

Tektronix Inc.

DisplayPort Standard

**Revision 1.0
05-20-2008**



**DisplayPort Standard
Tektronix MOI for Cable Tests
(DSA8200 based sampling instrument with IConnect
software)**

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Modification Records

October 15, 2007: Eugene Mayevskiy created a first draft

May 17th, 2008: Modifications due to the latest CTS changes.

May 20th, 2008: Added alternative fixture in the instrumentation requirements section.

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Instrumentation Requirements

Passive Cables

DSA8200 mainframe or equivalent.
4 80E04 sampling modules¹
IConnect software (80SSPAR)
A set of DisplayPort cable compliance test fixtures: TPA-P and TPA-R fixtures from Efficere Technologies (Order a set as ET-DP-TPA-S). Any fixture that meets DisplayPort compliance requirements for the test fixtures can be used.
8 pcs. equal length (~1.5ft) SMA cables 18GHz bandwidth or equivalent
4 pcs. SMA female-to-female adaptors.
12 pcs. 50 Ohm terminations to terminate unused channels

Active (Hybrid) Cables²

DSA8200 mainframe or equivalent.
2pcs 80E04 sampling modules or equivalent.
1 80A06 pattern sync module
IConnect software (80SSPAR)
80SJNB software for jitter analysis
A set of DisplayPort test fixtures for active cable tests
4 pcs. equal length short (~1.5ft) SMA cables 18GHz bandwidth or equivalent
1 long (~3ft) SMA cable to connect from AWG to the pattern sync module
1 short (~1ft) SMA cable to connect trigger from the pattern sync module
2 pcs. SMA female-to-female adaptors.
50 Ohm terminations to terminate unused channels
High Speed Signal Source: AWG7102 with options 1.6.

¹ The testing can be performed with two 80E04s. However, this will require physical changes in the setup.

² Only Far End Noise (5.3) and Near End Noise (5.7) are performed for compliance testing. The test procedure for active cables has the same informative/normative properties as the referenced tests.

Outline of the testing

Perform compensation for all channels and the mainframe.

Connect matched SMA cables to the sampling heads of the mainframe.

Perform differential deskew procedure for all channels at the SMA interface (Appendix A).

Perform differential deskew procedure for all channels at the fixture interface³. The deskew should be done first at the SMA interface, and then calibrated with TDR steps at the open fixture in acquisition (Vertical menu).

Perform instrument settings, and save setups for the following measurements:

Inter-pair skew measurements (informative).

Intra-pair skew measurements

Far End Noise measurements, and acquire reference waveforms

Bulk Cable and Connector impedance measurements and acquire reference waveforms for the SMA open and fixture open configuration.

Insertion Loss measurements and acquire reference waveforms.

Near End Noise measurements and acquire reference waveforms.

The reference and calibration waveform acquisition procedure is described in the Appendix C.

Note: When acquiring time domain data for long cable it is important to acquire the waveforms that have enough time domain points (resolution) to ensure sufficient bandwidth in frequency. In general, someone needs to acquire at least 4000 points per each 50ns of time domain data. To acquire long data (more than 4000 points) with IConnect Long Record mode should be enabled.

³ Only acquisition deskew part is required, it can be performed by looking at the differential TDR response in “rho” mode for each channel and minimizing the delay between the rising edges.

Connection of the Cable Assembly to Measurement Instrument

The cable assembly has to be connected as shown in Figure 3.1.1. This setup allows to completely characterize two pairs of the cable assembly without connect/disconnect operation. In the following sections it is assumed that two differential pairs being analyzed are AUX and ML3. It is also assumed that the far end noise (FEN) is measured with the contribution of a single aggressor. Lane0 in the following subsections corresponds to the AUX channel on the diagram and Lane1 corresponds to the ML3 differential pair of the cable. Ch1 and Ch2 constitute the measurement port 1 (P1), Ch3 and Ch4 constitute the measurement port 2 (P2), Ch5 and Ch6 constitute the measurement port 3 (P3), and Ch7 and Ch8 constitute the measurement port 4 (P4)

The test instrument has to be compensated as required by the instrument's manual. The deskew procedure has to be performed on all channels to ensure that the most accurate measurement. The deskew procedure is outlined in the Appendix A.

To measure the delay between sampling modules the differential stimulus can be applied to both pairs on the same side of the cable. The delay between differential transmission responses from the pairs have to be measured at the other side of the cable assembly. This number can be used in the informative inter-pair skew test.

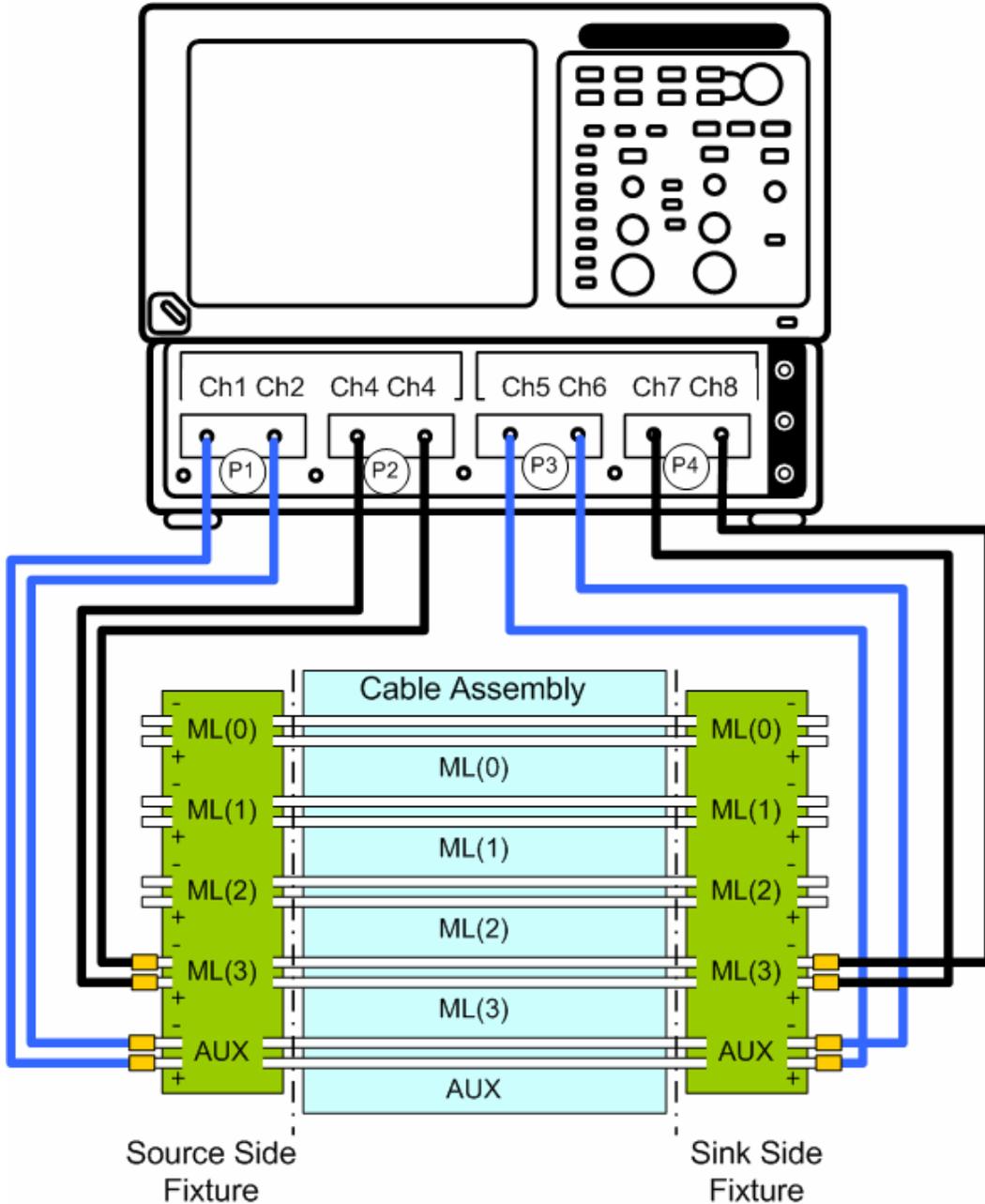


Figure 3.1.1 DisplayPort passive cable test setup connection diagram. The unused SMA ports of the test fixture have to be terminated with 50Ohm terminations. The SMA cables can be reconnected to different differential pairs, but the thru connections between the ports P1/P3 and P2/P4 has to be preserved.

Inter-pair skew test (5.1) (Informative)

This test is run on the instrument directly, and it does not require the use of IConnect

TDR Oscilloscope Settings⁴

Average Mode: 50 samples

Stop After Condition: Average Complete

Record Length: 4000pts

Horizontal scale of the MainTB: 30ns/div

Horizontal scale of the Mag1TB: 3ns/div

Vertical Scale: 100mV/div

Reference Skew Calibration

Verify that rise time at the output of the 2x trace of the fixture is faster than 50ps +/- 2ps (20-80%).

Generate diff TDR step at channels C1 and C2; set acquisition units to volts (V).

Generate diff TDR step at channels C3 and C4; set acquisition units to volts (V).

Set the math function M1 to C5-C6 and check On checkbox.

Set the math function M2 to C7-C8 and check On checkbox.

Set Measure 1 to measure time delay between Mag1_M1 and Mag1_M2 with the Relative Mid reference level of 15% for both sources.

Measure the time difference between the TDR step generators:

Connect SMA cables using SMA female-to-female adaptor (test adaptors have to be disconnected).

Display the TDR steps on the screen.

Run delay measurements (Measure 1) and record the delay number (Figure 5.1.1). This number will be subtracted from the measurements of the cable.

Save instrument setup in a file (DP5_1.stp).

Disconnect the SMA female adaptors.

⁴ If the saved setup is used make sure to update the acquisition and differential step skew numbers.

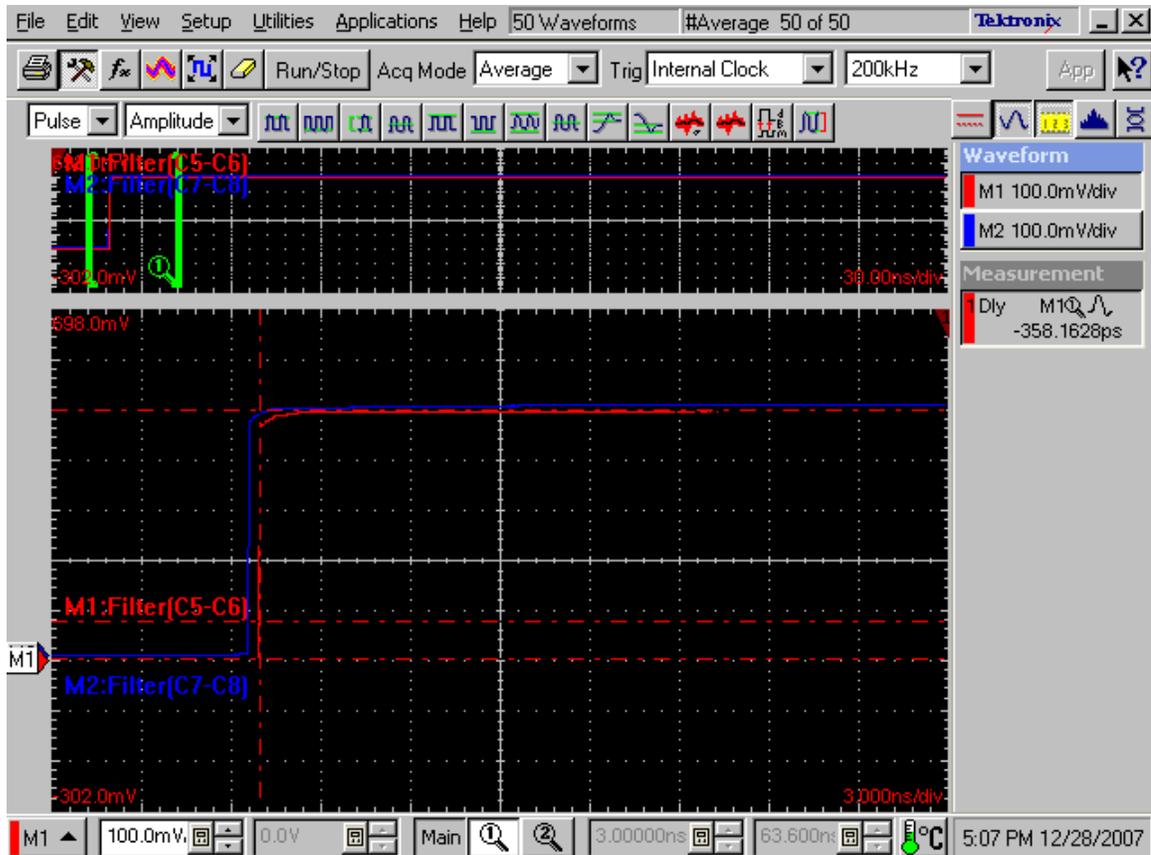


Figure 5.1.1. Delay measurements for intra pair skew calibration. The measured delay between differential lanes is -358ps.

Measure the inter-pair skew of the cable assembly

Connect the test fixtures to the measurement instrument (if not connected already).

Carefully plug the cable into the test fixtures.

Recall DP5_1.stp.

