User's Guide

LMH9135 Evaluation Module

TEXAS INSTRUMENTS

ABSTRACT

This document outlines the basic steps and functions that are required to ensure the proper operation and quick setup of the LMH9135RRL-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, LMH9135 EVM* and the term *evaluation module* are synonymous with the LMH9135RRL-EVM, unless otherwise noted.

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Trademarks

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1 Description

The LMH9135 evaluation module (EVM) is used to evaluate the LMH9135 device, which is a differential input to single-ended output RF gain block amplifier available in a 2-mm × 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 (AAS) while interfacing with the output of transceiver. The EVM is designed to quickly demonstrate the functionality and performance of the LMH9135 device in the 3.3-GHz to 4.2-GHz transmit frequency band with 900 MHz of 1-dB bandwidth.

By default, the board is set up for 100-Ω differential input matching and 50-Ω single-ended 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 single +3.3-V supply.
- Designed for differential 100-Ω input matching and 50-Ω single-ended output matching interface.
- Simple interface to the inputs and output through onboard SMA connectors.
- Power-down option available onboard using jumper connector.

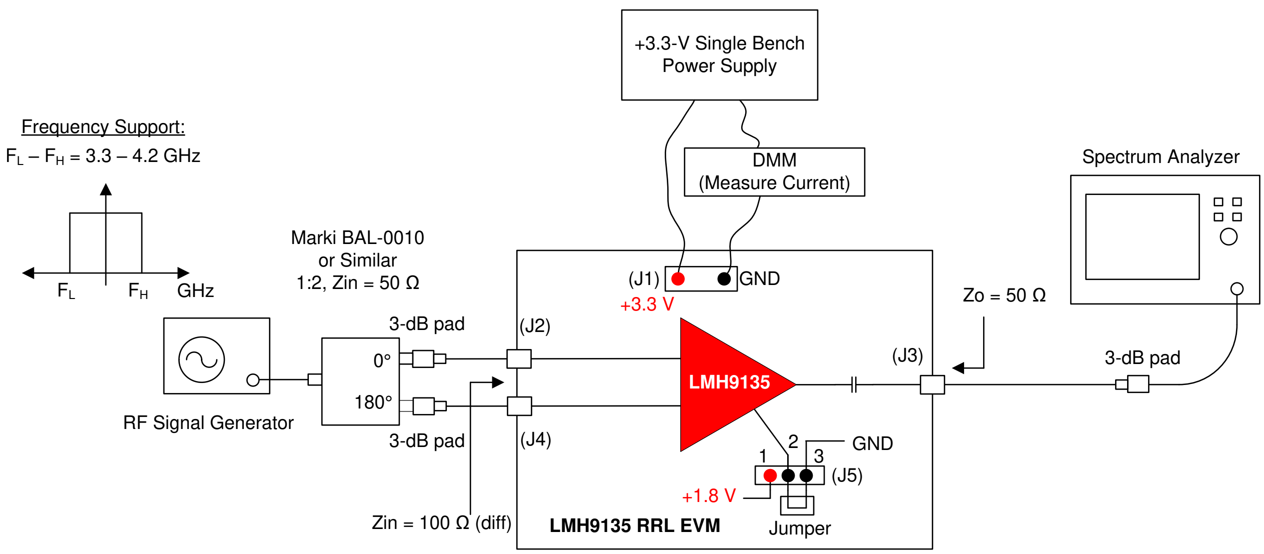


Figure 1-1. General Test Setup

1.2 General Usage Information

This section provides general usage information for the LMH9135 EVM. See Figure 1-1 for a general single-tone setup diagram as a reference point to the following instructions. Some components such as supply bypass capacitors, and power down reference voltage generation are omitted in Figure 1-1 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 200 mA.
   c. Making sure the supply is turned off, connect the power supply cables to the J1 connector.
   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 120 mA.
   e. If the supply current is low, ensure 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 LMH9135 device in its Power-down state. The supply current (I_Q) drawn should be < 15 mA.

2 EVM Overview

This section includes the schematic diagram, a BOM, PCB layer prints, and EVM stack-up information.

2.1 Schematic

Figure 2-1 shows the LMH9135 EVM schematic.

