Issues with sampling time and jitter in Annex 93A

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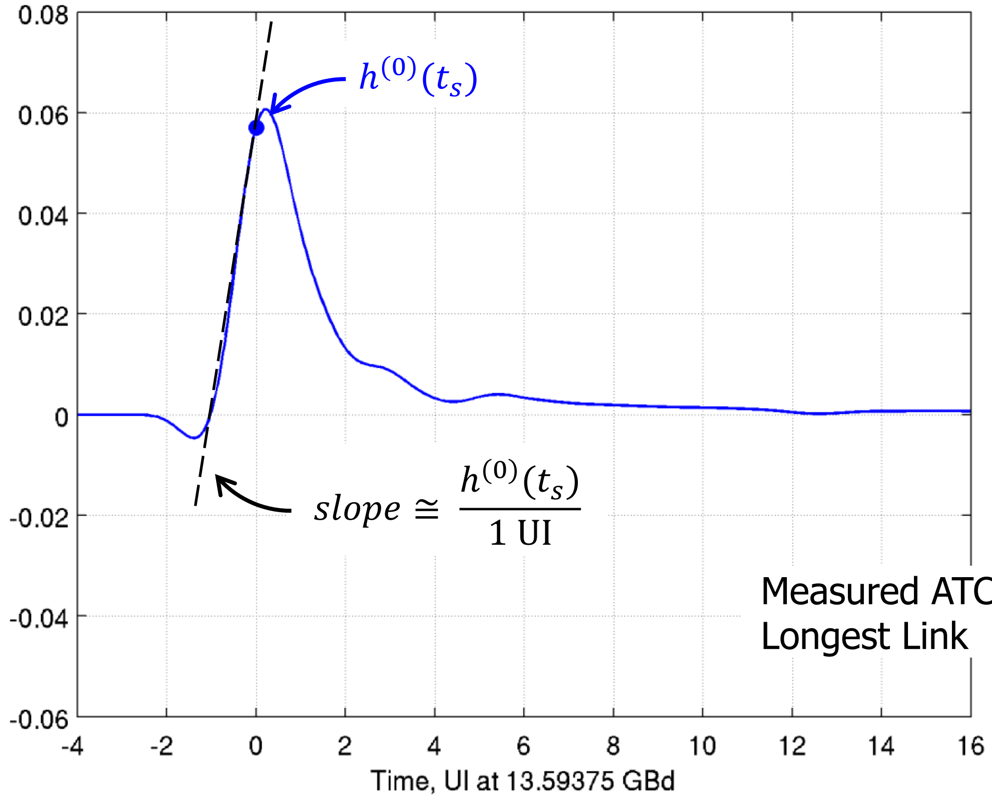
Part 1: Jitter (comment #157)

