# Jitter/dispersion transmitter tests for EFM


| | |
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# Competing methodologies

**Gigabit Ethernet way**

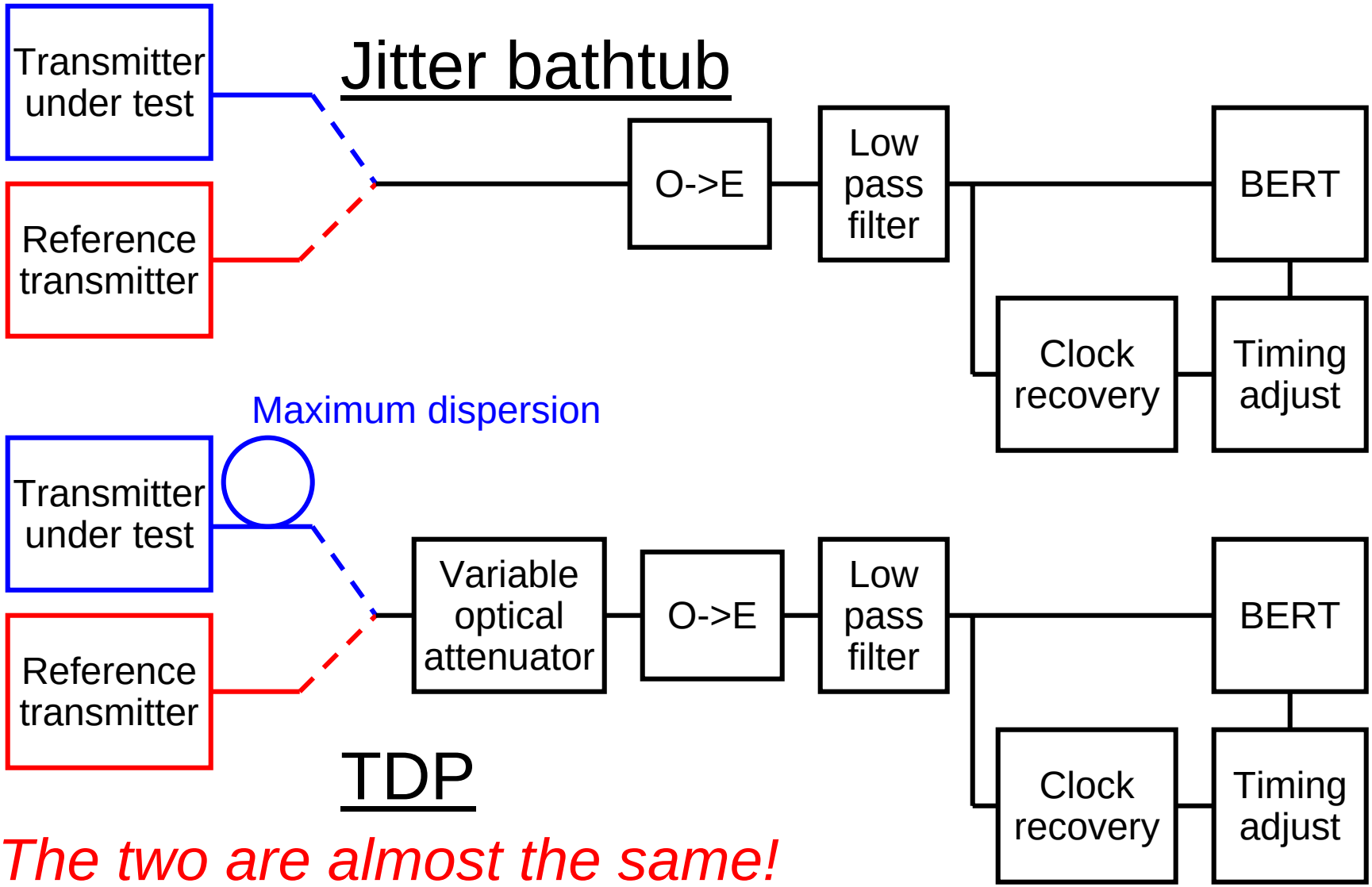
- Mean power
- Extinction ratio
- Total jitter
- Eye mask
- RIN
- Optical spectrum

**10G Ethernet way**

- OMA
- (Extinction ratio)
- Transmitter and dispersion penalty
- Eye mask
- RIN
- Optical spectrum

*This presentation compares the two items marked*

# *Jitter bathtub vs. TDP in a nutshell*




*The two are almost the same!*

# Language in a standard

Have to be very careful with language

- A standard can say that a thing shall be “assured” under certain circumstances
  - Can be measured as described, or by another measurement, or sampling, extrapolation, rigorous proof…
- Or a standard can say “measured” or “tested” under certain circumstances
  - Essentially no discretion allowed
    - e.g. military or safety-critical items
- We can use “assured”

# Dispersion matters

## Worst-case dispersion penalties predicted by model

| | | |
|---|---|---|
| • 100BASE-LX | 1310 nm | 0.5 dB |
| • 100BASE-BX | 1310 nm | 0.3 |
| • 100BASE-BX | 1530 nm | 0.6 |
| • 1000BASE-EX | 1310 nm | infinite* |
| • 1000BASE-BX | 1310 nm | 3 |
| • 1000BASE-BX | 1490 nm | 0.3 |
| • 1000BASE-PX A up | 1310 nm | 3 |
| • 1000BASE-PX A down | 1490 nm | 1.7 |
| • 1000BASE-PX B up | 1310 nm | 0.9 |
| • 1000BASE-PX B down | 1490 nm | 0.35 |

