Design guide for low-noise transistors in WLAN front ends for 6 to 7 GHz

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). In this document, the transistor-based LNA schematics, printed circuit board (PCB) layouts and measurement results are shown. This document is relevant to the following low-noise transistors:

- BFP740 Low-noise transistor for 6 to 7 GHz WLAN
- BFP840ESD Low-noise transistor for 6 to 7 GHz WLAN
- BFP840FESD Low-noise transistor for 6 to 7 GHz WLAN
- BFR840L3RHESD Low-noise transistor for 6 to 7 GHz WLAN

Intended audience

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

Table of contents

1 Introduction

1.1 WLAN radio front ends

Due to the increased number of WiFi-enabled devices in daily life, there is more demand to connect these devices to a network. WiFi 6 provides fast data throughput with increased connected device capacity. WLAN is one of the most important connectivity functions between WLAN access points and smartphones, tablets and laptops. WLAN standards have been widely implemented according to IEEE 802.11ax at 6 to 7 GHz. The WiFi 6 application is an extension of WiFi applications covering a wide frequency spectrum of 1200 MHz. Target wake time (TWT) increases power and network efficiency. WiFi 6 also provides additional spectrum capacity, with 14 additional channels of 80 MHz bandwith or 7 additional channels of 160 MHz bandwidth.

Key performance metrics for WLAN applications 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 requires 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 power amplifier (PA) close to the antenna is a popular method to improve the signal quality.

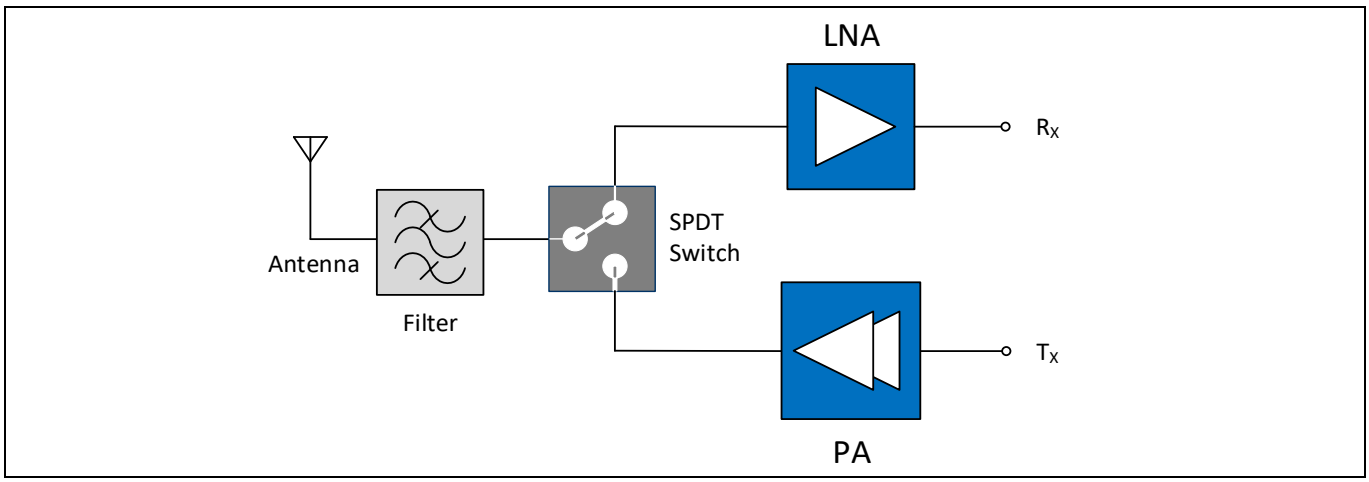

Figure 1 Block diagram of a WLAN radio front end

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 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 6 to 7 GHz WLAN bands. These LNAs are designed for U-NII-5 (Unlicensed National Information Infrastructure 5295 to 6425 MHz), U-NII-6 (6425 to 6525 MHz), U-NII-7 (6525 to 6875 MHz) and U-NII-8 (6875 to 7125 MHz) bands, which covers the complete WiFi 6 1200 MHz bandwidth. The transistors maximize design flexibility to suit customer requirements.

2 6 to 7 GHz band WLAN LNA application circuits

2.1 Performance overview

The following tables shows the performance of the 6 to 7 GHz band WLAN low-noise transistors.

Table 1 Summary of measurement results for the 6 to 7 GHz band WLAN LNAs with SOT-343 packaged transistors

Parameter	Symbol	Value				Unit	Notes
Device		BFP740		BFP840ESD			
Bias voltage	V_{CC}	3.3		3.3		V	
Bias current	I_{CC}	14.5		9.5		mA	
Frequency	f	5.93	7.13	5.93	7.13	GHz	
Gain	G	14.3	12.6	17.1	15.0	dB	
NF	NF	0.94	1.36	1.19	1.35	dB	PCB and SMA loss subtracted: 0.2 dB
Input return loss	RL_{in}	9.6	8.5	15.7	10.5	dB	
Output return loss	RL_{out}	16.4	16.9	15.9	10.5	dB	
Reverse isolation	ISO_{rev}	21.5	20.1	23.7	22.4	dB	
Output 1 dB compression point	OP_{1dB}	10.9		6.0		dBm	Measured at 6.6 GHz
Output third-order intercept point	OIP_3	24.7		18.5		dBm	Input power: -25 dBm Tone 1: 6600 MHz Tone 2: 6601 MHz
Stability	K	More than 1					Measured from 10 MHz to 14 GHz

Table 2 Summary of measurement results for the 6 to 7 GHz band WLAN LNAs with TSLP and TSFP packaged transistors

Parameter	Symbol	Value				Unit	Notes
Device		BFP840FESD		BFR840L3RHESD			
Bias voltage	V_{CC}	3.3		3.3		V	
Bias current	I_{CC}	14.6		12.6		mA	
Frequency	f	5.93	7.13	5.93	7.13	GHz	
Gain	G	18	16.7	15.4	14.2	dB	
NF	NF	1.36	1.26	1.10	1.13	dB	PCB and SMA loss subtracted: 0.2 dB
Input return loss	RL_{in}	13.5	9.4	9.9	12.0	dB	
Output return loss	RL_{out}	10.4	23.5	11.1	12.5	dB	
Reverse isolation	ISO_{rev}	26.3	25.1	24.3	22.8	dB	
Output 1 dB compression point	OP_{1dB}	8.7		6.9			Measured at 6.6 GHz
Output third-order intercept point	OIP_3	20.7		13.8		dBm	Input power: -25 dBm Tone 1: 6600 MHz Tone 2: 6601 MHz
Stability	K	More than 1					Measured from 10 MHz to 14 GHz

2.2 Schematic

The following figure shows the schematic of the 6 to 7 GHz band WLAN LNAs with Infineon eighth-generation and seventh-generation RF low-noise SiGe transistors BFP840ESD, BFP840FESD, BFR840L3RHESD and BFP740. The transistors are manufactured in different packages. The parasitic inductances of different transistor packages are slightly different to each other, so the emitter degeneration length fabricated on the PCB for the LNA circuits has been selected differently (see section 2.4). 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 L3. 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.

