Design guide for low-noise transistors in FM radio front ends

RF bipolar transistors

About this document

Scope and purpose

This application note provides application circuit design examples of Infineon's low-noise bipolar silicon (Si) and silicon germanium: carbon (SiGe:C) transistors for FM radio applications. In this document, the transistor-based low noise amplifier (LNA) schematics, PCB layouts and measurement results are presented. This document is relevant to the following low-noise transistors:

- BFR340F FM antenna LNA for 76 to 108MHz
- BFR460L3 FM antenna LNA for 76 to 108MHz
- BFP460 FM antenna LNA for 76 to 108MHz
- BFP540ESD FM antenna LNA for 76 to 108MHz
- BGB707L7ESD FM antenna LNA for 76 to 108MHz

Intended audience

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

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1 Introduction

1.1 FM radio front end

News and music available over the air are part of our daily life. Over the past 60 years, FM radio has been popular, and widely used in society. The optimum antenna length for FM radio is 75 centimeters. This length cannot be integrated into mobile devices, but shorter antennas cause signal loss and poor receiver performance. This application note shows Infineon FM radio LNAs, which can be used for active matching for FM reception with small antennas in all kinds of devices such as PDAs, portable FM radio, and shark-fin antennas, etc. to enhance the receiver sensitivity.

A general topology for the FM radio front end is as shown in Figure 1. Variations of the given application schematic are possible based on the complete system design and concept. These may include systems with an external antenna only, an internal embedded antenna only, or both antennas co-existing. In all cases, an ESD protection circuit is needed at the antenna to protect the receiver system from ESD strikes, as the antenna is susceptible to ESD events. More details and Infineon solutions for ESD protection can be found here.

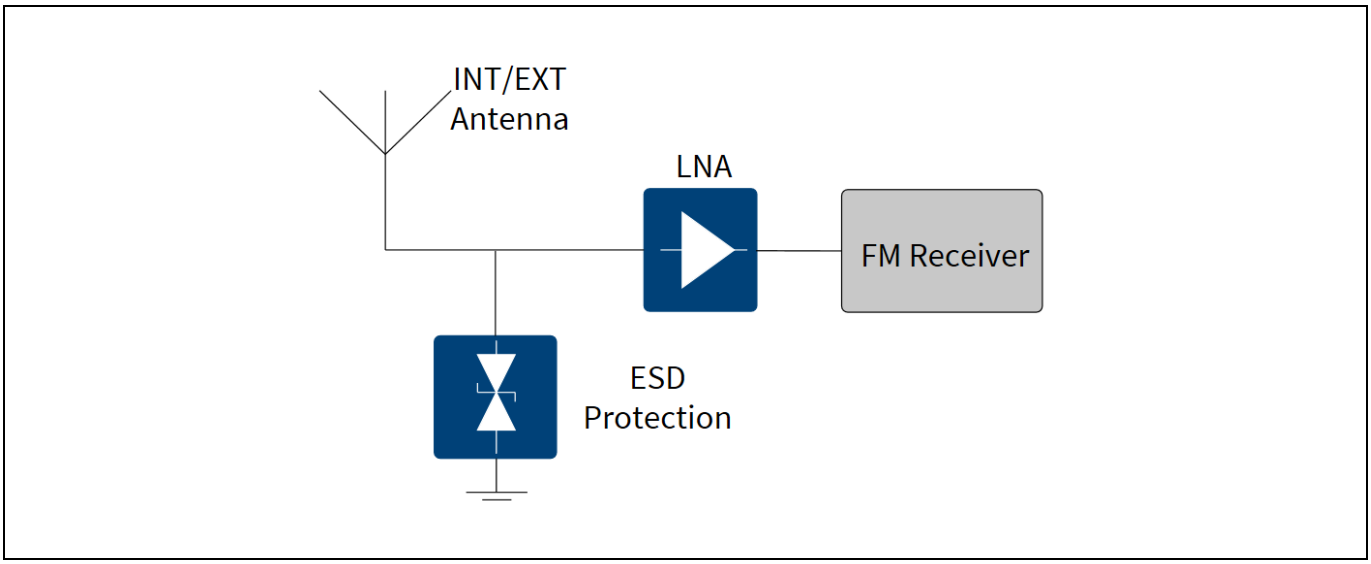


Figure 1 Block diagram example of a FM radio front end

1.2 Infineon's RF transistor family

Infineon Technologies provides high-performance radio frequency (RF) transistors targeting FM radio 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 third-, fourth- and fifth-generation transistors are based on bipolar Si technologies, and the seventh-generation is based on robust ultra low-noise SiGe:C technologies. Their optimized inner transistor cell structure leads to best-in-class power gains and NFs at worldwide FM band (76 to 108 MHz). The transistors maximize the design flexibility to customer requirements.

2 FM antenna LNAs matched to high impedance at the input

In systems with internal antennas, due to the very small size, the antenna impedance is very high and so the LNA has to be matched to this high impedance. The LNAs described in this section are designed to have high impedance at the input, which can be easily matched to the desired antenna, and the output of the LNAs is designed to match to a 50 Ω system.

2.1 Performance overview

The following table shows the performance of the FM antenna LNAs matched to high impedance at the input with TSFP-3, TSLP-3-1 and SOT343 packaged transistors.

Table 1 Summary of measurement results for FM antenna LNAs matched to high impedance at the input[1)]

Parameter	Symbol	Value			Unit	Notes
Device		BFR340F	BFR460L3	BFP540ESD		
Bias voltage	V_{CC}	1.8	1.8	1.8	V	
Bias current	I_{CC}	3.3	3.5	2.4	mA	
Frequency	f	100	100	100	MHz	
Gain	G	15.9	14.6	11.9	dB	
NF	NF	1.69	1.04	1.20	dB	
Input return loss	RL_{in}	1.0	0.9	0.8	dB	
Output return loss	RL_{out}	26.6	16.0	16.2	dB	
Reverse isolation	ISO_{rev}	41.4	40.0	45.6	dB	
Output 1 dB compression point	OP_{1dB}	-13.7	-15.5	-18.6	dBm	
Output third-order intercept point	OIP_3	1.5	-1.4	-4.3	dBm	P_{IN} = -40 dBm per tone f_1 = 100 MHz f_2 = 101 MHz
Stability	K	>1	>1	>1		Measured from 10 MHz to 10 GHz

Note: 1) All measurements done in a 50 Ω system.

2.2 Schematic

The following figure shows the schematic of the FM antenna LNAs matched to high impedance at the input with TSFP-3, TSLP-3-1 and SOT343 packaged transistors. Emitter degeneration provides a negative feedback to achieve the transistor impedance matching and low-noise matching at the same time. Please refer to the detailed settings in Figure 3, Figure 4 and Figure 4 respectively. In the LNA circuit, resistors R1 and R3 stand for transistor voltage and current bias; meanwhile, they form a negative DC feedback mechanism to stabilize the transistor bias points in various conditions. Capacitor C3 serves as the RF bypass. Transistor input matching is achieved by C1. The output matching network is formed by C2, C4, L1, R2 and R4. Resistors R2 and R4 also have the function of improving the circuit stability.

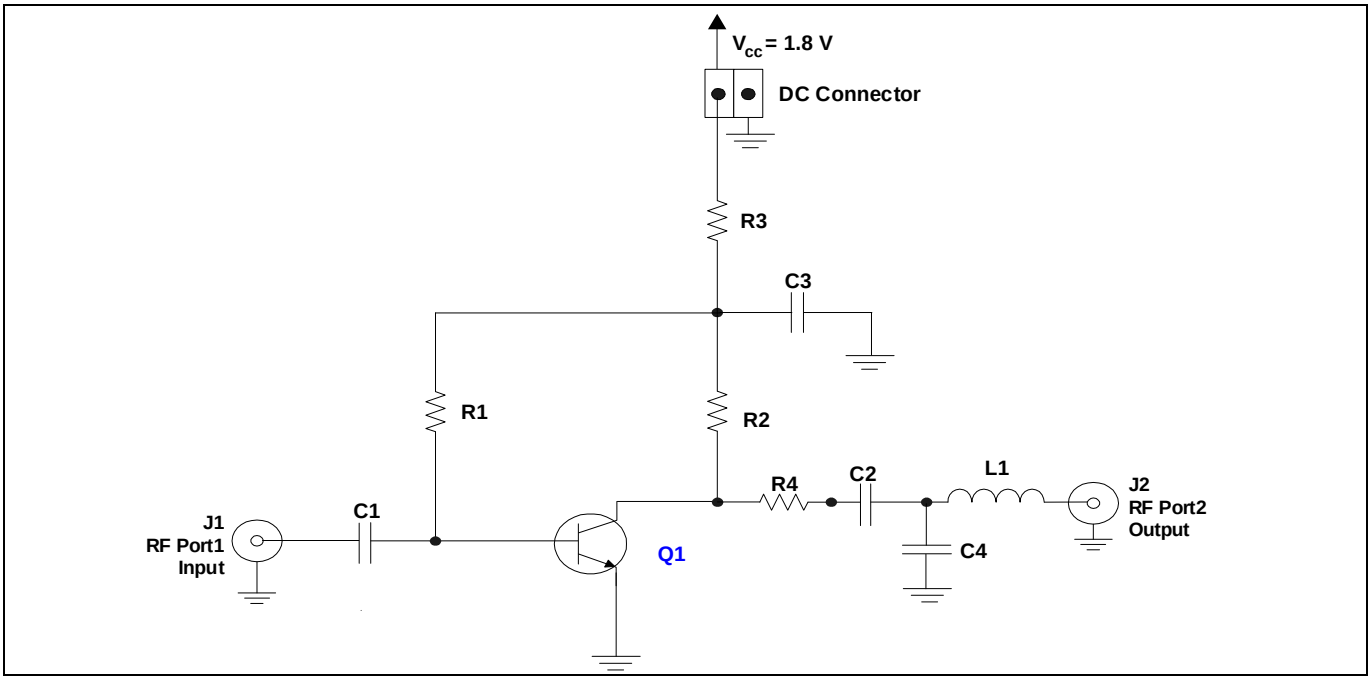


Figure 2 **Schematic of the FM antenna LNAs matched to high impedance at the input**

2.3 Bill of Materials (BOM)

Table 2 **BOM of the FM antenna LNAs matched to high impedance at the input**

Symbol	Value (component package)			Manufacturer	Notes
Q1	BFR340F (TSFP-3)	BFR460L3 (TSLP-3-1)	BFP540ESD (SOT343)	Infineon	Si bipolar transistor
C1	330 pF	330 pF	330 pF	Various	DC blocking
C2	330 pF	330 pF	330 pF	Various	DC blocking
C3	47 nF	47 nF	47 nF	Various	RF decoupling
C4	15 pF	n.c.[1)]	n.c.	Various	Output matching
R1	33 kΩ	33 kΩ	39 kΩ	Various	DC biasing for transistor base
R2	100 Ω	56 Ω	56 Ω	Various	Biasing, output matching and stability improvement
R3	10 Ω	56 Ω	47 Ω	Various	DC bias and DC negative feedback
R4	10 Ω	10 Ω	10 Ω	Various	Output matching and high frequency stability improvement
L1	91 nH	n.c.	n.c.	Murata LQW	Output matching

Note: 1) Not connected (n.c.).
2) Passive components are in 0402 size.

2.4 Evaluation boards and PCB layout information

The evaluation boards for the FM antenna LNAs matched to high impedance at the input with TSFP-3, TSLP-3-1 and SOT343 packaged transistors:

- PCB material: FR4
- PCB marking:
  - BFR340F BFRxxxF
  - BFR460L3 BFR3/4xxL3
  - BFP540ESD M111117

The photo of the evaluation boards for the FM antenna LNAs matched to high impedance at the input and the detailed description of the PCB stack are shown in the following figures.

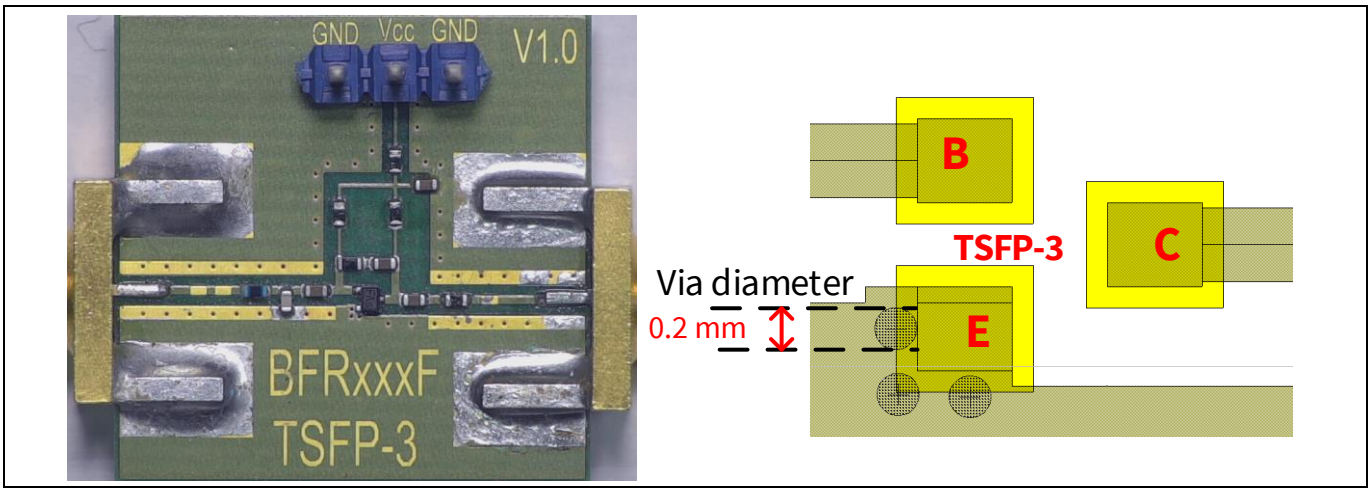


Figure 3 Photo of the evaluation board with PCB marking BFRxxxF (left) and emitter grounding details (right)

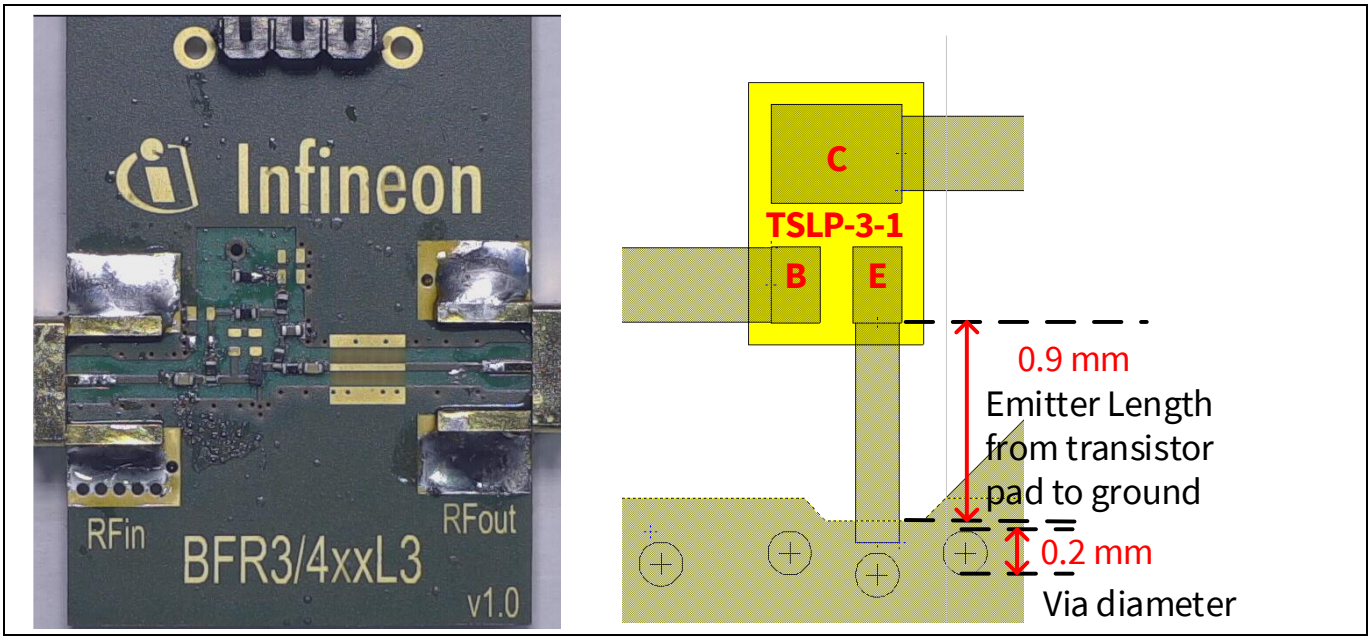


Figure 4 Photo of the evaluation board with PCB marking BFR3/4xxL3 (left) and emitter degeneration details (right)

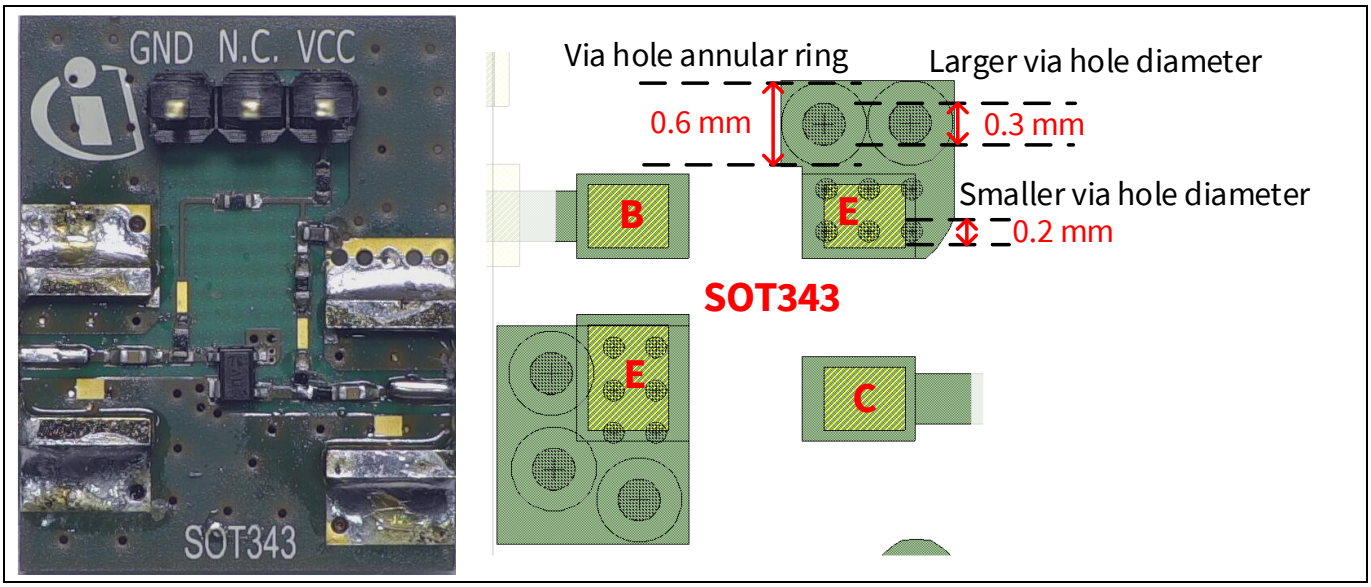


Figure 5 **Photo of the evaluation board with PCB marking M111117 (left) and emitter grounding details (right)**

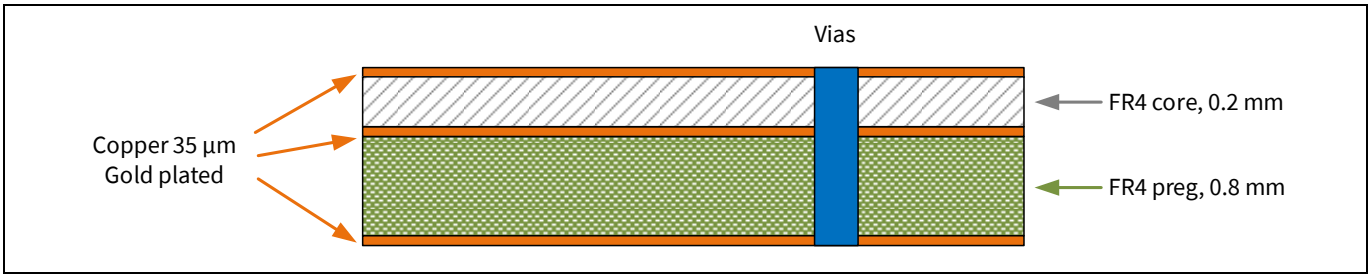


Figure 6 **PCB stack information for the evaluation boards with PCB marking BFRxxxF, BFR3/4xxL3 and M111117**

