Proposed Draft

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Document History

Version	Date	Comments
0	August 7, 2013	Initial release.
1	August 8, 2013	Phy meeting updates.
2	August 21, 2013	Phy meeting updates.
3	October 9, 2013	Phy meeting updates ECN P102 changed to ECN073.
4	October 23, 2013	Member review copy.

1 Introduction

1.1 Problem Statement

The specification provides for two methods to measure transmit amplitude, transmit jitter, and receiver tolerance for Gen3 using a compliance interconnect channel (CIC), physical and mathematical (simulated). The physical and mathematical CIC test methods are not equivalent as depicted in the figures. This leads to conflicting measurement results.

The CIC loss characteristic is not sufficiently bounded to ensure unique test results.

1.2 Solution Summary

The loss of mated connector pairs was found to be significant and the number of pairs to include was inconsistent across tests. Since receive tolerance can only be done with a physical setup, equivalence is necessary between mathematical (simulated) and physical test setups. Ensure equivalence of test setups.

The specification is used as a basis for some proprietary vendor/customer relationships using amplitude or jitter as an exchange metrics. The CIC is unbounded on the higher loss side, thus a unique number for amplitude and jitter are not available using valid test setups (valid CIC can have unbounded high loss). Establish deviations from the ideal CIC as measurement error.

This reflects current testing procedures and does not change testing requirements.

1.3 Background (optional)

During development of the SATA 6 Gbps specification, measurement of a sample 1 m cable assembly including two mated connector pairs plus adapters provided a differential insertion loss approximately - 6 dB at 4.5 Gbps. The cable specification limits the loss including two mated connector pairs to - 6 dB up to 4.5 Gbps. Sample lab quality hardware was also measured targeting this same loss profile and was then used as the basis for the mathematical TCTF.

The development of the compliance interconnect channel (CIC) and transmitter compliance transfer function (TCTF) was based on the cable specification. Both the physical hardware and the mathematical equation were selected to provide - 6 dB differential insertion loss at 4.5 GHz. This number comes from Table 36 Internal cable / connector measurement parameter and requirements row maximum insertion loss of cable (10 MHz to 4 500 MHz). Since the cable specification is based on a 1 m cable including two mated connector pairs the CIC and TCTF both include the loss of two mated connector pairs.

2 Technical Specification Changes

2.1 <Title of section being changed>

[Editor's note: Existing text is black. New text is marked as underlined in blue color. Material to be deleted ~~is red with strikethrough markings.~~]

2.1.1 <7.4.8> Compliance interconnect channels (Gen3i, Gen3u)

2.1.1.1 <7.4.8.1> Compliance interconnect channels overview

For Gen3i, a Compliance Interconnect Channel (CIC) is defined as a set of calibrated physical test circuits applied to the Transmitter mated connector, intended to be representative of the highest-loss interconnect. For Gen3u, the Gen3i CIC is used to set up the lab-sourced signal and then removed prior to applying the signal to the UHost receiver under test (see Table 58). A CIC is not used in testing the UHost transmitter.

The CIC is used to verify that the signal electrical characteristics at the Transmitter mated connector are sufficient to ensure compliance to the input electrical specifications for Gen3i receivers as delivered through worst-case media. The magnitude of this worst-case loss as a function of frequency is defined mathematically as a Transmitter Compliance Transfer Function (TCTF). ~~Any linear, passive, differential two-port (e.g., a SATA cable) with loss greater than the TCTF at all frequencies and that meets the ISI loss constraint (defined below) is defined to be a CIC (See 7.4.8.2).~~ A CIC (see 7.4.8.2) is a linear, passive, differential two-port (e.g., a SATA cable, or physical test fixture, or mathematical computation). A CIC shall have a loss greater than or equal to the TCTF loss at all frequencies and meet the ISI loss constraint (defined below). Any deviations of the CIC loss from the TCTF loss is a measurement error. Deviation of the CIC from the specified differential impedance results in measurement error. To reduce the measurement error, the CIC loss should match the TCTF without violation.

A combination of a zero-length test load (i.e., the Laboratory Load) plus the applicable CIC (Gen3i) is used for the specification of the host-controller or device transmitter characteristics.

A Gen3i transmitter signal is specified by meeting:

a) all parameters in Table 54 for Gen3i when transmitting into a Laboratory Load; and
b) Table 54 VdiffTx and total jitter (TJ) after CIC requirements for Gen3i when transmitting through the appropriate Gen3i CIC into a Laboratory Load while using the same transmitter settings (emphasis, amplitude, etc.) as in the first test.

NOTE 27 - Note that the Transmitter Compliance Specifications are defined and measured into a Laboratory Load. Received signal attenuation or amplification due to actual receiver terminator tolerance as well as additional received signal ISI due to the actual receiver return loss may further degrade the actual receiver's input signal. Transmitter Compliance Specifications are expected to be only slightly tighter than Receiver Specifications.

