Transmit Waveform Calibration for Receiver Testing

Kevin Witt & Mahbubul Bari

**Jan 15, 2008**

07-492r1

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MAXIM
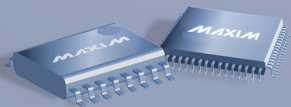
Goal

- **Evaluate ISI Calibration of the Delivered Signal for the Stressed Receiver Sensitivity Test (07-486 & 07-380)**

Outline

1. **Review Proposed Rx Test Block Diagram & ISI Calibration Proposal**

2. **Comparison of D24.3 Simulate and Measured Response**

3. **Comparison of Simulated xWDP and StatEye on SAS-2 Channels**

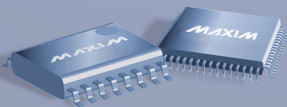4. **Compute WDP of Delivered Signal for Stressed Receiver Sensitivity Test**
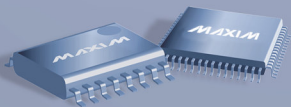
Stressed Receiver Sensitivity Test Block Diagram

- **To avoid "Golden Hardware" we need to Calibrate the Delivered Signal to the Design Under Test.**
- **Need Metrics to Adjust Tx Amplitude and ISI**
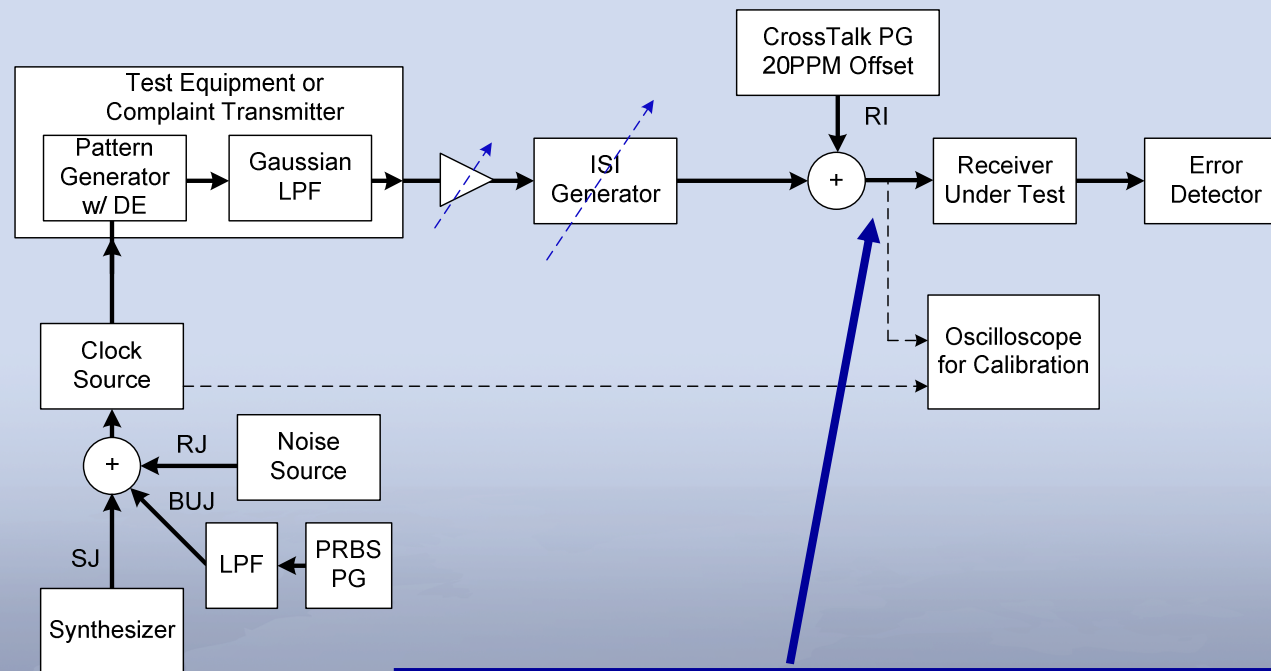
How do we know if this
is stressful enough (ISI) to represent the
SAS-2 Reference Channel?

Proposed Calibration

1. **Measure Inner Eye with D24.3 to Ensure Delivered Amplitude.**

2. **Compute WDP of Delivered Signal with SAS CJTPAT for the budgeted PALLOC? Could this be a StatEye Simulation based on the Measured Delivered Signal? TBD.**

3. **Setup Tx Jitter with Standard Test Equipment Options.**

4. **Setup Additional Cross talk as needed to meet NEXT limit.**
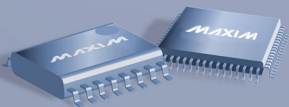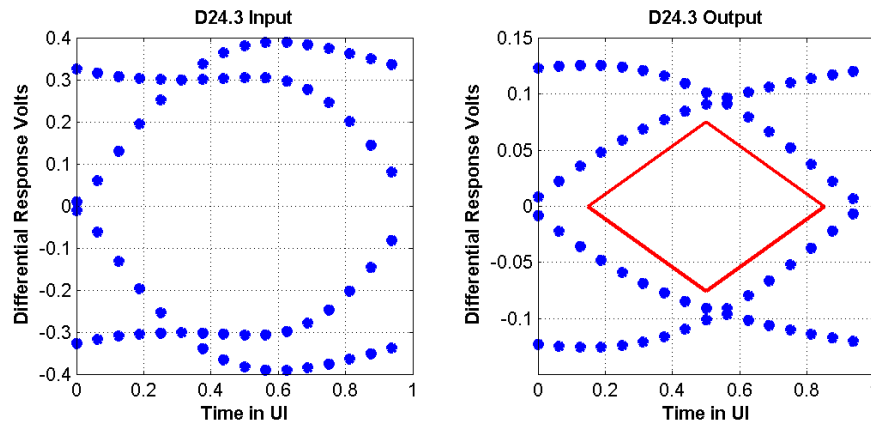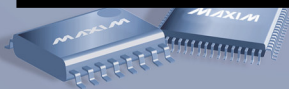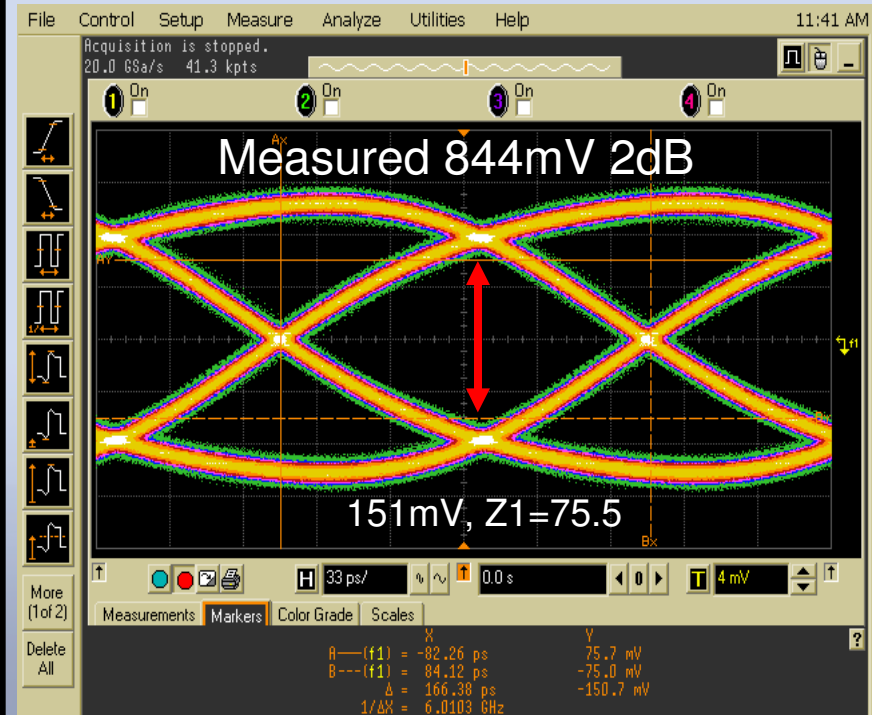
Comparison of D24.3 Simulate and Measured Response

