CALIBRATION PROCEDURE

NI PXIe-5693

RF Preselector Module

This document contains the verification and adjustment procedures for the National Instruments PXIe-5693 (NI 5693) RF preselector module. Refer to `ni.com/calibration` for more information about calibration solutions.

Contents

Required Software

Calibrating the NI 5693 requires you to install the following software on the calibration system.

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

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

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

Related Documentation

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

- *NI 5693 RF Preselector Module Getting Started Guide*
- *NI 5667 (3.6 GHz) Spectrum Monitoring Receiver Getting Started Guide*
- *NI 5667 (7 GHz) Spectrum Monitoring Receiver Getting Started Guide*
- *NI RF Vector Signal Analyzers Help*
- *NI PXIe-5693 Specifications*
- *NI PXIe-5667 (3.6 GHz) Specifications*
- *NI PXIe-5667 (7 GHz) Specifications*

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

This calibration procedure calibrates the NI 5693 as an independent module. To calibrate the NI 5693 as a part of the NI PXIe-5667 (NI 5667), refer to the *NI PXIe-5667 Calibration Procedure* document available at `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 5693 Calibration

Equipment	Recommended Models	Where Used	Minimum Requirements
Noise source	NoiseCom NC346B Precision	Noise figure verification	Frequency: 10 MHz to 8 GHz Output ENR: 14 dB to 16 dB VSWR: 1.25
Spectrum analyzer	Rohde & Schwarz FSU26 Options B23, B25	Test system characterization Verifications: • Noise figure • In-band third order intercept • Out-of-band third order intercept • Reverse isolation	Frequency range: 20 MHz to 8 GHz Internal preamplifier Noise source control (28 V supply, BNC connector)
Power meter	Anritsu ML2438A	Test system characterization Verifications: • In-band third order intercept • Out-of-band third order intercept • Reverse isolation • Calibration signal amplitude accuracy Adjustments: • RF gain • Calibration tone power accuracy	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

Table 1. Recommended Equipment for NI 5693 Calibration (Continued)

Equipment	Recommended Models	Where Used	Minimum Requirements
(2x) Power sensor (power sensor A) (power sensor B)	Anritsu MA2473D	Test system characterization Verifications: • In-band third order intercept • Out-of-band third order intercept • Reverse isolation • Calibration signal amplitude accuracy Adjustments: • RF gain • Calibration tone power accuracy	Power range: -55 dBm to 20 dBm Frequency range: 10 MHz to 8 GHz Input VSWR: 10 MHz to 50 MHz........................<1.90 50 MHz to 2 GHz..........................<1.12 2 GHz to 8 GHz ....<1.22 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 8 GHz ....<1.9%

Table 1. Recommended Equipment for NI 5693 Calibration (Continued)

Equipment	Recommended Models	Where Used	Minimum Requirements
(2x) Signal generator (RF source 1) (RF source 2)	Anritsu MG3692C Options 2A, 3, 4, 15A, and 22	Test system characterization Verifications: • In-band third order intercept • Out-of-band third order intercept • Reverse isolation • Calibration signal amplitude accuracy Adjustments: • RF gain • Calibration tone power accuracy	Frequency range: 8 MHz to 8 GHz Leveled power: -115 dBm to 18 dBm Power accuracy: ±1.5 dB Harmonics: 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 ≤8 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 ≤8 GHz.....................<-60 dBc Output VSWR: <2.0
(4x) SMA (m)-to-SMA (m) cable (36 in.)	MegaPhase G916-SISI-36	—	Frequency range: DC to 8 GHz Insertion loss: ≤2 dB at 8 GHz Impedance: 50 Ω VSWR: ≤1.35 at 8 GHz
SMA (f)-to-SMA (m) semi-rigid cable (1.08 in. with slight angle bend)	Rosenberger 166782A-01	—	Frequency range: DC to 8 GHz

Table 1. Recommended Equipment for NI 5693 Calibration (Continued)

Equipment	Recommended Models	Where Used	Minimum Requirements
(2x) BNC (m)-to-BNC (m) cable (36 in.)	NI 763485-01	Noise figure verification	—
(2x) BNC (m)-to-BNC (m) cable	—	—	—
SMA (m)-to-SMA (m) adapter	Huber+Suhner 32_SMA-50-0-52/199_NE	Verifications: • In-band third order intercept • Out-of-band third order intercept • Reverse isolation • Calibration signal amplitude accuracy Adjustments: • RF gain • Calibration tone power accuracy	Frequency range: DC to 8 GHz VSWR: <1.14
SMA (f)-to-SMA (f) adapter	Huber+Suhner 31_SMA-50-0-1/111_NE	Noise figure verification	Frequency range: DC to 8 GHz

Table 1. Recommended Equipment for NI 5693 Calibration (Continued)

Equipment	Recommended Models	Where Used	Minimum Requirements
SMA (m)-to-SMA (f) 10 dB attenuator	Huber+Suhner 6610_SMA-50-1/199N	Test system characterization Verifications: • In-band third order intercept • Out-of-band third order intercept • Reverse isolation	Frequency range: DC to 8 GHz Attenuation: 10 dB (nominal) Power rating: 2 W average Impedance: 50 Ω VSWR: DC to 4 GHz ..... ≤1.15 4 GHz to 8 GHz ..... ≤1.20
SMA (m)-to-SMA (f) 20 dB attenuator	Huber+Suhner 6620_SMA-50-1/199N	Test system characterization Verifications: • In-band third order intercept • Out-of-band third order intercept • Reverse isolation • Calibration signal amplitude accuracy	Frequency range: DC to 8 GHz Attenuation: 20 dB (nominal) Power rating: 2 W average Impedance: 50 Ω VSWR: DC to 4 GHz ..... ≤1.15 4 GHz to 8 GHz ..... ≤1.20
SMA (m)-to-SMA (f) 6 dB attenuator	Anritsu 41KB-6	Test system characterization Calibration signal amplitude accuracy verification Adjustments: • RF gain • Calibration tone power accuracy	Frequency range: DC to 8 GHz Attenuation: 6 dB Power rating: 2 W average

Table 1. Recommended Equipment for NI 5693 Calibration (Continued)

Equipment	Recommended Models	Where Used	Minimum Requirements
Power splitter (two-resistor type)	Aeroflex/Weinschel 1593	Test system characterization Verifications: • In-band third order intercept • Out-of-band third order intercept • Reverse isolation • Calibration signal amplitude accuracy Adjustments: • RF gain • Calibration tone power accuracy	Frequency range: DC to 8 GHz Amplitude tracking: <0.25 dB Phase tracking: <4° Insertion loss: ≤8.5 dB (6 dB, nominal) Power rating: 1 W Impedance: 50 Ω VSWR: DC to 8 GHz ....≤1.25 Equivalent output VSWR: DC to 8 GHz ....≤1.25 Connectors: 3.5 mm (f)
Low frequency power combiner	Mini Circuits ZFSC-2-5-S+	Test system characterization Verifications: • In-band third order intercept • Out-of-band third order intercept	Frequency range: 10 MHz to 1.5 GHz Isolation: 10 MHz to 100 MHz......................≥15 dB 100 MHz to 750 MHz....................≥20 dB 750 MHz to 1.5 GHz......................≥18 dB Insertion loss: 10 MHz to 100 MHz......................≤3.6 dB 100 MHz to 750 MHz....................≤4.0 dB 750 MHz to 1.5 GHz......................≤4.5 dB Connectors: SMA (f)

Table 1. Recommended Equipment for NI 5693 Calibration (Continued)

Equipment	Recommended Models	Where Used	Minimum Requirements
High frequency power combiner	Agilent 87302C	Test system characterization Verifications: • In-band third order intercept • Out-of-band third order intercept	Frequency range: 500 MHz to 8 GHz Isolation: 500 MHz to 8 GHz ....≥19 dB Insertion loss: 500 MHz to 8 GHz ....≤4.5 dB Connectors: 3.5 mm (f)
Torque wrench	—	—	Refer to *Test Conditions* for torque wrench specifications.

Test Conditions

The following setup and environmental conditions are required to ensure the NI 5693 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 the relative humidity between 10% and 90%, noncondensing.
- 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 about maintaining adequate air circulation in your PXI/PXI Express chassis, refer to the *Maintain Forced-Air Cooling Note to Users* document available at `ni.com/manuals`.
- 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 5693. The warm-up time ensures that the NI 5693 and test instrumentation are at a 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 and 100 ms for each other iteration.
- Use an appropriate torque wrench or torque screwdriver and SMA driver bit to tighten all module RF connectors (SMA or 3.5 mm). NI recommends use of 1 N · m (9 lb · in.).
- Lock all test equipment to the REF OUT signal on the back of the PXI Express chassis. Refer to the *NI 5667 Timing Configurations* topic in the *NI RF Vector Signal Analyzers Help* for more information about configuring clocking sources.

Initial Setup

Refer to the *NI 5693 RF Preselector Module Getting Started Guide* for information about how to install the software and hardware and how to configure the NI 5693 in Measurement & Automation Explorer (MAX).

Characterizing the Test System

You use the measured response of the test system during verification tests.

The power splitter and attenuation response is measured at the RF input frequencies used in the verification tests.

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

Designating the Power Splitter Reference Output

Designate one of the two outputs of the power splitter as the reference output. Consistently use the same output as the reference output throughout the characterization and verification procedures.

Zeroing and Calibrating the Power Sensor

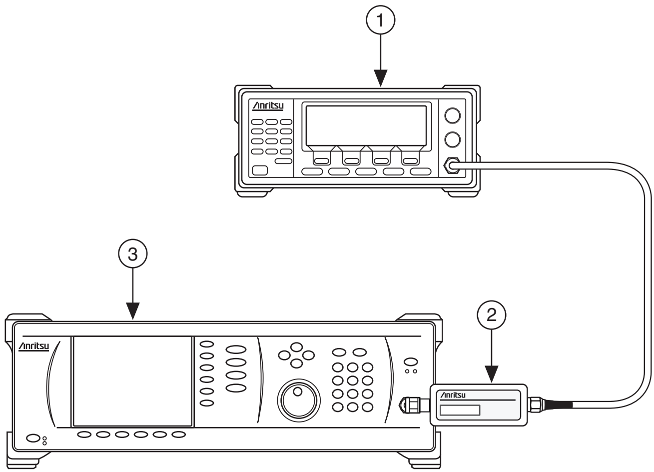
1. Connect channel A of the power meter to power sensor A.
2. Connect channel B of the power meter to power sensor B.
3. Zero and calibrate the power sensors using the built-in functions in the power meter.

Characterizing the RF Source 1 Power (Direct)

Note Zero and calibrate the power sensor using the procedure in the *Zeroing and Calibrating the Power Sensor* section prior to starting this procedure.

1. Connect the RF source 1 output directly to the power sensor B input.
2. Connect power sensor B to channel B of the power meter. Figure 1 shows the completed equipment setup.