Treatment of jitter in COM Draft 2.0

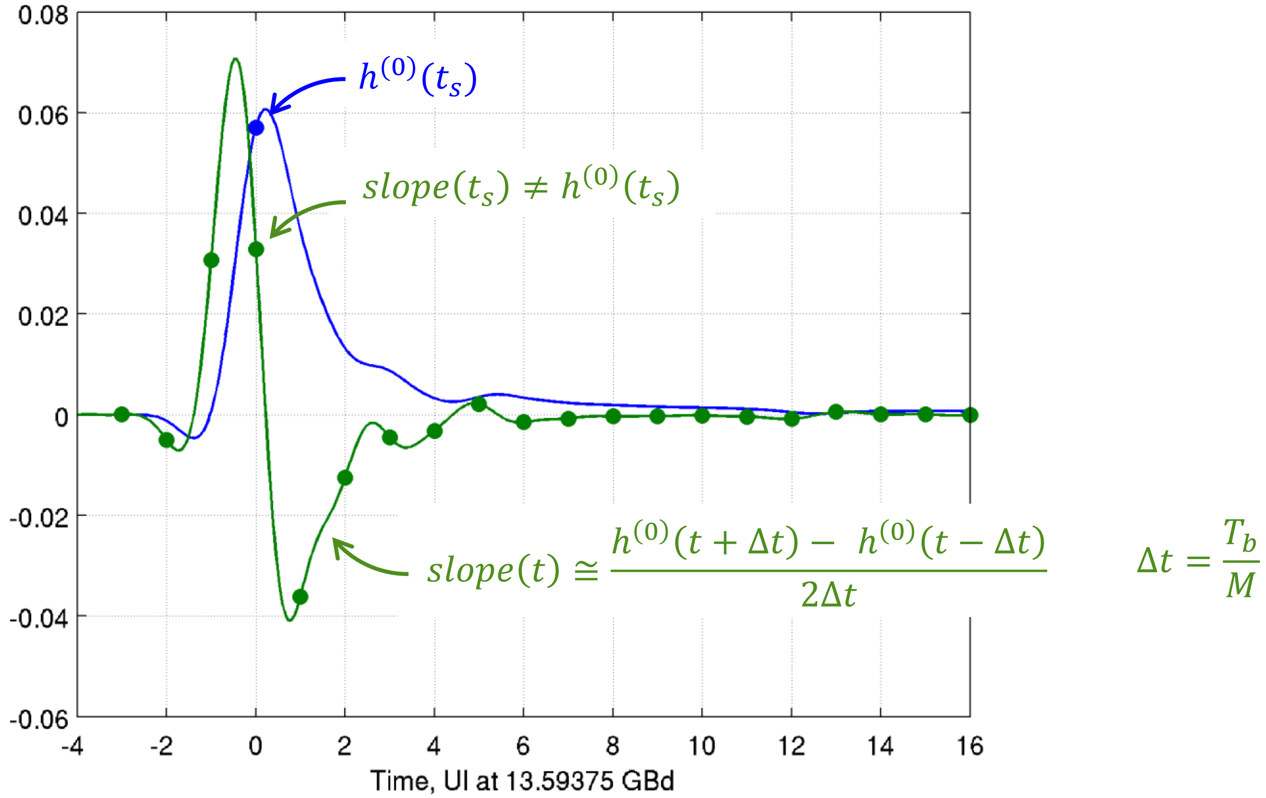


Measured ATCA Backplane Channel [1]
Longest Link

- (amplitude error, V) = (timing error, UI) x (slope, V/UI)
- Estimate the slope to be the amplitude of the pulse response at time t_s
- Assume the slope around pre- and post-cursor samples is negligible

NOTE: In Draft 2.0, the pulse response amplitude includes the factor $1/(L-1)$. This presentation assumes that this factor is removed per comment #156.

Testing the assumptions



- The slope around t_s <u>is not</u> necessarily the signal amplitude
- The slope around pre- and post-cursor samples <u>is not</u> negligible
- Predictions of the impact of jitter may not be accurate

A better, but still simple, estimate

- Calculate the slope of the pulse response

$$h_J(t) = \frac{d}{dt} h^{(0)}(t)$$

May be estimated using the expression on slide 4.

- Sample the slope at 1 UI intervals around t_s

$$h_J(n) = h_J\,(t_s + nT_b)$$

- Estimate the variance of the amplitude error due to timing error

$$\sigma_J^2 = \left(A_{DD}^2 + \sigma_{RJ}^2\right)\sigma_X^2 \sum_n h_J^2(n)$$

Similar to calculation of σ_{ISI}^2, see Equation (93A-25)

- In Equation (93A-27) replace $(A_s \sigma_{RJ})^2$ term in denominator with σ_J^2

In the spirit of comment #74

A better, but still simple, estimate (continued)

- Modify Equation (93A-32) as follows, replacing $(A_s \sigma_{RJ})^2$ term

$$\sigma_G^2 = \sigma_{RJ}^2 \sigma_X^2 \sum_n h_J^2(n) + \sigma_r^2$$

Comment #73 also proposes to modify the definition of σ_r.

