SPECIFICATIONS

mmWave Transceiver System

2 GHz Bandwidth mmWave Transceiver System

Contents

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 performance met by a majority of models.
- *Nominal* specifications describe an attribute that is based on design, conformance testing, or supplemental testing.

NATIONAL INSTRUMENTS

Specifications are *Characteristics* unless otherwise noted.

Conditions

Specifications are valid under the following conditions unless otherwise noted.

- Ambient temperature of 23 °C ± 5 °C.
- The device is warmed up for 25 minutes.
- The PXI Express chassis fan speed is set to HIGH, the fan filters are clean if present, and the empty slots contain PXI chassis slot blockers and filler panels.

System Performance and Characteristics

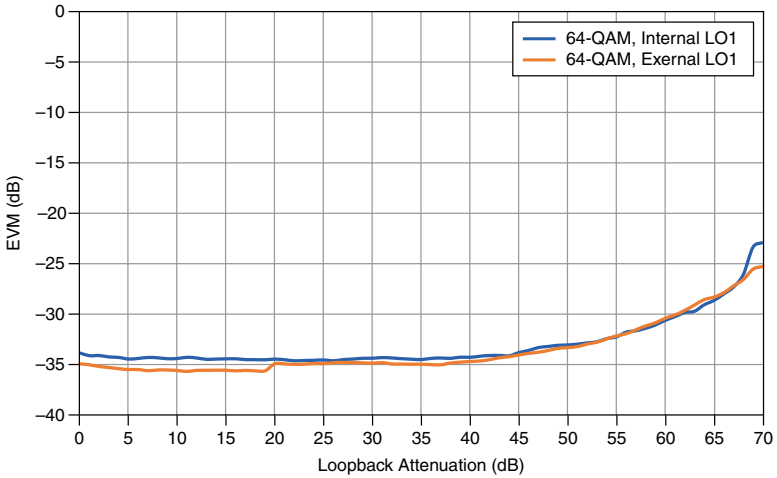
Note Single-point calibration is used to correct for image rejection, and an equalizer is used to correct for amplitude ripple and phase nonlinearity within the instantaneous bandwidth. The internal LO2 is utilized for all measurements. Separate LO1s are utilized for the transmitter and receiver in all measurements.

Note The NI-mmWave instrument driver configures the appropriate intermediate frequency (IF) frequency by default. The following system performance graphs and characteristics may be inaccurate if a custom IF frequency is set when using a mmWave radio head.

24.25 GHz to 33.40 GHz mmWave Transceiver System

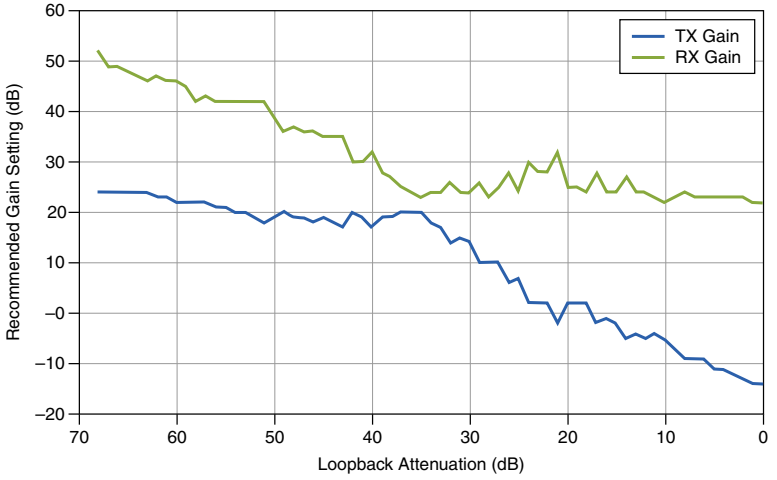
A variable attenuator is placed between the transmitter (TX) and receiver (RX) to simulate path loss at 28.5 GHz. The error vector magnitude (EVM) of various single-carrier signals at a symbol rate of 768 MBaud (root-raised-cosine (RRC) filter $\alpha = 0.3$) is shown in the following figure.

Figure 1. EVM Versus Loopback Attenuation



The transmitter and receiver gain settings used for the EVM measurement are shown in the following figure.

Figure 2. Transmitter and Receiver Gain Settings

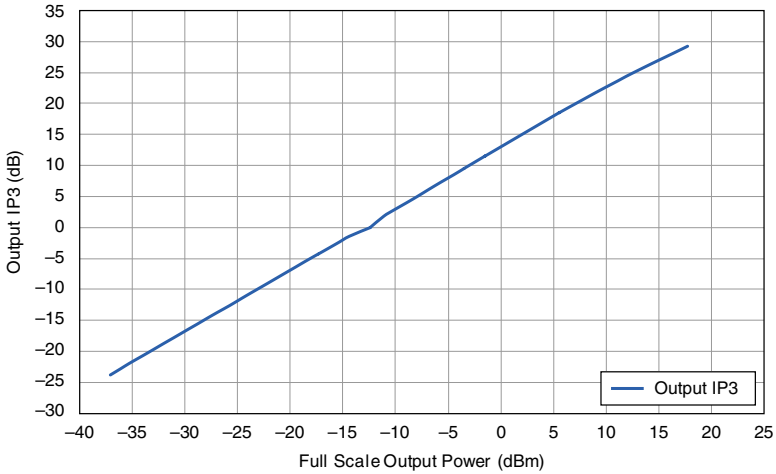


Transmitter

Tuning range	24.25 GHz to 33.40 GHz
Instantaneous bandwidth	2 GHz

Connector	2.92 mm
Analog gain range	55 dB
Saturated power[1]	26 dBm (approximately)
Output third order intercept point (IP3)[1]	29 dBm

