TDECQ: R_{LM} and threshold adjust

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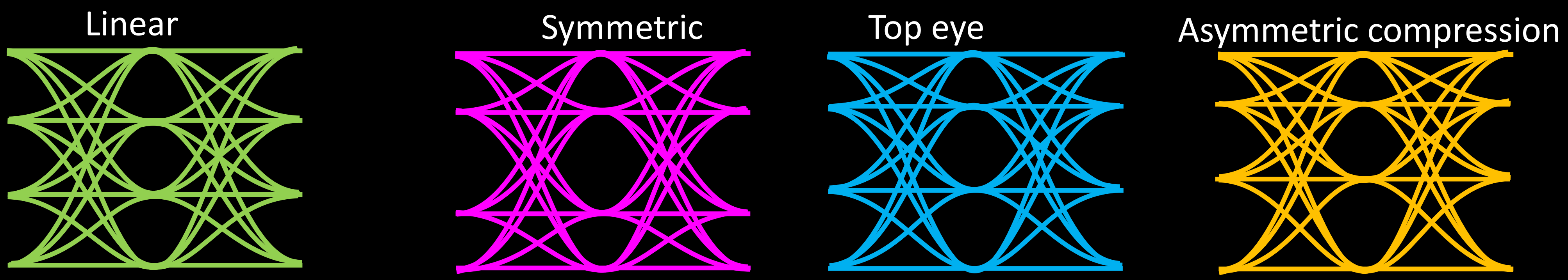
A simple model

- Considers modulation levels at time-centre of eye opening
- Assumes receiver noise limited (RIN is negligible)
  - so that optimized thresholds are in the middle of each sub-eye
- 3 cases, each with same OMA_{outer}:
  - **Symmetric compression around P_{ave}**
  - **Top eye only compression**
  - **Asymmetric power compression (higher optical levels see more compression)**



- Calculate modulation levels, D3.0 thresholds, optimum thresholds, R_{LM}, Q penalty
  - Q penalty is calculated from the average of the partial error probabilities for each modulation level and nearest threshold pair (analogous to the calculations performed in TDECQ; Q penalty is a proxy for TDECQ)

R_{LM}

proposed as a spec to limit sub-eye inequality

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

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

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

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

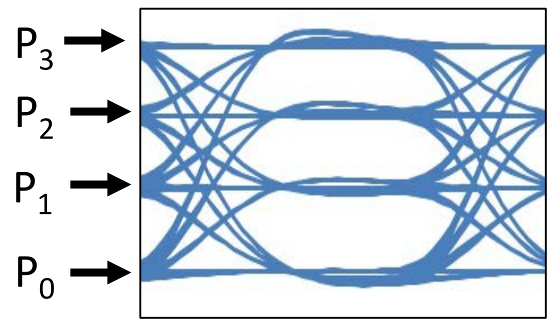
$$R_{LM} = \min((3 \times ES1), (3 \times ES2), (2 - 3 \times ES1), (2 - 3 \times ES2)) \qquad (120D\text{–}6)$$

- Optical R_{LM}: Optical modulation levels substituted for the voltage definition here:

$$P_{mid} = \frac{P_0 \; - P_3}{2} \qquad ES1 = \frac{P_1 \; - Pmi_d}{P_0 - Pm_{id}} \qquad ES2 = \frac{P_2 \; - Pmi_d}{P_3 - Pm_{id}}$$

