Medium-power amplifiers for sub-GHz ISM band smart meter range extension

RF medium-power bipolar transistors

About this document

Scope and purpose

This application note provides application circuit design examples with Infineon's medium-power transistors for power amplifiers (PA) in sub-GHz industrial, scientific and medical (ISM) band applications, especially for the smart meter range extension. In this document, the schematics, PCB layouts and measurement results of the 433 MHz PAs with the 200 mW transistor BFP780 and the 500 mW transistor BFQ790 are shown.

Intended audience

This document is intended for engineers who need to design PAs for sub-GHz ISM band smart metering applications.

Table of contents

1 Introduction

1.1 Introduction to medium-power amplifiers in smart meter applications

Driven by energy efficiency demands, the traditional electricity meter is gradually being replaced by the smart meter. The smart meter is a key device in the next-generation efficient, flexible and intelligent energy distribution network, which provides not only advanced energy grid management capability for the utility companies, but also detailed energy consumption reports for the end users.

The communication unit in a smart meter plays an important role since the data communication between smart meters, and the power grid should be guaranteed in terms of quality, time, and security. As a result, more than one technology is adopted at the same time to fulfill the requirements. Among all the communication standards, communication through the sub-GHz ISM channel is one of the most important ways to connect the smart meters and the data collectors or concentrators. The sub-GHz wireless technology, combines with low data-rate GFSK/GMSK modulation scheme, benefits in long-range capability, better sensitivity and lower interference. Owning to the advantages of sub-GHz wireless technology features, the output power of the system is in the medium-power range, which is perfectly matched with Infineon's medium-power transistors' specifications. The block diagram of the sub-GHz radio front end for smart meter application is shown in Figure 1.

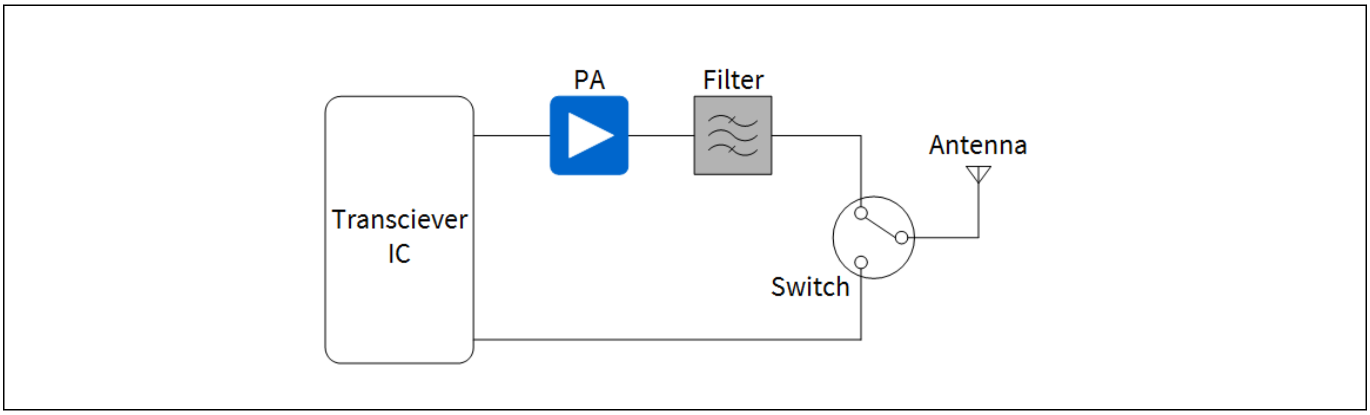

Figure 1 A block diagram example of the sub-GHz radio front end for smart meter application

1.2 Infineon medium-power transistor family

The BFQ790 and the BFP780 are general-purpose radio frequency (RF) medium-power transistors based on Infineon's cost-effective silicon germanium (SiGe) technology, which can be produced in high volumes, and are designed for wireless infrastructure applications. These include mobile base stations' transceivers, cellular repeaters, ISM band amplifiers, and test equipments. Their operating frequency range can be as high as 3.6 GHz, and the application circuits can be optimized for specific frequency bands with the adoption of external matching components.

The BFQ790 is a single-stage, high-linearity, medium-power transistor with the capability of an output 1 dB compression point of 27 dBm (500 mW) and is available in a 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 25 K/W, which leads to moderate junction temperatures even at high dissipated power values. The proper die attachment with good thermal contact is 100 percent tested, so that there is minimal variation of thermal properties. The collector design allows safe operation with 5 V supply voltage, and protects it from thermal runaway secondary breakdown, which makes it rugged when exposed to mis-match at the output. The special design of the emitter-base diode makes it robust and allows for high maximum RF input power.

The BFP780 is a single-stage medium-power amplifier with high linearity and high power gain. Its output 1 dB compression point is 23 dBm (200 mW). The chip is housed in a halogen-free industry standard package SOT343. The proper die attachment with good thermal contact is 100 percent tested and verified. The collector design also allows safe operation with 5 V supply voltage.

For further information about the BFQ790 and the BFP780, please refer to their datasheets and application notes.

2 Application circuits and performance overview

2.1 Performance overview

The following table summarizes the performance of the 433 MHz PAs with the BFP780 and the BFQ790 transistors respectively.

Table 1 Summary of the measurement results for the 433 MHz PAs with BFP780 and BFQ790

Parameter	Symbol	Value		Unit	Notes
Device		BFP780	BFQ790		
Bias voltage	V_{CC}	5.0	5.0	V	
Quiescent bias current	I_{CQ}	80	220	mA	
Frequency	f	387.7 to 460.0	409.7 to 437.9	MHz	Frequency range for the input and output return loss better than 10 dB
Gain	G	26.1	21.1	dB	At 433.5 MHz
Output 1 dB compression point	OP_{1dB}	22.7	26.7	dBm	At 433.5 MHz
Output third-order intercept point	OIP_3	35.7	40.6	dBm	f_1 = 433.85 MHz, f_2 = 433.95 MHz; P_{out} = 10 dBm / tone with BFP780 PA P_{out} = 14 dBm / tone with BFQ790 PA
Input return loss	RL_{in}	>10	>10	dB	
Output return loss	RL_{out}	>10	>10	dB	
Reverse isolation	ISO_{rev}	>30	>33	dB	
Stability factor	K	>1	>1		Measured from 10 MHz to 6 GHz

2.2 Schematics

The following figure shows the schematic of the 433 MHz PA with the BFP780. The transistor is biased through a voltage divider with resistors R2 and R3 for the transistor base; meanwhile, the resistor R3 has the feedback function for input and output matching. The resistor R1 improves the circuit stability with a small value of 3 Ω. The amplifier’s input matching is achieved by the capacitor C1 and the inductor L1. Capacitors C4 and C5 serve as the RF bypass. The inductor L2 and the capacitor C2 form a shunt resonant tank to filter out the harmonics and provide the DC bias path to the transistor collector. The capacitor C3 acts as the DC block and is selected according to the capacitor’s self-resonance frequency.

