# Signal metrics for 10GBASE-LRM


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|---|---|
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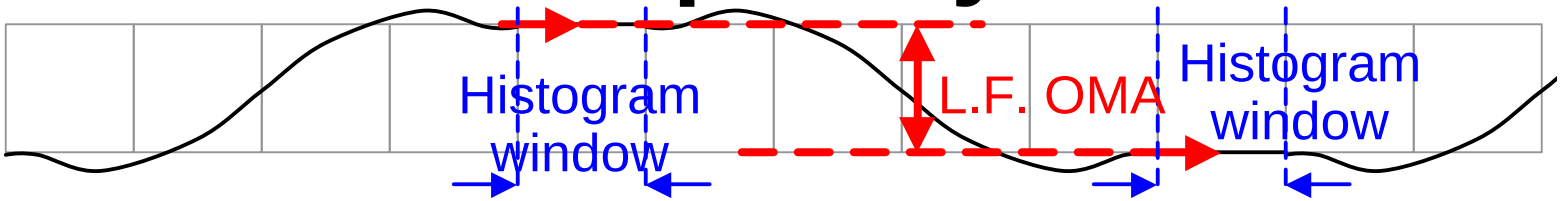
# Statement of problem

- Measure signal strength and quality
  - Need: from data terminal equipment (DTE) at TP2
  - Need: from stressed eye tester at TP3
  - Want? need?: from DTE after fiber at TP3
- Clock may not be available
  - Pattern trigger unlikely to be available
  - Have to recover these with e.g. CDR or not use them
- Eye may be much more closed than other standards

# Candidate metrics

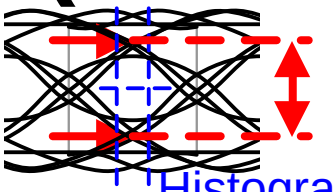
- Low frequency OMA
- “High” (mixed) frequency OMA
- Alternative estimate of L.F. OMA
- Asynchronous OMA
- (AC) RMS signal strength
- Mean power
  - *more…*

# Low frequency OMA



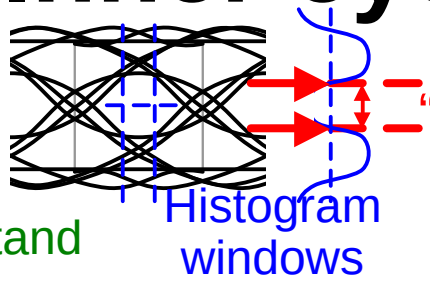

- Uses pattern such as 00001111 to 0000000000011111111111
- Easy to understand
- Good basis for analysis
- Used in 802.3ae
- Goes with 8B/10B code
- Not (much) affected by dispersion in channel
- **Not mission mode**
  - **DTE under test has to be put into non-usual operation – may not be practicable. Can't be used in service.**
- Clocking or triggering
  - Benefits from a clock synchronised to signal, but pattern's transition density is unusually low – CDR often will not lock to it
  - However, can trigger the scope to the pattern – if the edges aren't too poor – **needs checking out**
- Not very reproducible
  - Reading depends on fine details of frequency response of DUT at (harmonics of) pattern length
- Not very representative
  - Does not reflect useful signal except in limit of no distortion
- Little affected by noise

# “High” (mixed) frequency OMA



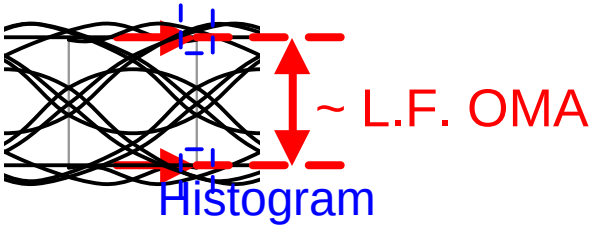

- Easy to understand
- Goes with scrambled code
- Used in EFM. The implicit basis of SONET specs
- Not the starting point for analysis – an “output” quantity rather than an “input”
- Affected by dispersion in channel
  - In non-EDC systems this effect is small
  - In EDC systems this effect is beneficial:
- Representative – Reflects useful signal even with distortion and pattern dependent effects – more representative with EDC than not
- **Mission mode**
  - **No special patterns needed. Can measure in-service signal. No control over DUT needed**
- Needs a clock synchronised to signal – Inconvenient if eye is near or fully closed
- Good for clock recovery – Normal transition density, can use available CDRs
  - Does not need pattern trigger
- Fairly reproducible
  - Reading depends a little on fine details of frequency response of scope
- Little affected by noise, robust measurement

