Analysis of contributed channels using the COM method

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Introduction

- This presentation shows performance of several contributed channels using the proposed COM figure of merit (detailed in mellitz_01_0712).
- Channel selection follows recommended list sent by Charles Moore.
- Some analysis parameters are suggested.
- Each channel is analyzed in 4 ways – combinations of
  - Assuming either DFE only, or DFE with linear equalization (CTLE and FFE, exhaustive search)
  - Using either exact distribution of noise terms, or Gaussian distribution with the same power.
- The benefit of exact calculation with equalization is demonstrated for several cases.

Why COM analysis?

- The most important elements of COM are:
  1. Applying equalization effect assuming minimum-capability receiver and specified transmitter.
  2. Calculation of specific noise distribution and quantiles.
- Agreement on a common reference is a necessary step for making a meaningful decision.
  - We will show that combined simple-linear and DFE as reference equalization produces better results than each one alone.
  - Assumed minimal capability. Not recommend implementation.
- Detailed calculation of crosstalk and ISI distributions is more justifiable than assuming a Gaussian distribution (as in most textbooks). Results are sometimes very different.
- Adding arbitrary margins to cope with wide range of inaccuracies, as done in the past, would put many “manageable” channels below passing mark.
- Using COM provides a more precise discrimination between channels, assuming minimal capabilities.

COM parameters used in this analysis

(see also mellitz_01_0712)

Frequency-domain parameters

- TX filter – 2nd-order Butterworth at $0.55*f_B$ for THRU and FEXT, $1*f_B$ for NEXT
- RX filter – 4th-order Butterworth at $0.75*f_B$ [1]
- Terminations – 45 Ω || 0.25 pF S/E on all ports
  - Simplified package model until a more detailed model is agreed on
- Conversion to time domain done using in-house tools.

1. This slightly differs from current proposal which includes Bessel-Thomson filter

Equalization

- Parameters used for search:
  - DFE length – 8 taps for NRZ, 16 taps for PAM4
  - 3-tap TXFFE, $-0.2 \le C_{-1} \le 0$, $-0.4 \le C_{+1} \le 0$, resolution: 0.02
  - CTLE with pole at fs/4 and variable zero location; $-14\ \text{dB} \le A_{DC} \le 0\ \text{dB}$, in 2 dB steps
  - Parameters not finalized
- Optimization of Signal/ISI power ratio, without XTALK, but assuming additional noise of 0.5 mV RMS
  - Additional noise required to prevent choosing "channel inverting" solution
  - Parameter is not finalized
- This search yields settings that should be repeatable by anyone using this method.

Signal and interference

- Thru channel assumed 800 mV PtP launch; phase is selected to maximize S/ISI
  - For PAM4, signal divided by 3
- Interference comprised of:
  - ISI (residual after equalization)
  - Xtalk: FEXT 800 mV, TXFFE applied; NEXT 1200 mV, TXFFE not applied; CTLE applied to both
  - Alien noise modeled as ±1 mV deterministic + 0.4 mV AWGN; CTLE effective gain applied[1]
- Distribution of total interference is calculated; I_peak defined as the "BER quantile"
  - NRZ analyzed w/o FEC (1e-12 quantile)
  - PAM4 analyzed with FEC (1e-5 quantile)

1. Alien noise is not currently addressed, but something should be assumed. CTLE effect assumes wide band interference (average gain).

COM calculation

COM = 20*log10(S/I_peak) – Allowance

- Allowance set to 8 dB, comprised of:
  - 2 dB for TX jitter & distortion
  - 1.5 dB for RX jitter & distortion
  - 1.5 dB for RX sensitivity
  - 3 dB for RX package loss and xtalk effects
    - Can be reduced with more accurate package model
- Final allowance factors may vary
  - May also be different for NRZ and PAM4

Results

COM results summary – NRZ

Labels from Charles Moore's table

Channel nickname	IL @ 12.9 GHz [dB]	Available signal [mV]	Peak distortion [mV]	COM [dB]
FCI_short_4	4.4	213.7	104.5	-1.8
IBM_40db	41.9	10.1	10.4	-8.3
IBM_35db	36.6	17.4	11.9	-4.7
FCI_short_2	5.5	224.5	94.9	-0.5
TE_30_Nelco6_simulated_1104	34.7	18.6	9	-1.7
FCI_short_7	4	225.8	84.2	0.6
FCI_long_4	19.7	50.5	20.6	-0.2
IBM_20db	23.9	36.4	22.2	-3.7
FCI_long_7	18.7	46.6	14.1	2.4
TE_42_Meg6_simulated_1104	26.9	27.5	10.7	0.2

Bad

Borderline

Good

Most cases with negative COM are likely to work well if FEC is used

COM results summary – PAM4

Labels from Charles Moore's table

Channel nickname	IL @ 7 GHz [dB]	Available signal [mV]	Peak distortion [mV]	COM [dB]	
Tyco_AP_Case7	23.6	36	46.6	-10.2	Bad
peters_01_0605_B20	23.6	12.8	25.4	-13.9	
ENP_long_1	20.8	22.8	17.7	-5.8	Borderline
ENP_Shortest_0	17.4	36.5	19.2	-2.4	
FCI_short_4	2.9	93.4	18.3	6.2	
FCI_short_7	3	74.9	14.2	6.4	Good
TE_42_Meg6_simulated_1104	17	14.7	4	3.3	
IBM_35db	20.6	16.5	5.3	1.9	Not labeled
IBM_40db	24.9	11.2	5.8	-2.3	
TE_42_Nelco6_simulated_1104 [1]	29.4	5.9	3.1	-2.4	

