Simplified 100GBASE-SR4 transmitter testing

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Transmitter signal quality must be controlled

- Point of interest is after fibre, connectors and receiver front end
- Fibre contributes loss, filtering and noise
- Connectors contribute loss and noise
- Receiver contributes filtering and noise
- Item of interest is BER
  - Strictly, frame loss ratio after FEC correction

- We want metric(s) that:
- We can measure at TP2
- Correlate to BER after receiver front end
- Treat different transmitters with the same link penalties reasonably equally
- Treat transmitters with different link penalties reasonably proportionately
- Avoiding false passes (test escapes)
- Keeping false fails to a reasonable level
- Repeatable, reproducible, cost effective

Control is by a combination of specifications

Spec	10GBASE-SR	40GBASE-SR4	16GFC 1600-SN	32GFC 3200-SN	100GBASE-SR4 D2.1	Notes
TDP	Y	Y	-	-	Y	
OMA-TDP	Y	Y	-	-	Y	
OMA	Triple trade-off with wavelength	Y	Y	Y	Y	
Spectral width		Y	Y	Y	Y	
Eye mask	Y	Y		Y	Y	
VECPq	-	-	Y	Y	-	
RIN_OMA	Y	-	Y	Y	-	
Extinction ratio	Y	Y	-	-	Y (relaxed)	

- Primary control of signal quality is OMA-TDP

Test equipment required

Spec	Optical power meter	Scope	Reference Tx	Optical attenuator	Reference Rx	BERT	Noise meter or spectrum analyser
TDP (no FEC)	Y	Y (for OMA) C (for VECP)	C	Y	Y	Y	-
TDP (for FEC)	-	Y	-	-	(scope)	-	-
OMA-TDP (no FEC)	Y	C (for OMA) C (for VECP)	C	Y	Y	Y	-
OMA-TDP (for FEC)	Y	Y	-	-	(scope)	-	-
OMA	Y	Y	-	-	-	-	-
Eye mask	-	Y	-	-	-	-	-
VECPq	-	Y			-		
RIN_OMA	Y	Y (for OMA)	-	-	Y	-	Y
Extinction ratio	-	Y	-	-		-	-

- Y = needed testing each time, C for calibration (once per shift/month/whatever)
- Implementers can think of alternative methods that use different equipment

Simplified transmitter testing 1/2

- For BER <= 1e-12, TDP is done with a reference receiver and BERT because the sampling rate of a scope doesn't collect enough statistics in a reasonable time
  - Some extrapolation could be used
  - A lot of extrapolation could leave holes in the spec
- Reference receiver's sensitivity is calibrated to an ideal signal
- Something close to an ideal signal has to be generated (the reference transmitter), and the impairments in it calibrated out
  - Which is done with a scope
  - When we have learnt how to measure the penalty of the reference transmitter with a scope, we are on our way to knowing how to do transmitter testing with a scope

Simplified transmitter testing 2/2

- For BER <= 5e-5, TDP or other signal metric can be done with a sampling scope in a reasonable time
- Receiver noise can be included by calculation
- Same scope measurement can find apparent OMA (as seen by the scope)
  - Don't need to know what it really is, for finding TDP
- So everything is relative, from the same instrument
  - No need for a reference transmitter
  - Scope's own noise contribution does not dominate and can be measured and corrected for if desired
- No reference transmitter needed! No reference transmitter calibration

- To find OMA-TDP, need power meter to calibrate scope's apparent OMA

What makes a good signal metric?

- We want metric(s) that:
  - ...
  - Correlate to BER after receiver front end
  - Treat different transmitters with the same link penalties reasonably equally
  - Treat transmitters with different link penalties reasonably proportionately
  - ...