- **Measure Inner Eye with D24.3 to Ensure Delivered Amplitude**

Simulated 800mV 2dB

Measured 844mV 2dB

151mV, Z1=75.5

This Seems to Work
Proposed Spec was 75→100mV
Maybe 60→90mV is Better
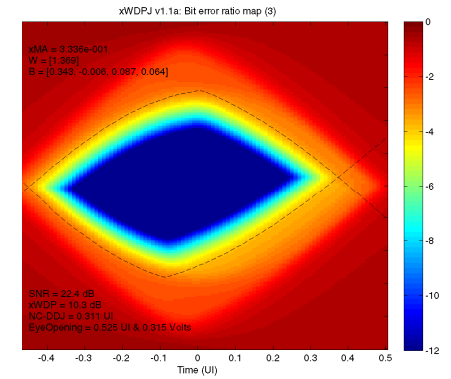
Simulated xWDP and StatEye on SAS-2 Reference Channel

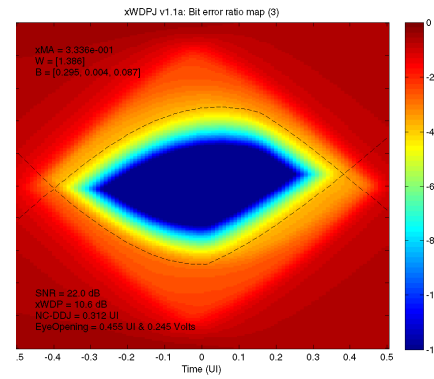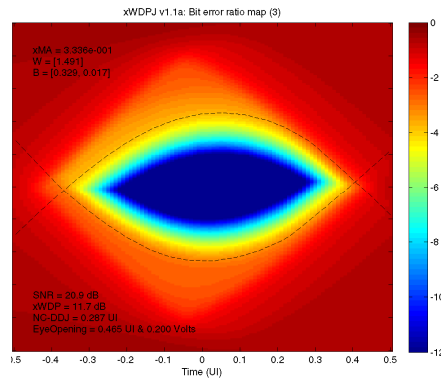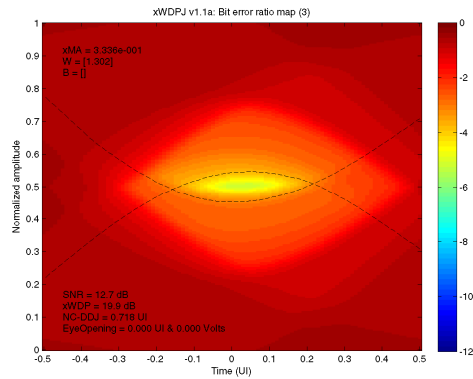- ## V1.1a xWDPJ Output SAS CJTPAT Tx = 800mV

2dB DE 0-tap DFE	2dB DE 2-tap DFE	2dB DE 3-tap DFE	2dB DE 4-tap DFE

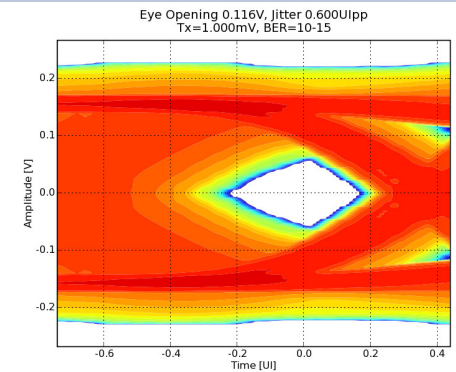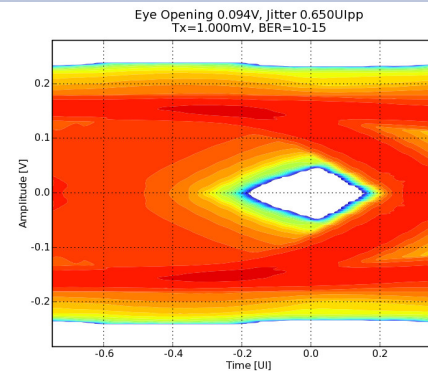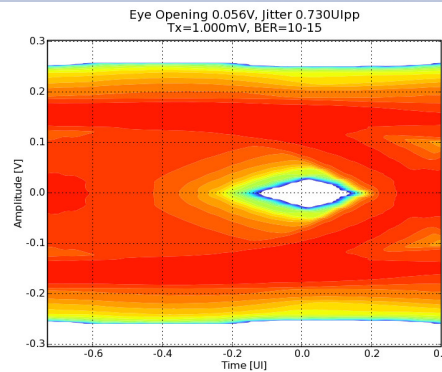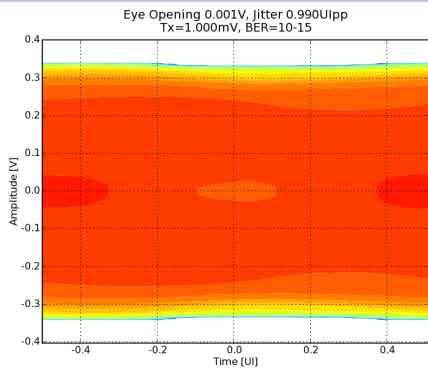|	**11.7dB, 0.465UI, 200mV**	**10.6dB, 0.455UI, 245mV**	**10.3dB, 0.525UI, 315mV**

