SAS-2 Zero-Length Test Load Characterization (07-013r5)

Barry Olawsky

Hewlett Packard

(4/26/2007)

Zero-Length Test Load

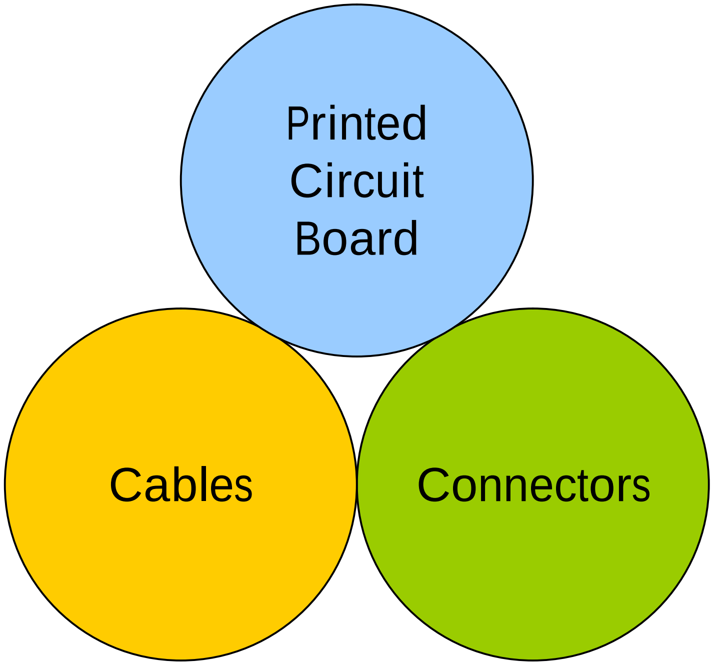
- Provides ideal connection between compliance point and instrumentation reference plane.
- May consist of printed circuit board traces, connectors and cables
- Trace structure variations of width, length and dielectric material are typical. Test board designs need to meet impedance targets but exact effect of insertion loss is considered negligible but usually unknown
- Connector footprint variations are a common source of varied test board performance.
- Instrumentation cables vary in length, insertion loss, termination quality and type (rigid, semi-rigid, hand-formable, etc)
- These effects can be de-embedded when using some instrumentation but can not with most

Zero-Length Test Load Misconceptions

- All good quality SMA cables have similar electrical characteristics
- If you use connector footprint provided in the standard you will meet the impedance specifications of the standard
- The common mode impedance of trace structures on the test fixture has no effect. Only the differential impedance is important.

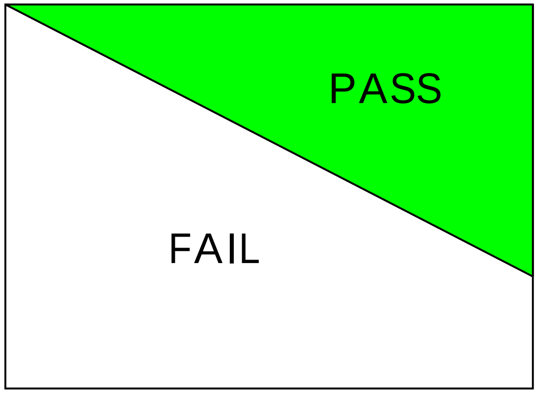
Challenges of Characterization

- Some compliance points utilize connectors while others don't. How do we account for these differences?
- Of those that use connectors not all are the same
- Connector and IC component footprints dictate PCB routing methodology
- Must resolve the discrepancies or de-embed the PCB effects



Challenges of Characterization

- To limit the insertion loss variations an S_{21} mask is one possible approach. This approach is problematic if other parameters are less than ideal
- Can we make that assumption?
- Just how good do the other parameters have to be?
- Simulations can help answer this question



Measurement Objectives

- Network analyzer measurements are suited to de-embedding. Frequency limitations exist with calibration structures but we may be below those limits
- Time domain instrumentation (oscilloscope) does not yet have the same level of de-embedding features
- Need to evaluate each usage case for zero-length test load and determine what specifications are necessary and appropriate

Test Fixture Budgeting (Early Targets)

	Printed Circuit Board	Cable	Connectors & Footprints
Insertion Loss	< 2dB @ 3GHz	< 1dB @ 3GHz	< 1dB @ 3GHz
Return Loss	< -20dB thru 3GHz	< -30dB thru 3GHz	< -15dB thru 3GHz
Conversion	< -30dB thru 3GHz	< -30dB thru 3GHz	< -30dB thru 3GHz
Common Mode	?	Not Applicable	?

Since most of these parameters are sensitive to interaction with other components, individual budgeting is of minimal value beyond a first guess estimate

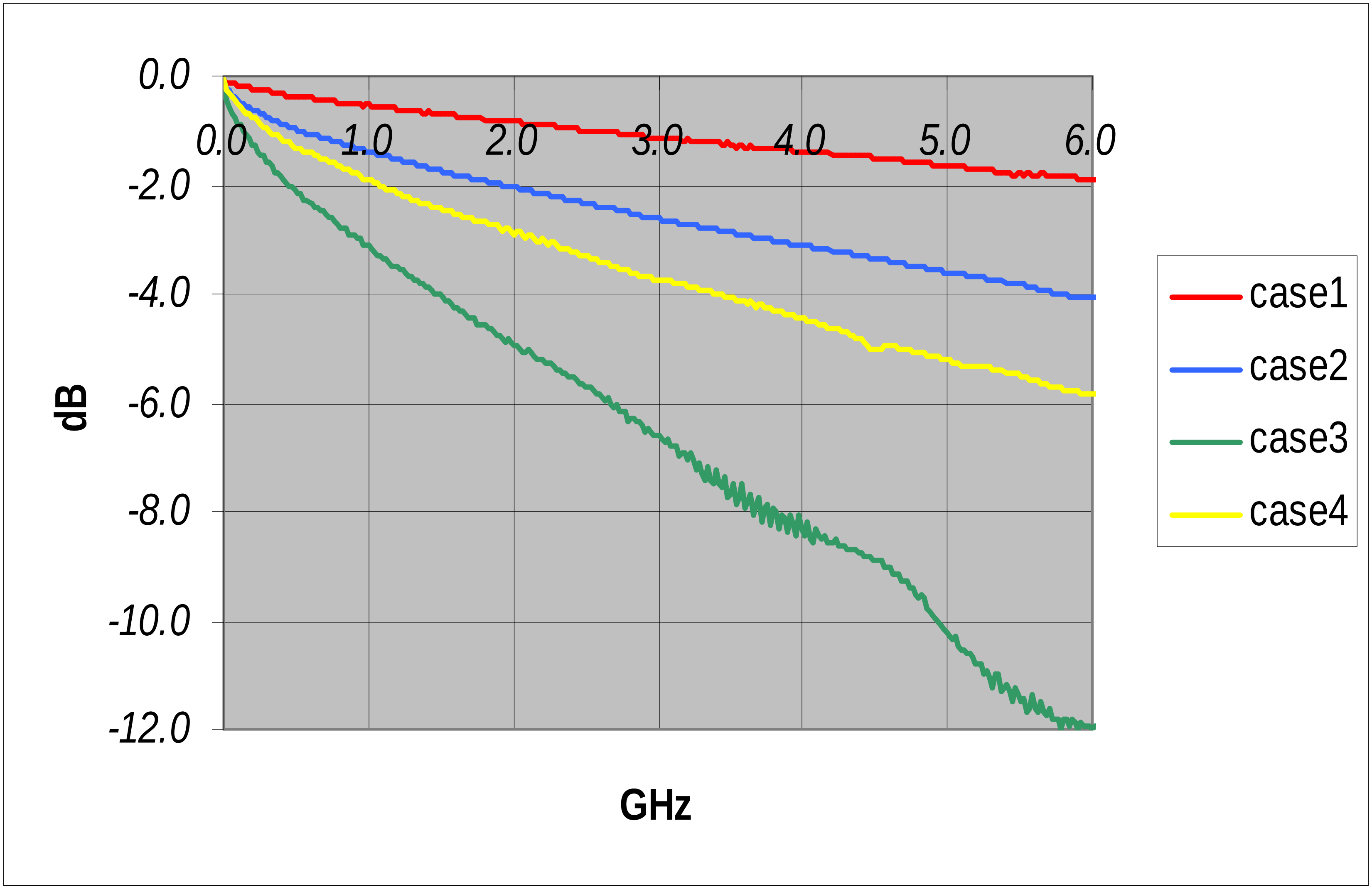
Next Actions

- The biggest issue is probably how to specify parameters that will yield consistent zero-length fixtures. Simulations should help.
- Zero-length specification should be influenced by the types of measurements to be performed in SAS-2. We must consider each type.

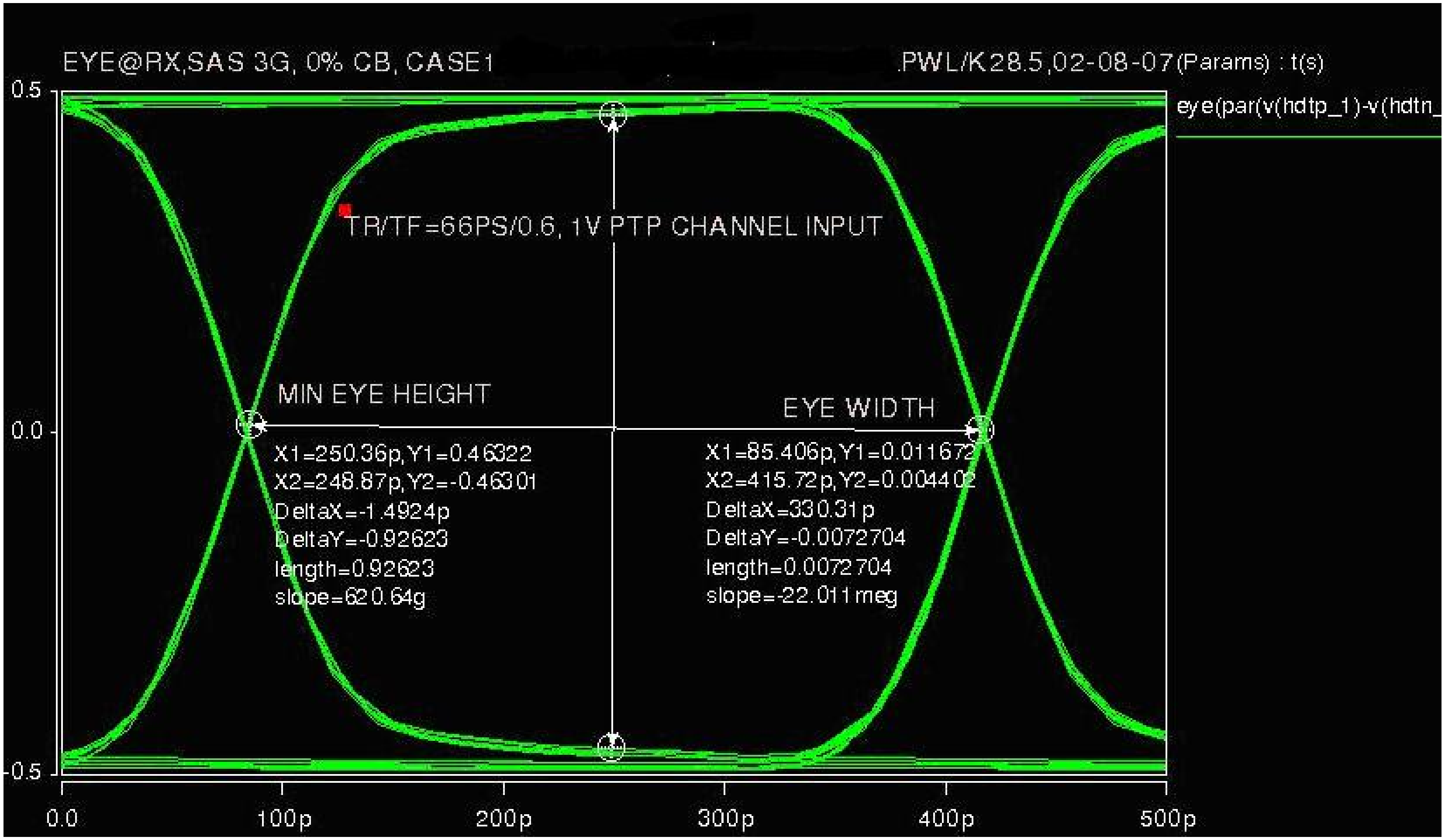
Simulation Approach

- Three different fixtures will be considered
  - Case #1: Lowest insertion loss (short trace, SMA launch and bulky 24 inch instrumentation cable)
  - Case #2: Lowest return loss (slightly longer trace, better SMA launch and thin 1 meter instrumentation cable)
  - Case #3: 2 meter miniSAS (includes fixturing losses)
  - Case#4: Mated miniSAS interface (slightly longer trace, same SMA launch and cable as #2)
- Characterize each and simulate eye diagrams to compare effects of fixtures at 3 and 6Gbps. Use 1000mV K28.5 transmitter model with fast and slow edge rates.

