Analysis of SAS 6Gbps Backplanes Using Annex 69B of 802.3

SEAGATE

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Introduction

- 51 channel configurations were compared
  - They are listed on the last slide of this presentation
  - The configurations weren't always clear, so some assumptions were made
- Annex 69B methodology was used to compare the SAS channels to 1000BASE-KX, 10GBASE-KX4, and 10GBASE-KR informative interconnect characteristics

Spec Compliance Points Comparison

The compliance points of the two standards

- They both include the mated connectors
  - 802.3: TP1 -> TP4
  - SAS: ITs -> IR
- What is unclear is the how the characteristics of the rest of the channel compares
  - SAS provides a reference Tx and Rx model with -1.8dB of insertion loss each at 3.125GHz

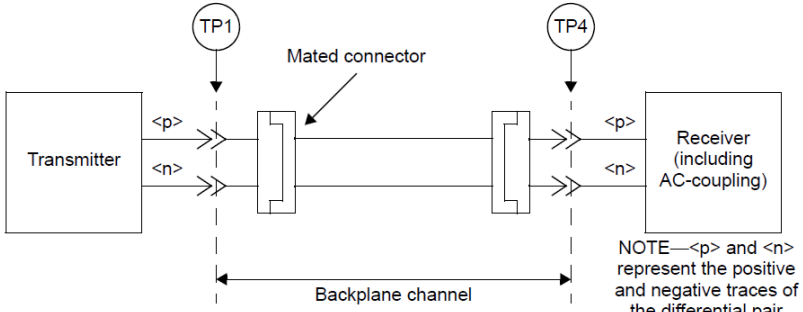
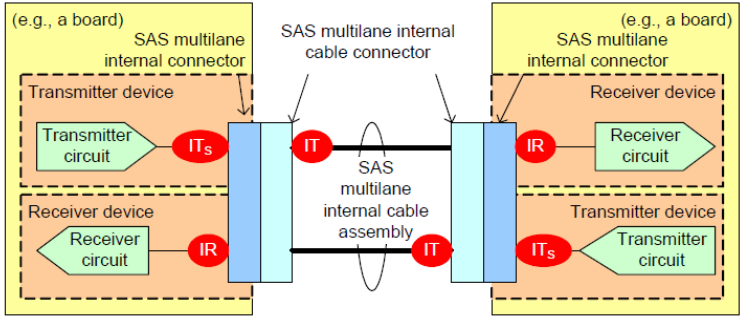


Figure 69B–1—Interconnect reference model



Spec Compliance Points Comparison Cont'd

- The wording in Annex 69B makes it sound like this is a full channel (die-to-die) spec
- This presentation compares the channels directly, so the channel performance to spec comparisons may not be apples-to-apples

Informative characteristics and methods of calculation for the insertion loss, insertion loss deviation, return loss, crosstalk, and the ratio of insertion loss to crosstalk between TP1 and TP4 are defined in 69B.4.3, 69B.4.4, 69B.4.5, 69B.4.6, and 69B.4.6.4 respectively. These characteristics may be applied to a specific implementation of the full path (including transmitter and receiver packaging and supporting components) for a complete assessment of system performance and the interaction of these components.

Annex 69B of 802.3

Various frequency ranges are used for the different parameters

- Fitted Attenuation (IL Fit)
  - f_1 to f_2
- Insertion Loss
  - f_{min} to f_{max}
- Insertion Loss Deviation (ILD)
  - f_1 to f_2
- Return Loss
  - 50 MHz to line rate
- ICR Fit
  - f_a to f_b

Table 69B–1—Insertion loss parameters

Parameter	1000BASE-KX	10GBASE-KX4	10GBASE-KR 40GBASE-KR4	Units
f_{min}	0.05			GHz
f_{max}	15.00			GHz
b_1	2.00×10^{-5}			
b_2	1.10×10^{-10}			
b_3	3.20×10^{-20}			
b_4	-1.20×10^{-30}			
f_1	0.125	0.312	1.000	GHz
f_2	1.250	3.125	6.000	GHz
f_a	0.100	0.100	0.100	GHz
f_b	1.250	3.125	5.15625	GHz

Fitted Attenuation

Fitted attenuation is the least mean squared line fit of the insertion loss from f_1 to f_2