and

$$R_{LM} = min(\,(3xES1), (3xES2), 2\text{-}(3xES1), (2\text{-}3xES2)\,)$$



D3.0 thresholds

$$D3.0\ Pt_{h1} = P_{th2} - \frac{P_3 - P_0}{3}$$

$$D3.0\ Pt_{h2} = \frac{P_0 + P_1 + P_2 + P_3}{4}$$

$$D3.0\ Pt_{h3} = P_{th2} + \frac{P_3 - P_0}{3}$$

Optimum thresholds

$$Opt\ Pth_1 = \frac{P_0 + P_1}{2}$$

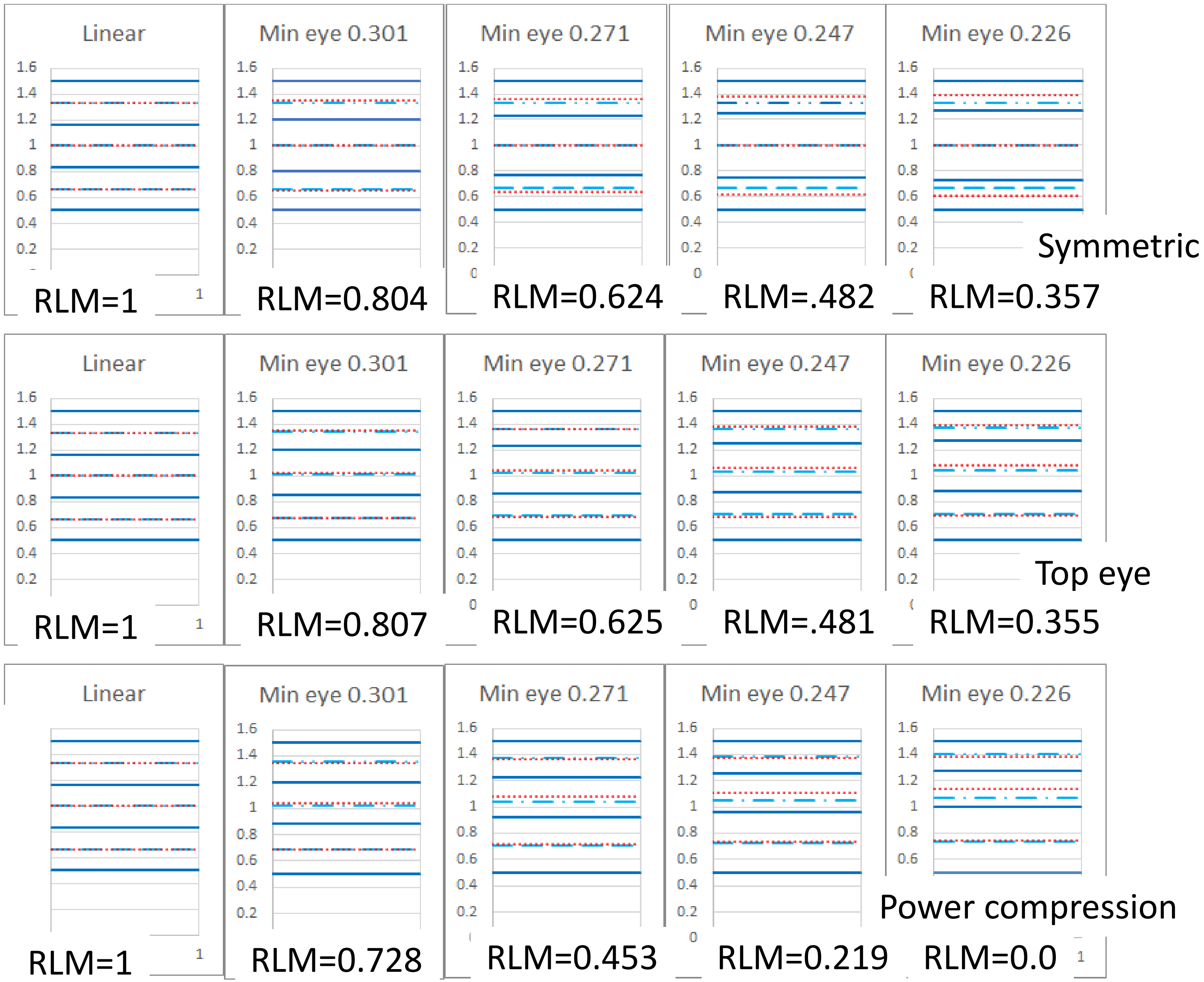
$$Opt\ Pth_2 = \frac{P_1 + P_2}{2}$$

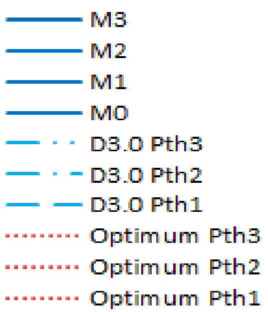
$$Opt\ Pth_3 = \frac{P_2 + P_3}{2}$$

Eye test

Modulation levels, D3.0 and optimum thresholds, for various R_{LM}

- ‘D3.0’ thresholds are as defined in clause 121 (dashed blue); ‘Optimum’ thresholds set to mid point of each sub eye (red dots)
- Symmetric distortion produces largest difference between the D3.0 and optimum thresholds:
  - 2.5 % of OMA_{outer} at R_{LM} = 0.7
  - 0.8% of OMA_{outer} at R_{LM} = 0.9