- It seems we achieve this with:

- Right bandwidth Most important
- Right statistics Much more important for 100GBASE-SR4 than 40GBASE-SR4
  - At 1e-12, dual Dirac model is reasonably valid
  - At 5e-5, it seems it isn't
- Right noise Take proper account of transmitter and channel noises

Candidate metrics vs. criteria

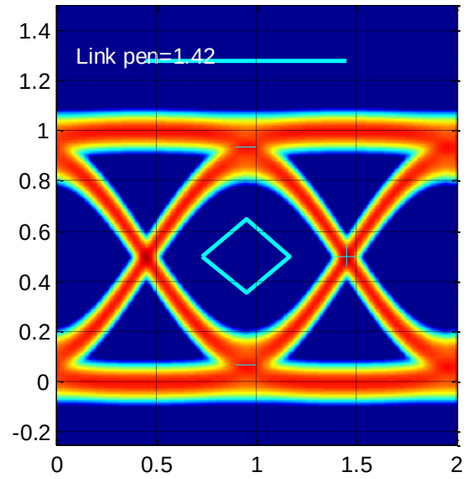
	Right bandwidth?	Right statistics?	Right noise?	Practical pattern length
TDP with BERT	Yes	Yes	Mostly	Unlimited
TDP with 12.6 GHz scope	Yes	Yes	Mostly (could be yes)	Unlimited
TDP with 19 GHz scope	Post-processed	Yes	Mostly (could be yes)	PRBS15?*
VECPq in 19 GHz	No	Yes	No^	PRBS15?*
VECPq in 12.6 GHz (actual or post-processed)	Yes	Yes	No^	PRBS15?*
"VECP" (all but x%) in 19 GHz	No	Poor	Some	Unlimited
"VECP" in 12.6 GHz	Yes	Poor	Some	Unlimited or PRBS15*

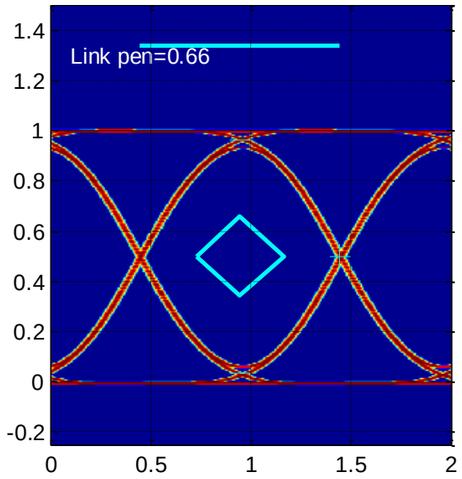
* PMA pattern is PRBS9 but external pattern generator could be used
  Long pattern is good for a solid spec
^ Could add a separate RIN_OMA spec – not attractive

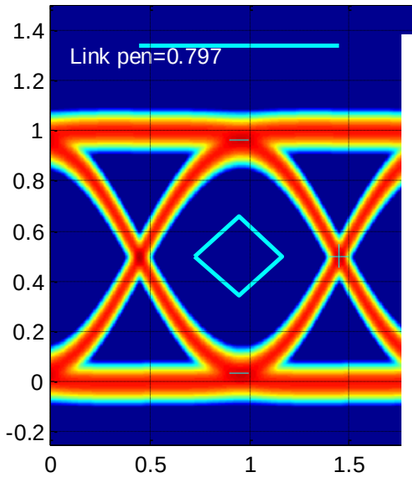
Availability of test equipment

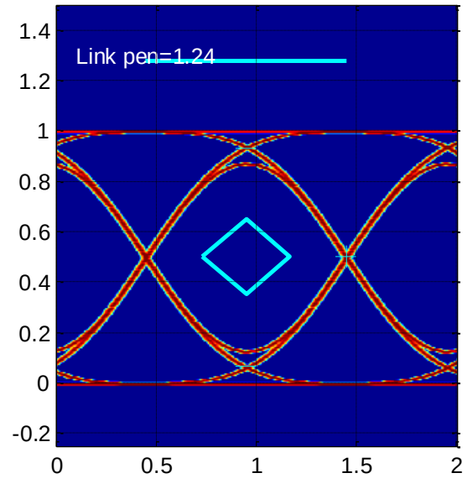
- 19 GHz scopes are expected anyway: several optical PMD specs expect them for eye mask
- 10.5 GHz and 19.33 GHz scopes are available
  - 16.2 GHz would be suitable
- Software to post-process a waveform to a different bandwidth is available with new scopes
  - If pattern is not too long
  - Noise is not changed
- Ability to post-process for algorithms such as VECPq or soft TDP is available in new scopes

