Changes to clause 95 to include TxVEC ‘improved’

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95.7 PMD to MDI optical specifications for 100GBASE-SR4

The operating range for the 100GBASE-SR4 PMD is defined in Table 95–5. A 100GBASE-SR4 compliant PMD operates on 50/125 µm multimode fibers, type A1a.2 (OM3) or type A1a.3 (OM4), according to the specifications defined in Table 95–12. A PMD that exceeds the operating range requirement while meeting all other optical specifications is considered compliant (e.g., a 100GBASE-SR4 PMD operating at 120 m meets the operating range requirement of 0.5 m to 100 m).

Table 95–5—100GBASE-SR4 operating range

PMD type	Required operating range[a]
100GBASE-SR4	0.5 m to 70 m for OM3
	0.5 m to 100 m for OM4

[a]The RS-FEC correction function may not be bypassed for any operating distance.

95.7.1 100GBASE-SR4 transmitter optical specifications

Each lane of a 100GBASE-SR4 transmitter shall meet the specifications in Table 95–6 per the definitions in 95.8.

Table 95–6—100GBASE-SR4 transmit characteristics

Description	Value	Unit
Signaling rate, each lane (range)	25.78125 ± 100 ppm	GBd
Center wavelength (range)	840 to 860	nm
RMS spectral width[a] (max)	0.6	nm
Average launch power, each lane (max)	2.4	dBm
Average launch power, each lane (min)	–9.1	dBm
Optical Modulation Amplitude (OMA), each lane (max)	3	dBm
Optical Modulation Amplitude (OMA), each lane (min)[b]	–7.1	dBm
Launch power in OMA minus ~~TDP~~ TxVEC (min)	–8	dBm
Transmitter ~~and dispersion penalty~~ vertical eye closure (~~TDP~~TxVEC), each lane (max)	5	dB
Average launch power of OFF transmitter, each lane (max)	–30	dBm
Extinction ratio (min)	2	dB
Optical return loss tolerance (max)	12	dB
Encircled flux[c]	≥ 86% at 19 µm ≤ 30% at 4.5 µm	
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}	{0.3, 0.38, 0.45, 0.35, 0.41, 0.5}	

[a]RMS spectral width is the standard deviation of the spectrum.
[b]Even if the ~~TDP~~ TxVEC < 0.9 dB, the OMA (min) must exceed this value.
[c]If measured into type A1a.2 or type A1a.3 50 µm fiber in accordance with IEC 61280-1-4.

Table 95–8—100GBASE-SR4 illustrative link power budget

Parameter	OM3	OM4	Unit
Effective modal bandwidth at 850 nm[a]	2000	4700	MHz.km
Power budget (for max ~~TDP~~TxVEC)	8.2		dB
Operating distance	0.5 to 70	0.5 to 100	m
Channel insertion loss[b]	1.8	1.9	dB
Allocation for penalties[c] (for max ~~TDP~~TxVEC)	6.3		dB
Additional insertion loss allowed	0.1	0	dB

[a]per IEC 60793-2-10.
[b]The channel insertion loss is calculated using the maximum distance specified in Table 95–5 and cabled optical fiber attenuation of 3.5 dB/km at 850 nm plus an allocation for connection and splice loss given in 95.11.2.1.
[c]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

95.8.1 Test patterns for optical parameters

While compliance is to be achieved in normal operation, specific test patterns are defined for measurement consistency and to enable measurement of some parameters. Table 95–10 gives the test patterns to be used in each measurement, unless otherwise specified, and also lists references to the subclauses in which each parameter is defined. Any of the test patterns given for a particular test in Table 95–10 may be used to perform that test. As Pattern 3 is more demanding than Pattern 5 (which itself is the same or more demanding than other 100GBASE-R bit streams) an item that is compliant using Pattern 5 is considered compliant even if it does not meet the required limit using Pattern 3. The test patterns used in this clause are shown in Table 95–9.

Table 95–9—Test patterns

Pattern	Pattern description	Defined in
Square wave	Square wave (8 ones, 8 zeros)	83.5.10
3	PRBS31	83.5.10
4	PRBS9	83.5.10
5[a]	RS-FEC encoded scrambled idle	82.2.10[a]

[a]The pattern defined in 82.2.10 as encoded by Clause 91 RS-FEC for 100GBASE-SR4

95.8.1.1 Multi-lane testing considerations

~~TDP is defined for each lane, at the BER specified in 95.1.1 on that lane.~~ Stressed receiver sensitivity is defined for an interface at the BER specified in 95.1.1. The interface BER is the average of the four BERs of the receive lanes when they are stressed.

