NRZ and Duobinary Compatibility

IEEE 802.3ap Task Force

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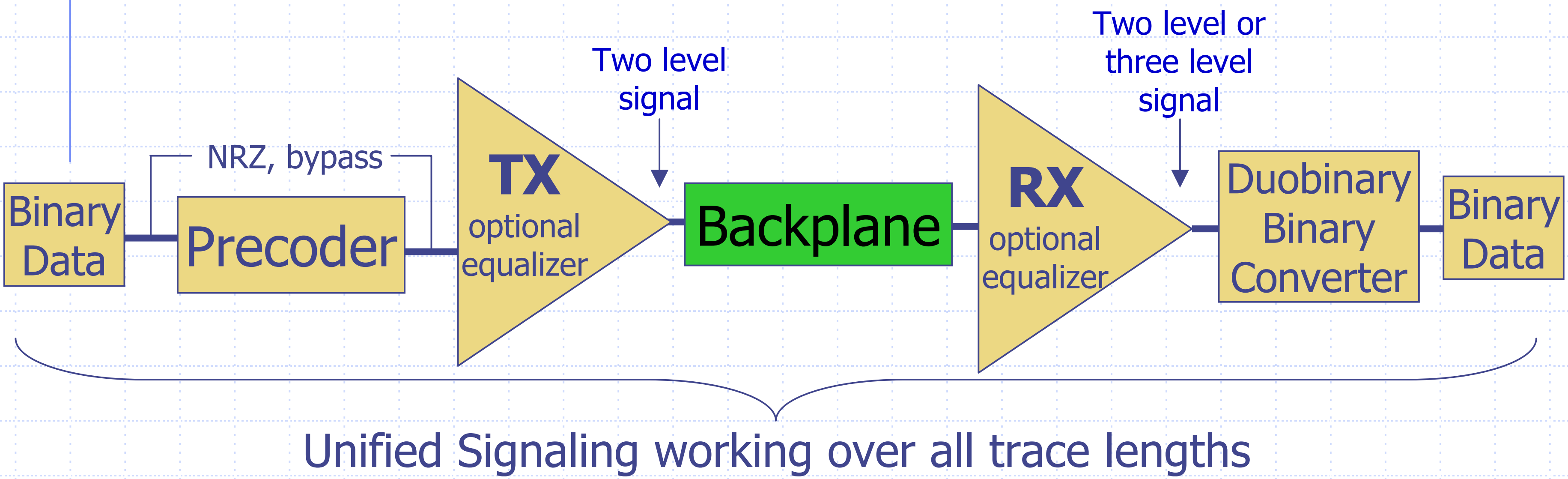
Agenda

- Duobinary and NRZ Compatibility
- NRZ & Duobinary short trace simulation
- NRZ & Duobinary long trace simulation
- Summary

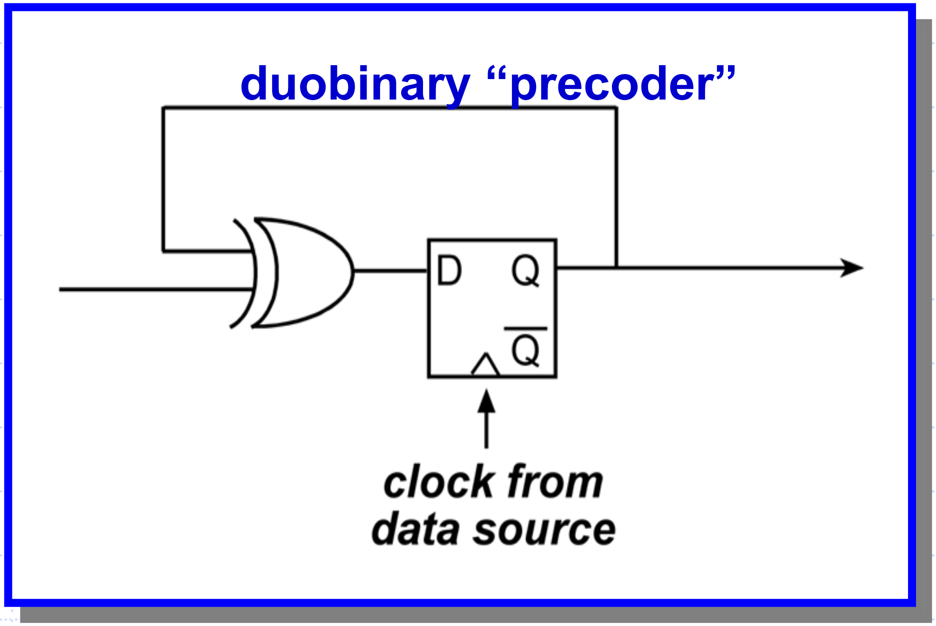
Why NRZ and Duobinary ?

