On guarding against overshoot and undershoot in standards using TDECQ measurement

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Supporters

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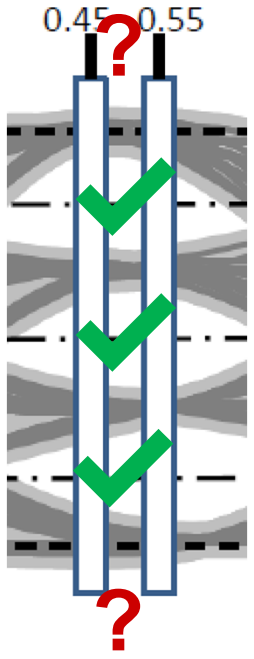
Requirements for a overshoot / undershoot guarding in standards using TDECQ



Problem statement:

- TDECQ penalty measurement properly takes into account the SER of the 3 eyes of PAM4 signal, as these are the primary contributors to the error rate …
  but TDECQ does only little* to evaluate the impact of the top of eye 3 or the bottom of the eye 1 on the SER.
- For simplicity we'll use the terms overshoot and undershoot in this document for the eye area above the top resp. lowest eye.
- Overshoot and undershoot are less direct contributors to the error rate than eye closures, but should be controlled nevertheless because they do impact** the error rate when out of control

*The overshoot and undershoot levels do (at the decision time at least) have an impact on the eye threshold and on equalization, so certain amount of control is present, in particular

**Mild over/undershoot requires (in the receiver) either protection against saturation or increased dynamic rage of the input stages of the receiver (leads to SNR loss and/or cost-of-design increase). Severe over/undershoot can directly cause symbol errors through several possible mechanisms.

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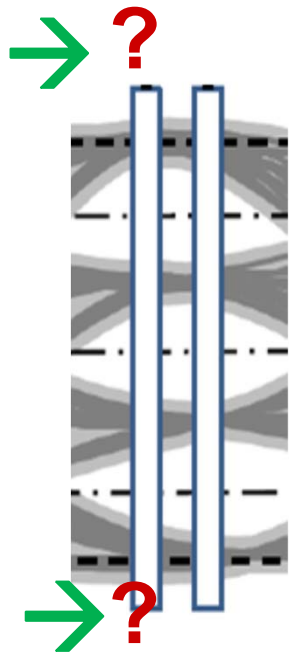
Methodology for a overshoot / undershoot guarding in standards using TDECQ

