

CALIBRATION PROCEDURE

PXIe-5654 with PXIe-5696

PXIe, 250 kHz to 20 GHz, PXI RF Analog Signal Generator with Amplitude Extender

This document contains the verification and adjustment procedures for the PXIe-5654 RF Analog Signal Generator when used with the PXIe-5696 Amplitude Extender.

Refer to ni.com/calibration for more information about calibration solutions.

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Required Software

Calibrating the PXIe-5654 requires you to install the following package on the calibration system:

- NI-RFSG 20.7 or later

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

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

Related Documentation

For additional information, refer to the following documents as you perform the calibration procedure:

- *PXIe-5654 Getting Started Guide*
- *PXIe-5654 Calibration Procedure*
- *PXIe-5696 Getting Started Guide*
- *PXIe-5654 Specifications* (includes specifications for the PXIe-5696)
- *NI RF Signal Generators Help*

Visit ni.com/manuals for the latest versions of these documents.

Test Equipment

The following table 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 following table.

Table 1. Recommended Equipment for PXIe-5654 Calibration

Equipment	Recommended Model	Where Used	Minimum Requirements
Signal source analyzer	Rhode & Schwarz (R&S) FSUP26 Signal Source Analyzer	Verifications: <ul style="list-style-type: none"> • <i>RF OUT frequency accuracy</i> • <i>RF OUT phase noise</i> • <i>RF OUT amplitude accuracy</i> • <i>RF OUT maximum power</i> Adjustments: <ul style="list-style-type: none"> • <i>Frequency reference accuracy</i> 	Frequency range: 0.25 MHz to 20 GHz Frequency counter resolution: 0.1 Hz Phase noise measurement using cross-correlation Frequency counter marker feature Spectrum analysis capabilities
Frequency reference	Symmetricom 8040C Rubidium Frequency Standard	Verifications: <ul style="list-style-type: none"> • <i>RF OUT amplitude accuracy</i> • <i>RF OUT maximum power</i> Adjustments: <ul style="list-style-type: none"> • <i>Frequency reference accuracy</i> 	Frequency: 10 MHz Frequency accuracy: $\pm 1 \times 10^{-9}$

Table 1. Recommended Equipment for PXIe-5654 Calibration (Continued)

Equipment	Recommended Model	Where Used	Minimum Requirements
Power meter	Anritsu ML2438A with a SC7413A Power Sensor	Verifications: <ul style="list-style-type: none"> • <i>RF OUT amplitude accuracy</i> • <i>RF OUT maximum power</i> Adjustments: <ul style="list-style-type: none"> • <i>RF attenuator accuracy</i> • <i>Amplitude accuracy (low harmonic paths)</i> • <i>Amplitude accuracy (high power paths)</i> • <i>Automatic Level Control (ALC)</i> 	Range: -40 dBm to 20 dBm Frequency range: 250 kHz to 20 GHz Accuracy: $\pm 4.0\%$
K(m)-to-K(m) cable, 36 in. (x2)	Florida RF Labs KMS-160-36.0-KMS	Verifications: <ul style="list-style-type: none"> • <i>RF OUT frequency accuracy</i> • <i>RF OUT phase noise</i> • <i>RF OUT amplitude accuracy</i> Adjustments: <ul style="list-style-type: none"> • <i>Frequency reference accuracy</i> 	Length: 36 in. Loss: <math>< 0.7</math> dB/ft. (typical) at 20 GHz Impedance: 50 Ω
K(m)-to-K(m) cable, 12 in. (x2)	Florida RF Labs KMS-160-12.0-KMS	Verifications: <ul style="list-style-type: none"> • <i>RF OUT amplitude accuracy</i> • <i>RF OUT maximum power</i> Adjustments: <ul style="list-style-type: none"> • <i>RF attenuator path</i> 	Length: 12 in. Loss: <math>< 0.5</math> dB/ft. (typical) at 20 GHz Impedance: 50 Ω

Table 1. Recommended Equipment for PXIe-5654 Calibration (Continued)

Equipment	Recommended Model	Where Used	Minimum Requirements
K(m)-to-K(f) 20 dB attenuator	Anritsu 41KB-20	Adjustments: <ul style="list-style-type: none"> <i>RF attenuator path</i> 	Frequency range: DC to 20 GHz Voltage standing wave ratio (VSWR): <1.18 Accuracy: $\leq \pm 0.5$ dB Impedance: 50 Ω
K(m)-to-K(f) 6 dB attenuator (x2)	Anritsu 41KB-6	<i>Test system characterization</i> Verifications: <ul style="list-style-type: none"> <i>RF OUT amplitude accuracy</i> <i>RF OUT maximum power</i> 	Frequency range: DC to 20 GHz VSWR: <1.18 Accuracy: $\leq \pm 0.5$ dB Impedance: 50 Ω
Power splitter	Aeroflex/Weinschel 1593	<i>Test system characterization</i> Verifications: <ul style="list-style-type: none"> <i>RF OUT amplitude accuracy</i> <i>RF OUT maximum power</i> 	Frequency range: DC to 20 GHz VSWR: <1.35 Insertion loss: <8.5 dB Impedance: 50 Ω
K(m)-to-K(f) adapter ¹	Anritsu K224B	<i>Test system characterization</i>	Frequency range: DC to 20 GHz VSWR: ≤ 1.12 Impedance: 50 Ω

¹ The connector on the power sensor listed above may be difficult to access with a torque wrench when there is adjacent connected hardware. Use this adapter if you need to extend the capabilities of the power sensor to make it accessible by a torque wrench.

Test Conditions

The following setup and environmental conditions are required to ensure the PXIe-5654 and PXIe-5696 meet published specifications.

- Keep cabling as short as possible. Long cables act as antennas, picking up extra noise that can affect measurements.
- Verify that all connections to the PXIe-5654 and PXIe-5696, including front panel connections and screws, are secure.
- Maintain an ambient temperature of $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$.
- Keep relative humidity between 10% and 90%, noncondensing.
- Allow a warm-up time of at least 30 minutes after the chassis is powered on. The warm-up time ensures that the PXIe-5654 and PXIe-5696 are at a stable operating temperature.
- In each verification procedure, insert a delay between configuring all instruments 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 chassis and the calibration instrument(s) into the same power strip to avoid ground loops.
- Use an appropriate torque wrench to tighten all module RF connectors (SMA, 3.5 mm, or K). NI recommends a $0.565\text{ N} \cdot \text{m}$ (5 lb · in) wrench for SMA connectors and a $0.90\text{ N} \cdot \text{m}$ (8 lb · in) wrench for 3.5 mm or K connectors.
- Connect the frequency reference source to the signal source analyzer REF IN back panel connector using a BNC(m)-to-BNC(m) cable, and connect the signal source analyzer REF OUT connector to the PXIe-5654 REF IN connector using a BNC(m)-to-SMA(m) cable.
- Ensure that the PXI 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 cooling, refer to the *Maintain Forced-Air Cooling Note to Users* document available at ni.com/manuals.
- Frequencies less than and equal to 10 GHz apply to the 10 GHz and 20 GHz PXIe-5654; frequencies above 10 GHz apply only to the 20 GHz PXIe-5654.
- The PXIe-5654 must be verified as a stand-alone device using the *PXIe-5654 Calibration Procedure* before performing the procedures in this document.

Initial Setup

Refer to the *PXIe-5654 Getting Started Guide* and *PXIe-5696 Getting Started Guide* for information about how to install the software and the hardware and how to configure the devices in MAX.

Test System Characterization

The following procedures characterize the test equipment used during verification.



Note Before starting characterization, unassociate the PXIe-5654 and PXIe-5696 in Measurement & Automation Explorer (MAX) by setting the PXIe-5696 connected to the PXIe-5654 to **None**.

Zeroing and Calibrating the Power Sensor

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

Characterizing the Power Splitter

Several procedures in this document require using a splitter that has been characterized to remove error from future measurements. Complete the following steps to characterize a splitter using a PXIe-5654, power meter, and signal source analyzer, as shown in the following figure.