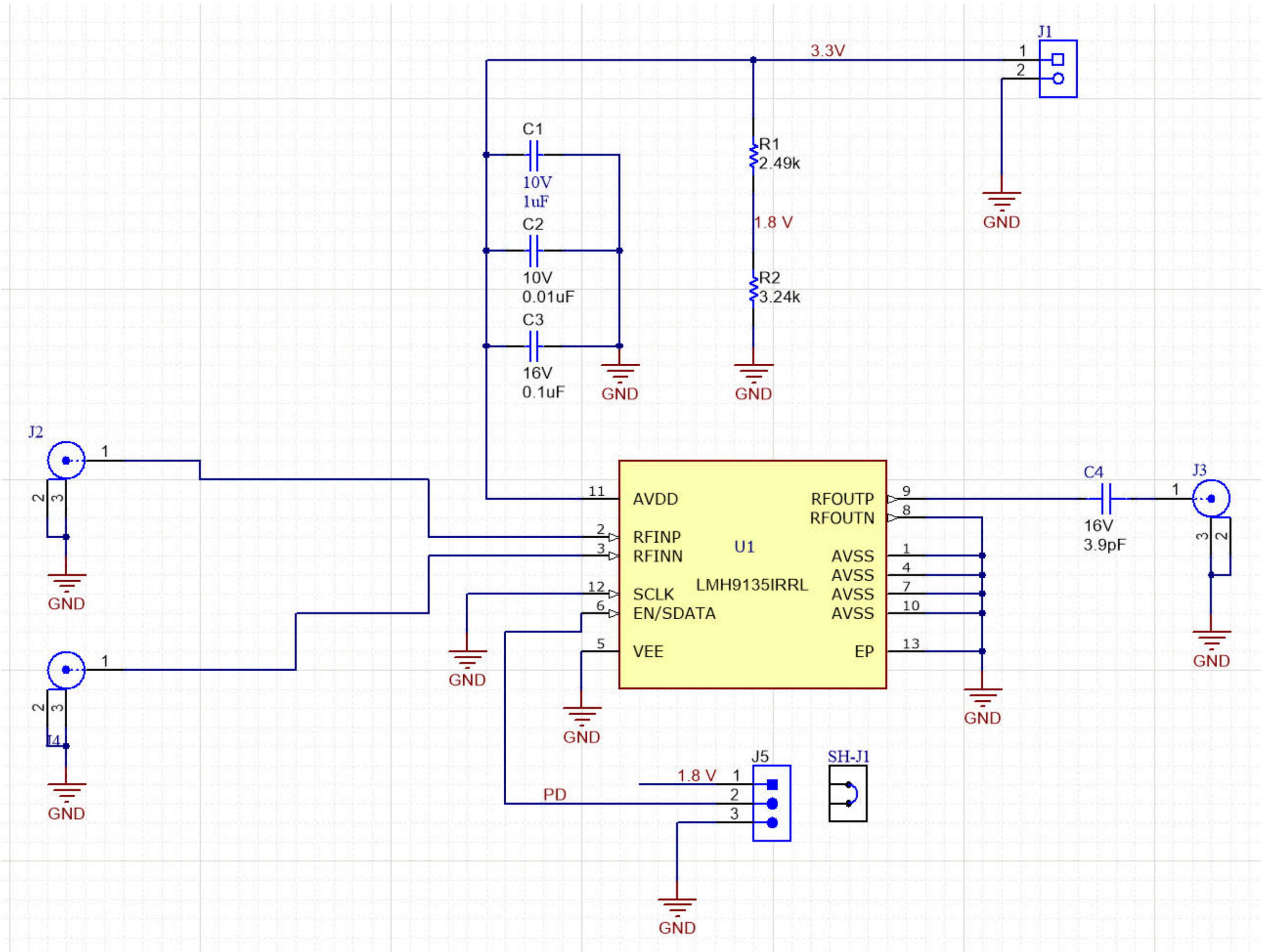


Figure 2-1. LMH9135 EVM Schematic

2.2 PCB Layers

Figure 2-2 through Figure 2-5 illustrate the PCB layers for this EVM.

