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T10/08-404r0
SAS-2: Tools for TX characterization
(and jitter tolerance setup qualification)

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Overview

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- Link to Previous Material
- Guiding Principles
- Transmitter Specifications
- Far-end Measurements Orthogonality
- Issues with SASWDP
- SAS_EYEOPENING
  - Presentation
  - Features
  - Operational Features
- SASWDP vs. SAS_EYEOPENING
- Summary
- To do

Link to Previous material (1)

- In 08-330r0 and 08-345r1 Kevin Witt presented results showing how the SASWDP program could be used to characterize transmitters at the far end, after the compliance channel.
  - The idea is to replace traditional near-end measurements with a single far-end metric
    - Makes the process more flexible to different TX features
    - Makes the process pattern-independent
    - Same point as for RX characterization - consistent
- The measurement is taken at the TX – as close as possible to the chip pin and convolved with the reference channel.

Guiding Principles (1)

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- 2 ways to view the TX compliance:
  1. Generate a waveform that an RX can recover
  2. Meet specific TX criterions that will ensure an RX can recover its output
- The WDP approach is of the first kind – verify if the RX can recover without checking the specific parameters directly
- To verify specific TX criterions is restrictive on the type of equalization that can be provided by a TX

Guiding Principles (2)

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- Spec. contains only few mandatory patterns to be generated by the TX
  - CJTPAT (Table 61, note g)
  - D10.2 or D21.5 (Table 61, note f)
  - PHY_TEST_PATTERN is not mandatory

- Specification measurements are usually done at the near end
  - Easier to setup
  - At 6 Gbs, de-embedding results at compliance points is an issue
  - Measurement at the chip removes uncertainty: Treats board as part of the channel
    - Minimal impact of testing probe – likely no de-embedding

Guiding Principles (3)

- Most TX specifications can be tested easily at the near end
  - Mostly DDJ remains, which is mostly orthogonal to other specifications
- Next slides review the standard TX specs:
  - Whether they are orthogonal to DDJ from TX and channel
  - How they relate to system performance
  - Whether they are covered easily by near-end measurements

Transmitter Specifications

Specification		Best Pattern	Near-End Measurement	Simulated Far-End Measurement	Comments
RJ		D10.2 or D24.3	Easy	Difficult Requires long capture	
BUJ	PJ	CJTPAT	Easy	Difficult Requires long capture	
	DCDJ	CJTPAT or D10.2	Easy	Possible	
	SSCJ	CJTPAT or D24.3	Easiest (but not easy)	Difficult Requires long capture	
DDJ		CJTPAT	Constrains de-emphasis type	Eye opening after DFE	Zero-Length Test Load must be de-embedded if used to capture tx signal
Amplitude		CJTPAT	Possible	Tap0 magnitude in CPR	
De-Emphasis		CJTPAT	Constrains de-emphasis type	Eye opening after DFE	
Rise/Fall Times		CJTPAT	Easy Relevant for EMI	Eye opening after DFE	

Far-end measurements orthogonality

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- Specs affected by channel are best measured at far-end
  - TX amplitude
  - TX De-emphasis
  - TX DDJ
  - TX Rise-Fall time
- RX eye opening is really a combination of all the specs.
  - Need a tool for far-end measurements that can ignore the effects of specs measured at the near-end.
    - I.e., the far-end specs must be measured orthogonally to the near-end ones.
- Can we use SASWDP?

Issues with SASWDP

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- Requires a PRBS pattern (new to spec)
  - Data must be properly captured to be periodic
- Requires the digital pattern
  - Data and pattern must be aligned
- Has large variations vs. pattern
  - Up to 0.8 dB between two PRBS10
- Sometimes the Clock Recovery does not converge
- Its CDR creates a new « hidden » spec.
- ncDDJ incorrectly measured?
  - Large variations anyway
- See next slide

Issues with SASWDP

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TX	TX de-emphasis	Pattern	Channel	SASWDP (original)	ncDDJ (original)
Generated 113ps rft 0-100%	3	*TxDataFile_6m-cjtpat*	10m SAS	11.4	0.578
Generated 113ps rft 0-100%	3	*TxDataFile_10m-prbs10*	10m SAS	10.6	0.297
Generated 113ps rft 0-100%	3	PRBS10, poly x204	10m SAS	11.2	0.263
Generated 113ps rft 0-100%	0	TxDataFile_6m-cjtpat	10m SAS	11.3	0.52
Generated 113ps rft 0-100%	0	TxDataFile_10m-prbs10	10m SAS	13.2	0.325
Generated 113ps rft 0-100%	0	PRBS10, poly x204	10m SAS	14	0.364
Generated 113ps rft 0-100%	3	TxDataFile_6m-cjtpat	HP24	**15.4**	0.725
Generated 113ps rft 0-100%	3	TxDataFile_10m-prbs10	HP24	10.6	0.368
Generated 113ps rft 0-100%	3	PRBS10, poly x204	HP24	10.3	0.397
Generated 113ps rft 0-100%	0	TxDataFile_6m-cjtpat	HP24	**24.3**	1
Generated 113ps rft 0-100%	0	TxDataFile_10m-prbs10	HP24	12	0.284
Generated 113ps rft 0-100%	0	PRBS10, poly x204	HP24	11.7	0.324

SAS_EYEOPENING.m

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- SAS_EYEOPENING.m script developed
- Evaluates pulse response from the channel (-4 pre-cursors to +40 post-cursors – inspired by SASWDP)
- Extracts sampling instant assuming a random input
  - Insensitive to input pattern
  - Could be improved to consider 8b10b?
- Re-computes the pulse response at this point
- Computes a simple « worst-case » 8b10b sequence
- Computes the eye opening due to DDJ, after a perfect 3-taps DFE
- Outputs information about each of the DFE's 3-taps compensation

