DEVICE SPECIFICATIONS

NI PXIe-5646R

Reconfigurable 6 GHz RF Vector Signal Transceiver with 200 MHz Bandwidth

This document lists specifications for the NI PXIe-5646R (NI 5646R) RF vector signal transceiver (VST).

In this document, the term *vector signal analyzer* (VSA) refers to the RF input subsystem of the VST, and the term *vector signal generator* (VSG) refers to the RF output subsystem of the VST.

Specifications are warranted by design and under the following conditions, unless otherwise noted:

- 30 minutes warm-up time.
- Calibration cycle is maintained.
- Chassis fan speed is set to High. In addition, NI recommends using slot blockers and EMC filler panels in empty module slots to minimize temperature drift.
- Calibration IP is used properly during the creation of custom FPGA bitfiles.
- Calibration Interconnect cable remains connected between CAL IN and CAL OUT front panel connectors.

Caution Do not disconnect the cable that connects CAL IN to CAL OUT. Removing the cable from or tampering with the CAL IN or CAL OUT front panel connectors voids the product calibration and specifications are no longer warranted.

Unless otherwise noted, specifications assume the NI 5646R is configured in the following default mode of operation:

- Reference Clock source: Internal
- RF IN reference level: 0 dBm
- RF OUT power level: 0 dBm
- LO tuning mode: Fractional
- LO PLL loop bandwidth: Medium
- LO step size: 200 kHz
- LO frequency: 2.4 GHz
- LO source: Internal

Note Within the specifications, *self-calibration °C* refers to the recorded device temperature of the last successful self-calibration. You can read the self-calibration temperature from the device using the appropriate software functions.

Specifications describe the warranted, traceable product performance over ambient temperature ranges of 0 °C to 55 °C, unless otherwise noted.

Typical values describe useful product performance beyond specifications that are not covered by warranty and do not include guardbands for measurement uncertainty or drift. Typical values may not be verified on all units shipped from the factory. Unless otherwise noted, typical values cover the expected performance of units over ambient temperature ranges of 23 °C ± 5 °C with a 90% confidence level, based on measurements taken during development or production.

2σ specifications describe the 95th percentile values in which 95% of the cases are met with a 95% confidence for any ambient temperature of 23 °C ± 5 °C.

Nominal values (or supplemental information) describe additional information about the product that may be useful, including expected performance that is not covered under *Specifications* or *Typical* values. Nominal values are not covered by warranty.

Specifications are subject to change without notice. For the most recent device specifications, visit *ni.com/manuals*.

National Instruments RF devices are capable of producing and/or acquiring accurate signals within common Medical Implantable Communication System (MICS) frequency bands. NI RF devices are tested and verified in manufacturing for many measurements. For more information about RF device applications, visit *ni.com/niglobal* to contact a National Instruments branch office.

Caution The protection provided by this equipment may be impaired if it is used in a manner not described in the documentation.

Caution Do not disconnect the cable that connects CAL IN to CAL OUT. Removing the cable from or tampering with the CAL IN to CAL OUT front panel connectors voids the product calibration and specifications are no longer warranted.

To access NI 5646R documentation, navigate to **Start»All Programs»National Instruments» Vector Signal Transceivers**.

Contents

Frequency

The following characteristics are common to both RF IN 0 and RF OUT 0 ports.

Frequency range	65 MHz to 6 GHz

Table 1. NI 5646R Bandwidth

Center Frequency	Instantaneous Bandwidth
≤109 MHz	20 MHz
>109 MHz to <200 MHz	80 MHz
200 MHz to 6 GHz	200 MHz

Tuning resolution[1]	888 nHz
LO step size	
Fractional mode	Programmable step size, 200 kHz default
Integer mode	2 MHz, 5 MHz, 10 MHz, 25 MHz

1 Tuning resolution combines LO step size capability and frequency shift DSP implemented on the FPGA.
2 Medium loop bandwidth is available only in fractional mode.

Frequency Settling Time

Table 2. Maximum Frequency Settling Time

Settling Time	Maximum Time (ms)		
	Low Loop Bandwidth	**Medium Loop Bandwidth[2] (default)**	**High Loop Bandwidth**
$\leq 1 \times 10^{-6}$ of final frequency	1.1	0.95	0.38
$\leq 0.1 \times 10^{-6}$ of final frequency	1.2	1.05	0.4
The default medium loop bandwidth refers to a setting that adjusts PLL to balance tuning speed and phase noise, and it does not necessarily result in loop bandwidth between low and high. This specification includes only frequency settling and excludes any residual amplitude settling.			

Internal Frequency Reference

Initial adjustment accuracy	$\pm 200 \times 10^{-9}$
Temperature stability	$\pm 1 \times 10^{-6}$, maximum
Aging	$\pm 1 \times 10^{-6}$ per year, maximum
Accuracy	*Initial adjustment accuracy* ± *Aging* ± *Temperature stability*

Frequency Reference Input (REF IN)

Refer to the *REF IN* section.

Frequency Reference/Sample Clock Output (REF OUT)

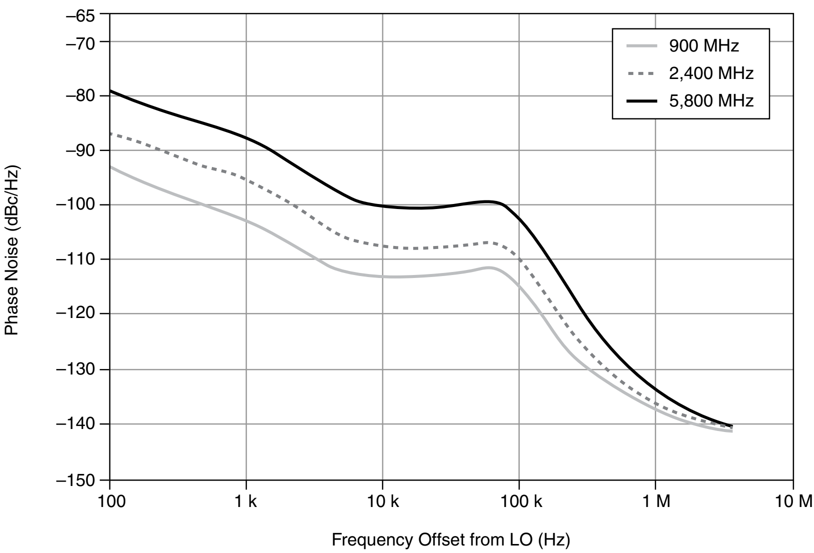
Refer to the *REF OUT* section.

Spectral Purity

Table 3. Single Sideband Phase Noise

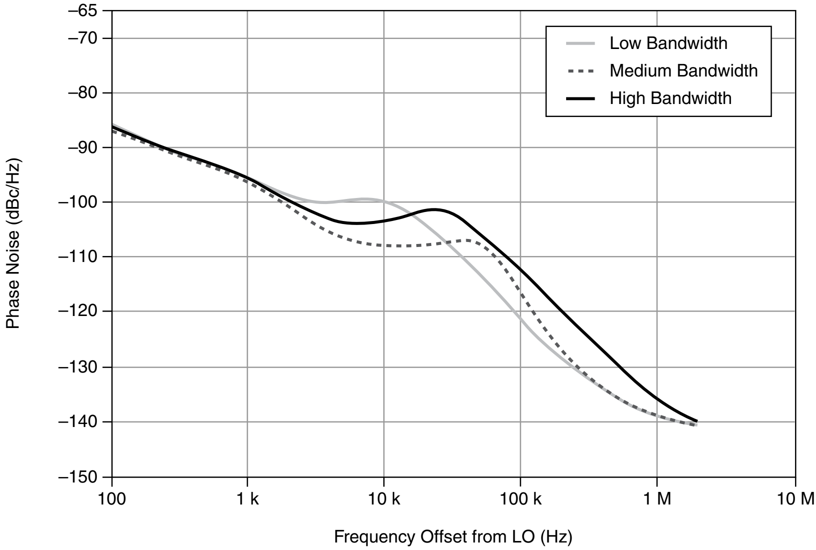
Frequency	Phase Noise (dBc/Hz), 20 kHz Offset (Single Sideband)		
	Low Loop Bandwidth	**Medium Loop Bandwidth**	**High Loop Bandwidth**
<3 GHz	-99	-99	-94
3 GHz to 4 GHz	-91	-93	-91
>4 GHz to 6 GHz	-93	-93	-87

Figure 1. Measured Phase Noise[3] at 900 MHz, 2.4 GHz, and 5.8 GHz



[3] Conditions: measured port: LO OUT; Reference Clock: internal; medium loop bandwidth.

Figure 2. Measured Phase Noise[4] at 2.4 GHz Vs. Loop Bandwidth



RF Input

Amplitude Range

Amplitude range	Average noise level to +30 dBm (CW RMS)
RF reference level range/resolution	≥60 dB in 1 dB nominal steps

Amplitude Settling Time

<0.1 dB of final value[5]	125 µs, typical
<0.5 dB of final value[6], with LO retuned	300 µs

[4] Conditions: measured port: LO OUT; Reference Clock: internal.
[5] Constant LO frequency, constant RF input signal, varying input reference level.
[6] LO tuning across harmonic filter bands, constant RF input signal, varying input reference level.