Figure 1. RF Source 1 Power (Direct) Characterization Equipment Setup



1	Power Meter	2	Power Sensor B	3	RF Source 1

3. Set the RF source 1 frequency according to the first row in Table 2.

Table 2. RF Source Power (Direct) Characterization Frequencies

Start Frequency	Stop Frequency	Step Size
10 MHz	100 MHz	10 MHz
100 MHz	187.5 MHz	87.5 MHz
190 MHz	199 MHz	9 MHz
200 MHz	612.5 MHz	100 MHz
700 MHz	3.6 GHz	100 MHz
3.6 GHz	7 GHz	200 MHz

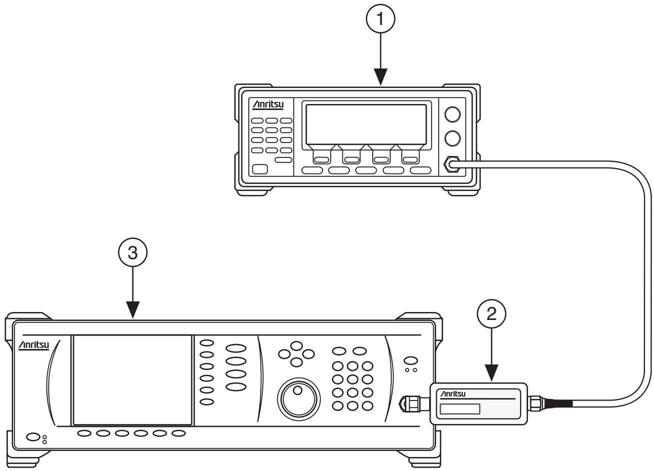
4. Set the RF source 1 power to 0 dBm.
5. Measure the channel B power using the appropriate calibration factor for the power sensor frequency. This value is the $\textit{RF Source 1 Power (Direct)}_B$.
6. Repeat steps 3 through 5 for all remaining frequencies described by Table 2.
7. Repeat steps 1 through 6 using power sensor A. This measured power is the $\textit{RF Source 1 Power (Direct)}_A$.

Characterizing the RF Source 2 Power (Direct)

Note Zero and calibrate the power sensor using the procedure in the *Zeroing and Calibrating the Power Sensor* section prior to starting this procedure.

1. Connect the RF source 2 output directly to the power sensor B input.
2. Connect power sensor B to channel B of the power meter. Figure 2 shows the completed equipment setup.

Figure 2. RF Source 2 Power (Direct) Characterization Equipment Setup



1	Power Meter	2	Power Sensor B	3	RF Source 2

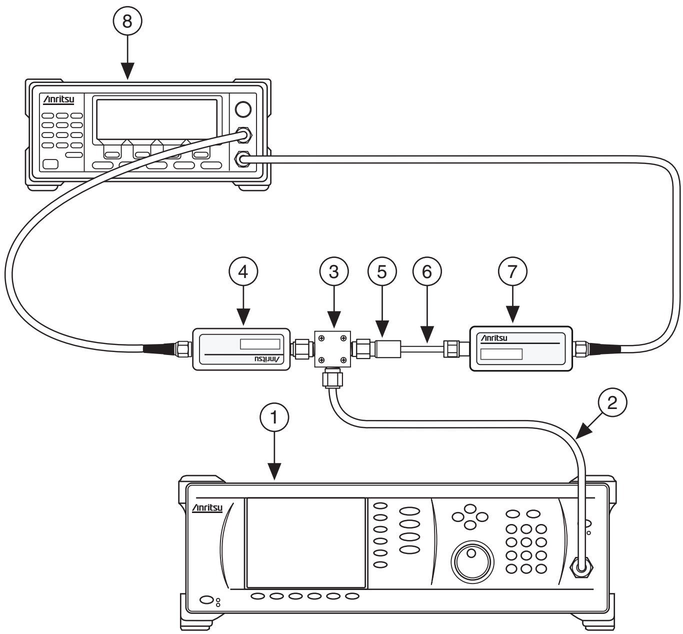
3. Set the RF source 2 frequency according to the first row in Table 2.
4. Set the RF source 2 power to 0 dBm.
5. Measure the channel B power using the appropriate calibration factor for the power sensor frequency. This value is the *RF Source 2 Power (Direct)*.
6. Repeat steps 3 through 5 for all remaining frequencies described by Table 2.

Characterizing the RF Source Power (with Splitter and Attenuator)

Note Zero and calibrate the power sensor and define the power splitter reference output using the procedures in the *Designating the Power Splitter Reference Output* and *Zeroing and Calibrating the Power Sensor* sections prior to starting this procedure.

1. Connect the RF source 1 output to the power splitter input using the SMA (m)-to-SMA (m) cable.
2. Connect power sensor A to the reference output of the power splitter.
3. Connect power sensor B to the other output of the power splitter using the SMA (f)-to-SMA (m) semi-rigid cable and the 6 dB attenuator. Figure 3 shows the completed equipment setup.

Figure 3. RF Source Power (through Splitter and Attenuator) Characterization Equipment Setup



1	RF Source 1	5	6 dB Attenuator
2	SMA (m)-to-SMA (m) Cable	6	SMA (f)-to-SMA (m) Semi-Rigid Cable
3	Power Splitter	7	Power Sensor B
4	Power Sensor A	8	Power Meter

4. Set the RF source 1 frequency according to the first row in Table 3.

Table 3. RF Source Power (through Splitter and Attenuator) Characterization Frequencies

Start Frequency	Stop Frequency	Step Size
10 MHz	100 MHz	10 MHz
100 MHz	187.5 MHz	87.5 MHz
190 MHz	199 MHz	9 MHz
200 MHz	612.5 MHz	100 MHz
700 MHz	3.6 GHz	100 MHz
3.6 GHz	7 GHz	200 MHz

5. Set the RF source 1 power to 0 dBm.
6. Measure the channel A power and the channel B power using the appropriate calibration factor for the RF source 1 frequency.
7. Calculate the splitter balance and 6 dB attenuator path loss and the RF source through splitter path loss using the following equations:

$$\textit{Splitter Balance and 6 dB Attenuator Path Loss}_{\mathrm{A\_OUT}} = \textit{Channel B Power} - \textit{Channel A Power}$$

$$\textit{RF Source through Splitter Path Loss}_{\mathrm{A\_OUT}} = \textit{RF Source 1 Power (Direct)}_{\mathrm{A}} - \textit{Channel A Power}$$

8. Repeat steps 4 through 7 for all remaining frequencies described by Table 3.
9. Repeat steps 2 through 8 after swapping the power sensor A and power sensor B connections.
10. Calculate the splitter balance and 6 dB attenuator path loss, and calculate the RF source through splitter path loss using the following equations:

$$\textit{Splitter Balance and 6 dB Attenuator Path Loss}_{B\_OUT} = \textit{Channel A Power} - \textit{Channel B Power}$$

$$\textit{RF Source through Splitter Path Loss}_{\mathrm{B\_OUT}} = \textit{RF Source 1 Power (Direct)}_{\mathrm{B}} - \textit{Channel B Power}$$

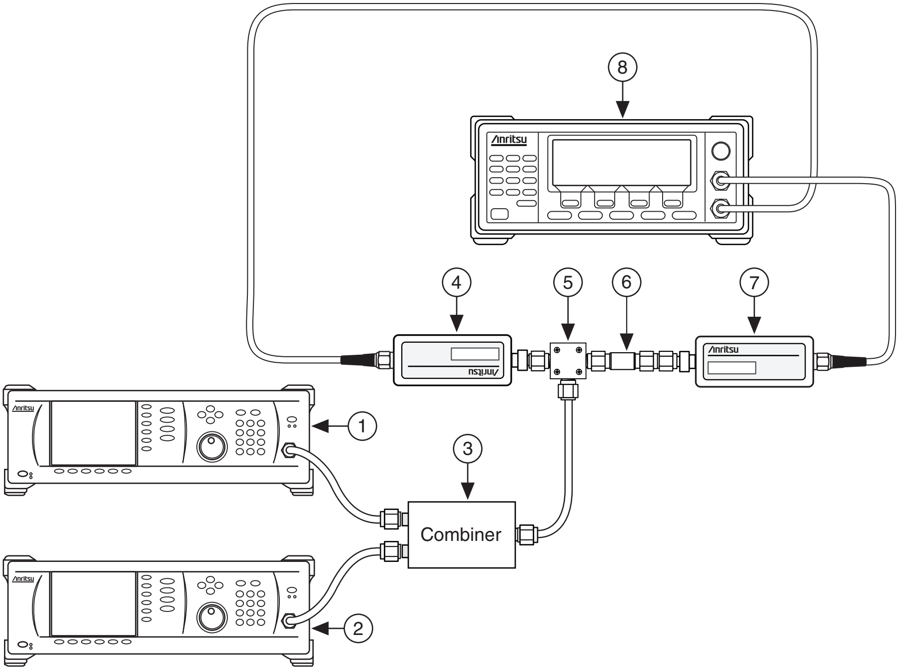
Characterizing the RF Source Power (with Combiner, Splitter, and 20 dB Attenuator)

Note Zero and calibrate the power sensor using the procedure in the *Zeroing and Calibrating the Power Sensor* section prior to starting this procedure.

1. Connect the RF source 1 output to connector 1 of the low frequency power combiner using the SMA (m)-to-SMA (m) cable.
2. Connect the RF source 2 output to connector 2 of the low frequency power combiner using the SMA (m)-to-SMA (m) cable.

3. Connect the sum connector of the low frequency power combiner to the power splitter input using the SMA (m)-to-SMA (m) cable.
4. Connect power sensor B to the reference output of the power splitter.
5. Connect power sensor A to the other output of the power splitter using the 20 dB attenuator. Figure 4 shows the completed equipment setup.

Figure 4. RF Source Power (with Combiner, Splitter, and 20 dB Attenuator) Characterization Equipment Setup



1	RF Source 1	4	Power Sensor B	7	Power Sensor A
2	RF Source 2	5	Power Splitter	8	Power Meter
3	Power Combiner	6	20 dB Attenuator		

6. Turn off the RF source 2 output.

7. Set the RF source 1 frequency according to the first row in Table 4.

Table 4. RF Source Power (with Combiner, Splitter, and 20 dB Attenuator) Characterization Frequencies

Start Frequency	Stop Frequency	Step Size
10 MHz	100 MHz	10 MHz
100 MHz	187.5 MHz	87.5 MHz
190 MHz	199 MHz	9 MHz
200 MHz	612.5 MHz	100 MHz
700 MHz	3.6 GHz	100 MHz
3.6 GHz	7 GHz	200 MHz

8. Set the RF source 1 power to 0 dBm.
9. Measure the channel A power and the channel B power using the appropriate calibration factor for the RF source 1 frequency.
10. Calculate the RF source 1 through splitter and combiner path loss and the sensor/20 dB attenuator/splitter tracking using the following equations:

$$\textit{RF Source 1 through Splitter and Combiner Path Loss} = \textit{RF Source 1 Power (Direct)}_B - \textit{Channel B Power}$$

$$\textit{Sensor/20 dB Attenuator/Splitter Tracking} = \textit{Channel B Power} - \textit{Channel A Power}$$

11. Repeat steps 7 through 10 for all remaining frequencies described by Table 4.

Note For frequencies >700 MHz, use the high frequency power combiner in place of the low frequency power combiner.

