RLM vs. PAM4 Threshold Adjustment

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Background

- The decision thresholds used in current TDECQ measurement are equally spaced without consideration for signal distortion.
- In reality, lower eye amplitudes are often seen in upper and/or lower eyes, which leads to unoptimized thresholds in TDECQ measurement, and hence overestimation of TDECQ penalty.
- There are suggestions to

  - limit the signal RLM (0.9 is one proposal)

  - limit the threshold change allowed (no # proposed yet)

Motivation

Can we link these two to converge to a single solution?

Ideal Case

$$P_{th1} = P_{ave} - \frac{OMA_{outer}}{3} \qquad (121\text{–}1)$$

$$P_{th2} = P_{ave} \qquad (121\text{–}2)$$

$$P_{th3} = P_{ave} + \frac{OMA_{outer}}{3} \qquad (121\text{–}3)$$

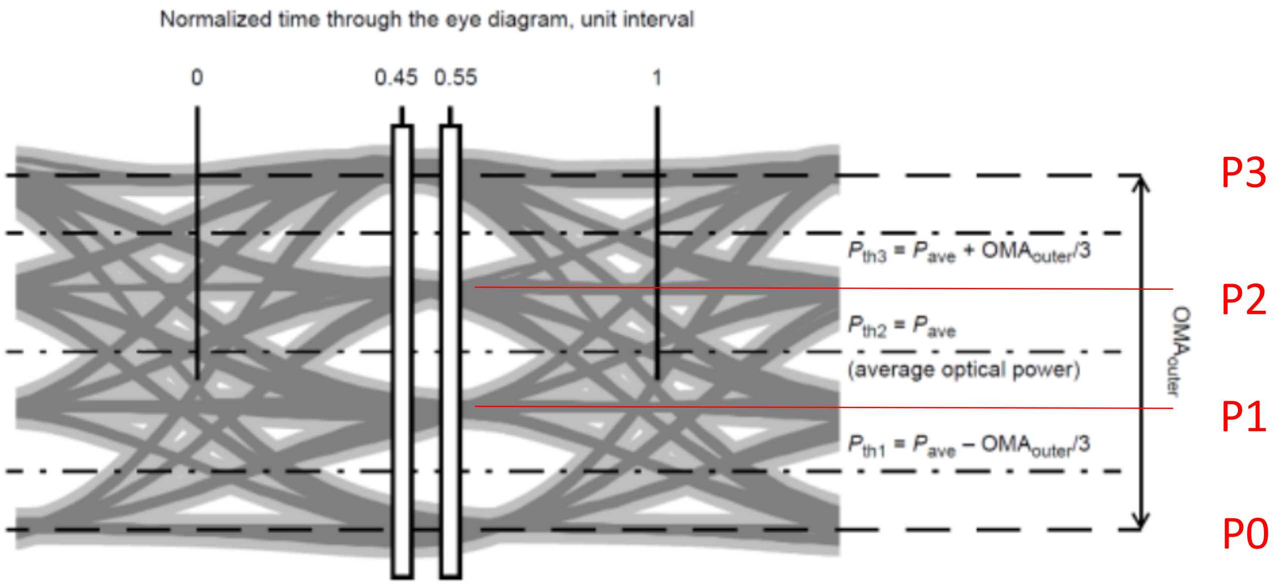


Figure 121–5—Illustration of the TDECQ measurement

$P_{th3} = (P_3 + P_2)/2$

$P_3 - P_2 = OMA/3$

$P_2 = P_{av} + OMA/6$

$P_3 = P_{av} + OMA/2$

RLM Definition from 802.3bs-2017