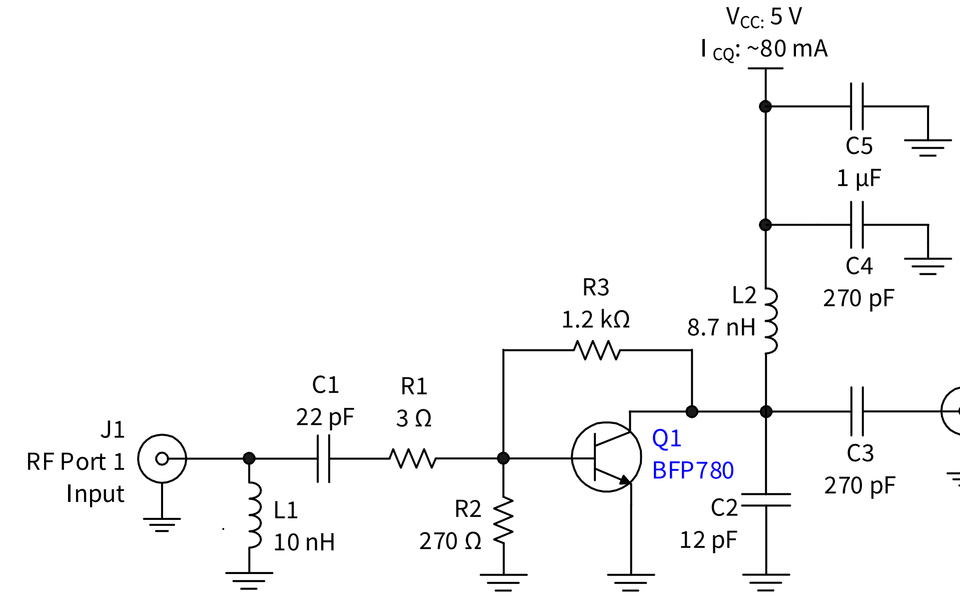

Figure 2 Schematic of the 433 MHz BFP780 PA

The following figure shows the schematic of the 433 MHz PA with the BFQ790. Like the transistor base bias configuration in the previous circuit, resistors R3 and R1 divide the supply voltage and provide the bias current to the transistor base. And the resistor R3 also provides the feedback function for input and output matching. The amplifier's input matching is achieved by the capacitor C1 and the inductor L1. The amplifier's output matching network is formed by C2, C3, L2, and L3. The capacitor C3 acts as the DC block in the meantime. Capacitors C4 and C5 serve as the RF bypass.

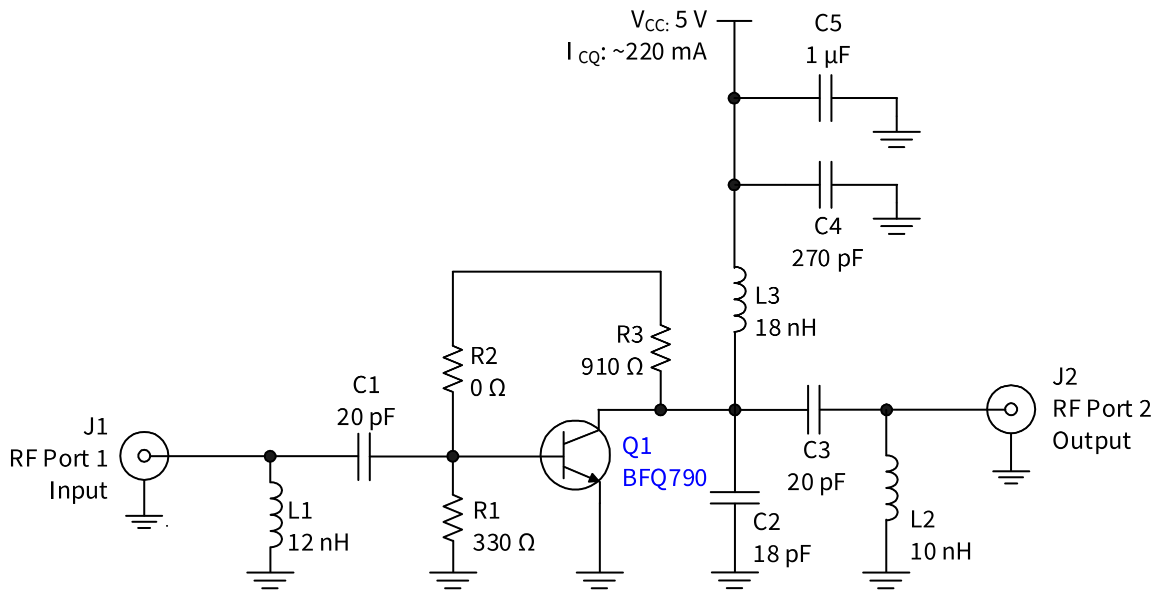

Figure 3 Schematic of the 433 MHz BFQ790 PA

2.3 Bill of materials (BOM)

Table 2 BOM of the 433 MHz BFP780 PA

Symbol	Value	Unit	Package	Manufacturer	Comment
Q1	BFP780		SOT343	Infineon	SiGe RF medium-power transistor
C1	22	pF	0402	Various	Input matching and DC block
C2	12	pF	0402	Various	Output matching
C3	270	pF	0402	Various	DC block
C4	270	pF	0402	Various	RF bypass
C5	1	µF	0402	Various	RF bypass
L1	10	nH	0402	Murata LQW	Input matching
L2	8.7	nH	0402	Murata LQW	Output matching and RF choke
R1	3	Ω	0402	Various	Stability improvement
R2	270	Ω	0402	Various	DC bias
R3	1.2	kΩ	0402	Various	DC bias

Table 3 BOM of the 433 MHz BFQ790 PA

Symbol	Value	Unit	Package	Manufacturer	Comment
Q1	BFQ790		SOT89	Infineon	SiGe RF medium-power transistor
C1	20	pF	0402	Various	Input matching and DC block
C2	18	pF	0402	Various	Output matching
C3	20	pF	0402	Various	Output matching and DC block
C4	270	pF	0402	Various	RF bypass
C5	1	µF	0402	Various	RF bypass
L1	12	nH	0402	Murata LQW	Input matching
L2	10	nH	0402	Murata LQW	Output matching
L3	18	nH	0402	Murata LQW	Output matching and RF choke
R1	330	Ω	0402	Various	DC bias
R2	0	Ω	0402	Various	Jumper
R3	910	Ω	0402	Various	DC bias

2.4 Evaluation boards and layout information

The evaluation board information for the 433 MHz BFP780 PA:

- PCB material: FR4
- PCB marking: M101022

A photo of the 433 MHz BFP780 PA evaluation board is shown in the following figure.

