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*Fiber Optic Solutions
for High-Speed Networks*

**TDEC Measurements Update
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Agenda

- Review of alternate measures of transmitter performance:
 - VECP_q
 - “OIF” form of TDEC
 - TDEC
- Case studies: how repeatable are TDEC measurements?
- Backup slides
 - Mapping signal-to-noise into bit error ratio
 - Mapping bit error ratio into signal-to-noise
 - What to do if there is no full featured math library

Comparing VECPq, “OIF” TDEC, and TDEC

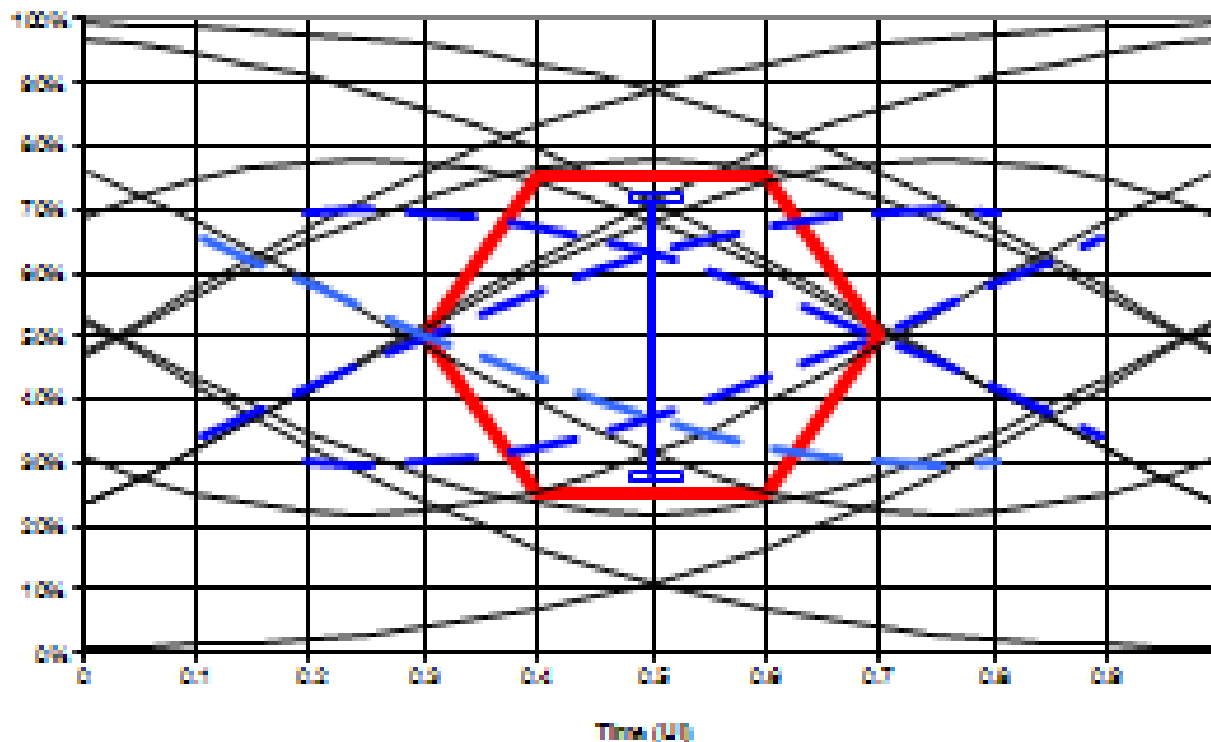
Impairment	VECPq	“OIF” TDEC	TDEC
ISI – data dependent jitter	Yes	Yes	Yes
Non-data dependent jitter	No	Yes	Yes
Laser noise	No	Yes	Yes
Link impairments: modal bandwidth, chromatic dispersion	Simulated	Simulated	Simulated
Baseline wander	No	No	Yes
Laser RIN	No	Yes	Yes
MPN, MN	No	Simulated	Simulated

Hardware requirements

	VECPq	“OIF” TDEC	TDEC
Test patterns	Short PRBS only	Short PRBS only	No restriction
Receiver bandwidth	Flexible – can adjust in software	Flexible – can adjust in software	Hardware only – non-traditional BT4 bandwidth required

Link budget assumes significant jitter

Tx eye diagram (no noise)
Black: Test Rx Blue: target link & Rx



Transmitter performance measure must capture jitter!

