Picosecond Pulse Labs

Application Note AN-10

Eye Diagrams of PSPL Coaxial Components

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PSPL has been designing and selling extremely broadband coaxial components since our founding in 1980. These components included attenuators, amplifiers, bias tees, dc blocks, low pass - risetime filters, transformers, power dividers, and pick-off tees. During the 1980s, many of these components had frequency responses extending from 100 kHz to 18 GHz. Today the best designs now cover from <1 kHz to beyond 50 GHz, with R&D working on even higher frequency components. The original components were designed as components for use inside of PSPL's picosecond risetime pulse generators. They were also sold individually as accessories for use with our pulse generators. They were all designed to have excellent pulse responses.

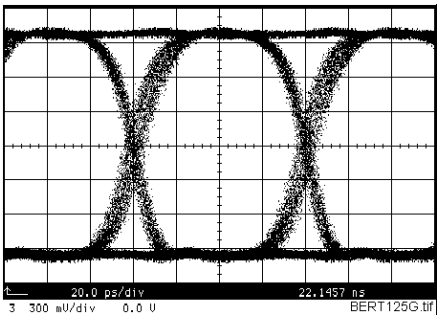
Starting in 1997, the long haul, fiber optics telecommunications industry began moving up from 2.5 Gb/s (OC-48) systems to 10 Gb/s (OC-192). Design engineers quickly found that the low frequency techniques they had used at lower frequencies would no longer work at 10 GHz. Some engineers in telecom R&D labs that had previously bought PSPL components as bench accessories in the late 80s and early 90s discovered that the ultra broadband performance of PSPL's components gave the extremely clean, pulse transient responses that they needed in their new 10 Gb/s systems. As a result, these engineers began designing these components into their new 10 Gb/s system. When this happened, high volume purchase orders starting rolling into PSPL, and PSPL entered into an explosive growth phase. The next generation fiber systems now under development in telecom R&D labs will be a factor of four higher, i.e., 40 Gb/s (OC-768). PSPL is already providing these R&D labs with higher performance components suitable for 40 Gb/s. PSPL is working on products for even higher frequencies.

There are many different tests typically performed on components to qualify them for use in Gb/s fiber optic systems. They include insertion loss / gain and return loss frequency responses from kHz to GHz, along with time domain TDR and pulse step response, using ps risetime pulse generators. The key measurement instrument for time domain tests is the ultra-wideband, digital sampling oscilloscopes. The current state of the art in oscilloscopes is 50 GHz. PSPL has historically provided this information in its specification sheets, using 50 GHz oscilloscopes and network analyzers.

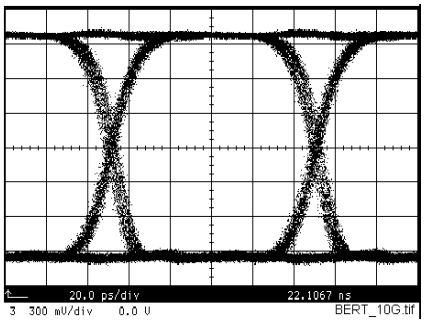
For digital telecom system engineers, their most important system measurements are the bit error rate and the eye diagram. They like to use the eye diagram to visually evaluate not just their system performance but also the performance of individual components. In response to many requests from engineers, PSPL is now issuing this application note showing the eye diagrams of many of our coaxial components. This note is organized to first show the eye diagrams of both active and passive components suitable for use in 12.5 Gb/s systems. This is followed by eye diagrams for components suitable for use in 10 Gb/s and 2.5 Gb/s systems. Components that will work well at higher data rates will work even better at lower bit rates. Eye diagrams are not shown at 40 Gb/s because PSPL does not have a 40 Gb/s pattern generator. Additional eye diagrams for products not shown or for different test conditions are available upon request. Please call PSPL's application engineers.