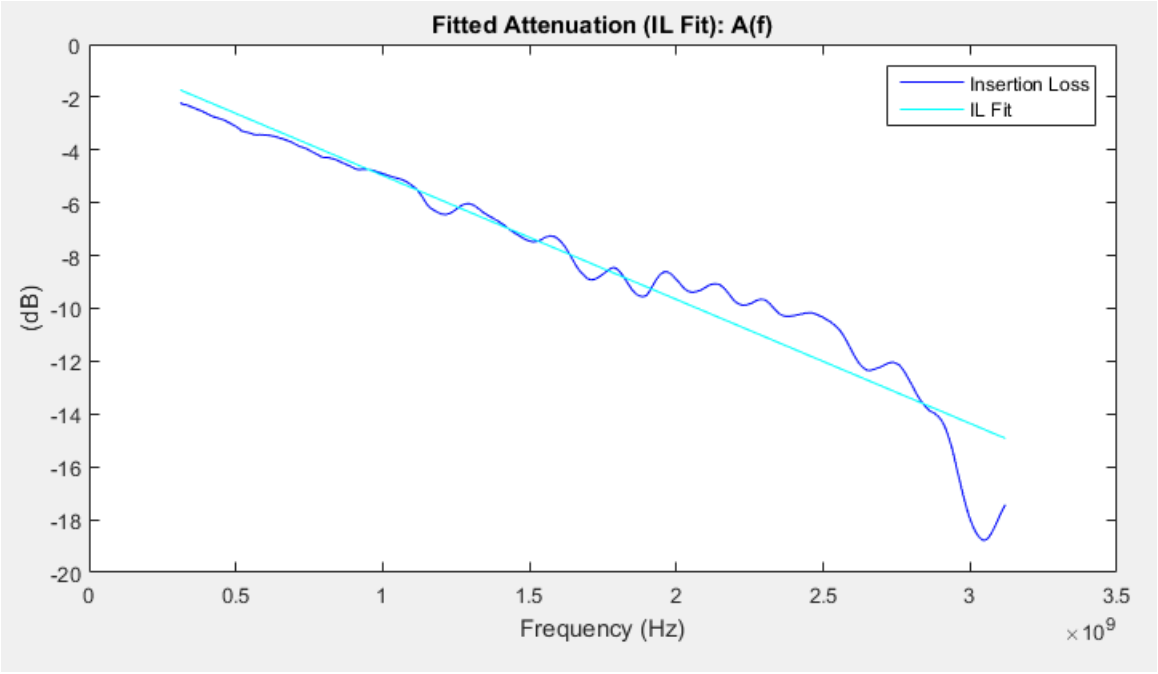
$$f_{avg} = \frac{1}{N}\sum_{n} f_n$$

$$IL_{avg} = \frac{1}{N}\sum_{n} IL(f_n)$$

$$m_A = \frac{\sum_{n}(f_n - f_{avg})(IL(f_n) - IL_{avg})}{\sum_{n}(f_n - f_{avg})^2}$$