Zero-Length Fixture Insertion Loss

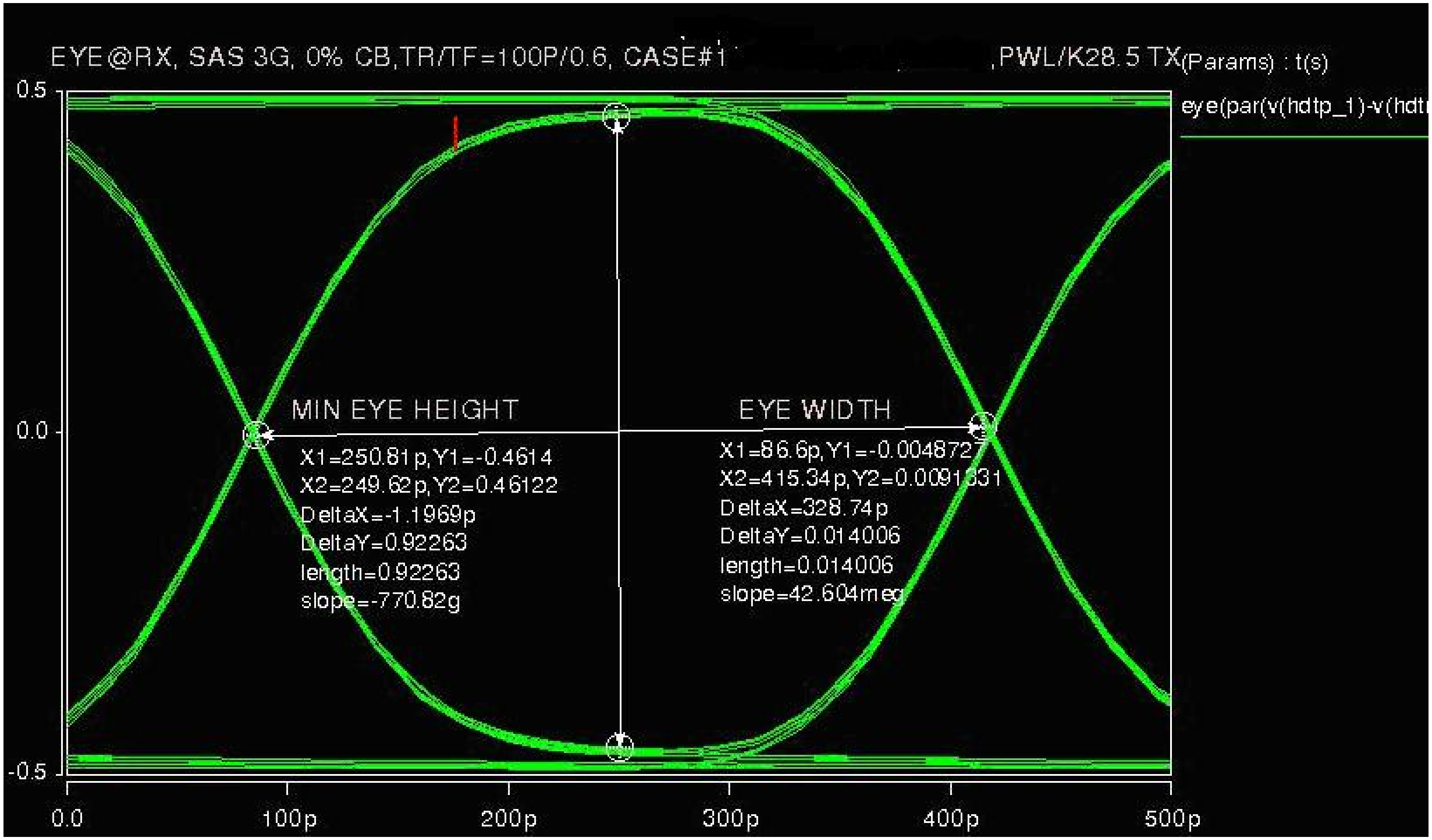


Case #1, 3Gbps, Tr: 66ps



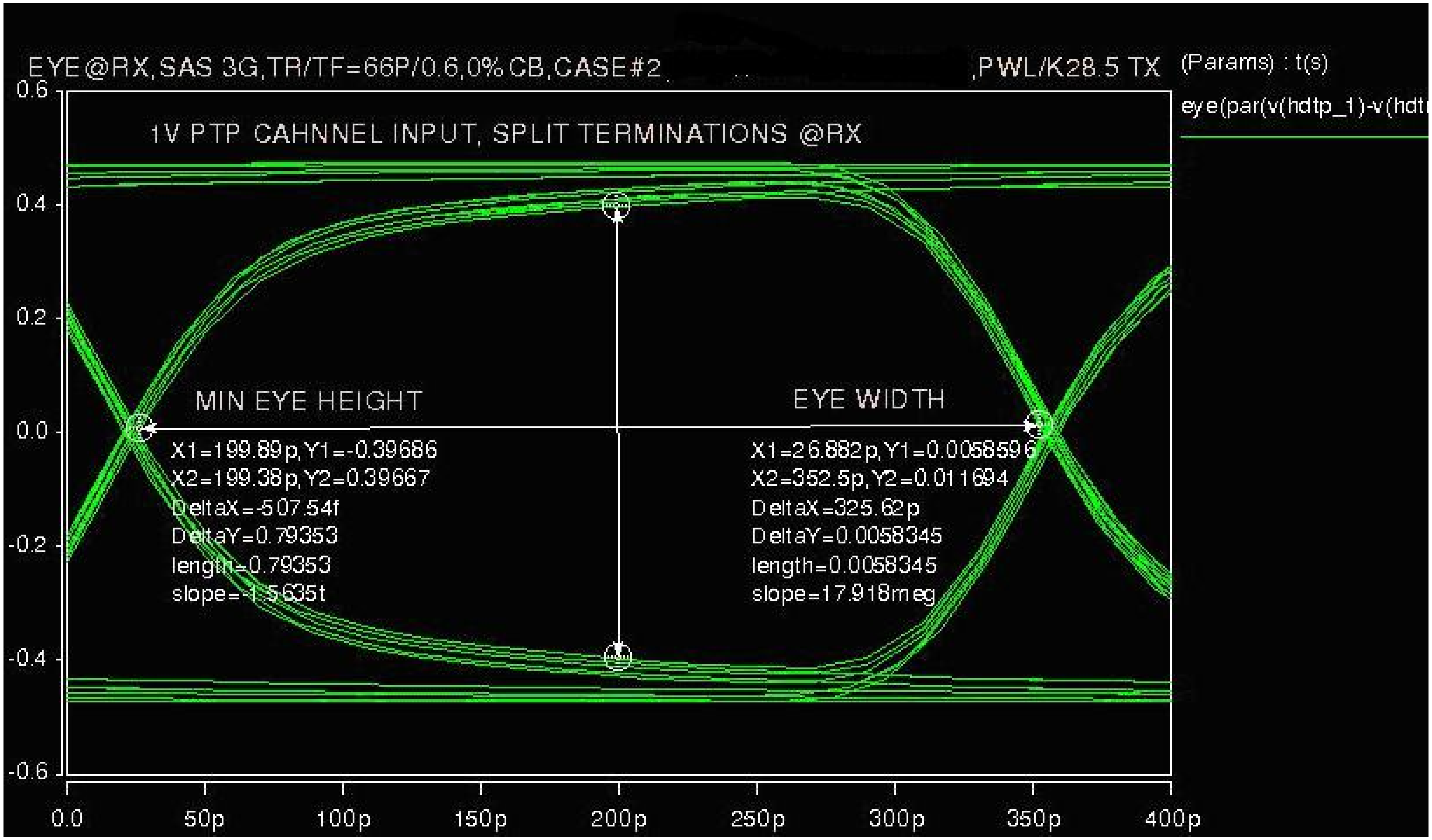
Eye Height: 926mV

Case #1, 3Gbps, Tr: 100ps



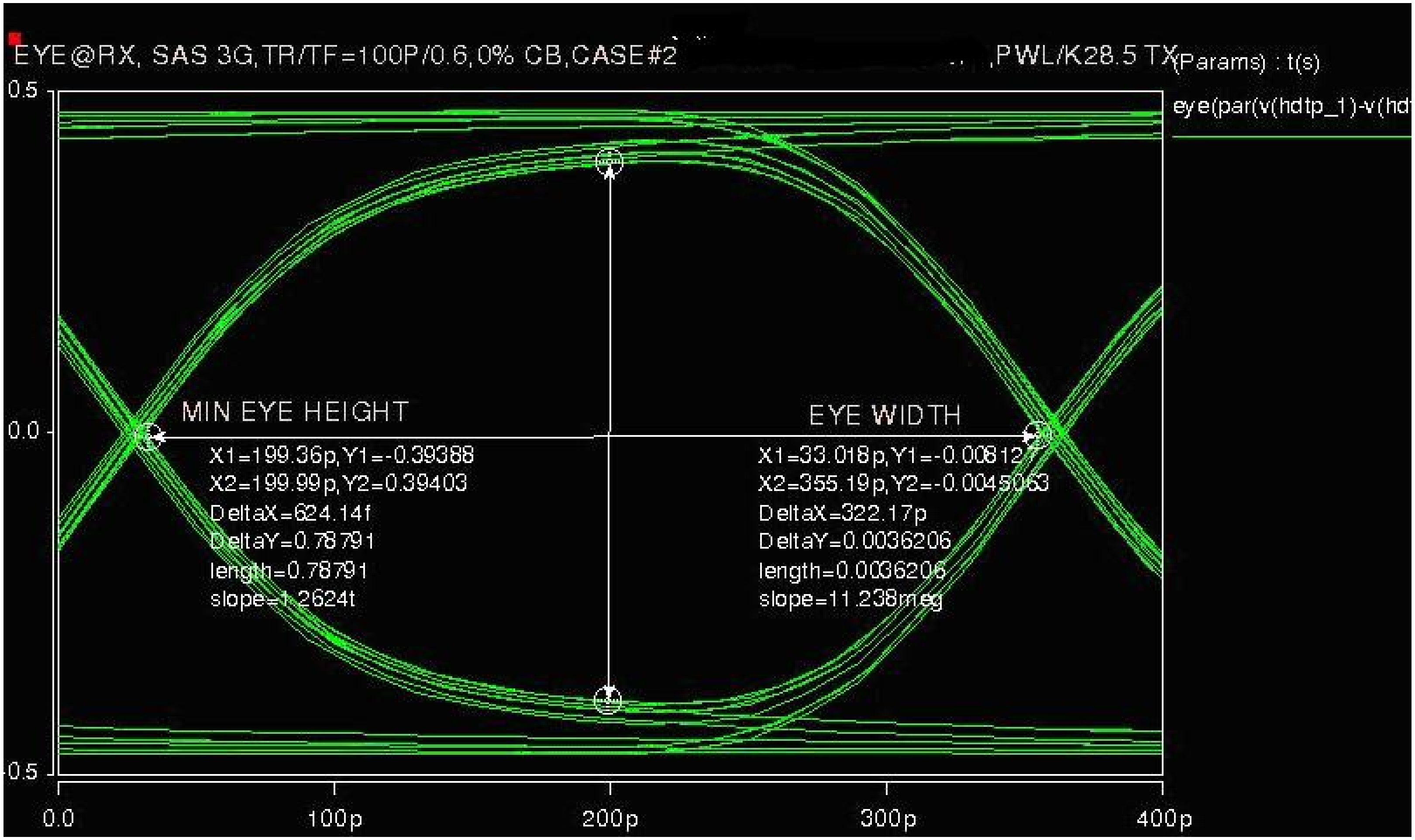
Eye Height: 923mV

Case #2, 3Gbps, Tr: 66ps



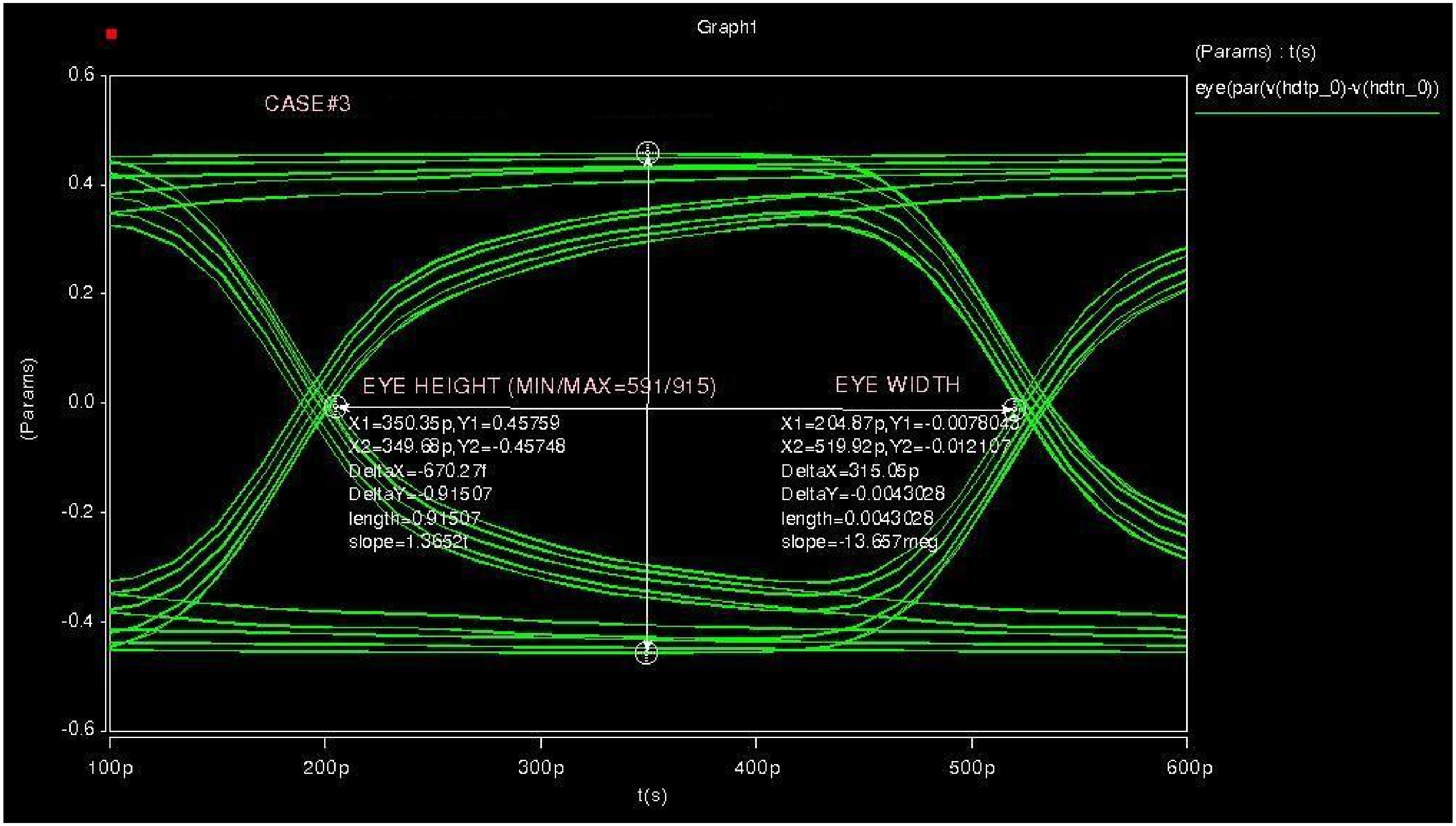
Eye Height: 794mV

Case #2, 3Gbps, Tr: 100ps



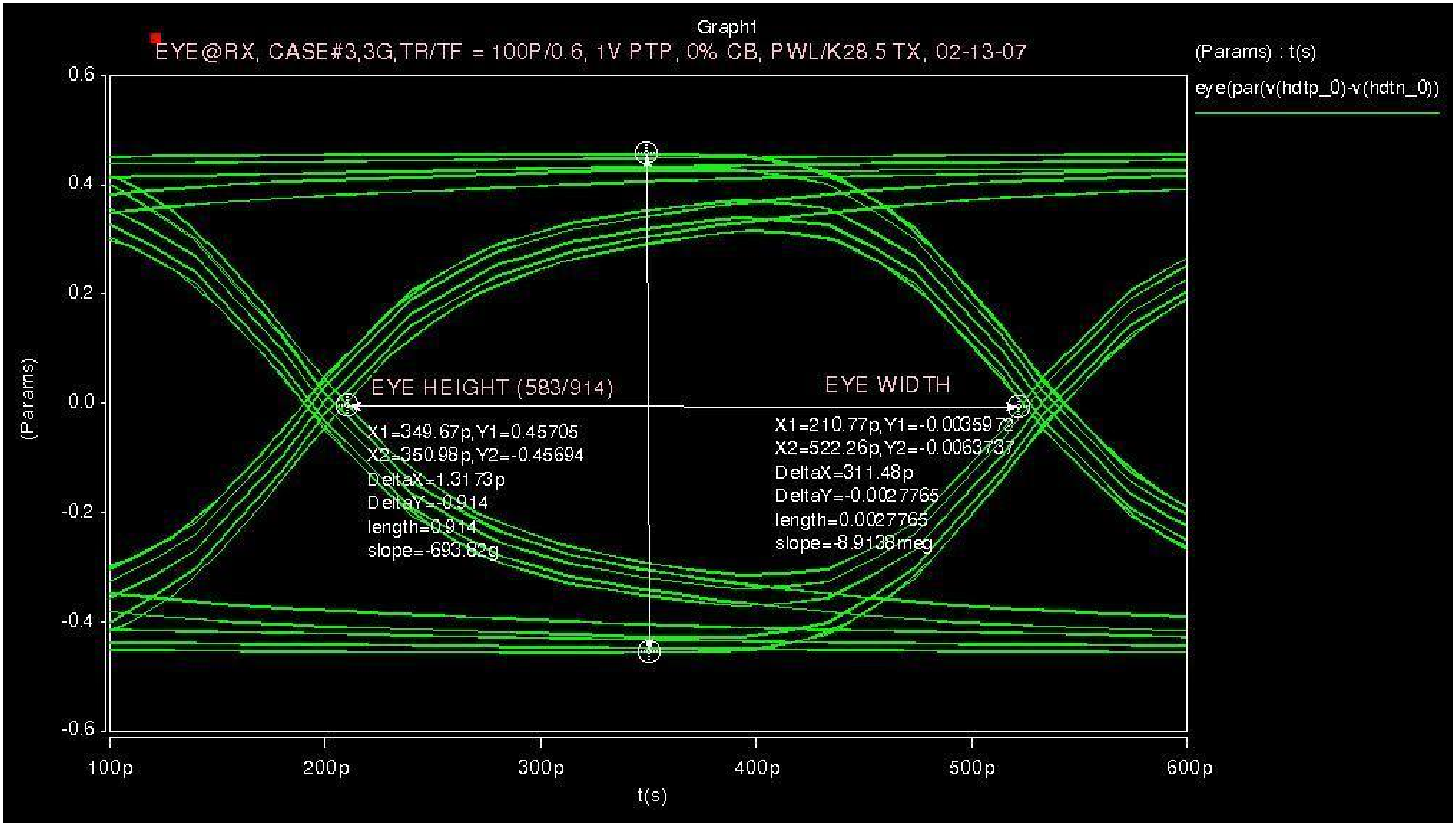
Eye Height: 788mV

Case #3, 3Gbps, Tr: 66ps



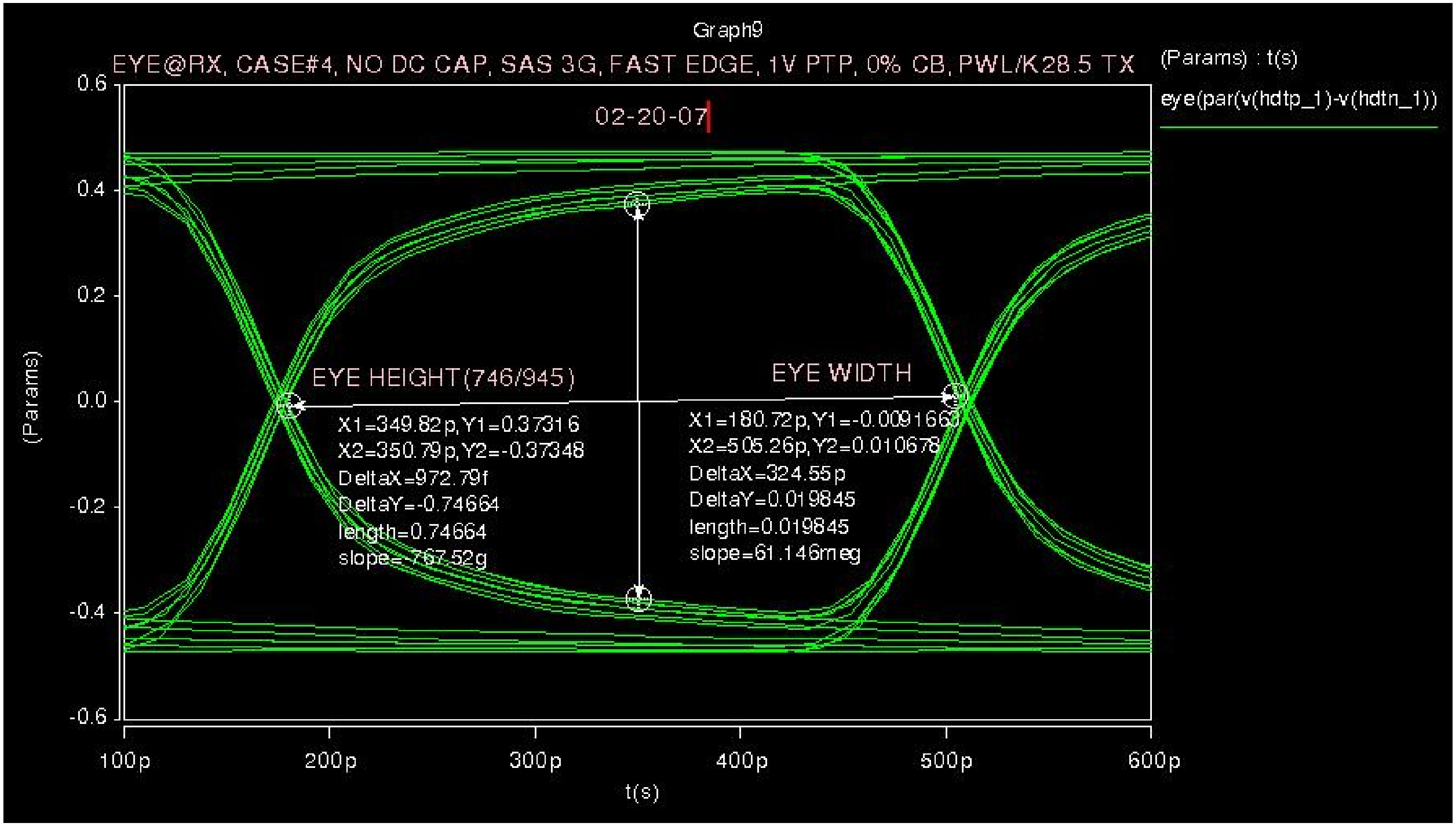
Eye Height: 591mV

Case #3, 3Gbps, Tr: 100ps



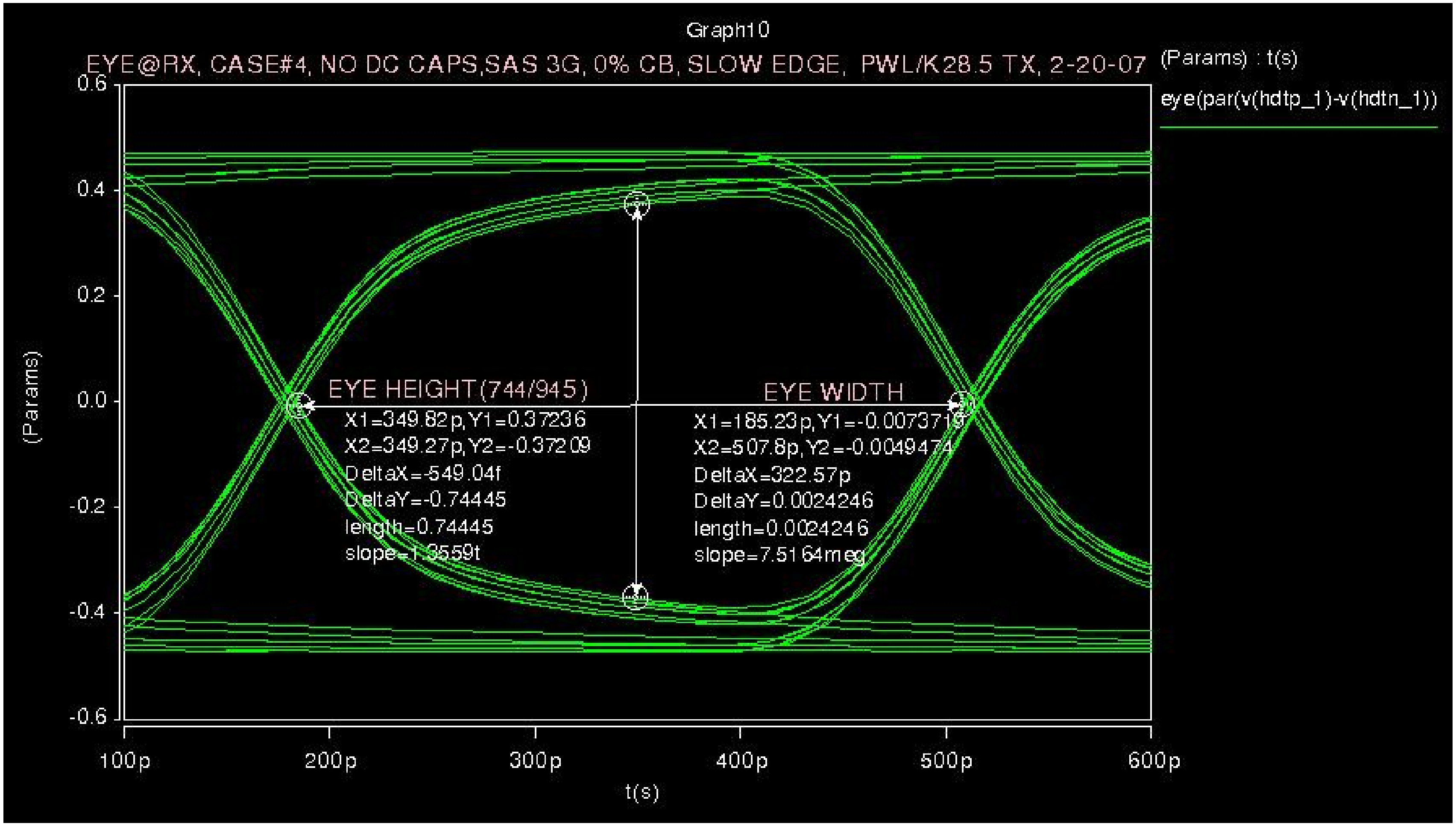
Eye Height: 583mV

Case #4, 3Gbps, Tr: 66ps



