Design guide for low-noise transistors in WLAN front ends

RF bipolar transistors

About this document

Scope and purpose

This application note provides application circuit design examples of Infineon's low-noise silicon germanium: carbon (SiGe:C) transistors for wireless local area network (WLAN) low noise amplifiers (LNAs) and a medium-power transistor for WLAN power amplifier. In this document, the transistor-based LNA and power amplifier (PA) schematics, printed circuit board (PCB) layouts and measurement results are shown. This document is relevant to the following low-noise transistors and medium-power transistor:

- BFP740 Low-noise transistor for 2.4 GHz WLAN
- BFP740ESD Low-noise transistor for 2.4 GHz WLAN
- BFP740F Low-noise transistor for 2.4 GHz WLAN
- BFP740FESD Low-noise transistor for 2.4 GHz WLAN
- BFP760 Low-noise transistor for 2.4 GHz WLAN
- BFP842ESD Low-noise transistor for 2.4 GHz WLAN
- BGB707L7ESD Low-noise transistor for 2.4 GHz WLAN
- BFP840ESD Low-noise transistor for 5 to 6 GHz WLAN
- BFP840FESD Low-noise transistor for 5 to 6 GHz WLAN
- BFR840L3RHESD Low-noise transistor for 2.4 GHz and 5 to 6 GHz WLAN
- BFQ790 High-linearity medium-power transistor.

Intended audience

This document is intended for engineers who need to design LNAs and PAs for WLAN applications.

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1 Introduction

1.1 WLAN radio front ends

The WLAN function is one of the most important connectivity functions between WLAN access points and smartphones, tablets, and laptops. WLAN standards according to IEEE 802.11b/g/n at 2.4 GHz have been widely implemented over the years. Due to the overcrowded WLAN at 2.4 GHz, the applications in the 5 to 6 GHz band according to IEEE 802.11a/ac/n are becoming popular for fast data throughput. Today, wireless high-quality multimedia data transmission requires even higher data throughput. Hence, the next generation standard 802.11ax will increase the data rate to 9.6 Gbps through the high-order modulation scheme (1024QAM) and 8×8 multi-user multiple-input and multiple-output (MU-MIMO).

Key performance metrics for WLAN application are the speed of data transfer and coverage, which are greatly influenced by transmitted power, receiver sensitivity, noise, and interference. High data throughput related to the high-order modulation scheme asks for better received signal quality, while the necessary solution of WLAN router for MU-MIMO with multiple antennas will introduce trace loss in the signal path to transceiver IC, resulting in a deteriorated signal quality. A radio front end including filter, switch, LNA and PA close to the antenna is a popular method to improve the signal quality.

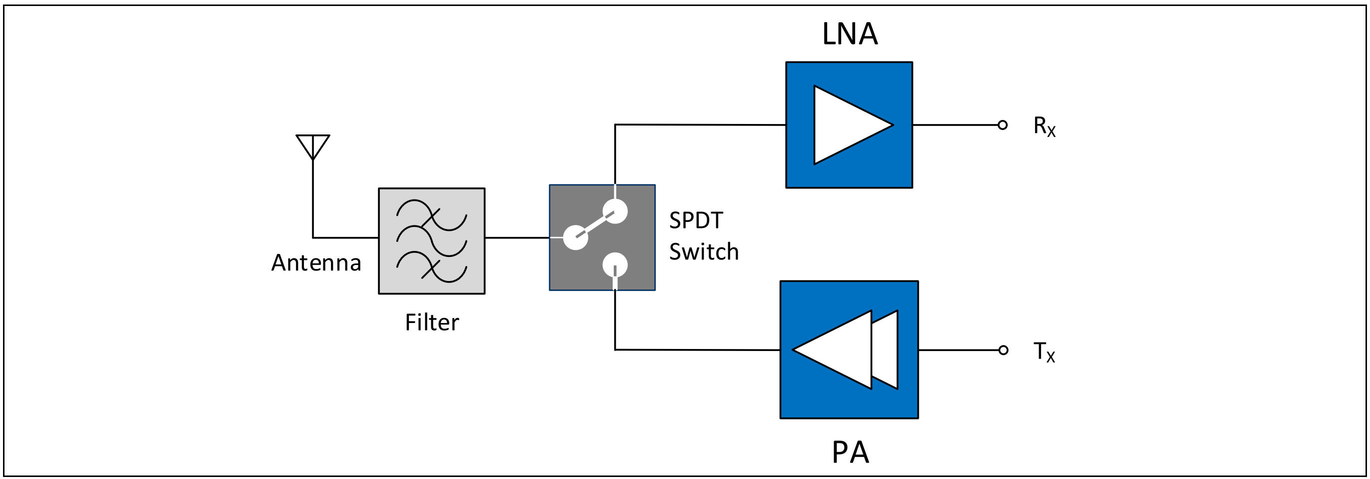


Figure 1 Block diagram example of a WLAN radio front end

1.2 Infineon RF transistor family

Infineon Technologies provides high-performance radio frequency (RF) transistors targeting WLAN LNA applications. Infineon's reliable high-volume RF transistors offer exceptionally low noise figure (NF), high gain and high linearity at low power consumption levels for RF applications. The sixth-, seventh-generation, and the latest high-performance eighth-generation transistors are based on robust ultra low-noise SiGe:C technologies. Their optimized inner transistor cell structure leads to best-in-class power gain and NF at high frequencies, including 2.4 GHz and 5 to 6 GHz WLAN bands. The transistors maximize the design flexibility for customer requirements.

In addition to low-noise transistors, Infineon offers BFQ790, a high-linearity medium-power transistor. Its output power level reaches 27 dBm (0.5 W), which is adequate for 2.4 GHz indoor WLAN signal power amplification. The device is housed in the halogen-free industry-standard SOT89 package. The high thermal conductivity of the silicon substrate and the low thermal resistance of the package add up to a thermal resistance of only 35 K/W, which leads to moderate junction temperatures even at high dissipated power values.

2 2.4 GHz band WLAN LNA application circuits

2.1 2.4 GHz band WLAN LNAs with SOT343 packaged low-noise transistors

2.1.1 Performance overview

The following table shows the performance of the 2.4 GHz band WLAN LNAs with SOT343 packaged low-noise transistors.

Table 1 Summary of measurement results for the 2.4 GHz band WLAN LNAs with SOT343 packaged transistors

Parameter	Symbol	Value				Unit	Notes
Device		BFP760	BFP740	BFP740ESD	BFP842ESD		
Bias voltage	V_{CC}	3.0	3.0	3.0	3.0	V	
Bias current	I_{CC}	16.6	13.5	13.5	8.6	mA	
Frequency	f	2.45	2.45	2.45	2.45	GHz	
Gain	G	16.0	18.9	18.8	18.5	dB	
NF	NF	0.82	0.81	0.76	0.76	dB	PCB and SMA loss subtracted: 0.1 dB
Input return loss	RL_{in}	10.8	10.1	10.6	14.3	dB	
Output return loss	RL_{out}	12.7	11.5	12.3	16.3	dB	
Reverse isolation	ISO_{rev}	24.0	25.2	25.7	23.2	dB	
Output 1 dB compression point	OP_{1dB}	6.6	5.2	5.0	8.9	dBm	
Output third-order intercept point	OIP_3	17.5	12.6	12.9	22.3	dBm	Input power: -25 dBm per tone Tone 1: 2450 MHz Tone 2: 2451 MHz
Stability	K	>1	>1	>1	>1		Measured from 15 MHz to 13 GHz

2.1.2 Schematic

The following figure shows the schematic of the 2.4 GHz band WLAN LNAs with SOT343 packaged transistors. Emitter degeneration provides negative feedback to achieve the transistor impedance matching and low-noise matching at the same time (see Figure 3 and Figure 4). In the LNA circuit, resistors R1 and R2 stand for transistor voltage and current bias, meanwhile, they form a negative DC feedback mechanism to stabilize the transistor bias points in various conditions. Capacitors C2 and C3 serve as the RF bypass. Transistor input matching is achieved by the inductors L1, L3, and the capacitor C1. The output matching network is formed by C4, C5, L2, L4, R3 and R4. Resistors R3 and R4 also have the function of improving circuit stability.

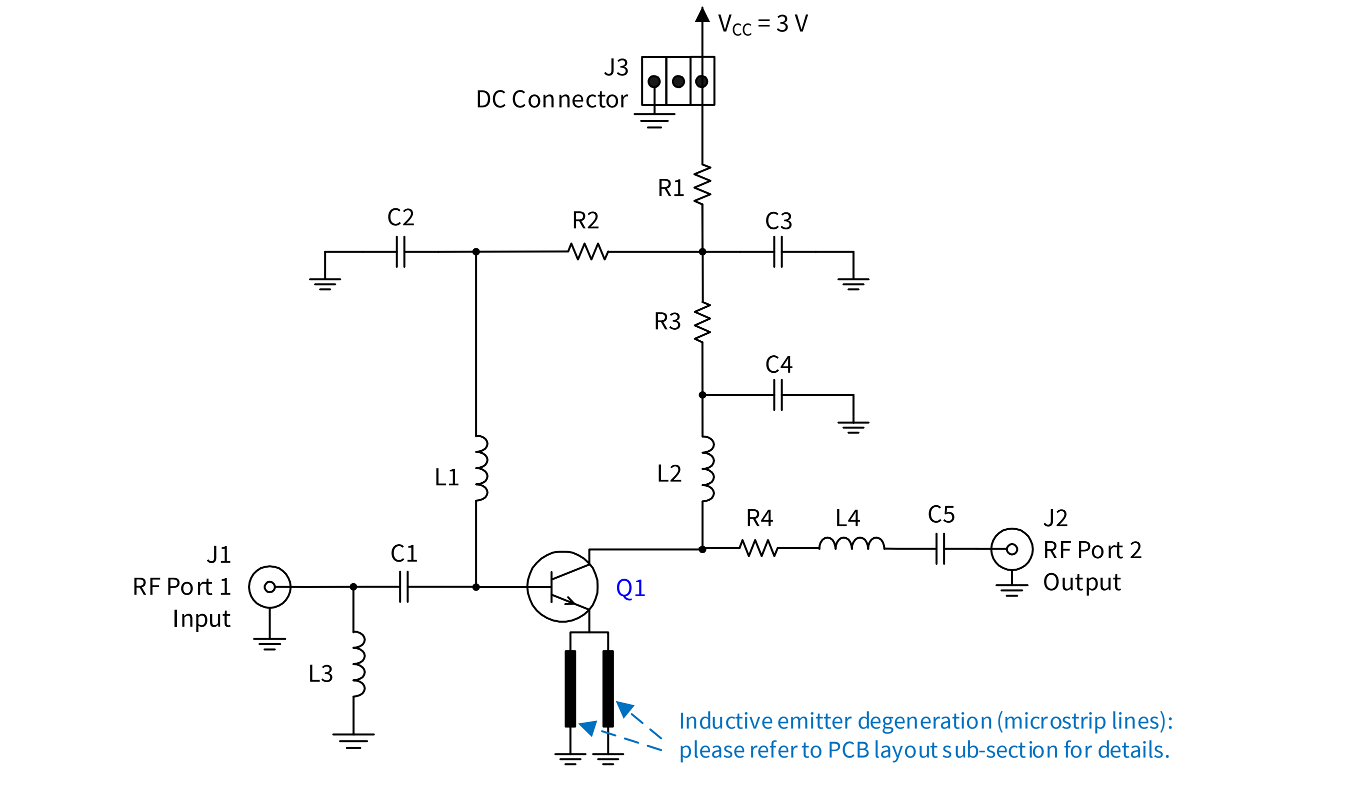


Figure 2 Schematic of the 2.4 GHz band WLAN LNAs with SOT343 packaged transistors

2.1.3 Bill of materials (BOM)

Table 2 BOM of the 2.4 GHz band WLAN LNAs with SOT343 packaged transistors

Symbol	Value				Unit	Size	Manu-facturer	Notes
Q1	BFP760	BFP740	BFP740ESD	BFP842ESD	–	–	Infineon	SiGe: C low-noise transistor
C1	1.8	8.2	8.2	10	pF	0402	Various	Input matching and DC blocking
C2	39	39	39	10	pF	0402	Various	RF decoupling
C3	n.c.	39	39	330	pF	0402	Various	RF decoupling
C4	n.c.	n.c.	n.c.	6.8	pF	0402	Various	Output matching and stability improvement
C5	1.8	22	22	1.5	pF	0402	Various	Output matching and DC blocking
R1	30	120	120	33	Ω	0402	Various	DC biasing
R2	33	22	22	39	kΩ	0402	Various	DC biasing
R3	82	24	24	22	Ω	0402	Various	Low-frequency stability improvement
R4	2.2	n.c.	n.c.	n.c.	Ω	0402	Various	Output matching and high-frequency stability improvement

L1	n.c.	2.2	2.2	3.3	nH	0402	Murata LQG	RF choke and input matching
L2	n.c.	2.2	2.2	1.8	nH	0402	Murata LQG	RF choke and output matching
L3	2	n.c.	n.c.	n.c.	nH	0402	Murata LQG	Input matching
L4	2.2	n.c.	n.c.	n.c.	nH	0402	Murata LQG	Output matching

Note: 1) Not connected (n.c.).

2.1.4 Evaluation boards and PCB layout information

The evaluation boards for the 2.4 GHz band WLAN LNAs with SOT343 packaged transistors:

- PCB material: FR4
- PCB marking:
  - BFP740 M130125
  - BFP740ESD M130125
  - BFP760 M130125
  - BFP842ESD M130225

The photo of the evaluation boards for the 2.4 GHz band WLAN LNAs with SOT343 packaged transistors and the detailed description of the PCB stack are shown in the following figures.

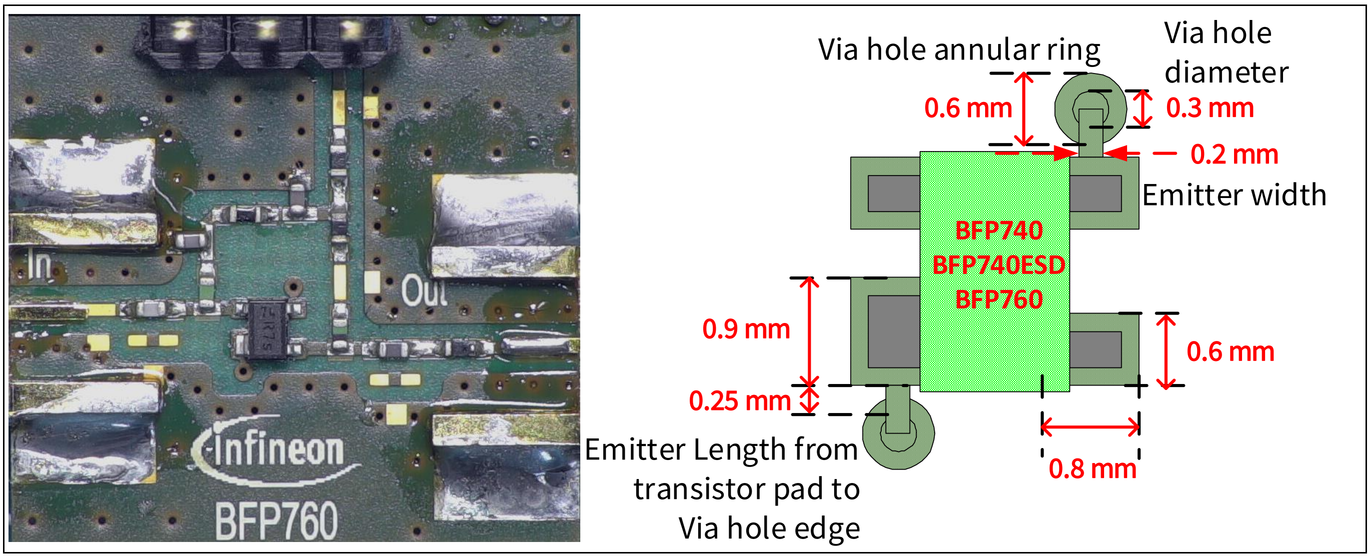


Figure 3 Photo of the evaluation board with PCB marking M130125 (left) and emitter degeneration details (right)

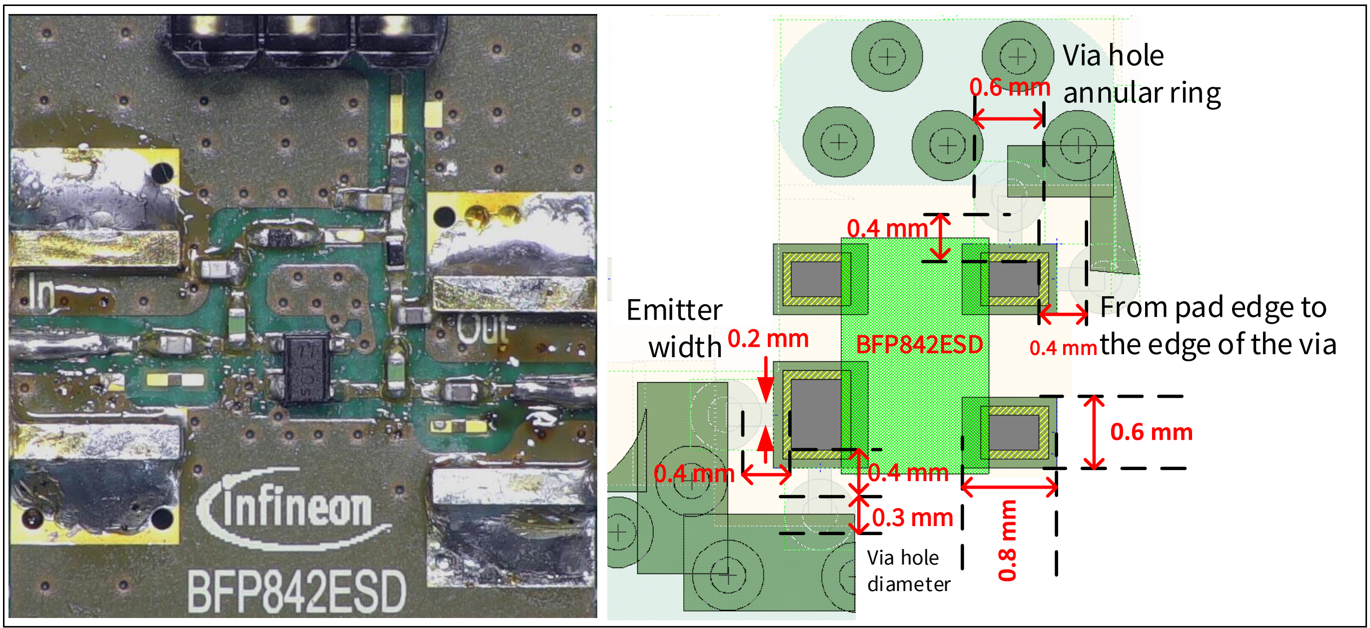


Figure 4 Photo of the evaluation board with PCB marking M130225 (left) and emitter degeneration details (right)

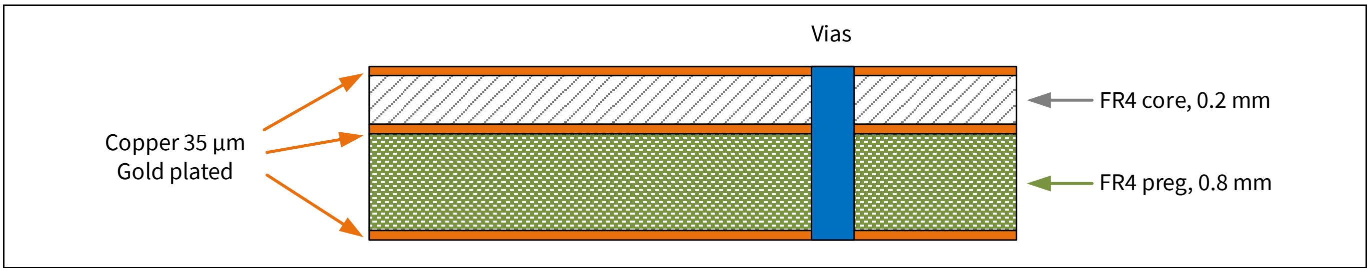


Figure 5 PCB stack information for the evaluation boards with PCB marking M130125 and M130225

2.1.5 Measurement results of 2.4 GHz band WLAN LNAs with SOT343 packaged low-noise transistors

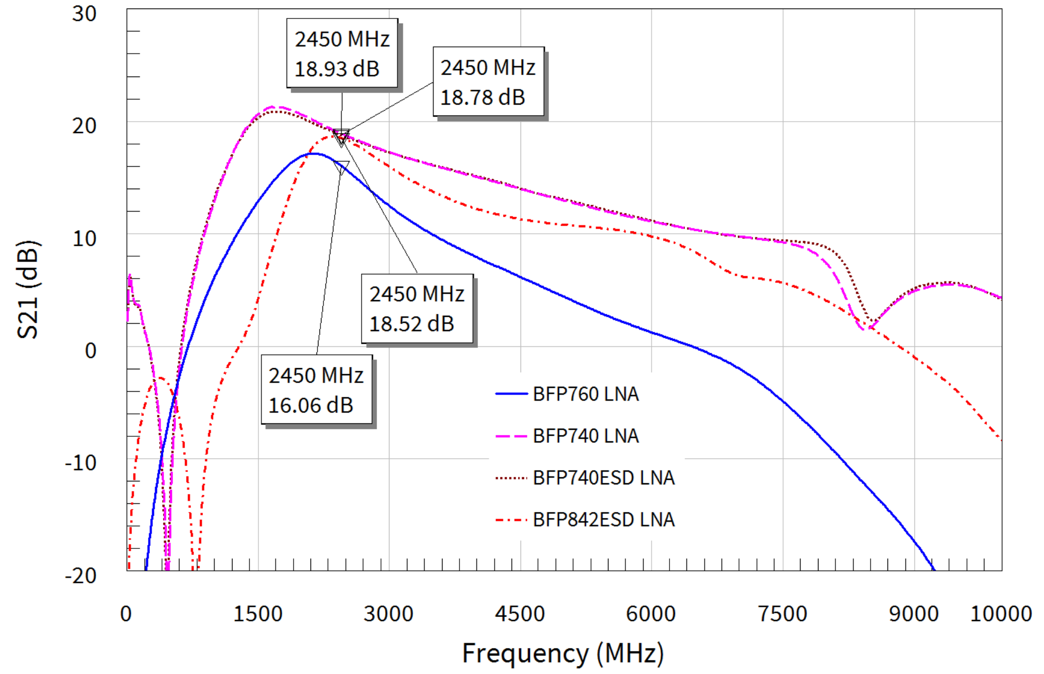


Figure 6 Small signal gain of the 2.4 GHz band WLAN LNAs with SOT343 packaged transistors

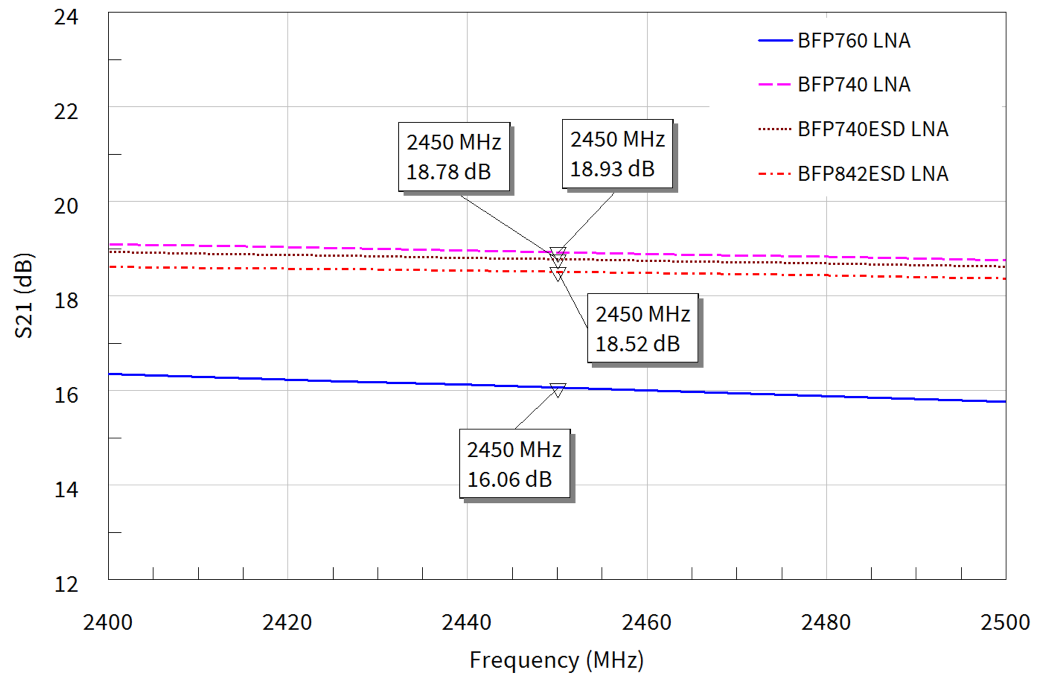


Figure 7 Small signal gain of the 2.4 GHz band WLAN LNAs with SOT343 packaged transistors (detail view)

Note: The graphs are generated with the AWR electronic design automation (EDA) software Microwave Office®.

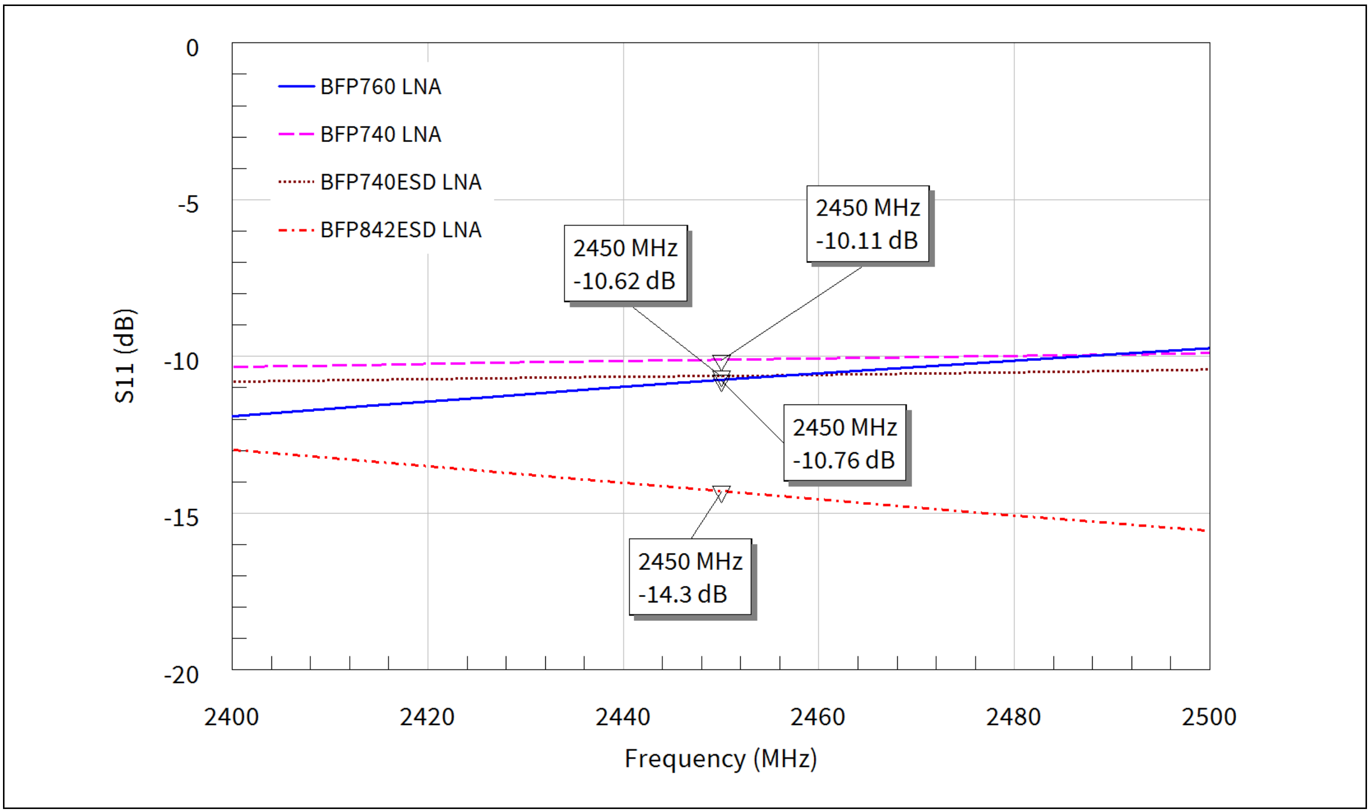


Figure 8 Input return loss measurement of the 2.4 GHz band WLAN LNAs with SOT343 packaged transistors

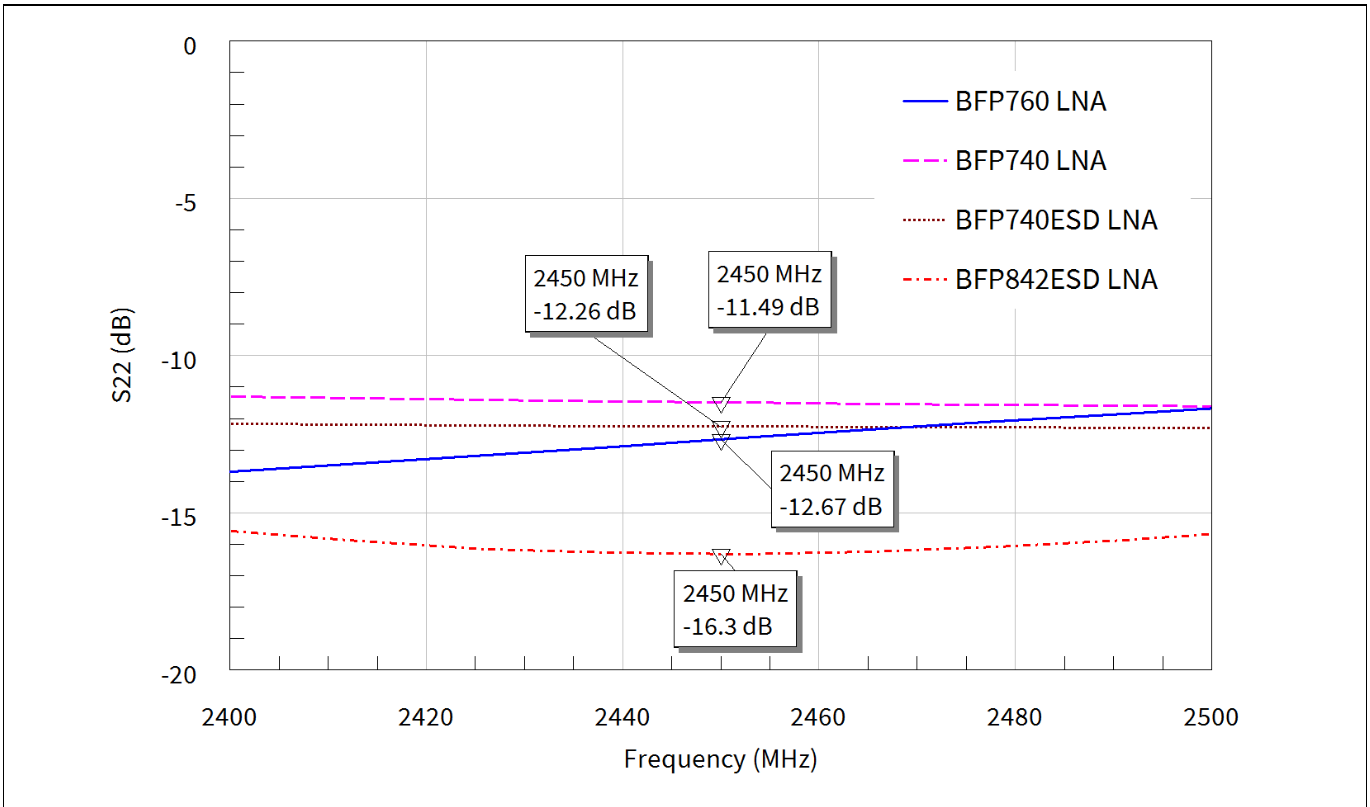


Figure 9 Output return loss measurement of the 2.4 GHz band WLAN LNAs with SOT343 packaged transistors

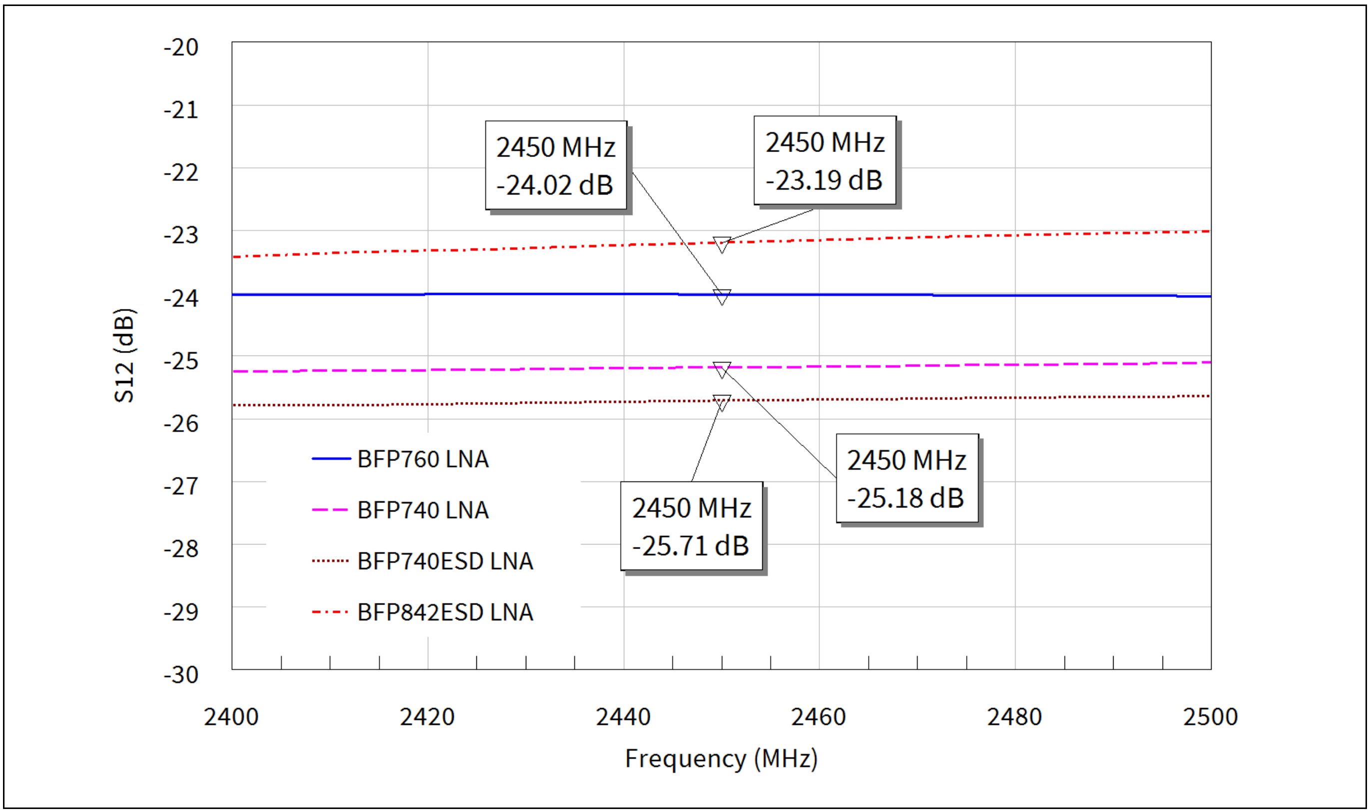


Figure 10 Reverse isolation measurement of the 2.4 GHz band WLAN LNAs with SOT343 packaged transistors