- ## V5.0 StatEye Output 8b10b Tx = 1V pk-pk (Thanks Rob)

2dB DE 0-tap DFE	2dB DE 2-tap DFE	2dB DE 3-tap DFE	2dB DE 4-tap DFE

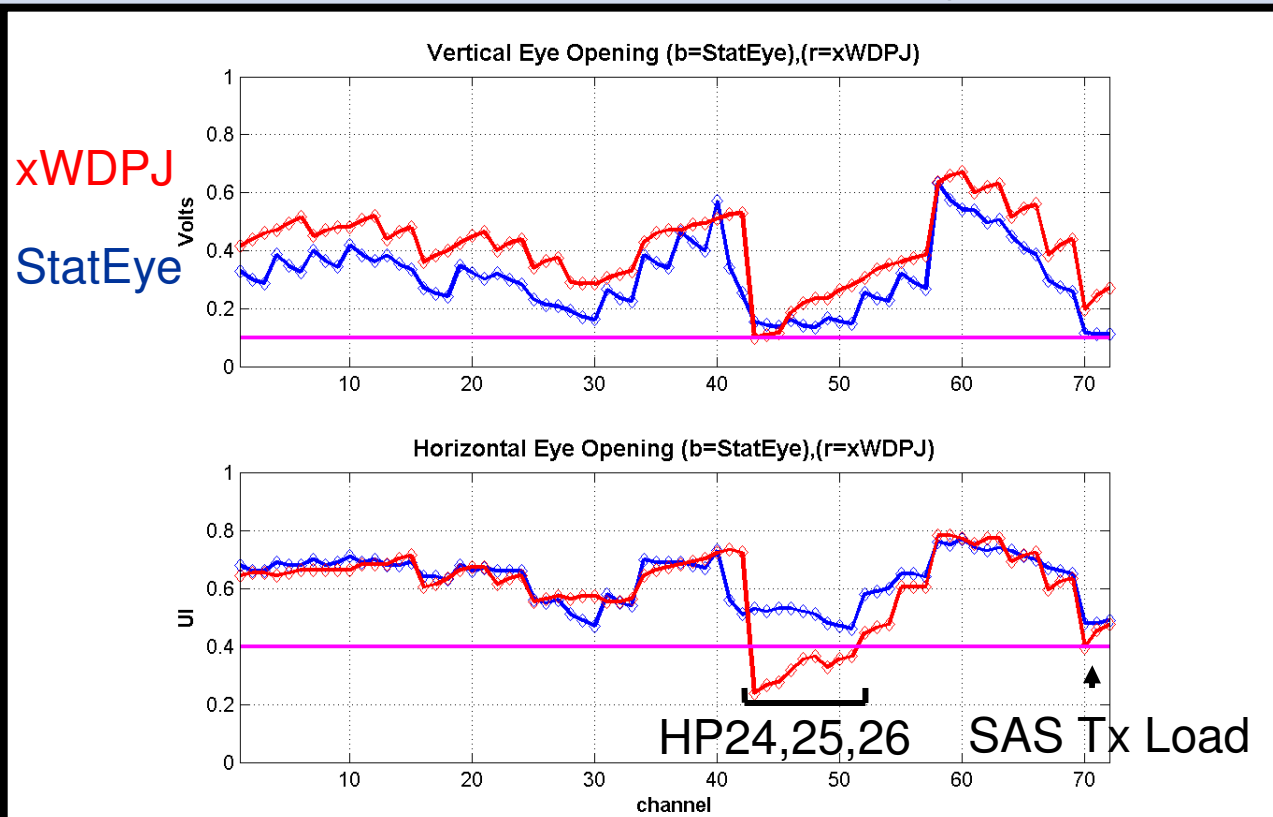|	**0.27UI, 56mV**	**0.35UI, 94mV**	**0.4UI, 116mV**

Simulated xWDP and StatEye on All SAS-2 Channels
Note: These are not meant to be compared

- **V4.0 StatEye from 08-031r0**
  - **Same channel order**
- **1e-12 xWDP vs. 1e-15, StatEye normalized to 800mV (0.4)**

xWDPJ

StatEye

Vertical Eye Opening (b=StatEye),(r=xWDPJ)

Horizontal Eye Opening (b=StatEye),(r=xWDPJ)

HP24,25,26   SAS Tx Load

Results Normalized to 800mV 1,2,

& 3 dB   Launch

Channels:

HP01-08, 27-28	05-384r2
HP09-11	05-389r0
HP12-14	05-390r0
HP24-26	06-017r0
MiniSAS_halfmeter	05-401r0
MiniSAS_onemeter	05-402r0
MiniSAS_threemeter	05-403r0
MiniSAS_sixmeter	05-404r0
SAS Transmitter test load (10m)	07-193r1

Note: 1. Highest Penalty with Most Difficult Channels
2. Slope difference w/ DE

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Simulated WDP on SAS-2 Channels

- **WDP**
  - **Same channel order as 08-031r0**
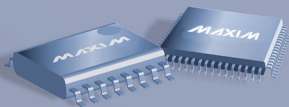 - **WDP ➔ 10 dB Channel Budget**