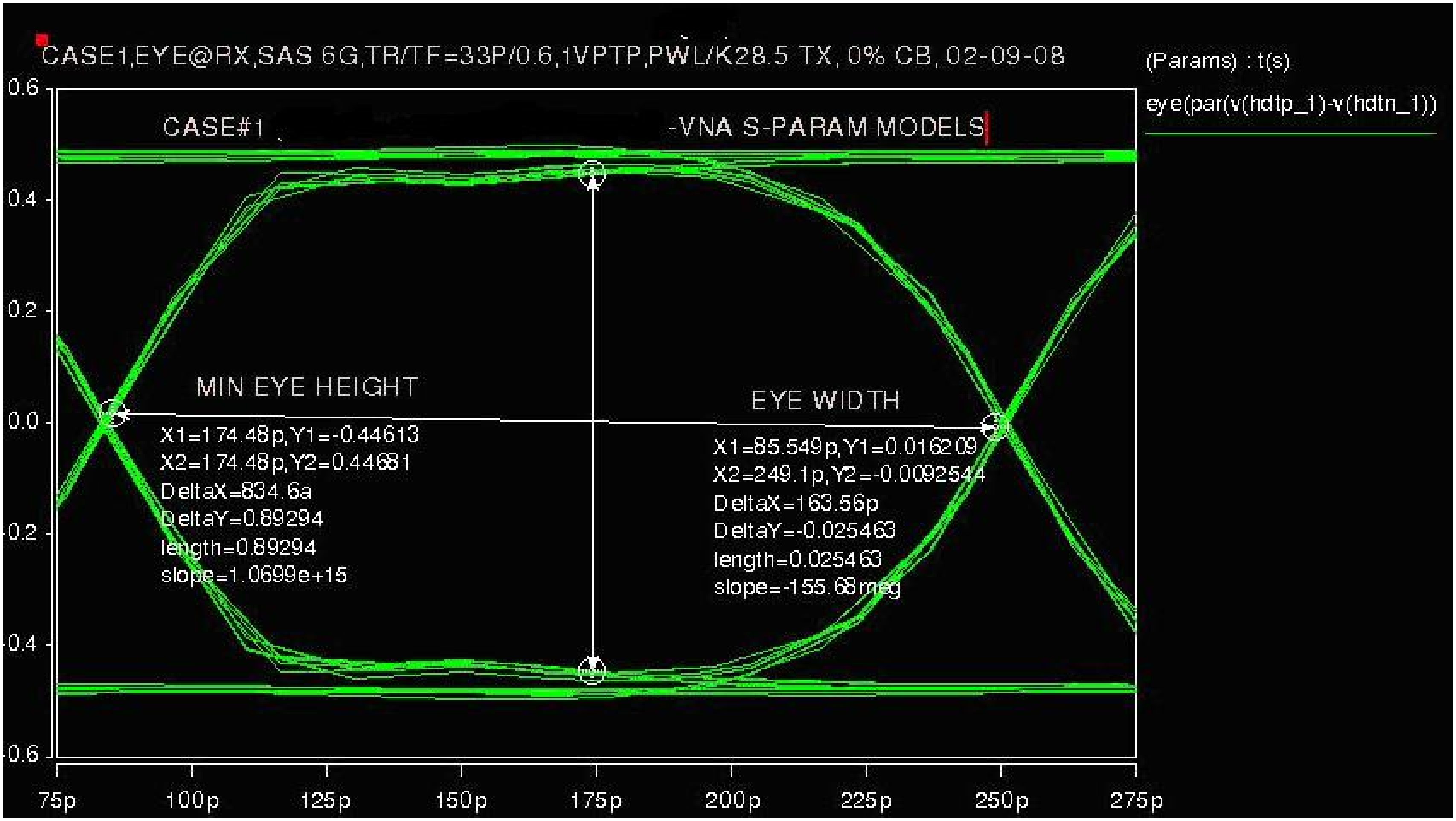
Eye Height: 746mV

Case #4, 3Gbps, Tr: 100ps



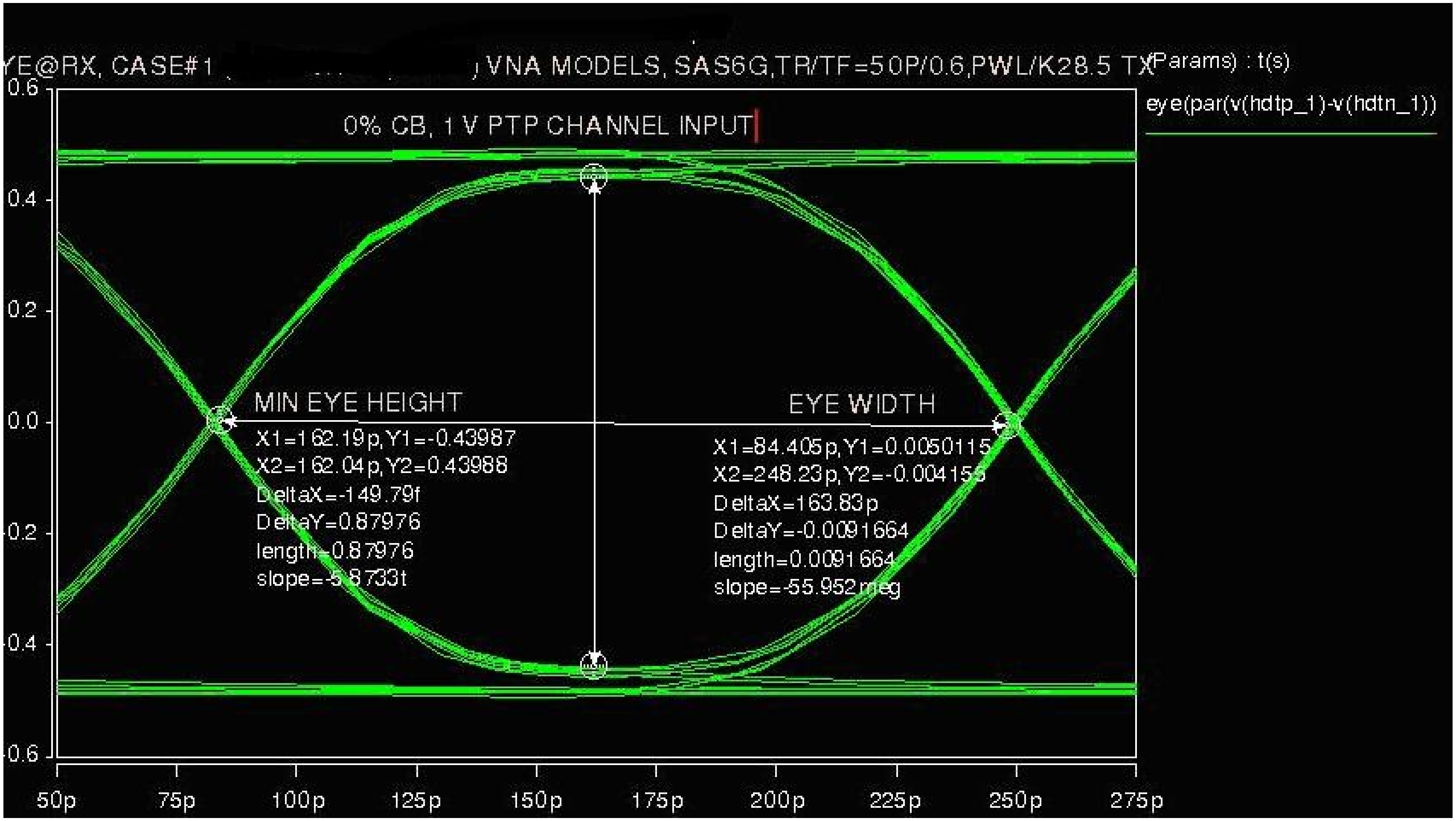
Eye Height: 744mV

Case #1, 6Gbps, Tr: 33ps



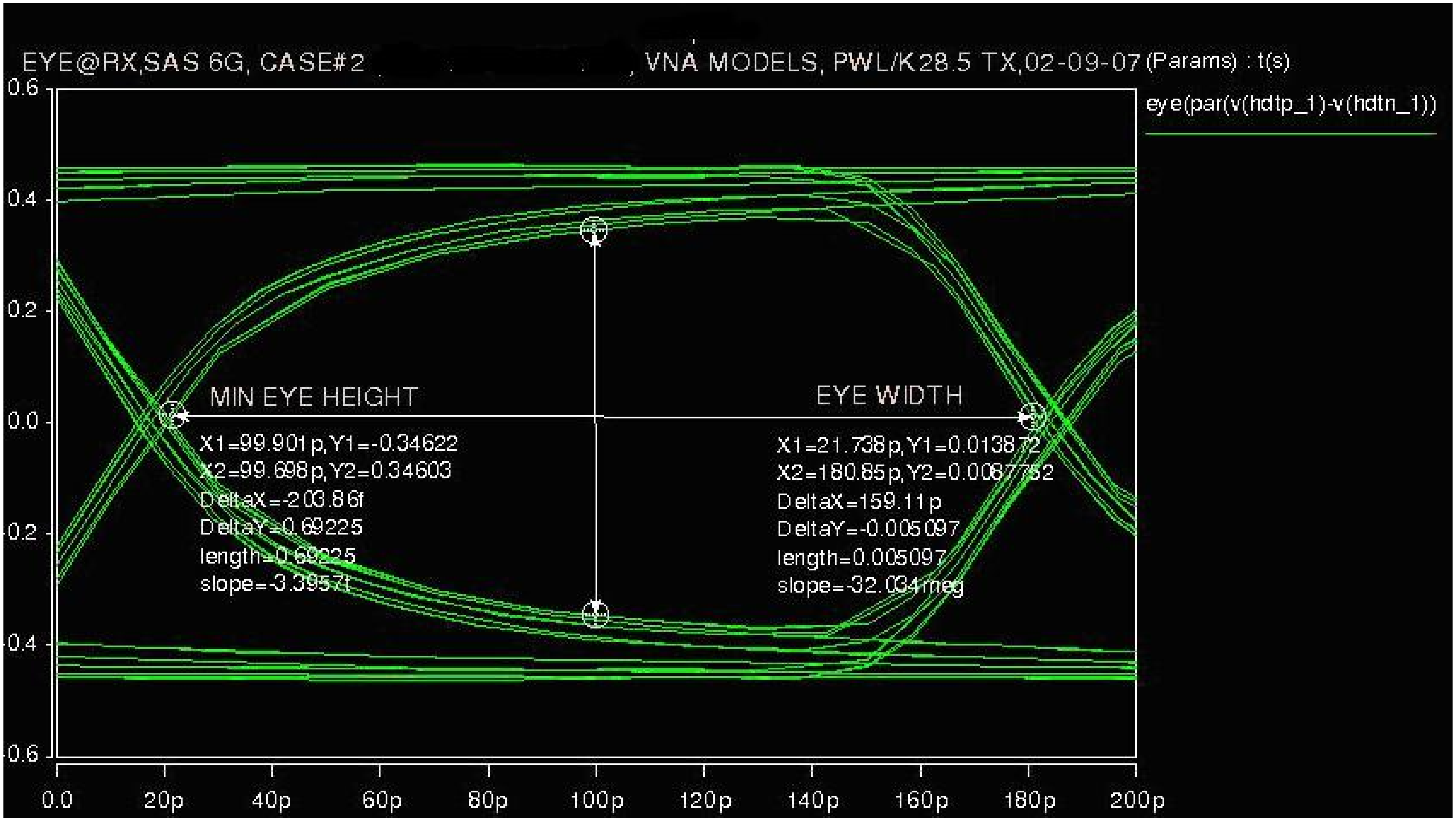
Eye Height: 893mV

Case #1, 6Gbps, Tr: 50ps



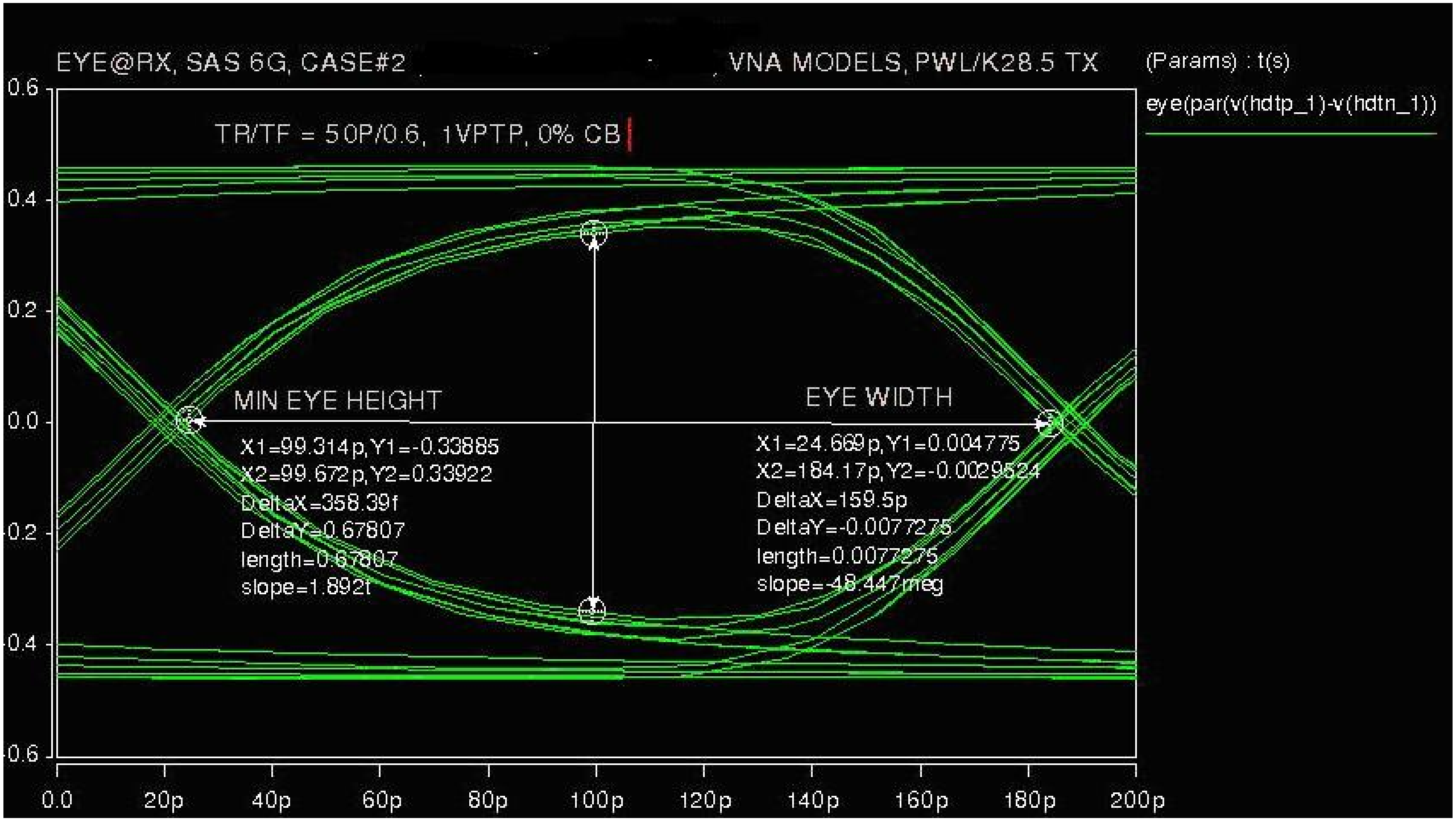
Eye Height: 880mV

Case #2, 6Gbps, Tr: 33ps



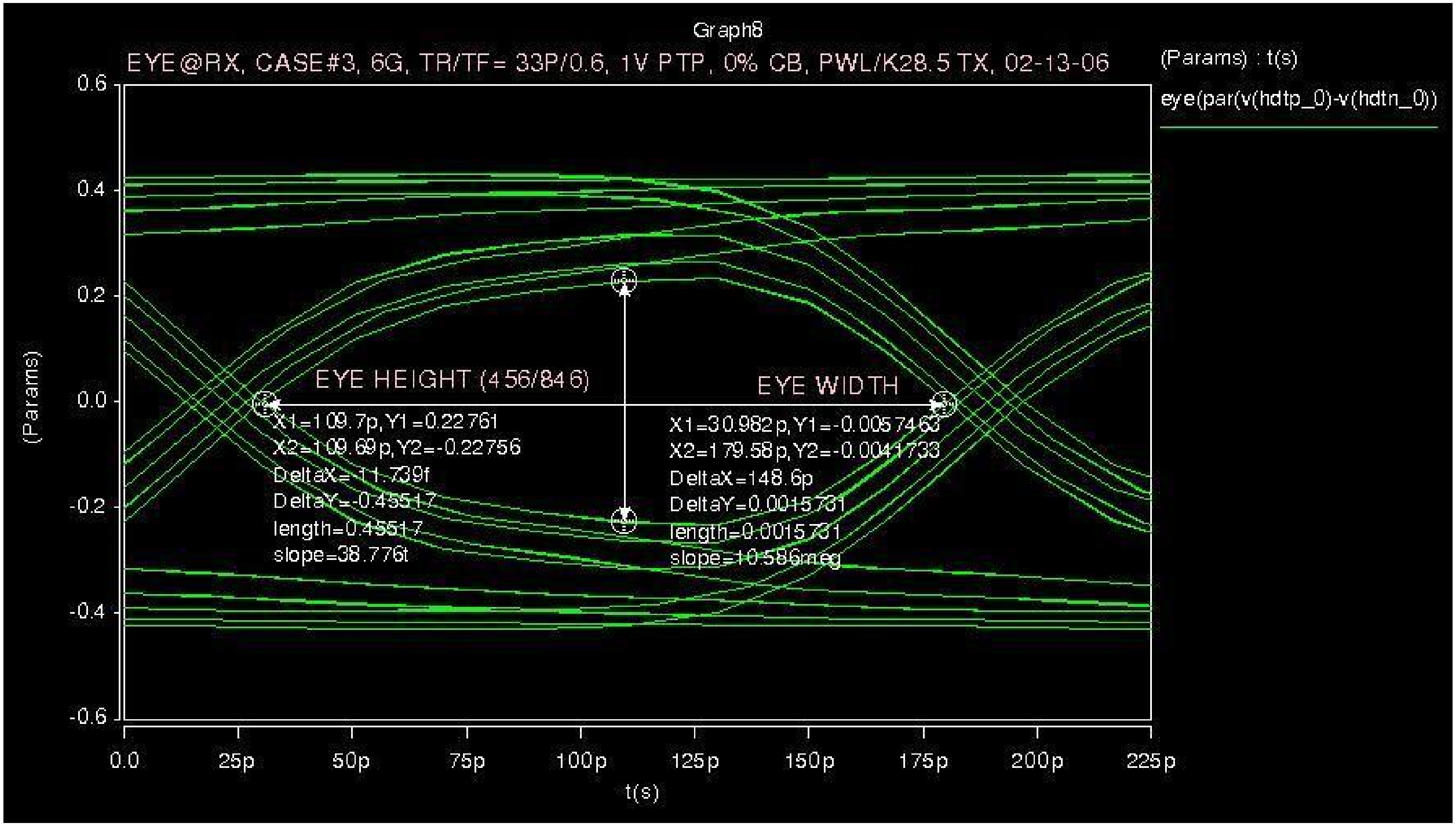
Eye Height: 692mV

Case #2, 6Gbps, Tr: 50ps



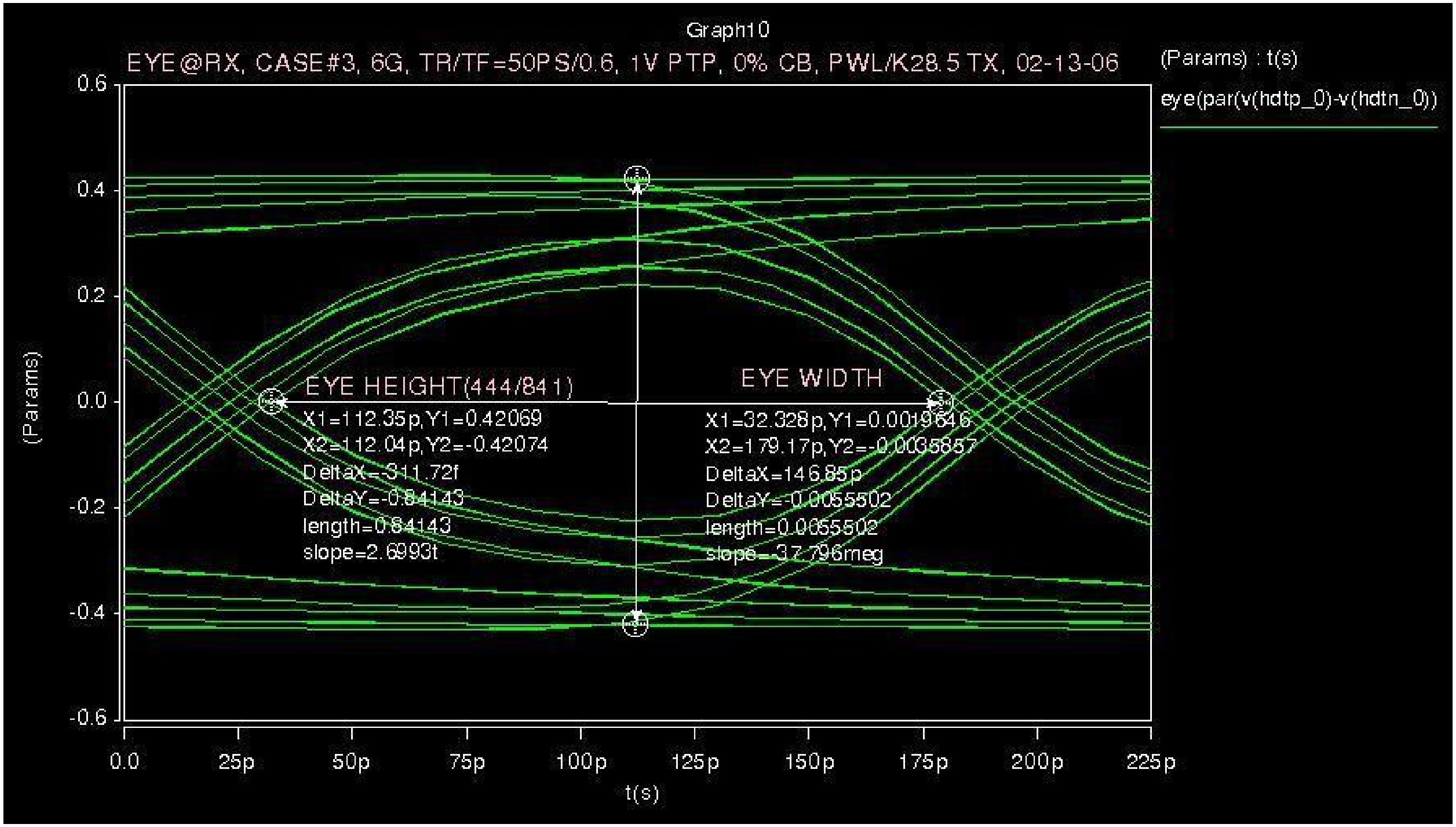
Eye Height: 678mV

Case #3, 6Gbps, Tr: 33ps



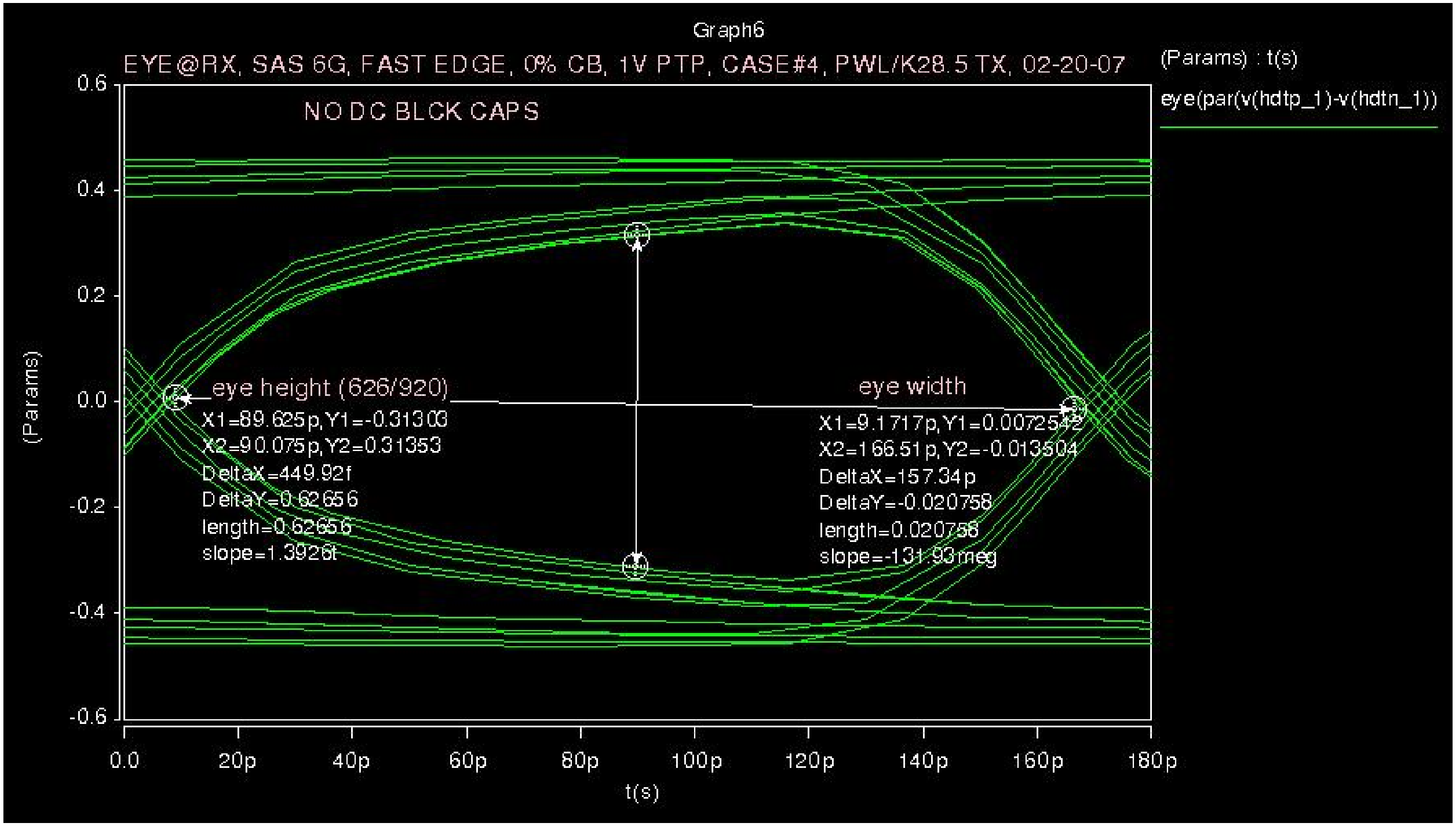
Eye Height: 456mV

Case #3, 6Gbps, Tr: 50ps



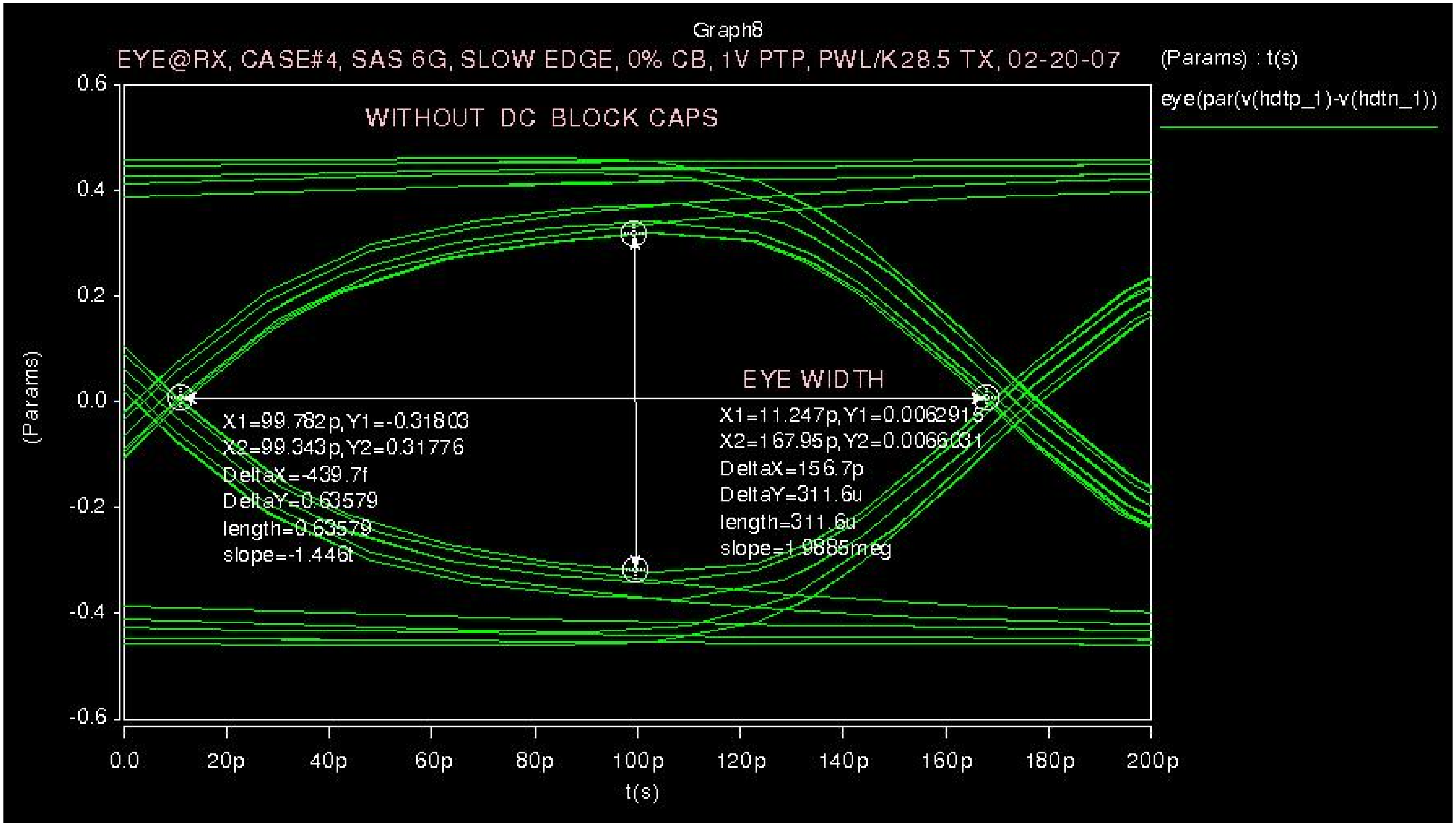