The transmission magnitude response, $|S_{DD21}|$, of the Gen3i TCTF satisfies the following two inequalities

$$| S_{DD21} | \leq -20 \times \log_{10}(e) \times ((3.0 \times 10^{-6} (f^{0.5})) + (1.1 \times 10^{-10} (f))) \text{ dB}$$

for 50 MHz < f < 9.0 GHz, (f expressed in Hz),

$$| S_{DD21} | \text{ at 600 MHz} - | S_{DD21} | \text{ at 3 000 MHz} > 2.7 \text{ dB}$$

NOTE 28 - Note that "e" in the first expression is the base of the natural logarithms, approximately 2.71828. Hence, the first factor, $20 \log_{10}(e)$, evaluates to approximately 8.6859. This value is the conversion factor from nepers (defined as the natural logarithm of a power ratio) to decibels.

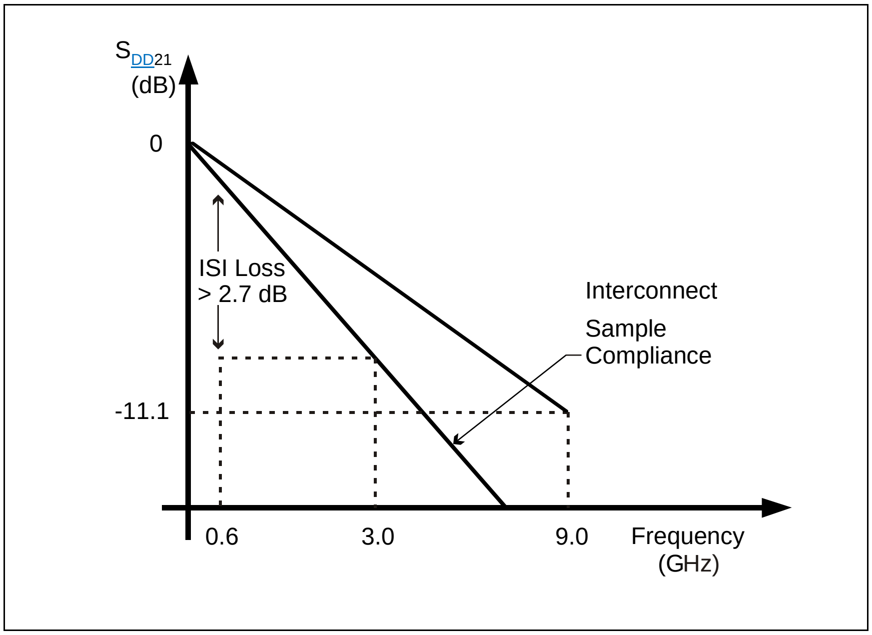


Figure 194 – Compliance Interconnect Channel loss for Gen3i

The second constraint, termed ISI loss, may be motivated as follows, $|S_{DD21}|$ at one tenth the data rate is the attenuation of the fundamental component of a repeating five-ones-five-zeroes pattern, the longest possible run lengths in 8b/10b encoded data. Similarly, $|S_{DD21}|$ at one half the data rate is the attenuation of the fundamental component of a repeating 0101b pattern, the shortest possible run lengths in 8b/10b encoded data.

Hence, for an output waveform of this TCTF, ISI loss approximates the ratio between:

a) the peak-peak voltage (established by the long run lengths); and
b) the inside vertical eye opening (established by the high frequency pattern).

A TCTF with a flatter loss characteristic (i.e., with more broadband attenuation) generates less inter-symbol interference (ISI) and therefore less output jitter. This constraint prohibits such a TCTF.

2.1.1.2 <7.4.8.2> Calibration of compliance interconnect channels

The TCTF defines the worst-case cable loss ~~exclusive~~ inclusive of the two SATA mated connector pairs ~~connectors~~ in the path from transmitter to receiver. ~~However, the~~ The loss due to these two mated connector pairs ~~connectors~~ shall be included in the transmitter characterization. That is, the transmitter shall be tested with the TCTF-defined loss ~~plus two mated SATA connector pairs~~.

For a CIC implemented with SubMiniature version A (SMA) connectors, ~~it is~~as seen in Figure 218 that the addition of a SATA adapter (plug) following the CIC and driving into a Laboratory Load provides the required combined total loss of TCTF (embodied in the CIC and adapter loss) ~~plus the loss of two SATA connectors~~.

