SPECIFICATIONS

PXIe-5644

Reconfigurable 6 GHz Vector Signal Transceiver

Contents

NATIONAL INSTRUMENTS™

Definitions

Warranted specifications describe the performance of a model under stated operating conditions and are covered by the model warranty.

Characteristics describe values that are relevant to the use of the model under stated operating conditions but are not covered by the model warranty.

- *Typical* specifications describe the expected performance met by a majority of the models.
- *2σ* specifications describe the 95th percentile values, in which 95% of the cases are met with a 95% confidence.
- *Nominal* specifications describe parameters and attributes that may be useful in operation.

Within the specifications, self-calibration °C refers to the recorded device temperature of the last successful self-calibration.

Specifications are *Warranted* unless otherwise noted.

Conditions

Specifications are valid 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.
- The cable connecting CAL IN to CAL OUT has not been removed or tampered with.
- 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

Frequency

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

Frequency range	65 MHz to 6 GHz
Bandwidth[1]	80 MHz
Tuning resolution[2]	<1 Hz
LO step size	
Fractional mode	Programmable step size, 200 kHz default
Integer mode	4 MHz, 5 MHz, 6 MHz, 12 MHz, 24 MHz

1 Digitally equalized RF input and RF output bandwidth. Bandwidth is restricted to 20 MHz for LO frequencies ≤ 109 MHz and restricted to 40 MHz for LO frequencies between 109 MHz and 375 MHz.

2 Tuning resolution combines LO step size capability and frequency shift DSP implemented on the FPGA.

Frequency Settling Time

Table 1. Maximum Frequency Settling Time

Settling Time	Maximum Time (ms)		
	Low Loop Bandwidth	Medium Loop Bandwidth[3] (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.

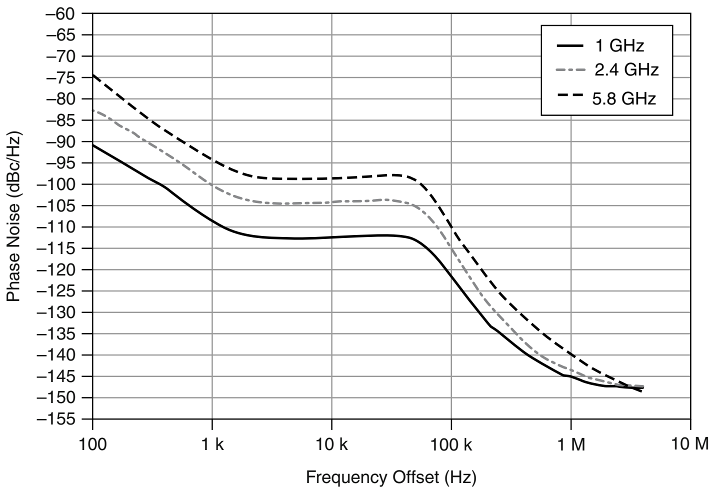
[3] Medium loop bandwidth is available only in fractional mode.

Spectral Purity

Table 2. Single Sideband Phase Noise

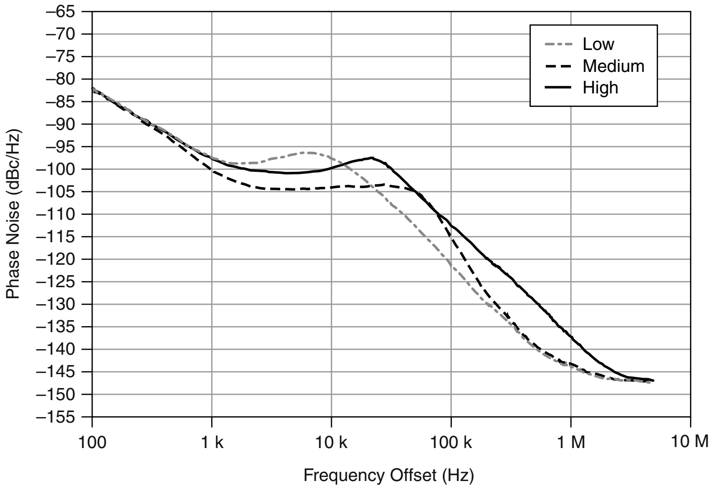
Frequency	Phase Noise (dBc/Hz), 20 kHz Offset (Single Sideband)		
	Low Loop Bandwidth	Medium Loop Bandwidth	High Loop Bandwidth
<3 GHz	-99	-99	-94
3 GHz to 4 GHz	-91	-93	-91
>4 GHz to 6 GHz	-93	-93	-87

Figure 1. Measured Phase Noise[4] at 1 GHz, 2.4 GHz, and 5.8 GHz



4 Conditions: Measured port: LO Out; Reference Clock: internal; medium loop bandwidth.

Figure 2. Measured Phase Noise[5] at 2.4 GHz Versus 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[6]	125 µs, typical
<0.5 dB of final value[7], with LO retuned	300 µs

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

Absolute Amplitude Accuracy

Table 3. 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 PXIe-5644 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.

