CALIBRATION PROCEDURE

NI PXIe-5694

This document contains the verification and adjustment procedures for the National Instruments PXIe-5694 IF conditioning module (NI 5694). Refer to `ni.com/calibration` for more information about calibration solutions.

Contents

NATIONAL INSTRUMENTS™

Software

Calibrating the NI 5694 requires you to install the following software on the calibration system:

- NI-RFSA version 14.1 or later
- NI Spectral Measurements Toolkit version 2.6 or later

You can download all required software from `ni.com/downloads`.

NI-RFSA supports programming the calibration procedures in the LabVIEW, C, and LabWindows™/CVI™ application development environments (ADEs). When you install NI-RFSA, you need to install support only for the ADE that you intend to use.

Documentation

You might find the following documents helpful as you perform the calibration procedure:

- *NI PXIe-5694 Getting Started Guide*
- *NI PXIe-5694 Specifications*
- *NI RF Vector Signal Analyzers Help*

The latest versions of these documents are available on `ni.com/manuals`.

Test Equipment

Table 1 lists the equipment NI recommends for the performance verification and adjustment procedures. If the recommended equipment is not available, select a substitute using the minimum requirements listed in the table.

Table 1. Recommended Equipment for NI 5694 Calibration

Equipment	Recommended Model	Where Used	Minimum Requirements
Power meter	Anritsu ML2438A	Characterizing RF source power Characterizing cable loss Verifying third-order intercept point out-of-band Adjusting IF gain for bypass path Adjusting IF gain Adjusting IF flatness	Display resolution: ≤0.01 dB Settling: ±0.1% Instrumentation accuracy: <±0.5% Noise, zero set, and drift: ≤±0.5% full-scale (lowest range) Reference power uncertainty: ≤±0.9% Reference output VSWR: <1.04:1
Power sensor (quantity: 2)	Anritsu MA247XD	Characterizing RF source power Characterizing cable loss Verifying third-order intercept point out-of-band Adjusting IF gain for bypass path Adjusting IF gain Adjusting IF flatness	Power range: -60 dBm to 20 dBm Frequency range: 10 MHz to 18 GHz Input VSWR: 10 MHz to 50 MHz .... <1.90:1 50 MHz to 2 GHz .... <1.12:1 2 GHz to 12.4 GHz .... <1:22:1 12.4 GHz to 18 GHz .... <1:25:1 Linearity: -60 dBm to 20 dBm............. <1.8% Calibration factor uncertainty: 10 MHz to 50 MHz .... <1.9% 50 MHz to 500 MHz .... <1.5% 500 MHz to 7 GHz............... <1.5% 7 GHz to 12.4 GHz .... <1.9% 12.4 GHz to 18 GHz .... <2.3%

Table 1. Recommended Equipment for NI 5694 Calibration (Continued)

Equipment	Recommended Model	Where Used	Minimum Requirements
IF digitizer	NI PXIe-5622	Adjusting IF gain for bypass path Adjusting IF gain Adjusting IF flatness	198941D-0XL
Signal generators (quantity: 2, *RF Source 1* and *RF Source 2*)	Anritsu MG3692C Options 2A, 3, 4, 15A, and 22	Characterizing RF source power Characterizing cable loss Verifying third-order intercept point out-of-band Adjusting IF gain for bypass path Adjusting IF gain Adjusting IF flatness	Frequency range: 8 MHz to 270 MHz Leveled power: -115 dBm to 18 dBm Power accuracy: ±1.5 dB Harmonics (typical): 0.1 MHz to ≤10 MHz ....<-30 dBc >10 MHz to ≤100 MHz ....<-40 dBc >100 MHz to ≤2.2 GHz........<-50 dBc >2.2 GHz to ≤20 GHz ....<-30 dBc Nonharmonic spurious: 0.1 MHz to ≤10 MHz ....<-30 dBc >10 MHz to ≤2.2 GHz..........<-60 dBc >2.2 GHz to ≤20 GHz ....<-60 dBc Output VSWR: <2.0:1 (typical)
Spectrum analyzer	Rohde & Schwarz FSU26	Characterizing RF source power Verifying third-order intercept point out-of-band	Frequency range: 10 MHz to 3.6 GHz Noise floor: <-152 dBm/Hz Third-order intercept point (entire frequency range): >10 dBm
SMA (m)-to-SMA (m) semi flexible cable	NI 190412B-04	Characterizing RF source power Characterizing cable loss	—

Table 1. Recommended Equipment for NI 5694 Calibration (Continued)

Equipment	Recommended Model	Where Used	Minimum Requirements
SMA (m)-to-SMA (m) cable (quantity: 4)	MegaPhase G916-SISI-36	Characterizing RF source power Characterizing cable loss Verifying third-order intercept point out-of-band Adjusting IF gain for bypass path Adjusting IF gain Adjusting IF flatness	Length: 36 in. Frequency range: DC to 18 GHz Insertion loss: ≤2 dB at 18 GHz Impedance: 50 Ω VSWR: ≤1.35:1 at 18 GHz
Low-frequency combiner	Mini Circuits ZFSC-2-5-S+	Characterizing RF source power Verifying third-order intercept point out-of-band	Frequency range: 10 MHz to 1.5 GHz Isolation: 10 MHz to 100 MHz .... ≥15 dB 100 MHz to 750 MHz .... ≥20 dB Insertion loss: 10 MHz to 100 MHz .... ≤3.6 dB 100 MHz to 750 MHz .... ≤4.0 dB Connectors: SMA (f)
SMA (m)-to-SMA (f) 10 dB attenuator (quantity: 2)	Huber+Suhner 6610_SMA-50-1/199N	Characterizing RF source power Verifying third-order intercept point out-of-band	Frequency range: 10 MHz to 18 GHz Attenuation: 10 dB (nominal) Power rating: 2 W average Impedance: 50 Ω VSWR: DC to 4 GHz .... ≤1.15:1

Table 1. Recommended Equipment for NI 5694 Calibration (Continued)

Equipment	Recommended Model	Where Used	Minimum Requirements
3.5 mm (m)-to- 3.5 mm (m) adapter	Huber+Suhner 32_PC35-50-0-2/ 199_NE	Verifying third-order intercept point out-of-band Adjusting IF gain for bypass path Adjusting IF gain Adjusting IF flatness	Frequency range: DC to 33 GHz Impedance: 50 Ω Return loss: DC to 1.5 GHz......................≥35 dB 1.5 GHz to 6.0 GHz.............≥30 dB 6.0 GHz to 18.0 GHz...........≥20 dB
3.5 mm (f)-to- 3.5 mm (f) adapter	Huber+Suhner 31_PC35-50-0-2/ 199_N	Characterizing cable loss	Frequency range: DC to 18 GHz Impedance: 50 Ω Return loss: DC to 1.5 GHz......................≥35 dB 1.5 GHz to 6.0 GHz.............≥30 dB 6.0 GHz to 18.0 GHz...........≥20 dB
BNC (m)-to- BNC (m) cable (quantity: 3)	—	Verifying third-order intercept point out-of-band Adjusting IF gain for bypass path Adjusting IF gain Adjusting IF flatness	Length: 36 in. Impedance: 50 Ω

Table 1. Recommended Equipment for NI 5694 Calibration (Continued)

Equipment	Recommended Model	Where Used	Minimum Requirements
Power splitter (2 resistor type)	Aeroflex/Weinschel 1593	Characterizing RF source power Characterizing cable loss Adjusting IF gain for bypass path Adjusting IF gain Adjusting IF flatness	Frequency range: DC to 26.5 GHz Amplitude tracking: <0.25 dB Phase tracking: <4° Insertion loss: ≤8.5 dB (6 dB, nominal) Power rating: 1 W VSWR: DC to 270 MHz....... ≤1.25:1 Equivalent output VSWR: DC to 270 MHz................... ≤1.25:1 Connectors: 3.5 mm (f)
Torque wrench	—	—	For SMA connectors: 0.565 N · m (5 lb · in.) For 3.5mm connectors: 0.90 N · m (8 lb · in.)

