Proposed subclause 999.7 on 100G BiDi definition of optical parameters and measurement methods

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P802.3dk TF December 2023 Meeting

Subclauses 140.7 and 160.7

- 140.7 specifies definition of optical parameters and measurement methods for 100GBASE PMDs
  - Optical parameters in the 100GBASE PMD tables and their measurement methods are covered
- 160.7 from 802.3cp is another reference of optical parameters and measurement methods
  - 160.7 is for 50G BiDi
- It is proposed to reuse these subclauses for 100G BiDi
- Following slides show content reuse and suggested minor changes
  - Black text: reused content from 140.7/160.7
  - Blue text: difference between 140.7 and 160.7
  - Red text: discussion point

Proposed subclause 999.7 (references: subclause 140.7)

999.7 Definition of optical parameters and measurement methods

All transmitter optical measurements shall be made through a short patch cable, between 2 m and 5 m in length, unless otherwise specified.

999.7.1 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 999–10 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 999–10 may be used to perform that test. The test patterns used in this clause are shown in Table 999–9.

Table 999–9—Test patterns

Pattern	Pattern description	Defined in
Square wave	Square wave (8 threes, 8 zeros)	120.5.11.2.4
3	PRBS31Q	120.5.11.2.2
4	PRBS13Q	120.5.11.2.1
5	Scrambled idle encoded by RS-FEC	82.2.11, 91
6	SSPRQ	120.5.11.2.3

Reference: Table 140-9 from Clause 140

Proposed subclause 999.7 (references: subclause 140.7)

Table 999–10—Test-pattern definitions and related subclauses

Parameter	Pattern	Related subclause
Wavelength	Square wave, 3, 4, 5, 6 or valid 100GBASE-R signal	999.7.2
Side-mode suppression ratio	3, 5, 6 or valid 100GBASE-R signal	999.7.2
Average optical power	3, 5, 6 or valid 100GBASE-R signal	999.7.3
Outer Optical Modulation Amplitude (OMA_{outer})	4 or 6	999.7.4
Transmitter and dispersion eye closure for PAM4 (TDECQ)	6	999.7.5
Transmitter eye closure for PAM4 (TECQ)	6	999.7.6
Over/under-shoot	6	999.7.7
Transmitter power excursion	6	999.7.8
Extinction ratio	4 or 6	999.7.9
Transmitter transition time	Square wave or 6	999.7.10
RIN*x*OMA	Square wave	999.7.11
Receiver sensitivity	3 or 5	999.7.12
Stressed receiver conformance test signal calibration	6	999.7.13
Stressed receiver sensitivity	3 or 5	999.7.13

Reference: Table 140-10 from Clause 140

Proposed subclause 999.7 (references: subclauses 140.7 and 160.7)

999.7.2 Wavelength and side-mode suppression ratio (SMSR)

The wavelength and SMSR shall be within the range given in Table 999–6 for 100GBASE-BRx, if measured per IEC 61280-1-3. The transmitter is modulated using the test pattern defined in Table 999–10.

999.7.3 Average optical power

The average optical power shall be within the limits given in Table 999–6 for 100GBASE-BRx if measured using the methods given in IEC 61280-1-1. The average optical power is measured using the test pattern defined in Table 999–10, per the test setup in Figure 53–6.

999.7.4 Outer Optical Modulation Amplitude (OMAouter)

The OMA_{outer} shall be within the limits given in Table 999–6 for 100GBASE-BRx. The OMA_{outer} is measured using a test pattern specified for OMA_{outer} in Table 999–10 as the difference between the average optical launch power level P_3, measured over the central 2 UI of a run of 7 threes, and the average optical launch power level P_0, measured over the central 2 UI of a run of 6 zeros, as shown in Figure 999–3.