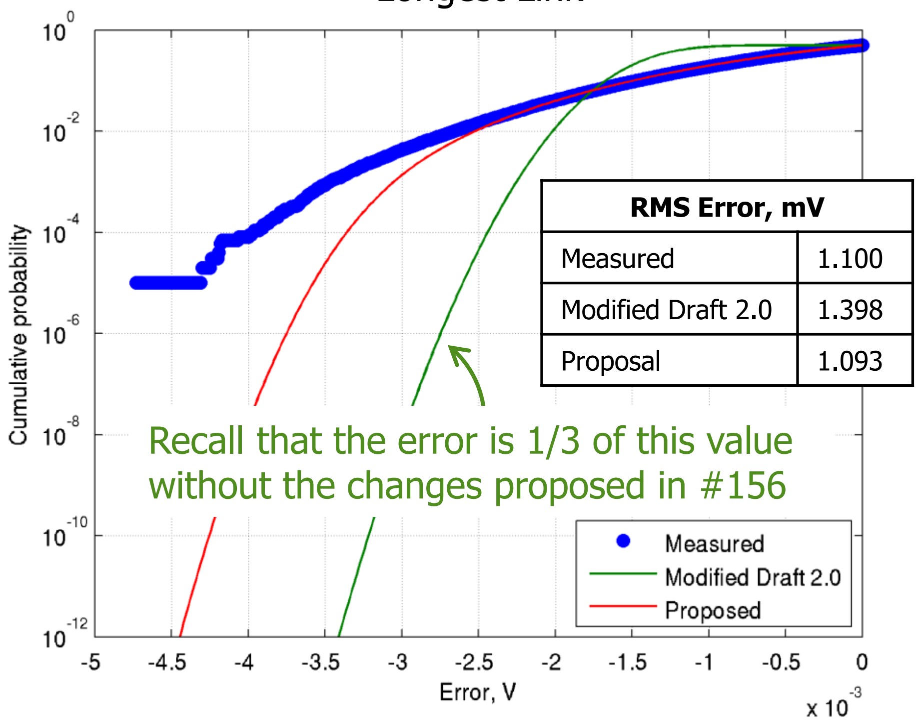
- Similarly for Equation (93A-42)

$$\sigma_G^2 = \sigma_{RJ}^2 \sigma_X^2 \sum_n h_J^2(n) + \sigma_r^2 + \sigma_{ne}^2$$

