Channel Ad Hoc – April 19

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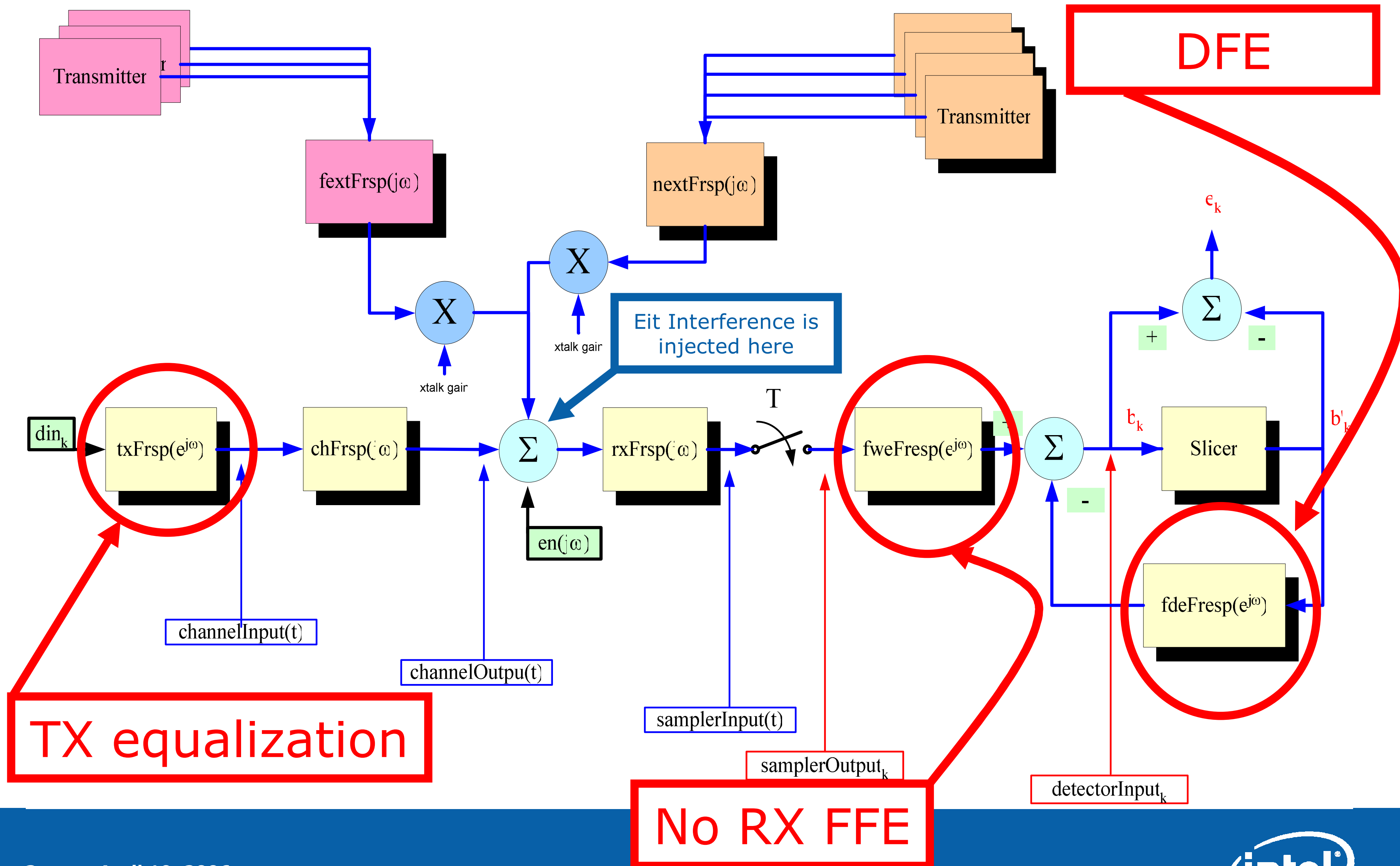
Objectives

1. Simulate three *test channels* which are near the limit of what we plan to support, under conditions which they are likely to see in actual use.
2. Simulate the interference tolerance test with varying levels of interference (EIT baseline).
3. Find the interference value (EIT baseline) which produces a receiver stress level equivalent to the worst stress seen in part 1. Note however that:
   - Receiver stress is left undefined.
   - Measure of receiver stress level will be simulator dependent. Set that as the EIT baseline value for 10GBASE-KR.
4. In light of interest in broadband (noise like) interference tolerance testing, repeat #2 with noise like interference of varying RMS value.
5. Find noise level which produces receiver stress equivalent to worst stress seen in part 1.