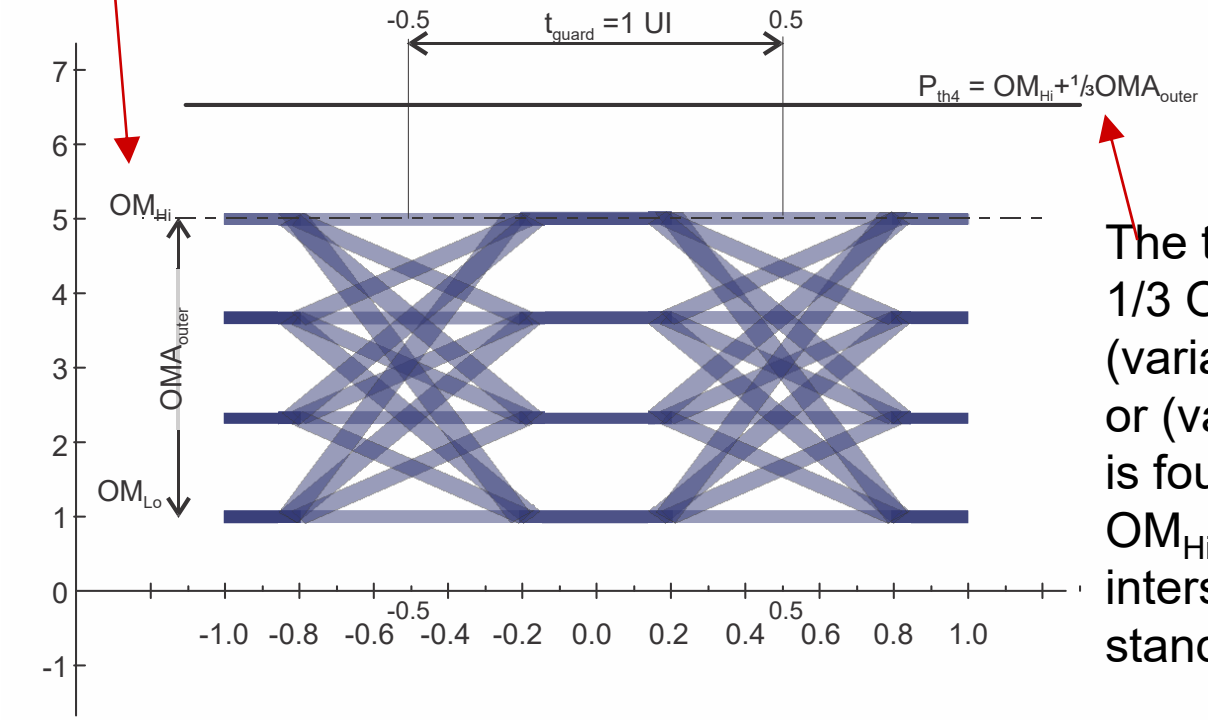


- Overshoot and undershoot should be controlled in a statistically effective way:
  1. peak-peak limiting should not be used since that improperly penalizes the longer, more statistically valid, acquisitions
  2. The oscilloscope noise should not impact the result (within the limits of the oscilloscope sensitivity); i.e., de-embed the oscilloscope noise
  3. Use same mechanism for oscilloscope noise de-embed as the mechanism used by TDECQ
- The time-span of the guard should be *the whole UI*
- The pattern used should be SSPRQ because
  - It presents a mix of frequencies, thus exciting more overshoot effects
  - It is practical – already used, no need to change the DUT into another mode
- The observation bandwidth is the same as for TDECQ measurement

Guarding against the overshoot / undershoot: defining the reference levels, *A (fixed threshold)*

- Focusing on the overshoot (above the eye 3). For reference of the threshold level OM_{Hi}: use the level P_3 (part of OMA_{outer} top level definition).

The time period (relative to the UI duration) over which the overshoot guard is active. Use 1 UI



The top guard P_{th4} is defined as 1/3 OMA_{outer} above the OM_{Hi} (variant A)
or (variant B):
is found as the threshold above OM_{Hi} at which the CDFs intersect at SER of this standard.

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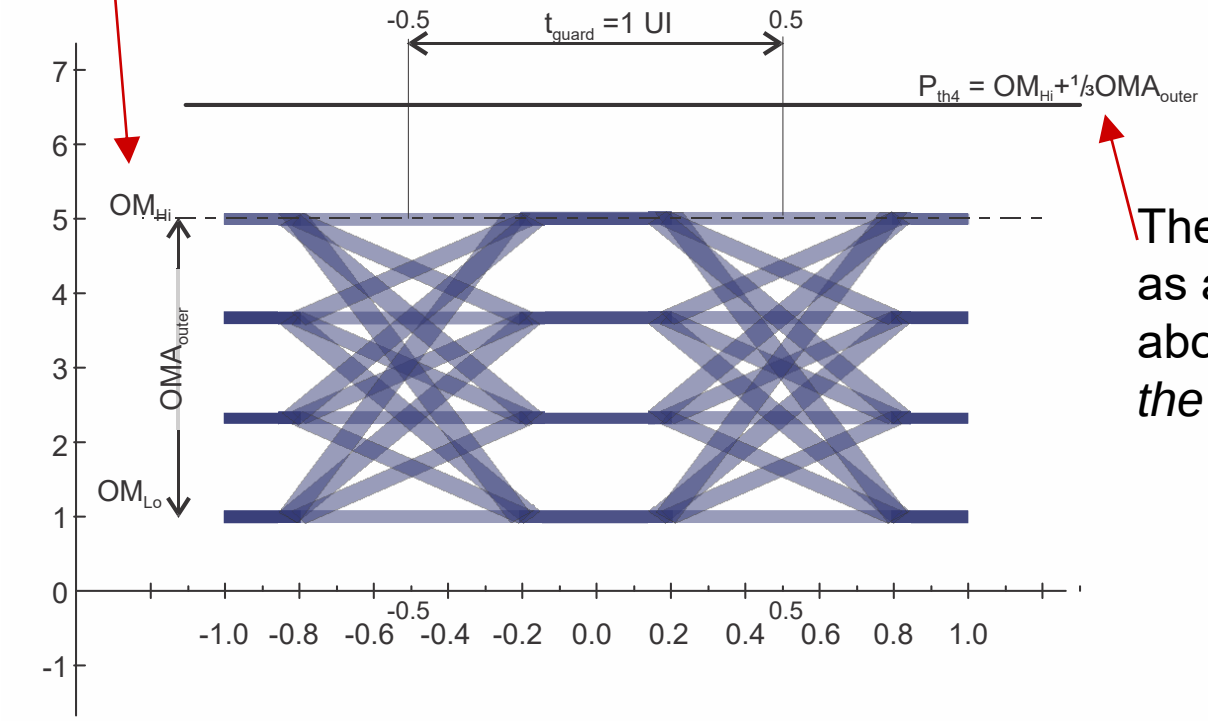
Guarding against the overshoot / undershoot: if A: define the reference levels, if B: find the threshold

