BGA855N6 as Low Noise Amplifier for GNSS L5 Band including >=30 dB Rejection Filter for N77/N78/N79 bands

About this document

Scope and purpose

This application note describes Infineon's GNSS MMIC: BGA855N6 as a Low Noise Amplifier for GNSS applications in the frequency range of 1164 MHz – 1214 MHz including rejection filters for frequencies above 3300 MHz.

1. The BGA855N6 is a Silicon Germanium Low Noise Amplifier supporting GNSS applications in the frequency range 1160 MHz – 1300 MHz.
2. The target applications are BDS/ Galileo/ GLONASS/ GPS/ NavIC / QZSS applications in the range of 1164 MHz – 1214 MHz.
3. In this application note, a low pass filter is implemented in front of BGA855N6 to allow lower frequencies pass through while rejecting N77/N78/N79 bands. With two additional external components, the BGA855N6 circuit is able to achieve ≥ 30 dB rejection at N77/N78/N79 bands. The trade-off is a slight reduction in gain and increase in noise figure.
4. Key performance parameters at 1.8 V, 1176 MHz (LQP03T inductor for matching):
   Noise Figure (NF) = 1.00 dB
   Insertion gain = 17.4 dB
   Rejection at N77/N78/N79 bands ≥ 30 dB
   Input return loss = 14 dB
   Output return loss = 15 dB
   Out-of-band IP3 = 12 dBm

Table of Contents

About this document **1**
Table of Contents **2**
List of Tables **3**
1 Introduction of Global Navigation Satellite Systems (GNSSs) **4**
1.1 Global Navigation Satellite Systems (GNSSs) 4
1.2 Out-of-band intermodulation from 4G/5G cellular signals 4
1.3 Key features of GNSS Low Noise Amplifiers 5
2 BGA855N6 Overview **6**
2.1 Features 6
2.2 Key Applications 6
3 Application circuit and performance overview **7**
3.1 Summary of measurement results 7
3.2 Schematics and Bill-of-Materials 10
4 Measurement graphs **11**
5 Evaluation Board and Layout Information **17**
6 Authors **19**
7 References **19**
8 Revision history **19**

List of Figures[1]

Figure 1 Frequency spectrum of GNSS applications 4
Figure 2 BGA855N6 in TSNP-6-10 6
Figure 3 Schematics of the BGA855N6 application circuit 10
Figure 4 Insertion power gain (narrowband) 11
Figure 5 Insertion power gain (wideband) 11
Figure 6 Noise figure (0201 inch LQP03T inductors for matching) 12
Figure 7 Input return loss 12
Figure 8 Output return loss 13
Figure 9 Reverse isolation 13
Figure 10 Stability factor k 14
Figure 11 Input 1dB compression point (f = 1176 MHz, Option A) 14
Figure 12 Input 1dB compression point (f = 1176 MHz, Option B) ..... **Error! Bookmark not defined.**
Figure 13 Out-of-band third-order intermodulation product (Option A, output referred) 15
Figure 14 Out-of-band third-order intermodulation product (Option B, output referred) **Error! Bookmark not defined.**
Figure 15 Out-of-band second-order intermodulation point (Option A, output referred) 15
Figure 16 Out-of-band second-order intermodulation point (Option B, output referred) **Error! Bookmark not defined.**
Figure 17 Inband third-order interception point (Pin = -30dBm, output referred) 16
Figure 18 Evaluation board (overview) 17
Figure 19 Evaluation board (detailed view) 17
Figure 20 PCB layer information 18

List of Tables

Table 1 Electrical characteristics at 1.8 V (at room temperature) 7
Table 2 Electrical characteristics at 2.8 V (at room temperature) 8
Table 3 Electrical characteristics at 1.2 V (at room temperature) 9
Table 4 Bill-of-Materials 10

1) The graphs were generated with the simulation program AWR Microwave Office®.

1 Introduction of Global Navigation Satellite Systems (GNSSs)

1.1 Global Navigation Satellite Systems (GNSSs)

Global Navigation Satellite Systems (GNSSs) are among the mostly commonly in use services in the electronic industry. Today, below GNSS systems are in operation: The United States GPS, the Russian GLobal Orbiting Navigation Satellite System (GLONASS), the Chinese BeiDou Navigation Satellite System (BDS), the European Union Galileo navigation system (Galileo), the Japanese Quasi-Zenith Satellite System (QZSS), and the Indian Regional Navigation Satellite System (IRNSS or NavIC). Main market segments include the GNSS-enabled mobile phones, Personal Navigation Devices (PND), GNSS-enabled portable devices and Internet-of-Things (IoT) devices.

For the GNSS-enabled mobile phones, the main challenges are to achieve high sensitivity and high immunity for safety and emergency reasons against interference from cellular signals and other wireless connectivity signals. The GNSS signals must be received at very low power levels (down to less than -130 dBm) in mobile phones in the vicinity of co-existing high-power cellular and other wireless connectivity signals.

The main challenges for the GNSS-enabled portable devices are to obtain a high system sensitivity for precise detection, and low Time-To-First Fix (TTFF) to quickly locate the device.

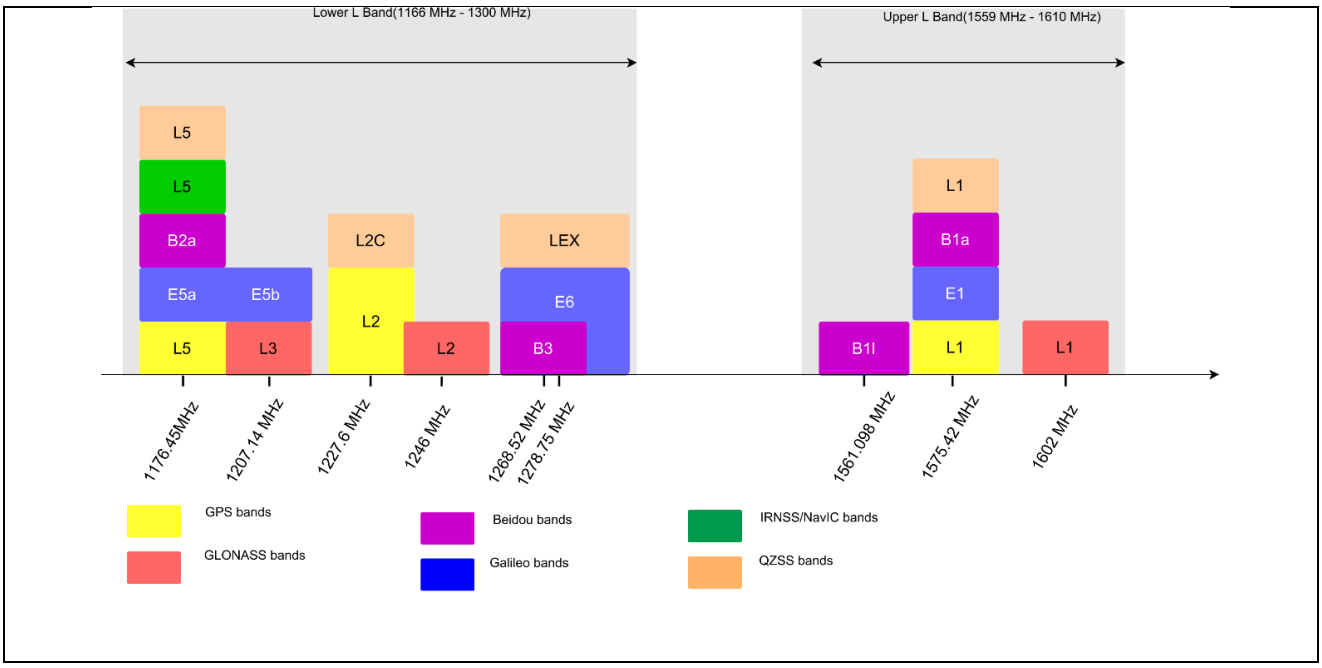

Figure 1 Frequency spectrum of GNSS applications

1.2 Out-of-band intermodulation from 4G/5G cellular signals

The GNSS-enabled devices often operate under co-existing cellular signals. The intermodulation products of cellular signals may fall into the GNSS frequency bands, such cellular signals are called out-of-band (OoB) jammer signals, as they originate from out-of-GNSS-band frequencies.