1. This case is NEXT limited. It can pass with large margin (COM=5..8 dB) with a different selection of NEXT channels.

Detailed example

FCI_long_4, NRZ

(“borderline FAIL” – COM=-0.2 dB)

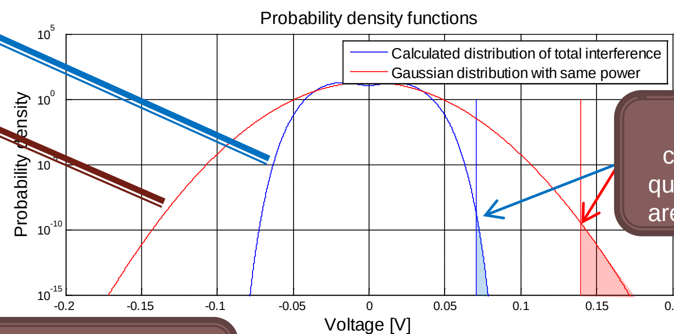
Assuming DFE only

Assuming FFE+CTLE+DFE

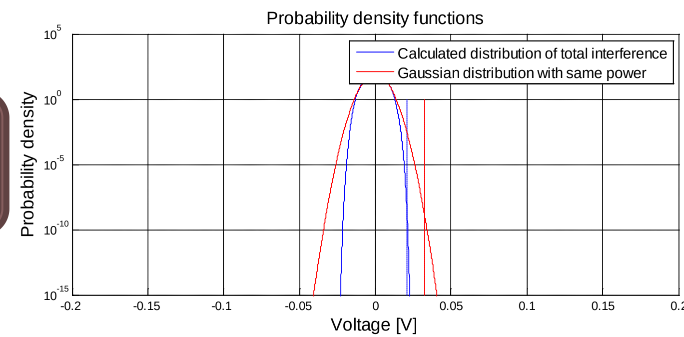
Top graph is PDF of total interference. This is not probability!

Calculated distribution

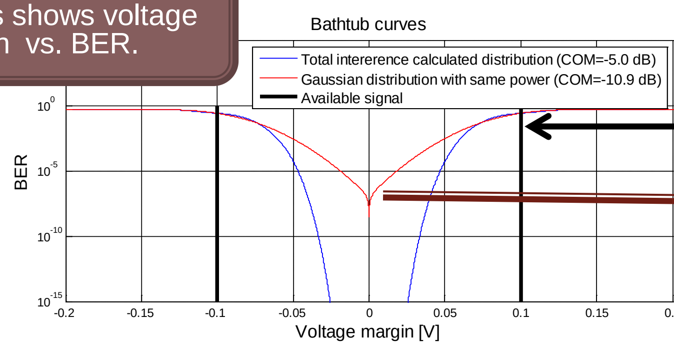
Gaussian, same power



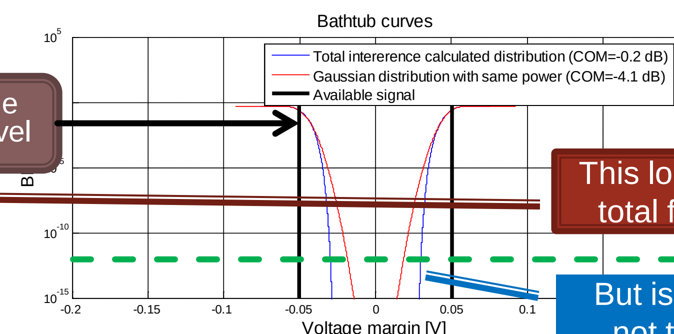
Peaks calculated by quantiles; these areas are 1e-12



Bottom plot is bathtub curve. This shows voltage margin vs. BER.



Available signal level



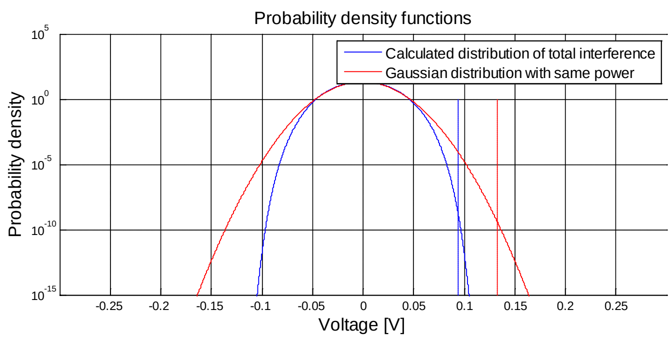
This looks like a total failure…

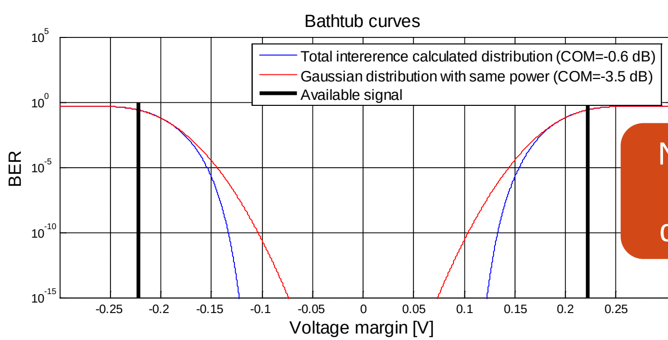
But is actually not too bad

Here, linear equalization reduces available signal, but reduces interference even more, thus COM is significantly increased. Note also the difference between actual noise distribution and the Gaussian model, and its effect on COM.