SAS_EYEOPENING.m

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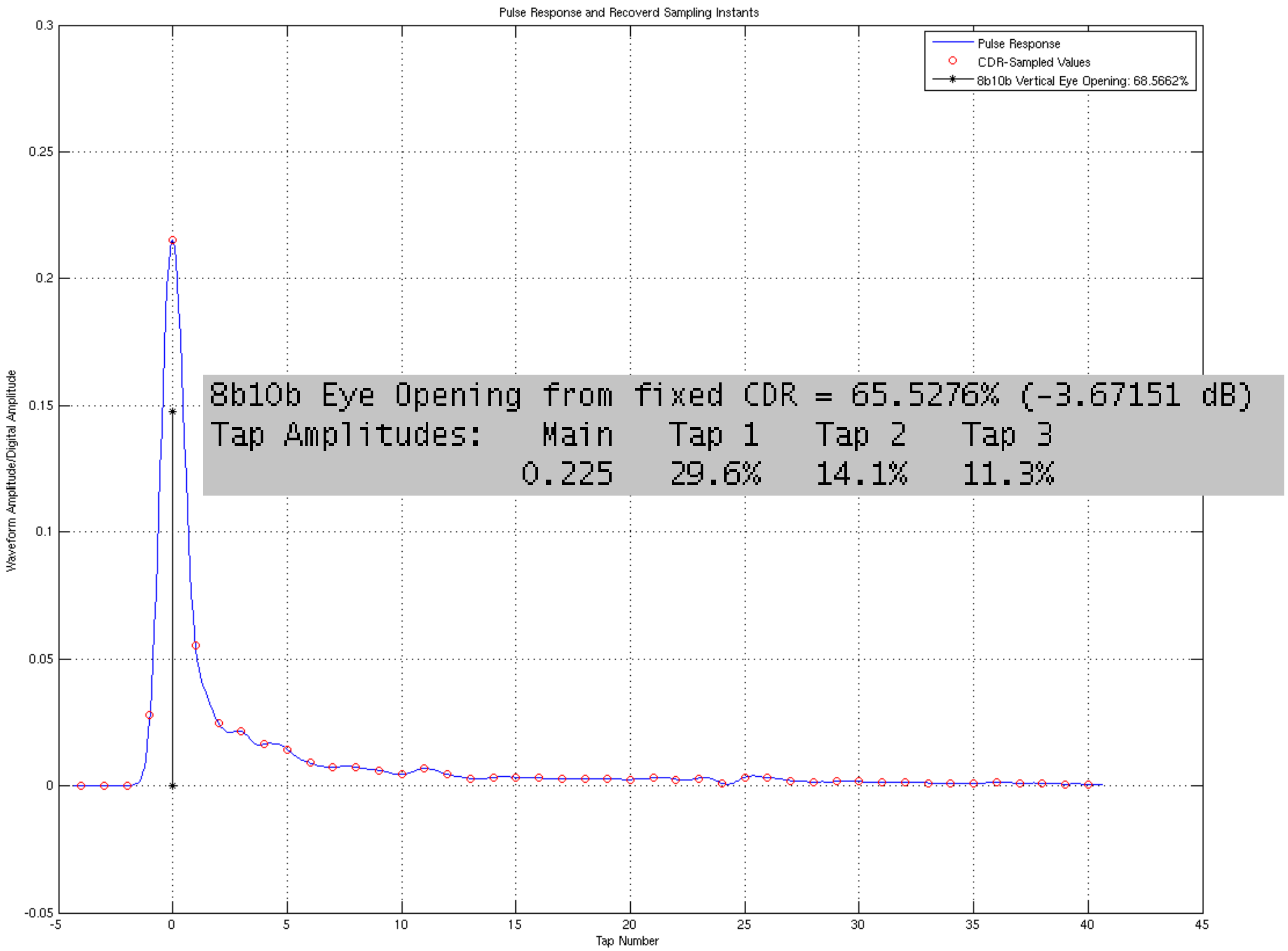
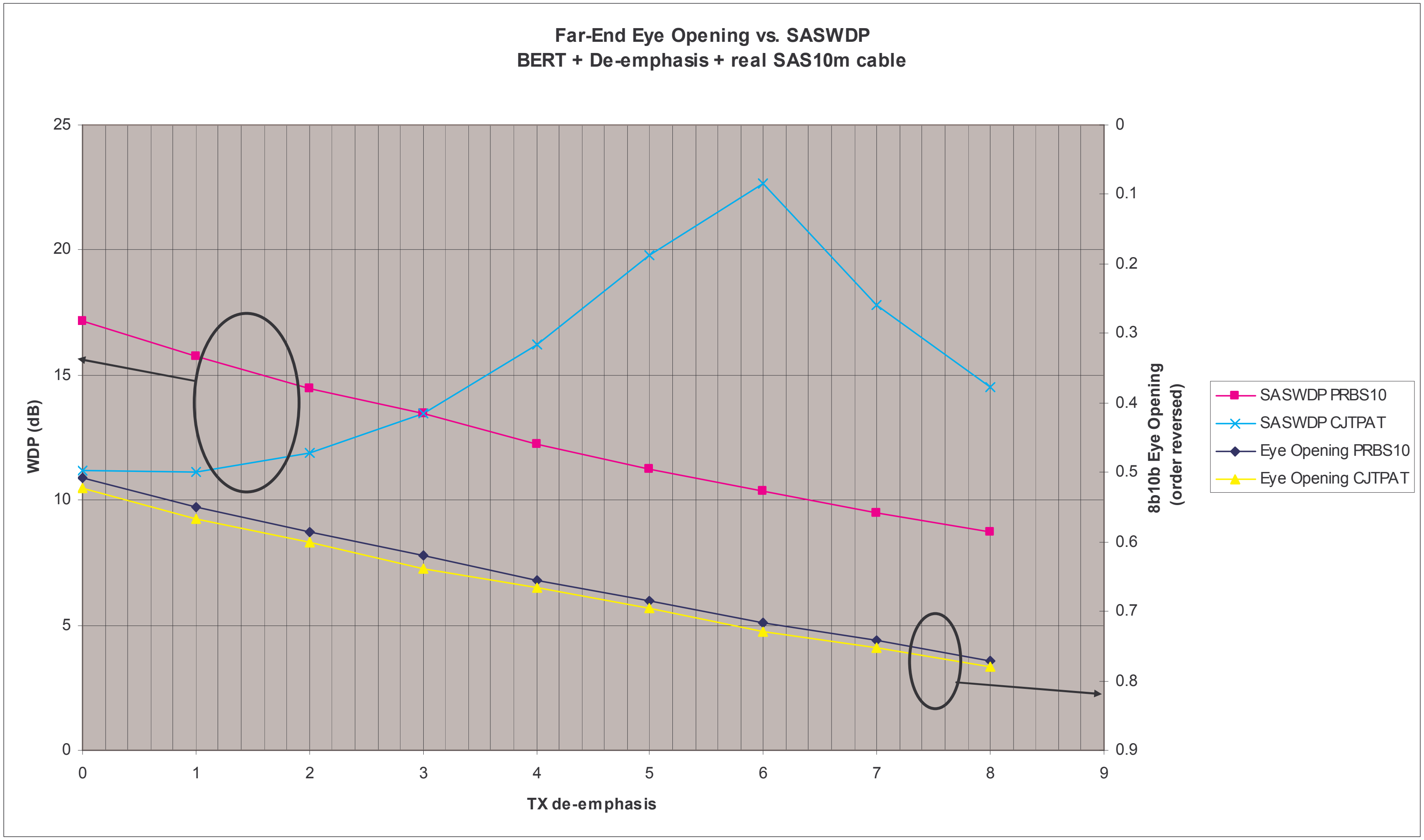


