10GBASE-CX4 Crosstalk Impact on System Performance Simulation

1. Outline

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- **Crosstalk Worst Case Analysis**
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  - Vertical eye reduction due to crosstalk
  - Jitter increase due to crosstalk

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  - Simulation environment for crosstalk impact
  - Vertical eye reduction due to crosstalk
  - Jitter increase due to crosstalk

- **Driver Output Level Variation Impact**
- **Conclusions and Recommendations**

2. Initial Considerations

- For drivers and input comparators, including package, models for the actual blocks will be used.

- Two pattern generators will be used for simulation, PRBS 2^7-1 and 1010.. continuous signal.

- For Near-End (NEXT) crosstalk, a model based on the power sum loss between a receive channel and the four transmit channels, MDNEXT Eq. 54.6, will be used.

- For Far-End (FEXT) crosstalk, a model based on the power sum loss between a duplex channel and the three adjacent disturbers, MDELFEXT Eq. 54.9, will be used.

- The transmitter jitter, maximum 0.35 UI_pp, was not included in the simulation.

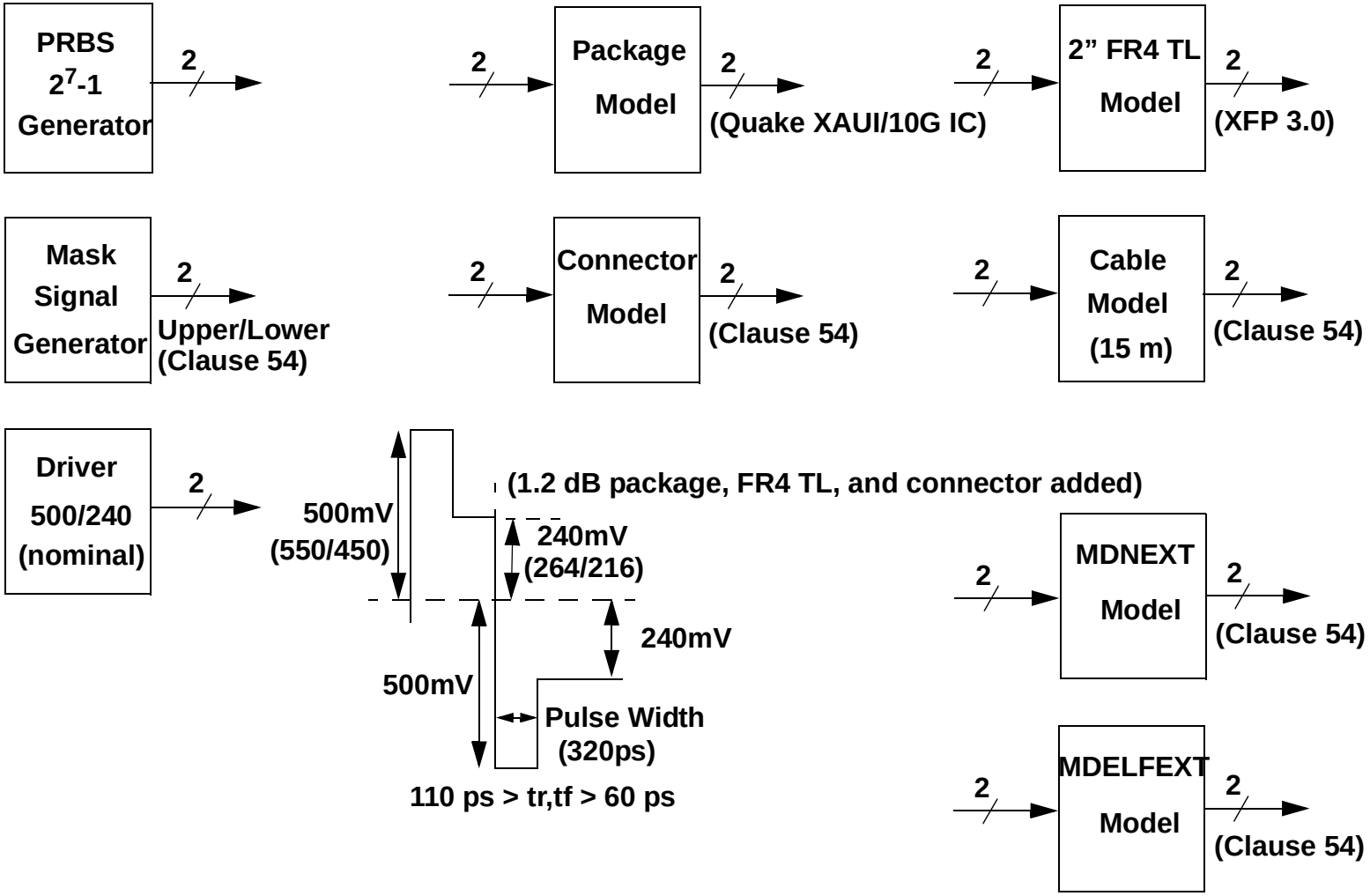
- The random jitter added by the simulation environment will be very small, such that the random jitter at the receiver input will be equal to the transmitter random jitter.

- The total deterministic jitter, at the receiver input, will be the sum of the transmitter deterministic jitter and the jitter introduced by the simulation environment.

- The additional degradations due to impedance variation was not included.

