Vector Signal Generator

NI PXIe-5673, NI PXIe-5673E

- 85 MHz to 6.6 GHz frequency range
- >100 MHz bandwidth
- Up to +10 dBm RF power
- 112 dBc/Hz phase noise at 10 kHz offset at 1 GHz
- 66 dBc adjacent-channel leakage ratio for WCDMA-like signals
- <7.5 ms tuning time
- -64 dBc typical image rejection at 2.4 GHz
- -64 dBc typical carrier suppression at 2.4 GHz
- Full bandwidth streaming from disk (100 MS/s)
- RF List Mode support for NI PXIe-5673E

Operating System
- Windows 7/Vista/XP/2000

Included Software
- NI Modulation Toolkit
- NI-RFSG driver

Programming API
- LabVIEW Real-Time
- LabWindows™/CVI
- C++/.NET

Overview

The NI PXIe-5673 and PXIe-5673E are wide-bandwidth 6.6 GHz RF vector signal generators. Combined with the appropriate software, an NI PXIe-5673/5673E can generate a variety of signals. With the NI Modulation Toolkit for LabVIEW, it can generate different waveforms including AM, FM, CPM, ASK, FSK, MSK, PSK, QAM (4, 16, 64, and 256), multitone signals, arbitrary waveforms, and many others. In addition, you can combine these vector signal generators with standard-specific software to generate signals for GPS, GSM/EDGE/WCDMA, WLAN, WiMAX, DVB-C/H/C, ISDB-T, ZigBee, and others. With NI PXIe-5673/5673E stream-from-disk capabilities, you can generate continuous waveforms that are up to several terabytes in length.

Basic Architecture

The NI PXIe-5673 uses direct RF upconversion from differential baseband I and Q signals. A block diagram of the system is shown in Figure 1.

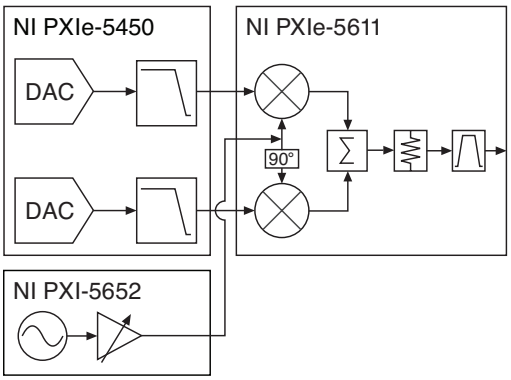

Figure 1. Block Diagram of the NI PXIe-5673

As Figure 1 illustrates, the NI PXIe-5673 consists of the NI PXIe-5611 RF upconverter, the NI PXI-5652 RF continuous wave (CW) source, and the NI PXIe-5450 dual-channel arbitrary waveform generator (AWG). The NI PXI-5652 CW source uses a voltage-controlled oscillator (VCO) architecture, enabling frequency tuning times no greater than 6.5 ms. In addition, the NI PXIe-5450 AWG 16-bit digital-to-analog converter (DAC) generates baseband I and Q signals at data rates of up to 200 MS/s. At this sample rate, the generator is capable of producing more than 100 MHz of RF bandwidth. Figure 2 shows a QPSK signal with more than 100 MHz of bandwidth at 5.8 GHz. The signal represented is configured for a symbol rate of 100 MS/s and a root raised cosine filter with an alpha of 0.22.

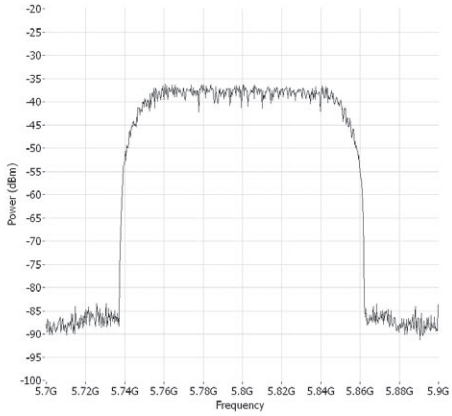

Figure 2. QPSK Signal with Wide Bandwidth

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Enhanced Architecture

The NI PXIe-5673E (E for enhanced) offers additional performance and features including RF List Mode support and configurable loop bandwidth for decreased tuning times. As with the NI PXIe-5673, the NI PXIe-5673E comprises three modular instruments. The NI PXIe-5450 is a dual-channel AWG that provides 16-bit digital-to-analog conversion and generates baseband I and Q signals at data rates of up to 200 MS/s. You then can use an enhanced NI PXIe-5611 RF upconverter with an NI PXIe-565x CW source acting as the local oscillator (LO) for direct upconversion to RF.

