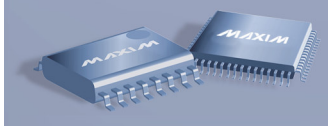
Reference Receiver Solutions for SAS-2 Compliance Testing

08-330r3

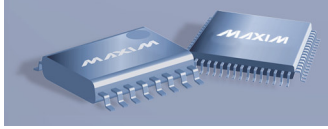
Kevin Witt

10-2-08



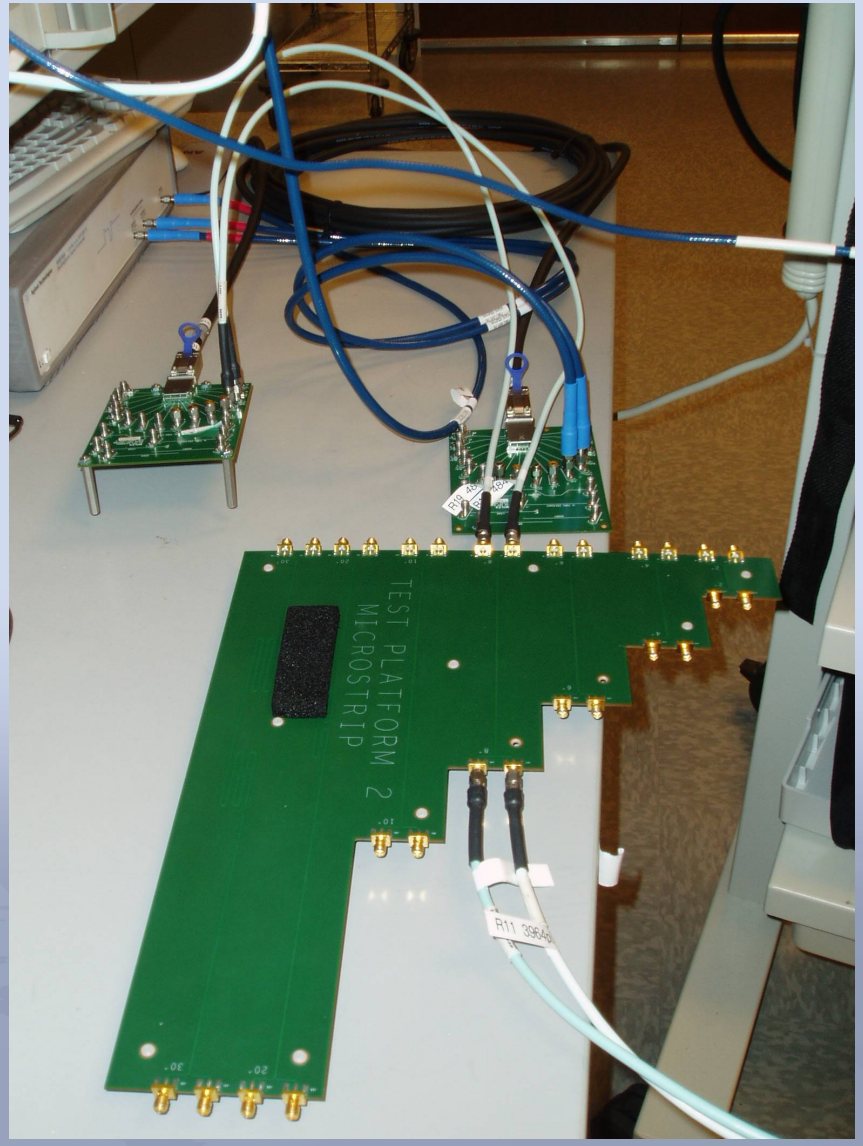
Overview

- SAS-2 specification compliance test are based on an eye opening after a reference DFE receiver
  - "StatEye or Equivalent" processing
- The SAS-2 user community needs a reference receiver software solution based on captured waveform data
  - Tx Compliance
    - Table 61 Ref Rx output (required 84mV x 0.5UI)
  - Stressed Rx Compliance ISI generator Calibration
    - Table 72 (required LDP 13dB)
- Goal
  - Investigate if these compliance test can be based on SASWDP 08-345v0
- Proposal
  - Provides processed synthesized and measured waveforms
  - Dry run the compliance test with test equipment
  - Proposed changes for Spec
  - Suggestions for enhancements of SASWDP code



