This document contains proposed changes to subclause 87.8.11 and 88.9.10.

Subclause 87.8.11 in Draft 2.1 is:

87.8.11 Stressed receiver sensitivity

Stressed receiver sensitivity shall be within the limits given in Table 87–8 for 40GBASE–LR4 if measured using the method defined in 53.9.12 and 53.9.15 with the conformance test signal at TP3 as described in 53.9.14 with the following exceptions:

a) Added sinusoidal jitter is as specified in Table 87–13.
b) The stressed eye jitter and vertical eye closure penalty are as specified in Table 87–8.
c) The test pattern is as specified in Table 87–11.
d) When setting the wavelengths of the channels adjacent to the channel under test, the center wavelengths of the adjacent channels are set within 0.3 nm of the edge of their channel's wavelength band while remaining within that wavelength band.

Table 87–13—Applied sinusoidal jitter

Frequency range	Sinusoidal jitter ($UI_{pk\ to\ pk}$)
$f < 40$ kHz	Not specified
40 kHz $< f \leq$ 4 MHz	$2 \times 10^5 / f + S - 0.05$[a]
4 MHz $< f <$ 10 LB[b]	$0.05 \leq S \leq 0.15$[a]

[a]*S* is the magnitude of sine jitter actually used in the calibration of the stressed eye per the methods of 52.9.9.3.
[b]*LB* = loop bandwidth; Upper frequency bound for added sine jitter should be at least 10 times the loop bandwidth of the receiver being tested.

For each lane, the stressed receiver sensitivity is defined with the transmit section in operation on all four lanes and with the receive lanes not under test in operation. Test patterns 3 or 5, or valid 40GBASE–R bit streams may be sent from the transmit section of the receiver under test. The data being transmitted is asynchronous to the received data.

Change this to become:

87.8.11 Stressed receiver conformance test

Stressed receiver sensitivity shall be within the limits given in Table 87–8 for 40GBASE–LR4 if measured using the method described in 87.8.11.1 and 87.8.11.5 with the conformance test signal at TP3 as described in 87.8.11.2.

For each lane, the stressed receiver sensitivity is defined with the transmit section in operation on all four lanes and with the receive lanes not under test also in operation. Pattern 3 or Pattern 5, or a valid 40GBASE–R signal is sent from the transmit section of the PMD under test. The signal being transmitted is asynchronous to the received signal.

87.8.11.1 Stressed receiver conformance test block diagram

A block diagram for the receiver conformance test is shown in Figure 87–3. The test pattern is specified in Table 87–11. The optical test signal is conditioned (stressed) using the stressed receiver methodology defined in 87.8.11.2, and has sinusoidal jitter applied as specified in 87.8.11.4.

A suitable test set is needed to characterize and verify that the signal used to test the receiver has the appropriate characteristics.

