



T e c h n o l o g y t o t h e C o r e

Jitter and Cross-talk Effects Using Infiniband Cables and their Implication on Equalization Techniques

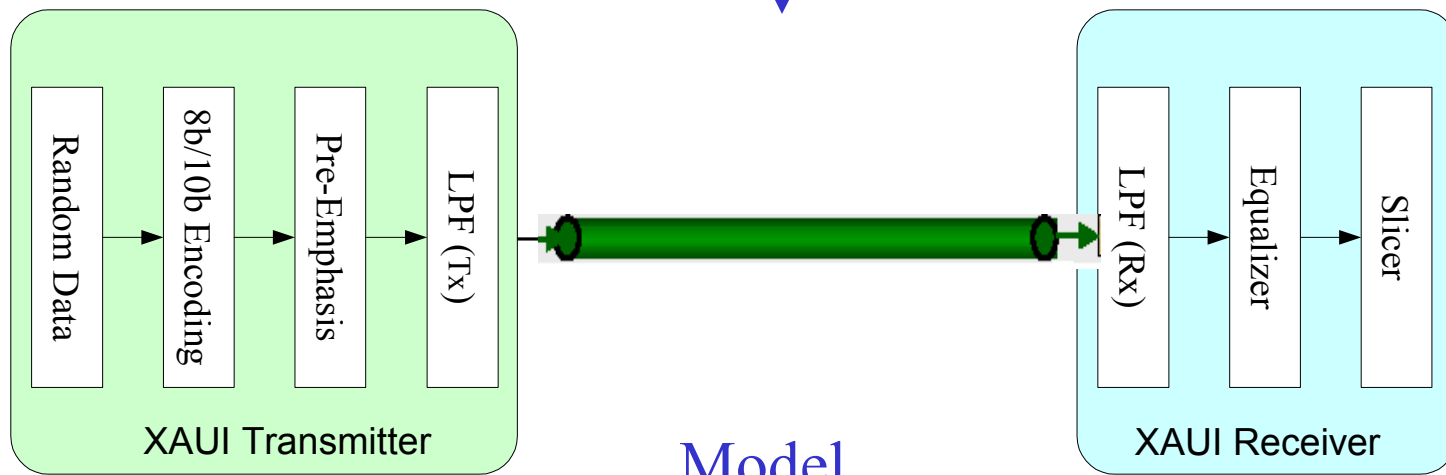
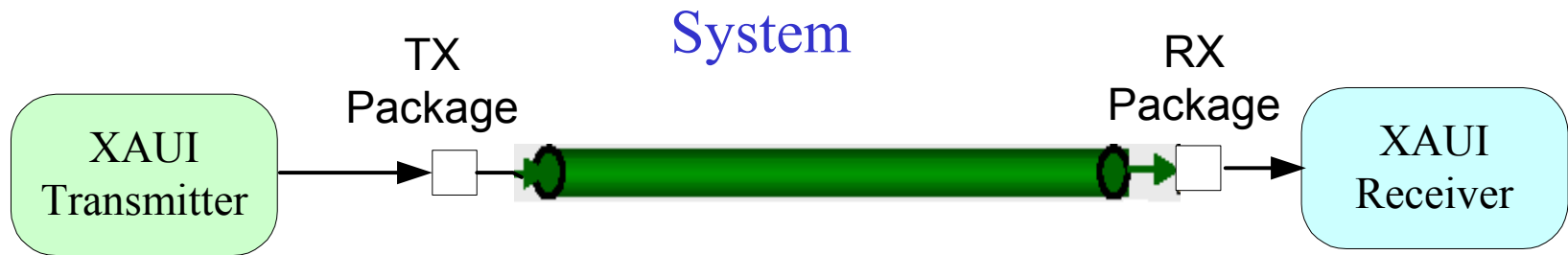
Dr. Ze'ev Roth

Mysticom

Overview

- Introduction
 - System description + assumptions
 - Definition of Preemphasis
 - Assess Preemphasis Effect on Jitter
 - Selecting Preemphasis value
- Estimate Cable length supported WITHOUT equalization
- Define equalization level
- Estimate required equalization at 15m
- Summary Recommendations & Conclusions

System Description

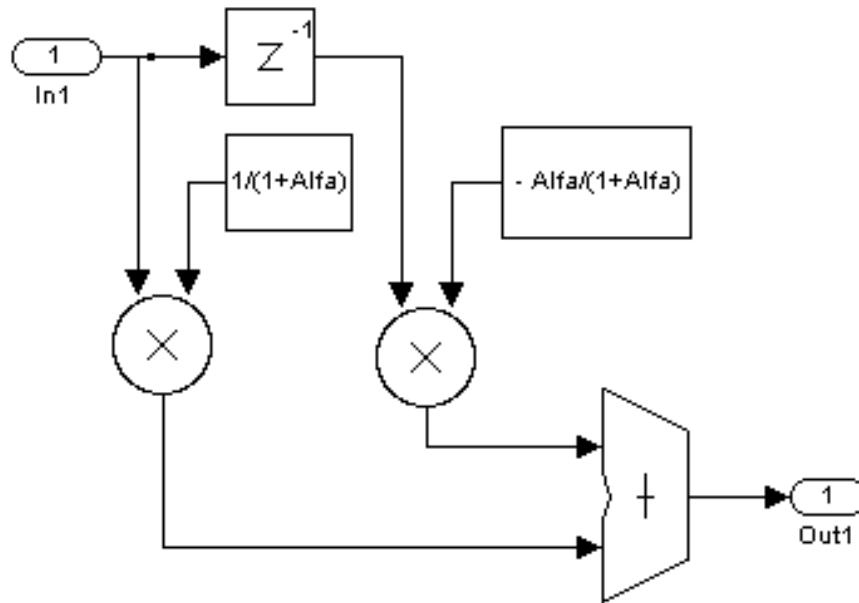


Model

Assumptions

- Transmitter + Tx Package
 - 2nd order LPF @ $1.2 \times \text{Half Baud Rate}$ ($\sim 1.9\text{GHz}$)
- Use typical Launch power allowed by XAUI
 - 0.6V peak
- Tx Jitter
 - $0.18\text{UI RJ} + 0.05\text{UI high frequency DJ} + 0.12\text{UI additional DJ}$ due to preemphasis (for 50%)
 - Total jitter is 0.35UI – as specified by XAUI
 - All jitters are given in peak to peak
- Cross-talk at receiver is modeled as:
 - High pass filtered transmitter output
 - 4% of Tx peak-to-peak

Pre-emphasis



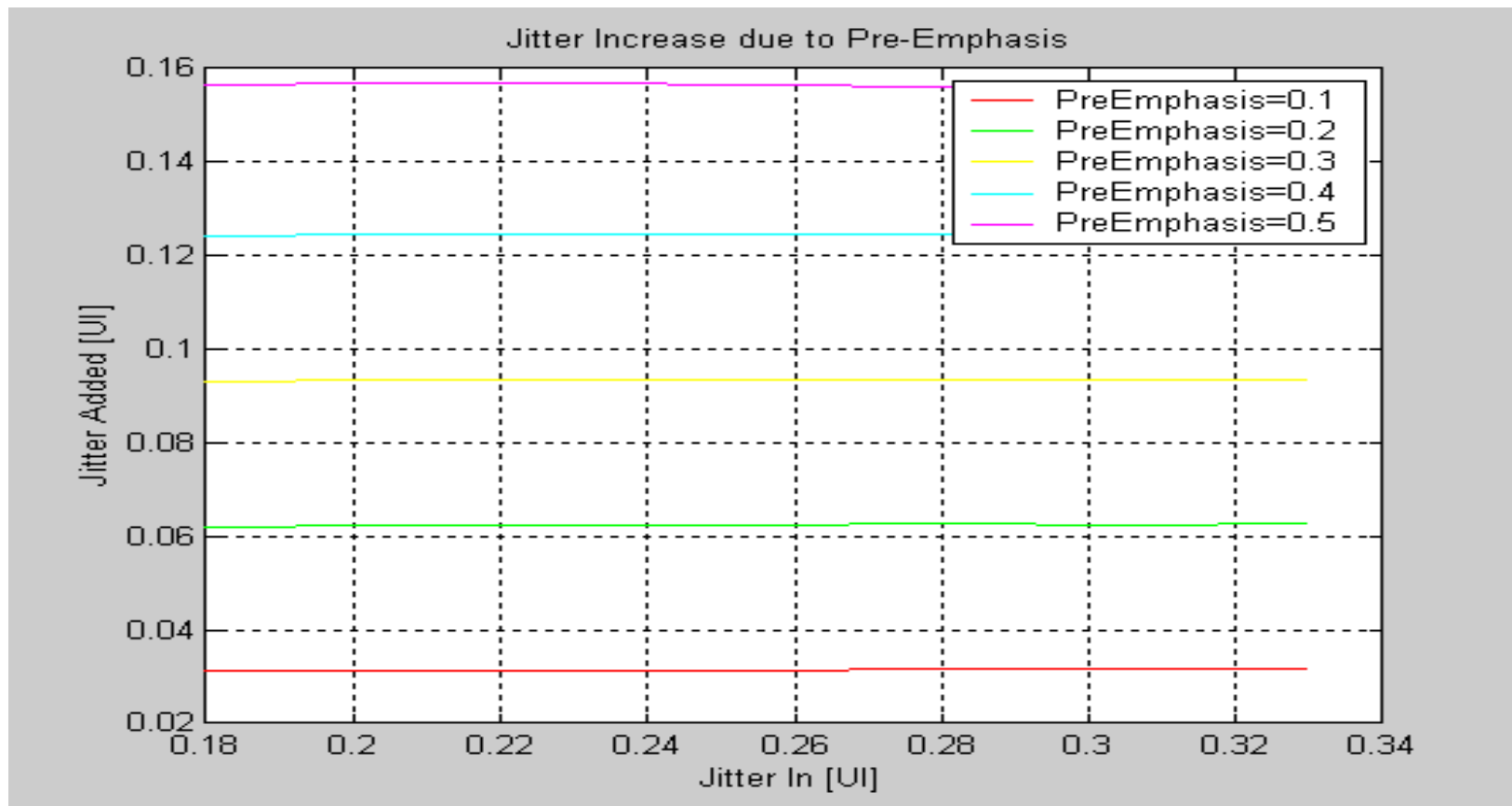
Pre-emphasis filter

$$H(z) = \frac{1}{1+\alpha} - \frac{\alpha}{1+\alpha} z^{-1}$$

Frequency response $|H(\theta)|^2 = \frac{1}{(1+\alpha)^2} (1 - 2\alpha \cos \theta + \alpha^2)$

