802.3ae Transmitter & Dispersion Penalty (TDP) and Stressed Eye sensitivity tests

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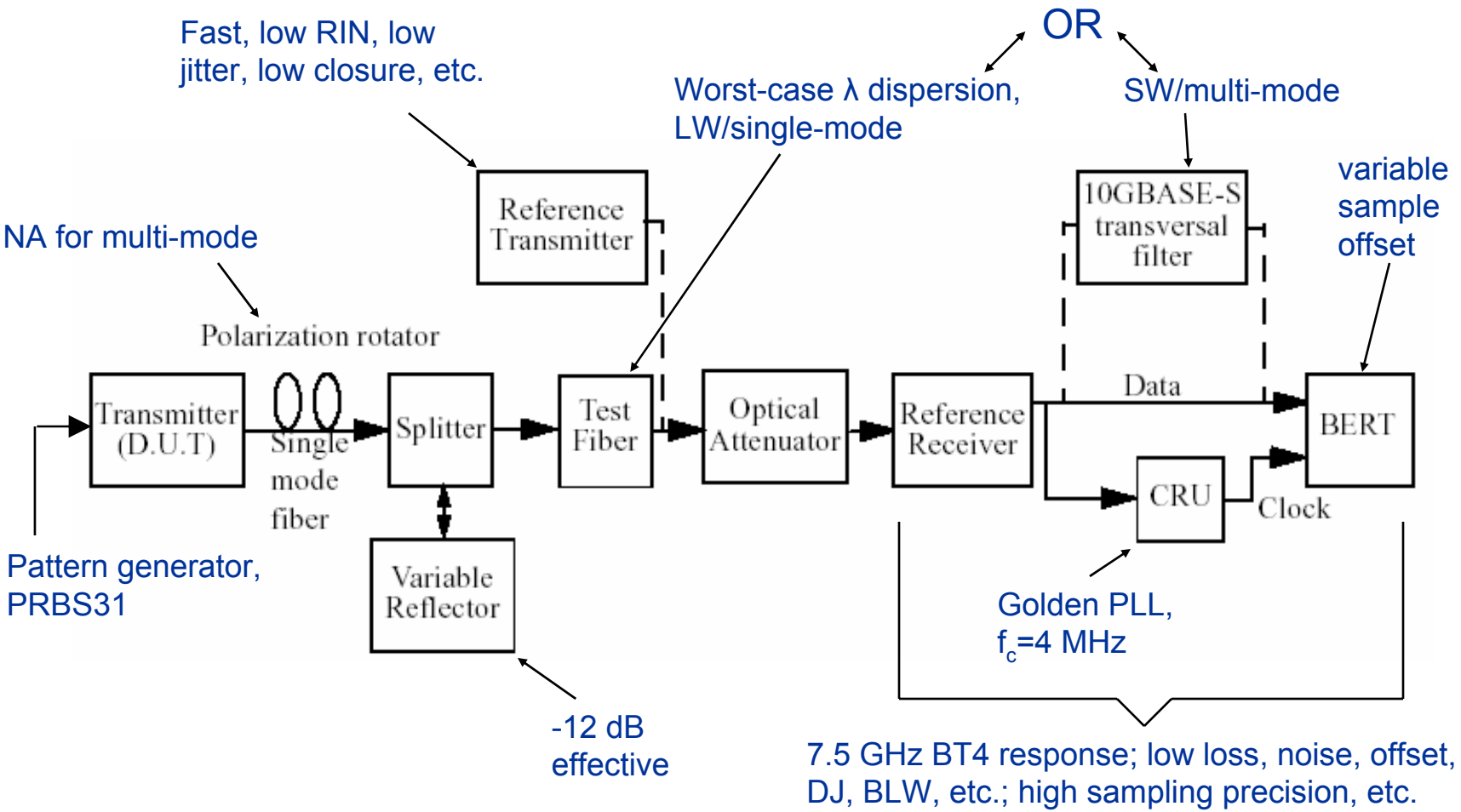
Contents of these slides courtesy of SyntheSys Research, Inc.