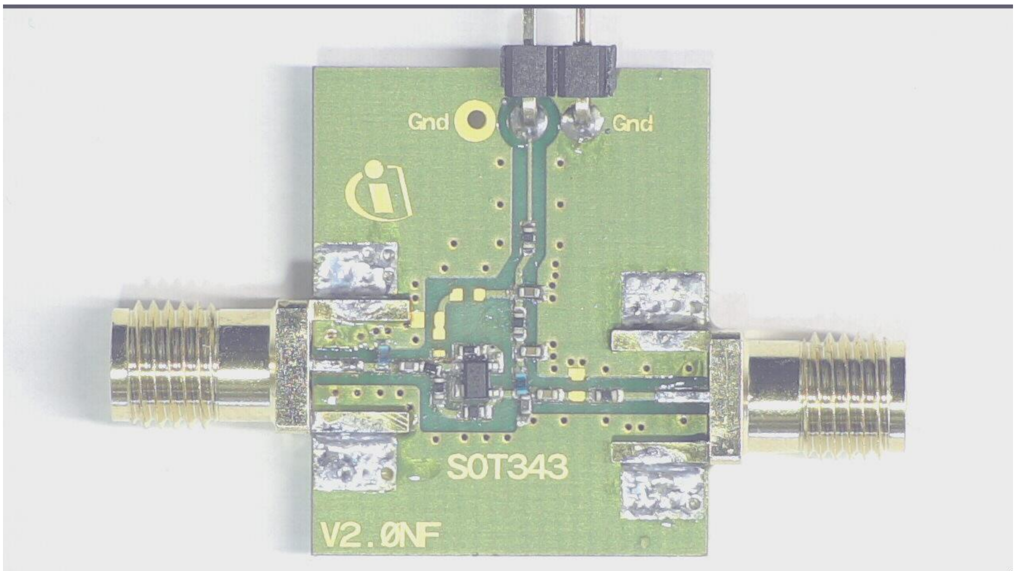

Figure 4 Photo of the 433 MHz BFP780 PA

The evaluation board information for the 433 MHz BFQ790 PA:

- PCB material: FR4
- PCB marking: M18061502

A photo of the 433 MHz BFQ790 PA evaluation board is shown in the following figure.

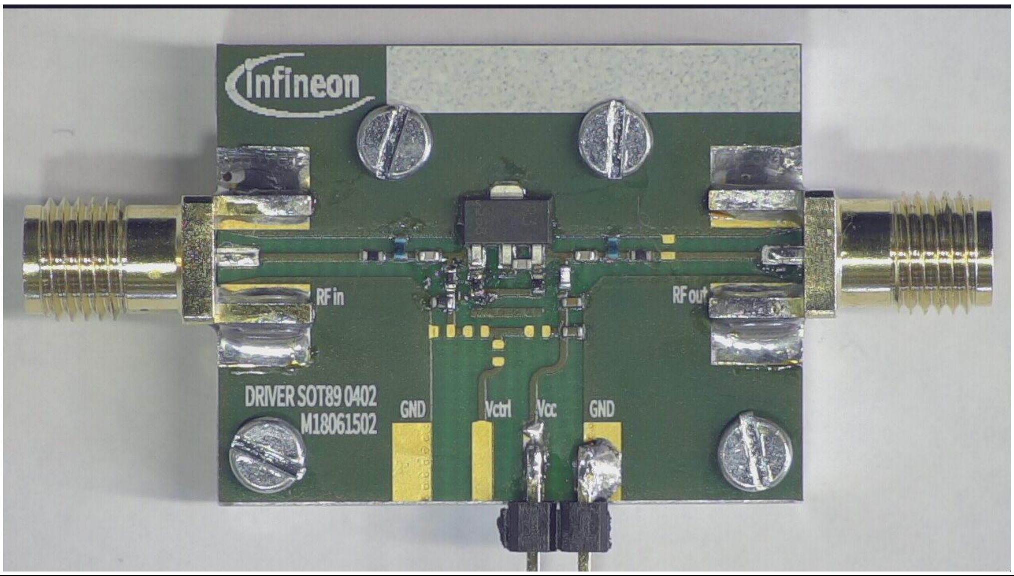

Figure 5 Photo of the 433 MHz BFQ790 PA

The PCB stack information for the evaluation boards is shown in the following picture.

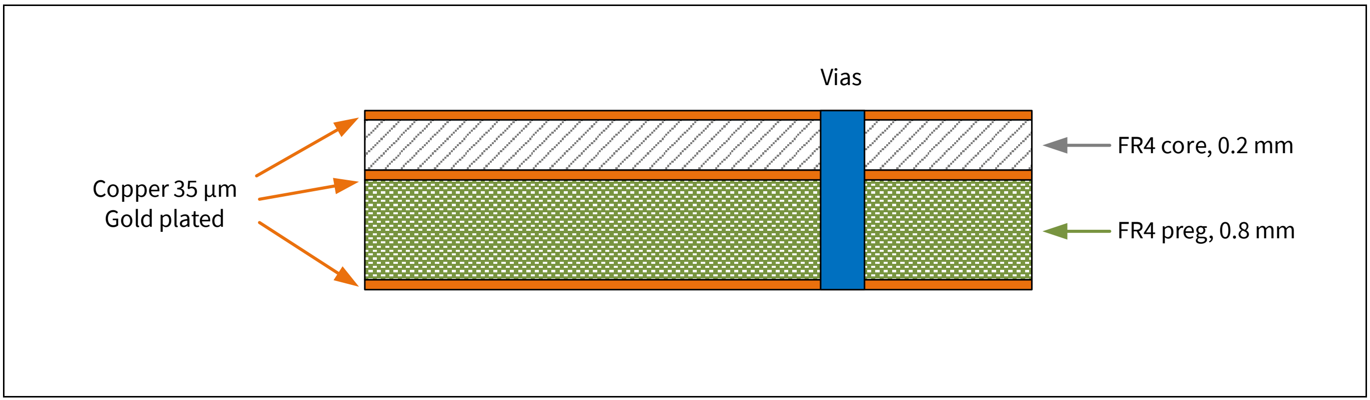

Figure 6 PCB stack information for the evaluation boards with marking M101022 and M18061502