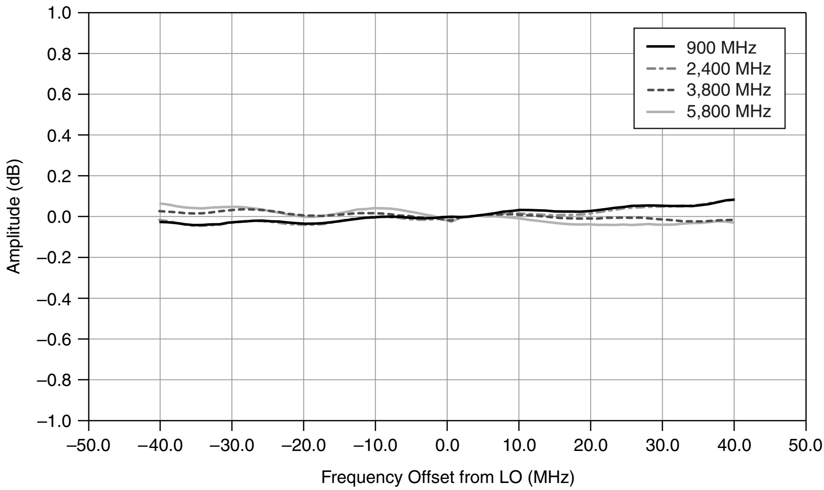
This specification is valid only when the module is operating within the specified ambient temperature range and within the specified range from the last self-calibration temperature, as measured with the onboard temperature sensors.

Frequency Response

Table 4. VSA Frequency Response (dB) (Amplitude, Equalized)

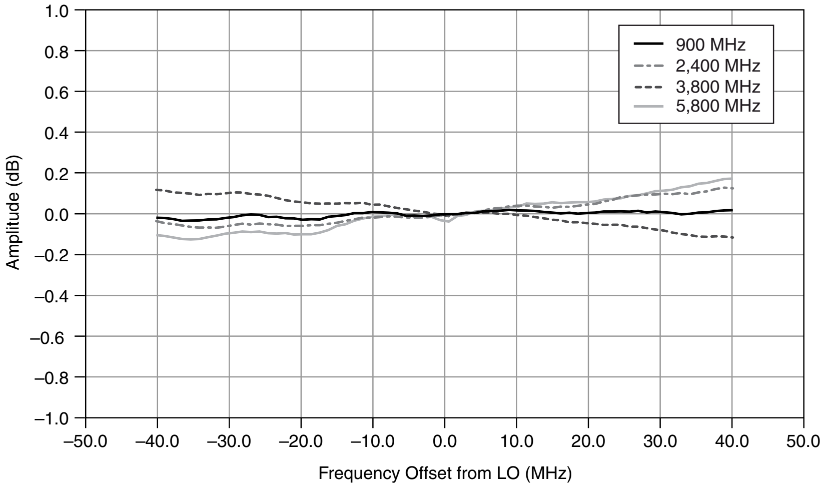
RF Input Frequency	Bandwidth	Self-Calibration °C ± 5 °C
≤109 MHz	20 MHz	±1.0, typical
>109 MHz to 375 MHz	20 MHz	±0.5
	40 MHz	±1.0, typical
>375 MHz to 6 GHz	80 MHz	±0.5
Conditions: Reference level -30 dBm to +30 dBm. This specification is valid only when the module is operating within the specified ambient temperature range and within the specified range from the last self-calibration temperature, as measured with the onboard temperature sensors.		

Figure 3. Measured Frequency Response,[8] 0 dBm Reference Level, Equalized



8 Measurement performed after self-calibration.

Figure 4. Measured Frequency Response,[8] -30 dBm Reference Level, Equalized



Average Noise Density

Table 5. 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 6. 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 7. VSA LO Residual Power (dBr[9])

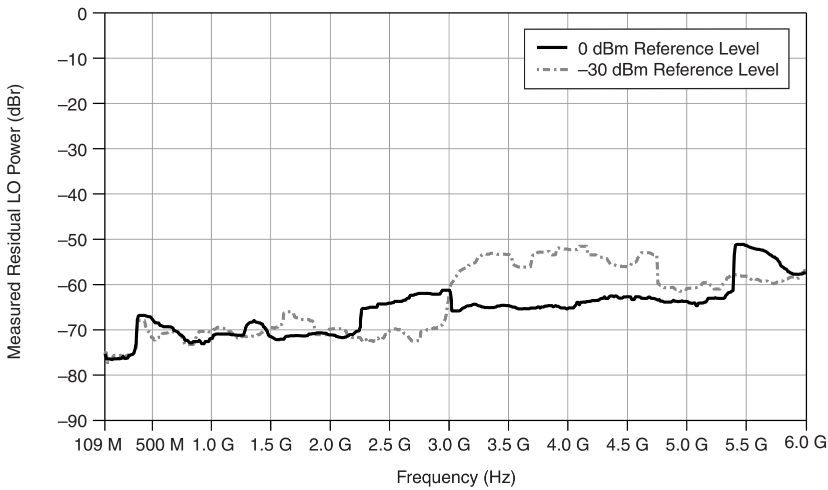
Center Frequency	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
≤109 MHz	—	-62
	-67, typical	-67, typical
>109 MHz to 375 MHz	—	-58
	-65, typical	-61, typical
>375 MHz to 1 GHz	—	-53
	-58, typical	-56, typical
1 GHz to 3 GHz	—	-52
	-58, typical	-56, typical
3 GHz to 4 GHz	—	-44
	-49, typical	-47, typical

