52.9.9 Stressed receiver conformance test

Stressed receiver tolerance testing shall be performed in accordance with the requirements of 52.9.9.1, 52.9.9.2, and 52.9.9.3.

Receivers must operate with BER less than 10^{-12} when tested with a conditioned input signal that combines vertical eye closure and jitter according to this clause.

The measurements in this subclause are performed with asynchronous data flowing out of the optical transmitter of the system under test. The output data pattern from the transmitter of the system under test is to be the same pattern defined for this measurement in 52.9.1.

52.9.9.1 Stressed receiver conformance test block diagram

A block diagram for the receiver conformance test is shown in Figure 52–10. A suitable pattern generator is used to continuously generate a signal or test pattern according to 52.9.1. The optical test signal is conditioned (stressed) using the methodology, as defined in 52.9.9.2, while applying sinusoidal jitter, as defined in 52.8.1. The receiver of the system under test is tested for conformance by enabling the error counter on the receiving side. As defined in section 49.2.12 and 50.3.8, the PCS or WIS is capable of detecting the data pattern and reporting any errors received. The optical power penalty for the stressed eye is intended to be similar to its vertical eye closure penalty. This is not necessarily the same as the highest TDP anticipated in service, but represents a standardized test condition for the receiver.

A suitable test set is needed to characterize and verify that the signal used to test the receiver has the appropriate characteristics. The test fiber called out for LW/LR and EW/ER and the transversal filter called out for SW/SR are not needed to characterize the receiver input signal; nor are they used during testing.

Figure 52–10—Stressed receiver conformance test block diagram

The fourth-order Bessel-Thomson filter is used to create ISI-induced vertical eye closure penalty (VECP). The sinusoidal amplitude interferer causes additional eye closure, but in conjunction with the slowed edge rates from the filter, also causes jitter. The nature of the jitter is intended to emulate instantaneous bit shrinkage that can occur with DDJ. This type of jitter cannot be created by simple phase modulation. The sinusoidal phase modulation represents other forms of jitter and also verifies that the receiver under test can track low-frequency jitter. The frequency of the sinusoidal interference may be set at any frequency between 100 MHz and 2 GHz, although be careful to avoid a harmonic relationship between the sinusoidal interference, the sinusoidal jitter, the data rate and the pattern repetition rate.

For improved visibility for calibration, it is imperative that the Bessel-Thomson filter and all other elements in the signal path (cables, DC blocks, E/O converter, etc.) have wide and flat frequency response and linear phase response throughout the spectrum of interest. Baseline wander and overshoot and undershoot should be minimized. 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 much improved trace visibility on sampling oscilloscopes. Actual patterns for testing the receiver shall be as specified in Table 52–22.

To further improve visibility for calibration, random noise effects, such as RIN and random clock jitter, should also be minimized. A small amount of residual noise and jitter from all sources is unavoidable, but should be less than 0.25 UI peak-peak of jitter.

The Bessel-Thomson filter should have the appropriate frequency response to result in the appropriate level of initial ISI eye closure before the sinusoidal terms are added. The E/O converter should be fast and linear such that the waveshape and edge rates are predominantly controlled or limited by the electrical circuitry. Electrical summing requires high linearity of all elements including the E/O modulator. Summing with an optical coupler after the modulator is an option that eases linearity requirements, but requires a second source for the interfering signal, will complicate settings of extinction ratio, and will add more RIN.

The vertical and horizontal eye closures to be used for receiver conformance testing are verified using an optical reference receiver with a 7.5 GHz fourth order ideal Bessel-Thomson response. Use of G.691 tolerance filters may significantly degrade this calibration. Care should be taken to ensure that all the light from the fiber is collected by the fast photodetector and that there is negligible mode selective loss, especially in the optical attenuator and the optical coupler, if used.

The clock output from the clock source in Figure 52–10 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 52–11) is required that is synchronized to the source clock, but not modulated with the jitter source.

52.9.9.2 Parameter definitions

The primary parameters of the conformance test signal are vertical eye closure penalty (VECP) and stressed eye jitter, J. 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) and is ~~the vertical eye closure penalty when~~ calculated relative to the measured OMA value. J is measured at the average optical power, which can be obtained with AC coupling. The values of these components are defined as above by their histogram results.

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The vertical eye closure penalty is given by Equation (52–4).

$$\text{Vertical eye closure penalty [dB, optical]} = 10 \times \log (OMA / A_O) \qquad (52\text{–}4)$$

where, A_O is the amplitude of the eye opening and *OMA* is the normal amplitude without ISI, as shown in Figure 52–11.

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52.9.9.3 Stressed receiver conformance test signal characteristics and calibration

The conformance test signal is used to validate that the PMD receiver meets BER requirements with near worst case waveforms including pulse width shrinkage, power, simulated channel penalties, and a swept frequency sinusoidal jitter contribution applied at TP3.

Signal characteristics are described below along with a suggested approach for calibration.

The test signal includes vertical eye closure and high-probability jitter components. For this test, these two components are defined by peak values that include all but 0.1% for VECP and all but 1% for jitter of their histograms. Histograms should include at least 10 000 hits, and should be about 1%-width in the direction not being measured. Residual low-probability noise and jitter should be minimized—that is, the outer slopes of the final histograms should be as steep as possible down to very low probabilities.