TDP - description

- Primary measure of Tx quality
  - TDP measures to 1E-12 probabilities
  - Also eye mask at TP2
    - Eye mask is high probability, qualitative test
- At virtual TP3: measured at output of test setup that includes worst case dispersion
- Take worse case of sampling +/-0.05 UI from eye center
  - Eye center defined by mid of 1E-3 points
  - Forces at least that much horizontal eye opening at TP3
- Bottom line spec, inherently includes parametric tradeoffs
  - Includes amplitude penalties

TDP – setup, Figure 52-12



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TDP - procedure

1. Ref Tx, short fiber; adjust attenuator to 1E-12 BER, measure OMA*
   - BERT threshold at average power, sample time at eye center
2. DUT, dispersion fiber (or transversal filter); adjust attenuator to 1E-12 BER, measure OMA*
   - BERT threshold at average power, sample time +/-0.05 UI from eye center, take result with less sensitivity
3. TDP = difference in OMAs

*OMA defined as averaged and settled pk-pk values with low frequency square

TDP - history

- 802.3z spec'd eye mask and jitter at 1E-12 BER, both at TP2
- 802.3ae *was* with eye mask at TP2 and bathtub jitter at TP3
- TDP proposed instead of jitter bathtub, Jan/02
  - At the time, BERT Rx unable to accurately measure jitter at 10G
    - Insufficient sensitivity, too much distortion, setup/hold, scanning inaccuracies, etc.
  - TDP is a (relative) power penalty test
    - Stronger relationship to link model
      - Weak relationship of jitter to vertical amplitude penalties
    - Goal: provide some compensation for shortcomings of Rx tester via difference measurement
- Aggressive 802.3ae schedule, TDP was not thoroughly tested or understood

TDP – limitations (see 03-387v0)

- Still suffers from equipment “challenges”
- Still uses BER Rx, *but they are getting much better…*
  - Poor Ref Rx equipment assumed caused by DUT, stresses yields
- Yet spec allows too much jitter from DUT
  - If Ref Rx exceeds requirements, inadequate jitter control
    - Before, jitter was insufficiently related to penalties, but now TDP is insufficiently related to jitter
    - TDP allows ~0.8 UI pk-pk jitter at TP3 output
      - Exceeds jitter of Stressed eye for Rx test
      - Exceeds jitter tolerance of most CDRs!
  - Poor Ref Tx reduces TDP reference, allows lower DUT quality

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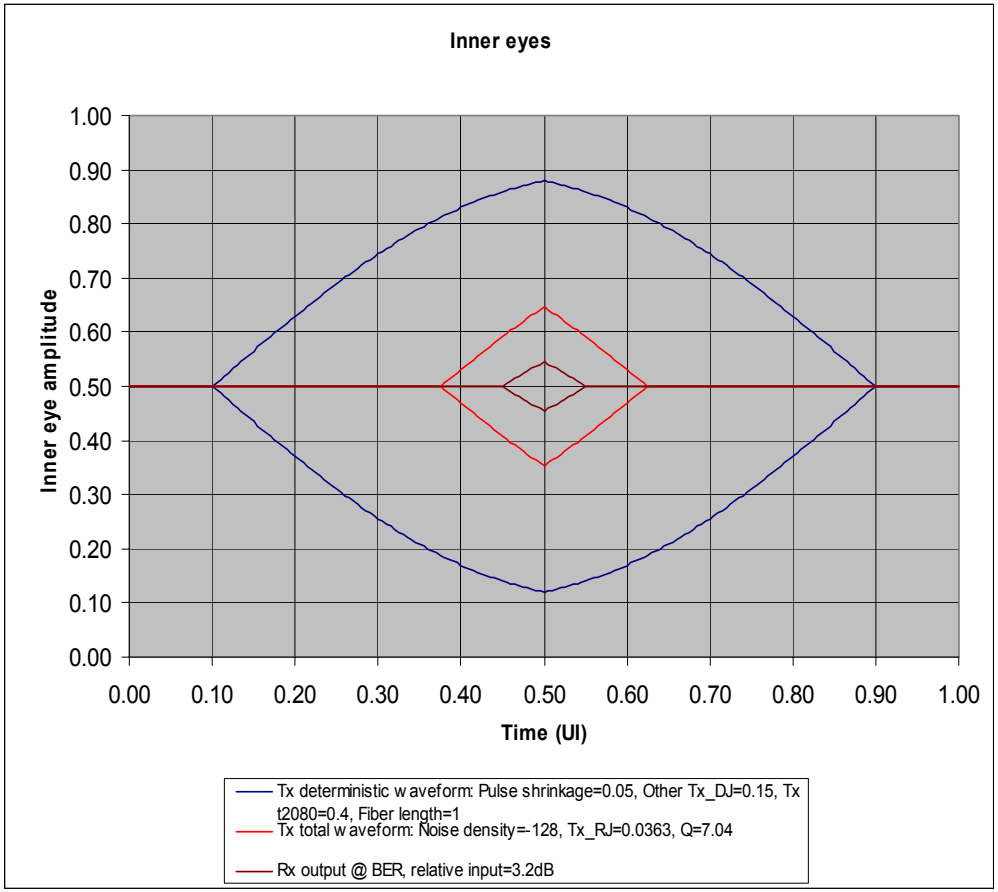
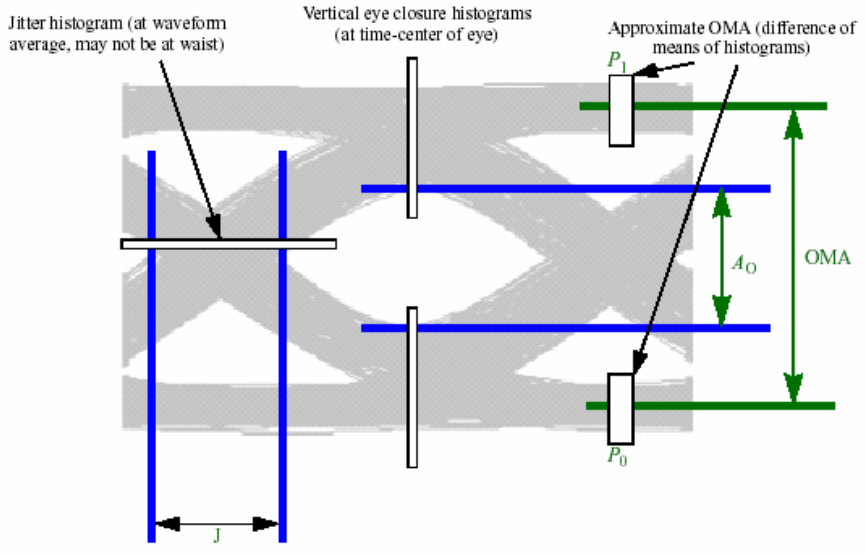
TDP – example of excessive jitter