SAS_EYEOPENING vs. SASWDP

TX	TX de-emphasis	Pattern	Channel	SASWDP (original)	ncDDJ (original)	"8b10b" eye opening
Generated 113ps rft 0-100%	3	*TxDataFile_6m-cjtpat*	10m SAS	11.4	0.578	65.6%
Generated 113ps rft 0-100%	3	*TxDataFile_10m-prbs10*	10m SAS	10.6	0.297	65.6%
Generated 113ps rft 0-100%	3	PRBS10, poly x204	10m SAS	11.2	0.263	65.5%
Generated 113ps rft 0-100%	0	TxDataFile_6m-cjtpat	10m SAS	11.3	0.52	56.7%
Generated 113ps rft 0-100%	0	TxDataFile_10m-prbs10	10m SAS	13.2	0.325	56.6%
Generated 113ps rft 0-100%	0	PRBS10, poly x204	10m SAS	14	0.364	56.6%
Generated 113ps rft 0-100%	3	TxDataFile_6m-cjtpat	HP24	15.4	0.725	65.4%
Generated 113ps rft 0-100%	3	TxDataFile_10m-prbs10	HP24	10.6	0.368	64.6%
Generated 113ps rft 0-100%	3	PRBS10, poly x204	HP24	10.3	0.397	64.6%
Generated 113ps rft 0-100%	0	TxDataFile_6m-cjtpat	HP24	24.3	1	61.4%
Generated 113ps rft 0-100%	0	TxDataFile_10m-prbs10	HP24	12	0.284	60.7%
Generated 113ps rft 0-100%	0	PRBS10, poly x204	HP24	11.7	0.324	60.6%

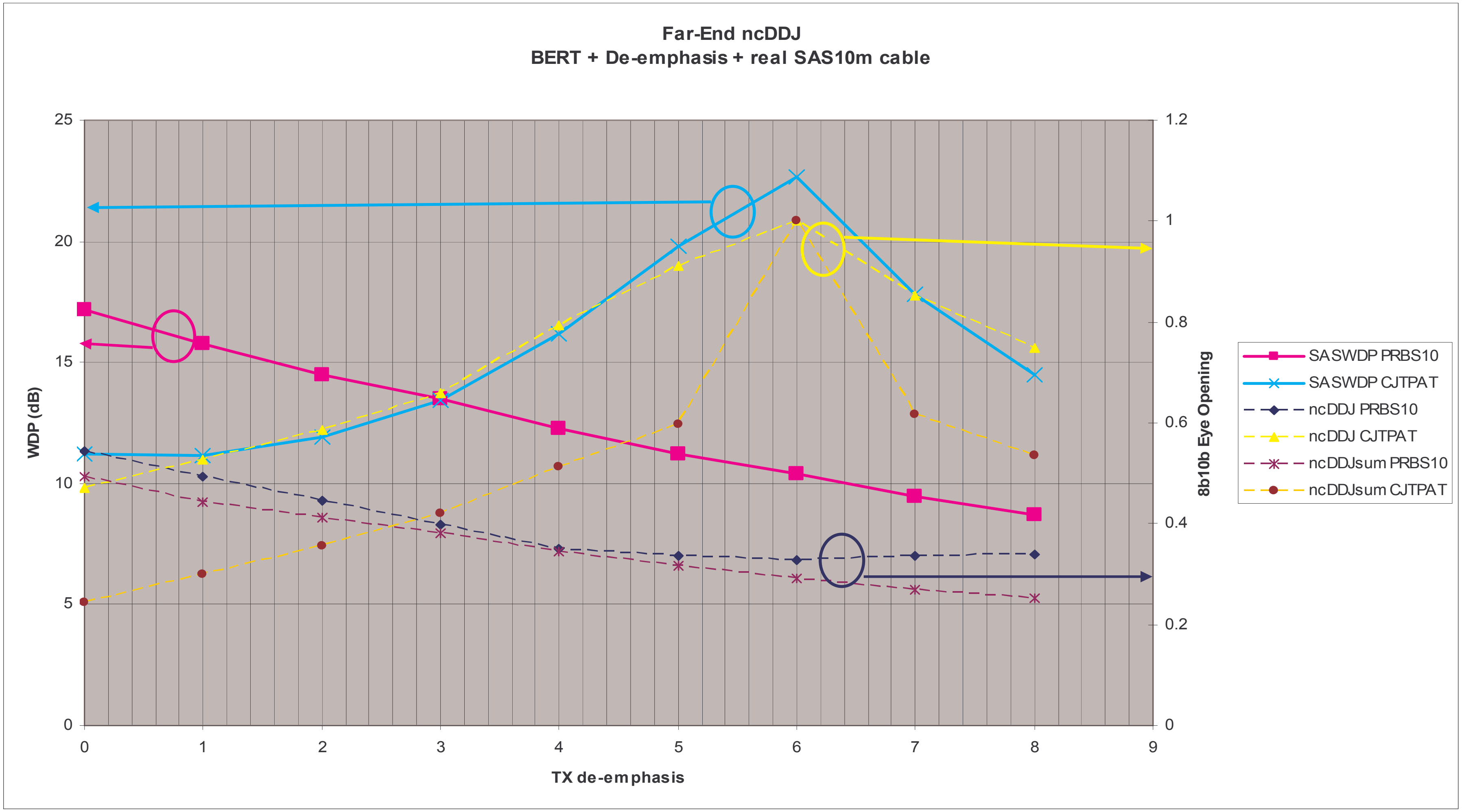
SAS_EYEOPENING vs. SASWDP

- SASWDP vs. SAS_EYEOPENING (PRBS10)