2.5 Measurement results of the FM antenna LNAs matched to high impedance at the input [1)]

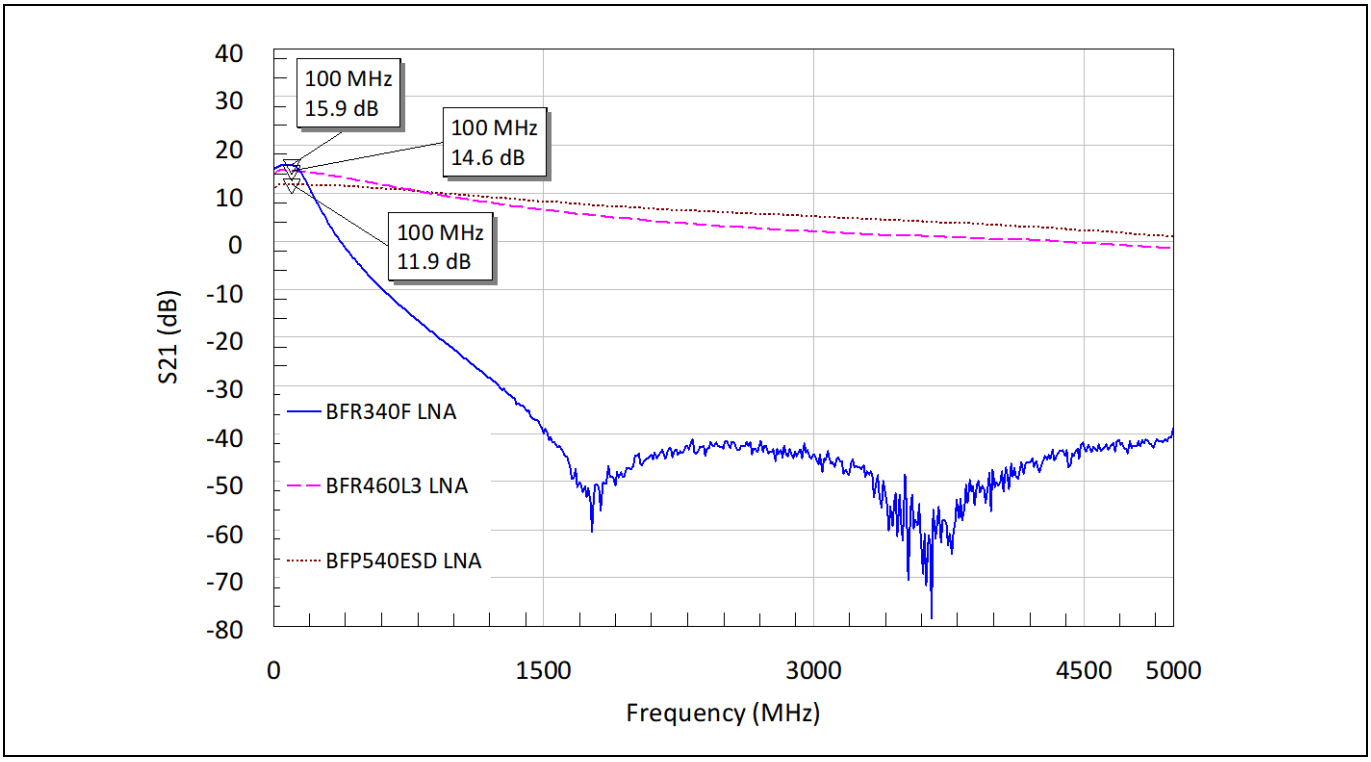


Figure 7 Small signal gain of the FM antenna LNAs matched to high impedance at the input

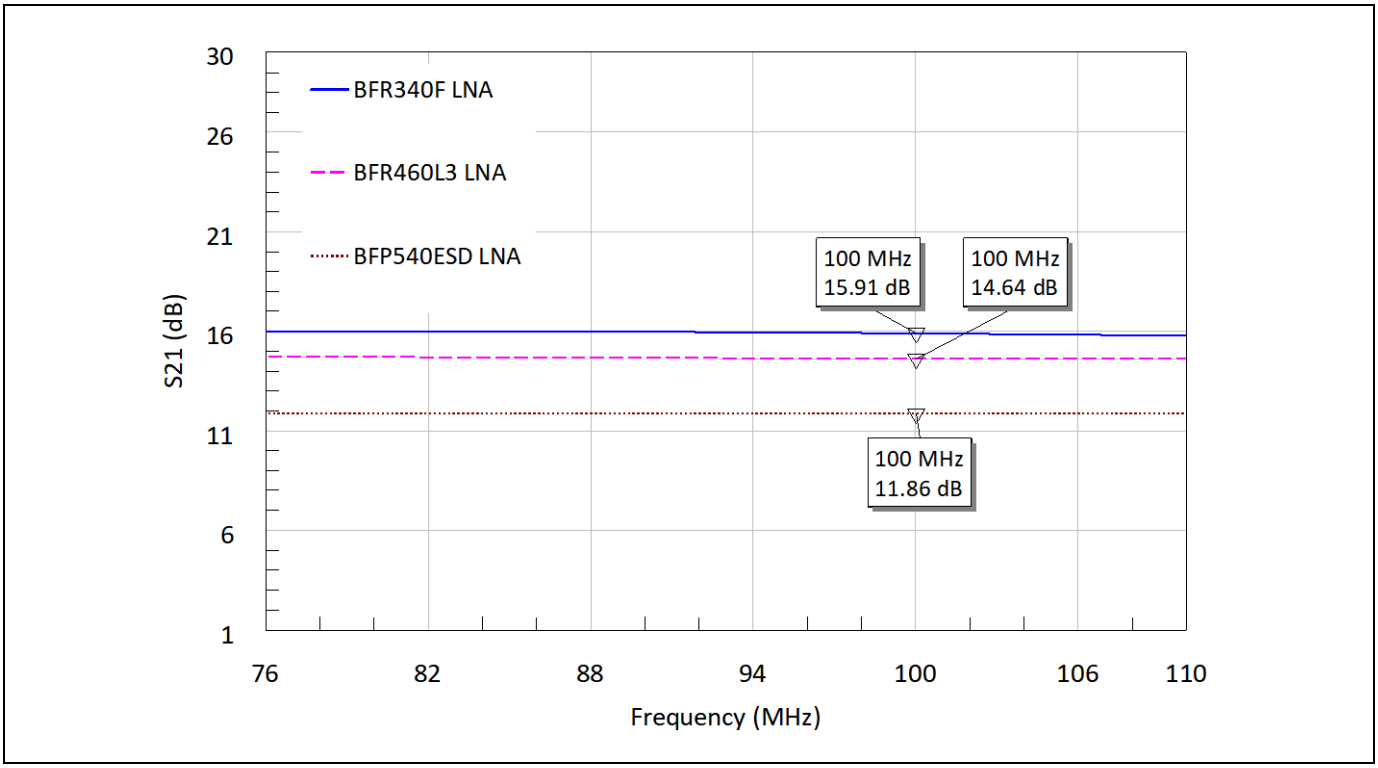


Figure 8 Small signal gain of the FM antenna LNAs matched to high impedance at the input (detail view)

Note: 1) The graphs are generated with the AWR electronic design automation (EDA) software Microwave Office®.

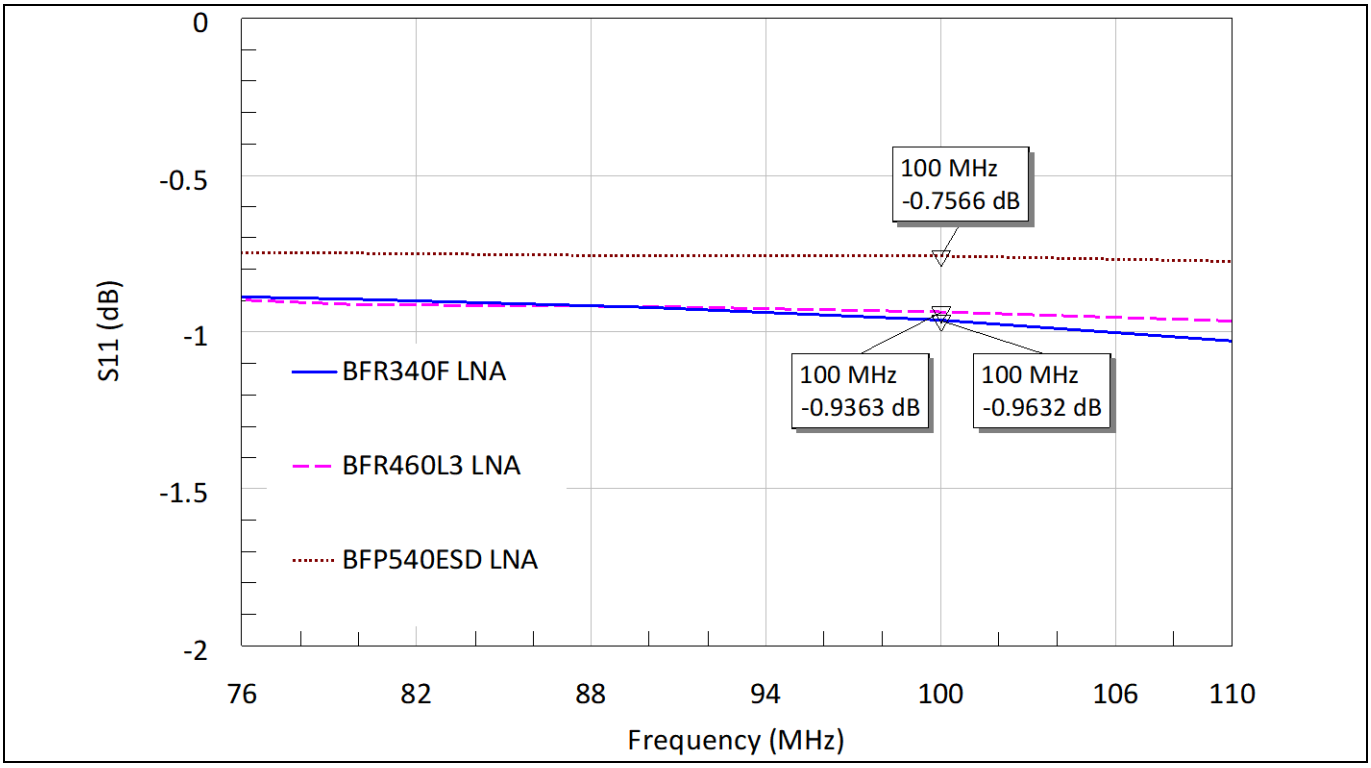


Figure 9 **Input return loss measurement of the FM antenna LNAs matched to high impedance at the input**

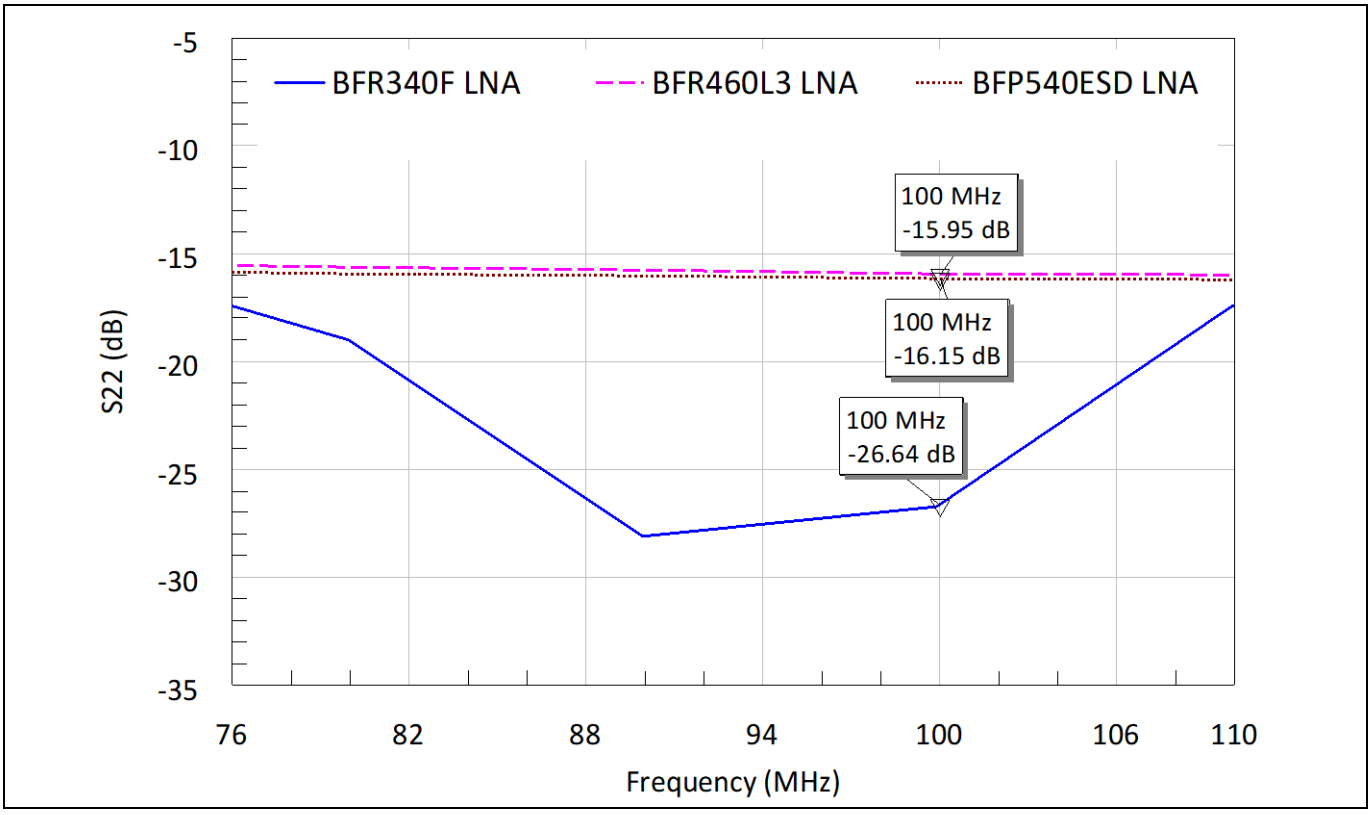


Figure 10 **Output return loss measurement of the FM antenna LNAs matched to high impedance at the input**

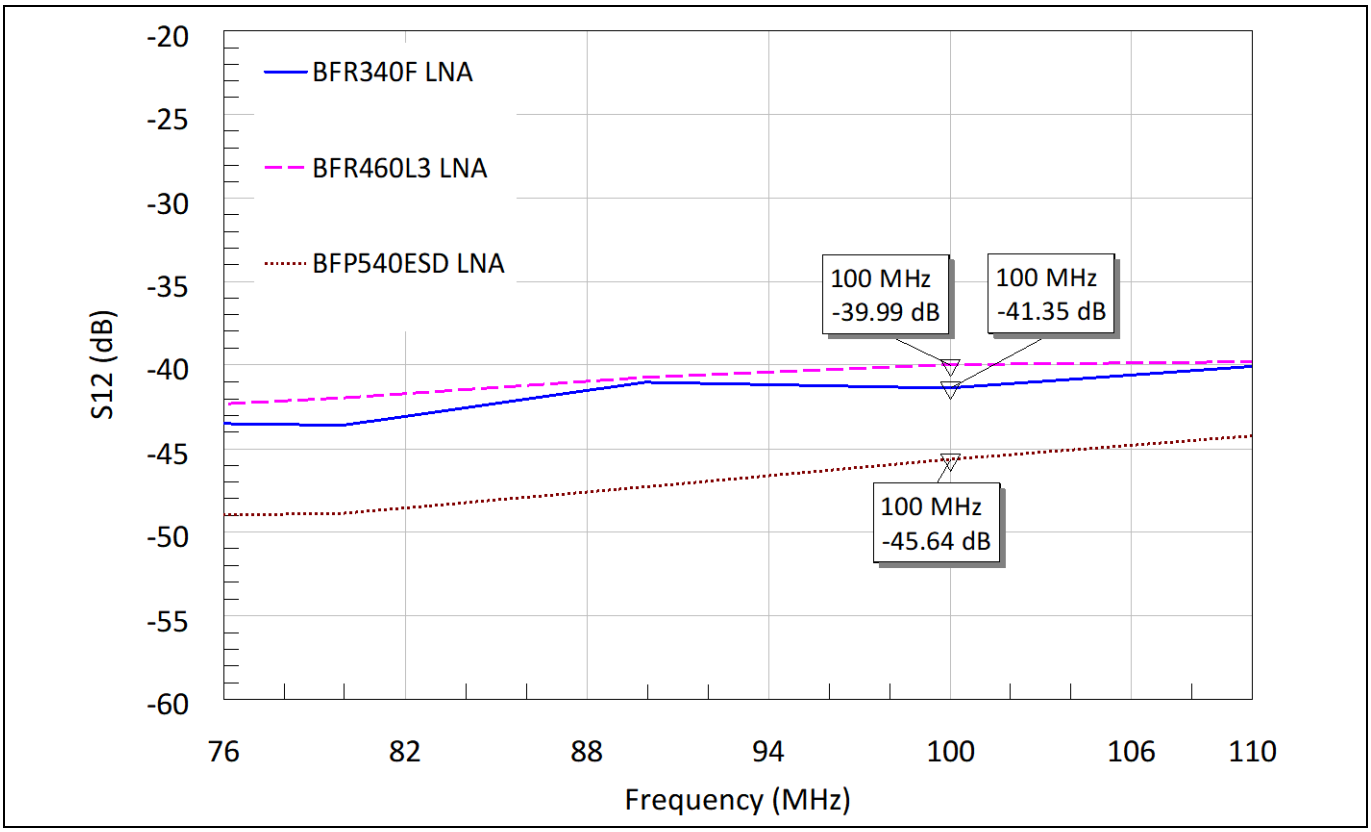


Figure 11 **Reverse isolation measurement of the FM antenna LNAs matched to high impedance at the input**

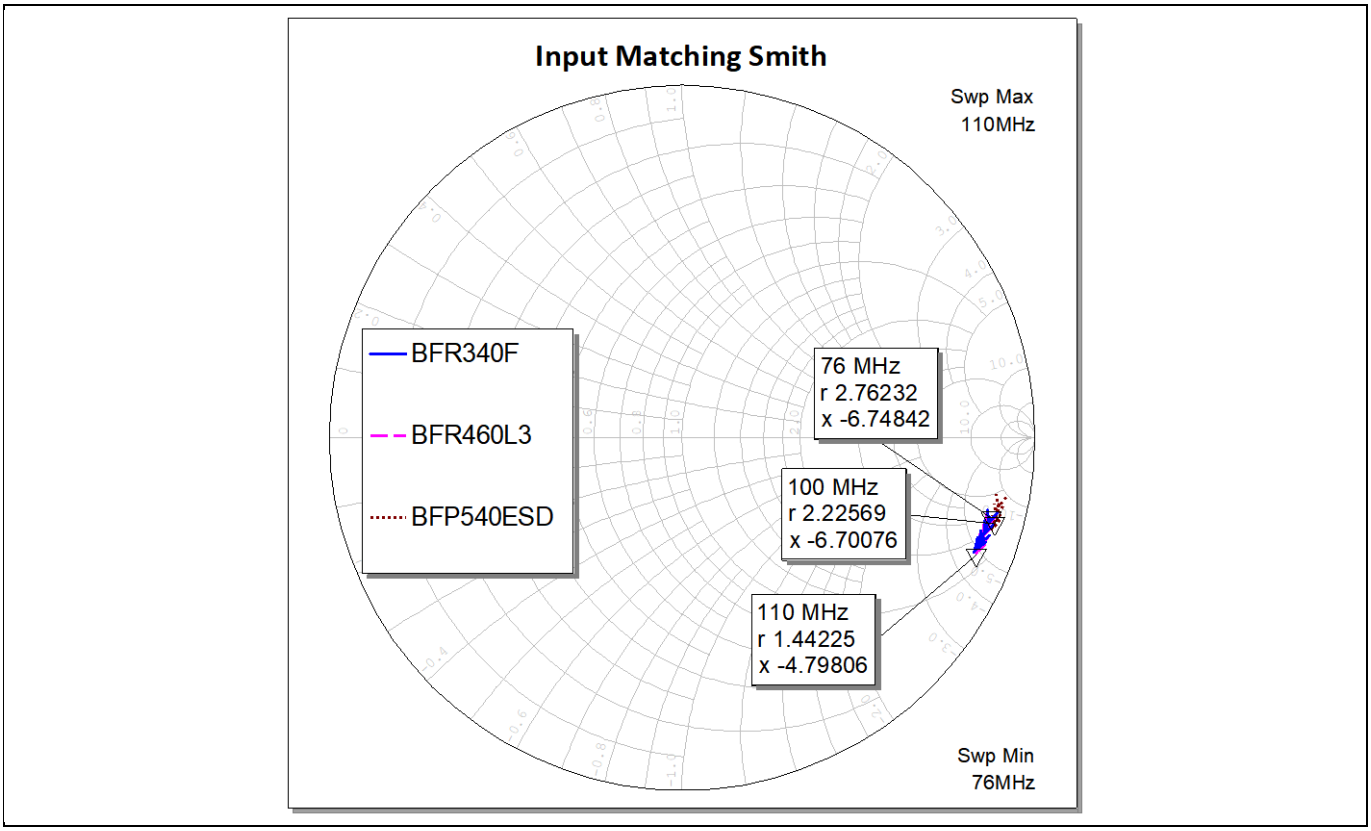


Figure 12 **Input matching of the FM antenna LNAs matched to high impedance at the input**

