Application Report
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# HIGH SPEED GIGABIT DATA TRANSMISSION ACROSS VARIOUS CABLE MEDIA AT VARIOUS LENGTHS AND DATA RATE

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## ABSTRACT

This application report focuses on characteristics of Gigabit signals across different cable media, transmission distance and data rate. The signal quality of four different cables is evaluated using eye measurements and TI's TLK2500 evaluation modules (EVMs). This document provides guidance for cable selection to use with Texas Instruments line of Gigabit parts.

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## Introduction

The transmission line plays an important role in network, communication. The signal quality is mainly decided by the cable performance. The general issue in communication's cabling is the ability to handle the required data rate over a given distance. This report shows the customer the characteristics of gigabit signals across different cable via different length and data rate.

Four different cables are tested using the TLK2500EVM board with TLK2500 multigiagabit transceiver and interface board for the cable under test. The TLK2500 evaluation module (EVM) board is used to evaluate the TLK2500 for data transmission applications. All tests are performed at room temperature with nominal performing TLK2500 devices.

# Base line eye measurement

## Description

This test is used to establish a base line eye measurement over three different R-Ref values and three different frequencies. The test uses the TLK2500EVM in test mode configured to generate $2^7$-1 PRBS (Pseudo Random Bit Stream) pattern.

TLK2500 offers the options for the voltage swing by adjusting reference resistor R_Ref and termination resistor Z. The equation for the de-emphasis is as follows.

Vod=(3.75/R_Ref)*Z  (in our case, Z=50 for the transmission line)

The theoretical values for the various R_Ref are as follows:

R_Ref=100  Vod=1875 mv

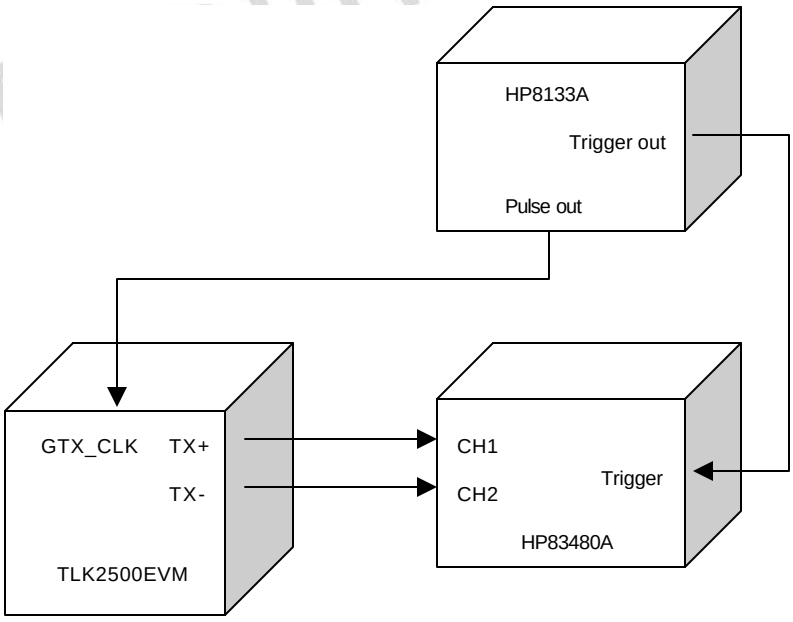
R_Ref=200  Vod=937.5 mv

R_Ref=500  Vod=375  mv

## Test setup

The test set up for the base line eye measurement is shown as below:

**Figure 1.  Base line test setup**




Baseline testing will be tested at boundary conditions that represent maximum, nominal and minimum high speed serial output voltage swing. This will require changing R-Ref resistor to 100, 200 and 500 Ohms.

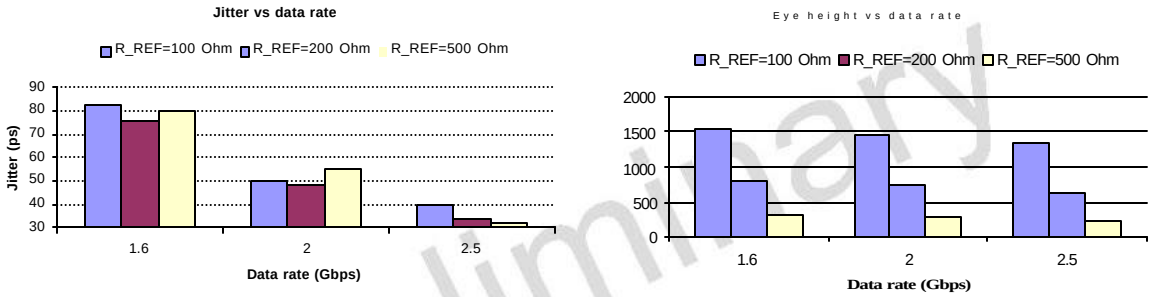
## Test result

At normal ambient, record eye measurements at different R-Ref values over various frequencies in the following table.

**Table 1. Base line eye measurements**

| R-Ref (Ohm) | 1.6 Gbps | | 2.0 Gbps | | 2.5 Gbps | |
|---|---|---|---|---|---|---|
| | Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) |
| **100** | 82.8 | 1551.49 | 50.1 | 1473.4 | 39.7 | 1336.1 |
| **200** | 75.6 | 784.10 | 48.9 | 732.61 | 33.3 | 633.30 |
| **500** | 80.4 | 314.76 | 55.4 | 291.02 | 31.9 | 228.85 |

**Figure 2. Bar chart of eye measurement**






## Conclusion

From the testing result, we can see with the R_REF=100, we got the maximum output swing via various different data rate, so we fix this value for the cable eye measurement for the different cable because cable length is more amplitude dependent than jitter dependent. Considering the jitter, we choose the R_Ref=200 for the default value on EVM to get the optimum result.

There exists little discrepancy between the theoretical value we got from the formula and the test result, this is mainly due to the cable and connector insertion loss.

# Cat5 cable eye measurement

## Description

This test is used to establish eye measurement over cable length and frequency. The test uses the TLK2500EVM in test mode configured to generate a PRBS pattern. The PRBS pattern will be sent across different cable length until a maximum length is reached. The maximum length is when the cable length exhibit either 60% eye closure or eye height drops below 200 mVCable selection

Since cable quality contributes strongly to signal quality, cable quality should be evaluated in detail. Three different cat5 cables are tested using TLK2500EVM.

- Cable A: BELDEN-E DATATWIST® 1585A

CAT5, specified up to 200MHz, blue cable in the following figure

- Cable B: BELDEN-M DATATWIST®1701A

CAT5 (exceeding CAT5), specified up to 350MHz, white cable in the following figure

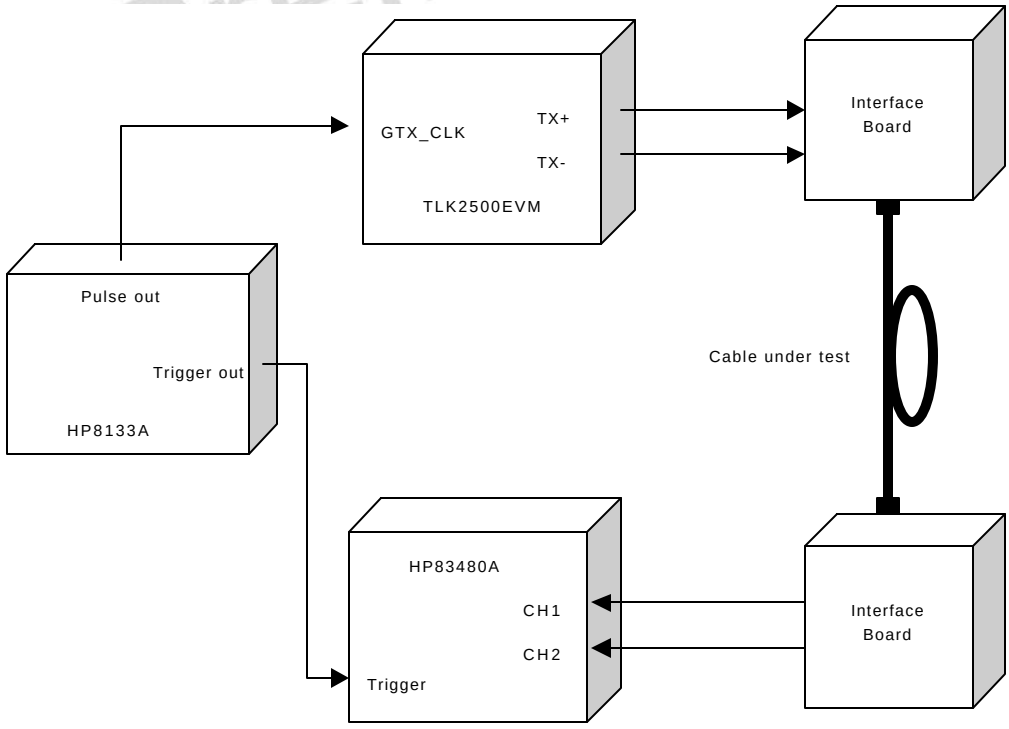
- Cable C: BELDEN-M MEDIATWIST® 1872A

CAT5 (exceeding CAT5), specified up to 350MHz, red cable in the following figure

**Figure 3. Picture of the cables**

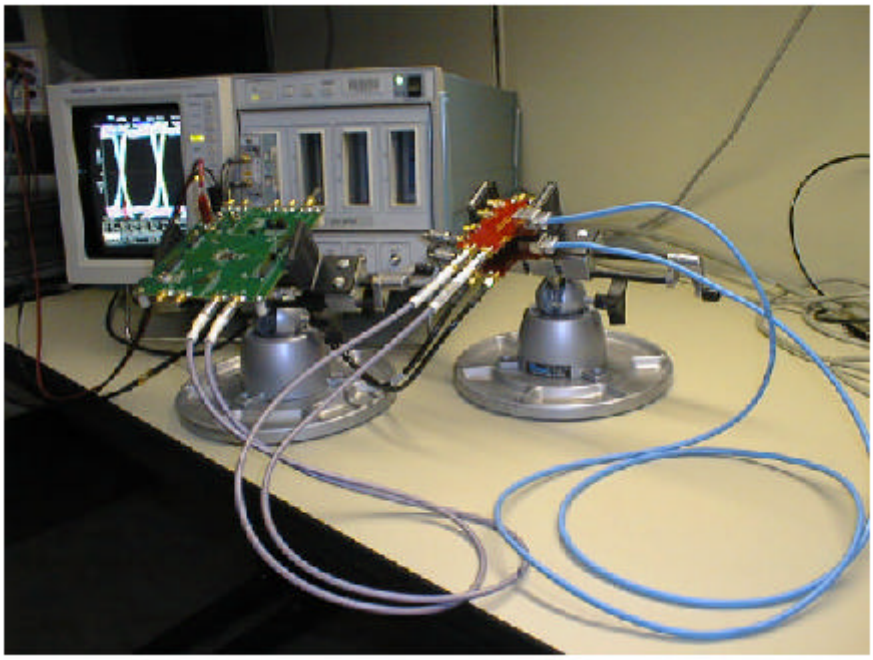
## Test setup

**Figure 4. Cable eye measurement test setup**



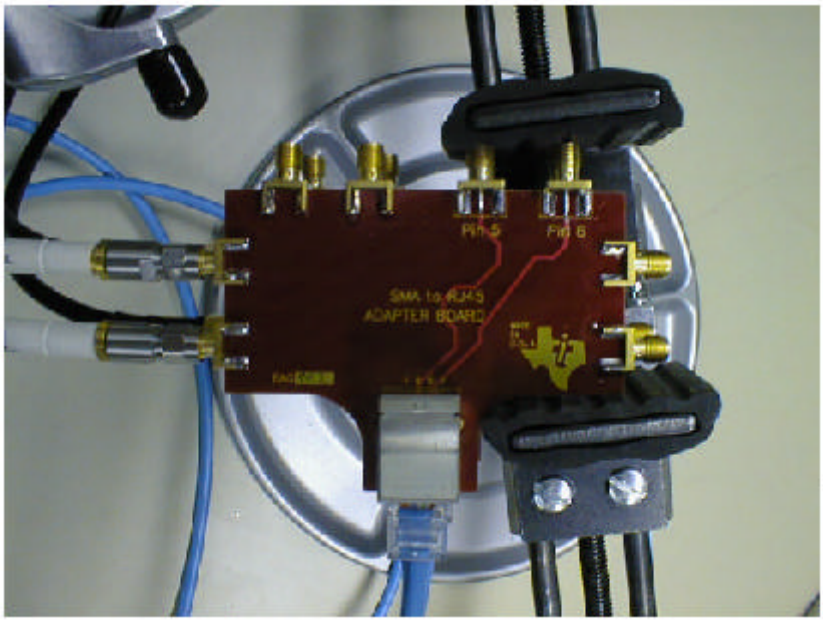
The picture of the above test setup is shown in the following.

**Figure 5. Picture of the test setup**



The interface board used for testing the Belden cable is SMA-to-RJ45 adapter board, the picture of it can be seen as belows.

**Figure 6. Picture of the SMA-to-RJ45 adapter board**



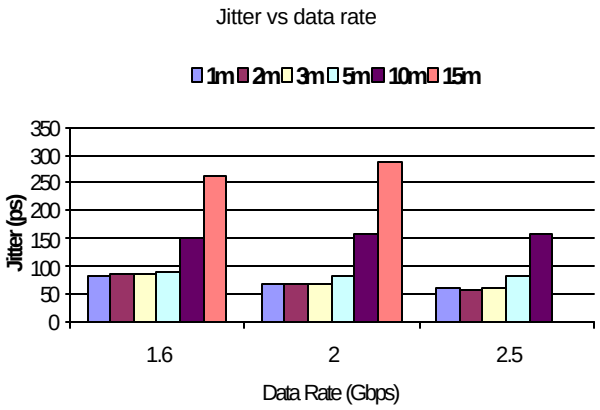
## Test result

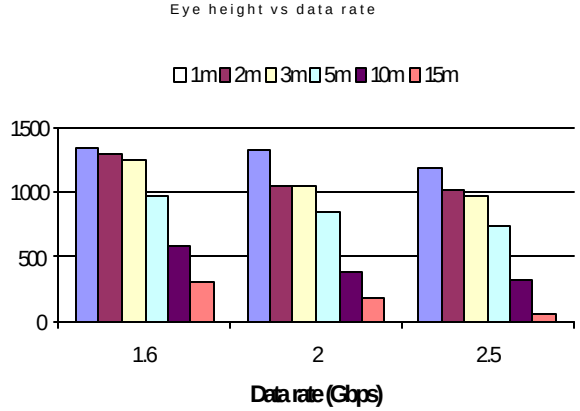
### 1. Cable A -----BELDEN-E DATATWIST® 1585A

**Table 2. Cable A eye measurement**

| LENGTH (m) | 1.6 Gbps | | 2.0 Gbps | | 2.5 Gbps | |
|---|---|---|---|---|---|---|
| | Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) |
| **1** | 81.3 | 1343.91 | 65.4 | 1316.43 | 58.7 | 1183.16 |
| **2** | 88.0 | 1295.36 | 69.3 | 1037.05 | 56.0 | 1012.78 |
| **3** | 84.0 | 1243.15 | 65.8 | 1040.26 | 60.0 | 955.82 |
| **5** | 90.0 | 979.29 | 79.3 | 842.77 | 80.0 | 746.13 |
| **10** | 148.9 | 582.78 | 157.1 | 387.60 | 158.7 | 315.44 |
| **15** | 264.0 | 301.54 | 286.2 | 174.75 | NO DATA | 54.41 |

**Figure 7. Jitter and eye height vs data rate of Cable A**



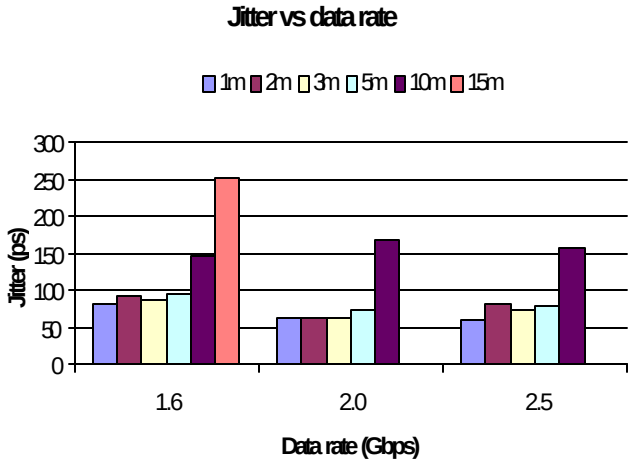



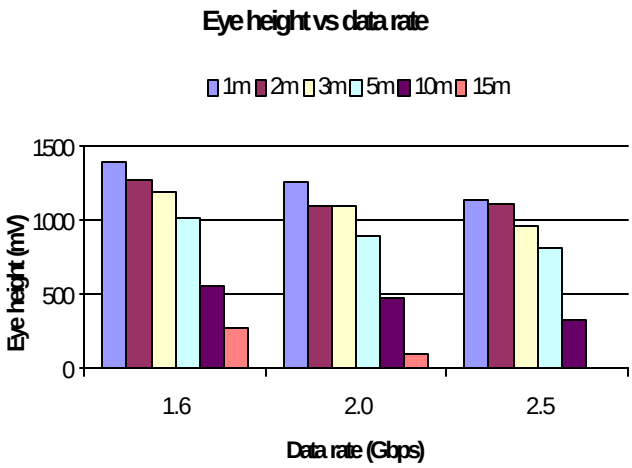

### 2. Cable B-----BELDEN-M DATATWIST ® 1701A

**Table 3. Cable B eye measurement**

| LENGTH (m) | 1.6 Gbps | | 2.0 Gbps | | 2.5 Gbps | |
|---|---|---|---|---|---|---|
| | Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) |
| **1** | 82.0 | 1399.32 | 63.8 | 1251.72 | 62.7 | 1147.04 |
| **2** | 92.0 | 1267.05 | 65.3 | 1105.86 | 81.3 | 1109.37 |
| **3** | 88.0 | 1186.89 | 63.8 | 1099.73 | 73.3 | 960.43 |
| **5** | 96.0 | 1008.59 | 74.7 | 901.53 | 80.0 | 815.01 |
| **10** | 146.0 | 546.12 | 169.6 | 475.03 | 158.7 | 332.15 |
| **15** | 252.0 | 266.76 | # N/A | 103.75 | # N/A | # N/A |