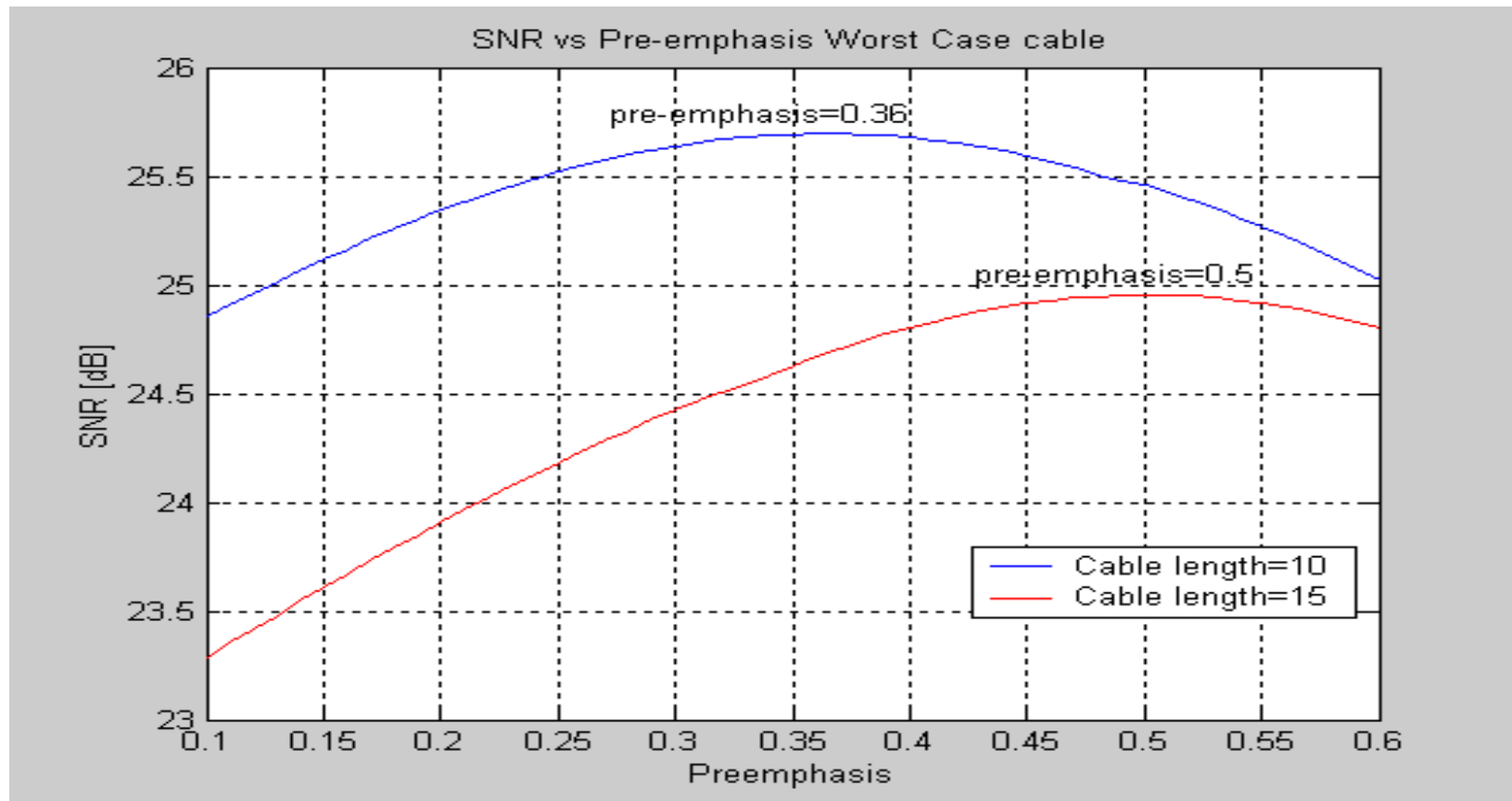
Properties $|H(0)|^2 = \frac{(1-\alpha)^2}{(1+\alpha)^2}$ $|H(\pi)|^2 = 1$

Pre-Emphasis Effect on Jitter at Tx Out



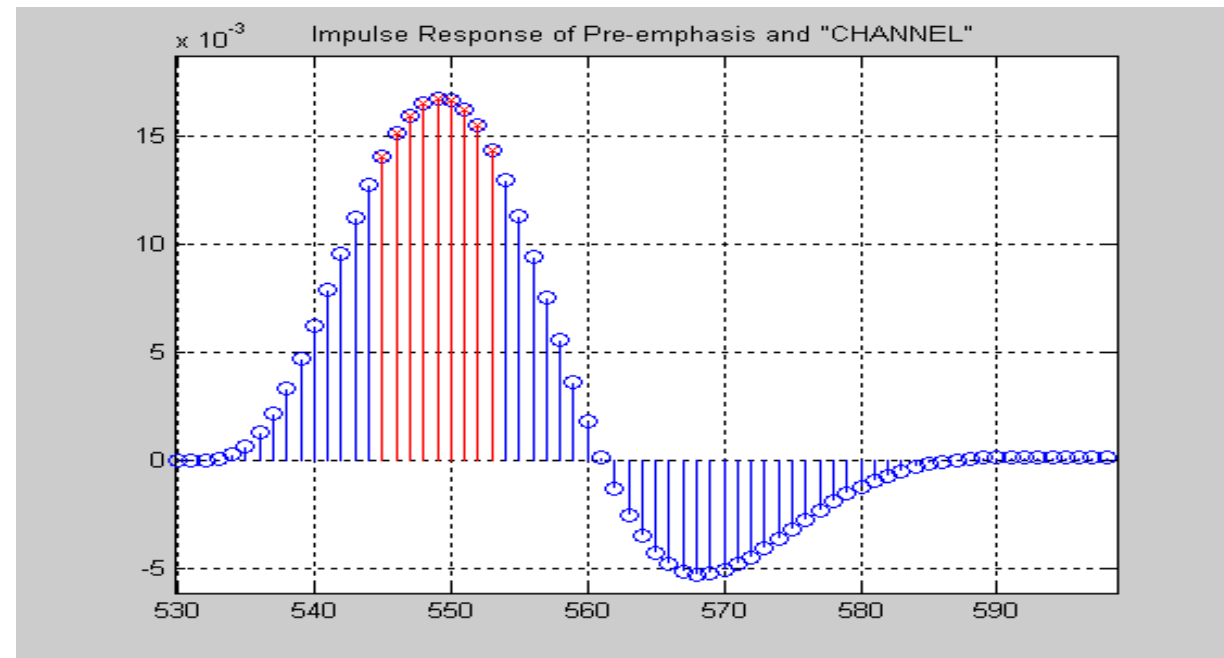
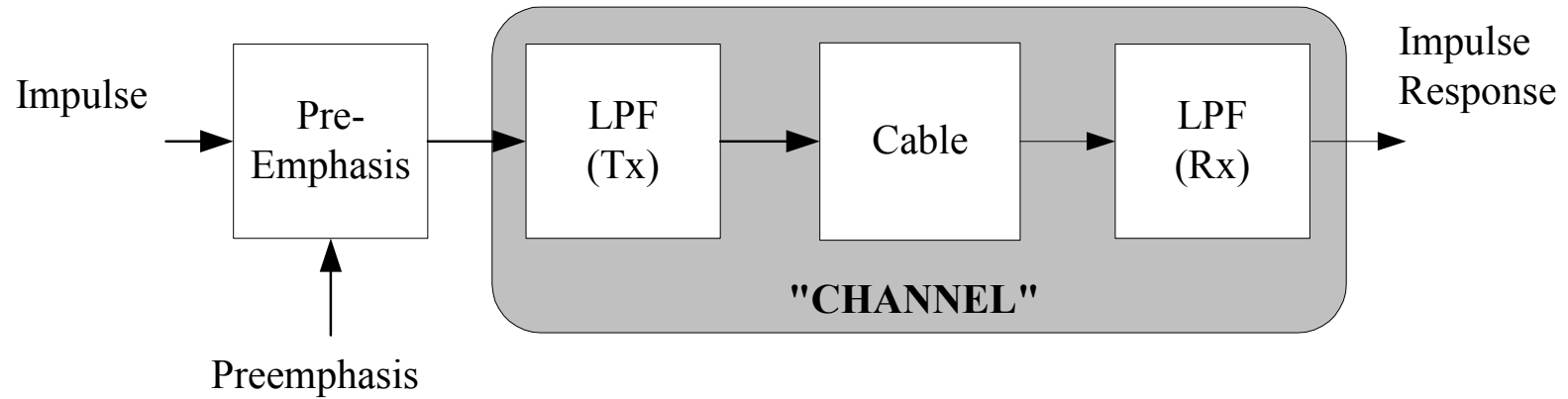
- Turning on pre-emphasis, increases the jitter measured at Tx output

Optimal Pre-emphasis for ISI reduction



Method: Calculate SNR due to ISI at equalizer input as a function of Pre-emphasis (neglect jitter)

SNR Calculation for Preemphasis Selection



Observation #1

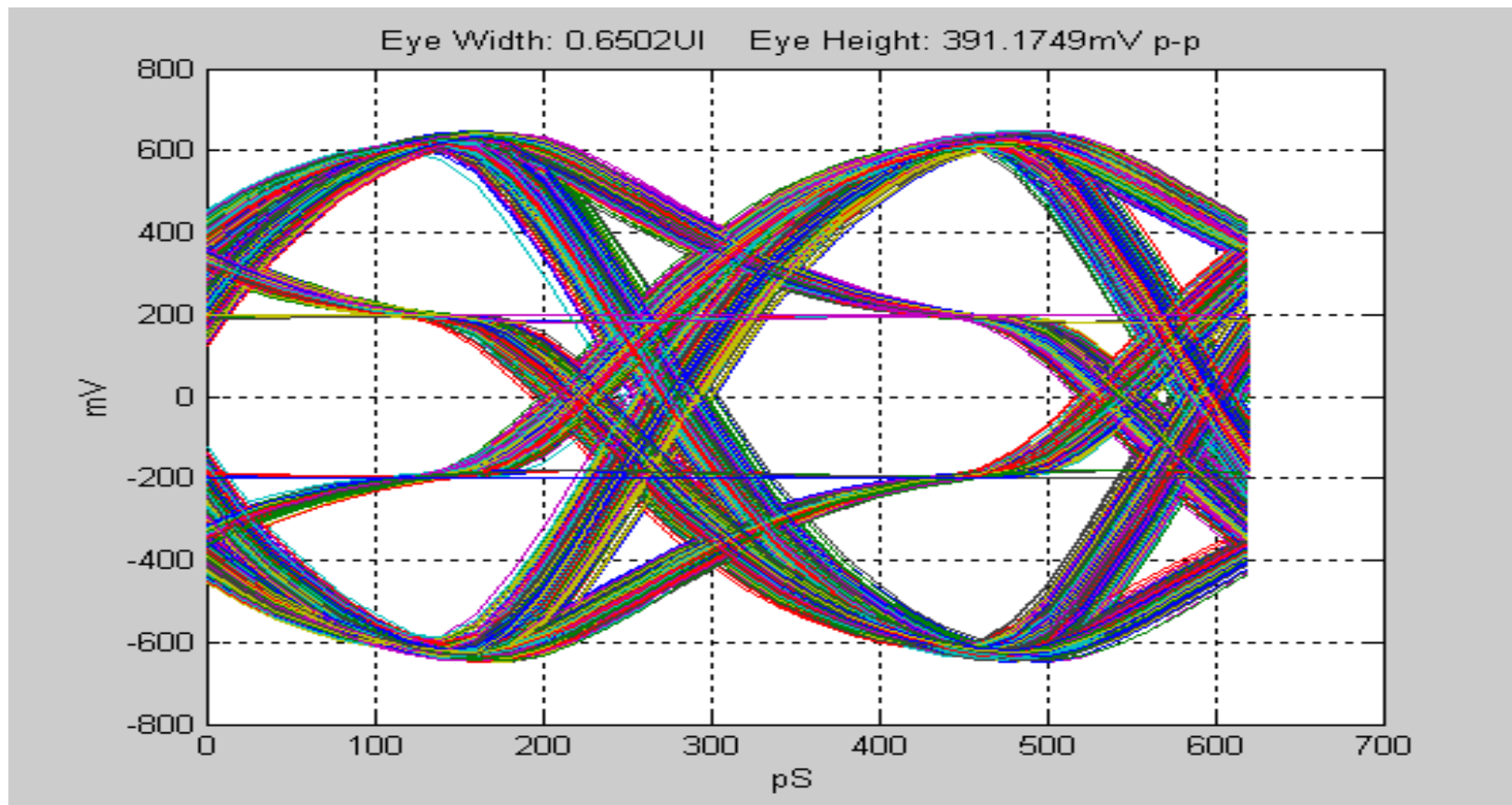
- Optimal Pre-Emphasis for Worst Case IB cable is:
 - 36% @ 10m
 - 50% @ 15m
 - Neglecting cross-talk noise, Gaussian noise, and reflections
 - Where we denote Pre-emphasis by multiplying the filter coefficient by 100 and the units are in %
- Simulations show that for Vendors B & C cables the optimal pre-emphasis is 4% lower than above.