2.1.1.3 <7.6.7.1> Transmitter amplitude overview

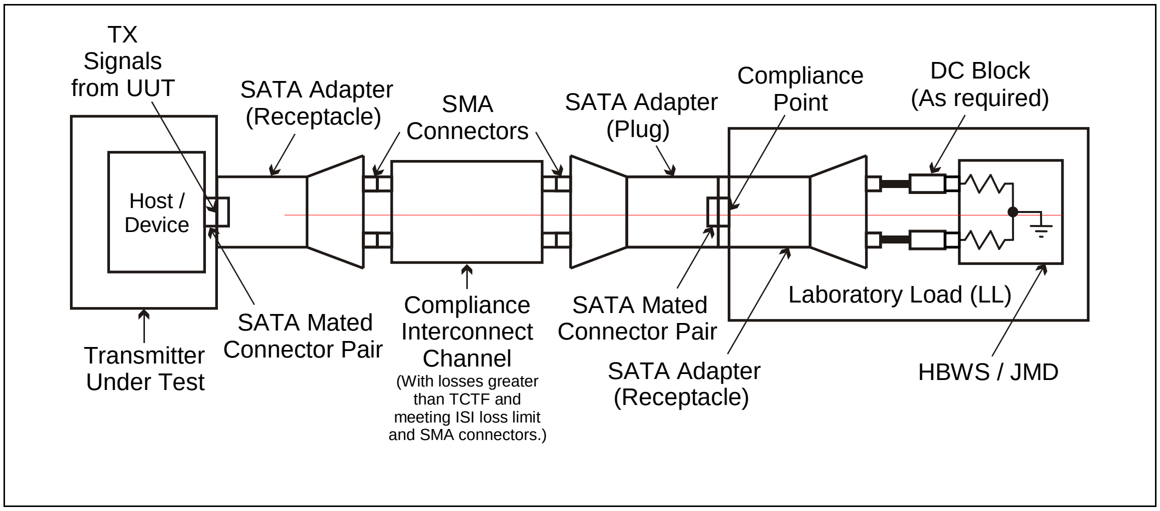
The transmitter amplitude values specified in Table 54 and Table 55 refer to the output signal from the unit under test (UUT) at the mated connector into a lab-load (for Gen1i, Gen1m, Gen1u, Gen2i, Gen2m, Gen2u, Gen3i, and Gen3u), or from the unit under test through a CIC into a Laboratory Load (for Gen3i only). The signals are not specified while attached to a system cable or backplane.

2.1.1.4 <7.6.7.3> Transmitter amplitude (Gen3i, Gen3u)

Transmitter minimum amplitude is measured with the Lone Bit Pattern (LBP). Amplitude specifications shall be met according to the measurement method as defined in 7.6.5.

The minimum amplitude value is measured during the Tx minimum voltage measurement interval defined in Table 54 and Table 55. The Reference Clock (see 7.5.3) defines the ideal (zero jitter) zero crossing times. The maximum amplitude is measured with the measurement method according to 7.6.5 using the MFTP waveform.

Figure 217 and Figure 218 or Figure 218-1 show test setups for measuring transmitter amplitude. See 7.6.7.2 for suggestions on compensating for losses in the test connections.



