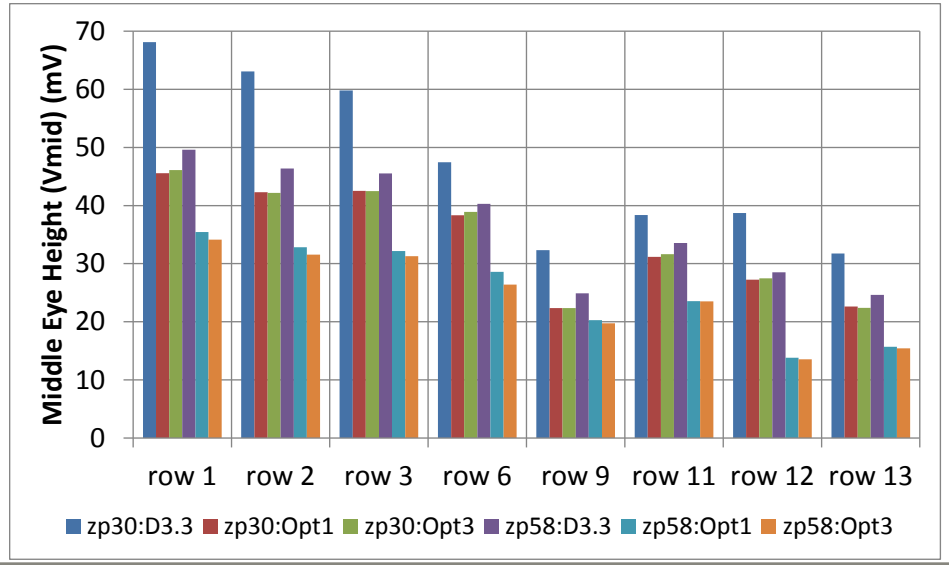
Eye Height with 30mm or 58mm Package

FUJITSU

- Drops for any option due to more peaking, i.e. lower DC gain







zp (mm)	30			58		
Lower (mV)	D3.3	Opt1	Opt3	D3.3	Opt1	Opt3
row 1	65.9	45.2	45.3	48.3	35.1	32.5
row 2	61.7	41.8	41.8	44.7	32.1	30.2
row 3	59.4	42.1	42.1	44.2	31.6	30.1
row 6	47.4	34.1	34.9	41.2	29.5	27.8
row 9	32.3	21.4	17.6	24.6	20.4	20.3
row 11	38.8	28.2	28.9	34.0	24.3	24.3
row 12	38.0	27.7	28.0	28.3	13.7	13.4
row 13	30.5	23.4	23.2	24.8	15.8	15.5

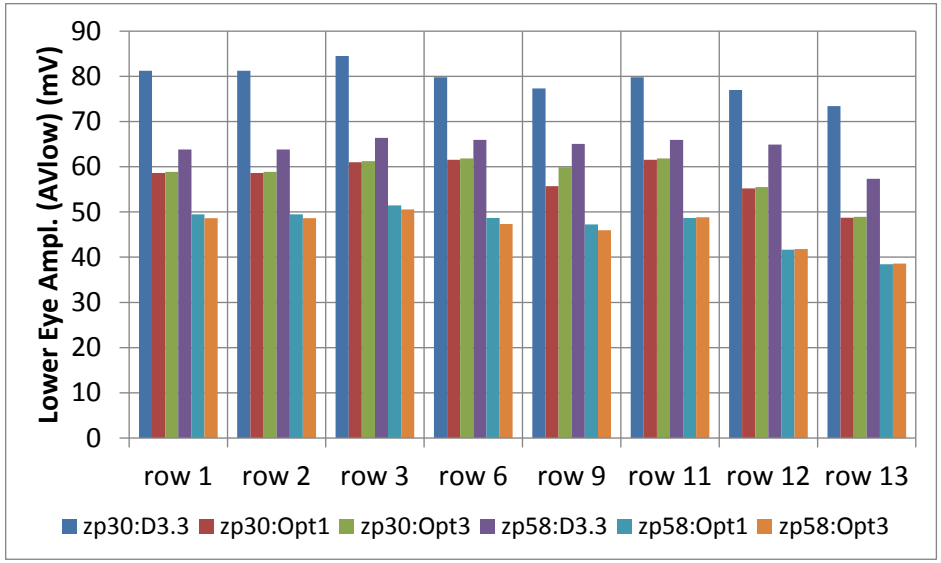
zp (mm)	30			58		
Upper (mV)	D3.3	Opt1	Opt3	D3.3	Opt1	Opt3
row 1	68.7	47.1	47.3	50.9	37.1	35.1
row 2	63.8	43.6	43.5	47.5	34.3	32.5
row 3	60.8	43.6	43.6	47.1	33.6	32.0
row 6	47.0	38.7	39.1	42.5	30.0	28.0
row 9	32.5	22.5	23.0	25.8	20.6	20.4
row 11	38.1	31.5	31.9	34.9	24.6	24.6
row 12	39.4	27.4	27.6	29.6	14.2	13.9
row 13	33.2	22.9	22.7	25.8	16.1	15.7

