CALIBRATION PROCEDURE

NI PXI-5650/5651/5652

This document describes the processes to calibrate the NI PXI-5650/5651/5652 (PXI-5650/5651/5652) RF signal generator. This document provides performance tests to verify whether the instrument is performing within the published specifications. For more information about calibration, visit `ni.com/calibration`.

Contents

NATIONAL INSTRUMENTS™

Required Software

To calibrate the PXI-5650/5651/5652, you must install NI-RFSG version 15.0.3 or later on the calibration system. NI-RFSG includes all the VIs necessary for calibration. You can download the latest version of NI-RFSG at `ni.com/downloads`.

NI-RFSG supports programming the calibration procedures in LabVIEW. Calibration VIs are accessible in LabVIEW from the Functions palette. Refer to Table 1 for file locations.

For more information about calibration VIs, refer to the *NI RF Signal Generators Help*, accessible at **Start»All Programs»National Instruments»NI-RFSG»Documentation» NI RF Signal Generators Help**.

Table 1. Calibration File Locations

File Name and Location	Description
`<IVI>\bin\niRFSG.dll`	NI-RFSG driver containing the entire NI-RFSG API, including calibration functions.
`<LabVIEW>\instr.lib\niRFSG\niRFSG5652calibration`	Folder containing NI-RFSG calibration VIs. You can access calibration VIs from the NI-RFSG calibration section of the LabVIEW Functions palette.

Related Documentation

You might find the following documentation helpful as you perform the verification procedures:

- Specifications for your device
- *NI PXI-5650/5651/5652 Getting Started Guide*
- *NI RF Signal Generators Help*

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

Password

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

Calibration Interval

The measurement accuracy requirements of your application determine how often you should calibrate your device. NI recommends that you perform a complete calibration for the PXI-5650/5651/5652 at least once a year. You can shorten this calibration interval based on the accuracy demands of your application.

Test Equipment

Table 2 lists the equipment required to calibrate the PXI-5650/5651/5652. If you do not have the recommended equipment, select a substitute calibration standard using the specifications listed in Table 2.

Table 2. Required Equipment Specifications for PXI-5650/5651/5652 Calibration

Required Equipment	Recommended Model	Where Used	Minimum Requirements
Spectrum analyzer	Rohde & Schwarz (R&S) FSU Spectrum Analyzer with Preamplifier (option B23 and B25)	Characterizing the spectrum analyzer Frequency accuracy Low power level accuracy Single sideband phase noise Harmonics Subharmonics Nonharmonics	Frequency range: 500 kHz to 13.2 GHz Noise floor: <-150 dBm/Hz
6 dB precision attenuator	Anritsu 41KB-6	Characterizing the spectrum analyzer Frequency accuracy Low power level accuracy Single sideband phase noise Harmonics Subharmonics Nonharmonics	Frequency range: 500 kHz to 6.6 GHz Power rating: 2 W Impedance: 50 Ω VSWR: ≤1.1:1
Power meter	Anritsu ML2438A with an Anritsu SC7400 thermal sensor	Characterizing the spectrum analyzer High power level accuracy	Range: -55 dBm to 20 dBm Frequency range: 100 kHz to 18 GHz

Table 2. Required Equipment Specifications for PXI-5650/5651/5652 Calibration (Continued)

Required Equipment	Recommended Model	Where Used	Minimum Requirements
Frequency reference	Symmetricon 8040C Rubidium Frequency Standard	Characterizing the spectrum analyzer Frequency accuracy High power level accuracy Low power level accuracy Single sideband phase noise Harmonics Subharmonics Nonharmonics	Frequency: 10 MHz Frequency accuracy: ≤±1E-9
BNC (m)-to-BNC (m) cable	Pomona 5697	—	—
SMA (m)-to-BNC (m) cable	Pasterneck Enterprises PE3696-36	—	—
SMA (m)-to-SMA (m) cable	MegaPhase G916-S1S1-36	—	Frequency range: DC to 6.6 GHz Insertion loss: ≤1.2 dB up to 6.6 GHz Impedance: 50 Ω VSWR: ≤1.25 : 1 up to 6.6 GHz
N (m)-to-SMA (f) adapter	Radiall R191.329.000	—	Frequency range: DC to 11 GHz Impedance: 50 Ω
PXI chassis	NI PXIe-1065	—	—

Test Conditions

The following setup and environmental conditions are required to ensure the PXI-5650/5651/5652 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.
- 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 cooling, refer to the *Maintain Forced-Air Cooling Note to Users* document available at `ni.com/manuals`.
- Keep relative humidity between 10% and 90%, noncondensing.
- Maintain an ambient temperature of 23 °C ±5 °C.
- Allow a warm-up time of at least 30 minutes after the chassis is powered on. The warm-up time ensures that the PXI-5650/5651/5652 is 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 subsequent frequency iteration.

Calibration Procedures

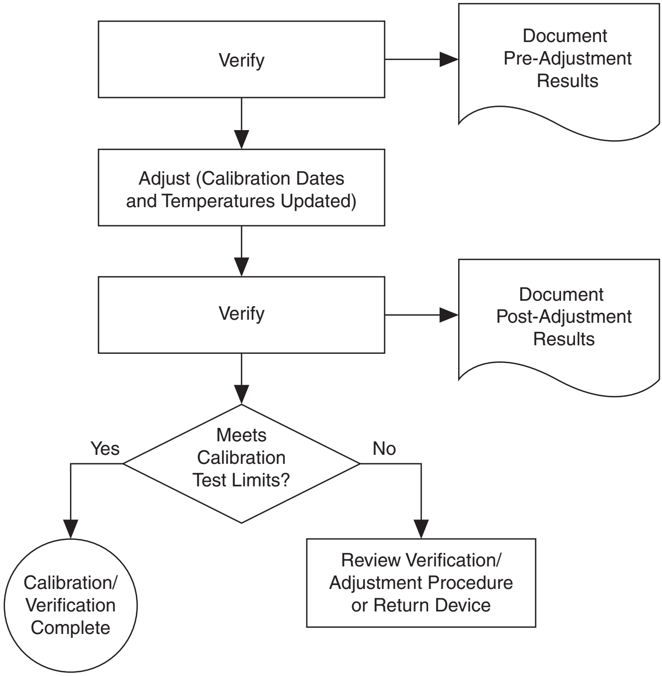
The calibration process includes the following steps:

1. *Initial Setup*—Install the device and configure it in Measurement & Automation Explorer (MAX).
2. *Verification*—Verify the existing operation of the device. This step confirms whether the device is operating within its specified range prior to adjustment.
3. *Adjustment*—Perform an external adjustment of the device that adjusts the calibration constants of the device.
4. *Reverification*—Repeat the verification procedure to ensure that the device is operating within its specifications after adjustment.

Perform a complete calibration to guarantee successful adjustment and performance of the PXI-5650/5651/5652 for a one-year calibration interval.

Figure 1 shows the programming flow for a complete calibration.

Figure 1. Complete Calibration Programming Flow



Initial Setup

Refer to the *NI PXI-5650/5651/5652 Getting Started Guide* for information about how to install the software and hardware and how to configure the device in MAX.

Characterizing the Test System

The following procedures characterize the test equipment used during verification and adjustment.

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.

Characterizing the Spectrum Analyzer

Complete the following steps to characterize the spectrum analyzer:

1. Connect the PXI-5650/5651/5652 REF IN/OUT front panel connector to the rubidium 10 MHz frequency reference signal using the SMA (m)-to-BNC (m) cable.

2. Connect the PXI-5650/5651/5652 RF OUT front panel connector to the power meter thermal sensor.
3. Call the niRFSG 5652 Get Calibration Frequencies.vi located in the `labview\instr.lib\niRFSG\niRFSG5652Calibration\SubVIs` directory. In the **Calibration procedure** control, specify `Attenuators`, and in the **Model** control, specify the device model name as `NI PXI-5650`, `NI PXI-5651`, or `NI PXI-5652`. A frequency array is generated.
4. Build another frequency array for the appropriate device model using the frequencies listed in Table 5, *Low-Level Accuracy Test Points and Limits (≤-40 dBm)*.
5. Concatenate the frequency arrays from step 3 and step 4. Pass the result into the niRFSG Sort Array and Remove Duplicates (DBL).vi located in the `labview\instr.lib\niRFSG\commonCalibration` directory. Record the resulting list of frequencies that is generated.
6. Generate a signal at -35 dBm, and measure the power at all of the frequency test points recorded in step 5.
7. Connect the rubidium 10 MHz frequency reference signal to the spectrum analyzer REF IN rear panel connector.
8. Connect the 6 dB precision attenuator to the PXI-5650/5651/5652 RF OUT front panel connector.
9. Connect the spectrum analyzer RF INPUT connector to the 6 dB precision attenuator.
10. Generate a single-tone signal after setting the following NI-RFSG property settings:
    - Frequency (Hz): 500 kHz
    - Power Level (dBm): -35 dBm
    - Generation Mode: CW
    - Reference Clock source: RefIn
11. Use the spectrum analyzer to measure the mean power of the RF output using the following spectrum analyzer settings:
    - Frequency: NI-RFSG frequency (Hz) value obtained in step 10
    - Reference level: -38 dBm
    - Resolution bandwidth: 30 Hz
    - Frequency span: 0 Hz
    - Reference Clock source: External
    - Trace averaging: 20 averages
12. Repeat step 11 for each of the frequencies in the array that you recorded in step 5.
13. Calculate the *Spectrum Analyzer Correction Factor* by subtracting each measurement in step 11 from the corresponding measurement in step 6 at the same frequency. Record the result.

Tip The numbers will be positive if the subtraction is performed correctly.

Note You must use the same attenuator used in this characterization when performing the corresponding verification and adjustment procedures.

Verification

This section describes the steps you must follow to verify the published specifications for the PXI-5650/5651/5652.

Verification includes the following functional test:

- ALC limts table validation

Verification tests the following PXI-5650/5651/5652 specifications:

- Frequency accuracy
- High power level accuracy
- Low power level accuracy
- Single sideband phase noise at 10 kHz offset
- Harmonics at an RF output level from -50 dBm to 0 dBm
- Subharmonics at an RF output level from -50 dBm to 0 dBm
- Nonharmonics at less than or equal to an RF output level of 0 dBm (>3 kHz and >100 kHz offsets)

Verification of the PXI-5650/5651/5652 is complete only after you have successfully completed all tests in this section.

Validating the ALC Limits Table

Complete the following steps to validate the ALC limits table on the device EEPROM:

1. Call the niRFSG Initialize External Calibration VI.
2. Call the niRFSG 5652 Validate ALC Limits Table VI.

   Note Any invalid ALC limits are reported in the **invalid limits** indicator. If this array is non-empty, adjust the device. If invalid limits persist after adjustment, the device specifications are not warranted over temperature at the specified **invalid limits** frequencies, and the device requires repair.

   Note If the **ALC poly range data present?** parameter is FALSE, adjust the device. The ALC limits table is validated using calibration data on the device and does not require any exernal measurements. ALC poly range data was added to the device EEPROM in NI-RFSG 15.0.3. This data is required to validate the ALC limits table. If the device was last adjusted using a version of NI-RFSG prior to NI-RFSG 15.0.3, the ALC limits table cannot be validated. The PXI-5652 may be used as an LO for the NI PXIe-5663 or NI PXIe-5673 in this case. When using the PXI-5650/5651/5652 as a stand-alone device, NI recommends adjusting the device using NI-RFSG 15.0.3 or later.