~~**Figure 218 – Transmit amplitude test with CIC**~~

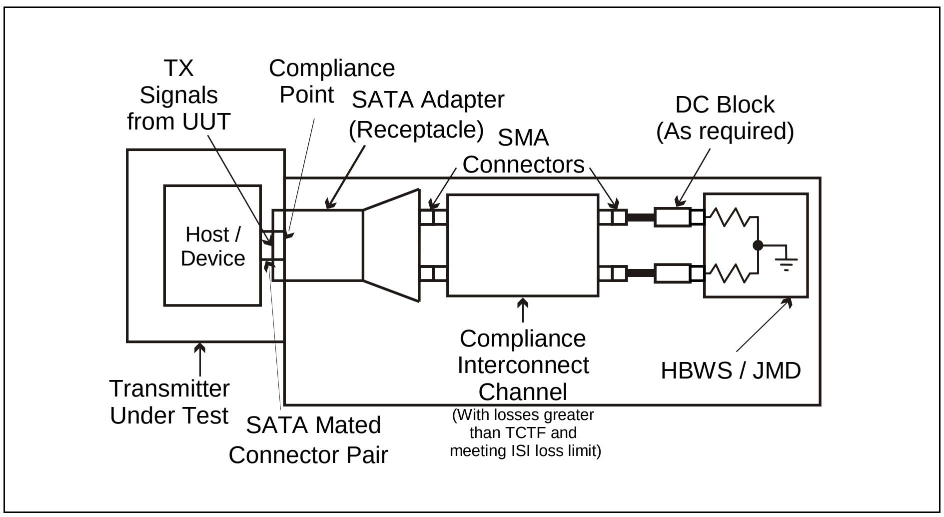


Figure 218 – Transmit amplitude test with physical CIC

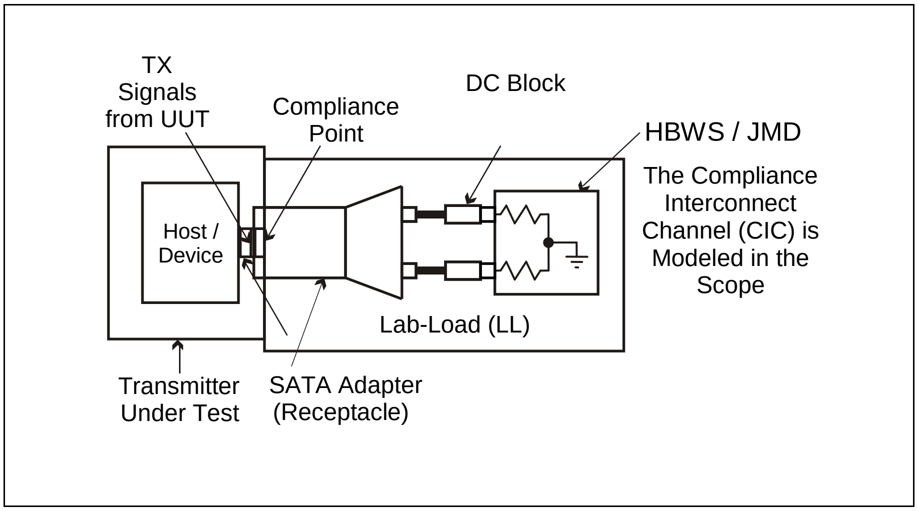


Figure 218 + 1 – Transmit amplitude test with simulated CIC

2.1.2 <7.6.12> Transmit jitter (Gen3i, Gen3u)

The Transmit Jitter values TJ(10^{-12}) and TJ(10^{-6}) specified in Table 54 and Table 55 refer to the output signal from the unit under test (UUT) at the mated connector into a lab-load, and, for Table 54, from the unit under test through a CIC into a Laboratory Load. The signals are not specified while attached to a system cable or backplane. All the interconnect characteristics of the transmitter, package, printed circuit board traces, and mated connector pair are included in the measured transmitter jitter. Since the SATA adapter is also included as part of the measurement, good matching and low loss in the adapter are desirable to minimize its contributions to the measured transmitter jitter.

The Total Jitter parameters are measured with each of the specified patterns as defined in 7.4.5.2 and 7.4.5.4.5. The measurement of jitter as defined in 7.6.10.

One of the measurements of the Transmit Total Jitter parameters on the Tx signal shall be measured directly into the Laboratory Load as is shown in Figure 228.

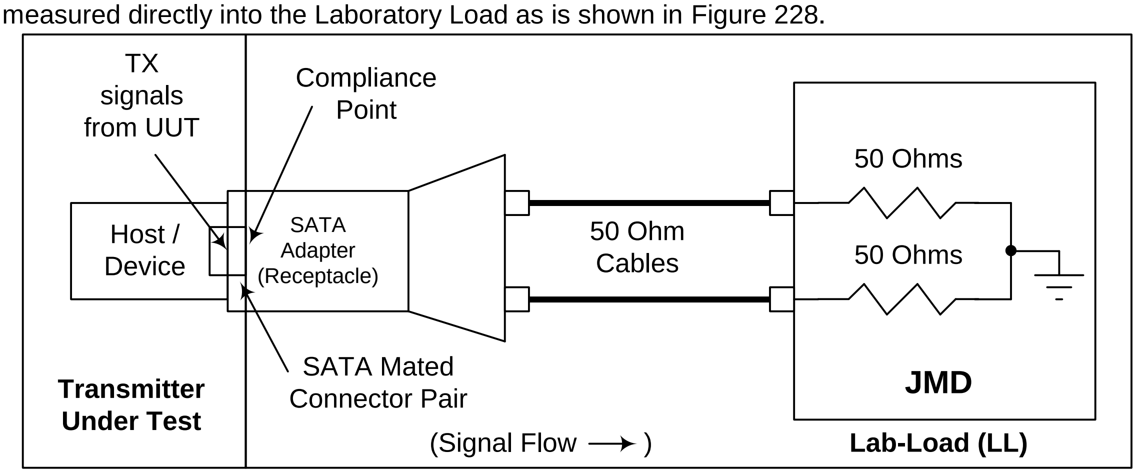


Figure 219 – Transmitter jitter test at Tx (Gen3i)

The second measurement of the Transmit Total Jitter parameters measures the jitter on the Tx signal after passing through the Gen3i CIC (see 7.4.8) into the Laboratory Load as is shown in Figure 229 Figure 218 or Figure 218+1. This measurement does not apply to Table 55 (i.e., Gen3u).