The 5G cellular system has started launching in recent years. As a by-product, the intermodulation between a few 5G cellular frequency bands and the existing 4G cellular signals fall into the GNSS bands.

For examples, the 2nd order intermodulation (IMD2) product between a 5G N78 signal (f_1 = 3726 MHz) and a LTE Band 1 signal (f_2 = 2550 MHz) may result in below signal:

$f_{IMD2} = f_1 - f_2 = 3726\ MHz - 2550\ MHz = 1176\ MHz$

Under such cases, the above IMD2 product presents a strong interference at GNSS's main operating frequencies.

In this application note, we introduce low pass filter solutions to let the lower frequency pass through while attenuating the 5G N77/N78/N79 signals, and thus reduce the above interference signal to an acceptable range for the GNSS receiver frontend.

1.3 Key features of GNSS Low Noise Amplifiers

Infineon is among the leading suppliers for GNSS Low Noise Amplifiers (LNAs) for navigation applications. The GNSS MMIC LNAs are designed with below features:

Low noise figure and high gain

The power levels of satellite signals received by a GPS/GNSS receiver are as low as -130 dBm. Such systems must be very sensitive. An external LNA with low noise figure and high gain helps to boost the system sensitivity and time to first fix (TTFF) significantly.

High linearity

In modern cell phones, GNSS signals coexist with strong out-of-band interfering cellular signals. The cellular signals can mix to produce intermodulation products in the GNSS receiver frequency band. To enhance interference immunity of the GNSSs, LNAs with high linearity characteristics, e.g. out-of-band IP3, are required.

Low power consumption

Power consumption is an important requirement for GNSS devices that are mainly battery-operated. Infineon's LNAs have an integrated power ON/OFF switch which provides for low power consumption and increased stand-by time for GNSS handsets. Moreover, the latest LNA generation features ultra-low current consumption (e.g. less than 1.5 mA) and the ability to function under 1.2 V. These features make Infineon's LNAs suitable for battery-saving applications such as GNSS-enabled wearable devices.

Please visit www.infineon.com for datasheets, application notes and simulation data of LNA types for GNSS applications.

2 BGA855N6 Overview

2.1 Features

• High insertion power gain: 17.8 dB

• Low noise figure: 0.60 dB

• Low current consumption: 4.8 mA

• High linearity performance IIP3: 0 dBm

• Operating frequencies: 1164 - 1300 MHz

• Supply voltage: 1.1 V to 3.3 V

•Ultra small TSNP-6-10 leadless package (footprint: 0.7 x 1.1 mm^2)

• B9HF Silicon Germanium technology

• RF output internally matched to 50 Ω

• Only one external matching component needed

• 2kV HBM ESD protection (including AI-pin)

• Pb-free (RoHS compliant) package

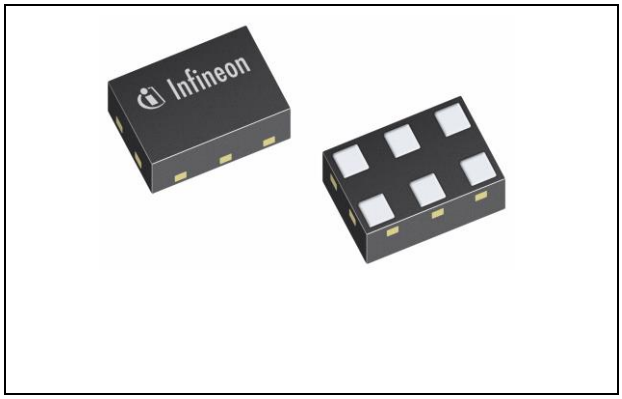

Figure 2 BGA855N6 in TSNP-6-10

2.2 Key Applications

BGA855N6 is designed to enhance GNSS signal sensitivity especially in the lower L bands:

- L2/L5 GPS signals
- E5a/E5b/E6 Galileo signals
- L2/L3 GLONASS signals
- B2/B3 BeiDou signals
- L2C/L5/LEX QZSS signals
- L5 IRNSS/NavIC signals

Please visit the product page of BGA855N6 for more information.

3 Application circuit and performance overview

In this chapter the performance of the application circuit, the schematic and bill-of-materials are presented.

Device: BGA855N6

Application: Low Noise Amplifier for GNSS applications in 1164 MHz – 1214 MHz including rejection filters for N77/N78/N79 bands

PCB marking : M110705

EVB order no.: EVAL BGA855N6 (AN619)

3.1 Summary of measurement results

The performance of the BGA855N6 for GNSS applications is summarized in the following tables.

Table 1 Electrical characteristics at 1.8 V (at room temperature)

Parameter	Symbol	Value			Unit	Comment/Test condition
Frequency range	Freq	1164	1176	1214	MHz	L5 frequency band
DC voltage	V_{CC}		1.8		V	
DC current	I_{CC}		5.0		mA	
Gain	G	17.3	17.4	17.3	dB	
Rejection at N77	$\|G_{3300M}\|$		30		dB	Measured at 3300 MHz, Minimum rejection at N77/N78/N79 bands
Noise Figure	NF	1.00	1.00	1.00	dB	LQP03TN inductors for matching[1]
Input return loss	RL_{in}	13	14	16	dB	
Output return loss	RL_{out}	14	15	17	dB	
Reverse isolation	IRev	24	23	22	dB	
Input P1dB	IP1dB		-13		dBm	f = 1176 MHz
Input IP3	IIP3		8		dBm	Power at input: -30 dBm f_1 = 1176 MHz, f_2 = 1175 MHz
Out-of-band IIM2[2]	OoB IIM2		-122		dBm	f_1 = 2550 MHz, f_2 = 3726 MHz Pin_1= -20 dBm, Pin_2= -20 dBm
Out-of-band OIM2[3]	OoB OIM2		-105		dBm	
Out-of-band IIP3[2]	OoB IIP3		12		dBm	f_1 = 1788 MHz, f_2 = 2400 MHz Pin_1= -20 dBm, Pin_2= -20 dBm
Out-of-band OIM3[3]	OoB OIM3		-66		dBm	
Switching time	$t_{ON/OFF}$		<3		µs	C1 = 100pF
Stability	k		>1		–	Measured up to 10 GHz

Notes: 1) Loss of input line & SMA connectors of 0.07 dB deembedded

2) LNA input referred, OoB IIMx = OoB OIMx - Gain 3) LNA output referred

Table 2 Electrical characteristics at 2.8 V (at room temperature)

Parameter	Symbol	Value			Unit	Comment/Test condition
Frequency range	Freq	1164	1176	1214	MHz	L5 frequency band
DC voltage	V_{CC}		2.8		V	
DC current	I_{CC}		5.1		mA	
Gain	G	17.4	17.5	17.4	dB	
Rejection at N77	$\|G_{3300M}\|$		30		dB	Measured at 3300 MHz, Minimum rejection at N77/N78/N79 bands
Noise Figure	NF	1.00	1.00	1.00	dB	LQP03TN inductors for matching[1]
Input return loss	RL_{in}	14	15	18	dB	
Output return loss	RL_{out}	14	15	17	dB	
Reverse isolation	IRev	24	23	23	dB	
Input P1dB	IP1dB		-11		dBm	f = 1176 MHz
Input IP3	IIP3		9		dBm	Power at input: -30 dBm f_1 = 1176 MHz, f_2 = 1175 MHz
Out-of-band IIM2[2]	OoB IIM2		-124		dBm	f_1 = 2550 MHz, f_2 = 3726 MHz Pin_1= -20 dBm, Pin_2= -20 dBm
Out-of-band OIM2[3]	OoB OIM2		-106		dBm	
Out-of-band IIP3[2]	OoB IIP3		12		dBm	f_1 = 1788 MHz, f_2 = 2400 MHz Pin_1= -20 dBm, Pin_2= -20 dBm
Out-of-band OIM3[3]	OoB OIM3		-67		dBm	
Switching time	$t_{ON/OFF}$		<3		µs	C1 = 100pF
Stability	k		>1		–	Measured up to 10 GHz

