Integrated Dual RF Transmitter, Receiver, and Observation Receiver

Data Sheet

ADRV9009

FEATURES

Dual transmitters
Dual receivers
Dual input shared observation receiver
Maximum receiver bandwidth: 200 MHz
Maximum tunable transmitter synthesis bandwidth: 450 MHz
Maximum observation receiver bandwidth: 450 MHz
Fully integrated fractional-N RF synthesizers
Fully integrated clock synthesizer
Multichip phase synchronization for RF LO and baseband clocks
JESD204B datapath interface
Tunable range: 75 MHz to 6000 MHz

APPLICATIONS

3G/4G/5G TDD macro cell base stations
TDD active antenna systems
Massive MIMO
Phased array radar
Electronic warfare
Military communications
Portable test equipment

GENERAL DESCRIPTION

The ADRV9009 is a highly integrated, radio frequency (RF), agile transceiver offering dual transmitters and receivers, integrated synthesizers, and digital signal processing functions. The IC delivers a versatile combination of high performance and low power consumption demanded by 3G, 4G, and 5G macro cell time division duplex (TDD) base station applications.

The receive path consists of two independent, wide bandwidth, direct conversion receivers with state-of-the-art dynamic range. The device also supports a wide bandwidth, time shared observation path receiver (ORx) for use in TDD applications. The complete receive subsystem includes automatic and manual attenuation control, dc offset correction, quadrature error correction (QEC), and digital filtering, thus eliminating the need for these functions in the digital baseband. Several auxiliary functions, such as analog to digital converters (ADCs), digital-to-analog converters (DACs), and general-purpose input/outputs (GPIOs) for the power amplifier (PA), and RF front-end control are also integrated.

In addition to automatic gain control (AGC), the ADRV9009 also features flexible external gain control modes, allowing significant flexibility in setting system level gain dynamically.

The received signals are digitized with a set of four high dynamic range, continuous time Σ-Δ ADCs that provide inherent antialiasing. The combination of the direct conversion architecture, which does not suffer from out of band image mixing, and the lack of aliasing, relaxes the requirements of the RF filters when compared to traditional IF receivers.

The transmitters use an innovative direct conversion modulator that achieves high modulation accuracy with exceptionally low noise.

The observation path consists of a wide bandwidth, direct conversion receiver with state-of-the-art dynamic range.

The fully integrated phase-locked loop (PLL) provides high performance, low power, fractional-N RF frequency synthesis for the transmitter (Tx) and receiver (Rx) signal paths. An additional synthesizer generates the clocks needed for the converters, digital circuits, and the serial interface. A multichip synchronization mechanism synchronizes the phase of the RF local oscillator and baseband clocks between multiple ADRV9009 chips. Precautions are taken to provide the isolation demanded in high performance base station applications. All voltage controlled oscillators (VCOs) and loop filter components are integrated.

The high speed JESD204B interface supports up to 12.288 Gbps lane rates resulting in two lanes per transmitter, and a single lane per receiver in the widest bandwidth mode. The interface also supports interleaved mode for lower bandwidths, thus reducing the total number of high speed data interface lanes to one. Both fixed and floating point data formats are supported. The floating point format allows internal AGC to be invisible to the demodulator device.

The core of the ADRV9009 can be powered directly from 1.3 V and 1.8 V regulators and is controlled via a standard 4-wire serial port. Comprehensive power-down modes are included to minimize power consumption in normal use. The ADRV9009 is packaged in a 12 mm × 12 mm, 196-ball chip scale ball grid array (CSP_BGA).

Rev. A Document Feedback

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REVISION HISTORY

6/2018—Revision A: Initial Version

FUNCTIONAL BLOCK DIAGRAM

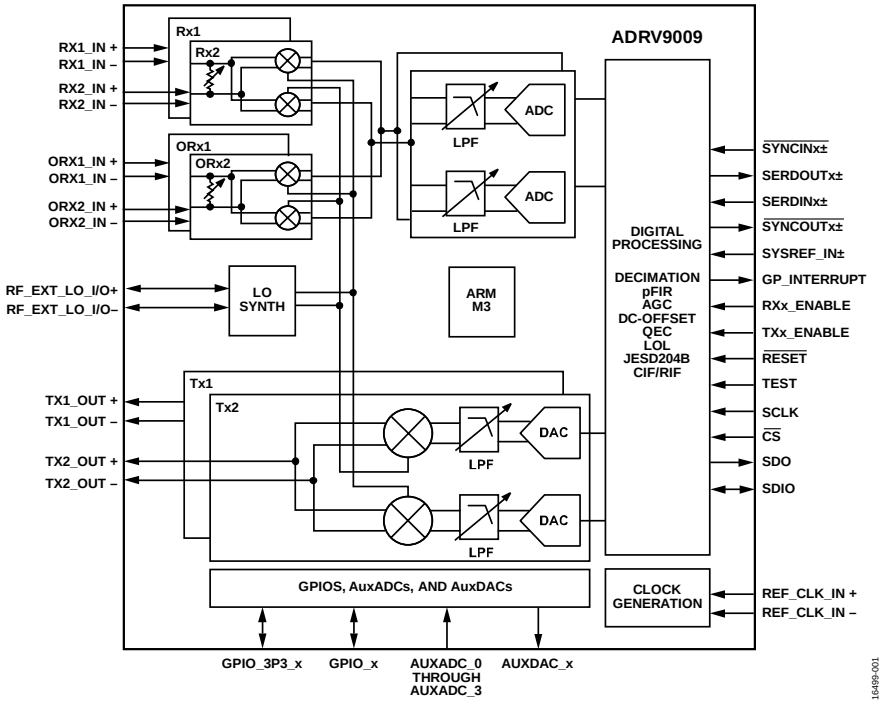

Figure 1.

SPECIFICATIONS

Electrical characteristics at VDDA1P3[1] = 1.3 V, VDDD1P3_DIG = 1.3 V, VDDA1P8_TX = 1.8 V, T_J = full operating temperature range. Local oscillator frequency (f_{LO}) = 1800 MHz, unless otherwise noted. The specifications in Table 1 are not deembedded. Refer to the Typical Performance Characteristics section for input/output circuit path loss. The device configuration profile, unless otherwise specified, is as follows: receiver = 200 MHz (in-phase quadrature (IQ) rate = 245.76 MHz), transmitter = 200 MHz/450 MHz (IQ rate = 491.52 MHz), observation receiver = 450 MHz (IQ rate = 491.52 MHz), JESD204B rate = 9.8304 GSPS, and device clock = 245.76 MHz.

Table 1.

Parameter	Symbol	Min	Typ	Max	Unit	Test Conditions/Comments
TRANSMITTERS						
Center Frequency		75		6000	MHz	
Transmitter Synthesis Bandwidth				450	MHz	
Transmitter Large Signal Bandwidth				200	MHz	
Peak to Peak Gain Deviation			1.0		dB	450 MHz bandwidth, compensated by programmable finite impulse response (FIR) filter
Gain Slope			±0.1		dB	Any 20 MHz bandwidth span, compensated by programmable FIR filter
Deviation from Linear Phase			1		Degrees	450 MHz bandwidth
Transmitter Attenuation Power Control Range		0		32	dB	Signal-to-noise ratio (SNR) maintained for attenuation between 0 dB and 20 dB
Transmitter Attenuation Power Control Resolution			0.05		dB	
Transmitter Attenuation Integral Nonlinearity	INL		0.1		dB	For any 4 dB step
Transmitter Attenuation Differential Nonlinearity	DNL		+0.04		dB	Monotonic
Transmitter Attenuation SPI-2 Timing						See Figure 4
Time from $\overline{CS}$ Going High to Change in Transmitter Attenuation	t_{SCH}	19.5		24	ns	
Time Between Consecutive Micro Attenuation Steps	t_{ACH}	6.5		8.1	ns	A large change in attenuation can be broken up into a series of smaller attenuation changes
Time Required to Reach Final Attenuation Value	t_{DCH}			800	ns	Time required to complete the change in attenuation from start attenuation to final attenuation value
Maximum Attenuation Overshoot During Transition		−1.0		+0.5	dB	
Change in Attenuation per Micro Step				0.5	dB	
Maximum Attenuation Change when $\overline{CS}$ Goes High			32		dB	
Adjacent Channel Leakage Ratio (ACLR) Long Term Evolution (LTE)						20 MHz LTE at −12 dBFS
			−67		dB	75 MHz < f ≤ 2800 MHz
			−64		dB	2800 MHz < f ≤ 4800 MHz
			−60		dB	4800 MHz < f ≤ 6000 MHz

Parameter	Symbol	Min	Typ	Max	Unit	Test Conditions/Comments
In Band Noise Floor						0 dB attenuation; in band noise falls 1 dB for each dB of attenuation for attenuation between 0 dB and 20 dB
			−148		dBm/Hz	600 MHz < f ≤ 3000 MHz
			−149		dBm/Hz	3000 MHz < f ≤ 4800 MHz
			−150.5		dBm/Hz	4800 MHz < f ≤ 6000 MHz
Out of Band Noise Floor						0 dB attenuation; 3 × bandwidth/2 offset
			−153		dBm/Hz	600 MHz < f ≤ 3000 MHz
			−154		dBm/Hz	3000 MHz < f ≤ 4800 MHz
			−155.5		dBm/Hz	4800 MHz < f ≤ 6000 MHz
Interpolation Images			−80		dBc	
Transmitter to Transmitter Isolation			85		dB	75 MHz < f ≤ 600 MHz
			75		dB	600 MHz < f ≤ 2800 MHz
			70		dB	2800 MHz < f ≤ 4800 MHz
			65		dB	4800 MHz < f ≤ 5700 MHz
			56		dB	5700 MHz < f ≤ 6000 MHz
Image Rejection						
Within Large Signal Bandwidth						QEC active
			70		dB	75 MHz < f ≤ 600 MHz
			65		dB	600 MHz < f ≤ 4000 MHz
			62		dB	4000 MHz < f ≤ 4800 MHz
			60		dB	4800 MHz < f ≤ 6000 MHz
Beyond Large Signal Bandwidth			40		dB	Assumes that distortion power density is 25 dB below desired power density
Maximum Output Power						0 dBFS, continuous wave tone into 50 Ω load, 0 dB transmitter attenuation
			9		dBm	75 MHz < f ≤ 600 MHz
			7		dBm	600 MHz < f ≤ 3000 MHz
			6		dBm	3000 MHz < f ≤ 4800 MHz
			4.5		dBm	4800 MHz < f ≤ 6000 MHz
Third Order Output Intermodulation Intercept Point	OIP3					0 dB transmitter attenuation
			29		dBm	75 MHz < f ≤ 600 MHz
			27		dBm	600 MHz < f ≤ 4000 MHz
			23		dBm	4000 MHz < f ≤ 6000 MHz
Carrier Leakage						With LO leakage correction active, 0 dB attenuation; scales decibel for decibel with attenuation; measured in 1 MHz bandwidth, resolution bandwidth and video bandwidth = 100 kHz, rms detector, 100 trace average
Carrier Offset from Local Oscillator (LO)			−84		dBFS	75 MHz < f ≤ 600 MHz
			−82		dBFS	600 MHz < f ≤ 4800 MHz
			−80		dBFS	4800 MHz < f ≤ 6000 MHz
Carrier on LO			−71		dBFS	

Parameter	Symbol	Min	Typ	Max	Unit	Test Conditions/Comments
Error Vector Magnitude (Third Generation Partnership Project (3GPP) Test Signals)	EVM					
75MHz LO			0.5		%	300 kHz RF PLL loop bandwidth
1900 MHz LO			0.7		%	50 kHz RF PLL loop bandwidth
3800 MHz LO			0.7		%	300 kHz RF PLL loop bandwidth
5900 MHz LO			1.1		%	300 kHz RF PLL loop bandwidth
Output Impedance	Z_{OUT}		50		Ω	Differential (see Figure 428)
OBSERVATION RECEIVER	ORx					
Center Frequency		75		6000	MHz	
Gain Range			30		dB	IIP3 improves decibel for decibel for the first 18 dB of gain attenuation; QEC performance optimized for 0 dB to 6 dB of attenuation only
Analog Gain Step			0.5		dB	For attenuator steps from 0 dB to 6 dB
Peak to Peak Gain Deviation			1		dB	450 MHz bandwidth, compensated by programmable FIR filter
Gain Slope			±0.1		dB	Any 20 MHz bandwidth span, compensated by programmable FIR filter
Deviation from Linear Phase			1		Degrees	450 MHz RF bandwidth
Receiver Bandwidth				450	MHz	
Receiver Alias Band Rejection		60			dB	Due to digital filters
Maximum Useable Input Level	P_{HIGH}					0 dB attenuation; increases decibel for decibel with attenuation; continuous wave corresponds to −1 dBFS at ADC
			−11		dBm	75 MHz < f ≤ 3000 MHz
			−9.5		dBm	3000 MHz < f ≤ 4800 MHz
			−8		dBm	4800 MHz < f ≤ 6000 MHz
Integrated Noise			−58.5		dBFS	450 MHz integration bandwidth
			−57.5		dBFS	491.52 MHz integration bandwidth
Second-Order Input Intermodulation Intercept Point	IIP2		62		dBm	Maximum observation receiver gain; P_{HIGH} − 14 dB per tone (see the Terminology section) 75 MHz < f ≤ 600 MHz
			62		dBm	Maximum observation receiver gain; P_{HIGH} − 8 dB per tone (see the Terminology section) 600 MHz < f ≤ 3000 MHz
Third-Order Input Intermodulation Intercept Point	IIP3					
Narrow Band			4		dBm	75 MHz < f ≤ 300 MHz; (P_{HIGH} − 14) dB/tone
			11		dBm	300 MHz < f ≤ 600 MHz; (P_{HIGH} − 14) dB/tone IM3 product < 130 MHz at baseband; (P_{HIGH} − 8) dB/tone
			12		dBm	600 MHz < f ≤ 3000 MHz
			12		dBm	3000 MHz < f ≤ 4800 MHz
			11		dBm	4800 MHz < f ≤ 6000 MHz

Parameter	Symbol	Min	Typ	Max	Unit	Test Conditions/Comments
Wide Band						
			7		dBm	600 MHz < f ≤ 3000 MHz
			7		dBm	3000 MHz < f ≤ 4800 MHz
			6		dBm	4800 MHz < f ≤ 6000 MHz
Third-Order Intermodulation Product	IM3					IM3 product < 130 MHz at baseband; two tones, each at (P_{HIGH} − 12) dB
			−70		dBc	600 MHz < f ≤ 3000 MHz
			−67		dBc	3000 MHz < f ≤ 4800 MHz
			−62		dBc	4800 MHz < f ≤ 6000 MHz
Fifth-Order Intermodulation Product (1800 MHz)	IM5		−80		dBc	IM5 product < 50 MHz at baseband; two tones, each at (P_{HIGH} − 14) dB
Seventh-Order Intermodulation Product (1800 MHz)	IM7		−80		dBc	IM7 product < 50 MHz at baseband; two tones, each at (P_{HIGH} − 14) dB
Spurious-Free Dynamic Range	SFDR		70		dB	Non IMx related spurs, does not include HDx; (P_{HIGH} − 11) dB input signal
Harmonic Distortion						(P_{HIGH} − 11) dB input signal
Second Order Harmonic Distortion Product	HD2		−80		dBc	In band HD falls within ±25 MHz
			−80		dBc	Out of band HD falls within ±50 MHz
Third-Order Harmonic Distortion Product	HD3		−70		dBc	In band HD falls within ±25 MHz
			−60		dBc	Out of band HD falls within ±50 MHz
Image Rejection						QEC active
Within Large Signal Bandwidth			65		dB	
Outside Large Signal Bandwidth			55		dB	
Input Impedance			100		Ω	Differential (see Figure 429)
Isolation						
			65		dB	600 MHz < f ≤5300 MHz
			55		dB	5300 MHz < f ≤ 6000 MHz
			65		dB	600 MHz < f ≤ 5300 MHz
			55		dB	5300 MHz < f ≤ 6000 MHz
RECEIVERS						
Center Frequency		75		6000	MHz	
Gain Range			30		dB	
Analog Gain Step			0.5		dB	Attenuator steps from 0 dB to 6 dB
			1		dB	Attenuator steps from 6 dB to 30 dB
Bandwidth Ripple			±0.5		dB	200 MHz bandwidth, compensated by programmable FIR filter
			±0.2		dB	Any 20 MHz bandwidth span, compensated by programmable FIR filter
Receiver Bandwidth				200	MHz	
Receiver Alias Band Rejection		80			dB	Due to digital filters
Maximum Useable Input Level	P_{HIGH}					0 dB attenuation, increases decibel for decibel with attenuation; continuous wave = 1800 MHz; corresponds to −1 dBFS at ADC
			−11		dBm	75 MHz < f ≤ 3000 MHz
			−10.2		dBm	3000 MHz < f ≤ 4800 MHz
			−9.5		dBm	4800 MHz < f ≤ 6000 MHz

Parameter	Symbol	Min	Typ	Max	Unit	Test Conditions/Comments
Noise Figure	NF					0 dB attenuation, at receiver port
			12		dB	600 MHz < f ≤ 3000 MHz
			13		dB	3000 MHz < f ≤ 4800 MHz
			15.2		dB	4800 MHz < f ≤ 6000 MHz
Ripple			1.8		dB	At band edge maximum bandwidth mode
Input Third-Order Intercept Point	IIP3					
Difference Product	IIP3, d		12		dBm	Two (P_{HIGH} − 12) dB tones near band edge
Sum Product	IIP3, s		12		dBm	Two (P_{HIGH} − 6) dB tones, at bandwidth/6 offset from the LO
HD3	HD3					(P_{HIGH} − 6) dB continuous wave tone at bandwidth/6 offset from the LO
			−66		dBc	600 MHz < f ≤ 4800 MHz
			−62		dBc	4800 MHz < f ≤ 6000 MHz
Second-Order Input Intermodulation Intercept Point	IIP2		62		dBm	0 dB attenuation, complex
Image Rejection			75		dB	Quadrature error correction (QEC) active, within 200 MHz receiver bandwidth
Input Impedance			100		Ω	Differential (see Figure 430)
			65		dB	600 MHz < f ≤ 4800 MHz
			61		dB	4800 MHz < f ≤ 6000 MHz
Receiver Band Spurs Referenced to RF Input at Maximum Gain			−95		dBm	No more than one spur at this level per 10 MHz of receiver bandwidth
Receiver LO Leakage at Receiver Input at Maximum Gain						Leakage decreases decibel for decibel with attenuation for first 12 dB
			−70		dBm	600 MHz < f ≤ 3000 MHz
			−65		dBm	3000 MHz < f ≤ 6000 MHz
Isolation						
			65		dB	600 MHz < f ≤ 4800 MHz
			55		dB	4800 MHz < f ≤ 6000 MHz
			65		dB	600 MHz < f ≤ 4800 MHz
			55		dB	4800 MHz < f ≤ 6000 MHz
LO SYNTHESIZER						
LO Frequency Step			2.3		Hz	1.5 GHz to 2.8 GHz, 76.8 MHz phase frequency detector (PFD) frequency
LO Spur			−85		dBc	Excludes integer boundary spurs
Integrated Phase Noise						2 kHz to 18 MHz
1900 MHz LO			0.2		°rms	Narrow PLL loop bandwidth (50 kHz)
3800 MHz LO			0.36		°rms	Wide PLL loop bandwidth (300 kHz)
5900 MHz LO			0.54		°rms	Wide PLL loop bandwidth (300 kHz)

Parameter	Symbol	Min	Typ	Max	Unit	Test Conditions/Comments
Spot Phase Noise						
1900 MHz LO						Narrow PLL loop bandwidth
100 kHz Offset			−100		dBc/Hz	
200 kHz Offset			−115		dBc/Hz	
400 kHz Offset			−120		dBc/Hz	
600 kHz Offset			−129		dBc/Hz	
800 kHz Offset			−132		dBc/Hz	
1.2 MHz Offset			−135		dBc/Hz	
1.8 MHz Offset			−140		dBc/Hz	
6 MHz Offset			−150		dBc/Hz	
10 MHz Offset			−153		dBc/Hz	
3800 MHz LO						Wide PLL loop bandwidth
100 kHz Offset			−104		dBc/Hz	
1.2 MHz Offset			−125		dBc/Hz	
10 MHz Offset			−145		dBc/Hz	
5900 MHz LO						Wide PLL loop bandwidth
100 kHz Offset			−99		dBc/Hz	
1.2 MHz Offset			−119.7		dBc/Hz	
10 MHz Offset			−135.4		dBc/Hz	
LO PHASE SYNCHRONIZATION						
Phase Deviation			1.6		ps/°C	Change in LO delay per temperature change
EXTERNAL LO INPUT						
Input Frequency	f_{EXTLO}	150		8000	MHz	Input frequency must be 2× the desired LO frequency
Input Signal Power		0		12	dBm	50 Ω matching at the source
			3		dBm	f_{EXTLO} ≤ 2 GHz; add 0.5 dBm/GHz above 2 GHz
			6		dBm	f_{EXTLO} = 8 GHz
External LO Input Signal Differential						To ensure adequate QEC
Phase Error				3.6	ps	
Amplitude Error				1	dB	
Duty Cycle Error				2	%	
Even-Order Harmonics				−50	dBc	
CLOCK SYNTHESIZER						
Integrated Phase Noise						1 kHz to 100 MHz
1966.08 MHz LO			0.4		°rms	PLL optimized for close in phase noise
Spot Phase Noise						
1966.08 MHz						
100 kHz Offset			−109		dBc/Hz	
1 MHz Offset			−129		dBc/Hz	
10 MHz Offset			−149		dBc/Hz	
REFERENCE CLOCK (REF_CLK_IN)						
Frequency Range		10		1000	MHz	
Signal Level		0.3		2.0	V p-p	AC-coupled, common-mode voltage (V_{CM}) = 618 mV; for best spurious performance, use <1 V p-p input clock

Parameter	Symbol	Min	Typ	Max	Unit	Test Conditions/Comments
AUXILIARY CONVERTERS						
ADC						
Resolution			12		Bits	
Input Voltage						
Minimum			0.05		V	
Maximum			VDDA_3P3 – 0.05		V	
DAC						
Resolution			10		Bits	Includes four offset levels
Output Voltage						
Minimum			0.7		V	1 V V_{REF}
Maximum			VDDA_3P3 – 0.3		V	2.5 V V_{REF}
Output Drive Capability			10		mA	
DIGITAL SPECIFICATIONS (CMOS)—SERIAL PERIPHERAL INTERFACE (SPI), GPIO_x, TXx_ENABLE, ORXx_ENABLE						
Logic Inputs						
Input Voltage						
High Level		VDD_INTERFACE × 0.8		VDD_INTERFACE	V	
Low Level		0		VDD_INTERFACE × 0.2	V	
Input Current						
High Level		−10		+10	µA	
Low Level		−10		+10	µA	
Logic Outputs						
Output Voltage						
High Level		VDD_INTERFACE × 0.8			V	
Low Level				VDD_INTERFACE × 0.2	V	
Drive Capability			3		mA	
DIGITAL SPECFICATIONS (CMOS)—GPIO_3P3_x						
Logic Inputs						
Input Voltage						
High Level		VDDA_3P3 × 0.8		VDDA_3P3	V	
Low Level		0		VDDA_3P3 × 0.2	V	
Input Current						
High Level		−10		+10	µA	
Low Level		−10		+10	µA	

Parameter	Symbol	Min	Typ	Max	Unit	Test Conditions/Comments
Logic Outputs						
Output Voltage						
High Level		VDDA_ 3P3 × 0.8			V	
Low Level				VDDA_ 3P3 × 0.2	V	
Drive Capability			4		mA	
DIGITAL SPECIFICATIONS (LVDS)						
Logic Inputs (SYSREF_IN±, SYNCINx±)						
Input Voltage Range		825		1675	mV	Each differential input in the pair
Input Differential Voltage Threshold		−100		+100	mV	
Receiver Differential Input Impedance			100		Ω	Internal termination enabled
Logic Outputs ($\overline{\text{SYNCOUTx±}}$)						
Output Voltage						
High				1375	mV	
Low		1025			mV	
Output Differential Voltage			225		mV	Programmable in 75 mV steps
Output Offset Voltage			1200		mV	
SPI TIMING						
SCLK Period	t_{CP}	20			ns	
SCLK Pulse Width	t_{MP}	10			ns	
$\overline{\text{CS}}$ Setup to First SCLK Rising Edge	t_{SC}	3			ns	
Last SCLK Falling Edge to $\overline{\text{CS}}$ Hold	t_{HC}	0			ns	
SDIO Data Input Setup to SCLK	t_S	2			ns	
SDIO Data Input Hold to SCLK	t_H	0			ns	
SCLK Rising Edge to Output Data Delay (3-Wire or 4-Wire Mode)	t_{CO}	3		8	ns	
Bus Turnaround Time, Read After BBP Drives Last Address Bit	t_{HZM}	t_H		t_{CO}	ns	
Bus Turnaround Time, Read After ADRV9009 Drives Last Data Bit	t_{HZS}	0		t_{CO}	ns	
JESD204B DATA OUTPUT TIMING						AC-coupled
Unit Interval	UI	81.38		320	ps	
Data Rate per Channel, Nonreturn to Zero (NRZ)		3125		12288	Mbps	
Rise Time	t_R	24	39.5		ps	20% to 80% in 100 Ω load
Fall Time	t_F	24	39.4		ps	20% to 80% in 100 Ω load
Output Common-Mode Voltage	V_{CM}	0		1.8	V	AC-coupled

Parameter	Symbol	Min	Typ	Max	Unit	Test Conditions/Comments
Differential Output Voltage	V_{DIFF}	360	600	770	mV	
Short-Circuit Current	I_{DSHORT}	−100		+100	mA	
Differential Termination Impedance		80	94.2	120	Ω	
Total Jitter			15.13		ps	Bit error rate (BER) = 10^{-15}
Uncorrelated Bounded High Probability Jitter	UBHPJ		0.56		ps	
Duty Cycle Distortion	DCD		0.369		ps	
SYSREF_IN± Setup Time to REF_CLK_IN_x		2.5			ns	See Figure 2
SYSREF_IN± Hold Time to REF_CLK_IN_x		−1.5			ns	See Figure 2
Latency	t_{LAT_FRM}					REF_CLK_IN = 245.76 MHz
			116.5		Clock cycles	Observation receiver bandwidth = 450 MHz, IQ rate = 491.52 MHz; lane rate = 9830.4 MHz, number of converters (M) = 4, number of lanes (L) = 2, converter resolution (N) = 16, number of samples per converter (S) = 1
			237.02		ns	
			89.4		Clock cycles	Receiver bandwidth = 200 MHz, IQ rate = 245.76 MHz; lane rate = 9830.4 MHz, M = 2, L = 2, N = 16, S = 1
			364.18		ns	
JESD204B DATA INPUT TIMING						AC-coupled
Unit Interval	UI	81.38		320	ps	
Data Rate per Channel (NRZ)		3125		12288	Mbps	
Differential Voltage	V_{DIFF}	125		750	mV	
VTT Source Impedance	Z_{TT}		8.9	30	Ω	
Differential Impedance	Z_{RDIFF}	80	105.1	120	Ω	
Termination Voltage	V_{TT}					
AC-Coupled		1.267		1.33	V	
Latency	t_{LAT_DEFRM}		74.45		Clock cycles	Device clock = 245.76 MHz, transmitter bandwidth = 200 MHz; IQ rate = 491.52 MHz, lane rate = 9830.4 MHz, M = 2, L = 2, N = 16, S = 1
			153.5		ns	

[1] VDDA1P3 refers to all analog 1.3 V supplies, including: VDDA1P3_RF_SYNTH, VDDA1P3_BB, VDDA1P3_RX_RF, VDDA1P3_RX_TX, VDDA1P3_RF_VCO_LDO, VDDA1P3_RF_LO, VDDA1P3_DES, VDDA1P3_SER, VDDA1P3_CLOCK_SYNTH, VDDA1P3_CLOCK_VCO_LDO, VDDA1P3_AUX_SYNTH, and VDDA1P3_AUX_VCO_LDO.

CURRENT AND POWER CONSUMPTION SPECIFICATIONS

Table 2.

Parameter	Min	Typ	Max	Unit	Test Conditions/Comments
SUPPLY CHARACTERISTICS					
VDDA1P3[1] Analog Supply	1.267	1.3	1.33	V	
VDDD1P3_DIG Supply	1.267	1.3	1.33	V	
VDDA1P8_TX Supply	1.71	1.8	1.89	V	
VDDA1P8_BB Supply	1.71	1.8	1.89	V	
VDD_INTERFACE Supply	1.71	1.8	2.625	V	CMOS and LVDS supply, 1.8 V to 2.5 V nominal range
VDDA_3P3 Supply	3.135	3.3	3.465	V	

Parameter	Min	Typ	Max	Unit	Test Conditions/Comments
POSITIVE SUPPLY CURRENT					LO at 2600 MHz
450 MHz Transmitter Bandwidth, Observation Receiver Disabled					Two transmitters enabled
VDDA1P3[1] Analog Supply		1520		mA	
VDDD1P3_DIG Supply		619		mA	Transmitter QEC active
VDDA1P8_TX Supply		455		mA	Transmitter RF attenuation = 0 dB, full-scale continuous wave
		135		mA	Transmitter RF attenuation = 15 dB, full-scale continuous wave
VDDA1P8_BB Supply		30		mA	
VDD_INTERFACE Supply		8		mA	VDD_INTERFACE = 2.5V
VDDA_3P3 Supply		3		mA	No AUXDAC_x or AUXADC_x enabled; if enabled, AUXADC_x adds 2.7 mA and each AUXDAC_x adds 1.5 mA
Total Power Dissipation		3.68		W	Typical supply voltages, 0 dB transmitter attenuation, transmitter QEC active
		3.11		W	Typical supply voltages, 15 dB transmitter attenuation, transmitter QEC active
450 MHz Transmitter Bandwidth, Observation Receiver Enabled					Two transmitters enabled, one ORX enabled
VDDA1P3[1] Analog Supply		2073		mA	
VDDD1P3_DIG Supply		1541		mA	Transmitter QEC tracking active, observation receiver QEC enabled, transmitter LTE20 centered on LO, observation receiver LTE20 at −16 dBm centered on LO
		2100		mA	Transmitter two tone = −99 MHz and +100 MHz at −7 dBFS each, observation receiver one tone = 100 MHz at −16 dBm.
VDDA1P8_TX Supply		455		mA	Transmitter RF attenuation = 0 dB, full-scale continuous wave
		135		mA	Transmitter RF attenuation = 15 dB, full-scale continuous wave
VDDA1P8_BB Supply		63		mA	
VDD_INTERFACE Supply		8		mA	VDD_INTERFACE = 2.5 V
VDDA_3P3 Power Supply		3		mA	No AUXDAC_x or AUXADC_x enabled; if enabled, AUXADC_x adds 2.7 mA and each AUXDAC_x adds 1.5 mA
Total Power Dissipation		5.66		W	Typical supply voltages, 0 dB transmitter attenuation, transmitter QEC active
		5.08		W	Typical supply voltages, 15 dB transmitter attenuation, transmitter QEC active
200 MHz Receiver Bandwidth, Observation Receiver Disabled					Two receivers enabled
VDDA1P3[1] Analog Supply		1645		mA	
VDDD1P3_DIG Supply		984		mA	Receiver QEC active
VDDA1P8_TX Supply		0.4		mA	
VDDA1P8_BB Supply		68		mA	
VDD_INTERFACE Supply		8		mA	
VDDA_3P3 Supply		3		mA	No AUXDAC_x or AUXADC_x enabled; if enabled, AUXADC_x adds 2.7 mA and each AUXDAC_x adds 1.5 mA
Total Power Dissipation		3.57		W	Typical supply voltages, Receiver QEC active

[1] VDDA1P3 refers to all analog 1.3 V supplies, including: VDDA1P3_RF_SYNTH, VDDA1P3_BB, VDDA1P3_RX_RF, VDDA1P3_RX_TX, VDDA1P3_RF_VCO_LDO, VDDA1P3_RF_LO, VDDA1P3_DES, VDDA1P3_SER, VDDA1P3_CLOCK_SYNTH, VDDA1P3_CLOCK_VCO_LDO, VDDA1P3_AUX_SYNTH, and VDDA1P3_AUX_VCO_LDO.

TIMING DIAGRAMS

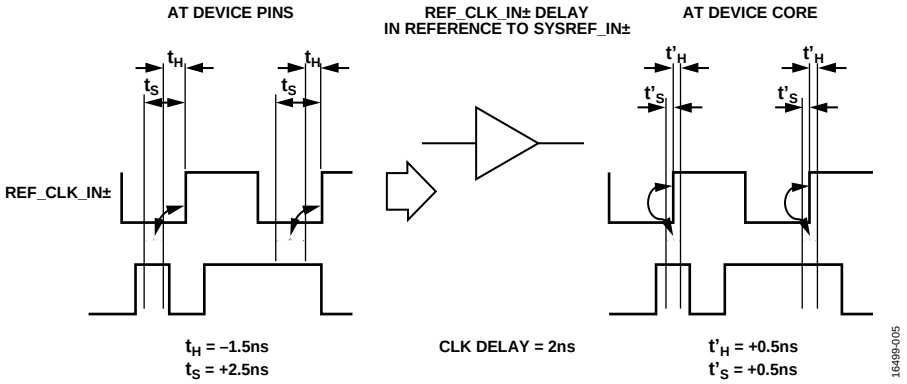

Figure 2. SYSREF_IN± Setup and Hold Timing

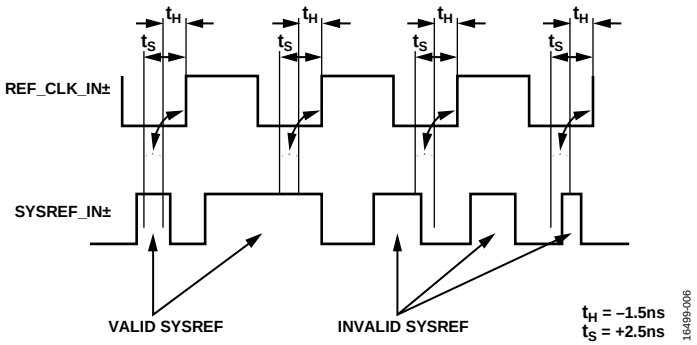

Figure 3. SYSREF_IN± Setup and Hold Timing Examples, Relative to Device Clock

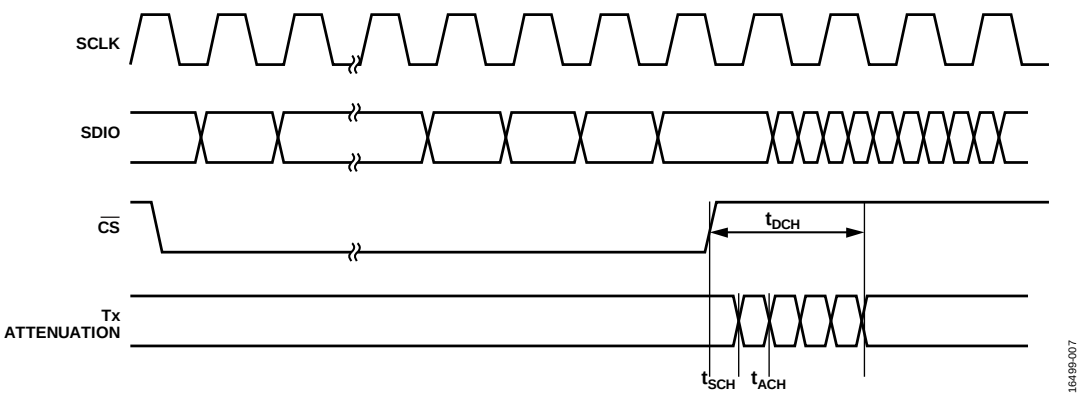

Figure 4. Transmitter Attenuation Update via SPI-2 Port

ABSOLUTE MAXIMUM RATINGS

Table 3.

Parameter	Rating
VDDA1P3[1] to VSSA	−0.3 V to +1.4 V
VDDD1P3_DIG to VSSD	−0.3 V to +1.4 V
VDD_INTERFACE to VSSA	−0.3 V to +3.0 V
VDDA_3P3 to VSSA	−0.3 V to +3.9 V
VDDA1P8_TX to VSSA	−0.3 V to +2.0 V
VDD_INTERFACE Logic Inputs and Outputs to VSSD	−0.3 V to VDD_INTERFACE + 0.3 V
JESD204B Logic Outputs to VSSA	−0.3 V to VDDA1P3_SER
JESD204B Logic Inputs to VSSA	−0.3 V to VDDA1P3_DES +0.3 V
Input Current to Any Pin Except Supplies	±10 mA
Maximum Input Power into RF Port	23 dBm (peak)
Maximum Transmitter Voltage Standing Wave Ratio (VSWR)	3:1
Maximum Junction Temperature	110°C
Storage Temperature Range	−65°C to +150°C

[1] VDDA1P3 refers to all analog 1.3 V supplies, including: VDDA1P3_RF_SYNTH, VDDA1P3_BB, VDDA1P3_RX_RF, VDDA1P3_RX_TX, VDDA1P3_RF_VCO_LDO, VDDA1P3_RF_LO, VDDA1P3_DES, VDDA1P3_CLOCK, VDDA1P3_TX_LO_BUFFER, and VDDA1P3_CLOCK_SYNTH.

Stresses at or above those listed under Absolute Maximum Ratings may cause permanent damage to the product. This is a stress rating only; functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

REFLOW PROFILE

The ADRV9009 reflow profile is in accordance with the JEDEC JESD204B criteria for Pb-free devices. The maximum reflow temperature is 260°C.

THERMAL MANAGEMENT

The ADRV9009 is a high power device that can dissipate over 3 W depending on the user application and configuration.

Because of the power dissipation, the ADRV9009 uses an exposed die package to provide the customer with the most effective method of controlling the die temperature. The exposed die allows cooling of the die directly. Figure 5 shows the profile view of the device mounted to a user printed circuit board (PCB) and a heat sink (typically the aluminum case) to keep the junction (exposed die) below the maximum junction temperature shown in Table 3. The device is designed for a lifetime of 10 years when operating at the maximum junction temperature.

THERMAL RESISTANCE

θ_{JA} is specified for the worst-case conditions, that is, a device soldered in a circuit board for surface-mount packages. Thermal resistance data for the ADRV9009 mounted on both a JEDEC 2S2P test board and a 10-layer Analog Devices, Inc., evaluation board are listed in Table 4. Do not exceed the absolute maximum junction temperature rating in Table 3. 10-layer PCB entries refer to the 10-layer Analog Devices evaluation board, which more accurately reflects the PCB used in customer applications.

Table 4. Thermal Resistance[1, 2]

Package Type	θ_{JA}	θ_{JC_TOP}	θ_{JB}	Ψ_{JT}	Ψ_{JB}	Unit
BC-196-13	21.1	0.04	4.9	0.3	4.9	°C/W

[1] For the θ_{JC} test, 100 µm thermal interface material (TIM) is used. TIM is assumed to have 3.6 thermal conductivity watts/(meter × Kelvin).
[2] Using enhanced heat removal techniques such as PCB, heat sink, airflow, and so on, improves the thermal resistance values.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

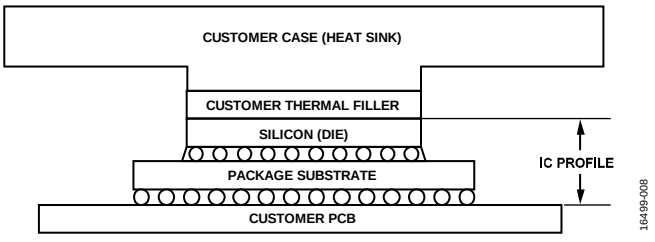

Figure 5. Typical Thermal Management Solution

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

Figure 6. Pin Configuration

Table 5. Pin Function Descriptions

Pin No.	Type	Mnemonic	Description
A1, A4, A7, A8, A11, A14, B2 to B6, B9 to B14, C4, C9, C11, D3 to D9, D11, D12, E6, E9, F1, F2, F5 to F10, F12 to F14, G1 to G4, G6, G10 to G14, H2 to H10, H13, J2, J13, K1, K2, K13, K14, L1, L2, M2, M9, N2, N7, N14, P2, P3, P10	Input	VSSA	Analog Supply Voltage (V_{SS}).
A2, A3	Input	ORX2_IN+, ORX2_IN–	Differential Input for Observation Receiver 2. When unused, connect these pins to ground.
A5, A6	Input	RX2_IN+, RX2_IN–	Differential Input for Main Receiver 2. When unused, connect these pins to ground.
A9, A10	Input	RX1_IN+, RX1_IN–	Differential Input for Main Receiver 1. When unused, connect these pins to ground.

Pin No.	Type	Mnemonic	Description
A12, A13	Input	ORX1_IN+, ORX1_IN−	Differential Input for Observation Receiver 1. When unused, connect these pins to ground.
B1	Input	VDDA1P3_RX_RF	Observation Receiver Supply.
B7, B8	Input	RF_EXT_LO_I/O−, RF_EXT_LO_I/O+,	Differential External LO Input/Output. If these pins are used for the external LO, the input frequency must be 2× the desired carrier frequency. When unused, do not connect these pins.
C1	Input/ output	GPIO_3P3_0	GPIO Pin Referenced to 3.3 V Supply. The alternate function is AUXDAC_4. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or this pin can be left floating, programmed as outputs, and driven low.
C2	Input/ output	GPIO_3P3_3	GPIO Pin Referenced to 3.3 V Supply. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or these pins can be left floating, programmed as outputs, and driven low.
C13	Input/ output	GPIO_3P3_9	GPIO Pin Referenced to 3.3 V Supply. The alternative function is AUXDAC_9. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or these pins can be left floating, programmed as outputs, and driven low.
D1	Input/ output	GPIO_3P3_1	GPIO Pin Referenced to 3.3 V Supply. The alternative function is AUXDAC_5. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or these pins can be left floating, programmed as outputs, and driven low.
D2	Input/ output	GPIO_3P3_4	GPIO Pin Referenced to 3.3 V Supply. The alternative function is AUXDAC_6. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or these pins can be left floating, programmed as outputs, and driven low.
D13	Input/ output	GPIO_3P3_8	GPIO Pin Referenced to 3.3 V Supply. The alternative function is AUXDAC_1. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or these pins can be left floating, programmed as outputs, and driven low.
D14	Input/ output	GPIO_3P3_10	GPIO Pin Referenced to 3.3 V Supply. The alternative function is AUXDAC_0. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or these pins can be left floating, programmed as outputs, and driven low.
E1	Input/ output	GPIO_3P3_2	GPIO Pin Referenced to 3.3 V Supply. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or these pins can be left floating, programmed as outputs, and driven low.
E2	Input/ output	GPIO_3P3_5	GPIO Pin Referenced to 3.3 V Supply. The alternative function is AUXDAC_7. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or these pins can be left floating, programmed as outputs, and driven low.
E3	Input/ output	GPIO_3P3_6	GPIO Pin Referenced to 3.3 V Supply. The alternative function is AUXDAC_8. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or these pins can be left floating, programmed as outputs, and driven low.
E13	Input/ output	GPIO_3P3_7	GPIO Pin Referenced to 3.3 V Supply. The alternative function is AUXDAC_2. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or these pins can be left floating, programmed as outputs, and driven low.

Pin No.	Type	Mnemonic	Description
E14	Input/ output	GPIO_3P3_11	GPIO Pin Referenced to 3.3 V Supply. The alternative function is AUXDAC_3. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or these pins can be left floating, programmed as outputs, and driven low.
C3	Input	VDDA1P3_RX_TX	1.3 V Supply for Transmitter/Receiver Baseband Circuits, Transimpedance Amplifier (TIA), Transmitter Transconductance (GM), Baseband Filters, and Auxiliary DACs.
C5, C6	Input	VDDA1P3_RF_VCO_LDO	RF VCO LDO Supply Inputs. Connect Pin C5 to Pin C6. Use a separate trace on the PCB back to a common supply point.
C7	Input	VDDA1P1_RF_VCO	1.1 V VCO Supply. Decouple this pin with 1 µF.
C8	Input	VDDA1P3_RF_LO	1.3 V LO Generator for the RF Synthesizer. This pin is sensitive to supply noise.
C10	Input	VDDA1P3_AUX_VCO_LDO	1.3 V Supply.
C12	Input	VDDA_3P3	General-Purpose Output Pull-Up Voltage and Auxiliary DAC Supply Voltage.
C14	Input/ output	RBIAS	Bias Resistor. Tie this pin to ground using a 14.3 kΩ resistor. This pin generates an internal current based on an external 1% resistor.
D10	Input	VDDA1P1_AUX_VCO	1.1 V VCO Supply. Decouple this pin with 1 µF.
E4	Input	VDDA1P8_BB	1.8 V Supply for the ADC and DAC.
E5	Input	VDDA1P3_BB	1.3 V Supply for the ADC, DAC, and AUXADC.
E7, E8	Input	REF_CLK_IN+, REF_CLK_IN−	Device Clock Differential Input.
E10	Output	AUX_SYNTH_OUT	Auxiliary PLL Output. When unused, do not connect this pin.
E12	Input	VDDA1P8_TX	1.8 V Supply for Transmitter.
F3, F4, F11, E11	Input	AUXADC_0 to AUXADC_3	Auxiliary ADC Input. When unused, connect these pins to ground with a pull-down resistor, or connect directly to ground.
G5	Input	VDDA1P3_CLOCK_SYNTH	1.3 V Supply Input for Clock Synthesizer. Use a separate trace on the PCB back to a common supply point.
G7	Input	VDDA1P3_RF_SYNTH	1.3 V RF Synthesizer Supply Input. This pin is sensitive to supply noise.
G8	Input	VDDA1P3_AUX_SYNTH	1.3 V Auxiliary Synthesizer Supply Input.
G9	Output	RF_SYNTH_VTUNE	RF Synthesizer VTUNE Output.
H11	Input/ output	GPIO_12	Digital GPIO, 1.8 V to 2.5 V. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
H12	Input/ output	GPIO_11	Digital GPIO, 1.8 V to 2.5 V. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
J11	Input/ output	GPIO_13	Digital GPIO, 1.8 V to 2.5 V. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
J12	Input/ output	GPIO_10	Digital GPIO, 1.8 V to 2.5 V. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
J3	Input/ output	GPIO_18	Digital GPIO, 1.8 V to 2.5 V. The joint test action group (JTAG) function is TCLK. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
J7	Input/ output	GPIO_2	Digital GPIO, 1.8 V to 2.5 V. The user sets the JTAG function to 0. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.

Pin No.	Type	Mnemonic	Description
J8	Input/ output	GPIO_1	Digital GPIO, 1.8 V to 2.5 V. The user sets the JTAG function to 0. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
K5	Input/ output	GPIO_5	Digital GPIO, 1.8 V to 2.5 V. The JTAG function is TDO. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
K6	Input/ output	GPIO_4	Digital GPIO, 1.8 V to 2.5 V. The JTAG function is $\overline{\text{TRST}}$. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
K7	Input/ output	GPIO_3	Digital GPIO, 1.8 V to 2.5 V. The user sets the JTAG function to 1. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
K8	Input/ output	GPIO_0	Digital GPIO, 1.8 V to 2.5 V. The user sets the JTAG function to 1. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
K11	Input/ output	GPIO_14	Digital GPIO, 1.8 V to 2.5 V. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
K12	Input/ output	GPIO_9	Digital GPIO, 1.8 V to 2.5 V. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
L5	Input/ output	GPIO_6	Digital GPIO, 1.8 V to 2.5 V. The JTAG function is TDI. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
L6	Input/ output	GPIO_7	Digital GPIO, 1.8 V to 2.5 V. The JTAG function is TMS. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
L11	Input/ output	GPIO_15	Digital GPIO, 1.8 V to 2.5 V. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
L12	Input/ output	GPIO_8	Digital GPIO, 1.8 V to 2.5 V. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
M10	Input/ output	GPIO_17	Digital GPIO, 1.8 V to 2.5 V. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
M11	Input/ output	GPIO_16	Digital GPIO, 1.8 V to 2.5 V. Because this pin contains an input stage, the voltage on the pin must be controlled. When unused, this pin can be tied to ground through a resistor (to safeguard against misconfiguration), or it can be left floating, programmed as output, and driven low.
H14, J14	Output	TX1_OUT+, TX1_OUT–	Transmitter 1 Output. When unused, do not connect these pins.
H1, J1	Output	TX2_OUT–, TX2_OUT+	Transmitter 2 Output. When unused, do not connect these pins.

Pin No.	Type	Mnemonic	Description
J4	Input	$\overline{\text{RESET}}$	Active Low Chip Reset.
J5	Output	GP_INTERRUPT	General-Purpose Digital Interrupt Output Signal. When unused, do not connect this pin.
J6	Input	TEST	Pin Used for JTAG Boundary Scan. When unused, connect this pin to ground.
J9	Input/ output	SDIO	Serial Data Input in 4-Wire Mode or Input/Output in 3-Wire Mode.
J10	Output	SDO	Serial Data Output. In SPI 3-wire mode, do not connect this pin.
K3, K4	Input	SYSREF_IN+, SYSREF_IN–	LVDS Input.
K9	Input	SCLK	Serial Data Bus Clock.
K10	Input	$\overline{\text{CS}}$	Serial Data Bus Chip Select, Active Low.
L3, L4	Input	$\overline{\text{SYNCIN1–}}$, $\overline{\text{SYNCIN1+}}$	LVDS Input. These pins form the sync signal associated with receiver channel data on the JESD204B interface. When unused, connect these pins to ground with a pull-down resistor, or connect these pins directly to ground.
L7, L10	Input	VSSD	Digital V_{SS}.
L8, L9	Input	VDDD1P3_DIG	1.3 V Digital Core. Connect Pin L8 and Pin L9 together. Use a wide trace to connect to a separate power supply domain.
L13, L14	Output	$\overline{\text{SYNCOUT1–}}$, $\overline{\text{SYNCOUT1+}}$	LVDS Output. These pins form the sync signal associated with transmitter channel data on the JESD204B interface. When unused, do not connect these pins.
M1	Input	VDDA1P1_CLOCK_VCO	1.1 V VCO Supply. Decouple this pin with 1 µF.
M3, M4	Input	$\overline{\text{SYNCIN0–}}$, $\overline{\text{SYNCIN0+}}$	LVDS Input. These pins form the sync signal associated with receiver channel data on the JESD204B interface. When unused, connect these pins to ground with a pull-down resistor, or connect these pins directly to ground.
M5	Input	RX1_ENABLE	Receiver 1 Enable Pin. When unused, connect this pin to ground with a pull-down resistor, or connect this pin directly to ground.
M6	Input	TX1_ENABLE	Transmitter 1 Enable Pin. When unused, connect this pin to ground with a pull-down resistor, or connect this pin directly to ground.
M7	Input	RX2_ENABLE	Receiver 2 Enable Pin. When unused, connect this pin to ground with a pull-down resistor, or connect this pin directly to ground.
M8	Input	TX2_ENABLE	Transmitter 2 Enable Pin. When unused, connect this pin to ground with a pull-down resistor, or connect this pin directly to ground.
M12	Input	VDD_INTERFACE	Input/Output Interface Supply, 1.8 V to 2.5 V.
M13, M14	Output	$\overline{\text{SYNCOUT0–}}$, $\overline{\text{SYNCOUT0+}}$	LVDS Output. These pins form the sync signal associated with transmitter channel data on the JESD204B interface. When unused, do not connect these pins.
N1	Input	VDDA1P3_CLOCK_ VCO_LDO	1.3 V Use Separate Trace to Common Supply Point.
N3, N4	Output	SERDOUT3–, SERDOUT3+	RF Current Mode Logic (CML) Differential Output 3. When unused, do not connect these pins.
N5, N6	Output	SERDOUT2–, SERDOUT2+	RF CML Differential Output 2. When unused, do not connect these pins.
N8, P8	Input	VDDA1P3_SER	1.3 V Supply for JESD204B Serializer.
N9, P9	Input	VDDA1P3_DES	1.3 V Supply for JESD204B Deserializer.
N10, N11	Input	SERDIN1–, SERDIN1+	RF CML Differential Input 1. When unused, do not connect these pins.
N13, N12	Input	SERDIN0+, SERDIN0–	RF CML Differential Input 0. When unused, do not connect these pins.
P1	Output	AUX_SYNTH_VTUNE	Auxiliary Synthesizer VTUNE Output.
P4, P5	Output	SERDOUT1–, SERDOUT1+,	RF CML Differential Output 1. When unused, do not connect these pins.
P6, P7	Output	SERDOUT0–, SERDOUT0+,	RF CML Differential Output 0. When unused, do not connect these pins.
P11, P12	Input	SERDIN3–, SERDIN3+	RF CML Differential Input 3. When unused, do not connect these pins.
P13, P14	Input	SERDIN2–, SERDIN2+	RF CML Differential Input 2. When unused, do not connect these pins.

TYPICAL PERFORMANCE CHARACTERISTICS

The temperature settings refer to the die temperature

75 MHz TO 525 MHz BAND

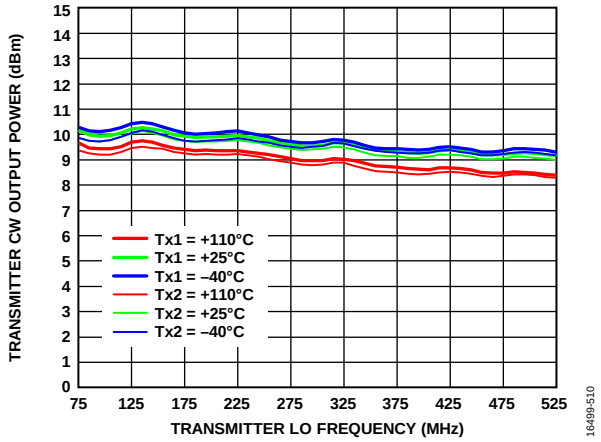

Figure 7. Transmitter Continuous Wave Output Power vs. Transmitter LO Frequency, Transmitter QEC and External LO Leakage Active, Transmitter 50 MHz/100 MHz Bandwidth Mode, IQ Rate = 122.88 MHz, Attenuation = 0 dB. Not Deembedded

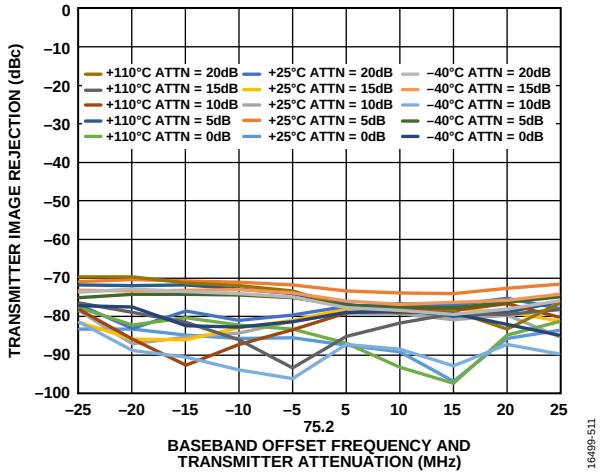

Figure 8. Transmitter Image Rejection Across Large Signal Bandwidth vs. Baseband Offset Frequency and Transmitter Attenuation QEC Trained with Three Tones Placed At 10 MHz, 48 MHz, and 100 MHz (Tracking On); Total Combined Power = –10 dBFS; Correction Then Frozen (Tracking Turned Off); Continuous Wave Tone Swept Across Large Signal Bandwidth; LO = 75 MHz

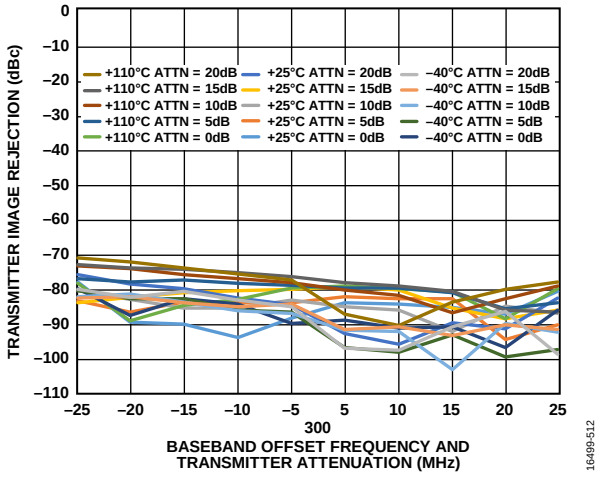

Figure 9. Transmitter Image Rejection Across Large Signal Bandwidth vs. Baseband Offset Frequency and Transmitter Attenuation; QEC Trained with Three Tones Placed at 10 MHz, 48 MHz, and 100 MHz (Tracking On), Total Combined Power = –10 dBFS; Correction Then Frozen (Tracking Turned Off); Continuous Wave Tone Swept Across Large Signal Bandwidth, LO = 300 MHz

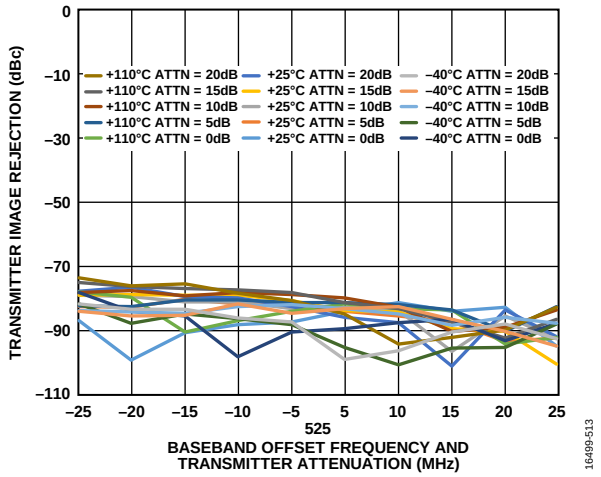

Figure 10. Transmitter Image Rejection Across Large Signal Bandwidth vs. Baseband Offset Frequency and Transmitter Attenuation; QEC Trained with Three Tones Placed at 10 MHz, 48 MHz, and 100 MHz (Tracking On); Total Combined Power = –10 dBFS; Correction Then Frozen (Tracking Turned Off); Continuous Wave Tone Swept Across Large Signal Bandwidth; LO = 525 MHz

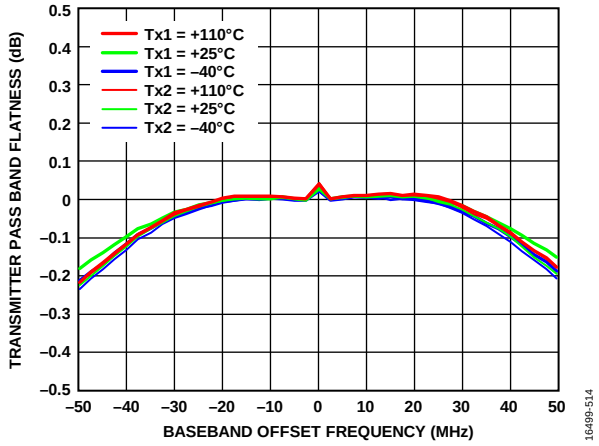

Figure 11. Transmitter Pass Band Flatness vs. Baseband Offset Frequency, Off Chip Match Response Deembedded, LO = 300 MHz, Calibrated at 25°C

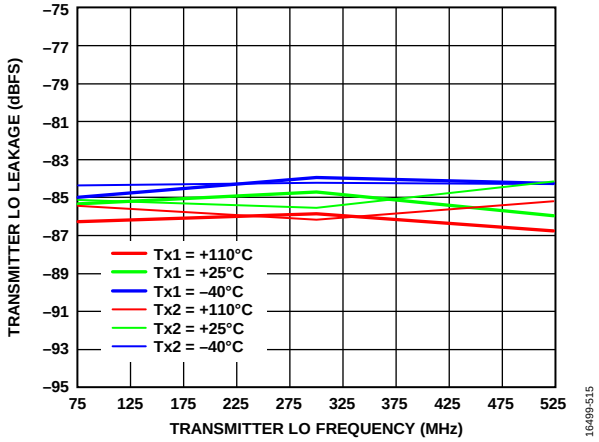

Figure 12. Transmitter LO Leakage vs. Transmitter LO Frequency, Transmitter Attenuation = 0 dB, Baseband Tone Frequency = 10 MHz, Tracked

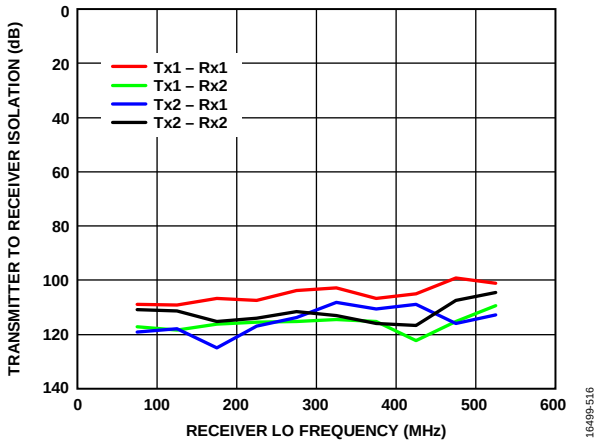

Figure 13. Transmitter to Receiver Isolation vs. Receiver LO Frequency, Temperature = 25°C

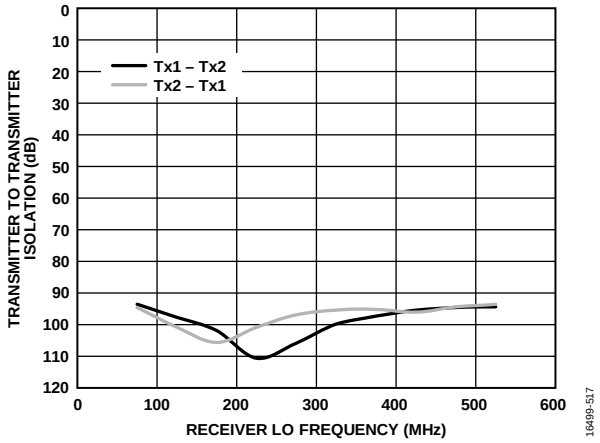

Figure 14. Transmitter to Transmitter Isolation vs. Receiver LO Frequency, Temperature = 25°C

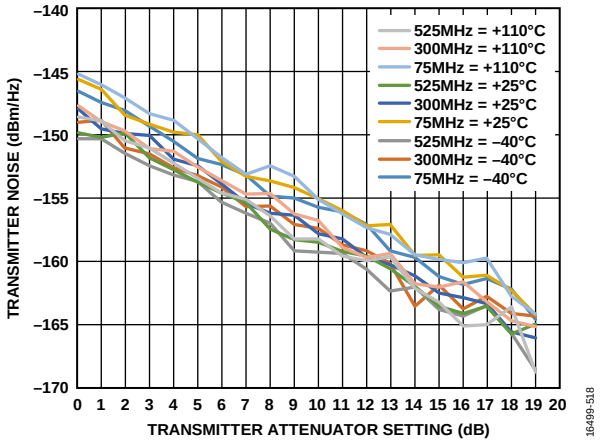

Figure 15. Transmitter Noise vs. Transmitter Attenuation Setting, 50 MHz Offset

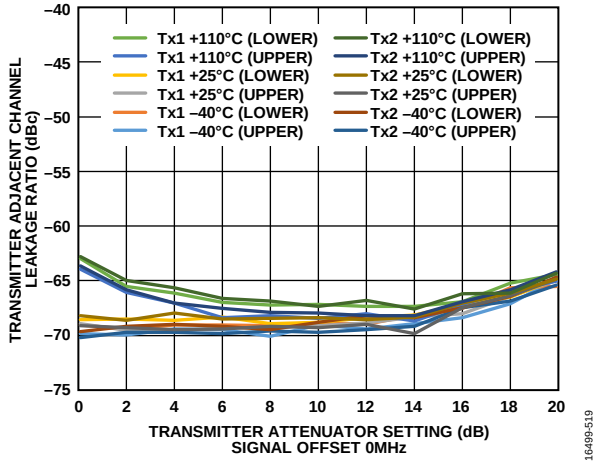

Figure 16. Transmitter Adjacent Channel Leakage Ratio vs. Transmitter Attenuation Setting, Signal Offset = 0 MHz, LO = 75 MHz, LTE20 Peak to Average Ratio (PAR) = 12 dB, DAC Boost Normal, Upper Side and Lower Side, Performance Limited by Spectrum Analyzer at Higher Attenuation Settings

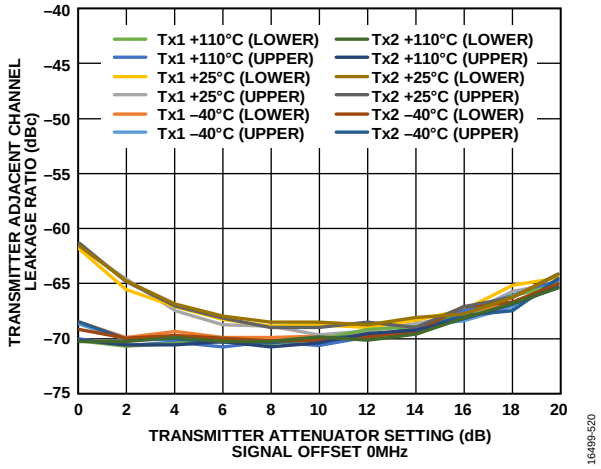

Figure 17. Transmitter Adjacent Channel Leakage Ratio vs. Transmitter Attenuation Setting, LO = 300 MHz, LTE20 PAR = 12 dB, DAC Boost Normal, Upper Side and Lower Side, Performance Limited by Spectrum Analyzer at Higher Attenuation Settings

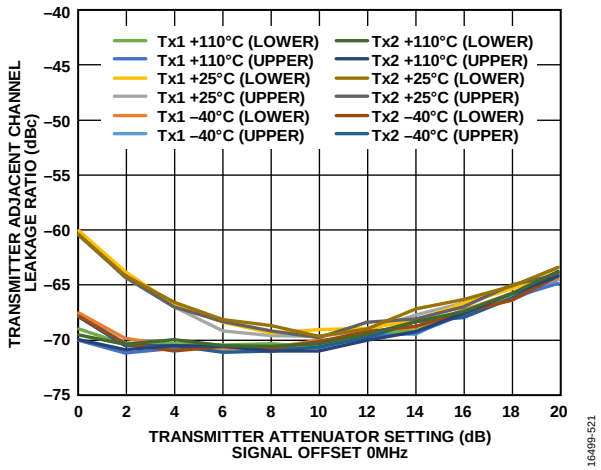

Figure 18. Transmitter Adjacent Channel Leakage Ratio vs. Transmitter Attenuation Setting, LO = 525 MHz, LTE20 PAR = 12 dB, DAC Boost Normal, Upper Side and Lower Side, Performance Limited by Spectrum Analyzer at Higher Attenuation Settings

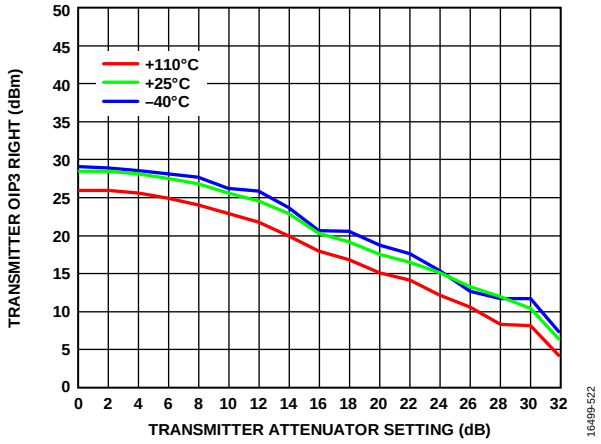

Figure 19. Transmitter OIP3 Right vs. Transmitter Attenuation Setting, LO = 75 MHz, Total RMS Power = –12 dBFS, 20 MHz/25 MHz Tones

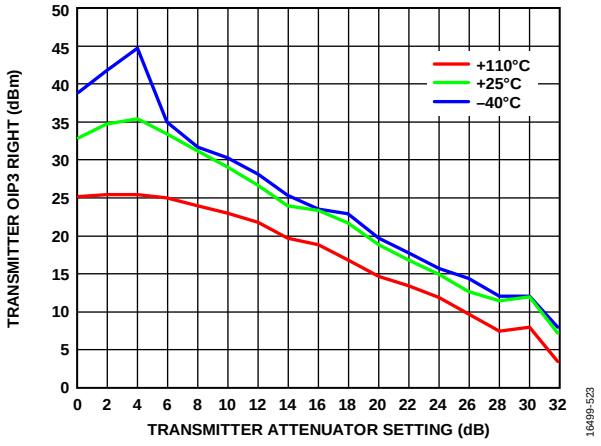

Figure 20. Transmitter OIP3 Right vs. Transmitter Attenuation Setting, LO = 300 MHz, Total Root Mean Square (RMS) Power = –12 dBFS, 20 MHz/25 MHz Tones

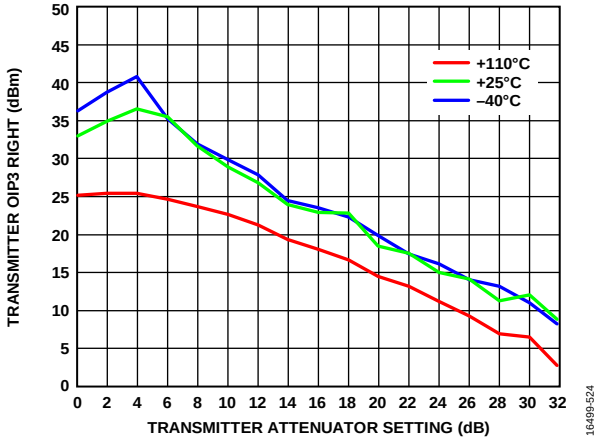

Figure 21. Transmitter OIP3 Right vs. Transmitter Attenuation Setting, LO = 525 MHz, Total RMS Power = –12 dBFS, 20 MHz/25 MHz Tones

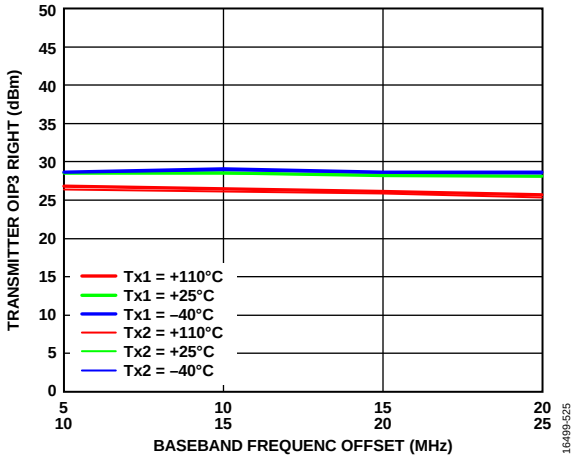

Figure 22. Transmitter OIP3 Right vs. Baseband Tone Pair Swept Across Pass Band, LO = 75 MHz, Total RMS Power = –12 dBFS, 4 dB Transmitter Attenuation

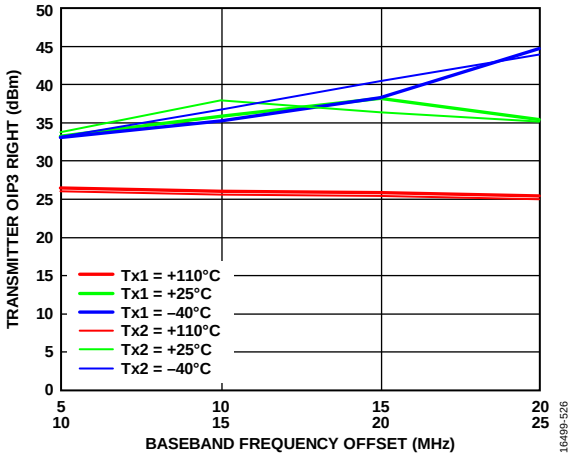

Figure 23. Transmitter OIP3 Right vs. Baseband Frequency Offset, LO = 300 MHz, Total RMS Power = −12 dBFS, 4 dB Transmitter Attenuation

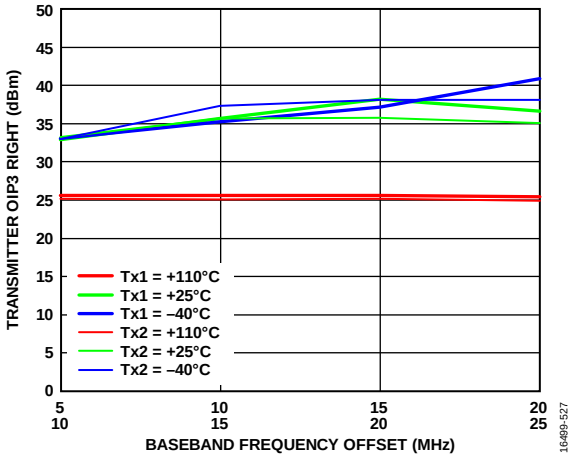

Figure 24. Transmitter OIP3 Right vs. Baseband Frequency Offset, LO = 525 MHz, Total RMS Power = −12 dBFS, 4 dB Transmitter Attenuation

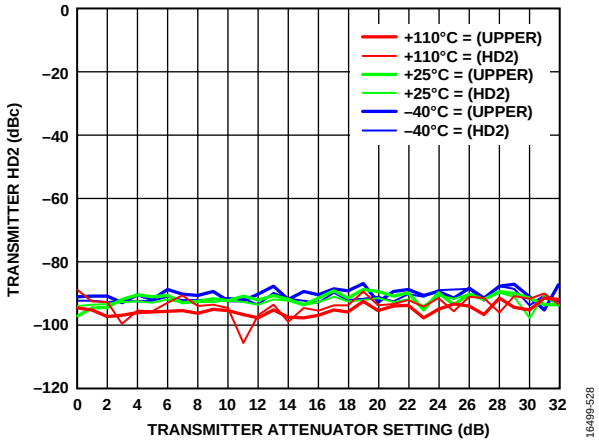

Figure 25. Transmitter HD2 vs. Transmitter Attenuator Setting, Baseband Frequency = 10 MHz, LO = 75 MHz, Continuous Wave = −15 dBFS

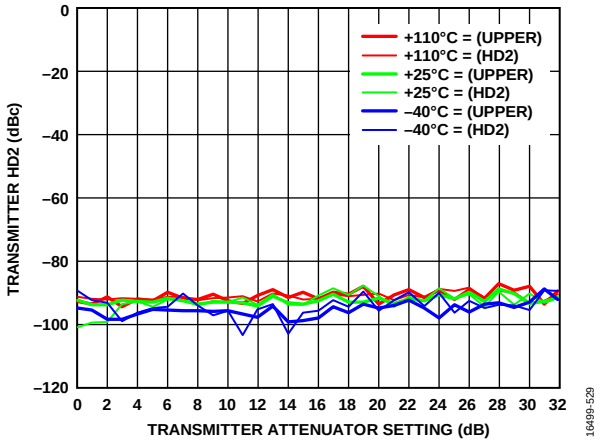

Figure 26. Transmitter HD2 vs. Transmitter Attenuation} Baseband Frequency = 10 MHz, LO = 300 MHz, Continuous Wave = −15 dBFS

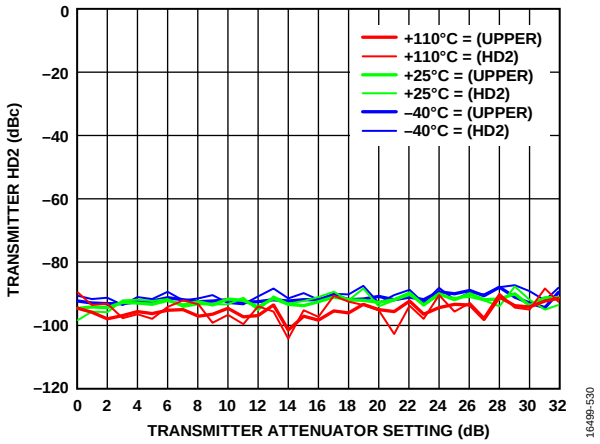

Figure 27. Transmitter HD2 vs. Transmitter Attenuator Setting, Baseband Frequency = 10 MHz, LO = 525 MHz, Continuous Wave = −15 dBFS

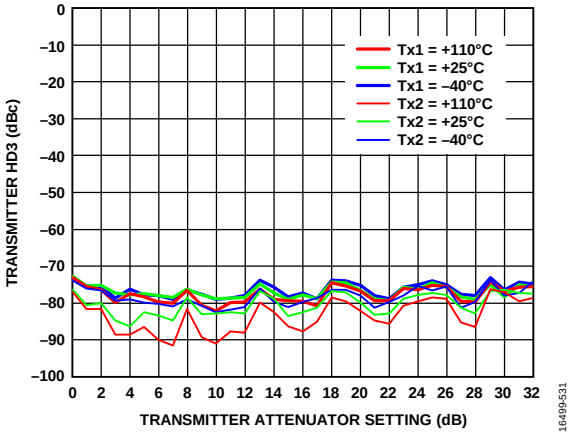

Figure 28. Transmitter HD3 vs. Transmitter Attenuation Setting, LO = 75 MHz, Continuous Wave = −15 dBFS, Baseband Frequency = 10 MHz

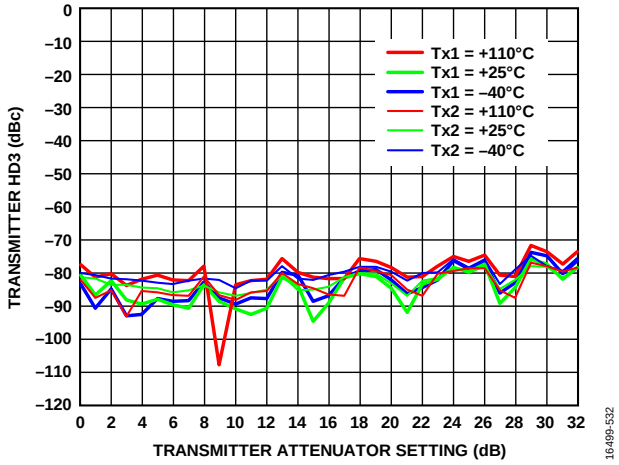

Figure 29. Transmitter HD3 vs. Transmitter Attenuation Setting, LO = 300 MHz, Continuous Wave = −15 dBFS, Baseband Frequency = 10 MHz

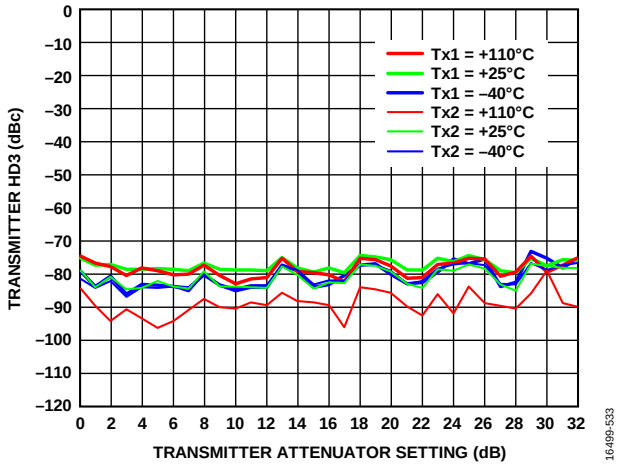

Figure 30. Transmitter HD3 vs. Transmitter Attenuation Setting, LO = 525 MHz, Continuous Wave = −15 dBFS, Baseband Frequency = 10 MHz