- Focusing on the overshoot (above the eye 3). For reference of the threshold level OM_{Hi}: use the level P_3 (part of OMA_{outer} top level definition).

The time period (relative to the UI duration) over which the overshoot guard is active. Use 1 UI



The top guard P_{th4} is *found* as as a fraction of OMA_{outer} above the OM_{Hi} that *yilds just the SER needed*

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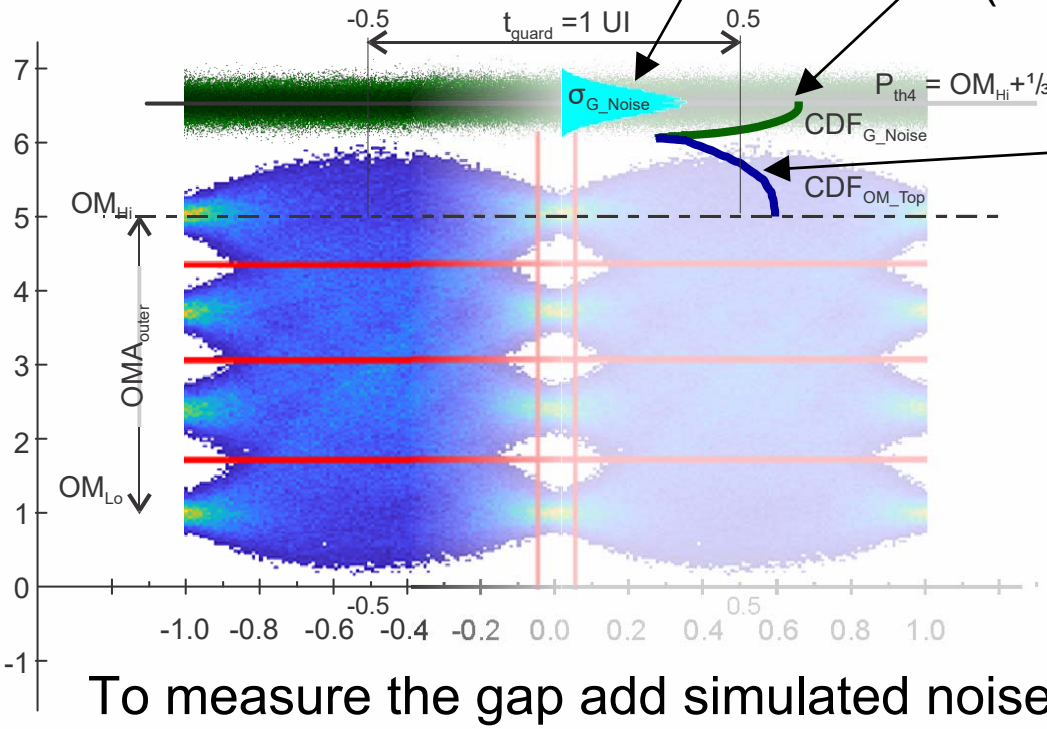
If A: Measure the width of the gap between the top threshold P_{th4} and the signal above the OM_{Hi} level



To measure the gap add simulated noise at the top guard mean level P_{th4} till the intersect of the overshoot and the noise close to the specified (worst) SER of this standard.

