LMH9235 Evaluation Module

This document outlines the basic steps and functions that are required to ensure the proper operation and quick setup of the LMH9235RRL-EVM. This document also includes a schematic diagram, a bill of materials (BOM), printed-circuit board (PCB) layouts, and test block diagrams. Throughout this document, the abbreviations *EVM, LMH9235 EVM* and the term *evaluation module* are synonymous with the LMH9235RRL-EVM, unless otherwise noted.

Contents

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1 Description

The LMH9235 evaluation module (EVM) is used to evaluate the LMH9235 device, which is a single-ended input to differential output RF gain block amplifier available in a 2 × 2-mm^2, 12-pin RRL package. The device is well-suited to support requirements for the next generation 5G m-MIMO active antenna system while interfacing with the input of transceiver. The EVM is designed to quickly demonstrate the functionality and performance of the LMH9235 device in the 3.3-GHz to 3.8-GHz receive frequency band with 700 MHz of 1-dB bandwidth.

By default, the board is set up for 50-Ω single-ended input matching and 100-Ω differential output matching for easy interface with 50-Ω test equipment. The EVM is ready to connect to a +3.3-V power supply, signal source, and test instruments through the use of onboard connectors.

1.1 Features

- Operates on a single +3.3-V supply.
- Designed for a single-ended 50-Ω input matching and 100-Ω differential output matching interface.
- Simple interface to the inputs and output through onboard SMA connectors.
- Power down option available onboard using a jumper connector.
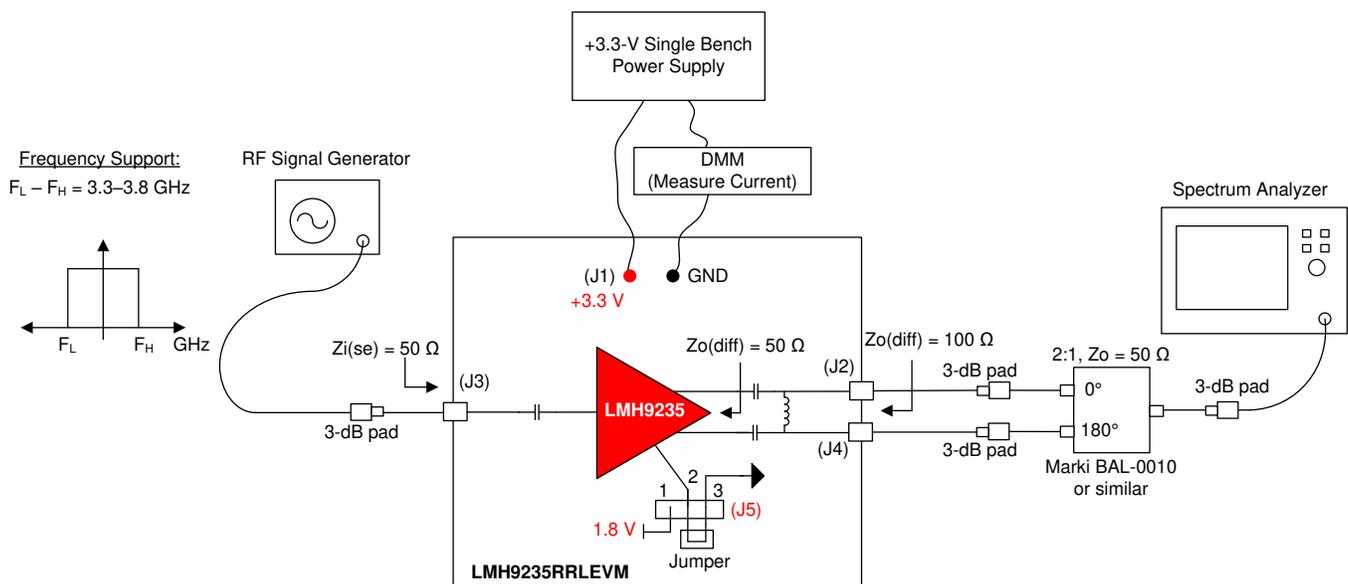

Figure 1. Single Tone Setup for Gain and Output P1dB

1.2 General Usage Information

This section provides general usage information for the LMH9235 EVM. See Figure 1 for a general single tone setup diagram as a reference point for the following instructions. Some components such as supply bypass capacitors and power down reference voltage generation circuits are omitted in Figure 1 for clarity.