With the enhanced NI PXIe-5673E, you can configure a wide- or narrow-loop bandwidth for the VCO of an NI PXIe-565x. By using a wide-loop bandwidth, you increase tuning time at the expense of additional phase noise; if you require lower phase noise over faster tuning times for a particular measurement, you can specify a narrow phase-locked loop (PLL) bandwidth for best performance. You can achieve tuning times of less than 300 µs to under 0.1 ppm of the final frequency when using the wide-loop bandwidth configuration.

Fast Waveform Downloads

One of the biggest advantages of PXI Express instrumentation is the benefit of high-speed waveform transfer rates. Using an NI PXIe-5673/5673E, you can download waveforms onto an instrument's memory significantly faster than with traditional instrumentation. Using a x4 PCI Express interface, you can download waveforms to memory at speeds of up to 800 MB/s.

Phase-Coherent Generation

The flexible architecture of an NI PXIe-5673/5673E enables multiple instruments to share a common start trigger, reference clock, and even an LO. As a result, you can synchronize up to four NI PXIe-5673/5673E RF vector signal generators for phase-coherent signal generation. A typical configuration of two synchronized generators is shown in Figure 3. With up to four channels of synchronized RF signal generation, you can easily address MIMO and beamforming applications.

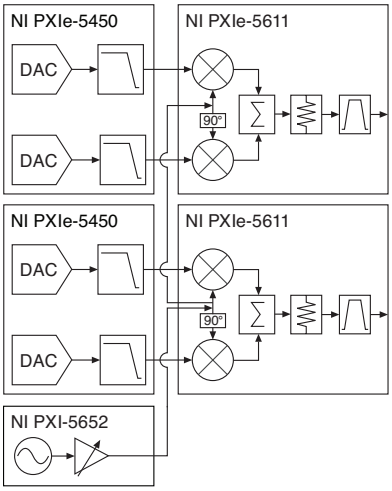

Figure 3. Simplified Block Diagram of Synchronized RF Vector Signal Generators

RF List Mode

The NI PXIe-5673E provides list mode support for fast and deterministic RF configuration changes. You supply a configuration list, and the RF modules proceed through the list without additional interaction with the host system and driver, making the configuration changes deterministic. Figure 4 illustrates this determinism with a single tone at 1 GHz stepping through six power levels in 7 dB steps starting with -10 dBm and ending with -45 dBm and a 500 µs dwell time specified for each step. Analysis was performed using the NI PXIe-5663E vector signal analyzer.

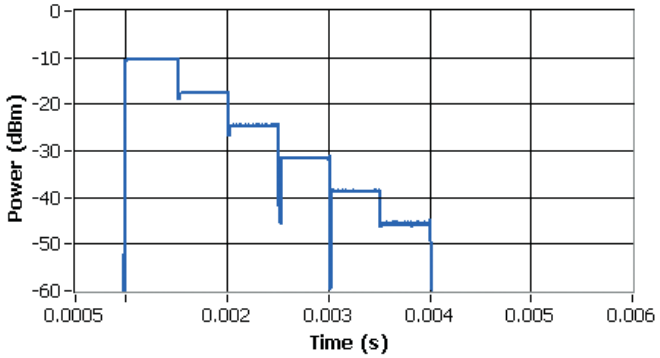

Figure 4. Deterministic 500 µs Power Steps Using the NI PXIe-5673E and RF List Mode

You can use the NI PXIe-5673E in both open- and closed-loop scenarios to specify the source for the configuration trigger that advances from one configuration to the next. In an open-loop situation, the NI PXIe-5673E advances through the list based on a user-defined time specification for each step. The closed-loop scenario relies on an external trigger that may be provided by the device under test to advance through the RF configuration list.

RF Record and Playback

You can combine an NI PXIe-5673/5673E with a PXI RF vector signal analyzer for record and playback applications. Using a 2 TB redundant array of inexpensive disks (RAID) volume, you can continuously generate up to 100 MHz (400 MB/s) for more than 1.5 hours. In this application, an NI PXIe-5663/5663E vector signal analyzer records up to two hours of continuous RF signal and the data is stored as a binary file on a RAID volume. The NI PXIe-5673/5673E then streams recorded waveforms from disk. In addition to recorded waveforms, you can use streaming technology to generate large simulated waveforms.