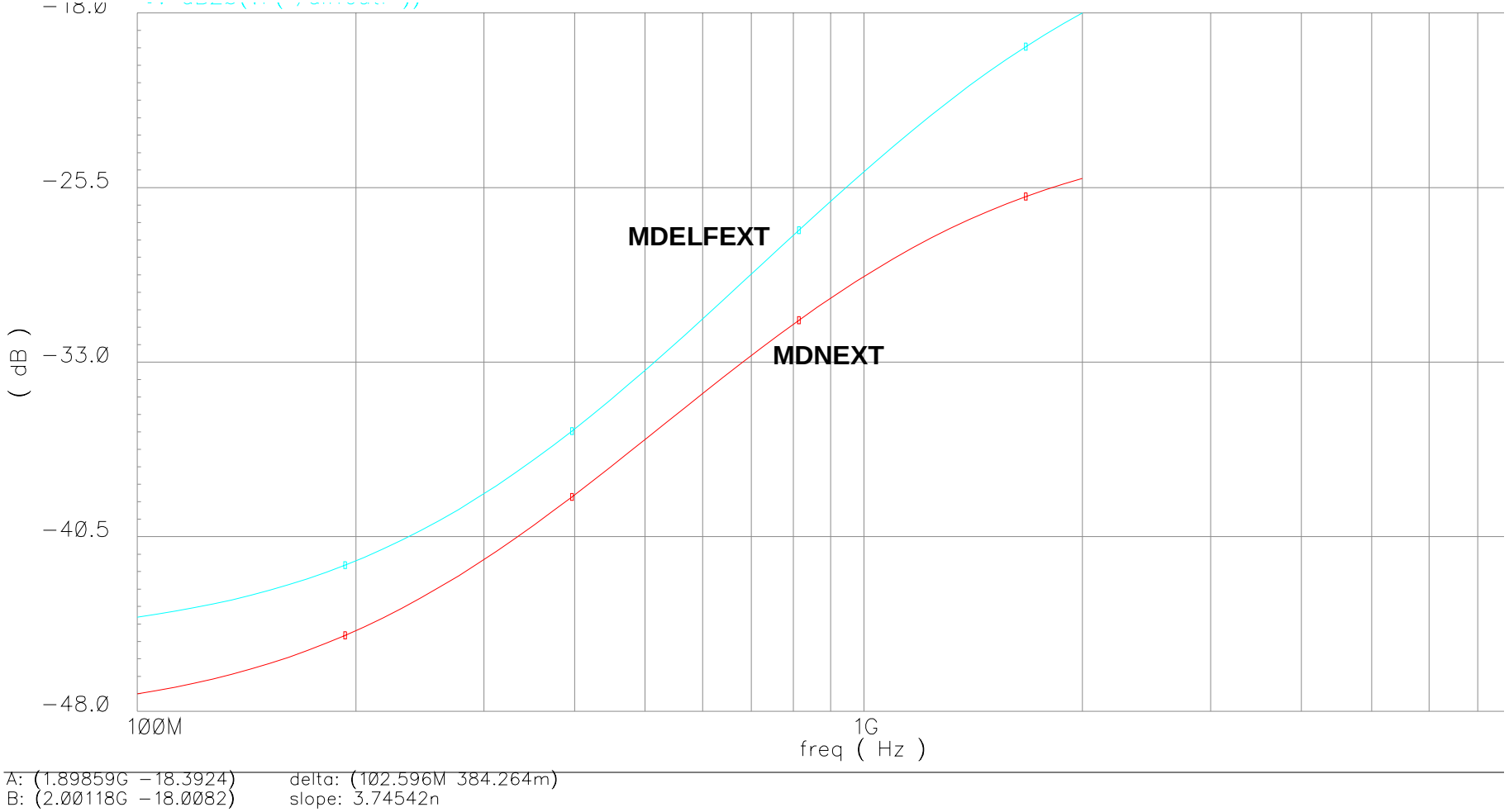
3. Simulation Environment

Figure 1. Simulation Models



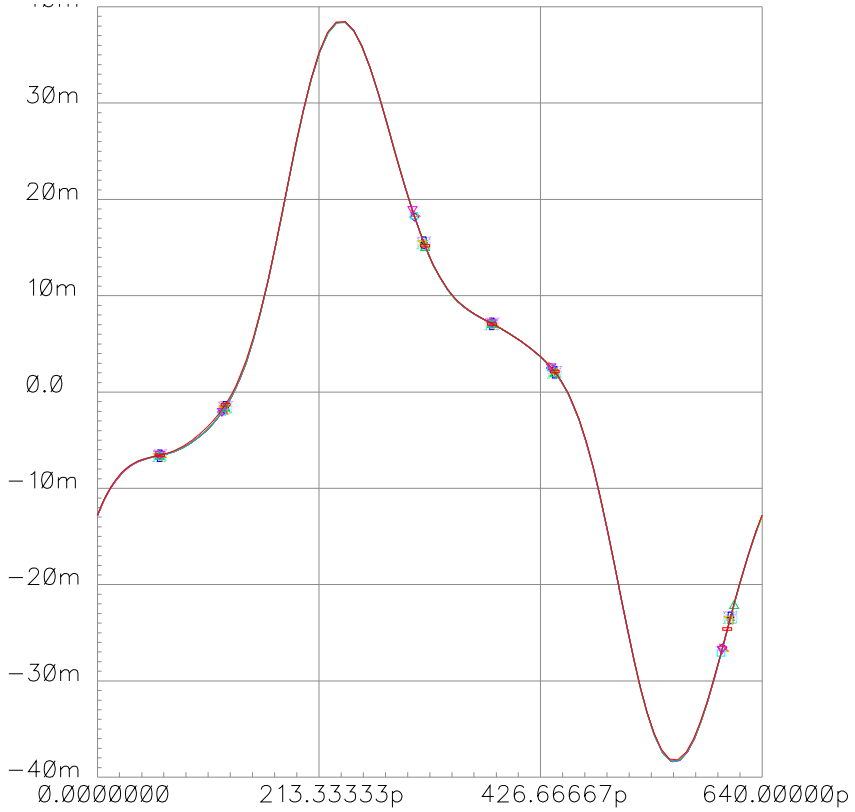
4. MDNEXT and MDELFEXT Models, Frequency Response

Figure 2. Frequency Response

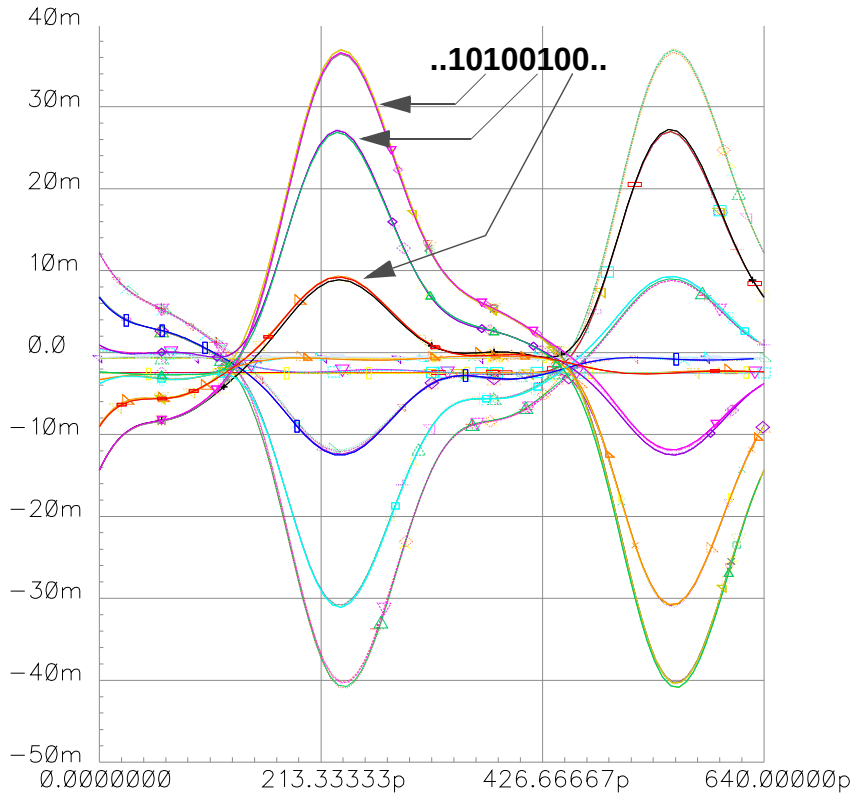


5. Crosstalk Worst Case Analysis

Figure 3. MDNEXT Disturber PRBS (2^7-1) and 1010.. Pattern Comparison



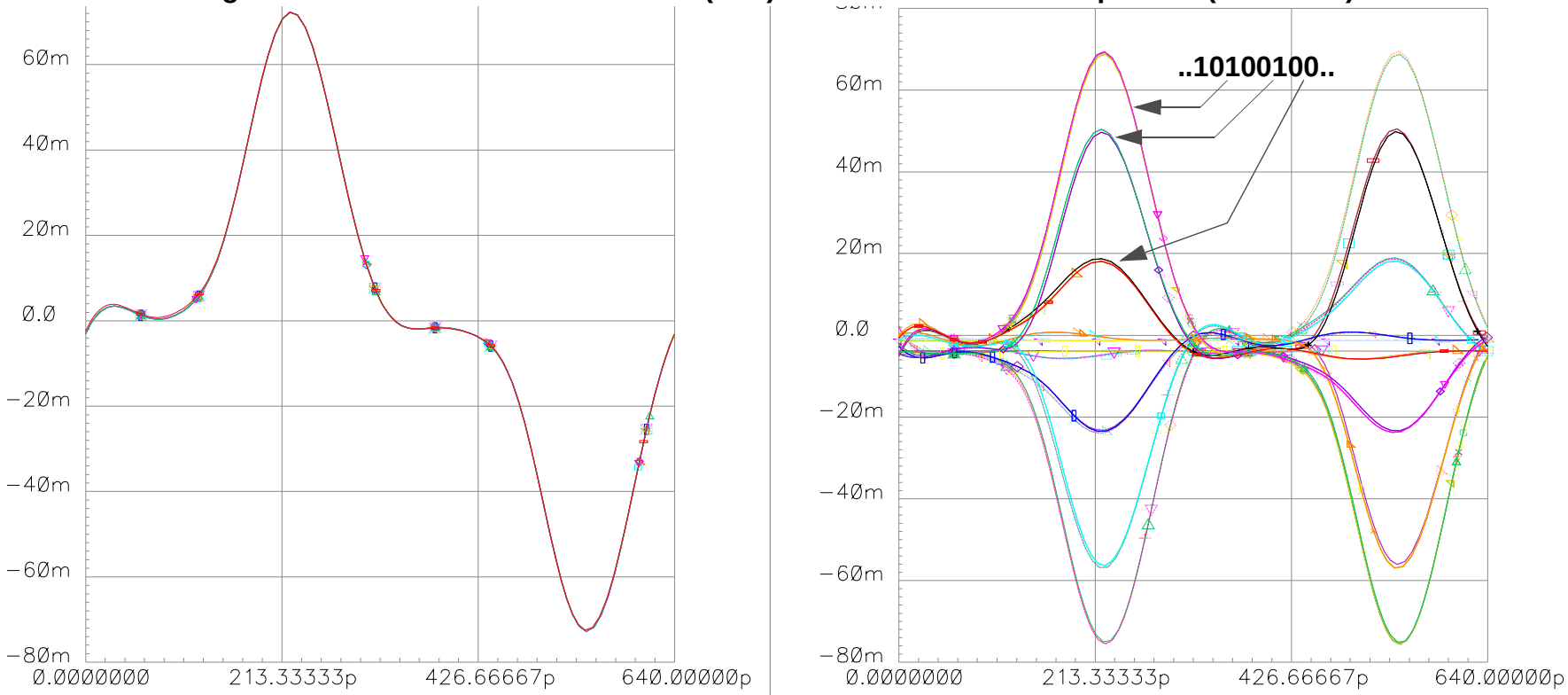
1010.. Pattern



PRBS (2^7-1) Pattern

Worst case disturber amplitude, using PRBS pattern, is the same as the disturber generated using a 1010.. pattern. The advantage of the 1010.. pattern is that the disturber is active every bit time.
Using 1010.. pattern, will generate the worst possible case for every bit. Using a PRBS pattern, the probability of a worst case disturber, for a given bit, is much lower.

