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00-104R0:
Ultra-320 SCSI Compensation Techniques

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From 99-335R0: Next Steps

- We will collect more data on different configurations:
  - heavily and lightly loaded busses
  - ✓ typical and atypical
  - point-to-point
- We will investigate:
  - ✓ can lower amplitudes be used to address large chip power requirements?
  - ✓ how bad will common-mode degrade for large amplitudes?
  - ✓ would receiver compensation work?
  - ✓ how much capacitance will be added by larger drivers?
  - how much capacitance is acceptable?
  - could we use a different terminator scheme?

Part I:
Pre-compensation with XTALK

Objectives

- Further investigate write pre-compensation for Ultra-320.
- Estimate amplitude and timing factors to define eye mask:
  - Clocking;
  - De-skew.
- Measure the signal degradations to find eye opening with ISI and reflections for typical configurations:
  - Amplitude noise;
  - Timing shift;
  - Miscellaneous noise.
- Measure the signal degradations with XTALK as well.
- How much does pre-comp aid reception:
  - Setup margin;
  - Amplitude margin.

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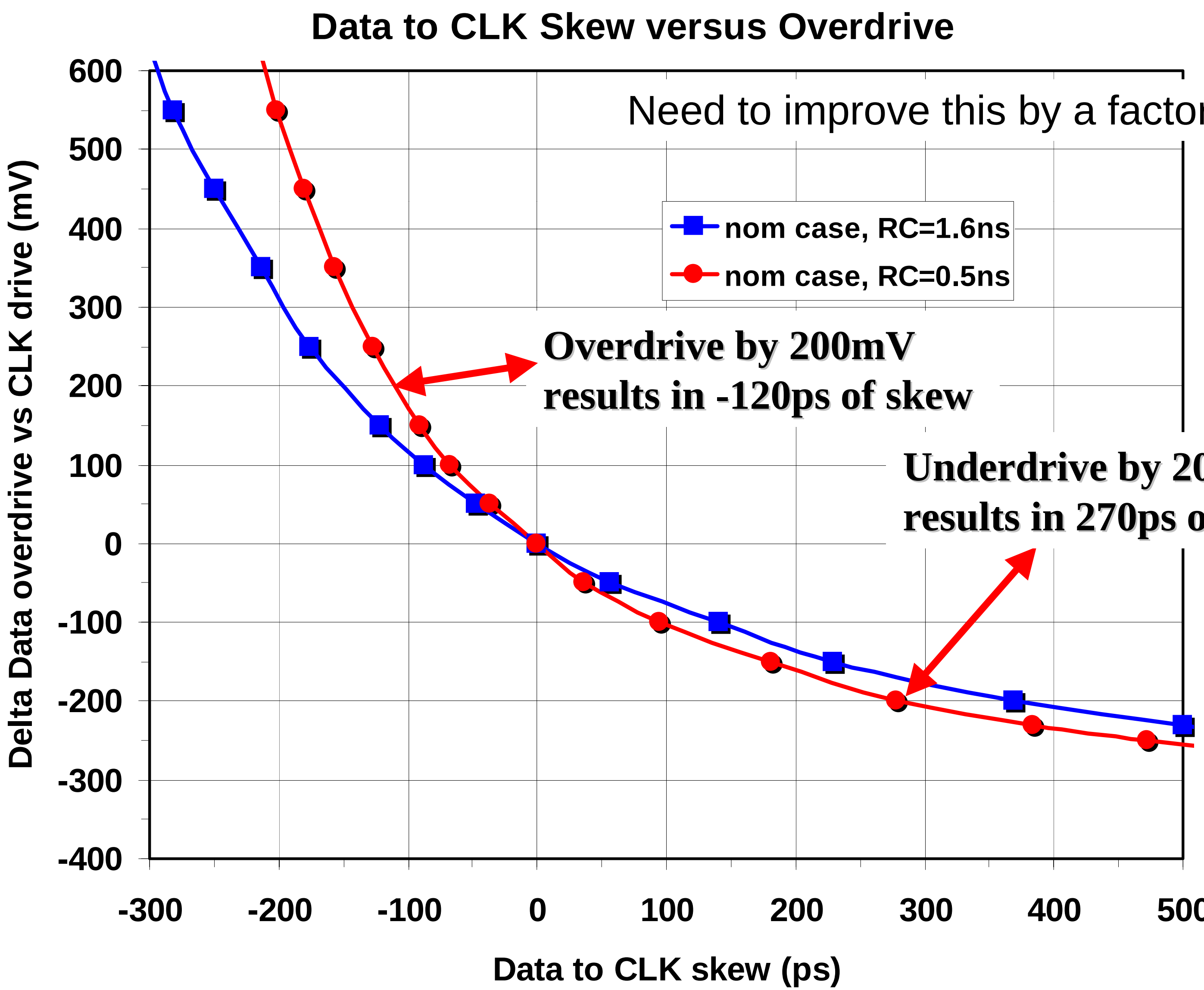
Estimated Ultra-320 Error Sources

Random amplitude (0-to-pk)	**Terminator voltage mismatch**	**(SPI-3: Tab20)**	**13mV**
	Terminator resistance mismatch	**(SPI-3: Tab20)**	**5mV**
	Driver error	**(SPI-3: TabA2)**	**40mV**
	Receiver comparator	**(SPI-3: TabA5)**	**30mV**
	Root sum squares of random amplitude		**52mV**
Deterministic Amplitude: (0-to-pk)	**Cable + back-plane resistance**	**(cable spec + meas)**	**28mV**
	Comparator overdrive requirement	**(SPI-3: Fig48)**	**70mV**
	Total amplitude 0-to-pk factors:		**150mV**
Timing factors (0-to-pk)	**Low Vt vs substrate noise**	**(99-261r1)**	**100ps**
	Receiver clock jitter	**(99-261r1)**	**125ps**
	Residual de-skew	**(99-261r1)**	**125ps**
	De-skew stability	**(temperature)**	**100ps**
	Input slew rate dependent skew	**(99-261r1)**	**100ps**
	Receiver amp dependent delay	**(99-261r1*)**	**150ps**
	Receiver FF rise/fall prop delay difference		**300ps**
	Total 0-to-pk timing factors:		**1.0ns**

These are the error sources that are not accounted for by our test setup as well as those in the SPI-3 budget.
0-to-pk values converted from pk-to-pk numbers by a factor of 1/2.
* refer to diagram on next page.

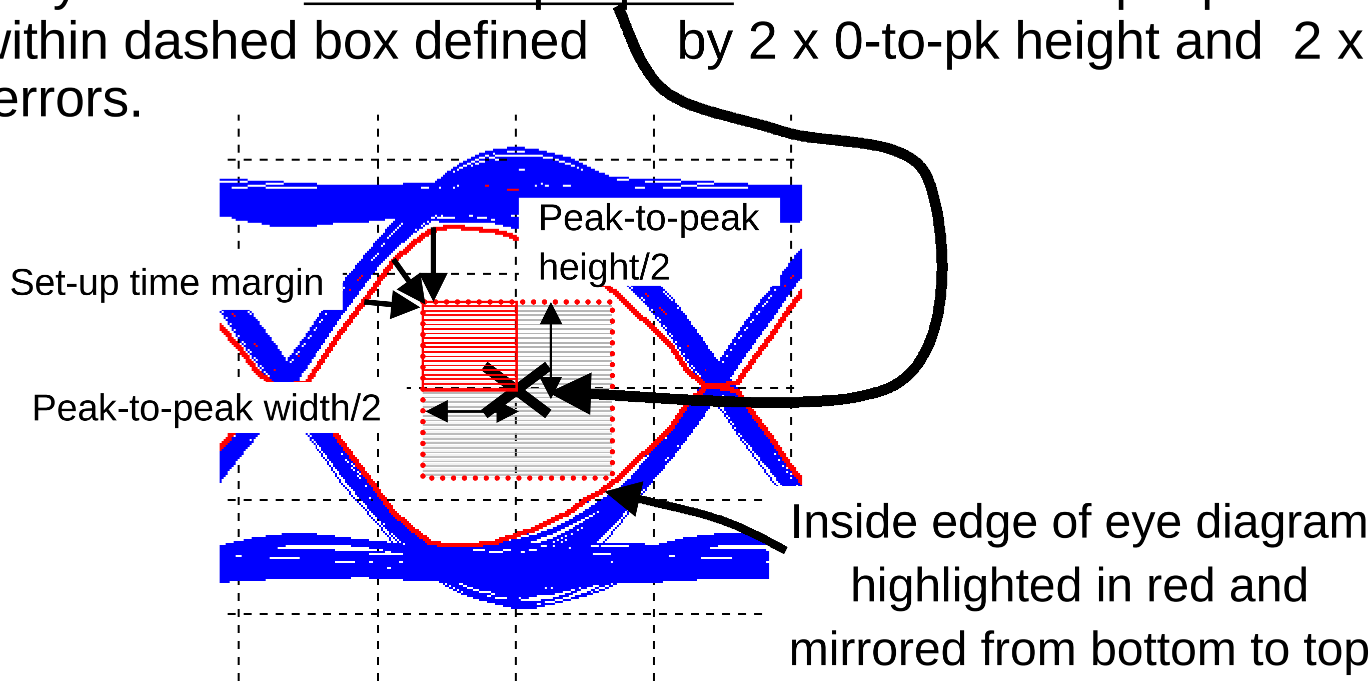
Dynamic Receiver Characteristics

Typical U-160 Receiver Amplitude Dependent Delay



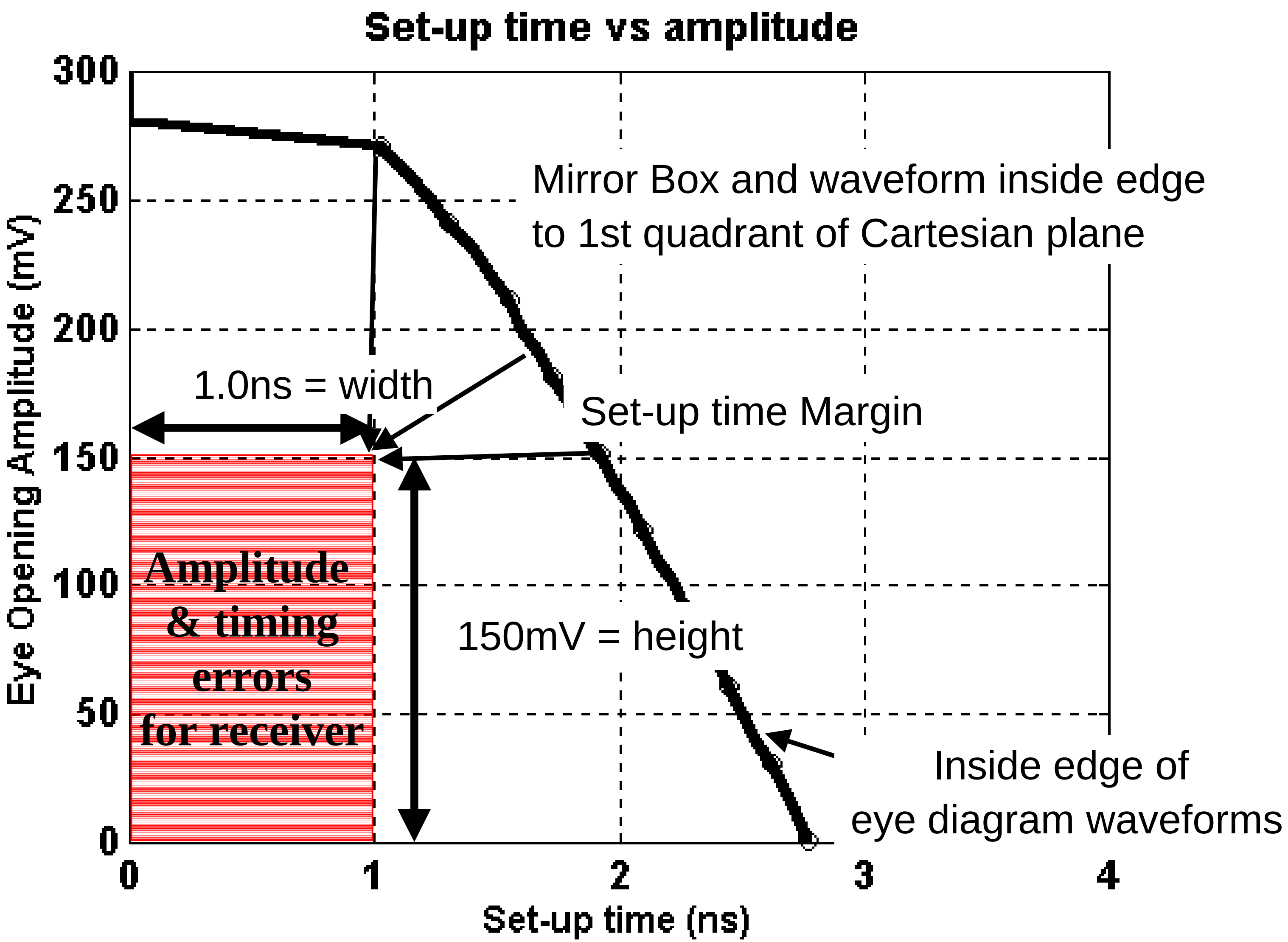
Ultra-320 Error Sources on Eye

- Error sources are used to define range over which receiver characteristic may typically vary from the ideal sample point. I.e. actual sample point may lie anywhere within dashed box defined by 2 x 0-to-pk height and 2 x 0-to-pk width of errors.