Note: 1. Highest Penalty with Most Difficult Channels
       2. Start with Channel WDP of 10dB w/ Palloc of 15.4 dB
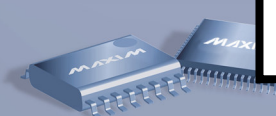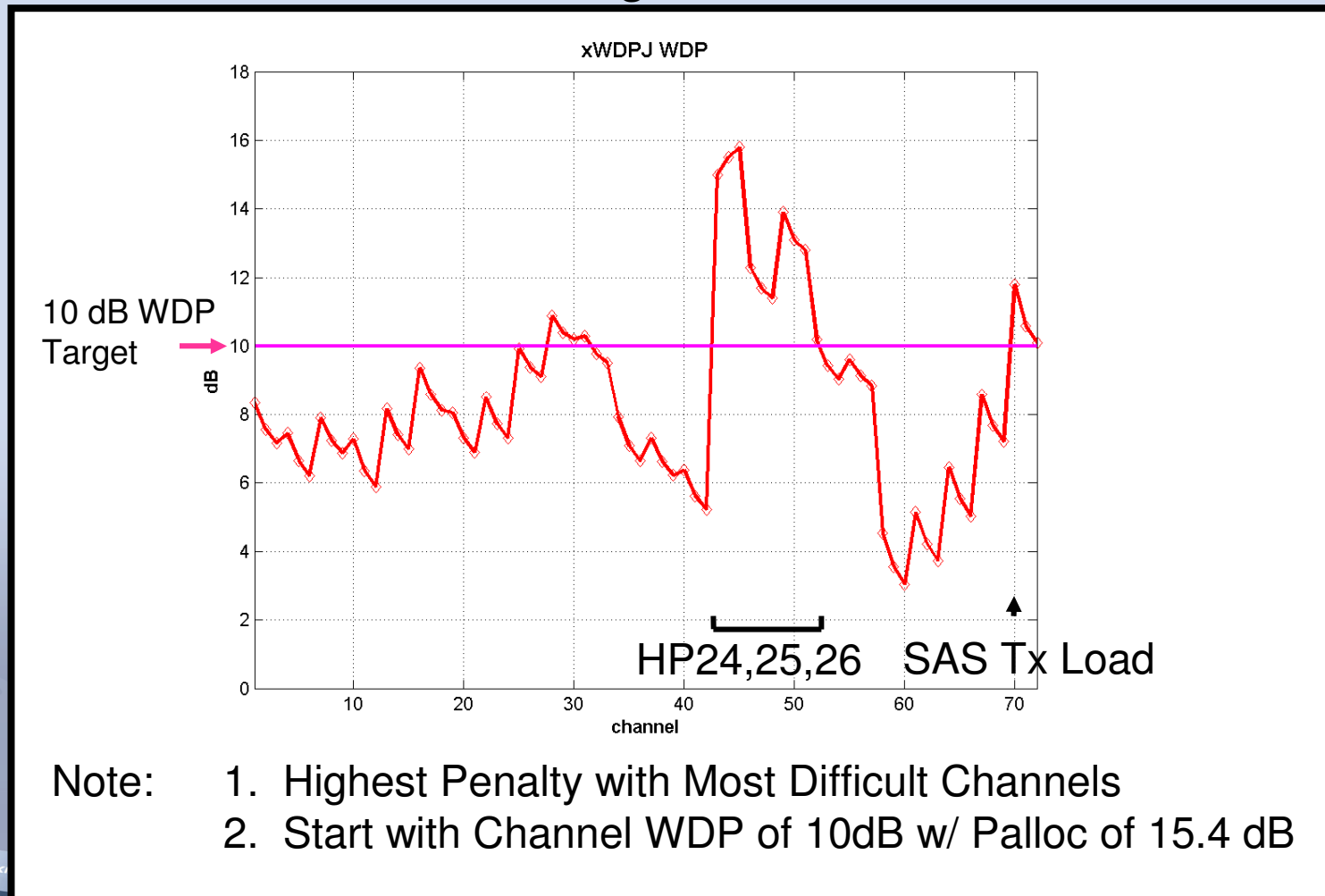
WDP on Measured Data

- **6m & 10m MiniSAS**
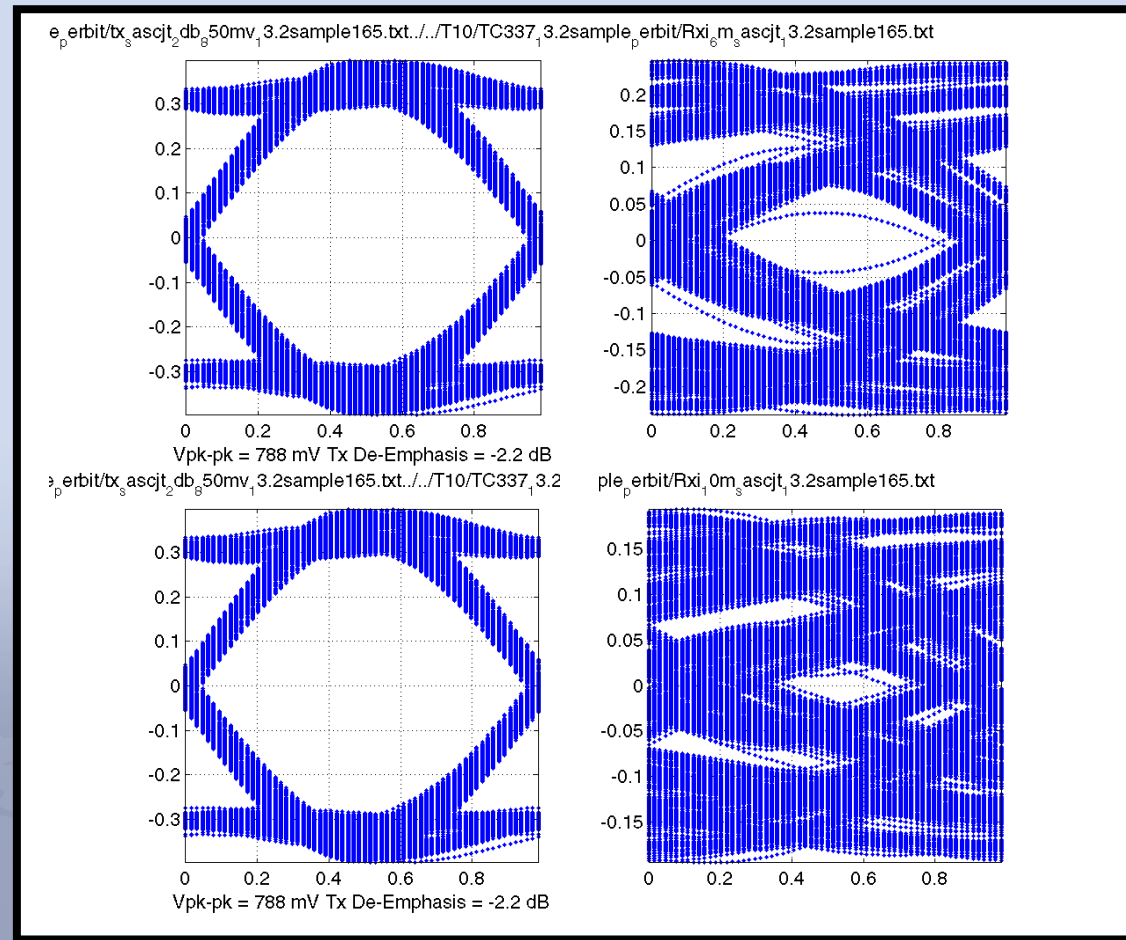 - **How Much WDP do we add for a real Transmitter ?**