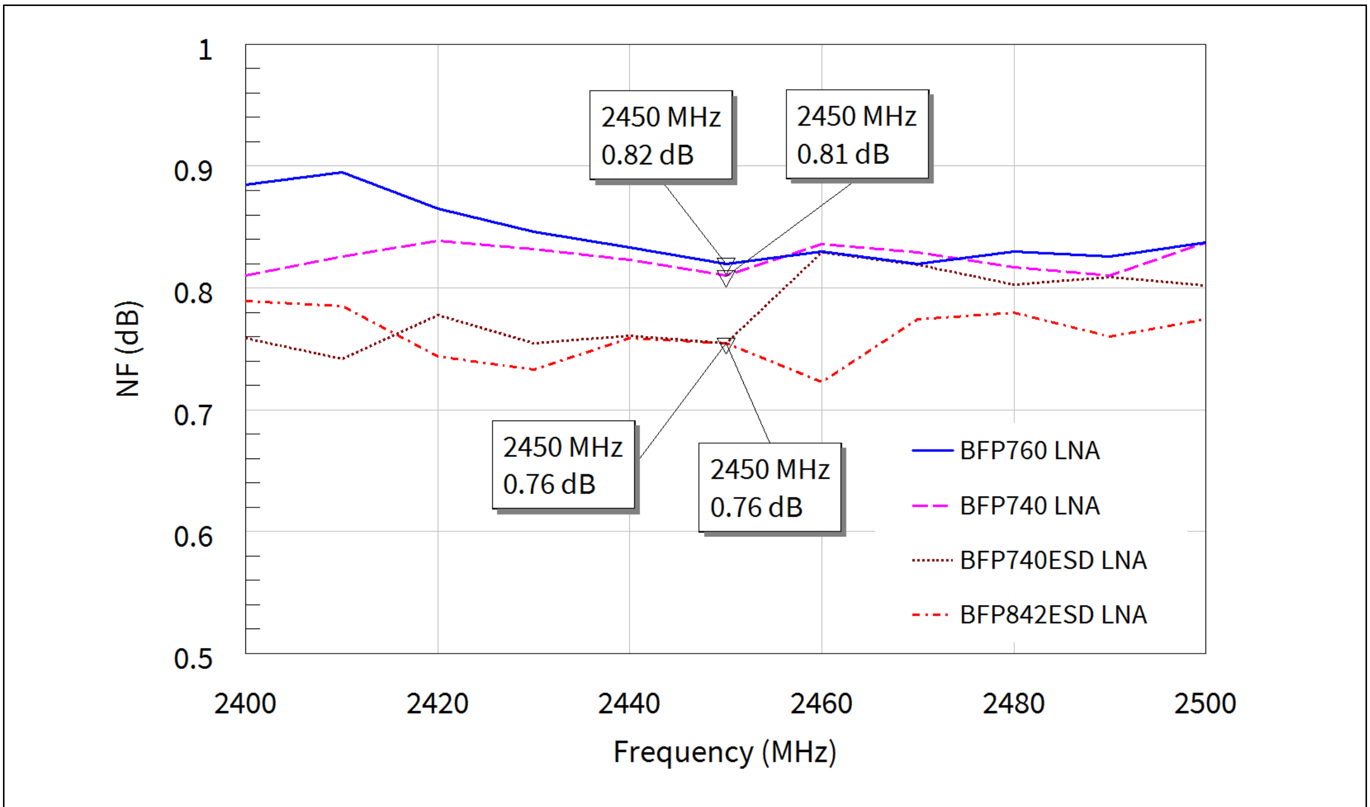


Figure 11 NF measurement of the 2.4 GHz band WLAN LNAs with SOT343 packaged transistors

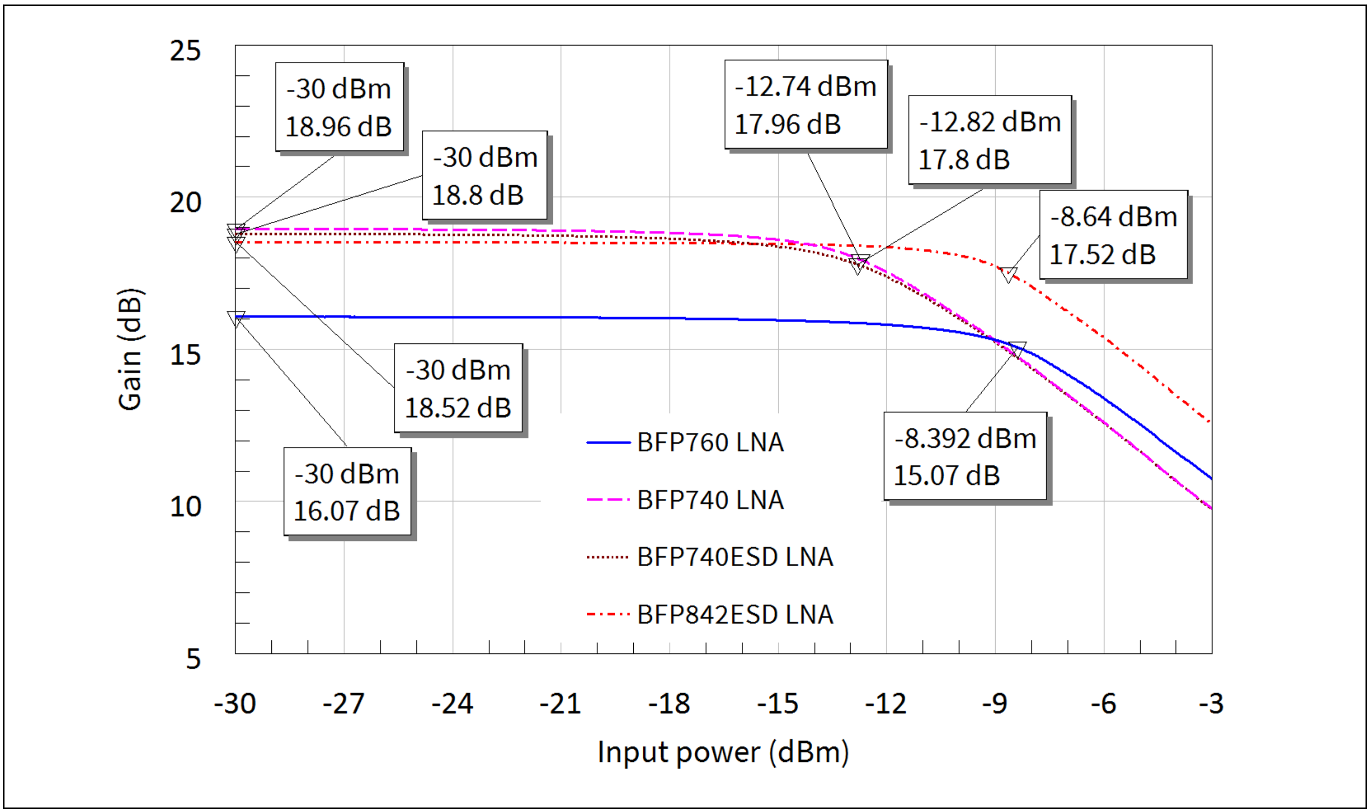


Figure 12 Input 1 dB compression point measurement of the 2.4 GHz band WLAN LNAs with SOT343 packaged transistors

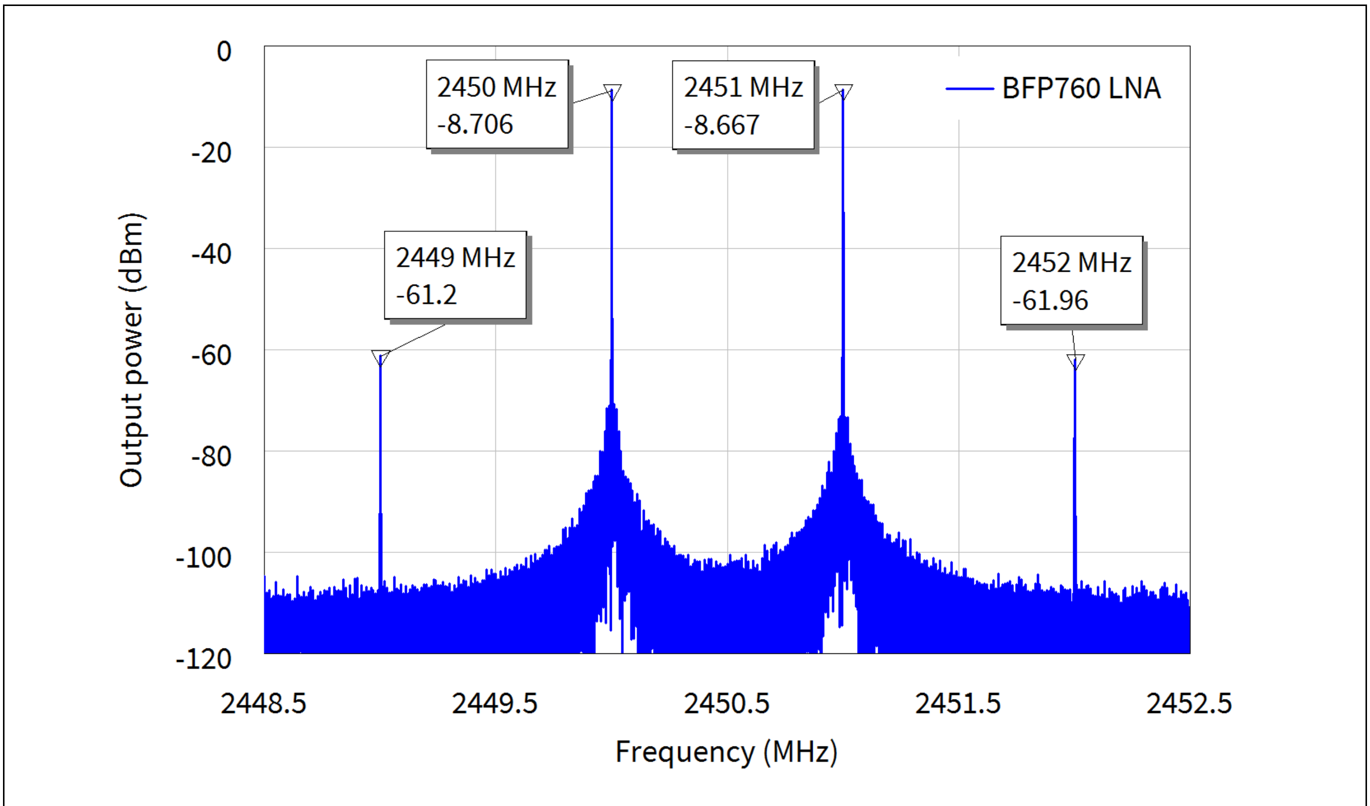


Figure 13 Output third-order intermodulation distortion (IMD_3) measurement of the 2.4 GHz band WLAN LNA with BFP760

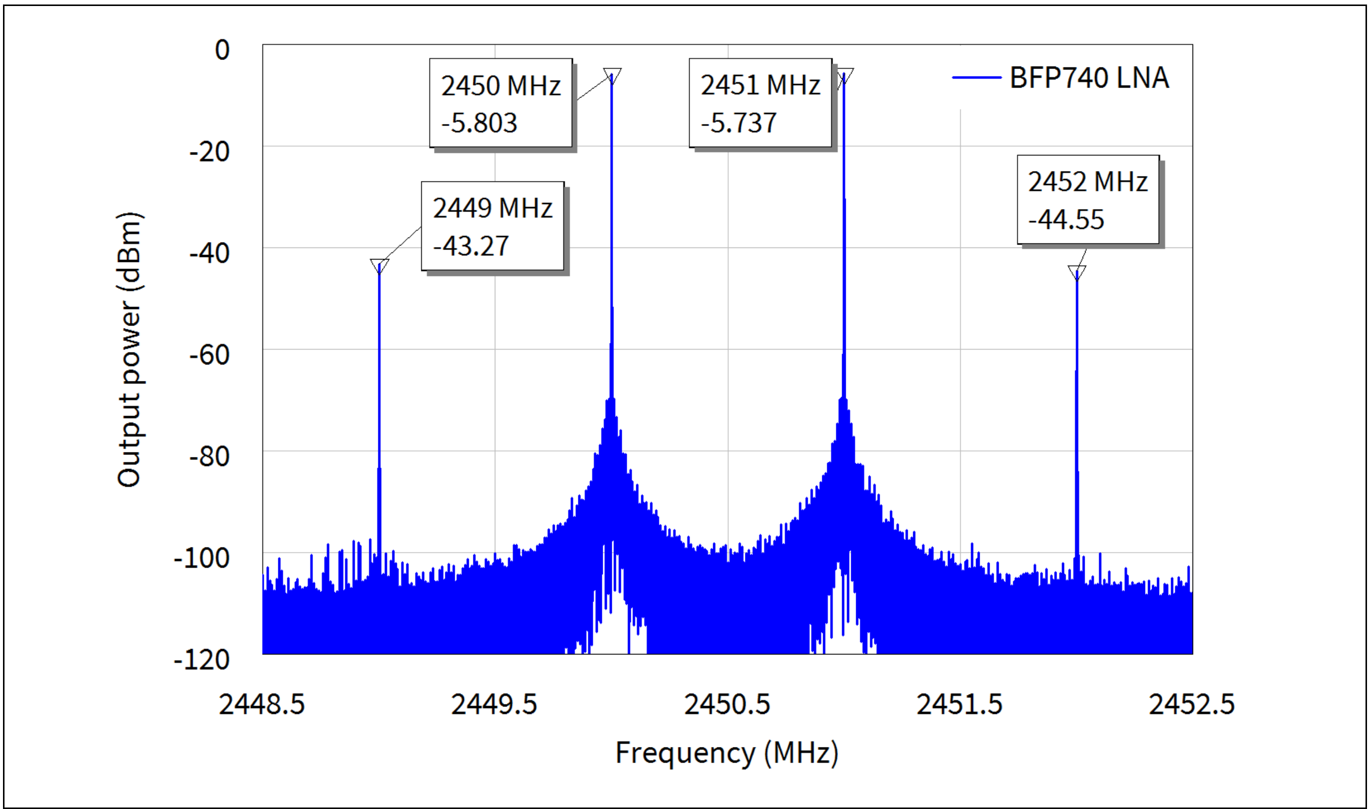


Figure 14 Output IMD_3 measurement of the 2.4 GHz band WLAN LNA with BFP740

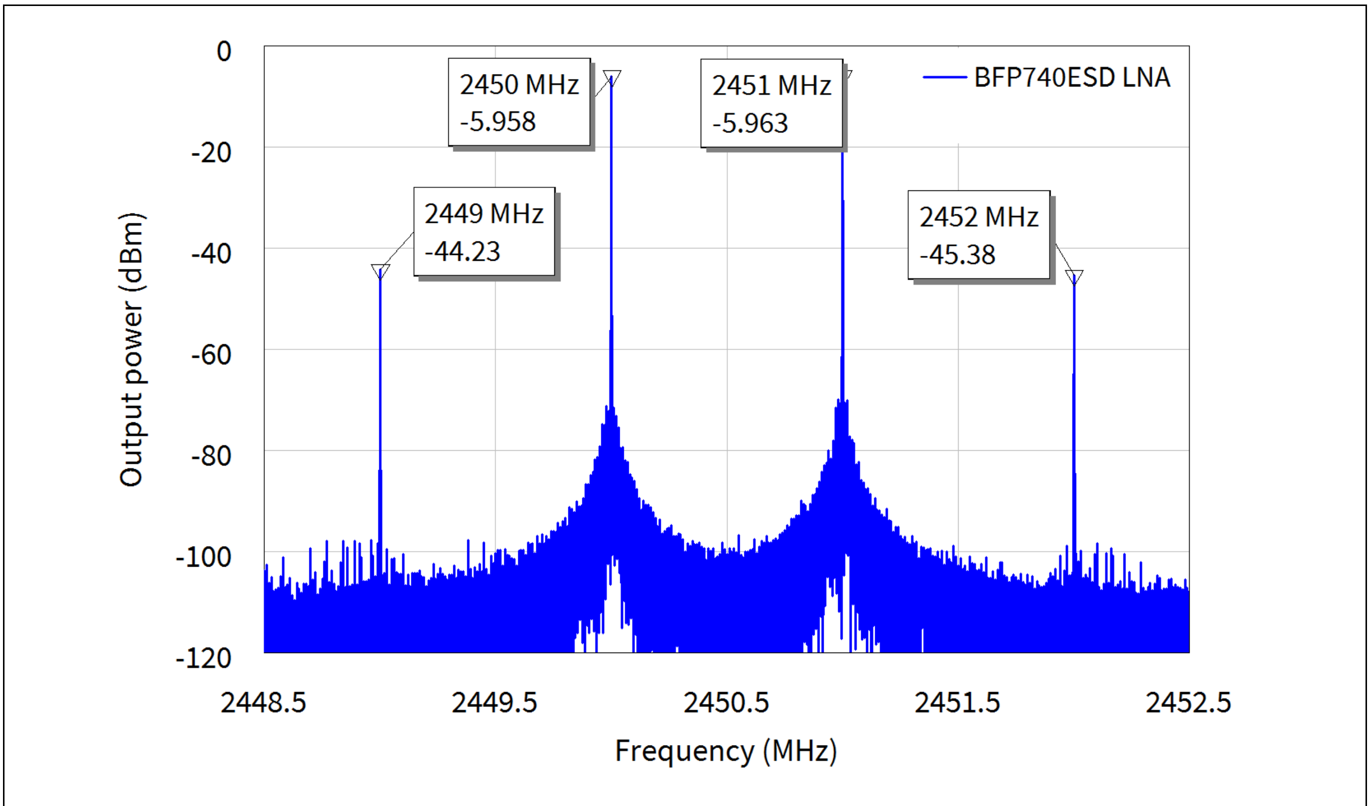


Figure 15 Output IMD_3 measurement of the 2.4 GHz band WLAN LNA with BFP740ESD

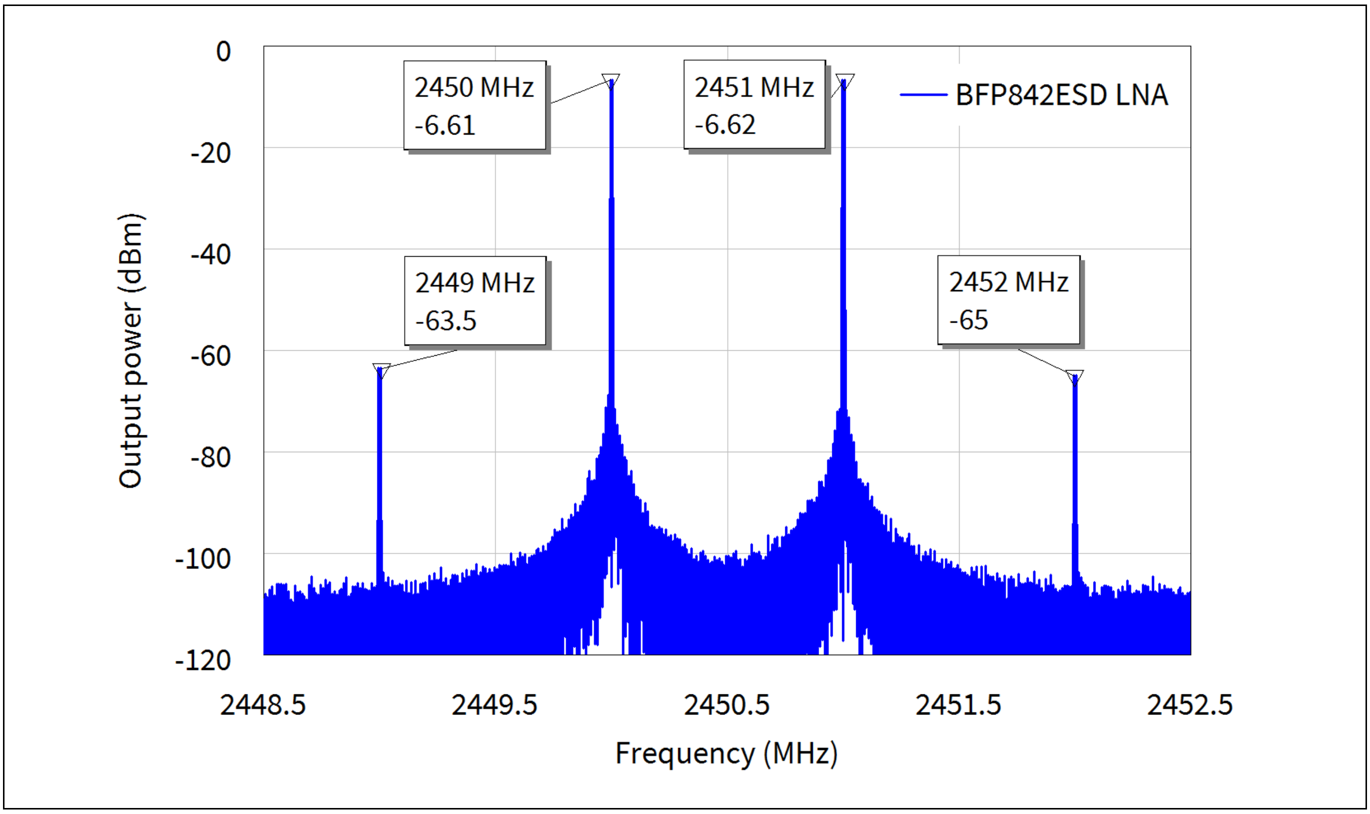


Figure 16 Output IMD$_3$ measurement of the 2.4 GHz band WLAN LNA with BFP842ESD

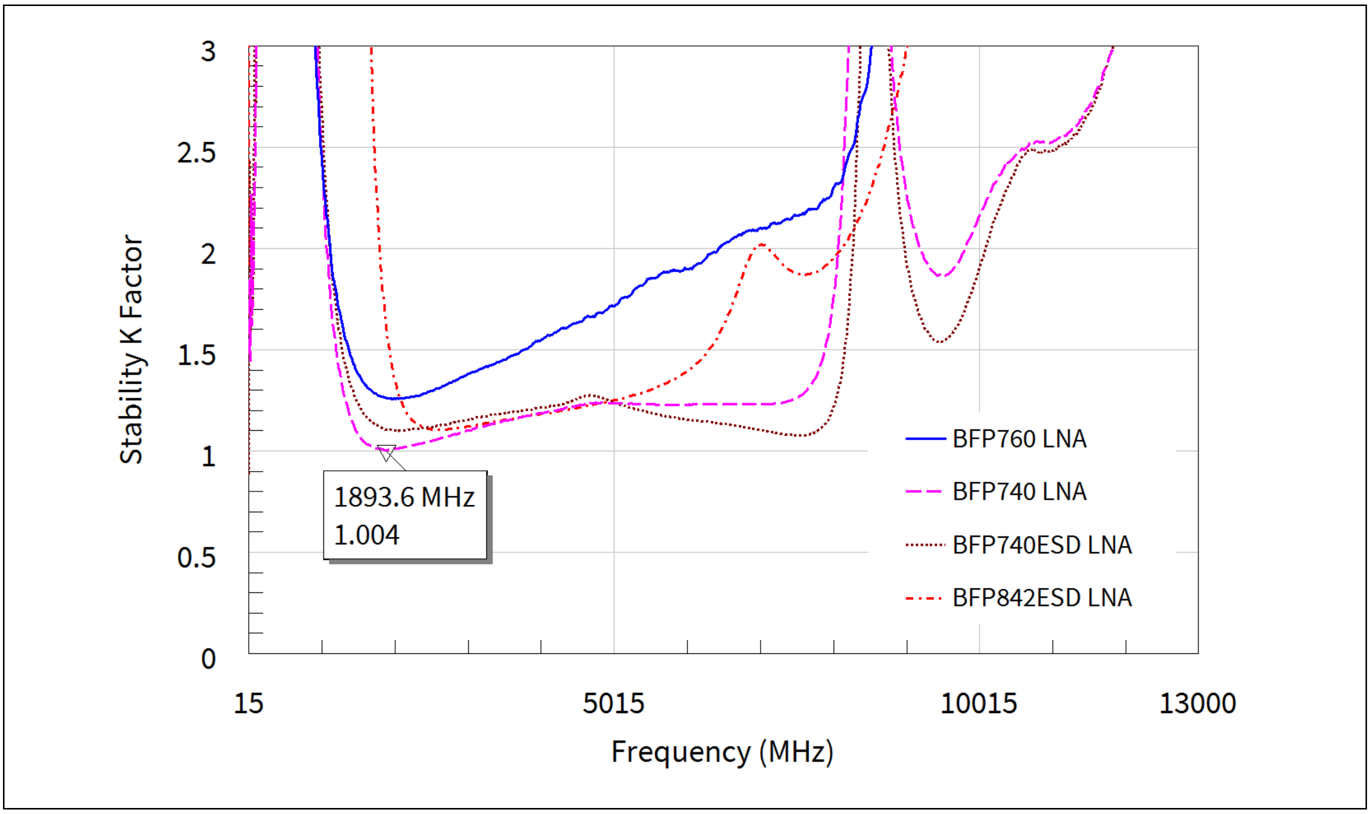


Figure 17 Stability K-factor plots of the 2.4 GHz band WLAN LNAs with SOT343 packaged transistors

2.2 2.4 GHz band WLAN LNAs with small and flat leaded TSFP packaged low-noise transistors

2.2.1 Performance overview

The following table shows the performance of the 2.4 GHz band WLAN LNAs with small and flat leaded TSFP packaged low-noise transistors.

Table 3 Summary of measurement results for the 2.4 GHz band WLAN LNAs with small and flat leaded TSFP packaged low-noise transistors

Parameter	Symbol	Value		Unit	Notes
Device		BFP740F	BFP740FESD		
Bias voltage	V_{CC}	3	3	V	
Bias current	I_{CC}	11.6	11	mA	
Frequency	f	2.45	2.45	GHz	
Gain	G	17.1	16.6	dB	
NF	NF	0.71	0.76	dB	PCB and SMA loss subtracted: 0.1 dB
Input return loss	RL_{in}	10	10	dB	
Output return loss	RL_{out}	11	9.8	dB	
Reverse isolation	ISO_{rev}	28.8	29.2	dB	
Output 1 dB compression point	OP_{1dB}	2.1	1.5	dBm	
Output third-order intercept point	OIP_3	11.1	10.7	dBm	Input power: -25 dBm per tone Tone 1: 2450 MHz Tone 2: 2451 MHz
Stability	K	>1	>1		Measured from 10 MHz to 13 GHz

2.2.2 Schematic

The following figure shows the schematic of the 2.4 GHz band WLAN LNAs with small and flat leaded TSFP packaged low-noise transistors. Like the previous LNA circuits, emitter degeneration has been adopted to achieve the transistor impedance matching and low-noise matching at the same time. Please refer to the detailed setting in Figure 19. In the LNA circuit, resistors R1 and R2 form the negative DC feedback mechanism to stabilize the transistor bias points in various conditions. Capacitors C2 and C3 serve as the RF bypass. Transistors' input matching is achieved by the capacitor C1 and the inductor L1. The output matching network is formed by C4, C5, L2, R3 and R4. Resistors R3 and R4 also have the function of improving circuit stability.

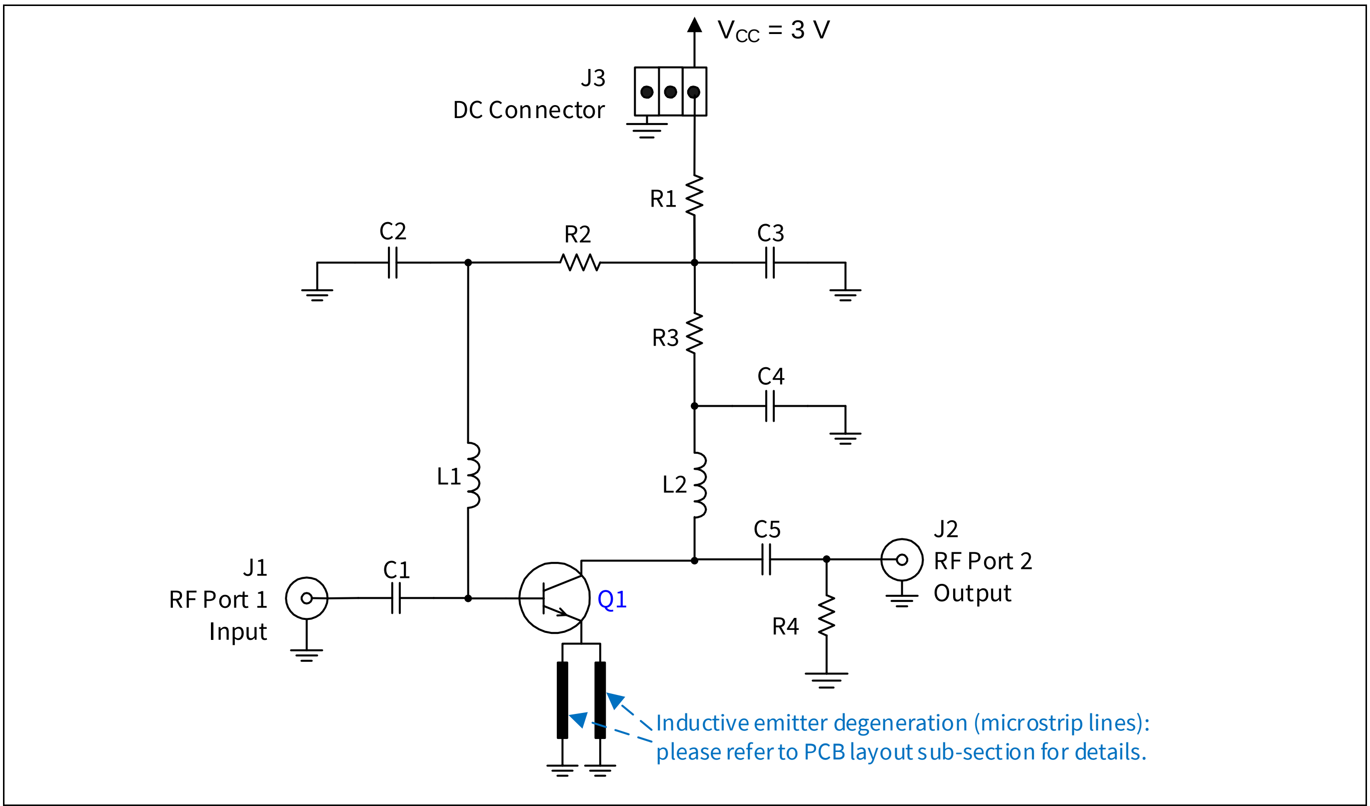


Figure 18 Schematic of the 2.4 GHz band WLAN LNAs with small and flat leaded TSFP packaged transistors

2.2.3 BOM

Table 4 BOM of the 2.4 GHz band WLAN LNAs with small and flat leaded TSFP packaged transistors

Symbol	Value		Unit	Size	Manufacturer	Comment
Q1	BFP740F	BFP740FESD	–	–	Infineon	SiGe:C low-noise transistor
C1	22	22	pF	0402	Various	Input matching and DC blocking
C2	39	39	pF	0402	Various	RF decoupling
C3	39	39	pF	0402	Various	RF decoupling
C4	3.3	3.3	pF	0402	Various	Output matching and stability improvement
C5	1.8	1.8	pF	0402	Various	Output matching and DC blocking
R1	30	30	Ω	0402	Various	DC biasing
R2	51	43	kΩ	0402	Various	Base DC biasing
R3	30	30	Ω	0402	Various	Low-frequency stability improvement
R4	100	100	Ω	0402	Various	Output matching and stability improvement
L1	10	10	nH	0402	Murata LQG	RF choke and input matching
L2	5.1	5.6	nH	0402	Murata LQG	RF choke and output matching

2.2.4 Evaluation board and PCB layout information

The evaluation board for the 2.4 GHz band WLAN LNAs with small and flat leaded TSFP packaged transistors:

- PCB material: FR4
- PCB marking: M11118

The photo of the evaluation board for the 2.4 GHz band WLAN LNAs with small and flat leaded TSFP packaged transistors and the detailed description of the PCB stack are shown in the following figures.

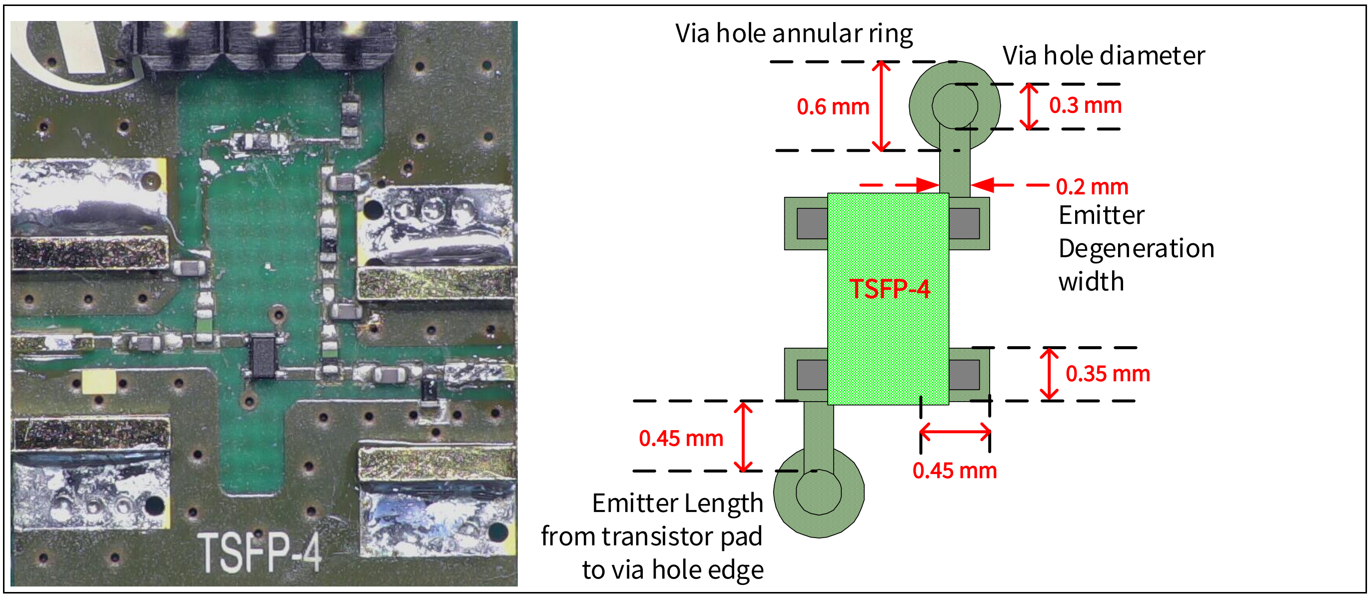


Figure 19 Photo of the evaluation board with PCB marking M11118 (left) and emitter degeneration details (right)

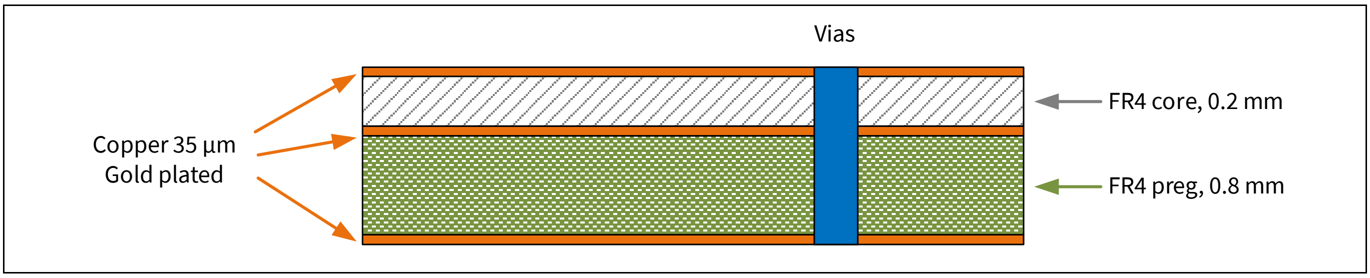


Figure 20 PCB stack information for the evaluation board with PCB marking M11118

2.2.5 Measurement results of 2.4 GHz band WLAN LNAs with small and flat leaded TSFP packaged low-noise transistors

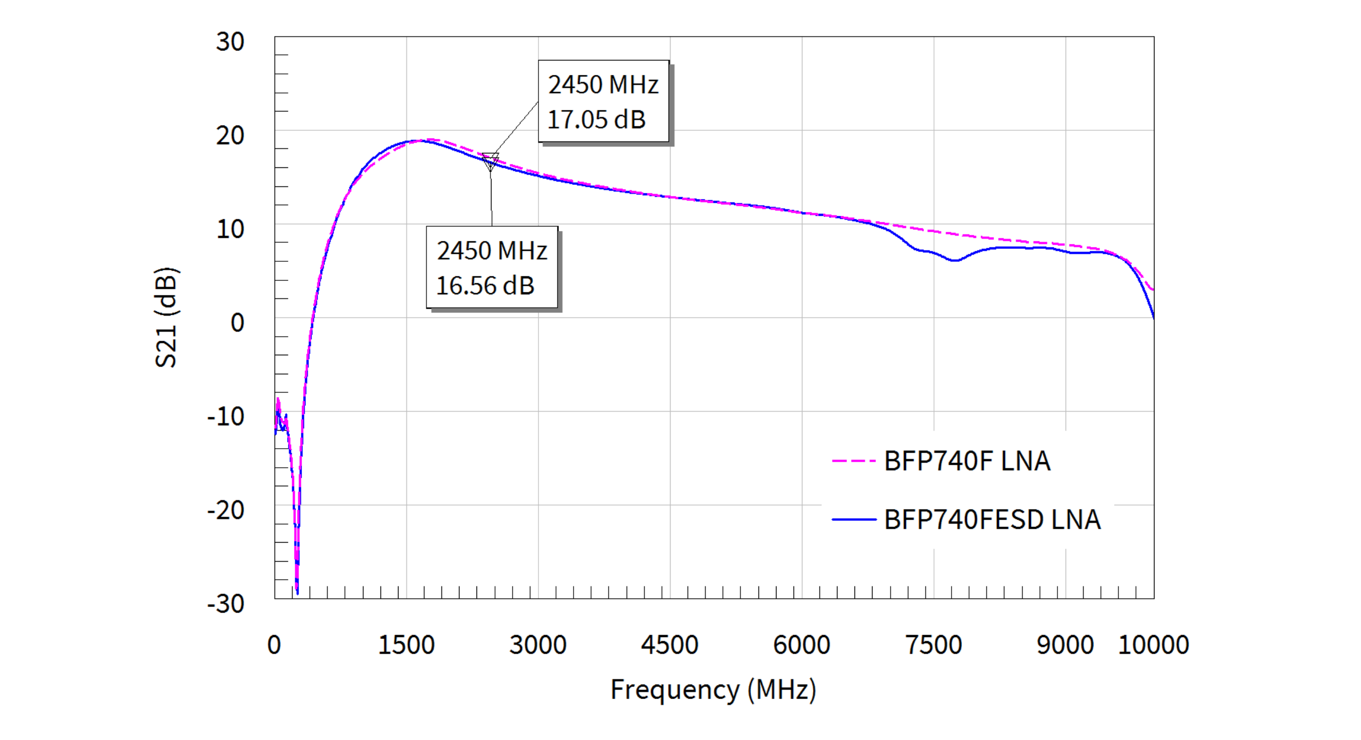


Figure 21 Small signal gain of the 2.4 GHz band WLAN LNAs with TSFP packaged transistors