1. Recommended power up sequence:
   a. Before connecting the power-supply cables to the EVM, set the DC output power supply to +3.3 V.
   b. Set the current limit of the DC output power supply at 150 mA.
   c. Making sure the supply is turned off, connect the power supply cables to the J1 connector of the EVM.
   d. Now turn on the DC power supply of VCC = +3.3 V. The supply current (I_Q) drawn from the power supply should be approximately 80 mA.
   e. If the supply current is low, ensure that the device is not disabled by shorting the jumper connection for J5 between 2 and 3 header pins.
2. Power-down option:

    a. Short terminals 1 and 2 on J5 to put the LMH9235 device in its power down state. The supply current (I_Q) drawn should be < 15 mA.

3. Single tone measurement setup recommendation:

    a. Connect an RF signal generator to input J3 SMA connector.

    b. The RF signal generator used must support 3.3-GHz to 3.8-GHz signal frequency for testing out the LMH9235 EVM.

    c. When measuring the EVM for single tone distortion products, TI recommends using an RF band pass filter (not shown in Figure 1) between the signal source and J3 SMA input.

    d. The LMH9235 device input is tuned to 50-Ω matching impedance in the 3.3-GHz to 3.8-GHz frequency band of operation. To minimize signal reflections due to impedance mismatch, TI recommends using an attenuator pad of approximately 3-dB to 6-dB between the source and J3 SMA input.

    e. The EVM outputs are fully differential (or 180° out-of-phase) at J2 and J4 SMA connectors. Although the LMH9235 device output is internally matched to 50-Ω differential impedance, the onboard discrete L and C components transform the differential output impedance to 100-Ω in the 3.3-GHz to 3.8-GHz frequency band. See Table 1 for the discrete L and C component values used on the LMH9235 EVM.

    f. When connecting to a spectrum analyzer single-ended input, the differential signal out of the EVM should be converted to a single-ended signal using a passive balun as shown in Figure 1.

    g. It is recommended to use a balun which operates in the same frequency band as the LMH9235 device to avoid any setup issues. Also, using an attenuator pad of approximately 3-dB to 6-dB is recommended at the three terminals of the passive balun for 50-Ω matching between the EVM output and spectrum analyzer input.

    h. Lastly, it is recommended to properly characterize and account for the insertion loss of RF coaxial (coax) cables, attenuator pads, and passive baluns to measure accurate gain and power levels for the device.

4. Matching or tuning options:

    a. Solder mask has been removed along the RF signal paths and VCC path allowing an easy method to slide surface mount components along these traces for optimal tuning.

    b. The device differential output is tuned for 100-Ω differential impedance in the 3.3-GHz to 3.8-GHz frequency band using discrete L and C components. The trace impedance is calculated by the stack-up configuration as given in Section 2.4. See Table 1 for the L and C component values used on the LMH9235 EVM.

2   EVM Overview

This section includes the schematic diagram, a bill of materials (BOM), PCB layer prints, and EVM stack-up information.