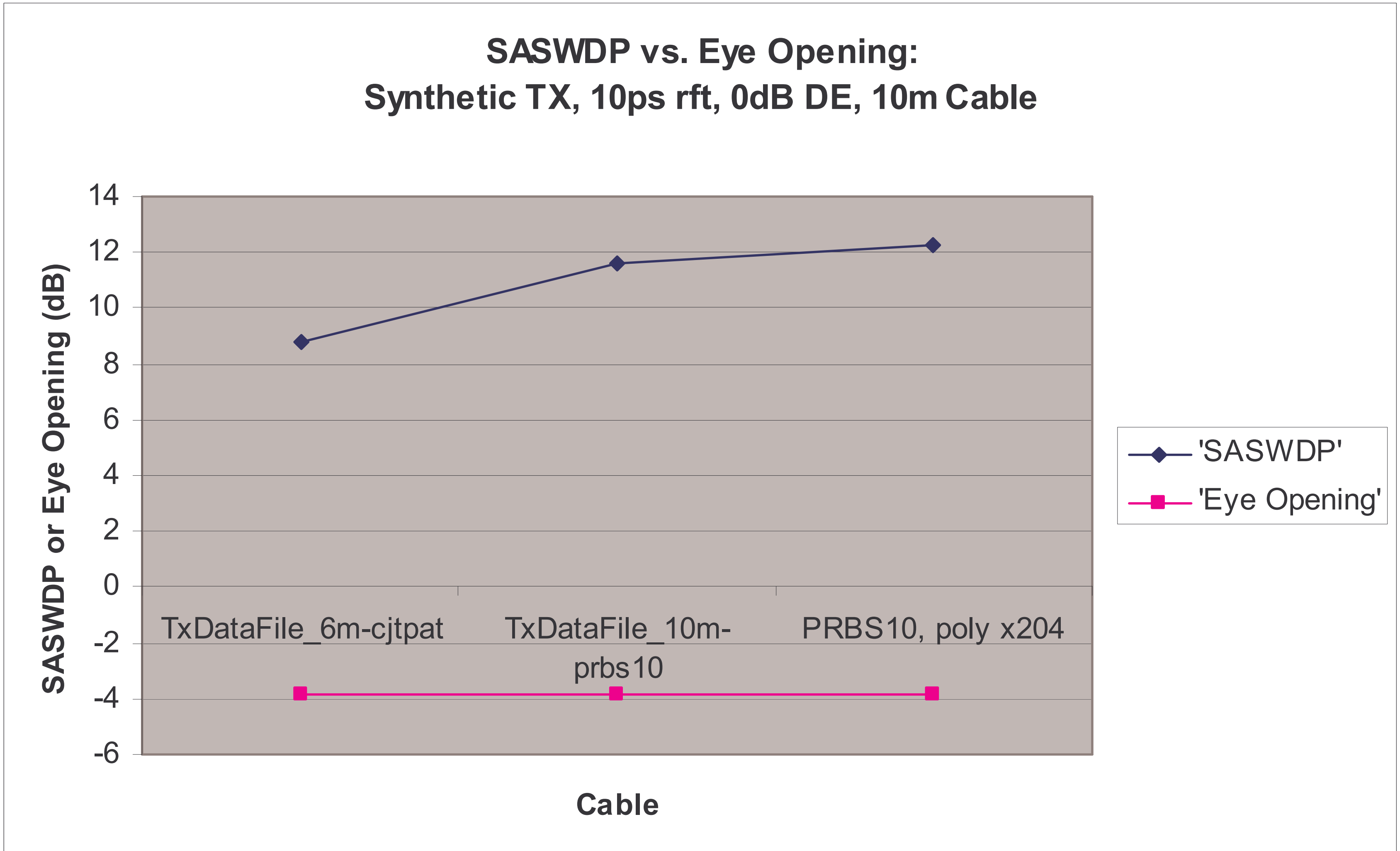
SAS_EYEOPENING vs. SASWDP

- SASWDP: CJTPAT vs. PRBS10 (results averaged)
  - PRBS10 gives consistent results vs. De-emphasis



