MTTFPA (Mean Time to False Packet Accept) for a DFE Design

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Process

- Given: Raw target BER=1e-15 and a DFE5
- Determine conditional probabilities of propagating errors
- Relate those probabilities to criteria which corresponds to the life time of the universe
- The below equation represents the probabilities of propagating errors
- From the original PDF of the noise, we can calculate new PDFs including addition of the binary noise terms.
  - We assume that an error occurs when the noise level exceeds $\frac{A_S}{10^{\frac{COM\_threshold}{20}}}$.
  - So the COM threshold affects the expected BER of a channel (we don't always use 1e-15!) and the probabilities of error propagation.
  - From the original PDF of the noise, we can calculate new PDFs including addition of the binary noise terms
  - This is the same as adding a Dual Dirac of noise associated with that sign reversal
  - Next slides will graphically illustrate how we implemented in COM code

Calculation Details

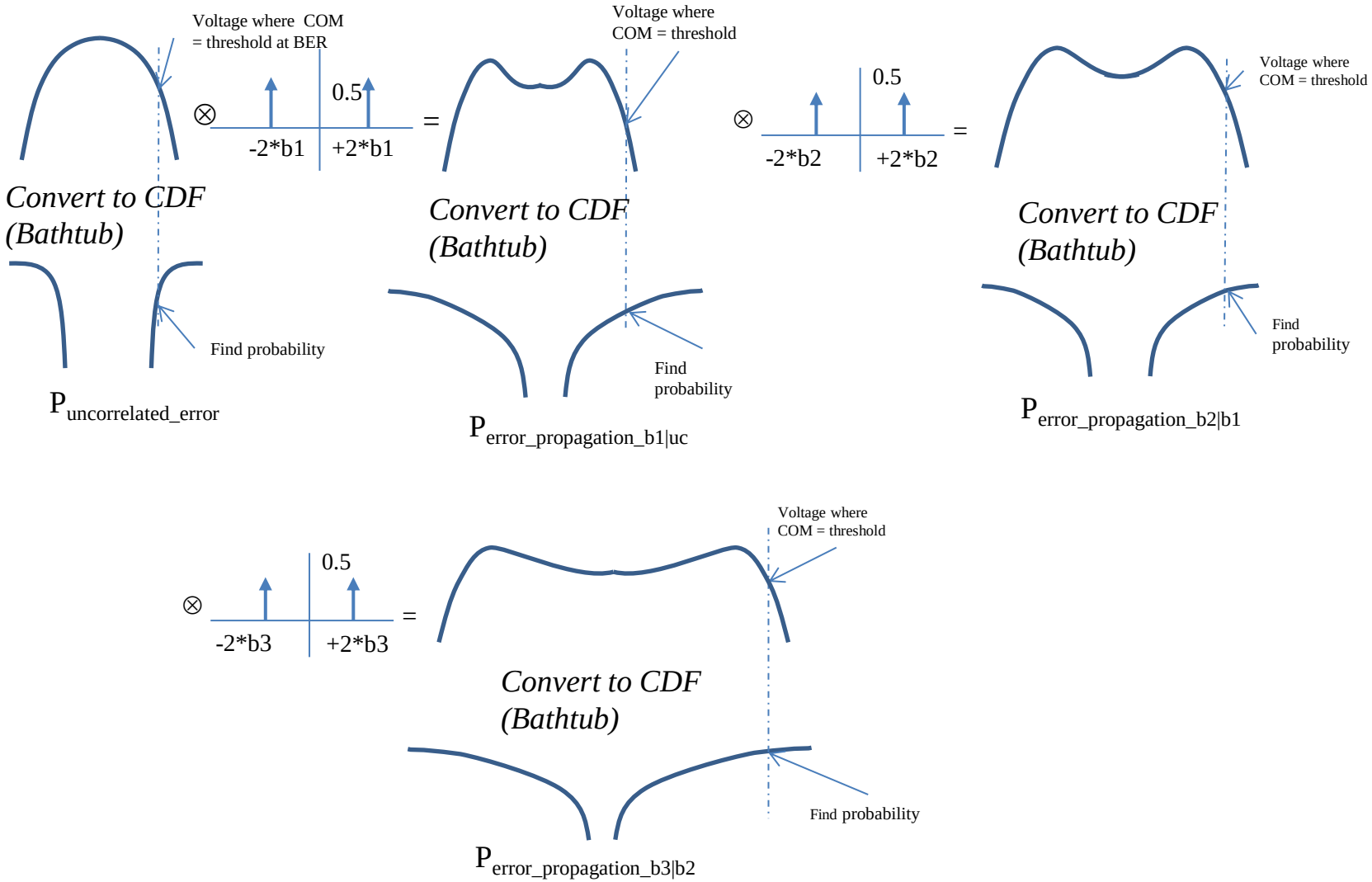
Conditional probabilities of DFE propagated burst errors are found with recursive convolution of respective PDFs