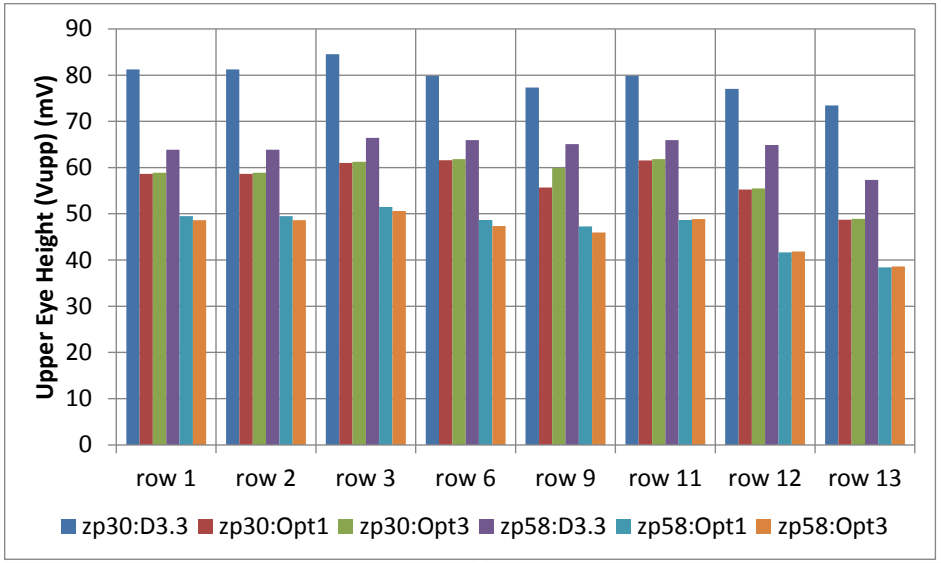
zp (mm)	30			58		
Middle (mV)	D3.3	Opt1	Opt3	D3.3	Opt1	Opt3
row 1	68.1	45.6	46.1	49.6	35.4	34.1
row 2	63.1	42.3	42.2	46.4	32.8	31.5
row 3	59.8	42.5	42.5	45.5	32.2	31.3
row 6	47.4	38.3	38.9	40.3	28.6	26.4
row 9	32.3	22.3	22.4	24.9	20.3	19.8
row 11	38.4	31.2	31.6	33.6	23.6	23.5
row 12	38.7	27.2	27.5	28.5	13.8	13.5
row 13	31.7	22.6	22.4	24.6	15.7	15.4