High-Performance Signal Generation

Higher-order modulation schemes such as 256-QAM require strong dynamic range and phase noise performance. Using an NI PXIe-5673/5673E, you can generate a variety of signals with significant accuracy. As shown in Figure 5, a loopback configuration with an NI PXIe-5673/5673E and NI PXIe-5663/5663E yields a typical EVM (RMS) measurement of 0.5 percent (1250 symbols, software equalization disabled).

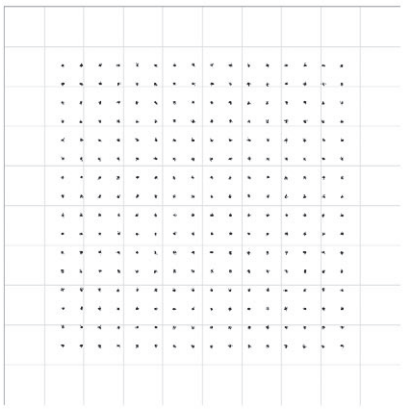

Figure 5. Constellation Plot of 256-QAM

In Figure 5, a center frequency of 1 GHz, a symbol rate of 5.36 MS/s, and a root raised cosine filter with 0.12 alpha was used. The RF power was set to -10 dBm and analysis was performed with the NI PXIe-5663. In addition, the wide bandwidth of an NI PXIe-5673/5673E combined with high-performance image rejection enabled the generation of modulated signals at high symbol rates. For example, Figure 5 shows a constellation plot of a 64-QAM signal at 40.99 MS/s with an RMS EVM of 0.9 percent (1250 symbols, equalization disabled).

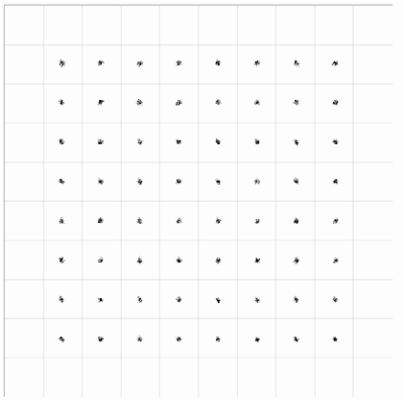

Figure 6. Constellation Plot of QPSK with 50 MHz of Bandwidth

In Figure 6, a center frequency of 825 MHz was used. The RF power was set to -10 dBm and analysis was performed with the NI PXIe-5663. While an EVM of 0.9 percent is a nominal value, the typical result is 1.1 percent.

In addition, the combination of high dynamic range and a linear front end yields high-performance adjacent channel power measurements. In Figure 7, observe the spectrum for a QPSK signal at 1 GHz center frequency.

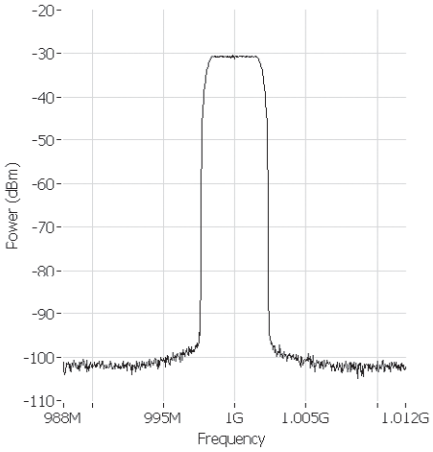

Figure 7. Spectrum of QPSK Signal at 1 GHz

A symbol rate of 3.84 MS/s and a root raised cosine filter with alpha 0.22 is used. As Figure 7 illustrates, an NI PXIe-5673/5673E yields an adjacent channel power measurement of better than -69 dBc rejection when configured with the settings described.

Flexible Software

With NI Modulation Toolkit for LabVIEW software, you can operate an NI PXIe-5673/5673E as a general-purpose vector signal generator. Using NI LabVIEW or LabWindows/CVI example programs, you can generate a variety of modulated signals.

These modules are programmed with the NI-RFSG driver, which contains several performance-enhancing characteristics. Using an optimized driver stack combined with fast-settling VCO-based hardware, you can tune an NI PXIe-5673/5673E to 0.1 ppm of its settling frequency with a typical tuning time of less than 1.5 ms. With the NI PXIe-5673E, a wide-loop bandwidth configuration results in tuning times to within 0.1 ppm of the final frequency in under 300 µs.