Figure 4. MDELFEXT Disturber PRBS (2^7-1) and 1010.. Pattern Comparison (0 m cable)



1010.. Pattern

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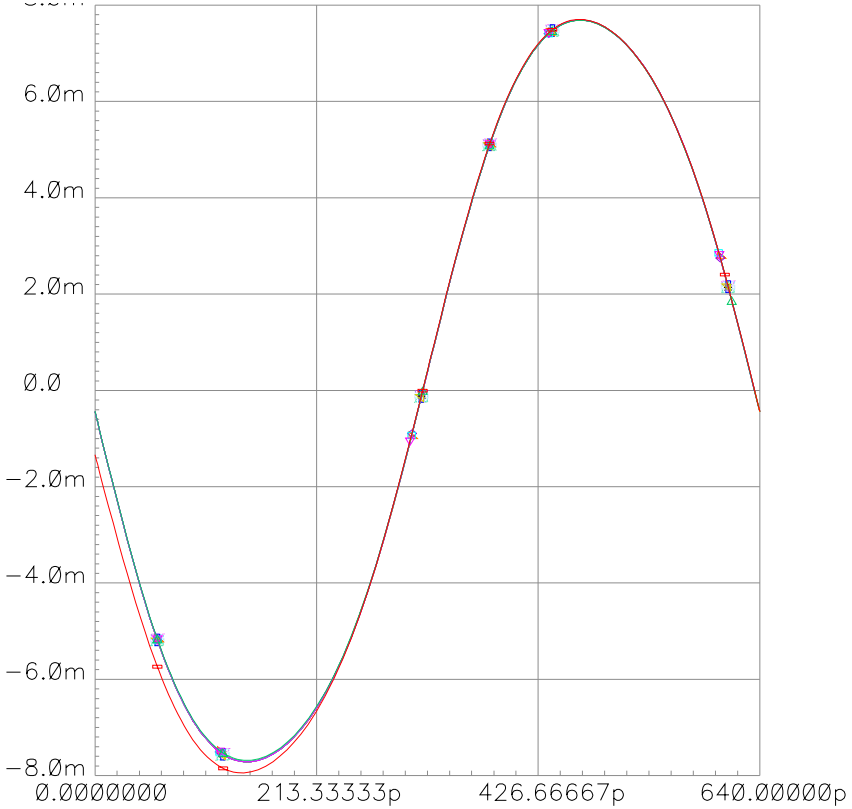
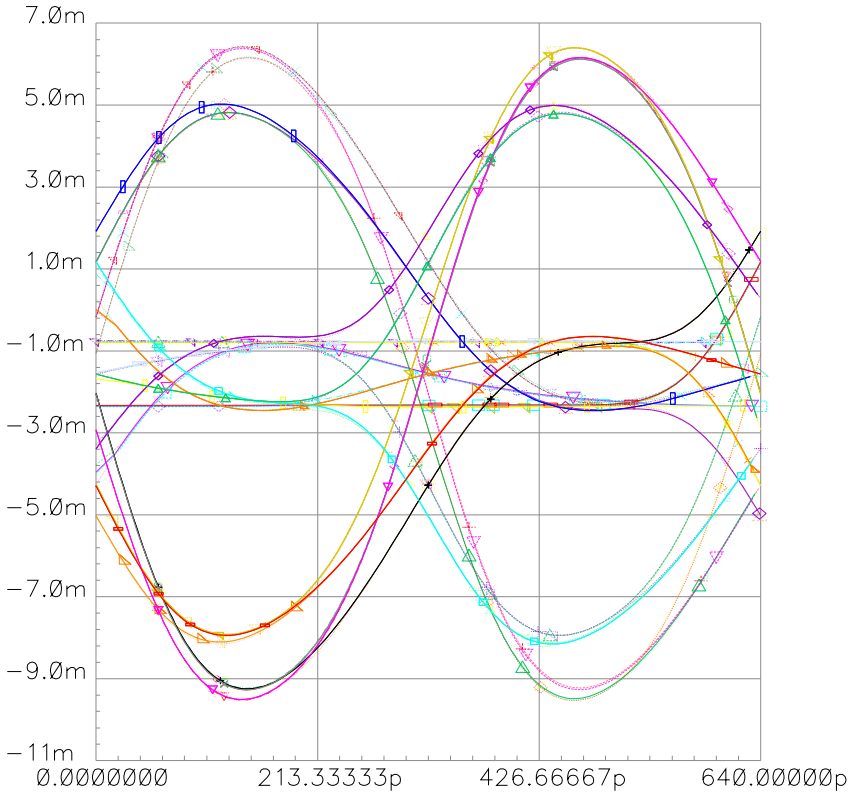
Figure 5. MDELFEXT Disturber PRBS (2^7-1) and 1010.. Pattern Comparison (15 m cable)



1010.. Pattern



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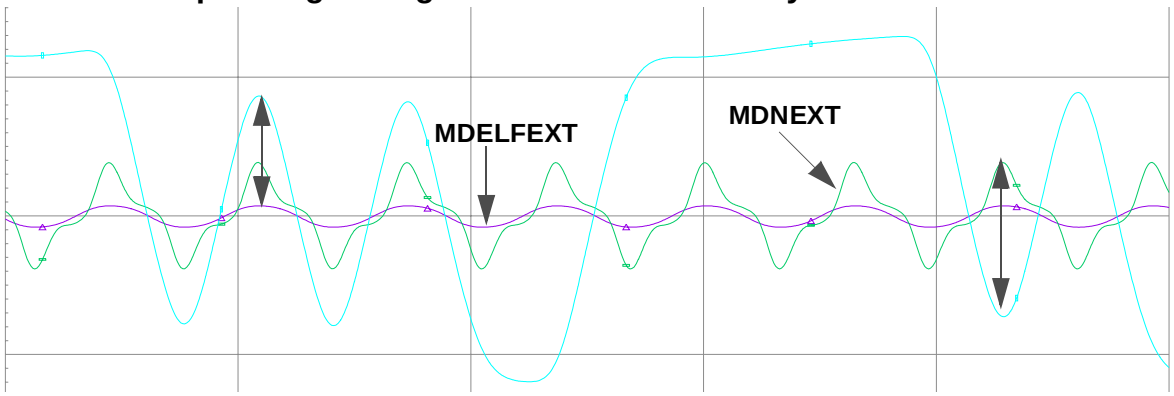
Using 1010.. pattern, will generate the worst possible case for every bit. Using a PRBS pattern, the probability of a worst case disturber, for a given bit, is much lower.

Crosstalk Worst Case Definition

- **case 1: Vertical Eye Opening Reduction due to Crosstalk**

  - MDNEXT and MDELFEXT (101010.. pattern) signals are aligned in phase
  - MDNEXT and MDELFEXT peak signal aligned with the received eye centre



- **case2: Jitter Increase due to Crosstalk**

  - MDNEXT and MDELFEXT (101010.. pattern) signals are aligned in phase
  - MDNEXT and MDELFEXT peak signal aligned with the received eye crossings

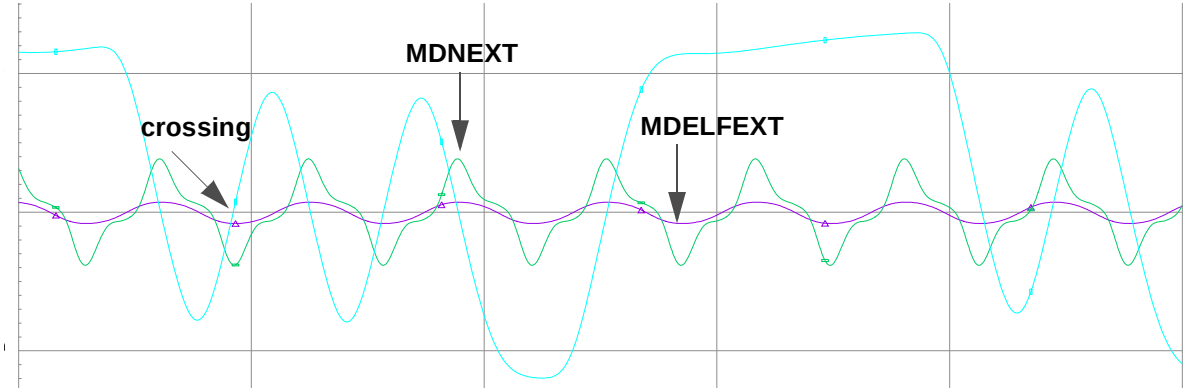


Figure 6. Simulation Environment for Crosstalk Impact (15 m cable assembly)