* At present: no triple trade off or similar limits in D1.0

# Need to guard against MPN

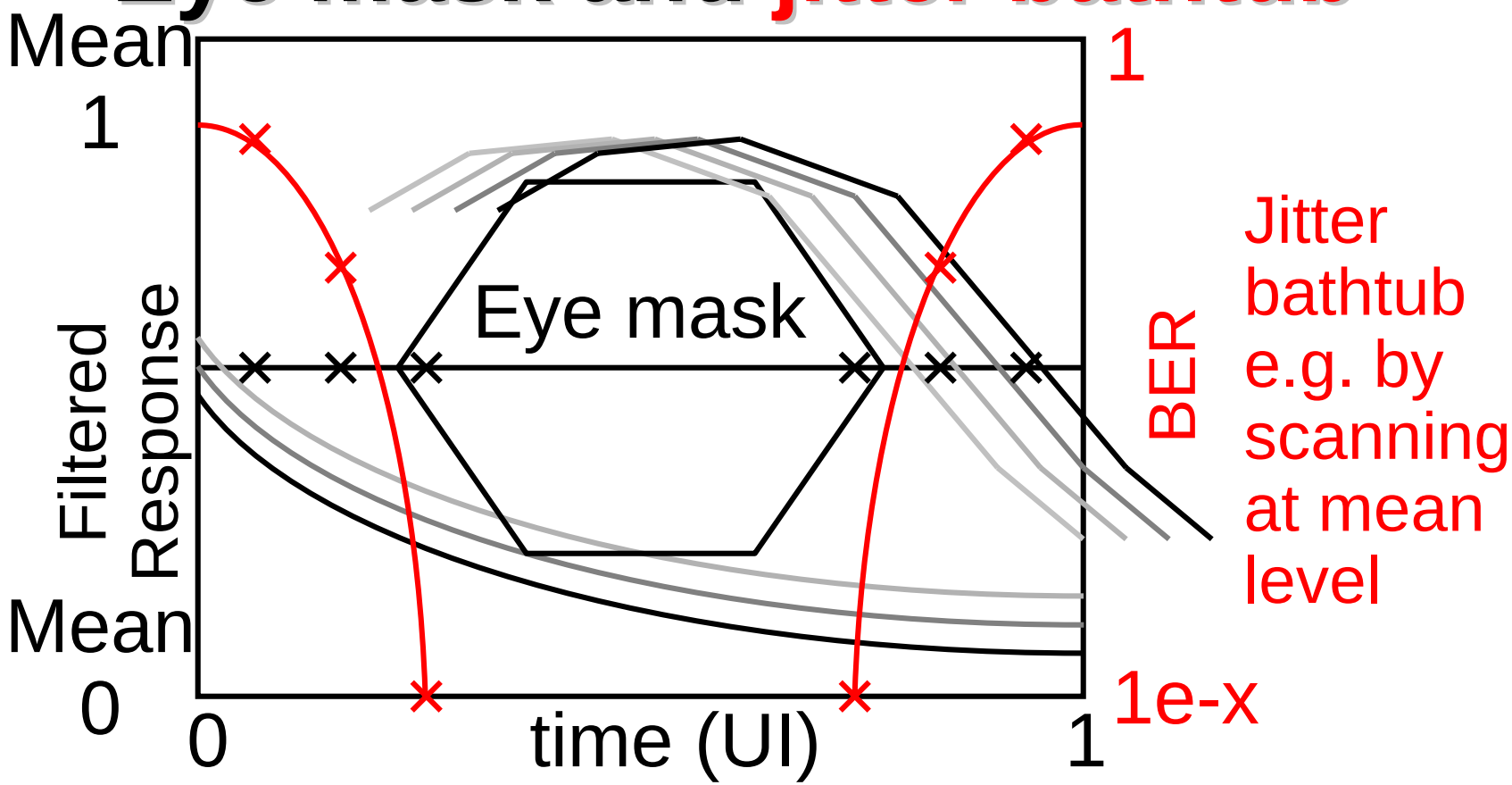
*MPN = mode partition noise*

- Slower standards specify wavelength and spectral width separately (“box”)
- Faster standards can use DFBs
- For 1.25 GBd x 10 km, we are on the edge:
- Rectangular box spec is either unsafe
  - level of knowledge of MPN is not very precise
- or too onerous
  - would box in our operating temperature range and give implementers a hard time with wasted margin