Notes: 1) Loss of input line & SMA connectors of 0.07 dB deembedded

2) LNA input referred, OoB IIMx = OoB OIMx - Gain

3) LNA output referred

Table 3 Electrical characteristics at 1.2 V (at room temperature)

Parameter	Symbol	Value			Unit	Comment/Test condition
Frequency range	Freq	1164	1176	1214	MHz	L5 frequency band
DC voltage	V_{CC}		1.2		V	
DC current	I_{CC}		4.9		mA	
Gain	G	17.2	17.3	17.2	dB	
Rejection at N77	$\|G_{3300M}\|$		30		dB	Measured at 3300 MHz, Minimum rejection at N77/N78/N79 bands
Noise Figure	NF	0.95	0.95	1.00	dB	LQP03TN inductors for matching[1]
Input return loss	RL_{in}	12	13	15	dB	
Output return loss	RL_{out}	14	15	17	dB	
Reverse isolation	IRev	24	23	22	dB	
Input P1dB	IP1dB		-15		dBm	f = 1176 MHz
Input IP3	IIP3		7		dBm	Power at input: -30 dBm f_1 = 1176 MHz, f_2 = 1175 MHz
Out-of-band IIM2[2]	OoB IIM2		-121		dBm	f_1 = 2550 MHz, f_2 = 3726 MHz Pin_1= -20 dBm, Pin_2= -20 dBm
Out-of-band OIM2[3]	OoB OIM2		-104		dBm	
Out-of-band IIP3[2]	OoB IIP3		11		dBm	f_1 = 1788 MHz, f_2 = 2400 MHz Pin_1= -20 dBm, Pin_2= -20 dBm
Out-of-band OIM3[3]	OoB OIM3		-65		dBm	
Switching time	$t_{ON/OFF}$		<3		µs	C1 = 100pF
Stability	k		>1		–	Measured up to 10 GHz

Notes: 1) Loss of input line & SMA connectors of 0.07 dB deembedded

2) LNA input referred, OoB IIMx = OoB OIMx - Gain 3) LNA output referred

3.2 Schematics and Bill-of-Materials

The schematic of BGA855N6 for GNSS applications is presented in Figure 3 and its Bill-of-Materials is shown in Table 4.

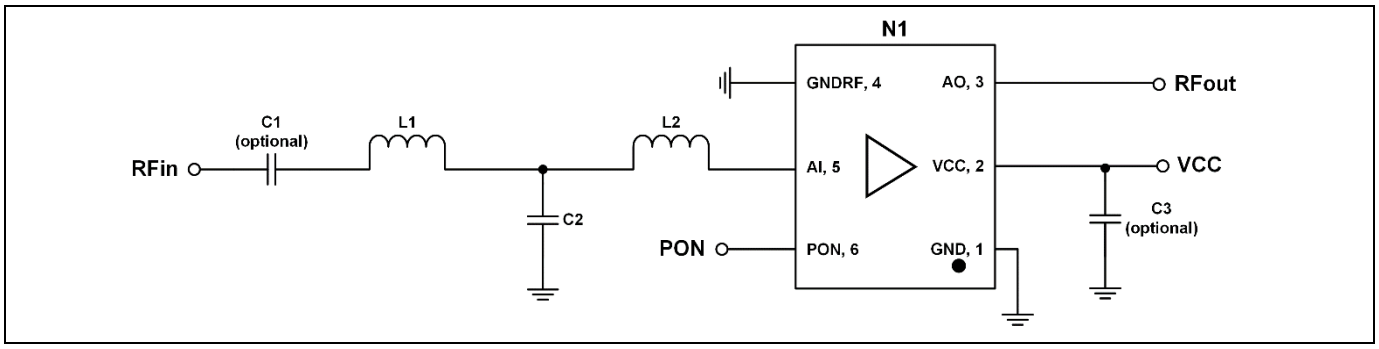

Figure 3 Schematics of the BGA855N6 application circuit

Table 4 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	100	pF	0402/0201	Various	DC block [1)]
C2	2.0	pF	0402/0201	Various	Input matching/low pass filter
C3	1	nF	0402/0201	Various	RF bypass[3)]
L1	3.3	nH	0402/0201	Murata LQW15 / Murata LQP03TN	Input matching/low pass filter
L2	12	nH	0402/0201	Murata LQW15 / Murata LQP03TN	Input matching/low pass filter
N1	BGA855N6	TSNP-6-10		Infineon Technologies	SiGe LNA

Note:

1) *DC block function is not integrated at the input of the BGA855N6. The DC block capacitor C1 is not necessary if the DC block function on the RF input line can be ensured by the previous stage. The value of 100 pF is selected to reduce the ON/OFF switching time.*

2) *When using 0201-inch LQP03TN inductor for matching, C2 of 2.0 pF is used.*

3) *The RF bypass capacitor C3 at the DC power supply pin filters out the power supply noise and stabilizes the DC supply. The RF bypass capacitor C3 is not necessary if a clean and stable DC supply can be ensured.*

4 Measurement graphs

The performance of the application circuit is presented with the following graphs.

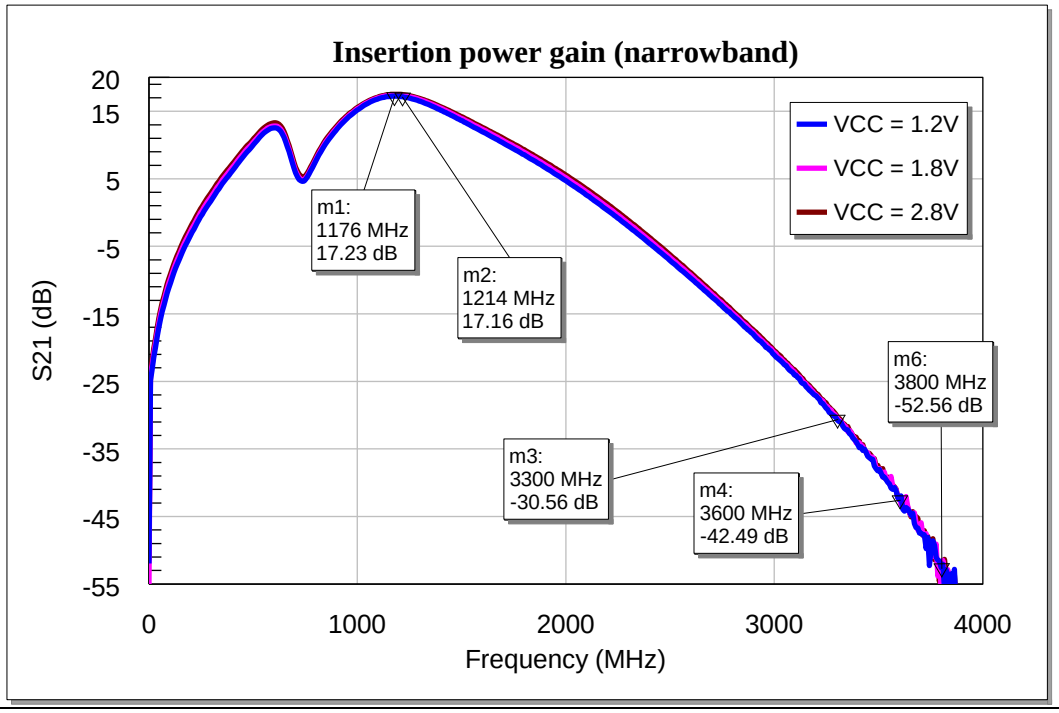

Figure 4 Insertion power gain (narrowband)