- Industry acceptance for NRZ in multiple applications and standards, e.g. XAUI, XFI, OIF
- NRZ and Duobinary use same transmission techniques & easily modified receiver, allowing for unification within design
- Data over short trace lengths can be transmitted via Duobinary or NRZ
  - Not all systems will require 1 meter trace
  - Unified signaling for long & short traces in single IC
- Data over longer trace length, where traditional NRZ may hit its limit, can still be transferred

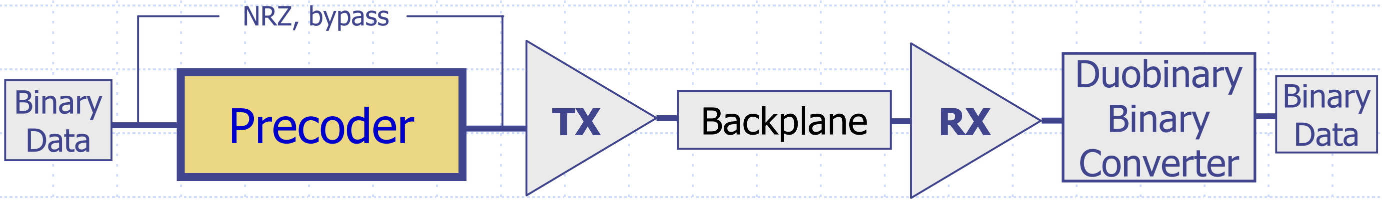
Simplified Building Blocks for Unified Signaling



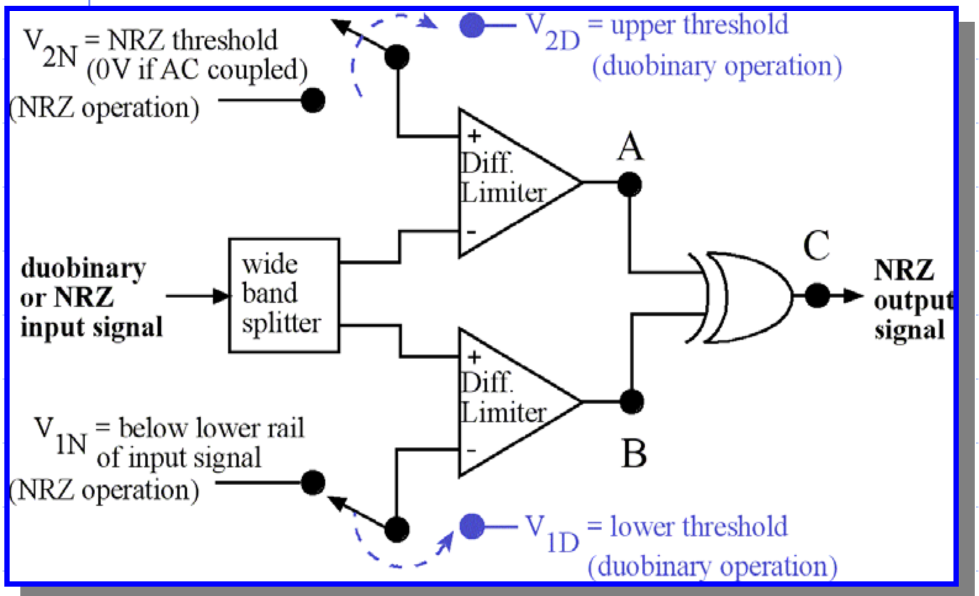
Duobinary Precoder



A duobinary "precoder" is placed at the transmitter. This can be done in the ASIC core with a parallel implementation. Easily bypassed for NRZ applications.

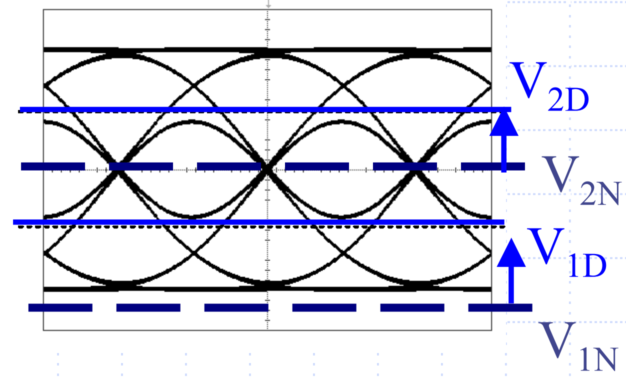


Duobinary to Binary Converter

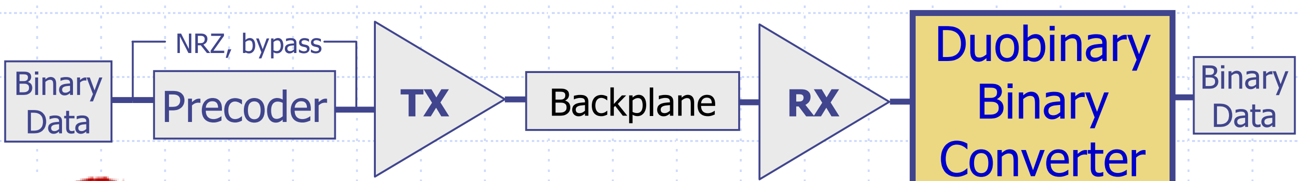


* For more details on the decoder architecture, see IEEE IMS-2004 article entitled, "10-Gb/s Electrical Backplane Transmission using Duobinary Signaling," by Sinsky, Adamiecki, and Duelk – *Lucent Technologies*.

