BGA855N6 as LNA for GNSS applications in L1/L2/L5 bands from 1166 MHz to 1610 MHz

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 1166 MHz – 1300 MHz and 1559 MHz - 1610 MHz.

The BGA855N6 is a Silicon Germanium Low Noise Amplifier supporting 1160 MHz – 1300 MHz.

1. The target application of this circuit is retuning BGA855N6 to GPS/Galileo/GLONASS/Beidou/QZSS bands in the range of 1166 MHz to 1300 MHz and 1559 MHz to 1610 MHz.

2. In this report, the performance of BGA855N6 is investigated on a Megtron 6 board. Two circuit options are implemented: Option A when using 0201 size components, and Option B when using 0402 size components. Noise figure deviation, when matched with 0201 size LQP03TN inductors, is presented.

3. Key performance parameters at 1.8 V, 1176 MHz:

   Option A
   I_{CC} = 5.0 mA
   Insertion gain = 17.3 dB
   Noise figure = 0.80 dB
   Input return loss = 9 dB
   Output return loss = 13 dB
   Out-of-band IP3 = 3 dBm

   Option B
   I_{CC} = 5.0 mA
   Insertion gain = 17.6 dB
   Noise figure = 0.70 dB
   Input return loss = 8 dB
   Output return loss = 15 dB
   Out-of-band IP3 = 4 dBm

4. Key performance parameters at 1.8 V, 1228 MHz:

   Option A
   I_{CC} = 5.0 mA
   Insertion gain = 17.3 dB
   Noise figure = 0.80 dB
   Input return loss = 10 dB
   Output return loss = 16 dB

   Option B
   I_{CC} = 5.0 mA
   Insertion gain = 17.6 dB
   Noise figure = 0.70 dB
   Input return loss = 10 dB
   Output return loss = 16 dB

5. Key performance parameters at 1.8 V, 1575 MHz:

   Option A
   I_{CC} = 5.0 mA
   Insertion gain = 15.4 dB
   Noise figure = 0.80 dB
   Input return loss = 10 dB
   Output return loss = 17 dB
   Out-of-band IP3 = 12 dBm

   Option B
   I_{CC} = 5.0 mA
   Insertion gain = 15.7 dB
   Noise figure = 0.70 dB
   Input return loss = 10 dB
   Output return loss = 14 dB
   Out-of-band IP3 = 10 dBm

Table of Contents

List of Figures[1]

List of Tables

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: GPS, GLONASS, BDS, Galieo, QZSS, and 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.

Traditionally, positioning service are through the main GNSS bands in the upper L band from 1559 MHz to 1610 MHz. Recently, GNSS applications in the lower L bands, ranging from 1164 MHz to 1300 MHz, have started to emerge into civil use. For example, the GPS L5 band hosts a civilian safety-of-life signal, and is intended to provide a means of radio navigation secure and robust enough for life-critical applications, such as aircraft precision approach guidance. The GPS L2 band has been used for high-precision location navigation.

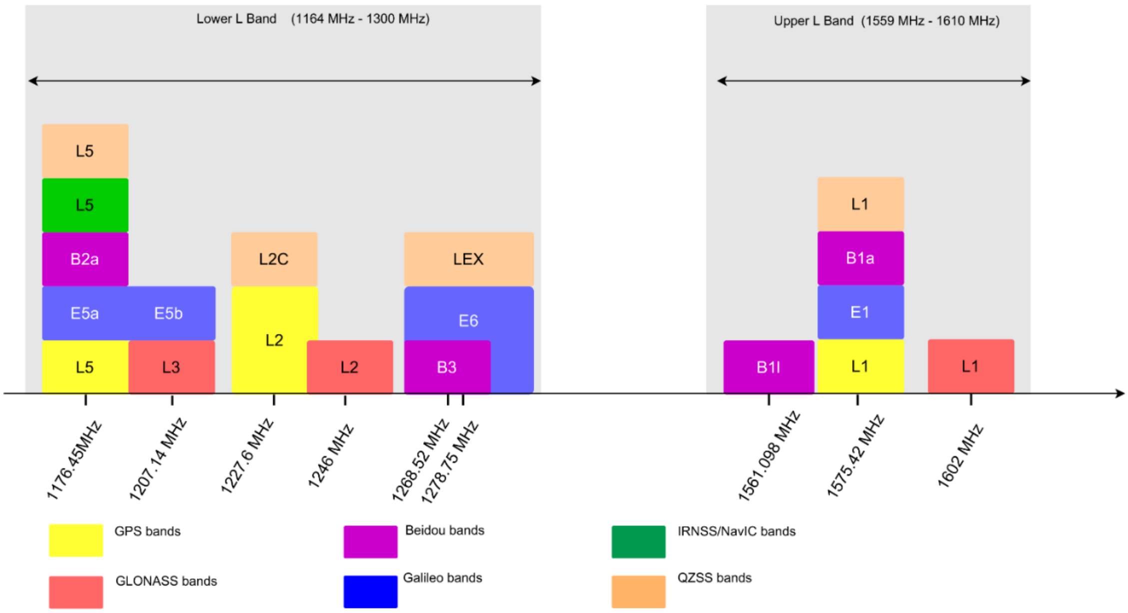

Figure 1 Frequency Allocation GNSS Systems, Upper L Bands and Lower L Bands

1.2 Dualband GNSS Solutions

As GNSS chipset suppliers have been developing chipsets which support both upper L bands (e.g. L1 band) and lower L bands (e.g. L5 band), RF designers have investigated the dualband concept for GNSS RF frontend.

For example, one antenna is placed for receiving signals both from the upper L bands, and the lower L bands. The circuit then passes through band pass filters which supports both the higher L and lower L bands, and a dualband LNA to enhance the receiving path's signal-to-noise ratio (SNR). Such dualband solution benefits from compact board design and cost saving, and is an alternative solution to the single band concepts.

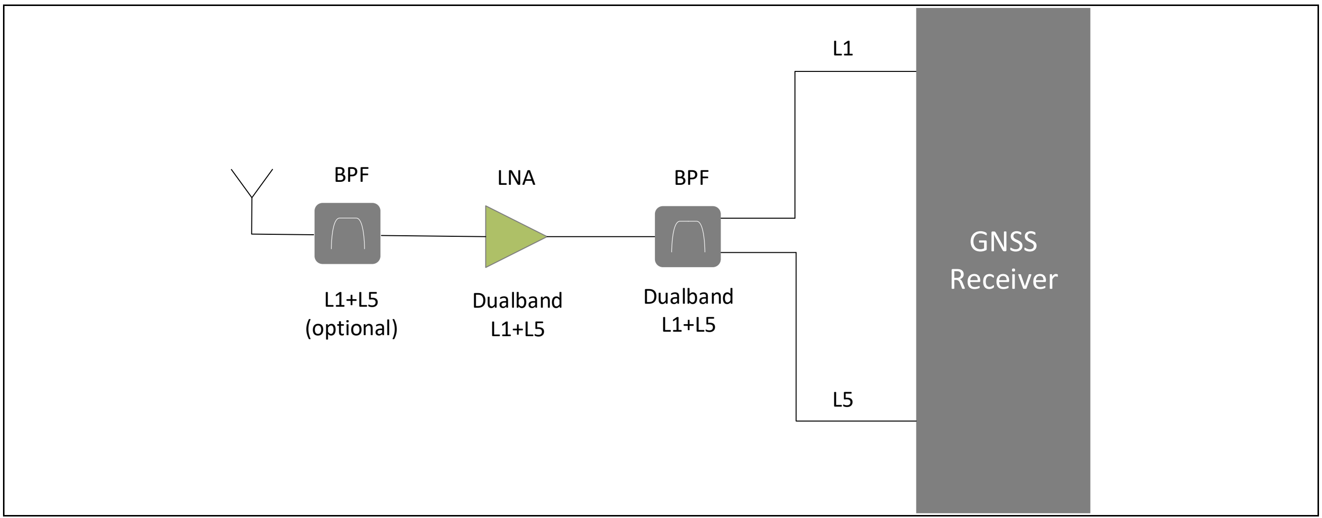

Figure 2 **Application Diagram: Receiver Frontend of the Global Navigation Satellite System**

1.3 Key challenges of modern GNSS reception

This section summarizes the main technical challenges for GNSS-enabled mobile devices.

