Time-domain SNR Analysis for Contributed Channels

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Outline

- Several channel s-parameter models were contributed so far
- From these channels we can create time-domain signals and extract certain metrics:
  - Desired signal level
  - ISI levels
  - Crosstalk power (or RMS level)
  - Effect of reflections from imperfectly-matched terminations
  - Jitter sensitivity
- From these metrics we try to assess whether a channel can work or not, and what is it sensitive to
- Analysis method will be described only briefly
  - In-depth description planned for future sessions
  - Suggested as a tool for the project

Assumptions

- Receiver and transmitter will have imperfect matching (e.g. due to pad capacitance)
  - This will cause reflections and put return losses into the picture
  - Calculated in the frequency domain
  - Impedances are parameters of this analysis
- Receiver and transmitter implementation will have limited bandwidth
  - This effect will be convolved with the channel in the time domain
  - Bandwidths are also parameters
- Adaptive equalization will be used
  - Assumed: 3-tap FFE at the transmitter, N-tap DFE at the receiver (N is a parameter)
  - Tap values optimized to maximize Signal-to-ISI (neglecting other noise sources) – not strictly MMSE but close

Assumptions (cont.)

- Transmitter will have some allowed jitter (specified); receiver assumed similar (though not specified)
  - Jitter effect will be translated into effective voltage noise
- Implementations will be sub-optimal in various aspects; channels may vary
  - Margins should be taken for implementation penalties and channel tolerances
- Noise sources are uncorrelated to each other, and can be power-summed
  - Using the Central Limit Theorem – if elements have similar variances, their sum approaches a Gaussian distribution (although it's never strictly Gaussian)
  - Gaussian noise is a useful abstraction for SNR-to-BER conversion
  - Gaussian distribution causes the worst BER for a given SNR

How realistic is it?

- Receivers can do better than this analysis – e.g. use CTLE, longer DFE, lower penalty, innovation, “magic”
  - But the “reference” adaptive receiver-transmitter combination is realizable
- Time-domain signals are used in practically all simulations, and can be measured or extracted in real systems
- Effects of impedance mismatches are well-known
- ISI, crosstalk and jitter contributions in the time domain are well-studied and used in statistical analysis tools
- There is still place for errors in the analysis… but current goal is to compare existing channels