Decision Thresholds for Binary and Duobinary



The duobinary-to-binary converter in the receiver can serve as a binary decision circuit by setting one of the two thresholds, V_1 or V_2, to the upper or lower rail respectively.



Lucent Technologies Bell Labs Innovations

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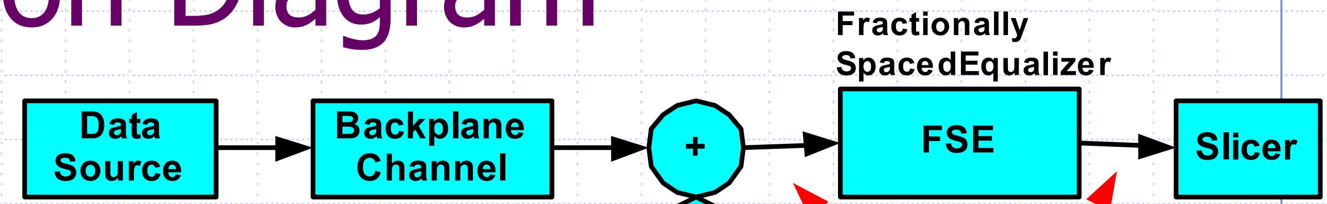
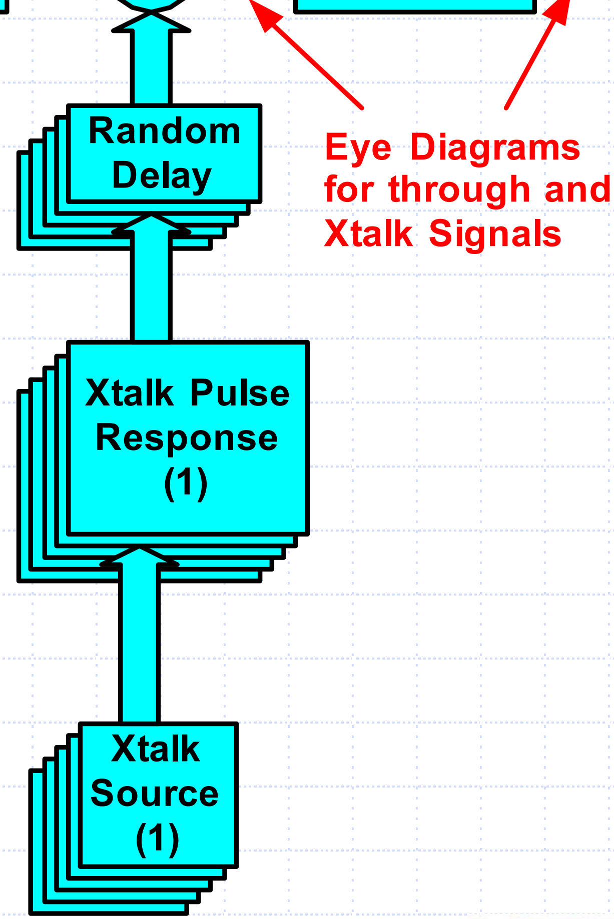
Simulation Diagram