1.3.1 Noise figure degradation due to weak incoming signal and high-power jammer signal

The GNSS satellite signal transmits at an extremely low power level of about -130 dBm. High-power jammer signals can leak into the GNSS receiver and affect the receiver's sensitivity by overdriving the receiver's LNA. This presents a major challenge to RF FE designers to maintain the receiver's sensitivity to weak incoming GNSS signals.

1.3.2 Out-of-band interference

In a cell phone, GNSS and other wireless functions coexist in a compact area. Coupling from other wireless transceivers to the GNSS receive path results in intermixing of high-frequency signals into GNSS RF FE, such as intermodulation between LTE band 2 and band 3 signals, and between the 5G NR band N77 and LTE band 3 signals, etc. Such intermodulation products introduce strong jammer signals to the GNSS receiver.

1.4 BGA855N6 Overview

- 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 mm2)
- B9HF Silicon Germanium technology
- RF output internally matched to 50 Ohm
- Only one external matching component needed
- 2kV HBM ESD protection (including AI-pin)
- Pb-free (RoHS compliant) package

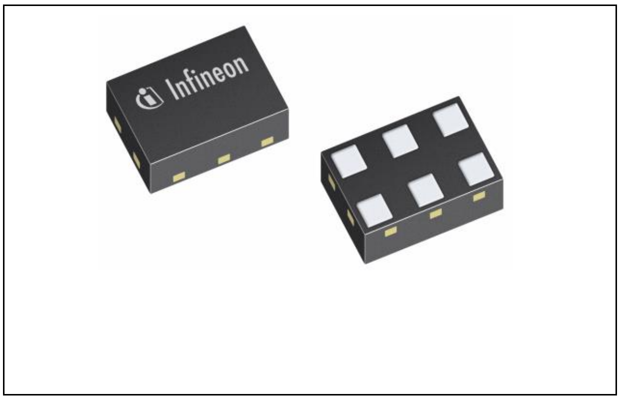

Figure 3 BGA855N6 in TSNP-6-10

1.5 Key Applications of BGA855N6

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.

2 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 L1/L2 /L5 bands from 1166 MHz to 1610 MHz

EVB Order No.: EVAL BGA855N6 (AN596)

2.1 Summary of Measurement Results

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

Table 1 Electrical characteristics at T_A = 25°C, V_{CC} = 1.8 V

Parameter	Symbol	Value						Unit	Comment/Test Condition
DC Voltage	V_{CC}	1.8						V	
Option	O	Option A			Option B			--	
DC Current	I_{CC}	5.0			5.0			mA	
Frequency	Freq	1176	1228	1575	1176	1228	1575	MHz	B1/E1/L1 center frequencies
Gain	G	17.3	17.3	15.4	17.6	17.6	15.7	dB	
Noise figure	NF	0.80	0.80	0.80	0.70	0.70	0.70	dB	Loss of input line of 0.04 dB is deembedded[1)]
Input Return Loss	RL_{IN}	9	10	10	8	10	10	dB	
Output Return Loss	RL_{OUT}	13	16	17	15	16	14	dB	
Reverse Isolation	I_{REV}	23	23	21	22	22	21	dB	
Input P1dB	IP_{1dB}	-13	-12	-7	-12	-12	-7	dBm	
Input IP3	IIP3	2			-2			dBm	Power @ Input: -30 dBm f1 =1575 MHz f2= 1576 MHz
Out-of-band Input IP3	Oob_IIP3	3			4			dBm	Power @ input: -20 dBm f1 = 1785 MHz, f2 = 2401 MHz, Oob_IM3 measured @ 1169 MHz
Out-of-band Output IM3	Oob_OIM3	-49			-50			dBm	
Out-of-band Input IP3	Oob_IIP3	12			10			dBm	Power @ input: -20 dBm f1 =1712 MHz, f2= 1850 MHz Oob_IM3 measured @ 1574 MHz
Out-of-band Output IM3	Oob_OIM3	-68			-65			dBm	
Out-of-band Input IP2	Oob_IIP2	2			1			dBm	Power @ input: -20 dBm f1 =825 MHz , f2= 2400 MHz Oob_IM2 measured @ 1575 MHz
Out-of-band Output IM2	Oob_OIM2	-42			-41			dBm	
Stability	k	>1						--	Measured up to 10 GHz

Table 2 Electrical characteristics at T_A = 25°C, V_{CC} = 2.8 V

Parameter	Symbol	Value						Unit	Comment/Test Condition
DC Voltage	V_{CC}	2.8						V	
Option	O	Option A			Option B			--	
DC Current	I_{CC}	5.5			5.5			mA	
Frequency	Freq	1176	1228	1575	1176	1228	1575	MHz	B1/E1/L1 center frequencies
Gain	G	17.4	17.4	15.6	17.7	17.7	15.7	dB	
Noise figure[1)]	NF	0.80	0.80	0.80	0.70	0.70	0.70	dB	Loss of input line of 0.04 dB is deembedded[1)]
Input Return Loss	RL_{IN}	9	11	11	9	10	10	dB	
Output Return Loss	RL_{OUT}	13	16	18	14	17	15	dB	
Reverse Isolation	I_{REV}	24	23	22	23	22	21	dB	
Input P1dB	IP_{1dB}	-13	-11	-4	-11	-11	-4	dBm	
Input IP3	IIP3	3			-1			dBm	Power @ Input: -30 dBm f1 =1575 MHz f2= 1576 MHz
Out-of-band Input IP3	Oob_IIP3	4			4			dBm	Power @ input: -20 dBm f1 = 1785 MHz, f2 = 2401 MHz, Oob_IM3 measured @ 1169 MHz
Out-of-band Output IM3	Oob_OIM3	-50			-50			dBm	
Out-of-band Input IP3	Oob_IIP3	11			10			dBm	Power @ input: -20 dBm f1 =1712 MHz, f2= 1850 MHz Oob_IM3 measured @ 1574 MHz
Out-of-band Output IM3	Oob_OIM3	-66			-65			dBm	
Out-of-band Input IP2	Oob_IIP2	2			1			dBm	Power @ input: -20 dBm f1 =825 MHz , f2= 2400 MHz Oob_IM2 measured @ 1575 MHz
Out-of-band Output IM2	Oob_OIM2	-42			-41			dBm	
Stability	k	>1						--	Measured up to 10 GHz

Table 3 Electrical characteristics at T_A = 25°C, V_{CC} = 1.2 V

Parameter	Symbol	Value						Unit	Comment/Test Condition
DC Voltage	V_{CC}	1.2						V	
Option	O	Option A			Option B			--	
DC Current	I_{CC}	4.6			4.6			mA	
Frequency	Freq	1176	1228	1575	1176	1228	1575	MHz	B1/E1/L1 center frequencies
Gain	G	17.0	17.0	15.0	17.4	17.4	15.2	dB	
Noise figure	NF	0.80	0.80	0.80	0.70	0.70	0.70	dB	Loss of input line of 0.04 dB is deembedded

Table 3 Electrical characteristics at T_A = 25°C, V_{CC} = 1.2 V

Parameter	Symbol	Value						Unit	Comment/Test Condition
Input Return Loss	RL_{IN}	8	9	9	8	9	9	dB	
Output Return Loss	RL_{OUT}	13	16	16	15	16	14	dB	
Reverse Isolation	I_{REV}	23	22	21	22	22	21	dB	
Input P1dB	IP_{1dB}	-17	-17	-11	-16	-16	-10	dBm	
Input IP3	IIP3	1			-2			dBm	Power @ Input: -30 dBm f1 =1575 MHz f2= 1576 MHz
Out-of-band Input IP3	Oob_IIP3	3			3			dBm	Power @ input: -20 dBm f1 = 1785 MHz, f2 = 2401 MHz, Oob_IM3 measured @ 1169 MHz
Out-of-band Output IM3	Oob_OIM3	-48			-49			dBm	
Out-of-band Input IP3	Oob_IIP3	12			10			dBm	Power @ input: -20 dBm f1 =1712 MHz, f2= 1850 MHz Oob_IM3 measured @ 1574 MHz
Out-of-band Output IM3	Oob_OIM3	-69			-65			dBm	
Out-of-band Input IP2	Oob_IIP2	1			0			dBm	Power @ input: -20 dBm f1 =825 MHz, f2= 2400 MHz Oob_IM2 measured @ 1575 MHz
Out-of-band Output IM2	Oob_OIM2	-41			-40			dBm	
Stability	k	>1						--	Measured up to 10 GHz

2.2 Schematics and Bill-of-Materials

The schematic of BGA855N6 for GNSS applications is presented in Figure 4 and its bill-of-materials is shown in Table 4. The only difference between Option A and B is a different inductor value.