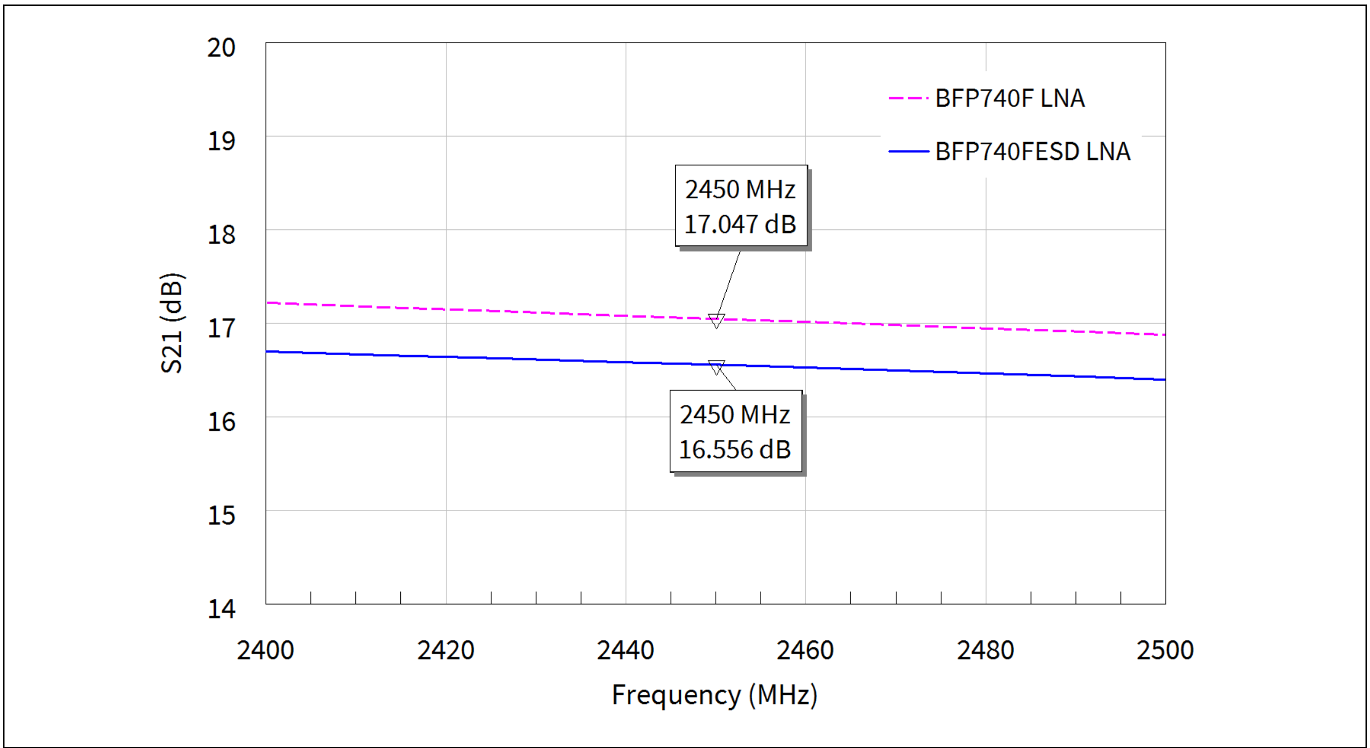


Figure 22 Small signal gain of the 2.4 GHz band WLAN LNAs with TSFP packaged transistors (detail view)

Note: *The graphs are generated with the AWR EDA software Microwave Office®.*

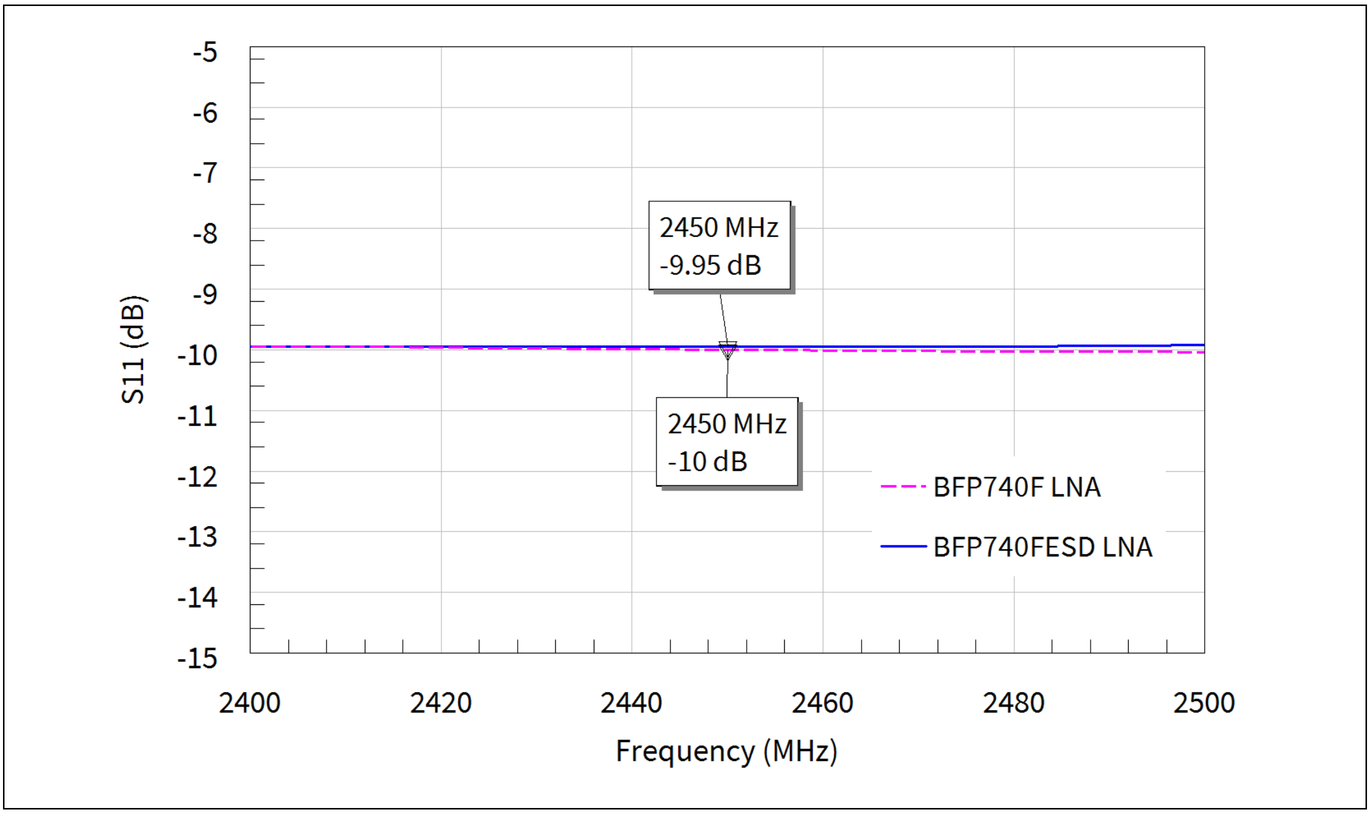


Figure 23 Input return loss measurement of the 2.4 GHz band WLAN LNAs with TSFP packaged transistors

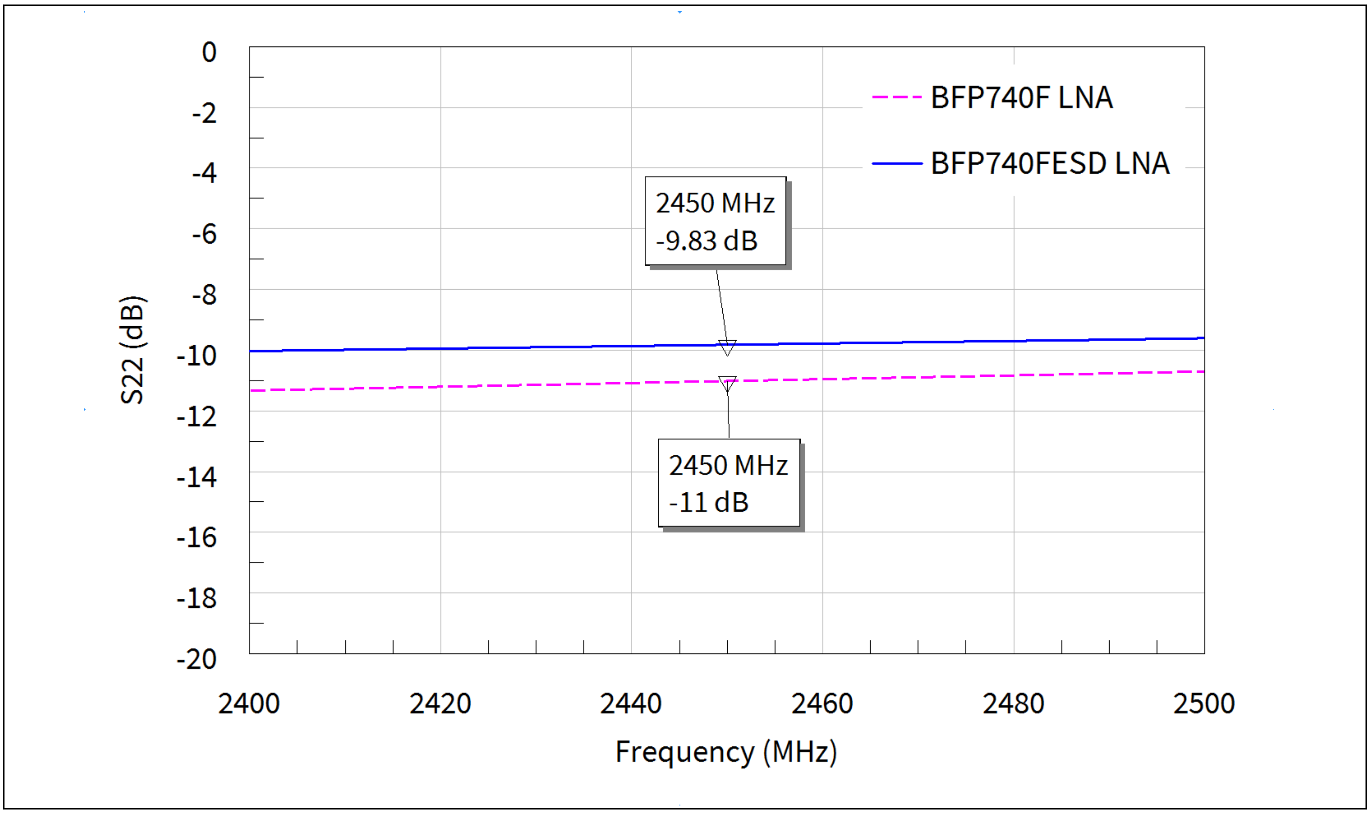


Figure 24 Output return loss measurement of the 2.4 GHz band WLAN LNAs with TSFP packaged transistors

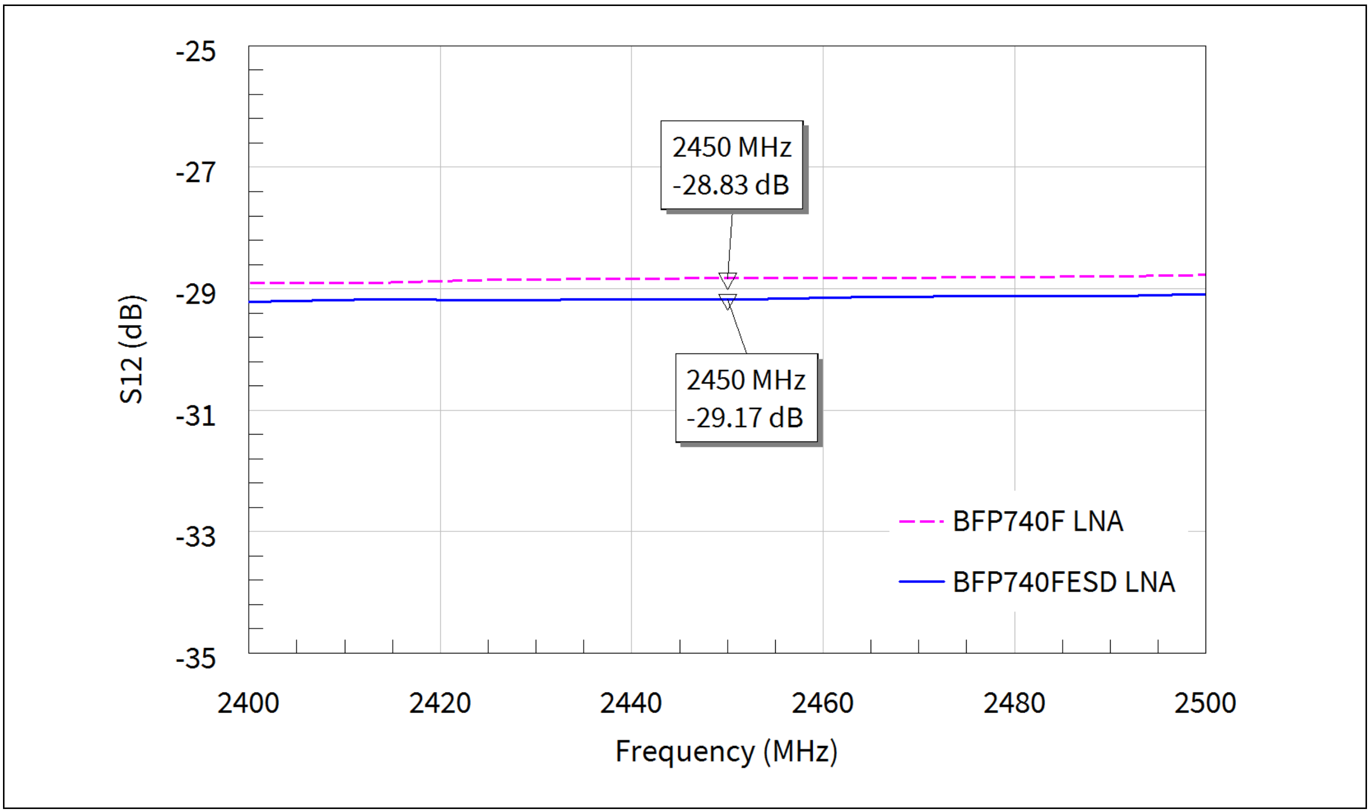


Figure 25 Reverse isolation measurement of the 2.4 GHz band WLAN LNAs with TSFP packaged transistors

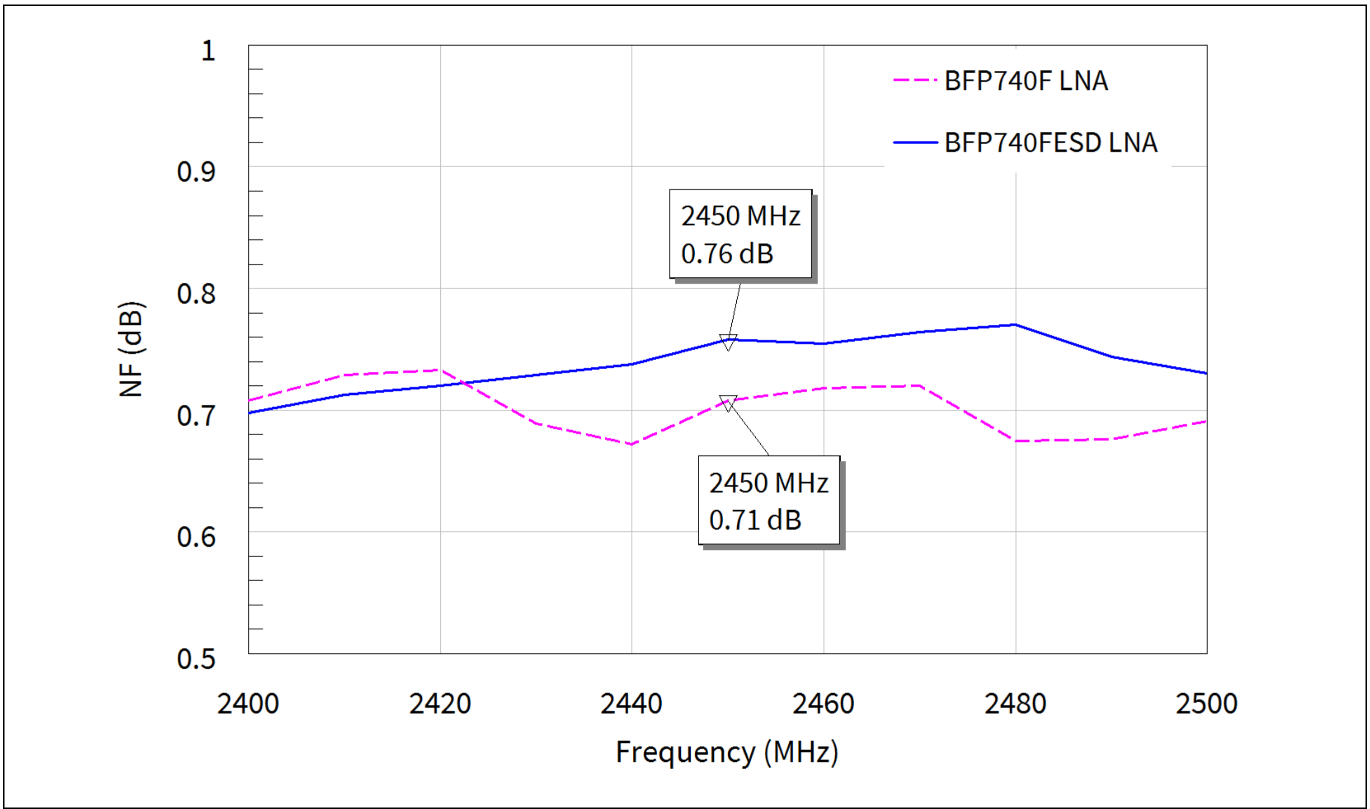


Figure 26 NF measurement of the 2.4 GHz band WLAN LNAs with TSFP packaged transistors

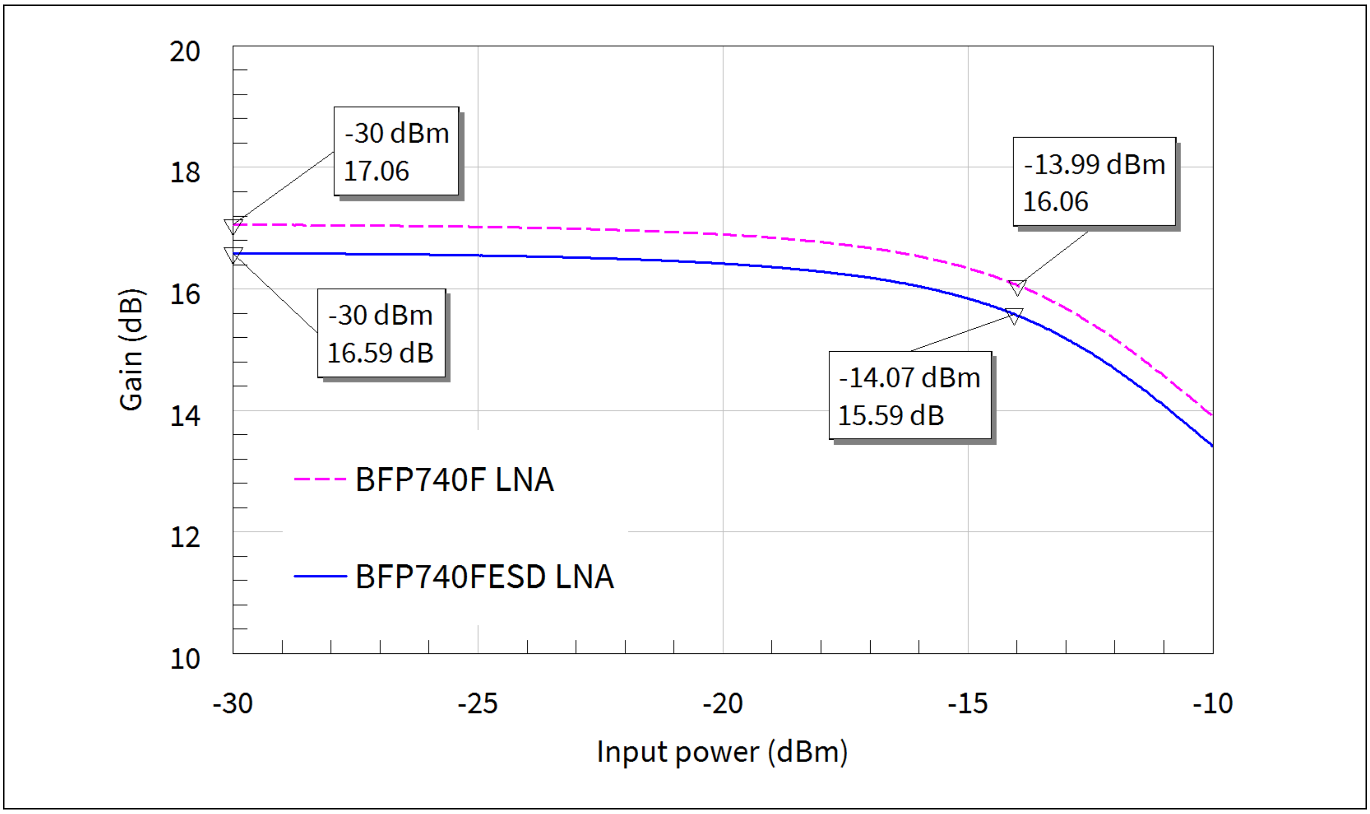


Figure 27 Input 1 dB compression point measurement of the 2.4 GHz band WLAN LNAs with TSFP packaged transistors

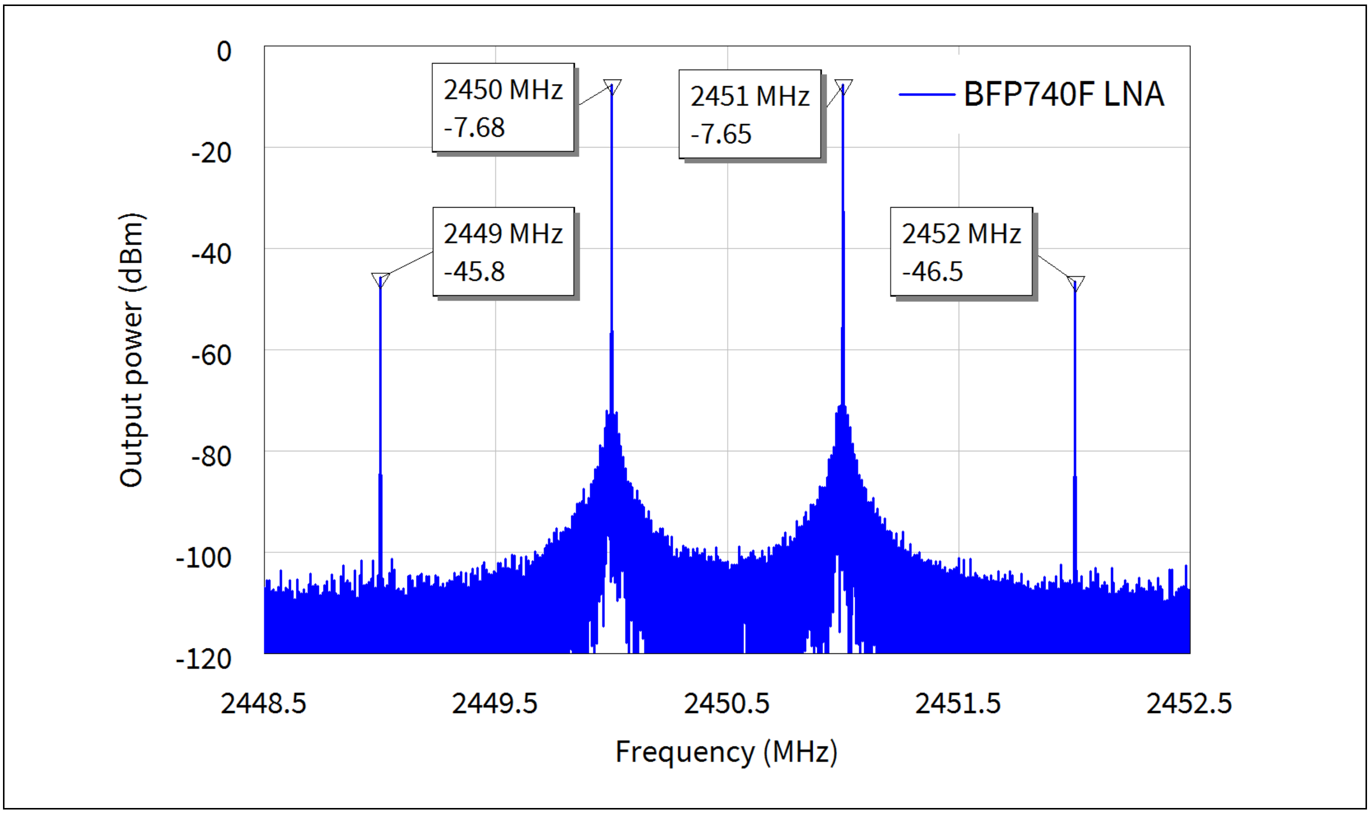


Figure 28 Output IMD_3 measurement of the 2.4 GHz band WLAN LNA with BFP740F

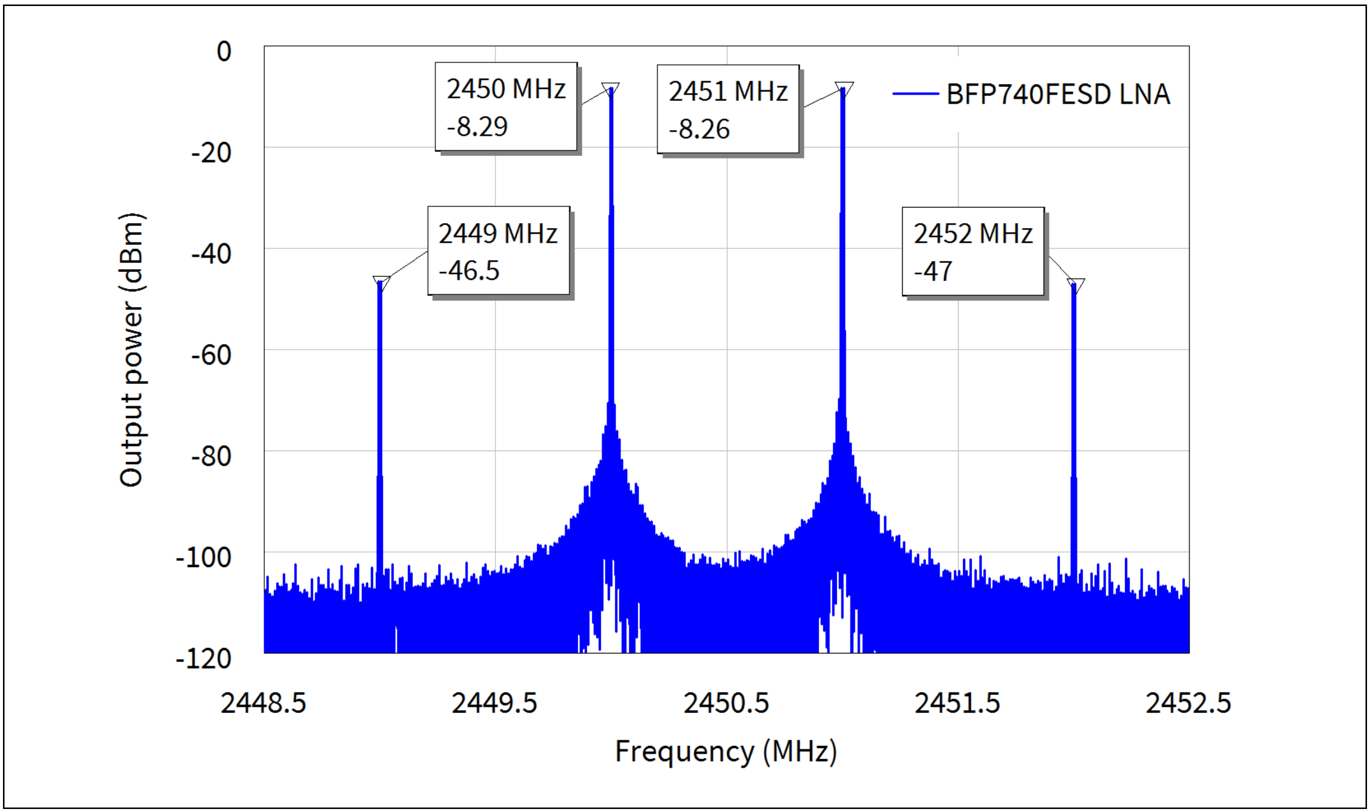


Figure 29 Output IMD_3 measurement of the 2.4 GHz band WLAN LNA with BFP740FESD

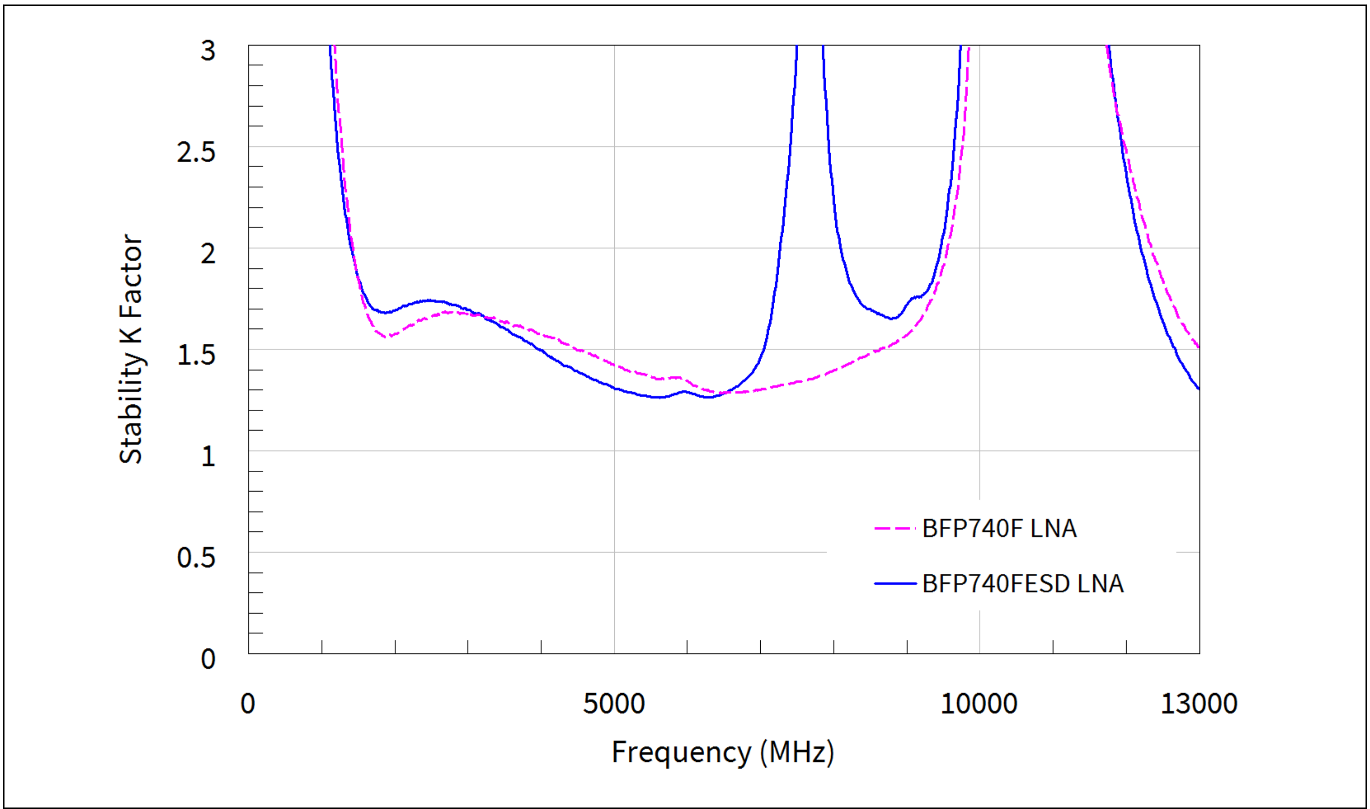


Figure 30 Stability K-factor plots of the 2.4 GHz band WLAN LNAs with TSFP packaged transistors

2.3 2.4 GHz band WLAN LNA with small leaded three-pin low-noise transistor BFR840L3RHESD

2.3.1 Performance overview

The following table shows the performance of the 2.4 GHz band WLAN LNA with small leaded three-pin TSLP packaged low-noise transistor BFR840L3RHESD.

Table 5 Summary of measurement results for the 2.4 GHz band WLAN LNA with BFR840L3RHESD

Parameter	Symbol	Value	Unit	Notes
Device		BFR840L3RHESD		
Bias voltage	V_{CC}	3.0	V	
Bias current	I_{CC}	11.4	mA	
Frequency	f	2.45	GHz	
Gain	G	18.5	dB	
NF	NF	1.02	dB	PCB and SMA connector losses subtracted: 0.1 dB
Input return loss	RL_{in}	12.5	dB	
Output return loss	RL_{out}	23.9	dB	
Reverse isolation	ISO_{rev}	28.4	dB	
Output 1 dB compression point	OP_{1dB}	0.6	dBm	
Output third-order intercept point	OIP_3	11.4	dBm	Input power: -30 dBm per tone Tone 1: 2450 MHz Tone 2: 2451 MHz
Stability	K	>1		Stability measured from 100 MHz to 13 GHz

2.3.2 Schematic

The following figure shows the schematic of the 2.4 GHz band WLAN LNA with the small leaded three-pin TSLP packaged transistor BFR840L3RHESD. Emitter degeneration provides negative feedback to achieve the transistor impedance matching and low-noise matching at the same time (see **Figure 32**). In the LNA circuit, resistors R1 and R2 stand for transistor voltage and current bias; meanwhile, they form a negative DC feedback mechanism to stabilize the transistor bias points in various conditions. Capacitors C2 and C3 serve as the RF bypass. Transistor input matching is achieved by the capacitor C1 and the inductor L1. The output matching network is formed by C4, L2, R4 and R5. Resistors R4 and R5 also have the function of improving circuit stability.