Absolute Amplitude Accuracy

Table 4. VSA Absolute Amplitude Accuracy (dB)

Center Frequency	15 °C to 35 °C		0 °C to 55 °C	
	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
65 MHz to <375 MHz	—	±0.70	—	±0.75
	—	±0.65 (95th percentile, ≈ 2σ)	—	±0.65 (95th percentile, ≈ 2σ)
	±0.34, typical	±0.50, typical	±0.36, typical	±0.55, typical
375 MHz to <2 GHz	—	±0.65	—	±0.70
	—	±0.55 (95th percentile, ≈ 2σ)	—	±0.55 (95th percentile, ≈ 2σ)
	±0.17, typical	±0.35, typical	±0.22, typical	±0.40, typical
2 GHz to <4 GHz	—	±0.70	—	±0.75
	—	±0.55 (95th percentile, ≈ 2σ)	—	±0.60 (95th percentile, ≈ 2σ)
	±0.23, typical	±0.40, typical	±0.26, typical	±0.40, typical
4 GHz to 6 GHz	—	±0.90	—	±0.95
	—	±0.75 (95th percentile, ≈ 2σ)	—	±0.80 (95th percentile, ≈ 2σ)
	±0.30, typical	±0.55, typical	±0.33, typical	±0.55, typical

Conditions: reference level -30 dBm to +30 dBm; measured at 3.75 MHz offset from the configured center frequency; measurement performed after the NI 5646R has settled.

For reference levels <-30 dBm, absolute amplitude gain accuracy is ±0.6 dB, typical for frequencies ≤ 4 GHz, and ±0.8 dB, typical for frequencies > 4 GHz. Performance depends on signal-to-noise ratio.

This specification is valid only when the module is operating within the specified ambient temperature range and within the specified range from the last self-calibration temperature, as measured with the onboard temperature sensors.

Frequency Response

Table 5. VSA Frequency Response (dB) (Amplitude, Equalized)

RF Input Frequency	Bandwidth	Self-Calibration °C ± 5 °C
≤109 MHz	20 MHz	±1.0 dB, typical
>109 MHz to <200 MHz	40 MHz	±0.5 dB
	80 MHz	±1.0 dB, typical
≥200 MHz to 6 GHz	80 MHz	±0.5 dB
	200 MHz	±0.5 dB, typical
Conditions: reference level -30 dBm to +30 dBm. This specification is valid only when the module is operating within the specified ambient temperature range and within the specified range from the last self-calibration temperature, as measured with the onboard temperature sensors. Frequency response represents the relative flatness within a specified instantaneous bandwidth. Frequency response specifications are valid within any given frequency range and not the LO frequency itself.		

Figure 3. Measured 80 MHz Frequency Response, 0 dBm Reference Level, Equalized

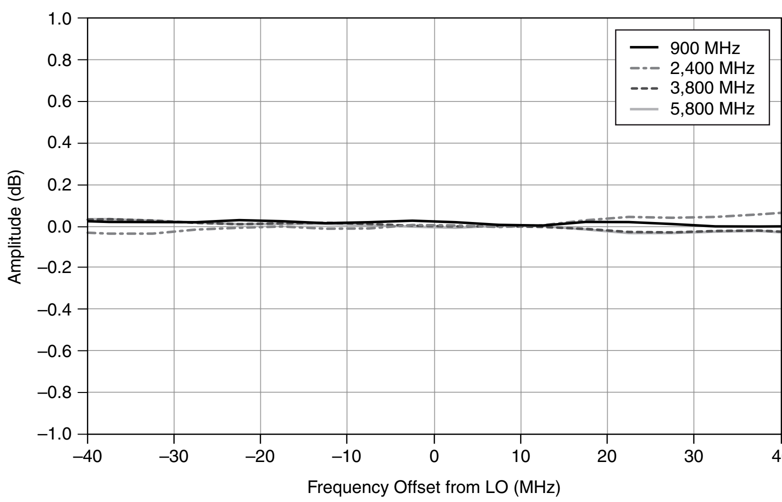


Figure 4. Measured 80 MHz Frequency Response, -30 dBm Reference Level, Equalized

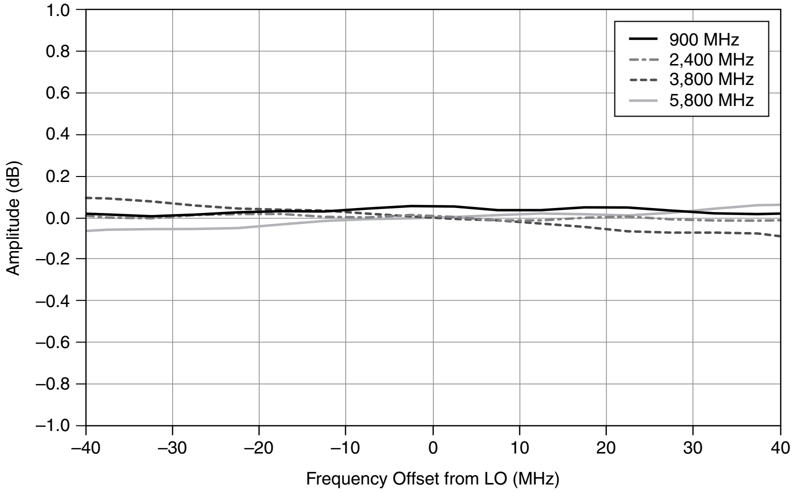


Figure 5. Measured 200 MHz Frequency Response, 0 dBm Reference Level, Equalized

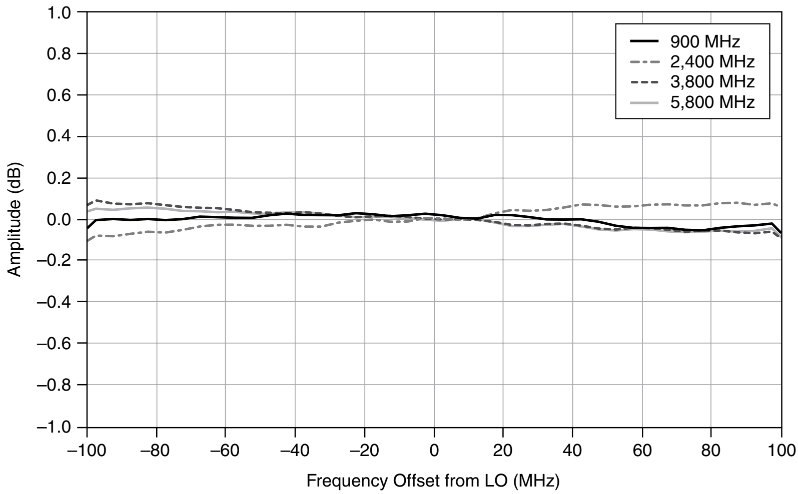
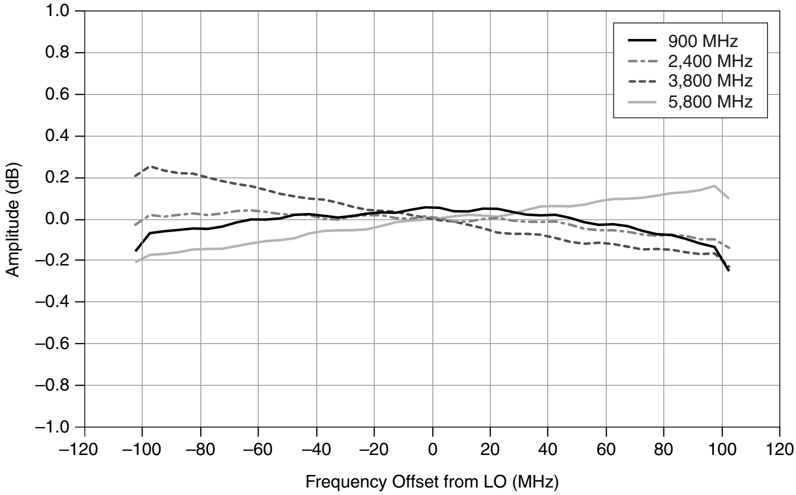


Figure 6. Measured 200 MHz Frequency Response, -30 dBm Reference Level, Equalized



Average Noise Density

Table 6. Average Noise Density (dBm/Hz)

Center Frequency	Average Noise Level	
	-50 dBm Reference Level	**-10 dBm Reference Level**
65 MHz to 4 GHz	-159	-145
	-161, typical	-148, typical
>4 GHz to 6 GHz	-156	-144
	-158, typical	-146, typical
Conditions: input terminated with a 50 Ω load; 50 averages; RMS average noise level normalized to a 1 Hz noise bandwidth. The -50 dBm reference level configuration has the inline preamplifier enabled, which represents the high sensitivity operation of the receive path.		

Spurious Responses

Nonharmonic Spurs

Table 7. Nonharmonic Spurs (dBc)

Frequency	<100 kHz Offset	≥100 kHz Offset	>1 MHz Offset
65 MHz to 3 GHz	<-55, typical	<-60	<-75
>3 GHz to 6 GHz	<-55, typical	<-55	<-70
Conditions: reference level ≥-30 dBm. Measured with a single tone, -1 dBr, where dBr is referenced to the configured RF reference level.			

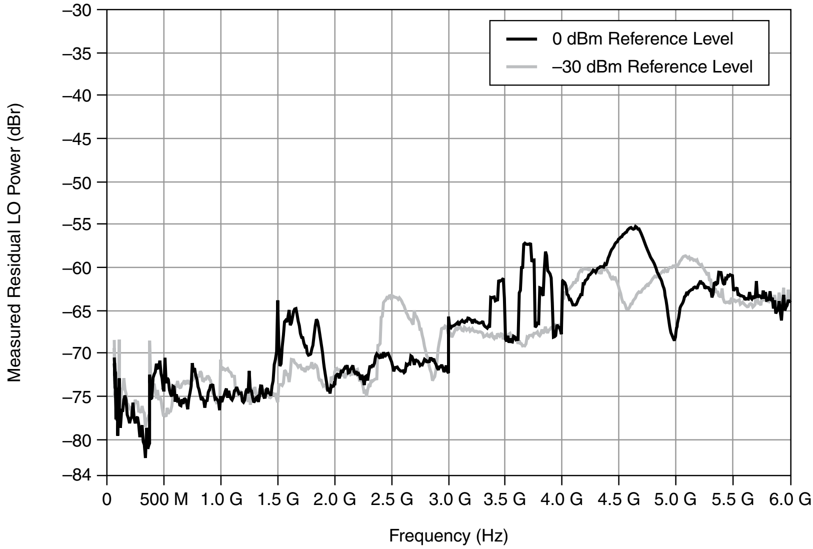
LO Residual Power

Table 8. VSA LO Residual Power (dBr[7])

Center Frequency	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
≤109 MHz	—	-62
	-70, typical	-67, typical
>109 MHz to 2 GHz	—	-58
	-65, typical	-61, typical
>2 GHz to 3 GHz	—	-55
	-60, typical	-58, typical
>3 GHz to 6 GHz	—	-45
	-56, typical	-48, typical
Conditions: reference levels -30 dBm to +30 dBm; measured at ADC. This specification is valid only when the module is operating within the specified ambient temperature range and within the specified range from the last self-calibration temperature, as measured with the onboard temperature sensors. For optimal performance, NI recommends running self-calibration when the NI 5646R temperature drifts ± 5 °C from the temperature at the last self-calibration. For temperature changes >±5 °C from self-calibration, LO residual power is -35 dBr.		