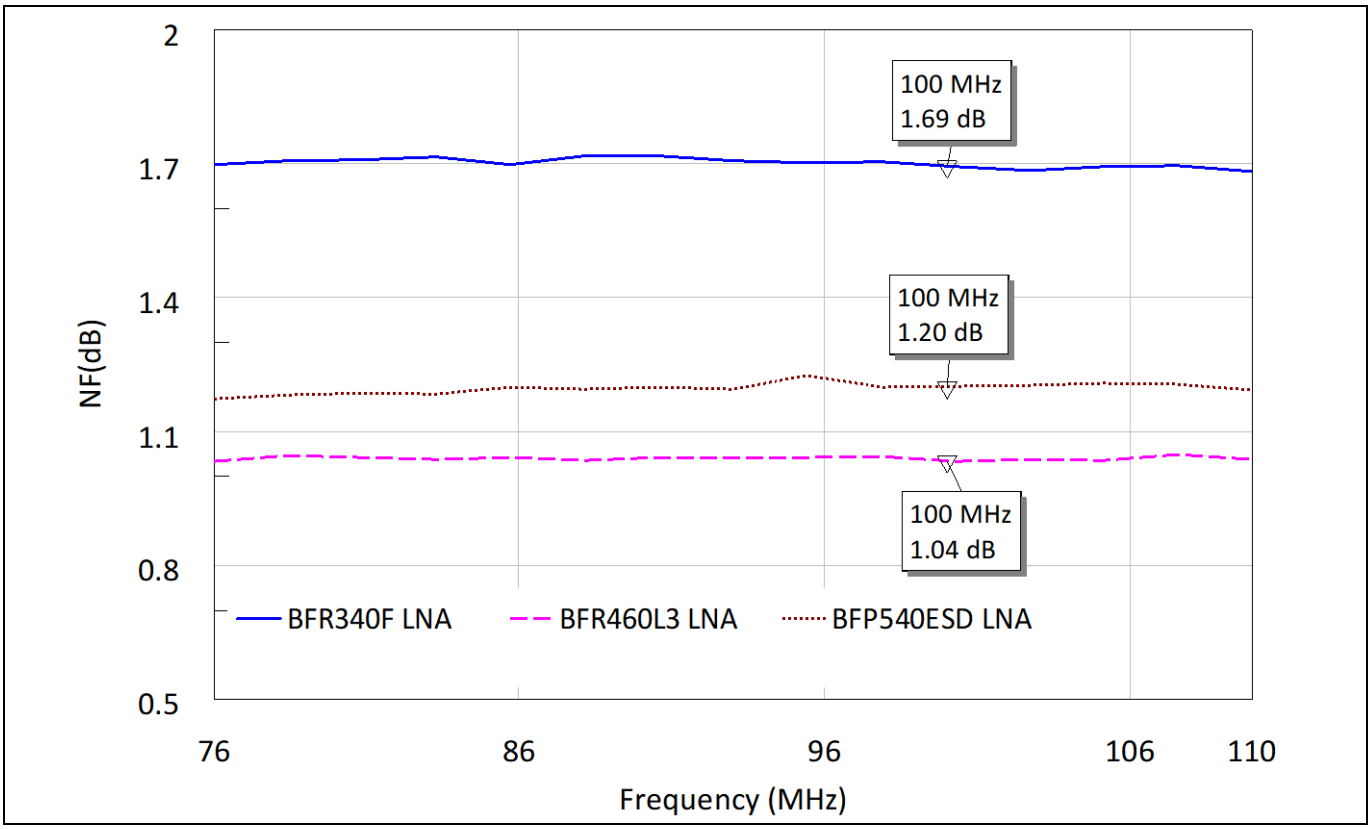


Figure 13 **NF measurement of the FM antenna LNAs matched to high impedance at the input**

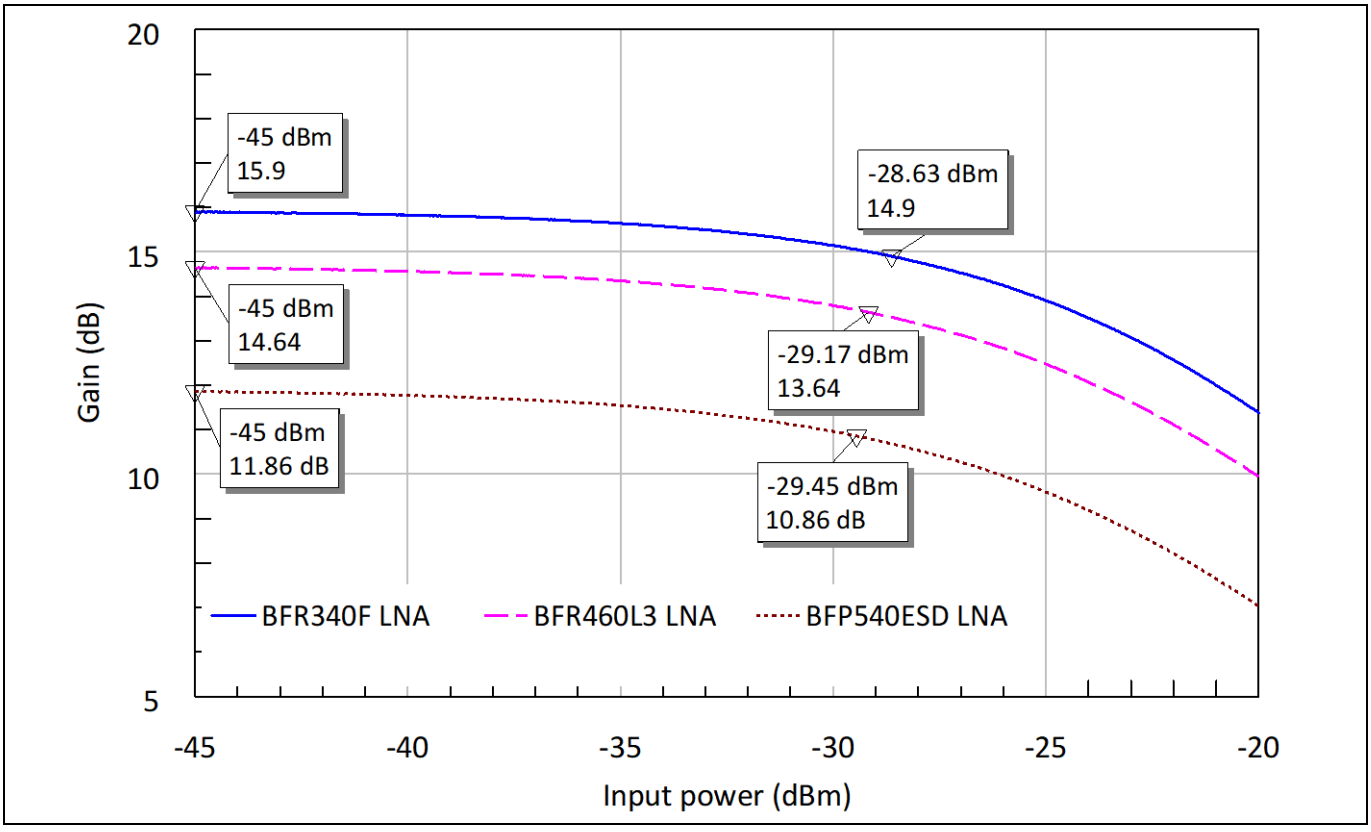


Figure 14 **Input 1 dB compression point measurement of the FM antenna LNAs matched to high impedance at the input**

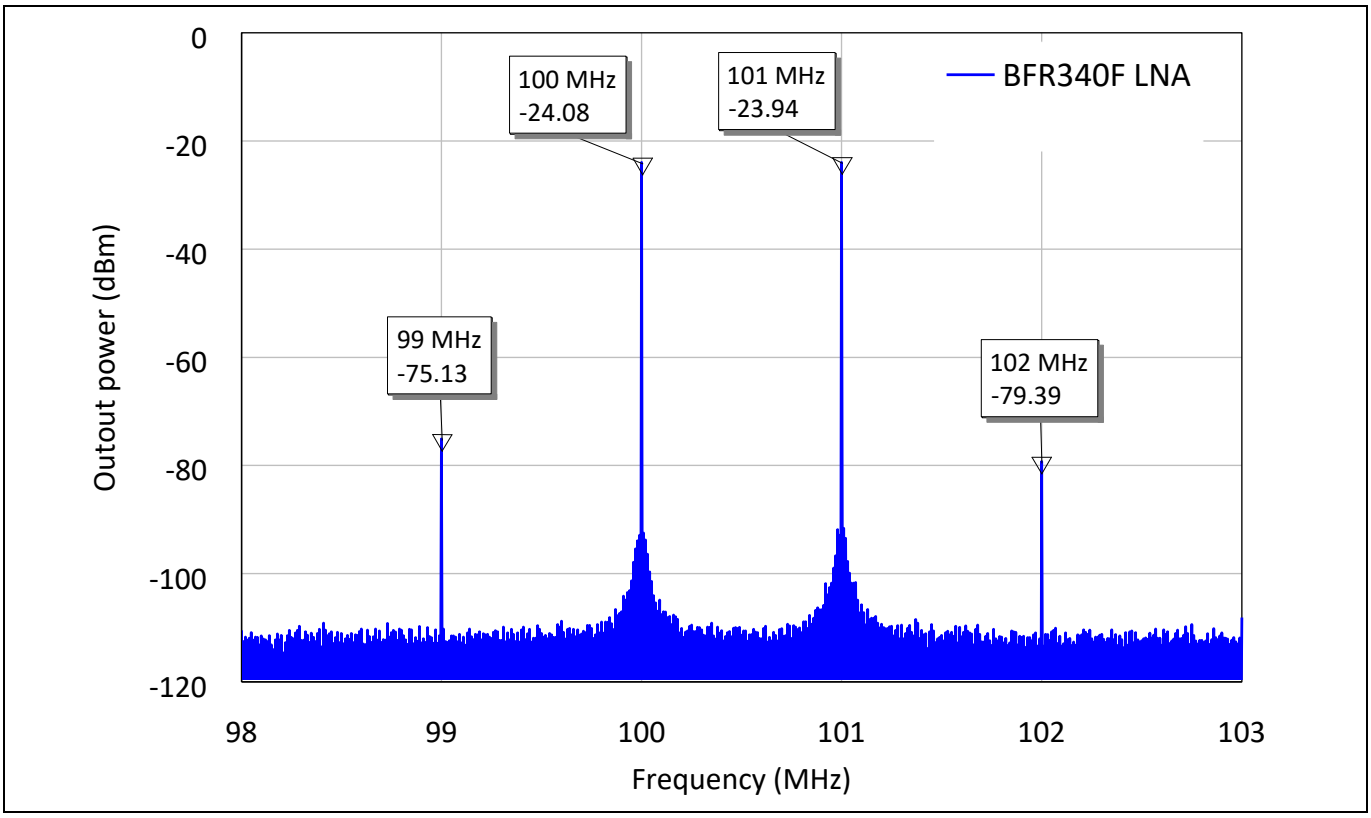


Figure 15 **Output third-order intermodulation distortion (IMD_3) measurement of the BFR340F FM antenna LNA**