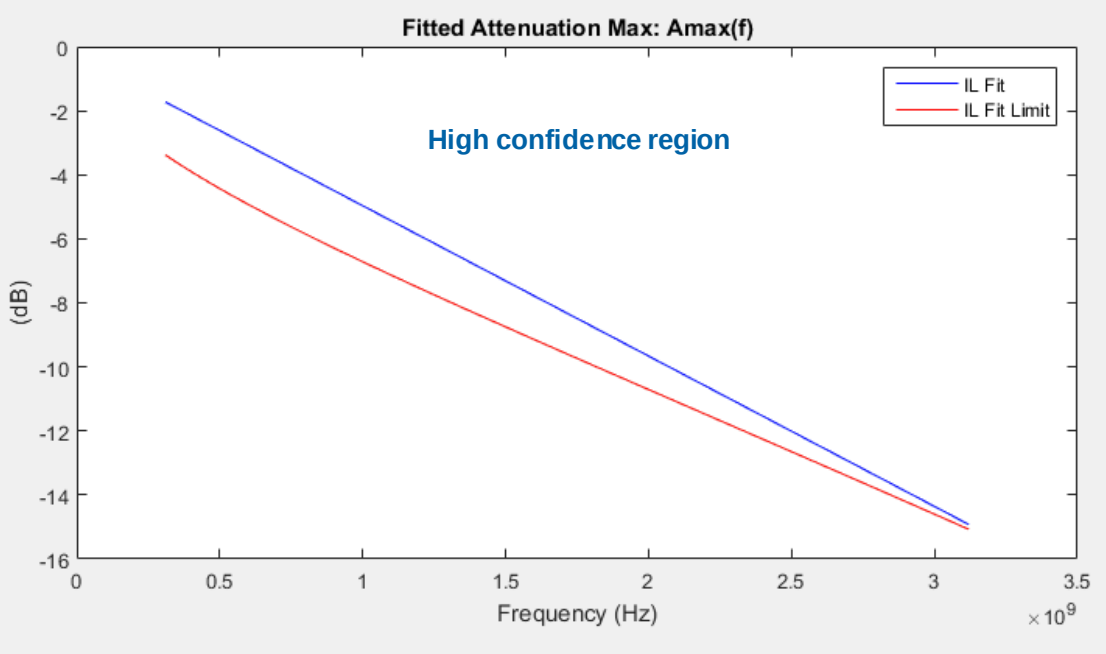
$$b_A = IL_{avg} - m_A f_{avg}$$

$$A(f) = m_A f + b_A$$



Fitted Attenuation Spec

$$A(f) \le A_{\max}(f) = 20\log_{10}(\mathrm{e}) \times (b_1\sqrt{f} + b_2 f + b_3 f^2 + b_4 f^3)$$



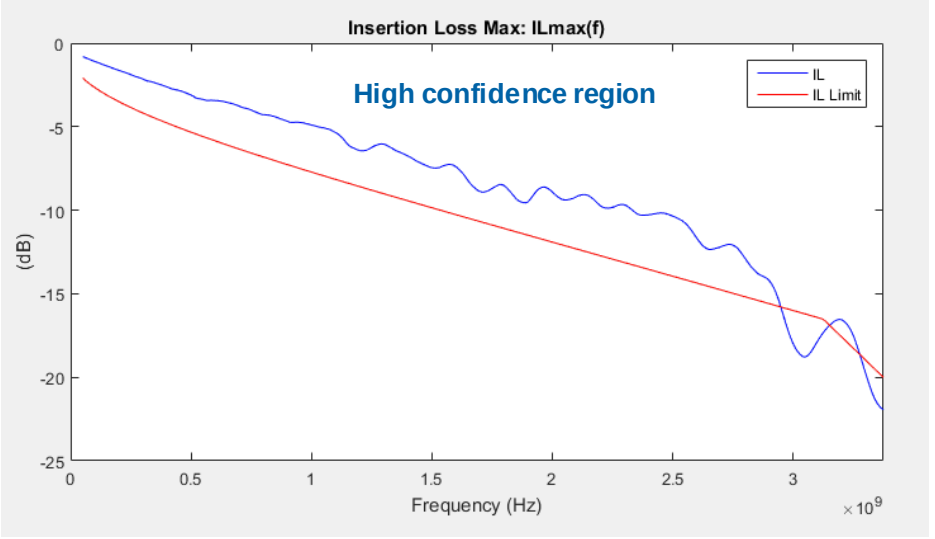
Insertion Loss Spec

$$IL(f) \le IL_{\max}(f) = A_{\max}(f) + 0.8 + 2.0\times10^{-10} f$$

for $f_{\min} \le f \le f_2$

$$IL(f) \le IL_{\max}(f) = A_{\max}(f) + 0.8 + 2.0\times10^{-10} f_2 + 1\times10^{-8}(f - f_2)$$