1. Connect the frequency reference source to the signal source analyzer REF IN back panel connector using a BNC(m)-to-BNC(m) cable, and connect the signal source analyzer REF OUT connector to the PXIe-5654 REF IN connector using a BNC(m)-to-SMA(m) cable.
2. Connect the power meter power sensor to the PXIe-5654 RF OUT front panel connector.
3. Create a new device session for the PXIe-5654.
4. Create a list of test frequencies using the values in the following table.

Table 2. Power Splitter Characterization Test Frequencies

Start Frequency (MHz)	Stop Frequency (MHz)	Frequency Step (MHz)
0.25	—	—
25	250	112.5
275	1,000	145
1,250	20,000	250

5. Configure the PXIe-5654 using the following settings:
 - **Frequency:** Frequency from the list in step 4.
 - **Power Level:** -10 dBm
6. Commit the settings to hardware if this is the first iteration of running this procedure; otherwise skip to step 9.
7. Initiate signal generation.
8. Enable the RF output.
9. Check the signal generation status and verify that there are no reported errors or warnings.

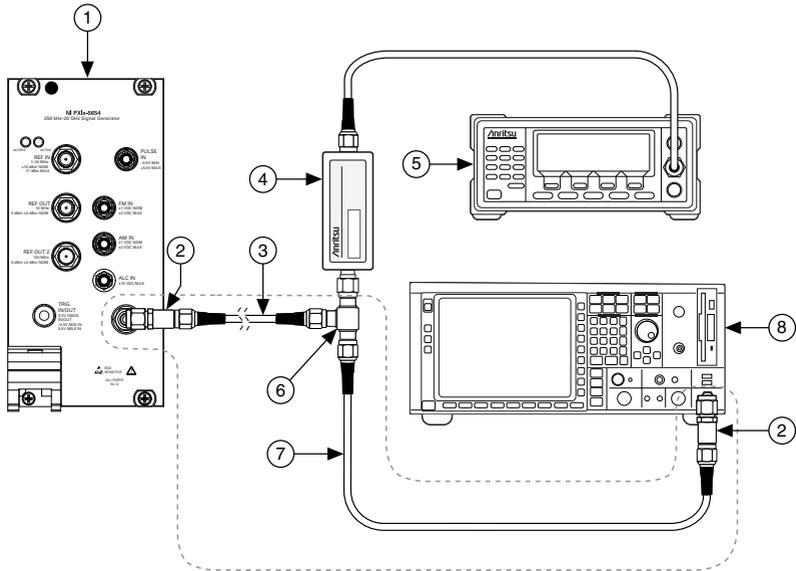
10. Use the power meter to measure the output power. Store this value as the *Power Meter Reading*.
11. Repeat steps 5 through 10 for each remaining test frequency in the list created in step 4.
12. Disconnect the power meter from the PXIe-5654 RF OUT front panel connector.
13. Connect the PXIe-5654 RF OUT front panel connector to the 6 dB attenuator.
14. Connect the open end of the attenuator to the input of the power splitter using a K(m)-to-K(m) 12 in. cable.
15. Connect an available output port of the power splitter to the power sensor.
16. Connect a 6 dB attenuator to the signal source analyzer RF input.
17. Connect the other available output port of the power splitter to the attenuator connected to the signal source analyzer RF input connector using a K(m)-to-K(m) 36 in. cable.

The hardware setup is shown in the following image, with the dotted line surrounding the equipment fixture.



Note After assembling the hardware and performing characterization, do not disassemble or alter the torque applied to the connectors of the fixture. If any hardware within the fixture is altered, you must characterize again.

Figure 1. Power Splitter Characterization Equipment Setup



- | | |
|---|-------------------------------|
| 1. PXIe-5654 RF Analog Signal Generator | 5. Power Meter |
| 2. K(m)-to-K(f) 6 dB Attenuator | 6. Power Splitter |
| 3. K(m)-to-K(m) Cable, 12 in. | 7. K(m)-to-K(m) Cable, 36 in. |
| 4. Power Sensor | 8. Signal Source Analyzer |

18. Configure the reference level of the spectrum analyzer to -30 dBm.

The spectrum analyzer is used only for termination.

19. Configure the PXIe-5654 using the following settings:
 - **Frequency:** Frequency from the list in step 4.
 - **Power Level:** -10 dBm
20. Check the signal generation status and verify that there are no reported errors or warnings.
21. Use the power meter to measure the output power. Store this value as *Splitter*.
22. Calculate the splitter loss using the following formula:
$$\text{Splitter Loss} = \text{Power Meter Reading} - \text{Splitter}$$
23. Store the calculated values.
24. Repeat steps 19 through 23 for each remaining test frequency in the list created in step 4.
25. Close the device session.

As-Found and As-Left Limits

The as-found limits are the published specifications for the PXIe-5654 with PXIe-5696. NI uses these limits to determine whether the PXIe-5654 with PXIe-5696 meets the specifications when it is received for calibration. Use the as-found limits during initial verification.

The as-left calibration limits are equal to the published NI specifications for the PXIe-5654 with PXIe-5696, less guard bands for 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. Use the as-left limits when performing verification after adjustment.

Verification

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

Before starting verification, complete the following steps.

1. Complete the verification procedures for the PXIe-5654 as a stand-alone device.
2. Associate the PXIe-5654 and PXIe-5696 in MAX.
3. Make the following reference connections.
 - a) Connect the frequency reference source to the signal source analyzer REF IN back panel connector using a BNC(m)-to-BNC(m) cable.
 - b) Connect the signal source analyzer REF OUT connector to the PXIe-5654 REF IN connector using a BNC(m)-to-SMA(m) cable.

Related Information

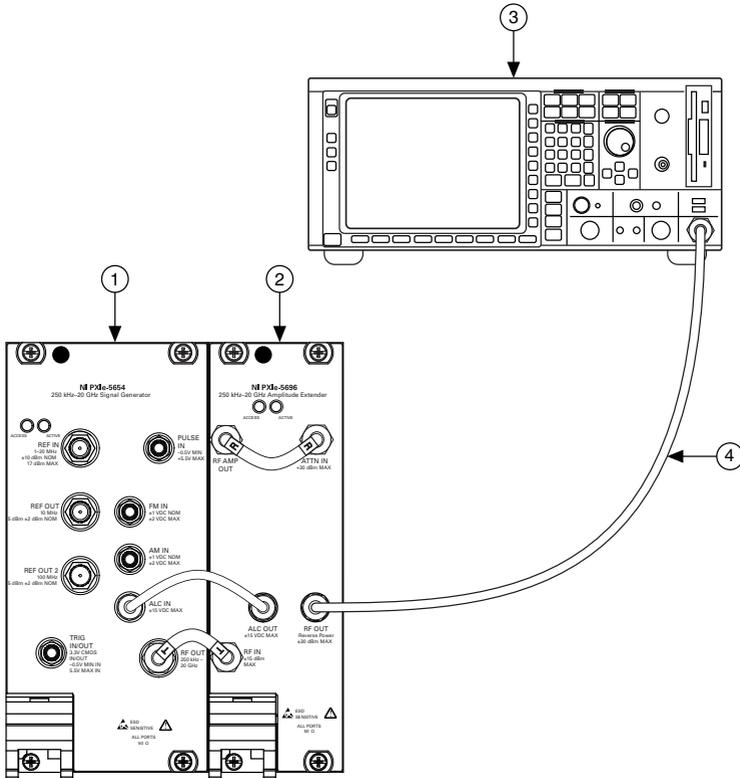
For instructions on verifying the PXIe-5654 as a stand-alone device, refer to the [PXIe-5654 Calibration Procedure](#).

Verifying RF OUT Frequency Accuracy

This procedure verifies that the internal signal generation circuitry is adjusted for correct frequency accuracy.

1. Connect the PXIe-5654 to the PXIe-5696.
2. Connect the PXIe-5696 RF OUT front panel connector to the signal source analyzer RF input connector using the K(m)-to-K(m) cable, as shown in the following figure.

Figure 2. RF OUT Frequency Accuracy Verification Equipment Setup (Reference Connections Not Shown)



- | | |
|---|---------------------------|
| 1. PXIe-5654 RF Analog Signal Generator | 3. Signal Source Analyzer |
| 2. PXIe-5696 Amplitude Extender | 4. K(m)-to-K(m) Cable |

3. Create a new device session for the PXIe-5654 with PXIe-5696.
4. Create a list of test frequencies, including endpoints, containing 100 MHz and 1 GHz, according to the frequency range of your PXIe-5654 model, with 1 GHz increments.