Rotate the Position knob to position the rising edge of the TDT response in the first 25% of the Mag1 window as shown in Figure 5.1.2

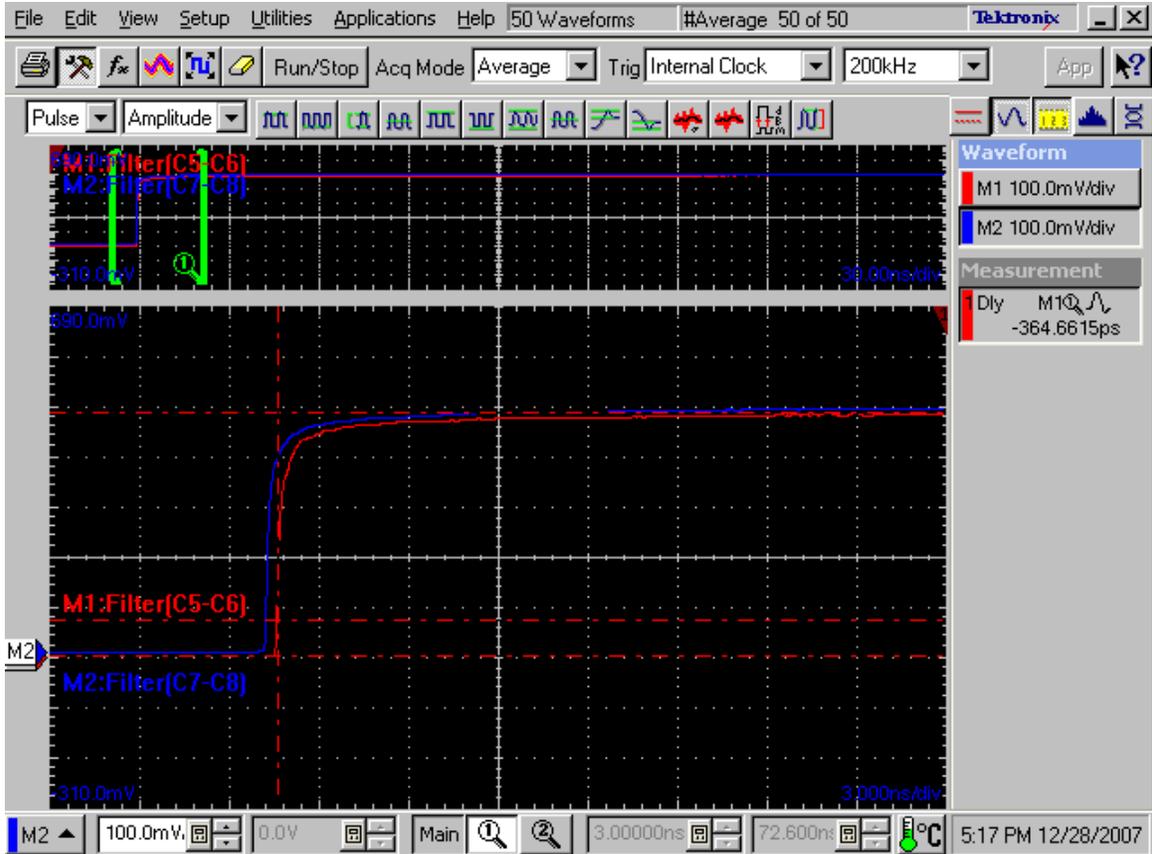


Figure 5.1.2 Intra pair skew measurements. The measured delay is -365ps.

Press the RUN/STOP button. Record the delay value (Measure 1) as IntraDelay.

Compute the intra-pair skew: $\text{IntraSkew} = \text{IntraDelay} - \text{TDRskew}$.

Check pass/fail condition of this test:

If $\text{abs}(\text{IntraSkew}) > 2\text{UIs}^5$: Fail, else: Pass.

Example: For the data shown in the figures the IntraSkew is $-358\text{ps} - (-365\text{ps}) = 7\text{ps}$, which is pass.

⁵ 2UI for RBR is 1234ps, and 2UI for HBR is 740.8ps

Intra-pair skew test (5.2)

This test is run on the instrument directly, and it does not require the use of IConnect.

Set the TDR oscilloscope

Average Mode: 50 samples
Stop After Condition: Average Complete
Record Length: 4000pts
Horizontal scale of the MainTB: 30ns/div
Horizontal scale of the Mag1TB: 3ns/div
Vertical Scale: 100mV/div

Reference Skew Calibration

Verify that TDR rise time measured through 2x trace of the test fixture is faster than 50ps (20-80%)

Setup for channels C1 and C2 (lane0):

Generate diff TDR step at channels C1 and C2; set acquisition units to volts (V)

Set Measure 1 to measure time delay between C5 and C6:

Select C5 as the Source1 with RefLevel of Mid value set to 15%

Set the slope edges in Region tab to +/-

Select C6 as the Source2 with RefLevel of Mid value set to 85%

Set the slope edges in Region tab to +/-

Setup for channels C3 and C4 (lane1):

Generate diff TDR step at channels C3 and C4; set acquisition units to volts (V)

Set Measure 2 to measure time delay between C7 and C8:

Select C7 as the Source1 with RefLevel of Mid value set to 15%

Set the slope edges in Region tab to +/-

Select C8 as the Source2 with RefLevel of Mid value set to 85%

Set the slope edges in Region tab to +/-

Save instrument setup in a file (DP5_2.stp)

To ensure the most accurate results the setup skew can be measured with ports P1 connected to P3 and P2 connected to P4 with SMA female-to-female adaptors. The skew measurements can be run now the skews numbers recorded (Figure 5.2.1). These numbers can be subtracted from the measurements with the cable assembly inserted.

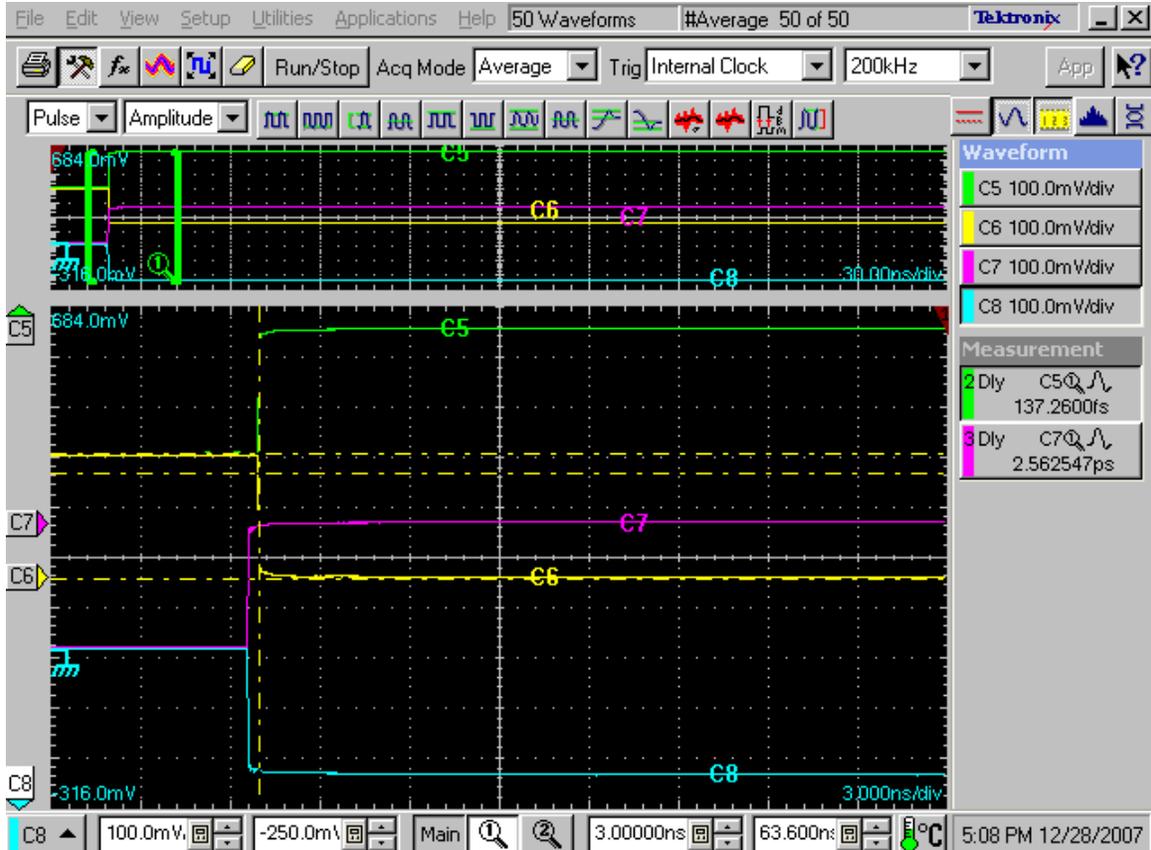


Figure 5.2.1. Delay measurements for inter pair skew calibration. The measured delays 0ps and 2.6 ps for P3 and P4 respectively.

Measure the intra-pair skew of the cable assembly

- Connect the test fixtures measurement instrument (if not connected already)
- Carefully plug the cable into the test fixtures
- Recall DP5_2.stp and press the RUN/STOP button
- Rotate the Position knob to position the rising edge of the TDT response in the first 25% of the Mag1 window as shown in Figure 5.2.2
- Record the delay values (Measure 1 and Measure 2).
- Subtract respective delay measurement from the calibration step
- Check pass/fail condition of this test for both tests:
 - If $\text{abs}(\text{delay}) > 50\text{ps}$: Fail, else: Pass.



Figure 5.2.2. Delay measurements for inter pair skew calibration. The measured delays -12ps and -15ps for Port3 and Port4 respectively.

Far End Noise tests (5.3)

With this procedures specify tests 1 and 5 in section 5.3.3 of the VESA DisplayPort PHY Compliance Test Standard can be tested. The referenced table is copied below:

Test #	Aggressor(s) Channel(s) (Source Side)	Victim Channel (Sink Side)
1	Main Link(2)	Main Link(3)
2	Main Link(1) + Main Link(3)	Main Link(2)
3	Main Link(0) + Main Link(2)	Main Link(1)
4	Main Link(1) + AUX Ch.	Main Link(0)
5	Main Link(0)	AUX Ch.

To test combinations 2-4 the procedure needs to be separately performed on each combination of victim-aggressor, and then the power sum of the FEN need to be performed.

For instance, to obtain FEN for test 2, measure Main Link(0) and Main Link(1) crosstalk, then measure Main Link(2) and Main Link(1) crosstalk, and finally combine their effects using power sum⁶. The power summation formula is defined below (section 5.3.3 of the VESA DisplayPort PHY Compliance Test Standard)

$$TotalFEN(f) = 10 \times \log \sum_1^n 10^{\left(\frac{FEN_n(f)}{10}\right)}$$

where $FEN_n(f)$ is the far end noise of the individual contributor in dB

Set the TDR oscilloscope

Average Mode: 500 samples

Stop After Condition: Average Complete

Record Length: better than 4000pts per 50ns window

Horizontal scale: ~4-5 times prop delay of the cable⁷

Reference Plane Calibration

Acquire references for measuring FEN at lane 1 with respect to the source at lane 0:

Set the M4 math function to display a difference between C7 and C8

Set the differential TDR step at channels C1 and C2

Check the acquisition checkboxes

Physically connect C1 to C2 and C7 to C8 using SMA female-to-female adaptors

⁶ Usually only test 5 is used at the plug tests

⁷ The prop delay of the cable can be found by measuring the time difference between the open reference position and the rising edge of the TDR response. Alternatively it can be approximated from the physical length of the cable by assuming the step propagates 1 foot in 1ns. For example, if a cable is 10 feet long, the corresponding time window can be approximated as follows: 10feet*1ns/foot*5=50ns or 5ns/div. When using IConnect use long acquisition feature when measuring the cables with window longer than 50ns.

Save instrument setup in a file (DP5_3_FEN41.stp)
Press Run/Stop button to measure TDT response from slot 1 to slot 4
Acquire the reference waveform (M4) with IConnect and save it as Ref_Tdd41.wfm file.
Disconnect the SMA adaptors from the SMA cables
Press Run/Stop button to measure the noise in slot 4
Acquire the noise reference waveform (MATH1) with IConnect and save it in Noise_Tdd44.wfm file

Measure the Far End Noise

Connect the test fixtures measurement instrument and carefully plug the cable into the test fixtures.

Perform measurements of the Far End Noise induced at lane0:

Recall DP5_3_FEN41.stp and press the RUN/STOP button
Acquire M4 waveform with IConnect
Using Math function of IConnect subtract noise reference (Noise_Tdd44.wfm) from the M4 waveform and save it as Tdd41.wfm
Using S-parameter computational function and Ref_Tdd41.wfm waveform compute S-parameter response
Save the S-parameter response as Sdd41_FEN
Using IConnect cursors measure the acquired waveform to test the compliance limits for HBR. The example of the FEN measurement is shown in Figure 5.3.1.

Pass/Fail Criteria

The observed isolation can be no more than -26dB measured from .1GHz to 4.05GHz for RBR, and from .1GHz to 7GHz measured for HBR.

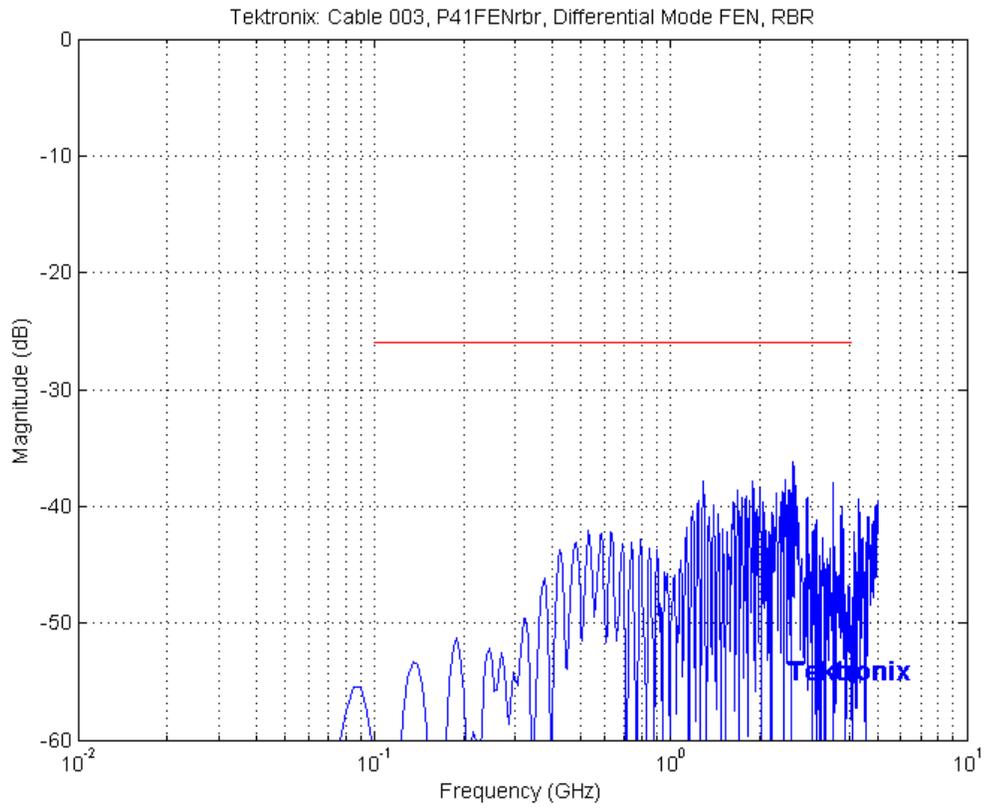


Figure 5.3.1 FEN measurements for RBR. The maximum crosstalk value is below -26dB; the cable assembly passes the test.

