Eye mask and TDP proposal to replace jitter bathtub

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Motivation

- Don’t want to cost more than SONET
  - Dollar cost in building transmitter
  - Thermal cost
  - Optimize eye for direct modulation
  - Now have some experimental evidence from feasibility study
- Need to replace unworkable jitter bathtub measurement

Compare optical standards 1 of 2

SDH and SONET OC-192

- Rectangular mask
- 0.2 UI long
- 50% of eye height high
- Mask is allowed to float in time and vertically

10G Ethernet

- Hexagonal mask
- Inner rectangle 0.2 UI long
- Outer hexagon 0.4 UI long ⟵ *Additional*
- 50% of eye height high
- Mask is fixed in center: NOT allowed to float in time and vertically

More stringent

Compare optical standards 2 of 2

SDH and SONET OC-192

- Imposes minimum Tx bandwidth (via mask)
- Allows transmitters with distorted eyes
  (because mask is a rectangle)
- Does not protect CDR from high jitter >few MHz

10G Ethernet

- Excludes transmitters with distorted eyes
  - Experience shows, it is harsher than necessary
- Outer hexagon gives some protection vs. jitter
- Separate jitter bathtub measurement would provide stronger protection against jitter
  - But can't be calibrated at 10G - unworkable

BERT bathtub

For

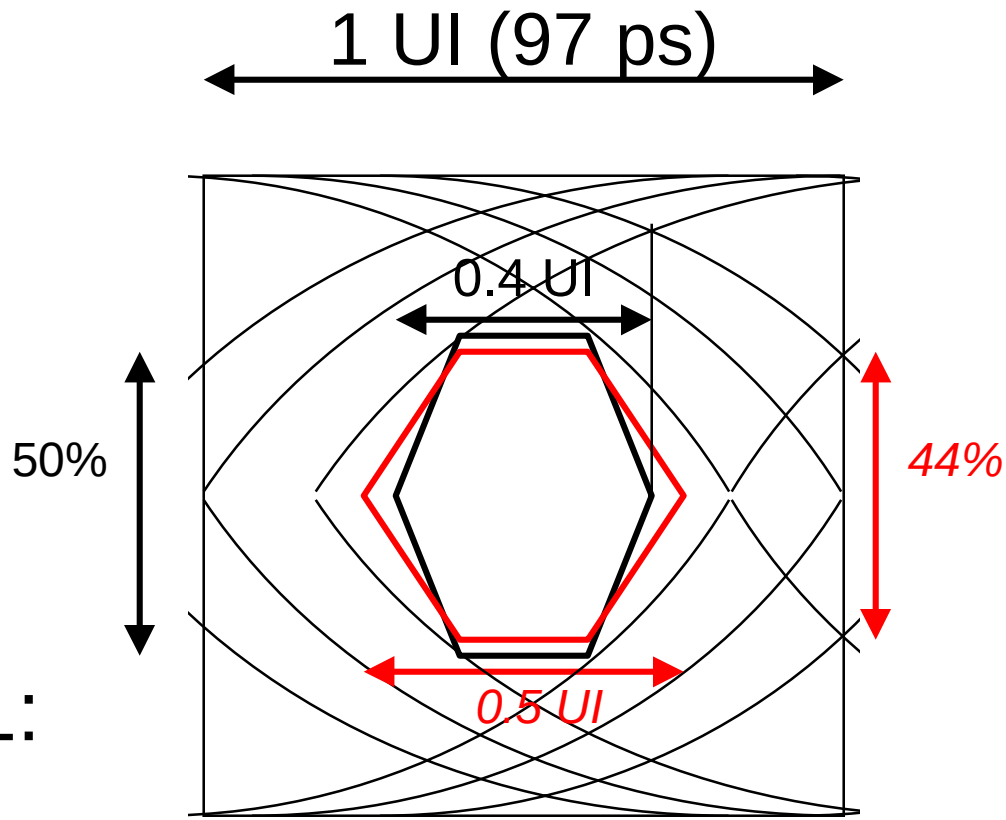
- BERT really measures low probability events (depending on the pattern)
- Good for diagnostics
  - Can separate W and sigma
- Technique has been tried in at least two labs and can be automated