5. Configure the PXIe-5654 with PXIe-5696 using the following settings:
 - **Frequency:** Frequency from the list in step 4
 - **Power Level:** 0 dBm
 - **Reference Clock Source:** Onboard Clock
6. Commit the settings to hardware if this is the first iteration of running this procedure; otherwise skip to step 9.
7. Initiate signal generation.
8. Enable the RF output.
9. Check the signal generation status and verify that there are no reported errors or warnings.
10. Configure the signal source analyzer using the following settings:
 - **Center frequency:** Frequency from the list in step 4
 - **Reference level:** 20 dBm
 - **Frequency span:** 1 MHz
 - **Reference Clock source:** External
 - **Frequency counter resolution:** 0.1 Hz
 - **Sweep:** Manual
 - **Number of sweeps:** 1
 - **Auto Sweep Time**
11. Measure the frequency of the peak that is returned by the signal source analyzer at approximately the corresponding point in the frequency list you created in step 4.
12. Calculate the deviation using the following formula:

$$\Delta f = \left| \frac{f_{\text{Measured}}(\text{MHz}) - f_{\text{Expected}}(\text{MHz})}{f_{\text{Expected}}(\text{MHz})} \right| \text{ ppm}$$

13. Ensure that the deviation found in the previous step is less than the result of the following equations:

As Left Calculation: *Initial Accuracy + Temperature Stability*

As Found Calculation: *Initial Accuracy + Aging + Temperature Stability*

where

Initial Accuracy = ±0.1 ppm

Temperature Stability (15 °C to 35 °C) = ±0.2 ppm

Ten Year Aging = 1.25 ppm

14. Repeat steps 5 through 13 for the remaining frequencies in the list created in step 4.
15. Close the device session.

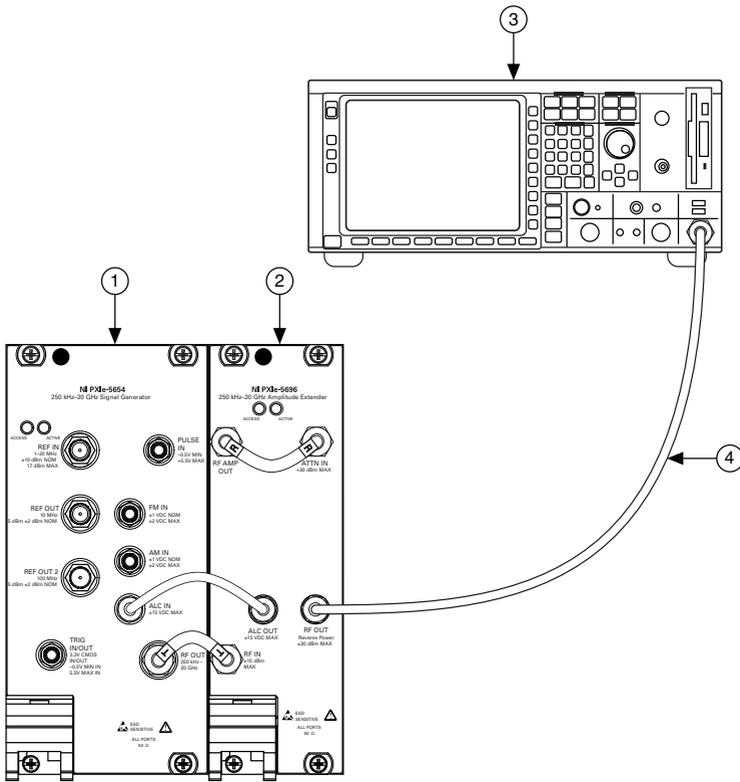
Verifying RF OUT Phase Noise

This procedure verifies that the internal frequency generation circuitry is adjusted for correct phase noise accuracy.

1. Connect the PXIe-5654 to the PXIe-5696.
2. Connect the PXIe-5696 RF OUT front panel connector to the signal source analyzer RF input connector using the K(m)-to-K(m) cable.

The hardware setup is shown in the following figure.

Figure 3. RF OUT Phase Noise Verification Equipment Setup (Reference Connections Not Shown)



1. PXIe-5654 RF Analog Signal Generator
 2. PXIe-5696 Amplitude Extender
 3. Signal Source Analyzer
 4. K(m)-to-K(m) Cable
3. Create a new device session for the PXIe-5654 with PXIe-5696.

4. Configure the signal source analyzer using the following settings:
 - Phase noise measurement using cross-correlation phase-locked loops (PLLs) and internal generators
 - Automatic device under test (DUT) detection
 - Spur suppression enabled
 - Fast Fourier transform (FFT) mode with Blackman-Harris window
 - Measurement span from 100 Hz to 1 MHz (offset frequencies)
5. Use the signal source analyzer to perform a manual frequency sweep at the settings listed in the following table.

Table 3. RF OUT Manual Sweep Settings

Carrier Frequency Offset	Resolution Bandwidth	Cross Correlation
100 Hz to 300 Hz	10 Hz	100
300 Hz to 1 kHz	30 Hz	1,000
1 kHz to 3 kHz	100 Hz	10,000
3 kHz to 10 kHz	300 Hz	10,000
10 kHz to 30 kHz	1 kHz	10,000
30 kHz to 100 kHz	1 kHz	5,000
100 kHz to 300 kHz	3 kHz	1,000
300 kHz to 1 MHz	10 kHz	1,000

6. Configure the PXIe-5654 with PXIe-5696 using the following settings:
 - **Frequency:** 500 MHz
 - **Power Level:** +8 dBm
7. Commit the settings to hardware if this is the first iteration of running the procedure; otherwise skip to step 10.
8. Initiate signal generation.
9. Enable the RF output.
10. Set the signal source analyzer center frequency to 500 MHz if the signal source analyzer does not automatically center for phase noise measurements.
11. Check the signal generation status and verify that there are no reported errors or warnings.
12. Measure the phase noise using the signal source analyzer for every offset value in the following table. Record the measurements.
13. Ensure that the recorded measurements are within the limits set in the following tables.

Table 4. RF OUT Phase Noise (dBc/Hz), As-Found Limits

Offset	Carrier Frequency				
	500 MHz	1 GHz	5 GHz	10 GHz	20 GHz
100 Hz	≤-107	≤-101	≤-87	≤-81	≤-75
1 kHz	≤-126	≤-121	≤-109	≤-103	≤-97
10 kHz	≤-135	≤-130	≤-120	≤-114	≤-108
100 kHz	≤-137	≤-131	≤-122	≤-117	≤-111
1 MHz	≤-138	≤-132	≤-125	≤-119	≤-113

Table 5. RF OUT Phase Noise (dBc/Hz), As-Left Limits

Offset	Carrier Frequency				
	500 MHz	1 GHz	5 GHz	10 GHz	20 GHz
100 Hz	≤-108.5	≤-102.5	≤-88.5	≤-82.5	≤-76.5
1 kHz	≤-127.5	≤-122.5	≤-110.5	≤-104.5	≤-98.5
10 kHz	≤-135.5	≤-130.5	≤-120.5	≤-114.5	≤-108.5
100 kHz	≤-138	≤-132	≤-123	≤-118	≤-112
1 MHz	≤-138.5	≤-132.5	≤-125.5	≤-119.5	≤-113.5

14. Repeat steps 6 through 13 for 1 GHz, 5 GHz, 10 GHz, and 20 GHz carrier frequencies.
15. Close the device session.

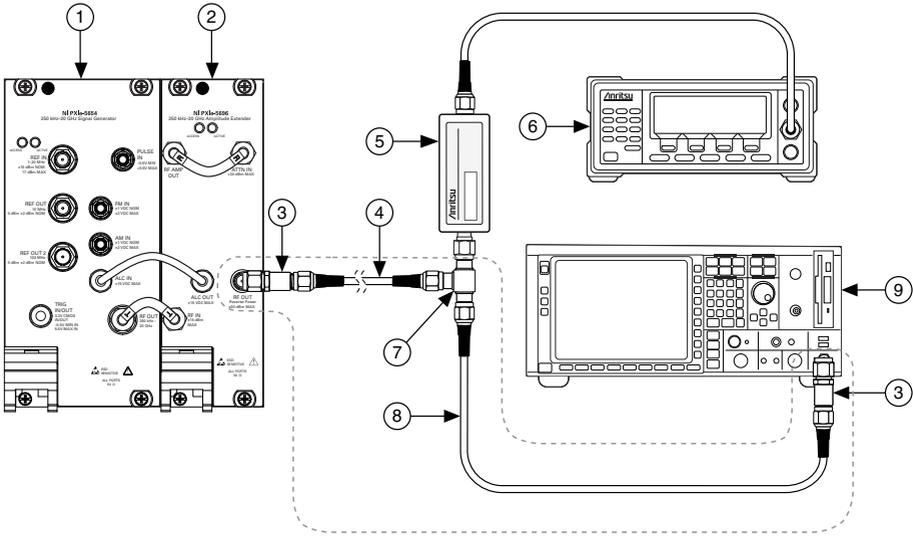
Verifying RF OUT Amplitude Accuracy

This procedure verifies that the PXIe-5654 with PXIe-5696 is adjusted for correct amplitude accuracy.