Bulk Cable and Connector Impedance measurements (5.4)

This test uses IConnect to compute time domain impedance profile with peeling algorithm. The implementation can be automated using GPIB interface to acquire the data and IConnect's CLI to compute impedance profile. The Zo value used in IConnect can be measured by connecting the SMA cables directly to the sampling head, and measuring impedance of the flat region by the oscilloscope. The recommended threshold number is 45%.

Note, that extra degrees of the calibration can be achieved by using optional 50Ohm calibration standard.

Set the TDR oscilloscope

Average Mode: 500 samples

Stop After Condition: Average Complete

Record Length: 4000

Horizontal scale: 300ps/div

Vertical scale: 100mV division

Acquire references for measuring the bulk cable and connector impedance of lane 0 at side A:

Reference Calibration

Change the window width to 150ps/div, and calibrate rise time to 130ps (20-80%) or faster measured as TDT rise time from 2x trace of the fixture.

Set the M1 math function to display a filtered TDT response. The digital filter has to be 180ps rise time measured between 10-90%. Set the measurement to read rise time of the TDT response with the tracking method set to min/max. Adjust the filter value to measure no slower 130ps (20-80%) rise time at the fixture output.

Open References Acquisition

Set the differential TDR step at the channels C1 and C2 and at the channels C3 and C4
Adjust the time window do display an open from the end of the SMA in the middle of the leftmost division of the acquisition window.

Change the window width back to 300ps/div; the window has to be positioned in such a way that the open from SMA interface is included in the measurements.

Set the math function M1 to a filtered value of C1-C2. The filter value is obtained from the rise time calibration described above. Set the math function M2 to a filtered value of C3-C4. The filter value is obtained from the rise time calibration described above.

Acquire open fixture reference waveforms and save them as FixOpen_ZTdd11.wfm and FixOpen_ZTdd2.wfm for ports 1 and 2 respectively

Disconnect the test fixture

Save instrument setup in a file (DP5_4_P1P2.stp)

Press Clear Data and then Run/Stop buttons to measure open references from the ends of SMA cables.

Acquire the reference waveforms (MATH1 and MATH2) with IConnect and save it as Ref_Z_Tdd11.wfm and Ref_Z_Tdd22.wfm respectively.
Repeat the above steps for port 3 and port4 naming waveforms as Ref_Z_Tdd33.wfm and Ref_Z_Tdd44.wfm respectively. The setup for ports 3 and 4 can be saved as DP5_4_P3P4.stp

50 Ohm Calibration (Optional)

This step is performed if extra degree of accuracy is desired.
Set the math function to acquire filtered C1, and connect a high-precision 50Ohm load to the SMA output from the connecting cable (instead of the test fixture). The math should be set to $M5=Filter(C1)$, with the filter set to the same value that is used in rise time calibration.

Press Run/Stop button to measure the 50Ohm response from M5 and acquire filtered CH1 response with IConnect. Disconnect the 50 Ohm load from C1 and connect it to the SMA output from C2.

Perform the above steps for C2:

Set the math function to acquire filtered C2, and connect a high-precision 50Ohm load to the SMA output from the connecting cable (instead of the test fixture).. The math should be set to $M6=Filter(C2)$, with the filter set to the same value that is used in rise time calibration.

Using IConnect's Waveform Math calculate the difference of M5 and M6 and save the resulting waveform as Cal100Ohm_ZTdd11.wfm

Repeat the above steps for other ports (port 2, port 3, and port4)

Measure the bulk cable and connector impedance

Connect the test fixtures measurement instrument and carefully plug the cable into the test fixtures

Perform measurements of the impedance at side A (P1 and P2):

Recall DP5_4_P1P2.stp and press the RUN/STOP button

Acquire MATH1 and MATH2 waveforms with IConnect and save them as ZTdd11.wfm ZTdd22.wfm files respectively

Using Z-line computational load ZRef_Tdd11.wfm, Cal100Ohm_ZTdd11.wfm (optional), and ZTdd11.wfm into IConnect and compute true impedance profile. Save the waveform as ZlineTdd11.wfm

Using IConnect cursors measure the acquired waveform to test the compliance limits.

The starting time position for the impedance measurements can be found from the FixOpen_ZTdd11.wfm waveform. The beginning of the mask can be found by subtracting 120ps, which roughly corresponds to the length of the mated connector receptacle. From this point, the mated connector and wire management region continues for about 900ps followed by 240ps of the bulk cable region as shown in the Figure 5.4.1. Repeat the above steps for port 2.

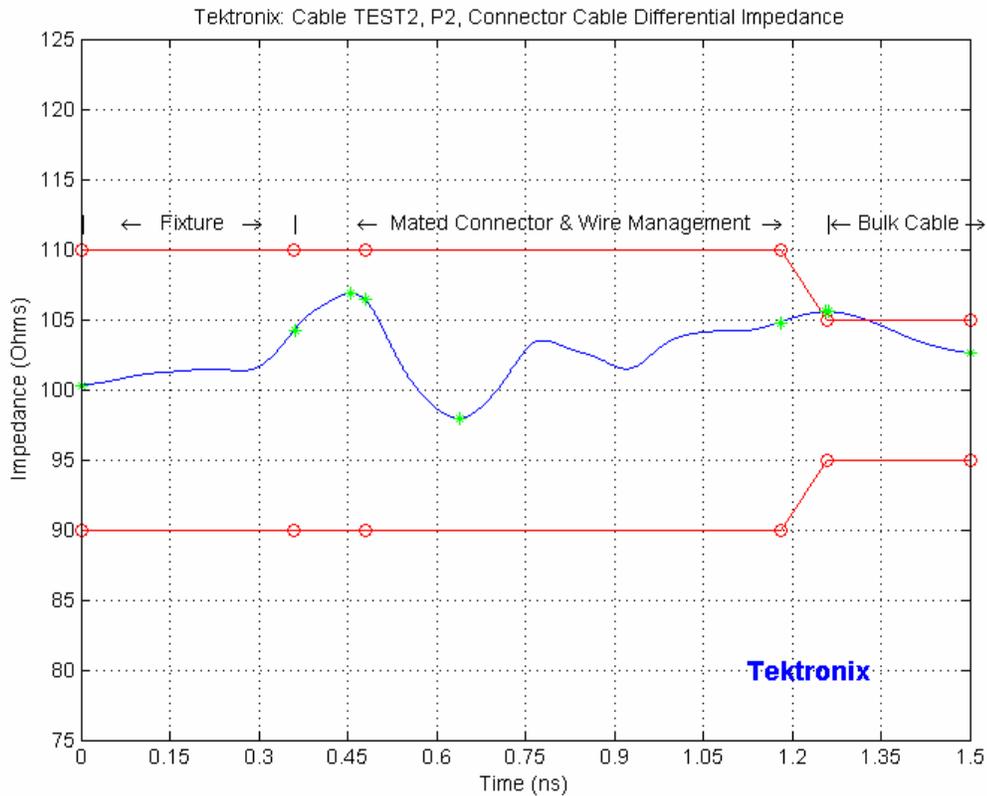


Figure 5.4.1 Impedance measurements of the port 1. The starting position for the mask is determined by the open reference taken at the end of the fixture.

Perform measurements of the impedance at side B (P3 and P4):

Recall DP5_4_P3P4.stp and press the RUN/STOP button
 Acquire MATH3 and MATH4 waveforms with IConnect and save them as ZTdd33.wfm ZTdd44.wfm files respectively
 Using Z-line computational load ZRef_Tdd33.wfm, Cal100Ohm_ZTdd33.wfm (optional), and ZTdd33.wfm into IConnect and compute true impedance profile. Save the waveform as ZlineTdd33.wfm
 Using IConnect cursors measure the acquired waveform to test the compliance limits. The reference time position for the impedance measurements can be found from the FixOpen_ZTdd33.wfm waveform. The beginning of the mask can be found by subtracting 120ps, which roughly corresponds to the length of the mated connector receptacle. From this point, the mated connector and wire management region continues for about 900ps followed by 240ps of the bulk cable region
 Repeat the above steps for port 4.

Pass/Fail Criteria

Bulk Cable Portion: The observed impedance should be within the limits of 5% of 100 Ohms through the cable region of the cable assembly. Refer to the Table 5.4.1.

Connector portion: The observed impedance should be within the limits of 10% of 100 Ohms through the connector region of the cable assembly. Both sides of the cable assembly are required to test, and it shall pass these conditions.

Table 5.4.1.: Impedance and Tolerances

Segment	Differential Impedance Value	Maximum Tolerance	Comment
Fixture	100 Ω	$\pm 10\%$	See Note 1
Connector	100 Ω		
Cable Management	100 Ω		Transition from $\pm 10\%$ to $\pm 5\%$ shall have a slope of 5 Ω /80ps See Note 2
Cable	100 Ω	$\pm 5\%$	

Insertion Loss measurements (5.5)

This test uses IConnect to compute frequency domain S-parameters. The fixture effects can be de-embedded using a 2x reference trace from the fixture to measure the thru reference waveform.

Set the TDR oscilloscope

Average Mode: 500 samples

Stop After Condition: Average Complete

Record Length: better than 4000pts per 50ns window

Horizontal scale: ~4-5 times prop delay of the cable⁸

Reference Plane Calibration

Acquire references for measuring the Insertion Loss of lane 0 and lane 1:

Set the M3 math function to display a difference between C5 and C6, and M4 math function to display a difference between C7 and C8

Set the differential TDR step at port 1 (channels C1 and C2) and port 2 (channels C3 and C4).

Physically connect P1 and P2 to P3 and P4 respectively using SMA female-to-female adaptors. Optionally, you can use 2x fixture cal traces to de-embed fixture's effects from the cable assembly measurements.

Save instrument setup in a file (DP5_5_IL.stp)

Press Run/Stop button to measure TDT responses from port 1 to port 3 and from port 2 to port 4.

Acquire the reference waveforms (MATH3 and MATH4) with IConnect and save them as Ref_Tdd31.wfm and Ref_Tdd42.wfm respectively.

Disconnect the SMA adaptors (or 2x traces of the test fixture) from the SMA cables

Press Run/Stop button to measure the noise in port 3 and port 4

Acquire the noise reference waveforms (MATH1 and MATH2) with IConnect and save them as Noise_Tdd33.wfm file and Noise_Tdd44 respectively.

Insertion Loss Measurements

Connect the test fixtures measurement instrument (if not connected already)

Carefully plug the cable into the test fixtures

Perform measurements of the Insertion Loss at lane0 and lane1:

Recall DP5_5_IL.stp and press the RUN/STOP button

Acquire MATH3 and MATH4 waveforms with IConnect and name them as Tdd31.wfm and Tdd42.wfm respectively

Using IConnect's S-parameter computational tool, compute S-parameters (Insertion loss) for lane 0 and lane 1. The noise waveforms (Noise_Tdd33.wfm and Noise_Tdd44.wfm)

⁸ The prop delay of the cable can be found by measuring the time difference between the open reference position and the rising edge of the TDT response. Alternatively it can be approximated from the physical length of the cable by assuming the step propagates 1 foot in 1ns. For example, if a cable is 10 feet long, the corresponding time window can be approximated as follows: 10feet*1ns/foot*5=50ns or 5ns/div

have to be loaded in IConnect Calibration field (50 Ohm is checked, and Return loss is selected). This will ensure proper noise subtraction.

Using IConnect cursors measure the acquired waveform to test the compliance limits.

The test limits for reduced bit rate (RBR) and high bit rate (HBR) are shown in Figure 5.5.1 and Figure 5.5.2. respectively. For HBR specified cable assemblies the upper frequency limit is 5 GHz and for RBR-specified cable assemblies the upper frequency limit is 2.5 GHz.