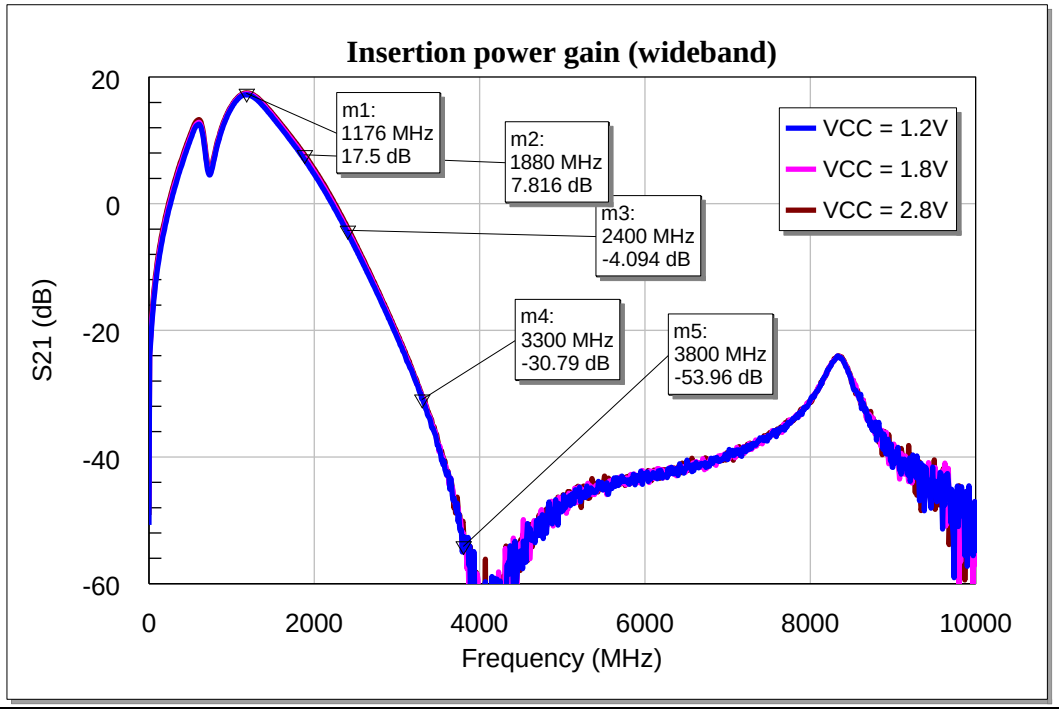

Figure 5 Insertion power gain (wideband)

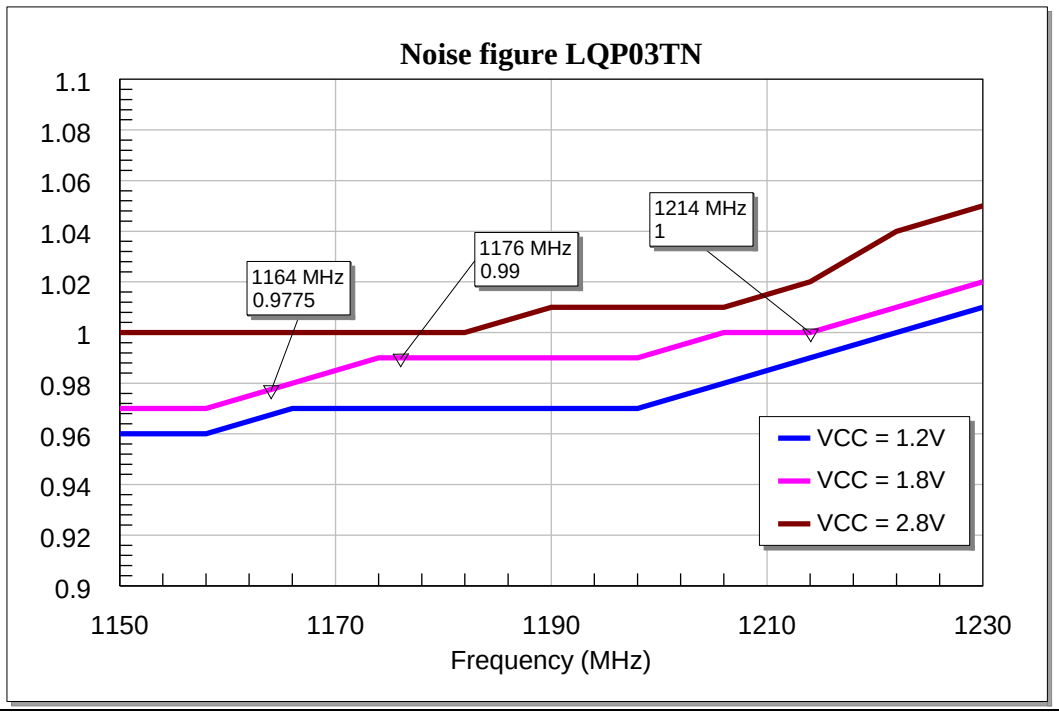

Figure 6 Noise figure (0201 inch LQP03TN inductors for matching)