Test Conditions

The following setup and environmental conditions are required to ensure the NI 5694 meets published specifications.

- Keep cabling as short as possible. Long cables and wires act as antennas, picking up extra noise that can affect measurements.
- Verify that all connections, including front panel connections and screws, are secure.
- Maintain an ambient temperature of 23 °C ±5 °C.
- Keep relative humidity between 10% and 90%, noncondensing.
- Allow a warm-up time of at least 30 minutes after the chassis is powered on and NI-RFSA is loaded and recognizes the NI 5694. The warm-up time ensures that the NI 5694 and test instrumentation are at stable operating temperature.
- In each verification procedure, insert a delay between configuring all devices and acquiring the measurement. This delay may need to be adjusted depending on the instruments used but should always be at least 1,000 ms for the first iteration, 1,000 ms when the power level changes, and 100 ms for each other iteration.
- Plug the PXI Express chassis and the calibrator into the same power strip to avoid ground loops.
- Use a torque wrench appropriate for the type of RF connector that you are using. NI recommends a 0.565 N · m (5 lb · in.) wrench for SMA connectors and a 0.90 N · m (8 lb · in.) wrench for 3.5 mm connectors.
- Ensure that the PXI Express chassis fan speed is set to HIGH, that the fan filters, if present, are clean, and that the empty slots contain filler panels. For more information, refer to the *Maintain Forced-Air Cooling Note to Users* document, available at `ni.com/manuals`.

Initial Setup

Refer to the *NI 5694 Getting Started Guide* for information about how to install the NI-RFSA software, the NI 5694 hardware, and how to configure the NI 5694 in Measurement & Automation Explorer (MAX).

As-Found and As-Left Limits

The as-found limits are the published specifications for the NI 5694. NI uses these limits to determine whether the NI 5694 meets the device specifications when it is received for calibration.

The as-left limits are equal to the published NI specifications for the NI 5694, less guard bands for measurement uncertainty, temperature drift, and drift over time. NI uses these limits to reduce the probability that the instrument is no longer calibrated at the end of the calibration cycle.

Characterization

Complete each of the following procedures to characterize the test system. The information obtained in characterization is used when verifying the system behavior.

Caution The connectors on the device under test (DUT) and test equipment are fragile. Perform the steps in these procedures with great care to prevent damaging any DUTs or test equipment.

Determining Power Splitter Reference Output

You must designate one of the two power splitter outputs as the reference output. Use only this output as the reference output for all procedures.

Calibrating Power Sensor Zero Settings

Complete this procedure before beginning any characterization process to ensure that the power sensor returns appropriate readings.

1. Connect channel A of the power meter to power sensor A.
2. Connect channel B of the power meter to power sensor B.
3. Zero and calibrate the power sensor using the built-in functions in the power meter.

Characterizing RF Source Power

Complete this procedure to characterize the output power of the RF sources through the cables, attenuators, and combiner. The procedures listed in *Verifying Third-Order Intercept Point Out-of-Band* require that the power levels of the sources be in accord with the specification definition.

Synchronizing the Signal Generators

Complete this procedure to synchronize RF source 1, RF source 2, and the spectrum analyzer to the same 10 MHz clock reference.

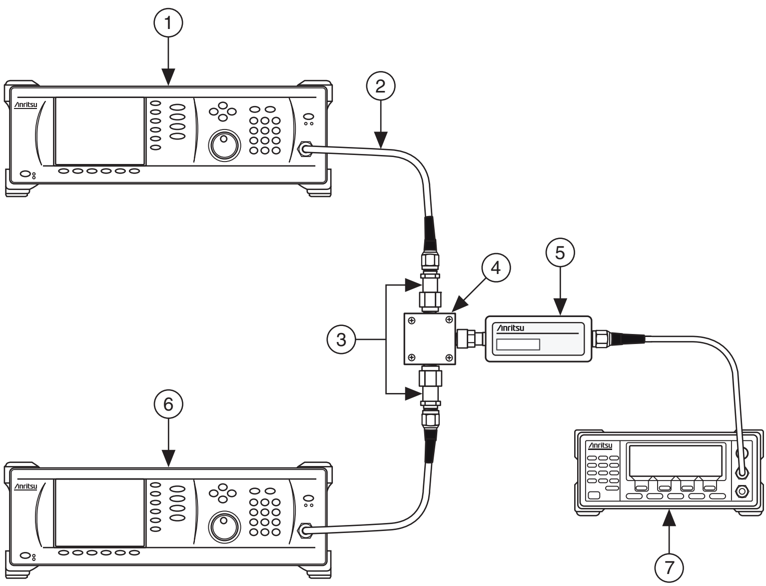
1. Connect the 10 MHz clock reference output on RF source 1 back panel to the 10 MHz clock reference input on the RF source 2 back panel. Use a BNC (m)-to-BNC (m) cable.
2. Connect the 10 MHz clock reference output on the RF source 2 back panel to the 10 MHz clock reference input on the spectrum analyzer back panel. Use a BNC (m)-to-BNC (m) cable.
3. Configure the spectrum analyzer to use the external reference. On the Rohde & Schwarz FSU26 analyzer, press the **Setup** button and select **External Reference**.

Configuring the Hardware

Complete this process to connect the two sources to a power sensor and power meter, preparing the configuration for verification and characterization. This assembly is used in *Verifying Third-Order Intercept Point Out-of-Band*.

1. Connect the spectrum analyzer REF OUT connector to the REF IN connector on the back of the PXI Express chassis. Use a standard BNC (m)-to-BNC (m) cable.
2. Connect one 10 dB attenuator to a non-common low-frequency combiner connector. Label both the low-frequency combiner connector and the attenuator *P1*.
3. Connect the remaining 10 dB attenuator to the remaining non-common low-frequency combiner connector. Label both the low-frequency combiner connector and the attenuator *P2*.
4. Use an SMA (m)-to-SMA (m) cable to connect RF source 1 to the 10 dB attenuator labeled *P1*. Label the signal generator *Source 1*. Label the cable *S1P*.
5. Use an SMA (m)-to-SMA (m) cable to connect RF source 2 to the 10 dB attenuator labeled *P2*. Label the signal generator *Source 2*. Label the cable *S2P*.
6. Connect the combiner common connector to power sensor A.
7. Connect channel A of the power meter to power sensor A.

Figure 1. Configuration for Power Level Characterization



1	RF Source 1	4	Low-Frequency Combiner	7	Power Meter
2	SMA (m)-to-SMA (m) Cable	5	Power Sensor A		
3	10 dB Attenuator	6	RF Source 2		

Characterizing the Source Signal Power Levels

Complete this process to characterize the power level of the RF source generators. This information is required in the verification procedures.

1. Ensure that the RF source 1 generator output is ON and the RF source 2 generator output is OFF.
2. Set the RF source 1 generator to the first frequency listed in Table 2.