**Figure 8. Jitter and eye height vs data rate of Cable B**



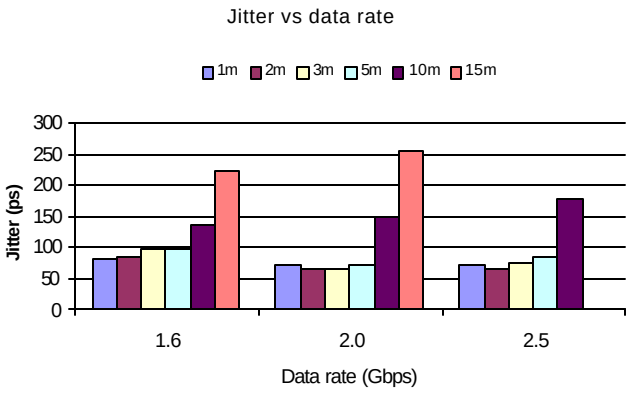

## 3. Cable C-----BELDEN-M MEDIATWIST ® 1872A

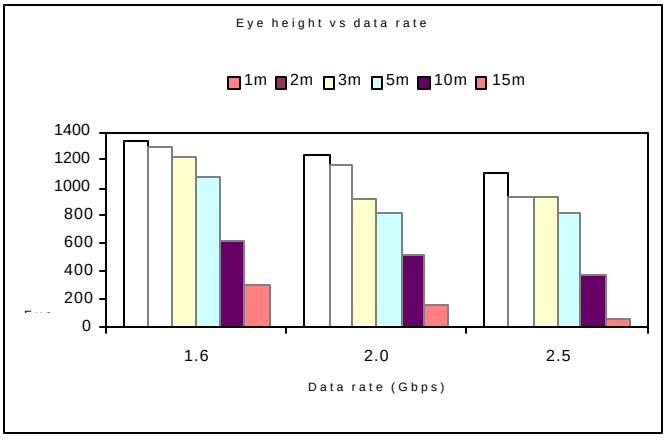
**Table 4. Cable C eye measurement**

| LENGTH (m) | 1.6 Gbps | | 2.0 Gbps | | 2.5 Gbps | |
|---|---|---|---|---|---|---|
| | Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) |
| **1** | 80.0 | 1327.65 | 71.6 | 1236.05 | 70.7 | 1099.56 |
| **2** | 84.0 | 1293.16 | 65.3 | 1155.19 | 65.3 | 930.06 |
| **3** | 96.0 | 1227.02 | 65.3 | 922.72 | 73.3 | 924.81 |
| **5** | 98.0 | 1083.61 | 68.4 | 812.17 | 81.3 | 825.06 |
| **10** | 136.0 | 615.47 | 149.3 | 519.26 | 177.3 | 384.28 |
| **15** | 224.0 | 302.92 | 255.0 | 160.96 | #N/A | 60.79 |



**Figure 9. Jitter and eye height vs data rate of Cable C**




## Conclusion

In summary, the whole characteristic of the cable testing are shown in belows:

**Figure 10. Jitter Vs Cable Length**

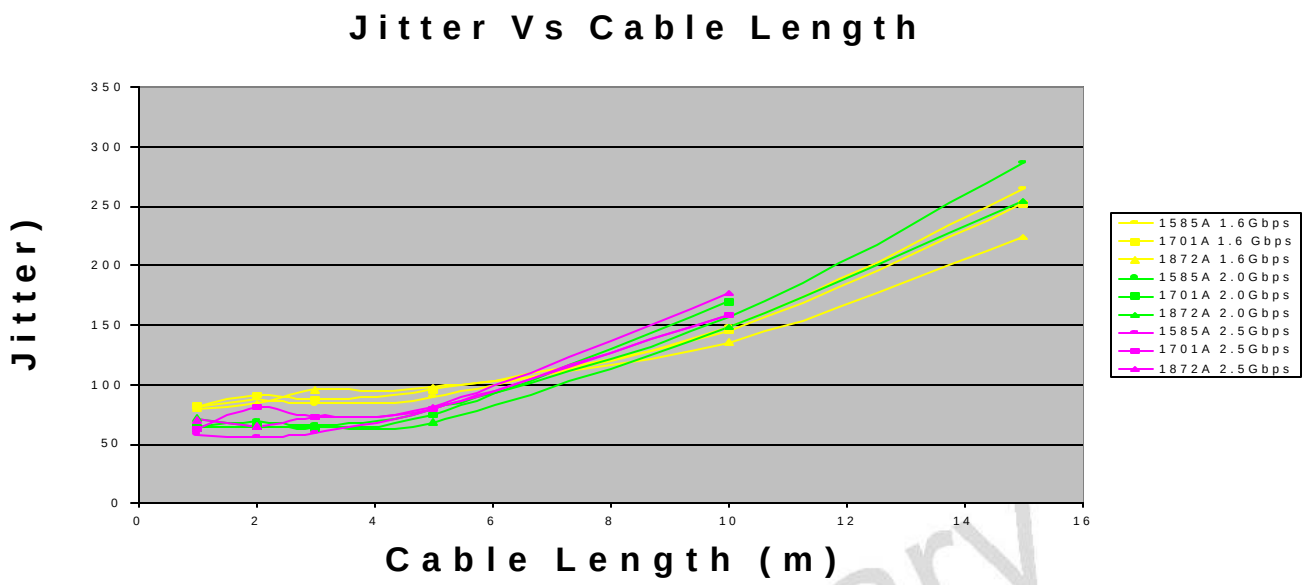
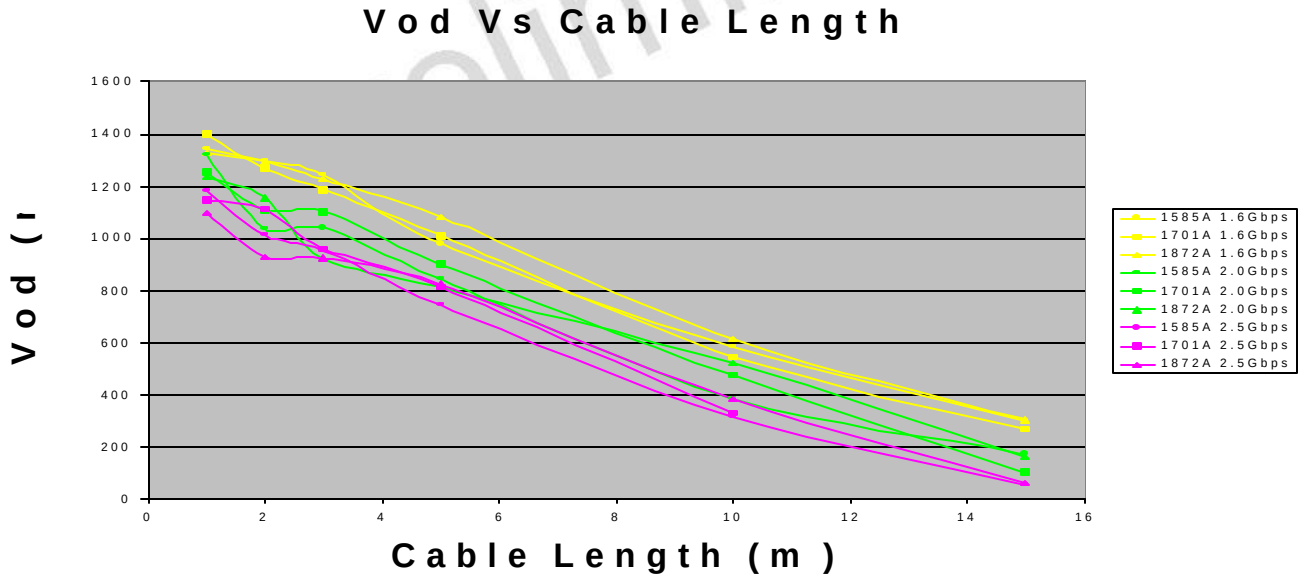



**Figure 11. Vod Vs Cable Length**




The eye height decreased with an increase in frequency and may be limited by rise time.

At short length, the PLL jitter improves with increasing the data rate, but at long length, the cable length will dominate the PLL jitter performance. We can see at some length, the jitter increased with increasing the data rate.

The amplitude loss is more significant than jitter in long distance transmission. This amplitude loss could have resulted due to connector reflections or cable loss.

From the test results of the four cables, we can see that the MediaTwist® 1872A Cable is the best solution, the maximum length is 10m at 2.5Gbps.

## Twinax cable eye measurement

In this measurement, we choose Gore DXSN2095 twinax cable for testing. We used the same test set up except for the interface board is Teradyne VHDM backplane open-ended differential part #494_5010-002.

The cable is shown in the figure10 and the interface board is shown in figure11.

**Figure 12. Picture of Gore twinax cable**

**Figure 13. Interface board**

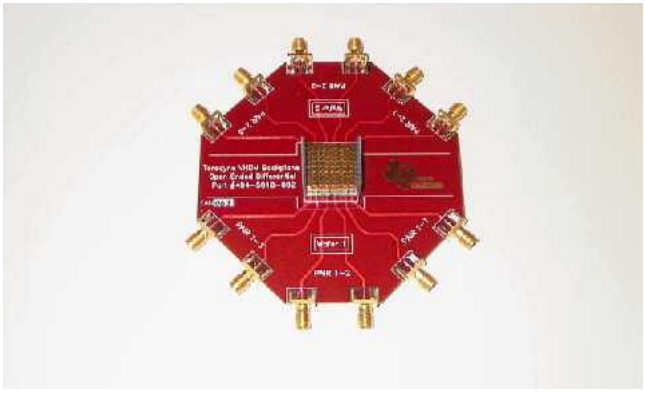
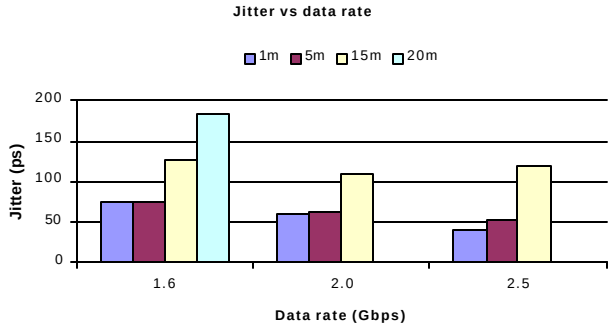
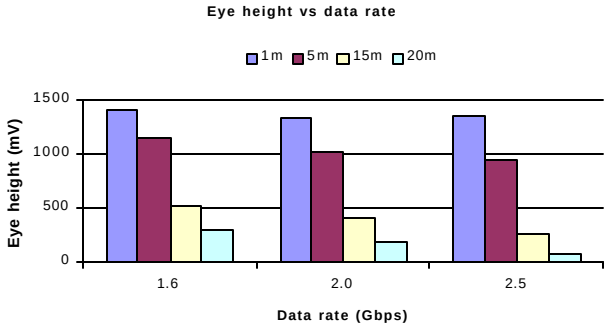


**Table 5. Cable D eye measurement**

| LENGTH | 1.6 Gbps | | 2.0 Gbps | | 2.5 Gbps | |
|---|---|---|---|---|---|---|
| (m) | Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) | Jitter (ps) | Vod (mV) |
| **1** | 74.0 | 1416.87 | 59.1 | 1337.79 | 41.3 | 1353.12 |
| **5** | 76.0 | 1154.59 | 62.2 | 1022.12 | 52.0 | 947.81 |
| **15** | 126.0 | 528.13 | 110.4 | 400.26 | 117.3 | 266.89 |
| **20** | 182.0 | 293.36 | #N/A | 183.45 | #N/A | 86.97 |

**Figure 14. Jitter and eye height vs data rate of Cable D**




Cat5 cable is cost effective vs Gore Twinax cable, but the Gore cable gives the better performance, whose maximum length is 15m @ 2.5Gbps.

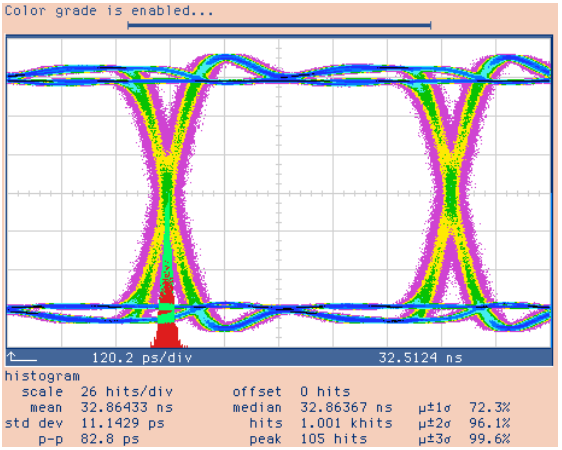
## References


1. *DATATWIST® 5 – 1585A Specifications Rev.13E* , Belden Technical papers (11/19/99)
2. *DATATWIST® 350 – 1701A Specifications Rev.12,* Belden Technical papers (12/02/99)
3. *MEDIATWIST® 5 – 1872A Specifications Rev.6* , Belden Technical papers (12/02/99)
4. *Performance of LVDS With Different Cables Application Report* (SLLA053), Aug, 1999


## Appendix

**Figure 15. Eye measurement @ R_Ref=100 Ohm captured from HP83480A**

Figure 8a. @ 1.6GHz data rate



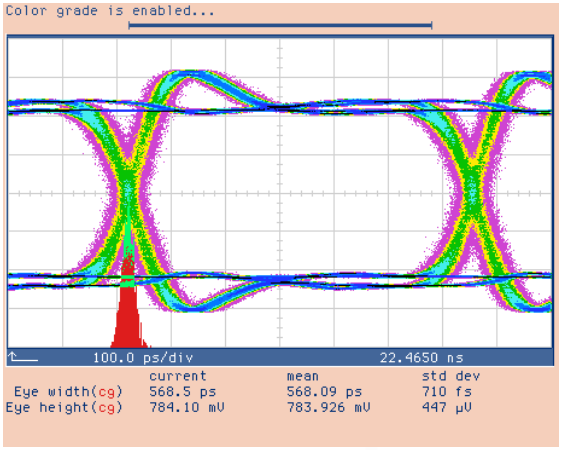
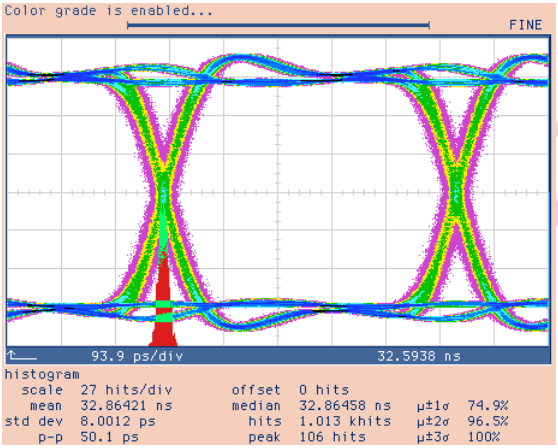




Figure 8b. @ 2.0Gbps date rate



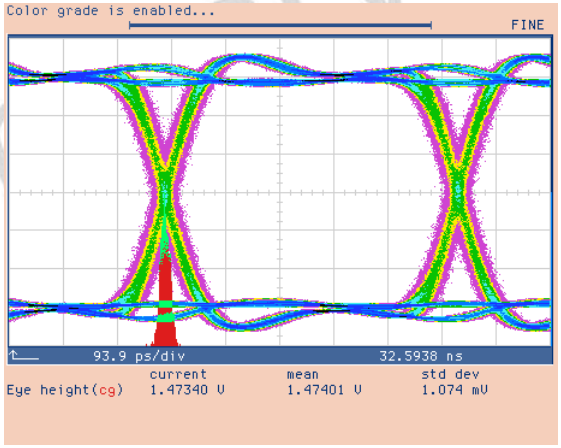
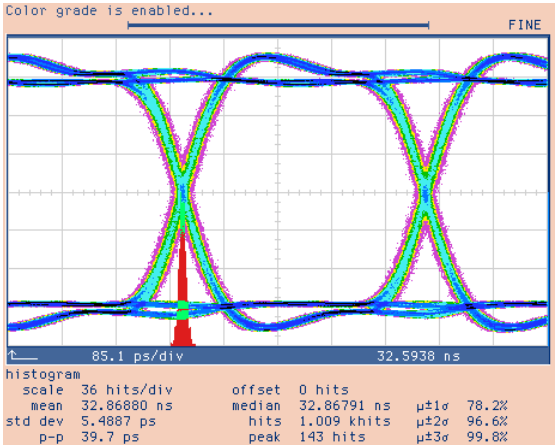




Figure 8c. @ 2.5Gbps data rate



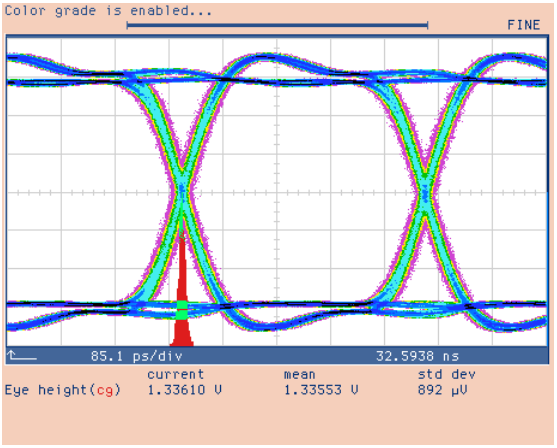
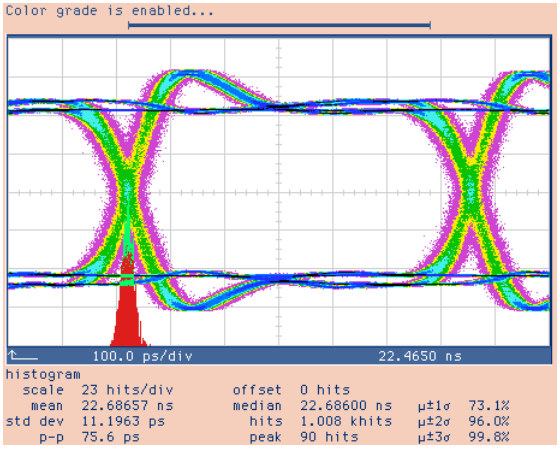



**Figure 16. Eye measurement @ R_Ref=200 Ohm captured from HP83480A**

Figure 9a. @ 1.6Gbps data rate



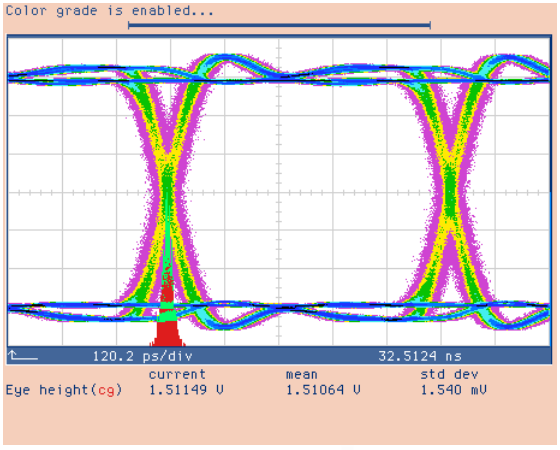
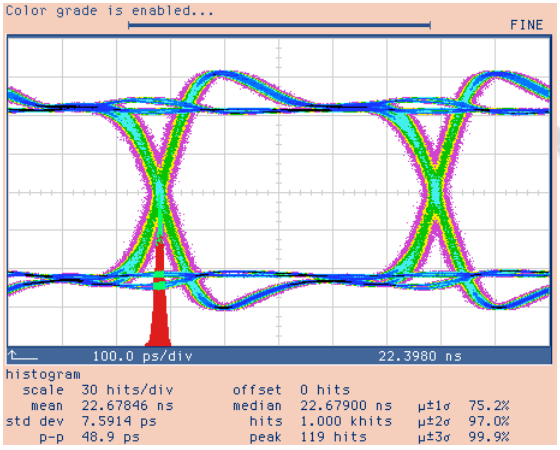




