



GRL Platform Solutions

MIPI M-PHY® High-Speed Receiver Physical Layer User Guide & Method of Implementation (MOI) Using Anritsu MP1900A BERT, High Performance Real-Time Oscilloscope, and GRL-MIPI-MPHY-HS-RXA Calibration and Test Software

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1 Introduction

This User Guide & MOI describes how to set up the GRL-MIPI-MPHY-HS-RXA Gear5(A/B) Receiver Calibration and Test Software for receiver (Rx) calibration and testing based on the MIPI M-PHY High-Speed (HS) Specification (for up to 23.32 Gb/s). The GRL-MIPI-MPHY-HS-RXA software automates the Anritsu MP1900A BERT and a high-performance real-time oscilloscope to calibrate the stressed eye opening and test the M-PHY HS receiver conformance.

The GRL-MIPI-MPHY-HS-RXA software uses industry standard test methods for supported HS GEAR modes of HS-G1, HS-G2, HS-G3, HS-G4 and HS-G5 (from 1.248 Gb/s to 23.32 Gb/s for both A & B rates). By supporting variable ISI automation, the GRL-MIPI-MPHY-HS-RXA software enables calibration to be performed with minimum reconfiguration of the setup, which allows measurements to be more fully automated. The GRL-MIPI-MPHY-HS-RXA software also uses the SigTest standard post processing analysis software in the final calibrated eye diagram to achieve the final stressed eye calibration.

The MIPI M-PHY HS Rx test suite helps users evaluate the M-PHY physical layer functionality of their MIPI products and determine if the products conform to specifications defined in the MIPI Alliance Specification for M-PHY (hereafter referred to as the “M-PHY Specification”). When combined with a satisfactory level of interoperability testing, these tests provide a reasonable level of confidence that the Device Under Test (DUT) will function properly in many MIPI environments.

Note: The Appendixes in this Guide describe the manual CTS calibration and test methodology for M-PHY HS receiver conformance as well as setup information for supported oscilloscopes.

2 Resource Requirements

2.1 Equipment Requirements

TABLE 1. EQUIPMENT REQUIREMENTS – SYSTEMS AND ACCESSORIES

Equipment	Qty.	Description	Key Specification Requirement
Keysight/Tektronix Oscilloscope	1	High Performance Real-time Oscilloscope ^[a]	≥ 50 GHz bandwidth with Windows 7+ OS ^[b]
Anritsu MP1900A BERT	1	MP1900A Signal Quality Analyzer, with following modules: - MU181000A/B 12.5 GHz Synthesizer - MU181500B Jitter Modulation Source - MU195020A 21G/32G bit/s SI Pulse Pattern Generator - MU196020A 64.2G bit/s or 64.2G baud PAM4 Pulse Pattern Generator - MU195040A 21G/32G bit/s Error Detector	
ISI Generator	1	M-PHY Spec compliant Fixed or Variable ISI Channel (Artek CLE1000-A2 recommended)	
500 MHz RF Signal Generator	2	As external SJ Fixed source (Rigol DSG800 or Keysight N5182B MXG X-Series recommended) <Setup requires either two Rigol DSG800 units OR one Keysight N5182B unit & one Rigol DSG800 unit>	
6 dB Attenuator	2	If using MU195020A SI Pulse Pattern Generator only <MU196020A PAM4 Pulse Pattern Generator does not require attenuators>	
Combiner	1	For merging RF signals from multiple RF signal generators into a single output signal (Keysight 11667A recommended)	

^[a] Oscilloscope with scope software requirements as specified in vendor specific MOI's. For example, when using the Keysight Scope, scope software such as Keysight InfiniiSim / EZ-JIT / Serial Data Analysis / Serial Data Equalization that are required for testing and signal processing must be pre-installed on the Scope. Similarly, the Tektronix Scope shall be used with DPOJET (Jitter and Eye Analysis Tools) software for making measurements.

^[b] Oscilloscope with scope bandwidth as specified in vendor specific MOI's.

Note: Cable connector type and length requirements may vary according to the lab setup and the dimensions of the DUT board. Table below is a recommended list. Please also refer to the respective manufacturer for detailed cabling recommendations related to M-PHY.

TABLE 2. EQUIPMENT REQUIREMENTS – CABLES

Cable	Qty.	Key Specification Requirement
Anritsu J1624A SMA-SMA cable	4	30 cm
Anritsu J1625A SMA-SMA cable	6	100 cm
Anritsu J1551A K-K phase matched cable pair	3 pairs	3 ft
Rosenberger L71-456-102 phase matched SMA-SMP adapters	2 pairs	

Cable	Qty.	Key Specification Requirement
Coaxial cable with N connector (male) to SMA connector (male)	2	For connecting Rigol DSG800/Keysight N5182B MXG X-Series RF output to MU181500B External Jitter Input

2.2 Software Requirements

TABLE 3. SOFTWARE REQUIREMENTS

Software	Source
GRL-MIPI-MPHY-HS-RXA	GRL Platform Solutions MIPI M-PHY (up to 23.32 Gb/s) Specification Receiver Conformance Calibration & Test Automation Software (for High-Speed GEAR testing) – www.grlps.com Included with Node Locked License to single oscilloscope or PC OS
VISA (Virtual Instrument Software Architecture) API Software	VISA Software is required to be installed on the controller PC running GRL- MIPI-MPHY-HS-RXA software. GRL Platform Solutions' software framework has been tested to work with all three versions of VISA available on the Market: 1. NI-VISA: http://www.ni.com/download/ni-visa-17.0/6646/en/ 2. Keysight IO Libraries: www.keysight.com (Search on IO Libraries) 3. Tektronix TekVISA: www.tek.com (Downloads > Software > TekVisa)
SigTest	Standard Post Processing Analysis Software (for final eye calibration) – www.intel.com/content/www/us/en/design/technology/high-speed-io/tools.html <i>[SigTest Version 4.0.52 is required]</i>
SDLA Visualizer (for Tektronix scope)	Tektronix Serial Data Link Analysis Advanced Version 3.0.13.62 64-bit <i>[This software must be installed on the Tektronix scope for HS-G5 only]</i>

3 Setting Up GRL-MIPI-MPHY-HS-RXA Software

This section provides the procedures to start up and pre-configure the GRL-MIPI-MPHY-HS-RXA automation software before running tests. It also helps users familiarize themselves with the basic operation of the software.

Note: The GRL-MIPI-MPHY-HS-RXA software installer will automatically create shortcuts in the Desktop and Start Menu when installing the software.

To start using the GRL-MIPI-MPHY-HS-RXA software, follow the procedures in the following sections.

3.1 Download GRL-MIPI-MPHY-HS-RXA Software

Download and install the GRL-MIPI-MPHY-HS-RXA software as follows:

1. If the GRL-MIPI-MPHY-HS-RXA software is to be installed on a PC (where it is referred to as 'control PC'), install VISA (Virtual Instrument Software Architecture) on to the PC where GRL-MIPI-MPHY-HS-RXA is to be used (see Section 2.2).
2. Download the software ZIP file package from the GRL Platform Solutions support site.
3. The ZIP file contains:
 - a) **MIPIPHYGear4PatternFilesInstallationxxxxxxxxxxSetup.exe** – Run this on the Anritsu MP1900A BERT Signal Quality Analyzer to install the pattern setup files.
 - b) **MIPIPHYGear4RxTestApplicationxxxxxxxxxxSetup.exe** – Run this on the control PC or oscilloscope to install the GRL-MIPI-MPHY-HS-RXA application.
 - c) **MIPIPHYGear4RxTestScopeSetupFilesInstallationxxxxxxxxxxSetup** – Run this on the oscilloscope to install the scope setup files.

3.2 Launch and Set Up GRL-MIPI-MPHY-HS-RXA Software

1. Once the software is installed, open the GRL folder from the Windows Start menu. Click on **GRL – Automated Test Solutions** within the GRL folder to launch the GRL Platform Solutions software framework.

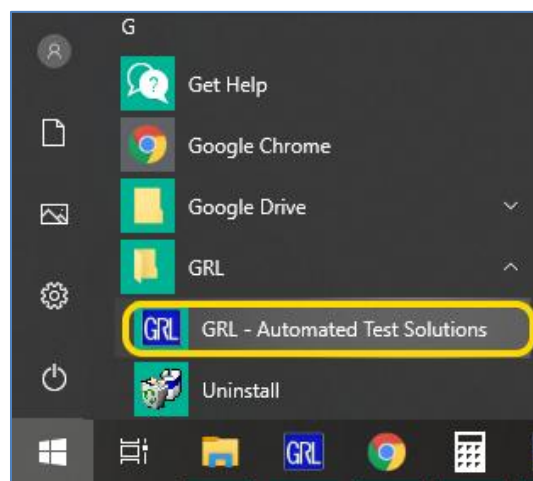


FIGURE 1. SELECT AND LAUNCH GRL PLATFORM SOLUTIONS FRAMEWORK

2. From the **Application** → **Rx Test Solution** drop-down menu, select “**Anritsu MIPI M-PHY HS Rx Test**” to start the GRL-MIPI-MPHY-HS-RXA application. If the selection is grayed out, it means that your license has expired.

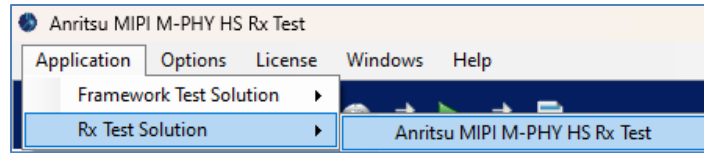


FIGURE 2. START GRL-MIPI-MPHY-HS-RXA APPLICATION

3. To enable license, go to **License** → **License Info**.

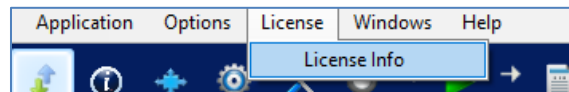


FIGURE 3. SEE LICENSE DETAILS

- a) Check the license status for the installed application.

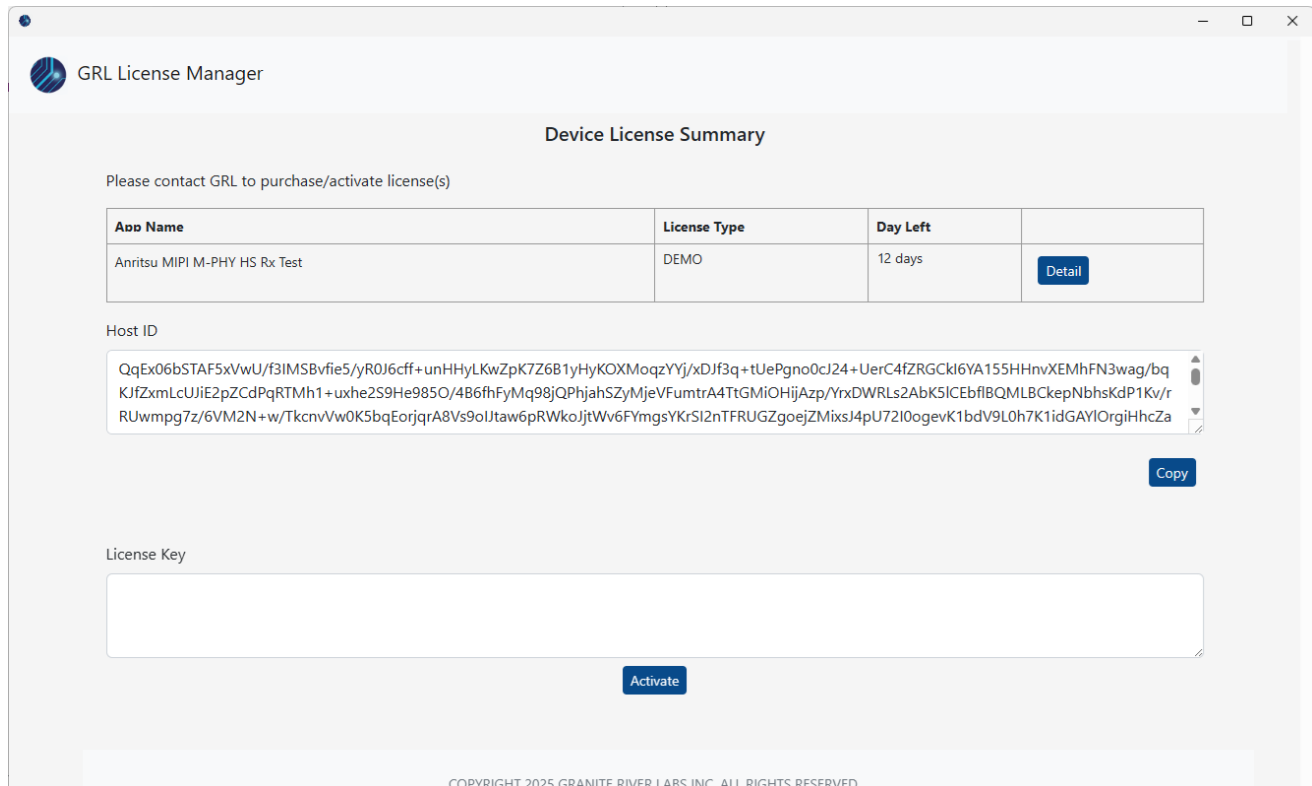


FIGURE 4. CHECK LICENSE FOR INSTALLED APPLICATION

- b) Activate a License:

- If you have an Activation Key, enter it in the box provided, and select **Activate**.
- If you do not have an Activation Key, select **Close** to use the software for 10 days free of charge.

Note: Once the 12-day trial period ends, you will need to request an Activation Key to continue using the application on the same computer by contacting support@grlps.com.

3.2.1 Connection Configuration

- Connect the Anritsu MP1900A BERT via LAN to the GRL-MIPI-MPHY-HS-RXA enabled Scope or PC. The BERT and MX183000A software can be connected using connection string formats similar to the following examples:
 - BERT: “TCPIP0::192.168.0.14::5001::SOCKET” or “192.168.0.14:5001”
 - MX183000A: “TCPIP0::192.168.0.14::5000::SOCKET” or “192.168.0.14:5000”

Note the IP addresses listed above are only examples and should be changed according to the actual network connection being used.

- Connect the oscilloscope with the controller PC through either GPIB, USB or LAN. *(Note: Additional information for connecting the Keysight and Tektronix oscilloscopes to the controller PC is provided in the Appendix of this MOI.)*

3.2.2 Launch and Set Up GRL-MIPI-MPHY-HS-RXA Software (on the Scope or Controller PC)

1. Launch the GRL Platform Solutions Host Application from “Start Menu → GRL → GRL – Automated Test Solutions”.
2. Select “Application → Rx Test Solution → Anritsu MIPI M-PHY HS Rx Test”.
3. On the Scope or controller PC, obtain the network addresses for all the connected instruments from the device settings. Note these addresses as they will be used to connect the instruments to the GRL-MIPI-MPHY-HS-RXA software.

4. On the Equipment Setup  page of the GRL-MIPI-MPHY-HS-RXA application, type in the address of each connected instrument into the ‘Address’ field.

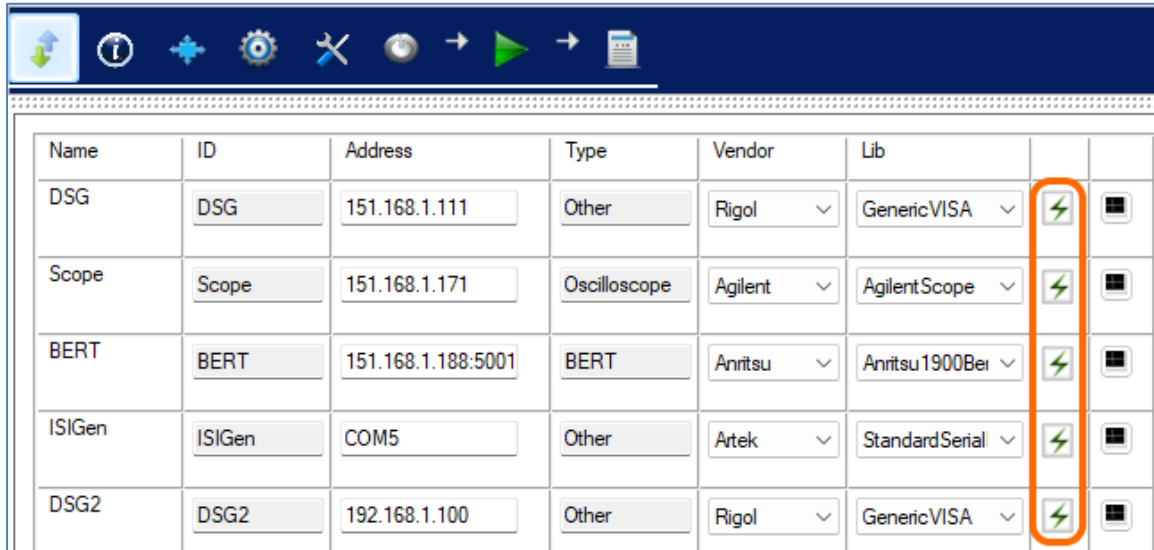
*(Note: If the GRL-MIPI-MPHY-HS-RXA software is installed on the **Tektronix Scope**, ensure the Scope is connected via GPIB and type in the GPIB network address, for example “GPIB8::1::INSTR”.)*

If the GRL-MIPI-MPHY-HS-RXA software is installed on the PC to control the Scope, type in the Scope IP address, for example “TCPIP0::192.168.0.110::inst0::INSTR”. Note to **omit** the Port number from the address.

*(Note: If the GRL-MIPI-MPHY-HS-RXA software is installed on the **Keysight Scope**, and if there is error in connection, type in the Scope IP address as “TCPIP0::192.168.0.4::5025::SOCKET”.)*

5. Then select the “lightning” button  for each connected instrument. The “lightning” button should turn green  once the software has successfully established connection with each instrument.

(Note: If two Rigol DSG800 units are used in the setup, enter the address of the other connected Rigol DSG800 unit in the “DSG2” row.)



Name	ID	Address	Type	Vendor	Lib	Status
DSG	DSG	151.168.1.111	Other	Rigol	GenericVISA	⚡
Scope	Scope	151.168.1.171	Oscilloscope	Agilent	AgilentScope	⚡
BERT	BERT	151.168.1.188:5001	BERT	Anritsu	Anritsu1900Ber	⚡
ISIGen	ISIGen	COM5	Other	Artek	StandardSerial	⚡
DSG2	DSG2	192.168.1.100	Other	Rigol	GenericVISA	⚡

FIGURE 5. CONNECT INSTRUMENTS WITH GRL-MIPI-MPHY-HS-RXA SOFTWARE

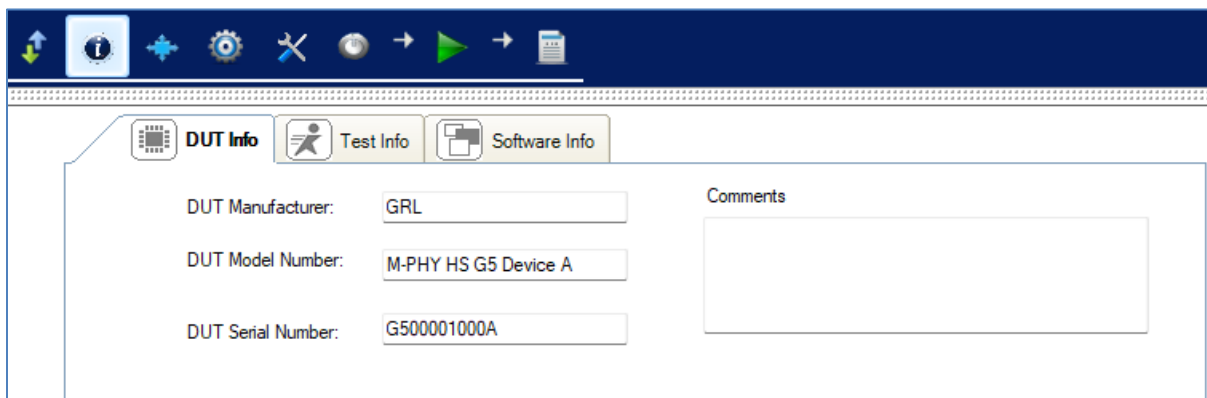
3.3 Configuring the GRL-MIPI-MPHY-HS-RXA Software Before Calibration

Once all equipment is successfully connected from the previous section, proceed to set up the preliminary settings before going to the advanced measurement setup.

3.3.1 Enter Test Session Information

Select  from the menu to access the **Session Info** page. Enter the information as required for the test session that is currently being run. The information provided will be included in the test report generated by the software once tests are completed.

- The fields under **DUT Info** and **Test Info** are defined by the user.
- The **Software Info** field is automatically populated by the software.













DUT Manufacturer:
DUT Model Number:
DUT Serial Number:
Comments:

FIGURE 6. SESSION INFO PAGE

3.3.2 Set Measurement Conditions

Select  from the menu to access the **Conditions** page to set the conditions for calibration and testing. The GRL-MIPI-MPHY-HS-RXA software will perform calibration and testing for the selected HS GEAR(s) with respective A/B rate(s) and SJ Frequencies.

Recommended procedure:

- *Step 1:* When calibrating, select all required conditions and perform the calibration.
 - *Step 2:* Once calibration is completed and ready for testing, re-select the conditions that will be used for specific tests. For example, if required to test only one HS GEAR rate at a time, then select the appropriate conditions for testing.
- a) **HS Gear** tab: Select the GEAR(s) supported by the DUT for HS-Rx calibration or testing.

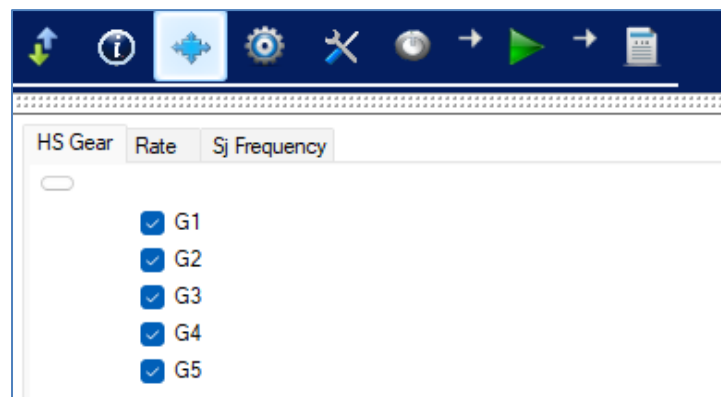


FIGURE 7. SELECT HS GEAR(S)

- b) **Rate** tab: Select the A- and/or B-series Rate(s) for the HS GEAR(s) supported by the DUT.

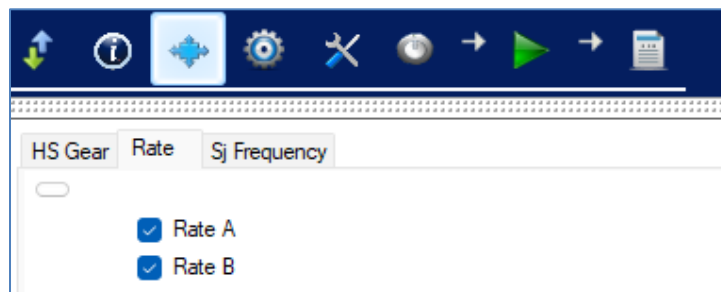


FIGURE 8. SELECT GEAR RATE(S)

- c) **Sj Frequency** tab: Select the range of SJ Frequencies for HS-Rx calibration or testing.

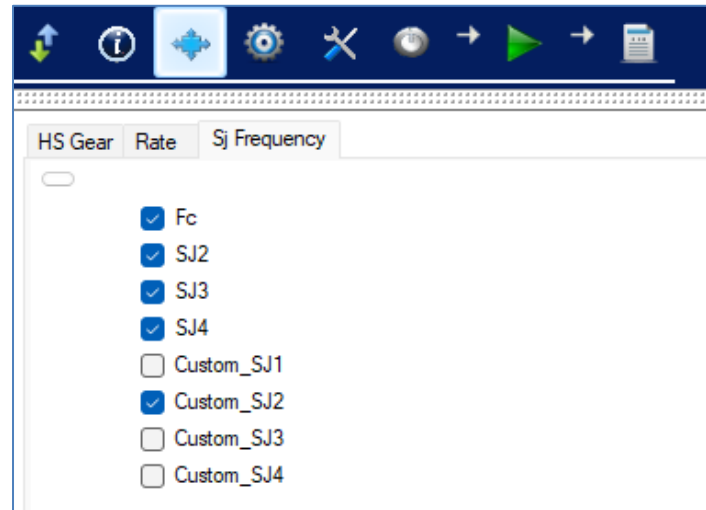


FIGURE 9. SELECT SJ FREQUENCY(S)

3.3.3 Set Up Measurement Requirements

Select  from the menu to access the **Setup Configuration** page. Use this page to configure the necessary measurement-related settings prior to running calibration and tests.