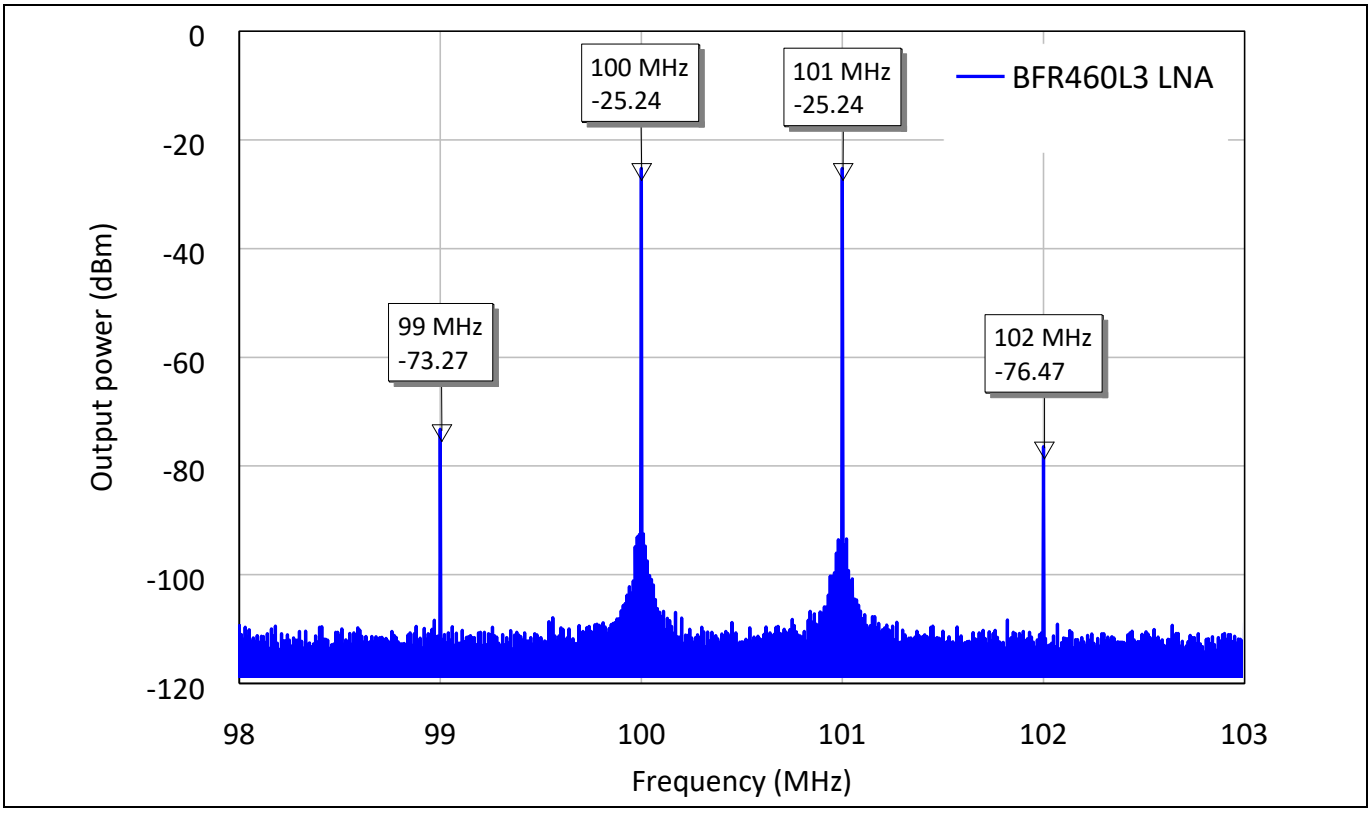


Figure 16 **Output IMD_3 measurement of the BFR460L3 FM antenna LNA**

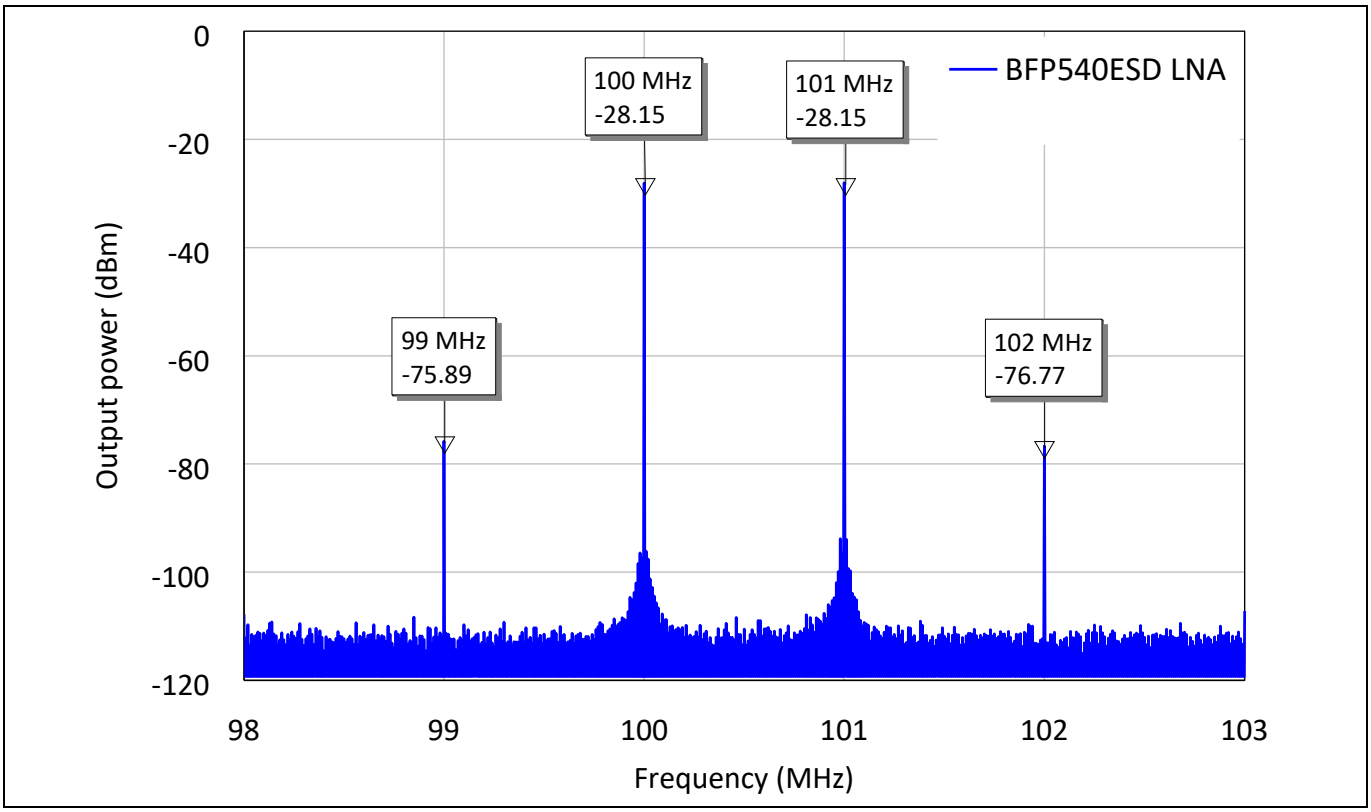


Figure 17 Output IMD$_3$ measurement of the BFP540ESD FM antenna LNA

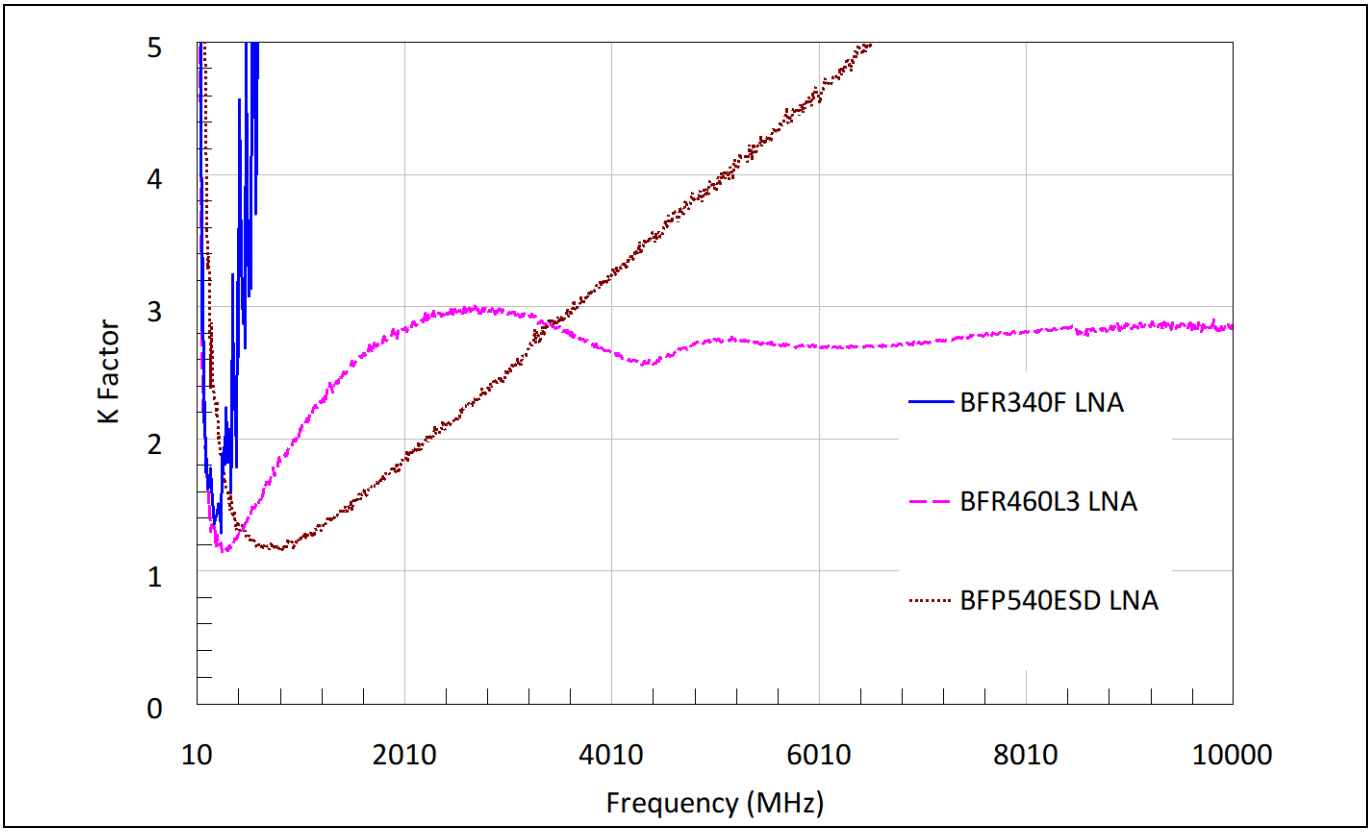


Figure 18 Stability K-factor plots of the FM antenna LNAs matched to high impedance at the input

3 FM antenna LNAs matched to 50 Ω at the input

In systems with external antennas, the antenna size is a bit more relaxed and can be increased. Therefore, the antenna impedance is reduced to around 50 Ω. The LNAs described in this section are designed to match to the 50 Ω at the input, which can be easily matched to the desired antenna, and the output of the LNAs is designed to match to a 50 Ω system.

3.1 Performance overview

The following table shows the performance of the FM antenna LNAs matched to 50 Ω at the input with SOT343 and TSFP-3 packaged transistors.

Table 3 Summary of measurement results for the FM antenna LNAs matched to 50 Ω at the input

Parameter	Symbol	Value			Unit	Notes
Device		BFP460	BFP460	BFR340F		
Bias voltage	V_{CC}	1.8	2.6	1.8	V	
Bias current	I_{CC}	3.1	4.6	3.0	mA	
Frequency	f	100	100	100	MHz	
Gain	G	15.2	18.7	16.2	dB	
NF	NF	1.41	1.24	1.86	dB	
Input return loss	RL_{in}	10.0	11.8	12.4	dB	
Output return loss	RL_{out}	12.8	13.1	16.9	dB	
Reverse isolation	ISO_{rev}	28.3	30.0	26.7	dB	
Output 1 dB compression point	OP_{1dB}	-13	-8.7	-11.3	dBm	
Output third-order intercept point	OIP_3	-0.8	2.4	0.5	dBm	P_{IN} = -40 dBm per tone f_1 = 100 MHz f_2 = 101 MHz
Stability	K	>1	>1	>1		Measured from 10 MHz to 10 GHz

3.2 Schematic

The following figure shows the schematic of the FM antenna LNAs matched to 50 Ω at the input with SOT343 and TSFP-4 packaged transistors. In the LNA circuit, resistors R1, R2 and R3 stand for transistor voltage and current bias; meanwhile, R1 and R3 form a negative DC feedback mechanism to stabilize the transistor bias point in various conditions. The resistor R4 and the capacitor C6 serve as the negative feedback to improve the input and output impedance matching. The capacitor C4 serves as the RF bypass. The transistor input matching is achieved by C1, C2 and L1. The output matching network is formed by C3, C5, L2 and R2. The resistor R2 also has the function of improving the circuit stability.

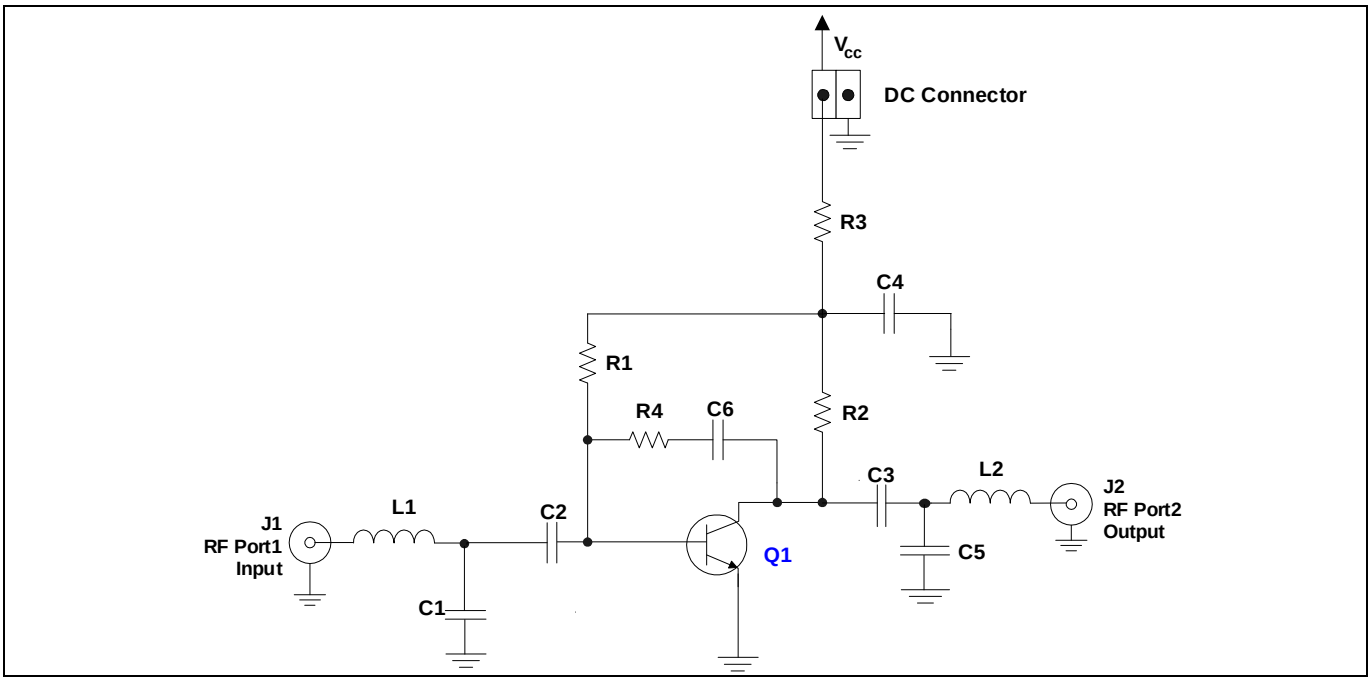


Figure 19 Schematic of the FM Antenna LNAs matched to 50 Ω at the input

3.3 BOM

Table 4 BOM of the FM antenna LNAs matched to 50 Ω at the input

Symbol	Value (component package)			Manufacturer	Notes
Q1	BFP460 1.8 V supply (SOT343)	BFP460 2.6 V supply (SOT343)	BFR340F (TSFP-3)	Infineon	Si bipolar transistor
C1	10 pF	12 pF	12 pF	Various	Input matching
C2	330 pF	330 pF	330 pF	Various	DC blocking
C3	330 pF	330 pF	330 pF	Various	DC blocking
C4	47 nF	47 nF	47 nF	Various	RF decoupling
C5	10 pF	12 pF	n.c.[1)]	Various	Output matching
C6	330 pF	330 pF	330 pF	Various	DC blocking
R1	33 kΩ	47 kΩ	39 kΩ	Various	DC biasing for transistor base
R2	56 Ω	68 Ω	100 Ω	Various	Biasing, output matching and stability improvement
R3	56 Ω	68 Ω	10 Ω	Various	DC bias and DC negative feedback
R4	1.5 kΩ	1.8 kΩ	3 kΩ	Various	Negative feedback
L1	100 nH	100 nH	100 nH	Murata LQW	Input matching
L2	42 nH	39 nH	n.c.	Murata LQW	Output matching

Note: 1) Not connected (n.c.).
2) Passive components are in 0402 size.

3.4 Evaluation boards and PCB layout information

The evaluation boards for the FM antenna LNAs matched to 50 Ω at the input with SOT343 and TSFP-3 packaged transistors:

- PCB material: FR4
- PCB marking:
  - BFP460 BFP460 V2.0
  - BFR340F BFRxxxF

The photo of the evaluation boards for the FM antenna LNAs matched to 50 Ω at the input with SOT343 and TSFP-3 packaged transistors and the detailed description of the PCB stack are shown in the following figures.

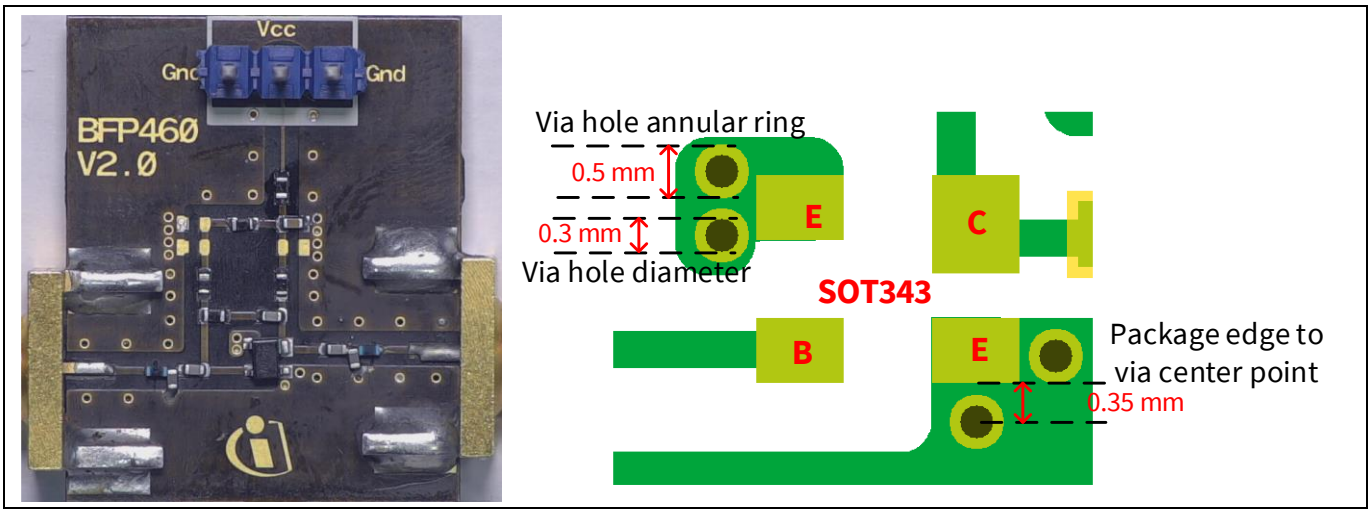


Figure 20 Photo of the evaluation board with PCB marking BFP460 V2.0 (left) and emitter grounding details (right)

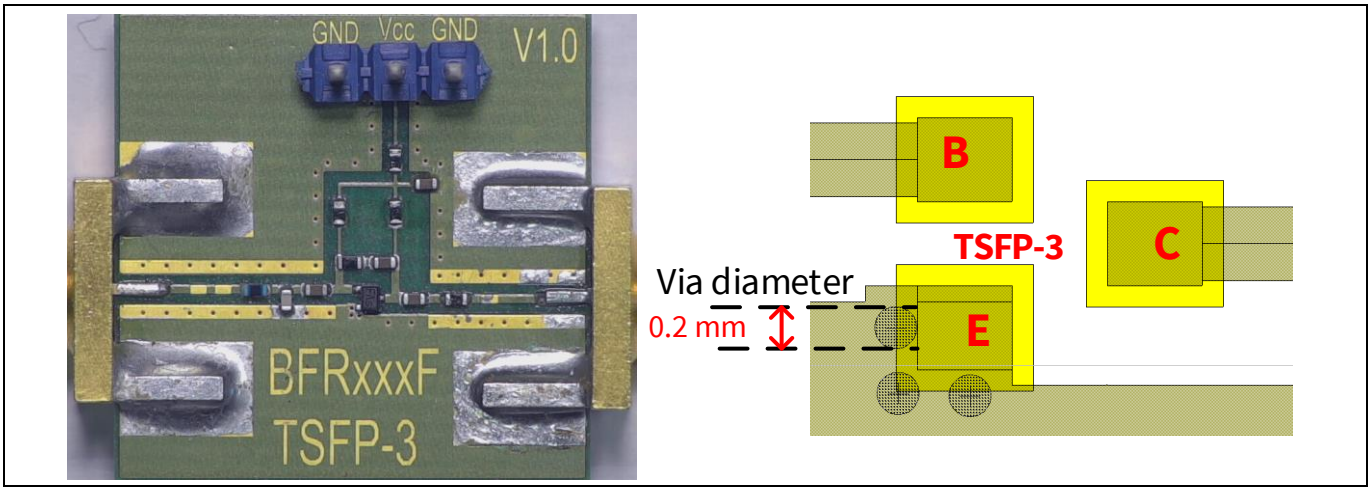


Figure 21 Photo of the evaluation board with PCB marking BFRxxxF (left) and emitter grounding details (right)

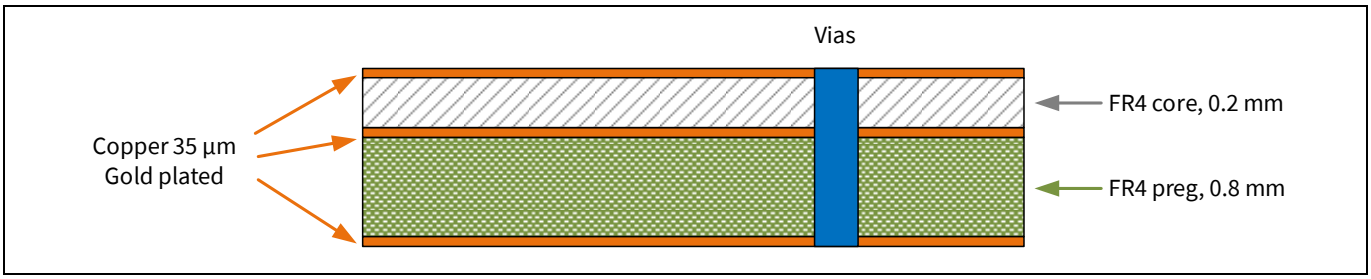


Figure 22 **PCB stack information for the evaluation boards with PCB marking BFP460 V2.0 and BFRxxxF**

3.5 Measurement results of the FM antenna LNAs matched to 50 Ω at the input[1)]

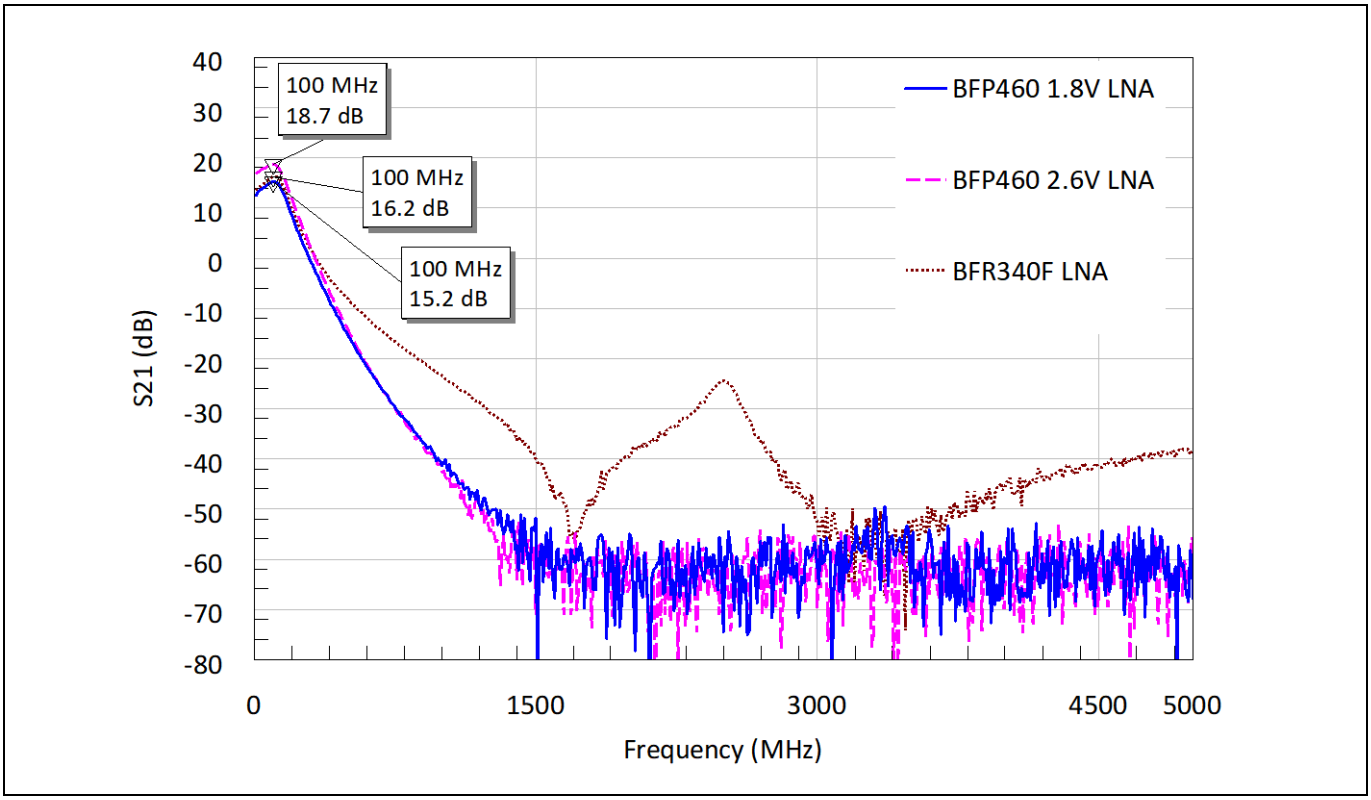


Figure 23 **Small signal gain of the FM antenna LNAs matched to 50 Ω at the input**