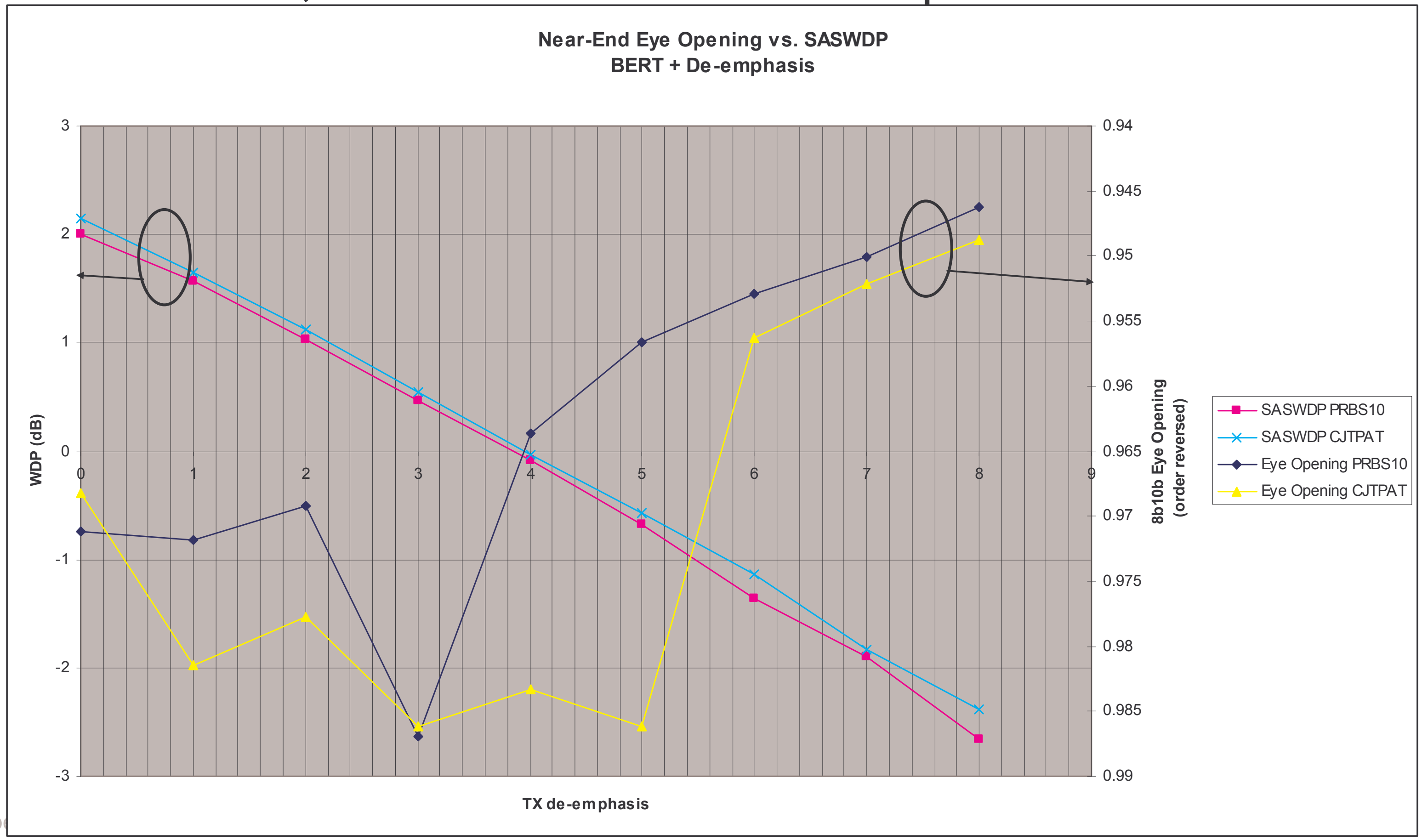
SAS_EYEOPENING vs. SASWDP

- SASWDP vs. SAS_EYEOPENING (PRBS10)



SAS_EYEOPENING vs. SASWDP

- SASWDP vs. SAS_EYEOPENING (PRBS10 & CJTPAT)
  - Why is SASWDP WDP dropping? Eye should stay open at near end, or reduce with too much post-cursor.



SAS_EYEOPENING vs. SASWDP

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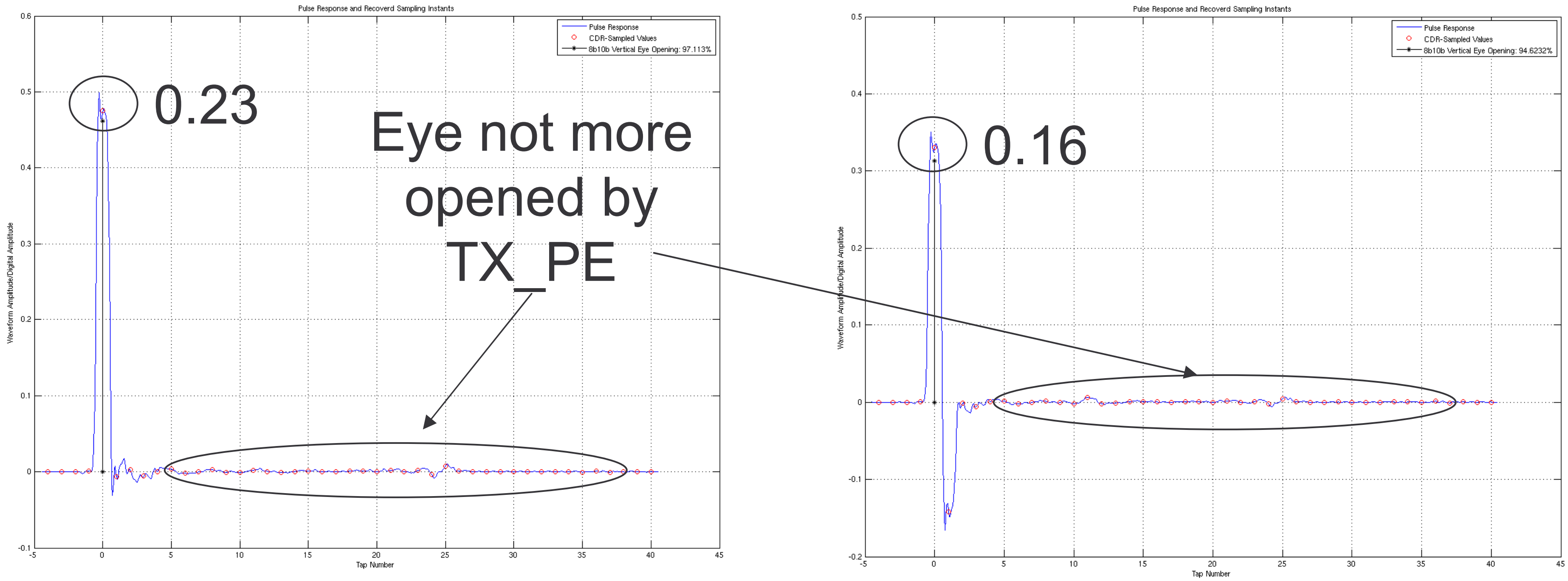
- As DE increases, the main cursor amplitude drops
  - This explains why eye opening slightly degrades: the small energy beyong Tap 3 is scaled by a smaller main cursor