3.3.3.1 ISI Generator Tab

Select the type of supported ISI generators to be used:

- “None”: This is the recommended method which is used to provide the required physical channel Insertion Loss for calibration and conformance testing.
- “Artek”: This is provided as an Option. The Artek CLE1000-A2 ISI channel can be used in the setup for ISI automation.

Note: The ISI source will be used for both calibration and conformance testing.

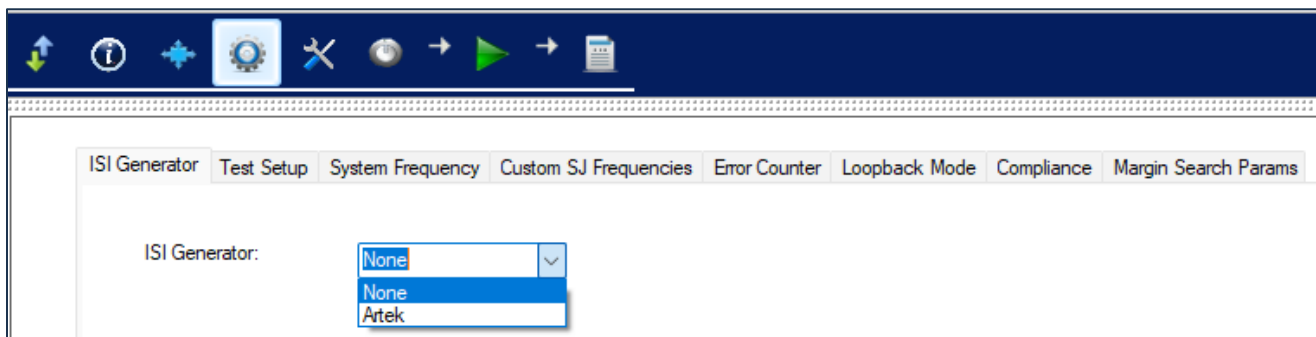


FIGURE 10. ISI GENERATOR SELECTION

3.3.3.2 Test Setup Tab

Select the Lane Under Test supported by the DUT for HS Rx conformance tests.

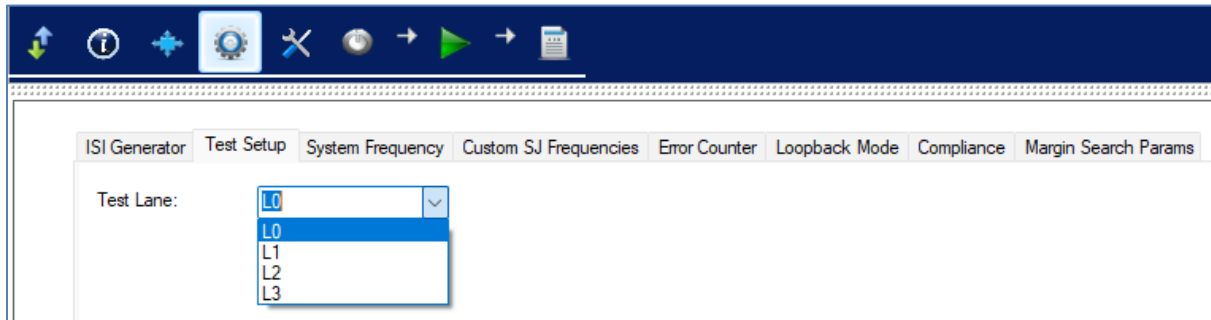


FIGURE 11. TEST LANE SELECTION

3.3.3.3 System Frequency Tab

Select the System Frequency of the DUT, which is also the frequency for SJ1.

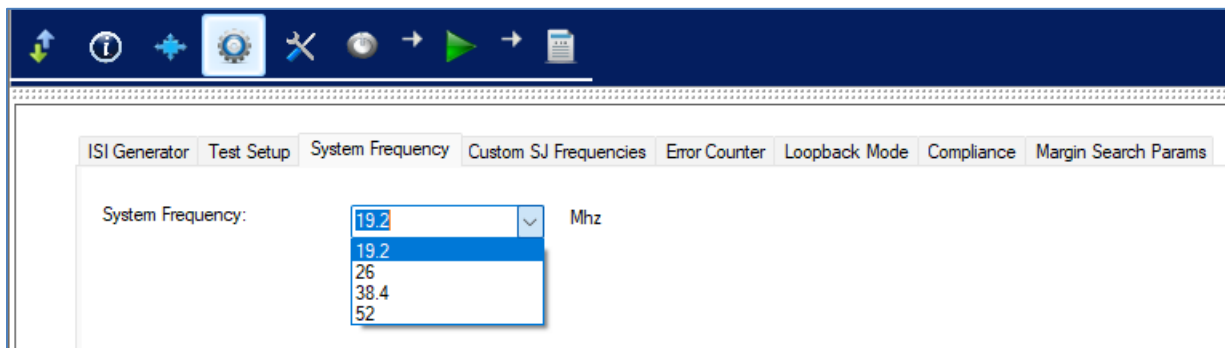


FIGURE 12. SYSTEM FREQUENCY SELECTION

3.3.3.4 Custom SJ Frequencies Tab

Specify the value for each Custom SJ Frequency selected from the 'Conditions' page (see Section 3.3.2).

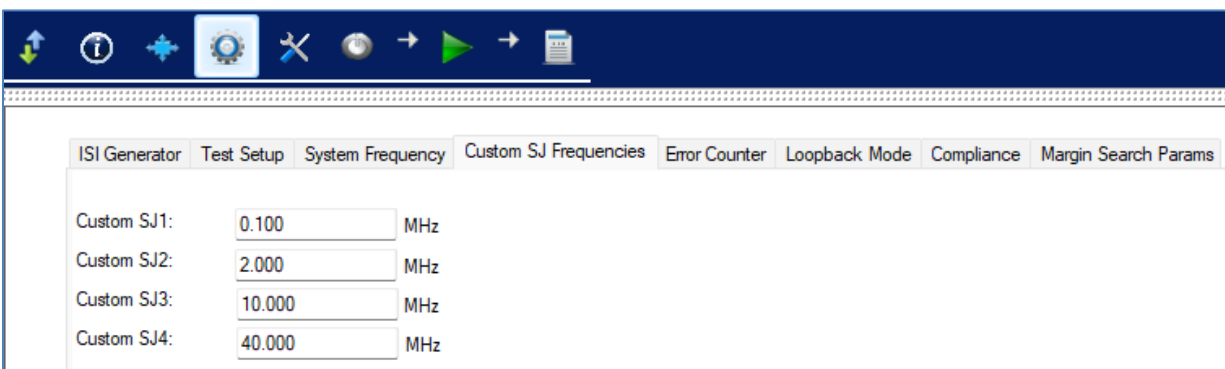


FIGURE 13. CUSTOM SJ FREQUENCIES SETUP

3.3.3.5 Error Counter Tab

Define the method to perform error count for target BER conformance.

- **Prompt Before Load Pattern:** Select the option to receive prompts prior to loading the test pattern.
- **Error Count Method:** Select to perform the error count manually or using a Local Script or Loopback mode.
 - **Manual:** User will be prompted to key in the number of errors detected.
 - **Local Script:** The GRL-MIPI-MPHY-HS-RXA software will execute an error counter user script for the DUT with IBER Capability. To use this feature, please contact GRL Platform Solutions for more details.
 - **LoopBack:** The GRL-MIPI-MPHY-HS-RXA software will utilize the Error Detector of the BERT to be used with the DUT with loopback capability.
- **Script File:** If a test script is used, enter the file path to be called by the GRL-MIPI-MPHY-HS-RXA software.

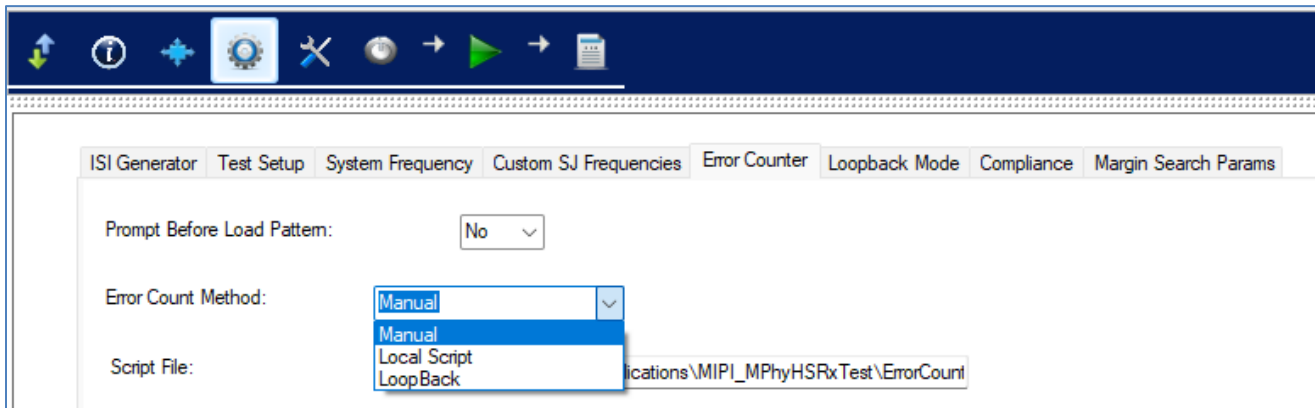


FIGURE 14. ERROR COUNT SETUP

3.3.3.6 Loopback Mode Tab

Set up the loopback mode if “LoopBack” is selected as the Error Count Method from the “Error Counter” tab.

- **Clock Recovery Method:** Specify how the Error Detector clock is configured to sample loopback data.
 - **Clock Recovery:** Use the Clock Recovery Unit to recover clock data. If this method is selected, the loop bandwidth can be specified at the **Clock Recovery Loop Bandwidth** field.
 - **Config File:** Use the Clock Recovery Unit to recover clock data. If this method is selected, an appropriate configuration file can be specified for the Clock Recovery Unit at the **Clock Recovery Config File** field.
 - **None:** No Clock Recovery Unit is used. The BERT Error Detector clock will sample loopback data supplied from an external clock recovery device or equivalent, to its clock input.
- **Lock Range:** Set the lock range for clock recovery.

- **Custom Pattern for Error Detector:** Select this checkbox if a custom test pattern is used for loopback error detection and enter the pattern format at the **ED Pattern** field.
- **Custom Pattern for Generator:** Select this checkbox if a custom test pattern is used for pattern generation and enter the pattern format at the **PG Pattern** field.

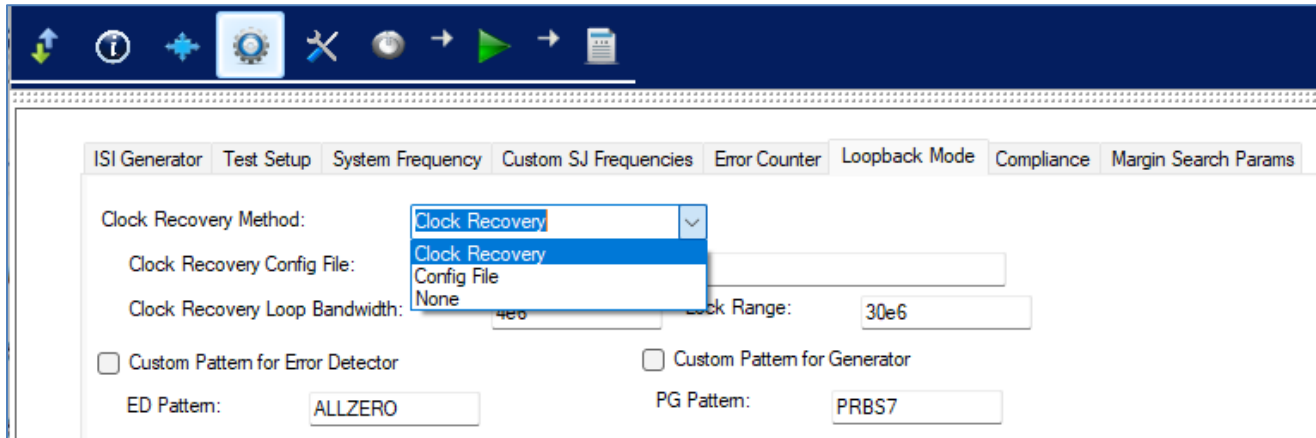


FIGURE 15. LOOPBACK MODE SETUP

3.3.3.7 Compliance Tab

Specify the target BER for DUT conformance testing, which overwrites existing test conditions. Also specify the maximum tolerance limit for error conformance in order to pass the test.

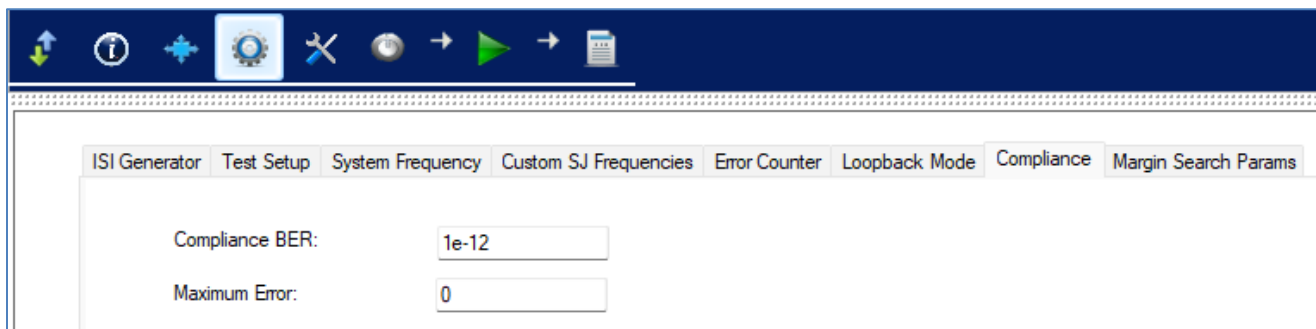
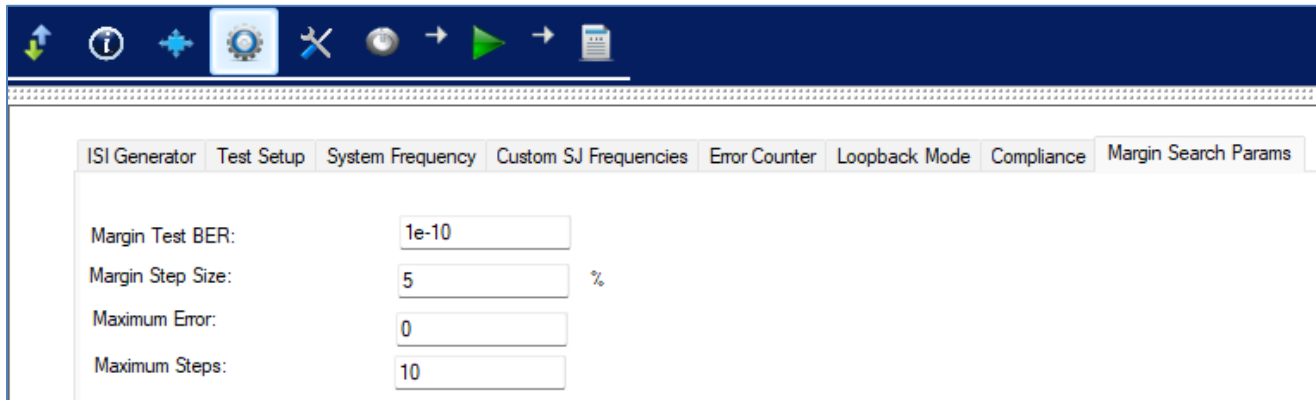


FIGURE 16. DUT CONFORMANCE LIMIT SETUP

3.3.3.8 Margin Search Params Tab

Specify the target BER for jitter tolerance margin tests, the step size for each iteration in the margin test as well as the maximum iteration for margin testing and conformance error limit.



ISI Generator Test Setup System Frequency Custom SJ Frequencies Error Counter Loopback Mode Compliance Margin Search Params

Margin Test BER:

Margin Step Size: %

Maximum Error:

Maximum Steps:

FIGURE 17. MARGIN SEARCH TEST SETUP

4 Calibrating Using GRL-MIPI-MPHY-HS-RXA Software

High-Speed Receiver level and jitter calibration are performed at specified HS GEAR A/B data rates, with and without ISI generation, per conformance test requirements.

After the GRL-MIPI-MPHY-HS-RXA software has been pre-configured from the previous section, continue with the calibration setup. The following procedures show how to set up the physical connections supported by the GRL-MIPI-MPHY-HS-RXA software to perform automated M-PHY HS Rx calibration.

The signal will be validated and measured for stress tolerance to final stressed eye conformance. The GRL-MIPI-MPHY-HS-RXA software supports automation using the SigTest standard post processing analysis software in the final calibrated eye diagram to achieve the final stressed eye calibration.

Figure 18 to Figure 22 show the HS-Rx calibration setup diagrams without and with ISI generation for specific calibration.

4.1 Non-ISI Related Calibration Setup

Figure 19 shows the HS-Rx calibration setup diagram without ISI generation using the MU196020A PAM4 Pulse Pattern Generator.

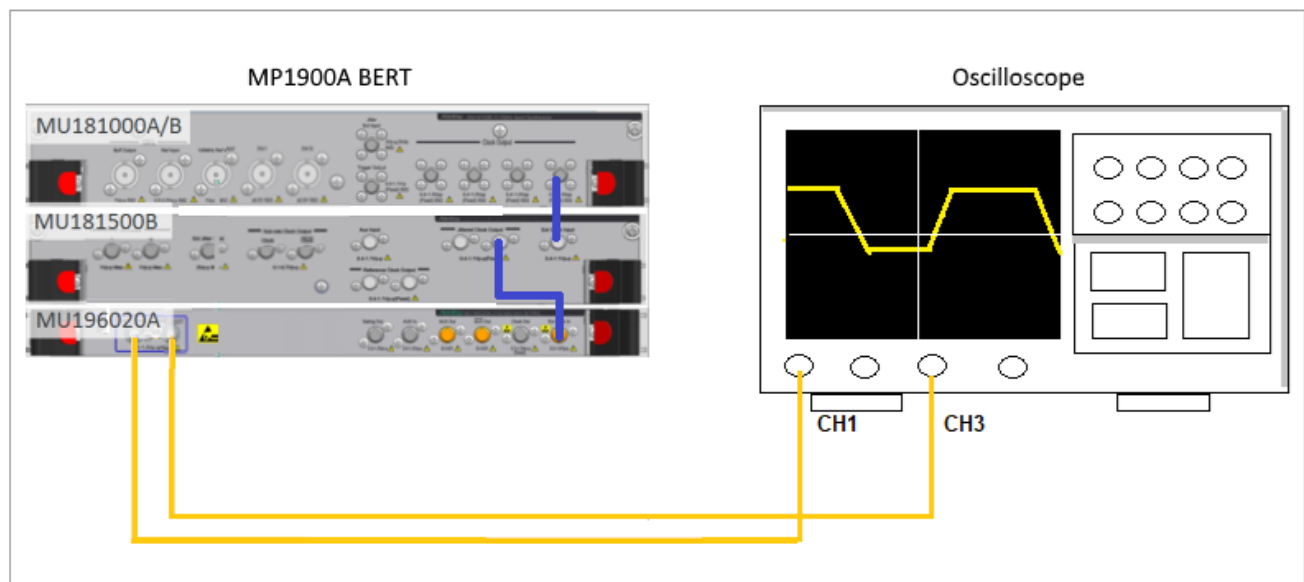


FIGURE 18. SETUP FOR HS-RX CALIBRATION WITHOUT ISI USING MU196020A PAM4 PPG

Figure 19 shows the HS-Rx calibration setup diagram without ISI generation using the MU195020A SI Pulse Pattern Generator and 6 dB attenuators.

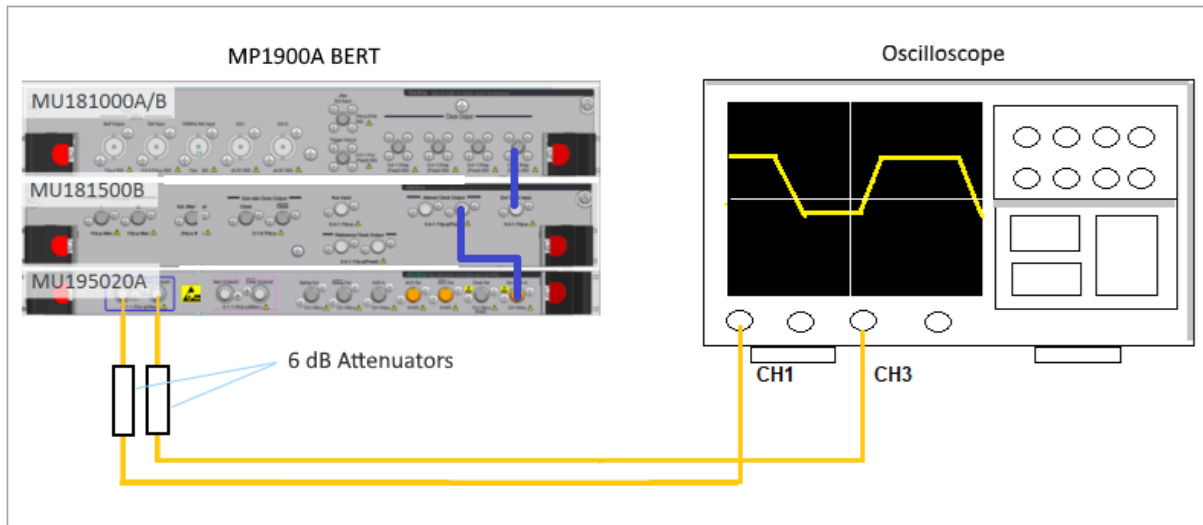


FIGURE 19. SETUP FOR HS-RX CALIBRATION WITHOUT ISI USING MU195020A SI PPG AND 6 dB ATTENUATORS

Connection Steps:

1. Using a SMA-SMA short cable, connect the MU181000A/B clock output to the MU181500B Ext clock input.
2. Using a SMA-SMA short cable, connect the MU181500B jittered clock output to the MU195020A / MU196020A Ext clock input.
3. Using phase matched K-K coaxial cables, connect the MU195020A / MU196020A data outputs to Channels 1 and 3 on the oscilloscope directly (if using the MU196020A PAM4 Pulse Pattern Generator) or through 6 dB attenuators (if using the MU195020A SI Pulse Pattern Generator).

4.1.1 Select High-Speed Level Calibration

The following calibration are performed without ISI generation.

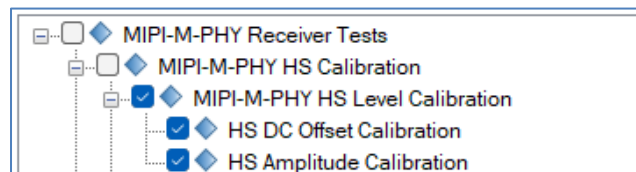


FIGURE 20. HS LEVEL CALIBRATION SELECTION

The GRL-MIPI-MPHY-HS-RXA software automatically performs these calibration when initiated.

The test selection panel allows the calibration/tests that need to be performed to be selected. Initially, when starting for the first time or changing anything in the setup, it is suggested to run calibration first. If the calibration is not completed, the DUT tests will throw an error when initiated.

4.2 ISI Related Calibration Setup

4.2.1 High-Speed ISI Calibration

Figure 21 shows the setup diagram for high-speed ISI calibration with ISI generation using the MU196020A PAM4 Pulse Pattern Generator.

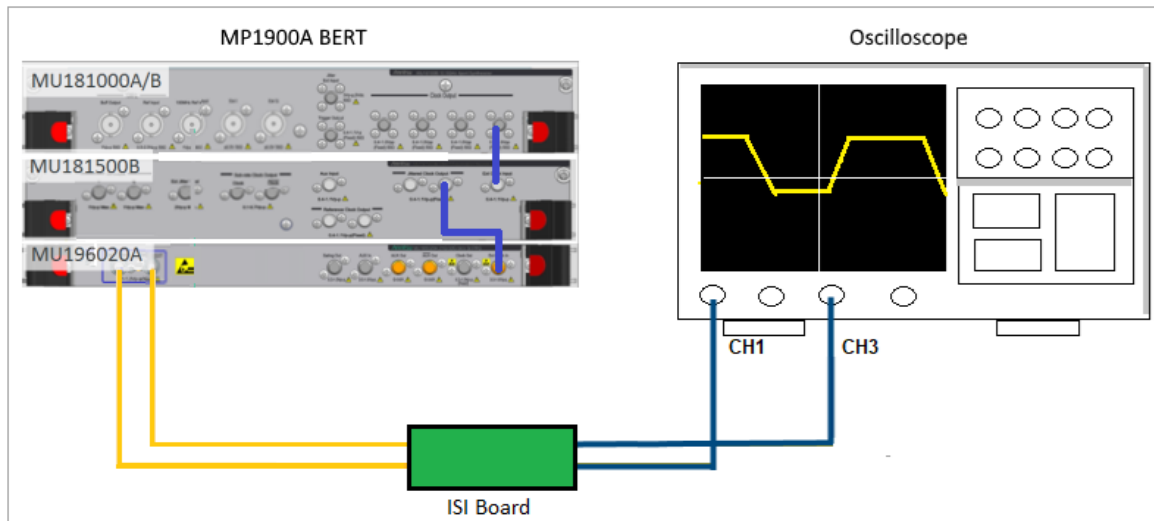


FIGURE 21. SETUP FOR HS ISI CALIBRATION WITH ISI USING MU196020A PAM4 PPG

Figure 22 shows the setup diagram for high-speed ISI calibration with ISI generation using the MU195020A SI Pulse Pattern Generator and 6 dB attenuators.