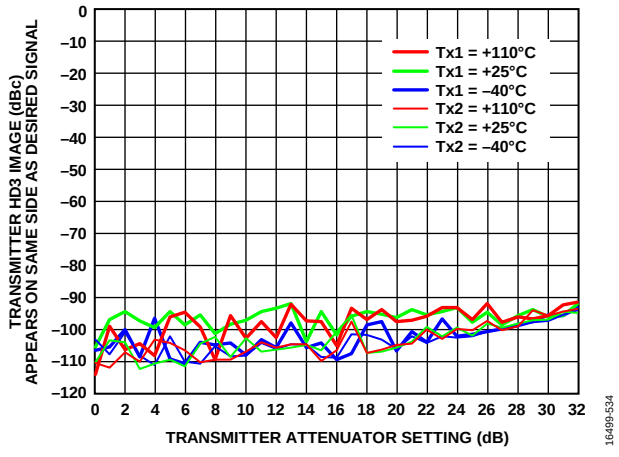

Figure 31. Transmitter HD3 Image on Same Side as Desired Signal vs. Transmitter Attenuation Setting, LO = 75 MHz, Continuous Wave = −15 dBFS

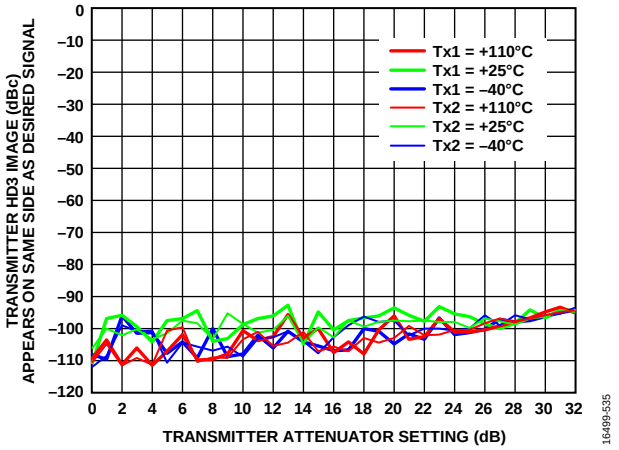

Figure 32. Transmitter HD3 Image, Appears on Same Sideband as Desired Signal vs. Transmitter Attenuation Setting, LO = 300 MHz, Continuous Wave = −15 dBFS

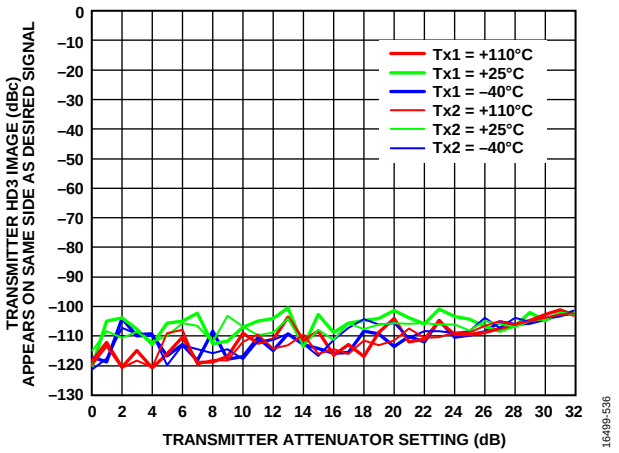

Figure 33. Transmitter HD3 Image on Same Side as Desired Signal vs. Transmitter AttenuationSetting, LO = 525 MHz, Continuous Wave = −15 dBFS

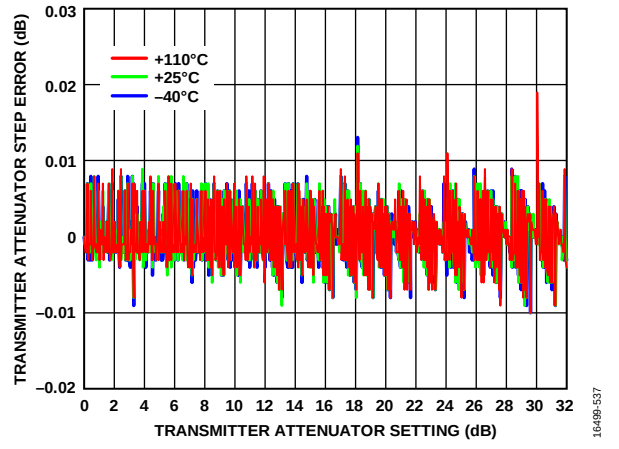

Figure 34. Transmitter Attenuation Step Error vs. Transmitter Attenuation Setting, LO = 75 MHz, Baseband Frequency = 10 MHz, Backoff = 15 dBFS

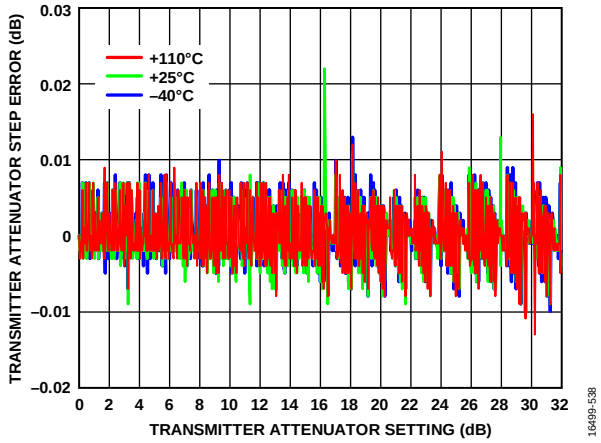

Figure 35. Transmitter Attenuation Step Error vs. Transmitter Attenuation Setting, LO = 300 MHz, Baseband Frequency = 10 MHz, Backoff = 15 dBFS

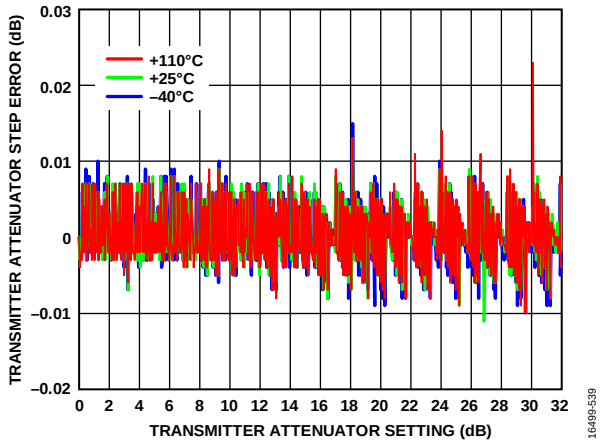

Figure 36. Transmitter Attenuation Step Error vs. Transmitter Attenuation Setting, LO = 525 MHz, Baseband Frequency = 10 MHz, Backoff = 15 dBFS

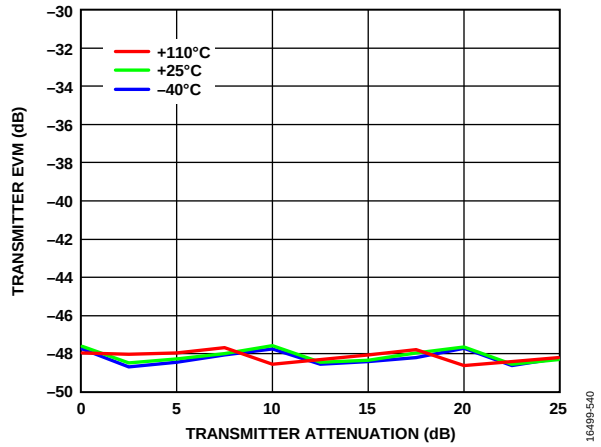

Figure 37. Transmitter EVM vs. Transmitter Attenuation, 20 MHz LTE Signal Centered on DC, LO = 75 MHz

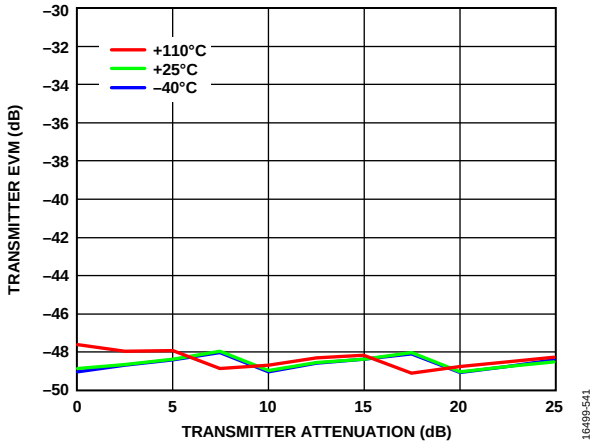

Figure 38. Transmitter EVM vs. Transmitter Attenuation, 20 MHz LTE Signal Centered on DC, LO = 300 MHz

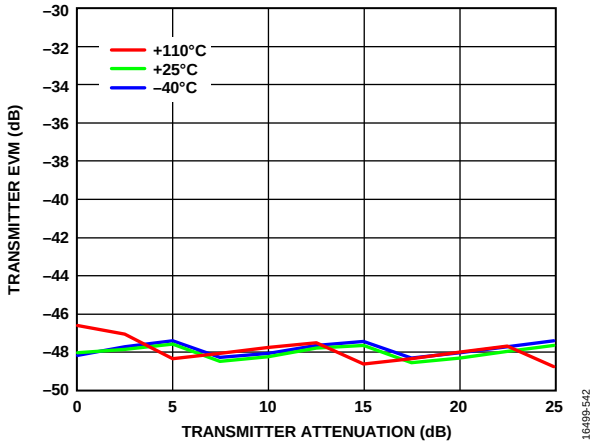

Figure 39. Transmitter EVM vs. Transmitter Attenuation, 20 MHz LTE Signal Centered on DC, LO = 525 MHz

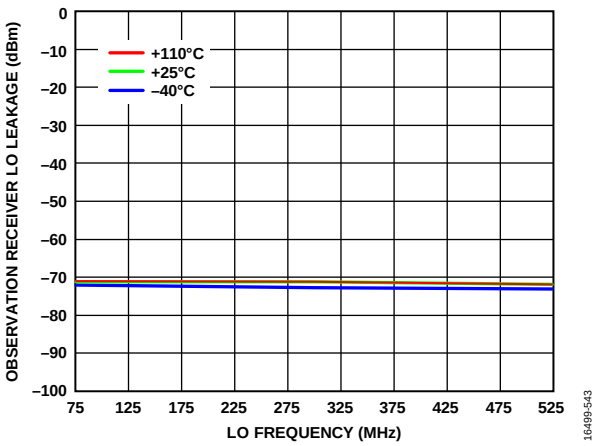

Figure 40. Observation Receiver LO Leakage vs. LO Frequency, 75 MHz, 300 MHz, 525 MHz; Attenuation = 0 dB

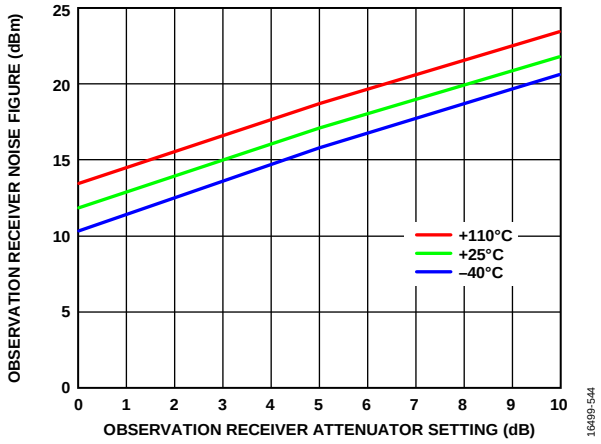

Figure 41. Observation Receiver Noise Figure vs. Observation Receiver Attenuator Setting, 75 MHz, Total Nyquist Integration Bandwidth

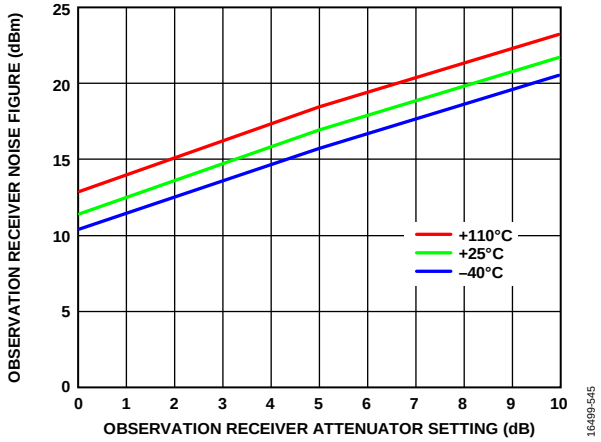

Figure 42. Observation Receiver Noise Figure vs. Observation Receiver Attenuator Setting, LO = 300 MHz, Total Nyquist Integration Bandwidth

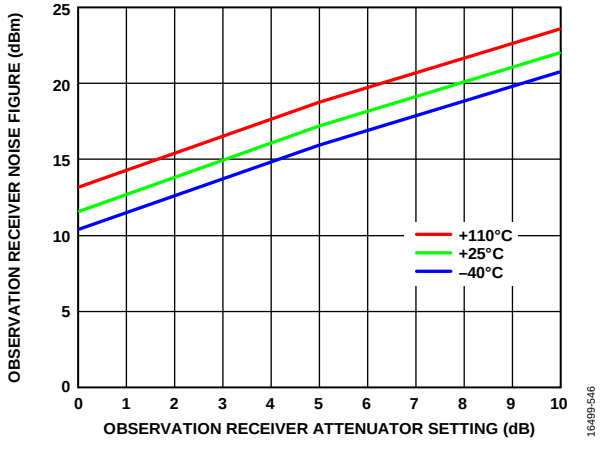

Figure 43. Observation Receiver Noise Figure vs. Observation Receiver Attenuator Setting, LO = 525 MHz, Total Nyquist Integration Bandwidth

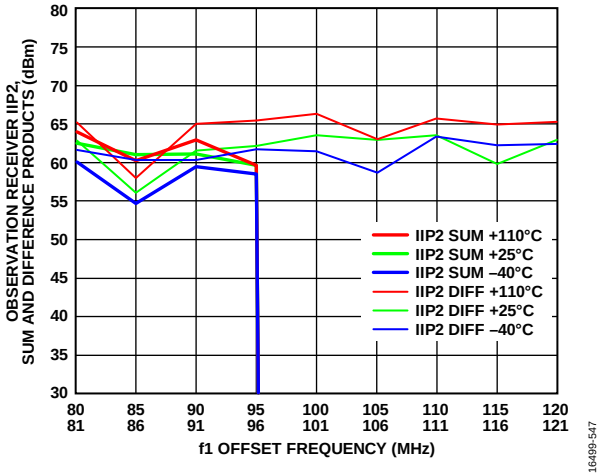

Figure 44. Observation Receiver IIP2, Sum and Difference Products vs. f1 Offset Frequency, Tones Separated by 1 MHz Swept Across Pass Band at –25 dBm Each, LO = 75 MHz, Attenuation = 0 dB

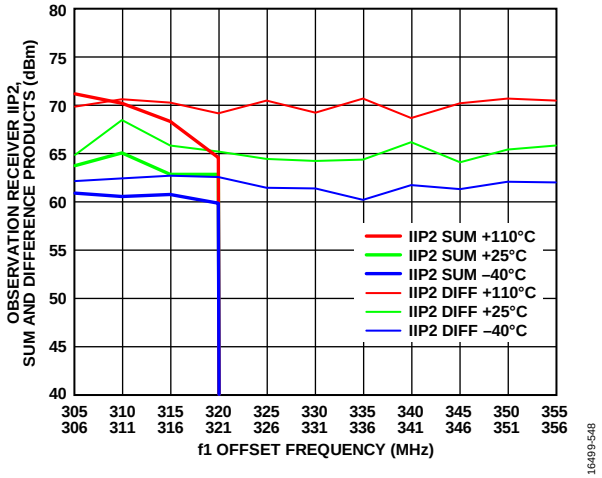

Figure 45. Observation Receiver IIP2 Sum and Difference Products vs. f1 Offset Frequency Tones Separated by 1 MHz Swept Across Pass Band at –25 dBm Each, LO = 300 MHz, Attenuation = 0 dB

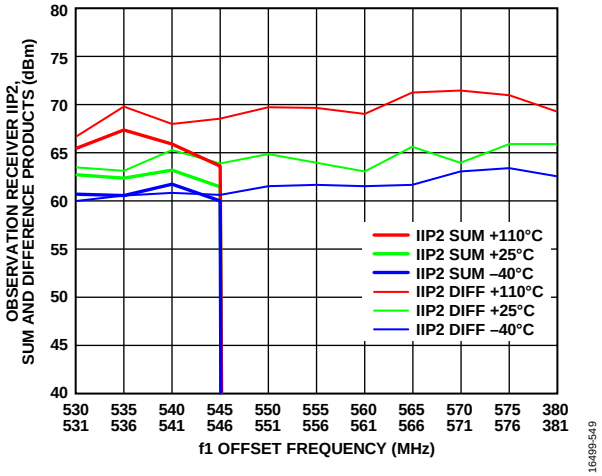

Figure 46. Observation Receiver IIP2, Sum and Difference Products vs. f1 Offset Frequency, Tones Separated by 1 MHz Swept Across Pass Band at –25 dBm Each, LO = 525 MHz, Attenuation = 0 dB

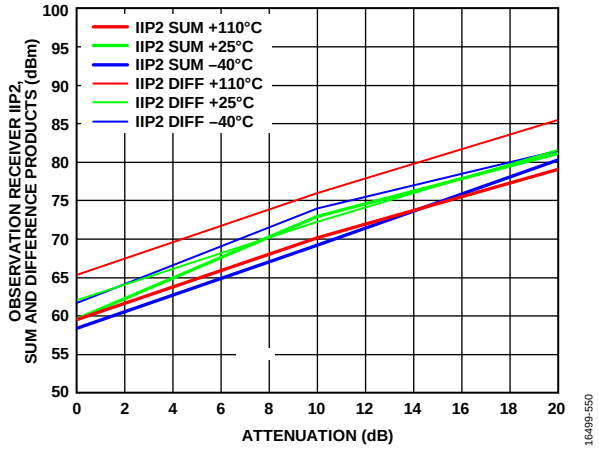

Figure 47. Observation Receiver IIP2, Sum and Difference Products vs. Attenuation, LO = 75 MHz, Tone 1 = 95 MHz, Tone 2 = 96 MHz at –25 dBm Plus Attenuation

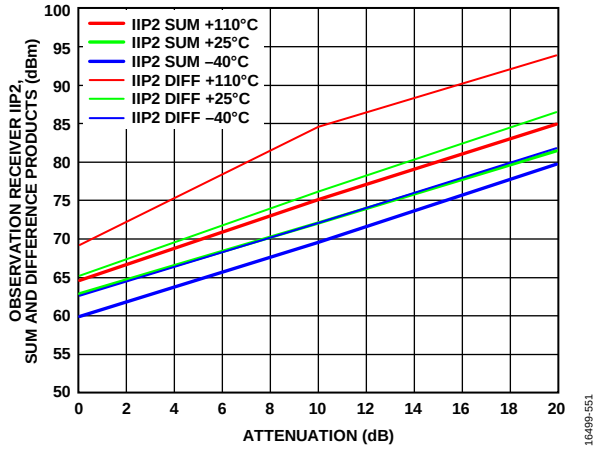

Figure 48. Observation Receiver IIP2, Sum and Difference Products vs. Attenuation. LO = 300 MHz, Tone 1 = 320 MHz, Tone 2 = 321 MHz at –25 dBm Plus Attenuation

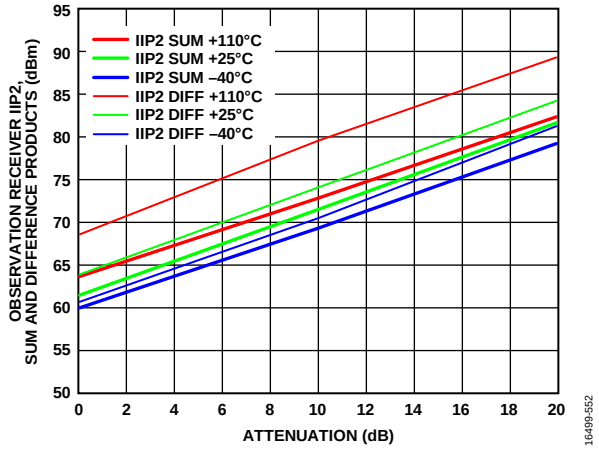

Figure 49. Observation Receiver IIP2, Sum and Difference Products vs. Attenuation, LO = 525 MHz, Tone 1 = 545 MHz, Tone 2 = 546 MHz at –25 dBm Plus Attenuation

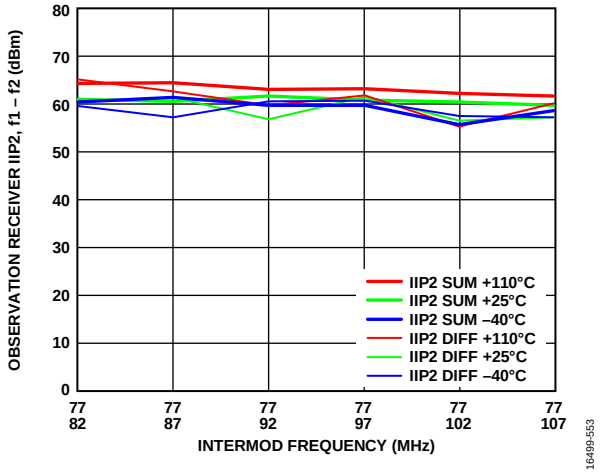

Figure 50. Observation Receiver IIP2, f1 – f2 vs. Intermod Frequency, LO = 75 MHz, Tone 1 = 77 MHz, Tone 2 is Swept, –25 dBm Each, Attenuation = 0 dB

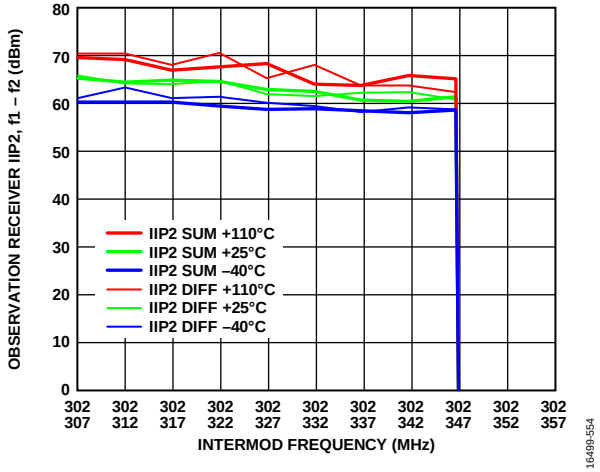

Figure 51. Observation Receiver IIP2, f1 – f2 vs. Intermod Frequency, LO = 300 MHz, Tone 1 = 302 MHz; Tone 2 = Swept, –25 dBm Each, Attenuation = 0 dB

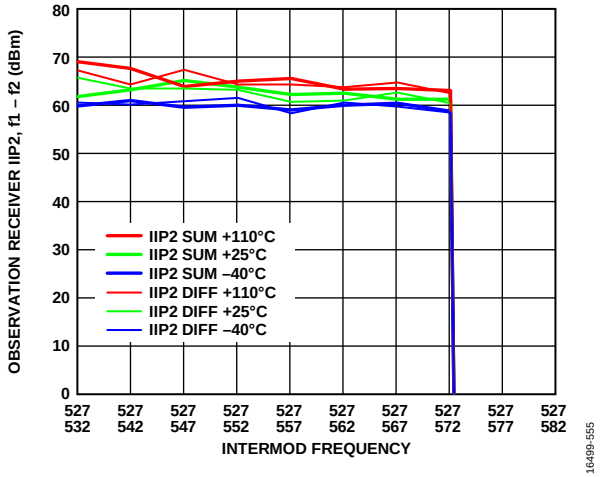

Figure 52. Observation Receiver IIP2, f1 – f2 vs. Intermod Frequency, LO = 525 MHz, Tone 1 = 527 MHz, Tone 2 = Swept, –25 dBm Each, Attenuation = 0 dB

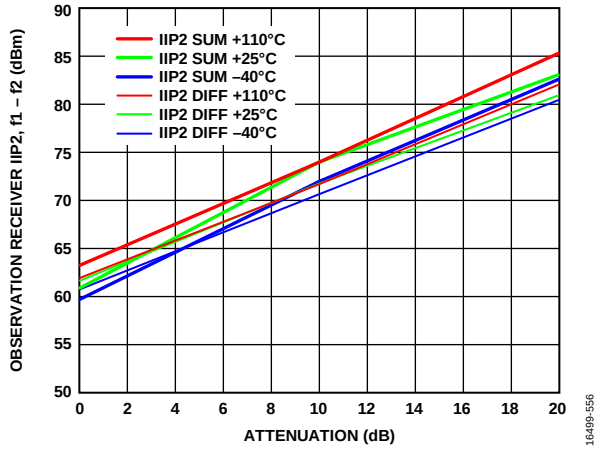

Figure 53. Observation Receiver IIP2, f1 – f2 vs. Attenuation, LO = 75 MHz, Tone 1 = 77 MHz, Tone 2 = 97 MHz at –25 dBm Plus Attenuation

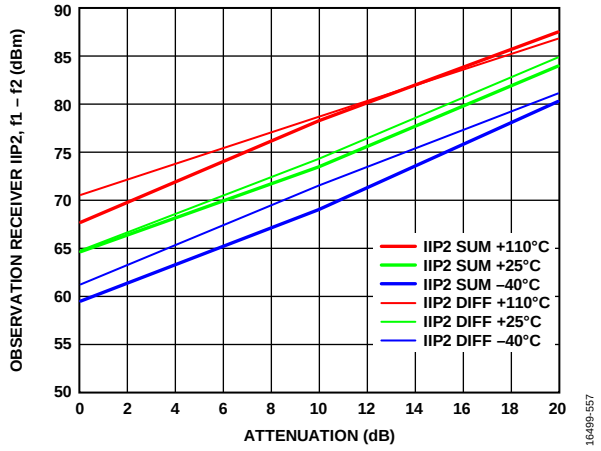

Figure 54. Observation Receiver IIP2, f1 – f2 vs. Attenuation, LO = 300 MHz, Tone 1 = 302 MHz, Tone 2 = 322 MHz at –25 dBm Plus Attenuation

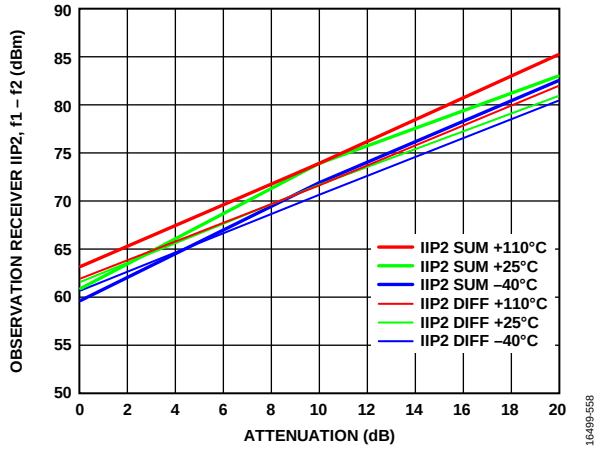

Figure 55. Observation Receiver IIP2, f1 – f2 vs. Attenuation, LO = 525 MHz, Tone 1 = 527 MHz, Tone 2 = 547 MHz at –25 dBm Plus Attenuation

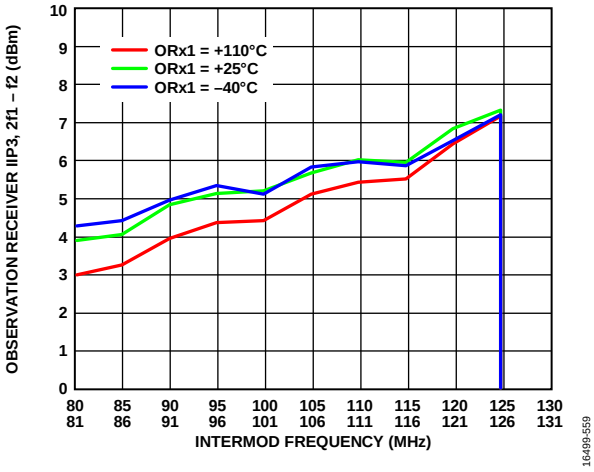

Figure 56. Observation Receiver IIP3, 2f1 – f2 vs. Intermod Frequency, LO = 75 MHz, Attenuation = 0 dB, Tones Separated By 1 MHz Swept Across Pass Band at –25 dBm Each

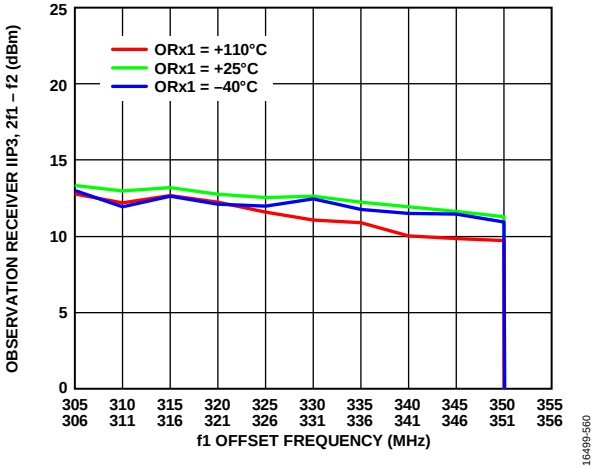

Figure 57. Observation Receiver IIP3, 2 f1 – f2 vs. f1 Offset Frequency, LO = 300 MHz, Attenuation = 0 dB, Tones Separated By 1 MHz Swept Across Pass Band at –25 dBm Each

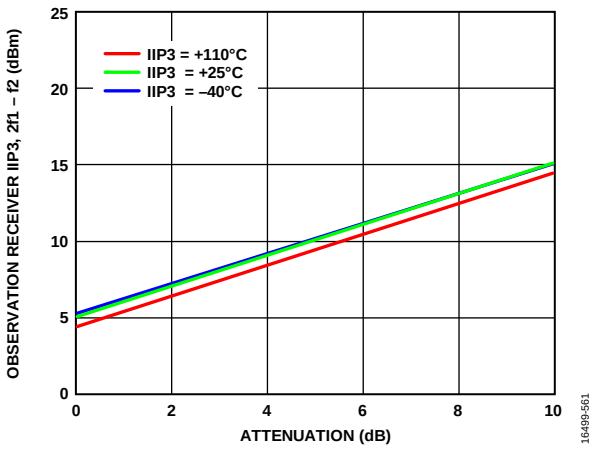

Figure 58. Observation Receiver IIP3, 2 f1 – f2 vs. Attenuation, LO = 75 MHz, Tone 1 = 100 MHz, Tone 2 = 101 MHz at –24 dBm Plus Attenuation

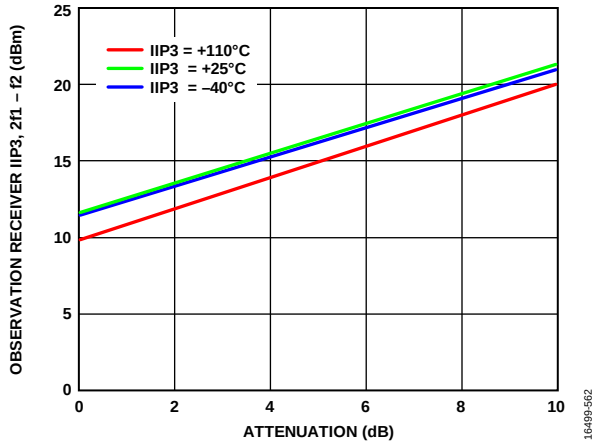

Figure 59. Observation Receiver IIP3, 2f1 – f2 vs. Attenuation, LO = 300 MHz, Tone 1 = 345 MHz, Tone 2 = 346 MHz at – 24 dBm Plus Attenuation

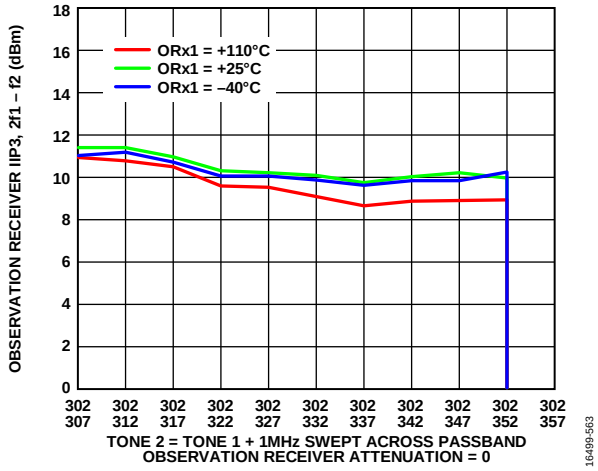

Figure 60. Observation Receiver IIP3, 2f1 – f2vs. f1 Offset Frequency, LO = 300 MHz, Attenuation = 0 dB, Tones Separated by 1 MHz Swept Across Pass Band at –19 dBm Each

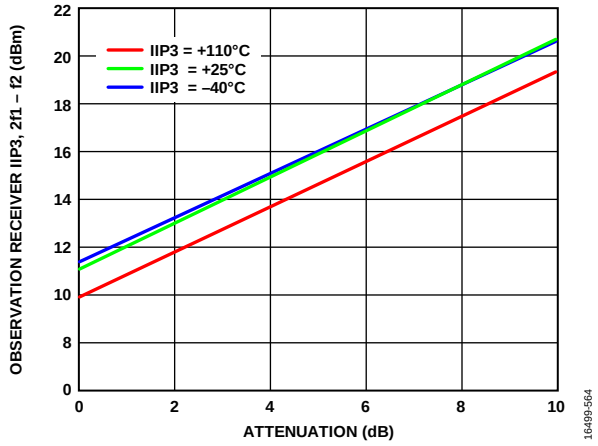

Figure 61. Observation Receiver IIP3, 2f1 – f2 vs. Attenuation, LO = 300 MHz, Tone 1 = 302 MHz, Tone 2 = 352 MHz at –19 dBm Plus Attenuation

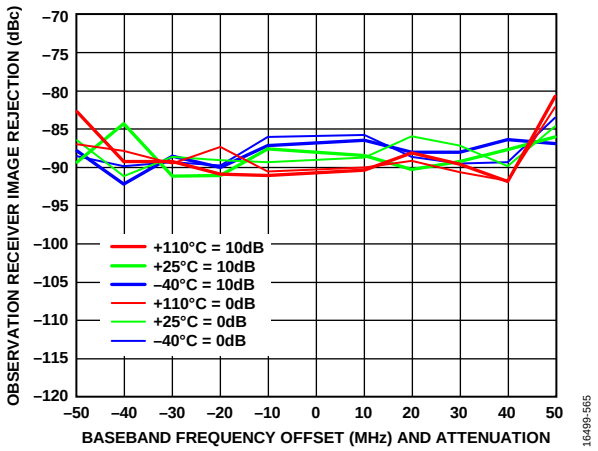

Figure 62. Observation Receiver Image Rejection vs. Baseband Frequency Offset and Attenuation, Continuous Wave Signal Swept Across the Band, LO = 75 MHz

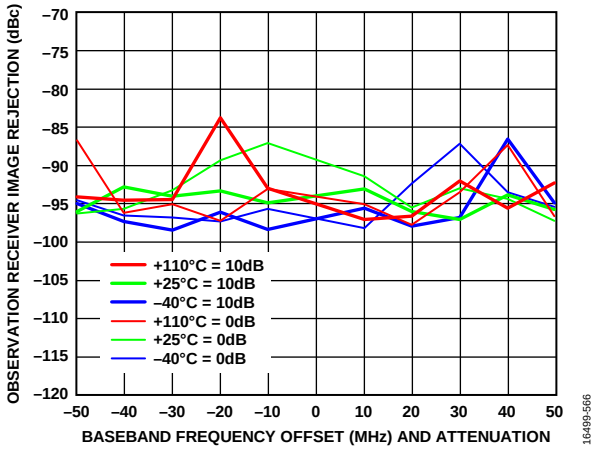

Figure 63. Observation Receiver Image Rejection vs. Baseband Frequency Offset and Attenuation, Continuous Wave Signal Swept Across the Band, LO = 300 MHz

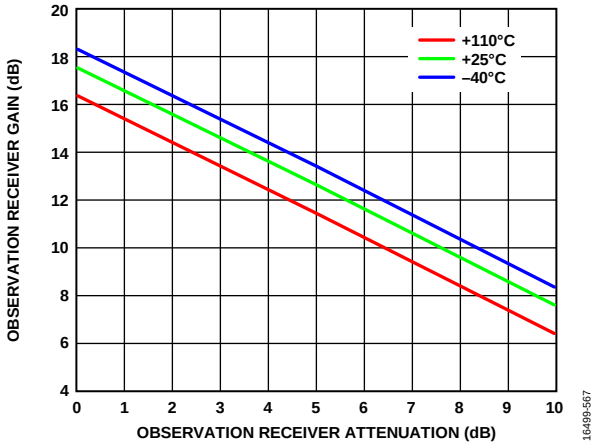

Figure 64. Observation Receiver Gain vs. Observation Receiver Attenuation, LO = 75 MHz

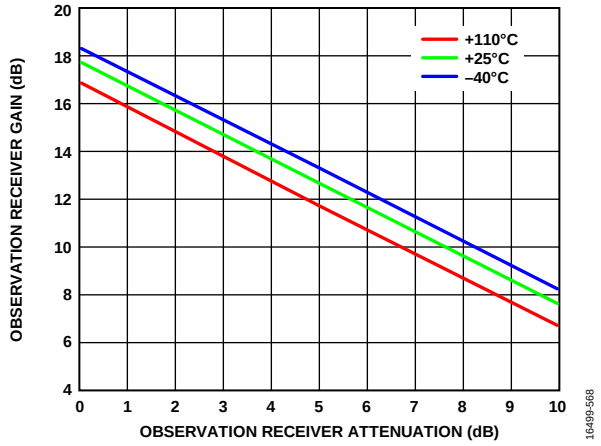

Figure 65. Observation Receiver Gain vs. Observation Receiver Attenuation, LO = 300 MHz

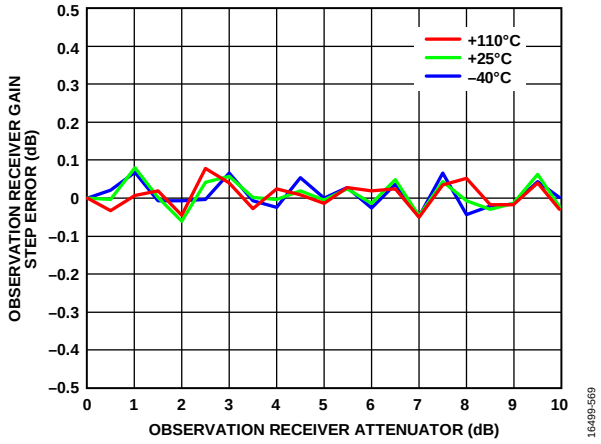

Figure 66. Observation Receiver Gain Step Error vs. Observation Receiver Attenuator, LO = 75 MHz

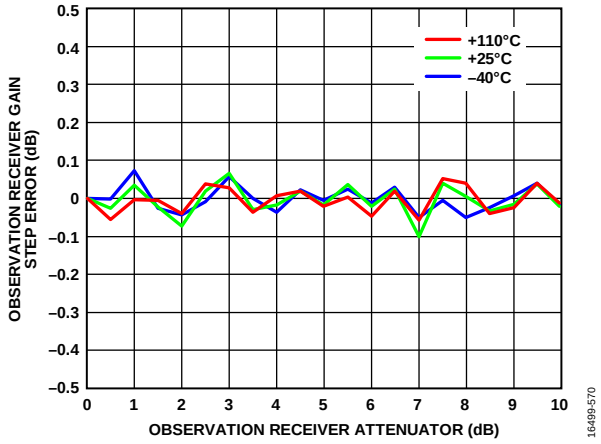

Figure 67. Observation Receiver Attenuator Gain Step Error vs. Observation Receiver Attenuator, LO = 325 MHz

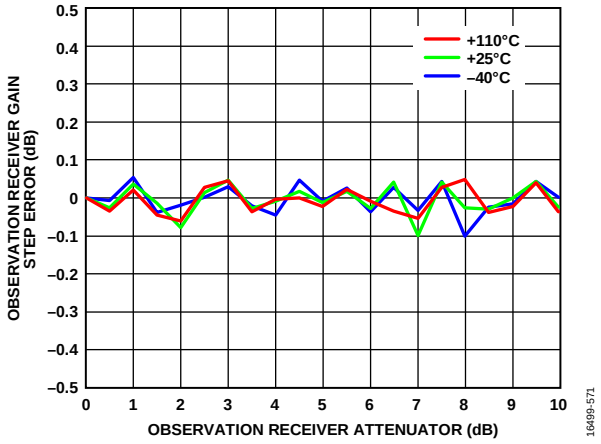

Figure 68. Observation Receiver Attenuator Gain Step Error vs. Observation Receiver Attenuator, LO = 525 MHz

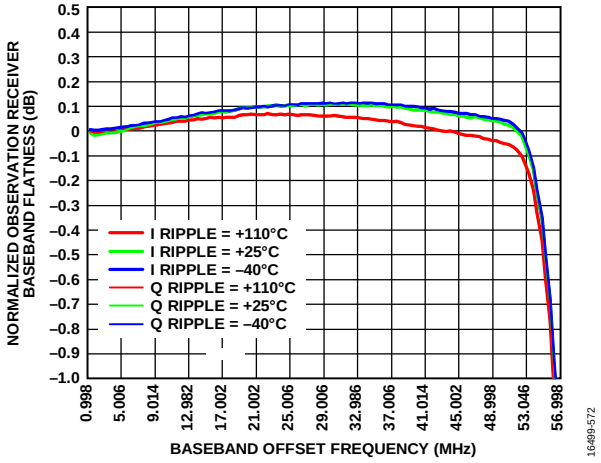

Figure 69. Normalized Observation Receiver Baseband Flatness vs. Baseband Offset Frequency, LO = 75 MHz, 0 dB Attenuation

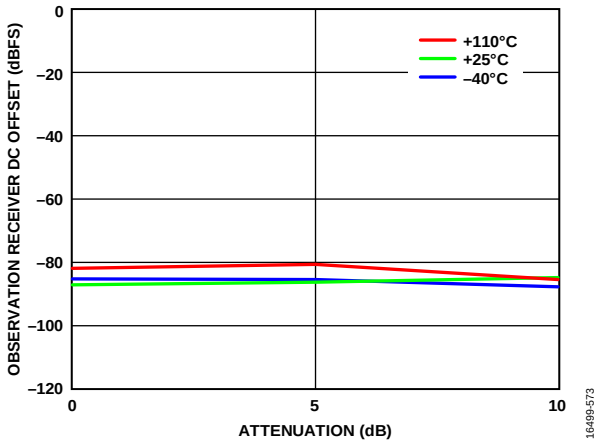

Figure 70. Observation Receiver DC Offset vs. Attenuation, LO = 75 MHz, Baseband Frequency = 50 MHz

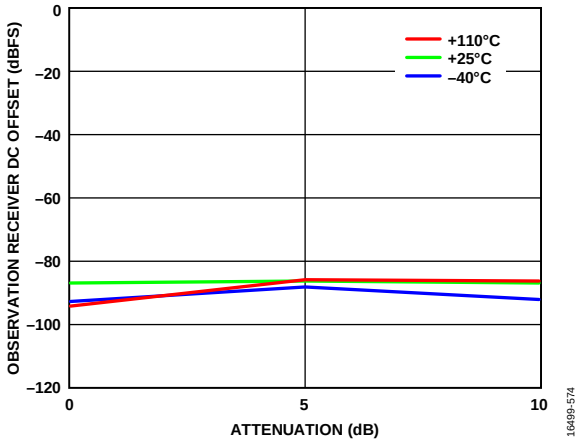

Figure 71. Observation Receiver DC Offset vs. Attenuation, LO = 325 MHz, Baseband Frequency = 50 MHz

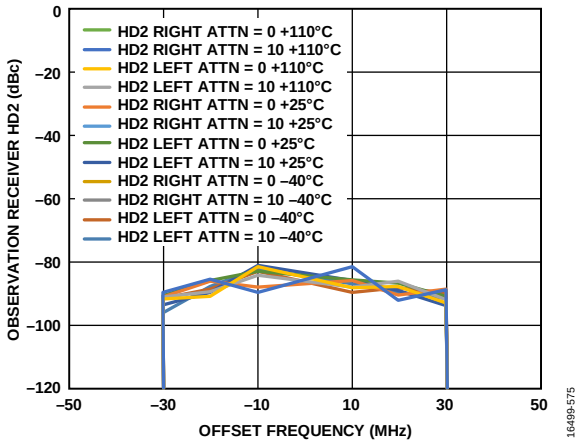

Figure 72. Observation Receiver HD2 vs. Offset Frequency and Attenuation, LO = 75 MHz, Tone Level = –21 dBm Plus Attenuation

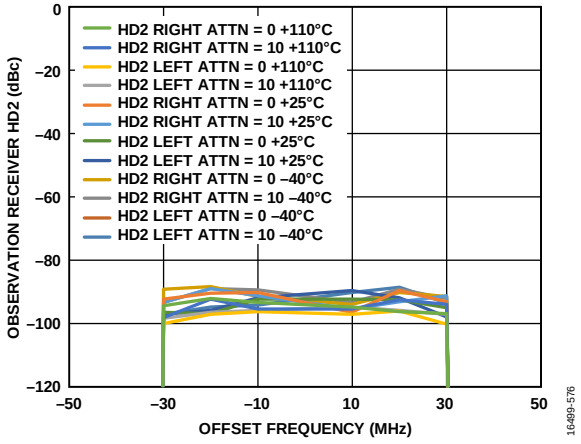

Figure 73. Observation Receiver HD2 vs. Offset Frequency and Attenuation, LO = 300 MHz, Tone Level = –22 dBm Plus Attenuation

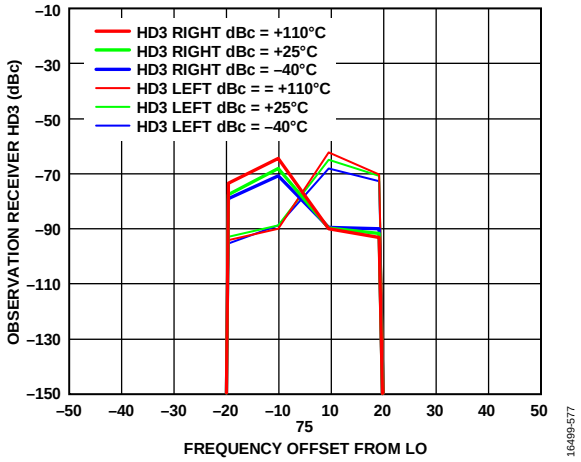

Figure 74. Observation Receiver HD3 Left and Right vs. Frequency Offset from LO, Tone Level –21 dBm at Attenuation = 0, LO = 75 MHz

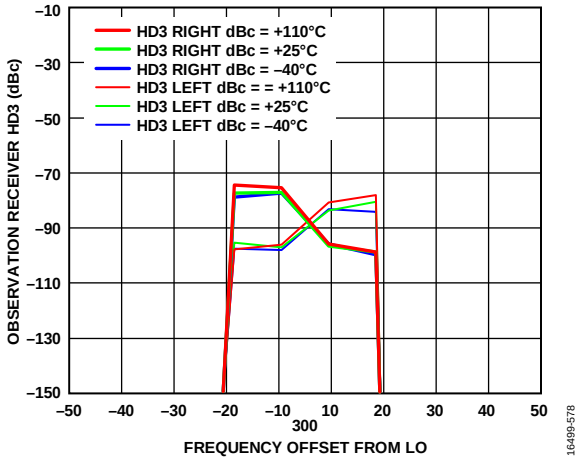

Figure 75. Observation Receiver HD3 Left and Right vs. Frequency Offset from LO, Tone Level –22 dBm at Attenuation = 0, LO = 300 MHz

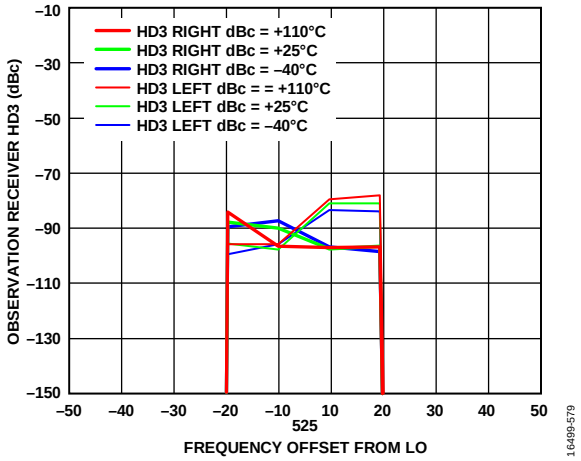

Figure 76. Observation Receiver HD3 Left and Right vs. Frequency Offset from LO, Tone Level –22 dBm at Attenuation = 0, LO = 525 MHz

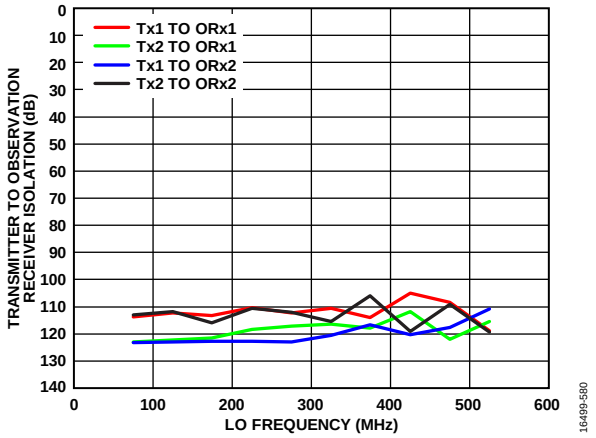

Figure 77. Transmitter to Observation Receiver Isolation vs. LO Frequency, Temperature = 25°C

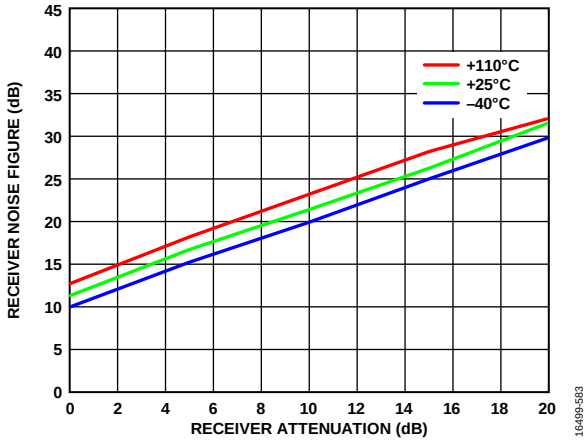

Figure 80. Receiver Noise Figure vs. Receiver Attenuation, 300 MHz LO, 50 MHz Bandwidth, Sample Rate = 61.44 MSPS, 1 MHz to 25 MHz Integration Bandwidth

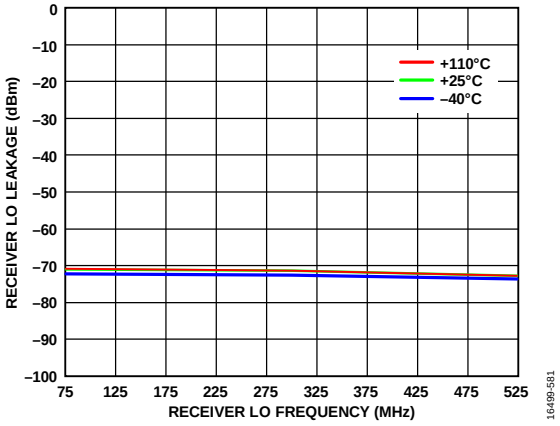

Figure 78. Receiver LO Leakage vs. Receiver LO Frequency, 75 MHz, 300 MHz, 525 MHz, Receiver Attenuation = 0 dB, RF Bandwidth = 50 MHz, Sample Rate = 61.44 MSPS

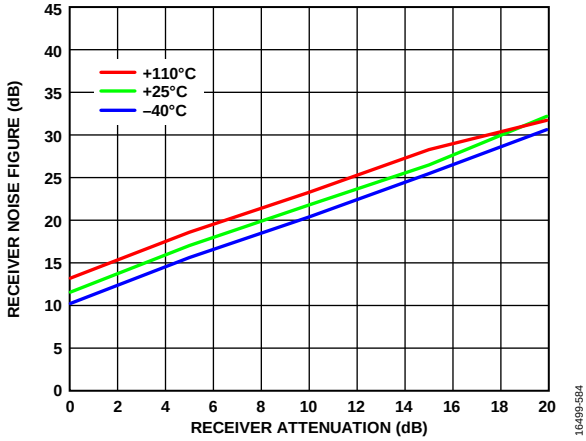

Figure 81. Receiver Noise Figure vs. Receiver Attenuation, LO = 525 MHz, Bandwidth = 50 MHz, Sample Rate = 61.44 MSPS, Integration Bandwidth = 1 MHz to 25 MHz

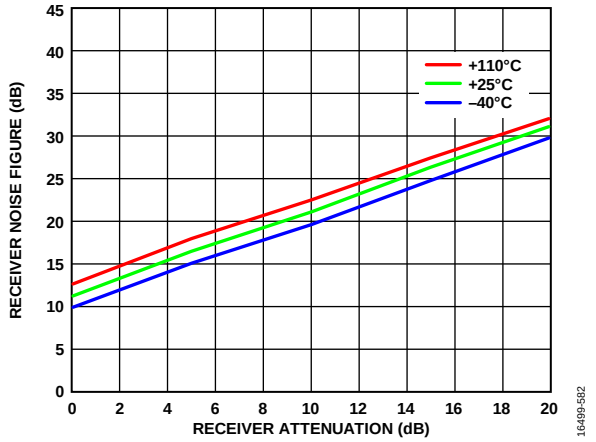

Figure 79. Receiver Noise Figure vs. Receiver Attenuation, LO = 75 MHz, Bandwidth = 50 MHz, Sample Rate = 61.44 MSPS, 1 MHz to 25 MHz Integration Bandwidth

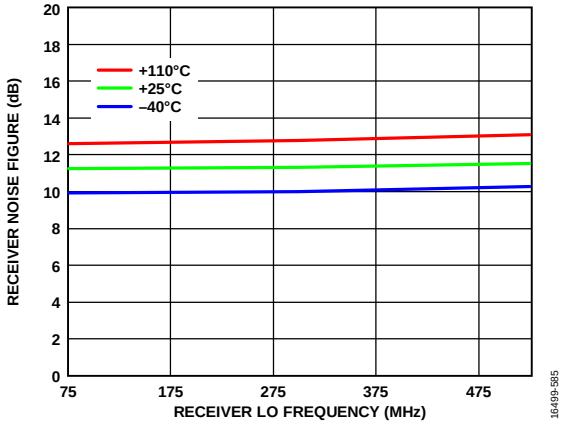

Figure 82. Receiver Noise Figure vs. Receiver LO Frequency, Receiver Attenuation = 0 dB, RF Bandwidth = 50 MHz, Sample Rate = 61.44 MSPS, Integration Bandwidth = ±25 MHz

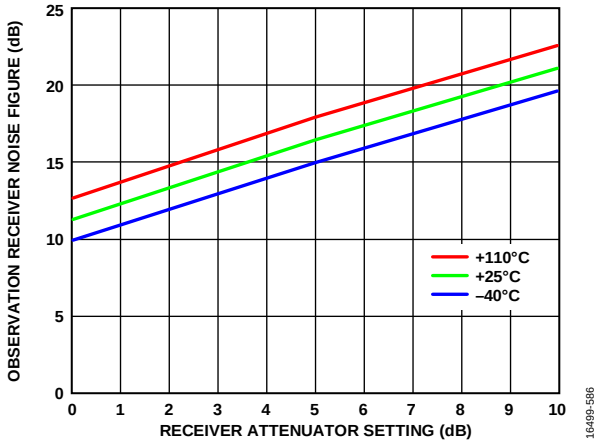

Figure 83. Observation Receiver Noise Figure vs. Receiver Attenuator Setting, Total Nyquist Integration Bandwidth = 75 MHz

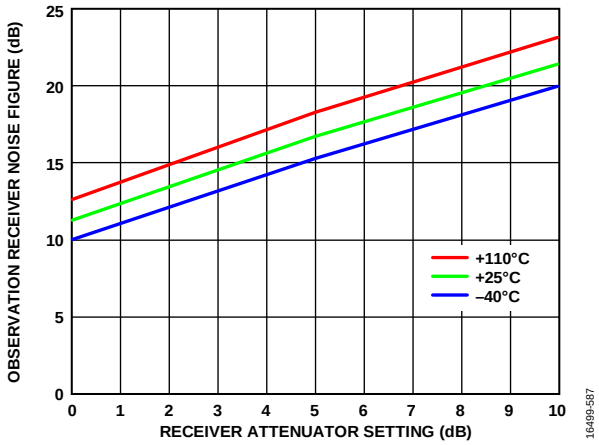

Figure 84. Observation Receiver Noise Figure vs. Receiver Attenuator Setting, 300 MHz, Total Nyquist Integration Bandwidth

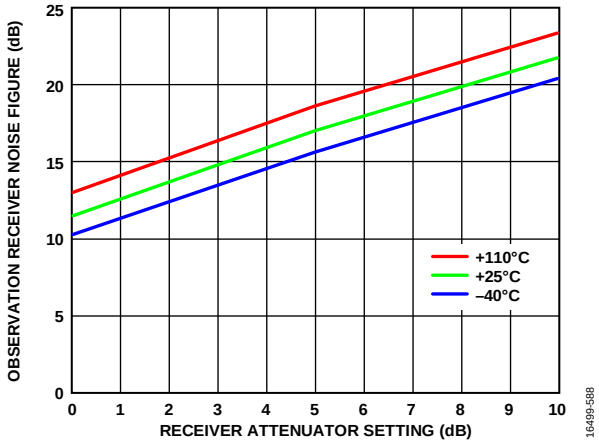

Figure 85. Observation Receiver Noise Figure vs. Receiver Attenuator Setting, 525 MHz, Total Nyquist Integration Bandwidth

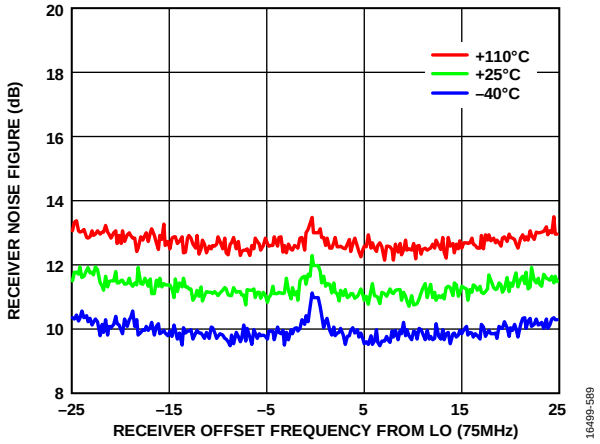

Figure 86. Receiver Noise Figure vs. Receiver Offset Frequency from LO, LO = 75 MHz

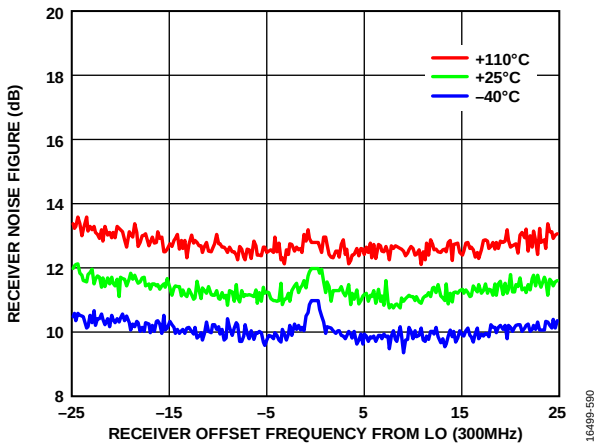

Figure 87. Receiver Noise Figure vs. Receiver Offset Frequency from LO, LO = 300 MHz

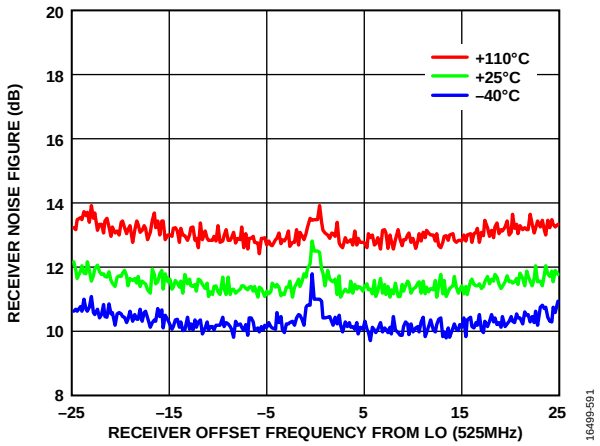

Figure 88. Receiver Noise Figure vs. Receiver Offset Frequency from LO, LO = 525 MHz

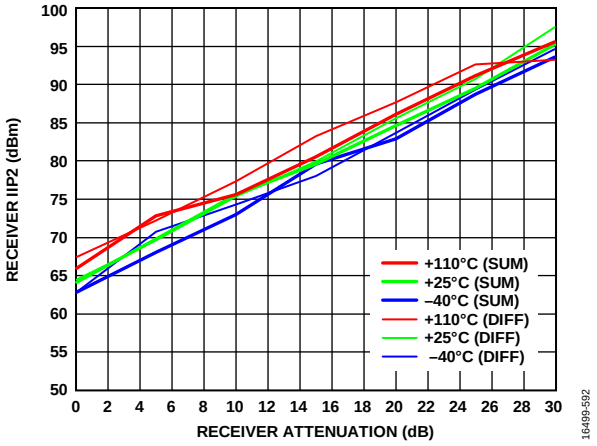

Figure 89. Receiver IIP2 vs. Receiver Attenuation, LO = 75 MHz, Tones Placed at 82.5 MHz and 83.5 MHz, −23.5 dBm Plus Attenuation

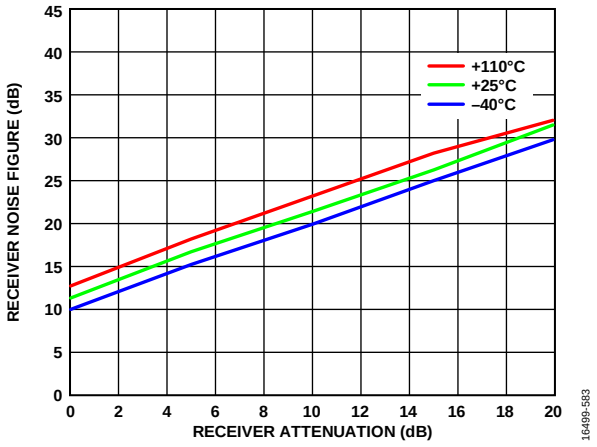

Figure 90. Receiver IIP2 vs. Receiver Attenuation, 300 MHz LO, Tones Placed at 310 MHz and 311 MHz, −23.5 dBm Plus Attenuation

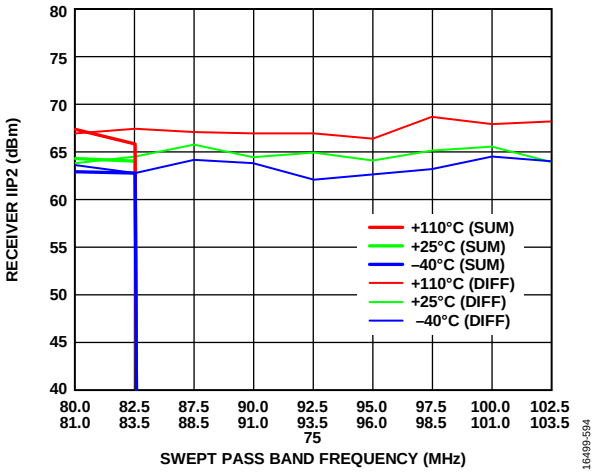

Figure 91. Receiver IIP2 Sum and Difference Across Bandwidth, Receiver Attenuation = 0 dB, LO = 75 MHz, 10 Tone Pairs, −23.5 dBm Each

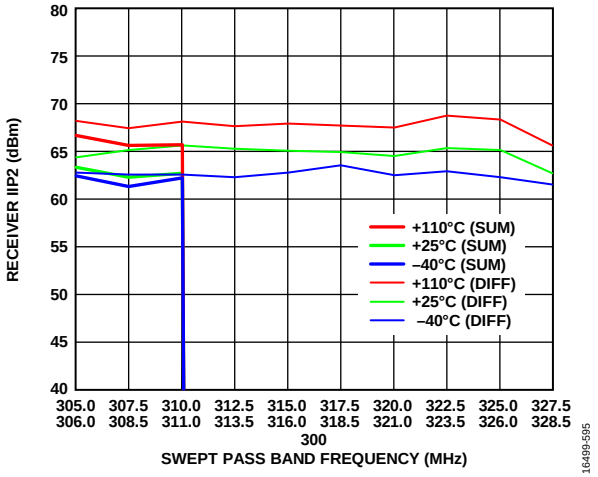

Figure 92. Receiver IIP2 Sum and Difference Across Bandwidth, Receiver Attenuation = 0 dB, LO = 300 MHz, 10 Tone Pairs, −23.5 dBm Each

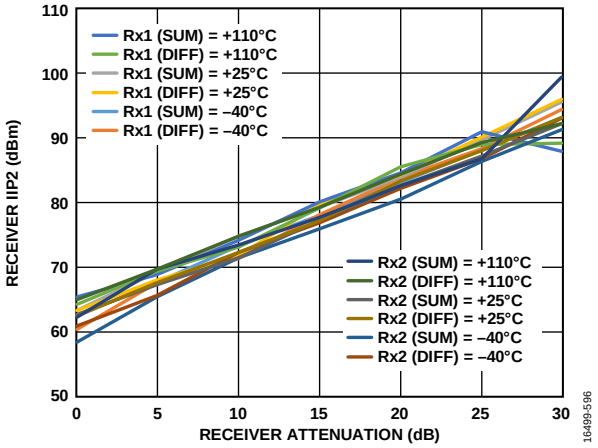

Figure 93. Receiver IIP2 vs. Receiver Attenuation, LO = 75 MHz, Tones Placed at 77 MHz and 97 MHz, −23.5 dBm Plus Attenuation

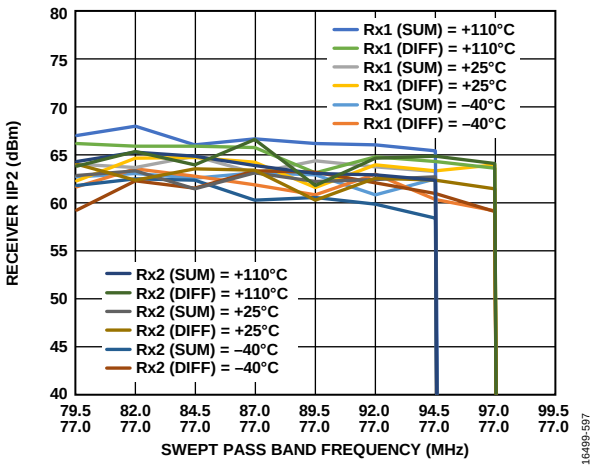

Figure 94. Receiver IIP2 Sum and Difference Across Bandwidth, 0 dB Receiver Attenuation, LO = 75 MHz, Tone 1 = 77 MHz, Tone 2 Swept, −23.5 dBm Each

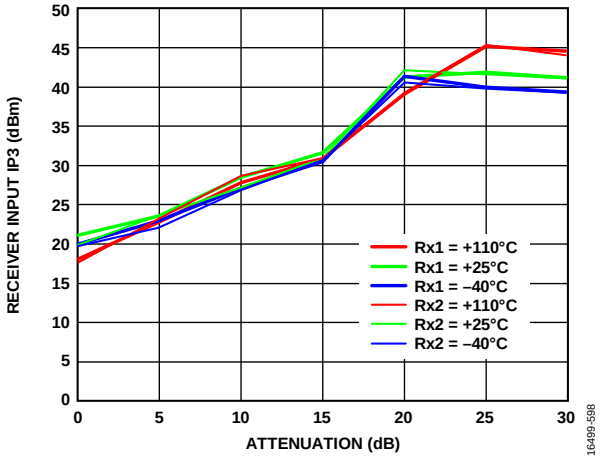

Figure 95. Receiver IIP3 vs. Attenuation, LO = 300 MHz, Tone 1 = 325 MHz, Tone 2 = 326 MHz, −21 dBm Plus Attenuation

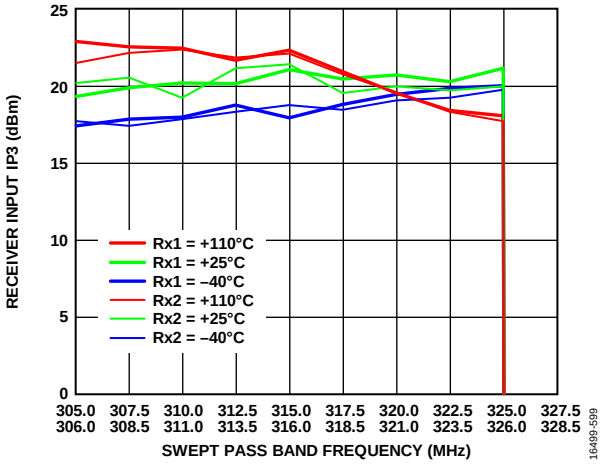

Figure 96. Receiver IIP3 Across Bandwidth Receiver Attenuation = 0 dB, LO = 300 MHz, Tone 2 = Tone 1 + 1 MHz, −21 dBm Each, Swept Across Pass Band

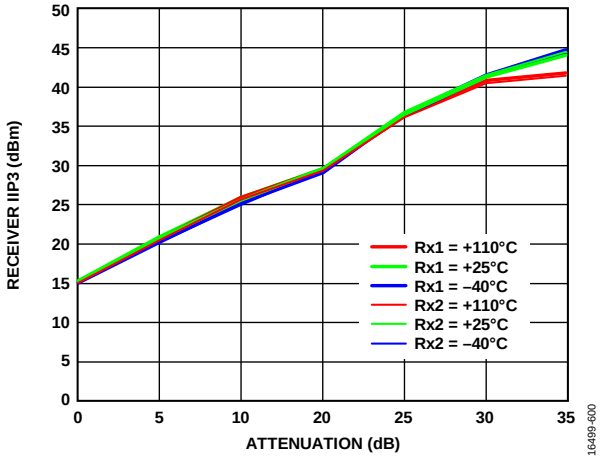

Figure 97. Receiver IIP3 vs. Attenuation, LO = 300 MHz, Tone 1 = 302 MHz, Tone 2 = 322 MHz, −19 dBm Plus Attenuation

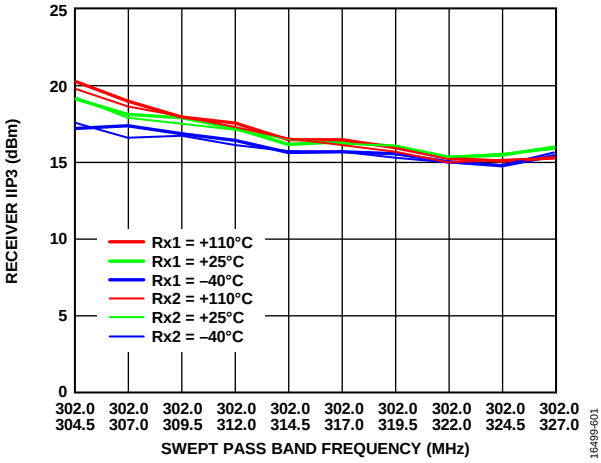

Figure 98. Receiver IIP3 Across Bandwidth, 0 dB Receiver Attenuation, 300 MHz LO, Tone 1 = 302MHz, Tone 2 Swept Across Pass Band, −19 dBm Each

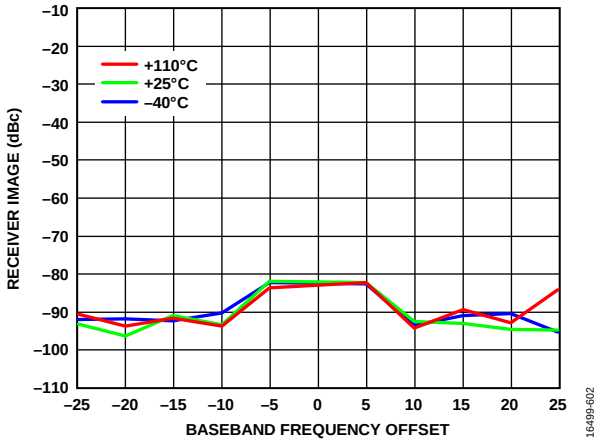

Figure 99. Receiver Image vs. Baseband Frequency Offset, Attenuation = 0 dB, RF Bandwidth = 50 MHz, Tracking Calibration Active, Sample Rate = 61.44 MSPS, LO = 75 MHz

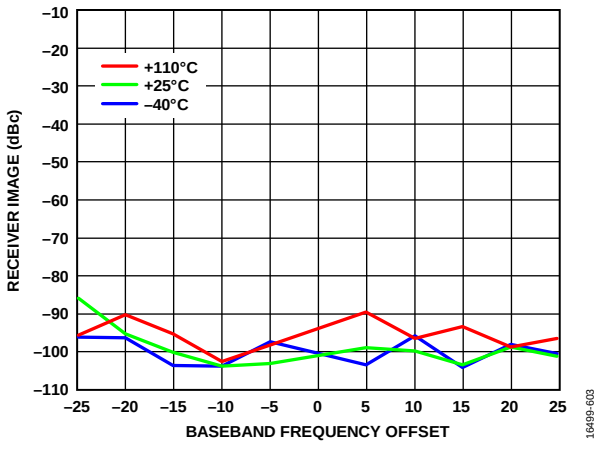

Figure 100. Receiver Image vs. Baseband Frequency Offset, Attenuation = 0 dB, RF Bandwidth = 50 MHz, Tracking Calibration Active, Sample Rate = 61.44 MSPS, LO = 300 MHz

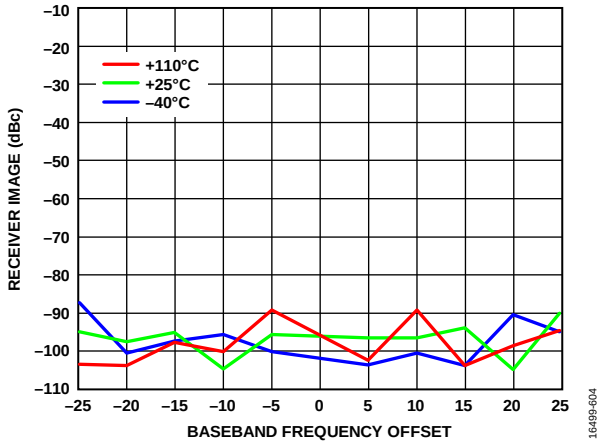

Figure 101. Receiver Image vs. Baseband Frequency Offset, Attenuation = 0 dB, RF Bandwidth = 50 MHz, Tracking Calibration Active, Sample Rate = 61.44 MSPS, LO = 525 MHz

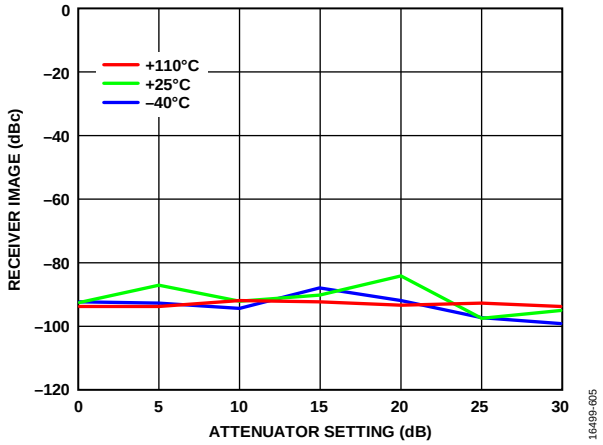

Figure 102. Receiver Image vs. Attenuation Setting, RF Bandwidth = 25 MHz, Tracking Calibration Active, Sample Rate = 61.44 MSPS, LO = 75 MHz, Baseband Frequency = 25 MHz

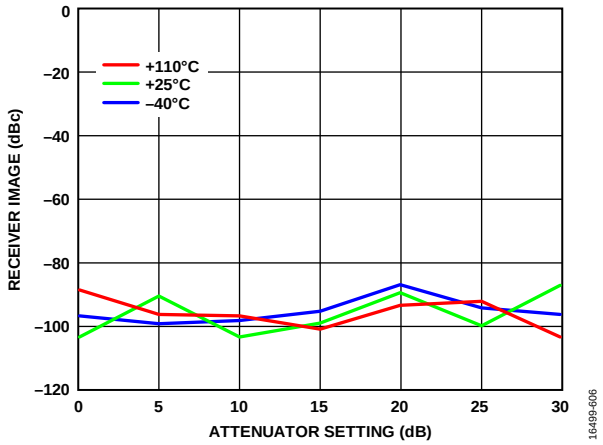

Figure 103. Receiver Image vs. Attenuation Setting, RF Bandwidth = 25 MHz, Tracking Calibration Active, Sample Rate = 61.44 MSPS, LO = 32 5MHz, Baseband Frequency = 25 MHz

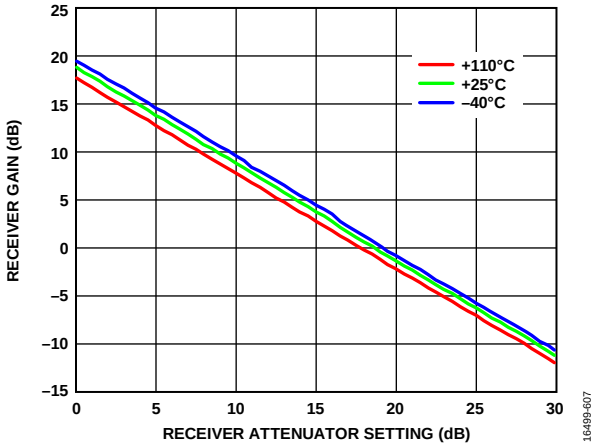

Figure 104. Receiver Gain vs. Receiver Attenuation Setting, RF Bandwidth = 50 MHz, Sample Rate = 61.44 MSPS, LO = 75 MHz