Eye Height: 444mV

Case #4, 6Gbps, Tr: 33ps



Eye Height: 626mV

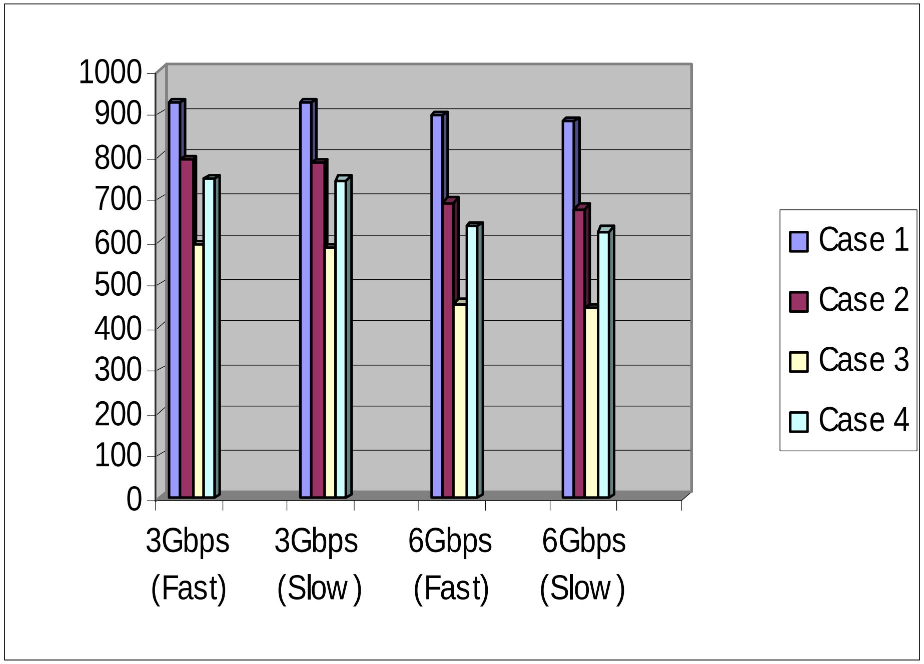
Case #4, 6Gbps, Tr: 50ps



Eye Height: 636mV

Simulation Summary

	Case 1	Case 2	Case 3	Case 4
3Gbps (Fast)	926mV	794mV	591mV	746mV
3Gbps (Slow)	923mV	788mV	583mV	744mV
6Gbps (Fast)	893mV	692mV	456mV	636mV
6Gbps (Slow)	880mV	678mV	444mV	626mV

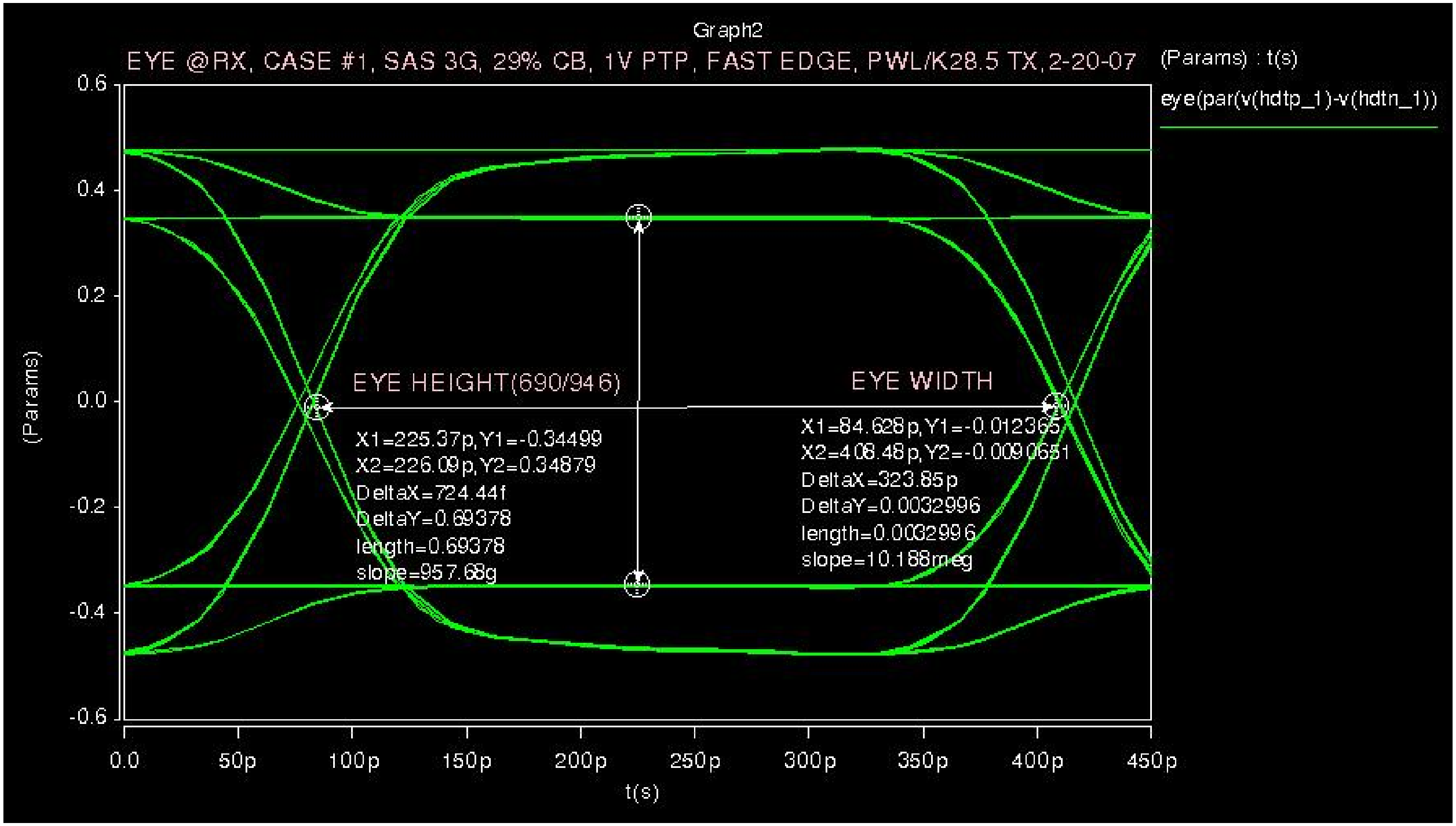


No pre-emphasis used

Measurements with Pre-emphasis

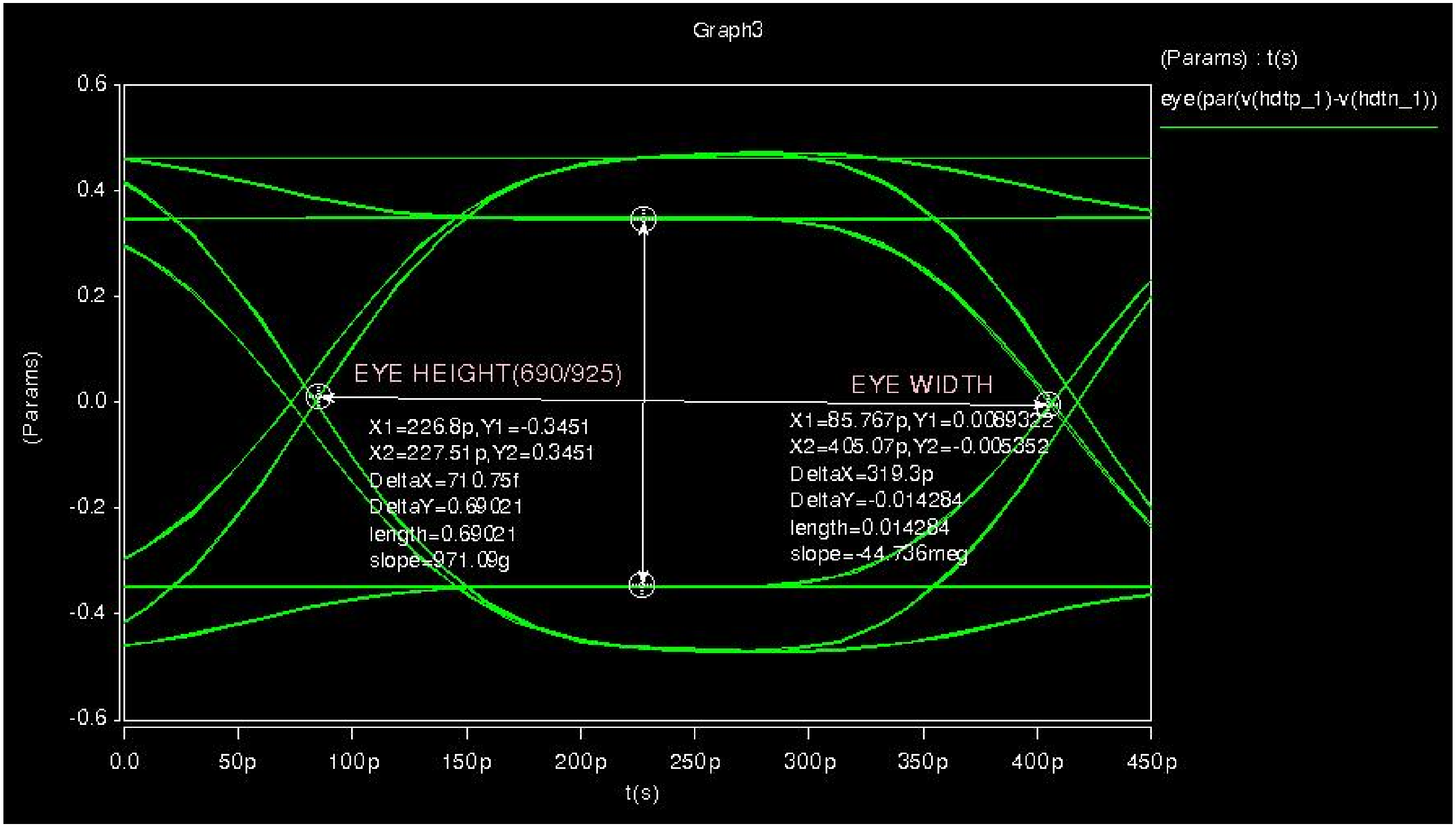
- Focusing on cases 1 and 2, how do the eye height and peak-to-peak values compare for the pre-emphasis settings of 0dB, 3dB and 6dB