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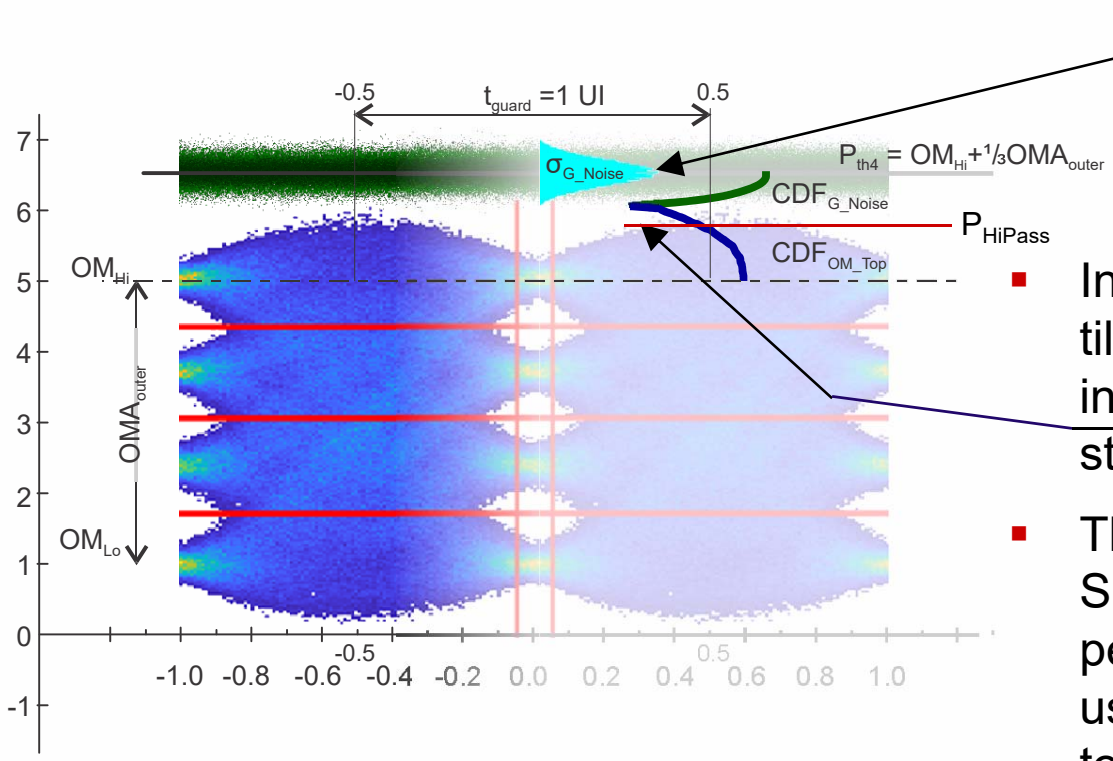
If A: Evaluate the result



Simulated noise

- Increase the simulated noise σ_{noise} till the CDFs intersect at the SER of the standard
- There is no intend to count the SER as the part of the TDECQ penalty. The error level is simply used for consistency/symmetry of top eye

- Overshoot test passes if the CDF reaches the standard SER below the level P_{HiPass} = mean(OM_{Hi} ; P_{th4})
- If a higher threshold is needed the P_{th4} should be moved outwards, else there's no room for the oscilloscope noise compensation.