Comparing VECpq and TDEC

Impairment	VECPq	TDEC
ISI – data dependent jitter	Yes	Yes
Non-data dependent jitter	No	Yes
Laser noise	No	Yes
Link impairments: modal bandwidth, chromatic dispersion	Simulated	Simulated
Laser RIN	No	Yes
MPN, MN	No	Simulated

Acquisition speed

- VECPq – moderately slow
 - E.g., PRBS9 with 16X oversampling and 64 waveform averaging: **523,264 samples**
- “OIF” TDEC – very slow
 - E.g., PRBS9 with 16X oversampling and 1024 pattern capture: **8,372,224 samples**
- TDEC – very fast
 - E.g., 16,384 samples per histogram x 4 histograms: **65,536 samples**

Start TDEC analysis by taking histograms

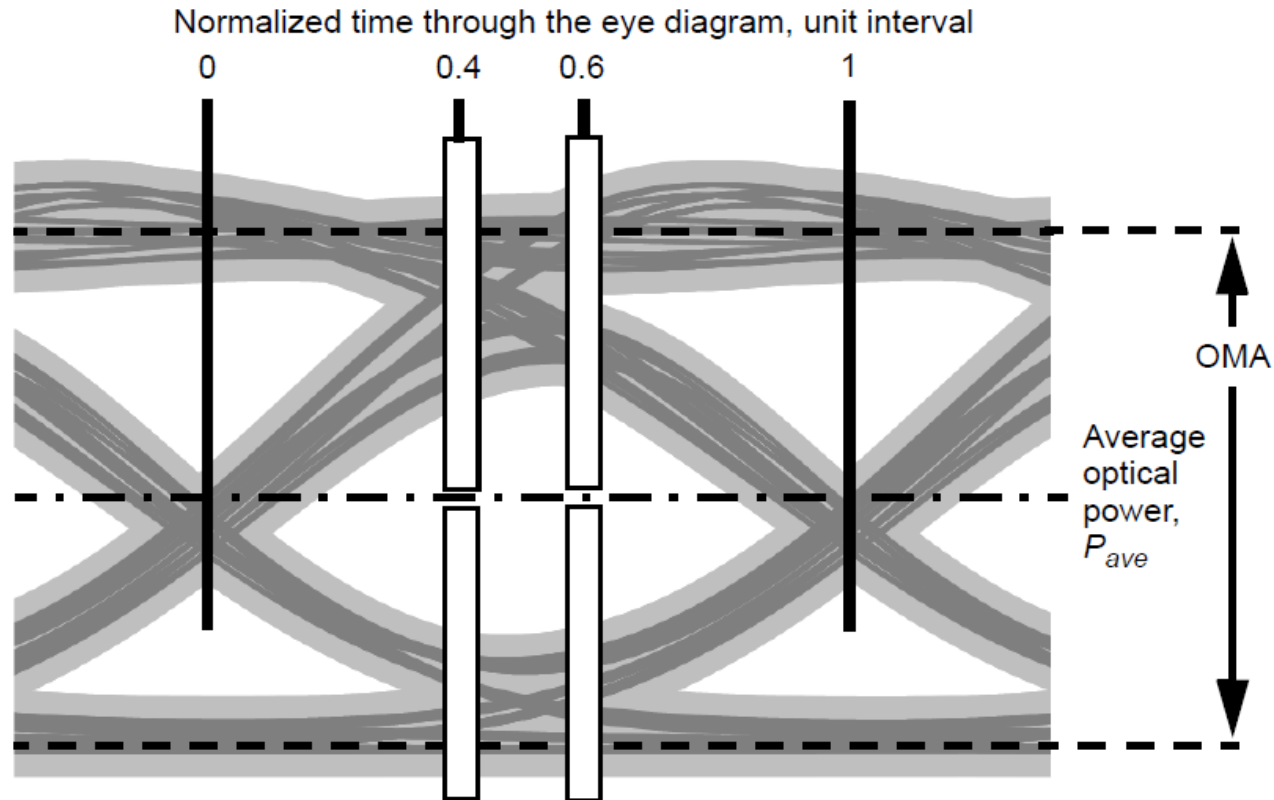
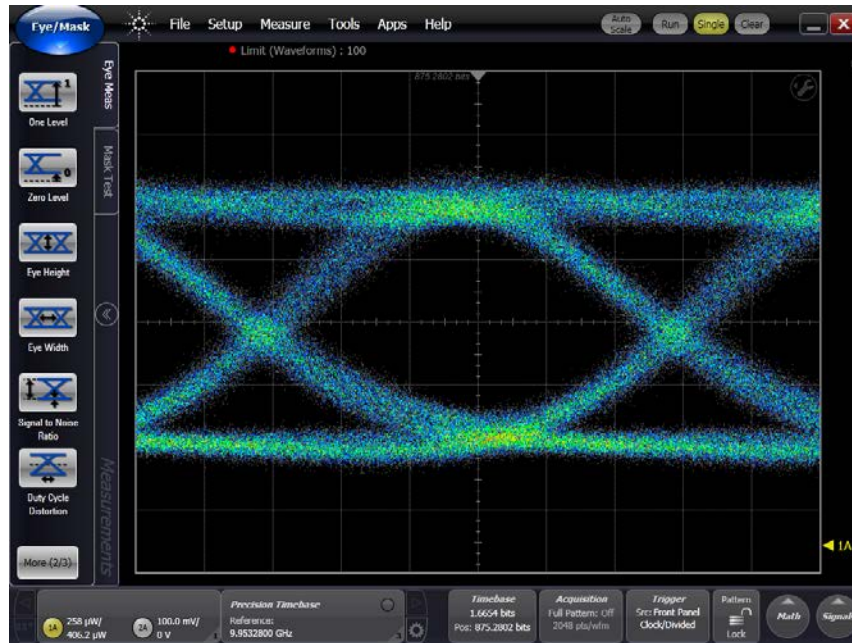