FCI_short_7, NRZ
(“borderline PASS” – COM=+0.6 dB)

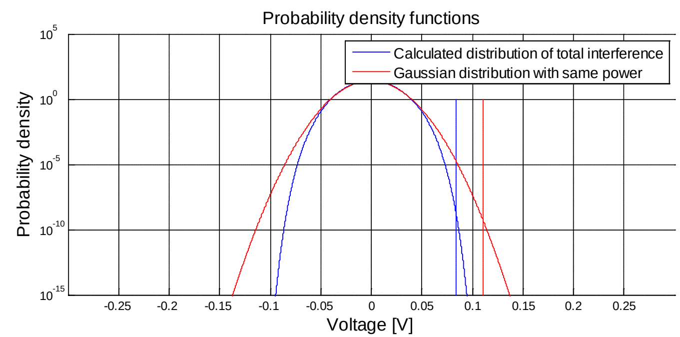
Assuming DFE only

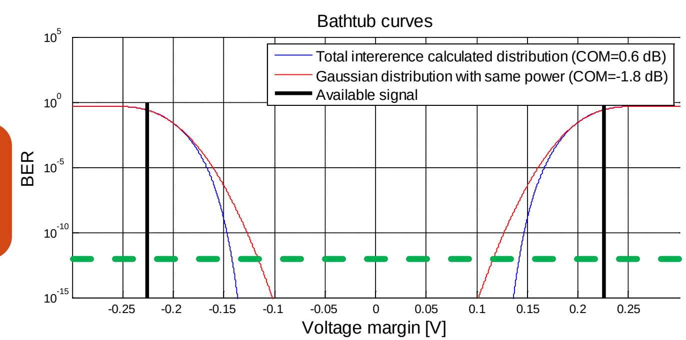




Not such a big difference!

Assuming FFE+CTLE+DFE



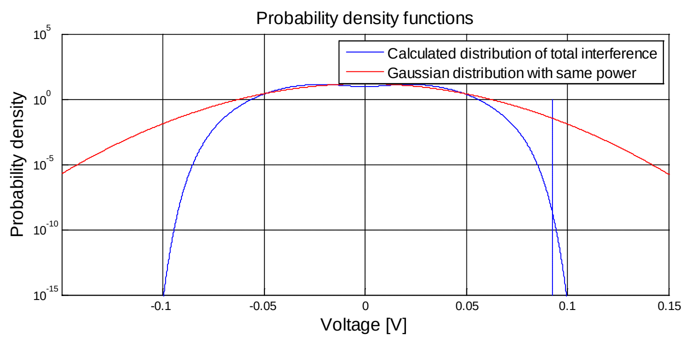


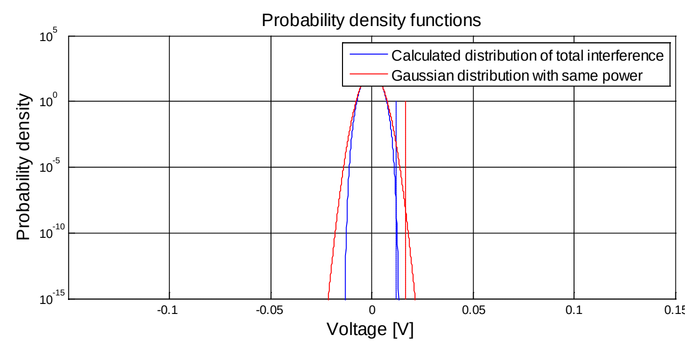
Here, linear equalization does not improve performance, but assuming Gaussian distribution still yields worse results than exact analysis.

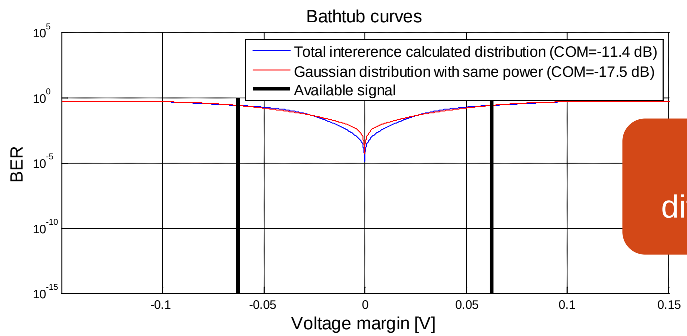
IBM_35db, NRZ
(FAIL – COM=-4.7 dB)

Assuming DFE only

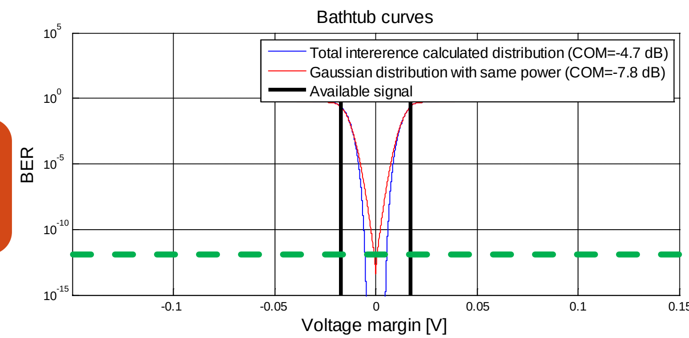
Assuming FFE+CTLE+DFE







Huge difference!