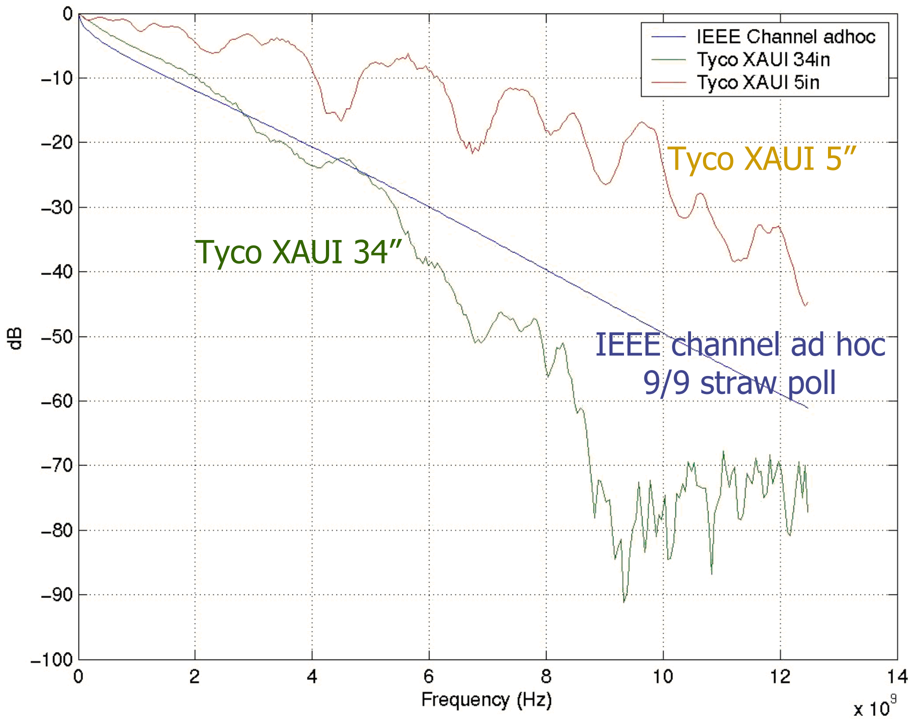


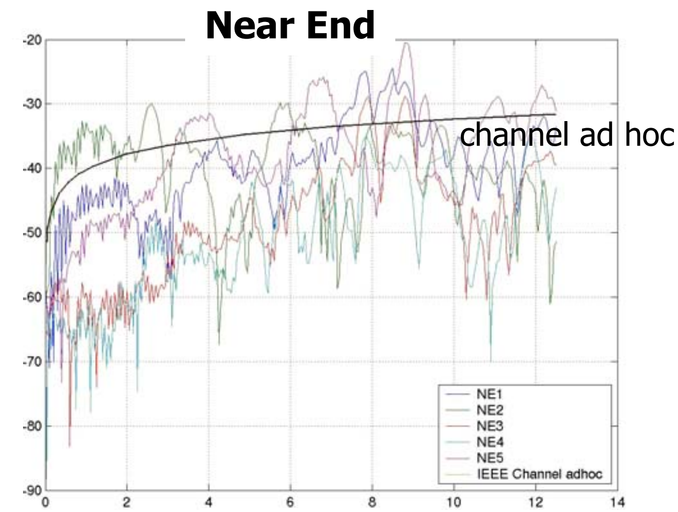
<u>Crosstalk:</u> 5 near-end and 5 far-end aggressors with random relative delays (measured S parameters)

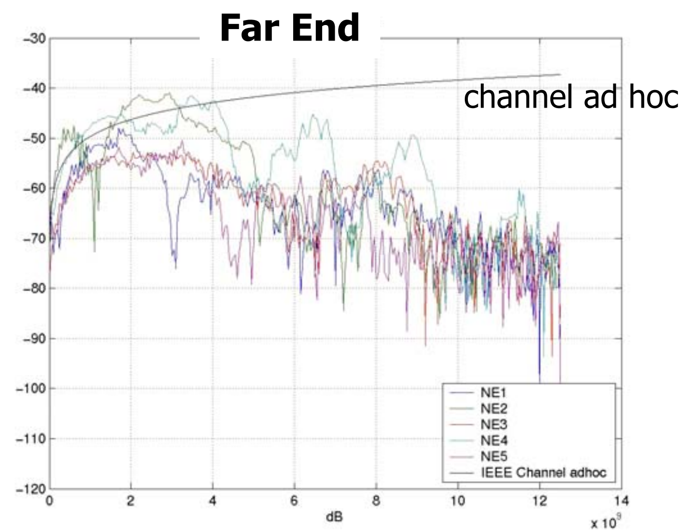
<u>FSE</u> (Fractionally Spaced Equalizer): Used as a model to estimate the required boost