3 Measurement graphs

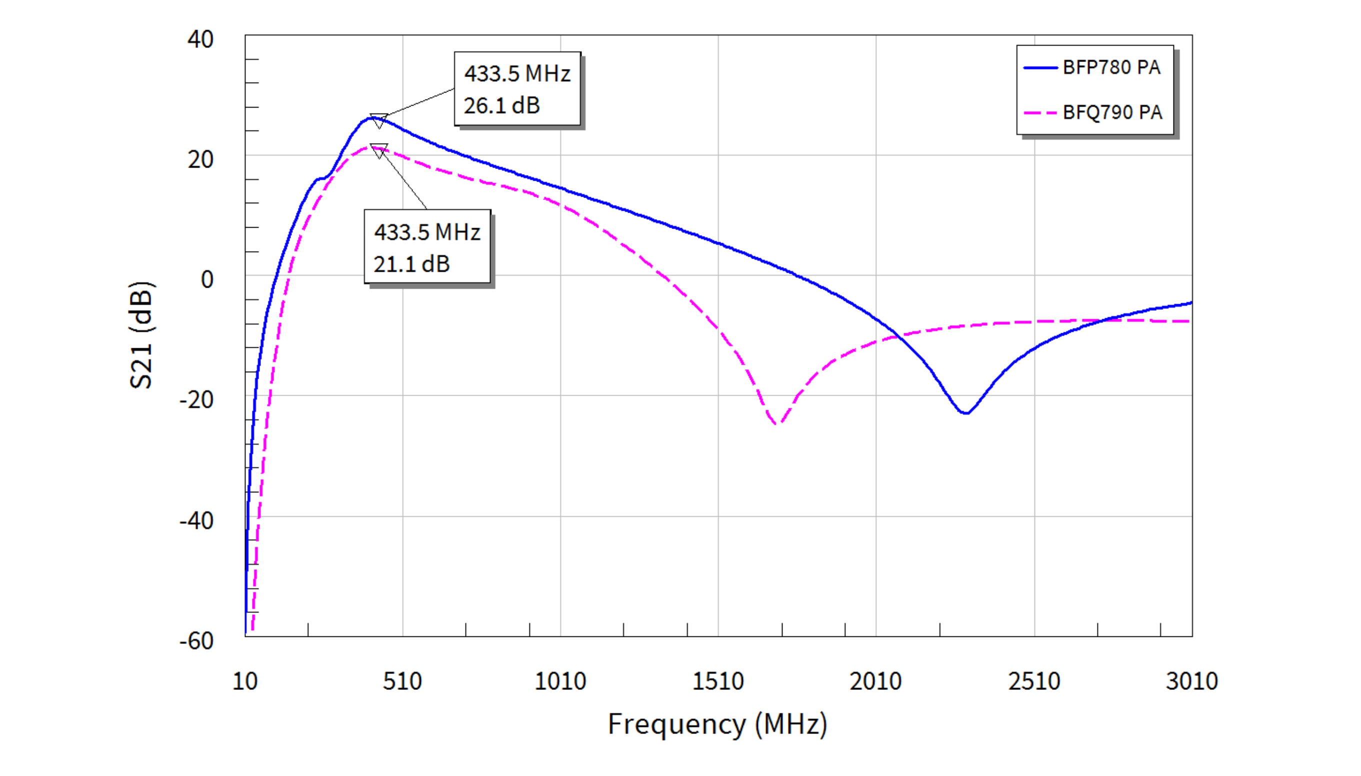

Figure 7 The small signal gain measurements of the 433 MHz PAs

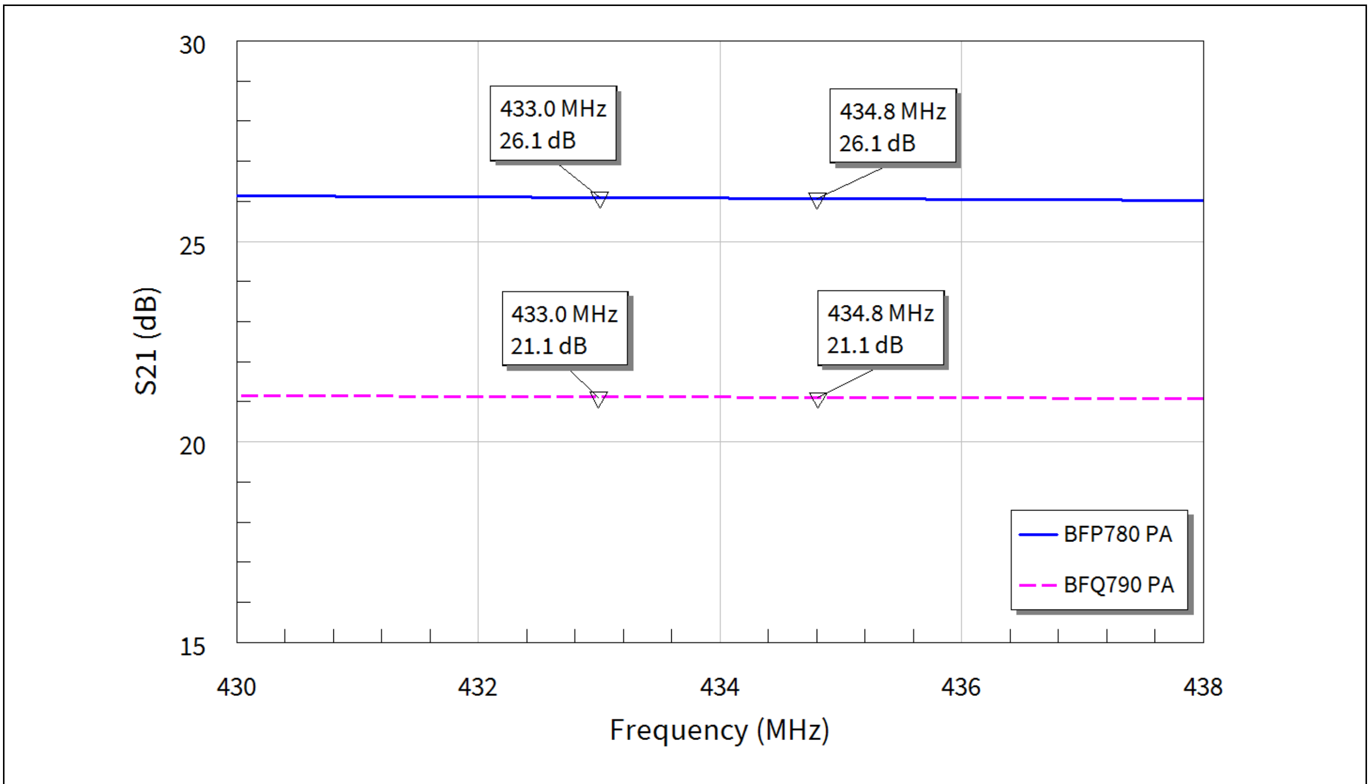

Figure 8 The small signal gain measurements of the 433 MHz PAs (detail view)