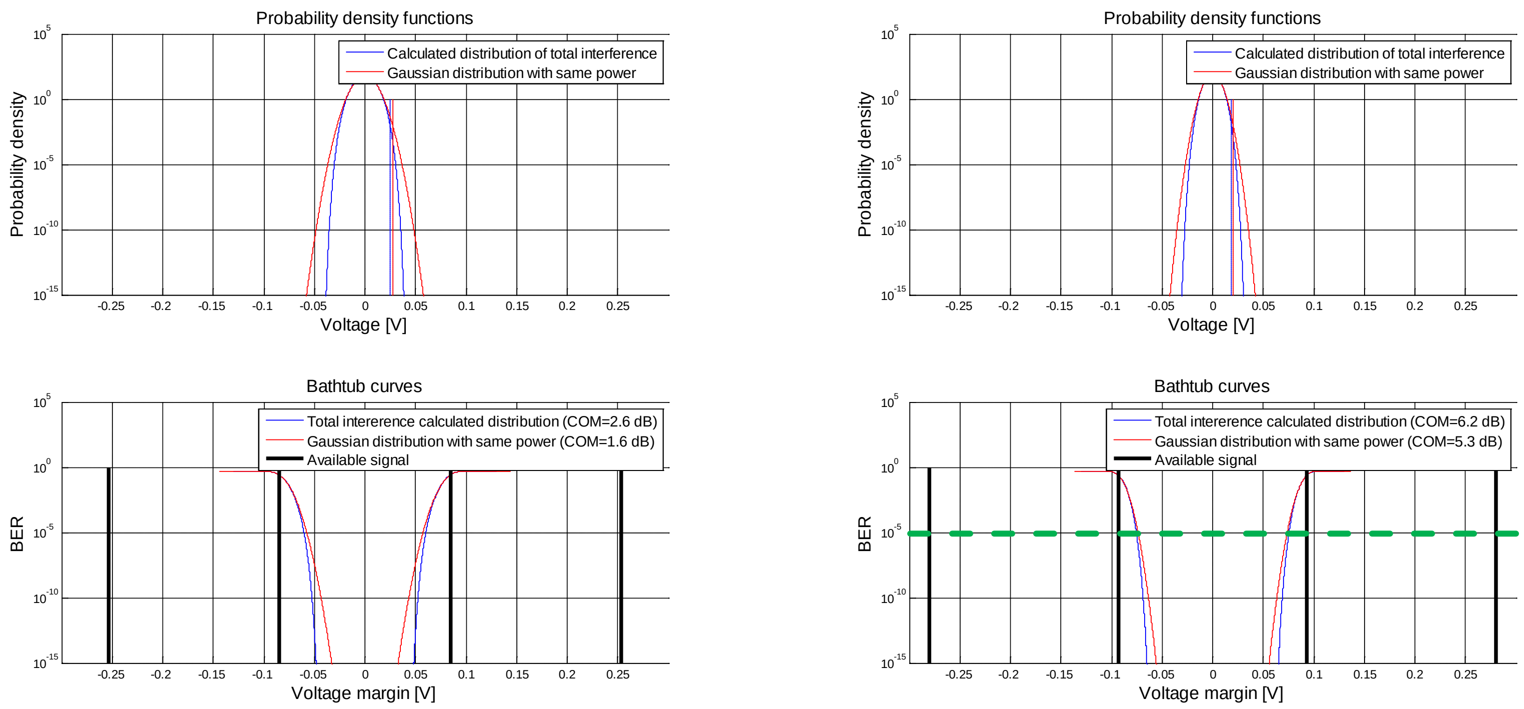


Without linear equalization there is no margin even at low BER. Equalization helps but doesn't leave enough margin. FEC and/or better receiver are required.

FCI_short_4, PAM4
(PASS – COM=+6.2 dB)