Case #1, 3Gbps, Tr: 66ps, 3dB



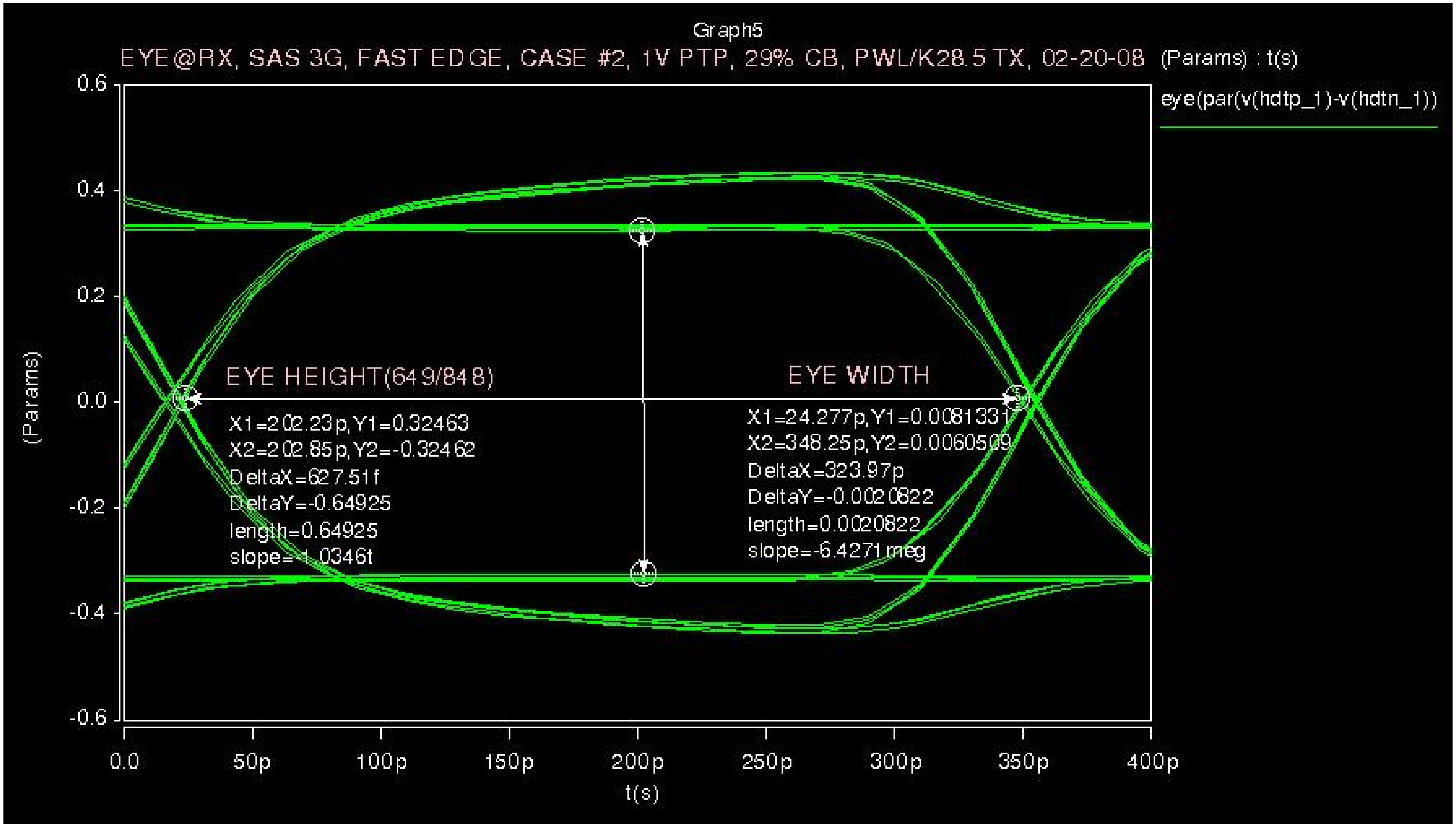
Eye Height / Max Eye: 690mV / 946mV

Case #1, 3Gbps, Tr: 100ps, 3dB



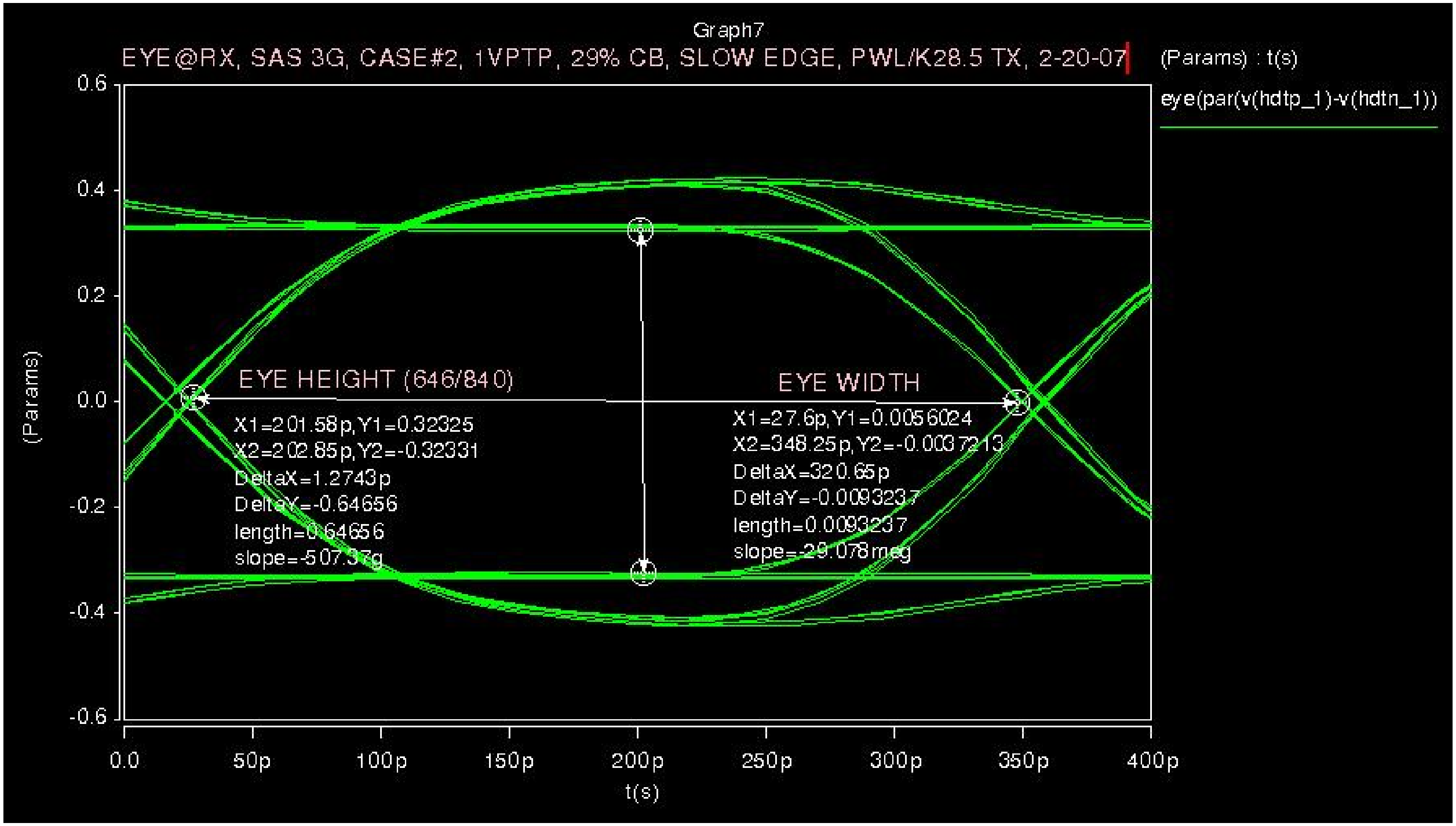
Eye Height / Max Eye: 690mV / 925mV

Case #2, 3Gbps, Tr: 66ps, 3dB



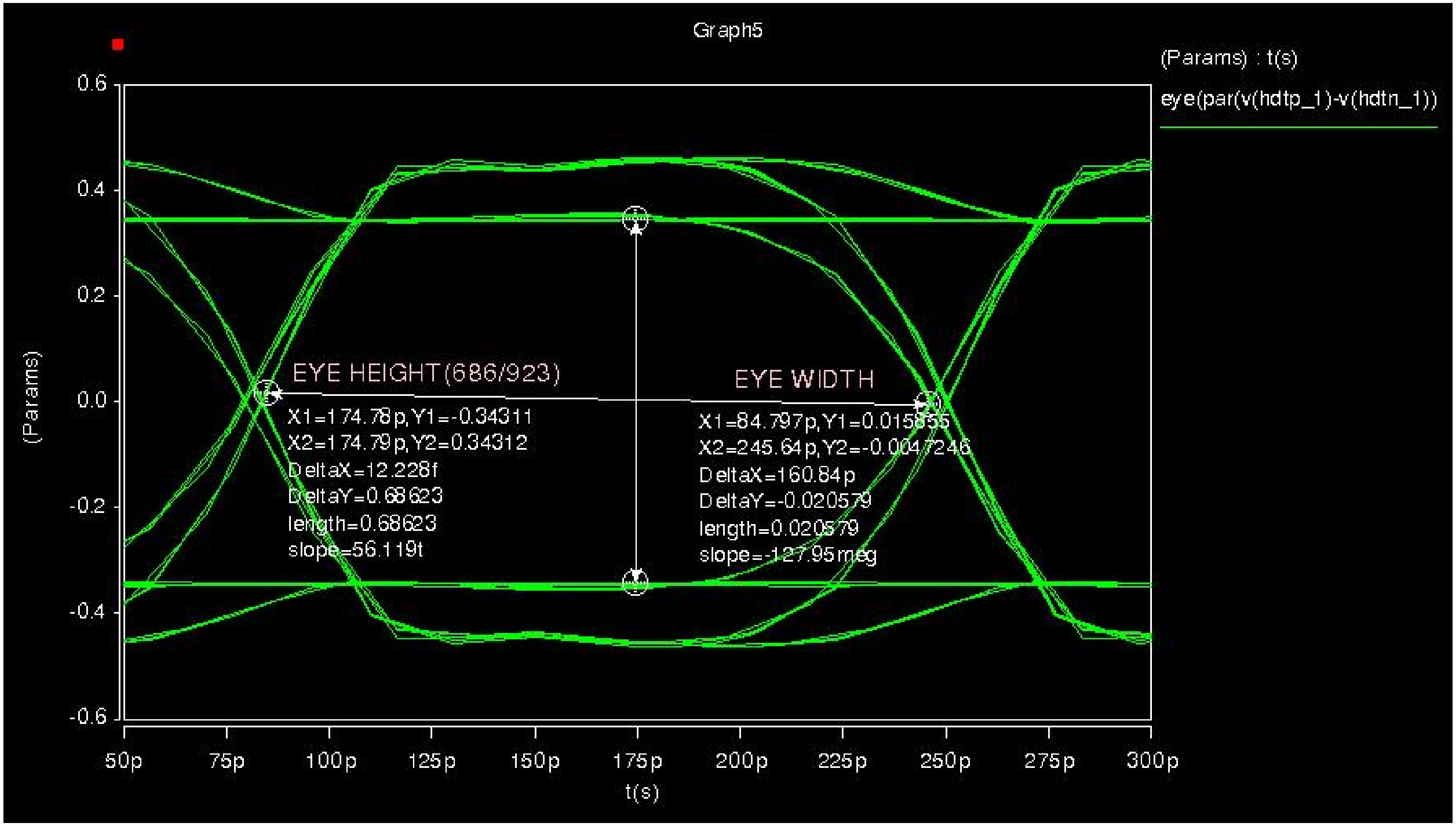
Eye Height / Max Eye: 649mV / 848mV

Case #2, 3Gbps, Tr: 100ps, 3dB



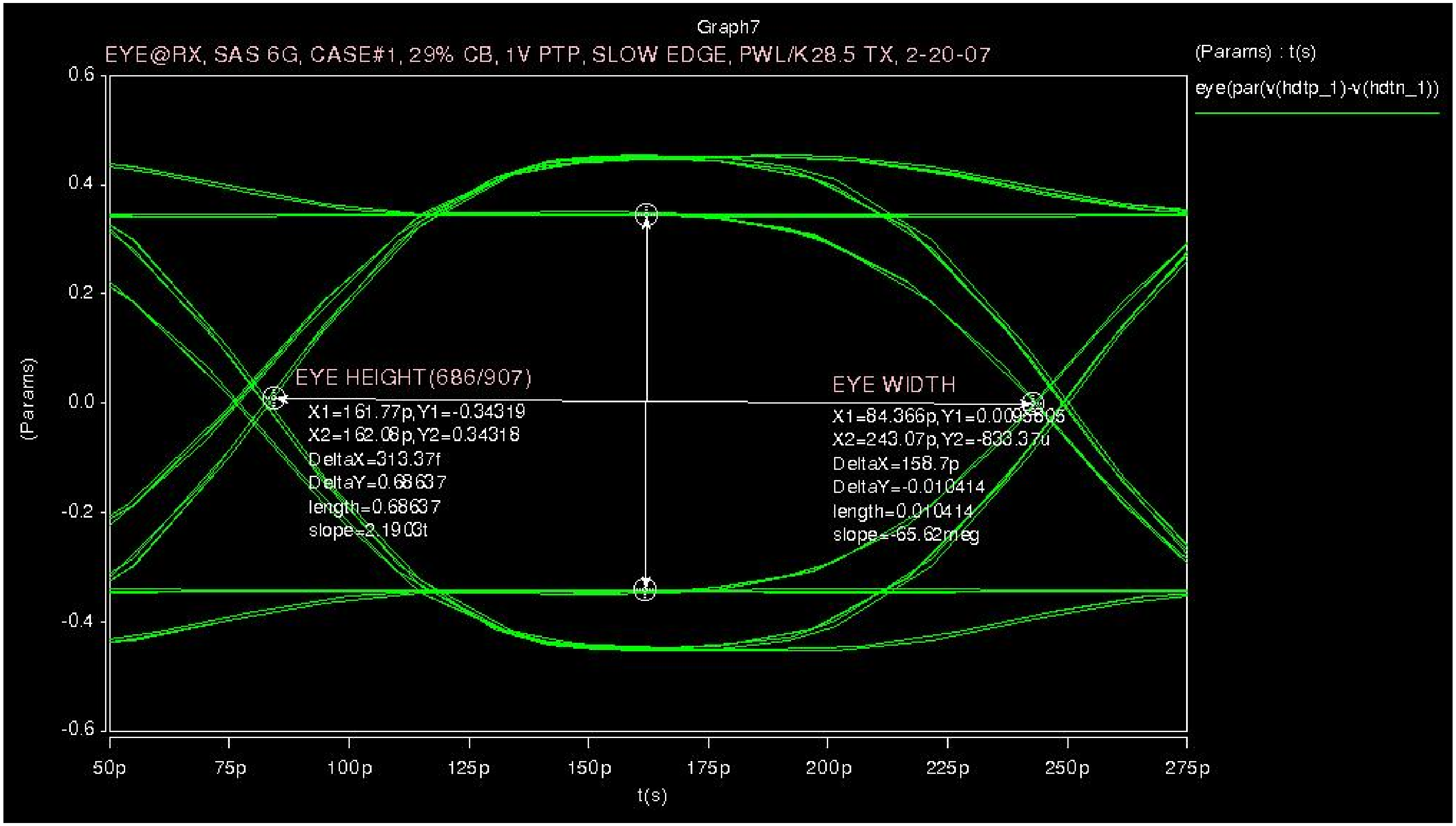
Eye Height / Max Eye: 646mV / 840mV

Case #1, 6Gbps, Tr: 33ps, 3dB



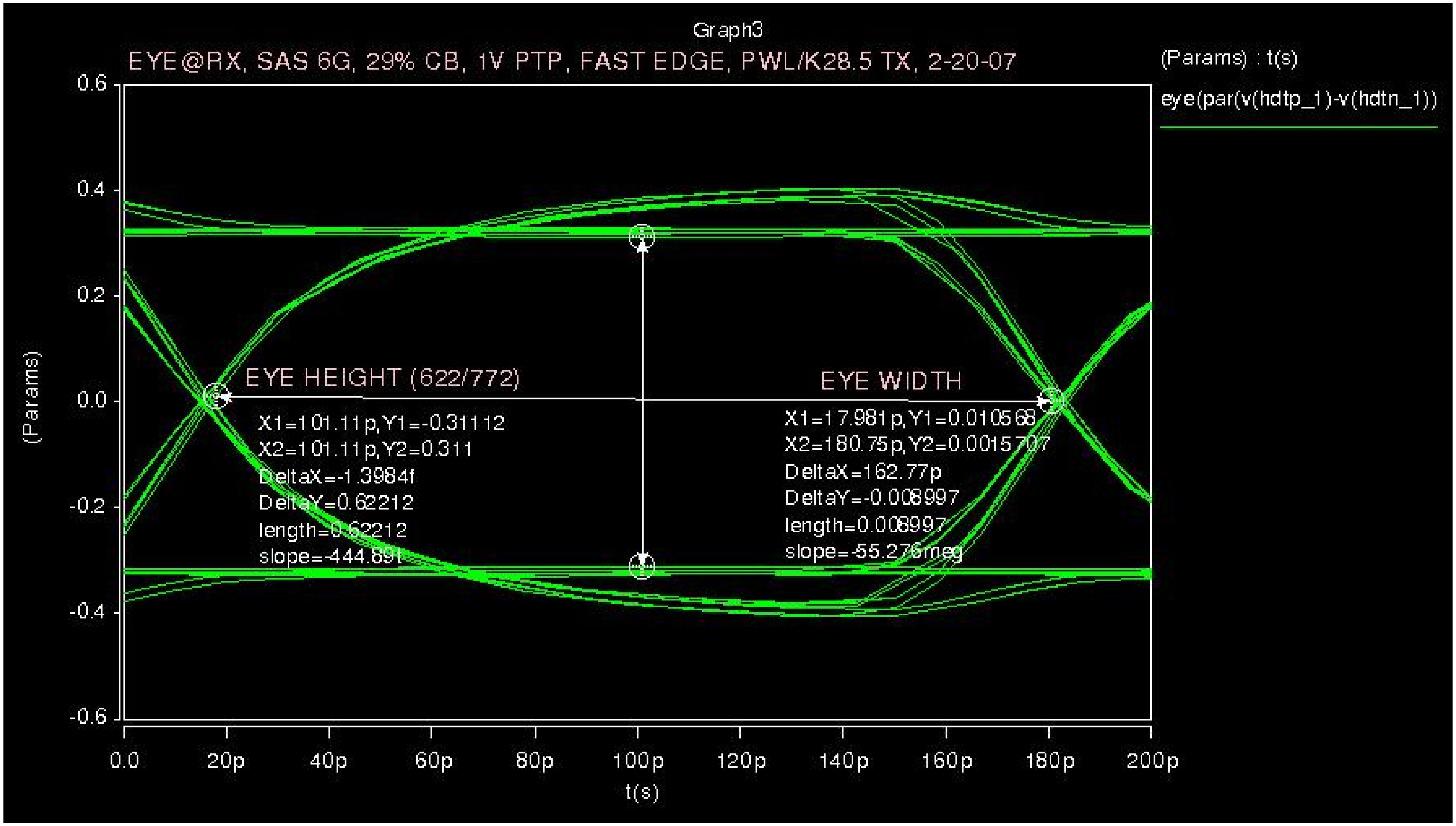
Eye Height / Max Eye: 686mV / 923mV

Case #1, 6Gbps, Tr: 50ps, 3dB



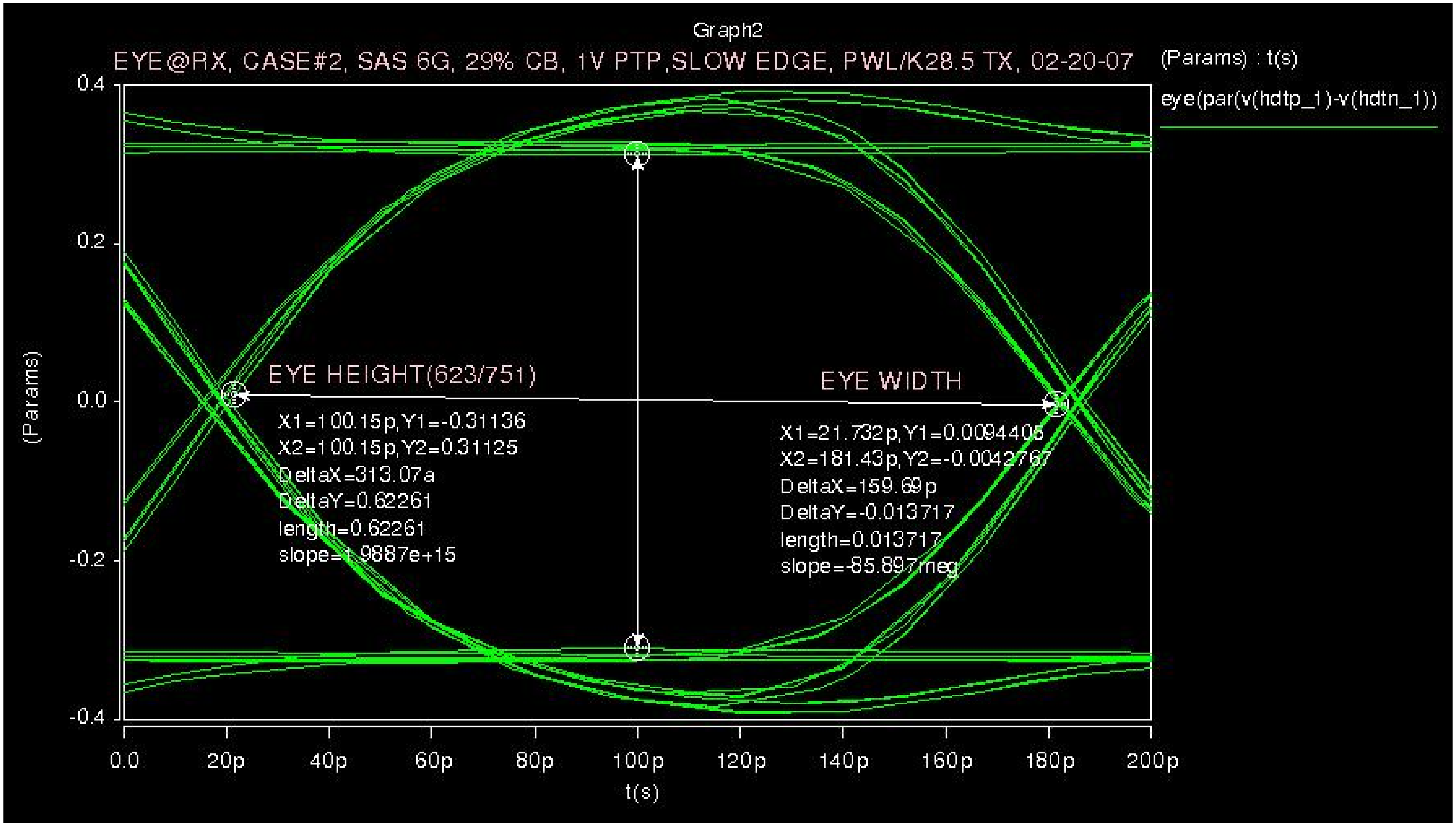
Eye Height / Max Eye: 686mV / 907mV

Case #2, 6Gbps, Tr: 33ps, 3dB



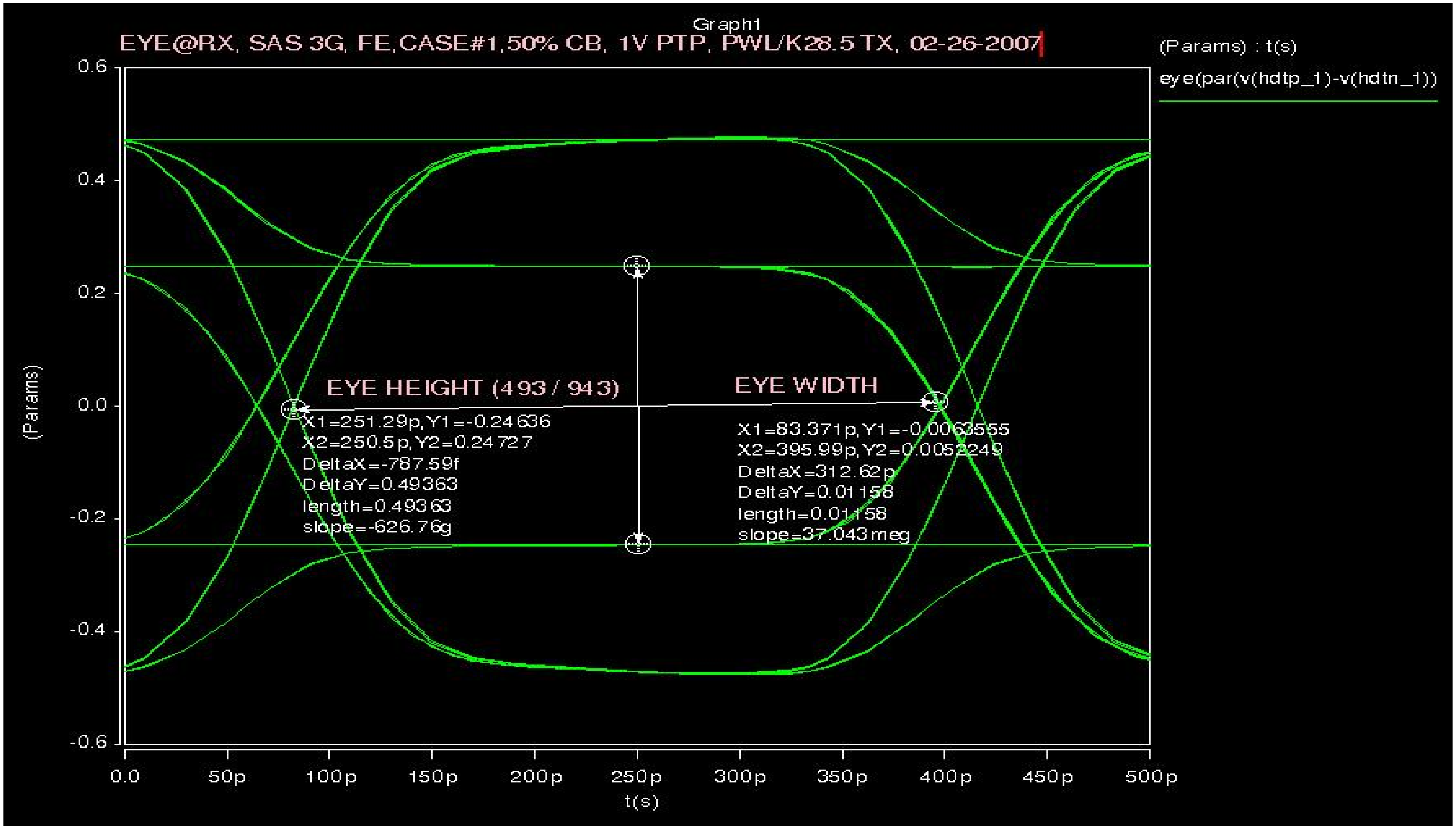
Eye Height / Max Eye: 622mV / 772mV

Case #2, 6Gbps, Tr: 50ps, 3dB



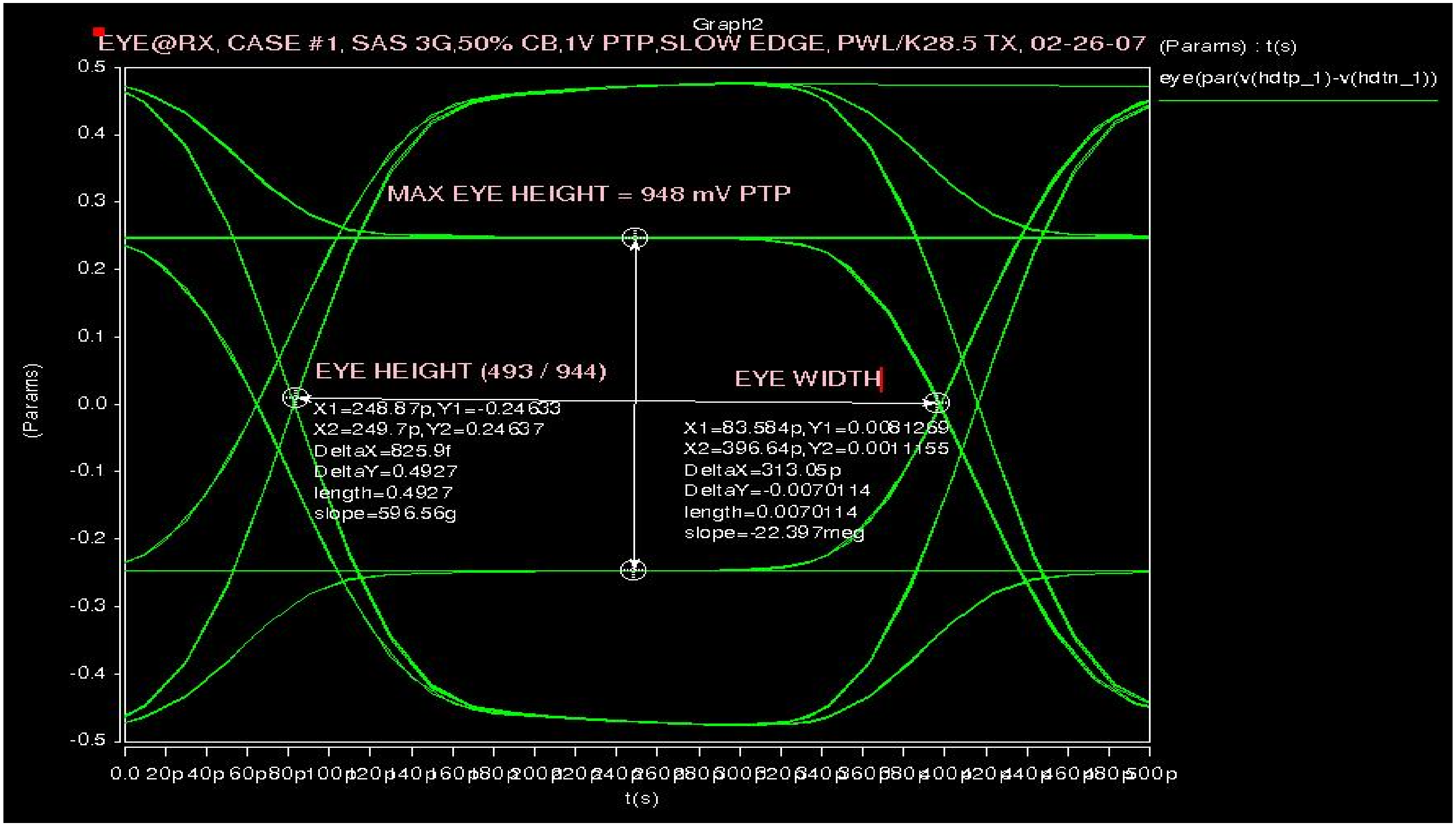
Eye Height / Max Eye: 623mV / 751mV

Case #1, 3Gbps, Tr: 66ps, 6dB



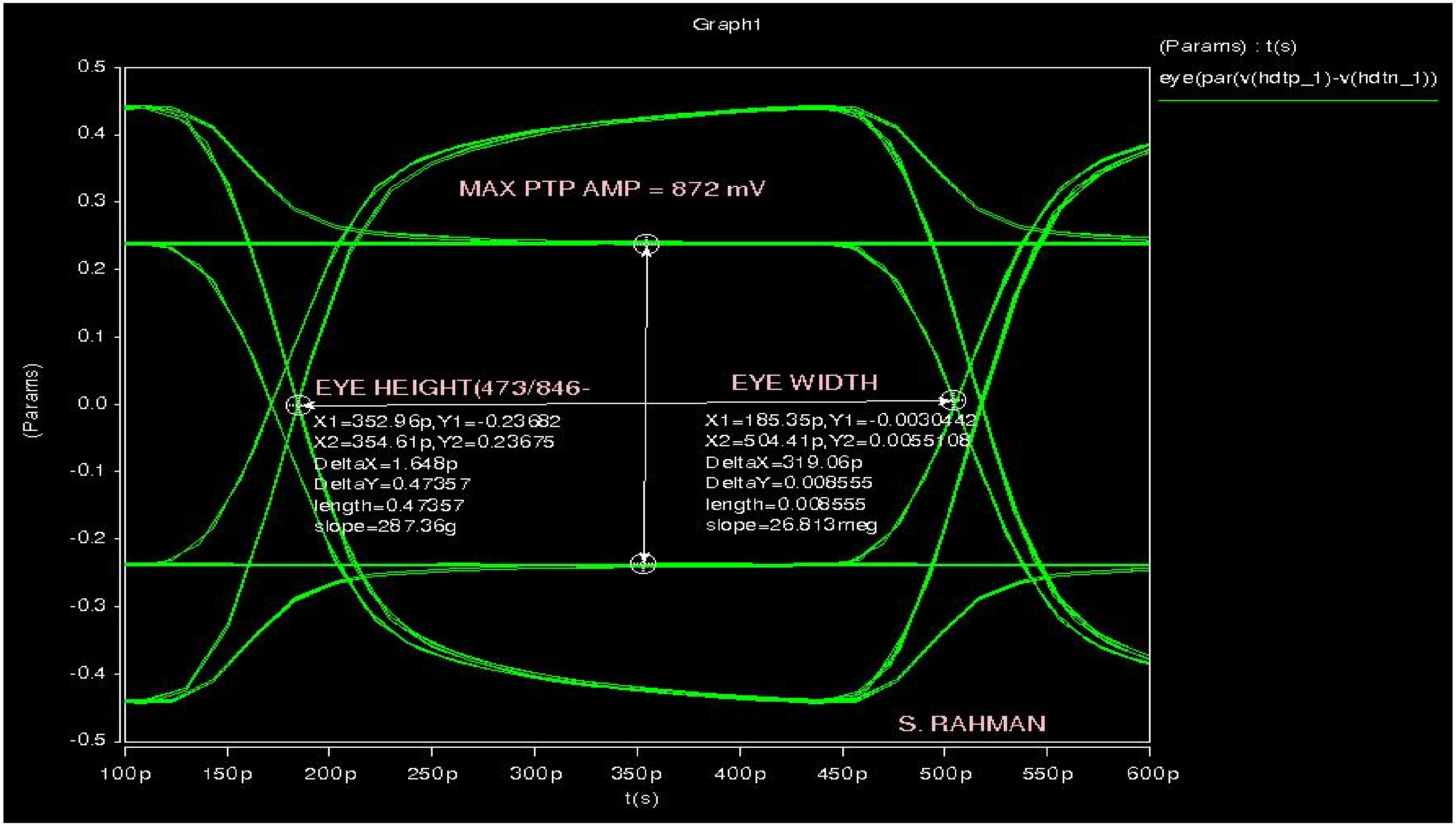
Eye Height / Max Eye: 493mV / 943mV

Case #1, 3Gbps, Tr: 100ps, 6dB