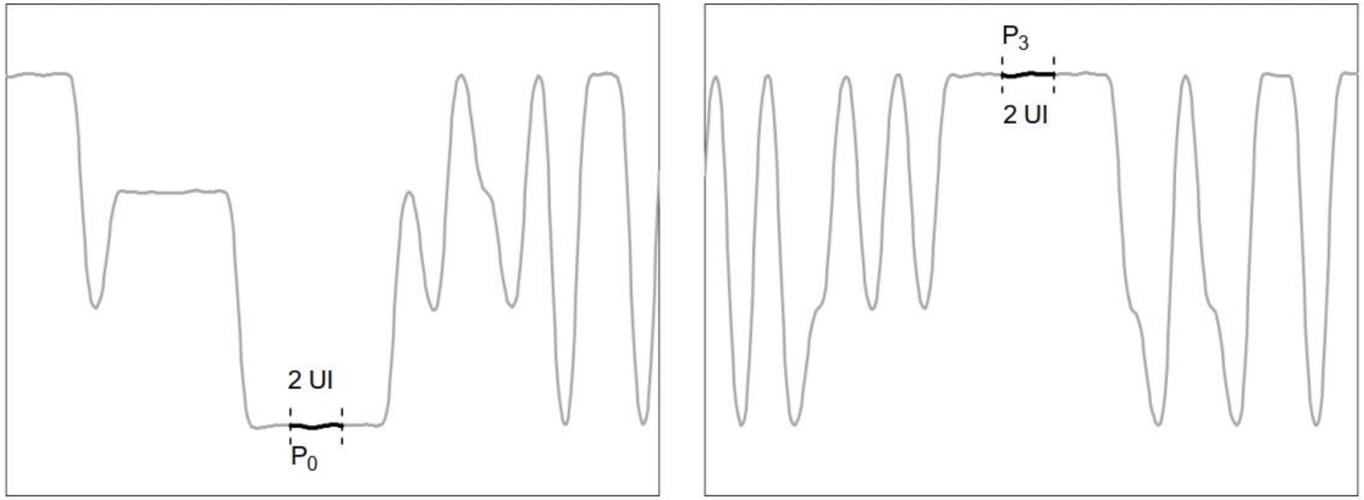

Figure 999–3—Example power levels P_0 and P_3 from PRBS13Q test pattern

Additional contents in Clause 140

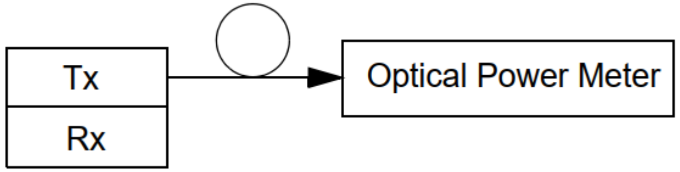

Figure 53–6—Optical power measurement test set-up

Proposed subclause 999.7 (references: subclause 160.7)

999.7.5 Transmitter and dispersion eye closure for PAM4 (TDECQ)

The TDECQ shall be within the limits given in Table 999–6 for 100GBASE-BRx if measured using the methods specified in 999.7.5.1, 999.7.5.2, and 999.7.5.3. TDECQ is a measure of each optical transmitter's vertical eye closure when transmitted through a worst case optical channel (specified in 999.7.5.2), as measured through an optical to electrical converter (O/E) with a bandwidth equivalent to a reference receiver, and equalized with the reference equalizer (as described in 999.7.5.4). The reference receiver and equalizer may be implemented in software or may be part of the oscilloscope.

Table 999–10 specifies the test patterns to be used for measurement of TDECQ.

999.7.5.1 TDECQ conformance test setup

A block diagram for the TDECQ conformance test is shown in Figure 999–4. Other equivalent measurement implementations may be used with suitable calibration.

The optical splitter and variable reflector are adjusted so that each transmitter is tested with the optical return loss specified in Table 999–11. The state of polarization of the back reflection is adjusted to create the greatest RIN. The signal is tested with the optical channel described in 999.7.5.2. The combination of the O/E converter and the oscilloscope has a 3 dB bandwidth of approximately 26.5625 GHz with a fourth-order Bessel-Thomson response to at least 1.3 × 53.125 GHz and at frequencies above 1.3 × 53.125 GHz the response should not exceed –20 dB. Compensation may be made for any deviation from an ideal fourth-order Bessel-Thomson response.