Figure 9b. @ 2.0Gbps data rate



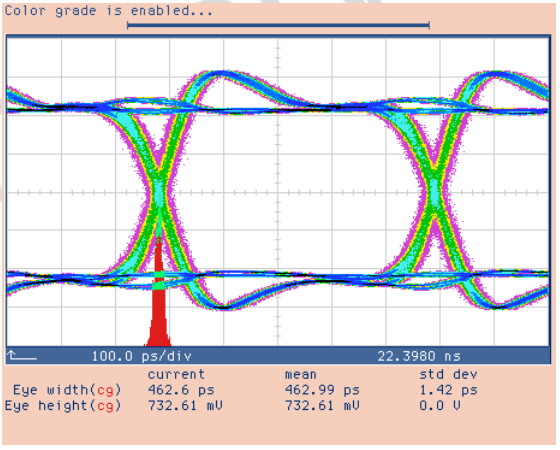
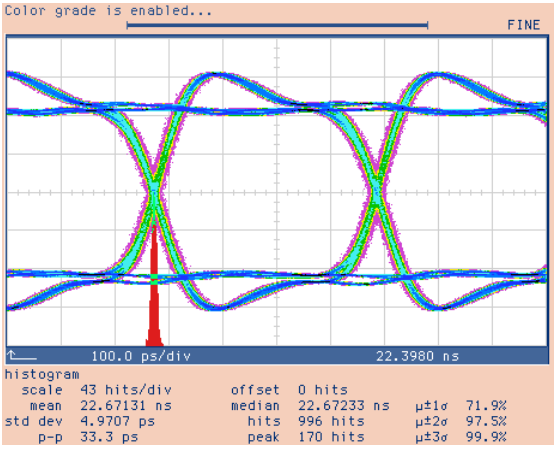




Figure 9c. @ 2.5Gbps data rate



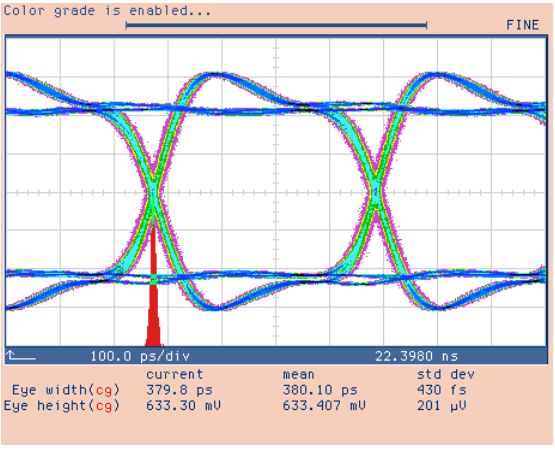



**Figure 17. Eye measurement @ R_Ref=500 Ohm captured from HP83480A**

Figure 10a. @ 1.6Gbps data rate

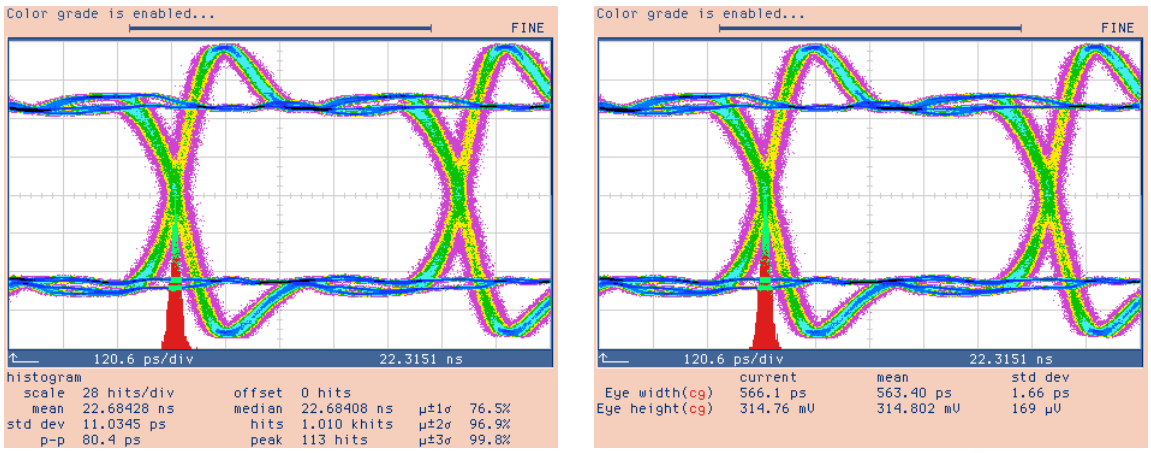



Figure 10b. @ 2.0Gbps data rate

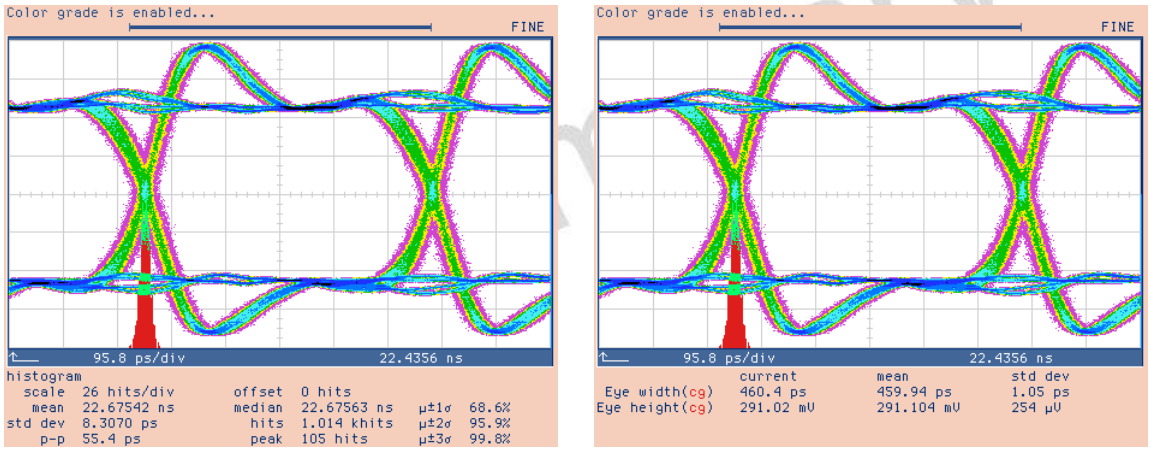



Figure 9c. @ 2.5Gbps data rate

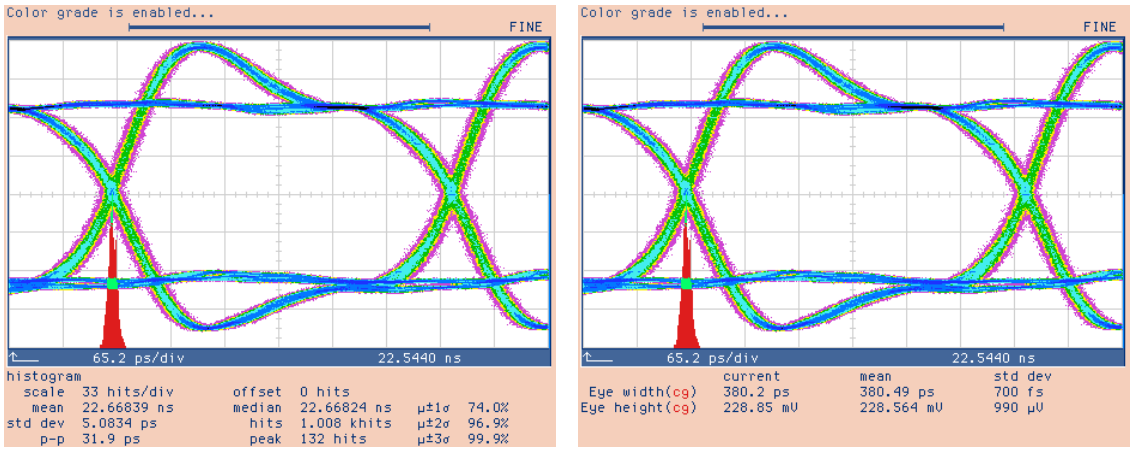


**Figure 18. Cable A eye measurement @ 1m captured from HP83480A**

Figure 11a. @ 1.6Gbps data rate

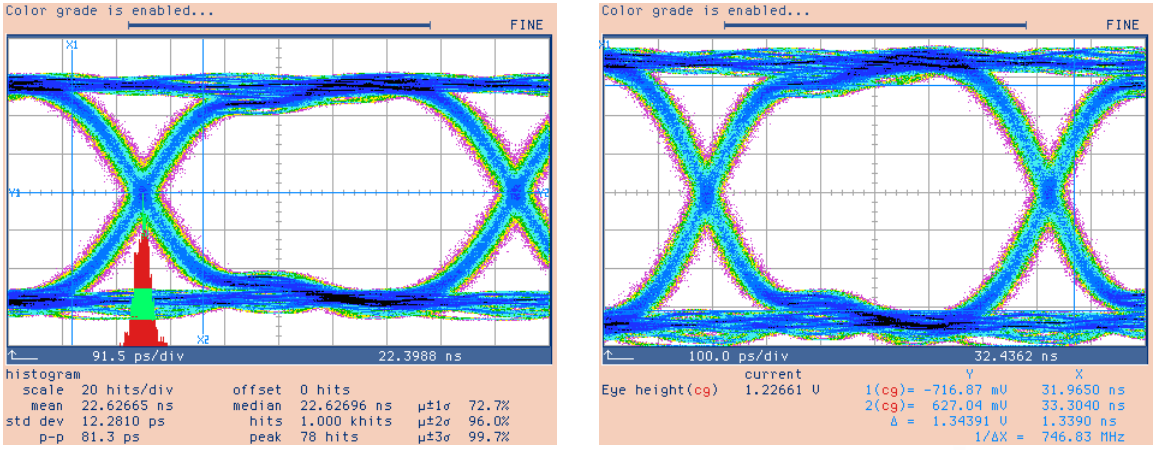



Figure 11b. @ 2.0Gbps data rate

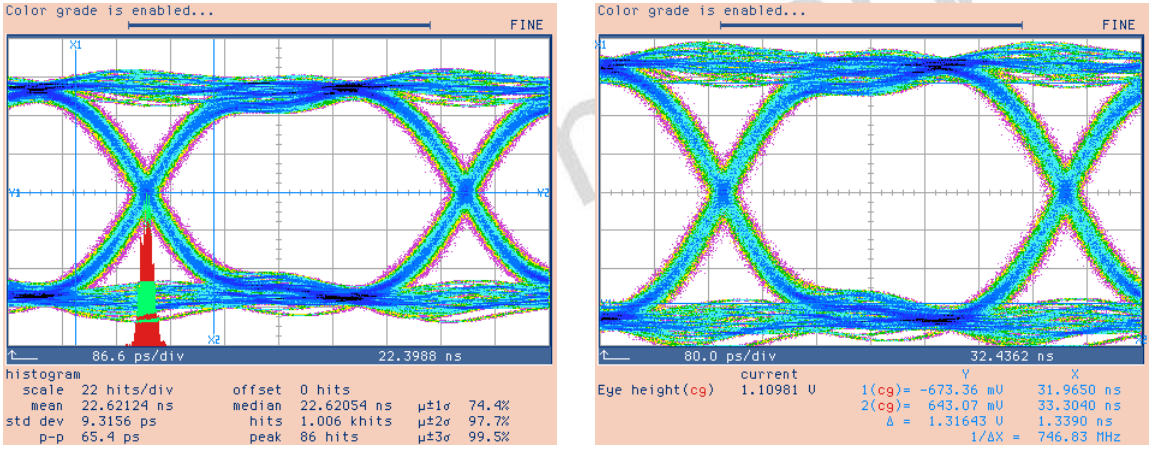



Figure 11c. @ 2.5Gbps data rate

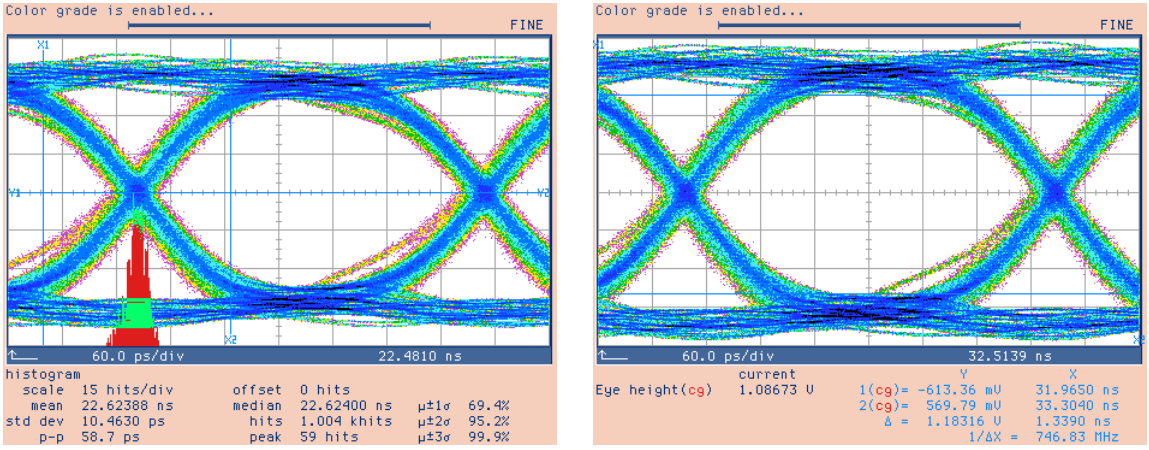
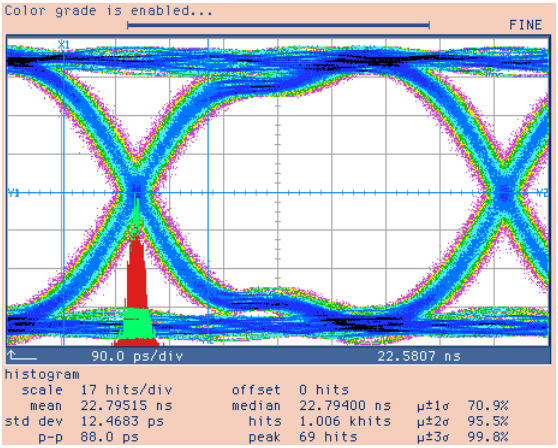


**Figure 19. Cable A eye measurement @ 2m captured from HP83480A**

Figure 12a. @ 1.6Gbps data rate



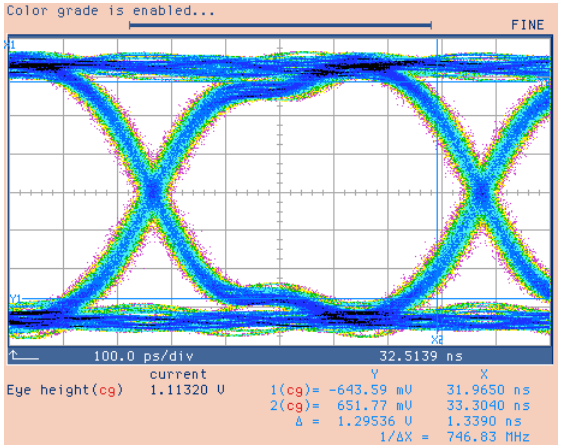
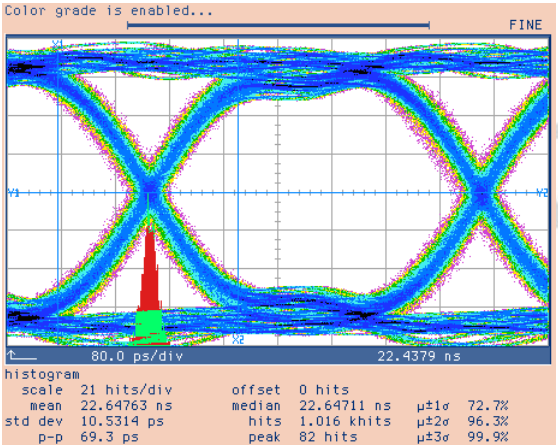




Figure 12b. @ 2.0Gbps data rate



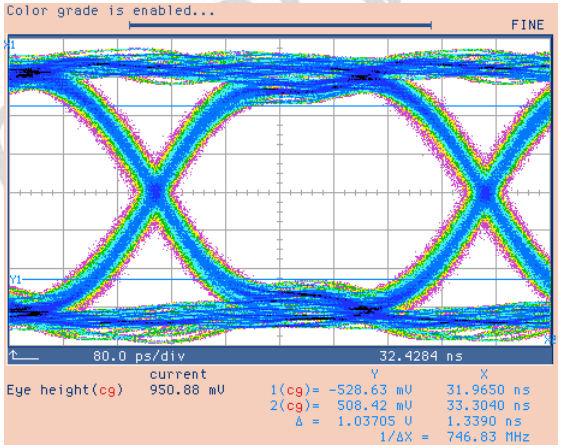
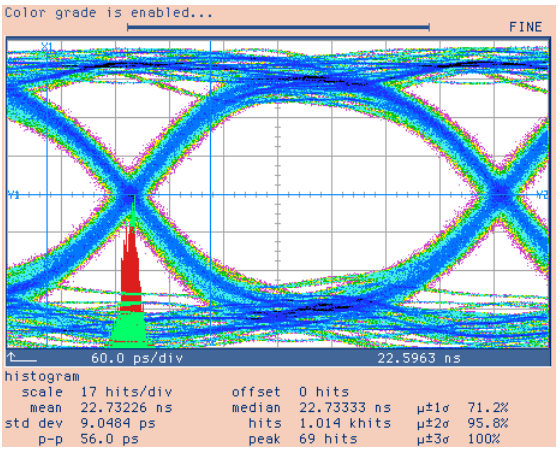