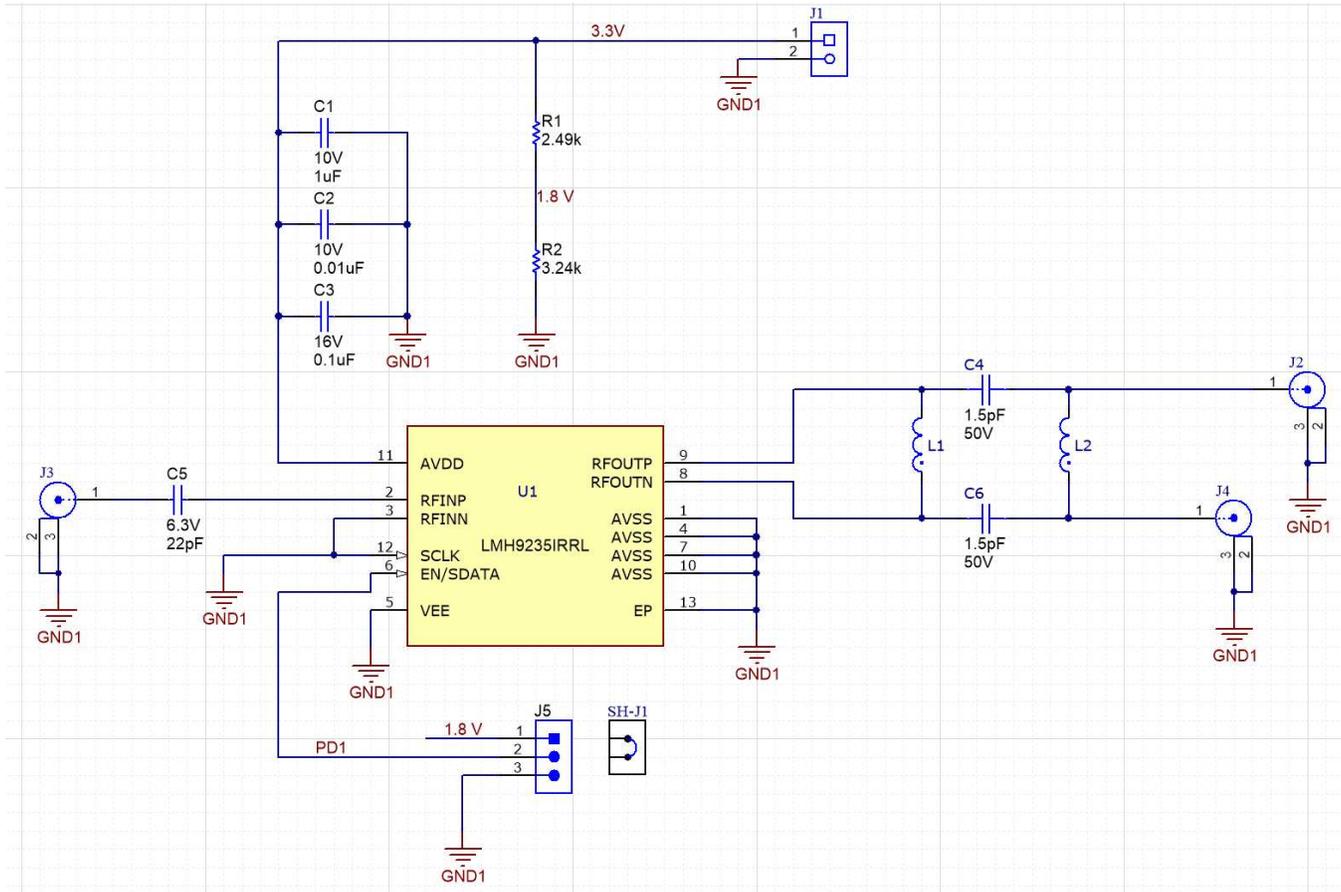### 2.1   *Schematic*

Figure 2 shows the LMH9235 EVM schematic.