3. Call the niRFSG Close External Calibration VI to close the session. Set the **write calibration to hardware?** parameter to FALSE.

Verifying Frequency Accuracy

Complete the following steps to verify the frequency accuracy of the PXI-5650/5651/5652 module using a spectrum analyzer:

1. Connect the 6 dB precision attenuator to the PXI-5650/5651/5652 RF OUT front panel connector.
2. Connect the spectrum analyzer RF INPUT connector to the 6 dB precision attenuator.
3. Connect the rubidium 10 MHz frequency reference signal to the spectrum analyzer REF IN rear panel connector.
4. Configure the spectrum analyzer with the following settings:
   - Center frequency: 400 MHz
   - Reference level: -20 dBm
   - Resolution bandwidth: 100 Hz
   - Span: 100 kHz
   - Reference Clock source: External
   - Frequency counter resolution: 1 Hz
5. Generate a signal after setting the following NI-RFSG property settings:
   - Frequency (Hz): 400 MHz
   - Power Level (dBm): -20 dBm
   - Generation Mode: CW
   - Reference Clock source: Onboard Clock
6. Use the spectrum analyzer to measure the frequency of the peak tone.
7. Verify that the measurement in step 6 is within the limits in Table 3, with respect to 400 MHz.

Table 3. Frequency Accuracy Test Limit

Device	Test Limit
PXI-5650/5651/5652	9 ppm

Verifying High Power Level Accuracy

Complete the following steps to verify the high power level accuracy of the PXI-5650/5651/5652 module using a power meter:

1. Connect the PXI-5650/5651/5652 REF IN/OUT front panel connector to the rubidium 10 MHz frequency reference signal.
2. Connect the PXI-5650/5651/5652 RF OUT front panel connector to the power meter thermal sensor.
3. Generate a single-tone signal after setting the following NI-RFSG property settings:
   - Frequency (Hz): 500 kHz
   - Power Level (dBm): 5 dBm
   - Generation Mode: CW
   - Reference Clock source: RefIn

4. Use the power meter to measure the RF OUT power. Compare the measured RF OUT power to the *Test Limit* listed in Table 4.

Table 4. High Power Level Accuracy Test Points and Limits

Device	Frequency	Start Power (dBm)	Test Limit (dB)
PXI-5650/5651/5652	500 kHz	5	±1.6
	1 MHz	5	
	2 MHz	5	
	5 MHz	5	
	10 MHz	8	±0.75
	20 MHz	8	
	50 MHz	10	
	100 MHz	10	
	150 MHz	10	
	200 MHz	10	
	500 MHz	10	
	1 GHz	10	
PXI-5651/5652	1.5 GHz	10	±0.75
	2 GHz	8	
	2.5 GHz	8	
	3 GHz	8	
	3.3 GHz	7	
PXI-5652	3.5 GHz	7	±1.0
	4 GHz	5	
	4.5 GHz	5	
	5 GHz	0	
	5.5 GHz	0	
	6 GHz	0	
	6.6 GHz	0	

5. Repeat steps 3 through 4 for every power level down to -38 dBm, using a step size of 2 dB on the even values (5, 4, 2, 0, ..., -38).
6. Repeat step 5 for the remaining frequencies using the corresponding *Start Power* listed in Table 4.

Verifying Low Power Level Accuracy

Note Prior to starting this procedure, characterize the spectrum analyzer according to the *Characterizing the Spectrum Analyzer* section of this document.

Complete the following steps to verify the low power level accuracy (≤-40 dBm) of the PXI-5650/5651/5652 module using a spectrum analyzer:

1. Connect the PXI-5650/5651/5652 REF IN/OUT front panel connector to the rubidium 10 MHz frequency reference signal.
2. Connect the 6 dB precision attenuator to the PXI-5650/5651/5652 RF OUT front panel connector.

Note You must use the same attenuator you used in the *Characterizing the Spectrum Analyzer* procedure.

3. Connect the spectrum analyzer RF INPUT connector to the 6 dB precision attenuator.
4. Connect the rubidium 10 MHz frequency reference signal to the spectrum analyzer 10 MHz REF IN rear panel connector.
5. Generate a single-tone signal after setting the following NI-RFSG property settings:
   - Frequency (Hz): 500 kHz
   - Power Level (dBm): -40 dBm
   - Generation Mode: CW
   - Reference Clock source: RefIn
6. Use the NI-RFSG Property Node to read the actual frequency of the generated signal. The actual frequency varies slightly from the configured frequency.
7. Configure the spectrum analyzer with the following settings:
   - Frequency: NI-RFSG frequency (Hz) value obtained in step 6
   - Reference level: -44 dBm
   - Resolution bandwidth: 30 Hz
   - Frequency span: 0 Hz
   - Reference Clock source: External
   - Trace averaging: 20 traces

8. Use the spectrum analyzer to measure the PXI-5650/5651/5652 RF OUT power. Add the *Spectrum Analyzer Correction Factor* recorded in the *Characterizing the Spectrum Analyzer* section to each power measurement in this step at the corresponding frequency. Compare the value to the *Test Limit* listed in Table 5.

Table 5. Low-Level Accuracy Test Points and Limits (≤-40 dBm)

Device	Frequency	Stop Power (dBm)	Test Limit (dB)
PXI-5650/5651/5652	500 kHz	-90	±2.2
	1 MHz	-90	
	2 MHz	-90	
	5 MHz	-90	
	10.1 MHz	-90	±1.8
	20.1 MHz	-90	
	50.1 MHz	-90	
	100.1 MHz	-90	
	150.1 MHz	-90	
	200.1 MHz	-90	
	500.1 MHz	-90	
	1 GHz	-90	
PXI-5651/5652	1.5 GHz	-90	±1.8
	2 GHz	-80	
	2.5 GHz	-80	
	3 GHz	-70	
	3.3 GHz	-60	

Table 5. Low-Level Accuracy Test Points and Limits (≤-40 dBm) (Continued)

Device	Frequency	Stop Power (dBm)	Test Limit (dB)
PXI-5652	3.5 GHz	-60	±2.0
	4 GHz	-50	
	4.5 GHz	-50	
	5 GHz	-50	
	5.5 GHz	-50	
	6 GHz	-50	
	6.6 GHz	-50	

9. Repeat steps 5 through 8 for every power level down to the *Stop Power* listed in Table 5, using a step size of 5 dB.
10. Repeat steps 5 through 9 for the remaining frequencies listed in Table 5.