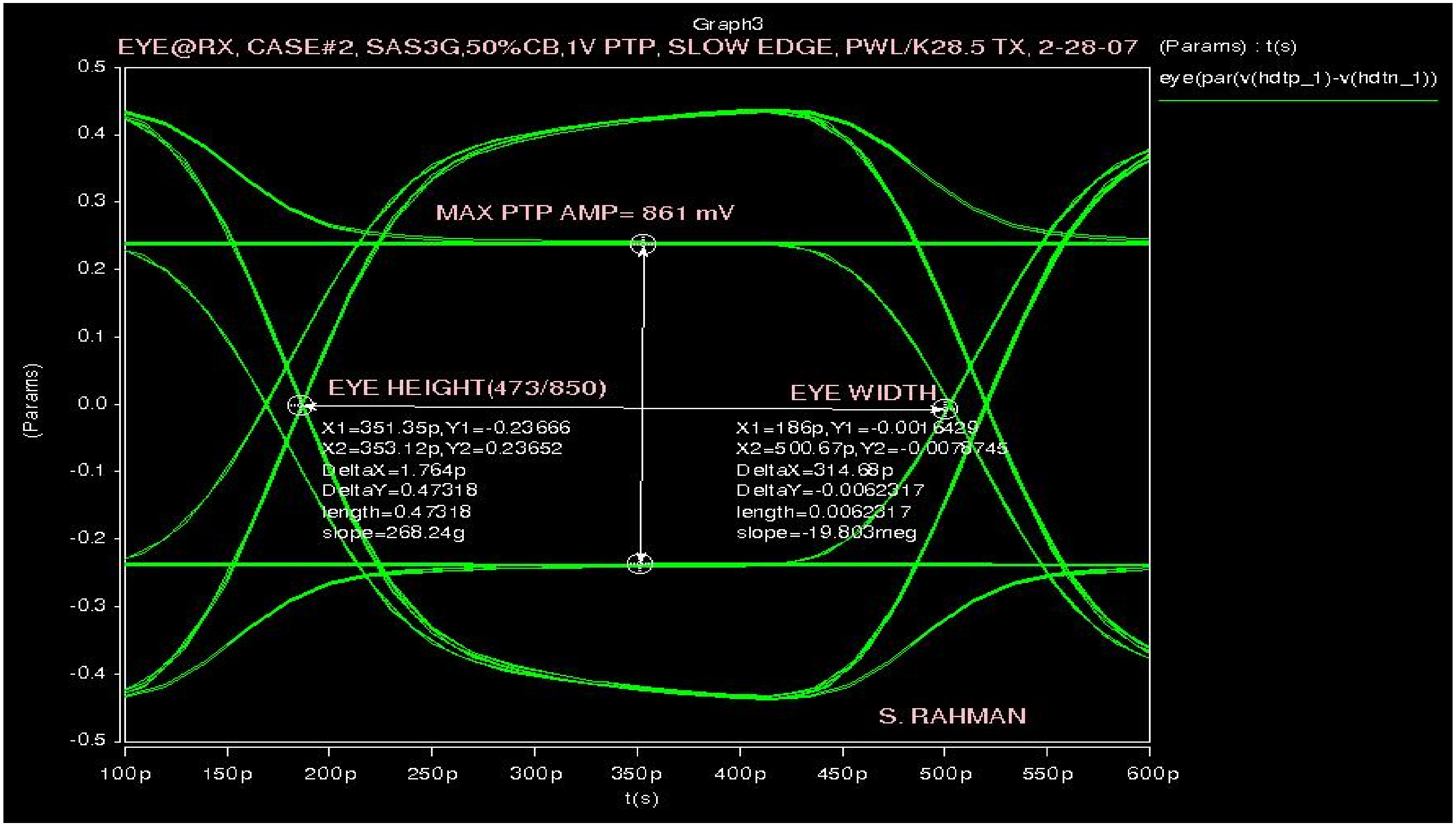
Eye Height / Max Eye: 493mV / 944mV

Case #2, 3Gbps, Tr: 66ps, 6dB



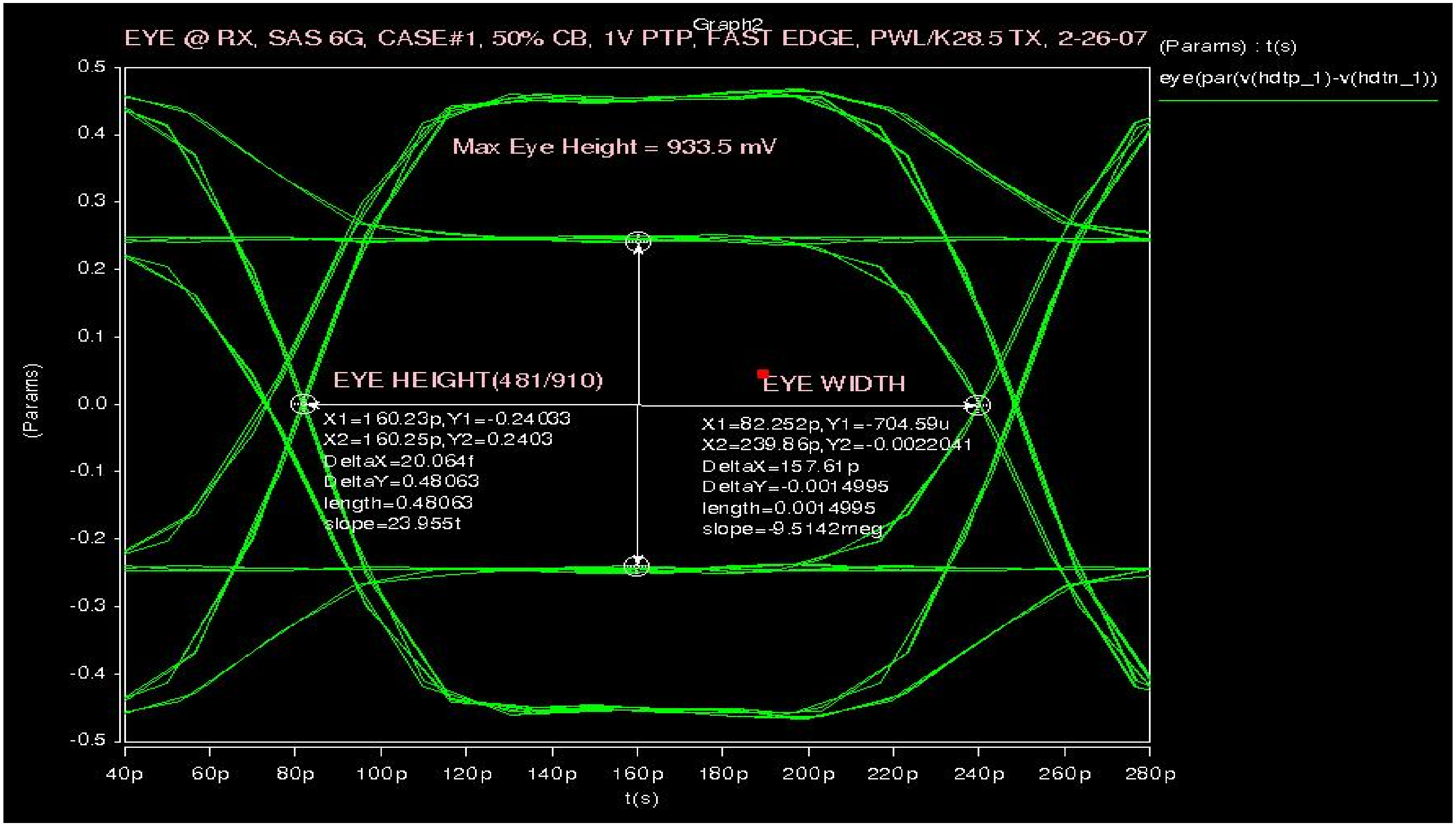
Eye Height / Max Eye: 473mV / 846mV

Case #2, 3Gbps, Tr: 100ps, 6dB



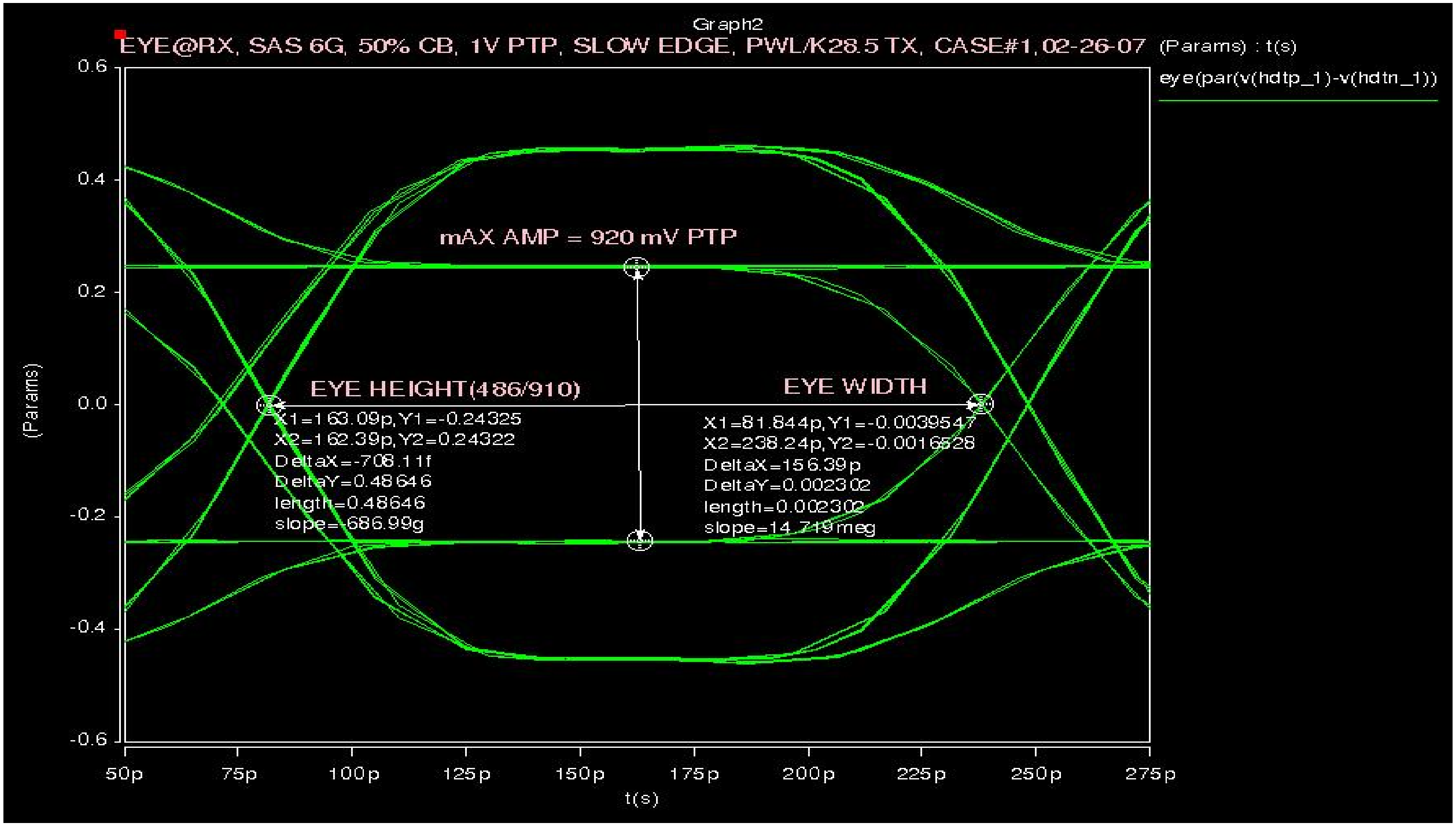
Eye Height / Max Eye: 473mV / 850mV

Case #1, 6Gbps, Tr: 33ps, 6dB



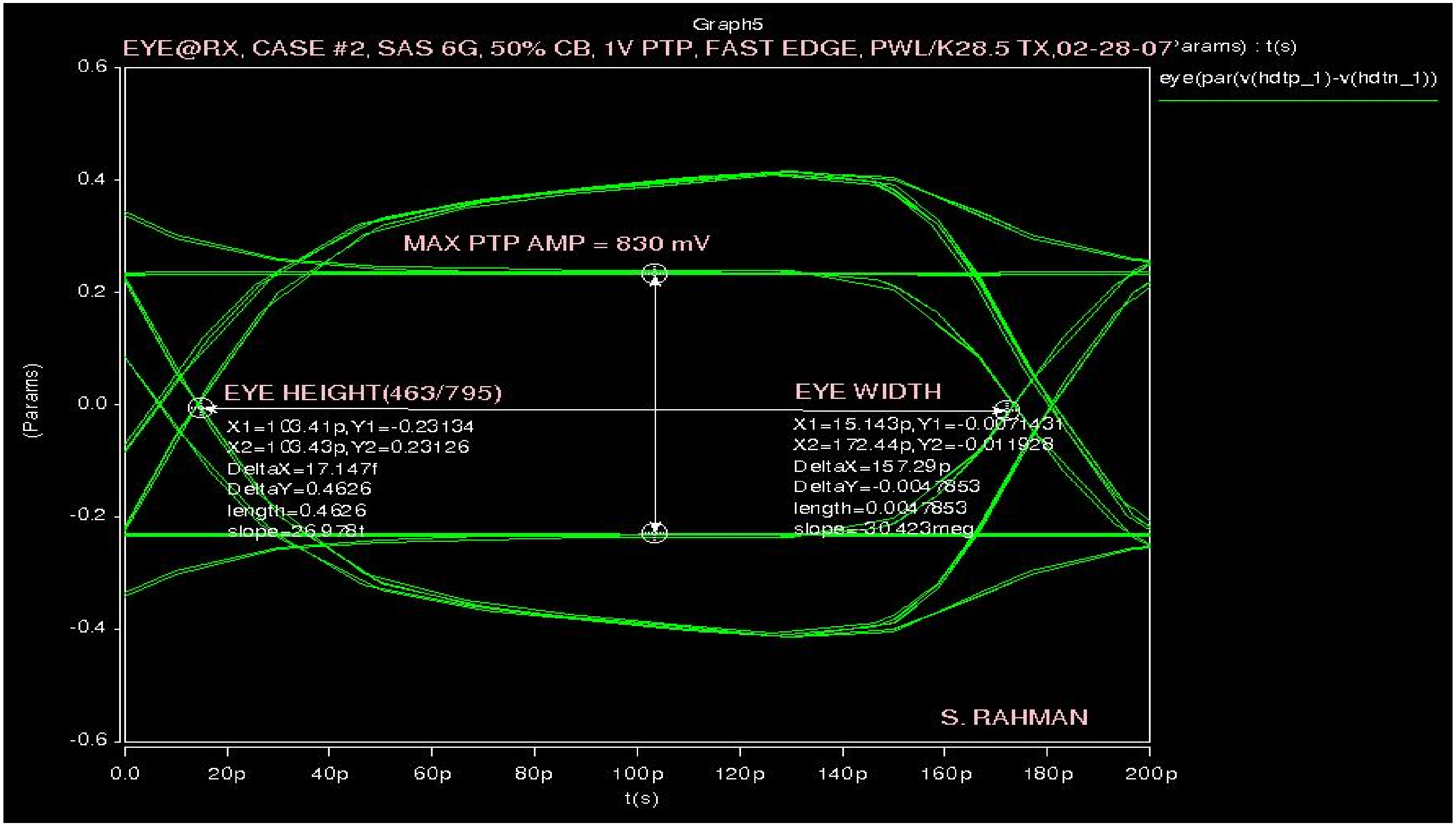
Eye Height / Max Eye: 481mV / 910mV

Case #1, 6Gbps, Tr: 50ps, 6dB



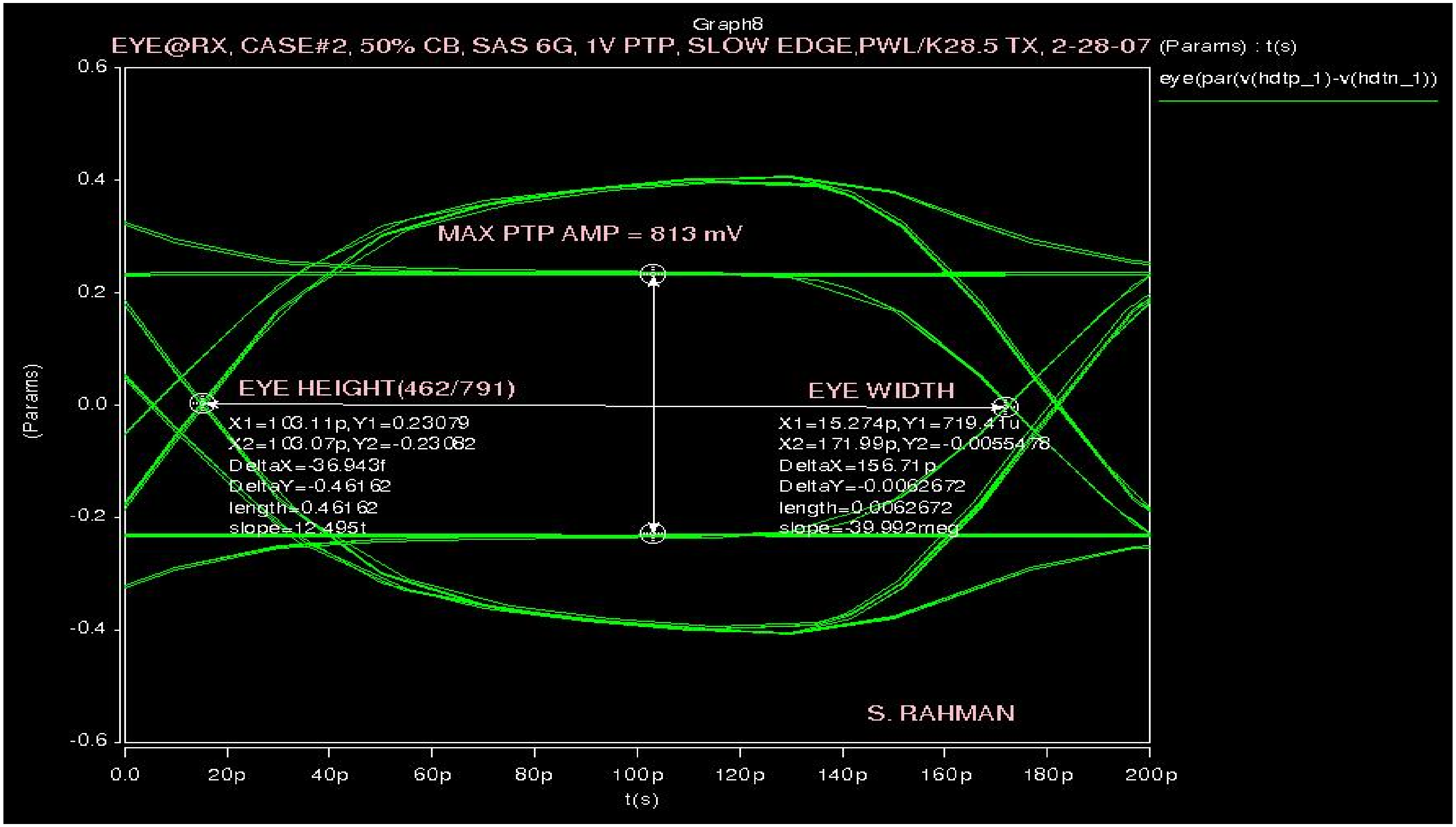
Eye Height / Max Eye: 486mV / 910mV

Case #2, 6Gbps, Tr: 33ps, 6dB



Eye Height / Max Eye: 463mV / 795mV

Case #2, 6Gbps, Tr: 50ps, 6dB



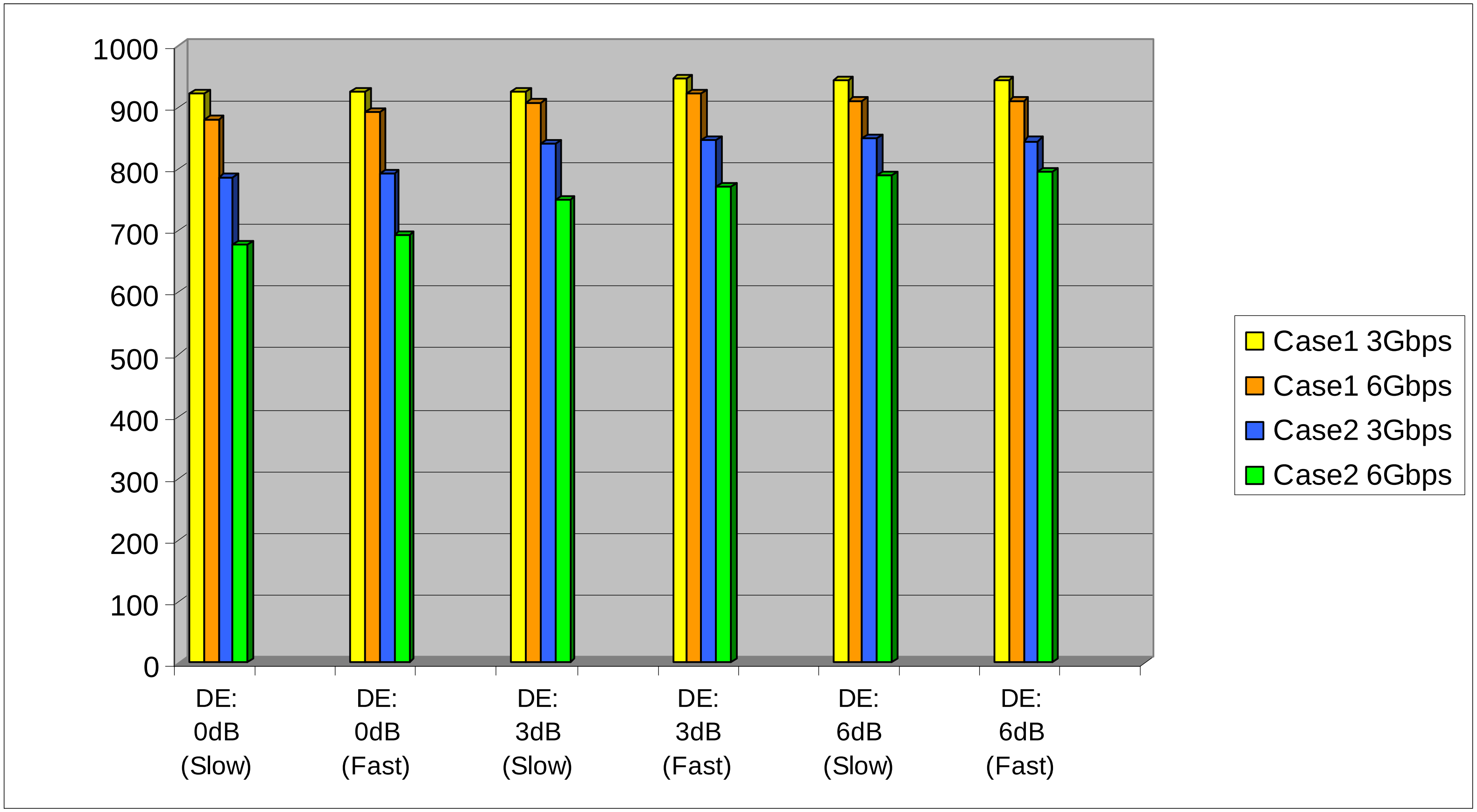
Eye Height / Max Eye: 462mV / 791mV

Simulation Summary

	Case1 3Gbps	Case1 6Gbps	Case2 3Gbps	Case2 6Gbps
DE: 0dB (Slow)	923mV	880mV	788mV	678mV
DE: 0dB (Fast)	926mV	893mV	794mV	692mV
DE: 3dB (Slow)	925mV	907mV	840mV	751mV
DE: 3dB (Fast)	946mV	923mV	848mV	772mV
DE: 6dB (Slow)	944mV	910mV	850mV	791mV
DE: 6dB (Fast)	943mV	910mV	846mV	795mV