# “Inner eye opening”




- Easy to understand
- Used in 802.3ae
- **Method fails if eye completely closed**
- Not the starting point for analysis – an “output” quantity rather than an “input”
- Affected by dispersion in channel
  - In non-EDC systems this effect is small
  - In EDC systems this effect is beneficial:
- Representative – Reflects useful signal even with distortion and pattern dependent effects – very relevant and representative without EDC, ~-ISI
- Mission mode
  - No special patterns needed if accuracy not critical. Can measure in-service signal. No control over DUT needed
- Needs a clock synchronised to signal – Inconvenient if eye is near closed, fails if eye is closed
- Good for clock recovery – Normal transition density, can use available CDRs – if the eye is open
  - Does not need pattern trigger
- Reading depends a little on fine details of frequency response of scope
- Affected by noise, needs careful definition of statistical significance

# Alternative estimate of L.F. OMA

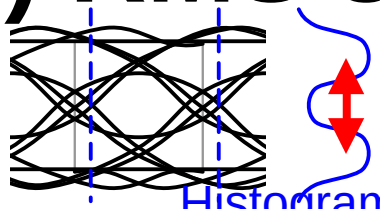



- Suggested in 802.3ae
- Goes with scrambled code
- Not the starting point for analysis – an "output" quantity rather than an "input"
- Weakly affected by dispersion in channel
- Not very representative
  - Does not reflect useful signal except in limit of no distortion
- **Mission mode**
  - **No special patterns needed. Can measure in-service signal. No control over DUT needed**
- Needs a clock synchronised to signal – Inconvenient if eye is near or fully closed
- Good for clocking – Normal transition density, can use available CDRs – if the eye is open
  - Does not need pattern trigger
- Little affected by noise
- Not a robust measurement
  - If edges cross histogram window, reading is polluted
  - Problem for fast ringy signals
  - Use of peaks ("modes") rather than means may help for manual measurement

# Asynchronous OMA

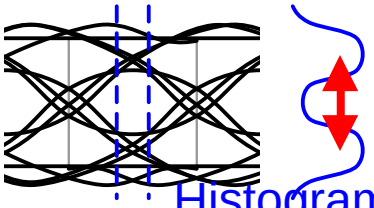

- Described in G.697
- Goes with scrambled code
- Not the starting point for analysis – an "output" quantity rather than an "input"
- Affected by dispersion in channel
  - In EDC systems this effect is beneficial:
- Representative – Reflects useful signal even with distortion and pattern dependent effects – more representative with EDC than not
- **Mission mode**
  - **No special patterns needed. Can measure in-service signal. No control over DUT needed**
- **Simple**
- No clock needed! Scope can be asynchronous to pattern
  - If clock used, set window to 1 UI long
    - Normal transition density, can use available CDRs
- Doesn't work well (I think) if eye is closed
- Little affected by noise
- Can be enhanced to provide a measure of distortion – TP2 metric?
- (If there is no overshoot, range of histogram ~ OMA + 2.noise)

# (AC) RMS signal strength



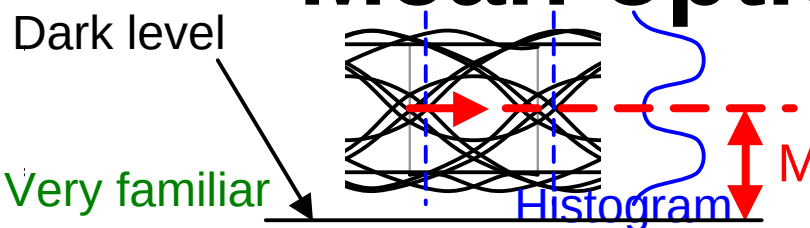

- Very familiar concept
- Goes with scrambled code
- Not the starting point for analysis – an "output" quantity rather than an "input"
- Affected by dispersion in channel – in EDC systems this effect is beneficial:
- Representative – Reflects useful signal even with distortion and pattern effects – more representative with EDC than not
  - **Good TP3 metric for assessing real signals and fibre plant**
- **Mission mode**
  - **No special patterns needed. Can measure in-service signal. No control over DUT needed**
- **Very simple**
- No clock needed! Scope can be asynchronous to pattern
  - If clock used, set window to 1 UI long
    - Normal transition density, can use available CDRs
- No scope needed! Can use RF power meter with right bandwidth filter
- **Keeps working even if eye is fully closed!**
- By comparison with e.g. OMA, provides a measure of distortion
  - TP2 metric, even TP3 metric!
- Weakly affected by noise – Correcting for instrument noise is well known