You also can use the NI-RFSG driver to enhance the RF performance. With an RF impairments API, you can manually or programmatically adjust I/Q impairments such as gain imbalance, DC offset, and quadrature skew. A LabVIEW property node that illustrates how you can adjust these parameters on the fly is shown in Figure 8.

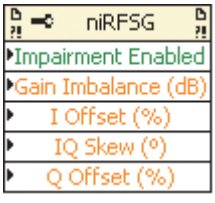

Figure 8. RFSG Impairments Property Node

Vector Signal Generator

Typical out-of-the-box image and carrier suppression is better than -60 dBc, but you can reduce suppression to better than -80 dBc for a particular frequency and temperature by adjusting quadrature impairments through the RFSG VQ impairments API. Figure 9 illustrates the carrier suppression at 1 GHz for a 10 MHz tone.

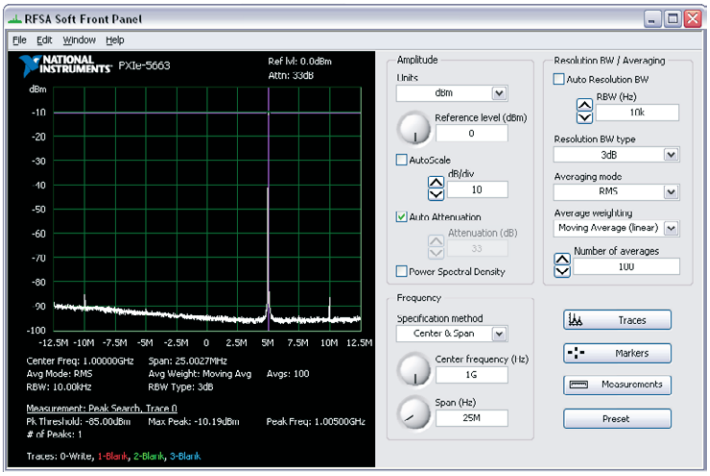

Figure 9. Use the impairments API to reduce image and carrier suppression.

Ordering Information

NI PXIe-5673

128 MB onboard memory..... 780418-01
512 MB onboard memory..... 780418-02

NI PXIe-5673E

128 MB onboard memory..... 781263-01
512 MB onboard memory..... 781263-02

Phase Coherent VSGs

NI PXIe-5673/5673E VSG channel extension kit..... 780485-01
NI PXIe-5673E two-channel VSG..... 781340-02
NI PXIe-5673E three-channel VSG..... 781340-03
NI PXIe-5673E four-channel VSG..... 781340-04

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Specifications

Frequency

Frequency Range	NI PXIe-5673 Part Number
85 MHz to 6.6 GHz	780418-0X
85 MHz to 3.3 GHz	780417-0X
85 MHz to 1.3 GHz	780416-0X

Note: NI PXIe-5673 part numbers vary according to memory size.

Bandwidth

Modulation bandwidth

(3 dB double sideband)..... >100 MHz

The modulation bandwidth specification assumes the frequency range is between 85 MHz and 6.6 GHz. For example, 100 MHz bandwidth can be achieved at a frequency of 135 MHz but not 85 MHz.

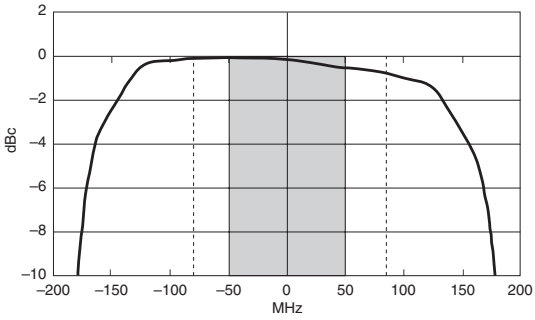

Figure 1. Typical Modulation Bandwidth at 1 GHz Carrier Frequency

In figures 1 through 5, typical modulation bandwidths show the actual baseband response. The usable bandwidth is limited by the NI 5450 I/Q generator sample rate from -80 to 80 MHz. The shaded area between the solid lines indicates the frequency range covered by this specification.