Two instruments are required to measure eye diagrams. They are a high performance oscilloscope and a pulse pattern generator. The oscilloscope used for these measurements was a Hewlett-Packard model 54750A. This oscilloscope had a 50 GHz bandwidth and 9 ps risetime. The pulse pattern generator was an Advantest model D-3186. This generator produces 2 V amplitude NRZ pulses with 25 ps risetime and 19 ps falltime. The generator was capable of running at data rates from 100 Mb/s to 14 Gb/s. For the eye pattern tests, the generator was set to produce a Pseudo Random Binary Sequence (PRBS) of 2^{31} - 1 length. To avoid overdriving the oscilloscope, the generator's pulses were attenuated using precision PSPL model 5510-K, 2.9 mm attenuators. These attenuators have risetimes of < 5 ps. The oscilloscope was triggered by the pattern generator's clock pulse. The time base was set to display two clock cycles, with the eye pattern centered on the CRT screen. The CRT's persistence was set to one second to show any long-term effects on the eye patterns. Tests were performed at bit rates of 12.5 Gb/s, 10 Gb/s, and 2.5 Gb/s. The plots in Figure 1 show the input signal eye diagrams, with the pattern generator connected directly to the oscilloscope.

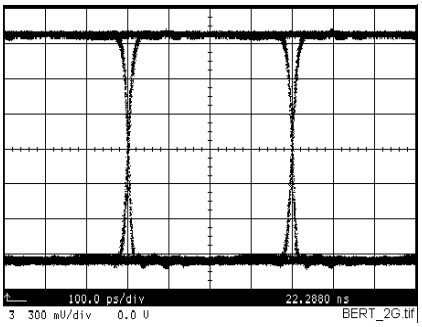
Figure 1



12.5 Gb/s Input Signal, NRZ, PRBS, $2^{31} - 1$ 20 ps/div



10 Gb/s Input Signal, NRZ, PRBS, $2^{31} - 1$, OC-192 20 ps/div



2.5 Gb/s Input Signal, NRZ, PRBS, $2^{31} - 1$, OC-48 100 ps/div

12.5 Gb/s EYES

Active and passive PSPL products suitable for use at 12.5 Gb/s that were tested included:

Product	Model Number(s)
Amplifiers	5828 & 5840
DC Blocks	5500A, 5501A, 5508 & 5509
Bias Tees	5542, 5541A & 5545
Attenuators	5510-K & 5510-NC (SMA)
6 dB Power Divider	5350
14 dB Pick-Off Tee	5361
Inverting Transformer	5100

All of these components show wide-open eye diagrams at 12.5 Gb/s. (See Figure 2.) The time scale is 20 ps/div. The 5828 & 5840 amplifiers were tested under two conditions. The vertical scale factor is 500 mV/div. One eye diagram is for operation in the linear region, with an output amplitude of 2 V_{ptp}. The other eye diagram is for operation at the -1 dB gain compression point, with output amplitudes of 2.6 to 2.8 V_{ptp}. The 5828 is an inverting amplifier with 10 dB gain. The 5840 is a two stage version of the 5828. It is a non-inverting amplifier with 23 dB gain. Both amplifiers are suitable for driving electro-absorption modulators.

10 Gb/s EYES

Active and passive PSPL products suitable for use at 10 Gb/s that were tested included:

Product	Model Number(s)
Low Pass Filter	5915-7.5GHz & 5930-7.5GHz
Amplifiers	5828 & 5840
Bias Tees	5550B, 5547, 5575A & 5580
6 dB Power Dividers	5331 & 5536

All of these components show good, open eye diagrams at 10 Gb/s. (See Figure 4.) The time scale is 20 ps/div. The 5828 & 5840 amplifiers were again tested for outputs of 2 V_{ptp} and for -1dB gain compression outputs of 2.8 V_{ptp}.