Test bench



Transmitter
Transmitter
DFE
fextFrsp(jω)
nextFrsp(jω)
X
X
xtalk gain
xtalk gain
Eit Interference is injected here
e_k
Σ
+
-
T
din_k
txFrsp($e^{jω}$)
chFrsp(jω)
Σ
rxFrsp(jω)
fweFresp($e^{jω}$)
Σ
b_k
Slicer
b'_k
-
en(jω)
fdeFresp($e^{jω}$)
channelInput(t)
channelOutput(t)
samplerInput(t)
$samplerOutput_k$
$detectorInput_k$
TX equalization
No RX FFE

Simulation Conditions (1)

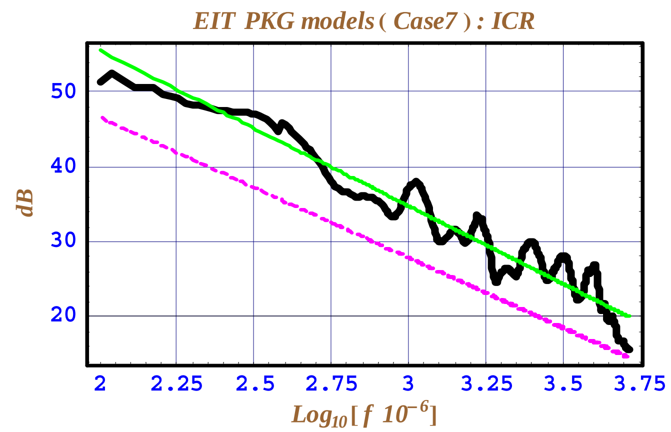
1. Test channels

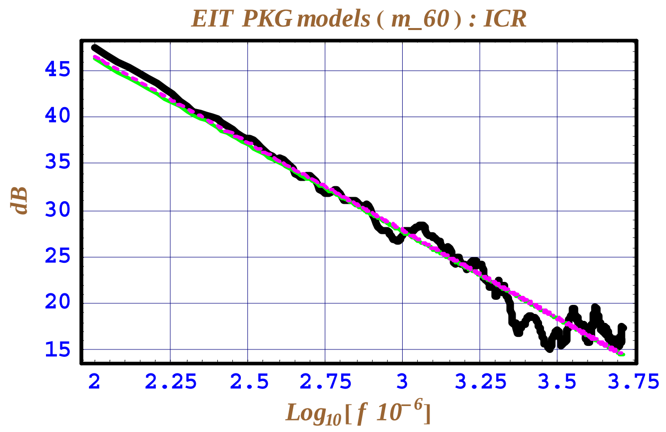
```
a) Tyco Case7
    i.    Thru= Dambrosia_7T    Case7_FM_13SI_1_T_D13SI_L6.s4p
    ii.   Next1=DAmbrosia_7N1   Case7_FM_13SI_1_N1_D13SI_L6.s4p
    iii.  Next2=DAmbrosia_7N2   Case7_FM_13SI_1_N2_D13SI_L6.s4p
    iv.   Fext=DAmbrosia_7F     Case7_FM_13SI_1_F_D13SI_L6.s4p

 b) m_82_ripple_90 with crosstalk from Dambrosia_7T.
    i.   Thru= m_82_ripple_90   m_82_ripple_90.s4p
    ii.  Next1=DAmbrosia_7N1    Case7_FM_13SI_1_N1_D13SI_L6.s4p
    iii. Next2=DAmbrosia_7N2    Case7_FM_13SI_1_N2_D13SI_L6.s4p
    iv.  Fext=DAmbrosia_7F      Case7_FM_13SI_1_F_D13SI_L6.s4p

 c) m_60_ripple_98 with crosstalk  from Molex_Inthru3
     i.   Thru=m_60_ripple_98   m_60_ripple_98.s4p
     ii.  Next1=Molex_Innext23  sj3k3g2h2_SPARS_NEXT.s4p
     iii. Next2=Molex_Innext33  sj3k3g3h3_SPARS_NEXT.s4p
     iv.  Next3=Molex_Innext43  sj3k3g4h4_SPARS_NEXT.s4p
     v.   Next4=Molex_Innext53  sj3k3g5h5_SPARS_NEXT.s4p
     vi.  Fext1=Molex_Infext23  sj3k3g2h2_SPARS_FEXT.s4p
     vii. Fext2=Molex_Infext43  sj3k3g4h4_SPARS_FEXT.s4p
     viii Fext3=Molex_Infext53  sj3k3g5h5_SPARS_FEXT.s4p

 d) ittc_20db_returnloss
```