for $f_2 < f \le f_{\max}$



Insertion Loss Deviation and Corresponding Spec

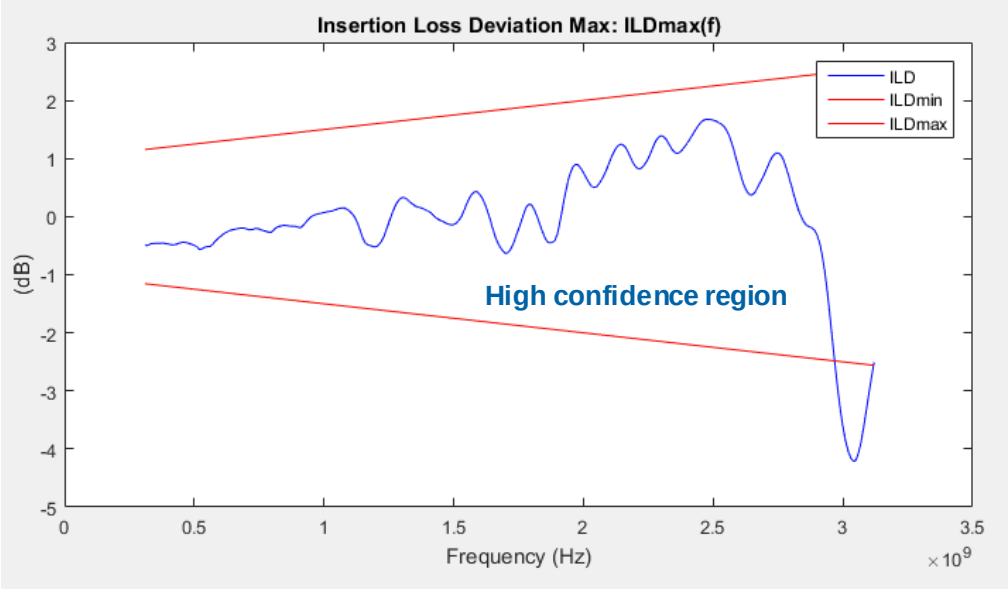
Insertion loss deviation is the difference between the insertion loss and the fitted attenuation

$$ILD(f) = IL(f) - A(f)$$

$$ILD(f) \geq ILD_{\min}(f) = -1.0 - 0.5\times10^{-9} f$$

$$ILD(f) \leq ILD_{\max}(f) = 1.0 + 0.5\times10^{-9} f$$

for $f_1 \leq f \leq f_2$.



Return Loss Spec

$$RL(f) \geq RL_{\min}(f) = 12$$

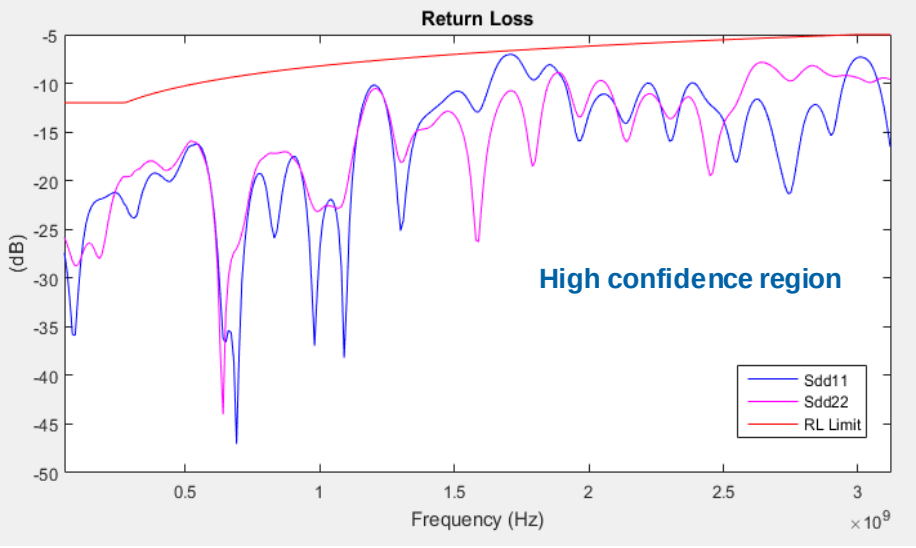
for $50\ \text{MHz} \leq f < 275\ \text{MHz}$ and

$$RL(f) \geq RL_{\min}(f) = 12 - 6.75\log_{10}\left(\frac{f}{275\ \text{MHz}}\right)$$

for $275\ \text{MHz} \leq f < 3000\ \text{MHz}$ and

$$RL(f) \geq RL_{\min}(f) = 5$$

for $3000\ \text{MHz} \leq f \leq 10312.5\ \text{MHz}$.