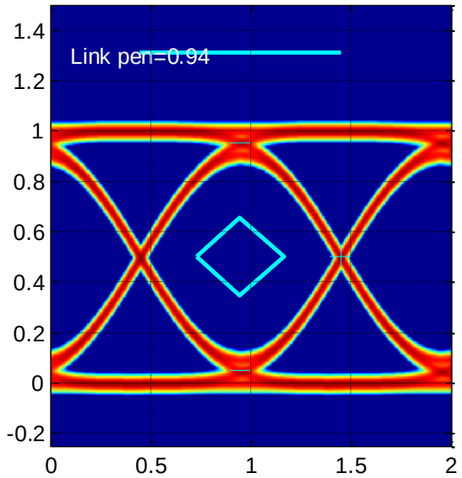
Different compliant reference transmitters

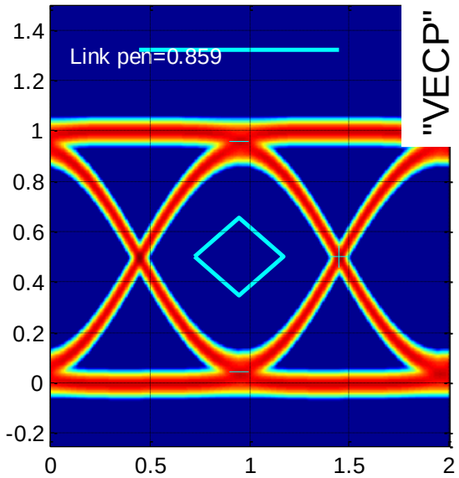