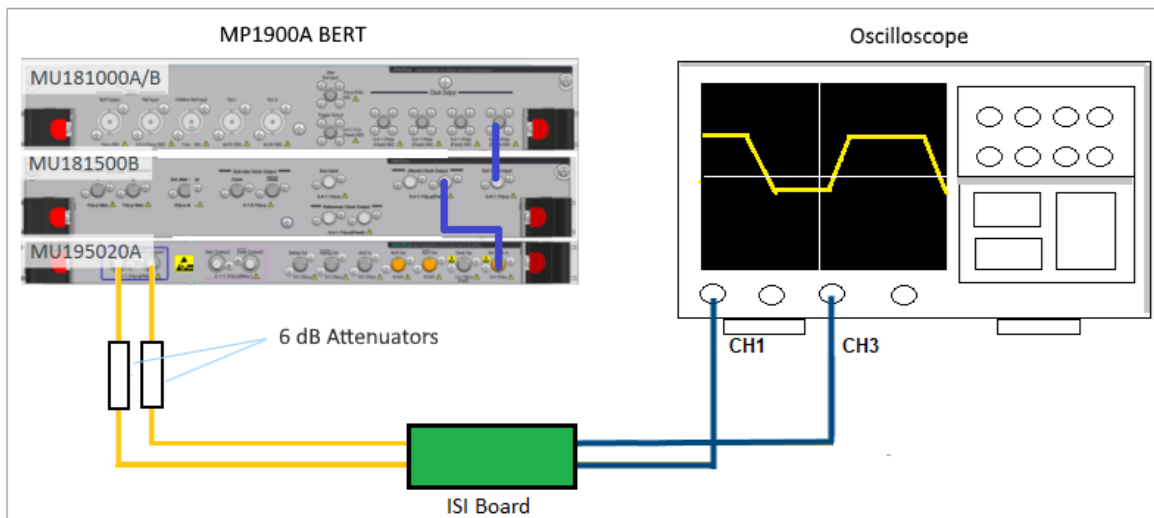


FIGURE 22. SETUP FOR HS ISI CALIBRATION WITH ISI USING MU195020A SI PPG AND 6 DB ATTENUATORS

Connection Steps:

1. Using back the same BERT connections from the non-ISI related calibration in Section 4.1, disconnect the MU195020A / MU196020A data outputs from the oscilloscope channels.

2. Connect the MU195020A / MU196020A data outputs to an ISI board/channel directly (if using the MU196020A PAM4 Pulse Pattern Generator) or through 6 dB attenuators (if using the MU195020A SI Pulse Pattern Generator).
3. Connect the ISI board/channel to Channels 1 and 3 on the oscilloscope.

4.2.2 High-Speed High/Low Frequency RJ/SJ and Eye Width/Eye Height Calibration

Figure 23 shows the setup diagram for high-speed high/low frequency RJ/SJ calibration and eye width/eye height calibration with ISI generation using the MU196020A PAM4 Pulse Pattern Generator.

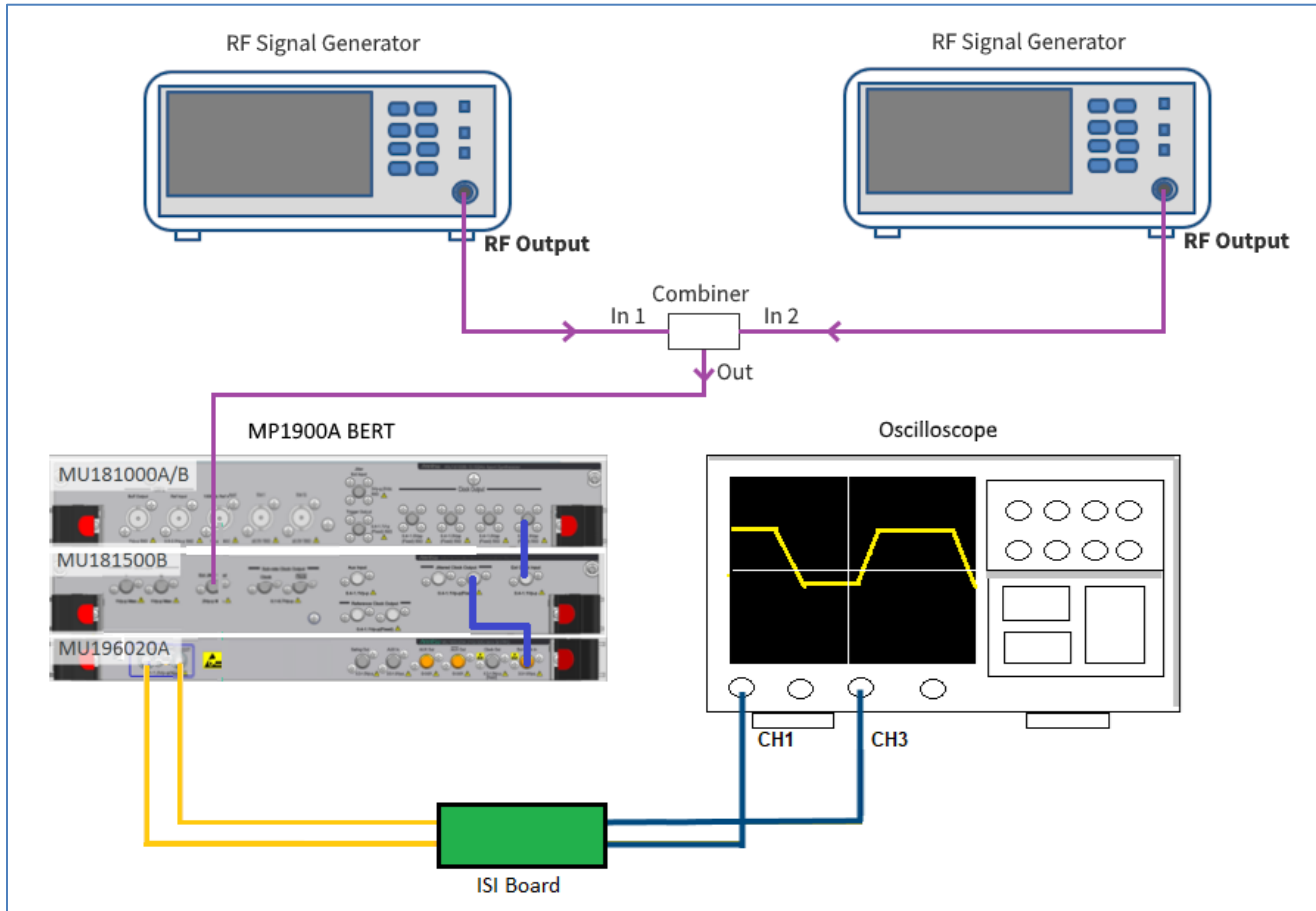


FIGURE 23. SETUP FOR HS HIGH/LOW FREQUENCY RJ/SJ AND EYE WIDTH/EYE HEIGHT CALIBRATION WITH ISI USING MU196020A PAM4 PPG

Figure 24 shows the setup diagram for high-speed high/low frequency RJ/SJ calibration and eye width/eye height calibration with ISI generation using the MU195020A SI Pulse Pattern Generator and 6 dB attenuators.

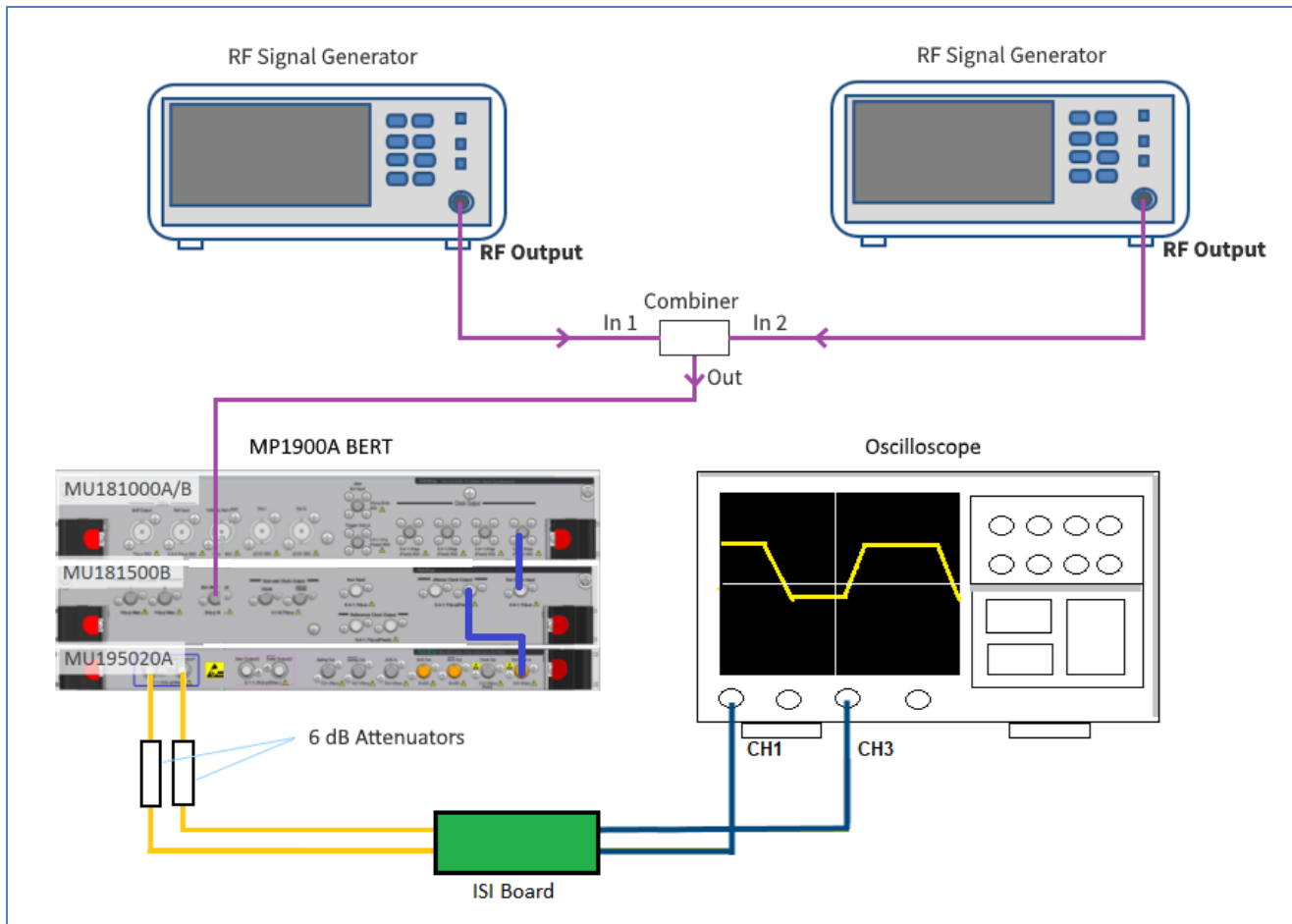


FIGURE 24. SETUP FOR HS HIGH/LOW FREQUENCY RJ/SJ AND EYE WIDTH/EYE HEIGHT CALIBRATION WITH ISI USING MU195020A SI PPG AND 6 DB ATTENUATORS

Connection Steps:

1. Using back the same BERT connections from Section 4.2.1, High-Speed ISI Calibration, connect the RF output of each RF Signal Generator to a Combiner input.
2. Connect the Combiner output to the MU181500B External Jitter Input.

4.2.3 Select High-Speed Jitter Calibration

The following calibration are performed with ISI generation.

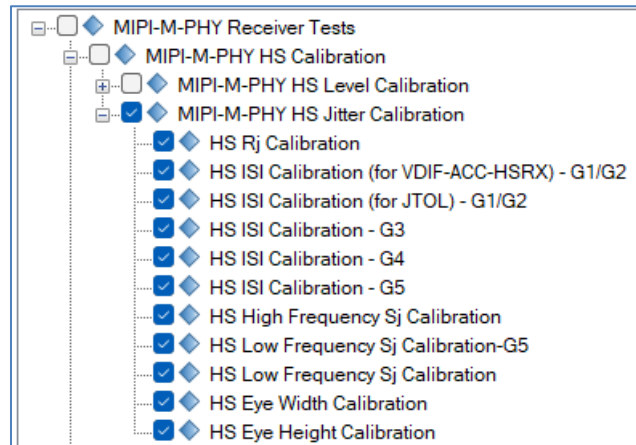


FIGURE 25. HS JITTER CALIBRATION SELECTION

The GRL-MIPI-MPHY-HS-RXA software automatically performs these calibration when initiated.

The test selection panel allows the calibration/tests that need to be performed to be selected. Initially, when starting for the first time or changing anything in the setup, it is suggested to run calibration first. If the calibration is not completed, the DUT tests will throw an error when initiated.

4.3 Configure Calibration Parameters

After selecting the desired calibration, the user can select  from the menu to access the **Configurations** page. Set the required parameters for calibration as described below.

To return all parameters to their default values, select the 'Set Default' button.

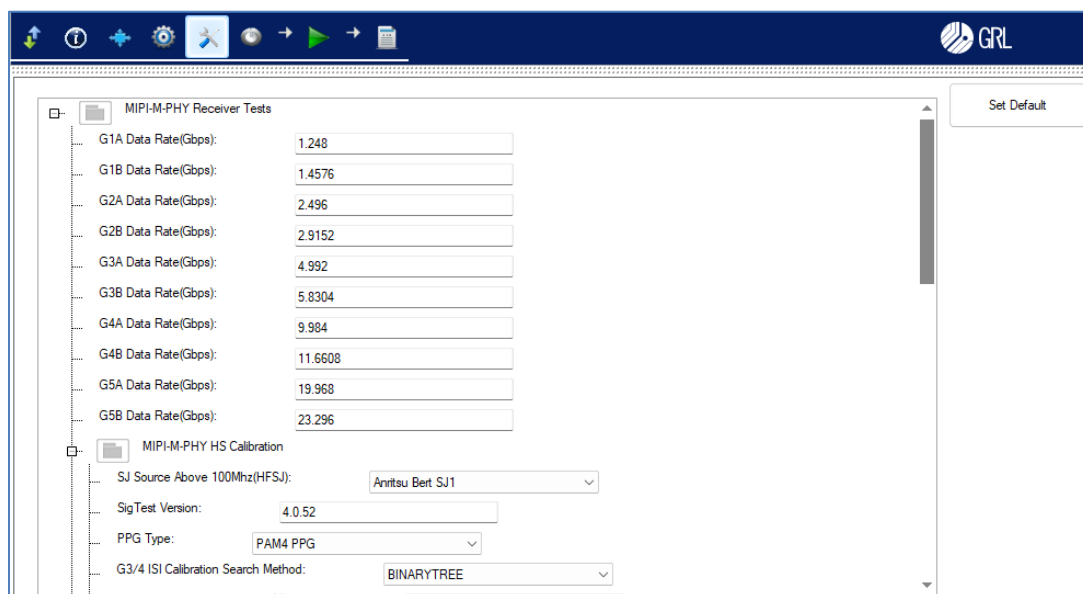


FIGURE 26. CALIBRATION PARAMETERS CONFIGURATION PAGE

TABLE 4. CALIBRATION PARAMETERS DESCRIPTION

Parameter	Description
G1/2/3/4/5A/B Data Rate (Gbps)	Specify the data rates for all supported HS GEAR's A/B-series, as required for various calibration and test cases.
SJ Source Above 100MHz (HFSJ)	Select the SJ source to be used for HS High Frequency SJ calibration.
SigTest Version	Enter the Version number of the SigTest signal quality test to be run during calibration to ensure waveform conformance. Make sure that the SigTest application is already installed in the test controller system.
PPG Type	Select the MU196020A PAM4 Pulse Pattern Generator or MU195020A SI Pulse Pattern Generator to be used for calibration and testing.
G3/4 ISI Calibration Search Method	Select either linear search or binary search or a combination of both linear search and binary search to be used as the search method in the G3 or G4 ISI calibration.
Max Rigol Output (V) (for MP1900 Safety)	Specify the maximum output voltage from the Rigol DSG800 RF Signal Generator to protect the MU181500B jitter module from high input voltage.
Max Keysight Sig Gen Output (V) (for MP1900 Safety)	Specify the maximum output voltage from the Keysight N5182B MXG X-Series RF Signal Generator to protect the MU181500B jitter module from high input voltage.
Data Channels	Select the oscilloscope channel pair to be connected for calibration.
LFSJ Source	Select the SJ source to be used for the HS Low Frequency SJ calibration.

4.4 Run Calibration at TP3



Select  from the menu to select the following run options and then start running the selected calibration.

- **Skip Test if Result Exists**– If previous calibration results exist, the GRL-MIPI-MPHY-HS-RXA software will *skip* the calibration steps that have existing reports.
- **Replace if Result Exists**– If previous calibration results exist, the GRL-MIPI-MPHY-HS-RXA software will *replace* each step in the calibration with new results.

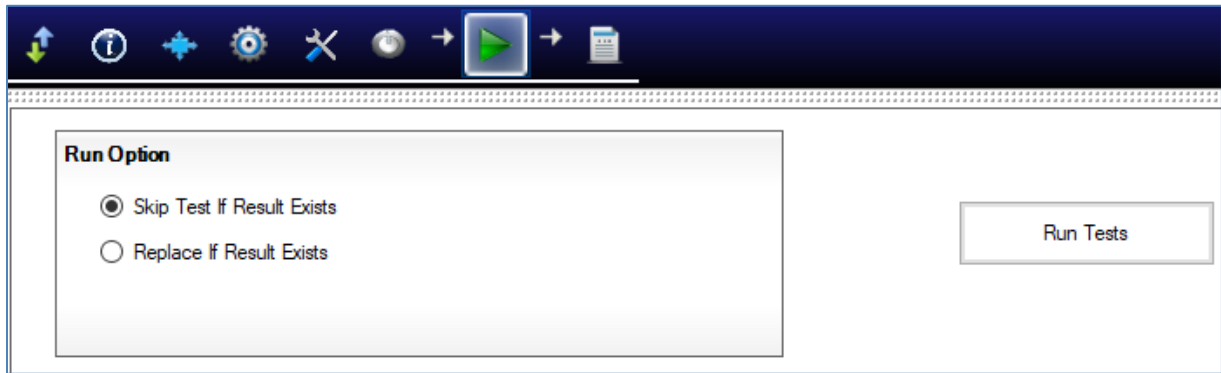


FIGURE 27. RUN TESTS

Select the **Run Tests** button to start running calibration.

When running calibration, the GRL-MIPI-MPHY-HS-RXA software will display the connection diagram as a first step to help the user make sure all connections are proper before calibration is performed.

4.5 Configure Calibration Target Values

For debugging purposes ONLY, the default calibration target values can be changed for

any of the calibration. To do this, select  from the menu to access the Calibration page.

By default, the calibration target values are those defined in the specification. To change the values, deselect the Use Default Value checkbox. In case the default values are required again, just select the checkbox to allow all existing values to be reset to default.

Note: The PID Control setting is used to adjust the step width for steps calculation if the target measurement cannot be met with the current step. To adjust, use a lower PID Control value to reduce the subsequent step or increase the control value to make the subsequent step bigger.

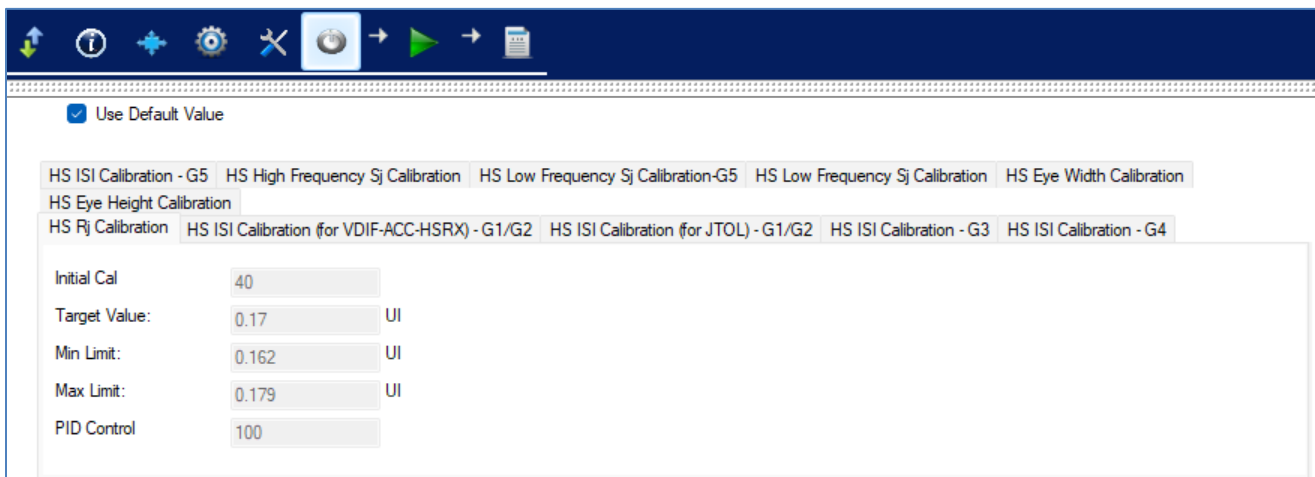


FIGURE 28. CALIBRATION TARGET OVERWRITE PAGE

5 Testing Using GRL-MIPI-MPHY-HS-RXA Software

After calibration has completed, then testing the Receiver DUT for conformance can be performed.

For most HS-Rx conformance tests, observable bits of minimum $3E+10$ (@ $1E-10$ target BER) or $3E+12$ (@ $1E-12$ target BER) shall be transmitted to the DUT, and the DUT shall report zero received errors in order to be conformant.

The following procedures describe how to set up the physical connections to perform automated M-PHY HS Rx conformance testing for the receiver device.

5.1 Non-ISI Related Test Setup

Figure 29 below shows the connection setup for HS-Rx tests that do not require ISI generation using the MU196020A PAM4 Pulse Pattern Generator.

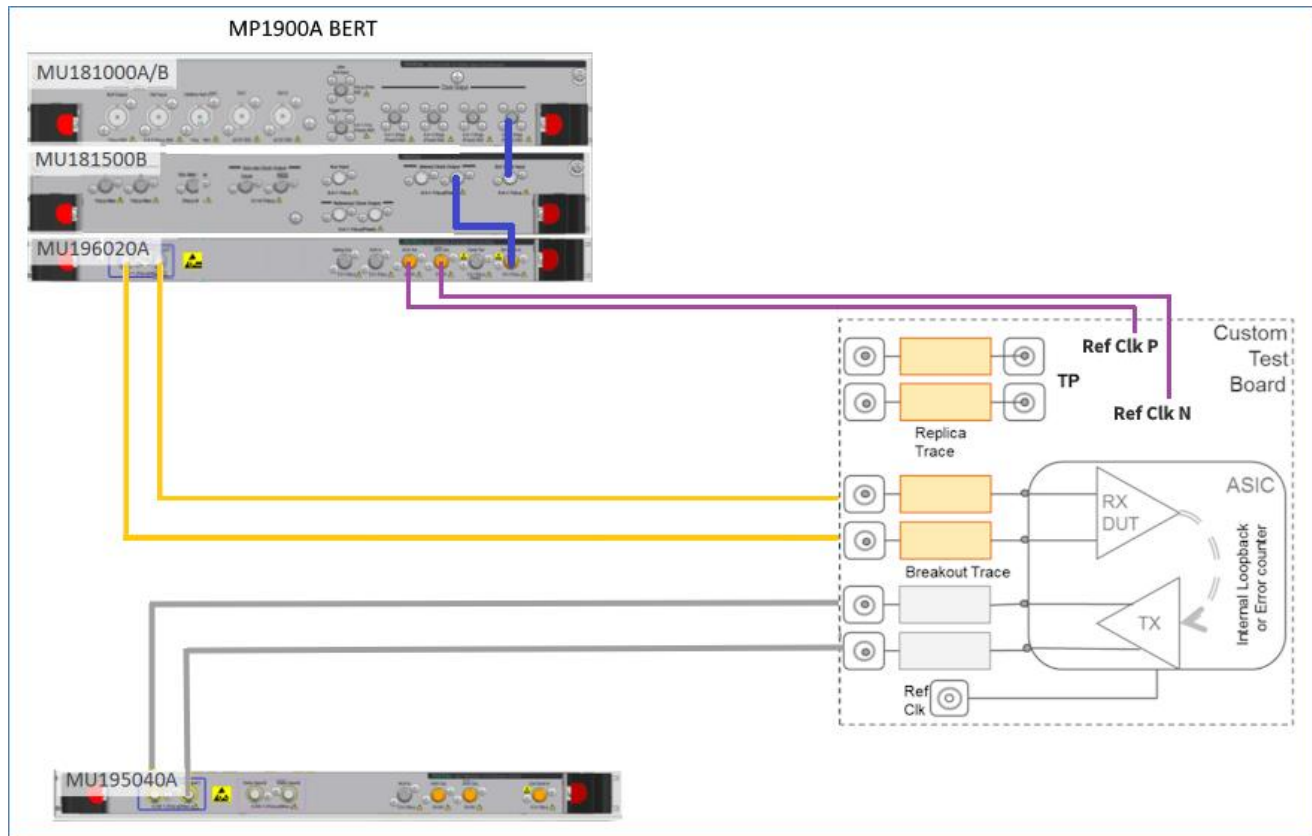


FIGURE 29. RECEIVER TEST SETUP WITHOUT ISI USING MU196020A PAM4 PPG

Figure 30 below shows the connection setup for HS-Rx tests that do not require ISI generation using the MU195020A SI Pulse Pattern Generator and 6 dB attenuators.