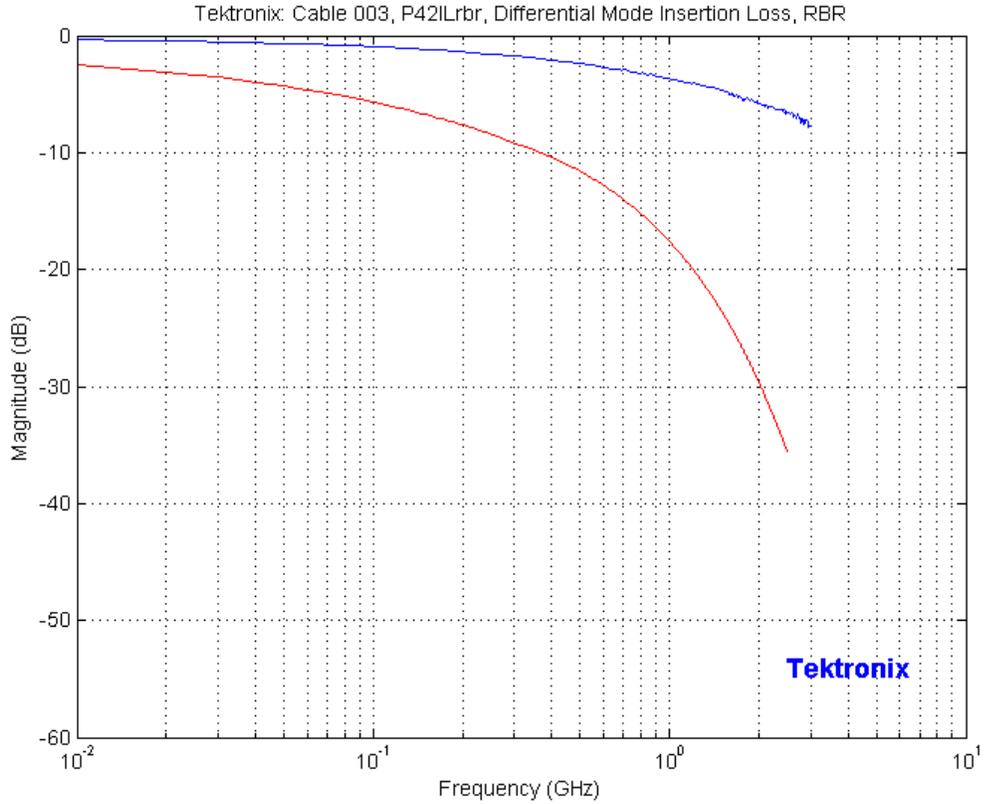


Figure 5.5.1 Insertion Loss testing for RBR cable assembly

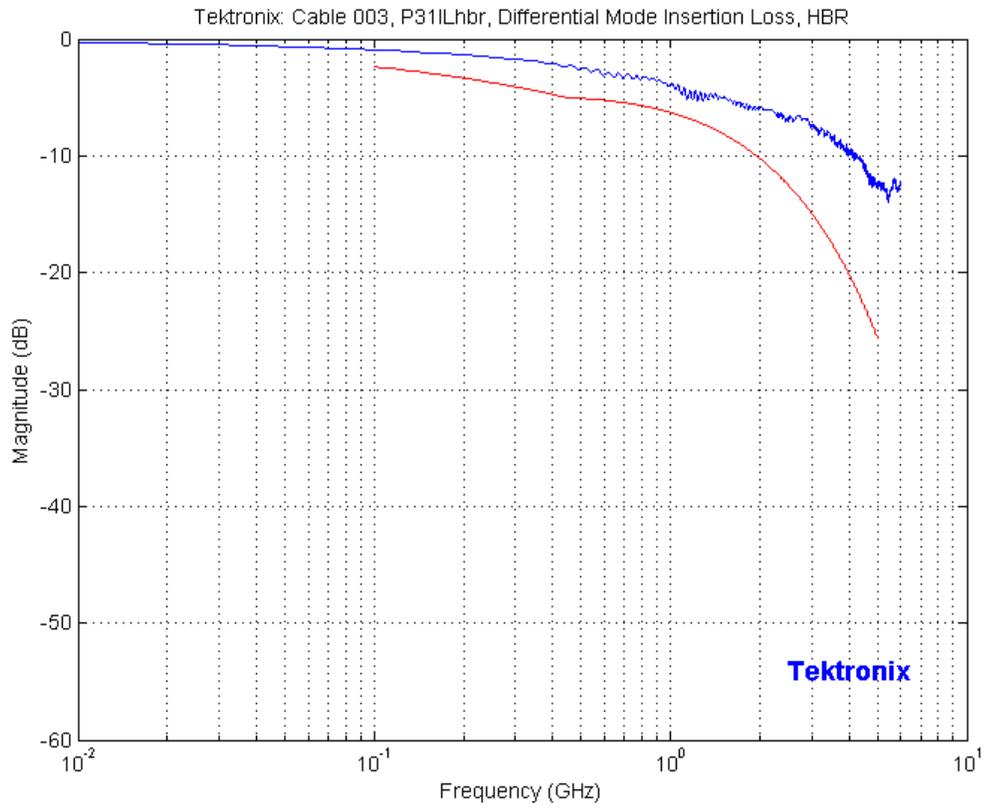


Figure 5.5.2 Insertion Loss testing for HBR cable assembly

Near End Noise Measurements (5.6)

This test uses IConnect to compute frequency domain S-parameters.

Set the TDR oscilloscope

Average Mode: 500 samples

Stop After Condition: Average Complete

Record Length: better than 4000pts per 50ns window

Horizontal scale: ~4-5 times prop delay of the cable⁹

Reference Plane Calibration

Acquire references for measuring NEN at side A (P1 and P2):

Set the MATH2 math function to display a difference between C3 and C4

Set the differential TDR step at channels C1 and C2

Physically connect C3 to C1 and C4 to C2 using SMA female-to-female adaptors carefully mating SMA connectors

Save instrument setup in a file (DP5_6_NEN21.stp)

Press Run/Stop button to measure TDT response from port 1 to port 2

Acquire the reference waveform (MATH2) with IConnect and save it as Ref_Tdd21.wfm file

Disconnect the SMA adaptors from the SMA cables

Press Run/Stop button to measure the noise in port 2

Acquire the noise reference waveform (MATH2) with IConnect and save it in Noise_Tdd22.wfm file

Acquire references for measuring NEN at side B (P3 and P4):

Set the MATH4 math function to display a difference between C7 and C8

Set the differential TDR step at channels C5 and C6

Physically connect C5 to C7 and C6 to C8 using SMA female-to-female adaptors carefully mating SMA connectors

Save instrument setup in a file (DP5_6_NEN43.stp)

Press Run/Stop button to measure TDT response from port 3 to port 4

Acquire the reference waveform (MATH4) with IConnect and save it as Ref_Tdd34.wfm file

Disconnect the SMA adaptors from the SMA cables

Press Run/Stop button to measure the noise in port 4

Acquire the noise reference waveform (MATH2) with IConnect and save it in Noise_Tdd44.wfm file

⁹ The prop delay of the cable can be found by measuring the time difference between the open reference position and the rising edge of the TDT response. Alternatively it can be approximated from the physical length of the cable by assuming the step propagates 1 foot in 1ns. For example, if a cable is 10 feet long, the corresponding time window can be approximated as follows: 10feet*1ns/foot*5=50ns or 5ns/div

Measure the Near End Noise

Connect the test fixtures measurement instrument (if not connected already) and carefully plug the cable into the test fixtures.

Perform measurements of the Near End Noise at side A (P1 and P2):

Recall DP5_6_NEN21.stp and press the RUN/STOP button

Acquire MATH2 waveform with IConnect and save it as Tdd21.wfm

Using IConnect's S-parameter computational tool, compute S-parameters (Crosstalk) for lane 0 and lane 1 at side A. The noise waveform (Noise_Tdd22.wfm) has to be loaded in IConnect Calibration field (50 Ohm is checked, and Return loss is selected). This will ensure proper noise subtraction.

Using IConnect cursors measure the acquired waveform to test the compliance limits.

The compliance test limits for RBR and HBR are shown in figure 5.6.1 and figure 5.6.2 respectively.

Perform measurements of the Near End Noise at side B (P3 and P4):

Recall DP5_6_NEN43.stp and press the RUN/STOP button

Acquire MATH4 waveform with IConnect and save it as Tdd43.wfm

Using IConnect's S-parameter computational tool, compute S-parameters (Crosstalk) for lane 0 and lane 1 at side B. The noise waveform (Noise_Tdd44.wfm) has to be loaded in IConnect Calibration field (50 Ohm is checked, and Return loss is selected). This will ensure proper noise subtraction.

Using IConnect cursors measure the acquired waveform to test the compliance limits.

The compliance test limits for RBR and HBR are shown in figure 5.6.1 and figure 5.6.2 respectively.

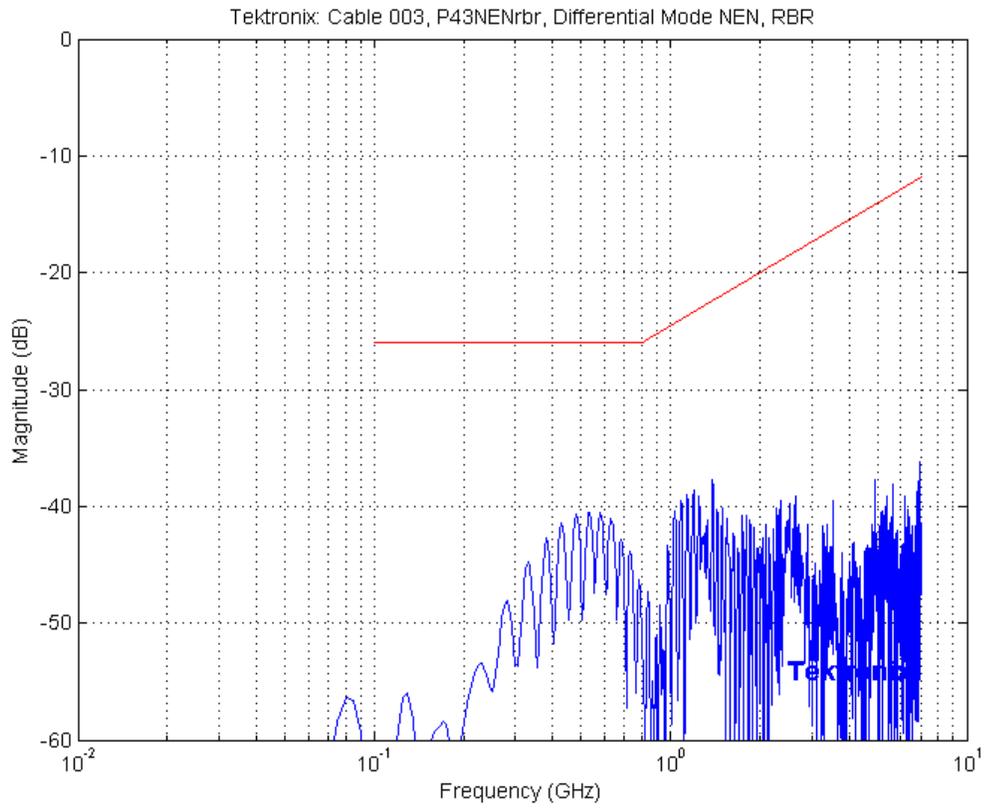


Figure 5.6.1 Near end noise (NEN) testing for RBR cable assembly

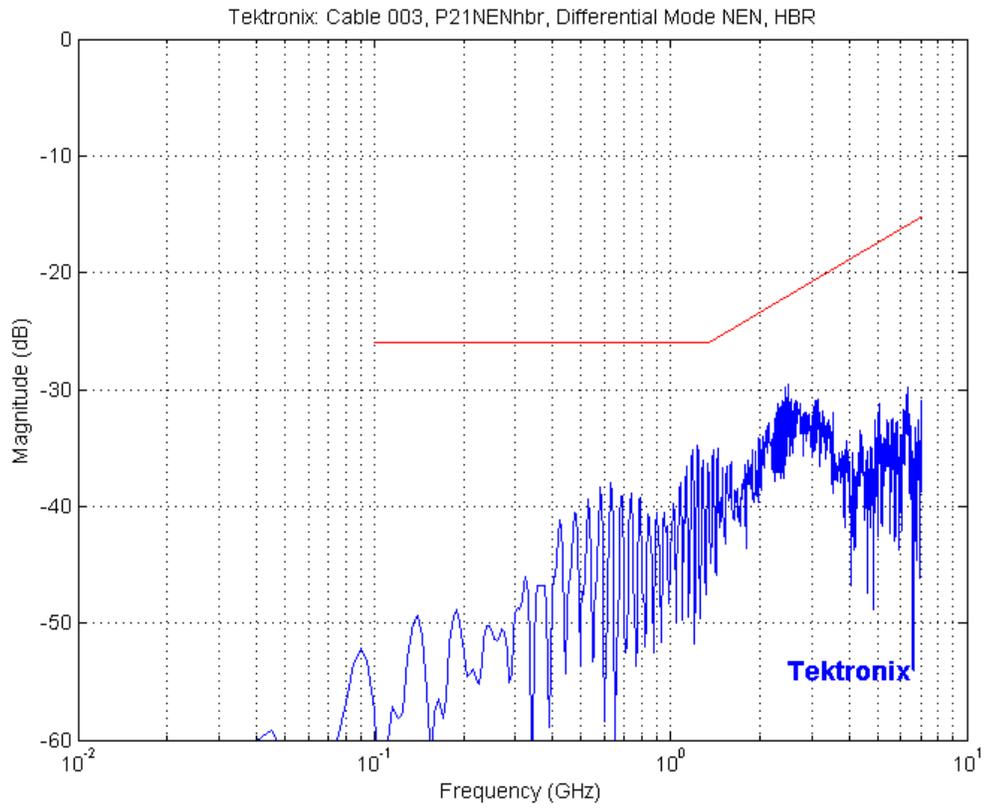


Figure 5.6.2 Near end noise (NEN) testing for HBR cable assembly

Return Loss Measurements (5.7)

This test uses IConnect to compute frequency domain S-parameters. The implementation can be automated using GPIB interface to acquire the data and IConnect's CLI to compute S-parameters.

Set the TDR oscilloscope

Average Mode: 500 samples

Stop After Condition: Average Complete

Record Length: better than 4000pts per 50ns window

Horizontal scale: ~4-5 times prop delay of the cable¹⁰

Reference Plane Calibration

Acquire references for measuring the return loss of lane 0 at side A:

Set the M1 math function to display a difference between C1 and C2.

Set the differential TDR step at channels C1 and C2

Adjust the time window do display an open response from MATH1 in the middle of the leftmost division of the acquisition window.

Acquire MATH1 with IConnect

Save the resulting waveform as Ref_Tdd11.wfm

Save instrument setup in a file (DP5_7_RL_P1.stp)

Acquire references for measuring the return loss of lane 1 at side A:

Set the MATH2 math function to display a difference between C3 and C4.

Set the differential TDR step at channels C3 and C4

Adjust the time window do display an open response from MATH2 in the middle of the leftmost division of the acquisition window.

Acquire the MATH2 with IConnect

Using IConnect save the resulting waveform as Ref_Tdd22.wfm

Save instrument setup in a file (DP5_7_RL_P2.stp)

Acquire references for measuring the return loss of lane 0 at side B:

Set the M3 math function to display a difference between C5 and C6.

Set the differential TDR step at channels C5 and C6

Adjust the time window do display an open response from MATH3 in the middle of the leftmost division of the acquisition window.