Verifying Single Sideband Phase Noise at 10 kHz Offset

Complete the following steps to verify the single sideband (SSB) phase noise of an PXI-5650/5651/5652 module using a spectrum analyzer:

1. Connect the PXI-5650/5651/5652 REF IN/OUT front panel connector to the rubidium 10 MHz frequency reference signal.
2. Connect the 6 dB precision attenuator to the PXI-5650/5651/5652 RF OUT front panel connector.
3. Connect the spectrum analyzer RF INPUT connector to the 6 dB precision attenuator.
4. Connect the rubidium 10 MHz frequency reference signal to the spectrum analyzer 10 MHz REF IN rear panel connector.
5. Generate a signal after setting the following NI-RFSG property settings:
   - Frequency: 500 MHz
   - Power Level: 0 dBm
   - Generation Mode: CW
   - Reference Clock source: RefIn
6. Configure the spectrum analyzer with the following settings:
   - Frequency: 500 MHz
   - Reference level: 0 dBm
   - Resolution bandwidth: 10 Hz
   - Frequency span: 100 Hz
   - Reference Clock source: External
   - Level range: Log 120 dB

7. Measure the maximum power within the configured span of the spectrum analyzer and record this data. Reference this measurement for steps 8 through 13.
8. Reconfigure the spectrum analyzer with the following settings:
   - Frequency: 500 MHz + 10 kHz offset
   - Reference level: Value measured in step 7
   - Resolution bandwidth: 10 Hz
   - Frequency span: 100 Hz
   - Reference Clock source: External
   - Level range: Log 120 dB
   - Trace averaging: 20 traces
9. Measure the mean value within the configured span of the spectrum analyzer and record this value.
10. Apply the following equation to the value measured in step 9:

$$\textit{phase noise}_{SSB}\ \textit{at 10 KHz offset} = \textit{Measurement} - 10\log(\textit{RBW})$$

    where

    Measurement = value measured in step 9

    RBW = resolution bandwidth
11. Subtract the measurement recorded in step 7 from the value calculated in step 10.
12. Verify that the value calculated in step 11 meets the *Test Limit* as specified in Table 6.
13. Repeat steps 5 through 12 for the remaining frequencies listed in the *Frequency* column in Table 6, if applicable to the device.

Table 6. Single Sideband Phase Noise at 10 kHz Offset

Device	Frequency	Test Limit (dBc/Hz)
PXI-5650/5651/5652	500 MHz	<-111
	1 GHz	<-105
PXI-5651/5652	2 GHz	<-98
	3 GHz	<-95
PXI-5652	4 GHz	<-93
	5 GHz	<-90
	6.6 GHz	<-90

Note The main frequency synthesis occurs between 1.6 GHz and 3.3 GHz using one of four voltage-controlled oscillators (VCO). Frequencies outside this range are generated by using dividers or multipliers. For frequencies lower than 1 GHz, the SSB phase noise can be characterized by the following relationship (use the 1 GHz measurement as your reference):

$$SSB\ Phase\ Noise_{TEST} = SSB\ Phase\ Noise_{REFERENCE} - 20\log(n)$$

where

$SSB\ Phase\ Noise_{TEST}$ = SSB phase noise at the center frequency of interest in dBc/Hz

$SSB\ Phase\ Noise_{REFERENCE}$ = SSB phase noise at the referenced center frequency of interest in dBc/Hz

$n = Reference/Test$ in Hz/Hz

Verifying Nonharmonics at 0 dBm to -20 dBm Output Power

Complete the following steps to verify the nonharmonic levels of an PXI-5650/5651/5652 module using a spectrum analyzer:

1. Connect the PXI-5650/5651/5652 REF IN/OUT front panel connector to the rubidium 10 MHz frequency reference signal.
2. Connect the 6 dB precision attenuator to the PXI-5650/5651/5652 RF OUT front panel connector.
3. Connect the spectrum analyzer RF INPUT connector to the 6 dB precision attenuator.
4. Connect the rubidium 10 MHz frequency reference signal to the spectrum analyzer 10 MHz REF IN rear panel connector.
5. Generate a signal after setting the following NI-RFSG property settings:
    - Frequency (Hz): 35.125 MHz
    - Power Level (dBm): 0 dBm
    - Generation Mode: CW
    - Reference Clock source: RefIn
6. Configure the spectrum analyzer with the following settings:
    - Frequency: 35.125 MHz
    - Reference level: +5 dBm
    - Resolution bandwidth: 1 kHz
    - Span: 500 kHz
    - Reference Clock source: External
7. Measure the peak power of the fundamental tone using the spectrum analyzer and record the value. This value is your reference value for steps 8 through 16.
8. Reconfigure the spectrum analyzer with the following settings:
    - Center frequency: 35.125 MHz + 51.5 kHz offset
    - Reference level: +5 dBm
    - Span: 97 kHz

- Reference Clock source: External
- Resolution bandwidth: 100 Hz

9. Measure the peak power using the spectrum analyzer with the settings from step 8 and record the value. This value is the highest peak between 3 kHz and 100 kHz offset from the fundamental frequency.
10. Subtract the measurement in step 7 from the measurement in step 9.
11. Verify that the result calculated in step 10 is within the *>3 kHz Offset* limits listed in Table 7.