Figure 12c. @ 2.5Gbps data rate



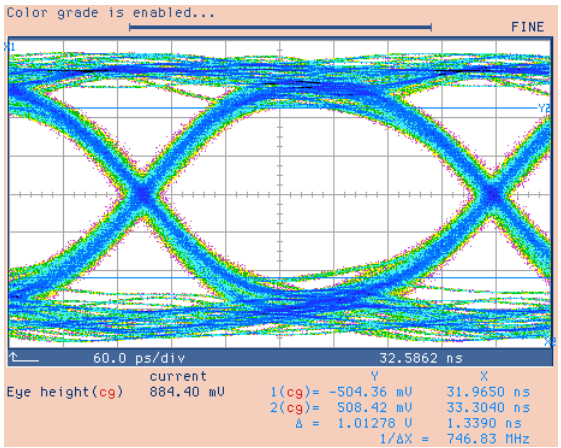



**Figure 20. Cable A eye measurement @ 3m captured from HP83480A**

Figure 13a. @ 1.6Gbps data rate

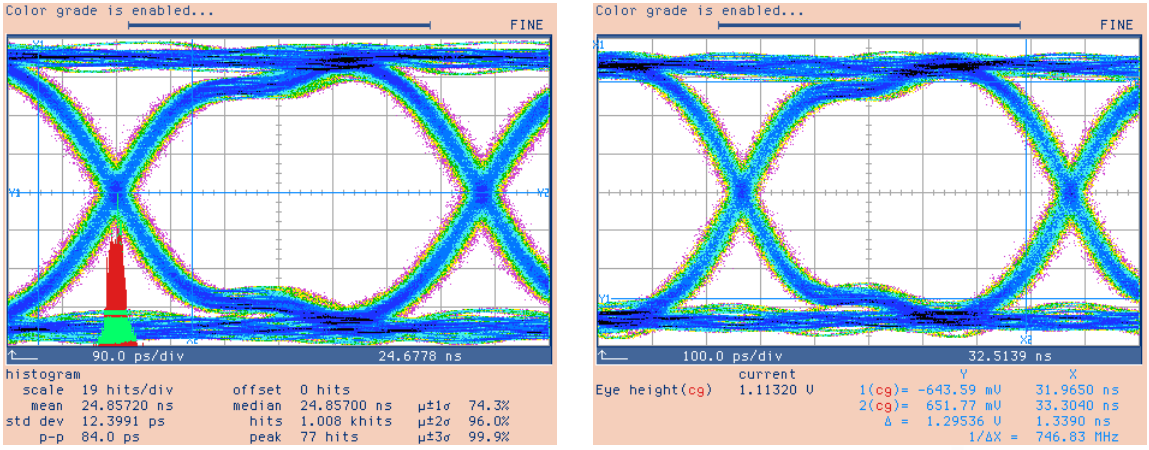



Figure 13b. @ 2.0Gbps data rate

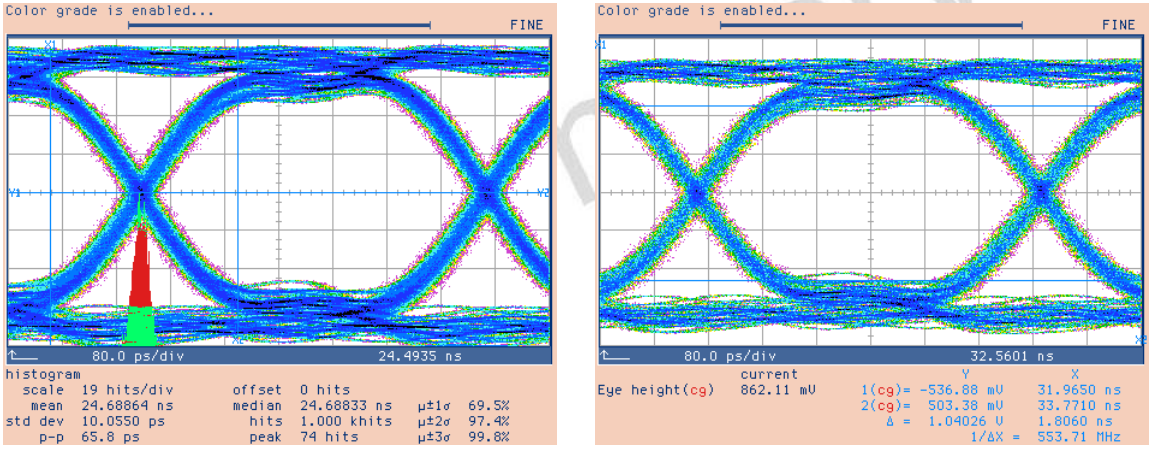



Figure 13c. @ 2.5Gbps data rate

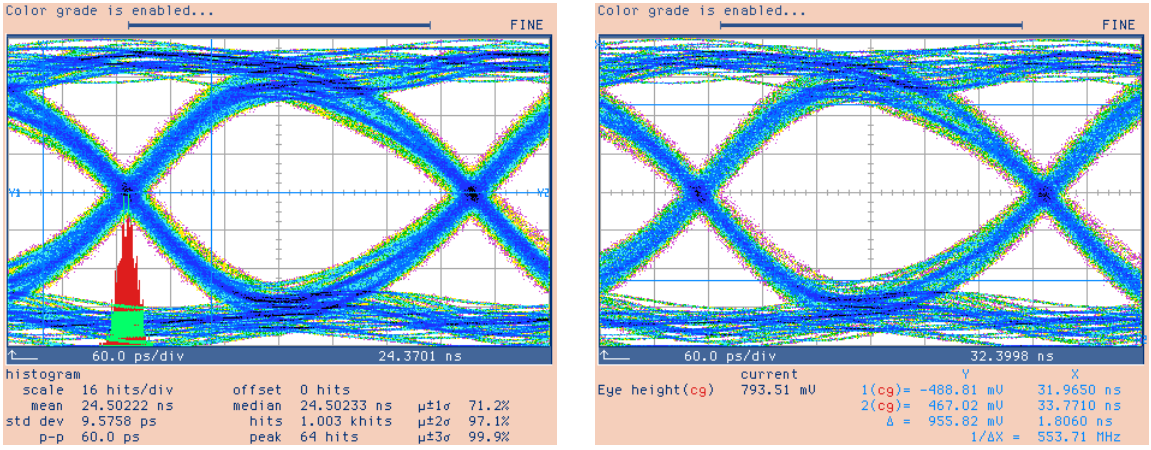
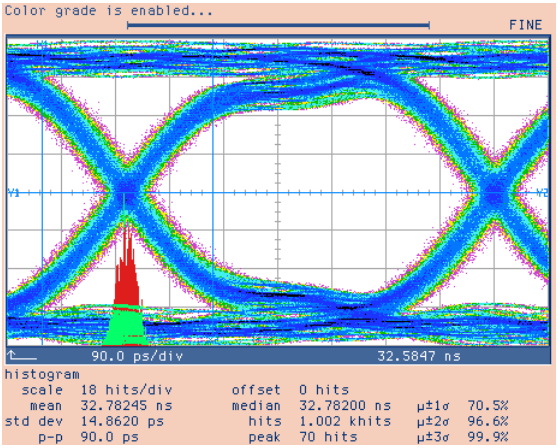


**Figure 21. Cable A eye measurement @ 5m captured from HP83480A**

Figure 14a. @ 1.6Gbps data rate



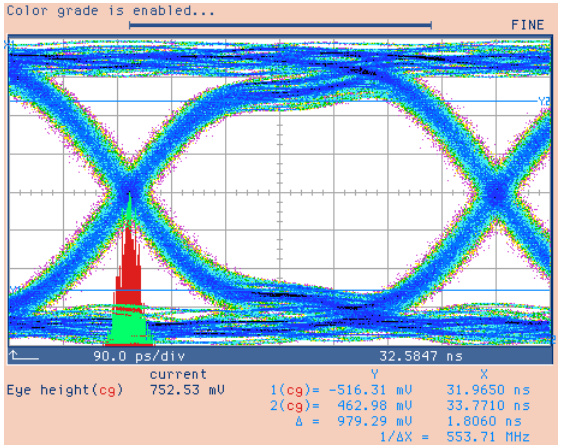
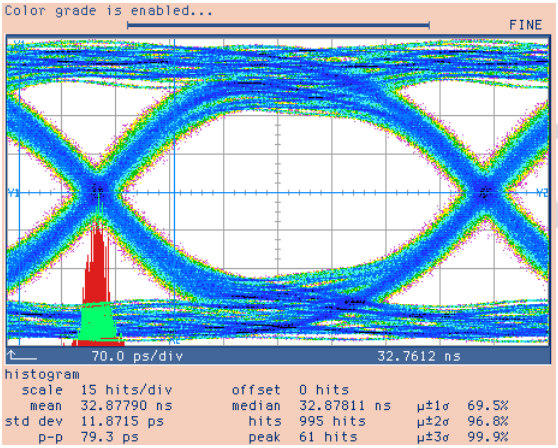




Figure 14b. @ 2.0Gbps data rate



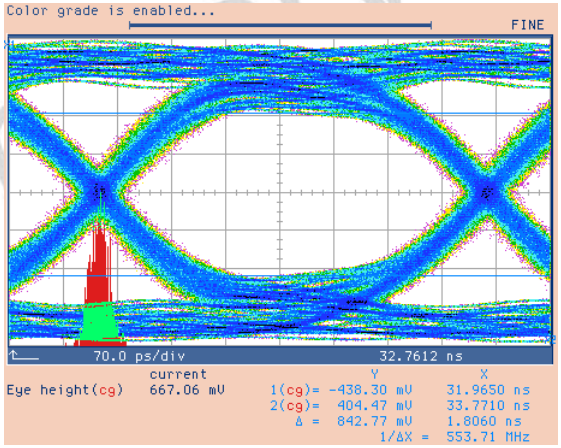
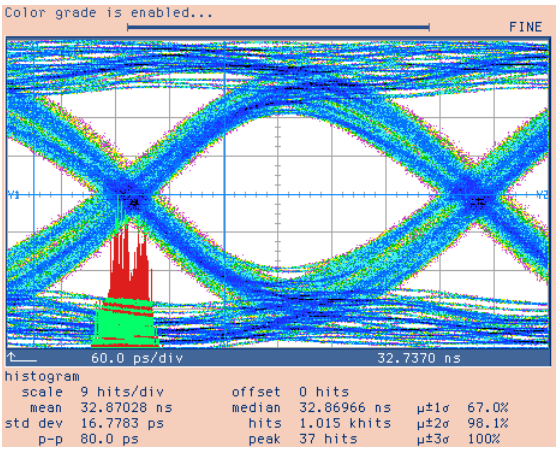




Figure 14c. @ 2.5Gbps data rate



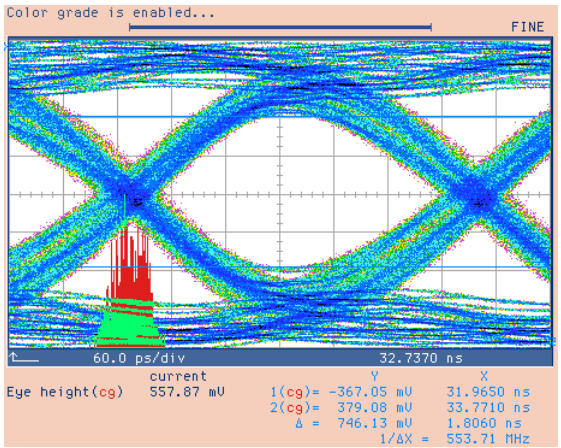



**Figure 22. Cable A eye measurement @ 10m captured from HP83480A**

Figure 15a. @ 1.6Gbps data rate

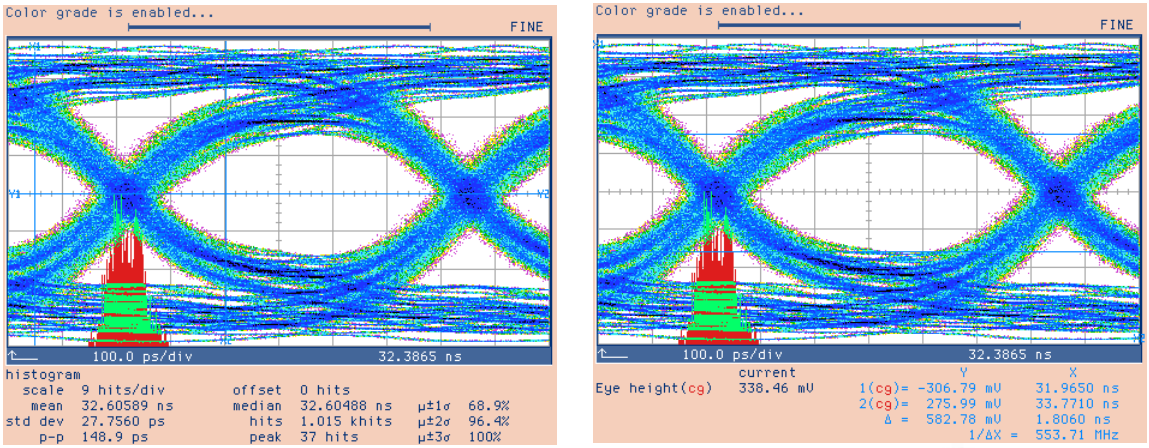



Figure 15b. @ 2.0Gbps data rate

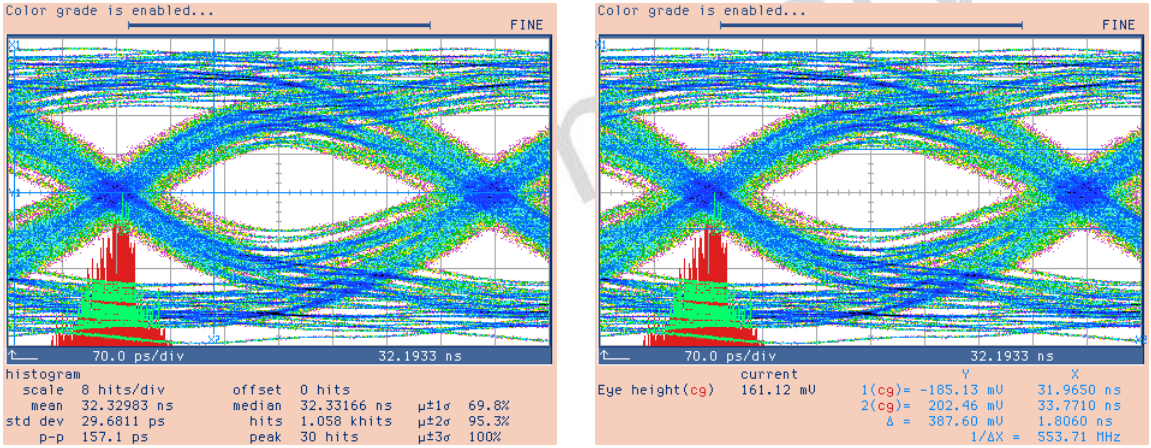



Figure 15c. @ 2.5Gbps data rate

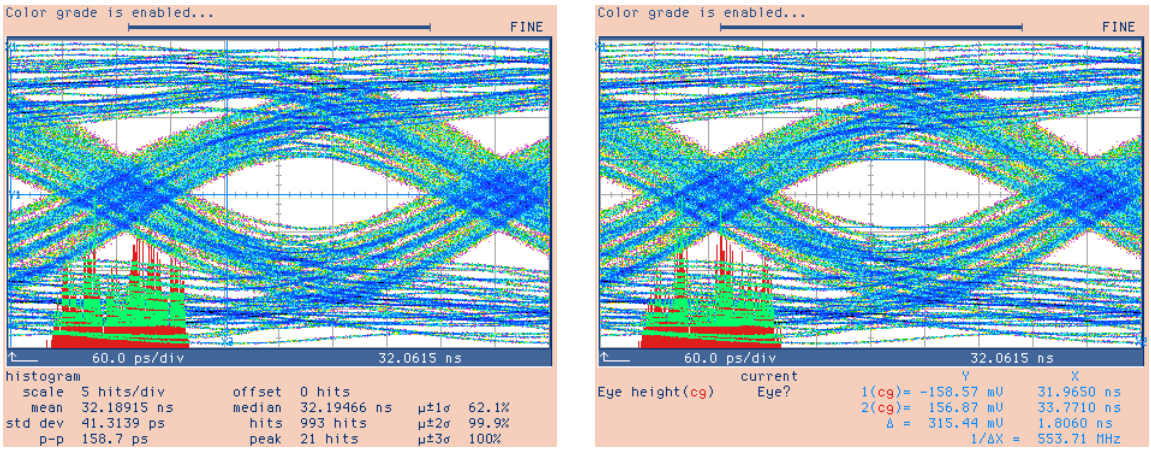
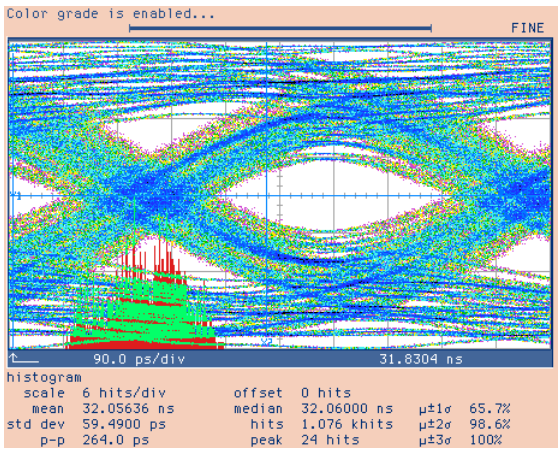


**Figure 23. Cable A eye measurement @ 15m captured from HP83480A**

Figure 16a. @ 1.6Gbps data rate



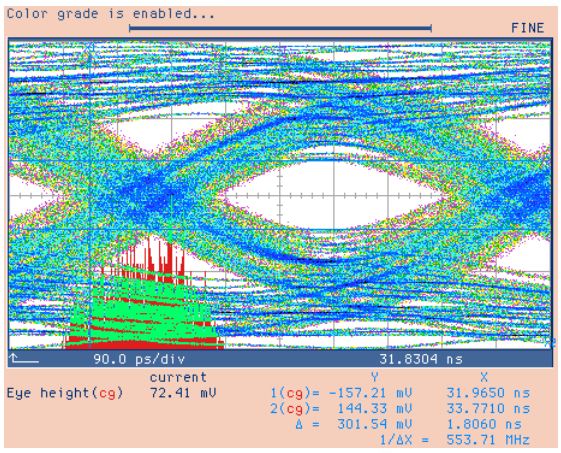
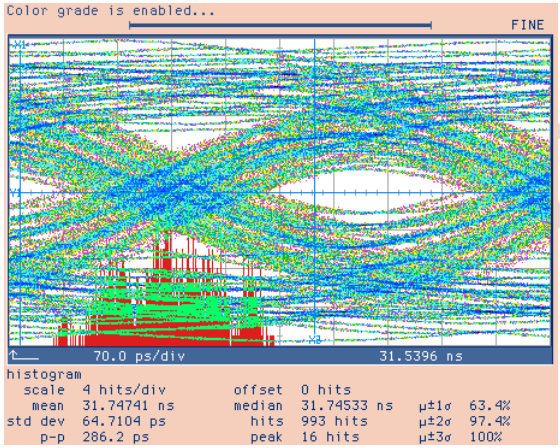




Figure 16b. @ 2.0Gbps data rate



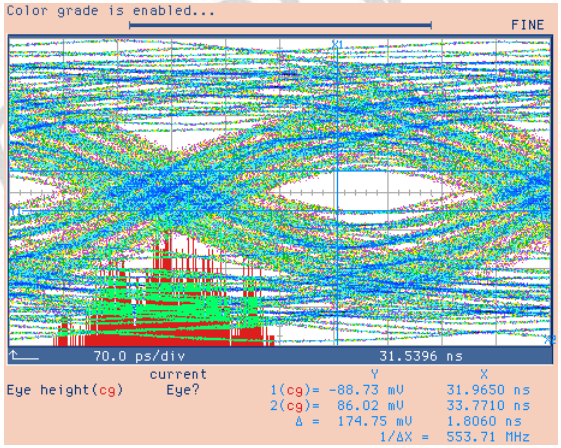




Figure 16c. @ 2.5Gbps data rate

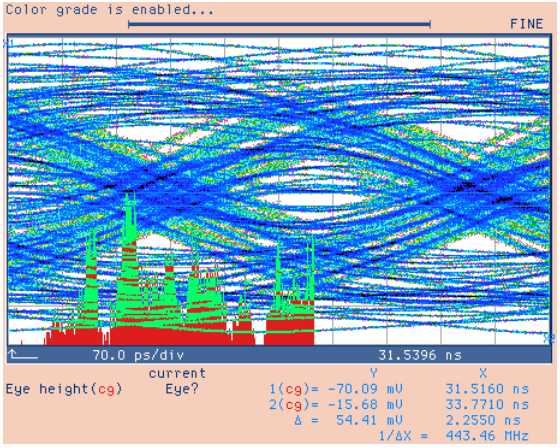
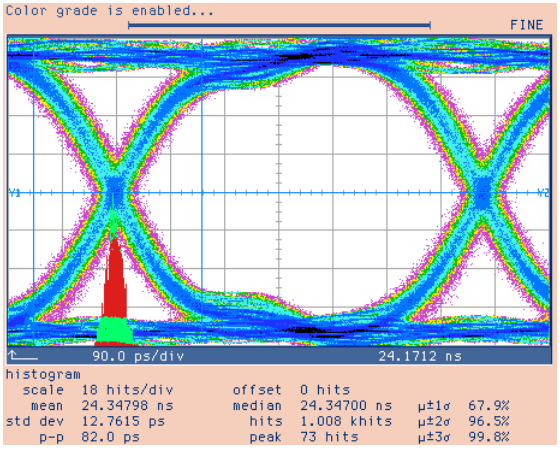