Note: *1) The graphs are generated with the AWR EDA software Microwave Office®.*

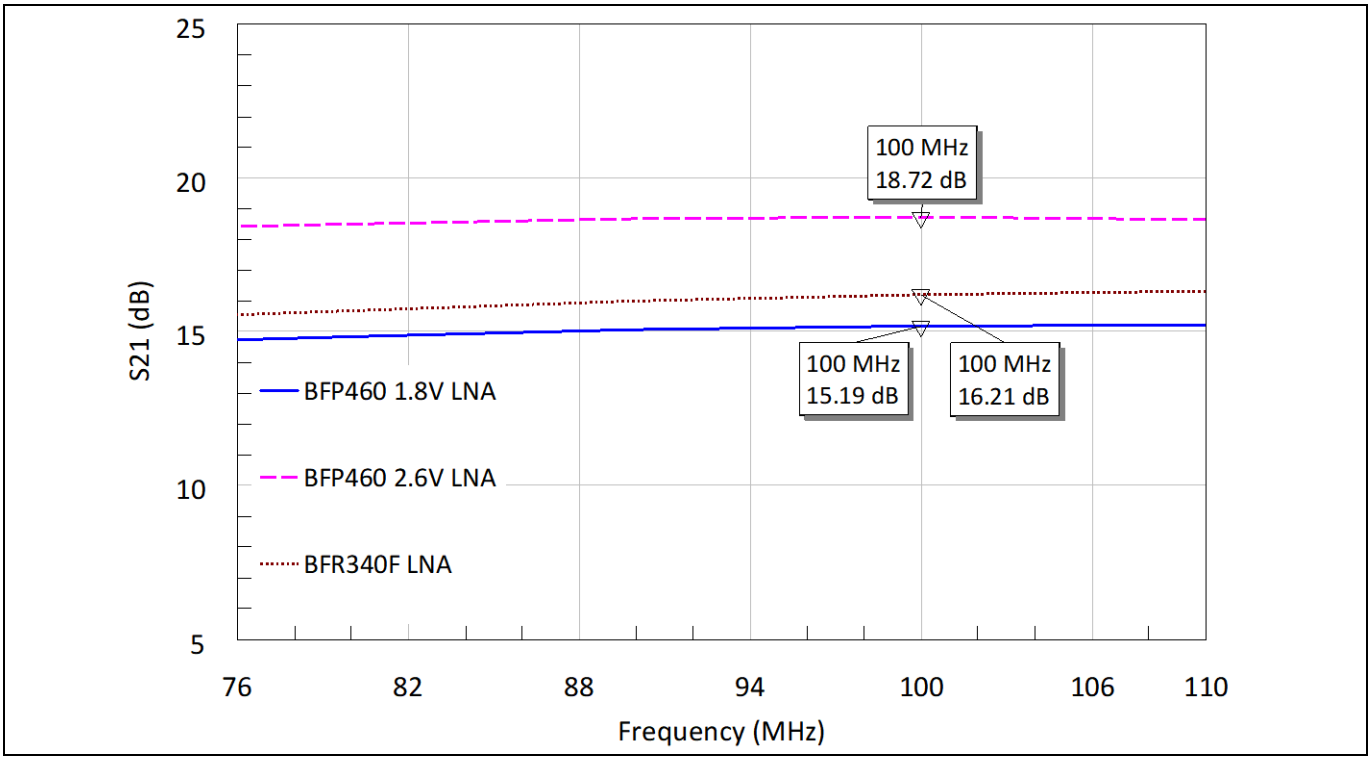


Figure 24 Small signal gain of the FM antenna LNAs matched to 50 Ω at the input (detail view)

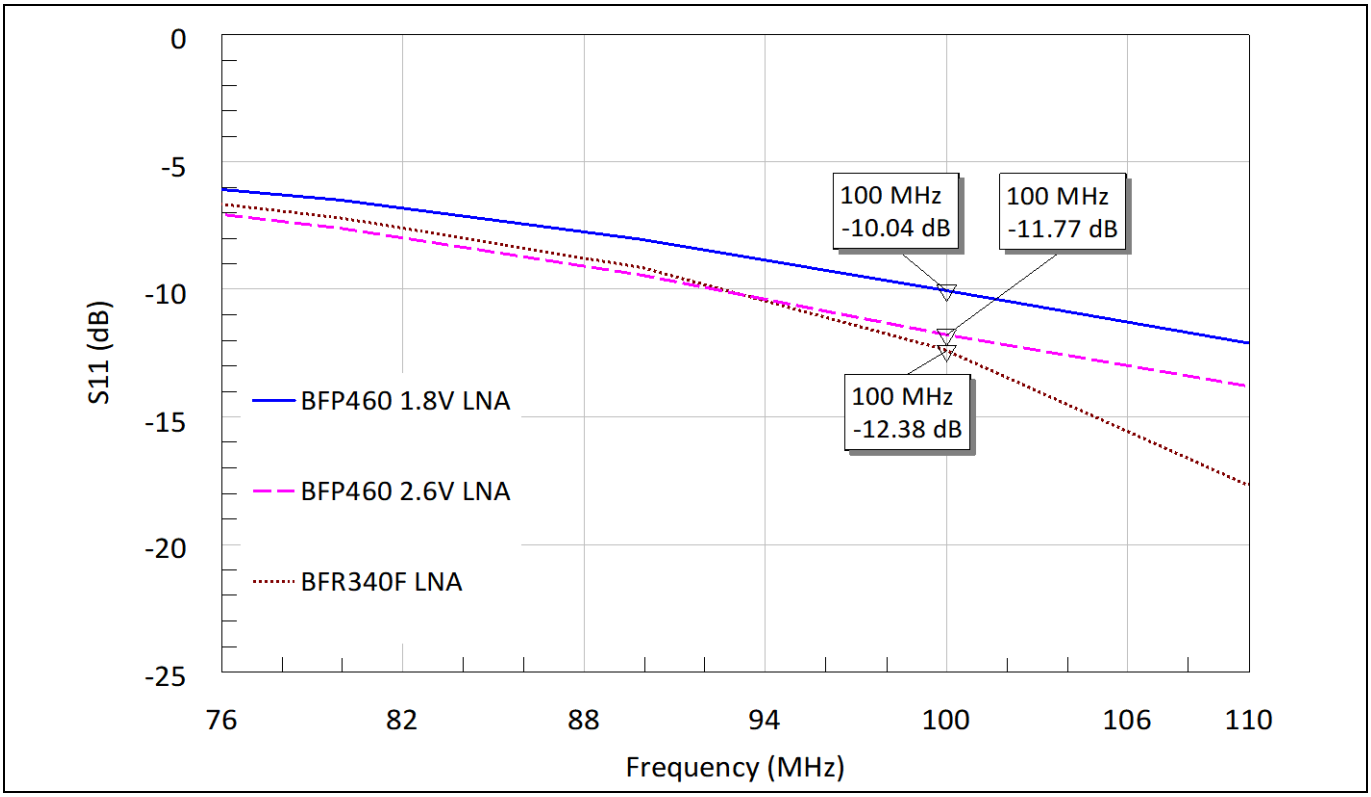


Figure 25 Input return loss measurement of the FM antenna LNAs matched to 50 Ω at the input

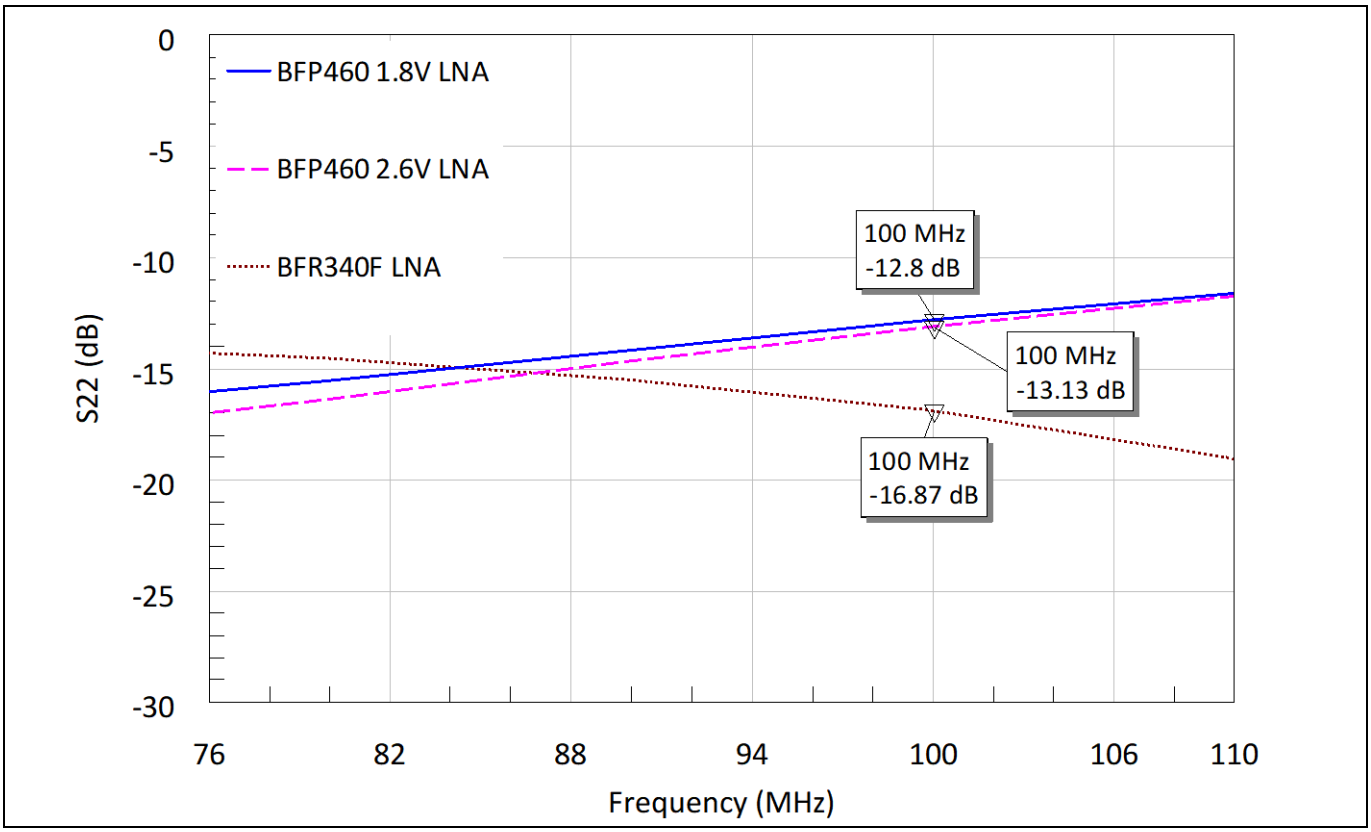


Figure 26 **Output return loss measurement of the FM antenna LNAs matched to 50 Ω at the input**

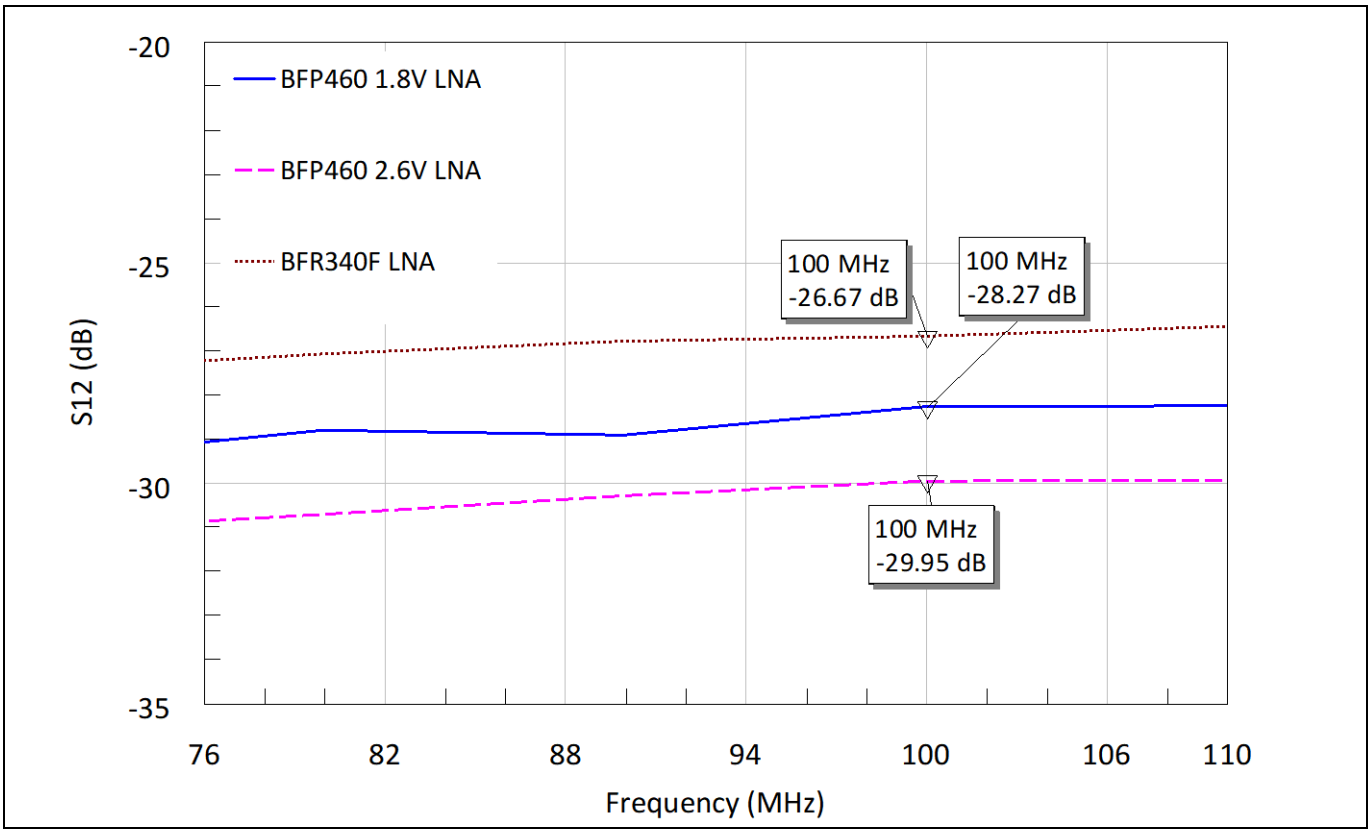


Figure 27 **Reverse isolation measurement of the FM antenna LNAs matched to 50 Ω at the input**

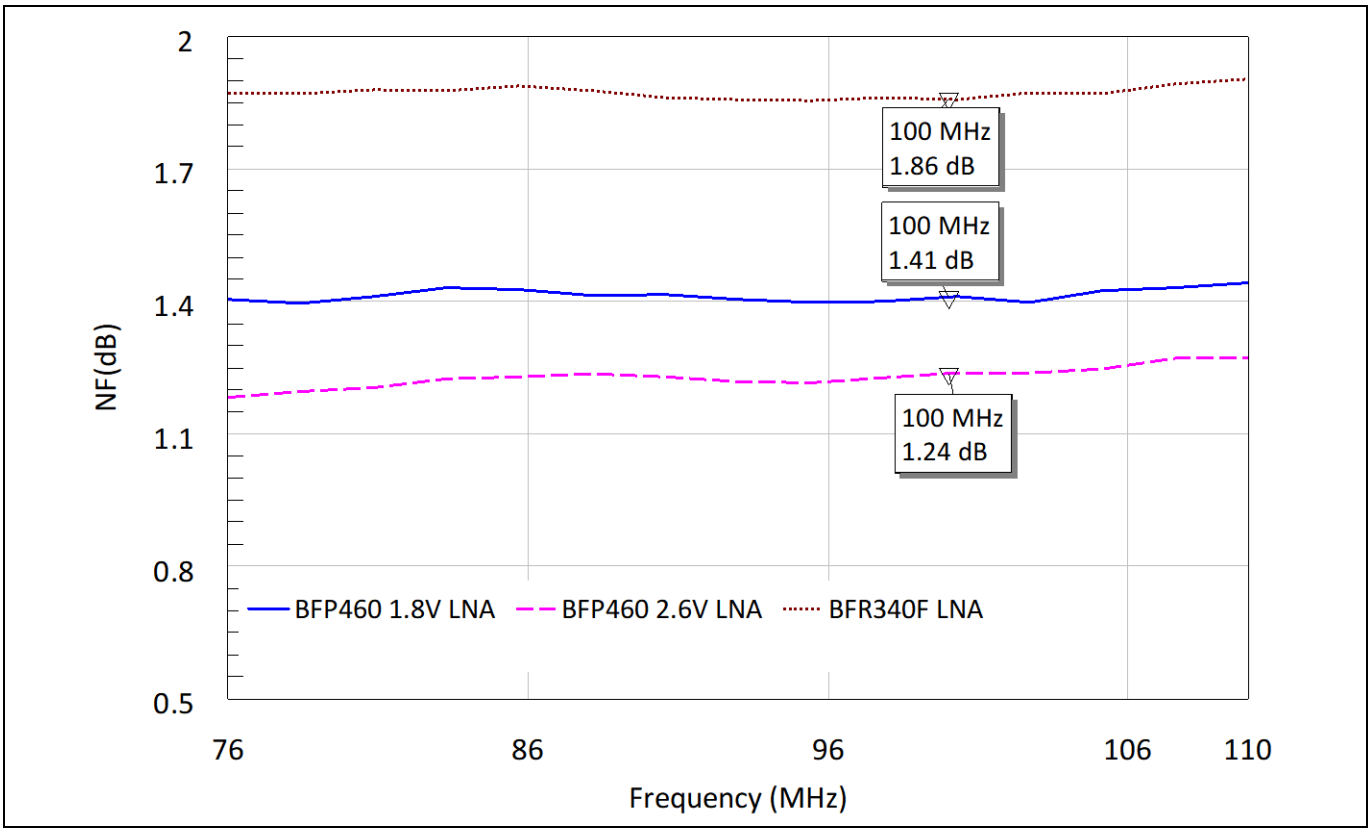


Figure 28 NF measurement of the FM antenna LNAs matched to 50 Ω at the input

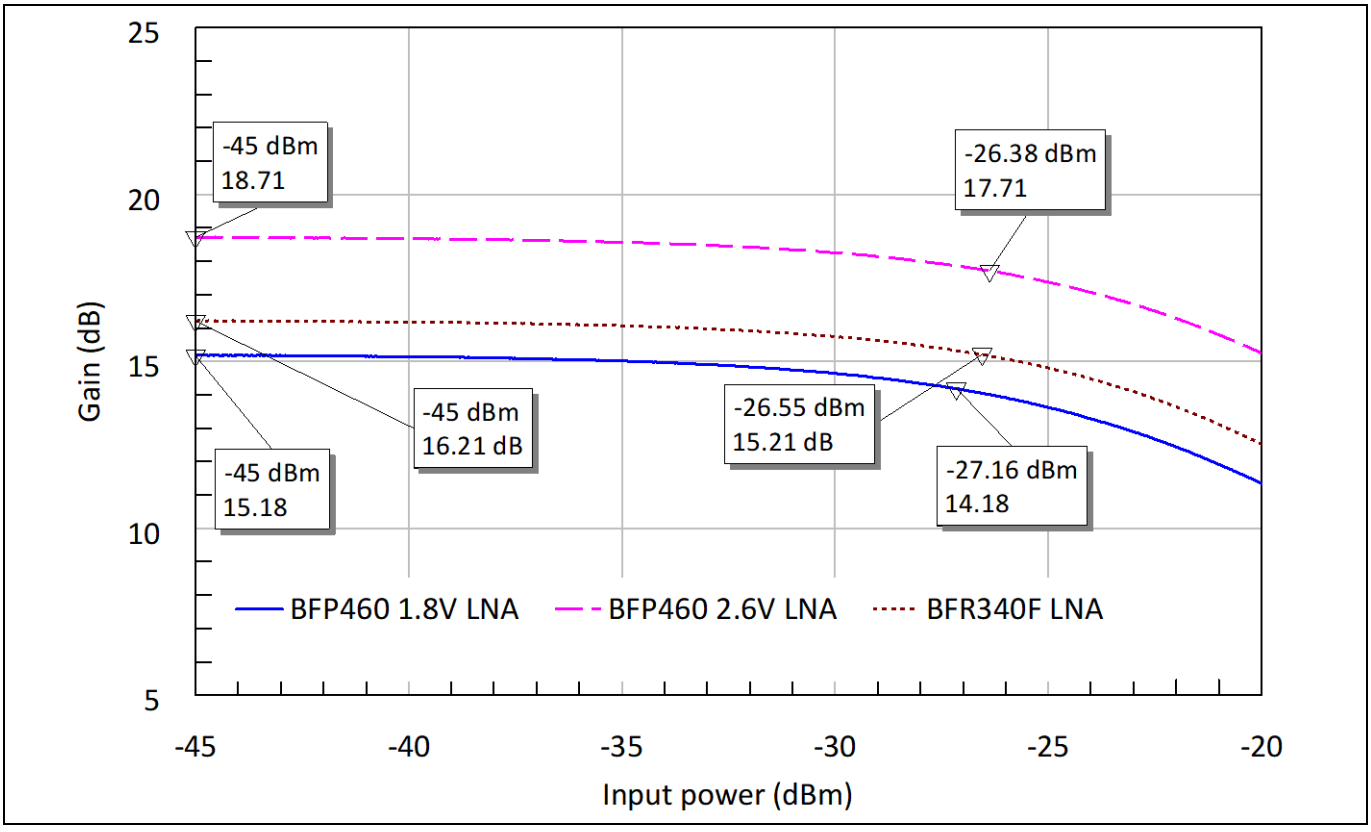


Figure 29 Input 1 dB compression point measurement of the FM antenna LNAs matched to 50 Ω at the input