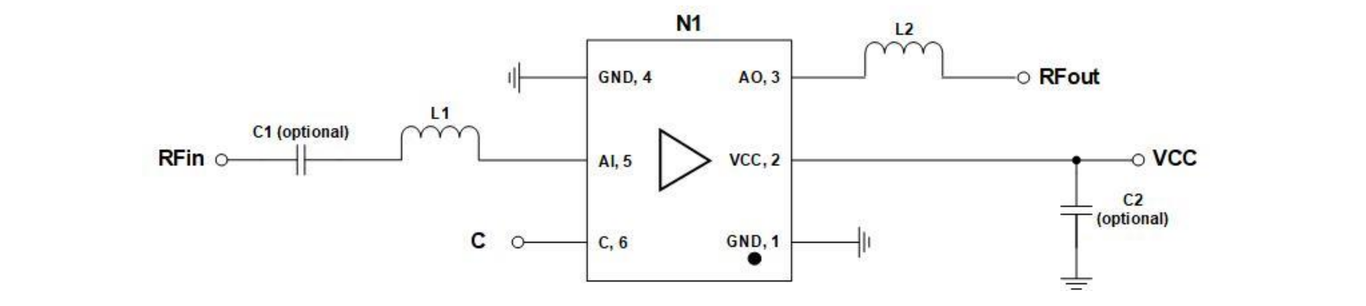

Figure 4 Schematics of the BGA855N6 Application Circuit (Option A/B)

Table 4 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	1	nF	0402/0201	Various	DC block (optional)
C2	≥ 1	nF	0402/0201	Various	RF bypass (optional)
L1	8.2[A)]	nH	0201	Murata LQP03TN	Input Matching
L1	9.1[B)]	nH	0402	Murata LQW15	Input Matching
L2	2.4	nH	0402/0201	Murata LQW15 / Murata LQP03TN	Output Matching
N1	BGA855N6	TSNP-6-10		Infineon Technologies	SiGe LNA

Note: *DC block function is NOT integrated at input of BGA855N6. The DC block might be realized with pre-filter in GNSS applications.*

The RF bypass capacitor C2 at the DC power supply pin filters out the power supply noise and stabilizes the DC supply. The C2 is not necessary if a clean and stable DC supply can be ensured.

A) Circuit Option A

B) Circuit Option B

3 Measurement Graphs

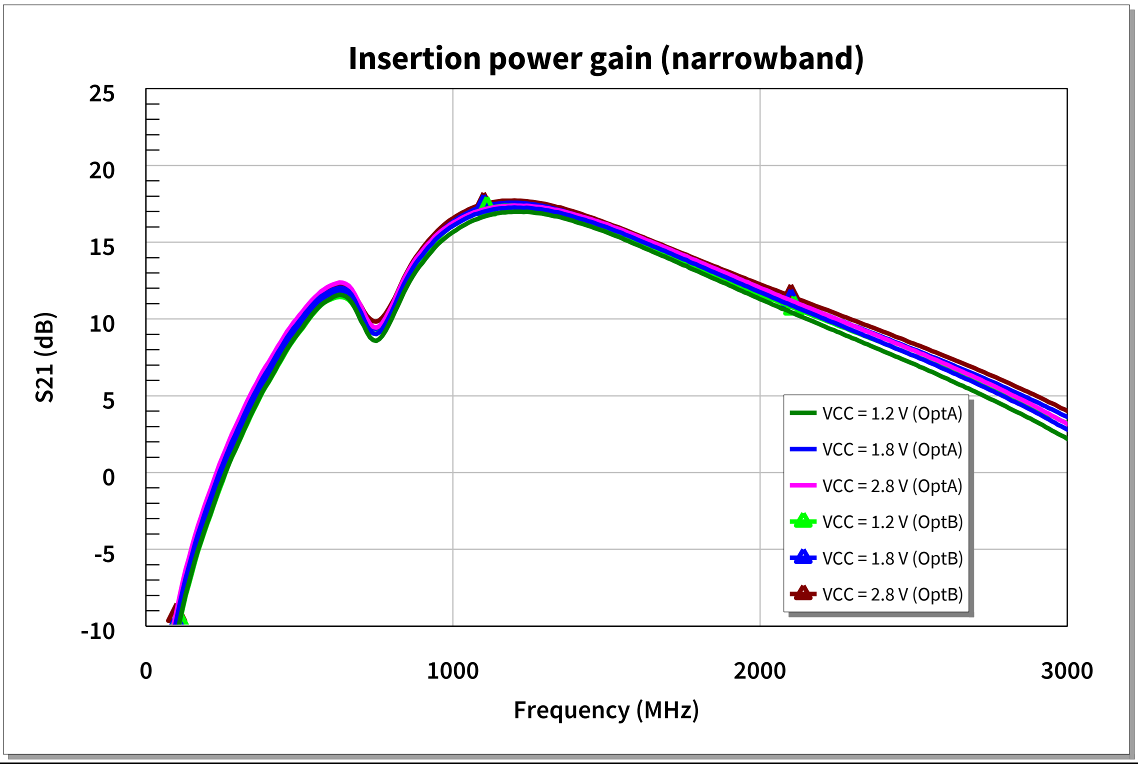

Figure 5 Insertion power gain (narrowband)

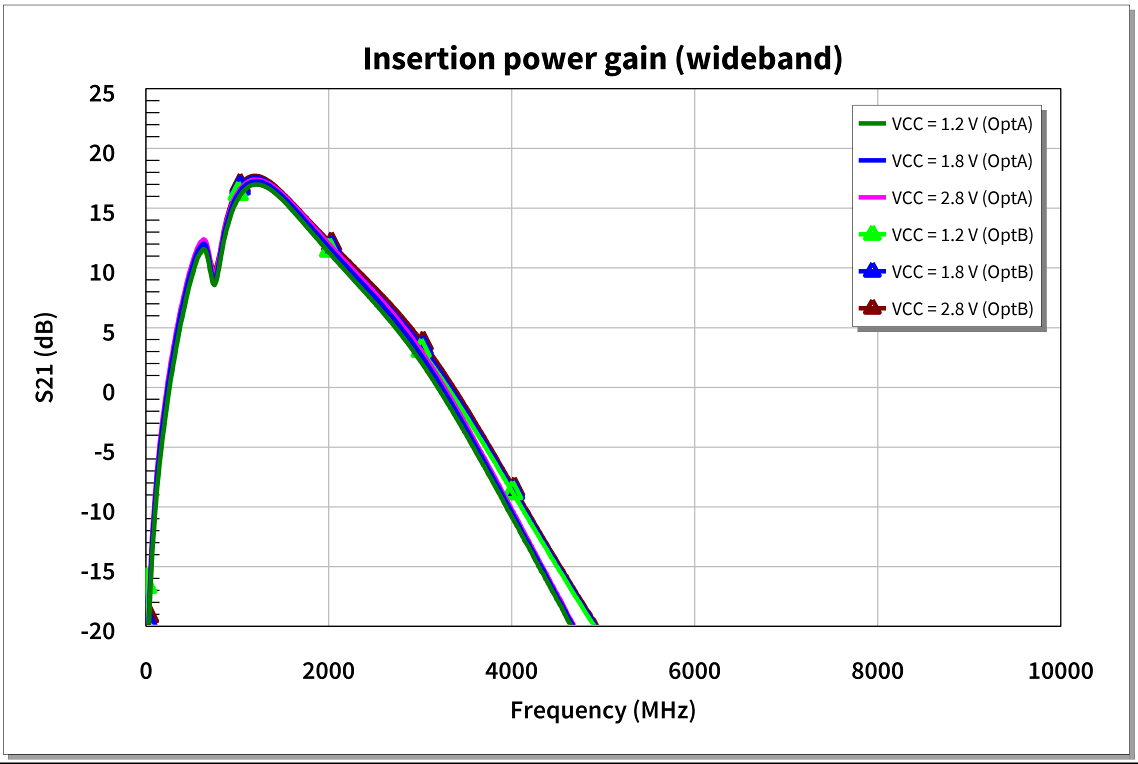

Figure 6 Insertion power gain (wideband)