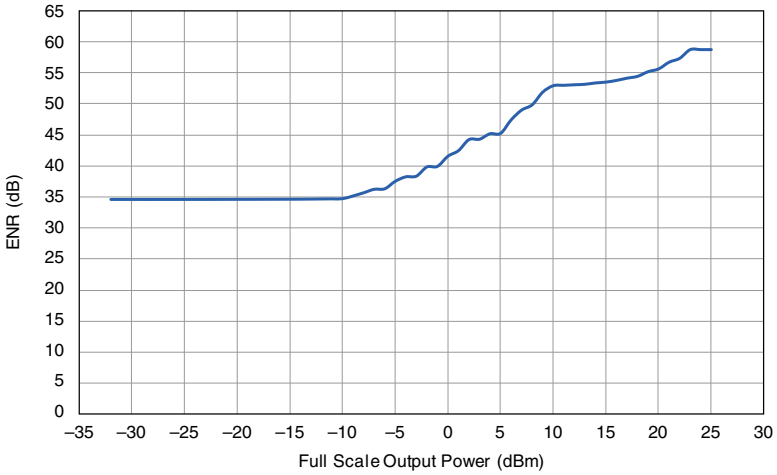
Figure 3. mmRH-3642 mmWave Radio Head Simulated Output IP3[2]



[1] At maximum gain.

[2] Driven by the PXIe-3610 Waveform Generator and the PXIe-3620 RF Upconverter and Downconverter Module with a two-tone signal at -7 dBFS.

Figure 4. mmRH-3642 mmWave Radio Head Excess Noise Ratio (ENR)[3]



Note mmRH-3642 simulated output IP3[3] and ENR[3] is very similar to that of the mmRH-3602 mmWave Radio Head.

Receiver

Tuning range	24.25 GHz to 33.40 GHz
Instantaneous bandwidth	2 GHz
Connector	2.92 mm
Analog gain range	50 dB
1 dB gain compression[4]	-10 dBm to -15 dBm
Noise figure[5]	6 dB

[3] Driven by the PXIe-3610 and the PXIe-3620 with a two-tone signal at -7 dBFS.
[4] Near minimum gain. For lower gain settings, 1 dB compression is higher than full-scale.
[5] At maximum gain.

Figure 5. mmRH-3652 mmWave Radio Head Simulated Input IP3[6]

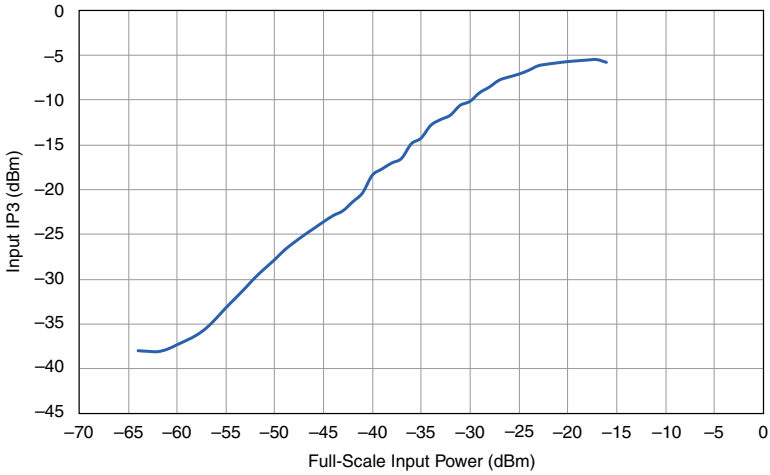
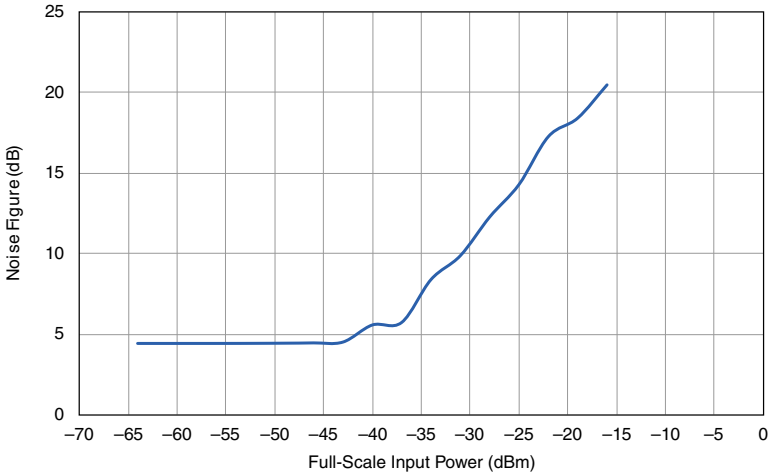
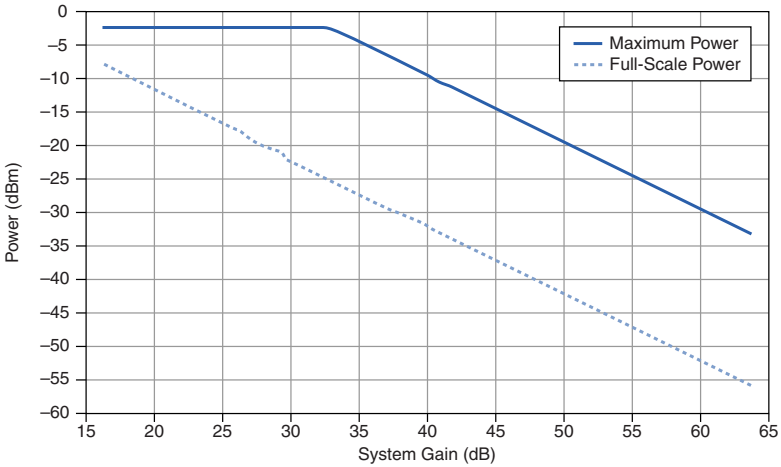


Figure 6. mmRH-3652 mmWave Radio Head Noise Figure[6]



[6] With the PXIe-3620 and the PXIe-3630 Digitizer.