Table 7. Nonharmonics at ≤0 dBm Output Power

RF Output Frequency	Test Limits	
	>3 kHz Offset (dBc)	**>100 kHz Offset (dBc)**
500 kHz to <50 MHz	<-57	<-57
50 MHz to <3.3 GHz	<-65	<-70
3.3 GHz to 6.6 GHz	<-50	<-65

The following steps measure the nonharmonic levels *freqOffset* > 100 kHz where *freqOffset* is the frequency offset from the tone being generated.

12. Configure the spectrum analyzer with the following settings:
    - Center frequency: 200 MHz
    - Reference level: +5 dBm
    - Resolution bandwidth: 500 Hz
    - Span: 100 kHz
    - Reference Clock source: External
13. Measure the peak power using the spectrum analyzer with the settings from step 12, and record the value.
14. Subtract the measurement from step 13 from the measurement in step 7.
15. Verify that the result is within the *>100 kHz Offset* limits specified in Table 7.
16. Repeat steps 12 through 15 for the remaining frequencies listed in the *Test Point* column in Table 8.
17. Repeat steps 5 through 16 using the *Center Frequency* shown in Table 9.

Table 8. Test Points for Nonharmonic Test

Device	Test Point (MHz)
PXI-5650/5651/5652	200
	400
	600
	800
	1,000
	1,200
PXI-5651/5652	1,400
	1,600
	1,800
	2,000
	2,200
	2,400
	2,600
	2,800
	3,000
	3,200

Table 8. Test Points for Nonharmonic Test (Continued)

Device	Test Point (MHz)
PXI-5652	3,400
	3,600
	3,800
	4,000
	4,200
	4,400
	4,600
	4,800
	5,000
	5,200
	5,400
	5,600
	5,800
	6,000
	6,200
	6,400
	6,600

Table 9. Center Frequencies for Nonharmonic Test

Device	Center Frequency (MHz)
PXI-5650/5651/5652	35.125
	1,235.125
PXI-5651/5652	3,235.125
PXI-5652	6,535.125

Optional Verification

Use the following procedures to verify nonwarranted specifications for the PXI-5650/5651/5652.

Verifying Harmonics at 0 dBm (Functional Test)

Complete the following steps to verify the harmonic levels of the PXI-5650/5651/5652 module using a spectrum analyzer:

1. Connect the PXI-5650/5651/5652 REF IN/OUT front panel connector to the rubidium 10 MHz frequency reference signal.
2. Connect the 6 dB precision attenuator to the PXI-5650/5651/5652 RF OUT front panel connector.
3. Connect the spectrum analyzer RF INPUT connector to the 6 dB precision attenuator.
4. Connect the rubidium 10 MHz frequency reference signal to the spectrum analyzer 10 MHz REF IN rear panel connector.
5. Configure the spectrum analyzer with the following settings:
   - Center frequency: 10 MHz
   - Reference level: +5 dBm
   - Resolution bandwidth: 1 kHz
   - Frequency span: 500 kHz
   - Reference Clock source: External
6. Generate a signal after setting the following NI-RFSG property settings:
   - Power Level (dBm): 0 dBm
   - Frequency (Hz): 10 MHz
   - Generation Mode: CW
   - Reference Clock source: RefIn
7. Measure the peak signal value of the fundamental frequency using the current settings on the spectrum analyzer. Record this value.
8. Reconfigure the spectrum analyzer with the following settings:
   - Center frequency: Twice the center frequency from step 5
   - Reference level: +5 dBm
   - Resolution bandwidth: 1 kHz
   - Frequency span: 500 kHz
   - Reference Clock source: External
9. Measure the peak signal value of the second harmonic using the settings of the spectrum analyzer configured in step 8. Record this value.
10. Subtract the measurement in step 7 from the measurement in step 9.
11. Verify that the result calculated in step 10 meets the *Test Limit* of the minimum difference from the generated signal power (dBc) as shown in Table 10.

Table 10. Harmonics at -50 dBm to 0 dBm Output Power

Device	Frequency	Test Limit (dBc)
PXI-5650/5651/5652	10 MHz	<-15
	20 MHz	
	50 MHz	
	100 MHz	
	150 MHz	
	200 MHz	
	400 MHz	
	800 MHz	
	1.0 GHz	
PXI-5651/5652	1.6 GHz	<-20
	2.0 GHz	
	2.5 GHz	
	3.0 GHz	
	3.3 GHz	
PXI-5652	3.5 GHz	<-20
	3.7 GHz	
	4.0 GHz	
	4.5 GHz	
	5.0 GHz	
	5.5 GHz	
	6.0 GHz	
	6.6 GHz	
The limits in this table are *typical* values. Typical values describe useful product performance beyond specifications that are not covered by warranty and do not include guardbands for measurement uncertainty or drift.		

12. Repeat steps 5 through 10 for the remaining frequency points shown in Table 10.

Verifying Harmonics at -50 dBm (Functional Test)

Complete the following steps to verify the harmonic levels of the PXI-5650/5651/5652 module using a spectrum analyzer:

1. Connect the PXI-5650/5651/5652 REF IN/OUT front panel connector to the rubidium 10 MHz frequency reference signal.
2. Connect the 6 dB precision attenuator to the PXI-5650/5651/5652 RF OUT front panel connector.
3. Connect the spectrum analyzer RF INPUT connector to the 6 dB precision attenuator.
4. Connect the rubidium 10 MHz frequency reference signal to the spectrum analyzer 10 MHz REF IN rear panel connector.
5. Configure the spectrum analyzer with the following settings:
   - Center frequency: 10 MHz
   - Reference level: -45 dBm
   - Resolution bandwidth: 50 Hz
   - Frequency span: 500 Hz
   - Reference Clock source: External
6. Generate a signal after setting the following NI-RFSG property settings:
   - Power Level (dBm): -50 dBm
   - Frequency (Hz): 10 MHz
   - Generation Mode: CW
   - Reference Clock source: RefIn
7. Measure the peak signal value of the fundamental frequency using the current settings on the spectrum analyzer. Record this value.
8. Reconfigure the spectrum analyzer with the following settings:
   - Center frequency: Twice the center frequency from step 5
   - Reference level: -45 dBm
   - Resolution bandwidth: 50 Hz
   - Frequency span: 500 Hz
   - Reference Clock source: External
9. Measure the peak signal value of the second harmonic using the settings of the spectrum analyzer configured in step 8. Record this value.
10. Subtract the measurement in step 7 from the measurement in step 9.