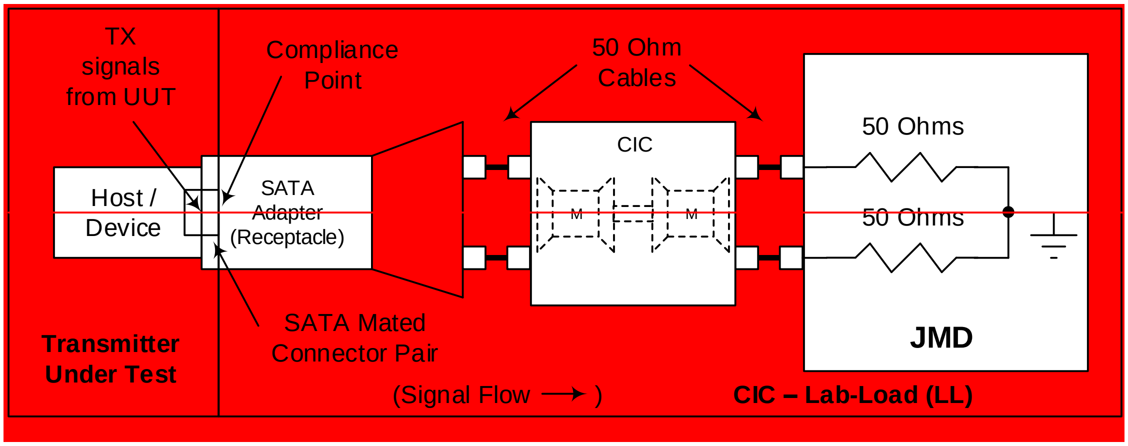


Figure 229 – Transmitter jitter test through the CIC (Gen3i)

The Transmit Jitter shall meet both the TJ(10^{-12}) and TJ(10^{-6}) requirements as described in Table 54 both directly at the Tx and after the Gen3i CIC.

The TJ(10^{-6}) requirement is calculated from the TJ(10^{-12}) requirement of 0.52 UI pp and the specification for the maximum RJ pp value of 0.18 UI at a BER of 10^{-12}. If the nominal data rate UI time span is used for conversion to ps, this equates to a TJ(10^{-12}) of 86.667 ps and a RJ 1 sigma value of 2.143 ps.

This calculation is performed using the dual Dirac equation TJ(BER) = ($2Q_{BER} \times \sigma$) + $DJ_{\delta\delta}$, where σ is the 1 sigma value of RJ, and $2Q_{BER}$ is based on a single Gaussian RJ distribution with a transition density of 0.5. This is equivalent to a dual Diac distribution with a transition density of 1.0.

At a BER level of 10^{-12}, $DJ_{\delta\delta}$ = TJ(10^{-12}) - ($14.069 \times \sigma$) = 86.667 ps – (14.069 × 2.143 ps) = 56.517 ps.

At a BER level of 10^{-6}, TJ(10^{-6}) = ($9.507 \times \sigma$) + $DJ_{\delta\delta}$ = (9.507 × 2.143 ps) + 56.517 ps = 76.891 ps pp or 0.46 UI.

The tighter requirement at TJ(10^{-6}) is added to constrain the DJ component of TJ, without requiring actual jitter separation that is possible to contain variable results depending on the method used. A tradeoff between RJ versus DJ is possible with this criteria, but the DJ component is limited more than measuring TJ(10^{-12}) alone. If the RJ 1 sigma value is 1.0 ps, then the allowable $DJ_{\delta\delta}$ is able to be 19 % larger than the 56.5 ps derived in the calculation above. If the $DJ_{\delta\delta}$ was 20.0 ps, then the RJ 1 sigma value is able to be 4.74 ps. These calculations are based on the equations above as an example of the trade off between RJ and DJ allowed by these maximum jitter criteria. The $DJ_{\delta\delta}$ used in these equations should not be confused with DJ_{pp} that is not equivalent in the general case.

The full population BERT scan is the jitter measurement reference standard for both the TJ(10^{-6}) and TJ(10^{-12}) measurements for all JMD TJ estimation methods. A full population BERT scan is one that has analyzed a sufficient population of bits versus errors to achieve a 95 % confidence level.

Transmitter jitter is measured into the lab-load, or in conjunction with the Compliance Interconnect Channel. Both have very good impedance matching. The jitter in an actual system is higher since load and interconnects impedance mismatch results in reflections and additional data dependent jitter. It is generally not possible to remove the effects of the SATA adapter on jitter since jitter due to mismatch depends on the entire test setup.

2.1.3 <7.6.14> Receiver tolerance (Gen3i, Gen3u)

The performance measure for receiver tolerance and Common Mode interference rejection is the correct detection of data by the receiver. While measuring receiver and Common Mode tolerance it is necessary to set the maximum allowable jitter and Common Mode interference on the signal sent to the receiver and monitor data errors.

The data signal source provides a data signal with jitter, and a controlled rise/fall time with a matched output impedance. Additional DJ (ISI) is added by the CIC. The sine wave source provides common mode interference with a matched output impedance. The two sources are combined with resistive splitters to calibrate the data signal source for the receiver under test. Equivalent signal generation methods that provide the data with jitter, common mode interference, and an impedance-matched output are allowed. All the interconnect characteristics of the receiver, mated connector pair, printed circuit board traces, and package are included in the measured receiver jitter tolerance.