<u>TX:</u> No pre-emphasis is used, PRBS 2^{31}-1

S-parameters and Crosstalk



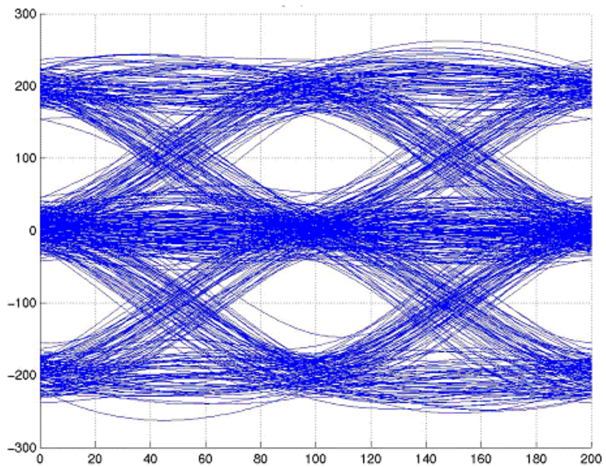


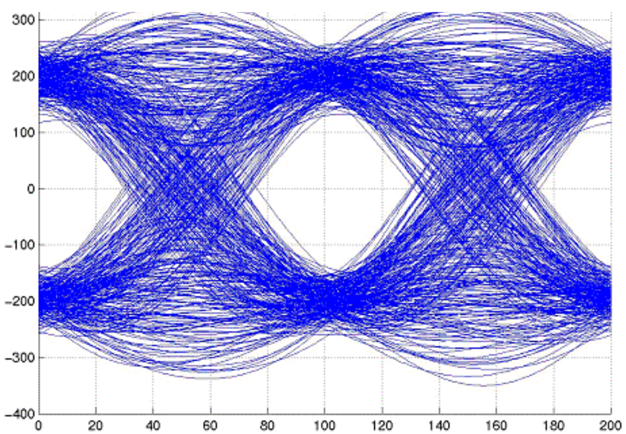


Total of 10 aggressors, 5 near/5 far, each synchronous with random delay w/ respect to measured signal, near end is more dominate

Required FSE Boost @ slicer– 5”

no crosstalk





Duobinary after 5 inches, two connector pairs

Magnitude of FSE Response

0 dB boost required

NRZ after 5 inches, two connector pairs

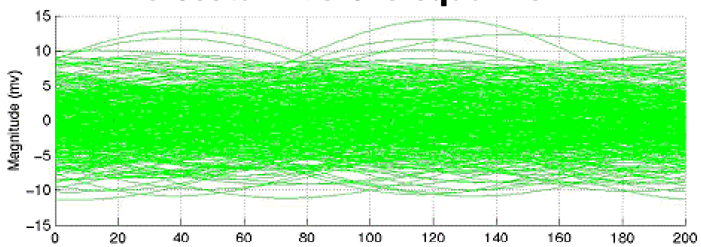
Magnitude of FSE Response

7 dB boost at 5GHz required

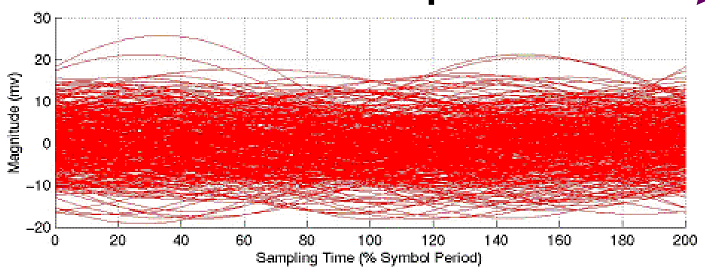
✓ Minimum boost required for aggressive crosstalk over 5 inches

NRZ crosstalk @ slicer – 5”