Assuming DFE only

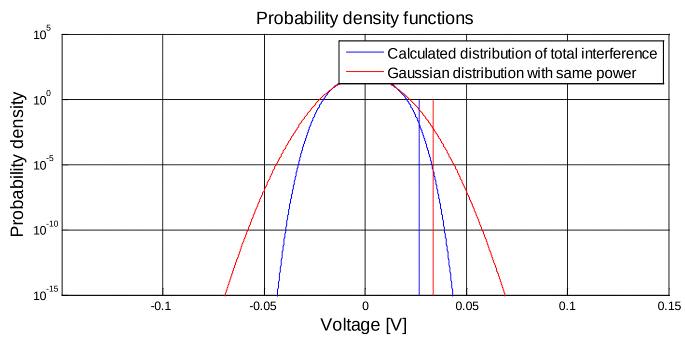
Assuming FFE+CTLE+DFE

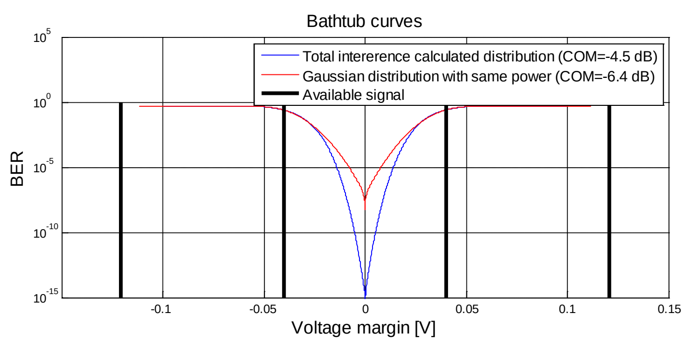


Although this channel passes even without linear equalization, adding it improves the margin considerably.

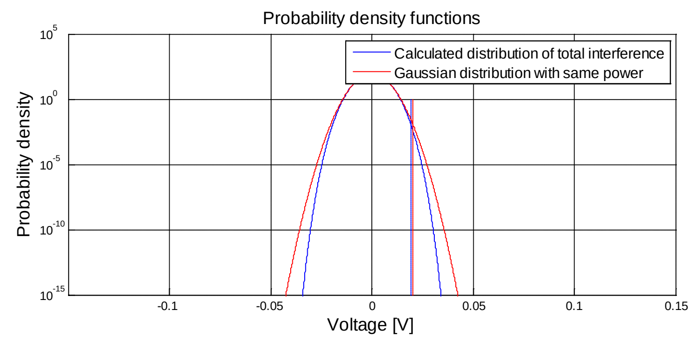
ENP_Shortest_0, PAM4
(FAIL – COM=-2.4 dB)

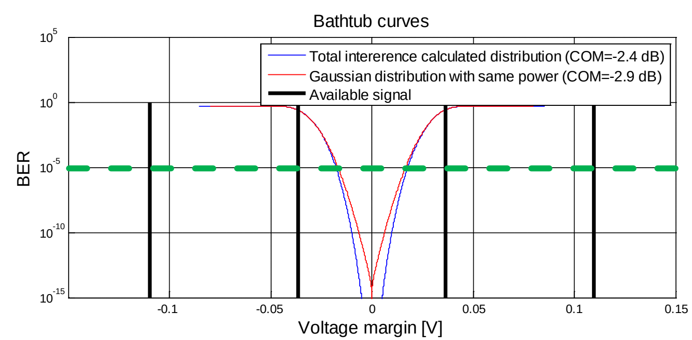
Assuming DFE only





Assuming FFE+CTLE+DFE





Linear equalization improves a lot but not enough to pass.
Notice that assuming Gaussian distribution does not change the results significantly.

Summary

- COM results (with conservative parameter values) were shown for contributed channel selection.
  - New low-loss channels have near-zero COM for NRZ; higher loss channels are negative. Most are expected to work if FEC is used.
  - New channels have positive COM for PAM4 operation. This is partly due to equalization assumption.
  - Parameters and allowances need refinement.
- Benefits of equalization and noise distribution calculation were demonstrated.
  - Differences are sometimes big and at other times small; any fixed correction factor would be inaccurate.
- Meeting the high loss objectives requires a fine degree of discrimination between “good” and “bad” which was not possible with previous methods.
- **We recommend using COM to specify/qualify channels.**