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

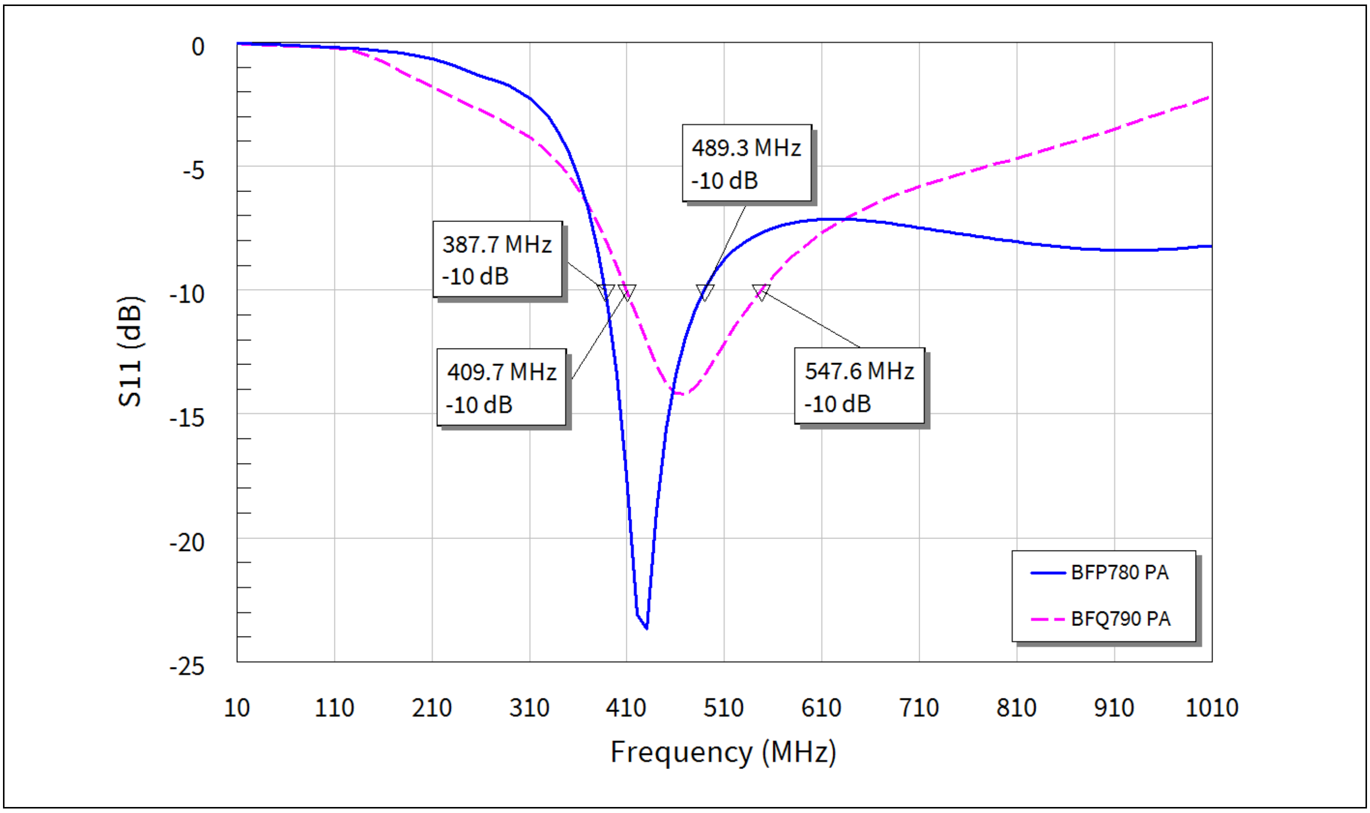

Figure 9 Input return loss measurements of the 433 MHz PAs

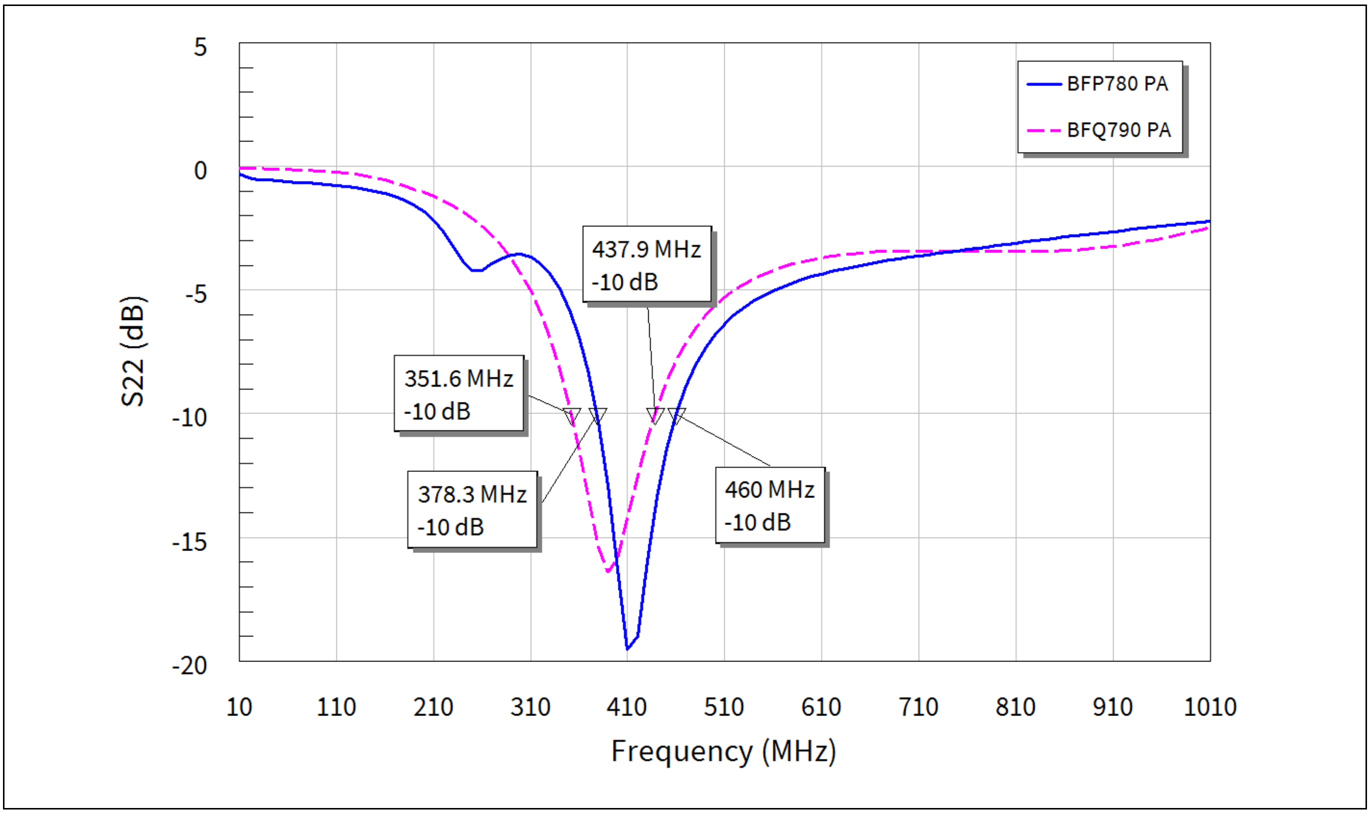