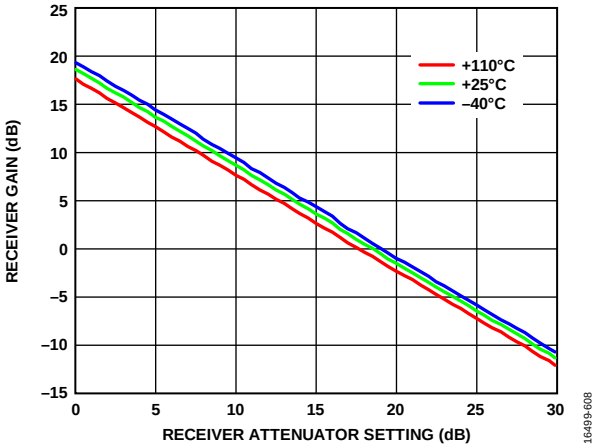

Figure 105. Receiver Gain vs. Receiver Attenuation Setting, RF Bandwidth = 50 MHz, Sample Rate = 61.44 MSPS, LO = 325 MHz

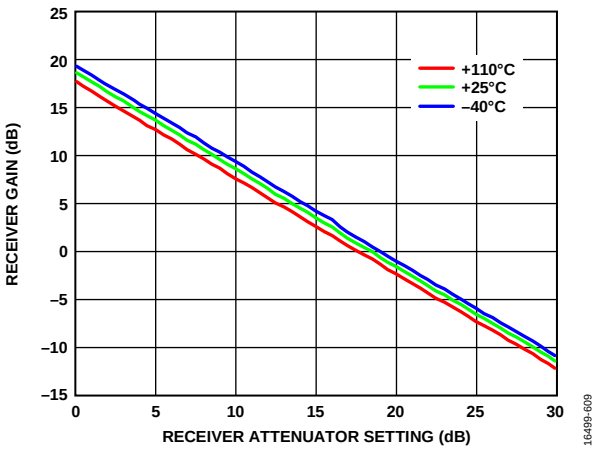

Figure 106. Receiver Gain vs. Receiver Attenuation Setting, RF Bandwidth = 50 MHz, Sample Rate = 61.44 MSPS, LO = 525 MHz

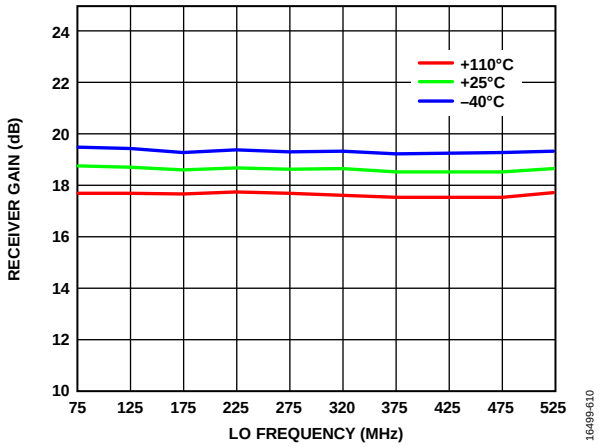

Figure 107. Receiver Gain vs. LO Frequency, RF Bandwidth = 50 MHz, Sample Rate = 61.44 MSPS

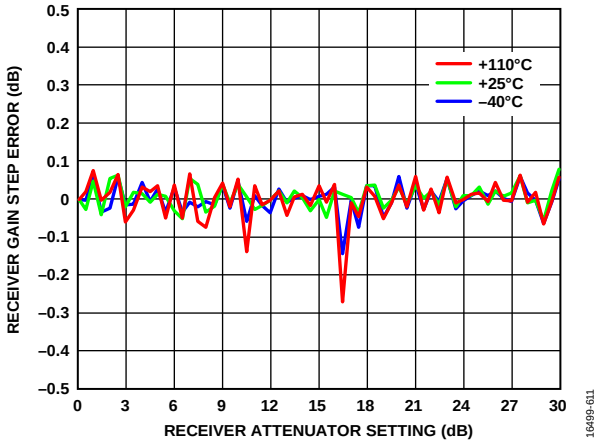

Figure 108. Receiver Attenuator Gain Step Error vs. Receiver Attenuator Setting, LO = 75 MHz

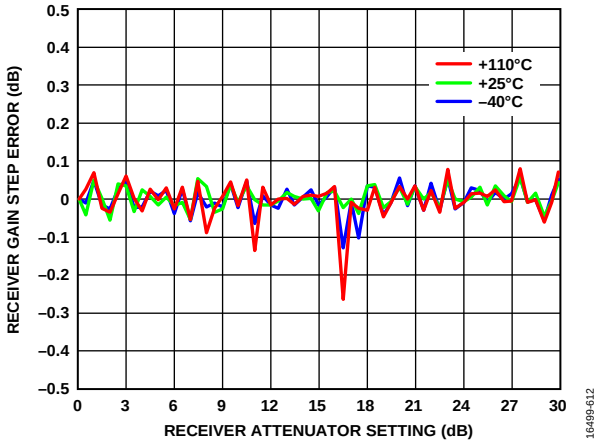

Figure 109. Receiver Attenuator Gain Step Error vs. Receiver Attenuator Setting, LO = 325 MHz

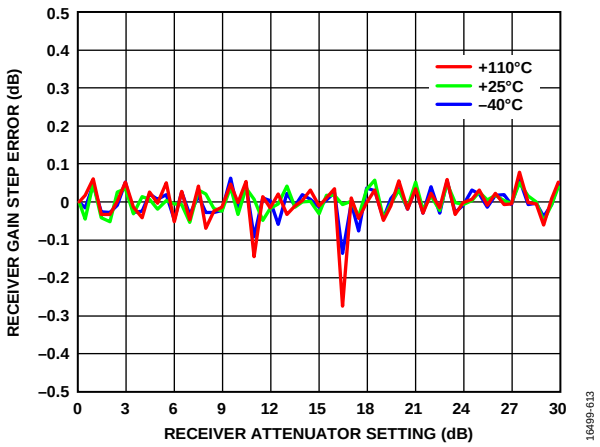

Figure 110. Receiver Attenuator Gain Step Error vs. Receiver Attenuator Setting, LO = 525 MHz

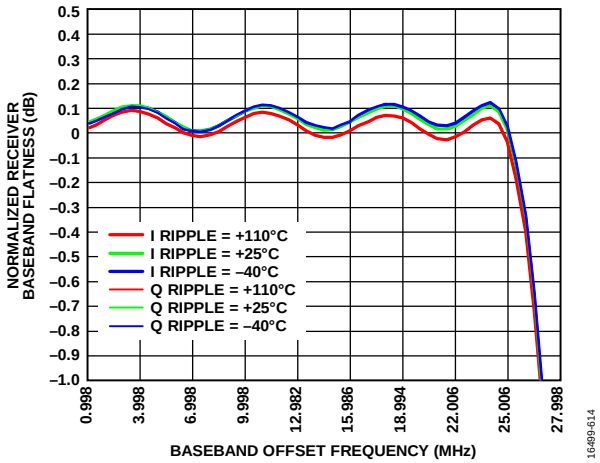

Figure 111. Normalized Receiver Baseband Flatness vs. Baseband Frequency (Receiver Flatness), LO = 75 MHz

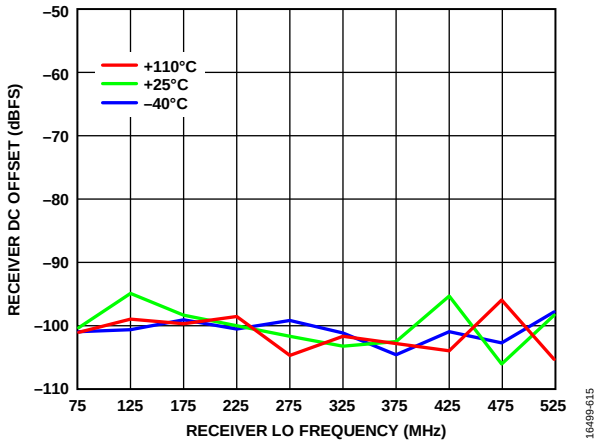

Figure 112. Receiver DC Offset vs. Receiver LO Frequency

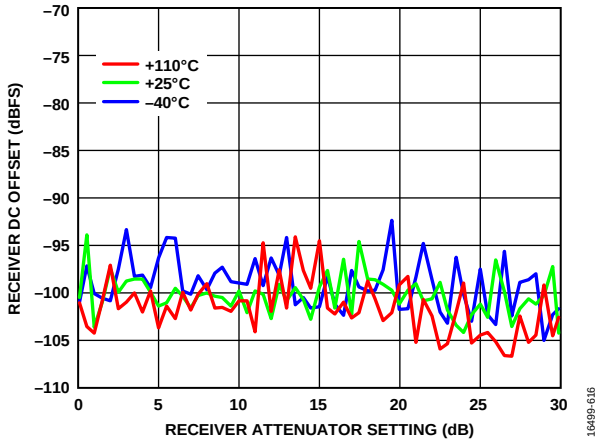

Figure 113. Receiver DC Offset vs. Receiver Attenuator Setting, LO = 75MHz

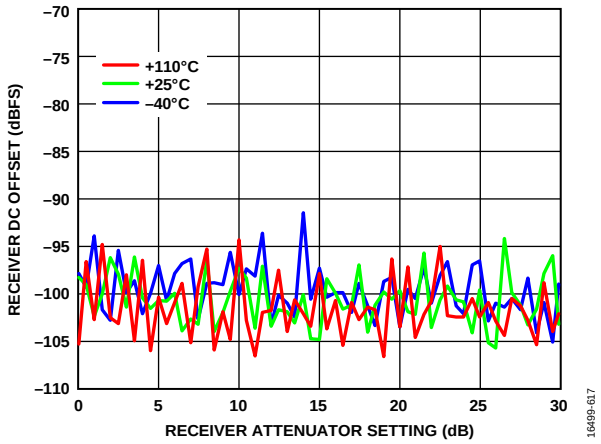

Figure 114. Receiver DC Offset vs. Receiver Attenuator Setting), LO = 525 MHz

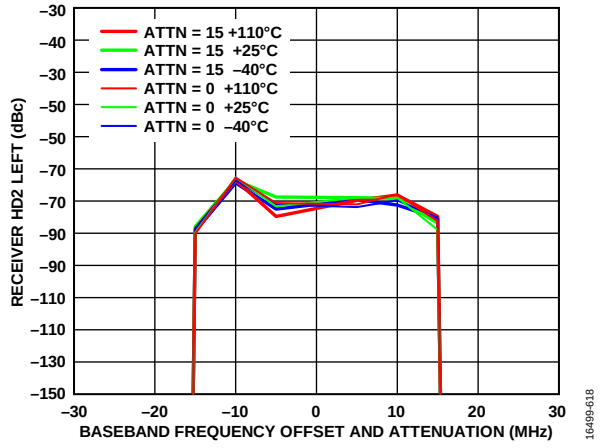

Figure 115. Receiver HD2 Left vs. Baseband Frequency Offset and Attenuation, Tone Level = –21 dBm at Attenuation = 0, X-Axis is Baseband Frequency Offset of Fundamental Tone, Not Frequency of HD2 Product (HD2 Product is 2× Baseband Frequency), HD2 Canceller Disabled, LO = 75MHz

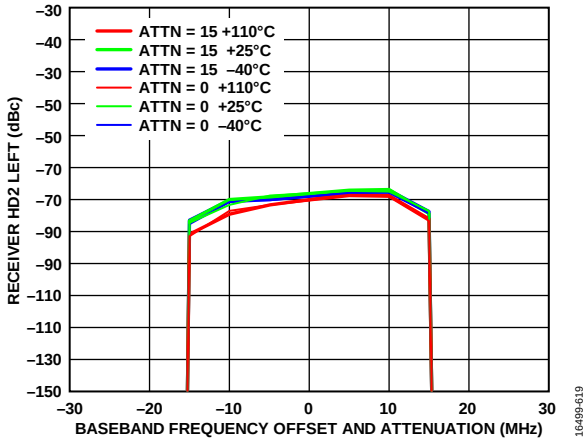

Figure 116. Receiver HD2 Left vs. Baseband Frequency Offset and Attenuation, Tone Level –21 dBm at Attenuation = 0, X-Axis is Baseband Frequency Offset of Fundamental Tone, Not Frequency of HD2 Product (HD2 Product is 2× Baseband Frequency), HD2 Canceller Disabled, LO = 300 MHz

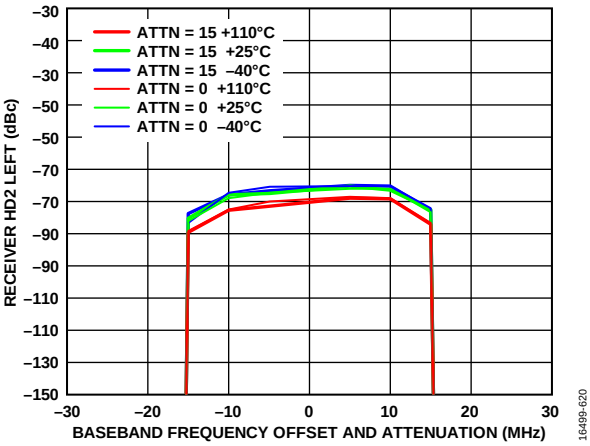

Figure 117. Receiver HD2 Left vs. Baseband Frequency Offset and Attenuation, Tone Level –21 dBm at Attenuation = 0, X-Axis is Baseband Frequency Offset of Fundamental Tone, Not Frequency of HD2 Product (HD2 Product is 2× Baseband Frequency), HD2 Canceller Disabled, LO = 525 MHz

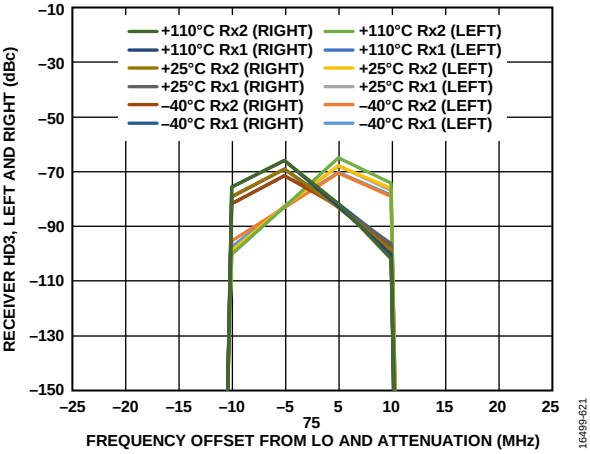

Figure 118. Receiver HD3 Left and Right vs. Frequency Offset from LO and Attenuation, Tone Level = –16 dBm at Attenuation = 0, LO = 75 MHz

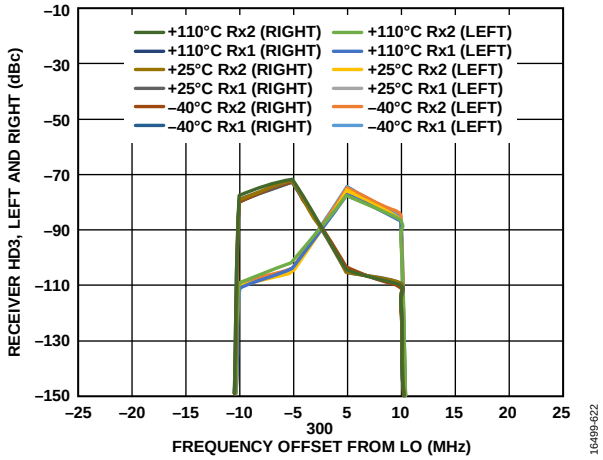

Figure 119. Receiver HD3 Left and Right vs. Attenuation, Tone Level = −17 dBm at Attenuation = 0, LO = 300 MHz

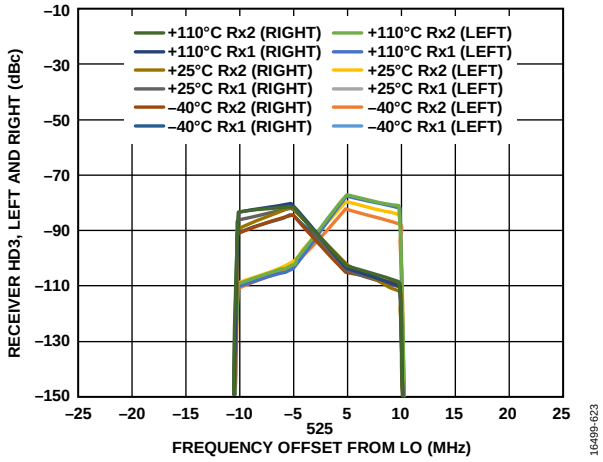

Figure 120. Receiver HD3 Left and Right vs. Frequency Offset from LO, Tone Level = −17 dBm at Attenuation = 0, LO = 525 MHz

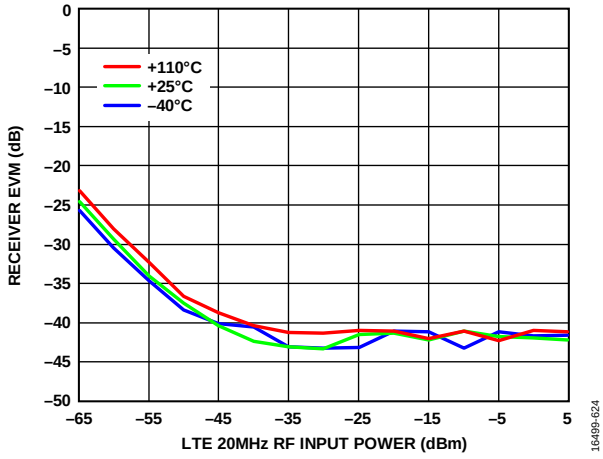

Figure 121. Receiver EVM vs. RF Input Power, LTE20 RF Signal, LO = 75 MHz, Default AGC Settings

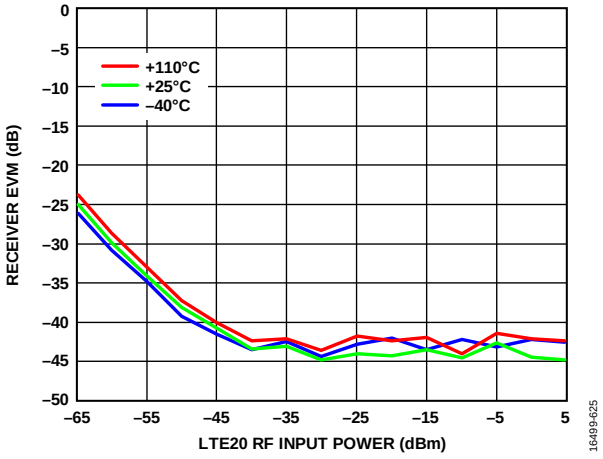

Figure 122. Receiver EVM vs. RF Input Power, LTE20 RF Signal, LO = 300 MHz, Default AGC Settings

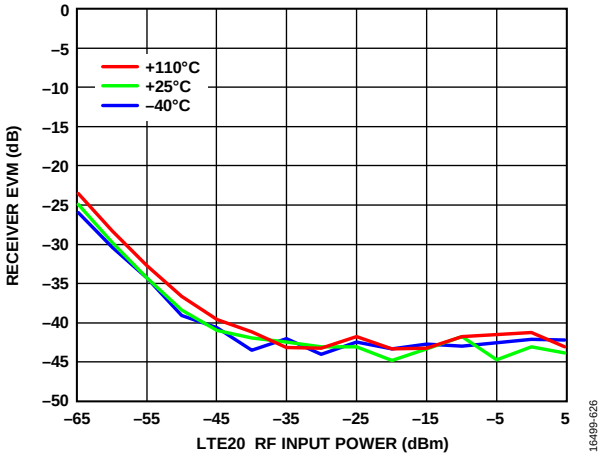

Figure 123. Receiver EVM vs. RF Input Power, LTE20 RF Signal, LO = 525 MHz, Default AGC Settings

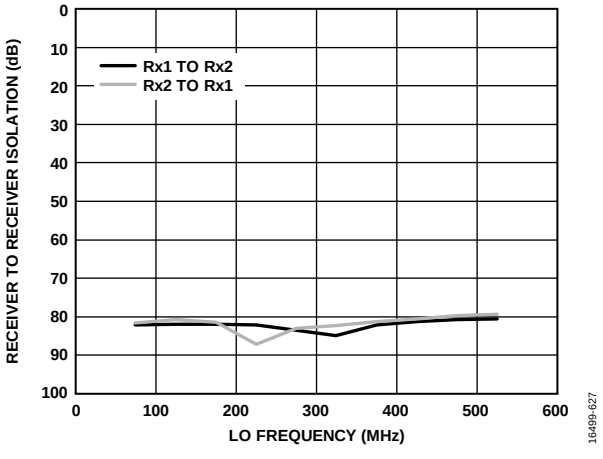

Figure 124. Receiver to Receiver Isolation vs. LO Frequency, Baseband Frequency = 10 MHz

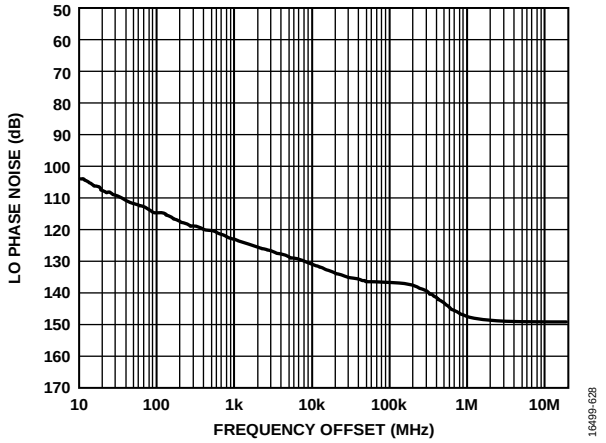

Figure 125. LO Phase Noise vs. Frequency Offset, LO = 75 MHz, RMS Phase Error Integrated from 2 kHz to 18 MHz, PLL Loop Bandwidth = 300 kHz

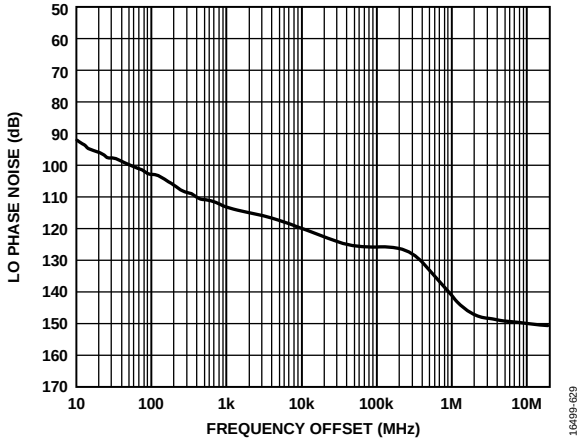

Figure 126. LO Phase Noise vs. Frequency Offset, LO = 300 MHz, RMS Phase Error Integrated from 2 kHz to 18 MHz, PLL Loop Bandwidth = 300 kHz

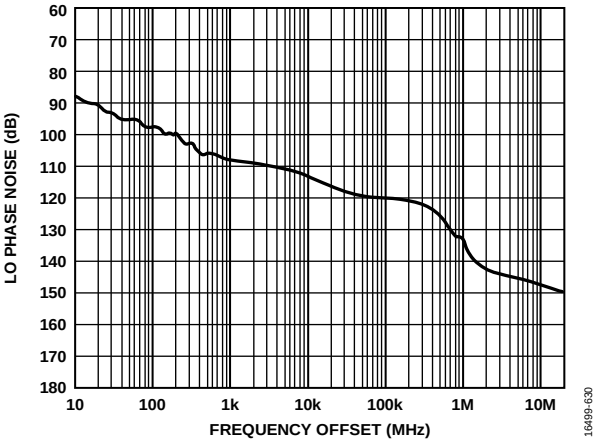

Figure 127. LO Phase Noise vs. Frequency Offset, LO = 525 MHz, RMS Phase Error Integrated from 2 kHz to 18 MHz, PLL Loop Bandwidth = 300 kHz

650 MHz TO 3000 MHz BAND

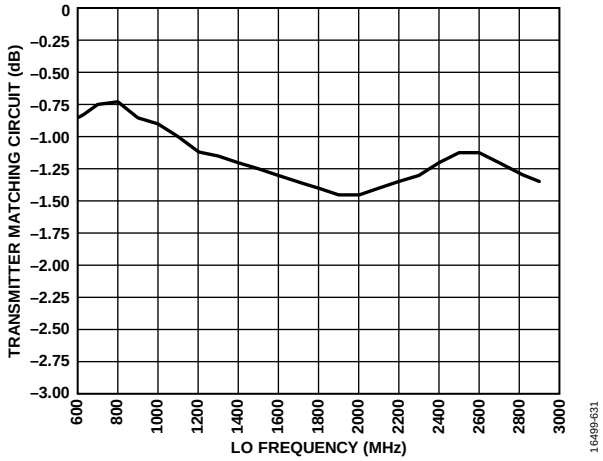

Figure 128. Transmitter Matching Circuit Path Loss vs. LO Frequency (Can Be Used for Deembedding Performance Data)

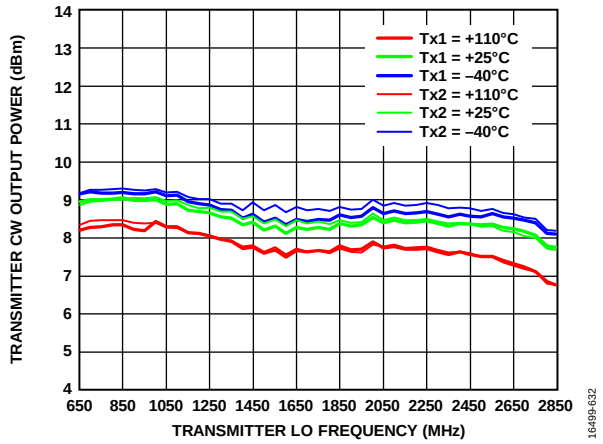

Figure 129. Transmitter Continuous Wave Output Power vs. Transmitter Frequency, Transmitter QEC and External LO Leakage Active, Transmitter in 200 MHz/450 MHz Bandwidth Mode, IQ Rate = 491.52 MHz, 0 dB Attenuation (Not Deembedded)

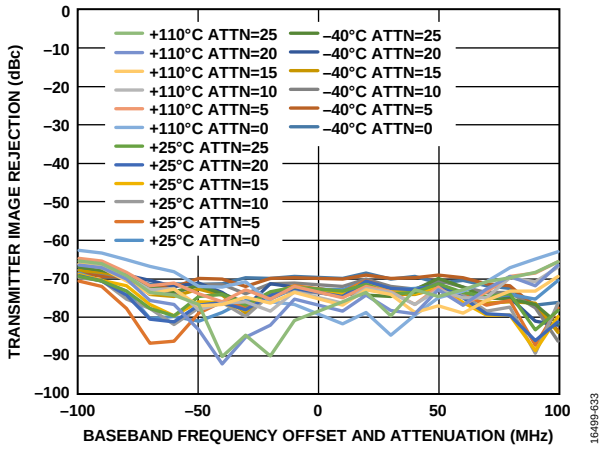

Figure 130. Transmitter Image Rejection Across Large Signal Bandwidth vs. Offset Frequency and Attenuation, QEC Trained with Three Tones Placed at 10 MHz, 50 MHz, and 100 MHz (Tracking On), Total Combined Power = –6 dBFS, Correction Then Frozen (Tracking Turned Off), Continuous Wave Tone Swept Across Large Signal Bandwidth

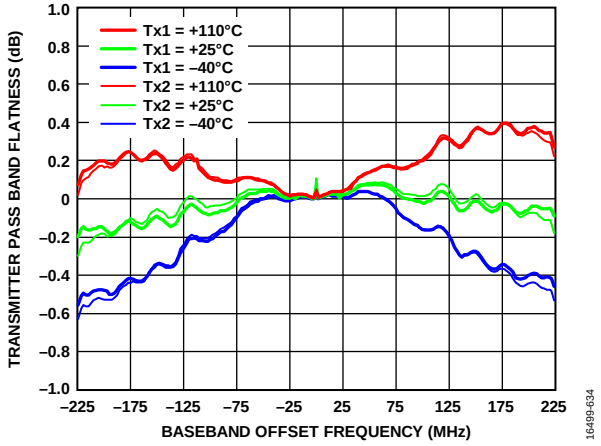

Figure 131. Transmitter Pass Band Flatness vs. Baseband Offset Frequency, LO = 2600 MHz

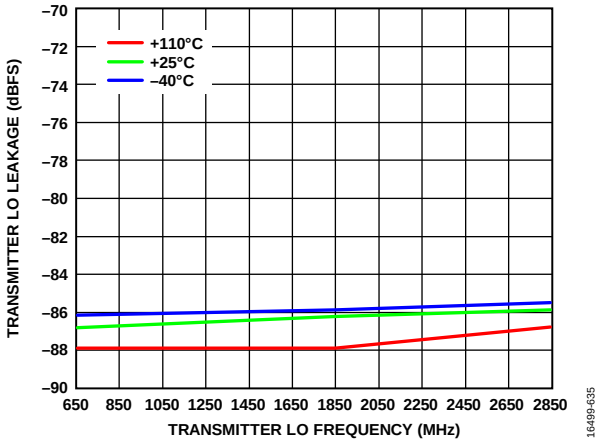

Figure 132. Transmitter LO Leakage vs. Baseband LO Frequency, Transmitter Attenuation = 0 dB

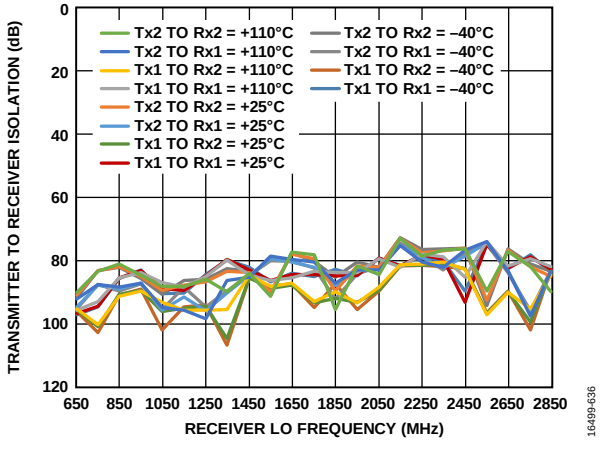

Figure 133. Transmitter to Receiver Isolation vs. Receiver LO Frequency

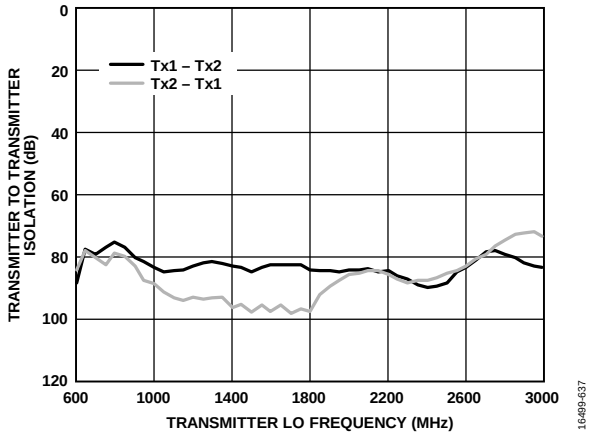

Figure 134. Transmitter to Transmitter Isolation vs. Transmitter LO Frequency, Temperature = 25°C

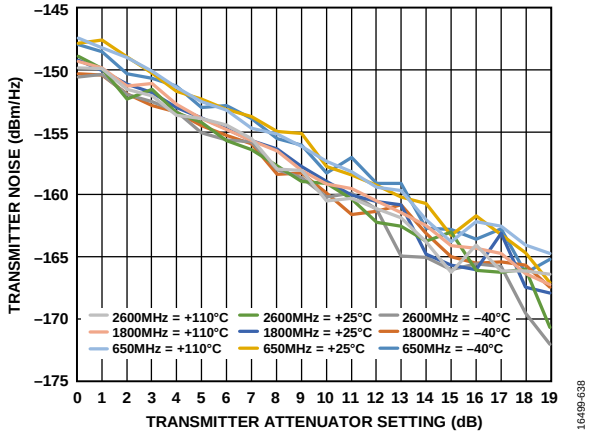

Figure 135. Transmitter Noise vs. Transmitter Attenuator Setting,

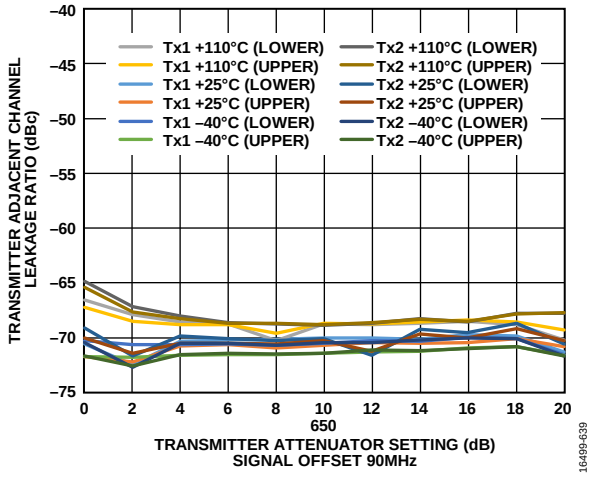

Figure 136. Transmitter Adjacent Channel Leakage Ratio vs. Transmitter Attenuator Setting, Signal Offset 90 MHz, LO = 650 MHz, LTE20 PAR = 12 dB, Upper Side and Lower Side

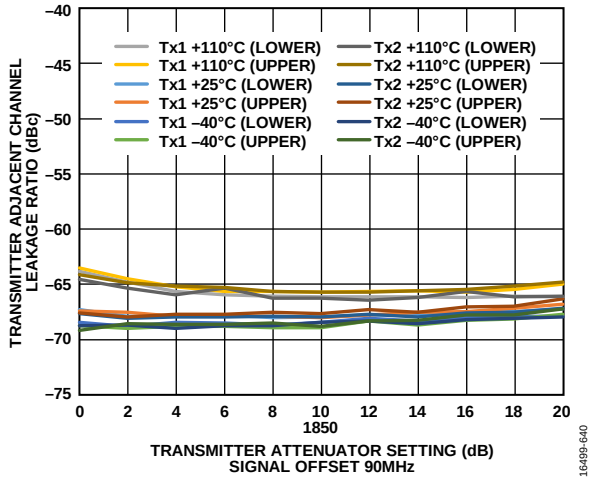

Figure 137. Transmitter Adjacent Channel Leakage Ratio vs. Transmitter Attenuator Setting, Signal Offset = 90 MHz, LO = 1850 MHz, LTE20 MHz PAR = 12 dB, Upper Side and Lower Side

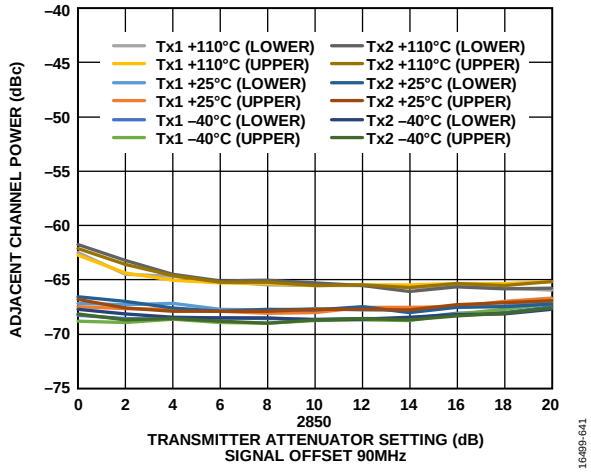

Figure 138. Transmitter Adjacent Channel Leakage Ratio vs. Transmitter Attenuator Setting, Signal Offset = 90 MHz, LO = 2850 MHz, LTE20 MHz PAR = 12 dB, Upper Side and Lower Side

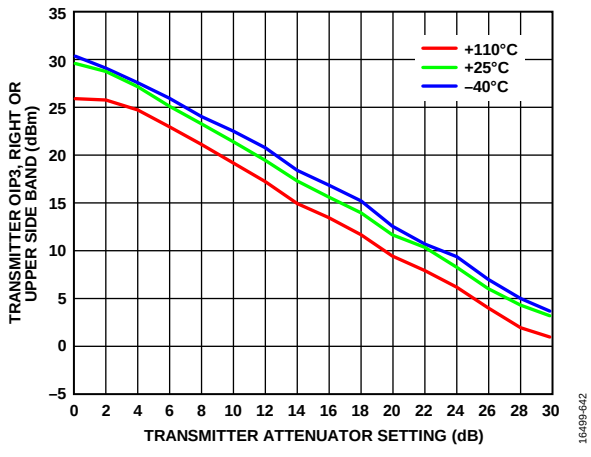

Figure 139. Transmitter OIP3, Right or Upper Sideband Response vs. Transmitter Attenuator Setting, LO = 850 MHz, 15 dB Digital Backoff per Tone

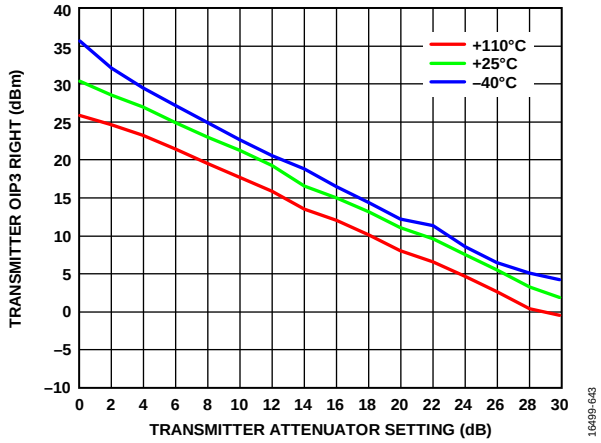

Figure 140. Transmitter OIP3, Right vs. Transmitter Attenuation, LO = 1850 MHz, 15 dB Digital Backoff per Tone

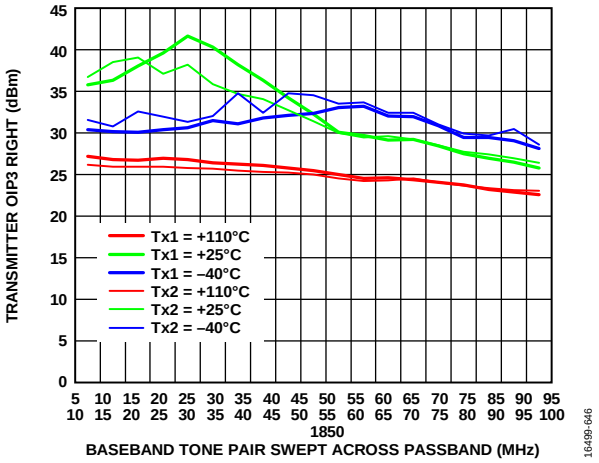

Figure 143. Transmitter OIP3, Right vs. Baseband Tone Pair Swept Across Pass Band, LO = 1850 MHz, 15 dB Digital Backoff per Tone

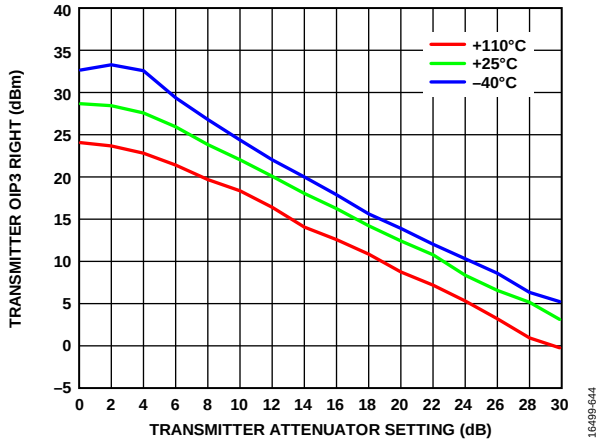

Figure 141. Transmitter OIP3 Right vs. Transmitter Attenuator Setting, LO = 2650 MHz, 15 dB Digital Backoff per Tone

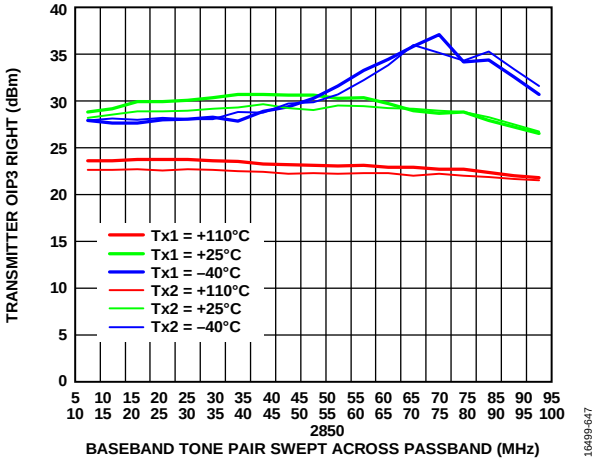

Figure 144. Transmitter OIP3, Right vs. Baseband Tone Pair Swept Across Pass Band, LO = 2850 MHz,15 dB Digital Backoff per Tone

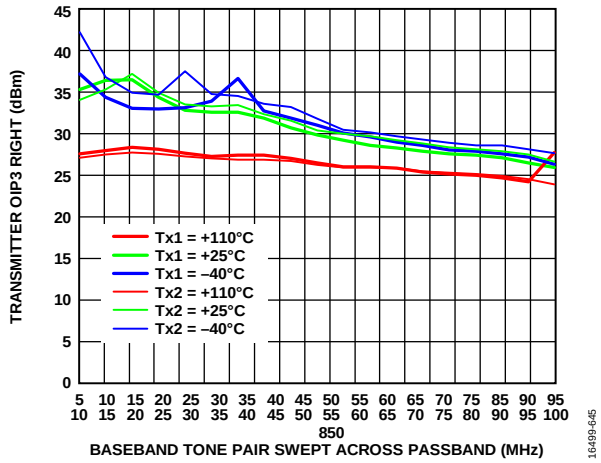

Figure 142. Transmitter OIP3, Right vs. Baseband Tone Pair Swept Across Pass Band, LO = 850 MHz, 15 dB Digital Backoff per Tone

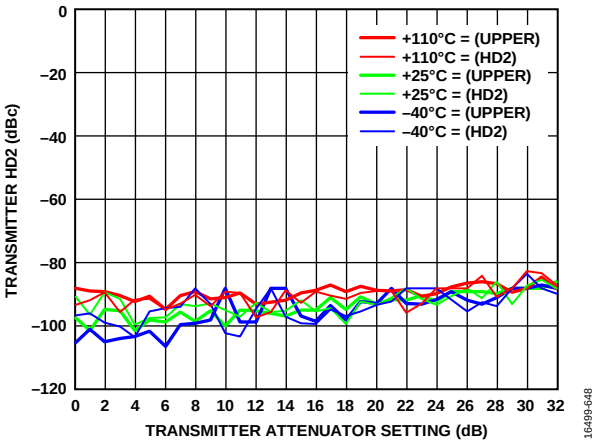

Figure 145. Transmitter HD2 vs. Transmitter Attenuator Setting (MHz), Baseband Frequency = 10 MHz, LO = 1850 MHz, 15 dB Digital Backoff

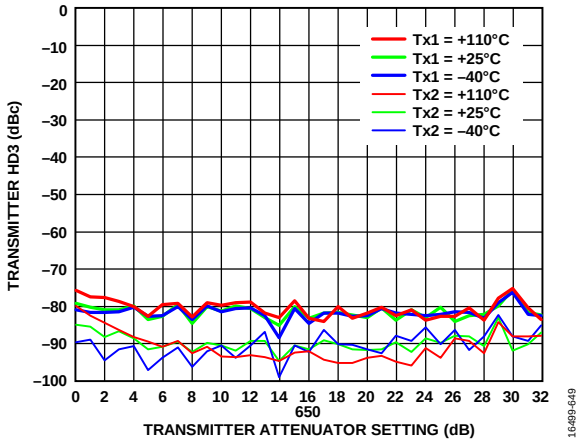

Figure 146. Transmitter HD3 vs. Transmitter Attenuator Setting, LO = 650 MHz, Digital Backoff = 15 dB

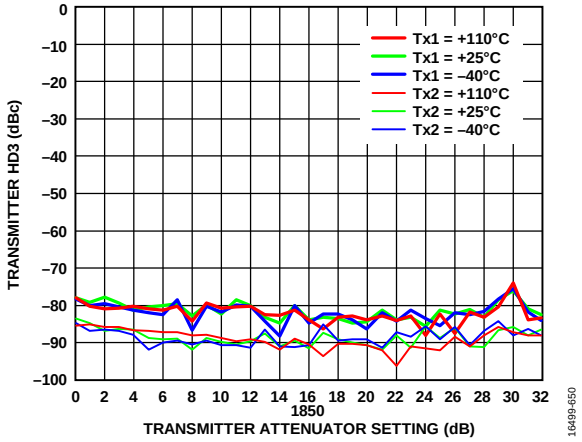

Figure 147. Transmitter HD3 vs. Transmitter Attenuator Setting, LO = 1850 MHz, Digital Backoff = 15 dB

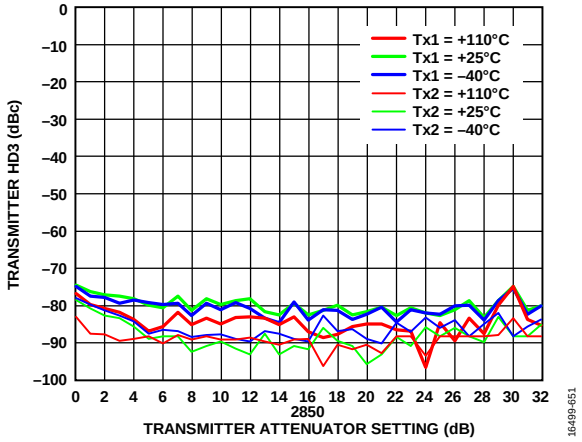

Figure 148. Transmitter HD3 vs. Transmitter Attenuator Setting, LO = 2850 MHz, Digital Backoff = 15 dB

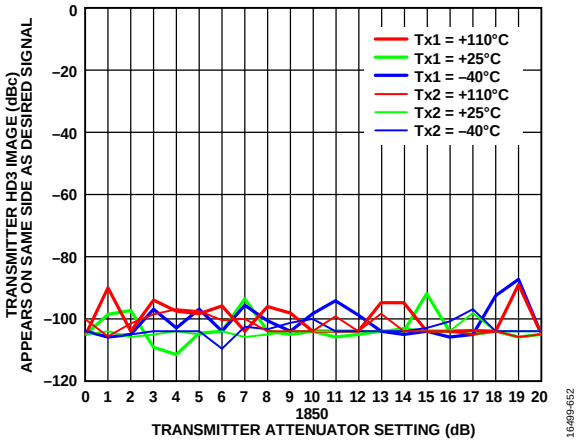

Figure 149. Transmitter HD3 on Same Sideband as Desired Signal vs. Transmitter Attenuator Setting, LO = 1850 MHz, Digital Backoff = 15 dB

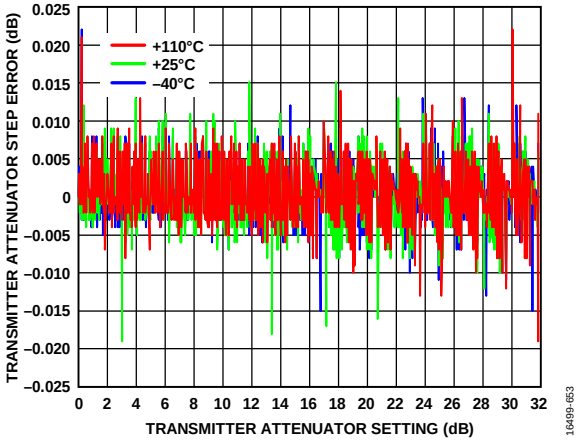

Figure 150. Transmitter Attenuation Step Error vs. Transmitter Attenuator Setting, LO = 650 MHz

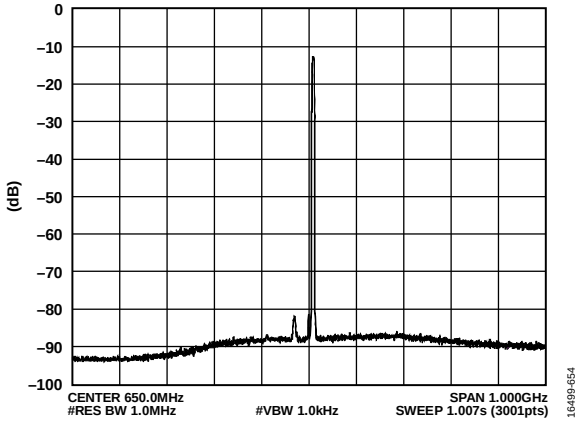

Figure 151. Transmitter Output Spurious, Transmitter 1 = 650 MHz, 5 MHz LTE, Offset = 10 MHz, RMS = −12 dBFS, Temperature = 25°C

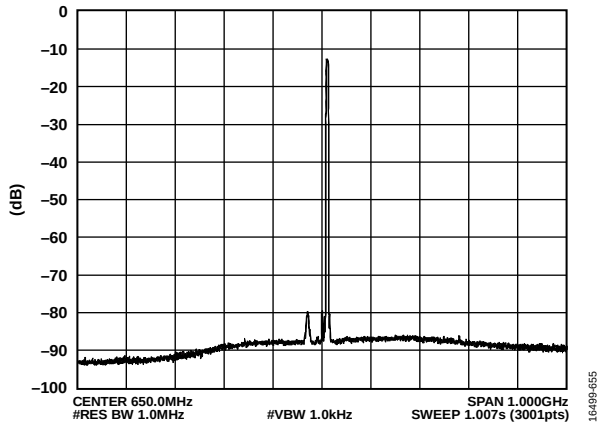

Figure 152. Transmitter Output Spurious, Transmitter 2 = 650 MHz, LTE = 5 MHz, Offset = 10 MHz, RMS −12 dBFS, Temperature = 25°C

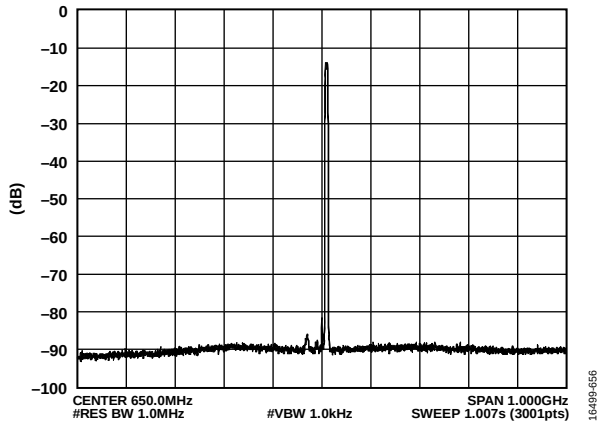

Figure 153. Transmitter Output Spurious, Transmitter 1 = 1850 MHz, LTE = 5 MHz, Offset = 10 MHz, RMS −12 dBFS, Temperature = 25°C

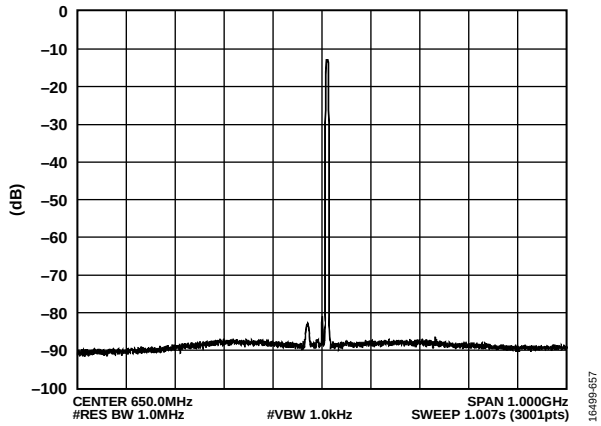

Figure 154. Transmitter Output Spurious, Transmitter 2 = 1850 MHz, LTE = 5 MHz, Offset = 10 MHz, RMS −12 dBFS, Temperature = 25°C

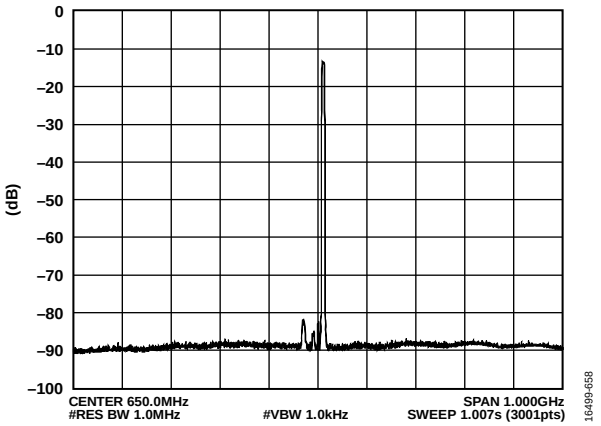

Figure 155. Transmitter Output Spurious, Transmitter 1 = 2850 MHz, LTE = 5 MHz, Offset = 10 MHz, RMS −12 dBFS, Temperature = 25°C

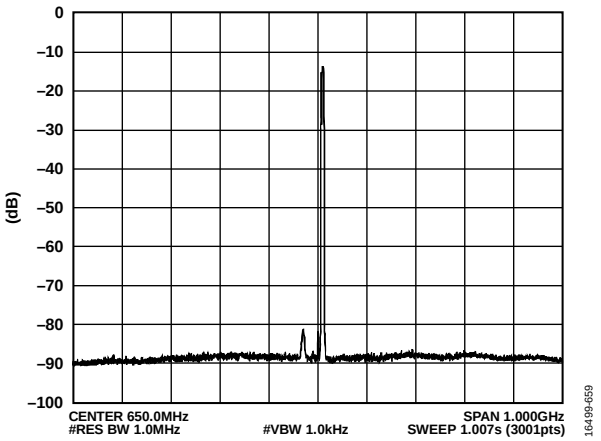

Figure 156. Transmitter Output Spurious, Transmitter 2 = 2850 MHz, LTE = 5 MHz, Offset = 10 MHz, RMS −12 dBFS, Temperature = 25°C

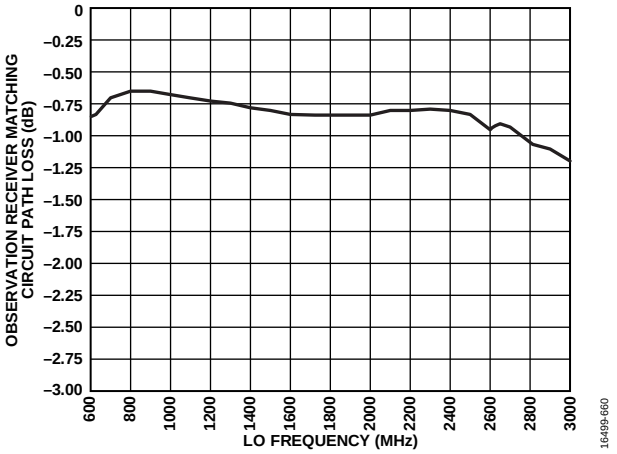

Figure 157. Observation Receiver Matching Circuit Path Loss vs. Frequency, Can Be Used for Deembedding Performance Data

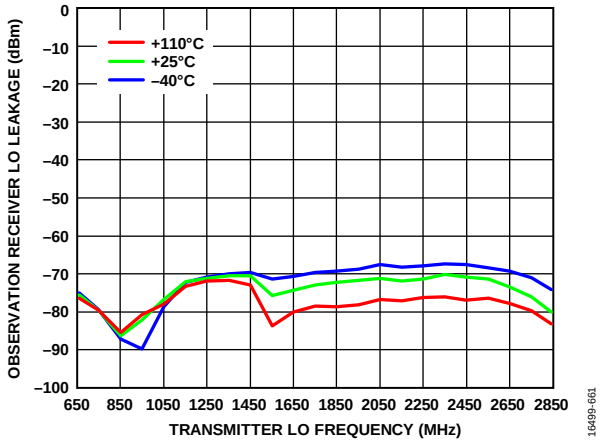

Figure 158. Observation Receiver LO Leakage vs. Transmitter LO Frequency,

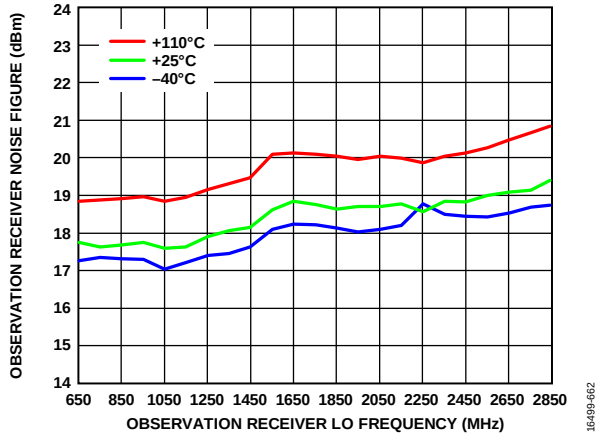

Figure 159. Observation Receiver Noise Figure vs. Observation Receiver LO Frequency, Total Nyquist Integration Bandwidth

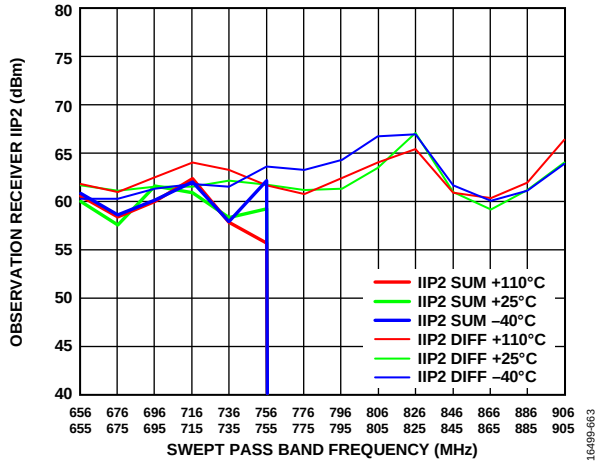

Figure 160. Observation Receiver IIP2, Sum and Difference Products vs. f1 Offset Frequency, Tones Separated by 1 MHz Swept Across Pass Band at –19 dBm Each, 650 MHz, Attenuation = 0 dB

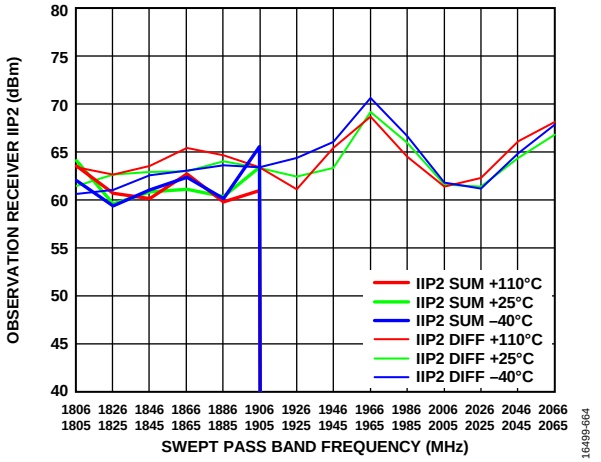

Figure 161. Observation Receiver IIP2, Sum and Difference Products vs. f1 Offset Frequency, Tones Separated by 1 MHz Swept Across Pass Band at –19 dBm Each, 1800 MHz, Attenuation = 0 dB

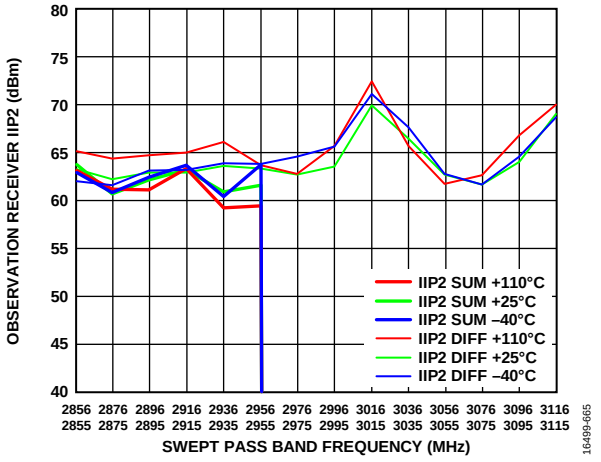

Figure 162. Observation Receiver IIP2, Sum and Difference Products vs. f1 Offset Frequency, Tones Separated by 1 MHz Swept Across Pass Band at –19 dBm Each, 2850 MHz, Attenuation = 0 dB

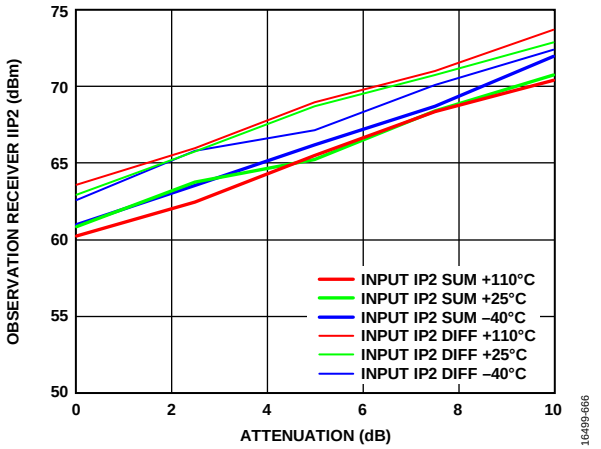

Figure 163. Observation Receiver IIP2, Sum and Difference Products vs. Attenuation, Tone 1 at 1845 MHz, Tone 2 at 1846 MHz at –19 dBm Plus Attenuation, LO = 1800 MHz

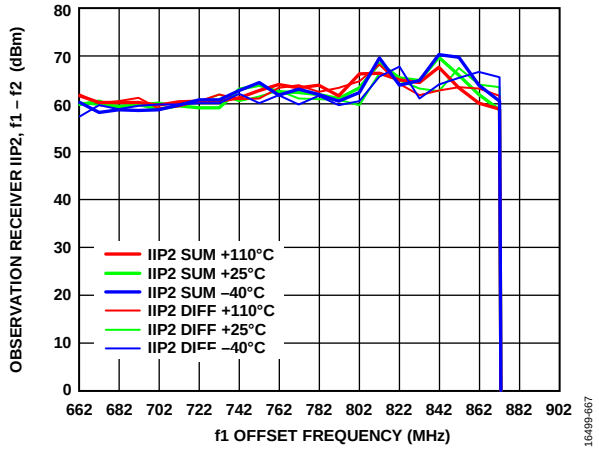

Figure 164. Observation Receiver IIP2, f1 – f2 vs. Intermodulation Frequency, LO = 650 MHz, Tone 1 = 652 MHz, Tone 2 Swept at –19 dBm Each, Attenuation = 0 dB

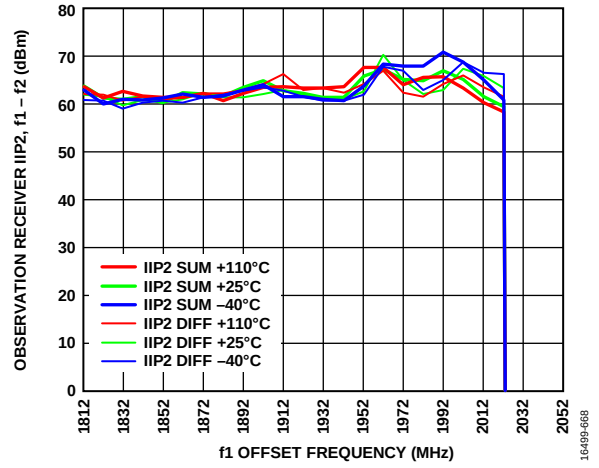

Figure 165. Observation Receiver IIP2, f1 – f2 vs. Intermodulation Frequency, LO = 1800 MHz, Tone 1 = 1802 MHz, Tone 2 Swept at –19 dBm Each, Attenuation = 0 dB

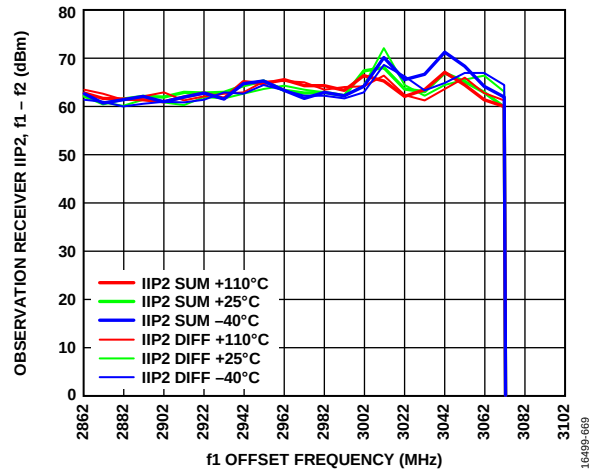

Figure 166. Observation Receiver IIP2, f1 – f2 vs. Intermodulation Frequency, LO = 2850 MHz, Tone 1 = 2852 MHz, Tone 2 Swept at –19 dBm Each, Attenuation = 0 dB

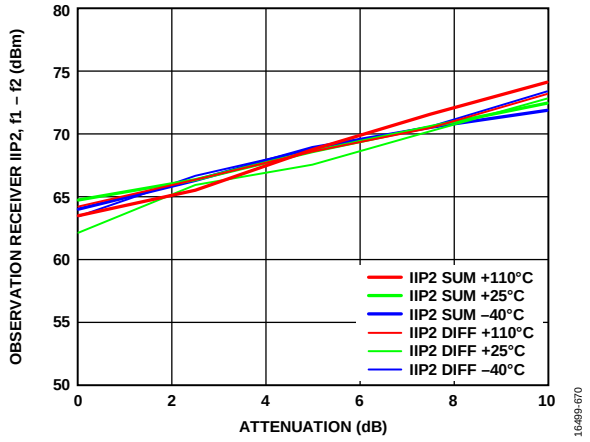

Figure 167. Observation Receiver IIP2, f1 – f2 vs. Attenuation, LO = 1800 MHz, Tone 1 = 1802 MHz, Tone 2 = 1902 MHz at –19 dBm Plus Attenuation

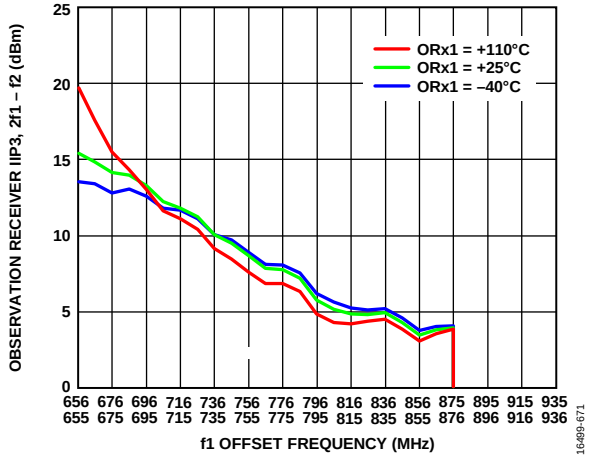

Figure 168. Observation Receiver IIP3, 2f1 – f2 vs. f1 Offset Frequency, 650 MHz, Attenuation = 0 dB, Tones Separated by 1 MHz Swept Across Pass Band at –19 dBm Each

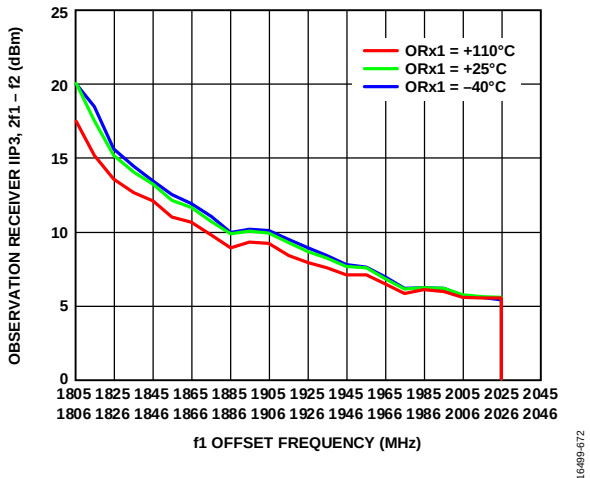

Figure 169. Observation Receiver IIP3, 2f1 – f2 vs. f1 Offset Frequency, 1800 MHz, Attenuation = 0 dB, Tones Separated by 1 MHz Swept Across Pass Band at –19 dBm Each

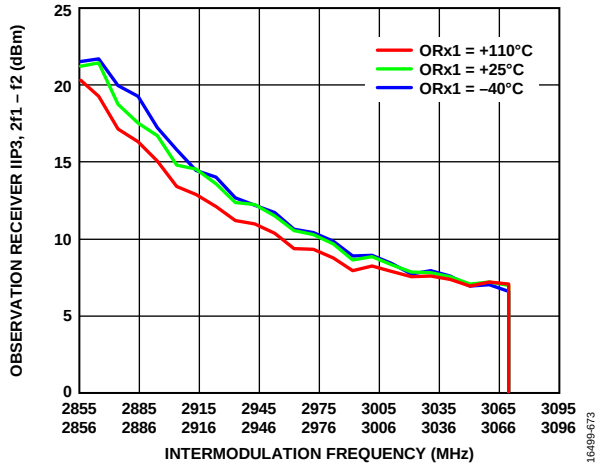

Figure 170. Observation Receiver IIP3, 2f1 – f2 vs. f1 Offset Frequency, LO = 2850 MHz, Attenuation = 0 dB, Tones Separated by 1 MHz Swept Across Pass Band at –19 dBm Each

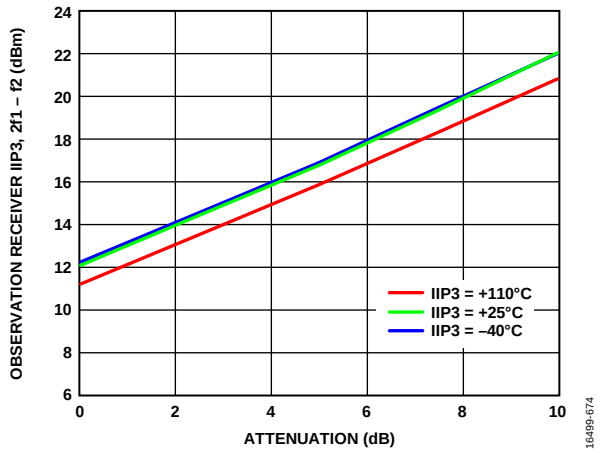

Figure 171. Observation Receiver IIP3, 2f1 – f2 vs. Attenuation, LO = 1800 MHz, Tone 1 = 1895 MHz, Tone 2 = 1896 MHz at –19 dBm Plus Attenuation

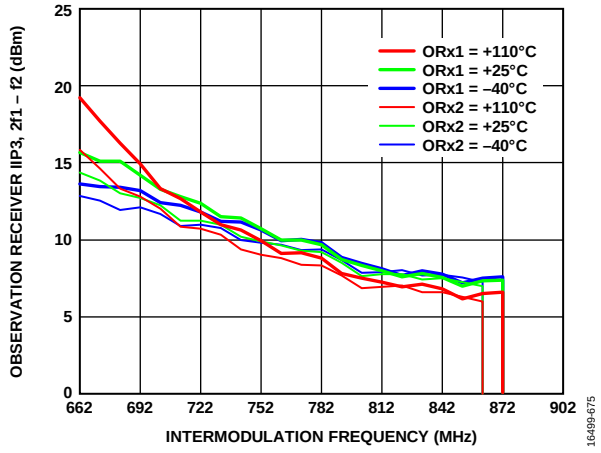

Figure 172. Observation Receiver IIP3, 2f1 – f2 vs. Intermodulation Frequency, LO = 650 MHz, Tone 1 = 652 MHz, Tone 2 Swept at –19 dBm Each

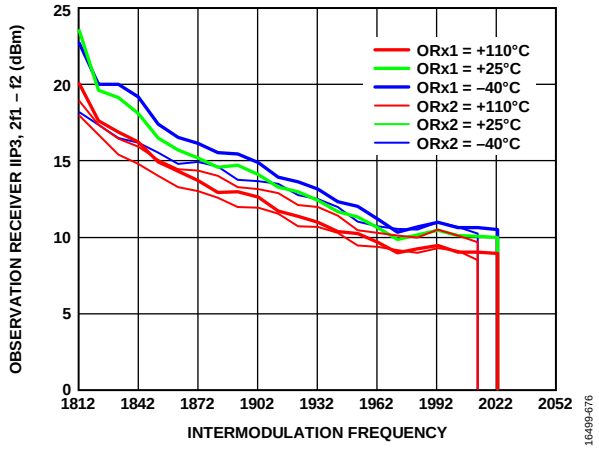

Figure 173. Observation Receiver IIP3, 2f1 – f2 vs. Intermodulation Frequency, LO = 1800 MHz, Tone 1 = 1802 MHz, Tone 2 Swept at –19 dBm Each

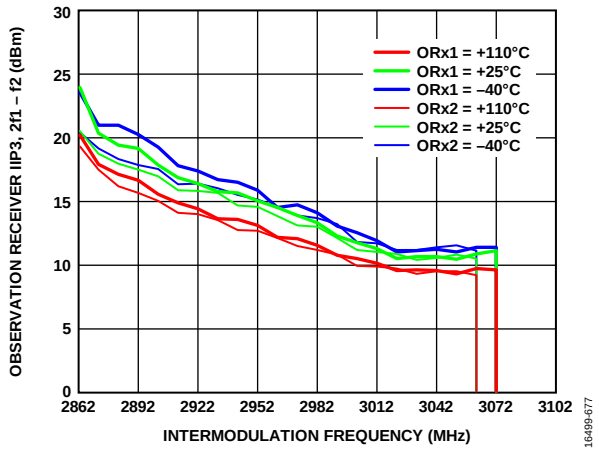

Figure 174. Observation Receiver IIP3, 2f1 – f2 vs. Intermodulation Frequency, LO = 2850 MHz, Tone 1 = 2852 MHz, Tone 2 Swept at –19 dBm Each

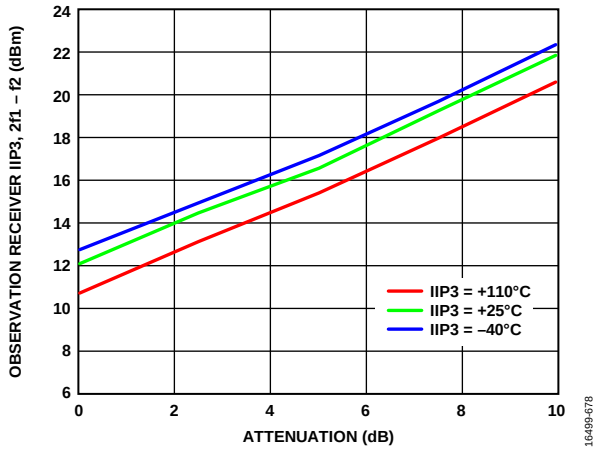

Figure 175. Observation Receiver IIP3, 2f1 – f2 vs. Attenuation, LO = 1800 MHz, Tone 1 = 1802 MHz, Tone 2 = 1922 MHz at –19 dBm Plus Attenuation

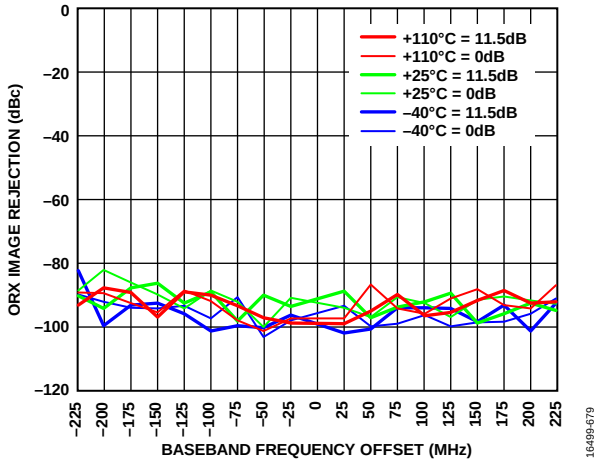

Figure 176. Observation Receiver Image Rejection vs. Baseband Frequency Offset, Continuous Wave Signal Swept Across the Band, LO = 650 MHz

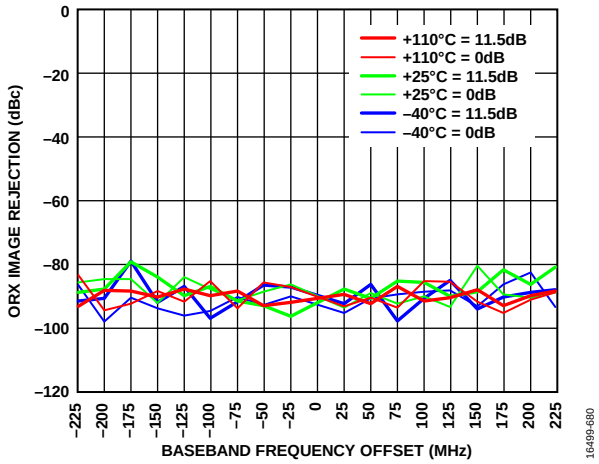

Figure 177. Observation Reciever Image Rejection vs. Baseband Frequency Offset, Continuous Wave Signal Swept Across the Band, LO = 1850 MHz

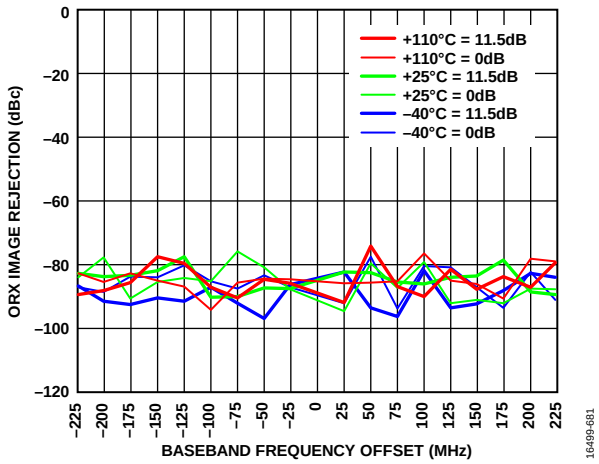

Figure 178. Observation Receiver Image Rejection vs. Baseband Frequency Offset, Continuous Wave Signal Swept Across the Band, LO = 2850 MHz

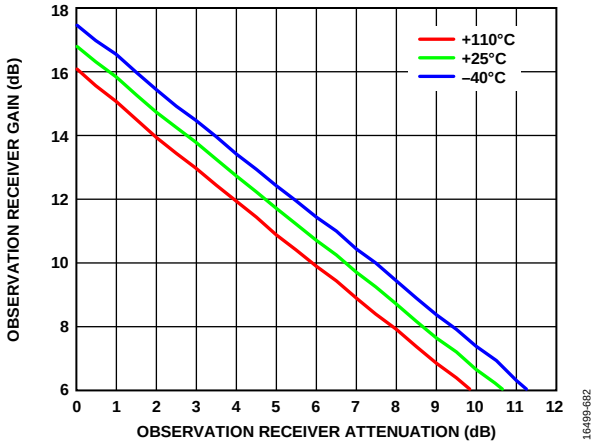

Figure 179. Observation Receiver Gain vs. Observation Receiver Attenuation, LO = 650 MHz