Three and six dB measurements are pk-pk at eye midpoint of the emphasized bit. Zero dB measurements are of the eye opening.

Simulation Summary



Zero dB results are slightly misleading.

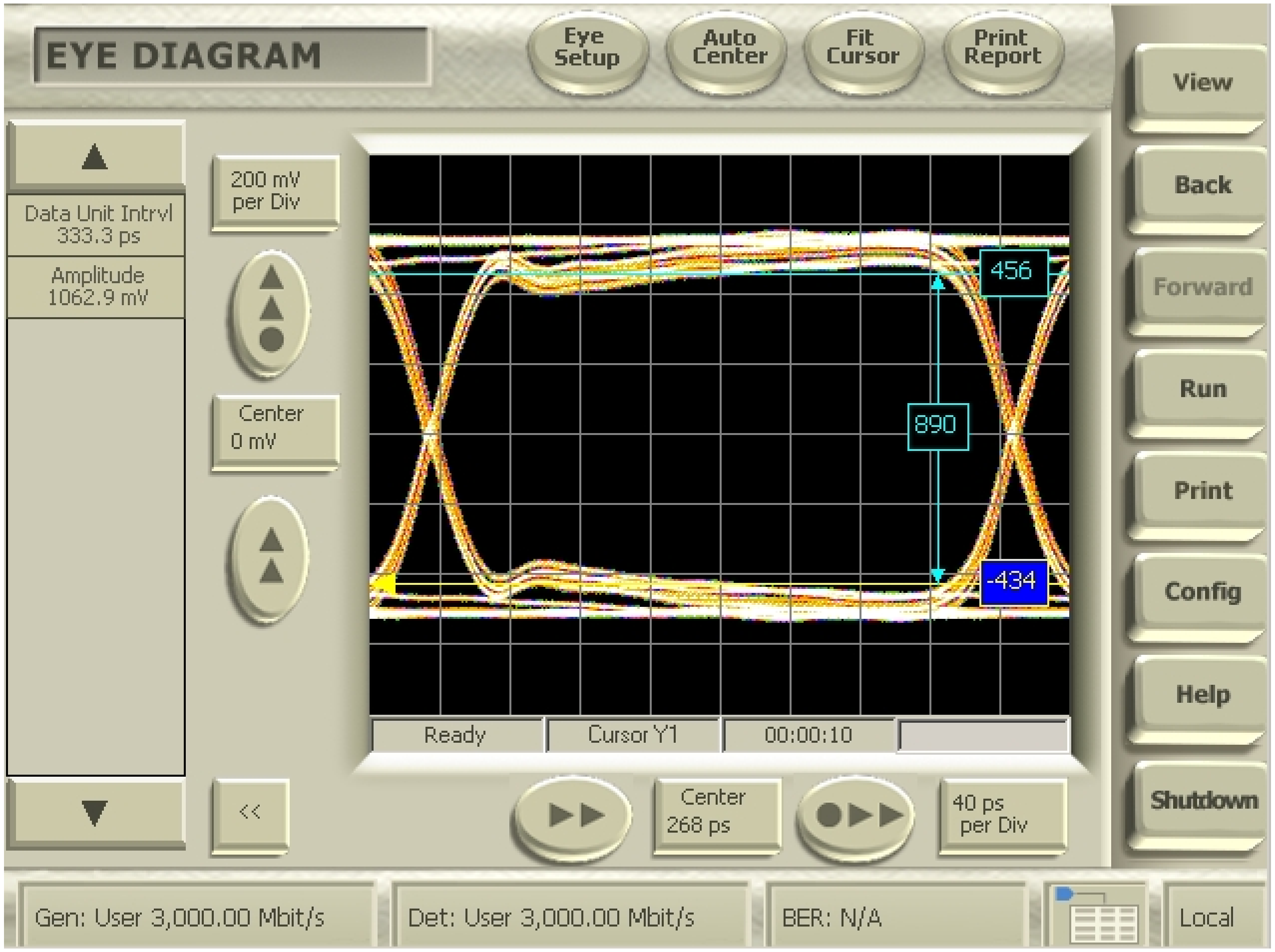
Eye Height vs. Insertion Loss

- To better understand how insertion loss effects eye height simulations were repeated with PCB trace models. The trace structure was selected to obtain 100 ohms differential and noticeable skin effect losses. The trace length was computed to obtain 0.5 to 6dB of insertion loss at 3GHz in increments of 0.5dB
- Eye height measurements were made by taking approximating the average value obtained after transition bits

Measurement Correlation

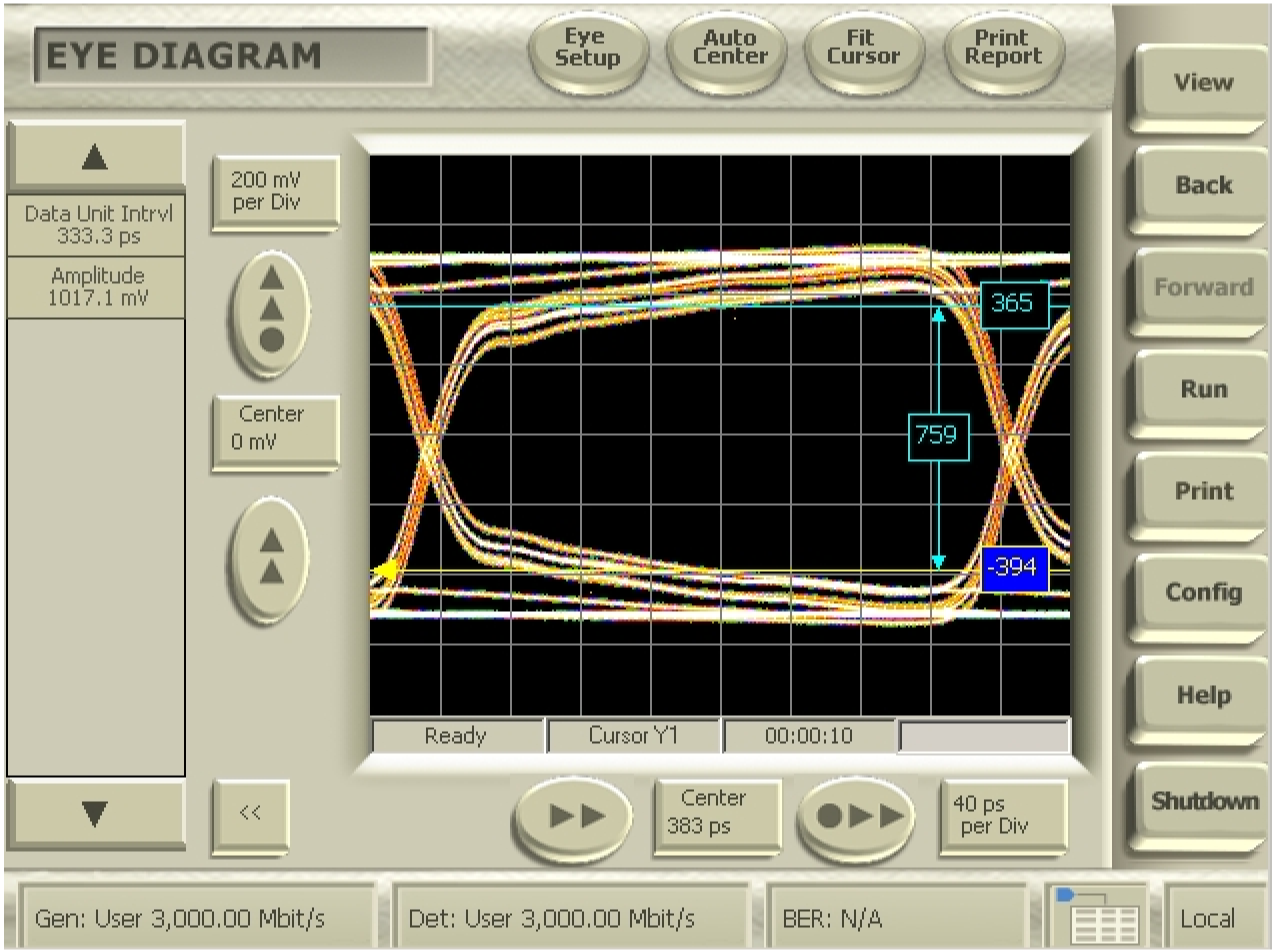
- All previous simulations utilized S-Parameter files of the interconnect.
- To validate the simulation results, measurements were made with using the actual hardware of case #1 and #2.
- Due to hardware limitations, only the 0dB cases are measured

Case #1, 3Gbps, 0dB



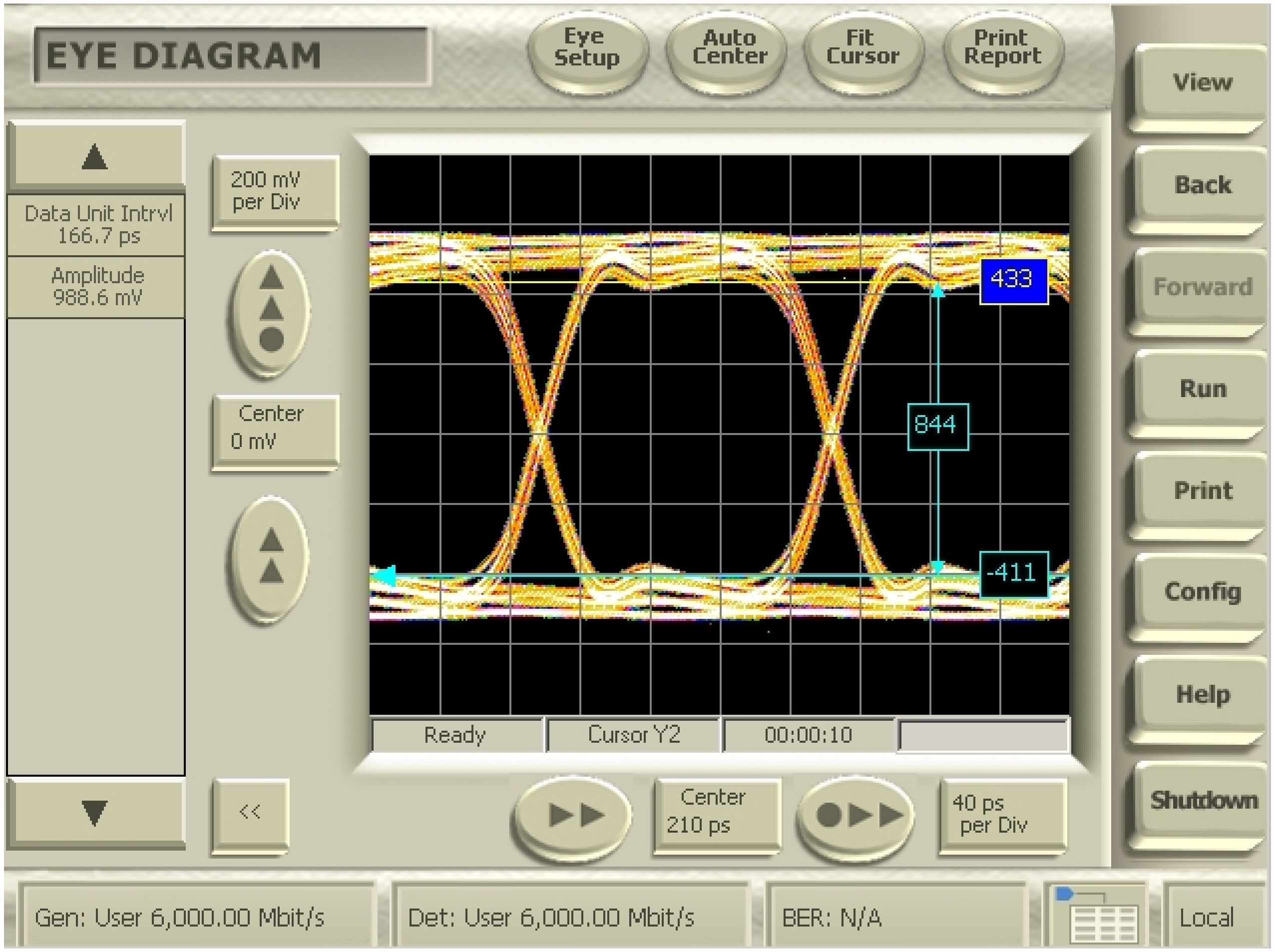
Eye Height Measured / Simulated: 890mV / 926mV