$$\begin{cases} i = 1, \;\; P_{k-ndfe-1} = BER \;\; and\; defined\; PDF_{k-ndfe-1}\; as \;\; found\; in\; Clause\; 93a \\ i = 2{:}\, ndfe\,, \{P_{k-ndfe-i} | P_{k-ndfe-i-1}\} = \int_{COM_{threshold}}^{\infty} \left(conv\{PDF_{k-ndfe-i} | PDF_{k-ndfe-i-1}\}, DDirac(A_s 2b_i) \right) \end{cases}$$

The probability a DFE propagated burst error is the product of the conditional probabilities

$$P_{nburst} = P_{k-ndfe-1} \prod_{i=1}^{nburst-1} \{P_{k-ndfe-i} | P_{k-ndfe-i-1}\}$$

Graphic Illustration



Probability of 4 bit burst errors caused by DFE

$P_{burst\_of\_4} = P_{uncorrelated\_error} * P_{error\_propagation\_b1|uncorrelated\_error} * P_{error\_propagation\_b2|b1} * P_{error\_propagation\_b3|b2} * P_{error\_propagation\_b4|b3}$

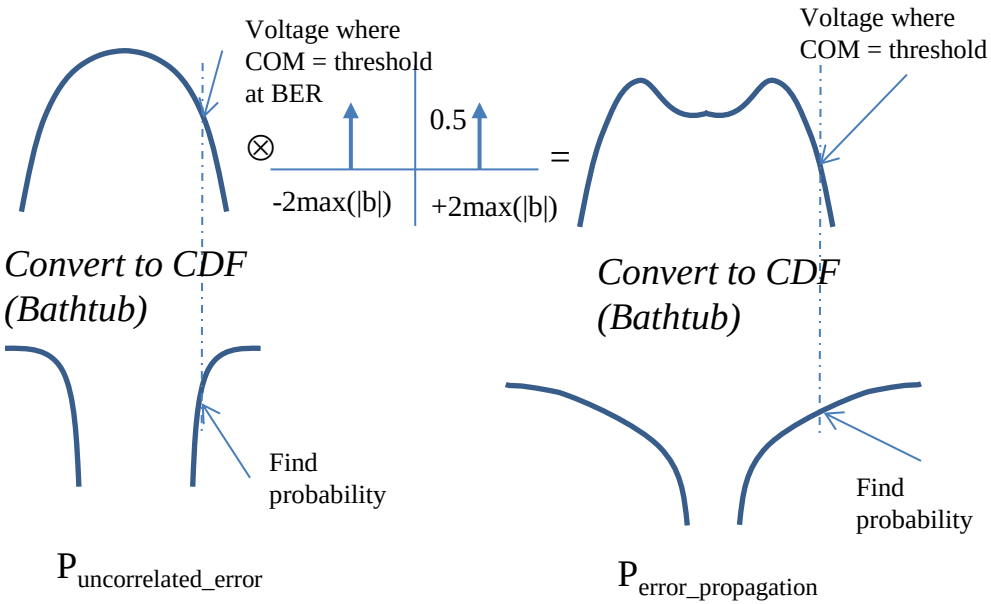
Compare to lifetime of the universe ~ 1.3e10 years

< ~1.0162e-19

(60*60*24*365*4*1.3*10^10/38.8e-12)^-1*2^32)

This number should be refined

Simple Approximation



This reduces the 3 different error propagation probabilities to a single number, as was done in previous analysis. (anslow_03_0913_optx , cideciyan_01_0112)