Table 2. Source 1 Signal Characterization

Source 1 Frequency (MHz)	Power Level at 0 dBm	Power Level at -5 dBm	Power Level at -12 dBm
21.4			
163.6			
186.1			
191.5			
193			
193.51			
193.6			
193.765			
194.2			
195.7			
201.1			
223.6			

3. Adjust the RF source 1 output power until the power level at the low-frequency combiner common connector, measured by the power meter, is within 0.1 dB of 0 dBm.
4. Record the RF source 1 power level in the empty cell corresponding to the appropriate frequency and power level.
5. Repeat steps 2 through 4 for each of the remaining frequency and power level combinations in Table 2. Retain this information for use during the verification procedures.
6. Ensure that the RF source 1 generator output is OFF and the RF source 2 generator output is ON.

7. Repeat steps 2 through 4 for each of the frequency and power level combinations in Table 3, recording the RF source 2 power level in place of RF source 1.

Table 3. Source 2 Signal Characterization

Source 2 Frequency (MHz)	Power Level at 0 dBm	Power Level at -5 dBm	Power Level at -12 dBm
21.4			
133.6			
178.6			
189.4			
192.4			
193.27			
193.6			
193.93			
194.8			
197.8			
208.6			
253.6			

Characterizing the Source 2 Signal Correction Level

Complete this process to characterize the power level of the RF source 2 generator. This information is required in the verification procedures.

1. Ensure that the RF source 1 output is OFF and the RF source 2 output is ON.
2. Set the output power level of RF source 2 to -20 dBm.
3. Set RF source 2 to the first frequency listed in Table 4.

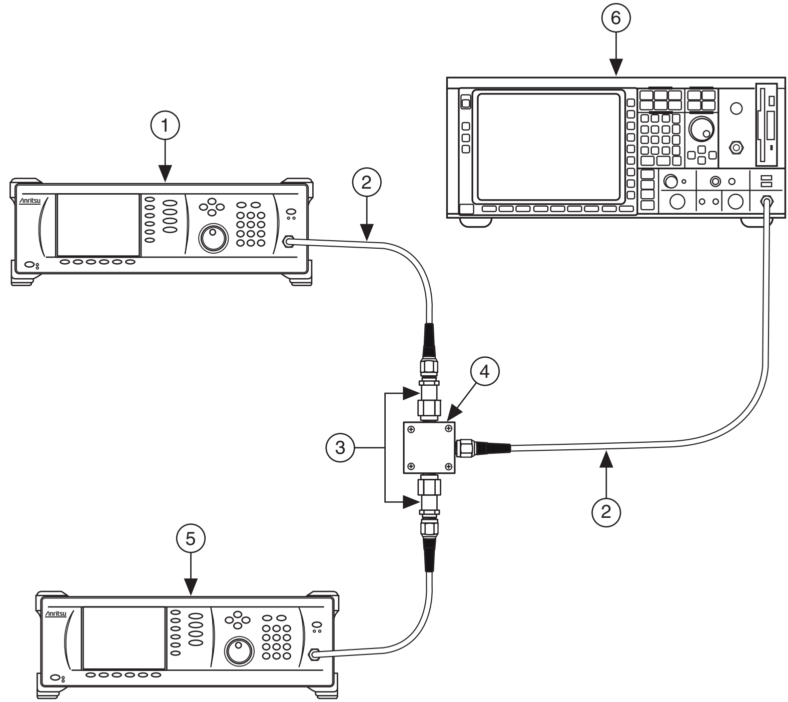
Table 4. Signal Correction

Source 2 Frequency (MHz)	Power Meter Reference (dBm)	Spectrum Analyzer (dBm)	Correction (dB)
193.6			
21.4			

4. Record the power level reading on the power meter in the *Power Meter Reference* cell corresponding to the appropriate frequency.
5. Repeat steps 3 and 4 for the remaining frequency listed in Table 4.
6. Remove the power sensor from the combiner.

7. Connect the low-frequency combiner common connector to the spectrum analyzer RF INPUT connector with the remaining SMA (m)-to-SMA (m) cable. Label the cable *DS*.

Figure 2. Configuration for Power Level Correction Characterization



1	RF Source 1	3	10 dB Attenuator	5	RF Source 2
2	SMA (m)-to-SMA (m) Cable	4	Low-Frequency Combiner	6	Spectrum Analyzer

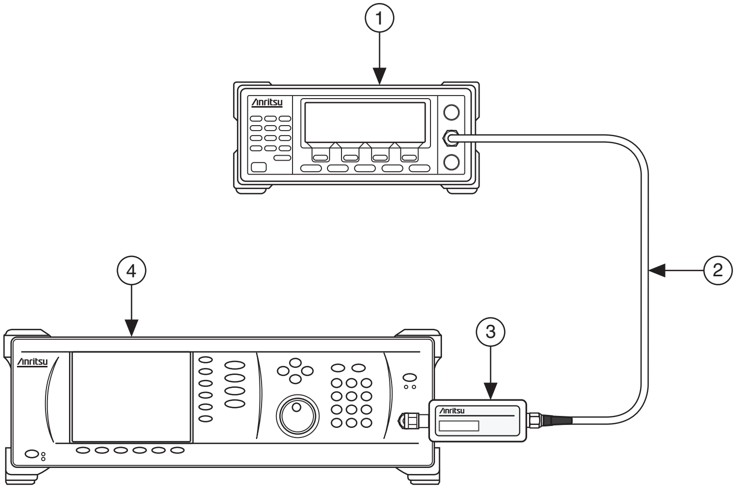
8. Configure the spectrum analyzer as follows:
   - Center frequency: the first frequency listed in Table 4
   - Span: 0 Hz
   - Reference level: 10 dBm
   - Resolution bandwidth: 100 kHz
   - Video bandwidth: 300 kHz
   - Number of averages: 100
9. Set RF source 2 to the same frequency configured for the spectrum analyzer in step 8.
10. Record the power level reading on the spectrum analyzer in the *Spectrum Analyzer* cell in Table 4 corresponding to the appropriate frequency.
11. Repeat steps 8 through 10 for the remaining frequency listed in Table 4.
12. For each of the two frequencies in Table 4, subtract the value in the *Power Meter Reference* cell from the value in the *Spectrum Analyzer* cell and record it in the *Correction* cell.

Characterizing Cable Loss

Complete this procedure to characterize the loss of the system cables.

1. Recalibrate the power sensor zero settings.
2. Ensure that the RF source 1 output is ON and that the RF source 2 output is OFF.
3. Connect power sensor B to the RF source 1 output.