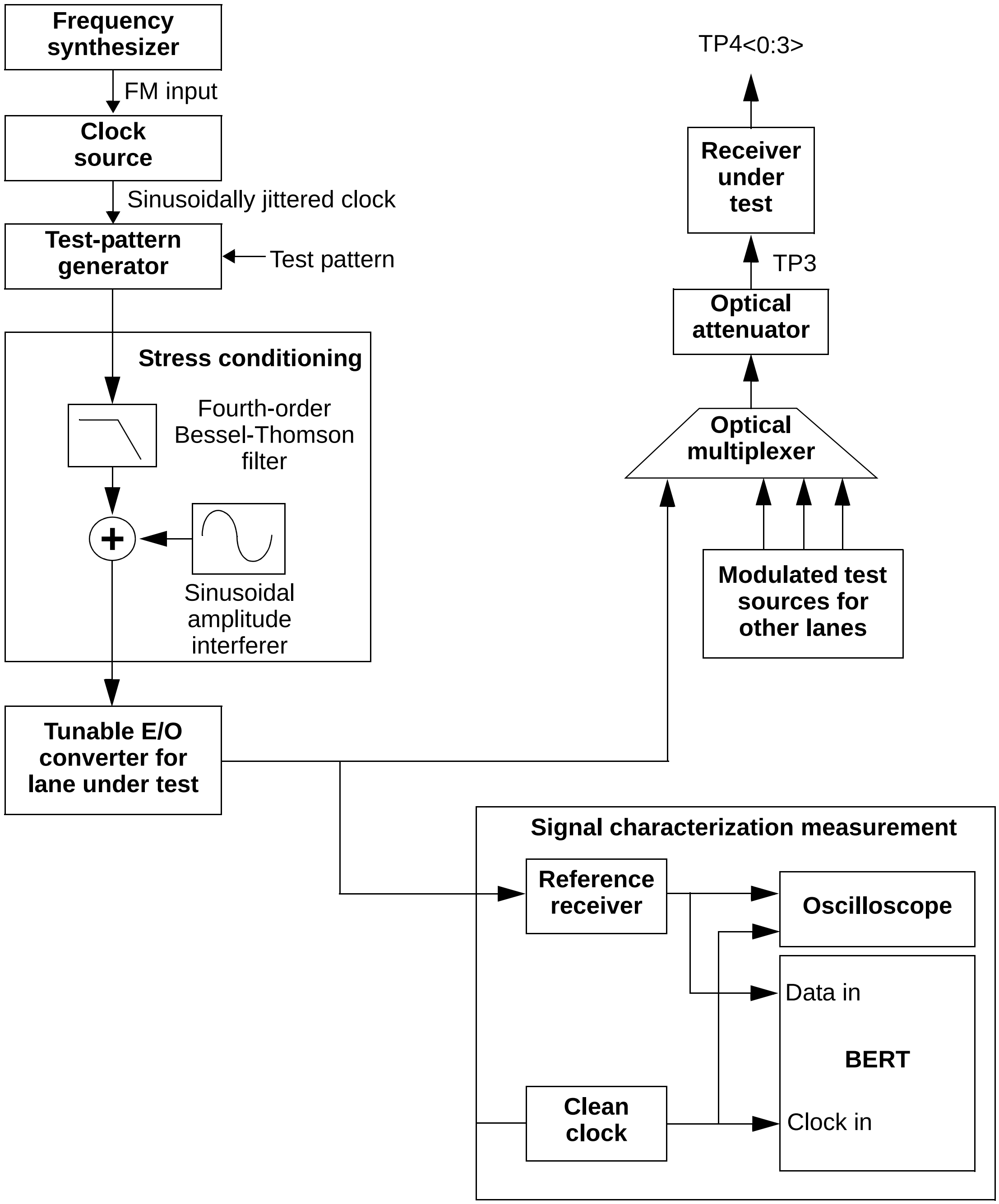

Figure 87–3—Stressed receiver conformance test block diagram

The fourth-order Bessel-Thomson filter is used to create ISI-induced vertical eye closure penalty (VECP). The Bessel-Thomson filter, when combined with the E/O converter, should have a frequency response which results in the appropriate level of initial vertical eye closure before the sinusoidal terms are added.

The sinusoidal amplitude interferer causes additional eye closure, but in conjunction with the slowed edge rates from the filter, also causes jitter intended to emulate Duty Cycle Distortion (DCD). DCD cannot be created by simple phase modulation alone. The sinusoidally jittered clock represents other forms of jitter and also verifies that the receiver under test can track low-frequency jitter.

The sinusoidal amplitude interferer may be set at any frequency between 100 MHz and 2 GHz, although care should be taken to avoid harmonic relationships between the sinusoidal interference, the sinusoidal jitter, the data rate and the pattern repetition rate.

For improved visibility for calibration, the Bessel-Thomson filter and all other elements in the signal path (cables, DC blocks, E/O converter, etc.) should have wide and smooth frequency response, and linear phase response, throughout the spectrum of interest. Baseline wander and overshoot and undershoot should be minimized. Random noise effects, such as RIN and random clock jitter, should also be minimized. Some residual noise and jitter from all sources is unavoidable, but should be less than 0.25 UI peak-peak jitter at the 10^{-12} points. If this is achieved, then data dependent effects should be minimal, and short data patterns can be used for calibration with the benefit of providing better trace visibility on sampling oscilloscopes.

