Date: March 26, 2007
To: T10 Technical Committee
From: Alvin Cox (alvin.cox@seagate.com)
Subject: SAS-2 6Gbps PHY Electrical Specification

Abstract: The attached information defines the electrical requirements for 6 Gbps transmitter devices and receiver device. In addition, updates may include reference transmitter and receiver device definitions to provide a means of determining if a channel is compliant and a cable specification section with requirements for 6Gbps usage. Editor notes are included as reminders for specification development. Revisions will not include redlines.

Revision History:
r0: Initial posting that is very preliminary and nowhere near complete, provided as a starting point and a basis to leverage the final PHY proposal from rather than a PowerPoint format.
r1: Updated emphasis measurement, changed SCD22 to SCD11 and corrected receiver common mode impedance value.
r2: Updated emphasis measurement, changed SCD11 back to SCD22 and updated the figure for SCD22.
r3: Updated emphasis measurement, included reference receiver definition.

r4 will contain updates from 07-001 and 07-071.

Reference proposals:

07-037 SAS-2 Common Mode Generation Specification [Witt, Bari]
07-007 Proposed 6G SAS Phy Specs for EMI Reduction [Jenkins]
07-001 Proposal for 6G SAS Phy Specification [Jenkins]
06-419 SAS-2 Reference Transmitter and Receiver Specification Proposal [Witt]
06-206 SAS-2 Data Eyes vs. De-Emphasis [Witt]
06-053 Roadmap to SAS-2 Physical Layer Specification [Witt]
06-052 Enhanced SFF-8470, SFF-8086 and SATA Cable at 6Gbps [Witt]
06-049 Comparison of Equalization Schemes for 6Gbps SAS Channels [Caroselli]
05-204 Towards a SAS-2 Physical Layer Specification [Witt]
05-426 SAS-2 Cable Reach Objective and Crosstalk [Witt]
05-425 SAS-2 Channel Model Simulations [Witt]
05-342 SAS-2 Adaptive Equalizer Physical Layer Feasibility [Witt]
05-341 Updated Test and Simulation Results in Support of SAS-2 [Witt]
05-203 SAS-2 6Gbps Test Results [Witt]
06-496 SAS-2 Electrical Specification Proposal [Witt]
07-071 Return loss measurement methodology discussion [Bari]
07-120 SAS-2 Transmitter De-Emphasis Measurement [Johnson, Bari]
07-135 StatEye Tap Defined [Newman]

Transmitter:

Editor notes:

Rob doesn't like "transmitter device" and "receiver device" because "device" has so many meanings. I have left them in place until a viable alternative is proposed.

No maximum transition time is included since this is limited by the pk-pk voltage requirement. The minimum rise time may also be dropped as a result of the SCD22 plot.

Transmitter equalization needs to be informative rather than normative because of emphasis schemes and desire by large OEM's to have custom settings.
A default transmitter equalization value of 3 dB is currently the recommended value. In some extraordinary cases, additional equalization is recommended.

Common mode, return loss, and EMI concerns are specified through s-parameter plots.

Jitter:
All indications are that the present measurement method using a type 1 filter with a corner frequency of fbaud/1667 will not allow measurement with SSC. Probably needs a type 2 filter, but details need to be determined.

General:
Values need some amount of description for measurement methodology similar to what was done in SATA. Need pictorial representation.

Transmitter device	Min	Nominal	Max	Units
Bit Rate		6000		Mbps
AC Coupling Cap (if attaches to SATA)			12	nF
Differential Voltage Swing (pk-pk) Vpk	800		1200	mV
Transition Time (20%-80%)	41.667 (0.25)			ps (UI)
Tx Equalization (informative default de-emphasis)	2	3	4	dB
SDD22 Differential Return Loss			see Figure xxy	dB
SCC22 Common Mode Return Loss			see Figure xxy	dB
Reference Diff Impedance		100		ohm
Reference Common Impedance		25		ohm
SCD22 Differential to Common Mode Conversion (N value, see Figure xxz)			-12.7dB	dB
Random Jitter			0.15 ?	UI
Deterministic Jitter			0.15 ?	UI
Total Jitter			0.3 ?	UI

Equalization measurement

1. The equalization measurement shall be based on a mode measurement for V_{vma} and a peak-to-peak measurement for $V_{pk\text{-}pk}$ using a TWO_DWORDS phy test pattern of D30.3 (see Table 215 in 10.2.9.1). If the phy test function is not supported, a vendor-specific method may be used to produce this pattern.