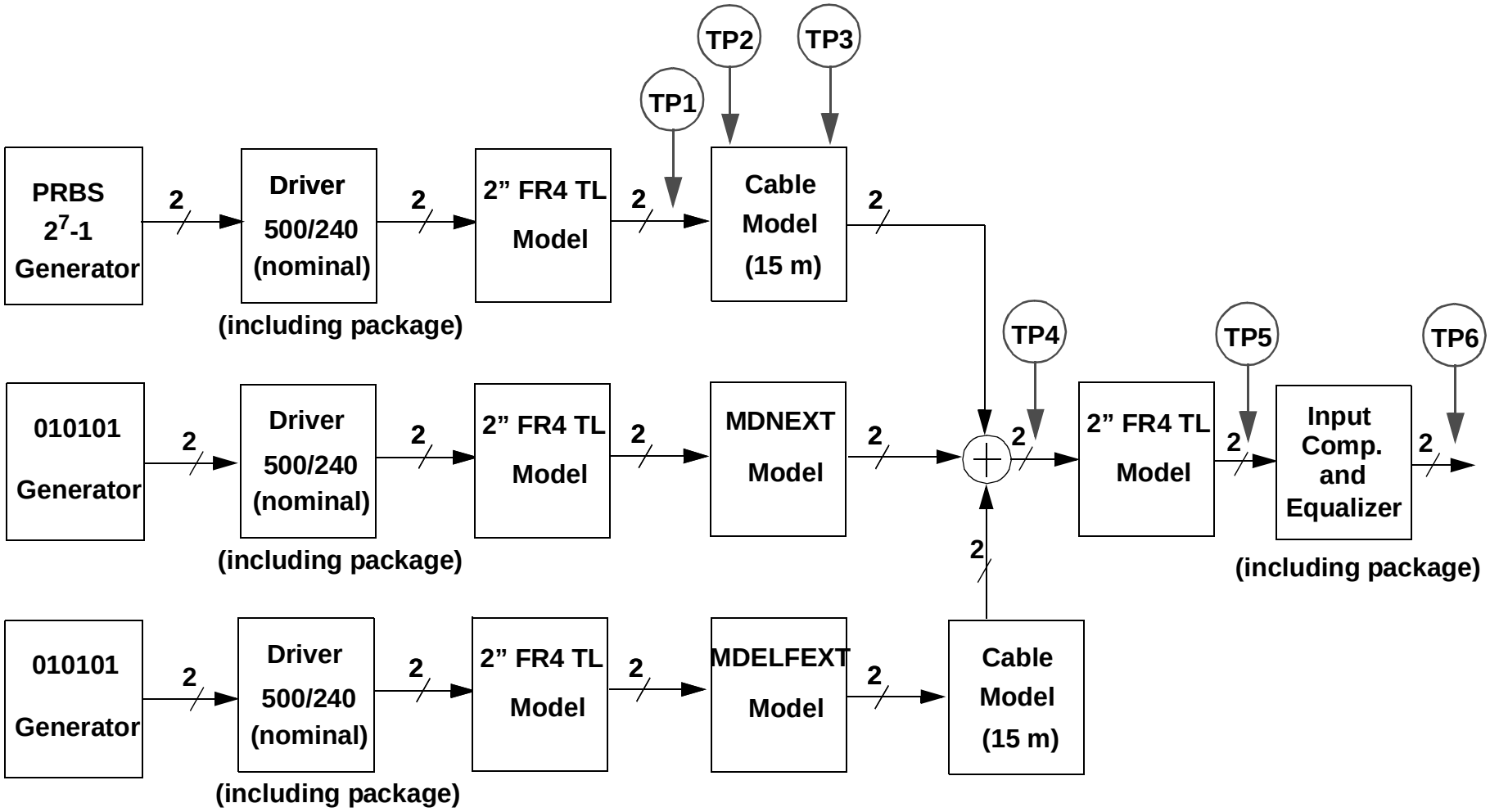
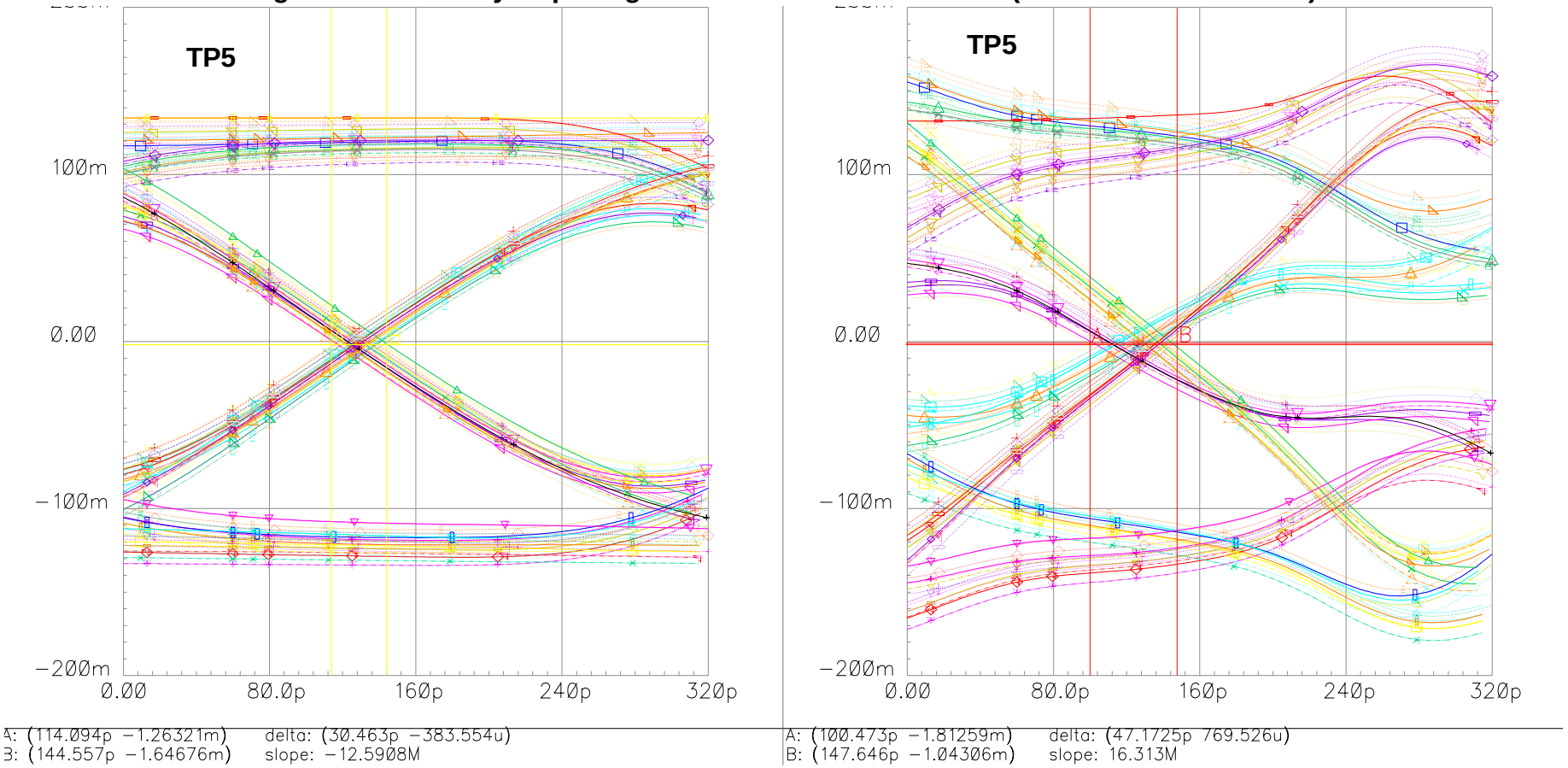


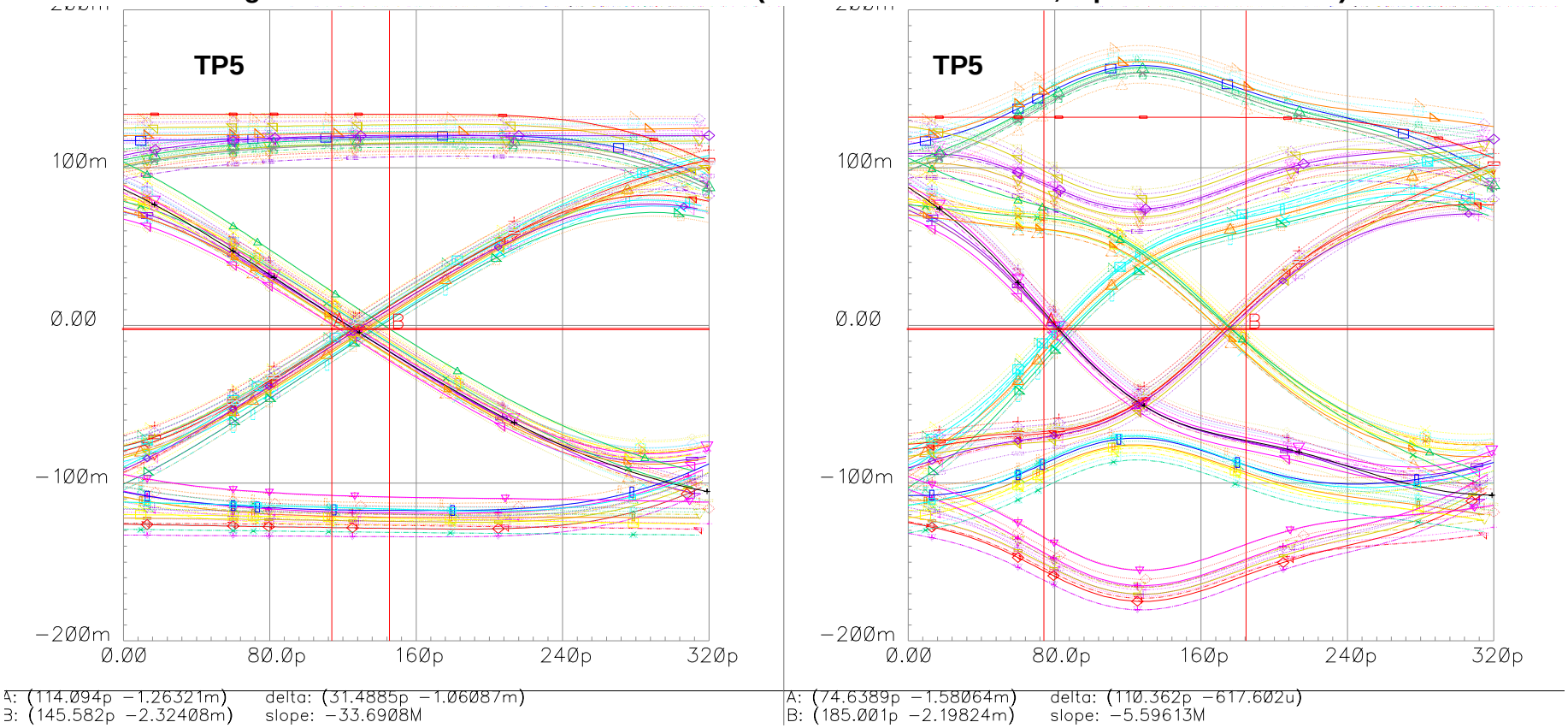
Figure 7. Vertical Eye Opening Reduction due to Crosstalk (worst case 15 m cable)