Measurements with Pattern 3 (PRBS31) allow lane-by-lane BER measurements. Measurements with Pattern 5 (RS-FEC encoded scrambled idle) give the interface BER if all lanes are stressed at the same time.

Table 95–10—Test-pattern definitions and related subclauses

Parameter	Pattern	Related subclause
Wavelength, spectral width	3, 5 or valid 100GBASE-SR4 signal	95.8.2
Average optical power	3, 5 or valid 100GBASE-SR4 signal	95.8.3
Optical modulation amplitude (OMA)	Square wave or 4	95.8.4
Transmitter ~~and dispersion penalty~~ vertical eye closure (~~TDP~~TxVEC)	3 or 5	95.8.5
Extinction ratio	3, 5 or valid 100GBASE-SR4 signal	95.8.6
Transmitter optical waveform	3, 5 or valid 100GBASE-SR4 signal	95.8.7
Stressed receiver sensitivity	3 or 5	95.8.8
Vertical eye closure penalty calibration	3 or 5	87.8.11

If each lane is stressed in turn, the BER is diluted by the three unstressed lanes, and the BER for that stressed lane alone must be found, e.g., by multiplying by four if the unstressed lanes have low BER. ~~To allow TDP measurement with Pattern 5, unstressed lanes for the error detector may be created by setting the power at the reference receivers well above their sensitivities, or by copying the contents of the transmit lanes not under BER test to the error detector by other means.~~ In stressed receiver sensitivity measurements, unstressed lanes may be created by setting the power at the receiver under test well above its sensitivity and/or not stressing those lanes with ISI and jitter, or by other means. Each receive lane is stressed in turn while all are operated. All aggressor lanes are operated as specified. To find the interface BER, the BERs of all the lanes when stressed are averaged.

Where relevant, parameters are defined with all co-propagating and counter-propagating lanes operational so that crosstalk effects are included. Where not otherwise specified, the maximum amplitude (OMA or VMA) for a particular situation is used, and for counter-propagating lanes, the minimum transition time is used. Alternative test methods that generate equivalent results may be used. While the lanes in a particular direction may share a common clock, the Tx and Rx directions are not synchronous to each other. If Pattern 3 is used for the lanes not under test using a common clock, there is at least 31 UI delay between the PRBS31 patterns on one lane and any other lane.

95.8.2 Center wavelength and spectral width

The center wavelength and RMS spectral width of each optical lane shall be within the range given in Table 95–6 if measured per TIA/EIA-455-127-A or IEC 61280-1-3. The lane under test is modulated using the test pattern defined in Table 95–10.

95.8.3 Average optical power

The average optical power of each lane shall be within the limits given in Table 95–6 if measured using the methods given in IEC 61280-1-1. The average optical power is measured using the test pattern defined in Table 95–10.

95.8.4 Optical Modulation Amplitude (OMA)

OMA shall be within the limits given in Table 95–6 if measured as defined in 52.9.5 for measurement with a square wave (8 ones, 8 zeros) test pattern or 68.6.2 (from the variable MeasuredOMA in 68.6.6.2) for measurement with a PRBS9 test pattern, with the exception that each optical lane is tested individually. See 95.8.1 for test pattern information.

95.8.5 ~~Transmitter and dispersion penalty (TDP)~~

~~Transmitter and dispersion penalty (TDP) shall be as defined for 10GBASE-S in 52.9.10 with the following exceptions:~~

a) ~~Each optical lane is tested individually with all other lanes in operation.~~

b) ~~The test pattern is as defined in Table 95–10~~

c) ~~The transmitter is tested using an optical channel with an optical return loss of 12 dB.~~

d) ~~The reference transmitter rise/fall times should be less than 12 ps at 20% to 80%, and should pass the eye mask test of 95.8.7. The reference transmitter optical waveform is measured for vertical eye closure penalty (VECP), as defined in Equation (52-4), but evaluated at ± 0.11 UI from the eye center, using a receiver with a fourth-order Bessel-Thomson filter response with a bandwidth of 12.6 GHz.~~

e) ~~The reference receiver (including the effect of the decision circuit) has a fourth-order Bessel-Thomson filter response with a bandwidth of 12.6 GHz. The transversal filter of 52.9.10.3 is not used.~~

f) ~~The clock recovery unit (CRU) used in the TDP measurement has a corner frequency of 10 MHz and a slope of 20 dB/decade.~~