# Limited resource

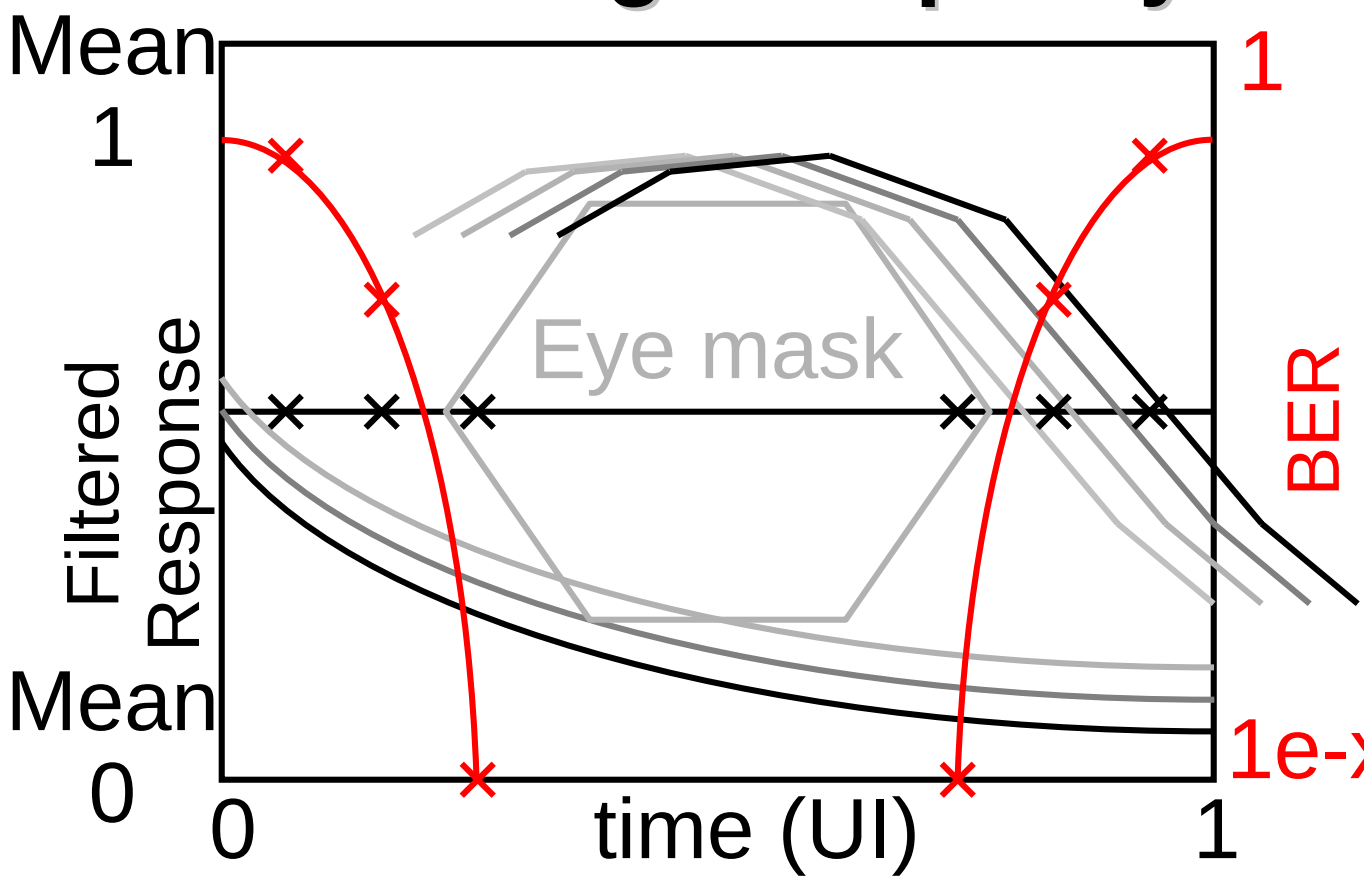
- EFM has 10 PMDs!
- We cannot afford to develop different test methods for each
- This presentation shows a generic approach which can be simplified where dispersion is not a problem

# Gigabit Ethernet way: Eye mask and jitter bathtub




- Eye mask measured with scope
- Bathtub measured with BERT

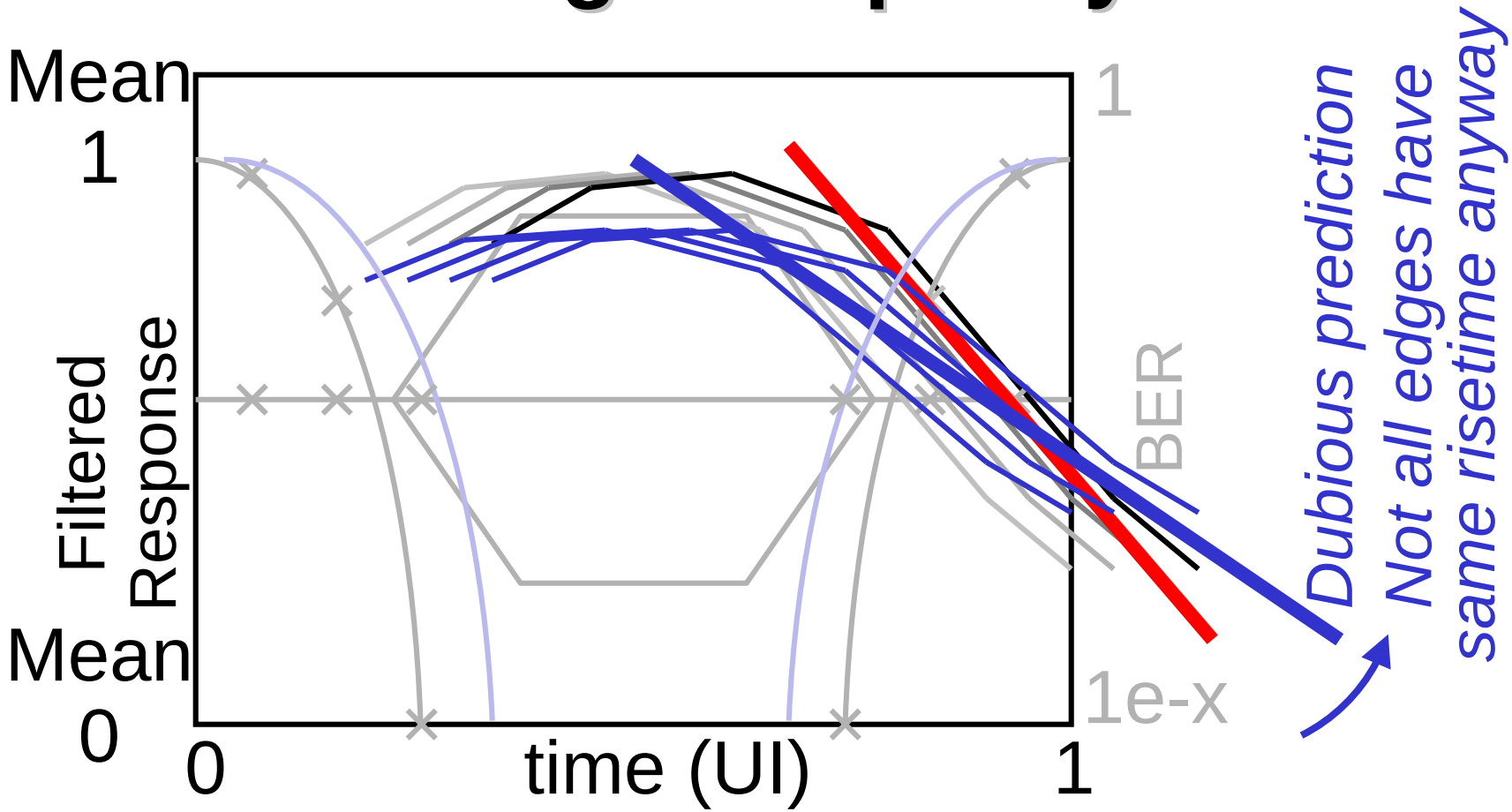
# Jitter bathtub detail: Predicting link quality 1/4