To calibrate the test signal for Receiver Tolerance testing, the Data Signal Source is measured using two procedures, one for RJ and a second for TJ and the common mode signal content.

The rise time and fall time of the Data Signal Source in the following figures shall meet the requirements as described in Table 57 and Table 58 for the Gen3i and Gen3u lab-sourced signal. This defines the signal rise time and fall time characteristics in the signal path before the CIC. This requirement shall be met using the rise time and fall time methods as defined in 7.6.5.4.

Figure 232 show the test configuration for setting the RJ level as is defined in Table 57 and Table 58 for the Gen3i and Gen3u lab-sourced signal. The RJ level is set using a Gen3i MFTP pattern. This method minimizes the measurement errors of RJ, compared to the case while other signal degradations are present, and shall be done before adding additional jitter components and common mode signals.

This second procedure is performed after the RJ level of the Data Signal Source is set, as described above. Figure 233 shows one example approach for setting the TJ and the common mode signal level. The actual calibration plane is at the SMA connectors that shall be applied to the SATA to SMA adaptor during the Receiver Tolerance test. This is shown in Figure 233 as a dotted vertical line. The JMD is used as the standard for measuring jitter, and the HBWS is used as the standard for measuring the common mode interference and signal amplitude. Since the SATA adapter is not included while setting the level of jitter, good matching and low loss in the adapter are desirable to minimize contributions to the amount of receiver jitter used in testing. Unlike other measurements, it is generally not possible to remove the effects of the SATA adapter on jitter since jitter due to mismatch depends on the entire test setup.

The measurement of the minimum and maximum amplitude levels of the test signal at the calibration plane, are performed in the same method used for these parameters for the Tx amplitude tests (see 7.6.5). In general the maximum peak-to-peak amplitude of a Gen3 MFTP pattern is the maximum limit, and the minimum eye height (see 7.6.5.4) of a Gen3 LBP is the minimum limit. The test signal minimum amplitude calibration shall be performed with SSC off, and all the jitter sources used during the tolerance test active, at their calibrated levels. The Gen3i CIC is used to calibrate the lab-sourced signal minimum amplitude for Gen3u receiver tolerance testing; however, the Gen3i CIC losses shall be removed from the lab-sourced signal prior to testing of the Gen3u receiver under test.

Figure 234 shows the calibrated lab-sourced signal applied to the Gen3i Receiver Under Test. Figure 231 shows the calibrated lab-sourced signal applied to the Gen3u Receiver Under Test.

The receiver tolerance test shall be conducted over variations in parameters:

a) SSC on and SSC off;
b) minimum amplitude and maximum amplitude;
c) common mode interference over the specified frequency range; and
d) jitter that includes the maximum:
    A) random; and
    B) deterministic jitter of various types:
        a) data dependent;
        b) periodic; and
        c) duty cycle distortion;

while sourcing the test pattern FCOMP as defined in 7.4.5.4.8.
The receiver tolerance to the impairments is required over all signal variations.