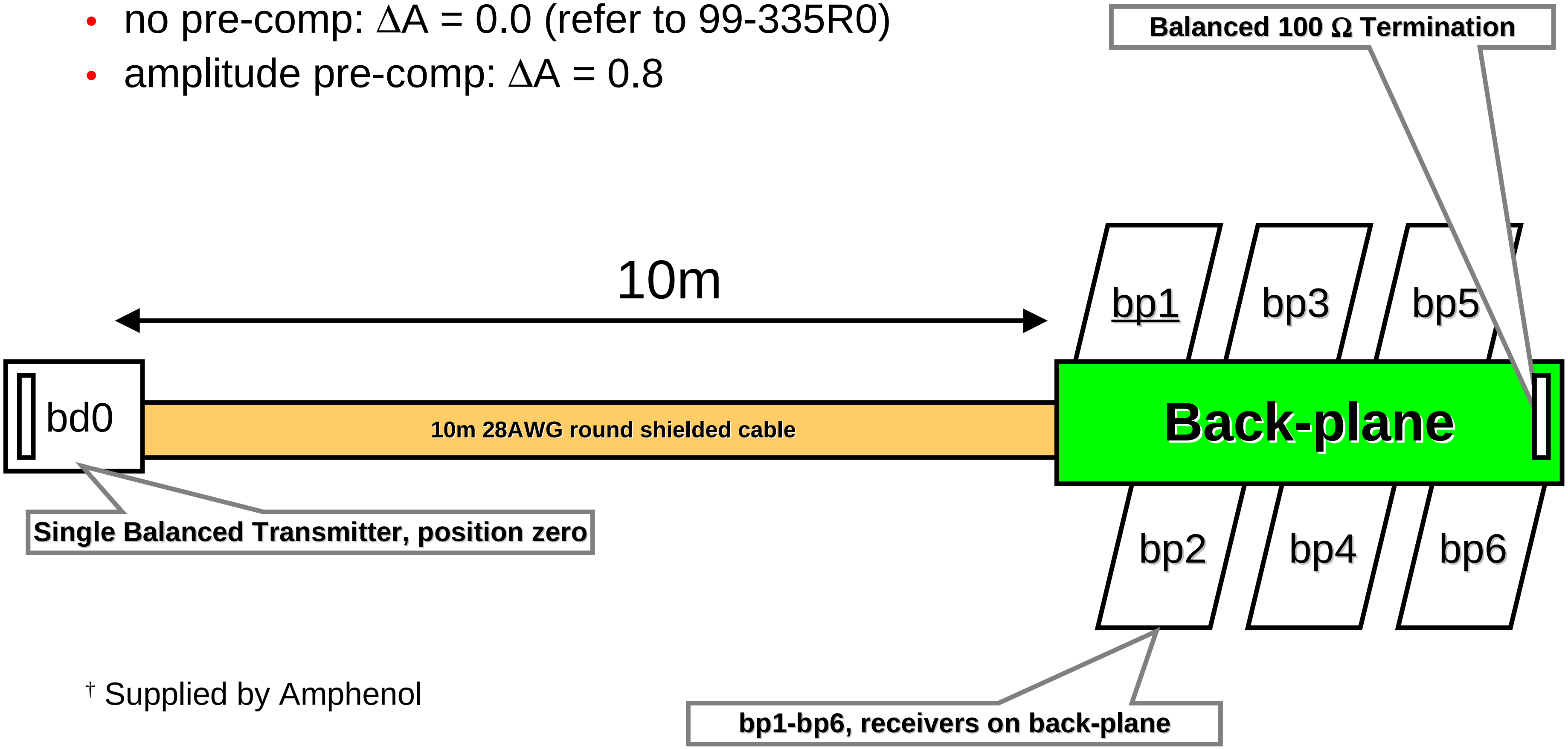
- Amplitude error sources define height & Timing error sources define width.
- E.g. set-up time margin is measured as distance from eye diagram waveform to box.
- Mirror top/bottom waveforms and box to first quadrant to visualize margin.
- Only concerned with set-up time in this presentation.

Margin is distance from box



Config 1 Long Cable + Back-plane

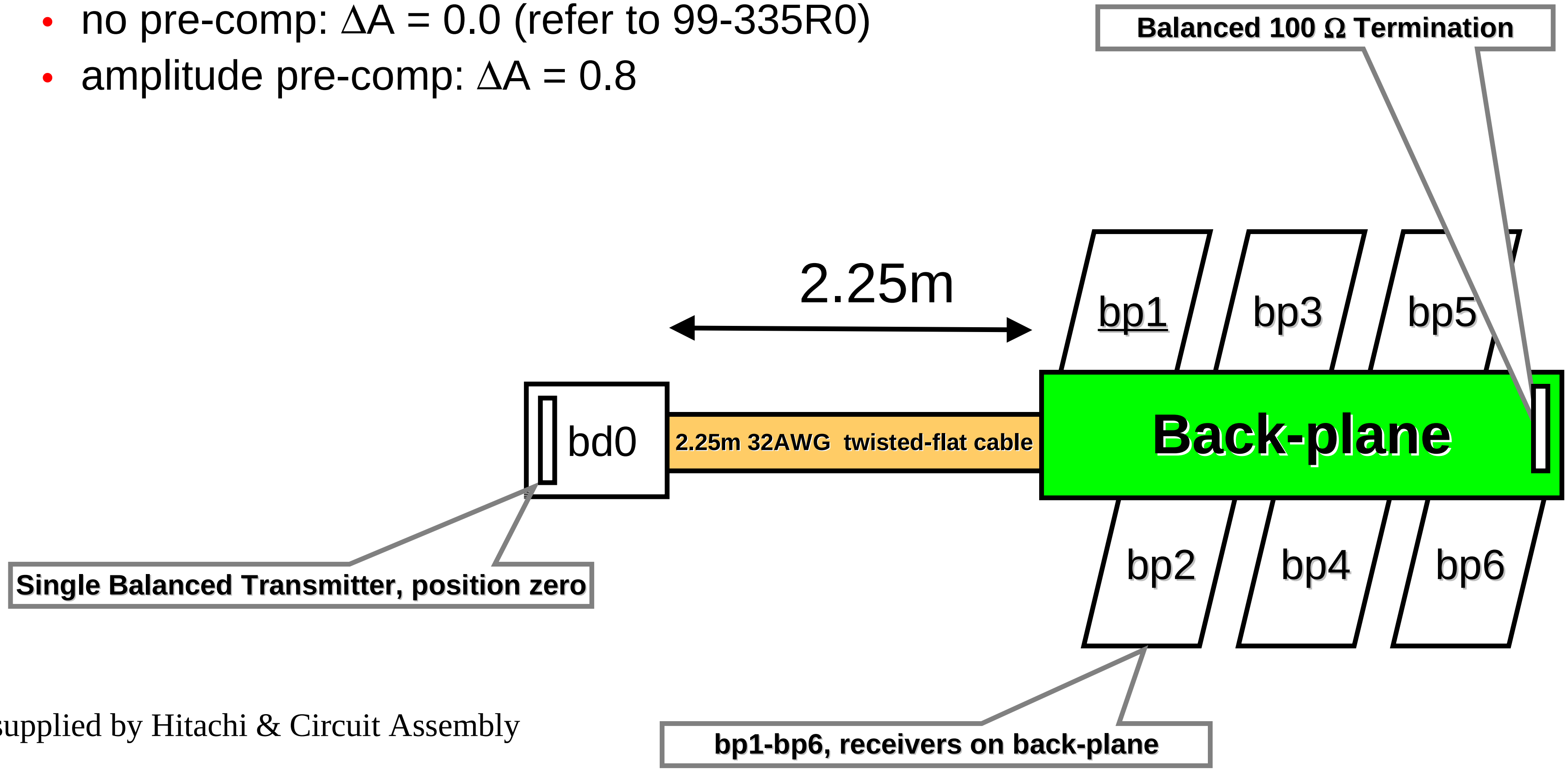
- 10 meter, Madison 28AWG† round shielded cable, plus 6-slot back-plane.
- Waveforms captured @ 4Gs/s:
  - no pre-comp: ΔA = 0.0 (refer to 99-335R0)
  - amplitude pre-comp: ΔA = 0.8



† Supplied by Amphenol

Config 2 Short Cable + Back-plane

- 2.25 meter, Hitachi 32AWG twisted-flat cable†, plus 6-slot back-plane.
- Waveforms captured @ 4Gs/s:
  - no pre-comp: ΔA = 0.0 (refer to 99-335R0)
  - amplitude pre-comp: ΔA = 0.8



†supplied by Hitachi & Circuit Assembly

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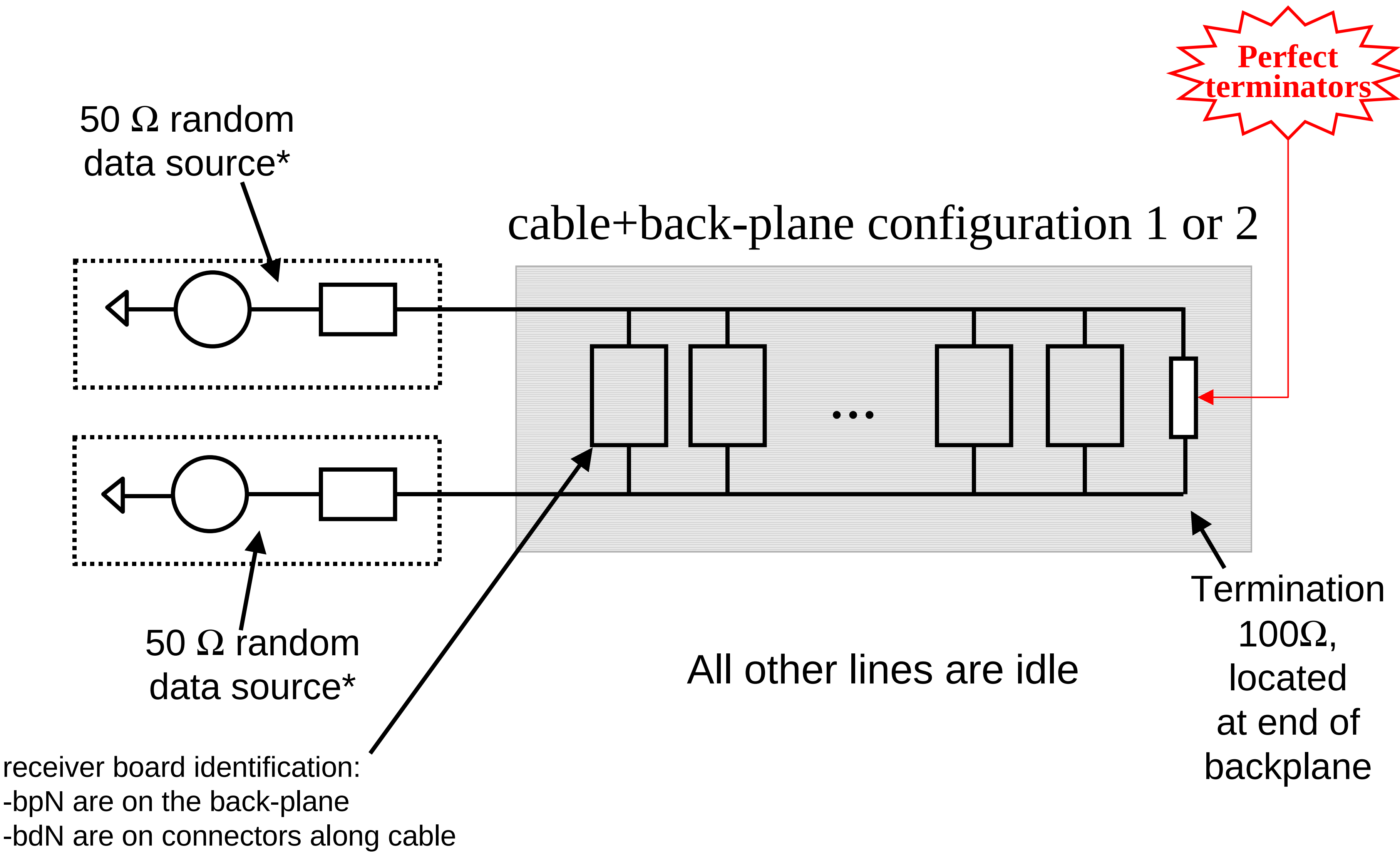
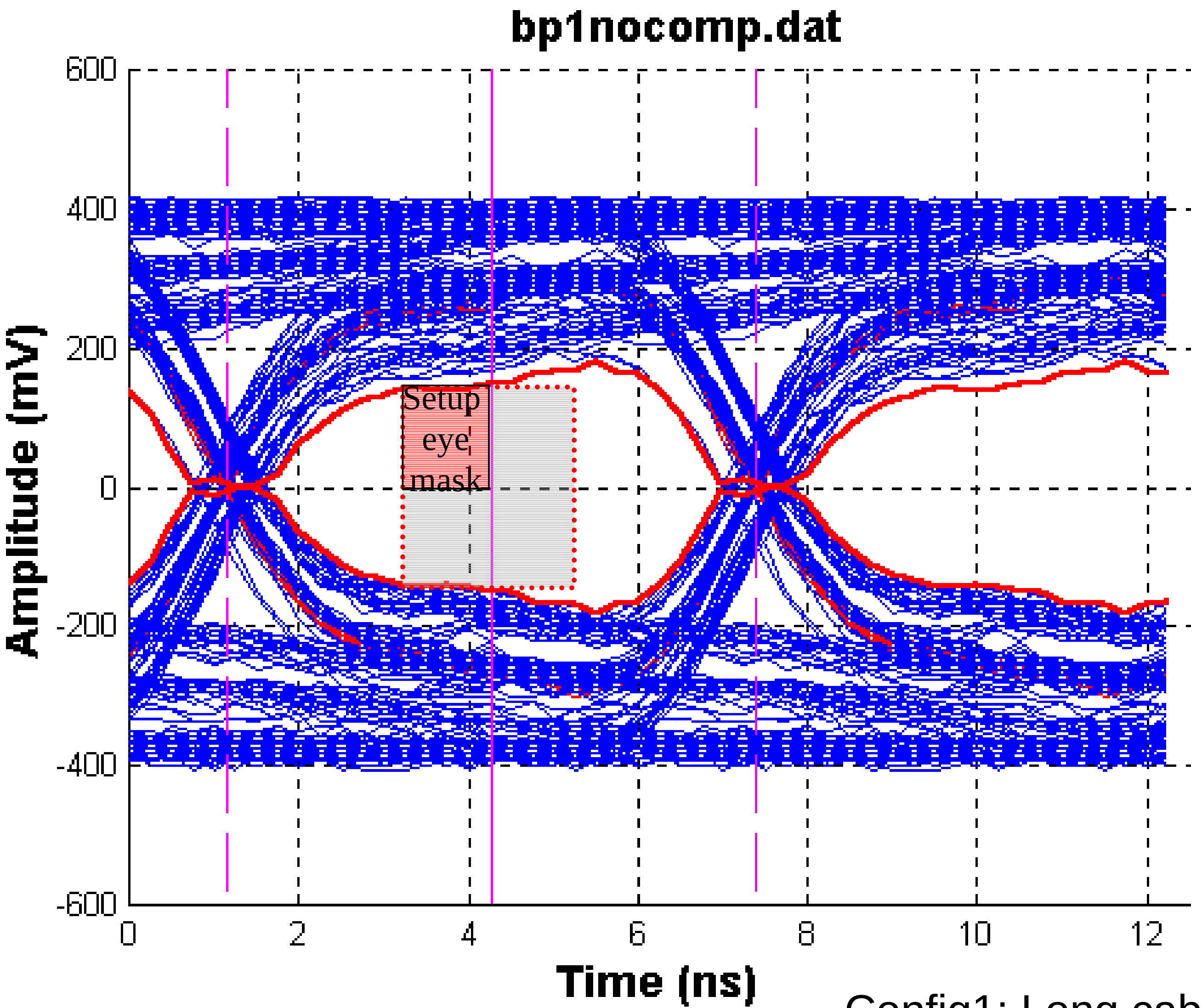
Test #1: ISI + reflections