[7] dBr is relative to the full scale of the configured RF reference level.

Figure 7. VSA LO Residual Power[8] , Typical



Residual Sideband Image

Table 9. VSA Residual Sideband Image (dBc)

Center Frequency	Bandwidth	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
≤109 MHz	20 MHz	—	-40
		-60, typical	-50, typical
>109 MHz to <200 MHz	80 MHz	—	-40
		-50, typical	-45, typical
≥200 MHz to 500 MHz	200 MHz	—	-40
		-50, typical	-45, typical

[8] Conditions: VSA frequency range 109 MHz to 6 GHz. Measurement performed after self-calibration.

Table 9. VSA Residual Sideband Image (dBc) (Continued)

Center Frequency	Bandwidth	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
>500 MHz to 3 GHz	≤180 MHz	—	-62
		-75, typical	-70, typical
	>180 MHz to 200 MHz	—	-60
		-75, typical	-65, typical
>3 GHz to 6 GHz	≤180 MHz	—	-60
		-70, typical	-67, typical
	>180 MHz to 200 MHz	—	-59
		-70, typical	-63, typical

Conditions: reference levels -30 dBm to +30 dBm.

Frequency response specifications are valid within any given frequency range, not the LO frequency itself.

This specification describes the maximum residual sideband image within a 200 MHz bandwidth at a given RF center frequency. Bandwidth is restricted to 20 MHz for LO frequencies ≤ 109 MHz.

This specification is valid only when the module is operating within the specified ambient temperature range and within the specified range from the last self-calibration temperature, as measured with the onboard temperature sensors.

For optimal performance, NI recommends running self-calibration when the NI 5646R temperature drifts ± 5 °C from the temperature at the last self-calibration. For temperature changes >± 5 °C from self-calibration, residual image suppression is -40 dBc.

Figure 8. VSA Residual Sideband Image[9], 0 dBm Reference Level, Typical

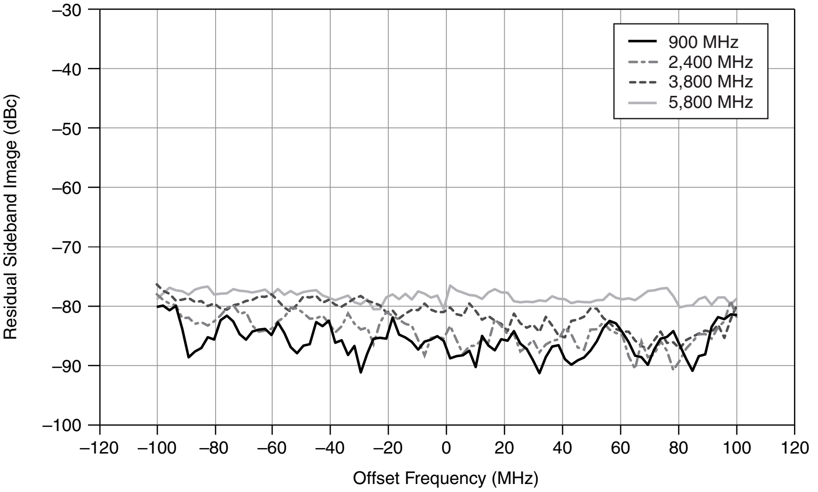
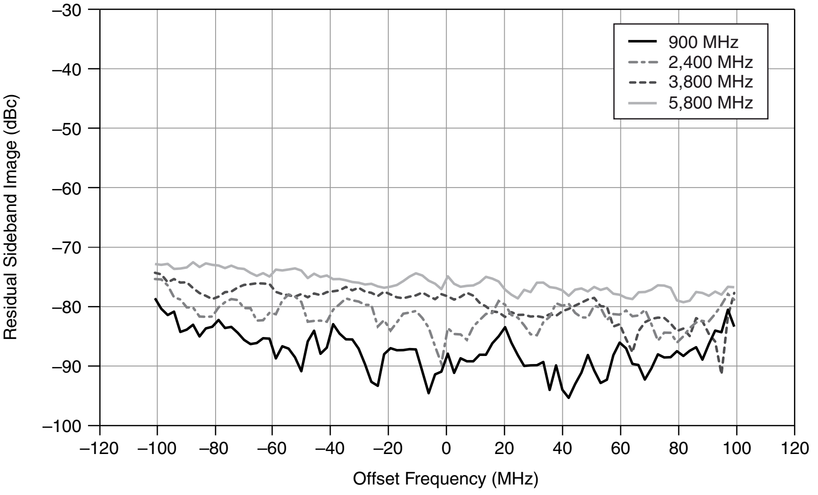


Figure 9. VSA Residual Sideband Image[9], -30 dBm Reference Level, Typical



[9] Measurement performed after self-calibration.

Third-Order Input Intermodulation

Table 10. Third-Order Input Intercept Point (IIP_3), -5 dBm Reference Level, Typical

Frequency Range	IIP_3 (dBm)
65 MHz to 1.5 GHz	19
>1.5 GHz to 6 GHz	20
Conditions: two -10 dBm tones, 700 kHz apart at RF IN; reference level: -5 dBm <4 GHz, -2 dBm reference level otherwise; nominal noise floor: -148 dBm/Hz for -5 dBm reference level, -145 dBm/Hz for -2 dBm reference level.	

Table 11. Third-Order Input Intercept Point (IIP_3), -20 dBm Reference Level, Typical

Frequency Range	IIP_3 (dBm)
65 MHz to 200 MHz	9
>200 MHz to 2 GHz	11
>2 GHz to 3.75 GHz	8
>3.75 GHz to 4.25 GHz	6
>4.25 GHz to 5 GHz	4
>5 GHz to 6 GHz	1
Conditions: two -25 dBm tones, 700 kHz apart at RF IN; reference level: -20 dBm; nominal noise floor: -157 dBm/Hz.	

Second-Order Input Intermodulation

Table 12. Second-Order Input Intercept Point (IIP_2), -2 dBm Reference Level, Typical

Frequency Range	IIP_2 (dBm)
65 MHz to 1.5 GHz	67
>1.5 GHz to 4 GHz	58
>4 GHz to 6 GHz	52
Conditions: two -10 dBm tones, 700 kHz apart at RF IN; reference level: -2 dBm; nominal noise floor: -145 dBm/Hz.	

RF Output

Power Range

Table 13. Power Range

Output Type	Frequency	Power Range	
CW	<4 GHz	Noise floor to +10 dBm, average power[10]	Noise floor to +15 dBm, average power, nominal
	≥4 GHz	Noise floor to +7 dBm, average power[10]	Noise floor to +12 dBm, average power, nominal
Modulated[11]	<4 GHz	Noise floor to +6 dBm, average power	—
	≥4 GHz	Noise floor to +3 dBm, average power	—

Output attenuator resolution	2 dB, nominal
Digital attenuation resolution[12]	0.1 dB or better

Related Information

Refer to the Considering Average Power and Crest Factor topic of the NI RF Vector Signal Transceivers Help for more information about modulated signal power.

Amplitude Settling Time

0.1 dB of final value[13]	50 µs
0.5 dB of final value[14], with LO retuned	300 µs

10 Higher output is uncalibrated and may be compressed.
11 Up to 12 dB crest factor, based on 3GPP LTE uplink requirements.
12 Average output power ≥ -100 dBm.
13 Constant LO frequency, varying RF output power range. Power levels ≤ 0 dBm. 175 µs for power levels > 0 dBm.
14 LO tuning across harmonic filter bands.

Output Power Level Accuracy

Table 14. Output Power Level Accuracy (dB)

Center Frequency	15 °C to 35 °C		0 °C to 55 °C	
	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
65 MHz to <109 MHz	—	±0.70	—	±0.90
	—	±0.55 (95th percentile, ≈ 2σ)	—	±0.65 (95th percentile, ≈ 2σ)
	±0.26, typical	±0.40, typical	±0.36, typical	±0.50, typical
109 MHz to <270 MHz[15]		±0.75		±0.90
		±0.60 (95th percentile; ≈ 2σ)		±0.70 (95th percentile; ≈ 2σ)
	±0.26, typical	±0.45, typical	±0.36, typical	±0.55, typical
270 MHz to <375 MHz	—	±0.70	—	±0.90
	—	±0.55 (95th percentile, ≈ 2σ)	—	±0.65 (95th percentile, ≈ 2σ)
	±0.26, typical	±0.40, typical	±0.36, typical	±0.50, typical
375 MHz to <2 GHz	—	±0.75	—	±0.90
	—	±0.55 (95th percentile, ≈ 2σ)	—	±0.65 (95th percentile, ≈ 2σ)
	±0.26, typical	±0.40, typical	±0.36, typical	±0.50, typical
2 GHz to <4 GHz	—	±0.75	—	±0.90
	—	±0.60 (95th percentile, ≈ 2σ)	—	±0.70 (95th percentile, ≈ 2σ)
	±0.26, typical	±0.40, typical	±0.36, typical	±0.50, typical

[15] Harmonic suppression is reduced in this frequency range. As a result, offset errors may occur depending on whether you are using a true RMS device, such as a power meter.