$$P_{burst\_of\_4} = P_{uncorrelated\_error} * P_{error\_propagation}^{3}$$

Compare to lifetime of the universe ~ 1.3e10 years

< ~1.0162e-19

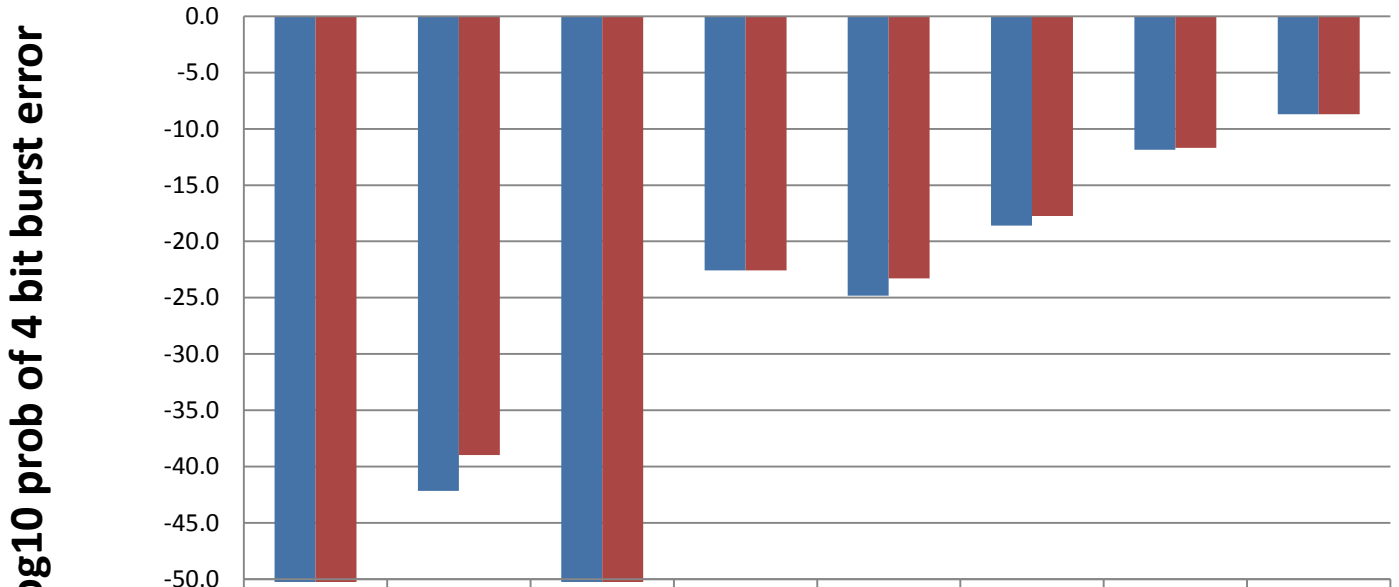
(60*60*24*365*4*1.3*10^10/38.8e-12)^-1*2^32), This number should be refined

Channel Evaluation with DFE5

- 12mm and 30 mm package used in these experiments
- Vary COM threshold to determine MTTFPA impact
  - COM threshold affects BER and error propagation probability in this analysis.

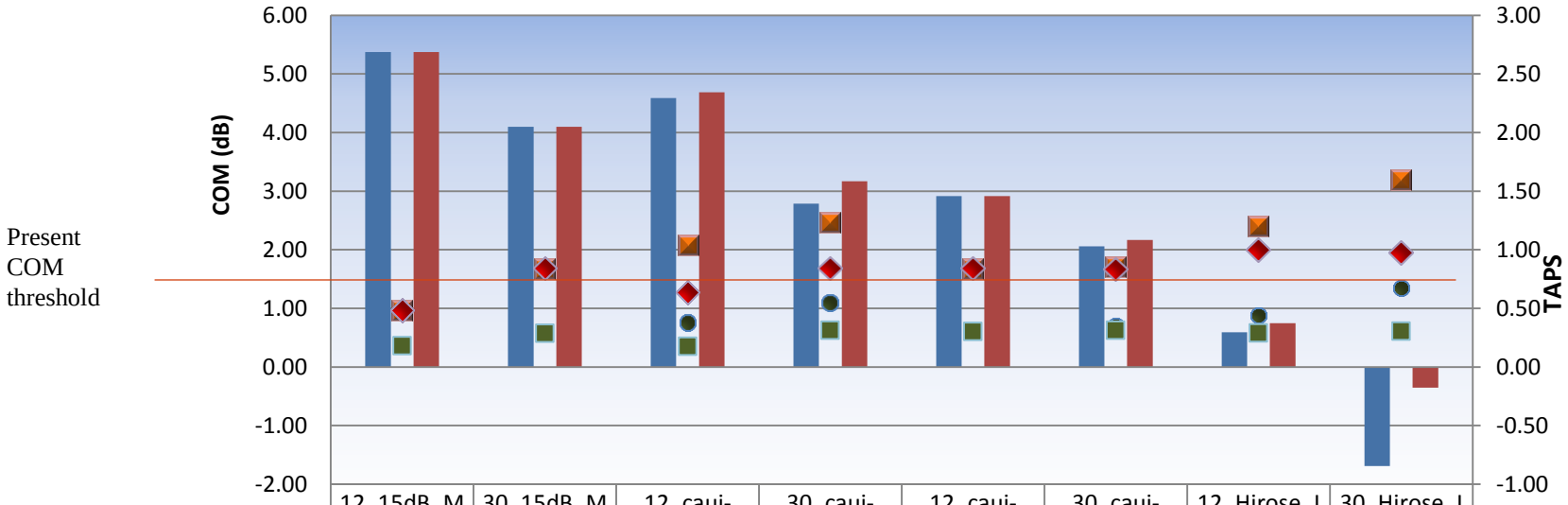
Channels	Package length(mm)
CAUI-4_chip2chip_oneboard_15dB_92_ohm_target_board_MEG6_Thru, NEXT, FEXT	12
CAUI-4_chip2chip_oneboard_15dB_92_ohm_target_board_MEG6_Thru, NEXT, FEXT	30
CAUI-4_chip2chip_oneboard_meg6_long_20dB_92_ohm_target_board_MEG6_Thru, NEXT, FEXT	12
CAUI-4_chip2chip_oneboard_meg6_long_20dB_92_ohm_target_board_MEG6_Thru, NEXT, FEXT	30
CAUI-4_chip2chip_twoboards_meg6a_13p39dB_92_110_ohm_target_board_meg6_Thru, NEXT, FEXT	12
CAUI-4_chip2chip_twoboards_meg6a_13p39dB_92_110_ohm_target_board_meg6_Thru, NEXT, FEXT	30
Hirose_IT5_20dB-channel_J9-L9_thru, NEXT, FEXT	12
Hirose_IT5_20dB-channel_J9-L9_thru, NEXT, FEXT	30