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

Table 7. VSA LO Residual Power (dBr[9]) (Continued)

Center Frequency	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
4 GHz to 6 GHz	—	-43
	-48, typical	-46, 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 PXIe-5644 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.		

Figure 5. VSA LO Residual Power,[10] Typical



9 dBr is relative to the full scale of the configured RF reference level.

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

Residual Sideband Image

Table 8. VSA Residual Sideband Image, 80 MHz Bandwidth (dBc)

Center Frequency	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
≤109 MHz	—	-40
	-60, typical	-50, typical
>109 MHz to 500 MHz	—	-40
	-50, typical	-45, typical
>500 MHz to 3 GHz	—	-65
	-75, typical	-70, typical
>3 GHz to 5 GHz	—	-55
	-70, typical	-60, typical
>5 GHz to 6 GHz	—	-60
	-70, typical	-65, typical

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

This specification describes the maximum residual sideband image within an 80 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 PXIe-5644 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 6. VSA Residual Sideband Image,[11] 0 dBm Reference Level, Typical

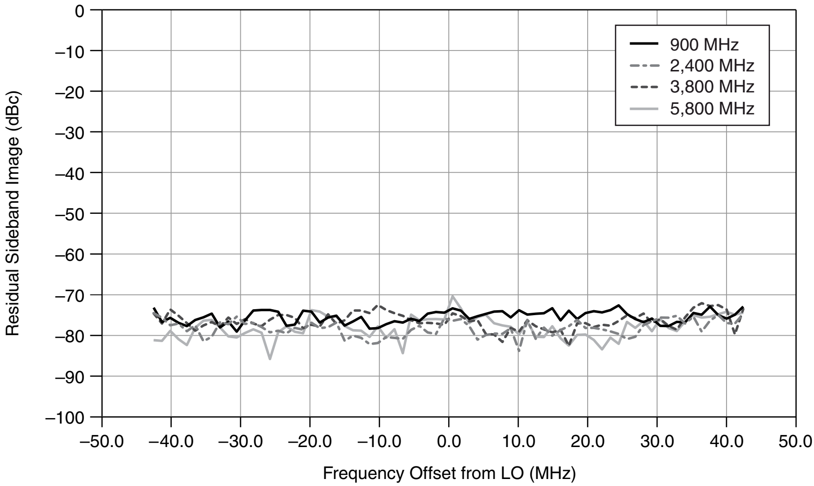
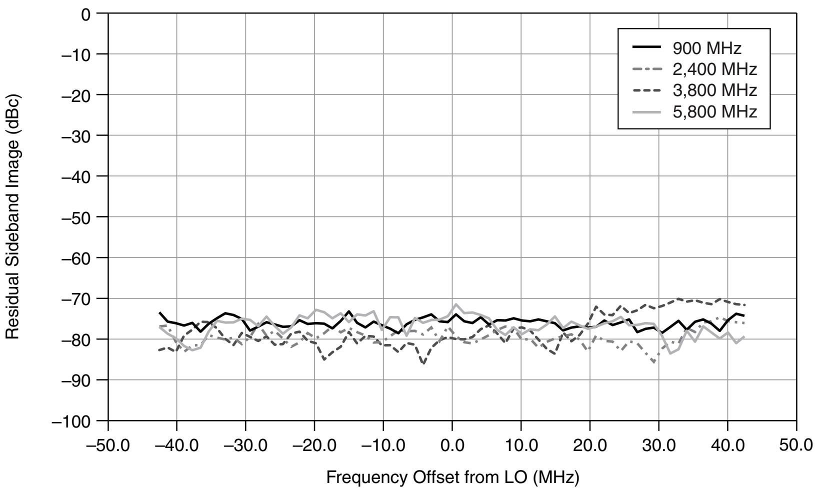


Figure 7. VSA Residual Sideband Image,[11] -30 dBm Reference Level, Typical



[11] Measurement performed after self-calibration.