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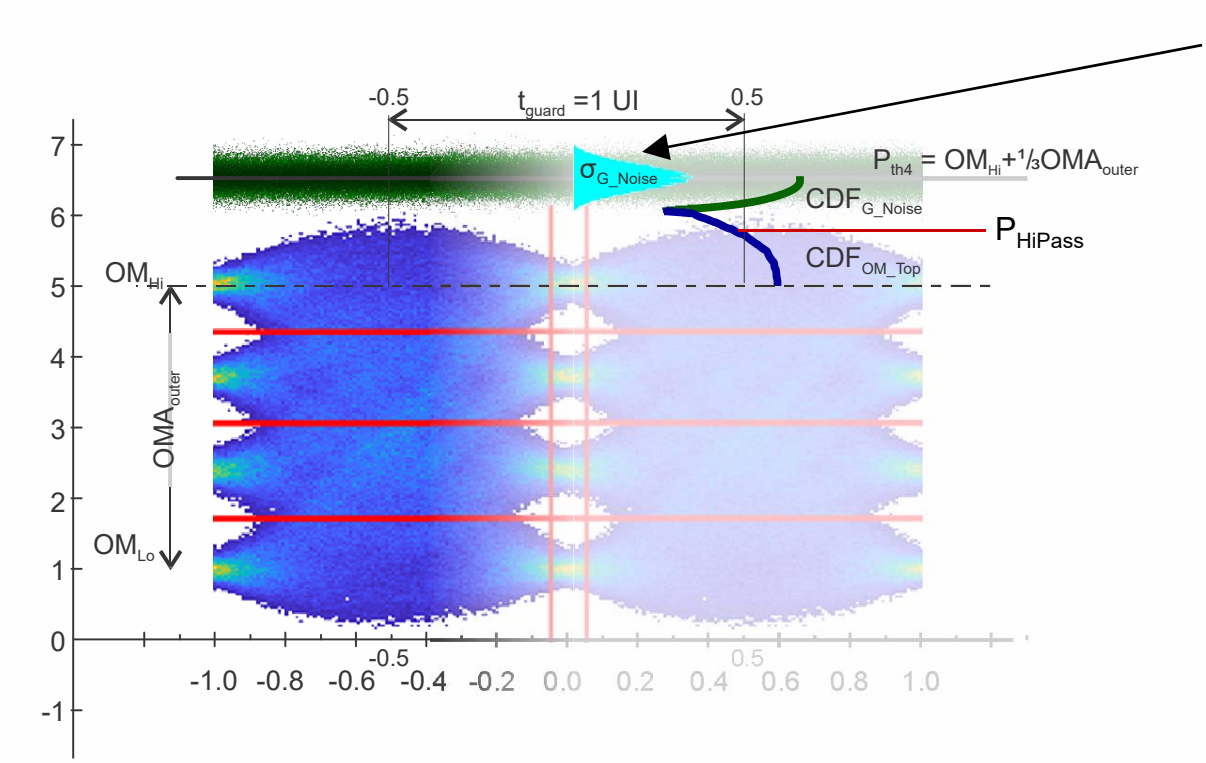
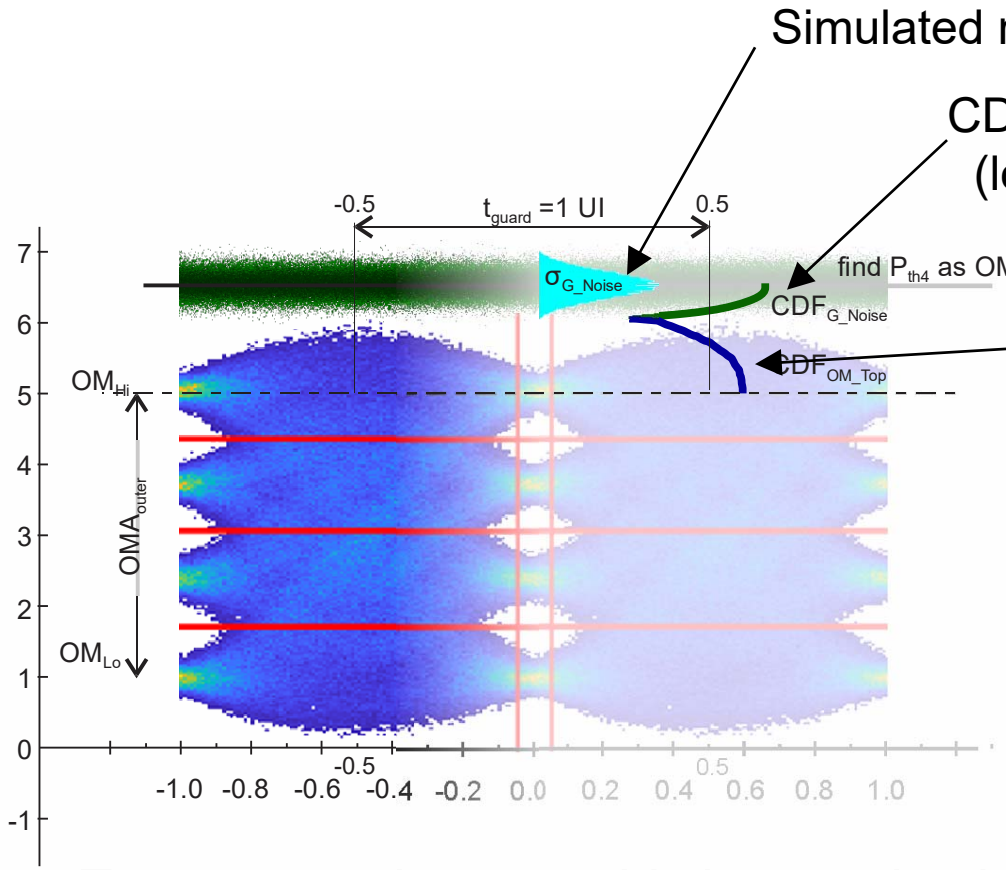
Impact of oscilloscope noise