*Low probability jitter measured here is not very relevant, drowned by Rx noise later anyway*

1. Measure 4 BERs and extrapolate (not guaranteed), or measure 2 very low BERs

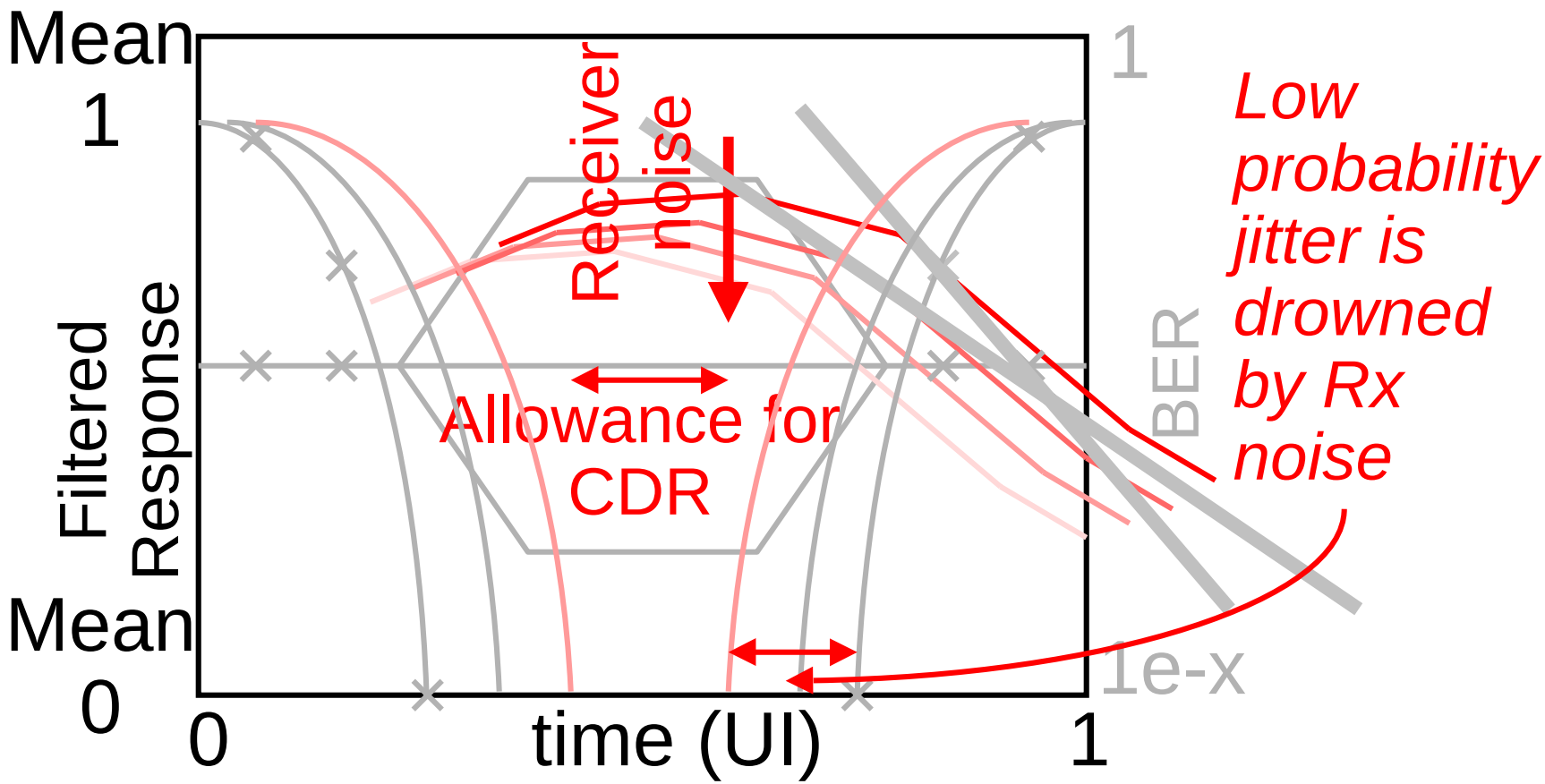
# Predicting link quality 2/4




2. Measure rise time at TP2, or assume limit set by mask

3. Predict rise time at TP3

# Predicting link quality 3/4




4. Calculate effect of receiver noise, predict if link OK or not

# Predicting link quality 4/4

- For single mode fibre
  - Noise limited links
  - Jitter bathtub is an indirect and inaccurate predictor of link quality
  - Equivalent direct measurement (TDP) more meaningful and equivalent in cost/time
- For multimode fibre
  - Distortion limited links
  - Jitter bathtub could be more relevant
  - Three options - see later (slide 28)