**Figure 24. Cable B eye measurement @ 1m captured from HP83480A**

Figure 17a. @ 1.6Gbps data rate



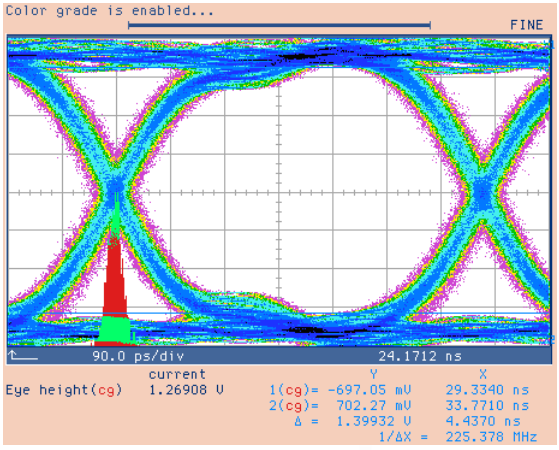
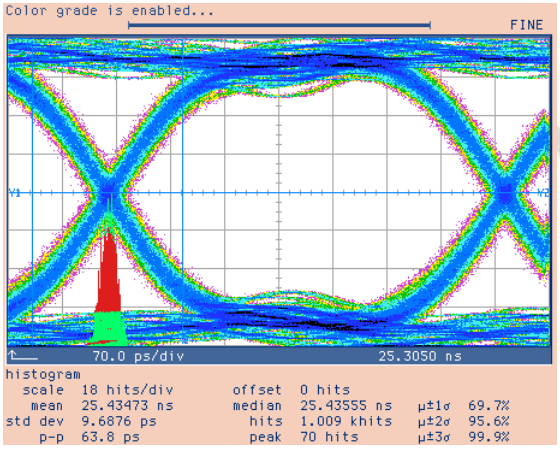




Figure 17b. @ 2.0Gbps data rate



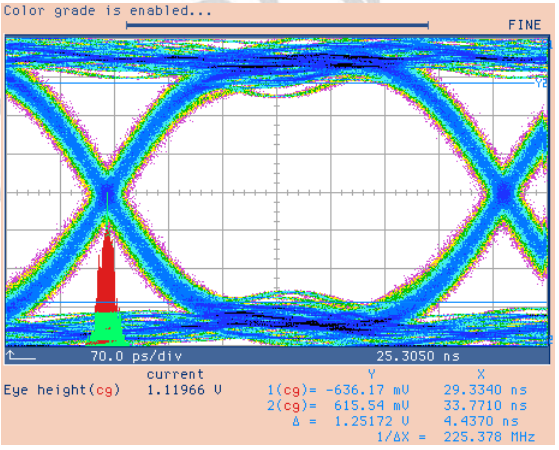
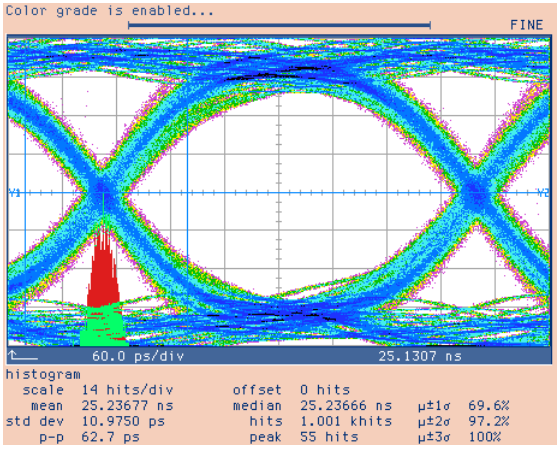




Figure 17c. @ 2.5Gbps data rate



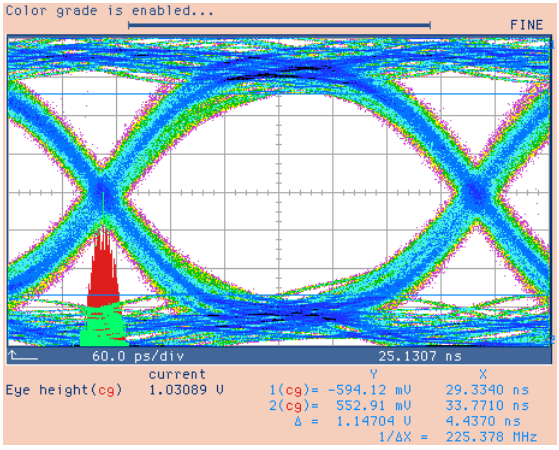



**Figure 25. Cable B eye measurement @ 2m captured from HP83480A**

Figure 18a. @ 1.6Gbps data rate

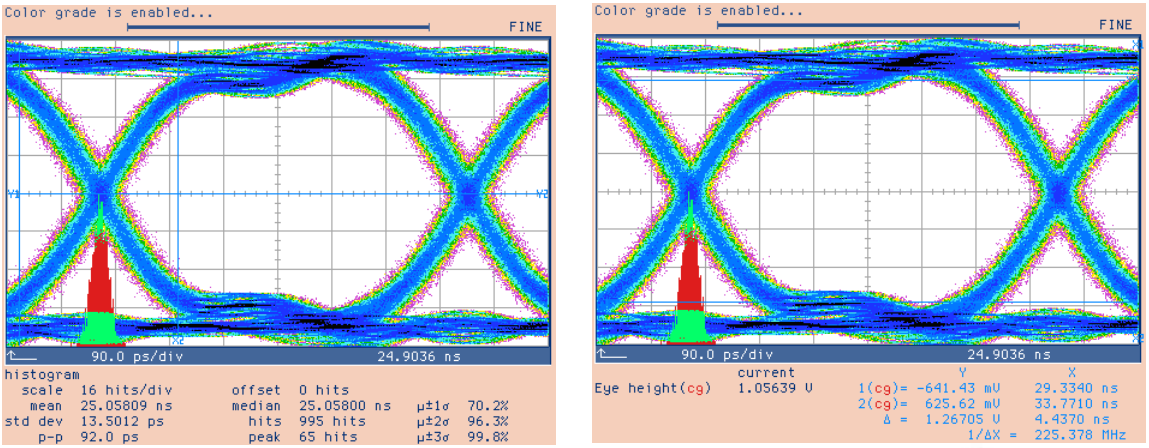



Figure 18b. @ 2.0Gbps data rate

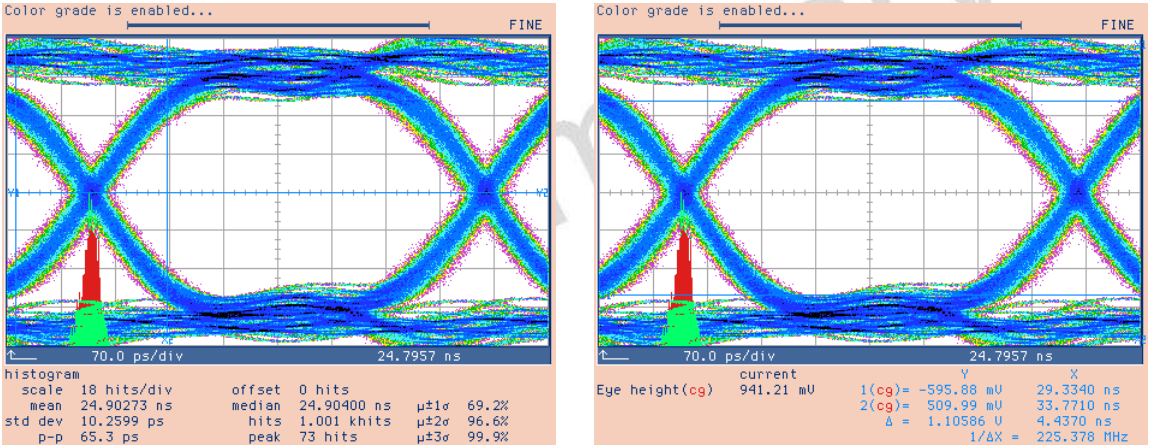



Figure 18c. @ 2.5Gbps data rate

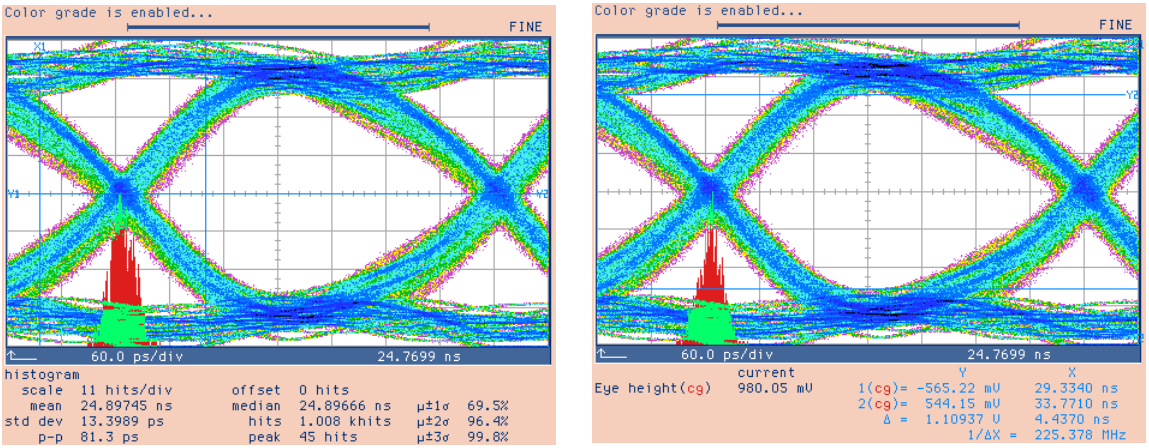


**Figure 26. Cable B eye measurement @ 3m captured from HP83480A**

Figure 19a. @ 1.6Gbps data rate

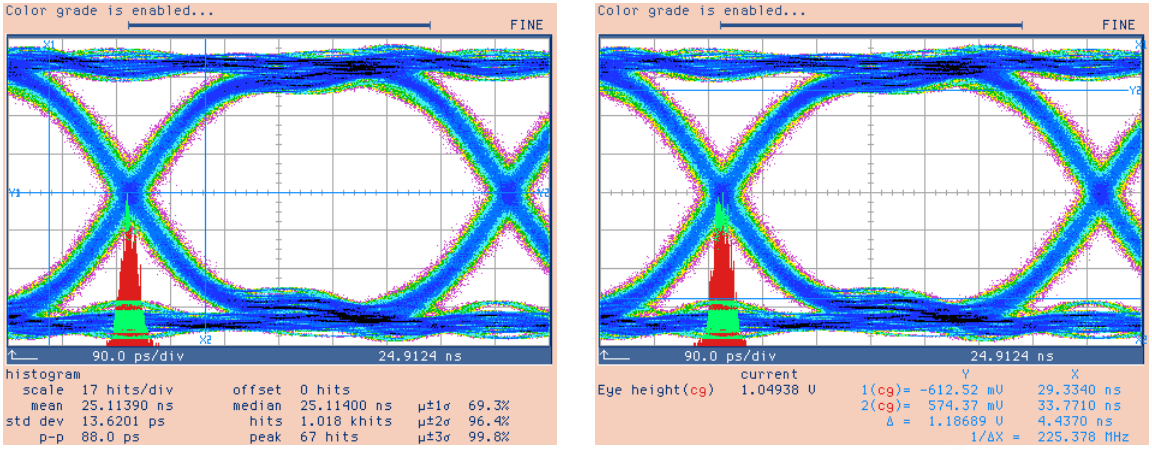



Figure 19b. @ 2.0Gbps data rate

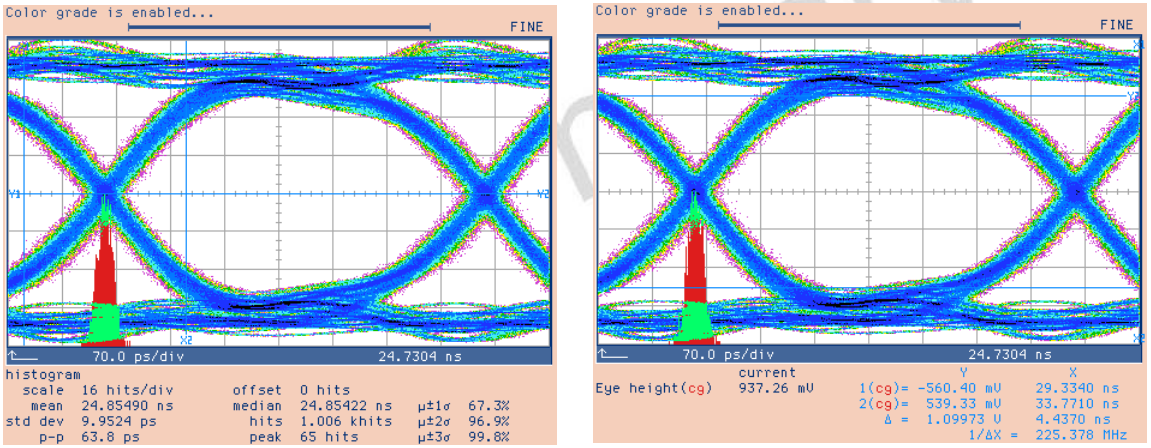



Figure 19c. @ 2.5Gbps data rate

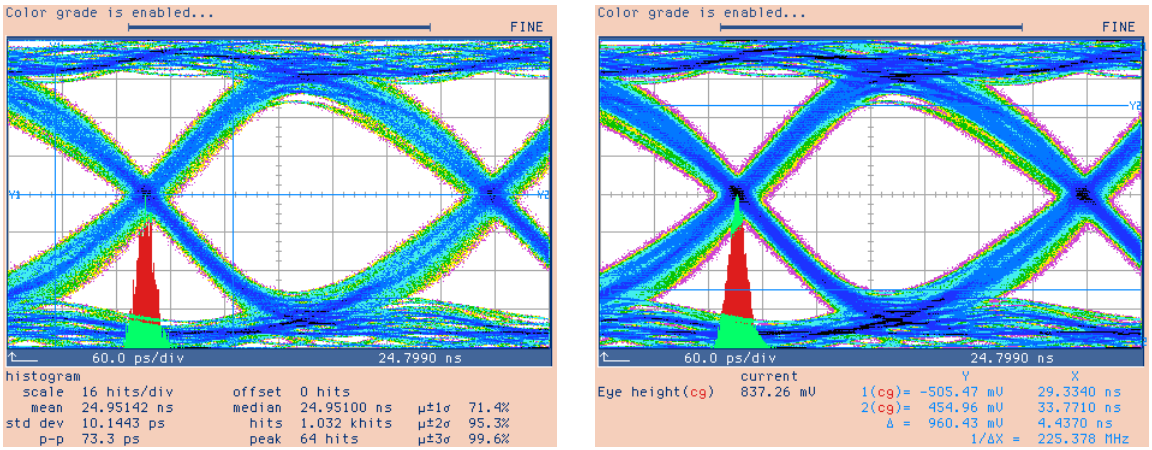


**Figure 27. Cable B eye measurement @ 5m captured from HP83480A**

Figure 20a. @ 1.6Gbps data rate

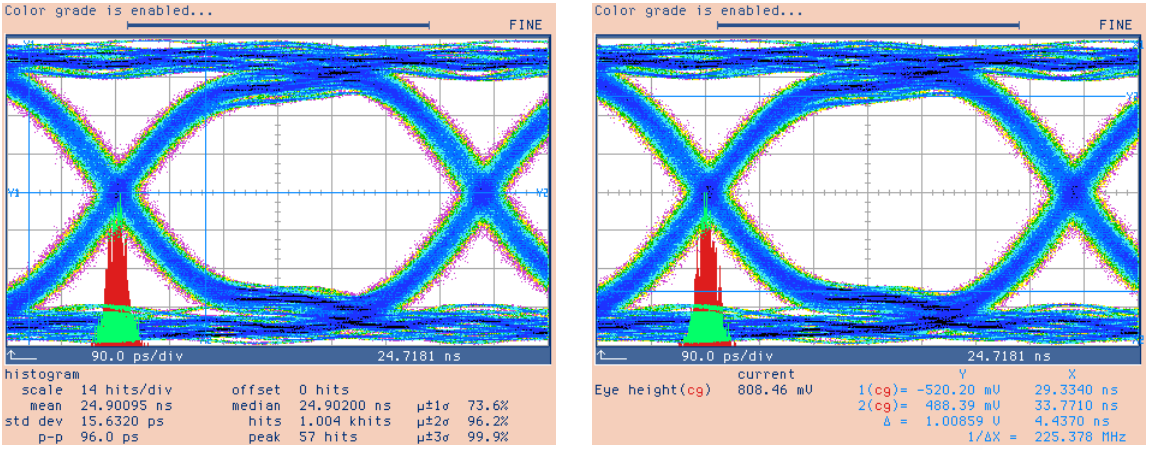



Figure 20b. @ 2.0Gbps data rate

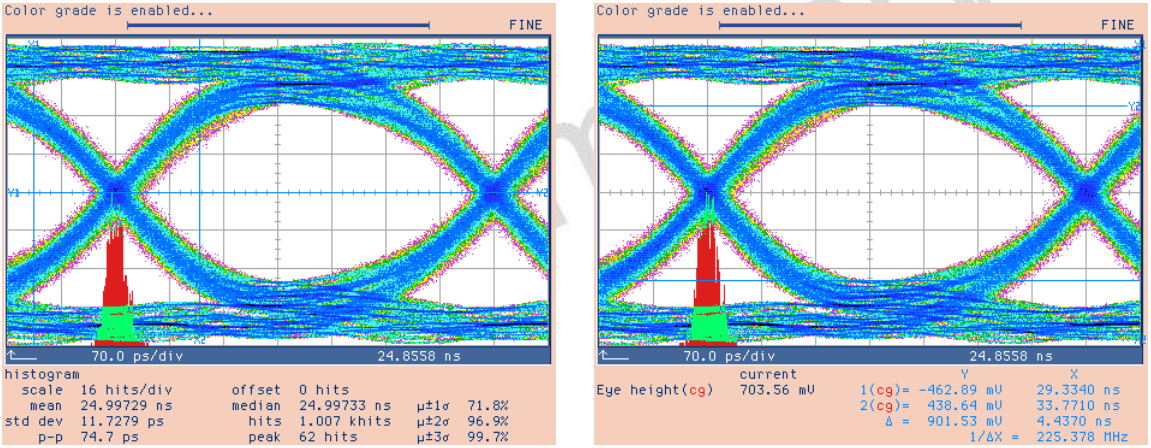



Figure 20c. @ 2.5Gbps data rate

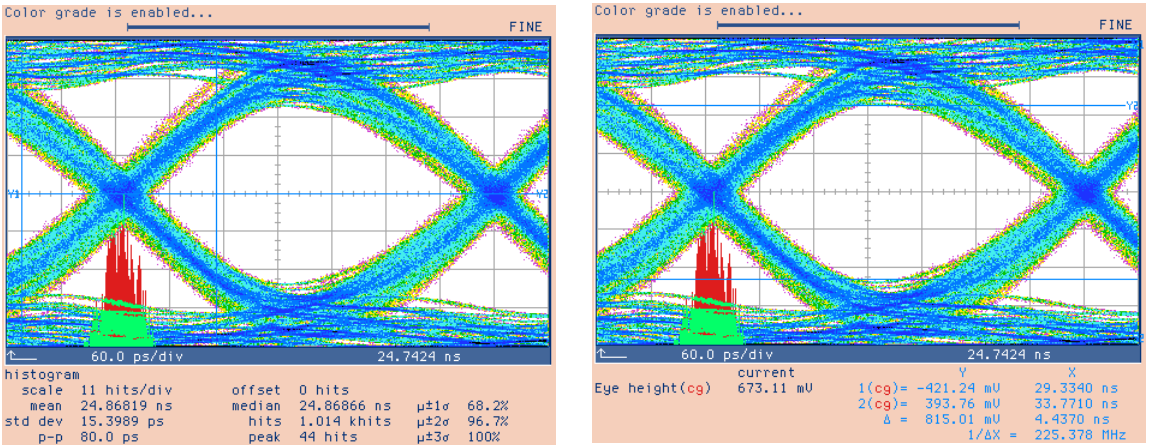
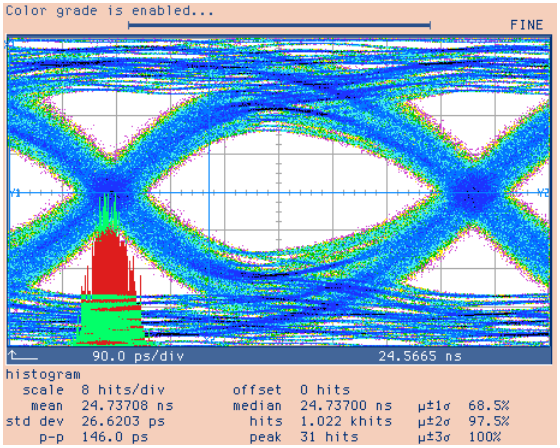


