Improvements to the dibit gain--SN method presented in moore_01_0311

Author Charles Moore, Avago Technologies

Supporters:

Brian Misek	Avago Technologies

A year ago Adam Healey and I presented a proposal to the study group for a method evaluating channels. Since then I have used the method to evaluate all of the channels submitted to the study group and the task force and presented the results to the group.

I have become aware of a number of problems with the method as presented and want to propose fixes for at least some of them:

1 The method seems to be pessimistic, it leave too much margin on the table.
2 No explicit allowance was made for slicer margin
3 Insertion loss fitting sometimes gave aberrant results
4 No allowance was made for DFE correction of near time ILD noise
5 The way it handles PAM4 is somewhat unclear
6 It is hard to compute

1. Method pessimism:

The degree to which the method is pessimistic or optimistic is primarily set by the values of the implementation penalties. For the initial draft I recommend that we use TBD for these parameters, at least until we can calibrate values versus accurate simulations.

Until values are found, for my own channel estimates I will use the values:

$$implementation\ noise\ factor = 0.010 \cdot A_t \sqrt{(g_{dibit})} \qquad was\ 0.024 \cdot A_t \sqrt{(g_{dibit})}$$

$$implementation\ gain\ factor = 0.850 \qquad was\ 0.667$$

Note:

A_t is the peak transmitted amplitude

g_{dibit} is dibit gain

2. No explicit allowance was made for slicer margin:

We should subtract a value called slicer margin from the A_s in the Signal to Noise calculation. I recommend that the value for NRZ case be TBD pending calibration with accurate simulation. Assuming that PAM4 will use an ADC and DSP and will have no explicit analog slicer I recommend that the PAM4 slicer margin be 0. The fact that an ADC is used will add quantization noise which will increase implementation noise but not show a dead band as slicer margin does.

Until values are found, for my own channel estimates I will use the values:

$$\textit{Slicer margin} = 10\text{mV} \qquad \text{for NRZ}$$
$$\textit{Slicer margin} = 0\text{mV} \qquad \text{for PAM4}$$

Note:

A_s is available signal

3. Insertion loss fitting sometimes gave aberrant results

Mike Dudek pointed out to me that when OIF does insertion loss fitting it puts limits on the allowed values of the parameters. I have also noticed that sometimes the insertion loss fitting gave positive values for that real part of a4. This usually resulted in a very bad fit at high frequency and a fitted insertion loss which will become a gain at some frequency, which is un-physical. Therefore I recommend that we follow OIF's lead and that if real(a4)>0 we force a4=0 and re-fit using only a0, a1, and a2.

4. No allowance was made for DFE correction of near time ILD noise

Explicitly adding a DFE should make the evaluation more optimistic and more realistic as well. This is pretty straightforward, I recommend that the calculation as follows:

1. Find ILD and extend it to DC with 0 values
2. Weight ILD with W_{ild}

$$W_{ILD} = \frac{\sin(\pi \cdot f / f_b)}{\pi \cdot f / f_b} \cdot \frac{A_t}{\sqrt{(1+(f/f_t)^4)}} \cdot \frac{1}{\sqrt{(1+(f/f_r)^8)}}$$

3. Perform a DFT on the weighted ILD function scaled so Parseval's theorem is not violated. This gives the ILD pulse function.
4. Find thru delay, τ_e, by the method described in moore_01_0311.pdf slide 20 equation A.3.
5. Multiply the ILD pulse functions by E_{DFE} from $t = 0$ to $(\tau_e + N_{DFE}) \cdot UI$
6. Find

$$Noise_{ILD} = \sqrt{\int_0^{100\text{n}} \frac{ILD_s^2}{UI} \cdot dt}$$

I recommend:

E_{DFE} =TBD

N_{DFE} =TBD

Until values are found, for my own channel estimates I will use the values:

E_{DFE} =0

N_{DFE} =8

Note: on previous slide:

A_t is the peak transmitted amplitude

f_b is baud rate

f_t is transmitter 3 dB frequency

f_b is receiver 3 dB frequency

τ_e is channel delay in UI

5. The way it handles PAM4 is somewhat unclear

In moore_01_0311.pdf we said that the required Signal to Noise ratio for PAM4 was

$$SNR_{PAM4} = SNR_{NRZ} \cdot \sqrt{\frac{4^2 - 1}{3}} = SNR_{NRZ} \cdot \sqrt{5}$$

(modified somewhat from equation on slide 15)

I find this confusing to work with since it says that PAM4 needs a higher SNR to reach the same BER when it seems intuitive to me that it should need the same SNR. In my opinion this can be fixed by dividing the available signal for PAM4 by 3 and dividing the noise by $3/\sqrt{5}$. In that case PAM4 would need the same SNR as NRZ to reach the same BER.

The division by 3 for signal level is commonly used. It is due to the 3 eyes of PAM4 being 1/3 as large as the single NRZ eye for the same peak amplitude. The factor of $3/\sqrt{5}$ because all the noise we evaluate comes from interference from signals of the same type and the RMS level of a PAM4 signal is $3/\sqrt{5}$ times smaller than the RMS of a NRZ signal for the same peak amplitude.

6. It is hard to compute

I intend to fix this by making available to the group a tool which will evaluate channels and save the results. This will be an updated version of the tool I used to evaluate all of the channels submitted to the group. At the time I am writing this I do not have it available but I anticipate having it in time for the March Plenary, if not shortly after. What I will provide is a zip file which will contain instructions, a linux executable, a windows executable, a sample control file, and sample channel data.