

## On guarding against overshoot and undershoot in standards using TDECQ measurement

- Pavel Zivny



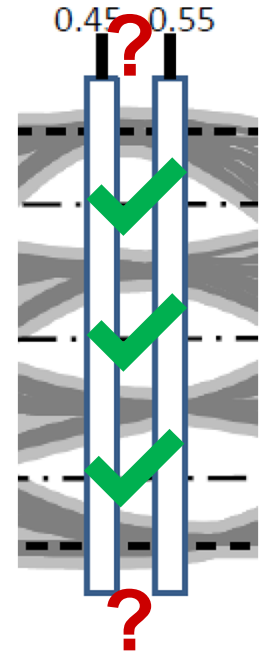
# Supporters

- TBD

# 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

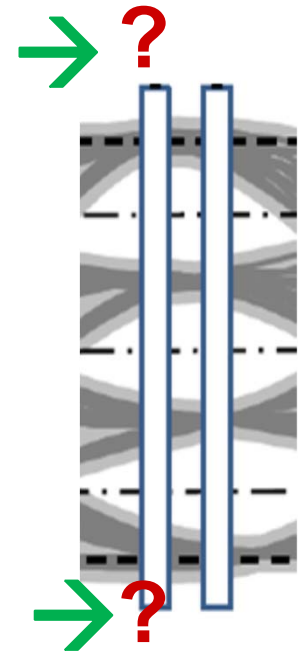


\*The overshoot and undershoot levels do (at the decision time at least) have an impact on the eye threshold and on equalization, so certain amount of control is present.

\*\*Mild over/undershoot requires (in the receiver) either protection against saturation or increased dynamic range 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.

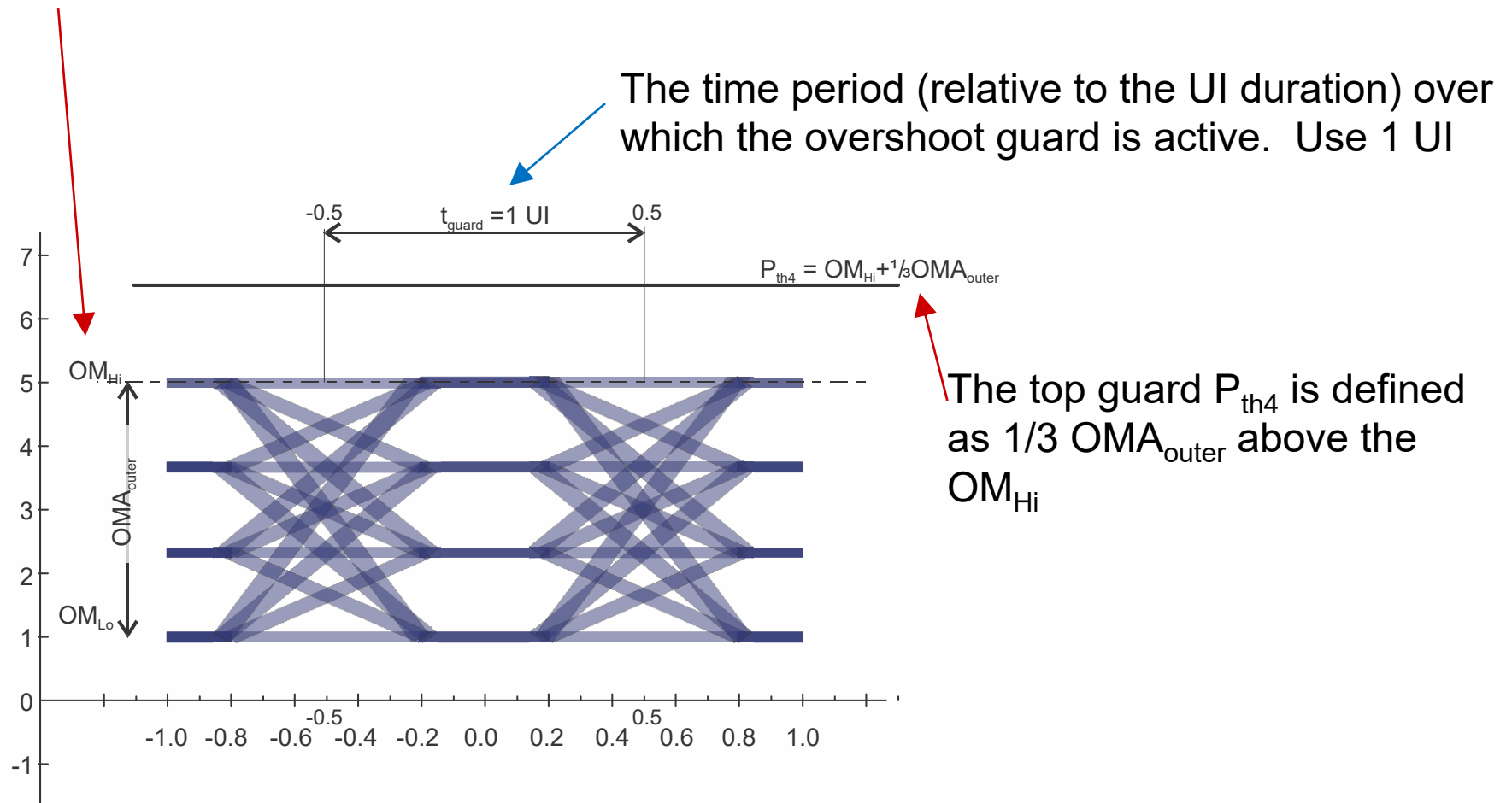
# Methodology for a overshoot / undershoot guarding in standards using TDECQ