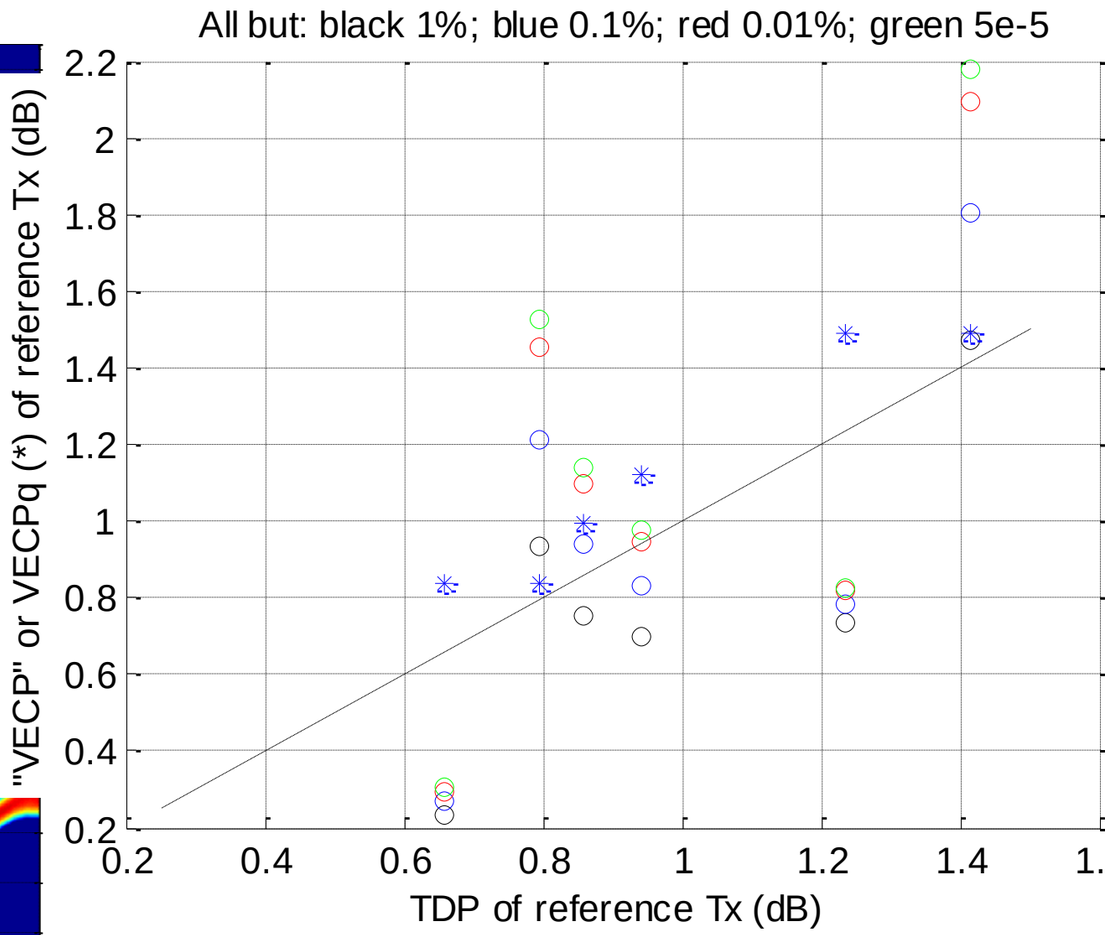






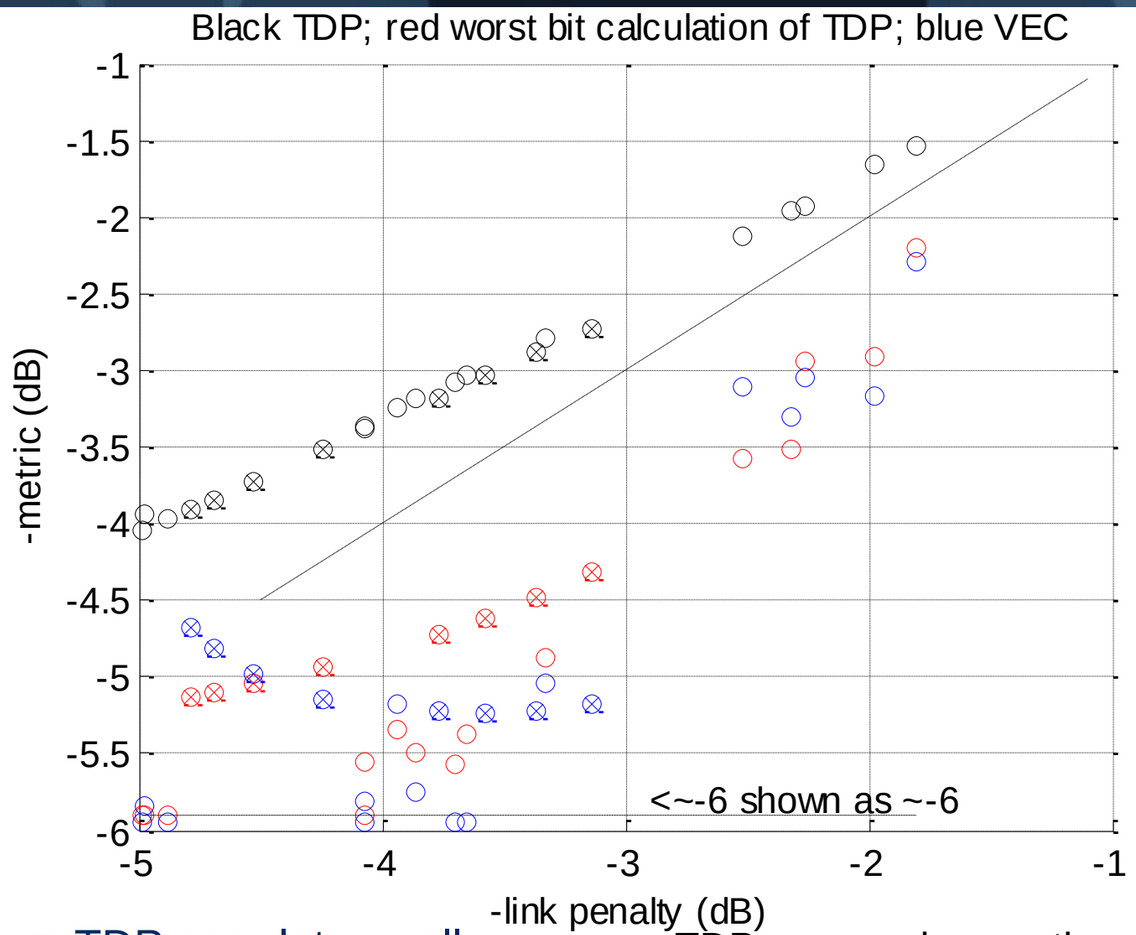


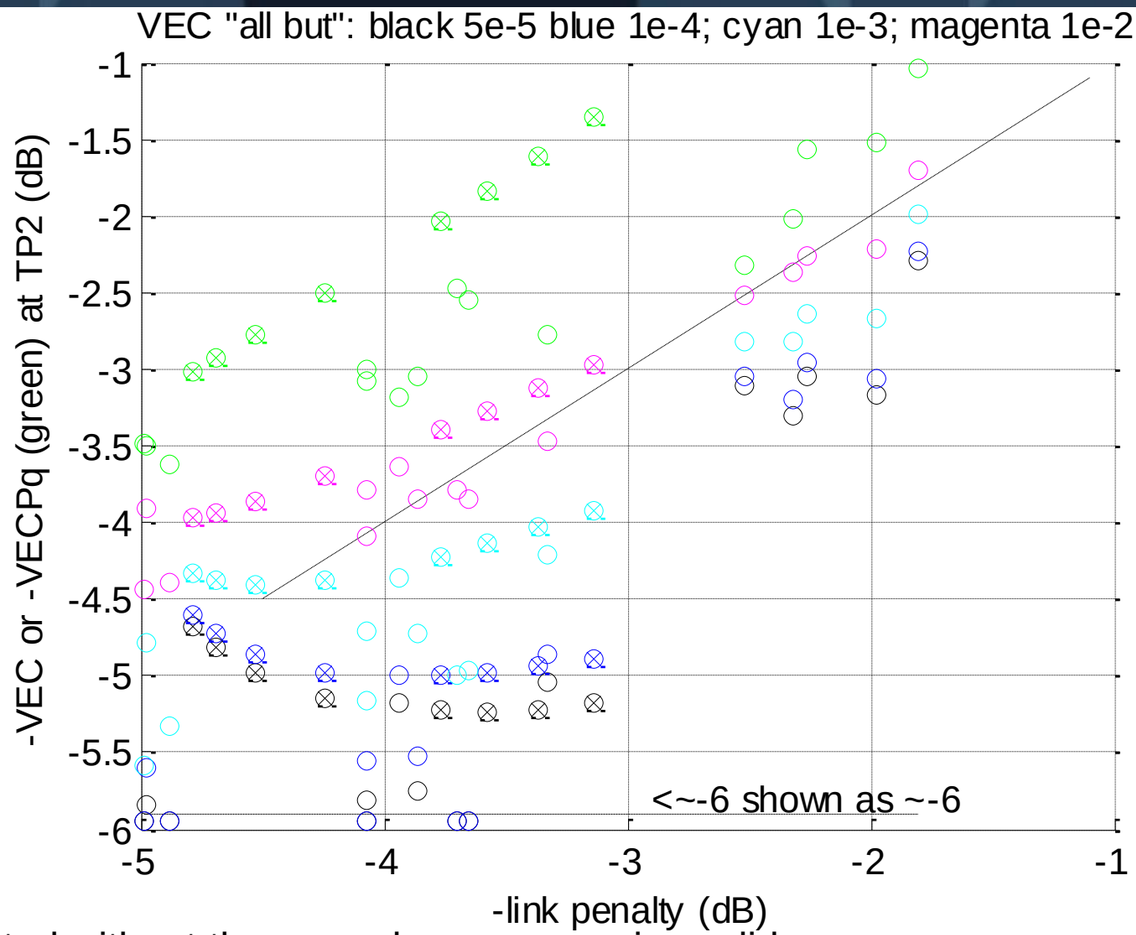




- Remarkably bad correlation with VECP
- In spite of its name, VECP is not a penalty
- VECPq works much better; tighter RIN spec could improve this