Acquire MATH3 with IConnect

Save the resulting waveform as Ref_Tdd33.wfm

Save instrument setup in a file (DP5_7_RL_P3.stp)

¹⁰ The prop delay of the cable can be found by measuring the time difference between the open reference position and the rising edge of the TDT response. Alternatively it can be approximated from the physical length of the cable by assuming the step propagates 1 foot in 1ns. For example, if a cable is 10 feet long, the corresponding time window can be approximated as follows: 10feet*1ns/foot*5=50ns or 5ns/div

Acquire references for measuring the return loss of lane 1 at side B:

Set the MATH4 math function to display a difference between C7 and C8.
Set the differential TDR step at channels C7 and C8
Adjust the time window do display an open response from MATH4 in the middle of the leftmost division of the acquisition window.
Acquire the MATH4 with IConnect
Using IConnect save the resulting waveform as Ref_Tdd44.wfm
Save instrument setup in a file (DP5_7_RL_P3.stp)

Measure the Return Loss

Connect the test fixtures measurement instrument (if not connected already)
Carefully plug the cable into the test fixtures

Perform measurements of the return loss of lane0 at side A:

Recall DP5_7_RL_P1.stp and press the RUN/STOP button
Acquire MATH1 waveform with IConnect and save it as Tdd22.wfm
Using S-parameter computational tool load Ref_Tdd11.wfm and Tdd11.wfm into IConnect and compute the return loss.
Save the waveform as Sdd11.wfm
Using IConnect cursors measure the acquired waveform to test the compliance limits.
The compliance test limits for RBR and HBR are shown in figure 5.7.1 and figure 5.7.2 respectively

Perform measurements of the return loss of lane1 at side A:

Recall DP5_7_RL_P2.stp and press the RUN/STOP button
Acquire MATH2 waveform with IConnect and save it as Tdd22.wfm
Using S-parameter computational tool load Ref_Tdd22.wfm and Tdd22.wfm into IConnect and compute the return loss.
Save the waveform as Sdd22.wfm
Using IConnect cursors measure the acquired waveform to test the compliance limits.
The compliance test limits for RBR and HBR are shown in figure 5.7.1 and figure 5.7.2 respectively.

Perform measurements of the return loss of lane0 at side B:

Recall DP5_7_RL_P3.stp and press the RUN/STOP button
Acquire MATH3 waveform with IConnect and save it as Tdd33.wfm
Using S-parameter computational tool load Ref_Tdd33.wfm and Tdd33.wfm into IConnect and compute the return loss.
Save the waveform as Sdd33.wfm
Using IConnect cursors measure the acquired waveform to test the compliance limits.
The compliance test limits for RBR and HBR are shown in figure 5.7.1 and figure 5.7.2 respectively

Perform measurements of the return loss of lane1 at side B:

Recall DP5_7_RL_P4.stp and press the RUN/STOP button

Acquire MATH4 waveform with IConnect and save it as Tdd44.wfm

Using S-parameter computational tool load Ref_Tdd22.wfm and Tdd44.wfm into IConnect and compute the return loss.

Save the waveform as Sdd44.wfm

Using IConnect cursors measure the acquired waveform to test the compliance limits.

The compliance test limits for RBR and HBR are shown in figure 5.7.1 and figure 5.7.2 respectively.

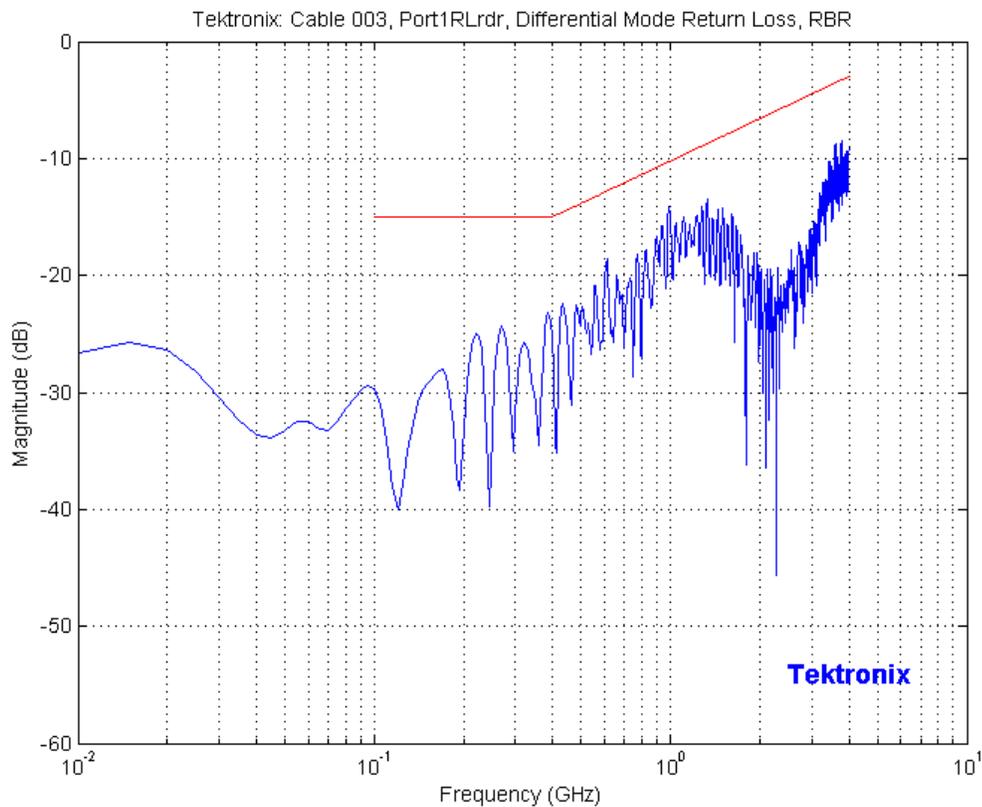


Figure 5.7.1 Return Loss testing for RBR cable assembly

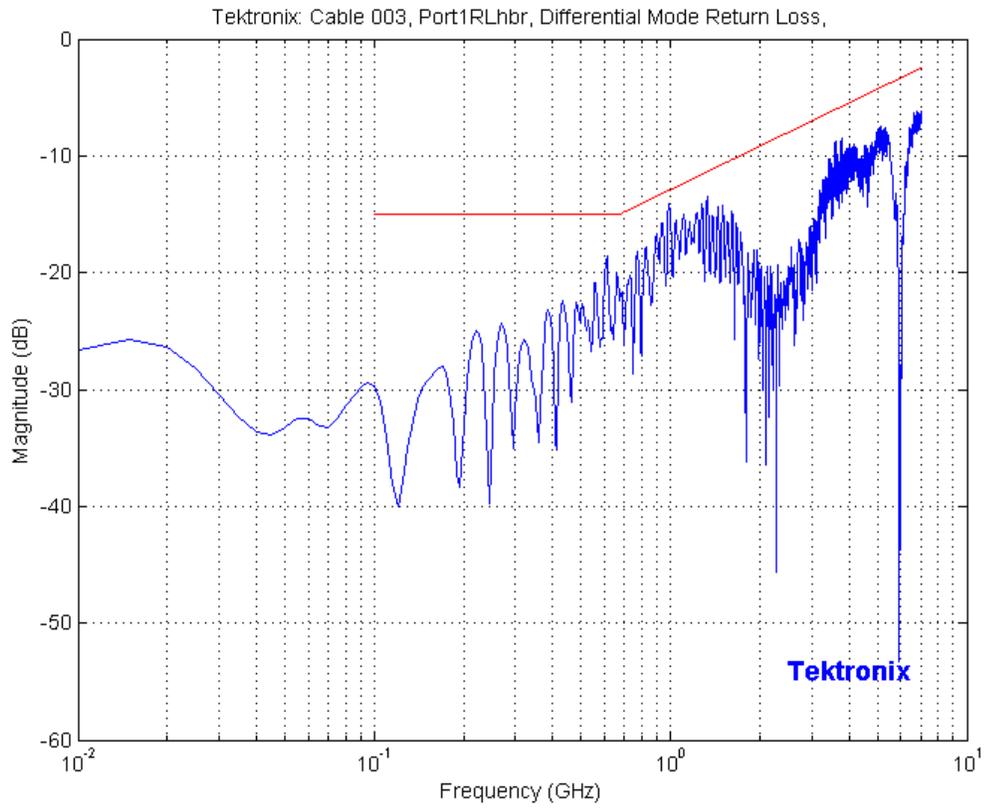


Figure 5.7.2 Return Loss testing for HBR cable assembly

Appendix A – Differential TDR Alignment and Acquisition Setup

Mixed Mode TDR Channel Alignment with Independent TDR Source

Introduction

This deskew procedure utilizes an independent acquisition source and assumes availability of two TDR sampling modules (80E04, 80E08, or 80E10). It can also be used with one TDR (80E04, 80E08, or 80E10), and one dual sampling module (80E03 or 80E09). It aligns both samplers and TDR steps allowing measuring mixed mode S-parameters. The procedure starts with the alignment of the samplers and concludes with alignment of the acquisition channels.

Required Equipment

- One sampling oscilloscope mainframe (TDS8000, TDS/CSA/DSA8200).
- Two TDR sampling modules (80E04, 80E08, or 80E10);
- Four matched SMA cables
- One SMA barrel (female-to-female) adaptor.



Figure 1: Equipment required to perform mixed mode deskew procedure. The wrist strap is important for ESD protection and a calibrated torque wrench is recommended to protect the connectors and to get good repeatability.

Match samplers to the ends of the cables

The purpose of this step is to set the samplers on each channel so that an input into the open end of each cable arrives at the sample gate at precisely the same time. This step compensates for cable and sampler differences. First stage is alignment of the channels 1-3 using the channel 4 as an independent TDR source, and then aligning acquisition of the channel 4 with respect to already aligned channel 3 using channel one as another independent source.¹¹ The deskew procedure is to be performed in *rho* mode.

Connect SMA cables to the sampling modules of the oscilloscope. For the best results, it is desired that the SMA cables used in the measurements have approximately the same quality and length (matched within 20ps).

Connect channel 1 and channel 4 with SMA barrel, activate TDR step on channel 4 and acquisition on channel 1 (see Figure 2).

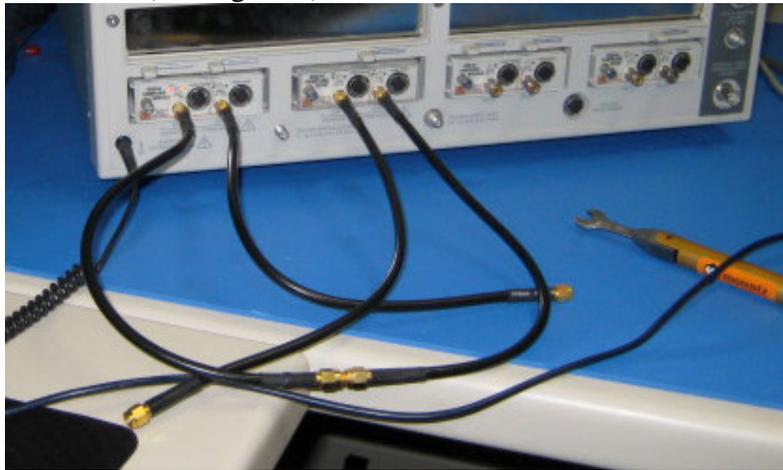


Figure 2: C1 is connected to C4 with SMA barrel. The TDR step is generated on C4 and acquired using C1.

Adjust the horizontal position and scale to get the rising edge on screen with good resolution (20ps/div). Record length should have the maximum number of 4000 points. Save channel one (C1) waveform as a reference trace. Channel 2 and 3 will be aligned with respect to it.

Connect channel two (C2) to the channel four (C4) using SMA barrel, and display C2 on the screen.

Turn on the delay measurement to measure the time difference between the rising edge on the reference trace and the rising edge of C2 as shown in Figure 3.

¹¹ When only one TDR and one sampling modules are available another TDR channel can be used as an independent TDR source.

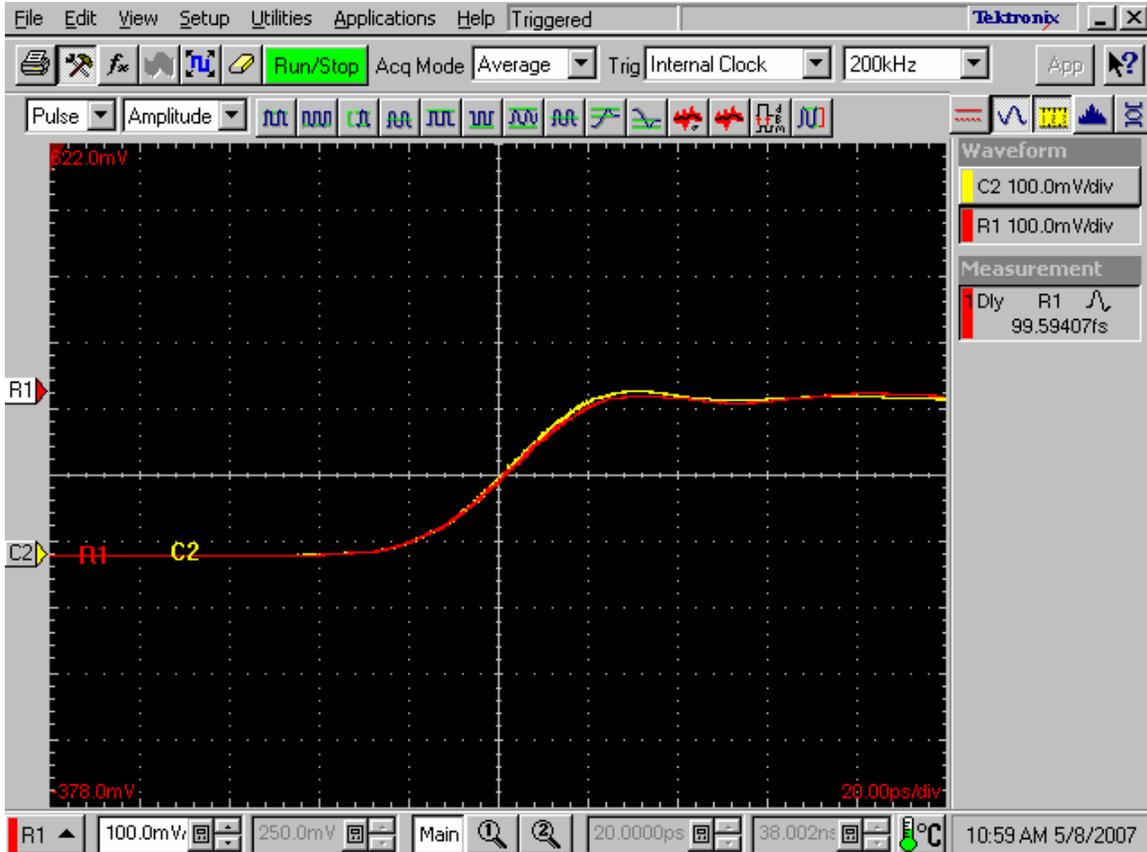


Figure 3: Delay measurements between the reference (R1) acquired from the channel one and the channel two (C2). It has to be the minimum for the best deskew value.