Test Channel

De-Emphasis Generator

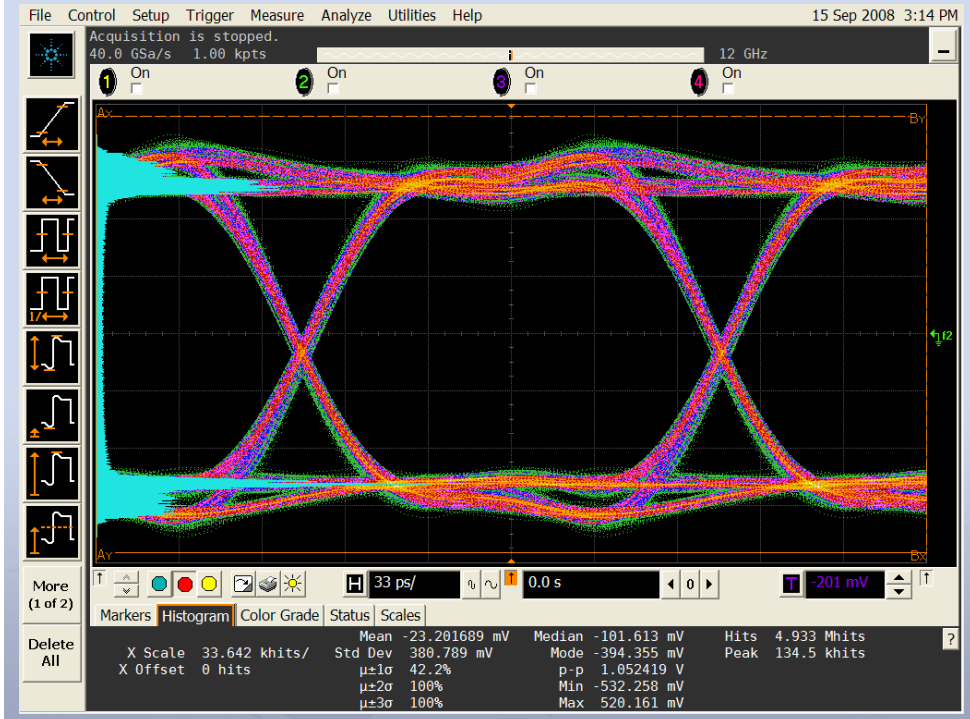


10m MiniSAS

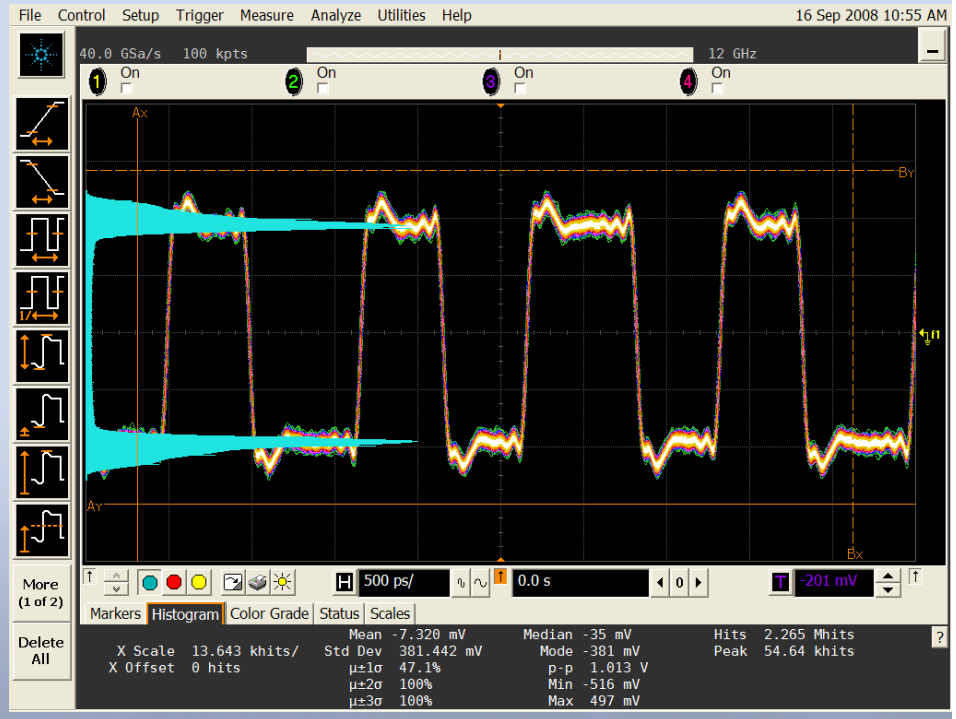
FR-4 Micro Strip Test Board

PG w/ DE Box

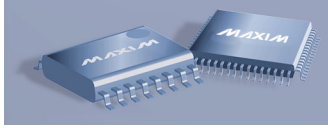
- 1000mV pk-pk
- 2.2dB DE



PRBS-7



D30.3
w/ pattern
trigger



Averaging Example

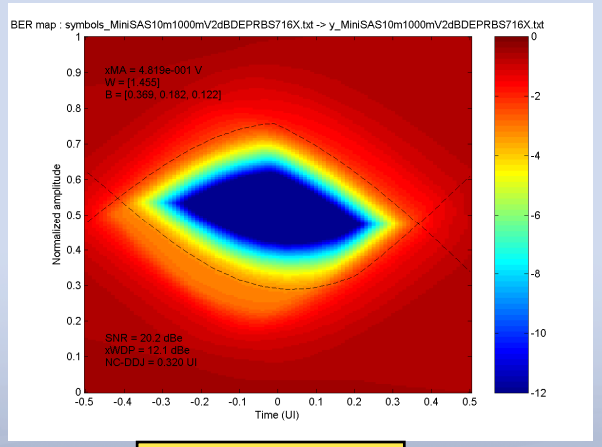
- **Measure the average of the differential signal with a pattern trigger**
- **RJ is virtually eliminated**

D30.3
1024 Averages w/ pattern trigger

Correlation Runs

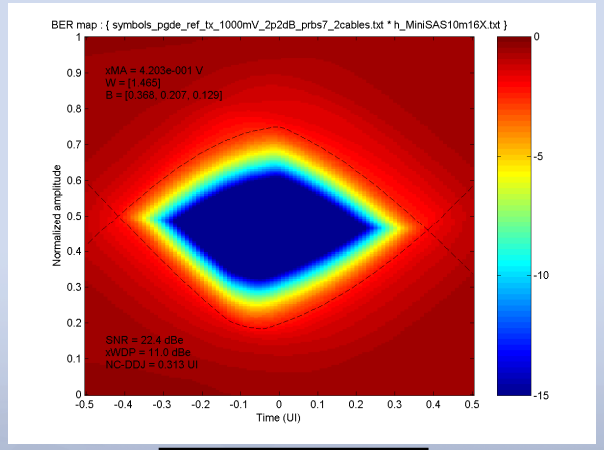
- **PRBS-7**

Synthesized Waveforms
SASWDP(TX_est*h_est)



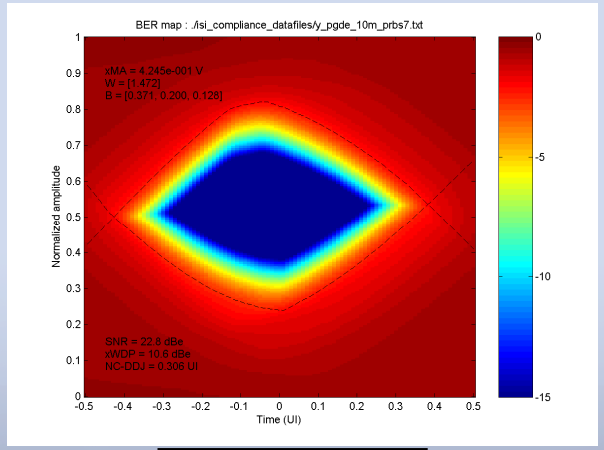
xWDP = 12.1
NC-DDJ =0.320

Tx Compliance Test (#1)
SASWDP(TX_lab*h_est)

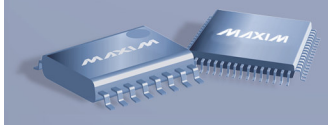


xWDP = 11.0
NC-DDJ =0.313

ISI Gen Compliance
SASWDP(RX_lab)