12. Turn off RF source 1 output.
13. Turn on RF source 2 output.
14. Set the RF source 2 frequency according to the first row in Table 4.
15. Set the RF source 2 power to 0 dBm.
16. Measure the channel A power and the channel B power using the appropriate calibration factor for the RF source 2 frequency.
17. Calculate the RF source 2 through splitter and combiner path loss using the following equation:

$$\textit{RF Source 2 through Splitter and Combiner Path Loss} = \textit{RF Source 2 Power (Direct)}_B - \textit{Channel B Power}$$

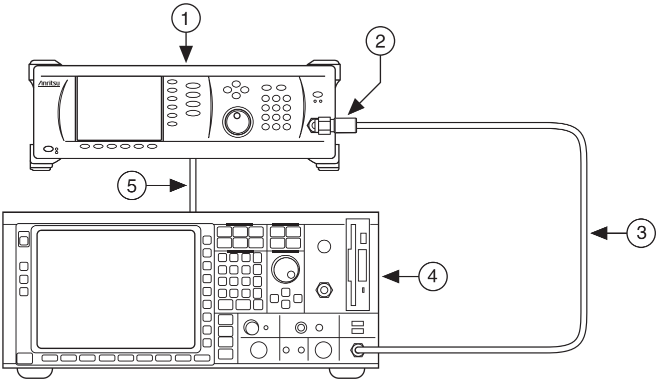
18. Repeat steps 14 through 17 for all remaining frequencies described by Table 4.

Note For frequencies >700 MHz, use the high frequency power combiner in place of the low frequency power combiner.

Characterizing the Spectrum Analyzer (with Cable and 10 dB Attenuator)

1. Connect one end of the 10 dB attenuator to the RF source 1 output and the other end to the RF input of the spectrum analyzer using the SMA (m)-to-SMA (m) cable.
2. Connect the RF source 1 10 MHz REF OUT connector to the spectrum analyzer REF IN connector using the BNC (m)-to-BNC (m) cable. Figure 5 shows the completed equipment setup.

Figure 5. Spectrum Analyzer (with Cable and 10 dB Attenuator) Characterization Equipment Setup



1	RF Source 1	3	SMA (m)-to-SMA (m) Cable	5	BNC (m)-to-BNC (m) Cable
2	10 dB Attenuator	4	Spectrum Analyzer		

3. Configure the spectrum analyzer according to the following settings:
   - Reference level: 0 dBm
   - Span: 3 kHz
   - Resolution bandwidth: 1 kHz
   - External reference source: EXT
4. Set the RF source 1 frequency to 4.6 GHz
5. Set the RF source 1 power to 0 dBm.
6. Set the spectrum analyzer center frequency according to step 4.
7. Measure the peak amplitude using the spectrum analyzer.
8. Calculate the cable and 10 dB attenuator loss using the following equation:

Cable and 10 dB Attenuator Loss = RF Source 1 Power (Direct)$_{B}$ *- Spectrum Analyzer Reading*

9. Repeat steps 3 through 8 for all frequencies between 4.6 GHz and 7.2 GHz, in 200 MHz steps.

As-Found and As-Left Limits

The as-found limits are the published specifications for the NI 5693. NI uses these limits to determine whether the NI 5693 meets the device specifications when it is received for calibration.

The as-left limits are equal to the published NI specifications for the NI 5693, less guard bands for manufacturing measurement uncertainty, temperature drift, and drift over time. NI uses these limits to reduce the probability that the instrument will be outside the published specification limits at the end of the calibration cycle.

Verification

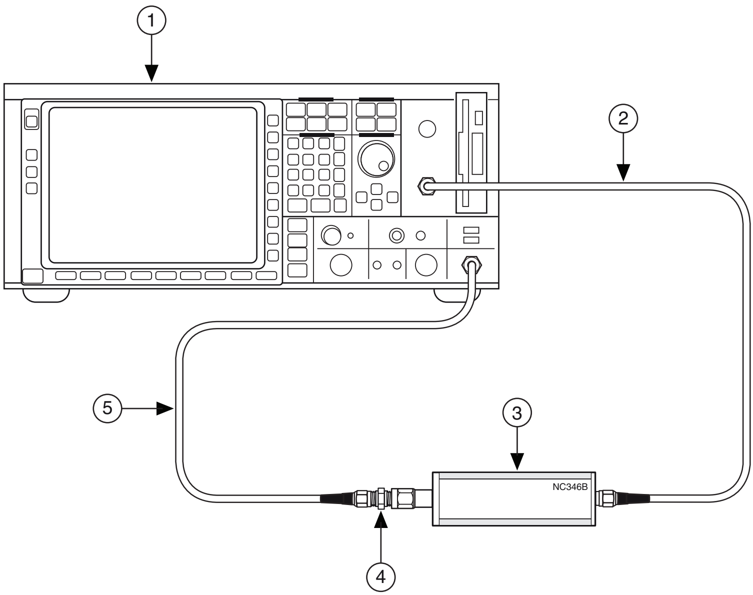
The performance verification procedures assume that adequate traceable uncertainties are available for the calibration references.

Verifying Noise Figure

1. Connect the noise source output to the spectrum analyzer RF input connector using the SMA (f)-to-SMA (f) adapter and the SMA (m)-to-SMA (m) cable.
2. Connect the noise source input to the spectrum analyzer noise source supply connector using the BNC (m)-to-BNC (m) cable. Figure 6 shows the completed equipment setup.

Note This measurement is sensitive to radiated electromagnetic interference (EMI) from outside sources such as cellular telephones, computers, unshielded cables, and so on. For best results, locate sources of EMI radiation as far as possible from the device under test.

Figure 6. Spectrum Analyzer Noise Figure Characterization Equipment Setup



1	Spectrum Analyzer	3	Noise Source	5	SMA (m)-to-SMA (m) Cable
2	BNC (m)-to-BNC (m) Cable	4	SMA (f)-to-SMA (f) Adapter		

3. Create a new session for the NI 5693.
4. Configure the NI 5693 according to the following settings:
   - Reference level: -60 dBm
   - Preamp enabled: Enabled
   - IF output power level: -10 dBm
5. Configure the spectrum analyzer according to the following settings:
   - Span: 0 Hz
   - Reference level: -50 dBm
   - Resolution bandwidth filter: 10 kHz
   - Video bandwidth filter: 30 Hz
   - RF attenuation: 0 dB
   - Preamp: On
   - Trace type: Average
   - Detector type: Sample
   - Average count: 100
6. Turn off the spectrum analyzer noise source control.

7. Set the spectrum analyzer center frequency according to the first row in Table 5.

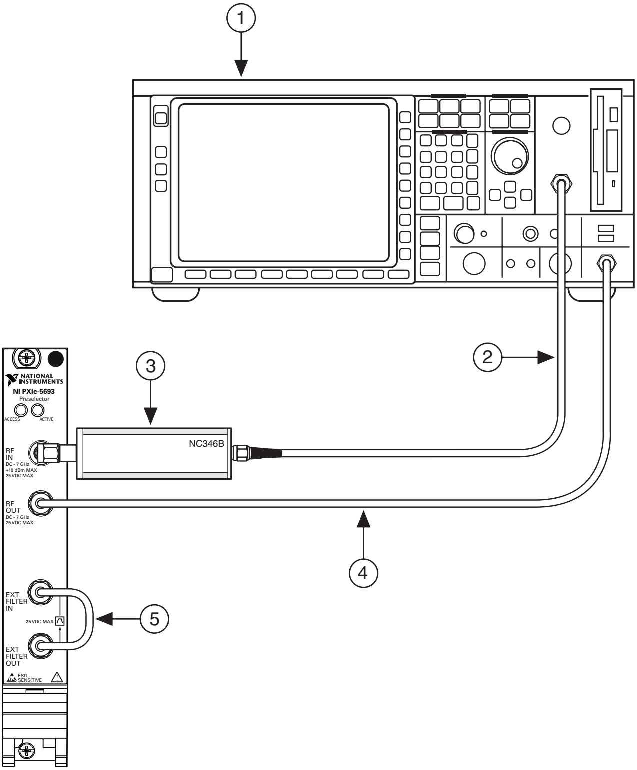
Table 5. Noise Figure Verification Test Frequencies

Start Frequency	Stop Frequency	Frequency Step
21.2 MHz	201.2 MHz	20 MHz
401.2 MHz	6,801.2 MHz	200 MHz
7 GHz	—	—

8. Commit the NI 5693 settings to hardware.
9. Record the spectrum analyzer marker amplitude.
10. Repeat steps 6 through 9 for all remaining frequencies described by Table 5. The results from steps 9 and 10 are referred to as *Cal Cold (dBm)*.
11. Repeat steps 6 through 10 with the spectrum analyzer noise source control turned on. The results from step 11 are referred to as *Cal Hot (dBm)*.
12. Connect the NI 5693 RF OUT connector to the spectrum analyzer RF IN connector using the SMA (m)-to-SMA (m) cable (36 in.).
13. Connect the noise source output to the NI 5693 RF IN connector.

14. Connect the noise source input to the spectrum analyzer noise source supply connector using the BNC (m)-to-BNC (m) cable. Figure 7 shows the completed equipment setup.

Figure 7. NI 5693 Noise Figure Verification Equipment Setup



1	Spectrum Analyzer	4	SMA (m)-to-SMA (m) Cable (36 in.)
2	BNC (m)-to-BNC (m) Cable	5	SMA (m)-to-SMA (m) Cable
3	Noise Source		

15. Turn off the spectrum analyzer noise source control.
16. Set the NI 5693 center frequency according to the first row in Table 5.
17. Commit the NI 5693 settings to hardware.
18. Record the spectrum analyzer marker amplitude.
19. Repeat steps 15 through 18 for all remaining frequencies described by Table 5. The results from steps 18 and 19 are referred to as *Meas Cold (dBm)*.

20. Repeat steps 15 through 19 with the spectrum analyzer noise source control turned on. The results from step 20 are referred to as *Meas Hot (dBm)*.
21. Record the ENR of the noise source for each frequency in Table 5. Use linear interpolation for frequencies between the calibration points of the noise source.
22. Calculate the noise figure by completing the following steps:
    a. At each measurement frequency in Table 5, convert the *Cal Cold (dBm)*, *Cal Hot (dBm)*, *Meas Cold (dBm)*, *Meas Hot (dBm)* and the *Noise Source*'s *ENR* dB values to linear values using the following equation:

    $$\text{Linear} = 10^{(x/10)}$$

    where x is the recorded value for each measurement.

    b. Calculate the noise figure using the following equations:

    $$Y^* = \frac{N2^*}{N1^*}$$

    $$Y = \frac{N2}{N1}$$

    $$F^* = \frac{ENR}{Y^* - 1}$$

    $$F = \frac{ENR}{Y - 1}$$

    $$Gain = \frac{N2 - N1}{N2^* - N1^*}$$

    $$Noise\ Figure\ (dB) = 10 \times \log 10\left[F - \left(\frac{F^* - 1}{Gain}\right)\right]$$

    where $N2^*$ = Cal Hot linear

    $N1^*$ = Cal Cold linear

    $N2$ = Meas Hot linear

    $N1$ = Meas Cold linear

23. Compare the calculated noise figure values to the verification test limits in Table 6.

Table 6. Noise Figure Verification Test Limits

Frequency	As-Found Limit (dB)	As-Left Limit (dB)
20 MHz to 150 MHz	13	11.1
>150 MHz to 2.5 GHz	14.5	12.9
>2.5 GHz to 3.2 GHz	15	13.5
>3.2 GHz to 5.5 GHz	18	16
>5.5 GHz to 7 GHz	18.5	17