The following steps describe a suggested method for calibrating a stressed eye generator:

1) Set the signaling speed of the test-pattern generator to satisfy the requirements of 52.5.2, 52.6.2, or 52.7.2.

2) Turn on the calibration pattern. A short pattern may be used for calibration if the conditions described in 52.9.9.1 are met, but increases the risk that the longer test pattern used during testing will overstress the device under test. In any case, a pattern shorter than PRBS10 is not recommended.

3) Set the extinction ratio to approximately the Extinction Ratio (min) value given in 52.5.1, 52.6.1, or 52.7.1. Sinusoidal interference and jitter signals should be turned off at this point. If optical summing is used, ER may need to be adjusted after the sinusoidal interference signal is added below.

4) Measure the OMA of the test signal (without attenuation). OMA is measured per the method in 52.9.5 using the square wave pattern.

5) The requirements for vertical eye closure and jitter of the stressed eye test signal are given by the Vertical eye closure penalty (VECP) and Stressed eye jitter (J) values given in Table 52–9 for 10GBASE-S, Table 52–13 for 10GBASE-L, or Table 52–17 for 10GBASE-E.

There are three components involved in calibration for vertical closure and J. These are a linear phase filter, sinusoidal interference, and sinusoidal jitter.

Without sinusoidal jitter or sinusoidal interference, greater than two thirds of the vertical eye closure penalty value should be created by use of a linear phase, low jitter filter (such as

Deleted: Vertical closure 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) and is the vertical eye closure penalty when calculated relative to the measured OMA value. J is measured at the average optical power, which can be obtained with AC coupling. The values of these components are defined as above by their histogram results.¶
The vertical eye closure penalty is given by Equation (52–4).¶
¶
Vertical eye closure penalty [dB, optical] = 10 × log (*OMA* / *AO*) (52–4)¶
¶
where, *AO* is the amplitude of the eye opening and *OMA* is the normal amplitude without ISI, as shown in Figure 52–11.

Bessel-Thomson). The filter should be tested with the prescribed test patterns to verify that residual jitter and baseline wander are small, not to exceed 0.25 UI peak-peak. If not, the stress may be more than desired, leading to conservative results. However, compensation is not allowed. Once done, revert to the calibration pattern, if different than the final test pattern specified in Table 52–22.

Any remaining vertical eye closure required must be created with sinusoidal interference or sinusoidal jitter.

Sinusoidal jitter (phase modulation) must be added per the template of Table 52–19. For calibration purposes, sinusoidal jitter frequencies must be well within the flat portion of the template greater than 4 MHz.

Iterate the settings for sinusoidal interference and/or jitter until all constraints are met, including jitter (J), vertical closure (VECP), and that sinusoidal jitter above 4 MHz is as specified in Table 52–19.

Verify that the optical power penalty for the stressed eye (relative to the reference transmitter per 52.9.10) is greater than or equal to VECP.

To emulate the effects of DCD or data-dependent jitter, at least 5 ps peak-peak of pulse shrinkage jitter should have been achieved.

6) Decrease the amplitude with the optical attenuator until the OMA complies with the OMA values given in Table 52–9 for 10GBASE-S, Table 52–13 for 10GBASE-L, Table 52–17 for 10GBASE-E. If high linearity exists, then the sinusoidal interference should not change the OMA value. OMA can be approximated with histograms as suggested in Figure 52–11. However, the normative definition for OMA is as given in 52.9.5.

7) For testing, turn on the actual required test pattern(s) per 52.9.1.

Figure 52–11—Required characteristics of the conformance test signal at TP3

Care should be taken when characterizing the signal used to make receiver tolerance measurements. In the case of a transmit jitter measurement, excessive and/or uncalibrated noise/jitter in the test system makes it more difficult to meet the specification and may have a negative impact on yield but will not effect interoperability. 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 and/or correct for the noise/jitter introduced by the reference receiver, filters, oscilloscope, and BERT. While the details of measurement and test equipment are beyond the scope of this standard it is recommended that the implementer fully characterize their test equipment and apply appropriate guard bands to ensure that the receive input signal meets the specified requirements.

52.9.9.3 Stressed receiver conformance test procedure

The test apparatus is set up as described in 52.9.9.1 and 52.9.9.2. The sinusoidal jitter is then stepped across the frequency and amplitude range specified in 52.8.1 while monitoring BER at the receiver. The BER is to be compliant at all frequencies in the specified frequency range. This method does not result in values for jitter contributed by the receiver. It does, however, guarantee that a receiver meeting the requirements of this test will operate with the worst-case optical input.

The value for sinusoidal jitter must be met at all test frequencies.

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Deleted: The frequency of the sinusoidal interference may be set at any frequency between 100 MHz and 2 GHz, although be careful to avoid a harmonic relationship between the sinusoidal interference, the sinusoidal jitter, the data rate and the pattern repetition rate.¶

Deleted: If high linearity exists, then the sinusoidal interference should not change the OMA value. OMA can be approximated with histograms as suggested in Figure 52–11. However, the normative definition for OMA is as given in 52.9.5.¶