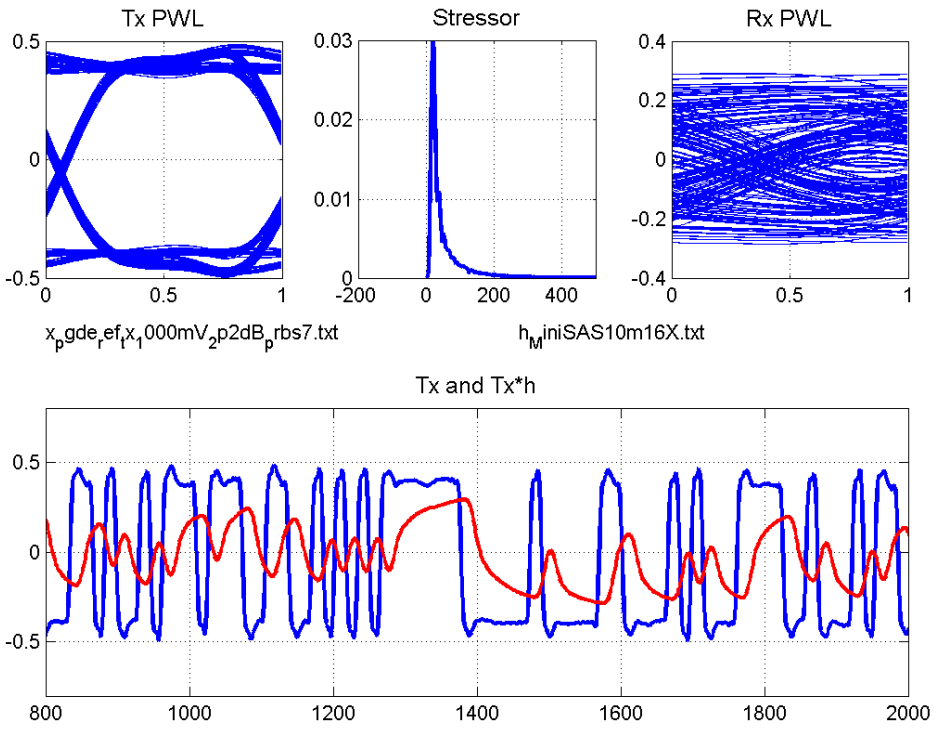


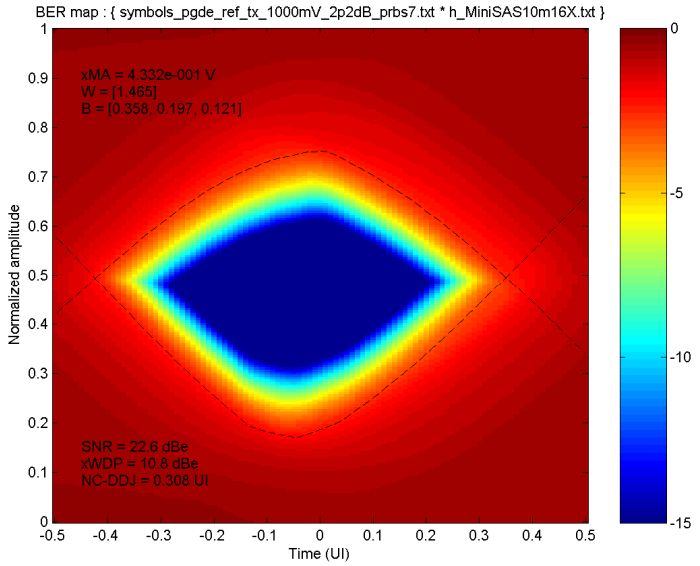
xWDP = 10.6
NC-DDJ =0.306



Tx Compliance
SASWDP

- **PG-DE: PRBS-7 : 1024 Averages, 256 Symbols**

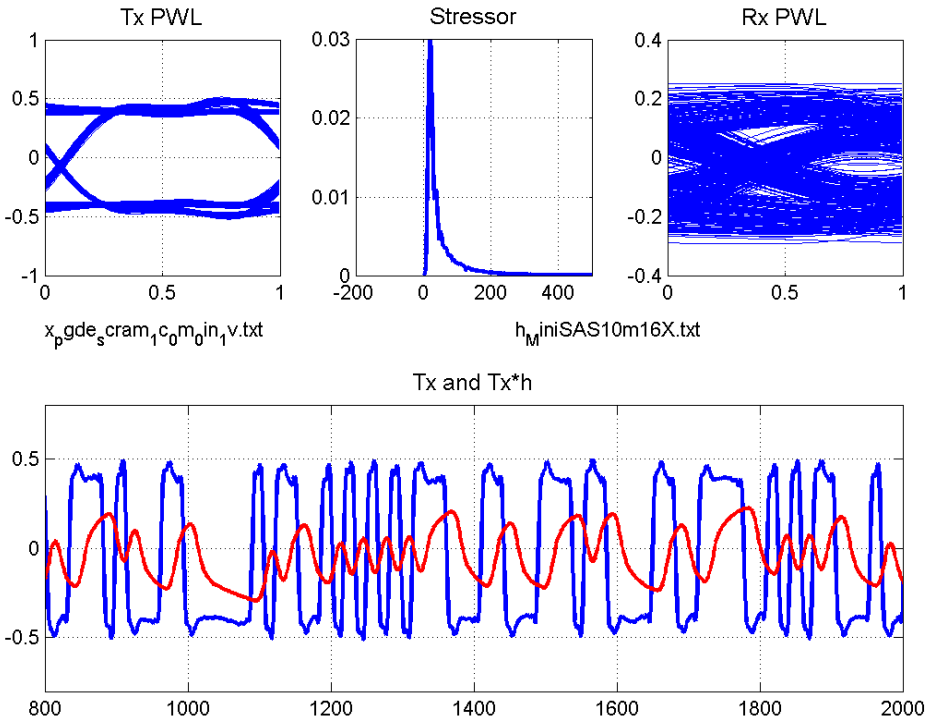


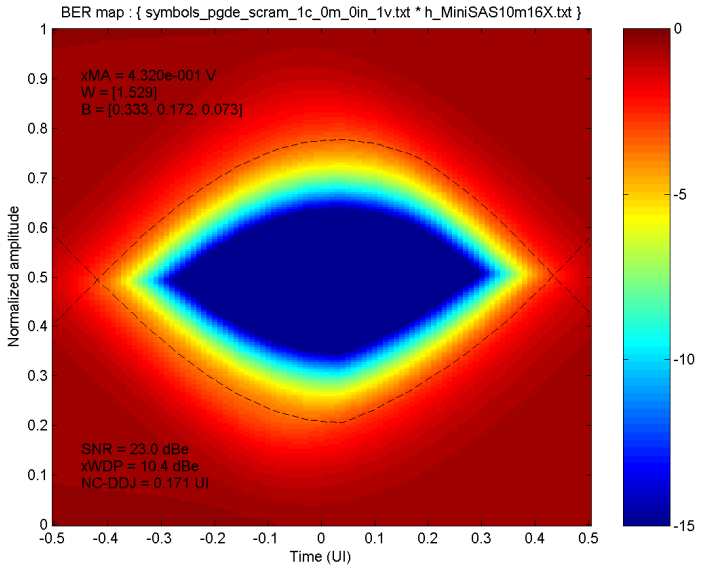


xWDP = 10.8 dBe
NC-DDJ =0.306

Tx Compliance
SASWDP

- **PG-DE: Scrambler Output : 1024 Averages, 2536 Symbols**

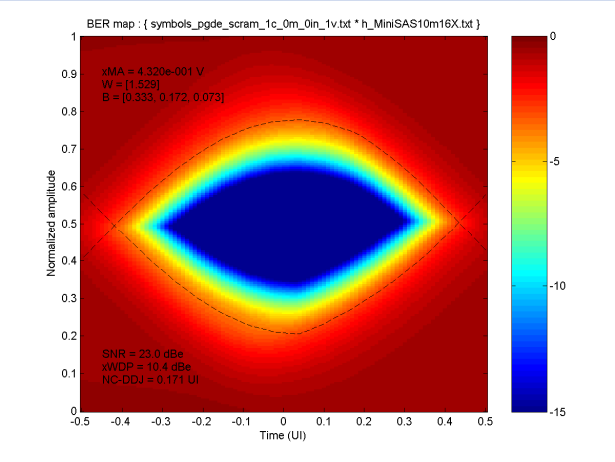




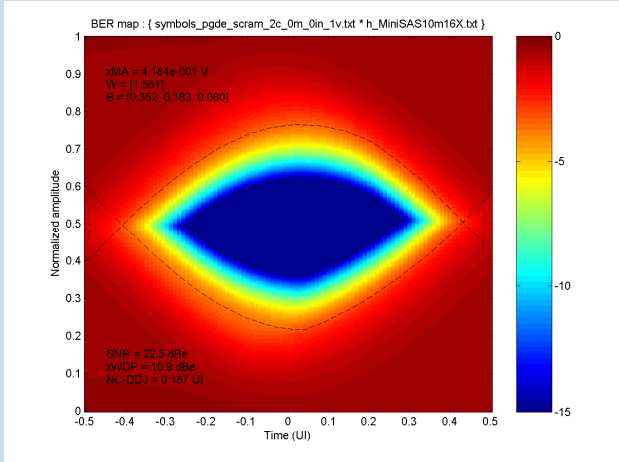
xWDP = 10.4 dBe
NC-DDJ =0.171

Tx Compliance (simulated 10m Cable & Scrambler Output)