24. Close the NI 5693 session.

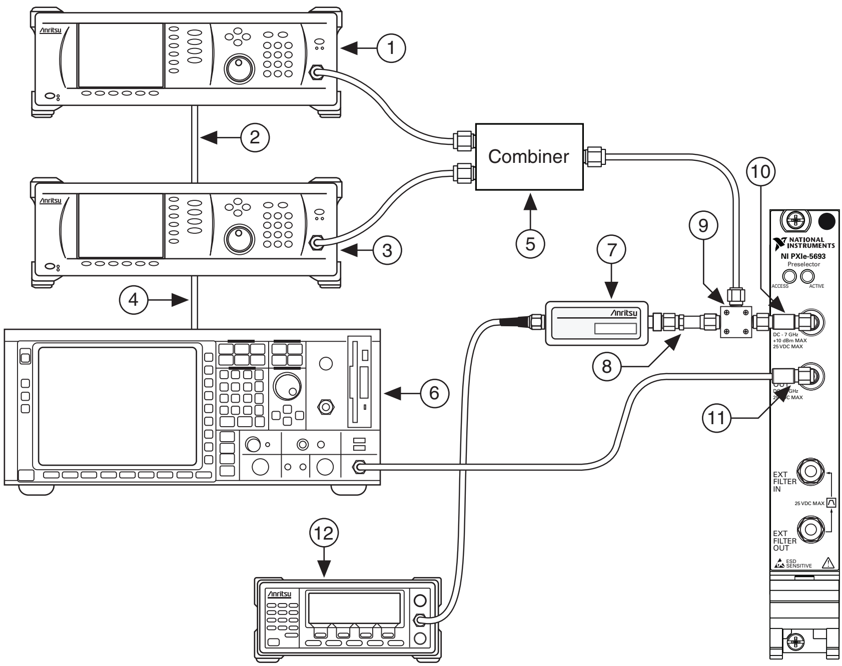
If the noise figure verification procedure determines that the NI 5693 is outside of its limits, refer to *Worldwide Support and Services* for information about support resources or service requests.

Verifying In-Band Third Order Intercept (TOI)

1. Connect the RF source 1 RF OUT connector to the low frequency power combiner input using the SMA (m)-to-SMA (m) cable.
2. Connect the RF source 2 RF OUT connector to the other low frequency power combiner input using the SMA (m)-to-SMA (m) cable.
3. Connect the low frequency power combiner output to the power splitter input using the SMA (m)-to-SMA (m) cable.
4. Connect the 20 dB attenuator to the reference output of the power splitter.
5. Connect power sensor A to the 20 dB attenuator.
6. Connect the other output of the power splitter to the NI 5693 RF IN connector using the SMA (m)-to-SMA (m) adapter.
7. Connect the 10 MHz clock reference output connector on the RF source 1 back panel to the 10 MHz clock reference input connector on the RF source 2 back panel using the BNC (m)-to-BNC (m) cable.
8. Connect the 10 MHz clock reference output connector on the RF source 2 back panel to the clock reference connector on the spectrum analyzer using the BNC (m)-to-BNC (m) cable.

9. Connect one end of the 10 dB attenuator to the NI 5693 RF OUT connector and the other end to the RF input of the spectrum analyzer using the SMA (m)-to-SMA (m) cable. Figure 8 shows the completed equipment setup.

Figure 8. In-Band TOI Verification Equipment Setup



1	RF Source 1	5	Combiner	9	Power Splitter
2	BNC (m)-to-BNC (m) Cable	6	Spectrum Analyzer	10	SMA (m)-to-SMA (m) Adapter
3	RF Source 2	7	Power Sensor A	11	10 dB Attenuator
4	BNC (m)-to-BNC (m) Cable	8	20 dB Attenuator	12	Power Meter

10. Create a new session for the NI 5693.
11. Configure the NI 5693 according to the following settings:
    - Reference level: -60 dBm
    - Preamp enabled: Disabled
    - IF output power level: -10 dBm
12. Configure the spectrum analyzer according to the following settings:
    - Span: 0 Hz
    - Reference level: 0 dBm
    - Resolution bandwidth filter: 100 Hz
    - Video bandwidth filter: 200 Hz
    - RF attenuation: 10 dB
    - Trace type average: Enabled

- Detector type: Auto Peak
- Average count: 5
- External reference source: EXT

13. Configure RF source 1 and RF source 2 according to the following settings:
    - Single frequency mode: On
    - Power level: -10 dBm
14. Set the power sensor A settling percentage to 0.1% and program the power meter to trigger when settled.
15. Set the NI 5693 center frequency according to the first row in Table 7.

Table 7. In-Band TOI Verification Test Frequencies

Center Frequency (MHz)	Tone Spacing (kHz)	Combiner
27	700	Low Frequency
47	700	Low Frequency
80	700	Low Frequency
130	700	Low Frequency
193	700	Low Frequency
288	700	Low Frequency
463	700	Low Frequency
763	700	High Frequency
1,255	700	High Frequency
1,780	700	High Frequency
2,250	700	High Frequency
2,750	700	High Frequency
3,400	700	High Frequency
4,200	700	High Frequency
5,200	700	High Frequency
6,400	700	High Frequency

16. For each NI 5693 center frequency in Table 7, calculate the following two frequencies:
    - *Tone 1 Frequency = NI 5693 Center Frequency* + 1.2 MHz - (700 kHz/2)
    - *Tone 2 Frequency = NI 5693 Center Frequency* + 1.2 MHz + (700 kHz/2

17. Tune RF source 1 to tone 1 frequency.
18. Tune RF source 2 to tone 2 frequency.
19. Commit the NI 5693 settings to hardware.
20. Turn off the RF source 2 output power.
21. Adjust the RF source 1 power level to have a -10 dBm target tone power at the DUT input connector using the following equation:

RF Source 1 = Target Tone Power + RF Source 1 through Splitter and Combiner Path Loss

22. Measure the channel A power using the appropriate calibration factor for the power sensor frequency.
23. Calculate the RF input tone 1 power using the following equation:

RF Input Tone 1 Power = Channel A Power + Sensor/20 dB Attenuator/Splitter Tracking

Note Use the Sensor/20 dB Attenuator/Splitter Tracking characterization value at the current RF source 1 frequency.

24. Turn off the RF source 1 output power.
25. Turn on the RF source 2 output power.
26. Adjust the RF source 2 power level to have a -10 dBm target tone power at the DUT input connector using the following equation:

RF Source 2 = Target Tone Power + RF Source 2 through Splitter and Combiner Path Loss

27. Measure the channel A power using the appropriate calibration factor for the power sensor frequency.
28. Calculate the RF input tone 2 power using the following equation:

RF Input Tone 2 Power = Channel A Power + Sensor/20 dB Attenuator/Splitter Tracking

Note Use the Sensor/20 dB Attenuator/Splitter Tracking characterization value at the current RF source 2 frequency.

29. Continue adjusting the RF source 2 power level until the difference between RF input tone 1 power and RF input tone 2 power is less than 0.1 dB.
30. Turn on the RF source 1 output power.
31. Determine the *Output Tone 1 Power* value by completing the following steps:
    a. Tune the spectrum analyzer center frequency to tone 1 frequency.
    b. Measure the spectrum analyzer peak amplitude. This value is the *Output Tone 1 Power*.
32. Determine the *Output Tone 2 Power* value by completing the following steps:
    a. Tune the spectrum analyzer center frequency to tone 2 frequency.
    b. Measure the spectrum analyzer peak amplitude. This value is the *Output Tone 2 Power*.

33. Determine the IMD_L value by completing the following steps:
    a. Tune the spectrum analyzer center frequency to tone 1 frequency - 700 kHz.
    b. Measure the spectrum analyzer peak amplitude. This value is IMD_L.
34. Determine the IMD_U value by completing the following steps:
    a. Tune the spectrum analyzer center frequency to tone 2 frequency + 700 kHz.
    b. Measure the spectrum analyzer peak amplitude. This value is IMD_U.
35. Correct all spectrum analyzer readings using the *Cable and 10 dB Attenuator Loss* values from steps 8 through 9 in the *Characterizing the Spectrum Analyzer (with Cable and 10 dB Attenuator)* section.
36. Calculate TOI_L using the following equation:

$$TOI_L = RF\ Input\ Tone\ 1\ Power + (Output\ Tone\ 2\ Power - IMD_L)/2$$

37. Calculate TOI_U using the following equation:

$$TOI_U = RF\ Input\ Tone\ 2\ Power + (Output\ Tone\ 1\ Power - IMD_U)/2$$

38. The smaller of the TOI_L or TOI_U values is the in-band TOI.
39. Repeat steps 15 through 37 for all remaining frequencies in Table 7.
40. Repeat steps 15 through 38 with the NI 5693 preamp enabled and the RF source 1 and RF source 2 power level set to -30 dBm. For steps 21 and 26, adjust the RF source to a target tone power of -30 dBm.
41. Compare the in-band TOI values to the verification test limits in Table 8 or Table 9 as appropriate.

Table 8. In-Band TOI Verification Test Limits Preamp Disabled

Frequency	As-Found Limit (dB)	As-Left Limit (dB)
20 MHz to 150 MHz	20	21.6
>150 MHz to 2.5 GHz	18	20
>2.5 GHz to 3.2 GHz	17	19
>3.2 GHz to 5.5 GHz	14	17.3
>5.5 GHz to 7 GHz	15	17.7

Table 9. n-Band TOI Verification Test Limits Preamp Enabled

Frequency	As-Found Limit (dB)	As-Left Limit (dB)
20 MHz to 150 MHz	-2	-1
>150 MHz to 2.5 GHz	-7	-5.8
>2.5 GHz to 3.2 GHz	-5.5	-4.1
>3.2 GHz to 5.5 GHz	-5	-3
>5.5 GHz to 7 GHz	-4.5	-2.9

42. Close the NI 5693 session.

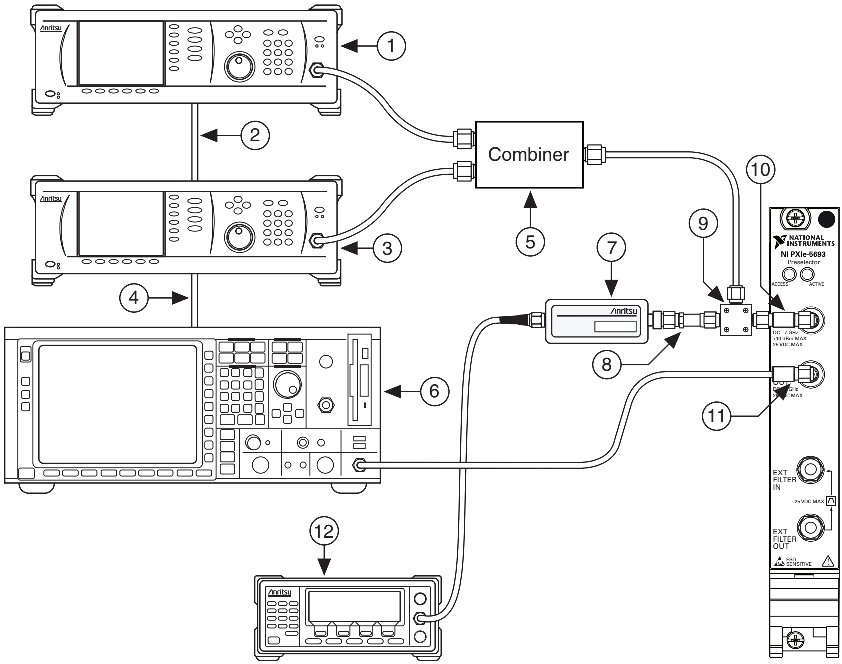
If the in-band TOI verification procedure determines that the NI 5693 is outside of its limits, refer to *Worldwide Support and Services* for information about support resources or service requests.

