Specifying Channels

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Overview

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2. Existing Methods
3. Proposed Method
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Specifying a Channel

In specifying a channel, generally we establish one or more figures of merit, if the figures exceed some standard the channel meets spec. The figures of merit should:

- **Predict with reasonable accuracy, whether or not a channel will work.**
- **Be reasonably easy to use.**
- **Provide the channel designer with feedback on how the channel can be improved.**

Existing Methods

The current methods of specifying a channel are as follows:

1. **Specifying Limits on S Parameters**
2. **StatEye**

Existing Methods (cont.)

Specifying Limits on S Parameters

Does this method meet the requirements for specifying a channel?

Requirement	Result
Predict if a channel will work	Does not predict well without calibration. Even with calibration it may not be accurate.
Easy to use	Very easy to use.
Provide designer feedback	Some feed back.

Existing Methods (cont.)

StatEye

Does this method meet the requirements for specifying a channel?

Requirement	Result
Predict if a channel will work	Should be accurate — potentially a source of calibration for other methods.
Easy to use	Seems to be very daunting.
Provide designer feedback	None.

Proposed Method

Divide channel characteristics into two areas:

1. General Signal Gain
2. Interference

The overall figure of merit should be either the ratio or difference of these two.

Proposed Methods (cont.)

General Signal Gain

General signal gain, called "signal gain," is computed from the following:

1. **SDD21 averaged around Nyquist frequency times 4/pi called "AC gain."**
2. **Ideally terminated peak response to 1 bit time pulse, called "pulse gain."**

Proposed Method (cont.)

Computing Signal Gain

Signal gain can be computed as:

"signal gain" = 0.5* "pulse gain" *(1-"AC gain")/(1-"pulse gain")

over most interesting gain ranges. A derivation and some slides from the channel ad-hoc presentation showing how the derivation works are in the supporting slides.

Proposed Method (cont.)

Interference

This method considers three sources of interference:

1. **Perturbations in the ideally terminated response to a peaked pulse, more than a few bit times after the cursor output.**
2. **Effects of interactions of channel return loss and Tx/Rx mismatch.**
3. **Crosstalk.**

Proposed Method (cont.)

Interference — Perturbations in Pulse Response

Looking at the pulse response in Figure 2, there is a ripple in the tail. The ripple from previous data causes errors in each bit time, with the sign depending on the sign of the earlier data, and the sign of the ripple at that delay. For some data pattern, the errors all add up with the same sign.

I call this worst case sum "self," and it can be computed by sampling the peaked pulse response every bit time after the cursor and summing at absolute values. The first 2 bit times after the cursor are skipped, assuming they are corrected by DFE.

Proposed Method (cont.)

Interference — Interactions of Channel Return Loss with Tx/Rx

The receiver and transmitter do not provide ideal terminations. If the impedance, or equivalently the return loss (magnitude and phase) of both the Tx and Rx, were known in detail, voltage transfer or system Z parameters could be used instead of SDD21.

In general all we know about the Rx and Tx return loss is that the magnitudes will be specified to be below some curve. This will not work.

Instead two discrete double reflections shown in Figure 3 are used.

Proposed Method (cont.)

Interference — Interactions of Channel Return Loss with Tx/Rx

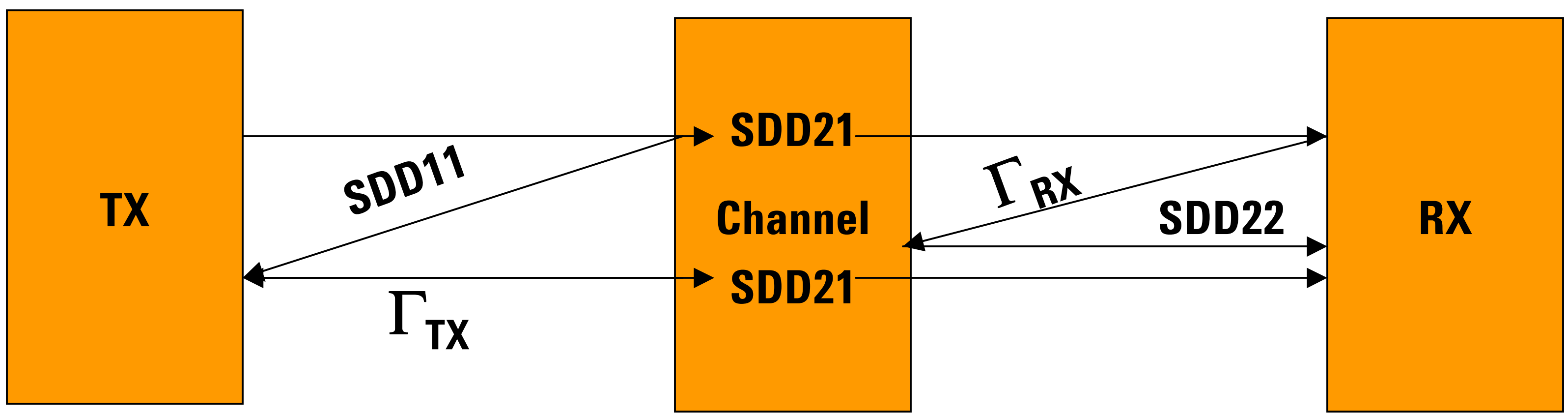


Figure 3: Channel Re-Reflection Metric

Proposed Method (cont.)

Interference — Interactions of Channel Return Loss with Tx/Rx

The following integral was used to find the contributions to interference from transmitter re-reflection and a similar one for receiver re-reflection.

$$\int_{0\,M}^{15\,G} |chS11| \cdot |\Gamma Tx| \cdot |chS21| \cdot 2 \cdot \frac{\sin(\pi f \cdot \tau)}{\pi f} d\,f$$

where ΓTx is the specified maximum Tx reflection coefficient.

and τ is the baud time.

Proposed Method (cont.)

Crosstalk

This was covered in "moore_01_704," pages 37-44. For more details see that presentation or look in the supporting slides.

Proposed Method (cont.)