Tx   **Rx**
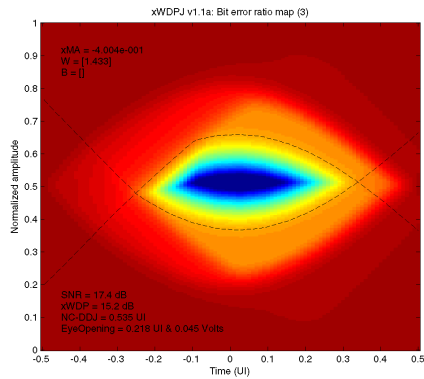
**2dB DE 788mV Tx
6m MiniSAS**
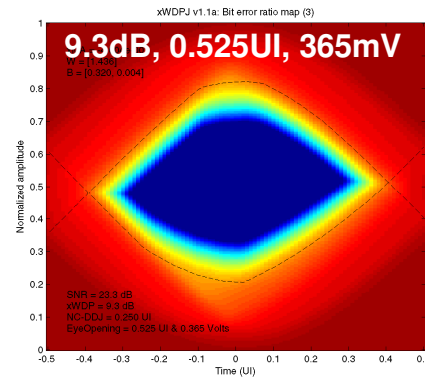
**2dB DE 788mV Tx
10m MiniSAS**

WDP on Measured Data

- **6m MiniSAS**

| 2dB DE 0-tap DFE | 2dB DE 2-tap DFE | 2dB DE 3-tap DFE | 2dB DE 4-tap DFE |

9.3dB, 0.525UI, 365mV 10dB, 0.525UI, 370mV 10.1dB, 0.564UI, 370mV
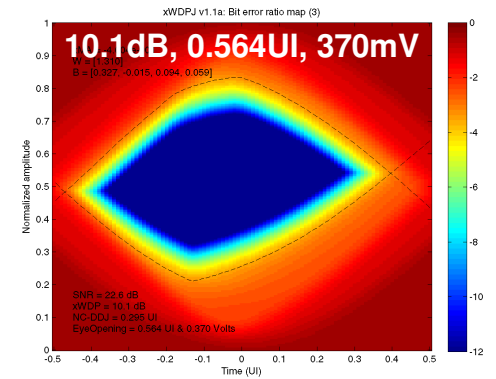
- **10m MiniSAS**

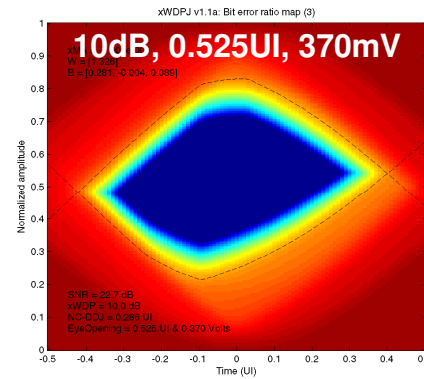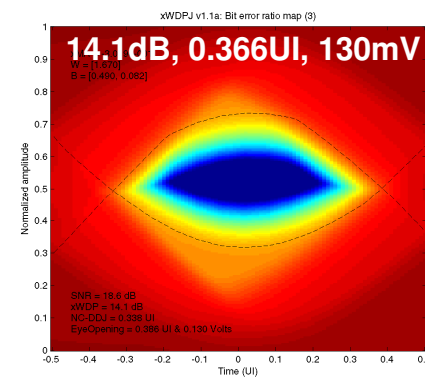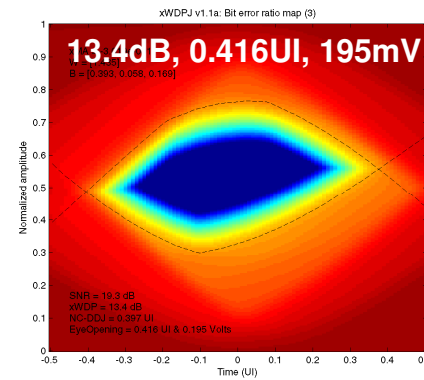| 2dB DE 0-tap DFE | 2dB DE 2-tap DFE | 2dB DE 3-tap DFE | 2dB DE 4-tap DFE |