Figure 2. LMH9235 EVM Schematic

2.2 PCB Layers

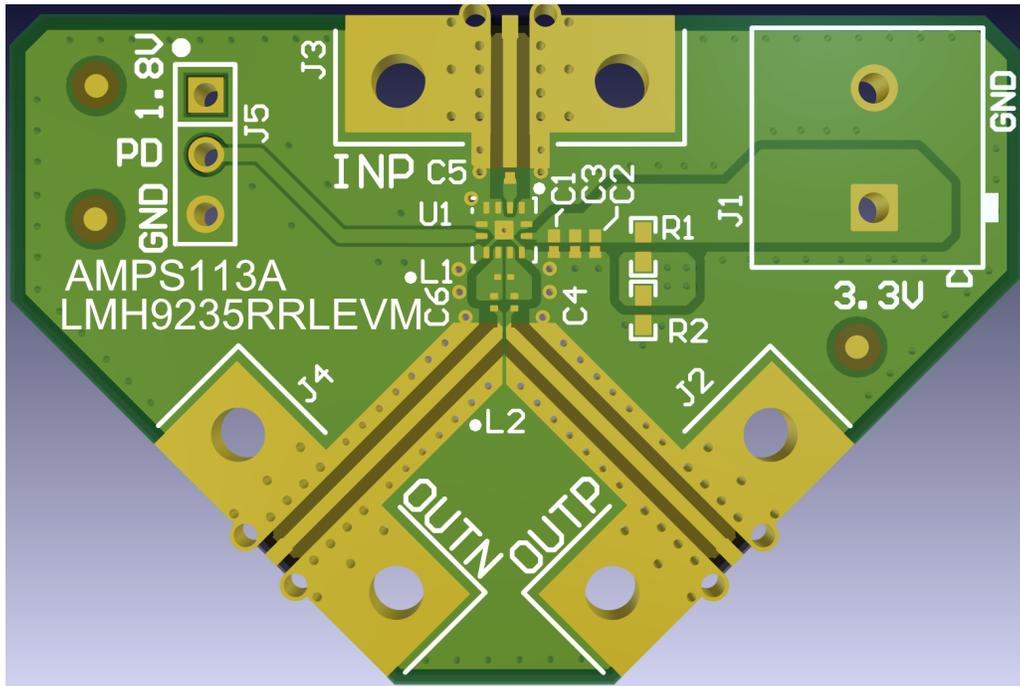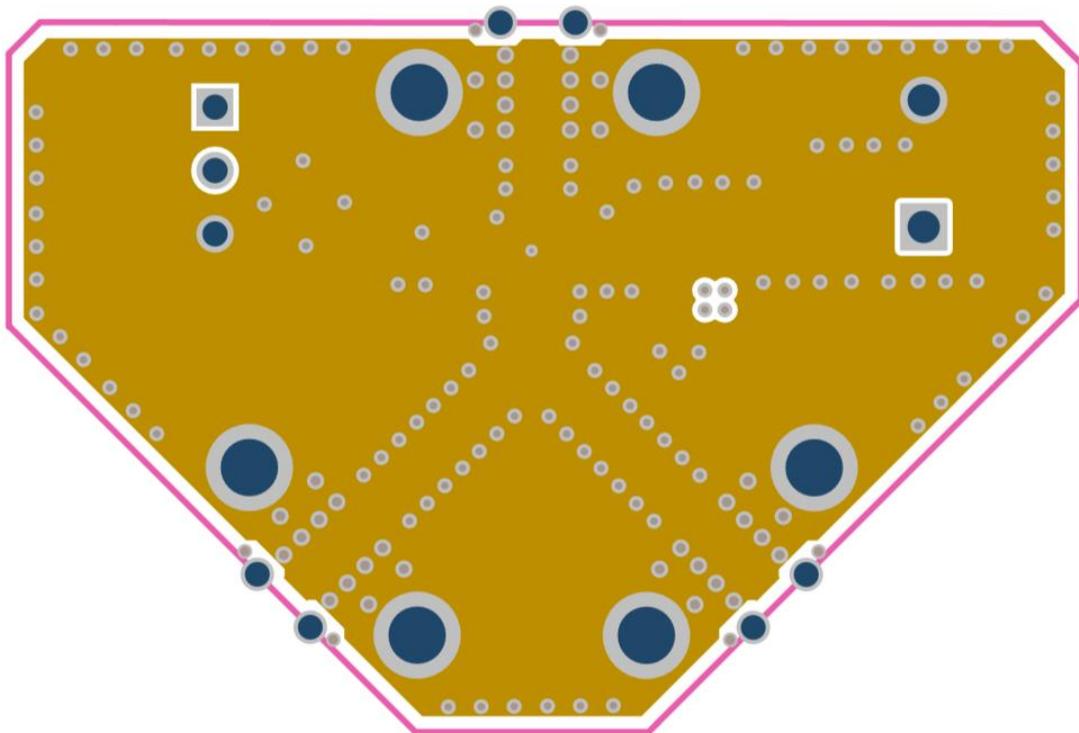Figure 3 through Figure 6 illustrate the PCB layers for this EVM.
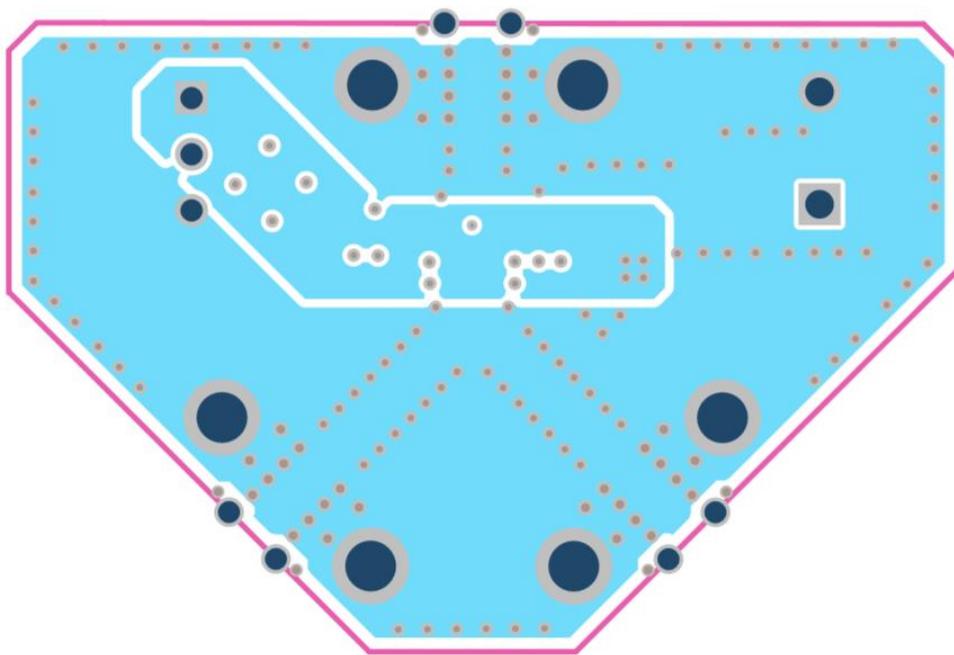