- Compute p_{DD} per 93A.1.7.1 using $h(n) = A_{DD} h_J(n)$

Current method versus proposal

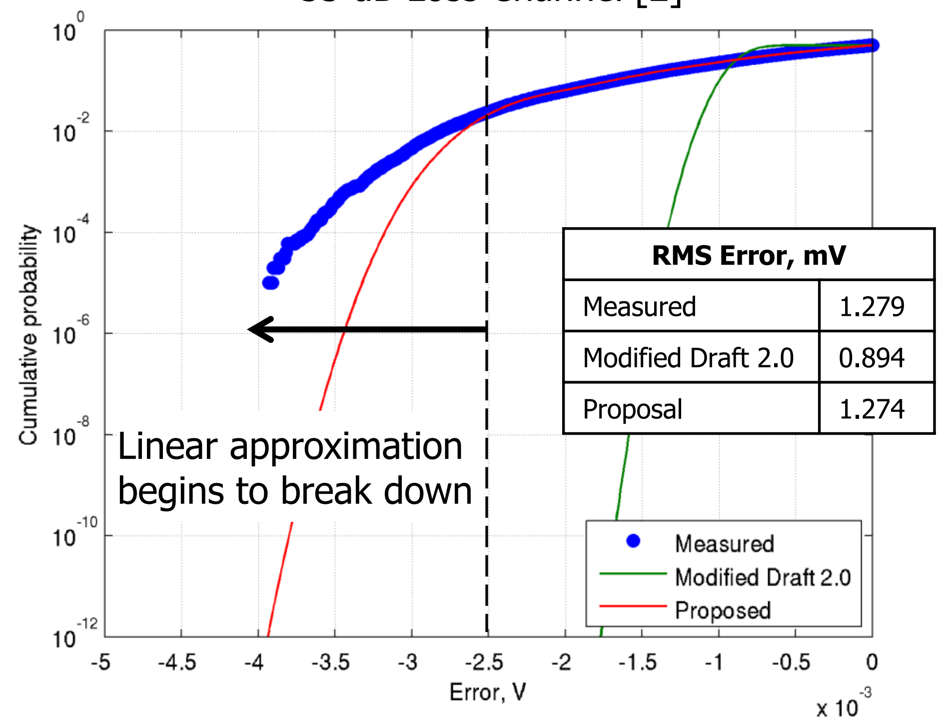
Longest Link



RMS Error, mV	
Measured	1.100
Modified Draft 2.0	1.398
Proposal	1.093

100GBASE-KP4, A_{DD} = 0.025, σ_{RJ} = 0.005

35 dB Loss Channel [2]



RMS Error, mV	
Measured	1.279
Modified Draft 2.0	0.894
Proposal	1.274

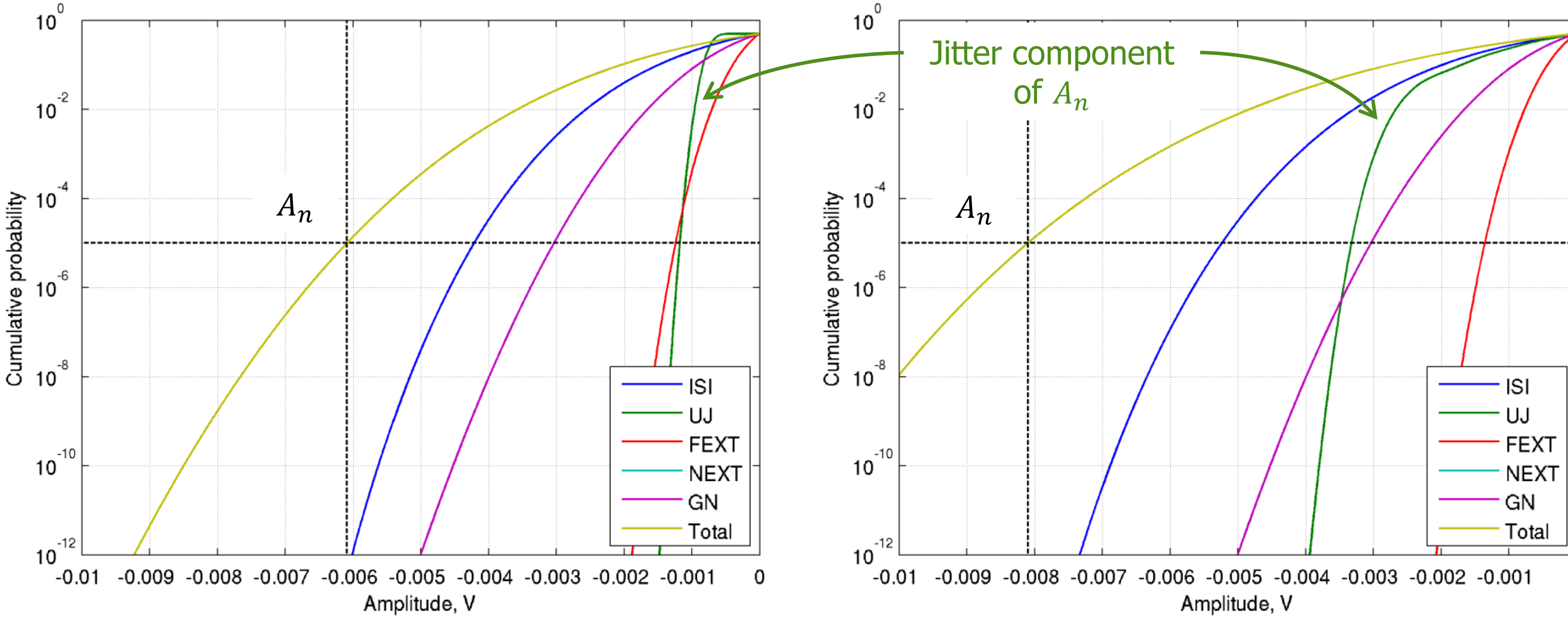
100GBASE-KR4, A_{DD} = 0.07, σ_{RJ} = 0.01