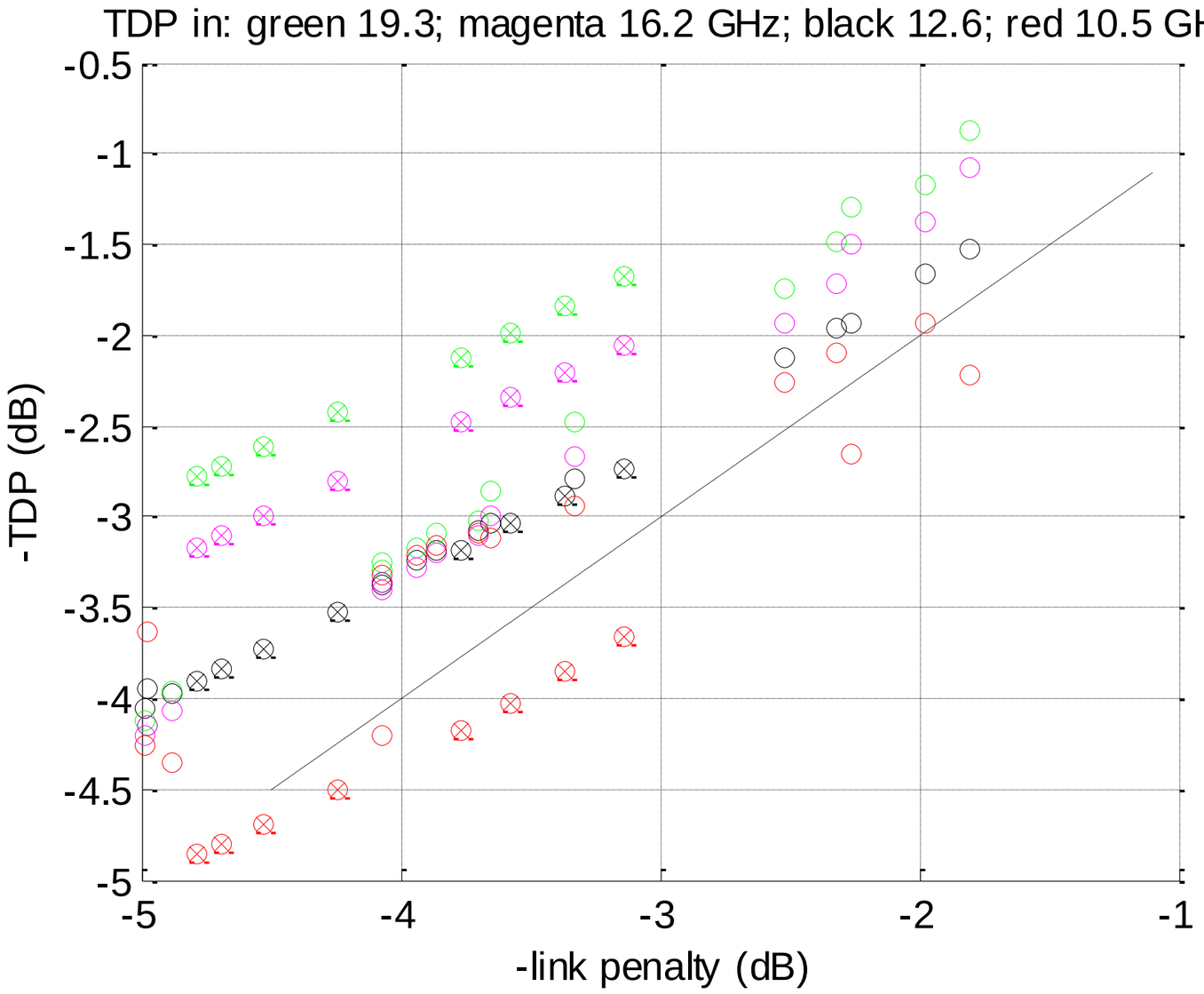
Different "product" transmitters





- TDP correlates well — TDP assumed correctly calibrated without the error shown on previous slide
- VECP doesn't. VECP tied to mean level of signal might be a bit better but points marked x would not change
  - According to petrilla_01_0114_optx.pdf slide 22, VECP flatters very slow or very noisy transmitters: would need additional spec(s) to screen them
- VECPq seems to work badly here, although apparently good enough for reference Tx calibration