# S.D. of middle of eye



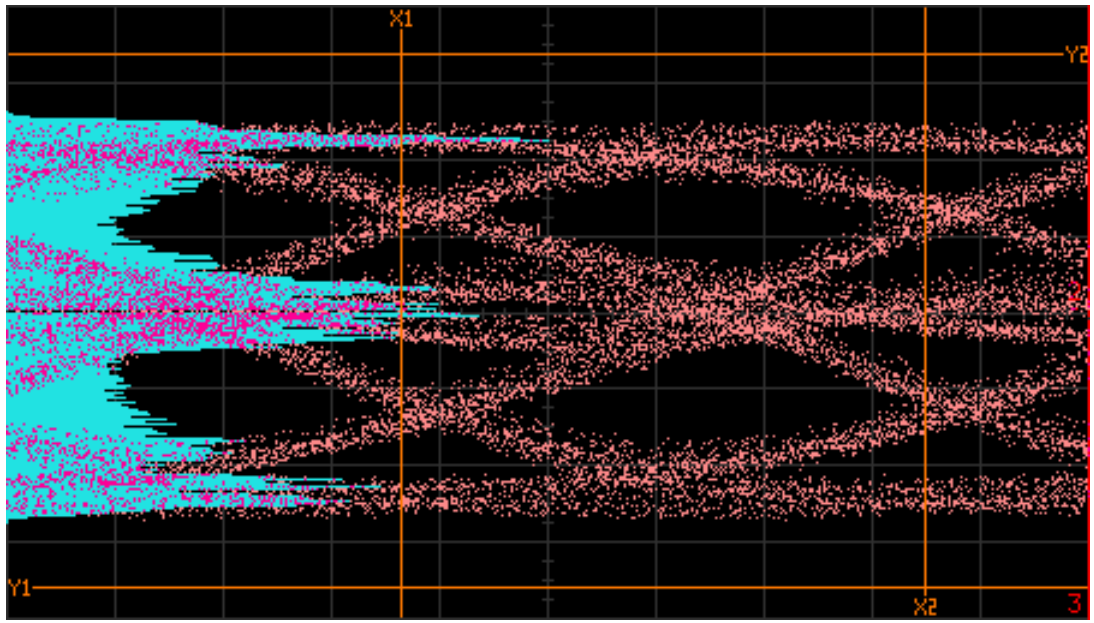

- Very familiar concept
- Goes with scrambled code
- Not the starting point for analysis –an “output” quantity rather than an “input”
- Affected by dispersion in channel – in EDC systems this effect is beneficial:
- Representative – Reflects useful signal even with distortion and pattern effects – more representative with EDC than not
- **Mission mode**
  - **No special patterns needed. Can measure in-service signal. No control over DUT needed**
- Needs a clock synchronised to signal – Inconvenient if eye is closed
- Good for clock recovery – Normal transition density, can use available CDRs – if the eye is open
  - Does not need pattern trigger
- Reading depends a little on fine details of frequency response of scope
- Little affected by noise
- **Fails if eye is fully closed and middle of eye cannot be identified**
- By comparison with e.g. OMA, provides a measure of distortion
- A useful lab technique, could be used as TP2 metric

# Mean optical power



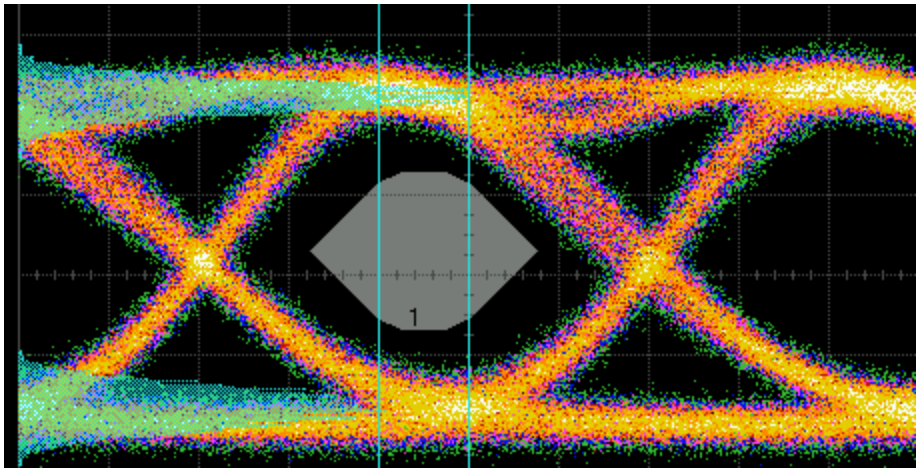

- Very familiar
- Appears in standards
- Code agnostic (if we believe the DUT controls mean power)
- Only weakly relevant for analysis – affects obscure things like reflection noise
- Relevant for eye safety and overload. Not affected by dispersion in channel
- **Not representative – Does not measure useful signal. Poor metric.**
- **Poor TP3 metric for highly distorted signals in 10GBASE-LRM where loss should be small**
- Reasonable TP3 metric for high-loss physical layers
- **Mission mode**
  - **No special patterns needed. Can measure in-service signal. No control over DUT needed**
- Seems simple – but need to find dark level – calibration step
- No clock needed! Scope can be asynchronous to pattern
  - If clock used, set window to 1 UI long.
  - Normal transition density, can use available CDRs
- No scope needed! Can use optical power meter
- **Keeps working even if eye is fully closed**
- Little affected by noise