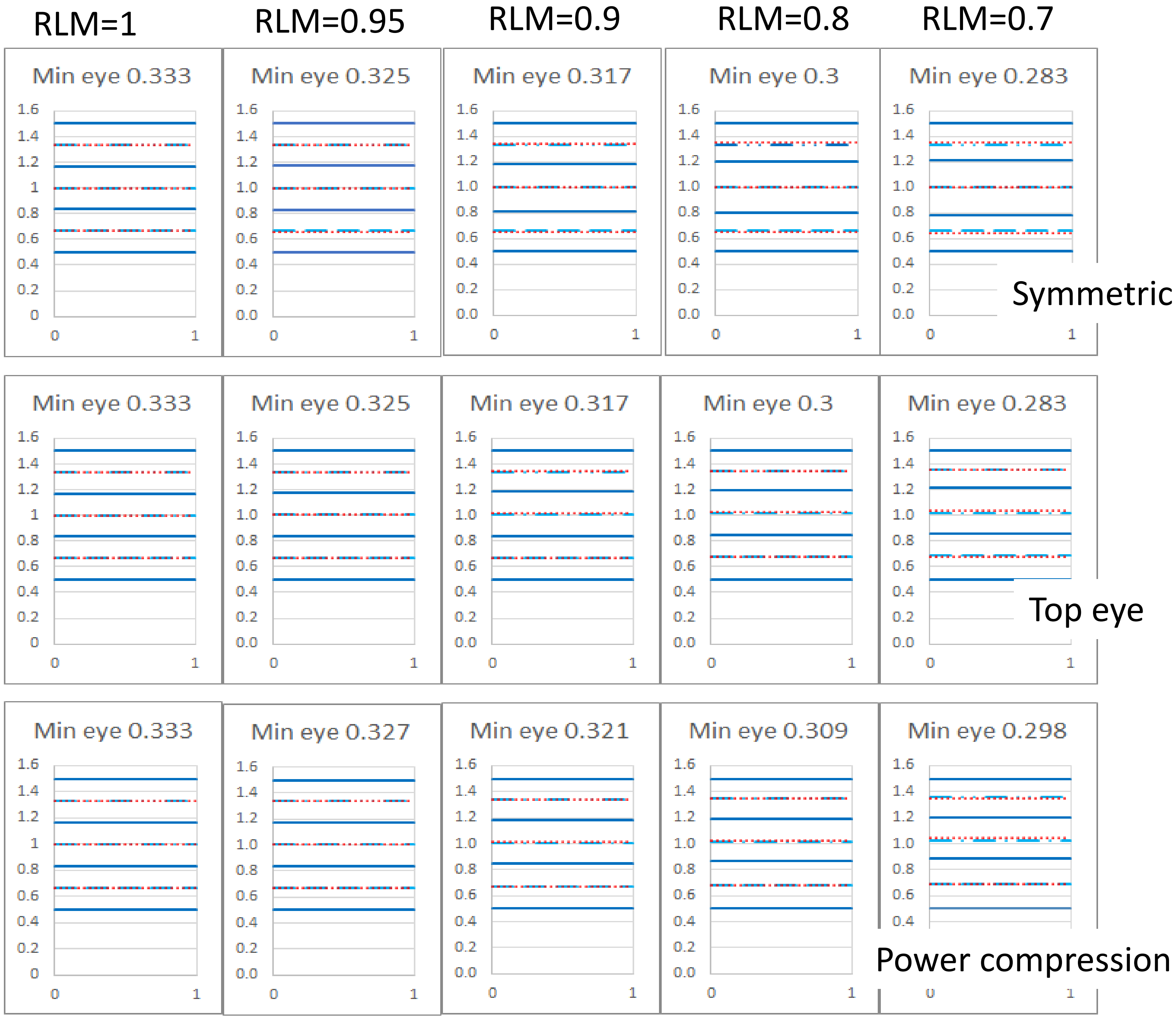


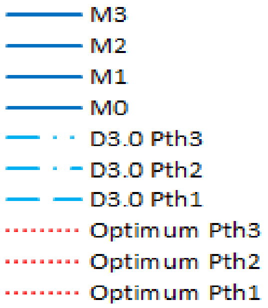


Eye test

Modulation levels, D3.0 and optimum thresholds, for various R_{LM}

- Eye inequality is small for RLM > 0.7
- ‘D3.0’ thresholds are as defined in clause 121 (dashed blue); ‘Optimum’ thresholds set to mid point of each sub eye (red dots)
- Symmetric distortion produces largest difference between the D3.0 and optimum thresholds:
  - 1.6% % of OMA_{outer} at R_{LM} = 0.8
  - 0.8% of OMA_{outer} at R_{LM} = 0.9