Different observation bandwidths



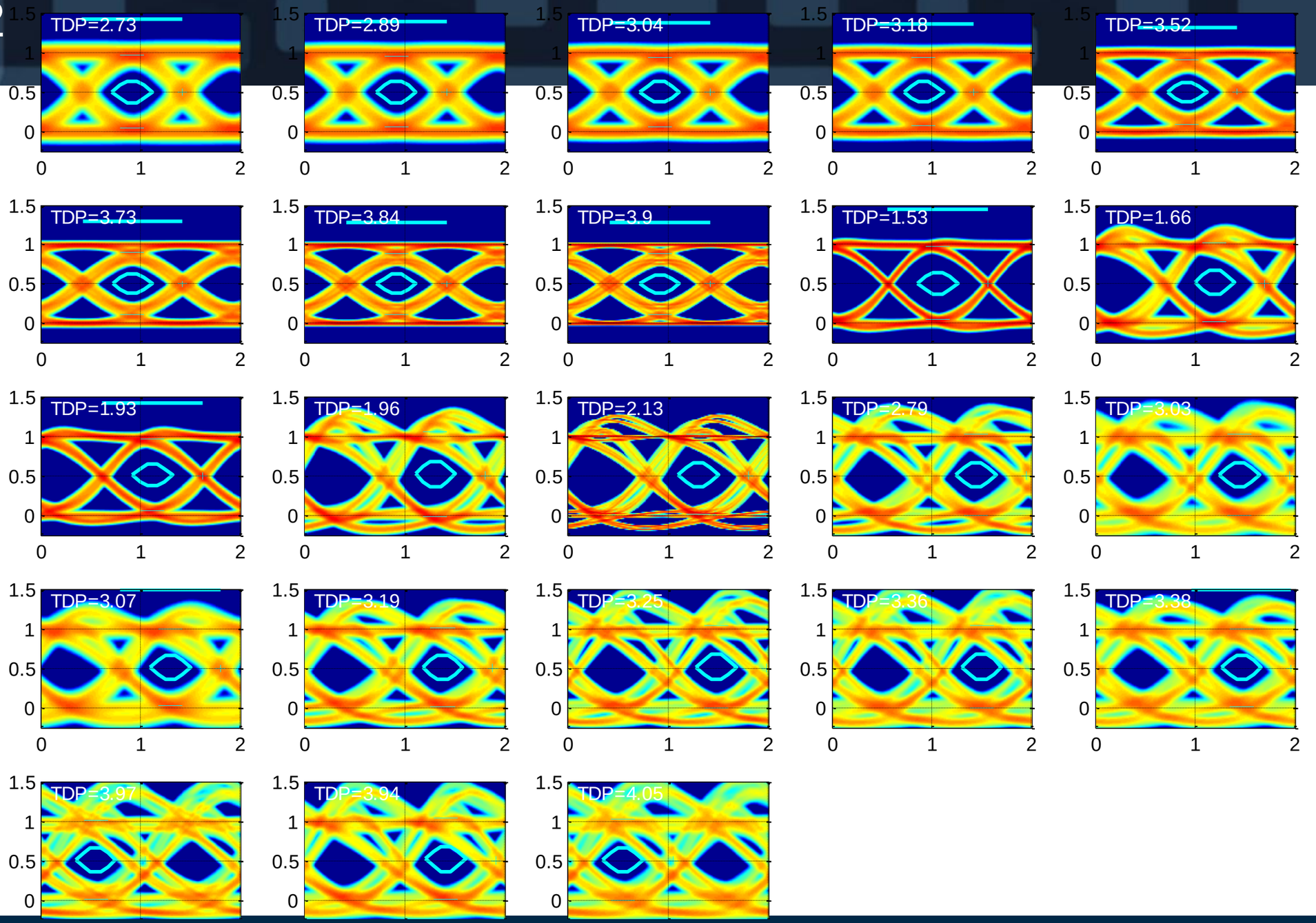
- Correct choice of observation bandwidth is important