* TEK 2041

Config 1 No comp on ISI + reflect



Config1: Long cable + back-plane

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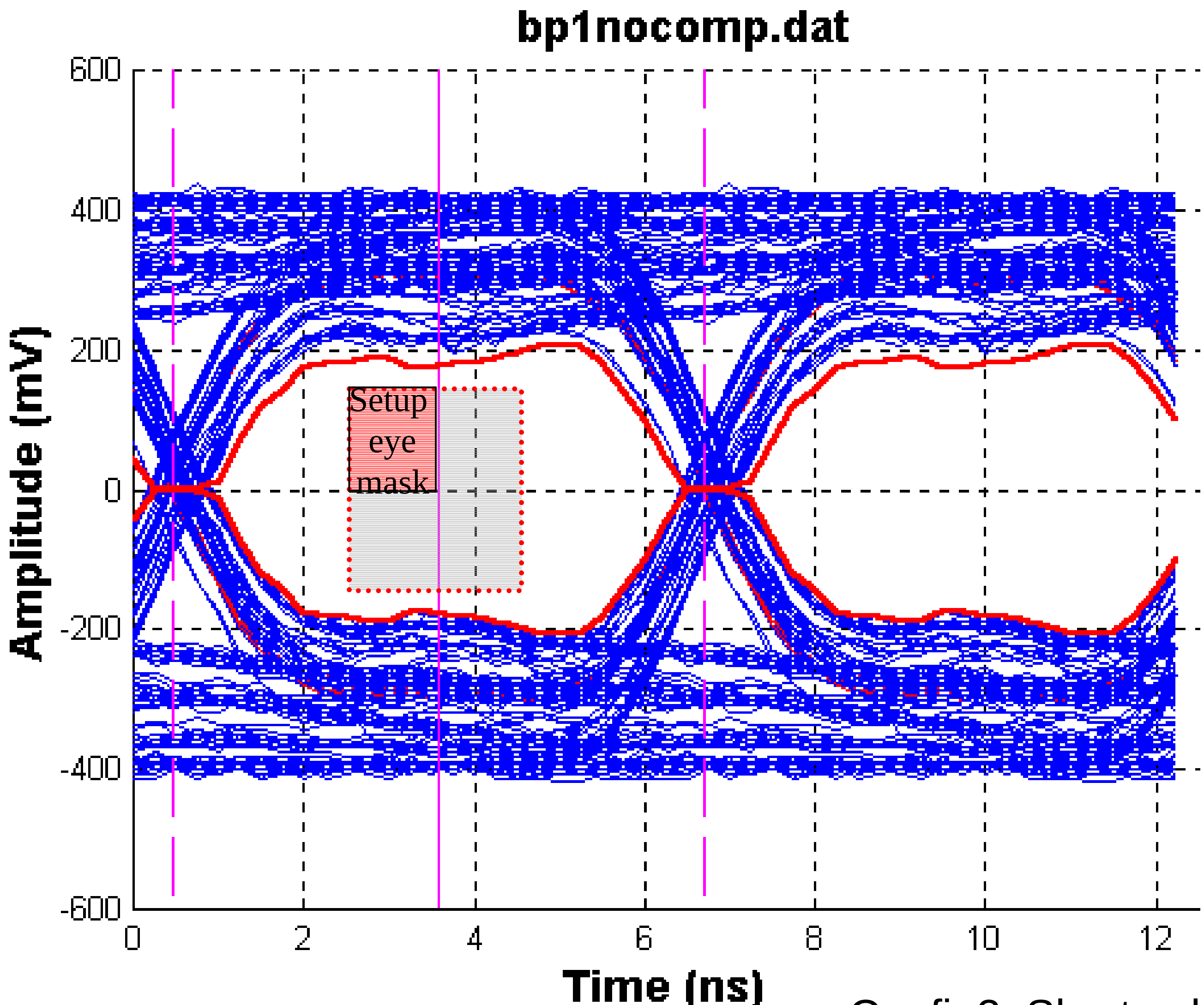
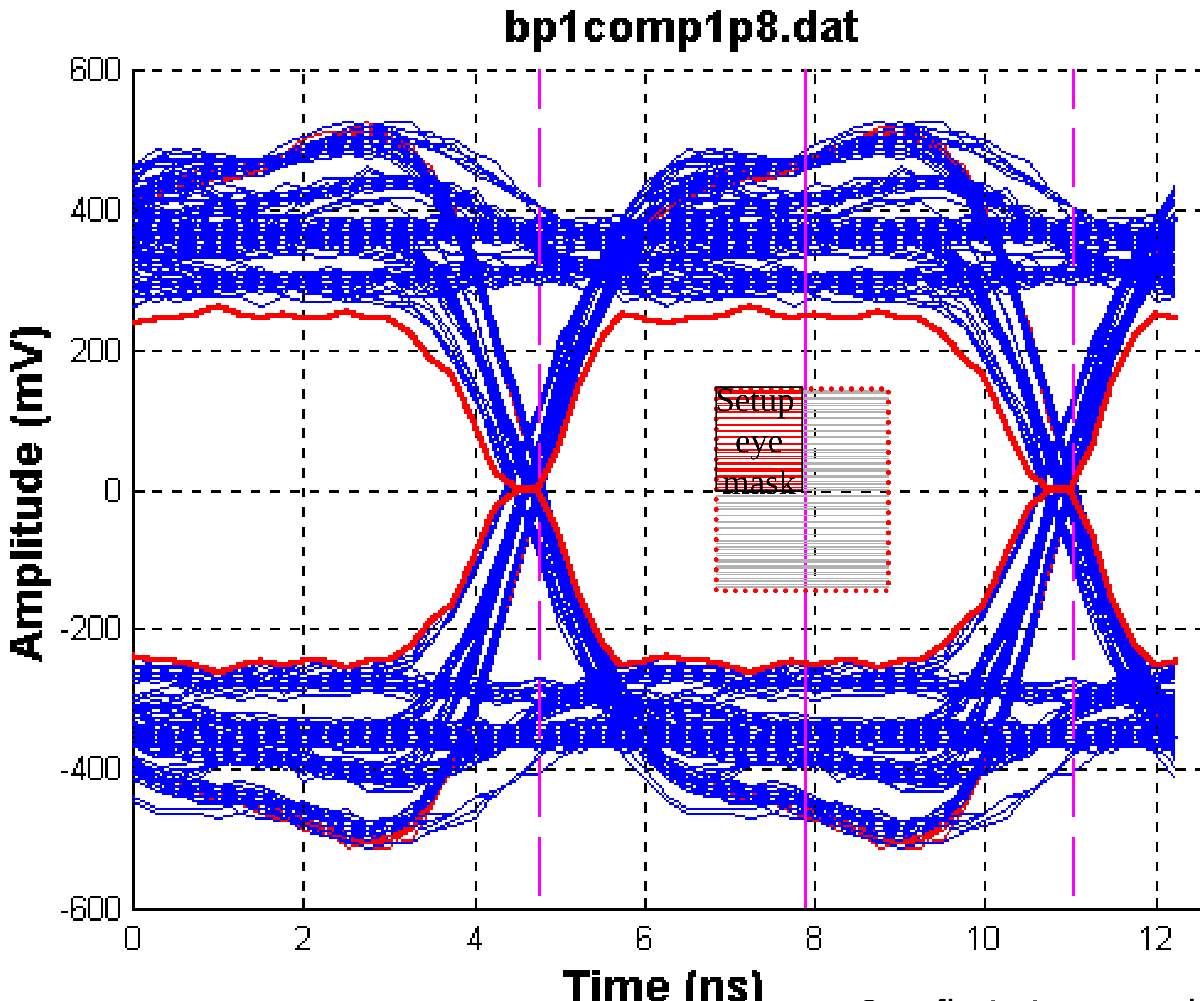
Config 2 No comp on ISI + reflect