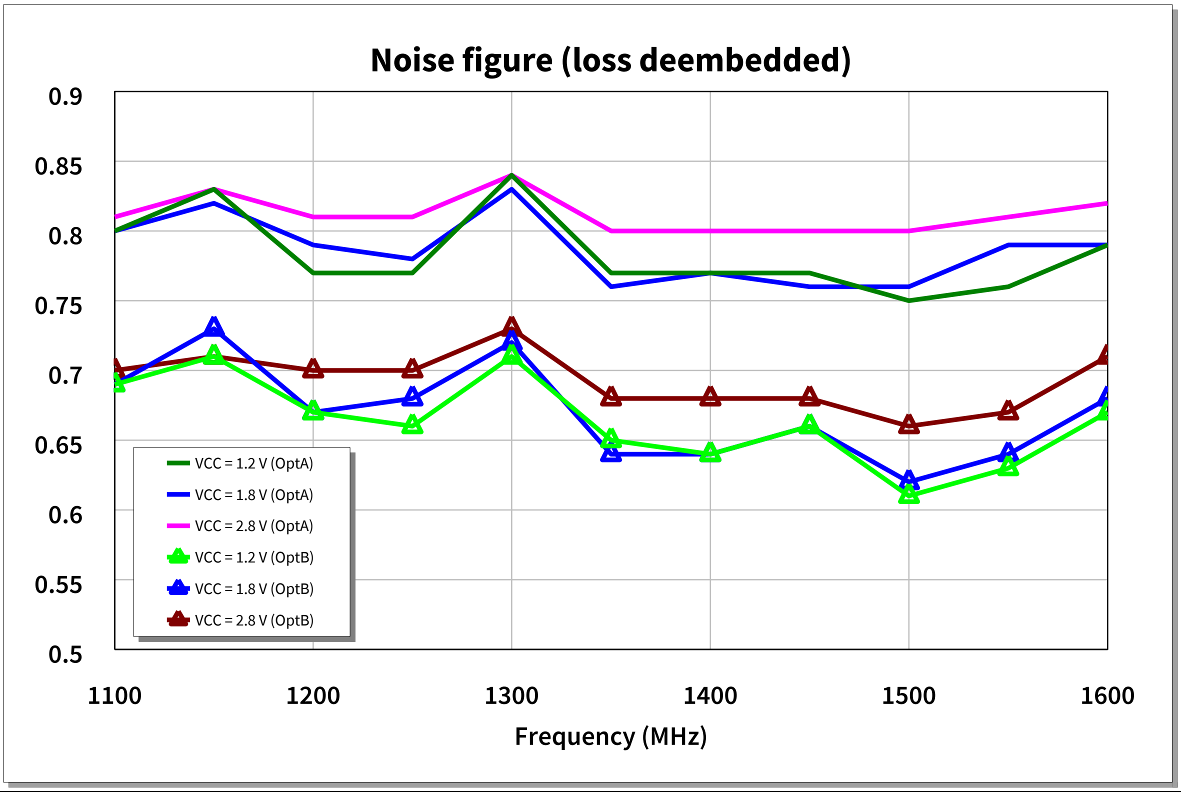

Figure 7 Noise figure (SMA and connector losses deembedded)