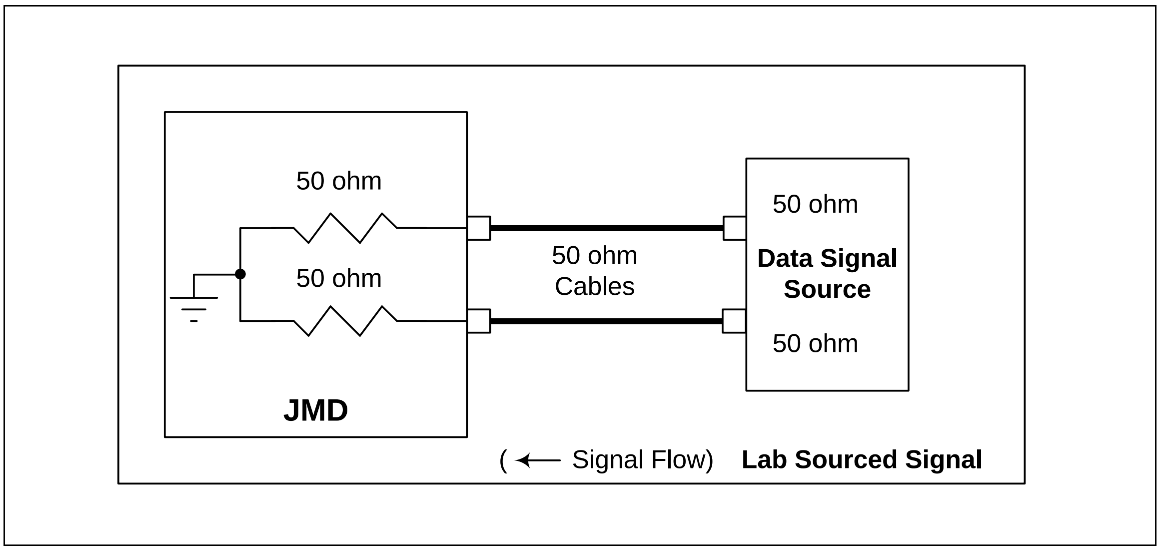
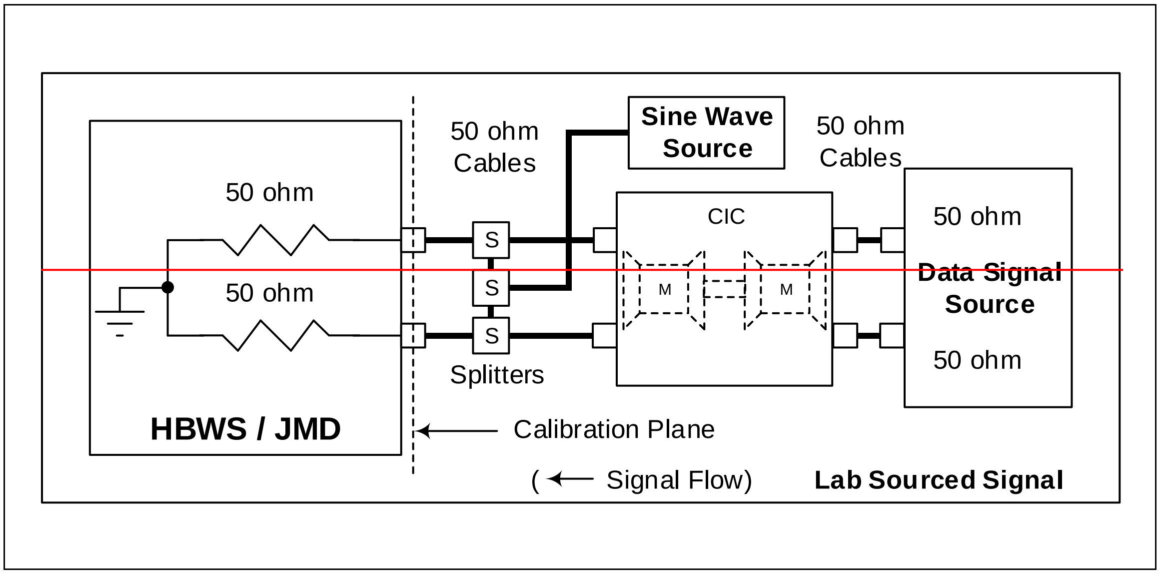


Figure 230 – Receiver jitter and CM tolerance test – setting RJ level (Gen3i)



~~Figure 231 – Receiver jitter and CM tolerance test – setting TJ and CM levels (Gen3i)~~

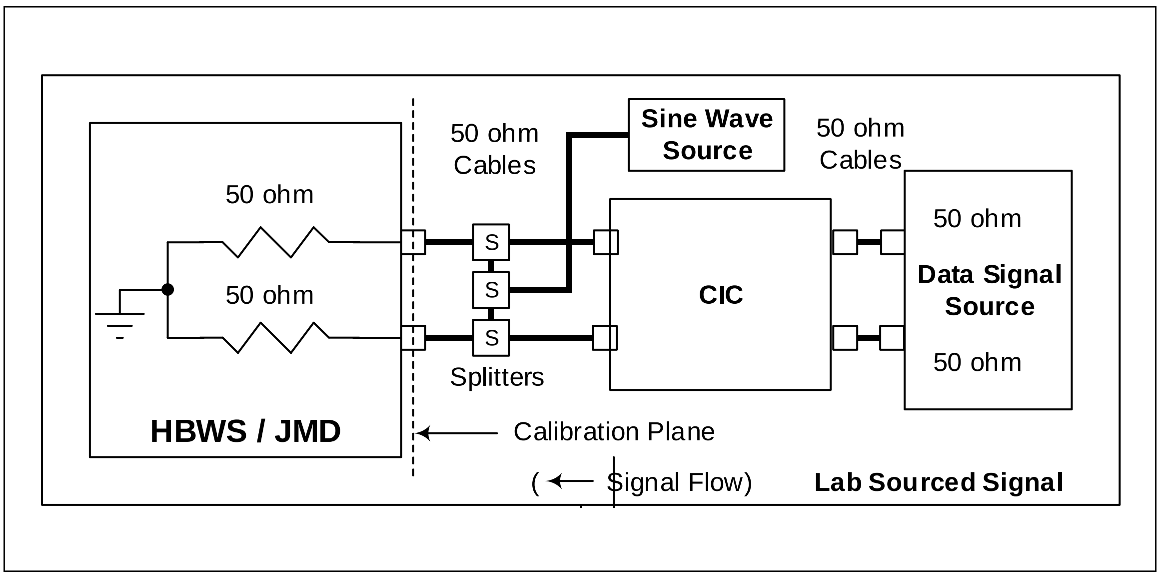


Figure 232 – Receiver jitter and CM tolerance test – setting TJ and CM levels (Gen3i)