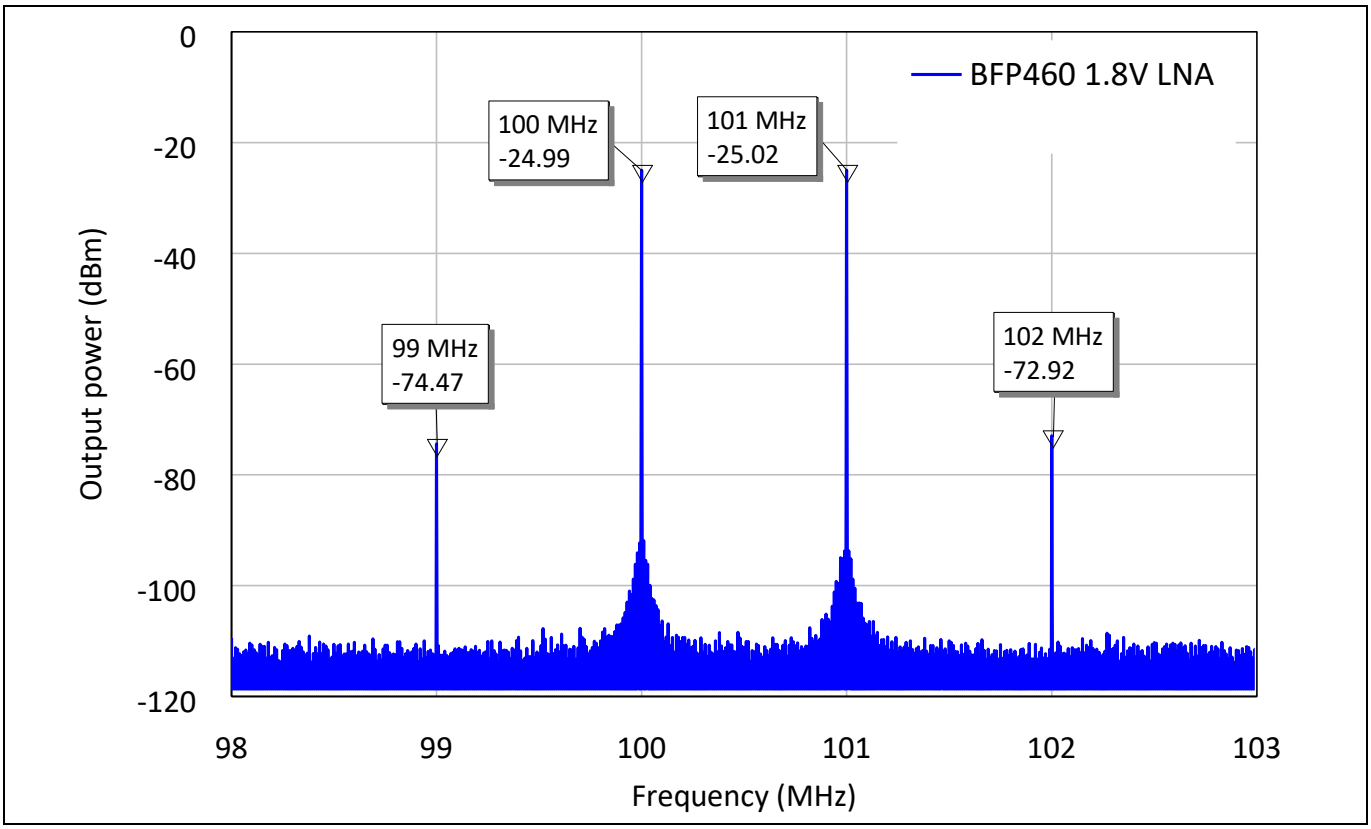


Figure 30 Output IMD$_3$ measurement of the BFP460 1.8 V FM antenna LNA

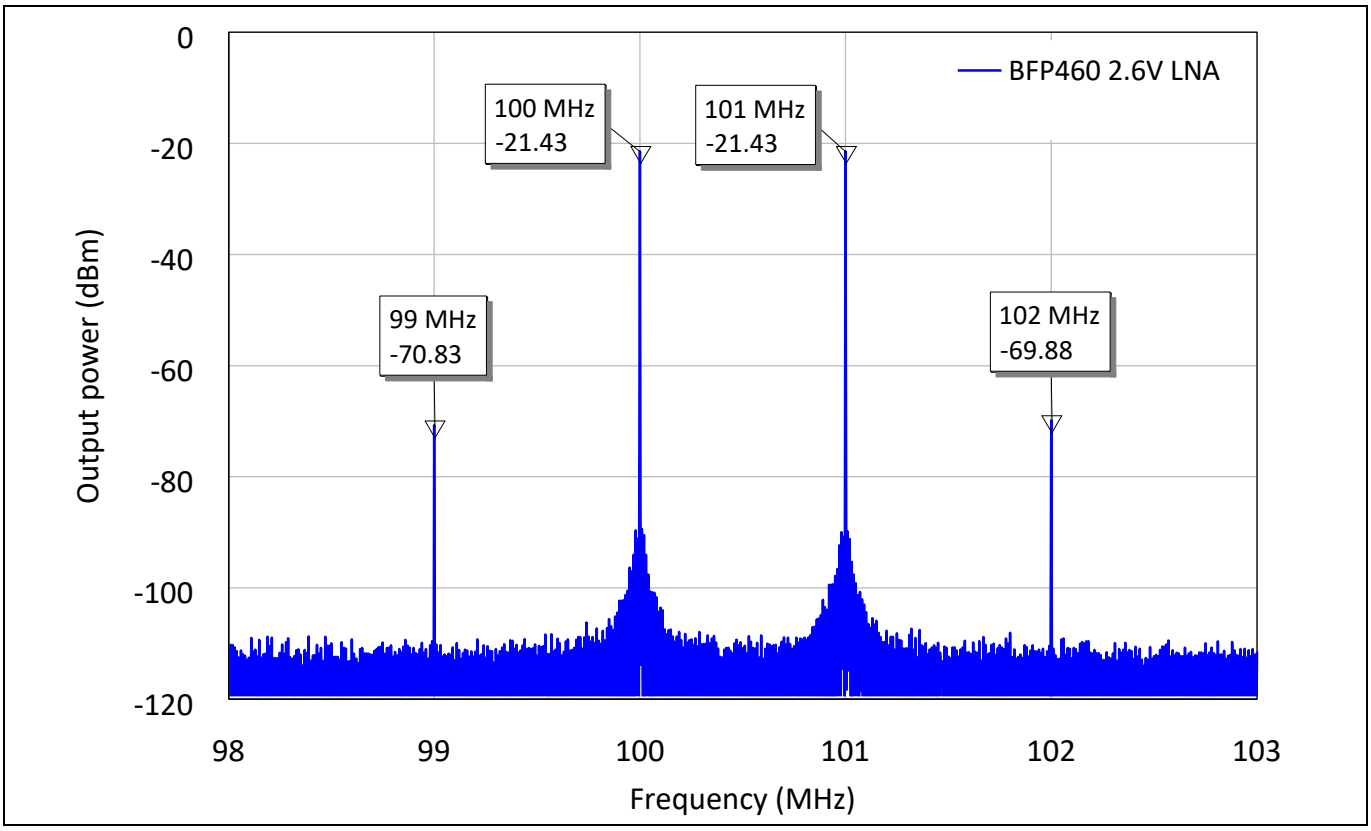


Figure 31 Output IMD$_3$ measurement of the BFP460 2.6 V FM antenna LNA

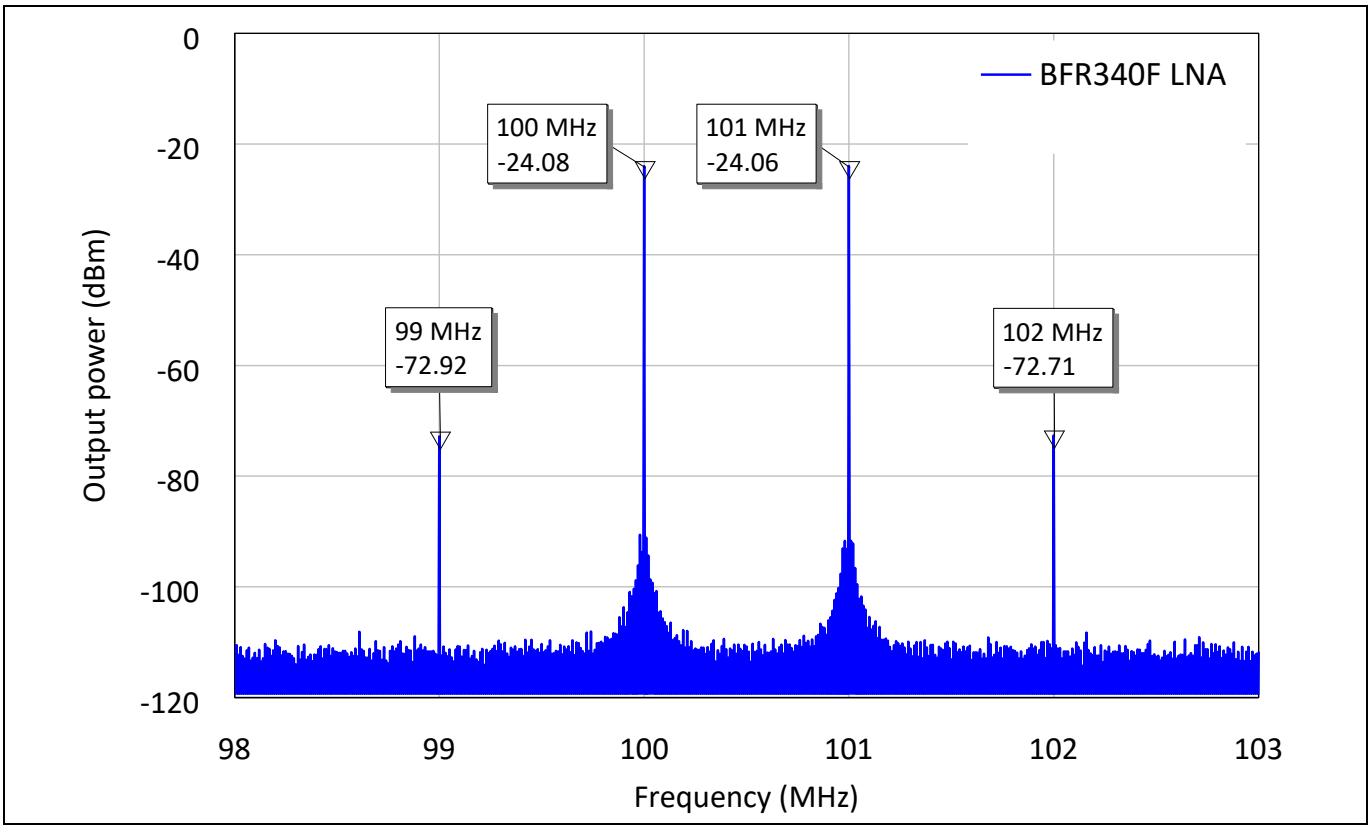


Figure 32 Output IMD_3 measurement of the BFR340F FM antenna LNA

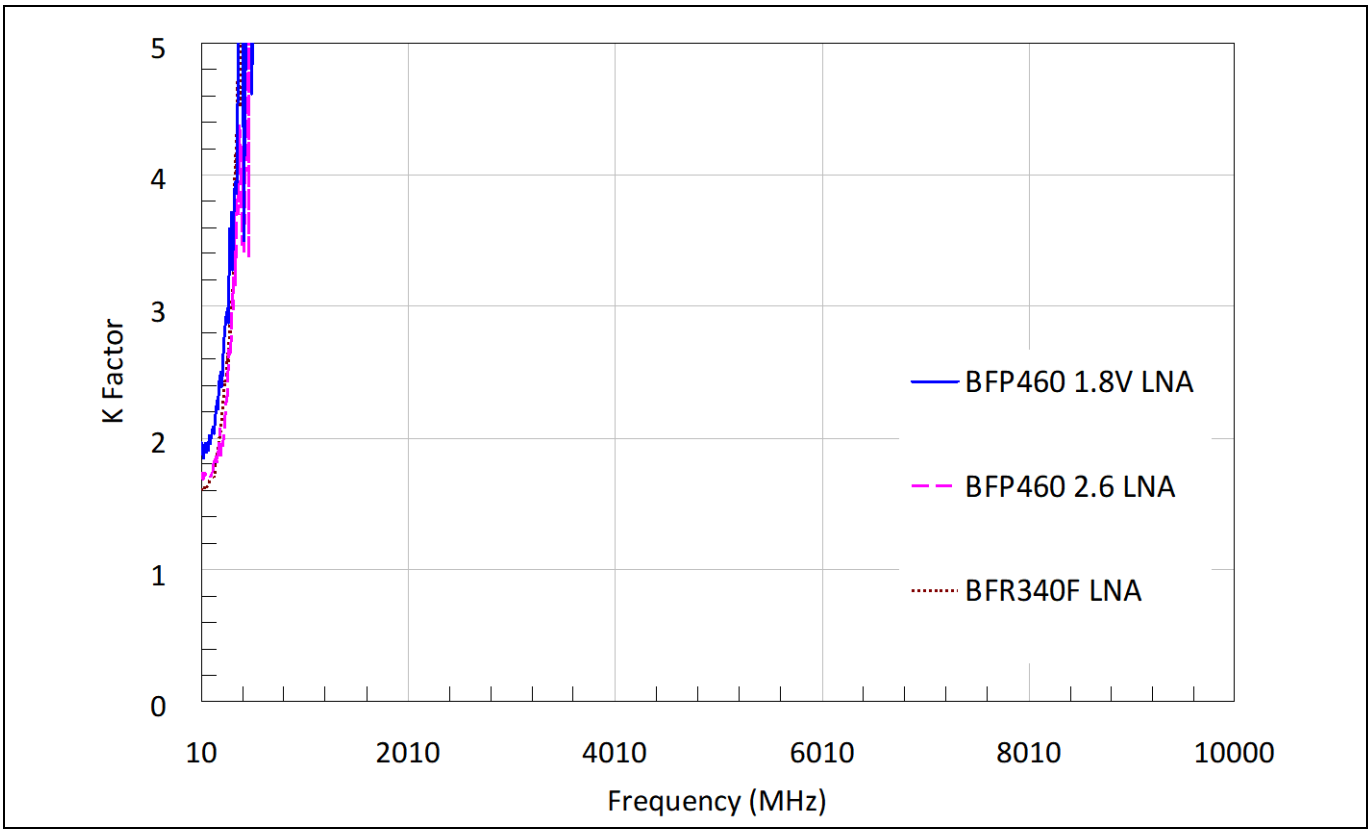


Figure 33 Stability K-factor plots of the FM antenna LNAs matched to 50 Ω at the input

4 FM antenna LNA with low-noise MMIC BGB707L7ESD

4.1 Performance overview

The following table shows the performance of an FM antenna LNA matched to 50 Ω at the input with low-noise MMIC BGB707L7ESD.

Table 5 Summary of measurement results for the FM antenna LNA with low-noise MMIC BGB707L7ESD

Parameter	Symbol	Value	Unit	Notes
Device		BGB707L7ESD		
Bias voltage	V_{CC}	2.8	V	
Bias current	I_{CC}	4.0	mA	
Frequency	f	100	MHz	
Gain	G	18.3	dB	
NF	NF	1.15	dB	
Input return loss	RL_{in}	9.2	dB	
Output return loss	RL_{out}	9.8	dB	
Reverse isolation	ISO_{rev}	28.3	dB	
Output 1 dB compression point	OP_{1dB}	3.3	dBm	
Output third-order intercept point	OIP_3	9.1	dBm	P_{IN} = -30 dBm per tone f_1 = 100 MHz f_2 = 101 MHz
Stability	K	>1		Measured from 10 MHz to 10 GHz

4.2 Schematic

The following figure shows the schematic of the FM radio LNA with low-noise MMIC BGB707L7ESD. In the circuit, the resistor R1 sets up the biasing current. The resistors R3 and R4 stabilize the circuit, whose firmness is measured up to 10 GHz. The resistor R2 and the capacitor C3 serve as the negative feedback to improve input and output impedance matching. The circuit input matching is achieved by the network of C1, L1 and L2. The network of R3, R4 and C5 matches the transistor to the output port. Capacitors C2 and C4 serve as the RF bypass.