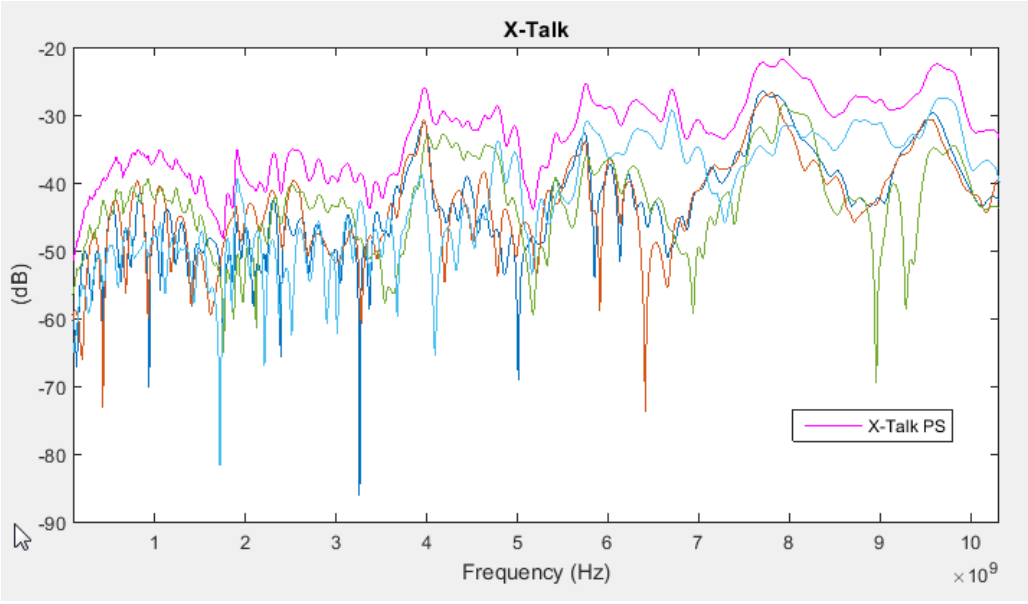
X-Talk

X-Talk is power summed for use in the ICR spec

$$PSXT(f) = -10\log\left(10^{-PSNEXT(f)/10} + 10^{-PSFEXT(f)/10}\right)$$

$$PSNEXT(f) = -10\log\left(\sum_n 10^{-NEXT_n(f)/10}\right)$$

$$PSFEXT(f) = -10\log\left(\sum_n 10^{-FEXT_n(f)/10}\right)$$

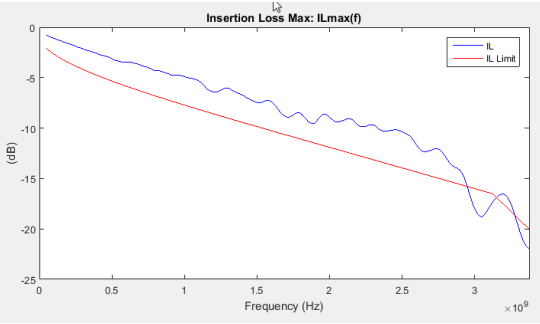


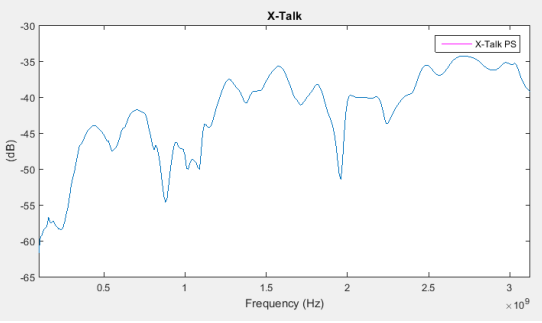
Insertion Loss To X-Talk Ratio (ICR)