Figure 10 Output return loss measurements of the 433 MHz PAs

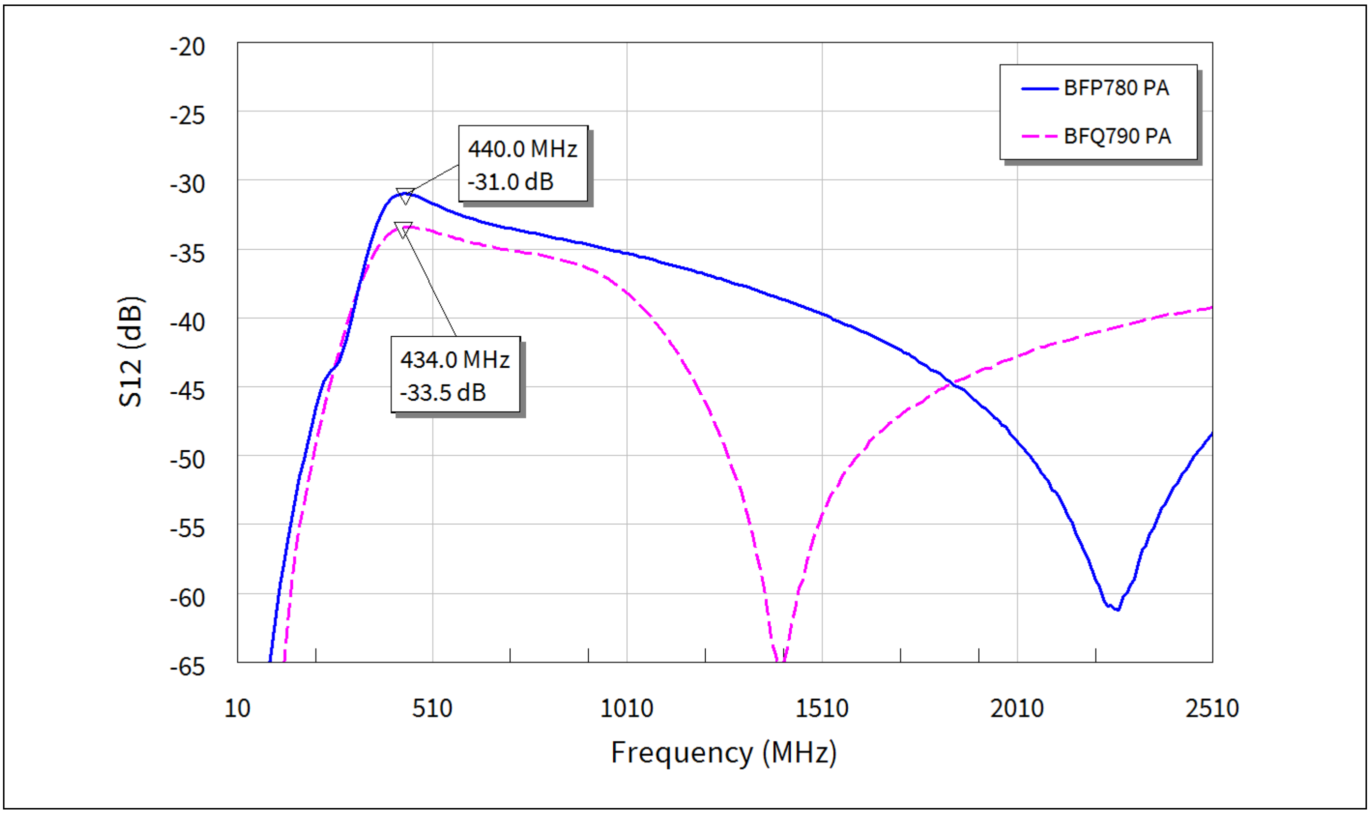

Figure 11 Reverse isolation measurements of the 433 MHz PAs

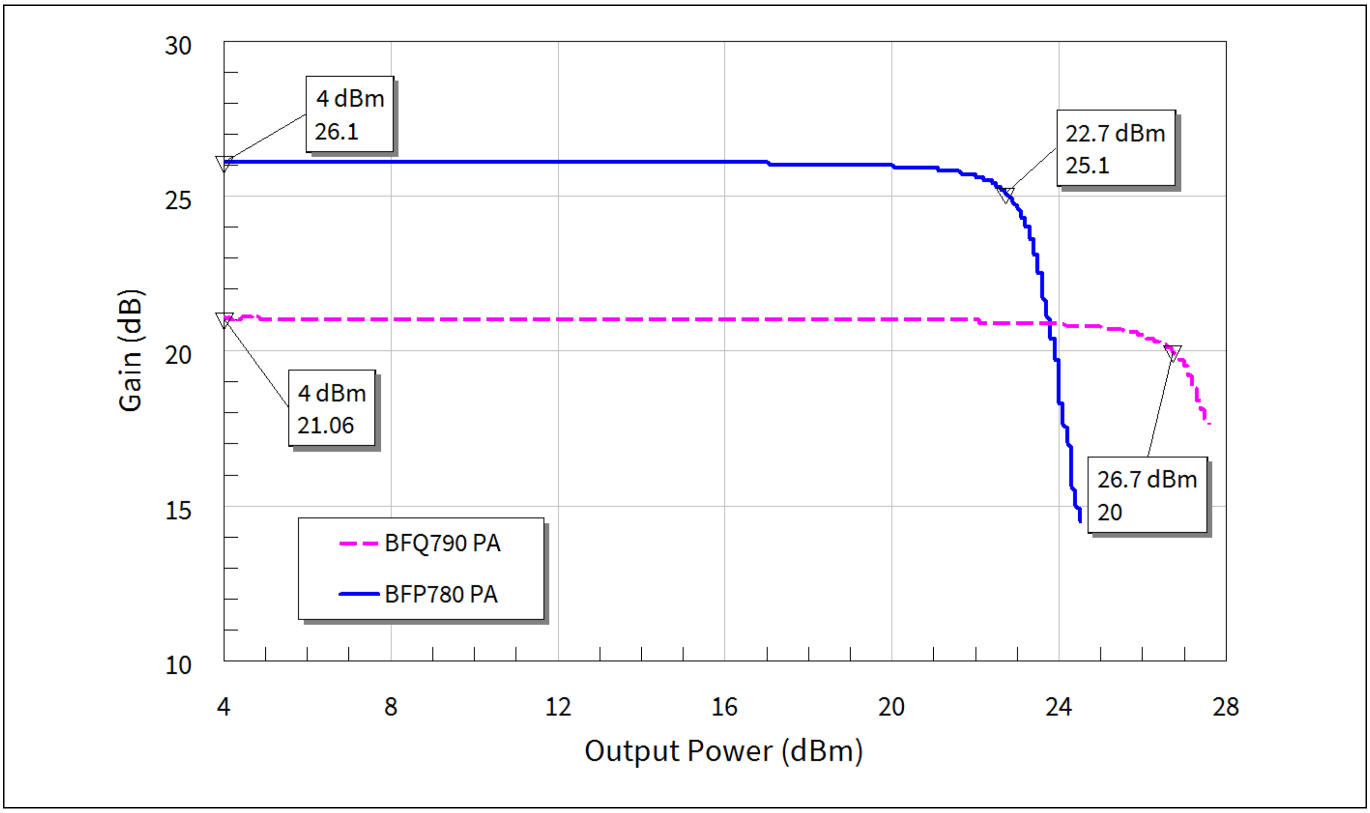