Figure 7. Receiver Maximum Power (Damage)[7]



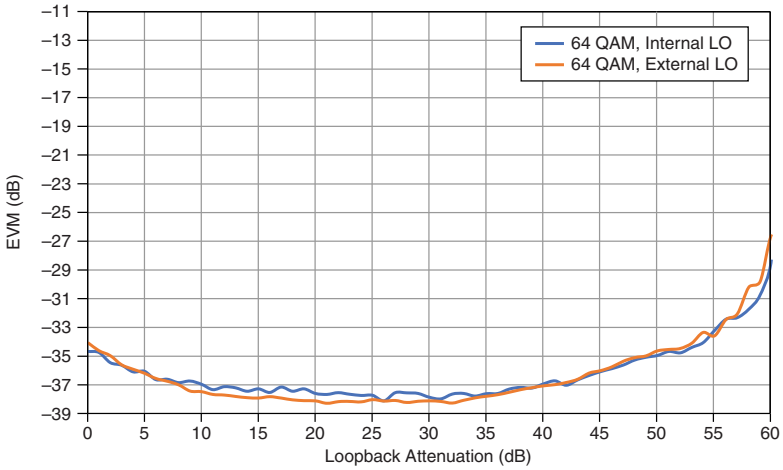
Note NI recommends keeping the incident power less than or equal to the full-scale power.

37 GHz to 43.5 GHz mmWave Transceiver System

A variable attenuator is placed between the transmitter and receiver to simulate path loss at 39 GHz. The EVM of various single-carrier signals at a symbol rate of 768 MBaud (RRC filter $\alpha = 0.3$) is shown in the following figure.

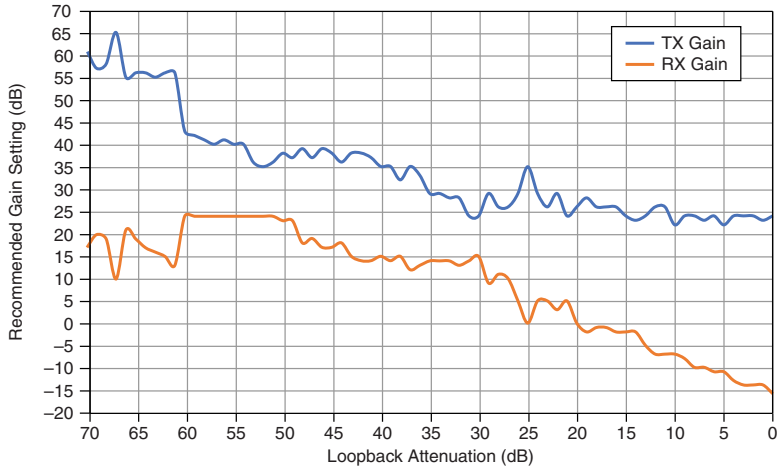
[7] Maximum power is the input power at which the receiver could be damaged.

Figure 8. EVM Versus Loopback Attenuation



The transmitter and receiver gain settings used for the EVM measurement are shown in the following figure.

Figure 9. Transmitter and Receiver Gain Settings

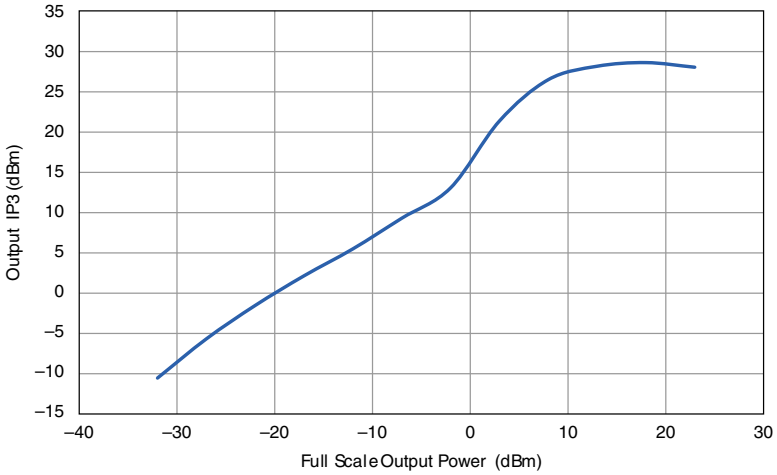


Transmitter

Tuning range	37 GHz to 43.5 GHz
Instantaneous bandwidth	2 GHz
Connector	2.4 mm

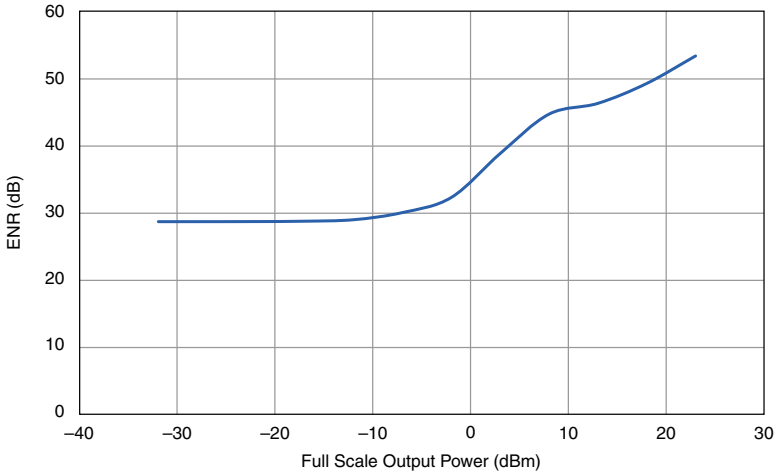
Analog gain range	55 dB
Saturated power[8]	26 dBm (approximately)
Output IP3[8]	28 dBm

Figure 10. mmRH-3643 mmWave Radio Head Simulated Output IP3[9]



[8] At maximum gain.
[9] Driven by the PXIe-3610 and the PXIe-3620 with a two-tone signal at -7 dBFS.