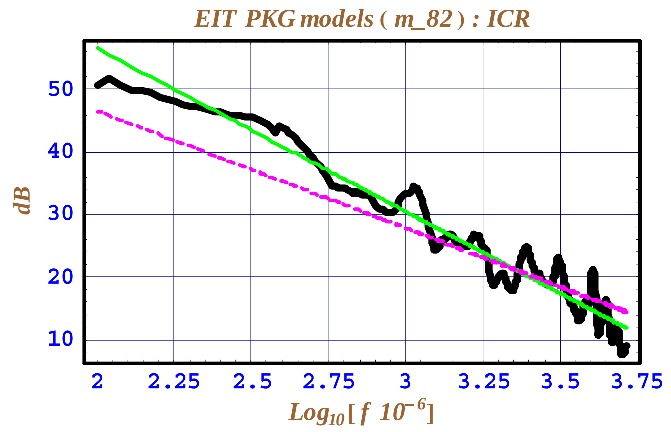
Simulation Conditions (2)
ICR limits for the three "test" backplanes

e) the thru channel – xtalk channel combinations were engineered to have characteristics very close to the current ICR limits.

f) m_62 and m_80 represent artificial situation where thru and xtalk come from different sets





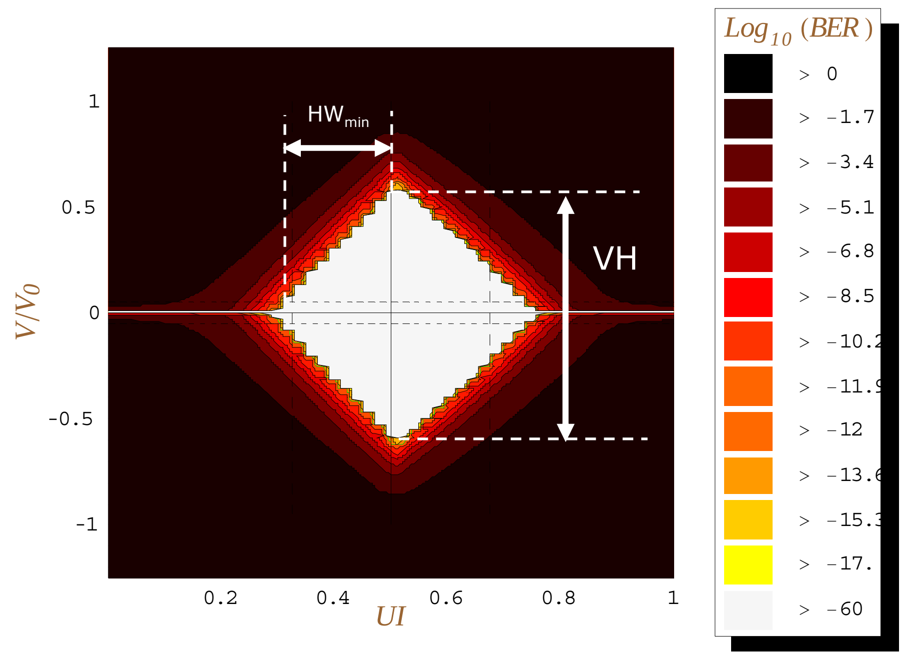


Simulation Conditions (3)

2. Package
   - Spec_RL_pkg_802_3.s4p
3. Configuration
   - Channel simulation is: pkg-channel-pkg
   - EIT simulation is : channel-pkg
   - DR : 10.3125Gb/s
4. Transmitter Output (at tx output)
   - 0.8 V_{pp}
   - Tr = Tf = 24 pS = 0.247 UI
   - PRBS15
   - Rs = 50 ohms
   - SJ = 0.075 UI_p @ 0.41 DR
   - RJ = 0.150 UI_{pp}
   - DCD = 0.0 UI_{pp}
5. Receiver
   - RL = 50 ohms
   - Bw = Two real poles @ {0.7 DR, 1.0 DR}
   - Input noise = 1.46mV_{rms}, flat psd to 10.3125 Ghz
6. 3 taps FIR
   - Floating point resolution
   - Meet the 802.3ap constraints
7. 5 taps DFE
   - Floating point resolution
8. Crosstalk characteristics
   - Amplitude:
     - Results are being collected for the case where the aggressors have same amplitude as thru channel and for the case where aggressors have **+4dB** gain with respect to the thru.
   - Rise/Fall : same as thru channel
   - Pattern : same as thru channel, with random offset
   - Jitter : none
   - Source Z : same as thru channel
   - Equalizer : same settings as TX in thru channel

Definition of Receiver Stress.