The test pattern (specified in Table 999–10) is transmitted repetitively and the oscilloscope is set up to capture the complete pattern for TDECQ analysis as described in 999.7.5.3. The clock recovery unit (CRU) has a corner frequency of 4 MHz and a slope of 20 dB/decade. The CRU can be implemented in hardware or software depending on oscilloscope technology.

Proposed subclause 999.7 (references: subclause 140.7 and 160.7)

999.7.5.2 Channel requirements

The transmitter is tested using an optical channel that meets the requirements listed in Table 999–11.

A 100GBASE-BRx transmitter is to be compliant with a total dispersion at least as negative as the "minimum dispersion" and at least as positive as the "maximum dispersion" columns specified in Table 999–11 for the wavelength of the device under test. This may be achieved with channels consisting of fibers with lengths chosen to meet the dispersion requirements.

To verify that the fiber has the correct amount of dispersion, the measurement method defined in IEC 60793-1-42 may be used. The measurement is made in the linear power regime of the fiber.

The channel provides an optical return loss specified in Table 999–11. The state of polarization of the back reflection is adjusted to create the greatest RIN.

The mean DGD of the channel is to be less than the value specified in Table 999–11.

Reference: Table 160-11 from Clause 160

Table 999–11—Transmitter compliance channel specifications

PMD type	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c]	Max mean DGD
	Minimum	Maximum			
100GBASE-BR10	$0.23 \times \lambda \times [1-(1324 / \lambda)^4]$	$0.23 \times \lambda \times [1-(1300 / \lambda)^4]$	Minimum	15.6	5
100GBASE-BR20	$0.46 \times \lambda \times [1-(1324 / \lambda)^4$	$0.46 \times \lambda \times [1-(1300 / \lambda)^4]$	Minimum	TBD	TBD
100GBASE-BR40	$0.92 \times \lambda \times [1-(1324 / \lambda)^4$	$0.92 \times \lambda \times [1-(1300 / \lambda)^4]$	Minimum	TBD	TBD

a The dispersion is measured for the wavelength of the device under test (λ in nm). The coefficient assumes 10 km for 100GBASE-BR10, 20 km for 10GBASE-BR20, and 40 km for 100GBASE-BR40. The link may be as short as 2 m, and the minimum or maximum dispersion may be 0.
b There is no intent to stress the sensitivity of the O/E converter associated with the oscilloscope.
c The optical return loss is applied at TP2.

Proposed subclause 999.7 (references: subclause 160.7)

999.7.5.3 TDECQ measurement method

TDECQ for 100GBASE-BRx is measured as described in 121.8.5.3 with the following exception:

— The reference equalizer is as specified in 999.7.5.4.

121.8.5.3: TDECQ measurement method

999.7.5.4 TDECQ reference equalizer

The reference equalizer for 100GBASE-BRx is a 5 tap, T spaced, feed-forward equalizer (FFE), where T is the symbol period. A functional model of the reference equalizer is shown in Figure 999–5. The sum of the equalizer tap coefficients is equal to 1. Tap 1, tap 2, or tap 3, has the largest magnitude tap coefficient, which is constrained to be at least 0.8.