# Example of closed TP3 eye and “asynchronous” histogram

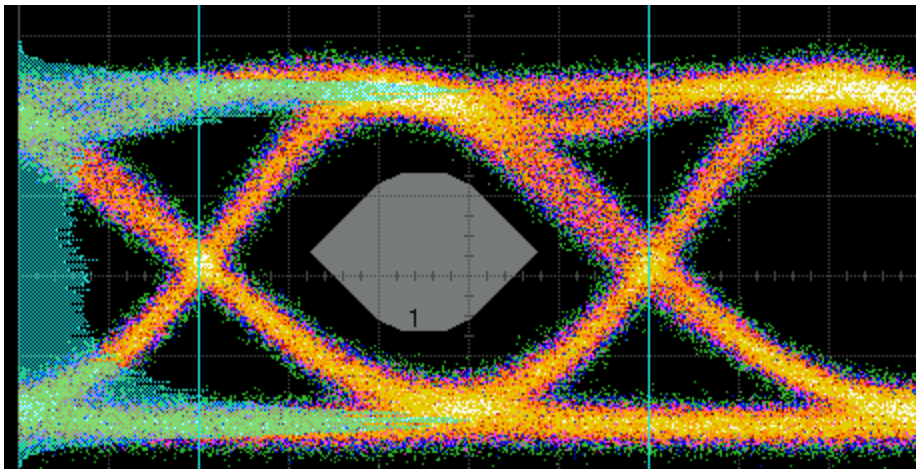



- Histogram is quite jagged
  - Can’t identify peaks with confidence
  - Statistical measures like mean and standard deviation still work well

# “Good to slow” transmitted eye – little overshoot

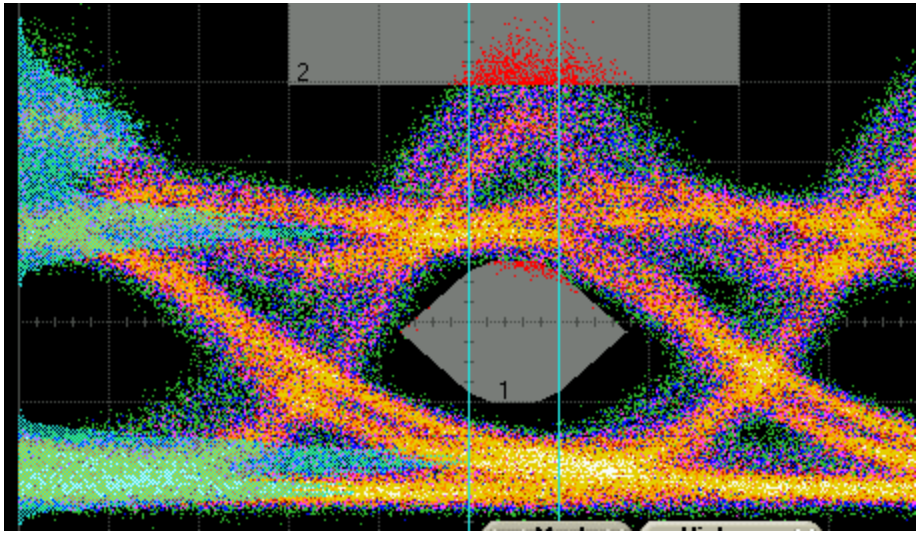


Histogram over central 0.2 UI

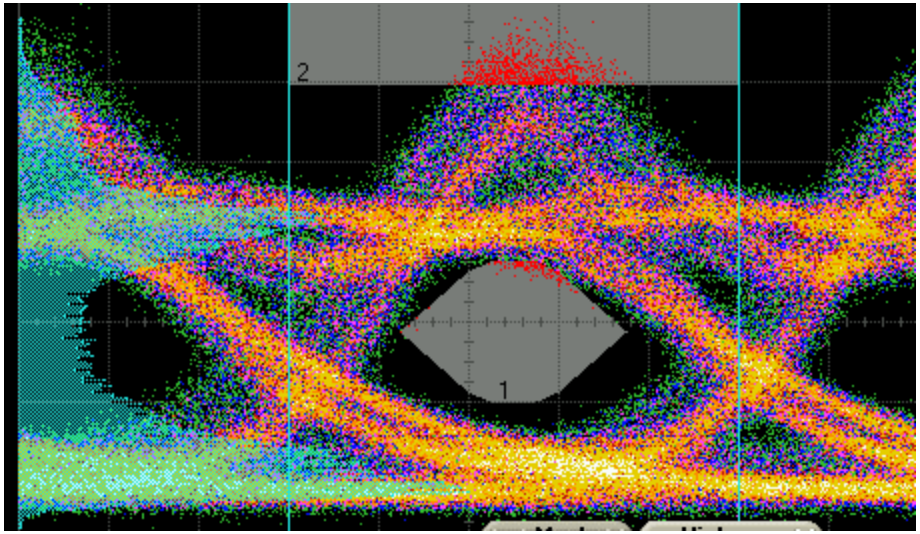


Histogram over 1 UI (same as asynchronous measurement)