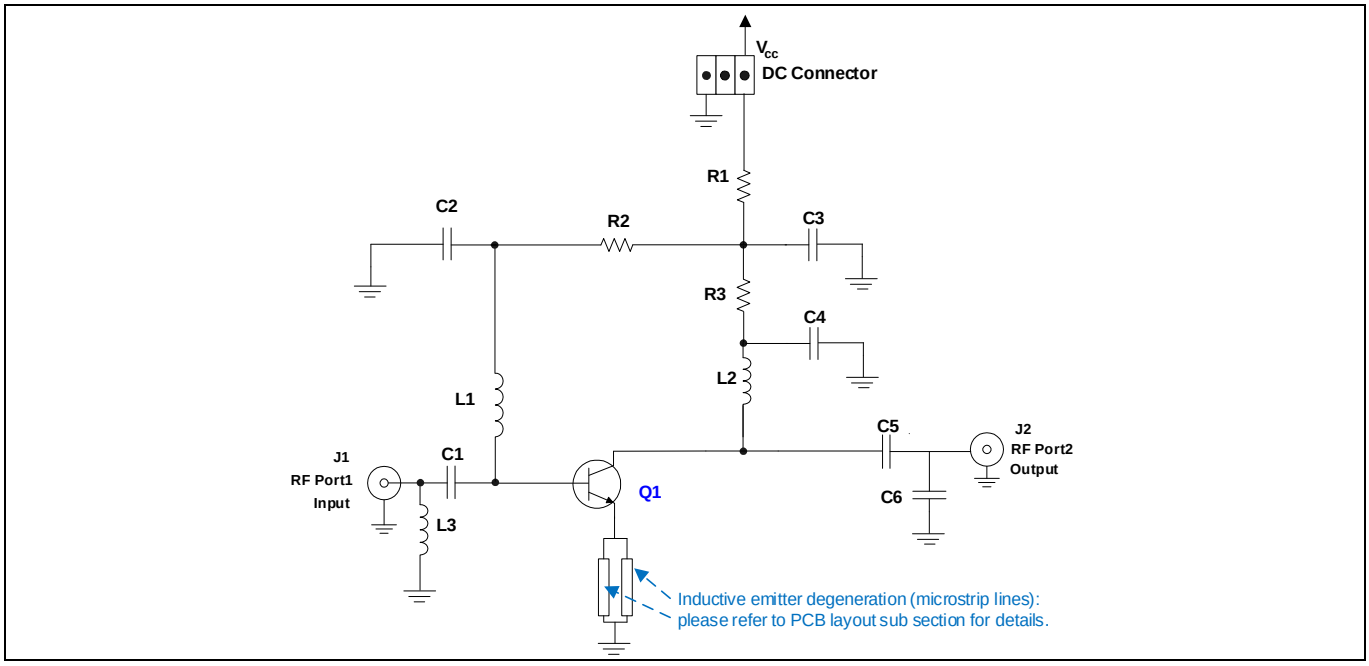

Figure 2 6 to 7 GHz band WLAN LNA schematic

2.3 Bill of materials

Table 3 BOM of the 6 to 7 GHz band WLAN LNAs

Symbol	Value (component package/size)				Manu-facturer	Notes
Q1	BFP840ESD (SOT-343)	BFP840FESD (TSFP-4-1)	BFR840L3RHESD (TSLP-3-9)	BFP740 (SOT-343)	Infineon	SiGe:C bipolar low-noise transistor
C1	3.3 pF (0402)	24 pF (0402)	1.5 pF (0201)	3.3 pF (0402)	Various	Input matching and DC blocking
C2	39 pF (0402)	n.c.[1)]	10 pF (0201)	n.c.[1)]	Various	RF decoupling
C3	39 pF (0402)	39 pF (0402)	10 pF (0201)	47 pF (0402)	Various	RF decoupling
C4	1.8 pF (0402)	0.5 pF (0402)	n.c.[1)]	1 pF (0402)	Various	Output matching and stability improvement
C5	5 pF (0402)	1.8 pF (0402)	1 pF (0201)	1.5 pF (0402)	Various	Output matching and DC blocking
C6	0.1 pF (0402)	n.c.[1)]	n.c.[1)]	n.c.[1)]	Various	High-frequency stability improvement
R1	82 Ω (0402)	51 Ω (0402)	120 Ω (0201)	22 Ω (0402)	Various	DC bias and DC negative feedback
R2	30 kΩ (0402)	27 kΩ (0402)	24 kΩ (0201)	33 kΩ (0402)	Various	DC biasing for transistor base

R3	82 Ω (0402)	51 Ω (0402)	15 Ω (0201)	82 Ω (0402)	Various	Low-frequency stability improvement
L1	2.2 nH (LQG/0402)	n.c.[1)]	3 nH (LQP03T/0201)	82 nH (LQG/0402)	Murata	RF choke and input matching
L2	1.6 nH (LQG/0402)	1.8 nH (LQG/0402)	1 nH (LQP03T/0201)	2 nH (LQG/0402)	Murata	RF choke and output matching
L3	n.c.[1)]	n.c.[1)]	n.c.[1)]	1.5 nH (LQG/0402)	Murata	Input matching

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

2.4 Evaluation boards and layout information

The evaluation boards for the 6 to 7 GHz band WLAN LNAs:

- PCB material: FR4
- PCB marking:
  - BFP840ESD M130120
  - BFP840FESD M12051302
  - BFR840L3RHESD M230420
  - BFP740 M18123109

The detailed description of the PCB stack and photos of the 6 to 7 GHz band WLAN LNAs' evaluation boards and are shown in the following figures.

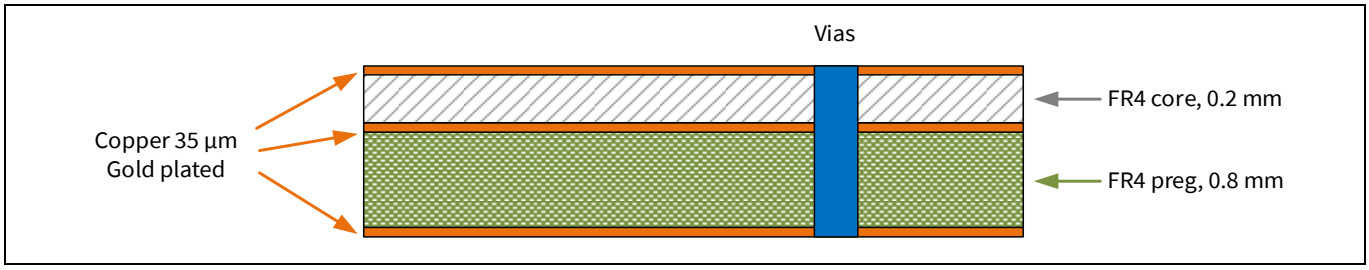

Figure 3 PCB stack information for the evaluation boards with markings M130120, M12051302, M230420 and M18123109

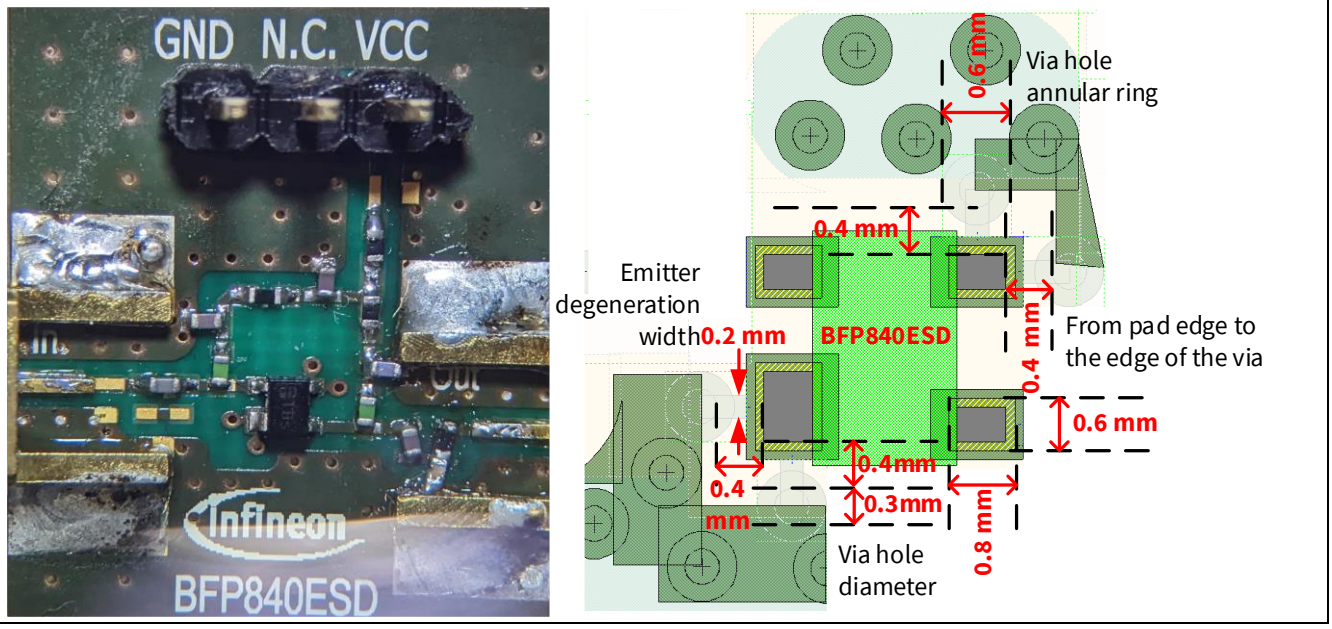

Figure 4 Photo of the evaluation board with marking M130120 (left) and emitter degeneration details (right)