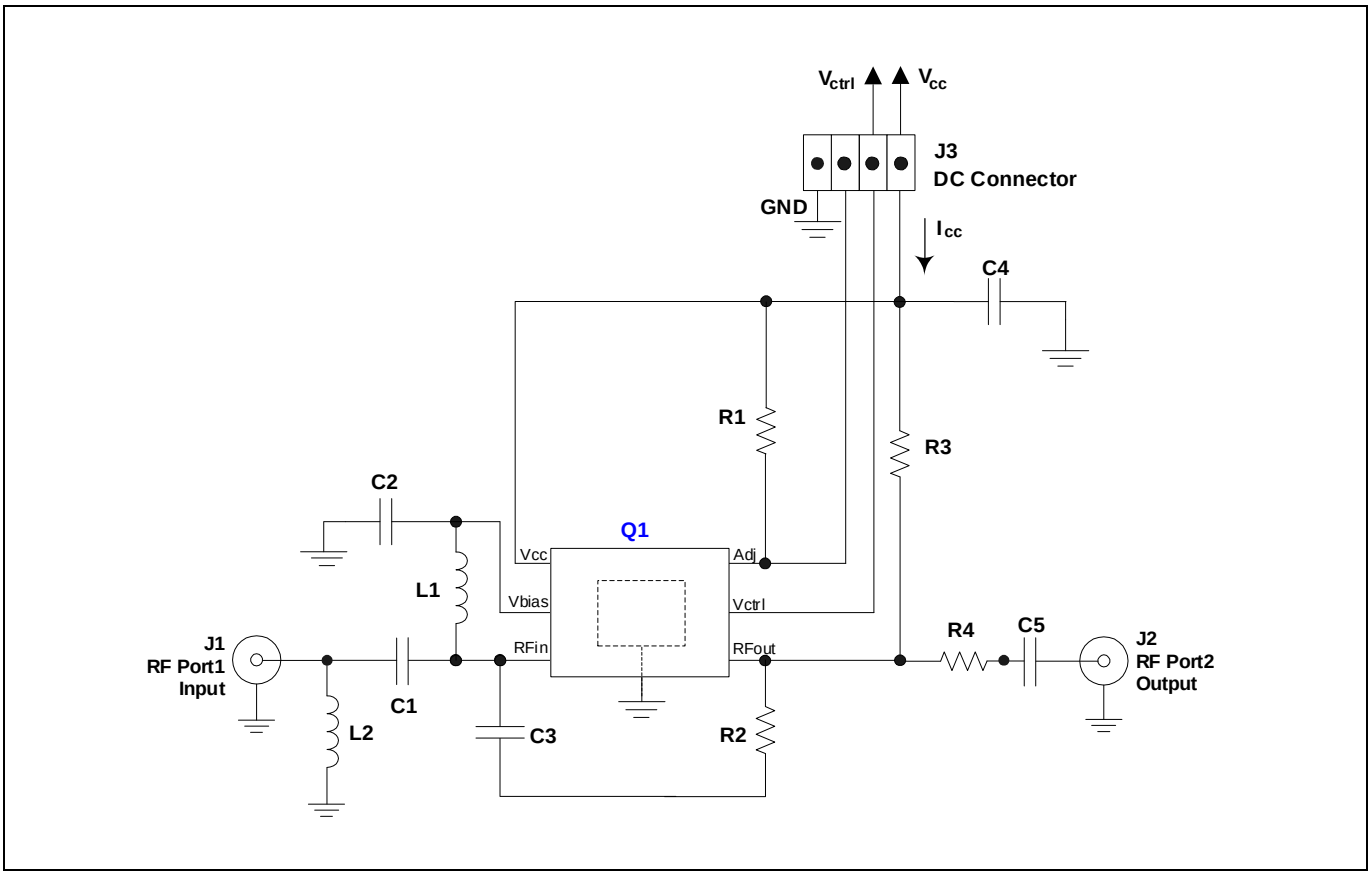


Figure 34 Schematic of the FM antenna LNA with low-noise MMIC BGB707L7ESD

4.3 BOM

Table 6 BOM of the FM antenna LNA with low-noise MMIC BGB707L7ESD

Symbol	Value	Unit	Size	Manufacturer	Comment
Q1	BGB707L7ESD		TSLP-7-1	Infineon Technologies	SiGe:C low-noise MMIC
C1	330	pF	0402	Various	Input matching and DC blocking
C2	47	nF	0402	Various	RF decoupling
C3	330	pF	0402	Various	DC blocking
C4	47	nF	0402	Various	RF decoupling
C5	330	pF	0402	Various	Output matching and DC blocking
L1	470	nH	0603	Murata LQW	Input matching and RF chock
L2	270	nH	0402	Murata LQG	Input matching
R1	4.7	kΩ	0402	Various	Base bias
R2	2.0	kΩ	0402	Various	Negative feedback
R3	180	Ω	0402	Various	Output matching and stability improvement
R4	10	Ω	0402	Various	Stability improvement

4.4 Evaluation board and PCB layout information

The evaluation board for the FM antenna LNA with low-noise MMIC BGB707L7ESD:

- PCB material: Rogers RO4003C
- PCB marking: M141017

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

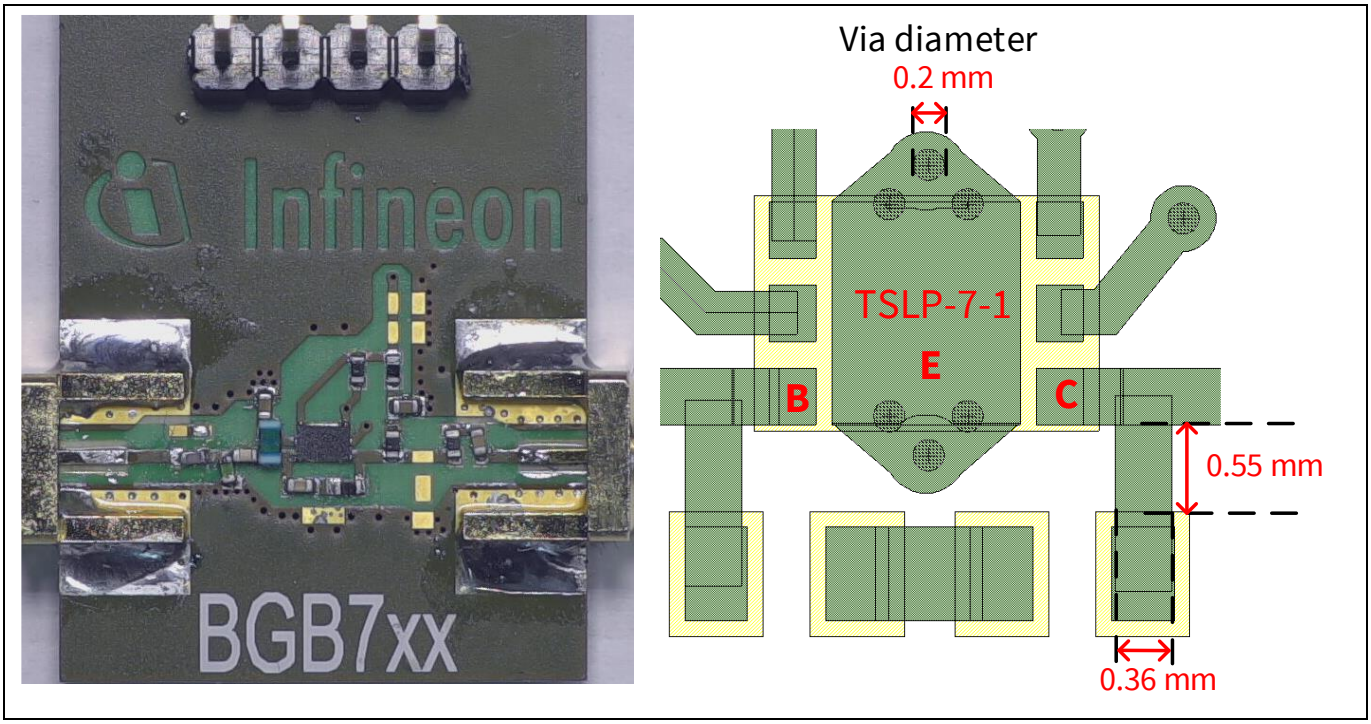


Figure 35 Photo of the evaluation board with PCB marking M141017 (left) and the PCB layout details (right)

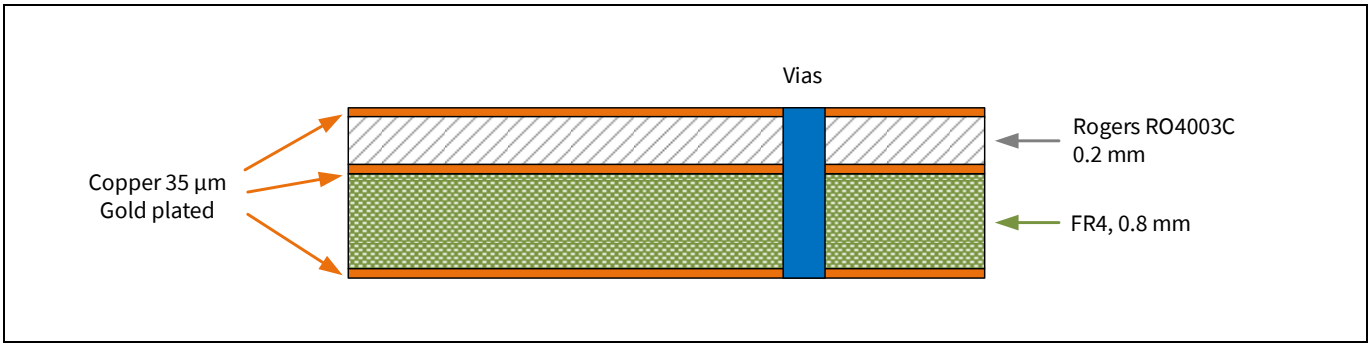


Figure 36 PCB stack information for the evaluation board with PCB marking M141017

4.5 Measurement results of the FM antenna LNA with low-noise MMIC BGB707L7ESD[1)]

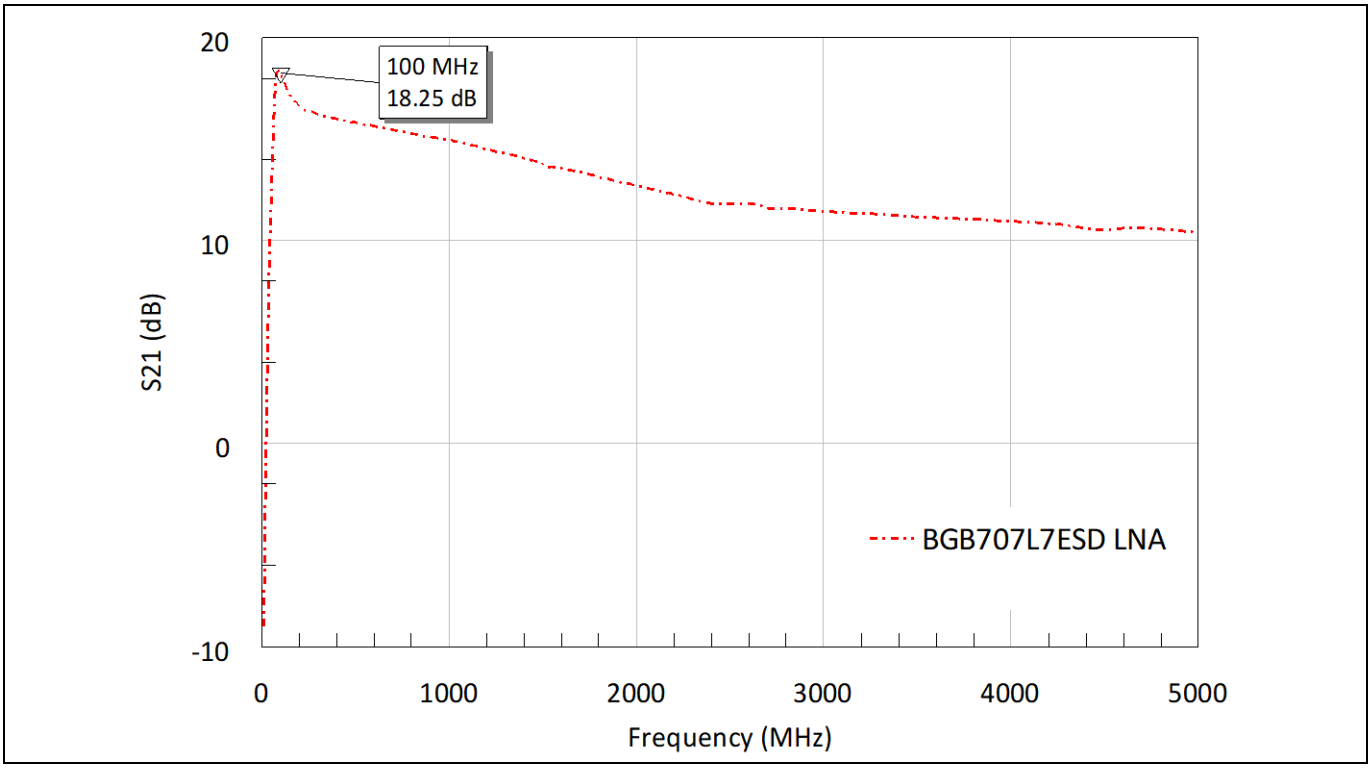


Figure 37 Small signal gain of the FM antenna LNA with low-noise MMIC BGB707L7ESD

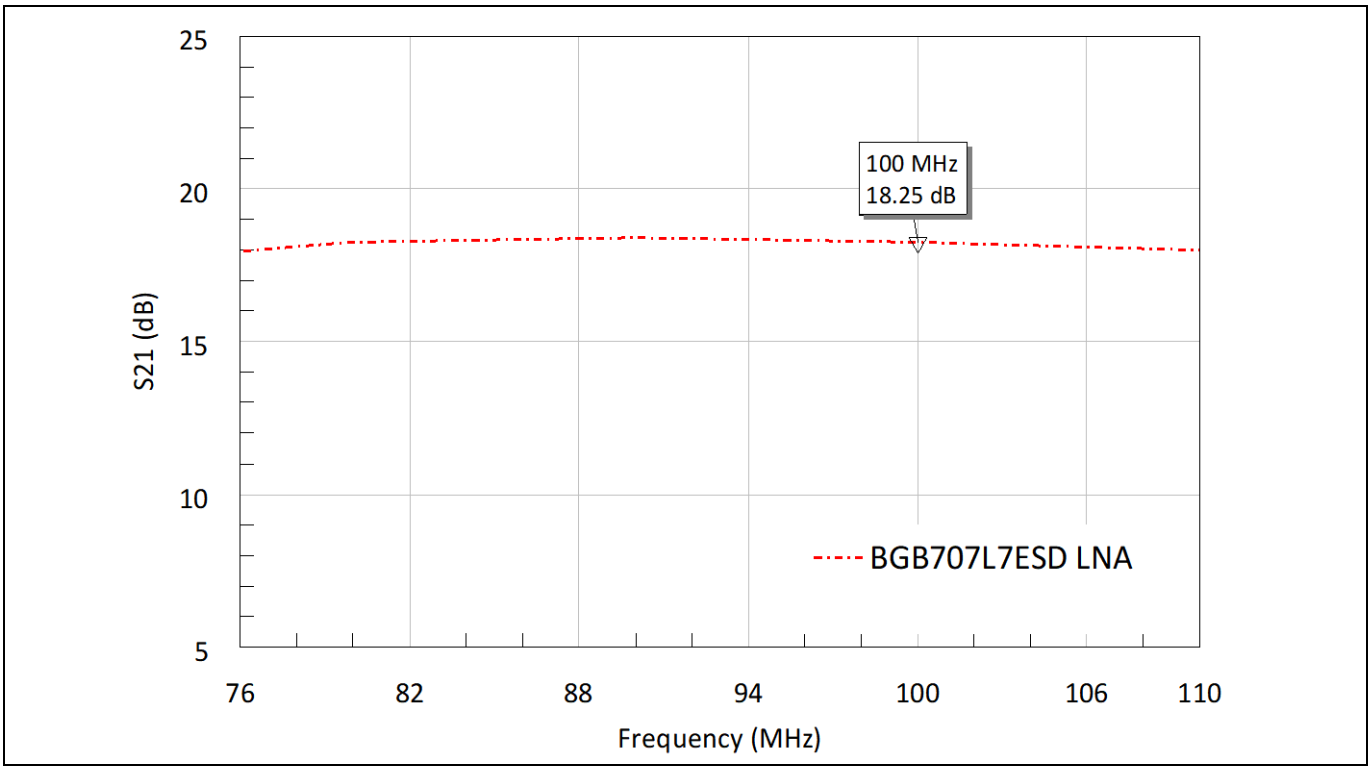


Figure 38 Small signal gain of the FM antenna LNA with low-noise MMIC BGB707L7ESD (detail view)

Note: 1) The graphs are generated with the AWR EDA software Microwave Office®.

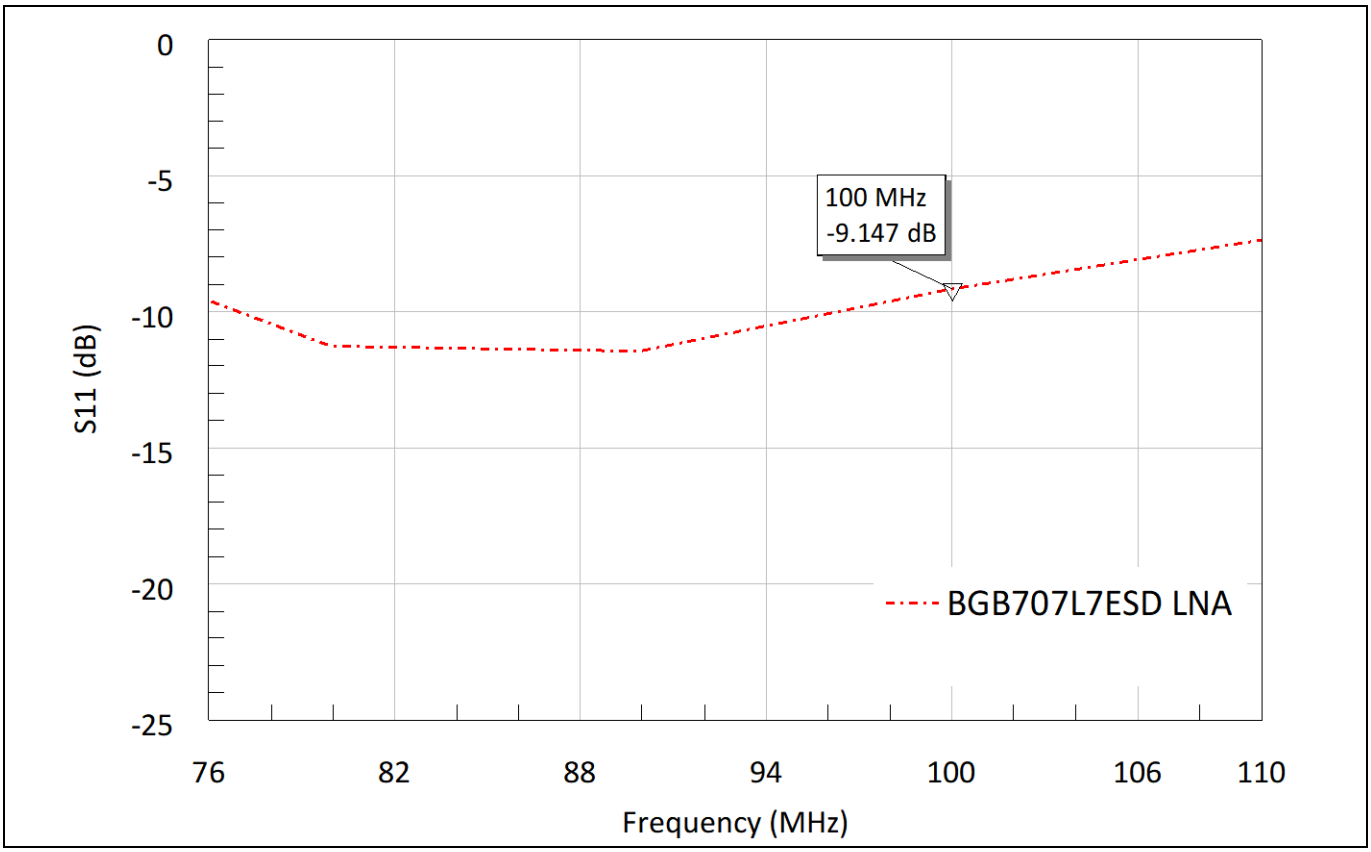


Figure 39 **Input return loss measurement of the FM antenna LNA with low-noise MMIC BGB707L7ESD**

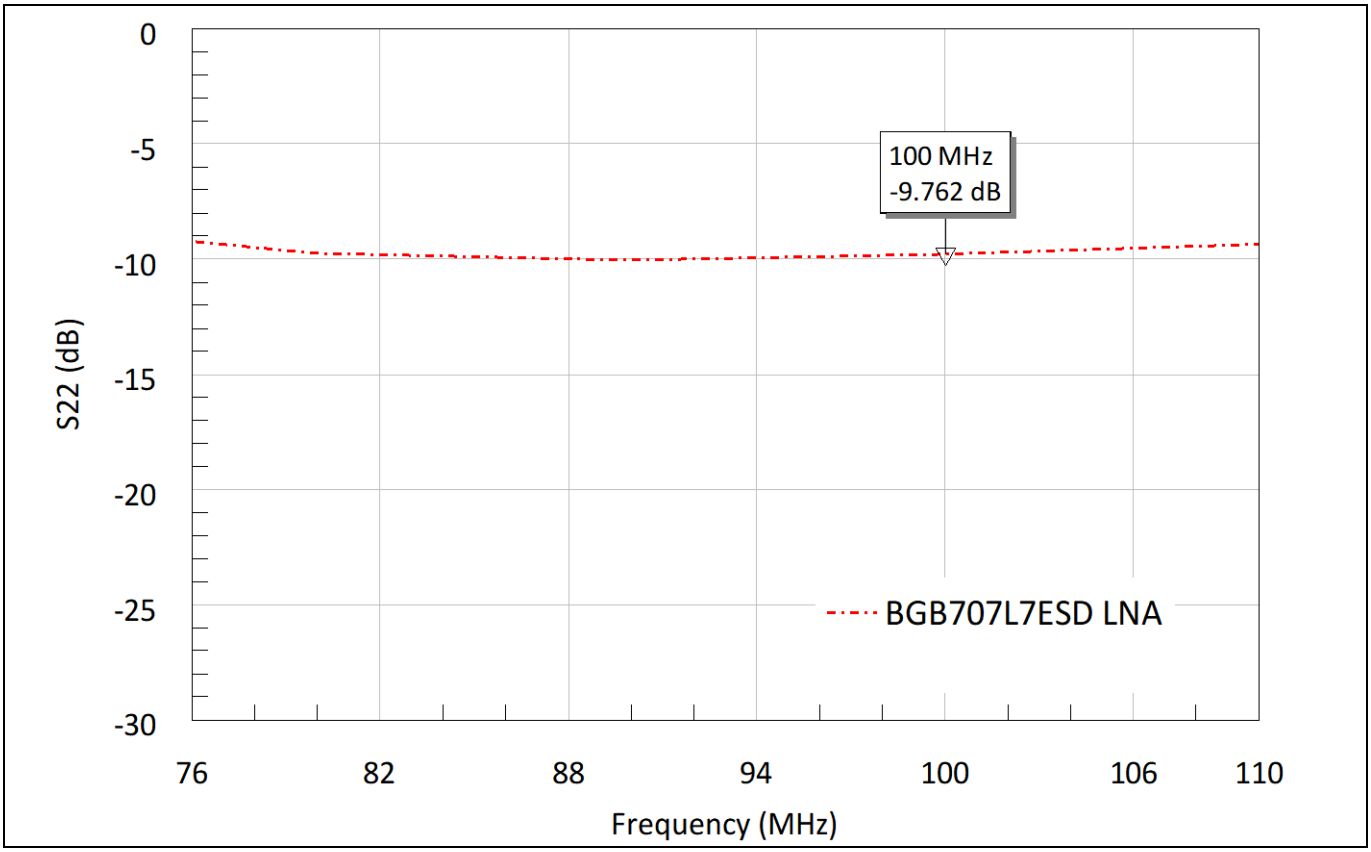


Figure 40 **Output return loss measurement of the FM antenna LNA with low-noise MMIC BGB707L7ESD**