Adjust the channel deskew value in the *Vertical* menu of the *Setups* dialog until a delay value within 1ps is achieved as show

Repeat steps 5-7 for the C3.

Now, when the acquisition of C1 through C3 is aligned, the same approach can be used to align C4. For this purpose generate a new reference by using the step of C1 and acquiring it on C3. C3 has to be connected to C1 with the SMA barrel.

Repeat steps 5-7 for the C4 using acquired reference from C3.

Now, all four acquisition channels have been deskewed within 1ps.

Match the TDR pulses to the ends of the cables

The purpose of this step is to adjust the TDR pulses so they arrive at the ends of the cables at precisely the same time. The deskew procedure has to be performed separately for odd and even TDR steps when 80E04 modules are used¹². This section describes only odd mode TDR step deskew. The deskew procedure has to be performed in *rho* mode.

¹² Odd mode (differential) is generated when TDR steps set to opposite polarity, while the even mode (common) is generated when both steps are of the same polarity.

Disconnect the SMA barrel and turn on TDR pulses of the appropriate polarity for each channel (C1 and C2). Use the differential TDR preset selection to activate odd mode. Adjust the horizontal position and scale so that the pulses as they arrive at the ends of the cables are visible on screen with good resolution. (Use *Average* mode and vectored display, a set time scale to 20ps/div).

Turn on the delay measurement to measure the time difference between the two pulse edges.

Adjust the *Step Deskew* in TDR menu to minimize the time difference between the C1 and C2 pulses. You might want to activate *Fine* button to reduce the increment of deskew as shown in Figure 4.

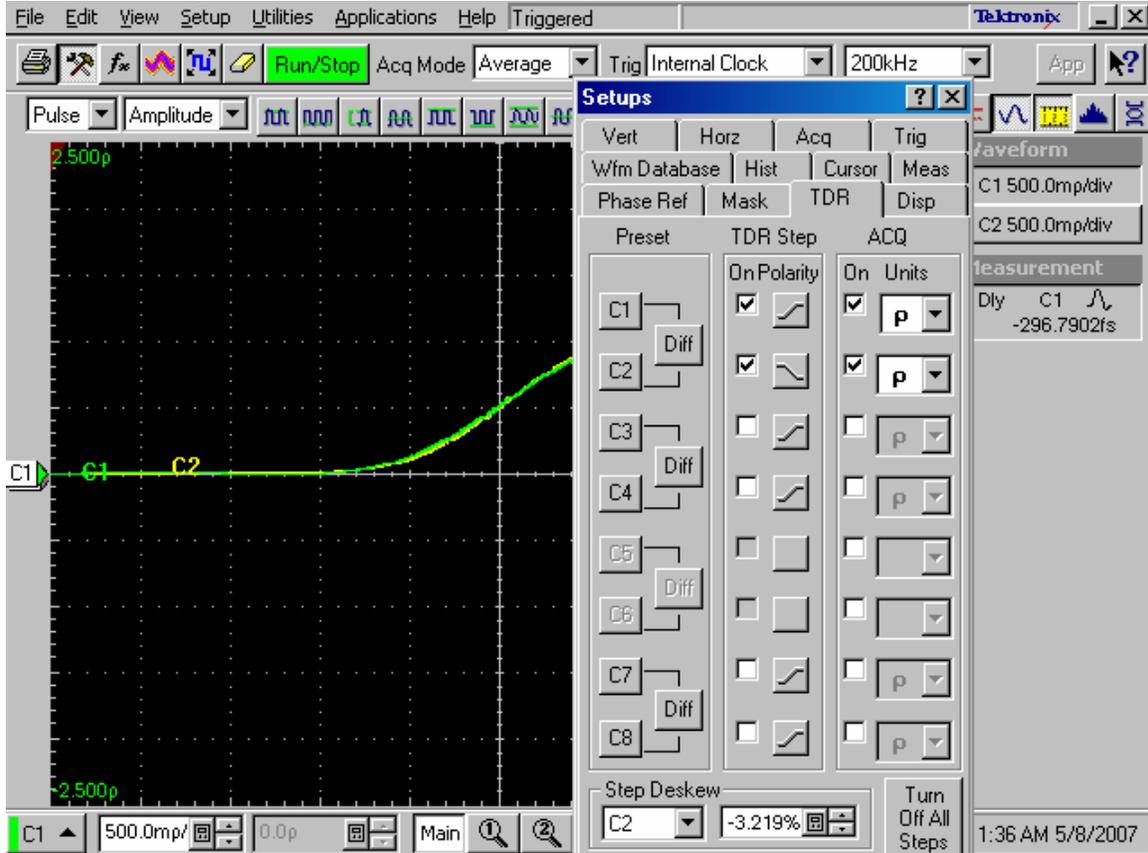


Figure 4 Differential TDR step deskew. The channels C1 and C2 are aligned within ~300fs.

Repeat steps 1-4 for C3 and C4, and save the instrument setup.

Repeat steps 1-5 in even mode if desired.

The instrument should now be set up to accurately make differential or common mode TDR measurements.

Appendix B - TDNA Measurement System Accuracy

Table B.1 summarizes characteristics of the TDNA system used for passive and active cable tests. The system is based on a standard 80E04 module that allows to perform both return and insertion loss measurements from time domain data.

Table B.1 TDR System Characteristics with a standard 80E04 module

Characteristics	Value
Input Impedance	50 \pm 0.5 Ω
TDR Step Amplitude	250 mV
TDR System Reflected Rise Time (10% to 90%)	\leq 35 ps
TDR System Incident Rise Time (10% to 90%)	\leq 28 ps (typical)
TDR Step Maximum Repetition Rate	200 kHz
DC Vertical Range Accuracy within 2°C of Compensated Temperature	\pm [2 mV + 0.007 (Offset) + 0.02 (Vertical Value-Offset)]
RMS Noise (typical/maximum)	600 μ V/ \leq 1.2 mV
Bandwidth	20GHz
Dynamic Range	50-60dB

Appendix C – Reference Waveforms Acquisition Procedure

The purpose of this procedure is to explain how the calibration waveform can be acquired if all tests need to be run for two lanes of a single cable. This procedure can be used to automate the calibration process and consists of 8 general steps before the data acquisition and analysis can be run on the cable. If the same pairs of the cable are to be tested, then the references are not need to be reacquired and the data acquisition process can be repeated for the next cable. It is assumed that the deskew procedure is done.

The following steps need to be performed:

All SMA are open. The setup for test 5.7 can be reused with all sources are “On.” The SMA cables are simply connected to the instrument and left open as shown in Figure C1. The open references can be acquired in this setup (Ref_Tdd11.wfm; Ref_Tdd22.wfm; Ref_Tdd33.wfm; Ref_Tdd44.wfm).

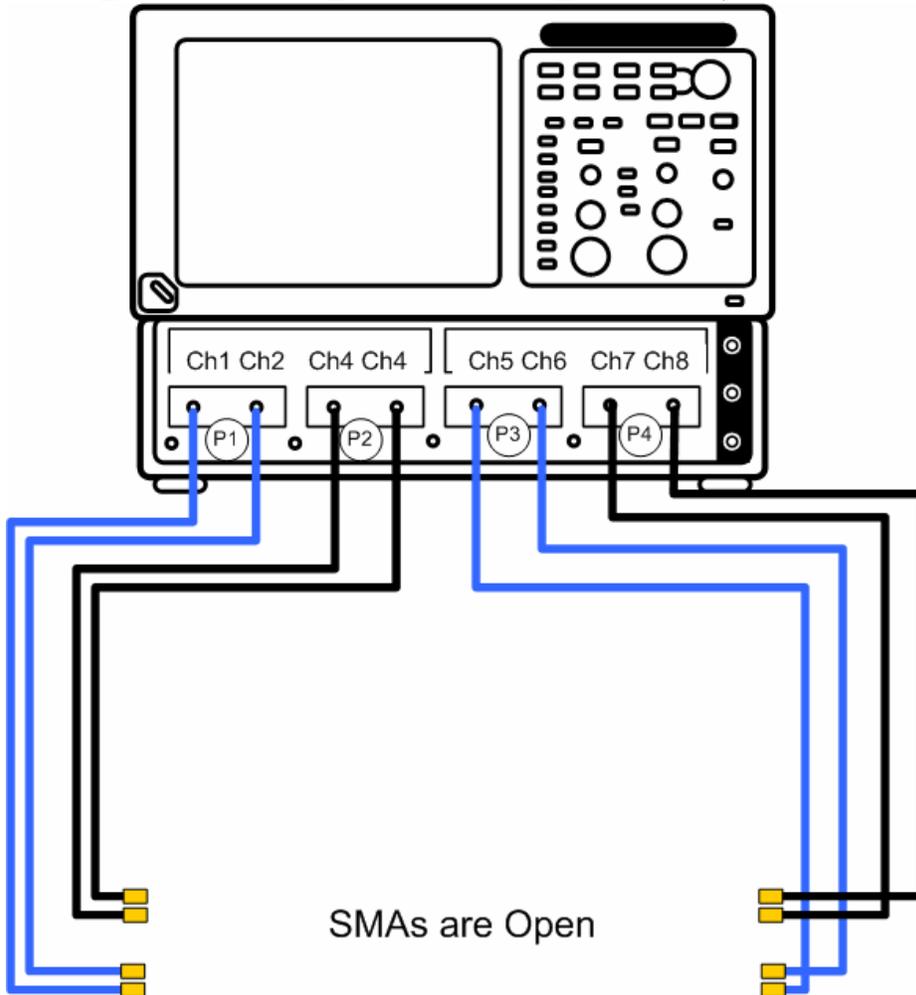


Figure C1 Step 1 of the calibration waveform acquisition. The SMA cables are left open, and the following waveforms are acquired: Ref_Tdd11.wfm; Ref_Tdd22.wfm; Ref_Tdd33.wfm; Ref_Tdd44.wfm.

All SMA are open. The setup for test 5.7 can be reused with all sources are “Off.” The SMA cables are simply connected to the instrument and left open as shown in Figure C2. The noise references can be acquired in this setup (Noise_Tdd22.wfm; Noise_Tdd33.wfm; Noise_Tdd44.wfm).

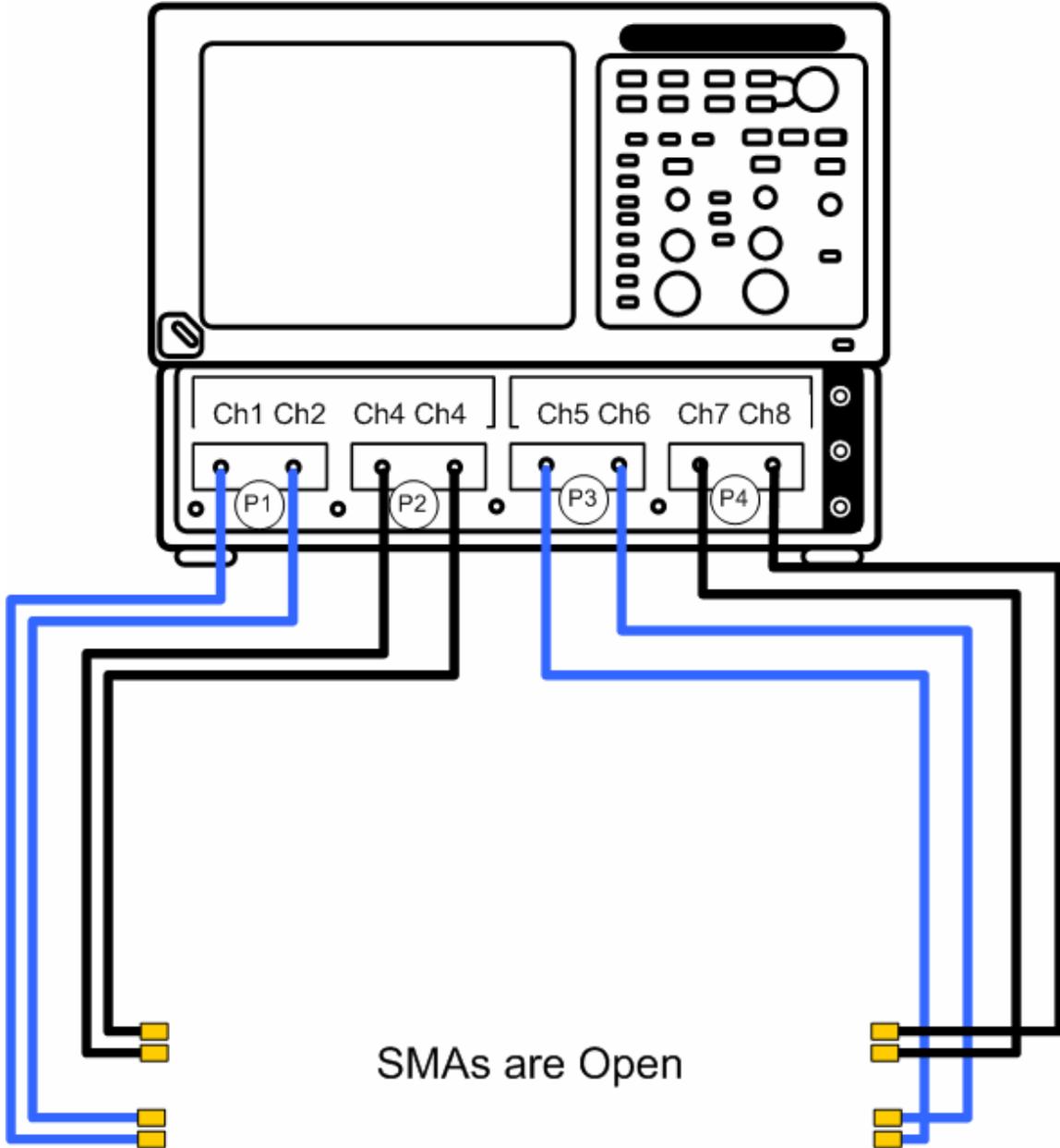


Figure C2 Step 2 of the calibration waveform acquisition. The SMA cables are left open, and the following waveforms are acquired: Noise_Tdd22.wfm; Noise_Tdd33.wfm; Noise_Tdd44.wfm.