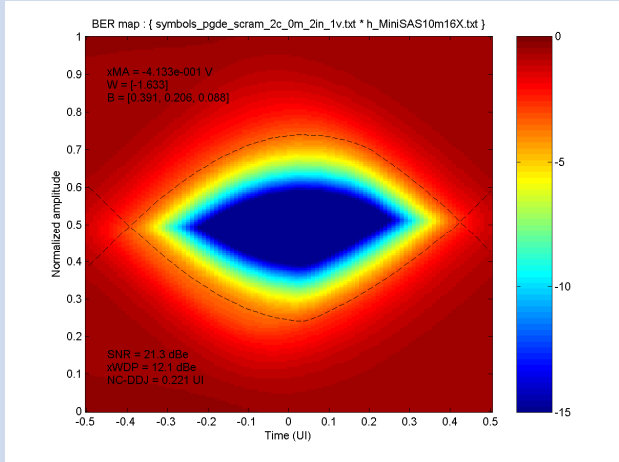
1 Cables + 10m MiniSAS



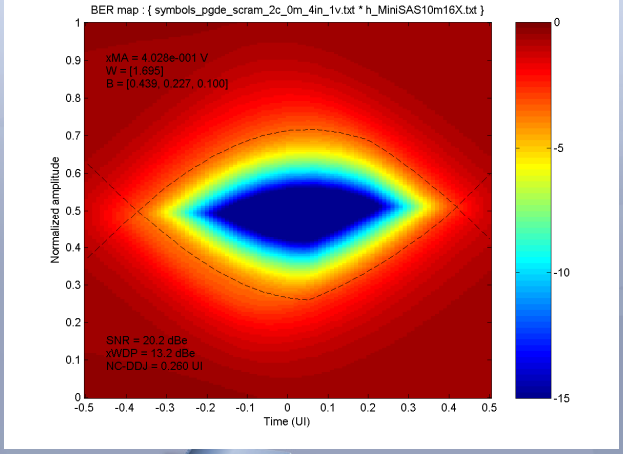
2 Cables + 10m MiniSAS



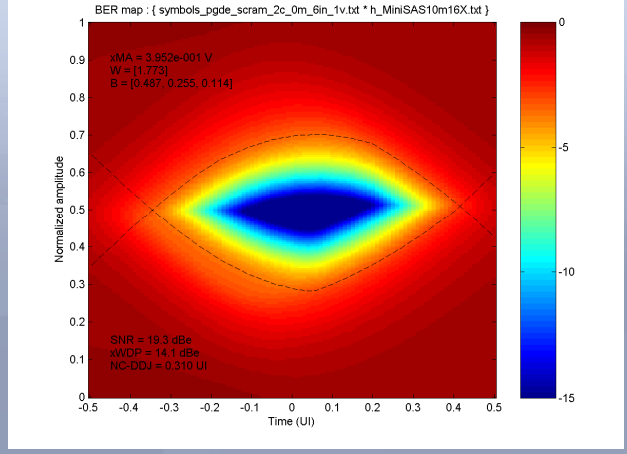
2 Cables + 10m MiniSAS + 2”FR4



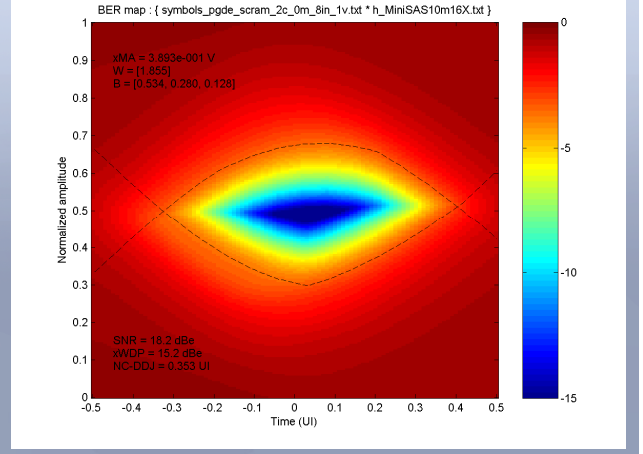
2 Cables + 10m MiniSAS + 4”FR4



2 Cables + 10m MiniSAS + 6”FR4



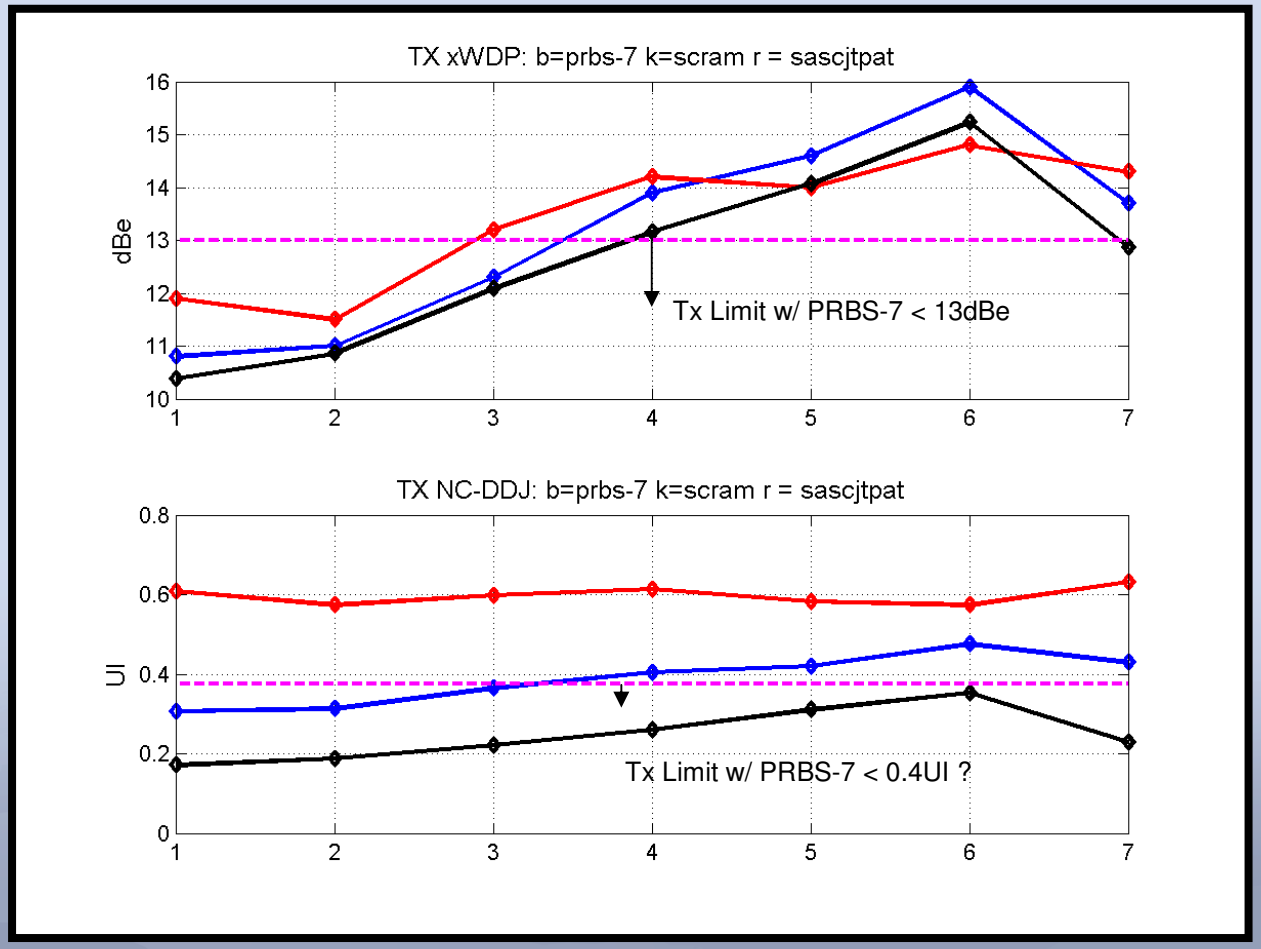
2 Cables + 10m MiniSAS + 8”FR4



Summary of Tx Compliance Test Results

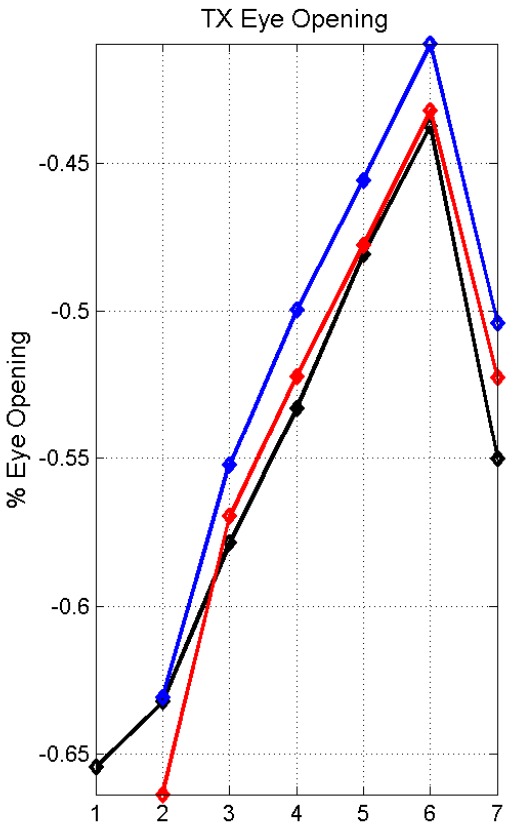
Test

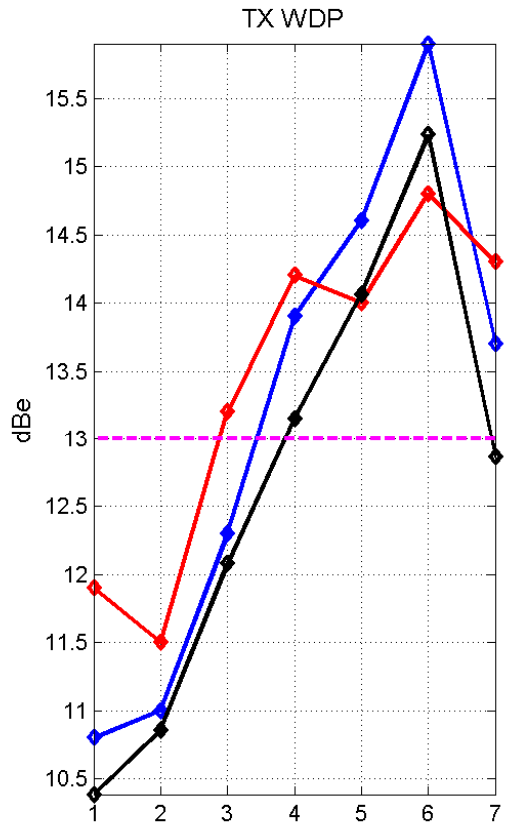
1. **PG-DE (1 Cable)**
2. **PG-DE (2 Cables)**
3. **PG-DE (2 Cables) + 2” FR-4**
4. **PG-DE (2 Cables) + 4” FR-4**
5. **PG-DE (2 Cables) + 6” FR-4**
6. **PG-DE (2 Cables) + 8” FR-4**
7. **PG-DE (2 Cables) + 8” FR-4 and re-optimized DE**