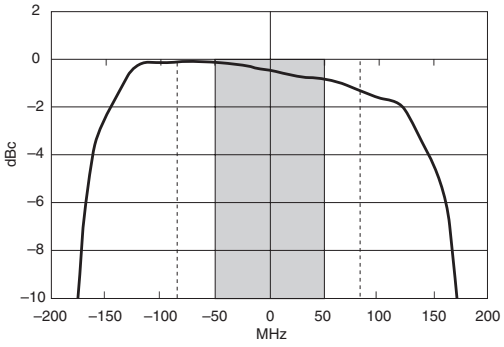

Figure 2. Typical Modulation Bandwidth at 2.4 GHz Carrier Frequency

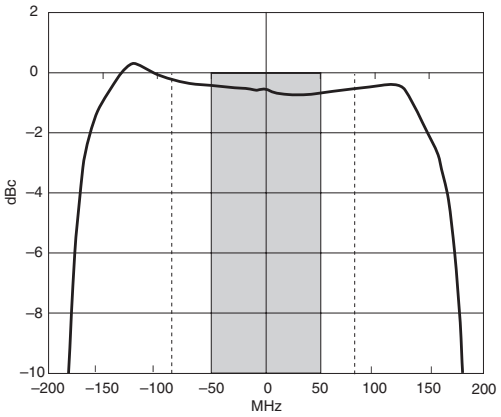

Figure 3. Typical Modulation Bandwidth at 5.8 GHz Carrier Frequency

Data streaming continuous

transfer rate..... 500 MB/s, nominal

Tuning Resolution (NI 5650/5651/5652)

<1.3 GHz..... <1 Hz

≤1.3 to ≤3.3 GHz..... <2 Hz

≤3.3 to ≤6.6 GHz..... <4 Hz

Frequency Settling Time

0.1 x 10^{-6} of final frequency..... <7.5 ms, maximum

0.1 x 10^{-6} of final frequency..... <3.5 ms, typical

The frequency settling time specification includes only frequency settling and excludes any residual amplitude settling that may occur as a result of large frequency changes.

Internal Frequency Reference (NI 5650/5651/5652)

Frequency..... 10 MHz

Initial accuracy..... ±3 x 10^{-6}

Temperature stability (15 to 35 °C)..... ±1 x 10^{-6}, maximum

Aging

Per year..... ±5 x 10^{-6}, maximum

External Reference Input (NI 5450)

Frequency..... 10 MHz

Amplitude..... 1.0 V_{pk-pk} to 5.0 V_{pk-pk} into 50 Ω

Input impedance..... 50 Ω

Coupling..... AC

External Reference Output (NI 5450)

Frequency..... 10 MHz

Reference clock out..... 0.7 V_{pk-pk} into 50 ½, nominal

Output impedance..... 50 ½

Coupling..... AC

Spectral Purity

Frequency	Phase Noise (dBc/Hz)
100 MHz	<-125
500 MHz	<-112
1 GHz	<-105
2 GHz	<-98
3 GHz	<-95
4 GHz	<-93
5 GHz	<-90
6.6 GHz	<-90

Table 1. Single Sideband Phase Noise at 10 kHz Offset

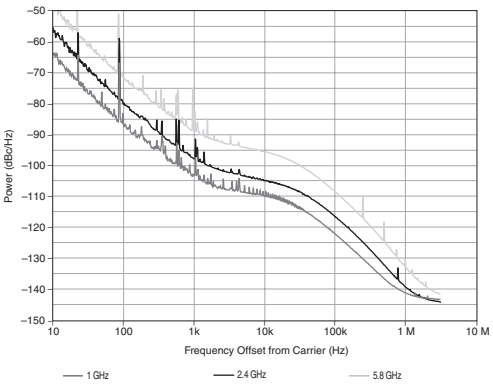

Figure 4. Typical Phase Noise at 1, 2.4, and 5.8 GHz

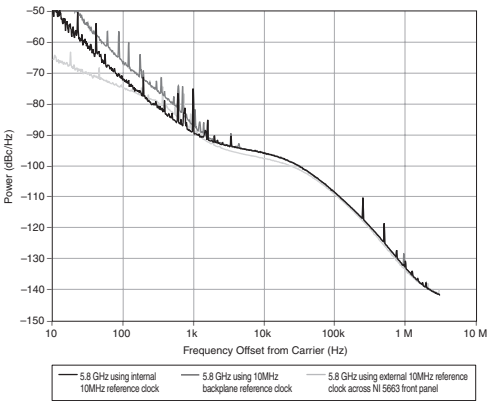

Figure 5. Typical Phase Noise at 5.8 GHz

Sideband Image Suppression

Frequency	2 MHz Modulation Bandwidth	20 MHz Modulation Bandwidth
≥85 MHz to ≤400 MHz	≤-43 dBc	≤-41 dBc
>400 MHz to ≤2.5 GHz	≤-50 dBc	≤-48 dBc
>2.5 GHz to ≤5.5 GHz	≤-46 dBc	≤-45 dBc
>5.5 GHz to ≤6.6 GHz	≤-43 dBc	≤-41 dBc