Figure 3. Top Layer
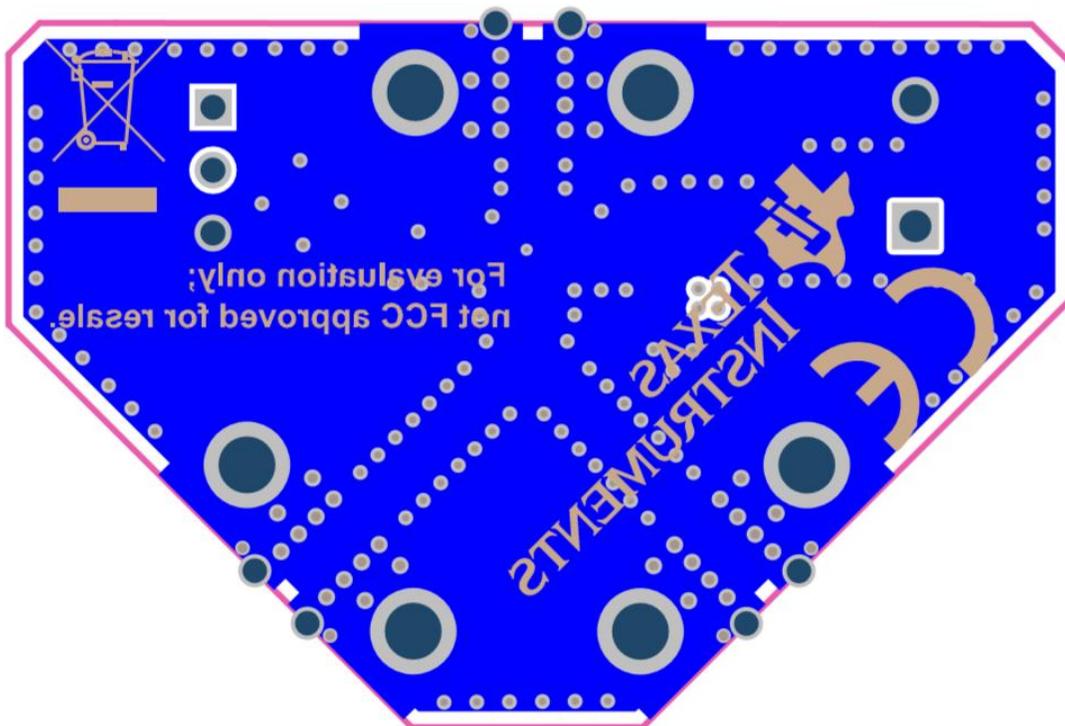

Figure 4. Layer 2

Figure 5. Layer 3

Figure 6. Bottom Layer

2.3 LMH9235 EVM Bill of Material

Table 1. LMH9235 EVM BOM

Item #	Designator	Quantity	Value	Description	Footprint	Manufacturer	Part Number
				Common BOM			
1	!PCB1	1		Printed Circuit Board		Any	AMPS094
2	C1	1	1 µF	CAP, CERM, 1 µF, 10 V, ±20%, X5R, 0201	0201	Samsung Electro-Mechanics	CL03A105MP3NSNC
3	C2	1	0.01 µF	CAP, CERM, 0.01 µF, 10 V, ±10%, X7R, 0201	0201	MuRata	GRM033R71A103KA01D
4	C3	1	0.1 µF	CAP, CERM, 0.1 µF, 16 V, ±10%, X5R, 0201	0201_033	MuRata	GRM033C71C104KE14D
5	C5	1	22 pF	CAP, CERM, 22 pF, 6.3 V, ±2%, C0G/NP0, 0201	0201_033	MuRata	GJM0335C0J220GB01D
6	J1	1		Terminal Block, 5.08 mm, 2×1, TH	PhoenixContact_1715721	Phoenix Contact	1715721
7	J2, J3, J4	3		SMA JACK 50 Ω, R/A, SMT	Rosenberger_32K243-40ML5	Rosenberger	32K243-40ML5
8	J5	1		Header, 100 mil, 3x1, Tin, TH	CONN_PEC03SAAN	Sullins Connector Solutions	PEC03SAAN
9	R1	1	2.49 kΩ	RES, 2.49 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	Vishay-Dale	CRCW04022K49FKED
10	R2	1	3.24 kΩ	RES, 3.24 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	Vishay-Dale	CRCW04023K24FKED
11	SH-J1	1	1×2	Shunt, 100 mil, Gold plated, Black	SNT-100-BK-G	Samtec	SNT-100-BK-G
12	FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	Fiducial10-20	N/A	N/A
13	C4, C6	2	1.5 pF	CAP, Film, 1.5 pF, 50 V, 0201 SMD	0201	AVX	02015J1R5PBSTR