Simulated noise is a convolution of the oscilloscope noise and an ideal Gaussian distribution. Oscilloscope noise is easily deconvolved from the pdf/cdf (as long as it knows and it is Gaussian as well; same conditions as for TDECQ)

- if a large overshoot should be allowable then the P_{th4} would need to move higher above its current position.

If B: Find the top threshold P_{th4} above the OM_{Hi} level such that the CDFs intersect at the SER of this standard



CDF of top eye diagram's waveform distribution above the *top* level (OM_{Hi}) only; normalized to its correct share of likelihood over the whole eye)

To measure the gap add simulated noise at the top guard mean level P_{th4} till the intersect of the overshoot and the noise close to the specified (worst) SER of this standard.

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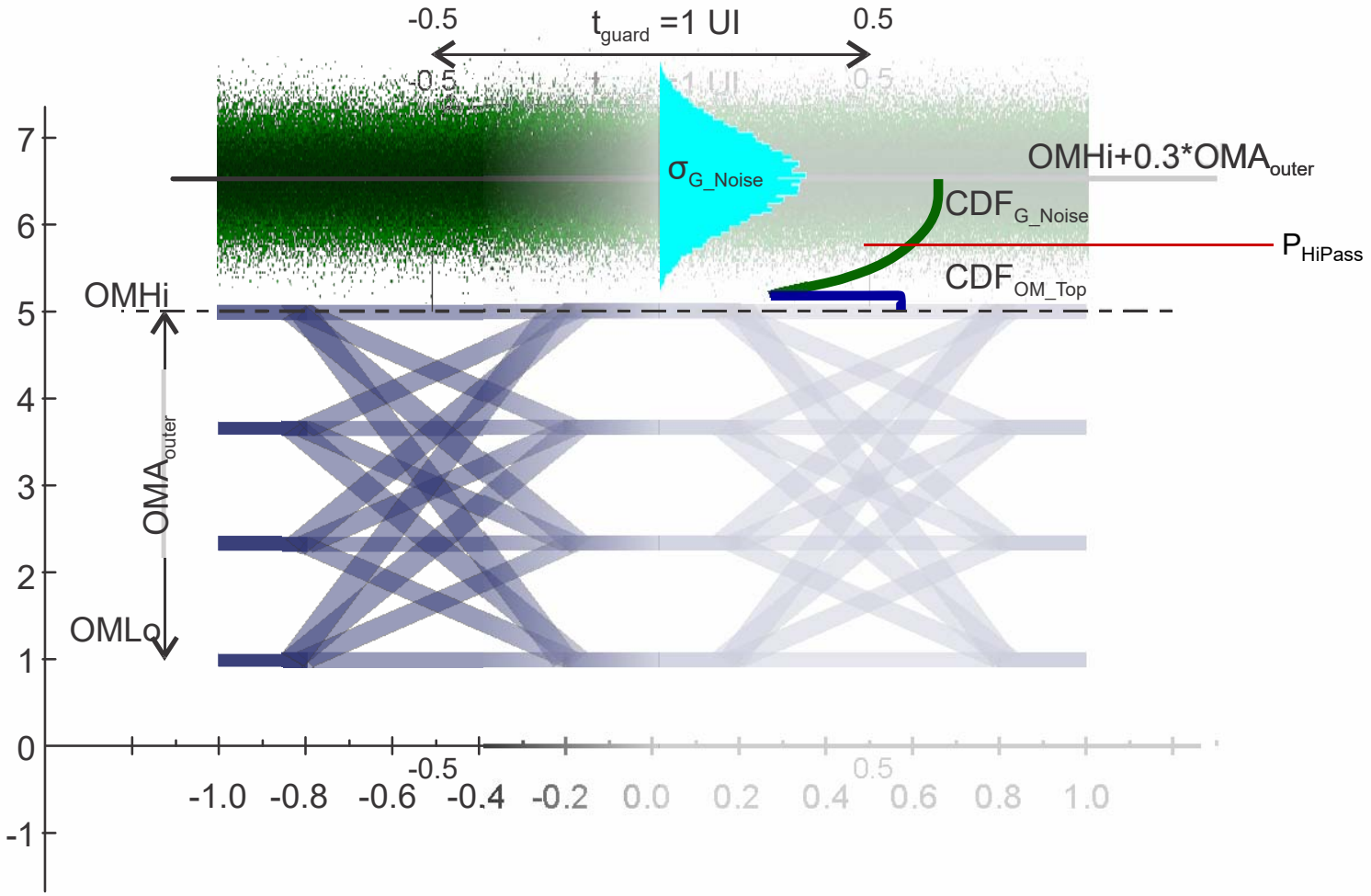
Example of an ideal eye passing with great margin the overshoot specification