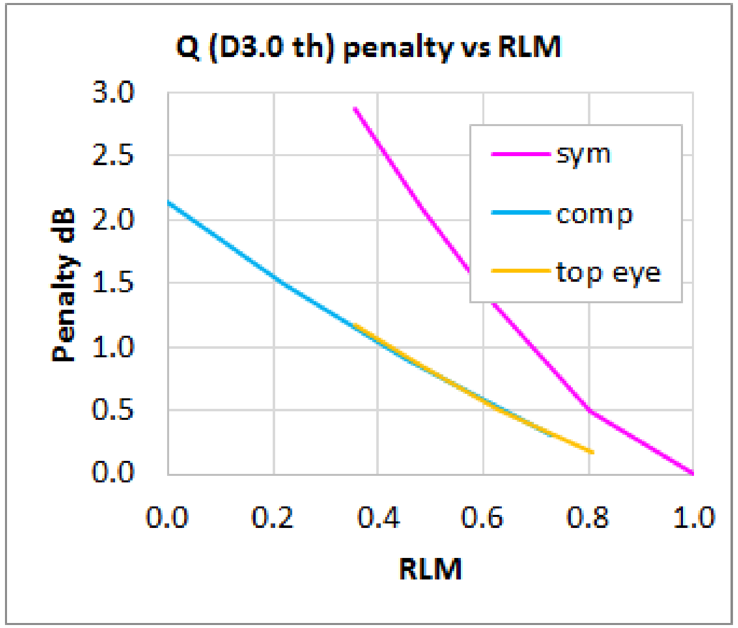


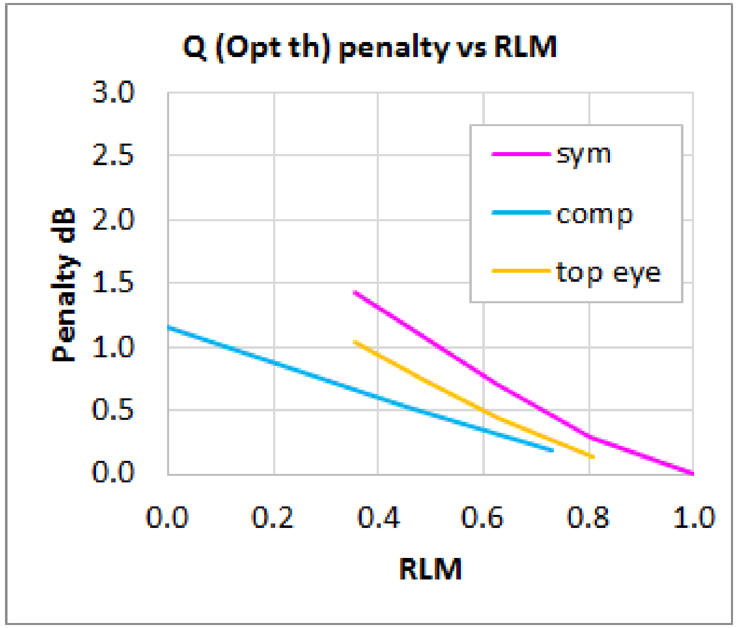
Eye test

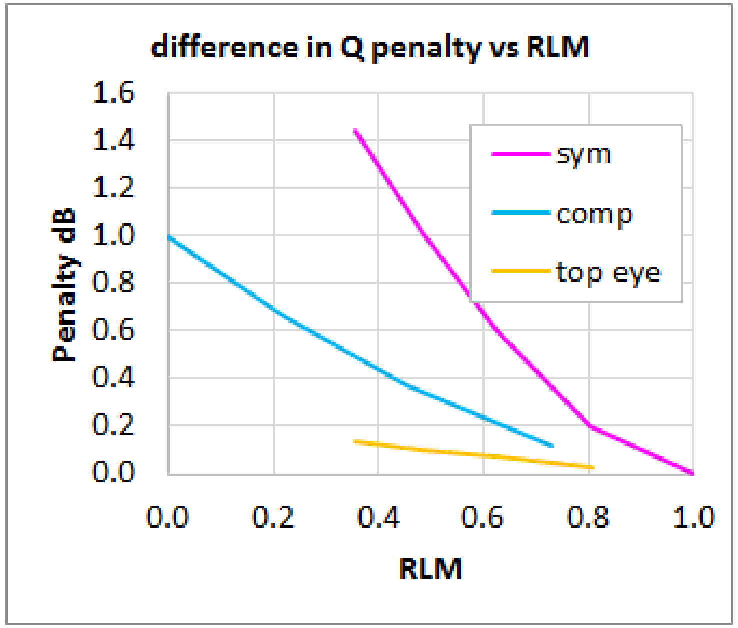
Table of results

												Sub-eye OMA			Threshold difference, OMA		
	0	1	2	3	D3.0	D3.0	D3.0	Optimum	Optimun	Optimum		OMAlo	OMAmid	OMAhi	delta Th		
	M0	M1	M2	M3	Pth1	Pth2	Pth3	Pth1	Pth2	Pth3	RLM				Popt1-Pth	Popt2-Pth	Popt3-Pth
Linear	0.5	0.833	1.167	1.5	0.667	1	1.333	0.667	1	1.333	1	0.333	0.333333	0.333333	0	0	0
Symmetric	0.5	0.801	1.199	1.5	0.667	1	1.333	0.650	1	1.350	0.804	0.301	0.398744	0.300628	-0.01635	0	0.016353
	0.5	0.771	1.229	1.5	0.667	1	1.333	0.635	1	1.365	0.624	0.271	0.458553	0.270723	-0.0313	0	0.031305
	0.5	0.747	1.253	1.5	0.667	1	1.333	0.623	1	1.377	0.482	0.247	0.506044	0.246978	-0.04318	0	0.043178
	0.5	0.726	1.274	1.5	0.667	1	1.333	0.613	1	1.387	0.357	0.226	0.547554	0.226223	-0.05356	0	0.053555