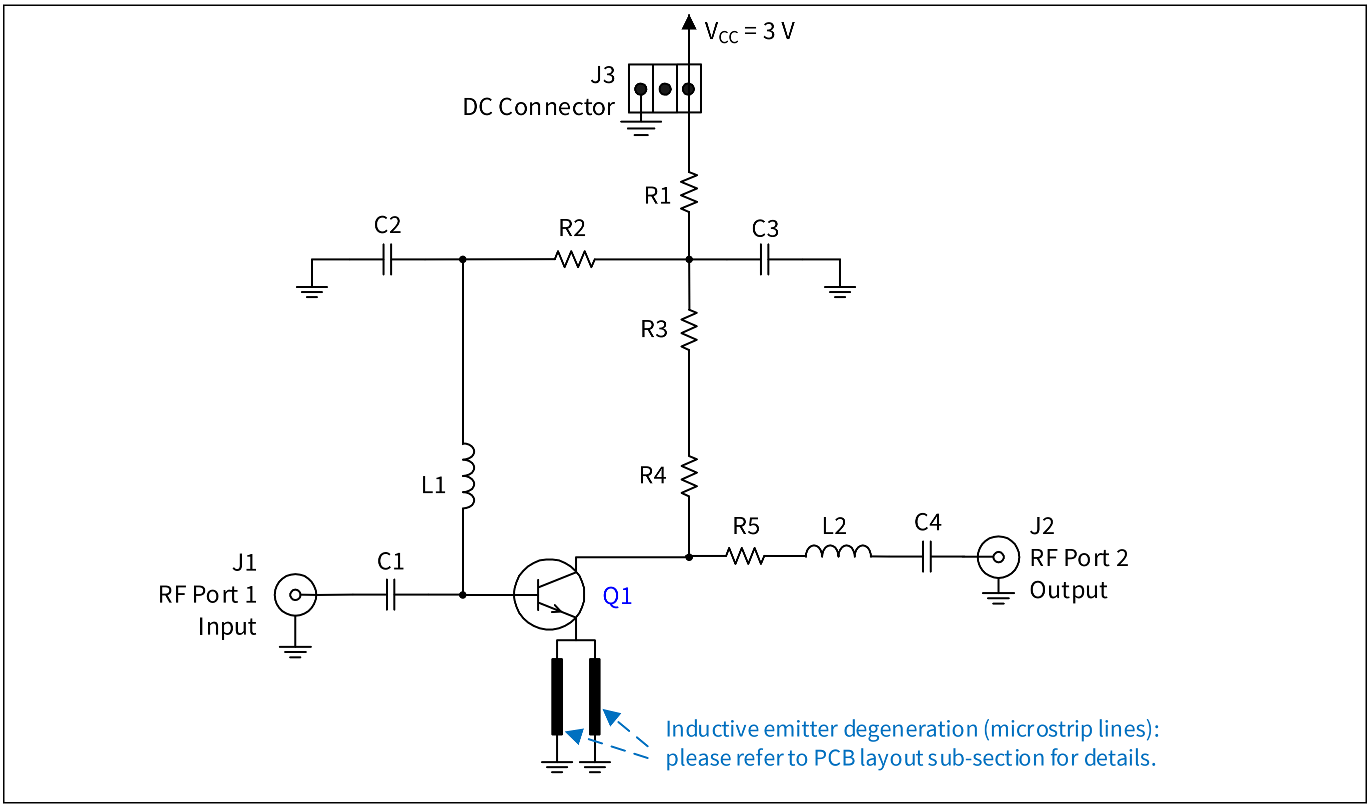


Figure 31 Schematic of the 2.4 GHz band WLAN LNA with BFR840L3RHESD

2.3.3 BOM

Table 6 BOM of the 2.4 GHz band WLAN LNA with BFR840L3RHESD

Symbol	Value	Unit	Size	Manufacturer	Comment
Q1	BFR840L3RHESD	–	–	Infineon	SiGe bipolar transistor
C1	2.2	pF	0201	Various	Input matching and DC blocking
C2	33	pF	0201	Various	RF decoupling
C3	33	pF	0201	Various	RF decoupling
C4	8.2	pF	0201	Various	Output matching and DC blocking
R1	100	Ω	0201	Various	DC biasing
R2	27	kΩ	0201	Various	Base DC biasing
R3	0	Ω	0201	Various	Jumper
R4	82	Ω	0201	Various	Stability improvement and output matching
R5	10	Ω	0201	Various	High-frequency stability improvement
L1	2.7	nH	0201	Murata LQP series	RF choke and input matching
L2	2.4	nH	0201	Murata LQP series	Output matching

2.3.4 Evaluation board and PCB layout information

The evaluation board for the 2.4 GHz band WLAN LNA with small leaded three-pin TSLP packaged transistor BFR840L3RHESD:

- PCB material: FR4
- PCB marking: M120131

The photo of the evaluation board for the 2.4 GHz band WLAN LNA with BFR840L3RHESD and the detailed description of the PCB stack are shown in the following figures.

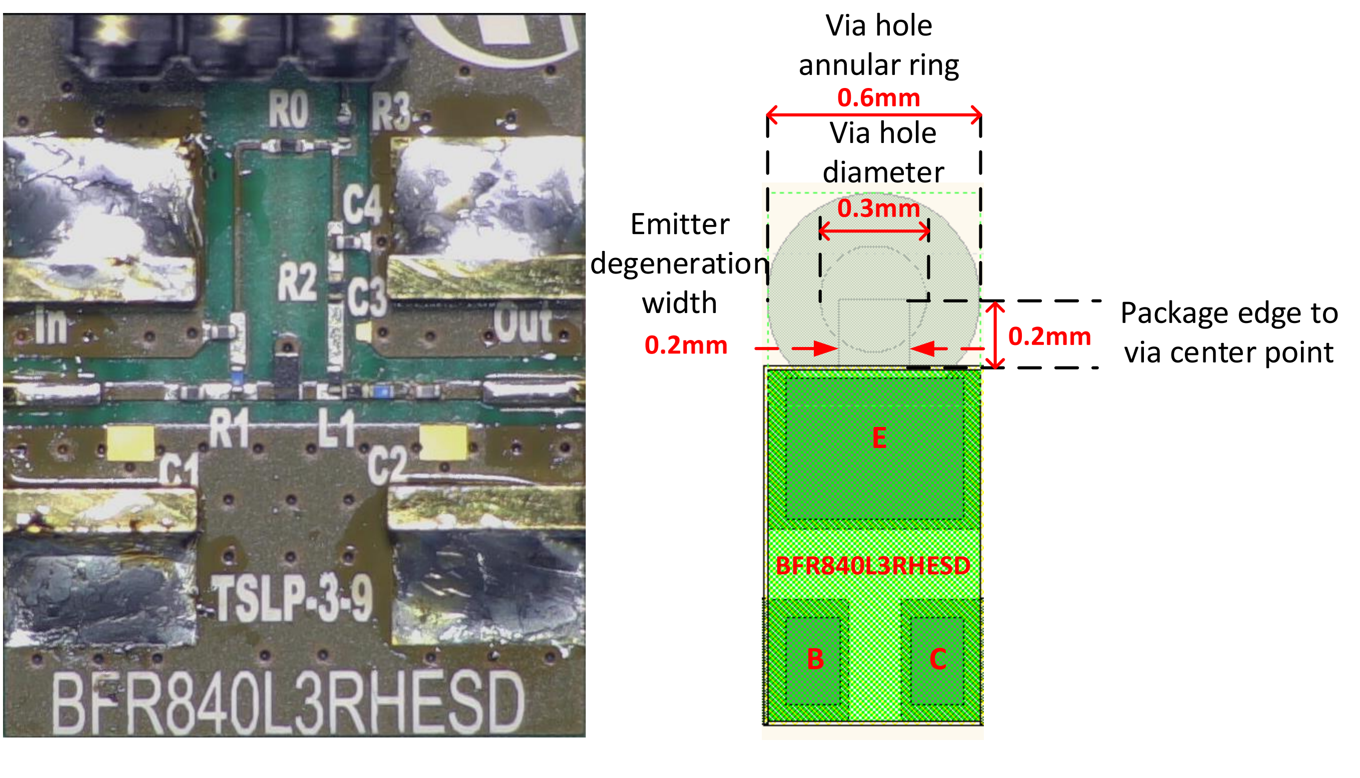


Figure 32 Photo of the evaluation board with the PCB marking M120131 (left) and emitter degeneration details (right)

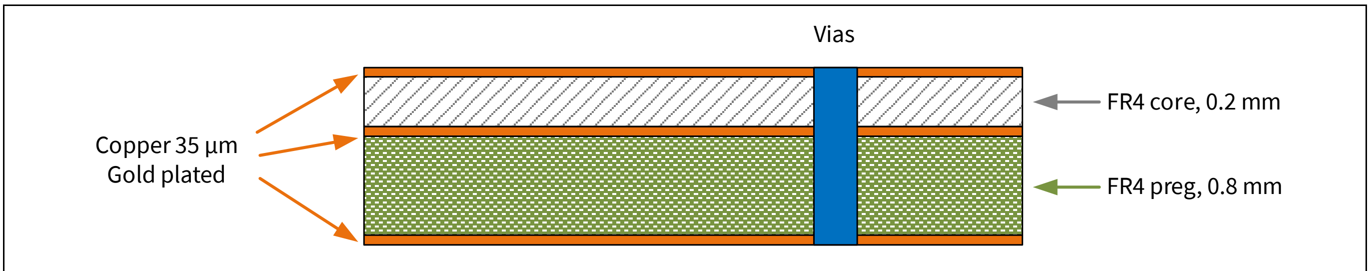


Figure 33 PCB stack information for the evaluation board with the PCB marking M120131

2.3.5 Measurement results of the 2.4 GHz band WLAN LNA with small leaded three-pin TSLP packaged low-noise transistor BFR840L3RHESD

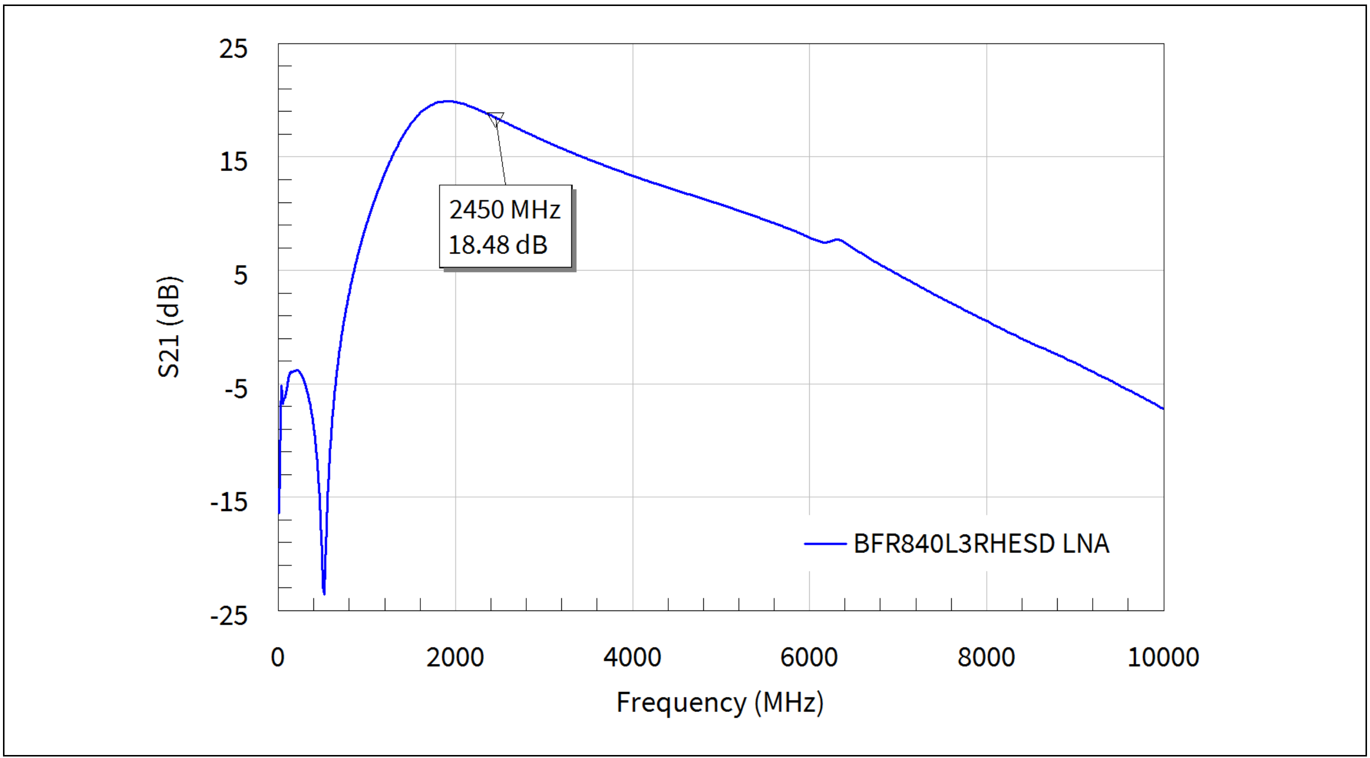


Figure 34 Small signal gain of the 2.4 GHz band WLAN LNA with BFR840L3RHESD

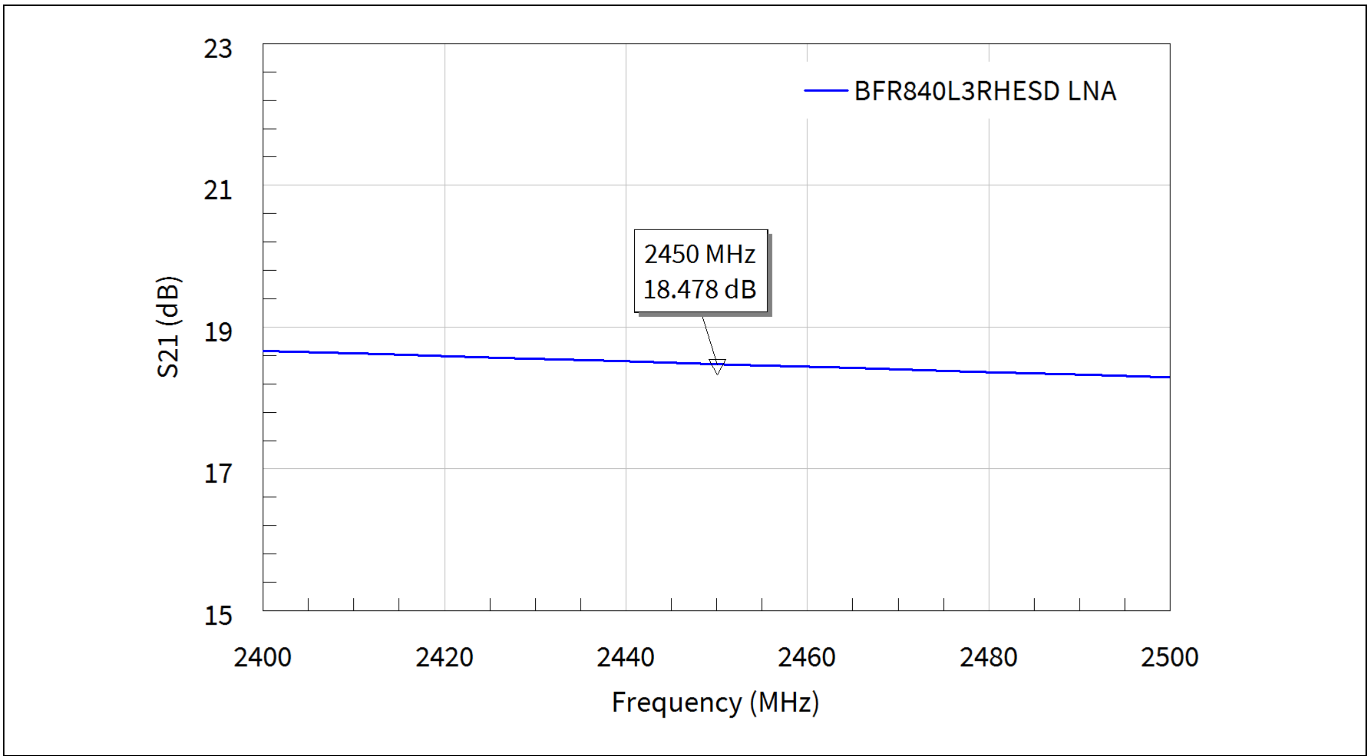


Figure 35 Small signal gain of the 2.4 GHz band WLAN LNA with BFR840L3RHESD (detail view)

Note: The graphs are generated with the AWR EDA software Microwave Office®.

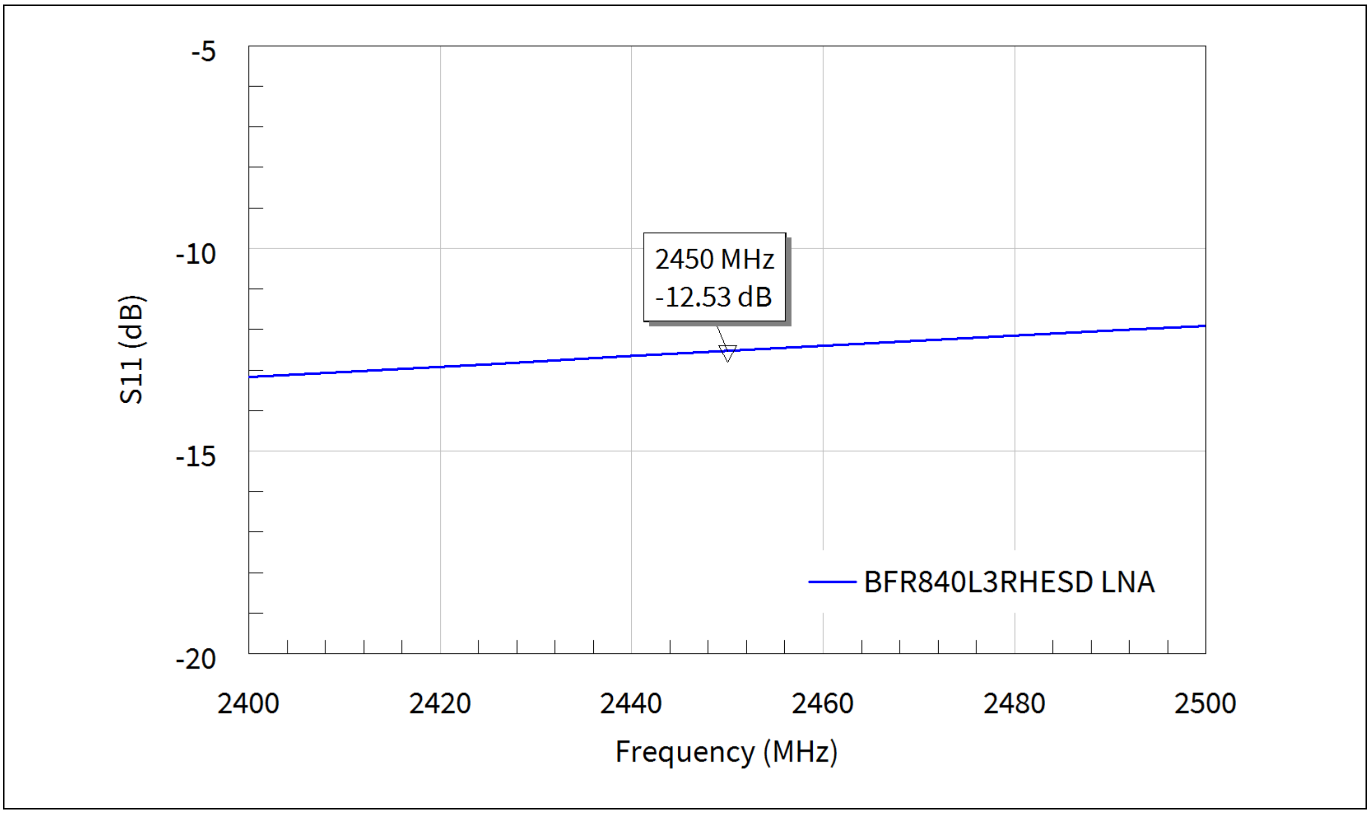


Figure 36 Input return loss measurement of the 2.4 GHz band WLAN LNA with BFR840L3RHESD

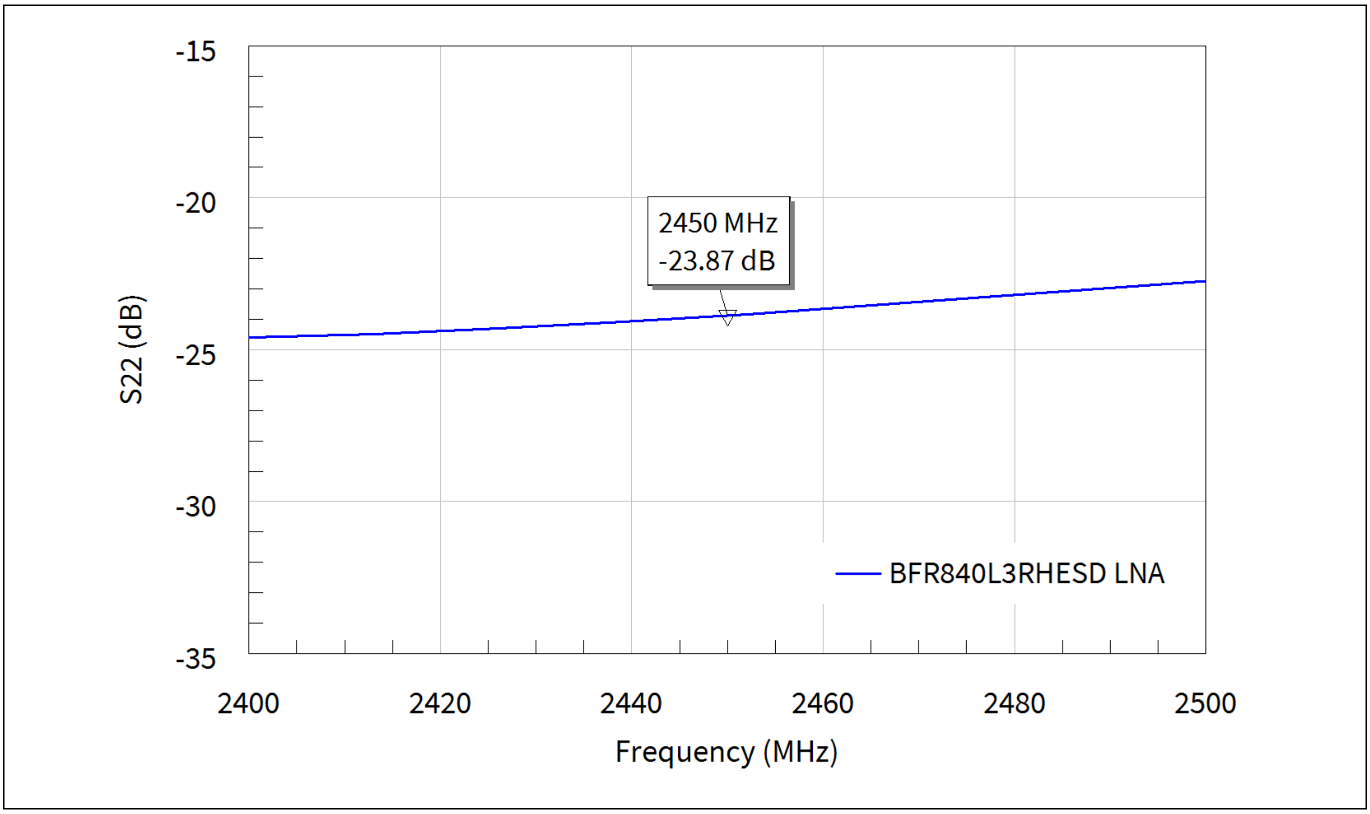


Figure 37 Output return loss measurement of the 2.4 GHz band WLAN LNA with BFR840L3RHESD

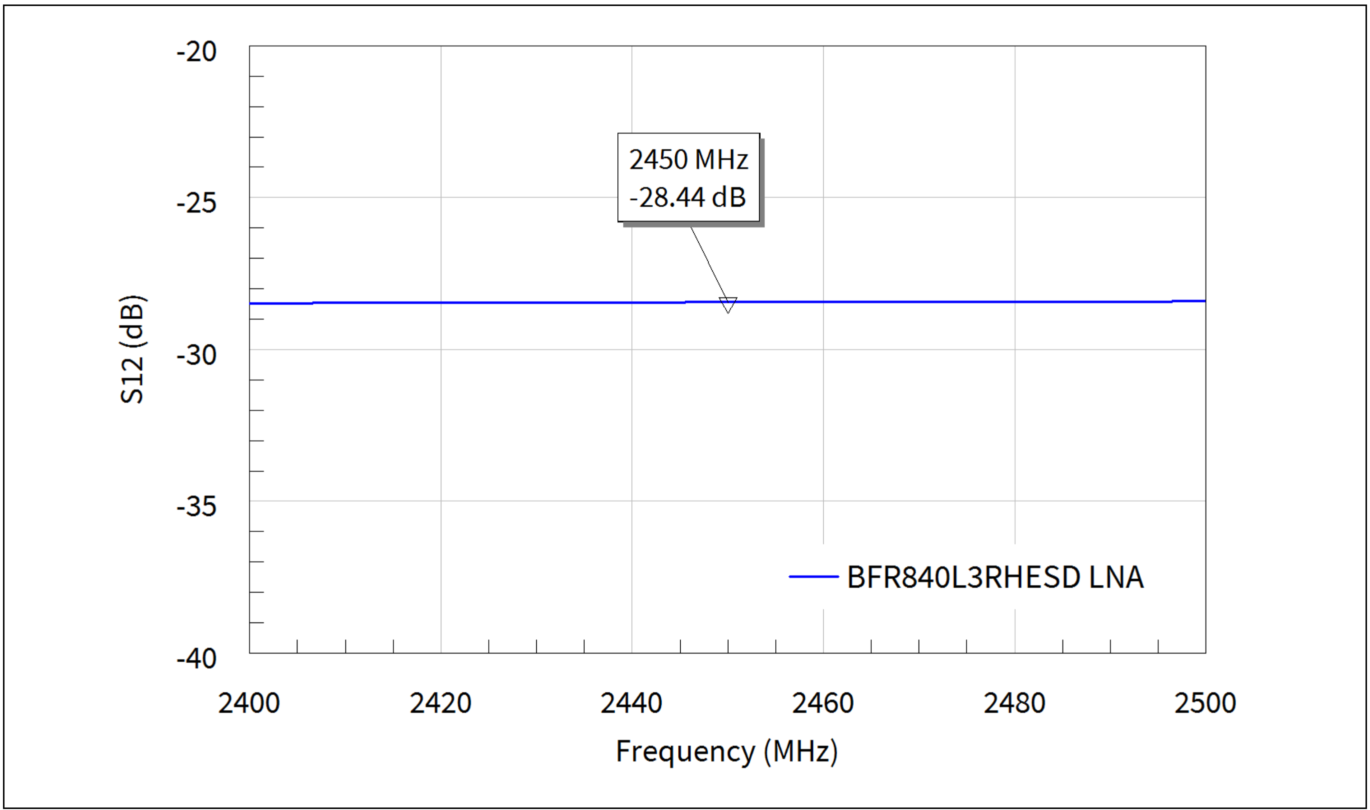


Figure 38 Reverse isolation measurement of the 2.4 GHz band WLAN LNA with BFR840L3RHESD

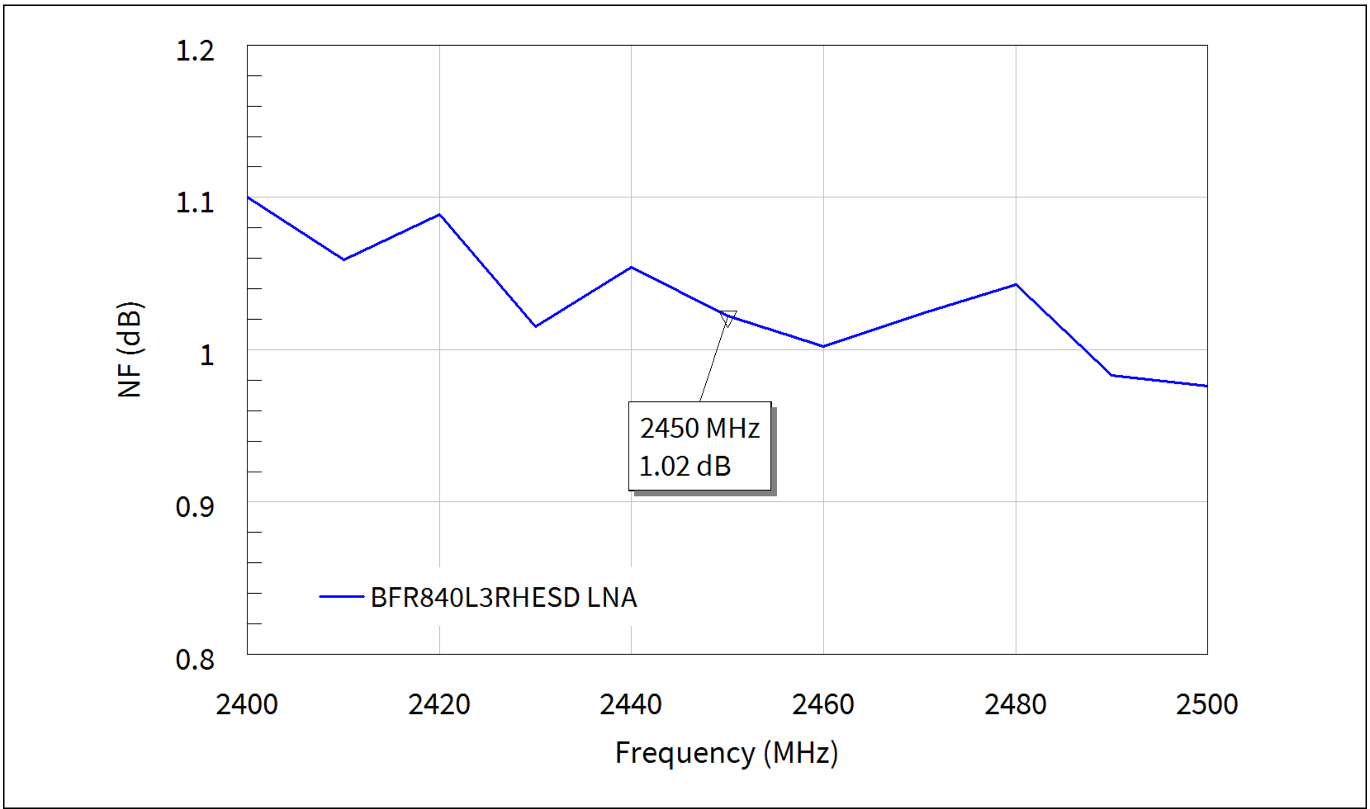


Figure 39 NF measurement of the 2.4 GHz band WLAN LNA with BFR840L3RHESD

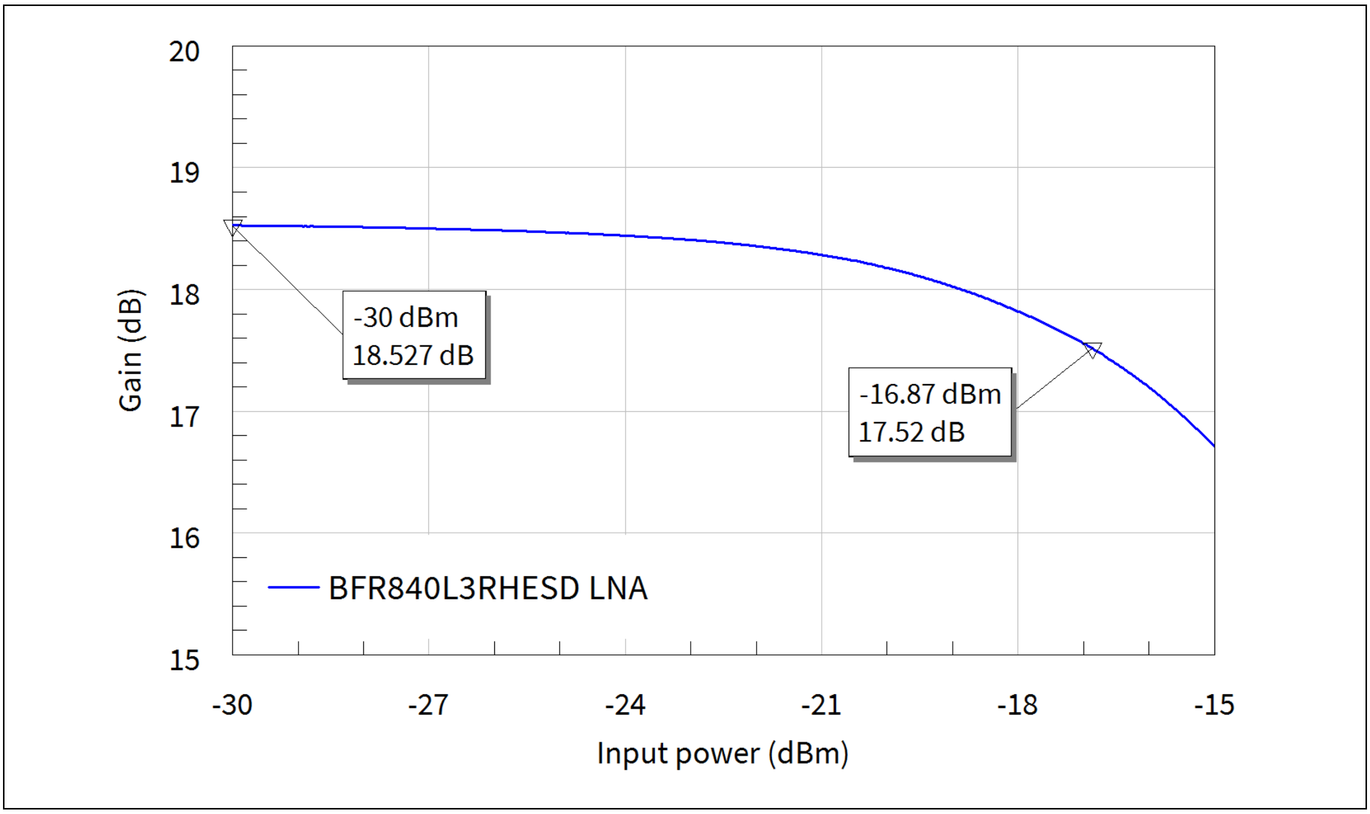


Figure 40 Input 1 dB compression point measurement of the 2.4 GHz band WLAN LNA with BFR840L3RHESD

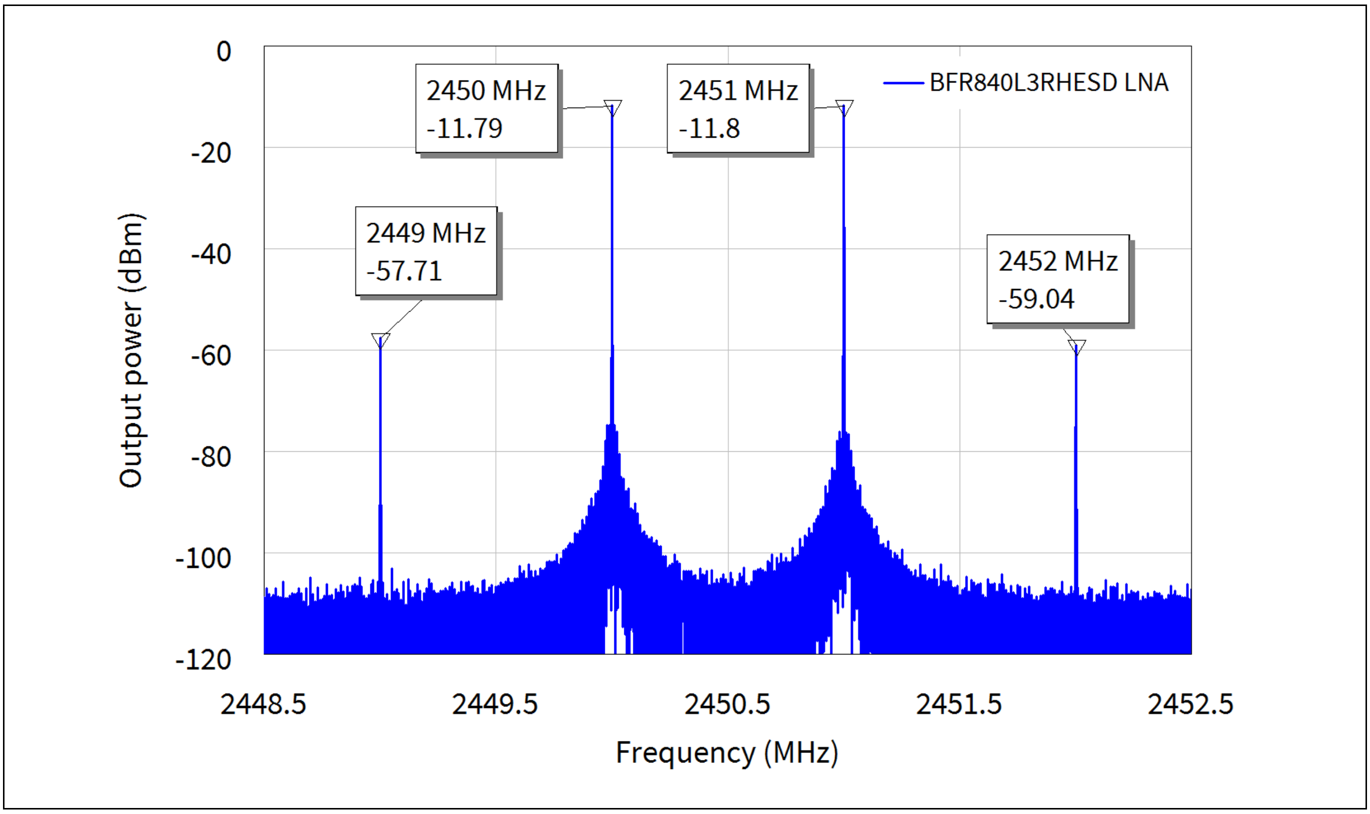


Figure 41 Output IMD_3 measurement of the 2.4 GHz band WLAN LNA with BFR840L3RHESD

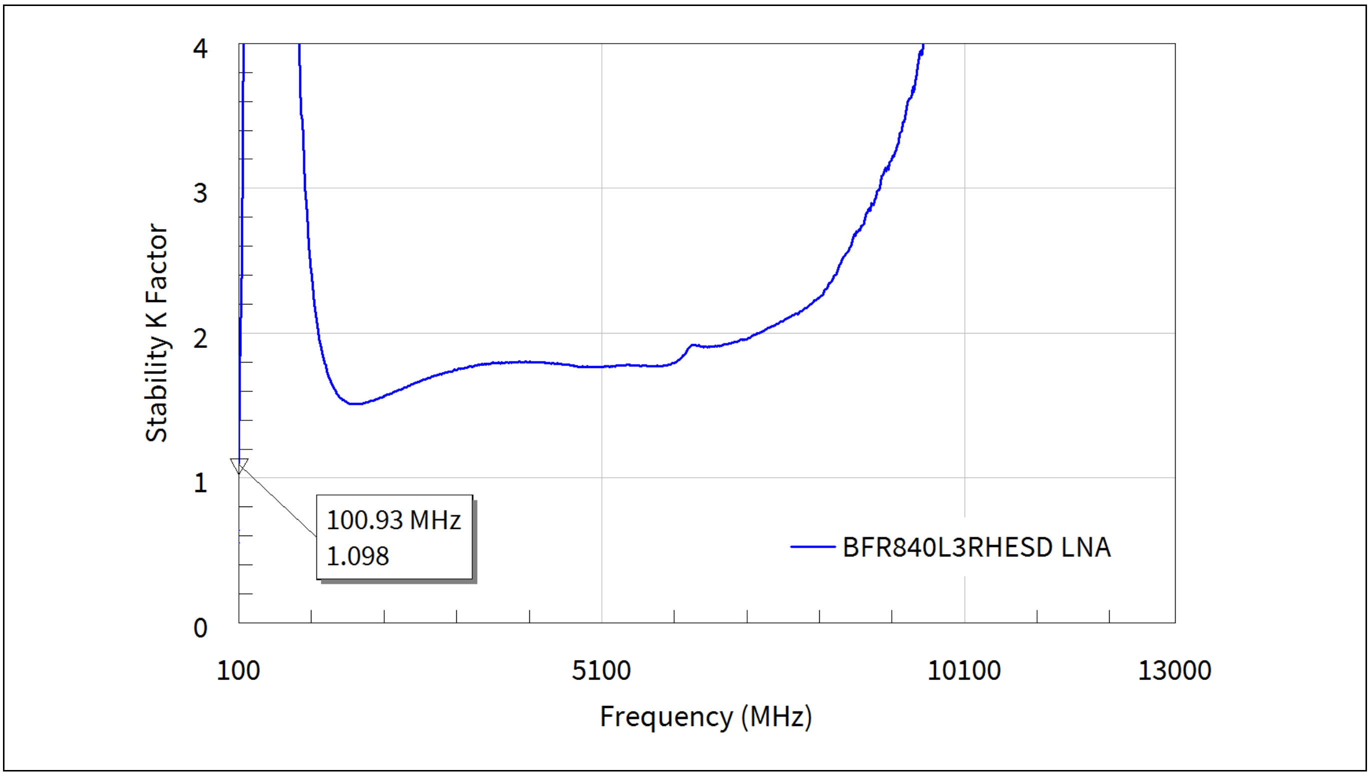


Figure 42 Stability K-factor plots of the 2.4 GHz band WLAN LNA with BFR840L3RHESD

2.4 2.4 GHz band WLAN LNA with low-noise MMIC BGB707L7ESD

2.4.1 Performance overview

The following table shows the performance of the 2.4 GHz band WLAN LNA with low-noise MMIC BGB707L7ESD.