g) ~~The reference sensitivity S and the measurement P_DUT are both measured with the sampling instant displaced from the eye center by ± 0.11 UI. Because the reference sensitivity test is done with a restricted bandwidth receiver, a correction is required to calculate S. S is equal to the measured sensitivity minus the measured reference transmitter VECP from item d). For each of the two cases (early and late), if P_DUT(*i*) is larger than S(*i*), the TDP(*i*) for the transmitter under test is the difference between P_DUT(*i*) and S(*i*), i.e. TDP(*i*) = P_DUT(*i*) – S(*i*). Otherwise, TDP(*i*) = 0. The TDP is the larger of the two TDP(*i*).~~

h) ~~The test setup illustrated in Figure 52-12 shows the reference method. Other measurement implementations may be used with suitable calibration.~~

i) ~~TDP is defined for each lane, at the BER specified in 95.1.1 and is for the lane under test on its own. See 95.8.1.1 for multi-lane pattern considerations.~~

~~NOTE—Sampling instant offsets have to be calibrated because practical receivers and decision circuits have noise and timing impairments. One method of doing this is via a jitter bathtub method using a known low-jitter signal.~~

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

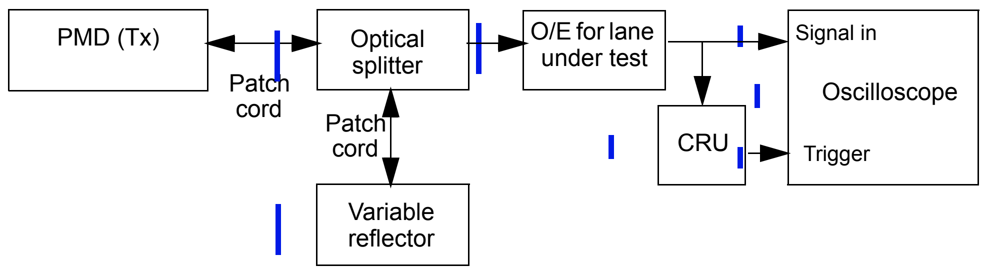

Figure 95–3—TxVEC conformance test block diagram

implementations may be used with suitable calibration.

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 for the transmitter under test, as illustrated in Figure 95–4.

OMA is measured according to 95.8.4.

The standard deviation of the noise of the O/E and oscilloscope combination, *S*, is determined with no optical input 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..

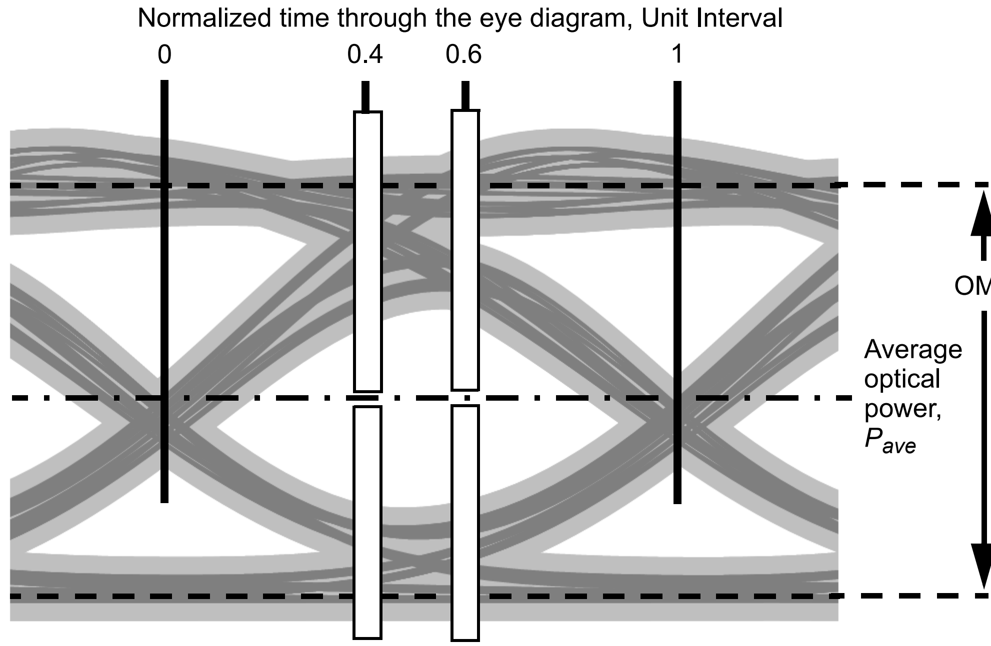

Figure 95–4—Illustration of the TxVEC measurement

The distributions of the two histograms on the left are each multiplied by Q functions which represent an estimate of the probability of errors caused by each part of the distribution for the greatest tolerable noise that could be added by an optical channel and a receiver. The resulting distributions are integrated and each integral is divided by the integral of the distribution it was derived from, giving two bit error probabilities. The Q function uses a standard deviation, σ_L, chosen so that the average of these two bit error probabilities is 5×10^{-5}. Similarly, for the two histograms on the right, a standard deviation, σ_R, is found.