14.1dB, 0.366UI, 130mV 13.4dB, 0.416UI, 195mV 13.6dB, 0.446UI, 190mV
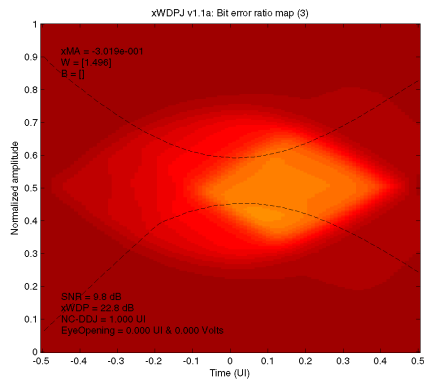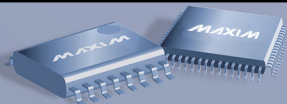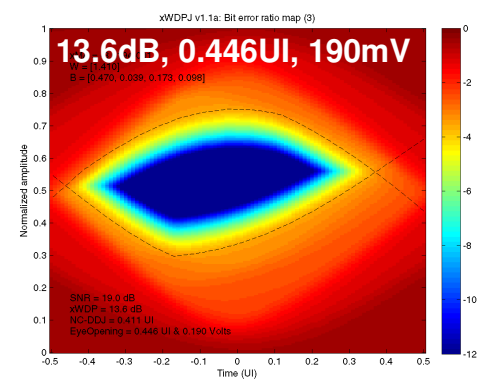
- **Simulated SAS Reference Channel and xWDPJ output**
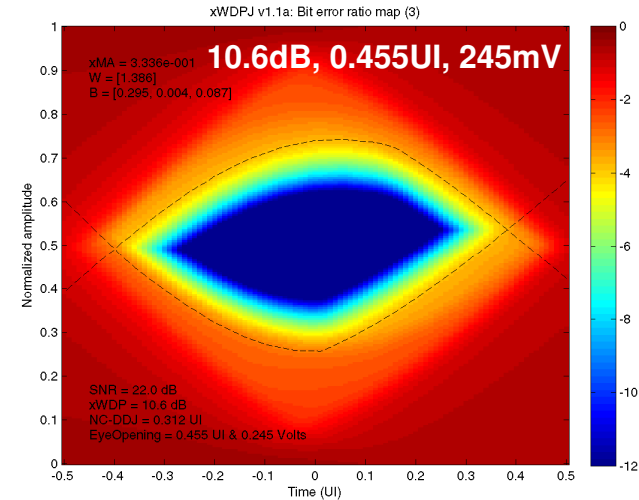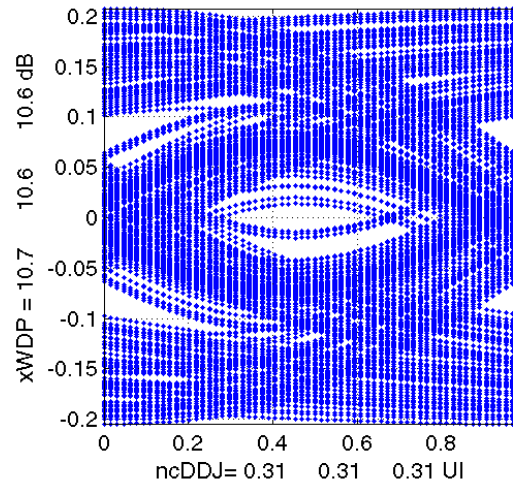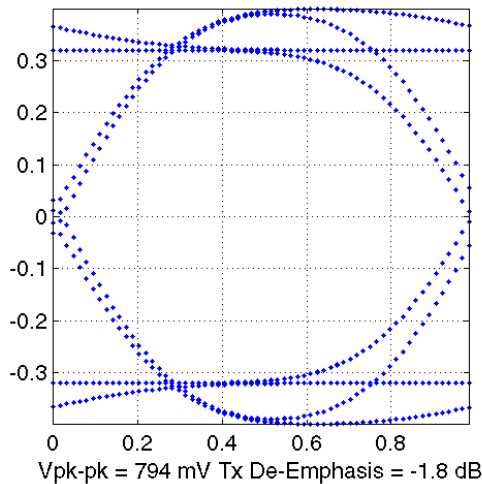
- **Measured SAS Reference Channel and xWDPJ output**
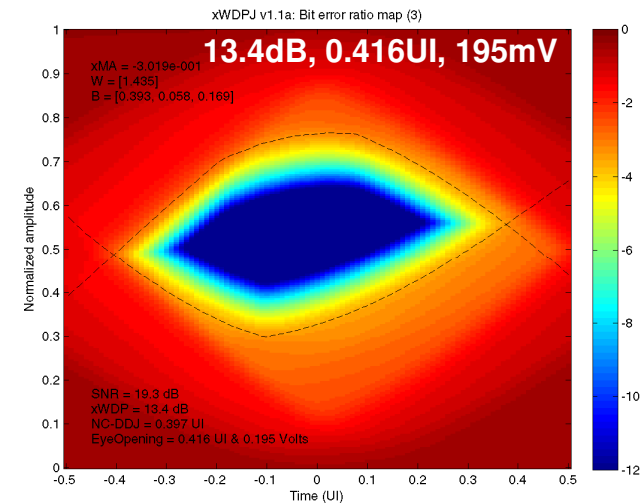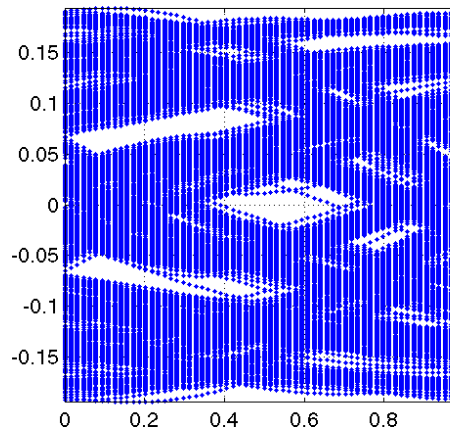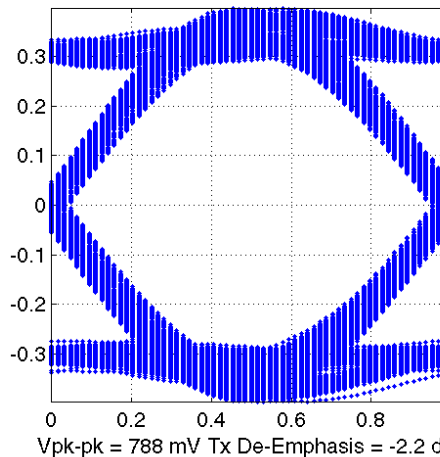
3dB WDP for a real Transmitter ?

Summary of Proposed Calibration
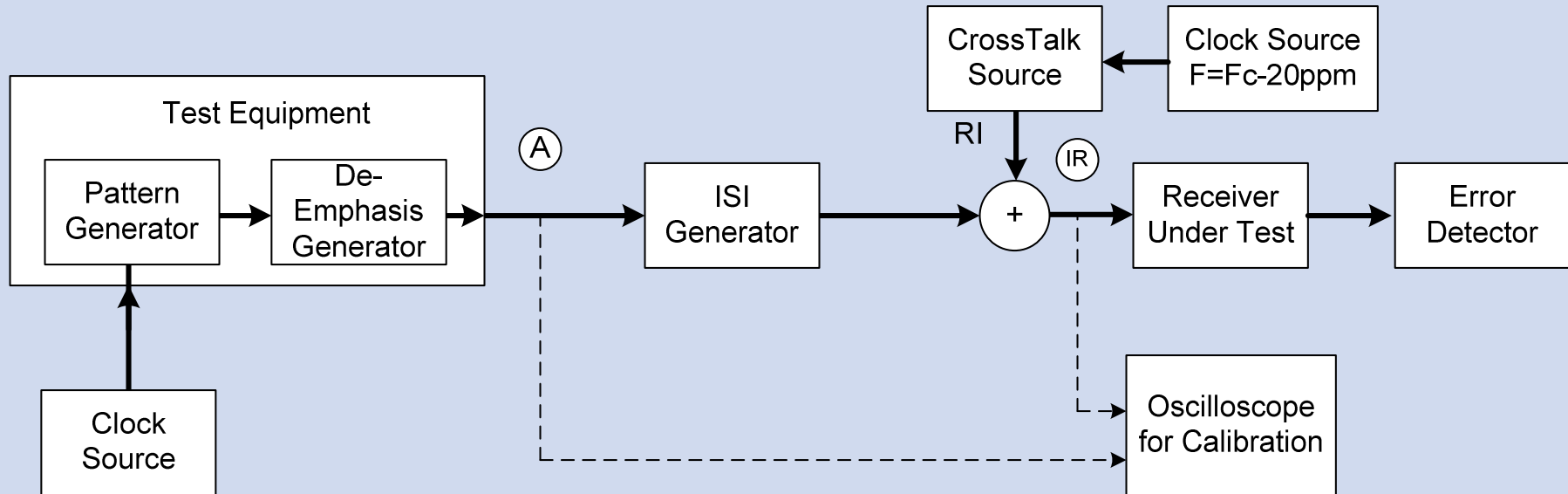
1. **Transmitter Amplitude Setup and ISI Generator @ IR**
   - **Use D24.3 Inner eye 60 → 90 mV**
   - **Compute TxWDP + WDP > 13dB of Delivered Signal**
2. **Transmitter Jitter Calibration @ A**
   - **Adjust RJ = 0.15 UI pk-pk**
   - **Adjust BUJ = 0.035 UI pk-pk**
3. **Crosstalk @ IR**
   - **PRBS-7 Crosstalk Source and Adjust Coupled Amplitude > 4mV rms**
4. **Test – Confirm BER < 1e-12**
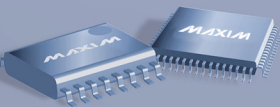
Summary