Top eye	0.5	0.849	1.199	1.5	0.679	1.012	1.345	0.675	1.024	1.349	0.807	0.349	0.349458	0.301084	-0.00403	0.012093	0.004031
	0.5	0.865	1.229	1.5	0.69	1.023	1.357	0.682	1.047	1.365	0.625	0.365	0.364556	0.270888	-0.00781	0.023417	0.007806
	0.5	0.877	1.253	1.5	0.699	1.032	1.366	0.688	1.065	1.377	0.481	0.377	0.376564	0.246871	-0.01081	0.032423	0.010808
	0.5	0.887	1.274	1.5	0.707	1.04	1.374	0.694	1.081	1.387	0.355	0.387	0.38705	0.2259	-0.01343	0.040288	0.013429
Power compression	0.5	0.879	1.199	1.5	0.686	1.019	1.353	0.689	1.039	1.349	0.728	0.379	0.320133	0.301228	0.0033	0.019353	-0.0033
	0.5	0.924	1.229	1.5	0.705	1.038	1.372	0.712	1.077	1.364	0.453	0.424	0.304399	0.271132	0.007233	0.038334	-0.00723
	0.5	0.963	1.253	1.5	0.721	1.054	1.387	0.732	1.108	1.376	0.219	0.463	0.289435	0.247102	0.010975	0.05409	-0.01097
	0.5	1	1.274	1.5	0.735	1.069	1.402	0.750	1.137	1.387	2E-04	0.5	0.274298	0.225741	0.014759	0.068555	-0.01476