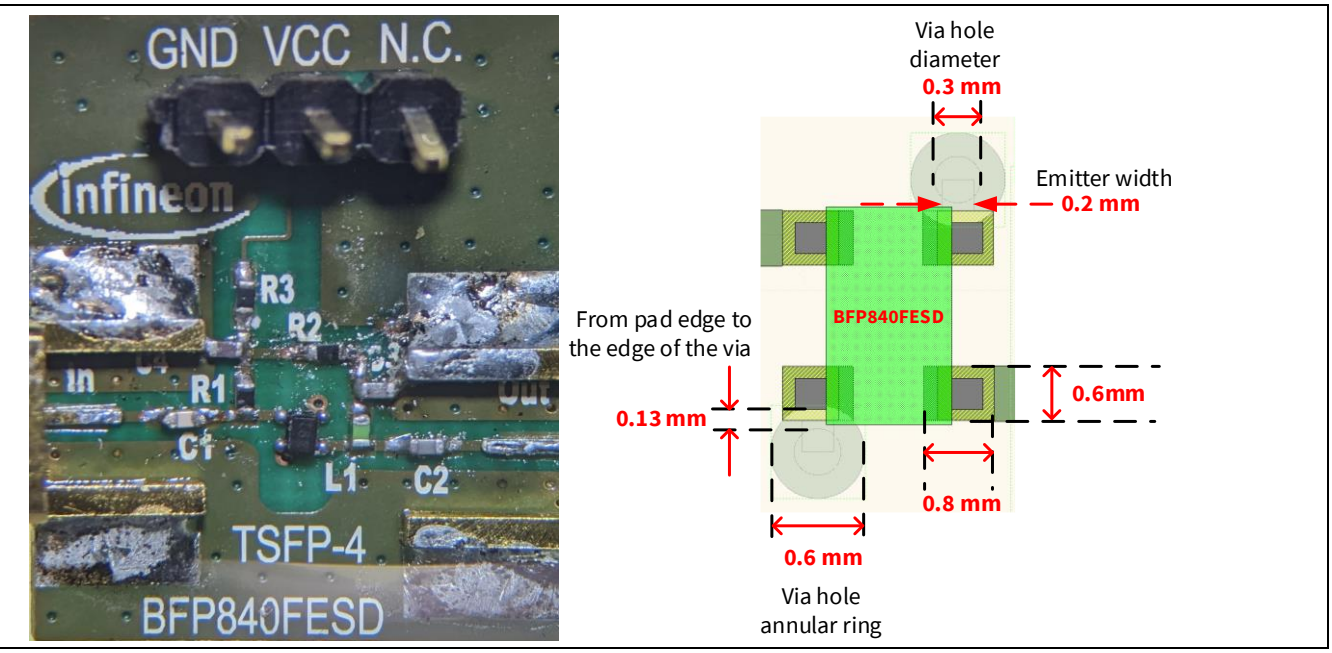

Figure 5 Photo of the evaluation board with marking M12051302 (left) and emitter degeneration details (right)

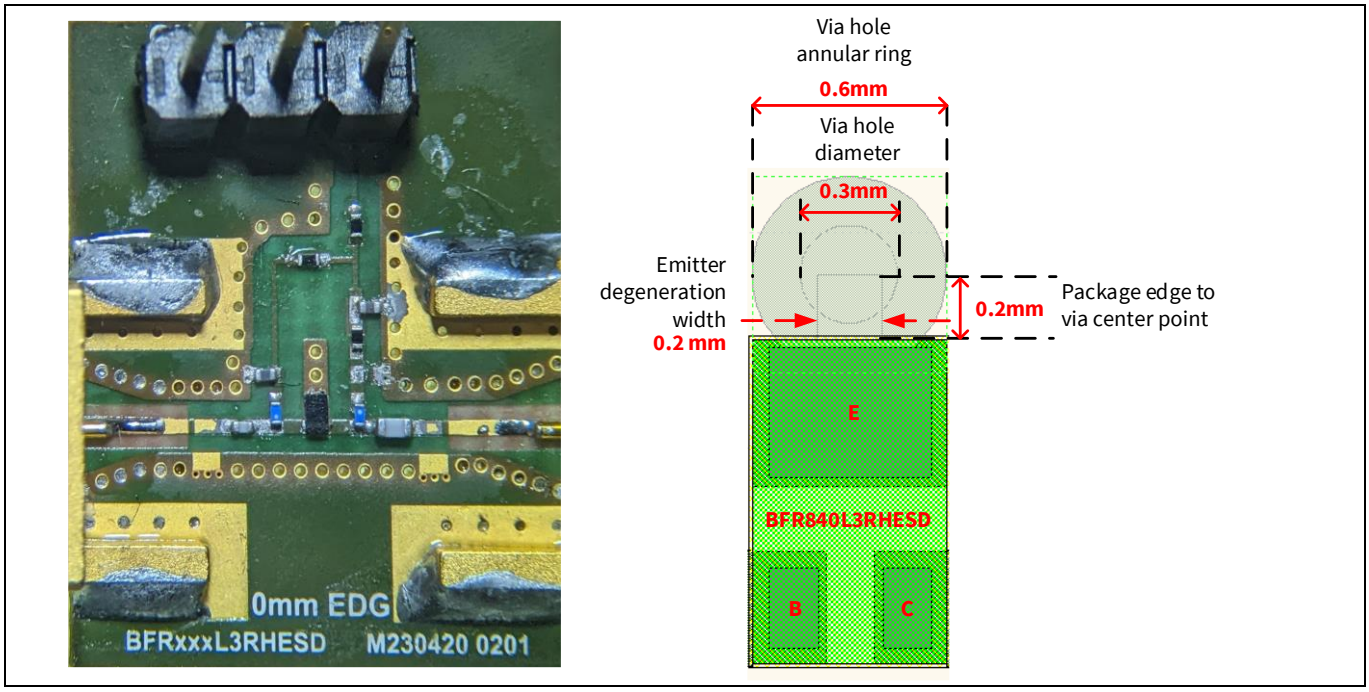

Figure 6 Photo of the evaluation board with marking M230420 (left) and emitter degeneration details (right)

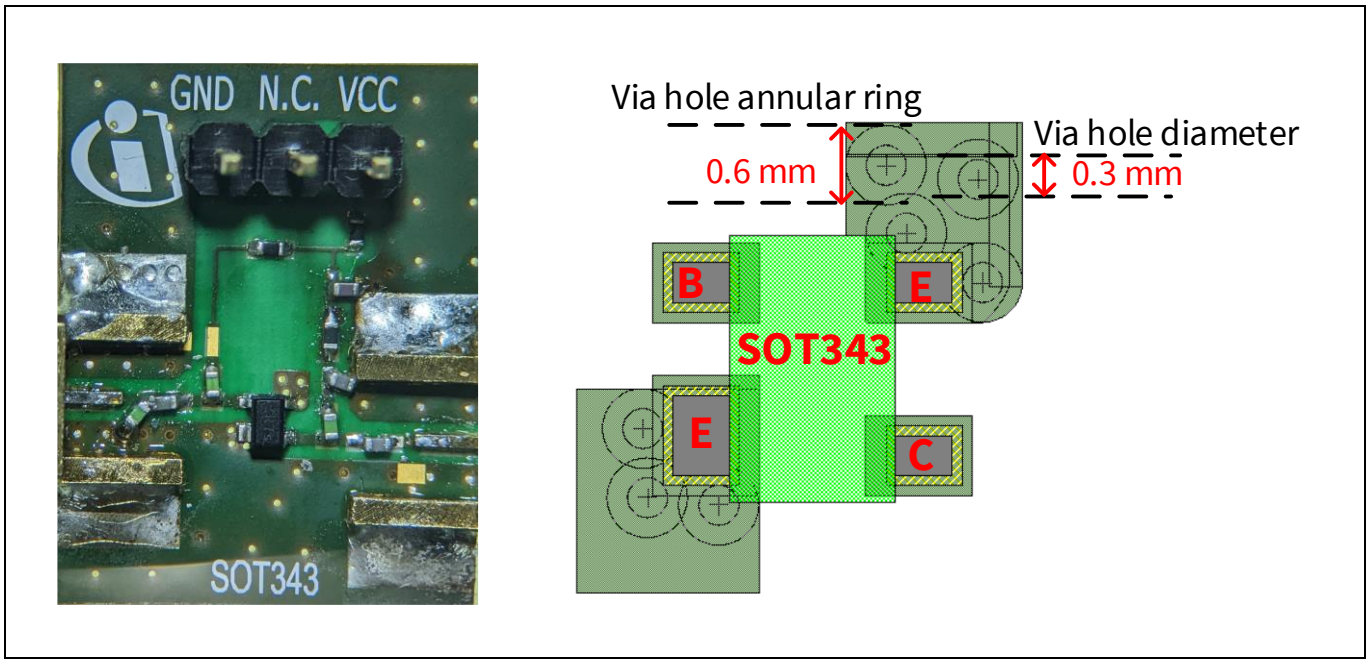

Figure 7 Photo of the evaluation board with marking M18123109 (left) and emitter degeneration details (right)