Figure 3. Power Meter to RF Source 1 Direct Connection



1	Power Meter	3	Power Sensor B
2	SMA (m)-to-SMA (m) Cable	4	RF Source 1

4. Configure RF source 1 as follows:
   - Power: 0 dBm
   - Frequency: The first frequency listed in the *Frequency* column in Table 5

Table 5. Digitizer Cable Loss

Frequency (MHz)	Reference Source Measurement	Digitizer Cable Loss	Splitter Tracking Error (dB)	RF Source Cable / Splitter Loss (dB)
10				
20				
30				
40				
50				
60				

Table 5. Digitizer Cable Loss (Continued)

Frequency (MHz)	Reference Source Measurement	Digitizer Cable Loss	Splitter Tracking Error (dB)	RF Source Cable / Splitter Loss (dB)
70				
80				
90				
100				
107.5				
109.1				
110.7				
112.3				
113.9				
115.5				
117.1				
117.5				
119.1				
120.7				
122.3				
123.9				
125.5				
127.1				
128.7				
130.3				
131.9				
133.5				
135				
135.1				
136.6				
138.2				

Table 5. Digitizer Cable Loss (Continued)

Frequency (MHz)	Reference Source Measurement	Digitizer Cable Loss	Splitter Tracking Error (dB)	RF Source Cable / Splitter Loss (dB)
139.8				
141.4				
143				
144.6				
146.2				
147.8				
149.4				
151				
152.5				
152.6				
154.1				
155.7				
157.3				
158.9				
160.5				
162.1				
163.7				
165.3				
166.9				
168.5				
170				
170.1				
171.6				
173.2				
174.8				
176.4				

Table 5. Digitizer Cable Loss (Continued)

Frequency (MHz)	Reference Source Measurement	Digitizer Cable Loss	Splitter Tracking Error (dB)	RF Source Cable / Splitter Loss (dB)
178				
179.6				
181.2				
182.8				
184.4				
186				
187.6				
189.2				
190.8				
192.4				
193.6				
195.2				
196.8				
198.4				
200				
201.6				
203.2				
204.8				
206.4				
208				
209.6				
211.2				
212.8				
213.5				
214.4				
215.1				

Table 5. Digitizer Cable Loss (Continued)

Frequency (MHz)	Reference Source Measurement	Digitizer Cable Loss	Splitter Tracking Error (dB)	RF Source Cable / Splitter Loss (dB)
216.7				
218.3				
219.9				
221.5				
223.1				
224.7				
226.3				
227				
228.6				
230.2				
231.8				
233.4				
235				
236.6				
238.2				
239.8				
240.5				
241.4				
242.1				
243.7				
245.3				
246.9				
248.5				
250.1				
251.7				
253.3				

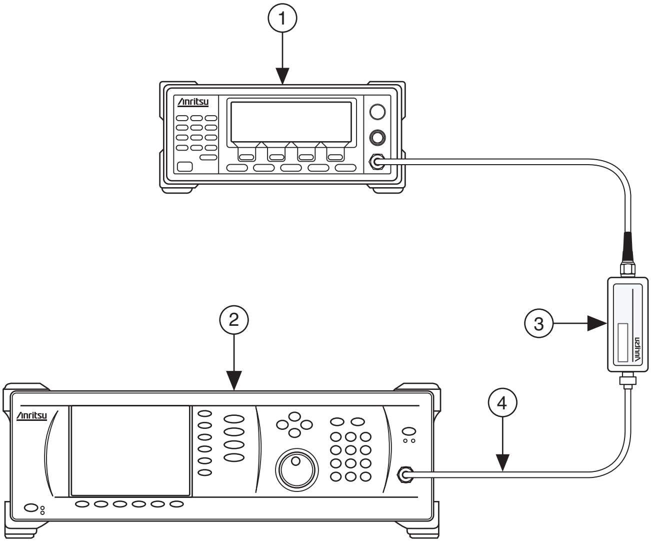
Table 5. Digitizer Cable Loss (Continued)

Frequency (MHz)	Reference Source Measurement	Digitizer Cable Loss	Splitter Tracking Error (dB)	RF Source Cable / Splitter Loss (dB)
254				
255.6				
257.2				
258.8				
260.4				
262				
263.6				
265.2				
266.8				
268.4				

5. Measure the channel B power using the appropriate sensor calibration factor for the configured frequency. Record this value in the corresponding *Reference Source Measurement* cell.
6. Repeat steps 4 and 5 for each frequency listed in Table 5.
7. Disconnect power sensor B from the RF source 1 output.
8. Connect the 3.5mm (m)-to-3.5mm (m) digitizer cable to the RF source 1 output.

9. Connect power sensor B to the digitizer cable. Use a 3.5 mm (f)-to-3.5 mm (f) adapter.

Figure 4. Power Meter-to-Digitizer Cable Connection



1	Power Meter	3	Power Sensor B
2	RF Source 1	4	Digitizer Cable

10. Reset RF source 1 to one of the frequencies listed in the *Frequency* column in Table 5.
11. Measure the channel B power using the appropriate sensor calibration factor for the frequency. Use the following equation to calculate and record the *Digitizer Cable Loss* for the frequency in Table 5.

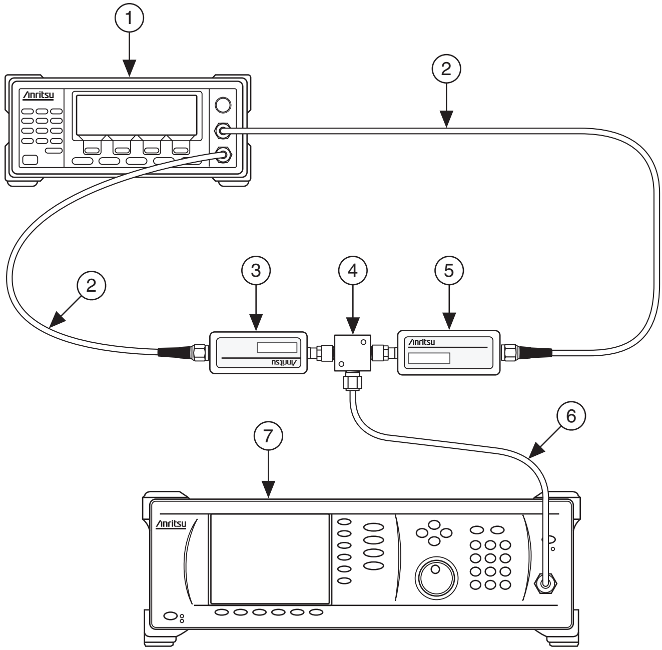
    Digitizer Cable Loss = *Reference Source Measurement* - *Channel B Power*

    where *Reference Source Measurement* is the corresponding measurement recorded in Table 5 for the frequency.

12. Repeat steps 10 and 11 for each frequency listed in Table 5.
13. Disconnect the digitizer cable and power sensor from the RF source 1 output.
14. Connect the RF source 1 output to the power splitter input. Use a 3.5 mm (m)-to-3.5 mm (m) RF source cable.
15. Connect the power splitter reference output to power sensor A.

16. Connect the remaining power splitter output to power sensor B.

Figure 5. Power Meter to Splitter Connection



1	Power Meter	4	Power Splitter	6	RF Source Cable
2	SMA (m)-to-SMA (m) Cable	5	Power Sensor A	7	RF Source 1
3	Power Sensor B				

17. Reset RF source 1 to one of the frequencies listed in the *Frequency* column on Table 5.
18. Measure the channel A power and the channel B power using the appropriate sensor calibration factor for the frequency. Use the following equation to calculate and record the *Splitter Tracking Error* value for the appropriate frequency in Table 5.

    Splitter Tracking Error = *Channel B Power* - *Channel A Power*

19. Use the following equation to calculate and record the *RF Source Cable/Splitter Loss* value for the appropriate frequency in Table 5.

    RF Source Cable/Splitter Loss = *Reference Source Measurement* - *Channel B Power*

    where *Reference Source Measurement* is the corresponding measurement recorded in Table 5 for the frequency.

20. Repeat steps 17 through 19 for each frequency in Table 5.

Verification

The performance verification procedures assume that adequate traceable uncertainties are available for the calibration references.

Synchronizing the Components

Complete the following procedure to synchronize RF source 1, RF source 2, the spectrum analyzer, and the PXI Express chassis to the same 10 MHz clock reference.