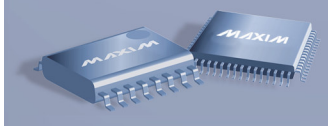
Summary of Tx Compliance Test Results
SASWDP & EYEOPENING

- Test
- PG-DE (1 Cable)
- PG-DE (2 Cables)
- PG-DE (2 Cables) + 2” FR-4
- PG-DE (2 Cables) + 4” FR-4
- PG-DE (2 Cables) + 6” FR-4
- PG-DE (2 Cables) + 8” FR-4
- PG-DE (2 Cables) + 8” FR-4 and re-optimized DE





Blue = prbs-7
Red = SAS CJTPAT
Black = scrambler output



Proposed Changes for Tx Compliance Comment Resolution

Changes

1. Remove eye opening specification
2. Add a maximum 13 dBe xWDP
3. Add a maximum 0.4 UI NC-DDJ (TBC)
4. Change Pattern to zero seed scrambler output
5. Add data collection note (h):
   - Collected with zero length test load (5.4.2.2)
   - Sufficient number of averages to minimize RJ
   - Pattern length (2536 bits)
6. Add Post Processing Note (i)
   - Convolve with impulse response of transmitter test load (5.4.2.5)
   - Extract Data bits
   - Process with SASWDP code
7. Add Appendices for SASWDP code
8. Add Appendices for Impulse response
9. ?

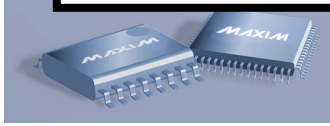
Table 60 — Transmitter device signal output characteristics for trained 1.5 Gbps, 3 Gbps, and 6 Gbps at IT and CT

Signal characteristic	Units	Minimum	Nominal	Maximum
Peak to peak voltage if SATA is not supported [a]	mV(P-P)	850		1 200
Transmitter device off voltage [b]	mV(P-P)			50
Withstanding voltage (non-operational)	mV(P-P)	2 000		
Rise/fall time [c]	UI	0.25 [d]		
Reference differential impedance [e]	ohm		100	
Reference common mode impedance [e]	ohm		25	
Common mode voltage limit (rms) [f]	mV			30
Random jitter (RJ) [g, j]	UI			0.15 [h]
[redacted]				
Minimum eye opening (i.e., 2 x Z1 in figure 127) [k]				

[a] See 5.4.6.4.5 for measurement method.
[b] The transmitter device off voltage is the maximum A.C. voltage measured at compliance points IT and CT when the transmitter is unpowered or transmitting D.C. idle (e.g., during idle time of an OOB signal).
[c] Rise/fall times are measured from 20 % to 80 % of the transition with a repeating 01b or 10b pattern (e.g., D10.2 or D21.5)(see table 237 in 10.2.9.2) on the physical link.
[d] 0.25 UI is 41.6 ps at 6 Gbps.
[e] For transmitter device S-parameters characteristics, see 5.4.6.4.2.
[f] This is a broadband limit. For additional limits on spectral content, see figure 131 and table 61.
[g] RJ is 14 times the RJ 1 sigma value, based on a BER of 10^{-12}. This test shall be performed with a repeating 01b or 10b pattern (e.g., D10.2 or D21.5)(see table 237 in 10.2.9.2) on the physical link. If the transmitter device supports SSC, then this measurement shall be performed with both SSC enabled and SSC disabled. For simulations based on a BER of 10^{-15}, the RJ specified is 17 times the RJ 1 sigma value.
[h] 0.15 UI is 25 ps at 6 Gbps.
[i] 0.30 UI is 50 ps at 6 Gbps.
[j] See 5.4.5.2 for JMD requirements.
[k] This value is obtained by simulation. It represents the resulting signal output within the reference receiver device (see 5.4.7.4.3) after equalization, when the transmitter device output signal of [redacted] is transmitted through the reference transmitter test load (see 5.4.2.5). The specific simulation program used (e.g., StatEye from http://www.stateye.org) is not specified by this standard.