- 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 over which the guard should be determined by the receiver designer feedback

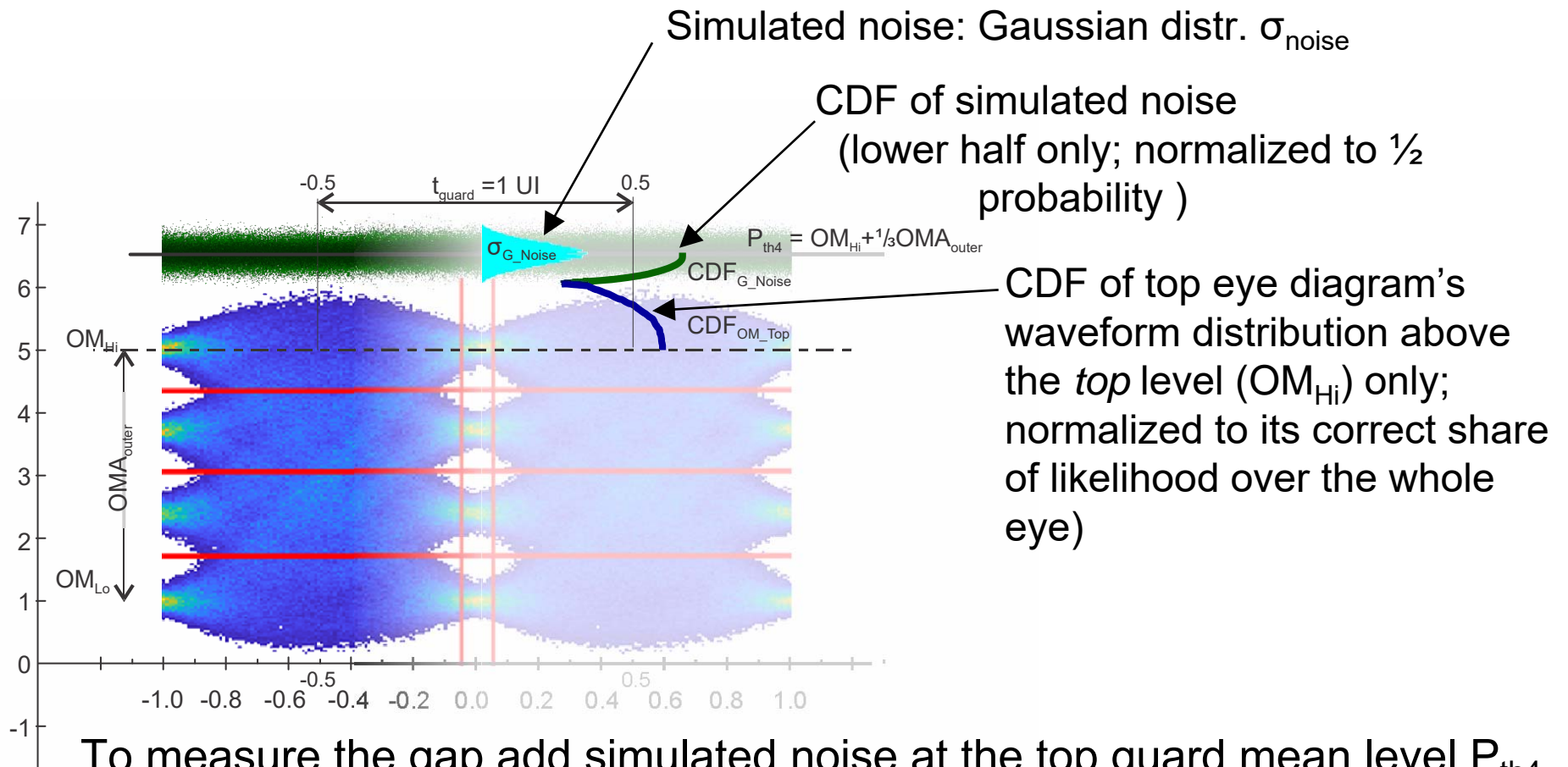


# Guarding against the overshoot / undershoot: defining the reference levels

- 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).

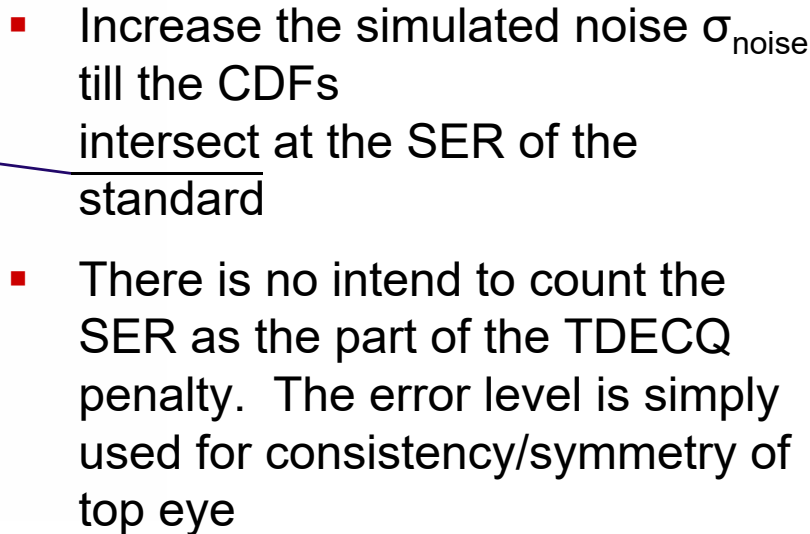