Summary

Having found the signal gain and the total interference (gain), you can either take the ratio and call it S/N and specify limits on it; or subtract interference (multiplied some scaling factor determined by calibration) from signal to define some nominal EYE opening, allow some margin for noise, etc., and make that the specification.

Proposed Method (cont)

For instance, if:

Signal gain = 0.206

"self" (interference) = 0.071

Re-reflection (interference) = 0.019

Ignore Cross talk

$$S/N = 0.206/(0.071+0.019) = 2.311$$

(these numbers are from the first line of Figure 4 in the supporting slides)

Proposed Method (cont.)

Summary

Applying the same requirements as applied to the existing methods, how well does this method look?

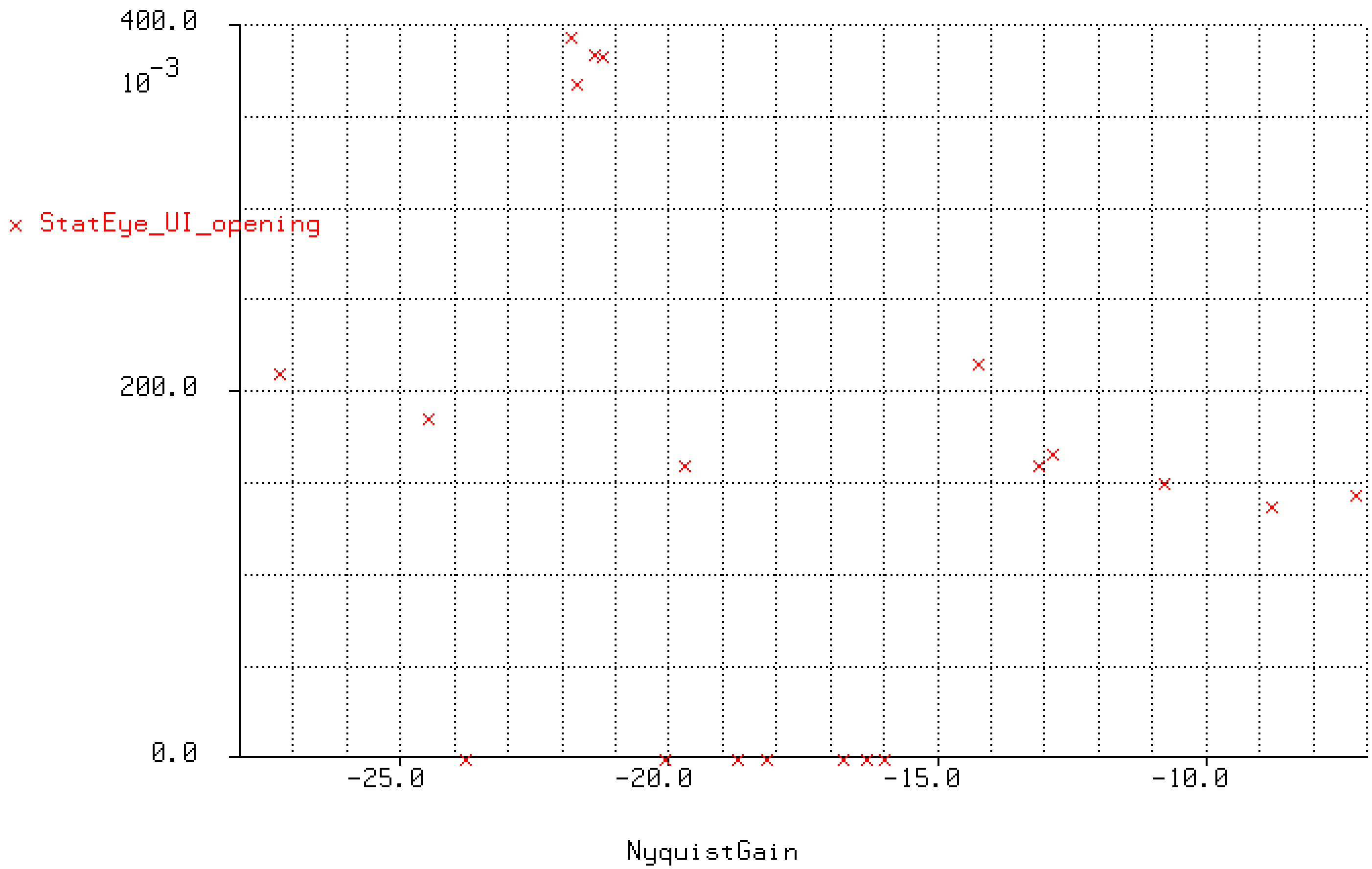
Requirement	Result
Predict if a channel will work	Requires calibration. With calibration, it is accurate enough to be useful.
Easy to use	Fairly easy to use.
Provide designer feedback	Separates gain, reflection, and crosstalk information, which is very useful.

Comparison to StatEye

StatEye simulations were done on a selected set of channels from the IEEE802.3ap channel database by Stephen D. Anderson of Xilinx. The data here represents:

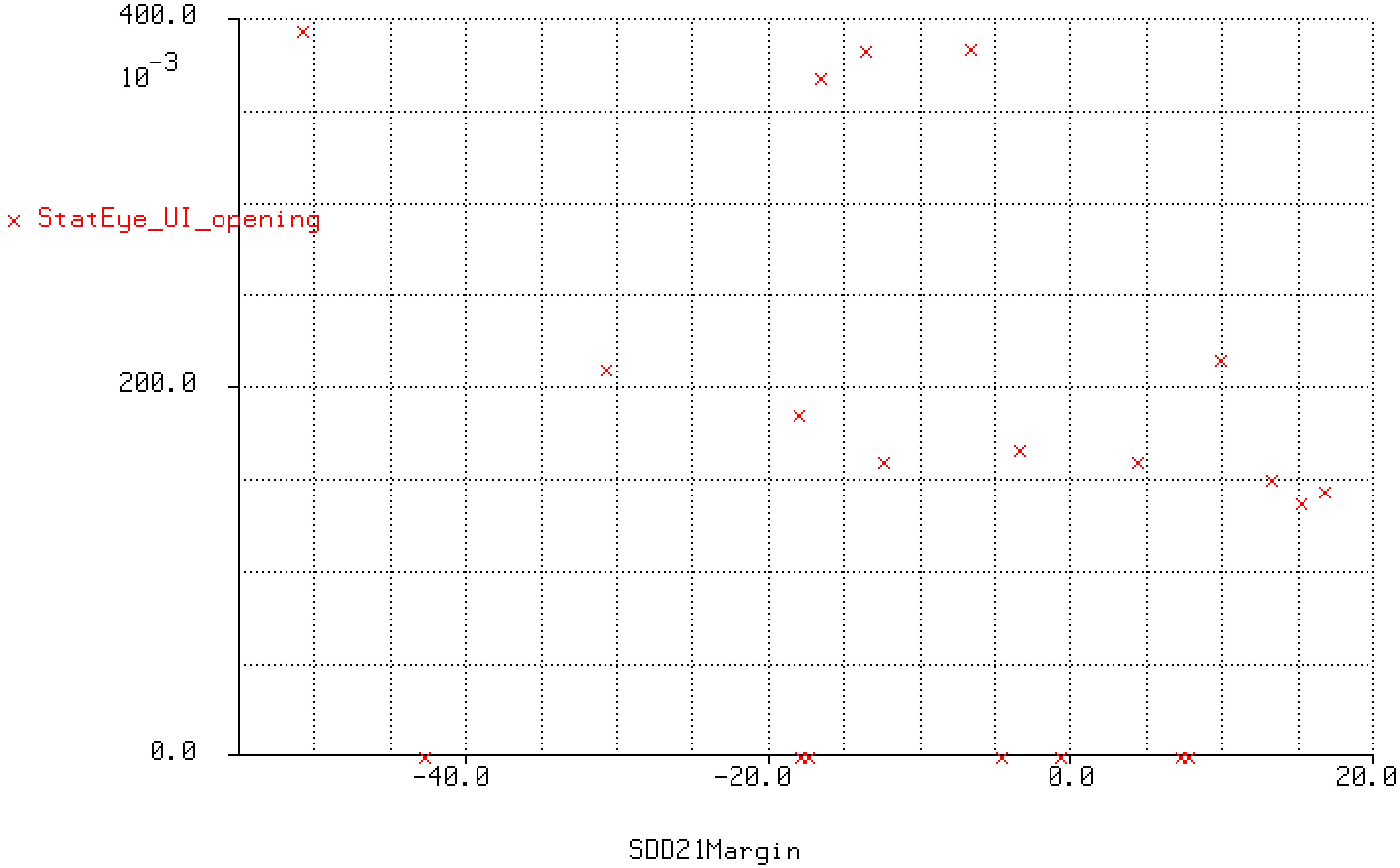
1. **Three tap Transmitter, 2 tap DFE receiver**
2. **Tj = 0.4UI (in a few cases, extrapolated)**
3. **Single cross talk source only, usually the worst available. In a few cases where no cross talk data was available, Stephen used the synthesized cross talk "xtalk_rev6"**
4. **Most cross talk exceeded informative model at least somewhere, none by as much as 8dB.**
5. **No additive noise and no constraint of EYE height.**

Comparison to StatEye



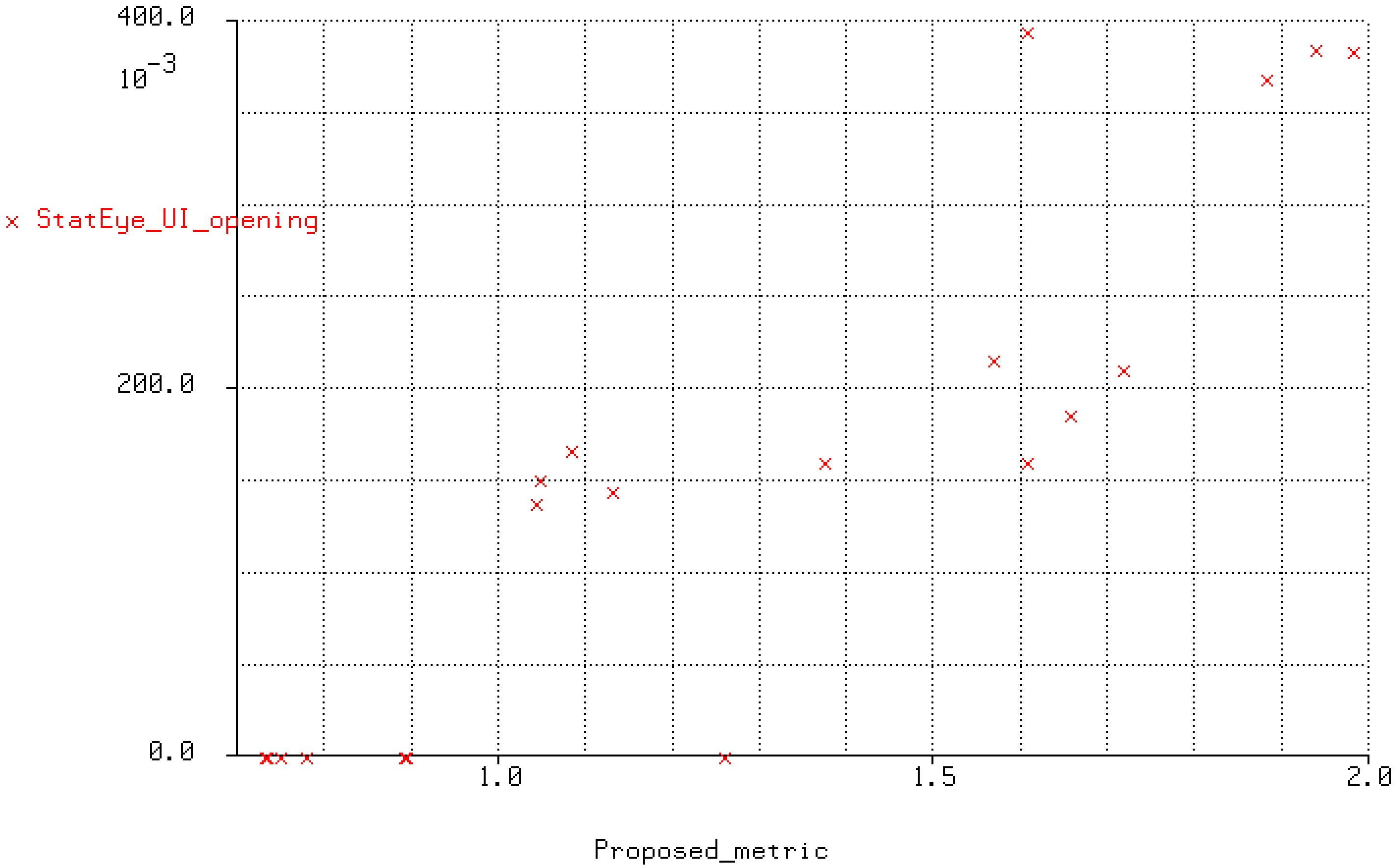
Stat Eye results are essentially un-correlated to gain at Nyquist frequency