Third-Order Input Intermodulation

Table 9. 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 10. 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 11. Second-Order Input Intercept Point (IIP_2), -2 dBm Reference Level, Typical[12]

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

12 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 12. Power Range

Output Type	Frequency	Power Range	
CW	<4 GHz	Noise floor to +10 dBm, average power[13]	Noise floor to +15 dBm, average power, nominal
	≥4 GHz	Noise floor to +7 dBm, average power[13]	Noise floor to +12 dBm, average power, nominal
Modulated[14]	<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[15]	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[16]	50 µs
0.5 dB of final value[17], with LO retuned	300 µs

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

Output Power Level Accuracy

Table 13. 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[18]		±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

[18] 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 13. 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

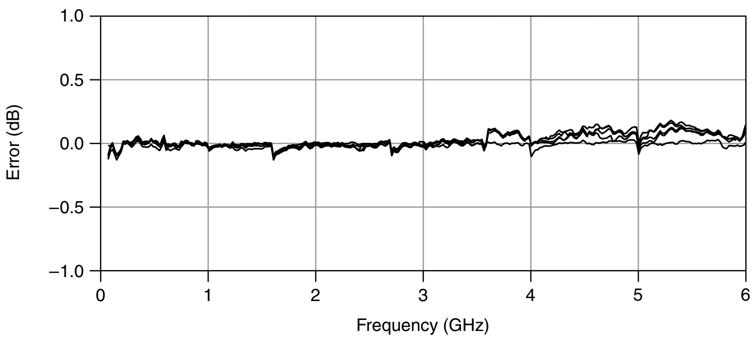
Conditions: CW average power -70 dBm to +10 dBm.

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 PXIe-5644 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 8. Relative Power Accuracy, -40 dBm to 10 dBm, 10 dB Steps, Typical

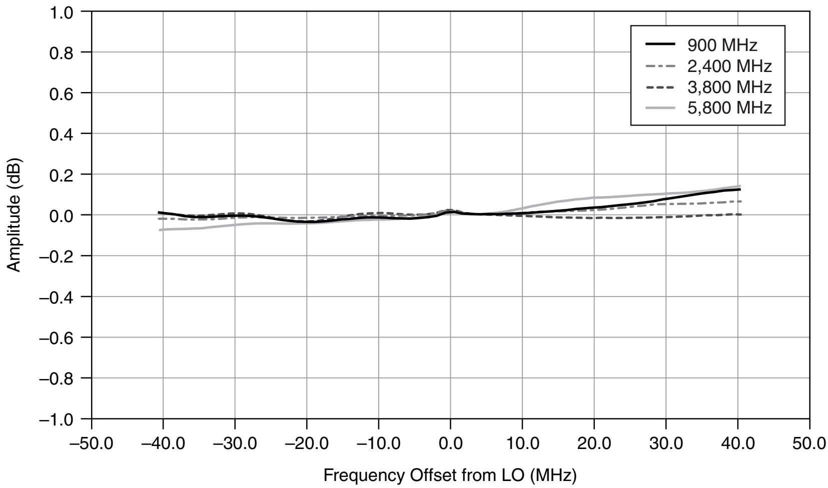


Frequency Response

Table 14. VSG Frequency Response (dB) (Amplitude, Equalized)

Output Frequency	Bandwidth	Self-Calibration °C ± 5 °C
≤109 MHz	20 MHz	±1.0, typical
>109 MHz to 375 MHz	20 MHz	±0.5
	40 MHz	±1.0, typical
>375 MHz to 6 GHz	80 MHz	±0.5
For this specification, frequency refers to the RF output frequency. 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 9. VSG Measured Frequency Response[19]



[19] Conditions: Output -10 dBm CW tone. Measurement performed after self-calibration.

Output Noise Density

Table 15. Average Output Noise Level (dBm/Hz)

Center Frequency	Power Setting		
	-30 dBm	0 dBm	10 dBm
65 MHz to 500 MHz	—	—	-136
	-168, typical	-150 , typical	-140, typical
>500 MHz to 2.5 GHz	-168, typical	-150	-141
>2.5 GHz to 3.5GHz	-168, typical	-149	-139
>3.5 GHz to 6 GHz	-165, typical	-147	-136
Conditions: Averages: 200 sweeps; baseband signal attenuation: -40 dB; noise measurement frequency offset: 4 MHz relative to output tone frequency.			

Spurious Responses

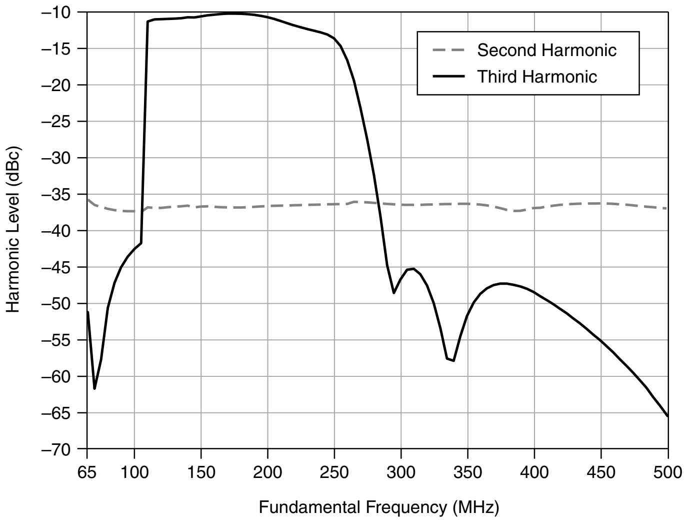
Harmonics

Table 16. Second Harmonic Level (dBc)