14	L2	1	4.3 nH	Inductor RF Chip Thin Film 4.3 nH 3% 500 MHz 14Q-Factor 350 mA 400 mΩ DCR 0201 Paper T/R	0201	Murata	LQP03TN4N3H02D
15	U1	1		LMH9235IRRL, RRL0012A (WQFN-12)	RRL0012A	Texas Instruments	LMH9235IRRL
16	L1	0					

2.4   Stack-Up and Material

The LMH9235 EVM is a 56-mil, 4-layer board whose material type is Isola® 370HR. The top layer routes the power, ground, and signals to and from the device. The signal impedance is targeted at 49.9 Ω. The bottom 3 layers are ground layers.
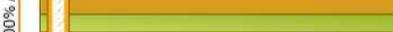
Layer	Stack up	Type	Supplier	Supplier Description	Description	Base Thickness	Impedance ID	Mask Thickness	Processed Thickness	εr
1		Copper			Copper Foil	0.579	1, 2, 3		1.760	
		FR4	isola	370HR	PrePreg 2116	4.331			4.308	4.100
		FR4	isola	370HR	PrePreg 2116	4.331			4.308	4.100
		FR4	isola	370HR	PrePreg 1080	2.559			2.546	3.930
2						1.181			1.181	
		FR4	isola	370HR	Core	27.953			27.953	4.360
3						1.181			1.181	
		FR4	isola	370HR	PrePreg 1080	2.559			2.546	3.930
		FR4	isola	370HR	PrePreg 2116	4.331			4.308	4.100
		FR4	isola	370HR	PrePreg 2116	4.331			4.308	4.100
4		Copper			Copper Foil	0.579	4, 5, 6		1.760	

62.99 +10.00% / -10.00%

Figure 7. LMH9235 EVM Stack-Up (Units in Mils)

3   Test Setup Diagrams

This section includes general recommendations for S-parameter, noise figure, and two-tone OIP3 setup while measuring the LMH9235 EVM.

3.1   S-Parameter Test Setup

Vector Network Analyzer

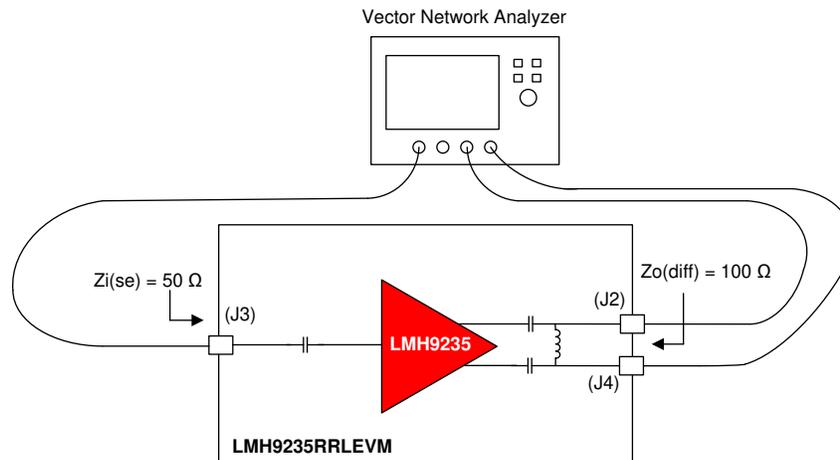Zi(se) = 50 Ω (J3)   LMH9235   Zo(diff) = 100 Ω (J2) (J4)