1. Connect the PXIe-5654 to the PXIe-5696.
2. Using the fixture that was previously characterized in [Characterizing the Power Splitter](#), connect the input of the fixture to the PXIe-5696 RF OUT front panel connector.
3. Connect the outputs of the fixture to the power sensor and to the signal source analyzer RF input connector, as shown in the following image.

All other connections should not have changed since characterization.

Figure 4. RF OUT Amplitude Accuracy Verification Equipment Setup



- | | |
|---|-------------------------------|
| 1. PXIe-5654 RF Analog Signal Generator | 6. Power Meter |
| 2. PXIe-5696 Amplitude Extender | 7. Power Splitter |
| 3. K(m)-to-K(f) 6 dB Attenuator | 8. K(m)-to-K(m) Cable, 36 in. |
| 4. K(m)-to-K(m) Cable, 12 in. | 9. Signal Source Analyzer |
| 5. Power Sensor | |

4. Create a new device session for the PXIe-5654 with PXIe-5696.
5. Create a list of test frequencies from the following table based on your current power level under test.

Table 6. RF OUT Amplitude Accuracy Test Settings

Power Level (dBm)	Start Frequency (MHz)	Stop Frequency (MHz)	Frequency Step (MHz)
-80	0.25	—	—
	25	250	112.5
	275	1,000	145
	1,250	3,000	250
	3,250	6,000	250
	6,250	15,000	250
	15,250	20,000	250

Table 6. RF OUT Amplitude Accuracy Test Settings (Continued)

Power Level (dBm)	Start Frequency (MHz)	Stop Frequency (MHz)	Frequency Step (MHz)
-40	0,25	—	—
	25	250	112.5
	275	1,000	145
	1,250	3,000	250
	3,250	6,000	250
	6,250	15,000	250
	15,250	20,000	250
-20	0,25	—	—
	25	250	112.5
	275	1,000	145
	1,250	3,000	250
	3,250	6,000	250
	6,250	15,000	250
	15,250	20,000	250
-10	0,25	—	—
	25	250	112.5
	275	1,000	145
	1,250	3,000	250
	3,250	6,000	250
	6,250	15,000	250
	15,250	20,000	250

Table 6. RF OUT Amplitude Accuracy Test Settings (Continued)

Power Level (dBm)	Start Frequency (MHz)	Stop Frequency (MHz)	Frequency Step (MHz)
-7	0.25	—	—
	25	250	112.5
	275	1,000	145
	1,250	3,000	250
	3,250	6,000	250
	6,250	15,000	250
	15,250	20,000	250
0	0.25	—	—
	25	250	112.5
	275	1,000	145
	1,250	3,000	250
	3,250	6,000	250
	6,250	15,000	250
	15,250	20,000	250
10	0.25	—	—
	25	250	112.5
18	15,250	20,000	250
20	275	1,000	145
	6,250	15,000	250
23	3,250	6,000	250
24	1,250	3,000	250

6. Configure the reference level of the spectrum analyzer to -30 dBm.
The spectrum analyzer is used only for termination.
7. Configure the PXIe-5654 with PXIe-5696 using the following settings:
 - **Frequency:** Frequency from the list in step 5
 - **Power Level:** Current power level from the preceding table, which is the *Expected Power (dBm)*
8. Commit the settings to hardware if this is the first iteration of running the procedure; otherwise skip to step 11.
9. Initiate signal generation.

10. Enable the RF output.
11. Check the signal generation status and verify that there are no reported errors or warnings.
12. Measure the power using the power meter. Correct the power meter reading for the RF frequency.

This measurement is the *Power Meter Reading*.

13. Correct the power meter reading with the characterization value from [Characterizing the Power Splitter](#).

Measured Power (dBm) = Power Meter Reading + Splitter Loss

14. Calculate the *Power Deviation (dB)* using the following formula:

Power Deviation (dB) = Measured Power (dBm) - Expected Power (dBm)

15. Verify that the *Power Deviation (dB)* results in the previous step are within the limits listed in the following tables.

Table 7. Amplitude Accuracy, As-Found Limits (dB)

Frequency	Maximum Leveled Power (dBm)	Power Deviation (dB)			
		-80 dBm to <-40 dBm	-40 dBm to <-10 dBm	-10 dBm to 13 dBm	>13 dBm to Maximum Leveled Power (dBm)
0.25 MHz to <20 MHz	≥10	±1.75	±1.20	±0.80	—
20 MHz to ≤250 MHz	≥10	±1.50	±1.20	±0.80	—
>250 MHz to ≤1,000 MHz	≥20	±1.50	±1.20	±0.80	±1.20
>1,000 MHz to ≤3,000 MHz	≥24	±1.50	±1.20	±0.80	±1.20
>3,000 MHz to ≤6,000 MHz	>23	±1.50	±1.20	±0.80	±1.20
>6,000 MHz to ≤8,000 MHz	>20	±1.50	±1.20	±0.80	±1.20
>8,000 MHz to ≤15,000 MHz	>20	±1.50	±1.20	±0.80	±1.30
>15,000 MHz to ≤20,000 MHz	>18	±1.50	±1.20	±0.80	±1.30

Table 8. Amplitude Accuracy, As-Left Limits (dB)

Frequency	Maximum Levelled Power (dBm)	Power Deviation (dB)			
		-80 dBm to < -40 dBm	-40 dBm to < -10 dBm	-10 dBm to 13 dBm	>13 dBm to Maximum Levelled Power (dBm)
0.25 MHz to ≤20 MHz	≥10	±1.00	±0.60	±0.35	—
>20 MHz to ≤250 MHz	≥10	±0.70	±0.60	±0.35	—
>250 MHz to ≤1,000 MHz	≥20	±0.70	±0.60	±0.35	±0.60
>1,000 MHz to ≤3,000 MHz	≥24	±0.70	±0.60	±0.35	±0.60
>3,000 MHz to ≤6,000 MHz	>23	±0.60	±0.60	±0.35	±0.60
>6,000 MHz to ≤8,000 MHz	>20	±0.60	±0.60	±0.35	±0.60
>8,000 MHz to ≤15,000 MHz	>20	±0.60	±0.60	±0.35	±0.60
>15,000 MHz to ≤20,000 MHz	>18	±0.60	±0.60	±0.35	±0.60

16. Repeat steps 7 through 15 for each test frequency in the frequency list created in step 5.
17. Repeat steps 7 through 15 for all output powers greater than -20 dBm in the frequency list.

The following steps apply to using an output power of -20 dBm.

18. Create a list of test frequencies from Table 7 that apply to a power level of -20 dBm.
19. Configure the PXIe-5654 with PXIe-5696 using the following settings:
 - **Frequency:** Frequency from the list in step 18
 - **Power Level:** -20 dBm, which is the *Expected Power (dBm)*
20. Commit the settings to hardware if this is the first iteration of running this procedure; otherwise skip to step 21.
21. Check the signal generation status and verify that there are no reported errors or warnings.
22. Configure the signal source analyzer with the following settings:
 - **Center frequency:** Frequency in step 18
 - **RF Input coupling:** DC
 - **Reference level:** -30 dBm
 - **Frequency span:** 0 Hz

- **Resolution bandwidth:** 100 Hz
- **Sweep time:** 20 ms
- **Reference Clock source:** External
- **RF attenuation:** 5 dB
- **Preamplifier:** On

23. Measure the power using the power meter. Correct the power meter reading for the RF frequency.

This measurement is the *Power Meter Reading*.