Comparison to StatEye



Correlation to margin with respect to informative SDD21 spec is no better

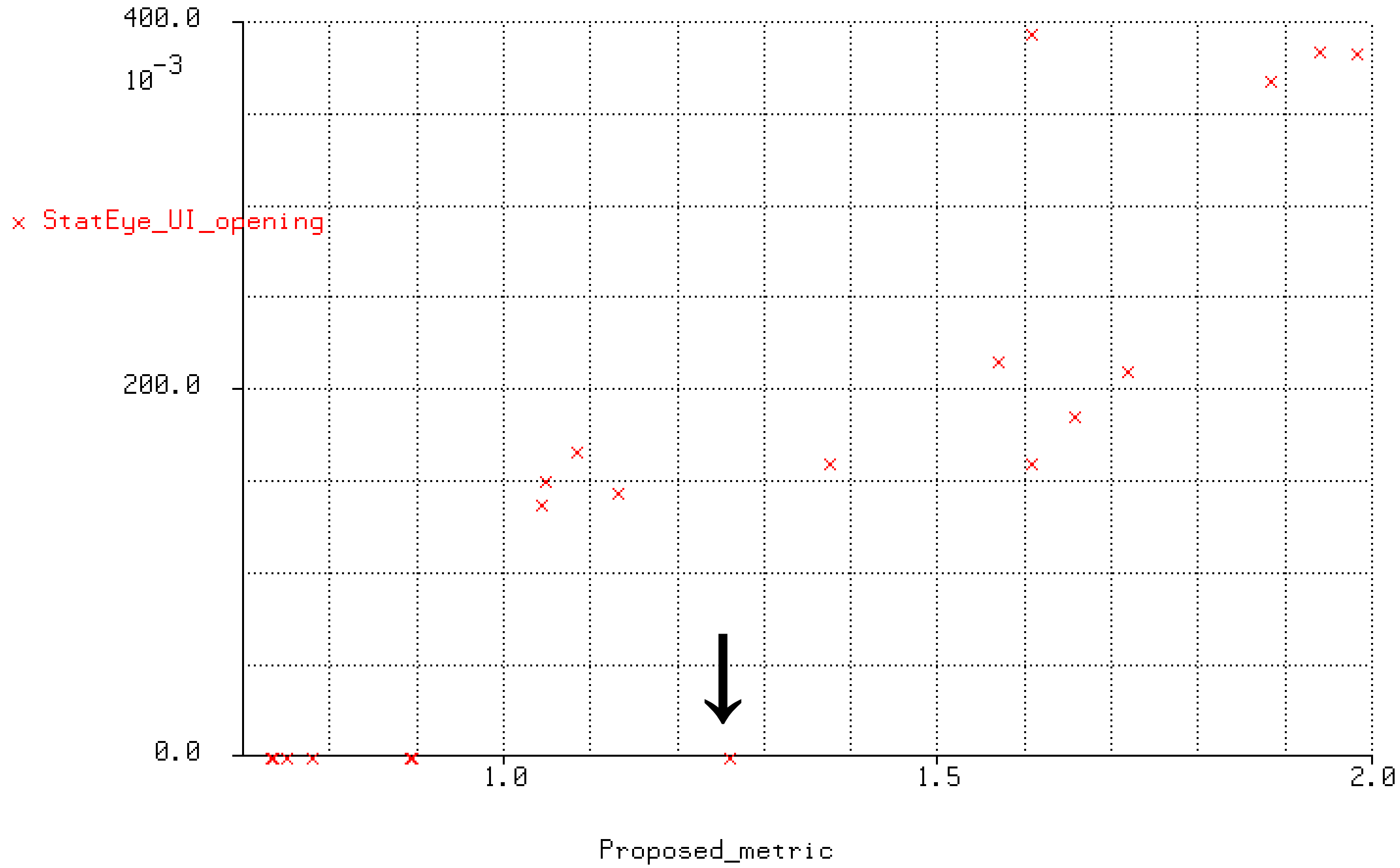
Comparison to StatEye



On the other hand, correlation to proposed metric is pretty good

Proposed metric is "S/N" from slide 16

Comparison to StatEye



Except one point

Conclusions

1. **Simple specifications based on magnitude of SDD21 will be of little value in predicting performance**
2. **Proposed metric does a a fairly good job of predicting horizontal EYE opening**
3. **Proposed metric will predict that bad channels will be good in a small number of cases**
4. **Proposed metric does not predict vertical EYE opening although it would be easy to add that capability**

Future work

1. Investigate the one case where proposed metric gave fairly promising value while Stat Eye showed clear failure
2. Add vertical EYE metric
3. Correlate to results of simulations done to select signaling method

Supporting Slides

The following slides contain additional data computing general signal gain.

Supporting Slides (cont.)