# “Bad” transmitted eye – large overshoot

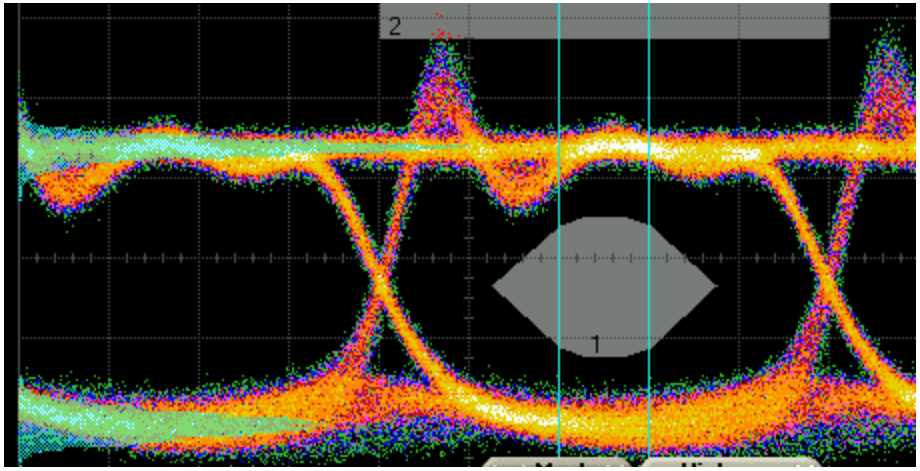


Histogram over central 0.2 UI

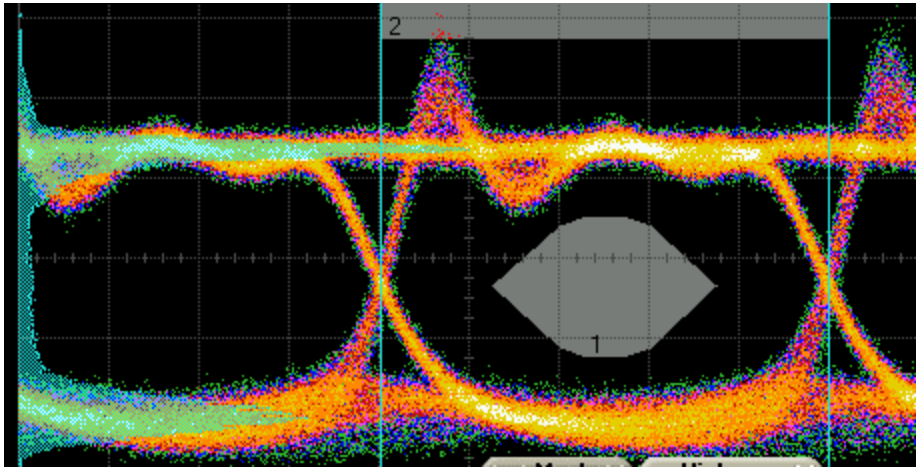


Histogram over 1 UI (same as asynchronous measurement)