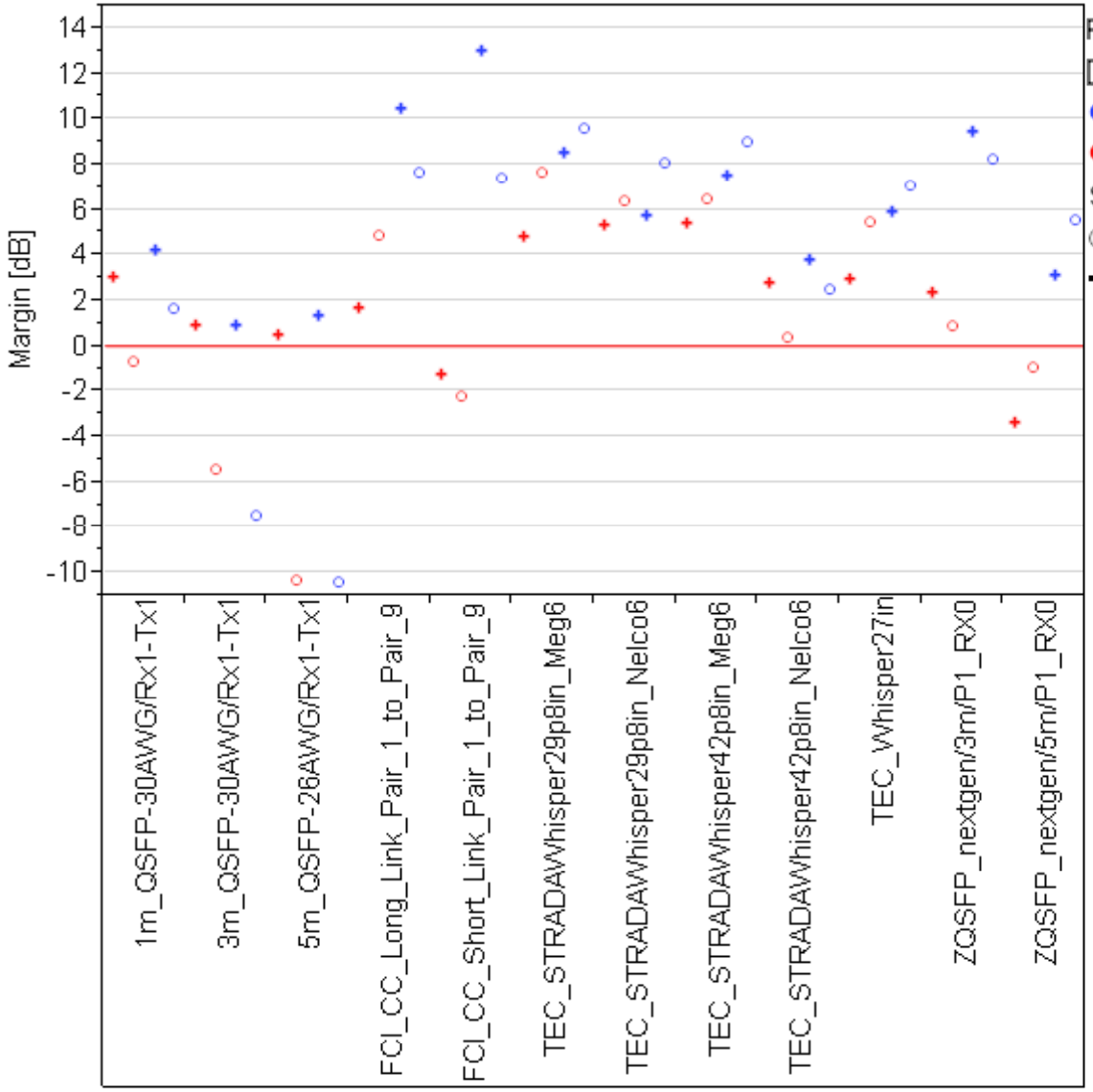
Analysis

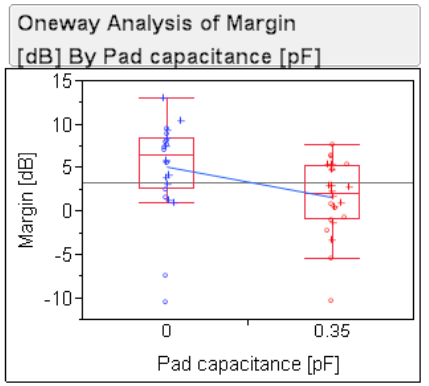
Analysis parameters

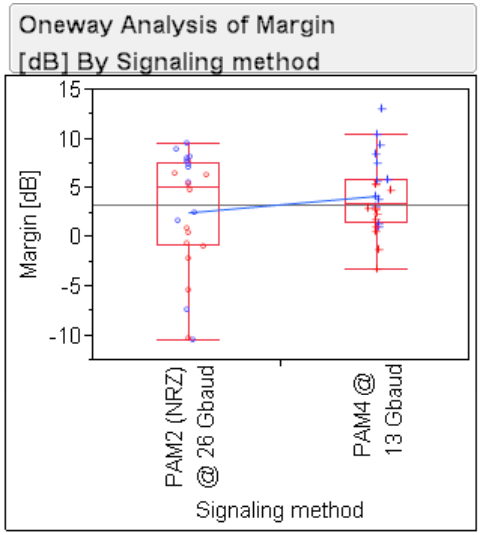
- For each submission, only one “through” channel is analyzed with all crosstalk aggressors accompanying it
- Signaling method: PAM2 (NRZ) / PAM4
  - Required SNR is 17 / 24 dB respectively; we will look at margins
- Transmitter BW: 0.8 * Baud rate (2^{nd} order)
- Receiver BW: 0.6 * Baud rate (4^{th} order)
- Impedance matching: 2 cases - 0 and 0.35 pF pad capacitance (both TX and RX)
- DFE length: 14 taps
- Jitter: DJ of 0.15 UI PTP and RJ of 0.01 UI RMS (total for TX and RX), no DCD
  - Jitter-induced noise is not Gaussian, and is effectively bounded
  - Its is typically much stronger than other noise sources – so CLT can’t be used
  - The calculated peak noise is subtracted from the signal (rather than being added to other noise sources)
- 1 V amplitude assumed for all transmitters (including NEXT)

Results Summary

Margin results







Observations

- Most channels have positive margin in this analysis
  - But usually too small for implementation penalties…
  - FEC seems to be required in many cases
- Adding pad capacitance (mismatched termination) generally degrades SNR
  - 3.5 dB degradation on average
- No strong preference for NRZ and PAM4
- Long channels and cables don’t have enough margin with NRZ and mismatched termination
  - Some may work better with PAM4
- Two cases don’t work with either NRZ or PAM4
  - One long cable, another short backplane…