TX_PE=0dB TX_PE=8dB



SAS_EYEOPENING vs. SASWDP

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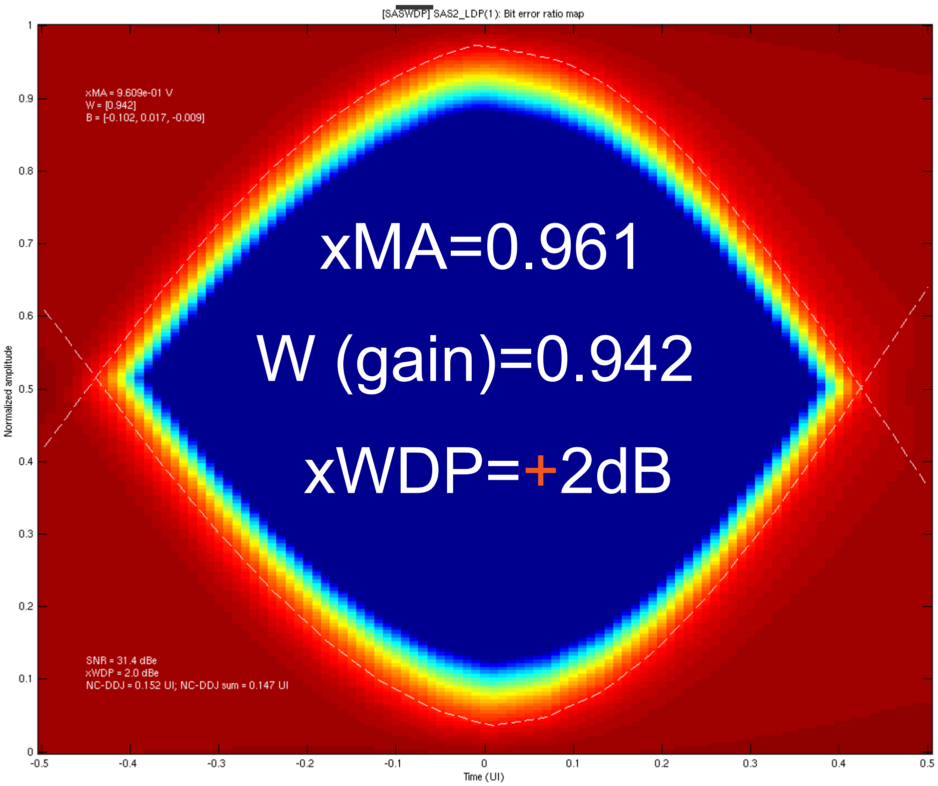
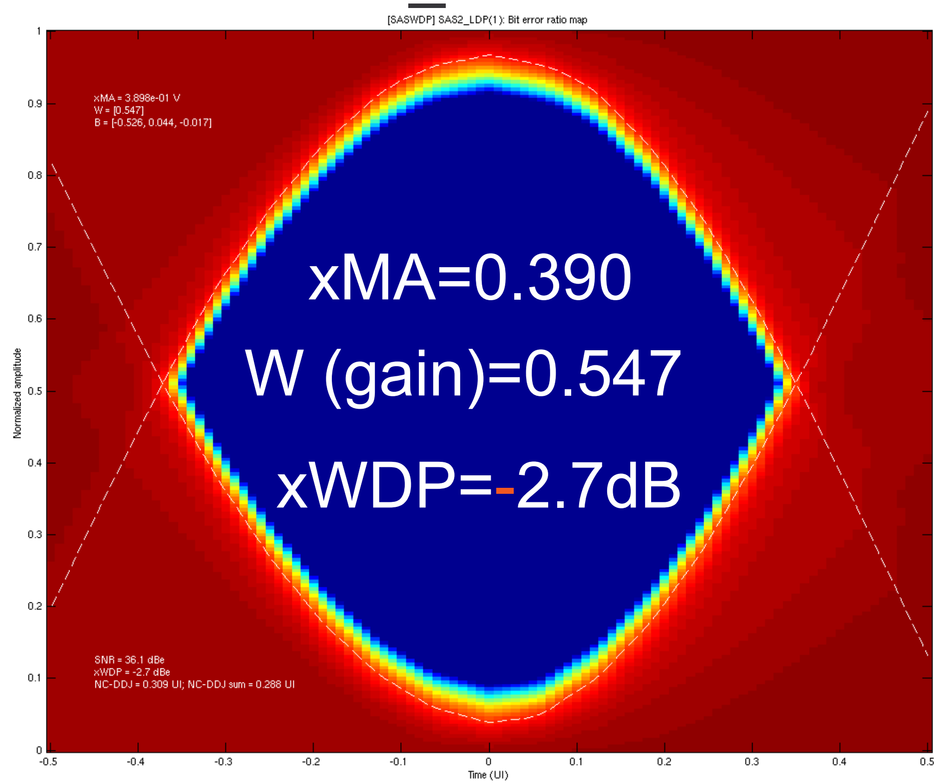
- xWDP gives strange results:
  - The original script reduces WDP (improves) as PE increases
  - Gain/xMA not constant – effect of CR? The amplitude after scaling by Gain/xMA is larger for PE=8dB, explaining the better SNR