Approach

- We target two channels:
 - “Compliant channel” (10m, 24awg, worst-case IB attenuation)
 - “Worst-case channel” (15m, 24awg, worst-case IB attenuation)
- For “Compliant channel” (10m) use only pre-emphasis
 - Require that at any cable length up to 10m eye meets XAUI receiver template (perhaps with some modifications)
- For “Worst case channel” (15m) use both pre-emphasis and equalizer
- Demonstrate on 3 types of cables:
 - Worst-Case IB, Vendor B, Vendor C

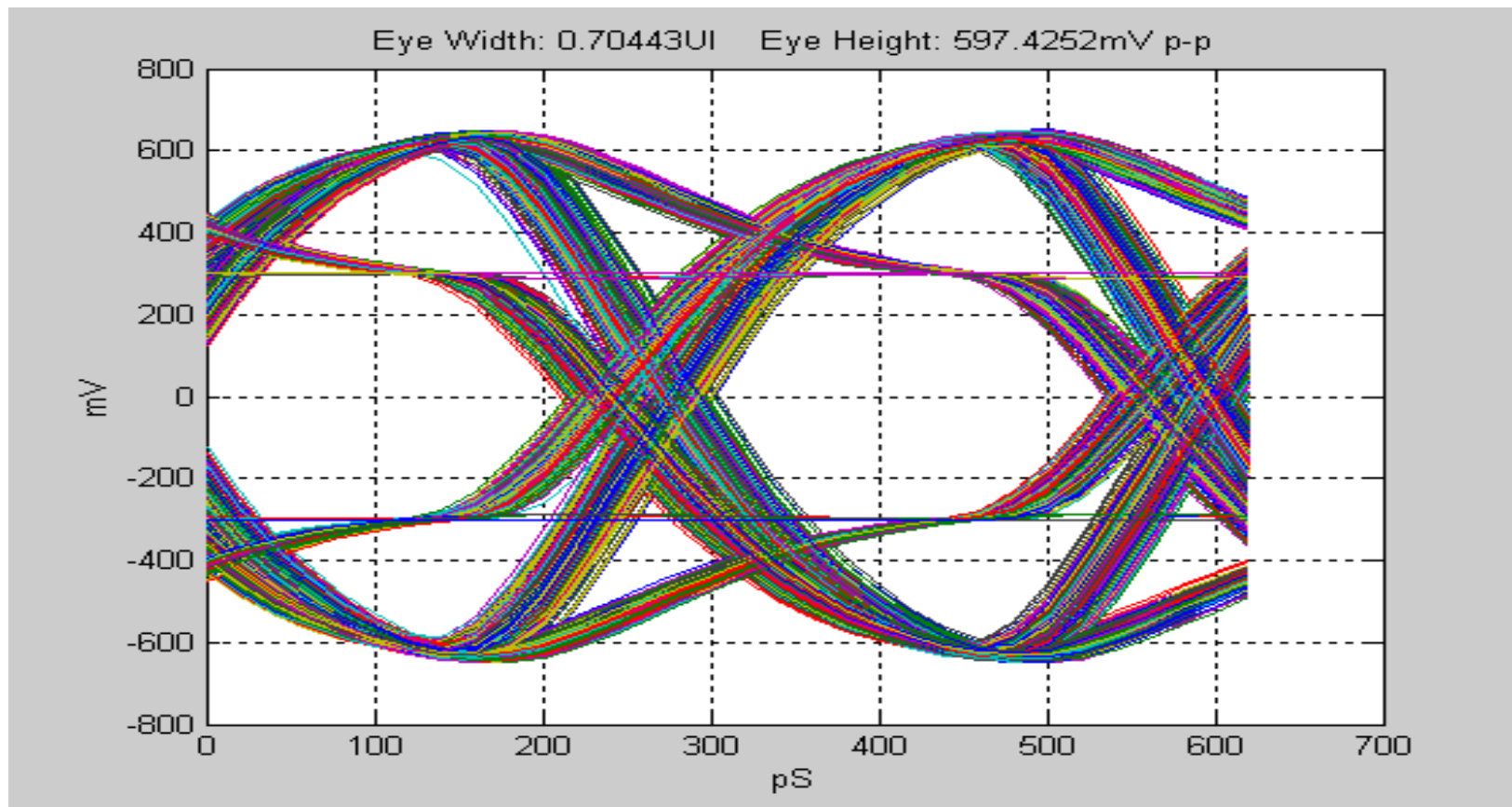
Tx Output: Pre-Emphasis 50%

Without Cross-Talk, without Gaussian noise
 $V_{\text{peak}} = 0.6\text{V peak}$



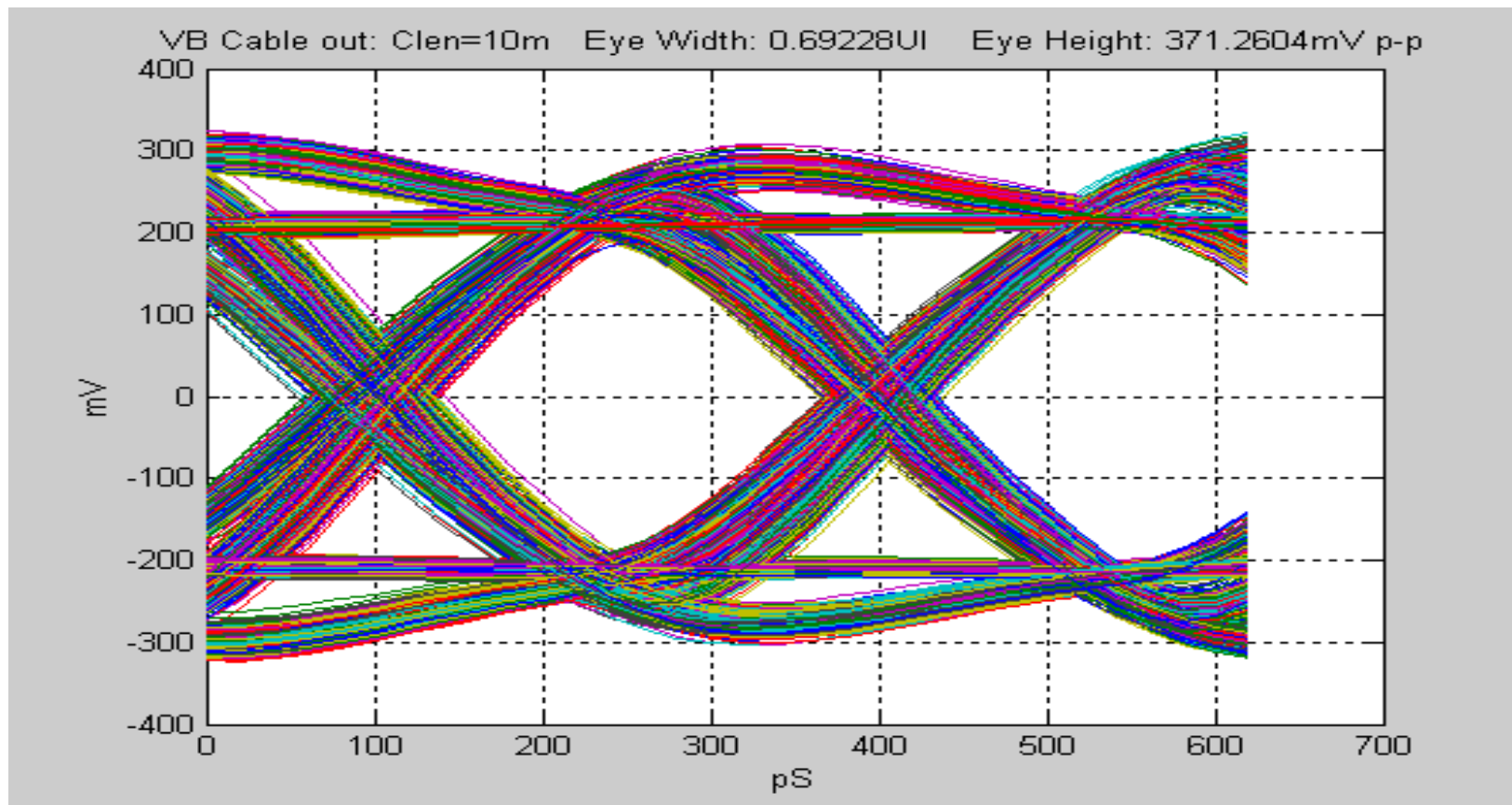
Tx Output: Pre-Emphasis 36%

Without Cross-Talk, without Gaussian noise
 $V_{\text{peak}} = 0.6\text{V peak}$



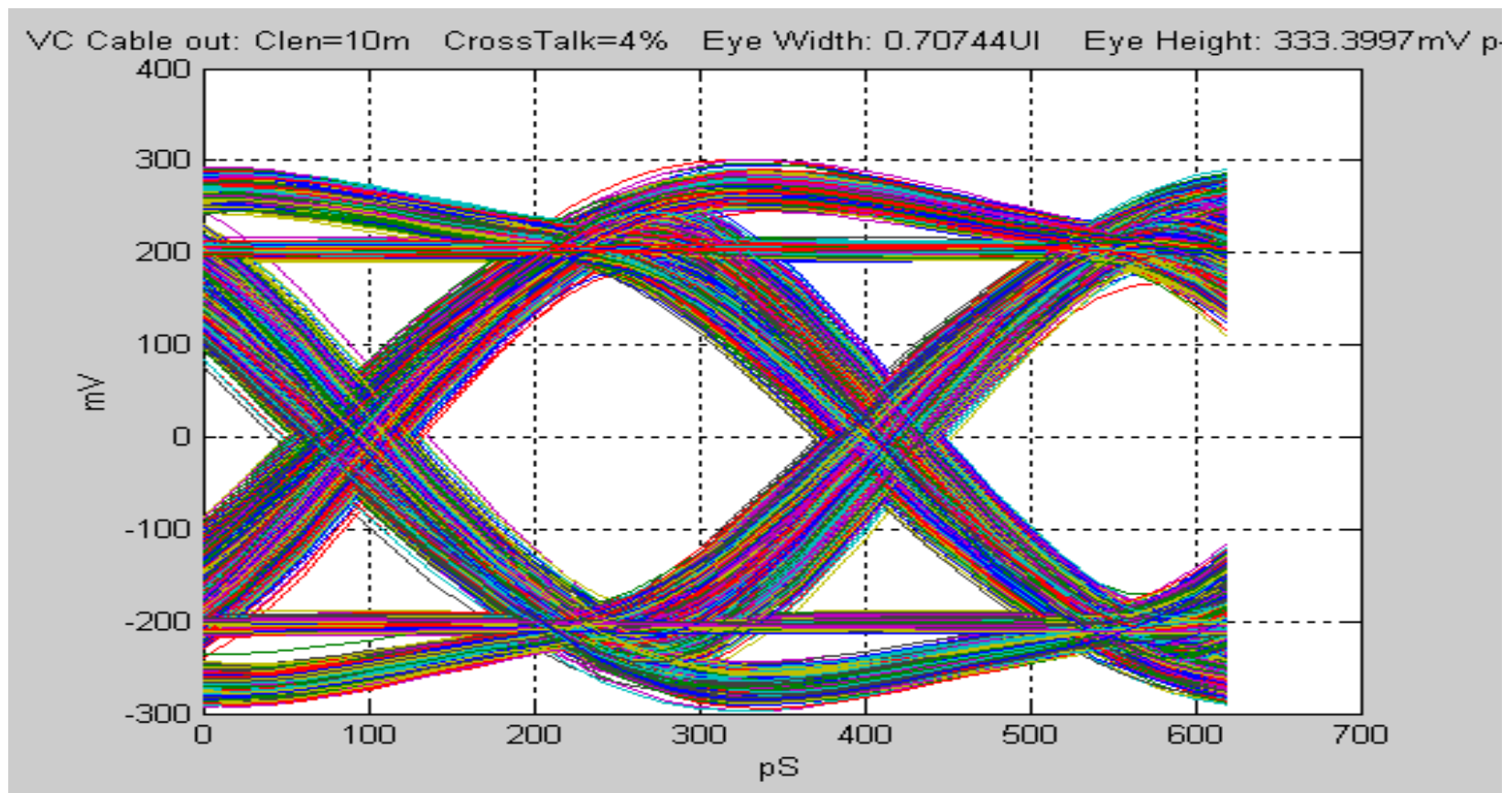
At Cable end: Vendor B, Length =10m

Without Cross-Talk, without Gaussian noise
 $V_{\text{peak}}=0.6\text{V}$ peak Pre_Emphasis = 36%