Conclusions

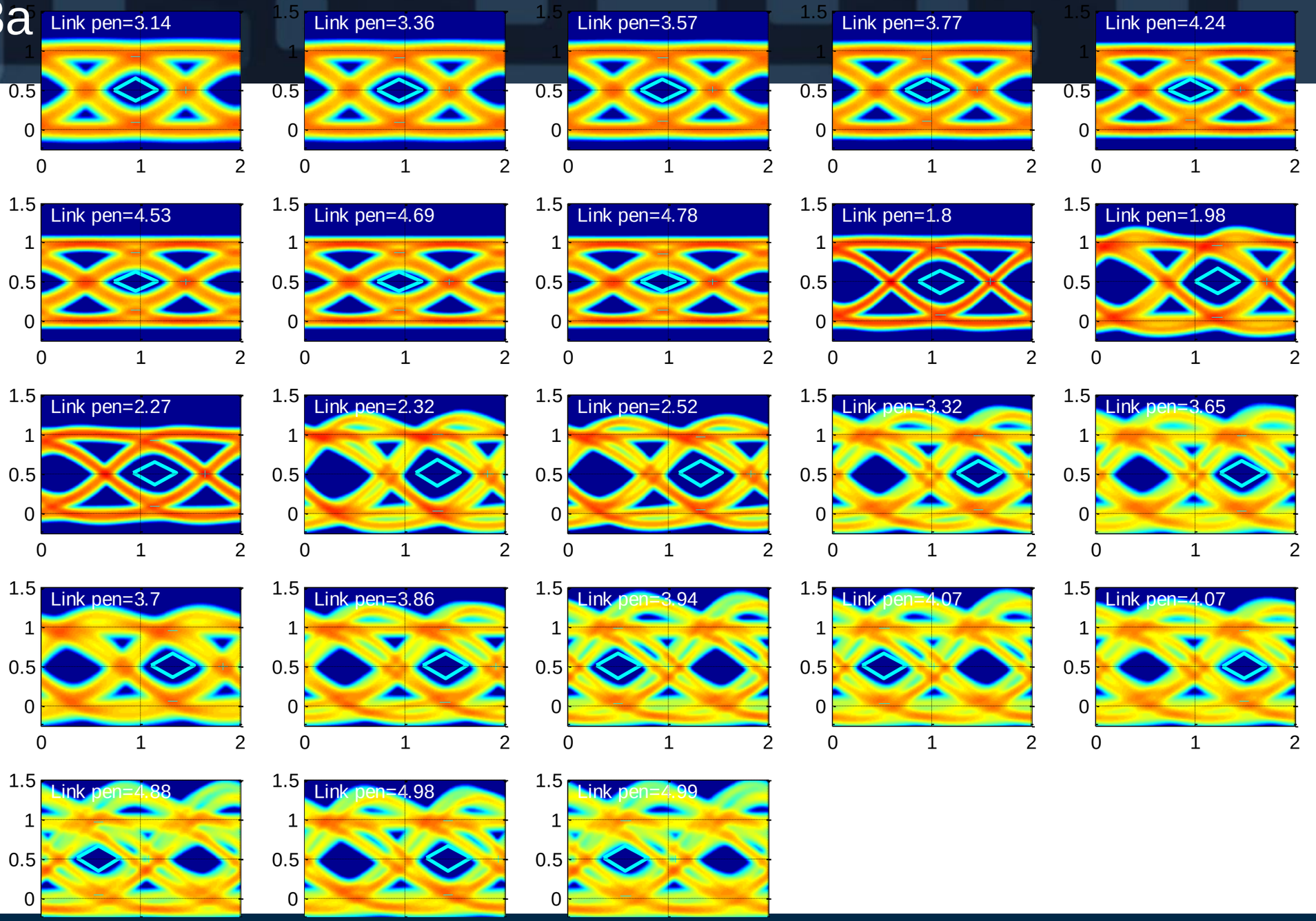
- We can eliminate the reference transmitter and its calibration
- Scopes with suitable bandwidth are available
  - Direct measurement allows long patterns
  - Post-processing to adjust bandwidth in software, for shorter patterns
- Using a scope, we can make our measure of signal quality less or more realistic
  - From VECP (which in spite of its name is not a penalty) – just histograms – via VECPq to TDP or "soft TDP"
  - We may think of something better
- The definition in the standard should be the accurate metric
  - Right bandwidth
  - Right statistics
  - Right noise
- Implementers can use the alternatives if they choose
- The present definition of TDP doesn't stop someone using a scope
  - We could make this explicit
  - We need to address the inaccurate VECP-based reference transmitter compensation method – we can specify what should be compensated rather than how

Backup

At TP2


TDP=2.73
TDP=2.89
TDP=3.04
TDP=3.18
TDP=3.52
TDP=3.73
TDP=3.84
TDP=3.9
TDP=1.53
TDP=1.66
TDP=1.93
TDP=1.96
TDP=2.13
TDP=2.79
TDP=3.03
TDP=3.07
TDP=3.19
TDP=3.25
TDP=3.36
TDP=3.38
TDP=3.97
TDP=3.94
TDP=4.05

At TP3a


Link pen=3.14
Link pen=3.36
Link pen=3.57
Link pen=3.77
Link pen=4.24
Link pen=4.53
Link pen=4.69
Link pen=4.78
Link pen=1.8
Link pen=1.98
Link pen=2.27
Link pen=2.32
Link pen=2.52
Link pen=3.32
Link pen=3.65
Link pen=3.7
Link pen=3.86
Link pen=3.94
Link pen=4.07
Link pen=4.07
Link pen=4.88
Link pen=4.98
Link pen=4.99

Thank You