Figure 11. mmRH-3643 mmWave Radio Head ENR[10]



Note mmRH-3643 simulated output IP3[10] and ENR[10] is very similar to that of the mmRH-3603 mmWave Radio Head.

Receiver

Tuning range	37 GHz to 43.5 GHz
Instantaneous bandwidth	2 GHz
Connector	2.4 mm
Analog gain range	50 dB
1 dB gain compression[11]	-10 dBm to -15 dBm
Noise figure[12]	6 dB

[10] Driven by the PXIe-3610 and the PXIe-3620 with a two-tone signal at -7 dBFS.
[11] Near minimum gain. For lower gain settings, 1 dB compression is higher than full-scale.
[12] At maximum gain.

Figure 12. mmRH-3653 mmWave Radio Head Simulated Input IP3[13]

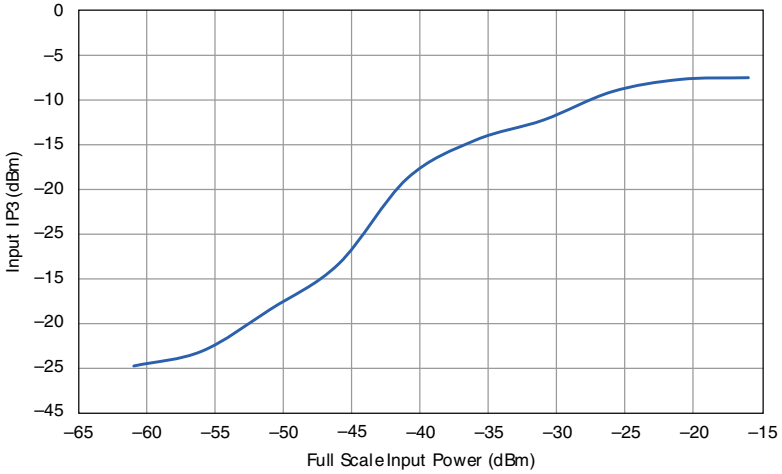
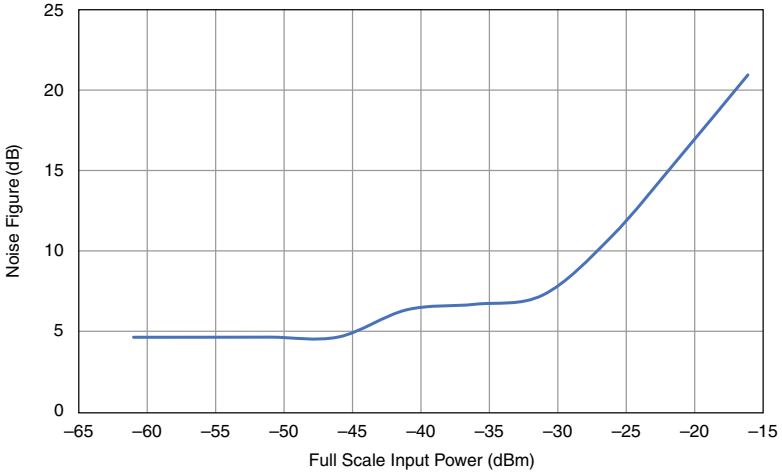
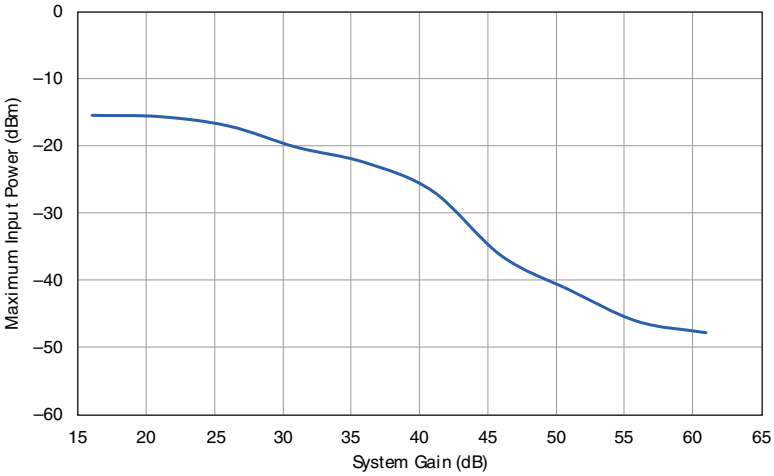


Figure 13. mmRH-3653 mmWave Radio Head Noise Figure[13]



[13] With the PXIe-3610 and the PXIe-3630.

Figure 14. Receiver Maximum Power (Damage)[14]



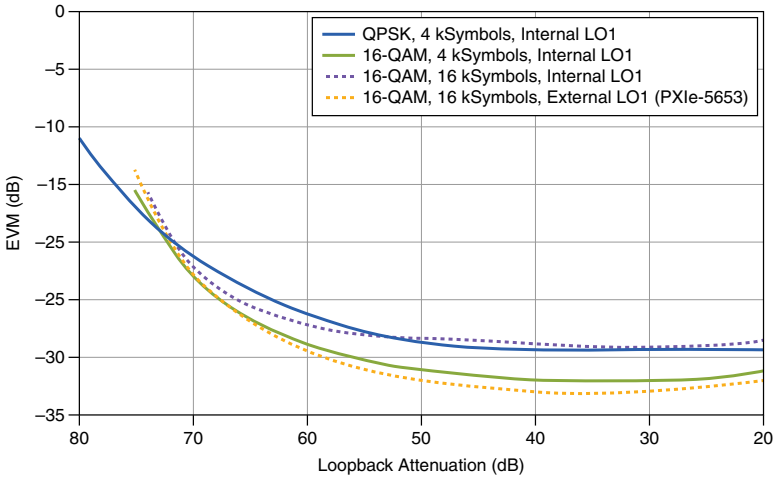
Note NI recommends keeping the incident power less than or equal to the full-scale power.