1. Connect the 10 MHz clock reference output on the RF source 1 back panel to the 10 MHz clock reference input on the RF source 2 back panel. Use a BNC (m)-to-BNC (m) cable.
2. Connect the 10 MHz clock reference output on the RF source 2 back panel to the 10 MHz clock reference input on the spectrum analyzer back panel. Use a BNC (m)-to-BNC (m) cable.
3. Configure the spectrum analyzer to use the external reference. On the Rohde & Schwarz FSU26 analyzer, press the **Setup** button and then select **External Reference**.
4. Connect the 10 MHz clock reference output on the spectrum analyzer back panel to the 10 MHz clock reference input on the PXI Express chassis back panel. Use a BNC (m)-to-BNC (m) cable.

Configuring the Hardware

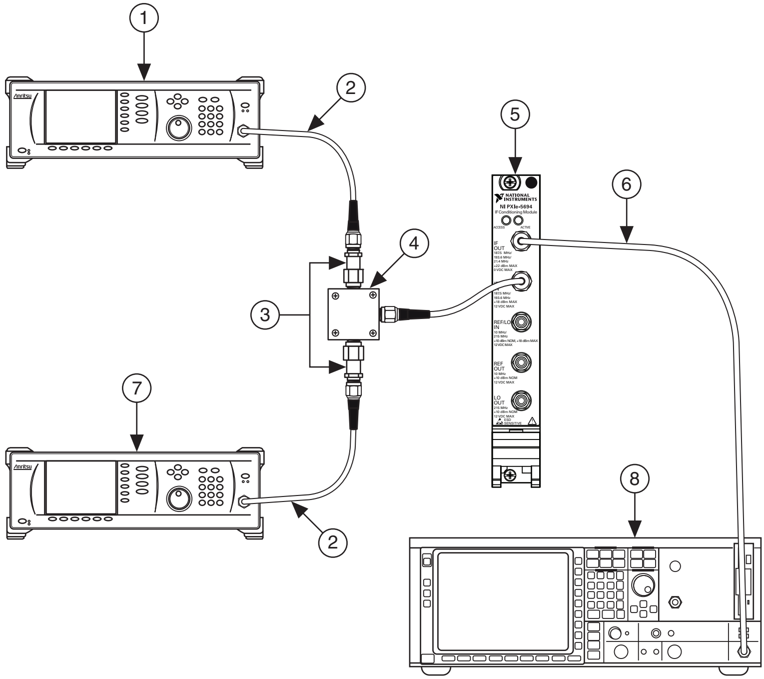
Complete the following procedure to configure the hardware for verification.

1. Connect the 10 dB attenuator labeled *P1* to the low-frequency combiner connector labeled *P1*.
2. Connect the 10 dB attenuator labeled *P2* to the low-frequency combiner connector labeled *P2*.
3. Connect the signal generator labeled *Source 1* to the 10 dB attenuator labeled *P1*. Use the SMA (m)-to-SMA (m) cable labeled *S1P*.
4. Connect the signal generator labeled *Source 2* to the 10 dB attenuator labeled *P2*. Use the SMA (m)-to-SMA (m) cable labeled *S2P*.
5. Connect the low-frequency combiner common connector to the NI 5694 IF IN connector. Use a 3.5 mm (m)-to-3.5 mm adapter.

Note The 3.5 mm (m)-to-3.5 mm adapter is uncharacterized and represents an uncertainty. This uncertainty is absorbed into the product specifications.

6. Connect the NI 5694 IF OUT connector to the spectrum analyzer RF INPUT connector. Use the SMA (m)-to-SMA (m) cable labeled *DS*.

Figure 6. Configuration for System Verification



1	RF Source 1	4	Low-Frequency Combiner	7	RF Source 2
2	SMA (m)-to-SMA (m) Cable	5	NI 5694	8	Spectrum Analyzer
3	10 dB Attenuator	6	SMA (m)-to-SMA (m) Cable		

Verifying Third-Order Intercept Point Out-of-Band

Complete the following procedures to determine the as-found status of the NI 5694. Third-order intercept point out-of-band (TOI-OB) places one signal within the passband and a second signal outside the passband.

Note Refer to the values recorded during system characterization to complete these procedures.

Determining the Path Gain

Complete the following procedure to determine system path gain.

1. Ensure that the RF source 1 output is OFF and the RF source 2 output is ON.
2. Configure the RF source 2 generator as follows:
   - Power level: -20 dBm
   - Frequency: 193.6 MHz
3. Configure the spectrum analyzer as follows:
   - Center frequency: 193.6 MHz
   - Span: 0 Hz
   - Reference level: 0 dBm
   - Resolution bandwidth: 10 kHz
   - Video bandwidth: 30 kHz
   - Number of averages: 100
4. Configure the NI 5694 as follows:
   - Reference level: -30 dBm
   - IF output power level: +10 dBm
   - IF conditioning downconversion enabled: Disabled
   - Device instantaneous bandwidth: The first value shown in the *Device Instantaneous Bandwidth* column in Table 6
   - Step gain: The value in the *Step Gain* column in Table 6 corresponding to the configured device instantaneous bandwidth

Table 6. Path Gain, Downconversion Disabled

Device Instantaneous Bandwidth (Path)	Step Gain	IF OUT Power (dBm)	Path Gain
20 MHz	Disabled		
	Enabled		
5 MHz	Disabled		
	Enabled		

Table 6. Path Gain, Downconversion Disabled (Continued)

Device Instantaneous Bandwidth (Path)	Step Gain	IF OUT Power (dBm)	Path Gain
1.4 MHz	Disabled		
	Enabled		
400 kHz	Disabled		
	Enabled		
110 kHz	Disabled		
	Enabled		

5. Execute a sweep using the spectrum analyzer and record the peak marker reading in the appropriate *IF OUT Power* cell in Table 6.
6. Use the following formula to compute the path gain and record it in the corresponding *Path Gain* cell.

$$\text{Path Gain} = P_{SA} - P_{CORR} - P_{REF}$$

where:

P_{SA} = *IF OUT Power* recorded in Table 6

P_{CORR} = Characterized correction recorded in Table 4 for the configured frequency

P_{REF} = Characterized reference power recorded in Table 4 for the configured frequency

7. Repeat steps 4 through 6 for each of the remaining values in the *Device Instantaneous Bandwidth* column in Table 6.
8. Reconfigure the spectrum analyzer as follows:
   - Center frequency: 21.4 MHz
   - Span: 0 Hz
   - Reference level: 10 dBm
   - Resolution bandwidth: 10 kHz
   - Video bandwidth: 30 kHz
   - Number of averages: 100

9. Reconfigure the NI 5694 as follows:
   - Reference Clock source: PXI_Clk
   - Reference level: -30 dBm
   - IF output power level: +10 dBm
   - Downconversion enabled: TRUE
   - Device instantaneous bandwidth: The first value shown in the *Device Instantaneous Bandwidth* column in Table 7
   - Step gain: The value in the *Step Gain* column in Table 7 corresponding to the configured device instantaneous bandwidth

Table 7. Path Gain, Downconversion Enabled

Device Instantaneous Bandwidth (Path)	Step Gain	IF OUT Power (dBm)	Path Gain
20 MHz	Disabled		
	Enabled		
5 MHz	Disabled		
	Enabled		
1.4 MHz	Disabled		
	Enabled		
400 kHz	Disabled		
	Enabled		
110 kHz	Disabled		
	Enabled		
30 kHz	Disabled		
	Enabled		

10. Record the power reported by the spectrum analyzer in the appropriate *IF OUT Power* cell in Table 7.
11. Use the formula from step 6 to compute the path gain and record it in the corresponding *Path Gain* cell in Table 7.
12. Repeat steps 9 through 11 for each of the remaining values in the *Device Instantaneous Bandwidth* column in Table 7.