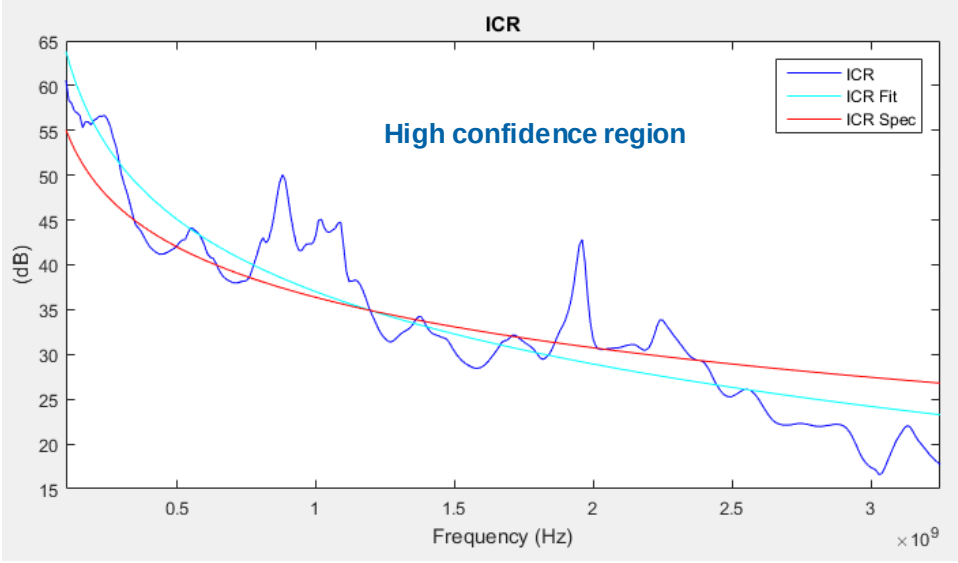
ICR is the difference between the insertion loss and the power sum of X-Talk

– A least mean square line fit is then done to ICR

$$ICR(f) = -IL(f) + PSXT(f)$$







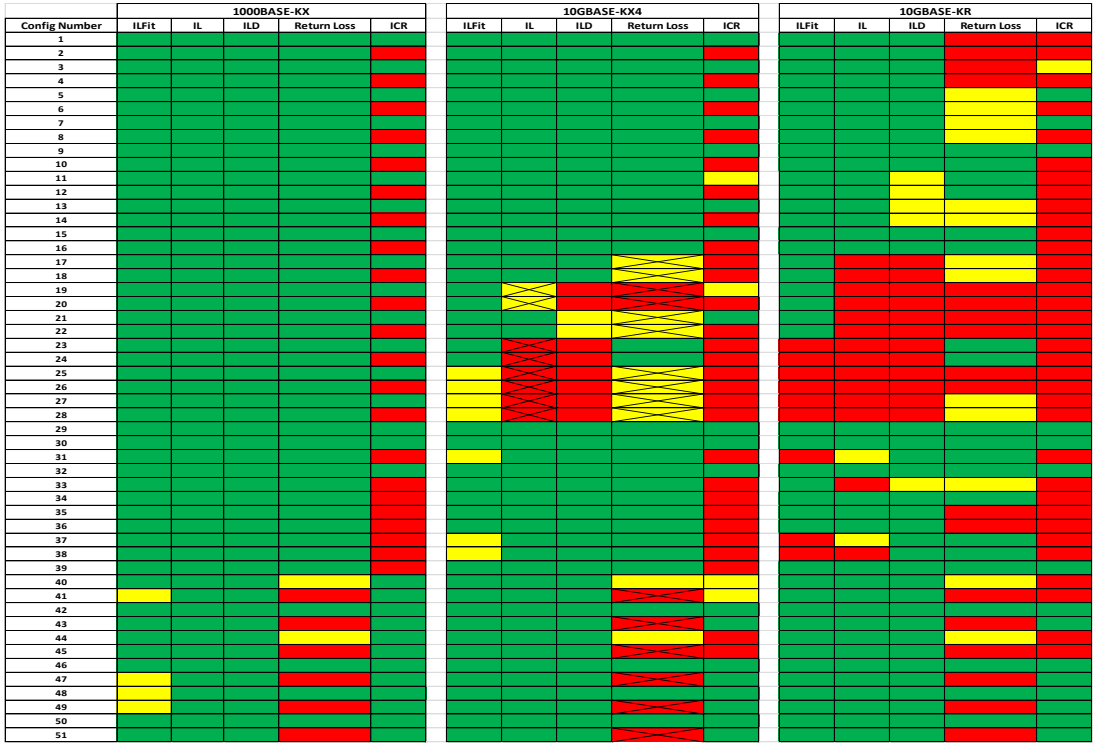
SAS Channel Analysis Results

- Color code
  - Green: Parameter is within the high confidence region
  - Yellow: Parameter is within 1dB of the high confidence region
  - Red: Parameter is outside of the high confidence region + 1dB padding