- Measured data based on time-step simulation of 100,000 random symbols
- Proposal in better agreement with empirical distribution
- Proposal is still an estimate – more terms are required to correctly model larger time offsets

Impact on COM

- Evaluate proposal with an implementation of IEEE P802.3bj/D2.0 Annex 93A
- Include the changes proposed by comments #155, #156, #80, #74, #73
- #73 implemented as two-sided noise spectral density $N_0/2$ at the input to the receiver noise filter ($N_0/2$ = 26 nV^2/Hz)
- The amplitude step Δy is set to 0.01 mV

IBM Experimental Backplane Test Fixture: 35 dB Loss Channel, 100GBASE-KR4



Draft 2.0 modified

Proposal

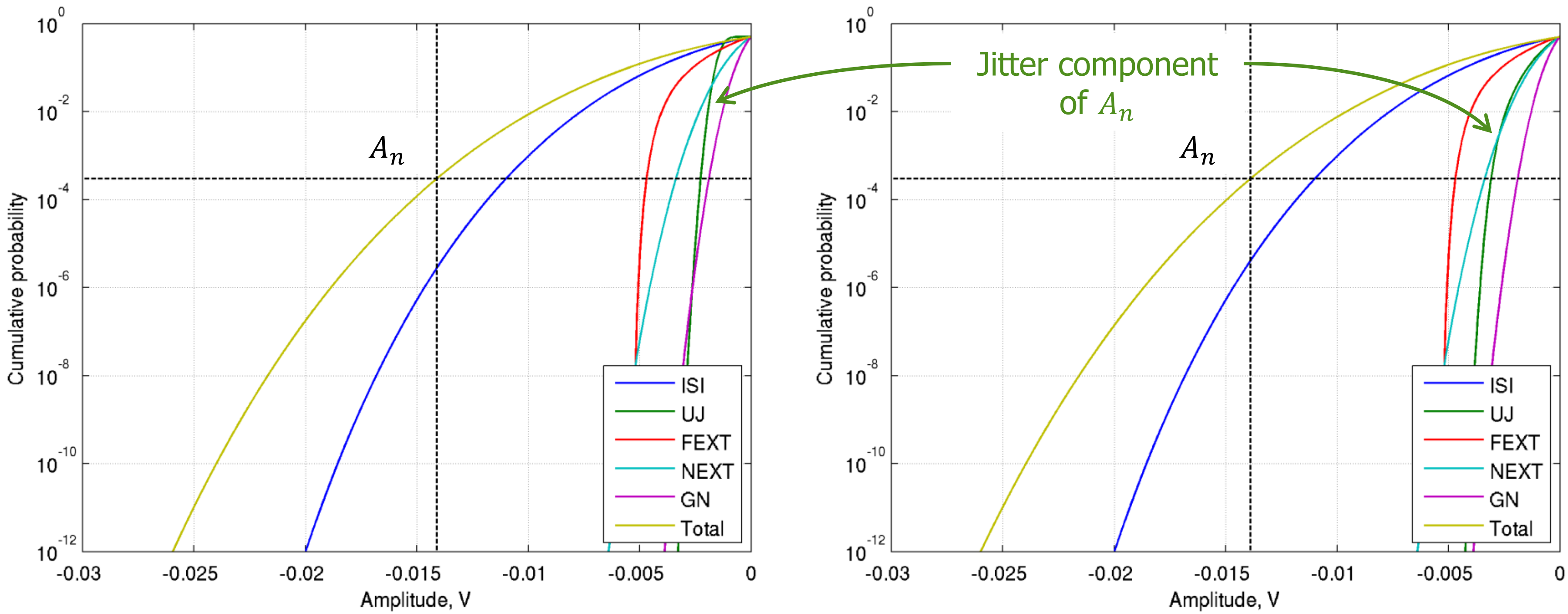
- Proposed estimate of the error variance influences equalizer configuration
- Proposed estimate of the error distribution influences the COM value