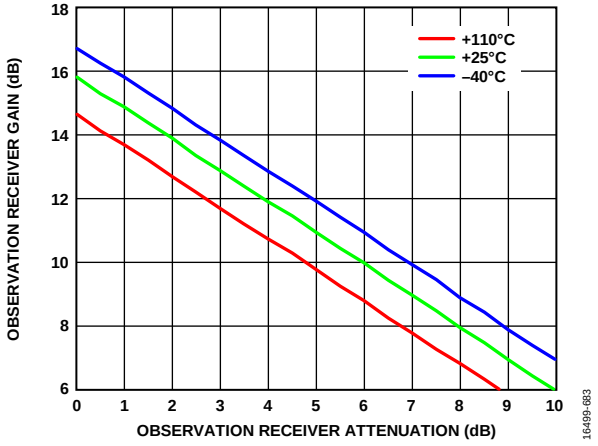

Figure 180. Observation Receiver Gain vs. Observation Receiver Attenuation, LO = 1800 MHz

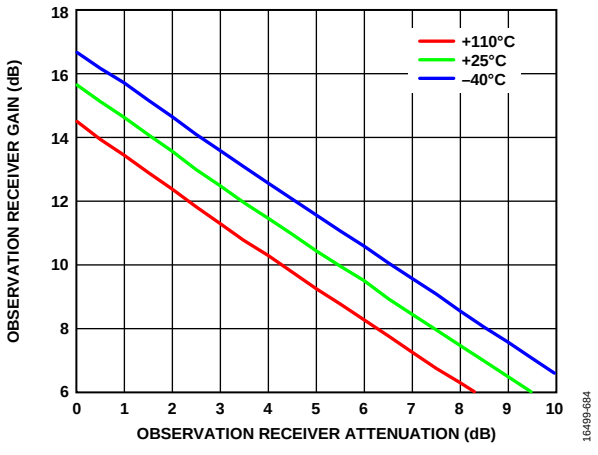

Figure 181. Observation Receiver Gain vs. Observation Receiver Attenuation, LO = 2800 MHz

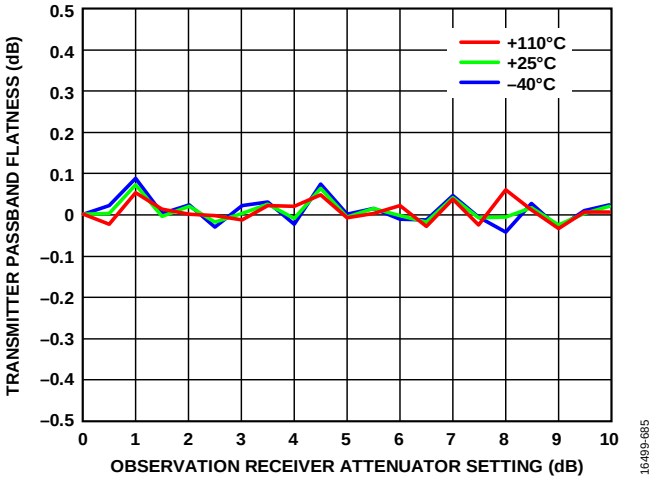

Figure 182. Observation Receiver Attenuator Step Accuracy, LO = 2600 MHz

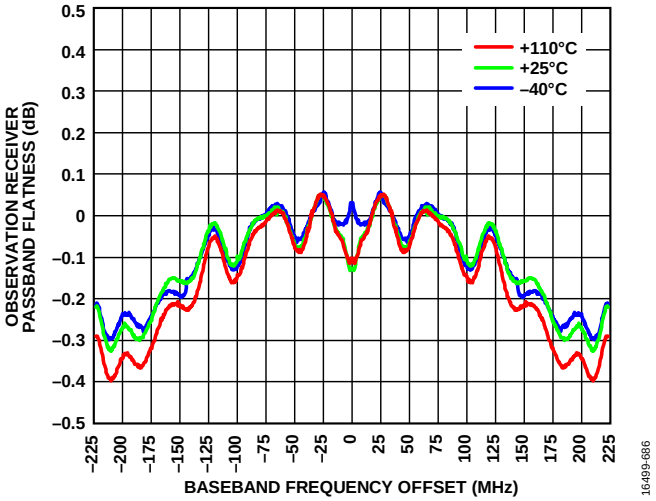

Figure 183. Observation Receiver Pass Band Flatness, LO = 1800 MHz

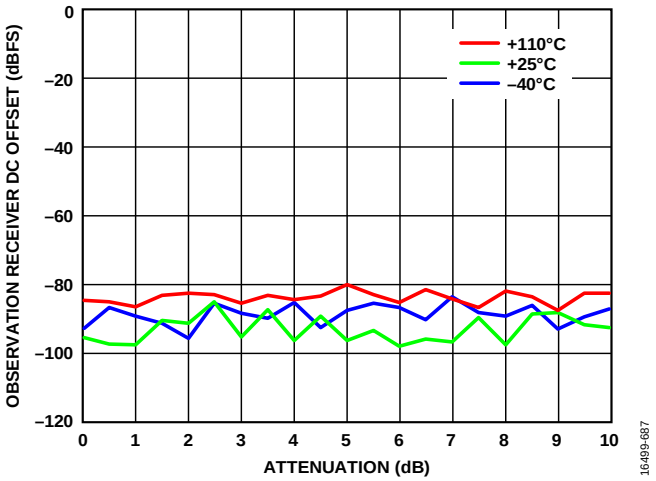

Figure 184. Observation Receiver DC Offset vs. Attenuation, LO = 1850 MHz

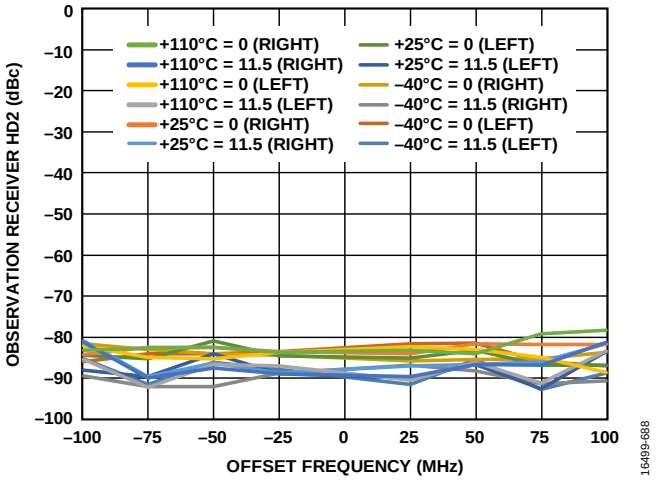

Figure 185. Observation Receiver HD2 vs. Offset Frequency and Attenuation, LO = 650 MHz Tone Level = –20 dBm at 0 dB Attenuation

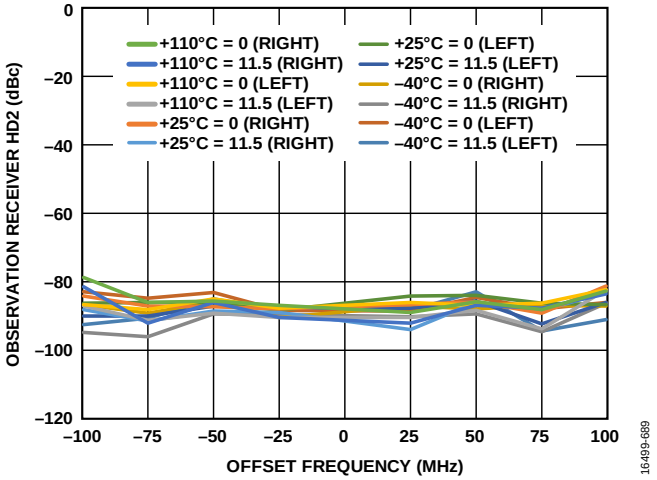

Figure 186. Observation Receiver HD2 vs. Offset Frequency and Attenuation, LO = 1850 MHz Tone Level = –20 dBm at 0 dB Attenuation

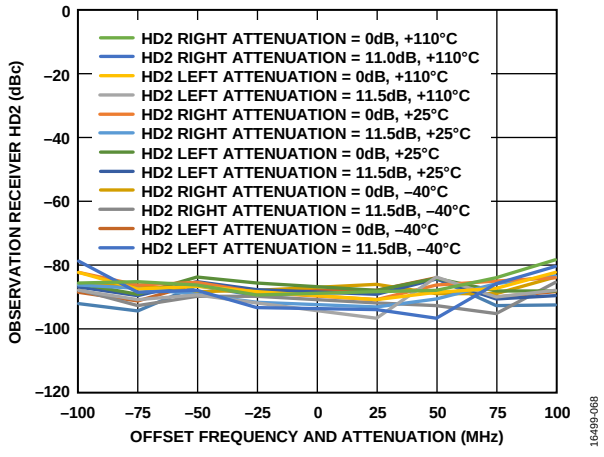

Figure 187. Observation Receiver HD2 vs. Offset Frequency and Attenuation, LO = 2850 MHz, Tone Level = –20 dBm at 0 dB Attenuation

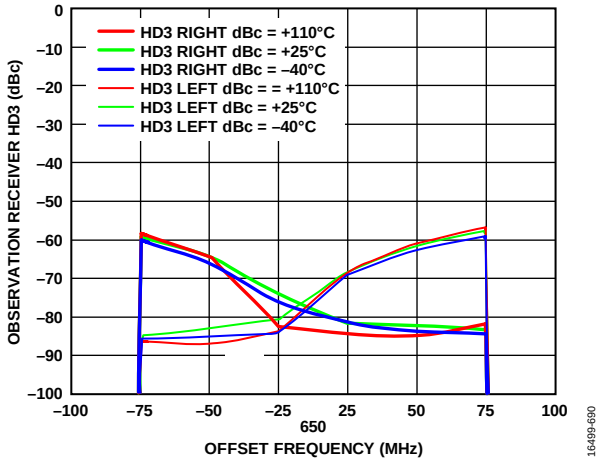

Figure 188. Observation Receiver HD3, Left and Right vs. Offset Frequency, LO = 650 MHz, Tone Level = −20 dBm at 0 dB Attenuation

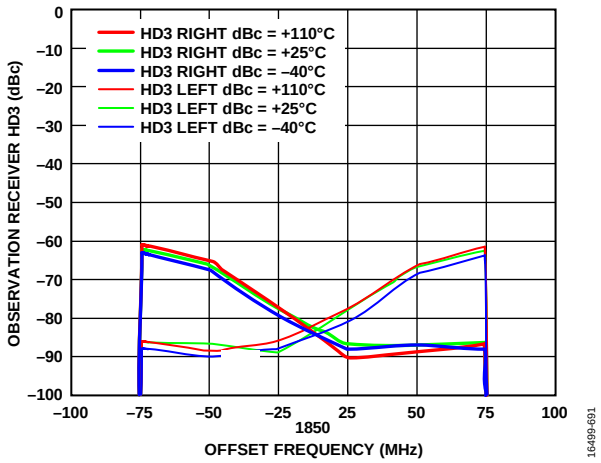

Figure 189. Observation Receiver HD3, Left and Right vs. Offset Frequency, LO = 1850 MHz, Tone Level = −20 dBm at 0 dB Attenuation

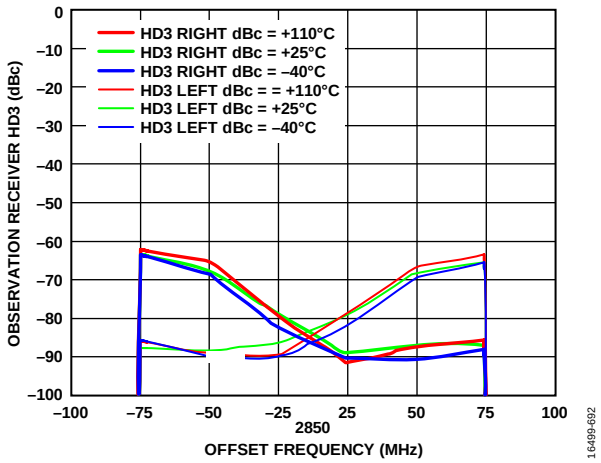

Figure 190. Observation Receiver HD3, Left and Right vs. Offset Frequency, LO = 2850 MHz, Tone Level = −20 dBm at 0 dB Attenuation

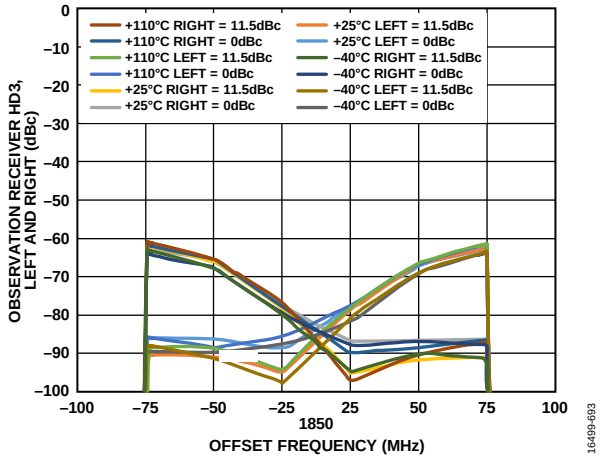

Figure 191. Observation Receiver HD3, Left and Right vs. Offset Frequency, LO = 1850 MHz, Observation Receiver Attenuation = 0 dB and 11.5 dB

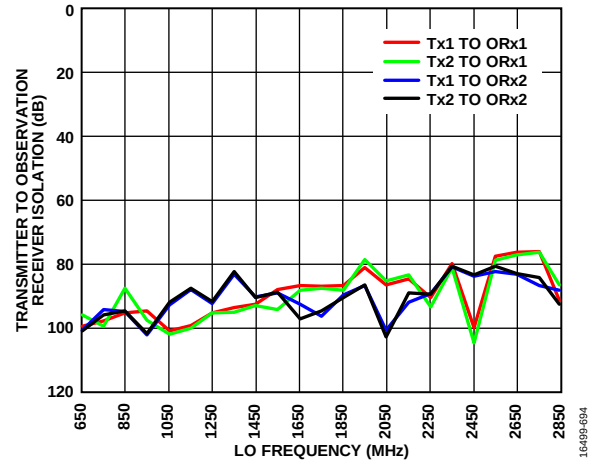

Figure 192. Transmitter to Observation Receiver Isolation vs. LO Frequency, Temperature = 25°C

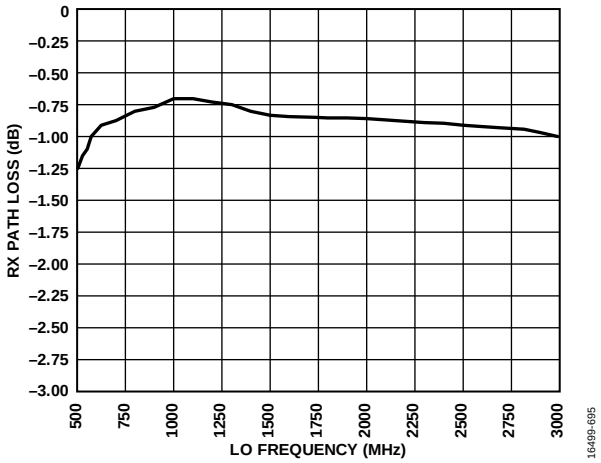

Figure 193. Receiver Matching Circuit Path Loss vs. Frequency, Can Be Used for Deembedding Performance Data

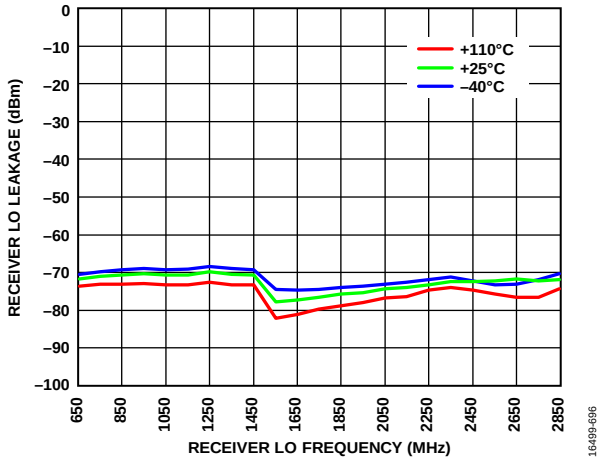

Figure 194. Receiver LO Leakage vs. Receiver LO Frequency, Receiver Attenuation = 0 dB, RF Bandwidth = 200 MHz, Sample Rate = 245.76 MSPS

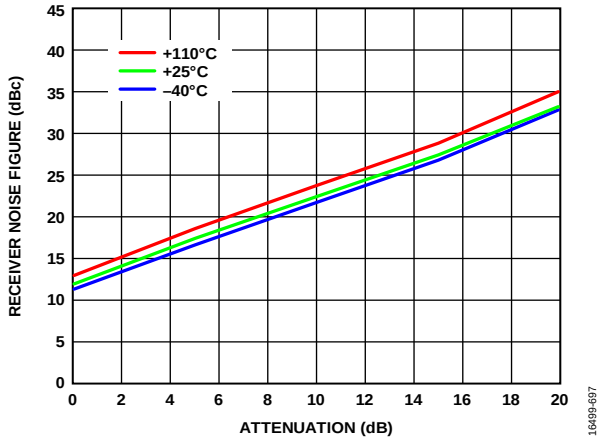

Figure 195. Receiver Noise Figure vs. Receiver Attenuation, LO = 650 MHz, 200 MHz Bandwidth, Sample Rate = 245.76 MSPS, Integration Bandwidth = 500 kHz to 100 MHz

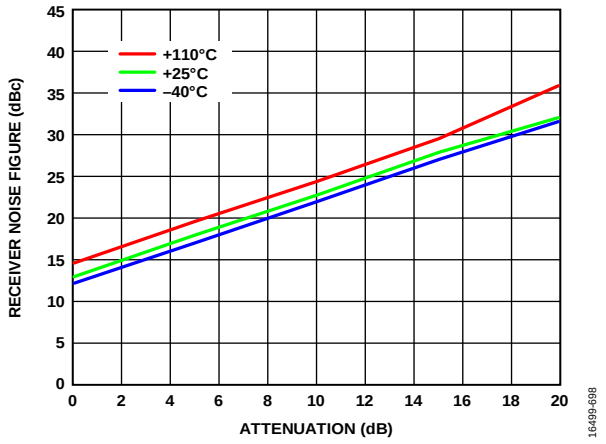

Figure 196. Receiver Noise Figure vs. Receiver Attenuation, LO = 1850 MHz, 200 MHz Bandwidth, Sample Rate = 245.76 MSPS, Integration Bandwidth = 500 kHz to 100 MHz

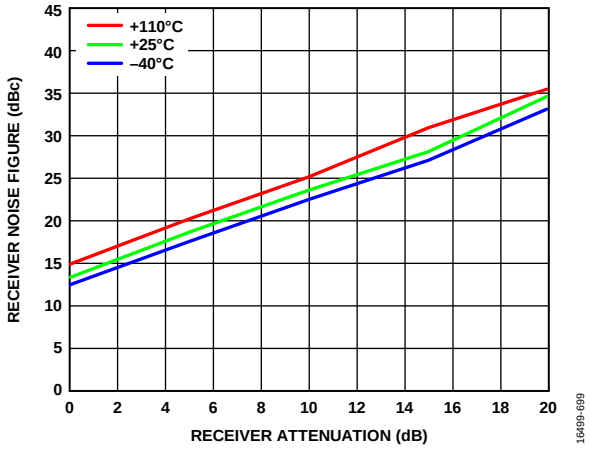

Figure 197. Receiver Noise Figure vs. Receiver Attenuation, LO = 2850 MHz, 200 MHz Bandwidth, Sample Rate = 245.76 MSPS, Integration Bandwidth = 500 kHz to 100 MHz

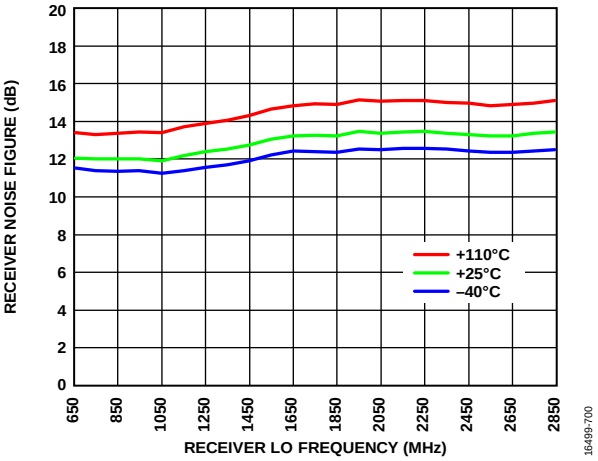

Figure 198. Receiver Noise Figure vs. Receiver LO Frequency, Receiver Attenuation = 0 dB, RF Bandwidth = 200 MHz, Sample Rate = 245.76 MSPS, Integration Bandwidth = ±100 MHz

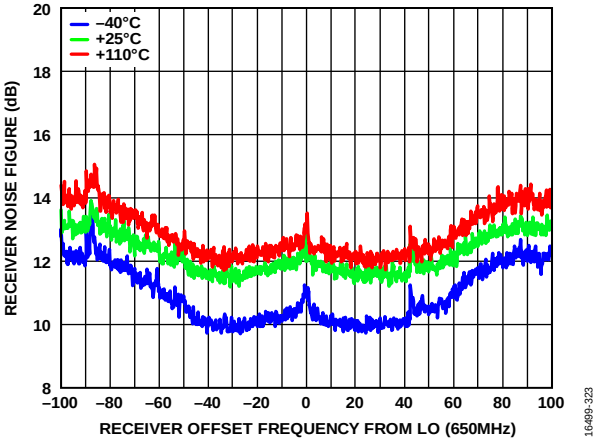

Figure 199. Receiver Noise Figure vs. Receiver Offset Frequency from LO, LO = 650 MHz

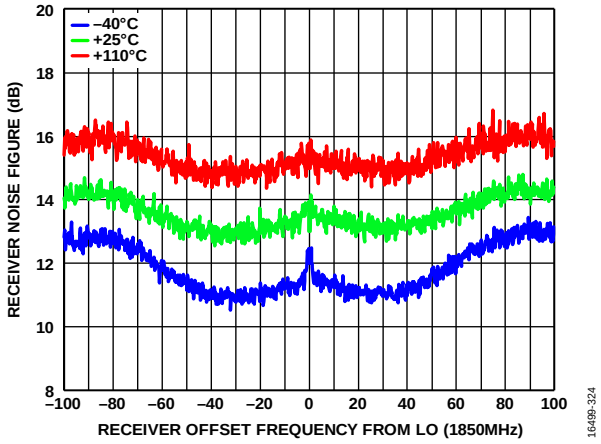

Figure 200. Receiver Noise Figure vs. Receiver Offset Frequency from LO LO = 1850 MHz

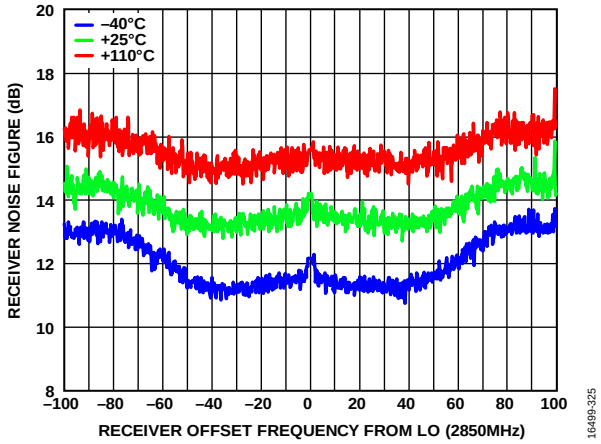

Figure 201. Receiver Noise Figure vs. Receiver Offset Frequency from LO

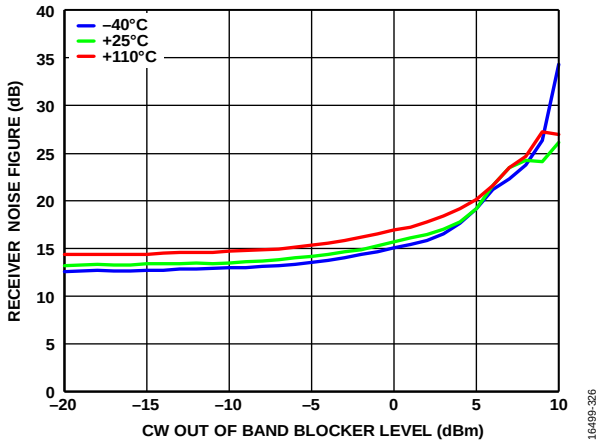

Figure 202. Receiver Noise Figure vs. Continuous Wave Out of Band Blocker Level, Receiver LO = 1685 MHz, Blocker = 2085 MHz

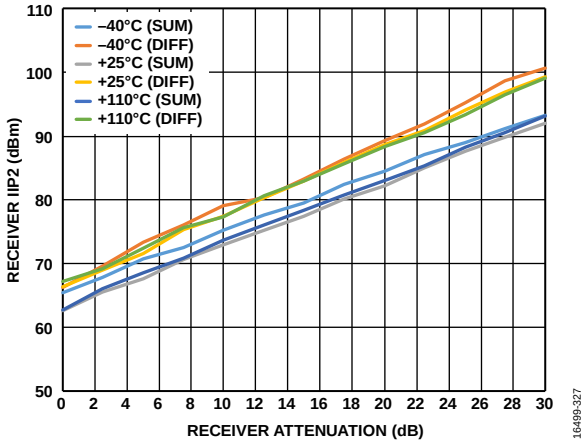

Figure 203. Receiver IIP2 vs. Receiver Attenuation, LO = 1800 MHz, Tones Placed at 1845 MHz and 1846 MHz, –21 dBm Each at Attenuation = 0 dB

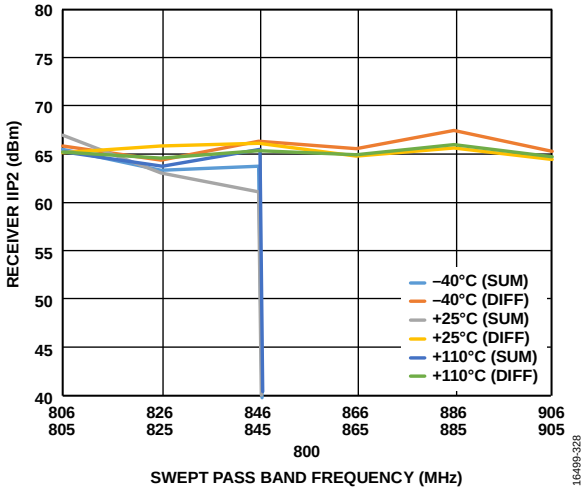

Figure 204. Receiver IIP2 Sum and Difference Across Bandwidth Receiver Attenuation = 0 dB, LO = 800 MHz, Six Tone Pairs, –21 dBm Each

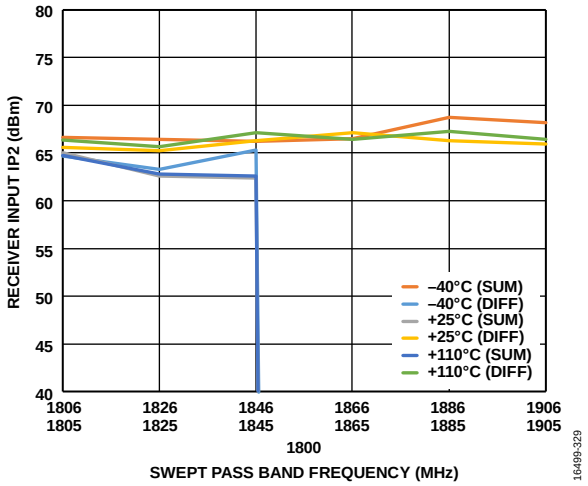

Figure 205. Receiver IIP2 Sum and Difference Across Bandwidth, Receiver Attenuation = 0 dB, LO = 1800 MHz, Six Tone Pairs, –21 dBm Each

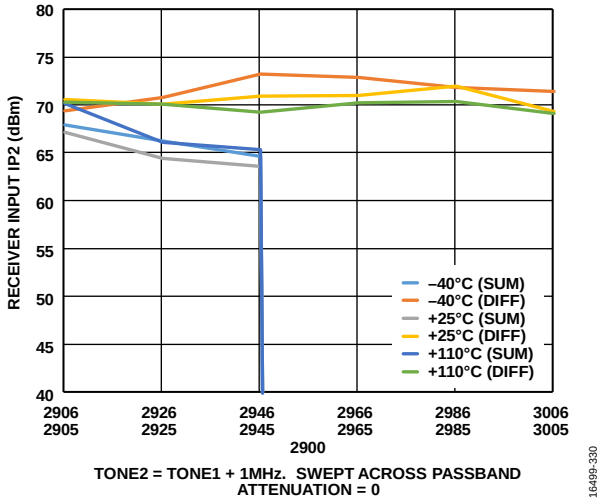

Figure 206. Receiver IIP2 Sum and Difference Across Bandwidth, Receiver Attenuation = 0 dB, LO = 2900 MHz, Six Tone Pairs, −21 dBm Each

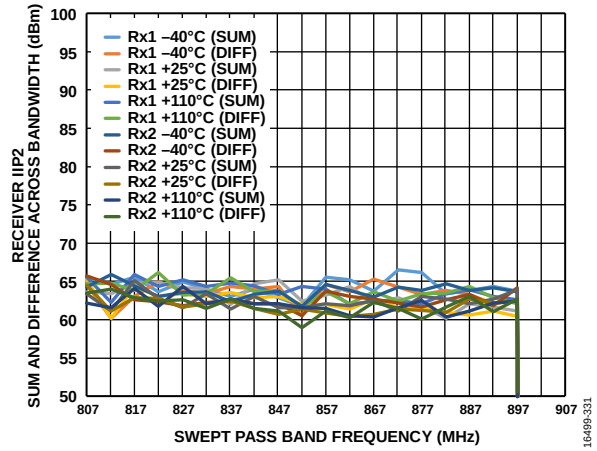

Figure 207. Receiver IIP2 vs. Swept Pass Band Frequency, LO = 1800 MHz, Tones Placed at 1802 MHz and 1892 MHz, −21 dBm Each at Attenuation = 0 dB

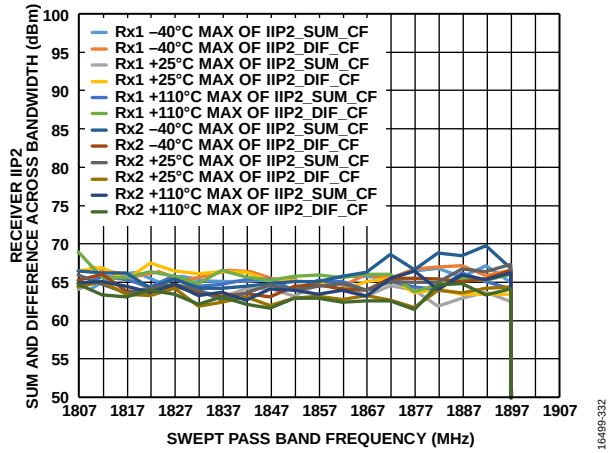

Figure 208. Receiver IIP2 Sum and Difference Across Bandwidth, Receiver Attenuation = 0 dB, LO = 800 MHz, Tone 1 = 802 MHz, Tone 2 Swept, −21 dBm Each

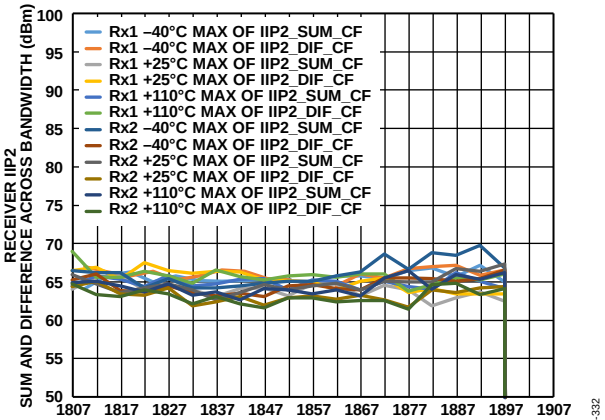

Figure 209. Receiver IIP2 Sum and Difference Across Bandwidth, Receiver Attenuation = 0 dB, LO = 1800 MHz, Tone 1 = 1802 MHz, Tone 2 Swept, −21 dBm Each

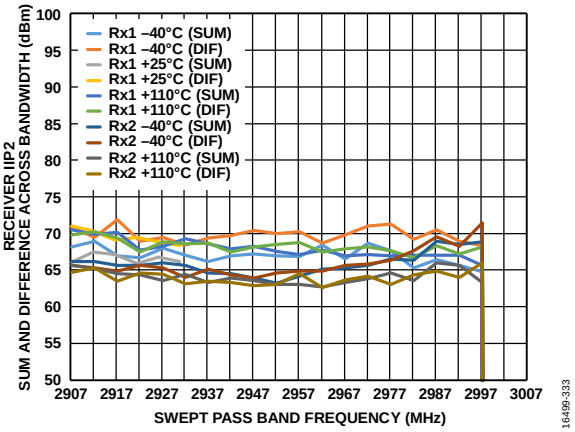

Figure 210. Receiver IIP2 Sum and Difference Across Bandwidth vs. Swept Pass Band Frequency, Receiver Attenuation = 0 dB, LO = 2900 MHz, Tone 1 = 2902 MHz, Tone 2 Swept, −21 dBm Each

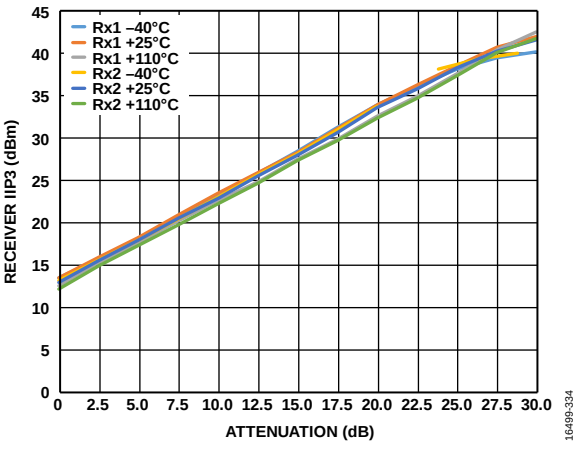

Figure 211. Receiver IIP3 vs. Attenuation, LO = 1800 MHz, Tone 1 = 1890 MHz, Tone 2 = 1891 MHz, −21 dBm Each at Attenuation = 0 dB

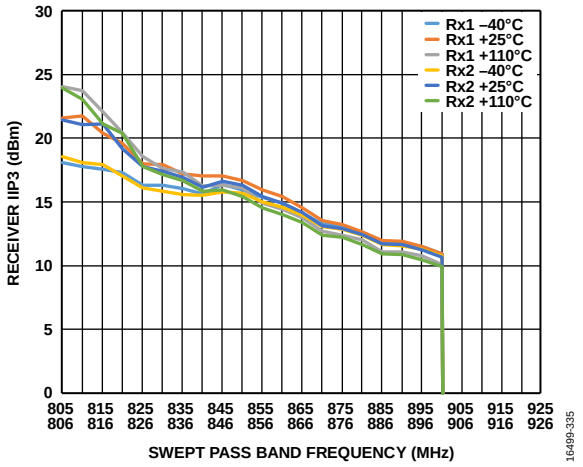

Figure 212. Receiver IIP3 Across Bandwidth vs. Swept Frequency Pass Band, Receiver Attenuation = 0 dB, LO = 800 MHz, Tone 2 = Tone 1 + 1 MHz, –21 dBm Each, Swept Across Pass Band

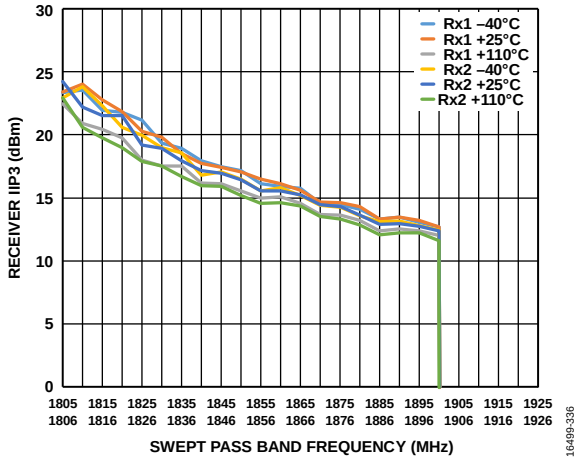

Figure 213. Receiver IIP3 Across Bandwidth vs. Swept Frequency Pass Band, Receiver Attenuation = 0 dB, LO = 1800 MHz, Tone 2 = Tone 1 + 1 MHz, –21 dBm Each, Swept Across Pass Band

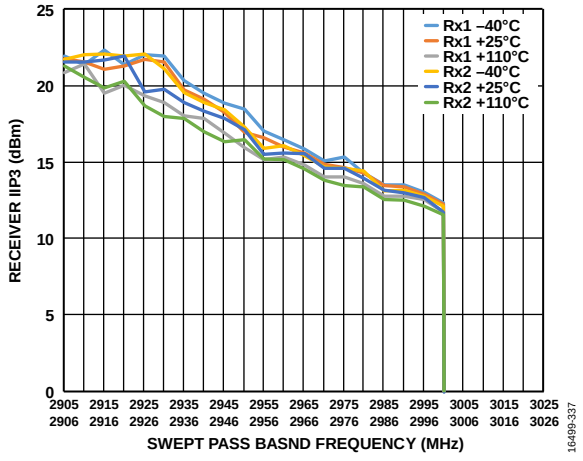

Figure 214. Receiver IIP3 Across Bandwidth vs. Swept Frequency Pass Band, Receiver Attenuation = 0 dB, LO = 2900 MHz, Tone 2 = Tone 1 + 1 MHz, –21 dBm Each, Swept Across Pass Band

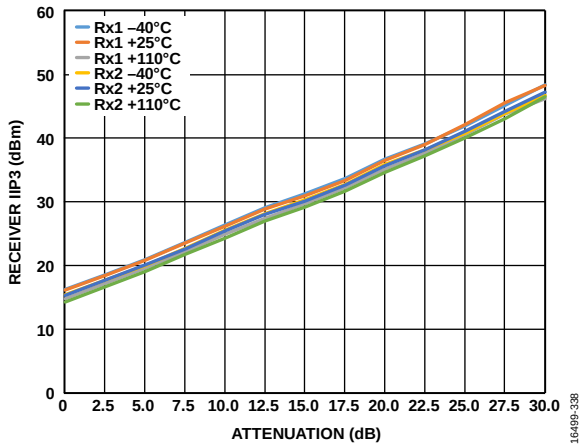

Figure 215. Receiver IIP3 vs. Attenuation, LO = 1800 MHz, Tone 1 = 1802 MHz, Tone 2 = 1892 MHz, –21 dBm each at Attenuation = 0 dB

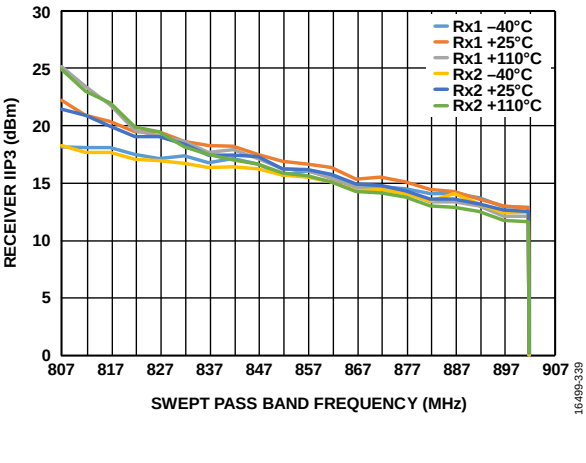

Figure 216. Receiver IIP3 Across Bandwidth vs. Swept Frequency Pass Band, Receiver Attenuation = 0 dB, LO = 800 MHz, Tone 1 = 802 MHz, Tone 2 Swept Across Pass Band, –21 dBm Each

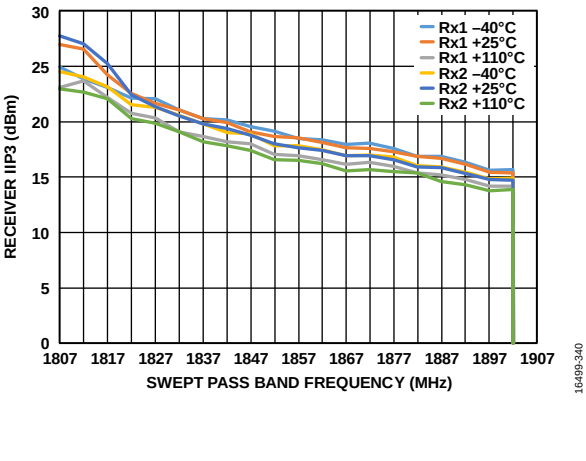

Figure 217. Receiver IIP3 Across Bandwidth vs Swept Frequency Pass Band, Receiver Attenuation = 0 dB, LO = 1800 MHz, Tone 1 = 1802 MHz, Tone 2 Swept Across Pass Band, –21 dBm Each

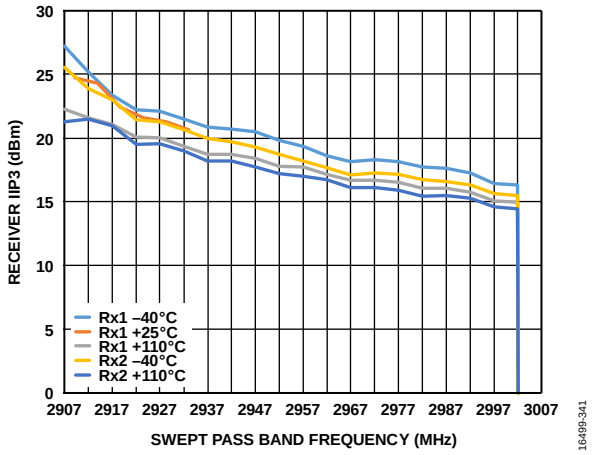

Figure 218. Receiver IIP3 Across Bandwidth vs. Swept Frequency Pass Band, Receiver Attenuation = 0 dB, LO = 2900 MHz, Tone 1 = 2902 MHz, Tone 2 Swept Across Pass Band, –21 dBm Each

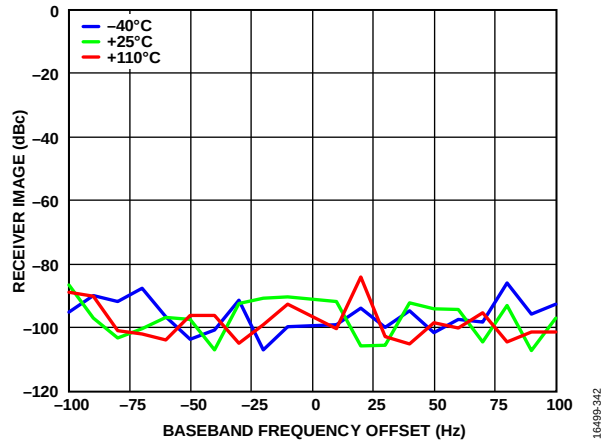

Figure 219. Receiver Image vs. Baseband Frequency Offset, Attenuation = 0 dB, 200 MHz RF Bandwidth, Tracking Calibration Active, Sample Rate = 245.76 MSPS, LO = 650 MHz

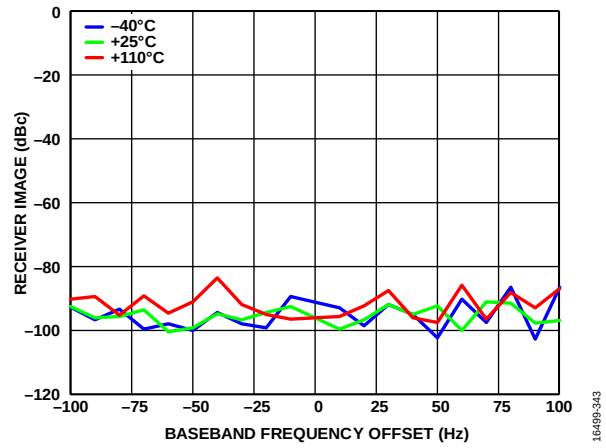

Figure 220. Receiver Image vs. Baseband Frequency Offset, Attenuation = 0 dB, RF Bandwidth = 200 MHz, Tracking Calibration Active, Sample Rate = 245.76 MSPS, LO = 1850 MHz

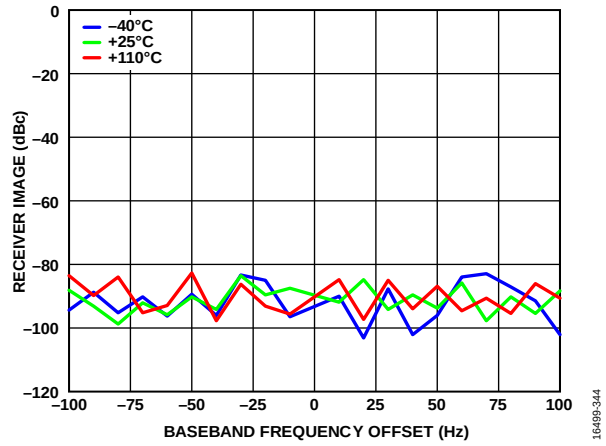

Figure 221. Receiver Image vs. Baseband Frequency Offset, Attenuation = 0 dB, RF Bandwidth = 200 MHz, Tracking Calibration Active, Sample Rate = 245.76 MSPS, LO = 2850 MHz

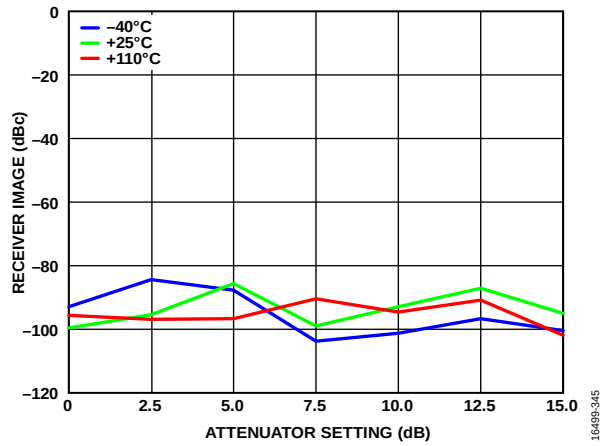

Figure 222. Receiver Image vs. Attenuator Setting, RF Bandwidth = 200 MHz, Tracking Calibration Active, Sample Rate = 245.76 MSPS, LO = 1850 MHz

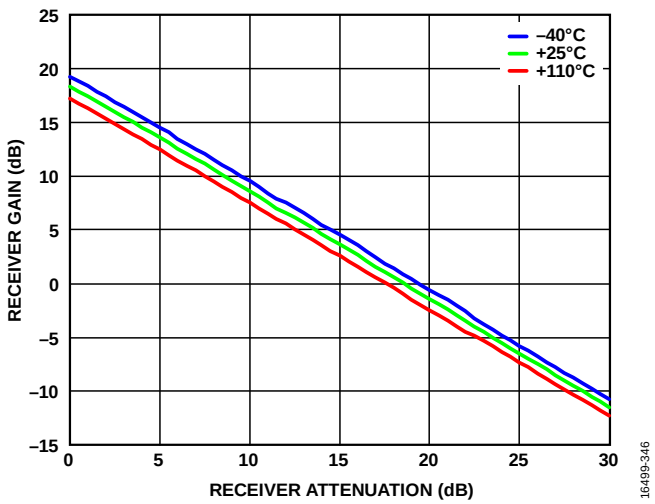

Figure 223. Receiver Gain vs. Receiver Attenuation, RF Bandwidth = 20 MHz, Sample Rate = 245.76 MSPS, LO = 1850 MHz

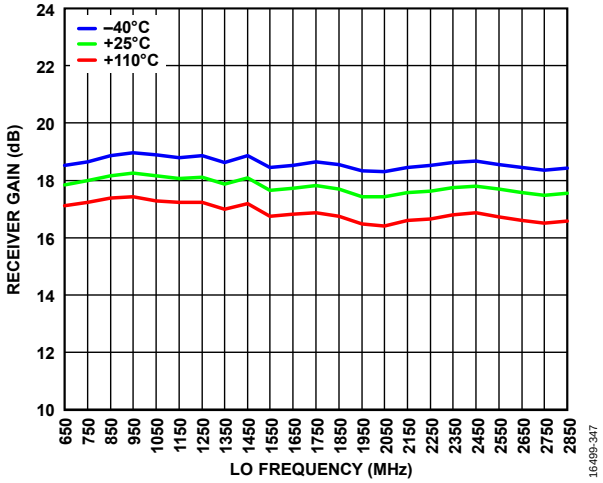

Figure 224. Receiver Gain vs. LO Frequency, RF Bandwidth = 20 MHz, Sample Rate = 245.76 MSPS

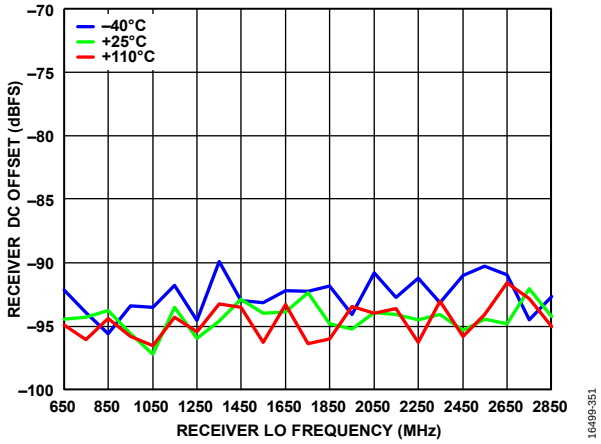

Figure 227. Receiver DC Offset vs. Receiver LO Frequency

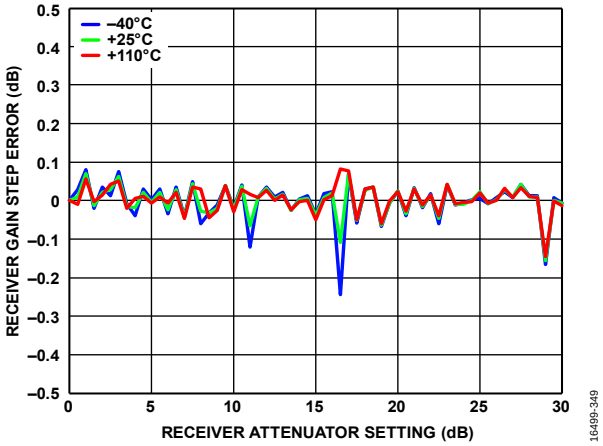

Figure 225. Receiver Gain Step Error vs. Receiver Attenuator Setting over Temperature

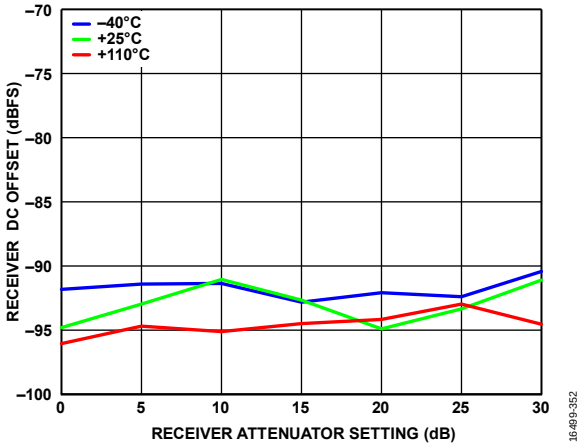

Figure 228. Receiver DC Offset vs. Receiver Attenuator Setting, LO = 1850 MHz

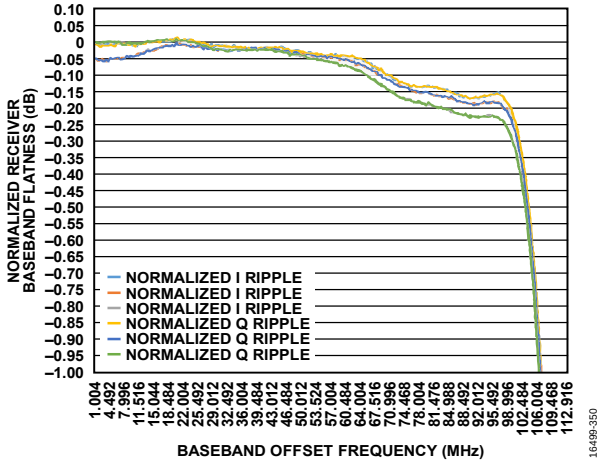

Figure 226. Normalized Receiver Baseband Flatness vs. Baseband Offset Frequency (Receiver Flatness), LO = 2600 MHz

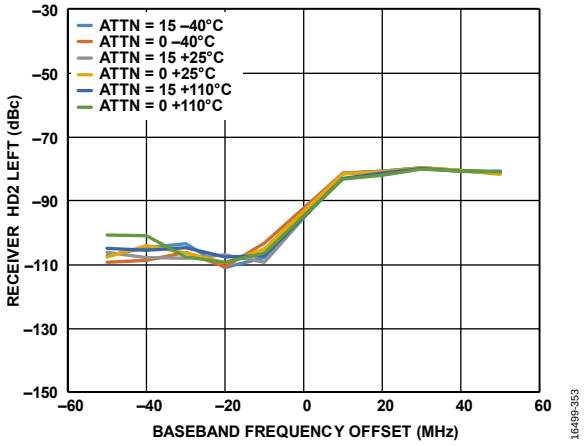

Figure 229. Receiver DC Offset vs. Receiver Attenuator Setting, Tone Level = –15 dBm at Attenuation = 0, HD2 Correction Configured for Low-Side Optimization, X-Axis = Baseband Frequency Offset of Fundamental Tone Not the Frequency of the HD2 Product (HD2 Product = 2× Baseband Frequency), LO = 650 MHz

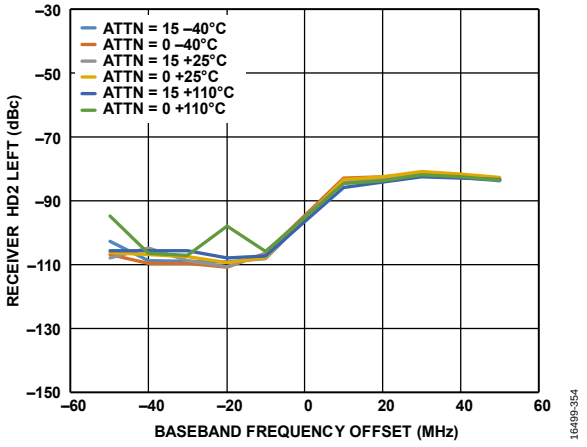

Figure 230. Receiver HD2, Left vs. Baseband Frequency Offset and Attenuation, Tone Level = −15 dBm at Attenuation = 0, HD2 Correction Configured for Low-Side Optimization, X-Axis = Baseband Frequency Offset of the Fundamental Tone Not the Frequency of the HD2 Product (HD2 Product = 2× the Baseband Frequency), LO = 1850 MHz

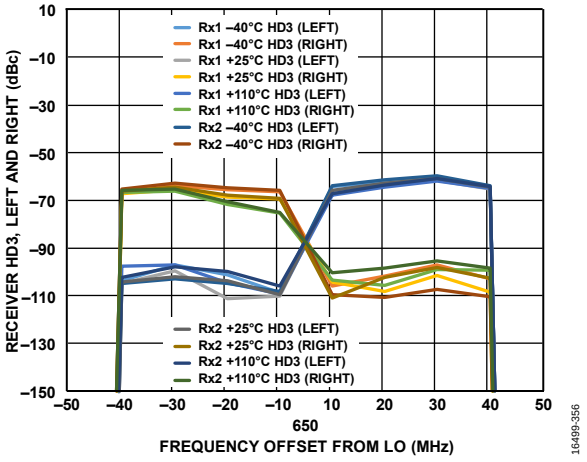

Figure 231. Receiver HD3, Left and Right vs. Frequency Offset from LO, Tone Level = −15 dBm at Attenuation = 0, LO = 650 MHz

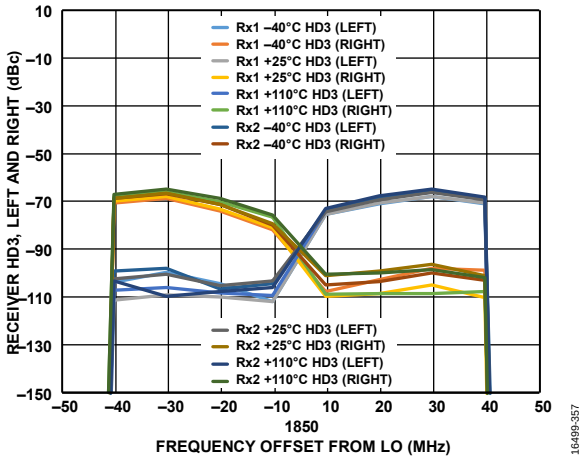

Figure 232. Receiver HD3, Left and Right vs. Frequency Offset from LO, Tone Level = −15 dBm at Attenuation = 0, LO = 1850 MHz

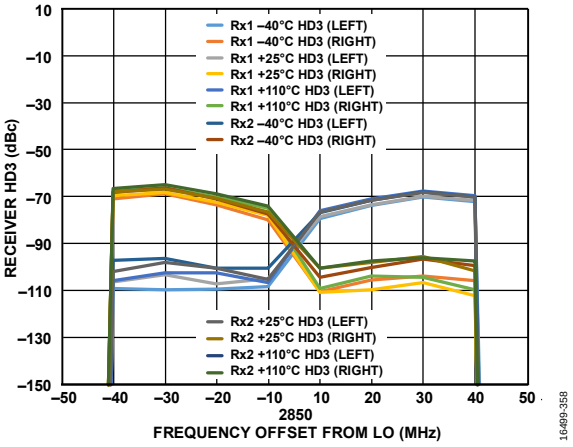

Figure 233. Receiver HD3, Left and Right vs. Frequency Offset from LO, Tone Level = −15 dBm at Attenuation = 0, LO = 2850 MHz

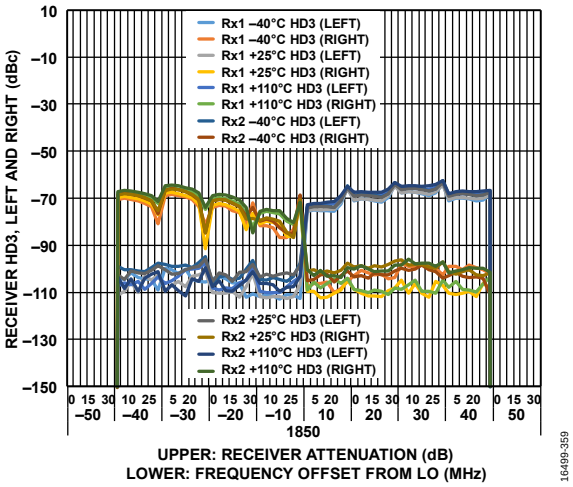

Figure 234. Receiver HD3, Left and Right vs. Frequency Offset from LO, Baseband Tone Held Constant, Tone Level Increased 1 for 1 as Attenuator is Swept from 0 dB to 30 dB, HD3 Right (High Side): Tone on Same Side as HD3 Product, HD3 Left (Low Side): Tone on Opposite Side as HD3 Product, Continuous Wave Signal, LO = 1850 MHz, Tone Level = −15 dBm at Attenuation = 0 dB

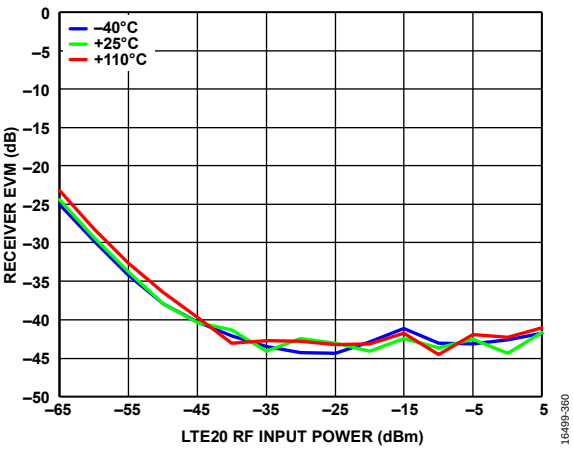

Figure 235. Receiver EVM vs. LTE20 MHz RF Input Power, LTE20 MHz RF Signal, LO = 600 MHz

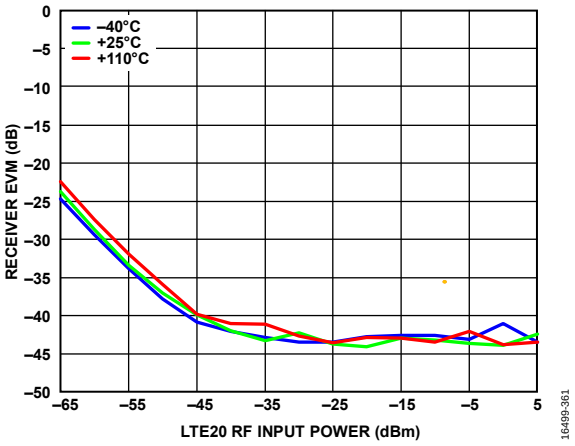

Figure 236. Receiver EVM vs. LTE 20 MHz RF Input Power, LTE20 MHz RF Signal, LO = 1800 MHz

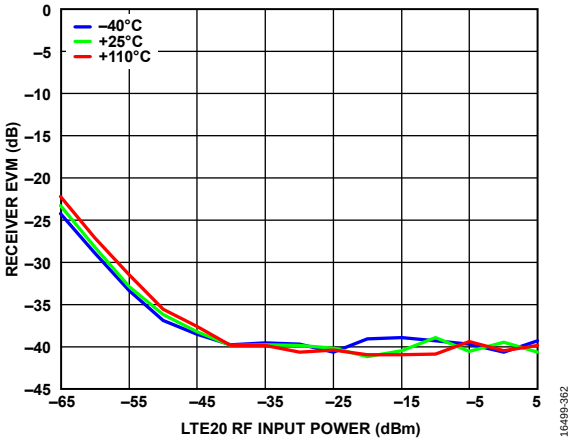

Figure 237. Receiver EVM vs. LTE 20 MHz RF Input Power, LTE 20 MHz RF Signal, LO = 2700 MHz

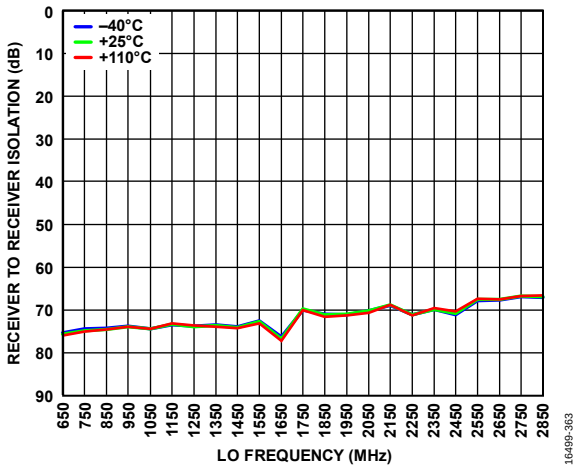

Figure 238. Receiver to Receiver Isolation (dB) vs. LO Frequency (MHz)

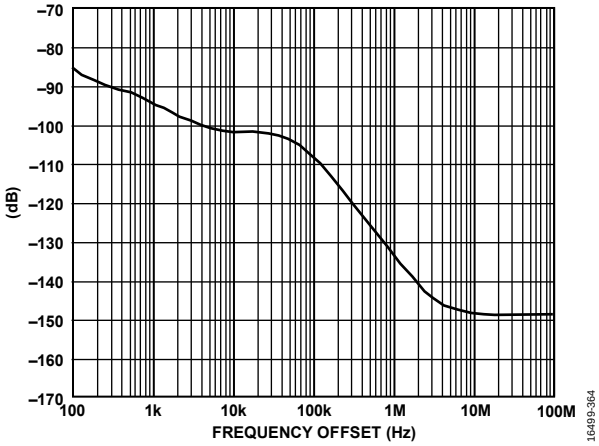

Figure 239. LO Phase Noise vs. Frequency Offset, LO = 1900 MHz, RMS Phase Error Integrated from 2 kHz to 18 MHz, Spectrum Analyzer Limits Far Out Noise

3400 MHz TO 4800 MHz BAND

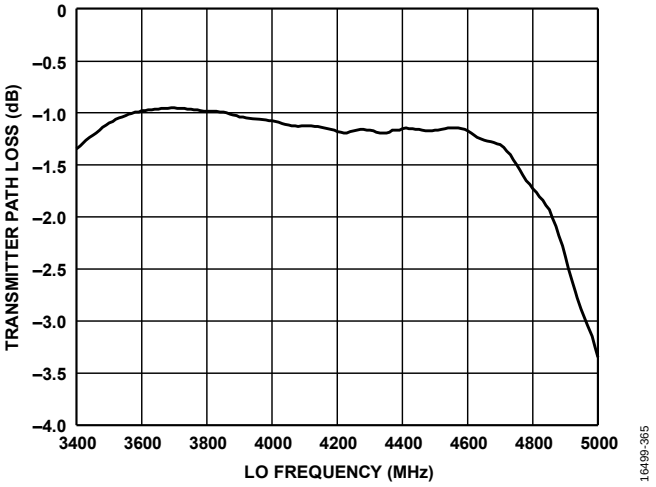

Figure 240. Transmitter Path Loss vs. LO Frequency (Simulation), Can Be Used for Deembedding Performance Data

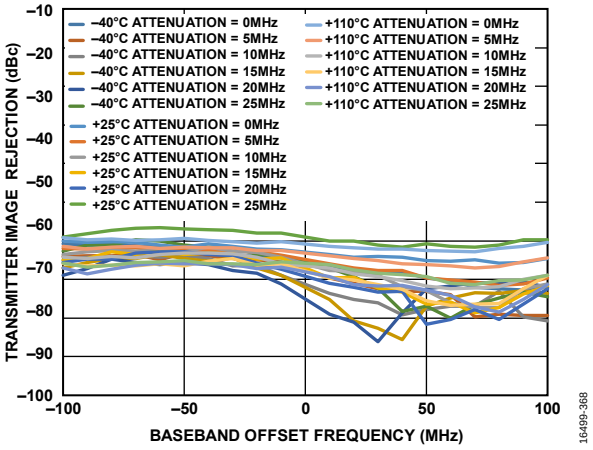

Figure 243. Transmitter Image Rejection Across Large Signal Bandwidth vs. Baseband Offset Frequency and Attenuation, QEC Trained with Three Tones (Tracking On), Total Combined Power = −6 dBFS, Correction Then Frozen (Tracking Turned Off), Continuous Wave Tone Swept Across Large Signal Bandwidth, LO = 4600 MHz

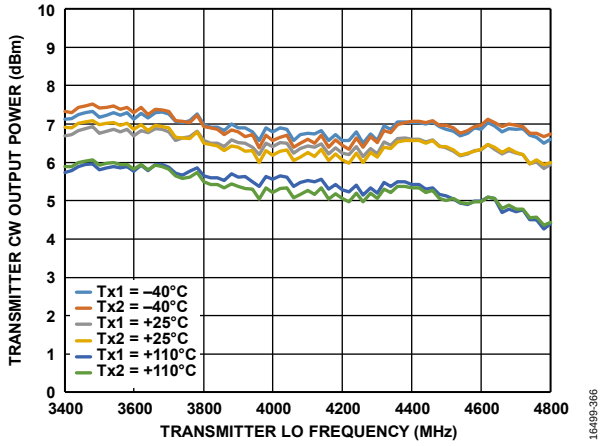

Figure 241. Transmitter Continuous Wave Output Power vs. Transmitter LO Frequency, Transmitter QEC and External LO Leakage Active, Transmitter in 200 MHz/450 MHz Bandwidth Mode, IQ Rate = 491.52 MHz, Attenuation = 0 dB, Not Deembedded

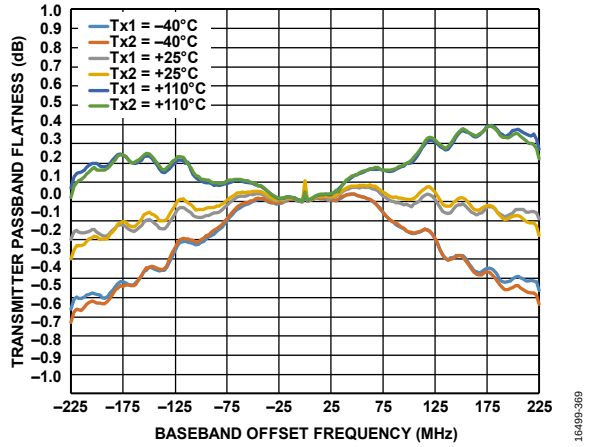

Figure 244. Transmitter Pass Band Flatness vs. Baseband Offset Frequency, Off Chip Match Response Deembedded, LO = 3600 MHz

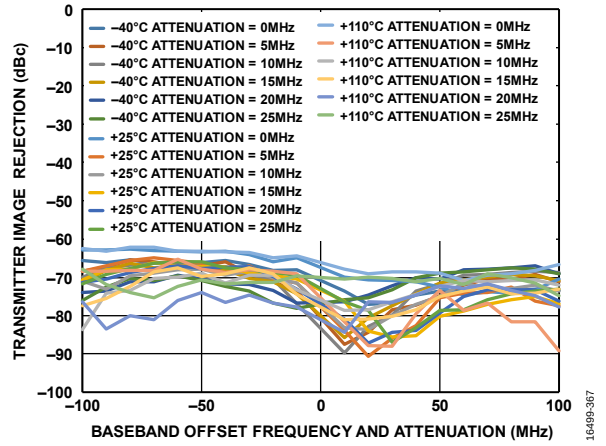

Figure 242. Transmitter Image Rejection Across Large Signal Bandwidth vs. Baseband Offset Frequency and Attenuation, QEC Trained with Three Tones Placed at 10 MHz, 50 MHz, and 100 MHz (Tracking On), Total Combined Power = −6 dBFS, Correction Then Frozen (Tracking Turned Off), Continuous Wave Tone Swept Across Large Signal Bandwidth, LO = 3700 MHz

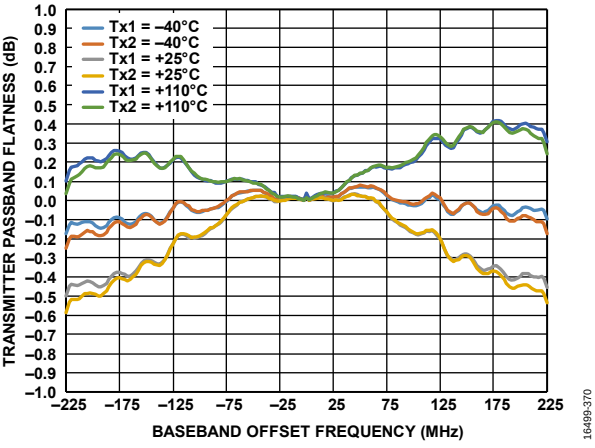

Figure 245. Transmitter Pass Band Flatness vs. Baseband Offset Frequency, Off Chip Match Response Deembedded, LO = 4600 MHz

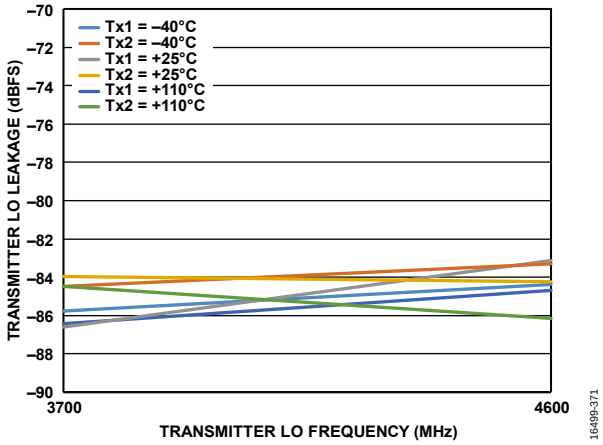

Figure 246. Transmitter LO Leakage vs. Transmitter LO Frequency, Transmitter Attenuation = 0 dB

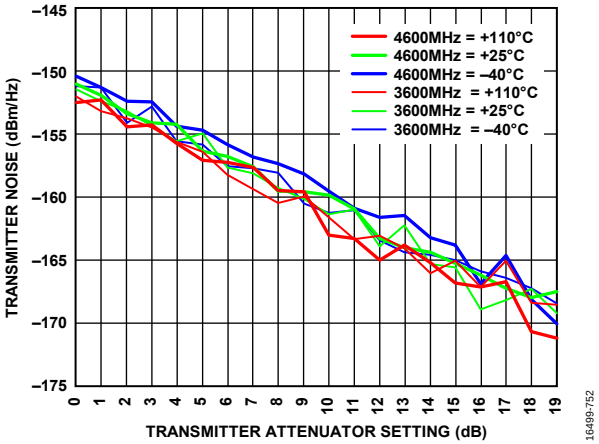

Figure 249. Transmitter Noise vs. Transmitter Attenuator Setting

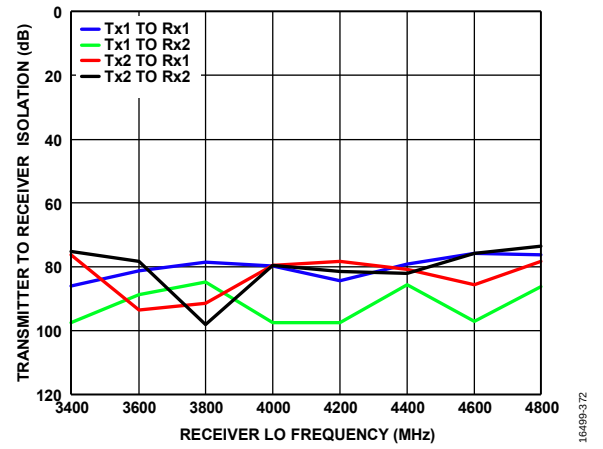

Figure 247. Transmitter to Receiver Isolation vs. Receiver LO Frequency, Temperature = –40°C, +25°C, and +110°C

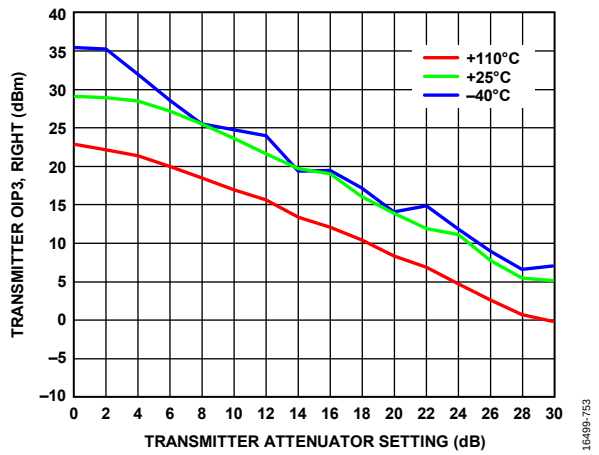

Figure 250. Transmitter OIP3, Right vs. Transmitter Attenuator Setting, LO = 3600 MHz. Total RMS Power = –12 dBFS.