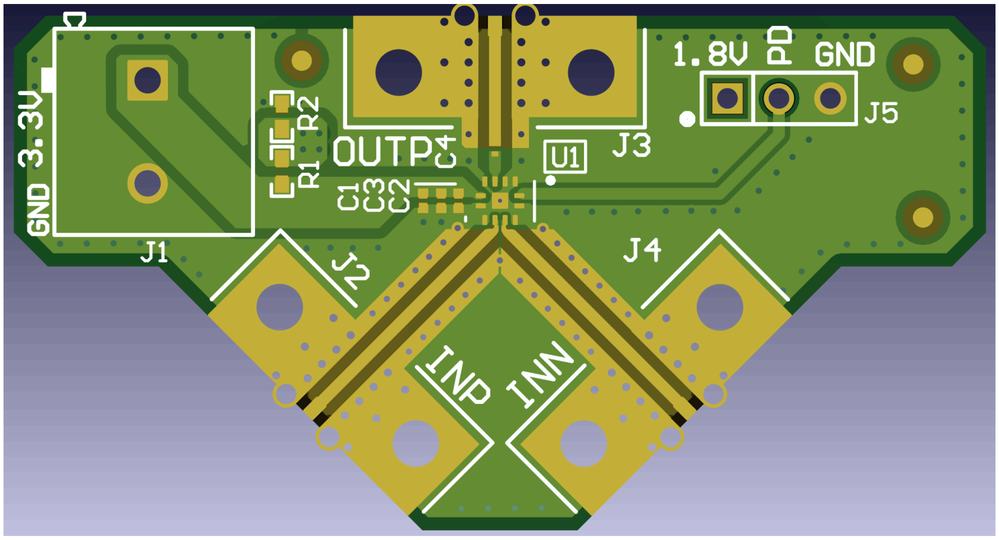


Figure 2-2. Top Layer

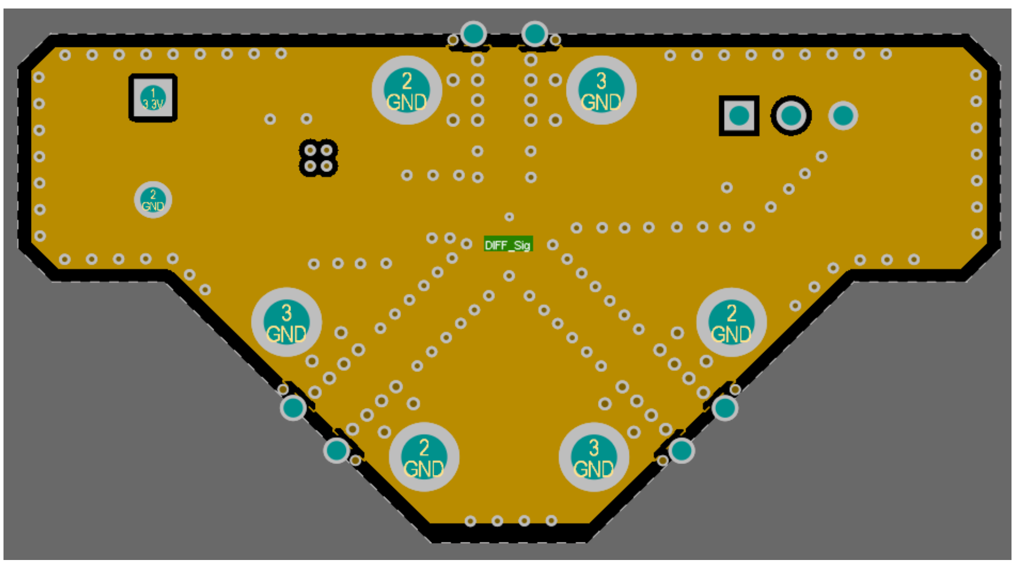


Figure 2-3. Layer 2

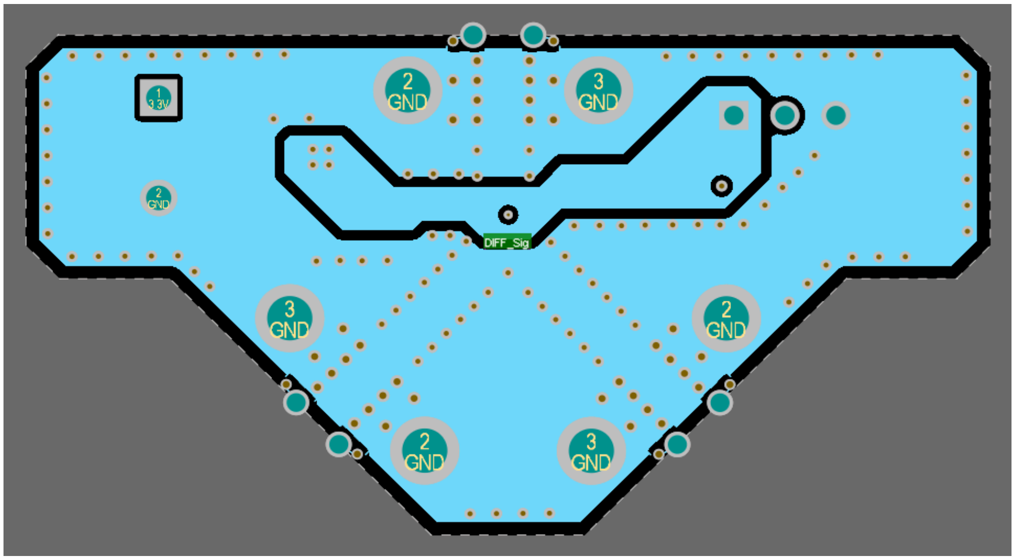


Figure 2-4. Layer 3

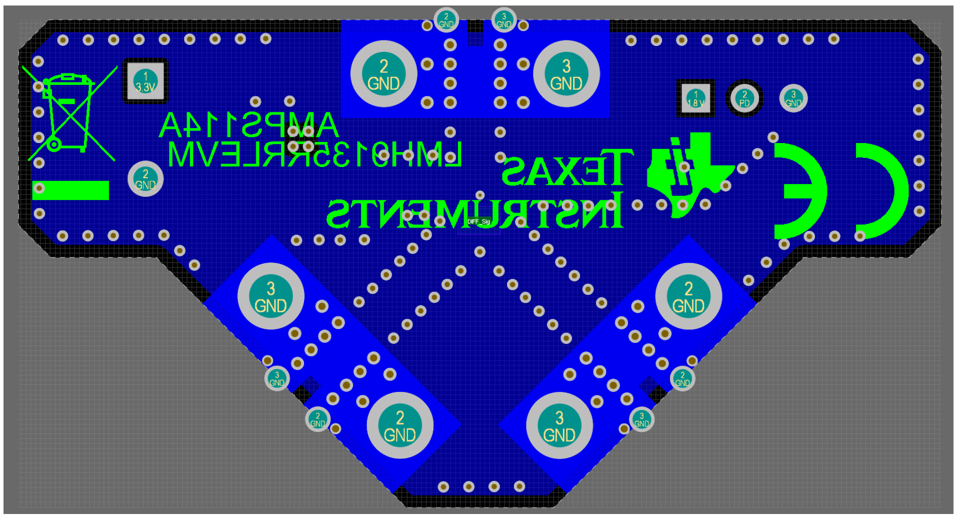


Figure 2-5. Bottom Layer

2.3 LMH9135 EVM Bill of Material

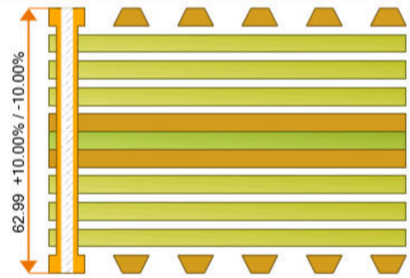
Table 2-1. LMH9135 EVM BOM

Item #	Designator	Qty	Value	Description	Footprint	PartNumber	Manufacturer	Alternate PartNumber	Alternate Manufacturer
1	!PCB1	1		Printed Circuit Board		AMPS087	Any		
2	C1	1	1 µF	CAP, CERM, 1 µF, 10 V, ± 20%, X5R, 0201	0201	CL03A105MP3NSNC	Samsung Electro-Mechanics		
3	C2	1	0.01 µF	CAP, CERM, 0.01 µF, 10 V, ± 10%, X7R, 0201	0201	GRM033R71A103KA01D	MuRata		