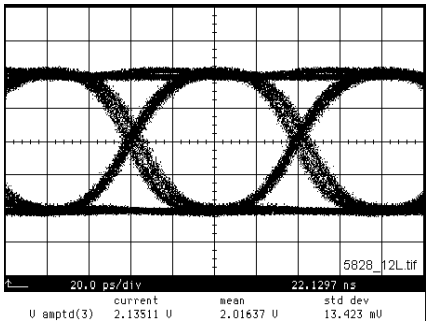
2.5 Gb/s EYES

Active and passive PSPL products suitable for use at 2.5 Gb/s that were tested included:

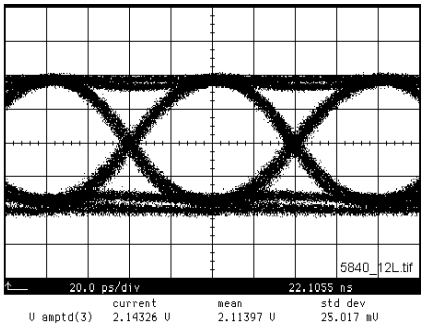
Product	Model Number
Low Pass Filter	5915-1.87GHz (OC-48)
Amplifier	5824

These are all excellent eye diagrams. (See Figure 3.) The time scale is 100 ps/div. The 5824 amplifier was tested under two conditions. The vertical scale factor is 1 V/div. One eye diagram is for operation in the linear region, with an output amplitude of 4 V_{ptp}. The other eye diagram is for operation at the -1 dB gain compression point, with output amplitude of 5.3 V_{ptp}. The 5824 is an inverting amplifier with 19 dB gain.

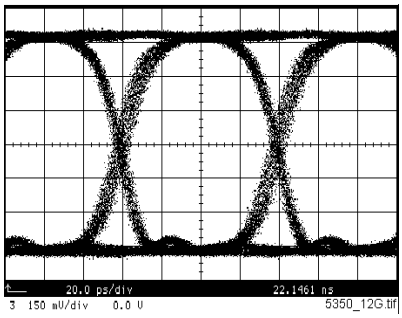
Figure 2: 12.5 Gb/s Eye Diagrams



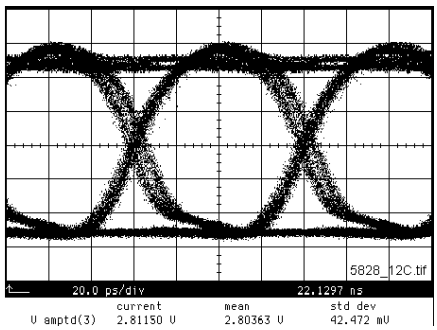
5828 Amplifier, 2 V_{ptp} output, Linear Gain, 12.5 Gb/s Eye



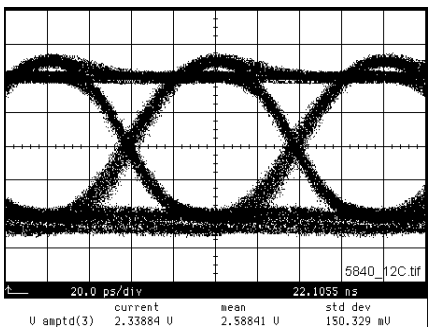
5840 Amplifier, 2 V_{ptp} output, Linear Gain, 12.5 Gb/s Eye



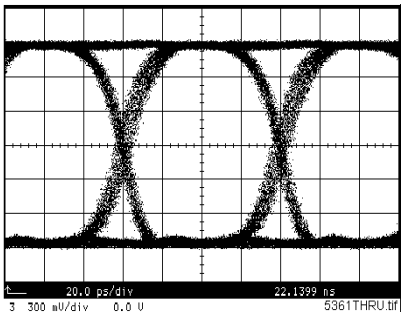
5350 6 dB Power Divider, 12.5 Gb/s Eye



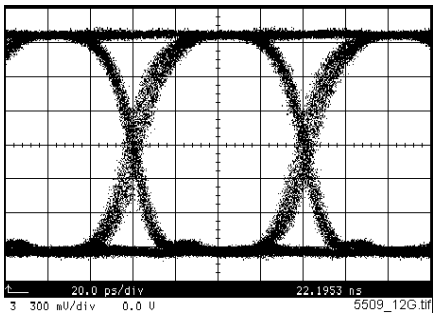
5828 Amplifier, 2.8 V_{ptp} output @ –1 dB gain comp.,12.5 Gb/s Eye