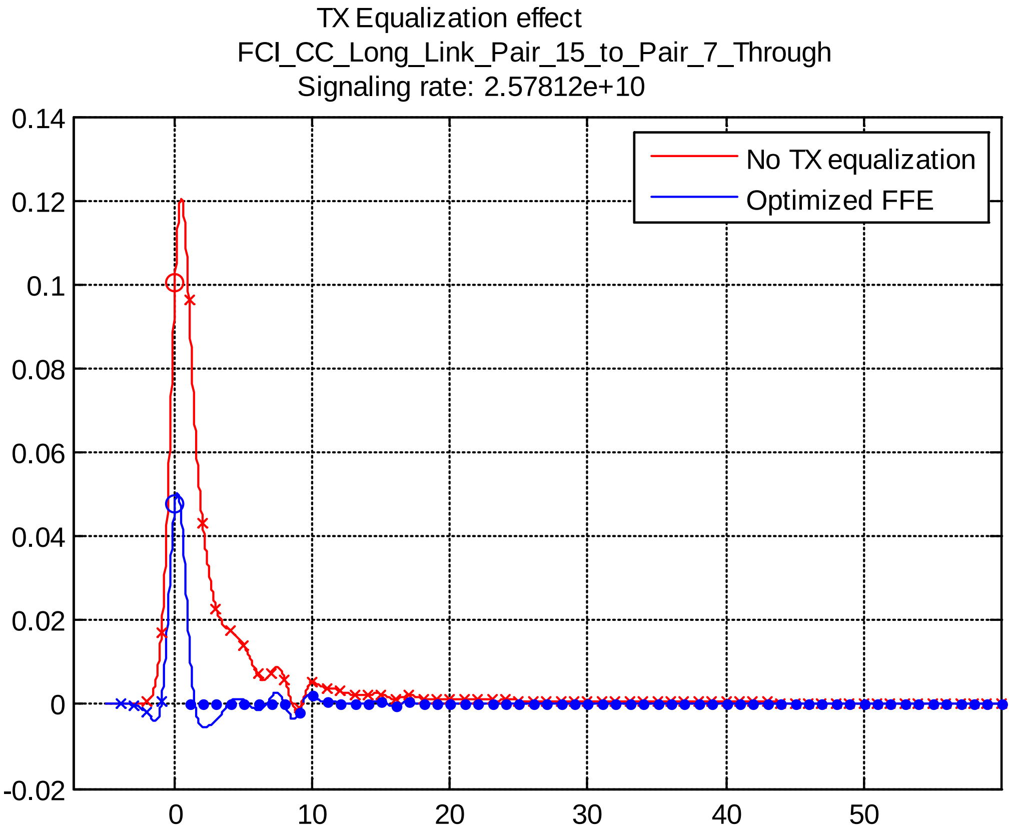
Backup

FCI_long_4, NRZ
("borderline FAIL" – COM=-0.2 dB)

S: 48 mV

ISI peak: 12 mV

XT peak: 8 mV

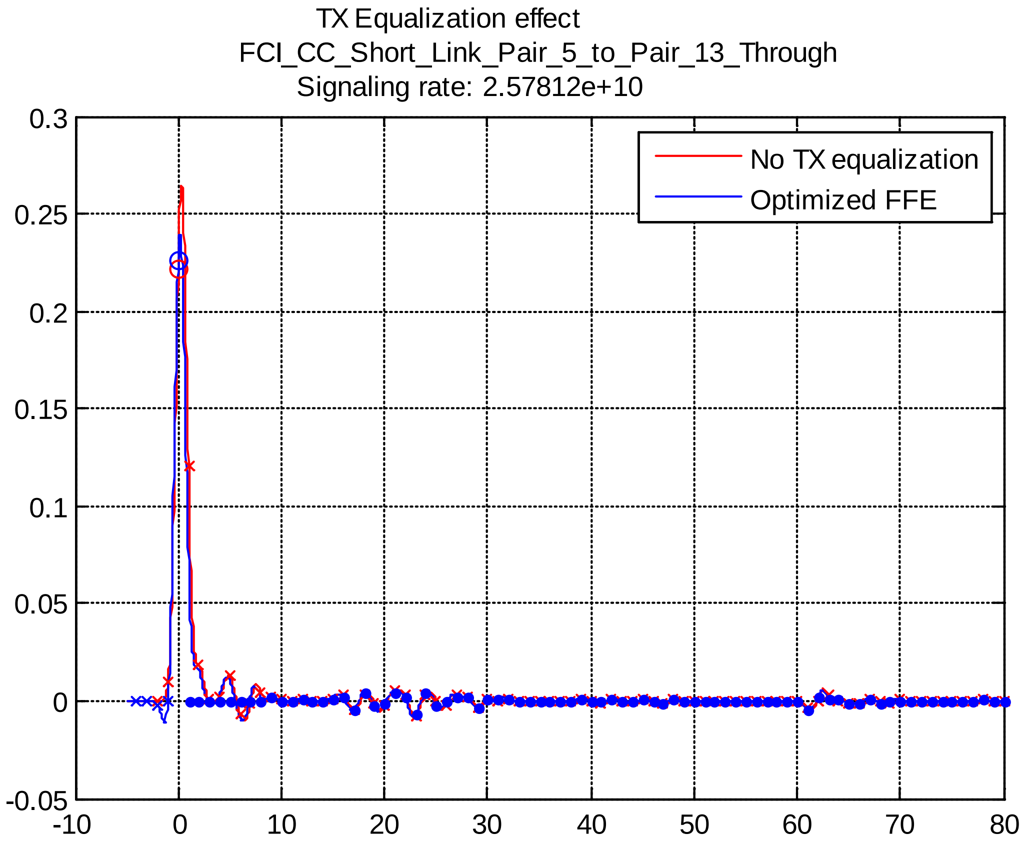


FCI_short_7, NRZ
(“borderline PASS” – COM=+0.6 dB)