Summary of results: 100GBASE-KR4

IBM Experimental Backplane Test Fixture

Channel	Model	$c(-1)$	$c(+1)$	g_{DC} (dB)	FOM (dB)	A_s (mV)	A_n (mV)	COM (dB)	Δ (dB)
25 dB Loss Channel	Draft 2.0	−0.14	0.00	−11	18.05	29.088	13.888	6.42	−1.14
	Proposal	−0.18	0.00	−6	16.86	34.951	19.031	5.28	
30 dB Loss Channel	Draft 2.0	−0.14	−0.06	−12	18.48	20.068	8.897	7.07	−1.53
	Proposal	−0.18	0.00	−10	16.85	23.514	12.436	5.53	
35 dB Loss Channel	Draft 2.0	−0.14	−0.18	−12	16.53	10.567	6.089	4.79	−0.92
	Proposal	−0.18	−0.08	−12	15.46	12.648	8.098	3.87	

Measured ATCA Backplane Channels: Longest Link, 100GBASE-KP4



Draft 2.0 modified

Proposal

- A_{DD} and σ_{RJ} significantly reduced relative to 100GBASE-KR4
- In these examples, COM is dominated by residual inter-symbol interference
- Impact of the proposal is muted by other impairments

Summary of results: 100GBASE-KP4

Measured ATCA Backplane Channels

Channel	Model	$c(-1)$	$c(+1)$	g_{DC} (dB)	FOM (dB)	A_s (mV)	A_n (mV)	COM (dB)	Δ (dB)
Shortest Link	Draft 2.0	−0.10	0.00	−4	15.63	26.389	14.274	5.34	0.18
	Proposal	−0.10	0.00	−4	16.01	26.389	13.975	5.52	
Middle Link	Draft 2.0	−0.10	−0.12	−3	13.13	21.433	15.002	3.10	0.17
	Proposal	−0.10	−0.12	−3	13.35	21.433	14.704	3.27	
Longest Link	Draft 2.0	−0.12	0.00	−6	12.65	18.271	14.098	2.25	0.14
	Proposal	−0.12	0.00	−6	12.84	18.271	13.875	2.39	

Summary and recommendation

- The treatment of jitter in COM can and should be improved
- Proposed algorithm that leverages concepts already established in Annex 93A
- Proposed algorithm incurs little computational overhead
- Comparisons indicate the current algorithm underestimates the impact of jitter by as much as 1.5 dB for the cases studied
- Recommend the changes described on slides 5 and 6

Part 2: Sampling time (comment #158)

Definition of the sampling time

- It is assumed the definition of t_s is based on the Mueller and Muller timing error detector (Type A) [3]

$$h^{(0)}(t_s - T_b) = h^{(0)}(t_s + T_b)$$

- An unconstrained decision feedback equalizer will always force $h^{(0)}(t_s + T_b) = 0$

$$h^{(0)}(t_s - T_b) = 0 = h^{(0)}(t_z)$$

- But the equalizer is constrained and, in the future, specifications may choose to use COM without a decision feedback equalizer

Proposed definition of the sampling time

- Define t_s to be the time that satisfies the following equation ($N_b = 0$)

$$h^{(0)}(t_s - T_b) = h^{(0)}(t_s + T_b)$$

- When $N_b > 0$, take the coefficient magnitude constraint $b_{max}(n)$ into account

$$h^{(0)}(t_s - T_b) = h^{(0)}(t_s + T_b) - h^{(0)}(t_s)b(1)$$

$$b(1) = \begin{Bmatrix} -b_{max}(1) & h^{(0)}(t_s + T_b)/h^{(0)}(t_s) < -b_{max}(1) \\ b_{max}(1) & h^{(0)}(t_s + T_b)/h^{(0)}(t_s) > b_{max}(1) \\ h^{(0)}(t_s + T_b)/h^{(0)}(t_s) & otherwise \end{Bmatrix}$$

Summary and recommendations

- A revised definition of the sampling time is proposed
- Proposed definition provides the correct result when the decision feedback equalizer is constrained or absent
- Computation time comparable to current sampling time definition
- Low impact when constraints are lax, e.g. 100GBASE-KR4 and as proposed for 100GBASE-KP4 by comment #80
- Recommend changes described on slide 16