Simple MTTFPA approximation produces similar results to more complete treatment of mutual probabilities



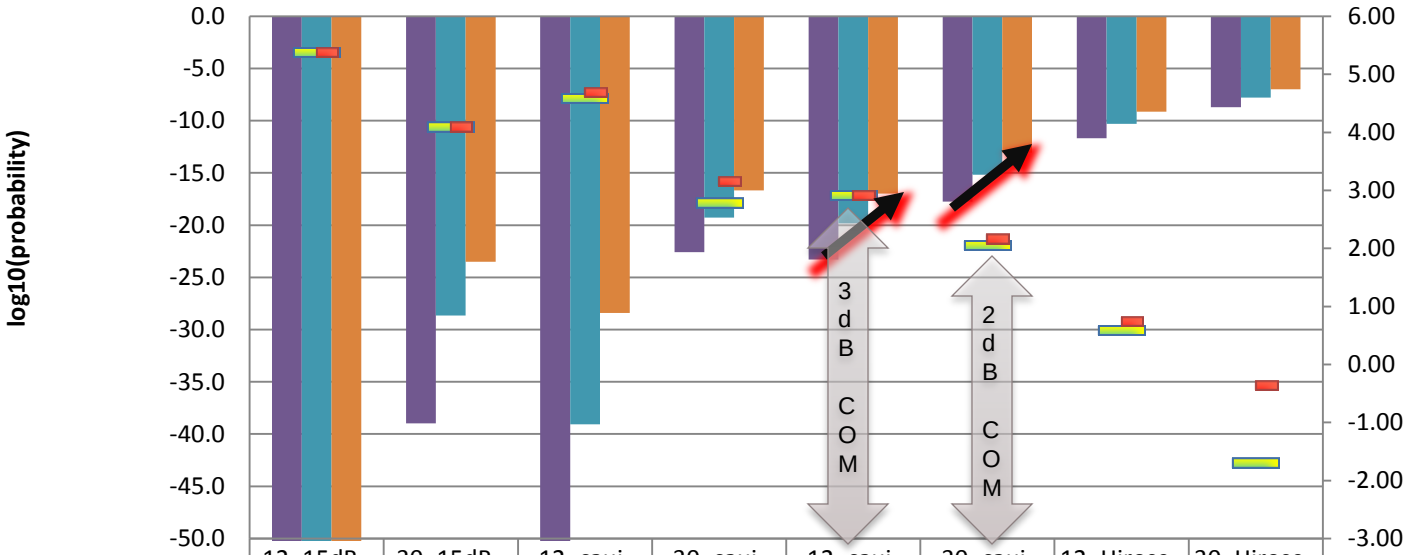
	12_15dB_Meg6_LowSR_one_brd_chip2chip--caui-4_chip2chi	30_15dB_Meg6_LowSR_one_brd_chip2chip--caui-4_chip2chi	12_caui-4_chip2chip_oneboard_meg6_long_20dB_92_ohm_ta	30_caui-4_chip2chip_oneboard_meg6_long_20dB_92_ohm_ta	12_caui-4_chip2chip_twoboards_meg6a_13p39dB_92_110_oh	30_caui-4_chip2chip_twoboards_meg6a_13p39dB_92_110_oh	12_Hirose_IT5_channel_touchstones--Hirose_IT5_20dB-ch	30_Hirose_IT5_channel_touchstones--Hirose_IT5_20dB-ch
log(Pe) using ^3	-99.0	-42.2	-99.0	-22.6	-24.8	-18.6	-11.9	-8.7
log(Pe) conv'd	-99.0	-39.0	-99.0	-22.6	-23.3	-17.7	-11.7	-8.7