Q penalty vs R_{LM}

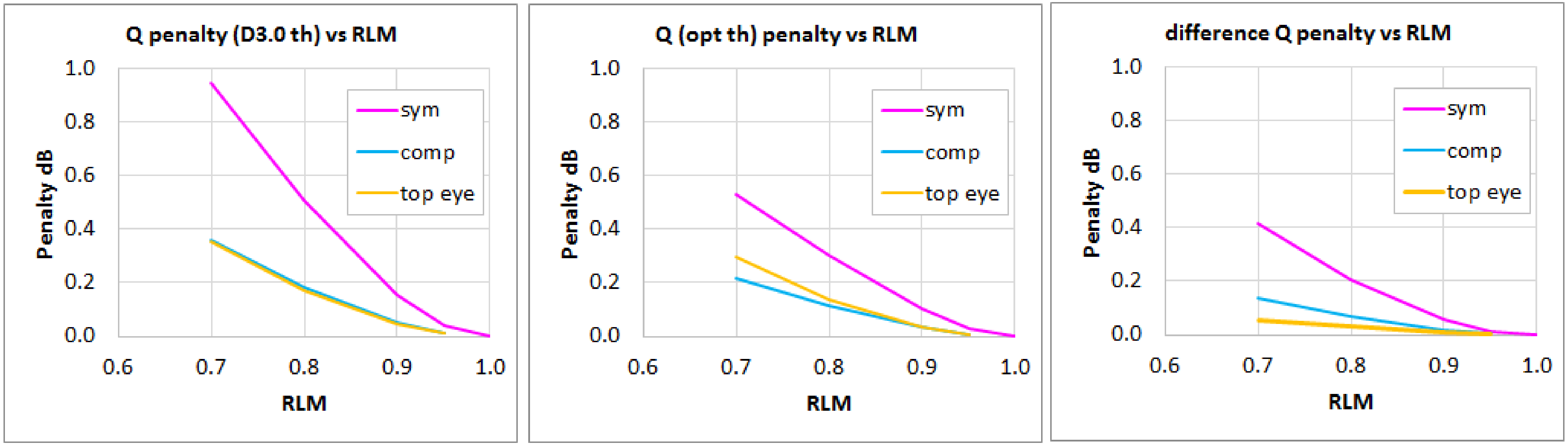






- Symmetric eye inequality produces higher penalty than other forms of eye distortion
- R_{LM} is a poor predictor of Q penalty

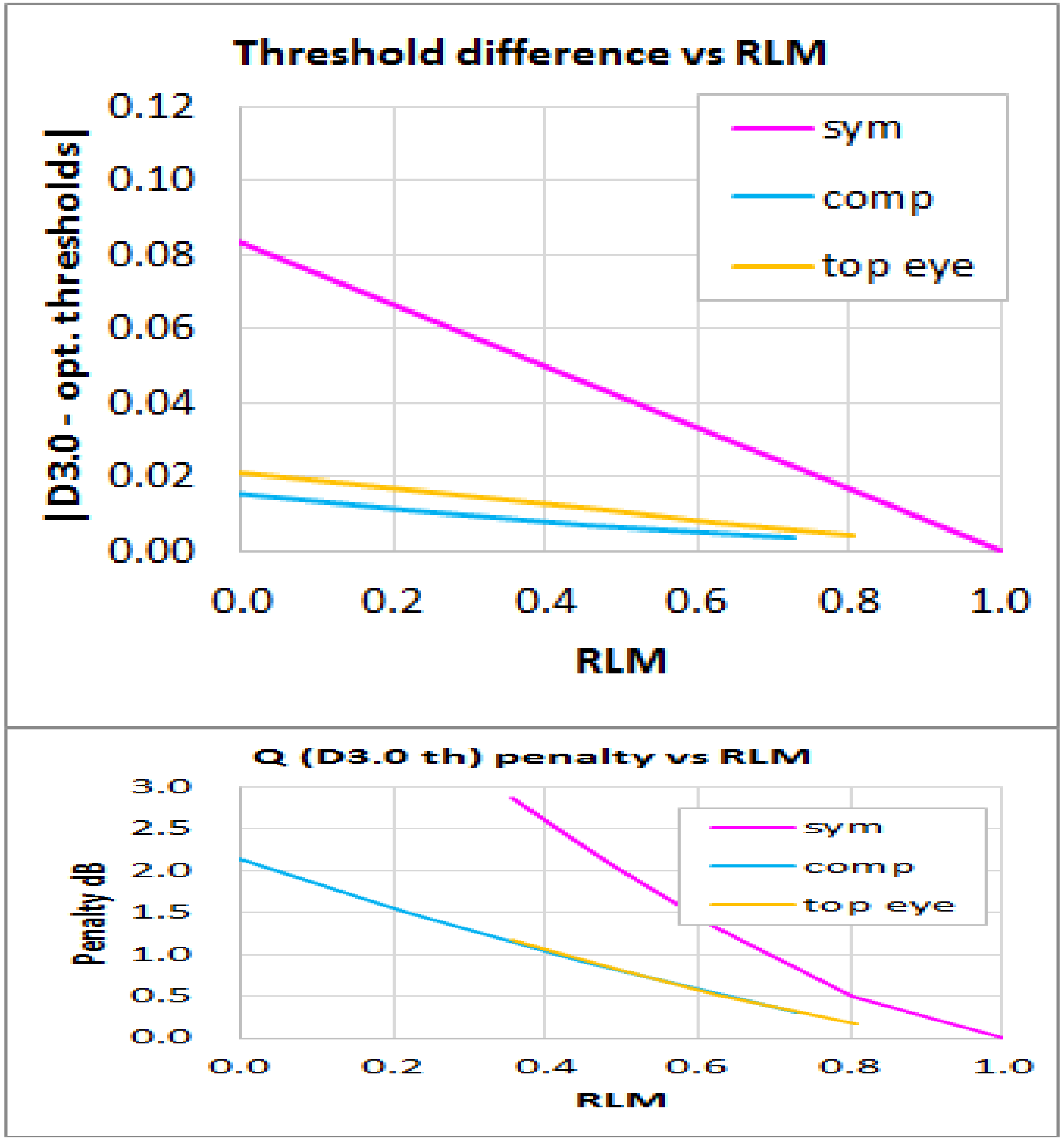
Q penalty vs R_{LM} (expanded view for $R_{LM} > 0.7$)