Verifying Third-Order Intercept Point Out-of-Band At Multiple Input Power Levels

Complete the following procedure to verify TOI-OB at multiple input power levels and downconversion settings.

1. Ensure that the RF source 1 output and the RF source 2 output are both ON.
2. Configure the spectrum analyzer as follows:
    - Frequency: 193.6 MHz
    - Span: 0 Hz
    - Reference level: -40 dBm
    - RBW: 10 Hz
    - VBW: 30 Hz
    - Number of averages: 30
3. Configure the NI 5694 as follows:
    - Reference level: -30 dBm
    - IF output power level: +10 dBm
    - Step gain: Disabled
    - IF conditioning downconversion enabled: Disabled
    - Device instantaneous bandwidth: The first value listed in the *Device Instantaneous Bandwidth* column in Table 8

Table 8. TOI-OB Calculation,
DUT Input Power 0 dBm, Downconversion Disabled

Device Instantaneous Bandwidth (Path)	RF Source 1 Frequency (MHz)	RF Source 2 Frequency (MHz)	IF OUT Power (dBm)	TOI-OB (dBm)
20 MHz	223.6	253.6		
	163.6	133.6		
5 MHz	201.1	208.6		
	186.1	178.6		
1.4 MHz	195.7	197.8		
	191.5	189.4		
400 kHz	194.2	194.8		
	193	192.4		
110 kHz	193.765	193.93		
	193.51	193.27		

4. Set RF source 1 to the first frequency listed in the *RF Source 1 Frequency* column of Table 8 corresponding to the configured device instantaneous bandwidth.
5. Set the RF source 1 output power to the appropriate characterized power recorded in Table 2 for the configured RF source 1 frequency and a device under test (DUT) input power of 0 dBm.
6. Set RF source 2 to the frequency listed in the *RF Source 2 Frequency* column of Table 8 corresponding to the configured RF source 1 frequency.
7. Set the RF source 2 output power to the characterized power recorded in Table 3 corresponding to the configured RF source 2 frequency and a DUT input power of 0 dBm.
8. Use the following equation to compute the IF OUT power and record the result in the corresponding cell in the *IF OUT Power* column in Table 8.

$$IF\ OUT\ Power = P_{SA} - P_{CORR}$$

   where:

   P_{SA} = Power reported by the spectrum analyzer

   P_{CORR} = Characterized correction (dB) recorded in Table 4 for the frequency 193.6 MHz

9. Repeat steps 3 through 8 for each of the remaining combinations of device instantaneous bandwidth, RF source 1 frequency, and RF source 2 frequency listed in Table 8.
10. Calculate the TOI-OB for the configured RF source 1 and RF source 2 frequencies using the following formula. Record the result in the corresponding cell in the *TOI-OB* cell in Table 8.

$$TOI_{OB} = P_{IN} + \frac{P_{IN} - (P_{OIMD} - G_K)}{2}$$

   where:

   TOI_{OB} = TOI out-of-band in dBm

   P_{IN} = Configured DUT input power, in this case 0 dBm

   P_{OIMD} = The greater of the two values recorded in the *IF OUT Power* column in Table 8 for the configured device instantaneous bandwidth

   G_K = The value recorded in the *Path Gain* column in Table 6 for the configured device instantaneous bandwidth with step gain disabled

11. Repeat step 10 for each combination of frequencies listed in Table 8.
12. Reconfigure the NI 5694, enabling step gain.

13. Repeat steps 4 through 11 with the new settings and the following changes:
    - When configuring RF source 1 and 2 output power, use a device under test (DUT) input power of -5 dBm instead of -0 dBm.
    - Record your results using Table 9.

Table 9. TOI-OB Calculation,
DUT Input Power -5 dBm (per Tone), Downconversion Disabled

Device Instantaneous Bandwidth (Path)	RF Source 1 Frequency (MHz)	RF Source 2 Frequency (MHz)	IF OUT Power (dBm)	TOI-OB (dBm)
20 MHz	223.6	253.6		
	163.6	133.6		
5 MHz	201.1	208.6		
	186.1	178.6		
1.4 MHz	195.7	197.8		
	191.5	189.4		
400 kHz	194.2	194.8		
	186.1	178.6		
110 kHz	193.765	193.93		
	193.435	193.51		

14. Reconfigure the spectrum analyzer for a frequency of 21.4 MHz.
15. Reconfigure the NI 5694, enabling IF conditioning downconversion and disabling step gain.

16. Repeat steps 4 through 18 with the new settings and the following changes:
    - When configuring RF source 1 and 2 output power, use a device under test (DUT) input power of -5 dBm instead of -0 dBm.
    - Record your results using Table 10.

Table 10. TOI-OB Calculation,
DUT Input Power -5 dBm (per Tone), Downconversion Enabled

Device Instantaneous Bandwidth (Path)	RF Source 1 Frequency (MHz)	RF Source 2 Frequency (MHz)	IF OUT Power (dBm)	TOI Out-of-Band (dBm)
5 MHz	201.1	208.6		
	186.1	178.6		
1.4 MHz	195.7	197.8		
	191.5	189.4		
400 kHz	194.2	194.8		
	193	192.4		
110 kHz	193.765	193.93		
	193.435	193.27		
30 kHz	193.645	193.69		
	193.555	193.51		

17. Repeat steps 4 through 18 with the following changes:
    - When configuring RF source 1 and 2 output power, use a device under test (DUT) input power of -12 dBm instead of -0 dBm.
    - Reconfigure the NI 5694 to enable step gain.
    - Record your results using Table 11.

Table 11. TOI-OB Calculation,
DUT Input Power -12 dBm (per Tone), Downconversion Enabled

Device Instantaneous Bandwidth (Path)	RF Source 1 Frequency (MHz)	RF Source 2 Frequency (MHz)	IF OUT Power (dBm)	TOI-OB (dBm)
5 MHz	201.1	208.6		
	186.1	178.6		
1.4 MHz	195.7	197.8		
	191.5	189.4		

Table 11. TOI-OB Calculation,
DUT Input Power -12 dBm (per Tone), Downconversion Enabled (Continued)

Device Instantaneous Bandwidth (Path)	RF Source 1 Frequency (MHz)	RF Source 2 Frequency (MHz)	IF OUT Power (dBm)	TOI-OB (dBm)
400 kHz	194.2	194.8		
	193	192.4		
110 kHz	193.765	193.93		
	193.435	193.51		
30 kHz	193.645	193.69		
	193.555	193.51		

18. Compare each of the values you recorded in the *PATH TOI-OB* column in each of the previous tables to the values listed in Table 12. If the value is equal to or greater than the value listed the table, the device passes verification. If the value is less than the value listed in the table, the device fails verification.

Table 12. TOI Verification Test Limits

Test Condition	As-Found Limit	As-Left Limit*
Downconversion: Disabled Gain: Off	40 dBm	41 dBm
Downconversion: Disabled Gain: On	32 dBm	33 dBm
Downconversion: Enabled Gain: Off	29 dBm	30 dBm
Downconversion: Enabled Gain: On	25 dBm	26 dBm
* The as-left limits cannot be linearly combined with the measurement uncertainty values to equal the warranted device specifications. Refer to the *As-Found and As-Left Limits* section of this document for more information about as-left limits		

Adjustment

Complete the following procedures to adjust the NI 5694. Following the adjustment procedures automatically updates the calibration date and temperature in the EEPROM of the NI 5694.