- **Calibration of Delivered Signal for Stressed Receiver Sensitivity Test Demonstrated**

- **A D24.3 Inner Eye opening of 60$\rightarrow$90mV and WDP + TxWDP of > 13dB w/ Palloc = 15.4 dB appears to be a reasonable Starting Point.**

- **Proposed Method of Calibrating the ISI Generator Appears Feasible and Avoids Golden Hardware.**
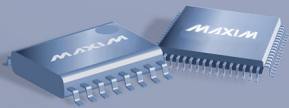
Additional Information

- **References**
- **Updated Link Budget (from 07-380r1)**
- **xWDPJ Simulation Modifications**
- **xWDPJ & StatEye Simulation Parameters**
- **XWDPJ SNR Output**
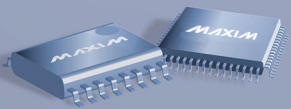
References

- T10/07-339r? SAS-2 6Gbps PHY Electrical Specification
- T10/07-380r1 Comprehensive Stressed Receiver Sensitivity Test (Kevin Witt)
- T10/07-493r0r0 Crosstalk Budget for Receiver Testing
- T10/07-365r0 Enhanced WDP for 6G SAS (Mike Jenkins)
- T10/07-448r0 DFEEYE and SAS-2 Channel Data (Kevin Witt & Mahbubul Bari)
- T10/07-365r0 Enhanced WDP for 6G SAS (Mike Jenkins)
- T10-07-193r1 Transmitter Test Load (Galen Fromm)
- T11/07-399v1 Beta and Epsilon Point Update (Adam Healey & Mark Marlett)
- T11/07-592v0 Migrating Beta and Epsilon Points to DFEEYE (Adam Healey & Mark Marlett)
- T11/07-344v0 Enhancing WDP (Adam Healey & Mark Marlett)
- T11/07-553v1 TWDP/WDP code for 8GFC SA and EA-delta points (Lindsay & Ghiasi)
- T11/07-644v0 Enhanced TWDP and WDP (Adam Healey & Mark Marlett)
- T11/07-706v0 Informative Eye Diagram Display for Enhanced TWDP and WDP (Adam Healey)

Link Budget

- ## From 07-365r0

	[mVpk-pk]	[mVrms]	[dB]		_Comments_

V_{P2P} (max) — **1200** — Tx peak-to-peak output voltage

5.53 — P_{TE} — Tx maximum equalization gain

VMA_T (max) — **800** — Tx maximum output amplitude

VMA_T (min) — **635** — Tx minimum output amplitude

-317 — **6.00** — P_A (max) — Channel VMA loss

VMA_R (min) — 318 — Rx minimum input amplitude

VMA at Output of Channel

13.00 — WDP — Tx waveform and Link dispersion penalty

3.10 — P_{ILD} — Insertion loss deviation

0.50 — P_{UJ} — Uncorrelated jitter
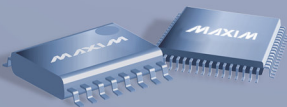
Tx Waveform and Channel Dispersion Penalty

22.28 — P_{ALLOC} — Total allocated dispersion penalty

5.68 — M — Unallocated margin (≥ 0, hopefully)

Theoretical Required VMA Post Equalization

VMA_{SX} — 61 — Sensitivity adjusted for crosstalk

Near End Cross Talk

σ_X — **2.7** — Crosstalk (RMS)

