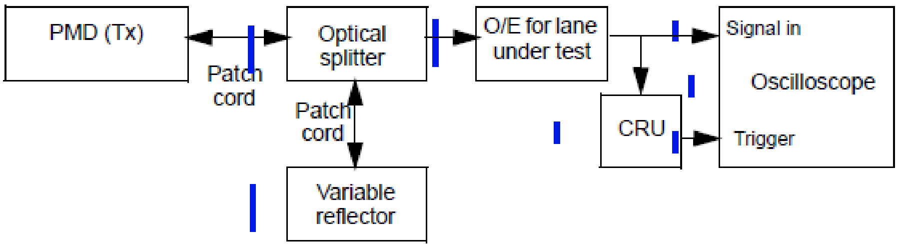
### 95.8.5 Transmitter vertical eye closure (TxVEC)

TxVEC of each lane shall be within the limits given in Table 95–6 if measured using the methods specified in 95.8.5.1 and 95.8.5.2.

TxVEC is a measure of each optical transmitter's vertical eye closure; it is based upon vertical histogram data from an eye diagram measured through an optical to electrical converter (O/E) with a bandwidth equivalent to a combined reference receiver and worst case optical channel. Table 95–10 specifies the test patterns to be used for measurement of TxVEC.

#### 95.8.5.1 TxVEC conformance test set-up

A block diagram for the TxVEC conformance test is shown in Figure 95–3. Other measurement implementations may be used with suitable calibration.




***Text from Figure 95–3 repeated for editing purposes below***

PMD (Tx) Patch cord Optical splitter Patch cord Variable reflector O/E for lane under test Oscilloscope Signal in Trigger CRU

**Figure 95–3—TxVEC conformance test block diagram**

Each optical lane is tested individually with all other lanes in operation. The optical splitter and variable reflector are adjusted so that each transmitter is tested with an optical return loss of 12 dB.

The combination of the O/E and the oscilloscope used to measure the optical waveform has a fourth-order Bessel-Thomson filter response with a bandwidth of 12.6 GHz. Compensation may be made for any deviation from an ideal fourth-order Bessel-Thomson response.

The clock recovery unit (CRU) has a corner frequency of 10 MHz and a slope of 20 dB/decade.

#### 95.8.5.2 TxVEC measurement method

The oscilloscope is set up to accumulate samples of the optical eye diagram of the transmitter under test, as illustrated in Figure 95–4.

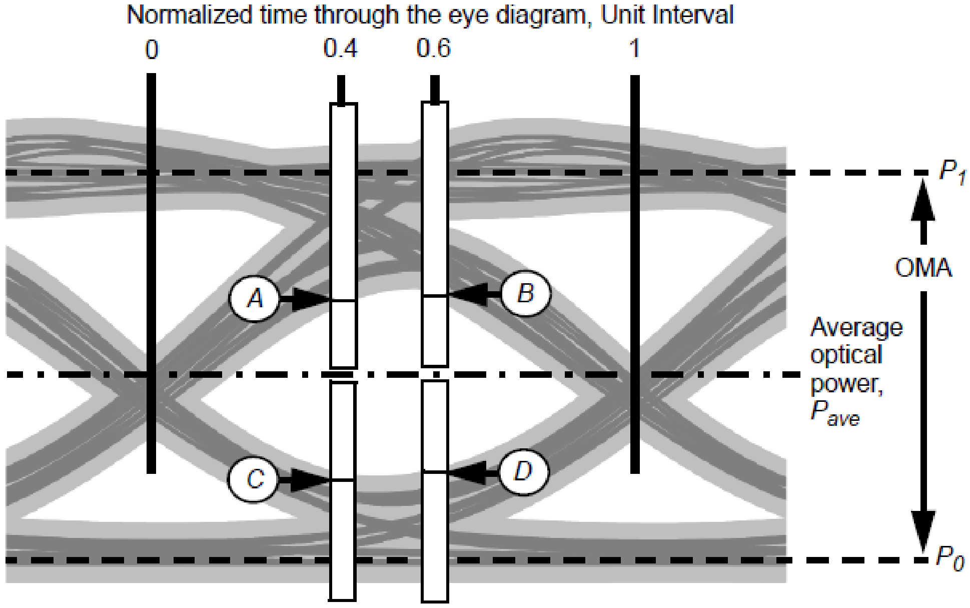
OMA is measured according to 95.8.4. ~~The power of the optical zeros (P0) and the power of the optical ones (P1) are recorded.~~ Also the standard deviation of the noise of the oscilloscope, *S*, is found with no input optical signal and the same settings as used to capture the histograms described below.