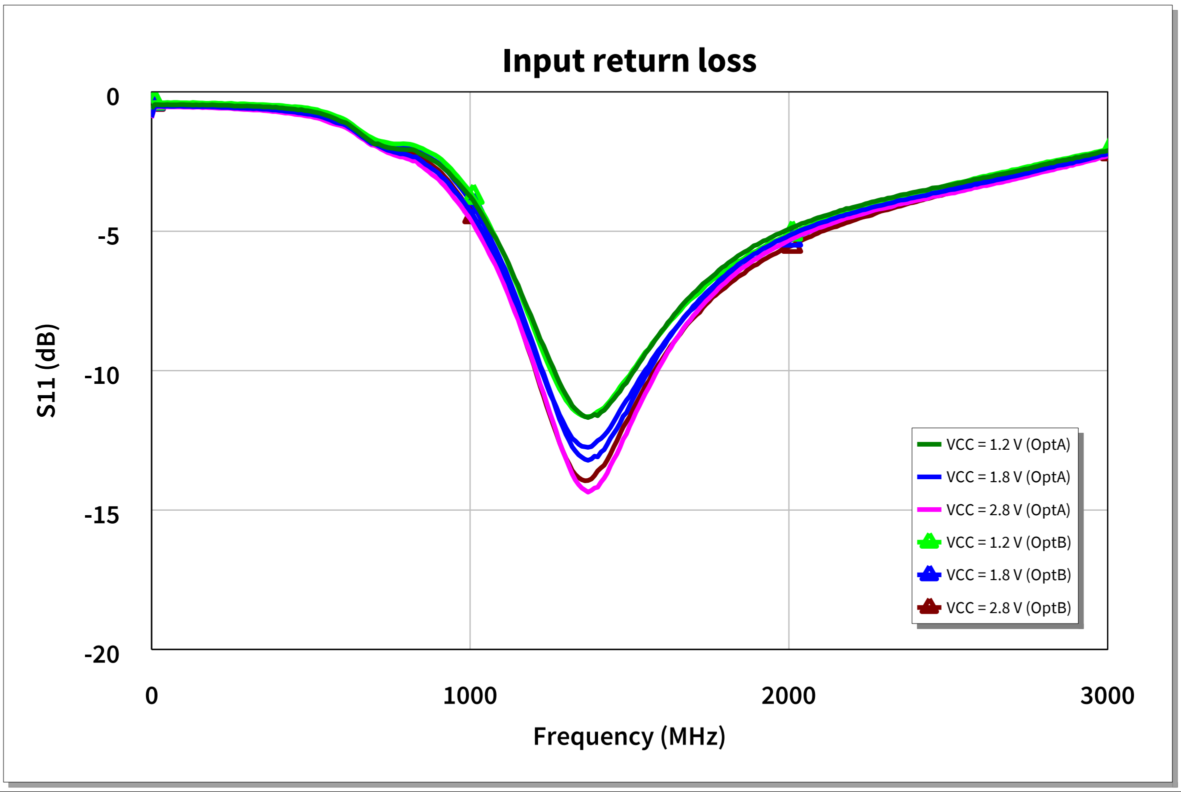

Figure 8 Input return loss

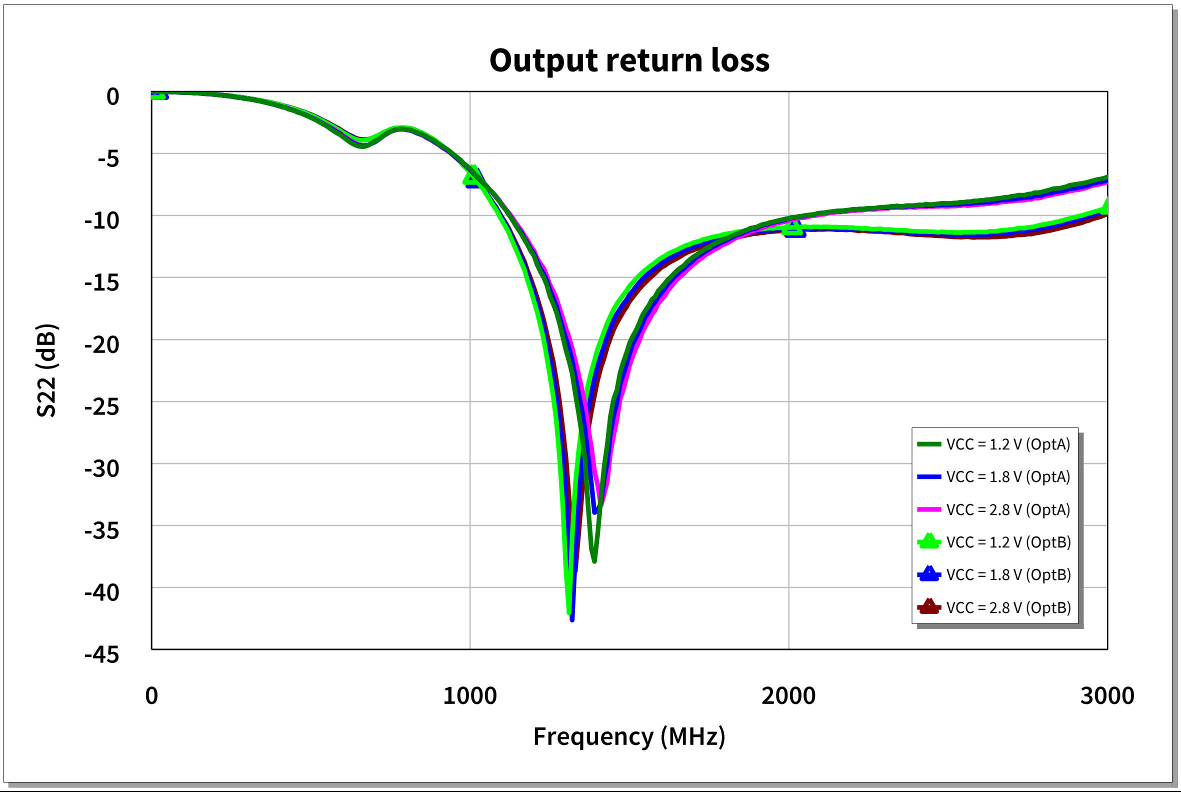

Figure 9 Output return loss

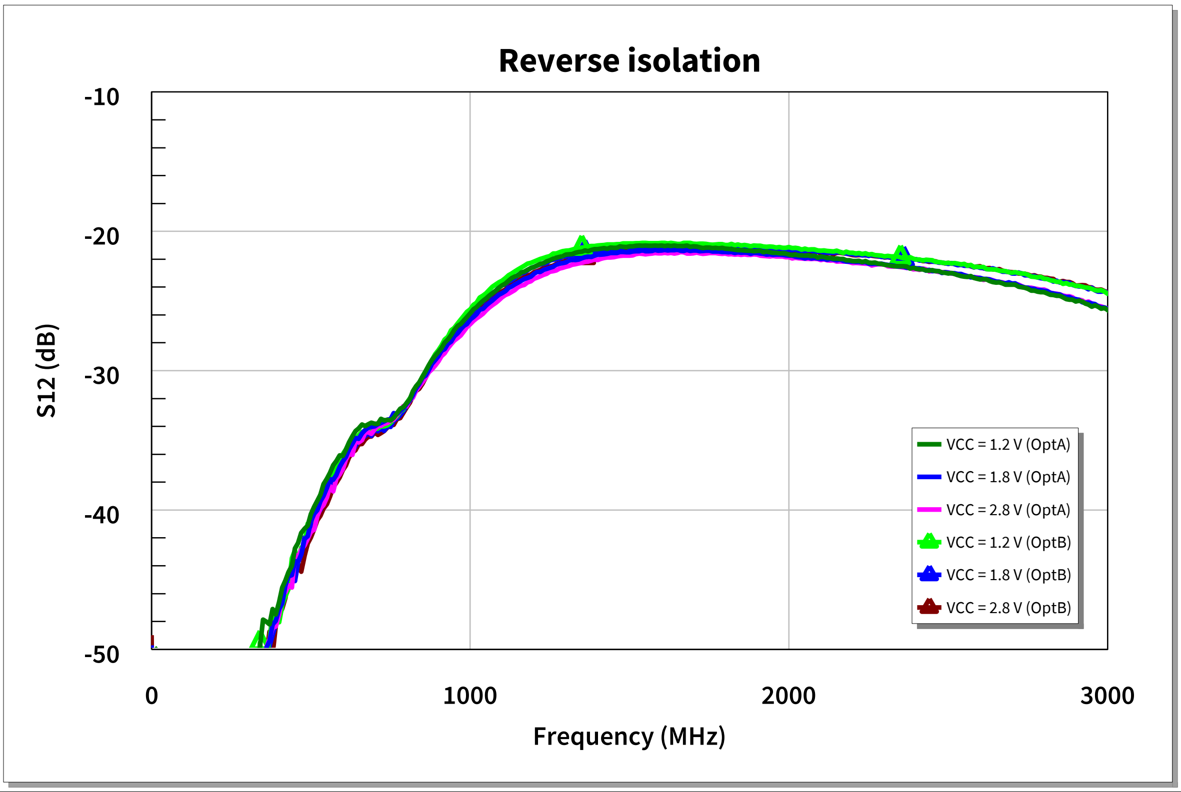

Figure 10 Reverse isolation

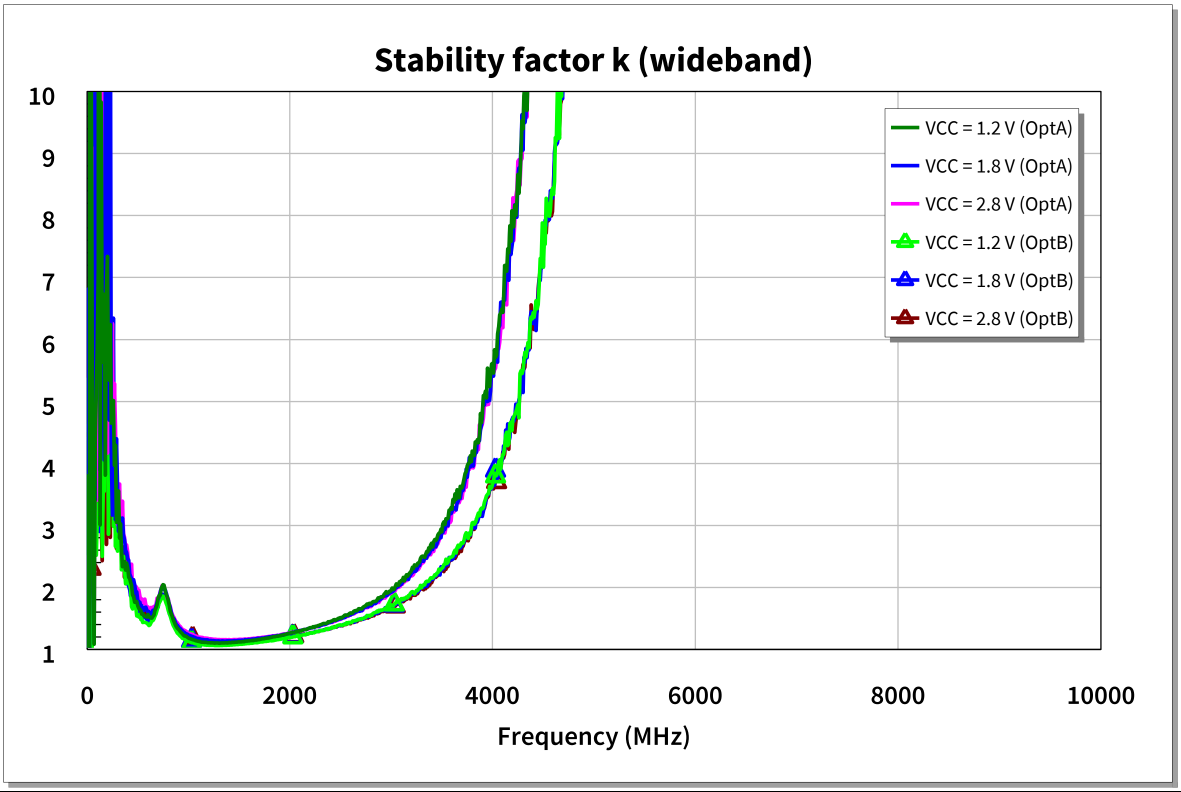

Figure 11 Stability k-factor