Figure 12 Output 1 dB compression point measurement of the 433 MHz PAs

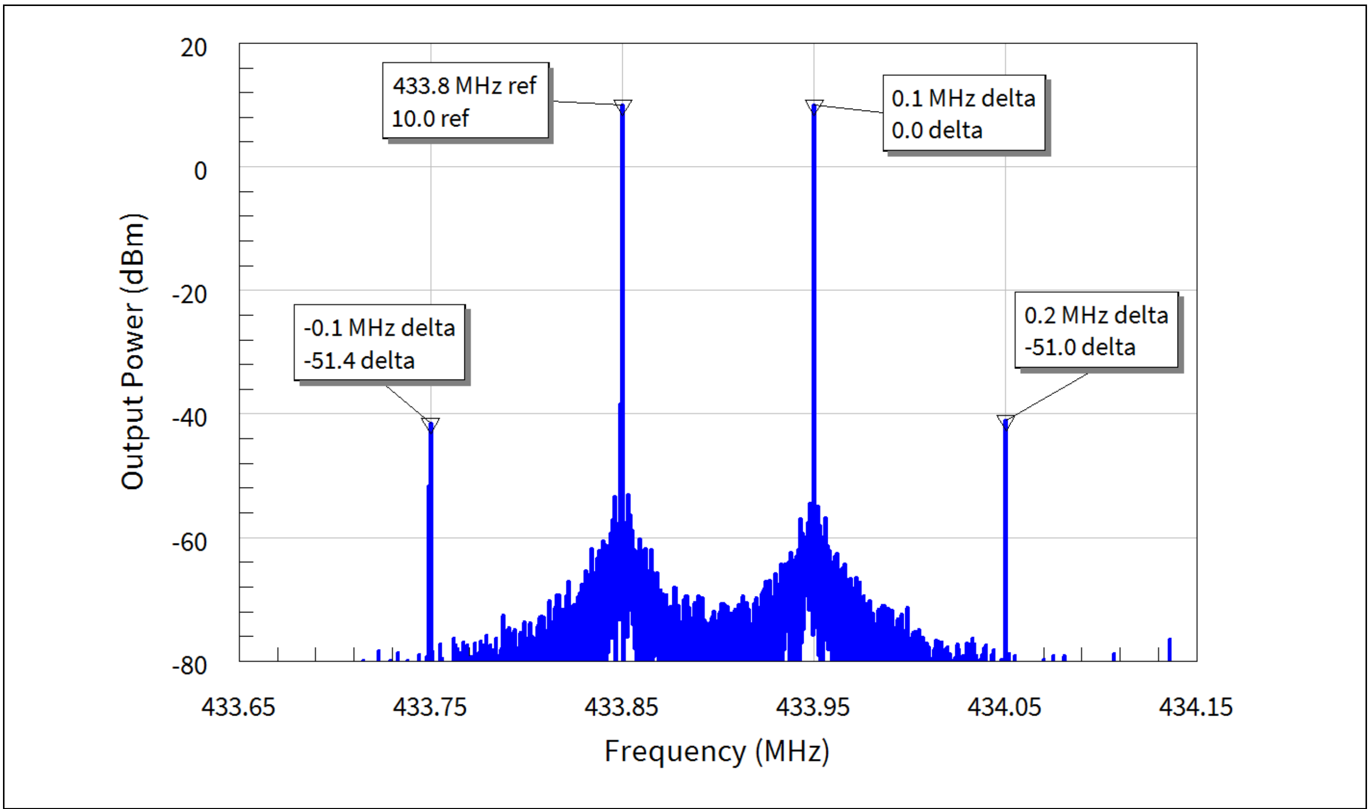

Figure 13 Output third-order intermodulation products of the 433 MHz [BFP780](BFP780) PA