1. Horizontal eye opening, HO = 2 Hw_{min}, is measured at a 10 mV_p overdrive level.
2. The vertical eye opening, VH, is the vertical opening observed in the eye.
3. Vertical and Horizontal openings are measured at a BER of 1E-12.
4. EIT interference level is reported as the peak amplitude of the sinusoidal interference signal at the receiver input.
   - The sinusoidal frequency is automatically selected to be equal to the frequency at which the RX input gain is maximum (in the range 1 GHZ, 6GHz defined by the standard)
     - This yields the smallest sinusoidal amplitude capable of inducing the observed receiver stress
5. For the case in which the interference is modeled with white Gaussian noise, the EIT interference level is reported in mV_{rms} at the receiver input.



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Test channel Results

Simulation Results : Table 1

	test channels	Xtalk[1]		Interference[2]			Xtalk + Tx Jitter[3]	
		VH (mV_{pp})	HO (UI_{pp})	EIL	VH (mV_{pp})	HO (UI_{pp})	VH (mV_{pp})	HO (UI_{pp})
Xtalk gain = 0db	Tyco Case7	150	0.40	25.36	150	0.36	99	0.16
	m_60	85	0.20	21.64	86	0.16	8	0.00
	m_82	65	0.12	20.93	66	0.12	2	0.00
Xtalk gain = 4db	Tyco Case7	143	0.4	38.13	112	0.28	66	0.08
	m_60	0.0	0.0	-	-	-	0.0	0.0
	m_82	0.0	0.0	-	-	-	0.0	0.0

sinusoid

(1) VH, HO = Horizontal and Vertical Eye Openings at the slicer input. No Tx Jitter.

(2) EIL=Equivalent Interference Level (mV_p or mV_{rms}) VH, HO = Horizontal and Vertical Eye Openings when xtalk is replaced by sinusoidal interference of amplitude eit

(3) VH, HO = Horizontal and Vertical Eye Openings at the slicer input.

Receiver stress as a function of the *interference level* on the *ittc_20dB_returnloss* channel.

Simulation Results : Table2

- To search for the EIT baseline is carried out by sweeping the interfering signal amplitude
  - There is no transmitter jitter
  - There is no (awgn) receiver input noise
  - The stressed eye parameters, VH and HO, are observed at the slicer input and are directly comparable to the parameters in Table 1, columns 2 and 3.

- The "working region" boundaries are determined by looking at the eye at the input of the slicer
  - VH > 10 mV_p
  - HO $\geq$ 0.44UI_{pp}
  - As we shall see, this corresponds to a 0.24 UI_{pp} horizontal opening when the Tx jitter is accounted for.

EIT baseline sweep[1]		
ilvl (mV_p)	VH (mV_{pp})	HO (UI_{pp})
2	330	0.60
4	310	0.56
6	290	0.52
8	268	0.48
10	248	0.48
12	228	0.44
14	208	0.40
16	188	0.36
18	168	0.32
20	146	0.28

"working" region

(1) ilvl =Sinusoid Amplitude
VH, HO = Horizontal and Vertical Eye Openings in the absence of transmitter jitter and Awgn noise.

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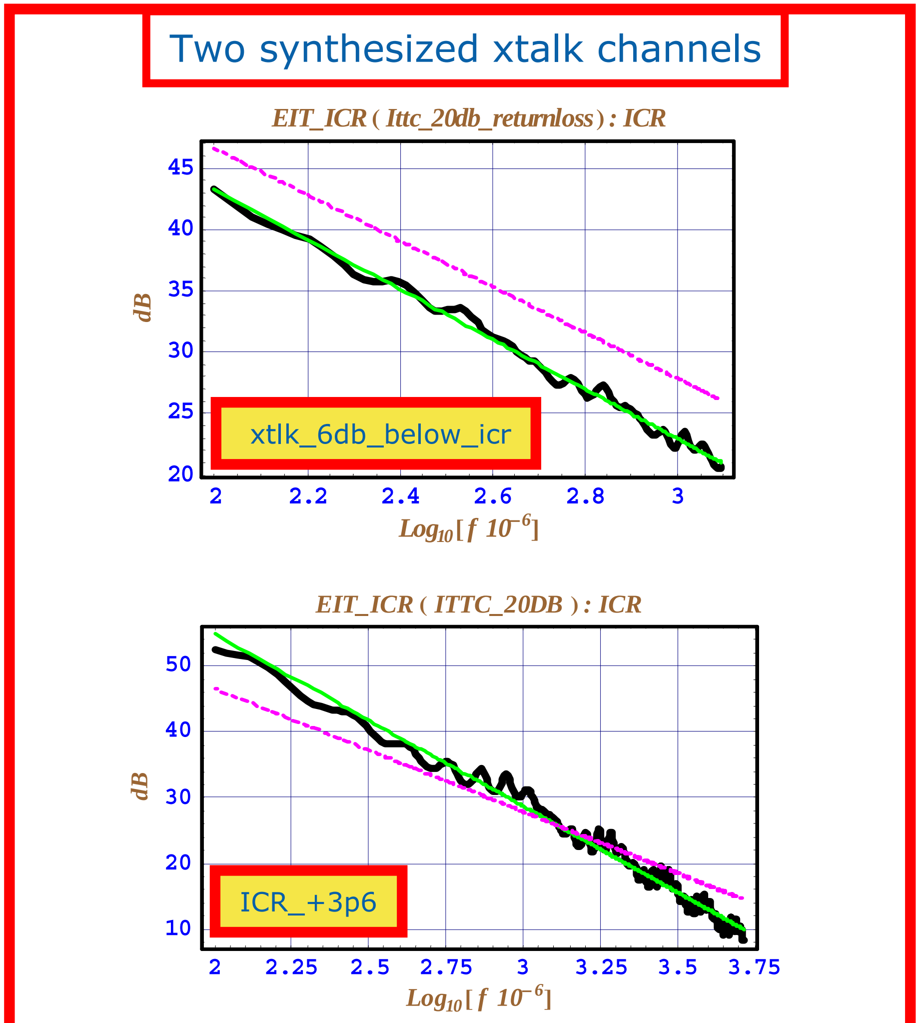
Observations