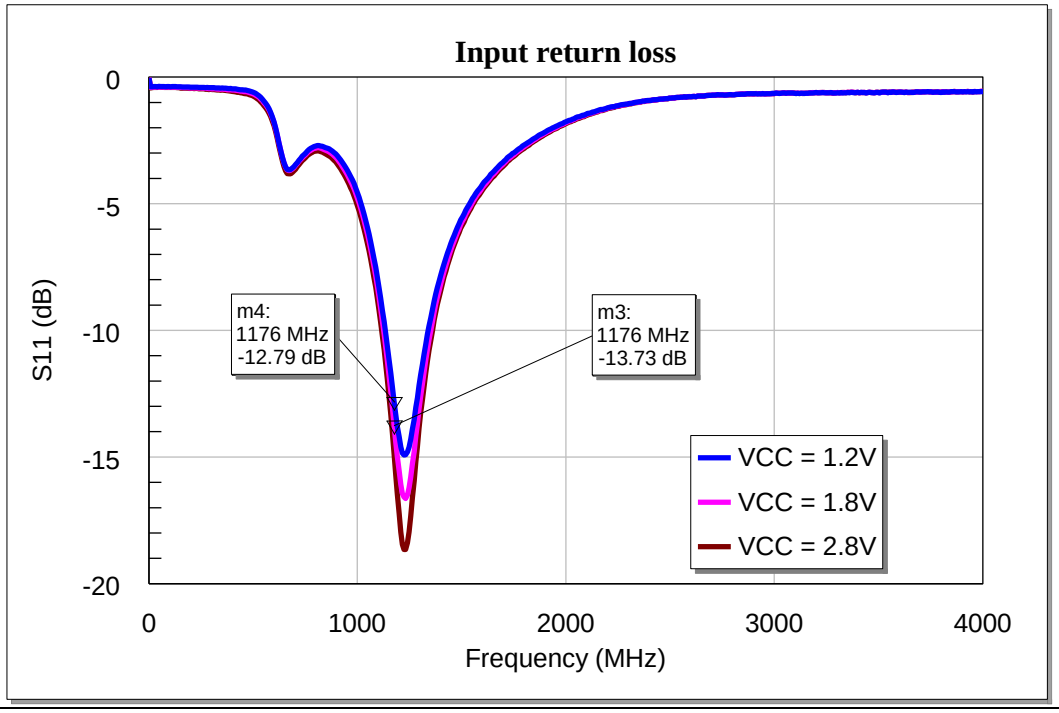

Figure 7 Input return loss

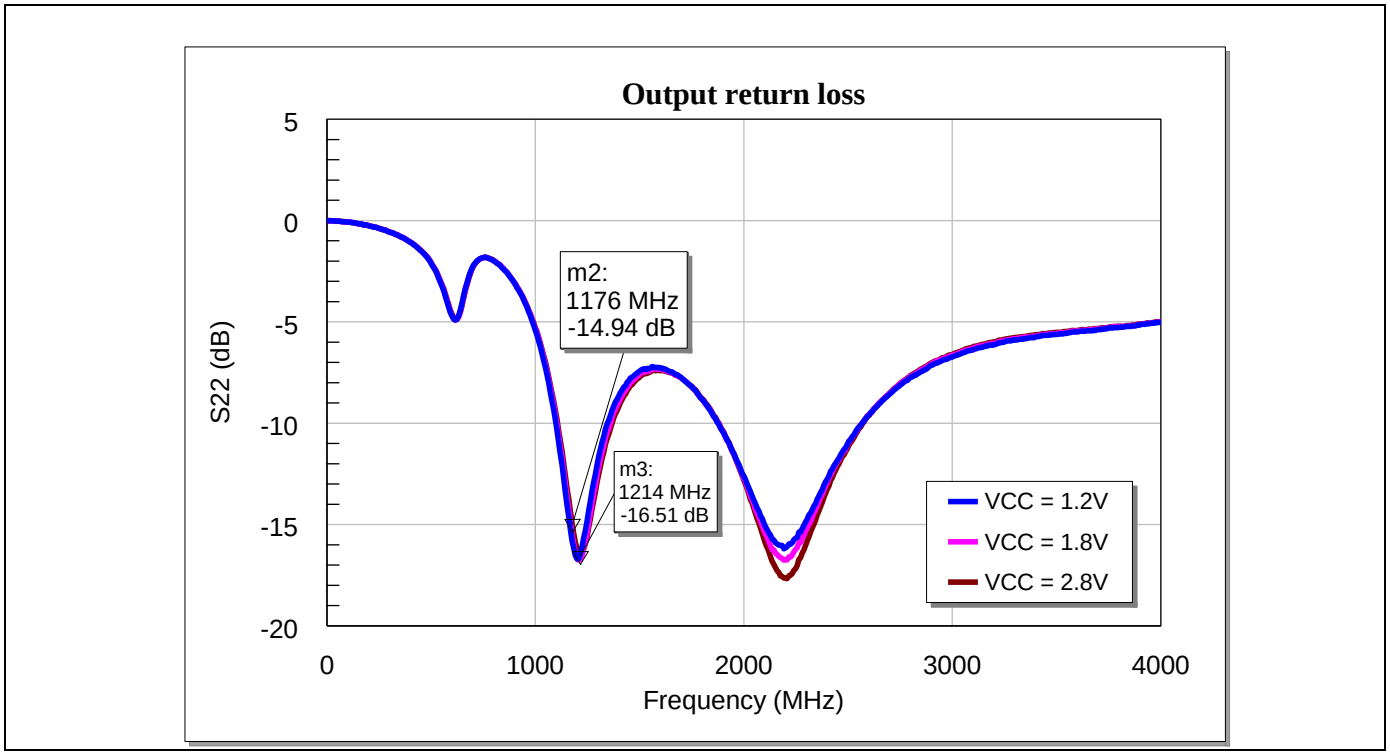

Figure 8 Output return loss

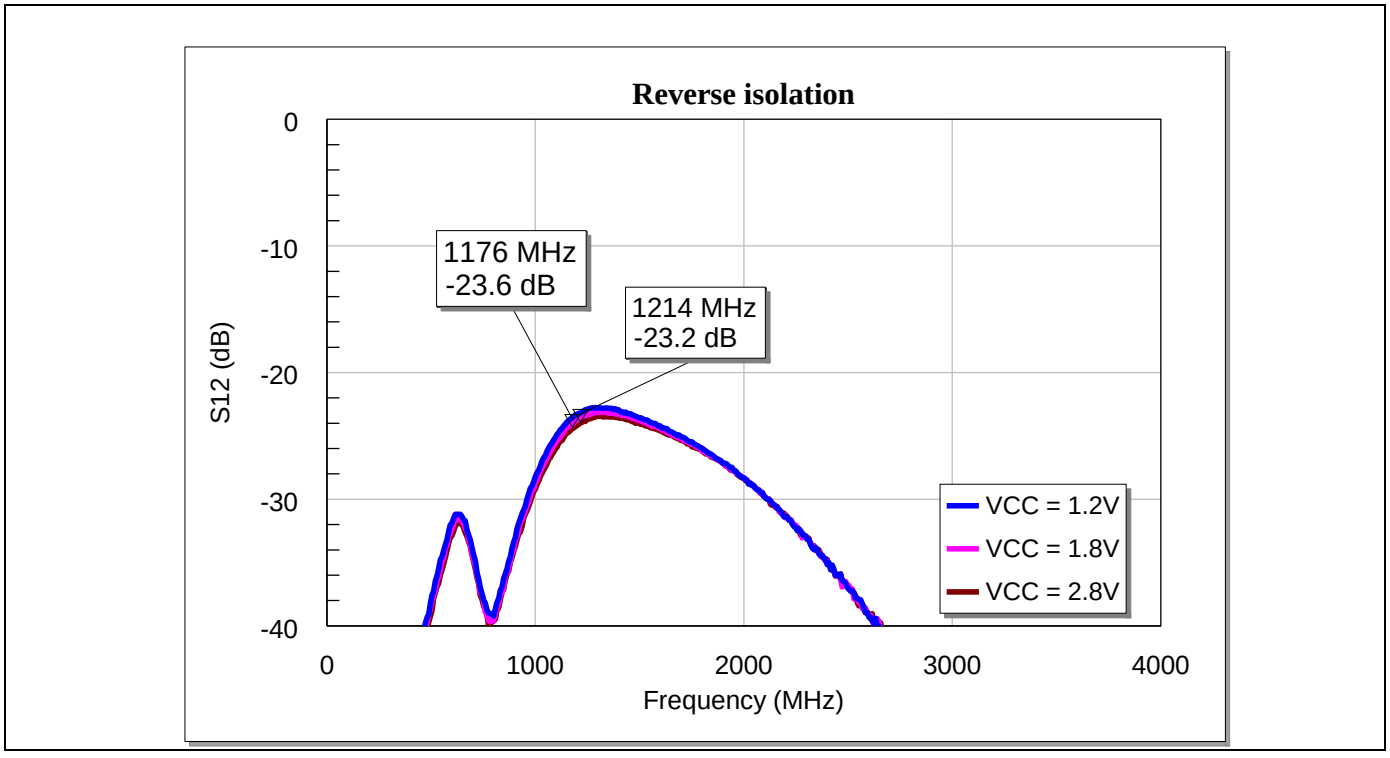

Figure 9 Reverse isolation

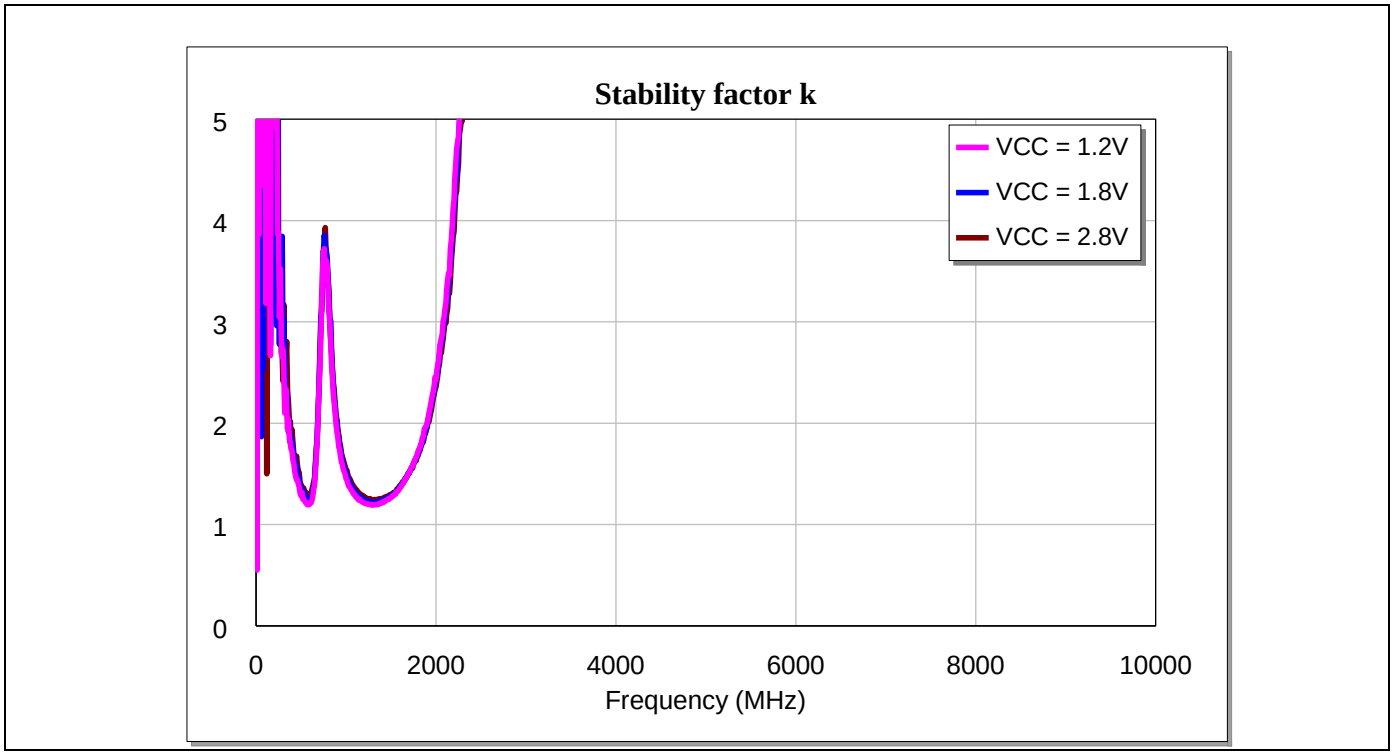