LMH9235RRLEVM

Figure 8. S-Parameter Test Setup

Use the following guidelines for S-parameter measurement:

1. S-parameter measurement is typically done using a Vector Network Analyzer (VNA), as Figure 8 shows. For measuring the LMH9235 EVM, a 4-port VNA is recommended which can generate and receive truly differential signals at the input and output ports.
2. Before connecting the RF coax cables to the LMH9235 EVM, you must calibrate the VNA along with the cables using a calibration kit. This accounts for any cable losses in the S-parameter calculation at the VNA and helps set reference impedance at the cable ends.
3. Make sure the frequency sweep and output power level from the VNA is set within the linear operating range of the LMH9235 devices. The resolution bandwidth (RBW) and dynamic range of the VNA can be adjusted to give optimum sweep time for the measurement.
4. It is important to account for onboard trace losses at the input and output pins of the device. De-embedding of the input and output traces is recommended to improve the S-parameter measurement

that is representative of the device performance. Figure 9 and Figure 10 give typical input and output trace losses measured on the LMH9235 EVM, respectively.
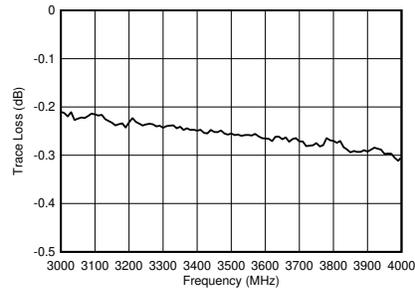

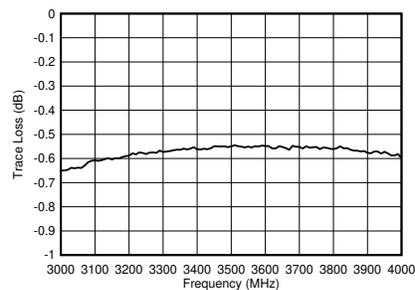**Figure 9. Input PCB Trace Loss vs Frequency**

Figure 10. Output PCB Trace Loss vs Frequency
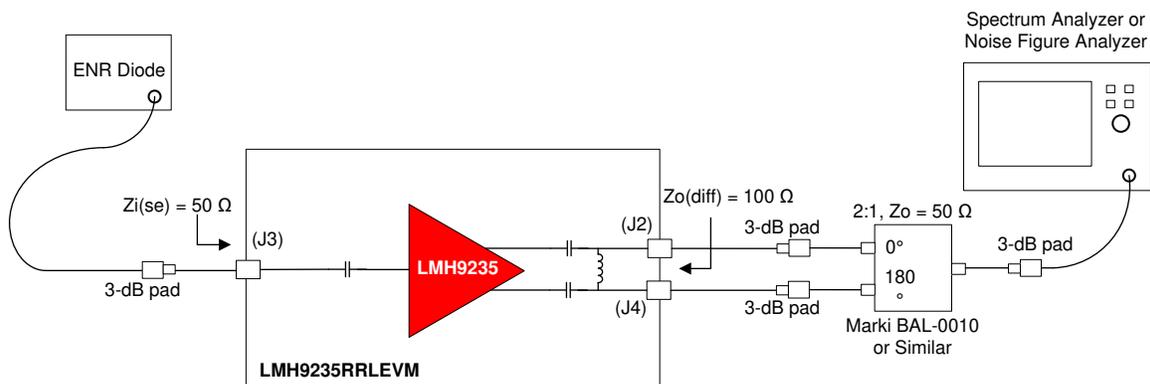
3.2 *Noise Figure Test Setup*

Figure 11. Noise Figure Test Setup

Use the following guidelines for Noise Figure (NF) measurement:

1. The traditional Y-factor method can be used for the NF measurement using a Noise Diode and a spectrum analyzer (or a Noise Figure Analyzer), as Figure 11 shows.
2. While doing the measurement, take into account any RF cable losses to the EVM board. Any external input attenuator added for matching will result in proportional NF degradation and must be calibrated out in the measurement.
3. Also, onboard losses of the input traces at the device input pin must be factored into the NF measurement.
4. If the device output loss is significant, it is important to factor the output loss into the NF measurement.
5. Using the *Friis* equation is helpful when calculating combined NF of the measurement setup, and then back calculating the individual device noise figure.
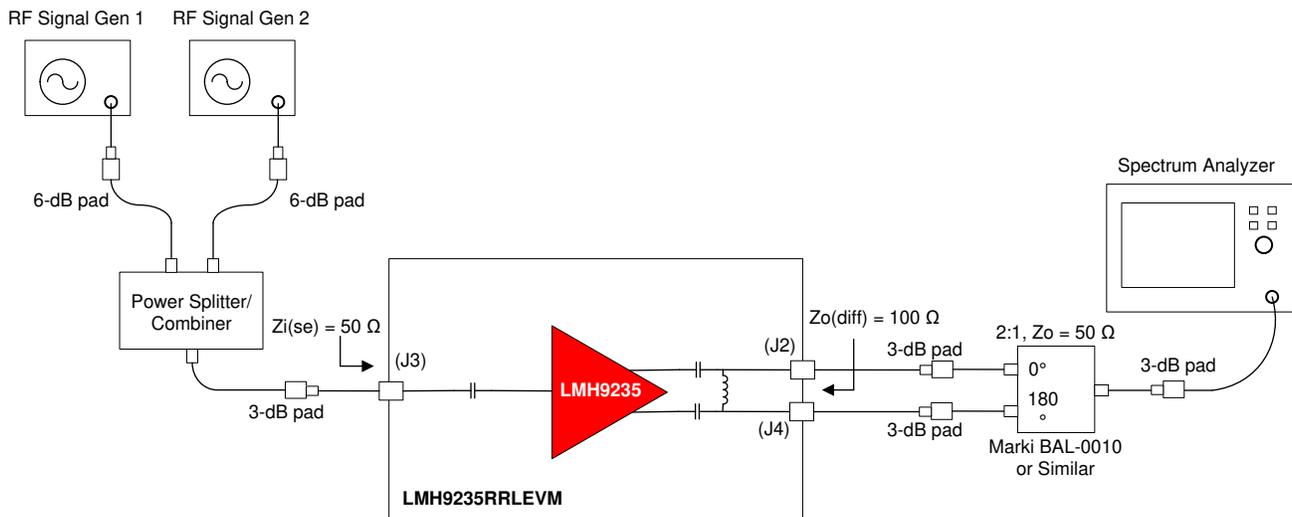
3.3 Two-Tone OIP3 Test Setup

Figure 12. OIP3 Test Setup

Use the following guidelines for two-tone OIP3 measurement:

1. As Figure 12 shows, combine two signal generator outputs using an in-phase power splitter and combiner. A 6-dB attenuator is recommended at the signal generator outputs to prevent the generators from talking to each other and resulting in signal generator IMD3 spurs.

2. Set both the signal generator outputs to a power level and frequency spacing such that it would yield the desired output power (P_{OUT}) at the device.

3. TI recommends that the output power level is within the linear operation range of the LMH9235 device. For example, if the total desired output power at the device is 8 dBm, then set the signal generators such that each of the fundamental output power results in 2 dBm per tone. However, if each output tone is at 8 dBm instead, the amplifier linearity will degrade as a result of higher total composite output power of 14 dBm at the device outputs. As a general rule, it is recommended to keep the total output power level approximately 6 to 8 dB lower than the 1-dB compression point. Also, see the device data sheet for the recommended output power levels supported by the device.

4. For the OIP3 test, the two tones can be spaced ±10 MHz with respect to the desired center frequency.

5. TI recommends setting the spectrum analyzer attenuation setting from 20 to 26 dB based on sweet spot of the incoming input power level.

6. Keep spectrum analyzer RBW and VBW settings identical for main tone and IM3 products.

7. For output IP3 calculation, take into account combined losses at the desired frequency band between the LMH9235 device output to the spectrum analyzer input. The combined power losses include loss due to PCB output trace, RF coax cable, 0/180°passive balun and any attenuator pad used for external matching purposes. The calculated OIP3 is given in the following equation:

Output IP3 = (P_{IN_SA} − IMD3) / 2 + P_{IN_SA} + P_{LOSS}

where,

- P_{IN_SA} = Input power per tone into the spectrum analyzer
- P_{LOSS} = Power loss from the device output to the spectrum analyzer input
- IMD3 = Higher power of the two inter-modulation distortion products recorded at either 2f1 − f2 or 2f2 − f1

8. The thing to note in is the P_{IN_SA} + P_{LOSS} = P_{OUT} which is the amplifier output power per tone.

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