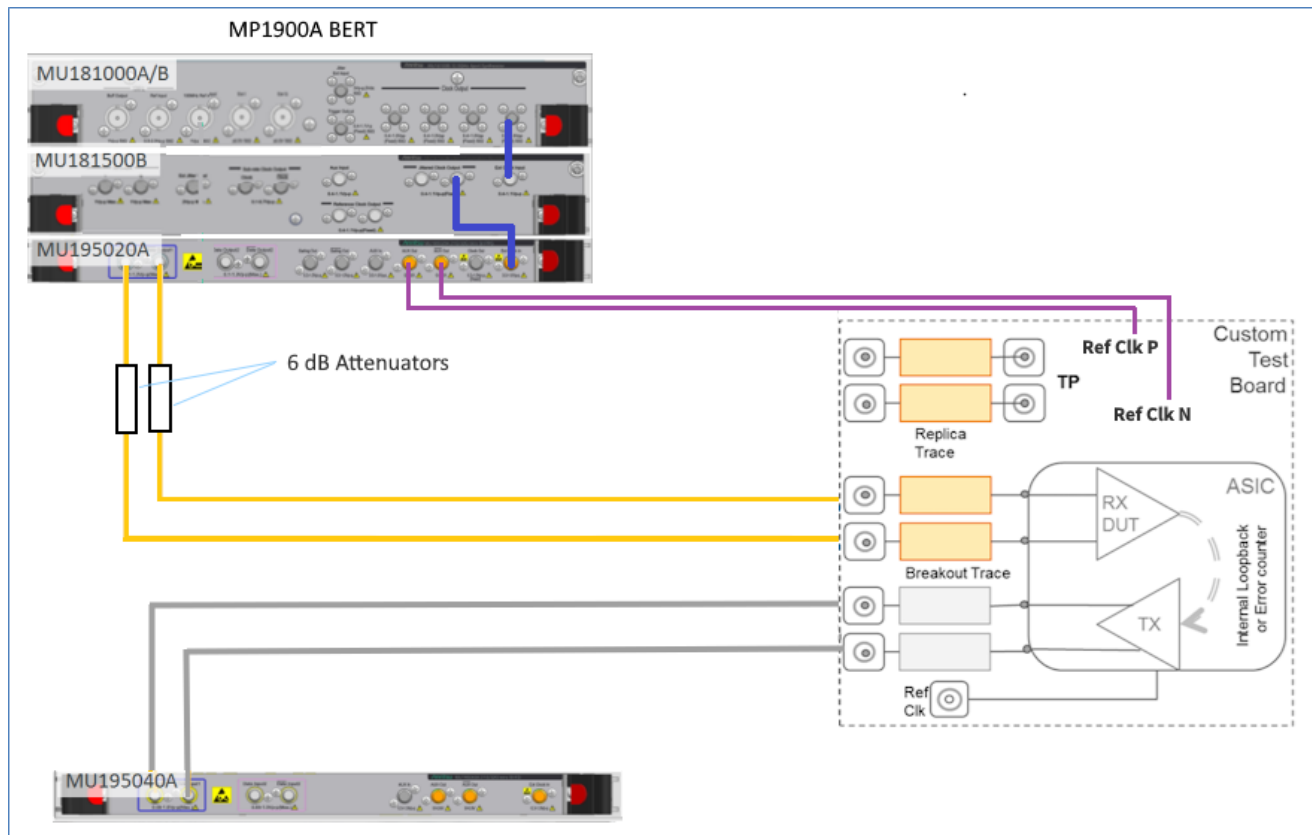


FIGURE 30. RECEIVER TEST SETUP WITHOUT ISI USING MU195020A SI PPG AND 6 DB ATTENUATORS

Connection Steps:

1. Using back the same BERT connections from Section 4.1, Non-ISI Related Calibration Setup, remove the oscilloscope connections from the MU195020A / MU196020A data outputs.
2. Connect the MU195020A / MU196020A Aux Out connectors to Ref Clk P and Ref Clk N respectively.
3. Connect the MU195020A / MU196020A data outputs to the Breakout Trace.
4. Connect the Breakout Trace to the Rx DUT.
5. Connect the DUT Tx outputs to the MU195040A data inputs for loopback error detection.

5.1.1 Select High-Speed Non-ISI Related Tests

The following DUT tests are performed without ISI generation.

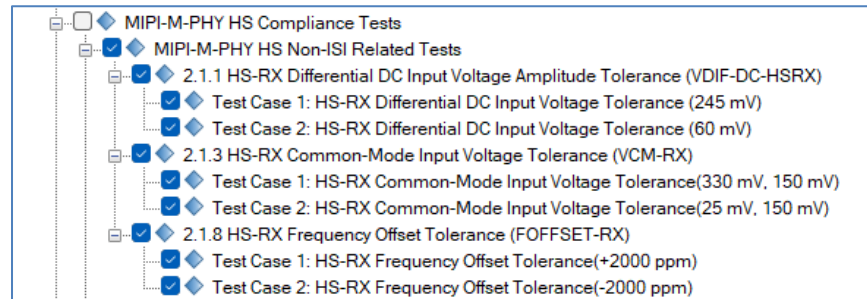


FIGURE 31. HS NON-ISI RELATED TESTS SELECTION

The GRL-MIPI-MPHY-HS-RXA software automatically performs these tests when initiated.

The test selection panel allows the calibration/tests that need to be performed to be selected. Initially, when starting for the first time or changing anything in the setup, it is suggested to run calibration first. If the calibration is not completed, the DUT tests will throw an error when initiated.

The HS Non-ISI related tests are run from the same screen as shown in Figure 27.

5.2 ISI Related Test Setup

5.2.1 Test 2.1.2 HS-Rx Accumulated Differential Input Voltage Tolerance (VDIF-ACC-HSRX)

Figure 32 below shows the connection setup for Test 2.1.2 HS-Rx Accumulated Differential Input Voltage Tolerance (VDIF-ACC-HSRX) with ISI generation using the MU196020A PAM4 Pulse Pattern Generator.

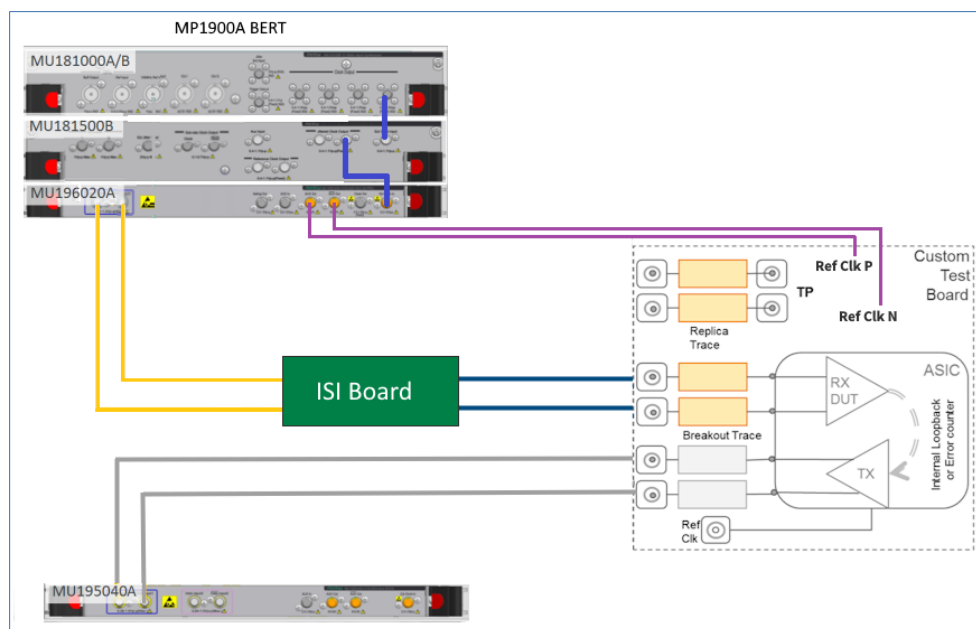


FIGURE 32. TEST 2.1.2 HS-Rx ACCUMULATED DIFFERENTIAL INPUT VOLTAGE TOLERANCE (VDIF-ACC-HSRX) SETUP WITH ISI USING MU196020A PAM4 PPG

Figure 33 below shows the connection setup for Test 2.1.2 HS-Rx Accumulated Differential Input Voltage Tolerance (VDIF-ACC-HSRX) with ISI generation using the MU195020A SI Pulse Pattern Generator and 6 dB attenuators.

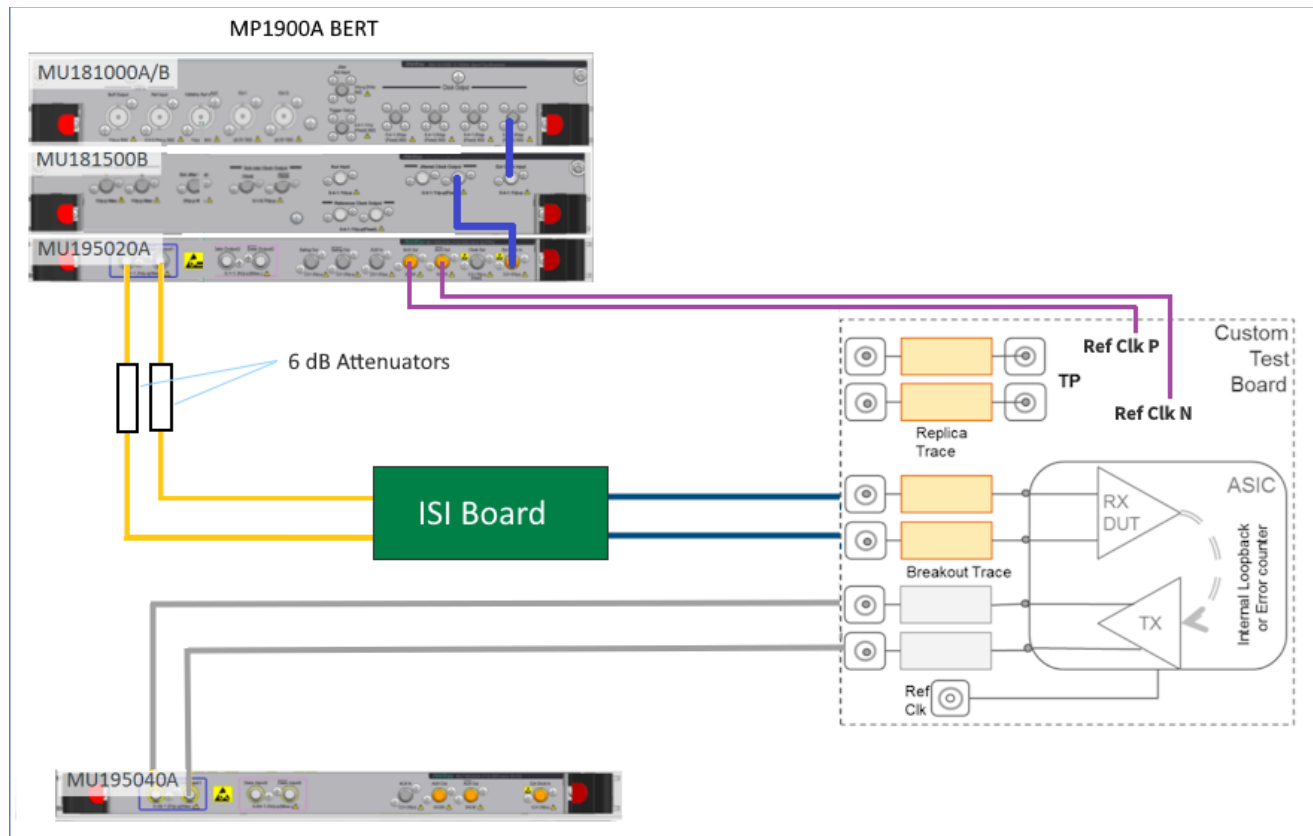


FIGURE 33. TEST 2.1.2 HS-RX ACCUMULATED DIFFERENTIAL INPUT VOLTAGE TOLERANCE (VDIF-ACC-HSRX) SETUP WITH ISI USING MU195020A SI PPG AND 6 dB ATTENUATORS

Connection Steps:

1. Using back the same BERT connections from Section 4.2.1, High-Speed ISI Calibration, remove the oscilloscope connections from the ISI board/channel.
2. Connect the MU195020A / MU196020A Aux Out connectors to Ref Clk P and Ref Clk N respectively.
3. Using phase matched K-K coaxial cables, connect the ISI board to the Breakout Trace.
4. Connect the Breakout Trace to the Rx DUT.
5. Connect the DUT Tx outputs to the MU195040A data inputs for loopback error detection.

5.2.2 Test 2.1.7 HS-Rx Jitter Tolerance (TJRX, DJRX, RJRX, STTJRX, STDJRX)

Figure 34 below shows the connection setup for Test 2.1.7 HS-Rx Jitter Tolerance (TJRX, DJRX, RJRX, STTJRX, STDJRX) with ISI generation using the MU196020A PAM4 Pulse Pattern Generator.

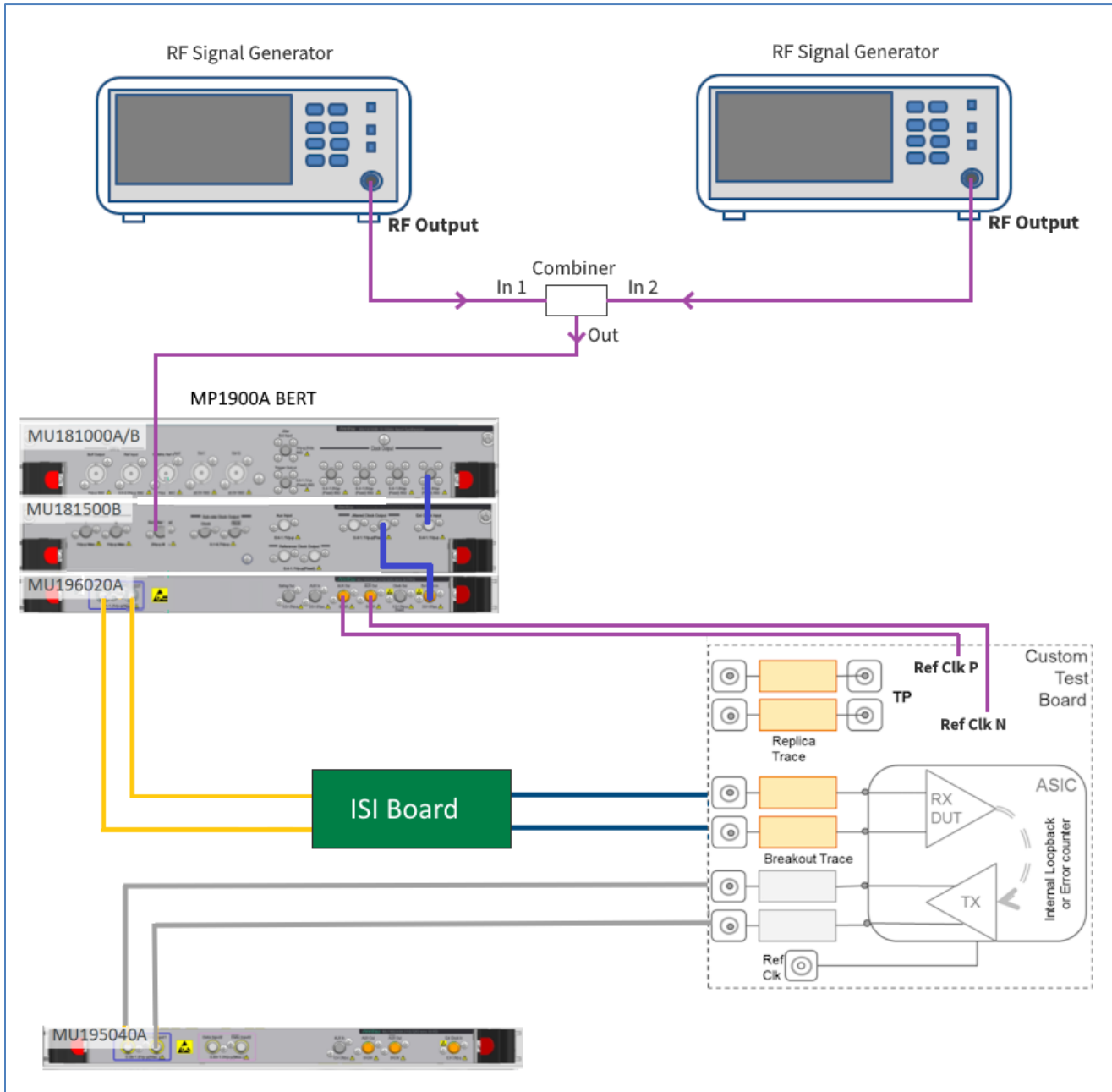


FIGURE 34. TEST 2.1.7 HS-RX JITTER TOLERANCE (TJRX, DJRX, RJRX, STTJRX, STDJRX) SETUP WITH ISI USING MU196020A PAM4 PPG

Figure 35 below shows the connection setup for Test 2.1.7 HS-Rx Jitter Tolerance (TJRX, DJRX, RJRX, STTJRX, STDJRX) with ISI generation using the MU195020A SI Pulse Pattern Generator and 6 dB attenuators.

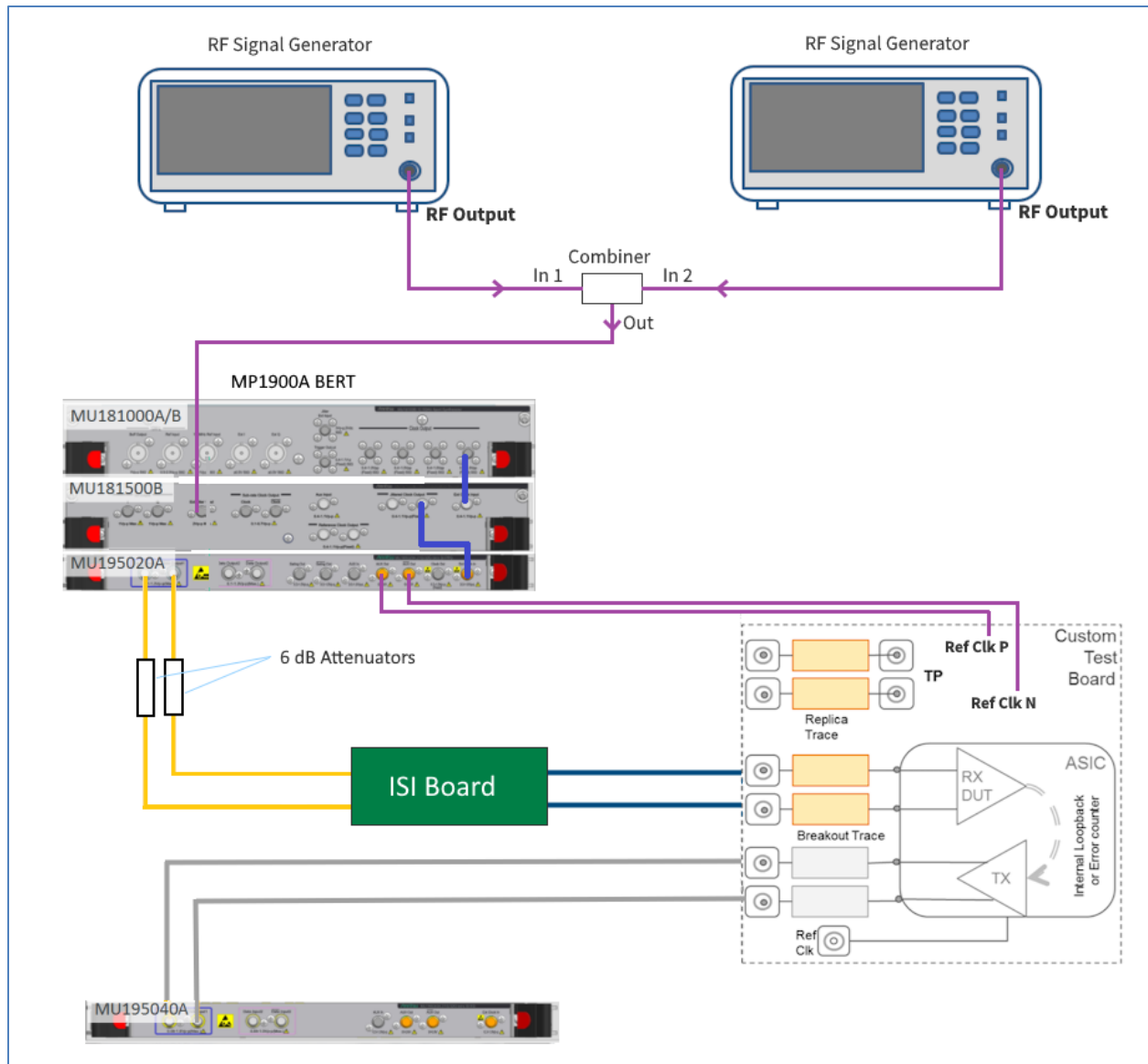


FIGURE 35. TEST 2.1.7 HS-RX JITTER TOLERANCE (TJRX, DJRX, RJRX, STTJRX, STDJRX) SETUP WITH ISI USING MU195020A SI PPG AND 6 DB ATTENUATORS

Connection Steps:

1. Using back the same BERT connections from Section 5.2.1, Test 2.1.2 HS-Rx Accumulated Differential Input Voltage Tolerance (VDIF-ACC-HSRX), connect the RF output of each RF Signal Generator to a Combiner input.
2. Connect the Combiner output to the MU181500B External Jitter Input.

5.2.3 Select High-Speed ISI Related Tests

The following DUT tests are performed with ISI generation.

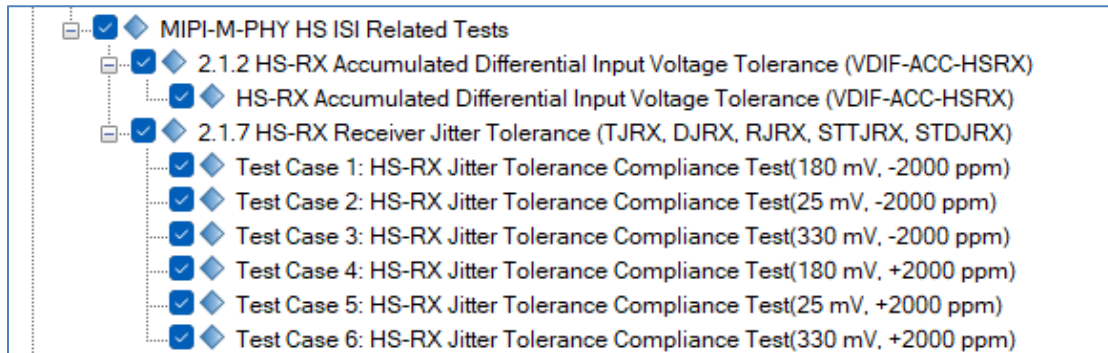


FIGURE 36. HS ISI RELATED TESTS SELECTION

The GRL-MIPI-MPHY-HS-RXA software automatically performs these tests when initiated.

The test selection panel allows the calibration/tests that need to be performed to be selected. Initially, when starting for the first time or changing anything in the setup, it is suggested to run calibration first. If the calibration is not completed, the DUT tests will throw an error when initiated.

The HS ISI related tests are run from the same screen as shown in Figure 27.

5.3 High-Speed Margin Tests

The user can select the HS Margin Tests if performing Jitter Tolerance Margin Search testing for the DUT. These tests are optional and not required for conformance.