# Problems with jitter bathtub 1/2

- Difficult to understand what it means
  - Fibre Channel jitter task force have been working on it for years
  - Most “random” jitter turns out to be pattern dependent (depending on line code)
- Demands a lot from test equipment
  - Big issue for 10G, not so much here
- Not very useful for a standard:
- Measures wrong thing at wrong place
  - Measures TP2 when we believe TP3 will be worse
  - Measures at wrong times in the eye at much different s/n ratio, as compared with real receiver

# Problems with jitter bathtub 2/2

- Not very useful for a standard continued
  - In healthy links, true and apparent random jitter is drowned by receiver noise - not a good metric
  - High probability (deterministic) jitter at TP2 does not in itself cause errors. A closed center region of the eye at TP3 does that. Again, not a good metric
  - High probability (deterministic) jitter is filtered by the CDR. Reasonable CDRs can create a good-enough recovered clock with BERs well worse than 10^-9. Spec limited by item above first, no need to spec for this reason. If we did, it would be relevant at TP3 not TP2
    - Aside: is this still true at 10^-3 BER for FEC?

# Gigabit Ethernet way

## Advantages

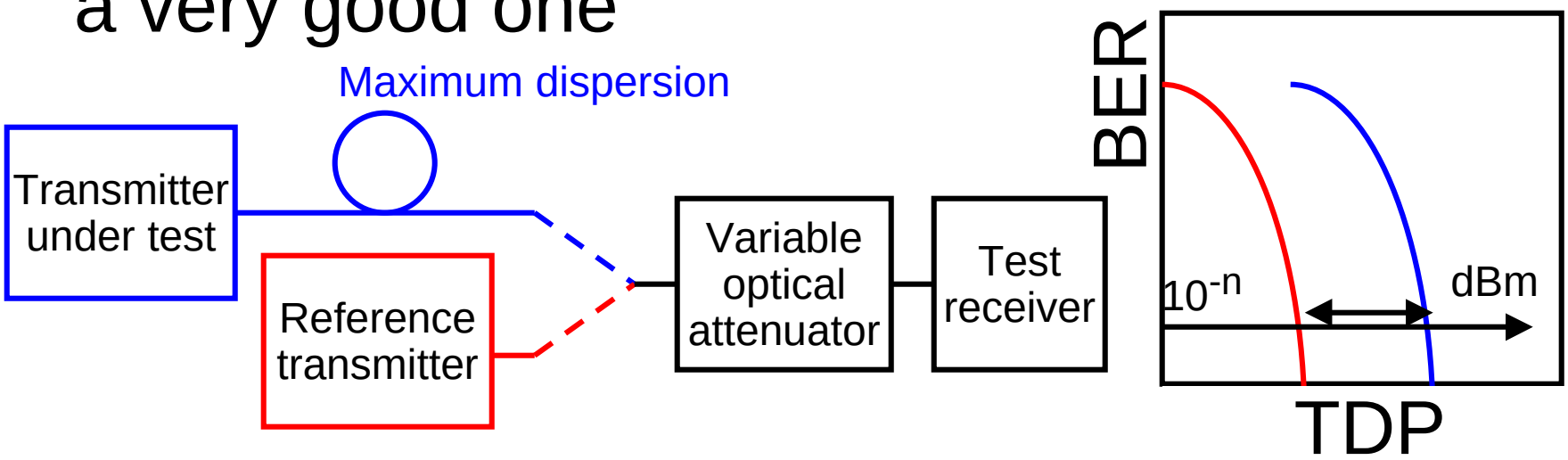
- Familiar to GigE players
- Used in several standards
- Partial theoretical foundation
- Useful if standardised channel (fiber) cannot be obtained
- Provides demarcation point transceiver : CDR

## Disadvantages

- Measurement overkill
  - Time consuming jitter bathtub
  - Needs very good test equipment
- Legislative overkill
  - Measures things that don't matter in themselves
- Product overkill
  - Results in products with more heat and cost than necessary
- Relies on calculations for link degradation
  - Inaccurate for MPN
  - Useless for DFB dispersion penalty
  - Variability risetime =>inaccuracy
- Needs separate RIN test
  - Which is not a system level test