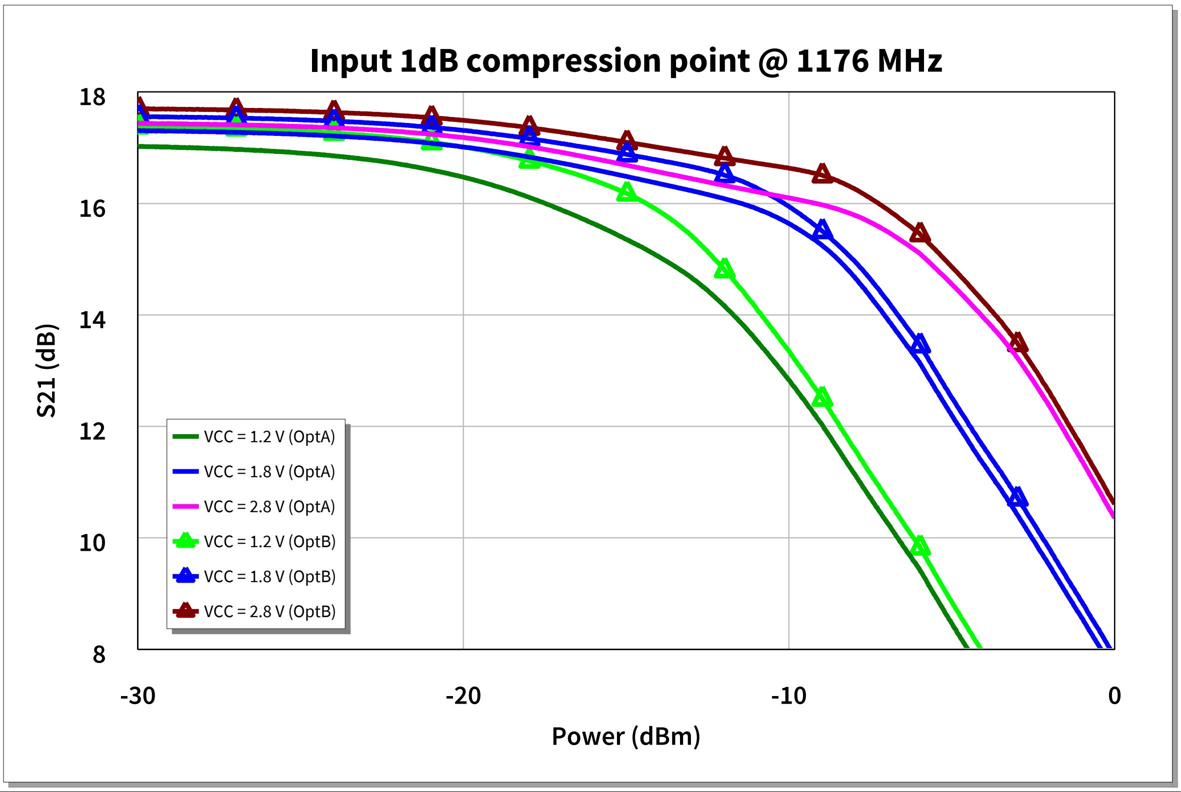

Figure 12 Input 1dB compression point at 1176 MHz

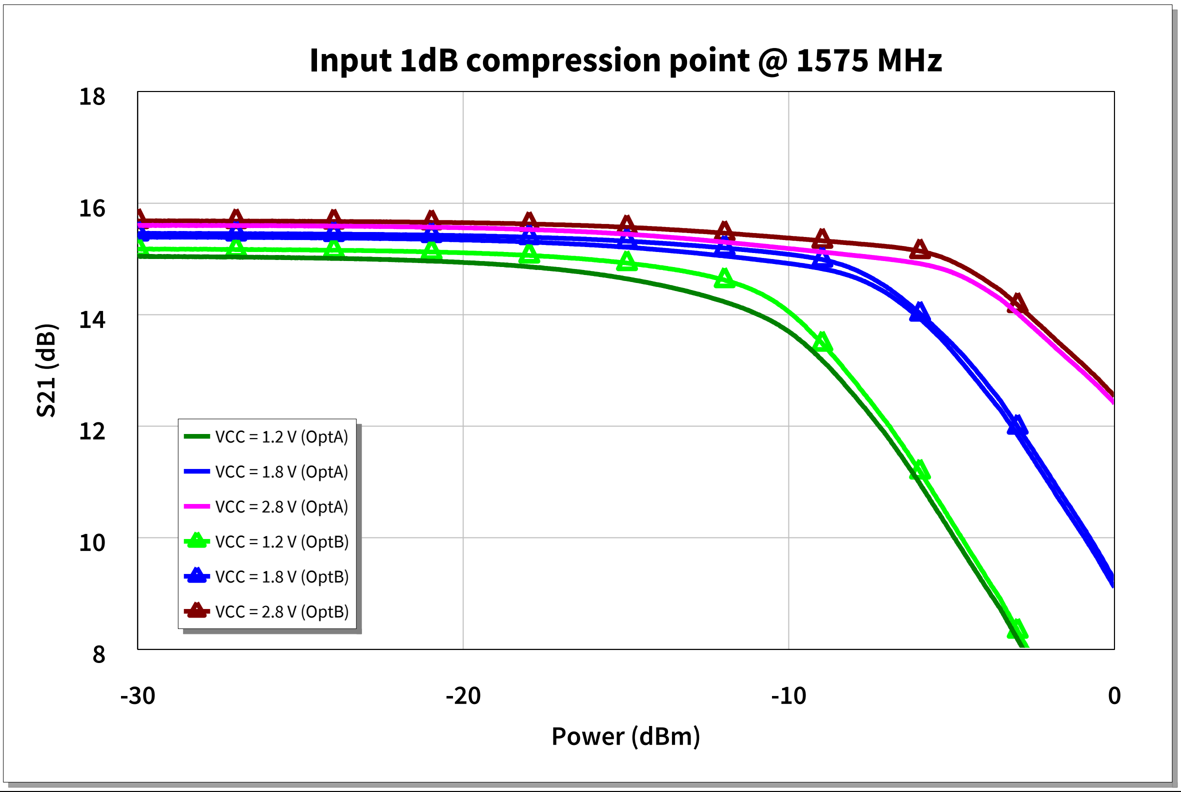

Figure 13 Input 1dB compression point at 1575 MHz

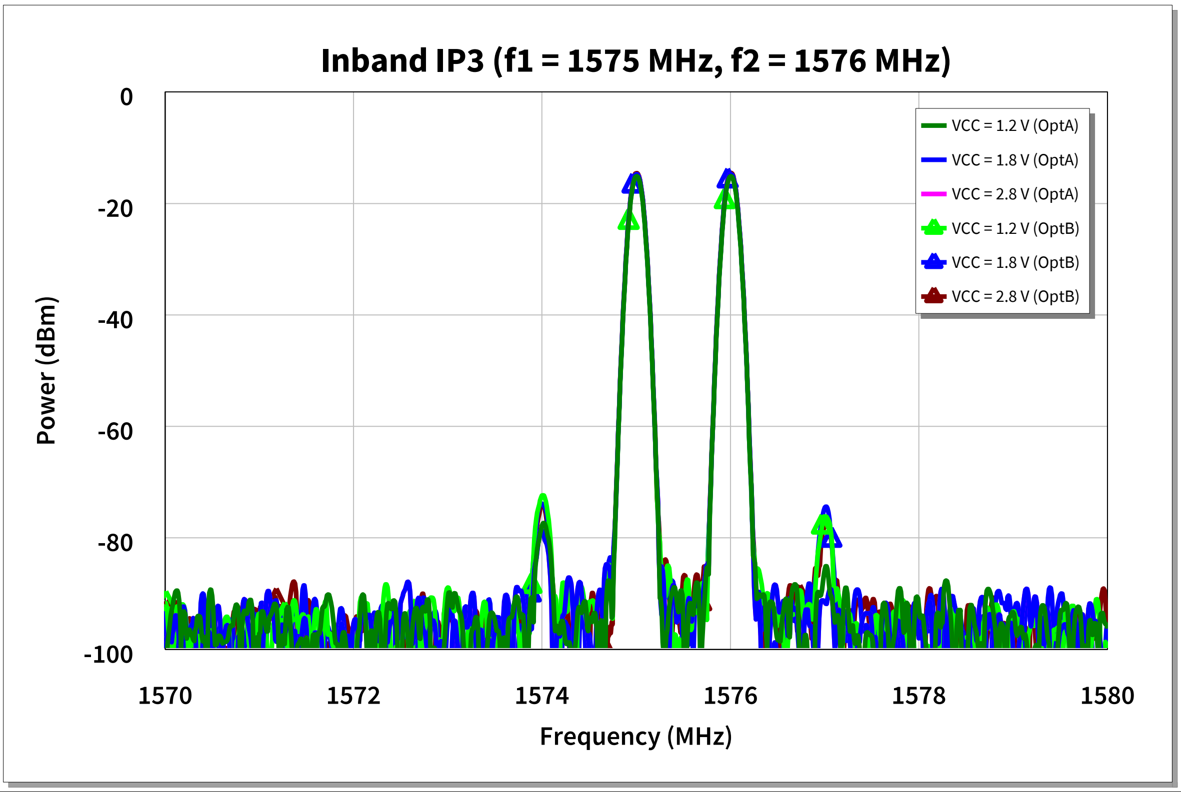

Figure 14 Inband third-order intermodulation point (1575 MHz, output referred)