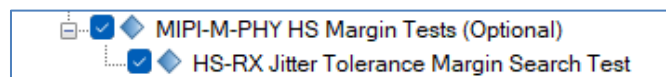


FIGURE 37. SELECTING HS MARGIN TESTS

The HS Margin tests are run from the same screen as shown in Figure 27.

5.4 Configure Receiver Test Parameters

Select  from the menu to access the **Configurations** page. Set the required parameters for testing as described below.

To return all parameters to their default values, select the 'Set Default' button.

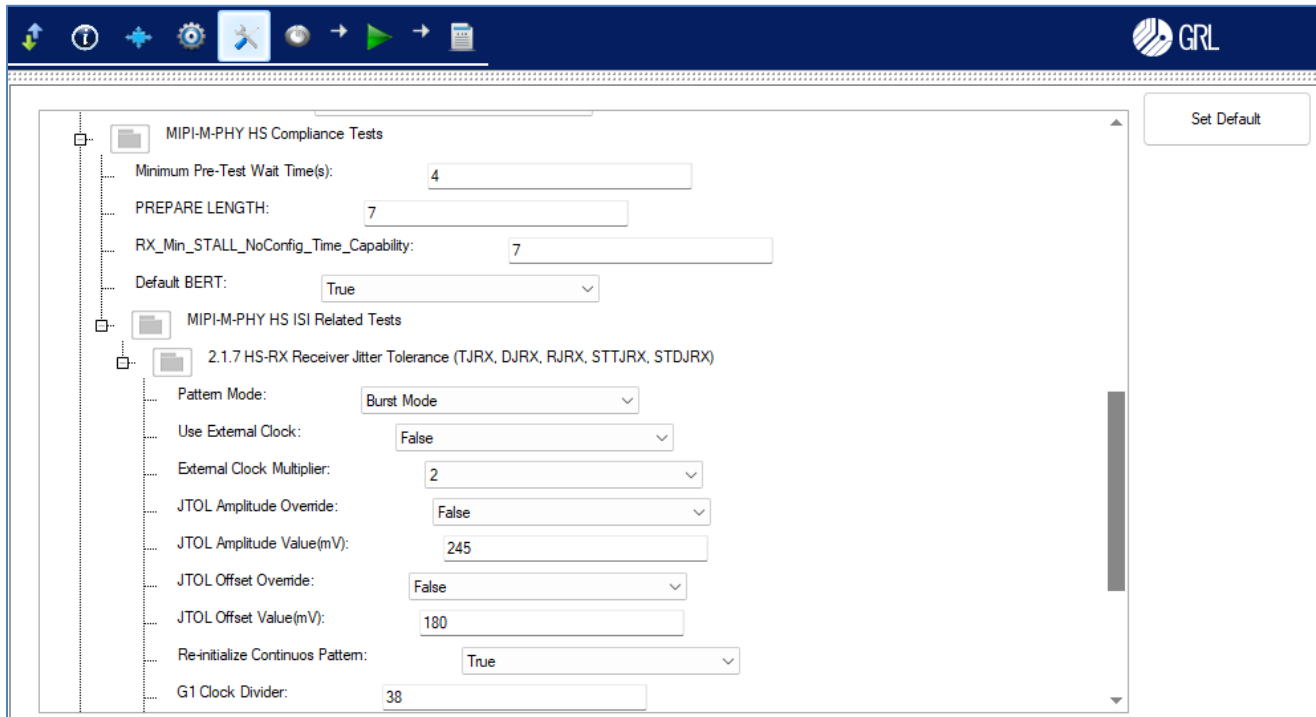


FIGURE 38. RECEIVER TEST PARAMETERS CONFIGURATION PAGE

TABLE 5. RECEIVER TEST PARAMETERS DESCRIPTION

Parameter	Description
Minimum Pre-Test Wait Time(s)	Specify the minimum wait duration for the initial ZERO pattern to end prior to loading the test pattern.
PREPARE LENGTH	Specify the RX_HS_PREPARE_LENGTH_Capability attribute value of the DUT.
RX_Min_STALL_NoConfig_Time_Capability	Specify the RX_Min_STALL_NoConfig_Time_Capability attribute value of the DUT.
Default BERT	Select 'True' to use the default BERT configuration for conformance testing.
Pattern Mode	Select to use the test pattern for Continuous or Burst Mode signaling per Test 2.1.7 requirements.
Use External Clock	Select 'True' to use an external clock in Test 2.1.7 for loopback testing.
External Clock Multiplier	Select the multiplier value for the external clock if selected to be used.
JTOL Amplitude/Offset Override	Select 'True' to allow new values to be specified and override existing amplitude or offset levels, per Test 2.1.7 case requirements.
JTOL Amplitude/Offset Value (mV)	Specify new values for amplitude or offset, if override is allowed.

Re-initialize Continuous Pattern	Select 'True' to re-generate continuous mode pattern signaling.
G1/2/3/4/5 Clock Divider	Specify the clock value to be generated by the clock divider unit for each supported HS GEAR.
Ignore Sync Error	Select 'True' to ignore sync errors that may occur during margin search tests.

6 Interpreting Test Report

The **Report** page has all the results from all the test runs displayed. If some of the results are not desired, they can be individually deleted by using the **Delete** button. Also for a PDF report, select the **Generate report** button. To have the calibration data plotted in the report, make sure the **Plot Calibration Data** box is checked.

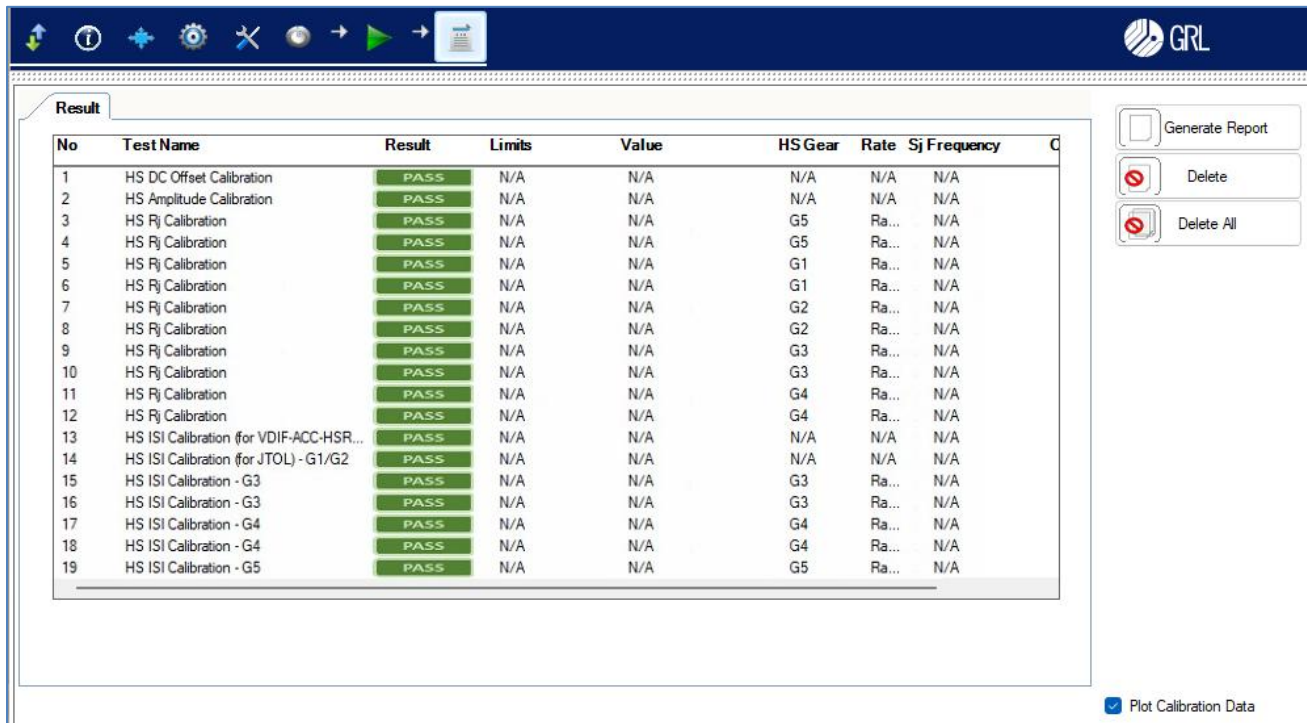


FIGURE 39. REPORT RESULTS PAGE

6.1 DUT Information

This portion is populated from the information in the DUT tab from the **Session Info** tab.

DUT Information	
DUT Manufacturer	: GRL
DUT Model Number	: M-PHY HS G5 Device A
DUT Serial Number	: G500001000A
DUT Comments	:
Test Information	
Test Lab	: GRL Platform Solutions Penang
Test Operator	: David
Test Date	: 7 May 2026
Software Version	
Software Revision	: 1.00.59

FIGURE 40. DUT INFORMATION

6.2 Summary Table

This portion is populated from the tests performed and its results. This gives an overall view of all the results and its test conditions.

No	TestName	Limits	Value	Results	HS Gear	Rate	Sj Frequency
1	HS DC Offset Calibration	N/A	N/A	Pass			
2	HS Amplitude Calibration	N/A	N/A	Pass			
3	HS Rj Calibration	N/A	N/A	Pass	G5	Rate A	N/A
4	HS Rj Calibration	N/A	N/A	Pass	G5	Rate B	N/A
5	HS Rj Calibration	N/A	N/A	Pass	G1	Rate A	N/A
6	HS Rj Calibration	N/A	N/A	Pass	G1	Rate B	N/A
7	HS Rj Calibration	N/A	N/A	Pass	G2	Rate A	N/A
8	HS Rj Calibration	N/A	N/A	Pass	G2	Rate B	N/A
9	HS Rj Calibration	N/A	N/A	Pass	G3	Rate A	N/A
10	HS Rj Calibration	N/A	N/A	Pass	G3	Rate B	N/A
11	HS Rj Calibration	N/A	N/A	Pass	G4	Rate A	N/A
12	HS Rj Calibration	N/A	N/A	Pass	G4	Rate B	N/A
13	HS ISI Calibration (for VDI-ACC-HSRX) - G1/G2	N/A	N/A	Pass			
14	HS ISI Calibration (for JTOL) - G1/G2	N/A	N/A	Pass			
15	HS ISI Calibration - G3	N/A	N/A	Pass	G3	Rate A	N/A
16	HS ISI Calibration - G3	N/A	N/A	Pass	G3	Rate B	N/A
17	HS ISI Calibration - G4	N/A	N/A	Pass	G4	Rate A	N/A
18	HS ISI Calibration - G4	N/A	N/A	Pass	G4	Rate B	N/A
19	HS ISI Calibration - G5	N/A	N/A	Pass	G5	Rate B	N/A
20	HS ISI Calibration - G5	N/A	N/A	Pass	G5	Rate A	N/A
21	HS High Frequency Sj Calibration	N/A	N/A	Pass	G1	Rate B	N/A
22	HS High Frequency Sj Calibration	N/A	N/A	Fail	G2	Rate A	N/A
23	HS High Frequency Sj Calibration	N/A	N/A	Fail	G2	Rate B	N/A
31	HS Low Frequency Sj Calibration-G5	N/A	N/A	Fail	G5	Rate A	Fc
32	HS Low Frequency Sj Calibration-G5	N/A	N/A	Pass	G5	Rate A	SJ2
33	HS Low Frequency Sj Calibration-G5	N/A	N/A	Pass	G5	Rate A	SJ3
34	HS Low Frequency Sj Calibration-G5	N/A	N/A	Pass	G5	Rate A	SJ4
35	HS Low Frequency Sj Calibration-G5	N/A	N/A	Pass	G5	Rate A	Custom_SJ2
36	HS Low Frequency Sj Calibration-G5	N/A	N/A	Fail	G5	Rate B	Fc
37	HS Low Frequency Sj Calibration-G5	N/A	N/A	Fail	G5	Rate B	SJ2
38	HS Low Frequency Sj Calibration-G5	N/A	N/A	Fail	G5	Rate B	SJ3
39	HS Low Frequency Sj Calibration-G5	N/A	N/A	Fail	G5	Rate B	SJ4
40	HS Low Frequency Sj Calibration-G5	N/A	N/A	Fail	G5	Rate B	Custom_SJ2
113	HS Eye Width Calibration	N/A	N/A	Pass	G5	Rate A	SJ3
114	HS Eye Width Calibration	N/A	N/A	Pass	G5	Rate A	SJ4
115	HS Eye Width Calibration	N/A	N/A	Pass	G5	Rate A	Custom_SJ2
116	HS Eye Width Calibration	N/A	N/A	Pass	G5	Rate B	Fc
117	HS Eye Width Calibration	N/A	N/A	Pass	G5	Rate B	SJ2
118	HS Eye Width Calibration	N/A	N/A	Pass	G5	Rate B	SJ3
159	HS Eye Height Calibration	N/A	N/A	Pass	G5	Rate A	Custom_SJ2
160	HS Eye Height Calibration	N/A	N/A	Pass	G5	Rate B	Fc

FIGURE 41. SUMMARY TABLE

6.3 Calibration/Test Results

If the Plot Calibration Data checkbox is checked, then the plots are shown in this part of the report.

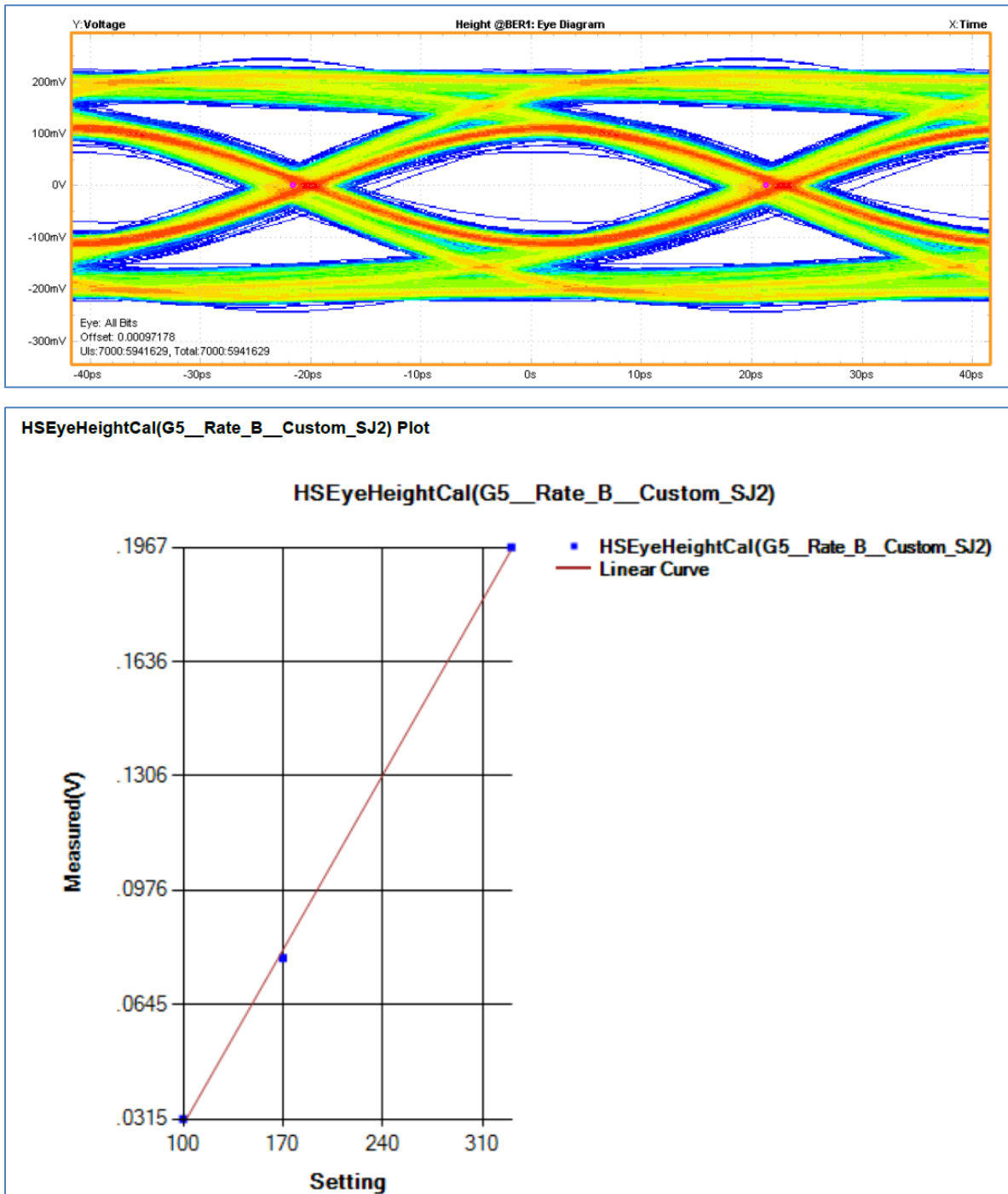


FIGURE 42. CALIBRATION RESULTS EXAMPLE

6.4 Delete Calibration/Test Results

To individually delete any unwanted calibration/test results, select the corresponding result row and **Delete** button.

To entirely remove all existing calibration/test results, select the **Delete All** button.

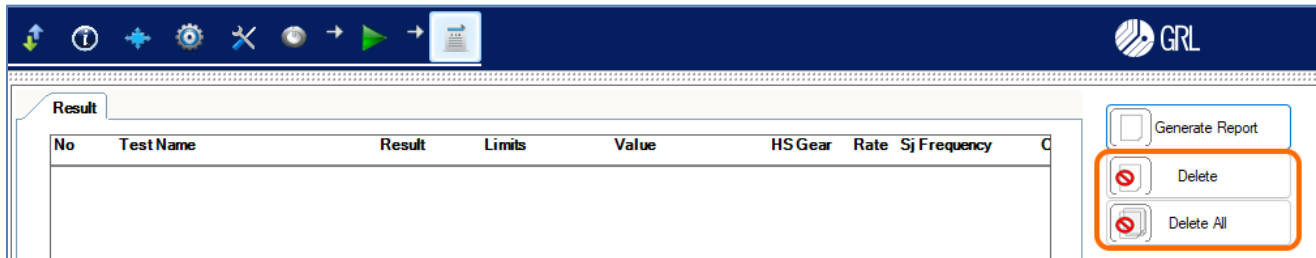


FIGURE 43. DELETE TEST RESULTS

7 Saving and Loading Test Sessions

The GRL-MIPI-MPHY-HS-RXA software enables calibration and test results to be created and maintained as a ‘Live Session’ in the application. This allows the user to quit the application and return later to continue where the user left off.

Save and Load Sessions are used to save a test Session that the user may want to recall later. The user can ‘switch’ between different sessions by saving and loading them when needed.

- To save a session, with all of the parameter information, the test results, and any waveforms, select the “Options” drop-down menu, then the “Save Session” option.
- To load a session back into the software, including the saved parameter settings, select the “Options” drop-down menu, then the “Load Session” option.
- To create a New session and return the application back to a default configuration, select the “Options” drop-down menu, then the “New Session” option.

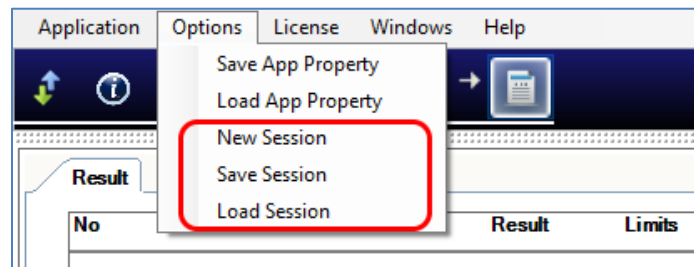


FIGURE 44. SAVING AND LOADING CALIBRATION AND TEST SESSIONS

The configuration and session results are saved in a file with the extension ‘.ses’, which is a compressed zip-style file, containing a variety of information.

8 Appendix A: Method of Implementation (MOI) for Manual CTS Calibration and Conformance Test

This section describes how to manually perform M-PHY High Speed Rx calibration and DUT conformance testing based on the MIPI M-PHY HS Electrical Conformance Test Suite.

8.1 Recommended HS-Rx Calibration Setups

Figure 45 and Figure 46 show the HS-Rx calibration setup diagrams without and with ISI generation respectively.

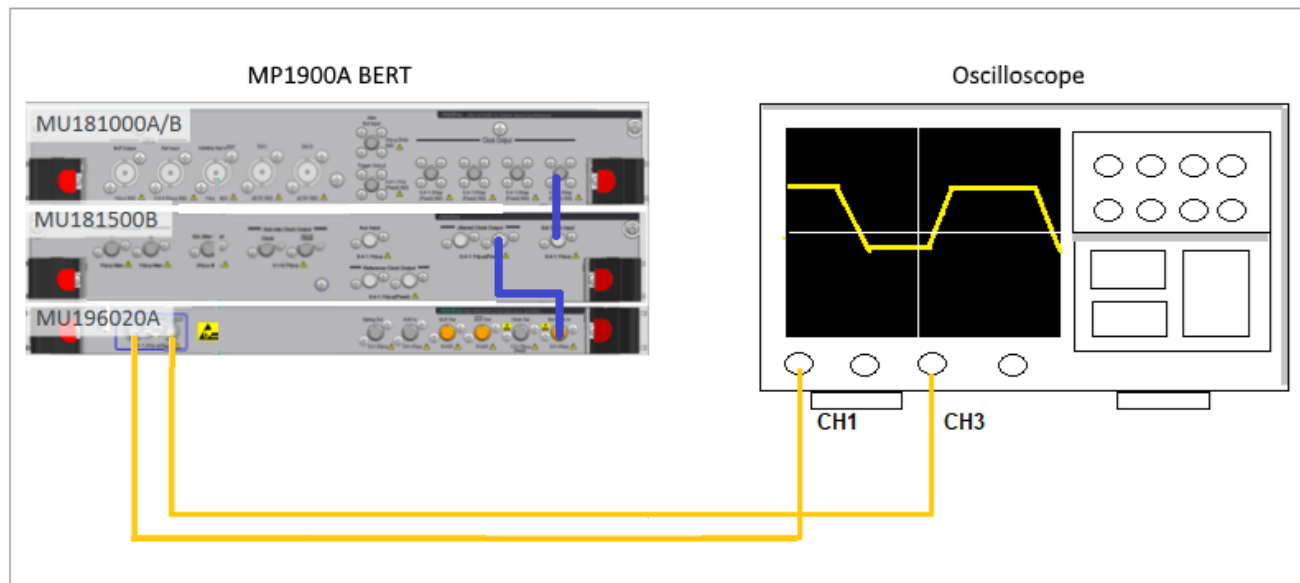


FIGURE 45. SETUP FOR HS-RX CALIBRATION WITHOUT ISI

Connection Steps:

1. Using a SMA-SMA short cable, connect the MU181000A/B clock output to the MU181500B Ext clock input.
2. Using a SMA-SMA short cable, connect the MU181500B jittered clock output to the MU196020A Ext clock input.
3. Using phase matched K-K coaxial cables, connect the MU196020A data outputs to Channels 1 and 3 on the oscilloscope.