"

if peak = 1

GAINac= "AC gain"

GAINpu= "pulse gain"

GAINsi= "signal gain"

Tap0 = cursor tap of Tx

Tap1 = post-cursor tap of Tx

GAINac = 4*out(Nyquist frequency)/pi

GAINpu = max(out)

select sust such that:

GAINpu * (1+sust) - sust = GAINac

GAINpu - GAINac = sust(1 - GAINpu)

sust = (GAINpu-GAINac)/(1-GAINpu)

if this gives sust < GAINac, then let:

GAINpu * (1+sust) - sust = sust

sust*(2 - GAINpu) = GAINpu

sust = GAINpu /(2-GAINpu)

GAINsi = (GAINac + sust)/2

= (GAINac + (GAINpu-GAINac)/(1-GAINpu))/2

= (GAINac - GAINac*GAINpu + GAINpu - GAINac)/(2*(1-GAINpu))

= GAINpu(1-GAINac)/(2*(1-GAINpu))

= 0.5*GAINpu(1-GAINac)/(1-GAINpu)

if Tap0-Tap1 = 1.0

Tap0+Tap1 = sust

Tap0 = (1+sust)/2

Tap1 = Tap0 - 1

Supporting Slides (cont.)

General Signal Gain — Computing

To compute signal gain, consider the following two plots.

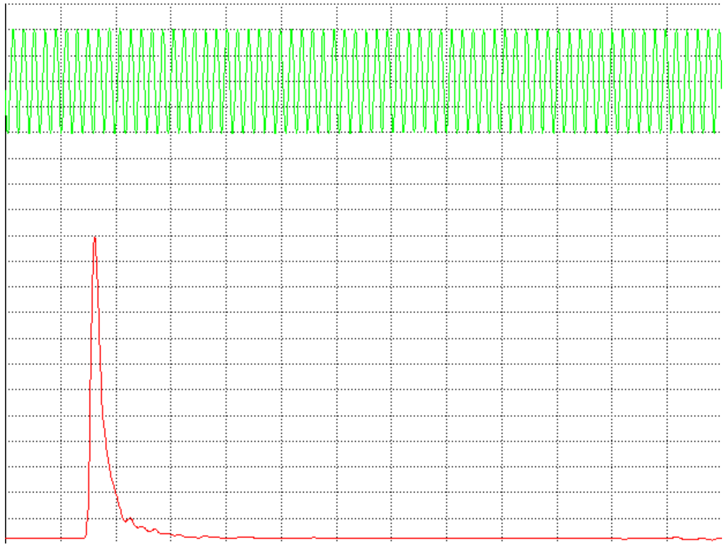


Figure 1:
Response to:
…10101010… & …0000100000…
without Tx Peaking

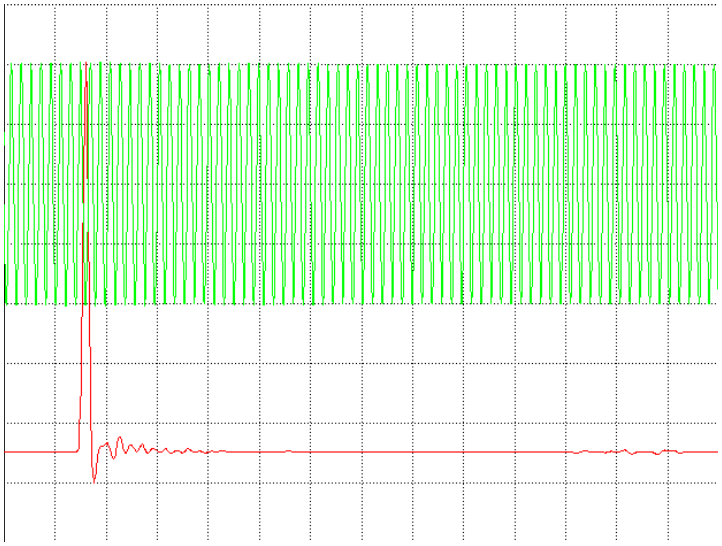


Figure 2:
Response to:
…10101010… & …0000100000…
with Tx Peaking

Supporting Slides (cont.)

General Signal Gain — Computing

In the un-peaked waveform, the isolated 1 does not cross 0 and would not be recognized as a 1.

With peaking, the 0 baseline from which the isolated 1 is raised so the 1 crossed 0 and the EYE is open. The amount of peaking is chosen so that the isolated peak equals the amplitude of the alternating 1–0 pattern.

Note that the tail of the isolated 1 is reduced.

Supporting Slides (cont.)

General Signal Gain — Computing

Even in the peaked case, the baseline of the isolated 1 has a larger absolute value than the 1 itself. A suitably setup DFE increases the amplitude of both the alternating 1–0 pattern and the isolated pulse at the expense to the amplitude of the baseline. If the DFE is set properly, the baseline, the alternating 1–0 pattern and the isolated pulse have the same amplitude. This amplitude is the "signal gain."

Supporting Slides

Crosstalk

This was covered in "moore_01_704," pages 37-44 – with the following excerpts discussed.

"Specify interference in terms of the peak interference caused by a worst–case interfering data pattern. Interference from several channels, including FEXT, NEXT, and self interference is added linearly to get total interference."

Supporting Slides

Crosstalk

"To determine the peak interference caused by a worst–case data pattern::

1. ***Simulate the interference channel with an input of a unit pulse, one baud period long. Include any IEEE802.3ap specified filtering, including low pass at the Tx and Rx, and any specified equalization.***
2. ***Sample the simulated signal at the receiver at the baud rate. Sum the samples.***
3. ***Shift all the sample points later by 0.1 baud period and re-sum. Repeat for all 10 possible shift values and find the largest sum. This is the peak interference. Actual peak interference has to be scaled by the transmitter output amplitude.***
4. ***If, for the worst–case sample point, the signs of the samples are saved in an array, and the array is reversed in order, this give the worst–case data pattern for this interference channel."***

Supporting Slides (Initial Results)

Figure 4 is a chart showing the results of applying the proposed method to 99 channels from the IEEE802.3ap database. This chart:

1. **If for (NRZ) data at 10.3125Gb/s. There is a similar chart for 5.15615Gb/s, but will not be shown today.**
2. **Does not include crosstalk. Due in part to the crosstalk data not being presented in a way as uniform as thru data, which would have made the chart messy.**
3. **As is, it took less than one hour of computer time to generate — which justifies the "fairly easy" claim.**
4. **Does not include channel names, since the focus of this discussion is specification, not channels.**

Supporting Slides (Initial Results cont.)