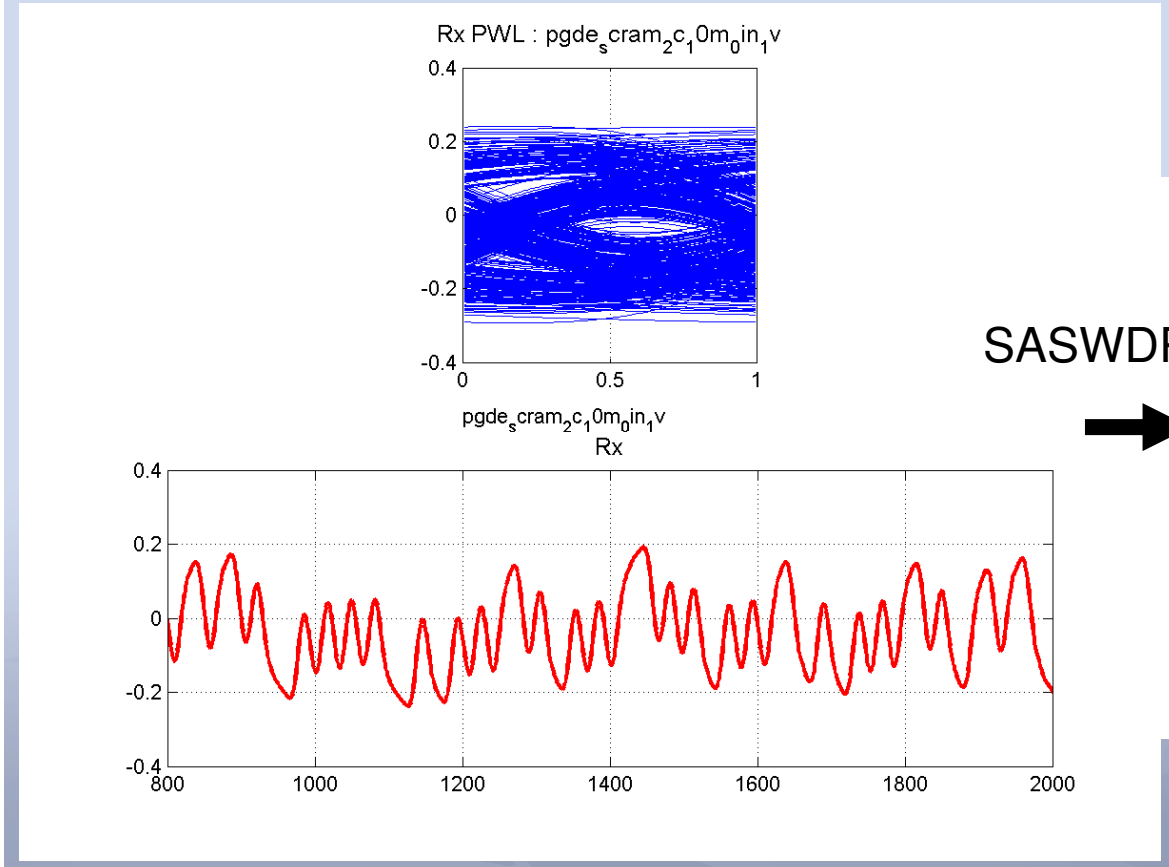
zero seed scrambler output

WDP calculation like saswdp

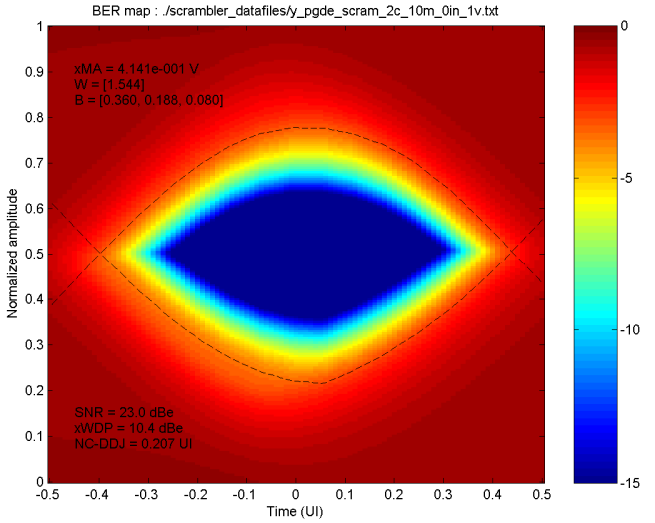


ISI Generator Calibration w/ Scrambler Output

- **Capture Receiver Device Input Signal**



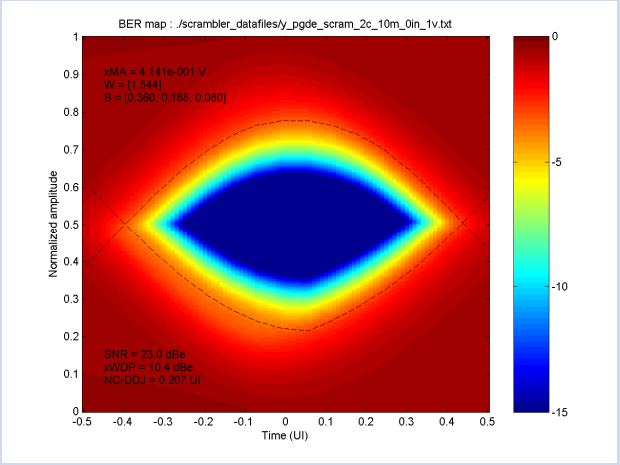
SASWDP



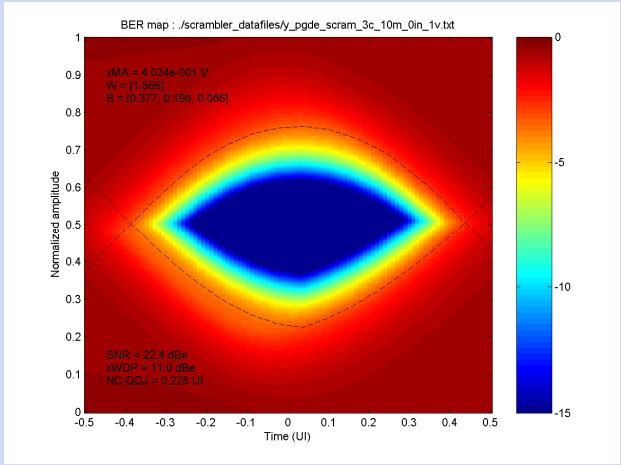
xWDP = 10.4 dBe
NC-DDJ =0.207

Stressed Receiver Device Compliance Test Calibration Examples
10m & Incremental FR-4 PG/DE (Scrambler)

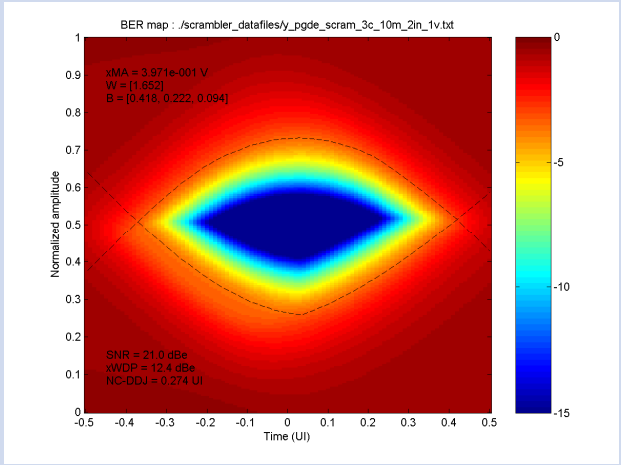
2Cables + 10m MiniSAS



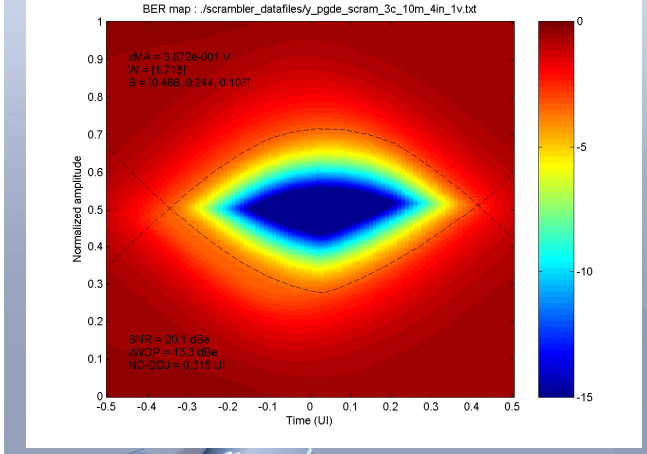
3Cables + 10m MiniSAS



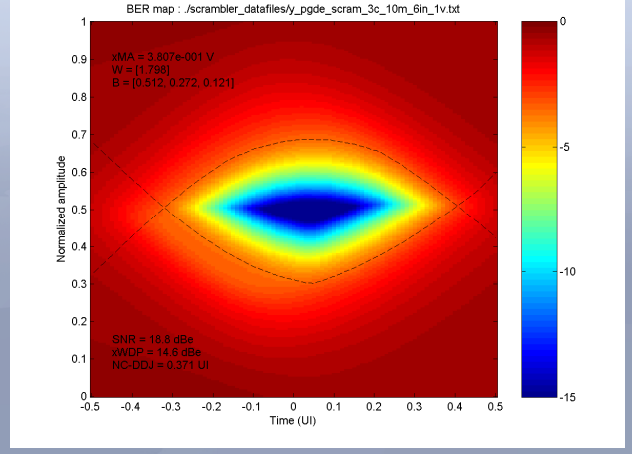
3Cables + 10m MiniSAS + 2”FR4



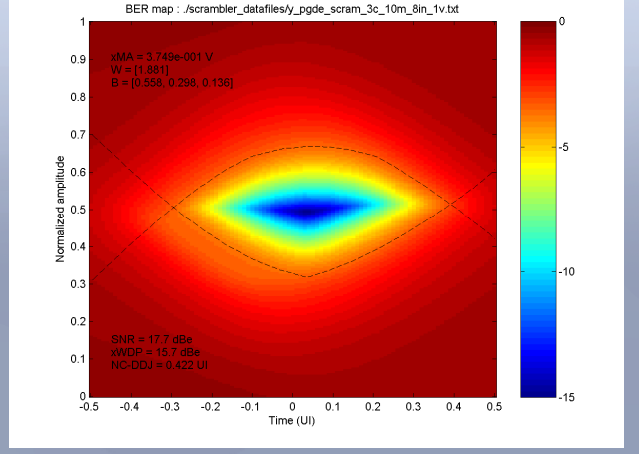
3Cables + 10m MiniSAS + 4”FR4



3Cables + 10m MiniSAS + 6”FR4



3Cables + 10m MiniSAS + 8”FR4



Summary of Stressed Receiver Device Compliance Test Calibration Examples with Increasing Stressor