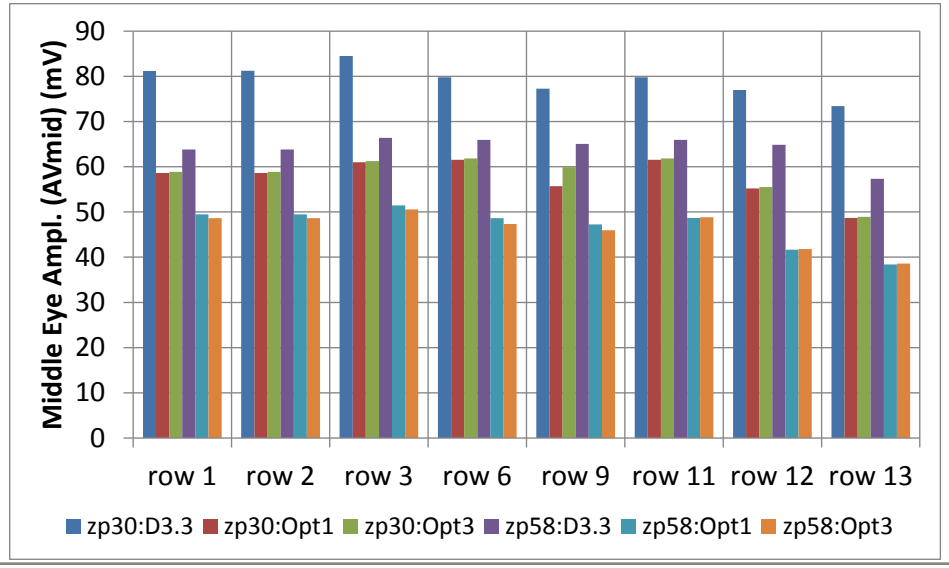
Eye Amplitude with 30mm or 58mm Package

FUJITSU

- Drops for any option due to more peaking, i.e. drop of DC gain







zp (mm)	30			58		
Lower (mV)	D3.3	Opt1	Opt3	D3.3	Opt1	Opt3
row 1	81.2	58.6	58.9	63.8	49.5	48.6
row 2	81.2	58.6	58.9	63.8	49.5	48.6
row 3	84.5	61.0	61.3	66.4	51.5	50.6
row 6	79.8	61.6	61.8	66.0	48.7	47.3
row 9	77.3	55.7	59.9	65.1	47.2	46.0
row 11	79.8	61.6	61.8	66.0	48.7	48.9
row 12	77.0	55.2	55.5	64.9	41.6	41.8
row 13	73.4	48.7	48.9	57.3	38.4	38.6

zp (mm)	30			58		
Upper (mV)	D3.3	Opt1	Opt3	D3.3	Opt1	Opt3
row 1	81.2	58.6	58.9	63.8	49.5	48.6
row 2	81.3	58.6	58.9	63.9	49.5	48.6
row 3	84.5	61.0	61.3	66.4	51.5	50.6
row 6	79.8	61.6	61.8	66.0	48.7	47.3
row 9	77.3	55.7	59.9	65.1	47.3	46.0
row 11	79.8	61.6	61.8	66.0	48.7	48.9
row 12	77.0	55.2	55.5	64.9	41.6	41.8
row 13	73.4	48.7	48.9	57.3	38.4	38.6

zp (mm)	30			58		
Middle (mV)	D3.3	Opt1	Opt3	D3.3	Opt1	Opt3
row 1	81.2	58.6	58.9	63.8	49.5	48.6
row 2	81.2	58.6	58.9	63.8	49.5	48.6
row 3	84.5	61.0	61.3	66.4	51.5	50.6
row 6	79.8	61.6	61.8	66.0	48.7	47.3
row 9	77.3	55.7	59.9	65.1	47.2	45.9
row 11	79.8	61.6	61.8	65.9	48.7	48.8
row 12	77.0	55.2	55.5	64.9	41.6	41.8
row 13	73.4	48.7	48.9	57.3	38.4	38.6

FUJITSU

Thank you