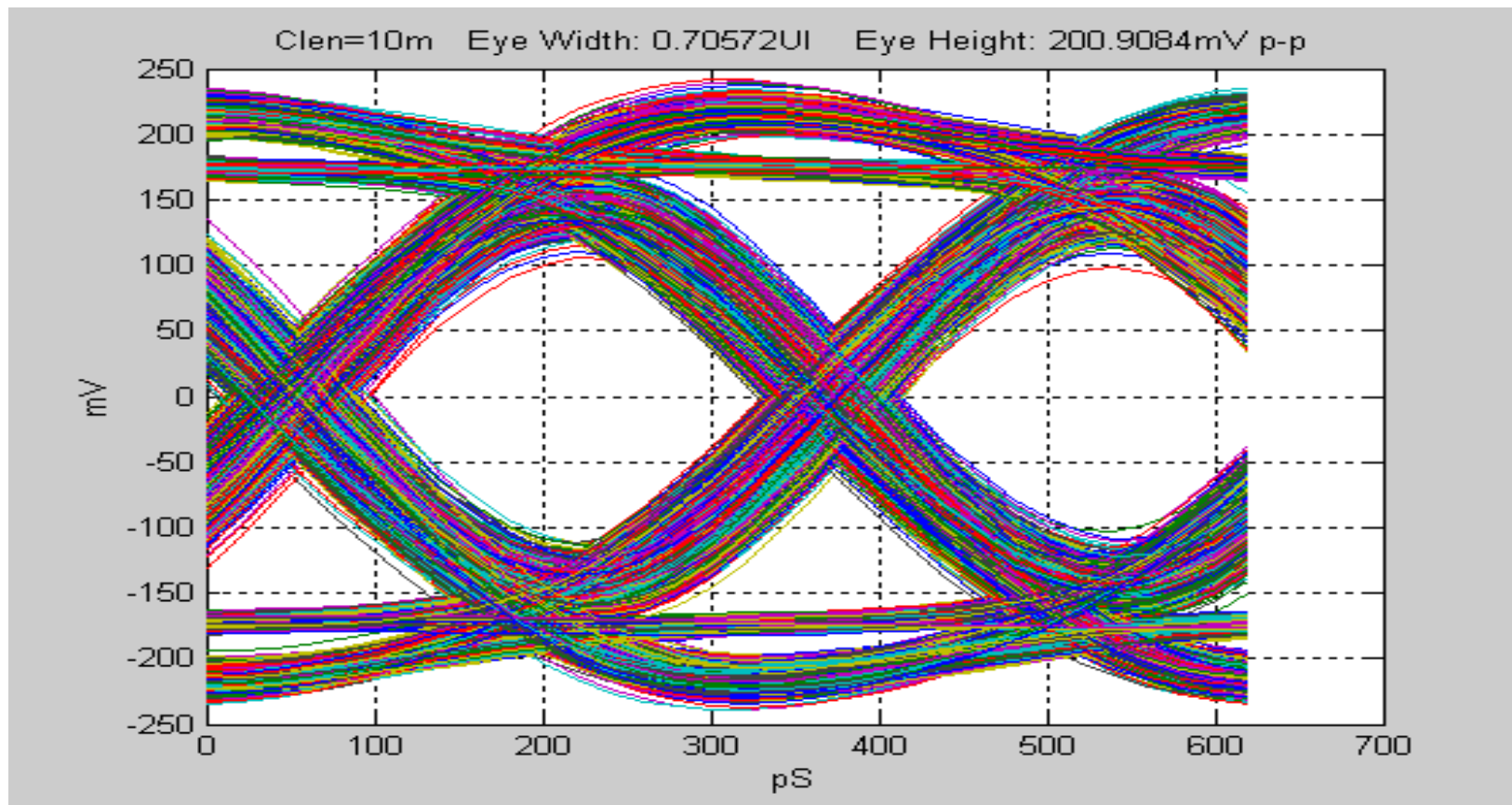
At Cable end: Vendor C, Length =10m

Without Cross-Talk, without Gaussian noise
 $V_{\text{peak}}=0.6\text{V peak}$ Pre_Empphasis = 36%

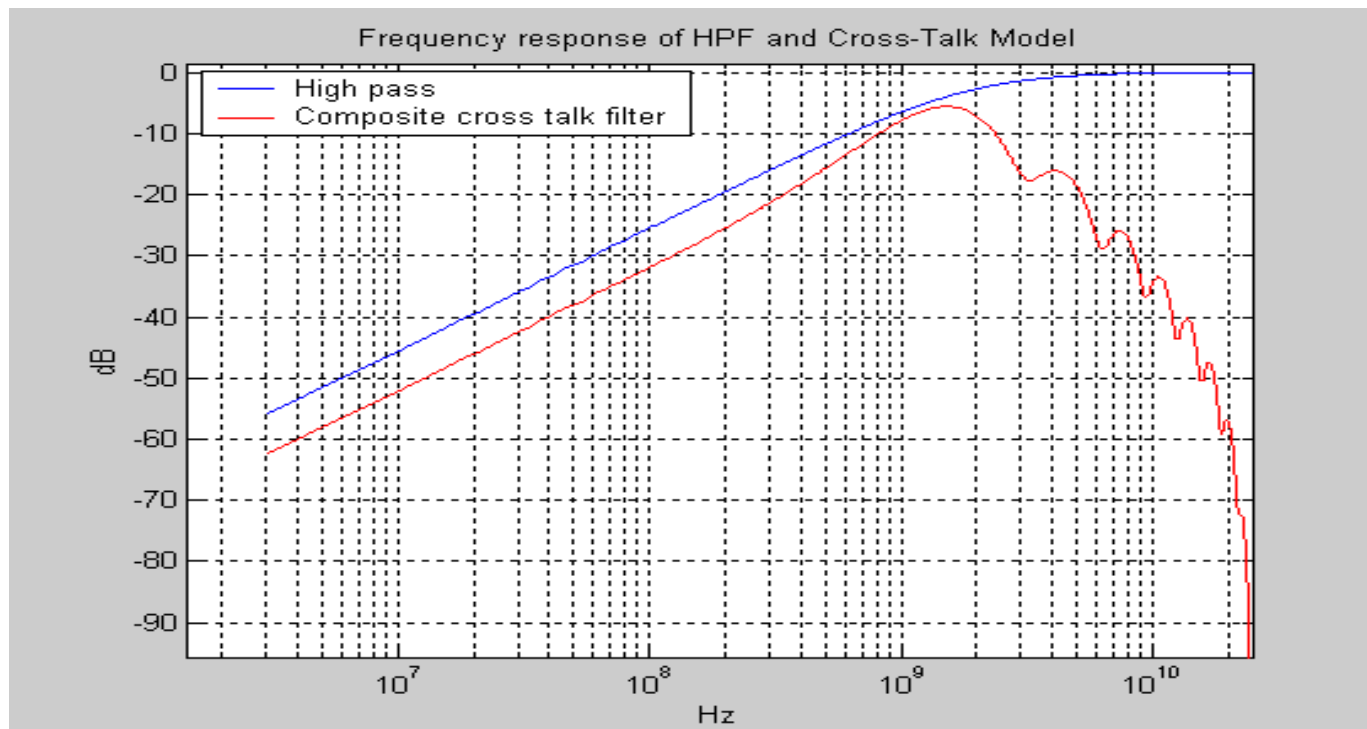
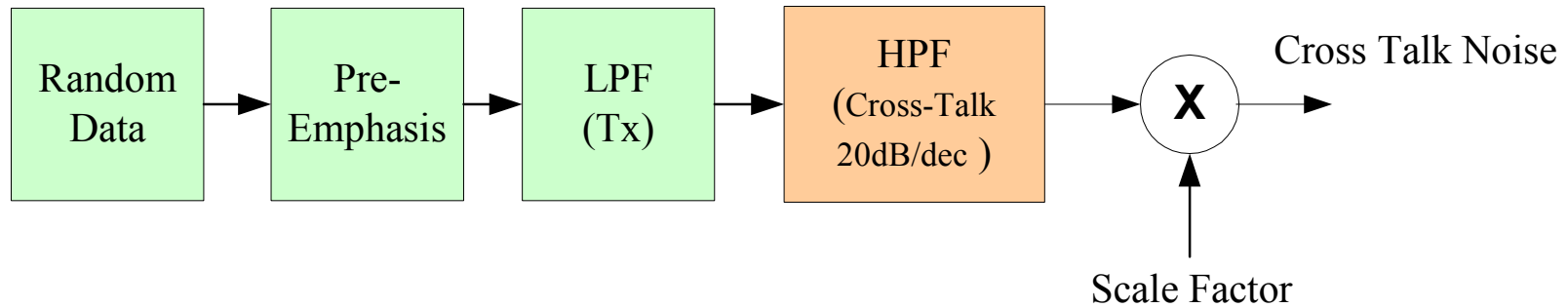


At Cable end: worst case IB, Length =10m

Without Cross-Talk, without Gaussian noise
 $V_{\text{peak}}=0.6\text{V peak}$ Pre_Emphasis = 36%