**Figure 28. Cable B eye measurement @ 10m captured from HP83480A**

Figure 21a. @ 1.6Gbps data rate



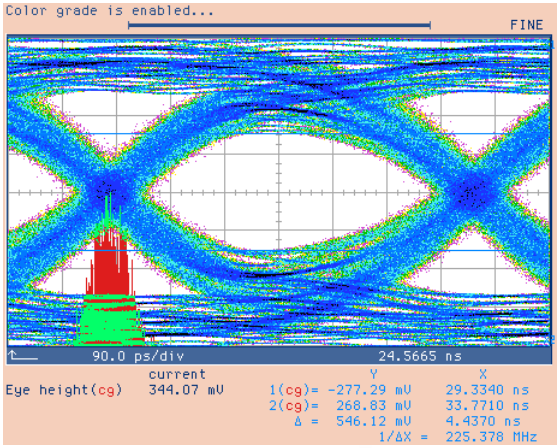
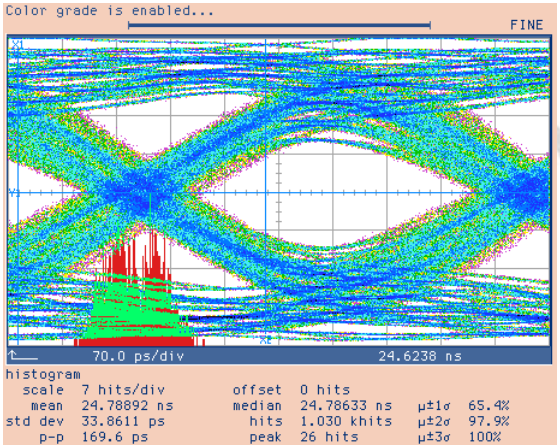




Figure 20b. @ 2.0Gbps data rate



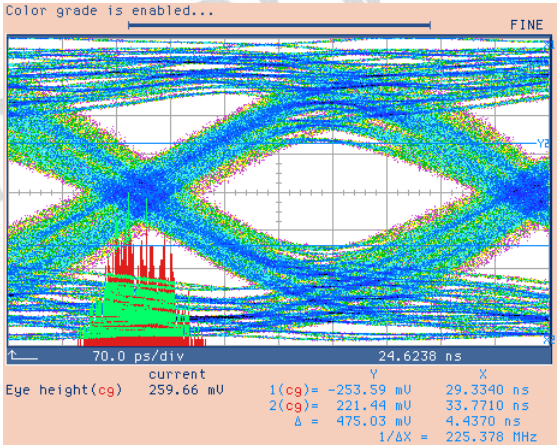
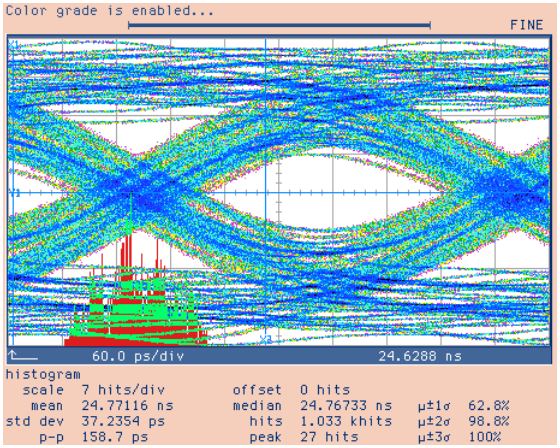




Figure 20c. @ 2.5Gbps data rate



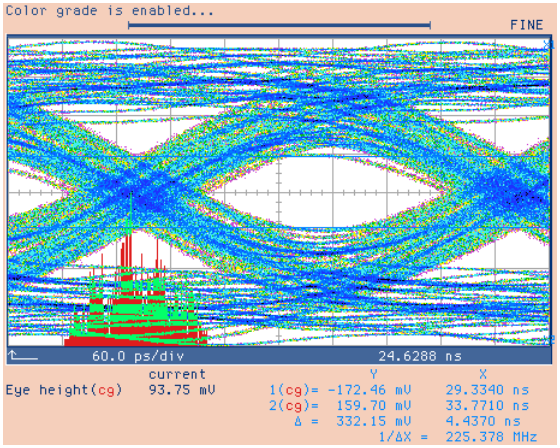



**Figure 29. Cable B eye measurement @ 15m captured from HP83480A**

Figure 22a @ 1.6Gbps data rate

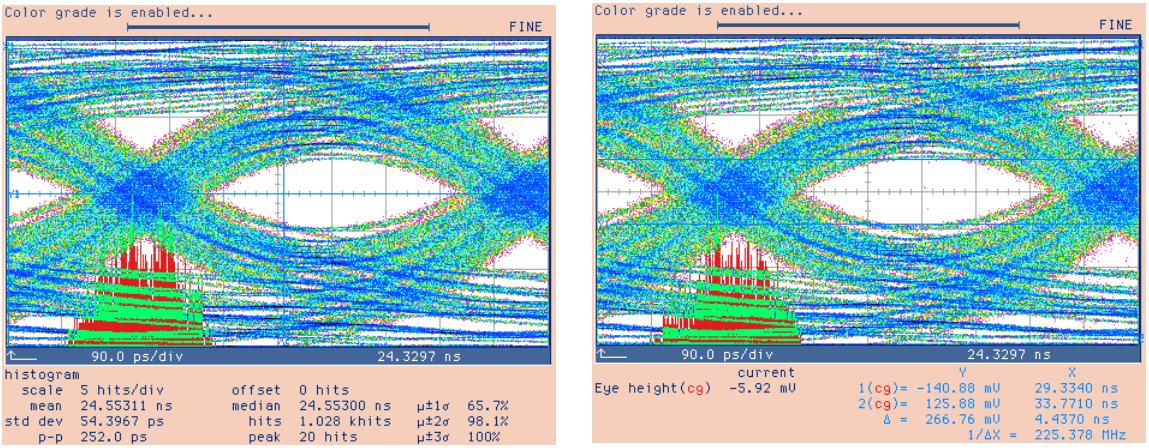



Figure 22b. @ 2.0Gbps data rate

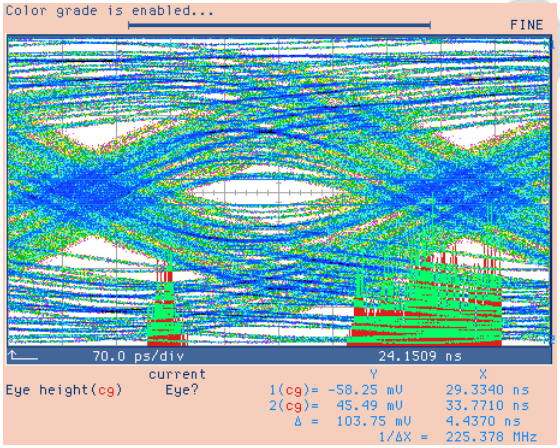



Figure 22c. @ 2.5Gbps data rate

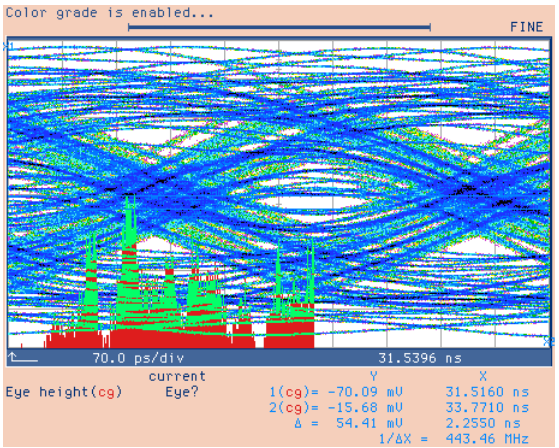


**Figure 30. Cable C eye measurement @ 1m captured from HP83480A**

Figure 23a. @ 1.6Gbps data rate

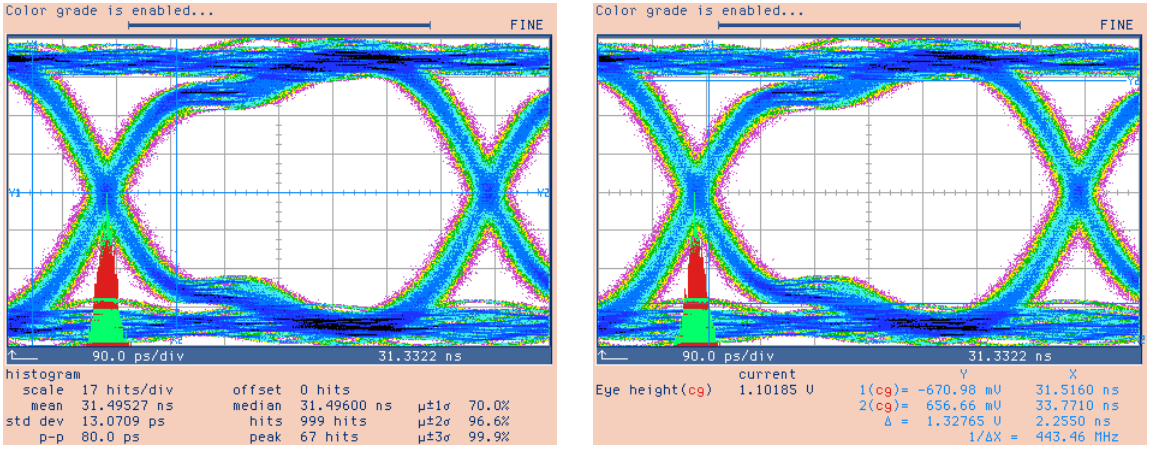



Figure 23b. @ 2.0Gbps data rate

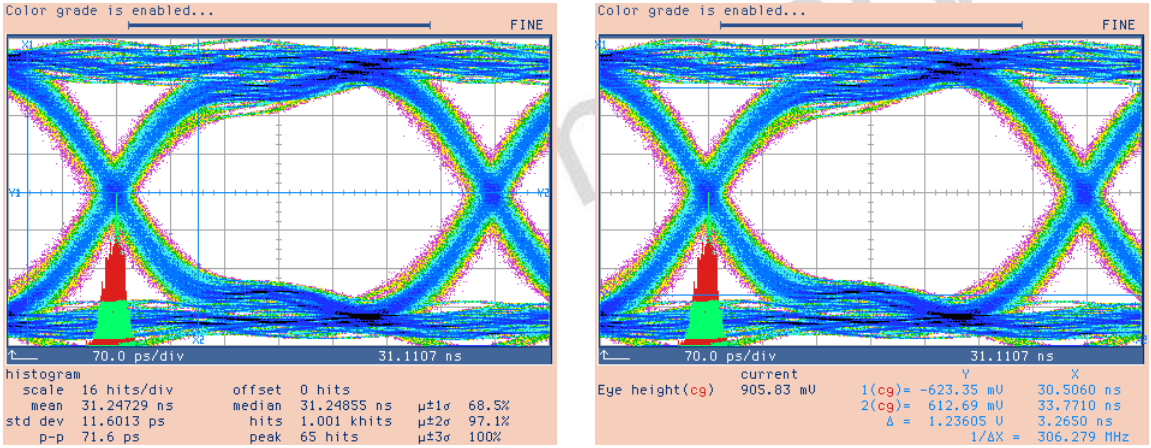



Figure 23c. @ 2.5Gbps data rate

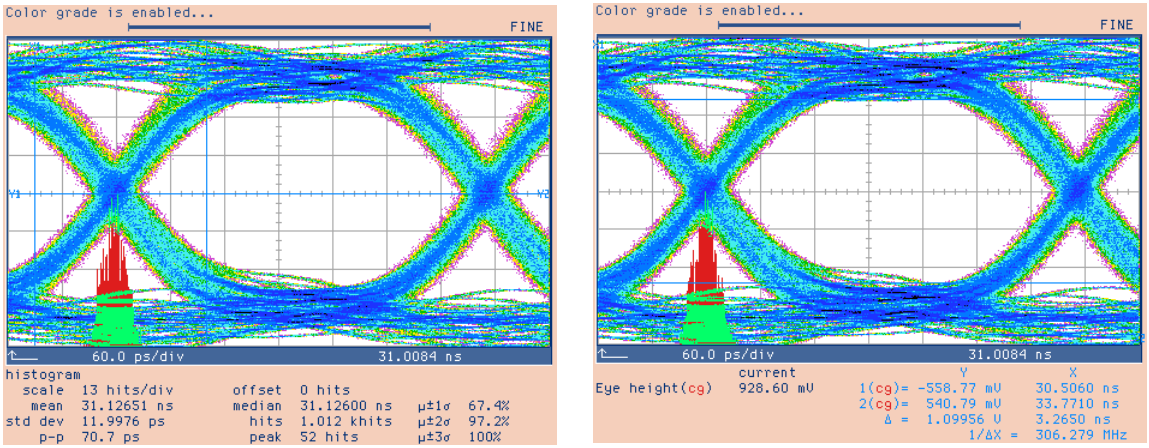
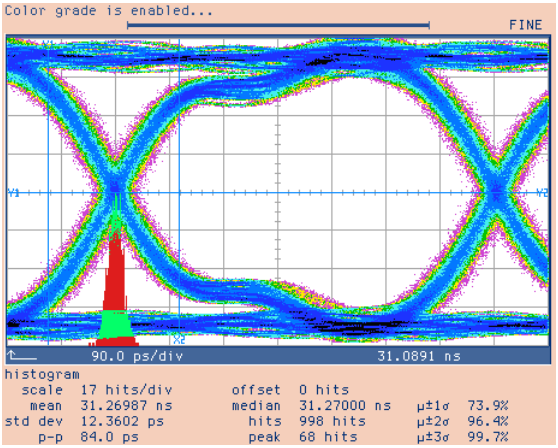


**Figure 31. Cable C eye measurement @ 2m captured from HP83480A**

Figure 24a. @ 1.6Gbps data rate



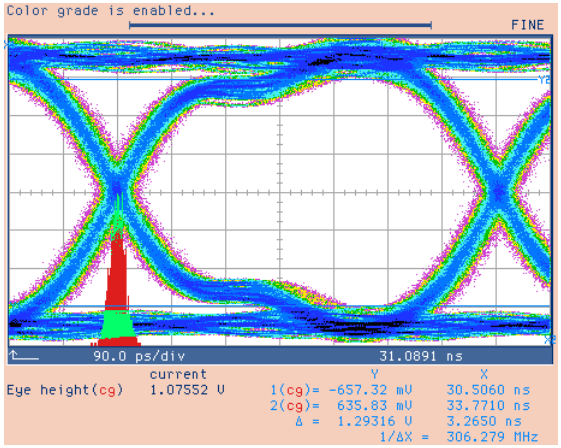
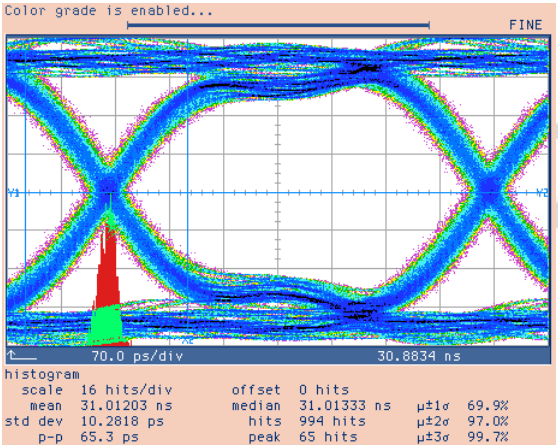




Figure 24b. @ 2.0Gbps data rate



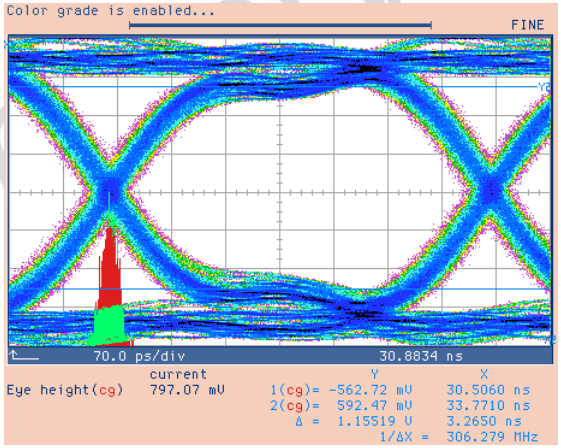
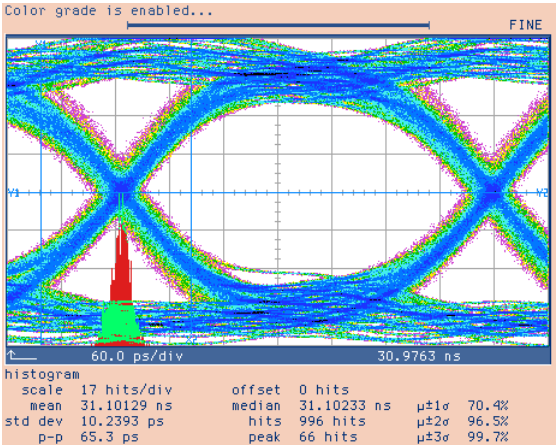