Decoder for column names:

Column	Description
ns Delay	Delay through path in ns.
Low Freq Gain	Subtracted from high frequency gain in estimating EYE opening.
Nyquist Gain	Gain at ½ baud rate.
SDD21 Margin	Margin by which SDD21 parameter passes (positive) or fails (negative) the informative SDD21 line at worst frequency.
AC Gain	Gain averaged near Nyquist frequency, relative to low frequency gain.
Pulse Gain	Peak response to a one-bit time unit pulse, relative to low frequency gain.
Signal Gain	Estimate of EYE opening without interference effects, relative to low frequency gain.
Sust	Tx output for long runs of bits, relative to peak output.
pkf	Indication (if it is 1) an alternate (low loss) EYE estimate algorithm is used.
Tx Tap 0	Tx cursor tap value used in estimating EYE.
Tx Tap 1	Tx post-cursor tap values used in estimating EYE. $\lvert$Tx Tap 0$\rvert$ + $\lvert$Tx Tap 1$\rvert$ = 1.0
Self	Self interference due to perturbations in tail of pulse response.
Re-Reflect	Interference due to Tx and Rx re-reflections.
Noise/Signal	Total (self + re-reflection) interference divided by signal gain.
Signal/Noise	Signal gain divided by total interference.

Supporting Slides (Initial Results cont.)