In this step differential Port 1 (Ch1 and Ch2) is connected to differential Port 3 (Ch5 and Ch6), and differential Port 2 (Ch3 and Ch4) is connected to differential Port 4 (Ch7 and Ch8). The setup for test 5.6 can be reused with differential Port 1 and Port 2 sources “On.” The SMA cables are simply connected to each other using SMA barrels as shown in Figure C3. The thru references (Ref_Tdd31.wfm; Ref_Tdd42.wfm) and the TDRskew number can be acquired in this setup.

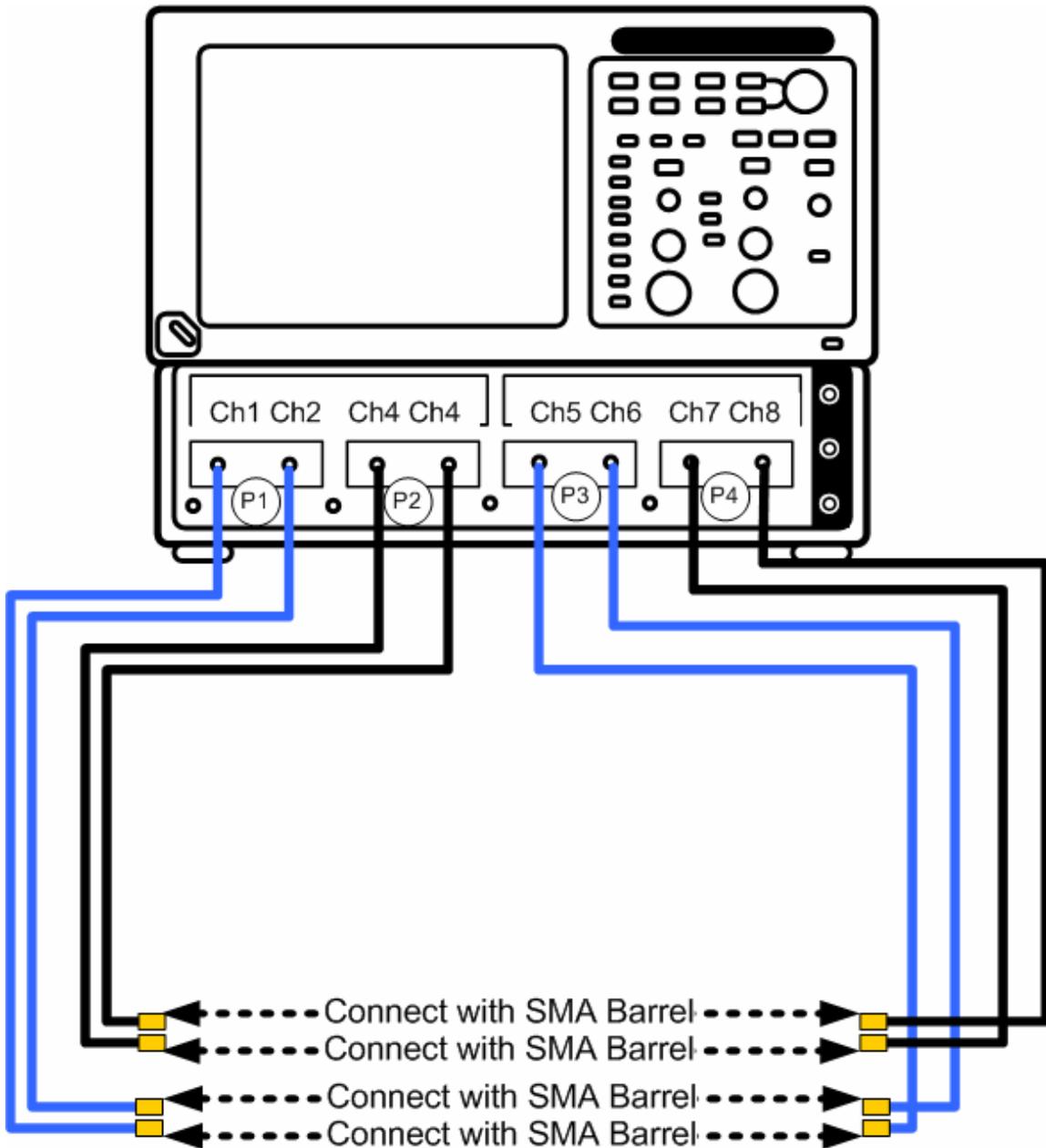


Figure C3 Step 3 of the calibration waveform acquisition. Port 1 (Ch1 and Ch2) is connected to differential Port 3 (Ch5 and Ch6), and differential Port 2 (Ch3 and Ch4) is connected to differential Port 4 (Ch7 and Ch8), and the following waveforms are acquired: Ref_Tdd31.wfm; Ref_Tdd42.wfm.

This step is similar to the previous one but now the differential Port 1 (Ch1 and Ch2) is connected to differential Port 2 (Ch3 and Ch4), and differential Port 3 (Ch5 and Ch6) is connected to differential Port 4 (Ch7 and Ch8) with SMA barrels. The setup for test 5.3 can be reused with differential Port 1 and Port 3 sources “On.” The SMA cables are simply connected to each other using SMA barrels as shown in

Figure C4. The thru references (Ref_Tdd21.wfm; Ref_Tdd43.wfm) can be acquired in this setup.

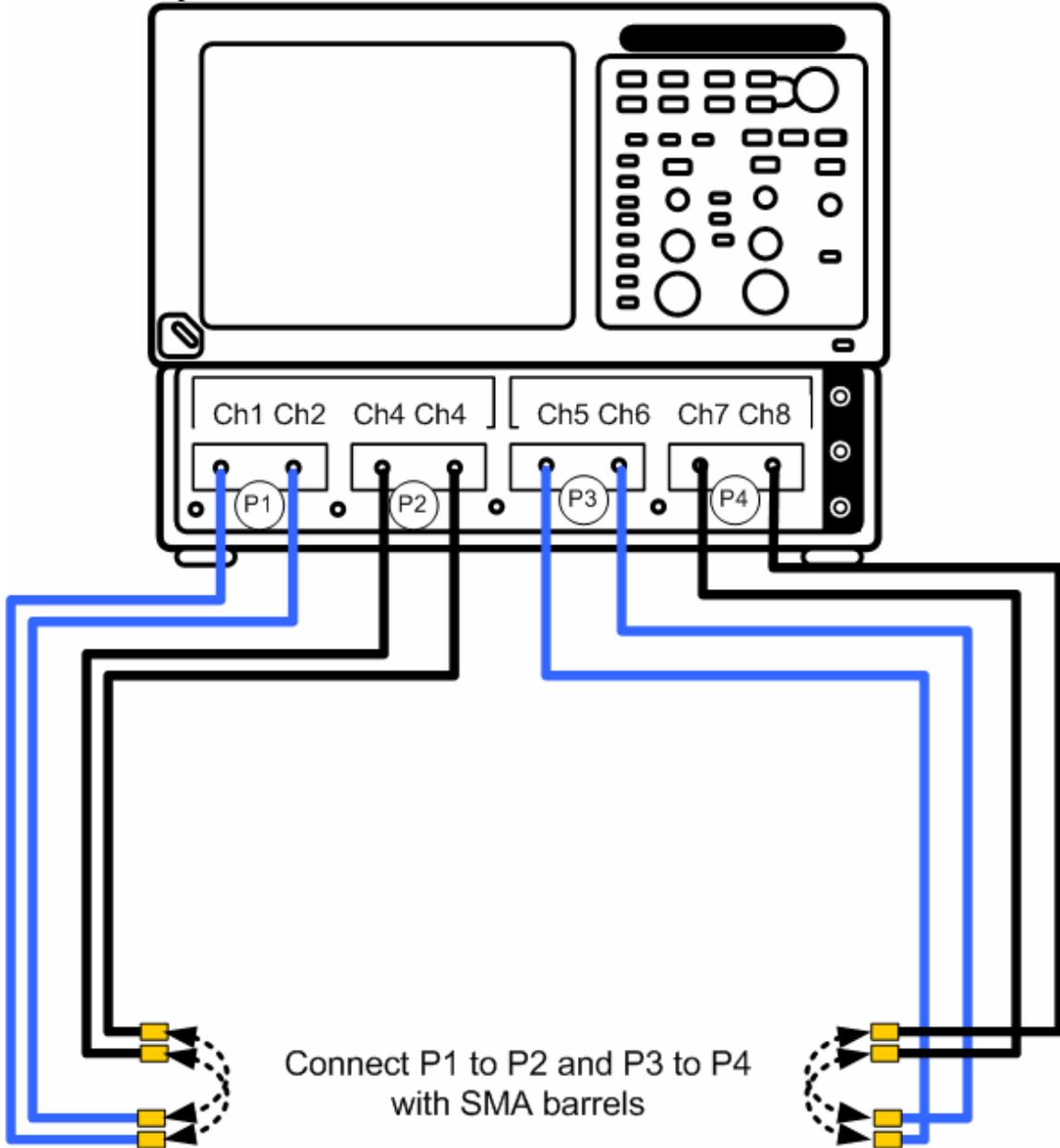


Figure C4 Step 4 of the calibration waveform acquisition. The differential Port 1 (Ch1 and Ch2) is connected to differential Port 2 (Ch3 and Ch4), and differential Port 3 (Ch5 and Ch6) is connected to differential Port 4 (Ch7 and Ch8) with SMA barrels, and the following waveforms are acquired: Ref_Tdd21.wfm; Ref_Tdd43.wfm.

In this step the reference for far end noise measurements is acquired. The differential Port 1 (Ch1 and Ch2) is connected to differential Port 4 (Ch7 and Ch8) with SMA barrels. The setup for test 5.3 can be reused with differential Port 1 and Port 4 sources "On." The SMA cables are simply connected to each other using SMA barrels as shown in Figure C5. The thru reference (Ref_Tdd41.wfm) can be acquired in this setup.

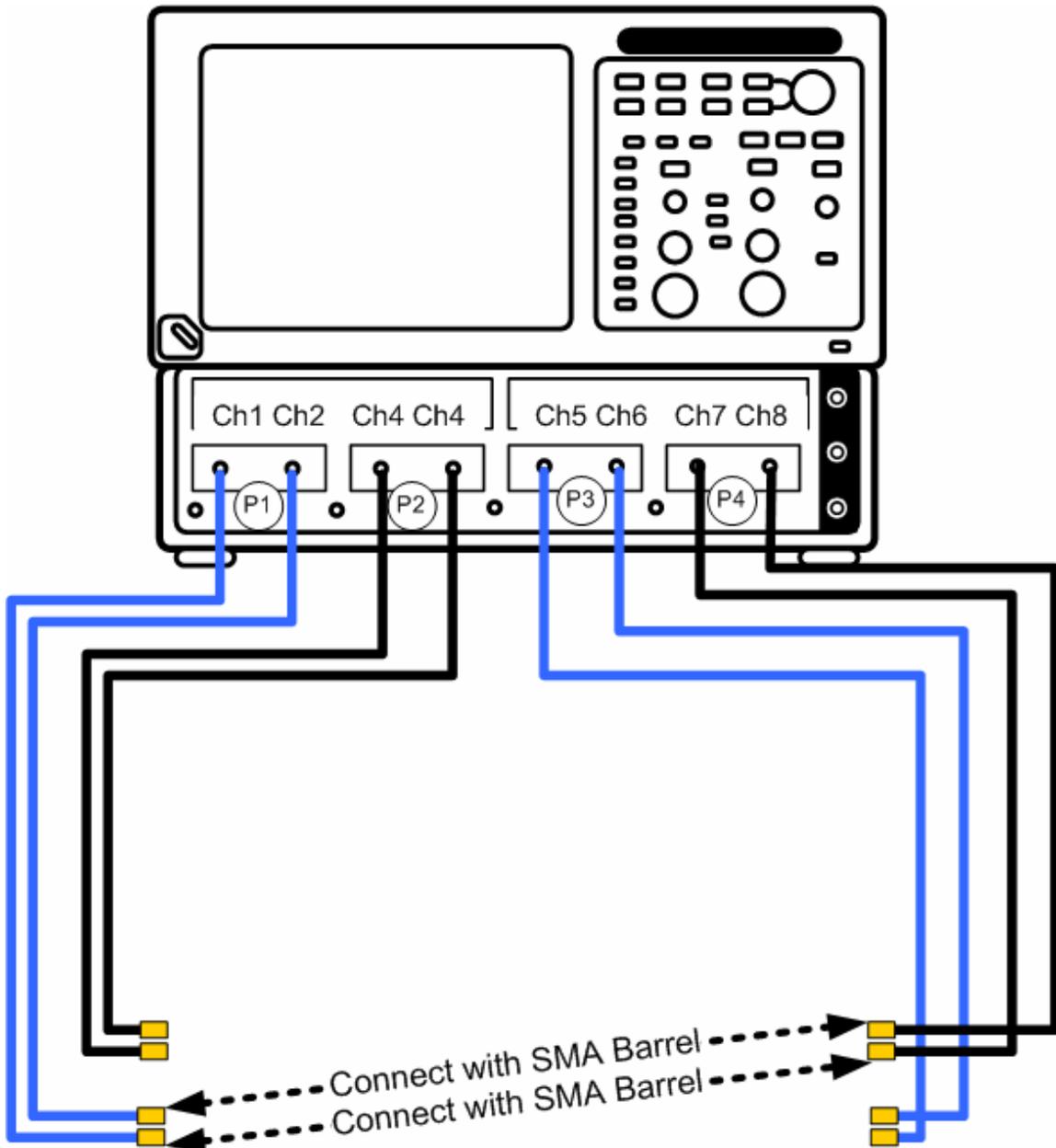


Figure C5 Step 5 of the calibration waveform acquisition. The differential Port 1 (Ch1 and Ch2) is connected to differential Port 4 (Ch7 and Ch8) with SMA barrels, and the following waveform is acquired: Ref_Tdd41.wfm.