11. Verify that the result calculated in step 10 meets the *Test Limit* of the minimum difference from the generated signal power (dBc) as shown in Table 11.

Table 11. Harmonics at -50 dBm to 0 dBm Output Power

Device	Frequency	Test Limit (dBc)
PXI-5650/5651/5652	10 MHz	<-15
	20 MHz	
	50 MHz	
	100 MHz	
	150 MHz	
	200 MHz	
	400 MHz	
	800 MHz	
	1.0 GHz	
PXI-5651/5652	1.6 GHz	<-20
	2.0 GHz	
	2.5 GHz	
	3.0 GHz	
	3.3 GHz	
PXI-5652	3.5 GHz	<-20
	3.7 GHz	
	4.0 GHz	
	4.5 GHz	
	5.0 GHz	
	5.5 GHz	
	6.0 GHz	
	6.6 GHz	

The limits in this table are *typical* values. Typical values describe useful product performance beyond specifications that are not covered by warranty and do not include guardbands for measurement uncertainty or drift.

12. Repeat steps 5 through 10 for the remaining frequency points in Table 11.

Verifying Subharmonics on the PXI-5652 at 0 dBm (Functional Test)

Complete the following steps to verify the subharmonic levels of an PXI-5652 RF signal generator using a spectrum analyzer:

This verification is valid *only* for the PXI-5652 RF signal generator.

1. Connect the PXI-5652 REF IN/OUT front panel connector to the rubidium 10 MHz frequency reference signal.
2. Connect the 6 dB precision attenuator to the PXI-5652 RF OUT front panel connector.
3. Connect the spectrum analyzer RF INPUT connector to the 6 dB precision attenuator.
4. Connect the rubidium 10 MHz frequency reference signal to the spectrum analyzer 10 MHz REF IN rear panel connector.
5. Configure the spectrum analyzer with the following settings:
   - Center frequency: 3.3 GHz
   - Reference level: +5 dBm
   - Resolution bandwidth: 1 kHz
   - Span: 500 kHz
   - Reference Clock source: External
6. Generate a single-sideband signal after setting the following NI-RFSG properties:
   - Frequency (Hz): 3.3 GHz
   - Power Level (dBm): 0 dBm
   - Generation Mode: CW
   - Reference Clock source: RefIn
7. Measure the peak power of the fundamental tone using the spectrum analyzer and record the value.
8. Reconfigure the spectrum analyzer with the following settings:
   - Center frequency: Half the frequency used in step 5
   - Reference level: +5 dBm
   - Resolution bandwidth: 1 kHz
   - Span: 500 kHz
   - Reference Clock source: External
9. Measure the peak power of the half harmonic and 1.5x harmonics using the spectrum analyzer with the settings from step 8 and record the values.
10. Subtract the measurement in step 7 from the measurements in step 9.

11. Verify that the measured signal powers in step 10 are within the corresponding *Test Limit* specified in Table 12.

Table 12. PXI-5652 Subharmonics at -50 dBm to 0 dBm Output Power

Center Frequency (GHz)	Subharmonic (0.5x) Frequency (GHz)	Subharmonic (0.5x) Test Limit (dBc)	Subharmonic (1.5x) Frequency (GHz)	Subharmonic (1.5x) Test Limit (dBc)
3.31	1.655	<-30	4.965	<-15
3.5	1.75		5.25	<-25
3.7	1.85		5.55	
3.9	1.95		5.85	
4.1	2.05		6.15	
4.2	2.10	<-25	6.30	<-20
4.5	2.25	<-20	6.75	<-25
4.7	2.35		7.05	
4.9	2.45		7.35	
5.1	2.55		7.65	
5.3	2.65		7.95	
5.5	2.75		8.25	
5.7	2.85		8.55	
5.9	2.95		8.85	
6.1	3.05		9.15	
6.3	3.15		9.45	
6.5	3.25		9.75	
6.6	3.30		9.90	

The limits in this table are *typical* values. Typical values describe useful product performance beyond specifications that are not covered by warranty and do not include guardbands for measurement uncertainty or drift.

12. Repeat steps 5 through 11 for the remaining frequencies in Table 12.

Verifying Subharmonics on the PXI-5652 at -50 dBm (Functional Test)

Complete the following steps to verify the subharmonic levels of an PXI-5652 RF signal generator using a spectrum analyzer:

This verification is valid *only* for the PXI-5652 RF signal generator.