24. Correct the power meter reading with the characterization value from *Characterizing the Power Splitter*.

$Measured\ Power\ (dBm) = Power\ Meter\ Reading + Splitter\ Loss$

25. Measure the power level with the signal source analyzer. Record the value as the *Signal Source Analyzer Reading*.

26. Calculate and store the characterization of the signal source analyzer.

$Correction = Measured\ Power - Signal\ Source\ Analyzer\ Reading$

27. Verify that the *Power Deviation (dB)* results in the preceding step are within the limits listed in Tables 8 and 9.

28. Repeat steps 19 through 27 for each test frequency in the frequency list created in step 18. The following steps apply to using an output power of <-20 dBm.

29. Create a list of test frequencies from Table 7 that apply to a power level of -40 dBm

30. Configure the PXIe-5654 with PXIe-5696 using the following settings:

- **Frequency:** Frequency from the list in step 29
- **Power Level:** -40 dBm, which is the *Expected Power (dBm)*

31. Commit the settings to hardware if this is the first iteration of running this procedure; otherwise skip to step 32.

32. Check the signal generation status and verify that there are no reported errors or warnings.

33. Configure the signal source analyzer with the following settings:

- **Center frequency:** Frequency in step 29
- **RF Input coupling:** DC
- **Reference level:** -30 dBm
- **Frequency span:** 0 Hz
- **Resolution bandwidth:** 100 Hz
- **Sweep time:** 20 ms
- **Reference Clock source:** External
- **RF attenuation:** 5 dB
- **Preamplifier:** On

34. Measure the power level with the signal source analyzer. Record the value as the *Signal Source Analyzer Reading*.

35. Correct the reading with previously stored characteristic values.

$Power\ Deviation\ (dB) = Signal\ Source\ Analyzer\ Reading + Corrections\ stored\ in\ step\ 26$

36. Verify that the *Power Deviation (dB)* results in the preceding step are within the limits listed in Tables 8 and 9.
37. Repeat steps 30 through 36 for each test frequency in the frequency list created in step 29. The following steps apply to using an output power of <-40 dBm.
38. Create a list of test frequencies from Table 7 that apply to a power level of -80 dBm
39. Configure the PXIe-5654 with PXIe-5696 using the following settings:
 - **Frequency:** Frequency from the list in step 38
 - **Power Level:** -80 dBm, which is the *Expected Power (dBm)*
40. Commit the settings to hardware if this is the first iteration of running this procedure; otherwise skip to step 41.
41. Check the signal generation status and verify that there are no reported errors or warnings.
42. Configure the signal source analyzer with the following settings:
 - **Center frequency:** Frequency in step 38
 - **RF Input coupling:** DC
 - **Reference level:** -30 dBm
 - **Frequency span:** 0 Hz
 - **Resolution bandwidth:** 500 Hz
 - **Sweep time:** 200 ms
 - **Reference Clock source:** External
 - **RF attenuation:** 5 dB
 - **Preamplifier:** On
43. Measure the power level with the signal source analyzer. Record the value as the *Signal Source Analyzer Reading*.
44. Correct the reading with previously stored characteristic values.

$$\text{Power Deviation (dB)} = \text{Signal Source Analyzer Reading} + \text{Corrections stored in step 26}$$
45. Verify that the *Power Deviation (dB)* results in the preceding step are within the limits listed in Tables 8 and 9.
46. Repeat steps 39 through 45 for each test frequency in the frequency list created in step 38.
47. Stop signal generation.
48. Close the device session.

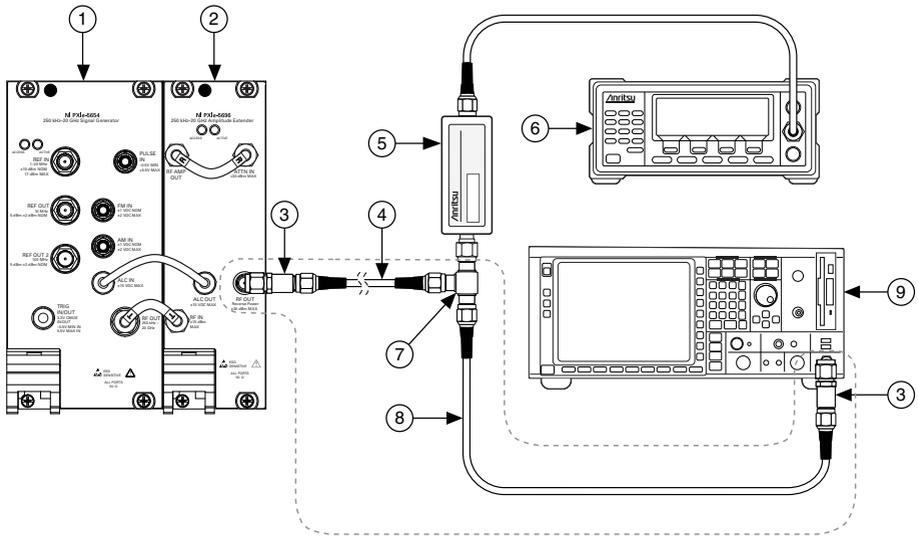
Verifying RF OUT Maximum Power

This procedure verifies that the PXIe-5654 with PXIe-5696 produces the correct maximum output power.

1. Connect the PXIe-5654 to the PXIe-5696.
2. Using the fixture that was previously characterized in [Characterizing the Power Splitter](#), connect the input of the fixture to the PXIe-5696 RF OUT front panel connector.
3. Connect the outputs of the fixture to the power sensor and to the signal source analyzer RF input connector, as shown in the following image.

All other connections should not have changed since characterization.

Figure 5. RF OUT Maximum Power Verification Equipment Setup



- 1. PXIe-5654 RF Analog Signal Generator
- 2. PXIe-5696 Amplitude Extender
- 3. K(m)-to-K(f) 6 dB Attenuator
- 4. K(m)-to-K(m) Cable, 12 in.
- 5. Power Sensor
- 6. Power Meter
- 7. Power Splitter
- 8. K(m)-to-K(m) Cable, 36 in.
- 9. Signal Source Analyzer

4. Configure the reference level of the spectrum analyzer to -30 dBm.

The spectrum analyzer is used only for termination.

- 5. Create a new device session for the PXIe-5654 with PXIe-5696.
- 6. Create a list of test frequencies using the values in the following table.

Table 9. RF OUT Maximum and Minimum Power Test Frequencies

Power Level (dBm)	Start Frequency (MHz)	Stop Frequency (MHz)	Frequency Step (MHz)
12	0,25	—	—
12	25	250	112.5
22	275	1,000	145
26	1,250	3,000	250
25	3,250	6,000	250
22	6,250	15,000	250
20	15,250	20,000	250

7. Configure the PXIe-5654 with PXIe-5696 using the following settings:
 - Frequency: Start frequency from the list in step 6
 - Power Level: Power level from the list in step 6
8. Initiate signal generation if this is the first iteration of running the procedure; otherwise skip to step 11.
9. Enable the RF output.
10. Measure the PXIe-5696 RF OUT front panel connector power using the power meter and the fixture created in *Characterizing the Power Splitter*. Correct the power meter reading for the RF frequency and previously characterized power splitter loss.
11. Verify that the power output measured in step 10 meets the limits in the following table.

Table 10. Maximum Power Limits

Frequency (MHz)	As-Found Limit (dBm)	As-Left Limit (dBm)
0.25 to \leq 250	\geq 10	\geq 11
$>$ 250 to \leq 1,000	\geq 20	\geq 21
$>$ 1,000 to \leq 3,000	\geq 24	\geq 25
$>$ 3,000 to \leq 6,000	$>$ 23	$>$ 24
$>$ 6,000 to \leq 15,000	$>$ 20	$>$ 21
$>$ 15,000 to \leq 20,000	$>$ 18	$>$ 19

12. Repeat steps 7 through 11 for each frequency from the list created in step 6.
13. Close the device session.

Adjustment

This section describes the steps needed to adjust the PXIe-5654 with PXIe-5696 to meet published specifications. The PXIe-5696 is adjusted while connected to the PXIe-5654.