No crosstalk present, 0.1 UI_pp added
Vertical eye opening, 142 mV_pp

Crosstalk present, 0.15 UI_pp added
Vertical eye opening, 50 mV_pp

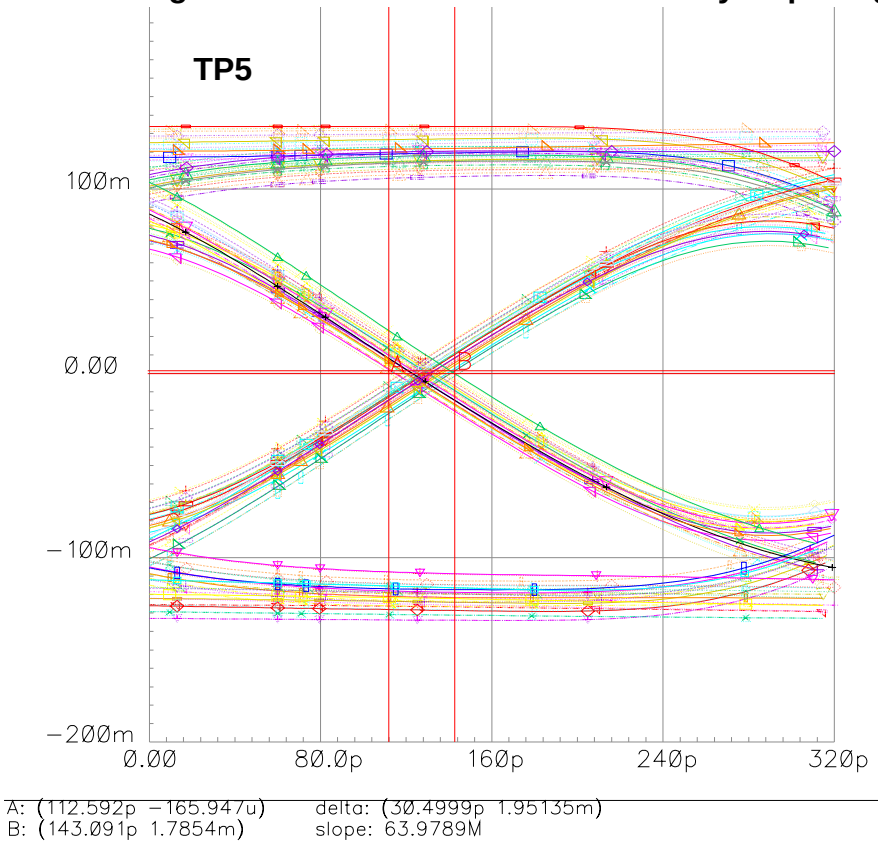
Figure 8. Jitter Increase due to Crosstalk (worst case 15 m cable, equal transmit levels)

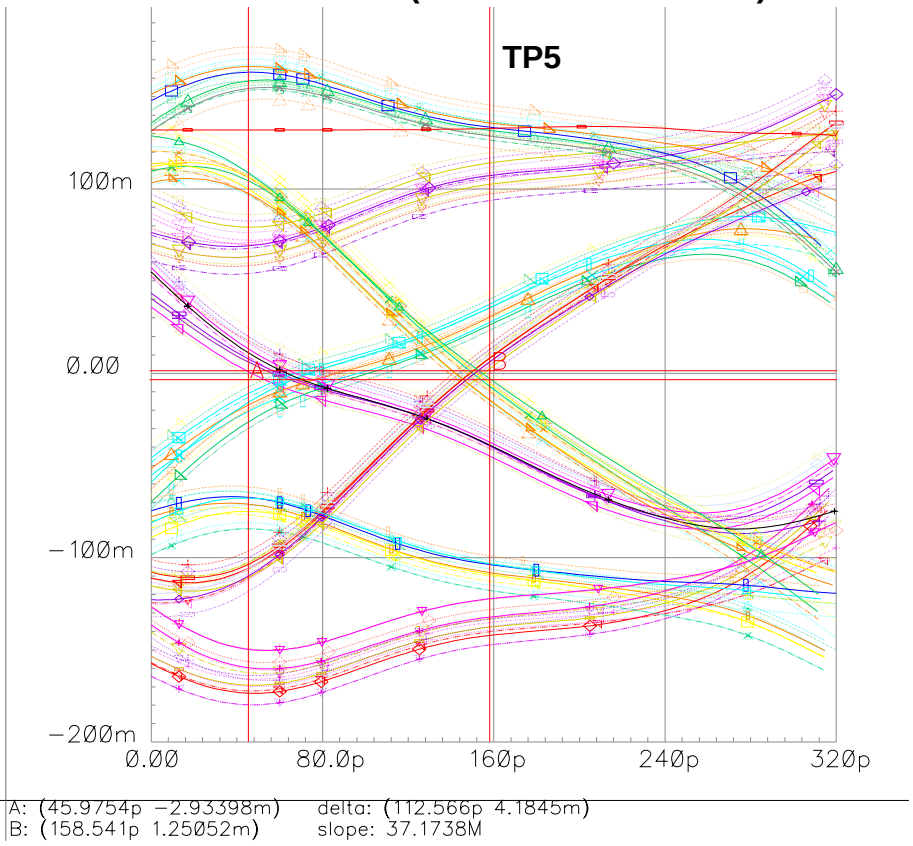


No crosstalk present, 0.1 UI_pp added

Crosstalk present, 0.35 UI_pp added

Figure 9. Jitter Increase and Vertical Eye Opening Reduction due to Crosstalk (worst case 15 m cable)





No crosstalk present, 0.1 UI_pp jitter added
Vertical eye opening, 143 mV_pp

Crosstalk present (mid point between crossing and centre)
0.35 UI_pp added jitter
Vertical eye opening, 128 mV_pp

Figure 10. Simulation Environment for Crosstalk Impact (0 m cable assembly)