4	C3	1	0.1 µF	CAP, CERM, 0.1 µF, 16 V, ± 10%, X5R, 0201	0201_033	GRM033C71C104KE14D	MuRata		
5	C4	1	3.9 pF [1]	3.9 pF Thin Film Capacitor 16 V 0201 (0603 Metric)	ACCU_0201	0201YJ3R9BBSTR	AVX		
6	J1	1		Terminal Block, 5.08 mm, 2x1, TH	PhoenixContact_1715721	1715721	Phoenix Contact		
7	J2, J3, J4	3		SMA JACK 50 OHM, R/A, SMT	Rosenberger_32K243-40ML5	32K243-40ML5	Rosenberger		
8	J5	1		Header, 100 mil, 3x1, Tin, TH	CONN_PEC03SAAN	PEC03SAAN	Sullins Connector Solutions		
9	R1	1	2.49 k	RES, 2.49 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04022K49FKED	Vishay-Dale		
10	R2	1	3.24 k	RES, 3.24 k, 1%, 0.063 W, AEC-Q200 Grade 0, 0402	0402	CRCW04023K24FKED	Vishay-Dale		
11	SH-J1	1	1x2	Shunt, 100 mil, Gold plated, Black	SNT-100-BK-G	SNT-100-BK-G	Samtec	969102-0000-DA	3M