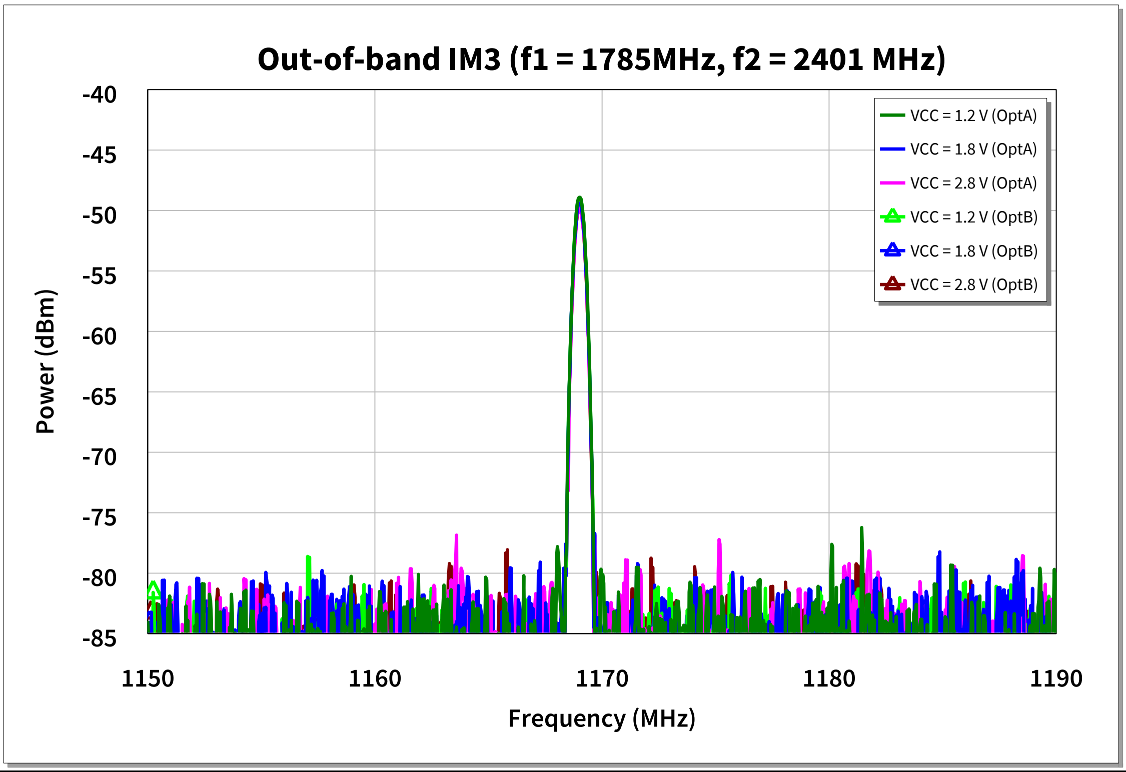

Figure 15 Out-of-band third-order intermodulation point (f1 = 1785 MHz, f2 = 2401 MHz, L5 band, output referred)

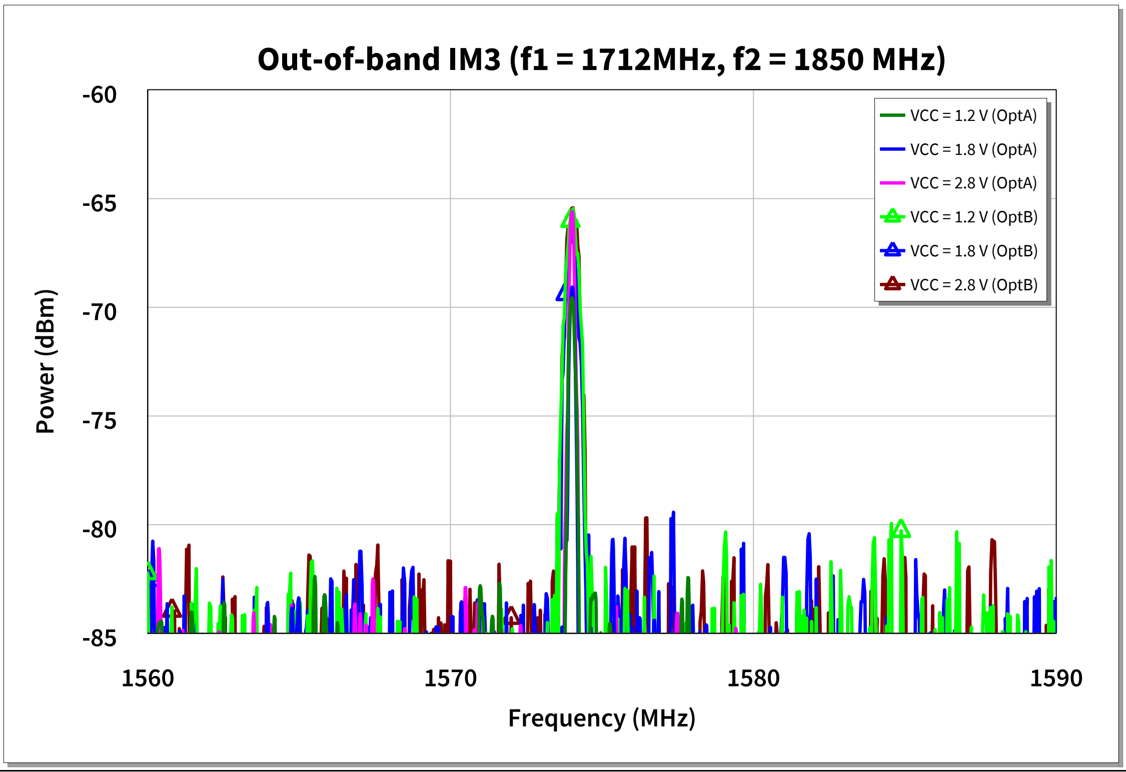

Figure 16 Out-of-band third-order intermodulation point (f1 = 1712 MHz, f2 = 1850 MHz, L1 band, output referred)