Figure 10 Stability factor k

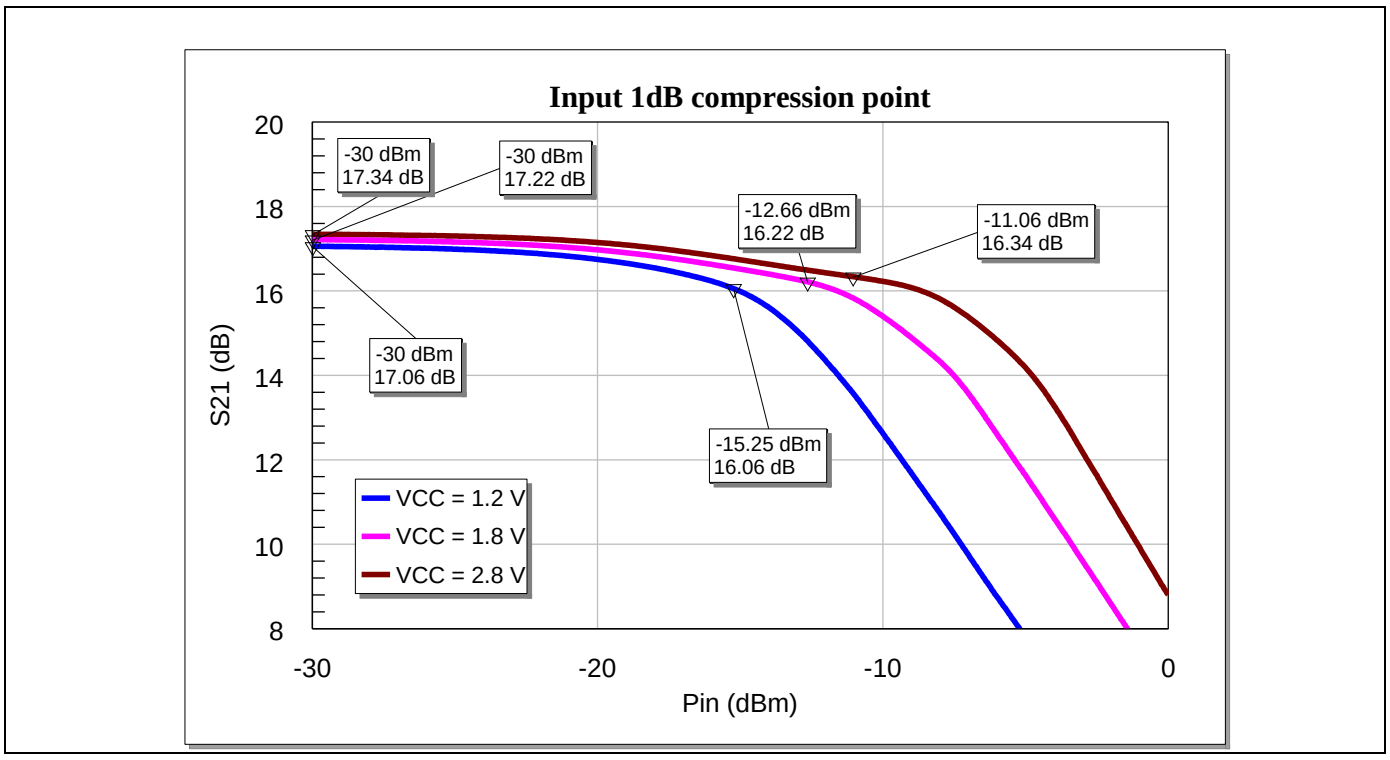

Figure 11 Input 1dB compression point (f = 1176 MHz)

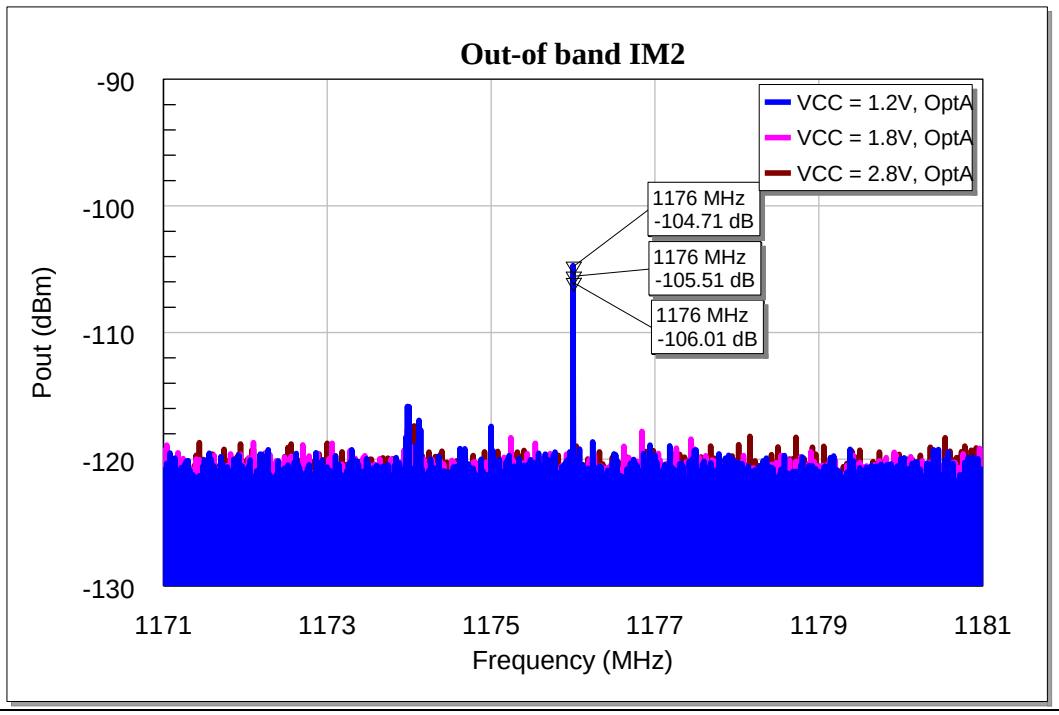

Figure 12 Out-of-band second-order intermodulation point (LNA output referred, Pin = -20 dBm)