2.5 Measurement results of the 6 to 7 GHz band WLAN LNAs

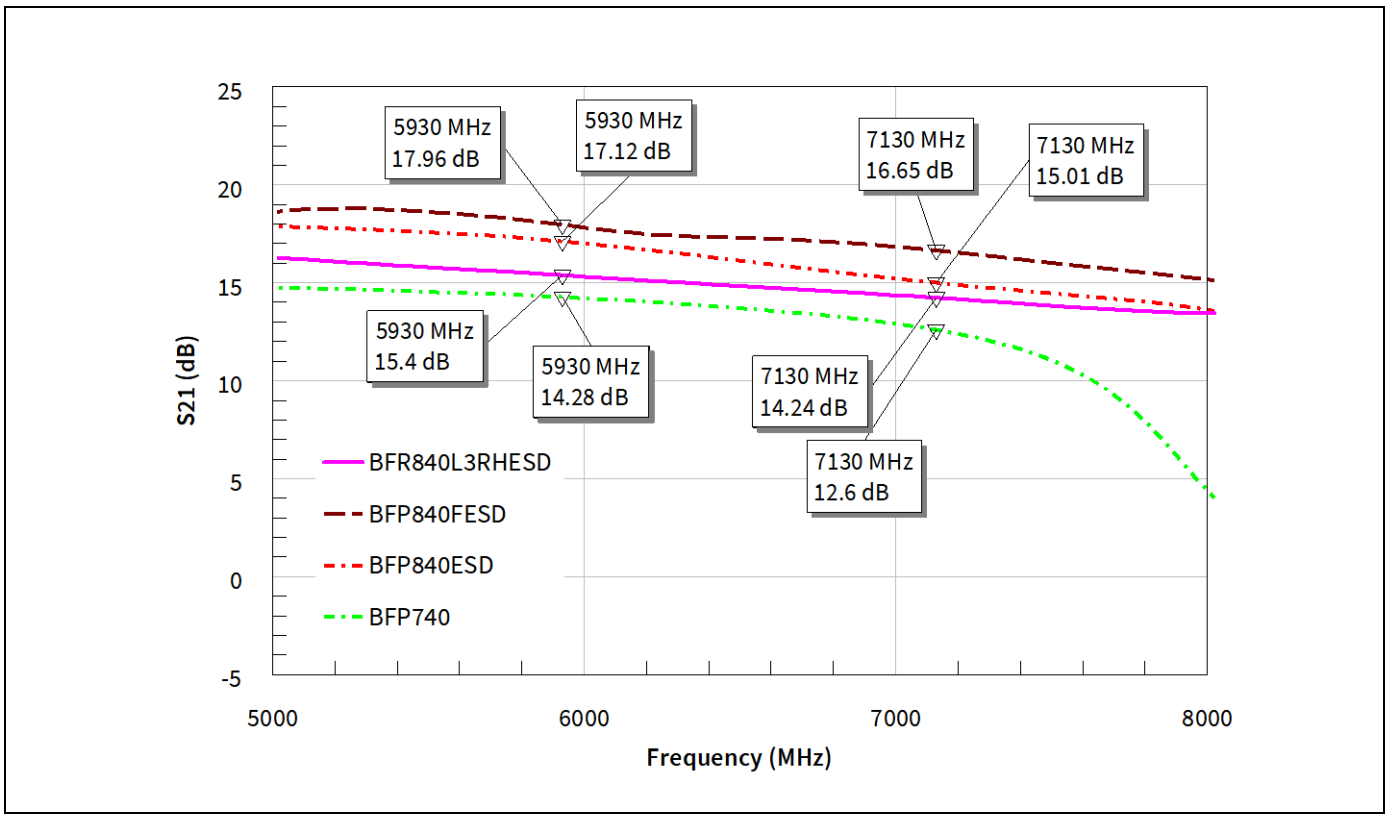

Figure 8 Small-signal gain of the 6 to 7 GHz band WLAN LNAs

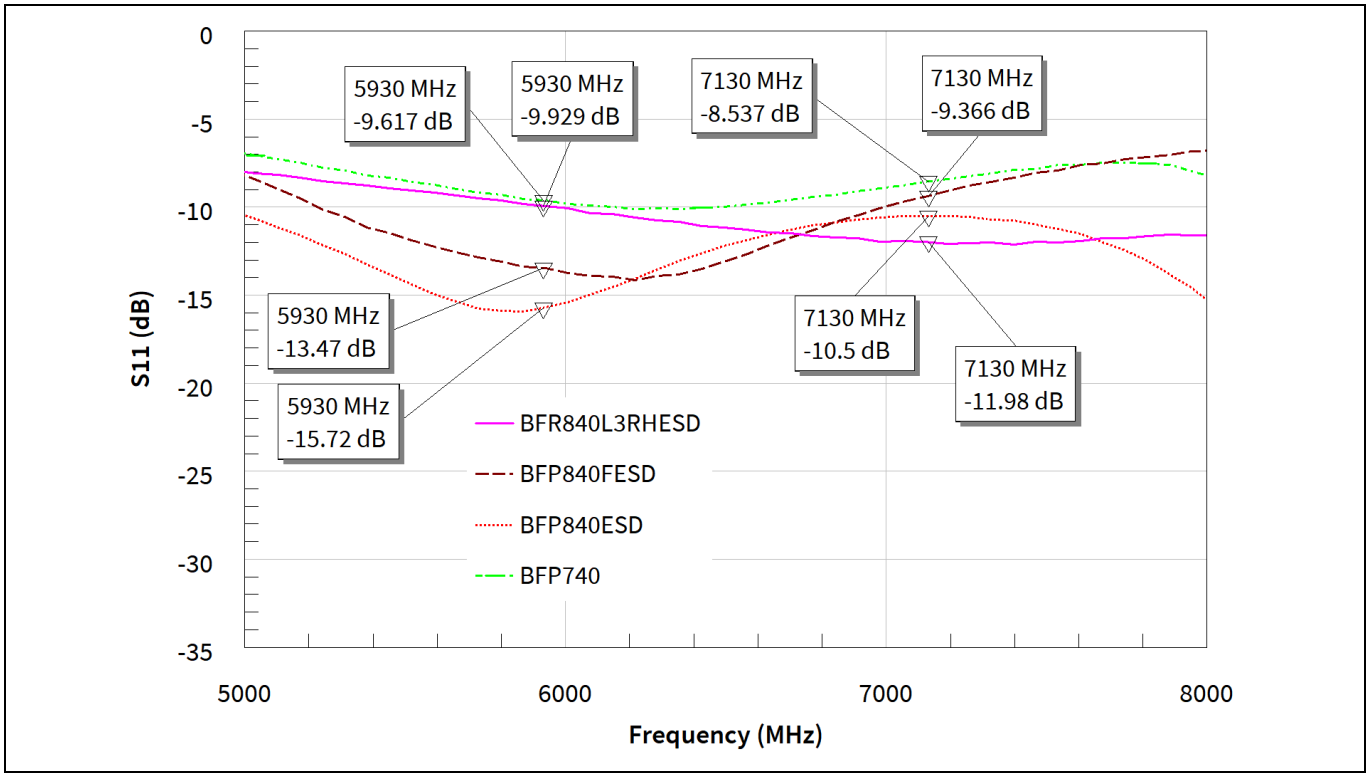

Figure 9 Input return loss measurement of 6 to 7 GHz band WLAN LNAs