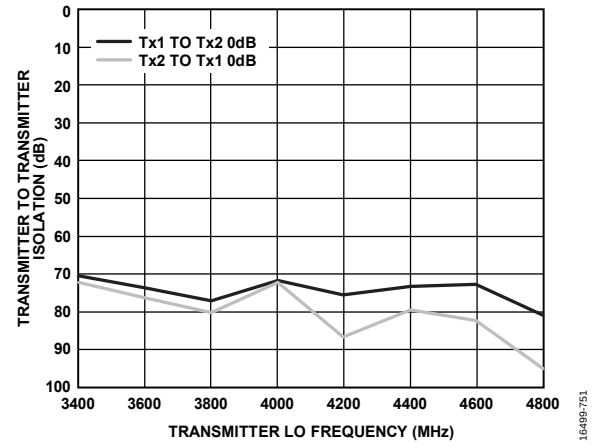

Figure 248. Transmitter to Transmitter Isolation vs. Transmitter LO Frequency, Temperature = 25°C

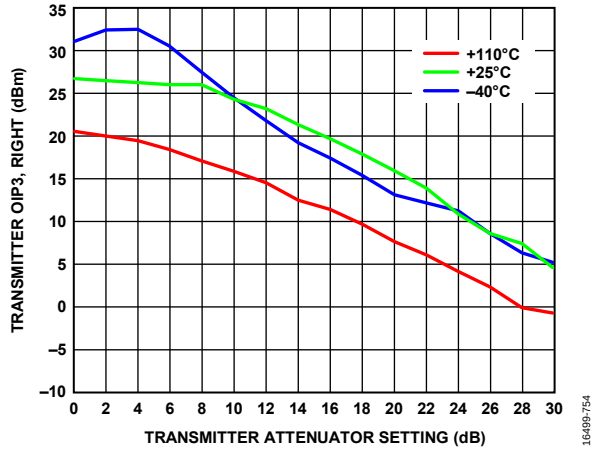

Figure 251. Transmitter OIP3, Right vs. Transmitter Attenuator Setting, LO = 4600 MHz, Total RMS Power = –12 dBFS

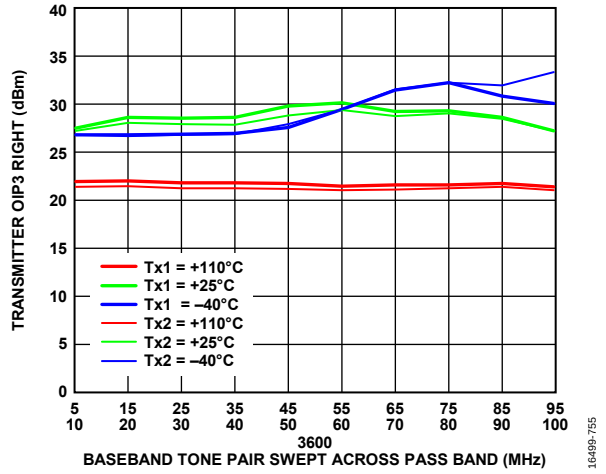

Figure 252. Transmitter OIP3, Right vs. Baseband Tone Pair Swept Across Pass Band, LO = 36000 MHz, Total RMS Power = −12 dBFS

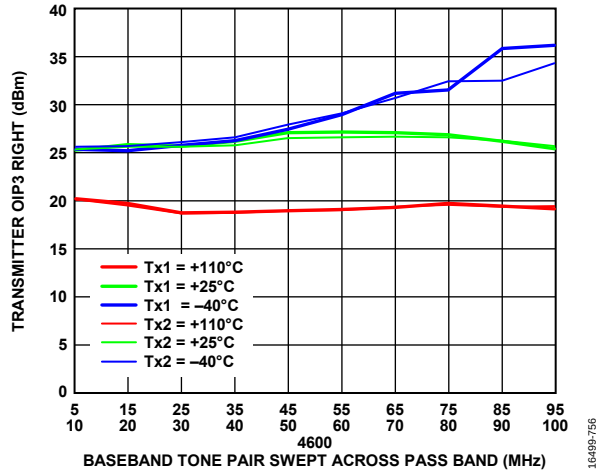

Figure 253. Transmitter OIP3, Right vs. Baseband Tone Pair Swept Across Pass Band, LO = 4600 MHz, Total RMS Power = −12 dBFS

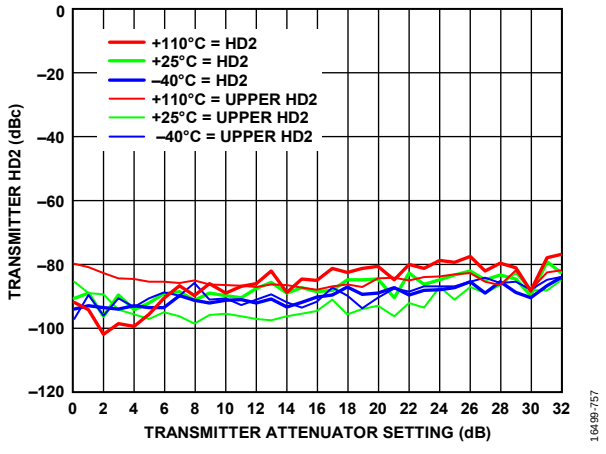

Figure 254. Transmitter HD2 vs. Transmitter Attenuator Setting, Baseband Frequency = 10 MHz, LO = 3600 MHz, Continuous Wave = −15 dBFS

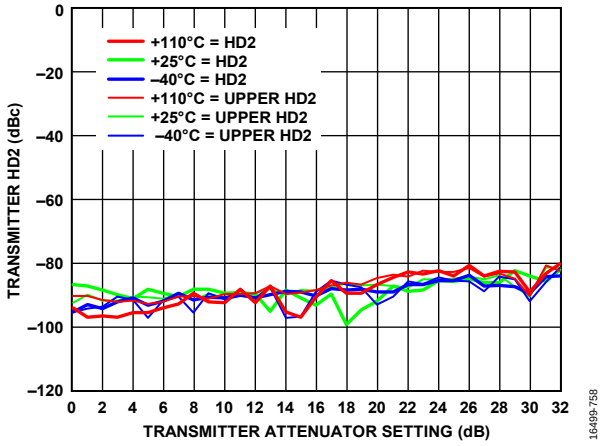

Figure 255. Transmitter HD2 vs. Transmitter Attenuator Setting, Baseband Frequency = 10 MHz, LO = 4600 MHz, Continuous Wave = −15 dBFS

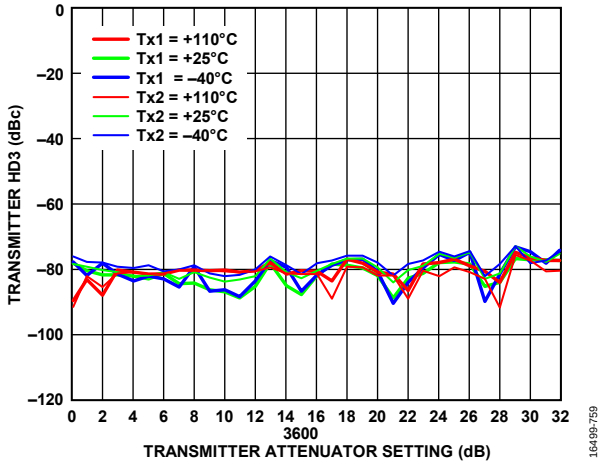

Figure 256. Transmitter HD3 vs. Transmitter Attenuator Setting, LO = 3600 MHz, Continuous Wave = −15 dBFS, Baseband Frequency = 10 MHz

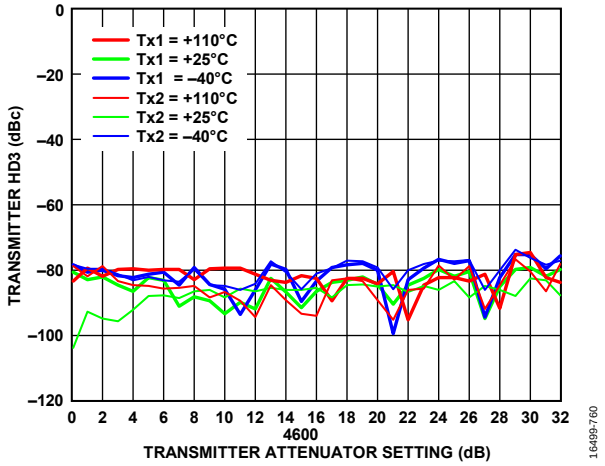

Figure 257. Transmitter HD3 vs. Transmitter Attenuator Setting, LO = 4600 MHz, Continuous Wave = −15 dBFS, Baseband Frequency = 10 MHz

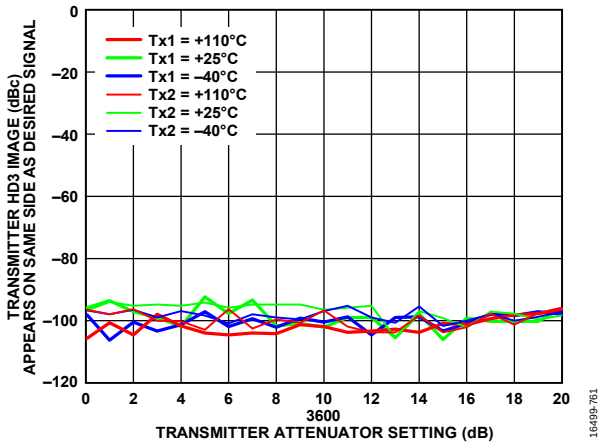

Figure 258. Transmitter HD3 Image Appears on Same Side as Desired Signal vs. Transmitter Attenuator Setting, LO = 3600 MHz, Continuous Wave = −15 dBFS

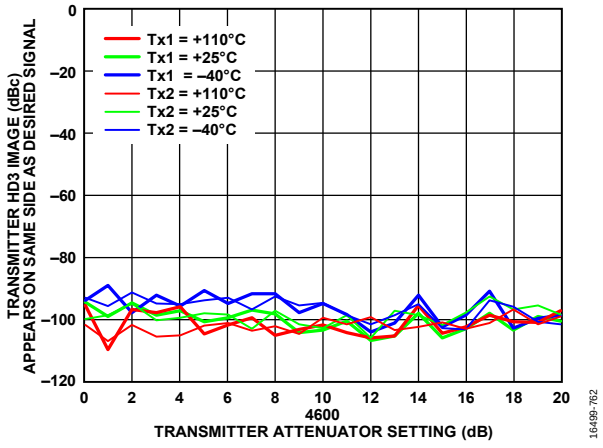

Figure 259. Transmitter HD3 Image Appears on Same Side as Desired Signal vs. Transmitter Attenuator Setting, LO = 4600 MHz, Continuous Wave = −15 dBFS

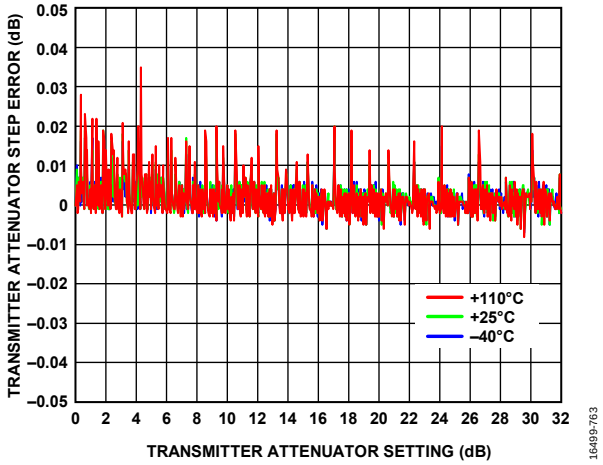

Figure 260. Transmitter Attenuator Step Error vs. Transmitter Attenuator Setting, LO = 3600 MHz

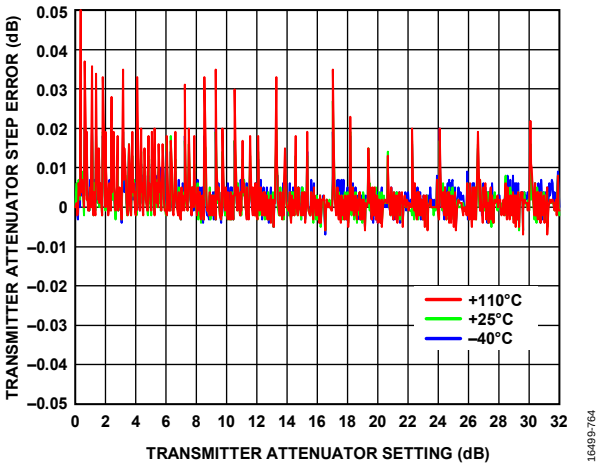

Figure 261. Transmitter Attenuator Step Error vs. Transmitter Attenuator Setting, LO = 4600 MHz

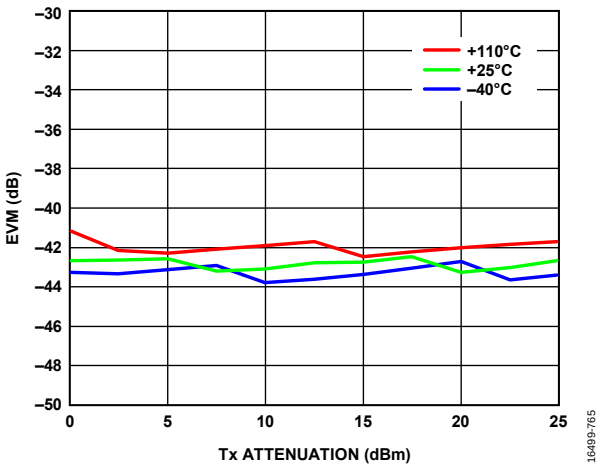

Figure 262. Transmitter EVM vs. Transmitter Attenuation, 20 MHz LTE Signal Centered on DC, LO = 3600 MHz

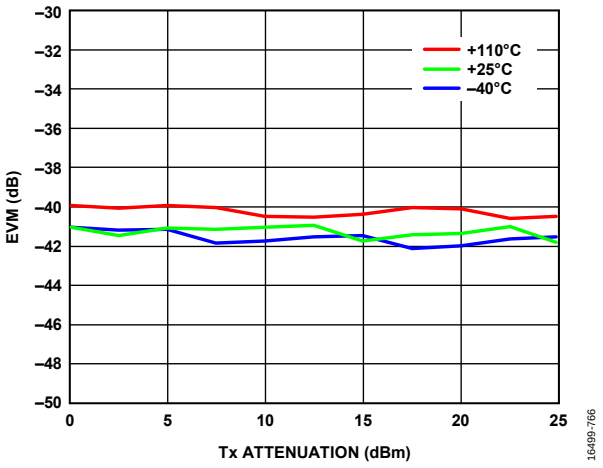

Figure 263. Transmitter EVM vs. Transmitter Attenuation, 20 MHz LTE Signal Centered on DC, LO = 4600 MHz

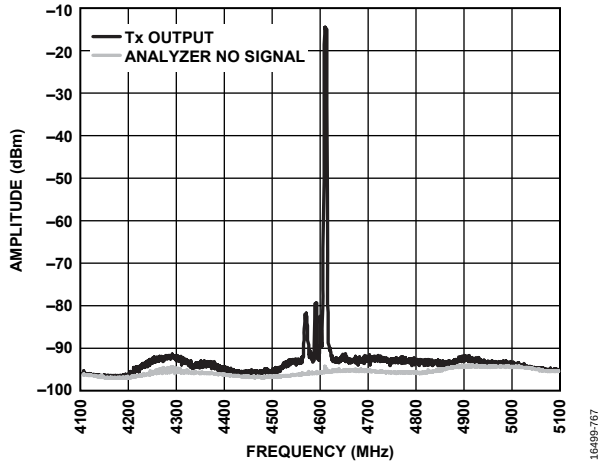

Figure 264. Amplitude vs. Frequency Transmitter Output Spurious, Transmitter 1 = 4600 MHz, LTE = 5 MHz, Offset = 10 MHz, RMS Ripple in Noise Floor Due to Spectrum Analyzer = −12 dBFS, Temperature = 25°C

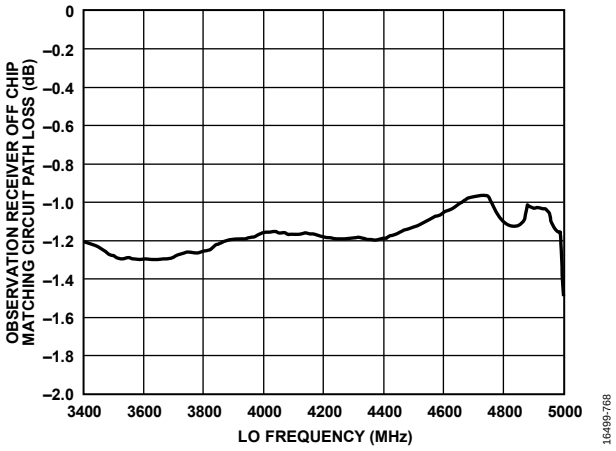

Figure 265. Observation Receiver Off Chip Matching Circuit Path Loss vs. LO Frequency (Simulation), Can Be Used for Deembedding Performance Data

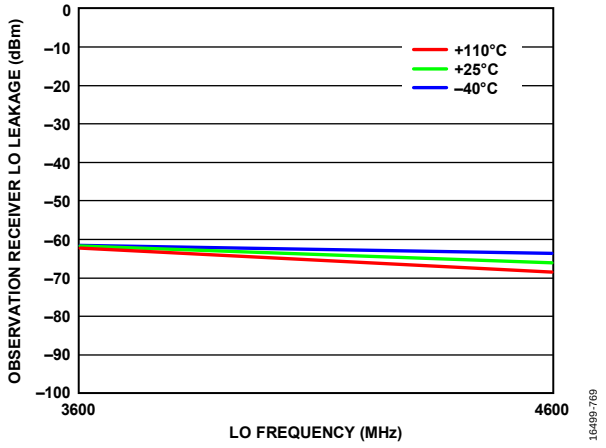

Figure 266. Observation Receiver LO Leakage vs. LO Frequency from 3600 MHz to 4600 MHz

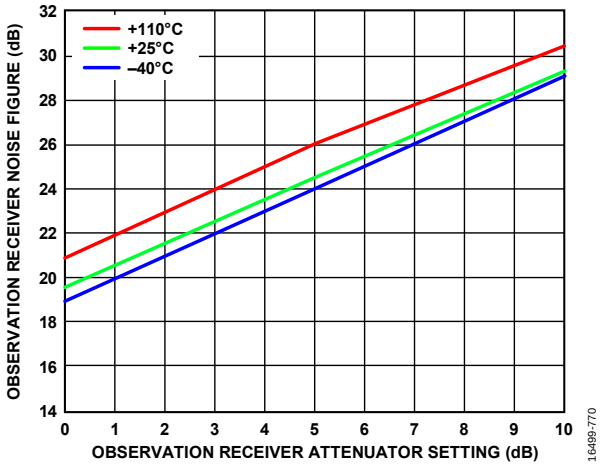

Figure 267. Observation Receiver Noise Figure vs. Observation Receiver Attenuator Setting, LO = 3600 MHz, Total Nyquist Integration Bandwidth

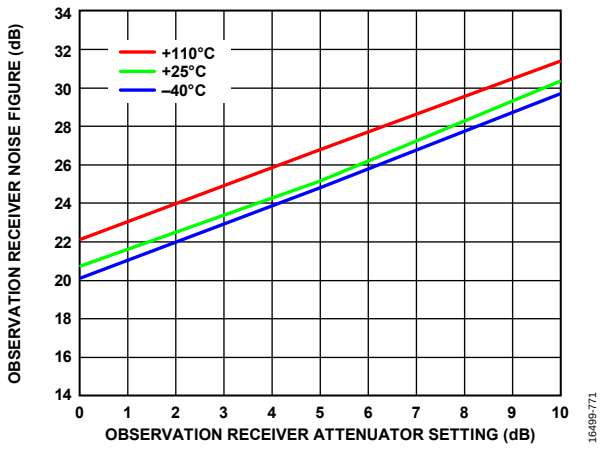

Figure 268. Observation Receiver Noise Figure vs. Observation Receiver Attenuator Setting, LO = 4600 MHz, Total Nyquist Integration Bandwidth

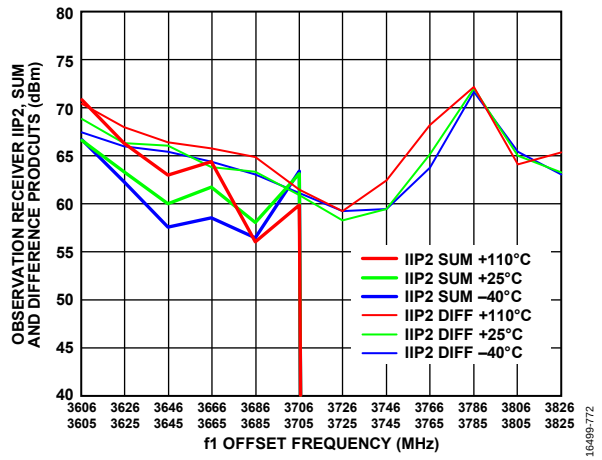

Figure 269. Observation Receiver IIP2, Sum and Difference Products vs. f1 Offset Frequency, Tones Separated by 1 MHz Swept Across Pass Band at −22 dBm Each, LO = 3600 MHz, Attenuation = 0 dB

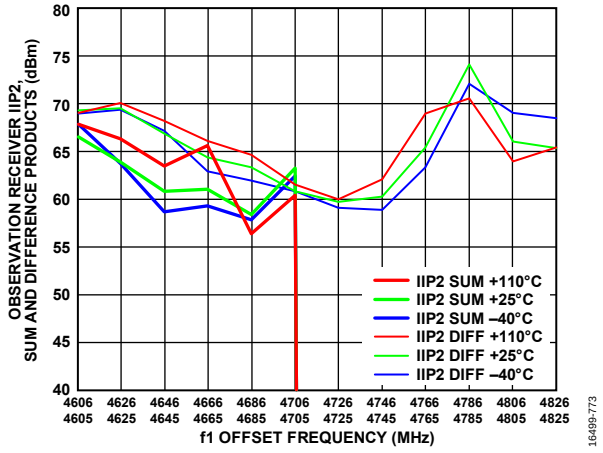

Figure 270. Observation Receiver IIP2, Sum and Difference Products vs. f1 Offset Frequency, Tones Separated By 1 MHz Swept Across Pass Band at –22 dBm Each, 4600 MHz, Attenuation = 0 dB

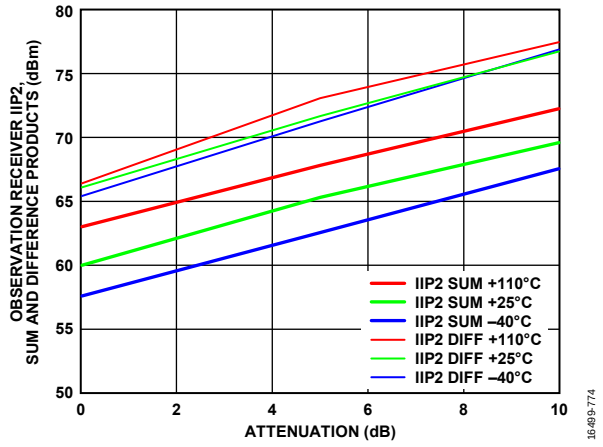

Figure 271. Observation Receiver IIP2, Sum and Difference Products vs. Attenuation, LO = 3600 MHz, Tone 1 = 3645 MHz, Tone 2 = 3646 MHz at –22 dBm Plus Attenuation

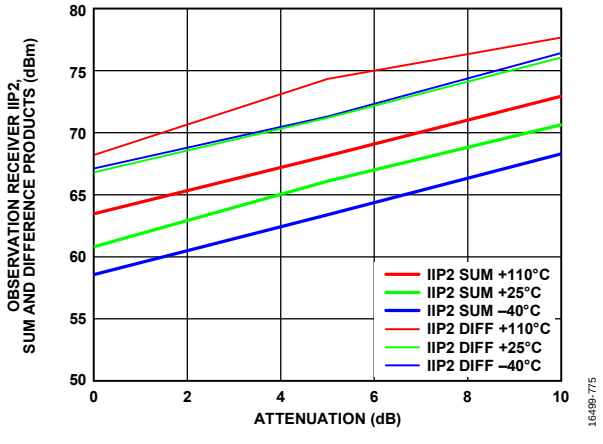

Figure 272. Observation Receiver IIP2, Sum and Difference Products vs. Attenuation, LO = 4600 MHz, Tone 1 = 4645 MHz, Tone 2 = 4646 MHz at –22 dBm Plus Attenuation

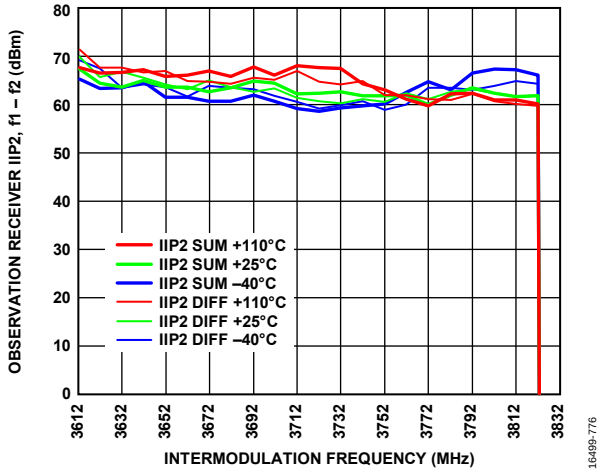

Figure 273. Observation Receiver IIP2, f1 – f2 vs. Intermodulation Frequency, LO = 3600 MHz, Tone 1 = 3602 MHz, Tone 2 Swept, –22 dBm Each, Attenuation = 0 dB

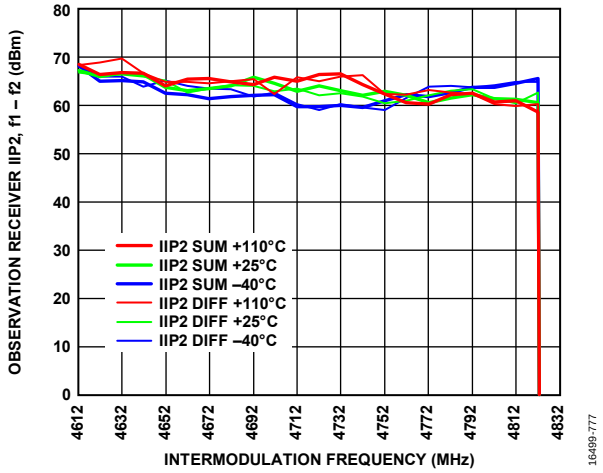

Figure 274. Observation Receiver IIP2, f1 – f2 vs. Intermodulation Frequency, LO = 4600 MHz, Tone 1 = 4602 MHz, Tone 2 Swept, –22 dBm Each, Attenuation = 0 dB

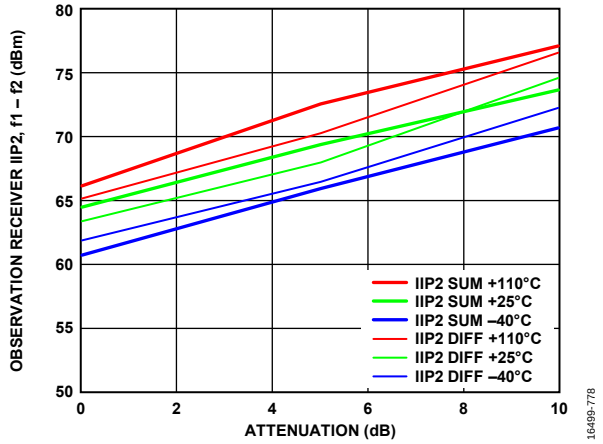

Figure 275. Observation Receiver IIP2, f1 – f2 vs. Attenuation, LO = 3600 MHz, Tone 1 = 3602 MHz, Tone 2 = 3702 MHz at –22 dBm Plus Attenuation

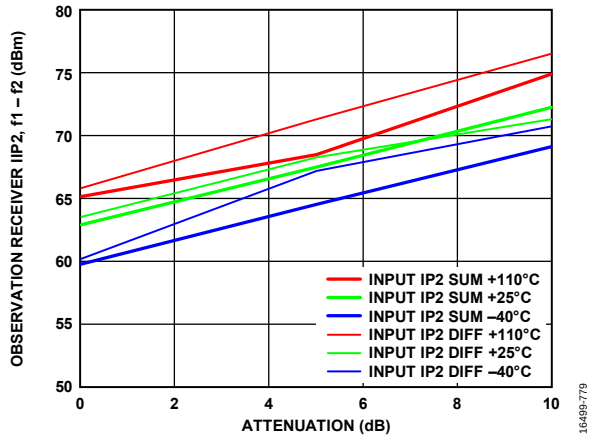

Figure 276. Observation Receiver IIP2, f1 − f2 vs. Attenuation, 4600 MHz, Tone 1 = 4602 MHz, Tone 2 = 4612 MHz at −22 dBm Plus Attenuation

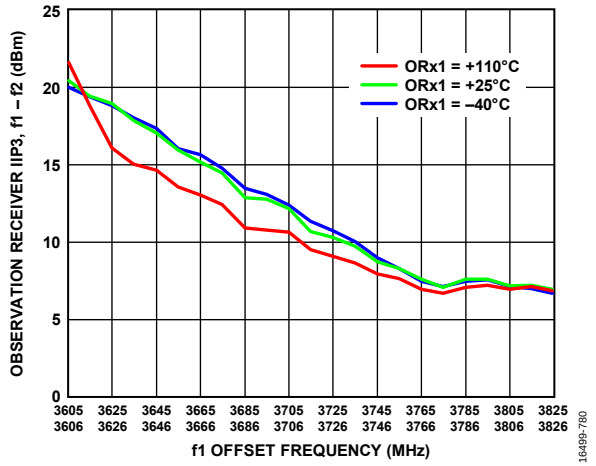

Figure 277. Observation Receiver IIP3, 2 f1 − f2 vs. f1 Offset Frequency, LO = 3600 MHz, Attenuation = 0 dB, Tones Separated by 1 MHz Swept Across Pass Band at −22 dBm Each

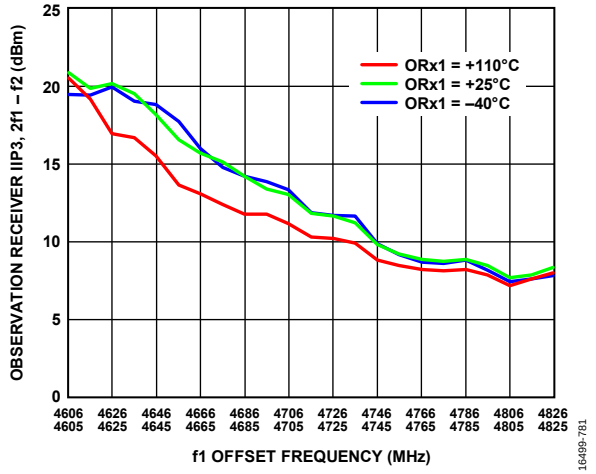

Figure 278. Observation Receiver IIP3, 2 f1 − f2vs. f1 Offset Frequency, LO = 4600 MHz, Attenuation = 0 dB, Tones Separated by 1 MHz Swept Across Pass Band at −22 dBm Each

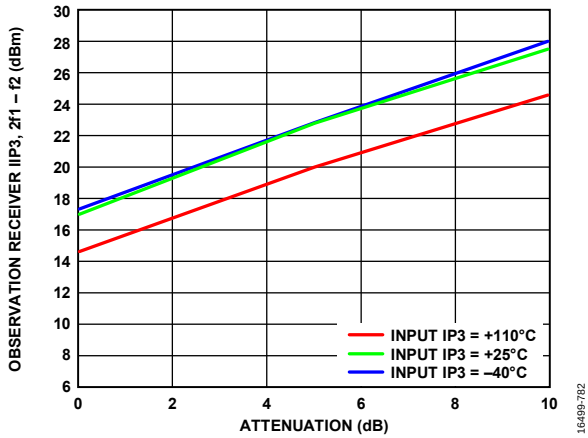

Figure 279. Observation Receiver IIP3, 2f1 − f2 vs. Attenuation, LO = 3600 MHz, Tone 1 = 3695 MHz, Tone 2 = 3696 MHz at −22 dBm Plus Attenuation

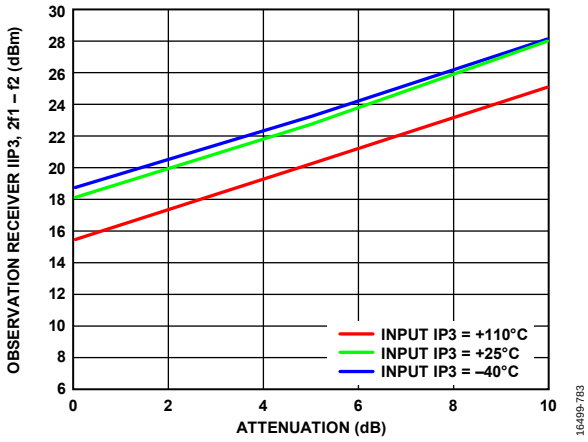

Figure 280. Observation Receiver IIP3, 2 f1 − f2 vs. Attenuation, LO = 4600 MHz, Tone 1 = 4695 MHz, Tone 2 = 4696 MHz at −22 dBm Plus Attenuation

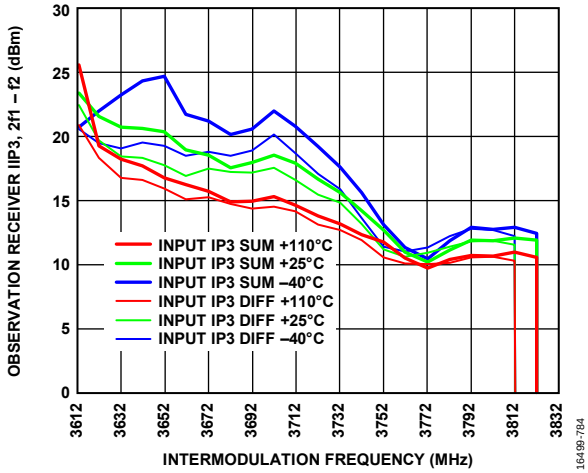

Figure 281. Observation Receiver IIP3, 2f1 − f2 vs. Intermodulation Frequency, LO = 3600 MHz, Tone 1 = 3602 MHz, Tone 2 Swept, −22 dBm Each

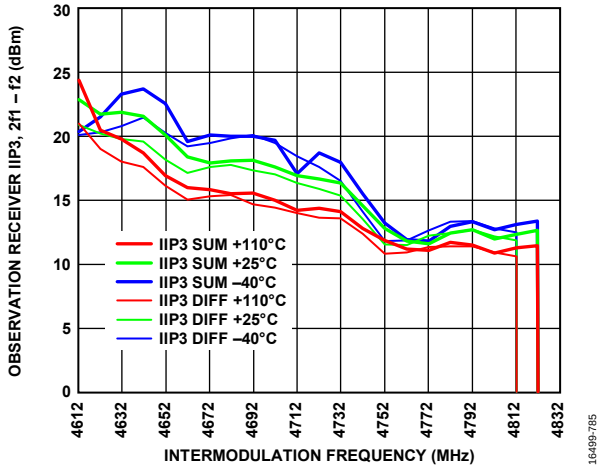

Figure 282. Observation Receiver IIP3, 2f1 – f2 vs. Intermodulation Frequency, LO = 4600 MHz, Tone 1 = 4602 MHz, Tone 2 Swept, –22 dBm Each

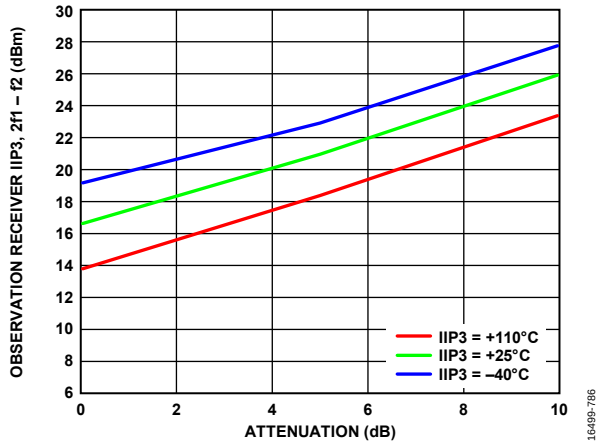

Figure 283. Observation Receiver IIP3, 2f1 – f2 vs. Attenuation, LO = 3600 MHz, Tone 1 = 3602 MHz, Tone 2 = 3722 MHz, –22 dBm Plus Attenuation Each

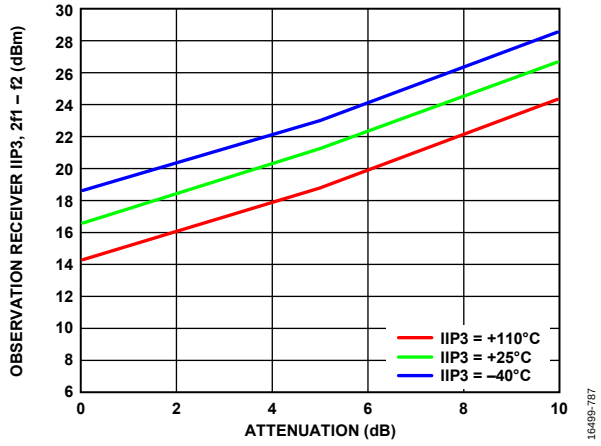

Figure 284. Observation Receiver IIP3, 2f1 – f2 vs. Attenuation, LO = 4600 MHz, Tone 1 = 4602 MHz, Tone 2 = 4722 MHz at –22 dBm Plus Attenuation Each

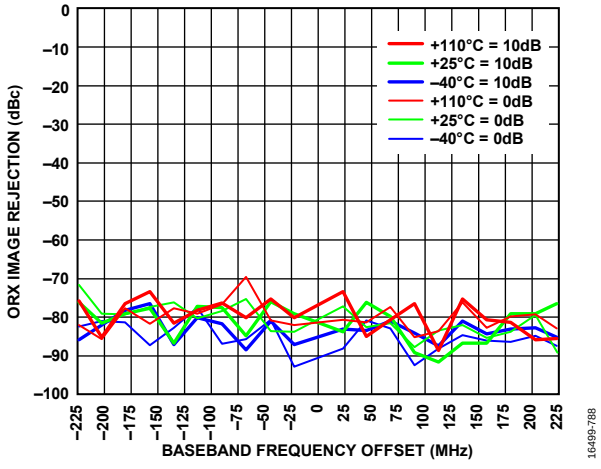

Figure 285. Observation Receiver Image Rejection vs. Baseband Frequency Offset, Continuous Wave Signal Swept Across the Band, LO = 3600 MHz

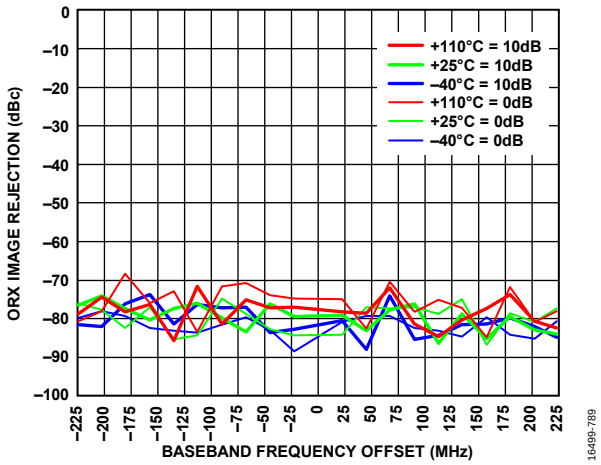

Figure 286. Observation Receiver Image Rejection vs. Baseband Frequency Offset, Continuous Wave Signal Swept Across the Band, LO = 4600 MHz

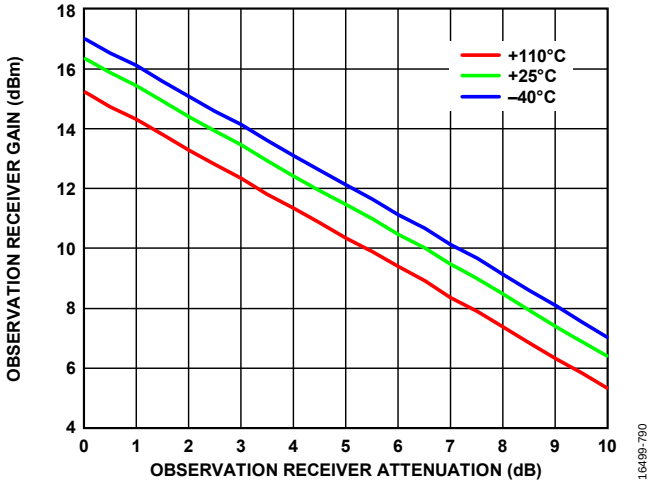

Figure 287. Observation Receiver Gain vs. Observation Receiver Attenuation, LO = 3600 MHz

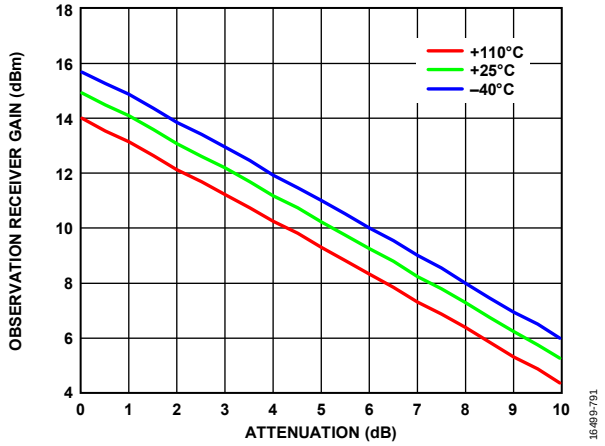

Figure 288. Observation Receiver Gain vs. Observation Receiver Attenuation, LO = 4600 MHz

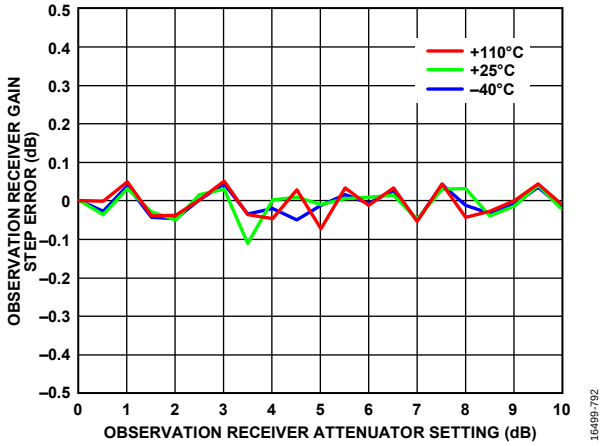

Figure 289. Observation Receiver Gain Step Error vs. Observation Receiver Attenuator Setting, LO = 3600 MHz

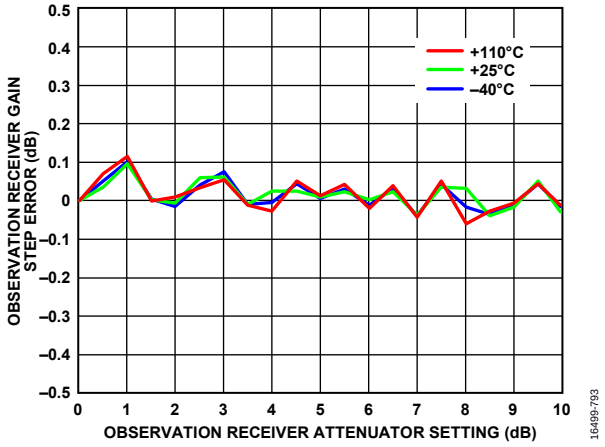

Figure 290. Observation Receiver Gain Step Error vs. Observation Receiver Attenuator Setting, LO = 4600 MHz

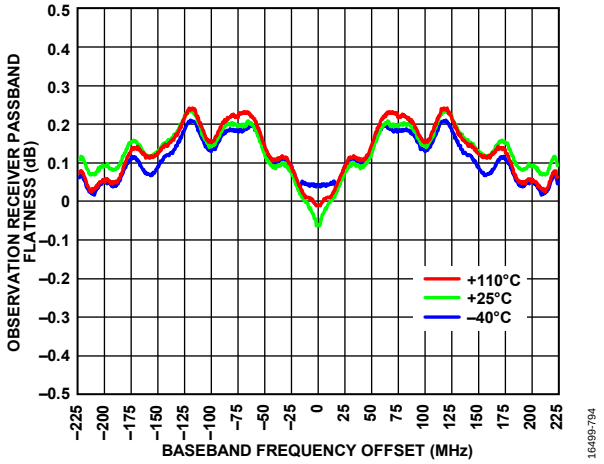

Figure 291. Observation Receiver Pass Band Flatness vs. Baseband Frequency Offset, LO = 3600 MHz

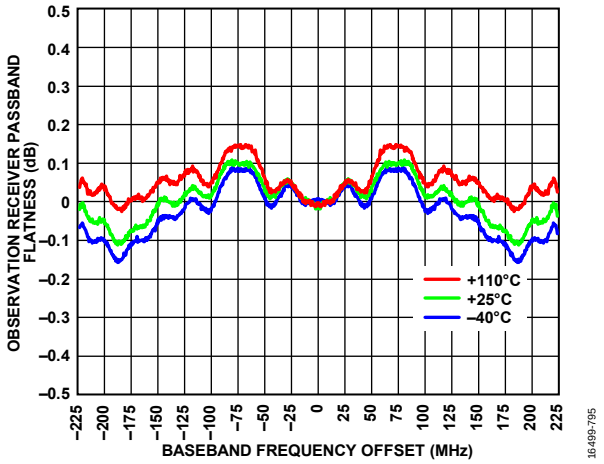

Figure 292. Observation Receiver Pass Band Flatness vs. Baseball Frequency Offset, LO = 4600 MHz

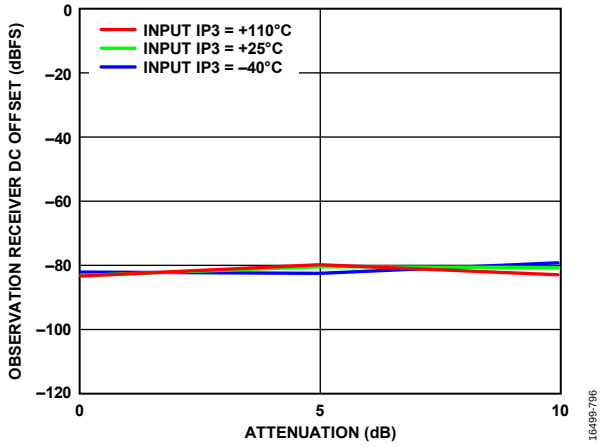

Figure 293. Observation Receiver DC Offset vs. Attenuation, LO = 3600 MHz

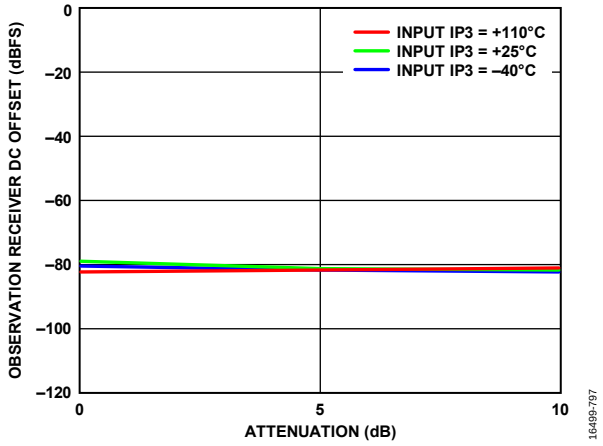

Figure 294. Observation Receiver DC Offset vs. Attenuation, LO = 4600 MHz

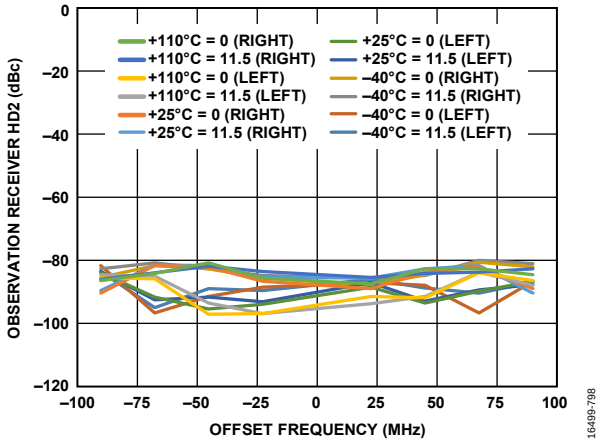

Figure 295. Observation Receiver HD2 vs. Offset Frequency, LO = 3600MHz, Tone Level = –20 dBm Plus Attenuation

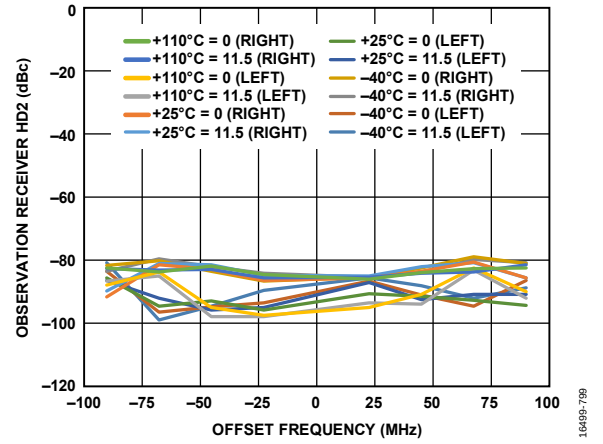

Figure 296. Observation Receiver HD2 vs. Offset Frequency, LO = 4600 MHz, Tone Level = –20 dBm Plus Attenuation

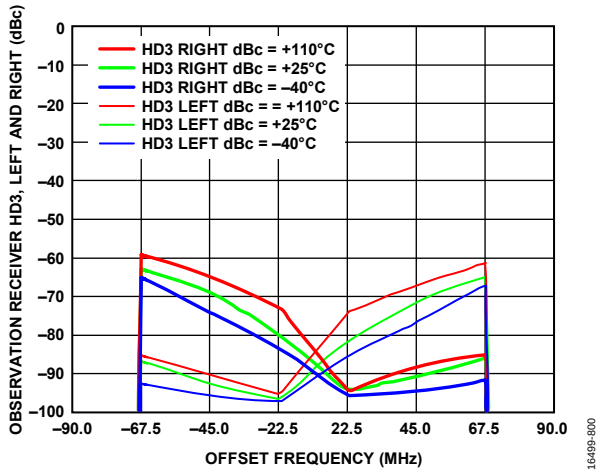

Figure 297. Observation Receiver HD3, Left and Right vs. Offset Frequency, LO = 3600 MHz, Tone Level = –20 dBm

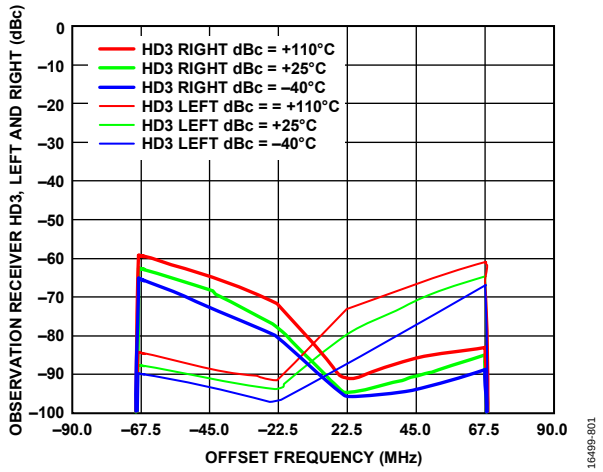

Figure 298. Observation Receiver HD3, Left and Right vs. Offset Frequency, LO = 4600 MHz, Tone Level = –20 dBm

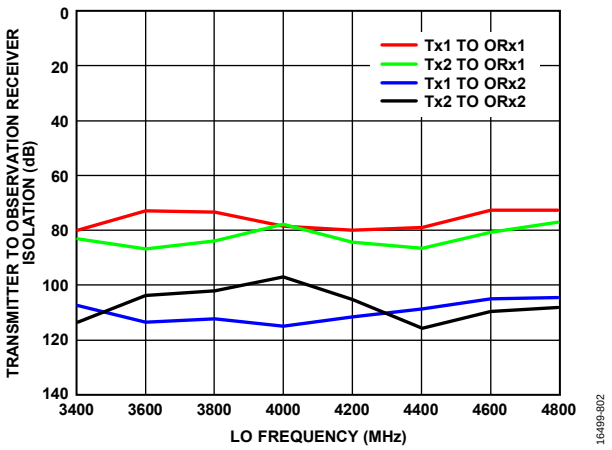

Figure 299. Transmitter to Observation Receiver Isolation vs. LO Frequency, Temperature = 25°C

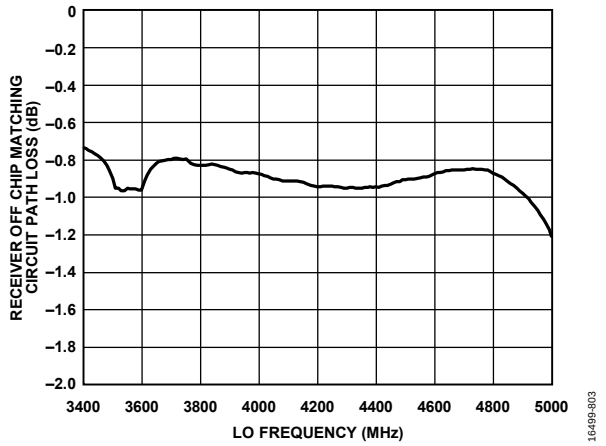

Figure 300. Receiver Off Chip Matching Circuit Path Loss vs. LO Frequency (Simulation), Can Be Used for Deembedding Performance Data

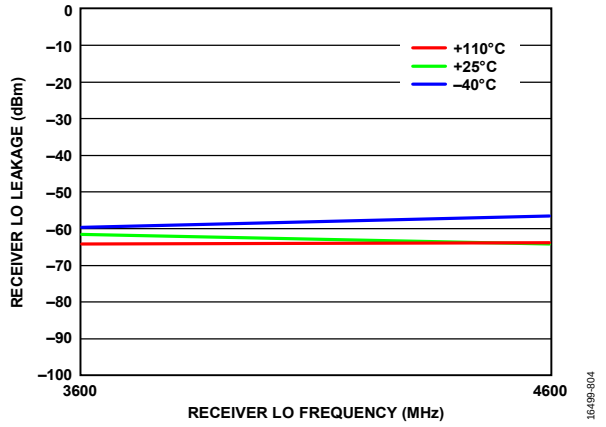

Figure 301. Receiver LO Leakage vs. Receiver LO Frequency, 0 dB Receiver Attenuation, 200 MHz RF Bandwidth, Sample Rate = 245.76 MSPS

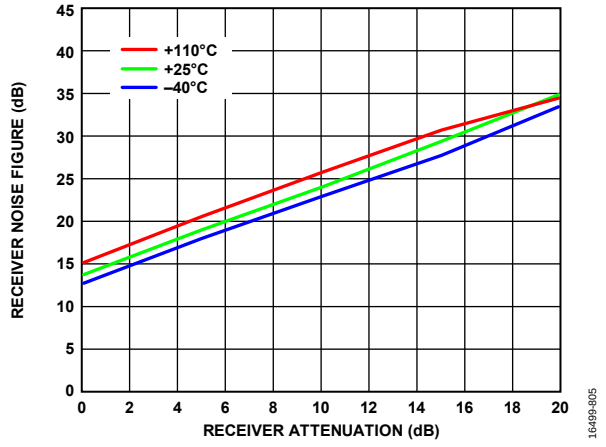

Figure 302. Receiver Noise Figure vs. Receiver Attenuation, LO = 3600 MHz, 200 MHz Bandwidth, Sample Rate = 245.76 MSPS, 500 kHz to 100 MHz Integration Bandwidth

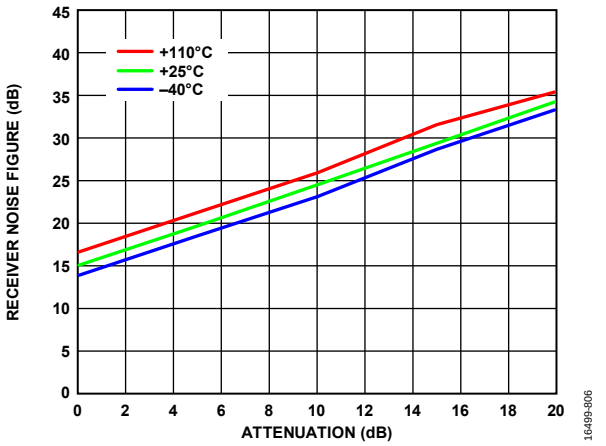

Figure 303. Receiver Noise Figure vs. Receiver Attenuation, LO = 4600 MHz, Bandwidth = 200 MHz, Sample Rate = 245.76 MSPS, 500 kHz to 100 MHz Integration Bandwidth

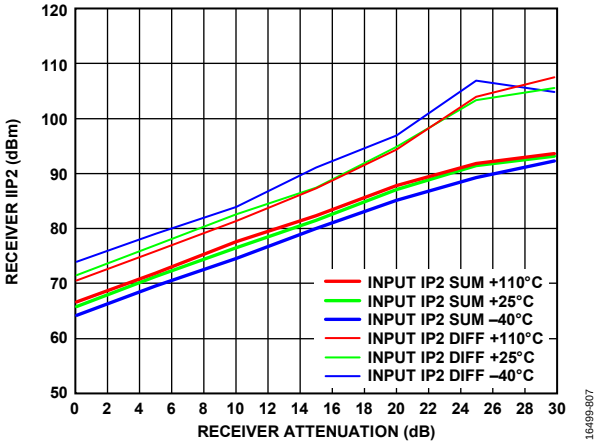

Figure 304. Receiver IIP2 vs. Receiver Attenuation, LO = 3600 MHz, Tones Placed at 3645 MHz and 3646 MHz, –21 dBm Plus Attenuation

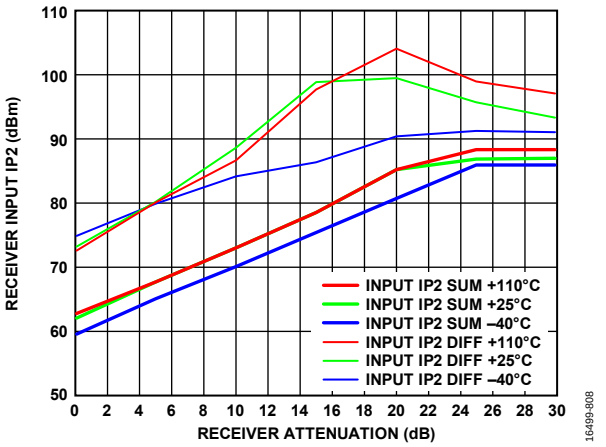

Figure 305. Receiver IIP2 vs. Receiver Attenuation, LO = 4600 MHz, Tones Placed at 4645 MHz and 4646 MHz, –21 dBm Plus Attenuation

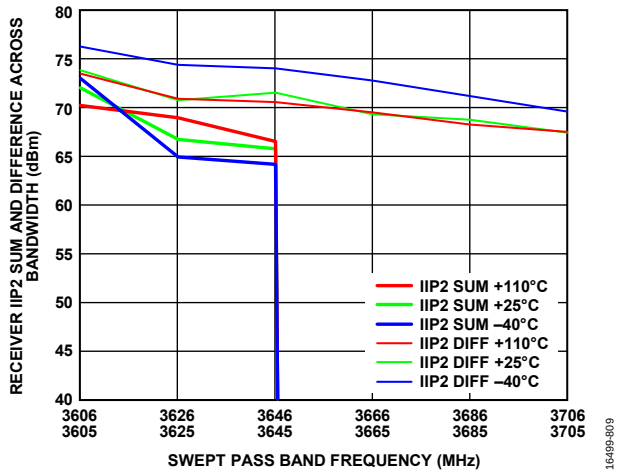

Figure 306. Receiver IIP2 Sum and Difference Across Bandwidth vs. Swept Pass Band Frequency, Receiver Attenuation = 0 dB, LO = 3600 MHz, Six Tone Pairs, –21 dBm Plus Attenuation Each

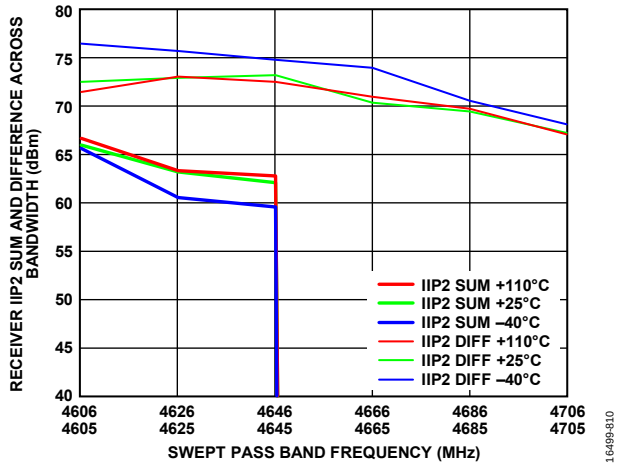

Figure 307. Receiver IIP2 Sum and Difference Across Bandwidth vs. Swept Pass Band Frequency, Receiver Attenuation = 0 dB, LO = 4600 MHz, Six Tone Pairs, –21 dBm Each

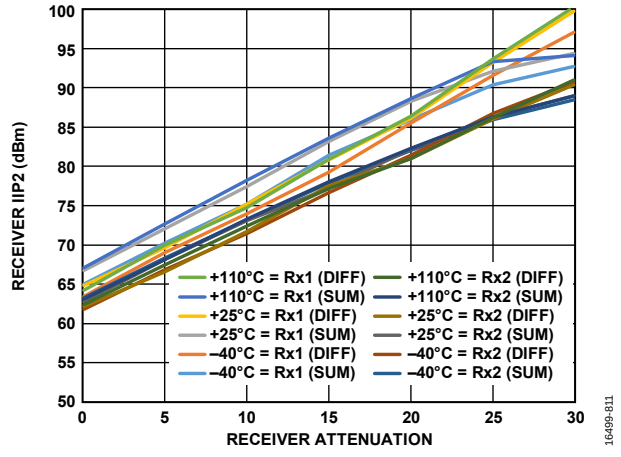

Figure 308. Receiver IIP2 vs. Receiver Attenuation, LO = 3600 MHz, Tones Placed at 3602 MHz and 3692 MHz, –21 dBm Plus Attenuation

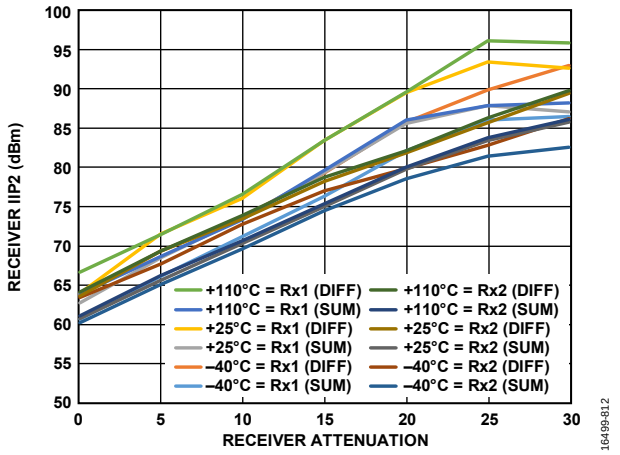

Figure 309. Receiver IIP2 vs. Receiver Attenuation, LO = 4600 MHz, Tones Placed at 4602 MHz and 4692 MHz, –21dBm Plus Attenuation

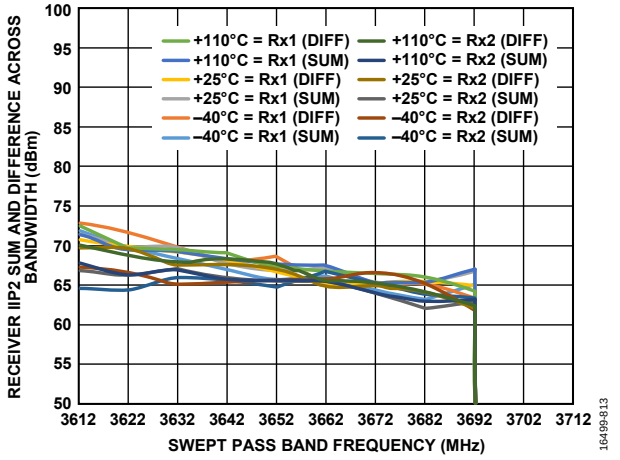

Figure 310. Receiver IIP2 Sum and Difference Across Bandwidth vs. Swept Pass Band Frequency, Receiver Attenuation = 0 dB, LO = 3600 MHz, Tone 1 = 3602 MHz, Tone 2 Swept, –21 dBm Each

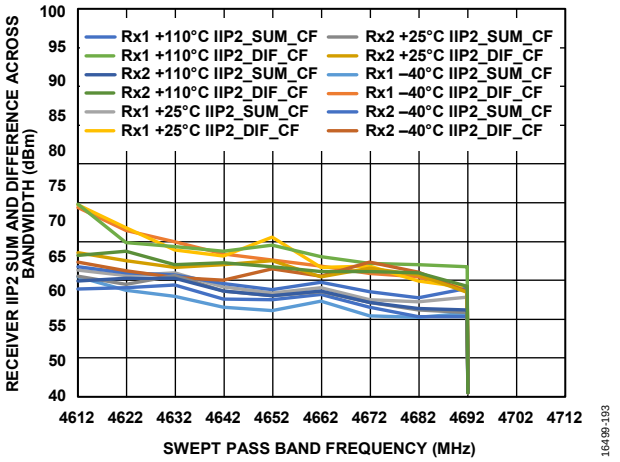

Figure 311. Receiver IIP2 Sum and Difference Across Bandwidth vs. Swept Pass Band Frequency, Receiver Attenuation = 0 dB, LO = 4600 MHz, Tone 1 = 4602 MHz, Tone 2 Swept, –21 dBm Each

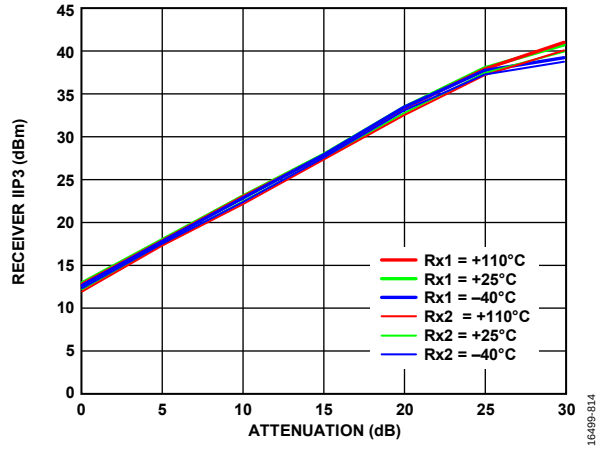

Figure 312. Receiver IIP3 vs. Attenuation, LO = 3600 MHz, Tone 1 = 3695 MHz, Tone 2 = 3696 MHz, −21 dBm Plus Attenuation

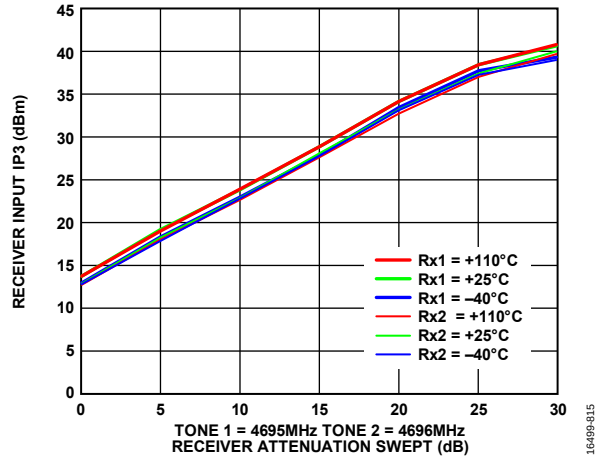

Figure 313. Receiver IIP3 vs. Swept Pass Band Frequency, LO = 4600 MHz, Tone 1 = 4695 MHz, Tone 2 = 4696 MHz, −21 dBm Plus Attenuation

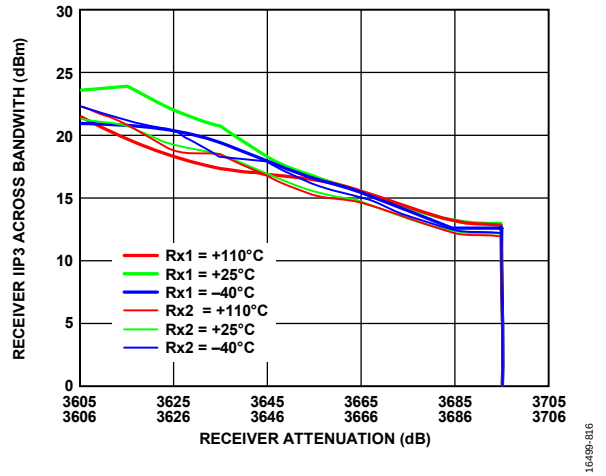

Figure 314. Receiver IIP3 Across Bandwidth vs. Swept Pass Band Frequency, Receiver Attenuation = 0 dB, LO = 3600 MHz, Tone 2 = Tone 1 + 1 MHz, −21 dBm Each, Swept Across Pass Band

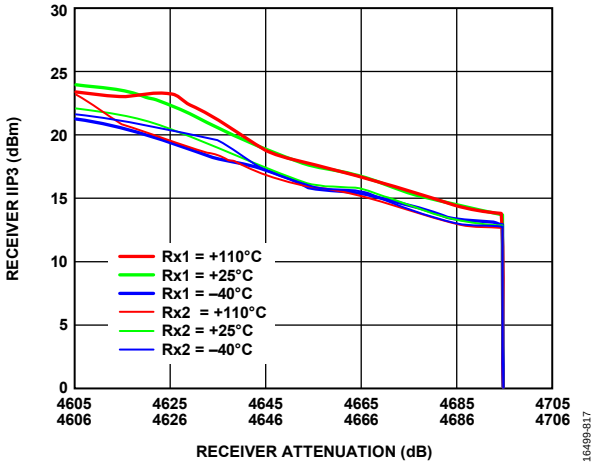

Figure 315. Receiver IIP3 Across Bandwidth vs. Receiver Attenuation, Receiver Attenuation = 0 dB, LO = 4600 MHz, Tone 2 = Tone 1 + 1 MHz, −21 dBm Each, Swept Across Pass Band

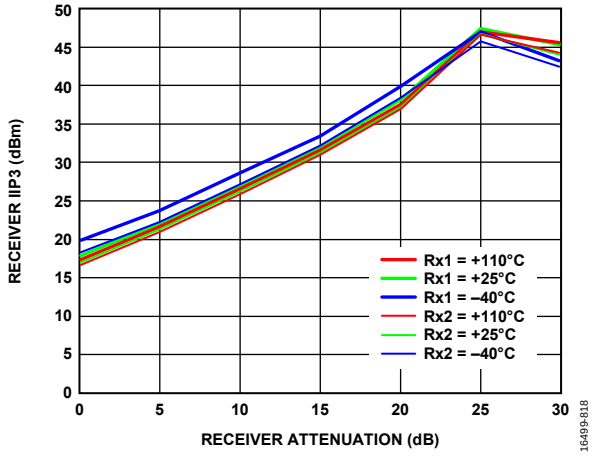

Figure 316. Receiver IIP3 vs. Receiver Attenuation, LO = 3600 MHz, Tone 1 = 3602 MHz, Tone 2 = 3692 MHz, −21 dBm Plus Attenuation

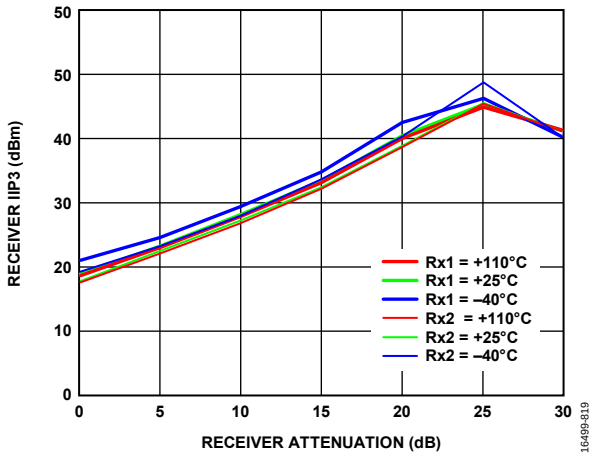

Figure 317. Receiver IIP3 vs. Receiver Attenuation, LO = 4600 MHz, Tone 1 = 4602 MHz, Tone 2 = 4692 MHz, −21 dBm Plus Attenuation

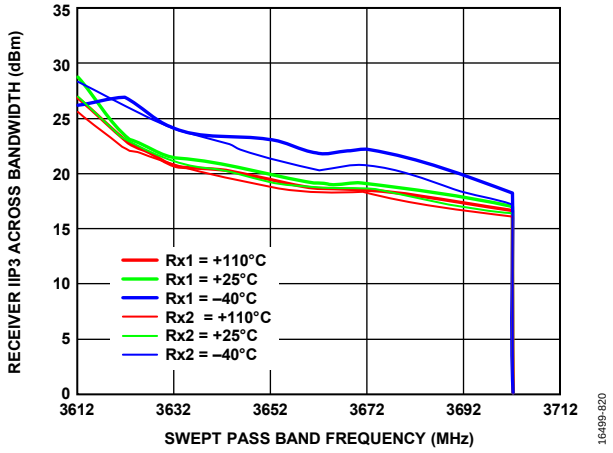

Figure 318. Receiver IIP3 Across Bandwidth vs. Swept Pass Band Frequency, Receiver Attenuation = 0 dB, LO = 3600 MHz, Tone 1 = 3602 MHz, Tone 2 Swept Across Pass Band, −21 dBm Each

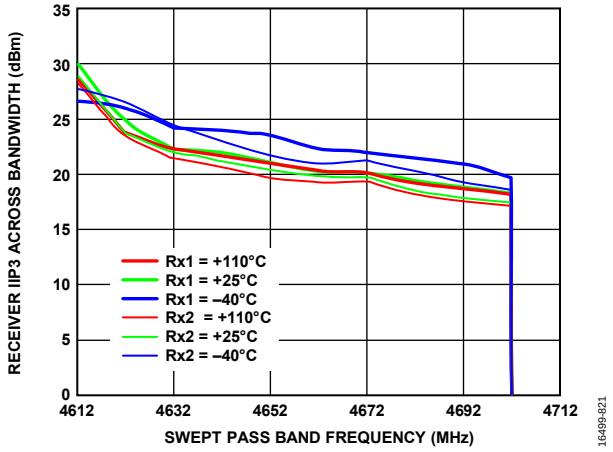

Figure 319. Receiver IIP3 Across Bandwidth vs. Swept Pass Band Frequency, Receiver Attenuation = 0 dB, LO = 4600 MHz, Tone 1 = 4602 MHz, Tone 2 Swept Across Pass Band, −21 dBm Each

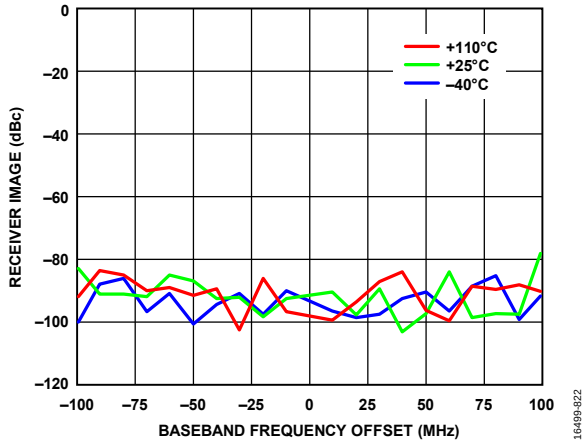

Figure 320. Receiver Image vs. Baseband Frequency Offset, Attenuation = 0 dB, RF Bandwidth = 200 MHz, Tracking Calibration Active, Sample Rate = 245.76 MSPS, LO = 3600 MHz

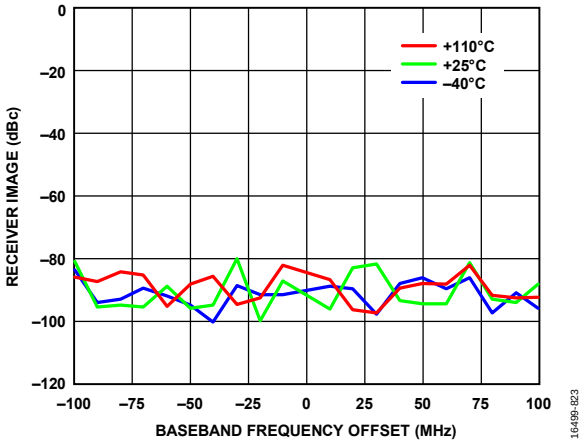

Figure 321. Receiver Image vs. Baseband Frequency Offset, Attenuation = 0 dB, RF Bandwidth = 200 MHz, Tracking Calibration Active, Sample Rate = 245.76 MSPS, LO = 4600 MHz

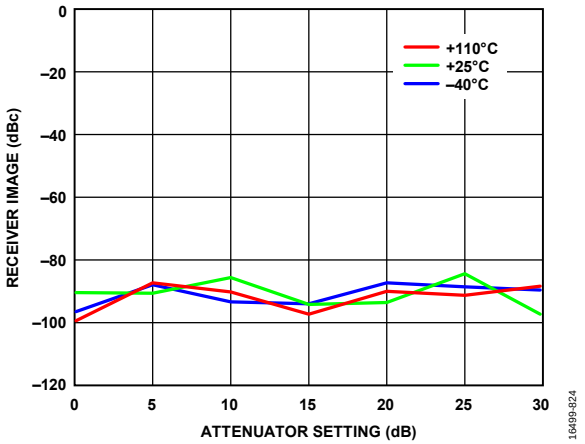

Figure 322. Receiver Image vs. Attenuator Setting, RF Bandwidth = 200 MHz, Tracking Calibration Active, Sample Rate = 245.76 MSPS, LO = 3600 MHz, Baseband Frequency= 10 MHz

Figure 320. Receiver Image vs. Baseband Frequency Offset, Attenuation = 0 dB, RF Bandwidth = 200 MHz, Tracking Calibration Active, Sample Rate = 245.76 MSPS, LO = 3600 MHz

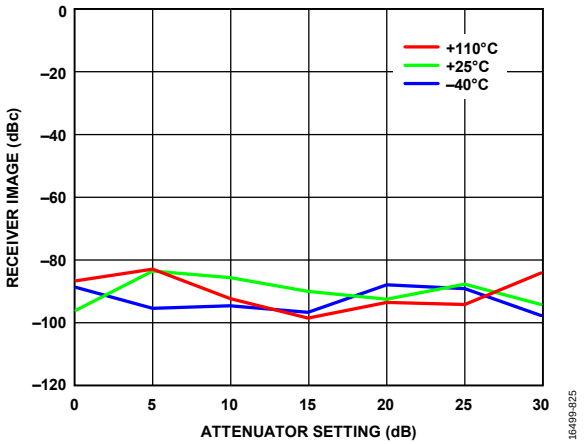

Figure 323. Receiver Image vs. Attenuator Setting, 200 MHz RF Bandwidth, Tracking Calibration Active, Sample Rate = 245.76 MSPS, LO = 4600 MHz, Baseband Frequency = 10 MHz

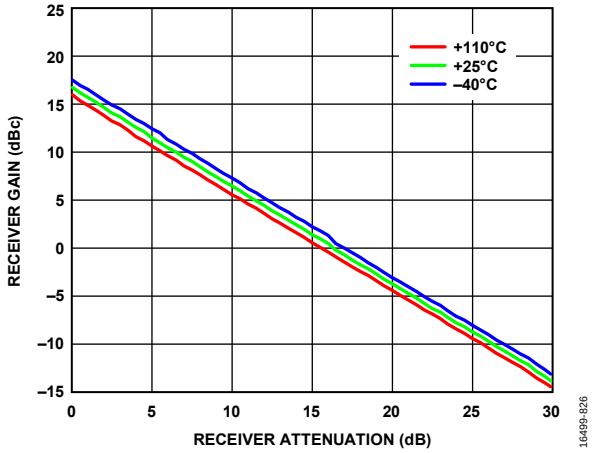

Figure 324. Receiver Gain vs. Receiver Attenuator Setting, RF Bandwidth = 20 MHz, Sample Rate = 245.76 MSPS, LO = 3600 MHz

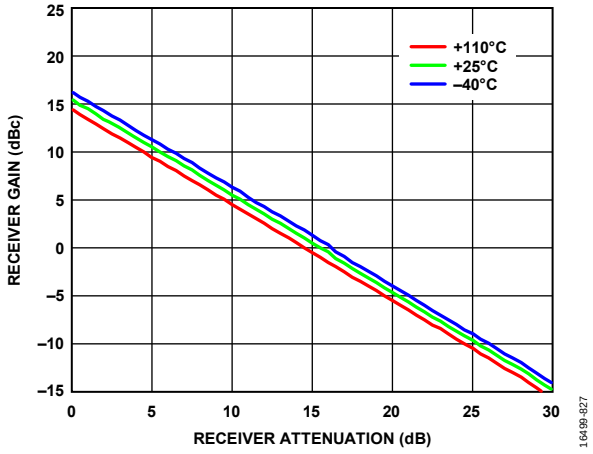

Figure 325. Receiver Gain vs. Receiver Attenuator Setting, RF Bandwidth = 20 MHz, Sample Rate = 245.76 MSPS, LO = 4600 MHz