COM results do not change much when the DFE is limited to 0.3



	12_15dB_Meg6_LowSR_one_brd_chip2chip--caui-4_chip2chi	30_15dB_Meg6_LowSR_one_brd_chip2chip--caui-4_chip2chi	12_caui-4_chip2chip_oneboard_meg6_long_20dB_92_ohm_ta	30_caui-4_chip2chip_oneboard_meg6_long_20dB_92_ohm_ta	12_caui-4_chip2chip_twoboards_meg6a_13p39dB_92_110_oh	30_caui-4_chip2chip_twoboards_meg6a_13p39dB_92_110_oh	12_Hirose_IT5_channel_touchstones--Hirose_IT5_20dB-ch	30_Hirose_IT5_channel_touchstones--Hirose_IT5_20dB-ch
COM w DFE tap limit 0.3	5.38	4.10	4.59	2.79	2.92	2.06	0.59	-1.69
COM	5.38	4.10	4.69	3.17	2.92	2.17	0.75	-0.35
SUM DFE taps	0.48	0.84	1.04	1.23	0.84	0.86	1.20	1.60
Max DFE tap	0.18	0.29	0.38	0.55	0.30	0.35	0.44	0.67
SUM DFE tap limit 0.3	0.48	0.84	0.64	0.84	0.84	0.84	1.00	0.97
Max DFE tap limit 0.3	0.18	0.29	0.18	0.31	0.30	0.31	0.29	0.31

COM threshold has orders of magnitude impact on probability of a burst of 4 errors occurring.



	12_15dB_Meg6_LowSR_one_brd_chip2chip--caui-4_chip2chi	30_15dB_Meg6_LowSR_one_brd_chip2chip--caui-4_chip2chi	12_caui-4_chip2chip_oneboard_meg6_long_20dB_92_ohm_ta	30_caui-4_chip2chip_oneboard_meg6_long_20dB_92_ohm_ta	12_caui-4_chip2chip_twoboards_meg6a_13p39dB_92_110_oh	30_caui-4_chip2chip_twoboards_meg6a_13p39dB_92_110_oh	12_Hirose_IT5_channel_touchstones--Hirose_IT5_20dB-ch	30_Hirose_IT5_channel_touchstones--Hirose_IT5_20dB-ch
log(Pe) conv'd	-99.0	-39.0	-99.0	-22.6	-23.3	-17.7	-11.7	-8.7
log10(PE) w COM threshold 2.5dB conv'd	-99.0	-28.7	-39.1	-19.3	-19.8	-15.2	-10.3	-7.8
log10(PE) w COM threshold 3dB conv'd	-99.0	-23.5	-28.4	-16.7	-17.0	-13.0	-9.1	-7.0
COM w DFE tap limit 0.3	5.38	4.10	4.59	2.79	2.92	2.06	0.59	-1.69
COM	5.38	4.10	4.69	3.17	2.92	2.17	0.75	-0.35

Observation & Conclusions

- The impact of DFE tap limits on the p4-burst seems minimal.
  - However more channel would be required confirm
  - A smaller sum of DFE taps also seems to have little impact when close to COM limit
  - It could be that channel with large DFE taps would indeed fail COM when the BER is low (like 1e-15)
- For a channel close to the COM threshold the p4_burst seems to marginally pass or fail.
- COM ½ dB above what the Rx is tested to at BER averts MTTFPA issues
  - ½ dB seems to respectively change MTTFPA by 2-3 order or magnitudes

backup

Decision Feedback Equalizer (DFE)

$$S_k = X_k - A_s * \sum_{i}^{ndfe} b_i \; sgn(S_{k-i})$$