Patterns that may be used for testing the receiver are specified in Table 87–11.

The stressed receiver conformance signal verification is described in 87.8.11.3.

87.8.11.2 Stressed receiver conformance test signal characteristics and calibration

The conformance test signal is used to validate that the PMD receiver of the lane under test meets BER requirements with near worst case waveforms at TP3.

The primary parameters of the conformance test signal are vertical eye closure penalty (VECP) and stressed eye jitter (SEJ). Vertical eye closure penalty is measured at the time center of the eye (halfway between 0 and 1 on the unit interval scale as defined in 52.9.7). The stressed eye jitter is defined from the 0.5th to the 99.5th percentile of the jitter histogram and is measured at the average optical power, which can be obtained with AC coupling. The values of these components are defined by their histogram results.

The vertical eye closure penalty is given by Equation (87–1).

$$\text{Vertical eye closure penalty [dB]} = 10 \times \log\frac{A_N}{A_O} \qquad (87\text{–}1)$$

where:

A_O is the amplitude of the eye opening from the 99.95th percentile of the lower histogram to the 0.05th percentile of the upper histogram, and
A_N is the normal amplitude without ISI, as shown in Figure 87–4.

Residual low-probability noise and jitter should be minimized so that the outer slopes of the final histograms are as steep as possible.

The following steps describe a possible method for setting up and calibrating a stressed eye conformance signal when using a stressed receiver conformance test set up as shown in Figure 87–3:

1) Set the signaling rate of the test pattern generator to meet the requirements in Table 87–8.
2) With sinusoidal interferer and sinusoidal jitter turned off, set the extinction ratio of the E-O to approximately the minimum specified in Table 87–7.

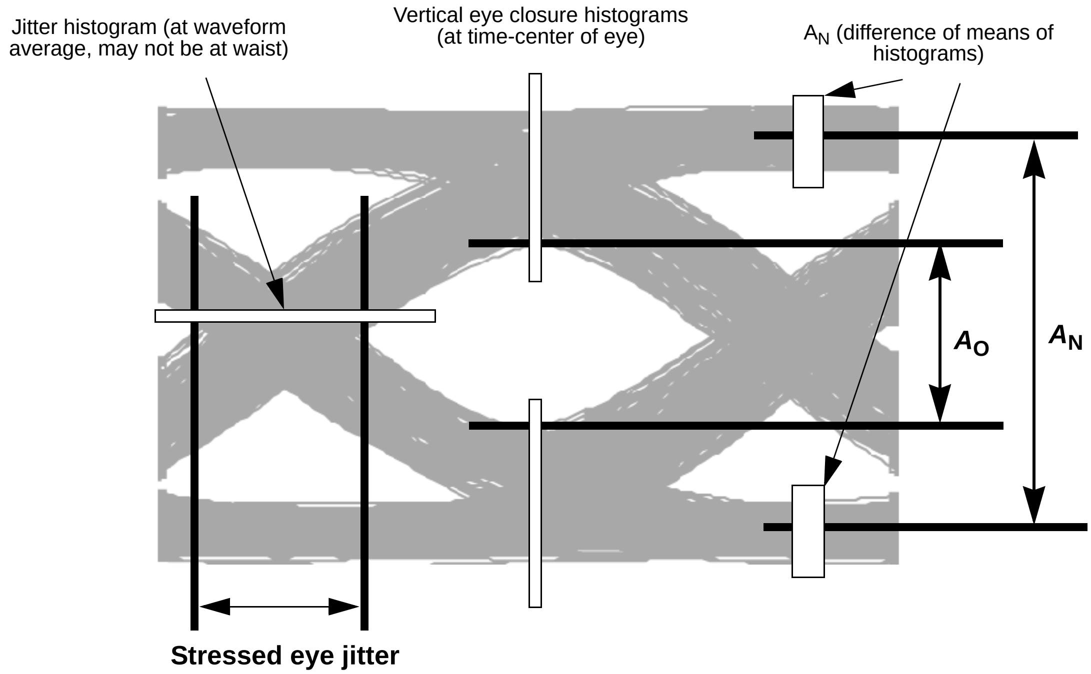

Figure 87–4—Required characteristics of the conformance test signal at TP3

3) The required values of VECP and SEJ of the stressed receiver conformance signal are given in Table 87–8.