TX_PE=0dB



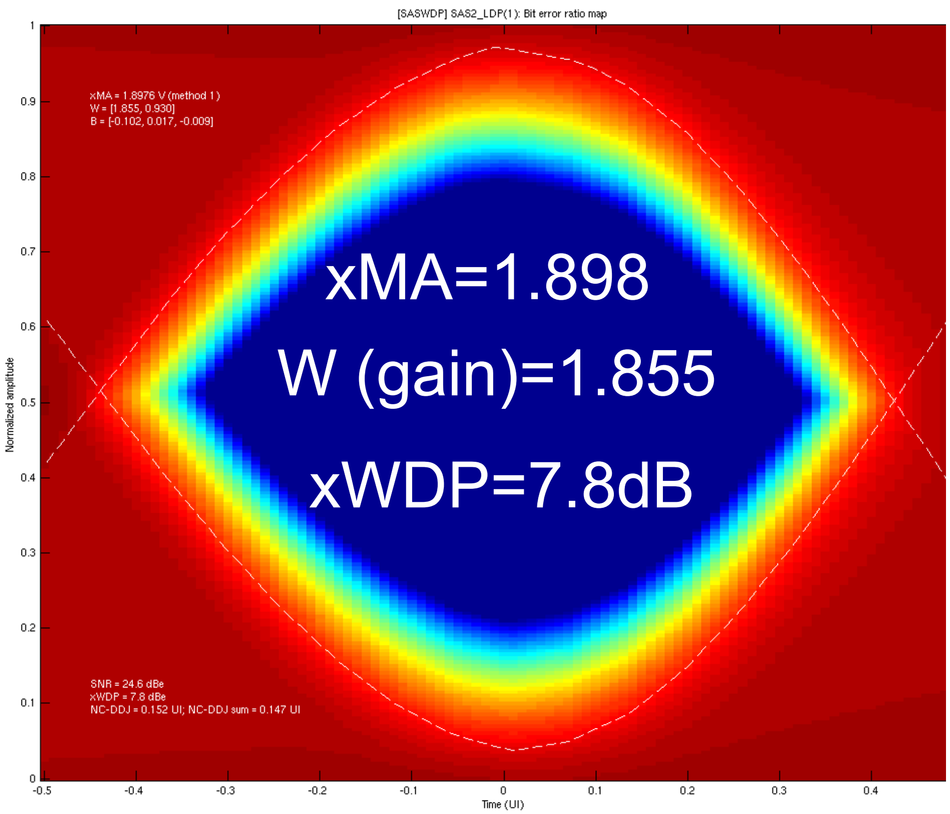
TX_PE=8dB



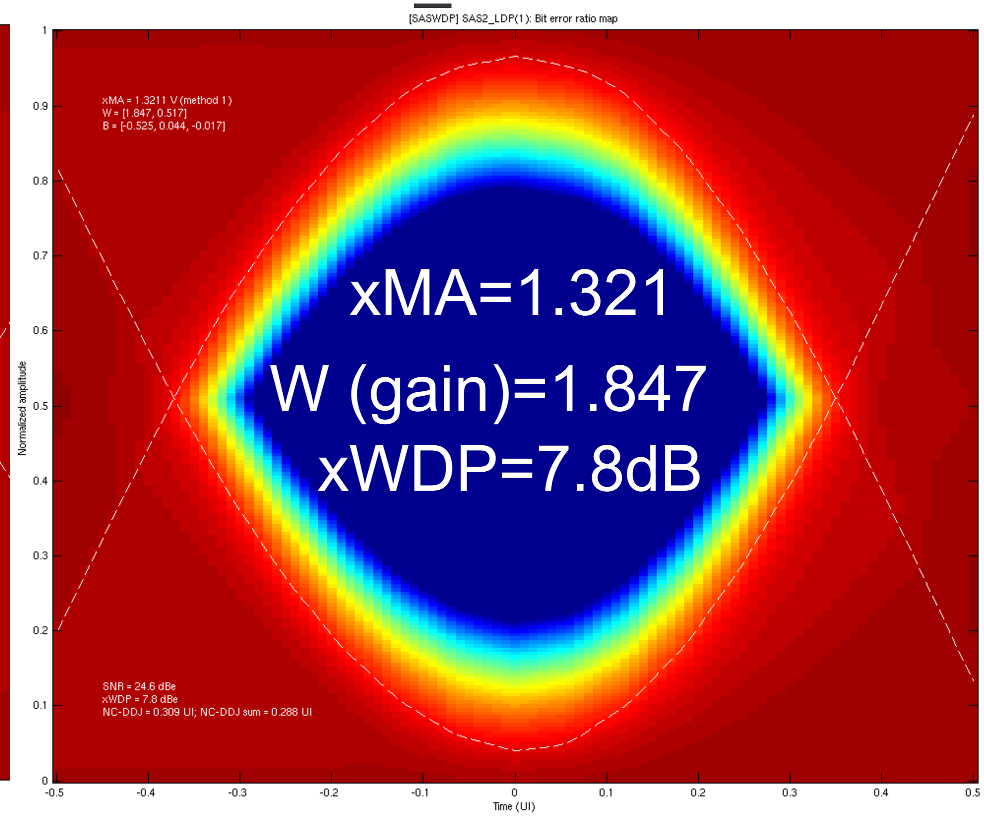
SAS_EYEOPENING vs. SASWDP

- If we fix the amplitude extraction (xMA) to use the main cursor's
  - Results are now more constant (only verified for one case)
  - This is what we should expect

TX_PE=0dB



TX_PE=8dB



SAS_EYEOPENING vs. SASWDP

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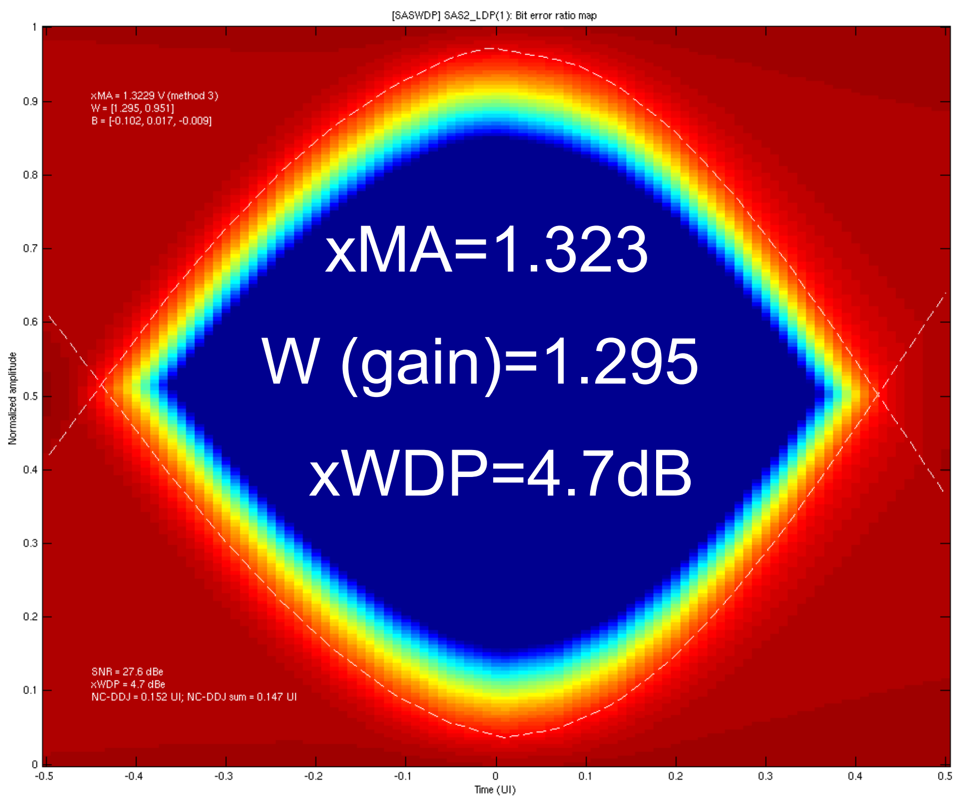
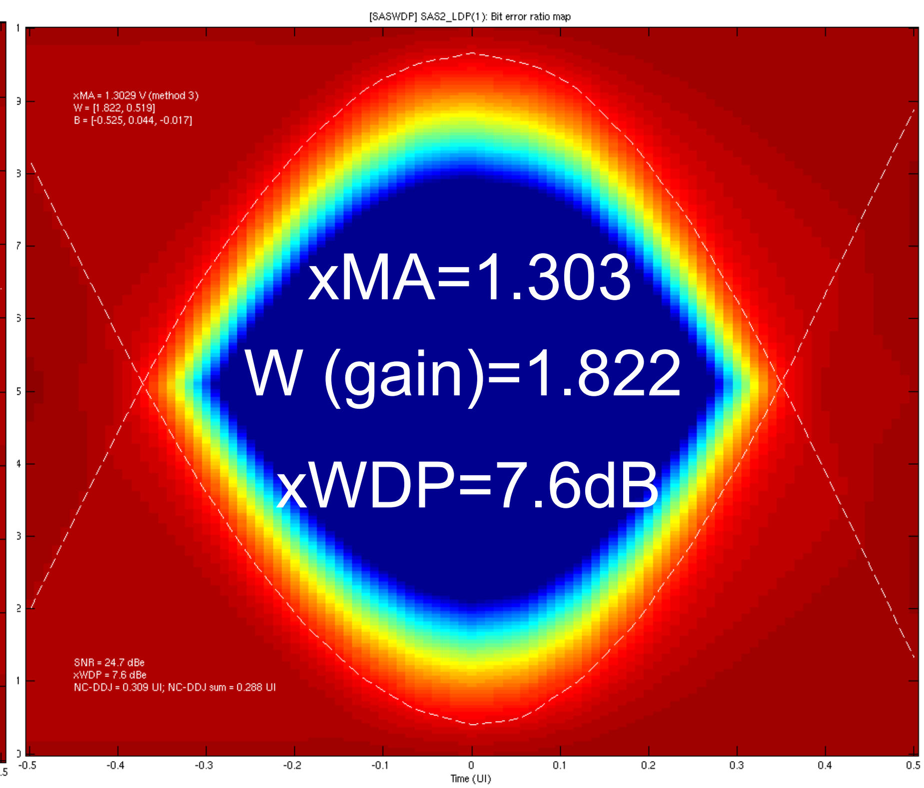
- If we fix the amplitude extraction to use the main cursor, but using SASWDP Clock recovery to set it's location
  - Now xWDP increases with increased TX_PE
  - -Due to optimization loop of DFE?