Figure 24c. @ 2.5Gbps data rate



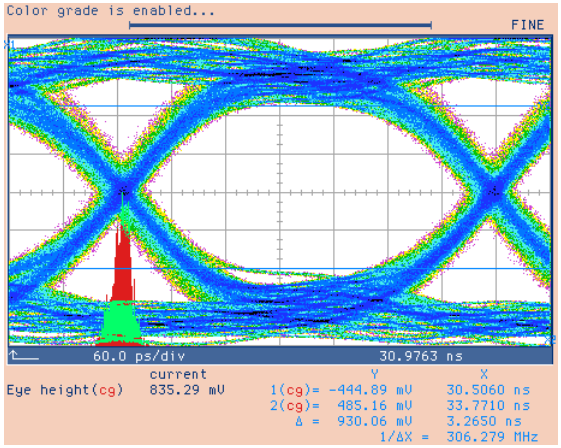



**Figure 32. Cable C eye measurement @ 3m captured from HP83480A**

Figure 25a. @ 1.6Gbps data rate

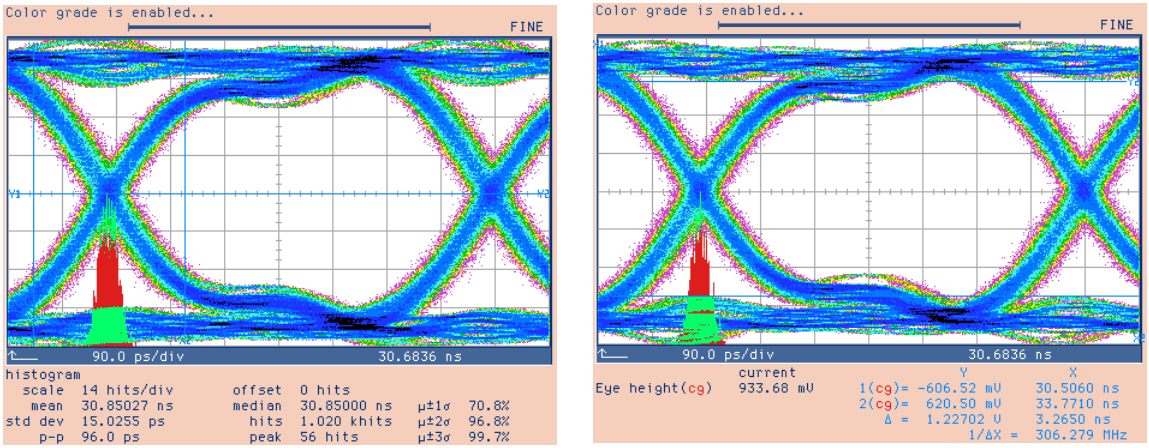



Figure 25b. @ 2.0Gbps data rate

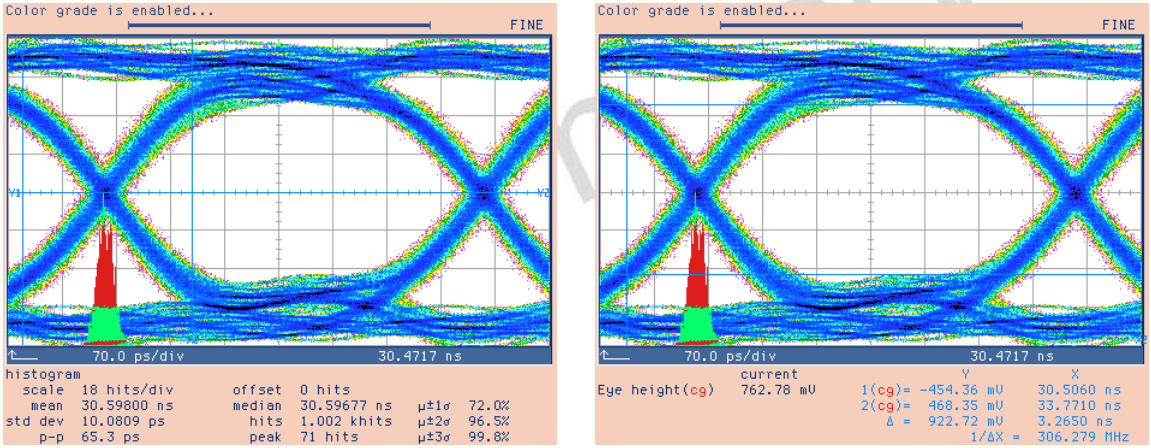



Figure 25c. @ 2.5Gbps data rate

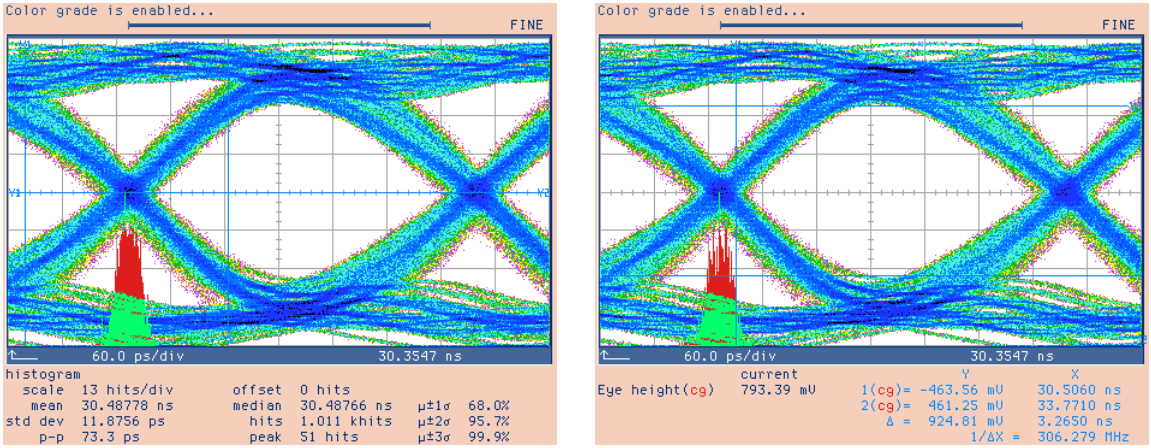
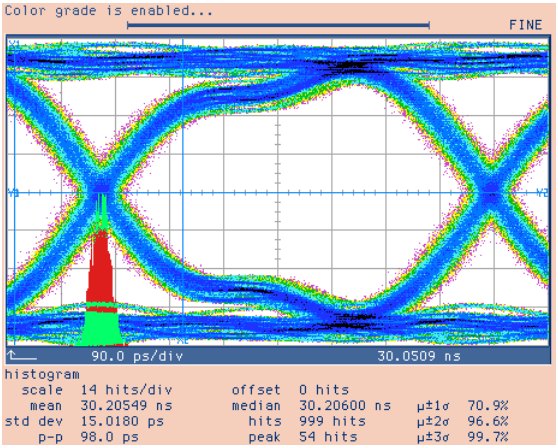


**Figure 33. Cable C eye measurement @ 5m captured from HP83480A**

Figure 26a. @ 1.6Gbps data rate



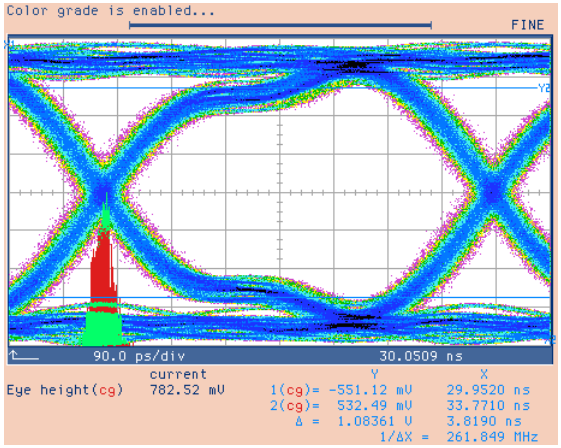
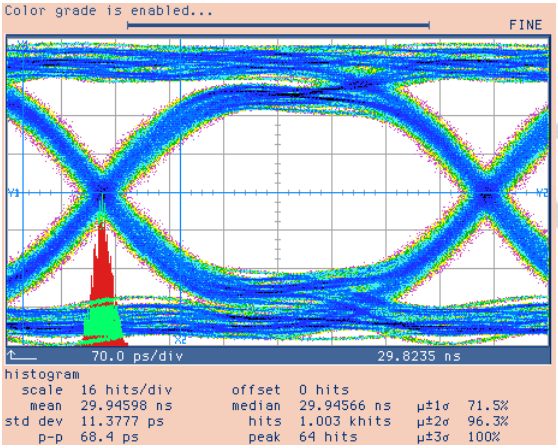




Figure 26b. @ 2.0Gbps data rate



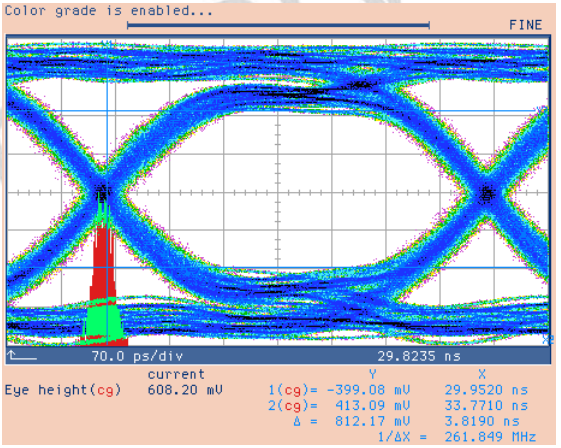
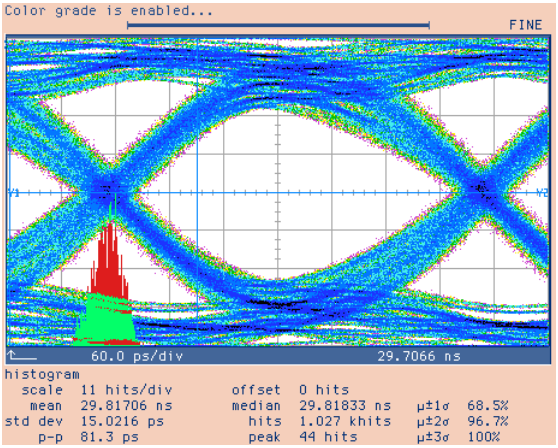




Figure 26c. @ 2.5Gbps data rate



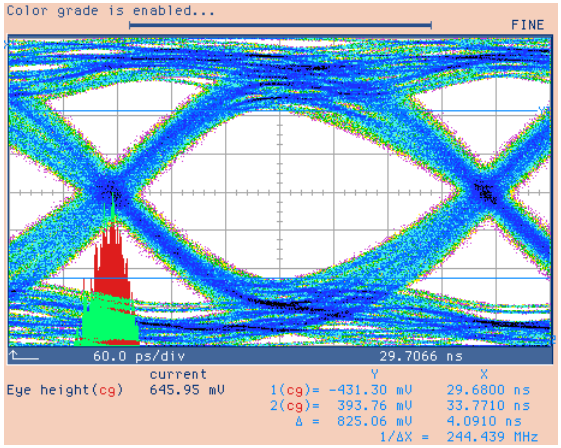



**Figure 34. Cable C eye measurement @ 10m captured from HP83480A**

Figure 27a. @ 1.6Gbps data rate

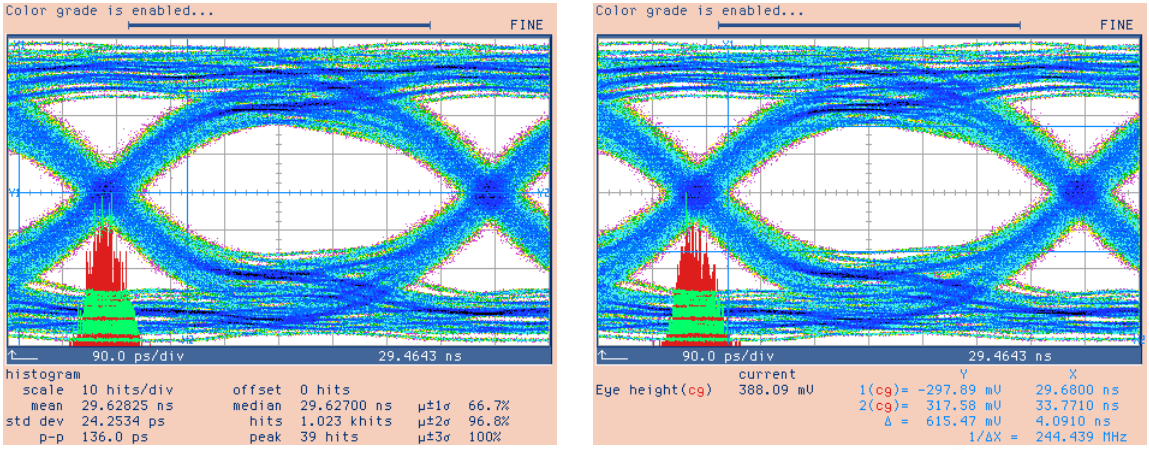



Figure 27b. @ 2.0Gbps data rate

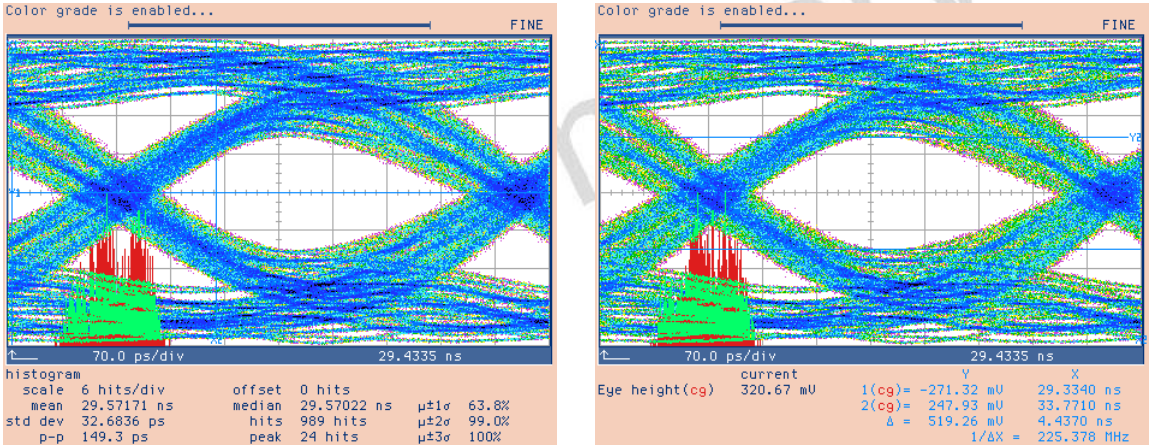



Figure 27c. @ 2.5Gbps data rate

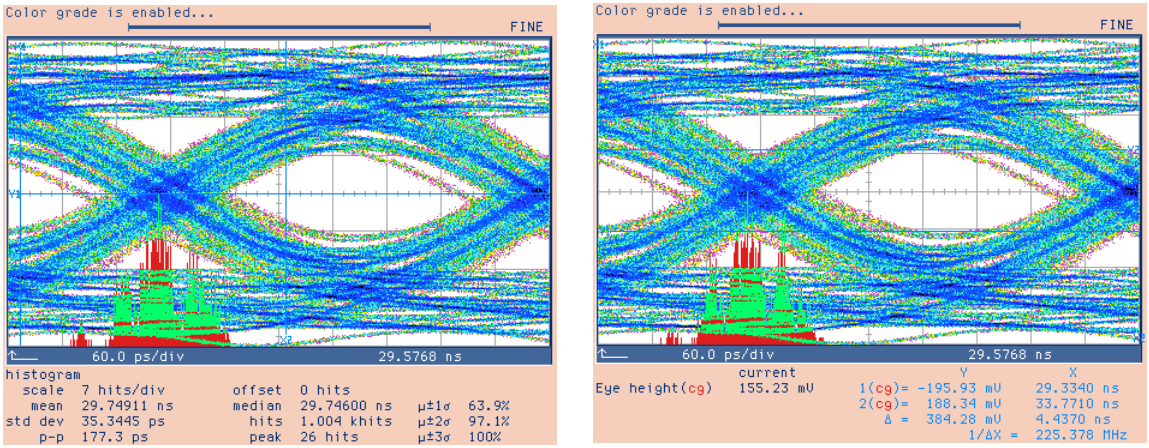
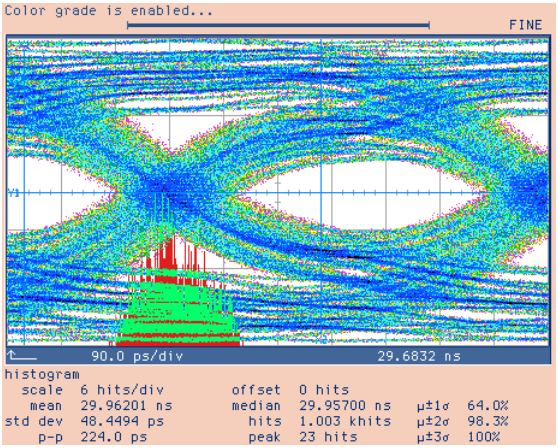


**Figure 35. Cable C eye measurement @ 15m captured from HP83480A**

Figure 28a. @ 1.6Gbps data rate



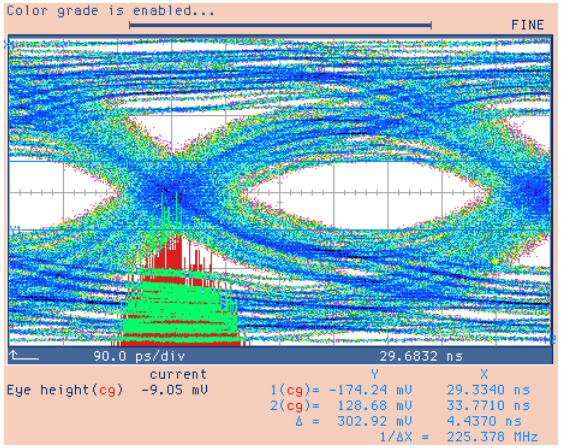
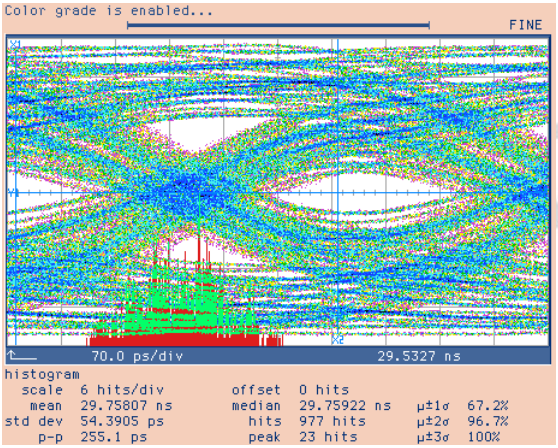