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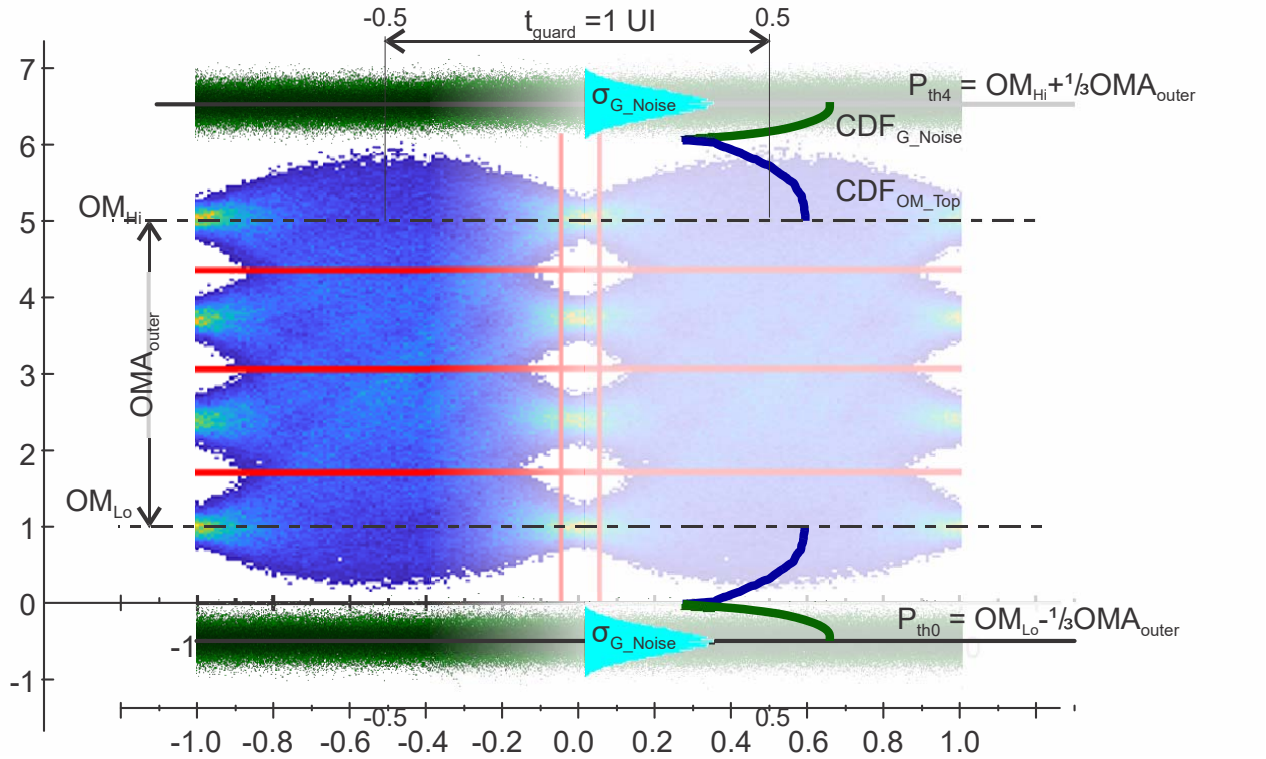
Example of an eye with an undershoot specification

- Note that the undershoot is limited already by the minimum allowable ER. However if a specification is desired/needed then it would be a virtual opposite of the high level, as per the pic below, and also perhaps with the value change due to the dark level being close.



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Question?:

- Thank you,

  Pavel