Verifying Out-of-Band TOI

1. Connect the RF source 1 RF OUT connector to the low frequency power combiner input using the SMA (m)-to-SMA (m) cable.
2. Connect the RF source 2 RF OUT connector to the other low frequency power combiner input using the SMA (m)-to-SMA (m) cable.
3. Connect the low frequency power combiner output to the power splitter input using the SMA (m)-to-SMA (m) cable.
4. Connect the 20 dB attenuator to the reference output of the power splitter.
5. Connect power sensor A to the 20 dB attenuator.
6. Connect the other output of the power splitter to the NI 5693 RF IN connector using the SMA (m)-to-SMA (m) adapter.
7. Connect the 10 MHz clock reference output connector on the RF source 1 back panel to the 10 MHz clock reference input connector on the RF source 2 back panel using the BNC (m)-to-BNC (m) cable.
8. Connect the 10 MHz clock reference output connector on the RF source 2 back panel to the clock reference connector on the spectrum analyzer using the BNC (m)-to-BNC (m) cable.

9. Connect one end of the 10 dB attenuator to the NI 5693 RF OUT connector and the other end to the RF input of the spectrum analyzer using the SMA (m)-to-SMA (m) cable. Figure 9 shows the completed equipment setup.

Figure 9. Out-of-Band TOI Verification Equipment Setup



1	RF Source 1	5	Combiner	9	Power Splitter
2	BNC (m)-to-BNC (m) Cable	6	Spectrum Analyzer	10	SMA (m)-to-SMA (m) Adapter
3	RF Source 2	7	Power Sensor A	11	10 dB Attenuator
4	BNC (m)-to-BNC (m) Cable	8	20 dB Attenuator	12	Power Meter

10. Create a new session for the NI 5693.
11. Configure the NI 5693 according to the following settings:
    - Reference level: -60 dBm
    - Preamp enabled: Disabled
    - IF output power level: -10 dBm
12. Configure the spectrum analyzer according to the following settings:
    - Span: 0 Hz
    - Reference level: -20 dBm
    - Resolution bandwidth filter: 100 Hz
    - Video bandwidth filter: 50 Hz
    - RF attenuation: 10 dB
    - Trace type averaging: Enabled

- Detector type: Auto Peak
- Average count: 50
- External reference source: EXT

13. Configure the RF source 1 and RF source 2 according to the following settings:
    - Single frequency mode: Enabled
    - Power level: -5 dBm
14. Set the power sensor A settling percentage to 0.1% and program the power meter to trigger when settled.
15. Set the NI 5693 center frequency according to the first row in Table 10. This is the *IMD Frequency*.

Table 10. Out-of-Band TOI Verification Test Frequencies

IMD Frequency (MHz)	Tone Spacing (MHz)	IMD Side
30	20	Lower
50	40	Lower
90	40	Lower
110	40	Upper
150	40	Lower
170	50	Upper
190	50	Lower
240	60	Upper
340	60	Lower
360	70	Upper
550	70	Lower
590	80	Upper
930	80	Lower
960	200	Upper
1,540	410	Lower
1,580	120	Upper
1,980	130	Lower
2,020	140	Upper
2,490	150	Lower

Table 10. Out-of-Band TOI Verification Test Frequencies (Continued)

IMD Frequency (MHz)	Tone Spacing (MHz)	IMD Side
2,520	300	Upper
2,980	300	Lower
3,020	300	Upper
3,780	300	Lower
3,820	300	Upper
4,580	300	Lower
4,620	300	Upper
5,780	300	Lower
5,820	300	Upper

16. Commit the NI 5693 settings to hardware.
17. If the *IMD Side* from Table 10 is lower, complete the following steps:
    a. Tune the RF source 1 frequency to the tone 1 frequency lower value using the following equation:

    $$\textit{Tone 1 Frequency Lower} = \textit{IMD Frequency} + 1.2\text{ MHz} + \textit{Tone Spacing}$$

    b. Tune the RF source 2 frequency to the tone 2 frequency lower value using the following equation:

    $$\textit{Tone 2 Frequency Lower} = \textit{IMD Frequency} + 1.2\text{ MHz} + (\textit{Tone Spacing} \times 2)$$

18. If the *IMD Side* from Table 10 is upper, complete the following steps:
    a. Tune the RF source 1 frequency to the tone 1 frequency upper value using the following equation:

    $$\textit{Tone 1 Frequency Upper} = \textit{IMD Frequency} + 1.2\text{ MHz} - (\textit{Tone Spacing} \times 2)$$

    b. Tune the RF source 2 frequency to the tone 2 frequency upper value using the following equation:

    $$\textit{Tone 2 Frequency Upper} = \textit{IMD Frequency} + 1.2\text{ MHz} - \textit{Tone Spacing}$$

19. Turn off the RF source 2 output power.
20. Set the RF source 1 power level to have a -5 dBm target tone power at the DUT input connector using the following equation:

    $$\textit{RF Source 1 Power Level} = \textit{Target Tone Power} + \textit{RF Source 1 through Splitter and Combiner Path Loss}$$

21. Measure the channel A power using the appropriate calibration factor for the power sensor frequency.
22. Calculate the RF input tone 1 power using the following equation:

RF Input Tone 1 Power = *Channel A Power* + *Sensor/20 dB Attenuator/Splitter Tracking*

23. Turn off the RF source 1 output power.
24. Turn on the RF source 2 output power.
25. Set the RF source 2 power level to have a -5 dBm target tone power at the DUT input connector using the following equation:

RF Source 2 Power Level = *Target Tone Power* +
RF Source 2 through Splitter and Combiner Path Loss

26. Measure the channel A power using the appropriate calibration factor for the power sensor frequency.
27. Calculate the RF input tone 2 power using the following equation:

RF Input Tone 2 Power = *Channel A Power* + *Sensor/20 dB Attenuator/Splitter Tracking*

28. Adjust the RF source 2 power level until the difference between RF input tone 1 power and RF input tone 2 power is less than 0.1 dB.
29. Turn on the RF source 1 output power.
30. Set the spectrum analyzer center frequency to the IMD frequency + 1.2 MHz.
31. Measure the spectrum analyzer peak amplitude. This value is the *Output IMD Power*.
32. Correct all spectrum analyzer readings using the *Cable and 10 dB Attenuator Loss* values from steps 8 through 9 in the *Characterizing the Spectrum Analyzer (with Cable and 10 dB Attenuator)* section.
33. Read the NI 5693 downconverter gain value. This value is the *DUT Gain*.
34. Calculate the delta using the following equation:

Delta = *RF Input Tone 1 Power* - (*Output IMD Power* - *DUT Gain*)

35. Calculate the out-of-band TOI using the following equation:

Out-of-Band TOI = *RF Input Tone 1 Power* + (*Delta*/2)

36. Repeat steps 15 through 35 for all remaining frequencies in Table 10.

Note For frequencies >700 MHz, use the high frequency power combiner in place of the low frequency power combiner.

37. Repeat steps 15 through 36 for all frequencies in Table 10 with the NI 5693 preamp enabled and the RF source 1 and RF source 2 power level set to -25 dBm. For steps 20 and 25, adjust the RF source target tone power to -25 dBm.

Note For frequencies >700 MHz, use the high frequency power combiner in place of the low frequency power combiner.

38. Compare the calculated out-of-band TOI values to the verification test limits in Table 11 and Table 12 as appropriate.

Table 11. Out-of-Band TOI Verification Test Limits Preamp Disabled

Center Frequency	As-Found Limit (dB)	As-Left Limit (dB)
20 MHz to 150 MHz	38	41.6
>150 MHz to 2.5 GHz	30	32
>2.5 GHz to 7 GHz	29	31

Table 12. Out-of-Band TOI Verification Test Limits Preamp Enabled

Center Frequency	As-Found Limit (dB)	As-Left Limit (dB)
20 MHz to 150 MHz	10	11.3
>150 MHz to 2.5 GHz	0	1.7
>2.5 GHz to 7 GHz	9	11.1

39. Close the NI 5693 session.

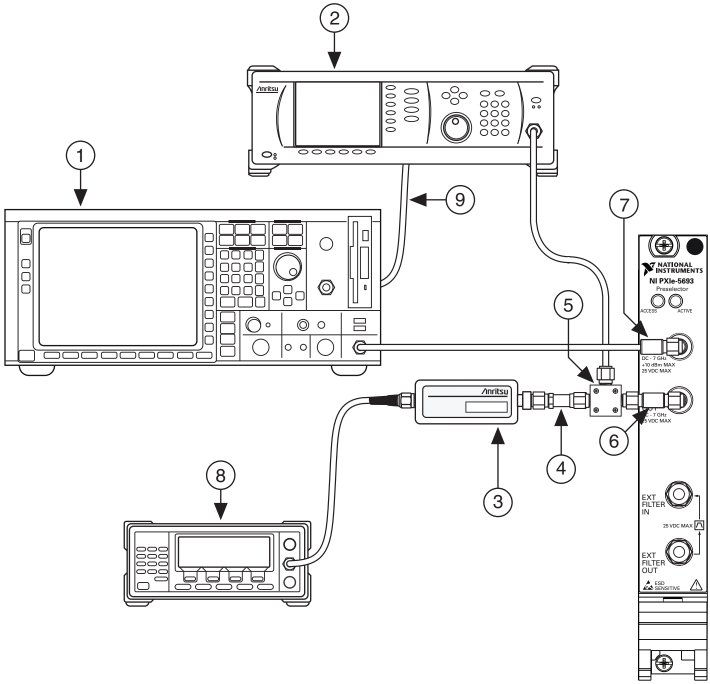
If the out-of-band TOI verification procedure determines that the NI 5693 is outside of its limits, refer to *Worldwide Support and Services* for information about support resources or service requests.

Verifying Reverse Isolation

1. Connect the RF source 1 to the power splitter input using the SMA (m)-to-SMA (m) cable.
2. Connect the 20 dB attenuator to the reference output of the power splitter.
3. Connect power sensor A to the 20 dB attenuator.
4. Connect the other output of the power splitter to the NI 5693 RF OUT connector using the SMA (m)-to-SMA (m) adapter.
5. Connect the 10 MHz clock reference output connector on the RF source 1 back panel to the spectrum analyzer REF IN connector using the BNC (m)-to-BNC (m) cable.

6. Connect one end of the 10 dB attenuator to the NI 5693 RF IN connector and the other end to the RF input of the spectrum analyzer using the SMA (m)-to-SMA (m) cable. Figure 10 shows the completed equipment setup.