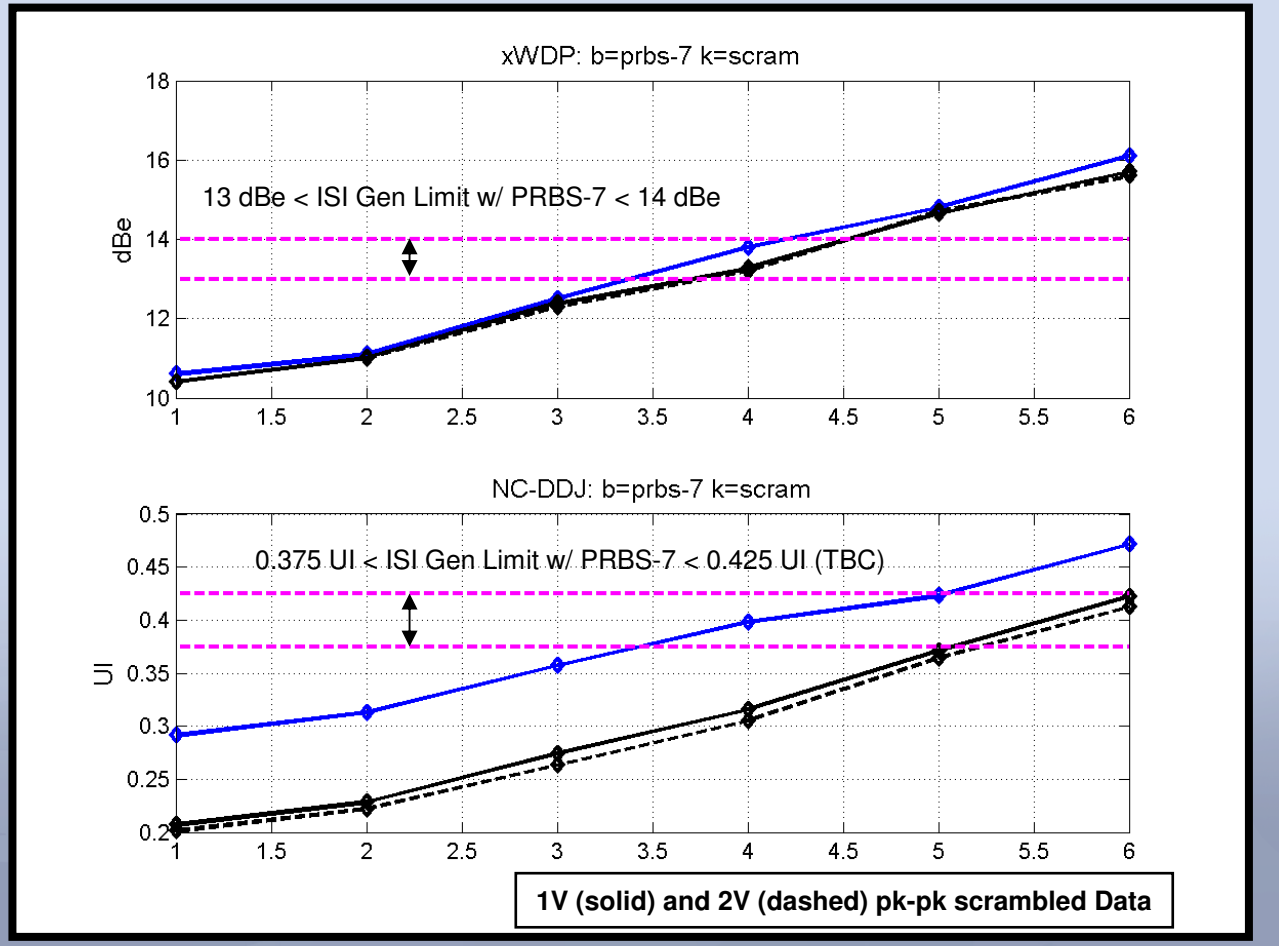
Test

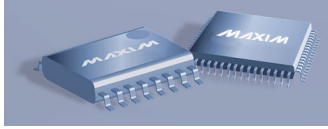
1. **PG-DE (2 Cables) + 10m MiniSAS**
2. **PG-DE (3 Cables) + 10m MiniSAS**
3. **PG-DE (3 Cables) + 10m MiniSAS + 2” FR-4**
4. **PG-DE (3 Cables) + 10m MiniSAS + 4” FR-4**
5. **PG-DE (3 Cables) + 10m MiniSAS + 6” FR-4**
6. **PG-DE (3 Cables) + 10m MiniSAS + 8” FR-4**

Observation

1m Cable ~0.5 dBe

2” FR-4 Micro strip ~ 1dBe





Summary of ISI Compliance Test Results
SASWDP & EYEOPENING

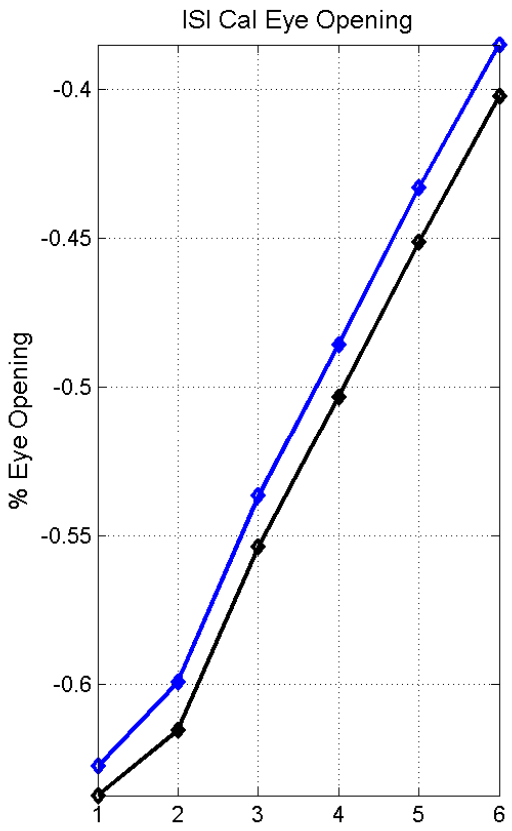
Test

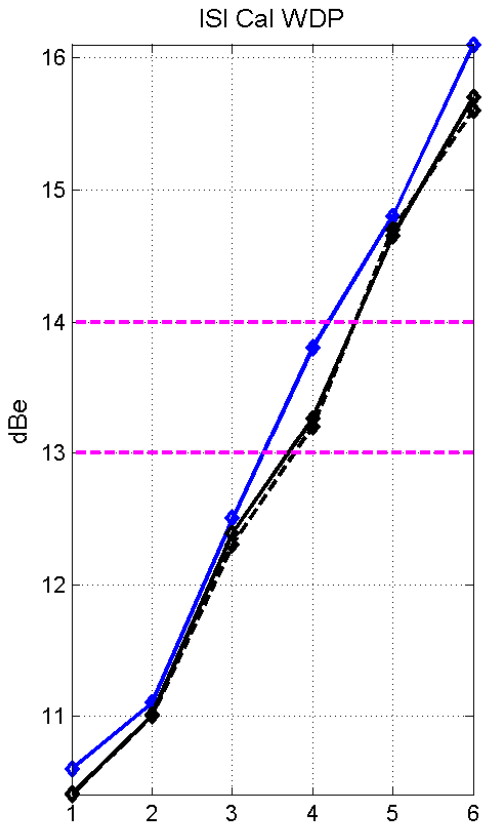
1. **PG-DE (2 Cables) + 10m MiniSAS**
2. **PG-DE (3 Cables) + 10m MiniSAS**
3. **PG-DE (3 Cables) + 10m MiniSAS + 2” FR-4**
4. **PG-DE (3 Cables) + 10m MiniSAS + 4” FR-4**
5. **PG-DE (3 Cables) + 10m MiniSAS + 6” FR-4**
6. **PG-DE (3 Cables) + 10m MiniSAS + 8” FR-4**