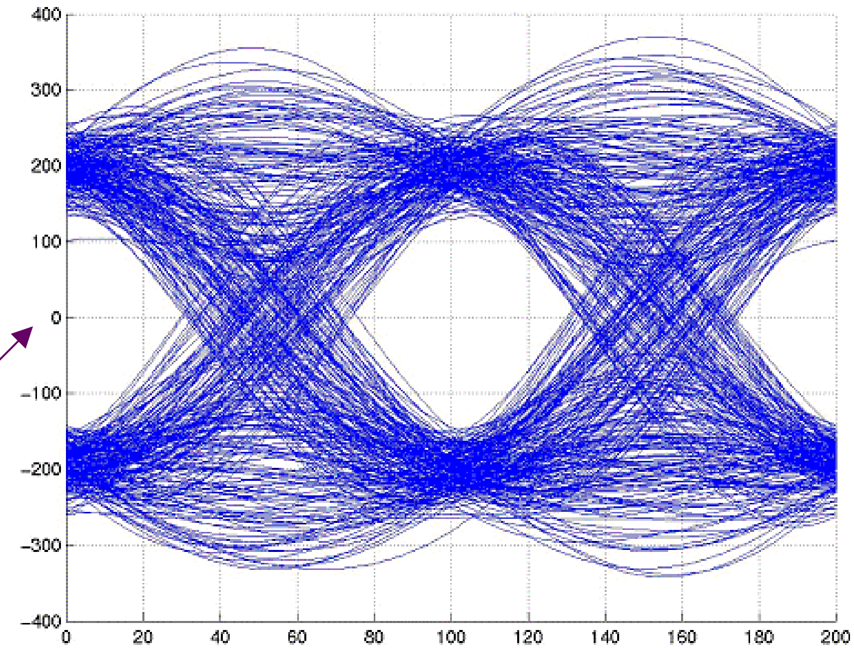
crosstalk before equalizer



crosstalk after equalizer



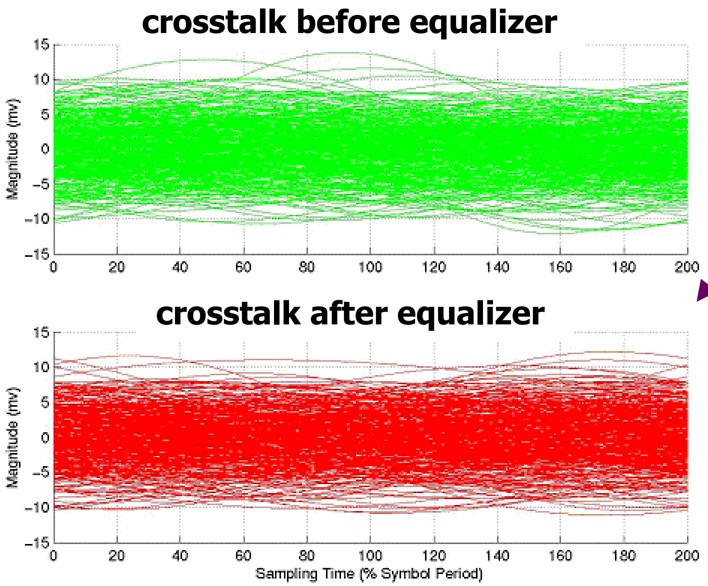
Slight difference in crosstalk before/after equalizer



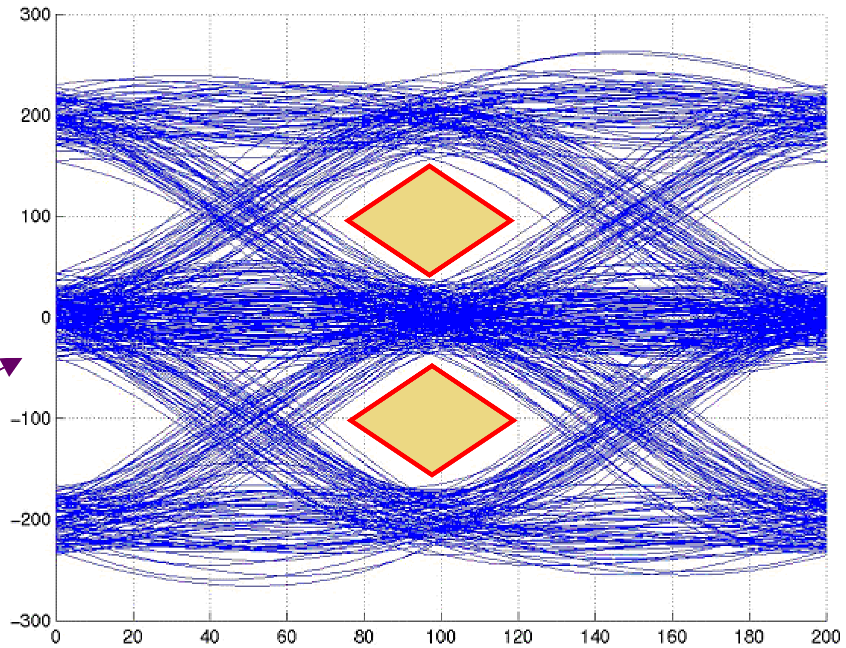
Minimal difference (△14mV) in data eye after aggressive crosstalk and 5 inch trace

Note: FSE results only, DFE not used

Duobinary crosstalk @ slicer – 5″



No difference in crosstalk before/after equalizer

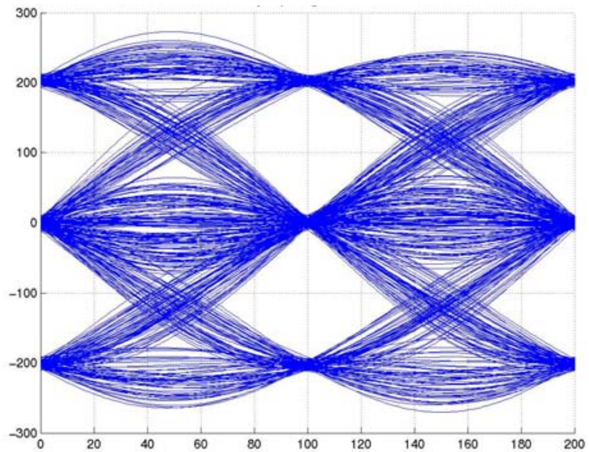


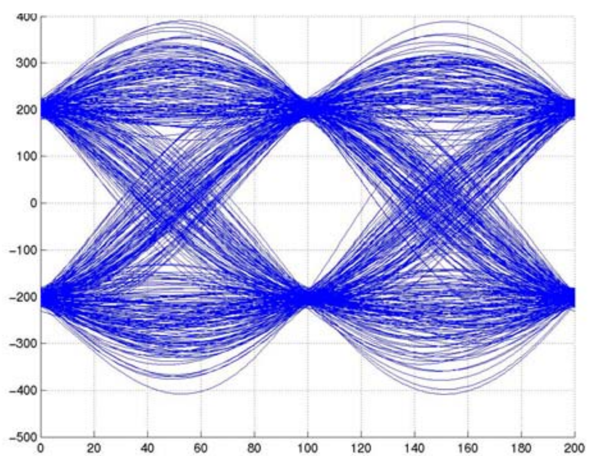
No change in data eye after aggressive crosstalk and 5 inch trace