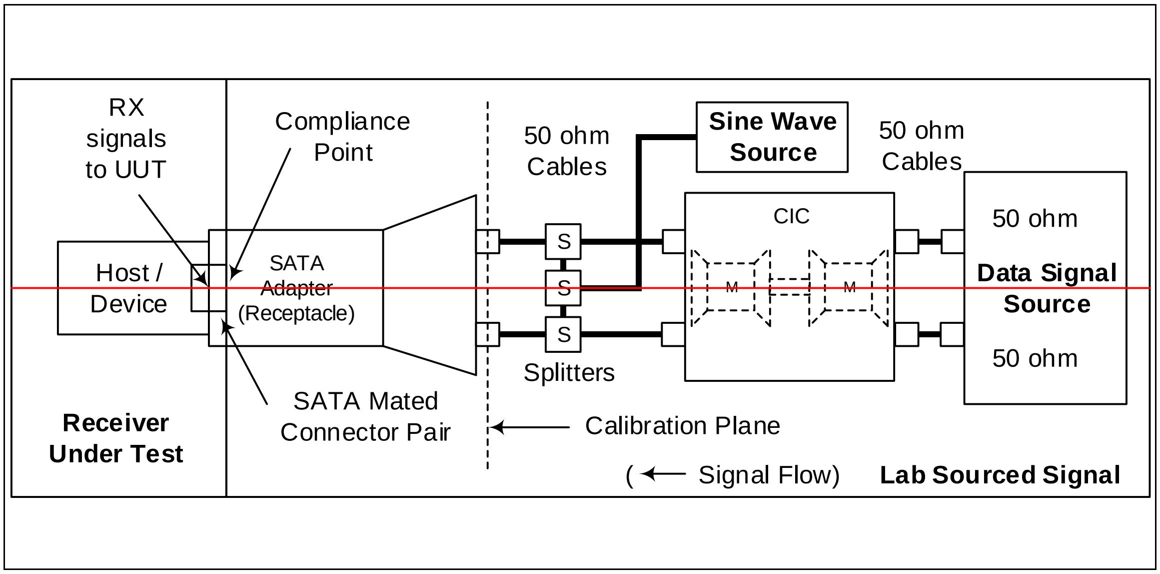


Figure 233 – Receiver jitter and CM tolerance test (Gen3i)

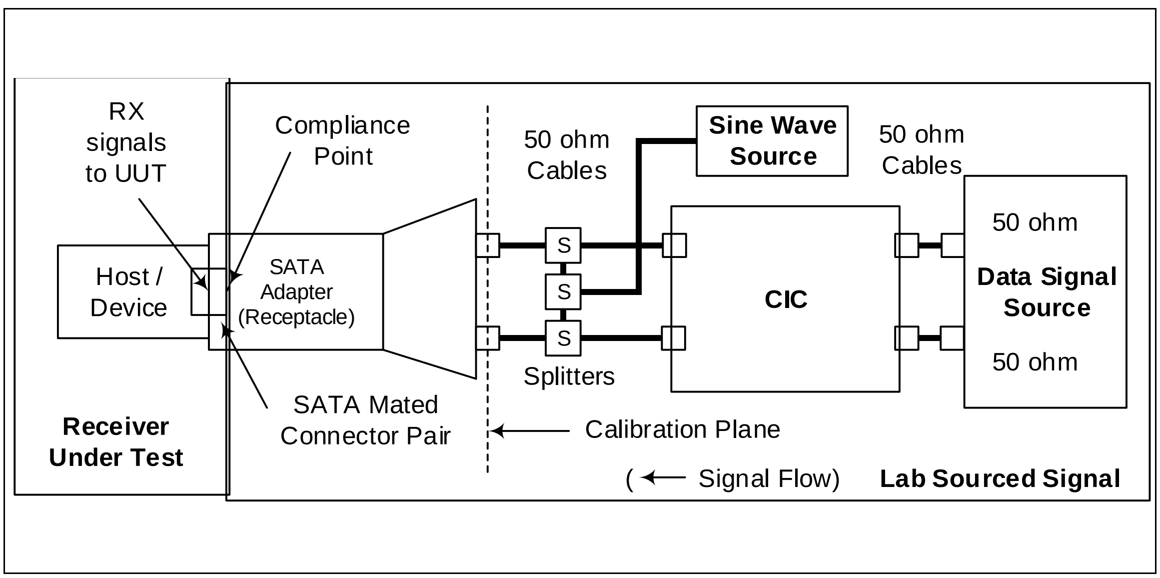


Figure 234 – Receiver jitter and CM tolerance test (Gen3i)