71 GHz to 76 GHz mmWave Transceiver System

A variable attenuator is placed between the transmitter and receiver to simulate path loss at 73 GHz. The EVM of various single-carrier signals at a symbol rate of 1,536 MBaud (RRC filter $\alpha = 0.3$) is shown in the following figure.

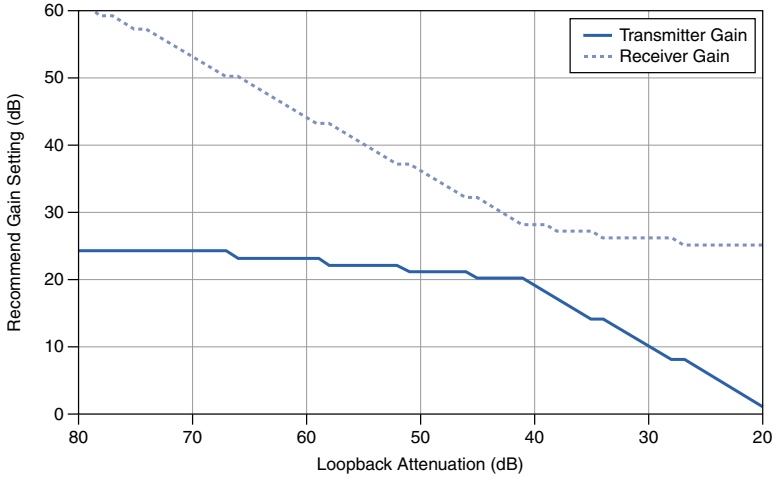
[14] Maximum power is the input power at which the receiver could be damaged.

Figure 15. EVM Versus Loopback Attenuation



The transmitter and receiver gain settings used for the EVM measurement are shown in the following figure.

Figure 16. Transmitter and Receiver Gain Settings

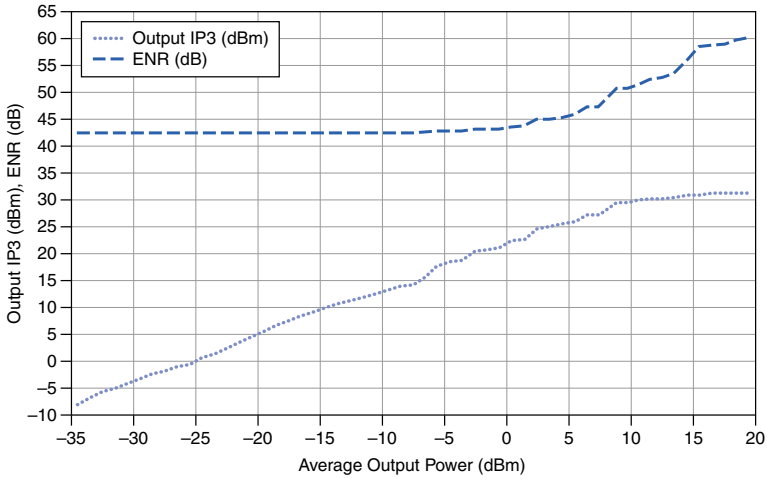


Transmitter

Tuning range	71 GHz to 76 GHz
Instantaneous bandwidth	2 GHz

Connector	WR-12
Analog gain range	55 dB
Saturated power[15]	+24 dBm
Output third-order intercept (IP3)[15]	+30 dBm
Local oscillator (LO) re-radiation[16]	<-90 dBm

Figure 17. mmRH-3647 mmWave Radio Head Simulated Output IP3 and ENR[17]



Receiver

Tuning range	71 GHz to 76 GHz
Instantaneous bandwidth	2 GHz
Connector	WR-12
Analog gain range	55 dB
1 dB gain compression[18]	-12 dBm
Noise figure[19]	6 dB
Image rejection[20]	>80 dB

15 At maximum gain.
16 Refers to super-heterodyne LO.
17 Driven by the PXIe-3610 and the PXIe-3620 with a two-tone signal at -7 dBFS.
18 Near minimum gain. For lower gain settings, 1 dB compression is higher than full-scale.
19 At maximum gain.
20 Refers to super-heterodyne image.

Figure 18. mmRH-3657 mmWave Radio Head Simulated Input IP3 and Noise Figure[21]