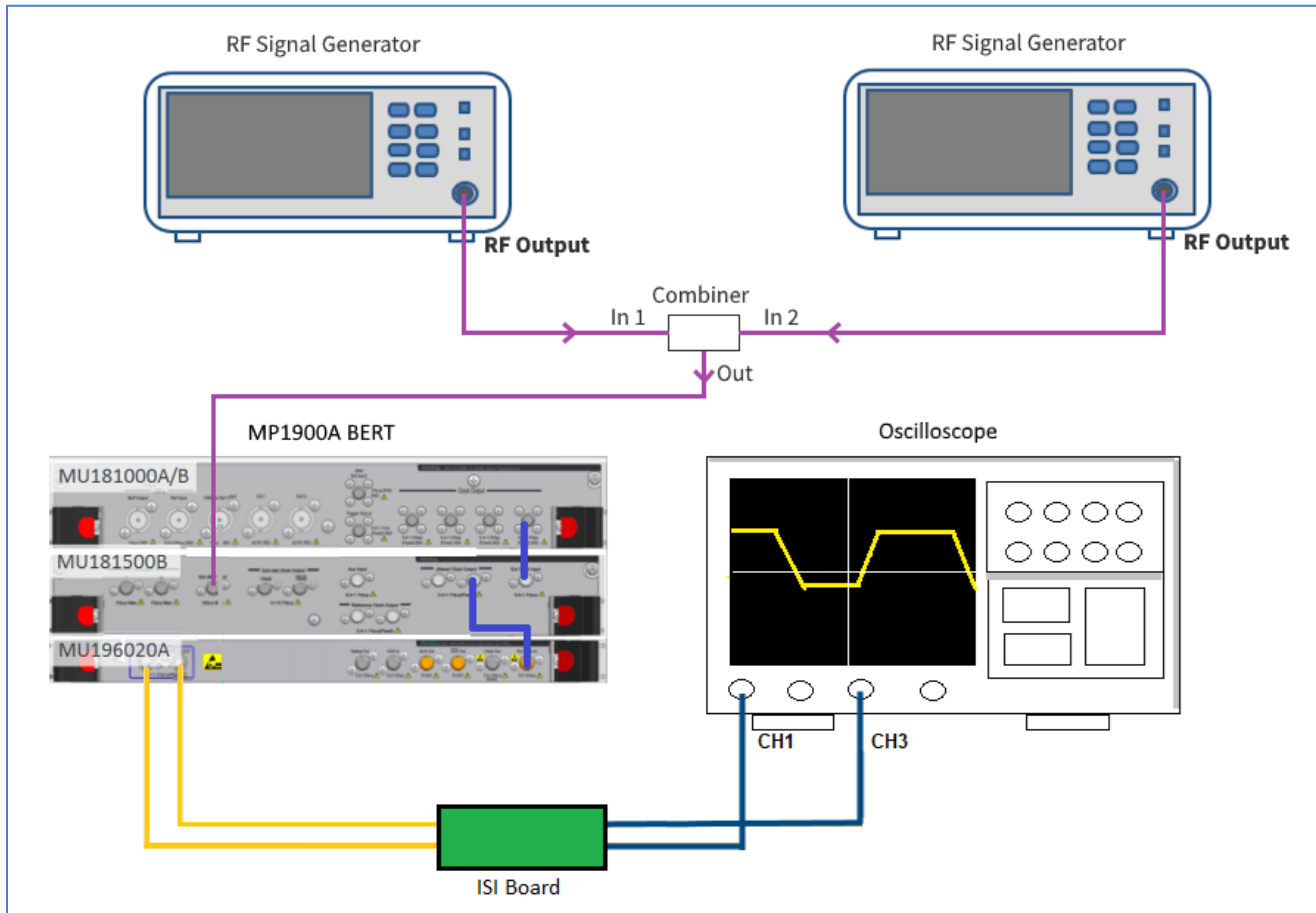


FIGURE 46. SETUP FOR HS-RX CALIBRATION WITH ISI

Connection Steps:

1. Using back the same BERT connections from the non-ISI related calibration in Section 4.1, disconnect the MU196020A data outputs from the oscilloscope channels.
2. Connect the MU196020A data outputs to an ISI board/channel.
3. Connect the ISI board/channel to Channels 1 and 3 on the oscilloscope.
4. Connect the RF output of each RF Signal Generator to a Combiner input.
5. Connect the Combiner output to the MU181500B External Jitter Input.

8.2 Recommended HS-Rx Conformance Test Setup and Configuration

Figure 47 below shows the connection setup for HS-Rx tests that do not require ISI generation.

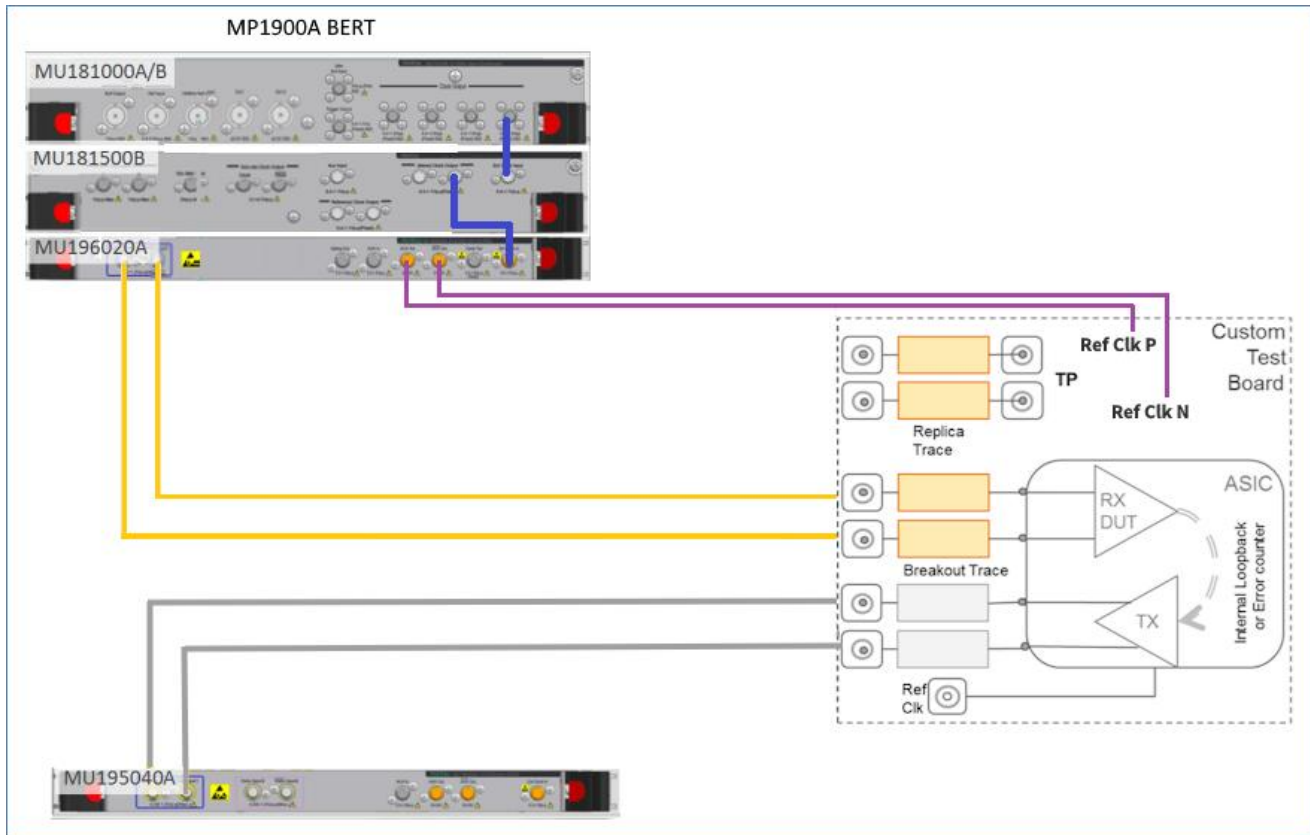


FIGURE 47. RECEIVER TEST SETUP WITHOUT ISI

Connection Steps:

1. Using back the same BERT connections from the non-ISI related calibration, remove the oscilloscope connections from the MU196020A data outputs.
2. Connect the MU196020A Aux Out connectors to Ref Clk P and Ref Clk N respectively.
3. Connect the MU196020A data outputs to the Breakout Trace.
4. Connect the Breakout Trace to the Rx DUT.
5. Connect the DUT Tx outputs to the MU195040A data inputs for loopback error detection.

Figure 48 below shows the connection setup for HS-Rx tests requiring ISI generation.

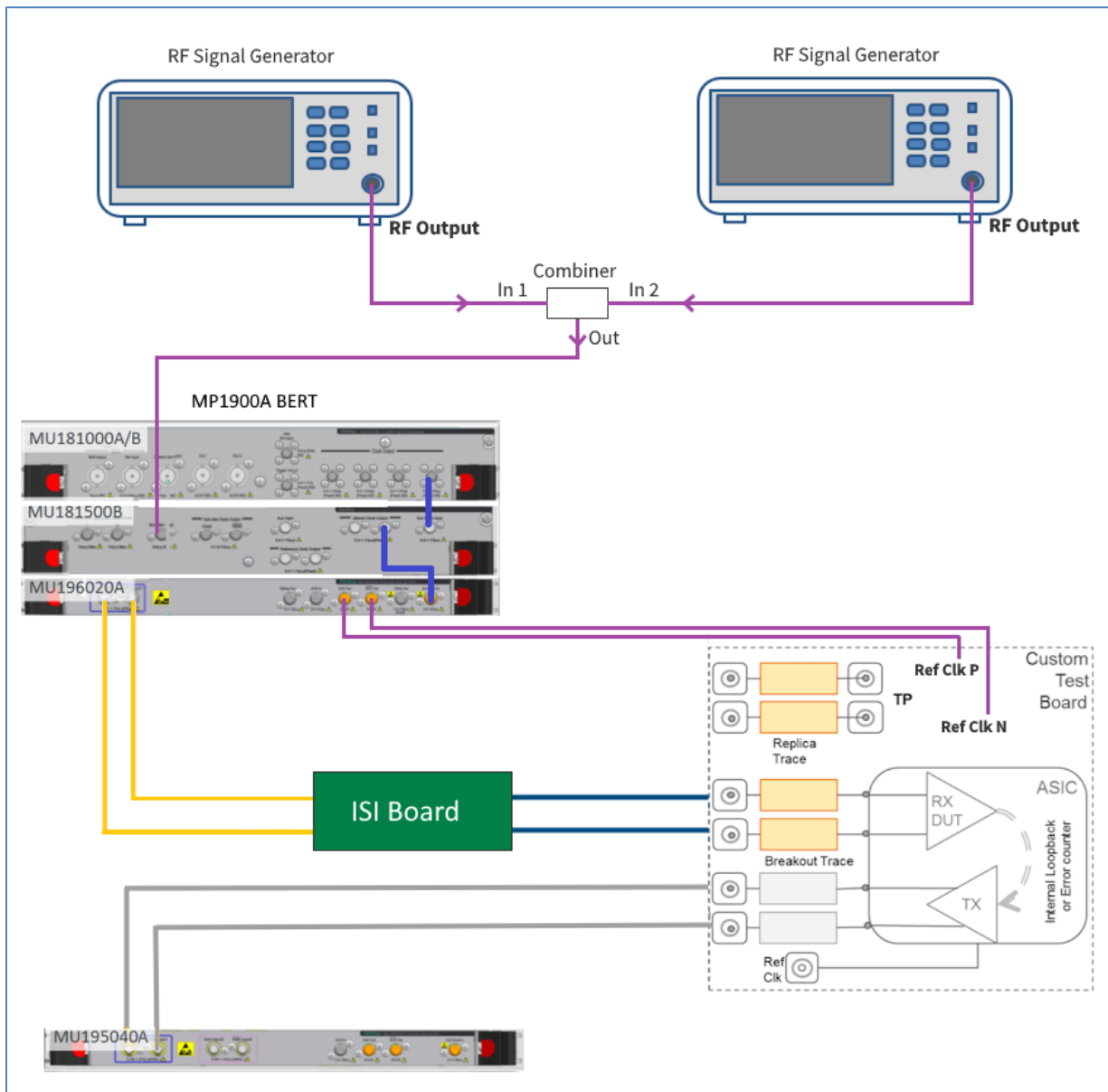


FIGURE 48. RECEIVER TEST SETUP WITH ISI

Connection Steps:

1. Using back the same BERT connections from the ISI-related calibration, remove the oscilloscope connections from the ISI board/channel.
2. Connect the MU196020A Aux Out connectors to Ref Clk P and Ref Clk N respectively.
3. Using phase matched K-K coaxial cables, connect the ISI board to the Breakout Trace.
4. Connect the Breakout Trace to the Rx DUT.
5. Connect the DUT Tx outputs to the MU195040A data inputs for loopback error detection.

8.2.1 HS-Rx Test Configuration Setup

8.2.1.1 Configure Clock Recovery (CR)

For receiver testing, most Clock Recovery parameters can be adjusted to the appropriate settings that work best for a certain DUT. However, these main parameters should be set:

- Set Bitrate to “Variable”
- Set LBW to “Variable”
- Set Target based on data rate

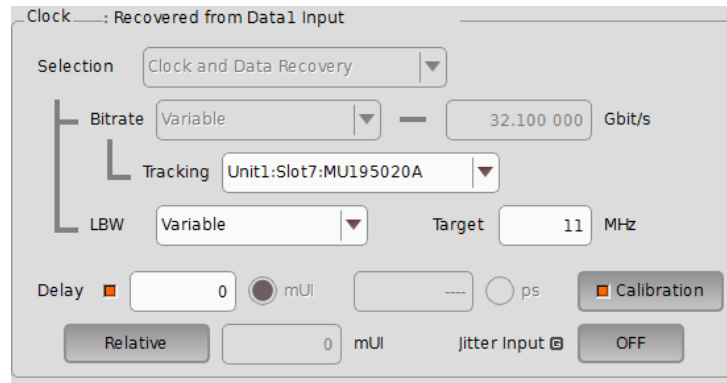


FIGURE 49. CONFIGURE CLOCK RECOVERY

8.2.1.2 Configure BERT Error Detector

CJTPAT must be selected as the pattern type on the Error Detector:

- Pattern: CJTPAT

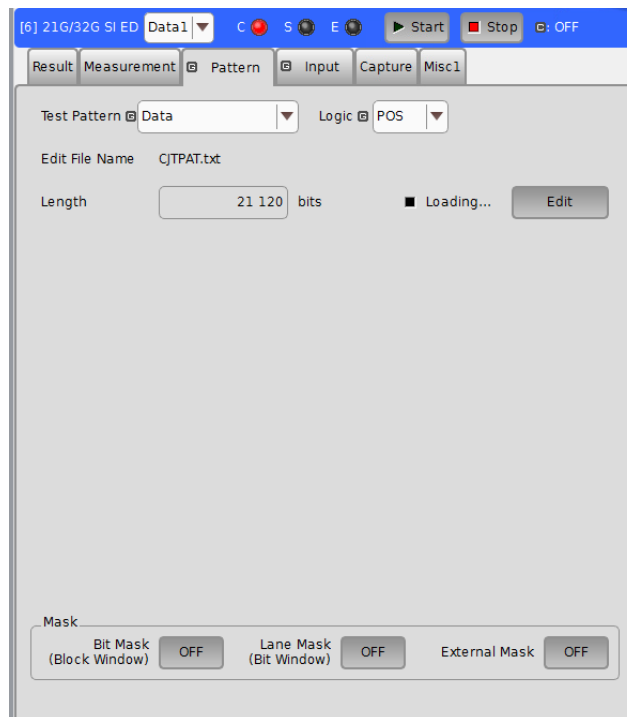
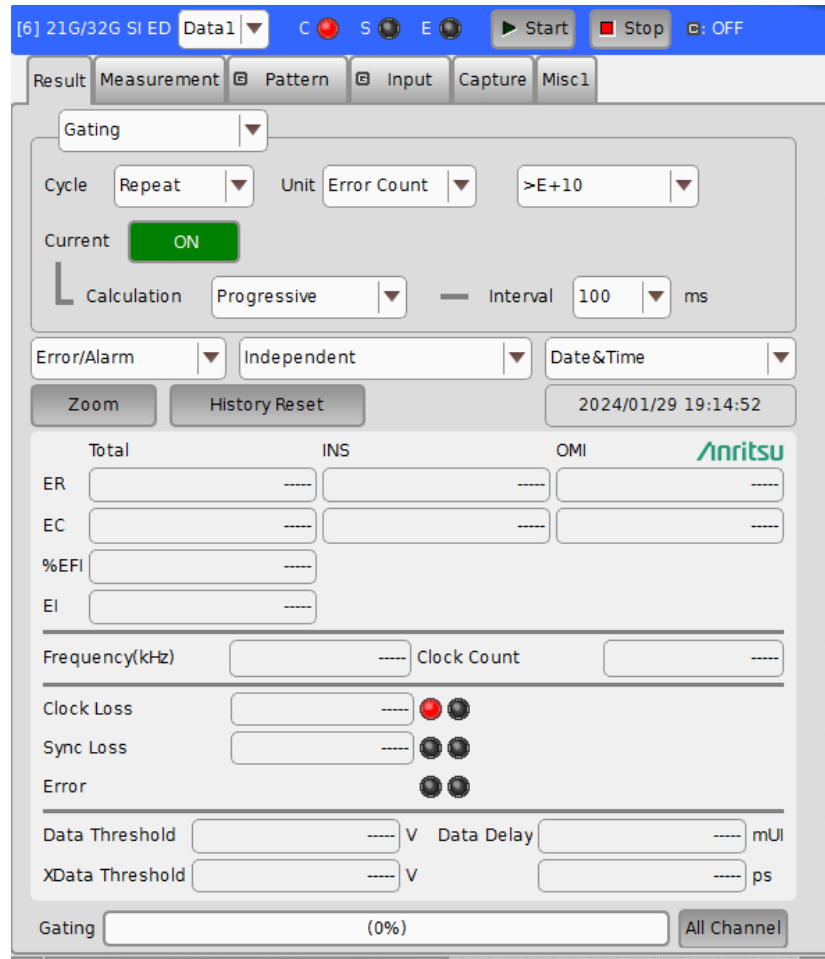


FIGURE 50. LOAD CJTPAT ON BERT ERROR DETECTOR (IF NOT LOADED)

8.2.1.3 Run BER Tests

Most tests for M-PHY HS-Rx need to be run over a duration of $3E+10$ observable bits (for target BER of $1E-10$) or $3E+12$ observable bits (for target BER of $1E-12$). No errors are allowed within this timeframe.



[6] 21G/32G SI ED Data1 C S E Start Stop OFF

Result Measurement Pattern Input Capture Misc1

Gating

Cycle Repeat Unit Error Count $>E+10$

Current ON

Calculation Progressive Interval 100 ms

Error/Alarm Independent Date&Time

Zoom History Reset 2024/01/29 19:14:52

	Total	INS	OMI
ER	----	----	----
EC	----	----	----
%EFl	----		
EI	----		

Frequency(kHz) ---- Clock Count ----

Clock Loss ----

Sync Loss ----

Error

Data Threshold ---- V Data Delay ---- mUI

XData Threshold ---- V ---- ps

Gating (0%) All Channel

FIGURE 51. RUN BER TEST FOR $3E+10$ BITS OR LONGER (DEPENDING ON TARGET BER)

8.3 Testing for 2.1.1 HS-Rx Differential DC Input Voltage Amplitude Tolerance ($V_{DIF_DC_HS_RX}$)

8.3.1 Calibration Setup for 2.1.1

Step 1: Configure BERT

1. Set *Data Rate* to appropriate HS DATA Rate. (In this example, HS-G1 A is used)
 - HS-G1 A: 1.2480 Gbps
 - HS-G1 B: 1.4576 Gbps
 - HS-G2 A: 2.496 Gbps
 - HS-G2 B: 2.9152 Gbps
 - HS-G3 A: 4.992 Gbps
 - HS-G3 B: 5.8304 Gbps
 - HS-G4 A: 9.984 Gbps
 - HS-G4 B: 11.6608 Gbps
 - HS-G5 A: 19.968 Gbps
 - HS-G5 B: 23.296 Gbps
2. Set *Generator Pattern* to **CJTPAT.txt**.
3. Set initial DATA amplitude to approximately 1V (2V p-p).

Step 2: Configure Oscilloscope

Note: It may be helpful to SAVE the scope configuration. This configuration will be used throughout this MOI for several additional tests.

1. Set up the following configuration on the Scope:
 - Bandwidth: 8GHz
 - Math 1: CH3-CH4 (*CH1-CH2 can be used if desired*).
 - RjDj Pattern Type: Arbitrary
 - RjDj Window Length: 5UI
 - Sample Rate: 50GS/s
 - Scale: 10 μ s
2. Select the following Scope measurements:
 - RJ- $\delta\delta$
 - TJ@BER (set to 1E-10)
 - DDJ
 - Eye Height
 - TIE

- Cycle Peak-to-Peak or Amplitude

Step 3: Calibrate Peak-to-Peak Amplitude

While adjusting the BERT **DATA** amplitude, measure peak-to-peak amplitude on the Scope until the target amplitude is met.

Note: Measure Channel 1 peak-to-peak amplitude as 310mV or Math 1 (Channel 1 - Channel 3) peak-to-peak amplitude as 620mV (assuming Dp is connected to Channel 1 and Dn is connected to Channel 3).

In this example, we will target:

Test Case # 1: 310mV differential peak voltage

Adjust the DATA amplitude on the BERT to achieve the target amplitude on the Scope.

Step 4: Calibrate DC Common Mode Voltage

Continuing with **Test Case #1**, the DC Common Mode offset needs to be configured.

To accurately measure DC Common Mode, the BERT will be set to transmit a “All Zeros” pattern. (Each output amplitude on the BERT is set to 0V.) The DATA offset on the BERT will then be used to reach the target DC Common Mode. On the Scope, only the common mode amplitude $(CH3+CH4)/2$ will be measured.

Note: You can also use the same pattern from peak-to-peak amplitude calibration.

The BERT DATA Offset will be used to adjust to the appropriate offset value: **Test Case 1: 150mV nominal**

Note: Apply an external 100-ohm termination in the calibration setup (between Replica Trace and Scope) to meet the target 150mV value. If you use the Scope termination, you can only achieve 75mV.

1. Set up the following configuration on the Scope:
 - Math 1: $(CH3+CH4)/2$
 - Measurement: MEAN amplitude measurement on Math 1
2. Set the BERT *Pattern* to “All Zeros”.
3. Adjust the DATA Offset on the BERT.
4. Measure DC Common Mode on the Scope to target 150mV.

This completes the calibration for Test Case #1 with 150mV nominal Common Mode Voltage and 310mV amplitude.

The above process must be completed for Test Case #2.

Note: The HS G1A amplitude/offset calibrations can be used for all Gears if supported.

8.3.2 Test Procedure

1. Configure the Lab Signal Source to generate Burst-Mode CJTPAT signaling, at HS-G1A, on a single LANE, with calibrated Test Case #1 settings of terminated V_{CM_RX} common-mode level of 150mV or 330mV, and a V_{DIF_RX} amplitude of 310mV, with no additional RJ, SJ or ISI jitter components.

2. Configure the DUT to receive Burst-Mode CJTPAT signaling in single-LANE, Terminated HS-Rx mode, in a manner that allows errors to be detected and/or counted in the received data stream for the HS LANE Under Test.
3. Connect the Lab Signal Source to the DUT, and transmit 3E10 observable bits to the DUT.
4. Record the number of errors observed by the DUT.
5. Repeat Steps 1-4 for Test Case #2.
6. Repeat Steps 1-5 for all other DUT HS LANE's.
7. Repeat Steps 1-6 for HS-G1B.
8. Repeat Steps 1-7 for HS-G2A/B (if supported), HS-G3A/B (if supported), HS-G4A/B (if supported) and HS-G5A/B (if supported).

8.3.3 Observable Results

For all Test Cases and all LANE's, verify that the number of received errors is zero.

8.3.4 Possible Problems

In the case where the DUT is not able to configure each receiver as LANE 0, then only a single LANE may be tested, and measurement of the other LANE's is considered Not Applicable.

Also, according to CTS, the Burst-Mode signaling is the preferred mode for this test; but with the exception that if the DUT does not support Burst-Mode operation for test purposes (e.g., if a synchronous loopback is being used), the test may be performed using the Continuous-Mode signaling.

8.4 Testing for 2.1.2 HS-Rx Accumulated Differential Input Voltage Tolerance ($V_{DIF_ACC_HS_RX}$)

8.4.1 Calibration Setup for 2.1.2

Step 1: Configure BERT

1. Set *Data Rate* to appropriate HS DATA Rate. (In this example, HS-G1 A is used)
 - HS-G1 A: 1.2480 Gbps
 - HS-G1 B: 1.4576 Gbps
 - HS-G2 A: 2.496 Gbps
 - HS-G2 B: 2.9152 Gbps
 - HS-G3 A: 4.992 Gbps
 - HS-G3 B: 5.8304 Gbps
 - HS-G4 A: 9.984 Gbps
 - HS-G4 B: 11.6608 Gbps
 - HS-G5 A: 19.968 Gbps
 - HS-G5 B: 23.296 Gbps
2. Set *Generator Pattern* to **CJTPAT.txt**.
3. Set initial DATA amplitude to approximately 1V (2V p-p).

Step 2: Calibrate ISI Loss Channel

The M-PHY CTS states [2]:

*“This test will use a calibrated ISI loss channel, which is designed specifically to meet the ISI test requirement of the specification. For HS-G1 and HS-G2, the channel is calibrated to introduce the **0.20 UI of Deterministic Jitter in the form of ISI** (at HS-G2B only), per the Rx jitter test requirements.”***

To achieve the required ISI, the **ISI Trace** will be used to generate the required ISI for this case.

Note: *ISI calibration for HS-G1A is not required for the accumulated differential voltage test.*

For this test:

- Calibrate the channel for 0.2UI ISI at HS-G2B, and use the same calibrated ISI loss channel for all accumulated differential voltage tests for HS-G1A/B, HS-G2A/B.
 - For HS-G3A/B and HS-G4A/B, use the Short Channel (CH1) (1 – T_{JRX} UI).
1. Link the ISI Trace to the BERT.
 2. Set the Data Rate.
 3. For **HS-G2B**: The selectable ISI will generate sufficient ISI to meet 0.2UI DDJ requirement.

4. Measure DDJ = 69ps to meet target of 0.2UI at 2.9152Gbps.

Step 3: Calibrate DC Common Mode

The final part of calibration is the 150mV Common Mode Voltage.

The DATA Offset on the BERT will be used to adjust to the required DC Common Mode Offset. Use the $V_{DIF_DC_HS_RX}$ amplitude of 60mV and the calibrated ISI channel.