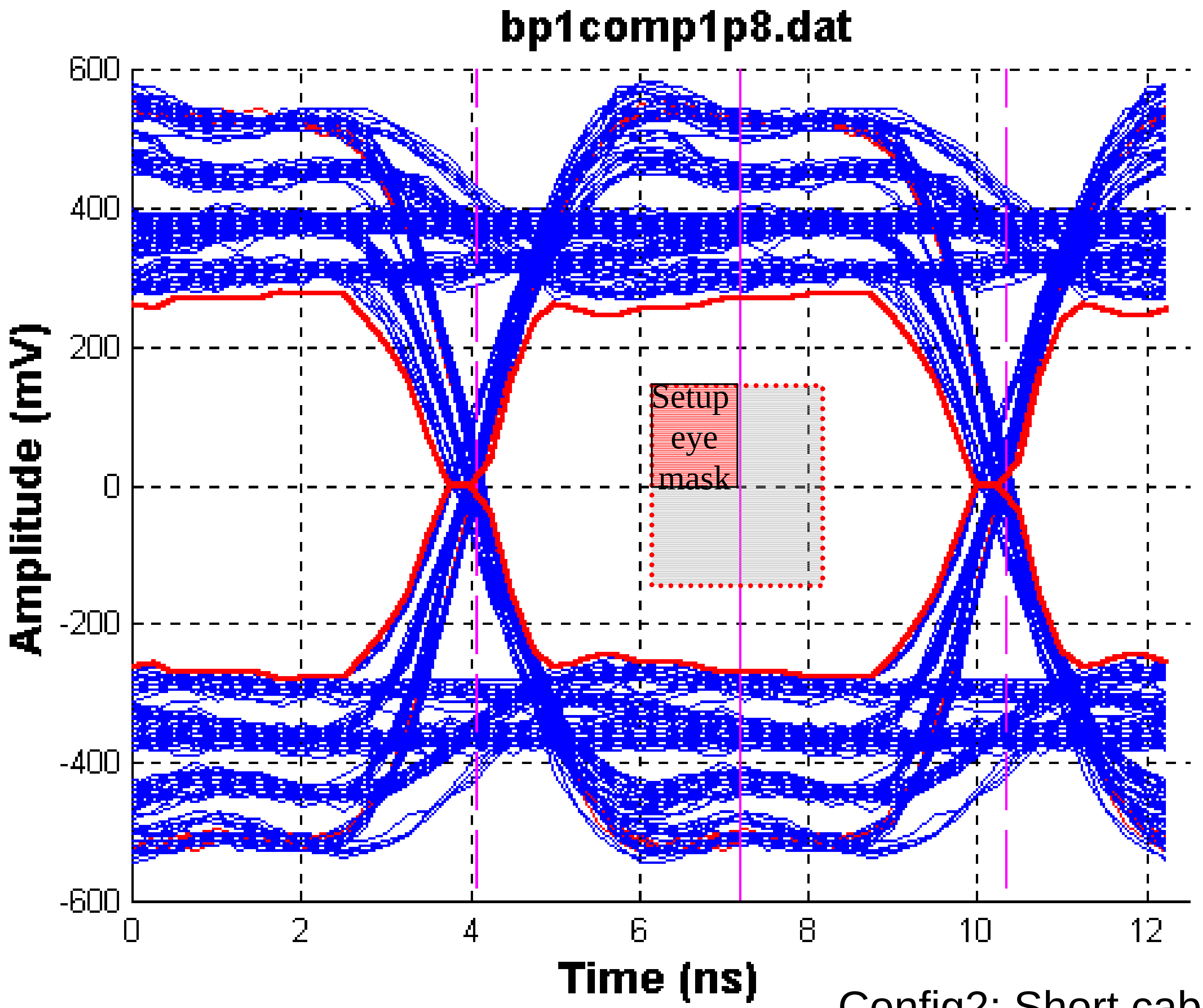
Config2: Short cable + back-plane

Config 1 Pre-comp on ISI + reflect



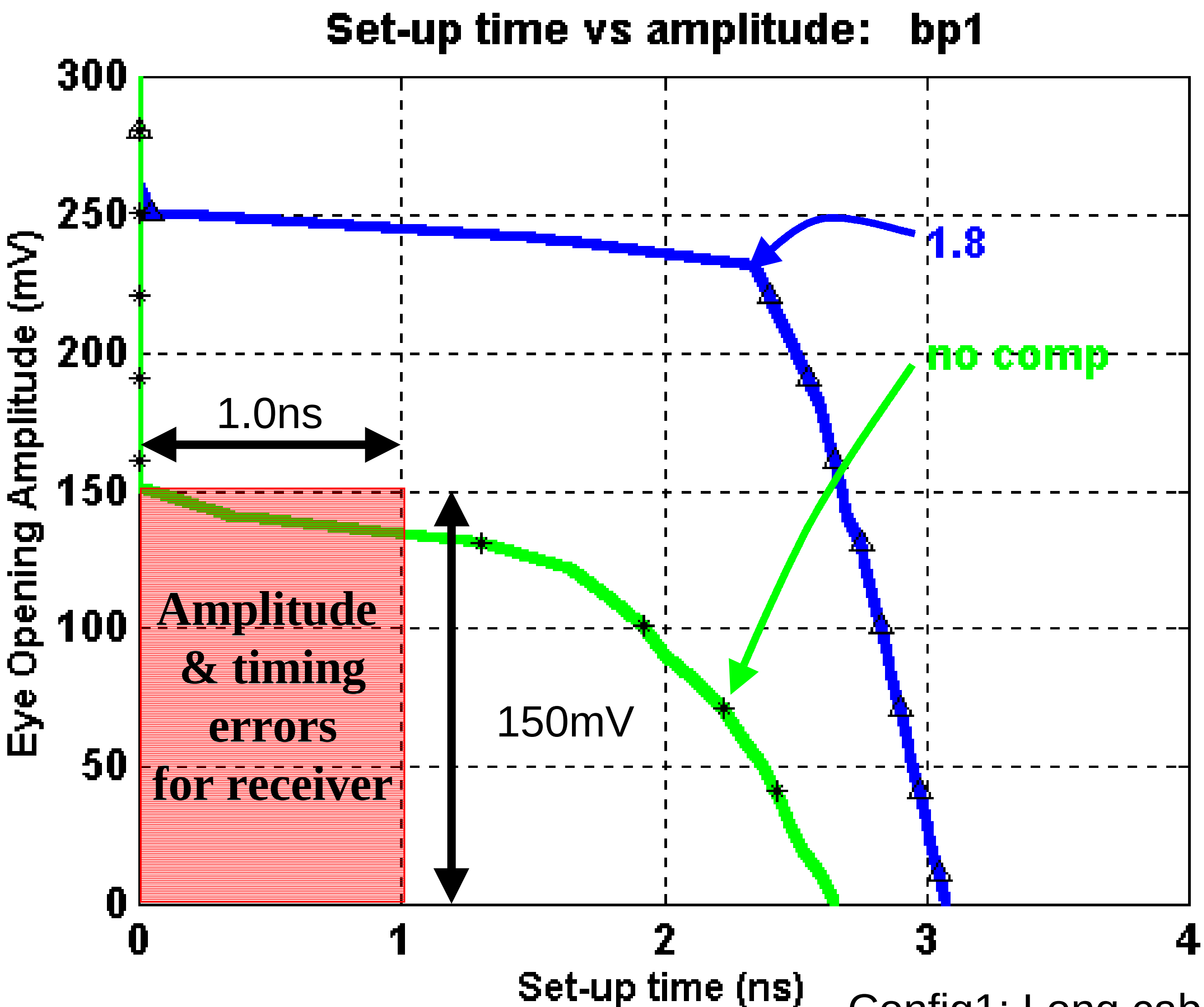
Config1: Long cable + back-plane

Config 2 Pre-comp on ISI + reflect



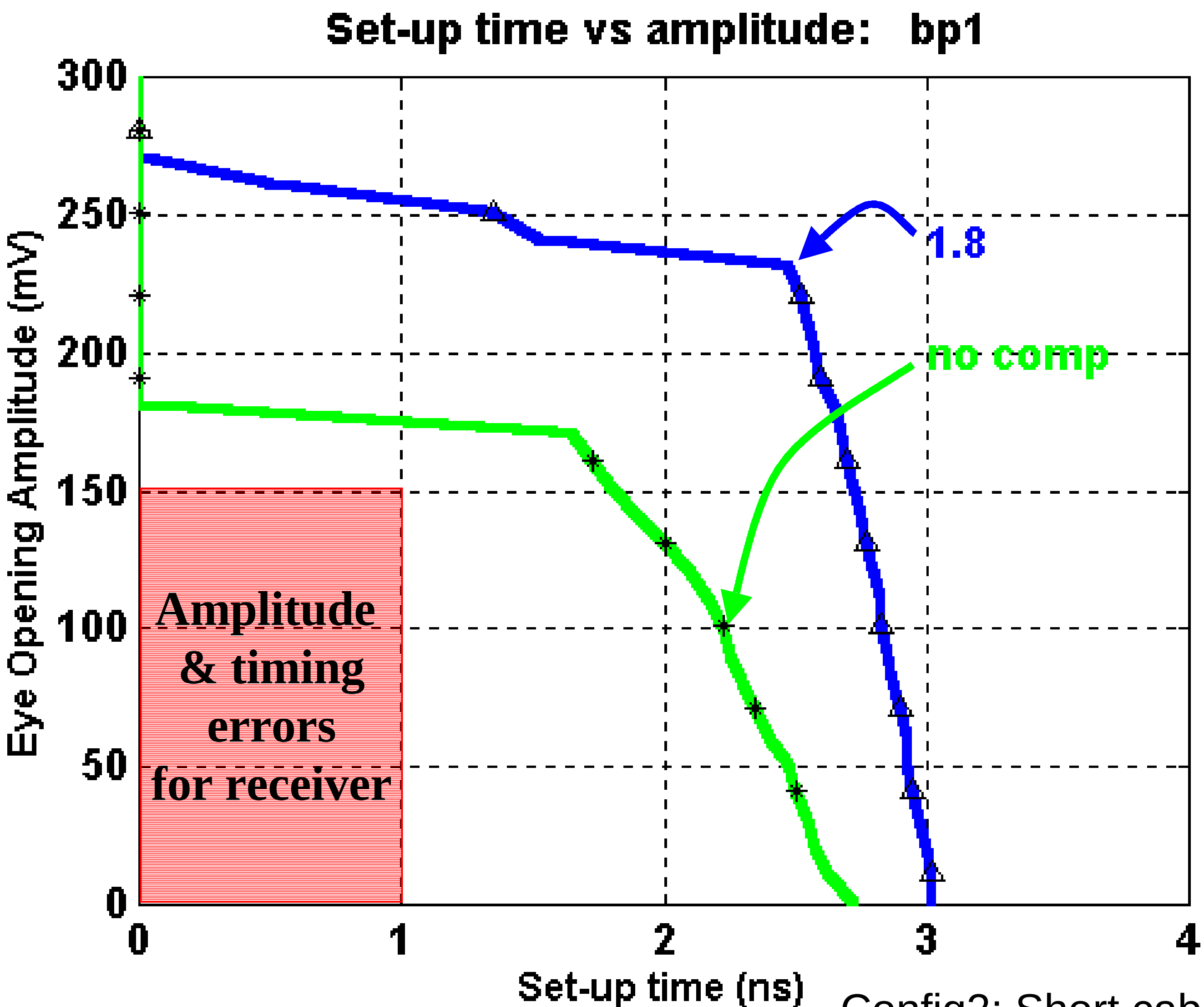
Config2: Short cable + back-plane

Config 1 Set-up time: ISI + reflect



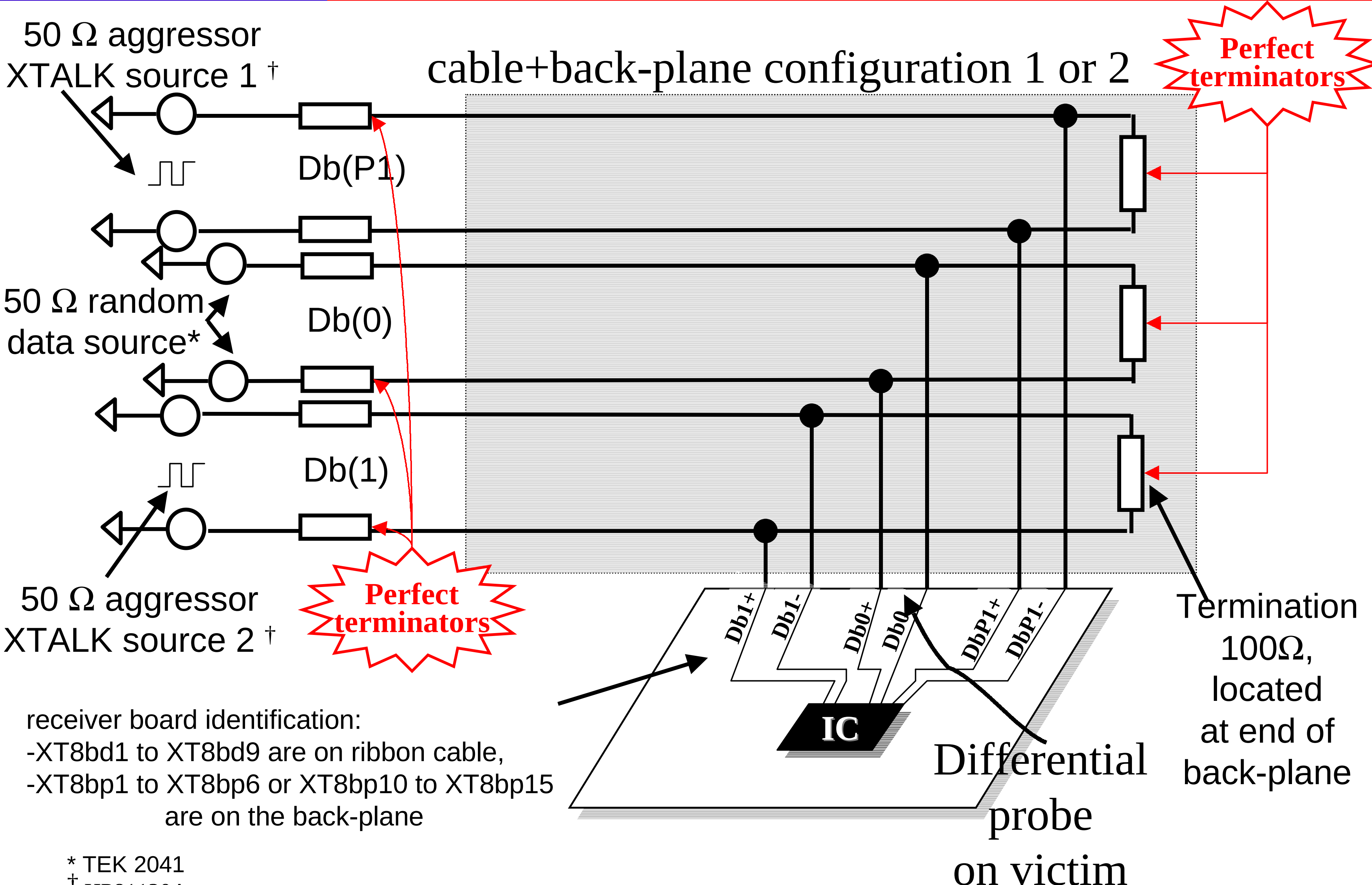
Config1: Long cable + back-plane

Config 2 Set-up time: ISI + reflect



Config2: Short cable + back-plane

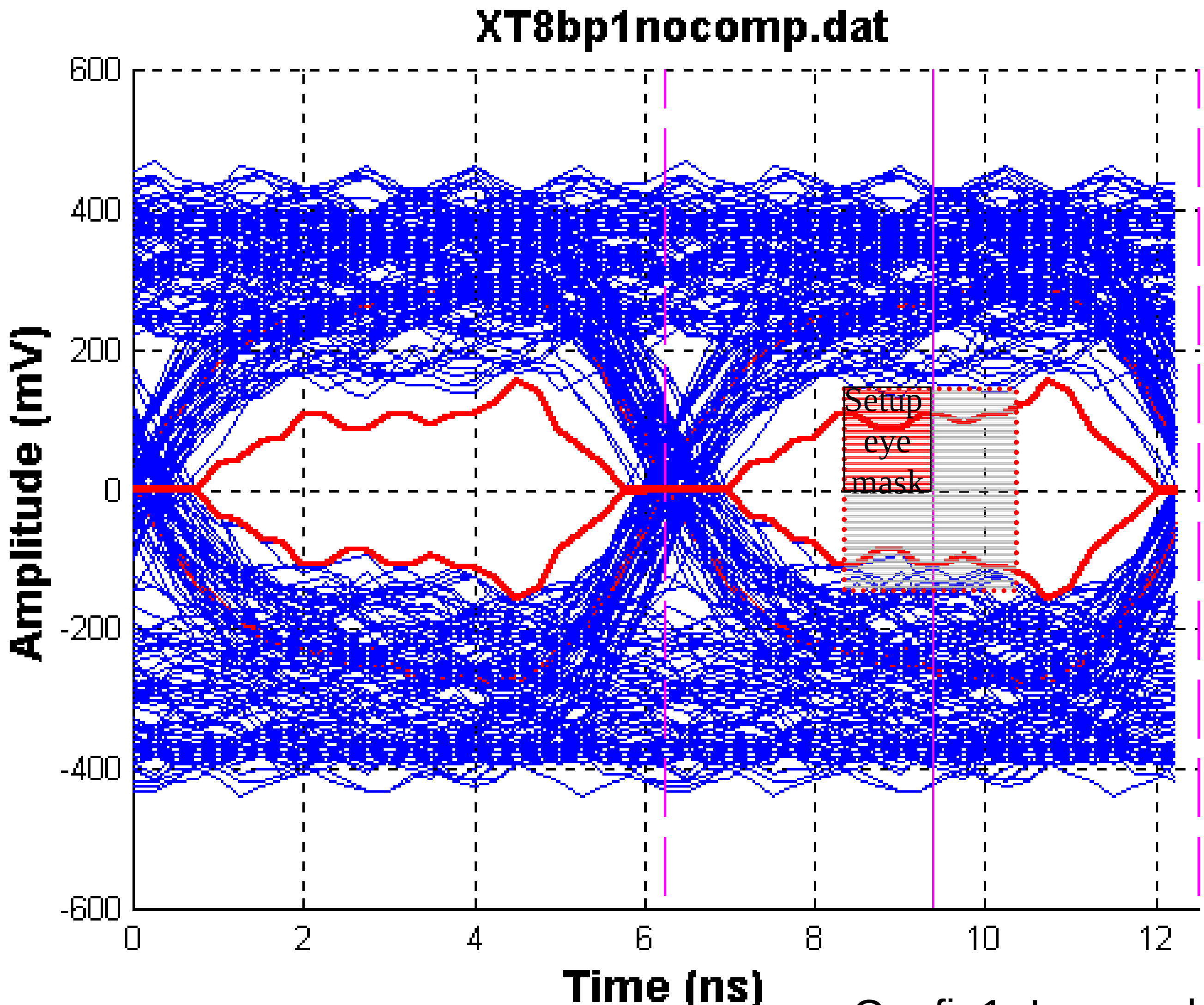
Test #2: XTALK + ISI + reflections



receiver board identification:
-XT8bd1 to XT8bd9 are on ribbon cable,
-XT8bp1 to XT8bp6 or XT8bp10 to XT8bp15
are on the back-plane