Figure 95-4—Illustration of the TDEC measurement

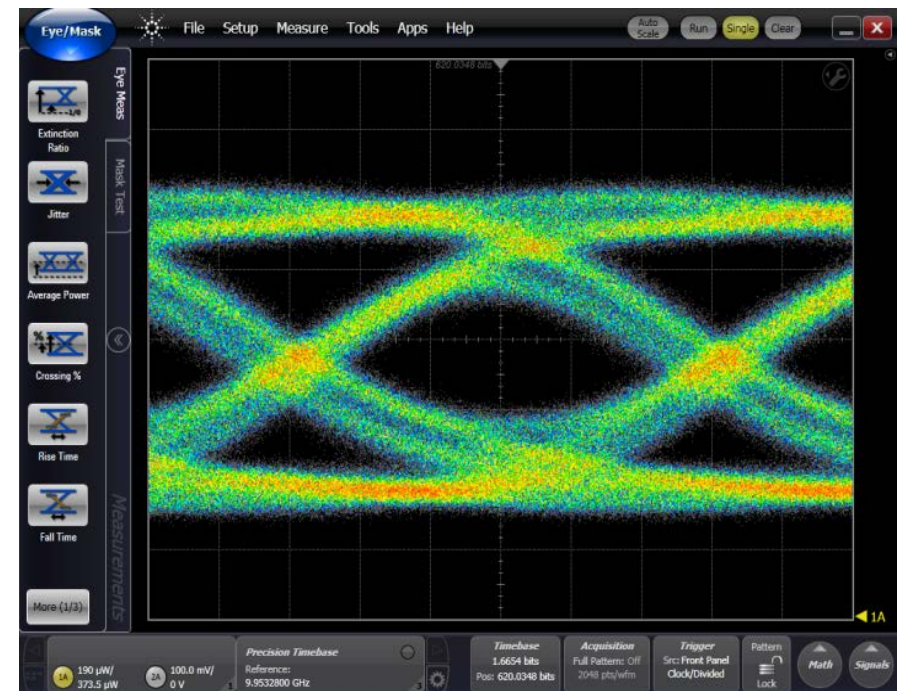
Sample Measurements

- 4-channel with CFP4 (instead of QSFP)
 - 25Gbps PRBS31 test pattern
 - 19 GHz BT4 filter – **wrong filter for TDEC!**
 - “Good” and “ugly” DUTs studied
 - Tx crosstalk, if critical, should appear
 - Waveform capture exhibited timing problems, not seen in eye diagram, not understood
- 1-channel with SFP+
 - 10Gbps PRBS31 test pattern
 - 8GFC filter – **wrong filter for TDEC!**
 - 4GFC and 10G SFP+ DUT