Against

- Test instrument data dependent jitter consumes a significant fraction of “W”
- DDJ cannot be calibrated out without very detailed edge-by-edge measurements
  - DDJ of DUT and apparatus is correlated: may add, subtract or anything in between
- Unknown errors --> extra margin needed in production test and/or design --> more $$$
  - Slow measurement $$$

Other points?

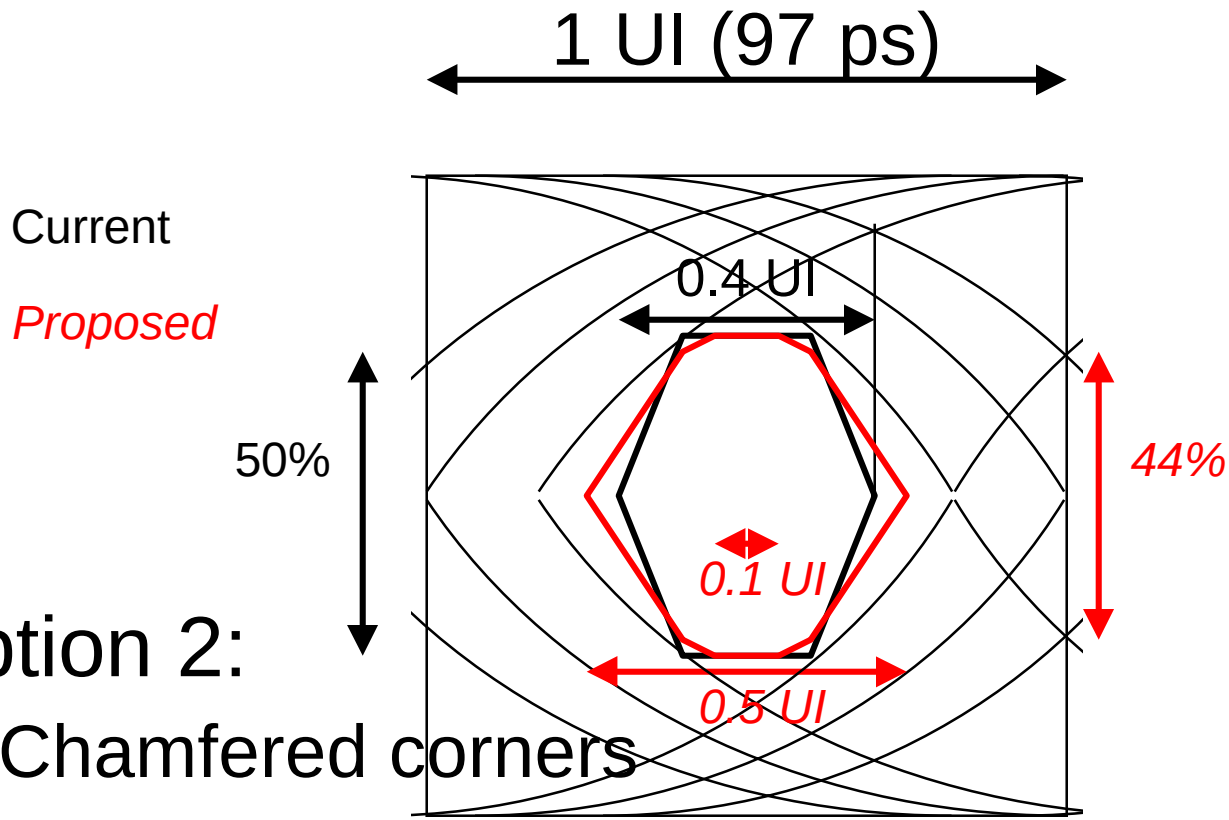
Proposed mask Option 1



Option 1:

- Lower
- Longer
- 3% more area under the curve

Proposed mask Option 2



Option 2:

- Chamfered corners
- Same height in center
- Longer
- 9% more area under the curve

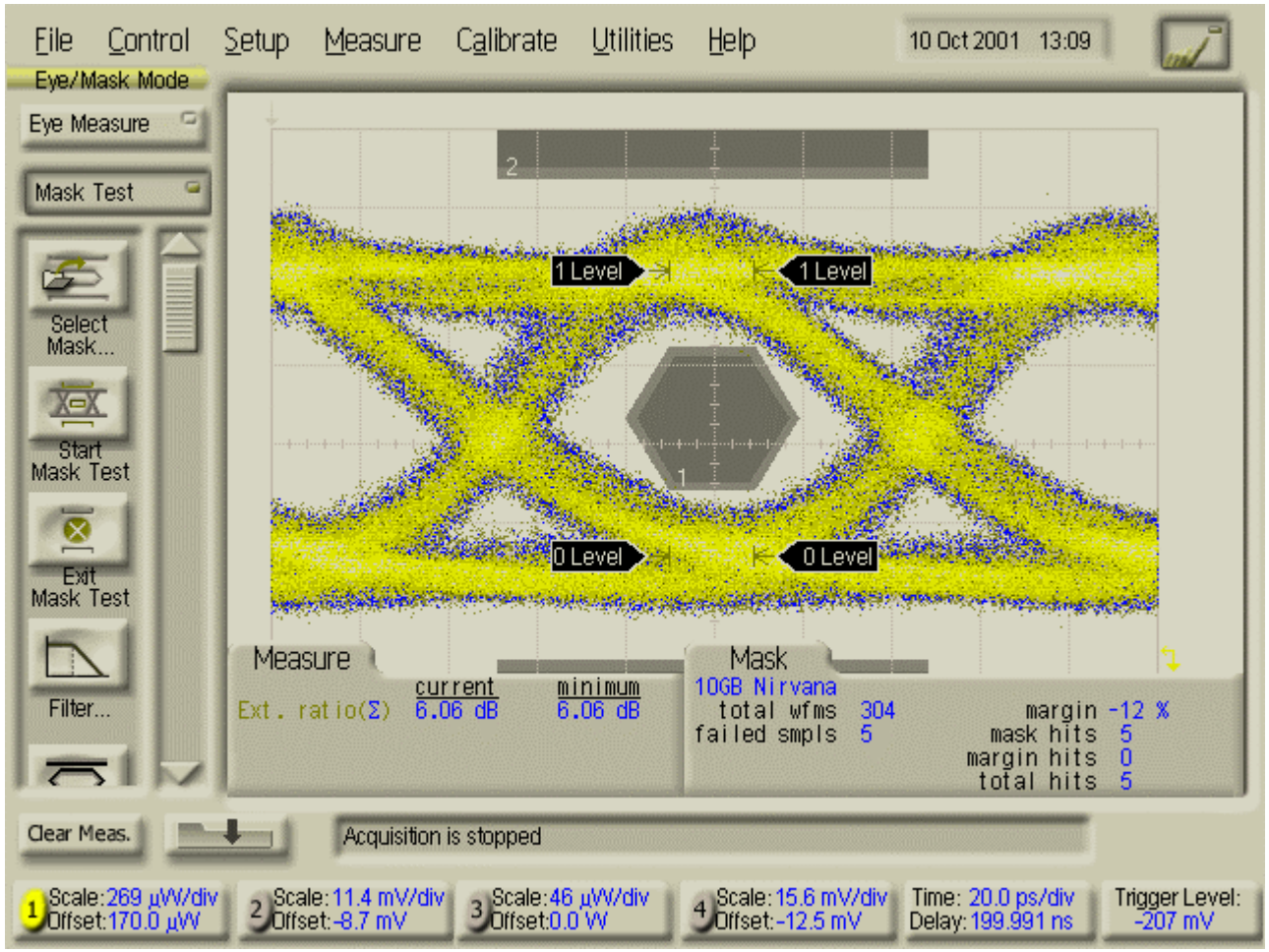
Proposed mask Option 1

Keep the hexagon idea

- Extend hexagon from 0.4 to 0.5 UI long
- Reduce height from 50% to 44%
- Keep the mask fixed in center
  - For reasons of interoperability and simplicity