Fundamental Frequency	23 °C ± 5 °C	0 °C to 55 °C
65 MHz to 3.5 GHz	-27	-24.8
	-29.5, typical	-27.2, typical
>3.5 GHz to 4.5 GHz	-26.3	-24
	-28.9, typical	-26.6, typical
>4.5 GHz to 6 GHz	-28.9	-26.6
	-33.3, 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 10. Harmonic Level,[20] 65 MHz to 500 MHz, Measured



Nonharmonic Spurs

Table 17. 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 18. 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	-53, typical	-53, typical

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

Table 18. Third-Order Output Intermodulation Distortion (IMD$_3$) (dBc), 0 dBm Tones (Continued)

Fundamental Frequency	Baseband DAC: -2 dBFS	Baseband DAC: -6 dBFS
>3 GHz to 5 GHz	-49, typical	-50, typical
>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 19. 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 20. 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 20. 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 21. VSG LO Residual Power (dBc)

Center Frequency	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
≤109 MHz	—	-50
	-57, typical	-55, typical
>109 MHz to 375 MHz	—	-42
	-47, typical	-45, typical
>375 MHz to 1.6 GHz	—	-55
	-62, typical	-60, typical
1.6 GHz to 2 GHz	—	-54
	-60, typical	-58, typical
2 GHz to 3 GHz	—	-47
	-53, typical	-51, typical
3 GHz to 4 GHz	—	-52
	-57, typical	-55, typical
4 GHz to 5 GHz	—	-51
	-60, typical	-56, typical

Table 21. VSG LO Residual Power (dBc) (Continued)

Center Frequency	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
5 GHz to 6 GHz	—	-47
	-56, typical	-52, 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 PXIe-5644 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 11. VSG LO Residual Power,[21] 109 MHz to 6 GHz, Typical

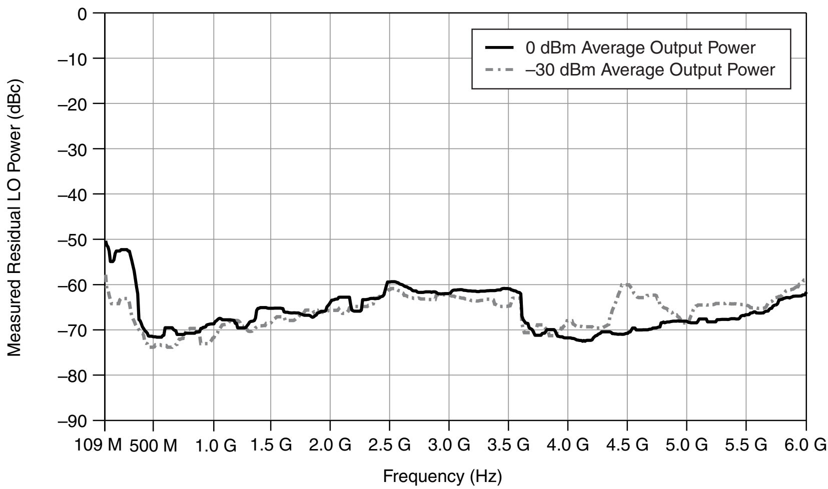


Table 22. VSG LO Residual Power (dBc), Low Power

Center Frequency	Self-Calibration °C ± 5 °C
≤109 MHz	—
	-49, typical

[21] Measurement performed after self-calibration.

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

Center Frequency	Self-Calibration °C ± 5 °C
>109 MHz to 375 MHz	-45
	-50, typical
>375 MHz to 2 GHz	-55
	-60, typical
>2 GHz to 3 GHz	-50
	-53, typical
>3 GHz to 4 GHz	-55
	-58, typical
>4 GHz to 5 GHz	—
	-40, typical
>5 GHz to 6 GHz	-43
	-45, 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 PXIe-5644 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 23. VSG Residual Sideband Image (dBc), 80 MHz Bandwidth

Center Frequency	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
≤109 MHz	—	-40
	-55, typical	-45, typical
>109 MHz to 375 MHz	—	—
	-45, typical	-40, typical

Table 23. VSG Residual Sideband Image (dBc), 80 MHz Bandwidth (Continued)

Center Frequency	Self-Calibration °C ± 1 °C	Self-Calibration °C ± 5 °C
>375 MHz to 2 GHz	—	-60
	-70, typical	-65, typical
>2 GHz to 4 GHz	—	-50
	-65, typical	-55, typical
>4 GHz to 6 GHz	—	-40
	-70, typical	-50, typical

Conditions: Configured power levels -50 dBm to +10 dBm.