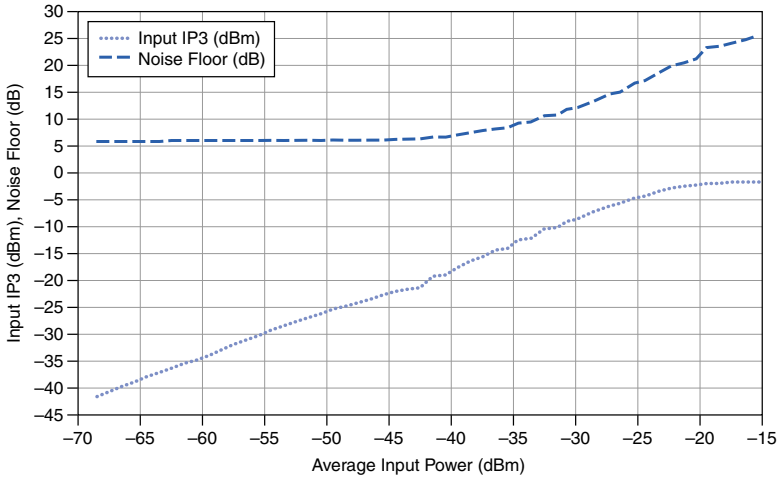
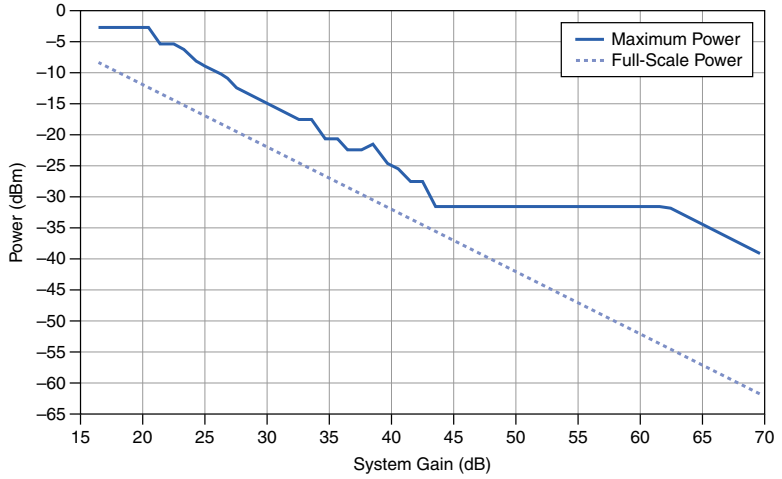


Figure 19. Receiver Maximum Power (Damage)[22]



Note NI recommends keeping the incident power less than or equal to the full-scale power.

[21] With the PXIe-3620 and the PXIe-3630.

[22] Maximum power is the input power at which the receiver could be damaged.

PXIe-3610 Waveform Generator

Sample rates	2.94912 GS/s 3.072 GS/s
DC offset	±40 mV
Second harmonics	-60 dBc
Third harmonics	-65 dBc
Bandwidth	
Per I or Q	DC to 1 GHz
Complex	2 GHz
I or Q Channels	
Connector	MMPX (100 Ω, differential)
Full-scale	+1 dBm; 1 V_{pk-pk}
Common-mode voltage	0 VDC
Flatness	±1.5 dB
Third-order intermodulation distortion (IMD3)[23]	-75 dBc at 100 MHz -65 dBc at 1,000 MHz
Noise density	-155 dBm/Hz
Amplitude mismatch[24]	±0.2 dB
Phase mismatch[24]	±0.5 degrees
REF IN	
Connector	MMPX (50 Ω)
Frequency	10 MHz
Power	0 dBm to +13 dBm
REF OUT	
Connector	MMPX (50 Ω)
Frequency	10 MHz
Power	+10 dBm
Digital input	Mini-SAS HD

[23] Two-tone signal at -7 dBFS.
[24] Calibrated.

PXIe-3620 RF Upconverter and Downconverter Module

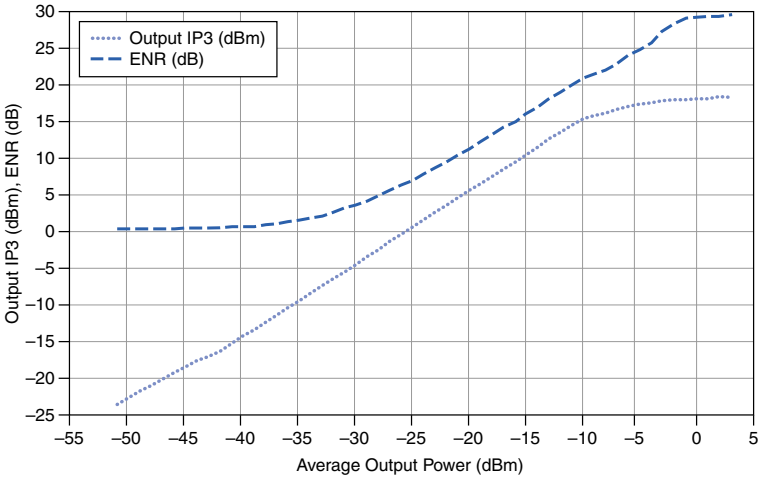
IF Interface	
IF OUT	
Connector	SMA female (50 Ω)
Tuning range	8.5 GHz to 13.5 GHz
Linear power	-40 dBm to 7 dBm
IF IN	
Connector	SMA female (50 Ω)
Tuning range	8.5 GHz to 13.5 GHz
Linear power	-25 dBm to +20 dBm
LO1 Interface	
LO1 TX/RX IN	
Connector	MMPX female (50 Ω)
Frequency	4 GHz to 8 GHz
Nominal input level	+9 dBm
Damage level	+18 dBm
LO1 TX/RX OUT	
Connector	MMPX female (50 Ω)
Frequency	4 GHz to 8 GHz
Maximum power	+8 dBm to +15 dBm
LO1 TX/RX mmWave OUT	
Connector	SMA female (50 Ω)
Frequency	4 GHz to 13.7 GHz
Maximum power	+10 dBm to +15 dBm
Internal LO1 Frequency Resolution	
4 GHz to 8 GHz	1 MHz
8 GHz to 13.7 GHz	2 MHz
LO2 Interface	
LO2 IN	
Connector	MMPX female (50 Ω)
Frequency	2.8 GHz to 4.5 GHz

Nominal input level	+9 dBm
Damage level	+18 dBm
LO2 OUT	
Connector	MMPX female (50 Ω)
Frequency	2.8 GHz to 4.5 GHz
Maximum power	+11 dBm to +13 dBm
LO2 REF IN/OUT	
Connector	MMPX female (50 Ω)
Frequency	10 MHz
Nominal level	1.6 V_{pk-pk}
Damage level	5 V_{pk-pk}
Internal LO2 frequency resolution	1 MHz
Baseband Interface	
I/Q OUT	
Connector	MMPX female (100 Ω differential)
Frequency	DC to 1 GHz
Nominal level[25]	+5 dBm
Common-mode voltage	0 V_{DC}
I/Q IN	
Connector	MMPX female (100 Ω)
Frequency	DC to 1 GHz
Nominal level[25]	+1 dBm
Damage level	+20 dBm
Common-mode voltage	0 V_{DC}

The following figure shows the simulated output IP3 and ENR of the PXIe-3620, when driven by the PXIe-3610 with a two-tone signal at -7 dBFS.