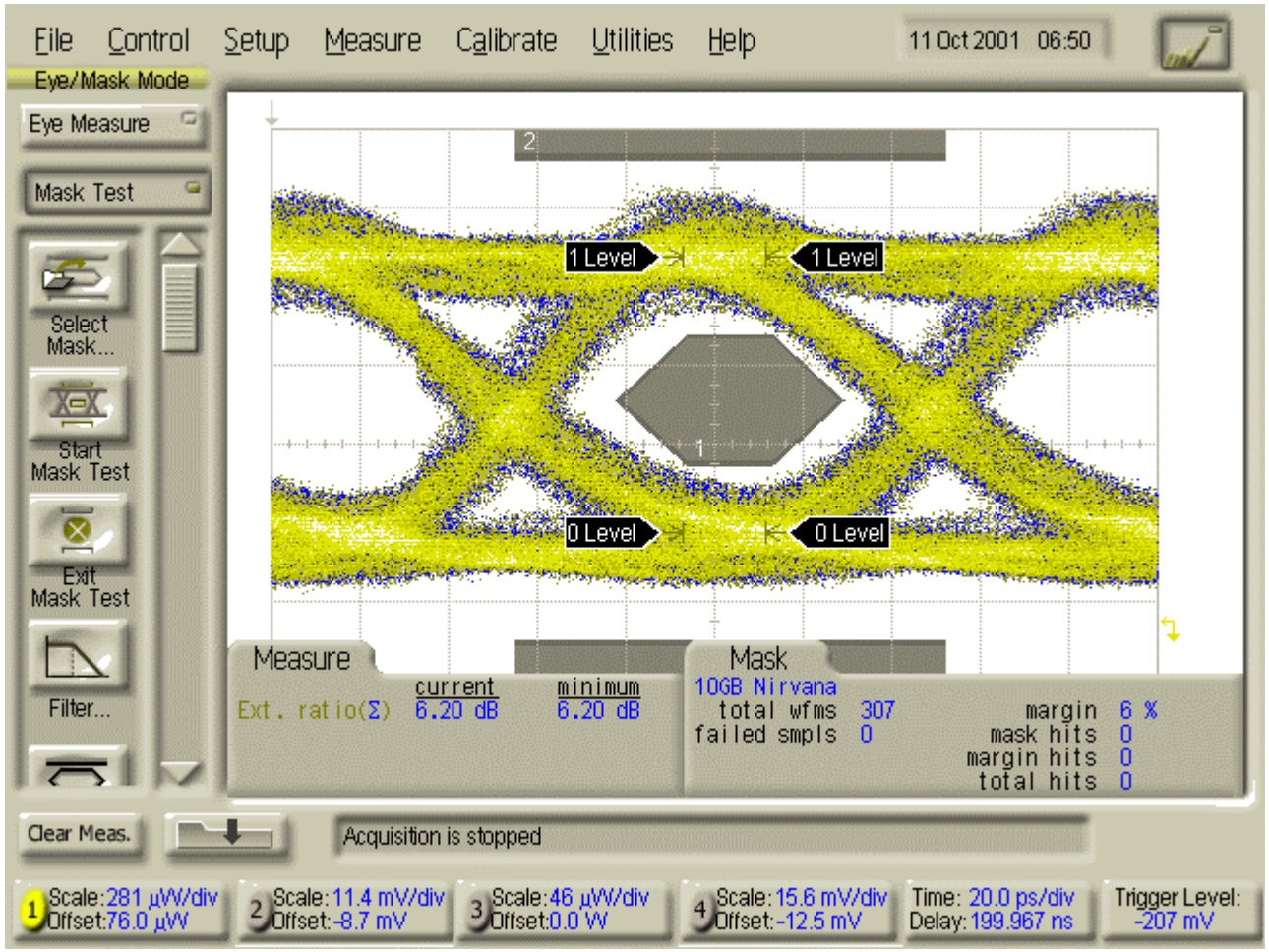
- This change allows slower eyes
  - Reduced power drivers, ultimately cheaper
- The lengthened mask allows us to drop the jitter bathtub measurement
  - Maintains quality by forcing reasonable jitter
  - Immediately cheaper: quicker measurement
- TDP measurement protects vs. excessive eye closure even with a less high mask