The average optical power ($P_{ave}$) and the crossing points of the eye diagram, and the four vertical histograms used to calculate TxVEC, are measured using Pattern 3 or Pattern 5.

The 0 UI and 1 UI crossing points are determined by the time average of the eye diagram crossing points, as measured at $P_{ave}$, as illustrated in Figure 95–4.

Four vertical histograms are measured through the eye diagram, centered at 0.4 UI and 0.6 UI, and above and below $P_{ave}$, as illustrated in Figure 95–4.

Each histogram window has a width of 0.04 UI. Each histogram window has an inner height boundary which is set close to $P_{ave}$ (so that no further samples would be captured by moving it closer to $P_{ave}$), and an outer height boundary which is set beyond the outer-most samples of the eye diagram, so that no further samples would be captured by increasing the outer boundary of the histogram. ~~Starting from the boundary of the histogram closest to the average optical power level, the optical power at which the cumulative distribution of each histogram equals the 0.005th percentile of the total number of samples for each histogram is recorded (these are the powers *A*, *B*, *C*, and *D* illustrated in Figure 95–4).~~




***In Figure 95–4, delete the round labels and arrows A, B, C D. The values of P1 and P2 are not used in the calculation; they could be deleted if desired***

***Text from Figure 95–4 repeated for editing purposes below***

Normalized time through the eye diagram, Unit Interval

0 0.4 0.6 1

Average optical power, $P_{ave}$

$P_1$ $P_0$[PD1] *OMA* ~~*C D A B*~~

**Figure 95–4—Illustration of the TxVEC measurement**

The distributions of the two histograms on the left are each convolved with a Gaussian function representing an estimate of the greatest tolerable noise that could be added by an optical channel and a receiver. The Gaussian function has a standard deviation $\sigma_L$ chosen so that the sum of the portion of the resulting upper distribution below $P_{ave}$ plus the portion of the resulting lower distribution above $P_{ave}$ is $5 \times 10^{-5}$ of the total of both distributions. Similarly, the distributions of the two histograms on the right are each convolved with a Gaussian function with a standard deviation $\sigma_R$ so that the sum of the portion of the resulting upper distribution below $P_{ave}$ plus the portion of the resulting lower distribution above $P_{ave}$ is $5 \times 10^{-5}$ of the total of both distributions. Each Gaussian function has a mean of zero.

Convolution is defined by

$$f(y) * G(y) = \int_{-\infty}^{\infty} f(z)G(y-z)dz \qquad (95\text{–}1)$$

where $f$ is one of the histograms. The Gaussian function $G$ can be written as

$$G(y) = \exp(-y^2 / (2\sigma_G^2)) / \sqrt{(2\pi\sigma_G^2)} \qquad (95\text{–}2)$$

where $\sigma_G$ is the standard deviation, $\sigma_L$ or $\sigma_R$.

The lesser of $\sigma_L$ and $\sigma_R$ is $N$.

The noise that could be added by a receiver, $R$, is given by

$$R = \sqrt{(N^2 + S^2 - M^2)} \qquad (95\text{–}3)$$

TxVEC is defined as the largest of the four quantities given by Equation (95–1) to Equation (95–4):

$$TxVEC(A) = 10\log_{10}( (P1 - Pave) / (A - Pave) ) \qquad (95\text{–}1)$$

$$TxVEC(B) = 10\log_{10}( (P1 - Pave) / (B - Pave) ) \qquad (95\text{–}2)$$

$$TxVEC(C) = 10\log_{10}( (Pave - P0) / (Pave - C) ) \qquad (95\text{–}3)$$

$$TxVEC(D) = 10\log_{10}( (Pave - P0) / (Pave - D) ) \qquad (95\text{–}4)$$

where $M$ is a term to account for the mode partition noise and modal noise that could be added by the optical channel, and $S$ is the standard deviation of the noise of the oscilloscope.

$$M = \sqrt{( (0.0257OMA)^2 + (0.01P_{ave})^2 )} \qquad (95\text{-}4)$$

where

$P_{ave}$ is the average optical power of the eye diagram, and
$P0$, $P1$ $OMA$ areis the optical modulation amplitude powers of 0 and 1 as defined for OMA in 95.8.4.
$A$, $B$, $C$, $D$ are the 0.005th percentile optical power levels of the four vertical histograms described in 95.8.5.2.

$TxVEC$ is given by:

$$TxVEC = 10\log_{10}(OMA / (2\times3.8906R) ) \qquad (95\text{-}5)$$

The factor 3.8906 is chosen for consistency with the BER of $5 \times 10^{-5}$ given in 95.1.1.

The method described in 95.8.5.2 is the reference measurement method. Other (equivalent) measurement methods may be used with suitable calibration.