12	U1	1		LMH9135RRL, RRL0012A (WQFN-12)	RRL0012A	LMH9135RRL	Texas Instruments		Texas Instruments
13	FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	Fiducial10-20	N/A	N/A		

1 Alternate 3.9 pF part: 02013J3R9BBSTR

2.4 Stack-Up and Material

The LMH9135 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	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	

Figure 2-6. LMH9135 EVM Stack-Up (Units in Mils)

3 Test Setup Diagrams

This section includes general recommendations for single-tone, S-parameter, noise figure, and two-tone OIP3 setup while measuring the LMH9135 EVM.

3.1 Single-Tone Measurement Test Setup

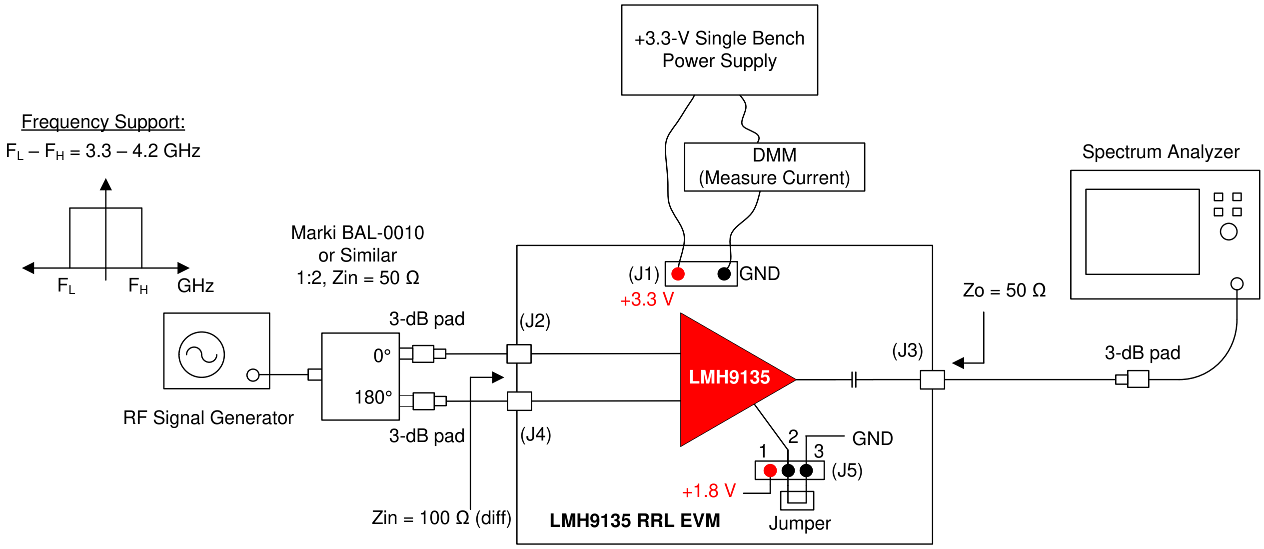


Figure 3-1. Single-Tone Setup for Gain and Output P1dB (1-dB Compression Point)