Table 7 Summary of measurement results for the 2.4 GHz band WLAN LNA with low-noise MMIC BGB707L7ESD

Parameter	Symbol	Value	Unit	Notes
Device		BGB707L7ESD		
Bias voltage	V_{CC}	3.0	V	
Bias current	I_{CC}	6.0	mA	
Frequency	f	2.45	GHz	
Gain	G	15.6	dB	
NF	NF	1.2	dB	PCB and SMA connector losses subtracted: 0.1 dB.
Input return loss	RL_{in}	15.9	dB	
Output return loss	RL_{out}	10.2	dB	
Reverse isolation	ISO_{rev}	25.1	dB	
Output 1 dB compression point	OP_{1dB}	6.3	dBm	
Output third-order intercept point	OIP_3	10.3	dBm	Input power: -30 dBm per tone, Tone 1: 2450 MHz, Tone 2: 2451 MHz.
Stability	K	>1		Stability measured from 100 MHz to 13 GHz.

2.4.2 Schematic

The following figure shows the schematic of the 2.4 GHz band WLAN LNA with low-noise MMIC BGB707L7ESD. In the circuit, the resistor R1 sets up the biasing current. The resistors R2 and R3 stabilize the circuit whose firmness is measured up to 13 GHz. The resistor R4 and the capacitor C5 serve as the negative feedback to improve the input and output impedance matching. The circuit input matching is achieved by the network of capacitors C1, C2 and the inductor L1. The network of L2 and C4 matches the transistor to the output port. The capacitors C2 and C3 serve as the RF bypass.

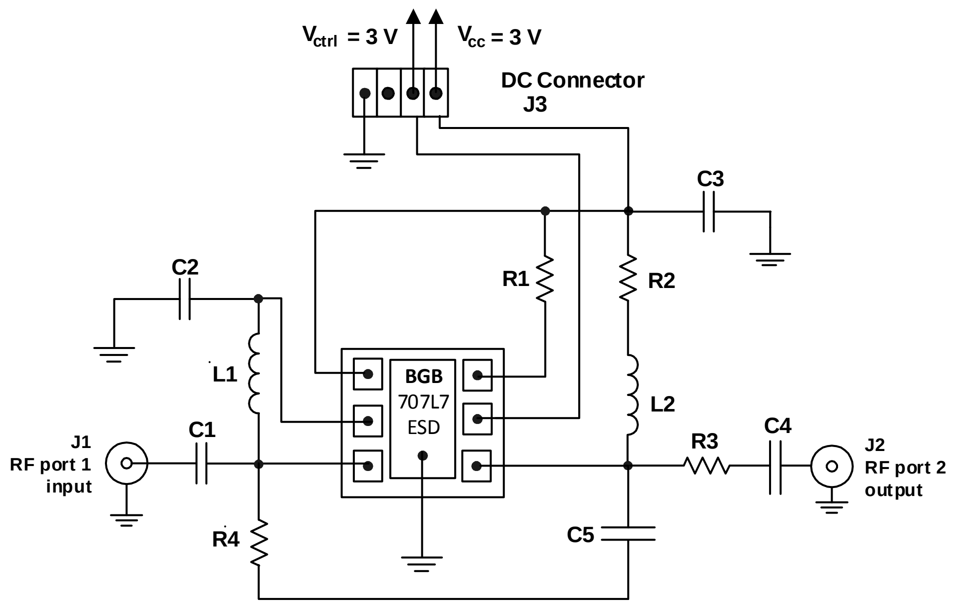


Figure 43 Schematic of the 2.4 GHz band WLAN LNA with low-noise MMIC BGB707L7ESD

2.4.3 BOM

Table 8 BOM of the 2.4 GHz band WLAN LNA with low noise MMIC BGB707L7ESD

Symbol	Value	Unit	Size	Manufacturer	Comment
Q1	BGB707L7ESD		TSLP-7-1	Infineon	SiGe:C low-noise MMIC
C1	3.9	pF	0402	Various	Input matching and DC blocking
C2	39	pF	0402	Various	RF decoupling
C3	39	pF	0402	Various	RF decoupling
C4	10	pF	0402	Various	Output matching and DC blocking
C5	39	pF	0402	Various	DC blocking
L1	2.9	nH	0402	Murata LQG series	Input matching and RF chock
L2	40	nH	0402	Murata LQG series	Output matching and RF chock
R1	2.7	kΩ	0402	Various	Base bias
R2	0	Ω	0402	Various	Stability improvement
R3	22	Ω	0402	Various	Stability improvement
R4	1.5	kΩ	0402	Various	Negative feedback

2.4.4 Evaluation board and PCB layout information

The evaluation board for the 2.4 GHz band WLAN LNA with low-noise MMIC BGB707L7ESD:

- PCB material: Rogers RO4003C
- PCB marking: M141017

The photo of the evaluation board for the 2.4 GHz band WLAN LNA with low-noise MMIC BGB707L7ESD and the detailed description of the PCB stack are shown in the following figures.

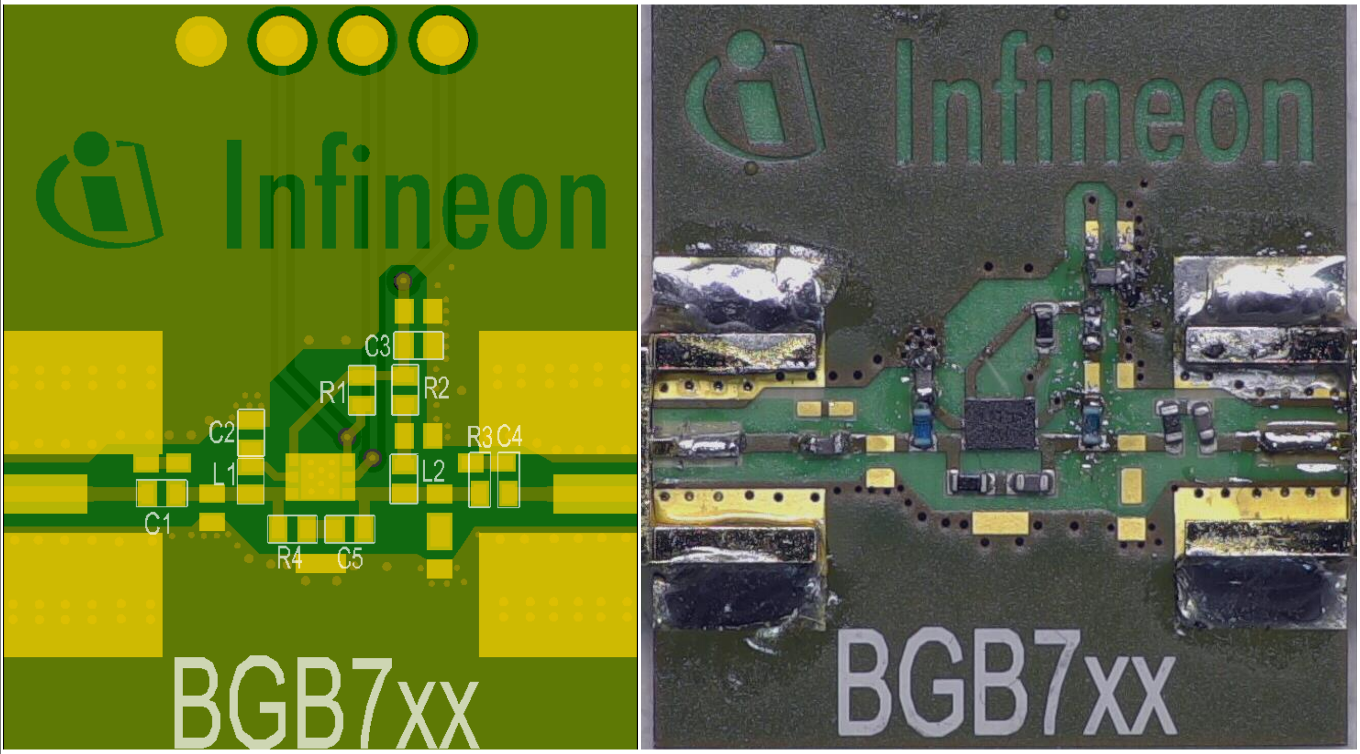


Figure 44 PCB layout with PCB marking M141017 (left) and photo (right)

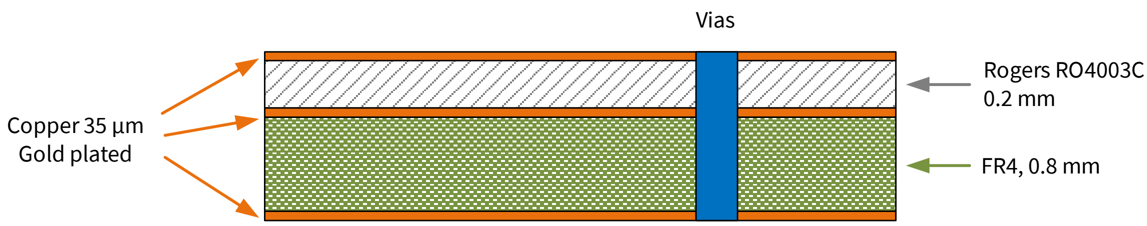


Figure 45 PCB stack information for the evaluation board M141017

2.4.5 Measurement results of the 2.4 GHz band WLAN LNA with low-noise MMIC BGB707L7ESD

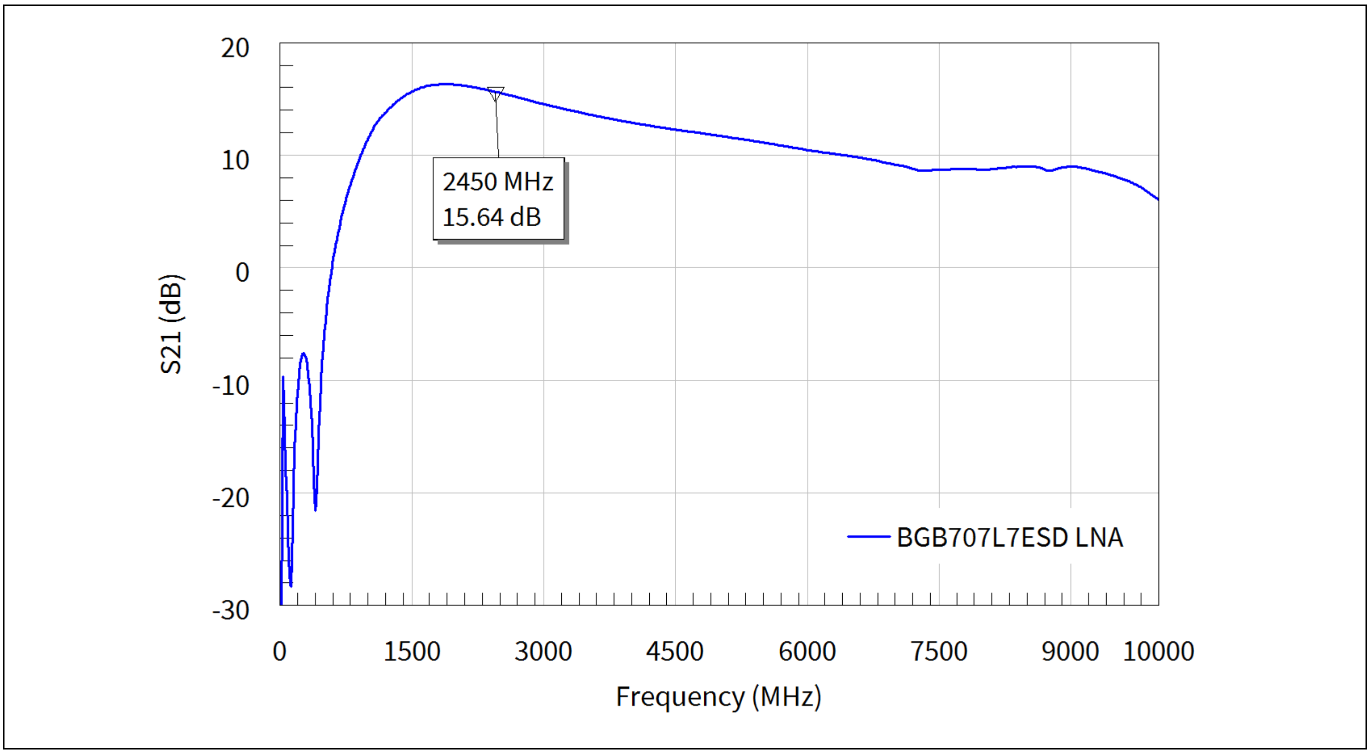


Figure 46 Small signal gain of the 2.4 GHz band WLAN LNA with BGB707L7ESD

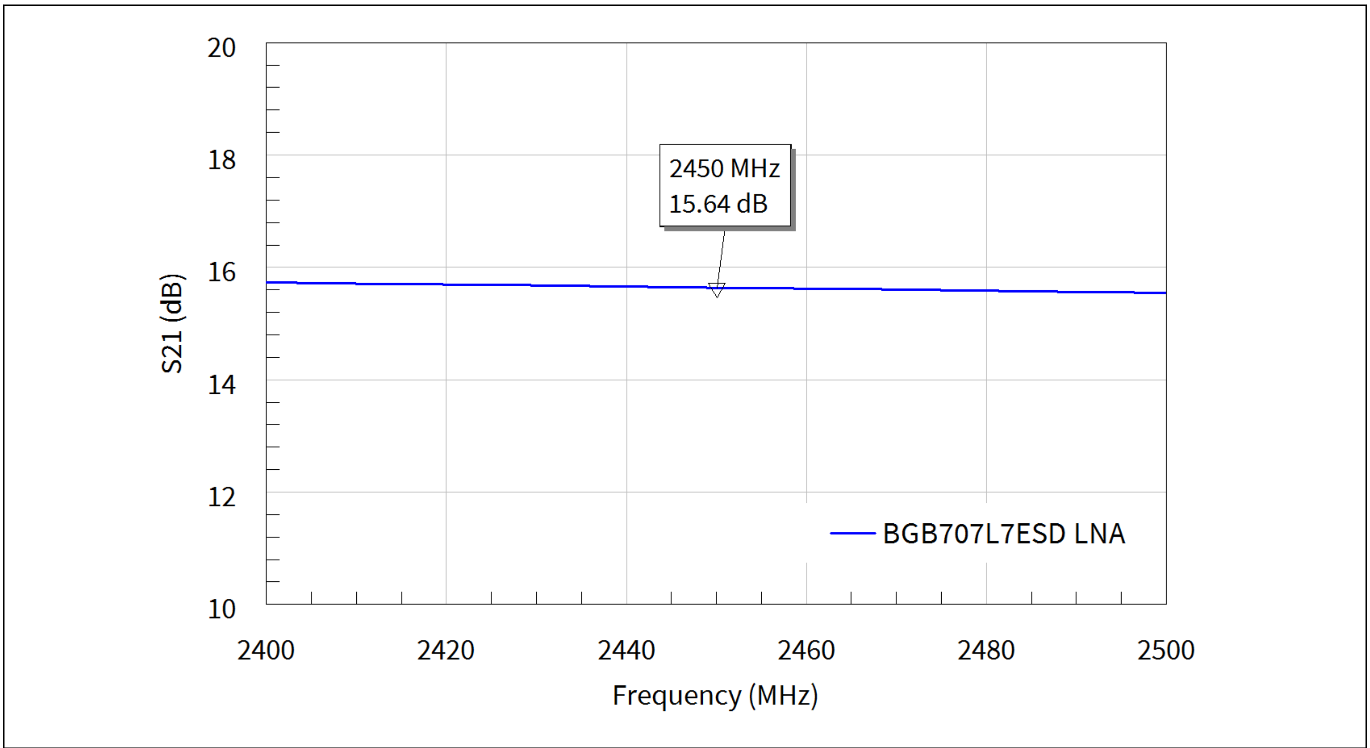


Figure 47 Small signal gain of the 2.4 GHz band WLAN LNA with BGB707L7ESD (detail view)

Note: The graphs are generated with the AWR EDA software Microwave Office®.

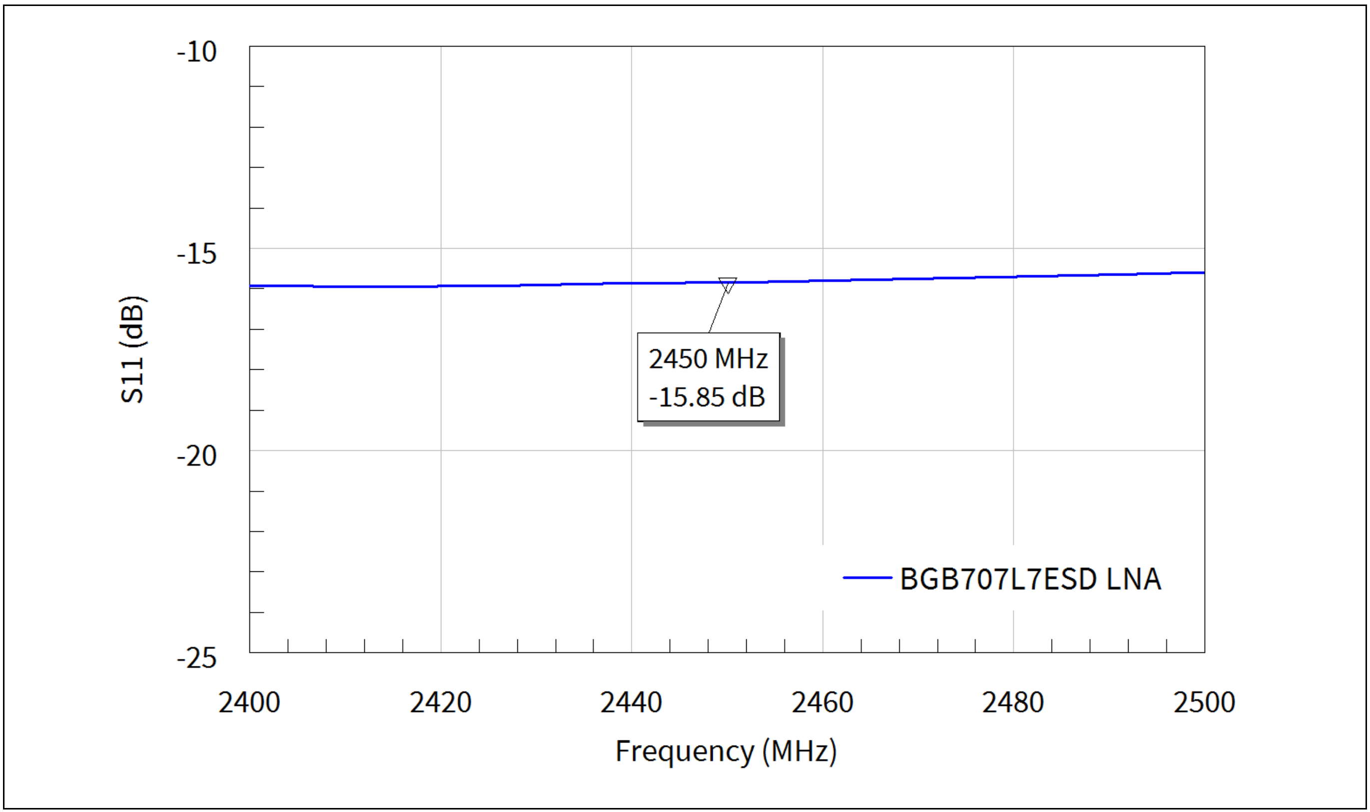


Figure 48 Input return loss measurement of the 2.4 GHz band WLAN LNA with BGB707L7ESD

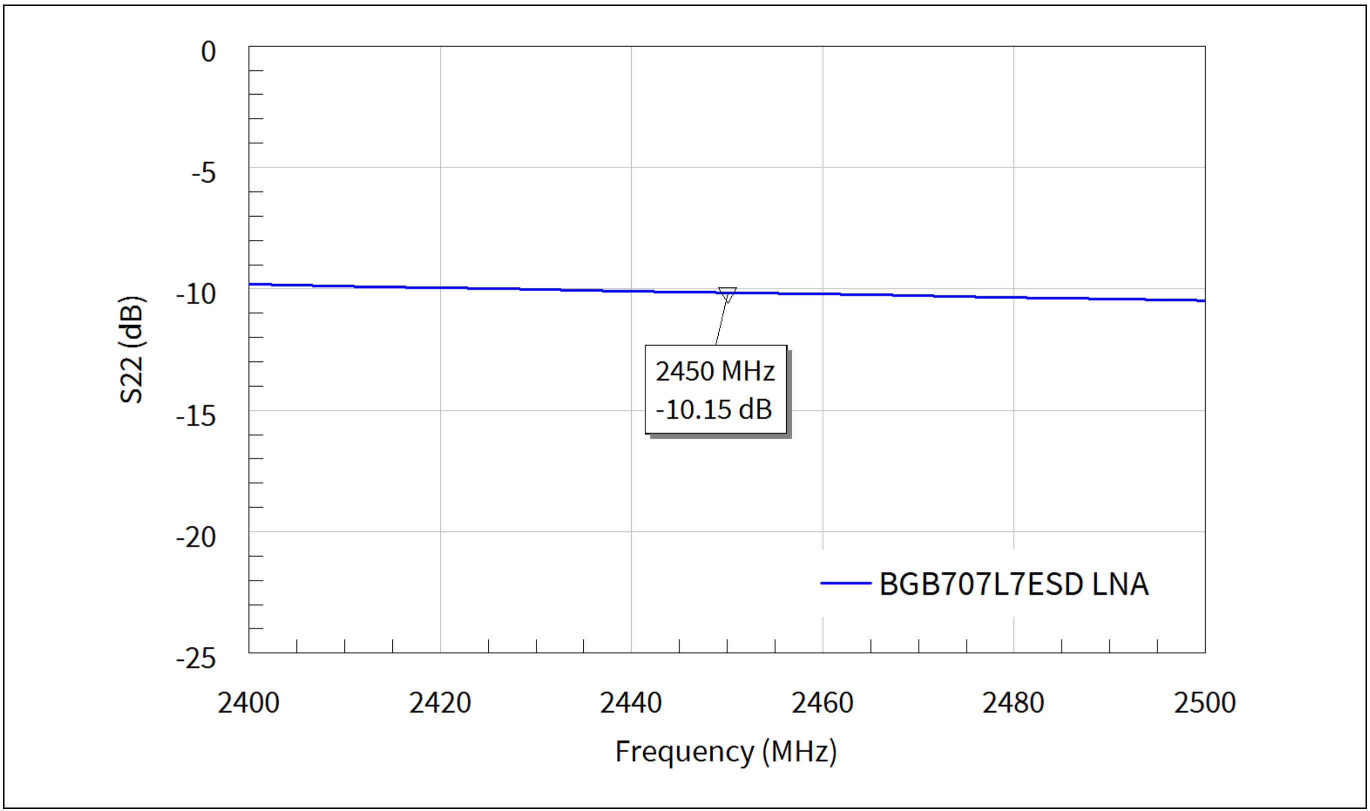


Figure 49 Output return loss measurement of the 2.4 GHz band WLAN LNA with BGB707L7ESD

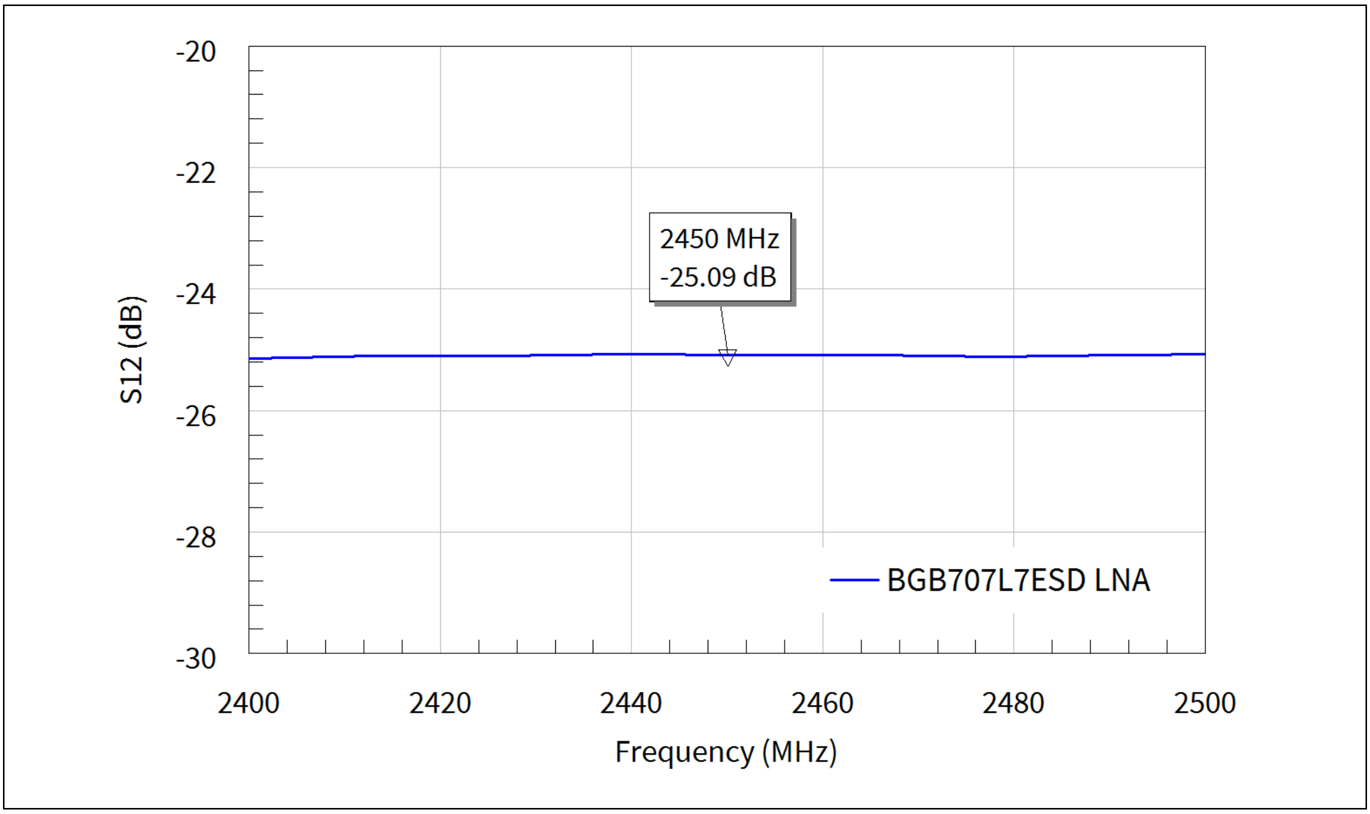


Figure 50 Reverse isolation measurement of the 2.4 GHz band WLAN LNA with BGB707L7ESD

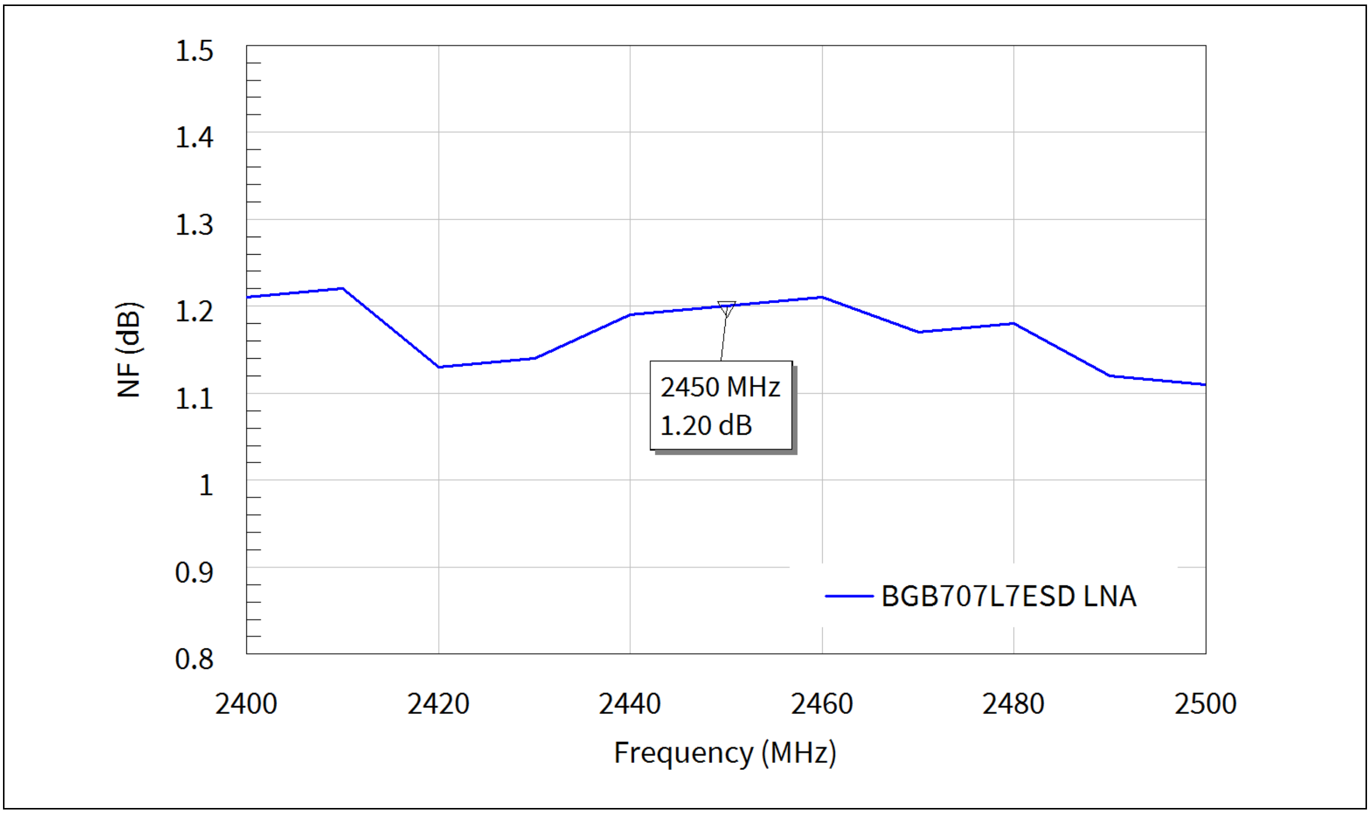


Figure 51 NF measurement of the 2.4 GHz band WLAN LNA with BGB707L7ESD

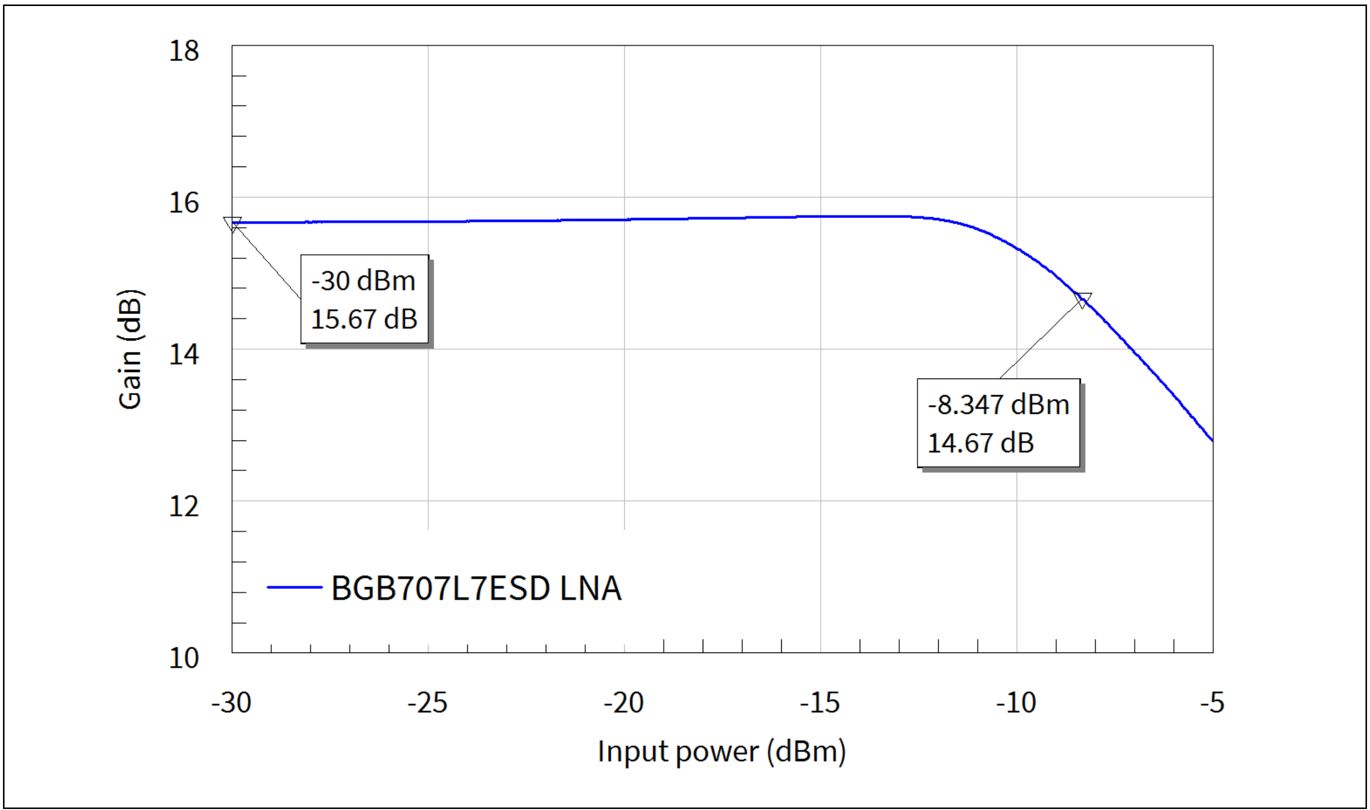


Figure 52 Input 1 dB compression point measurement of the 2.4 GHz band WLAN LNA with BGB707L7ESD