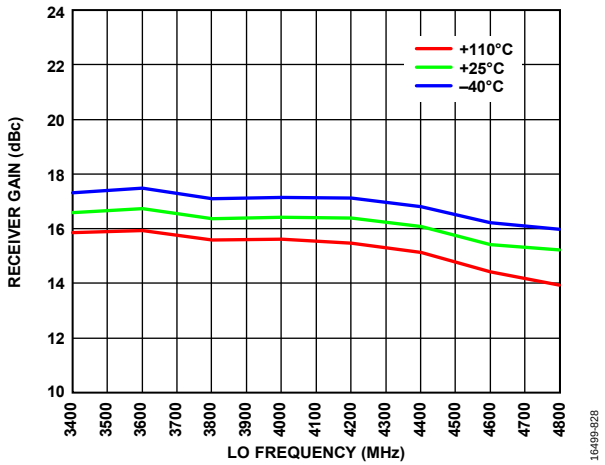

Figure 326. Receiver Gain vs. LO Frequency, RF Bandwidth = 200 MHz, Sample Rate = 245.76 MSPS

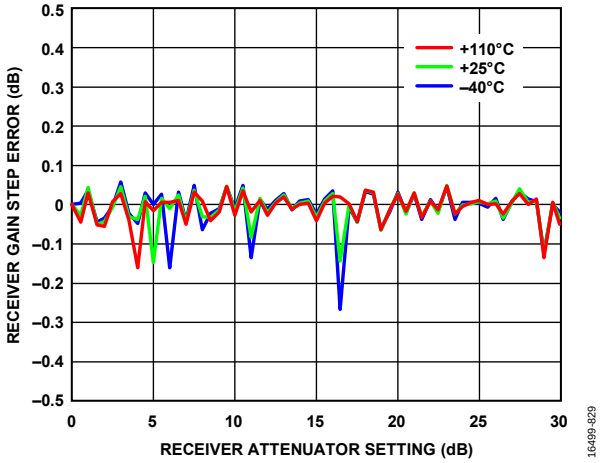

Figure 327. Receiver Attenuator Gain Step Error vs. Receiver Attenuator Setting, LO = 3600 MHz

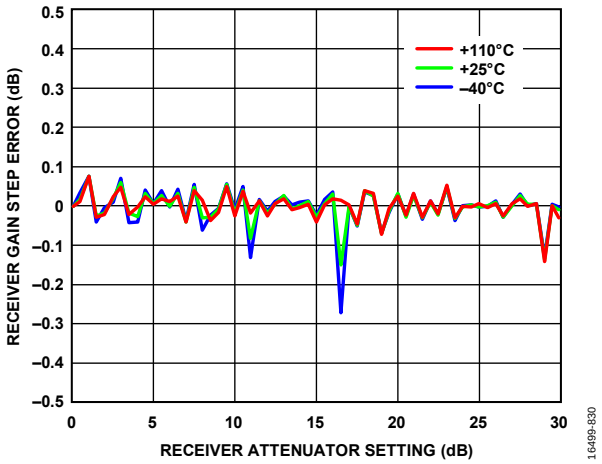

Figure 328. Receiver Attenuator Gain Step Error vs. Receiver Attenuator Setting, LO = 4600 MHz

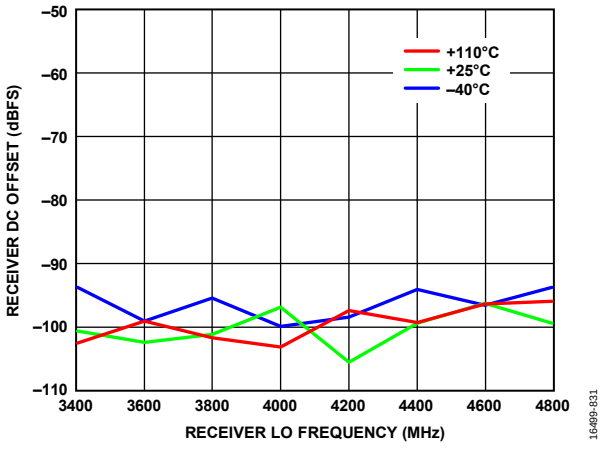

Figure 329. Receiver DC Offset vs. Receiver LO Frequency

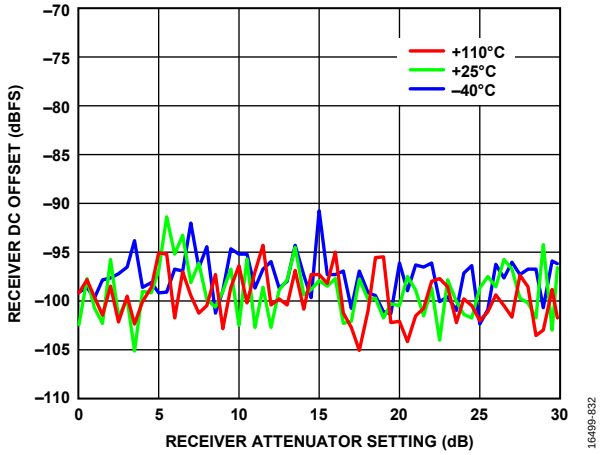

Figure 330. Receiver DC Offset vs. Receiver Attenuator Setting, LO = 3600 MHz

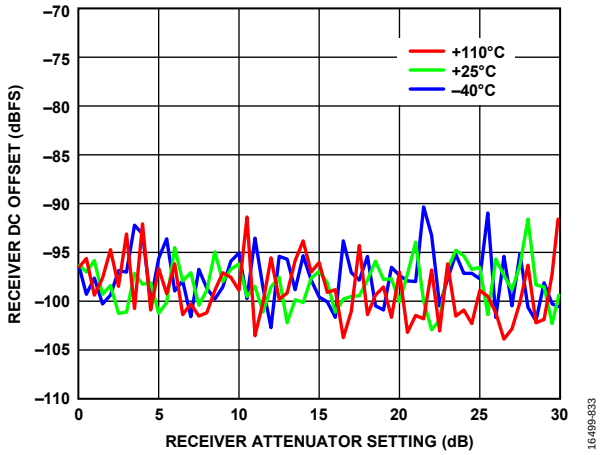

Figure 331. Receiver DC Offset vs. Receiver Attenuator Setting, LO = 4600 MHz

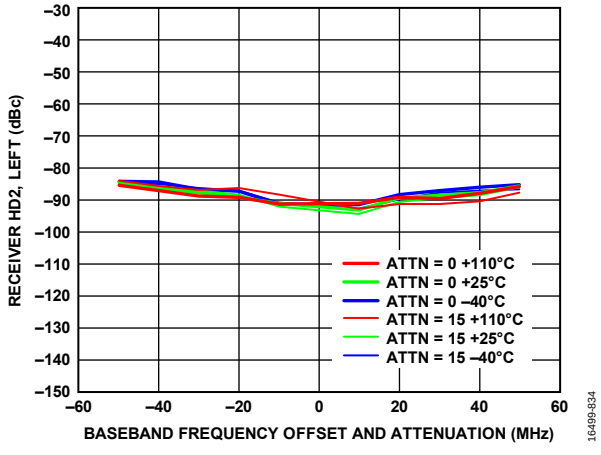

Figure 332. Receiver HD2, Left vs. Baseband Frequency Offset and Attenuation, Tone Level = −15 dBm at Attenuation = 0, X-Axis = Baseband Frequency Offset of the Fundamental Tone Not the Frequency of the HD2 Product (HD2 Product = 2× the Baseband Frequency), HD2 Canceller Disabled, LO = 3600 MHz

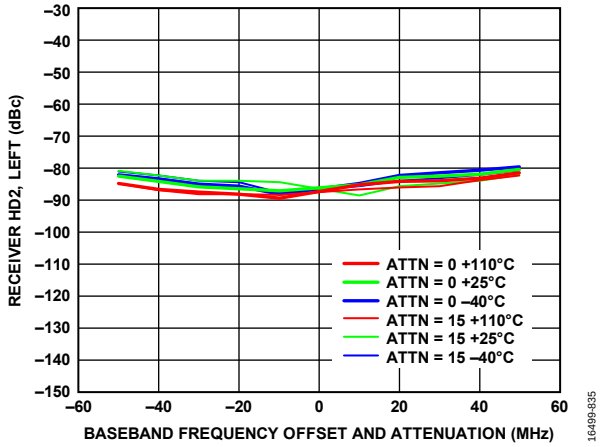

Figure 333. Receiver HD2, Left vs. Baseband Frequency Offset and Attenuation, Tone Level = −15 dBm at Attenuation = 0, X-Axis = Baseband Frequency Offset of the Fundamental Tone Not the Frequency of the HD2 Product (HD2 Product = 2× the Baseband Frequency), HD2 Canceller Disabled, LO = 4600 MHz

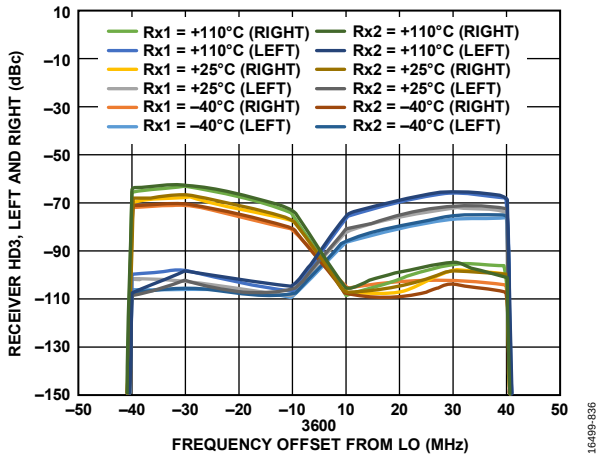

Figure 334. Receiver HD3, Left and Right vs. Frequency Offset from LO and Attenuation, Tone Level = −15 dBm at Attenuation = 0 dB, LO = 3600 MHz

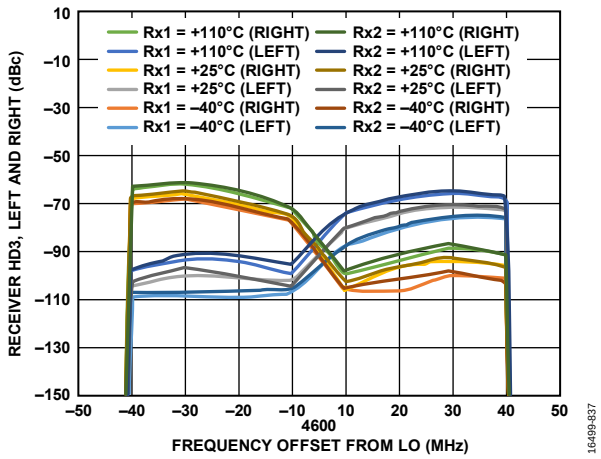

Figure 335. Receiver HD3, Left and Right vs. Frequency Offset from LO and Attenuation, Tone Level = −15 dBm at Attenuation = 0 dB, LO = 4600 MHz

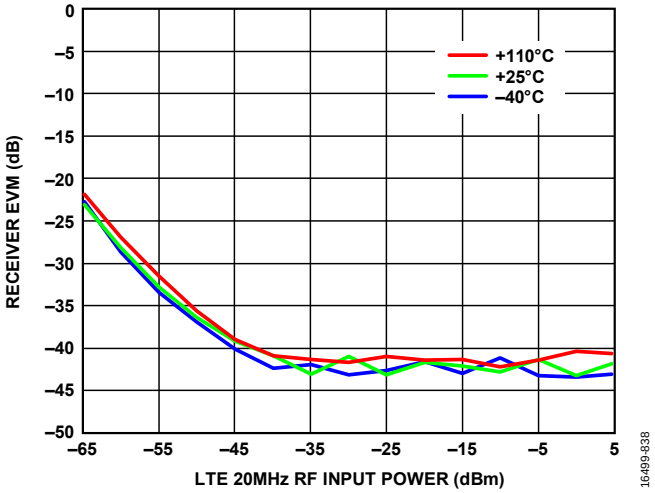

Figure 336. Receiver EVM vs. LTE 20 MHz RF Input Power, RF Signal = LTE 20 MHz, LO = 3600 MHz, Default AGC Settings

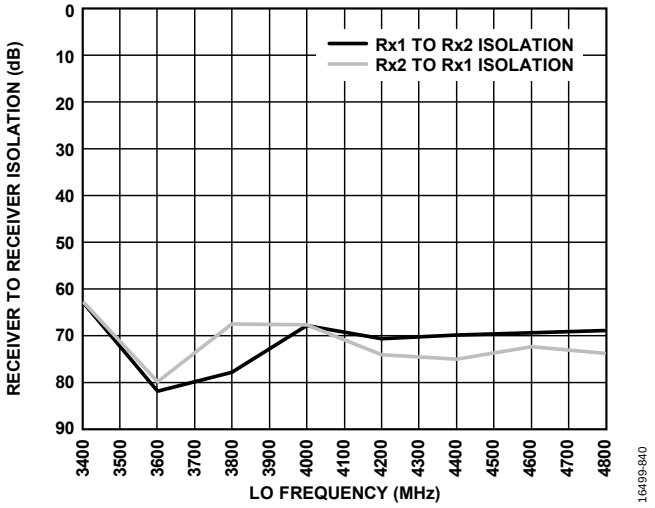

Figure 337. Receiver to Receiver Isolation vs. LO Frequency

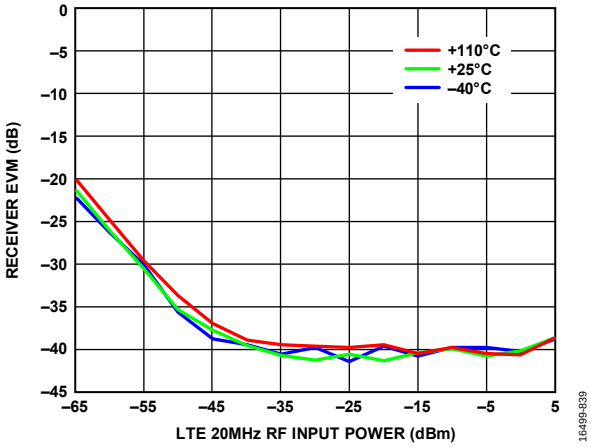

Figure 338. Receiver EVM vs. LTE 20 MHz RF Input Power, RF Signal = LTE 20 MHz, LO = 4600 MHz, Default AGC Settings

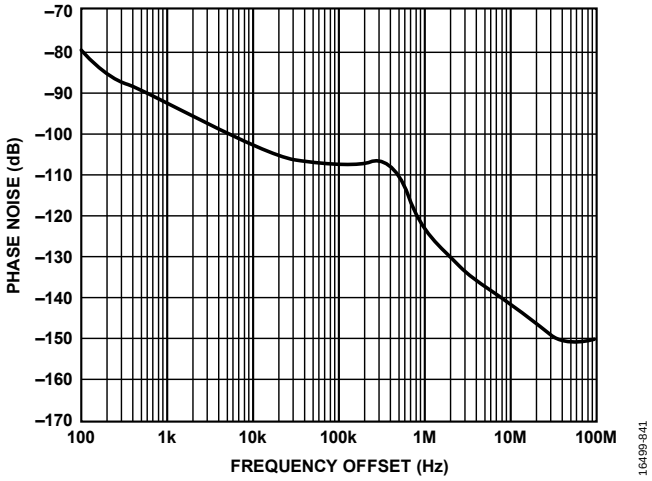

Figure 339. LO Phase Noise vs. Frequency Offset, LO = 3800 MHz, RMS Phase Error Integrated from 2 kHz to 18 MHz, PLL Loop Bandwidth = 300 kHz, Spectrum Analyzer Limits Far Out Noise

5100 MHz TO 5900 MHz BAND

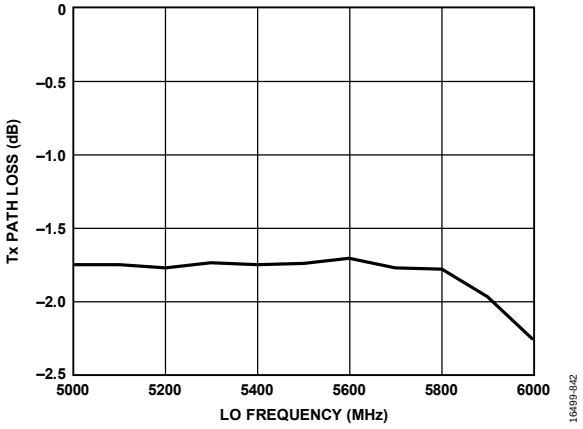

Figure 340. Transmitter Path Loss vs. LO Frequency (Simulation), Useful for Deembedding Performance Data

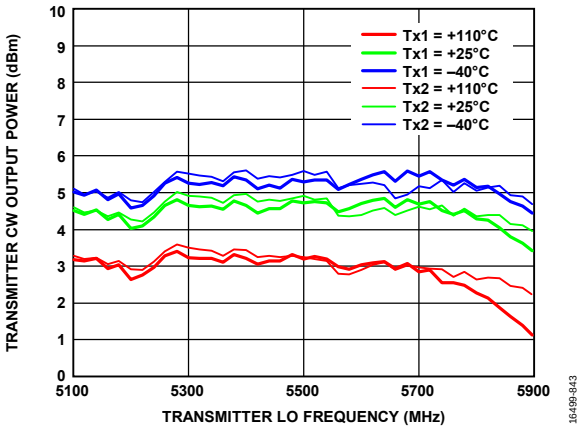

Figure 341. Transmitter Continuous Wave Output Power vs. Transmitter LO Frequency, Transmitter QEC, and External LO Leakage Active, Bandwidth Mode = 200 MHz/450 MHz, IQ Rate = 491.52 MHz, Attenuation = 0 dB, Not Deembedded

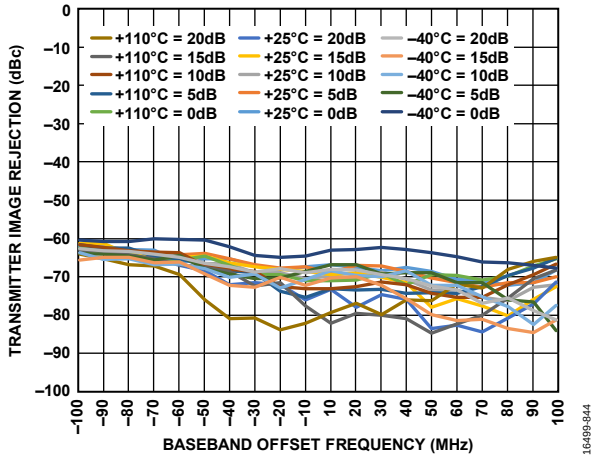

Figure 342. Transmitter Image Rejection Across Large Signal Bandwidth vs. Baseband Offset Frequency QEC Trained with Three Tones Placed at 10 MHz, 50 MHz, and 100 MHz (Tracking On), Total Combined Power = –6 dBFS, Correction Then Frozen (Tracking Turned Off), Continuous Wave Tone Swept Across Large Signal Bandwidth, LO = 5100 MHz

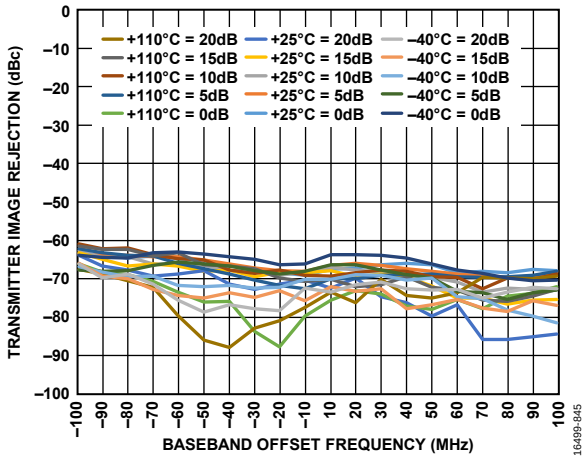

Figure 343. Transmitter Image Rejection Across Large Signal Bandwidth vs. Baseband Offset Frequency, QEC Trained with Three Tones Placed at 10 MHz, 50 MHz, and 100 MHz (Tracking On), Total Combined Power = –6 dBFS, Correction Then Frozen (Tracking Turned Off), Continuous Wave Tone Swept Across Large Signal Bandwidth, 5500 MHz

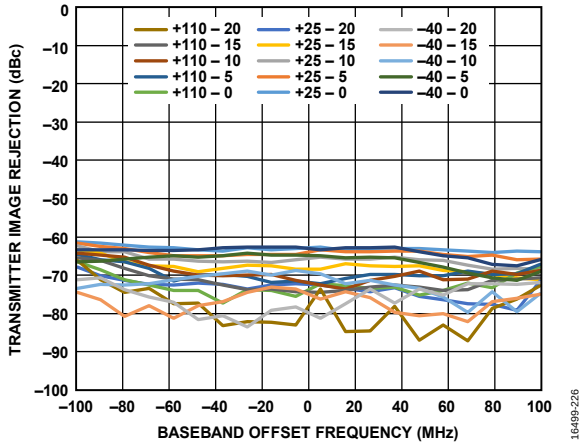

Figure 344. Transmitter Image Rejection Across Large Signal Bandwidth vs. Baseband Offset Frequency, QEC Trained with Three Tones Placed at 10 MHz, 50 MHz, and 100 MHz (Tracking On), Total Combined Power = –6 dBFS, Correction Then Frozen (Tracking Turned Off), Continuous Wave Tone Swept Across Large Signal Bandwidth, LO = 5900 MHz

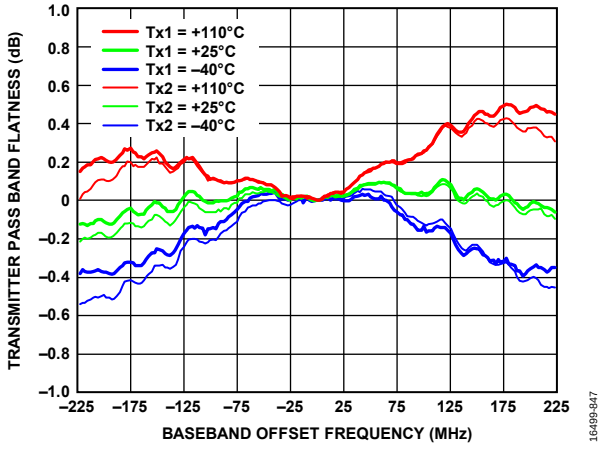

Figure 345. Transmitter Pass Band Flatness vs. Baseband Offset Frequency, Off Chip Match Response Deembedded, LO = 5700 MHz, Measurements Performed with Device Calibrated at 25°C

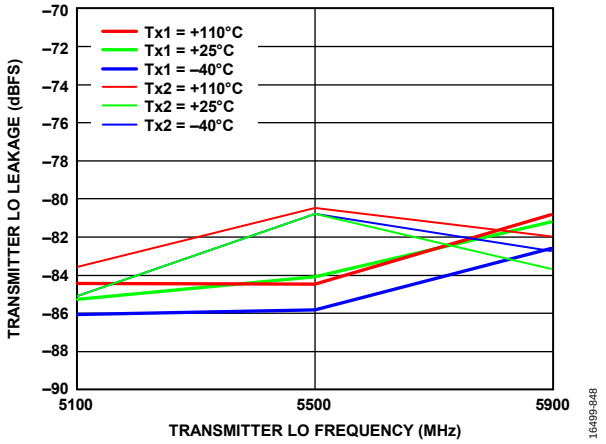

Figure 346. Transmitter LO Leakage vs. Transmitter LO Frequency, Transmitter Attenuation = 0 dB

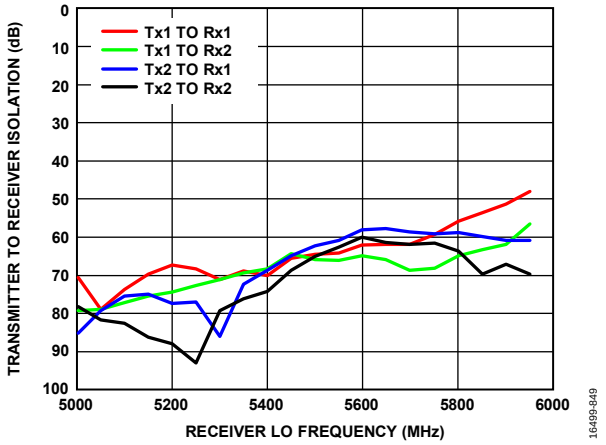

Figure 347. Transmitter to Receiver Isolation vs. Receiver LO Frequency, Temperature = 25°C

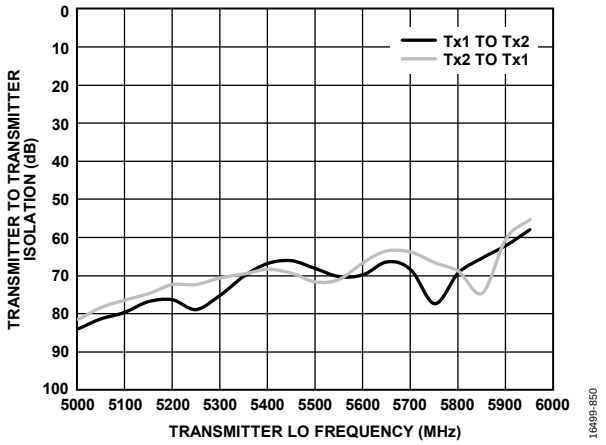

Figure 348. Transmitter to Transmitter Isolation vs. Transmitter LO Frequency; Temperature = 25°C

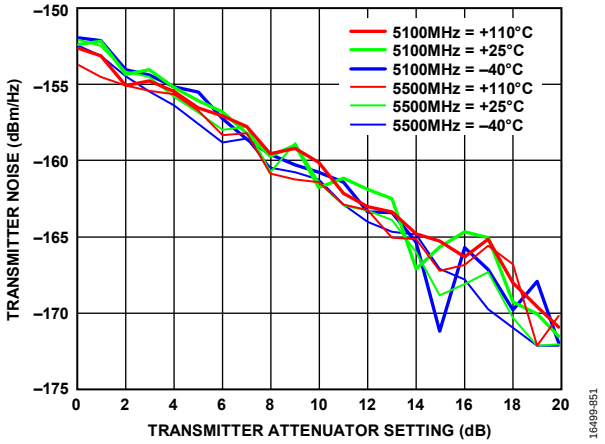

Figure 349. Transmitter Noise vs. Transmitter Attenuator Setting

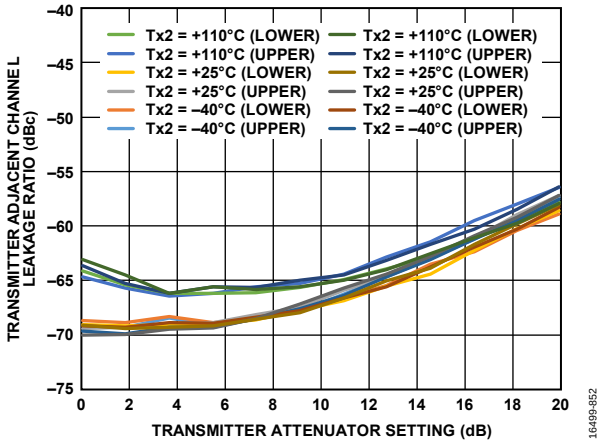

Figure 350. Transmitter Adjacent Channel Leakage Ratio (ACLR) vs. Transmitter Attenuator Setting, LO = 5100 MHz, LTE 20 MHz PAR = 12 dB, DAC Boost Normal, Upper Side and Lower Side, Decreasing ACLR at Higher Attenuation due to Spectrum Analyzer Noise Floor

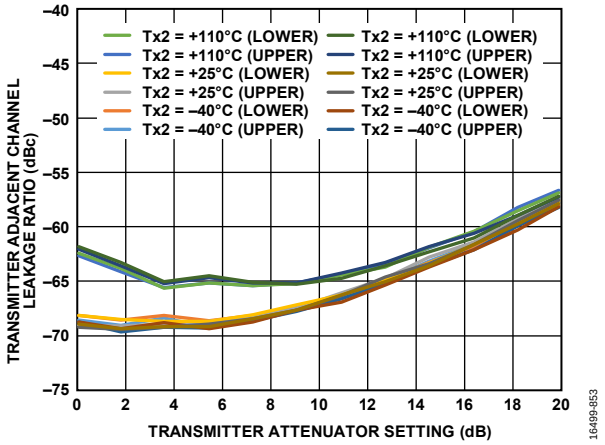

Figure 351. Transmitter Adjacent Channel Leakage Ratio (ACLR) vs. Transmitter Attenuator Setting, LO = 5500 MHz, LTE 20 MHz PAR = 12 dB, DAC Boost Normal, Upper Side and Lower Side, Decreasing ACLR at Higher Attenuation due to Spectrum Analyzer Noise Floor

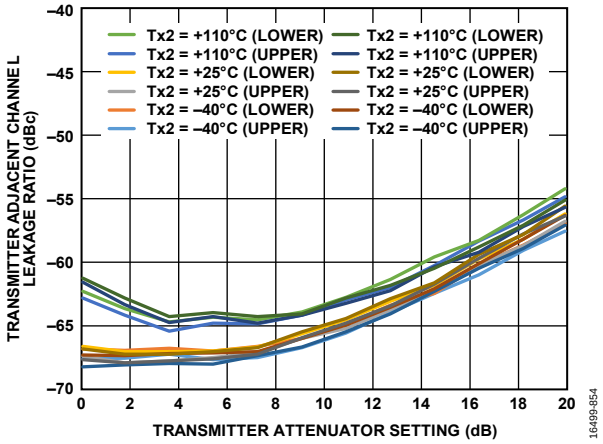

Figure 352. Transmitter Adjacent Channel Leakage Ratio vs. Transmitter Attenuator Setting, LO = 5900 MHz, LTE 20 MHz PAR = 12 dB, DAC Boost Normal, Upper Side and Lower Side, Decreasing ACLR at Higher Attenuation Due to Spectrum Analyzer Noise Floor

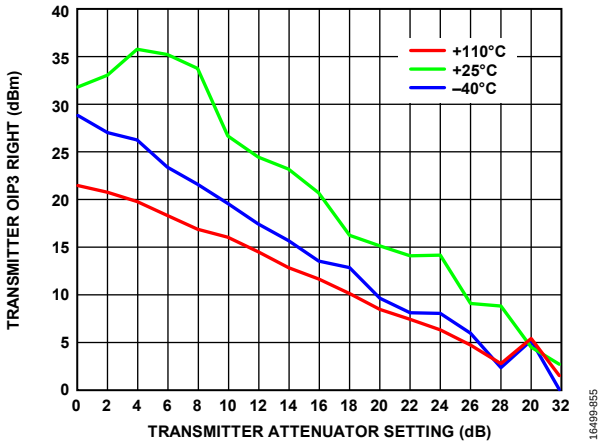

Figure 353. Transmitter OIP3 Right vs. Transmitter Attenuator Setting, LO = 5100 MHz, Total RMS Power = −12 dBFS

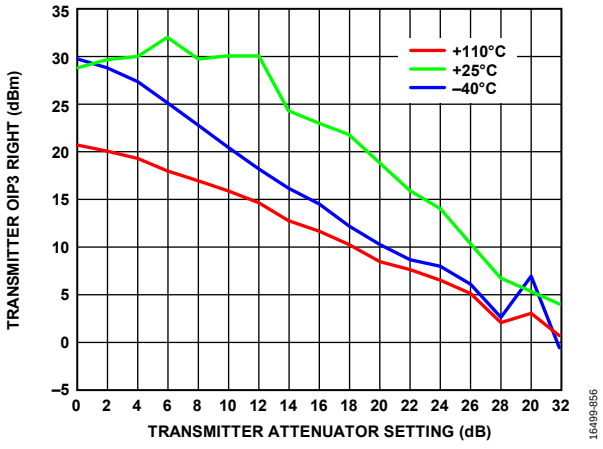

Figure 354. Transmitter OIP3 Right vs. Transmitter Attenuator Setting, LO = 5500 MHz, Total RMS Power = −12 dBFS

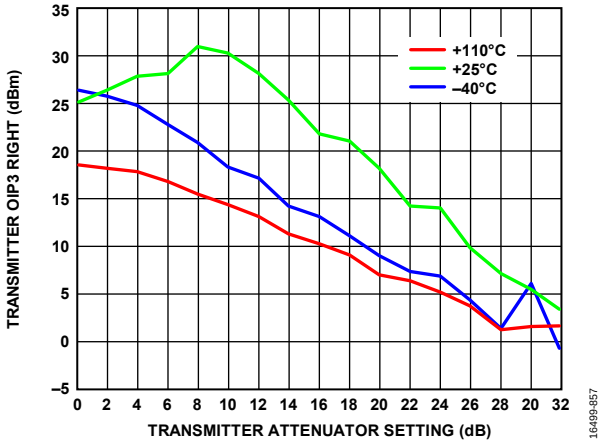

Figure 355. Transmitter OIP3, Right vs. Transmitter Attenuator Setting, LO = 5800 MHz, Total RMS Power = −12 dBFS

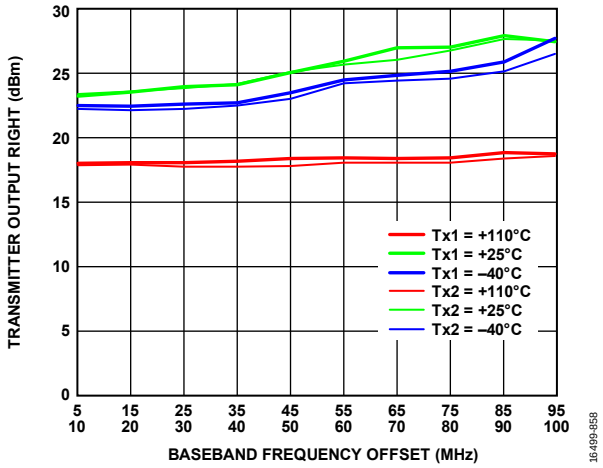

Figure 356. Transmitter OIP3 Right vs. Baseband Frequency Offset, LO = 5100 MHz, Total RMS Power = −12 dBFS Power, Transmitter Attenuation = 4 dB

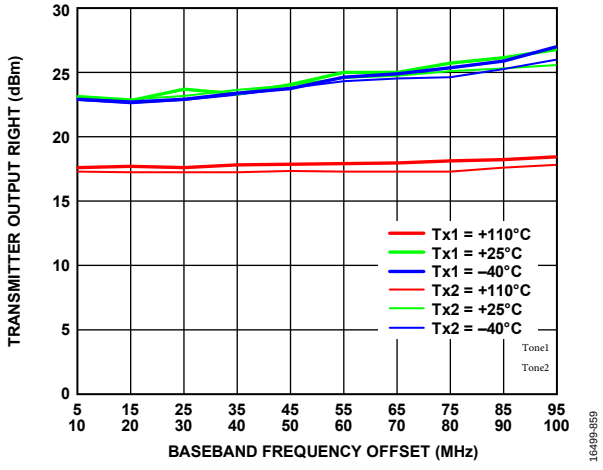

Figure 357. Transmitter OIP3 vs. Baseband Frequency Offset, LO = 5500 MHz, Total RMS Power = −12 dBFS, Transmitter Attenuation = 4 dB

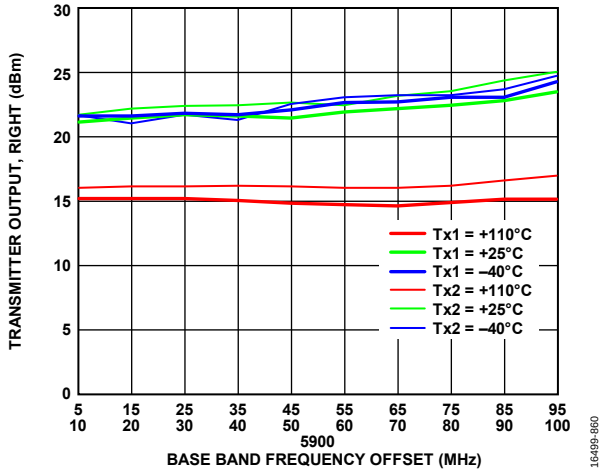

Figure 358. Transmitter Output, Right vs. Baseband Frequency Offset, LO = 5900 MHz, Total RMS Power = −12 dBFS, Transmitter Attenuation = 4 dB

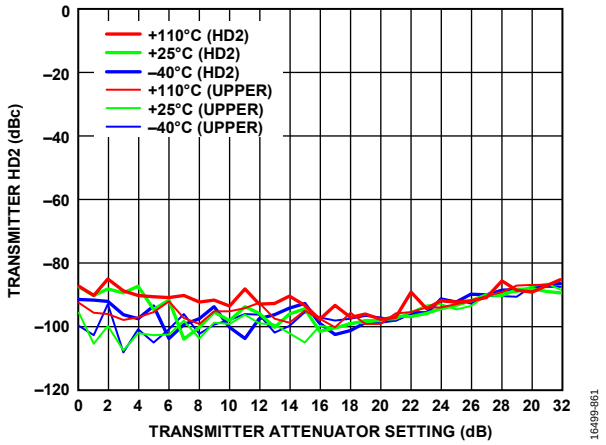

Figure 359. Transmitter HD2 vs. Transmitter Attenuation Setting, Baseband Frequency = 10 MHz, LO = 5100 MHz, Continuous Wave = −15 dBFS

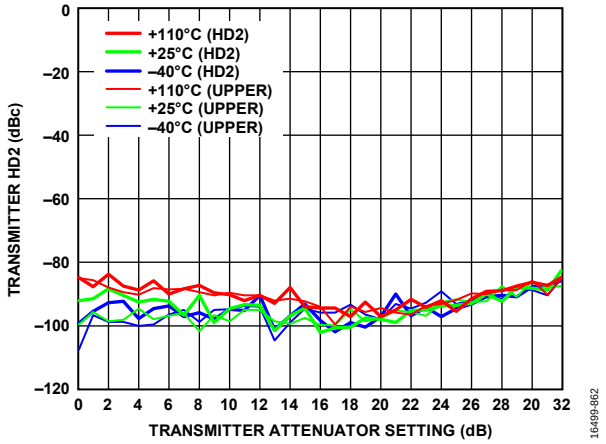

Figure 360. Transmitter HD2 vs. Transmitter Attenuator Setting, Baseband Frequency = 10 MHz, LO = 5500 MHz, Continuous Wave = −15 dBFS

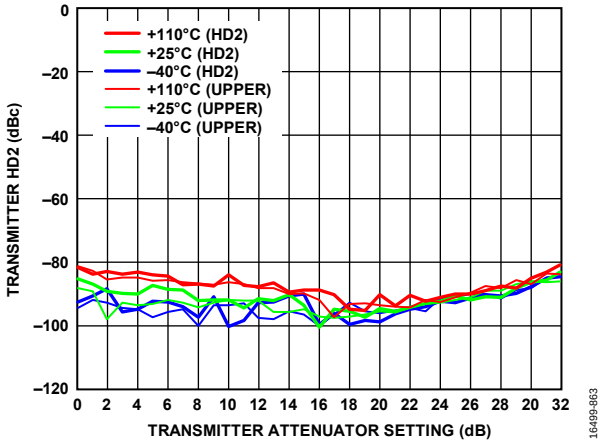

Figure 361. Transmitter HD2 vs. Transmitter Attenuator Setting, Baseband Frequency = 10 MHz, LO = 5900 MHz, Continuous Wave = −15 dBFS

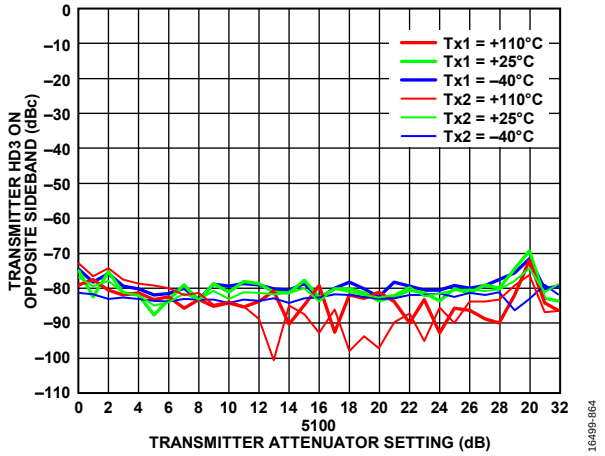

Figure 362. Transmitter HD3 on Opposite Sideband vs. Transmitter Attenuator Setting, LO = 5100 MHz, Continuous Wave = −15 dBFS, Baseband Frequency = 10 MHz

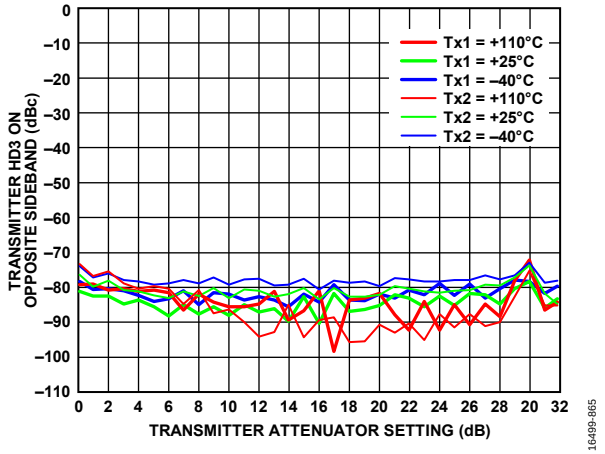

Figure 363. Transmitter HD3 on Opposite Sideband vs. Transmitter Attenuator Setting, LO = 5500 MHz, Continuous Wave = −15 dBFS, Baseband Frequency = 10 MHz

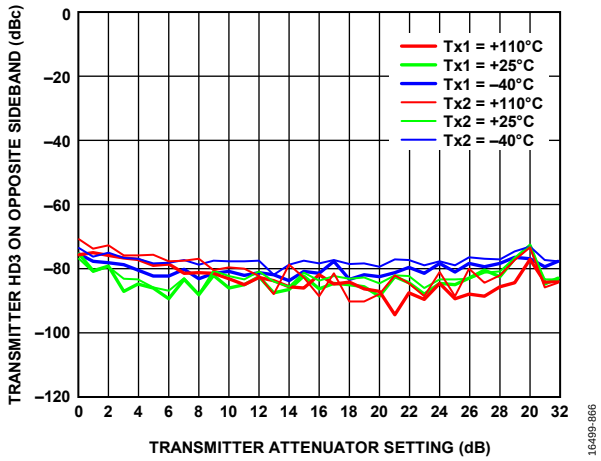

Figure 364. Transmitter HD3 on Opposite Sideband vs. Transmitter Attenuator Setting, LO = 5900 MHz, Continuous Wave = −15 dBFS, Baseband Frequency = 10 MHz

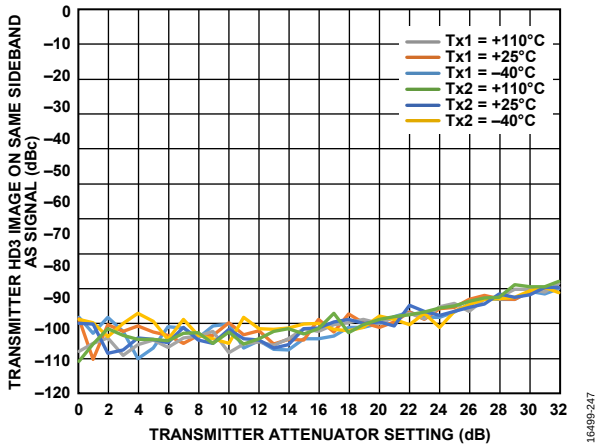

Figure 365. Transmitter HD3 on Same Sideband as Signal vs. Transmitter Attenuator Setting, LO = 5100 MHz, Continuous Wave = −15 dBFS

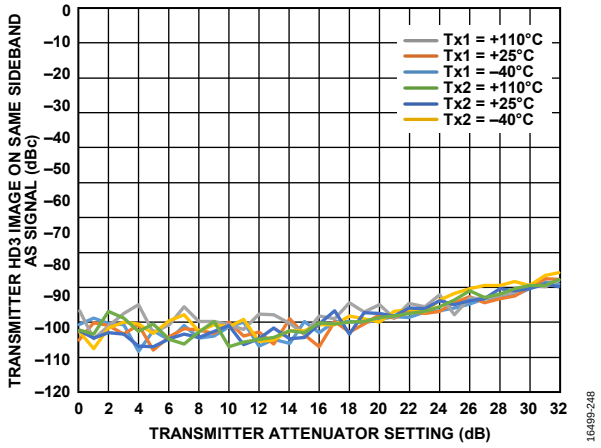

Figure 366. Transmitter HD3 on Same Sideband as Signal vs. Transmitter Attenuator Setting, LO = 5500 MHz, Continuous Wave = −15 dBFS

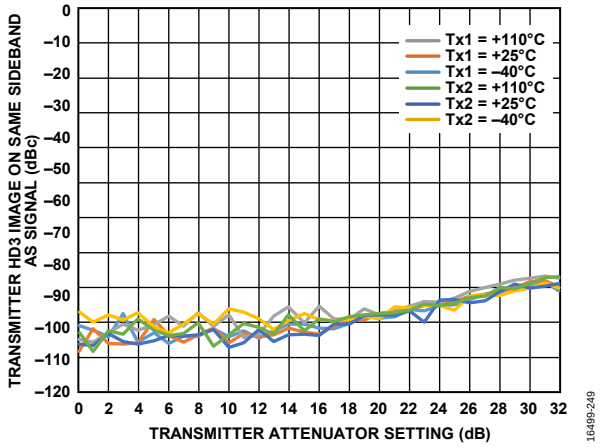

Figure 367. Transmitter HD3 on Same Sideband as Signal vs. Transmitter Attenuator Setting, LO = 5900 MHz, Continuous Wave = −15 dBFS

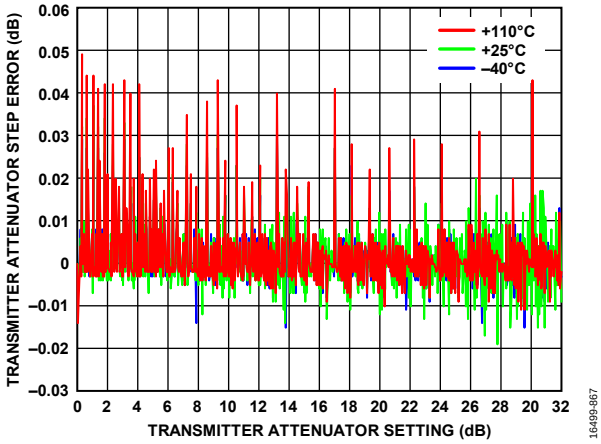

Figure 368. Transmitter Attenuation Step Error vs. Transmitter Attenuator Setting, LO = 5100 MHz

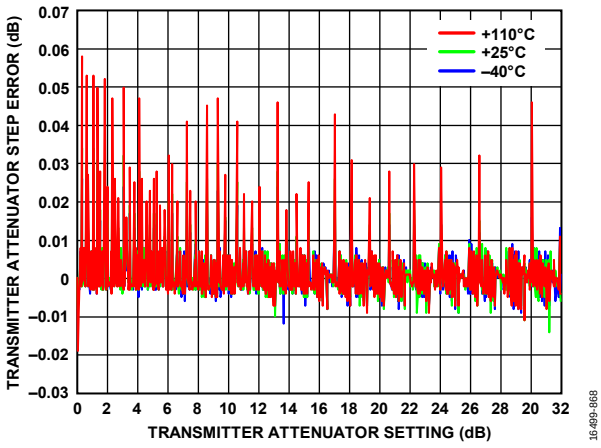

Figure 369. Transmitter Attenuation Step Error vs. Transmitter Attenuator Setting, LO = 5500 MHz

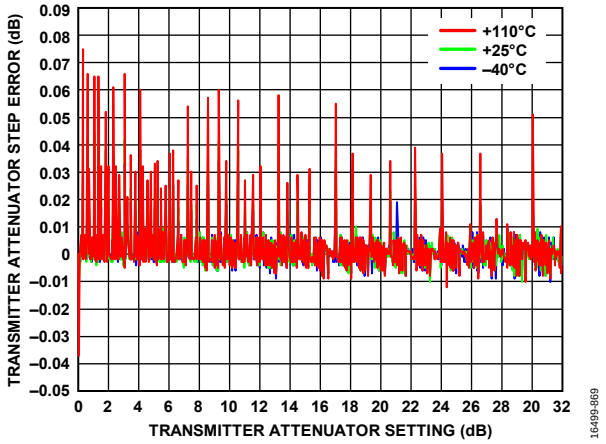

Figure 370. Transmitter Attenuator Step Error vs. Transmitter Attenuator Setting, LO = 5900 MHz

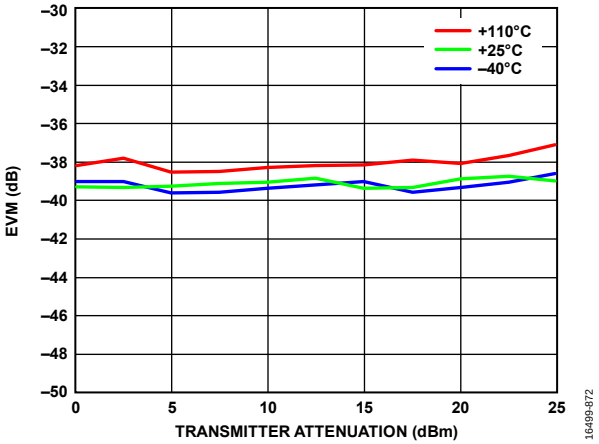

Figure 373. Transmitter EVM vs. Transmitter Attenuation, LTE Signal = 20 MHz, Centered on DC, LO = 5900 MHz

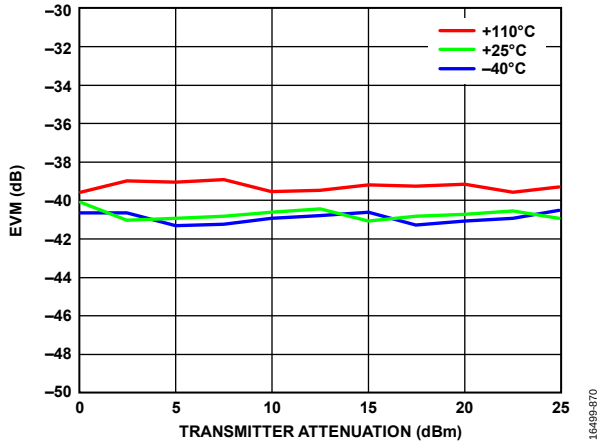

Figure 371. Transmitter EVM vs. Transmitter Attenuation, LTE Signal = 20 MHz Centered on DC, LO = 5100 MHz

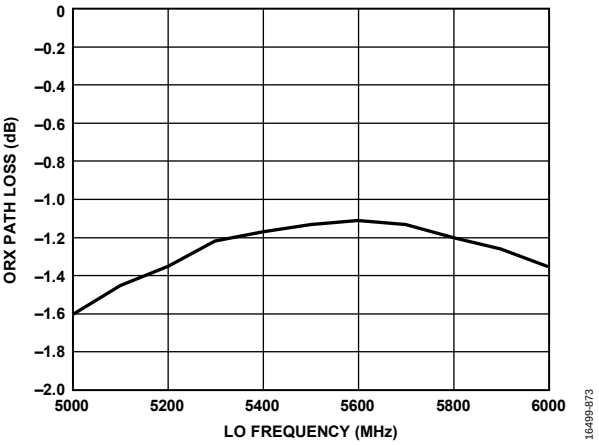

Figure 374. Observation Receiver Path Loss vs. LO Frequency (Simulation), Can Be Used for Deembedding Performance Data

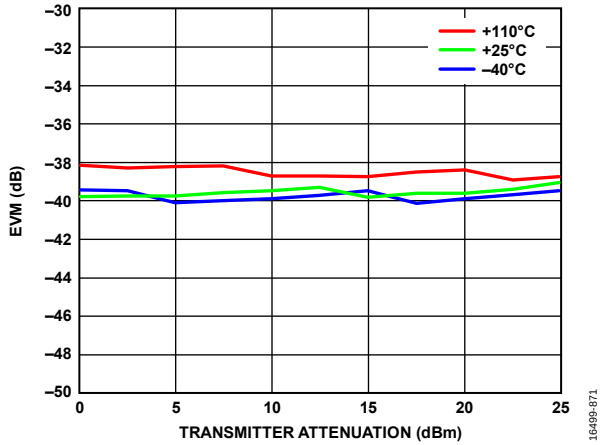

Figure 372. Transmitter EVM vs. Transmitter Attenuation, LTE Signal = 20 MHz, Centered on DC, LO = 5500 MHz

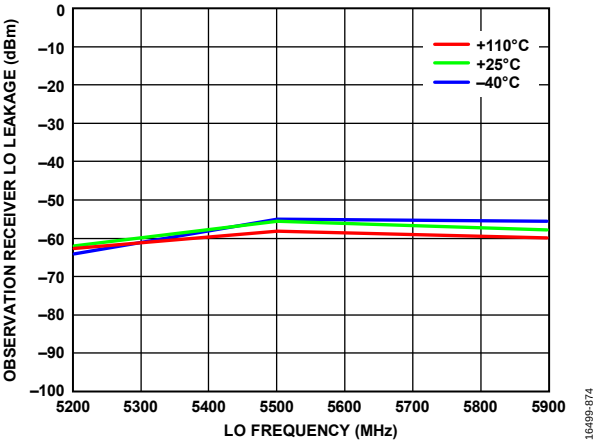

Figure 375. Observation Receiver LO Leakage vs. LO Frequency, 5200 MHz, 5500 MHz, and 5900 MHz

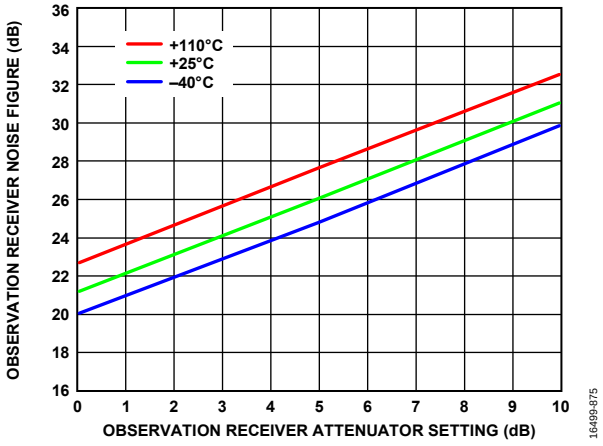

Figure 376. Observation Receiver Noise Figure vs. Observation Receiver Attenuator Setting, 5200 MHz, Total Nyquist Integration Bandwidth

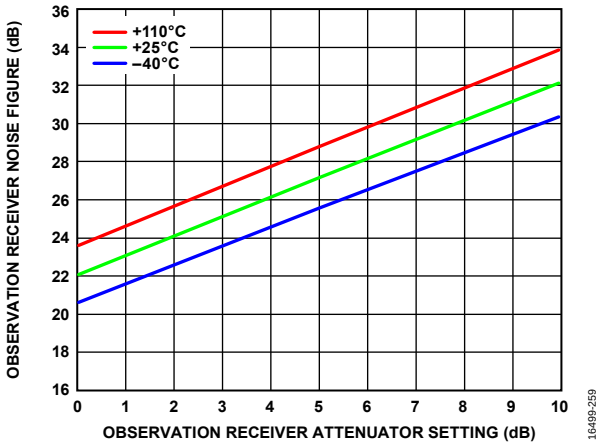

Figure 377. Observation Receiver Noise Figure vs. Observation Receiver Attenuator Setting, 5500 MHz, Total Nyquist Integration Bandwidth

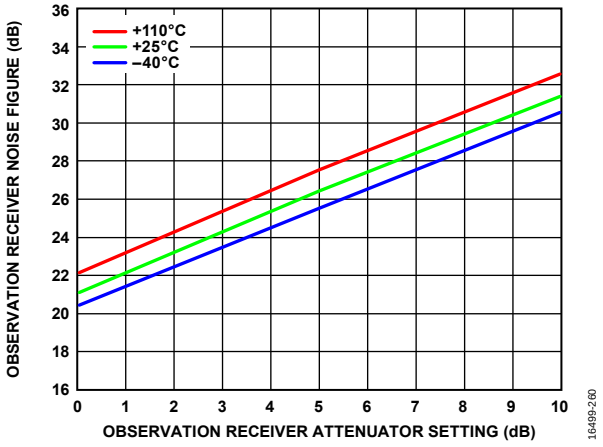

Figure 378. Observation Receiver Noise Figure vs. Observation Receiver Attenuator Setting, 5800 MHz, Total Nyquist Integration Bandwidth

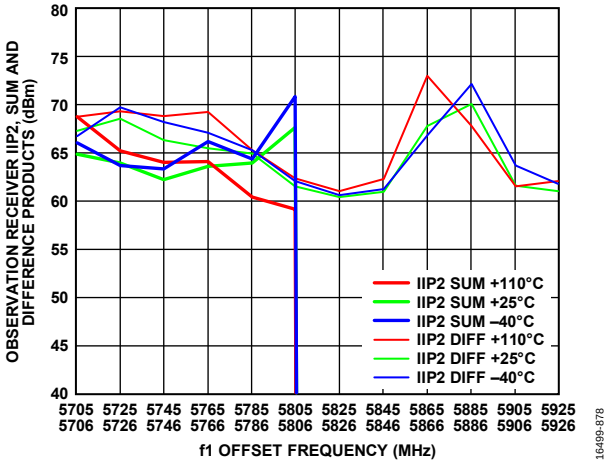

Figure 379. Observation Receiver IIP2, Sum and Difference Products vs. f1 Offset Frequency, Tones Separated by 1 MHz Swept Across Pass Band at –19 dBm Each, 5700 MHz, Attenuation = 0 dB

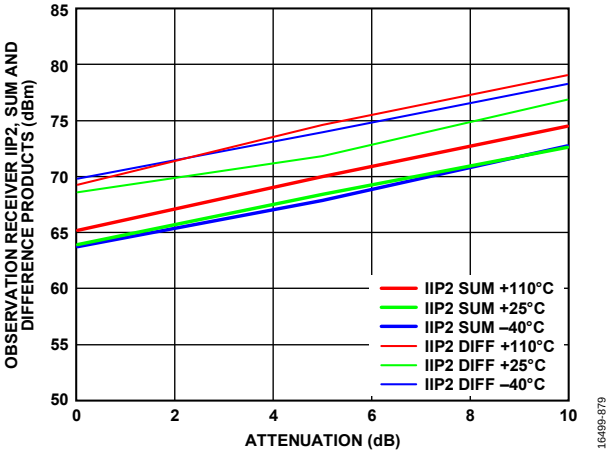

Figure 380. Observation Receiver IIP2, Sum and Difference Products vs. Attenuation, LO = 5700 MHz, Tone 1 = 5725 MHz, Tone 2 = 5726 MHz at –19 dBm Plus Attenuation

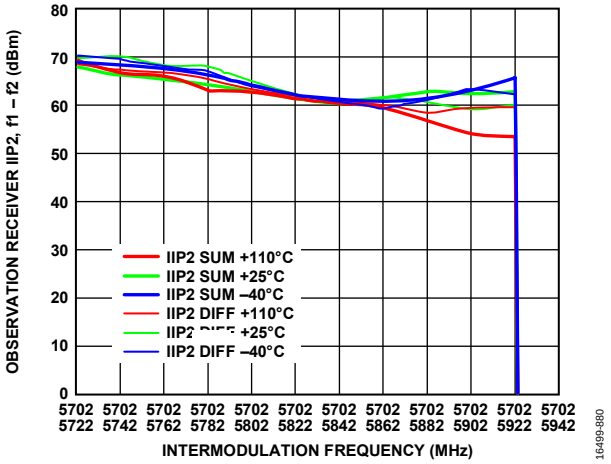

Figure 381. Observation Receiver IIP2, f1 – f2 vs. Intermodulation Frequency, LO = 5700 MHz, Tone 1 = 5702 MHz, Tone 2 Swept, –19 dBm Each, Attenuation = 0 dB

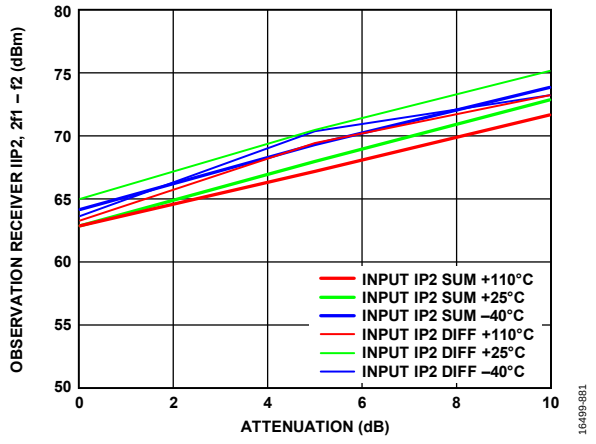

Figure 382. Observation Receiver IIP2, f1 –f2 vs. Attenuation, LO = 5700 MHz, Tone 1 = 5702 MHz, Tone 2 = 5802 MHz at –19 dBm Plus Attenuation

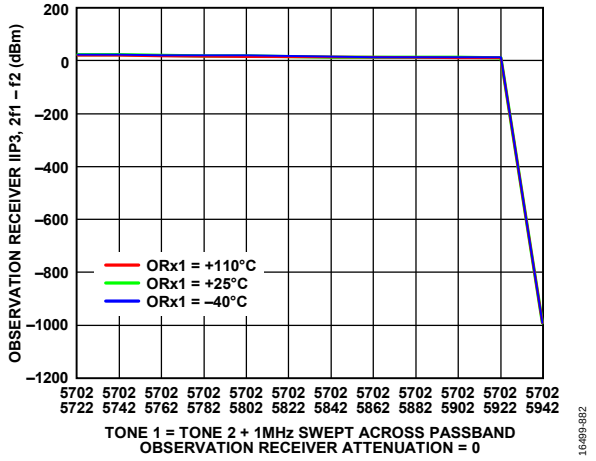

Figure 383. Observation Receiver IIP3, 2f1 – f2 vs. f1 Offset Frequency, LO = 5700 MHz, 0 dB Attenuation, Tones Separated by 1 MHz Swept Across Pass Band at –19 dBm Each

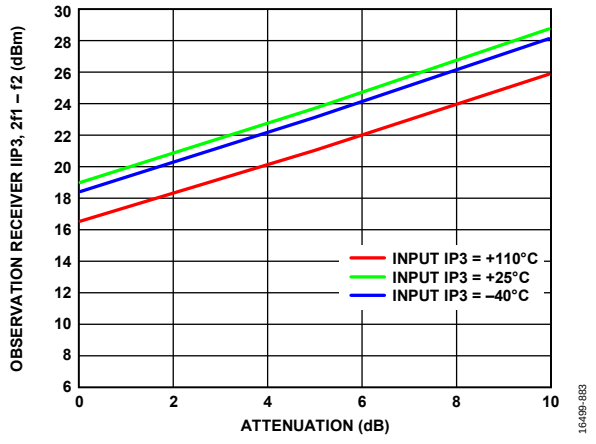

Figure 384. Observation Receiver IIP3, 2f1 – f2 vs. Attenuation, LO = 5700 MHz, Tone 1 = 5745 MHz, Tone 2 = 5746 MHz at –19 dBm Plus Attenuation

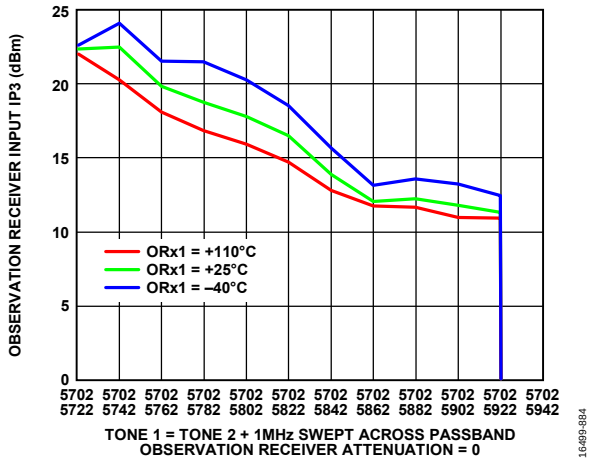

Figure 385. Observation Receiver IIP3, 2f1 – f2 vs. Attenuation, LO = 5700 MHz, Tone 1 = 5702 MHz, Tone 2 = 5722 MHz at –22 dBm Plus Attenuation Each

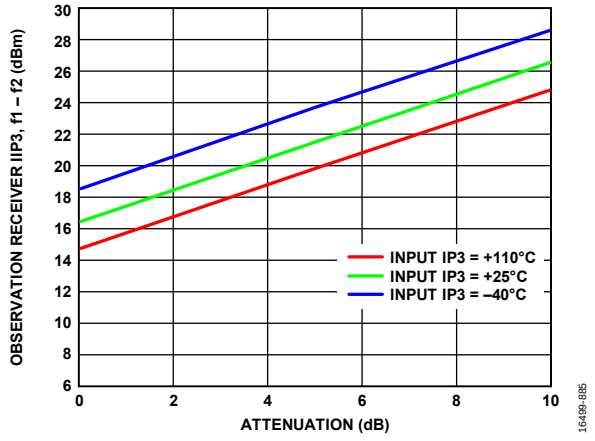

Figure 386. Observation Receiver IIP3, 2f1 – f2 vs. Attenuation, LO = 5700 MHz, Tone 1 = 5702 MHz, Tone 2 = 5822 MHz at –19 dBm Plus Attenuation

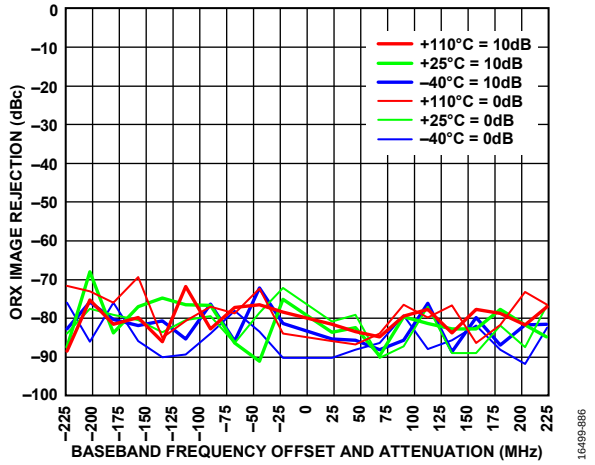

Figure 387. Observation Receiver Image Rejection vs. Observation Receiver Attenuation, Continuous Wave Signal Swept Across the Band, LO = 5200 MHz

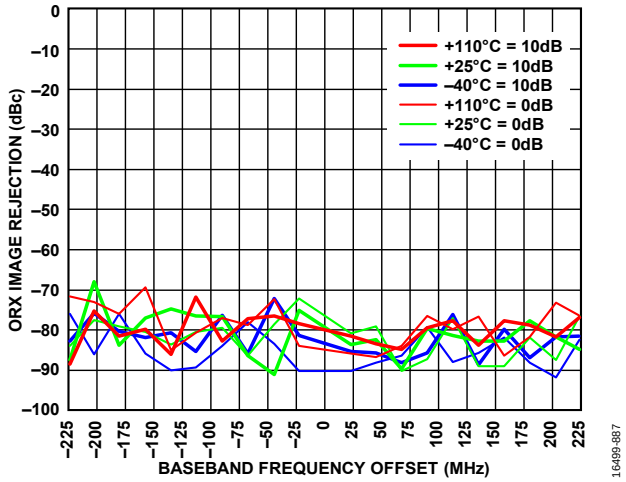

Figure 388. Observation Receiver Image Rejection vs. Baseband Frequency Offset and Observation Receiver Attenuation, Continuous Wave Signal Swept Across the Band, LO = 5700 MHz

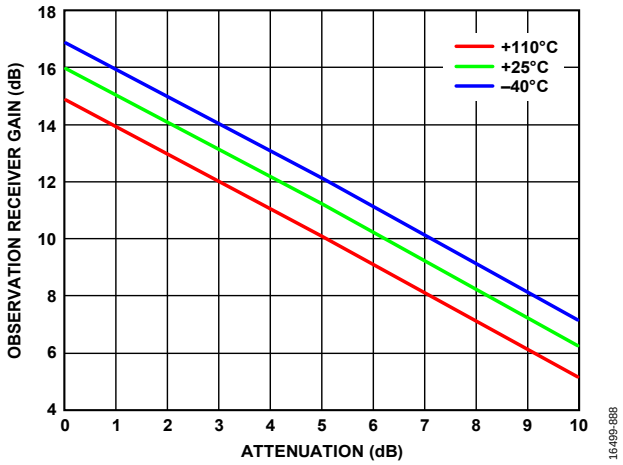

Figure 389. Observation Receiver Gain vs. Attenuation, LO = 5200 MHz

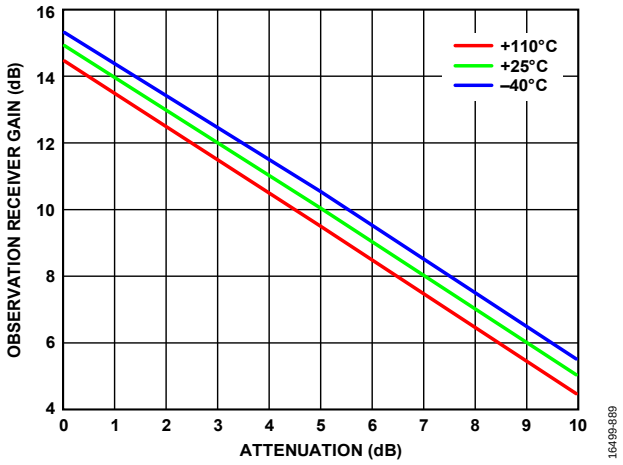

Figure 390. Observation Receiver Gain vs. Attenuation, LO = 5700 MHz

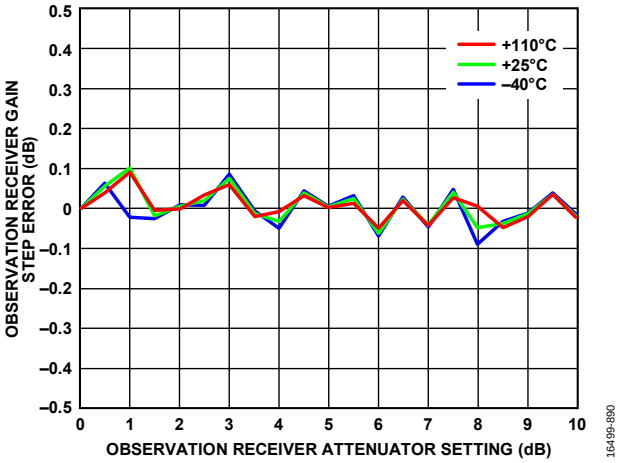

Figure 391. Observation Receiver Gain Step Error vs. Observation Receiver Attenuator Setting, LO = 5200 MHz

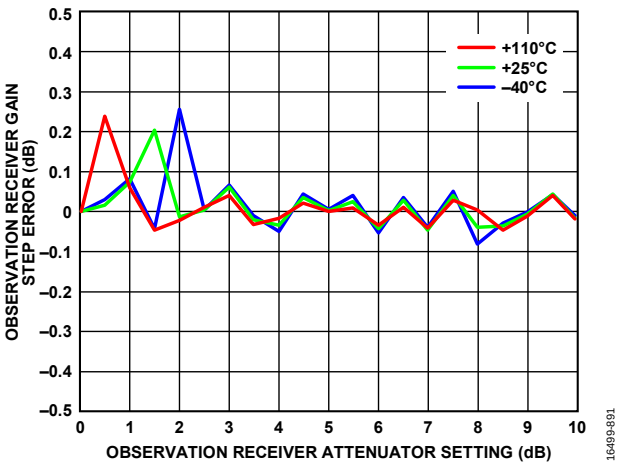

Figure 392. Observation Receiver Gain Step Error vs. Observation Receiver Attenuator Setting, LO = 5600 MHz

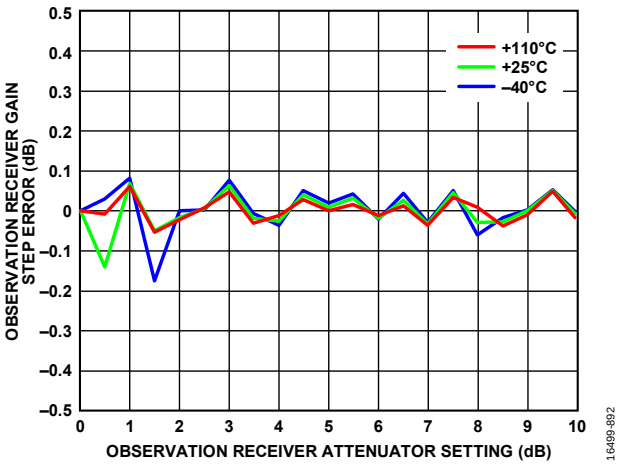

Figure 393. Observation Receiver Gain Step Error vs. Observation Receiver Attenuator Setting, LO = 5600 MHz

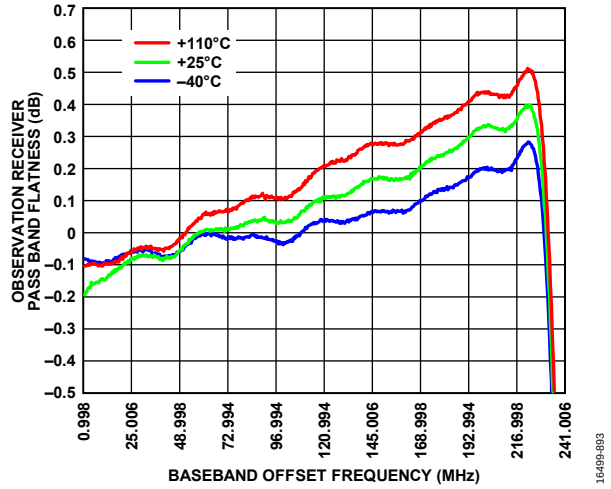

Figure 394. Observation Receiver Pass Band Flatness vs. Baseband Offset Frequency, LO = 5700 MHz

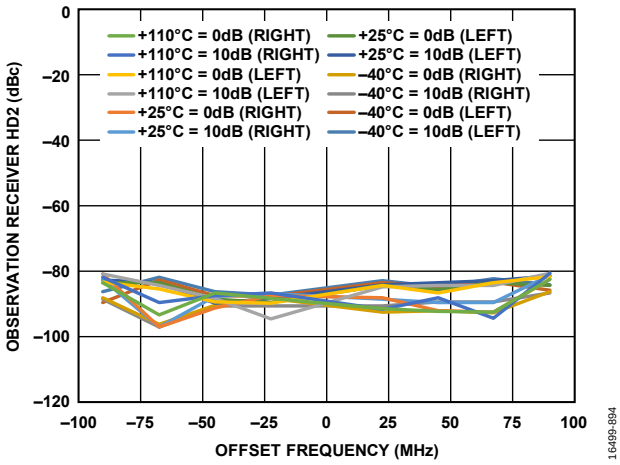

Figure 395. Observation Receiver HD2 vs. Offset Frequency, LO = 5200 MHz, Tone Level = –20 dBm Plus Attenuation

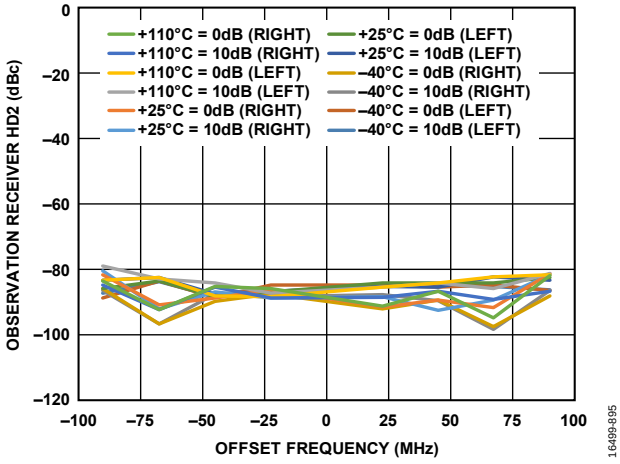

Figure 396. Observation Receiver HD2 vs. Offset Frequency, LO = 5700 MHz, Tone Level = –20 dBm Plus Attenuation

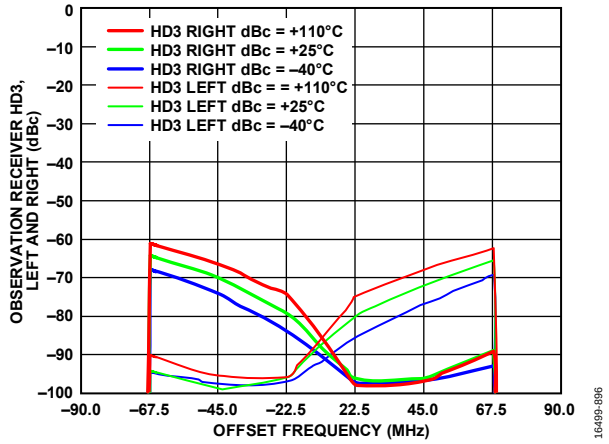

Figure 397. Observation Receiver HD3, Left and Right vs. Offset Frequency, LO = 5200 MHz, Tone Level = –20 dBm

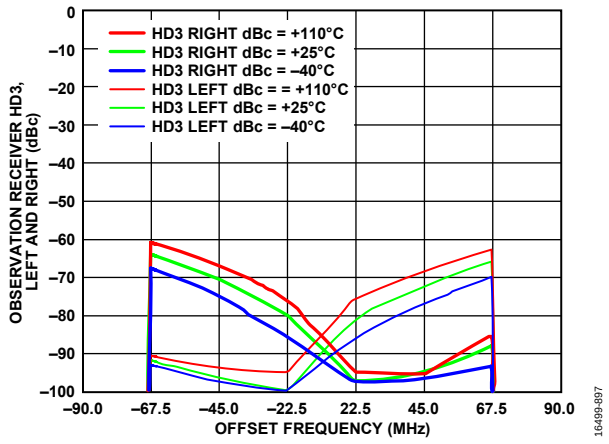

Figure 398. Observation Receiver HD3, Left and Right vs. Offset Frequency, LO = 5700 MHz, Tone Level = –20 dBm

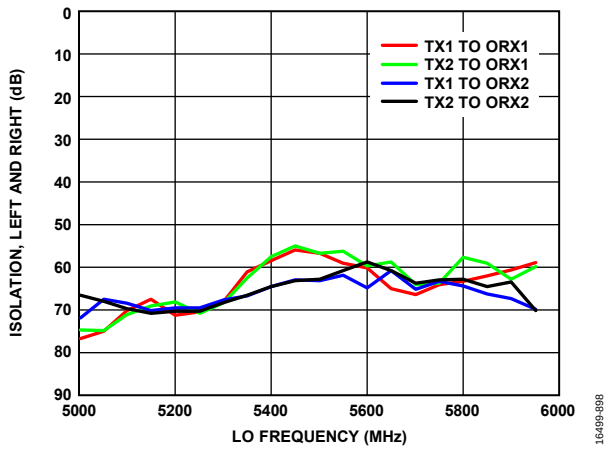

Figure 399. Transmitter to Observation Receiver Isolation vs. LO Frequency, Temperature = 25°C