Example: present eye



(Here, mask is total extent of gray)

Example: proposed eye



(Here, mask is inner lighter gray)

Proposed mask Option 2

Extend the hexagon idea: decagon *(see slide 7)*

- Extend mask from 0.4 to 0.5 UI long
- Move four corners from 50% to 44% apart in y
- Insert four new corners at x=0.4,0.6 y=25%,75% (50% apart; as previous corners)
- Keep the mask fixed in center
  - For reasons of interoperability and simplicity

- Benefits as Option 1, plus...
- Maintains central vertical eye opening
  - Minimizes impact on receiver

Option 3 Alternatively...

- Use an “absolute eye” not a relative eye
- Fix eye to mean signal level, not quite the same as mean of b1, b0 as in OFSTP-4A
- Fix eye height at transmitter as x mW high
  - x is affected by triple trade off as at present
- Likely still need a “relative eye” to protect from gross distortion and reflection noise
  - Suggest set “relative eye” height at 30-40% of eye height (y1 = 30% to 35%)
- Easier to meet
- Good for link performance
- More test development work

What about S, L, E?

Proposed change is:

- Very good for BASE-L (1310 nm)
- Very good for BASE-E (1550 nm)
- Very good for BASE-S (850 nm)
  - Long points needed to replace the jitter bathtub, like -L and -E
  - An effective higher vertical opening is imposed by the risetime spec
  - A taller eye could be used to eliminate the risetime spec: example, scaled OC-12 (hexagon 0.5 UI long overall, 60% high)

TP2 or TP3?

- Transmit eye is traditionally measured at TP2 (just after the transmitter)
- Jitter bathtub is specified for virtual TP3

- BASE-S Could measure eye at virtual TP3 if necessary
- BASE-L Difficult: fiber attenuation and scope noise. However, very little dispersion, maybe no need?
- BASE-E Could recover optical power with EDFA