- "X" Marking
  - "X" indicates that the parameter also fails the 6Gbps SAS spec
    - **IL, RL, and ICR were analyzed to the SAS spec**
  - There is no direct 6G SAS insertion loss spec. To establish spec compliance for a channel, a simulation must be run with the reference Tx and Rx. For the results in this presentation, I compared the insertion loss of the channel to the SAS 6G reference channel from 100MHz to 3GHz.
  - The 12G SAS ICR spec was used for ICR comparison
  - The "X" is only used on 10GBASE-KX4 results

Annex 69B Results

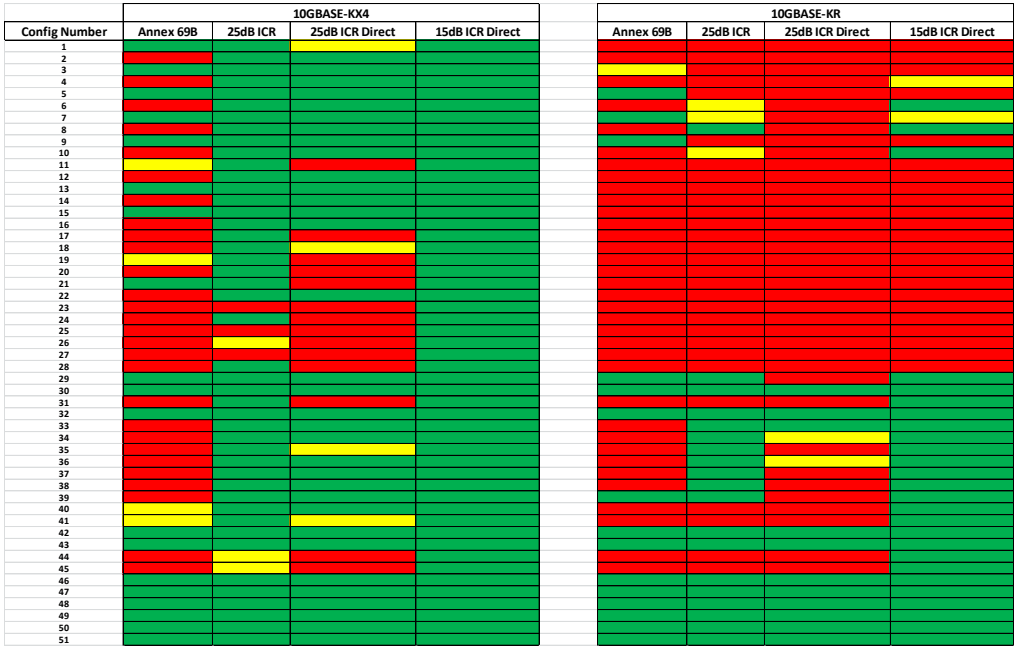
These results compare the channels directly to the spec in Annex 69B



- The ICR spec is very difficult for SAS channels as even 1000BASE-KX has a significant number of failures
- As expected, there is more red as you go higher in frequency
- Not all of these channels meet the SAS 6Gbps spec
- Good correlation (from a channel perspective) between the standards on IL and RL, but not ICR

ICR Comparison Using Different Spec's

1000BASE-KX is not shown, but is all green except for Annex 69B



ICR Descriptions

- Annex 69B
  - Spec as defined in Annex 69B
- 25dB ICR
  - A 25dB ICR spec was used across all frequencies
- 25dB ICR Direct
  - A 25dB ICR spec was used across all frequencies
  - An ICR fit was not used
  - The ICR was used directly
- 15dB ICR Direct
  - Same as above, but with a 15dB spec
  - 12G SAS is defined this way

Summary

- The ICR spec seems to be the biggest issue from a channel perspective
  - The port A connector on SAS was taken from SATA rev 1. This was back in 2003 and the line rate was 1.5Gbps
  - This connector is still in use today and provides a constant X-Talk battle at higher frequencies
  - The X-Talk results should improve if the SAS reference Tx and Rx are included as they would attenuate the X-Talk with added insertion loss
- Need PHY simulation results with these channels to understand system performance
- Need to understand the compliance point differences between SAS and Backplane Ethernet
  - The results will change if more loss is added to the current channels
- I see Annex 69B as a useful tool for system designers
  - The issue being that the ICR spec will fail most 6G SAS channels, so the pass/fail results aren't very useful
  - Should consider updating Annex 69B with CU4HDD standards and include a realistic ICR spec for SAS channels