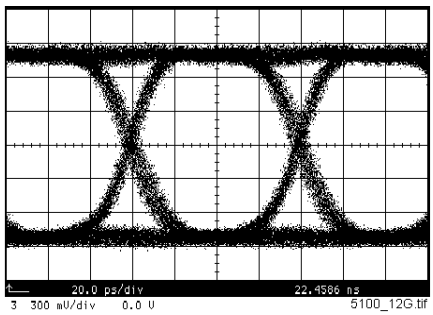
5840 Amplifier, 2.6 V_{ptp} output @ –1 dB gain comp.,12.5 Gb/s Eye



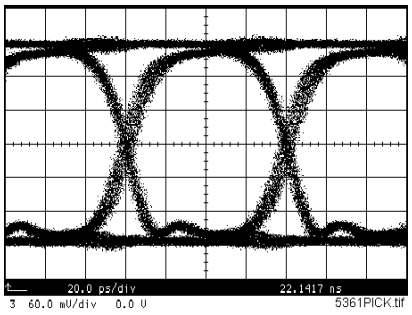
5361 5X Pick Off, Thru Line Signal, 12.5 Gb/s Eye



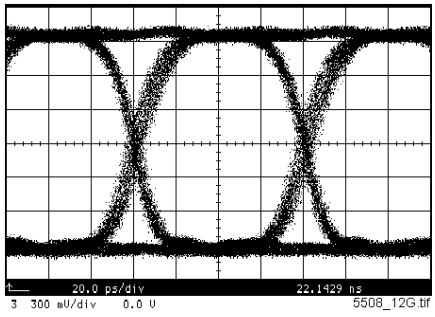
5509 DC Block, 12.5 Gb/s Eye



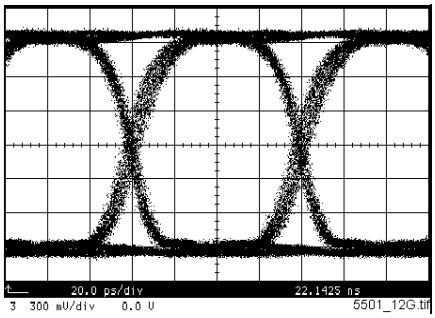
5100 Inverting Transformer, 12.5 Gb/s Eye



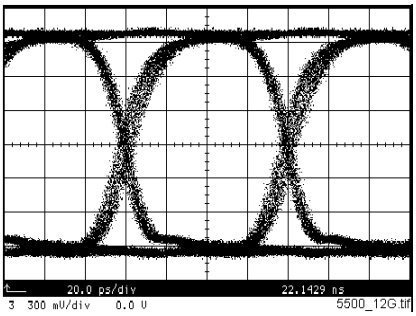
5361 5X Pick Off, –14 dB Pick-off Signal, 12.5 Gb/s Eye