Measure the width of the gap between the top threshold  $P_{th4}$  and the signal above the  $OM_{Hi}$  level



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.

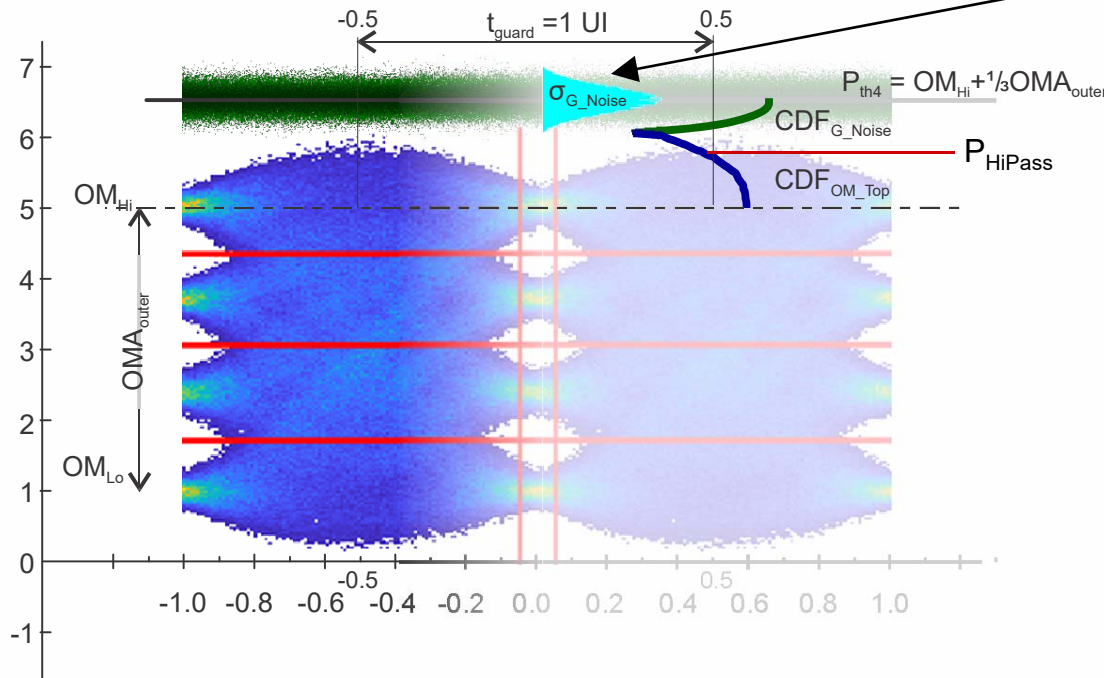
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- There is no intend to count the SER as the part of the TDECQ penalty. The error level is simply used for consistency/symmetry of top eye