In this step the 100 Ohm calibration references are acquired by connecting the 50 cal standard to each channel at the SMA interface. The setup for Cable and Connector impedance measurements can be used. The calibration references being acquired: Cal100Ohm_ZTdd11.wfm, Cal100Ohm_ZTdd22.wfm, Cal100Ohm_ZTdd33.wfm, and Cal100Ohm_ZTdd44.wfm.

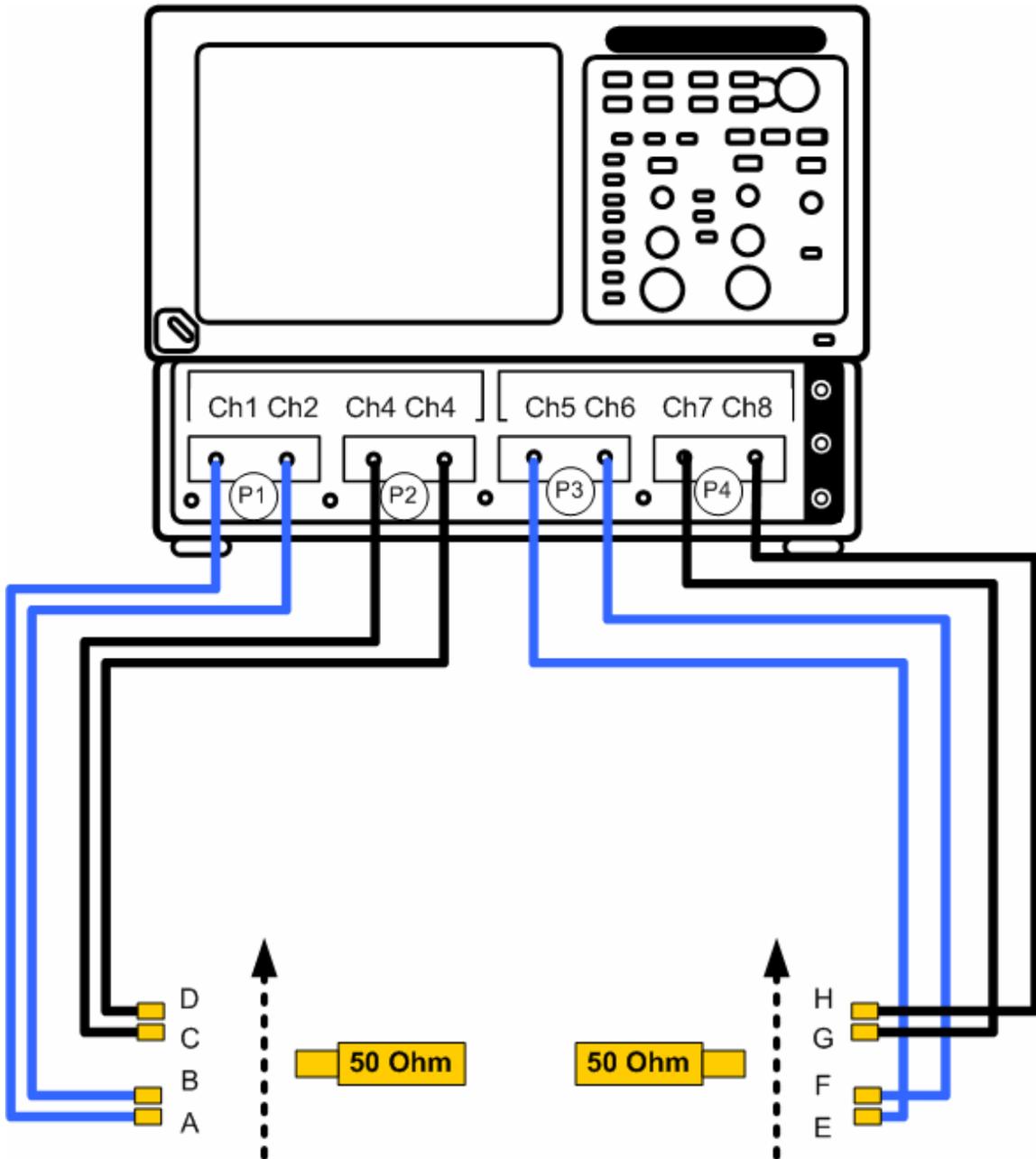


Figure C6 Step 6 of the calibration waveform acquisition. 100 Ohm calibration references are acquired by connecting the 50 cal standard to each channel at the SMA interface. The calibration references being acquired: Cal100Ohm_ZTdd11.wfm, Cal100Ohm_ZTdd22.wfm, Cal100Ohm_ZTdd33.wfm, and Cal100Ohm_ZTdd44.wfm

In this step the fixture open calibration references are acquired by connecting the test fixtures at the SMA interface as shown in Figure C7. The fixtures are left open and this measurement provides references for mask position for impedance test. The setup for Cable and Connector impedance measurements can be used with all ports are “On”. The calibration references being acquired: FixOpen_ZTdd11.wfm; FixOpen_ZTdd22.wfm; FixOpen_ZTdd33.wfm; FixOpen_ZTdd44.wfm.

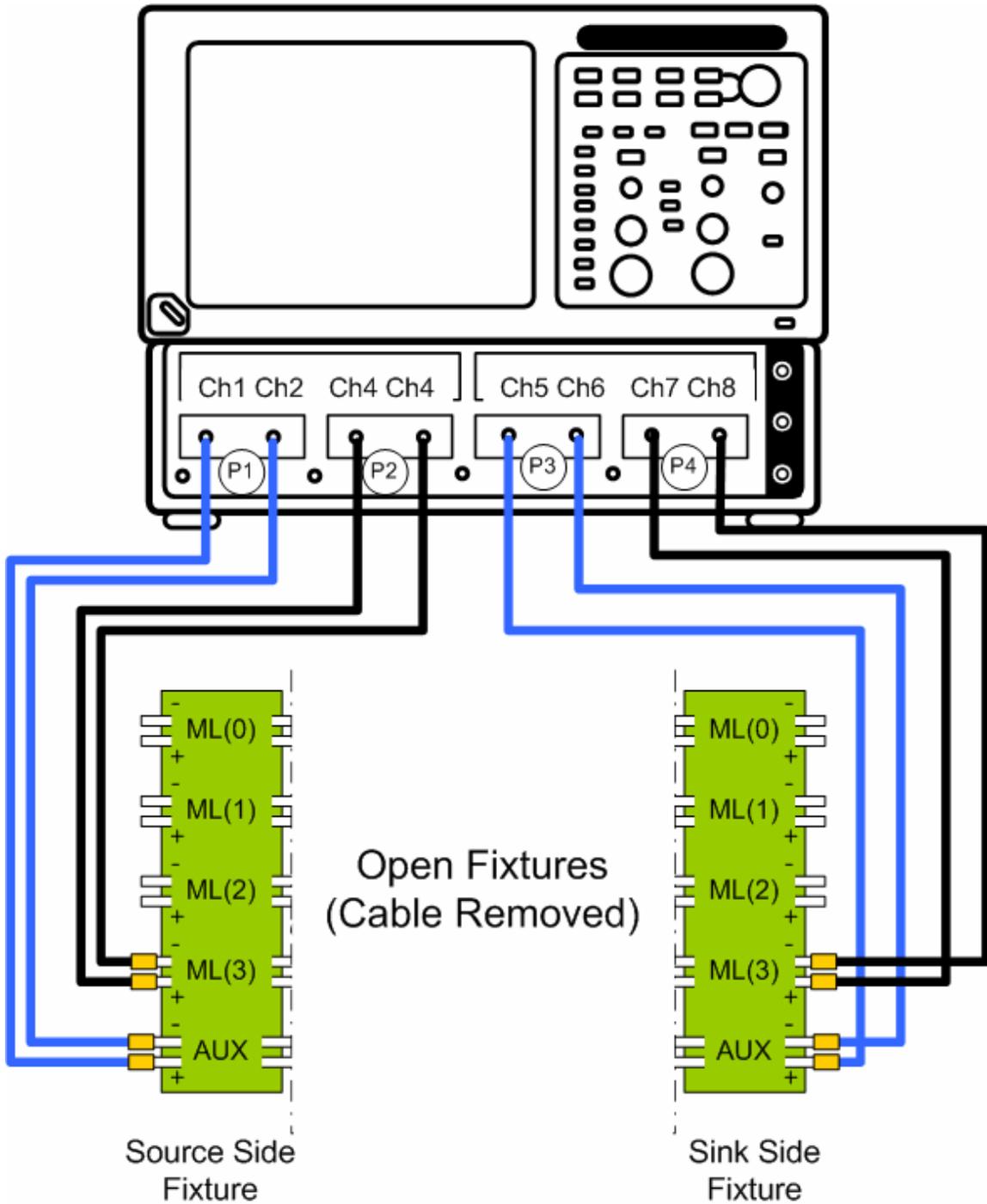


Figure C7 Step 7 of the calibration waveform acquisition. The fixtures are left open and this measurement provides references for mask position for impedance test. The calibration references being acquired: FixOpen_ZTdd11.wfm; FixOpen_ZTdd22.wfm; FixOpen_ZTdd33.wfm; FixOpen_ZTdd44.wfm.

The last step: connect the cable under test (Figure C8) and start the acquisition.

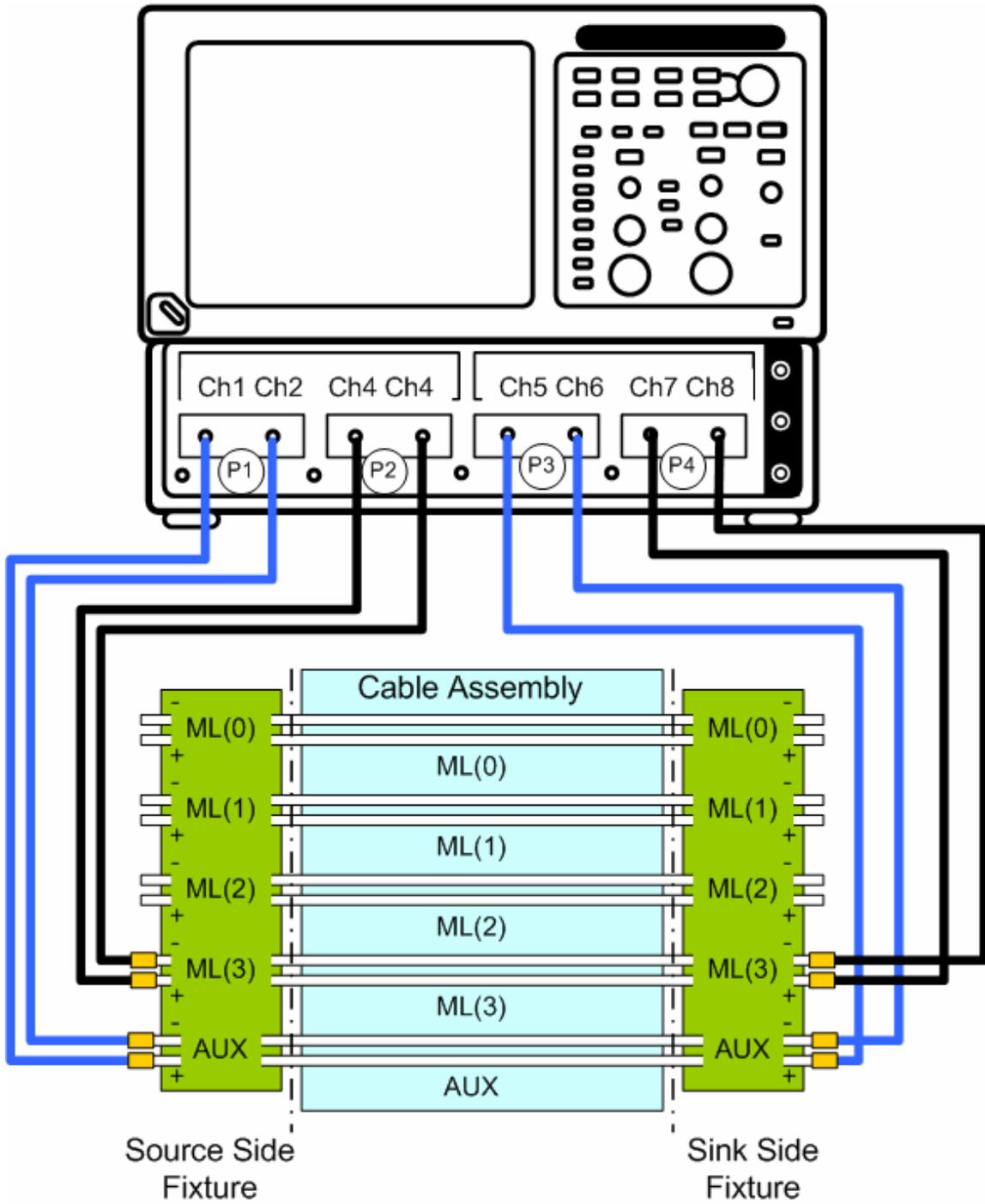


Figure C8 Cable under test is connected to the test fixtures.