Table 14. Output Power Level Accuracy (dB) (Continued)

Center Frequency	15 °C to 35 °C		0 °C to 55 °C	
	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
4 GHz to 6 GHz	—	±1.00	—	±1.15
	—	±0.80 (95th percentile, ≈ 2σ)	—	±0.90 (95th percentile, ≈ 2σ)
	±0.28, typical	±0.40, typical	±0.38, typical	±0.60, typical

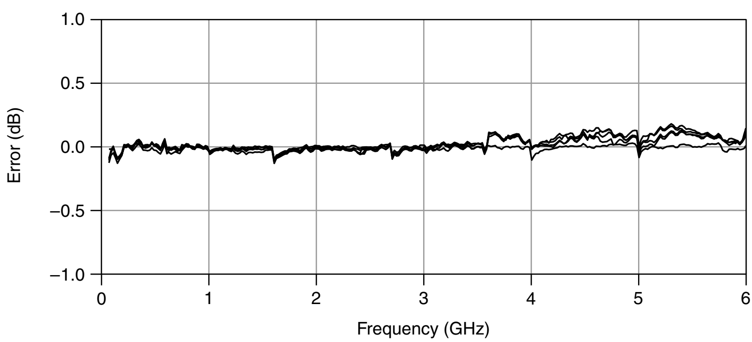
Conditions: CW average power -70 dBm to +10 dBm.

For power <-70 dBm, highly accurate generation can be achieved using digital attenuation, which relies on DAC linearity.

The absolute amplitude accuracy is measured at 3.75 MHz offset from the configured center frequency. The absolute amplitude accuracy measurements are made after the NI 5646R has settled.

This specification is valid only when the module is operating within the specified ambient temperature range and within the specified range from the last self-calibration temperature, as measured with the onboard temperature sensors.

Figure 10. Relative Power Accuracy, -40 dBm to 10 dBm, 10 dB Steps, Typical



Frequency Response

Table 15. VSG Frequency Response (dB) (Amplitude, Equalized)

Output Frequency	Bandwidth	Self-Calibration °C ± 5 °C
≤109 MHz	20 MHz	±1.0 dB, typical
>109 MHz to <200 MHz	40 MHz	±0.5 dB
	80 MHz	±1.0 dB, typical
≥200 MHz to 6 GHz	80 MHz	±0.5 dB
	200 MHz	±0.5 dB, typical
Conditions: reference level -30 dBm to +30 dBm. This specification is valid only when the module is operating within the specified ambient temperature range and within the specified range from the last self-calibration temperature, as measured with the onboard temperature sensors. Frequency response represents the relative flatness within a specified instantaneous bandwidth. Frequency response specifications are valid within any given frequency range and not the LO frequency itself.		

Figure 11. Measured 80 MHz Frequency Response, 0 dBm Output Power Level, Equalized

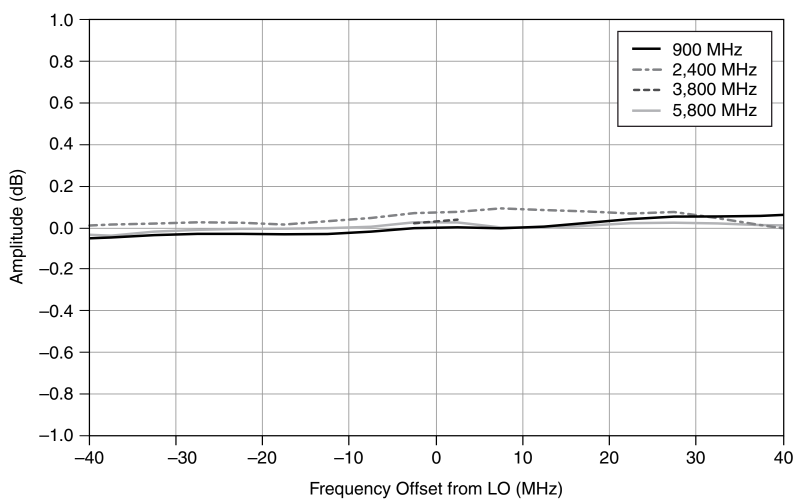


Figure 12. Measured 80 MHz Frequency Response, -50 dBm Output Power Level, Equalized

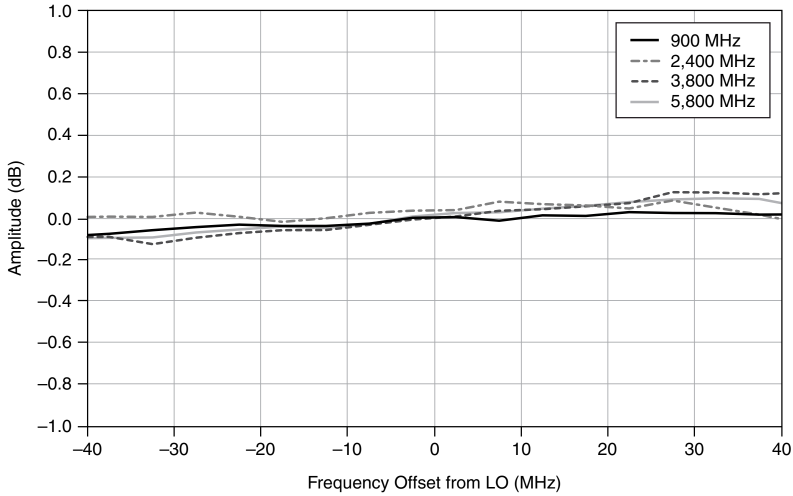


Figure 13. Measured 200 MHz Frequency Response, 0 dBm Output Power Level, Equalized

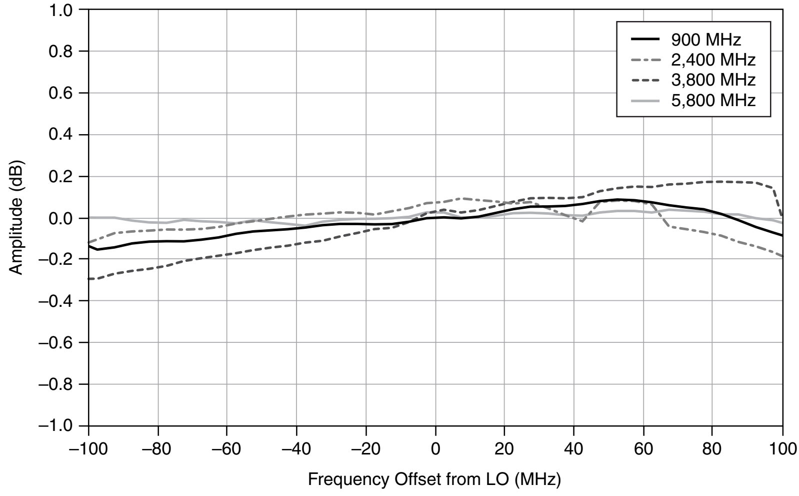
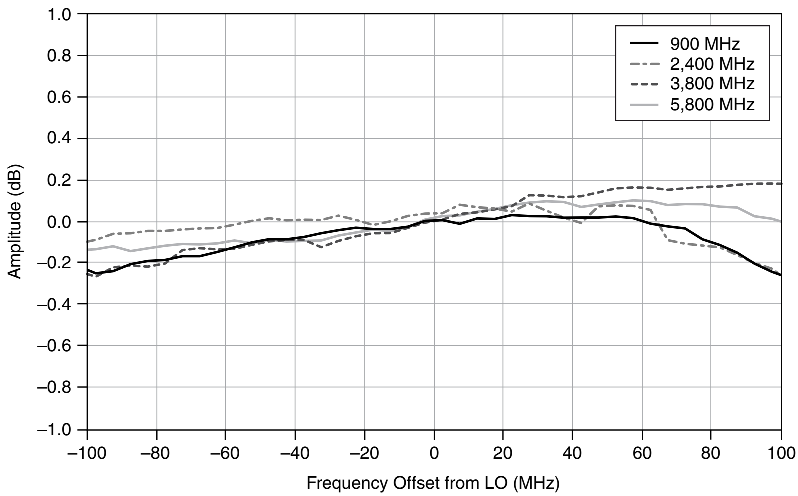


Figure 14. Measured 200 MHz Frequency Response, -50 dBm Output Power Level, Equalized



Output Noise Density

Table 16. Average Output Noise Level (dBm/Hz)

Center Frequency	Power Setting		
	-30 dBm	**0 dBm**	**10 dBm**
65 MHz to 500 MHz	—	—	-135
	-168, typical	-150, typical	-140, typical
>500 MHz to 1 GHz	—	—	—
	-168, typical	-147, typical	-140, typical
>1 GHz to 2.5 GHz	—	-149	-141
	-168, typical	-151, typical	-143, typical
>2.5 GHz to 3.5 GHz	—	-150	-140
	-168, typical	-153, typical	-143, typical
>3.5 GHz to 5 GHz	—	-144	-136
	-168, typical	-147, typical	-138, typical

Table 16. Average Output Noise Level (dBm/Hz) (Continued)

Center Frequency	Power Setting		
	-30 dBm	0 dBm	10 dBm
>5 GHz to 6 GHz	—	-147	-138
	-168, typical	-149, typical	-140, typical
Conditions: averages: 200 sweeps; baseband signal attenuation: -40 dB; noise measurement frequency offset: 4 MHz relative to output tone frequency.			