ns delay	lowFreq Gain	Nyquist Gain	SDD21 margin	AC gain	Pulse gain	Signal Gain	Sust	pkf	Tx Tap0	Tx Tap1	self	re-reflect	noise/signal	signal/noise
6.56	-1.01dB	-21.27dB	-13.65dB	0.124	0.320	0.206	0.289	0	0.645	-0.355	0.071	0.019	0.433	2.311
5.59	-0.97dB	-19.73dB	0.45dB	0.147	0.333	0.213	0.279	0	0.639	-0.361	0.071	0.022	0.439	2.280
6.56	-1.03dB	-21.41dB	-6.70dB	0.122	0.320	0.207	0.292	0	0.646	-0.354	0.073	0.018	0.444	2.253
6.89	-1.17dB	-24.50dB	-18.13dB	0.087	0.272	0.170	0.254	0	0.627	-0.373	0.064	0.012	0.447	2.237
7.09	-1.37dB	-27.28dB	-30.84dB	0.065	0.250	0.156	0.247	0	0.624	-0.376	0.061	0.009	0.449	2.227
6.55	-1.01dB	-21.75dB	-16.66dB	0.117	0.315	0.203	0.289	0	0.644	-0.356	0.074	0.019	0.458	2.184
3.92	-0.59dB	-14.27dB	0.80dB	0.264	0.445	0.296	0.328	0	0.664	-0.336	0.109	0.036	0.491	2.038
6.58	-3.33dB	-21.86dB	-50.89dB	0.151	0.412	0.298	0.444	0	0.722	-0.278	0.160	0.010	0.571	1.752
2.46	-0.33dB	-13.14dB	-12.52dB	0.292	0.542	0.419	0.546	0	0.773	-0.227	0.189	0.062	0.598	1.673
6.56	-1.02dB	-38.23dB	-44.00dB	0.018	0.281	0.192	0.367	0	0.684	-0.316	0.114	0.006	0.622	1.608
6.50	-0.76dB	-21.63dB	-43.76dB	0.115	0.312	0.201	0.286	0	0.643	-0.357	0.092	0.036	0.638	1.568
3.77	-0.56dB	-18.20dB	-42.80dB	0.167	0.405	0.283	0.400	0	0.700	-0.300	0.144	0.037	0.641	1.561
6.56	-1.04dB	-38.32dB	-35.22dB	0.017	0.286	0.197	0.376	0	0.688	-0.312	0.111	0.017	0.653	1.532
5.35	-0.72dB	-17.91dB	0.70dB	0.176	0.346	0.218	0.260	0	0.630	-0.370	0.104	0.039	0.658	1.519
3.05	-0.39dB	-11.07dB	1.05dB	0.372	0.508	0.356	0.340	1	0.670	-0.330	0.162	0.072	0.659	1.517
7.11	-0.86dB	-26.15dB	-36.69dB	0.069	0.286	0.186	0.303	0	0.652	-0.348	0.096	0.029	0.670	1.493
3.53	-0.44dB	-12.75dB	0.99dB	0.309	0.478	0.316	0.324	0	0.662	-0.338	0.148	0.063	0.670	1.493
6.55	-1.06dB	-37.84dB	-27.28dB	0.019	0.283	0.194	0.369	0	0.685	-0.315	0.114	0.017	0.672	1.488
6.55	-1.00dB	-38.14dB	-43.03dB	0.018	0.282	0.193	0.368	0	0.684	-0.316	0.115	0.017	0.687	1.455
6.55	-0.76dB	-32.78dB	-35.77dB	0.032	0.284	0.192	0.352	0	0.676	-0.324	0.103	0.029	0.689	1.452
5.68	-0.76dB	-18.33dB	0.67dB	0.169	0.336	0.210	0.252	0	0.626	-0.374	0.108	0.038	0.690	1.449
2.09	-0.23dB	-8.36dB	1.18dB	0.499	0.600	0.464	0.428	1	0.714	-0.286	0.219	0.102	0.692	1.444
4.15	-0.55dB	-14.59dB	0.87dB	0.253	0.427	0.279	0.304	0	0.652	-0.348	0.141	0.053	0.695	1.440
6.12	-0.83dB	-19.75dB	0.51dB	0.144	0.308	0.190	0.236	0	0.618	-0.382	0.098	0.034	0.696	1.437
4.63	-0.58dB	-16.09dB	0.84dB	0.214	0.367	0.228	0.242	0	0.621	-0.379	0.113	0.046	0.698	1.433
4.88	-0.64dB	-16.55dB	0.79dB	0.204	0.374	0.238	0.272	0	0.636	-0.364	0.123	0.044	0.703	1.423
3.20	-0.38dB	-11.55dB	1.02dB	0.352	0.483	0.335	0.318	1	0.659	-0.341	0.162	0.075	0.707	1.415
4.71	-0.64dB	-15.84dB	0.79dB	0.221	0.388	0.247	0.272	0	0.636	-0.364	0.124	0.053	0.714	1.400
4.61	-0.50dB	-16.64dB	-11.18dB	0.199	0.387	0.253	0.307	0	0.653	-0.347	0.133	0.055	0.741	1.350
4.68	-0.55dB	-28.35dB	-28.91dB	0.052	0.341	0.245	0.438	0	0.719	-0.281	0.142	0.040	0.744	1.345
5.22	-0.65dB	-21.17dB	-37.06dB	0.120	0.356	0.244	0.367	0	0.684	-0.316	0.141	0.043	0.755	1.324
4.62	-0.60dB	-16.30dB	0.82dB	0.209	0.376	0.239	0.269	0	0.634	-0.366	0.127	0.055	0.762	1.312
4.90	-0.61dB	-17.49dB	0.81dB	0.183	0.371	0.241	0.300	0	0.650	-0.350	0.132	0.053	0.767	1.304
4.65	-0.61dB	-16.83dB	0.83dB	0.197	0.378	0.244	0.291	0	0.646	-0.354	0.130	0.057	0.767	1.303
4.65	-0.61dB	-16.80dB	0.83dB	0.197	0.378	0.244	0.290	0	0.645	-0.355	0.130	0.057	0.768	1.302
2.40	-0.30dB	-13.08dB	-14.22dB	0.292	0.536	0.409	0.525	0	0.762	-0.238	0.228	0.087	0.771	1.296
5.36	-0.69dB	-18.61dB	0.74dB	0.162	0.345	0.221	0.279	0	0.640	-0.360	0.129	0.048	0.803	1.245
4.15	-0.52dB	-15.45dB	0.89dB	0.228	0.415	0.274	0.320	0	0.660	-0.340	0.157	0.063	0.804	1.244
3.19	-0.33dB	-12.90dB	-3.51dB	0.300	0.476	0.318	0.337	0	0.668	-0.332	0.181	0.075	0.805	1.242
4.15	-0.52dB	-15.48dB	0.90dB	0.228	0.415	0.274	0.320	0	0.660	-0.340	0.157	0.063	0.806	1.241
1.44	-0.13dB	-7.25dB	1.25dB	0.560	0.630	0.510	0.459	1	0.730	-0.270	0.288	0.125	0.810	1.234
3.30	-0.38dB	-23.94dB	-20.07dB	0.085	0.388	0.291	0.497	0	0.748	-0.252	0.184	0.053	0.815	1.227
2.08	-0.23dB	-8.77dB	1.18dB	0.476	0.588	0.447	0.417	1	0.708	-0.292	0.255	0.110	0.816	1.225
4.75	-0.61dB	-16.55dB	0.83dB	0.203	0.378	0.243	0.282	0	0.641	-0.359	0.142	0.057	0.822	1.217
2.08	-0.25dB	-8.78dB	1.18dB	0.477	0.593	0.449	0.422	1	0.711	-0.289	0.261	0.110	0.826	1.210
6.14	-0.79dB	-20.89dB	-0.73dB	0.126	0.300	0.187	0.249	0	0.624	-0.376	0.115	0.040	0.827	1.209
3.86	-0.47dB	-17.44dB	-22.87dB	0.181	0.425	0.303	0.426	0	0.713	-0.287	0.195	0.057	0.829	1.206
5.70	-0.74dB	-19.61dB	-0.30dB	0.145	0.334	0.215	0.284	0	0.642	-0.358	0.135	0.043	0.831	1.203
3.19	-0.39dB	-15.28dB	-9.66dB	0.229	0.471	0.342	0.456	0	0.728	-0.272	0.219	0.068	0.837	1.195
2.11	-0.27dB	-11.37dB	-13.33dB	0.355	0.556	0.405	0.454	0	0.727	-0.273	0.254	0.091	0.852	1.174
3.18	-0.37dB	-12.34dB	1.03dB	0.321	0.483	0.320	0.318	1	0.659	-0.341	0.191	0.082	0.854	1.171
2.55	-0.26dB	-10.80dB	1.12dB	0.378	0.533	0.371	0.364	1	0.682	-0.318	0.226	0.090	0.854	1.171
3.18	-0.42dB	-12.36dB	1.03dB	0.322	0.485	0.321	0.320	1	0.660	-0.340	0.192	0.082	0.855	1.170
3.19	-0.41dB	-12.09dB	1.00dB	0.332	0.494	0.330	0.328	1	0.664	-0.336	0.201	0.085	0.866	1.155
3.52	-0.43dB	-13.56dB	0.99dB	0.281	0.454	0.299	0.317	0	0.659	-0.341	0.188	0.073	0.871	1.148
3.52	-0.45dB	-13.55dB	0.97dB	0.282	0.456	0.300	0.319	0	0.659	-0.341	0.189	0.073	0.871	1.148
1.74	-0.16dB	-8.82dB	1.22dB	0.470	0.602	0.450	0.431	1	0.715	-0.285	0.280	0.114	0.876	1.142
2.09	-0.27dB	-8.41dB	1.15dB	0.499	0.602	0.465	0.431	1	0.715	-0.285	0.293	0.117	0.881	1.135
4.15	-0.56dB	-14.84dB	0.87dB	0.246	0.419	0.272	0.298	0	0.649	-0.351	0.175	0.065	0.883	1.133
3.04	-0.39dB	-12.21dB	1.04dB	0.326	0.488	0.325	0.323	1	0.662	-0.338	0.208	0.081	0.891	1.122

Figure 4: Proposed Specification Method

Supporting Slides (Initial Results cont.)