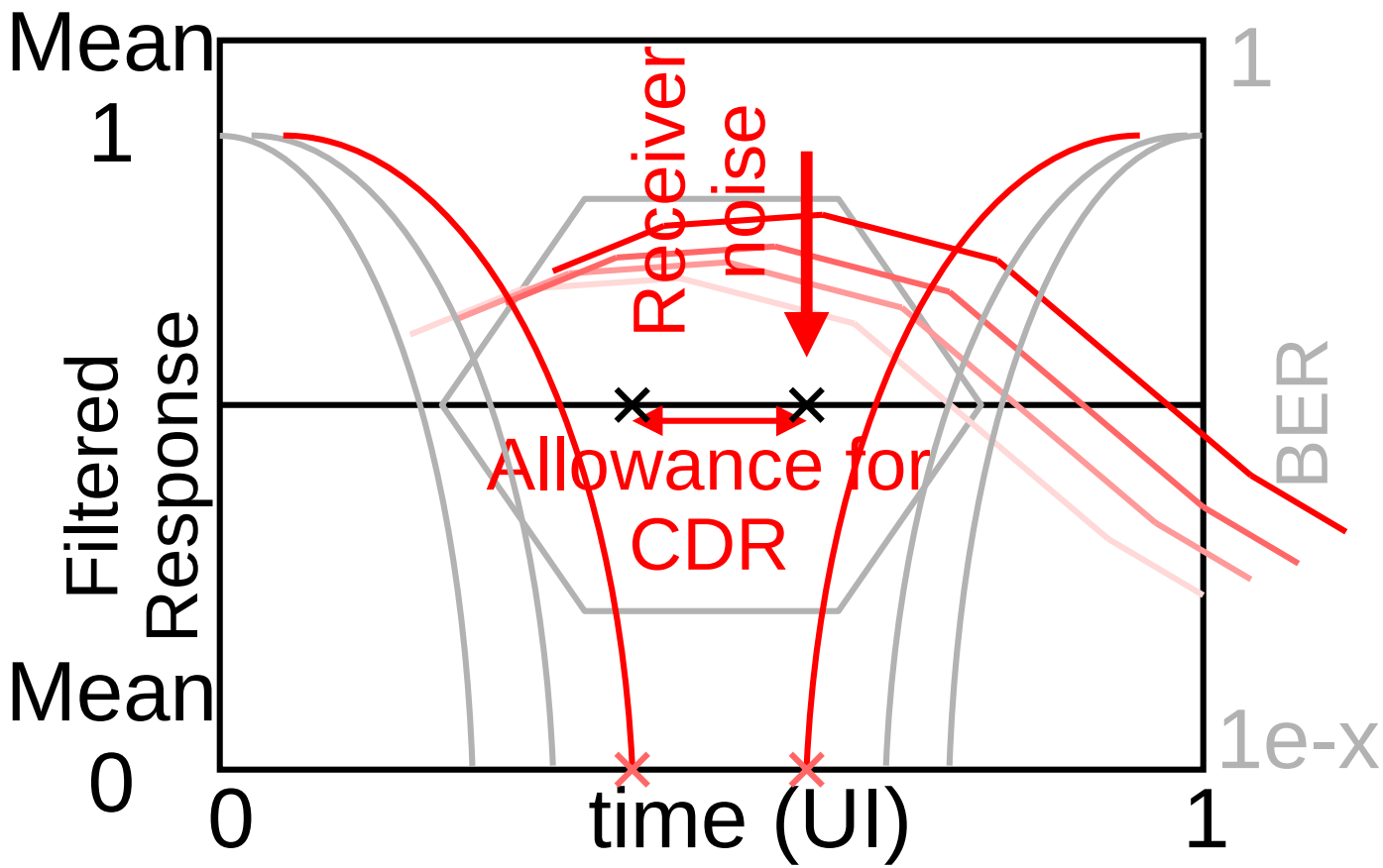
# 10G Ethernet way, TDP: Transmitter and Dispersion Penalty