 - Extensive histogram and waveform capture measurements to explore repeatability

CFP4 tests

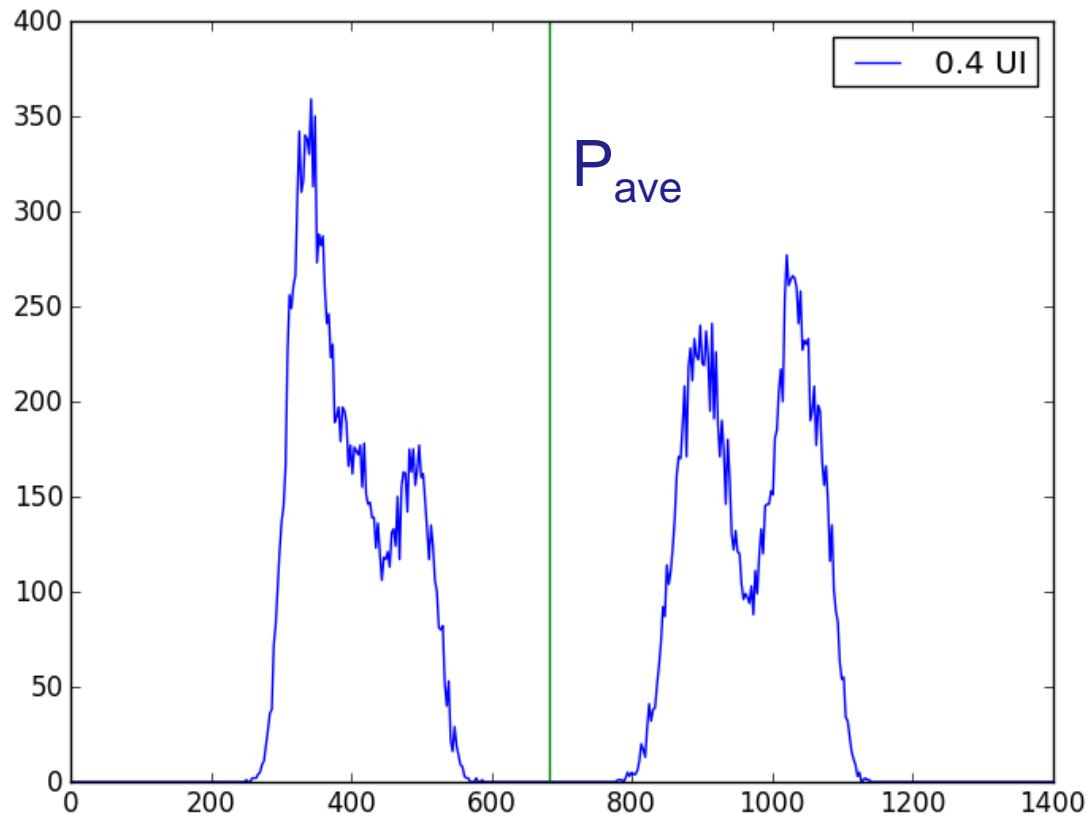


25 Gbps PRBS31 pattern
 19 GHz BT4 filter
(wrong filter!)



Stressed receiver transmitter →

Sample histogram (ugly eye)



Divide by total number of hits to get probability distribution function (pdf)

Repeatability study

	Upper left eye (good eye)	Lower right eye (ugly eye)
Minimum TDEC	0.735 dB	3.531 dB
Average TDEC	0.843 dB	4.391 dB
Maximum TDEC	1.227 dB	5.045 dB
Standard Deviation	0.116 dB	0.427 dB
Number of measurements	18	15