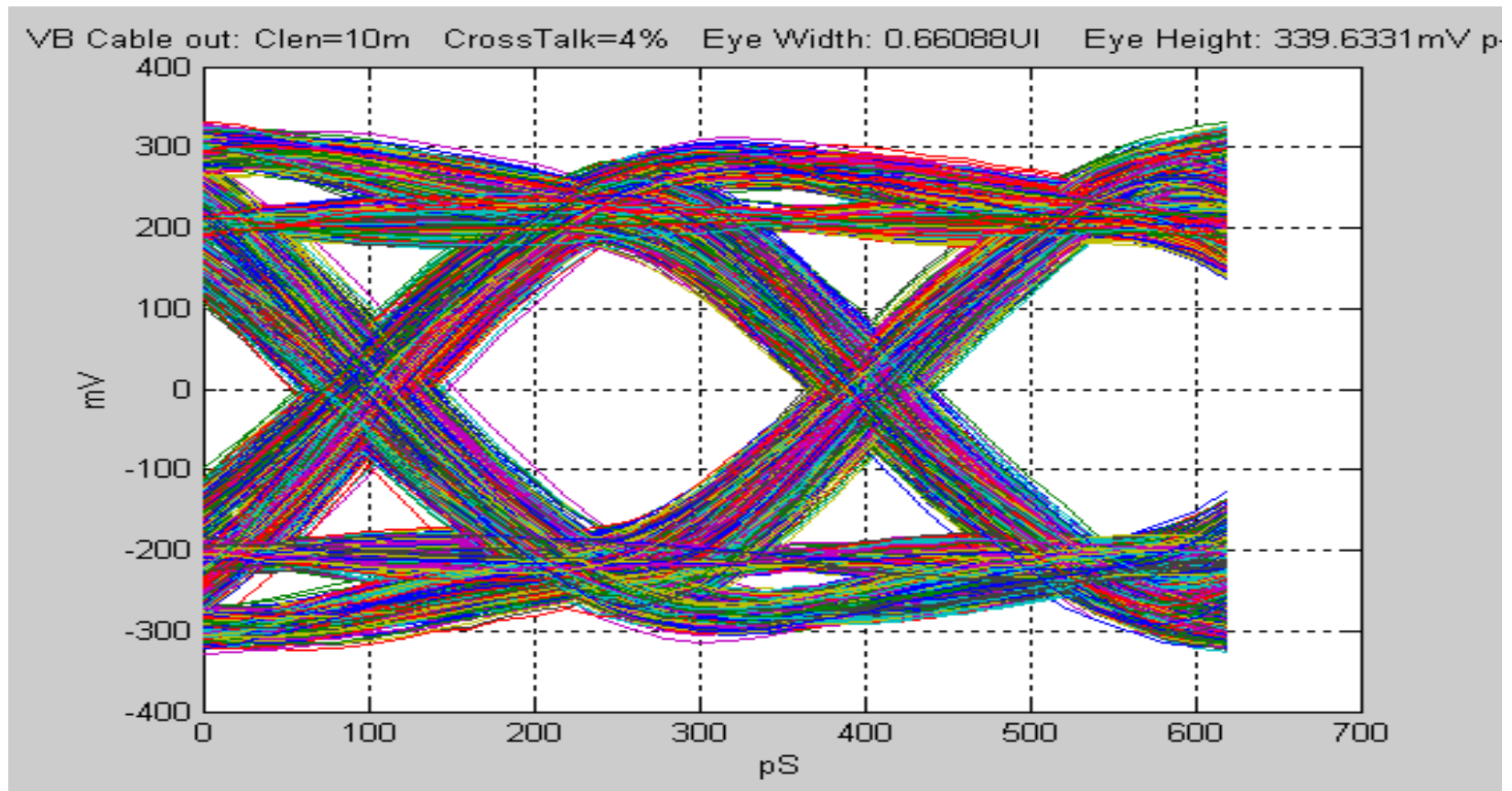


Now Adding Cross-Talk



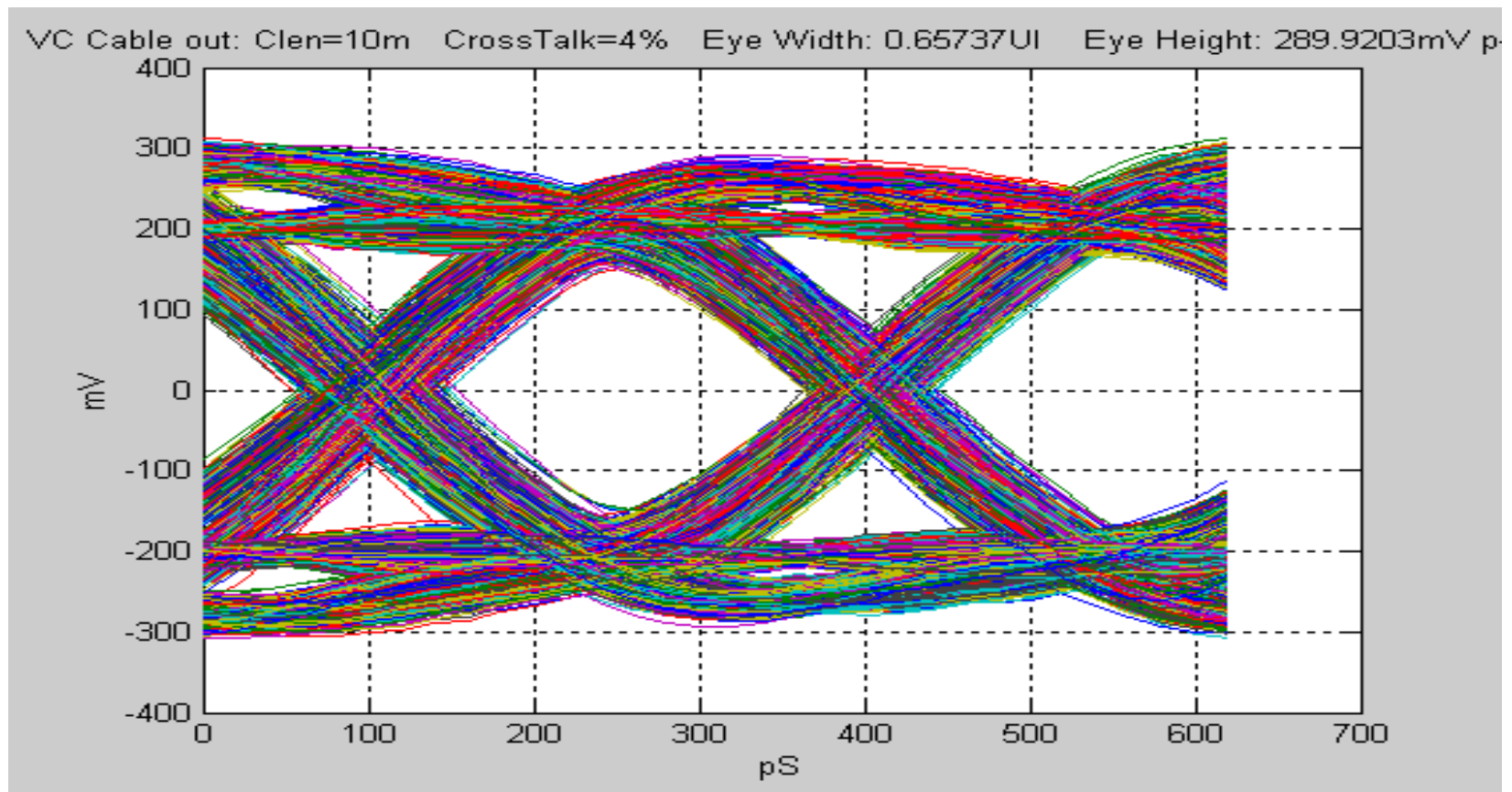
At Cable end: Vendor B, Length =10m

Cross-Talk =4%, Gaussian noise=0
 $V_{\text{peak}}=0.6\text{V peak}$ Pre_Emphasis = 36%



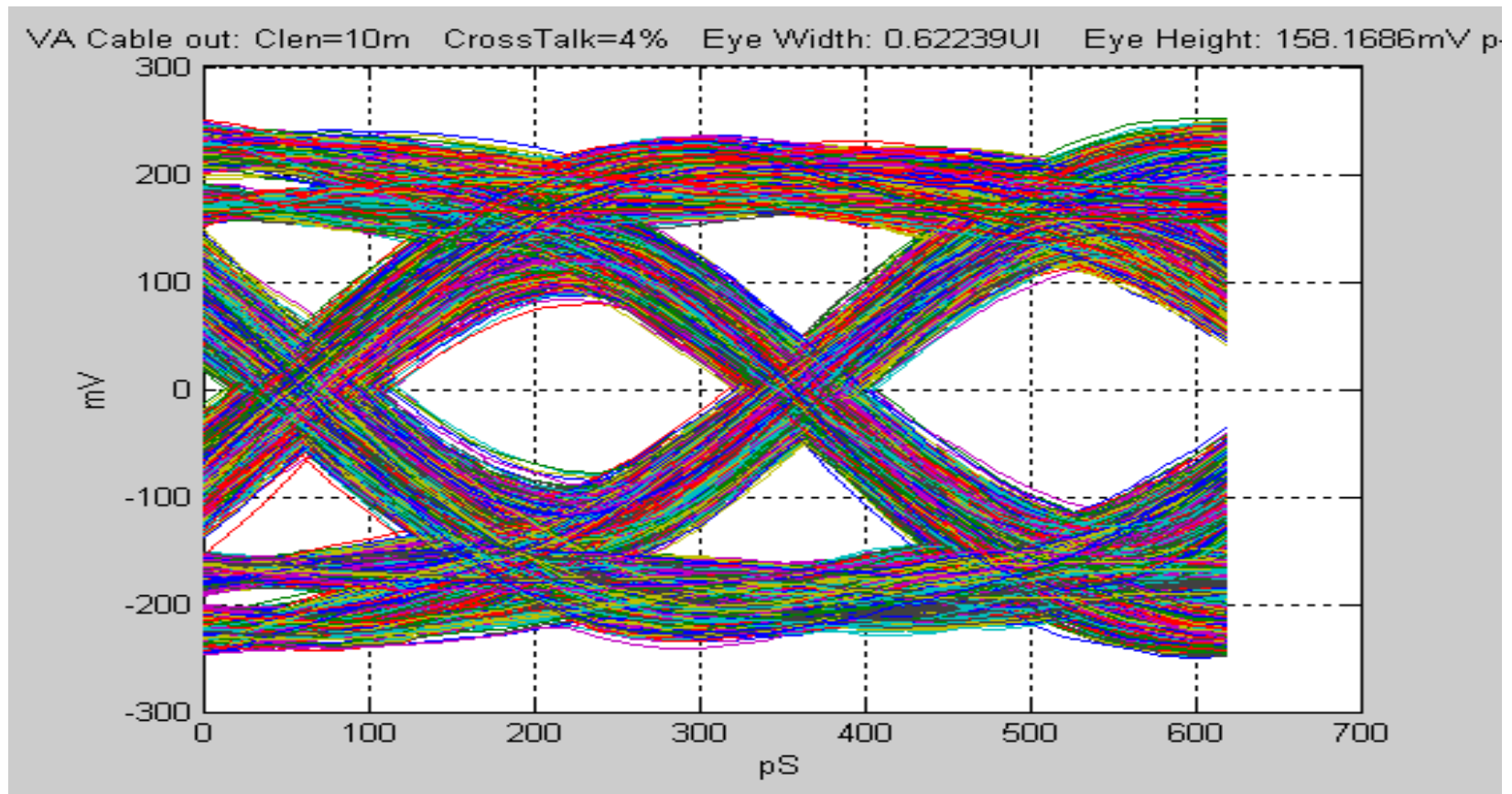
At Cable end: Vendor C, Length =10m

Cross-Talk =4%, Gaussian noise=0
V_{peak}=0.6V peak Pre_Emphasis = 36%



At Cable end: worst case IB, Length =10m

Cross-Talk =4%, Gaussian noise=0
V_{peak}=0.6V peak Pre_Emphasis = 36%



Note: Asymmetric eyes due to high frequency deterministic jitter

Observation #2

- Using pre-emphasis of 36%, without accounting for Gaussian noise or reflections,
 - Vendor B & vendor C, 10m cables eye opening at cable output meets XAUI Rx mask without equalization
 - assuming 4% cross-talk
 - For Worst-Case cable,
 - Without cross-talk eye opening at 10m cable output meets XAUI Rx mask without equalization
 - With 4% cross-talk Worst-Case cable at 10m does not meet 200mv peak-to-peak XAUI receiver requirement

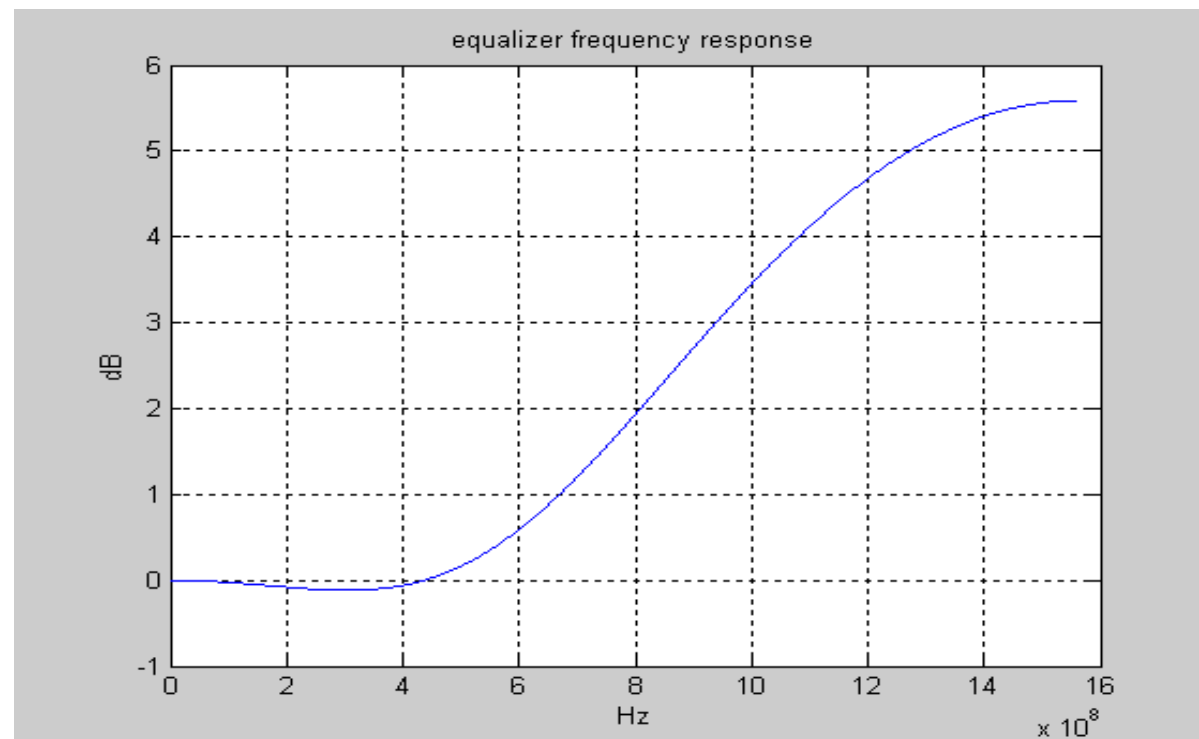
Equalization - definition

- To simplify matters use 3 parameters to define equalization:

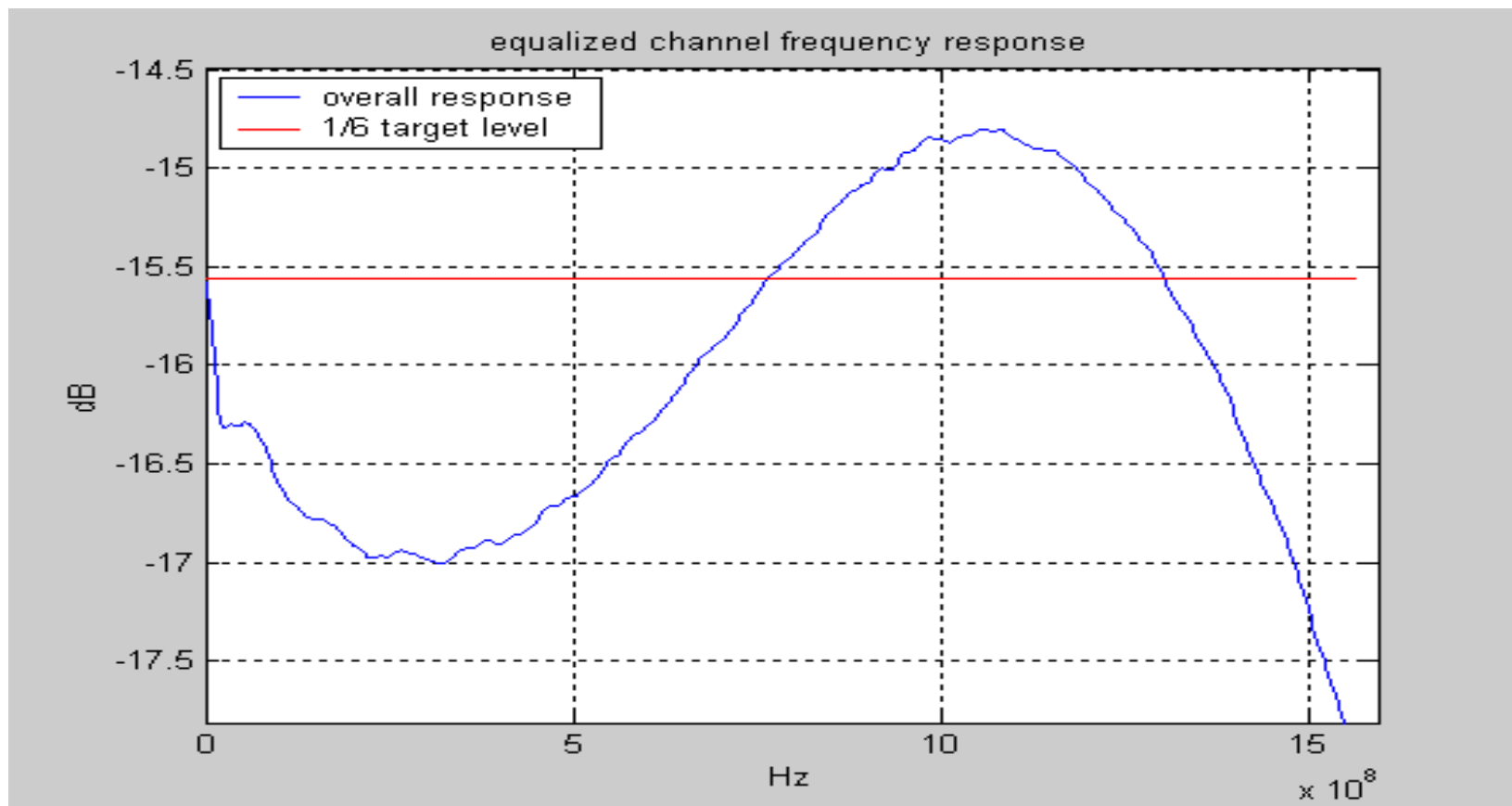
$$H(z) = (a_0 + a_1z^{-1} + z^{-2}) * 10^{Gain/20}$$

- Work on precursor of “channel”

Example
of
Equalizer



Equalized response



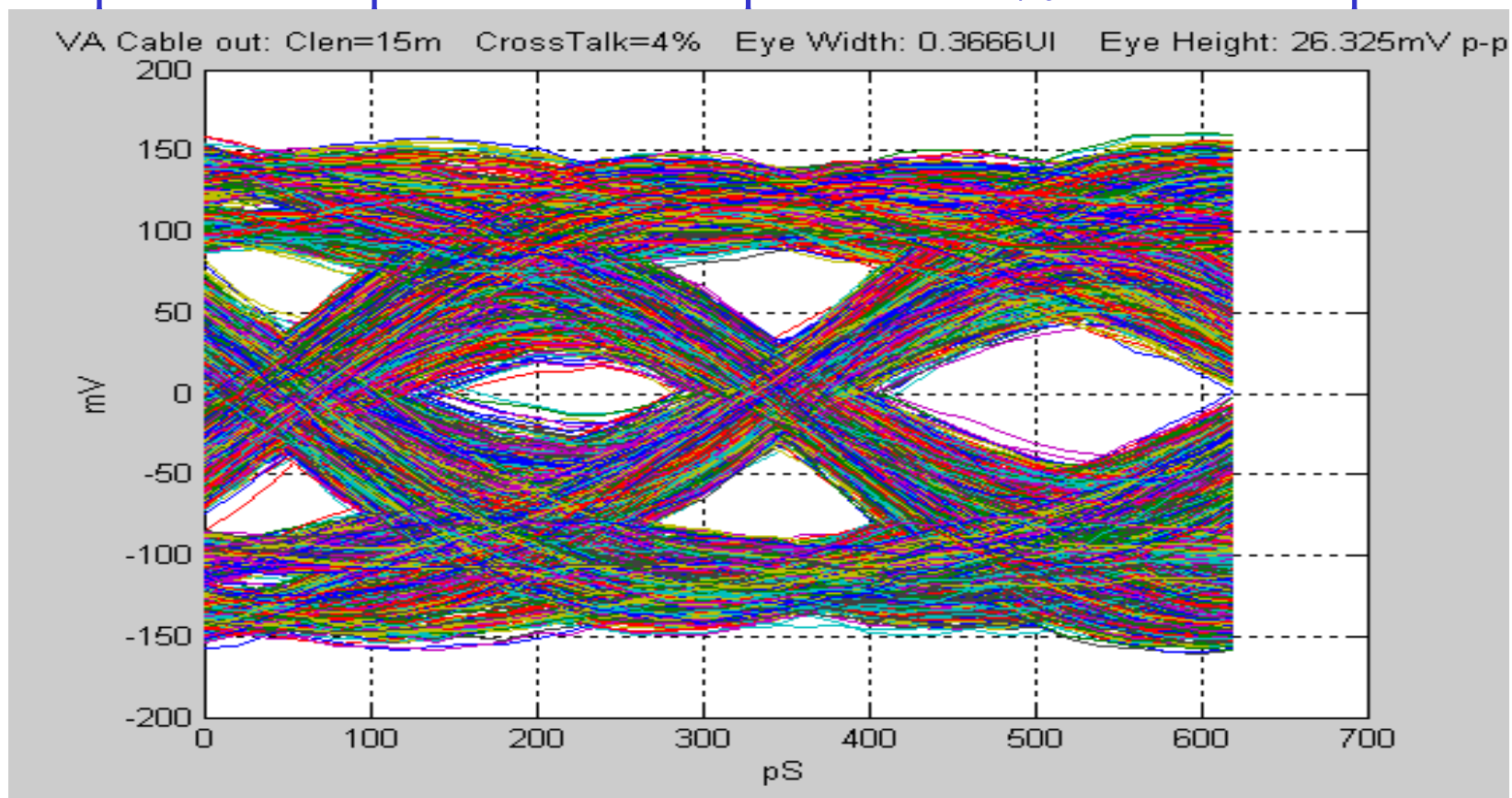
Approach

- Simulate all channels (worst case, B, C)
 - Using only Pre-emphasis
 - Using a combination of pre-emphasis and equalization
- Compare results to XAUI Rx mask

At Cable end: worst case IB, Length =15m

Cross-Talk =4%, Gaussian noise=0

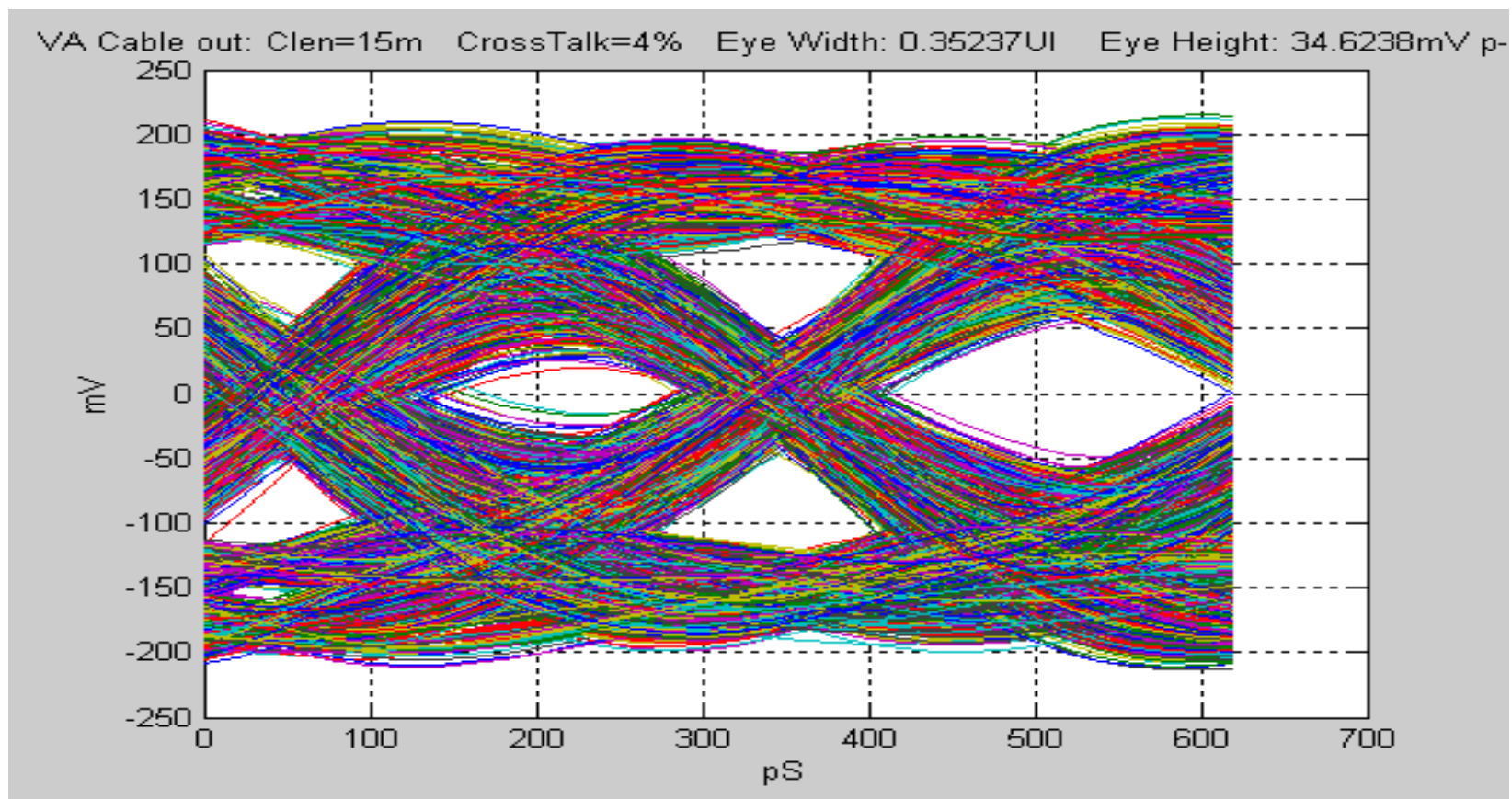
$V_{\text{peak}}=0.6\text{V}$ peak Pre Emphasis = 50% Without Equalizer