1. There seem to be more margin on the "vertical" opening than on the "horizontal" opening.
2. As the *interference level* is reduced we observe that the eye does not open up completely; this is probably associated with the channel quality (self-noise), equalizer effectiveness etc.
3. Some more insight may be obtained by relating the *interference level* to an equivalent level of xtalk for this ittc_20db_returnloss channel
   - This allows us to establish a correlation between the *interference level* and the ICR limit curve
   - This step was carried out by creating a set of synthesized xtalk channels built to provide different ICR profiles. Each one of this synthesized xtalk channels was characterized to determine the *equivalent interference level (EIL)*.



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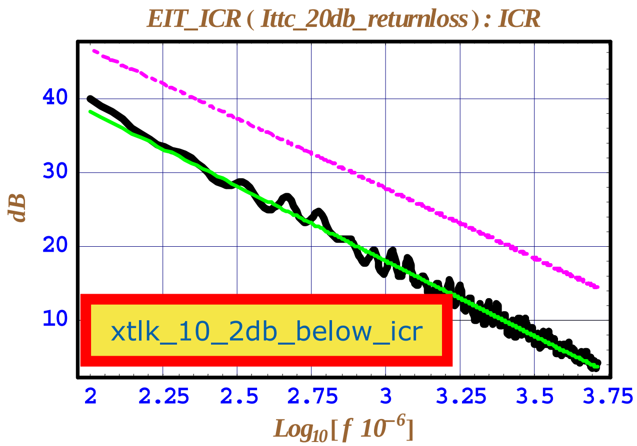
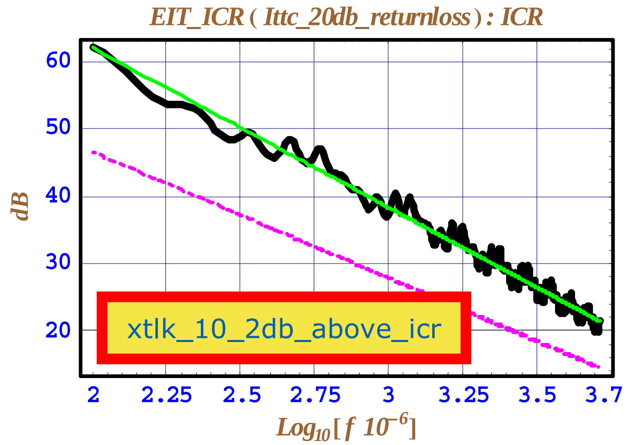
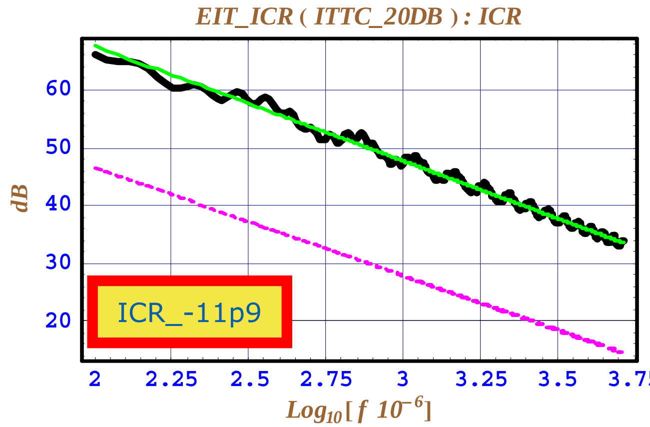
Simulation Results : Table 3