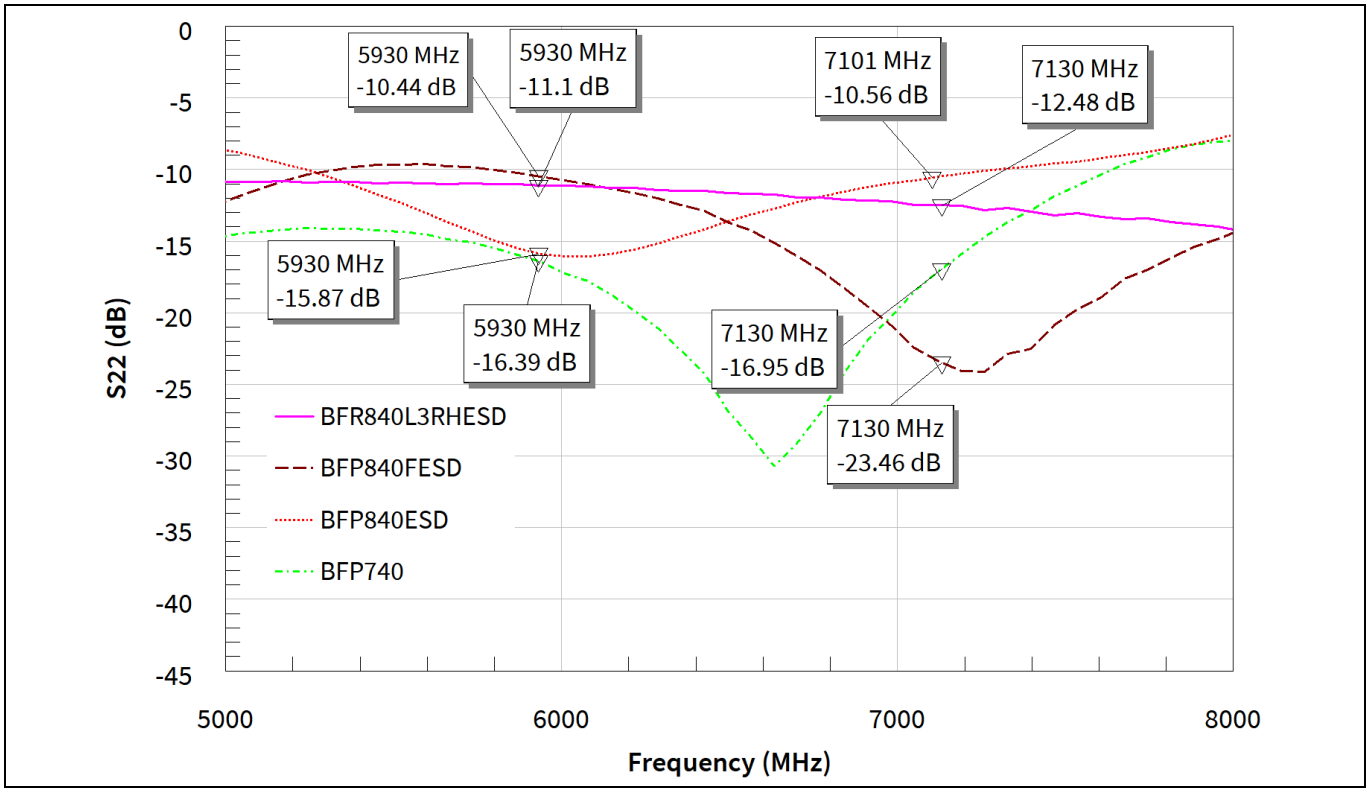

Figure 10 Output return loss measurement of the 6 to 7 GHz band WLAN LNAs

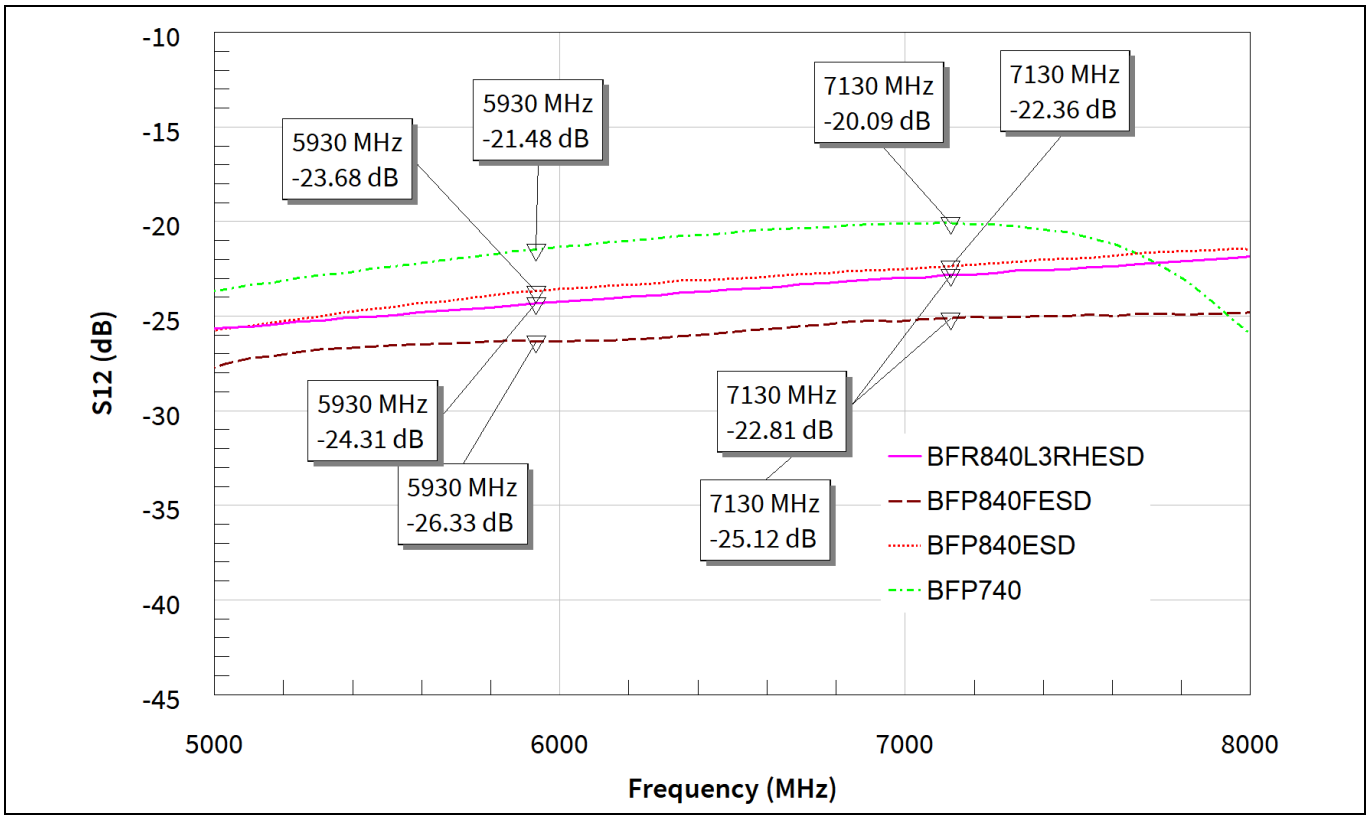

Figure 11 Reverse isolation measurement of the 6 to 7 GHz band WLAN LNAs

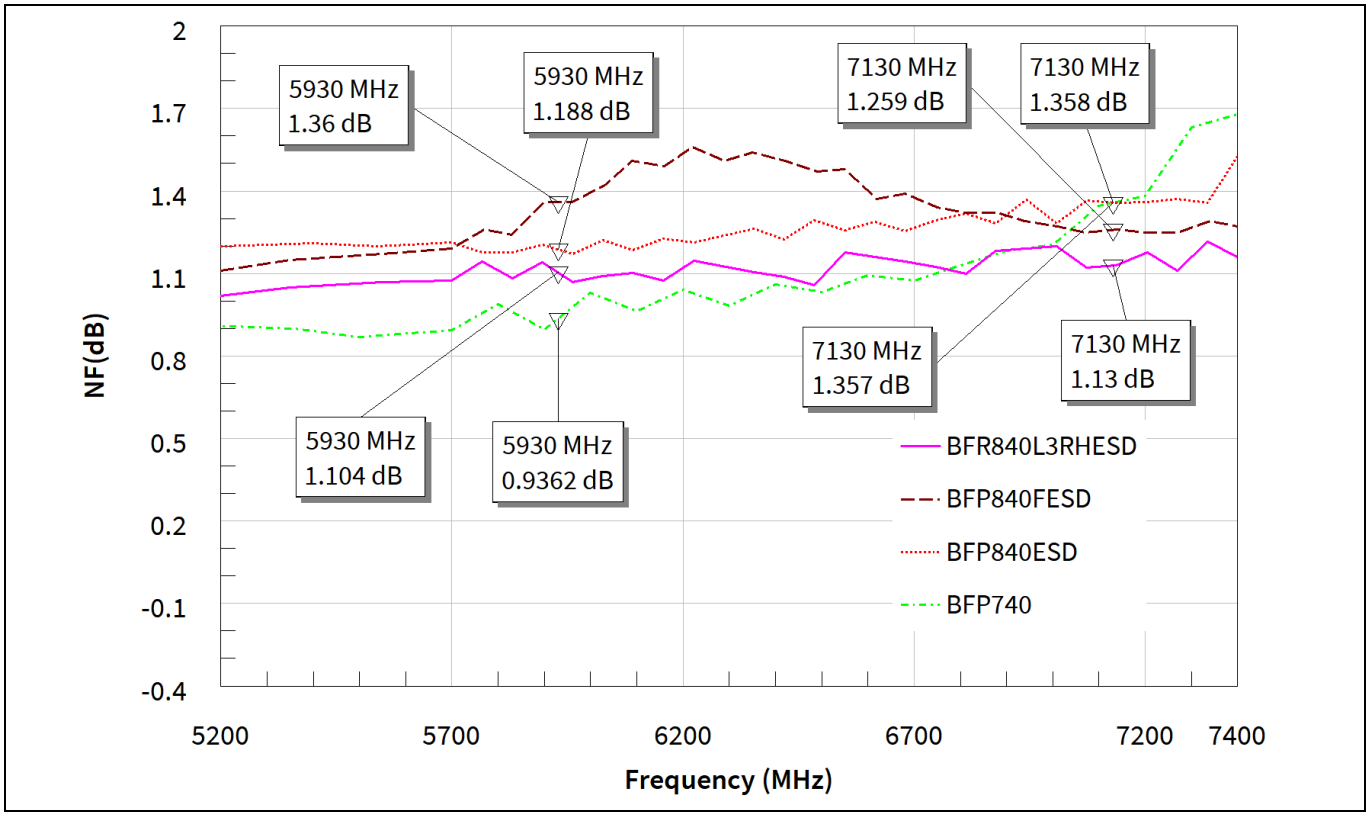