Note Adjusting the PXIe-5696 requires a calibrated 20 GHz PXIe-5654. If you performed verification using a 10 GHz PXIe-5654, power off the system and replace the 10 GHz PXIe-5654 with a 20 GHz PXIe-5654 prior to starting adjustment.



Note Before starting this adjustment on the PXIe-5654 with PXIe-5696, unassociate the PXIe-5654 and PXIe-5696 in MAX, then complete the adjustment procedures for the PXIe-5654 as a stand-alone device.

Related Information

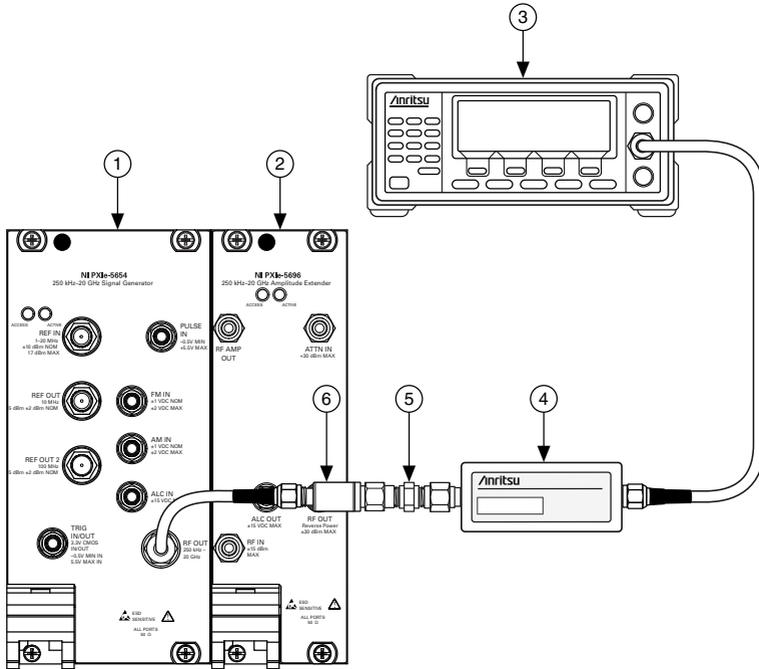
For instructions on adjusting the PXIe-5654 as a stand-alone device, refer to the [PXIe-5654 Calibration Procedure](#).

Measuring RF Attenuator Path Input Power

This procedure measures the input power used for PXIe-5696 attenuator path adjustments. Using the measured input power yields a more accurate adjustment for the PXIe-5696 attenuator paths.

1. Connect the PXIe-5654 RF OUT front panel connector to the power meter through the 20 dB attenuator as shown in the following figure.

Figure 6. PXIe-5696 RF Attenuator Path Input Power Measurement Equipment Setup



- | | |
|---|-----------------------------|
| 1. PXIe-5654 RF Analog Signal Generator | 4. Power Sensor |
| 2. PXIe-5696 Amplitude Extender | 5. SMA(f)-to-SMA(f) Adapter |
| 3. Power Meter | 6. 20 dB Attenuator |
2. Initialize the power meter.
 3. Initialize a new external calibration session for the PXIe-5696.
 4. Call the niRFSG Initialize External Calibration VI using the appropriate password.



Note The default password for password-protected operations is NI.

5. Call the niRFSG 5696 Attenuator Path Cal Initialize VI with the following inputs:
 - NI 5654 resource name
 - **measurement port**: Input Power
 - **input power file**: Specify a fully qualified path to the `Atten_Zero_Loss.bin` file

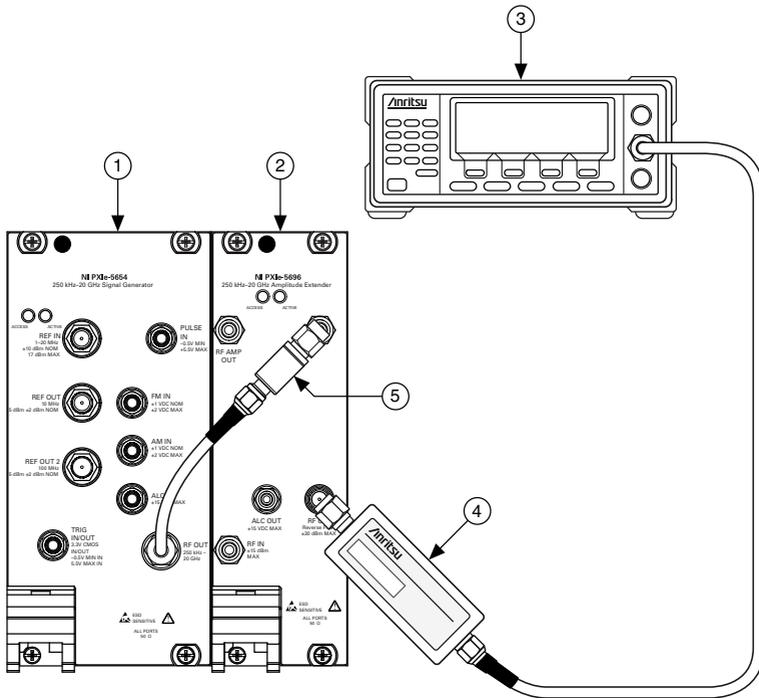
 **Note** The VI creates this file. Specify a path to a writeable location for the file.
6. Call the niRFSG 5696 Attenuator Path Cal Configure VI.
7. Measure the PXIe-5654 output power through the 20 dB attenuator with the power meter. Ensure that the power meter is settled within 0.1% before taking a measurement.
8. Correct the power meter reading for the RF frequency using the **frequency to measure** output of the niRFSG 5696 Attenuator Path Cal Configure VI.
9. Use the corrected reading from step 8 as the value of the **measured power** input of the niRFSG 5696 Attenuator Path Cal Adjust VI.
10. Repeat steps 6 through 9 until the **attenuator calibration complete** output of the niRFSG 5696 Attenuator Path Cal Adjust VI returns a value of TRUE.
11. Call the niRFSG Close External Calibration VI to close the session. Set the **write calibration to hardware?** parameter to TRUE.

Adjusting RF Attenuator Path

This procedure characterizes the RF attenuator path in the PXIe-5696 and updates the values stored in the PXIe-5696 EE PROM. This adjustment yields a more accurate output power for the PXIe-5696 RF OUT.

1. Connect the PXIe-5654 RF OUT to the PXIe-5696 ATTN IN front panel connector through the 20 dB attenuator.
2. Connect the PXIe-5696 ATTN OUT front panel connector to the power meter as shown in the following figure.

Figure 7. PXIe-5696 RF Attenuator Path Adjustment Equipment Setup



- | | |
|---|---------------------|
| 1. PXIe-5654 RF Analog Signal Generator | 4. Power Sensor |
| 2. PXIe-5696 Amplitude Extender | 5. 20 dB Attenuator |
| 3. Power Meter | |

- Initialize a new external calibration session for the PXIe-5696.
- Call the niRFSG Initialize External Calibration VI using the appropriate password.



Note The default password for password-protected operations is NI.

- Call the niRFSG 5696 Attenuator Path Cal Initialize VI with the following inputs:
 - NI 5654 resource name
 - measurement port:** Output Power
- Select the file created during *Measuring RF Attenuator Path Input Power* on page 24 as the **input power file** of the niRFSG Attenuator Path Cal Initialize VI.
- Call the niRFSG 5696 Attenuator Path Cal Configure VI.
- Measure the PXIe-5696 output power with the power meter. Correct the measurement using the **frequency to measure** output of the niRFSG 5696 Attenuator Path Cal Configure VI. Ensure that the power meter is settled within 0.1% before taking a measurement.
- Use the corrected measurement from step 8 as the value of the **measured power** input of the niRFSG 5696 Attenuator Path Cal Adjust VI.