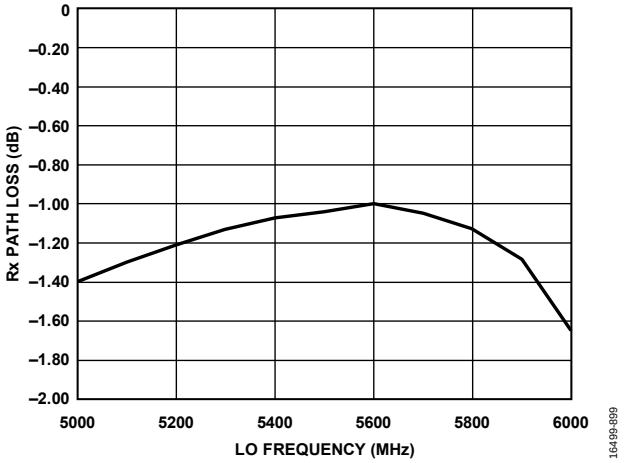

Figure 400. Receiver Path Loss vs. LO Frequency (Simulation), Can Be Used for Deembedding Performance Data

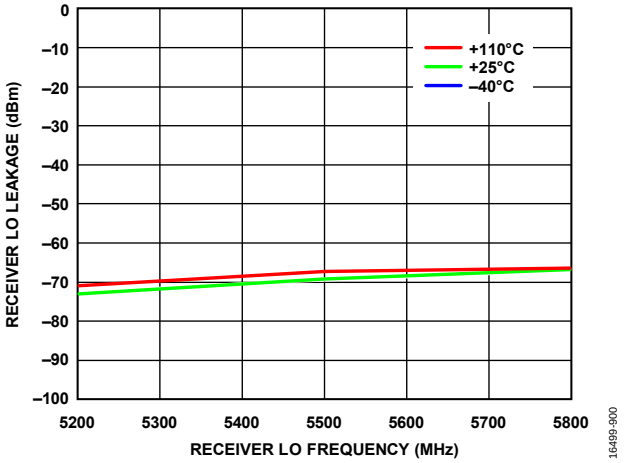

Figure 401. Receiver LO Leakage vs. Receiver LO Frequency, 5200 MHz, 5500 MHz, and 5800 MHz, Receiver Attenuation = 0 dB, RF Bandwidth = 200 MHz, Sample Rate = 245.76 MSPS

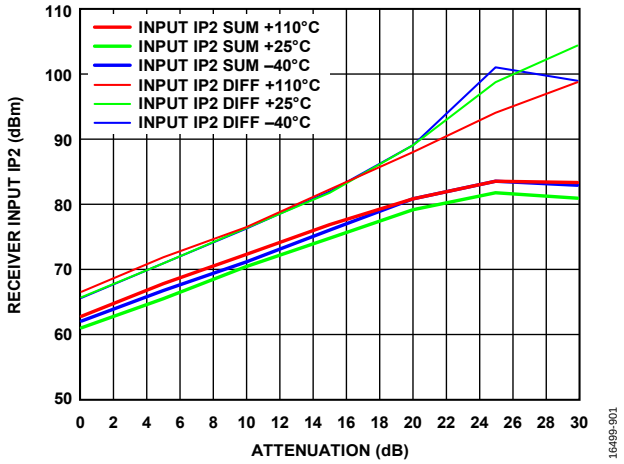

Figure 402. Receiver IIP2 vs. Attenuation, 5800 MHz LO, Tones Placed at 5845 MHz and 5846 MHz, –21 dBm Plus Attenuation

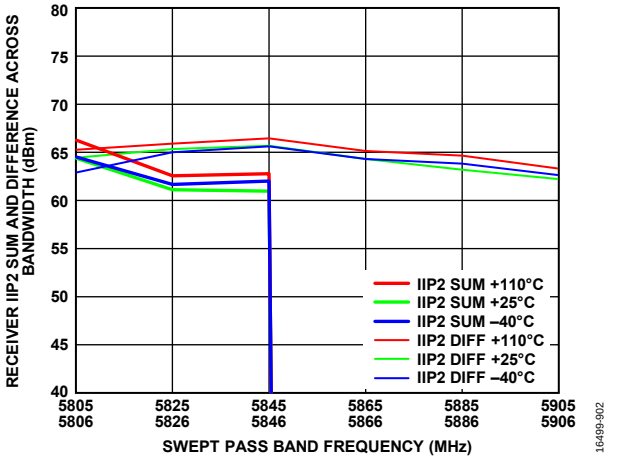

Figure 403. Receiver IIP2 Sum and Difference Across Bandwidth vs. Swept Pass Band Frequency, Receiver Attenuation = 0 dB, LO = 5800 MHz, Six Tone Pairs, –21 dBm Plus Attenuation Each

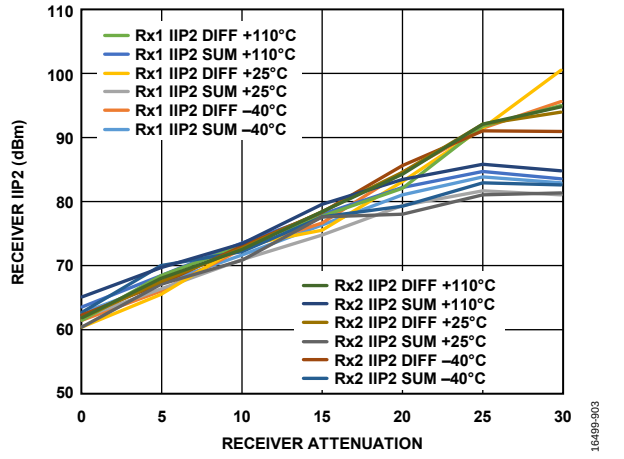

Figure 404. Receiver IIP2 vs. Receiver Attenuation, LO = 5800 MHz, Tones Placed at 5802 MHz and 5892 MHz, –21 dBm Plus Attenuation

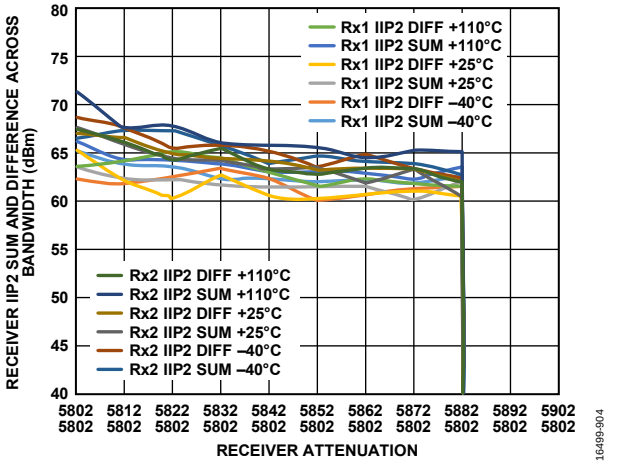

Figure 405. Receiver IIP2 Sum and Difference Across Bandwidth vs. Swept Pass Band Frequency, Receiver Attenuation = 0 dB, LO = 5800 MHz, Tone 1 = 5802 MHz, Tone 2 Swept, –21 dBm Each

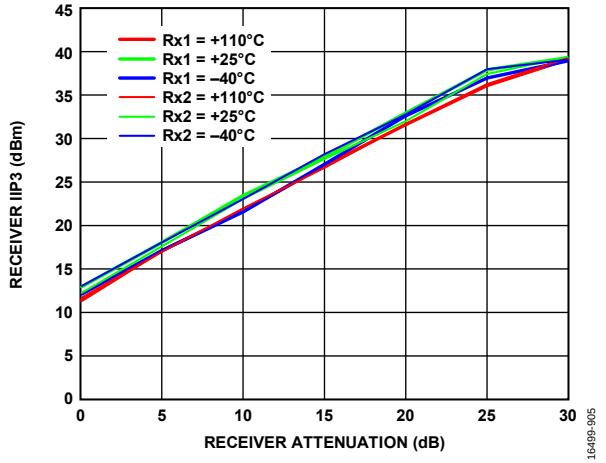

Figure 406. Receiver IIP3 vs. Receiver Attenuation, LO = 5800 MHz, Tone 1 = 5895 MHz, Tone 2 = 5896 MHz, −21dBm Plus Attenuation

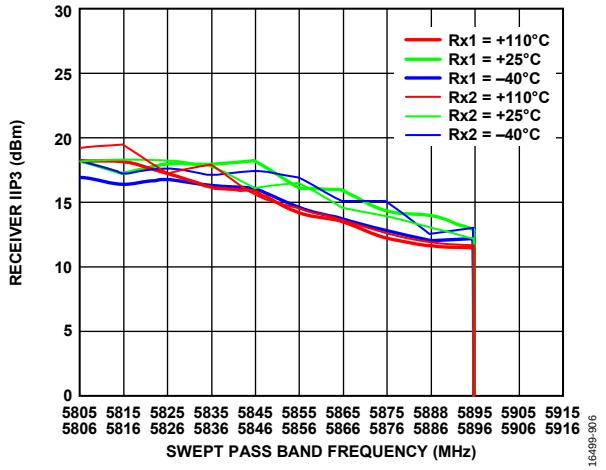

Figure 407. Receiver IIP3 Across Bandwidth vs. Swept Pass Band Frequency, Receiver Attenuation = 0 dB, LO = 5800 MHz, Tone 2 = Tone 1 + 1 MHz, −21 dBm each, Swept Across Pass Band

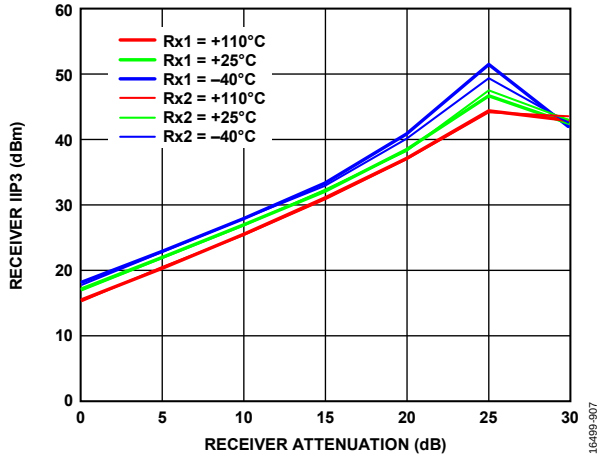

Figure 408. Receiver IIP3 vs. Receiver Attenuation, LO = 5800 MHz, Tone 1 = 5802 MHz, Tone 2 = 5892 MHz, −21 dBm Plus Attenuation

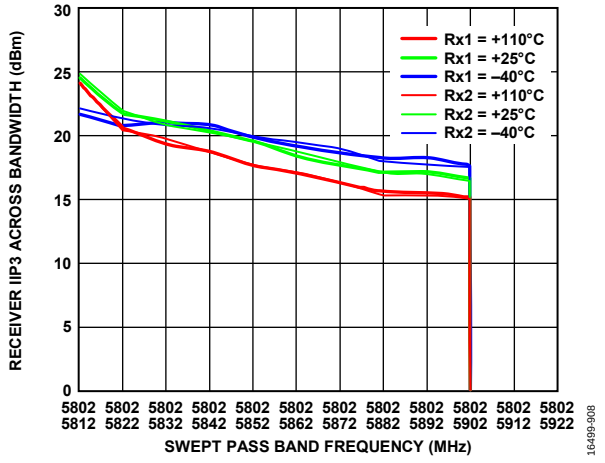

Figure 409. Receiver IIP3 Across Bandwidth vs. Swept Pass Band Frequency, Receiver Attenuation = 0 dB, LO = 5800 MHz, Tone 1 = 5802 MHz, Tone 2 Swept Across Pass Band, −21 dBm Each

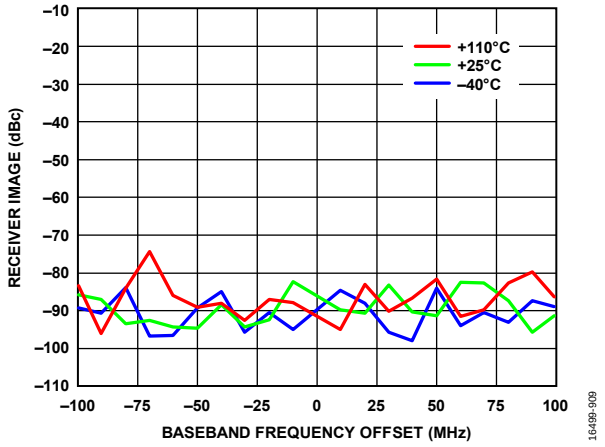

Figure 410. Receiver Image vs. Baseband Frequency Offset, Attenuation = 0 dB, RF Bandwidth = 200 MHz, Tracking Calibration Active, Sample Rate = 245.76 MSPS, LO = 5200 MHz

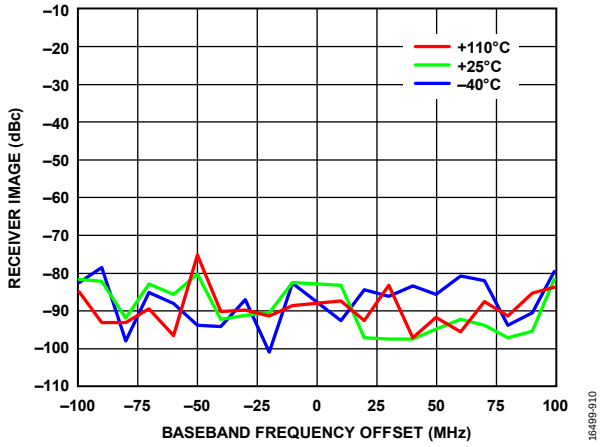

Figure 411. Receiver Image vs. Baseband Frequency Offset, 0 dB Attenuation, 200 MHz RF Bandwidth, Tracking Calibration Active, Sample Rate = 245.76 MSPS, LO = 5900 MHz

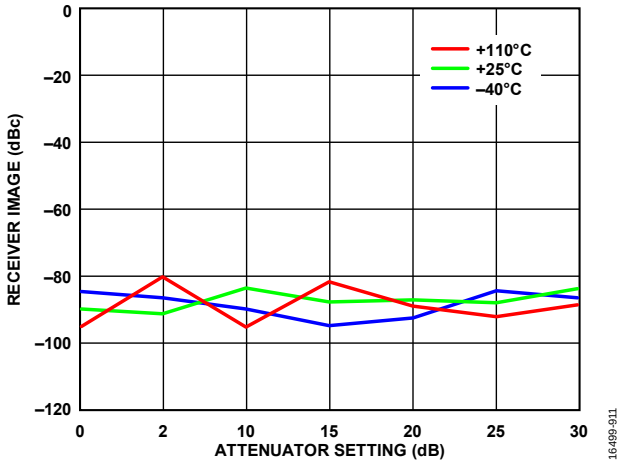

Figure 412. Receiver Image vs. Attenuator Setting, RF Bandwidth = 200 MHz, Tracking Calibration Active, Sample Rate = 245.76 MSPS, LO = 5200 MHz, Baseband Frequency= 10 MHz

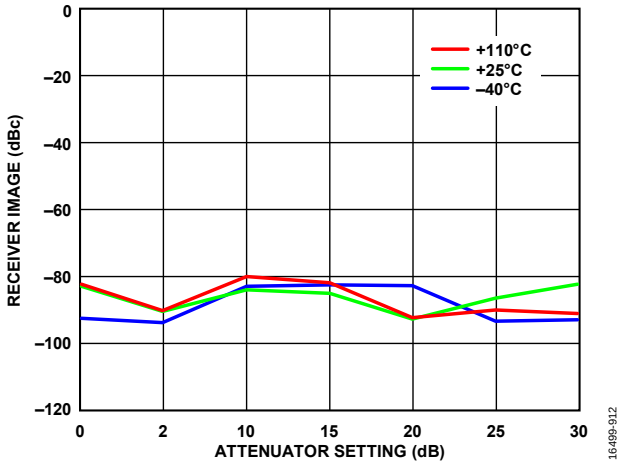

Figure 413. Receiver Image vs. Attenuator Setting, RF Bandwidth = 200 MHz, Tracking Calibration Active, Sample Rate = 245.76 MSPS, LO = 5900MHz, Baseband Frequency= 10 MHz

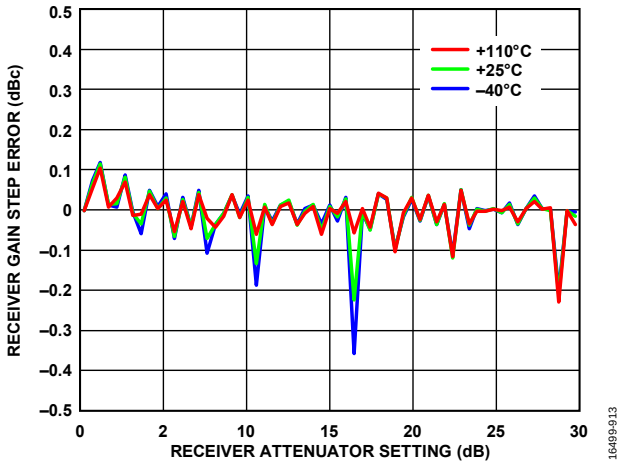

Figure 414. Receiver Gain Step Error vs. Receiver Attenuator Setting and Temperature, LO = 5200 MHz

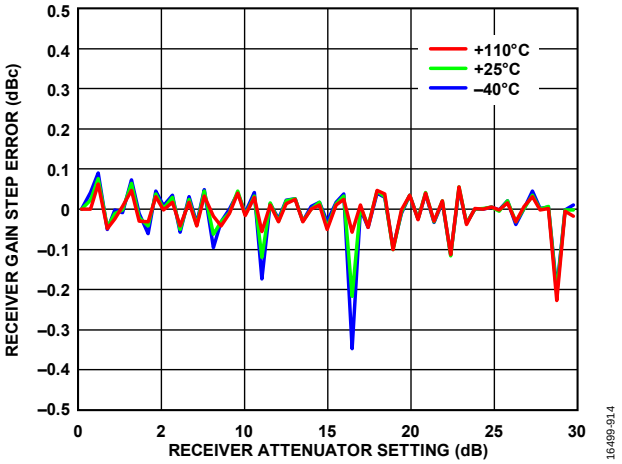

Figure 415. Receiver Gain Step Error vs. Receiver Attenuator Setting and Temperature, LO = 5600 MHz

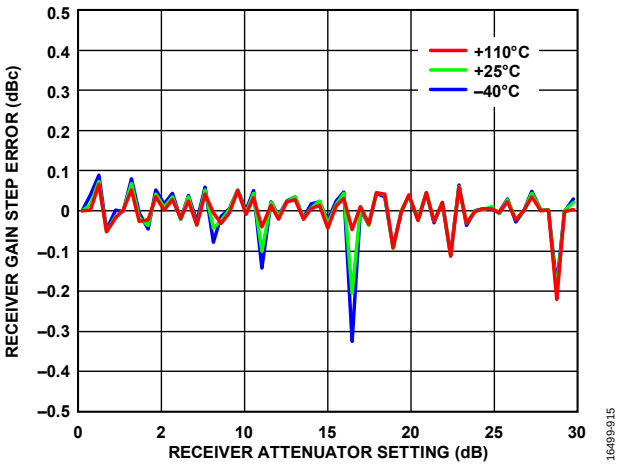

Figure 416. Receiver Gain Step Error vs. Receiver Attenuator Setting and Temperature, LO = 6000 MHz

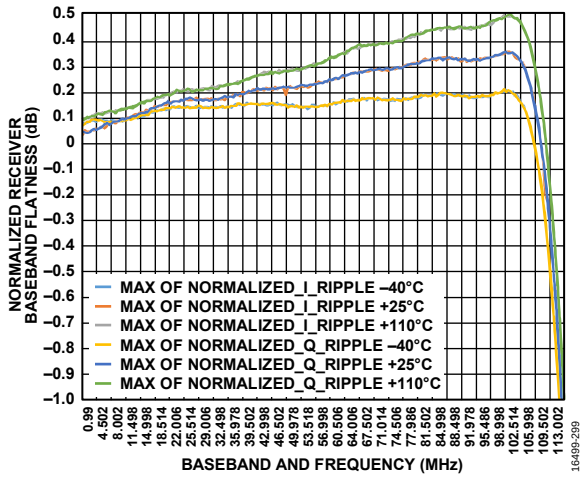

Figure 417. Normalized Receiver Baseband Flatness vs. Baseband Frequency (Receiver Flatness)

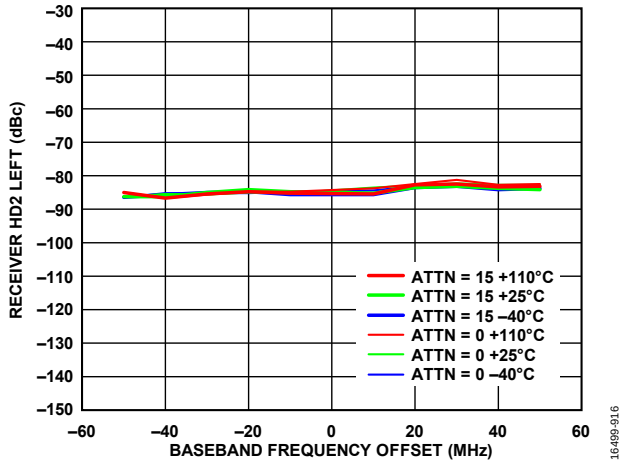

Figure 418. Receiver HD2 Left vs. Baseband Frequency Offset, Tone Level = −15 dBm at Attenuation = 0 dB, X-Axis = Baseband Frequency Offset of the Fundamental Tone Not the Frequency of the HD2 Product (HD2 Product = 2× the Baseband Frequency), HD2 Canceller Disabled, LO = 5200 MHz

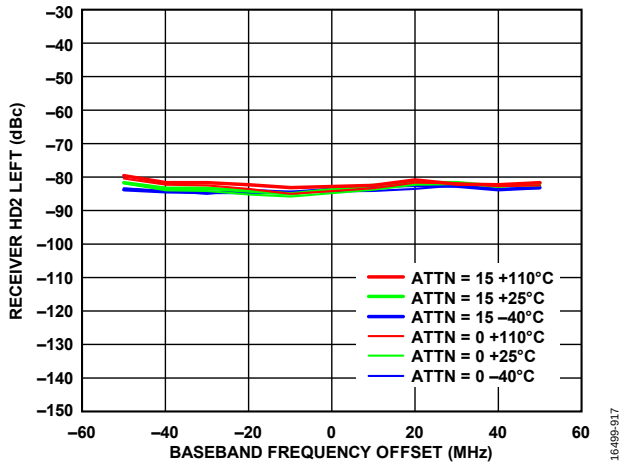

Figure 419. Receiver HD2, Left vs. Baseband Frequency Offset, Tone Level = −15 dBm at Attenuation = 0 dB, X-Axis = Baseband Frequency Offset of the Fundamental Tone Not the Frequency of the HD2 Product (HD2 Product = 2× the Baseband Frequency), HD2 Canceller Disabled, LO = 5900 MHz

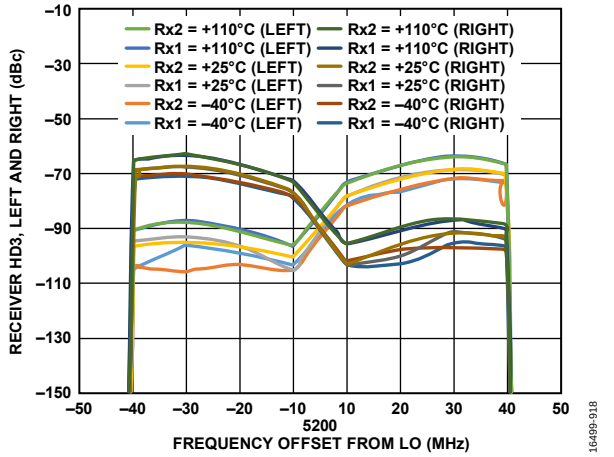

Figure 420. Receiver HD3, Left and Right vs. Frequency Offset from LO, Tone Level = −15 dBm at Attenuation = 0 dB, LO = 5200 MHz

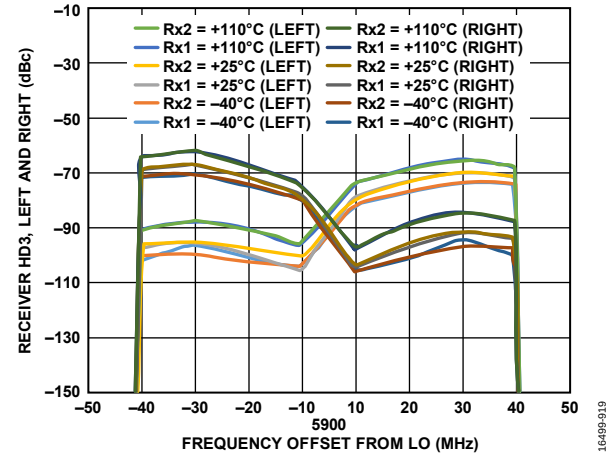

Figure 421. Receiver HD3, Left and Right vs. Frequency Offset from LO Tone Level = −15 dBm at Attenuation = 0 dB, LO = 5900 MHz

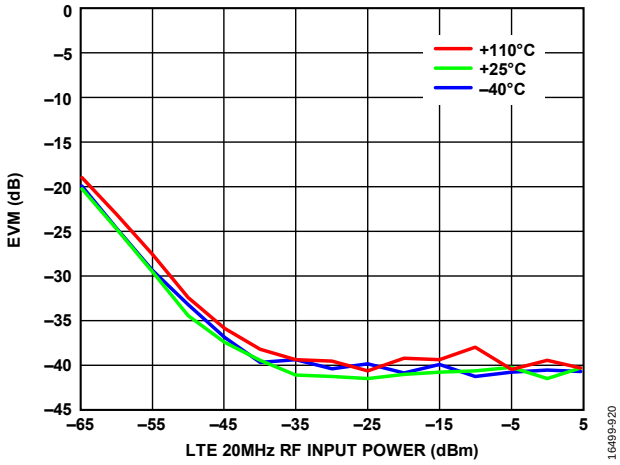

Figure 422. Receiver EVM vs. Input Power, LTE 20 MHz RF Signal, LO = 5200 MHz, Default AGC Settings

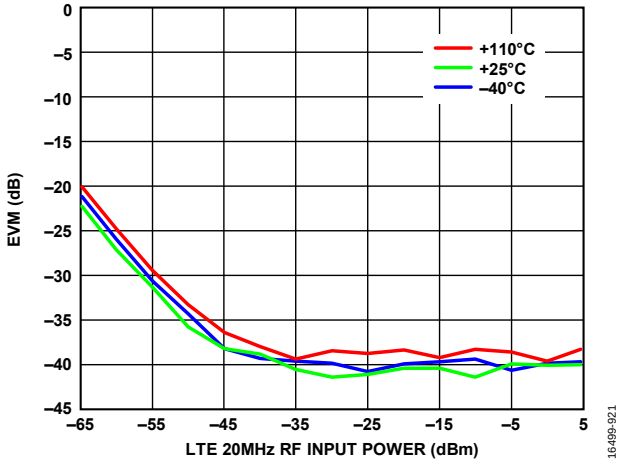

Figure 423. Receiver EVM vs. Input Power, LTE 20 MHz RF Signal, LO = 5500 MHz, Default AGC Settings

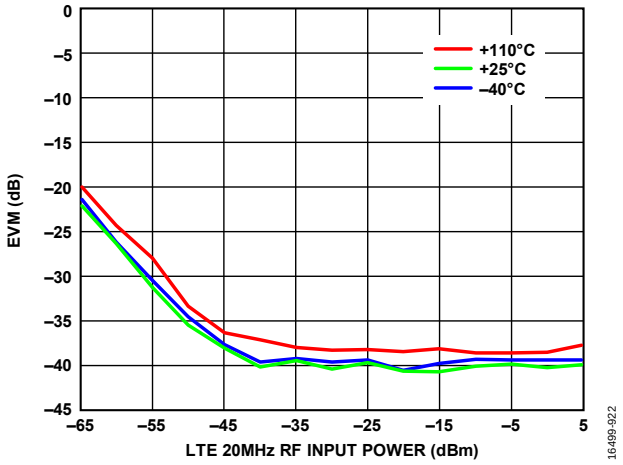

Figure 424. Receiver EVM vs. Input Power, LTE 20 MHz RF Signal, LO = 5800 MHz, Default AGC Settings

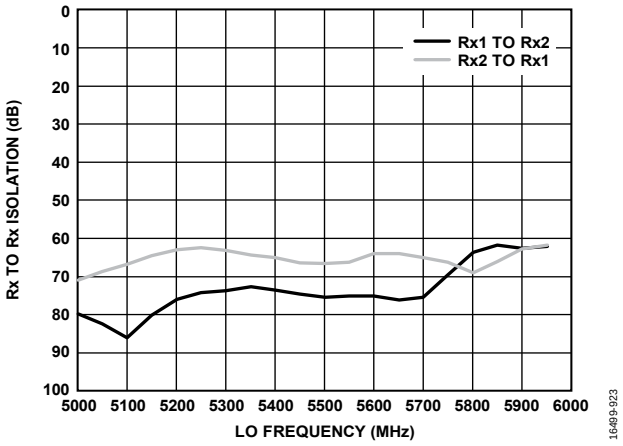

Figure 425. Receiver to Receiver Isolation vs. LO Frequency

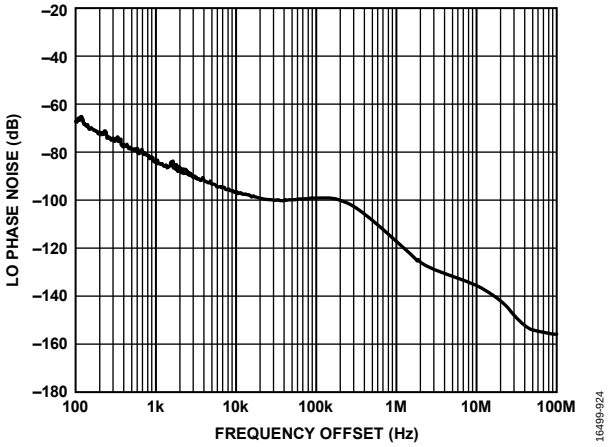

Figure 426. LO Phase Noise vs. Frequency Offset, LO = 5900 MHz, RMS Phase Error Integrated from 2 kHz to 18 MHz, PLL Loop Bandwidth > 300 kHz, Spectrum Analyzer Limits Far Out Noise

TRANSMITTER OUTPUT IMPEDANCE

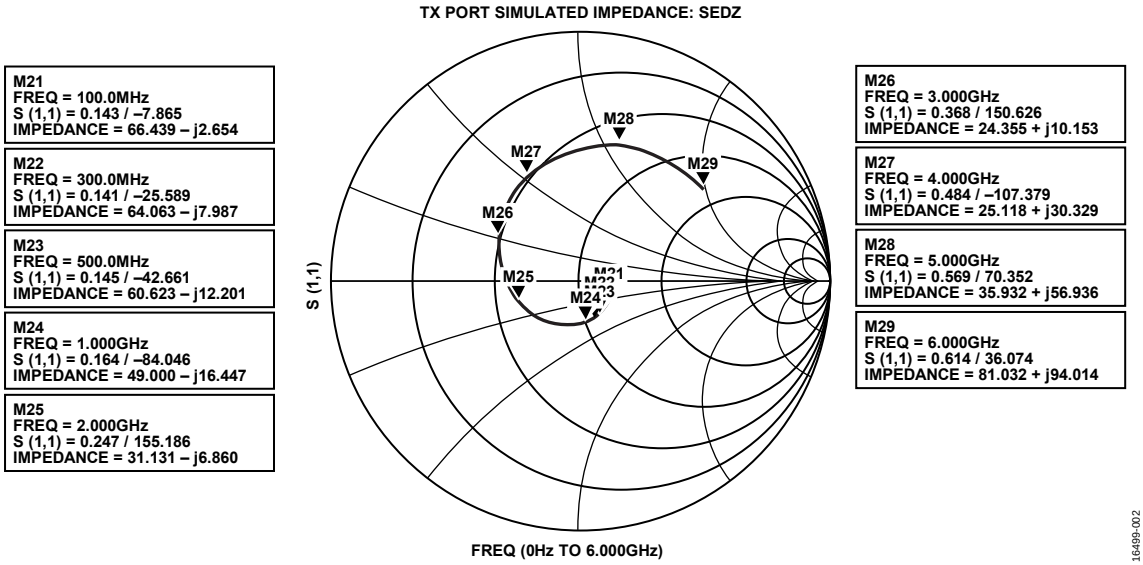

Figure 427. Transmitter Output Impedance Series Equivalent Differential Impedance (SEDZ)

OBSERVATION RECEIVER INPUT IMPEDANCE

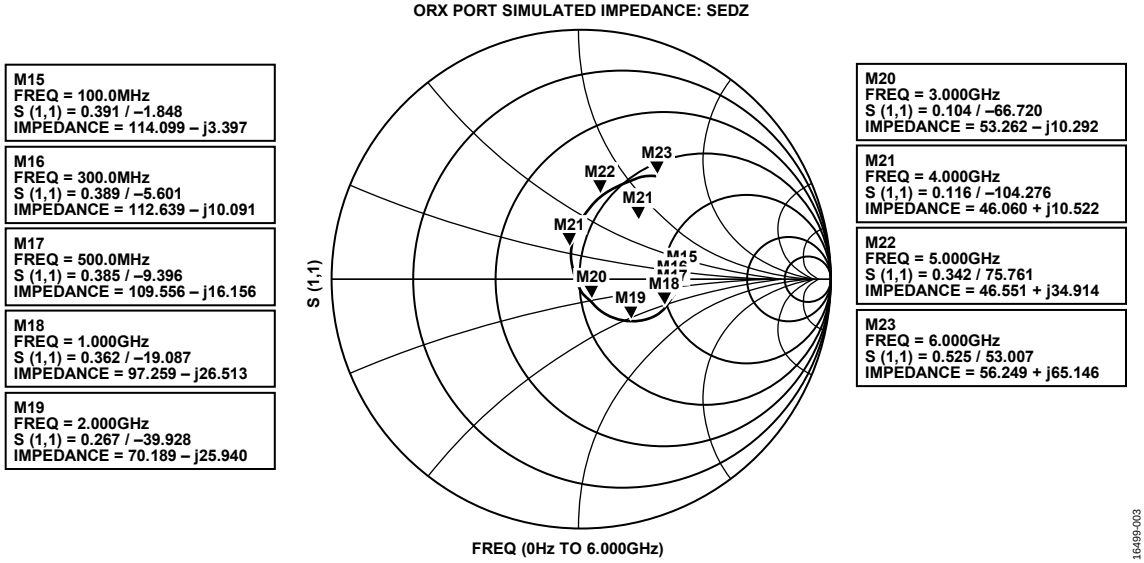

Figure 428. Observation Receiver Input Impedance SEDZ

RECEIVER INPUT IMPEDANCE

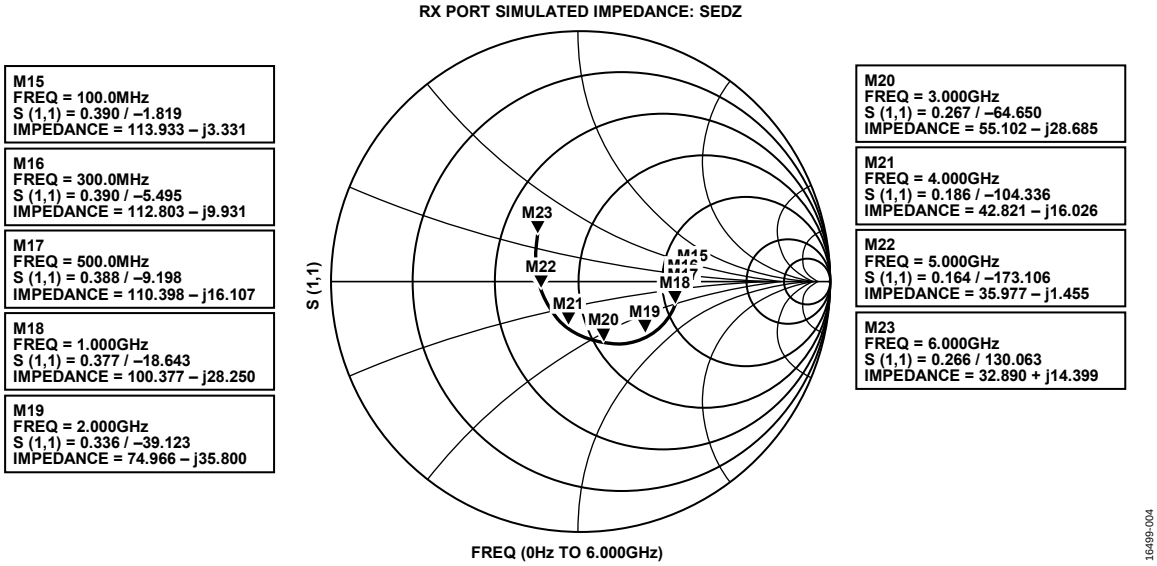

Figure 429. Receiver Input Impedance SEDZ

TERMINOLOGY

Large Signal Bandwidth
Large signal bandwidth, otherwise known as instantaneous bandwidth or signal bandwidth, is the bandwidth over which there are large signals. For example, for Band 42 LTE, the large signal bandwidth is 200 MHz.

Occupied Bandwidth
Occupied bandwidth is the total bandwidth of the active signals. For example, three 20 MHz carriers have a 60 MHz occupied bandwidth, regardless of where the carriers are placed within the large signal bandwidth.

Synthesis Bandwidth
Synthesis bandwidth is the bandwidth over which digital predistortion (DPD) linearization is transmitted. Synthesis bandwidth is the 1 dB bandwidth of the transmitter. The power density of the signal outside the occupied bandwidth is assumed to be 25 dB below the signal in the occupied bandwidth. This value assumes that the unlinearized PA achieves 25 dB ACLR.

Observation Bandwidth
Observation bandwidth is the 1 dB bandwidth of the observation receiver. With the observation receiver sharing the transmitter LO, the observation receiver sees similar power densities as in the occupied and synthesis bandwidths of the transmitter.

Backoff
Backoff is the difference (in dB) between full scale and the rms signal power.

P_{HIGH}
P_{HIGH} is the largest signal that can be applied without overloading the ADC for the receiver and/or observation receiver input. Due to the nature of continuous time, Σ-Δ ADCs, this input level results in slightly less than full scale at the digital output; this is because of the nature of the continuous time Σ-Δ ADCs, which exhibit a soft overload in contrast to the hard clipping of pipeline ADCs, for example.

THEORY OF OPERATION

The ADRV9009 is a highly integrated RF transmitter subsystem capable of configuration for a wide range of applications. The device integrates all RF, mixed-signal, and digital blocks necessary to provide all transmitter, traffic receiver, and DPD observation receiver functions in a single device. Programmability allows the transmitter to be adapted for use in many TDD and 3G/4G cellular standards. The ADRV9009 contains four high speed serial interface links for the transmitter chain, and two high speed links each for the receiver and observation receiver chains. The links are JESD204B, Subclass 1 compliant. The two receiver lanes can be reused for the observation receiver, providing a low pin count and a reliable data interface to field programmable gate arrays (FPGAs) or integrated baseband solutions.

The ADRV9009 also provides tracking correction of dc offset QEC errors, and transmitter LO leakage to maintain high performance under varying temperatures and input signal conditions. The device also includes test modes that allow system designers to debug designs during prototyping and to optimize radio configurations.

TRANSMITTER

The ADRV9009 transmitter section consists of two identical and independently controlled channels that provide all digital processing, mixed-signal, and RF blocks necessary to implement a direct conversion system while sharing a common frequency synthesizer. The digital data from the JESD204B lanes passes through a fully programmable, 128-tap FIR filter with variable interpolation rates. The FIR output is sent to a series of interpolation filters that provide additional filtering and interpolation prior to reaching the DAC. Each 14-bit DAC has an adjustable sample rate.

When converted to baseband analog signals, the in phase (I) and quadrature (Q) signals are filtered to remove sampling artifacts and are fed to the upconversion mixers. Each transmitter chain provides a wide attenuation adjustment range with fine granularity to optimize SNR.

RECEIVER

The ADRV9009 receiver contains all the blocks necessary to receive RF signals and convert them to digital data usable by a baseband processor (BBP). Each receiver can be configured as a direct conversion system that supports up to a 200 MHz bandwidth. Each receiver contains a programmable attenuator stage, followed by matched I and Q mixers that downconvert received signals to baseband for digitization.

Gain control can be achieved by using the on-chip AGC or by allowing the BBP make gain adjustments in a manual gain control mode. Performance is optimized by mapping each gain control setting to specific attenuation levels at each adjustable gain block in the receiver signal path. Additionally, each channel contains independent receive signal strength indicator (RSSI) measurement capability, dc offset tracking, and all circuitry necessary for self calibration.

The receivers include ADCs and adjustable sample rates that produce data streams from the received signals. The signals can be conditioned further by a series of decimation filters and a programmable FIR filter with additional decimation settings. The sample rate of each digital filter block is adjustable by changing decimation factors to produce the desired output data rate.

OBSERVATION RECEIVER

The ADRV9009 contains an independent DPD observation receiver front end with two multiplexed inputs and a common digital back end that is shared with the traffic receiver. The innovative configuration enables a highly efficient shared receiver/observation receiver mode where the device can support fast switching between receiver and observation receiver mode in TDD applications. The observation receiver shares the common frequency synthesizer with the transmitter.

The observation receiver is a direct conversion system that contains a programmable attenuator stage, followed by matched I and Q mixers, baseband filters, and ADCs.

The continuous time Σ-Δ ADCs have inherent antialiasing that reduces the RF filtering requirement.

The ADC outputs can be conditioned further by a series of decimation filters and a programmable FIR filter with additional decimation settings. The sample rate of each digital filter block is adjustable by changing decimation factors to produce the desired output data rate.

CLOCK INPUT

The ADRV9009 requires a differential clock connected to the REF_CLK_IN_x pins. The frequency of the clock input must be between 10 MHz and 1000 MHz and must have very low phase noise because this signal generates the RF LO and internal sampling clocks.

SYNTHESIZERS

RF PLL

The ADRV9009 contains a fractional-N PLL to generate the RF LO for the signal paths. The PLL incorporates an internal VCO and loop filter, requiring no external components. The LOs on multiple chips can be phase synchronized to support active antenna systems and beam forming applications.

Clock PLL

The ADRV9009 contains a PLL synthesizer that generates all the baseband related clock signals and serialization/deserialization (SERDES) clocks. This PLL is programmed based on the data rate and sample rate requirements of the system.

SERIAL PERIPHERAL INTERFACE (SPI)

The ADRV9009 uses an SPI interface to communicate with the BBP. This interface can be configured as a 4-wire interface with dedicated receiver and transmitter ports, or it can be configured as a 3-wire interface with a bidirectional data communications port. This bus allows the BBP to set all device control parameters using a simple address data serial bus protocol.

Write commands follow a 24-bit format. The first five bits set the bus direction and the number of bytes to transfer. The next 11 bits set the address where data is written. The final eight bits are the data to be transferred to the specific register address.

Read commands follow a similar format with the exception that the first 16 bits are transferred on the SDIO pin and the final eight bits are read from the ADRV9009, either on the SDO pin in 4-wire mode or on the SDIO pin in 3-wire mode.

JTAG BOUNDARY SCAN

The ADRV9009 provides support for JTAG boundary scan. There are five dual function pins associated with the JTAG interface. These pins access the on chip test access port. To enable the JTAG functionality, set the GPIO_3 pin through the GPIO_0 pin to 1001, and then pull the TEST pin high.

POWER SUPPLY SEQUENCE

The ADRV9009 requires a specific power-up sequence to avoid undesired power-up currents. In the optimal power-up sequence, the VDDD1P3_DIG and the VDDA1P3_x supplies (VDDA1P3_x includes all 1.3 V domains) power up first and together. If these supplies cannot be brought up simultaneously, then the VDDD1P3_DIG supply must come up first. Bring the VDDA_3P3, VDDA1P8_x, VDDA1P3_DES, and VDDA1P3_SER supplies up after the 1.3 V supplies. The VDD_INTERFACE supply can be brought up at any time. Note that no device damage occurs if this sequence is not followed. However, failure to follow this sequence may result in higher than expected power-up currents. It is also recommended to toggle the $\overline{\text{RESET}}$ signal after power stabilizes, prior to configuration. The power-down sequence is not critical. If a power-down sequence is followed, remove the VDDD1P3_DIG supply last to avoid any back biasing of the digital control lines.

GPIO_x PINS

The ADRV9009 provides 19 1.8 V to 2.5 V GPIO signals that can be configured for numerous functions. When configured as outputs, certain pins can provide real-time signal information to the BBP, allowing the BBP to determine receiver performance. A pointer register selects the information that is output to these pins. Signals used for manual gain mode, calibration flags, state machine states, and various receiver parameters are among the outputs that can be monitored on these pins. Additionally, certain pins can be configured as inputs and used for various functions, such as setting the receiver gain in real time.

Twelve 3.3 V GPIO_x pins are also included on the device. These pins provide control signals to external components.

AUXILIARY CONVERTERS

AUXADC_x

The ADRV9009 contains an auxiliary ADC that is multiplexed to four input pins (AUXADC_x). The auxiliary ADC is 12 bits with an input voltage range of 0.05 V to VDDA_3P3 − 0.05 V. When enabled, the auxiliary ADC is free running. The SPI reads provide the last value latched at the ADC output. The auxiliary ADC can also be multiplexed to a built in, diode-based temperature sensor.

AUXDAC_x

The ADRV9009 contains 10 identical auxiliary DACs (AUXDAC_x) that can be used for bias or other system functionality. The auxiliary DACs are 10 bits and have an output voltage range of approximately 0.7 V to VDDA_3P3 − 0.3 V and have a current drive of 10 mA.

JESD204B DATA INTERFACE

The digital data interface for the ADRV9009 uses JEDEC JESD204B Subclass 1. The serial interface operates at speeds of up to 12.288 Gbps. The benefits of the JESD204B interface include a reduction in required board area for data interface routing, resulting in smaller total system size. Four high speed serial lanes are provided for transmit and four high speed lanes are provided for the receiver and observation receiver. The ADRV9009 supports single lane or dual lane interfaces and fixed and floating point data formats for receiver and/or observation receiver data.

Table 6. Observation Path Interface Rates

		JESD204B	
Bandwidth (MHz)	**Output Rate (MSPS)**	**Lane Rate (Mbps)**	**Number of Lanes**
200	245.76	9830.4	1
200	307.2	12288	1
250	307.2	12288	1
450	491.52	9830.4	2
450	491.52	4915.2	4

Table 7. Transmitter Interface Rates (Other Output Rates, Bandwidth, and JESD204B Lanes Also Supported)

Bandwidth (MHz)	Input Rate (MSPS)	Single-Channel Operation		Dual Channel Operation	
		JESD204B Lane Rate (Mbps)	JESD204B Number of Lanes	JESD204B Lane Rate (Mbps)	JESD204B Number of Lanes
200	245.76	9830.4	1	9830.4	2
200	307.2	12288	1	12288	2
250	307.2	12288	1	12288	2
450	491.52	9830.4	2	9830.4	4

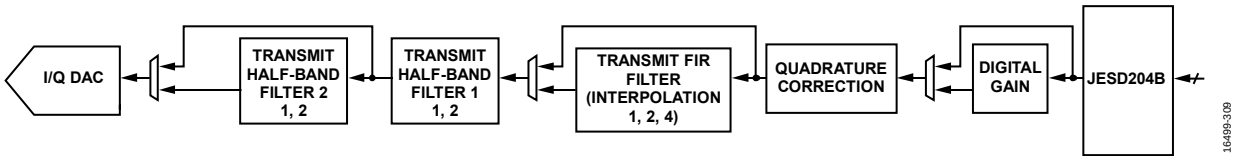

Figure 430. Transmitter Datapath Filter Implementation

Table 8. Example Receiver Interface Rates (Other Output Rates, Bandwidth, and JESD204B Lanes Also Supported)

Bandwidth (MHz)	Output Rate (MSPS)	Single-Channel Operation		Dual Channel Operation	
		JESD204B Lane Rate (Mbps)	JESD204B Number of Lanes	JESD204B Lane Rate (Mbps)	JESD204B Number of Lanes
80	122.88	4915.2	1	9830.4	1
100	153.6	6144	1	12288	1
100	245.76	9830.4	1	9830.4	2
200	245.76	9830.4	1	9830.4	2
200	245.76	4915.2	2	4915.2	4

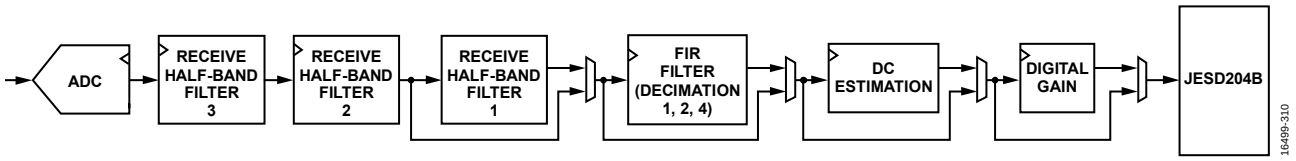

Figure 431. Receiver Datapath Filter Implementation

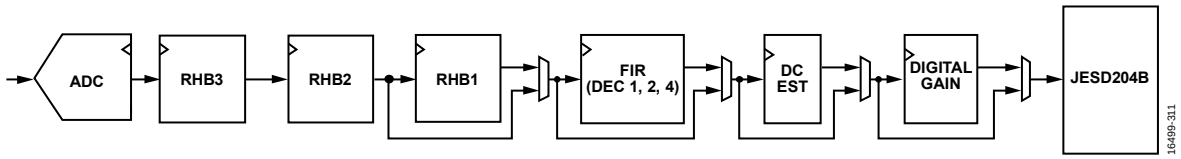

Figure 432. Observation Receiver Datapath Filter Implementation

APPLICATIONS INFORMATION

PCB LAYOUT AND POWER SUPPLY RECOMMENDATIONS

Overview

The ADRV9009 device is a highly integrated RF agile transceiver with significant signal conditioning integrated onto one chip. Due to the increased complexity of the device and its high pin count, careful PCB layout is important to get the optimal performance. This data sheet provides a checklist of issues to look for and guidelines on how to optimize the PCB to mitigate performance issues. The goal of this data sheet is to help achieve the optimal performance from the ADRV9009 while reducing board layout effort. This data sheet assumes that the reader is an experienced analog and RF engineer who understands RF PCB layout and has an understanding of RF transmission lines. This data sheet discusses the following issues and provides guidelines for system designers to achieve the optimal performance performance for the ADRV9009:

- PCB material and stack up selection
- Fanout and trace space layout guidelines
- Components placement and routing guidelines
- RF and JESD204B transmission line layout
- Isolation techniques used on the ADRV9009 customer card
- Power management considerations
- Unused pin instructions

PCB MATERIAL AND STACKUP SELECTION

Figure 434 shows the PCB stackup used for the ADRV9009 customer evaluation boards. The dielectric material used on the top and the bottom layers is 8 mil Rogers 4350B. The remaining dielectric layers are FR4-370 HR. The board design uses the Rogers laminate for the top and the bottom layers for its low loss tangent at high frequencies. The ground planes under the Rogers laminate (Layer 2 and Layer 13) are the reference planes for the transmission lines routed on the outer surfaces. These layers are solid copper planes without any splits under the RF traces. Layer 2 and Layer 13 are crucial to maintaining the RF signal integrity and, ultimately, ADRV9009 performance. Layer 3 and Layer 12 route power supply domains. To keep the RF section of the ADRV9009 isolated from the fast transients of the digital section, the JESD204B interface lines are routed on Layer 5 and Layer 10. Those layers have impedance control set to a 100 Ω differential. The remaining digital lines from ADRV9009 are routed on inner Layer 7 and inner Layer 8. RF traces on the outer layers must be a controlled impedance to get the best performance from the device. 0.5 ounce copper or 1 ounce copper is used for the inner layers in this board. The outer layers use 1.5 ounce copper so that the RF traces are less prone to pealing. Ground planes on this board are full copper floods with no splits except for vias, through-hole components, and isolation structures. The ground planes must route entirely to the edge of the PCB under the Surface-Mount Type A (SMA) connectors to maintain signal launch integrity. Power planes can be pulled back from the board edge to decrease the risk of shorting from the board edge.

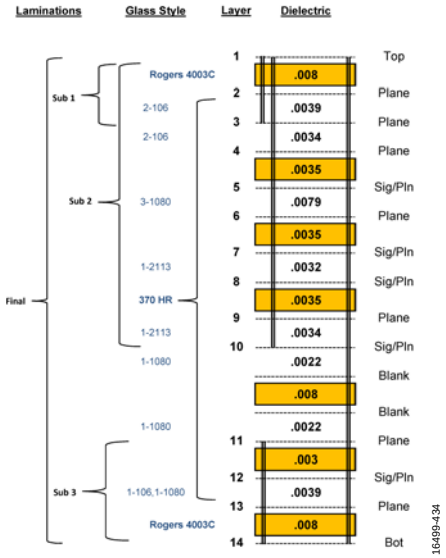

Figure 433. ADRV9009, ADRV9008-1, and ADRV9008-2 Customer Evaluation Board Trace Impedance and Stackup

Table 9. Customer Evaluation Board Single Ended Impedance and Stackup

Layer	Board Copper (%)	Starting Copper (oz.)	Finished Copper (oz.)	Single Ended Impedance	Designed Trace Single Ended	Finished Trace Single Ended	Calculated Impedance	Single-Ended Ref Layers
1	N/A[1]	0.5	1.71	50 Ω ±10%	0.0155	0.0135	49.97	2
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	65	1	1	N/A	N/A	N/A	N/A	N/A
3	50	0.5	1	N/A	N/A	N/A	N/A	N/A
4	65	1	1	N/A	N/A	N/A	N/A	N/A
5	50	0.5	0.5	50 Ω ±10%	0.0045	0.0042	49.79	4, 6
6	65	1	1	N/A	N/A	N/A	N/A	N/A
7	50	0.5	0.5	50 Ω ±10%	0.0049	0.0039	50.05	6, 9
8	50	0.5	0.5	50 Ω ±10%	0.0049	0.0039	50.05	6, 9
9	65	1	1	N/A	N/A	N/A	N/A	N/A
10	50	0.5	1	50 Ω ±10%	0.0045	0.0039	49.88	9, 11
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	65	0.5	1	N/A	N/A	N/A	N/A	N/A
12	50	1	1	N/A	N/A	N/A	N/A	N/A
13	65	1	1	N/A	N/A	N/A	N/A	N/A
14		0.5	1.64	50 Ω ±10%	0.0155	0.0135	49.97	13

[1] N/A means not applicable.

Table 10. Customer Evaluation Board Differential Impedance and Stackup[1]

Layer	Differential Impedance	Designed Trace/Gap Differential	Finished Trace/Gap Differential	Calculated Impedance	Differential Reference Layers
1	100 Ω ±10%	0.008/0.006	0.007/0.007	99.55	2
	50 Ω ±10%	0.0032/0.004	0.0304/0.0056	50.11	2
2	N/A[1]	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A
5	100 Ω ±10%	0.0036/0.0064	0.0034/0.0065	99.95	4, 6
6	N/A	N/A	N/A	N/A	N/A
7	100 Ω ±10%	0.0036/0.0064	0.0034/0.0066	100.51	6, 9
8	100 Ω ±10%	0.0038/0.0062	0.0034/0.0066	100.51	6, 9
9	N/A	N/A	N/A	N/A	N/A
10	100 Ω ±10%	0.0036/0.0064	0.003/0.007	100.80	9, 11
	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A	N/A
13	100 Ω ±10%	0.008/0.006	0.007/0.007	99.55	13
14	50 Ω ±10%	0.032	0.004	50.11	13

[1] N/A means not applicable.

FANOUT AND TRACE SPACE GUIDELINES

The ADRV9009 device uses a 196-ball chip scale ball grid array (BGA), 12 × 12 mm package. The pitch between the pins is 0.8 mm. This small pitch makes it impractical to route all signals on a single layer. RF pins have been placed on the outer edges of the ADRV9009 package. The location of the pins helps in routing the critical signals without a fanout via. Each digital signal is routed from the BGA pad using a 4.5 mil trace. The trace is connected to the BGA using via in the pad structure. The signals are buried in the inner layers of the board for routing to other parts of the system.

The JESD204B interface signals are routed on two signal layers that use impedance control (Layer 5 and Layer 10). The spacing between the BGA pads is 17.5 mil. After the signal is on the inner layers, a 3.6 mil trace (50 Ω) connects the JESD204B signal to the FPGA mezzanine card (FMC) connector. The recommended BGA land pad size is 15 mil.

Figure 435 shows the fanout scheme of the ADRV9009 evaluation card. As mentioned before, the ADRV9009 evaluation board uses via in the pad technique. This routing approach can be used for the ADRV9009 if there are no issues with manufacturing capabilities.

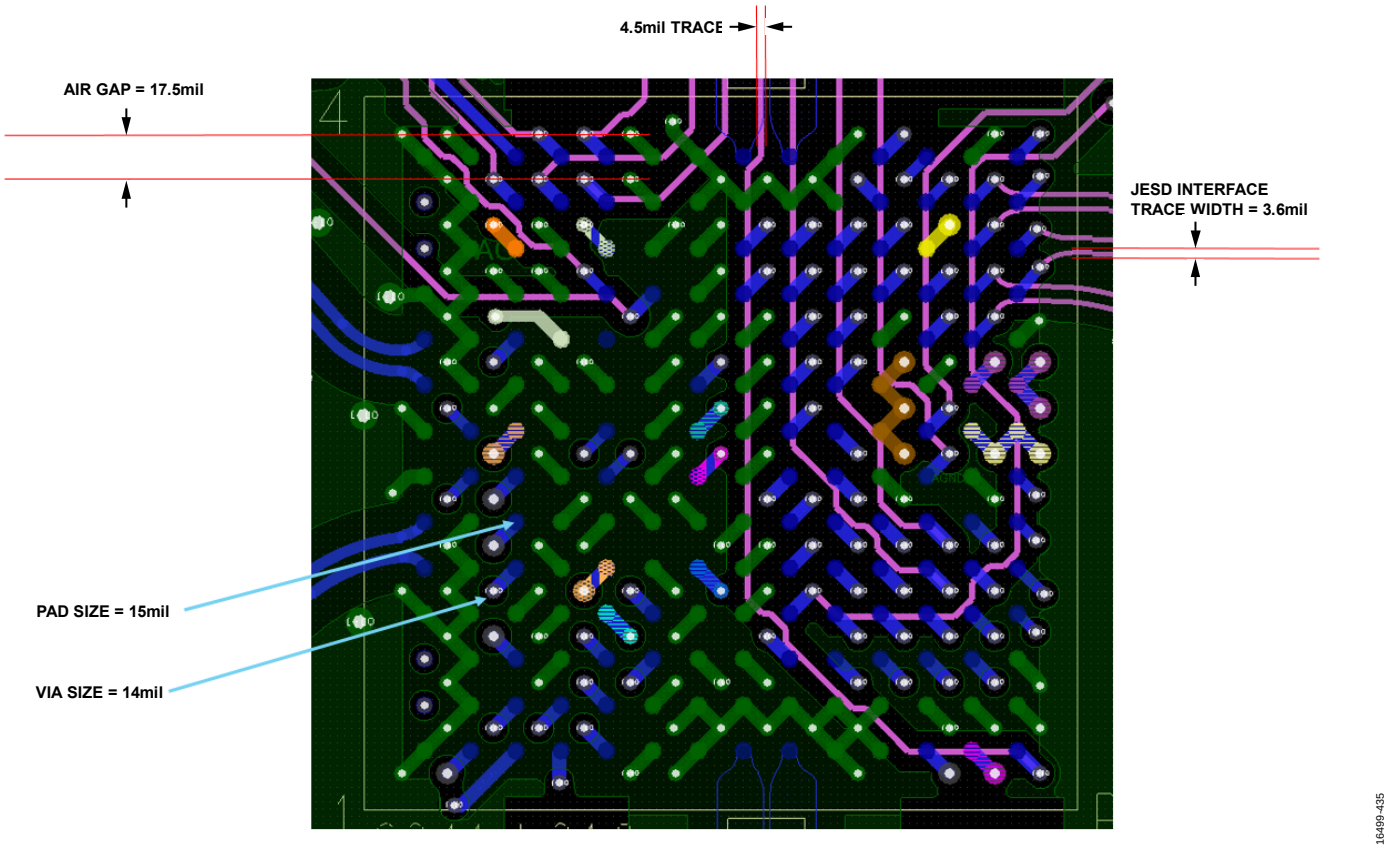

Figure 434. Trace Fanout Scheme on ADRV9009 Evaluation Card (PCB Layer Top and Layer 5 Enabled)

COMPONENT PLACEMENT AND ROUTING GUIDELINES

The ADRV9009 transceiver requires few external components to function, but those that are used require careful placement and routing to optimize performance. This section provides a checklist for properly placing and routing critical signals and components.

Signals with Highest Routing Priority

RF lines and JESD204B interface signals are the signals that are most critical and must be routed with the highest priority.

Figure 435 shows the general directions in which each of the signals must be routed so that they can be properly isolated from noisy signals.

The receiver and transmitter baluns and the matching circuits affect the overall RF performance of the ADRV9009 transceiver. Make every effort to optimize the component selection and placement to avoid performance degradation. The RF Routing Guidelines section describes proper matching circuit placement and routing in more detail. Refer to the RF Port Interface Information section for more information.

In cases in which ADRV9009 are used, install a 10 µF capacitor near the transmitter balun(s) VDDA1P8_TX dc feed(s) for RF transmitter outputs. This acts as a reservoir for the transmitter supply current. The Transmitter Balun DC Feed Supplies section discusses more details about the transmitter output power supply configuration.

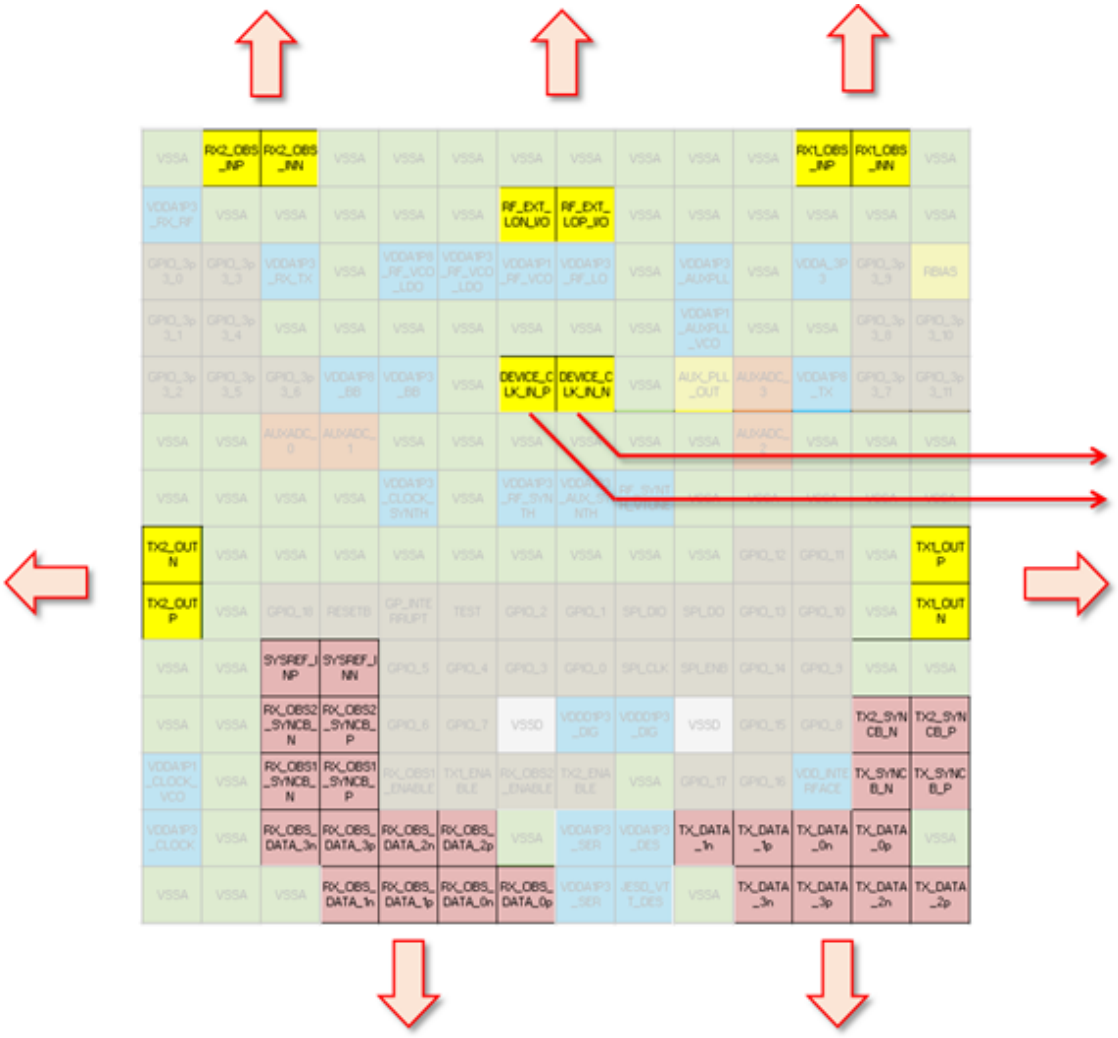

Figure 435. RF IO, DEV_CLK, and JESD204B Signal Routing Guidelines for ADRV9009

Figure 436 shows placement for ac coupling capacitors and a 100 Ω termination resistor near the ADRV9009 REF_CLK_IN± pins. Shield traces by ground surrounded with vias staggered along the edge of the trace pair. The trace pair creates a shielded channel that shields the reference clock from any interference from other signals. Refer to the ADRV9009 evaluation card layout, included board support files included with the evaluation board software, for exact details.

Route the JESD204B interface at the beginning of the PCB design and with the same priority as RF signals. The RF Routing Guidelines section outlines recommendations for JESD204B interface routing. Provide appropriate isolation between interface differential pairs. The Isolation Between JESD204B Lines section provides guidelines for optimizing isolation.

The RF_EXT_LO_I/O– (B7), RF_EXT_LO_I/O+ (B8) pins on all ADRV9009 variants are internally dc biased. If an external LO is used, connect it via ac coupling capacitors.

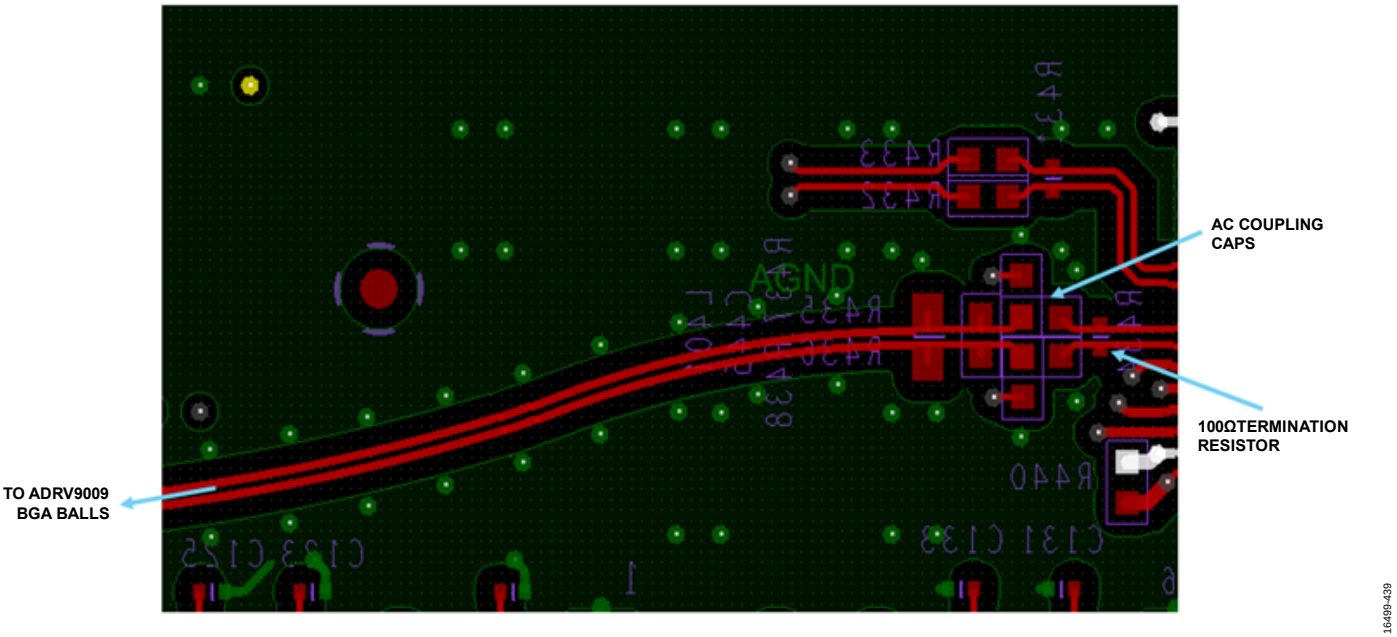

Figure 436. REF_CLK_IN Routing Recommendation

Signals with Second Routing Priority

Power supply quality has direct impact on overall system performance. To achieve optimal performance, follow recommendations regarding ADRV9009 power supply routing. The following recommendations outline how to route different power domains that can be connected together directly and that can be tied to the same supply, but are separated by a 0 Ω placeholder resistor or ferrite bead.

When the recommendation is to use a trace to connect power to a particular domain, make sure that this trace is surrounded by ground.

Figure 437 shows an example of such traces routed on the ADRV9009 evaluation card on Layer 12. Each trace is separated from any other signal by the ground plane and vias. Separating the traces from other signals is essential to providing necessary isolation between the ADRV9009 power domains.

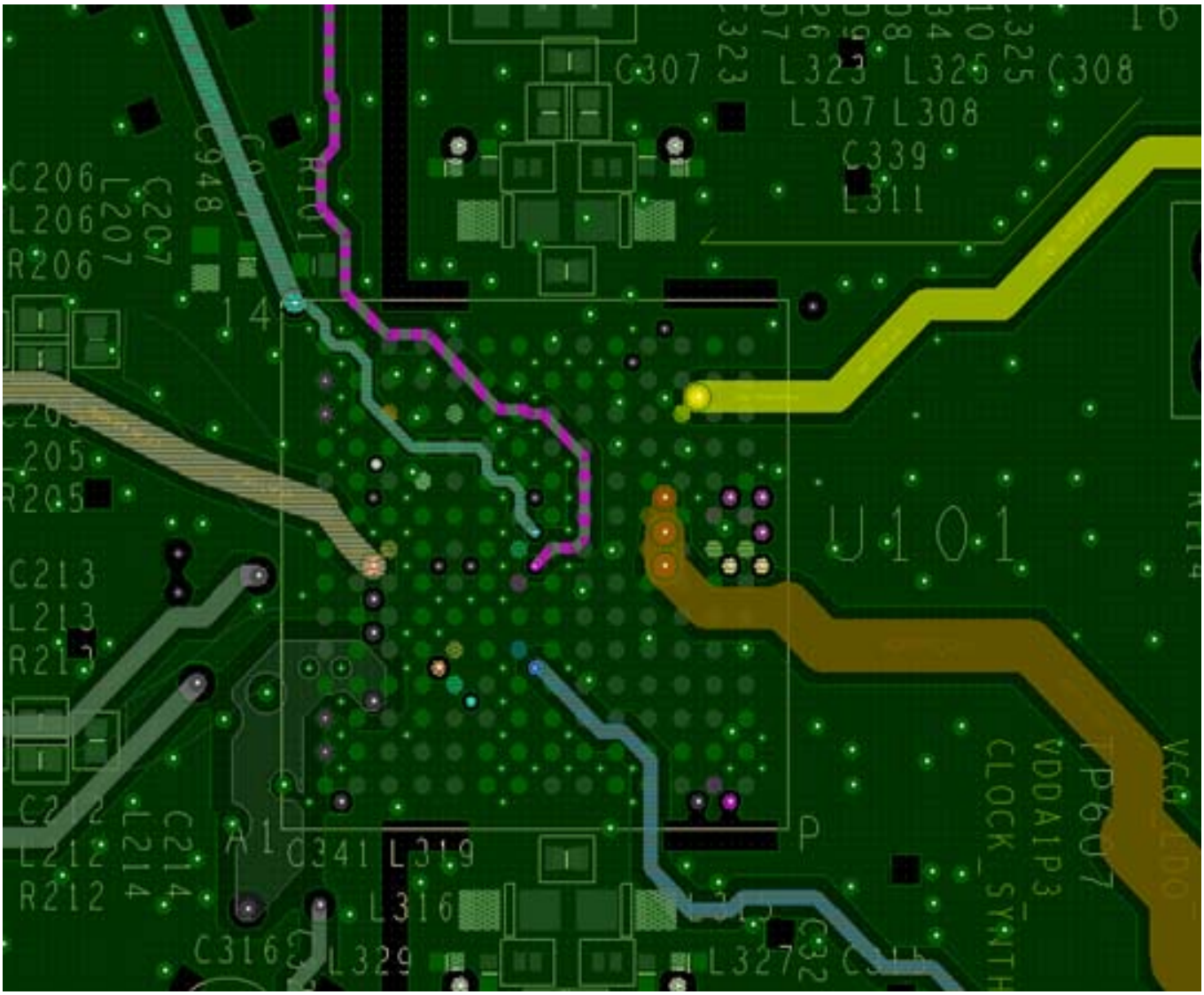

Figure 437. Layout Example of Power Supply Domains Routed with Ground Shielding (Layer 12 to Power)

Each power supply pin requires a 0.1 µF bypass capacitor near the pin at a minimum. Place the ground side of the bypass capacitor so that ground currents flow away from other power pins and their bypass capacitors.

For domains shown in Figure 438, like those domains that are powered through a 0 Ω placeholder resistor or ferrite bead (FB), place the 0 Ω placeholder resistors or ferrite beads further away from the device. Space 0 Ω placeholder resistors or ferrite beads apart from eachother to ensure the electric fields on the ferrite beads do not influence each other. Figure 439 shows an example of how the ferrite beads, reservoir capacitors, and decoupling capacitors are placed. The recommendation is to connect a ferrite bead between a power plane and the ADRV9009 at a distance away from the device The ferrite bead supplies a trace with a reservoir capacitor connected to it. Then shield that trace with ground and provide power to the power pins on the ADRV9009. Place a 100 nF capacitor near the power supply pin with the ground side of the bypass capacitor placed so that ground currents flow away from other power pins and their bypass capacitors.