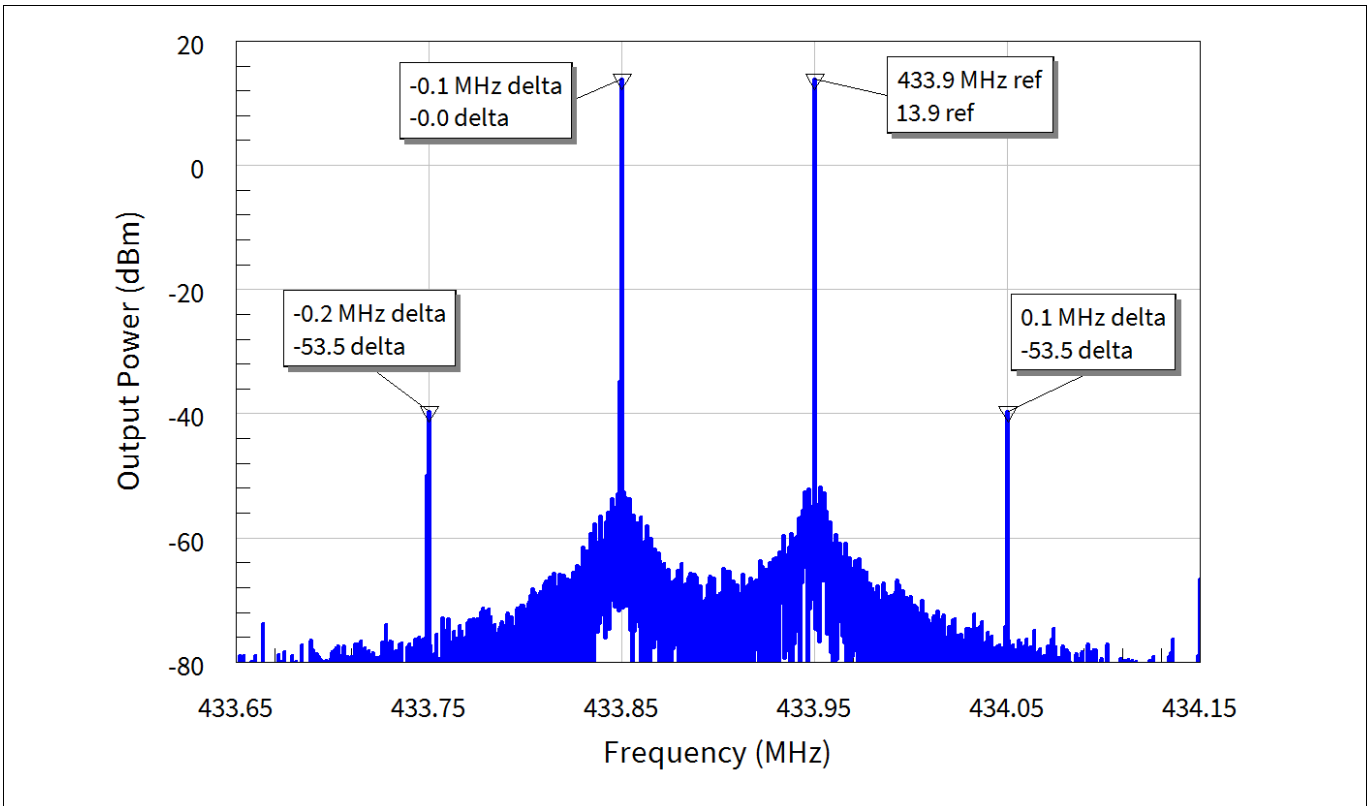

Figure 14 Output third-order intermodulation products of the 433 MHz [BFQ790](BFQ790) PA

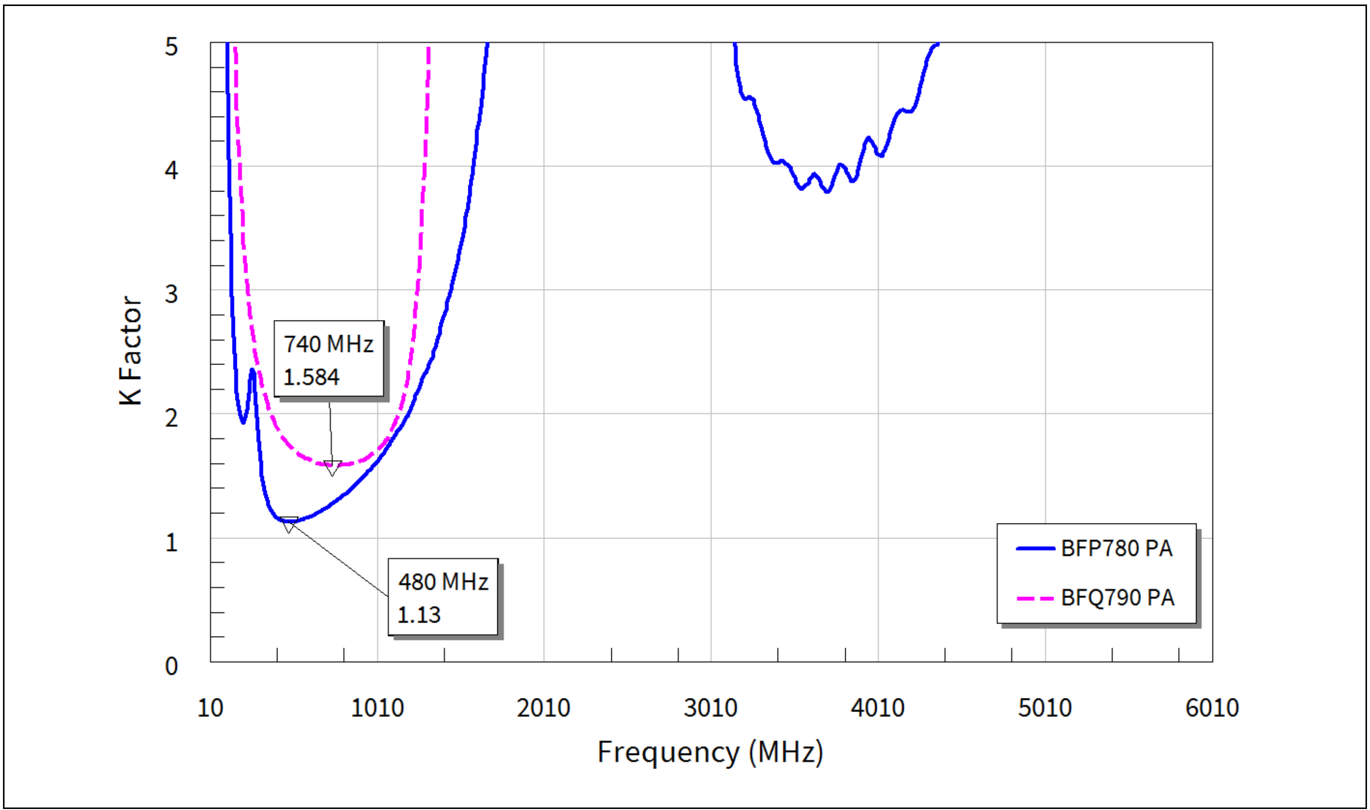

Figure 15 Stability K-factor measurements of the 433 MHz PAs

4 Author

Dr. Jie Fang, staff application engineer of business unit RF and Sensors.

Revision history

Document version	Date of release	Description of changes

Trademarks
All referenced product or service names and trademarks are the property of their respective owners.

Edition 2018-08-23

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference
AN_1808_PL32_1808_165626