Sample TDEC analysis parameters (good eye)

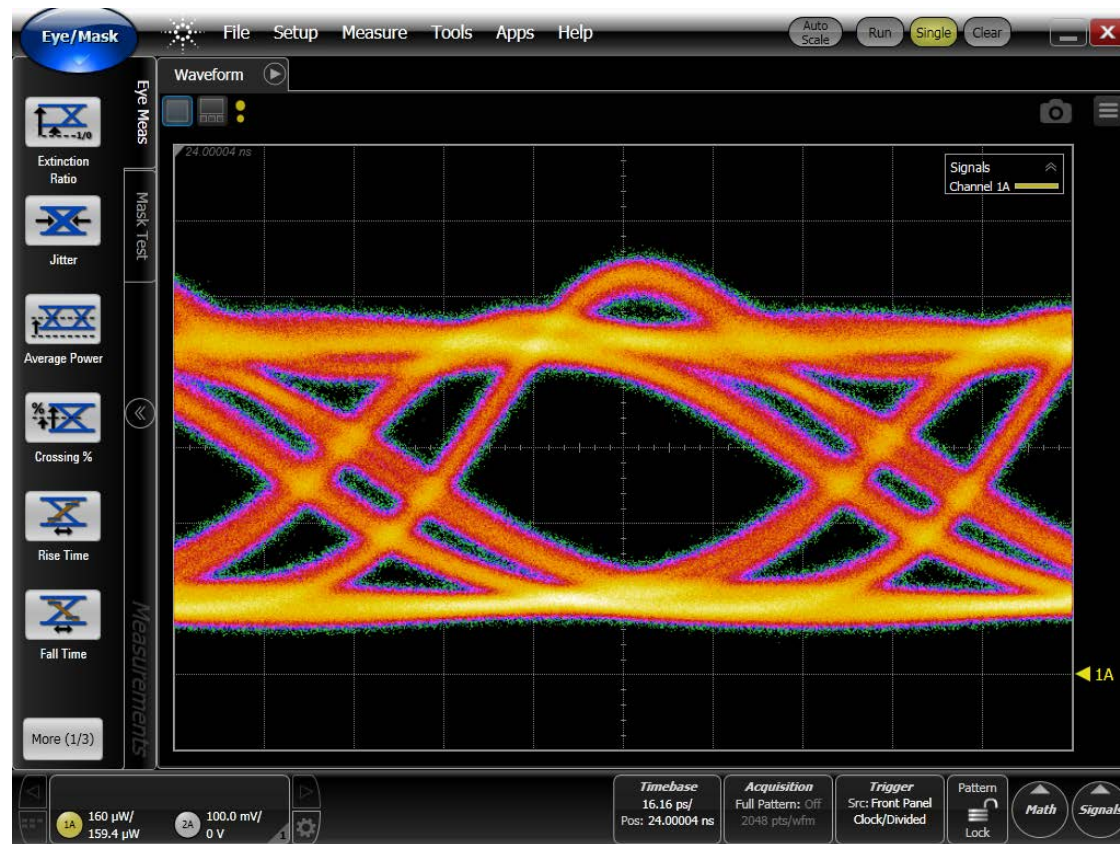
Measure	Value
OMA	899 μW
Pave	898 μW
0.4 UI noise	95 μW
0.6 UI noise	106 μW
MPN & MN noise	25 μW
Receiver noise	92 μW

Sample TDEC analysis parameters (ugly eye)

Measure	Value
OMA	595 μW
Pave	708 μW
0.4 UI noise	41 μW
0.6 UI noise	32 μW
MPN & MN noise	17 μW
Receiver noise	27 μW

Final study: how many histogram hits are needed?