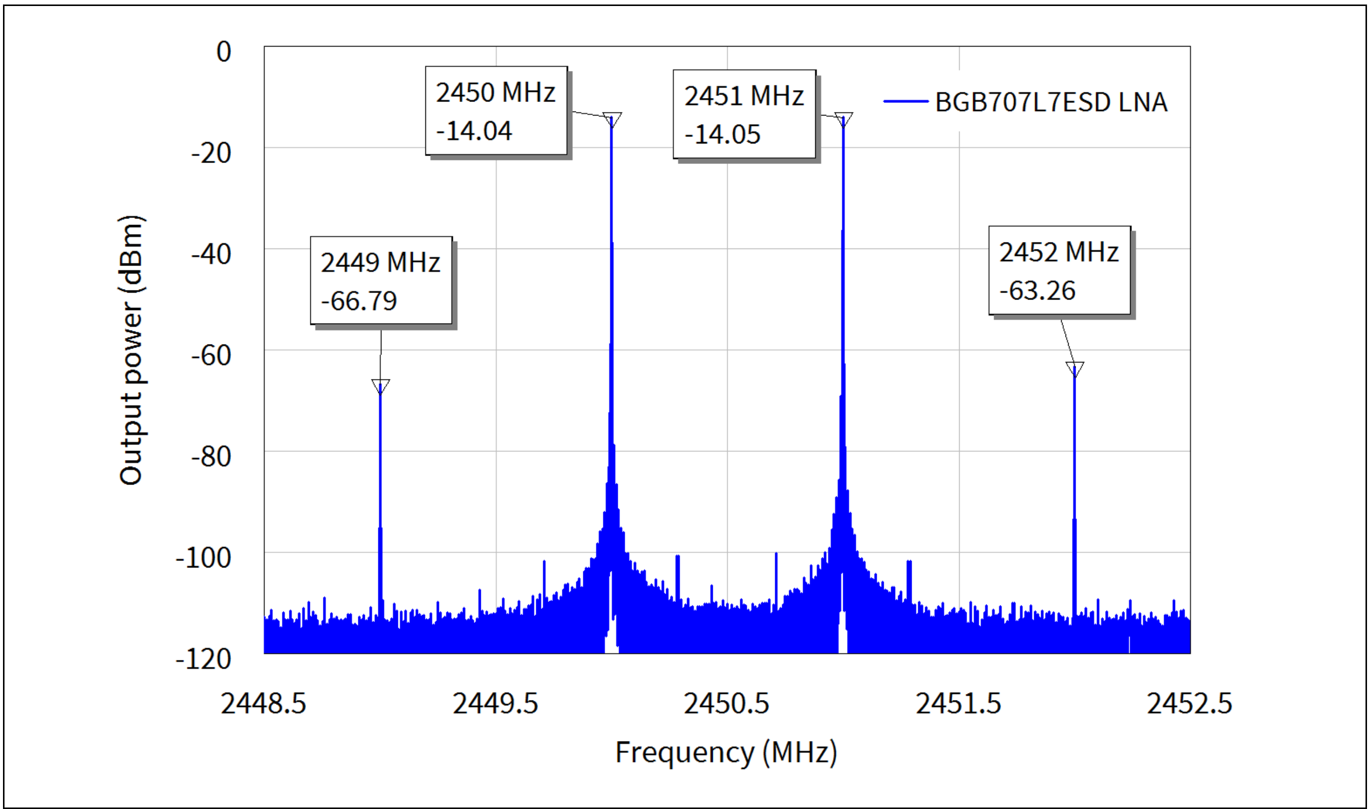


Figure 53 Output IMD_3 measurement of the 2.4 GHz band WLAN LNA with BGB707L7ESD

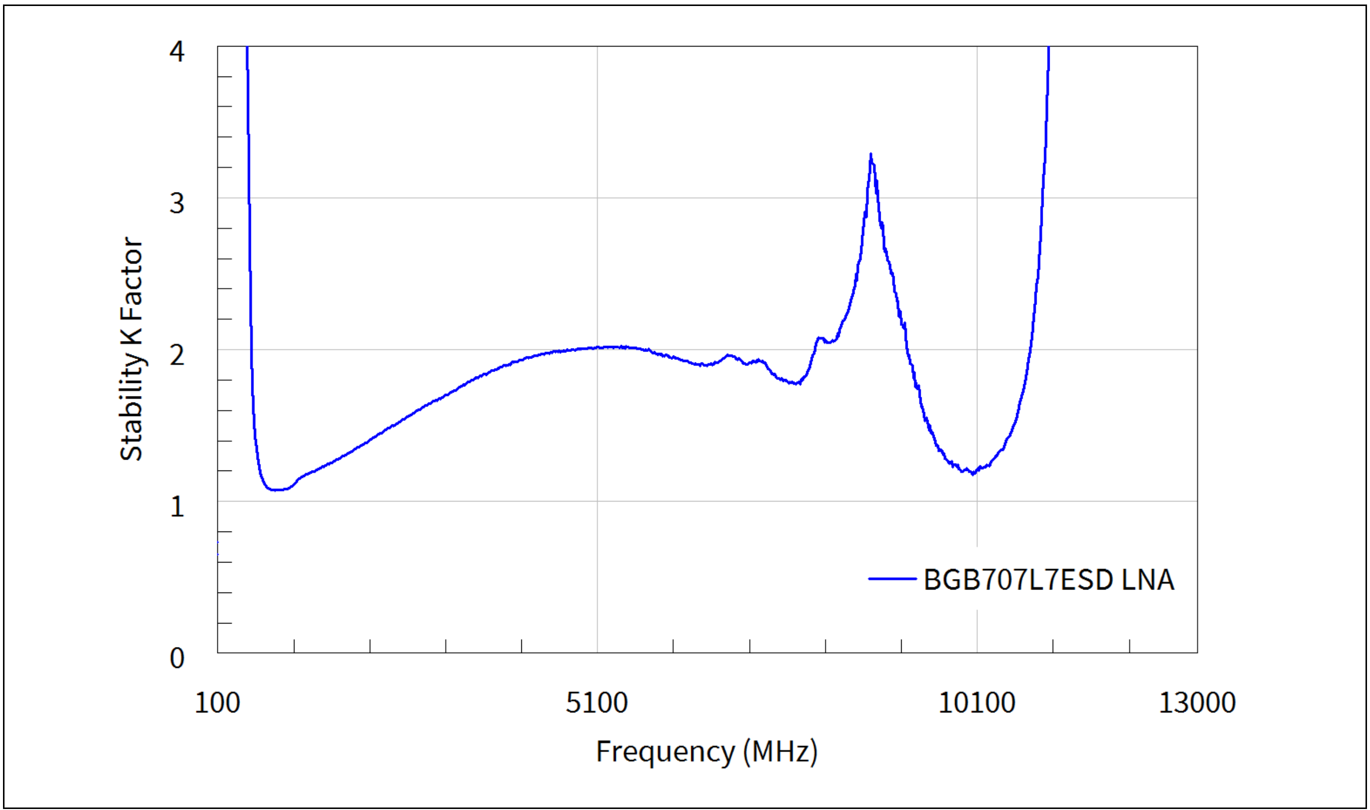


Figure 54 Stability K-factor plots of the 2.4 GHz band WLAN LNA with BGB707L7ESD

3 5 to 6 GHz band WLAN LNA application circuits

3.1 Performance overview

The following table shows the performance of the 5 to 6 GHz band WLAN LNAs.

Table 9 Summary of measurement results for the 5 to 6 GHz band WLAN LNAs

<table>
<tr><th>Parameter</th><th>Symbol</th><th colspan="6">Value</th><th>Unit</th><th>Notes</th></tr>
<tr><td>Device</td><td></td><td colspan="2">BFP840ESD</td><td colspan="2">BFP840FESD</td><td colspan="2">BFR840L3RHESD</td><td></td><td></td></tr>
<tr><td>Bias voltage</td><td>V_{CC}</td><td colspan="2">3.0</td><td colspan="2">3.0</td><td colspan="2">3.0</td><td>V</td><td></td></tr>
<tr><td>Bias current</td><td>I_{CC}</td><td colspan="2">10.3</td><td colspan="2">14.3</td><td colspan="2">9.2</td><td>mA</td><td></td></tr>
<tr><td>Frequency</td><td>f</td><td>5.1</td><td>5.9</td><td>5.1</td><td>5.9</td><td>5.1</td><td>5.9</td><td>GHz</td><td></td></tr>
<tr><td>Gain</td><td>G</td><td>16.3</td><td>15.3</td><td>19.2</td><td>18.0</td><td>15.0</td><td>14.1</td><td>dB</td><td></td></tr>
<tr><td>NF</td><td>NF</td><td>1.07</td><td>1.04</td><td>1.01</td><td>1.02</td><td>0.99</td><td>0.98</td><td>dB</td><td>PCB and SMA loss substracted: 0.15 dB</td></tr>
<tr><td>Input return loss</td><td>RL_{in}</td><td>12.2</td><td>18.8</td><td>10.2</td><td>10.5</td><td>10.3</td><td>12.5</td><td>dB</td><td></td></tr>
<tr><td>Output return loss</td><td>RL_{out}</td><td>17.8</td><td>15.6</td><td>11.7</td><td>12.1</td><td>11.6</td><td>13.5</td><td>dB</td><td></td></tr>
<tr><td>Reverse isolation</td><td>ISO_{rev}</td><td>26.4</td><td>25</td><td>26.3</td><td>25.7</td><td>21.6</td><td>20.2</td><td>dB</td><td></td></tr>
<tr><td>Output 1 dB compression point</td><td>OP_{1dB}</td><td colspan="2">4.9</td><td colspan="2">7.4</td><td colspan="2">4.9</td><td>dBm</td><td>Measured at 5.5 GHz</td></tr>
<tr><td>Output third-order intercept point</td><td>OIP_3</td><td colspan="2">16.4</td><td colspan="2">18.6</td><td colspan="2">16.4</td><td>dBm</td><td>Input power:
-30 dBm per tone
Tone 1: 5500 MHz
Tone 2: 5501 MHz</td></tr>
<tr><td>Stability</td><td>K</td><td colspan="2">>1</td><td colspan="2">>1</td><td colspan="2">>1</td><td></td><td>Measured from 10 MHz to 10 GHz</td></tr>
</table>

3.2 Schematic

The following figure shows the schematic of the 5 to 6 GHz band WLAN LNAs with Infineon eighth-generation RF low-noise SiGe transistors BFP840ESD, BFP840FESD, and BFR840L3RHESD. The transistors are manufactured in different packages. The parasitic inductances of different transistor packages are slightly different to each other. Hence the emitter degeneration length fabricated on the PCB for the LNA circuits has been selected differently (see section 3.4). In the LNA circuit, resistors R1 and R2 stand for transistor voltage and current bias; meanwhile, they form a negative DC feedback mechanism to stabilize the transistor bias points in various conditions. Capacitors C2 and C3 serve as the RF bypass. Transistor input matching is achieved by C1, L1 and C2. The output matching network is formed by C4, C5, C6, L2, R3 and R4. Resistors R3 and R4 also have the function of improving circuit stability.

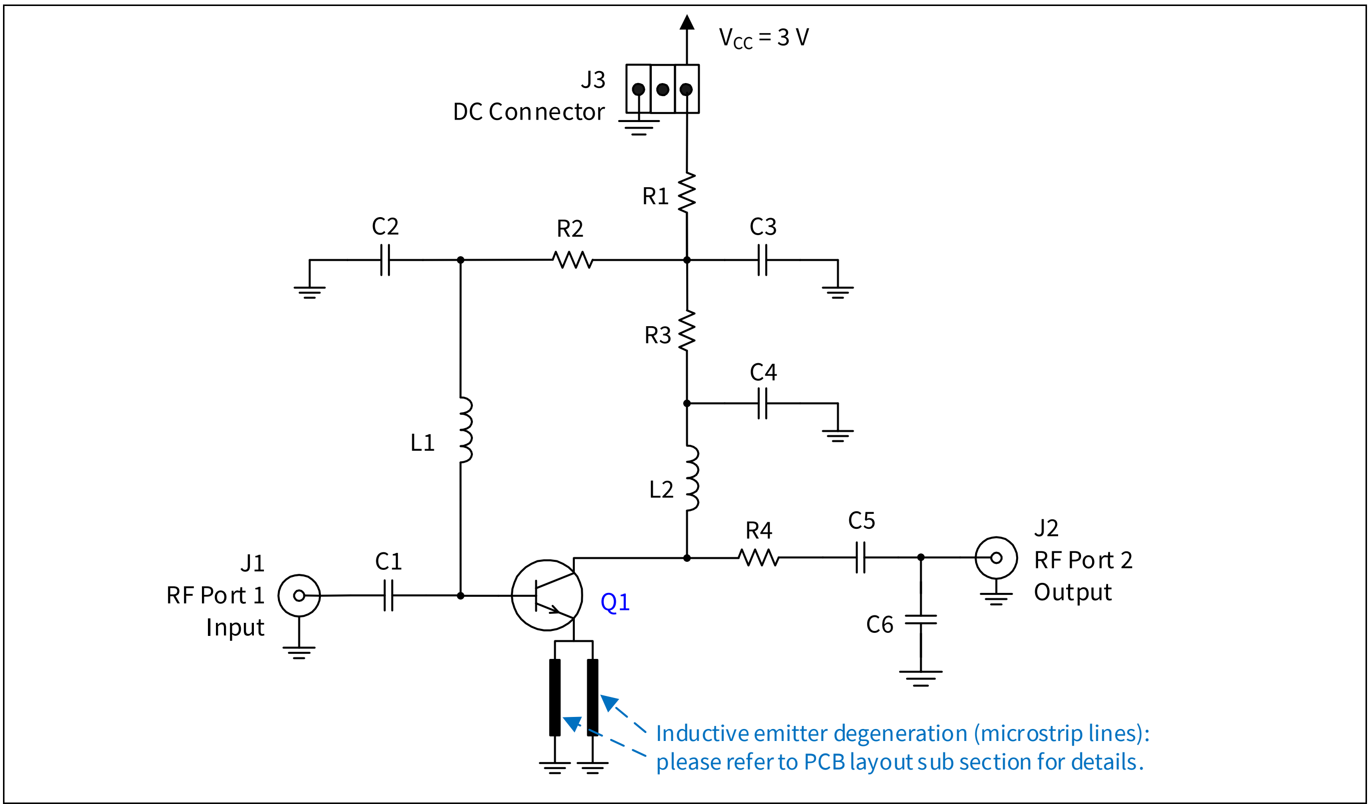


Figure 55 The 5 to 6 GHz band WLAN LNA schematic

3.3 BOM

Table 10 BOM of the 5 to 6 GHz band WLAN LNAs

Symbol	Value (component package/size)			Manu-facturer	Notes
Q1	BFP840ESD (SOT343)	BFP840FESD (TSFP-4-1)	BFR840L3RHESD (TSLP-3-9)	Infineon	SiGe:C bipolar low-noise transistor
C1	3.3 pF (0402)	22 pF (0402)	22 pF (0201)	Various	Input matching and DC blocking
C2	39 pF (0402)	n.c.[1)]	n.c.	Various	RF decoupling
C3	39 pF (0402)	33 pF (0402)	39 pF (0201)	Various	RF decoupling
C4	n.c.	1.0 pF (0402)	1.0 pF (0201)	Various	Output matching and stability improvement
C5	10 pF (0402)	1.0 pF (0402)	18 pF (0201)	Various	Output matching and DC blocking
C6	0.1 pF (0402)	n.c.	n.c.	Various	High-frequency stability improvement
R1	82 Ω (0402)	51 Ω (0402)	120 Ω (0201)	Various	DC bias and DC negative feedback

R2	30 kΩ (0402)	27 kΩ (0402)	33 kΩ (0201)	Various	DC biasing for transistor base
R3	82 Ω (0402)	51 Ω (0402)	27 Ω (0201)	Various	Low-frequency stability improvement
R4	10 Ω (0402)	n.c.	n.c.	Various	Output matching and high-frequency stability improvement
L1	5.1 nH (LQG/0402)	n.c.	n.c.	Murata	RF choke and input matching
L2	2.2 nH (LQG/0402)	1.8 nH (LQP15M/0402)	3.7 nH (LQP03T/0201)	Murata	RF choke and output matching

Note: 1) Not connected (n.c.).

3.4 Evaluation boards and layout information

The evaluation boards for the 5 to 6 GHz band WLAN LNAs:

- PCB material: FR4
- PCB marking:
  - BFP840ESD M130121
  - BFP840FESD M12051302
  - BFR840L3RHESD M120131

The photos of the 5 to 6 GHz band WLAN LNAs' evaluation boards and the detailed description of the PCB stack are shown in the following figures.

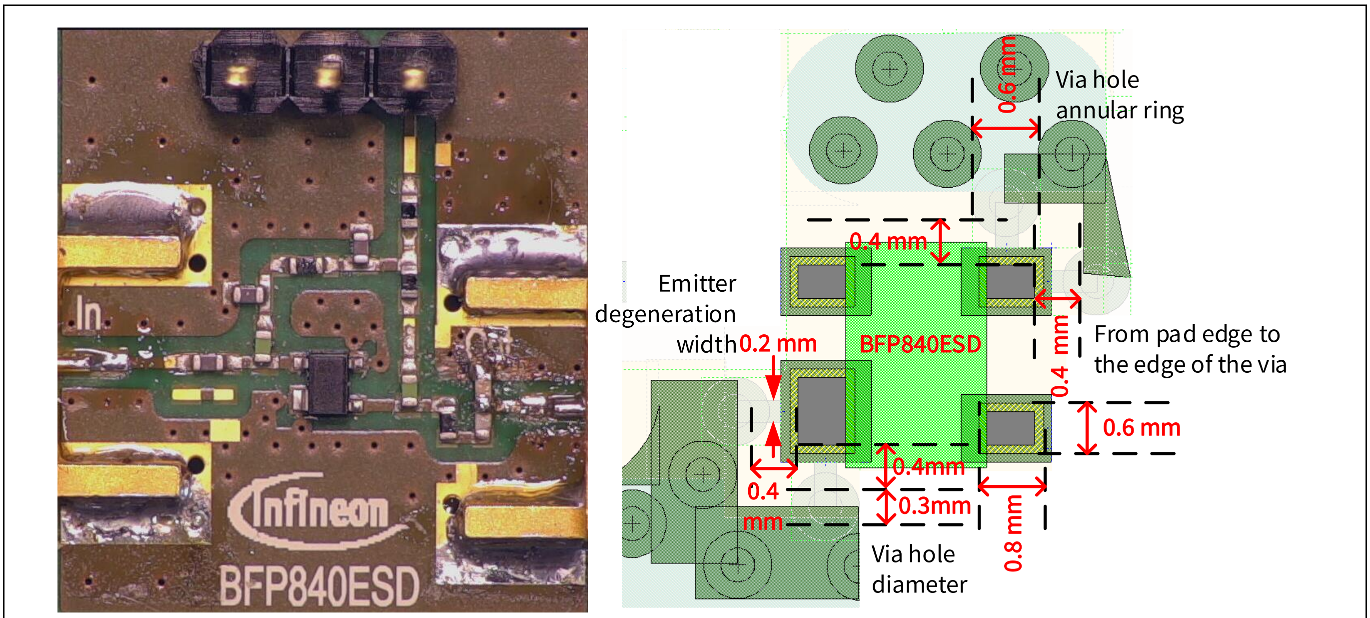


Figure 56 Photo of the evaluation board with marking M130121 (left) and emitter degeneration details (right)

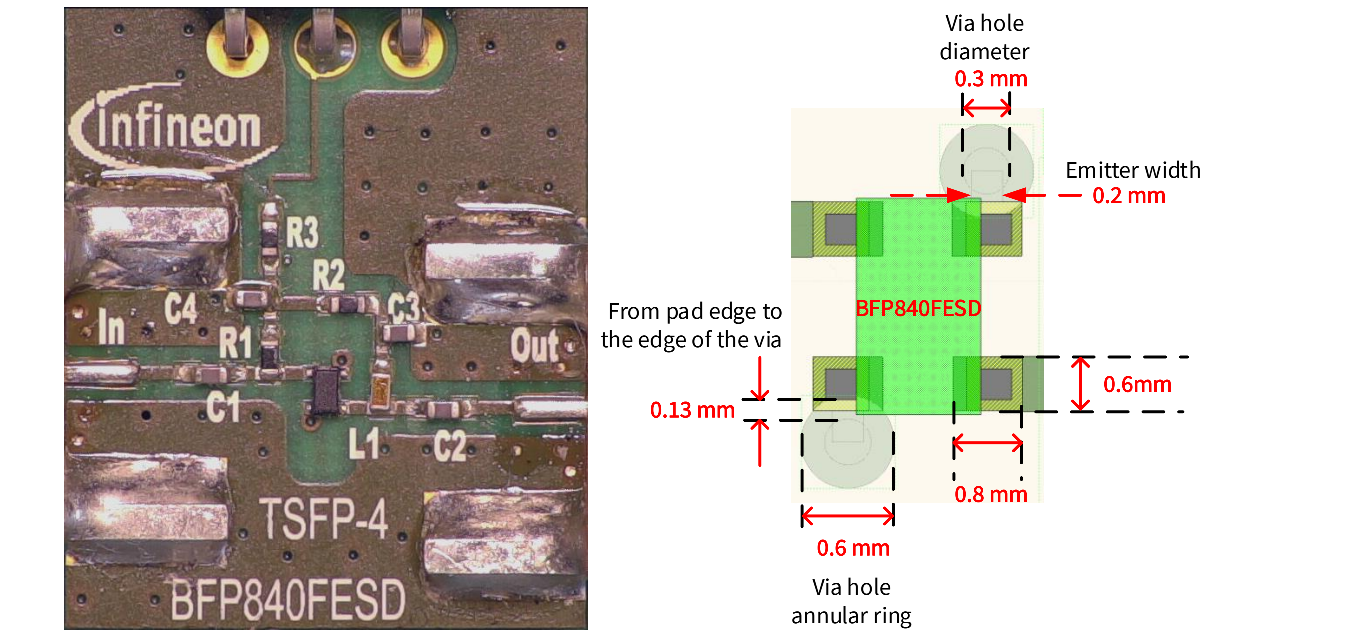


Figure 57 Photo of the evaluation board with marking M12051302 (left) and emitter degeneration details (right)

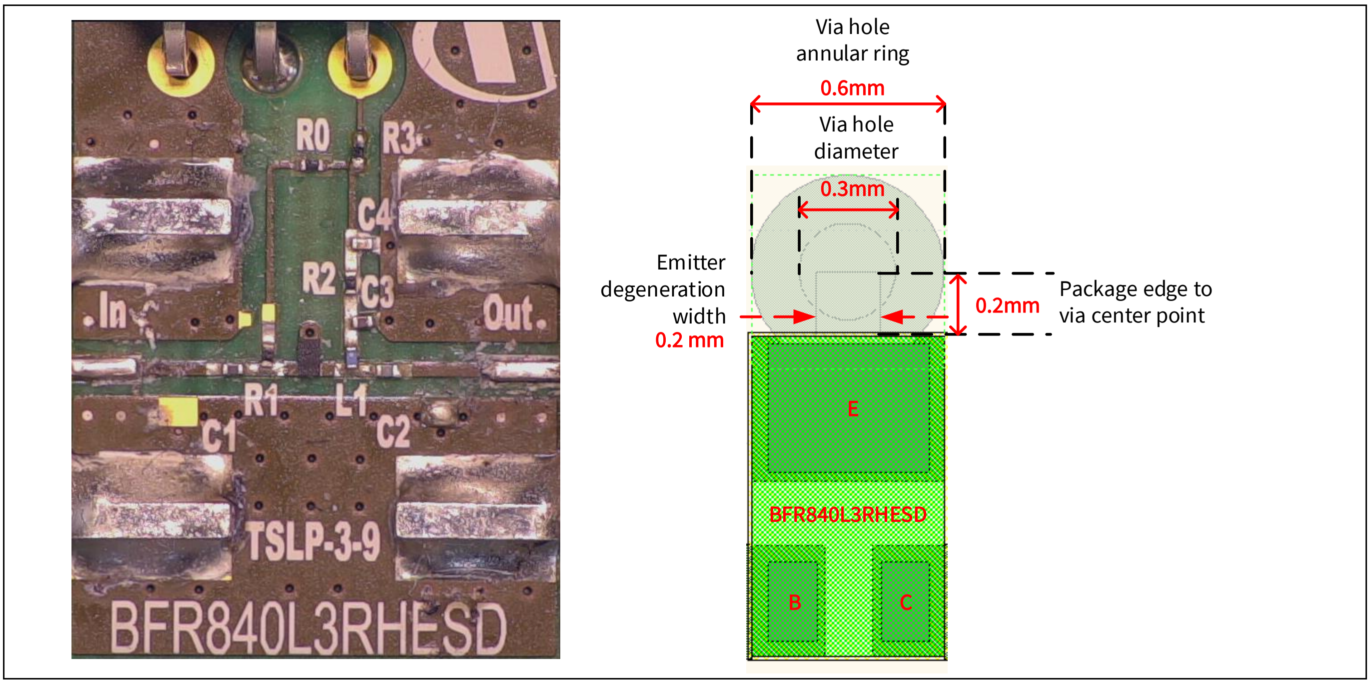


Figure 58 Photo of the evaluation board with marking M120131 (left) and emitter degeneration details (right)

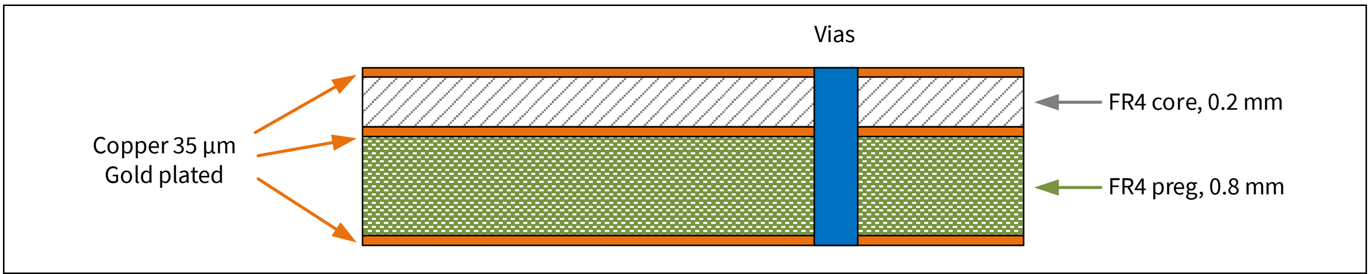


Figure 59 PCB stack information for the evaluation boards with marking M130121, M12051302, and M120131

3.5 Measurement results of the 5 to 6 GHz band WLAN LNAs

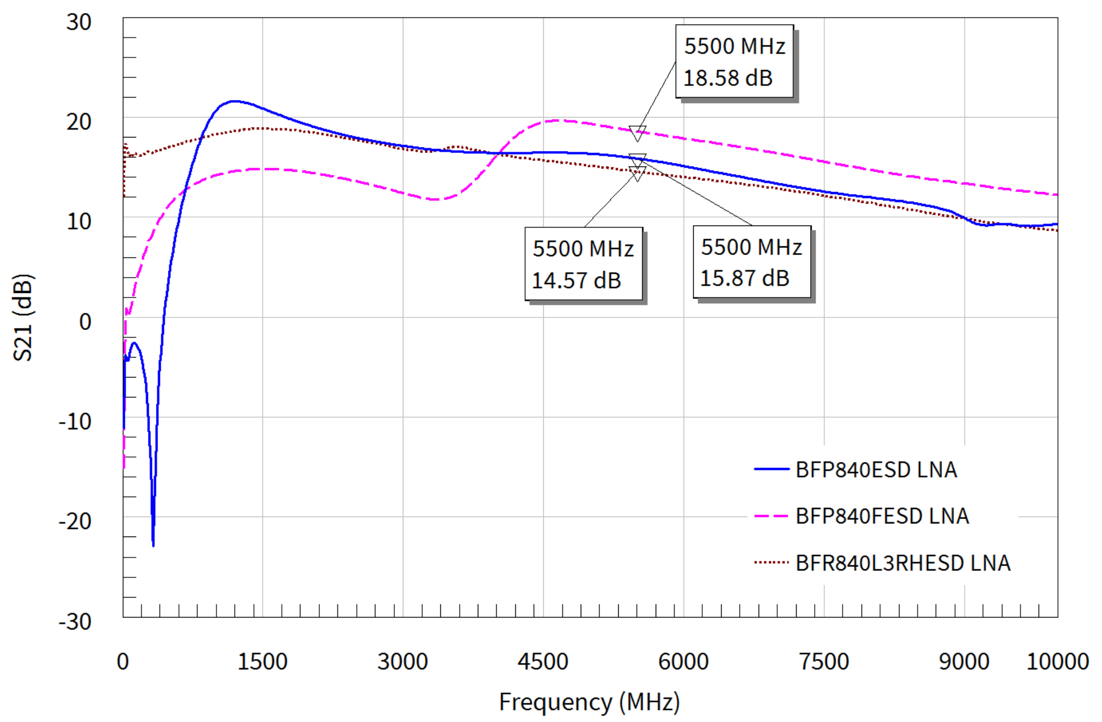


Figure 60 Small signal gain of the 5 to 6 GHz band WLAN LNAs

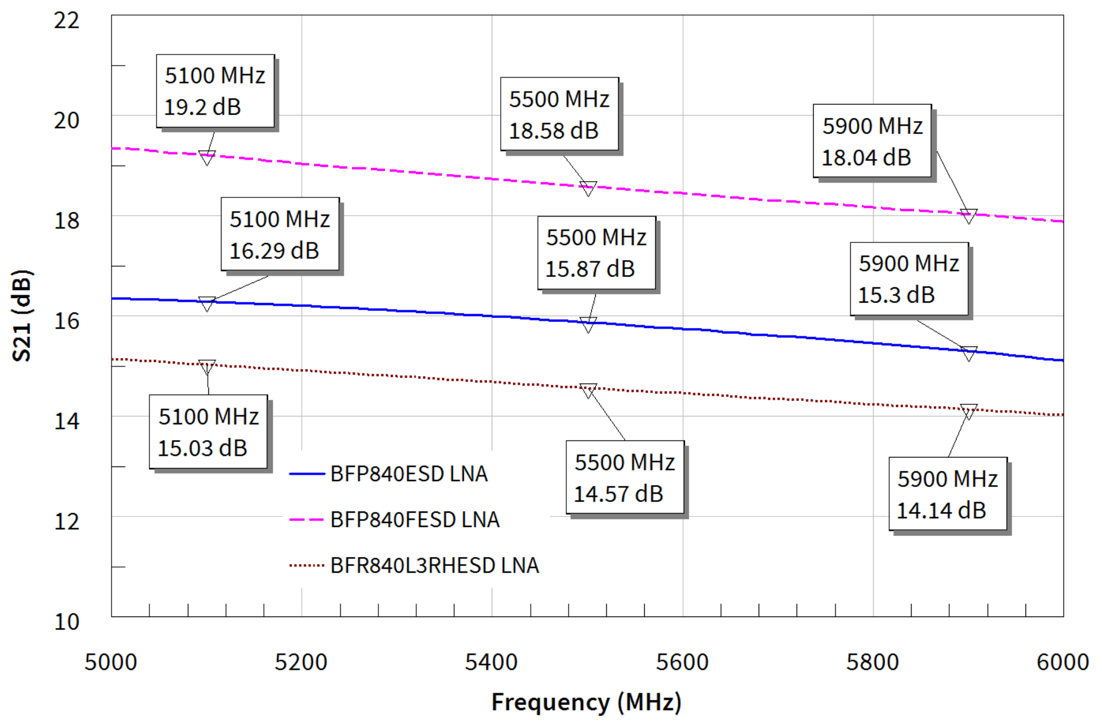


Figure 61 Small signal gain of the 5 to 6 GHz band WLAN LNAs (detail view)

Note: The graphs are generated with the AWR EDA software Microwave Office®.