# “Faster” transmitted eye

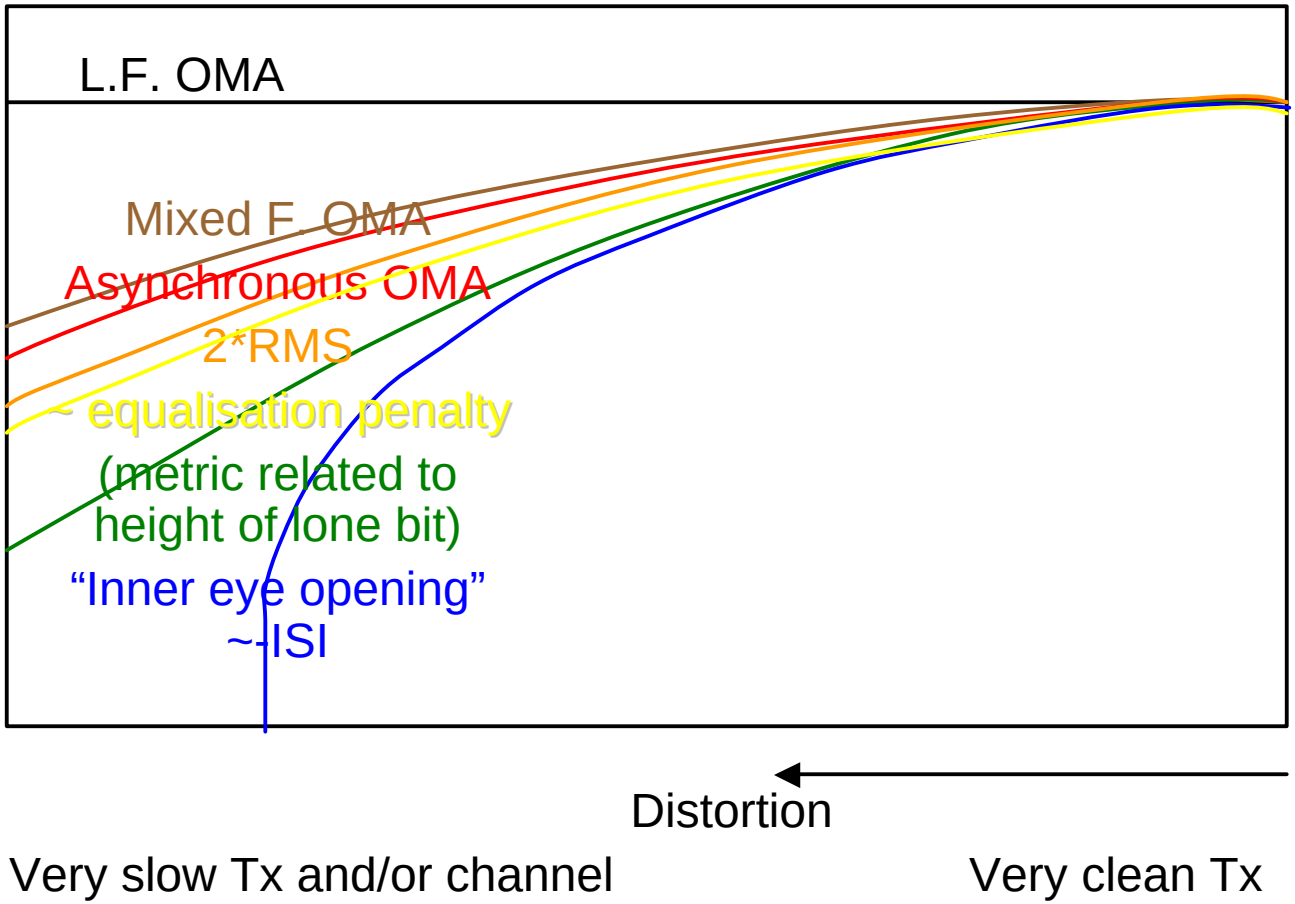


Histogram over central 0.2 UI



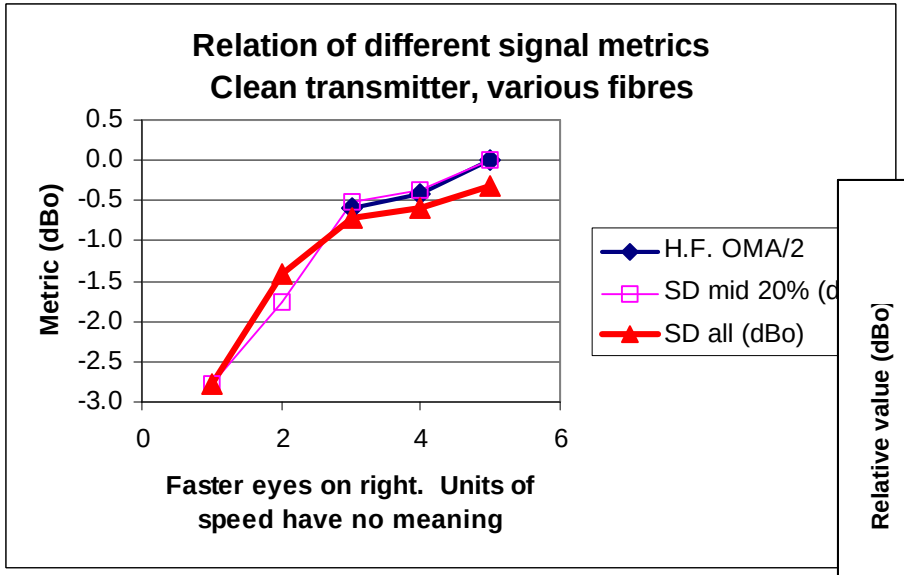
Histogram over 1 UI (same as asynchronous measurement)

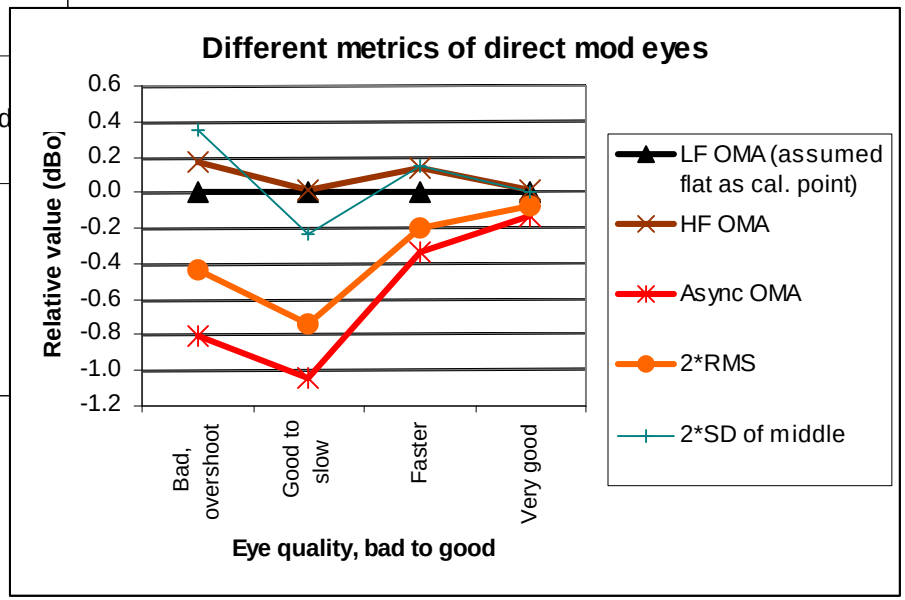
# Correlation among metrics




Expect several metrics to correlate tolerably to useful signal strength with equalising receiver