Case #2, 3Gbps, 0dB



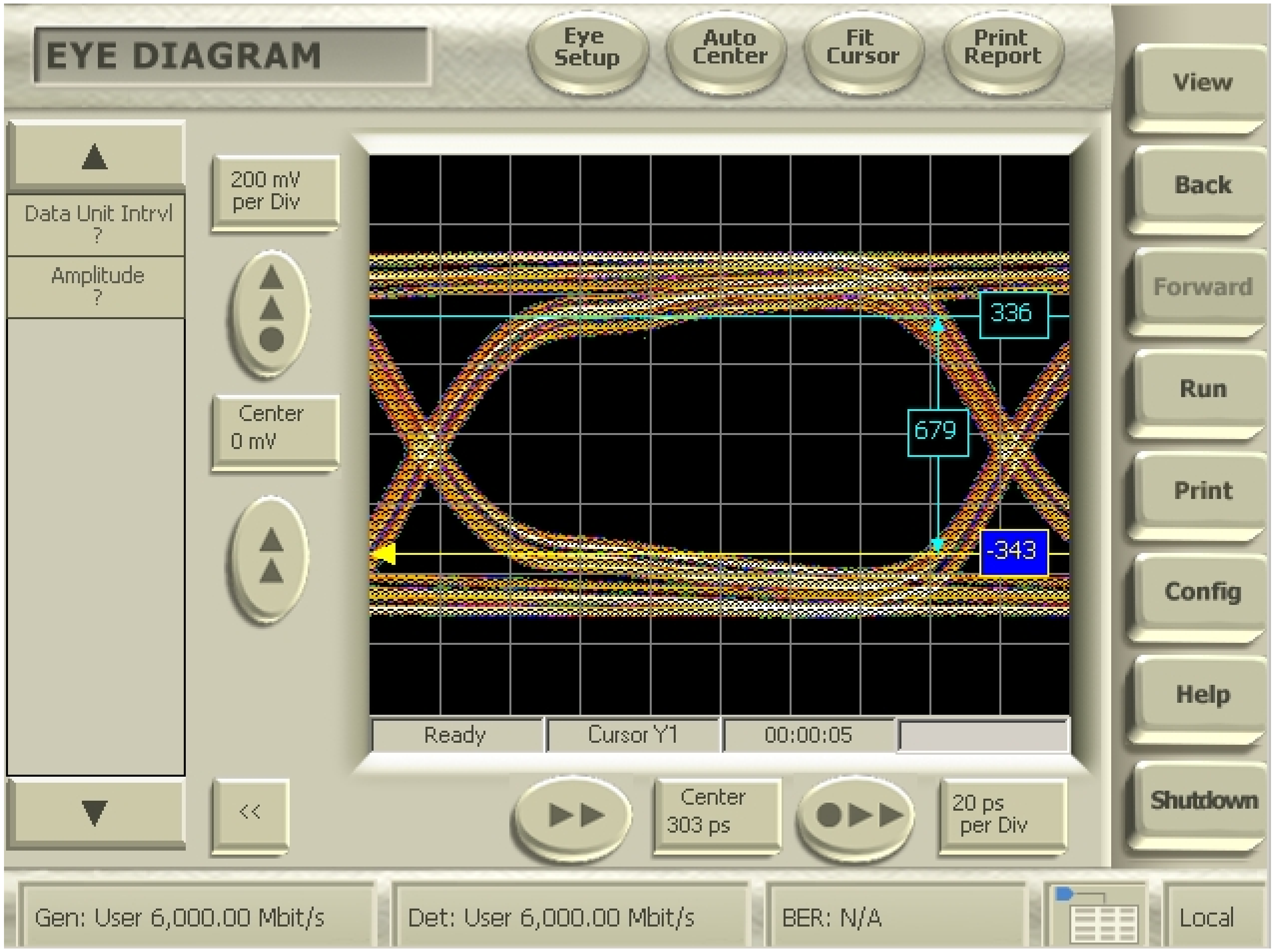
Eye Height Measured / Simulated: 759mV / 794mV

Case #1, 6Gbps, 0dB



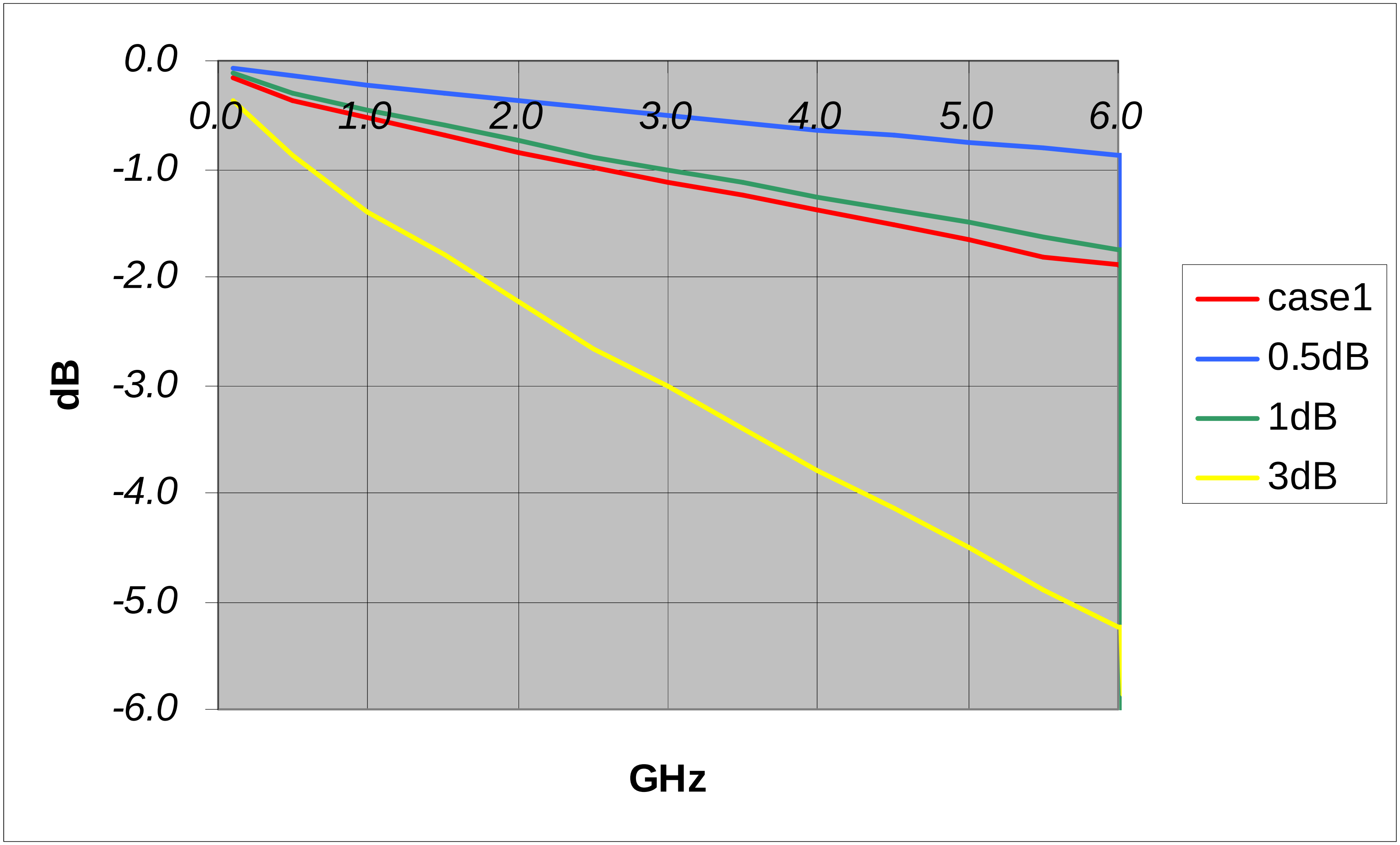
Eye Height Measured / Simulated: 844mV / 893mV

Case #2, 6Gbps, 0dB

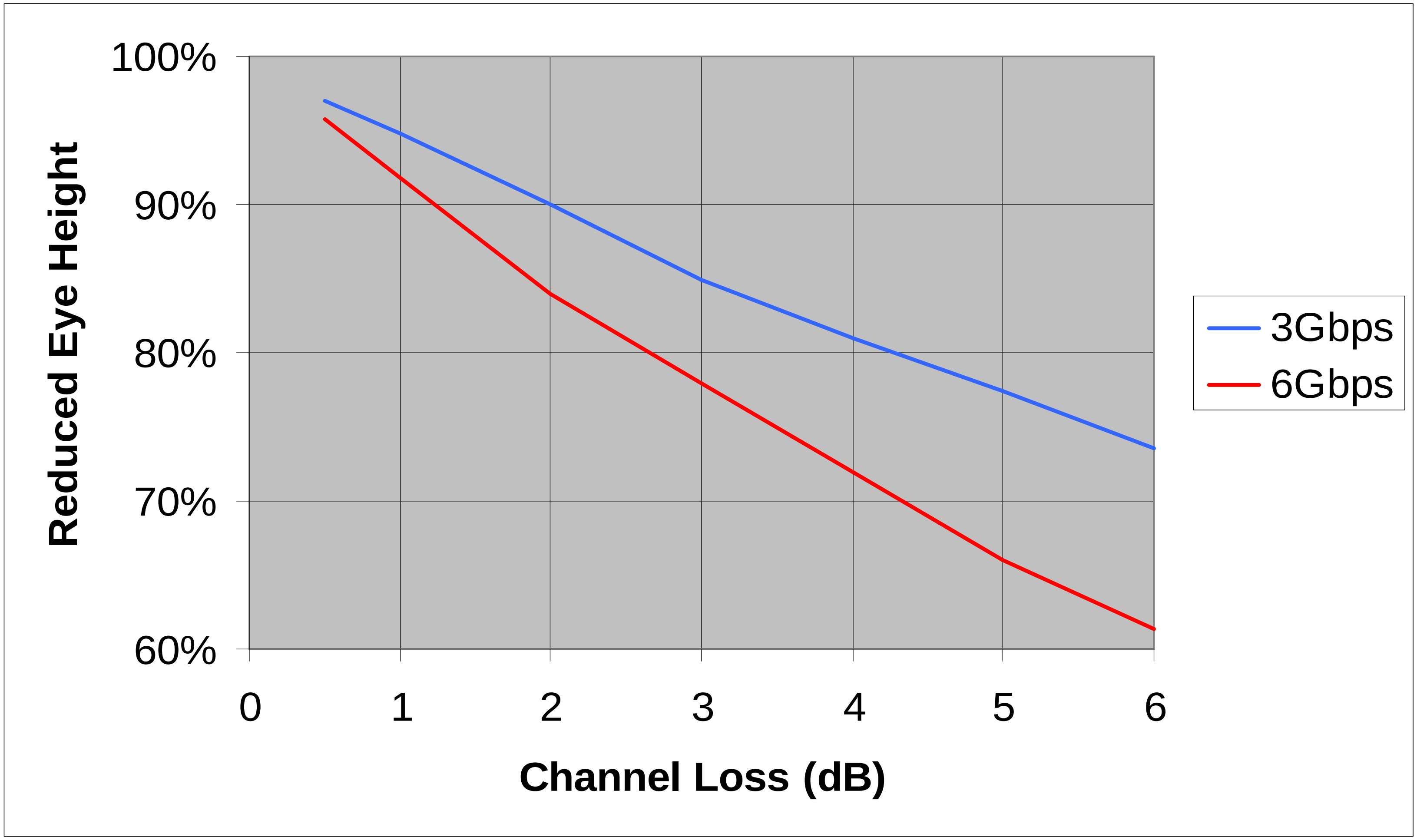


Eye Height Measured / Simulated: 679mV / 692mV

Trace Model Insertion Loss

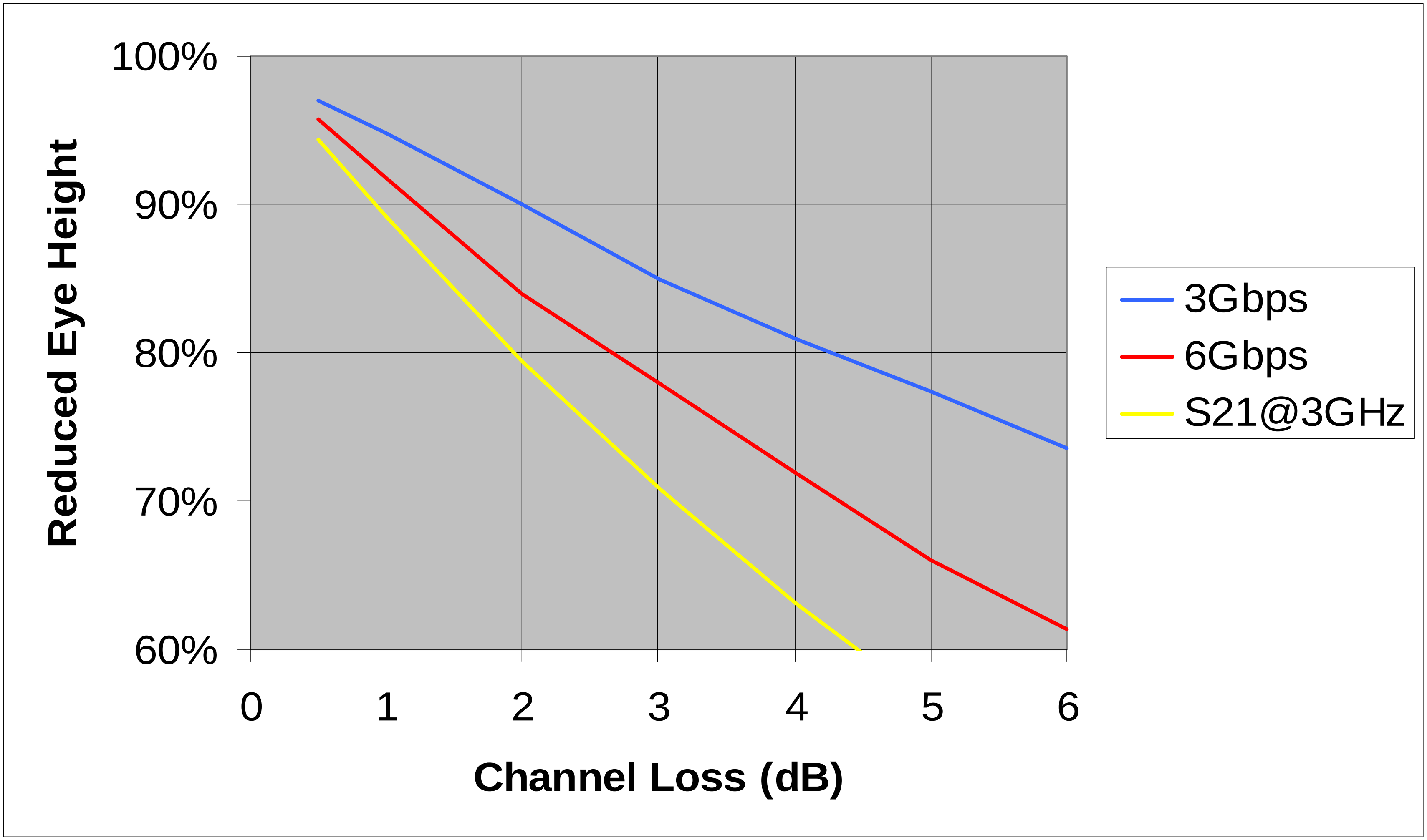


Eye Height vs. Channel Loss



(Insertion Loss Measured at 3GHz)

Comparison to Nyquist for 6Gbps

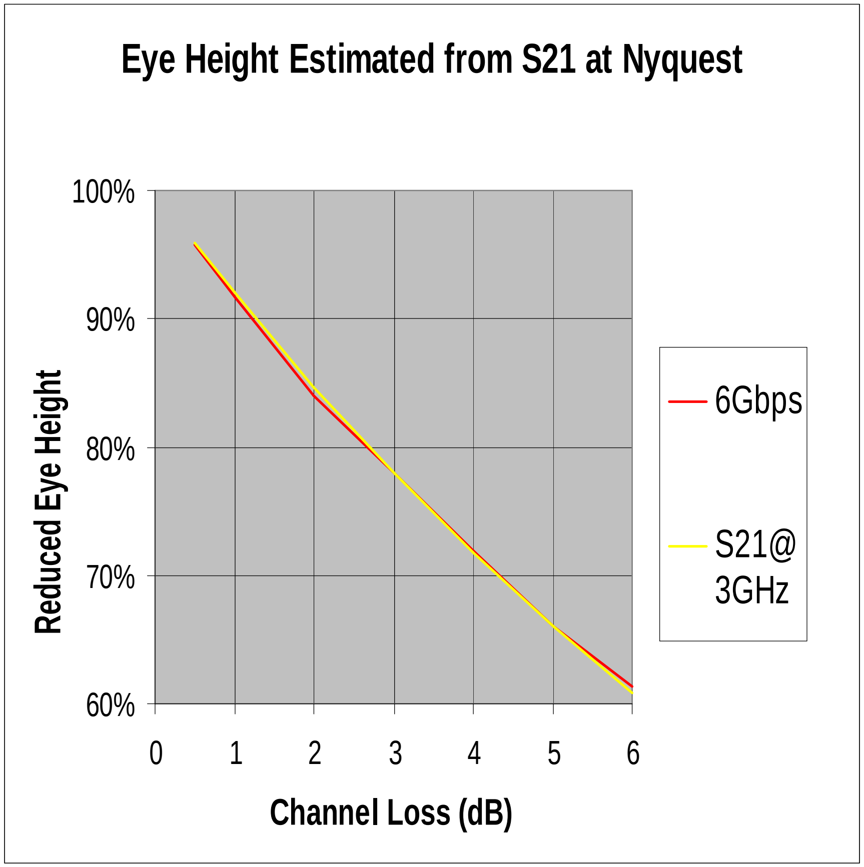


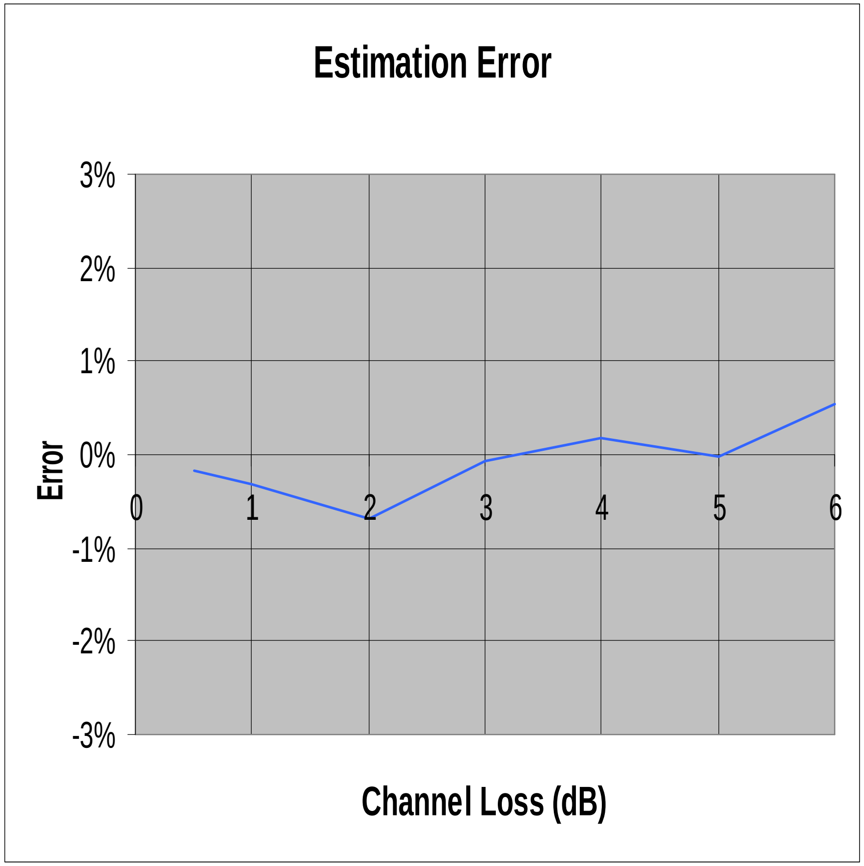
(Insertion Loss Measured at 3GHz)

Fixture De-embedding

- De-embedding appears to be a reasonable method for removing errors in near-end measurements induced by test fixtures and cables
- However, some level of expertise in modeling tools and the availability instrumentation that can characterize fixturing and cables is required
- Can we obtain a crude estimate of bit amplitude by measuring insertion loss at the Nyquist frequency and by applying fractional power x?
  - Estimate = $S_{21}(\text{Nyquist})^x$
  - For this case, x = 0.72 is selected

Results of Eye Height Estimation and Error





(Insertion Loss Measured at 3GHz)

Fixture De-embedding by Estimation from Nyquist

- This simple sample indicates that rigorous modeling of test fixture effects may not be required in order to obtain accurate estimates of transmitter waveforms
- This assumption may fail if return loss effects are no longer negligible

Fixture Return Loss

- Clearly the insertion loss is a major factor in the waveform degradation. The return loss may also be a factor.
- Three fixtures were measured to determine typical return loss values. Note that only the SMA launch and fixture trace are included.

Estimated Test Fixture Return Loss