Reference: Clause 160

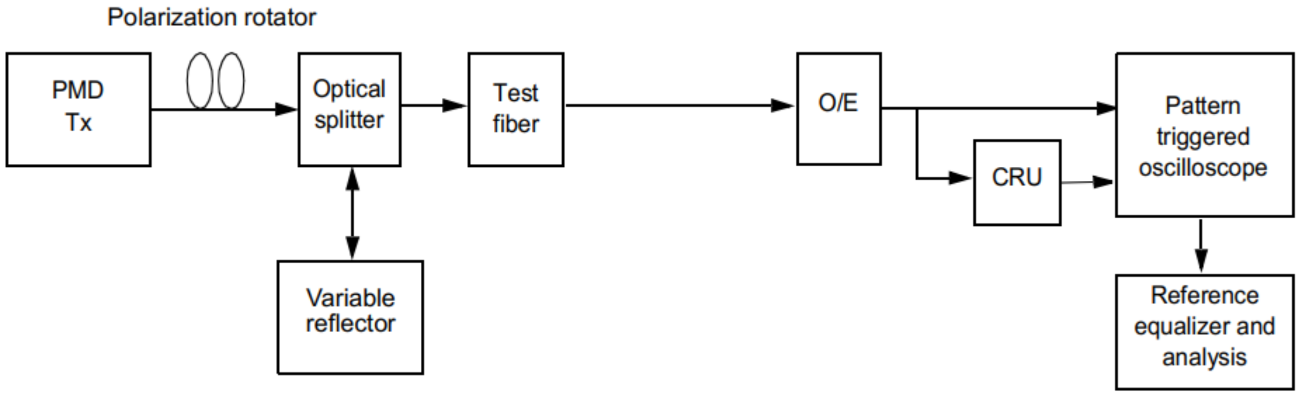

Figure 999–4—TDECQ conformance test block diagram

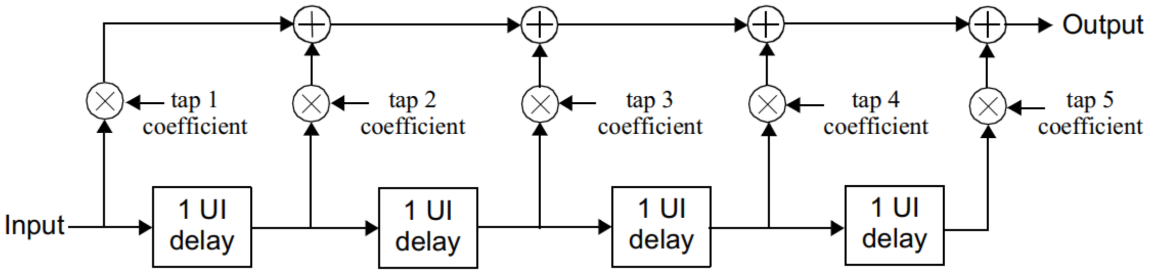

Figure 999–5—TDECQ reference equalizer functional model

NOTE—This reference equalizer is part of the TDECQ test and does not imply any particular receiver equalizer implementation.

Proposed subclause 999.7 (references: subclause 140.7)

999.7.6 Transmitter eye closure for PAM4 (TECQ)

The transmitter eye closure for PAM4 (TECQ) is a measure of the optical transmitter's eye closure at TP2. The TECQ of each lane shall be within the limits given in Table 999–6 for 100GBASE-BRx if measured using a test pattern specified for TECQ in Table 999–10. The TECQ of each lane is measured using the methods specified for TDECQ in 999.7.5, except that the test fiber is not used.

999.7.7 Over/under-shoot

The over/under-shoot shall be within the limits given in Table 999–6 for 100GBASE-BRx if measured using a test pattern specified for over/under-shoot in Table 999–10.

Over/under-shoot is measured using the waveforms captured for the TDECQ test (see 999.7.5) and the waveform captured for the TECQ test (see 999.7.6), but without the reference equalizer being applied in either case.

Overshoot is defined as the maximum power above the level three power and relative to the OMA_{outer} according to:

$$\text{Overshoot} = (P_{max} - P_3) / (OMA_{outer}) \times 100$$

Undershoot is defined as the minimum power from the transmitter (P_{min}) below the level zero power and relative to the OMA_{outer} according to:

$$\text{Undershoot} = (P_0 - P_{min}) / (OMA_{outer}) \times 100$$

where

P_{max}	is based on a 10^{-2} hit ratio, where P_{max} is the smallest power level that results in the number of samples above that level not exceeding the product of hit ratio and total number of observed samples, with all samples acquired in a single unit interval eye diagram.
P_{min}	is based on a 10^{-2} hit ratio, where P_{min} is the largest power level that results in the number of samples below that level not exceeding the product of hit ratio and total number of observed samples, with all samples acquired in a single unit interval eye diagram.
P_3	is the power of the PAM4 level three defined in 122.8.4.
P_0	is the power of the PAM4 level zero defined in 122.8.4.
OMA_{outer}	is the outer optical modulation amplitude defined in 122.8.4.