- Test a transmitter by substitution against a very good one



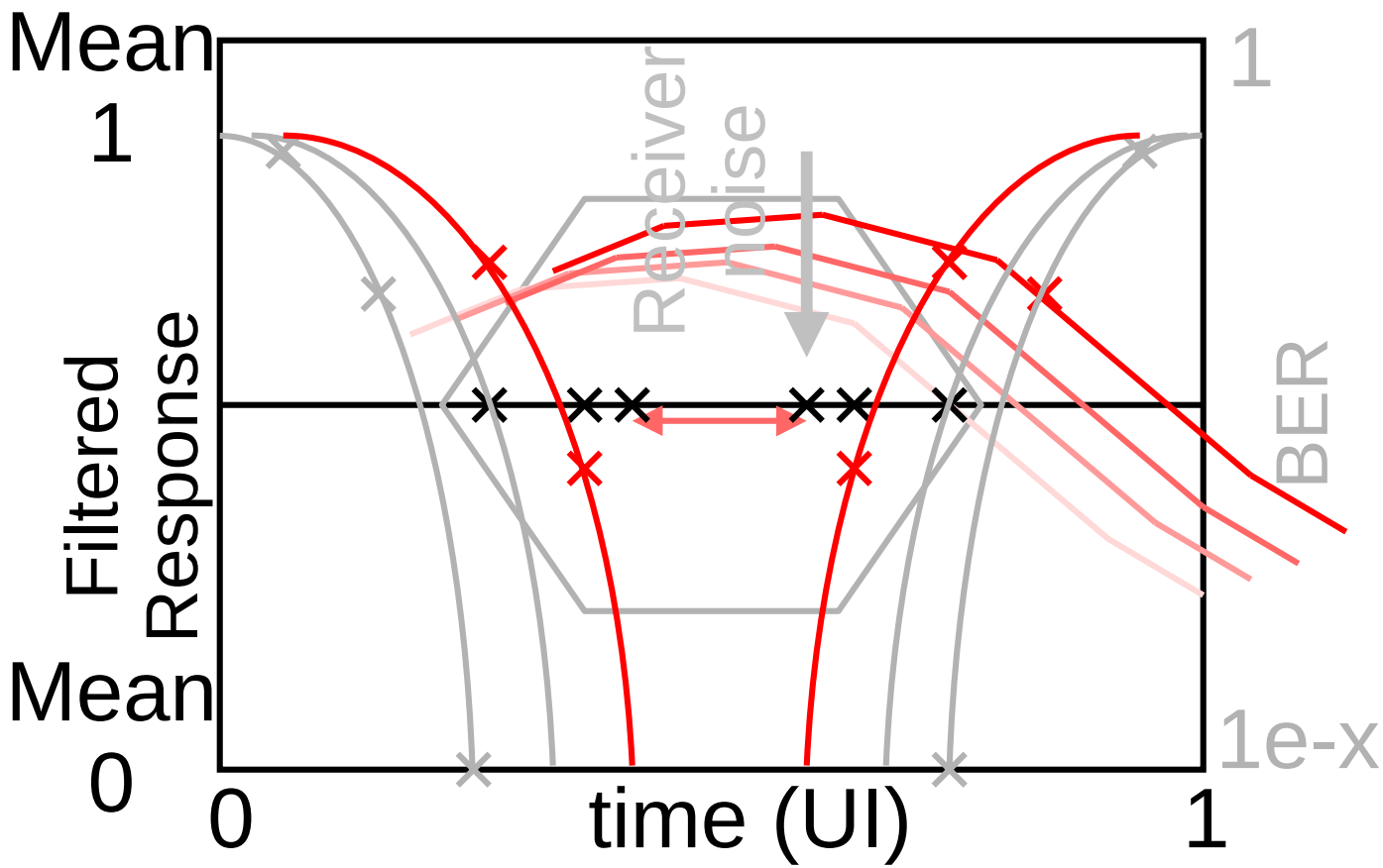

- Screens for total of most relevant effects
  - high probability e.g. ISI, jitter “W”
  - low probability e.g. RIN, BLW, jitter “sigma”
  - chromatic and (if MMF) simulated modal dispersion

# Measuring link quality




1. Measure BER (2 points) at rated power and dispersion. Know if link OK or not

# Extrapolating link quality




Extrapolation schemes to reduce test time, e.g. timing margin, optical power margin

# 10 Gigabit Ethernet way: Advantages

- Familiarity
  - to 10GigE players
  - Refinement of SONET “path penalty”
  - Compatible with .z style TP1/TP4 metrics
- Doesn’t need any more theoretical foundation
  - Good for DFB dispersion penalty
  - Partly useful for MPN
- Avoids measurement overkill
  - Not so demanding on test equipment
  - Possible opportunity for test time reduction
- Much more accurate
  - Direct measurement of what matters
  - Good with SMF which is very consistent
  - For MMF, use electrical transversal filter

# 10 Gigabit Ethernet way

## Advantages *continued*

- Avoids legislative overkill
  - Does not demand measurement of intermediate parameters
- Avoids product overkill
- More thorough
  - May show compliance without dispersion (no test fiber) by extrapolation for slower bit rates on SMF and Tx with margin, or at product characterisation only
  - "Assured" does not force "100% tested"