Use the following guidelines for single-tone measurement:

1. The input to the EVM is differential. Differential signal is generated from the single-ended output of the signal generator using an external passive balun such as shown in Figure 3-1. Use of at least 3-dB attenuator pads are recommended at the differential ports of the balun for better matching with the board.
2. The differential signals are fed into connectors J2 and J4.
3. The RF signal generator used must support 3.3-GHz to 4.2-GHz signal frequency for testing out the LMH9135 EVM.
4. When measuring the EVM for single-tone distortion products, TI recommends using an RF band pass filter (not shown in Figure 3-1) between the signal source and the balun.
5. The output of the EVM from connector J3 is fed to the spectrum analyzer. An attenuator pad of at least 3 dB is recommended at the output port of the EVM.
6. 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.

3.2 S-Parameter Test Setup

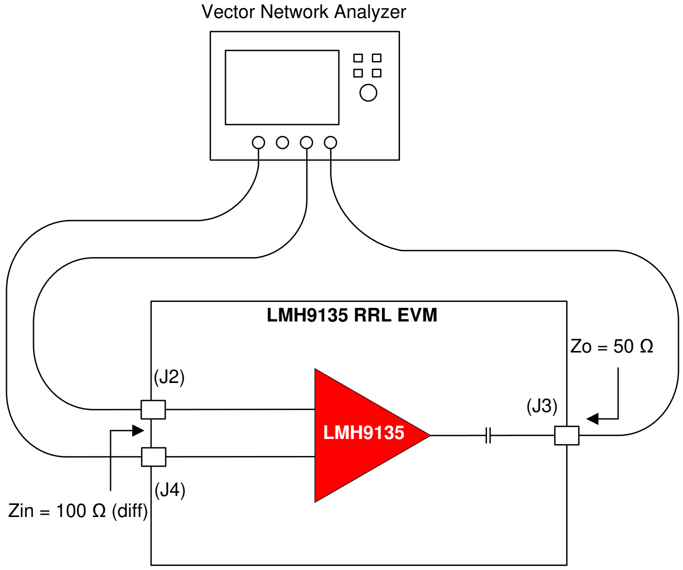


Figure 3-2. S-Parameter Test Setup

Use the following guidelines for S-parameter measurement:

1. S-parameter measurement is typically done using a Vector Network Analyzer (VNA), as Figure 3-2 shows. For measuring the LMH9135 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 LMH9135 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 LMH9135 devices. The resolution bandwidth (RBW) and dynamic range of the VNA can be adjusted to give optimum sweep time for the measurement.
4. The trace plus connector loss for the board is about 0.35 dB for the input trace (differential) and 0.3 dB for the output trace in the middle of the frequency band. This may be accounted for improved accuracy in the measurements.