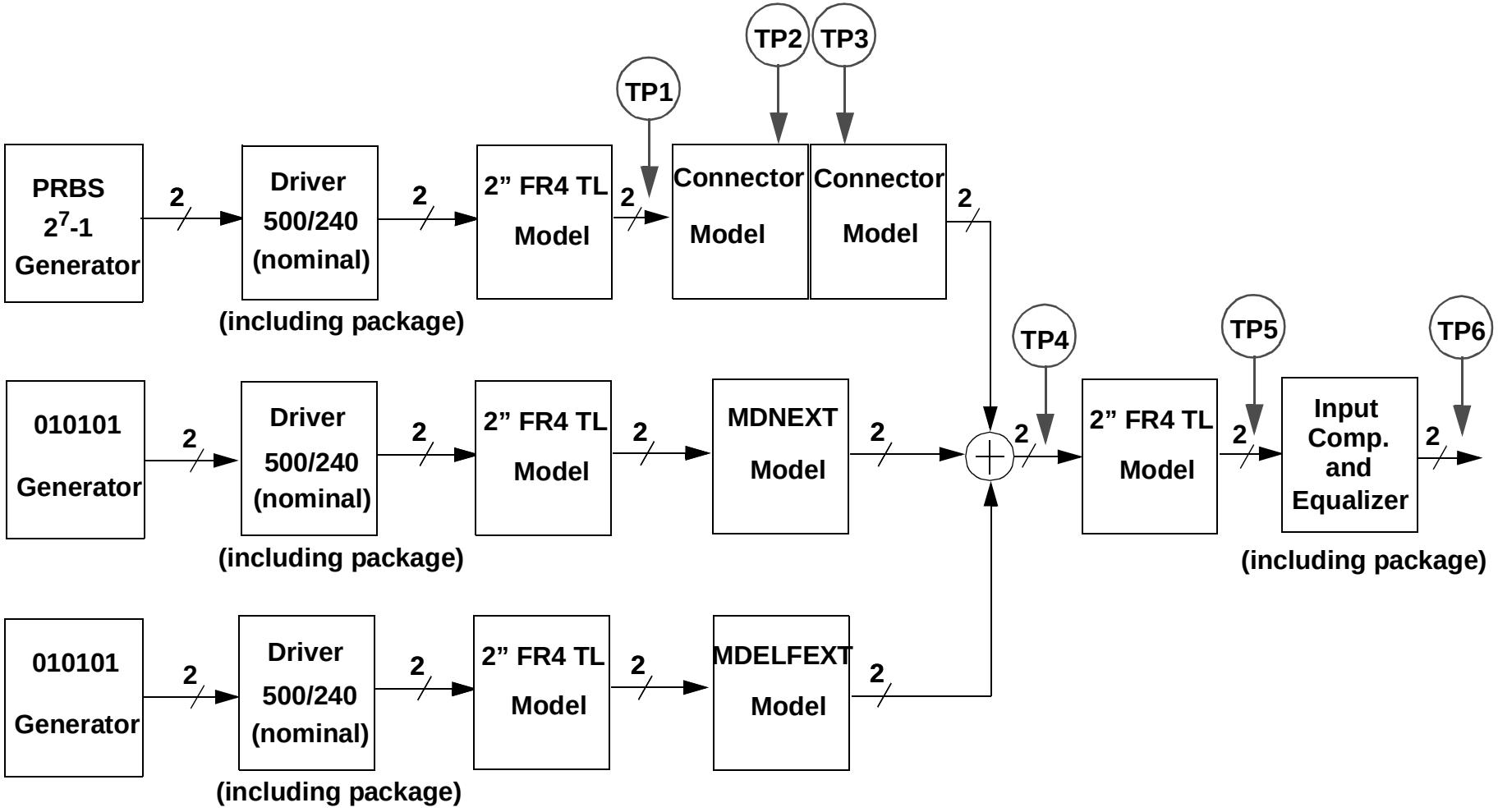
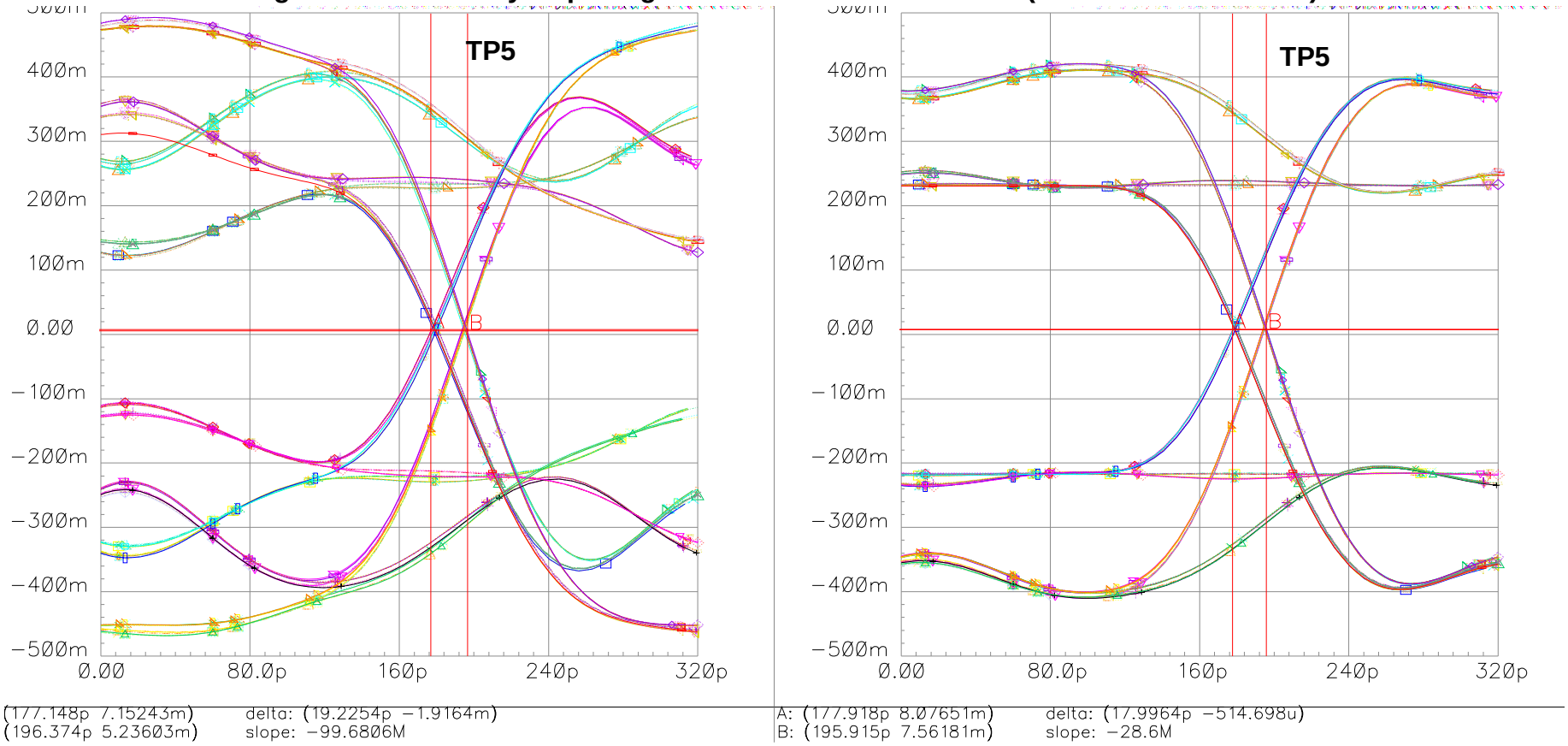


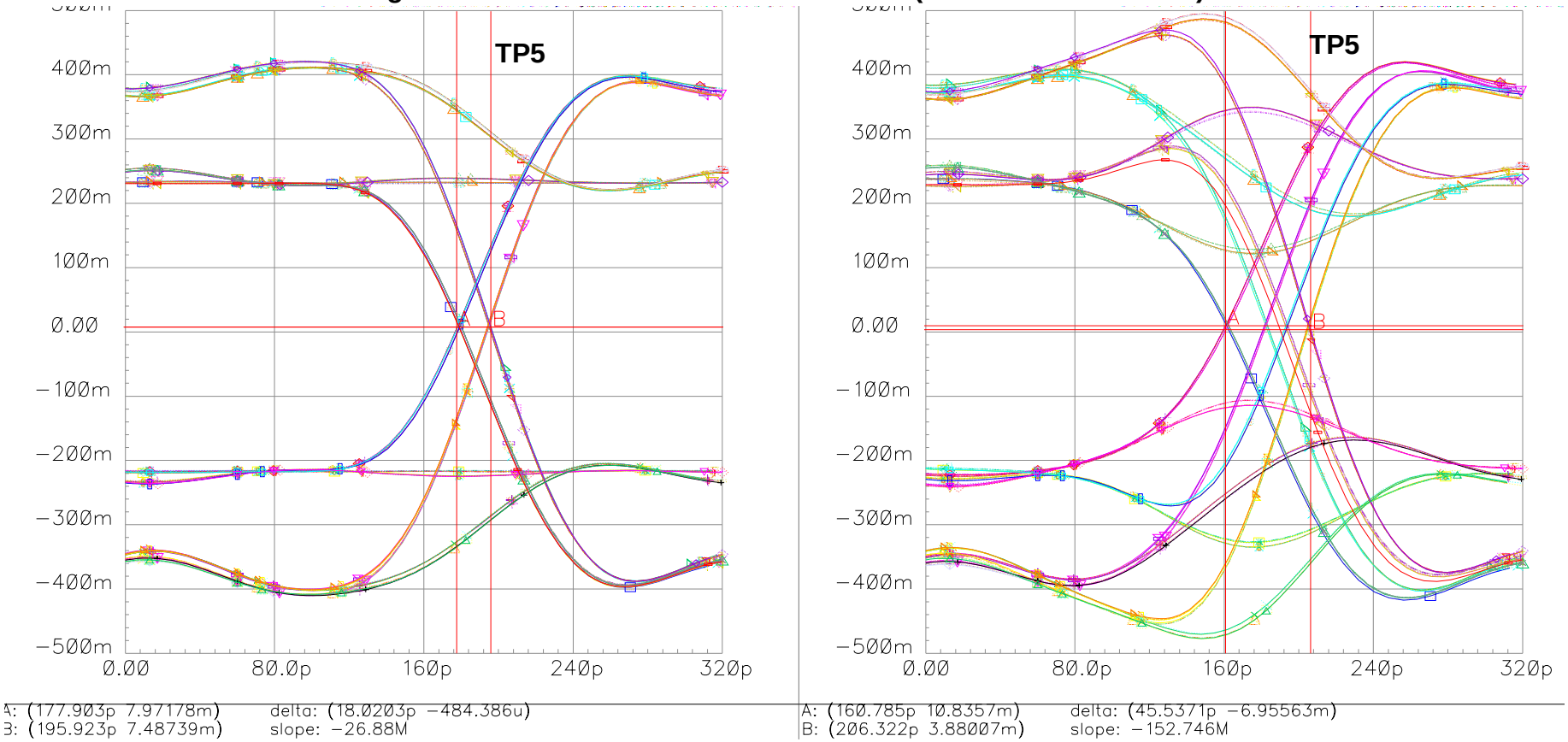
Figure 11. Vertical Eye Opening Reduction due to Crosstalk (worst case 0 m cable)



Eye opening reduced to 210 mVpp (differential)
Small (1.3 ps) increase in jitter.