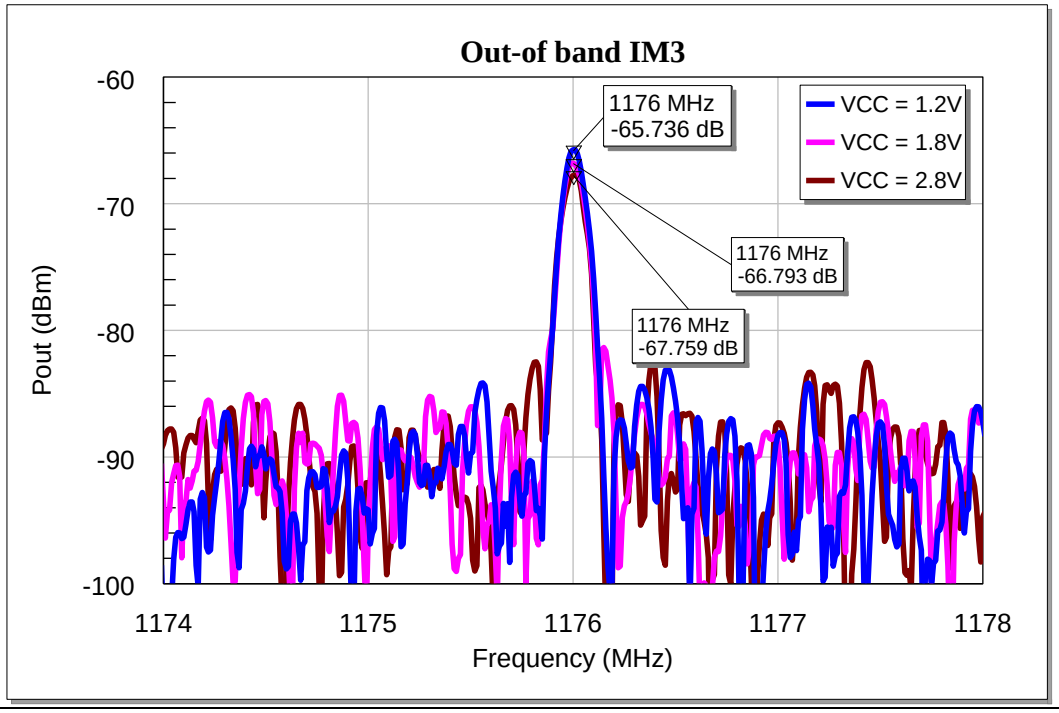

Figure 13 Out-of-band third-order intermodulation product (LNA output referred, Pin = -20 dBm)

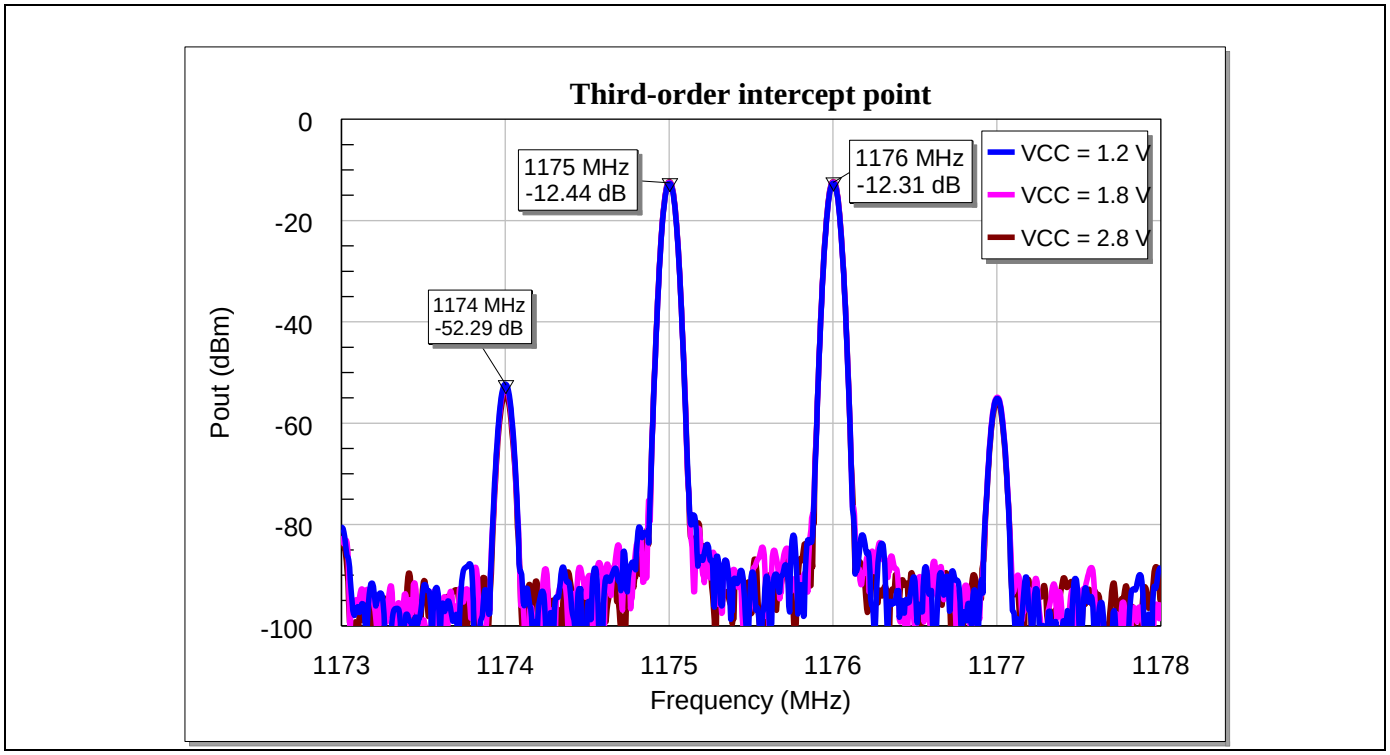

Figure 14 Inband third-order interception point (Pin = -30dBm, output referred)