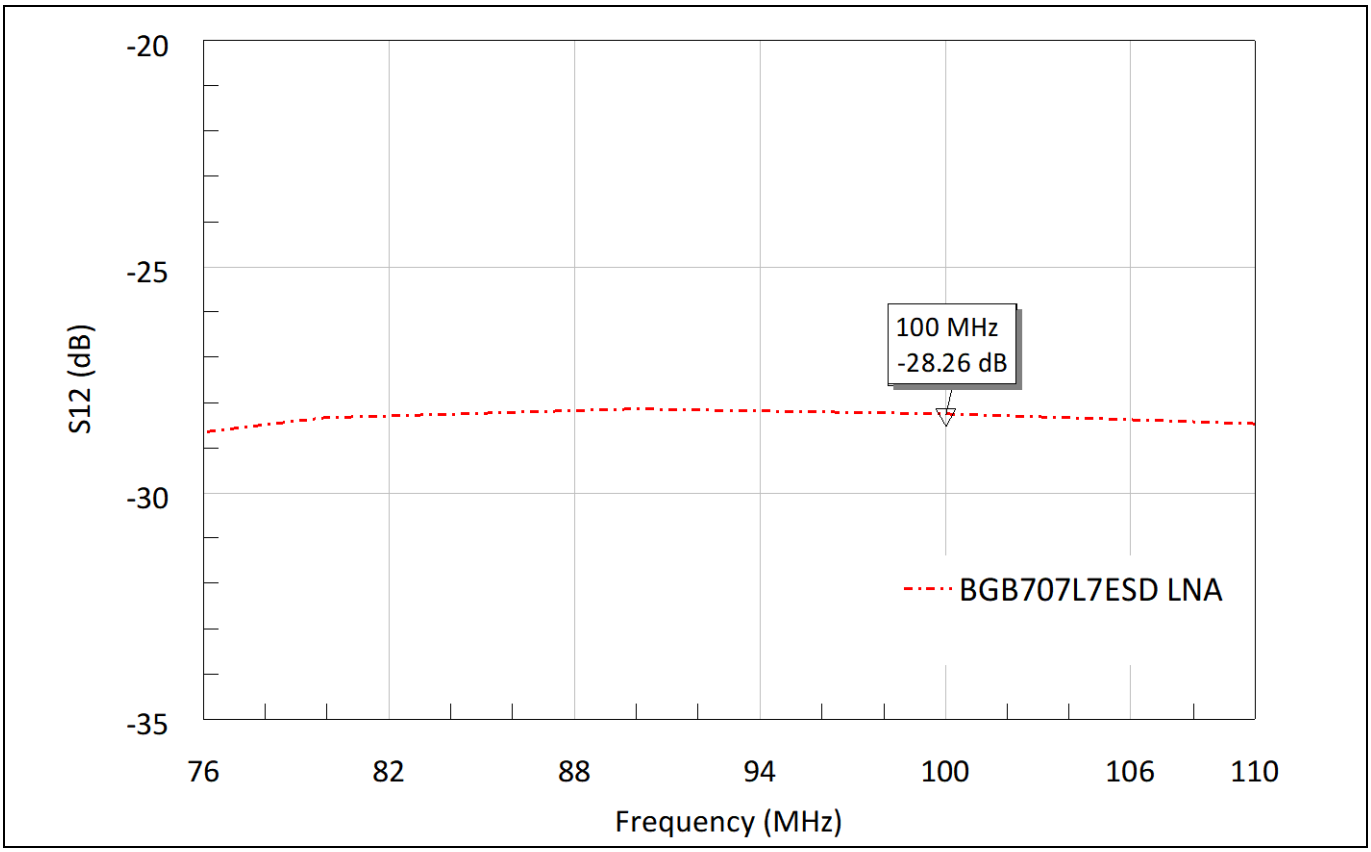


Figure 41 **Reverse isolation measurement of the FM antenna LNA with low-noise MMIC BGB707L7ESD**

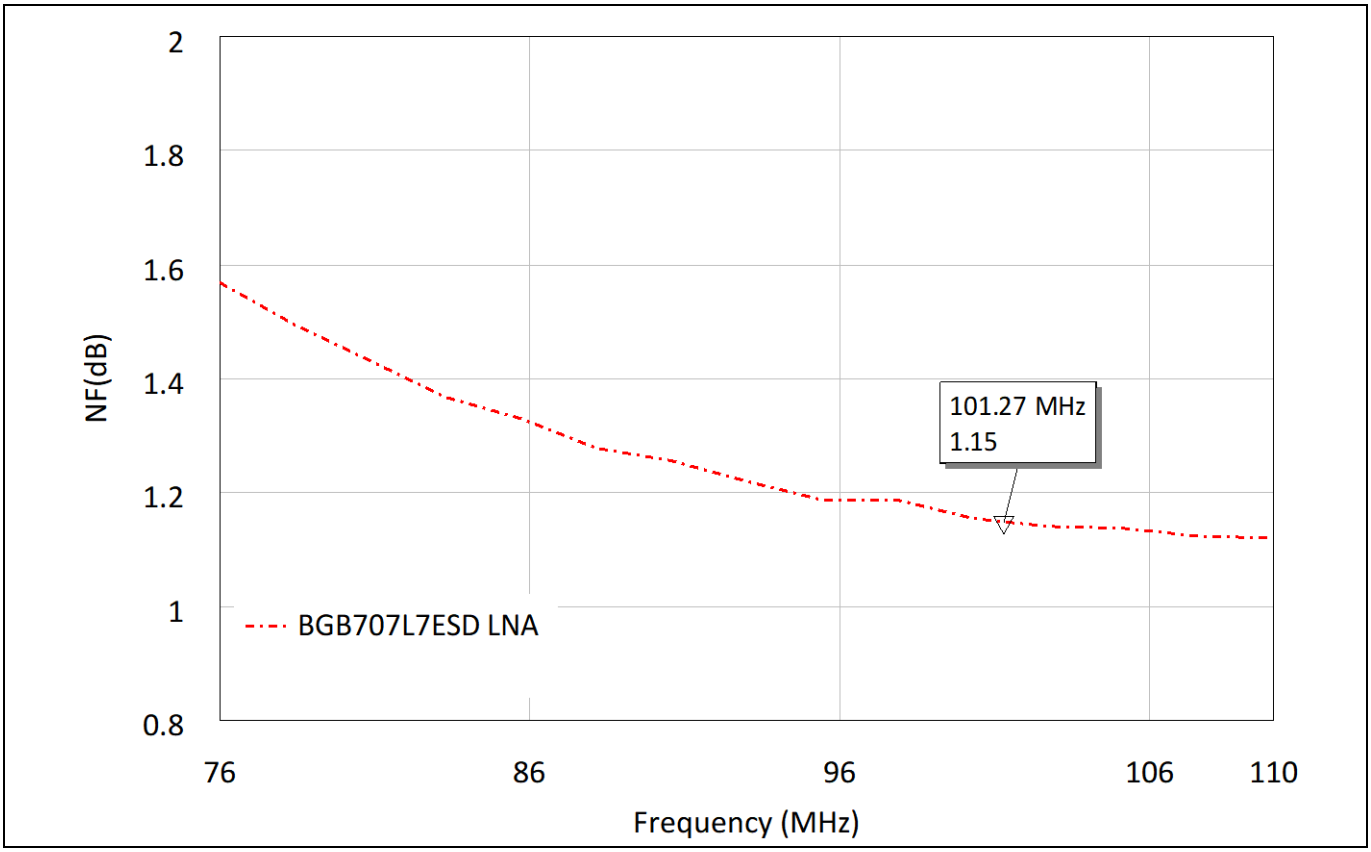


Figure 42 **NF measurement of the FM antenna LNA with low-noise MMIC BGB707L7ESD**

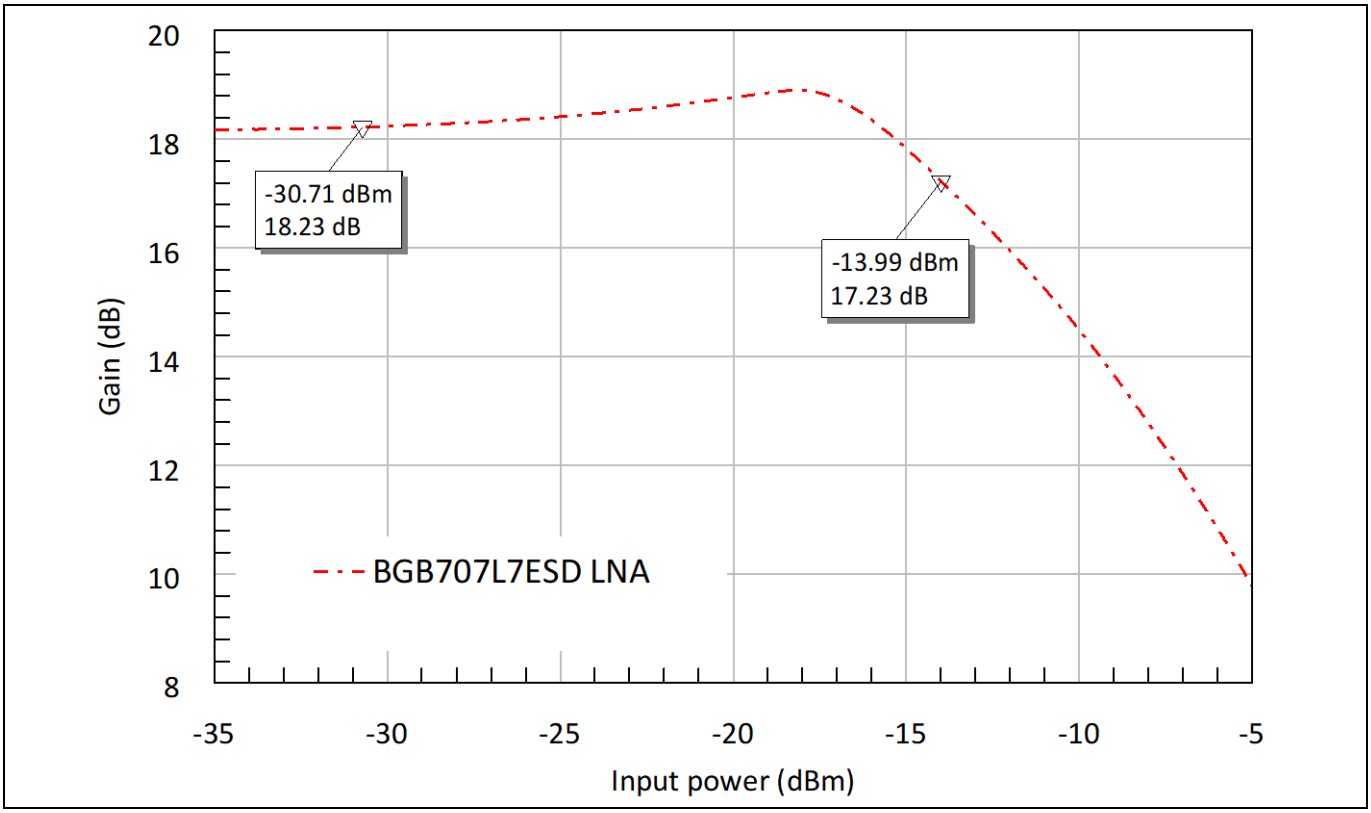


Figure 43 **Input 1 dB compression point measurement of the FM antenna LNA with low-noise MMIC BGB707L7ESD**

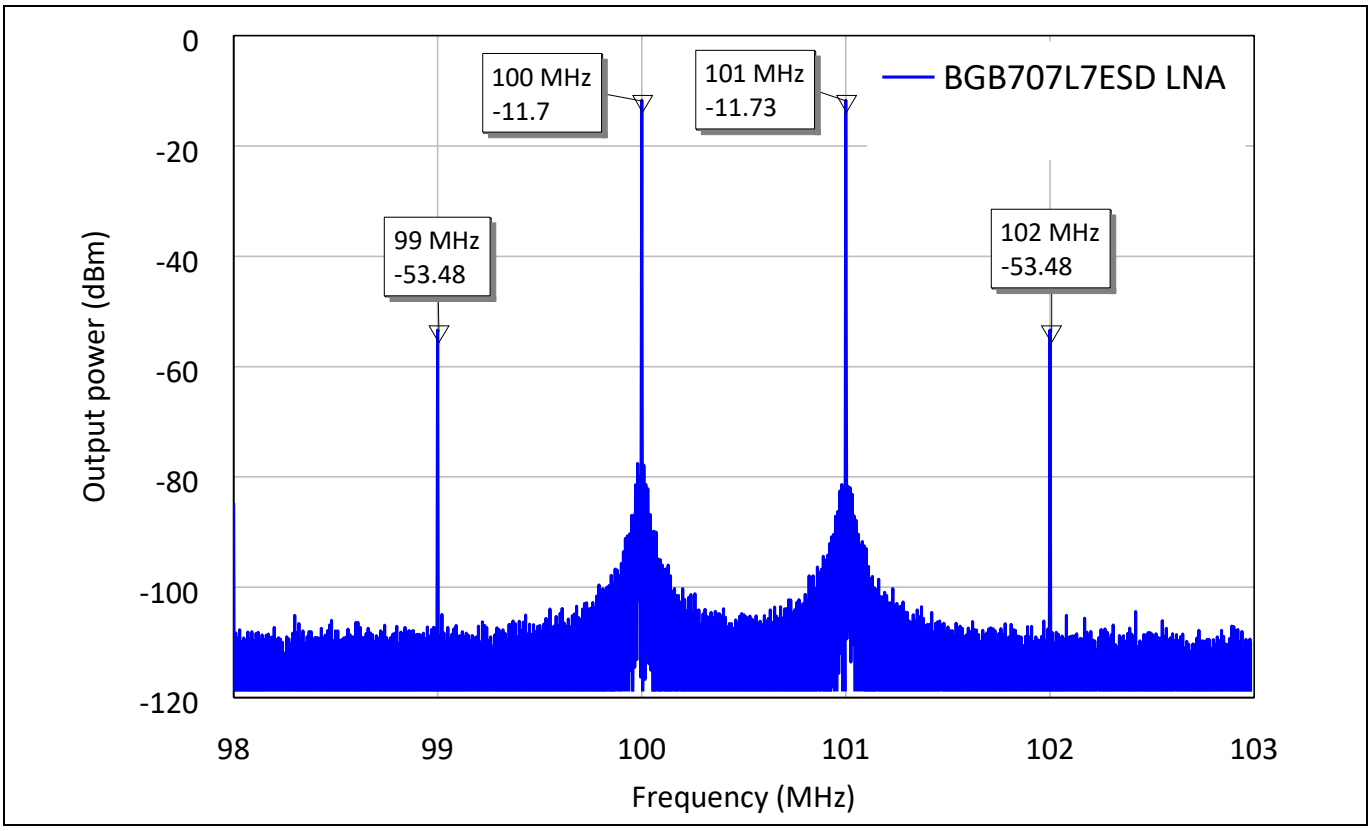


Figure 44 **Output IMD$_3$ measurement of the BGB707L7ESD FM antenna LNA**

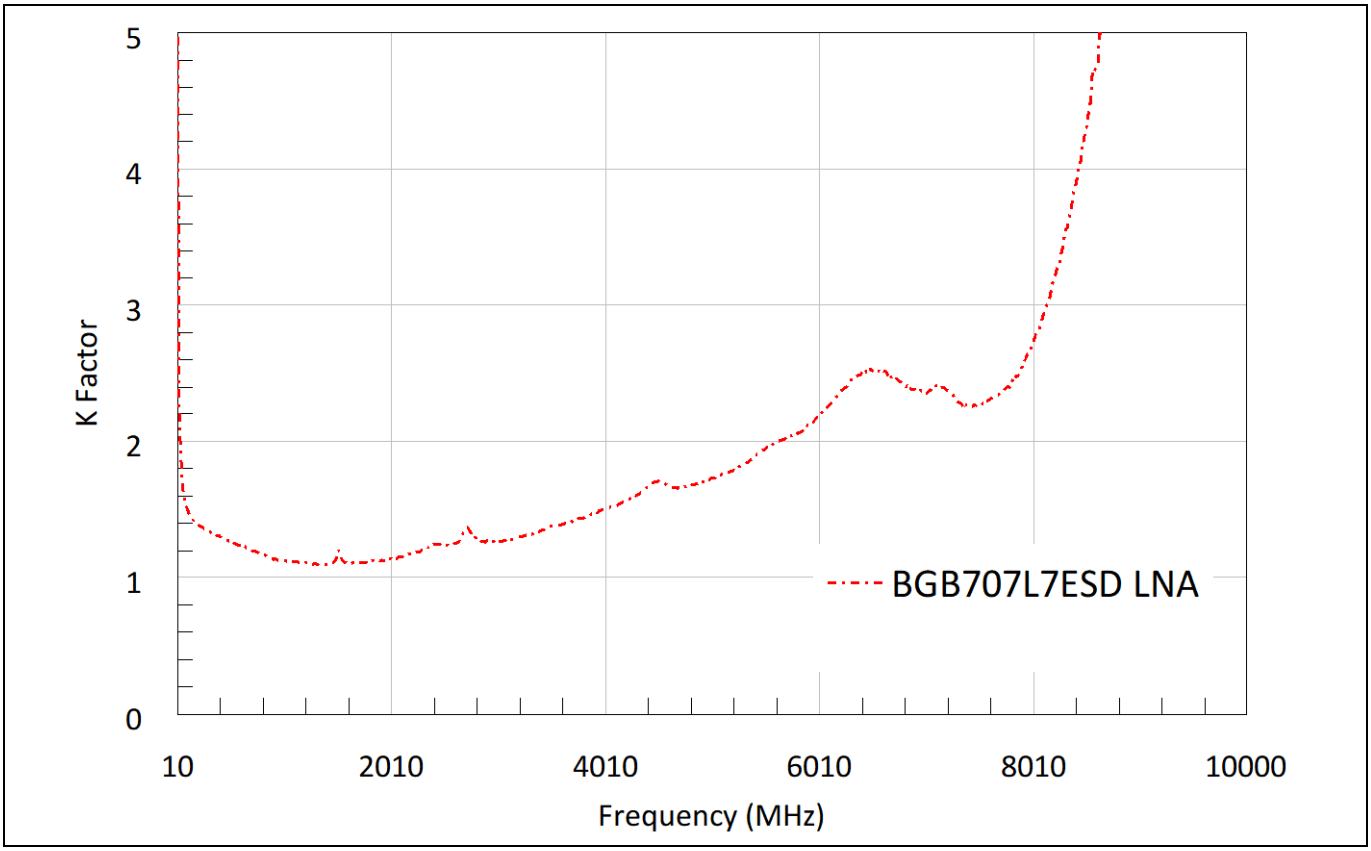


Figure 45 Stability K-factor plots of the FM antenna LNA with low-noise MMIC BGB707L7ESD

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Revision history

Document version	Date of release	Description of changes

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