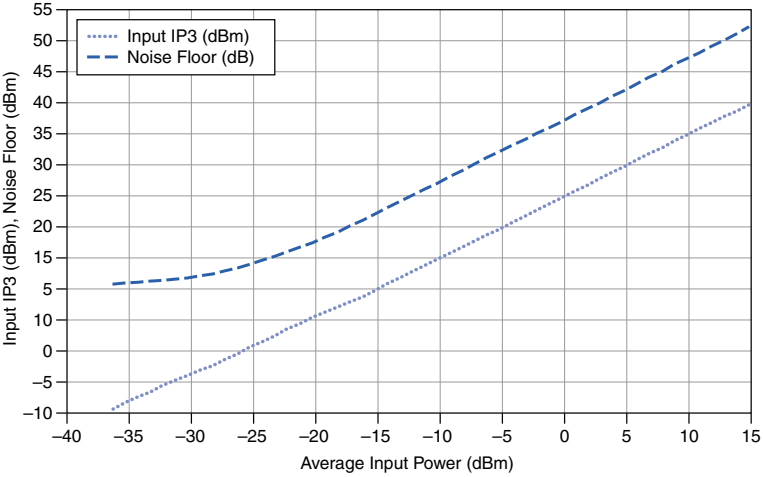
[25] For a single I or Q differential port.

Figure 20. IF Transmitter Noise and Distortion



The following figure shows the simulated input IP3 and noise figure of the PXIe-3620 with the PXIe-3630.

Figure 21. IF Receiver Noise and Distortion



The phase noise added by the mmWave radio heads is nominally $20 \times \log_{10}(x)$ dB higher, where x is the LO1 multiplication factor.

Table 1. LO1 Multiplication Factor

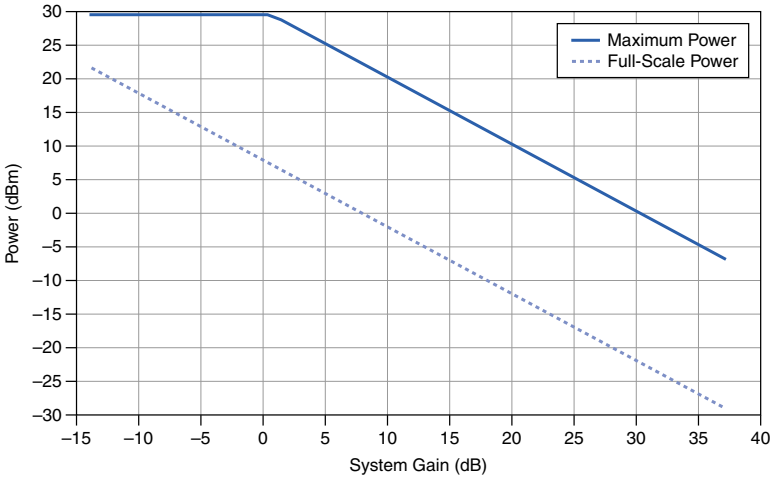
mmWave Radio Heads	LO1 Multiplication Factor *x*	Additional Information
mmRH-3602/3642/3652	8	A factor of 4 comes from the radio heads, and a factor of 2 comes from the LO1 doubler
mmRH-3603/3643/3653	6	A factor of 3 comes from the radio heads, and a factor of 2 comes from the LO1 doubler
mmRH-3647/3657	8	The factor of 8 comes exclusively from the radio heads

Nominal single sideband (SSB) phase noise for the internal LO1 and internal LO2 on a PXIe-3620 module is shown in the following table.

Table 2. SSB Phase Noise

Offset	LO1 (dBc/Hz)	LO2 (dBc/Hz)
100 Hz	-70	-70
1 kHz	-92	-92
10 kHz	-98	-98
100 kHz	-104	-104
1 MHz	-130	-130

Figure 22. IF Receiver Maximum Power[26] (Damage)



Note NI recommends keeping the incident power less than or equal to the full-scale power.

PXIe-3630 Digitizer

Sample rates	2.94912 GS/s 3.072 GS/s
DC offset	±10 mV
Second harmonics	-60 dBc
Third harmonics	-60 dBc
Bandwidth	
Per I or Q	DC to 1 GHz
Complex	2 GHz
I or Q Channels	
Connector	MMPX (100 Ω, differential)
Full-scale	+5 dBm, 1.59 V_{pk-pk}
Common-mode voltage	0 VDC
Flatness	±3.0 dB

[26] Maximum power is the input power at which the receiver could be damaged.