Figure 12 NF measurement of the 6 to 7 GHz band WLAN LNAs

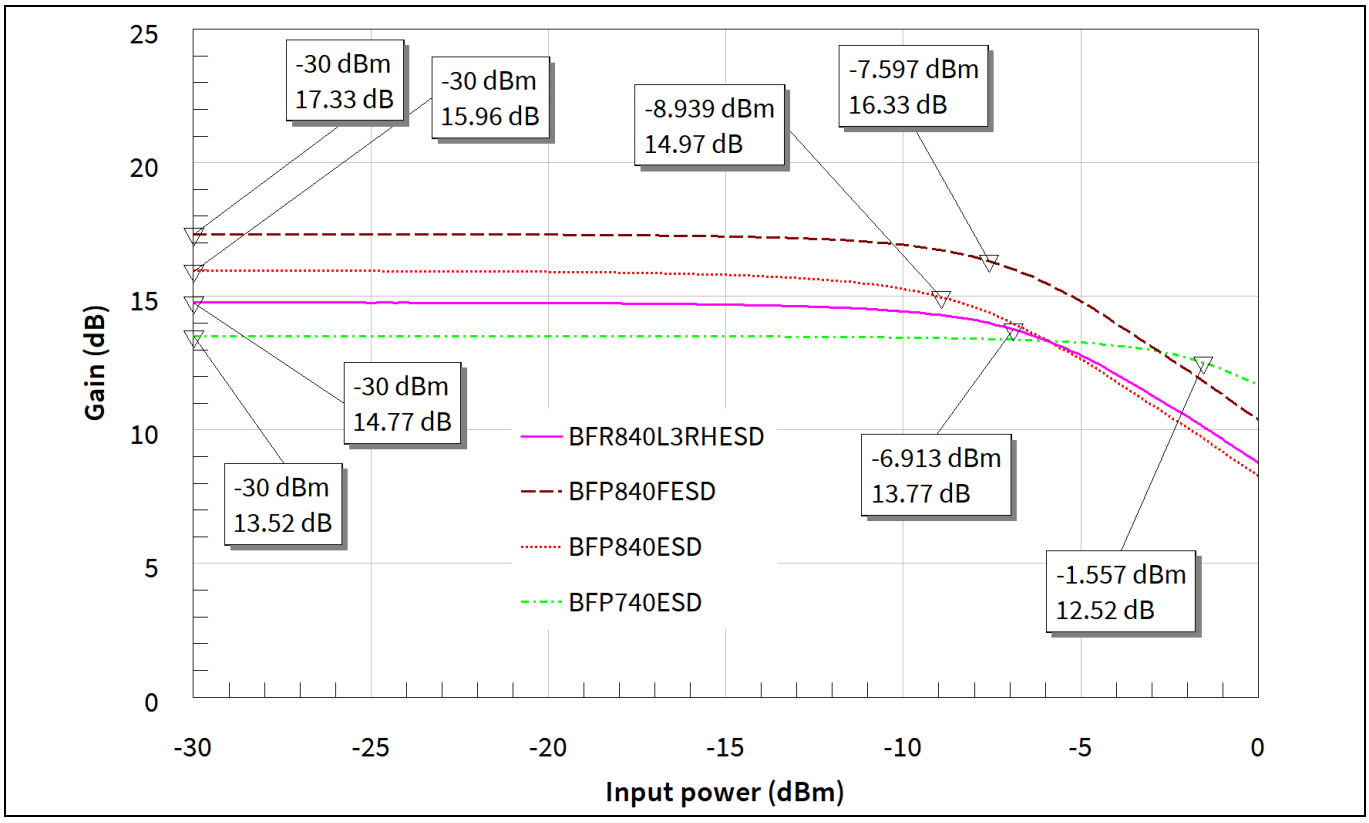

Figure 13 Input 1 dB compression point measurement at 6.6GHz

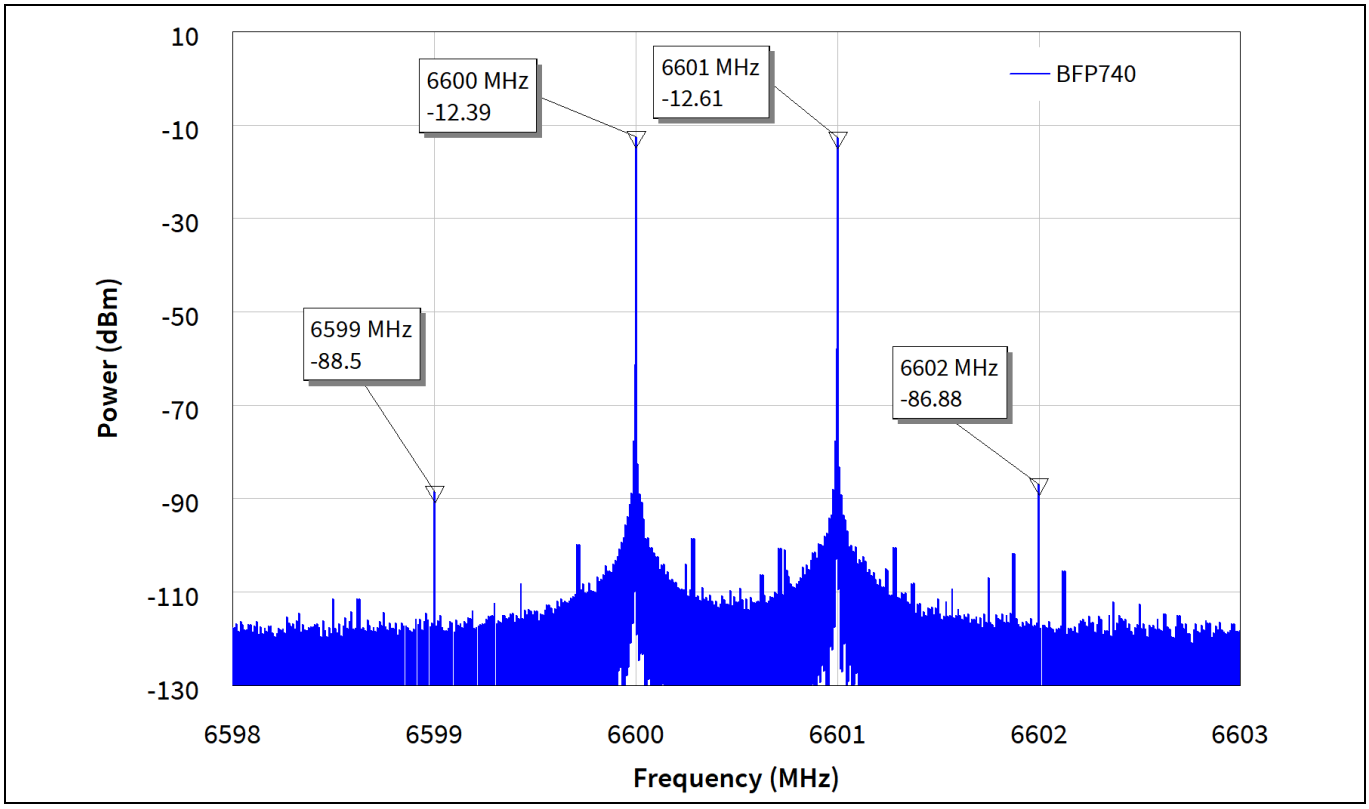

Figure 14 Output IMD$_3$ measurement of the 6 to 7 GHz band WLAN LNA with BFP740