References

[1] Meier, Wolfgang and Armin Jacht (Emerson Network Power), "Measured ATCA Backplane Channels", October 2011.
http://www.ieee802.org/3/100GCU/public/ChannelData/emerson_11_0928/meier_02_1011.zip
http://www.ieee802.org/3/100GCU/public/ChannelData/emerson_11_0928/meier_01_1011.pdf

[2] Patel, Pravin (IBM), "Experimental Backplane Test Fixture", May 2011.
http://www.ieee802.org/3/100GCU/public/ChannelData/IBM_11_0518/patel_01_0511.zip
http://www.ieee802.org/3/100GCU/public/ChannelData/IBM_11_0518/patel_02_0511.pdf

[3] Mueller, Kurt H. and Markus Muller, "Timing Recovery in Digital Synchronous Data Receivers", IEEE Transactions on Communications, Vol. COM-24, No. 5, May 1976.

Back-up slides

Clarification of assumptions

- Waveform samples in the absence of jitter are given by …

$$y_0[m] = y(t_s + mT_b) = \sum_n x_n h\left(t_s + (m-n)T_b\right)$$

- … where x_n is the n^{th} signal level transmitted

- This proposal assumes that transmitted jitter may be translated into jitter of the receiver's sampling clock

$$y[m] = y\left(t_s + \epsilon_m^{(RX)} + mT_b\right) = \sum_n x_n h\left(t_s + \epsilon_m^{(RX)} + (m-n)T_b\right)$$

- The amplitude error due to jitter is then given by …

$$y[m] - y_0[m] = \sum_n x_n \left[h\left(t_s + \epsilon_m^{(RX)} + (m-n)T_b\right) - h\left(t_s + (m-n)T_b\right)\right]$$

$$y[m] - y_0[m] \cong \epsilon_m^{(RX)} \sum_n x_n h_J\left(t_s + (m-n)T_b\right)$$

A better model

- The better model is given by the following …

$$y[m] = \sum_n [x_n - x_{n-1}] u_h \left(t_s + \epsilon_n^{(TX)} + (m-n)T_b\right)$$

- … where $u_h(t) = \sum_{i=0}^{\infty} h(t - iT_b)$ is the channel step response

- The amplitude error due to jitter is then given by …

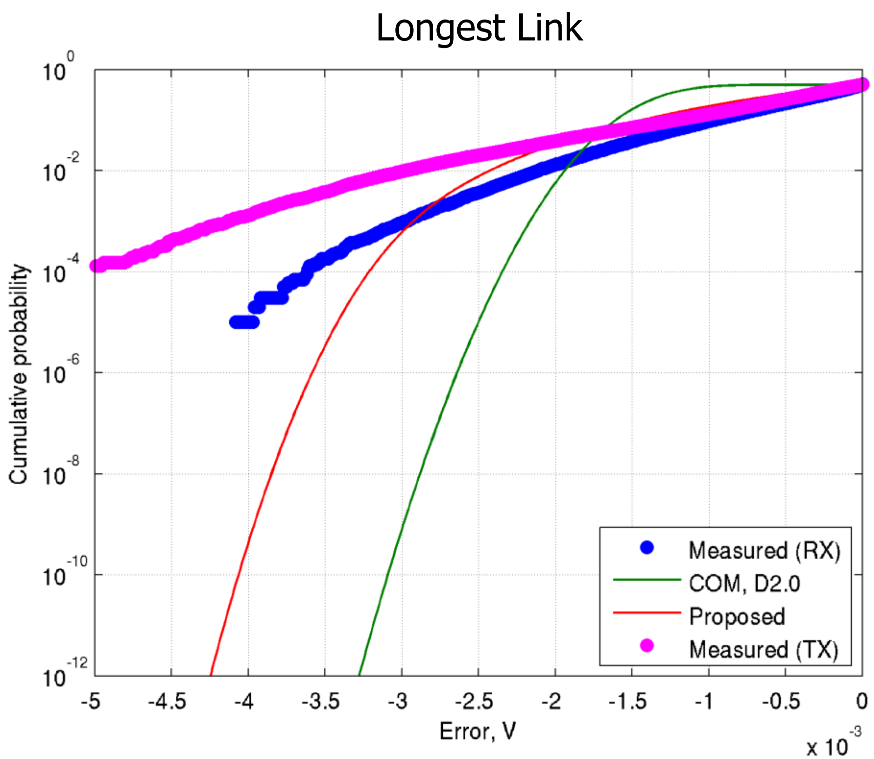
$$y[m] - y_0[m] = \sum_n [x_n - x_{n-1}] \left[u_h \left(t_s + \epsilon_n^{(TX)} + (m-n)T_b\right) - u_h \left(t_s + (m-n)T_b\right)\right]$$