122.8.4: Outer Optical Modulation Amplitude (OMA_{outer})

Proposed subclause 999.7 (references: subclause 140.7)

999.7.8 Transmitter power excursion

The transmitter power excursion shall be within the limits given in Table 999–6 for 100GBASE-BRx if measured using a test pattern specified for transmitter power excursion in Table 999–10.

Transmitter power excursion is measured using the waveforms captured for the TECQ test (see 999.7.6), but without the reference equalizer being applied.

Transmitter power excursion is defined as:

$$\text{Transmitter power excursion} = \max (P_{max} - P_{average} , P_{average} - P_{min})$$

where

P_{max} and P_{min}	are defined in 999.7.7
$P_{average}$	is the average optical power defined in 999.7.3

999.7.9 Extinction ratio

The extinction ratio shall be within the limits given in Table 999–6 if measured using a test pattern specified for extinction ratio in Table 999–10. The extinction ratio of a PAM4 optical signal is defined as the ratio of the average optical launch power level P_3, measured over the central 2 UI of a run of 7 threes, and the average optical launch power level P_0, measured over the central 2 UI of a run of 6 zeros, as shown in Figure 999–3.

Proposed subclause 999.7 (references: subclause 140.7 and 160.7)

999.7.10 Transmitter transition time

The transmitter transition time of each lane shall be within the limits given in Table 999–6 if measured using a test pattern specified for transmitter transition time in Table 999–10.

Transmitter transition time is defined as the slower of the time interval of the transition from 20% of OMA_{outer} to 80% of OMA_{outer}, or from 80% of OMA_{outer} to 20% of OMA_{outer}, for the rising and falling edges respectively, as measured through an O/E converter and oscilloscope with a combined 3 dB bandwidth of approximately 26.5625 GHz with a fourth-order Bessel-Thomson response to at least 1.3 × 53.125 GHz and at frequencies above 1.3 × 53.125 GHz the response should not exceed –20 dB. Compensation may be made for any deviation from an ideal fourth-order Bessel-Thomson response.

The 0% level and the 100% level are P_0 and P_3 as defined by the OMA_{outer} measurement procedure (see 999.7.4), with the exception that the square wave test pattern can be used. When the SSPRQ pattern is used, the rising edge used for the measurement is that within the 00000333333 symbol sequence and the falling edge is that within the 33333000000 symbol sequence.

999.7.11 Relative intensity noise (RIN_xOMA)

RIN shall be as defined by the measurement methodology of 52.9.6 with the following exceptions:

a) The optical return loss is 15.6 dB for 100GBASE-BR10.

b) The upper –3 dB limit of the measurement apparatus is to be approximately equal to the signaling rate (i.e., 53.2 GHz).

Reference: Clause 140

Proposed subclause 999.7 (references: subclause 160.7)

999.7.12 Receiver sensitivity

For 100GBASE-BR10, receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to 3.2 dB. Receiver sensitivity should meet Equation (999–1), which is illustrated in Figure 999–6.

RS = max (-6.1, SECQ-7.5) (999-1)

Figure 999–6—Illustration of receiver sensitivity (TBD)

Reference: Clause 160
For 100GBASE-BR20 and BR40: TBD

160.7.10 Receiver sensitivity

For 50GBASE-BR10, receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to 3.2 dB. Receiver sensitivity should meet Equation (160–1), which is illustrated in Figure 160–6.