# Impact of oscilloscope noise

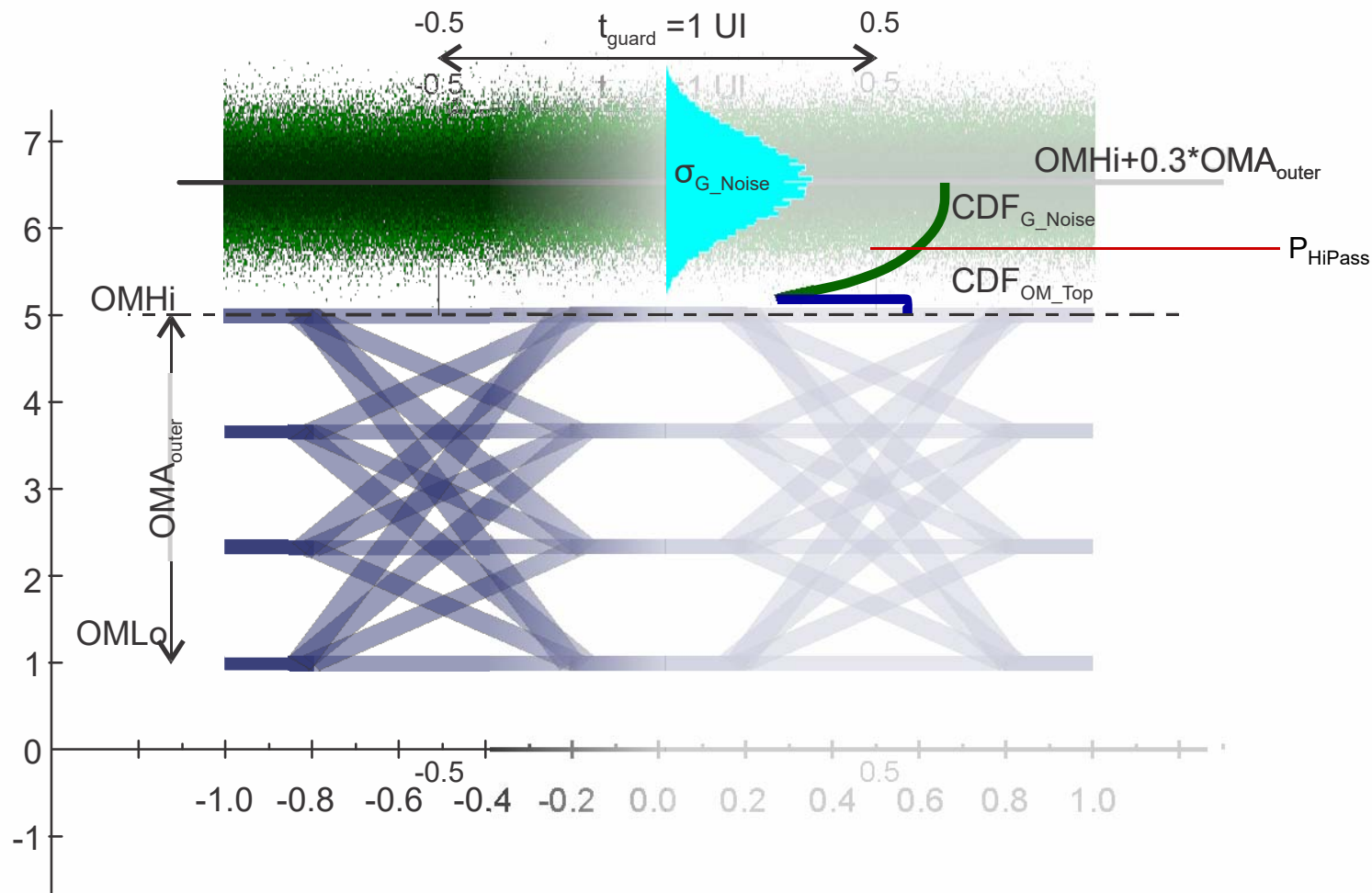


Simulated noise is a convolution of the oscilloscope noise and an ideal Gaussian distribution. Oscilloscope noise is easily deconvolved from the pdf/cdf (as long as it knows and it is Gaussian as well; same conditions as for TDECQ)