Spurious Responses

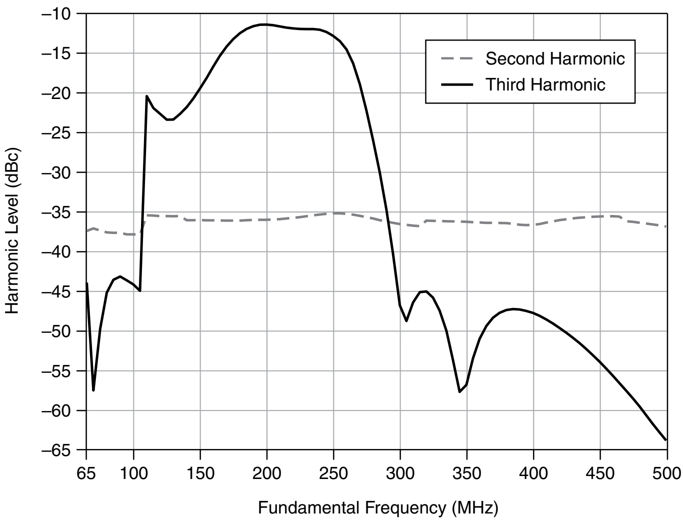
Harmonics

Table 17. Second Harmonic Level (dBc)

Fundamental Frequency	23 °C ± 5 °C	0 °C to 55 °C
65 MHz to 3.5 GHz	-27	-24
	-29, typical	-27, typical
>3.5 GHz to 4.5 GHz	-26	-24
	-28, typical	-26, typical
>4.5 GHz to 6 GHz	-28	-26
	-33, typical	-31, typical
Conditions: measured using 1 MHz baseband signal -1 dBFS; fundamental signal measured at +6 dBm CW; second harmonic levels nominally <-30 dBc for fundamental output levels of ≤5 dBm.		

Note Higher order harmonic suppression is degraded in the range of 109 MHz to 270 MHz and third harmonic performance is shown in the following figure. For frequencies outside the range of 109 MHz to 270 MHz, higher order harmonic distortion is equal to or better than the second harmonic level as specified in the previous table.

Figure 15. Harmonic Level[16], 65 MHz to 500 MHz, Measured



Nonharmonic Spurs

Table 18. Nonharmonic Spurs (dBc)

Frequency	<100 kHz Offset	≥100 kHz Offset	>1 MHz Offset
65 MHz to 3 GHz	<-55, typical	<-62	<-75
>3 GHz to 6 GHz	<-55, typical	<-57	<-70
Conditions: output full scale level ≥-30 dBm. Measured with a single tone at -1 dBFS.			

Third-Order Output Intermodulation

Table 19. Third-Order Output Intermodulation Distortion (IMD_3) (dBc), 0 dBm Tones

Fundamental Frequency	Baseband DAC: -2 dBFS	Baseband DAC: -6 dBFS
65 MHz to 1 GHz	-55, typical	-60, typical
>1 GHz to 3 GHz	-56, typical	-53, typical
>3 GHz to 5 GHz	-49, typical	-50, typical

[16] Measured using 1 MHz baseband signal -1 dBFS; fundamental signal measured at +6 dBm CW

Table 19. Third-Order Output Intermodulation Distortion (IMD_3) (dBc), 0 dBm Tones (Continued)

Fundamental Frequency	Baseband DAC: -2 dBFS	Baseband DAC: -6 dBFS
>5 GHz to 6 GHz	-44, typical	-45, typical
Conditions: two 0 dBm tones, 500 kHz apart at RF OUT. RF gain applied to achieve the desired output power per tone.		

Table 20. Third-Order Output Intermodulation Distortion (IMD_3) (dBc), -6 dBm Tones

Fundamental Frequency	Baseband DAC: -2 dBFS	Baseband DAC: -6 dBFS
65 MHz to 1.5 GHz	-50	-59
	-54, typical	-62, typical
>1.5 GHz to 3.5 GHz	-54	-59
	-57, typical	-62, typical
>3.5 GHz to 5 GHz	-50	-55
	-53, typical	-58, typical
>5 GHz to 6 GHz	-47	-51
	-50, typical	-54, typical
Conditions: two -6 dBm tones, 500 kHz apart at RF OUT. RF gain applied to achieve the desired output power per tone.		

Table 21. Third-Order Output Intermodulation Distortion (IMD_3) (dBc), -36 dBm Tones

Fundamental Frequency	Baseband DAC: -2 dBFS	Baseband DAC: -6 dBFS
65 MHz to 200 MHz	-52	-57
	-54, typical	-60, typical

Table 21. Third-Order Output Intermodulation Distortion (IMD_3) (dBc), -36 dBm Tones (Continued)

Fundamental Frequency	Baseband DAC: -2 dBFS	Baseband DAC: -6 dBFS
>200 MHz to 6 GHz	-52	-55
	-54, typical	-58, typical
Conditions: two -36 dBm tones, 500 kHz apart at RF OUT. RF gain applied to achieve the desired output power per tone.		

LO Residual Power

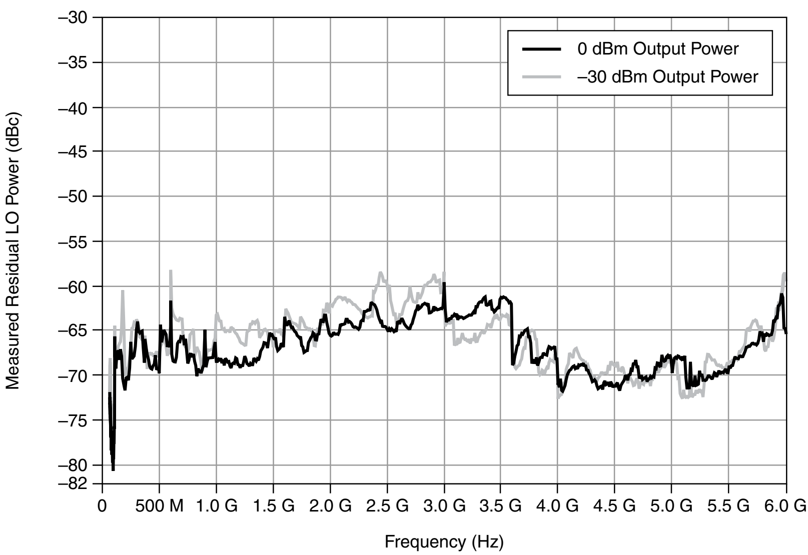
Table 22. VSG LO Residual Power (dBc)

Center Frequency	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
≤109 MHz	—	—
	-60, typical	-49, typical
>109 MHz to 200 MHz	—	-45
	-65, typical	-50, typical
>200 MHz to 2 GHz	—	-55
	-67, typical	-60, typical
>2 GHz to 3 GHz	—	-50
	-60, typical	-53, typical
>3 GHz to 5 GHz	—	-55
	-65, typical	-58, typical

Table 22. VSG LO Residual Power (dBc) (Continued)

Center Frequency	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
>5 GHz to 6 GHz	—	-50
	-60, typical	-55, typical
Conditions: configured power levels -50 dBm to +10 dBm. This specification is valid only when the module is operating within the specified ambient temperature range and within the specified range from the last self-calibration temperature, as measured with the onboard temperature sensors. For optimal performance, NI recommends running self-calibration when the NI 5646R temperature drifts ± 5 °C from the temperature at the last self-calibration. For temperature changes >± 5 °C from self-calibration, LO residual power is -40 dBc.		

Figure 16. VSG LO Residual Power[17], 109 MHz to 6 GHz, Typical



[17] Measurement performed after self-calibration.

Table 23. VSG LO Residual Power (dBc), Low Power

Center Frequency	Self-Calibration °C ± 5 °C
≤109 MHz	—
	-49, typical
>109 MHz to 375 MHz	—
	-50, typical
>375 MHz to 2 GHz	—
	-60, typical
>2 GHz to 3 GHz	—
	-53, typical
>3 GHz to 5 GHz	—
	-58, typical
>5 GHz to 6 GHz	—
	-55, typical
Conditions: configured power levels < -50 dBm to -70 dBm. This specification is valid only when the module is operating within the specified ambient temperature range and within the specified range from the last self-calibration temperature, as measured with the onboard temperature sensors. For optimal performance, NI recommends running self-calibration when the NI 5646R temperature drifts ± 5 °C from the temperature at the last self-calibration. For temperature changes >± 5 °C from self-calibration, LO residual power is -40 dBc.	

Residual Sideband Image

Table 24. VSG Residual Sideband Image (dBc)

Center Frequency	Bandwidth	Self-Calibration °C ± 1°C	Self-Calibration °C ± 5 °C
≤109 MHz	20 MHz	—	-40
		-55, typical	-42, typical

Table 24. VSG Residual Sideband Image (dBc) (Continued)

Center Frequency	Bandwidth	Self-Calibration °C ± 1°C	Self-Calibration °C ± 5 °C
>109 MHz to 200 MHz	80 MHz	—	—
		-45, typical	-40, typical
>200 MHz to 500 MHz	200 MHz	—	-45
		-45, typical	-50, typical
>500 MHz to 1 GHz	≤180 MHz	—	-60
		-70, typical	-63, typical
	≤180 MHz to 200 MHz	—	-57
		-70, typical	-60, typical
>1 GHz to 2 GHz	200 MHz	—	-60
		-70, typical	-63, typical
>2 GHz to 6 GHz	200 MHz	—	-50
		-65, typical	-55, typical

Conditions: reference levels -30 dBm to +30 dBm.

This specification describes the maximum residual sideband image within a 200 MHz bandwidth at a given RF center frequency. Bandwidth is restricted to 20 MHz for LO frequencies ≤109 MHz.

This specification is valid only when the module is operating within the specified ambient temperature range and within the specified range from the last self-calibration temperature, as measured with the onboard temperature sensors.