- 3.2 dB TDP
  - per 10GBASE-L
- 0.76 UI at TP3 (red)
  - Not worst case…
- Perfect test equipment
  - See previous slide



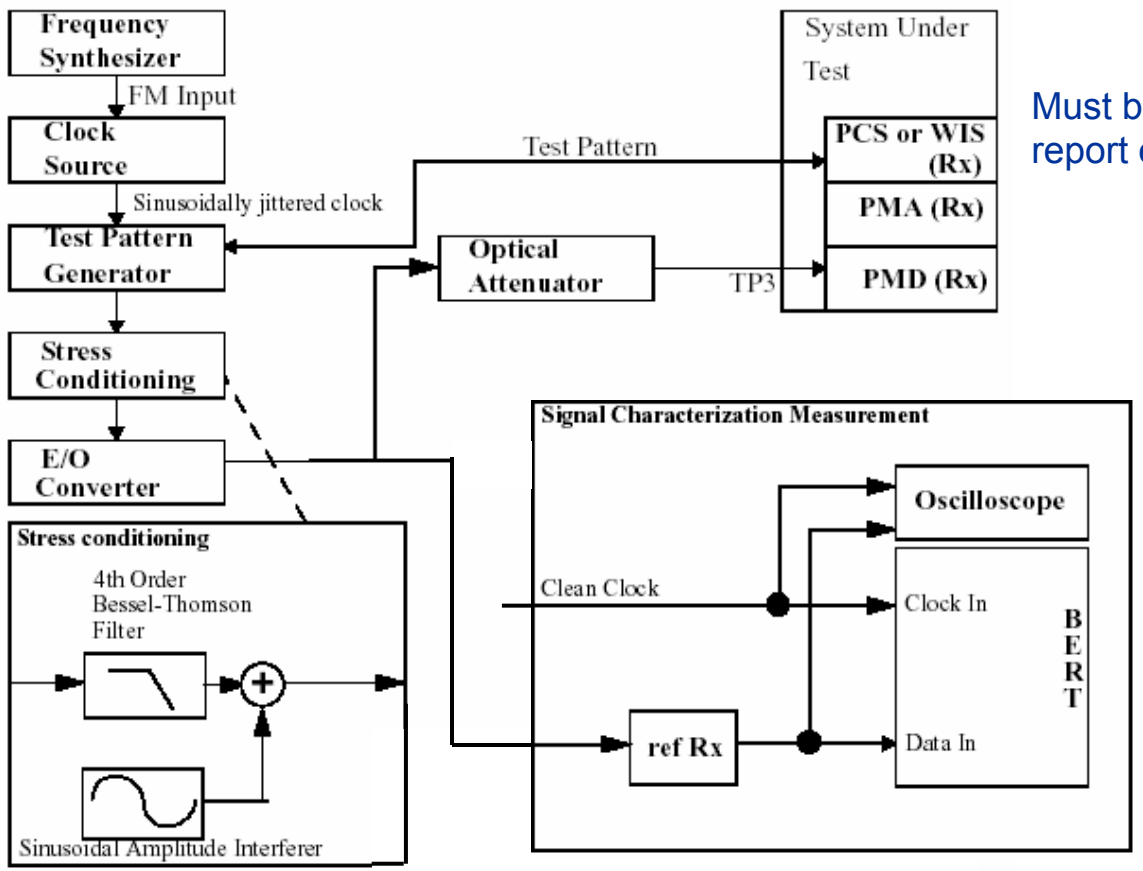
Navy is deterministic eye at TP3
Red is random/total eye at TP3
Brown is random/total eye at TP4