TX_PE=0dB



TX_PE=8dB



SAS_EYEOPENING vs. SASWDP

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- Thus using EYE_OPENING's main tap makes SASWDP results more consistent for processing near-end data
- Near-end data is not what we want to process
  - but that raises questions as whether SASWDP could be useful to process anything but results from a very well-defined environment
  - In theory, we should be able to qualify the TX at the near-end with the same tool

Far-end Measurements Orthogonality

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Specification		Impacts SASWDP result	Impacts SAS_EYE_OPENING result
RJ		No	No
BUJ	PJ	No	No
	DCDJ	Yes	No
	SSCJ	N/A	N/A
DDJ		Yes, that's the goal	Yes, that's the goal
Amplitude		Yes through W parameter	Yes, that's the goal
De-Emphasis		Yes, that's the goal	Yes, that's the goal
Rise/Fall Times		Yes, that's the goal	Yes, that's the goal
Pattern type		Yes	No

SAS_EYEOPENING Features

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- Independent to pattern. CJTPAT can be used.
- Little dependence to rise/fall times
  - This is somewhat part of the DDJ
- Low sensitivity to DCD
- Likely some sensitivity to TX impedance (?)
  - This is also somewhat part of the DDJ
- Does not support SSC
  - Same as SASWDP
- Can be used both at near and far ends
  - Will cover cables from 0 to 10m

SAS_EYEOPENING
Operational Features

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- Can self-correct digital errors
  - Can use data recovered from a closed eye
  - Can thus be used directly from simple time/value scope captures
  - Can re-align data
- Does not require a periodic capture
- Fast & simple to use
  - Long sequences can be used:
    - 120 kBits in ~3 minutes, including correcting > 6k digital errors in 7 passes
  - Insensitive to RJ without pre-averaging

SAS_EYEOPENING.m Operational Features

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- Example run output (from closed-eye recovered data)

```
Iteration 1...
   Number of digital errors: 1038
Iteration 2...
   Number of digital errors: 83
Iteration 3...
   Number of digital errors: 49
Iteration 4...
   Number of digital errors: 25
Iteration 5...
   Number of digital errors: 15
Iteration 6...
   Number of digital errors: 5
Iteration 7...
   Number of digital errors: 2
Iteration 8...
   Number of digital errors: 0
8b10b Eye Opening from fixed CDR = 65.5276% (-3.67151 dB)
Tap Amplitudes:    Main    Tap 1    Tap 2    Tap 3
                  0.225    29.6%    14.1%    11.3%
```

SAS_EYEOPENING Procedure: TX characterization

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- Measure Time/Values at TX near end
- Extract Exact Clock frequency from transitions
  - Or use a synchronous setup
- Extract data from opened-eye
  - Or provide exact sequence if known and align to get the best correlation
- Re-sample values at an integer multiple of the bit rate
  - 16 works fine
- Convolve with Channel
- Send Values and Digital Data to SAS_EYEOPENING
- Compare EyeClosure8b10b with spec.
  - Maybe also DFE 3 taps

SAS_EYEOPENING Procedure: RX characterization

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- Measure Time/Values at RX near end
- Extract Exact Clock frequency from transitions
  - Or use a synchronous setup
- Extract approximative data from closed-eye
  - Or provide exact sequence if known and align to get the best correlation
- Re-sample values at an integer multiple of the bit rate
  - 16 works fine
- Send Values and Digital Data to SAS_EYEOPENING
- Compare EyeClosure8b10b with spec.
  - Maybe also DFE's 3 taps

****Very similar to TX procedure****

Summary

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- Keep the same methodology as for SASWDP
  - Near-end measurement convolved for TX
  - Far-end measurement for RX
- Change the script from SASWDP to SAS_EYEOPENING
  - Change the spec from WDP & ncDDJ to 8b10b eye opening
  - Add Taps 0 to 3 amplitudes?
- More flexibility (use time/value captures, corrects errors)
- No question about CDR, ncDDJ, SASWDP variability

To do

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- Test orthogonality to more effects
  - BUJ, DCD
  - TX impedance
- Test with more TX and channels
- Try to make output WDP-like
- Look at StatEye's CDR
- Define a min. eye opening spec. for the TX
- Define a max. eye opening spec. for the RX
- Evaluate if a spec. on DFE coefficients is required
  - There is no such limit in the spec.
  - However, this is a direct indication of how hard a 3-tap DFE has to work
- Evaluate near-end results convolved with channel