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: **M110705**

PCB material: **FR4**

ε_r of PCB material: **4.3**

EVB Order No.: **EVAL BGA855N6 (AN619)**

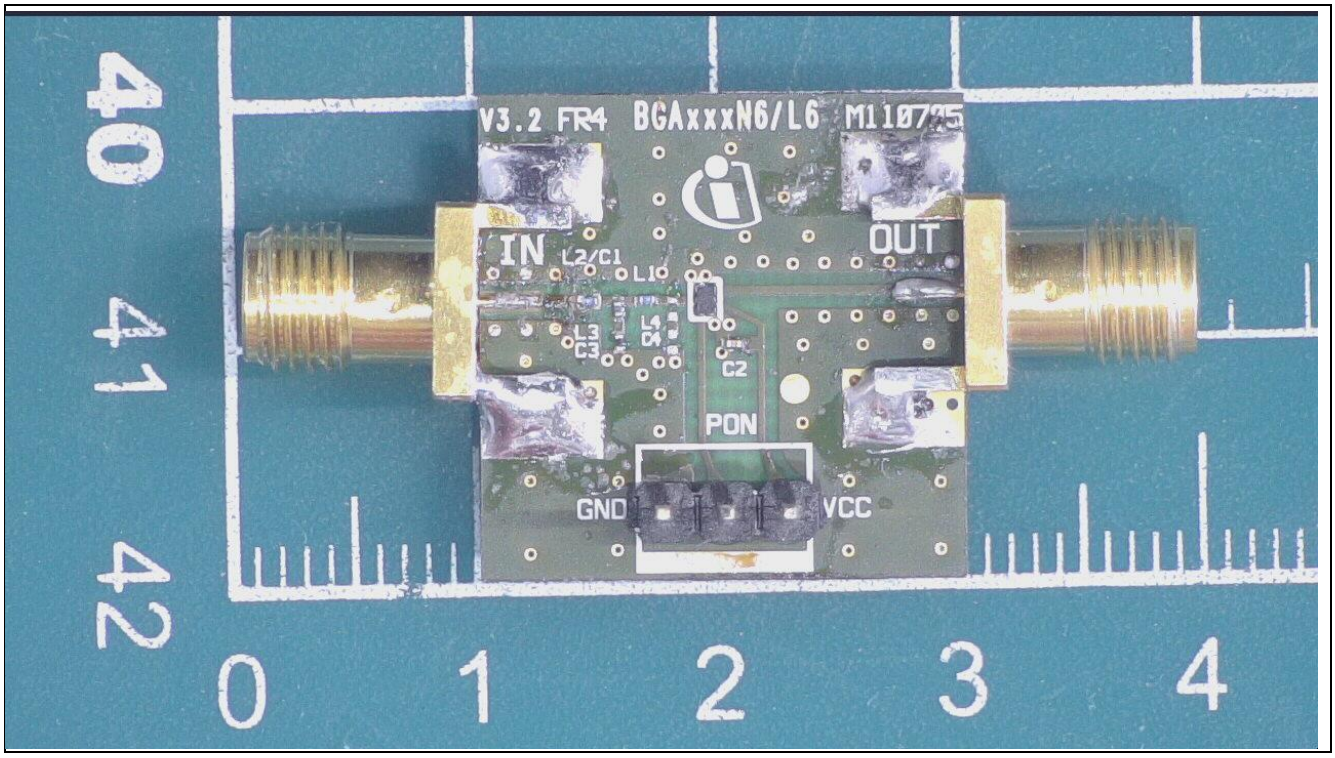

Figure 15 Evaluation board (overview)

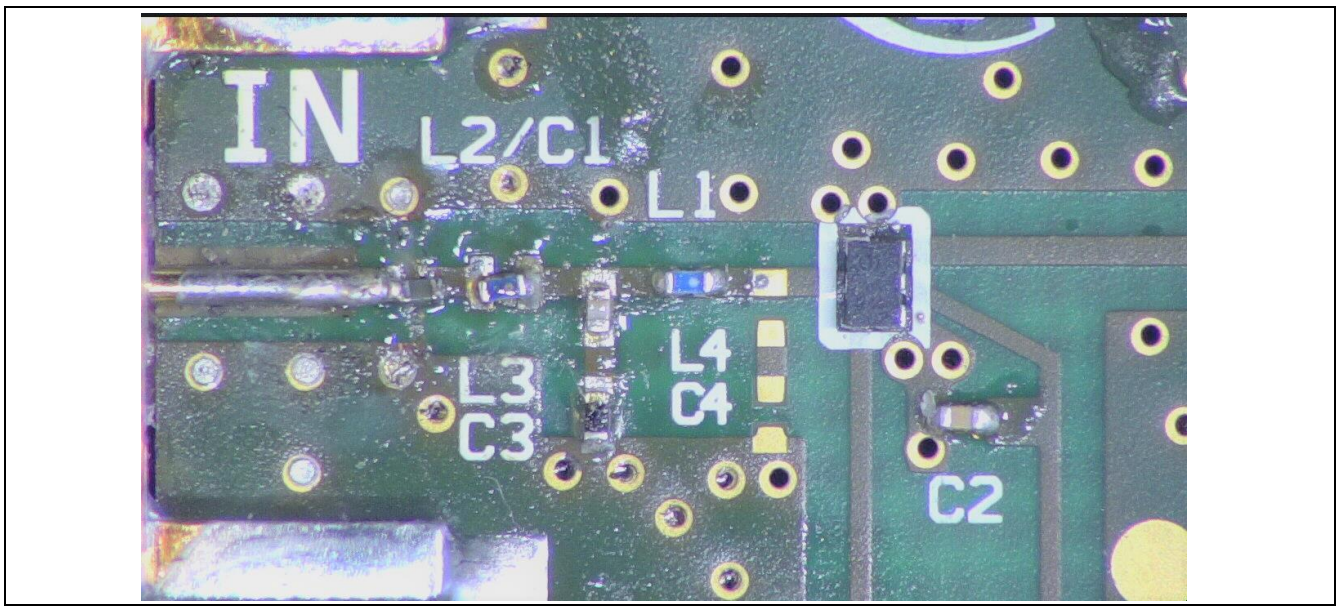

Figure 16 Evaluation board (detailed view)

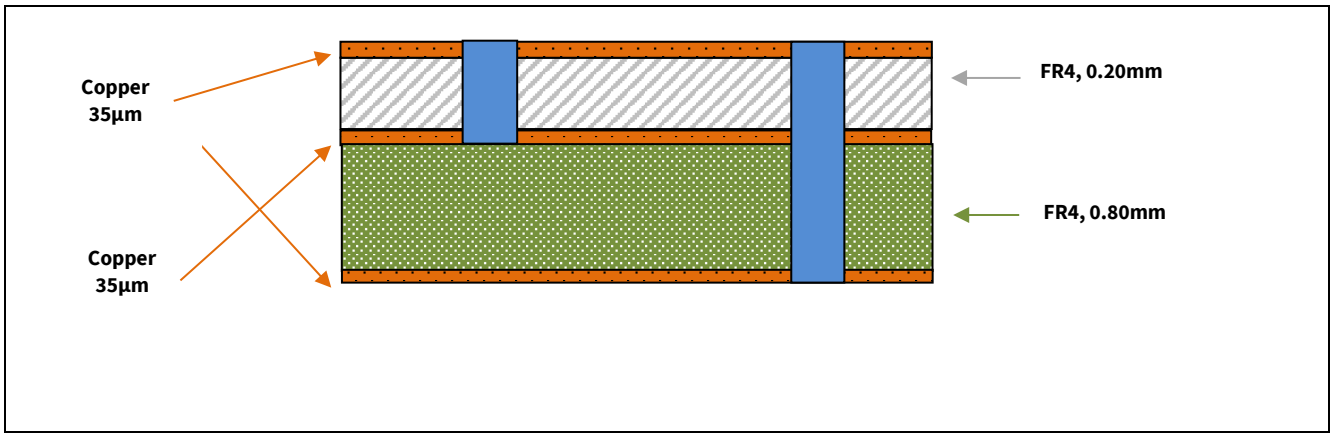

Figure 17 PCB layer information

6 Authors

Xiang Li, Staff Application Engineer of Business Unit “Radio Frequency and Sensors”

Ardit Shulemaja, Working Student of Business Unit “Radio Frequency and Sensors”

7 References

[1] https://en.wikipedia.org/wiki/GPS_signals

[2] https://galileognss.eu/galileo-frequency-bands/

[3] http://www.navipedia.net/index.php/GNSS_signal

[4] https://www.gps.gov/systems/gps/modernization/civilsignals/

8 Revision history

Major changes since the last revision

Page or reference	Description of change

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Edition 2020-10-01

Published by

Infineon Technologies AG

81726 Munich, Germany

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Document reference
AN_1903_PL55_1904_153753

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