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

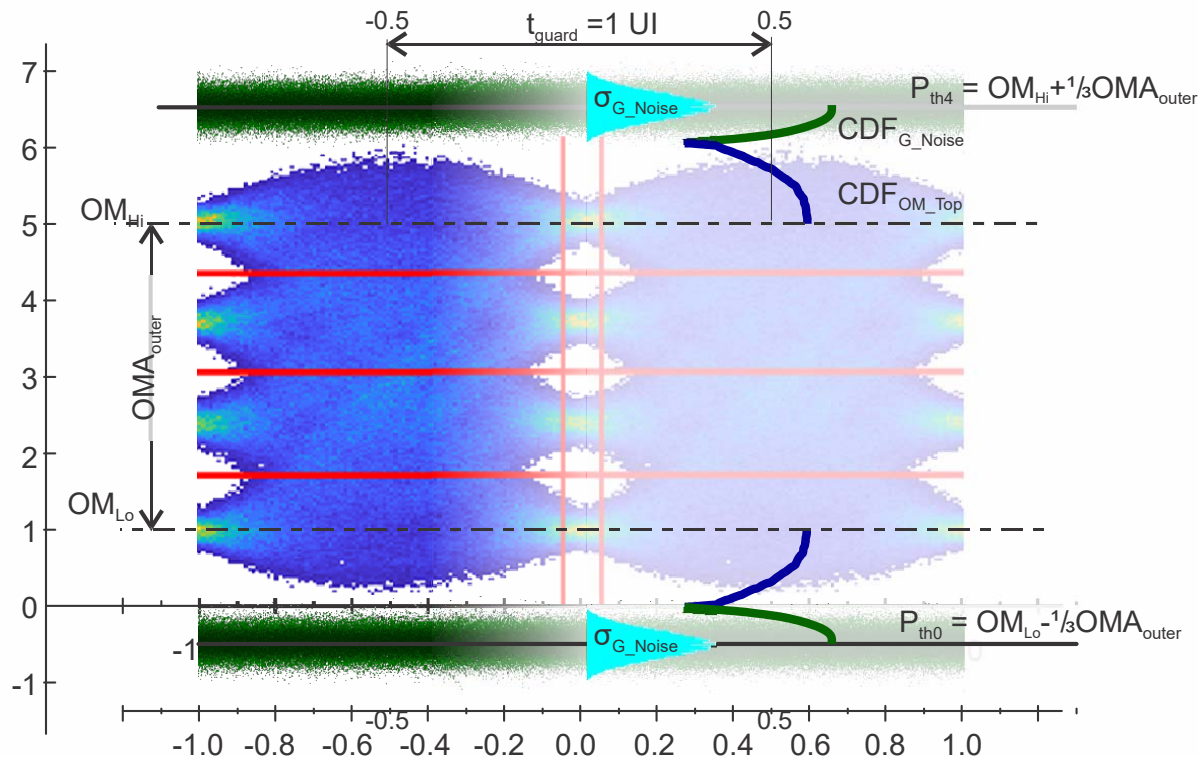


# Example of an ideal eye passing with great margin the overshoot specification



# 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.





## Question?:

- Thank you,

Pavel