Detailed Results – Backplane channels

FCI (balasubramanian_01_0211)

Channel	FCI_CC_Long_Link_Pair_1_to_Pair_9			
Pad capacitance [pF]	0		0.35	
Signaling method	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud
RX signal level [mV]	116	229	63	180
ISI RMS [mV]	3.2	2.6	3.2	5.8
Total Xtalk RMS [mV]	2.6	1.2	1.0	0.9
Jitter-induced noise peak [mV]	47	78	22	67
Total noise RMS [mV]	4.1	2.9	3.3	5.8
SNR [dB]	24.6	34.4	21.8	25.7
Required SNR [dB]	17	24	17	24
Margin [dB]	7.6	10.4	4.8	1.7

FCI (balasubramanian_01_0211)

Channel	FCI_CC_Short_Link_Pair_1_to_Pair_9			
Pad capacitance [pF]	0		0.35	
Signaling method	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud
RX signal level [mV]	646	713	381	627
ISI RMS [mV]	30.6	7.4	53.4	36.1
Total Xtalk RMS [mV]	8.5	3.1	3.2	2.1
Jitter-induced noise peak [mV]	121	145	88	133
Total noise RMS [mV]	31.8	8.0	53.5	36.2
SNR [dB]	24.3	37.0	14.7	22.7
Required SNR [dB]	17	24	17	24
Margin [dB]	7.3	13	-2.3	-1.3

TEC (simulated, shanbhag_02_0411)

Channel	TEC_STRADAWhisper29p8in_Meg6			
Pad capacitance [pF]	0		0.35	
Signaling method	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 Gbaud	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud
RX signal level [mV]	117	221	73.6	189
ISI RMS [mV]	1.9	1.7	2.6	4.2
Total Xtalk RMS [mV]	3.0	3.2	1.5	2.4
Jitter-induced noise peak [mV]	44	70	23	55
Total noise RMS [mV]	3.5	3.6	3.0	4.9
SNR [dB]	26.5	32.5	24.6	28.8
Required SNR [dB]	17	24	17	24
Margin [dB]	9.5	8.5	7.6	4.8

TEC (simulated, shanbhag_02_0411)

Channel	TEC_STRADAWhisper29p8in_Nelco6			
Pad capacitance [pF]	0		0.35	
Signaling method	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud
RX signal level [mV]	45	119	28.7	106
ISI RMS [mV]	1.3	1.7	1.1	2.1
Total Xtalk RMS [mV]	1.2	1.8	0.7	1.4
Jitter-induced noise peak [mV]	14	42	10	32
Total noise RMS [mV]	1.8	2.5	1.3	2.5
SNR [dB]	25.0	29.7	23.3	29.3
Required SNR [dB]	17	24	17	24
Margin [dB]	8	5.7	6.3	5.3

TEC (simulated, shanbhag_02_0411)

Channel	TEC_STRADAWhisper42p8in_Meg6			
Pad capacitance [pF]	0		0.35	
Signaling method	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud
RX signal level [mV]	70	152	42	124
ISI RMS [mV]	1.6	2.0	1.6	2.2
Total Xtalk RMS [mV]	1.8	2.2	0.9	1.7
Jitter-induced noise peak [mV]	20	40	14	41
Total noise RMS [mV]	2.4	3.0	1.9	2.8
SNR [dB]	25.9	31.5	23.4	29.4
Required SNR [dB]	17	24	17	24
Margin [dB]	8.9	7.5	6.4	5.4

TEC (simulated, shanbhag_02_0411)

Channel	TEC_STRADAWhisper42p8in_Nelco6			
Pad capacitance [pF]	0		0.35	
Signaling method	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud
RX signal level [mV]	17.6	70	12.9	59
ISI RMS [mV]	0.9	1.6	1.0	1.5
Total Xtalk RMS [mV]	0.9	1.3	0.5	1.0
Jitter-induced noise peak [mV]	5.9	19	4.5	18
Total noise RMS [mV]	1.3	2.0	1.2	1.8
SNR [dB]	19.4	27.8	17.3	26.8
Required SNR [dB]	17	24	17	24
Margin [dB]	2.4	3.8	0.3	2.8

TEC (measured, shanbhag_01_0511)