1. Configure the Scope to measure Common Mode as follows:
 - Math 1: $(CH3+CH4)/2$
 - Measurement: MEAN amplitude measurement on Math 1
2. Set the BERT pattern to “All Zeros”. This sets the output of the DATA amplitudes to 0V on each data output.
3. Adjust the offset.
4. Measure the DC Common Mode to target 150mV. With DATA amplitudes set to 0V, the measured amplitude for $(CH3+CH4)/2$ will reflect the DC or AC offset (if used).

This completes the calibration for HS-G1_A.

The above procedure should be followed by HS-G1_B.

Additionally, the above procedure should be followed for HS-G2, if desired.

8.4.2 Test Procedure

1. Configure the Lab Signal Source to generate Burst-Mode CJTPAT signaling, at HS-G1A, on a single LANE, with calibrated Test Case #1 settings of terminated V_{CM_RX} common-mode level of 150mV, and $V_{DIF_DC_HS_RX}$ amplitude of 60mV, using the ISI Trace, 240ps transition times, and no additional RJ or SJ components.
2. Configure the DUT to receive Burst-Mode CJTPAT signaling in Terminated HS-Rx mode, in a manner that allows errors to be detected and/or counted in the received data stream for the LANE Under Test.
3. Connect the Lab Signal Source to the DUT, and transmit $3E10$ observable bits to the DUT.
4. Record the number of errors observed by the DUT.
5. Repeat Steps 1-4 for all DUT HS LANE's.
6. Repeat Steps 1-5 for HS-G1B.
7. Repeat Steps 1-6 for HS-G2A/B (if supported), HS-G3A/B (if supported), HS-G4A/B (if supported) and HS-G5A/B (if supported).

8.4.3 Observable Results

For all Test Cases, verify that the number of received errors is zero.

8.4.4 Possible Problems

See Test 2.1.1. The same is applicable to this test.

8.5 Testing for 2.1.3 HS-Rx Common-Mode Input Voltage Tolerance ($V_{CM,RX}$)

8.5.1 Calibration Setup for 2.1.3

Step 1: Configure BERT

1. Set *Data Rate* to appropriate HS DATA Rate. (In this example, HS-G1A is used)

- HS-G1 A: 1.2480Gbps
- HS-G1 B: 1.4576Gbps
- HS-G2 A: 2.496Gbps
- HS-G2 B: 2.9152Gbps
- HS-G3 A: 4.992Gbps
- HS-G3 B: 5.8304Gbps
- HS-G4 A: 9.984 Gbps
- HS-G4 B: 11.6608 Gbps
- HS-G5 A: 19.968 Gbps
- HS-G5 B: 23.296 Gbps

2. Set *Generator Pattern* to **CJTPAT.txt**.

Note: Extended length of the DIF-P pattern and the DIF-N pattern can also be used as the test Pattern for amplitude calibration (repeated pattern of 32 or 64 SI DIF-P followed by 32 or 64 SI DIF-N (SI = 10UI)).

3. Set initial DATA amplitude to approximately 1V (2V p-p).

Step 2: Configure Oscilloscope

Note: It may be helpful to SAVE the Scope configuration. This configuration will be used through several additional tests.

1. Set up the following configuration on the Scope:

- Bandwidth to 8GHz.
- Math 1: CH3-CH4 (*CH1-CH2 can also be used if desired*)
- RjDj Pattern Type: Arbitrary
- RjDj Window Length: 5UI
- Sample Rate: 50GS/s
- Scale: 10 μ s

2. Select the following measurements on the Scope:

- RJ- $\delta\delta$
- TJ@BER (set to 1E-10)

- DDJ
- DJ-88
- Eye Height
- TIE
- Cycle Peak-to-Peak or Amplitude

Step 3: Calibrate Peak-to-Peak Amplitude

While adjusting the BERT DATA amplitude, measure peak-to-peak amplitude on the Scope until the target amplitude is met. In this example, we will target **Test Case #1: 150mV peak differential voltage**.

Note: Measure Channel 1 peak-to-peak amplitude as 150mV or Math 1 (Channel 1 - Channel 3) peak-to-peak amplitude as 300mV (assuming Dp is connected to Channel 1 and Dn is connected to Channel 3).

Adjust the DATA amplitude on the BERT to achieve the target amplitude on the Scope. Measure peak-to-peak amplitude on the Scope to target 150mV.

Step 4: Calibrate DC Common Mode Voltage

Continuing with Test Case #1, the DC Common Mode offset needs to be configured.

The BERT will be set to transmit the “All Zeros” pattern. On the Scope, the common-mode amplitude $(CH3+CH4)/2$ will be measured.

Note: You can also use the same pattern from peak-to-peak amplitude calibration.

The BERT DATA Offset will be used to adjust to the appropriate offset value: **Test Case #1: 330mV nominal**.

1. Set up the Scope as follows:
 - Math 1: $(CH3+CH4)/2$
 - Measurement: MEAN amplitude measurement on Math 1
2. Set the BERT Pattern to “All Zeros”.
3. Adjust the DATA offset.
4. Measure the DC Common Mode to target 330mV.

This completes calibration for Test Case #1.

The above process must be completed for Test Case #2.

Note the amplitudes required for Test Case#1 and Test Case #2 as they will be used for testing.

Note: The HS G1A amplitude/offset calibrations can be used for all Gears if supported.

8.5.2 Test Procedure

1. Configure the Lab Signal Source to generate Burst-Mode CJTPAT signaling in HS-G1A on a single LANE, with Test Case #1 settings of terminated V_{CM_RX} common-mode level of 330mV, and a V_{DIF_RX} amplitude of 150mV.

2. Configure the DUT to receive Burst-Mode CJTPAT signaling in Terminated HS-Rx mode, in a manner that allows errors to be detected and/or counted in the received data stream for the LANE Under Test.
3. Connect the Lab Signal Source to the DUT, and transmit 3E10 observable bits to the DUT.
4. Record the number of errors observed by the DUT.
5. Repeat Steps 1-4 for Test Case #2.
6. Repeat Steps 1-5 for all other DUT LANE's.
7. Repeat Steps 1-6 for HS-G1B.
8. Repeat Steps 1-7 for HS-G2A/B (if supported), HS-G3A/B (if supported), HS-G4A/B (if supported) and HS-G5A/B (if supported).

8.5.3 Observable Results

For all Test Cases and all LANE's, verify that the number of received errors is zero.

8.5.4 Possible Problems

See Test 2.1.1. The same is applicable to this test.

8.6 Testing for 2.1.7 HS-Rx Receiver Jitter Tolerance ($T_{J_{RX}}$, $D_{J_{RX}}$, $R_{J_{RX}}$, $STT_{J_{RX}}$, $STD_{J_{RX}}$)

8.6.1 Calibration Setup for 2.1.7 (for HS-G1 and HS-G2)

Note: Actual ISI traces are used on the ISI Conformance Channel during calibration.

Step 1: Verify Channel

The ISI generated by *ISI Traces+Cables+Adapters* needs to be verified.

On the BERT:

- For HS-G1 and HS-G2 calibration: Set to 2.915Gbps
- Set Pattern to CJTPAT.txt
- Set Generator DATA Amplitude to 2Vpp or 1V on each DATA output

Note: All stresses should be set to 0% UI or disabled on the BERT.

Set the BERT to HS-GEAR 2_B at 2.915Gbps, and Generator Pattern to CJTPAT.

ISI Conformance Channel:

Actual implementation of ISI is user-defined. If using the BERT ISI Board, use a initial 40-inch trace.

On the Scope:

- Press the Default Setup button on the Scope.
- Set the Bandwidth:
 - Menu Vertical > BW Enhanced > 8GHz
 - Select “Apply to All Channels”
- Set the acquisition memory:
 - Menu Horizontal/Acquisition > Horiz/Acq Setup > Constant Rate
 - Set sample rate to 50Gs/s
 - Set scale to 10 μ s (RL should now be 5.0M)
- Turn on CH2 on Scope:
 - Adjust CH1 & CH2 vertical scale to achieve the most use of the screen for the signal (make the signal as tall as possible, up to 80% of the screen height)
- Set up Math:
 - Menu Math > CH1 – CH2 (or CH3 – CH4 if desired)
 - Turn off CH1 and CH2
- Set up DPOJET:
 - Menu Analyze > DPOJET > Select
 - **SELECT** Tab -> **JITTER** Tab

- Rjδδ
- Tj@BER
- DDj
- **EYE** Tab
 - Height at BER
- **Period/Freq** Tab
 - Period
 - Frequency
- **CONFIGURE** Tab -> Tj at BER > RjDj
 - Set Pattern Type > Arbitrary, 5UI,100
 - Set BER to 1E-10
 - Select “Apply to all Channels”
 - Edges > Data (repeat Edges setting for all other measurements)
 - Global > Population > On > Configure
 - Limit By > Population
 - Limit > 10
 - Stop Condition > Last Measurement

Configure the Scope as follows:

- Bandwidth: 8GHz
- Sample Rate: 50GS/s
- Scale: 10μs
- Math 1: CH1-CH2 (*CH3-CH4 can also be used if desired*)
- BER Measurement: Set RjDj for Pattern Type: Arbitrary, Window Length: 5, Population: 100 and Jitter Target BER: 1E-10
- Measure DDJ:
 - Click “Single”
 - Add or remove ISI channels to achieve the target DDJ
 - Once satisfied, click “Run”
- Record the ISI Board configuration if using the BERT ISI Board:
 - _____inch pair +
 - _____inch pair +
 - _____inch pair.
- Record DDJ:
 - _____ mUI or _____ ps

Note: To see ps, select Options > Display units – Absolute in the DPOJET window.

The channel loss at test point TP is considered to be in the allowable range if the DDJ for HS-G2B for a continuous CJTPAT is within range of 156mUI and 196mUI.

Adjust ISI traces lengths on the BERT ISI to achieve the above value if needed.

Step 2: Set Up BERT DATA Rate and Pattern

On the BERT:

- Set the Data Rate to HS DATA Rate. (In this example, HS-G1B is used)
HS-G1 A: 1.248Gbps
HS-G1 B: 1.4576Gbps
HS-G2 A: 2.496Gbps
HS-G2 B: 2.9152Gbps
- Set the Pattern on the Generator to 1010.ram.
- Set the Generator DATA Amplitude to 2Vpp or 1V on each DATA output.
- If testing GEAR-1: 240ps (10/90%) rise-time filter
- If testing GEAR-2: 130ps (10/90%) rise-time filter

Step 3: Configure BERT Stresses

On the BERT:

- Enable all Stresses that will be used. All stress amplitudes should be set to 0% UI:
 - Enable **SINE JITTER**
 - Enable **EXT JITTER IN**
 - Enable **RANDOM JITTER**
 - Enable **SINE INTERFERENCE**. *Ensure that SI is set to the EXTERNAL mode.*

Step 4: Calibrate High Frequency RJ

On the BERT:

Set Initial RANDOM JITTER (10MHz – 1GHz) to 16% UI.

On the Scope:

1. For **HS-G1 and HS-G2**: Ensure High Pass Filter (F1) is set to 1/30UI. This ensures that only RJ above 1/30UI is measured*.
 - In DPOJET -> Configure Tab > Tj@BER > Filters > High Pass (F1) > Filter Spec -> 1st Order, Freq (F1) -> Set Freq as shown below

**High Pass Filter: Each Gear requires a specific HPF of 1/30UI where UI is determined by each data. F1 for TIE HPF on the Scope should be the following for each Gear:*

Gear1 A (1.248 Gbps): 41.6MHz
Gear1 B (1.4576 Gbps): 48.6MHz
Gear2 A (2.496 Gbps): 83.2MHz
Gear2 B (2.9152 Gbps): 97.2MHz

2. Select “Single”.

On the BERT:

3. For **HS-G1 and HS-G2**: Adjust RANDOM JITTER until the measured RJ on the Scope reaches $0.10\text{UI}_{\text{pp}}$ ($7.89\text{mUI}_{\text{RMS}}$).
4. Once satisfied, select “Run” on the Scope.
5. Record the RANDOM JITTER setting:

○ _____ %UI

6. Record RJ:

○ _____ mUI_{RMS} or

○ _____ ps_{RMS}

7. Record TJ@BER as TJ_{HFRJ} :

○ _____ mUI or _____ ps for use on the next section

Note: To see ps, select Options > Display units – Absolute in the DPOJET window.

Random Jitter should be increased/decreased to meet $\text{RJ} = 0.00789\text{UI}_{\text{RMS}}$ or $7.89\text{mUI}_{\text{RMS}}$.

Step 5: Calibrate Low Frequency RJ

Note: LFRJ is required only for HS-G1 and HS-G2.

On the BERT:

Configure the following settings:

- Run Mode -> Continuous
- Function -> Noise
- Amplitude – 2Vpp

On the Stressed Eye page, right-click on EXT JITTER IN and select 2V Reference Amplitude – set it to 40%UI.

On the Scope:

1. Ensure High Pass Filter is set to 1st Order, 1MHz (for Gear 1):
 - Select “Apply to ALL”
 - Select “Single”

Note: The cut-off F_L is 2MHz for Gear 2.

2. Adjust EXT JITTER IN until TJ@BER reaches:

- TJ_{HFRJ} _____ + 70 mUI = _____ mUI

3. Once satisfied, click “Run”.

4. Record EXT JITTER IN setting _____ %UI.
5. Record TJ@BER:

- _____ mUI or
- _____ ps

Note: To see ps, select Options > Display units – Absolute in the DPOJET window.

Target TJ is 0.17UIpp.

Step 6: High-Frequency SJ Calibration

On the BERT:

1. Turn RANDOM JITTER and EXT JITTER IN to 0% UI.

On the Scope:

2. Ensure No HP Filter is applied to incoming signal:
 - Select “Apply to ALL”
 - Select “Run”
 - Measure $TJ_{INT} = \text{_____ mUI}$

On the BERT:

3. Set the pattern to CJTPAT.txt.
4. Set initial SINE INTERFERENCE (SI) to 1.8V at 60MHz.
5. Adjust SI until TJ@BER equals:
 - $TJ_{SI} = 200 \text{ mUI} + TJ_{INT} \text{_____ mUI} = \text{_____ mUI}$
6. Once satisfied...

On the Scope:

7. ...select “Run”.
8. Record SINE INTERFERENCE setting _____ mV
9. Record TJ_{SI} :
 - _____ mUI or
 - _____ ps

Target TJ = 0.2UIpp

Step 7: Low-Frequency SJ Calibration

On the BERT:

1. Set initial SINE JITTER to 16% UI at 10MHz*.

**Low frequency SJ shall be calibrated for all the following frequencies:*

Gear 1: 1MHz, 10MHz, $f_{1/30UI} = 42\text{MHz}$

Gear 2: 2MHz, 10MHz, $f_{1/30UI} = 84\text{MHz}$

A fourth frequency, f_{system} , shall also be tested if $f_{system} < f_{1/30UI}$

(where f_{system} = system clock frequency)

On the Scope:

2. Ensure No HP Filter is applied to incoming signal.
3. Select “Single”.

On the BERT:

4. Adjust SINE JITTER until $TJ = 0.35UI_{pp}$.
5. Once satisfied...

On the Scope:

6. ...select “Run”.
 7. Record the SINE JITTER setting _____ %UI
 8. Record TJ@BER – 10MHz:
 - _____ mUI or
 - _____ ps
 9. On the BERT, set the SINE JITTER frequency to 1MHz/2MHz*.
 10. Repeat steps 3 to 7.
 11. Record TJ@BER – 1MHz/2MHz:
 - _____ mUI or
 - _____ ps
 12. On the BERT, set the SINE JITTER frequency to $f_{1/30UI}$ MHz*.
 13. Repeat steps 3 to 7.
 14. Record TJ@BER – $f_{1/30UI}$ MHz:
 - _____ mUI or
 - _____ ps
- If Required:*
15. On the BERT, set the SINE JITTER frequency to f_{SYSTEM} MHz*.
 16. Repeat steps 3 to 7.
 17. Record TJ@BER – f_{SYSTEM} MHz:
 - _____ mUI or
 - _____ ps

Step 8: Prorated Eye Mask Calibration

After calibrating all jitter sources, proceed with the following procedure.

(a) Configure Scope

- Bandwidth: 8GHz
- Sample Rate: 50GS/s
- Scale: 10 μ s
- Math 1: CH1-CH2 (*CH3-CH4 can also be used if desired*)
- Select Measurements: Height and Width@BER.

(b) Enable High Pass Filter

On the Scope:

Enable High Pass Filter to incoming signal. Ensure High Pass Filter is set to 1st Order, 1MHz (for Gear 1):

- Select “Apply to ALL”
- Select “Single”

Note: The cut-off F_L is 2MHz for Gear 2.

(c) Set BER Measurement

On the Scope:

Set RjDj for Pattern Type: Arbitrary, Window Length: 5UI, Population: 100 and Jitter Target BER: 6.

(d) Enable All Stresses

On the BERT:

Enable all calibrated jitter sources with calibrated jitter values from previous sections:

- RANDOM JITTER
- EXT JITTER IN
- SINE INTERFERENCE
- SINE JITTER

(e) Measure Eye Height

The target Eye Height to be reached is 45mV @BER 1E-12.

On the BERT:

1. Set DATA(+) and DATA(-) on the BERT to 290mV.
2. Ensure all calibrated stresses have been enabled.

On the Scope:

3. Measure the Eye Height.

On the BERT:

4. Adjust the amplitude on the BERT until the Eye Height target of 45mV is met.

(f) Measure Width@BER

The target Width@BER to be reached is 0.52+/- 5% UI @ 1E-6. Adjust the SJ value (Sine Jitter) on the BERTScope until target Width@BER is met.

Measure for all test cases and frequencies of each supported HS Gear's.

Step 9: Adjust Common Mode

Set the following target V_{CM_RX} for each jitter configuration by adjusting the offset:

- Test case 1: 180mV

- Test case 2: 25mV
 - Test case 3: 330mV
1. Disable stresses on the BERT.
 2. Set the Generator Pattern.
 3. On the Scope, set up Math 1 Function.
 4. On the BERT, adjust the signal level offset to an initial value.
 5. On the Scope, turn on Amplitude Measurement > Mean > Math 1.
 6. Press the Run/Stop button.
 7. On the BERT, adjust the signal level offset to achieve the target common mode voltages on Math 1.

Step 10: Perform jitter tolerance tests for all listed above jitter combination.

Step 11: Adjust to +/- 2000ppm offset

After performing the jitter tolerance tests, repeat the tests with +/- 2000ppm offset in the data rates by adjusting the data rates to below values.

On the BERT:

Adjust the BERT synthesizer to the appropriate +/- 2000ppm offset.

Note: Both the -2000ppm offset and +2000ppm offset will be applied to the B-series rates:

- HS-GEAR1 B (+2000ppm): 1.4605Gbps
- HS-GEAR1 B (-2000ppm): 1.4547Gbps
- HS-GEAR2 B (+2000ppm): 2.9192Gbps
- HS-GEAR2 B (-2000ppm): 2.9075Gbps

Step 12: Configure Minimum PREPARE Period and Minimum SYNC Period

Based on the following PHY attribute registers values, PREPARE and SYNC time should be configured to minimum values:

- RX_HS_G1_PREPARE_LENGTH_Capability
- RX_HS_G1_SYNC_LENGTH_Capability
- RX_HS_G2_PREPARE_LENGTH_Capability
- RX_HS_G2_SYNC_LENGTH_Capability

To set PREPARE Length and SYNC Length correctly on the BERT, you will need to obtain *RX_HS_Gn_PREPARE_LENGTH_Capability* and *RX_HS_G1_SYNC_LENGTH_Capability* from the DUT, respectively. PREPARE Length and SYNC Length will be defined in Symbol Intervals where

1 SI = 10 HS-UI. One SI is equal to 10 UI at the HS data rate.

PREPARE Length = XX **SI** (1 SI = 10 UI) from “*RX_HS_Gx_PREPARE_LENGTH_Capability*”

SYNC Length = XX **SI** (1 SI = 10 UI) from “*RX_HS_G1_SYNC_LENGTH_Capability*”

(where XX = User Programmable)

Note: You should be able to perform the configuration during testing.

Step 13: Perform All Test Cases

Perform jitter tolerance test for all test cases (as in Step 10) with Step 11 and Step 12 settings applied.

Step 14: Save Configuration on both the BERT and Scope.

8.6.2 Calibration Setup for 2.1.7 (for HS-G3/G4/G5)

Note: Actual ISI traces are used on the ISI Conformance Channel during calibration.

Step 1: Verify Channel

ISI needs to be calibrated for channel verification and also because it is part of STDJ.

On the BERT:

- **For HS-G3 calibration:** Set to 5.8304Gbps (HS-G3B)
 - HS-G3A (4.992Gbps)
 - HS-G3B (5.8304Gbps)
- **For HS-G4 calibration:** Set to 11.6608Gbps (HS-G4B)
 - HS-G4A (9.984Gbps)
 - HS-G4B (11.6608Gbps)
- **For HS-G5 calibration:** Set to 23.296Gbps (HS-G5B)
 - HS-G5A (19.968Gbps)
 - HS-G5B (23.296Gbps)
- Set Pattern to a continuous 64_zeros_64_ones
- Set Generator DATA Amplitude to 2Vpp or 1V on each DATA output

Note: All stresses should be set to 0% UI or disabled on the BERT.

Assuming HS-G3 is being tested, set the BERT to 5.8304Gbps and the above configuration.

ISI Conformance Channel:

- Actual implementation of ISI is user-defined. If using the BERT ISI Board, initially use a 40-inch trace.

On the Scope:

- Press the Default Setup button on the Scope.
- Set the Bandwidth:
 - Menu Vertical > BW Enhanced > 8GHz
 - Select “Apply to All Channels”
- Set the acquisition memory:

- Menu Horizontal/Acquisition > Horiz/Acq Setup
 - Select Constant Rate
 - Set sample rate to 50GS/s
 - Set scale to 10 μ s (RL should now be 5.0M)
- Turn on CH2 on Scope:
 - Adjust CH1 & CH2 vertical scale to achieve the most use of the screen for the signal (make the signal as tall as possible, up to 80% of the screen height)
- Set up Math:
 - Turn on Math1 > CH1 – CH2 (*or CH3 – CH4 if desired*)
 - Turn on Math2 and perform differentiation on Math1
 - Turn on Math3 and perform FFT Mag on Math2
- Measure the delta loss in interval between FHS/2 and FHSx2, where FHS_G3A = 2.496 and FHS_G3B = 2.9152.
Loss should be between 2.9 to 4.9dB.

On the BERT:

- Configure BERT Stresses:
Enable all Stresses that will be used. All stress amplitudes should be set 0% UI:
 - Enable **SINE JITTER**
 - Enable **RANDOM JITTER**
 - Enable **SINE INTERFERENCE**. *Ensure that SI is set to the EXTERNAL mode.*
 - Enable **EXT JITTER IN**

Step 2: Calibrate RJ**On the BERT:**

- Set up BERT DATA Rate and Pattern:
Set the Data Rate to HS DATA Rate. (In this example, HS-G3 B is used)
HS-G3 A: 4.992Gbps
HS-G3 B: 5.8304Gbps
- Set the Pattern on the Generator to a continuous 1010.ram pattern (Clock-like pattern).
- Set the Generator DATA Amplitude to 2Vpp or 1V on each DATA output.
- Set Initial RANDOM JITTER (10MHz – 1GHz) to around 16% UI.

On the Scope:

- Ensure 1st Order High Pass Filter is set to 8MHz in DPOJET.
- Select “Single”.

On the BERT:

- Adjust RANDOM JITTER until the measured RJ (rms) on the Scope reaches $13.36\text{mUI}_{\text{RMS}}$ ($0.17\text{UI}_{\text{p-p}}$). (*Entire RJ budget of 0.17UI is allotted to wideband RJ, above 10MHz .*)
- Once satisfied, select “Run” on the Scope.
- Record the RANDOM JITTER setting:
 - _____ %UI
- Record RJ:
 - _____ mUI_{RMS} or
 - _____ ps_{RMS}

Note: To see ps , select Options > Display units – Absolute in the DPOJET window.

Random Jitter should be increased/decreased to meet $\text{RJ} = 13.36\text{mUI}_{\text{RMS}}$ or $170\text{mUI}_{\text{p-p}}$.

Step 3: Calibrate STDJ

Note: The ISI channel should be considered when calibrating STDJ.

On the BERT:

- Turn RANDOM JITTER to 0% UI.
- Set the pattern to CJTPAT.

On the Scope:

- Ensure No HP Filter is applied to incoming signal:
 - Select “Apply to ALL”
 - Select “Single”
- Record the intrinsic TJ@BER :
 - $\text{TJ}_{\text{INT}} = \text{_____ mUI}$

On the BERT:

- Set the pattern to CJTPAT.txt.
- Set initial SINE INTERFERENCE (SI) to 1.6V at 240MHz. (*Note: Ensure that ‘External’ is selected on Sinusoidal Interference.*)
- Adjust SI until TJ@BER (TJ_{SI}) equals:
 - $\text{TJ@BER} - \text{TJ}_{\text{INT}} = 200\text{mUI}_{\text{pp}}$
- Once satisfied...