5508 DC Block, 12.5 Gb/s Eye

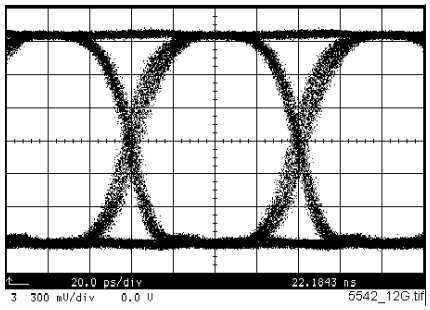


5501A DC Block, 12.5 Gb/s Eye

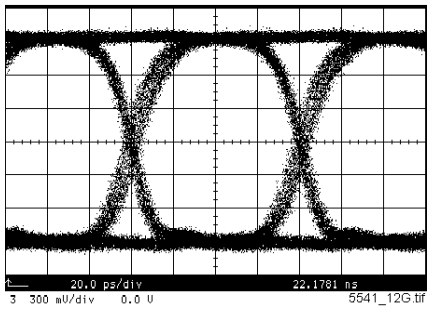


5500A DC Block, 12.5 Gb/s Eye

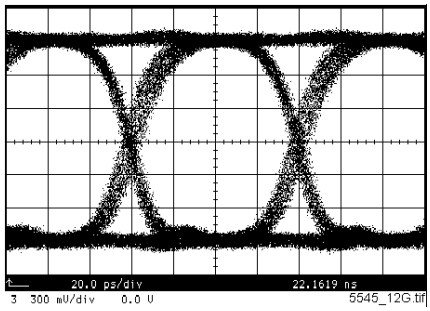
Figure 2: 12.5 Gb/s Eye Diagrams (continued)