Stressed eye - description



- Primary measure of receiver quality
- TP3 input
  - Same interface as TDP (output)
- Rx must receive with BER <1E-12
- Properties per link model
  - OMA
    - High quality pattern generator and E/O
    - Minimum Tx power - fiber loss - pk-pk random penalties (2*Q=14)
  - VECP (dB optical power opening between 0.1% cumulative hit regions)
    - Deterministic closure calculated from dispersion and slow Tx edge rates
    - Accomplished with 3-4 GHz BT4 filter & sine interference
  - J = deterministic jitter (time opening between 1% cumulative hit regions)
    - Accomplished with filter (minimal), sine interference and sine jitter

Stressed eye – setup, Figure 52-10



Must be able to report errors

All non-stress components are to have minimal jitter, noise, distortion, frequency loss, or other impairments. Stresses are to be highly deterministic to allow visibility on scope.

Must be high quality similar to TDP test, although scope expected to get most usage. CRU not required.

Stressed eye – stress mechanisms

- Filter - clean, vertical closure with minimal phase distortion & jitter
- Sine interference (SI)
  - Amplitude closure, also translates to jitter via waveshape
    - Jitter is modulated pulse-width (bit shrinkage)
    - Tough on Rx BW and sampling blocks
    - No phase shift, so cannot be tracked with PLL
  - SI frequency range (sweeping is optional, but *customer* is allowed to…)
    - 0.1 – 2 GHz
    - Above AC coupling, so must be dissipated
  - Deterministic, so can be measured on scope
- Sine jitter (SJ)
  - 1/f roll-up from 4 MHz down to 40 kHz
    - Verifies CDR tracking
  - Flat from 4 MHz to 10x DUT_loop_bandwidth, 0.05 - 0.15 UI
    - Also translates to amplitude closure via waveshape
  - Deterministic, so can be measured on scope
- High freq SJ amplitude, filter and SI co-adjusted to meet J = 0.3 UI
- Attenuator – reduce OMA to spec

Stressed eye - procedure

1. Interactively calibrate VECP, J, minimum SJ, pulse shrinkage (5-15 psec)
   - Short patterns may be used if frequency loss has been minimized
2. Adjust optical power (attenuator)
3. Set test pattern
4. Sweep SJ frequency range
   - Sweep SI frequency range (optional)
5. Confirm BER <1E-12

Stressed eye - history

- First used in 1G Ethernet (~1998)
  - Purpose – to be sure receivers have sufficient bandwidth to meet worst case waveform
    - Max BW already understood and controlled
- Adopted by FC-PI, FC-PI-2 (1,2,4G Fibre Channel, 1999-2003)
- Adopted and modified by 10GE (2002)
  - Clearer relationship of stressed eye to link model
  - Built from deterministic elements for better visibility and calibration
- Spec was rushed to meet schedule, not thoroughly understood

Stressed eye – limitations

- Stressed eye may not satisfy interoperability needs
  - Stressed eye minimizes random noises and jitter in test
    - Done so random signals can be observed reliably on scope; no low probability 10G instruments were sufficiently accurate at the time
    - However, random jitter can exist in application (clock jitter, RIN, etc.)
  - J = 0.3 UI pk-pk jitter calibrated at TP3 input
    - Some RJ will exist, but TJ likely <0.8 UI (from TDP spec)
- Limit on SI amplitude *may* prevent achieving J = 0.3
  - Spec requires >2/3 VECP from filter, yet ideal filter produces negligible jitter
  - Remaining 1/3 from SI and SJ (0.15 max) produces ~0.26 max
- Expect variation across industry
  - in settings (too many degrees of freedom)
  - in accuracy of calibration equipment