   With the sinusoidal interference and sinusoidal jitter turned off, greater than two thirds of the VECP value should be created by the selection of the appropriate bandwidth for the fourth-order Bessel-Thomson filter. Any remaining vertical eye closure must be created with sinusoidal interference or sinusoidal jitter.

   The sinusoidal amplitude interferer may be set at any frequency between 100 MHz and 2 GHz, although care should be taken to avoid harmonic relationships between the sinusoidal interference, the sinusoidal jitter, the data rate and the pattern repetition rate.

   Sinusoidal jitter is added as specified in Table 87–13. When calibrating the conformance signal, the sinusoidal jitter frequency should be well within the 4 MHz to 10 times LB as defined in Table 87–13 and illustrated in Figure 87–5.

   Iterate the adjustments of sinusoidal interference and sinusoidal jitter until the values of VECP and SEJ meet the requirements in Table 87–8, and sinusoidal jitter above 4 MHz is as specified in Table 87–13. The sinusoidal jitter added should result in at least 0.05 UI peak to peak DCD.

Figure 87–3 shows the stress conditioned signal being applied to a tunable E-O convertor. However, any optical source may be used which can meet the OMA and wavelength requirements for the lane under test as described in 87.8.11.5. Similarly, the other test sources which supply modulated signals to the other lanes may use any tunable or fixed sources which meet the OMA and wavelength requirements described in 87.8.11.5.

Each receiver lane is conformance tested in turn. The source for the lane under test is adjusted to supply a signal at the input to the receiver under test at the stressed receiver sensitivity OMA specified in Table 87–8, and the test sources for the other lanes are set to the required OMA as described in 87.8.11.5.

87.8.11.3 Stressed receiver conformance test signal verification

The stressed receiver conformance test signal can be verified using an optical reference receiver with an ideal fourth order Bessel-Thomson response at 0.75 times the baud rate. Use of G.691 tolerance filters may significantly degrade this calibration. The clock output from the clock source in Figure 87–3 will be modulated with the sinusoidal jitter. To use an oscilloscope to calibrate the final stressed eye jitter that includes the sinusoidal jitter component, a separate clock source (Clean clock of Figure 87–3) is required that is synchronized to the source clock, but not modulated with the jitter source.

Care should be taken when characterizing the test signal because excessive noise/jitter in the measurement system will result in an input signal that does not fully stress the receiver under test. Running the receiver tolerance test with a signal that is under-stressed may result in the deployment of non-compliant receivers. Care should be taken to minimize the noise/jitter introduced by the reference O-E, filters and BERT and/or to correct for this noise. While the details of a BER scan measurement and test equipment are beyond the scope of this document, it is recommended that the implementer fully characterize their test equipment and apply appropriate guard bands to ensure that the stressed receiver conformance input signal meets the minimum stress and sinusoidal jitter specified in 87.8.11.2 and 87.8.11.4.

87.8.11.4 Sinusoidal jitter for receiver conformance test

The sinusoidal jitter is used to test receiver jitter tolerance. The amplitude of the applied sinusoidal jitter is dependent on frequency as specified in Table 87–13 and is illustrated in Figure 87-6.

Table 87–13—Applied sinusoidal jitter

Frequency range	Sinusoidal jitter ($UI_{pk\ to\ pk}$)
$f < 40$ kHz	Not specified
40 kHz $< f \le 4$ MHz	$2 \times 10^5 / f + S - 0.05$[a]
4 MHz $< f < 10\ LB$[b]	$0.05 \le S \le 0.15$[a]

[a]*S* is the magnitude of sine jitter actually used in the calibration of the stressed eye per the methods of 87.8.11.2.
[b]*LB* = loop bandwidth; Upper frequency bound for added sine jitter should be at least 10 times the loop bandwidth of the receiver being tested.