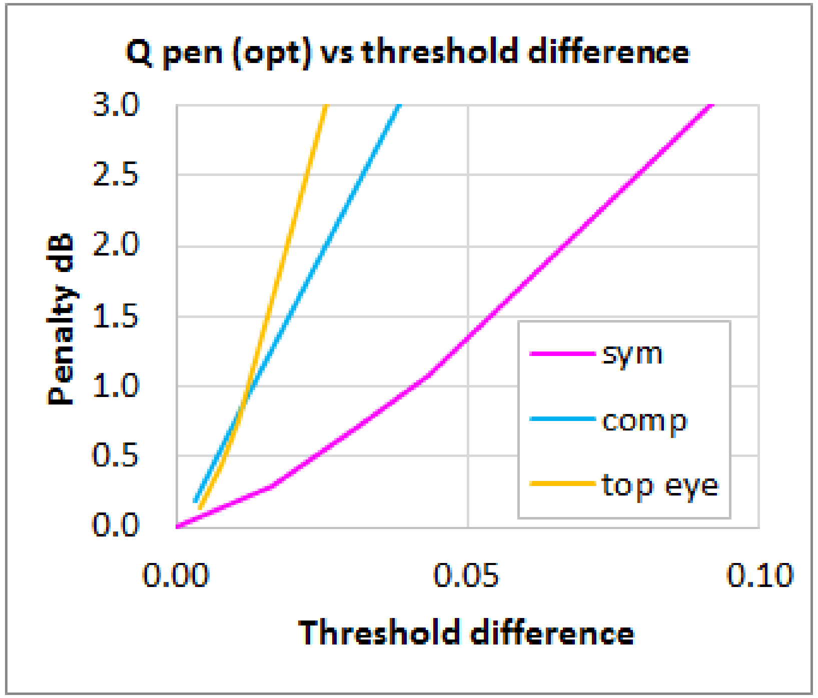
- The Q penalty difference between D3.0 threshold definitions and optimized thresholds is ≤ 0.05 dB for $R_{LM} \geq 0.9$
- R_{LM} is a poor predictor of Q penalty
  - Avoid using it as a spec limit