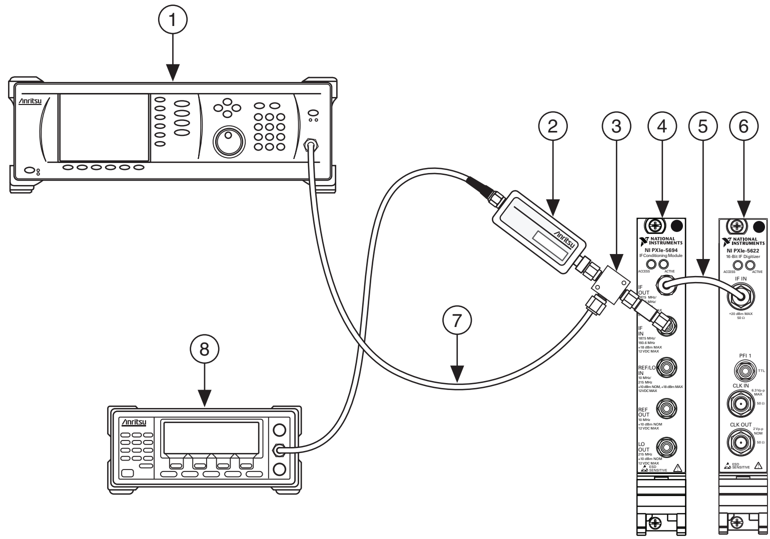
Note National Instruments recommends a complete adjustment of your device to renew the calibration interval.

Configuring the Hardware

Complete the following procedure to configure the hardware for adjustment.

1. Connect RF source 1 to the power splitter input. Use an SMA (m)-to-SMA (m) cable.
2. Connect Power Sensor A to power meter channel A and to one output of the power splitter.
3. Connect the remaining power splitter output to the NI 5694 IF IN connector. Use an SMA (m)-to-SMA (m) adapter.
4. Connect the NI 5694 IF OUT connector to the NI 5622 digitizer IF IN connector. Use an SMA (m)-to-SMA (m) cable.

Figure 7. Hardware Configuration for Adjustment



1	RF Source 1	4	NI 5694	7	SMA (m)-to-SMA (m) Cable
2	Power Sensor A	5	SMA (m)-to-SMA (m) Cable	8	Power Meter
3	Power Splitter	6	NI 5622 Digitizer		

Adjusting IF Gain for Bypass Path

Complete the following procedure to measure and adjust the IF gain for bypass path performance of the NI 5694 IF conditioning module.

1. Zero and calibrate the power sensors using the built-in functions in the power meter.
2. Ensure that the hardware is properly configured as described in *Configuring the Hardware*.
3. Run the self-calibration procedure for the NI 5622 digitizer.
4. Initialize an external calibration session for the NI 5694.
5. Initialize an IF attenuation calibration step.
6. Configure the NI 5694 as follows:
   - Signal conditioning: Bypassed
   - IF conditioning downconversion: Disabled
   - Step gain: Disabled
7. Configure RF source 1 as follows:
   - Single frequency mode
   - Frequency: 107.5 MHz
   - Power level: 0 dBm
8. Configure the power meter as follows:
   - Channel 1: Power sensor A
   - Trigger with settling delay
   - Sensor setting: 0.1%
9. Configure the NI 5622 digitizer as follows:
   - Sampling rate: 585.9375 kS/s
   - Number of samples to acquire: 40,960
   - Reference source: PXI_Clk
   - Reference Clock rate: 100 MHz
   - DDC enabled: TRUE
   - Data processing mode: Complex
   - Frequency translation enables: TRUE
   - DDC center frequency: 107.5 MHz
   - Dither enabled: FALSE
   - Bandpass filter enabled: FALSE
10. Read the power meter channel A power.
11. Calculate the NI 5694 *IF input power* using the following equation:

$$\textit{IF Input Power} = \textit{Channel A Power} + \textit{Splitter Tracking at RF Source Frequency}$$

12. Acquire a complex record with the NI 5622 digitizer and compute the *digitizer power* in dBm using the following equation:

$$Digitizer\ Power = 10 \times log_{10}\left(\frac{1}{N}\sum_{j=0}^{N-1}(I_j^2 + Q_j^2)\right) + 10$$

where:

N = Number of samples to acquire

I_j = Real part of the jth complex sample

Q_j = Imaginary part of the jth complex sample

13. Query the NI 5622 *digitizer frequency response* and retrieve the value at the DDC center frequency by linear interpretation.
14. Calculate the NI 5694 *gain* using the following equation:

Gain = Digitizer Power + Digitizer Cable Loss - Digitizer Frequency Response - Input Power

Note Refer to Table 5 for the characterized digitizer cable loss.

15. Record the calculated gain and the RF input frequency value to the NI 5694 EEPROM.
16. Increase the RF source 1 frequency and the digitizer DDC center frequency by 1.6 MHz.
17. Repeat steps 10 through 16 for all frequencies up to and including 267.5 MHz.
18. Close the IF attenuation calibration step.
19. Close the external calibration session.

Adjusting IF Gain

Complete the following procedure to measure and adjust the IF gain performance of the NI 5694 IF conditioning module.

1. Zero and calibrate the power sensors using the built-in functions in the power meter.
2. Ensure that the hardware is properly configured as described in *Configuring the Hardware*.
3. Run the self-calibration procedure of the NI 5622 digitizer.
4. Initialize an external calibration session for the NI 5694.
5. Initialize an IF attenuation calibration step.
6. Configure the NI 5694 as follows:
   - Signal conditioning: Enabled
   - Reference source: PXI_Clk
   - IF conditioning downconversion: Disabled
   - Step gain: Disabled

7. Configure RF source 1 as follows:
   - Single frequency mode
   - Frequency: 193.6 MHz
   - Power level: -6 dBm
8. Configure the power meter as follows:
   - Channel 1: Power sensor A
   - Trigger with settling delay
   - Sensor setting: 0.1%
9. Configure the digitizer as follows:
   - Sampling rate: 585.9375 kS/s
   - Number of samples to acquire: 40,960
   - Reference source: PXI_Clk
   - Reference Clock rate: 100 MHz
   - DDC enabled: TRUE
   - Data processing mode: Complex
   - Frequency translation enabled: TRUE
   - DDC center frequency: 193.6 MHz
   - Dither enabled: FALSE
   - Bandpass filter enabled: TRUE
10. Set the NI 5694 IF filter to 20 MHz.
11. Read the power meter channel A power.
12. Calculate the NI 5694 *IF input power* using the following equation:

$$IF\ Input\ Power = Channel\ A\ Power + Splitter\ Tracking\ at\ 193.6\ MHz$$

13. Set IF Attenuation Table Index to 0.
14. Acquire a record of complex samples with the NI 5622 digitizer and compute the *digitizer power* in dBm using the following equation:

$$Digitizer\ Power = 10 \times log_{10}\left(\frac{1}{N}\sum_{j=0}^{N-1}(I_j^2 + Q_j^2)\right) + 10$$

   where:

   N = Number of samples to acquire

   I_j = Real part of the jth complex sample

   Q_j = Imaginary part of the jth complex sample

15. Query the NI 5622 *digitizer frequency response* and retrieve the value at 193.6 MHz by linear interpolation.

16. Calculate the NI 5694 *gain* using the following equation:

Gain = Digitizer Power + Digitizer Cable Loss - Digitizer Frequency Response - Input Power

Note Refer to Table 5 for the characterized digitizer cable loss.