Q(x) is the area under a Normal curve for values larger than *x* (the tail probability, related to the "complementary error function"), as shown in Equation (95–1):

$$Q(x) = \int_x^{\infty} \frac{e^{(-z^2/2)}}{\sqrt{2\pi}} dz \qquad (95\text{–}1)$$

where

x is $(y - P_{ave})/\sigma_G$ or $(P_{ave} - y)/\sigma_G$, as in Equation (95–2).

This procedure finds a value of σ_G such that Equation (95–2) is satisfied:

$$\frac{1}{2}\left(\frac{\int fu(y)Q\left(\frac{y-P_{ave}}{\sigma_G}\right)dy}{\int fu(y)dy}\right)+\frac{1}{2}\left(\frac{\int fl(y)Q\left(\frac{P_{ave}-y}{\sigma_G}\right)dy}{\int fl(y)dy}\right) = 5\times10^{-5} \quad (95\text{–}2)$$

where

$fu(y)$, $fl(y)$	are the upper and lower distributions
σ_G	is the left or right standard deviation, σ_L or σ_R.

The lesser of σ_L and σ_R is N.

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

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

where

M	is a term to account for mode partition noise and modal noise that could be added by the optical channel, defined in Equation (95–4), and
S	is the standard deviation of the noise of the O/E and oscilloscope combination.

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

where

P_{ave}	is the average optical power of the eye diagram, and
OMA	is the optical modulation amplitude as defined in 95.8.4.

TxVEC is given by:

$$TxVEC = 10\log_{10}\left(\frac{OMA}{2} \times \frac{1}{3.8906R}\right) \quad (95\text{–}5)$$

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

The method described in 95.8.5.1 and 95.8.5.2 is the reference measurement method. Other equivalent measurement methods may be used with suitable calibration.

95.8.6 Extinction ratio

The extinction ratio of each lane shall be within the limits given in Table 95–6 if measured using the methods specified in IEC 61280-2-2. The extinction ratio is measured using one of the test patterns specified for extinction ratio in Table 95–10.

NOTE—Extinction ratio and OMA are defined with different test patterns (see Table 95–10).

95.12.4.3 PMD to MDI optical specifications for 100GBASE-SR4

Item	Feature	Subclause	Value/Comment	Status	Support
CSR1	Transmitter meets specifications in Table 95–6	95.7.1	Per definitions in 95.8	M	Yes [ ] N/A [ ]
CSR2	Receiver meets specifications in Table 95–7	95.7.2	Per definitions in 95.8	M	Yes [ ] N/A [ ]

95.12.4.4 Optical measurement methods

Item	Feature	Subclause	Value/Comment	Status	Support
COM1	Measurement cable	95.8	2 m to 5 m in length	M	Yes [ ]
COM2	Center wavelength and spectral width	95.8.2	Per TIA/EIA-455-127-A or IEC 61280-1-3 under modulated conditions	M	Yes [ ]
COM3	Average optical power	95.8.3	Per IEC 61280-1-1	M	Yes [ ]
COM4	OMA measurements	95.8.4	Each lane	M	Yes [ ]
COM5	~~Transmitter and dispersion penalty~~ <u>Transmitter vertical eye closure (TxVEC)</u>	95.8.5	Each lane	M	Yes [ ]
COM6	Extinction ratio	95.8.6	Per IEC 61280-2-2	M	Yes [ ]
COM7	Transmit eye	95.8.7	Each lane	M	Yes [ ]
COM8	Stressed receiver sensitivity	95.8.8	See 95.8.8	M	Yes [ ]

95.12.4.5 Environmental specifications

Item	Feature	Subclause	Value/Comment	Status	Support
CES1	General safety	95.9.1	Conforms to IEC 60950-1	M	Yes [ ]
CES2	Laser safety—IEC Hazard Level 1	95.9.2	Conforms to Hazard Level 1 laser requirements defined in IEC 60825-1 and IEC 60825-2	M	Yes [ ]
CES3	Electromagnetic interference	95.9.5	Complies with applicable local and national codes for the limitation of electromagnetic interference	M	Yes [ ]