Synthesized Xtalk channels	Xtalk[1]		EIT[2]			Xtalk + Tx Jitter[1]	
	VH (mV_{pp})	HO (UI_{pp})	eit (mV_p)	VH (mV_{pp})	HO (UI_{pp})	VH (mV_{pp})	HO (UI_{pp})
xtlk_10_2db_below_icr	64	0.12	28.07	64	0.12	0.0	0.00
xtlk_6db_below_icr	206	0.40	14.24	206	0.40	106	0.20
ICR_+3p6	230	0.44	11.77	230	0.44	132	0.24
xtlk_at_icr	278	0.52	6.90	280	0.52	174	0.32
xtlk_10_2db_above_icr	317	0.60	3.38	316	0.6	207	0.36
xtlk_5_8db_above_icr	326	0.60	2.29	326	0.6	214	0.36
ICR_-11p9	343	0.64	0.72	342	0.64	225	0.40

"working" region

(1) VH, HO = Horizontal and Vertical Eye Openings at the slicer input

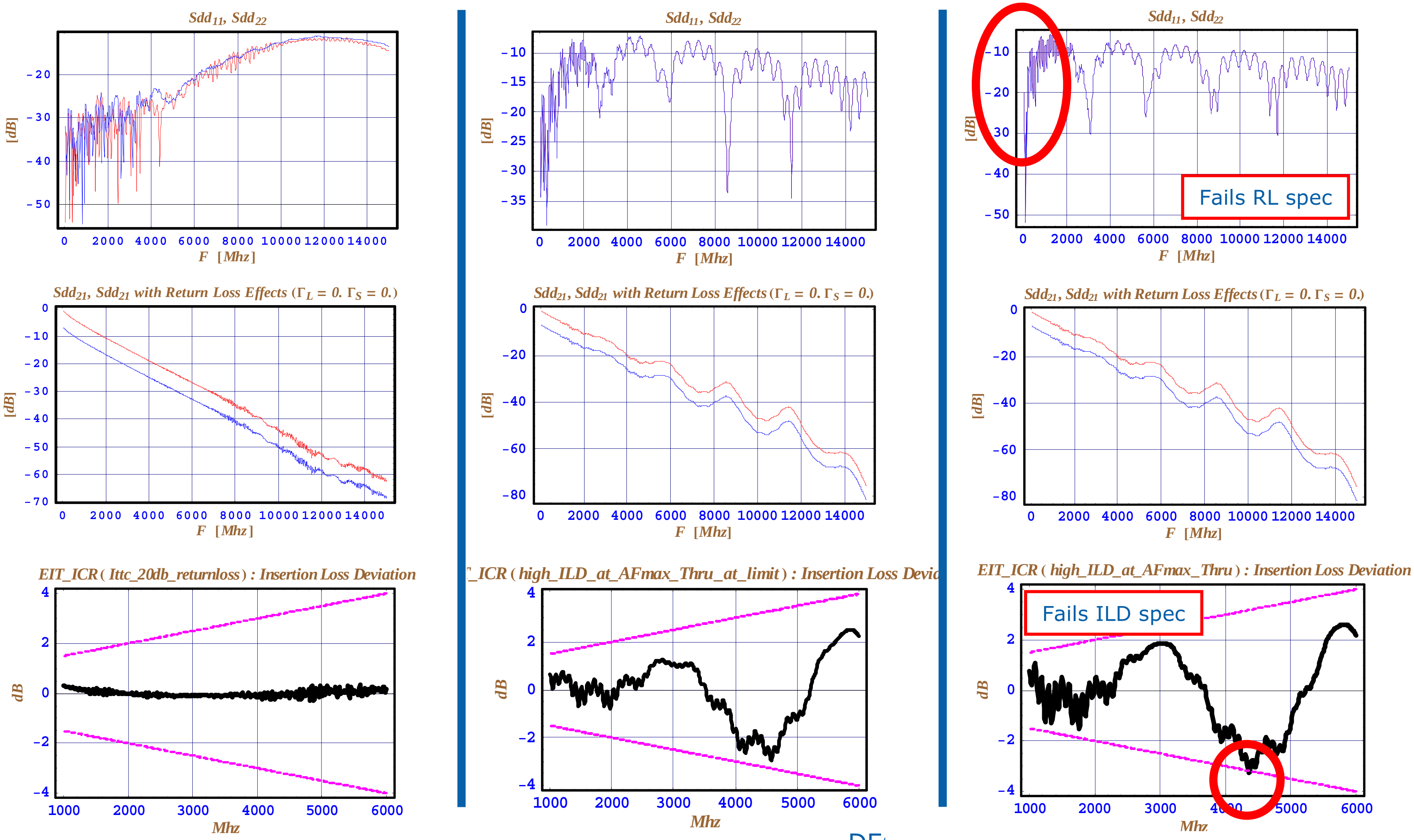
(2) eit=Sinusoid Amplitude
VH, HO = Horizontal and Vertical Eye Openings when xtalk is replaced by sinusoidal interference of amplitude eit