1.96 — P_{BT4} — Matched filter vs. Bessel filter

$$VMA = Q \cdot (\sigma_1 + \sigma_0)$$

VMA_{MFB} — 49 — Matched filter bound sensitivity

$$VMA = 7.03 * (3.4 + 3.4) = 48$$

VMA_S — 48 — Rx nominal sensitivity

3.4 — Electronics noise and slicer uncertainty

0

$$Q = \frac{VMA}{\sigma_1 + \sigma_0}$$

$Q_0 =$ — 7.03 — for BER — 1.0E-12 — Target signal-to-noise ratio

MAXIM
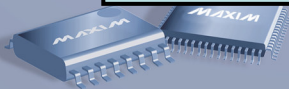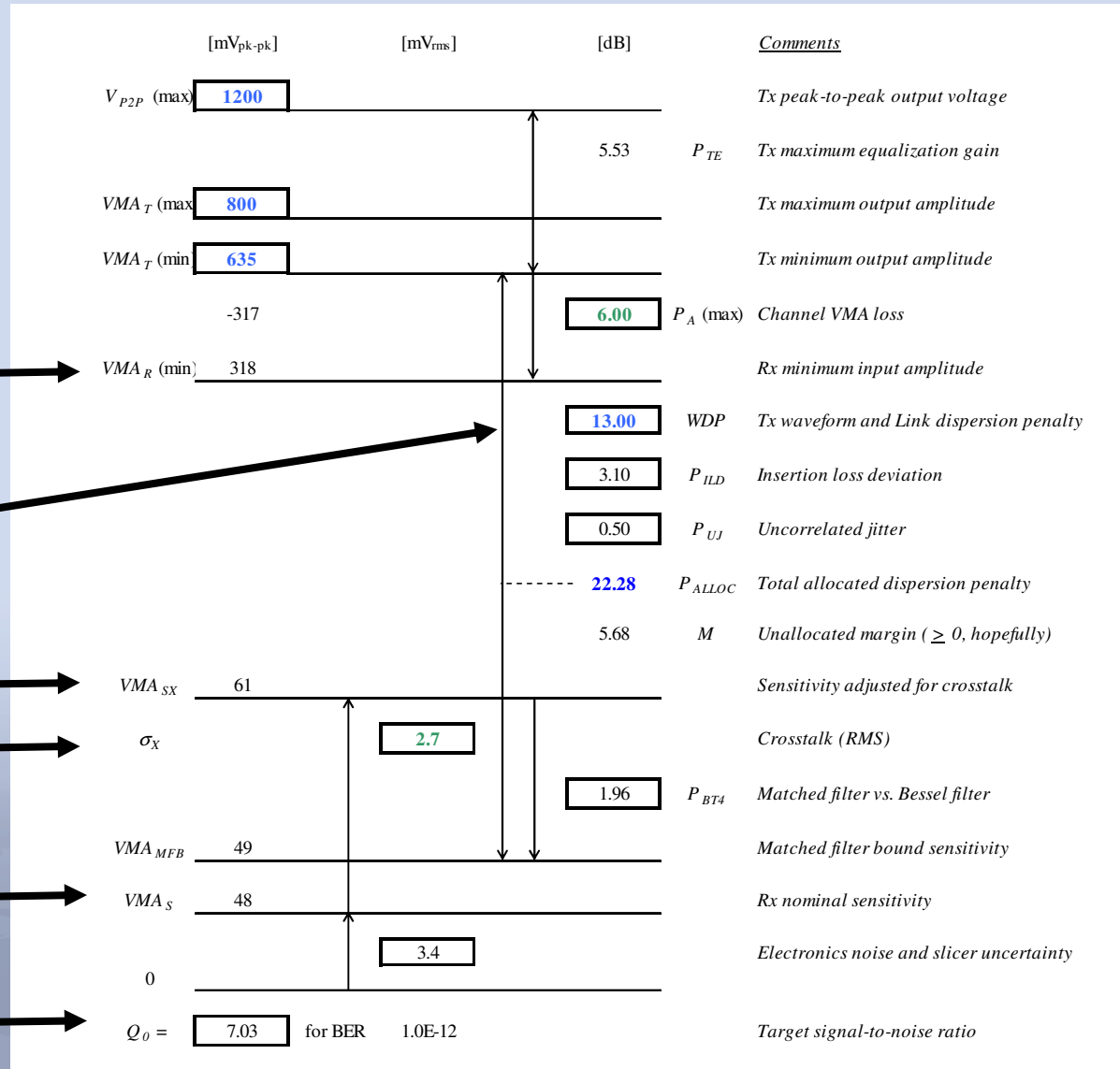
xWDPJ Simulation Modifications
(Code Provided to Author Waiting for Feedback)

- **numSymbols   = 3600;   %**
- **symbolPeriod   = 165e-12;**
- **eqNf = 1;**
- **eqNb = dfe_tap;   % sweep 1->4**
- **Palloc = [15.4];**

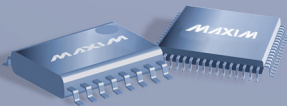### StatEye Simulation Parameters

dfeN: 0-tap and 3-tap DFE

deempN: 0, 1, 2, and 3 dB deemphasis

8b10b coding and random data

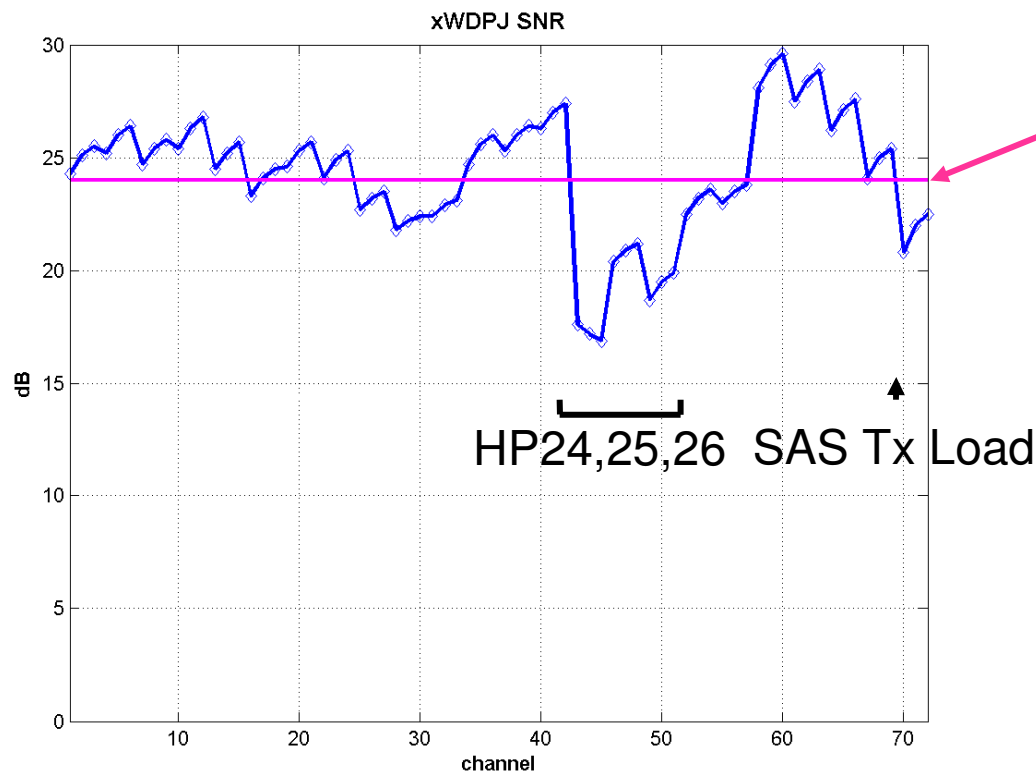pimin1: fixes DC extrapolation on some cables

All runs at 6 Gbps

DJ=.1, RJ=.01, BER=10^{-15}

Simulated WDP on SAS-2 Channels

- **SNR**
  - **Same channel order as 08-031r0**

$$BER = \frac{1}{2} erfc\left(\frac{SNR}{2\sqrt{2}}\right)$$

$$SNR = 2\sqrt{2}\, inverfc(2 \cdot BER)$$

24.0 dB SNR @ 1e-15 BER

xWDPJ SNR

HP24,25,26 SAS Tx Load

Note: 1. Highest Penalty with Most Difficult Channels