# Measured results



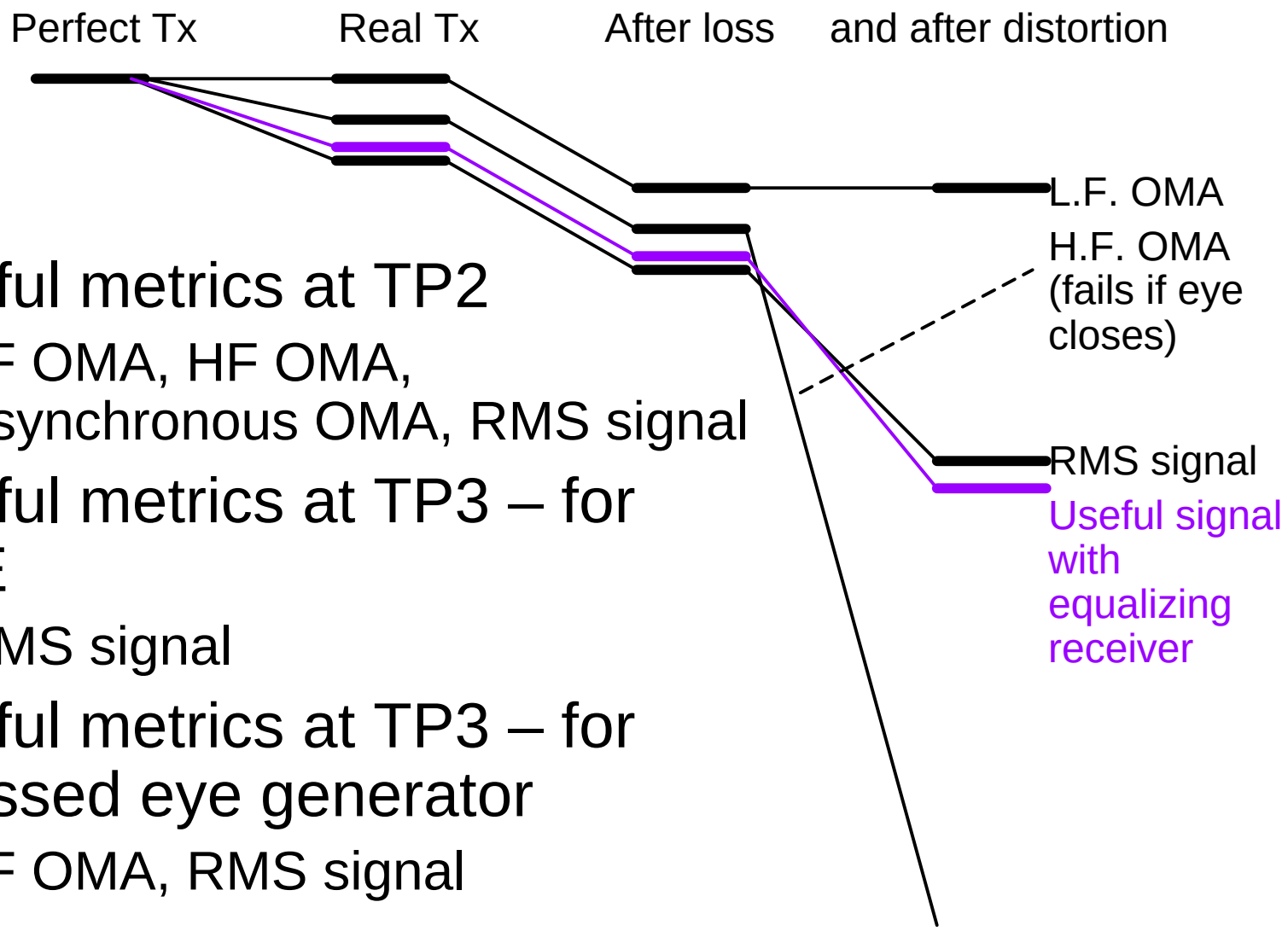




- Trends as expected except when overshoot dominates
  - Identifies channel-induced eye closure well
  - At TP2, little difference between LF and HF OMA