For optimal performance, NI recommends running self-calibration when the NI 5646R temperature drifts ± 5 °C from the temperature at the last self-calibration. For temperature changes >± 5 °C from self-calibration, residual image suppression is -40 dBc.

Figure 17. VSG Residual Sideband Image[18], 0 dBm Average Output Power, Typical

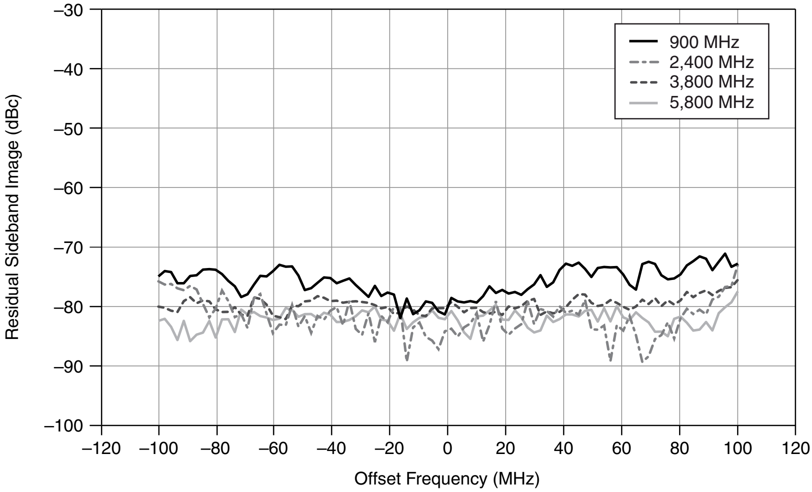
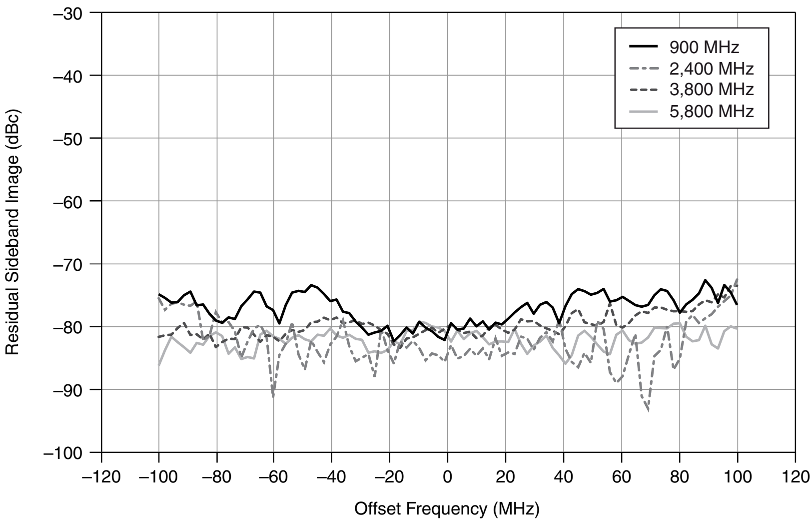


Figure 18. VSG Residual Sideband Image[18], -30 dBm Average Output Power, Typical



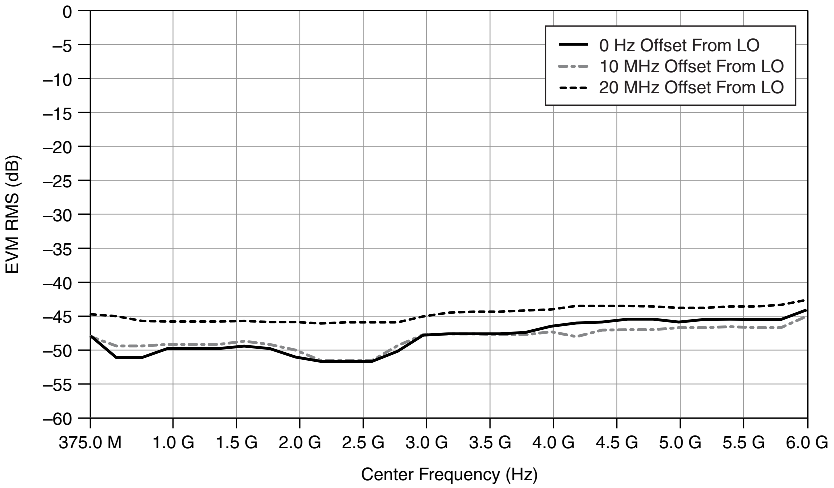
18 Measurement performed after self-calibration.

Error Vector Magnitude (EVM)

VSA EVM

20 MHz bandwidth 64-QAM EVM[19] 375 MHz to 6 GHz	-40 dB

Figure 19. VSA Error Vector Magnitude[20]



VSG EVM

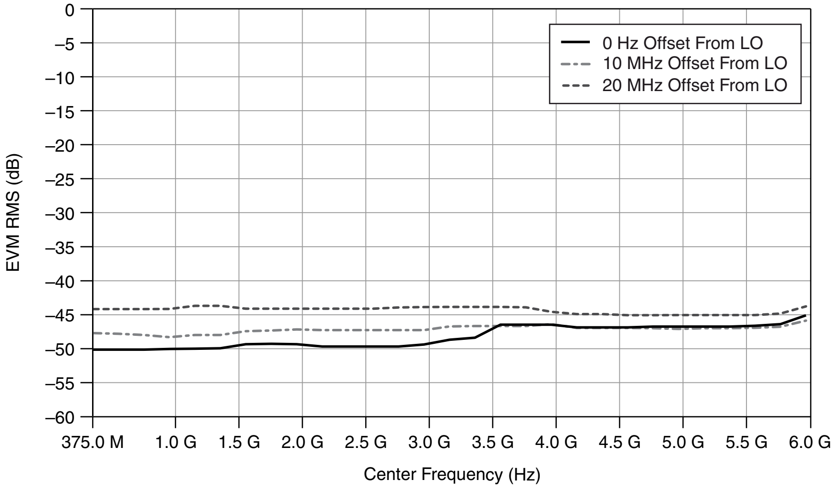
20 MHz bandwidth 64-QAM EVM[21] 375 MHz to 6 GHz	-40 dB

19 Conditions: EVM signal: 20 MHz bandwidth; 64 QAM signal. Pulse-shape filtering: root-raised-cosine, alpha=0.25; NI 5646R reference level: -10 dBm; Reference Clock source: internal; record length: 300 µs. Generator: NI PXIe-5673; power (average): -14 dBm; Reference Clock source: internal.

20 Conditions: 20 MHz bandwidth, 64 QAM; centered at LO frequency or offset digitally as listed.

21 Conditions: EVM signal: 20 MHz bandwidth; 64 QAM signal. Pulse-shape filtering: root-raised cosine, alpha=0.25; NI 5646R peak output power: -10 dBm; Reference Clock source: internal. Measurement instrument: NI PXIe-5665; reference level: -10 dBm; Reference Clock source: internal; record length: 300 µs.

Figure 20. VSG Error Vector Magnitude[22]



Application-Specific Modulation Quality

Typical performance assumes the NI 5646R is operating within ± 5 °C of the previous self-calibration temperature, and that the ambient temperature is 0 °C to 55 °C.

WLAN 802.11ac

OFDM[23]	
80 MHz bandwidth	-45 dB (rms), typical
80 MHz bandwidth (channel tracking enabled, preamble and data)	-50 dB (rms), typical
160 MHz bandwidth	-43 dB (rms), typical
160 MHz bandwidth (channel tracking enabled, preamble and data)	-47 dB (rms), typical

[22] Conditions: 20 MHz bandwidth, 64 QAM; centered at LO frequency or offset digitally as listed.
[23] Conditions: RF OUT loopback to RF IN; 5,800 MHz; average power: -30 dBm to -5 dBm; 20 packets; 16 OFDM data symbols; MCS=9; 256 QAM.

Figure 21. WLAN 802.11ac RMS EVM (dB) vs. Measured Average Power (dBm)

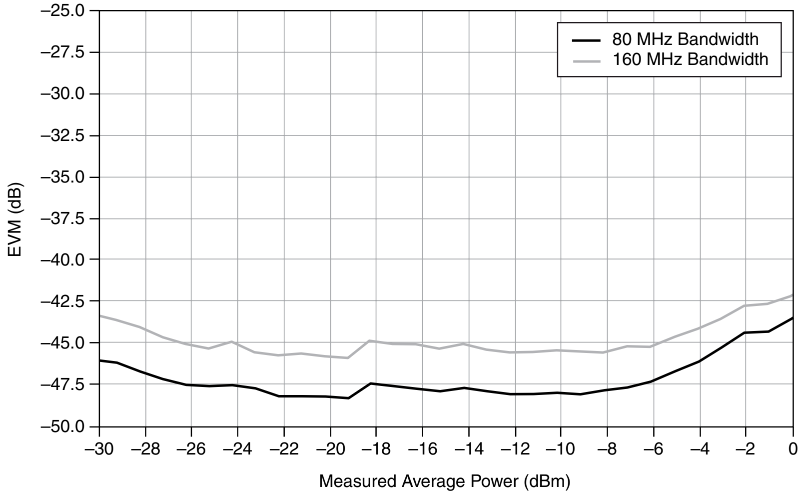
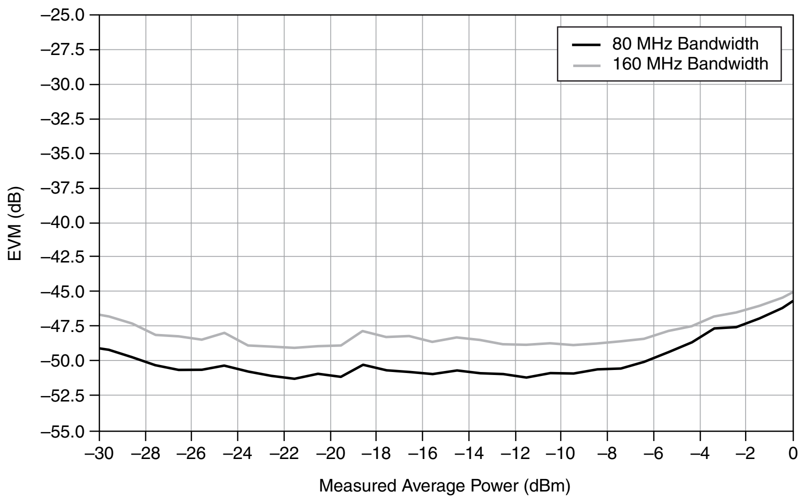


Figure 22. WLAN 802.11ac RMS EVM (dB) vs. Measured Average Power (dBm), Channel Tracking Enabled



WLAN 802.11n

Table 25. 802.11n OFDM EVM (rms) (dB), Typical

Frequency	20 MHz Bandwidth	40 MHz Bandwidth
2,412 MHz	-50	-50
5,000 MHz	-48	-46
Conditions: RF OUT loopback to RF IN; average power: -10 dBm; reference level: auto-leveled based on real-time average power measurement; 20 packets; 3/4 coding rate; 64 QAM.		