On the Scope:

- ...select “Run”.
- Record SINE INTERFERENCE setting _____ mV
- Record TJ_{SI} :
 - _____ mUI or

- _____ ps

Step 4: Calibrate SJ

Note: Low frequency SJ shall be calibrated for all the following frequency points (for each supported HS Gear).

List of Sinusoidal Frequency points:

- $F_{SJ0_RX_HSG3/G4/G5}$
- $F_{C_HS_G3/G4/G5_RX}$
- F_{SJ2_RX}
- $F_{SJ3}(\text{System Frequency})$
- $F_{SJ4_RX_HS_G3/G4/G5}$

On the BERT:

- Set initial SINE JITTER initially to 16% UI at 10MHz (F_{SJ2_RX}).

On the Scope:

- Ensure No HP Filter is applied to incoming signal.
- Select “Single”.

On the BERT:

- Adjust SINE JITTER until:
- $TJ = TJ_{SI} \text{ _____} + 0.15UI = \text{_____} \text{ mUI}$
- Once satisfied...

On the Scope:

- ...select “Run”.
- Record the SINE JITTER setting _____ %UI
- Record TJ@BER – 10MHz (F_{SJ2_RX}):
 - _____ mUI or
 - _____ ps

Step 5: Enable All Stresses

On the BERT:

- Enable all calibrated jitter sources with calibrated jitter values from previous sections:
 - RANDOM JITTER _____ %UI
 - SINE INTERFERENCE _____ mV
 - SINE JITTER _____ %UI (e.g., 800kHz)
 - SINE JITTER _____ %UI (e.g., 8MHz)
 - SINE JITTER _____ %UI (e.g., 10MHz)

- SINE JITTER _____%UI (F_{system} MHz)
- SINE JITTER _____%UI (e.g., 193.3 MHz)

Step 6: Prorated Eye Mask Calibration

On the Scope:

- Select Measurements: Eye Height and Eye Width @BER.
- Enable High Pass Filter to incoming signal. Ensure High Pass Filter is set to 1st Order, 8 MHz:
 - Select “Apply to ALL”
 - Select “Single”
- Set RjDj for Pattern Type: Arbitrary, Window Length: 5UI, Population: 100 and Jitter Target BER: 6.

On the BERT:

- Set DATA(+) and DATA(-) on the BERT to 290 mV.
- Ensure all calibrated stresses have been enabled.

On the Scope:

- Measure the Eye Height and Width @BER.

On the BERT:

- Adjust the DATA amplitude until the measured Eye Height target of 47 mV @BER $1E-12$ is met.
- Adjust the SJ value (Sine Jitter) until the measured Width @BER target of $0.52 \pm 5\%$ UI @ $1E-6$ is met.

Measure for all of the following frequency points for each supported HS Gear:

- $F_{\text{SJ0_RX_HSG3/G4/G5}}$
- $F_{\text{C_HS_G3/G4/G5_RX}}$
- $F_{\text{SJ2_RX}}$
- $F_{\text{SJ3(System Frequency)}}$
- $F_{\text{SJ4_RX_HS_G3/G4/G5}}$

Step 7: Adjust Common Mode

Set the following target common mode voltages for each jitter configuration by adjusting the offset:

- Test case 1: 180 mV
 - Test case 2: 25 mV
 - Test case 3: 330 mV
- Disable stresses on the BERT.

- Set the Generator Pattern.
- On the Scope, set up Math 1 Function.
- On the BERT, adjust the signal level offset to an initial value.
- On the Scope, turn on Amplitude Measurement:
 - Menu > Amplitude > Mean > Math 1
- Press the Run/Stop button.
- On the BERT, adjust the signal level offset to achieve the target common mode voltages on Math 1.

Step 8: Perform jitter tolerance tests for all listed above jitter combination.

Step 9: Adjust to +/- 2000ppm offset (frequency offset)

After performing the jitter tolerance tests, repeat the tests with +/- 2000ppm offset in the data rates by adjusting the data rates to below values.

On the BERT:

Adjust the BERT synthesizer to the appropriate +/- 2000ppm offset.

Note: Both the -2000ppm offset and +2000ppm offset will be applied to the B-series rates:

- HS-GEAR3 B (+2000ppm): 5.8384Gbps
- HS-GEAR3 B (-2000ppm): 5.8151Gbps
- HS-GEAR4 B (+2000ppm): 11.684Gbps
- HS-GEAR4 B (-2000ppm): 11.637Gbps

Note: Optionally you can also use the minimum PREPARE Length and SYNC Length.

Step 10: Configure Minimum PREPARE Period and Minimum SYNC Period

Based on the following PHY attribute registers, PREPARE and SYNC time should be configured to minimum values:

- RX_HS_G3/G4_PREPARE_LENGTH_Capability
- RX_HS_G3/G4_SYNC_LENGTH_Capability

To set PREPARE Length and SYNC Length correctly on the BERT, you will need to obtain *RX_HS_Gn_PREPARE_LENGTH_Capability* and *RX_HS_G1_SYNC_LENGTH_Capability* from the DUT, respectively. PREPARE Length and SYNC Length will be defined in Symbol Intervals where

1 SI = 10 HS-UI. One SI is equal to 10 UI at the HS data rate.

PREPARE Length = XX **SI** (1 SI = 10 UI) from “*RX_HS_Gx_PREPARE_LENGTH_Capability*”

SYNC Length = XX **SI** (1 SI = 10 UI) from “*RX_HS_G1_SYNC_LENGTH_Capability*”

(where XX = User Programmable)

Note: You should be able to perform the configuration during testing.

Step 11: Perform All Test Cases

Perform jitter tolerance test for all test cases (as in Step 8) with Step 9 and Step 10 settings applied.

Step 12: Save Configuration on both the BERT and Scope

8.6.3 Test Procedure

1. Configure the Lab Signal Source to generate Burst-Mode CJTPAT signaling in HS-G1B on a single LANE, with calibrated settings for V_{CM_RX} , all jitter sources having the low frequency SJ at f_{SJ0_RX} , prorated eye mask, frequency offset of ± 2000 ppm and minimum PREPARE and SYNC time.
2. Configure the DUT to receive Burst-Mode CJTPAT signaling in Terminated HS-Rx mode, in a manner that allows errors to be detected and/or counted in the received data stream for the LANE Under Test.
3. Connect the Lab Signal Source to the DUT, and transmit $3E10$ observable bits @target BER $1E-10$ or $3E12$ observable bits @target BER $1E-12$ to the DUT.
4. Record the number of errors observed by the DUT.
5. Repeat steps 1-4 for all applicable SJ frequencies.
6. Repeat steps 1-5 for all three common-mode amplitude test cases.
7. Repeat steps 1-6 for the HS-G1B rate, and a frequency offset of ± 2000 ppm.
8. Repeat steps 1-7 for all supported GEAR's in B-series rate.
9. Repeat steps 1-8 for all DUT LANE's.

8.6.4 Observable Results

For all LANE's, verify that the number of received errors is zero.

8.6.5 Possible Problems

The ± 2000 ppm offset should be applied relative to the nominal HS bitrate for DigRF/other applications that use a shared reference clock of a known frequency between Tx and Rx. Thus, the bitrate must be measured to the proper ± 2000 ppm value by adjusting the reference clock frequency. This is dependent on the reference frequency value and may not apply to all cases. Some common reference frequency values may produce a bitrate that is not an exact match to the A-series or B-series rate, however the default bitrate (i.e., for a 0ppm reference frequency) must be within the allowed ± 2000 ppm tolerance.

Also variation of the reference clock may not be possible if the reference clock is supplied by the DUT (e.g., in a host device). However for slave devices (which receive the reference clock), the test can be performed as described above.

Note that the ADAPT calibration sequence for HS-G4 must be performed as required prior to initiating loopback test.

8.7 Testing for 2.1.8 HS-Rx Frequency Offset Tolerance ($f_{\text{OFFSET_RX}}$)

8.7.1 Calibration Setup for 2.1.8

Step 1: Configure BERT

1. Set Data Rate to HS DATA Rate. (In this example, HS-G1A is used.)

Test Case #1: +2000 ppm

- HS-GEAR1 A (+2000ppm): 1.2504Gbps
- HS-GEAR1 B (+2000ppm): 1.4605Gbps
- HS-GEAR2 A (+2000ppm): 2.5009Gbps
- HS-GEAR2 B (+2000ppm): 2.9192Gbps
- HS-GEAR3 A (+2000ppm): 5.0019Gbps
- HS-GEAR3 B (+2000ppm): 5.8384Gbps
- HS-GEAR4 A (+2000ppm): 10.004Gbps
- HS-GEAR4 B (+2000ppm): 11.684Gbps

Test Case #2: -2000 ppm

- HS-GEAR1 A (-2000ppm): 1.2455Gbps
- HS-GEAR1 B (-2000ppm): 1.4547Gbps
- HS-GEAR2 A (-2000ppm): 2.4910Gbps
- HS-GEAR2 B (-2000ppm): 2.9075Gbps
- HS-GEAR3 A (-2000ppm): 4.982Gbps
- HS-GEAR3 B (-2000ppm): 5.8151Gbps
- HS-GEAR4 A (-2000ppm): 9.964Gbps
- HS-GEAR4 B (-2000ppm): 11.637Gbps

2. Set the Generator Pattern to CJTPAT.txt.
3. Set the DATA amplitude to approximately 1V (2V p-p) initially.

Step 2: Configure Scope

Note: It may be helpful to SAVE the scope configuration. This configuration can be used through several additional HS-Rx tests.

1. Set up the following configuration on the Scope:
 - Bandwidth: 8GHz.
 - Math 1: CH3-CH4 (*CH1-CH2 can also be used if desired*).
 - RjDj Pattern Type: Arbitrary
 - RjDj Window Length: 5UI
 - Sample Rate: 50GS/s
 - Scale: 10 μ s
2. Select the following measurements on the Scope:

- RJ- $\delta\delta$
- TJ@BER (set to 1E-10)
- DDJ
- DJ- $\delta\delta$
- Eye Height
- TIE
- Cycle Peak-to-Peak or Amplitude

Step 3: Calibrate Peak-to-Peak Amplitude

While adjusting BERT DATA amplitude, measure peak-to-peak amplitude on the Scope until target peak differential amplitude is met for **Test Case #1: 200mV differential peak voltage**.

Step 4: Calibrate DC Common Mode Voltage

Continuing with Test Case #1, the DC Common Mode offset needs to be configured.

The BERT will be set to transmit the “All Zeros” pattern. On the Scope, the common-mode amplitude (CH3+CH4)/2 will be measured.

The BERT DATA Offset will be used to adjust to the appropriate offset value: **Test Case 1: 200mV nominal**.

This completes calibration for Test Case #1.

The above process must be completed for Test Case #2.

Note the amplitudes required for Test Case #1 and Test Case #2. These amplitudes will be used for testing.

Note: The above calibrations will need to be completed for additional Gears if supported.

8.7.2 Test Procedure

1. Configure the Lab Signal Source to generate Burst-Mode CJTPAT signaling in HS-G1A on a single LANE, with Test Case #1 settings for voltage levels and frequency offset.
2. Configure the DUT to receive Burst-Mode CJTPAT signaling in Terminated HS-Rx mode, in a manner that allows errors to be detected and/or counted in the received data stream for the LANE Under Test.
3. Connect the Lab Signal Source to the DUT, and transmit 3E10 observable bits to the DUT.
4. Record the number of errors observed by the DUT.
5. Repeat steps 1-4 for Test Case #2.
6. Repeat steps 1-5 for HS-G1B.
7. Repeat steps 1-6 for Continuous-Mode CJTPAT signaling.
8. Repeat steps 1-7 for all DUT LANE's.

9. Repeat steps 1-8 for all supported HS GEAR's.

Note: 2 offsets x 2 RATE's x 2 modes (burst/cont) x 4 LANE's x 5 GEAR's = 160 test cases, worst-case.

8.7.3 Observable Results

For all cases, verify that the number of received errors is zero.

8.7.4 Possible Problems

None.

9 Appendix B: Connecting Keysight Oscilloscope to PC

If using a Keysight oscilloscope, refer to the following procedure on how to connect the Scope to be used with a PC. The Keysight Scope can be connected to the PC through GPIB, USB, or LAN.

1. Download the latest version of the Keysight IO Libraries Suite software from the Keysight website and install on the PC.
2. When installed successfully, the IO icon  will appear in the taskbar notification area of the PC.
3. Select the IO icon to launch the **Keysight Connection Expert**.
4. Click Rescan.

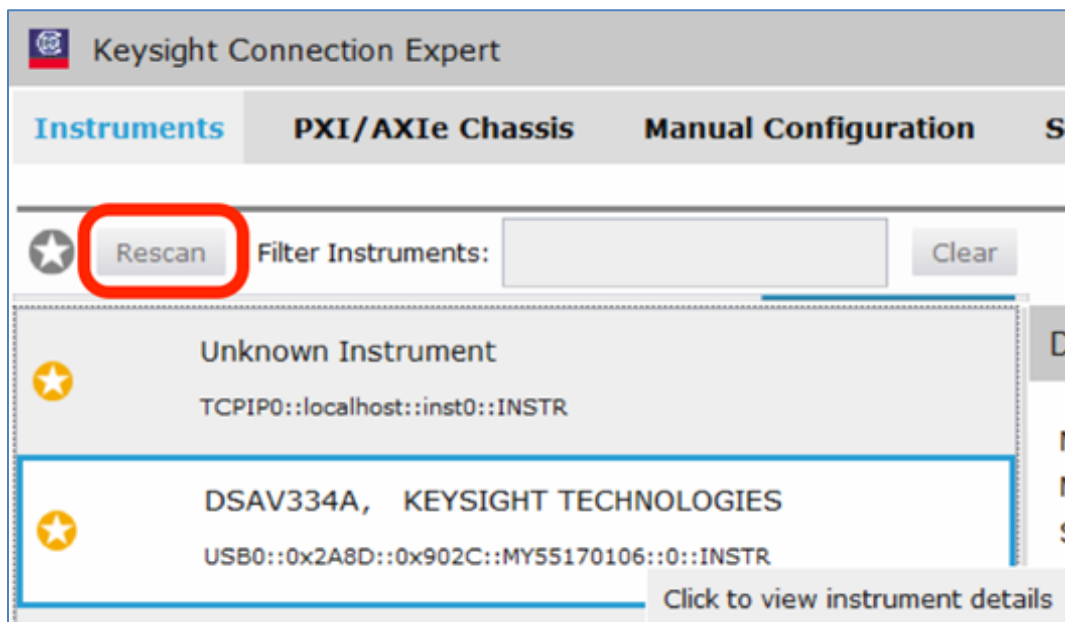


FIGURE 52. KEYSIGHT CONNECTION EXPERT

5. Refresh the system. The Keysight Scope is shown on the left pane and the VISA address is shown on the right pane.

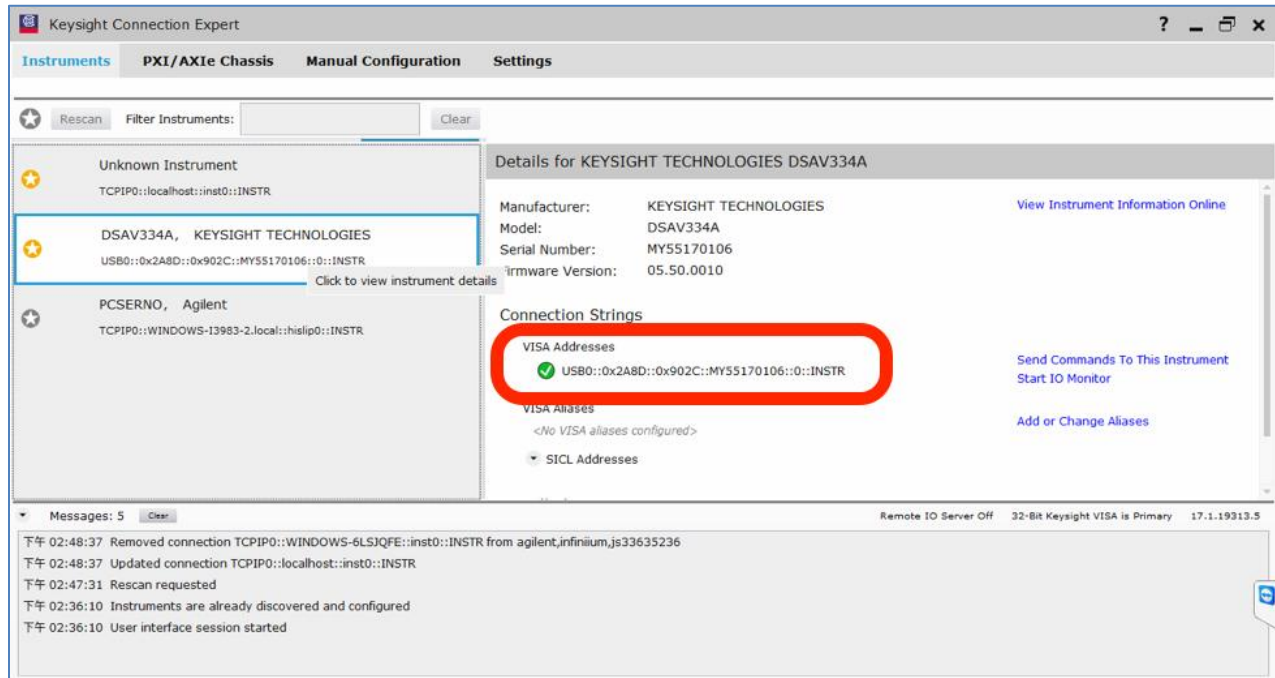


FIGURE 53. OSCILLOSCOPE'S VISA ADDRESS

6. When connecting the Keysight Scope to the PC through GPIB/USB, type in the VISA address into the 'Address' field on the Equipment Setup page of the GRL-MIPI-MPHY-HS-RXA application. If connected via LAN, type in the Scope IP address, for example "TCPIP0::192.168.0.110::inst0::INSTR". Note to **omit** the Port number from the address. If there is error in connection, type in the Scope IP address as "TCPIP0::192.168.0.4::5025::SOCKET".

10 Appendix C: Connecting Tektronix Oscilloscope to PC

If using a Tektronix DPOJET Series oscilloscope, refer to the following procedure on how to connect the Scope to be used with a PC. The Tektronix Scope can be connected to the PC through GPIB, USB, or LAN.

1. Download the latest version of the Tektronix TekVISA software from the Tektronix website and install it on the PC.
2. When installed successfully, open the OpenChoice Instrument Manager application.

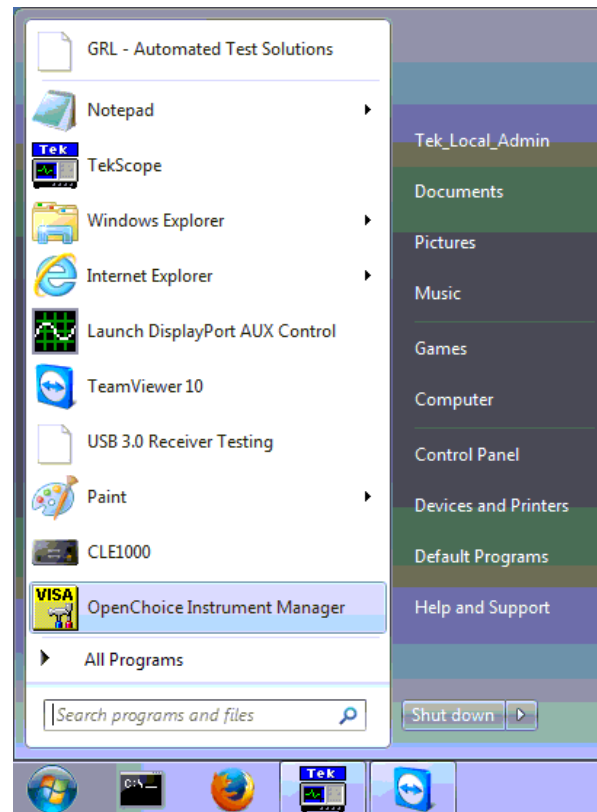


FIGURE 54. OPENCHOICE INSTRUMENT MANAGER IN START MENU

3. The left “Instruments” panel on the OpenChoice Instrument Manager will display all connected instruments. The functional buttons below the “Instruments” panel – “Instrument List Update”, “Search Criteria”, “Instrument Identify” and “Properties” can be used to detect the Scope in case it does not initially appear under “Instruments”.
 - a) “Instrument List Update”: Select to refresh the instrument list and locate new instruments connected to the PC.
 - b) “Search Criteria”: Select to configure the instrument search function.
 - c) “Instrument Identify”: Select to use a supported programming language to send a query to identify the selected instrument.
 - d) “Properties”: Select to display and view the selected instrument properties.

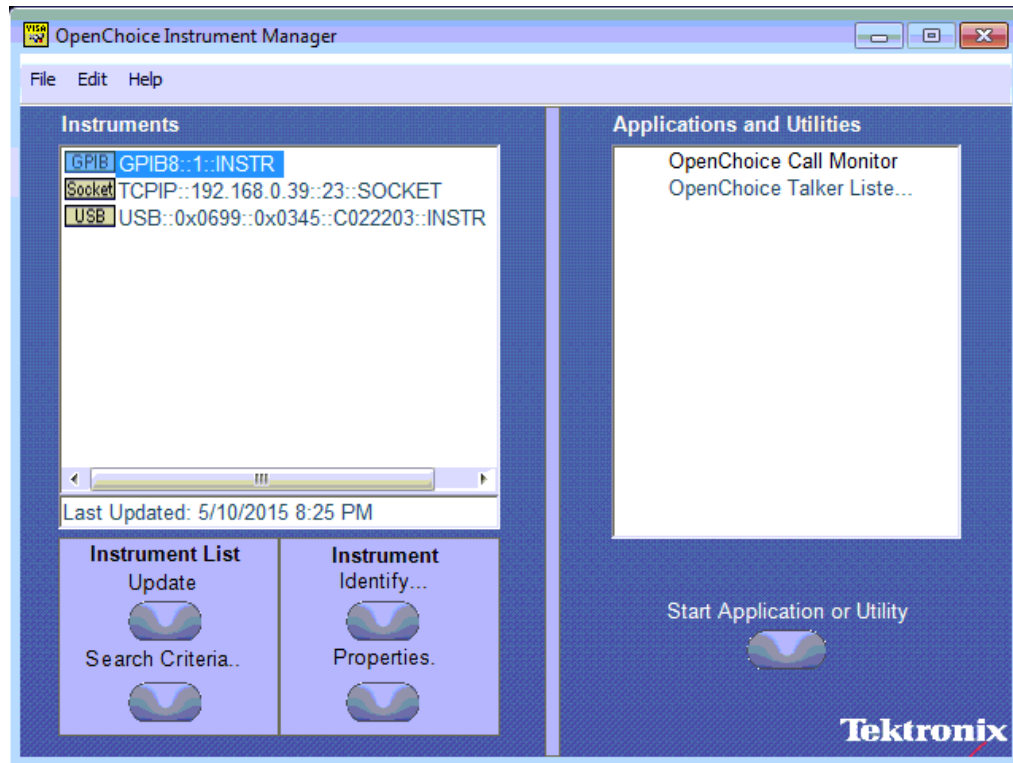


FIGURE 55. OPENCHOICE INSTRUMENT MANAGER MENU

4. If connecting the Tektronix Scope to the PC via USB, select the “Search Criteria” function to ensure that USB connection is enabled, and then select the “Instrument List Update” function. When the Scope appears on the “Instruments” panel, select it and then go to the “Instrument Identify” function. This will display the model and serial number of the Scope once detected. Select the “Properties” function to view the Scope address.
5. If connecting the Tektronix Scope to the PC via LAN, the Scope IP address must be pre-determined beforehand. Then select the “Search Criteria” function to ensure that LAN connection is enabled and type in the Scope IP address. When the Scope shows up in the list, select it followed by “Search”. The Scope should then appear on the “Instruments” panel. Select it and access the “Instrument Identify” function to view the Scope model and serial number as well as the “Properties” function to view the Scope address.
6. On the Equipment Setup page of the GRL-MIPI-MPHY-HS-RXA application, type in the Scope address into the ‘Address’ field. If the GRL-MIPI-MPHY-HS-RXA application is installed on the Tektronix Scope, ensure the Scope is connected via GPIB and type in the GPIB network address, for example “GPIB8::1::INSTR”. If GRL-MIPI-MPHY-HS-RXA is installed on the PC to control the Scope, type in the Scope IP address, for example “TCPIP0::192.168.0.110::inst0::INSTR”. Note to **omit** the Port number from the address.

END_OF_DOCUMENT