2. The voltage measurements shall be made with the transmitter device terminated through the interoperability point into a Zero Length Test Load.

3. The Vpk-pk and V_{vma} values shall be measured using the following or an equivalent procedure:

    a. An equivalent time sampling scope with a histogram function shall be used.
    b. The sampling scope shall be calibrated for measurement of a 3GHz signal.
    c. The scope capture window shall be set to a minimum of 5 UI for the histogram measurement.
    d. The V_{pk}-$_{pk}$ and V_{vma} values shall be determined as illustrated in Figure xxx. A sample size of 1000 minimum, 2000 maximum histogram hits for V_{vma} shall be used to determine the values. The histogram in the figure is a combination of two histograms, an upper histogram for TX+ and lower histogram for TX-.(The histograms on the left of the test pattern signal displayed on the right.)

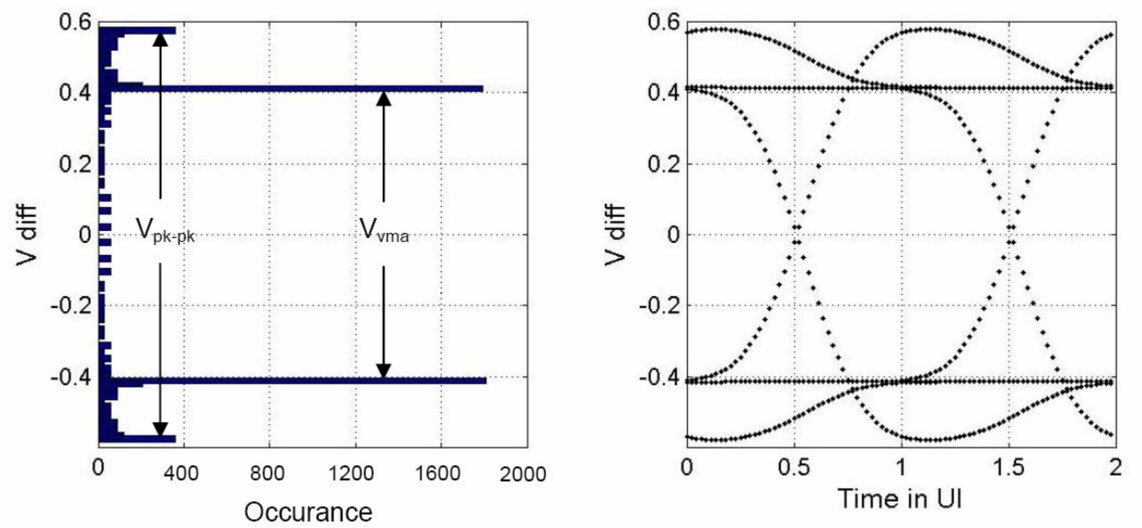


Figure xxx Transmitter equalization measurement

4. The following formula shall be used to calculate the equalization value:

$$DE_{dB} = 20Log_{10}\left(\frac{V_{pk-pk}}{V_{vma}}\right)$$

$$\text{for } 50MHz < f < 6\,GHz$$

$$SCC22 = \max\left\{-6, -7.9 + 13.3 * Log_{10}\left(\frac{f}{3.0G}\right)\right\}$$

$$SDD22 = \max\left\{-10, -7.9 + 13.3 * Log_{10}\left(\frac{f}{3.0G}\right)\right\}$$