Summary: NRZ or Duobinary are equally suited for short traces

Required FSE boost @ slicer – 34”

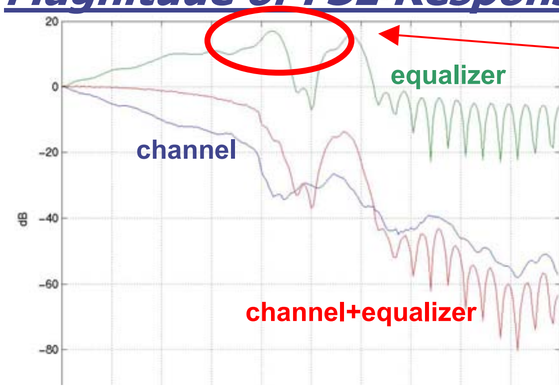
no crosstalk





Duobinary after 34 inches, two connector pairs

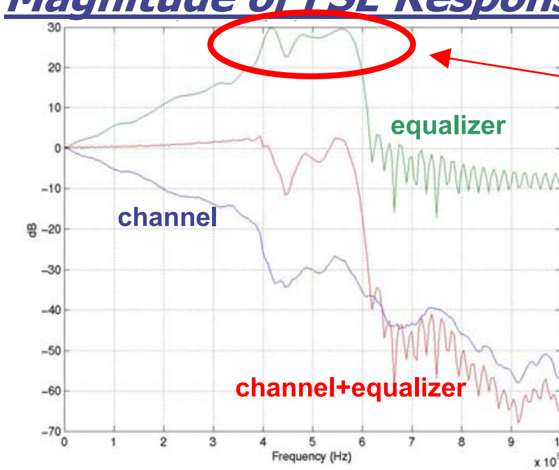
Magnitude of FSE Response, required boost



A boost of about 17 dB at 4.25 GHz is required.

NRZ after 34 inches, two connector pairs

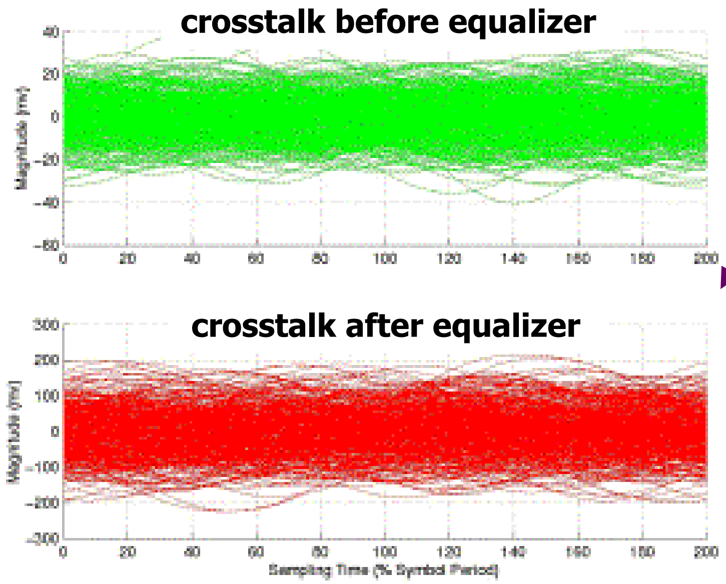
Magnitude of FSE Response, required boost



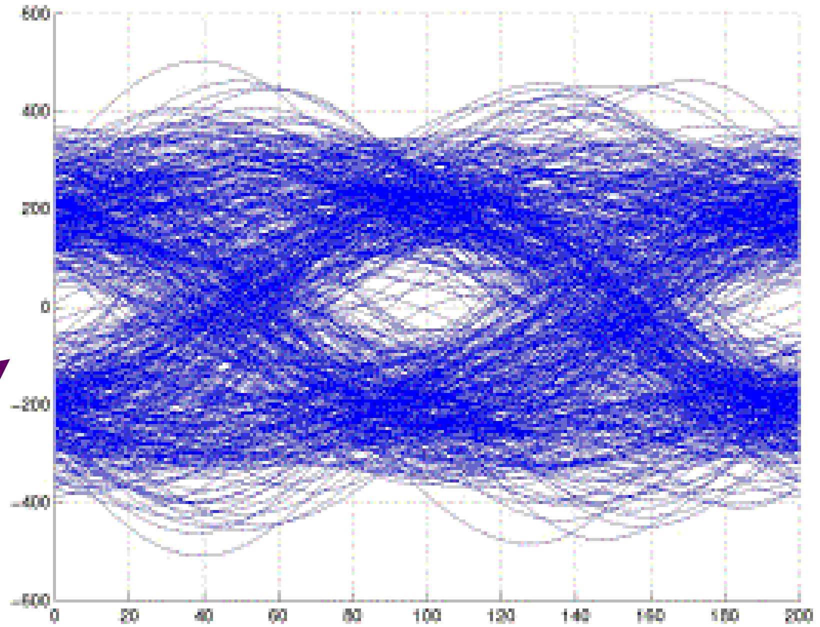
A boost of about 30 dB from 4 to 5.5 GHz is required.