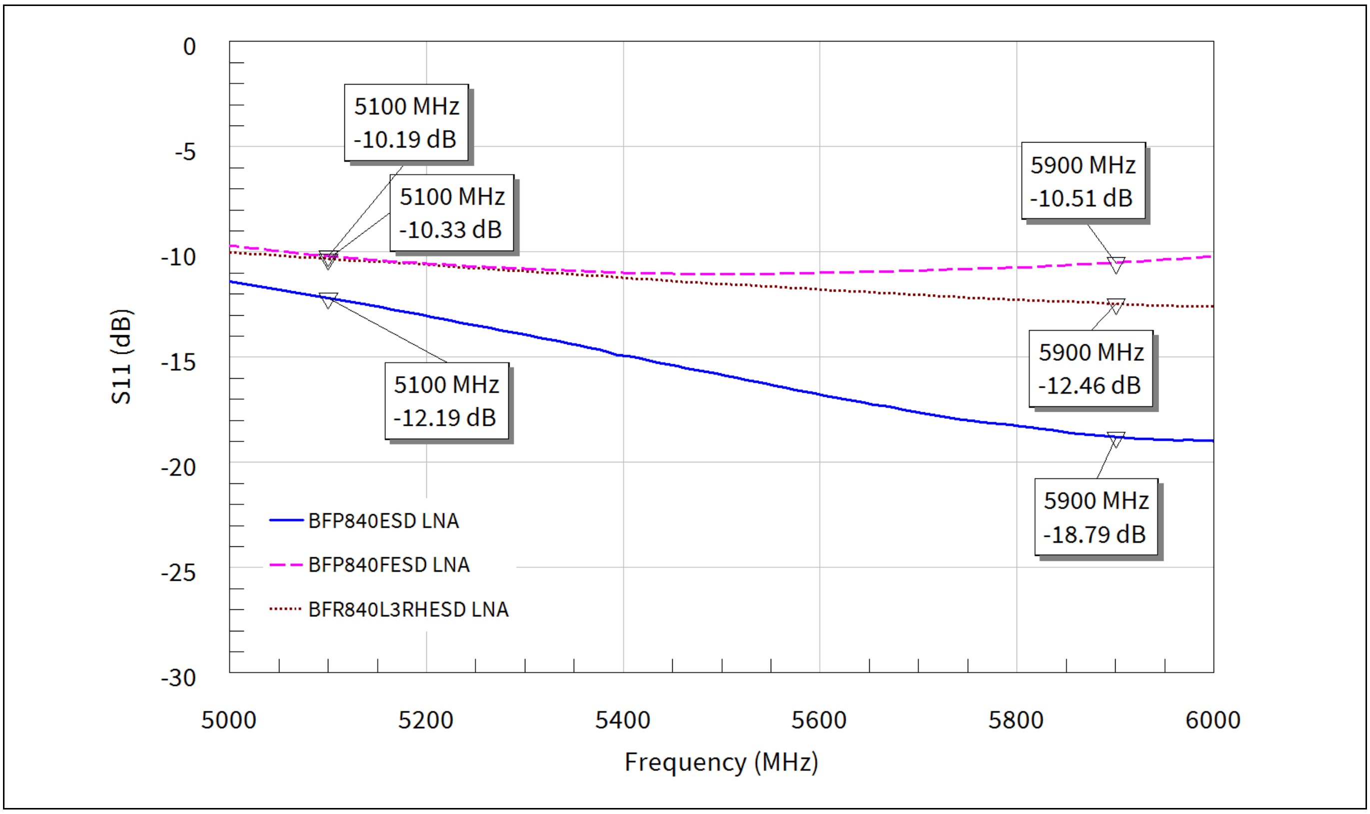


Figure 62 Input return loss measurement of the 5 to 6 GHz band WLAN LNAs

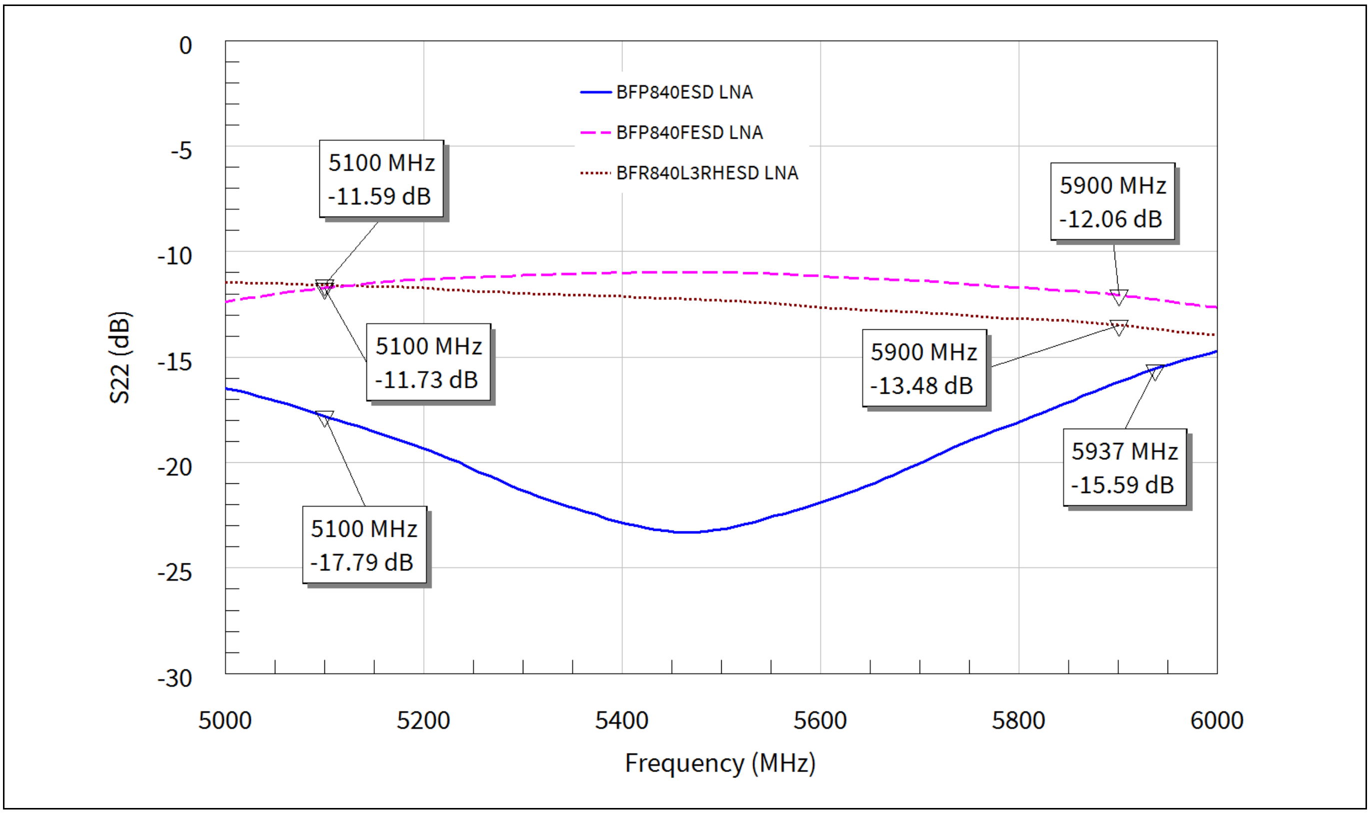


Figure 63 Output return loss measurement of the 5 to 6 GHz band WLAN LNAs

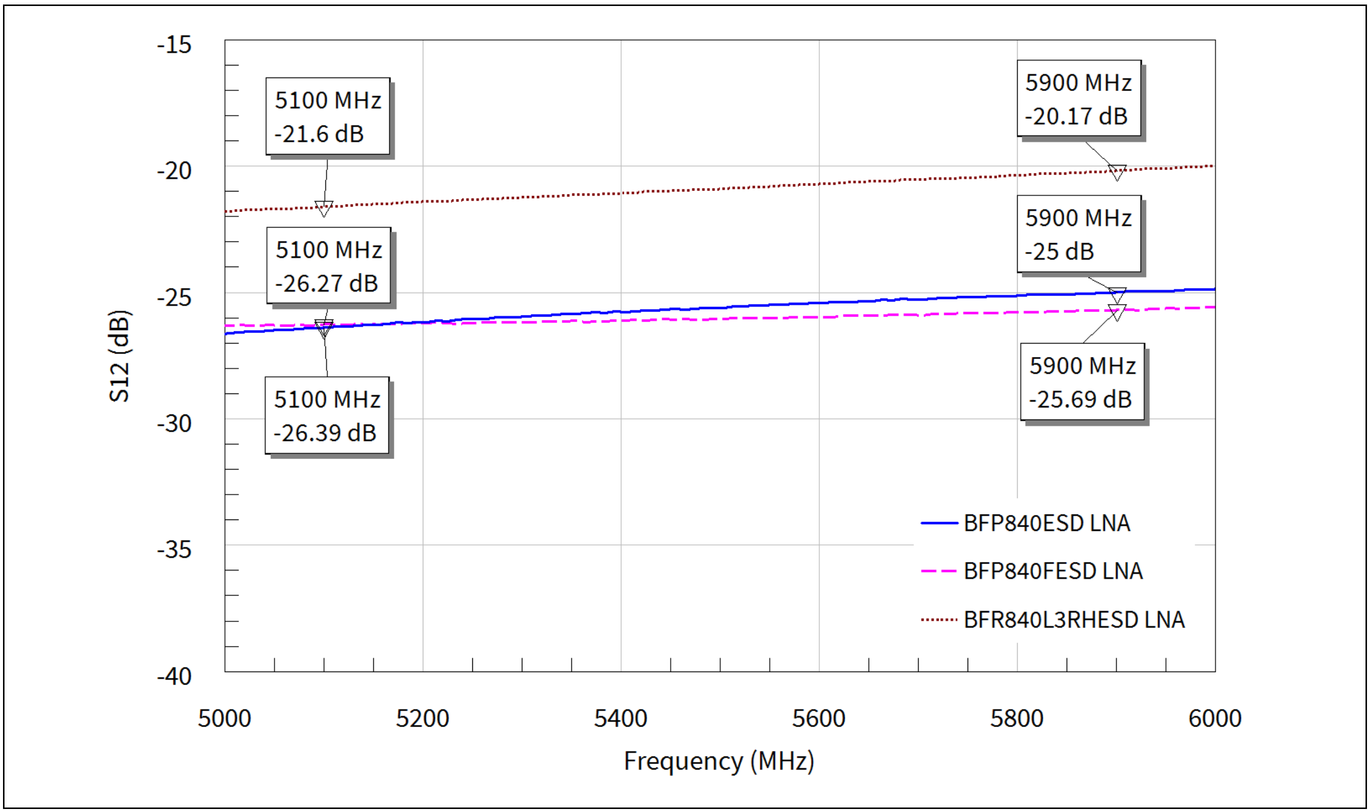


Figure 64 Reverse isolation measurement of the 5 to 6 GHz band WLAN LNAs

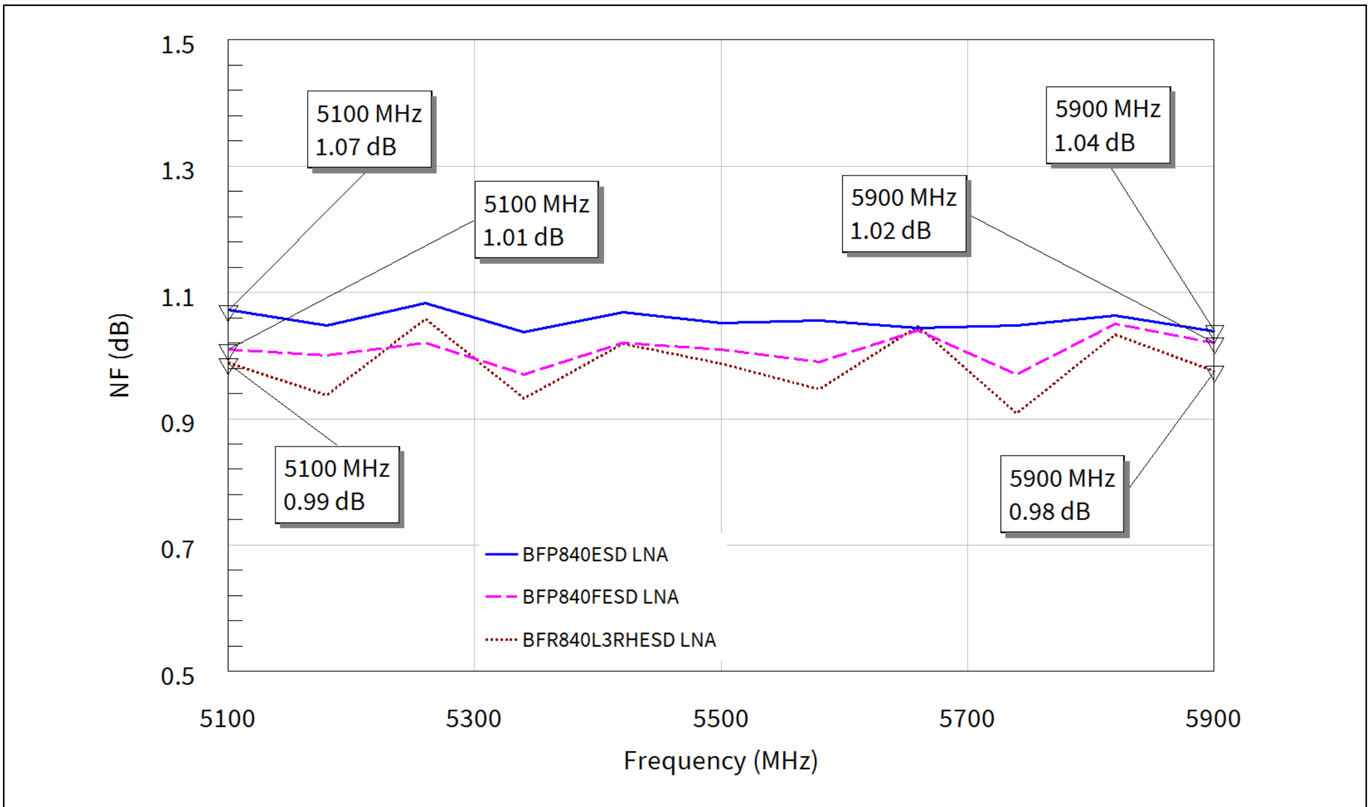


Figure 65 NF measurement of the 5 to 6 GHz band WLAN LNAs

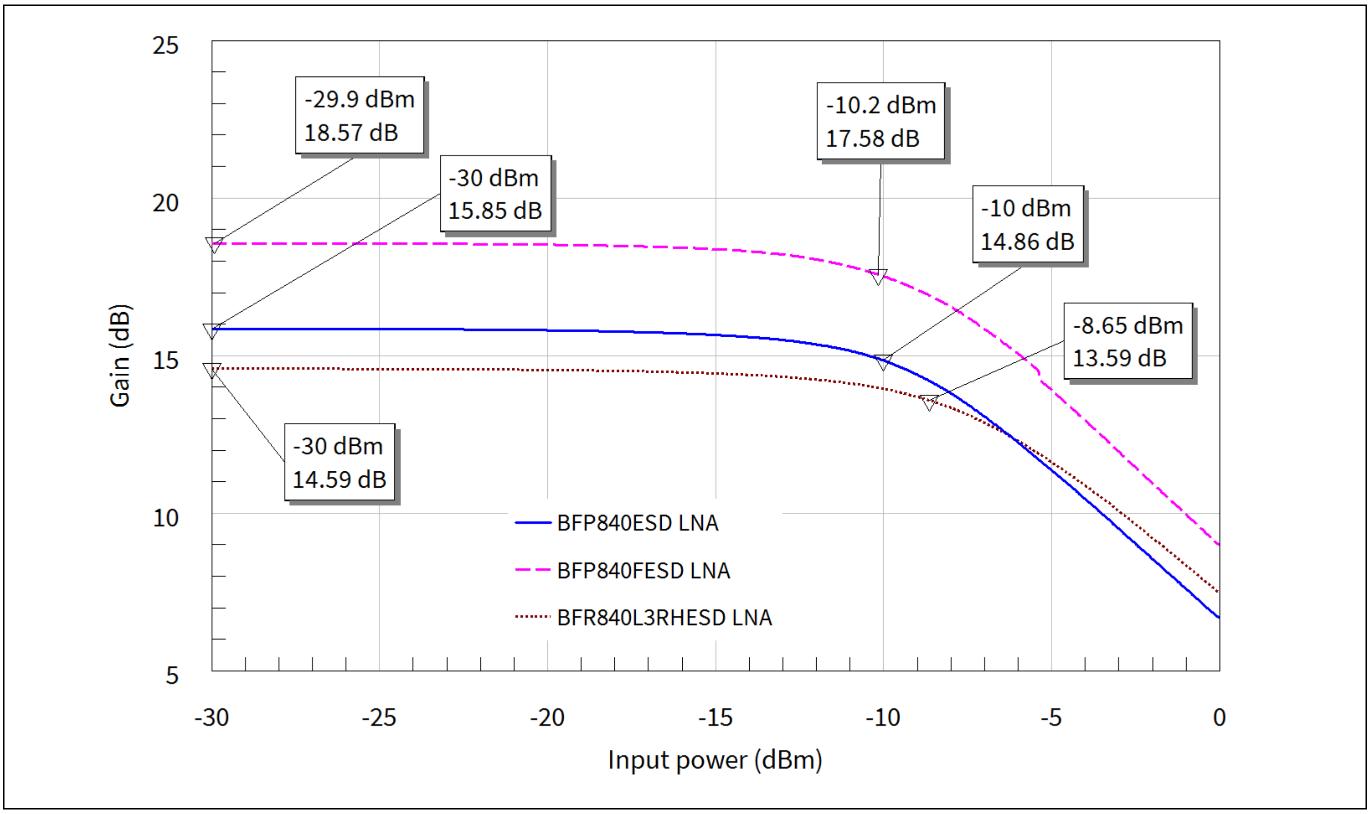


Figure 66 Input 1 dB compression point measurement of the 5 to 6 GHz band WLAN LNAs

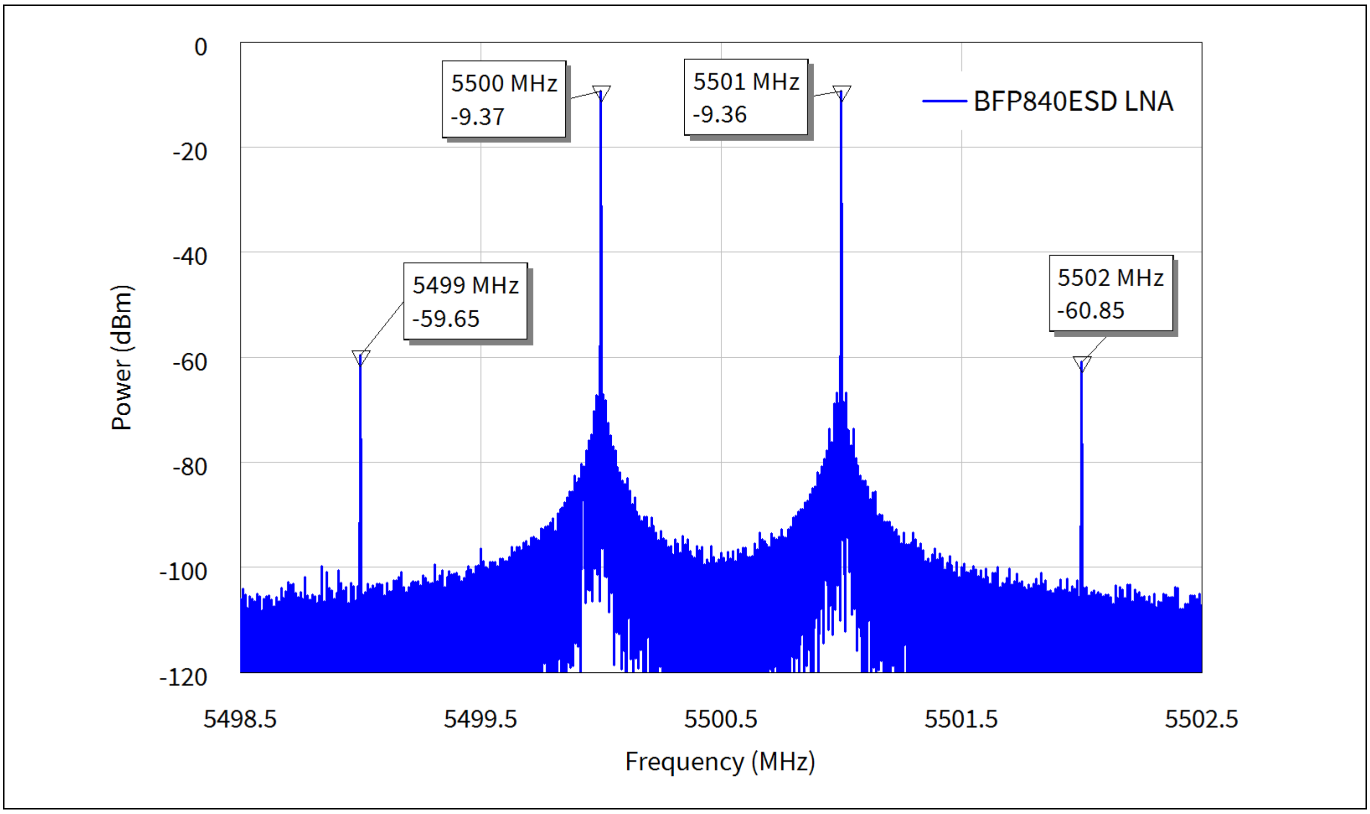


Figure 67 Output IMD_3 measurement of the 5 to 6 GHz band WLAN LNA with BFP840ESD

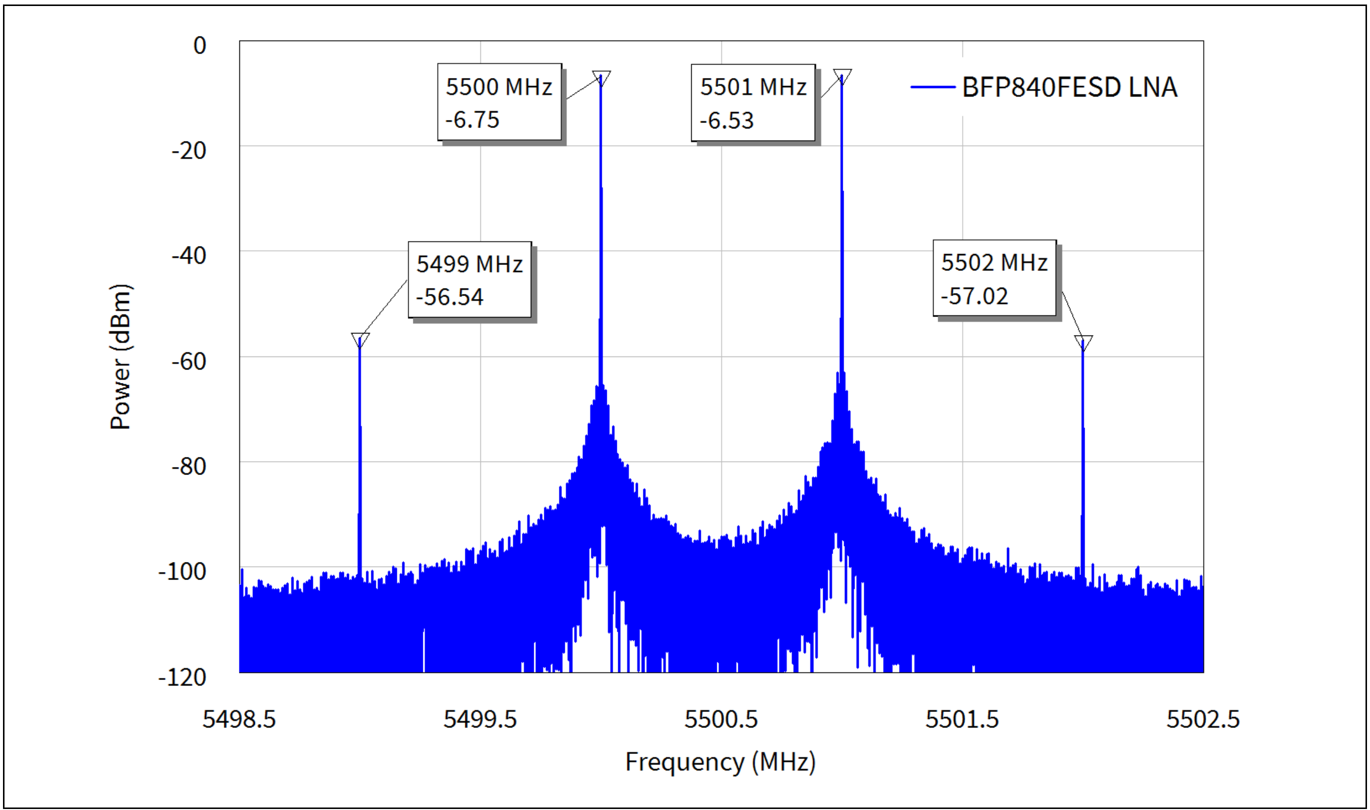


Figure 68 Output IMD_3 measurement of the 5 to 6 GHz band WLAN LNA with BFP840FESD

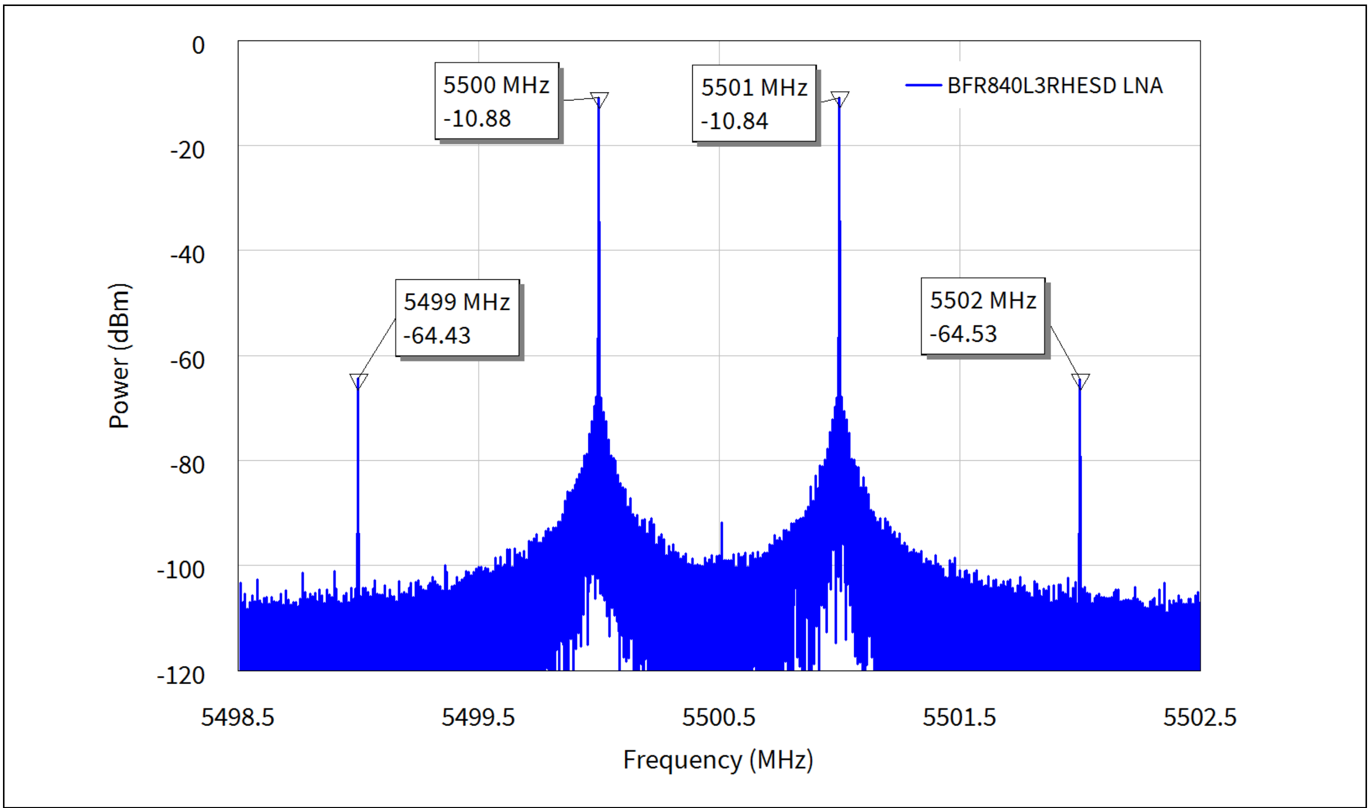


Figure 69 Output IMD_3 measurement of the 5 to 6 GHz band WLAN LNA with BFR840L3RHESD

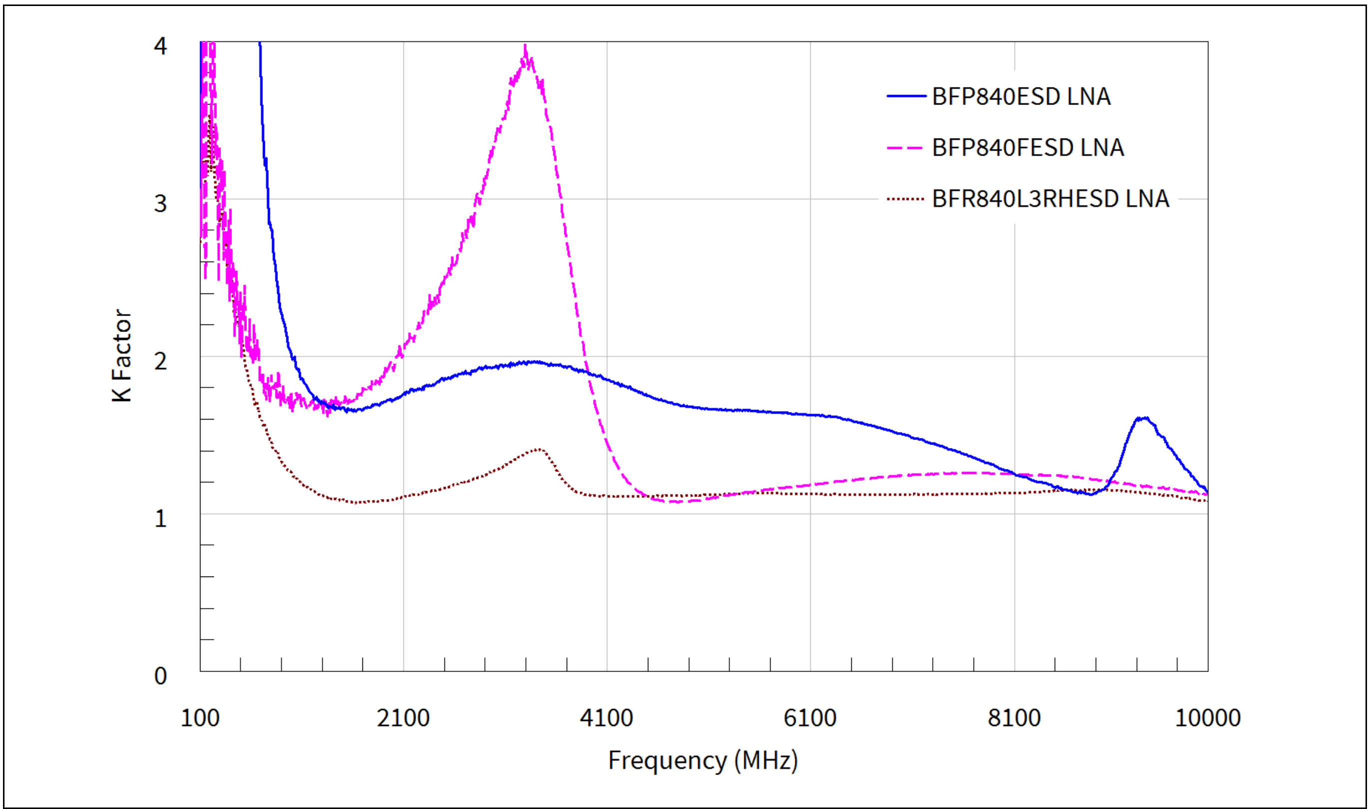


Figure 70 Stability K-factor plots of the 5 to 6 GHz band WLAN LNAs

4 2.4 GHz band WLAN BFQ790 power amplifier application circuit

4.1 Performance overview

The following table shows the performance of the BFQ790 medium-power amplifier at 2.412 GHz.

Table 11 Summary of measurement results for the 2.4 GHz band WLAN PA with BFQ790

Parameter	Symbol	Value	Unit	Notes
Bias voltage	V_{CC}	5.0	V	
Quiescent bias current	I_{CQ}	210	mA	
Gain	G	14	dB	
Input return loss	RL_{in}	> 10	dB	
Output return loss	RL_{out}	> 10	dB	
Reverse Isolation	ISO_{rev}	26.9	dB	
Output 1-dB compression point	OP_{1dB}	26.7	dBm	
Output third-order intercept point	OIP_3	39	dBm	Output power: 15 dBm per tone Tone 1: 2411.5 MHz Tone 2: 2412.5 MHz
Second harmonic	H_2	< -66	dBm	
Third harmonic	H_3	< -66	dBm	
Output power at error vector magnitude (EVM): -30 dB	$P_{out,avg}$	18	dBm	Signal: 802.11 n, VHT20, MCS7, 64QAM
Band edge power at 2390 MHz		< -45	dBm	
Stability factor	µ1, µ2	> 1		From 10 MHz up to 6 GHz

4.2 Schematic

The following figure shows the schematic of the 2.4 GHz band WLAN PA with RF medium-power transistor BFQ790. In the circuit, resistors R1, R2, and R3 stand for transistor base bias for a collector current of around 210 mA; meanwhile, R3 stabilizes the circuit at low frequency. Capacitors C3 and C4 together with inductor L2 form a low-pass structured output-matching circuit to maximize the output power and linearity and suppress the harmonic products. L1 is the RF choke, and the value is also chosen in consideration of the current allowance. Capacitors C1 and C2 build up the input-matching network to boost the gain of the BFQ790 power amplifier. Capacitors C6, C7 and C8 are for the RF bypass.

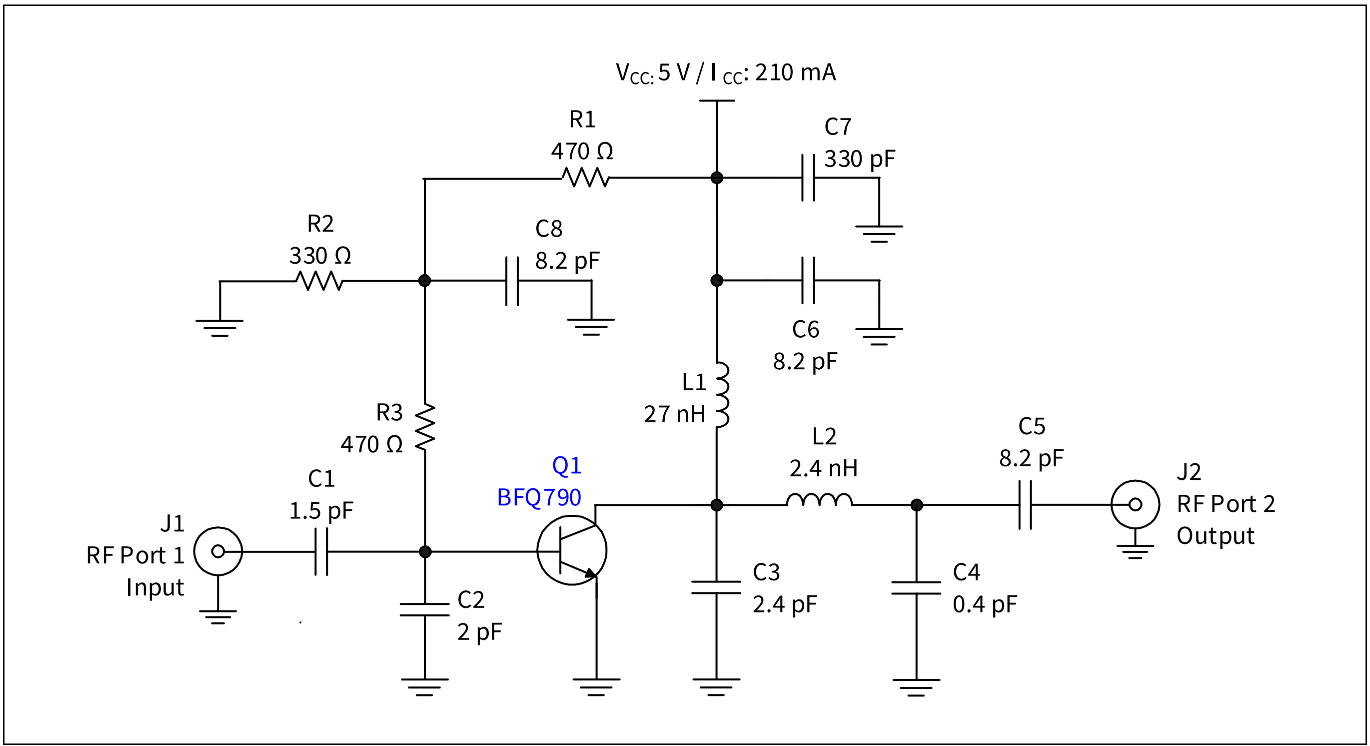


Figure 71 The BFQ790 2.4 GHz band WLAN power amplifier schematic

4.3 BOM

Table 12 BOM of the BFQ790 2.4 GHz band WLAN power amplifier

Symbol	Value	Unit	Package	Manufacturer	Notes
Q1	BFQ790		SOT89	Infineon	SiGe medium-power transistor
C1	1.5	pF	0402	Various	Input matching and DC blocking
C2	2	pF	0402	Various	Input matching
C3	2.4	pF	0402	Various	Output matching
C4	0.4	pF	0402	Various	Output matching
C5	8.2	pF	0402	Various	DC blocking
C6	8.2	pF	0402	Various	RF bypass
C7	330	pF	0402	Various	RF bypass
C8	8.2	pF	0402	Various	RF bypass
R1	470	Ω	0402	Various	DC bias
R2	330	Ω	0402	Various	DC bias
R3	470	Ω	0402	Various	DC bias and stability improvement
L1	10	nH	0402	Murata LQW	RF choke and output matching
L2	8.2	nH	0402	Murata LQW	Output matching

4.4 Evaluation board and layout information

The evaluation board for the BFQ790 2.4 GHz WLAN power amplifier:

- PCB marking: M141008 v1.2_2
- PCB material: FR4

The photo of the BFQ790 2.4 GHz WLAN power amplifier evaluation board and the detailed description of the PCB stack are shown in the following figures.