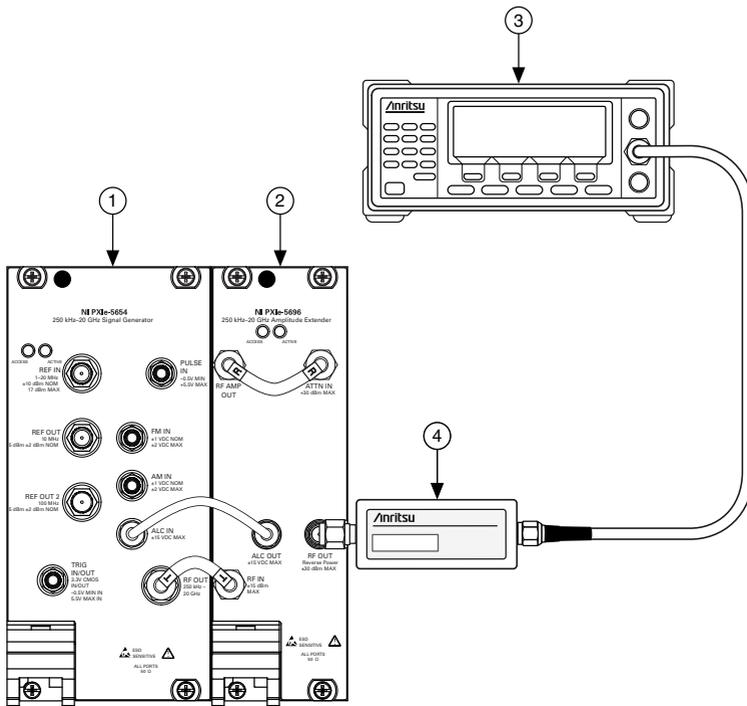
10. Repeat steps 7 through 9 until the **attenuator calibration complete** output of the niRFSG 5696 Attenuator Path Cal Adjust VI returns a value of TRUE.
11. Call the niRFSG Close External Calibration VI to close the session. Set the **write calibration to hardware?** parameter to TRUE to store the results to the EEPROM on the PXIe-5696.

Adjusting RF Attenuator Accuracy

This procedure characterizes the RF attenuator in the PXIe-5696 and updates the values stored in the PXIe-5696 EEPROM. This adjustment yields a more accurate output power for the PXIe-5696 RF OUT.

1. Connect the power sensor directly to the PXIe-5696 RF OUT front panel connector as shown in the following figure.

Figure 8. PXIe-5696 RF Attenuator Accuracy Adjustment Equipment Setup



- | | |
|---|-----------------|
| 1. PXIe-5654 RF Analog Signal Generator | 3. Power Meter |
| 2. PXIe-5696 Amplitude Extender | 4. Power Sensor |

2. Initialize a new external calibration session for the PXIe-5696.
3. Call the niRFSG Initialize External Calibration VI using the appropriate password.



Note The default password for password-protected operations is NI.

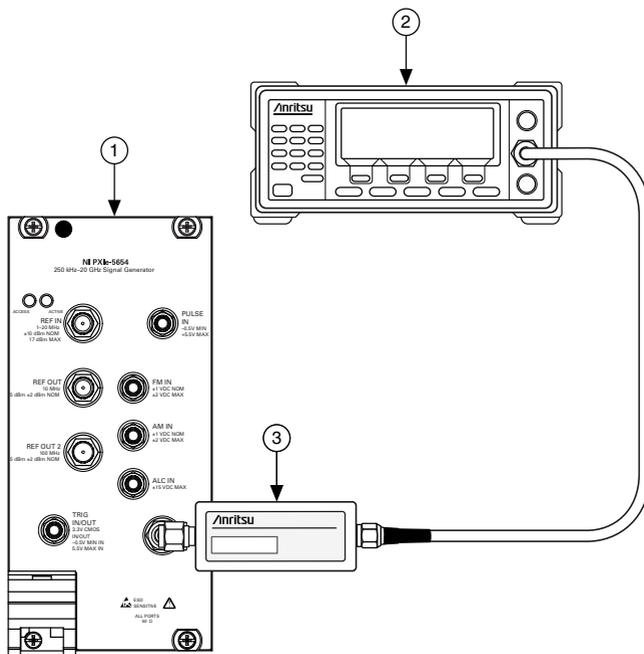
4. Call the niRFSG 5696 Attenuator Cal Initialize VI with the NI 5654 resource name as input.
5. Call the niRFSG 5696 Attenuator Cal Configure VI.
6. Measure the PXIe-5696 output power with the power meter. Correct the measurement using the **frequency to measure** output of the niRFSG 5696 Attenuator Cal Configure VI. Ensure that the power meter is settled within 0.1% before taking a reading.
7. Use the reading from step 6 as the value of the **measured power** input of the to niRFSG 5696 Attenuator Cal Adjust VI.
8. Repeat steps 6 and 7 until the **attenuator calibration complete** output of the niRFSG 5696 Attenuator Cal Adjust VI returns a value of TRUE.
9. Call the niRFSG Close External Calibration VI to close the session. Set the **write calibration to hardware?** parameter to TRUE to store the results to the EEPROM on the PXIe-5696.

Measuring Amplifier Path Input Power

This procedure measures the input power used for PXIe-5696 RF amplifier path adjustments. Using the measured input power yields a more accurate adjustment.

1. Connect the PXIe-5654 RF OUT front panel connector directly to the power meter as shown in the following figure.

Figure 9. PXIe-5696 Amplifier Path Input Power Measurement Equipment Setup



1. PXIe-5654 RF Analog Signal Generator
2. Power Meter
3. Power Sensor

2. Initialize the power meter.
3. Initialize a new external calibration session for the PXIe-5696.
4. Call the niRFSG Initialize External Calibration VI using the appropriate password.



Note The default password for password-protected operations is NI.

5. Call the niRFSG 5696 Amplifier Cal Initialize VI with the following inputs:
 - NI 5654 resource name
 - **path to calibrate:** High Power
 - **measurement port:** Input Power
 - **input power file:** Specify a fully qualified path to the High_Power_Path_Input_Power.bin file



Note The VI creates this file. Specify a path to a writeable location for the file.

6. Call the niRFSG 5696 Amplifier Cal Configure VI.
7. Measure the PXIe-5654 output power with the power meter. Ensure that the power meter is settled within 0.1% before taking a measurement.

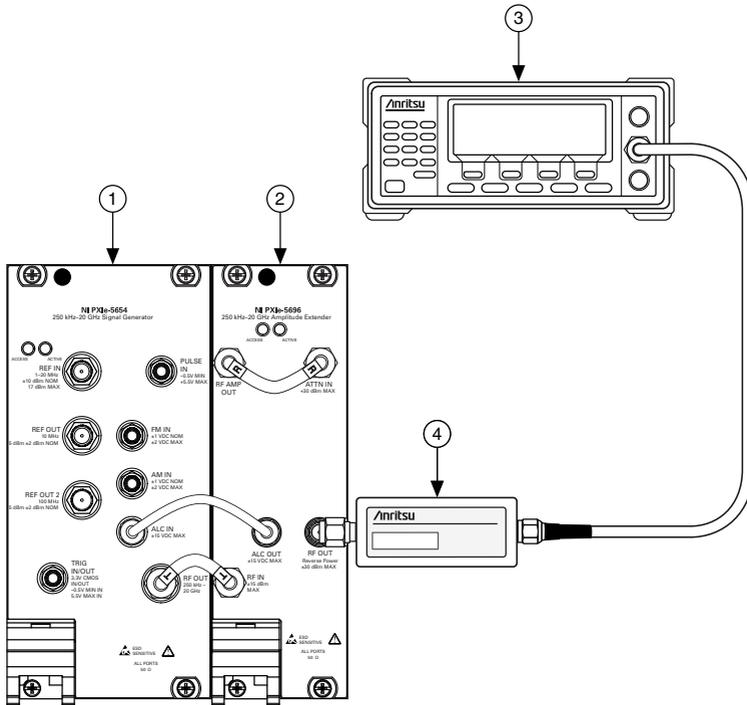
8. Correct the measurement from step 7 using the **frequency to measure** output of the niRFSG 5696 Amplifier Cal Configure VI.
 9. Use the corrected reading from step 8 as the value of the **measured power** input of the niRFSG 5696 Amplifier Cal Adjust VI.
 10. Repeat steps 6 through 9 until the **amp calibration complete** output of the niRFSG 5696 Amplifier Cal Adjust VI returns a value of TRUE.
 11. Call the niRFSG Close External Calibration VI to close the session. Set the **write calibration to hardware?** parameter to TRUE.
 12. Repeat steps 5 through 10 with the following inputs:
 - **path to calibrate:** Low Harmonic
 - **measurement port:** Input Power
 - **input power file:** Specify a fully qualified path to the `Low_Harmonic_Path_Input_Power.bin` file
-  **Note** The VI creates this file. Specify a path to a writeable location for the file.
13. Call the niRFSG Close External Calibration VI to close the session. Set the **write calibration to hardware?** parameter to TRUE.