Channel	TEC_Whisper27in			
Pad capacitance [pF]	0		0.35	
Signaling method	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud
RX signal level [mV]	110	241	68	206
ISI RMS [mV]	3.4	4.3	3.2	6.2
Total Xtalk RMS [mV]	3.1	2.9	1.5	2.2
Jitter-induced noise peak [mV]	38	79	21	61
Total noise RMS [mV]	4.6	5.2	3.5	6.5
SNR [dB]	24.0	29.9	22.4	26.9
Required SNR [dB]	17	24	17	24
Margin [dB]	7.0	5.9	5.4	2.9

Detailed Results – Cable channels

Molex (bugg_01_0111)

Channel	ZQSFP_nextgen/3m/P1_RX0			
Pad capacitance [pF]	0		0.35	
Signaling method	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud
RX signal level [mV]	150	277	120	334
ISI RMS [mV]	2.8	2.2	11.2	12.5
Total Xtalk RMS [mV]	4.1	3.5	1.8	2.6
Jitter-induced noise peak [mV]	59	84	32	71
Total noise RMS [mV]	5.0	4.1	11.4	12.8
SNR [dB]	25.2	33.4	17.8	26.3
Required SNR [dB]	17	24	17	24
Margin [dB]	8.2	9.4	0.8	2.3

Molex (bugg_01_0111)

Channel	ZQSFP_nextgen/5m/P1_RX0			
Pad capacitance [pF]	0		0.35	
Signaling method	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud
RX signal level [mV]	76	135	47	93
ISI RMS [mV]	2.2	1.6	4.9	3.8
Total Xtalk RMS [mV]	3.4	2.7	1.6	2.0
Jitter-induced noise peak [mV]	22	64	15	48
Total noise RMS [mV]	4.0	3.1	5.1	4.3
SNR [dB]	22.5	27.1	16.0	20.6
Required SNR [dB]	17	24	17	24
Margin [dB]	5.5	3.1	-1.0	-3.4

MC/LEONI (diminico_01_0111)

Note: This data is from measurements of 802.3ba compliant QSFP cable assemblies for the purpose of establishing baseline *noise impairments* beyond those currently specified in 802.3ba, and not for consideration as channels for 25 Gb/s

Channel	1m_QSFP-30AWG/Rx1-Tx1			
Pad capacitance [pF]	0		0.35	
Signaling method	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud
RX signal level [mV]	131	277	139	384
ISI RMS [mV]	4.7	2.3	14.2	12.3
Total Xtalk RMS [mV]	7.9	6.2	4.3	5.1
Jitter-induced noise peak [mV]	53	106	43	84
Total noise RMS [mV]	9.2	6.7	14.8	13.4
SNR [dB]	18.6	28.2	16.2	27.0
Required SNR [dB]	17	24	17	24
Margin [dB]	1.6	4.2	-0.8	3.0

MC/LEONI (diminico_01_0111)

Note: This data is from measurements of 802.3ba compliant QSFP cable assemblies for the purpose of establishing baseline *noise impairments* beyond those currently specified in 802.3ba, and not for consideration as channels for 25 Gb/s

Channel	3m_QSFP-30AWG/Rx1-Tx1			
Pad capacitance [pF]	0		0.35	
Signaling method	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud
RX signal level [mV]	36	136	29	118
ISI RMS [mV]	1.8	1.7	3.0	2.3
Total Xtalk RMS [mV]	3.9	4.0	2.6	3.5
Jitter-induced noise peak [mV]	23	60	14	45
Total noise RMS [mV]	4.3	4.3	3.9	4.2
SNR [dB]	9.5	24.9	11.5	24.9
Required SNR [dB]	17	24	17	24
Margin [dB]	-7.5	0.9	-5.5	0.9

MC/LEONI (diminico_01_0111)

Note: This data is from measurements of 802.3ba compliant QSFP cable assemblies for the purpose of establishing baseline *noise impairments* beyond those currently specified in 802.3ba, and not for consideration as channels for 25 Gb/s

Channel	5m_QSFP-26AWG/Rx1-Tx1			
Pad capacitance [pF]	0		0.35	
Signaling method	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud	PAM2 (NRZ) @ 26 GBaud	PAM4 @ 13 GBaud
RX signal level [mV]	29	121	21	121
ISI RMS [mV]	3.0	2.1	3.8	4.1
Total Xtalk RMS [mV]	3.6	2.7	2.1	2.4
Jitter-induced noise peak [mV]	19	58	12	42
Total noise RMS [mV]	4.7	3.4	4.3	4.7
SNR [dB]	6.5	25.3	6.6	24.5
Required SNR [dB]	17	24	17	24
Margin [dB]	-10.5	1.3	-10.4	0.5

Thank You