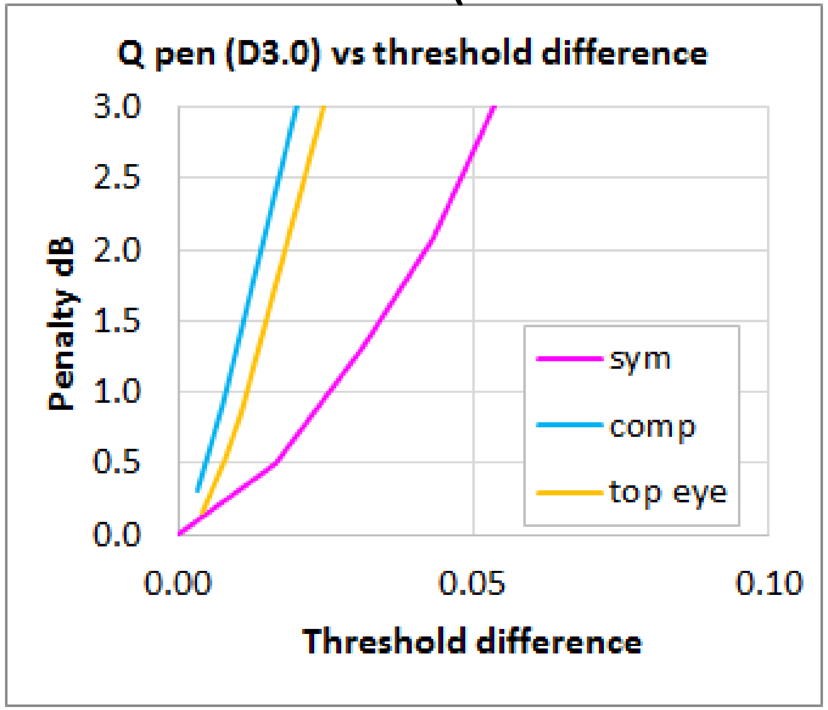
Difference in thresholds vs R_{LM}

- Top plot shows the absolute difference between D3.0 and optimum thresholds, as fraction of OMA_{outer}
- R_{LM} is a poor predictor of the difference between D3.0 thresholds and optimized thresholds



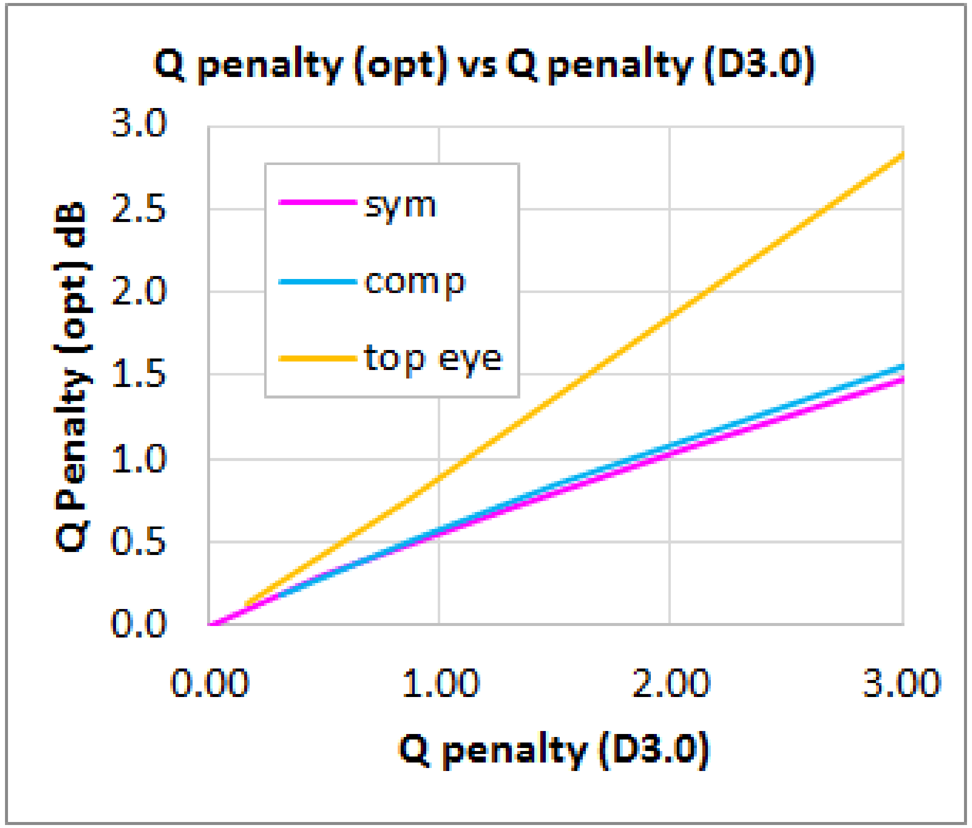
Q penalty vs threshold difference (D3.0 vs optimum)





- Threshold difference is a bad predictor of Q penalty
  - Avoid using it as a spec limit

Q penalty (optimum) vs Q penalty (D3.0)



- Q penalty (D3.0) is a reasonable predictor of worst case penalty for a receiver with optimized thresholds
  - Q penalty (D3.0) is a proxy for TDECQ with D3.0 definitions

Concluding remarks

- D3.0 definition of TDECQ limits sub-eye inequality by using thresholds which are referenced only to OMA_{outer} and average power
- D3.0 definition of TDECQ is a good predictor of worst case penalty for optimized thresholds
- R_{LM} is a poor predictor of Q penalty due to unequal sub-eyes
- The difference between D3.0 thresholds and optimum thresholds is a poor predictor of Q penalty due to unequal sub-eyes