At Cable end: worst case IB, Length =15m

Cross-Talk =4%, Gaussian noise=0

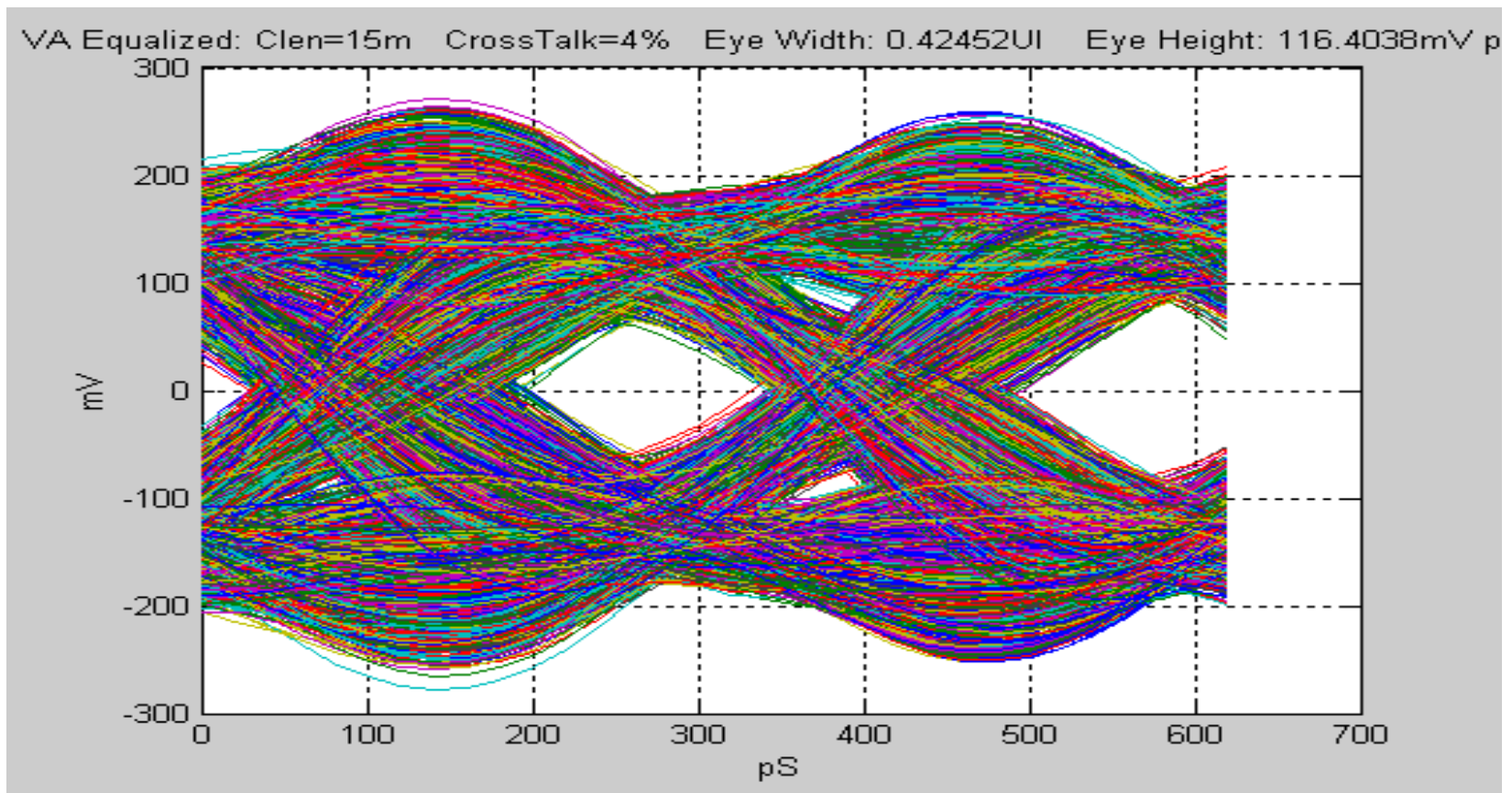
$V_{\text{peak}}=0.8\text{V}$ peak Pre_Emphasis = 50% Without Equalizer



Equalized: worst case IB, Length =15m

Cross-Talk =4%, Gaussian noise=0

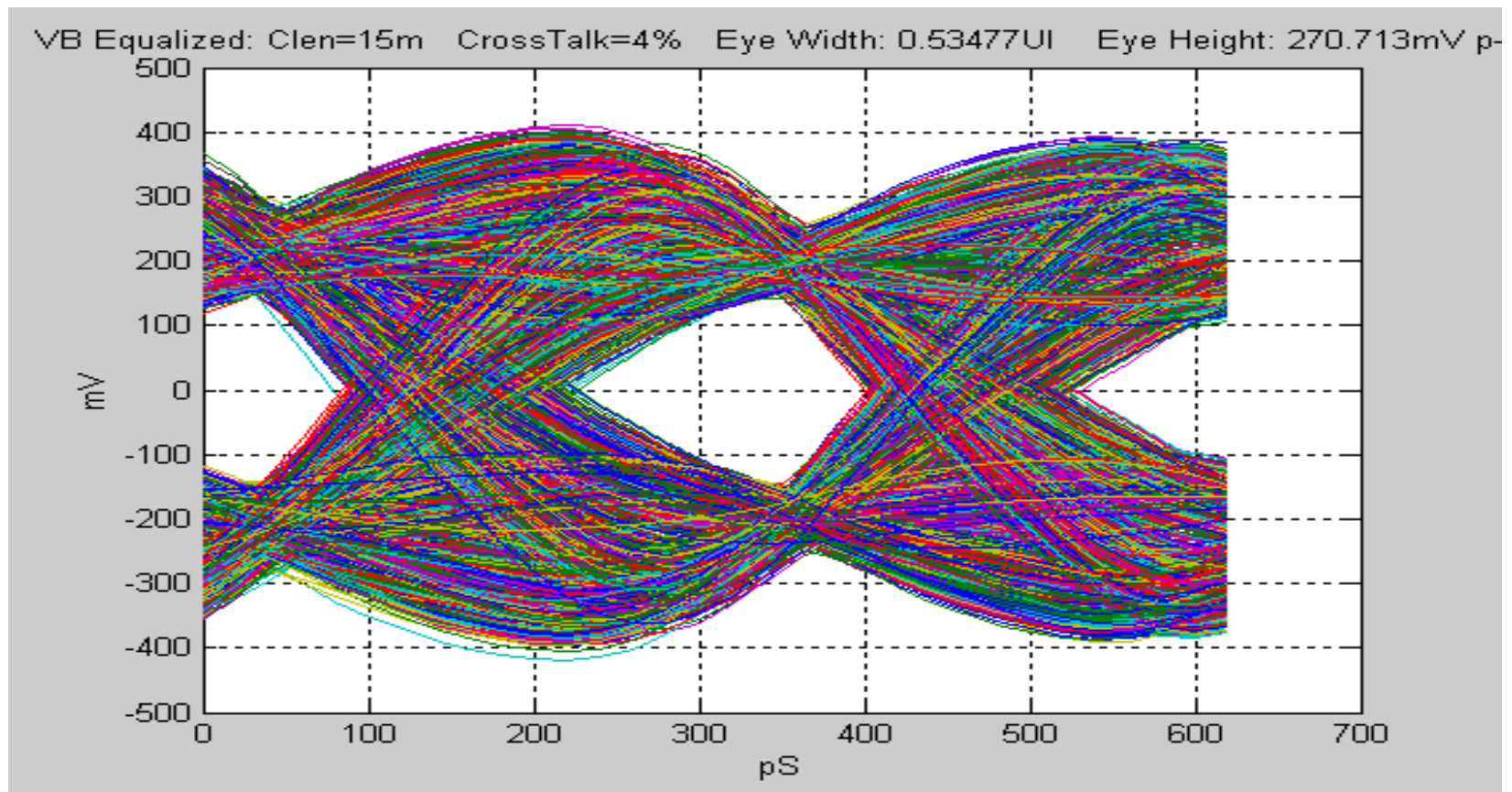
$V_{\text{peak}}=0.6\text{V}$ peak Pre_Emphasis = 36% With Equalizer



Equalized: Vendor B, Length =15m

Cross-Talk =4%, Gaussian noise=0

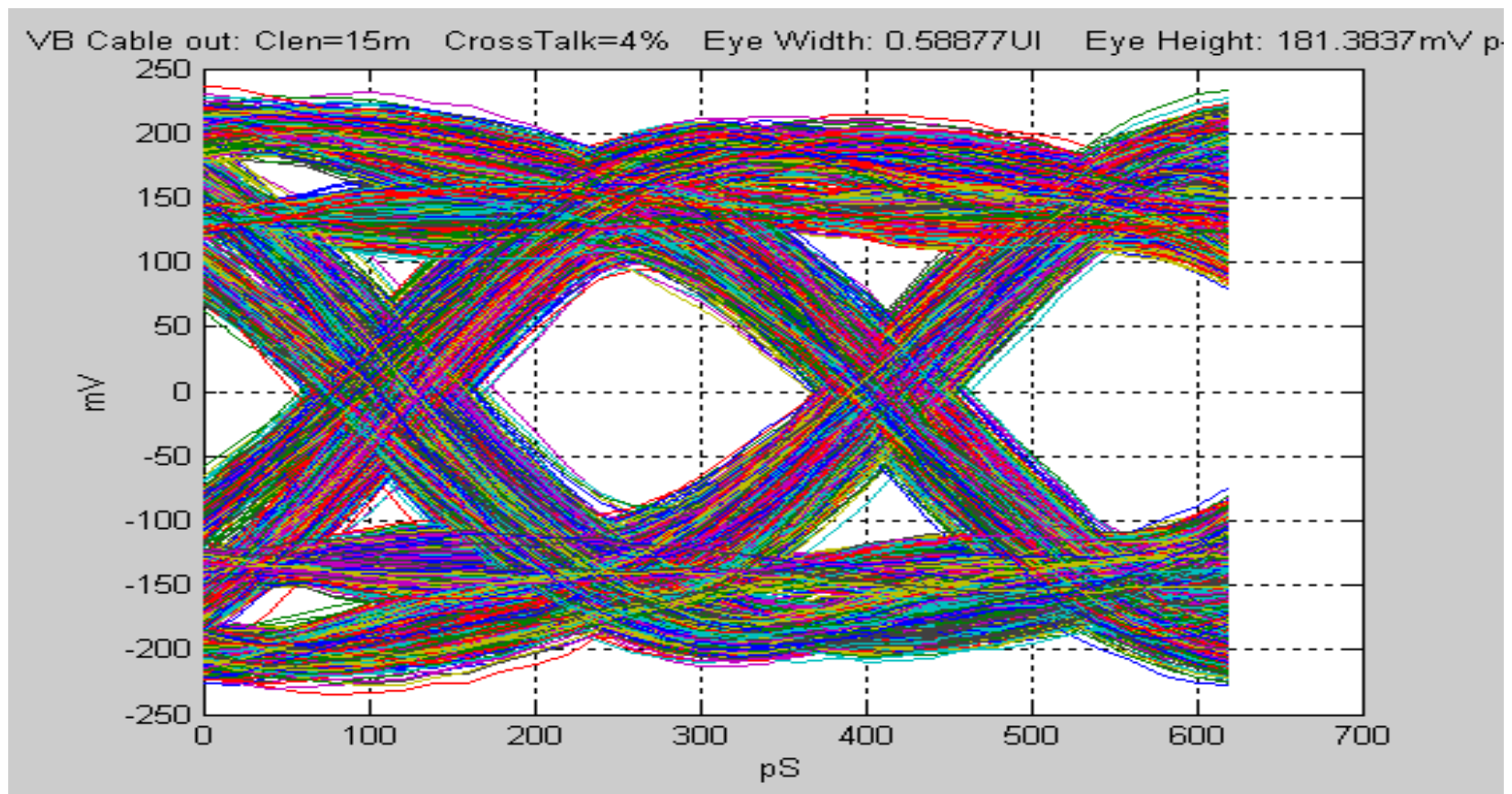
$V_{\text{peak}}=0.6\text{V peak}$ Pre_Emphasis = 36% With Equalizer