Figure 10. Reverse Isolation Verification Equipment Setup



1	Spectrum Analyzer	4	20 dB Attenuator	7	10 dB Attenuator
2	RF Source 1	5	Power Splitter	8	Power Meter
3	Power Sensor A	6	SMA (m)-to-SMA (m) Adapter	9	BNC (m)-to-BNC (m) Cable

7. Create a new session for the NI 5693.
8. Configure the NI 5693 according to the following settings:
   - Reference level: -60 dBm
   - Preamp enabled: Disabled
   - IF output power level: -10 dBm
9. Configure the spectrum analyzer according to the following settings:
   - Span: 0 Hz
   - Reference level: 0 dBm
   - Resolution bandwidth filter: 1,000 Hz
   - Trace type average: Enabled
   - Detector type: Auto Peak

- Average count: 5
- External reference source: EXT

10. Configure the RF source 1 according to the following settings:
    - Single frequency mode: Enabled
    - Power level: 0 dBm
11. Set the power sensor A settling percentage to 0.1% and program the power meter to trigger when settled.
12. Set the NI 5693 center frequency to the center frequency in the first row of Table 13.
13. Enable the NI 5693 filter 1 path.
14. Commit the NI 5693 settings to hardware.
15. Set the spectrum analyzer frequency to the source frequency in the first row Table 13.
16. Set the RF Source 1 center frequency to the source frequency in the first row of Table 13.

Table 13. Reverse Isolation Test Frequencies

Filter	Center Frequency (MHz)	Source Frequency (MHz)
1	27	4,639.5
2	47	4,659.5
3	80	4,692.5
4	130	4,742.5
5	193	4,805.5
6	288	4,900.5
7	463	5,075.5
8	763	5,375.5
9	1,255	5,867.5
10	1,780	6,392.5
11	2,250	6,862.5
12	2,750	7,362.5
13	3,400	4,012.5
14	4,200	4,812.5
15	5,200	5,812.5
16	6,400	7,012.5

17. Measure the channel A power using the appropriate calibration factor for the power sensor frequency.
18. Calculate the RF output power using the following equation:

    RF Output Power = Channel A Power + Sensor/20 dB Attenuator/Splitter Tracking

19. Measure the peak amplitude using the spectrum analyzer.
20. Calculate the RF input power using the following equation:

    RF Input Power = Peak Amplitude + Cable and 10 dB Attenuator Loss

21. Calculate the reverse isolation using the following equation:

    Reverse Isolation = RF Input Power - RF Output Power

22. Repeat steps 12 through 21 for all remaining filters and frequencies in Table 13.
23. Repeat steps 12 through 21 for all filters and frequencies in Table 13 with the NI 5693 preamp enabled.
24. Compare the calculated reverse isolation for filters 1 through 16 to the verification test limits in Table 15.
25. Disable the NI 5693 preamp.
26. Enable the NI 5693 notch filter path.
27. Set the NI 5693 center frequency according the first row in Table 14.
28. Commit the NI 5693 settings to hardware.
29. Set the spectrum analyzer center frequency according to the first row in Table 14.
30. Set the RF source 1 frequency according to the first row in Table 14.

Table 14. Reverse Isolation Test Frequencies for Notch Filter Path

Center Frequency (MHz)	Source Frequency (MHz)
35	4,647.5
70	4,682.5
100	4,712.5
130	4,742.5

31. Measure the channel A power using the appropriate calibration factor for the power sensor frequency.
32. Calculate the RF output power using the following equation:

    RF Output Power = Channel A Power + Sensor/20 dB Attenuator/Splitter Tracking

33. Measure the peak amplitude using the spectrum analyzer.

34. Calculate the RF input power using the following equation:

RF Input Power = Peak Amplitude + Cable and 10 dB Attenuator Loss

35. Calculate the reverse isolation using the following equation:

Reverse Isolation = RF Output Power - RF Input Power

36. Repeat steps 27 through 35 for all remaining frequencies in Table 14.
37. Compare the calculated notch filter reverse isolation values to the verification test limits in Table 15.

Table 15. Reverse Isolation Verification Test Limits

Filter Path	NI 5693 Preamp Enabled	NI 5693 Center Frequency	As-Found Limit (dB)	As-Left Limit (dB)
Filters 1 to 4	Off	20 MHz to 160 MHz	39	43
	On		39	43
Filters 5 to 8	Off	>160 MHz to 950 MHz	38	42
	On		38	42
Filters 9 to 12	Off	>950 MHz to 3 GHz	35	38
	On		35	38
Filters 13 to 16	Off	>3 GHz to 7 GHz	35	38
	On		35	38
Notch Filter	Off	32 MHz to 166 MHz	35	37

38. Close the NI 5693 session.

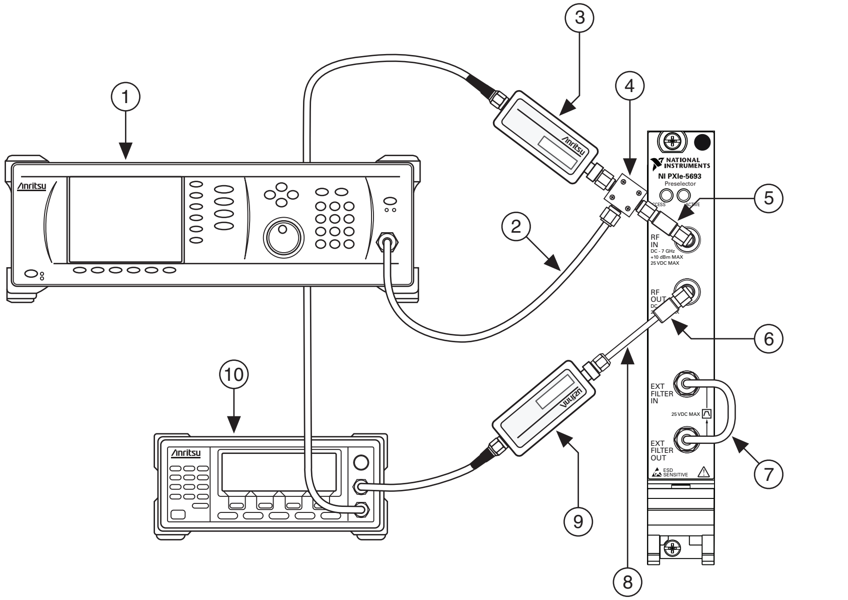
If the reverse isolation verification procedure determines that the NI 5693 is outside of its limits, refer to *Worldwide Support and Services* for information about support resources or service requests.

Verifying Calibration Signal Amplitude Accuracy

1. Connect the RF source 1 to the power splitter input using the SMA (m)-to-SMA (m) cable.
2. Connect power sensor B to channel B on the power meter and to the reference output of the power splitter.
3. Connect the other output of the power splitter to the NI 5693 RF IN connector using the SMA (m)-to-SMA (m) adapter.
4. Connect power sensor A to channel A on the power meter and to the NI 5693 RF OUT connector using the SMA (f)-to-SMA (m) semi-rigid cable and the 6 dB attenuator.

5. Connect the NI 5693 EXT FILTER IN connector to the NI 5693 EXT FILTER OUT connector using the SMA (m)-to-SMA (m) cable. Figure 11 shows the completed equipment setup.

Figure 11. Calibration Signal Amplitude Accuracy Verification Equipment Setup



1	RF Source 1	6	6 dB Attenuator	9	Power Sensor A
2	SMA (m)-to-SMA (m) Cable	7	SMA (m)-to-SMA (m) Cable	10	Power Meter
3	Power Sensor B	8	SMA (f)-to-SMA (m) Semi-Rigid Cable		
4	Power Splitter				
5	SMA (m)-to-SMA (m) Adapter				

6. Create a new session for the NI 5693.
7. Configure the NI 5693 according to the following property settings:
   - Reference level: -60 dBm
   - Preamp enabled: Enabled
   - IF output power level: -10 dBm
   - Downconverter cal tone mode: Disabled
8. Configure the RF source 1 to enable single frequency mode.
9. Set the power sensor A and the power sensor B settling percentage to 0.1% and program the power meter to trigger when settled.
10. Configure the power meter to read both channel A and channel B.
11. Turn on the RF source 1 output.

12. Set the NI 5693 center frequency to the start frequency in Table 16.

Table 16. Calibration Signal Amplitude Accuracy Verification Test Frequencies

Start Frequency (MHz)	Stop Frequency (MHz)	Frequency Step Size (MHz)	RF Preselector Cal Tone Mode
34.5	138	2	Low Band RF
140	550	5	Low Band RF
575	950	25	Low Band RF
975	7,000	25	High Band RF

13. Set the RF Source 1 frequency to the first start frequency in Table 16.
14. Commit the NI 5693 settings to hardware.
15. Set the RF source 1 power level using the following equation:

$$\textit{RF Source 1 Power Level} = -25\text{ dBm} + \textit{RF Source through Splitter Path Loss}_{A\_OUT}$$

16. Measure the NI 5693 RF IN power by reading the channel B power using the appropriate calibration factor for the power sensor frequency.
17. Read the power meter channel A power using the appropriate calibration factor for the power sensor frequency.
18. Calculate the gain using the following equation:

$$\textit{Gain} = (\textit{Channel A Power} + \textit{Splitter Balance and 6 dB Attenuator Path Loss}_{A\_OUT}) - \textit{Channel B Power}$$

19. Repeat steps 12 through 18 for all remaining frequencies described by Table 16.
20. Turn off the RF source 1 output.
21. Configure the power meter to read only channel A.
22. Set the NI 5693 center frequency to the first frequency listed in Table 16.
23. Set the NI 5693 RF preselector cal tone mode to low band RF or high band RF, according to Table 16.
24. Commit the NI 5693 settings to hardware.
25. Measure the NI 5693 cal tone output power by reading the channel A power using the appropriate calibration factor for the power sensor frequency.
26. Read the cal tone power referred to RF IN value from the NI 5693.
27. Calculate the calibration signal amplitude accuracy using the following equation:

$$\textit{Calibration Signal Amplitude Accuracy} = \textit{Cal Tone Power Referred to RF IN} - ((\textit{Channel A Power} + \textit{Splitter Balance and 6 dB Attenuator Path Loss}_{A\_OUT}) - \textit{Gain})$$

28. Repeat steps 22 through 27 for all the remaining frequencies described by Table 16.

29. Compare the calculated calibration signal amplitude accuracy values to the verification test limits in Table 17.

Table 17. Calibration Signal Amplitude Accuracy Verification Test Limits

Center Frequency	As-Found Limit (dB)	As-Left Limit (dB)
34.5 MHz to 3.2 GHz	±0.9	±0.5
>3.2 GHz to 5.5 GHz	±1.2	±0.52
>5.5 GHz to 7 GHz	±1.1	±0.73

30. Close the NI 5693 session.

If the calibration signal amplitude accuracy verification procedure determines that the NI 5693 is outside of its limits, refer to *Worldwide Support and Services* for information about support resources or service requests.