3.3 Noise Figure Test Setup

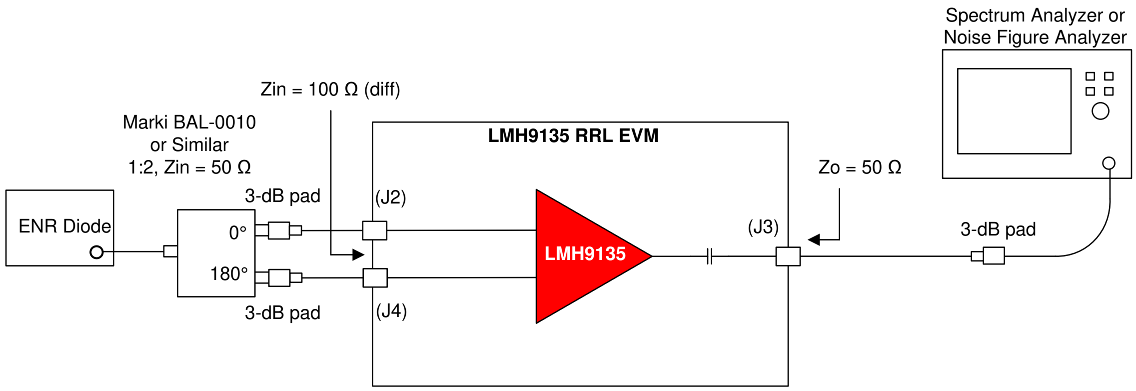


Figure 3-3. Noise Figure Test Setup

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 3-3 shows.
2. While doing the measurement, take into account any RF cable losses to the EVM board and also the balun loss. 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. Use the *Friis* equation to calculate the combined NF of the measurement setup and then back calculate the individual device noise figure.

3.4 Two-Tone OIP3 Test Setup

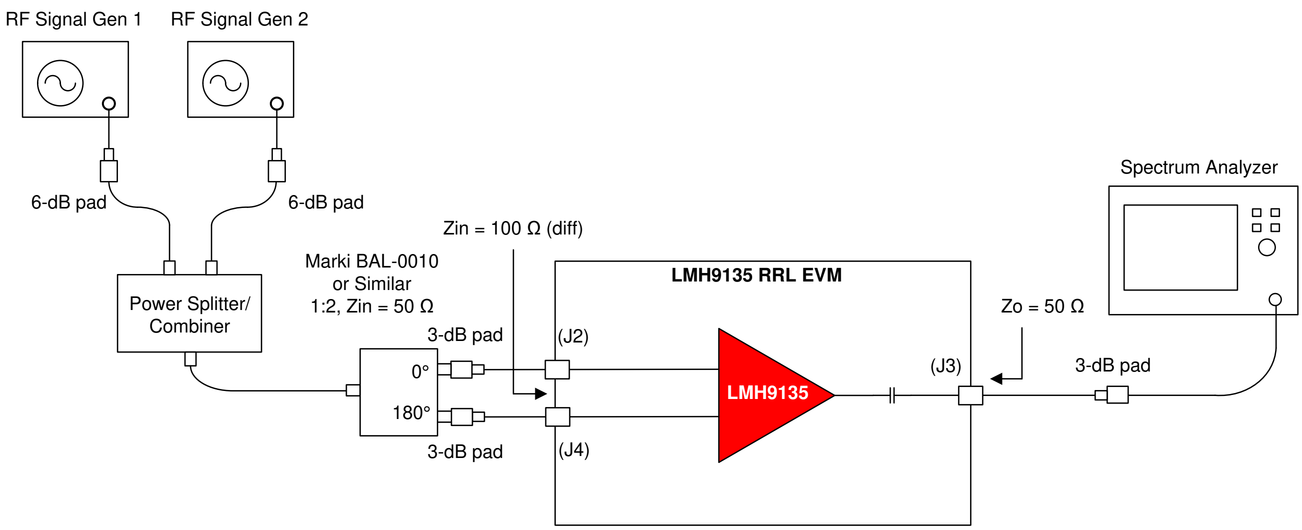


Figure 3-4. OIP3 Test Setup

Use the following guidelines for two-tone OIP3 measurement:

1. As Figure 3-4 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 coupling 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 LMH9135 device. As a general rule, it is recommended to keep the total output power level approximately 6 dB to 8 dB lower than the 1-dB compression point. For example, if the output 1-dB compression point of the device is 16 dBm, then set the signal generators such that each of the fundamental output power results in 2 dBm per tone.
4. For the OIP3 test, the two tones can be spaced at 10 MHz apart from each other and on either side of center frequency.
5. TI recommends setting the spectrum analyzer attenuation setting from 20 dB to 26 dB based on its sweet spot and 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 LMH9135 device output to the spectrum analyzer input. The combined power losses include loss due to PCB output trace, RF coax cable, and attenuator pad used for external matching. The calculated OIP3 is given by the following equation:

   $$\text{Output IP3} = (P_{IN\_SA} - IMD3) / 2 + P_{IN\_SA} + P_{LOSS}$$

   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. Note: $P_{IN\_SA} + P_{LOSS} = P_{OUT}$ is the amplifier output power per tone.