This specification describes the maximum residual sideband image within an 80 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 PXIe-5644 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 12. VSG Residual Sideband Image,[22] 0 dBm Average Output Power, Typical

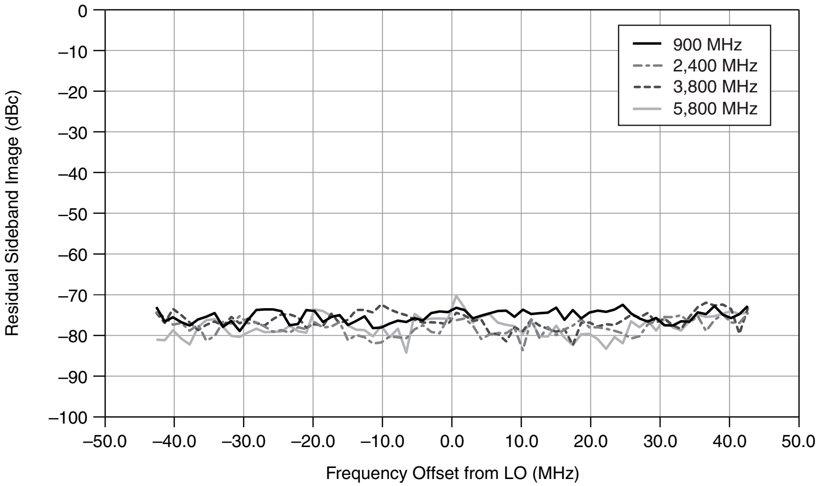
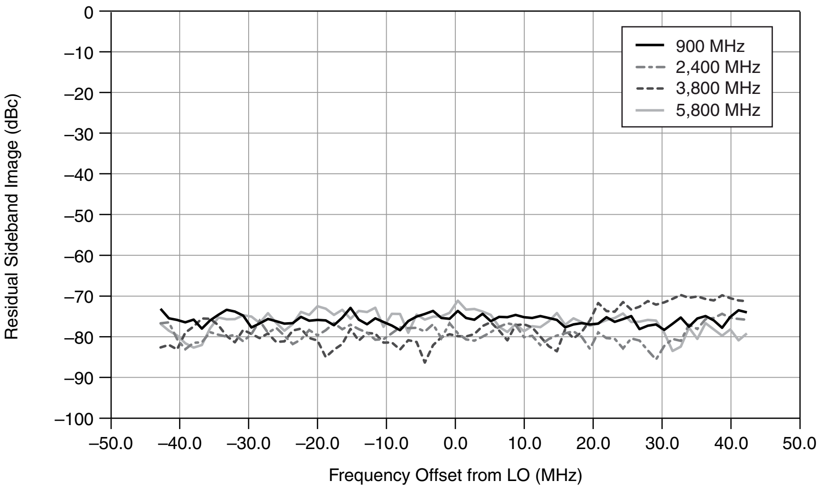


Figure 13. VSG Residual Sideband Image,[22] -30 dBm Average Output Power, Typical



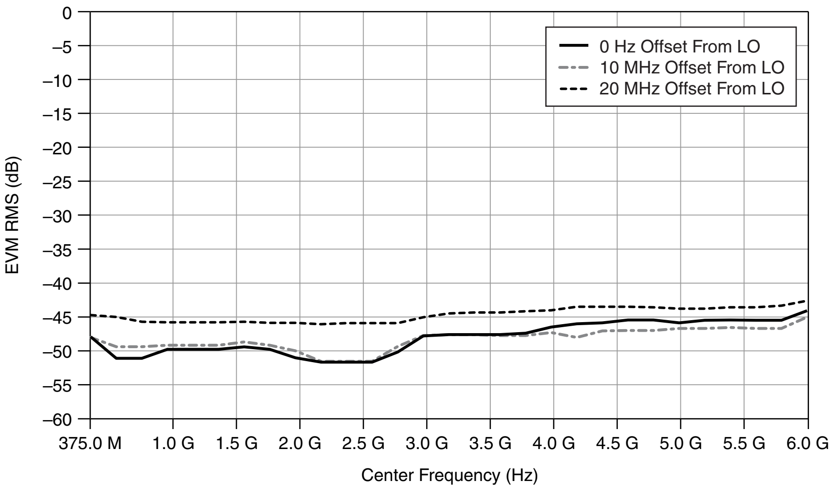
22 Measurement performed after self-calibration.