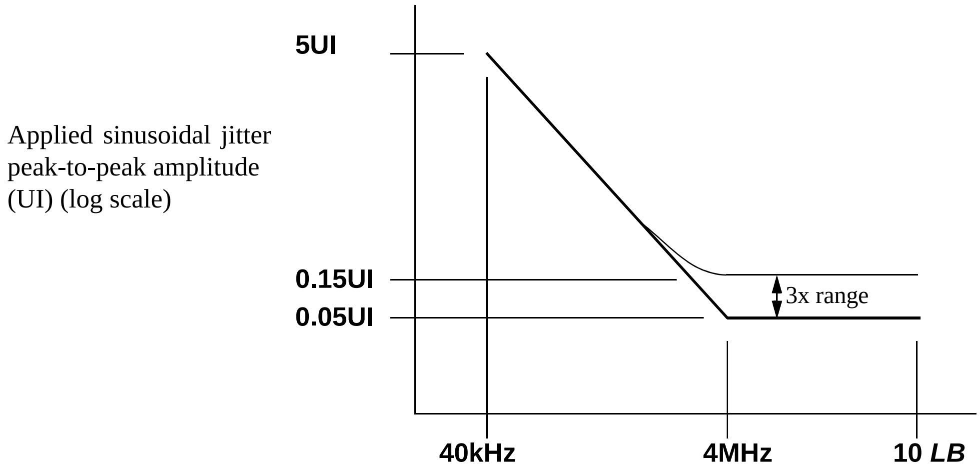

Figure 87–5—Illustration of the mask of the sinusoidal component of jitter tolerance

87.8.11.5 Stressed receiver conformance test procedure for WDM conformance testing

The receiver tests requiring the TP3 conformance test signal are performed on a per lane basis. For each lane, the stressed receiver sensitivity is defined with the transmit section in operation on all four lanes and with the receive lanes not under test also in operation. Pattern 3 or Pattern 5, or a valid 40GBASE–R signal is sent from the transmit section of the PMD under test. The signal being transmitted is asynchronous to the received signal. All test sources are modulated simultaneously, using valid 40GBASE-LR4 signals. The transmitter of the transceiver under test is operating with test patterns as defined in 87–11.

A rigorous method for testing WDM conformance using tunable test sources is described below:

a) The OMAs of the test sources in the lanes other than the lane under test are set to the highest OMA relative to the test source in the lane under test allowed by the ‘difference in receive power between any two lanes (OMA) (max)’ parameter in Table 87–8.
b) The test sources in the lanes other than the lane under test are tuned to wavelengths within their wavelength range corresponding to the worst case crosstalk to the lane under test.
c) The test source for the lane under test is tuned to the wavelength within its wavelength range corresponding to the worst case sensitivity for the receiver under test.

It is recognized that a test setup which uses multiple tunable sources, while allowing rigorous worst-case measurements to be made, is likely to be onerous in practice.

A more practical, alternative method for testing WDM conformance is described below. The alternative WDM conformance test avoids the need for tunable sources but may result in some over-stressing of the receiver under test:

1) The test sources in each lane can be at any wavelength within each lane’s wavelength range.
2) The OMAs of the test sources in the lanes other than the lane under test are set to the highest OMA relative to the test source in the lane under test allowed by the ‘difference in receive power between any two lanes (OMA) (max)’ parameter in Table 87–8, plus an increment corresponding to insertion loss variation within the lane under test (Note 1), plus an increment corresponding to the isolation variation of the lane in question (Note 2).

NOTE 1—The increment corresponding to the variation of insertion loss with wavelength within the lane under test is the equal to the dB insertion loss variation of measured receiver sensitivity as the test source wavelength is swept across the wavelength range of the lane under test.

NOTE 2—For each of the test sources in the lanes not under test, an increment corresponding to the isolation variation is applied which is equal to the dB variation in optical crosstalk measured in the lane under test as the wavelength of each test source in the lanes not under test are swept across their respective wavelength ranges.