Adjustment

Adjusting RF Gain

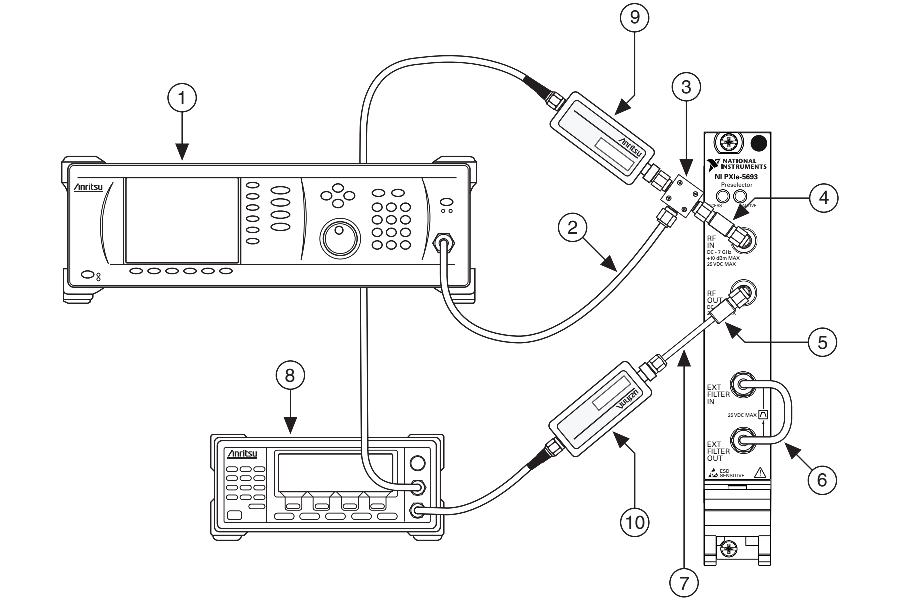
Refer to *Appendix A: Test Frequencies for RF Gain Adjustment* for RF calibration frequencies for this procedure.

Note Zero and calibrate the power sensor using the procedure in the *Zeroing and Calibrating the Power Sensor* section prior to starting this procedure.

1. Connect the RF source 1 to the power splitter input using the SMA (m)-to-SMA (m) cable.
2. Connect power sensor A to channel A on the power meter and to the reference output of the power splitter.
3. Connect the other output of the power splitter to the NI 5693 RF IN connector using the SMA (m)-to-SMA (m) adapter.
4. Connect power sensor B to channel B on the power meter and to the NI 5693 RF OUT connector using the SMA (f)-to-SMA (m) semi-rigid cable and the 6 dB attenuator.

5. Connect the NI 5693 EXT FILTER IN connector to the NI 5693 EXT FILTER OUT connector using the SMA (m)-to-SMA (m) cable. Figure 12 shows the completed equipment setup.

Figure 12. RF Gain Adjustment Equipment Setup



1	RF Source 1	5	6 dB Attenuator	8	Power Meter
2	SMA (m)-to-SMA (m) Cable	6	SMA (m)-to-SMA (m) Cable	9	Power Sensor A
3	Power Splitter	7	SMA (f)-to-SMA (m) Semi-Rigid Cable	10	Power Sensor B
4	SMA (m)-to-SMA (m) Adapter				

6. Create a new calibration session for the NI 5693.
7. Initialize a reference level calibration step.
8. Configure the RF source 1 according to the following settings:
   - Single frequency mode: Enabled
   - Power level: -10 dBm when the NI 5693 preamp is disabled, -25 dBm when the NI 5693 preamp is enabled,
9. Set the power sensor A settling percentage to 0.1% and program the power meter to trigger when settled.
10. Set the power sensor A as the input sensor and the power sensor B as the output sensor.
11. Set the NI 5693 center frequency according to Table 19 in *Appendix A: Test Frequencies for RF Gain Adjustment* as appropriate.
12. Set the RF source 1 center frequency according to Table 19 in *Appendix A: Test Frequencies for RF Gain Adjustment* as appropriate.

13. Configure the NI 5693 according to Table 18 as appropriate.

Table 18. RF Gain Adjustment Settings

RF Preselector Filter Path	Notch Filter Enabled	Notch Filter	Preamp Enabled	RF Attenuation Index
Low Frequency Bypass	Disabled	—	Disabled	0
Filter 1	Disabled	—	Disabled/Enabled	0 to 25
Filter 2	Disabled	—	Disabled/Enabled	0 to 25
Filter 3	Disabled	—	Disabled/Enabled	0 to 25
Filter 4	Disabled	—	Disabled/Enabled	0 to 25
Filter 5	Disabled	—	Disabled/Enabled	0 to 25
Filter 6	Disabled	—	Disabled/Enabled	0 to 25
Filter 7	Disabled	—	Disabled/Enabled	0 to 25
Filter 8	Disabled	—	Disabled/Enabled	0 to 25
Filter 9	Disabled	—	Disabled/Enabled	0 to 25
Filter 10	Disabled	—	Disabled/Enabled	0 to 25
Filter 11	Disabled	—	Disabled/Enabled	0 to 25
Filter 12	Disabled	—	Disabled/Enabled	0 to 25
Filter 13	Disabled	—	Disabled/Enabled	0 to 25
Filter 14	Disabled	—	Disabled/Enabled	0 to 25
Filter 15	Disabled	—	Disabled/Enabled	0 to 25
Filter 16	Disabled	—	Disabled/Enabled	0 to 25
External Filter	Disabled	—	Disabled	0 to 25
Filter 2	Enabled	N1	Disabled	0 to 25
Filter 3	Enabled	N2 and N3	Disabled	0 to 25
Filter 4	Enabled	N4	Disabled	0 to 25

14. Commit the NI 5693 settings to hardware.
15. Measure the NI 5693 RF IN power by reading the channel A power using the appropriate calibration factor for the power sensor frequency.

16. Measure the NI 5693 RF OUT power by reading the channel B power using the appropriate calibration factor for the power sensor frequency.
17. Calculate the output power using the following equation:

$$Output\ Power = Channel\ B\ Power + Splitter\ and\ 6\ dB\ Attenuator\ Path\ Loss$$

18. Calculate the gain using the following equation:

$$Gain = Output\ Power - Channel\ A\ power$$

19. Record the calculated *Gain* to the NI 5693 EEPROM.
20. Repeat steps 15 through 19 for each *RF Preselector Filter Path* listed in Table 18. For each path, step through all the RF attenuation indexes.
21. Repeat steps 11 through 20 for all frequencies in *Appendix A: Test Frequencies for RF Gain Adjustment*.
22. Close the calibration step for the NI 5693.
23. Close the calibration session for the NI 5693.

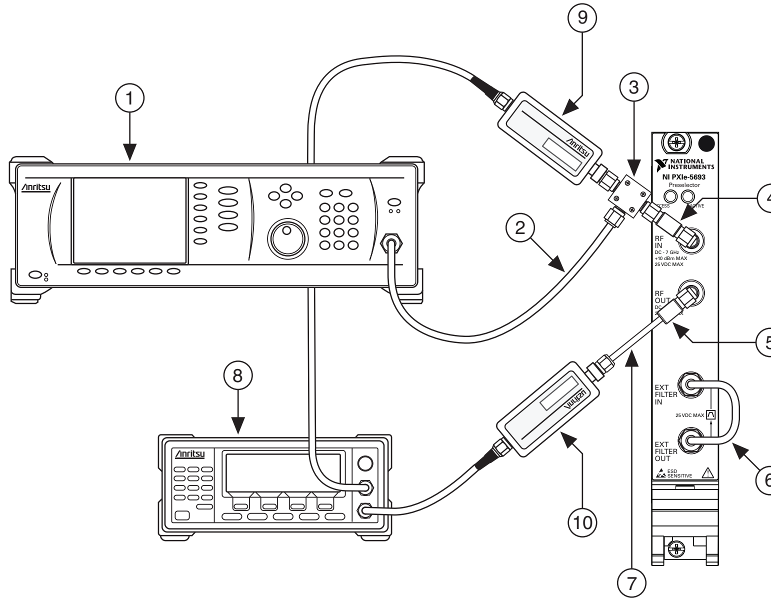
Adjusting Cal Tone Power Accuracy

Refer to *Appendix B: Test Frequencies for Cal Tone Amplitude Adjustment* for RF calibration frequencies for this procedure.

1. Connect the RF source 1 to the power splitter input using the SMA (m)-to-SMA (m) cable.
2. Connect power sensor A to channel A on the power meter and to the reference output of the power splitter.
3. Connect the other output of the power splitter to the NI 5693 RF IN connector using the SMA (m)-to-SMA (m) adapter.
4. Connect power sensor B to channel B on the power meter and to the NI 5693 RF OUT connector using the SMA (f)-to-SMA (m) semi-rigid cable and the 6 dB attenuator.

5. Connect the NI 5693 EXT FILTER IN connector to the NI 5693 EXT FILTER OUT connector using the SMA (m)-to-SMA (m) cable. Figure 13 shows the completed equipment setup.

Figure 13. Cal Tone Power Accuracy Adjustment Equipment Setup



1	RF Source 1	5	6 dB Attenuator	8	Power Meter
2	SMA (m)-to-SMA (m) Cable	6	SMA (m)-to-SMA (m) Cable	9	Power Sensor A
3	Power Splitter	7	SMA (f)-to-SMA (m) Semi-Rigid Cable	10	Power Sensor B
4	SMA (m)-to-SMA (m) Adapter				

6. Create a new session for the NI 5693.
7. Configure the NI 5693 according to the following settings:
   - External calibration
   - Calibration step: Gain Reference Calibration
   - Preamp: Enabled
   - RF attenuation index: 0
8. Configure the RF Source 1 according to the following settings:
   - Single frequency mode: Enabled
   - Power level: -25 dBm
9. Set the power sensor A settling percentage to 0.1% and program the power meter to trigger when settled.
10. Set the power sensor A as the input sensor and the power sensor B as the output sensor.
11. Turn off the RF source 1 output.
12. Configure the power meter to read only channel B.

13. Set the NI 5693 center frequency according to *Appendix B: Test Frequencies for Cal Tone Amplitude Adjustment*.
14. Set the downconverter tone mode to low band RF for calibration frequencies ≤950 MHz and to high band RF for calibration frequencies >950 MHz.
15. Set the NI 5693 cal tone step attenuation to 2 dB.
16. Measure the NI 5693 RF OUT power by reading the channel B power using the appropriate calibration factor for the power sensor frequency.
17. Calculate the cal tone output power with 2 dB attenuation using the following equation:

$$\textit{Cal Tone Output Power with 2 dB Attenuation} = \textit{Channel B Power} + \textit{Splitter Balance and 6 dB Attenuator Path Loss}_{\mathrm{B\_OUT}}$$

18. Store the calculated cal tone output power with 2 dB attenuation value in the NI 5693 EEPROM.
19. Set the NI 5693 cal tone step attenuation to 10 dB.
20. Measure the NI 5693 RF OUT power by reading the channel B power using the appropriate calibration factor for the power sensor frequency.
21. Calculate the cal tone output power with 10 dB attenuation using the following equation:

$$\textit{Cal Tone Output Power with 10 dB Attenuation} = \textit{Channel B Power} + \textit{Splitter Balance and 6 dB Attenuator Path Loss}_{\mathrm{B\_OUT}}$$

22. Store the calculated cal tone output power with 10 dB attenuation value in the NI 5693 EEPROM.
23. Repeat steps 13 through 22 for each frequency listed in *Appendix B: Test Frequencies for Cal Tone Amplitude Adjustment*.
24. Disable the NI 5693 cal tone.
25. Turn on the RF source 1 output.
26. Configure the power meter to read both channel A and channel B.
27. Set the NI 5693 center frequency according to *Appendix B: Test Frequencies for Cal Tone Amplitude Adjustment*.
28. Set the RF source 1 frequency according to *Appendix B: Test Frequencies for Cal Tone Amplitude Adjustment*.
29. Measure the NI 5693 RF OUT power by reading the channel B power using the appropriate calibration factor for the power sensor frequency.
30. Calculate the output power using the following equation:

$$\textit{Output Power} = \textit{Channel B Power} + \textit{Splitter Balance and 6 dB Attenuator Path Loss}_{\mathrm{B\_OUT}}$$

31. Adjust the RF source 1 power level until the *Output Power* value calculated in step 30 is within 0.05 dB from the *Cal Tone Output Power with 2 dB Attenuation* value calculated in step 17.
32. Measure the NI 5693 RF IN power by reading the channel A power using the appropriate calibration factor for the power sensor frequency.