17. Record the calculated gain to the NI 5694 EEPROM along with the RF source 1 frequency.
18. Repeat steps 13 through 17 for IF Attenuation Table Index values from 1 to 25, with a step size of 1.
19. Repeat steps 10 through 18 for each of the following IF filter frequency settings:
    - 5 MHz
    - 1.4 MHz
    - 400 kHz
    - 110 kHz
20. Reconfigure the NI 5694 to enable step gain.
21. Reconfigure RF source 1, adjusting the power level to -15 dBm.
22. Repeat steps 10 through 19 with the new settings.
23. Reconfigure the NI 5622 digitizer as follows:
    - DDC center frequency: 21.4 MHz
    - Bandpass filter enabled: FALSE
24. Reconfigure the NI 5694 as follows:
    - Step gain: Disabled
    - IF conditioning downconversion: Enabled
25. Repeat steps 10 through 19 with the new settings and the following changes:
    - In step 15, query the digitizer response at 21.4 MHz instead of 193.6 MHz
    - In step 19, add 30 kHz to the list of frequencies to be iterated over
26. Reconfigure RF source 1, adjusting the power level to -25 dBm.
27. Reconfigure the NI 5694, enabling step gain.
28. Repeat steps 10 through 19 with the new settings and the following changes:
    - In step 15, query the digitizer response at 21.4 MHz instead of 193.6 MHz
    - In step 19, add 30 kHz to the list of frequencies to measure
29. Close the IF attenuation calibration step.
30. Close the external calibration session.

Adjusting IF Flatness

Complete the following procedure to measure and adjust the IF flatness performance of the NI 5694 IF conditioning module.

1. Zero and calibrate the power sensors using the built-in functions in the power meter.
2. Ensure that the hardware is properly configured as described in *Configuring the Hardware*.
3. Run the self-calibration procedure of the NI 5622 digitizer.
4. Initialize an external calibration session for the NI 5694.
5. Initialize an IF response calibration step.
6. Configure the NI 5694 as follows:
   - Signal conditioning: Enabled
   - Reference source: PXI_Clk
   - IF conditioning downconversion: Disabled
   - Step gain: Disabled
7. Configure the RF source 1 generator as follows:
   - Single frequency mode
   - Frequency: 193.6 MHz
   - Power level: -6 dBm
8. Configure the power meter as follows:
   - Channel 1: Power sensor A
   - Trigger with settling delay
   - Sensor setting %: 0.1
9. Configure the digitizer as follows:
   - Sampling rate: 585.9375 kS/s
   - Number of samples to acquire: 40,960
   - Reference source: PXI_Clk
   - Reference Clock rate: 100 MHz
   - DDC enabled: TRUE
   - Data processing mode: Complex
   - Frequency translation enabled: TRUE
   - Dither enabled: TRUE
   - Bandpass filter enabled: TRUE

10. Set the NI 5694 IF filter to the first value listed in Table 13.

Table 13. IF Flatness Measurement Settings

IF Filter	Measurement Span	Lower RF Frequency Offset	Number of Frequency Points	
20 MHz	32 MHz	-16 MHz	IF attenuation index = 5	51
			All other indexes	15
5 MHz	10 MHz	-5 MHz	IF attenuation index = 5	41
			All other indexes	11
1.4 MHz	2 MHz	-1 MHz	IF attenuation index = 5	51
			All other indexes	21
400 kHz	600 kHz	-300 kHz	IF attenuation index = 5	31
			All other indexes	11
110 kHz	220 kHz	-110 kHz	IF attenuation index = 5	31
			All other indexes	21
30 kHz	40 kHz	-20 kHz	IF attenuation index = 5	61
			All other indexes	21

11. Set the NI 5694 IF attenuation table index to 0.
12. Calculate the list of RF frequency offsets using the following equation:

$$Current\ Frequency\ Offset = Lower\ RF\ Frequency\ Offset + j\left(\frac{Measurement\ Span}{Number\ of\ Frequency\ Points - 1}\right)$$

where:

Lower RF Frequency Offset = The value displayed in Table 13 corresponding to the configured IF filter

j = A range from 0 to *Number of Frequency Points* - 1

Measurement Span = The value displayed in Table 13 corresponding to the configured IF filter

Number of Frequency Points = The value displayed in Table 13 corresponding to the configured IF filter

13. Set the frequency of RF source 1 to 193.6 MHz plus the current frequency offset calculated in step 12.
14. Read the power meter channel A power.
15. Calculate the NI 5694 *IF input power* using the following equation:

$$Input\ Power = Channel\ A\ Power + Splitter\ Tracking\ at\ Current\ RF\ Source\ Frequency$$

16. Set the NI 5622 digitizer DDC center frequency to the RF source 1 frequency.
17. Acquire a record of complex samples with the NI 5622 digitizer and compute the *digitizer power* using the following equation:

$$Digitizer\ Power = 10 \times log_{10}\left(\frac{1}{N}\sum_{j=0}^{N-1}(I_j^2 + Q_j^2)\right) + 10$$

where:

N = Number of samples to acquire

I_j = Real part of the jth complex sample

Q_j = Imaginary part of the jth complex sample

18. Query the NI 5622 frequency response and retrieve the value at the current DDC center frequency by using linear interpolation.
19. Calculate the NI 5694 *gain* using the following equation:

Gain = *Digitizer Power* + *Digitizer Cable Loss* - *Digitizer Frequency Response* - *Input Power*

Note Refer to Table 5 for the characterized digitizer cable loss.

20. Record the calculated gain and the current frequency of RF source 1 to the NI 5694 EEPROM.
21. Repeat steps 13 through 20 for all the values in the frequency list computed in step 12.
22. Repeat steps 11 through 21 for IF attenuation table index values from 1 to 25, with a step size of 1.
23. Repeat steps 10 through 22 for each of the following IF filter values:
    - 5 MHz
    - 1.4 MHz
    - 400 kHz
    - 110 kHz
24. Reconfigure the NI 5694, enabling step gain.
25. Reconfigure RF source 1 for a power level of -15 dBm.
26. Repeat steps 10 through 23 with the new settings.
27. Reconfigure the NI 5622 digitizer, disabling the bandpass filter.
28. Reconfigure the NI 5694 as follows:
    - Step gain: Disabled
    - IF conditioning downconversion: Enabled
29. Repeat steps 10 through 23 with the new settings and the following changes:
    - In step 16, set the DDC center frequency to 215 MHz - *RF Source 1 Frequency*
    - In step 23, add 30 kHz to the list of frequencies to measure
30. Reconfigure RF source 1 for a power level of -25 dBm.
31. Reconfigure the NI 5694, enabling step gain.

32. Repeat steps 10 through 23 with the new settings and the following changes:
    - In step 16, set the DDC center frequency to 215 MHz - *RF Source 1 Frequency*
    - In step 23, add 30 kHz to the list of frequencies to measure
33. Close the IF response calibration step.
34. Close the external calibration session.

Reverification

Repeat the *Verification* section to determine the as-left status of the device.

Note If any test fails reverification after performing an adjustment, verify that you have met the *Test Conditions* before returning your device to NI. Refer to *Worldwide Support and Services* for information about support resources or service requests.

Worldwide Support and Services

The National Instruments website is your complete resource for technical support. At `ni.com/support` you have access to everything from troubleshooting and application development self-help resources to email and phone assistance from NI Application Engineers.

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