Error Vector Magnitude (EVM)

VSA EVM

20 MHz bandwidth 64-QAM EVM[23] 375 MHz to 6 GHz	-40 dB, typical

Figure 14. VSA Error Vector Magnitude, Typical[24]



VSG EVM

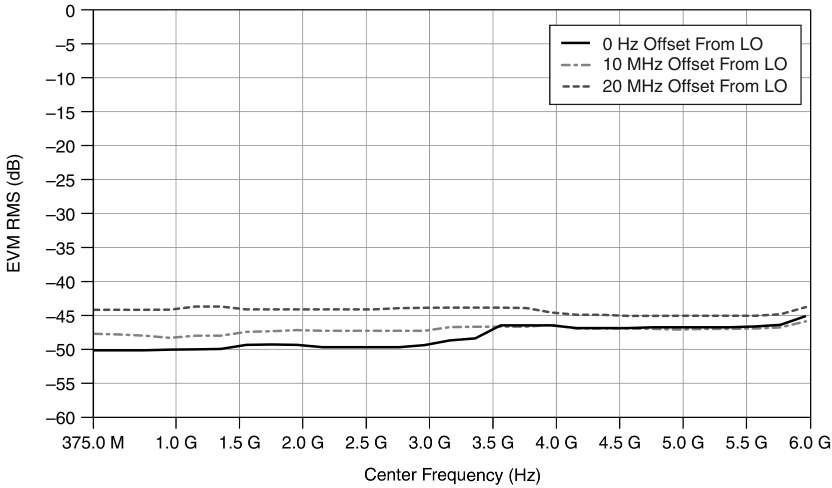
20 MHz bandwidth 64-QAM EVM[25] 375 MHz to 6 GHz	-40 dB, typical

23 Conditions: EVM signal: 20 MHz bandwidth; 64 QAM signal. Pulse-shape filtering: root-raised-cosine, alpha=0.25; PXIe-5644 reference level: -10 dBm; Reference Clock source: internal; record length: 300 µs. Generator: PXIe-5673; power (average): -14 dBm; Reference Clock source: internal.

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

25 Conditions: EVM signal: 20 MHz bandwidth; 64 QAM signal. Pulse-shape filtering: root-raised cosine, alpha=0.25; PXIe-5644 peak output power: -10 dBm; Reference Clock source: internal. Measurement instrument: PXIe-5665; reference level: -10 dBm; Reference Clock source: internal; record length: 300 µs.

Figure 15. RMS EVM (dB) versus Measured Average Power (dBm), Typical [26]



Application-Specific Modulation Quality

Typical performance assumes the PXIe-5644 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[27]	-45 EVM (rms) dB, typical

WLAN 802.11n

Table 24. 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.		

[26] Conditions: 20 MHz bandwidth, 64 QAM; centered at LO frequency or offset digitally as listed.
[27] Conditions: RF OUT loopback to RF IN; 5,800 MHz; 80 MHz bandwidth; average power: -30 dBm to -5 dBm; 20 packets; 16 OFDM data symbols; MCS=9; 256 QAM.

WLAN 802.11a/g/j/p

Table 25. 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 26. 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[28]	-48 EVM (rms) dB, typical

LTE

Table 27. SC-FDMA[29] (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

[28] 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.

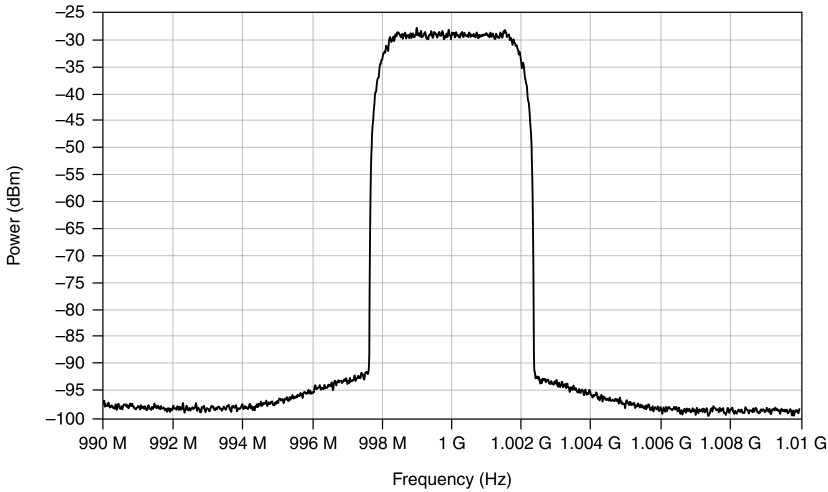
[29] Single channel uplink only.

Table 27. SC-FDMA[29] (Uplink FDD) EVM (rms) (dB), Typical (Continued)

Frequency	5 MHz Bandwidth	10 MHz Bandwidth	20 MHz Bandwidth
1,750 MHz	-51	-50	-50
1,900 MHz	-51	-50	-50
2,500 MHz	-50	-49	-49

WCDMA

Figure 16. WCDMA Measured Spectrum[30] (ACP)



Baseband Characteristics

Analog-to-digital converters (ADCs)

Resolution	16 bits
Sample rate[31]	120 MS/s
I/Q data rate[32]	1.84 kS/s to 120 MS/s

[29] Single channel uplink only.
[30] Conditions: DL Test Model 1 (64DPCH); RF output level: -10 dBm average; RF OUT loopback to RF IN; measured results better than -66 dB.
[31] ADCs are dual-channel components with each channel assigned to I and Q, respectively.
[32] I/Q data rates lower than 120 MS/s are achieved using fractional decimation.