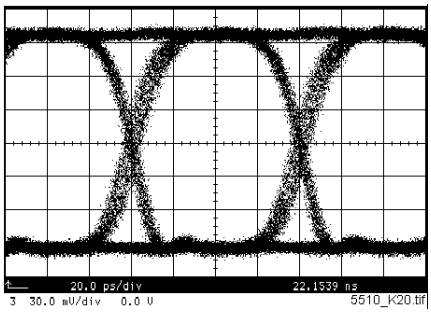
5542 Bias Tee, 12.5 Gb/s Eye



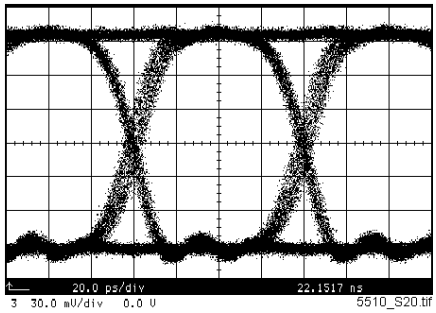
5541A Bias Tee, 12.5 Gb/s Eye



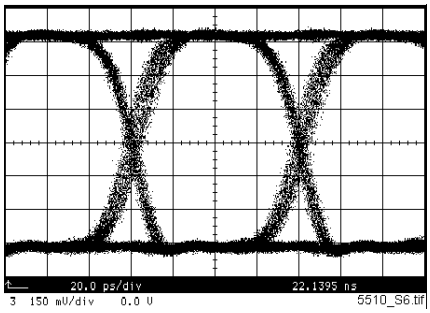
5545 Bias Tee, 12.5 Gb/s Eye



5510-K Attenuator, 20 dB,
2.9mm,12.5 Gb/s Eye

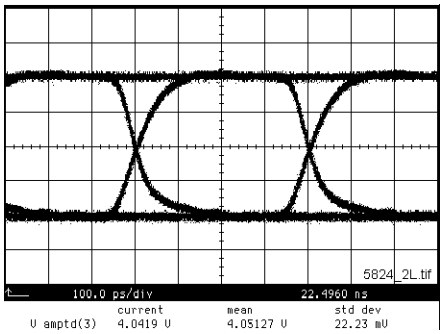


5510-NC Attenuator, 20 dB,
SMA, 12.5 Gb/s Eye

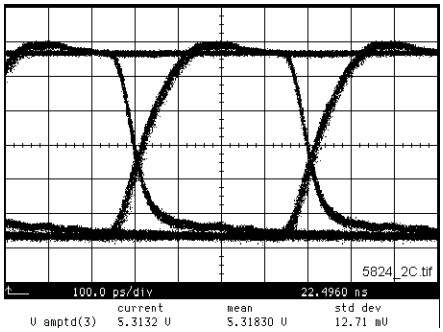


5510-NC Attenuator, 6 dB,
SMA, 12.5 Gb/s Eye

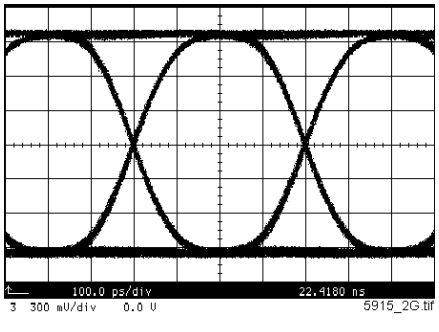
Figure 3: 2.5 Gb/s Eye Diagrams



5824 Amplifier, 4 V_{ptp} output,
Linear Gain, 2.5 Gb/s Eye

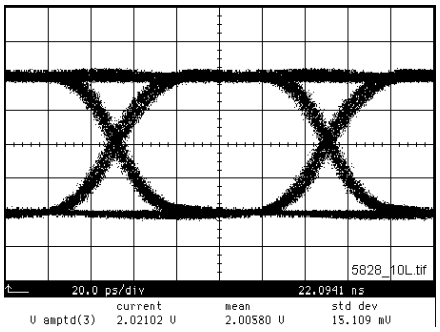


5824 Amplifier, 5.3 V_{ptp} output
@ –1 dB gain comp., 2.5 Gb/s Eye

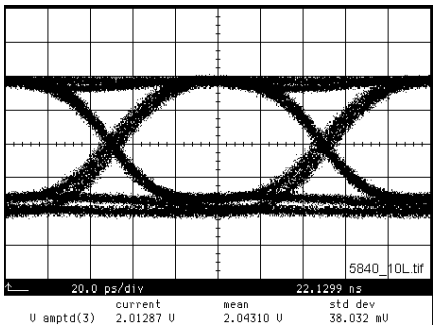


5915-1.87 GHz Low Pass Filter,
2.5 Gb/s Eye

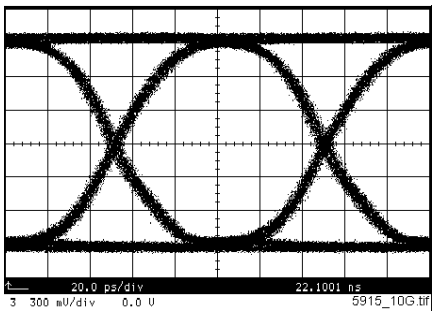
Figure 4: 10 Gb/s Eye Diagrams



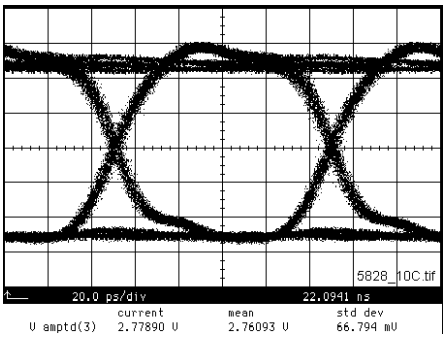
5828 Amplifier, 2 V_{ptp} output, Linear Gain, 10 Gb/s Eye



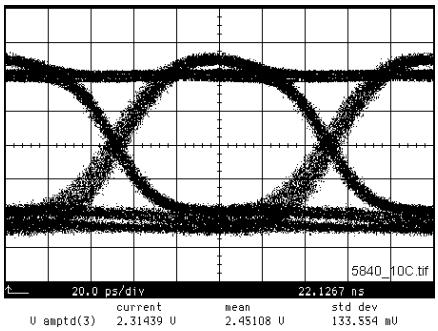
5840 Amplifier, 2 V_{ptp} output, Linear Gain, 10 Gb/s Eye