For 50GBASE-BR20 and 50GBASE-BR40, receiver sensitivity is informative and is defined for a transmitter with a value of SECQ up to 3.2 dB. Receiver sensitivity should meet Equation (160–2), which is illustrated in Figure 160–6.

$$RS = \max(-8.4, SECQ - 9.8) \quad \text{(dBm)} \qquad (160–1)$$

$$RS = \max(-15.1, SECQ - 16.5) \quad \text{(dBm)} \qquad (160–2)$$

where

RS is the receiver sensitivity
SECQ is the SECQ of the transmitter used to measure the receiver sensitivity

Proposed subclause 999.7 (references: subclause 160.7)

999.7.13 Stressed receiver sensitivity

Stressed receiver sensitivity shall be within the limits given in Table 999–7 for 100GBASE-BRx if measured using the method defined in 999.7.13.1 and 999.7.13.3, with the conformance test signal at TP3 as described in 999.7.13.2, using the test pattern specified for SRS in Table 999–10.

Any of the patterns specified for SRS in Table 999–10 is sent from the transmit section of the PMD under test. The signal being transmitted is asynchronous to the received signal. The reflectance of the optical link should be at its maximum level.

999.7.13.1 Stressed receiver conformance test block diagram

A block diagram for the receiver conformance test is shown in Figure 999–7. The patterns used for the received conformance signal are specified in Table 999–10. The optical test signal is conditioned (stressed) using the stressed receiver methodology defined in 999.7.13.2 and has sinusoidal jitter applied as specified in 121.8.9.4. A suitable test set is needed to characterize the signal used to test the receiver. Stressed receiver conformance test signal verification is described in 999.7.13.3.

The low-pass filter is used to create ISI. The sinusoidal amplitude interferer causes additional eye closure, but in conjunction with the finite edge rates, also causes some jitter.

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 interferer, the sinusoidal jitter, the signaling rate, and the pattern repetition rate. The Gaussian noise generator, the amplitude of the sinusoidal interferer, and the low-pass filter are adjusted so that the SECQ specified in Table 999–7 is met, according to the methods specified in 999.7.13.2.

For improved visibility for calibration, all 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 negligible.

Proposed subclause 999.7 (references: 160.7)

999.7.13.2 Stressed receiver conformance test signal characteristics and calibration

The stressed receiver conformance test signal characteristics and calibration methods are as described in 121.8.9.2 with the following exceptions:

— The SECQ of the stressed receiver conformance test signal is measured according to 999.7.5, except that the test fiber is not used. The transition time of the stressed receiver conformance test signal is no greater than the value specified in Table 999–6.

— With the Gaussian noise generator on and the sinusoidal jitter and sinusoidal interferer turned off, RIN15.6OMA, RIN15OMA, and RIN15OMA of the SRS test source for 100GBASE-BR10, 100GBASE-BR20, and 100GBASE-BR40, respectively, should be no greater than the values specified in Table 999–6.

— An example stressed receiver conformance test setup is shown in Figure 999–7; however, alternative test setups that generate equivalent stress conditions may be used.

— The signaling rate of the test pattern generator and the extinction ratio of the E/O converter are as given in Table 999–6 for 100GBASE-BRx.

— The required values of the “Stressed receiver sensitivity (OMA_{outer}) (max)” and “Stressed eye closure for PAM4 (SECQ)” are as given in Table 999–7 for 100GBASE-BRx.

999.7.13.3 Stressed receiver conformance test signal verification

The SECQ of the stressed receiver conformance test signal is measured according to 999.7.5, except that the test fiber is not used. The clock output from the clock source in Figure 999–7 is 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 999–7) 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 would 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. The noise/jitter introduced by the O/E, filters, and oscilloscope should be negligible or the results should be corrected for its effects. While the details of test equipment are beyond the scope of this standard, it is recommended that the implementer fully characterize the test equipment and apply appropriate guard bands to ensure that the stressed receiver conformance input signal meets the stress and sinusoidal jitter specified in 999.7.13.2 and 121.8.9.4.