$$V_{\text{mid}} = \frac{V_0 + V_3}{2} \qquad (120D\text{–}3)$$

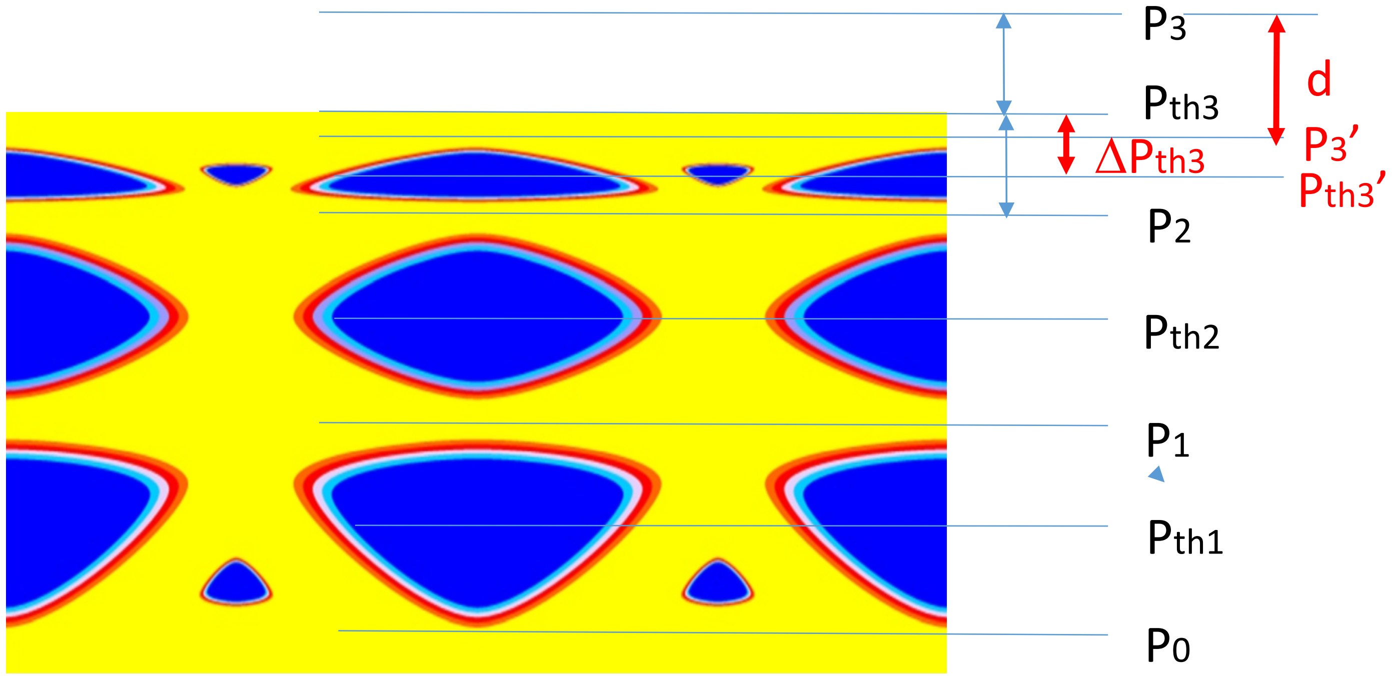
$$ES1 = \frac{V_1 - V_{\text{mid}}}{V_0 - V_{\text{mid}}} \qquad (120D\text{–}4)$$

$$ES2 = \frac{V_2 - V_{\text{mid}}}{V_3 - V_{\text{mid}}} \qquad (120D\text{–}5)$$

The level separation mismatch ratio R_{LM} is defined by Equation (120D–6).

$$R_{\text{LM}} = \min((3 \times ES1), (3 \times ES2), (2 - 3 \times ES1), (2 - 3 \times ES2)) \qquad (120D\text{–}6)$$

A Simplified Case with only Top Eye Compressed



In this case

$P_3' = P_3 – d$,

$P_2' = P_2$,

$P_0' = P_0$

$P_{av}' = (P_3' + P_0)/2 = P_{av} – d/2$

$OMA' = P_3' - P_0' = OMA – d$

$P_{th3}' = (P_3' + P_2')/2 = P_{th3} - d/2$

P_{th3} = Threshold for ideal case

$$\begin{aligned} RLM &= \min((3\,ES1,\ 3\,ES2,\ (2 – 3\,ES1),\ (2 – 3\,ES2)) = 2 – 3\,ES2 \\ &= 2 – 3\,(P_2' – P_{av}')/(P_3' – P_{av}') \\ &= 2 – 3\,(P_2 – P_{av} + d/2)/(P_3 – P_{av} – d/2) \\ &= 2 – 3\,(OMA/6 + d/2)/(OMA/2 – d/2) \\ &= (OMA - 5d)/(OMA – d) \\ &= (OMA' – 4d)/OMA' \end{aligned}$$