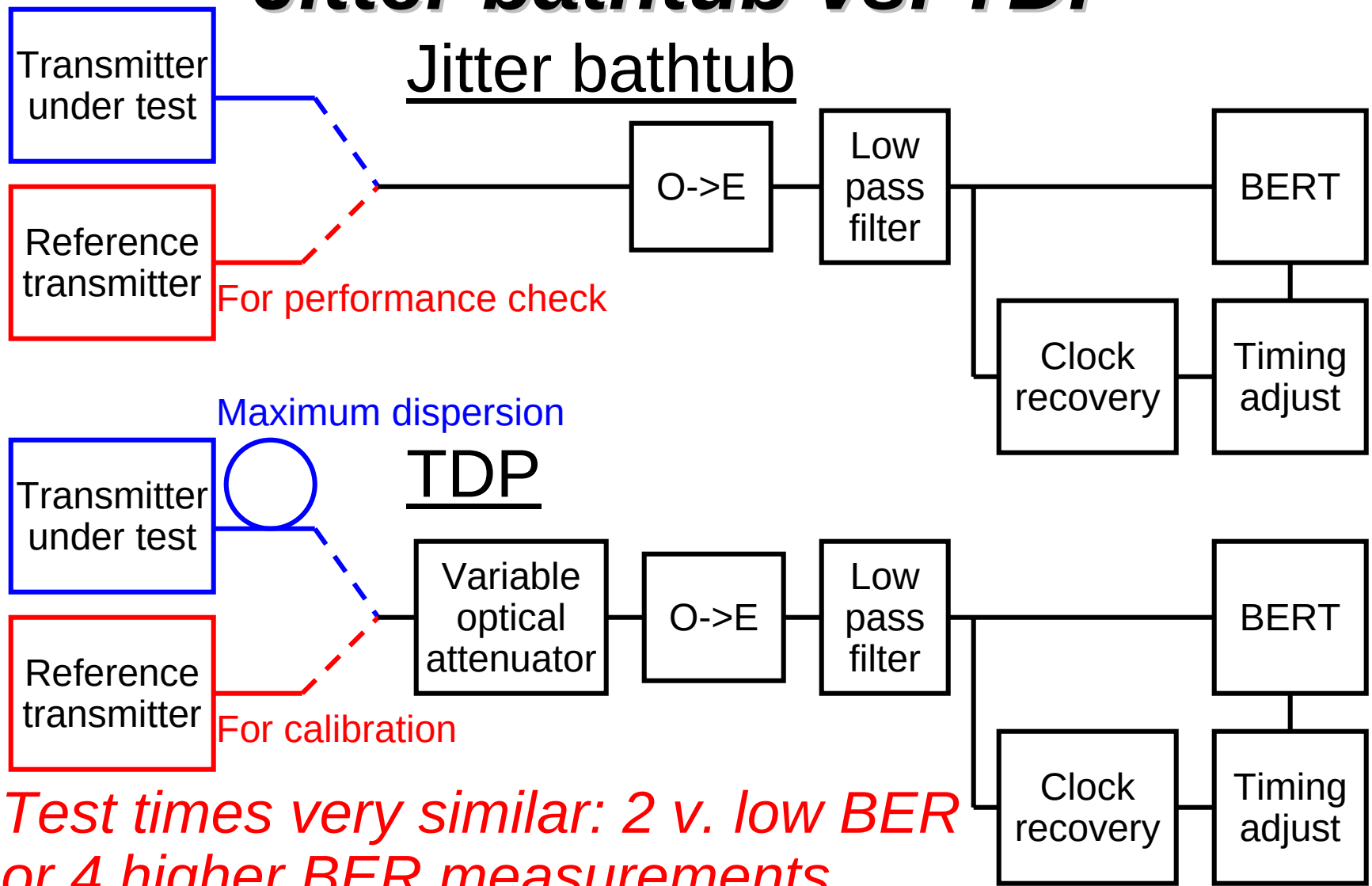
## Disadvantages

- Have to consider backwards compatibility for 1000BASE-EX
  - But we don't want to over-engineer the 10km spec, or we end up with different parts vs. what we set out to standardise!
- Still not ideal for time-varying impairments (RIN, MPN)
- May need a test channel
  - e.g. spool of fiber

# Do the differences matter?

- Over-engineering, heat, test time?
  - Yes especially for SoHo/domestic markets
- MPN?
  - Yes, especially 1000BASE-EX
- Need to address dispersion penalty?
  - DP is apparent, <~1dB (in the model, with current spectral values) in 1000BASE-EX, 1000BASE-PX B upstream (1310 nm),100BASE-BX 1550 nm
- Test equipment, test time
  - See next slide

# Jitter bathtub vs. TDP




*Test times very similar: 2 v. low BER or 4 higher BER measurements*

# Test coverage

| | Jitter bathtub | TDP |
|---|---|---|
| Measured | • Tx hi probability jitter<br>• Tx low prob. jitter<br>• (Tx risetime) | • Tx high prob. jitter / risetime combined effect (eye mask)<br>• Tx low prob. jitter, RIN, MPN<br>together with<br>• Tx high prob. Jitter / risetime / (systematic) chromatic dispersion,<br>• (Effect of reflection noise) |
| Separate test | • RIN | • RIN |
| Modelled or predicted | • (Systematic) chromatic dispersion<br>• MPN | • (Some MPN which you missed when you did the test!) |

# MPN and TDP: Testing vs. assurance again

- Implementers may not wish to measure TDP in production
  - Each implementer may devise a set of spectral width, center wavelength specs and allowance for MPN, and test the Tx against this reduced margin.
  - Each implementer may make a different choice for these parameters.
  - Allows trade-offs depending on the available technology and desired temperature range
- TDP methodology allows flexibility and low cost in practice

# Summary of comparison

- Two methods are very similar
  - Both use reference receiver with CDR and BERT, specified timing window
  - Both need good transmitter for cal
    - (Although jitter cal doesn't really work)
  - Use same TP1, TP4 metrics either way
- The advantages of the 10GE method are significant
  - Accuracy
  - Cost effectiveness
  - Test coverage: only game in town for MPN and dispersion penalty generally
- The disadvantages are minor

# How to proceed: 100M cases 1/2

- 100M inherits jitter specs at TP1, TP4 from FDDI
  - Check these are still appropriate, if so use them informatively (truncated “jitter budget” table)
  - TP4 jitter specs imply the timing offset for TDP measurement
  - Check mask is compatible with FDDI TP4 spec
- Choose sensible TDP limit (goes in transmitter spec table)
  - May be an apparently high number because of the line code
  - Need to choose any high pass filter in reference receiver carefully, because of the line code

# How to proceed: 100M cases 2/2

- Consider testing for MPN by 25% extra dispersion
  - e.g.100BASE-BX 1550 nm
- Offer suggestions on “no dispersion needed” extrapolation
  - e.g. 100BASE-BX 1310 nm, 100BASE-LX
- Copy or refer to Clause 52 TDP measurement procedure
  - Same BERT and CDR technique as jitter bathtub
- Reference Tx can be e.g. OC-48 lab grade

# How to proceed: 1000BASE-EX 1/2

- 1000BASE-EX inherits jitter specs at TP1, TP4 from 1000BASE-LX
  - Use them informatively (truncated “jitter budget” table)
  - TP4 jitter specs imply the timing offset for TDP measurement
- Use TDP method for 10 km SMF
  - We have to, because of MPN concerns
- Choices for MMF compliance:
  - TDP, can be measured
  - DJ/risetime tradeoff (precalculated)
  - or legacy method (one point from the DJ/risetime curve)

# How to proceed: 1000BASE-EX 2/2

- Choose sensible TDP limit for 10km SMF (goes in transmitter spec table)
- TDP for MMF may be implied by 1000BASE-LX specs already
- Test for MPN by 25% extra dispersion
  - Weakness in standard. Test isn't perfect but it's an improvement
- Offer suggestions on "no dispersion needed" extrapolation if applicable
- Copy or refer to Clause 52 TDP measurement procedure
  - Same BERT & CDR technique as jitter bathtub

# How to proceed: 1G EPON

- Similar to 1000BASE-EX SMF
- Need TDP method where MPN a concern
- Need to allow wider TP4 timing window because burst mode
- Need to account for additional power penalty (as well as the above) because burst mode
- Choose sensible TDP limit (goes in transmitter spec table)

# Conclusions

- Keep .z techniques at TP1, TP4
  - Now informative because system level standard
- Need to specify TDP method for TP3 in optics clauses
  - To provide a robust standard
    - Especially needed for MPN
  - To avoid over-specification
    - Unnecessary heat and cost
    - Extra performance left “in the grey economy” outside the standard (e.g. 5/10 km 1000BASE-LX)
- Use same test equipment as before
  - Add VOA and spool of fiber as needed
  - Test time is comparable
    - Simplification strategies can recover test time and complexity for .z way or TDP way