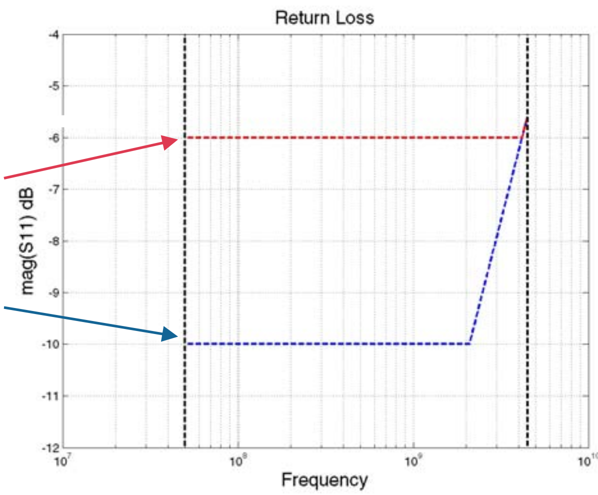


Figure xxy Transmitter Differential and Common Mode Return Loss

$$\text{for } 100MHz < f < 6GHz$$

$$SCD11 < \max\left\{L, \min\left\{H, N + S * Log_{10}\left(\frac{f}{3.0G}\right)\right\}\right\}$$

$$07-007r0 \quad L = -26,\ H = -10,\ N = -12.7,\ S = 13.3$$

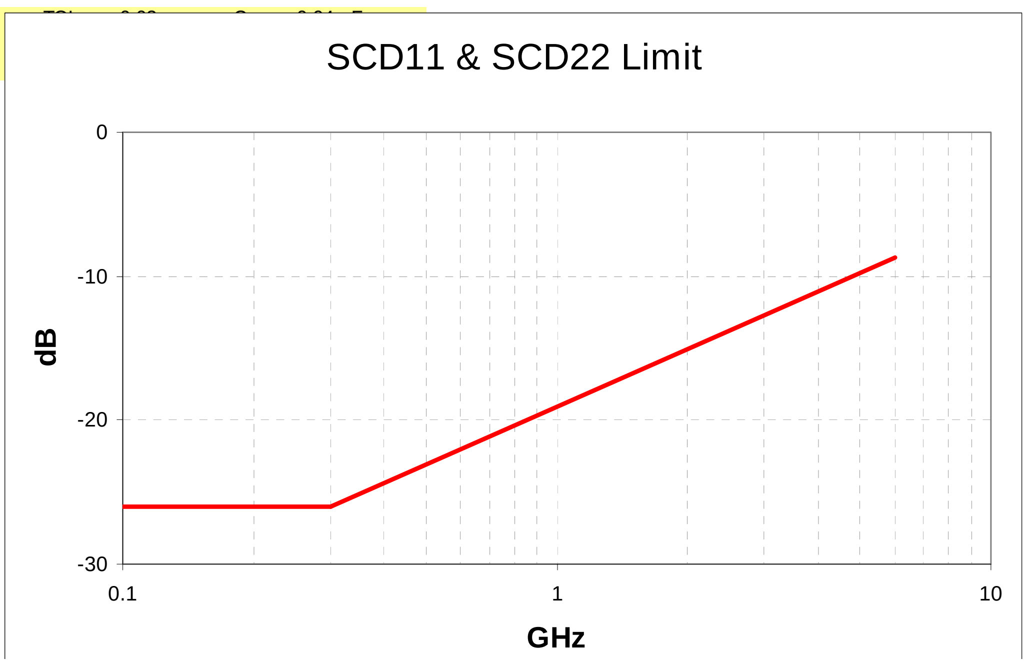


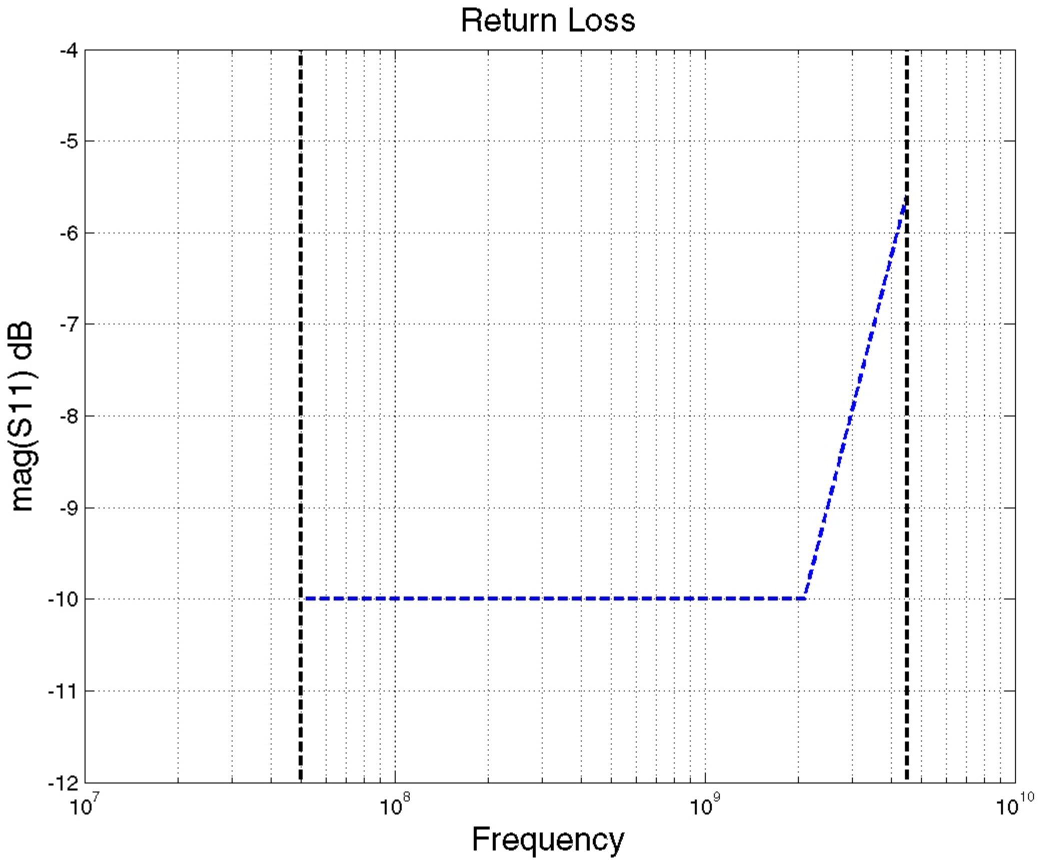
Figure xxz SCD22 Differential to Common Mode Conversion

Receiver:

Editor's note:
There are some factors at the far end that will complicate the receiver jitter tolerance specification. Since the receiver is expected to have an equalization function, a mathematical equalization equation will probably be needed to process the received signal at the compliance point to determine the resulting jitter is proper for testing the receiver device.

Adrian to provide:
Informative physical test with an 800mV launch from a compliant transmitter into a 10-meter ipass cable with some amount of jitter applied at the transmitter end, with SSC enabled, NEXT actively applied. Receiver to perform data recovery at 10e-12 with 95% confidence level.

Receiver device	Min	Nominal	Max	Units
SDD11 Differential Return Loss			See Figure xyx	dB
SCC11 Common Mode Return Loss			See Figure xyx	dB
Reference Diff Impedance		100		ohm
Reference Common Mode Impedance		25		ohm
Common Mode Tolerance (2-200MHz)	150			mV
Max Operational Differential Input Voltage @ 6,0 Gbps	1200			mV
Max Operational Differential Input Voltage @ 1,5 and 3,0 Gbps	1600			mV
Max Non-Operational Input Voltage	2000			mV
Skew? Included in jitter?				
Receiver amplitude: Reference receiver methodology could include				



$$\text{for } 50MHz < f < 6.0\,GHz$$

$$SCC22 = SDD22$$
$$= \max\left\{-10, -7.9 + 13.3 * Log_{10}\left(\frac{f}{3.0G}\right)\right\}$$

Figure xyx Receiver Differential and Common Mode Return Loss

Reference Receiver

The reference receiver is a 2 tap DFE with infinite precision taps and unit interval tap spacing. The reference coefficient adaptation algorithm is the Least Mean Squared (LMS). The receivers return loss is illustrated in Figure xyx.

A SAS-2 receiver device has the electrical characteristics illustrated in Table xx