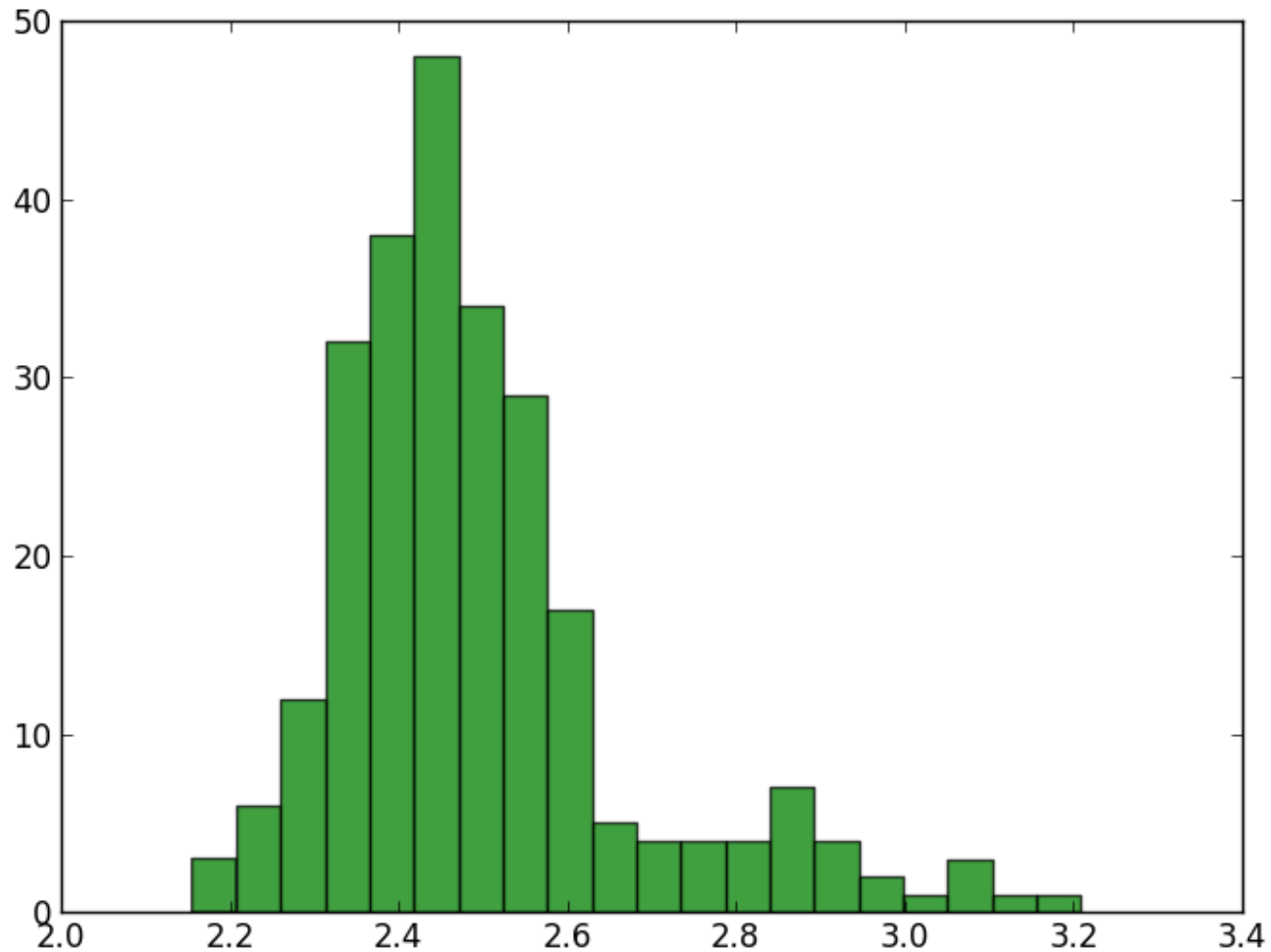
- For this next study I used 4GFC single lane transmitter driven with 10G PRBS31 signal and 8.5G BT4 filter.



How many histogram hits are needed?

	2^{14}	2^{16}	2^{18}
Min TDEC	2.226 dB	2.155 dB	2.212 dB
Avg TDEC	2.483 dB	2.495 dB	2.485 dB
Max TDEC	3.184 dB	3.209 dB	3.112 dB
Std Dev	0.180 dB	0.180 dB	0.169 dB
# tries	256	255	256

Typical distribution of TDEC measures



Conclusion for Fibre Channel

I consider TDEC a very good measure of transmitter performance, suitable for 4-lane transmitters, and well worth T11 consideration.