# Work to do

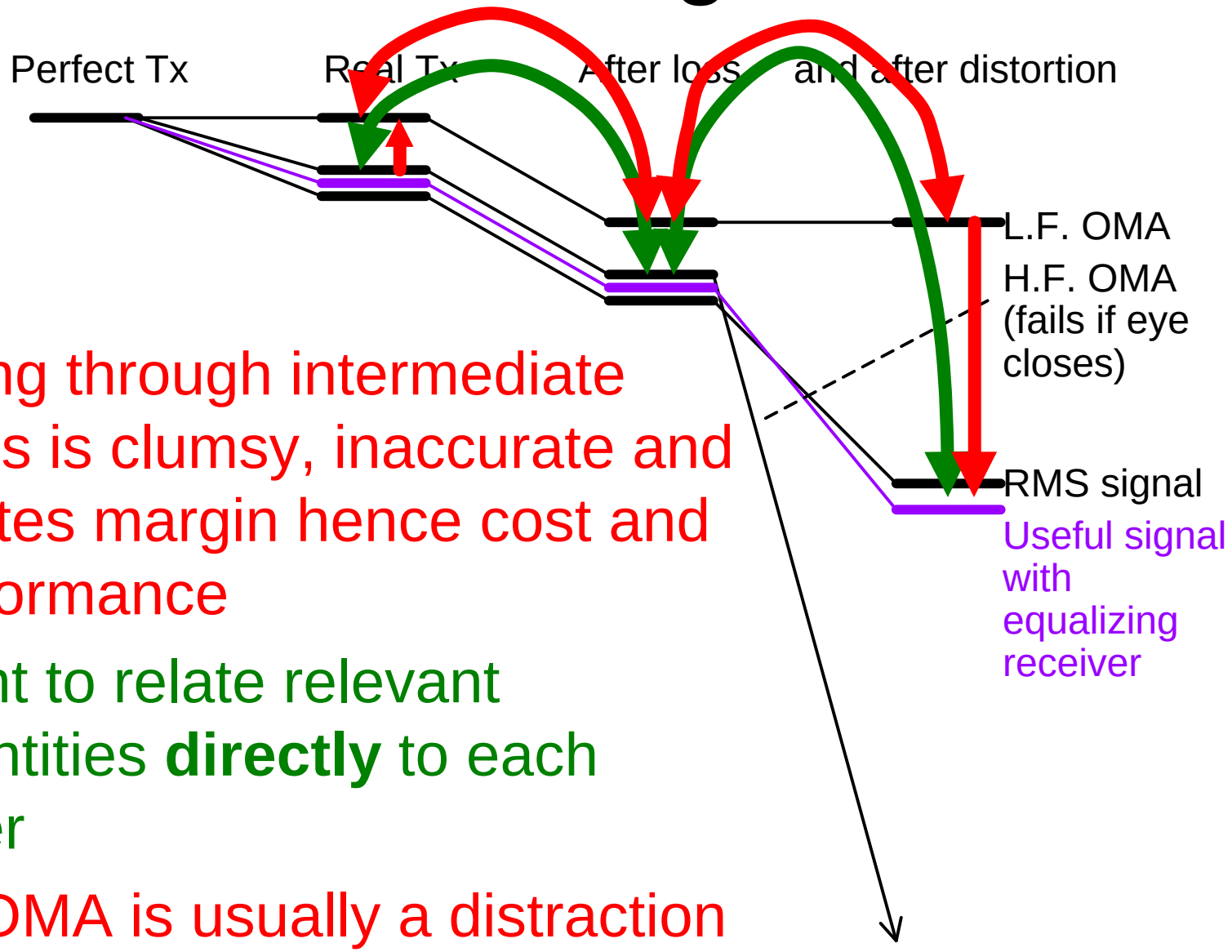
- Measures of variance are affected by laser overshoot
  - Need to study effect of overshoot on equalisers more anyway
- These metrics don't distinguish between deterministic, pattern dependent (correctable) impairments and truly random (not correctable) ones
  - Still need to study waveform capture techniques to quantify that issue

# Evolution through a link




- Useful metrics at TP2
  - LF OMA, HF OMA, Asynchronous OMA, RMS signal
- Useful metrics at TP3 – for DTE
  - RMS signal
- Useful metrics at TP3 – for stressed eye generator
  - LF OMA, RMS signal

# Evolution through a link




- Going through intermediate steps is clumsy, inaccurate and wastes margin hence cost and performance
- Want to relate relevant quantities **directly** to each other
- LF OMA is usually a distraction

# Recommendations

- Specify Tx high power limit by (H.F. or L.F.) OMA and mean power
- Specify Tx lower power limit by H.F. OMA and mean power
  - Values will depend on TP2 signal quality investigation
- Specify Tx distortion by eye mask…
  - With defined statistical significance per EFM
  - Coordinates TBC depending on TP2 signal quality investigation
- …And (LF OMA – 2•RMS signal strength) or other histogram-based metric as an EDC-relevant spec.
- Consider using (LF OMA – 2•RMS signal strength) as metric for stressed eye set-up
- Propose RMS signal strength as metric for TP2 and TP3 in network administration
  - E.g. diagnosing network problems: bad Tx, bad fibre or dirty connector?