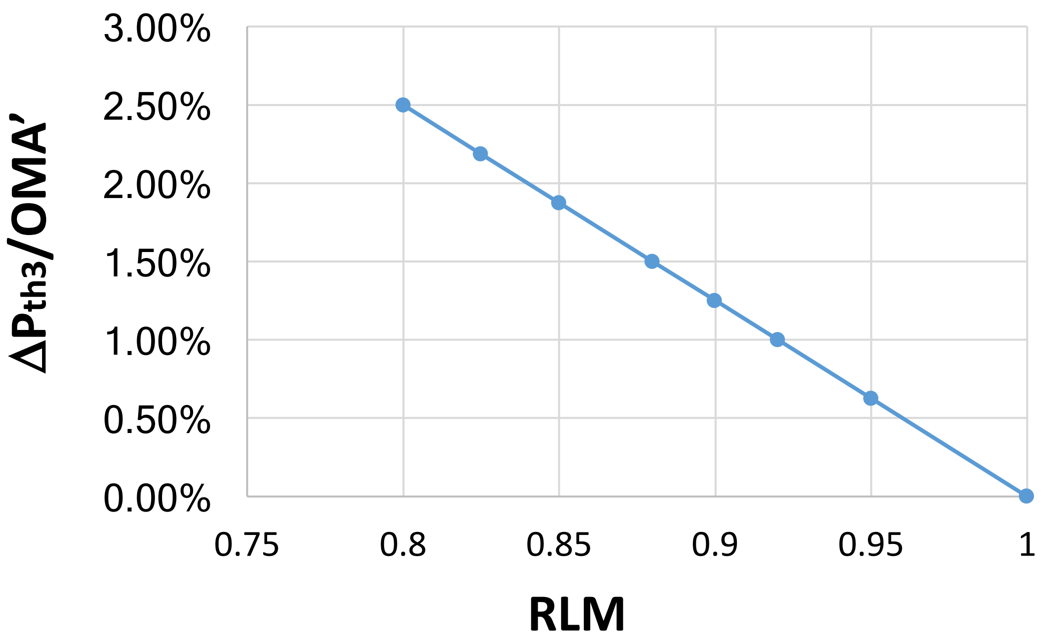
$\Rightarrow$ $d/OMA' = (1 - RLM)/4$

Relative to Threshold Change

- $P_{th3}' = P_{th3} - d/2$
- $\Delta P_{th3} = P_{th3} - P_{th3}' = d/2 = OMA' (1 - RLM)/8$
- If RLM = 0.9, $\Delta P_{th3} = OMA'/80$ $\Rightarrow$ 1.25% signal OMA

P_{th3} = Threshold for ideal case
The real case of $P_{th3}* = P_{av}' + OMA'/3$ is shown in backup

RLM	$\Delta P_{th3}/OMA'$
0.95	0.625%
0.9	1.25%
0.8	2.5%



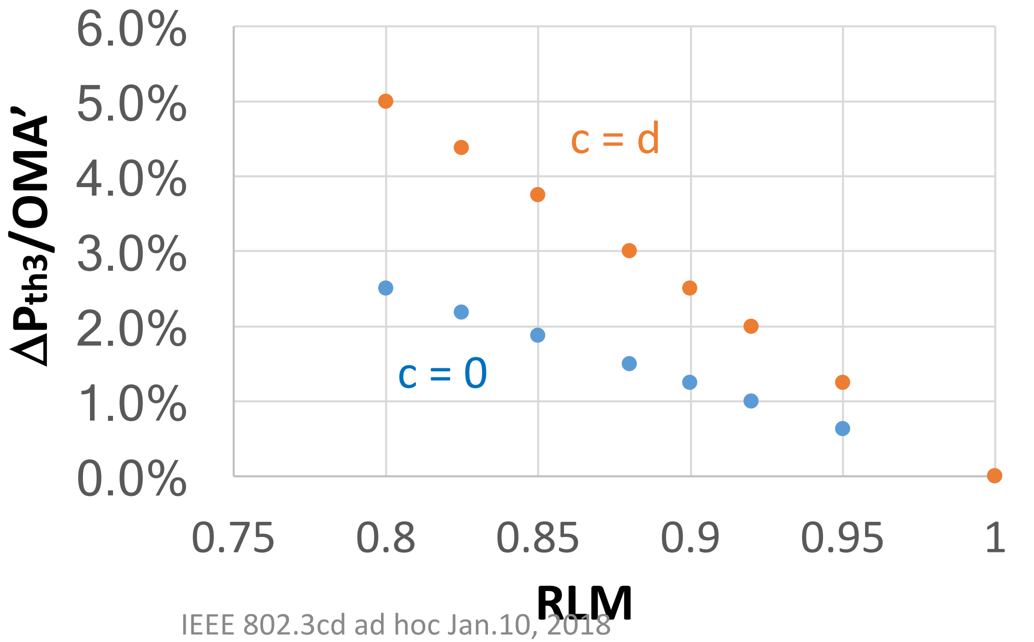
For RLM = 0.9, the threshold change is 1.25% of signal OMA

When both top and bottom eyes are compressed

- Assuming P_3' is lowered by d, P_0' is higher by c (c < d), P_1 & P_2 are unchanged
- A similar analysis shows $4d - 2c = OMA'(1 - RLM)$

When c = d (the worse case),

$\Delta P_{th3} = OMA'(1 - RLM)/4$ Threshold change is doubled.



Summary

- RLM and threshold change are correlated
- A simplified analysis shows ΔP_{th3}/OMA' = (1- RLM)/A (with A = 4 – 8)
- For RLM = 0.9, the maximum threshold change is 2.5% of signal OMA.

Discussions

- Amount of threshold adjustment by real receivers?

- The maximum threshold adjustment that would ensure the Tx units passed TDECQ tests will not cause problems in the link BER test?

Backup

When the initial threshold is set at $P_{av}' + OMA'/3$?

- Initial $P_{th3}^* = P_{av}' + OMA'/3$
- Final threshold = $(P_3' + P_2')/2 = (P_3 - d + P_2)/2 = P_{th3} - d/2$
- $\Delta P_{th3} = P_{th3} - d/2 - P_{av}' - OMA'/3$

  $= P_{av} + OMA/3 - d/2 - (P_{av} - d/2) - OMA'/3$

  $= OMA/3 - OMA'/3 = d/3 = OMA'\,(1 - RLM)/12$

For RLM = 0.9, ΔP_{th3} = 0.83%

This change is less than that compared to the ideal case