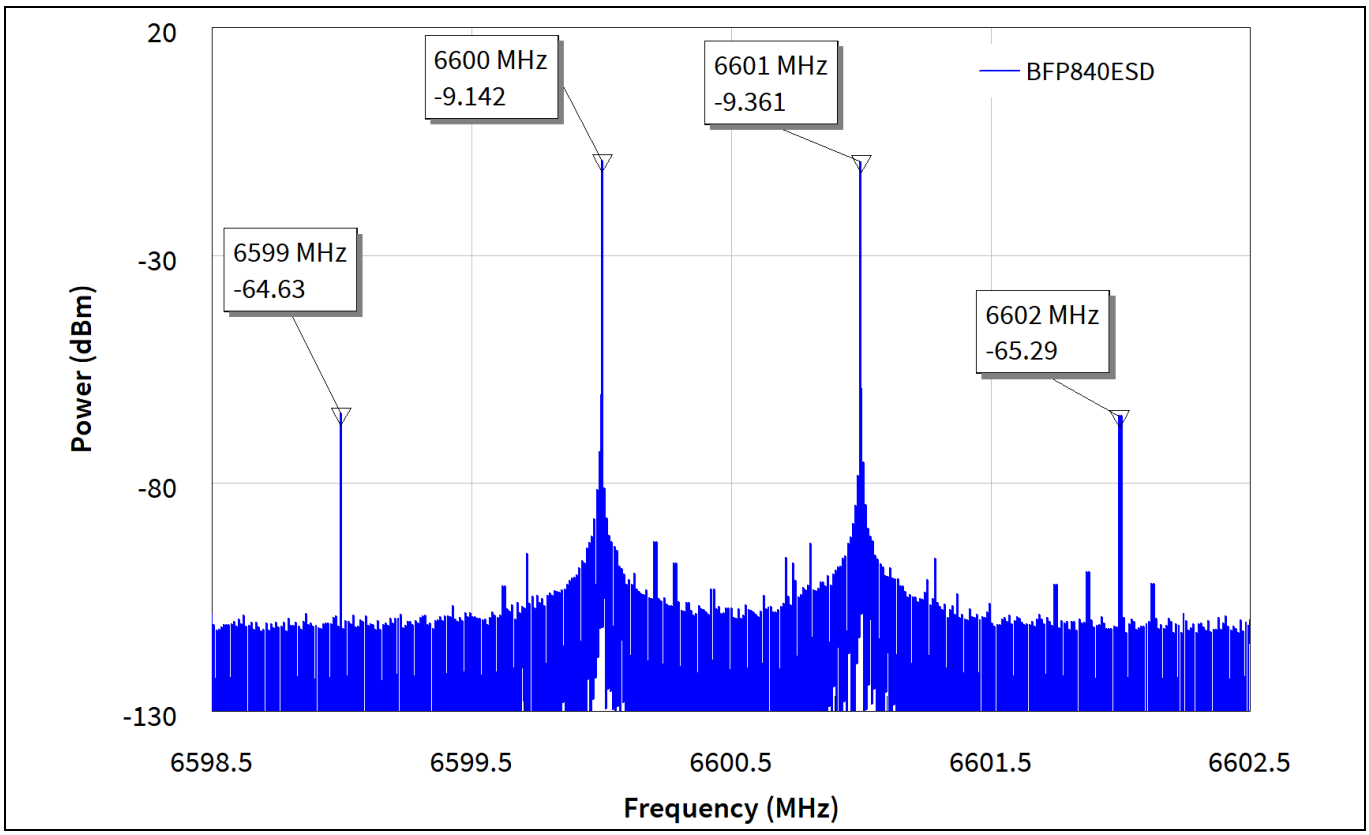

Figure 15 Output IMD$_3$ measurement of the 6 to 7 GHz band WLAN LNA with BFP840ESD

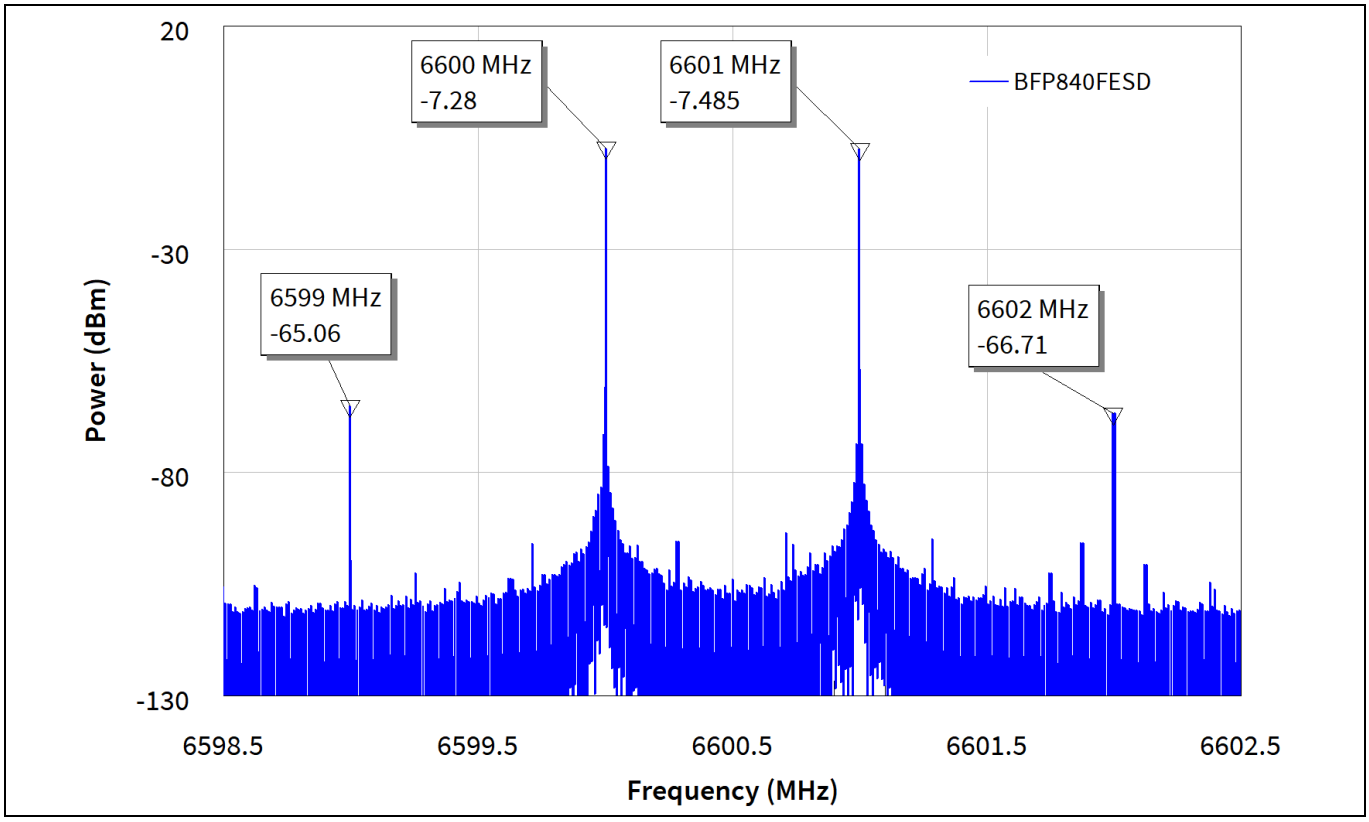

Figure 16 Output IMD$_3$ measurement of the 6 to 7 GHz band WLAN LNA with BFP840FESD