At Cable end: Vendor B, Length =15m

Cross-Talk =4%, Gaussian noise=0

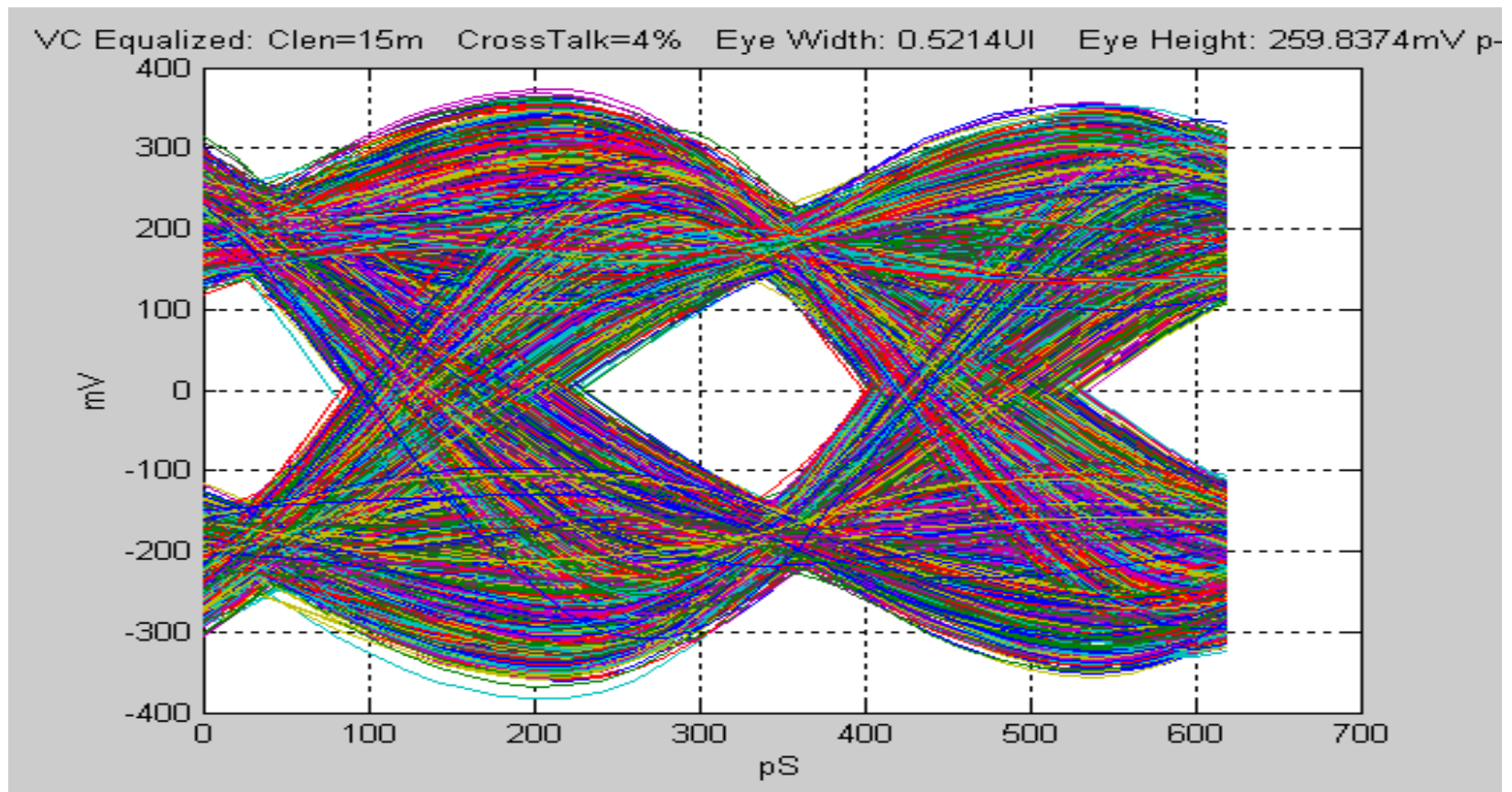
$V_{\text{peak}}=0.6\text{V}$ peak Pre_Emphasis = 50% Without Equalizer



Equalized: Vendor C, Length =15m

Cross-Talk =4%, Gaussian noise=0

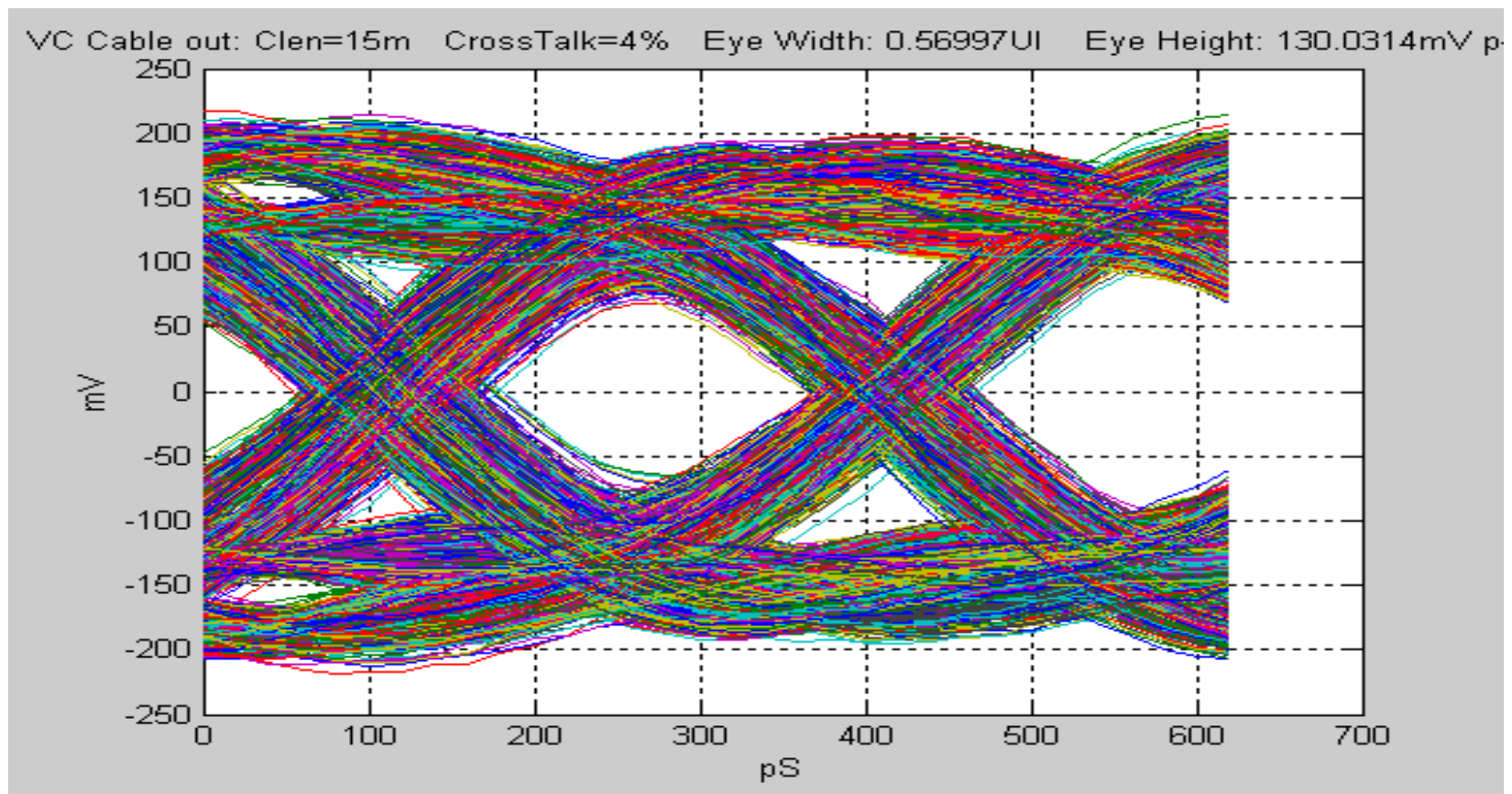
$V_{\text{peak}}=0.6\text{V}$ peak Pre_Empphasis = 36% With Equalizer



At Cable end: Vendor C, Length =15m

Cross-Talk =4%, Gaussian noise=0

$V_{\text{peak}}=0.6\text{V}$ peak Pre_Emphasis = 50% Without Equalizer



Observation #3

- At 15m without equalizer the resulting eye opening for all three cables (Worst case, Vendor B, Vendor C)
 - was much smaller than XAUI-Rx mask.
 - but this is due to the fact that the factors causing the eye closure were not separated – will elaborate later.
- At 15m with equalizer the resulting eye opening for Vendor B, Vendor C cables met the XAUI Rx mask
- Even with equalizer, eye opening of worst case cable was smaller than XAUI-Rx mask.

Table Summarizing the Results

Case	Cable Length m	Cable Type	Tx Peak Voltage Volt (peak)	Cross-Talk	Pre-emphasis	Equalizer	Eye opening mVolt p2p
1	0	NA	0.4	0%	60%	off	197
2	0	NA	0.6	0%	50%	off	391
3	0	NA	0.6	0%	36%	off	597
4	10	Vendor B	0.6	0%	36%	off	371
5	10	Vendor B	0.6	4%	36%	off	340
6	10	Vendor C	0.6	0%	36%	off	333
7	10	Vendor C	0.6	4%	36%	off	290
8	10	WC	0.6	0%	36%	off	200
9	10	WC	0.6	4%	36%	off	158
10	15	Vendor B	0.6	4%	50%	off	181
11	15	Vendor B	0.6	4%	36%	ON	271
12	15	Vendor C	0.6	4%	50%	off	130
13	15	Vendor C	0.6	4%	36%	ON	260
14	15	WC	0.6	4%	50%	off	26
15	15	WC	0.6	4%	36%	ON	116
16	15	WC	0.8	4%	50%	off	35

Summary

- For operation over “Compliant channel” (10m 24awg, worst-case IB attenuation)
 - Need to lower Tx mask minimal eye opening to 0.2v peak
 - From current 0.4v peak
 - To support 0.6V peak and 36% preemphasis
 - Lower eye opening at receiver to 100mv peak to peak
 - from current 200mv peak to peak
 - Use 36% Pre-emphasis at transmitter while equalization is not required
 - Assumed 4% cross-talk, neglected Gaussian noise and reflections

Summary Cont'd

- For operation over worst case channel (15m 24awg, worst-case IB attenuation)
 - With only pre-emphasis, eye opening of all three cables (worst case cable, Vendor B and Vendor C) is too small
 - Simple equalization for Vendor B and Vendor C cables increases eye openings to XAUI Rx mask level.
 - Applying both pre-emphasis and equalization to worst case cable results in eye opening of ~120mv peak to peak

Recommendations

- Rx mask:
 - Define Rx mask to be: as XAUI Rx mask at end of compatible channel (10m worst case IB attenuation) but with following modifications:
 - Allow eye height at receiver to be as low as 100mV peak
 - Allow larger jitter at receiver (if it's due to ISI)
 - Define Rx mask at end of “worst case channel” (15m worst case IB cable) to be such that with specified equalization, eye opening will conform to compatible cable Rx mask
 - Alternatively, can replace specified equalization by optimal equalization using first order equalizer

Recommendations Cont'd

- Tx mask – modify XAUI Tx mask according to:
 - At Tx output, relax minimal eye opening to be as low as 0.2V peak
 - To allow use of pre-emphasis
 - Requiring eye at the output of a “compatible cable” to conform to receive mask defined above

Issues

- There may be inconsistencies in the definition of Pre-emphasis
 - Try to agree on a single definition
- Further work required to assess effect of reflections
- Practical cable seems much better than worst case
 - Perhaps we can make the worst-case cable definition stricter
- Need to obtain from cable vendors their cable parameters
- Further work is required in verifying that cross-talk can be kept under 4%

Next Steps

- Run simulations with cable parameters of various vendors
- Study effects of reflections