Proposed subclause 999.7 (references: 160.7)

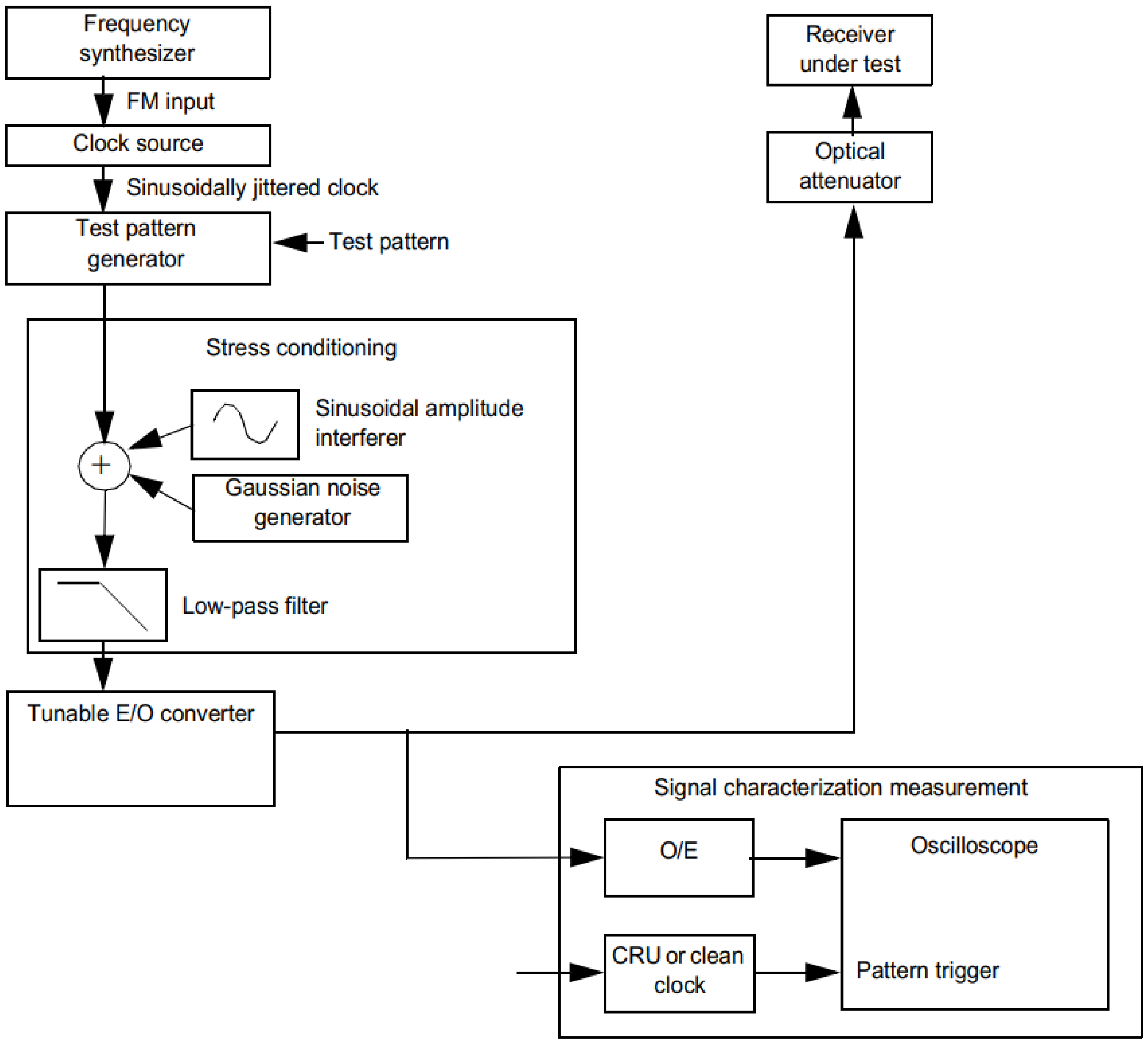

Figure 999–7—Stressed receiver conformance test block diagram

Thank you

Any questions?