33. Calculate the gain using the following equation:

$$Gain = Output\ Power - Channel\ A\ Power$$

34. Store the calculated *Gain* value in the NI 5693 EEPROM.
35. Repeat steps 27 through 34 for each frequency listed in *Appendix B: Test Frequencies for Cal Tone Amplitude Adjustment*
36. Close the calibration session for the NI 5693.
37. Close the session for the NI 5693.

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.

Appendix A: Test Frequencies for RF Gain Adjustment

Note Read the following table from left-to-right.

Table 19. RF Gain Adjustment Test Frequencies

Filter Path	Frequency (MHz)					
Low Frequency Bypass Path	10	12.5	15	17.5	20	22.5
	25	27.5	30			
Filter 1	19	19.5	20	22	23	25
	26.5	28.5	30.5	32	33.5	34.5
Filter 2	33	33.5	34.5	37	40	43
	46	48	50	52.5	55.5	57
	58.5	60	61			
Filter 3	59	60	61.5	66	69.5	73
	91	97.5	101	105.5	108	109
	110					

Table 19. RF Gain Adjustment Test Frequencies (Continued)

Filter Path	Frequency (MHz)					
Filter 4	90	92	96	101	106	112.5
	119	125	136.5	141.5	147.5	155
	162	165	167	169	170	
Filter 5	140	145	154.5	162.5	168	172
	180	185	189	213	219.5	229.5
	239.5	245				
Filter 6	205	209.5	213.5	218.5	222.5	229.5
	243	251	260	266.5	280.5	290
	306.5	310	319	325	337	340
	346.5	357	363	370		
Filter 7	330	338	349	368	388	408
	433	450	465	480.5	522.5	537
	552	570	575			
Filter 8	530	540	550	556.5	562	569
	576	583.5	593.5	612.5	618.5	650
	670	714	735	799.5	830	850
	880	890	905.5	945	975	
Filter 9	910	922	933.5	940	950	959
	981	1,017	1,049.5	1,080.5	1,108.5	1,157
	1,157.5	1,158	1,170	1,185	1,200	1,212
	1,234	1,261	1,321	1,349.5	1,384	1,431.5
	1,462	1,479	1,501.5	1,528	1,535	1,548
	1,557.5	1,570	1,600			
Filter 10	1,520	1,540	1,560	1,573.5	1,585	1,600
	1,619	1,634.5	1,650.5	1,687	1,706.5	1,738
	1,758	1,770	1,796	1,838	1,873	1,898
	1,935	1,978	1,992	2,012.5	2,040	

Table 19. RF Gain Adjustment Test Frequencies (Continued)

Filter Path	Frequency (MHz)					
Filter 11	1,960	1,974	1,989.5	2,022.5	2,030	2,037
	2,082.5	2,099	2,165.5	2,190	2,230	2,270
	2,292.5	2,310	2,320	2,369	2,400	2,444
	2,465.5	2,507	2,540			
Filter 12	2,460	2,487.5	2,531.5	2,555.5	2,577.5	2,607
	2,620	2,658	2,687	2,709	2,735	2,753
	2,781	2,811	2,861.5	2,885	2,910	2,930
	2,940	2,979	3,040			
Filter 13	2,960	3,000	3,020	3,040	3,060	3,085.5
	3,132	3,164.5	3,203.5	3,252	3,288.5	3,300
	3,304.5	3,330.5	3,350	3,398	3,421	3,444.5
	3,465	3,482.5	3,510	3,557.5	3,576	3,596.5
	3,600	3,628.5	3,670	3,706.5	3,741	3,765.5
	3,787.5	3,800	3,840			
Filter 14	3,760	3,785	3,835	3,862	3,879	3,899.5
	3,950	3,976.5	3,990	4,025.5	4,051.5	4,080
	4,105	4,150	4,190	4,230	4,278	4,358.5
	4,419.5	4,450	4,474.5	4,516	4,548	4,591
	4,640					
Filter 15	4,560	4,620.5	4,679.5	4,724.5	4,770	4,800
	4,824.5	4,880.5	4,954	4,995	5,037	5,050
	5,087	5,110.5	5,131	5,155.5	5,179	5,206
	5,230	5,283	5,306	5,330	5,348.5	5,366
	5,412	5,436.5	5,463	5,485.5	5,506.5	5,529
	5,577.5	5,606	5,641	5,675.5	5,718	5,755.5
	5,793.5	5,840				

Table 19. RF Gain Adjustment Test Frequencies (Continued)

Filter Path	Frequency (MHz)					
Filter 16	5,760	5,800	5,840	5,887	5,913	5,940
	5,977.5	6,023	6,052.5	6,077.5	6,143.5	6,183.5
	6,218	6,260	6,301.5	6,339.5	6,380	6,434
	6,460.5	6,484	6,513.5	6,550.5	6,632	6,658.5
	6,687	6,714	6,746	6,837.5	6,862.5	6,877.5
	6,903.5	6,925.5	7,000			
Notch Filter 1	33	33.5	34	35	38	39.5
	40.5	41	42.5	44		
Notch Filter 2 and 3	60	62	64.5	69.5	74	75.5
	77	90	92	95	97.5	100
	102.5	105	107.5	110		
Notch Filter 4	120	121.5	123	127	132	134
	136	138	140	143	145.5	150
	155	159.5	163	166		
External Filter	20	22.5	25.5	29.5	33.5	39
	44.5	57	75	98.5	170	250.5
	294	310	320	338	438	461
	518	573	618	754	900.5	968
	1,018	1,064.5	1,133.5	1,192	1,238	1,289
	1,378	1,438	1,489.5	1,583.5	1,641	1,679.5
	1,731.5	1,768	1,803.5	1,837	1,879.5	1,914
	1,944.5	1,983.5	2,000	2,021.5	2,063	2,107
	2,144	2,178	2,221	2,279	2,373	2,458
	2,481.5	2,558	2,674	2,758	2,828	2,877
	2,927	2,958.5	2,986	3,040		

Appendix B: Test Frequencies for Cal Tone Amplitude Adjustment

Note Read the following table from left-to-right.

Table 20. Cal Tone Amplitude Adjustment Test Frequencies

Frequency (MHz)					
34.5	35	35.5	36.5	38.75	42.75
45	45.25	45.5	45.75	46	50.25
52	55.75	58	58.25	58.5	58.75
59	59.75	59.996875	60	60.003125	62
63	64.75	68.746875	68.75	70.25	72.75
76	84.75	90.75	91	91.25	91.5
91.75	92	99.75	99.996875	100	100.003125
102.25	116	116.25	117	117.25	117.5
117.75	132	137.25	137.496875	137.5	137.50625
139.75	146.25	158.5	159.99375	160	160.00625
181.25	181.5	181.75	182.75	183	183.5
183.75	184	196.25	206.25	224.99375	225
225.00625	232	232.25	232.5	234	234.25
235.25	235.5	249.5	274	274.99375	275
275.0125	300	315	336	349	349.9875
350	350.0125	362	363	364	365
366	367	368	395	436	451
464	465	468	469	470	471
499	515	549.9875	550	550.025	554
554.975	555	555.025	599	612.5	649
691	726	727	731	732	735
736	762	783	848	876	929
930	936	937	941	942	949

Table 20. Cal Tone Amplitude Adjustment Test Frequencies (Continued)

Frequency (MHz)					
949.975	950	950.025	997	1,034	1,099.975
1,100	1,100.05	1,159	1,248	1,270	1,307
1,398	1,453	1,454	1,463	1,464	1,470
1,471	1,505	1,530	1,558	1,559	1,559.95
1,560	1,560.05	1,573	1,604	1,622	1,675
1,699	1,755	1,767	1,818	1,838	1,859
1,860	1,873	1,874	1,883	1,884	1,898
1,924	1,972	1,999	1,999.95	2,000	2,000.05
2,027	2,047	2,069	2,109	2,134	2,179
2,199	2,199.95	2,200	2,200.1	2,201	2,221
2,247	2,288	2,317	2,338	2,386	2,408
2,463	2,480	2,499	2,4999	2,500	2,500.1
2,501	2,525	2,547	2,578	2,613	2,631
2,651	2,689	2,711	2,734	2,779	2,806
2,821	2,861	2,872	2,907	2,908	2,928
2,929	2,941	2,942	2,999.9	3,000	3,000.1
3,001	3,030	3,043	3,074	3,121	3,157
3,159	3,204	3,208	3,220	3,221	3,241
3,242	3,264	3,267	3,268	3,300	3,304
3,306	3,318	3,331	3,333	3,348	3,350
3,371	3,372	3,378	3,396	3,397	3,403
3,417	3,419	3,442	3,443	3,465	3,466
3,489	3,490	3,514	3,515	3,533	3,537
3,538	3,558	3,562	3,563	3,588	3,590
3,599.9	3,600	3,600.1	3,610	3,611	3,638
3,639	3,650	3,666	3,667	3,671	3,687
3,689	3,718	3,719	3,725	3,747	3,748

Table 20. Cal Tone Amplitude Adjustment Test Frequencies (Continued)

Frequency (MHz)					
3,767	3,768	3,775	3,799	3,799.9	3,800
3,800.1	3,819	3,833	3,860	3,884	3,922
3,945	3,985	3,993	4,000	4,050	4,063
4,121	4,128	4,199	4,199.9	4,200	4,200.1
4,202	4,207	4,231	4,280	4,300	4,304
4,328	4,373	4,399.9	4,400	4,400.2	4,422
4,425	4,450	4,491	4,517	4,525	4,542
4,561	4,599	4,599.8	4,600	4,600.2	4,637
4,671	4,675	4,691	4,715	4,757	4,782
4,800	4,812	4,842	4,873	4,909	4,974
5,014	5,071	5,129	5,166	5,191	5,233
5,269	5,290	5,315	5,333	5,360	5,399
5,457	5,507	5,590	5,634	5,657	5,681
5,699	5,727	5,752	5,794	5,799	5,799.8
5,800	5,800.2	5,801	5,814	5,815	5,816
5,856	5,857	5,875	5,892	5,912	5,964
5,978	6,000	6,028	6,113	6,167	6,203
6,243	6,306	6,358	6,409	6,485	6,538
6,565	6,566	6,567	6,619	6,697	6,698
6,715	6,743	6,761	6,793	6,832	6,836
6,877	6,891	6,918	6,932	6,952	7,000

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374003B-01 May14