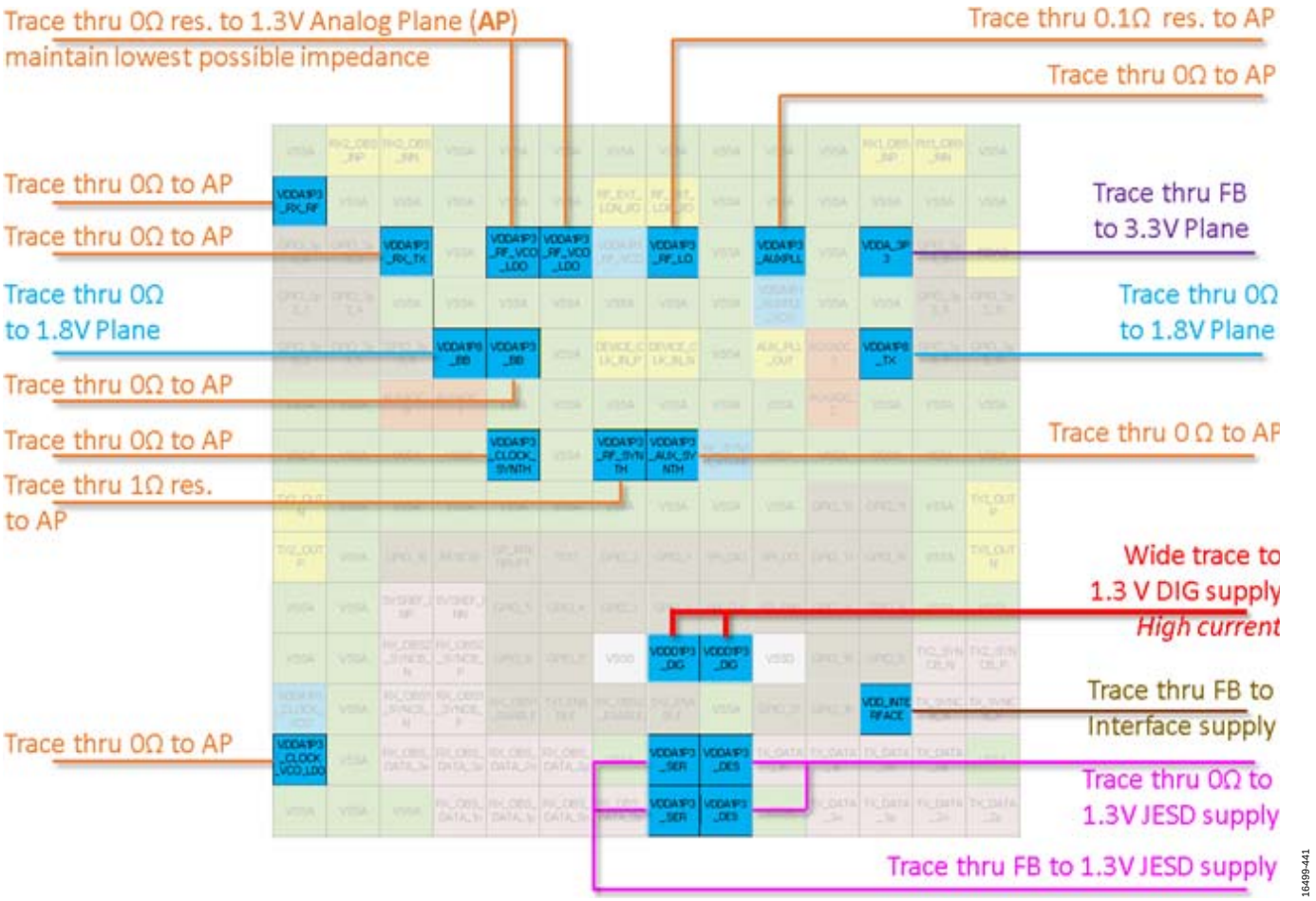

Figure 438. ADRV9009 Power Supply Domains Interconnection Guidelines

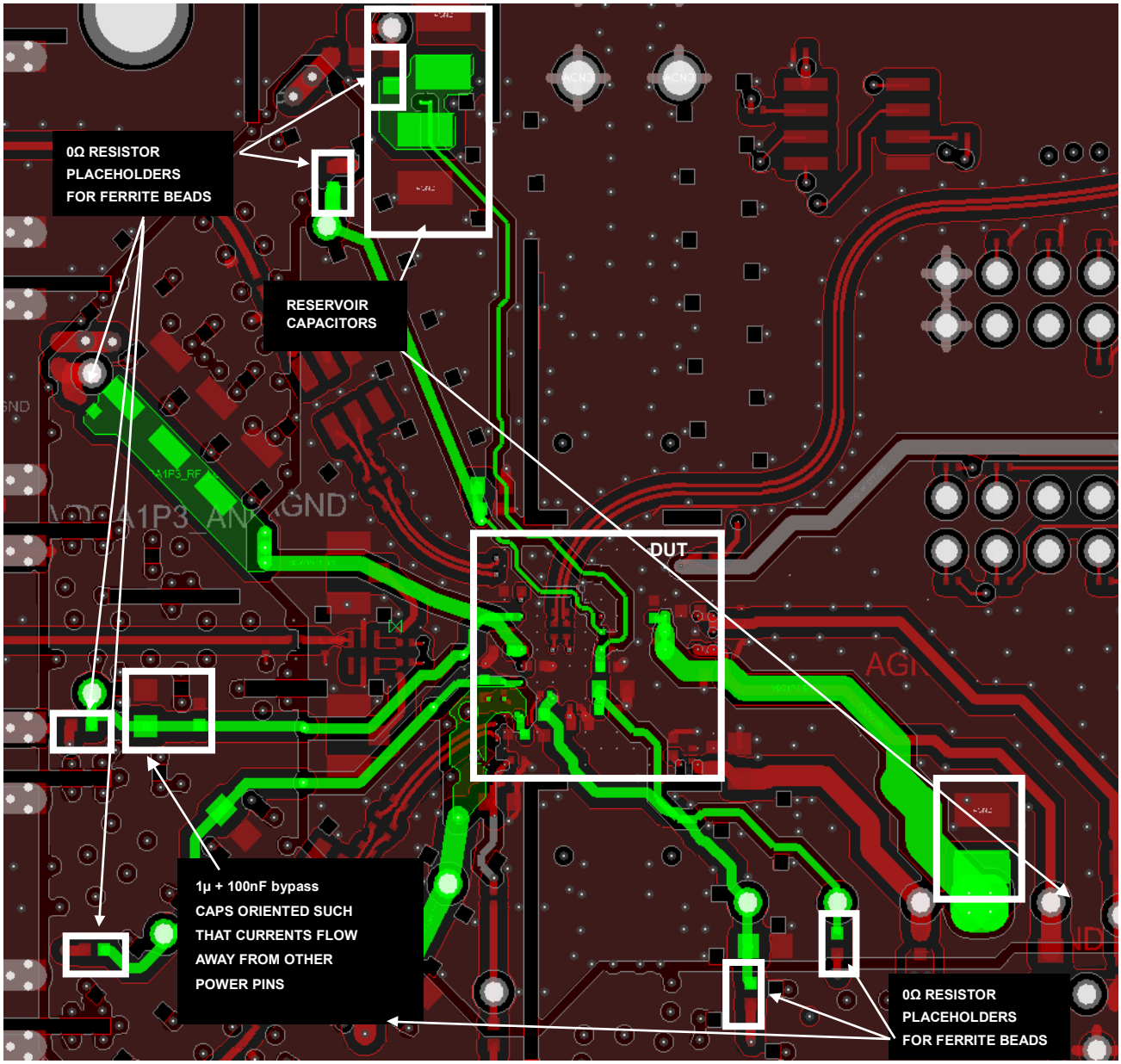

Figure 439. Placement Example of 0 Ω Resistor Placeholders for Ferrite Beads, Reservoir and Bypass Capacitors on ADRV9009 Customer Card (Layers: 12 to Power and Bottom)

Signals with Lowest Routing Priority

As a last step while designing the PCB layout, route signals shown in Figure 440. The following list outlines the recommended order of signal routing:

1. Use ceramic 1 µF bypass capacitors at the VDDA1P1_RF_VCO, VDDA1P1_AUX_VCO, and VDDA1P1_CLOCK_VCO pins. Place them as close as possible to the ADRV9009device with the ground side of the bypass capacitor placed so that ground currents flow away from other power pins and their bypass capacitors, if at all possible.
2. Connect a 14.3 kΩ resistor to the RBIAS pin (C14). This resistor must have a 1% tolerance.
3. Pull the TEST (J6) pin to ground for normal operation. The device has support for JTAG boundary scan, and this pin accesses the JTAG boundary scan. Refer to the JTAG Boundary Scan section for JTAG boundary scan information.
4. Pull the $\overline{\text{RESET}}$ pin (J4) high with a 10 kΩ resistor to VDD_INTERFACE for normal operation. To reset the device, drive the $\overline{\text{RESET}}$ pin low.

When routing analog signals such as GPIO3P3_n/AUXDAC_n or AUXADC_n, it is recommended to route them away from the digital section (Row H through Row P). Do not cross the analog section of the ADRV9009 highlighted by a red dotted line in Figure 440, by any digital signal routing.

When routing digital signals from Row H and below, it is important to route them away from the analog section (Row A through Row G). Do not cross the analog section of the ADRV9009 highlighted by a red dotted line in Figure 440 by any digital signal routing.

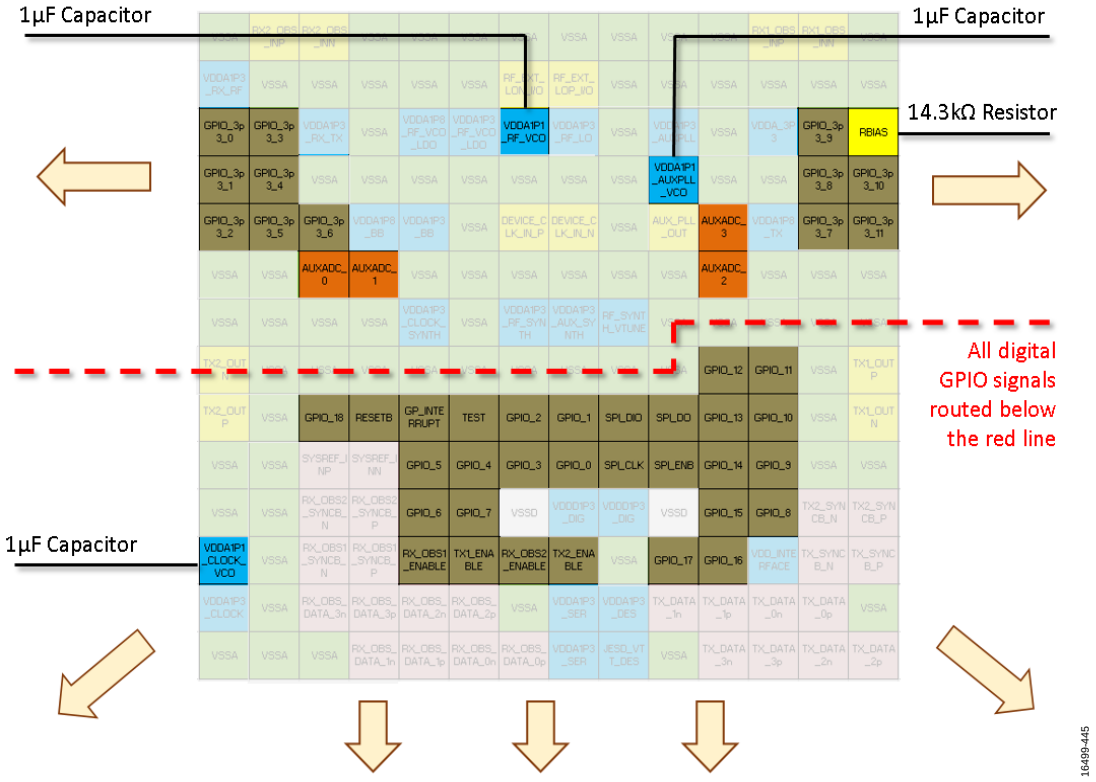

Figure 440. ADRV9009 Auxiliary ADC, Analog and Digital GPIO Signals Routing Guidelines

RF AND JESD204B TRANSMISSION LINE LAYOUT

RF Routing Guidelines

The ADRV9009 customer evaluation boards use microstrip type lines for receiver, observation receiver, and transmitter RF traces. In general, Analog Devices does not recommend using vias to route RF traces unless a direct line route is not possible. Differential lines from the balun to the receiver, observation receiver, and transmitter pins must be as short as possible. Make the length of the single-ended transmission line also short to minimize the effects of parasitic coupling. It is important to note that these traces are the most critical when optimizing performance and are, therefore, routed before any other routing. These traces have the highest priority if trade-offs are needed.

Figure 442 shows pi matching networks on the single-ended side of the baluns. The receiver front end is dc biased internally, so the differential side of the balun is ac-coupled. The system designer can optimize the RF performance with a proper selection of the balun, matching components, and ac coupling capacitors. The external LO traces and the REF_CLK_IN± traces may require matching components as well to ensure optimal performance.

All the RF signals mentioned above must have a solid ground reference under each trace. Do not run any of the critical traces over a section of the reference plane that is discontinuous. The ground flood on the reference layer must extend all the way to the edge of the board. This flood length ensures good signal integrity for the SMA launch when an edge launch connector is used.

Refer to the RF Port Interface Information section for more information on RF matching recommendations for the device.

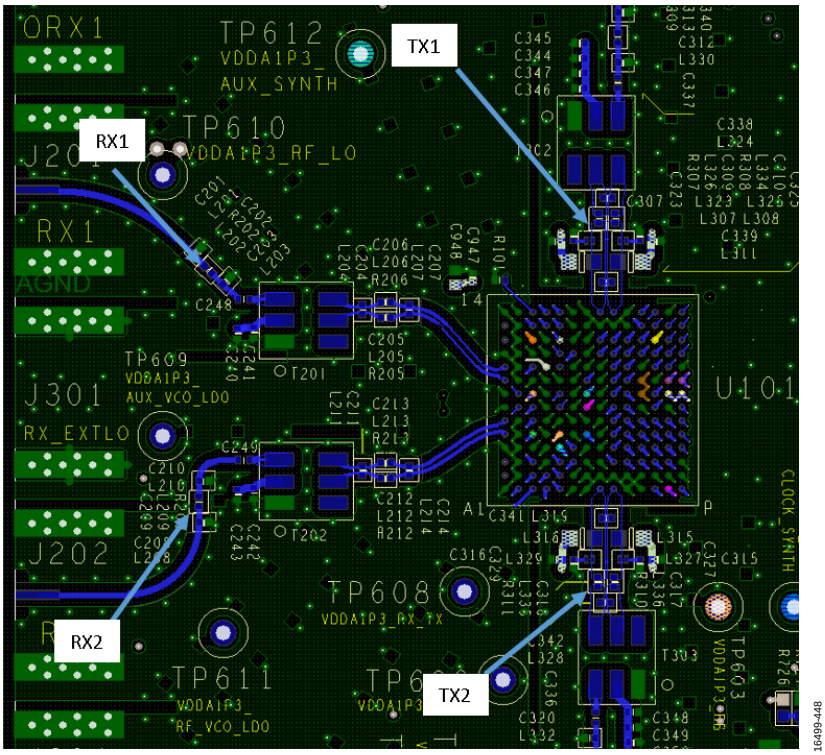

Figure 441. Pi Network Matching Components Available on Different RF Nets (Using the ADRV9009 Evaluation Card as an Example)

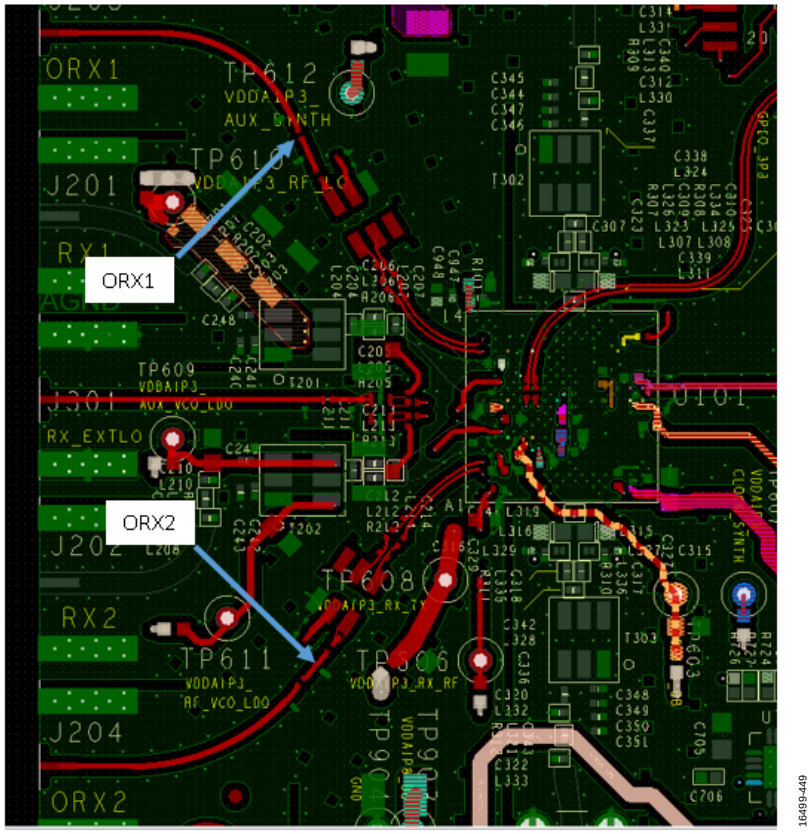

Figure 442. Pi Network Matching Components Available on Different RF Nets (Using ADRV9009 Evaluation Card as an Example)

Transmitter Balun DC Feed Supplies

Each transmitter requires approximately 200 mA supplied through an external connection. On the ADRV9008-2 and ADRV9009 customer evaluation cards, bias voltages are supplied at the dc feed of the baluns. Layout of both boards allows the use of external chokes to provide a 1.8 V power domain to the ADRV9009 outputs. This is useful in scenarios where a balun used at the transmitter output is not capable to conduct the current necessary for transmitter outputs to operate. To reduce switching transients when attenuation settings change, power the balun dc feed or transmitter output chokes directly by the 1.8 V plane. Design the geometry of the 1.8 V plane so that each balun supply or each set of two chokes is isolated from the other. This geometry can affect tansmitter to transmitter isolation. Figure 443 shows the layout configuration used on the ADRV9009 evaluation card.

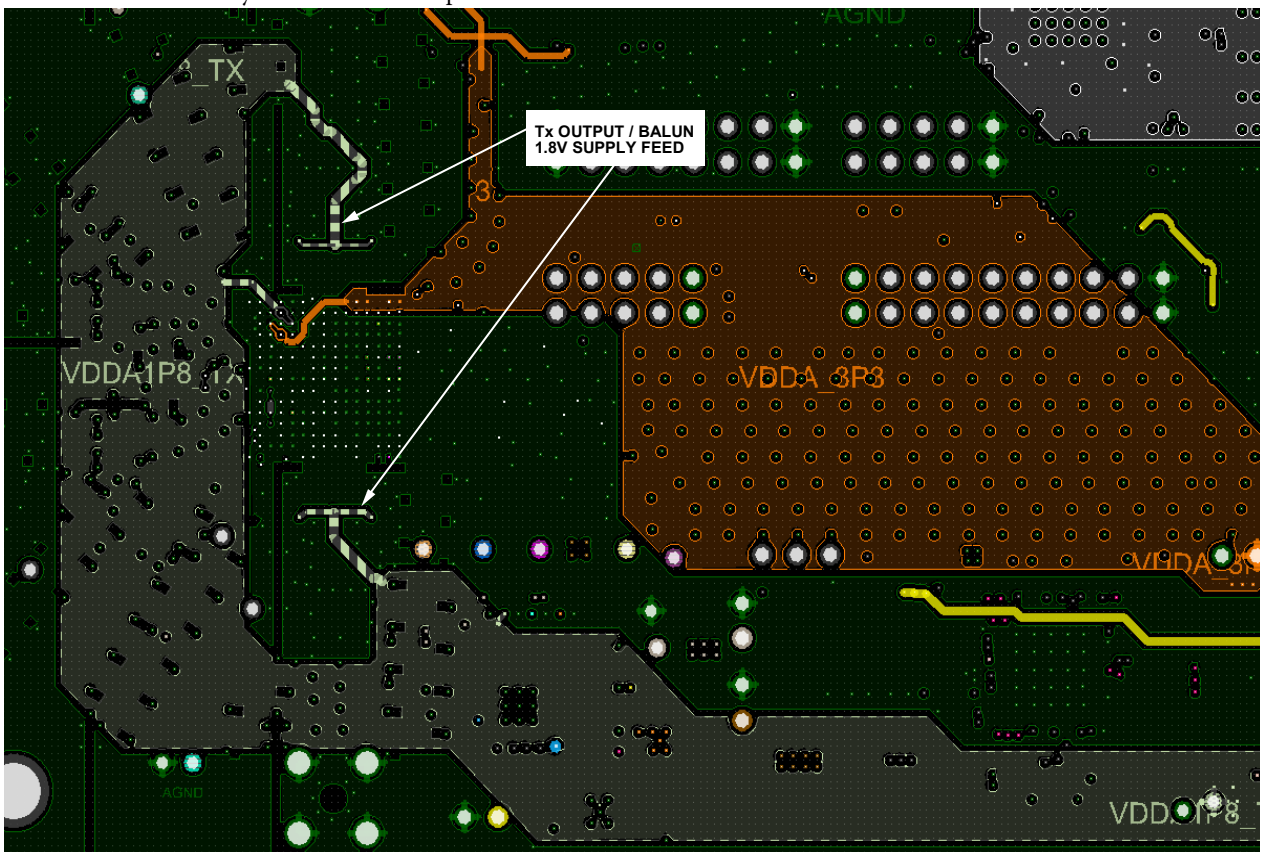

Figure 443. Transmitter Power Supply Planes (VDDA1P8_TX) on the ADRV9008-2 Evaluation Card

The positive and negative transmitter pins must be biased with 1.8 V. The biasing of the pins is accomplished on the evaluation board through dc chokes and decoupling capacitors, as shown in Figure 444. Match both chokes and their layout to avoid potential current spikes. Difference in parameters between both chokes can cause unwanted emission at transmitter outputs. Place the decoupling caps that are near the transmitter balun as close as possible to the dc feed of the balun or the ground pin. Make the orientation of the decoupling caps perpendicular to the device so that the return current forms as small a loop as possible with the ground pins surrounding the transmitter input. A combination network of capacitors provides a wideband and low impedance ground path and eliminates transmitter spectrum spurs and dampens the transients.

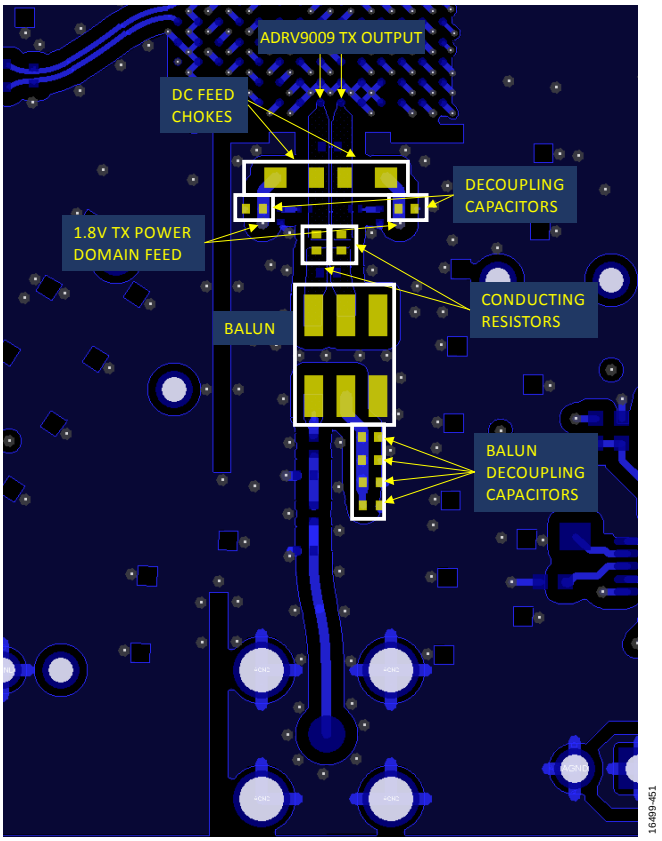

Figure 444. The Transmitter DC Chokes and Balun Feed Supply

JESD204B Trace Routing Recommendations

The ADRV9009 transceiver uses the JESD204B, high speed serial interface. To ensure optimal performance of this interface, keep the differential traces as short as possible by placing ADRV9009 as close as possible to the FPGA or BBP, and route the traces directly between the devices. Use a PCB material with a low dielectric constant (< 4) to minimize loss. For distances greater than 6 inches, use a premium PCB material such as RO4350B or RO4003C.

Routing Recommendations

Route the differential pairs on a single plane using a solid ground plane as a reference on the layers above and/or below these traces.

All JESD204B lane traces must be impedance controlled to achieve 50 Ω to ground. The differential pair is coplanar and loosely coupled. An example of a typical configuration is 5 mil trace width and 15 mil edge to edge spacing, with the trace width maximized as shown in Figure 445.

Match trace widths with pin and ball widths while maintaining impedance control. If possible, use 1 oz. copper trace widths of at least 8 mil (200 µm). The coupling capacitor pad size must match JESD204B lane trace widths If trace width does not match pad size, use a smooth transition between different widths.

The pad area for all connector and passive component choices must be minimized due to a capacitive plate effect that leads to problems with signal integrity.

Reference planes for impedance controlled signals must not be segmented or broken for the entire length of a trace.

The REF_CLK_IN signal trace and the SYSREF signal trace are impedance controlled for Z0 = 50 Ω.

Stripline Transmission Lines vs. Microstrip Transmission Lines

Stripline has less singal loss and emits less electromagnetic interference than microstrip, but stripline requires the use of vias that add line inductance, increasing the difficulty of controlling the impedance.

Microstrip is easier to implement if the component placement and density allow routing on the top layer. Microstrip makes controlling the impedance easier.

If the top layer of the PCB is used by other circuits or signals or if the advantages of stripline are more desirable over the advantages of microstrip, follow these recommendations:

- Minimize the number of vias.
- Use blind vias wherever possible to eliminate via stub effects, and use micro vias to minimize via inductance.
- When using standard vias, use maximum via length to minimize the stub size. For example, on an 8-layer board, use Layer 7 for the stripline pair.
- Place a pair of ground vias near each via pair to minimize the impedance discontinuity.

Route the JESD204B lines on the top side of the board as a differential 100 Ω pair (microstrip). For the customer evaluation board, the JESD204B differential signals are routed on inner layers of the board (Layer 5 and Layer 10) as differential 100 Ω pairs (stripline). To minimize potential coupling, these signals are placed on an inner layer using a via embedded in the component footprint pad where the ball connects to the PCB. The ac-coupling capacitors (100 nF) on these signals are placed near the connector and away from the chip to minimize coupling. The JESD204B interface can operate at frequencies of up to 12 GHz. Ensure the signal integrity from the chip to the connector is maintained.

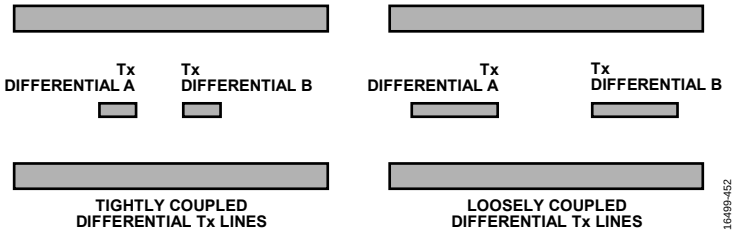

Figure 445. Routing JESD204B Differential A and Differential B Corresponding to Differential Positive Signals or Negative Signals (One Differential Pair)

ISOLATION TECHNIQUES USED ON THE ADRV9009 CUSTOMER CARD

Isolation Goals

Significant isolation challenges were overcome in designing the ADRV9009 customer card. The following isolation requirements accurately evaluate the ADRV9009 transceiver performance:

- Transmitter to transmitter, 75 dB out to 6 GHz
- Transmitter to receiver, 65 dB out to 6 GHz
- Receiver to receiver, 65 dB out to 6 GHz
- Transmitter to observation receiver, 65 dB out to 6 GHz

To meet these isolation goals with significant margin, isolation structures were introduced.

Figure 446 shows the isolation structures used on the ADRV9009 customer evaluation card. These structures consist of a combination of slots and square apertures. These structures are present on every copper layer of the PCB stack. The advantage of using square apertures is that signals can be routed between the openings without affecting the isolation benefits of the array of apertures. When using these isolation structures, make sure to place ground vias around the slots and apertures.

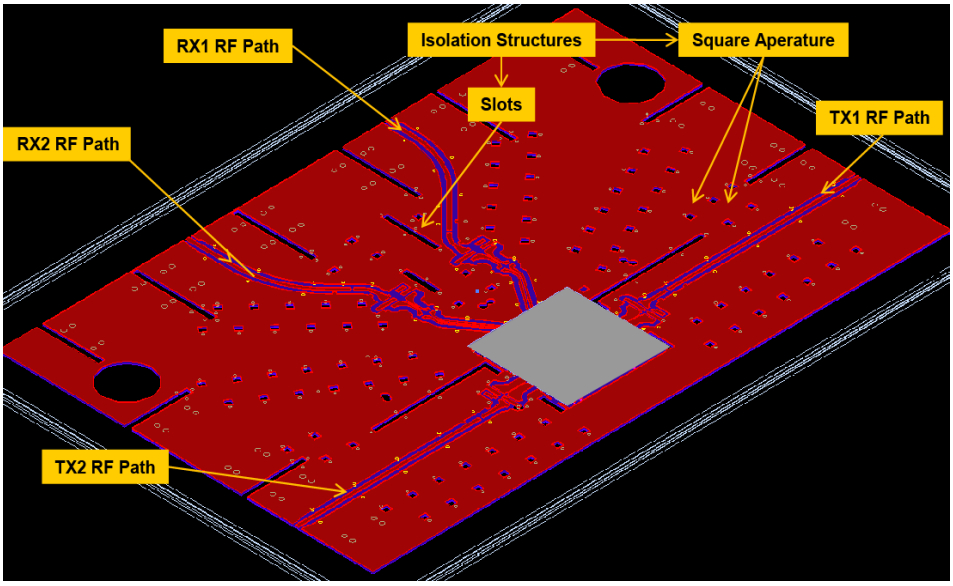

Figure 446. Isolation Structures on the ADRV9009 Customer Card

Figure 447 outlines the methodology used on the ADRV9009 evaluation card. When using slots, ground vias must be placed at the ends of the slots and along the sides of the slots. When using square apertures, at least one single ground via must be placed adjacent to each square. These vias must be through-hole vias from the top to the bottom layer. The function of these vias is to steer return current to the ground planes near the apertures.

For accurate slot spacing and square apertures layout, use simulation software when designing a PCB for the ADRV9009 transceiver. Spacing between square apertures must be no more than 1/10 of a wavelength.

Calculate the wavelength using Equation 1:

$$Wavelength\ (m) = \frac{300}{Frequency\ (\text{MHz}) \times \sqrt{E_R}} \quad (1)$$

where E_R is the dielectric constant of the isolator material. For RO4003C material, microstrip structure (+ air) E_R = 2.8. For FR4-370HR material, stripline structure E_R = 4.1.

For example, if the maximum RF signal frequency is 6 GHz, and E_R = 2.8 for RO4003C material, microstrip structure (+ air), the minimum wavelength is approximately 29.8 mm.

To follow the 1/10 wavelength spacing rule, square aperture spacing must be 2.98 mm or less.

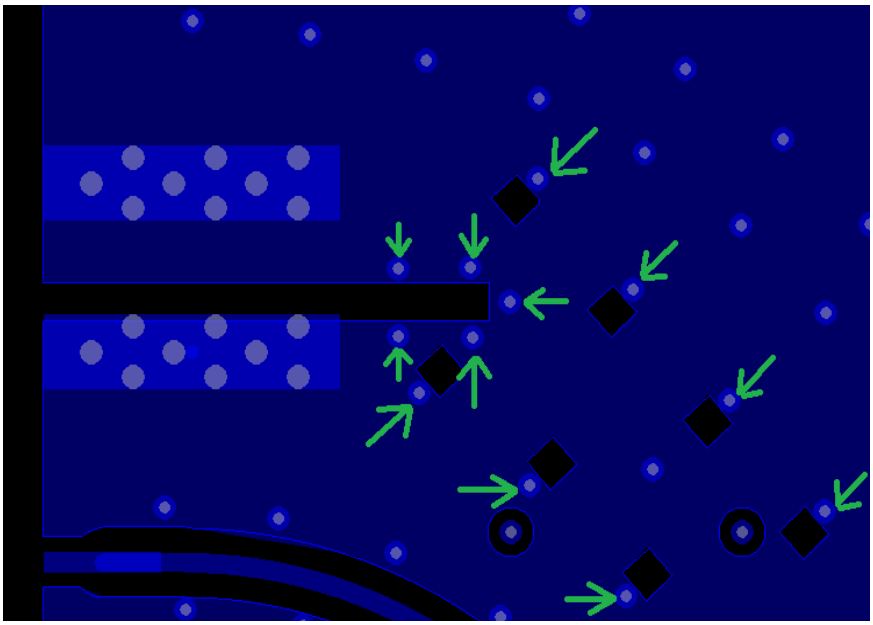

Figure 447. Current Steering Vias Placed Next to Isolation Structures

Isolation Between JESD204B Lines

The JESD204B interface uses eight line pairs that can operate at speeds of up to 12 GHz. When configuring the PCB layout, make sure these lines are routed according to the rules outlined in the JESD204B Trace Routing Recommendations section. Use isolation techniques to prevent crosstalk between different JESD204B lane pairs.

Figure 448 shows a technique used on the ADRV9009 evaluation card that involves via fencing. Placing ground vias around each JESD204B pair provides isolation and decreases crosstalk. The spacing between vias is 1.2 mm.

Figure 448 shows the rule provided in Equation 1. JESD204B lines are routed on Layer 5 and Layer 10 so that the lines use stripline structures. The dielectric material used in the inner layers of the ADRV9009 customer card PCB is FR4-370HR.

For accurate spacing of the JESD204B fencing vias, use layout simulation software. Input the following data into Equation 1 to calculate the wavelength and square aperture spacing:

- Maximum JESD204B signal frequency is approximately 12 GHz.
- For FR4-370HR material, stripline structure, E_R = 4.1, the minimum wavelength is approximately 12.4 mm.

To follow the 1/10 wavelength spacing rule, spacing between vias must be 1.24 mm or less. The minimum spacing recommendation according to transmission line theory is 1/4 wavelength.

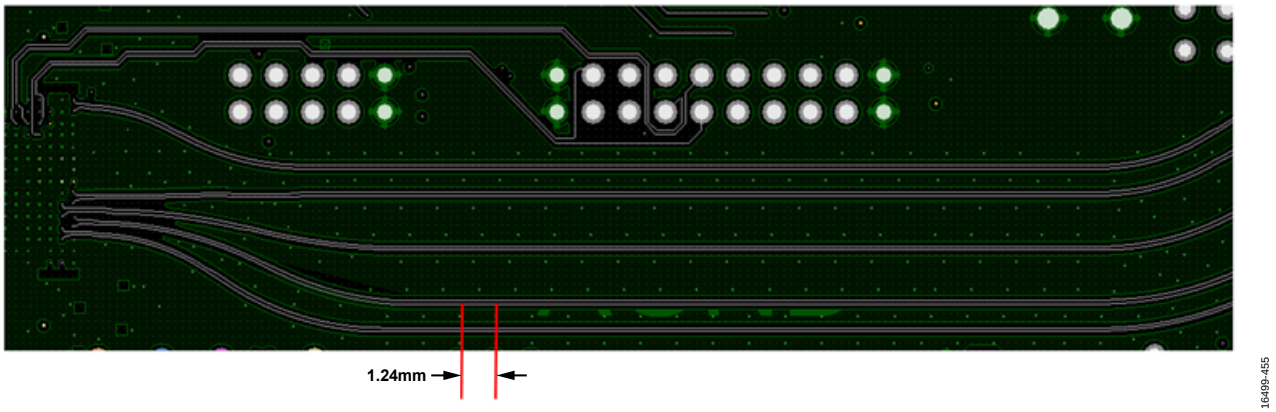

Figure 448. Via Fencing Around JESD204B Lines, PCB Layer 10

RF PORT INTERFACE INFORMATION

RF Port Interface Overview

This section details the RF transmitter and receiver interfaces for optimal device performance. This section also includes data for the anticipated ADRV9009 RF port impedance values and examples of impedance matching networks used in the evaluation platform. This section also provides information on board layout techniques and balun selection guidelines.

The ADRV9009 is a highly integrated transceiver with transmit, receive, and observation (DPD) receive signal chains. External impedance matching networks are required on the transmitter and receiver ports to achieve the performance levels described in this data sheet.

Analog Devices recommends the use of simulation tools in the design and optimization of impedance matching networks. To achieve the closest match between computer simulated results and measured results, accurate models of the board environment, SMD components (including baluns and filters), and ADRV9009 port impedances are required.

RF Port Impedance Data

This section provides the port impedance data for all transmitters and receivers in the ADRV9009 integrated transceiver. Note the following:

- Z0 is defined as 50 Ω.
- The ADRV9009 ball pads are the reference plane for this data.
- Single-ended mode port impedance data is not available. However, a rough assessment is possible by taking the differential mode port impedance data and dividing both the real and imaginary components by 2.
- Contact Analog Devices applications engineering for the impedance data in Touchstone format.

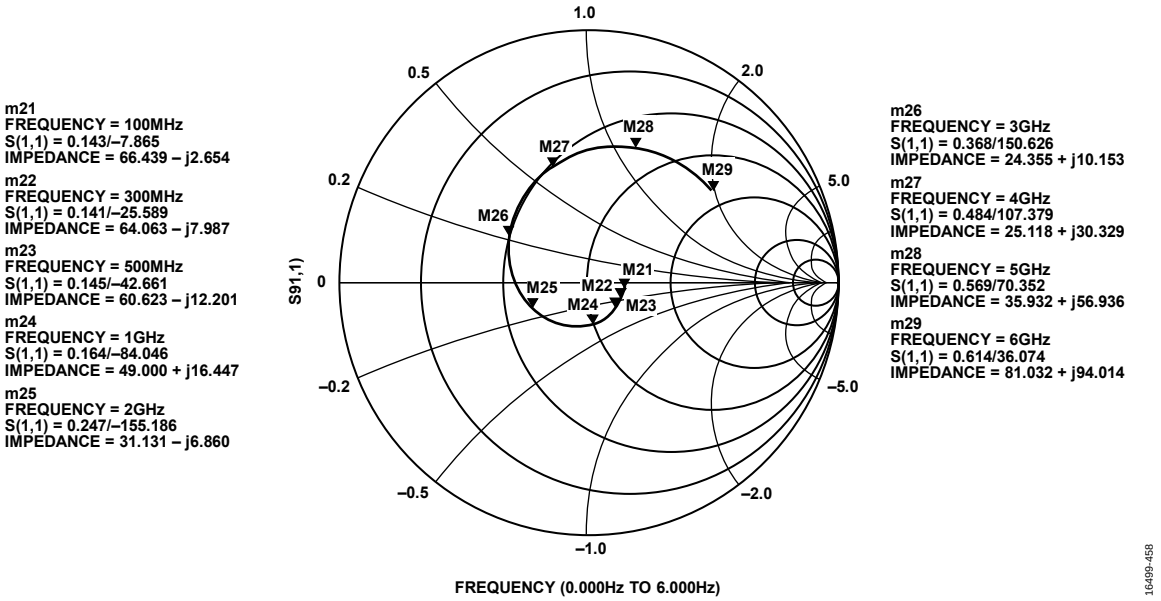

Figure 449. Transmitter 1 and Transmitter 2 SEDZ and PEDZ Data

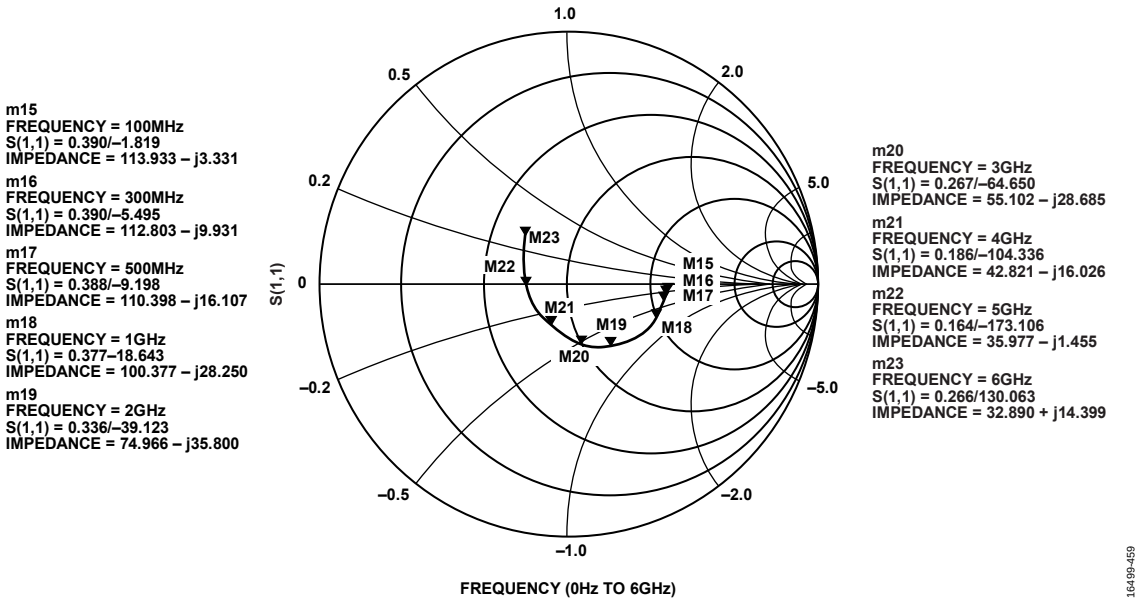

Figure 450. Receiver 1 and Receiver 2 SEDZ and PEDZ Data

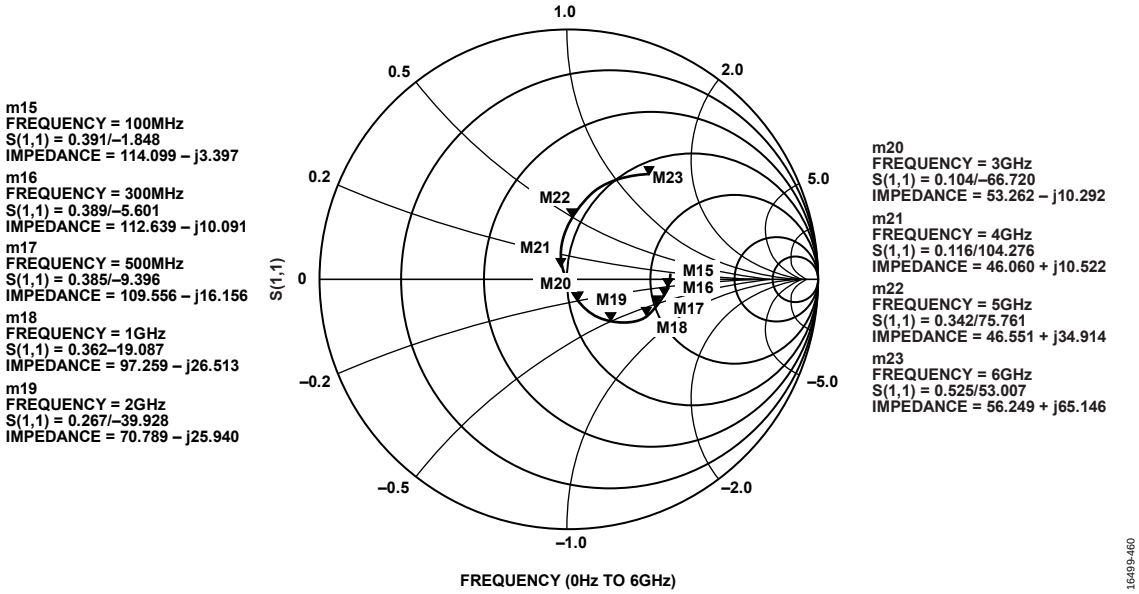

Figure 451. Observation Receiver 1 and Observation Receiver 2 SEDZ and PEDZ Data

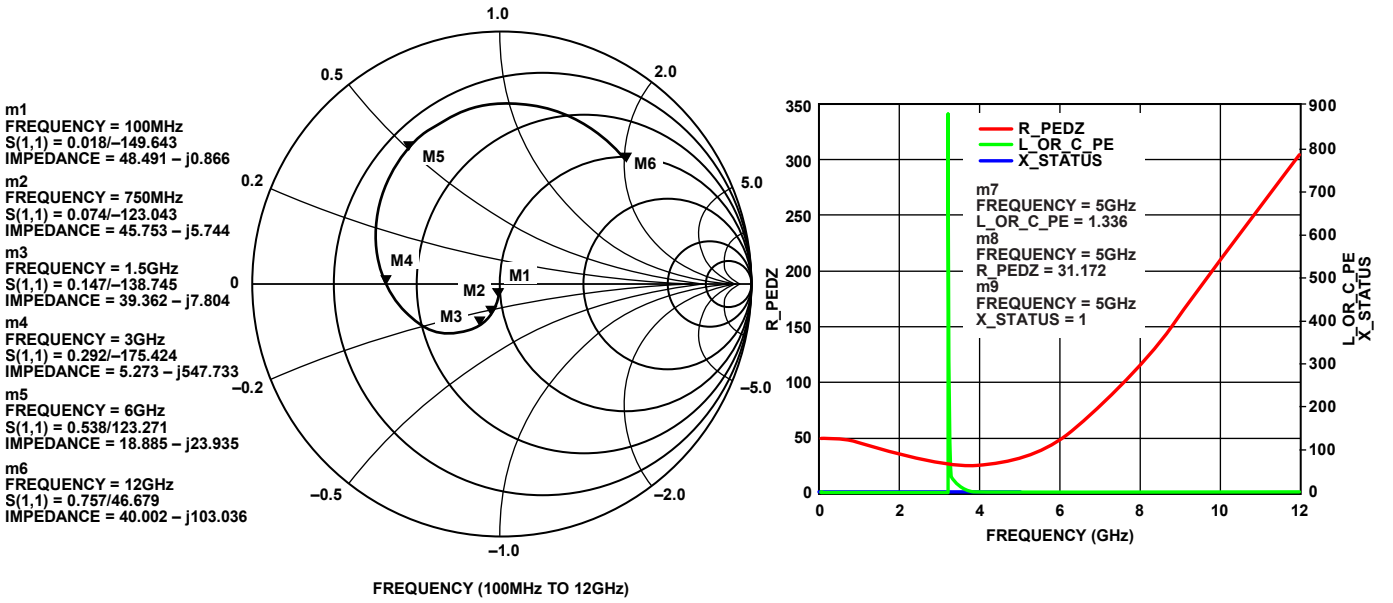

Figure 452. RF_EXT_LO_I/O± SEDZ and PEDZ Data

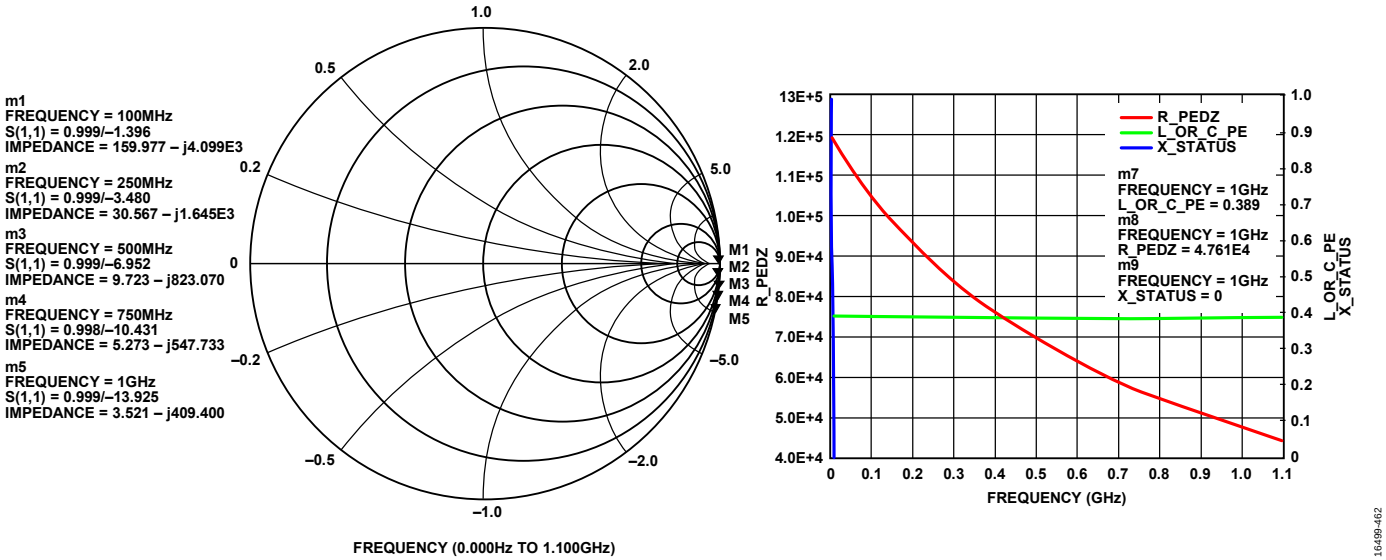

Figure 453. ADRV9009 REF_CLK_IN± SEDZ and PEDZ Data (On Average, the Real Part of the Parallel Equivalent Differential Impedance (R_P) = ~ 70 kΩ)

Advanced Design System (ADS) Setup Using the DataAccessComponent and SEDZ File

Analog Devices supplies the port impedance as an **.s1p** file that can be downloaded from the ADRV9009 product page. This format allows simple interfacing to ADS by using the data access component. In Figure 454, Term 1 is the single-ended input or output, and Term 2 represents the differential input or output RF port on ADRV9009. The pi on the single-ended side and the differential pi configuration on the differential side allow maximum flexibility in designing matching circuits. The pi configuration is suggested for all design layouts because the pi configuration can step the impedance up or down as needed with appropriate component population.

The mechanics of setting up a simulation for impedance measurement and impedance matching is as follows:

1. The data access component block reads the **rf port.s1p** file. This is the device RF port reflection coefficient.
2. The two equations convert the RF port reflection coefficient to a complex impedance. The result is the RX_SEDZ variable.
3. The RF port calculated complex impedance (RX_SEDZ) is utilized to define the Term 2 impedance.
4. Term 2 is used in a differential mode, and Term 1 is used in a single-ended mode.
5. Setting up the simulation this way allows one to measure the S11, S22, and S21 of the three port system without complex math operations within the display page.

For highest accuracy, EM modelling result of the PCB artwork and S-parameters of the matching components and balun must be used in the simulations.

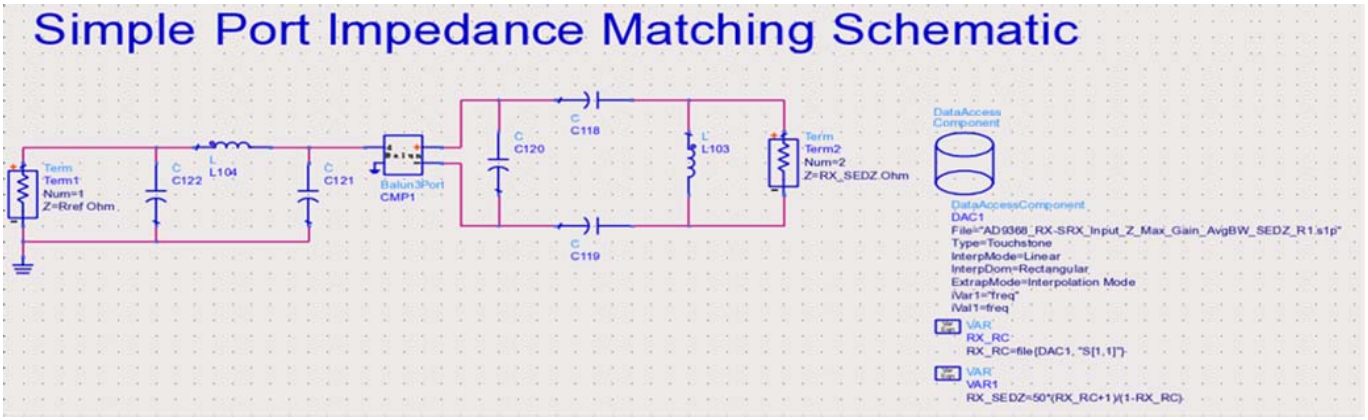

*Figure 454. Simulation Setup in ADS with SEDZ **.s1p** Files and DataAccessComponent*

Transmitter Bias and Port Interface

This section considers the dc biasing of the ADRV9009 transmitter outputs and how to interface to each transmitter port. The ADRV9009 transmitters operate over a range of frequencies. At full output power, each differential output side draws approximately 100 mA of dc bias current. The transmitter outputs are dc biased to a 1.8 V supply voltage using either RF chokes (wire wound inductors) or a transformer center tap connection.

Careful design of the dc bias network is required to ensure optimal RF performance levels. When designing the dc bias network, select components with low dc resistance (R_{DCR}) to minimize the voltage drop across the series parasitic resistance element with either of the suggested dc bias schemes suggested in Figure 455. The R_DCR resistors indicate the parasitic elements. As the impedance of the parasitics increases, the voltage drop (ΔV) across the parasitic element increases, which causes the transmitter RF performance ($P_{O,1dB}$, $P_{O,MAX}$, and so on) to degrade. The choke inductance (L_C) must be at least 3× times higher than the load impedance at the lowest desired frequency so that it does not degrade the output power (see Table 11).

The recommended dc bias network is shown in Figure 456. This network has fewer parasitics and fewer total components.

Figure 457 through Figure 460 identify four basic differential transmitter output configurations. Except for in cases in which impedance is already matched, impedence matching networks (balun single-ended port) are required to achieve optimum device performance from the device. In applications in which the transmitter is not connected to another circuit that requires or can tolerate dc bias on the transmitter outputs, the transmitter outputs must be ac-coupled in because of the dc bias voltage applied to the differential output lines of the transmitter.

The recommended RF transmitter interface is shown in Figure 455 to Figure 460 featuring a center tapped balun. This configuration offers the lowest component count of the options presented.

Descriptions of the transmitter port interface schemes are as follows:

- In Figure 457, the center tapped transformer passes the bias voltage directly to the transmitter outputs.
- In Figure 458, RF chokes bias the differential transmitter output lines. Additional coupling capacitors (C_C) are added in the creation of a transmission line balun
- In Figure 459, RF chokes bias the differential transmitter output lines and connect into a transformer
- In Figure 460, RF chokes bias the differential output lines that are ac-coupled into the input of a driver amplifier.

If a transmitter balun that requires a set of external dc bias chokes is selected, careful planning is required. It is necessary to find the optimum compromise between the choke physical size, choke dc resistance (RDCR), and the balun low frequency insertion loss. In commercially available dc bias chokes, resistance decreases as size increases. As choke inductance increases, resistance increases. It is undesirable to use physically small chokes with high inductance because small chokes exhibit the greatest resistance. For example, the voltage drop of a 500 nH 0603 choke at 100 mA is roughly 50 mV.

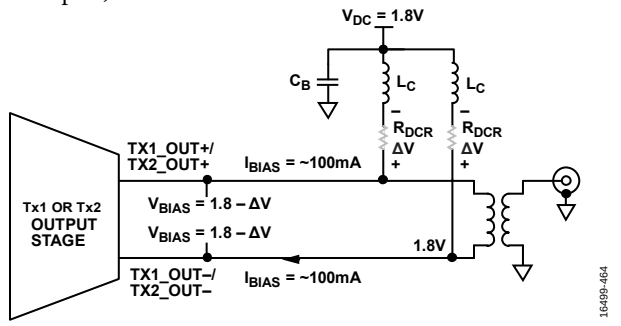

Figure 455. ADRV9009 RF DC Bias Configurations Depicting Parasitic Losses due to Wire Wound Chokes

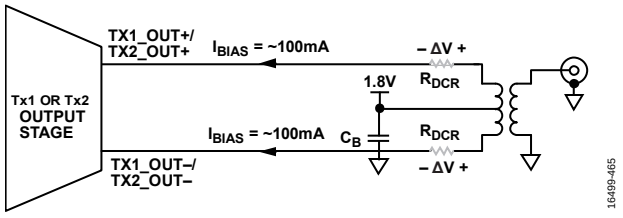

Figure 456. ADRV9009 RF DC Bias Configurations Depicting Parasitic Losses due to Center Tapped Transformers

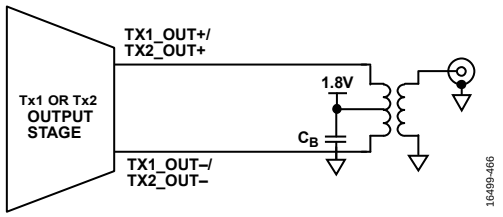

Figure 457. ADRV9009 RF Transmitter Interface Configurations

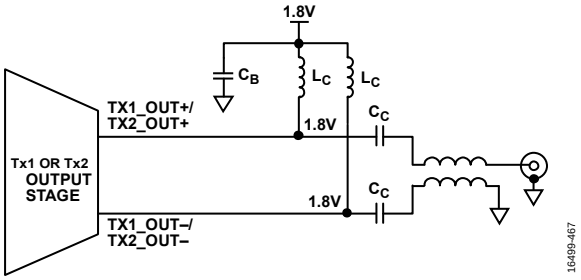

Figure 458. ADRV9009 RF Transmitter Interface Configurations

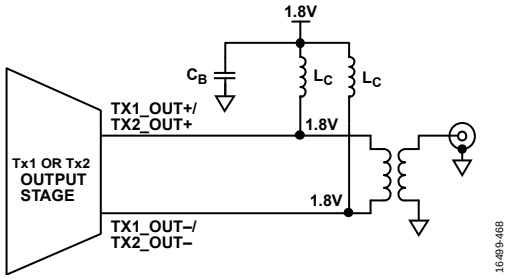

Figure 459. ADRV9009 RF Transmitter Interface Configurations

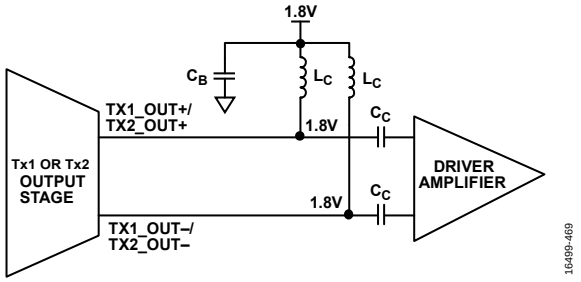

Figure 460. ADRV9009 RF Transmitter Interface Configurations

Table 11. Sample Wire Wound DC Bias Choke Resistance vs. Size vs. Inductance

Inductance (nH)	Resistance (Size: 0603)	Resistance (Size: 1206)
100	0.10	0.08
200	0.15	0.10
300	0.16	0.12
400	0.28	0.14
500	0.45	0.15
600	0.52	0.20

General Receiver Path Interface

The ADRV9009 has three types of receivers. These receivers include two main receive pathways (Receiver 1 and Receiver 2) and two observation or DPD receivers (Observation Receiver 1 and Observation Receiver 2). The receivers can support up to a 200 MHz bandwidth, and the observation receivers can support up to a 450 MHz bandwidth. The receiver channels and observation receiver channels are designed for differential use.

The ADRV9009 receivers support a wide range of operation frequencies. In the case of the receiver channels and observation receiver channels, the differential signals interface to an integrated mixer. The mixer input pins have a dc bias of approximately 0.7 V and may need to be ac-coupled, depending on the common-mode voltage level of the external circuit.

Important considerations for the receiver port interface are as follows:

- The device to be interfaced (filter, balun, T/R switch, external LNA, external PA, and so on).
- The receiver and observation receiver maximum safe input power is 23 dBm (peak).
- The receiver and observation receiver optimum dc bias voltage is 0.7 V bias to ground.
- The board design (reference planes, transmission lines, impedance matching, and so on).

Figure 461 and Figure 462 show possible differential receiver port interface circuits. The options in Figure 461 and Figure 462 are valid for all receiver inputs operating in differential mode, though only the Receiver 1 signal names are indicated. Impedance matching may be necessary to obtain the performance levels described in the data sheet.

Given wide RF bandwidth applications, SMD balun devices function well. Decent loss and differential balance are available in a relatively small (0603, 0805) package.

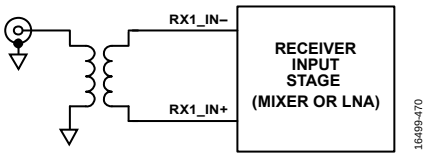

Figure 461. Differential Receiver Interface Using a Transformer

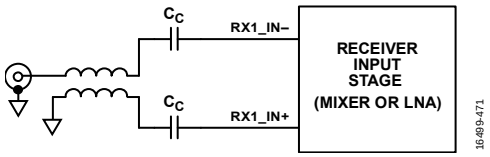

Figure 462. Differential Receiver Interface Using a Transmission Line Balun

Impedance Matching Network Examples

Impedance matching networks are required to achieve the ADRV9009 performance levels. This section provides example topologies and components used on the ADRV9009 customer evaluation boards.

Device models, board models, balun and SMD component models are required to build an accurate system level simulation. The board layout model can be obtained from an electromagnetic momentum (EM) simulator. The balun and SMD component models can be obtained from the device vendors or built locally. Contact Analog Devices applications engineering for ADRV9009 modeling details.

The impedance matching networks provided in this section have not been evaluated in terms of mean time to failure (MTTF) in high volume production. Consult with component vendors for long-term reliability concerns. Consult with balun vendors to determine appropriate conditions for dc biasing.

Figure 465 shows three elements in parallel marked do not install (DNI). However, only one set of SMD component pads is placed on the board. For example, R202, L202, and C202 components only have one set of SMD pads for one SMD component. Figure 465 shows that in a generic port impedance matching network, the shunt or series elements may be a resistor, inductor, or capacitor.

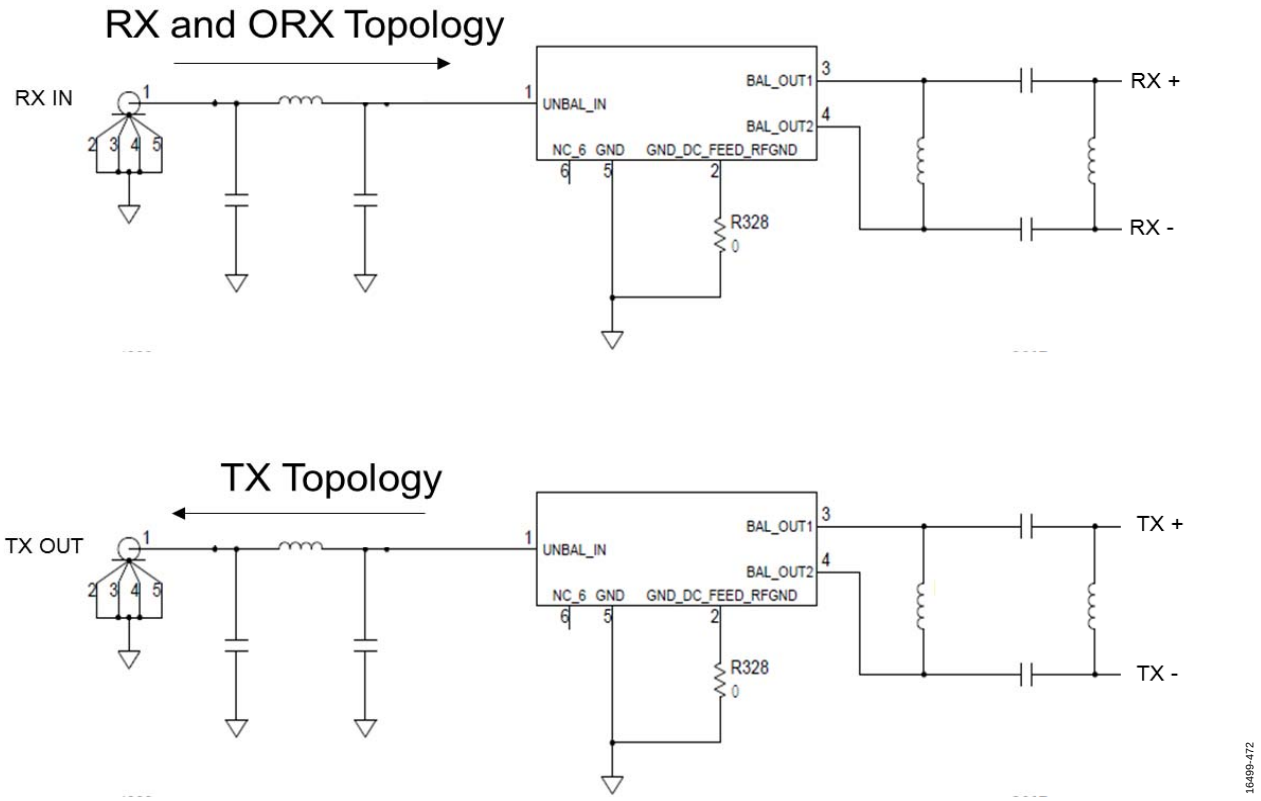

Figure 463. Impedance Matching Topology

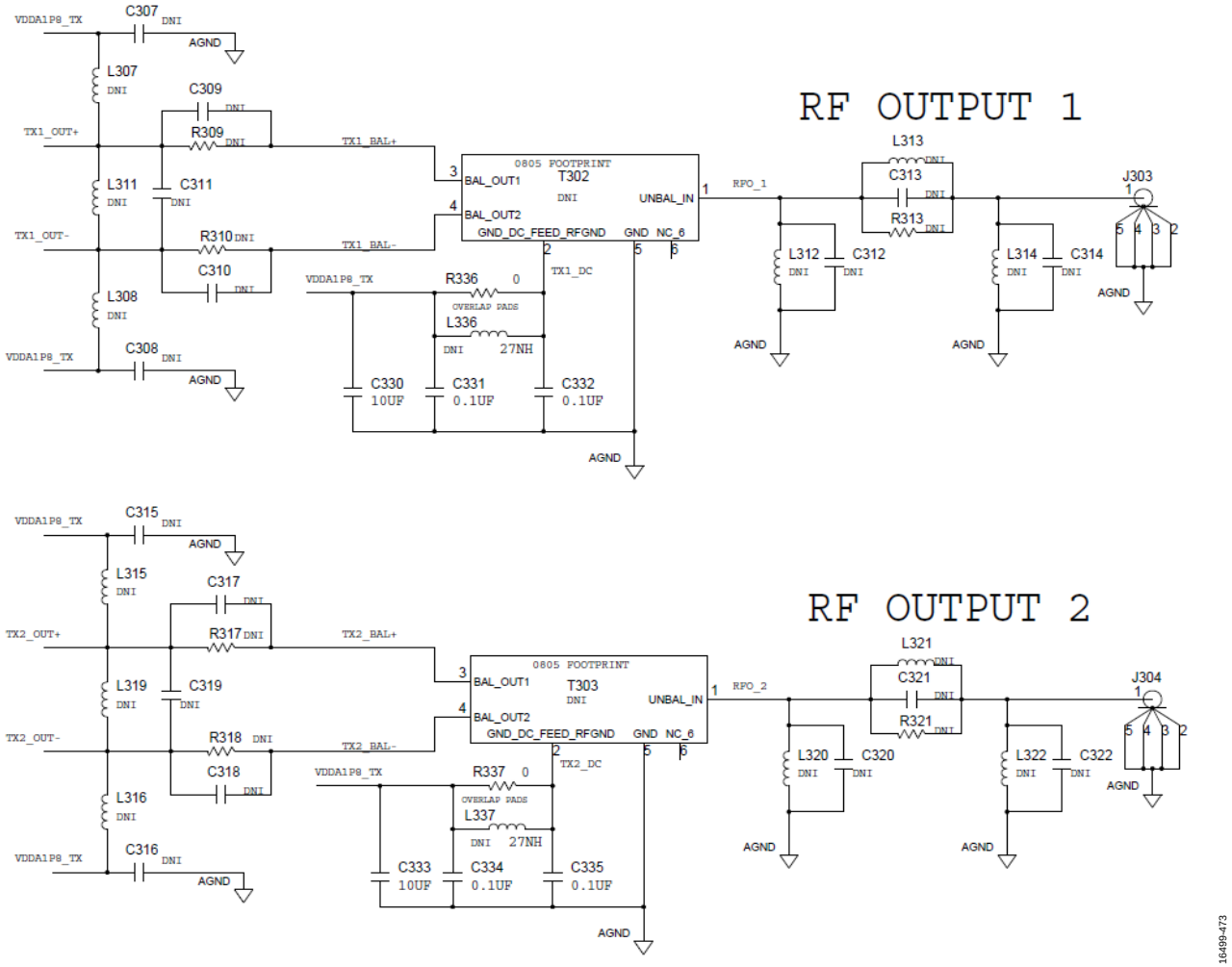

Figure 464. Transmitter 1 and Transmitter 2 Generic Matching Network Topology

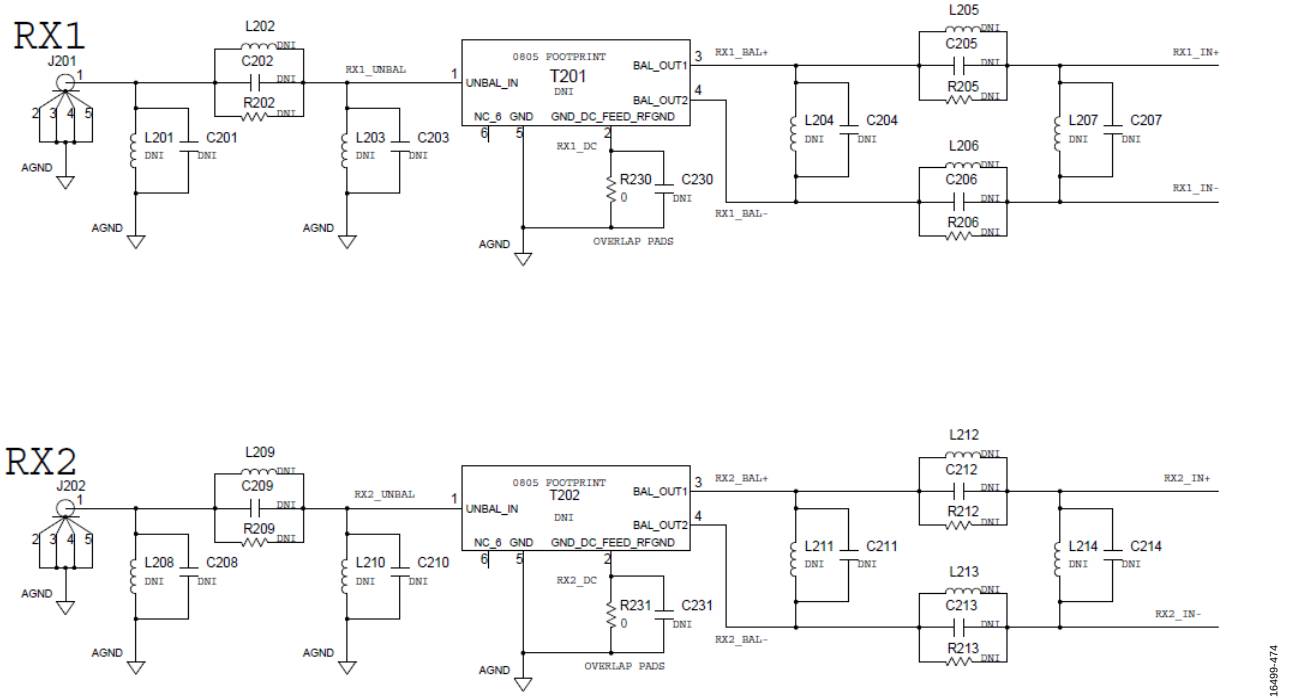

Figure 465. Receiver 1 and Receiver 2 Generic Matching Network Topology

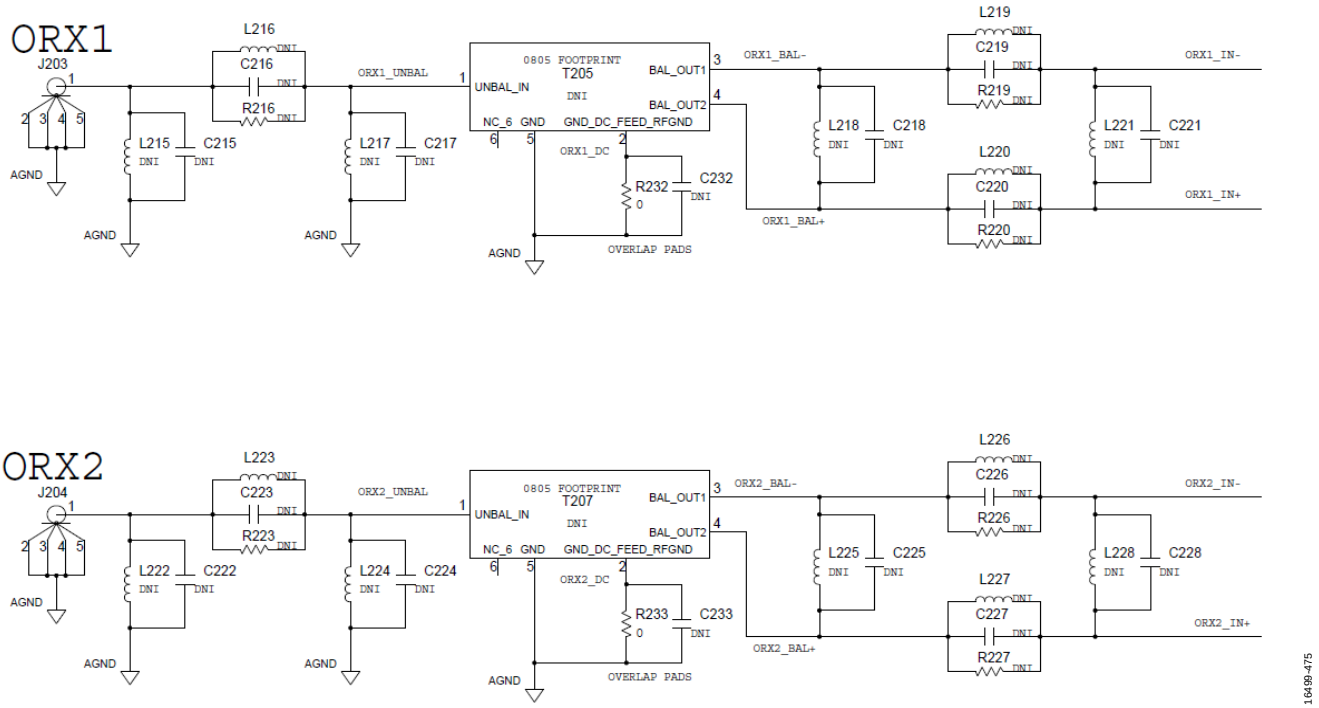

Figure 466. Observation Receiver 1 and Observation Receiver 2 Generic Matching Network Topology

Table 12 through Table 17 show the selected balun and component values used for three matching network sets. Refer to the ADRV9009 schematics for a wideband matching example that operates across the entire device frequency range with somewhat reduced performance.

The RF matching used in the ADRV9009 evaluation board allows the device to operate across the entire chip frequency range with slightly reduced performance. See the board support files included with the evaluation board software for component configuration and device numbers.

Table 12. Receiver 1 EVB Matching Components

Frequency Band	201	202	203	204	205, 206	207	T201
625 MHz to 2815 MHz	22 nH	12 pF	62 nH	180 nH	39 pF	91 nH	Johanson 1720BL15A0100
3400 MHz to 4800 MHz	DNI[1]	0 Ω	DNI	18 nH	1.3 nH	0.4 pF	Anaren BD3150L50100AHF
5300 MHz to 5900 MHz	DNI	0.6 nH	DNI	DNI	0.4 pF	4.3 nH	Johanson 5400BL15B200

[1] DNI means do not install.

Table 13. Receiver 2 EVB Matching Components

Frequency Band	208	209	210	211	212, 213	214	T202
625 MHz to 2815 MHz	22nH	12 pF	62 nH	180 nH	39 pF	91 nH	Johanson 1720BL15A0100
3400 MHz to 4800 MHz	DNI[1]	0 Ω	DNI	18 nH	1.3 nH	0.4 pF	Anaren BD3150L50100AHF
5300 MHz to 5900 MHz	DNI	0.6 nH	DNI	DNI	0.4 pF	4.3 nH	Johanson 5400BL15B200

[1] DNI means do not install.

Table 14. Observation Receiver 1 EVB Matching Components

Frequency Band	215	216	217	218	219, 220	221	T205
625 MHz to 2815 MHz	DNI[1]	0 Ω	DNI	56 nH	5.6 pF	180 nH	Johanson 1720BL15A0100
3400 MHz to 4800 MHz	0.3 pF	1.6 pF	2 nH	6.8 nH	1.7 nH	220 nH	Anaren BD3150L50100AHF
5300 MHz to 5900 MHz	100nH	6.8 pF	5.6 nH	DNI	0.8 pF	1.5 nH	Johanson 5400BL15B200

[1] DNI means do not install.

Table 15. Observation Receiver 2 EVB Matching Components

Frequency Band	222	223	224	225	226, 227	228	T207
625 MHz to 2815 MHz	DNI[1]	0 Ω	Do not install	56 nH	5.6 pF	180 nH	Johanson 1720BL15A0100
3400 MHz to 4800 MHz	0.3 pF	1.6 pF	2 nH	6.8 nH	1.7 nH	220 nH	Anaren BD3150L50100AHF
5300 MHz to 900 MHz	100 nH	6.8 pF	5.6 nH	DNI	0.8 pF	1.5 nH	Johanson 5400BL15B200

[1] DNI means do not install.

Table 16. Transmitter 1 EVB Matching Components[1]

Frequency Band	314	313	312	309, 310	311	T302	T302 Pin 2, Bypass Capacitor C332	C307, C308, L307, L308
625 MHz to 2815 MHz	22 nH	4.7 pF	43 nH	0 Ω	0.2 pF	Johanson 1720BL15B0050	33 pF	DNI
3400 MHz to 4800 MHz	DNI[2]	0 Ω	DNI	2.7 nH	0.2 pF	Anaren BD3150L50100AHF	3.9 pF	DNI
5300 MHz to 5900 MHz	DNI	0 Ω	DNI	0.9 nH	8.2 nH	Johanson 5400BL14B100	1.8 pF	DNI

[1] These matches provide VDDA1P8_TX to the TXx_OUT± pins through the balun.
[2] DNI means do not install.

Table 17. Transmitter 2 EVB Matching Components[1]

Frequency Band	322	321	320	317, 318	319	T303	T303 Pin 2, Bypass Capacitor C335	C315, C316, L315, L316
625 MHz to 2815 MHz	22 nH	4.7 pF	43 nH	0 Ω	0.2 pF	Johanson 1720BL15B0050	33 pF	DNI
3400 MHz to 4800 MHz	DNI[2]	0 Ω	DNI	2.7 nH	0.2 pF	Anaren BD3150L50100AHF	3.9 pF	DNI
5300 MHz to 5900 MHz	DNI	0 Ω	DNI	0.9 nH	8.2 nH	Johanson 5400BL14B100	1.8 pF	DNI

[1] These matches provide VDDA1P8_TX to the TXx_OUT± pins through the balun.
[2] DNI means do not install.

OUTLINE DIMENSIONS

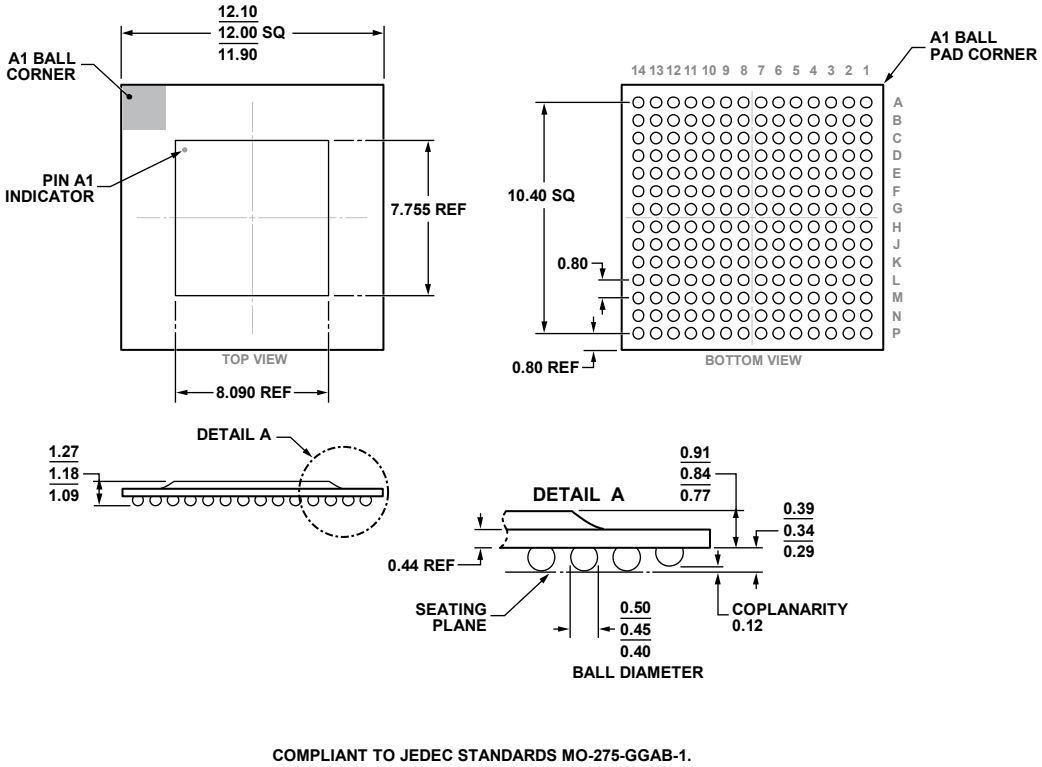

Figure 467. 196-Ball Chip Scale Package Ball Grid Array [CSP_BGA]
(BC-196-13)
Dimensions shown in millimeters

ORDERING GUIDE

Model[1]	Temperature Range[2]	Package Description	Package Option
ADRV9009BBCZ	−40°C to +85°C	196-Ball Chip Scale Package Ball Grid Array [CSP_BGA]	BC-196-13
ADRV9009BBCZ-REEL	−40°C to +85°C	196-Ball Chip Scale Package Ball Grid Array [CSP_BGA]	BC-196-13
ADRV9009-W/PCBZ		Pb-Free Evaluation Board, 75 MHz to 6000 MHz	

[1] Z = RoHS Compliant Part.
[2] See the Thermal Management section.