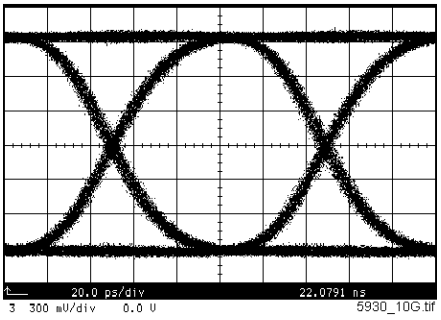
5915-7.5 GHz Low Pass Filter, 10 Gb/s Eye



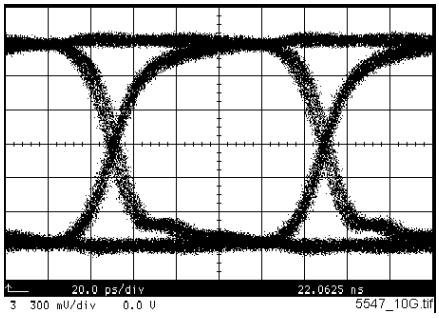
5828 Amplifier, 2.8 V_{ptp} output @ –1 dB gain comp., 10 Gb/s Eye



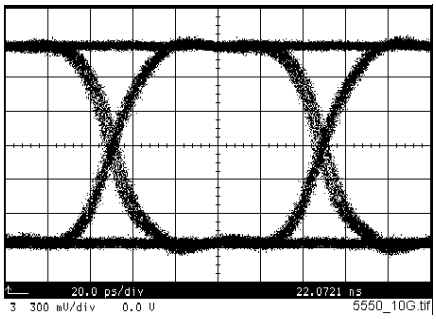
5840 Amplifier, 2.6 V_{ptp} output @ –1 dB gain comp., 10 Gb/s Eye



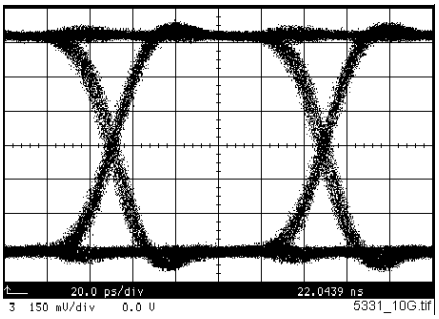
5930-7.5 GHz Low Pass Filter, 10 Gb/s Eye



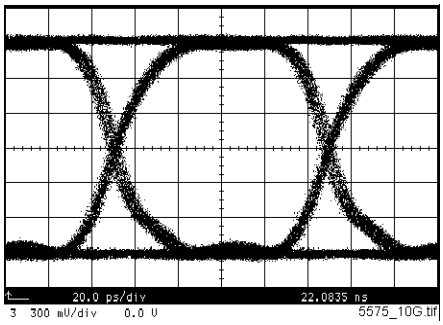
5547 Bias Tee, 10 Gb/s Eye



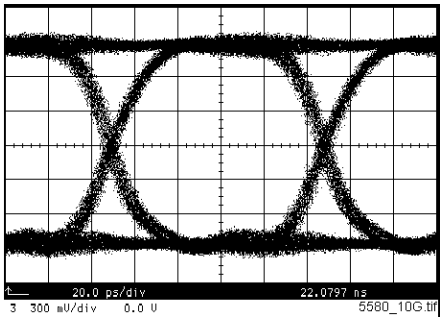
5550B Bias Tee, 10 Gb/s Eye



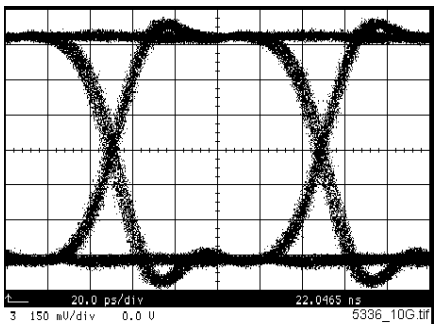
5331 6 dB Power Splitter, 10 Gb/s Eye



5575A Bias Tee, 10 Gb/s Eye



5580 Bias Tee, 10 Gb/s Eye



5336 6 dB Power Splitter, 10 Gb/s Eye