(3) Fext = Xtalk power at slicer input
SNR = measured at slicer input

More observations

- The ICR_+3p6 synthesized xtalk channel represents the boundary between the "operational" and the "non-operational" regions.
  - This is based on the eye openings observed at the slicer input when TX jitter and noise are present. (VH > 10 mV_p, HO > 0.24 UI_{pp})
- The current ICR_{min} limit curve seems to be in line with this definition of an acceptable region of operation.
- Why, then, are the three test cases failing? After all, these test cases where built to represent situations which are near the limit of what we plan to support and from an ICR point of view are not worse than the ICR_+3p6 (and in fact in some cases are better). We note that:
  a) The EIT baseline above which the link ceases to be operational is around 12 $mV_{p.}$
  b) Table1 and Table 2 suggest that the EIT baseline to be derived for the three test cases is much higher than 12 mV_p.
  c) Since the three test cases are, from an ICR perspective, at most borderline, this suggests that while the current ICR_{min} curve may represent a reasonable limit for a "clean" channel, it may not represent a realistic limit for channels with self-noise.
     - This is because the total noise power at the slicer input needs to remain bounded below a certain limit for the link to be operational; if self-noise is present then the xtalk power will need to be reduced.
- In the next set of simulations this relation between crosstalk, self noise and eit is further explored: here the *eit reference channel* tolerance to sinusoidal interference is compared against the one exhibited by two new synthesized channels:
  - The high_ILD_at_AFmax_Thru_at_limit has a Return loss which hugs the limit line
  - The high_ILD_at_AFmax_Thru has a Return loss worse than the limit line
  - Both channels have an ILD characteristic significantly different than the ittc_20db_returnloss channel.

Tolerance to sinusoidal interference



Ittc_20db_return loss

high_ILD_at_AFmax_Thru_at_limit

high_ILD_at_AFmax_Thru

Simulation results: Table 4

sinusoidal interference

"working region"

ittc_20db_returnloss			high_ILD_at_AFmax_Thru_at_limit			high_ILD_at_AFmax_Thru		
TA (mV_{peak})	**VH (mV_{pp})**	**HO (UI_{pp})**	**TA (mV_{peak})**	**VH (mV_{pp})**	**HO (UI_{pp})**	**TA (mV_{peak})**	**VH (mV_{pp})**	**HO (UI_{pp})**
2.0	**330**	**0.60**	2.0	**296**	**0.52**	2.0	**242**	**0.44**
4.0	**310**	**0.56**	4.0	**276**	**0.52**	4.0	222	0.40
6.0	**290**	**0.52**	6.0	**256**	**0.48**	6.0	202	0.36
8.0	**268**	**0.48**	8.0	**234**	**0.44**	8.0	180	0.32
10.0	**248**	**0.48**	10.0	214	0.40	10.0	160	0.28
12.0	**228**	**0.44**	12.0	194	0.36	12.0	140	0.28
14.0	208	0.40	14.0	174	0.32	14.0	120	0.24
16.0	188	0.36	16.0	154	0.28	16.0	100	0.20
18.0	168	0.32	18.0	134	0.24	18.0	80	0.16
20.0	146	0.28	20.0	112	0.20	20.0	58	0.12

Simulation results: Table 5

white noise interference

ittc_20db_returnloss			high_ILD_at_AFmax_Thru_at_limit			high_ILD_at_AFmax_Thru		
TA (mV_{rms})	VH (mV_{pp})	HO (UI_{pp})	TA (mV_{rms})	VH (mV_{pp})	HO (UI_{pp})	TA (mV_{rms})	VH (mV_{pp})	HO (UI_{pp})
0.5	**331**	**0.60**	0.5	**277**	**0.52**	0.5	**263**	**0.44**
1.0	**308**	**0.60**	1.0	**256**	**0.48**	1.0	**242**	**0.44**
1.5	**286**	**0.56**	1.5	**237**	**0.44**	1.5	220	0.40
2.0	**263**	**0.52**	2.0	**218**	**0.44**	2.0	199	0.40
2.5	**240**	**0.48**	2.5	198	0.40	2.5	178	0.36
3.0	**216**	**0.48**	3.0	178	0.36	3.0	155	0.32
3.5	191	0.36	3.5	157	0.32	3.5	133	0.28
4.0	166	032	4.0	136	0.24	4.0	110	0.20
4.5	146	0.28	4.5	115	0.20	4.5	87	0.12

"working region"

More information is needed.