WLAN 802.11a/g/j/p

Table 26. 802.11a/g/j/p OFDM EVM (rms) (dB), Typical

Frequency	20 MHz Bandwidth
2,412 MHz	-53
5,000 MHz	-50
Conditions: RF OUT loopback to RF IN; average power: -10 dBm; reference level: auto-leveled based on real-time average power measurement; 20 packets; 3/4 coding rate; 64 QAM.	

WLAN 802.11g

Table 27. 802.11g DSSS-OFDM EVM (rms) (dB), Typical

Frequency	20 MHz Bandwidth
2,412 MHz	-53
5,000 MHz	-50
Conditions: RF OUT loopback to RF IN; average power: -10 dBm; reference level: auto-leveled based on real-time average power measurement; 20 packets; 3/4 coding rate; 64 QAM.	

WLAN 802.11b/g

DSSS[24]	-48 EVM (rms) dB, typical

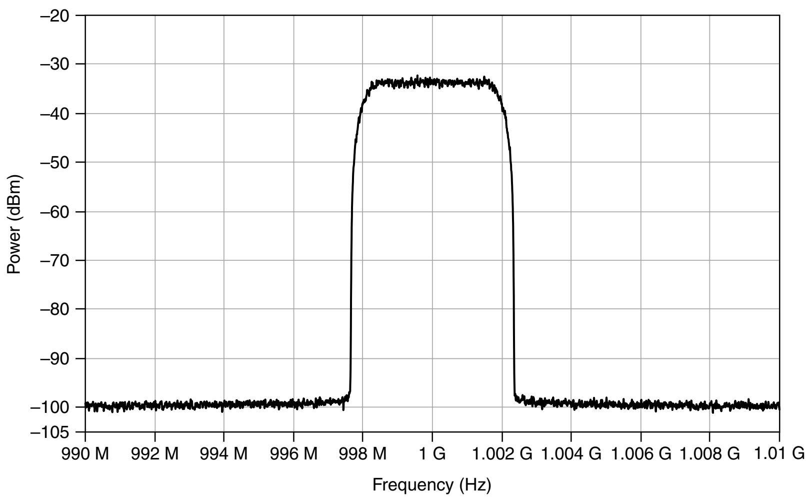
LTE

Table 28. SC-FDMA[25] (Uplink FDD) EVM (rms) (dB), Typical

Frequency	5 MHz Bandwidth	10 MHz Bandwidth	20 MHz Bandwidth
700 MHz	-56	-56	-54
900 MHz	-55	-55	-53
1,430 MHz	-54	-54	-53
1,750 MHz	-51	-50	-50
1,900 MHz	-51	-50	-50
2,500 MHz	-50	-49	-49

WCDMA

Figure 23. WCDMA Measured Spectrum[26] (ACP)



24 Conditions: RF OUT loopback to RF IN; 2,412 MHz; 20 MHz bandwidth; average power -10 dBm; reference level: auto-leveled based on real-time average power measurement; averages: 10; pulse-shaping filter: Gaussian reference; CCK 11 Mbps.

25 Single channel uplink only.

26 Conditions: DL Test Model 1 (64DPCH); RF output level: -10 dBm average; RF OUT loopback to RF IN; measured results better than -65 dB.

Baseband Characteristics

Analog-to-digital converters (ADCs)	
Resolution	14 bits
Sample rate[27]	250 MS/s
I/Q data rate[28]	4 kS/s to 250 MS/s
Digital-to-analog converters (DACs)	
Resolution	16 bits
Sample rate[29]	250 MS/s
I/Q data rate[30]	4 kS/s to 250 MS/s

Onboard FPGA

FPGA	Xilinx Virtex-6 LX240T
LUTs	150,720
Flip-flops	301,440
DSP48 slices	768
Embedded block RAM	14,976 kbits
Data transfers	DMA, interrupts, programmed I/O
Number of DMA channels	16

Onboard DRAM

Memory size	2 banks, 512 MB per bank
Theoretical maximum data rate	2.1 GB/s per bank

Onboard SRAM

Memory size	2 MB
Maximum data rate (read)	40 MB/s
Maximum data rate (write)	36 MB/s

[27] ADCs are dual-channel components with each channel assigned to I and Q, respectively.
[28] I/Q data rates lower than 250 MS/s are achieved using fractional decimation.
[29] DACs are dual-channel components with each channel assigned to I and Q, respectively. DAC sample rate is internally interpolated to 1 GS/s, automatically configured.
[30] I/Q data rates lower than 250 MS/s are achieved using fractional interpolation.

Front Panel I/O

RF IN

Connector	SMA (female)
Input impedance	50 Ω, nominal, AC coupled
Maximum DC input voltage without damage	8 V
Absolute maximum input power[31]	+33 dBm (CW RMS)

Input Return Loss (Voltage Standing Wave Ratio (VSWR))

Table 29. Input Return Loss (dB) (VSWR)

Frequency	Typical
109 MHz ≤ f < 2.4 GHz	15.5 (1.40:1)
2.4 GHz ≤ f < 4 GHz	12.7 (1.60:1)
4 GHz ≤ f ≤ 6 GHz	11.0 (1.78:1)
Return loss for frequencies <109 MHz is typically better than 14 dB (VSWR <1.5:1).	

RF OUT

Connector	SMA (female)
Output impedance	50 Ω, nominal, AC coupled
Absolute maximum reverse power[32]	
<4 GHz	+33 dBm (CW RMS)
≥4 GHz	+30 dBm (CW RMS)

Output Return Loss (VSWR)

Table 30. Output Return Loss (dB) (VSWR)

Frequency	Typical
109 MHz ≤ f < 2 GHz	19.0 (1.25:1)
2 GHz ≤ f < 5 GHz	14.0 (1.50:1)

31 For modulated signals, peak instantaneous power not to exceed +36 dBm.
32 For modulated signals, peak instantaneous power not to exceed corresponding peak power of specified CW.

Table 30. Output Return Loss (dB) (VSWR) (Continued)

Frequency	Typical
5 GHz ≤ f ≤ 6 GHz	11.0 (1.78:1)
Return loss for frequencies <109 MHz is typically better than 20 dB (VSWR <1.22:1).	

CAL IN, CAL OUT

Connector	SMA (female)
Impedance	50 Ω, nominal

Caution Do not disconnect the cable that connects CAL IN to CAL OUT. Removing the cable from or tampering with the CAL IN or CAL OUT front panel connectors voids the product calibration and specifications are no longer warranted.

LO OUT (RF IN 0 and RF OUT 0)

Connectors	SMA (female)
Frequency range[33]	65 MHz to 6 GHz
Power	
LO OUT (RF IN 0) 65 MHz to 6 GHz	0 dBm ±2 dB, typical
LO OUT (RF OUT 0)	
65 MHz to 3.6 GHz	0 dBm ±2 dB, typical
≥3.6 GHz to 6 GHz	3 dBm ±2 dB, typical
Output power resolution	0.25 dB, nominal
Output impedance	50 Ω, nominal, AC coupled
Output return loss	>11.0 dB (VSWR <1.8:1), typical
Output isolation (state: disabled)	
<2.5 GHz tuned LO	-45 dBc, nominal
≥2.5 GHz tuned LO	-35 dBc, nominal

LO IN (RF IN 0 and RF OUT 0)

Connectors	SMA (female)
Frequency range[34]	65 MHz to 6 GHz

33 When tuning to 65 MHz to 375 MHz using the RF IN channel, the exported LO is twice the RF frequency requested.
34 When tuning to 65 MHz to 375 MHz using the RF IN channel, the exported LO is twice the RF frequency requested.

Expected input power	
LO IN (RF IN 0) 65 MHz to 6 GHz	0 dBm ±3 dB, nominal
LO IN (RF OUT 0)	
65 MHz to 3.6 GHz	0 dBm ±3 dB, nominal
≥3.6 GHz to 6 GHz	3 dBm ±1 dB, nominal
Input impedance	50 Ω, nominal, AC coupled
Input return loss	>11.7 dB (VSWR <1.7:1), typical
Absolute maximum power	+15 dBm
Maximum DC voltage	±5 VDC

REF IN

Connector	SMA (female)
Frequency	10 MHz
Tolerance[35]	$\pm 10 \times 10^{-6}$
Amplitude	
Square	0.7 V_{pk-pk} to 5.0 V_{pk-pk} into 50 Ω, typical
Sine[36]	1.4 V_{pk-pk} to 5.0 V_{pk-pk} into 50 Ω, typical
Input impedance	50 Ω, nominal
Coupling	AC

REF OUT

Connector	SMA (female)
Frequency	
Reference Clock[37]	10 MHz, nominal
Sample Clock	250 MHz, nominal
Amplitude	1.65 V_{pk-pk} into 50 Ω, nominal
Output impedance	50 Ω, nominal
Coupling	AC

35 Frequency accuracy = tolerance × reference frequency
36 1 V_{rms} to 3.5 V_{rms}, typical. Jitter performance improves with increased slew rate of input signal.
37 Refer to the *Internal Frequency Reference* for accuracy.