Configurations used

Config Number	Channel	X-Talk
1	HP01	HP19_XT
2	HP01	HP15_XT+HP16_XT+HP17_XT+HP18_XT+HP17_XT+HP18_XT
3	HP02	HP19_XT
4	HP02	HP15_XT+HP16_XT+HP17_XT+HP18_XT+HP17_XT+HP18_XT
5	HP03	HP19_XT
6	HP03	HP15_XT+HP16_XT+HP17_XT+HP18_XT+HP17_XT+HP18_XT
7	HP04	HP19_XT
8	HP04	HP15_XT+HP16_XT+HP17_XT+HP18_XT+HP17_XT+HP18_XT
9	HP05	HP19_XT
10	HP05	HP15_XT+HP16_XT+HP17_XT+HP18_XT+HP17_XT+HP18_XT
11	HP06	HP19_XT
12	HP06	HP15_XT+HP16_XT+HP17_XT+HP18_XT+HP17_XT+HP18_XT
13	HP07	HP19_XT
14	HP07	HP15_XT+HP16_XT+HP17_XT+HP18_XT+HP17_XT+HP18_XT
15	HP08	HP19_XT
16	HP08	HP15_XT+HP16_XT+HP17_XT+HP18_XT+HP17_XT+HP18_XT
17	HP09	HP19_XT
18	HP09	HP15_XT+HP16_XT+HP17_XT+HP18_XT+HP17_XT+HP18_XT
19	HP10	HP19_XT
20	HP10	HP15_XT+HP16_XT+HP17_XT+HP18_XT+HP17_XT+HP18_XT
21	HP11	HP19_XT
22	HP11	HP15_XT+HP16_XT+HP17_XT+HP18_XT+HP17_XT+HP18_XT
23	HP24	HP19_XT
24	HP24	HP15_XT+HP16_XT+HP17_XT+HP18_XT+HP17_XT+HP18_XT
25	HP25	HP19_XT
26	HP25	HP15_XT+HP16_XT+HP17_XT+HP18_XT+HP17_XT+HP18_XT
27	HP26	HP19_XT
28	HP26	HP15_XT+HP16_XT+HP17_XT+HP18_XT+HP17_XT+HP18_XT
29	long_board_to_drive_oldconn	long_board_to_drive_oldconn_next
30	short_board_to_drive_oldconn	short_board_to_drive_oldconn_next
31	long_board_to_board	long_board_to_board_FEXT
32	short_board_to_board	short_board_to_board_FEXT
33	b1_thru	b1_next_hdd
34	b2_thru	b2_next_hdd
35	c1_thru	c1_next_hdd
36	c2_thru	c2_next_hdd
37	d1_thru	d1_next_hdd
38	d2_thru	d2_next_hdd
39	a2_thru	a2_next_hdd
40	Intel_HDD_BP_C_MB_03_thru	Intel_HDD_BP_C_MB_03_FEXT
41	Intel_HDD_BP_C_MB_04_thru	Intel_HDD_BP_C_MB_04_FEXT
42	Intel_HDD_SC_MB_11	Intel_HDD_SC_MB_11_FEXT
43	Intel_HDD_SC_MB_12	Intel_HDD_SC_MB_12_FEXT
44	Intel_MB_C_BP_HDD_01_thru	Intel_MB_C_BP_HDD_01_FEXT
45	Intel_MB_C_BP_HDD_02_thru	Intel_MB_C_BP_HDD_02_FEXT
46	Intel_MB_LC_HDD_05	Intel_MB_LC_HDD_05_FEXT
47	Intel_MB_LC_HDD_06	Intel_MB_LC_HDD_06_FEXT
48	Intel_MB_LC_HDD_07	Intel_MB_LC_HDD_07_FEXT
49	Intel_MB_LC_HDD_08	Intel_MB_LC_HDD_08_FEXT
50	Intel_MB_SC_HDD_09	Intel_MB_SC_HDD_09_FEXT
51	Intel_MB_SC_HDD_10	Intel_MB_SC_HDD_10_FEXT