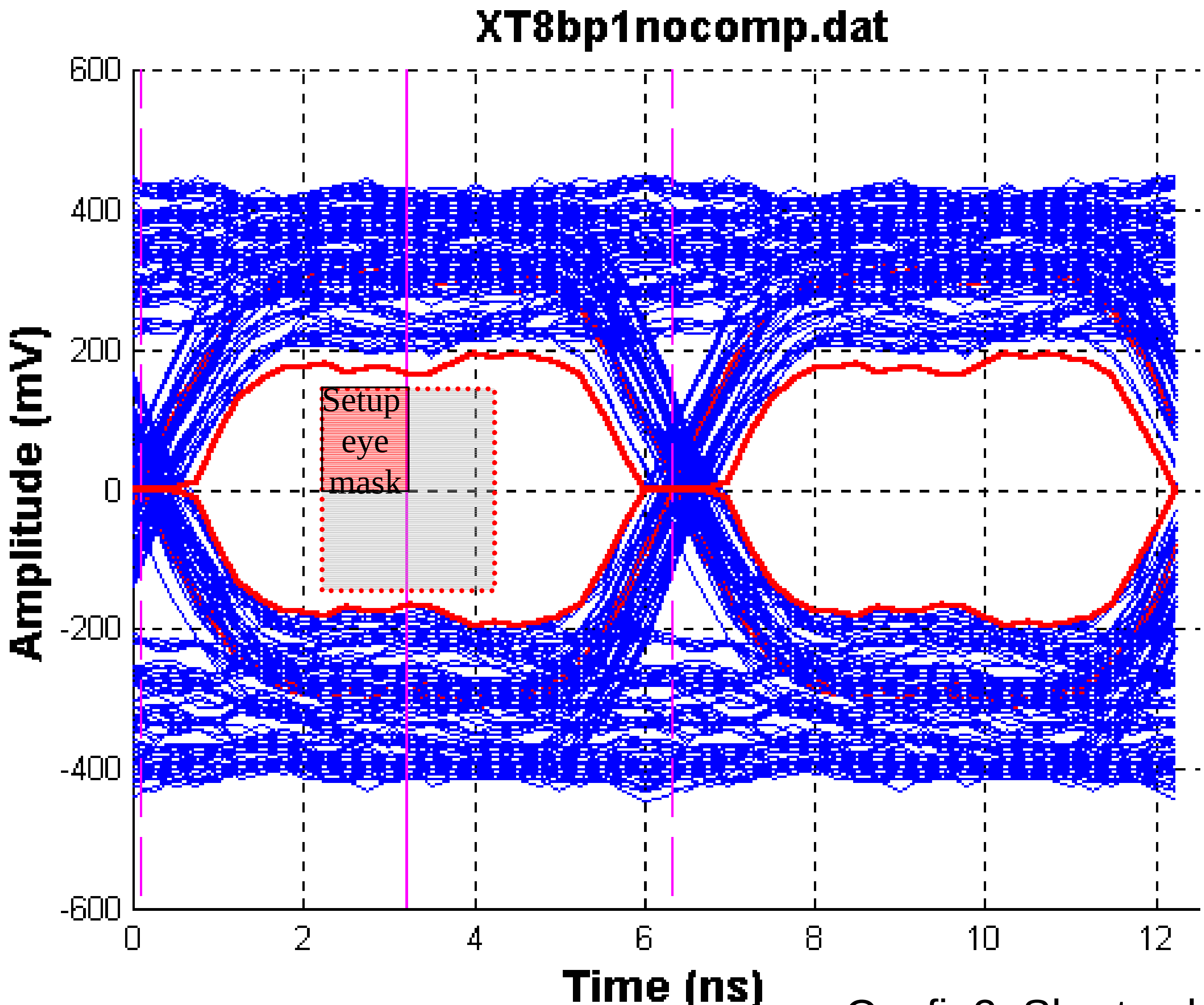
* TEK 2041
† HP81130A

Config 1 No comp on Xtalk ISI reflect



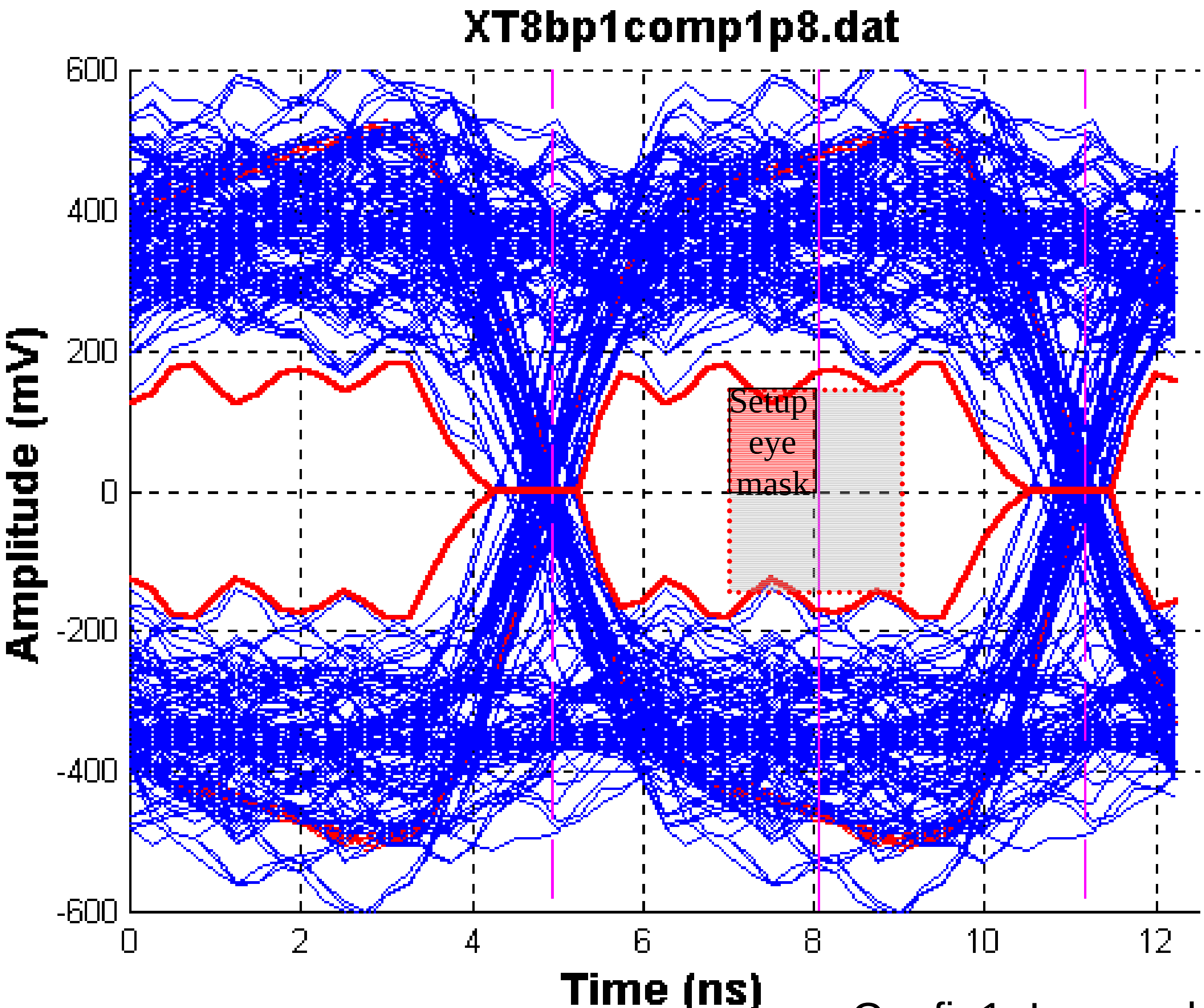
Config1: Long cable + back-plane

Config 2 No comp on Xtalk ISI reflect



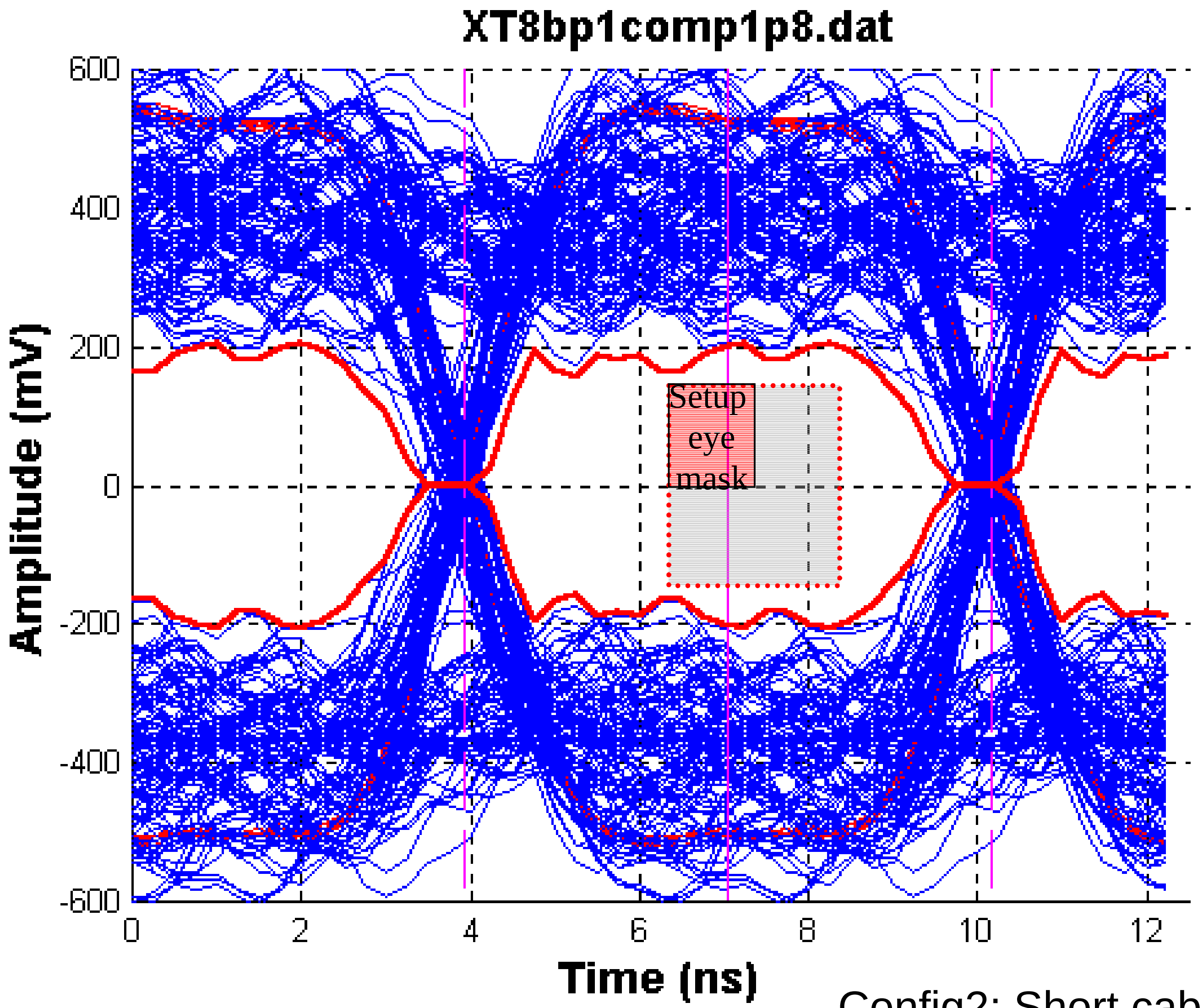
Config2: Short cable + back-plane

Config 1 Pre-comp on Xtalk ISI reflect



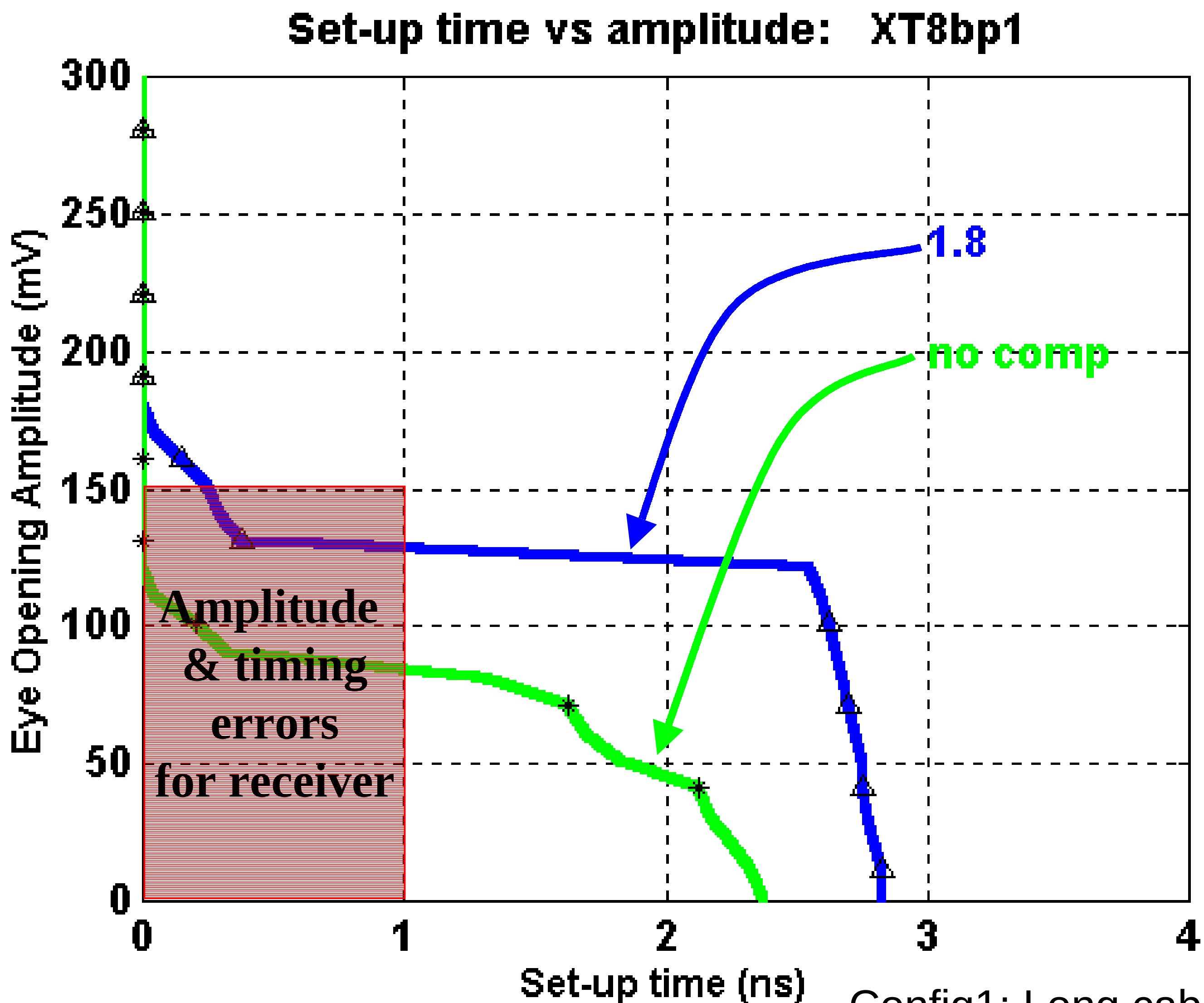
Config1: Long cable + back-plane

Quantum™ Config 2 Pre-comp on Xtalk ISI reflect



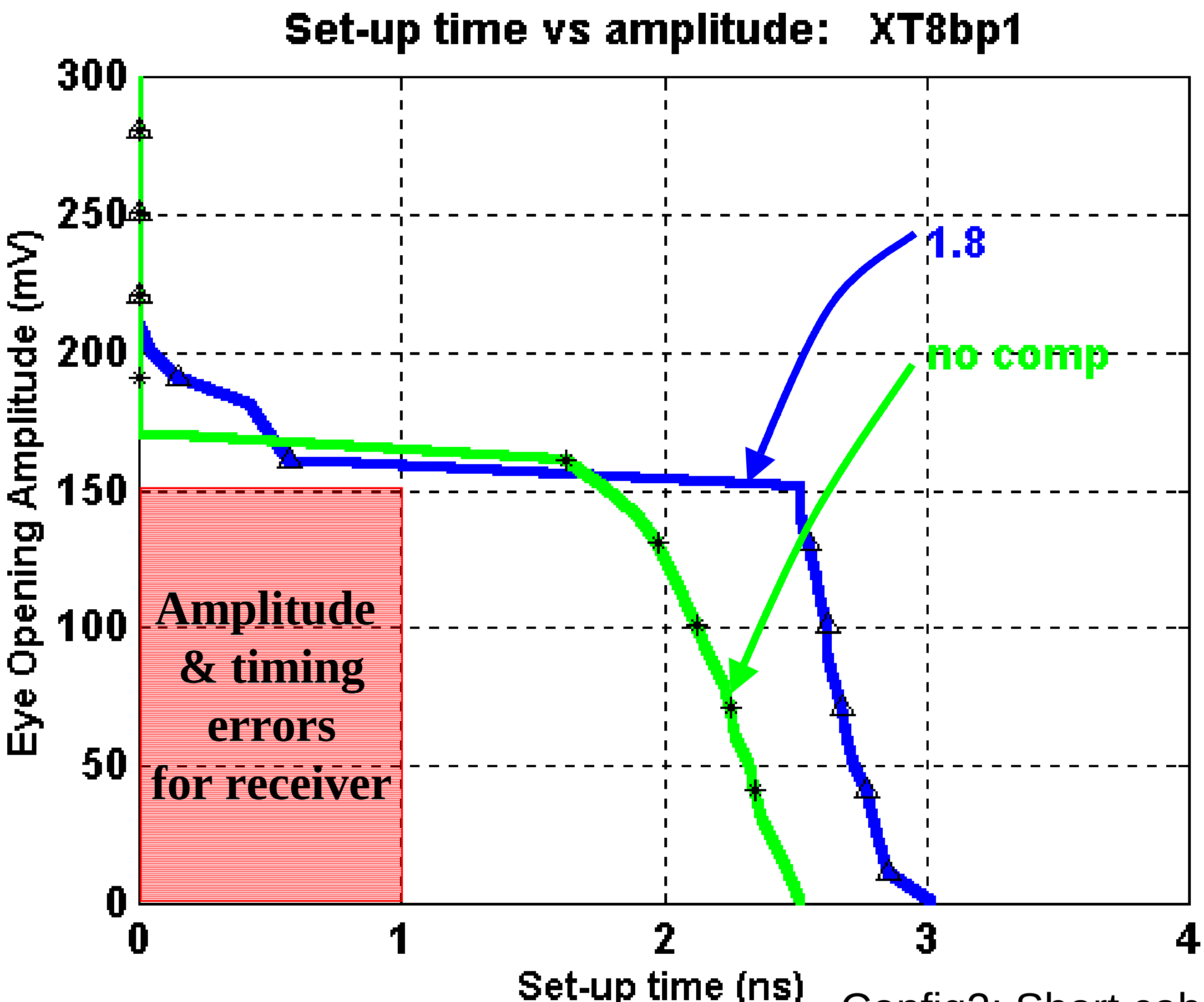
Config2: Short cable + back-plane

Quantum™ Config 1 Set-up time: Xtalk ISI reflect



Config1: Long cable + back-plane

Config 2 Set-up time: Xtalk ISI reflect



Config2: Short cable + back-plane

Part I: Summary

❶ If XTALK is included, transmitter pre-compensation becomes untenable for long configuration:

- no setup margin
- no amplitude margin

❷ Also, this data is optimistic:

- Only two adjacent channels are used for our XTALK measurements,
- In round cable adjacency relation is unknown; XTALK could be much worse,
- Sheathed flat cable adjacency is also unknown,
- Back-plane adjacency is another factor.

❸ For short flat cable configuration pre-comp does not buy much:

- slight improvement in set-up margin
- no improvement in amplitude margin

❹ We do not believe Pre-comp will work for Ultra-320.

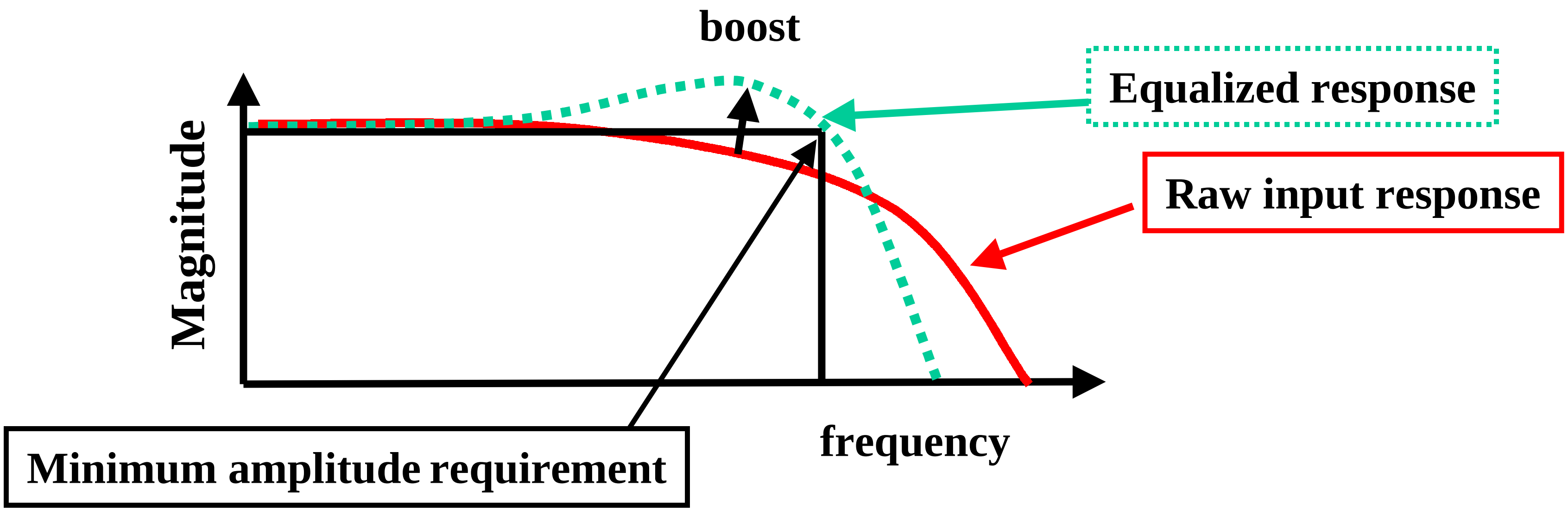
Part II
Receiver Compensation Technique

Objectives

- Receiver equalization overview
- Investigate receiver equalization for Ultra-320 SCSI.
- Demonstrate simulated response to measured data for different configurations.
- Compare receiver eye diagrams for Rx equalizer vs 1.8X pre-comp
  - 400mV peak transmit amplitude used for Rx equalization data
  - 400mV / 720mV transmit amplitudes for 1.8X pre-comp data

Receiver Equalization

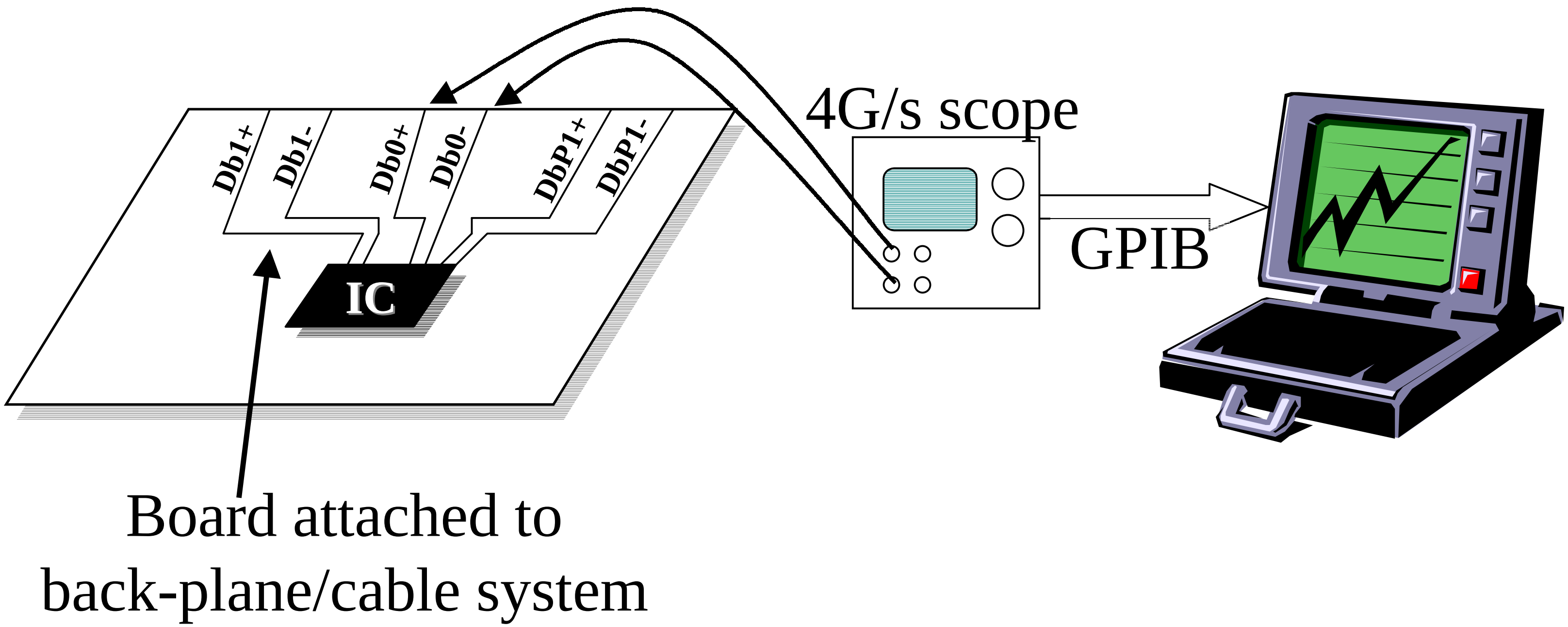
- Boost AC magnitude response of cable plant to increase amplitude of isolated pulses. Use high frequency roll-off to minimize noise.



- Need to adapt boost to varying cable conditions, using a pre-defined training pattern so that minimum amplitude response is met for all possible conditions.

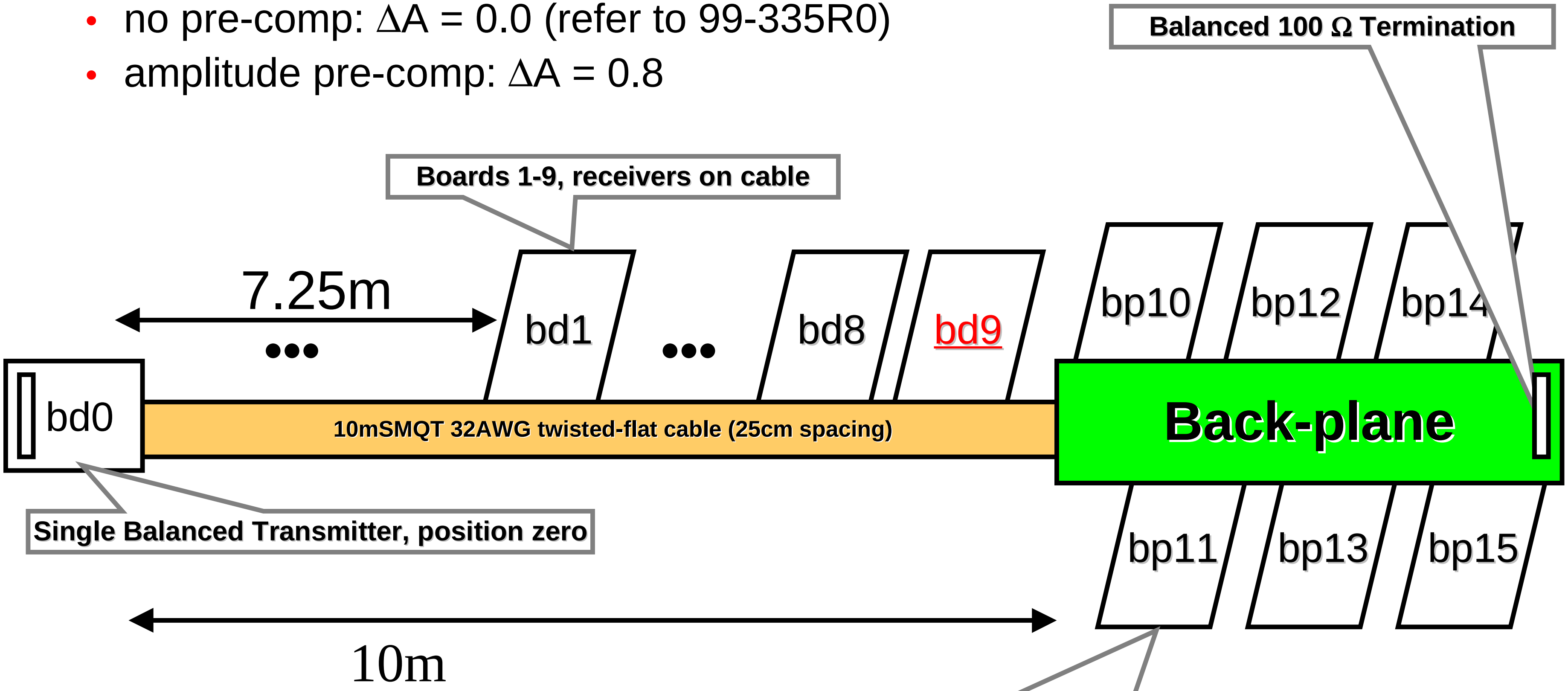
Method for Calculating Equalized Eye

- Capture differential data from a cable and back-plane setup.
- Send raw data to a PC to run mathematical simulation script:
  - same data sets as earlier discussions
  - numerical adaptive equalization
  - evaluate eye diagrams



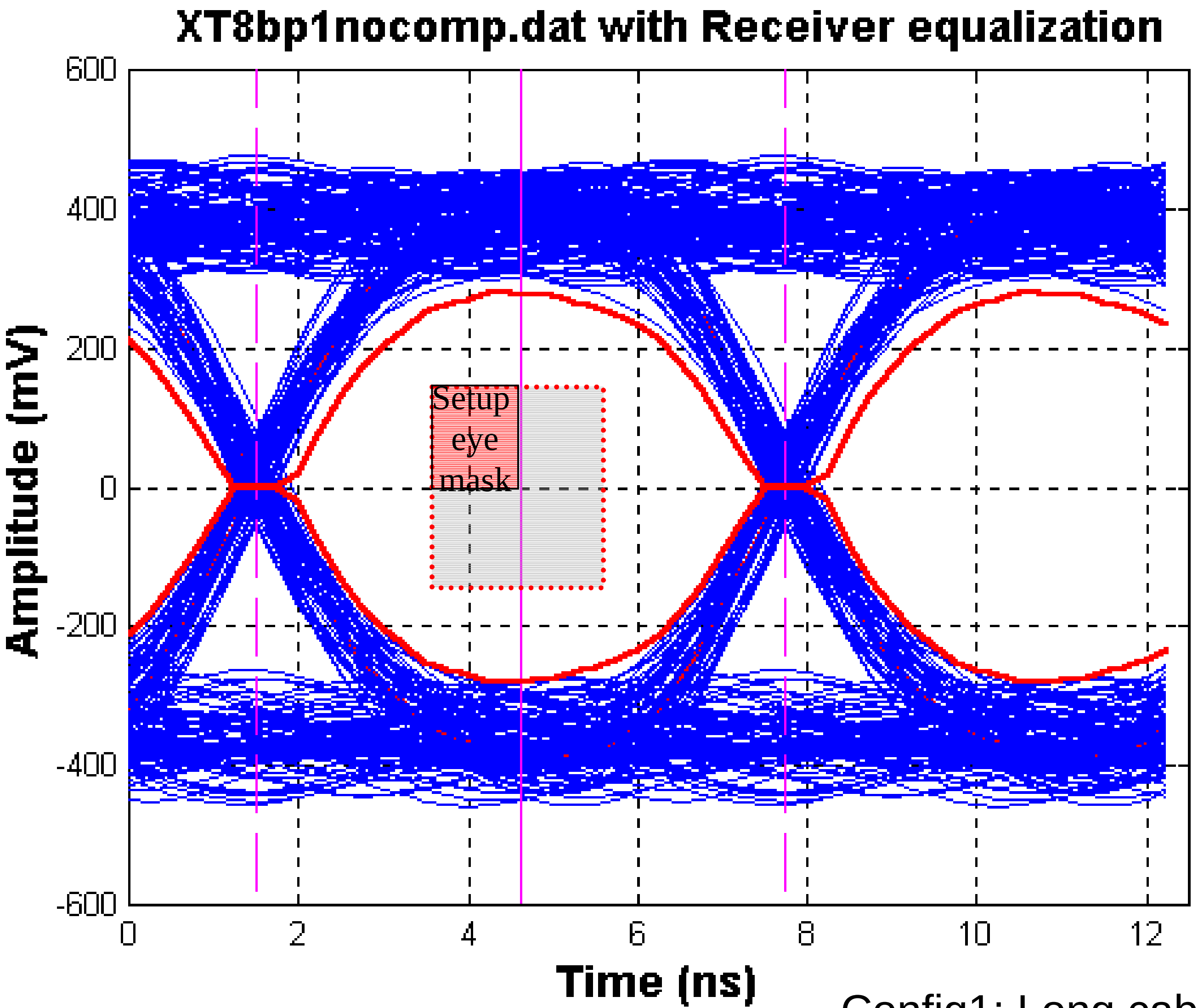
Config 3 Loaded Long Cable + BP

- Hitachi 10 meter, 32AWG twisted-flat ribbon cable†, 25cm load spacing, plus 6-slot back-plane.
- Waveforms captured @ 4Gs/s:
  - no pre-comp: ΔA = 0.0 (refer to 99-335R0)
  - amplitude pre-comp: ΔA = 0.8