IMD3[23]	-65 dBc at 100 MHz -60 dBc at 1,000 MHz
Noise density	-148 dBFS/Hz at 100 MHz -143 dBFS/Hz at 1,000 MHz
Amplitude mismatch[24]	±0.2 dB
Phase mismatch[24]	±1.5 degrees
REF IN	
Connector	MMPX (50 Ω)
Frequency	10 MHz
Power	0 dBm to +13 dBm
REF OUT	
Connector	MMPX (50 Ω)
Frequency	10 MHz
Power	+10 dBm
Digital output	Mini-SAS HD

PXIe-7902 High-Speed Serial Instrument

Refer to the *PXIe-7902 Specifications*, available online at *ni.com/manuals*, for specifications related to the PXIe-7902 High-Speed Serial Instrument.

mmRH-3602 mmWave Radio Head

RF IN/OUT	
Connector	2.92 mm female
Tuning range	24.25 GHz to 33.40 GHz
IF IN/OUT	
Connector	SMA female (50 Ω)
Frequency range	9.56 GHz to 11.56 GHz
LO IN	
Connector	SMA female (50 Ω)
Frequency range	9,515 MHz to 10,015 MHz
Power	+5 dBm

DC Power	2.5 A at +12 V
Weight	2.4 lbs
Dimensions (L × W × H)	14.0 cm × 12.7 cm × 7.87 cm (5.5 in. × 5.0 in. × 3.1 in.)

mmRH-3603 mmWave Radio Head

RF IN/OUT	
Connector	2.4 mm female
Tuning range	37 GHz to 43.5 GHz
IF IN/OUT	
Connector	SMA female (50 Ω)
Frequency range	9.56 GHz to 11.56 GHz
LO IN	
Connector	SMA female (50 Ω)
Frequency range	9,515 MHz to 10,015 MHz
Power	+5 dBm
DC Power	2.5 A at +12 V
Weight	2.4 lbs
Dimensions (L × W × H)	14.0 cm × 12.7 cm × 7.87 cm (5.5 in. × 5.0 in. × 3.1 in.)

mmRH-3642 mmWave Radio Head

RF OUT	
Connector	2.92 mm female
Tuning range	24.25 GHz to 33.40 GHz
IF OUT	
Connector	SMA female (50 Ω)
Frequency range	9.56 GHz to 11.56 GHz
LO IN	
Connector	SMA female (50 Ω)
Frequency range	9,515 MHz to 10,015 MHz
Power	+5 dBm

DC Power	2.0 A at +12 V
Weight	1.8 lbs
Dimensions (L × W × H)	14.0 cm × 12.7 cm × 7.87 cm (5.5 in. × 5.0 in. × 3.1 in.)

mmRH-3643 mmWave Radio Head

RF OUT	
Connector	2.4 mm female
Tuning range	37 GHz to 43.5 GHz
IF OUT	
Connector	SMA female (50 Ω)
Frequency range	9.56 GHz to 11.56 GHz
LO IN	
Connector	SMA female (50 Ω)
Frequency range	9,515 MHz to 10,015 MHz
Power	+5 dBm
DC Power	2.0 A at +12 V
Weight	1.8 lbs
Dimensions (L × W × H)	14.0 cm × 12.7 cm × 7.87 cm (5.5 in. × 5.0 in. × 3.1 in.)

mmRH-3647 mmWave Radio Head

RF OUT	
Connector	WR-12
Tuning range	71 GHz to 76 GHz
IF OUT	
Connector	SMA female (50 Ω)
Frequency range	11 GHz to 13 GHz
LO IN	
Connector	SMA female (50 Ω)
Frequency range	7,375 MHz to 8,000 MHz
Power	+5 dBm

DC Power	1.8 A at +12 V
Weight	4.8 lbs
Dimensions (L × W × H)	19.1 cm × 11.7 cm × 6.1 cm (7.5 in. × 4.6 in. × 2.4 in.)

mmRH-3652 mmWave Radio Head

RF IN	
Connector	2.92 mm female
Tuning range	24.25 GHz to 33.40 GHz
IF IN	
Connector	SMA female (50 Ω)
Frequency range	9.56 GHz to 11.56 GHz
LO IN	
Connector	SMA female (50 Ω)
Frequency range	9,515 MHz to 10,015 MHz
Power	+5 dBm
DC Power	1.5 A at +12 V
Weight	1.8 lbs
Dimensions (L × W × H)	14.0 cm × 12.7 cm × 7.87 cm (5.5 in. × 5.0 in. × 3.1 in.)

mmRH-3653 mmWave Radio Head

RF IN	
Connector	2.4 mm female
Tuning range	37 GHz to 43.5 GHz
IF IN	
Connector	SMA female (50 Ω)
Frequency range	9.56 GHz to 11.56 GHz
LO IN	
Connector	SMA female (50 Ω)
Frequency range	9,515 MHz to 10,015 MHz
Power	+5 dBm

DC Power	1.5 A at +12 V
Weight	1.8 lbs
Dimensions (L × W × H)	14.0 cm × 12.7 cm × 7.87 cm (5.5 in. × 5.0 in. × 3.1 in.)

mmRH-3657 mmWave Radio Head

RF IN	
Connector	WR-12
Tuning range	71 GHz to 76 GHz
IF IN	
Connector	SMA female (50 Ω)
Frequency range	11 GHz to 13 GHz
LO IN	
Connector	SMA female (50 Ω)
Frequency range	7,375 MHz to 8,000 MHz
Power	+5 dBm
DC Power	1.2 A at +12 V
Weight	4.8 lbs
Dimensions (L × W × H)	19.1 cm × 11.7 cm × 6.1 cm (7.5 in. × 4.6 in. × 2.4 in.)

Compliance and Certifications

Safety Compliance Standards

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 *Product Certifications and Declarations* section.

Electromagnetic Compatibility Standards

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
- AS/NZS CISPR 11: Group 1, Class A emissions
- FCC 47 CFR Part 15B: Class A emissions
- ICES-003: Class A emissions

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 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.

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)
- 2011/65/EU; Restriction of Hazardous Substances (RoHS)

Product Certifications and Declarations

Refer to the product Declaration of Conformity (DoC) for additional regulatory compliance information. To obtain product certifications and the DoC for NI products, visit *ni.com/product-certifications*, search by model number, and click the appropriate link.

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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