How do we live without the jitter bathtub? 1 of 2

Jitter bathtub was proposed to specify

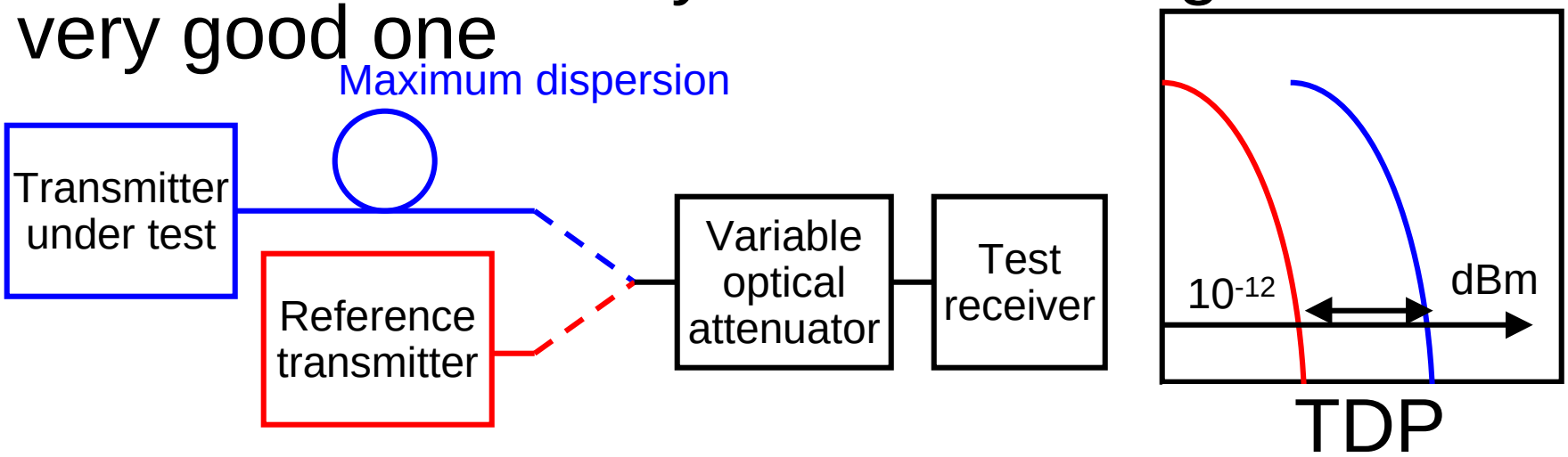
- W High probability jitter
  - Perhaps 1/3 of “W” comes from test equipment
  - Much pattern dependent jitter
  - Very hard to distinguish Tx and Rx side jitter
  - Two pattern dependent jitters might add, subtract or anything in between
    - Impossible to calibrate out pattern dependent jitter without measuring individual edges in pattern
  - Mask based test is a cheaper, simpler, more accurate substitute
    - Scope has less pattern dependent jitter than other instruments
- sigma Low probability jitter (see next slide)

How do we live without the jitter bathtub? 2 of 2

- sigma Low probability jitter
  - Jitter bathtub probably worked
  - Values were near 2 ps with 2^31 PRBS, a little lower with 30k long patterns
  - Still may have significant instrument DDJ
    - Two pattern dependent jitters might add, or subtract
    - Cannot calibrate out pattern dependent jitter without measuring individual edges in pattern
    - Not sure if low prob. DDJ cal is different to high prob. DDJ “W” cal problem
  - Apparent low probability jitter is ubiquitous but not a serious problem
  - Scope does not see low probability events
  - BER measurement does: TDP or simple transmitter penalty measurements screen against jitter affecting link performance

TDP: Transmitter and Dispersion Penalty

- Test a transmitter by substitution against a very good one



- Screens for total of most relevant effects
  - high probability e.g. ISI, jitter “W”
  - low probability e.g. RIN, BLW, jitter “sigma”
- For BASE-S, dispersion is modal not chromatic: simulated by transversal filter after O to E conversion

TDP for BASE-L

- Can obtain fiber with dispersion minimum:
  - "nominal" (SMF)
  - Longer wavelength (several kinds)
  - Not at shorter wavelength
- To test <~1290 nm transmitter, if linewidth is significant, need longer wavelength dispersion minimum
- To test >~1330 nm, if linewidth is significant, need shorter ... minimum
  - We can live without it
  - Or we could remove >1330 nm, wide spectral width transmitters from the standard
- Obtaining dispersion extremes is already a problem in D4.0

Eye center or wider?

- TDP method might miss a high jitter but otherwise good transmitter
- Receiver with poor timing might respond badly to same
- Could in principle dither the decision point in the test receiver
  - Raises more equipment problems
  - In practice, probably don't need to
  - Product silicon appears very good, better than test equipment

Conclusion

- Options 1, 2 are less radical, have been shown to work
- Proposed change will make the 10GBASE-L transmitter

  Cheaper, or
  Lower power, or
  Able to run hotter

  – This may benefit port density
- Proposed change is necessary to make testing feasible for all S, L, E