S: 226 mV

ISI peak: 72 mV

XT peak: 27 mV

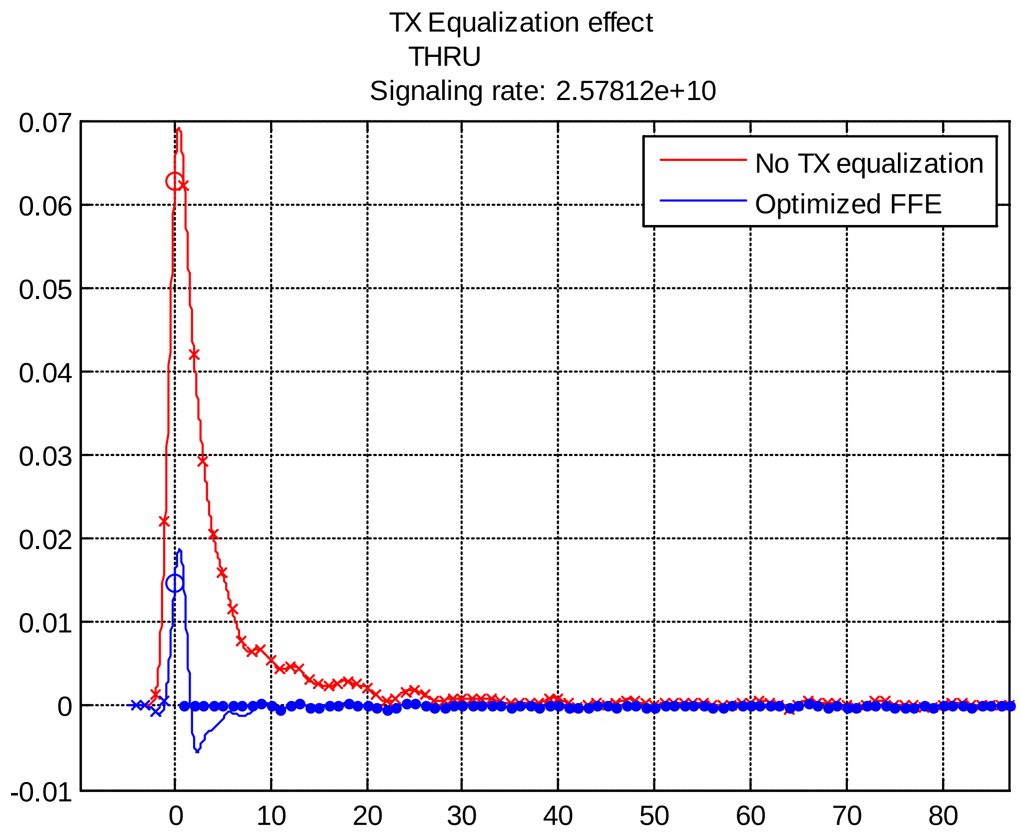


IBM_35db, NRZ
(FAIL – COM=-4.7 dB)

S: 17.4 mV

ISI peak: 10 mV

XT peak: 0.6 mV



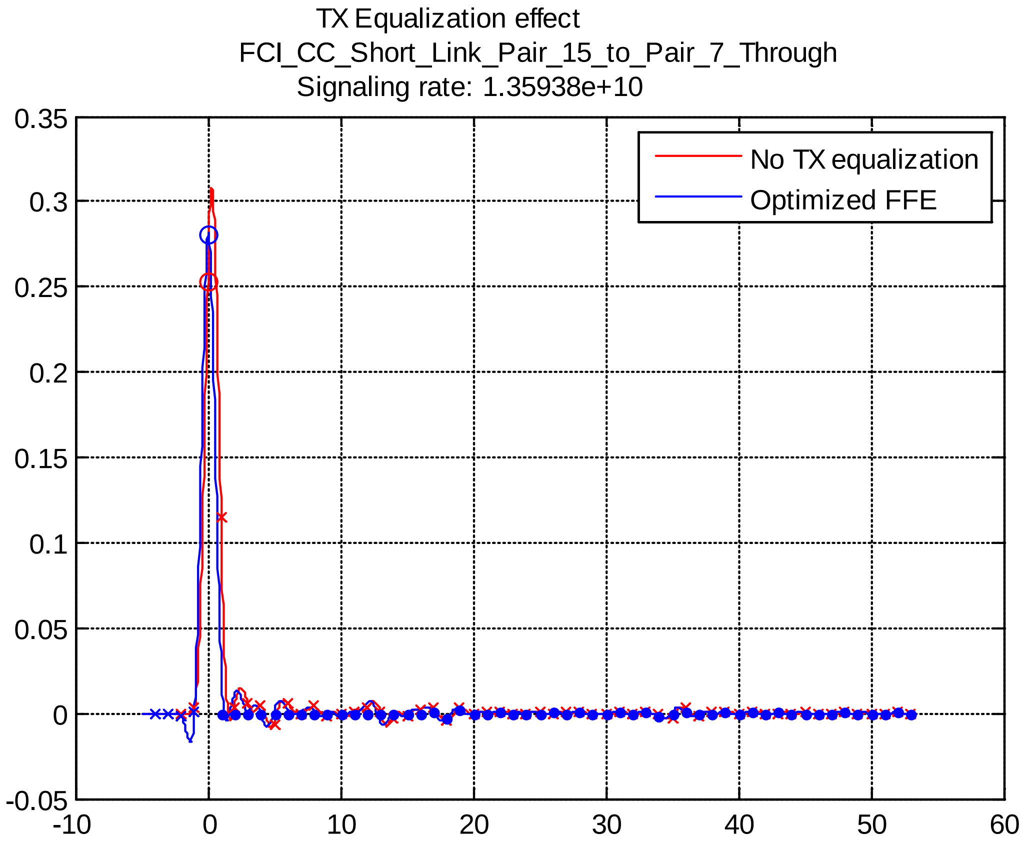
FCI_short_4, PAM4
(PASS – COM=+6.2 dB)

S: 93 mV

(1/3 of full swing)