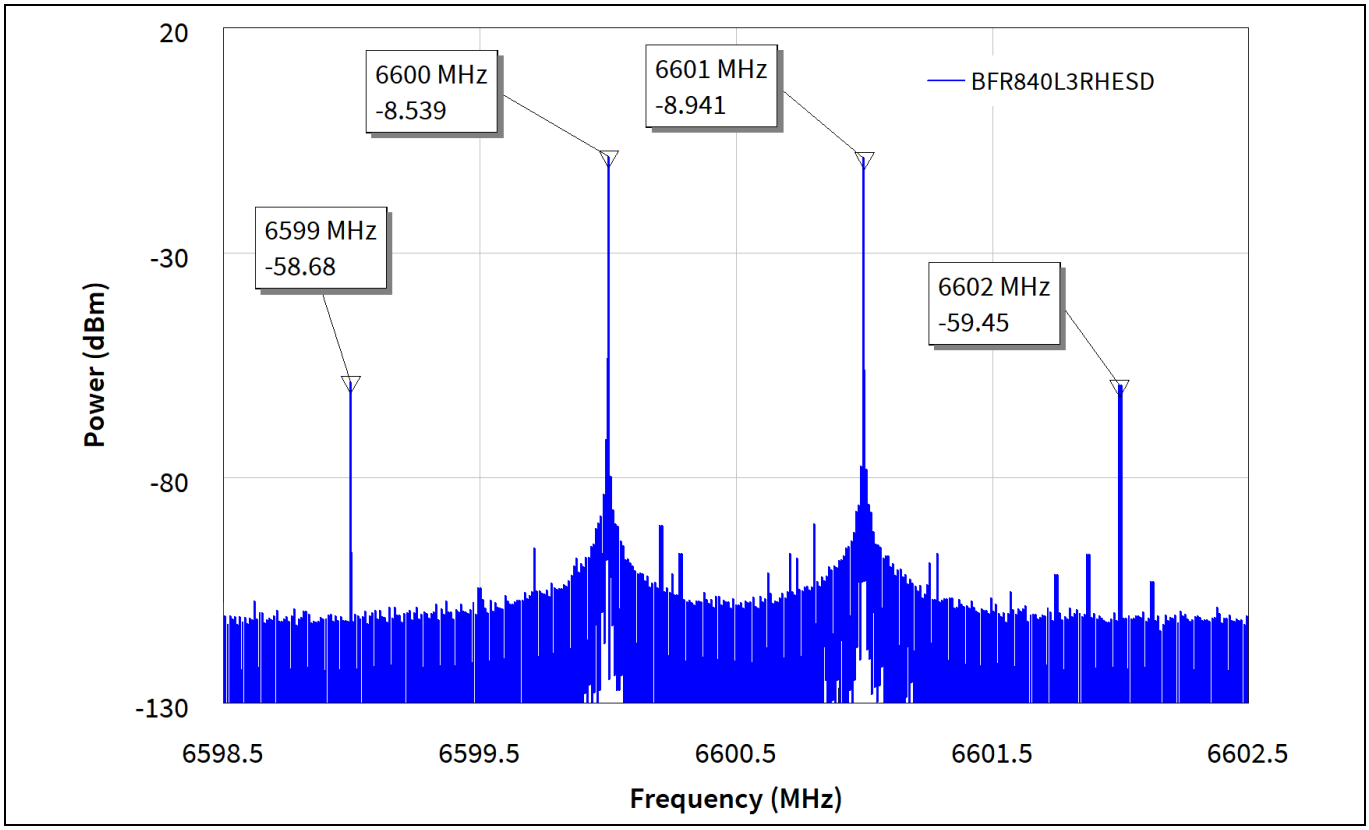

Figure 17 Output IMD$_3$ measurement of the 6 to 7 GHz band WLAN LNA with BFR840L3RHESD

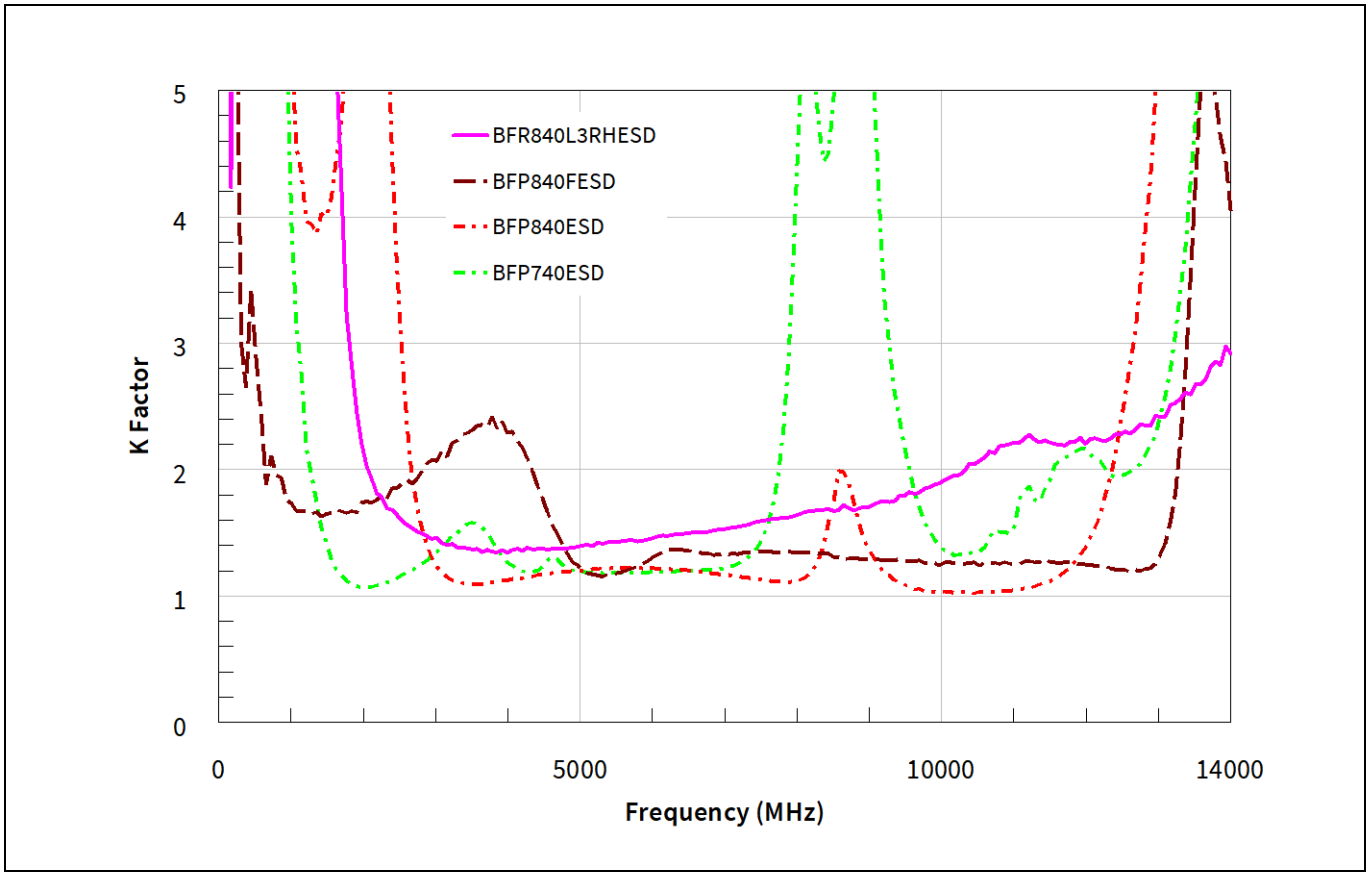

Figure 18 Stability K-factor plots of the 6 to 7 GHz band WLAN LNAs

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Revision history

Document version	Date of release	Description of changes
V1.0	25.10.2022	Application note release
V1.1	13.12.2022	Graphs and evaluation board pictures updated

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