PFI 0

Connector	SMA (female)
Voltage levels[38]	
Absolute maximum input range	-0.5 V to 5.5 V
V_{IL}	0.8 V
V_{IH}	2.0 V
V_{OL}	0.2 V with 100 µA load
V_{OH}	2.9 V with 100 µA load
Input impedance	10 kΩ, nominal
Output impedance	50 Ω, nominal
Maximum DC drive strength	24 mA
Minimum required direction change latency[39]	48 ns + 1 clock cycle

DIGITAL I/O

Connector	VHDCI

Table 31. DIGITAL I/O Signal Characteristics

Signal	Direction	Port Width
DIO <23..20>	Bidirectional, per port	4
DIO <19..16>	Bidirectional, per port	4
DIO <15..12>	Bidirectional, per port	4
DIO <11..8>	Bidirectional, per port	4
DIO <7..4>	Bidirectional, per port	4
DIO <3..0>	Bidirectional, per port	4
PFI 1	Bidirectional	1
PFI 2	Bidirectional	1

38 Voltage levels are guaranteed by design through the digital buffer specifications.
39 Clock cycle refers to the FPGA clock domain used for direction control.

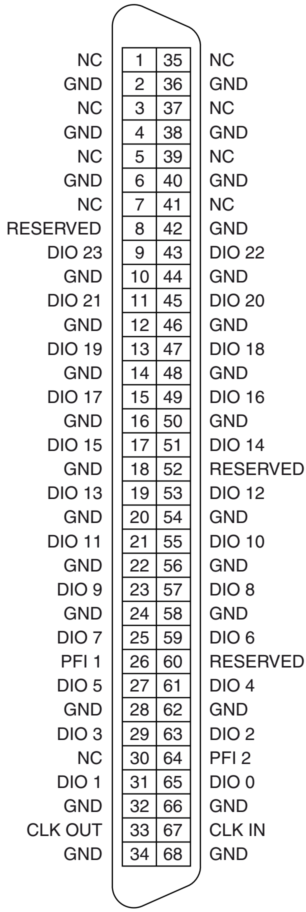
Table 31. DIGITAL I/O Signal Characteristics (Continued)

Signal	Direction	Port Width
Clock In	Input	1
Clock Out	Output	1

Voltage levels[40]	
Absolute maximum input range	-0.5 V to 4.5 V
V_{IL}	0.8 V
V_{IH}	2.0 V
V_{OL}	0.2 V with 100 µA load
V_{OH}	2.9 V with 100 µA load
Input impedance	
DIO <23..0>, CLK IN	10 kΩ, nominal
PFI 1, PFI 2	100 kΩ pull up, nominal
Output impedance	50 Ω, nominal
Maximum DC drive strength	12 mA
Minimum required direction change latency[41]	48 ns + 1 clock cycle
Maximum toggle rate	125 MHz, typical

40 Voltage levels are guaranteed by design through the digital buffer specifications.
41 Clock cycle refers to the FPGA clock domain used for direction control.

Figure 24. DIGITAL I/O VHDCI Connector



Power Requirements

Table 32. Power Requirements

Voltage (V_{DC})	Typical Current (A)	Maximum Current (A)
+3.3	4.7	5.4
+12	3.5	4.2
Power is 58 W, typical. Consumption is from both NI PXI Express backplane power connectors.		

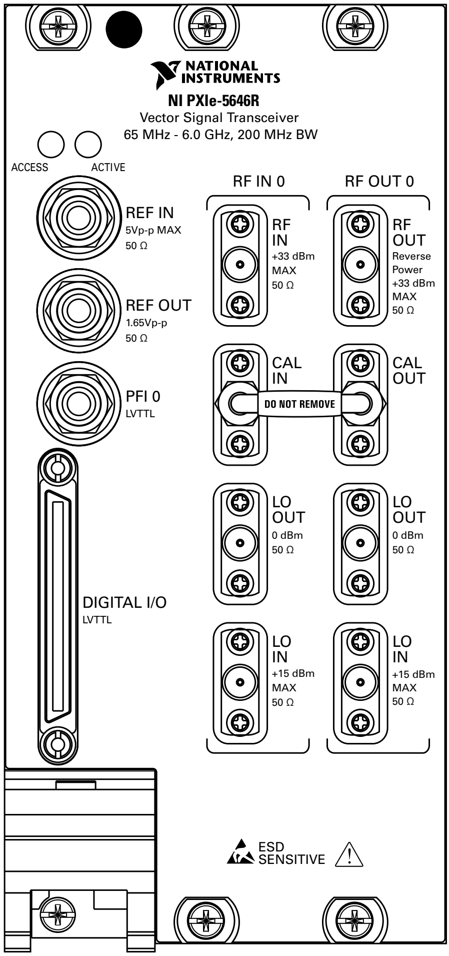
Calibration

Interval	1 year

Note For the two-year calibration interval, add 0.2 dB to one year specifications for *Absolute Amplitude Accuracy*, RF input *Frequency Response*, *Output Power Level Accuracy*, and RF output *Frequency Response*.

Hardware Front Panel

Figure 25. NI 5646R Front Panel



Physical Characteristics

NI 5646R module	3U, three slot, PXI Express module 6.1 cm × 12.9 cm × 21.1 cm (2.4 in × 5.6 in × 8.3 in)
Weight	1,360 g (48.0 oz)

Environment

Maximum altitude	2,000 m (800 mbar) (at 25 °C ambient temperature)
Pollution Degree	2

Indoor use only.

Operating Environment

Ambient temperature range	0 °C to 55 °C (Tested in accordance with IEC 60068-2-1 and IEC 60068-2-2. Meets MIL-PRF-28800F Class 3 low temperature limit and MIL-PRF-28800F Class 2 high temperature limit.)
Relative humidity range	10% to 90%, noncondensing (Tested in accordance with IEC 60068-2-56.)

Storage Environment

Ambient temperature range	-40 °C to 71 °C (Tested in accordance with IEC 60068-2-1 and IEC 60068-2-2. Meets MIL-PRF-28800F Class 3 limits.)
Relative humidity range	5% to 95%, noncondensing (Tested in accordance with IEC 60068-2-56.)

Shock and Vibration

Operating shock	30 g peak, half-sine, 11 ms pulse (Tested in accordance with IEC 60068-2-27. Meets MIL-PRF-28800F Class 2 limits.)
Random vibration	
Operating	5 Hz to 500 Hz, 0.3 g_{rms}
Nonoperating	5 Hz to 500 Hz, 2.4 g_{rms} (Tested in accordance with IEC 60068-2-64. Nonoperating test profile exceeds the requirements of MIL-PRF-28800F, Class 3.)

Compliance and Certifications

Safety

This product is designed to meet the requirements of the following electrical equipment safety standards for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA 61010-1

Note For UL and other safety certifications, refer to the product label or the *Online Product Certification* section.

Electromagnetic Compatibility

This product meets the requirements of the following EMC standards for electrical equipment for measurement, control, and laboratory use:

- EN 61326-1 (IEC 61326-1): Class A emissions; Basic immunity
- EN 55011 (CISPR 11): Group 1, Class A emissions
- EN 55022 (CISPR 22): Class A emissions
- EN 55024 (CISPR 24): Immunity
- AS/NZS CISPR 11: Group 1, Class A emissions
- AS/NZS CISPR 22: Class A emissions
- FCC 47 CFR Part 15B: Class A emissions
- ICES-001: Class A emissions

Note In the United States (per FCC 47 CFR), Class A equipment is intended for use in commercial, light-industrial, and heavy-industrial locations. In Europe, Canada, Australia, and New Zealand (per CISPR 11), Class A equipment is intended for use only in heavy-industrial locations.

Note Group 1 equipment (per CISPR 11) is any industrial, scientific, or medical equipment that does not intentionally generate radio frequency energy for the treatment of material or inspection/analysis purposes.

Note For EMC declarations, certifications, and additional information, refer to the *Online Product Certification* section.

CE Compliance CE

This product meets the essential requirements of applicable European Directives, as follows:

- 2014/35/EU; Low-Voltage Directive (safety)
- 2014/30/EU; Electromagnetic Compatibility Directive (EMC)

Online Product Certification

Refer to the product Declaration of Conformity (DoC) for additional regulatory compliance information. To obtain product certifications and the DoC for this product, visit *ni.com/certification*, search by model number or product line, and click the appropriate link in the Certification column.

Environmental Management

NI is committed to designing and manufacturing products in an environmentally responsible manner. NI recognizes that eliminating certain hazardous substances from our products is beneficial to the environment and to NI customers.

For additional environmental information, refer to the *Minimize Our Environmental Impact* web page at *ni.com/environment*. This page contains the environmental regulations and directives with which NI complies, as well as other environmental information not included in this document.

Waste Electrical and Electronic Equipment (WEEE)

EU Customers At the end of the product life cycle, all NI products must be disposed of according to local laws and regulations. For more information about how to recycle NI products in your region, visit *ni.com/environment/weee*.

电子信息产品污染控制管理办法（中国 RoHS）

中国客户 National Instruments 符合中国电子信息产品中限制使用某些有害物质指令(RoHS)。关于 National Instruments 中国 RoHS 合规性信息，请登录 `ni.com/environment/rohs_china`。(For information about China RoHS compliance, go to `ni.com/environment/rohs_china`.)

376125D-01 Oct15