Eye opening (no crosstalk) 440 mVpp (differential)

Figure 12. Jitter Increase due to Crosstalk (worst case 0 m cable)



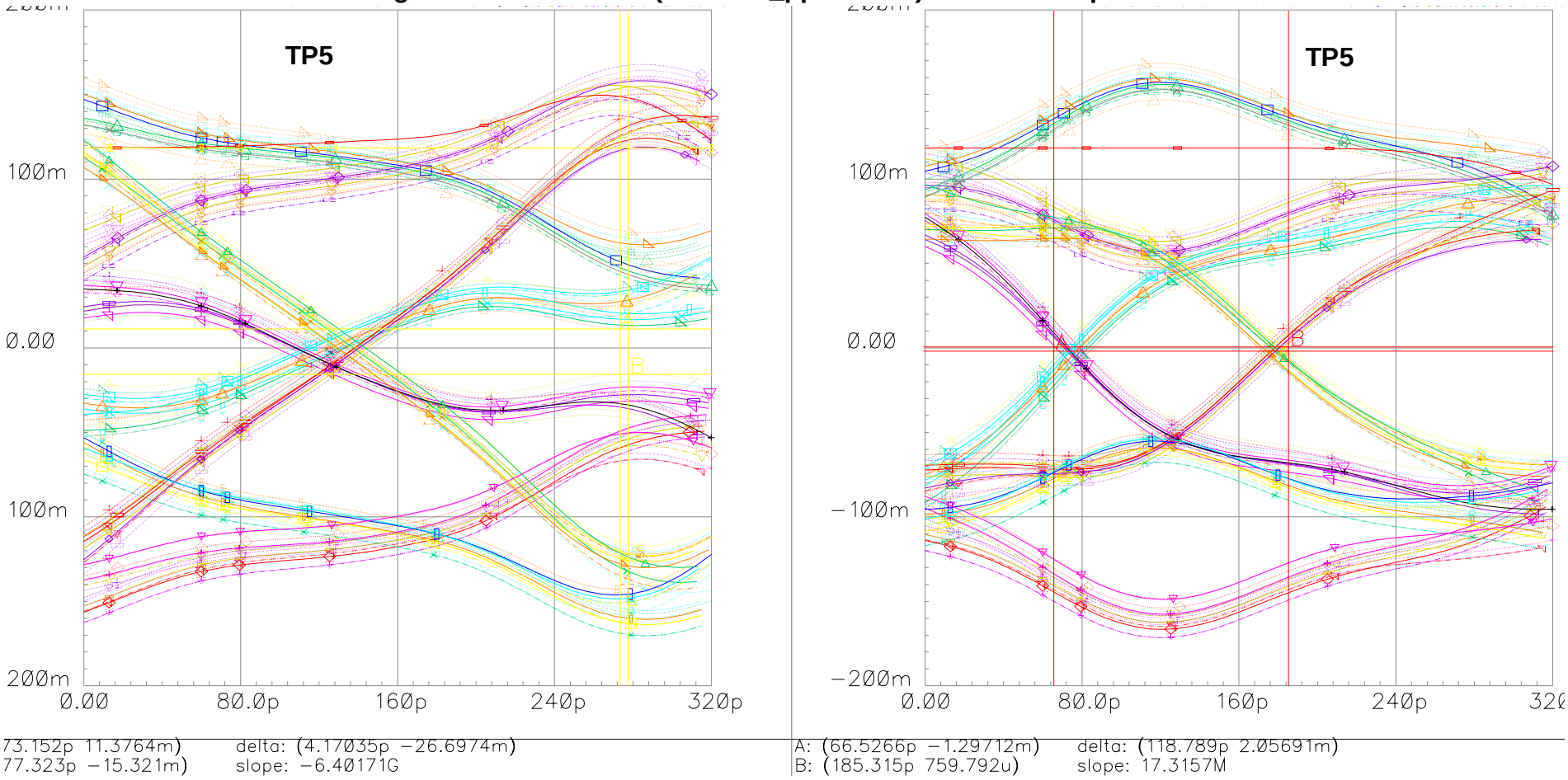
No crosstalk present, 0.06 UI_pp added

Crosstalk present, 0.14 UI_pp added jitter

6. Driver Output Level Variation Impact

- 802.3ak D4.0 specification 800 to 1600 mVpp (1200 mV +/- 33%) will not work.
- Restrict the output level variation to +/- 10%.
- Include output level variation in worst case definition:
  - assume victim driver output level - 10%,
  - assume all other drivers (NEXT and FEXT) + 10%,
  - simulate worst case crosstalk impact (jitter and vertical eye closure) for +/- 10% output level variation,
  - include receiver equalizer contribution.

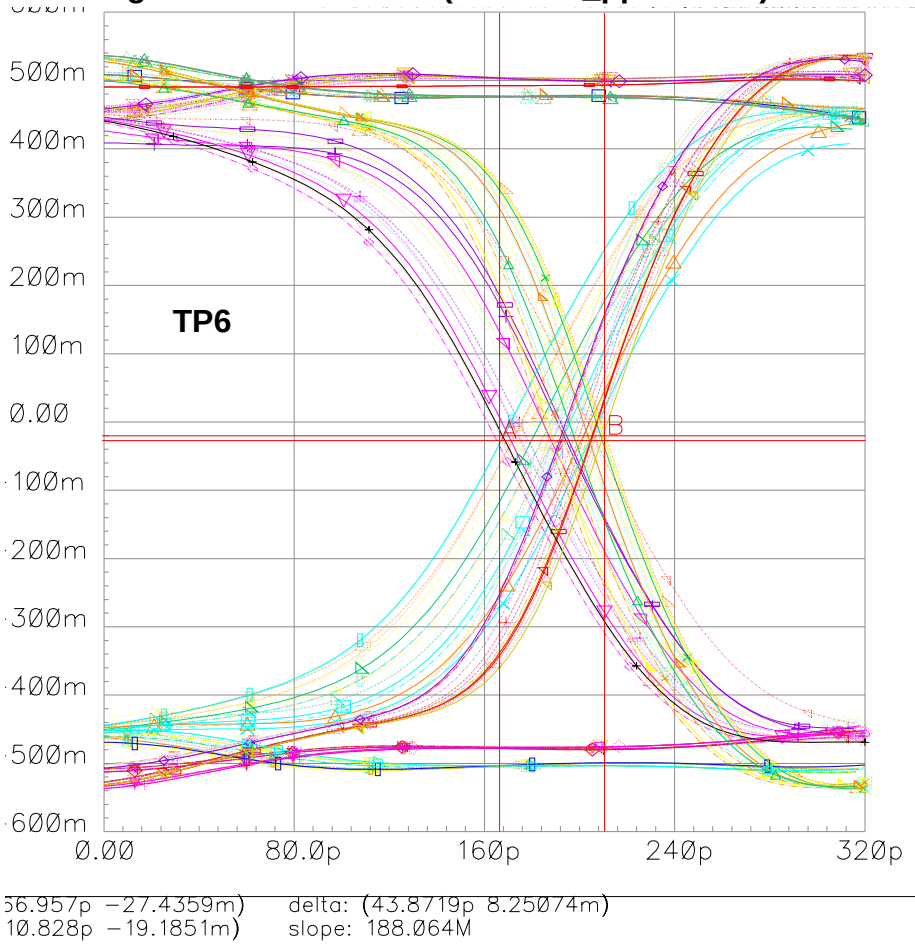
Figure 13. Worst Case (1000 mV_pp +/- 10%) Crosstalk Impact