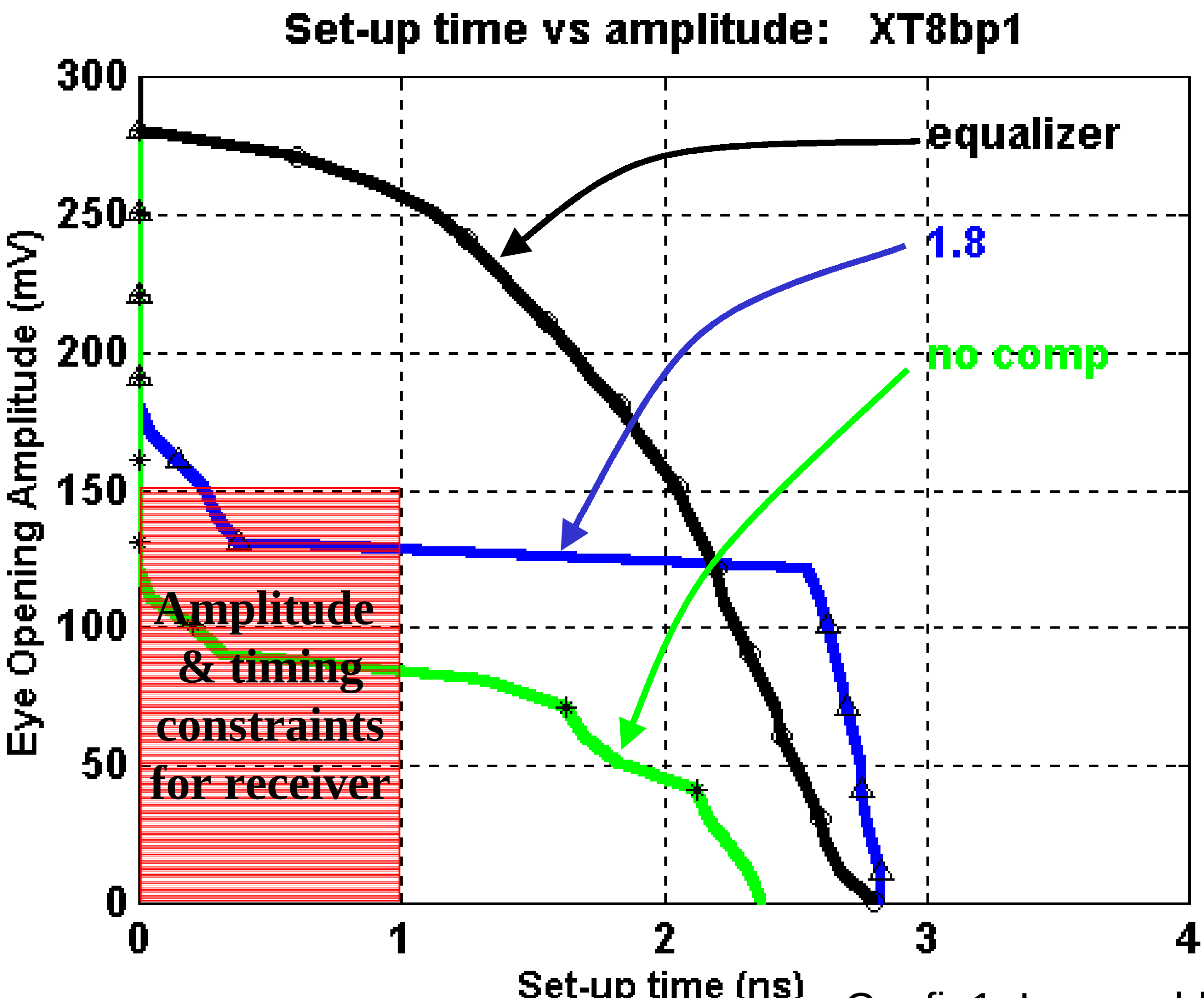
†supplied by Hitachi & Circuit Assembly

Config 1 EQ on Xtalk ISI reflect



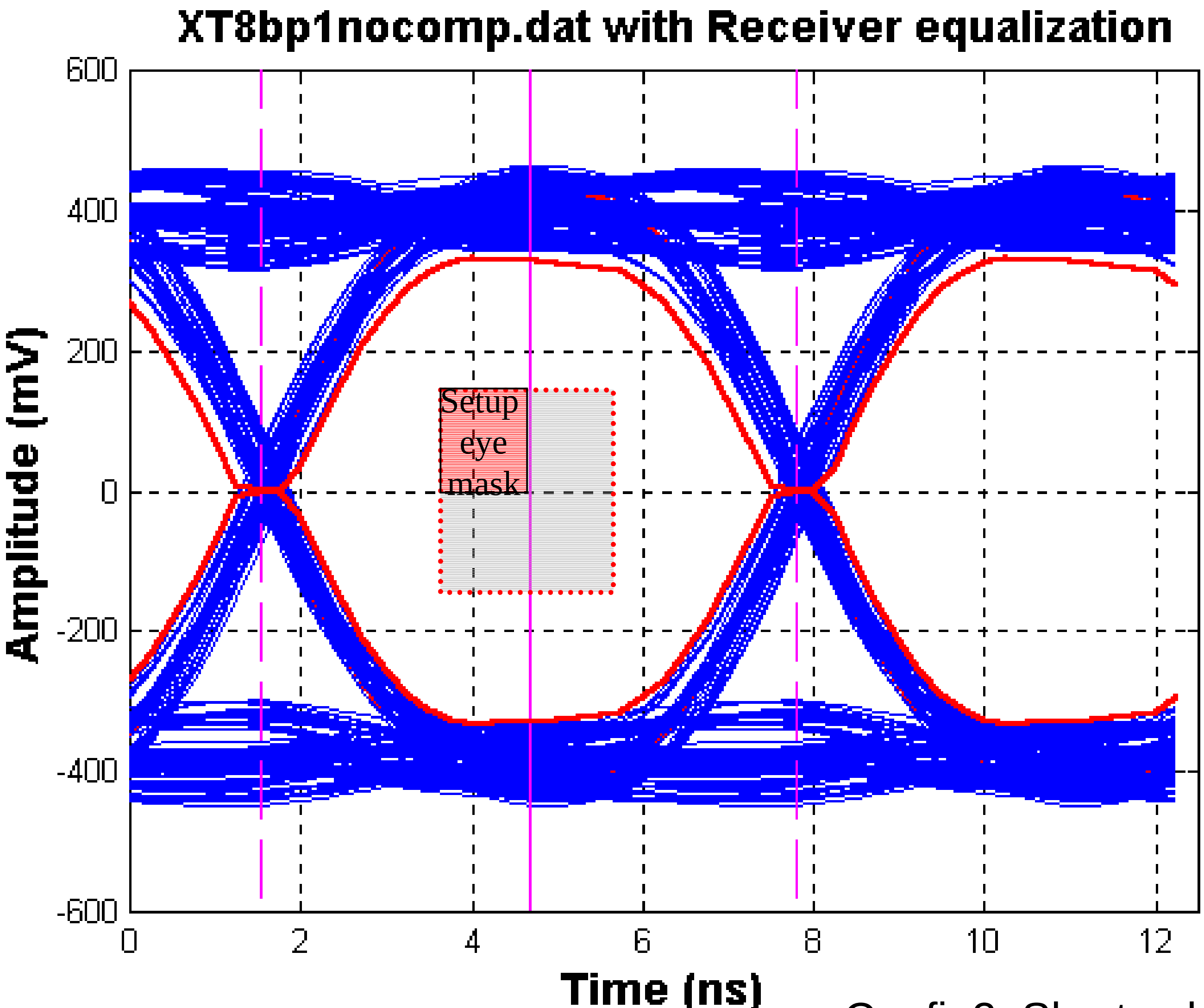
Config1: Long cable + back-plane

Config 1 Set-up time: Xtalk ISI reflect



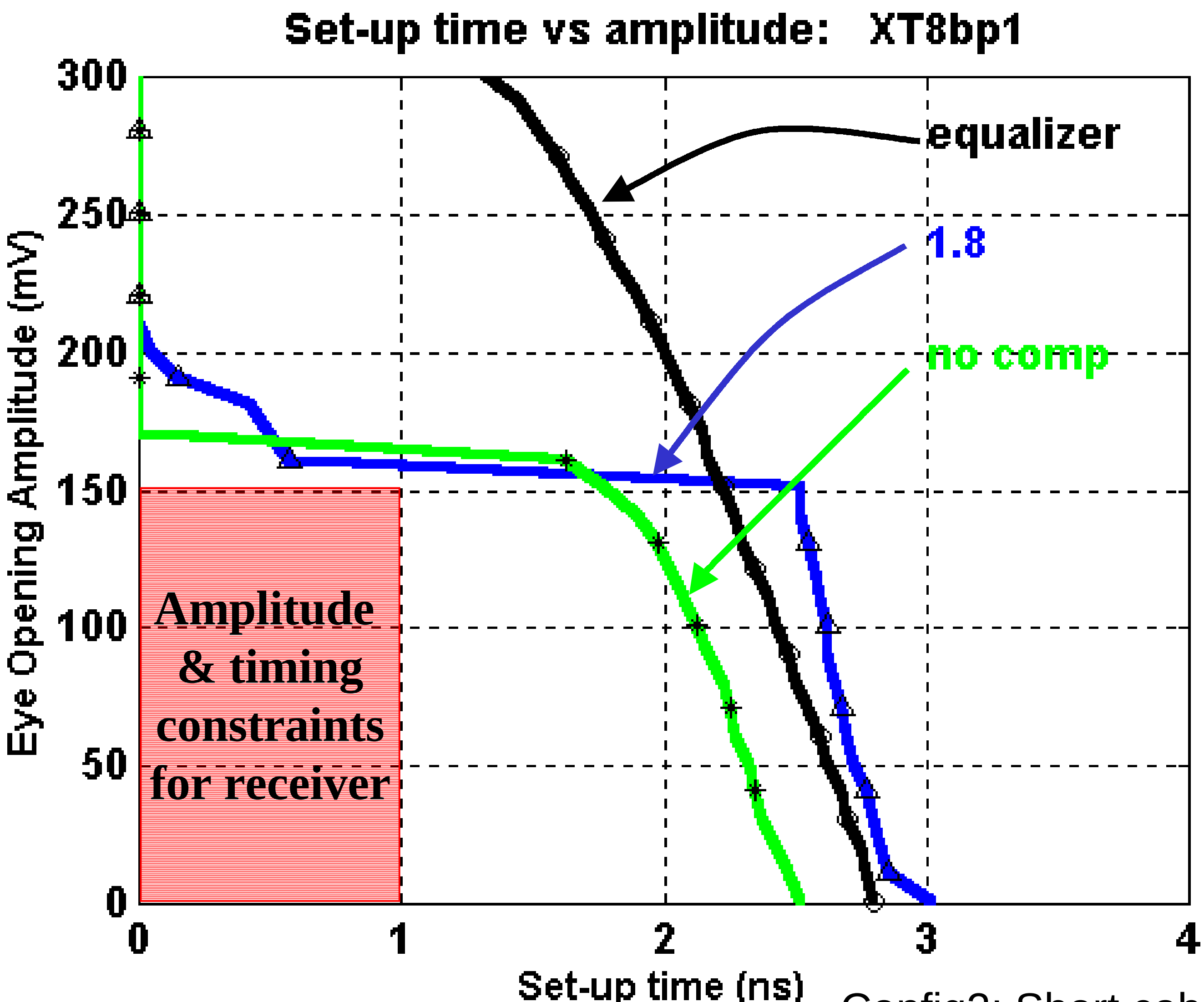
Config1: Long cable + back-plane

Config 2 EQ on Xtalk ISI reflect



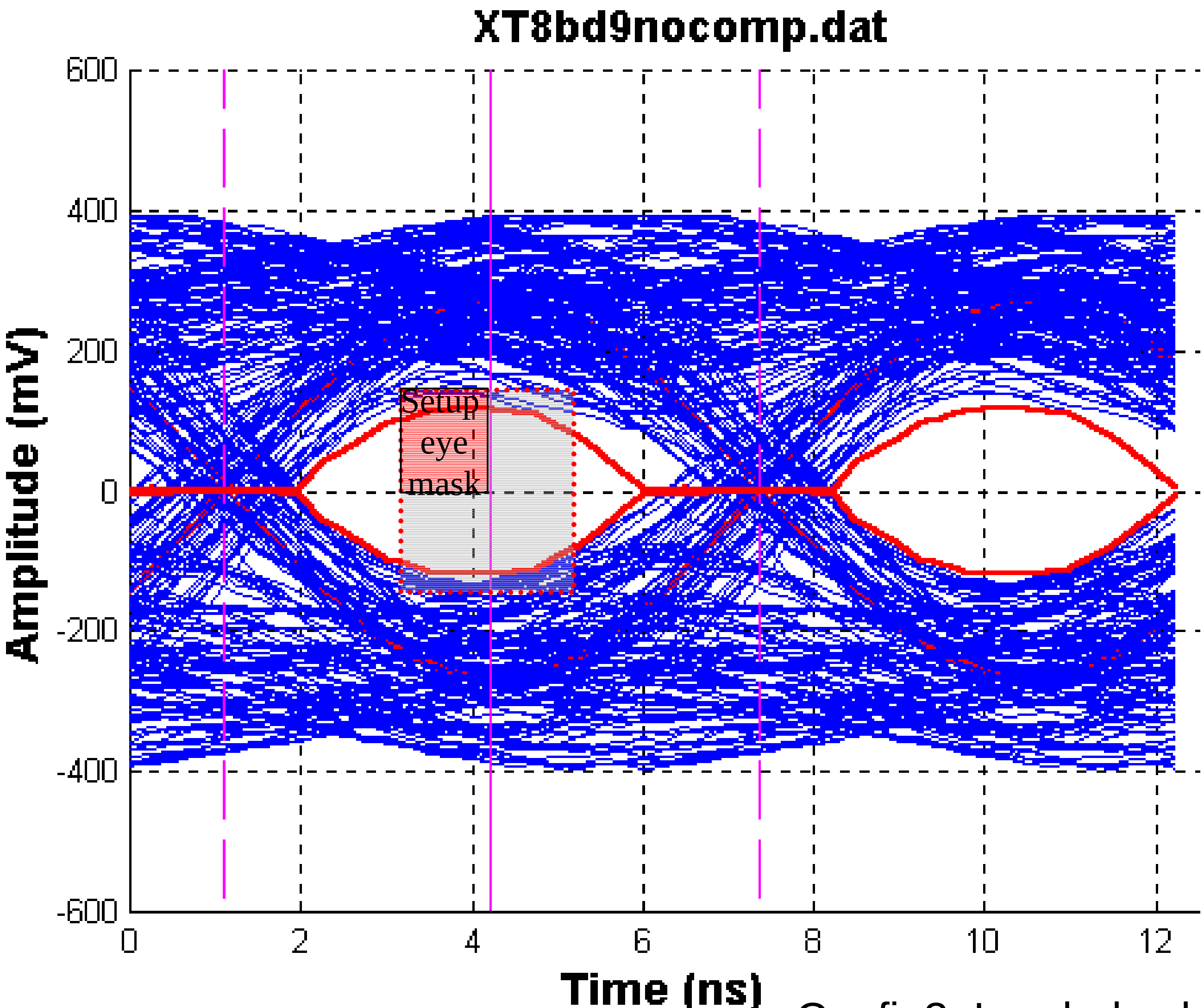
Config2: Short cable + back-plane

Config 2 Set-up time: Xtalk ISI reflect



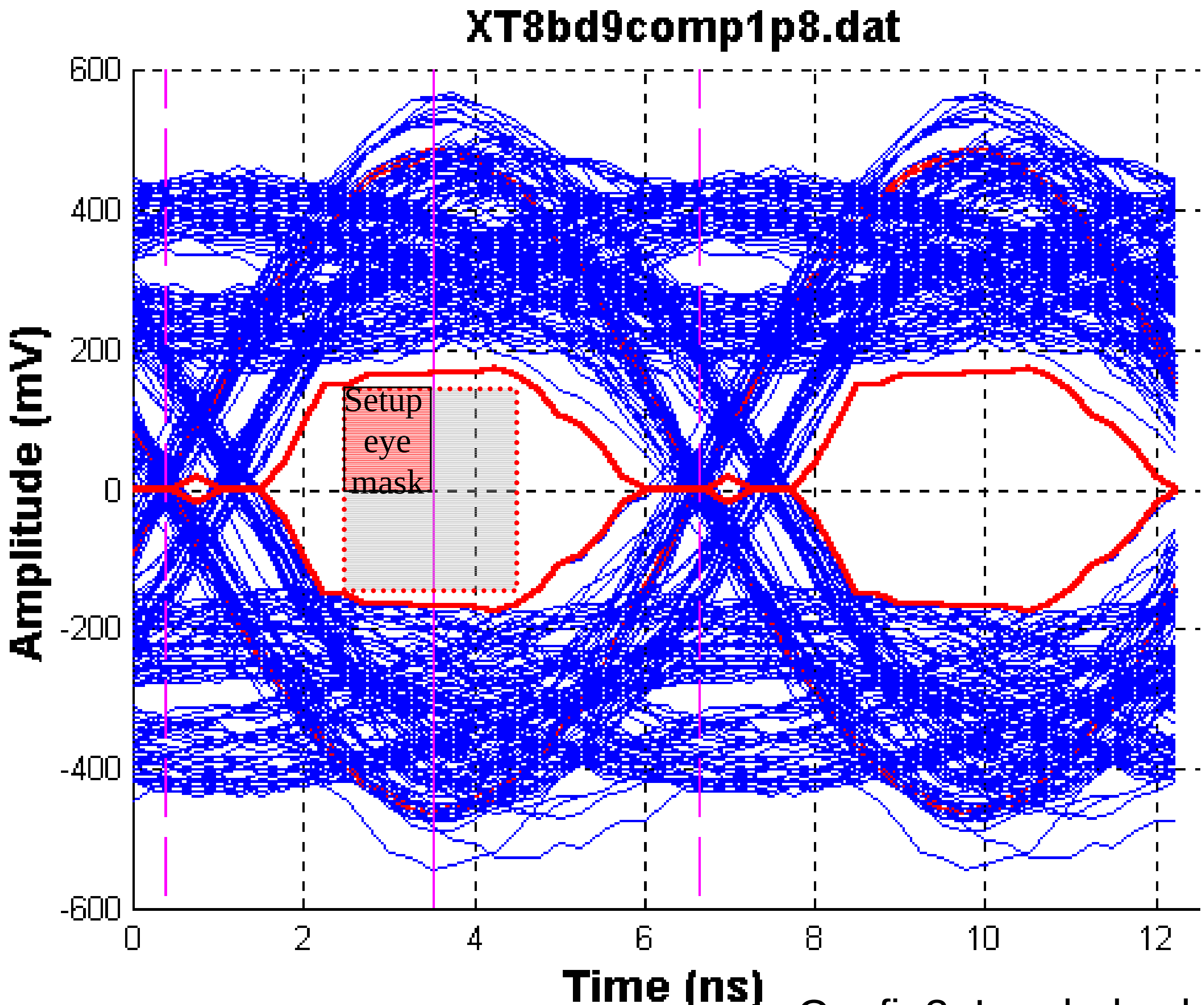
Config2: Short cable + back-plane

Quantum™ Config 3 No comp on Xtalk ISI reflect



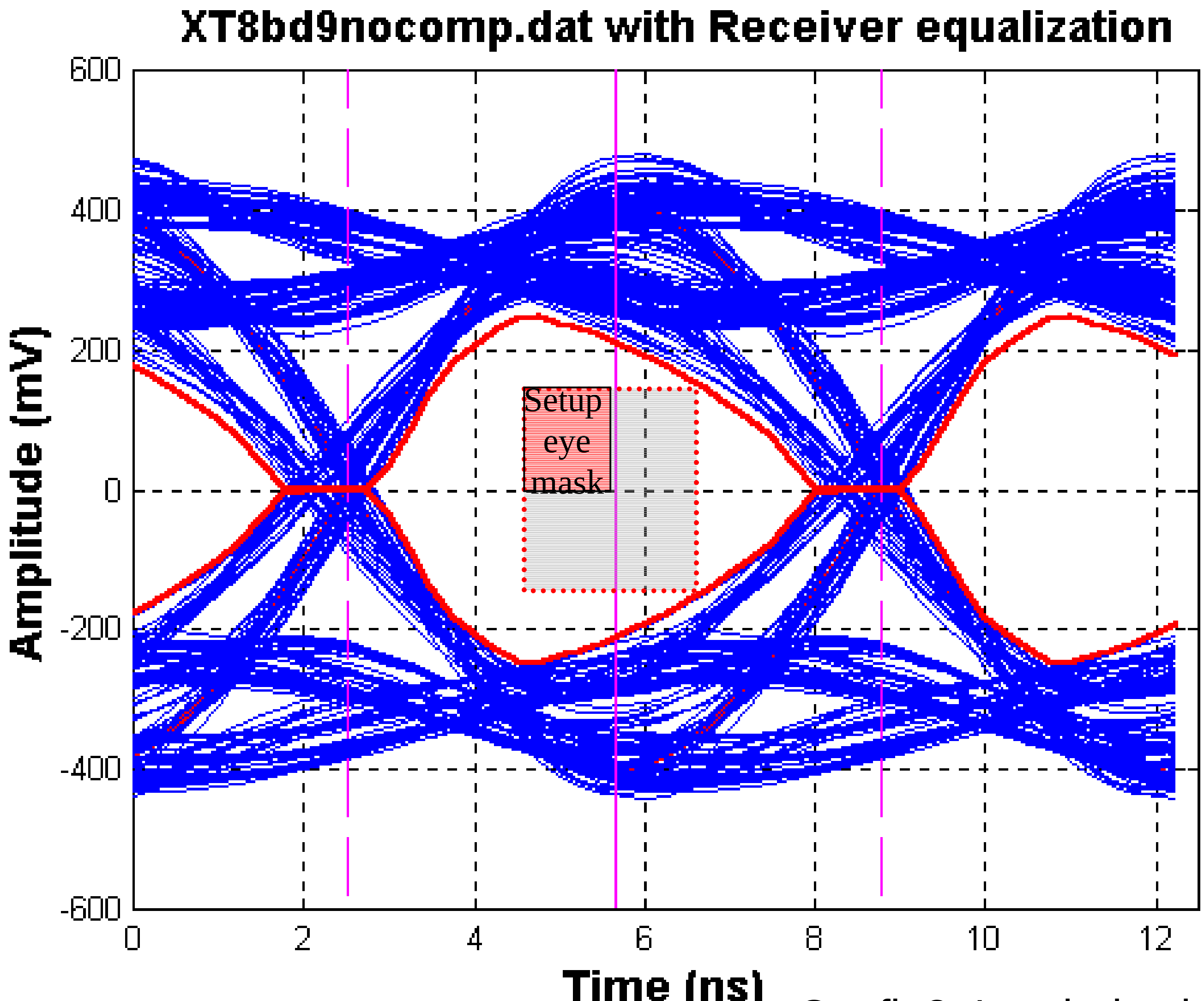
Config3: Loaded cable + back-plane

Config 3 Pre-comp on Xtalk ISI reflect



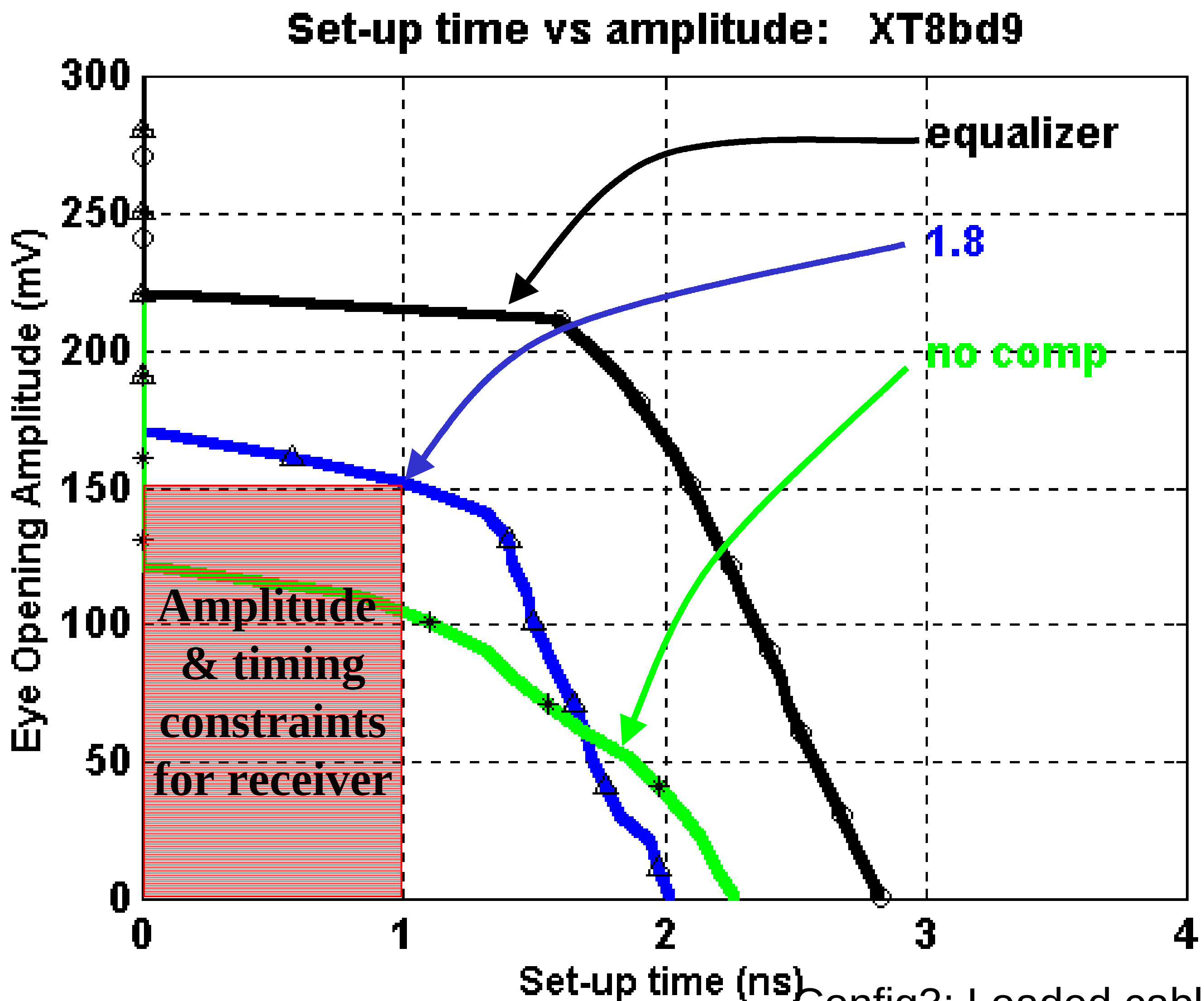
Config3: Loaded cable + back-plane

Config 3 EQ on Xtalk ISI reflect



Config3: Loaded cable + back-plane

Config 3 Set-up time: Xtalk ISI reflect



Config3: Loaded cable + back-plane

Part II: Summary

❶ Receiver equalization boosts performance in all cases

❷ More setup time

❸ Performance improvements without boosting transmitted signal amplitude

- no increase in power or transmitter output stage complexity
- Rx Equalized Data is for a 400mV transmit level, leaving the option of higher transmit levels for improved margins if required.
- 1.8x pre-comp transmit level is 720mV, leaving no room for improvement.

❹ Implemented with a “simple adaptive analog” algorithm.

❺ Adapts on a simple training pattern.

❻ Optimum equalization for each bus receiver