Note:
FSE results only,
DFE not used

NRZ crosstalk @ slicer – 34”



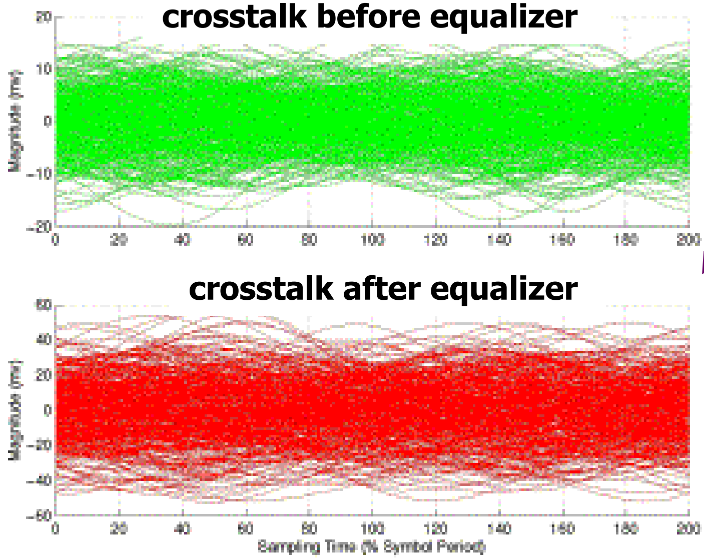
Crosstalk after equalizer is approximately 5x greater than before equalizer



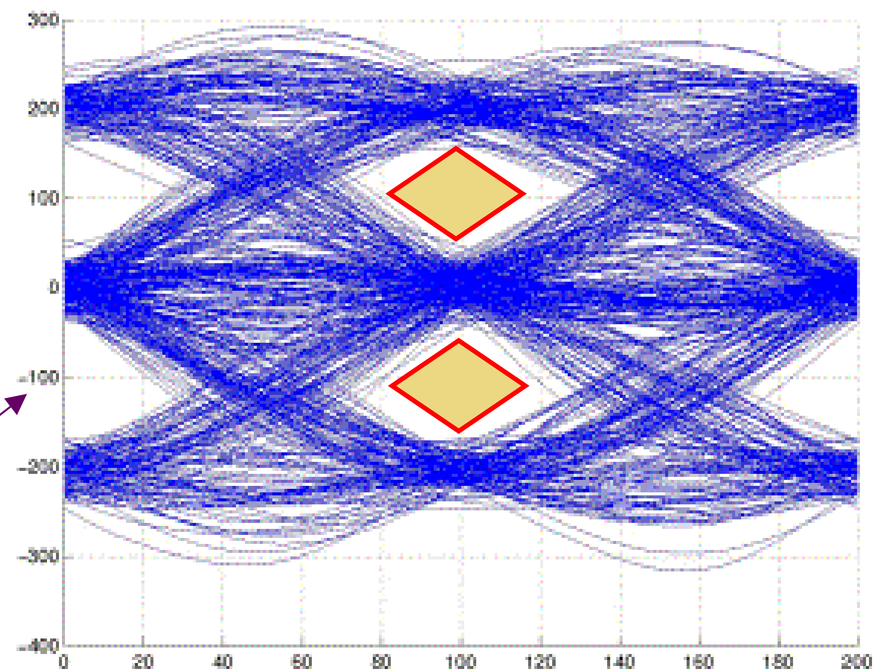
Multiple tap DFE or other approaches required to fully recover data

Note: FSE results only, DFE not used

Duobinary crosstalk @ slicer – 34"



Crosstalk after equalizer is approximately 2.8x greater than before equalizer



Recoverable data within Duobinary data eye, aiding 10Gb/s operation in systems

Note: FSE results only, DFE not used

Summary

- NRZ and Duobinary have similar transmitter properties
- NRZ and Duobinary are equally efficient for short traces
- Duobinary has advantages over traditional NRZ in long traces, where NRZ requires much more equalization.
- Unified signaling approach is feasible for integration within an IC

Additional simulations/comparisons by Vitesse
Barazande_pour_01_0504.pdf
Barazande_pour_01_0704.pdf