ISI peak: 19 mV

XT peak: 13 mV



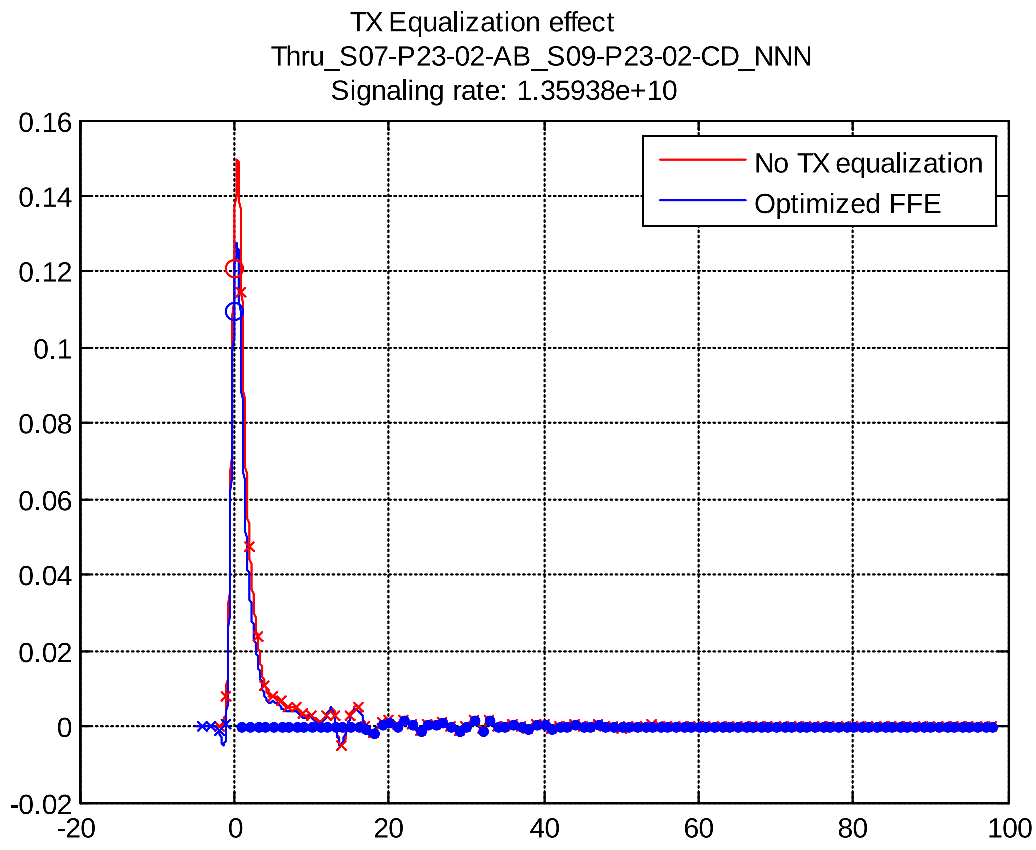
ENP_Shortest_0, PAM4
(FAIL – COM=-2.4 dB)

S: 37 mV

(1/3 of full swing)

ISI peak: 20 mV

XT peak: 16 mV



Channel selection

Nickname	Source	Thru channel
Tyco_AP_Case7	dambrosia_m1_0904.zip	Case7 FM 13SI 1 T D13SI L6.s4p
peters_01_0605_B20	peters_m1_0605.zip	peters_01_0605_B20_thru.s4p
ENP_Long_1	emerson_11_0928/Longest Link.zip	Thru_S06-P20-10-EF_S14-P23-04-GH_NNN.s4p
ENP_Shortest_0	emerson_11_0928/Shortest Link.zip	Thru_S07-P23-02-AB_S09-P23-02-CD_NNN.s4p
FCI_short_4	FCI_11_0218/FCI_CC_Short_Link.zip	FCI_CC_Short_Link_Pair_15_to_Pair_7_Through.s4p
FCI_short_7	FCI_11_0218/FCI_CC_Short_Link.zip	FCI_CC_Short_Link_Pair_5_to_Pair_13_Through.s4p
TE_42_Meg6_simulated_1104	TEC_STRADAWhisper42p8in_Meg6_Channel_IEEE802_3_100GbCu_04282011.zip	TEC_Whisper42p8in_Meg6_THRU_C8C9.s4p
IBM_40dB	IBM_11_0518/40db_Loss_Channel.zip	THRU.s4p
IBM_35dB	IBM_11_0518/35db_Loss_channel.zip	THRU.s4p
FCI_short_2	FCI_11_0218/FCI_CC_Short_Link.zip	FCI_CC_Short_Link_Pair_12_to_Pair_4_Through.s4p
TE_30_Nelco6_simulated_1104	TEC_STRADAWhisper29p8in_Nelco6_Channel_IEEE802_3_100GbCu_04282011.zip	TEC_Whisper29p8in_Nelco6_THRU_C8C9.s4p
FCI_Long4 *	FCI_11_0218/FCI_CC_Long_Link.zip	FCI_CC_Long_Link_Pair_15_to_Pair_7_Through.s4p
IBM_20dB	IBM_11_0518/20db_Loss_Cahnnel.zip	THRU.s4p
FCI_Long_7 *	FCI_11_0218/FCI_CC_Long_Link.zip	FCI_CC_Long_Link_Pair_5_to_Pair_13_Through.s4p
TE_42_Nelco6_simulated_1104	TEC_STRADAWhisper42p8in_Nelco6_Channel_IEEE802_3_100GbCu_04282011.zip	TEC_Whisper42p8in_Nelco6_THRU_C8C9.s4p