There are many ways to determine the size of the increments required, two example methods are given below. Note that each lane will have one insertion loss variation value, and three values of optical crosstalk variation (one for each of the other lanes)

Example method 1: If a measure of the received signal strength is available for each lane, scan a tunable laser across the wavelength range of each lane while simultaneously recording the received signal in all lanes. As the laser sweeps across the wavelength range of a particular lane the dB variation in observed signal in that lane is equal to the insertion loss variation. The dB variation in signal observed in each of the other lanes is equal to the optical crosstalk variation.

Example method 2: If a discrete optical demultiplexer and discrete receivers are used, scan a tunable laser across the wavelength range of each channel while simultaneously recording the optical power of all four demultiplexer outputs. As the laser sweeps across the wavelength range of a particular channel, the dB variation in observed optical power in that lane's output is equal to the insertion loss variation. The dB variation in optical power observed in each of the other lanes outputs is equal to the optical crosstalk variation.

Subclause 88.9.10 in Draft 2.1 is:

88.9.10 Stressed receiver sensitivity

Stressed receiver sensitivity shall be within the limits given in Table 88–8 for 100GBASE–LR4 or Table 88–12 for 100GBASE–ER4 if measured using the method defined in 53.9.12 and 53.9.15 with the conformance test signal at TP3 as described in 53.9.14 with the following exceptions:

a) Added sinusoidal jitter is as specified in Table 87–13.
b) The stressed eye jitter and vertical eye closure penalty are as given in Table 88–8 for 100GBASE–LR4 or Table 88–12 for 100GBASE–ER4.
c) The test pattern is as given in Table 88–15.
d) When setting the wavelengths of the channels adjacent to the channel under test, the center wavelengths of the adjacent channels are set within 0.1 nm of the edge of their channel's wavelength band while remaining within that wavelength band.

Table 88–17—Applied sinusoidal jitter

Frequency range	Sinusoidal jitter ($UI_{pk\ to\ pk}$)
$f < 100$ kHz	Not specified
100 kHz $< f \leq$ 10 MHz	$2 \times 10^5 / f + S - 0.05$[a]
10 MHz $< f <$ 10 LB[b]	$0.05 \leq S \leq 0.15$[a]

[a]S is the magnitude of sine jitter actually used in the calibration of the stressed eye per the methods of 52.9.9.3.
[b]LB = loop bandwidth; Upper frequency bound for added sine jitter should be at least 10 times the loop bandwidth of the receiver being tested.

For each lane, the stressed receiver sensitivity is defined with the transmit section in operation on all four lanes and with the receive lanes not under test in operation. Test patterns 3 or 5, or a valid 100GBASE–R signal may be sent from the transmit section of the receiver under test. The signal being transmitted is asynchronous to the received data.

Change this to become:

88.9.10 Stressed receiver sensitivity

Stressed receiver sensitivity shall be within the limits given in Table 88–8 for 100GBASE–LR4 or Table 88–12 for 100GBASE–ER4 if measured using the method defined in 87.8.11 with the following exceptions:

a) Added sinusoidal jitter is as specified in Table 88–17.
b) The stressed eye jitter and vertical eye closure penalty are as given in Table 88–8 for 100GBASE–LR4 or Table 88–12 for 100GBASE–ER4.
c) The test pattern is as given in Table 88–15.

Table 88–17—Applied sinusoidal jitter

Frequency range	Sinusoidal jitter (UI $_{\text{pk to pk}}$)
$f < 100$ kHz	Not specified
100 kHz $< f \leq$ 10 MHz	$2 \times 10^5 / f + S - 0.05$[a]
10 MHz $< f <$ 10 LB[b]	$0.05 \leq S \leq 0.15$[a]

[a]S is the magnitude of sine jitter actually used in the calibration of the stressed eye per the methods of 87.8.11.2.
[b]LB = loop bandwidth; Upper frequency bound for added sine jitter should be at least 10 times the loop bandwidth of the receiver being tested.