1. Connect the PXI-5652 REF IN/OUT front panel connector to the rubidium 10 MHz frequency reference signal.
2. Connect the 6 dB precision attenuator to the PXI-5652 RF OUT front panel connector.
3. Connect the spectrum analyzer RF INPUT connector to the 6 dB precision attenuator.
4. Connect the rubidium 10 MHz frequency reference signal to the spectrum analyzer 10 MHz REF IN rear panel connector.
5. Configure the spectrum analyzer with the following settings:
   - Center frequency: 3.3 GHz
   - Reference level: -45 dBm
   - Resolution bandwidth: 50 Hz
   - Span: 500 Hz
   - Reference Clock source: External
6. Generate a single-sideband signal after setting the following NI-RFSG properties:
   - Frequency (Hz): 3.3 GHz
   - Power Level (dBm): -50 dBm
   - Generation Mode: CW
   - Reference Clock source: RefIn
7. Measure the peak power of the fundamental tone using the spectrum analyzer and record the value.
8. Reconfigure the spectrum analyzer with the following settings:
   - Center frequency: Half the frequency used in step 5
   - Reference level: -45 dBm
   - Resolution bandwidth: 50 Hz
   - Span: 500 Hz
   - Reference Clock source: External
9. Measure the peak power of the half harmonic and 1.5x harmonics using the spectrum analyzer with the settings from step 8 and record the values.
10. Subtract the measurement in step 7 from the measurements in step 9.

11. Verify that the measured signal powers in step 10 are within the corresponding *Test Limit* specified in Table 13.

Table 13. PXI-5652 Subharmonics at -50 dBm to 0 dBm Output Power

Center Frequency (GHz)	Subharmonic (0.5x) Frequency (GHz)	Subharmonic (0.5x) Test Limit (dBc)	Subharmonic (1.5x) Frequency (GHz)	Subharmonic (1.5x) Test Limit (dBc)
3.31	1.65	<-30	4.95	<-15
3.5	1.75		5.25	<-25
3.7	1.85		5.55	
3.9	1.95		5.85	
4.1	2.05		6.15	
4.2	2.10	<-25	6.30	<-20
4.5	2.25	<-20	6.75	<-25
4.7	2.35		7.05	
4.9	2.45		7.35	
5.1	2.55		7.65	
5.3	2.65		7.95	
5.5	2.75		8.25	
5.7	2.85		8.55	
5.9	2.95		8.85	
6.1	3.05		9.15	
6.3	3.15		9.45	
6.5	3.25		9.75	
6.6	3.30		9.90	

The limits in this table are *typical* values. Typical values describe useful product performance beyond specifications that are not covered by warranty and do not include guardbands for measurement uncertainty or drift.

12. Repeat steps 5 through 11 for the remaining frequencies in Table 13.

Adjustment

Following the adjustment procedure automatically updates the calibration date and temperature in the EEPROM of the PXI-5650/5651/5652.

Adjustment involves the following PXI-5650/5651/5652 procedures:

- Automatic level control (ALC)
- Attenuators
- ALC limits
- Frequency accuracy

Note Adjustment procedures *must* be performed in the order listed.

Adjusting ALC

This procedure measures the response of the ALC circuit. This response is used to generate accurate power levels at the PXI-5650/5651/5652 RF OUT front panel connector. Complete the following steps to adjust the ALC of the PXI-5650/5651/5652 using the power meter thermal sensor:

1. Connect the PXI-5650/5651/5652 RF OUT front panel connector to the power meter thermal sensor.
2. Call the niRFSG Initialize External Calibration VI.
3. Call the niRFSG 5652 Update ALC Limits Table VI, and set the **update max power spec** parameter to TRUE and the **update other table limits** parameter to FALSE.
4. Call the niRFSG 5652 Initialize ALC Calibration VI, and set the **measurement range** parameter to **Above 10 MHz**.
5. Call the niRFSG 5652 Configure ALC Calibration VI.
6. Use the power meter to measure the RF OUT power at the frequency specified by the **frequency to measure** parameter of the niRFSG 5652 Configure ALC Calibration VI.
7. Call the niRFSG 5652 Adjust ALC Calibration VI, and wire the measured value from step 6 to the **measured RF OUT power** parameter.
8. Repeat steps 5 through 7 until the **ALC calibration complete** parameter of the niRFSG 5652 Adjust ALC Calibration VI returns a value of TRUE.
9. Connect the PXI-5650/5651/5652 RF OUT front panel connector to the power meter thermal sensor.
10. Call the niRFSG 5652 Initialize ALC Calibration VI, and set the **measurement range** parameter to **Below 10 MHz**.
11. Call the niRFSG 5652 Configure ALC Calibration VI.
12. Use the power meter to measure the RF OUT power at the frequency specified by the **frequency to measure** parameter of the niRFSG 5652 Configure ALC Calibration VI.
13. Call the niRFSG 5652 Adjust ALC Calibration VI, and wire the measured value from step 12 to the **measured RF OUT power** parameter.

14. Repeat steps 11 through 13 until the **ALC calibration complete** parameter of the niRFSG 5652 Adjust ALC Calibration VI returns a value of TRUE.
15. 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 PXI-5650/5651/5652.

Adjusting Attenuators

This procedure measures the frequency response of the attenuator circuit. This response is used to generate accurate power levels at the PXI-5650/5651/5652 RF OUT front panel connector. Complete the following steps to adjust the PXI-5650/5651/5652 attenuators using a power meter and spectrum analyzer:

1. Connect the PXI-5650/5651/5652 RF OUT front panel connector to the power meter thermal sensor.
2. Disconnect the PXI-5650/5651/5652 REF IN/OUT front panel connector from any clock source, if connected.
3. Connect any available rubidium frequency reference rear panel BNC connector to the spectrum analyzer REF IN rear panel connector.
4. Connect any available rubidium frequency reference rear panel BNC connector to the 10 MHz REF IN connector on the back of the PXI chassis.
5. Call the niRFSG Initialize External Calibration VI.
6. Call the niRFSG 5652 Initialize Attenuator Calibration VI, and set the **measurement range** parameter to **Above -40 dBm (Below 10 MHz)**.
7. Call the niRFSG 5652 Configure Attenuator Calibration VI.
8. Use the power meter to measure the RF OUT power at the frequency specified by the **frequency to measure** parameter of the niRFSG 5652 Configure Attenuator Calibration VI.
9. Call the niRFSG 5652 Adjust Attenuator Calibration VI, and wire the measured value from step 8 to the **measured RF OUT power** parameter.
10. Repeat steps 7 through 9 until the **attenuator calibration complete** parameter of the niRFSG 5652 Adjust Attenuator Calibration VI returns a value of TRUE.
11. Connect the PXI-5650/5651/5652 RF OUT front panel connector to the power meter thermal sensor.
12. Call the niRFSG 5652 Initialize Attenuator Calibration VI, and set the **measurement range** parameter to **Above -40 dBm (Above 10 MHz)**.
13. Call the niRFSG 5652 Configure Attenuator Calibration VI.
14. Use the power meter to measure the RF OUT power at the frequency specified by the **frequency to measure** parameter of the niRFSG 5652 Configure Attenuator Calibration VI.
15. Call the niRFSG 5652 Adjust Attenuator Calibration VI, and wire the measured value from step 14 to the **measured RF OUT power** parameter.
16. Repeat steps 13 through 15 until the **attenuator calibration complete** parameter of the niRFSG 5652 Adjust Attenuator Calibration VI returns a value of TRUE.