Adjusting Amplitude Accuracy (Low Harmonic Paths)

This procedure characterizes the low harmonic paths in the PXIe-5696 and updates the values stored in the PXIe-5696 EEPROM. This adjustment yields a more accurate output power for the PXIe-5696 RF OUT.

1. Connect the power sensor directly to the PXIe-5696 RF OUT front panel connector as shown in the following figure.

Figure 10. PXIe-5696 Amplitude Accuracy (Low Harmonic Paths) Adjustment Equipment Setup



- | | |
|---|-----------------|
| 1. PXIe-5654 RF Analog Signal Generator | 3. Power Meter |
| 2. PXIe-5696 Amplitude Extender | 4. Power Sensor |

- Initialize a new external calibration session for the PXIe-5696.
- Call the niRFSG Initialize External Calibration VI using the appropriate password.



Note The default password for password-protected operations is NI.

- Call the niRFSG 5696 Amplifier Cal Initialize VI with the following inputs:
 - path to calibrate:** Low Harmonic
 - measurement port:** Output Power
- Select the file created during *Measuring Amplifier Path Input Power* on page 28 for the Low Harmonic path as the **input power file** of the niRFSG Amplifier Cal Initialize VI.
- Call the niRFSG 5696 Amplifier Cal Configure VI.
- Measure the PXIe-5696 output power with the power meter. Correct the measurement using the **frequency to measure** output of the niRFSG 5696 Amplifier Cal Configure VI. Ensure that the power meter is settled within 0.1% before taking a reading.
- Use the reading from step 7 as the value of the **measured power** input of the niRFSG 5696 Amplifier Cal Adjust VI.

2. Initialize a new external calibration session for the PXIe-5696.
3. Call the niRFSG Initialize External Calibration VI using the appropriate password.



Note The default password for password-protected operations is NI.

4. Call the niRFSG 5696 Amplifier Cal Initialize VI with the following input parameters:
 - **path to calibrate:** High Power
 - **measurement port:** Output Power
5. Select the file created during *Measuring Amplifier Path Input Power* on page 28 for the High Power path as the **input power file** of the niRFSG Amplifier Cal Initialize VI.
6. Call the niRFSG 5696 Amplifier Cal Configure VI.
7. Measure the PXIe-5696 output power with the power meter. Correct the measurement using the **frequency to measure** output of the niRFSG 5696 Amplifier Cal Configure VI. Ensure that the power meter is settled within 0.1% before taking a reading.
8. Use the reading from step 7 as the value of the **measured power** input of the niRFSG 5696 Amplifier Cal Adjust VI.
9. Repeat steps 7 and 8 until the **amp calibration complete** output from the niRFSG 5696 Amplifier Cal Adjust VI returns a value of TRUE.
10. Call the niRFSG Close External Calibration VI to close the session. Set the **write calibration to hardware?** parameter to TRUE to store the results to the EEPROM on the PXIe-5696.

Related Information

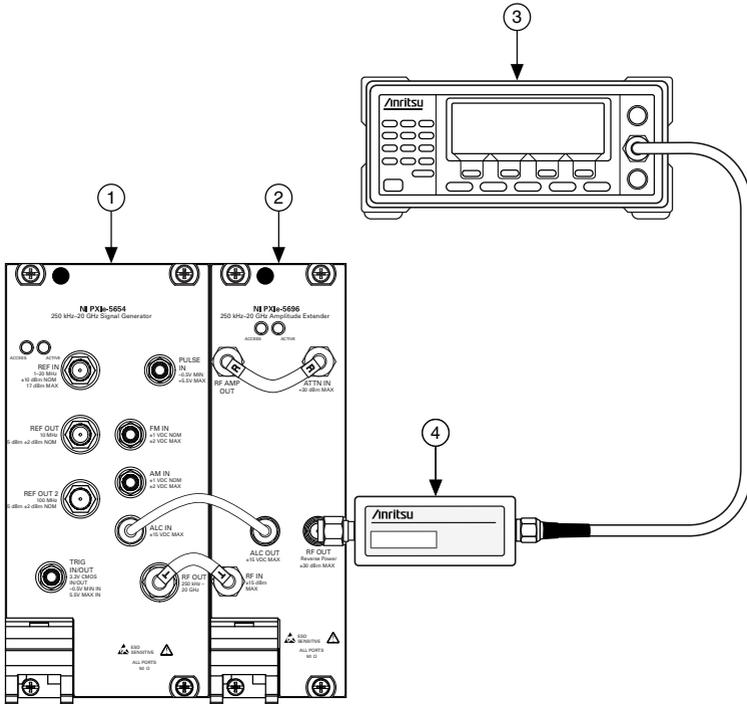
[Measuring Amplifier Path Input Power](#) on page 28

Adjusting ALC

This procedure characterizes the ALC path in the PXIe-5654 with PXIe-5696 and updates the values stored in the PXIe-5696 EEPROM. This adjustment yields a more accurate output power for the PXIe-5696 RF OUT.

1. Connect the power sensor directly to the PXIe-5696 RF OUT front panel connector as shown in the following figure.

Figure 12. PXIe-5696 ALC Adjustment Equipment Setup



- | | |
|---|-----------------|
| 1. PXIe-5654 RF Analog Signal Generator | 3. Power Meter |
| 2. PXIe-5696 Amplitude Extender | 4. Power Sensor |

- Initialize a new external calibration session for the PXIe-5696.
- Call the niRFSG Initialize External Calibration VI using the appropriate password.



Note The default password for password-protected operations is NI.

- Call the niRFSG 5696 ALC Cal Initialize VI.
- Call the niRFSG 5696 ALC Cal Configure VI
- Measure the PXIe-5696 output power with the power meter. Correct the measurement using the **frequency to measure** output of the niRFSG 5696 ALC Cal Configure VI. Ensure that the power meter is settled within 0.1% before taking a reading.
- Use the reading from step 6 as the **measured power** input of the niRFSG 5696 ALC Cal Adjust VI.
- Repeat steps 6 and 7 until **ALC calibration complete** output of the niRFSG 5696 ALC Cal Adjust VI returns a value of TRUE.
- Call the niRFSG Close External Calibration VI to close the session. Set the **write calibration to hardware?** parameter to TRUE to store the results to the EEPROM on the PXIe-5696.

Reverification

Repeat the [Verification](#) section to determine the as-left status of the PXIe-5654 or the PXIe-5696.



Note If any test fails reverification after performing an adjustment, verify that you have met the test conditions before returning your PXIe-5654 to NI. Refer to the [NI Services](#) section for information about support resources or service requests.

Updating Calibration Date and Time

This procedure updates the date and time of the last calibration of the PXIe-5696.

1. Call the niRFSG Initialize External Calibration VI.
2. Call the niRFSG Update External Calibration Date and Time VI.
3. Call the niRFSG Close External Calibration VI to close the session. Set the **write calibration to hardware?** parameter to TRUE to store the results to the EEPROM on the PXIe-5696.

Revision History

Table 11. Revision History for the *PXIe-5654 with PXIe-5696 Calibration Procedure*

Revision	Affected Section(s)	Change(s)
376183A-01 (November 2016)	—	This is the initial release of the <i>PXIe-5654 with PXIe-5696 Calibration Procedure</i> .
3761823-01 (March 2019)	—	Made calibration updates and fixed various issues.
376183C-01 (June 2021)	<i>Verification</i>	Removed the following <i>Optional Verification</i> procedure: <ul style="list-style-type: none">• <i>Verifying PULSE IN Operation</i>

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376183C-01 June 9, 2021