Figure 28b. @ 2.0Gbps data rate



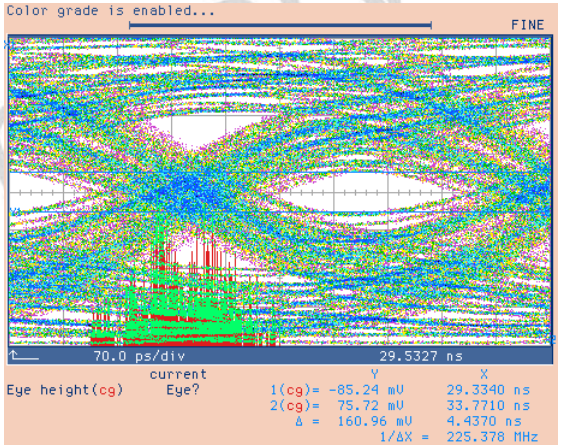




Figure 28c. @ 2.5Gbps data rate

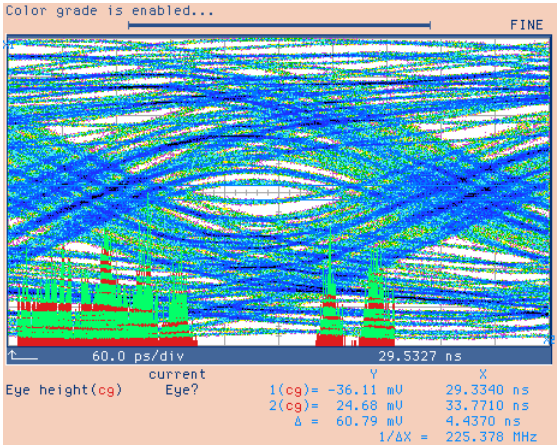


**Figure 36. Cable D eye measurement @ 1m captured from HP83480A**

Figure 29a. @ 1.6Gbps data rate

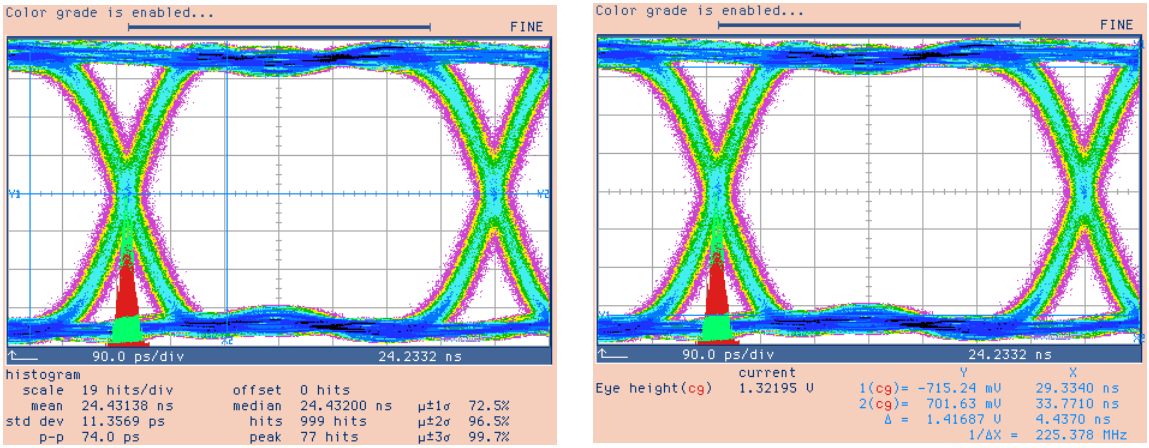



Figure 29b. @ 2.0Gbps data rate

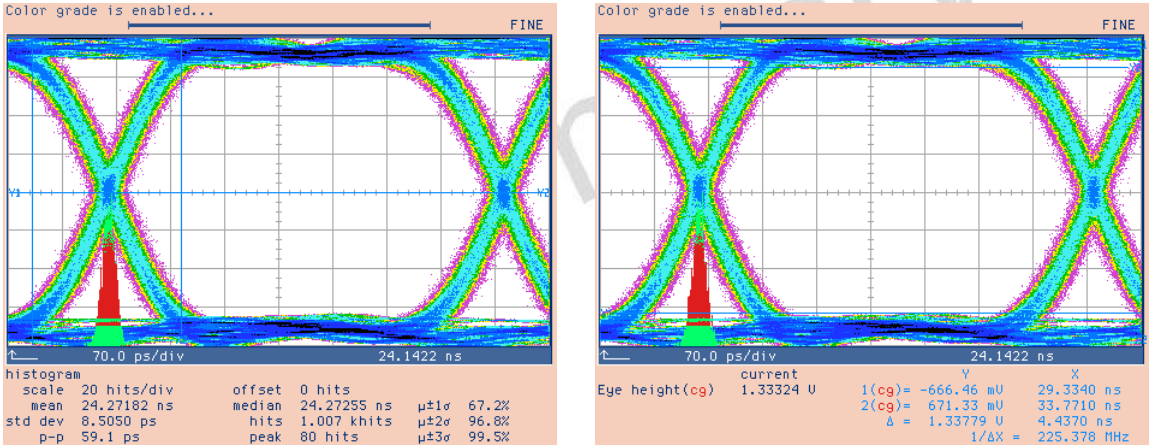



Figure 29c. @ 2.5Gbps data rate

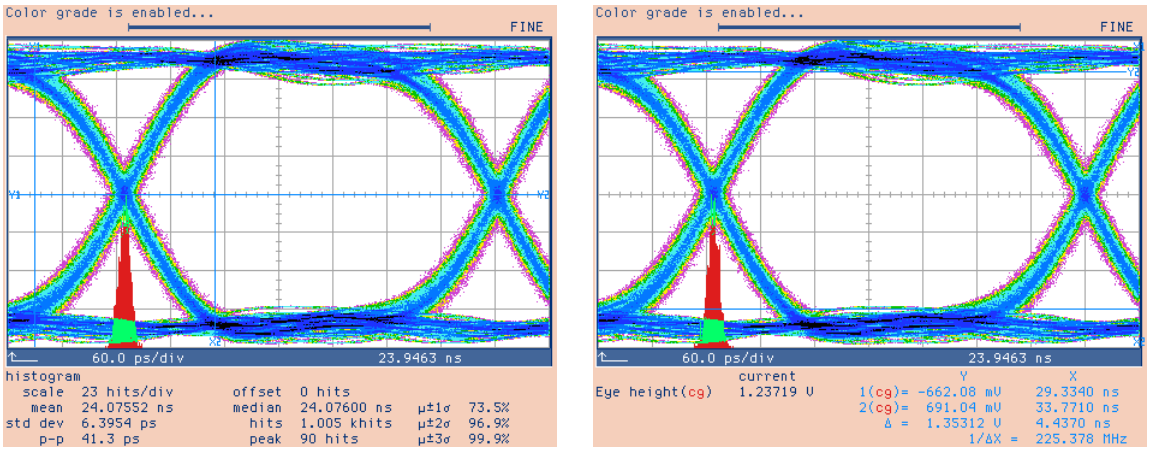
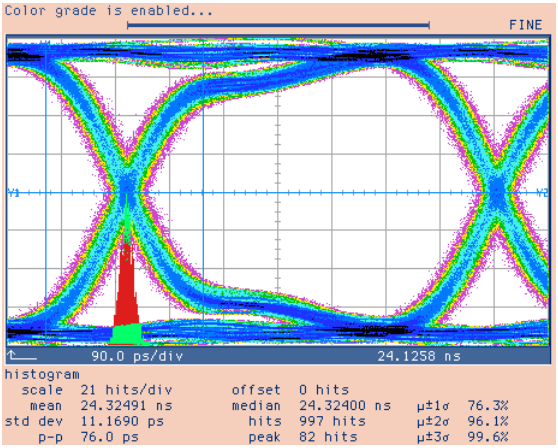


**Figure 37. Cable D eye measurement @ 5m captured from HP83480A**

Figure 30a. @ 1.6Gbps data rate



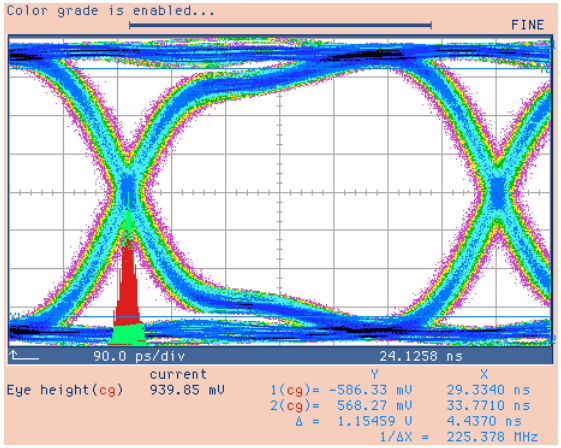
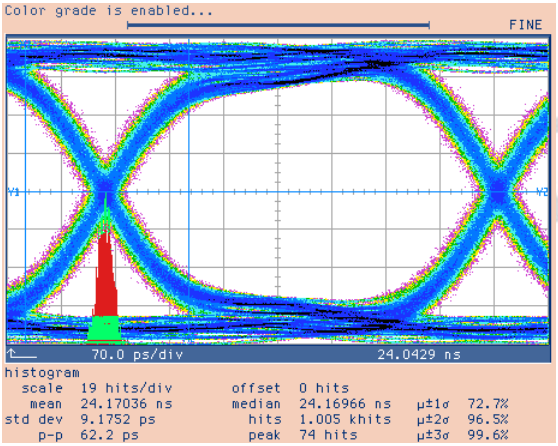




Figure 30b. @ 2.0Gbps data rate



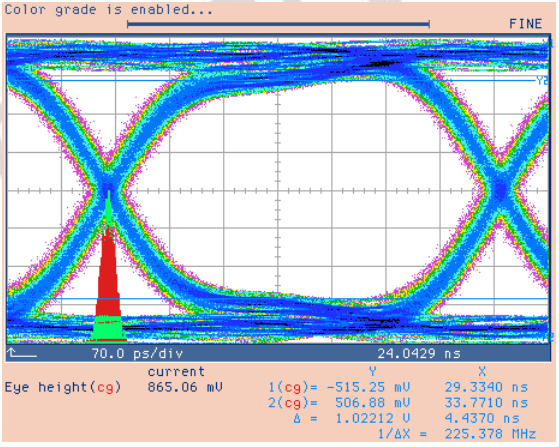
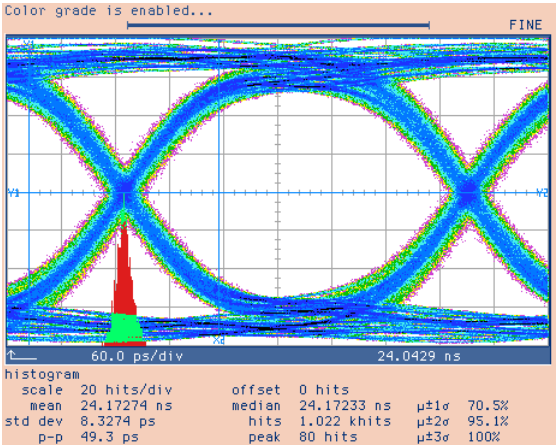




Figure 30c. @ 2.5Gbps data rate



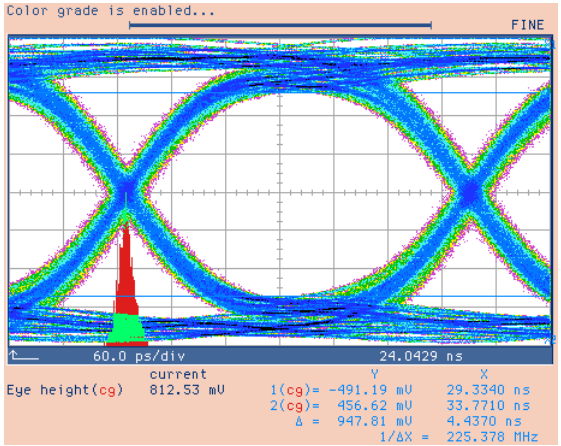



**Figure 38. Cable D eye measurement @ 15m captured from HP83480A**

Figure 31a. @ 1.6Gbps data rate

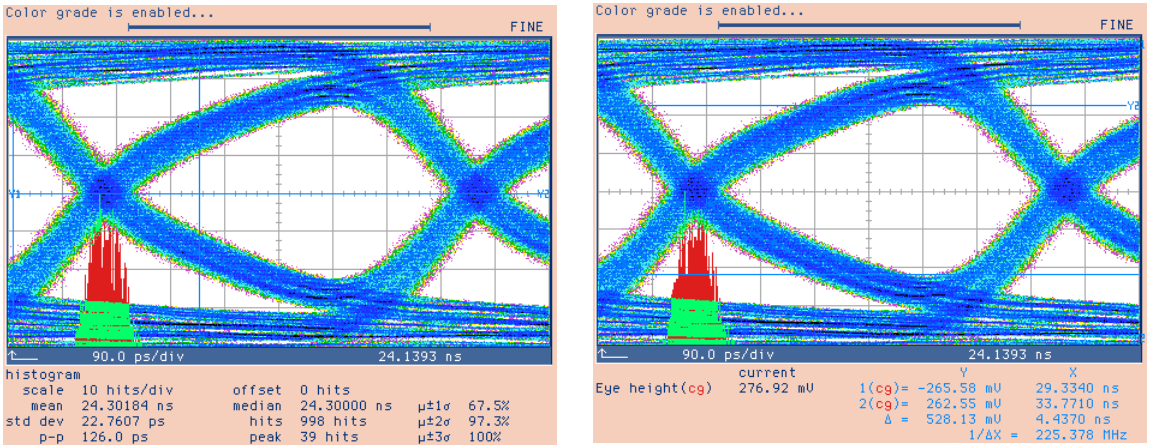



Figure 31b. @ 2.0Gbps data rate

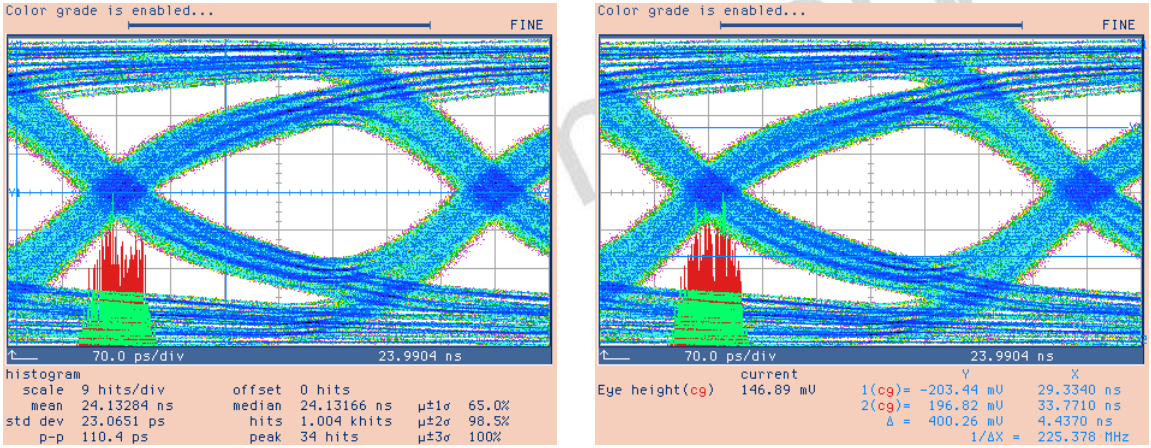



Figure 31c. @ 2.5Gbps data rate

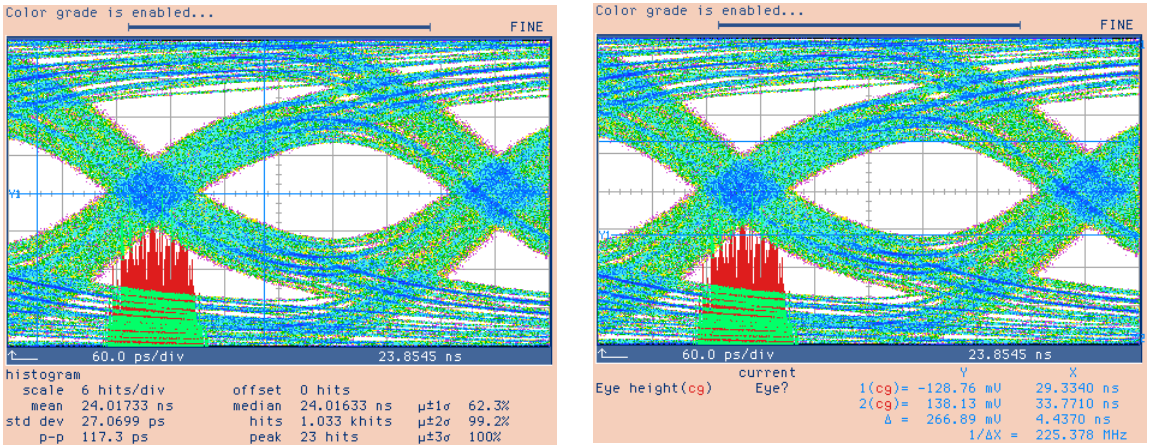


**Figure 39. Cable D eye measurement @ 20m captured from HP83480A**

Figure 32a. @ 1.6Gbps data rate

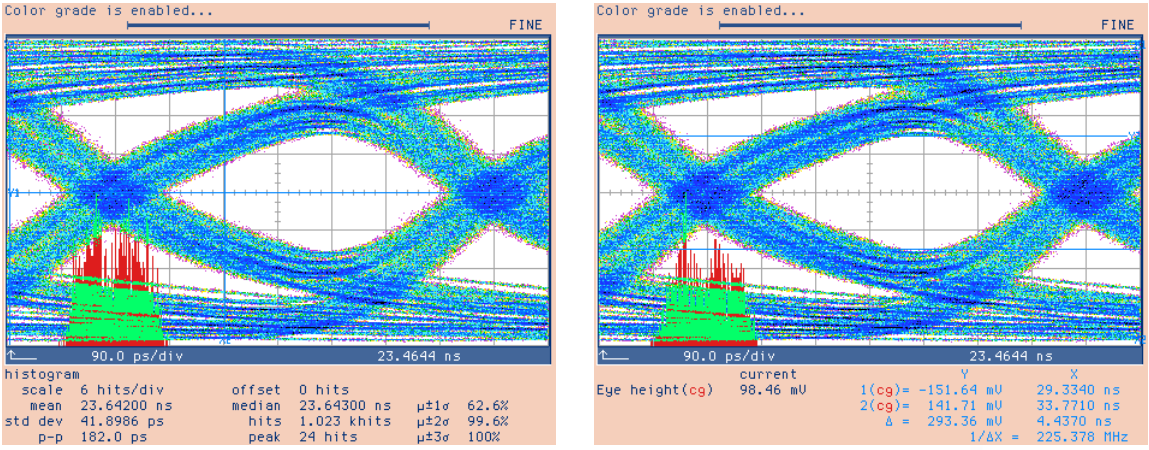



Figure 32b. @ 2.0Gbps data rate

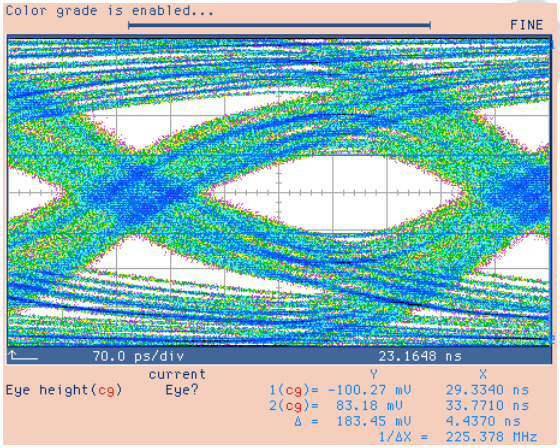



Figure 32c. @ 2.5Gbps data rate