ns delay	lowFreq Gain	Nyquist Gain	SDD21 margin	AC gain	Pulse gain	Signal Gain	Sust	pkf	Tx Tap0	Tx Tap1	self	re-reflect	noise/signal	signal/noise
3.04	-0.38dB	-12.20dB	1.04dB	0.327	0.488	0.325	0.323	1	0.661	-0.339	0.209	0.081	0.893	1.119
5.13	-0.70dB	-18.93dB	-0.53dB	0.156	0.334	0.211	0.267	0	0.633	-0.367	0.149	0.041	0.900	1.112
4.00	-0.52dB	-15.07dB	0.89dB	0.238	0.423	0.279	0.320	0	0.660	-0.340	0.192	0.060	0.900	1.111
6.68	-0.90dB	-23.10dB	-4.42dB	0.099	0.282	0.177	0.255	0	0.628	-0.372	0.133	0.029	0.909	1.100
4.71	-0.61dB	-16.43dB	0.80dB	0.206	0.371	0.234	0.261	0	0.631	-0.369	0.156	0.057	0.913	1.095
5.18	-0.66dB	-19.68dB	-0.95dB	0.143	0.331	0.212	0.281	0	0.641	-0.359	0.149	0.046	0.918	1.089
2.93	-0.37dB	-12.32dB	1.05dB	0.322	0.480	0.319	0.316	1	0.658	-0.342	0.212	0.082	0.923	1.084
6.12	-0.81dB	-20.52dB	-1.63dB	0.132	0.306	0.192	0.252	0	0.626	-0.374	0.135	0.043	0.928	1.078
4.77	-0.63dB	-17.97dB	-0.41dB	0.173	0.357	0.230	0.287	0	0.643	-0.357	0.165	0.048	0.928	1.077
4.88	-0.68dB	-18.81dB	0.08dB	0.158	0.339	0.216	0.273	0	0.637	-0.363	0.143	0.058	0.934	1.071
2.63	-0.31dB	-22.50dB	-19.55dB	0.099	0.417	0.322	0.546	0	0.773	-0.227	0.242	0.060	0.937	1.067
3.53	-0.46dB	-12.99dB	0.98dB	0.301	0.458	0.299	0.297	1	0.649	-0.351	0.199	0.083	0.941	1.063
5.92	-0.78dB	-22.06dB	-1.78dB	0.110	0.304	0.194	0.278	0	0.639	-0.361	0.144	0.039	0.942	1.062
5.36	-0.73dB	-18.53dB	-1.58dB	0.164	0.333	0.209	0.254	0	0.627	-0.373	0.146	0.052	0.948	1.055
2.93	-0.36dB	-13.33dB	1.07dB	0.286	0.474	0.322	0.358	0	0.679	-0.321	0.221	0.087	0.954	1.048
4.02	-0.53dB	-16.01dB	0.90dB	0.214	0.398	0.260	0.305	0	0.653	-0.347	0.189	0.059	0.956	1.047
5.60	-0.73dB	-21.06dB	-2.46dB	0.123	0.323	0.209	0.295	0	0.648	-0.352	0.156	0.044	0.957	1.045
6.70	-0.89dB	-23.82dB	-4.66dB	0.091	0.272	0.170	0.249	0	0.624	-0.376	0.130	0.033	0.963	1.039
3.97	-0.53dB	-13.95dB	0.88dB	0.272	0.432	0.277	0.282	0	0.641	-0.359	0.195	0.073	0.969	1.032
5.56	-0.70dB	-20.32dB	-1.87dB	0.133	0.312	0.197	0.260	0	0.630	-0.370	0.153	0.040	0.978	1.022
5.67	-0.76dB	-19.16dB	-2.42dB	0.153	0.326	0.205	0.257	0	0.628	-0.372	0.154	0.048	0.986	1.014
3.99	-0.50dB	-14.28dB	0.93dB	0.260	0.413	0.260	0.260	1	0.630	-0.370	0.189	0.068	0.989	1.011
2.94	-0.38dB	-12.59dB	1.06dB	0.312	0.480	0.317	0.323	0	0.661	-0.339	0.224	0.092	0.996	1.004
4.03	-0.53dB	-15.21dB	0.91dB	0.235	0.409	0.265	0.294	0	0.647	-0.353	0.211	0.054	1.002	0.998
3.04	-0.43dB	-11.43dB	1.01dB	0.359	0.493	0.343	0.327	1	0.663	-0.337	0.257	0.087	1.003	0.997
5.87	-0.77dB	-20.62dB	-1.54dB	0.130	0.296	0.183	0.236	0	0.618	-0.382	0.151	0.035	1.016	0.984
1.55	-0.18dB	-16.01dB	-17.39dB	0.206	0.475	0.359	0.511	0	0.756	-0.244	0.282	0.084	1.021	0.980
1.84	-0.21dB	-20.09dB	-17.96dB	0.129	0.461	0.372	0.615	0	0.808	-0.192	0.309	0.071	1.023	0.978
5.15	-0.66dB	-19.56dB	-1.60dB	0.145	0.325	0.206	0.267	0	0.633	-0.367	0.170	0.049	1.063	0.941
4.03	-0.51dB	-16.16dB	0.92dB	0.210	0.400	0.263	0.316	0	0.658	-0.342	0.216	0.064	1.066	0.938
4.01	-0.52dB	-16.63dB	0.66dB	0.199	0.389	0.255	0.311	0	0.655	-0.345	0.208	0.067	1.076	0.929
4.78	-0.65dB	-18.24dB	-1.21dB	0.168	0.357	0.231	0.293	0	0.646	-0.354	0.197	0.057	1.103	0.907
4.03	-0.51dB	-16.77dB	0.78dB	0.196	0.371	0.238	0.279	0	0.640	-0.360	0.199	0.063	1.104	0.906
5.56	-0.74dB	-20.70dB	-3.04dB	0.128	0.315	0.200	0.273	0	0.636	-0.364	0.174	0.049	1.113	0.899
4.78	-0.60dB	-18.74dB	-0.80dB	0.158	0.341	0.218	0.278	0	0.639	-0.361	0.190	0.053	1.115	0.897
4.05	-0.51dB	-16.35dB	0.93dB	0.206	0.398	0.263	0.320	0	0.660	-0.340	0.242	0.061	1.154	0.867
6.64	-0.88dB	-23.57dB	-5.56dB	0.093	0.272	0.170	0.246	0	0.623	-0.377	0.159	0.037	1.155	0.866
5.88	-0.79dB	-21.09dB	-2.47dB	0.123	0.294	0.183	0.242	0	0.621	-0.379	0.170	0.042	1.159	0.863
5.34	-6.31dB	-22.22dB	-6.07dB	0.204	0.332	0.202	0.199	1	0.600	-0.400	0.175	0.079	1.259	0.794

Figure 4: Proposed Specification Method (cont.)