Note: Measured with a test signal at a baseband frequency of 1 MHz.

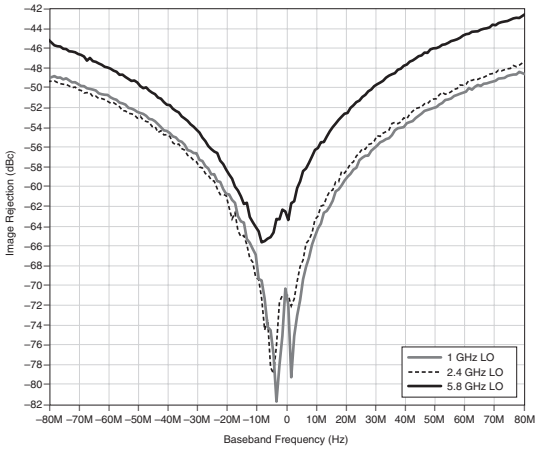

Figure 6. Typical Image Rejection versus Baseband Frequency

Carrier Suppression

LO Frequency	Carrier Suppression
85 MHz to 5.5 GHz	-44 dBc, maximum
5.5 GHz to 6.6 GHz	-41 dBc, maximum

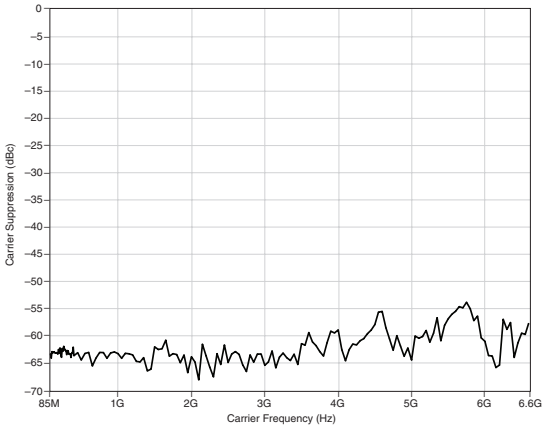

Figure 7. Typical Carrier Suppression

Digital Modulation[1]

(Nominal)

Quadrature Phase-Shift Keying (QPSK)

			EVM (%)			MER (dB)		
Symbol Rate (MS/s)	**Bandwidth**	**Root Raised Cosine Filter Alpha Value**	**825 MHz**	**3,400 MHz**	**5,800 MHz**	**825 MHz**	**3,400 MHz**	**5,800 MHz**
Onboard Reference Clock Source								
0.16	200.00 kHz	0.25	0.3	0.7	1.0	51	43	40
0.80	1.00 MHz	0.22	0.4	0.7	1.0	48	42	40
4.09	4.98 MHz	0.25	0.6	0.8	1.2	45	42	38
QPSK, External Reference Clock Source (PXI Express Backplane Clock)								
0.16	200.00 kHz	0.25	0.7	2	2.9	43	34	30
0.80	1.00 MHz	0.22	0.9	1.3	1.7	41	38	36
4.09	4.98 MHz	0.25	1.1	1.3	1.5	39	38	36
16-QAM, Onboard Reference Clock Source								
17.6	22 MHz	0.25	0.7	1.4	1.8	41	35	32
32.0	40 MHz	0.25	1.1	2.4	2.5	36	29	29
16-QAM, External Reference Clock Source (PXI Express Backplane Clock)								
17.6	22 MHz	0.25	1	1.5	1.9	37	34	32
32.0	40 MHz	0.25	1.4	2.5	2.6	35	29	29
64-QAM, Onboard Reference Clock Source								
5.36	6.16 MHz	0.15	0.4	0.6	1	44	40	37
6.95	7.99 MHz	0.15	0.5	0.7	1	43	39	36
40.99	50.00 MHz	0.22	1.3	2.8	2.6	34	27	28
64-QAM, External Reference Clock Source (PXI Express Backplane Clock)								
5.36	6.16 MHz	0.15	0.9	1	1.2	38	36	35
6.95	7.99 MHz	0.15	0.9	1.1	1.2	38	36	35
40.99	50.00 MHz	0.22	1.5	2.8	2.7	33	27	28
256-QAM, Onboard Reference Clock Source								
6.95	7.99 MHz	0.15	0.5	0.8	1.8	43	38	32
256-QAM, External Reference Clock Source (PXI Express Backplane Clock)								
6.95	7.99 MHz	0.15	0.8	2	2.3	37	32	29