$$y[m] - y_0[m] \cong \sum_n [x_n - x_{n-1}] \epsilon_n^{(TX)} \delta_h \left(t_s + (m-n)T_b\right)$$

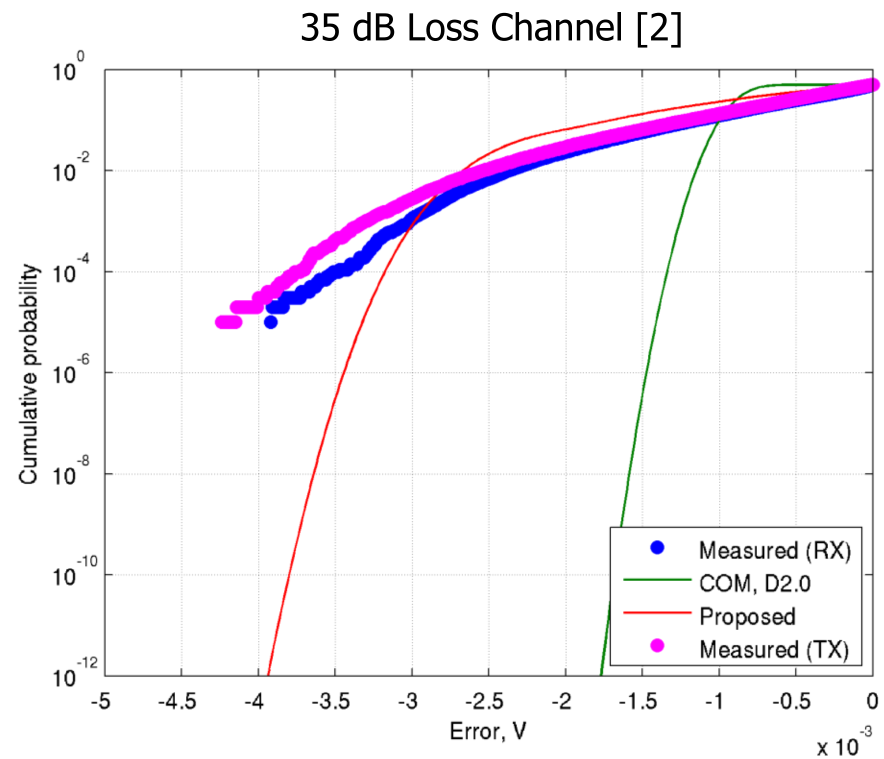
- … where $\delta_h(t) = \sum_{i=0}^{\infty} h_J(t - iT_b)$ is the channel impulse (not pulse) response

- There is no closed form solution for the distribution of error amplitudes using this model

Model comparison



100GBASE-KP4, A_{DD} = 0.025, σ_{RJ} = 0.005



100GBASE-KR4, A_{DD} = 0.07, σ_{RJ} = 0.01

- Measured data based on time-step simulation of 100,000 random symbols
- Deterministic jitter for time-step simulation is sinusoidal with amplitude A_{DD} and period $500T_b$
- Proposal makes simplifying assumption and is not a precise representation
- But, it is less optimistic than the current treatment

Additional references

[4] Oh, Kyung Suk (Dan) et al., “Accurate System Voltage and Timing Margin Simulation in High-Speed I/O System Designs”, IEEE Transactions on Advanced Packaging, Vol. 31, No. 4, November 2008.