- Both *sinusoidal* and *awgn* interference show the same trend: channels with higher self-noise can tolerate less interference (i.e. less xtalk).
- The backplane designer (and the system architect) can trade-off one form of noise for the other (i.e. allow more xtalk and reduce the self noise) but, in practice, this maybe somewhat difficult without providing some further information. This additional information could take the form of :
  1. an additional ICR limit curve, derived from a channel with **maximum self noise** (e.g. max RL and/or max ILD).
     - This would bound the amount of xtalk allowable when maximum self-noise is present
  2. an additional return loss curve (or ILD curve) derived from a channel with **minimum ICR limit**
     - This would bound the amount of self-noise allowable when maximum xtalk is present

Defining the EIT baseline from the Receiver Stress observed in the test channels

Simulation results: Table 6

- To determine the EIT baseline, we need to determine the amplitude of the sinusoidal interference which produces the same vertical eye closure observed in the three test cases (Table 1, columns 2 – 3), when the backplane is the ittc_20db_returnloss.
- In all cases, the simulator uses the vertical opening (@ BER 1E-12) to determine the *interference level* required.
- The data in the table below refers to the case where xtalk gain = 0dB
  - The case in which xtalk gain = 4dB yields a closed eye.

Test cases	VH (mV_{pp})	HO (UI_{pp})	EIT (mVp)	VH (mV_{pp})	HO (UI_{pp})	EIT (mV_{rms})	VH (mV_{pp})	HO (UI_{pp})
Tyco Case7	150	0.40	14.25	150	0.32	4.21	150	0.28
m_60	85	0.20	25.28	85	0.16	5.43	85	0.16
m_82	65	0.12	27.15	65	0.12	5.77	65	0.12

From Table 1 | Sinusoid Interference | AWGN Interference

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Comments to Table 6

- Sinusoid and AWGN interference show the same trend.
- The (sinusoidal) EIT baseline is in all cases greater than the 12 mV_p limit-value found in Table 2.
  - it is not possible to use these values to determine the EIT baseline for Annex 69A
- The data from Table 6 seem to be pointing to an horizontal compression effect.
  - This may be due to round-off/quantization errors but …
  - … it could also point out to the fact that since the ittc_20db_returnloss channel has less self noise than the three test cases considered here the interference level needs to be artificially increased to produce the same vertical closure.
    - If this hypothesis is confirmed it could indicate that the interference methodology (be it sinusoid or awgn) is not well suited to emulate the effects of self-noise
  - Work is in ongoing to determine if this is a numerical problem.

Conclusions

- The first two steps in the plan outlined in slide #2 were successfully carried out.
  - It was found (Table 2) that the ittc_20db_returnloss channel could successfully made to operate with interference level of up to 12mV_p’ This established a *de-facto* upper limit for the EIT baseline.
- The third step could not be completed because in all three cases the EIT baseline (Table 6) exceeded the 12 mV_p limit.
- Something is still missing in the channel definition (guidelines) in that we are not able to distinguish a “good” channel from a “marginal” or even a “bad” one.
  - The discussion on the relationship between *tolerance to interference* and *self-noise* indicates the need to augment the informative channel annex with additional information. A suggestion to this effect was presented on slide #18.
- The sinusoidal interference can be used to effectively emulate the effects of xtalk in a given channel (EIL).
  - I could not find big differences when using AWGN instead of a sinusoidal interference. As a *caveat* I should however add that this was not the main focus of this work, so more analysis may be in order.
- It is possible to define a Receiver Compliance Test in terms of a reference channel like the ittc_20db_returnloss.
  - A sweep like the one in Table 2 indicates that a value for the EIT baseline could be quickly determined. As an example, .given the assumptions made here, the EIT baseline would be in the order of 12 mV_p.
- However…
  - It is not clear how to handle deviations from the ittc_20db_returnloss characteristics.
  - Relating this limit to the “noise” observed in a real backplane is problematic:
    - This is particularly the case if the *horizontal compression* observed in Table 6 turns out not to be a round-off/quantization problem because it would indicate that the sinusoidal interference (or awgn interference) does not emulate the channel self-noise in a realistic manner.
  - Finally, it should be noted that the tolerable interference level is a function of the overall equalization partition.

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