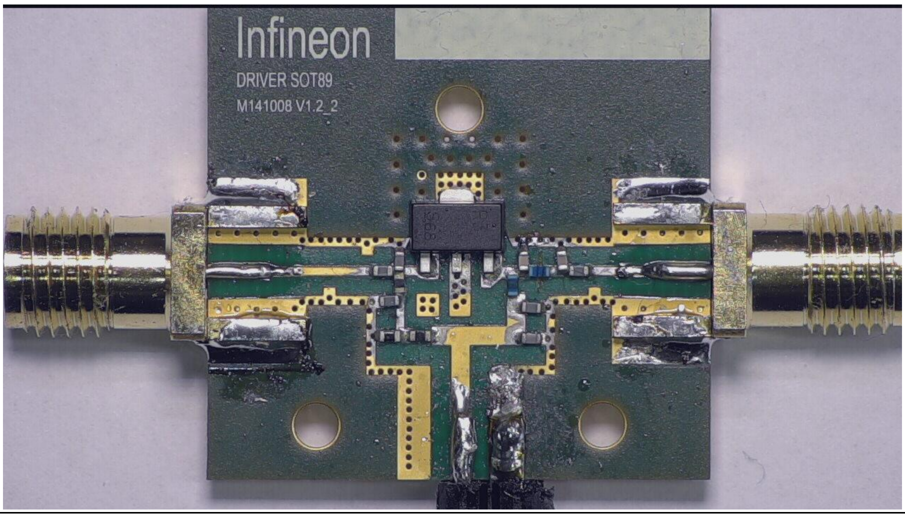


Figure 72 Photo of the BFQ790 2.4 GHz power amplifier evaluation board for WLAN application

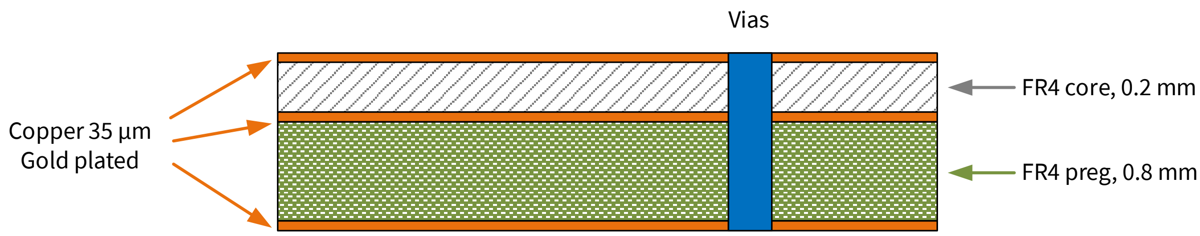


Figure 73 PCB stack information for the evaluation board M141008 v1.2_2

4.5 Measurement results of the BFQ790 2.4 GHz band WLAN power amplifier

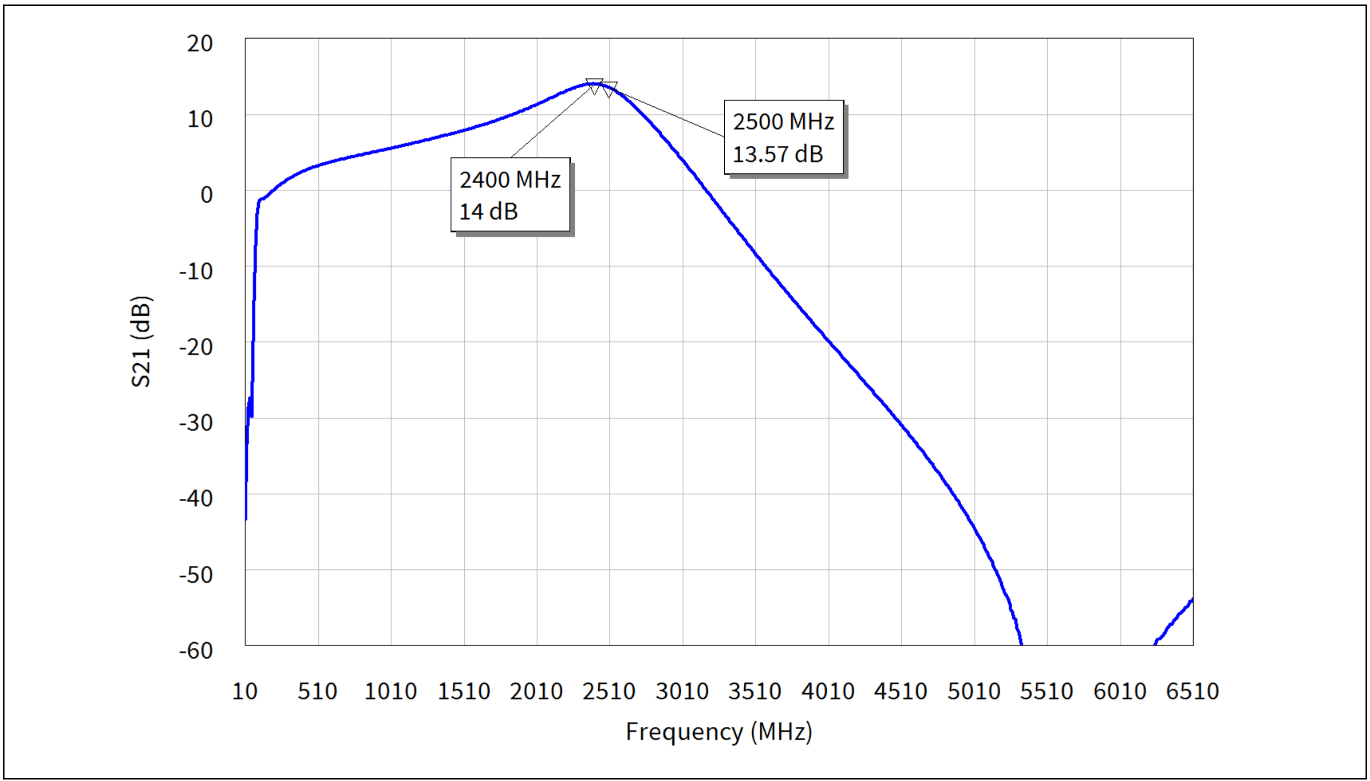


Figure 74 Small signal gain of the BFQ790 2.4 GHz WLAN power amplifier

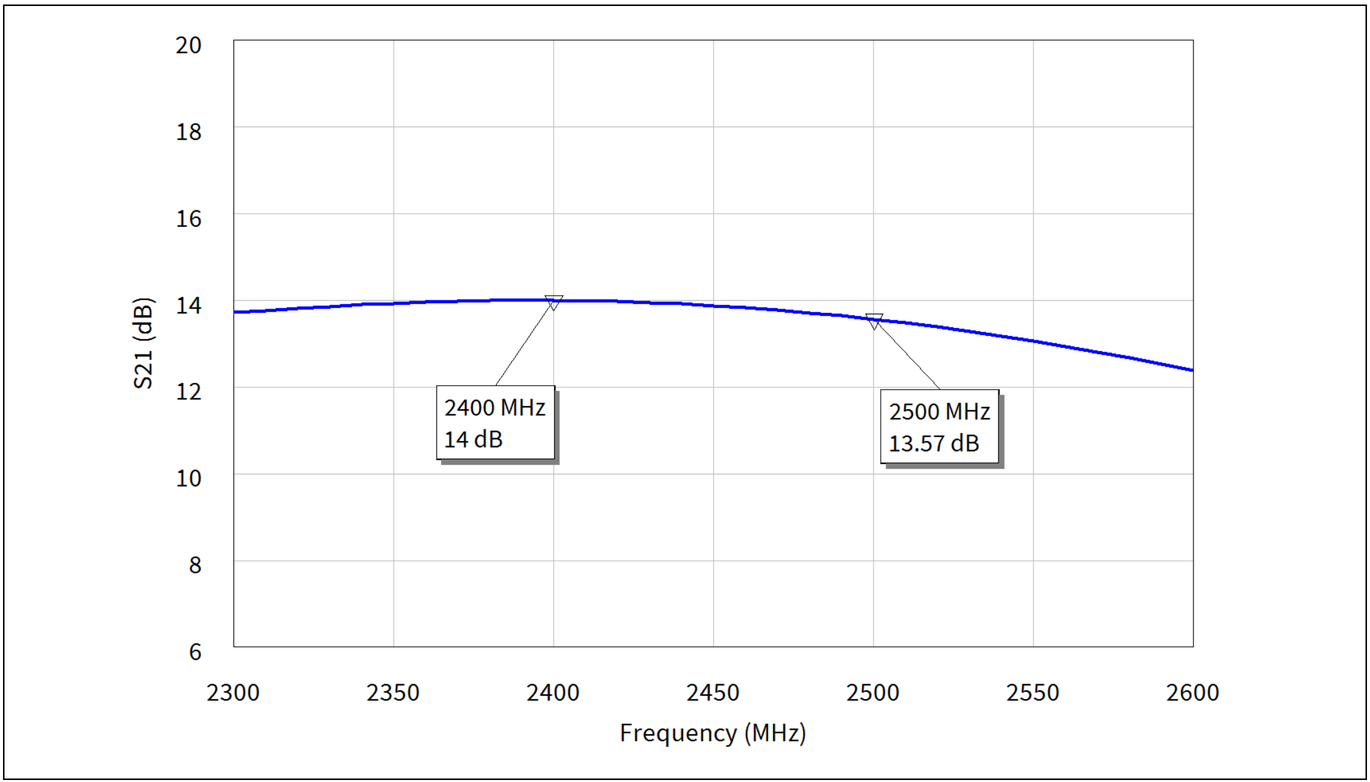


Figure 75 Small signal gain of the BFQ790 2.4 GHz WLAN power amplifier (detail view)

Note: The graphs are generated with the AWR EDA software Microwave Office®.

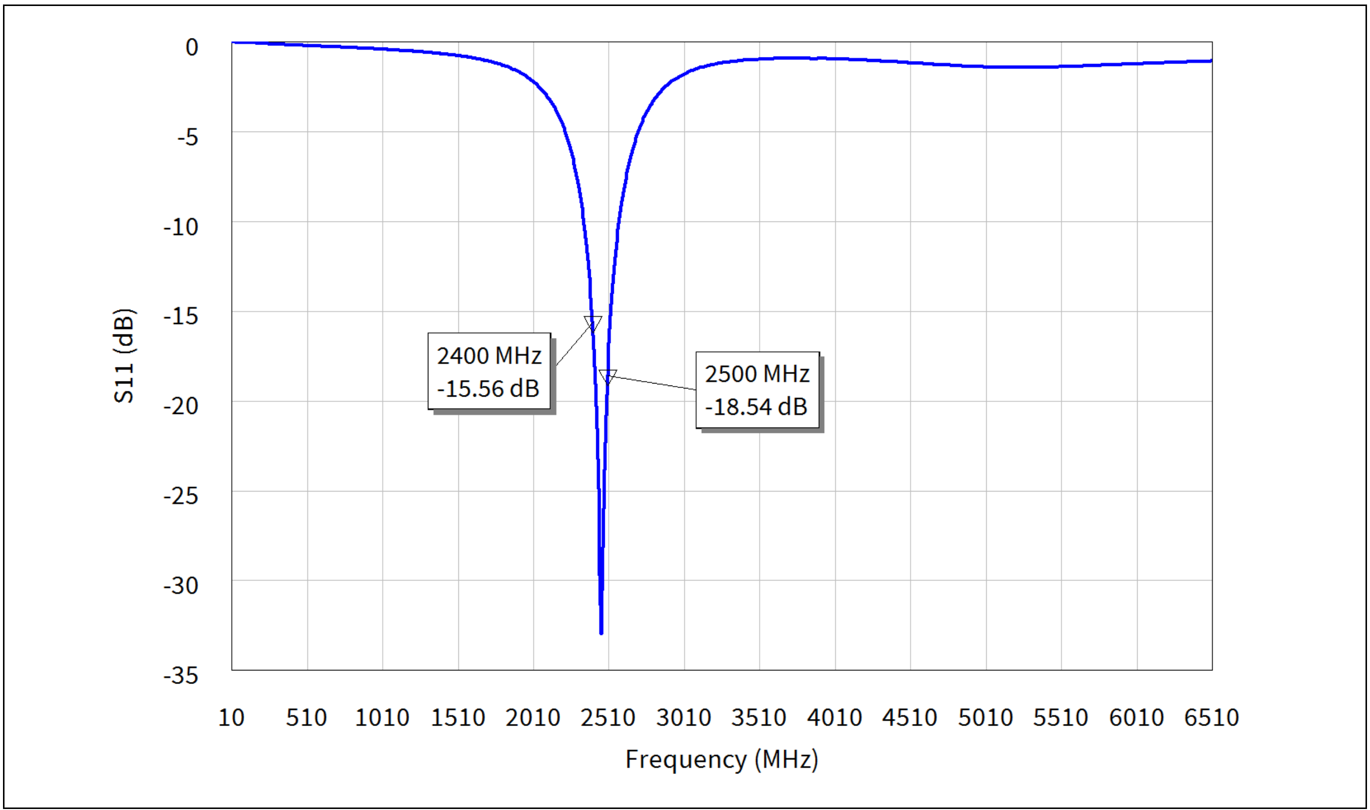


Figure 76 Input return loss measurement of the BFQ790 2.4 GHz WLAN power amplifier

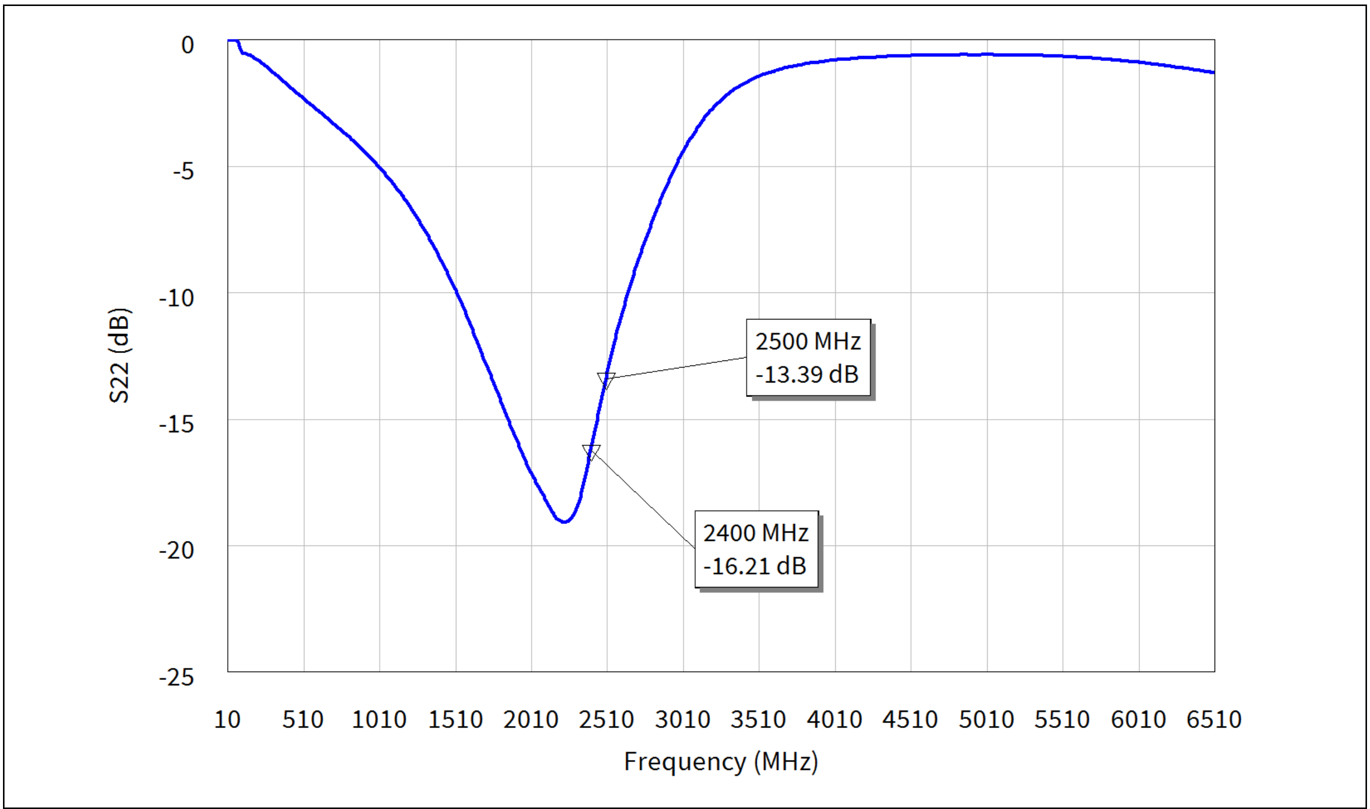


Figure 77 Output return loss measurement of the BFQ790 2.4 GHz WLAN power amplifier

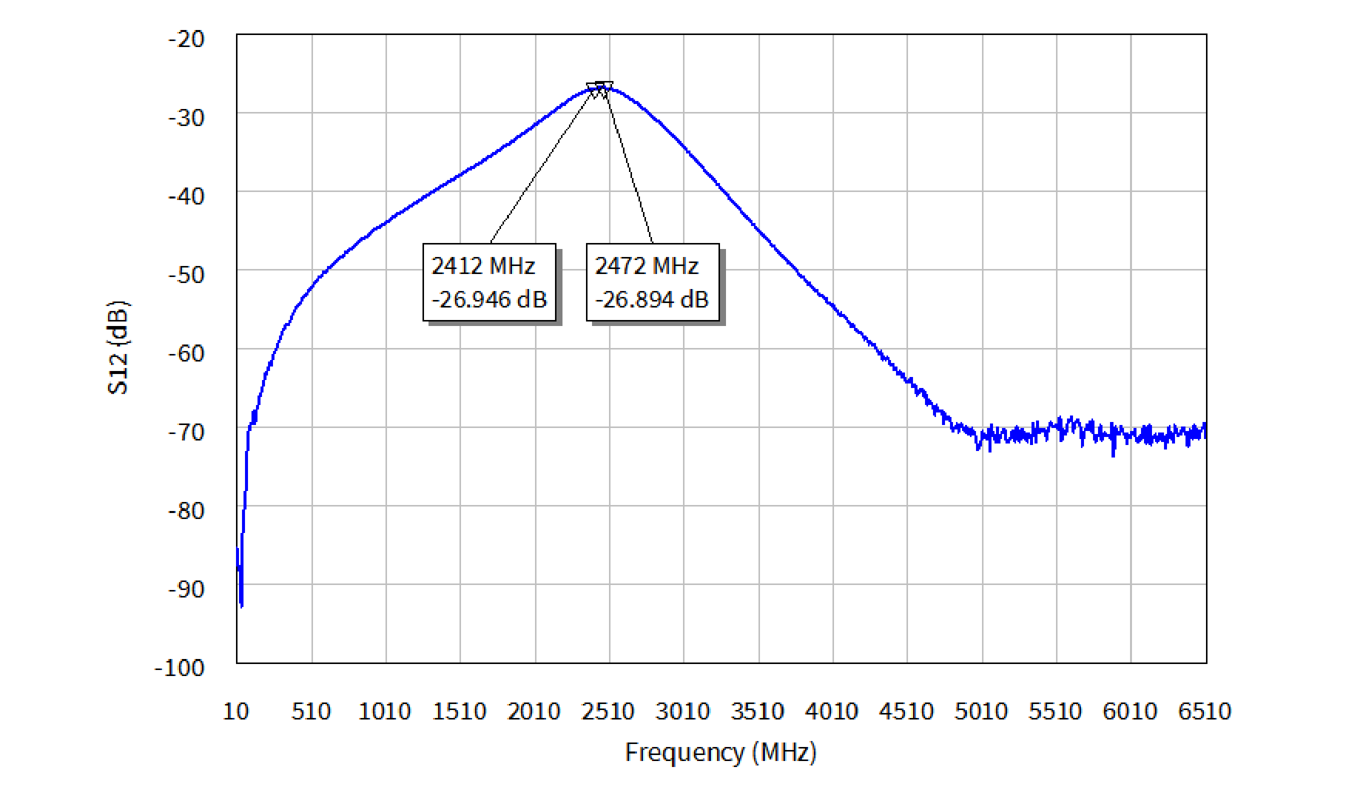


Figure 78 Reverse isolation measurement of the BFQ790 2.4 GHz WLAN power amplifier

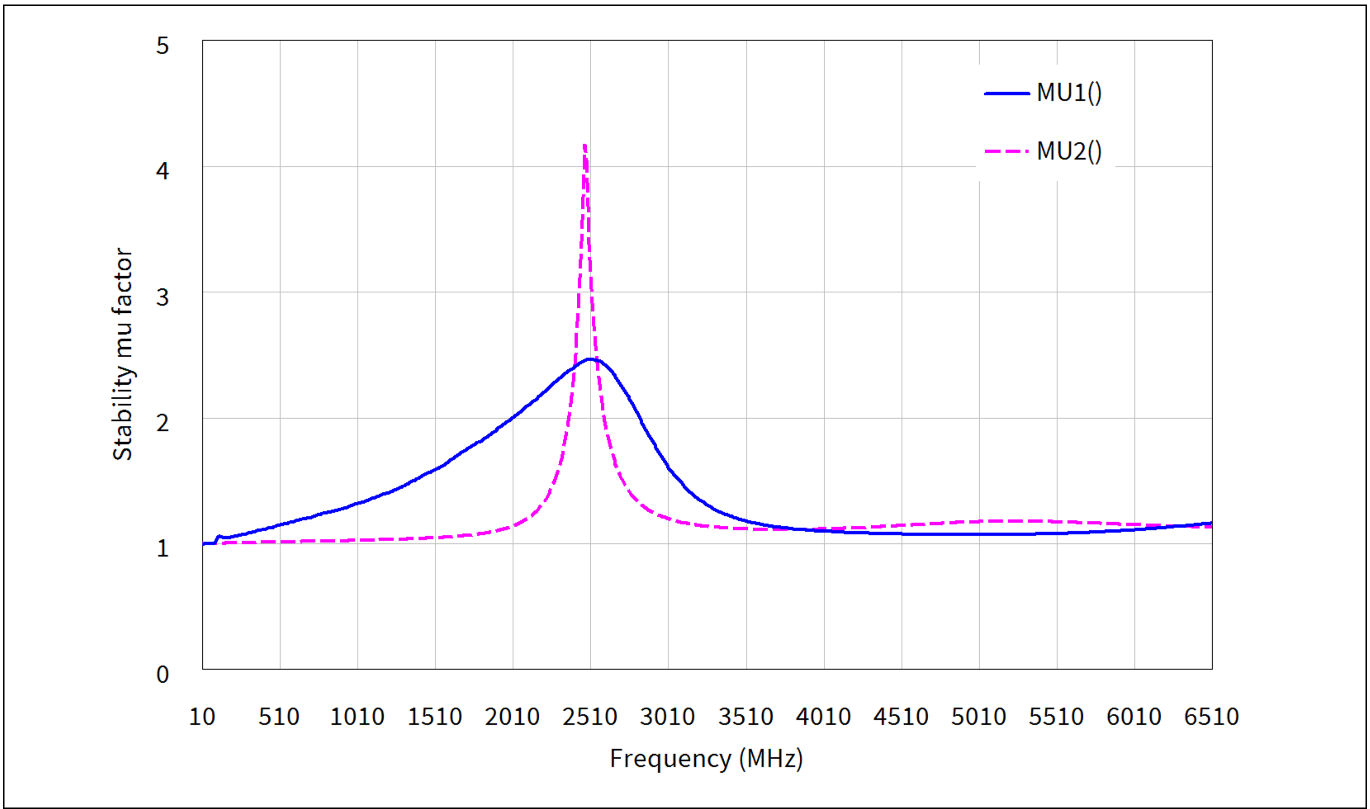


Figure 79 Stability µ-factor plots of the BFQ790 2.4 GHz WLAN power amplifier

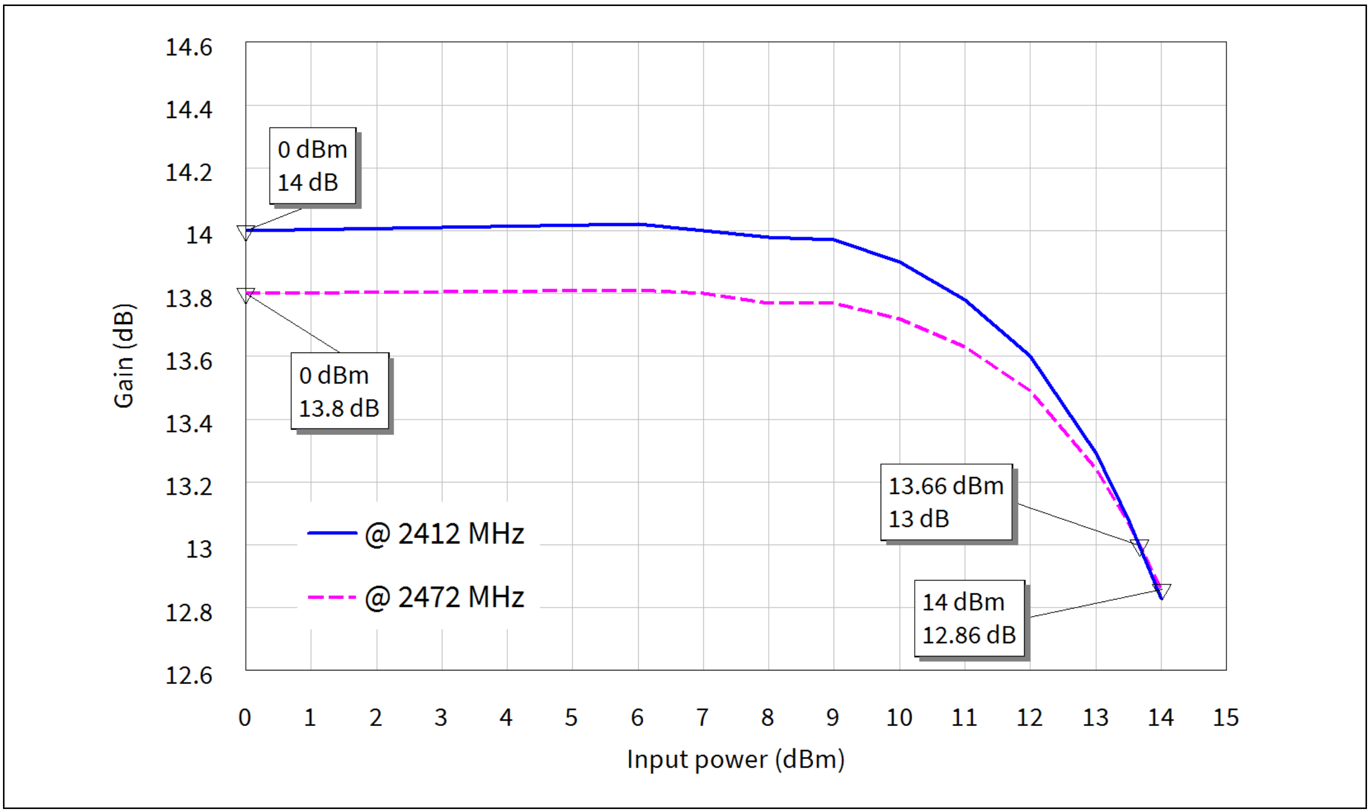
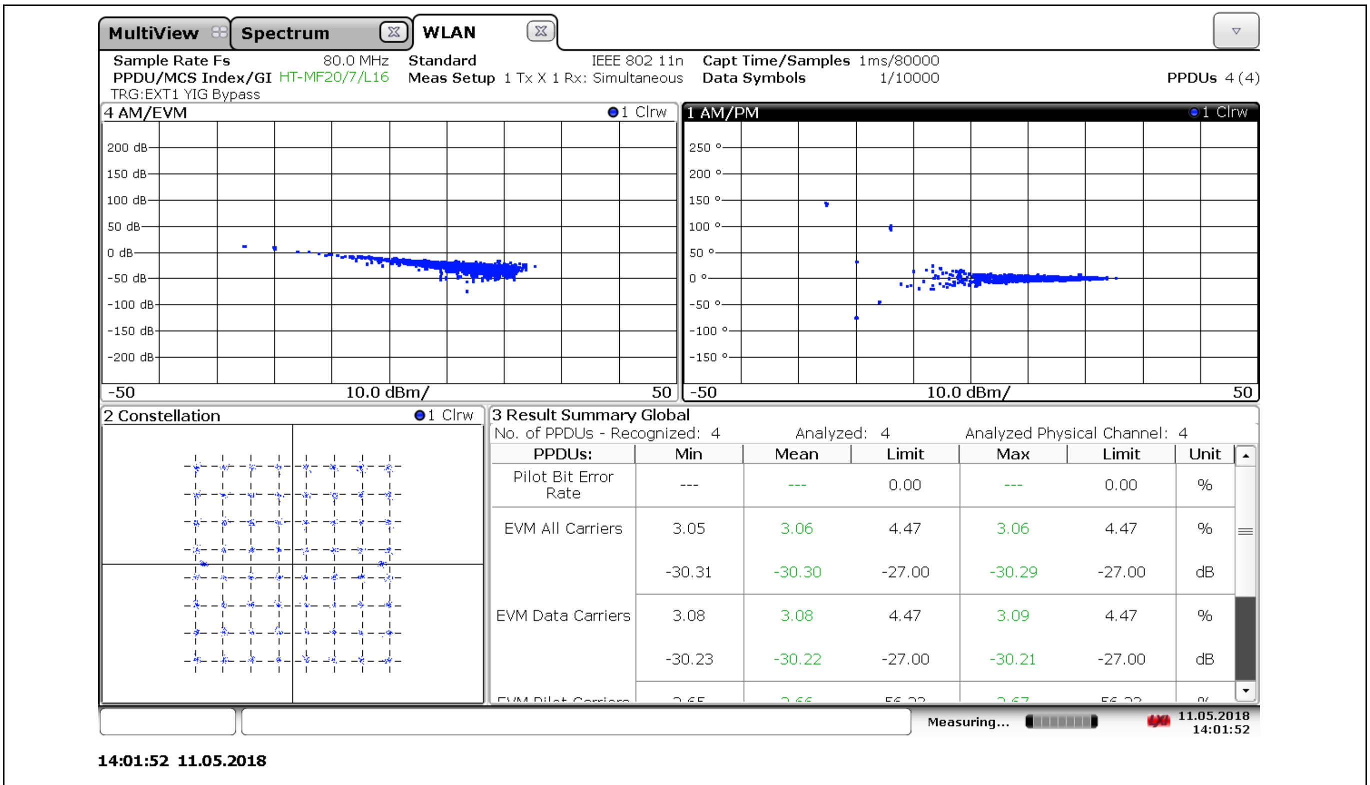


Figure 80 Input 1 dB compression point measurement of the BFQ790 2.4 GHz WLAN power amplifier



PPDUs:	Min	Mean	Limit	Max	Limit	Unit
Pilot Bit Error Rate	---	---	0.00	---	0.00	%
EVM All Carriers	3.05	3.06	4.47	3.06	4.47	%
	-30.31	-30.30	-27.00	-30.29	-27.00	dB
EVM Data Carriers	3.08	3.08	4.47	3.09	4.47	%
	-30.23	-30.22	-27.00	-30.21	-27.00	dB

Figure 81 Measured BFQ790 2.4 GHz WLAN power amplifier output signal EVM of -30 dB at 17.8 dBm average output power level with 802.11n MCS7 64QAM signal at center frequency 2.412 GHz

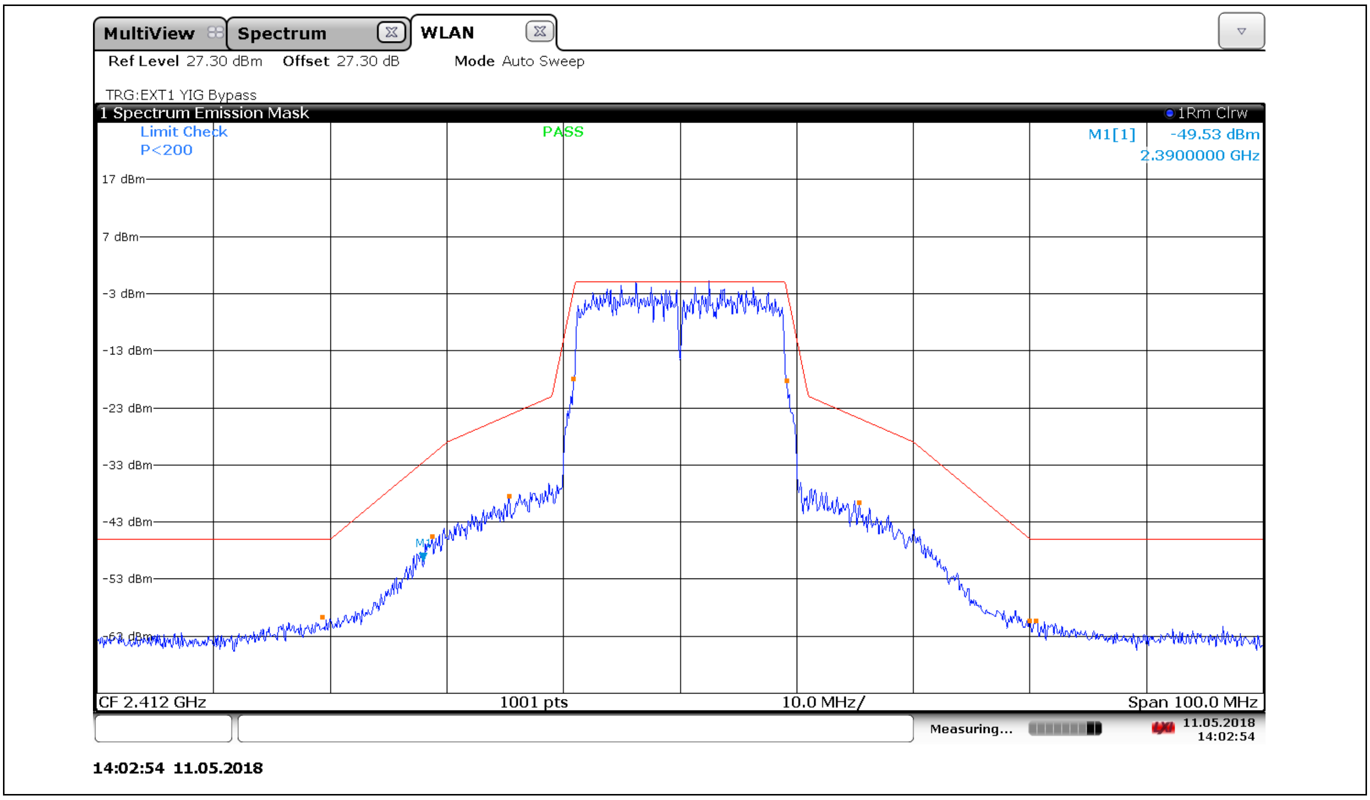


Figure 82 Output signal spectrum mask measurement of the BFQ790 2.4 GHz WLAN power amplifier with 802.11n MCS7 64QAM signal at center frequency 2.412 GHz

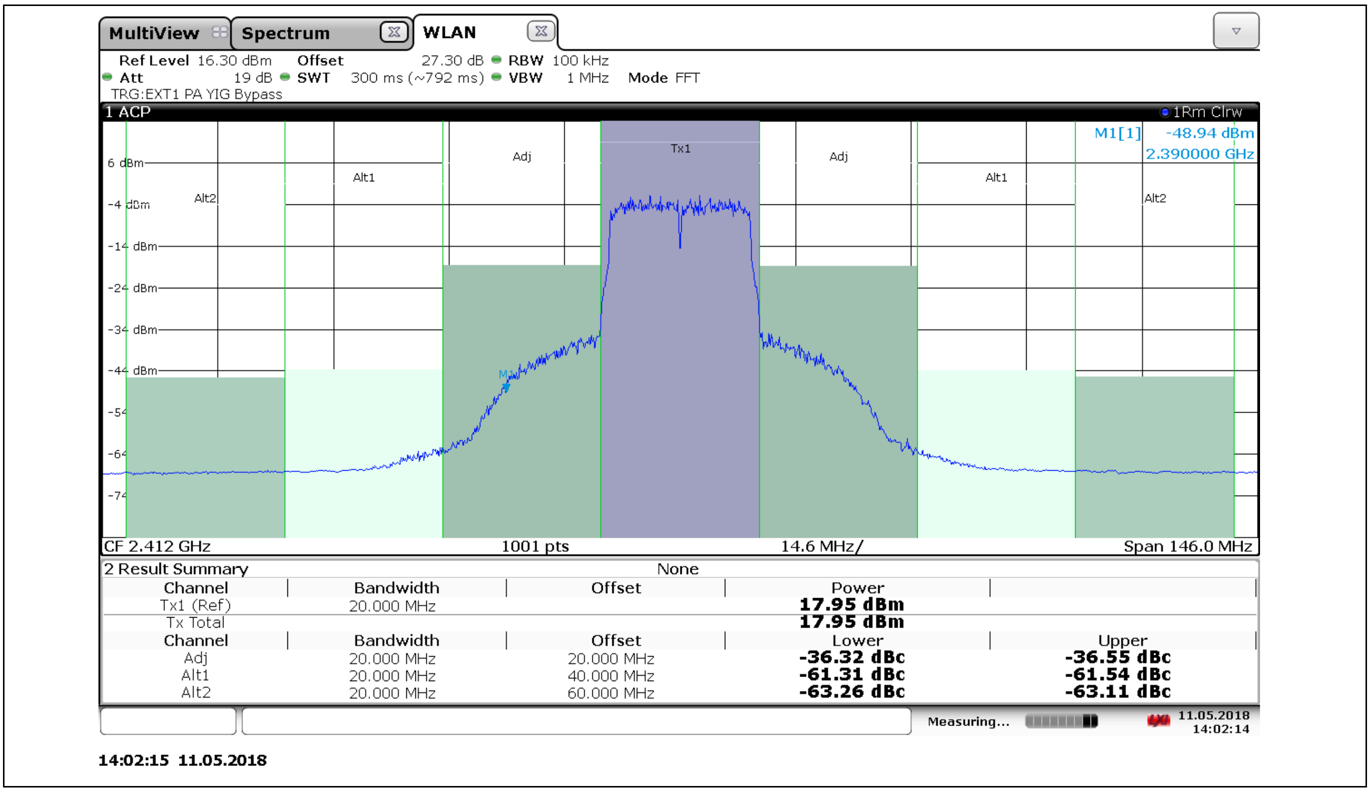


Figure 83 Output signal adjacent channel power measurement of the BFQ790 2.4 GHz WLAN power amplifier with 802.11n MCS7 64QAM signal at center frequency 2.412 GHz

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