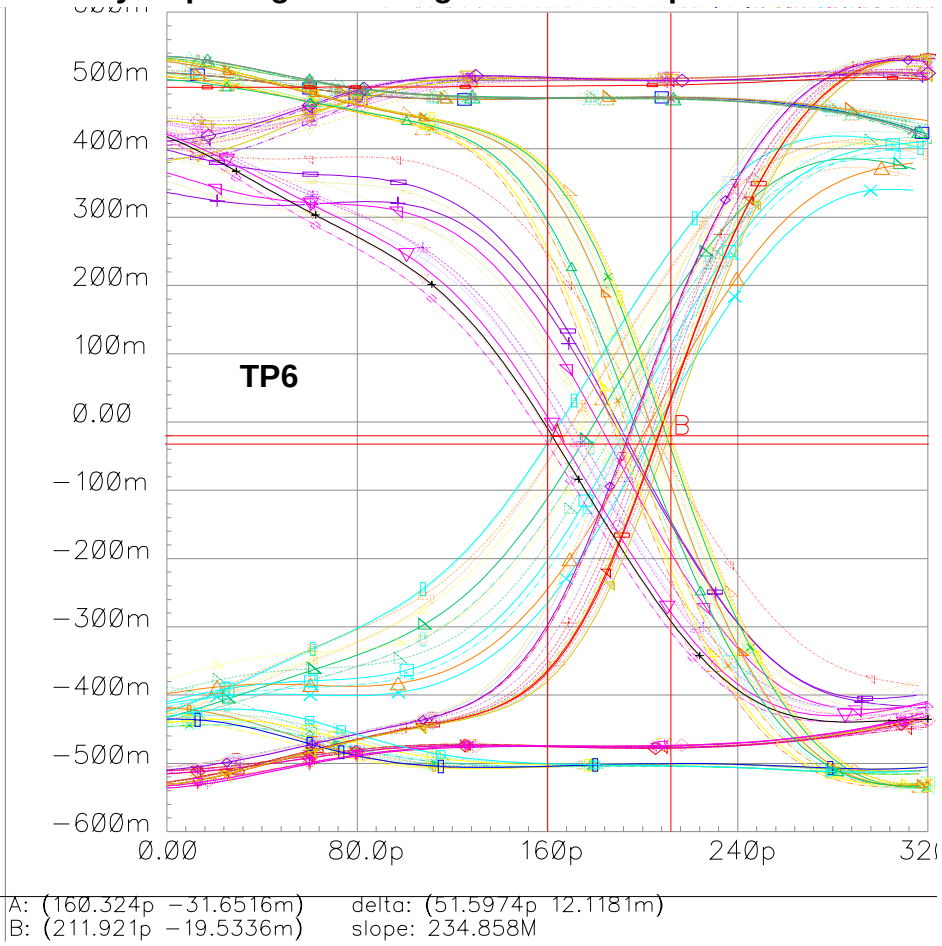


Worst case vertical eye closure
Vertical eye opening, 26.69 mV_pp

Worst case horizontal eye closure
119 ps (0.37 UI_pp) added jitter

Figure 14. Worst Case (1000 mV_pp +/- 10%) Received Vertical Eye Opening Assuming First Order Equalizer

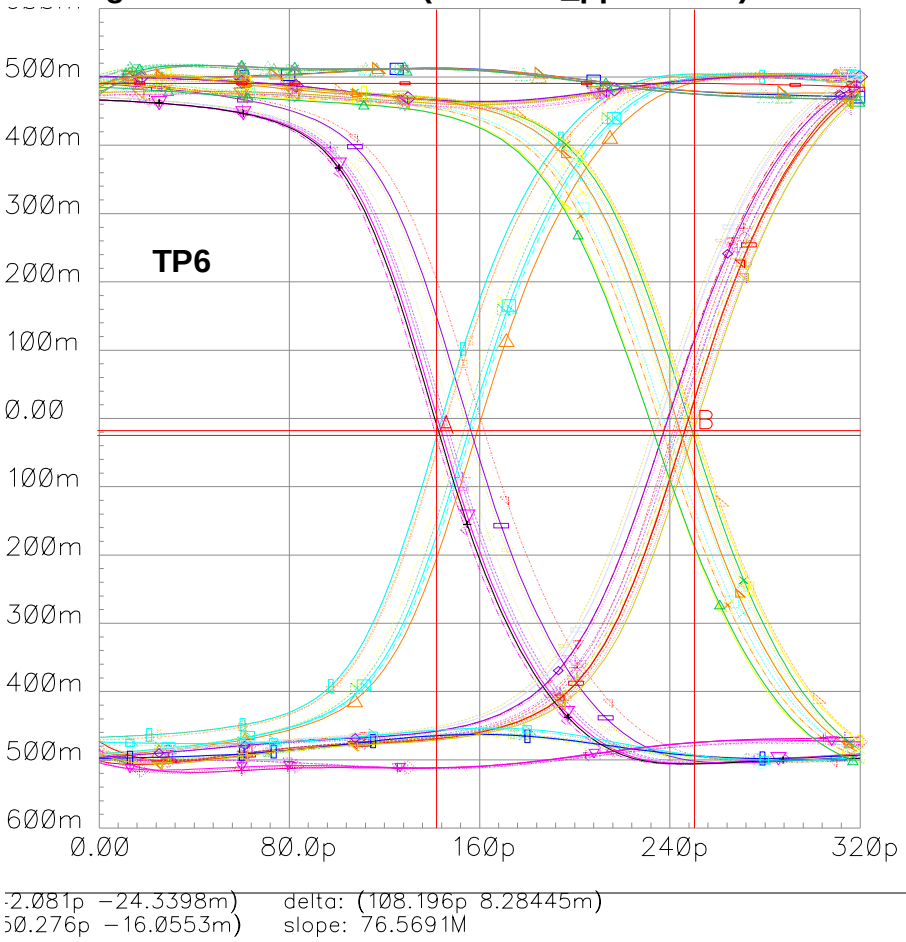


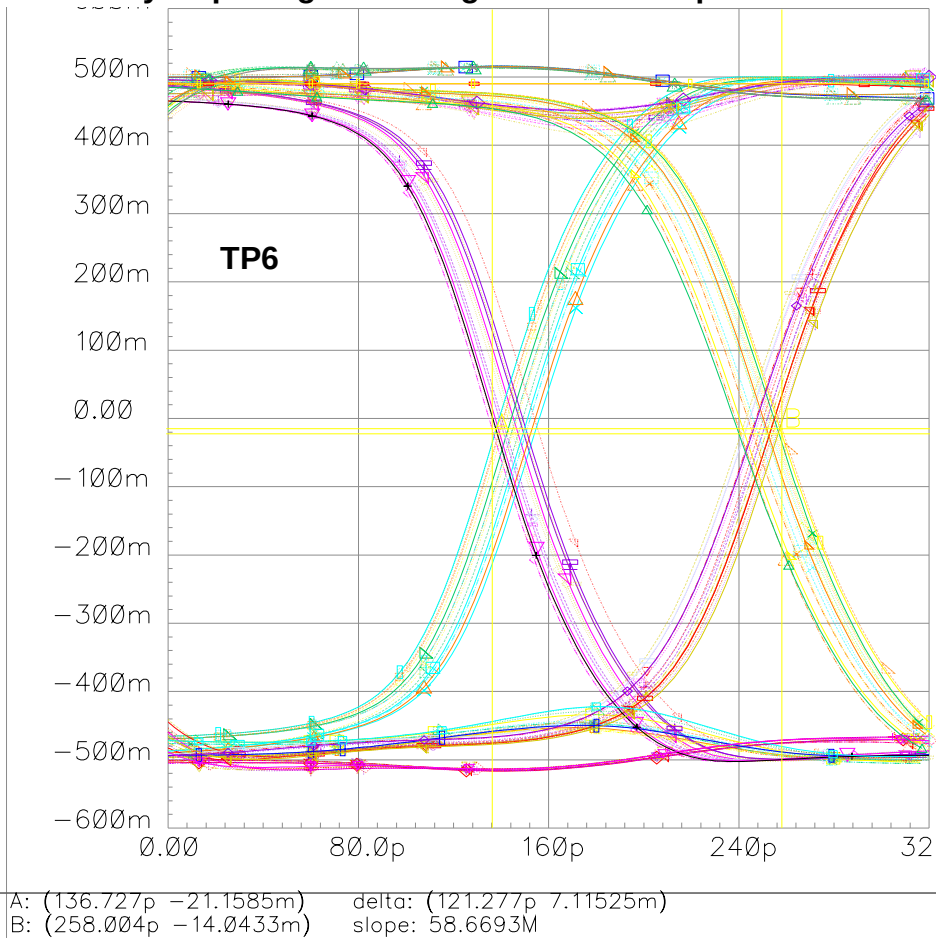


Worst case vertical eye closure, equal levels
Vertical eye opening, 400 mV_pp, 0.14 UI_pp jitter added.

Worst case vertical eye closure, worst case levels
Vertical eye opening 320 mV_pp, 0.16 UI_pp added jitter

Figure 15. Worst Case (1000 mV_pp +/- 10%) Received Horizontal Eye Opening Assuming First Order Equalizer





Worst case horizontal eye closure, equal levels
Vertical eye opening, 460 mV_pp, 0.34 UI_pp jitter added.

Worst case horizontal eye closure, worst case levels
Vertical eye opening 450 mV_pp, 0.38 UI_pp added jitter

7. Conclusions and Recommendations

- The receiver input eye degradation (vertical and horizontal eye opening) will increase with the cable length.

- The assumption, that the receive signal and MDELFEXT disturber are coherent, is valid.

- The main contributor to signal degradation for long cables is MDNEXT.

- Driver differential peak amplitude at TP2 (Table 54-6) allows for +/- 33% and needs to be changed. For driver differential peak amplitude1000 mV_pp +/- 10%, the worst case simulation results are:

    - minimum differential vertical eye opening at TP5 is 26.69 mV_pp and can be improved using a first order equalizer (TP6),

    - worst case total jitter contribution of the cable assembly (TP4) is 0.37 UI_pp (Table 54-9 allows for 0.18 UI_pp), the equalizer (TP6) may reduce the jitter by a small amount (nominal 0.1 UI_pp, worst case 0.05 UI_pp).

- We recommend the following changes:

    - Driver differential peak amplitude at TP2 (Table 54-6), maximum 1000 mV_pp and minimum 800 mV_pp,

    - Cable assembly total jitter contribution at TP4 (Table 54-9), maximum 0.37 UI_pp,

    - Total jitter at TP4 (Table 54-9), maximum 0.84 UI_pp.