[1]All measurements were made with an NI 5673 and NI 5663 not phase-locked together.
Number of symbols = 1,250 pseudorandom bit sequence (PRBS) at -30 dBm for all measurements.
No equalization in receiver demodulation.

Vector Signal Generator

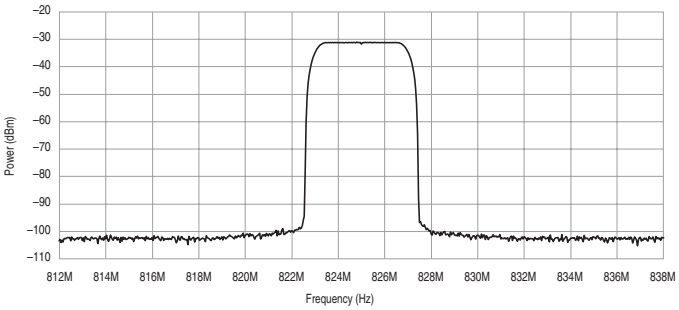

Figure 8. Typical Adjacent Channel Power at 825 MHz

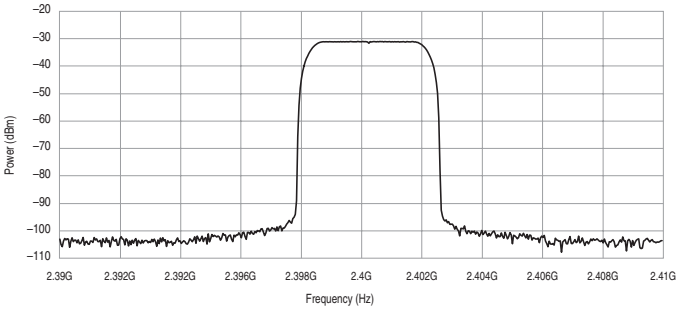

Figure 9. Typical Adjacent Channel Power at 2.4 GHz

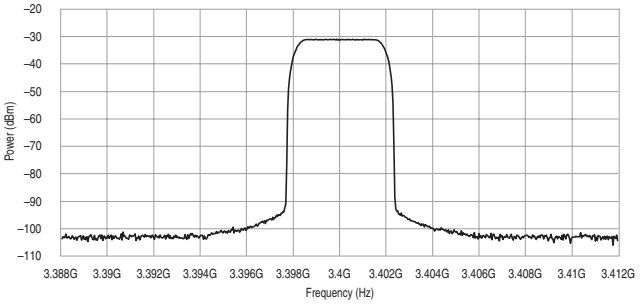

Figure 10. Typical Adjacent Channel Power at 3.4 GHz

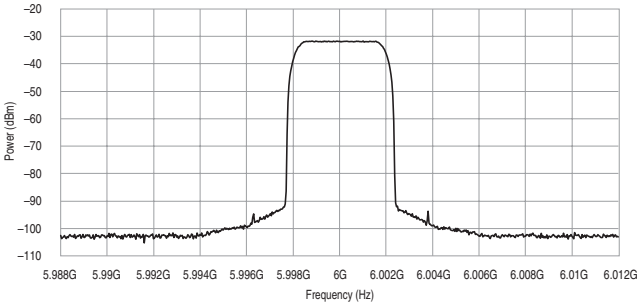

Figure 11. Typical Adjacent Channel Power at 5.8 GHz

The specifications in figures 8 through 11 were measured under the following conditions:

- Modulation: QPSK
- Symbol rate: 3.84 MS/s
- Filter: root raised cosine with alpha value of 0.22
- Filter length: 128 symbols
- RF power: set to -10 dBm
- Prefilter gain: set to -5 dB
- Number of averages by receiver: 100
- Noise cancellation: On

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