Digital-to-analog converters (DACs)	
Resolution	16 bits
Sample rate[33]	120 MS/s
I/Q data rate[34]	1.84 kS/s to 120 MS/s

Onboard FPGA

FPGA	Xilinx Virtex-6 LX195T
LUTs	124,800
Flip-flops	249,600
DSP48 slices	640
Embedded block RAM	12,384 kbits
Data transfers	DMA, interrupts, programmed I/O
Number of DMA channels	16

Onboard DRAM

Memory size	2 banks, 256 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

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[35]	+33 dBm (CW RMS)

33 DACs are dual-channel components with each channel assigned to I and Q, respectively. DAC sample rate is internally interpolated to 960 MS/s, automatically configured.
34 I/Q data rates lower than 120 MS/s are achieved using fractional interpolation.
35 For modulated signals, peak instantaneous power not to exceed +36 dBm.

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

Table 28. 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[36]	
<4 GHz	+33 dBm (CW RMS)
≥4 GHz	+30 dBm (CW RMS)

Output Return Loss (VSWR)

Table 29. 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)
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.

[36] For modulated signals, peak instantaneous power not to exceed corresponding peak power of specified CW.

LO OUT (RF IN 0 and RF OUT 0)

Connectors	SMA (female)
Frequency range[37]	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[38]	65 MHz to 6 GHz
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

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

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

REF IN

Connector	SMA (female)
Frequency	10 MHz
Tolerance[39]	$\pm 10 \times 10^{-6}$
Amplitude	
Square	0.7 $V_{pk\text{-}pk}$ to 5.0 $V_{pk\text{-}pk}$ into 50 Ω, typical
Sine[40]	1.4 $V_{pk\text{-}pk}$ to 5.0 $V_{pk\text{-}pk}$ into 50 Ω, typical
Input impedance	50 Ω, nominal
Coupling	AC

REF OUT

Connector	SMA (female)
Frequency	
Reference Clock[41]	10 MHz, nominal
Sample Clock	120 MHz, nominal
Amplitude	1.65 Vpk-pk into 50 Ω, nominal
Output impedance	50 Ω, nominal
Coupling	AC

PFI 0

Connector	SMA (female)
Voltage levels[42]	
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

39 *Frequency Accuracy* = *Tolerance* × *Reference Frequency*
40 1 V_{rms} to 3.5 V_{rms}, typical. Jitter performance improves with increased slew rate of input signal.
41 Refer to the *Internal Frequency Reference* for accuracy.
42 Voltage levels are guaranteed by design through the digital buffer specifications.

Maximum DC drive strength	24 mA
Minimum required direction change latency[43]	48 ns + 1 clock cycle

DIGITAL I/O

Connector	VHDCI

Table 30. DIGITAL I/O Signal Characteristics

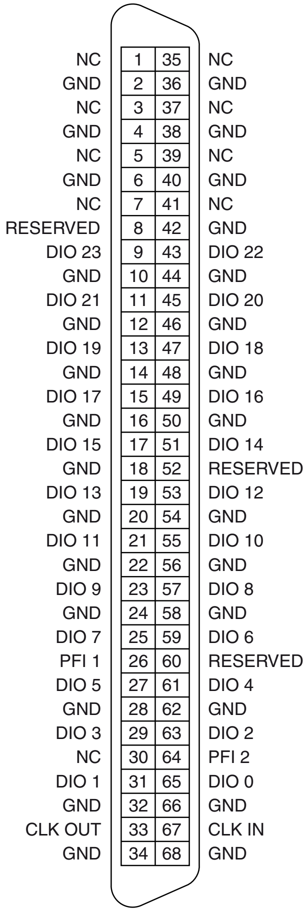
Signal	Direction	Port Width
DIO <23..20>	Bidirectional, per port	4
DIO <19..16>	Bidirectional, per port	4
DIO <15..12>	Bidirectional, per port	4
DIO <11..8>	Bidirectional, per port	4
DIO <7..4>	Bidirectional, per port	4
DIO <3..0>	Bidirectional, per port	4
PFI 1	Bidirectional	1
PFI 2	Bidirectional	1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

Voltage levels[44]	
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

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

Output impedance	50 Ω, nominal
Maximum DC drive strength	12 mA
Minimum required direction change latency[45]	48 ns + 1 clock cycle
Maximum toggle rate	125 MHz, typical

Figure 17. DIGITAL I/O VHDCI Connector



45 Clock cycle refers to the FPGA clock domain used for direction control.

Power Requirements

Table 31. Power Requirements

Voltage (V_{DC})	Typical Current (A)	Maximum Current (A)
+3.3	4.9	5.3
+12	3.3	4.2
Power is 56 W, typical. Consumption is from both 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*.

Physical Characteristics

PXIe-5644 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} (Tested in accordance with IEC 60068-2-64.)
Nonoperating	5 Hz to 500 Hz, 2.4 g_{rms} (Tested in accordance with IEC 60068-2-64. 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 C22.2 No. 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`.)

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