17. Connect the 6 dB precision attenuator to the PXI-5650/5651/5652 RF OUT front panel connector.
18. Connect the spectrum analyzer RF IN connector to the 6 dB precision attenuator.

Note You must use the same attenuator you used in the *Characterizing the Spectrum Analyzer* procedure.

19. Call the niRFSG 5652 Initialize Attenuator Calibration VI, and set the **measurement range** parameter to **Below -40 dBm**.
20. Call the niRFSG 5652 Configure Attenuator Calibration VI.
21. Use the spectrum analyzer to measure the mean power of the RF output using the following spectrum analyzer settings:
    - Center frequency: Value returned by the **frequency to measure** parameter of the niRFSG 5652 Configure Attenuator Calibration VI
    - Reference level: -38 dBm
    - Frequency span: 0 Hz
    - Resolution bandwidth: 30 Hz
    - Sweep time: 5 ms
    - Reference Clock source: External
22. Add the *Spectrum Analyzer Correction Factor* recorded in the *Characterizing the Spectrum Analyzer* section to the power measurement from step 21 at the corresponding frequency.
23. Call the niRFSG 5652 Adjust Attenuator Calibration VI, and wire the measured value from step 22 to the **measured RF OUT power** parameter.
24. Repeat steps 20 through 23 until the **attenuator calibration complete** parameter of the niRFSG 5652 Adjust Attenuator Calibration VI returns a value of TRUE.
25. 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 PXI-5650/5651/5652.

Adjusting ALC Limits

This procedure updates the ALC limits table of the device based on the results of the ALC and attenuator adjustments. The ALC limits table determines which attenuator and path NI-RFSG uses for each frequency and power combination. Complete the following steps to adjust the ALC limits table of the PXI-5650/5651/5652:

1. Call the niRFSG Initialize External Calibration VI.
2. Call the niRFSG 5652 Update ALC Limits Table VI, and set the **update max power spec** parameter to FALSE and the **update other table limits** parameter to TRUE.
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 PXI-5650/5651/5652.

Adjusting Frequency Accuracy

This adjustment yields a more accurately tuned VCO frequency. Complete the following steps to adjust the frequency accuracy of the PXI-5650/5651/5652 using a spectrum analyzer:

1. Connect the 6 dB precision attenuator to the PXI-5650/5651/5652 RF OUT front panel connector.
2. Connect the spectrum analyzer RF INPUT connector to the 6 dB precision attenuator.
3. Connect any available rubidium frequency reference rear panel BNC connector to the spectrum analyzer REF IN rear panel connector.
4. Configure the spectrum analyzer with the following settings:
   - Reference Clock source: External
   - Reference level: 10 dBm
   - Center frequency: 400 MHz
5. Call the niRFSG Initialize External Calibration VI.
6. Call the niRFSG 5652 Initialize Reference Clock Calibration VI.
7. Call the niRFSG 5652 Configure Reference Clock Calibration VI.
8. Use the spectrum analyzer to measure the peak power using the following spectrum analyzer settings:
   - Frequency span: Value returned by the **frequency span** parameter of the niRFSG 5652 Configure Reference Clock Calibration VI
   - Center frequency: Value returned by the **center frequency** parameter of the niRFSG 5652 Configure Reference Clock Calibration VI
9. Use the spectrum analyzer frequency counter to measure the frequency of the peak.
10. Call the niRFSG 5652 Adjust Reference Clock Calibration VI. Wire the measured value from step 8 to the **measured REF OUT power** parameter and wire the measured value from step 9 to the **measured REF OUT frequency** parameter.
11. Repeat steps 7 through 10 until the **reference clock calibration complete** parameter of the niRFSG 5652 Adjust Reference Clock Calibration VI returns a value of TRUE.
12. 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 PXI-5650/5651/5652.

You have finished adjusting the PXI-5650/5651/5652. Repeat the *Verification* section to reverify the performance of the PXI-5650/5651/5652 after adjustments.

Updating Calibration Date and Time

This procedure updates the date and time of the last calibration of the PXI-5650/5651/5652.

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 PXI-5650/5651/5652.

Appendix A: Calibration Utilities

NI-RFSG provides a full complement of external calibration VIs. You can use these VIs to retrieve information about adjustments performed on the PXI-5650/5651/5652. The External Calibration palette includes the following VIs:

- niRFSG Initialize External Calibration VI
- niRFSG Get External Calibration Last Date And Time VI
- niRFSG Change External Calibration Password
- niRFSG Update External Calibration Date and Time VI
- niRFSG Close External Calibration VI

Calibration VI References

The VIs used in this procedure, including all calibration VIs, are documented in the *NI-RFSG VI Reference,* which you can access from the *NI RF Signal Generators Help* at **Start»All Programs»National Instruments»NI-RFSG»Documentation**.

Worldwide Support and Services

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

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