Observation

1m Cable ~0.5 dBe

2” FR-4 Micro strip ~ 1dBe

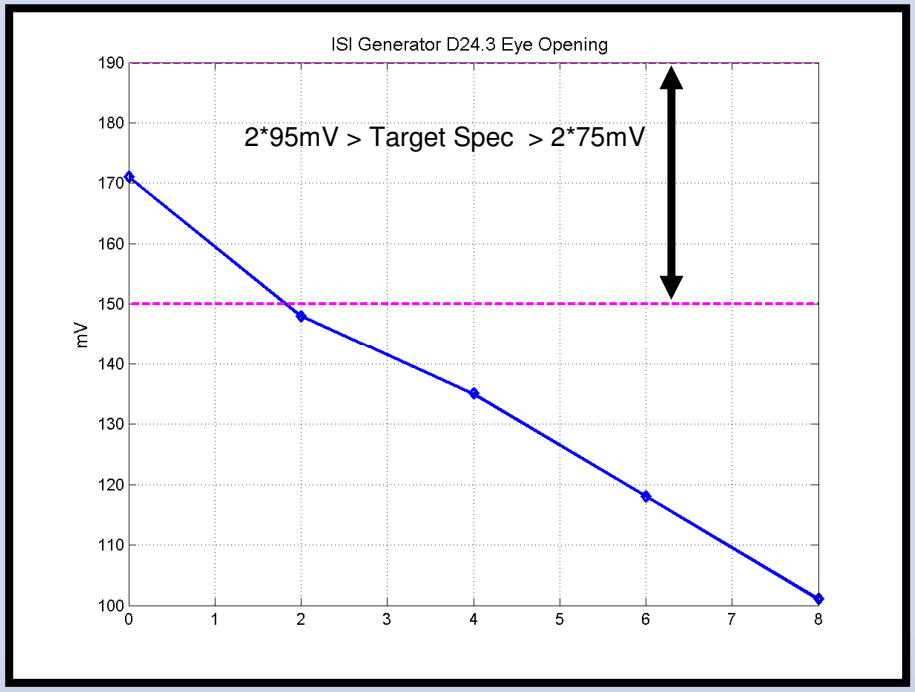




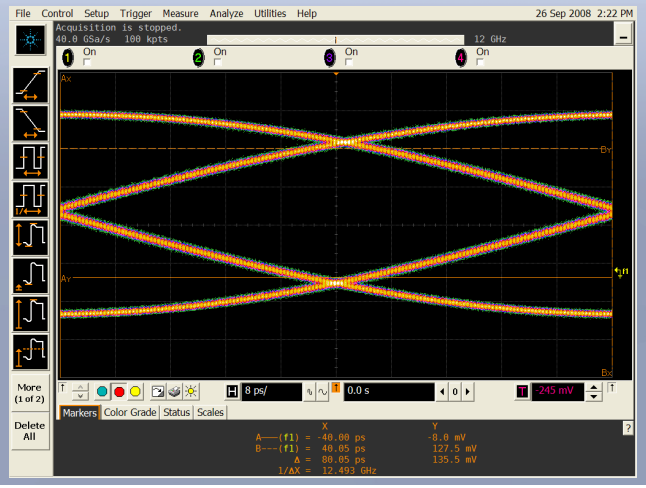
D24d3 ISI Calibration

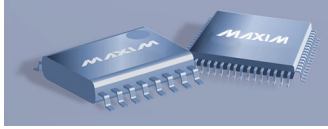
- **D24d3 vs. FR-4 Adder**
  - **800mV 2dB Tx**
  - **900mV 2dB TX ➔150mV**

Test	
1.	PG-DE (2 Cables) + 10m MiniSAS
2.	PG-DE (3 Cables) + 10m MiniSAS
3.	PG-DE (3 Cables) + 10m MiniSAS + 2” FR-4
4.	PG-DE (3 Cables) + 10m MiniSAS + 4” FR-4
5.	PG-DE (3 Cables) + 10m MiniSAS + 6” FR-4
6.	PG-DE (3 Cables) + 10m MiniSAS + 8” FR-4



Far End 10m + 4” FR4





Spec Typo

- **Figure 123 was not updated to match Table 71**

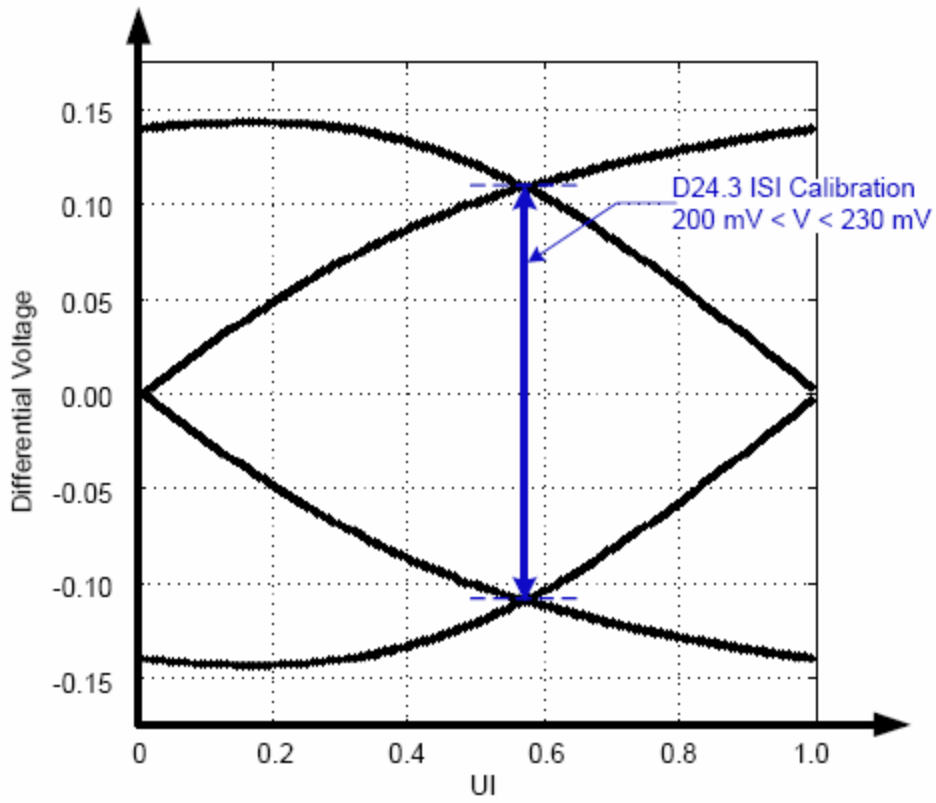


Figure 123 — Reference transmitter test load D24.3 response

This should be 150→ 190mV
Per: Table 71 in SAS2r14e

Spec Changes to Resolve Comments

1. **Change Pattern to Scrambler (see table 223)**
2. **Rename LDP to WDP 13 min, 15 max**
3. **Include SASWDP Code as Appendix**

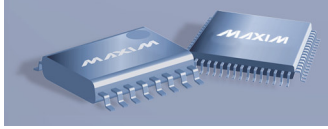
This is obsolete →

Table 71 — Stressed receiver device sensitivity test characteristics

Characteristic	Units	Minimum	Typical	Maximum	Reference
Tx data pattern	Scrambler with Zero Seed				Annex A
Tx peak to peak voltage	mV(P-P)			800	5.4.6.4.1
Tx minimum rise/fall time	UI	0.24 [a]			5.4.6.4.1
Transmitter equalization	dB			2	5.4.6.4.5
Tx RJ	UI	0.15 [b]			5.4.6.4.1
Tx bounded uncorrelated jitter	UI	0.000 22 [c]			
Waveform Dispersion Penalty	dB	13		15	5.4.7.4.4.8
D24.3 delivered eye opening (Δ1) [c]	mV	75		95	5.4.5.4
[redacted]		[b]			
NEXT offset frequency [e]	ppm	20			
Total crosstalk amplitude [e, f]	mV_{rms}	4			

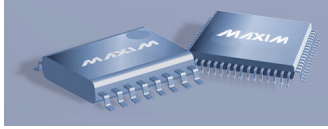
[a] 0.24 UI is 41.6 ps at 6 Gbps.
[b] 0.15 UI is 25 ps at 6 Gbps.
[c] 0.000 22 UI is 0.036 ps at 6 Gbps.
[d] Link dispersion penalty is the WDP of the delivered signal computed with Palloc = 15.4 dB.
[e] This specification pertains to the delivered signal at IR or CR during the receiver device compliance test. All adjacent phys in the receiver device shall be active with representative traffic with their maximum amplitude and maximum frequency of operation. Additional pseudo-random crosstalk shall be added, if needed, to meet the total crosstalk amplitude specification.
[f] Observed with a histogram of at least 1 000 hits.

Editor's Note 2: Numerous changes are piled up for that table, awaiting work on SASWDP to complete. See 08-202, 08-330, 08-345.



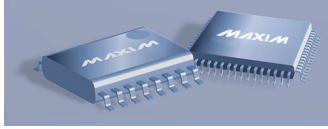
SASWDP Enhancements

- Change Q0=7.9419; % for BER = 10^(-15)
- Normalize Eye for no AGC eye opening, W = 1, like DFEEYE
- Return vertical and horizontal eye opening, like DFEEYE
  - 1e-15
  - ISI only (eye lid)
- Change hard coded baud rate in specification to variable
- Small robustness enhancements
  - min(find(…
  - Enable row or column vectors as inputs
- NC_DDJ (sum of both sides vs. 2 x 1 side?)
- More Robustness to waveform dependencies
  - SAS CJTPAT vs. PRBS-7, PRBS-10 (see T10/08-330r0/1/2)



Summary

- Dry run of SASWDP based Tx compliance test results presented
- Changes proposed to results Table 61 & 71 comments
- Early look at ISI calibration results provided



EYE_OPENING & SASWDP Results

Test

1. **PG-DE (2 Cables) + 10m MiniSAS**
2. **PG-DE (3 Cables) + 10m MiniSAS**
3. **PG-DE (3 Cables) + 10m MiniSAS + 2” FR-4**
4. **PG-DE (3 Cables) + 10m MiniSAS + 4” FR-4**
5. **PG-DE (3 Cables) + 10m MiniSAS + 6” FR-4**
6. **PG-DE (3 Cables) + 10m MiniSAS + 8” FR-4**

Observation

1m Cable ~0.5 dBe

2” FR-4 Micro strip ~ 1dBe