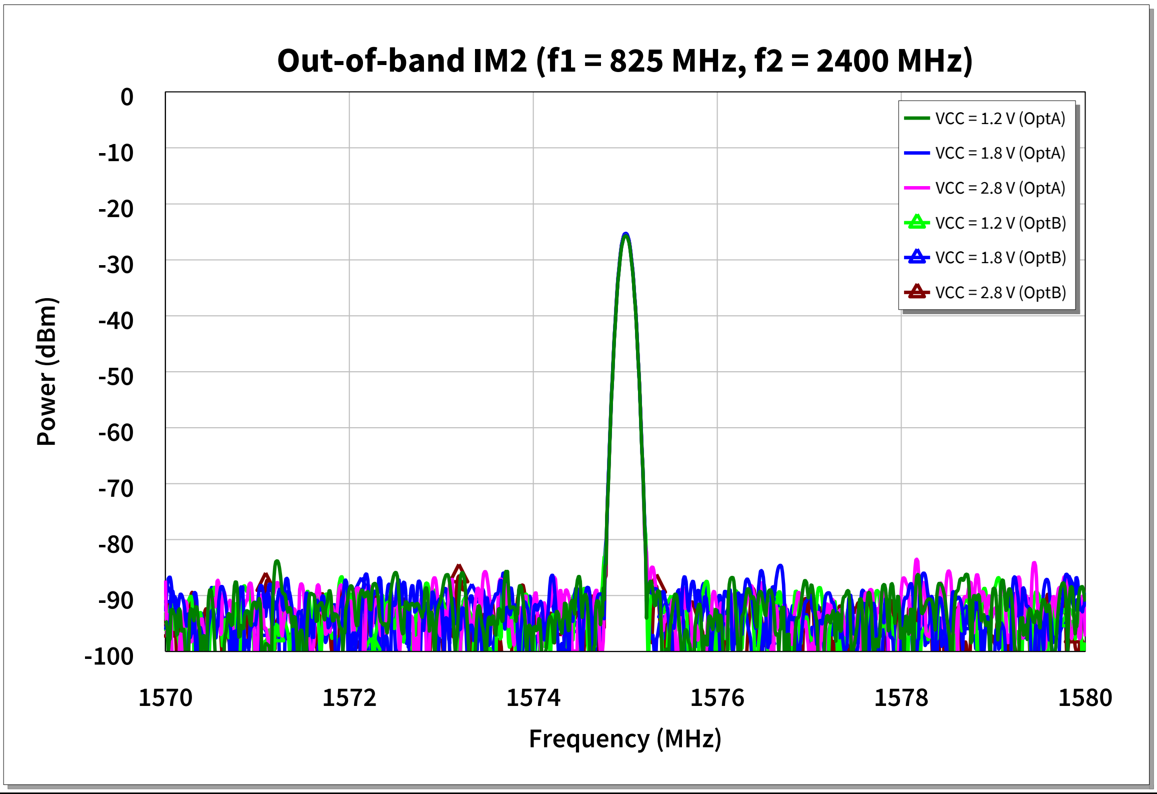

Figure 17 OoB second-order intermodulation point (f1 = 825 MHz, f2 = 2400 MHz, output referred)

4 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: **080920**

PCB material: **Megtron 6**

ε_r of PCB material: **3.7**

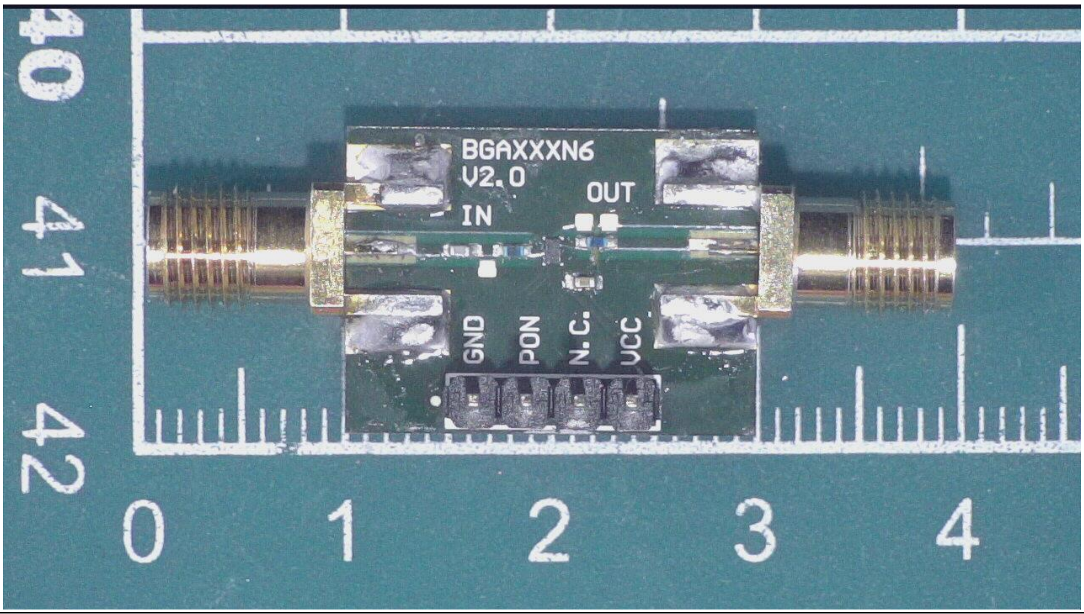

Figure 18 **Evaluation board (overview)**

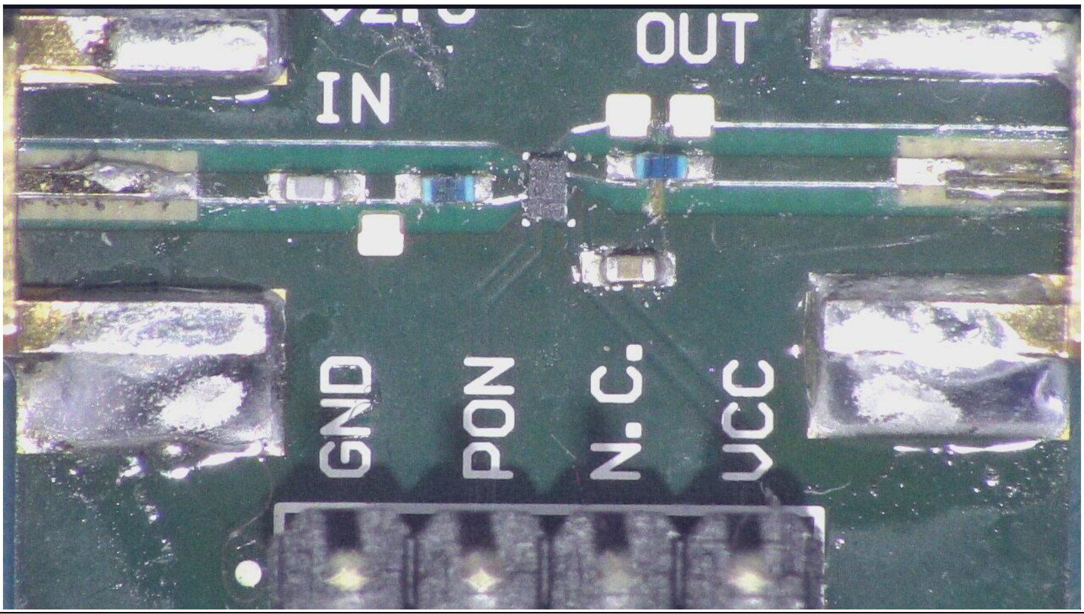

Figure 19 **Evaluation board (detailed view)**

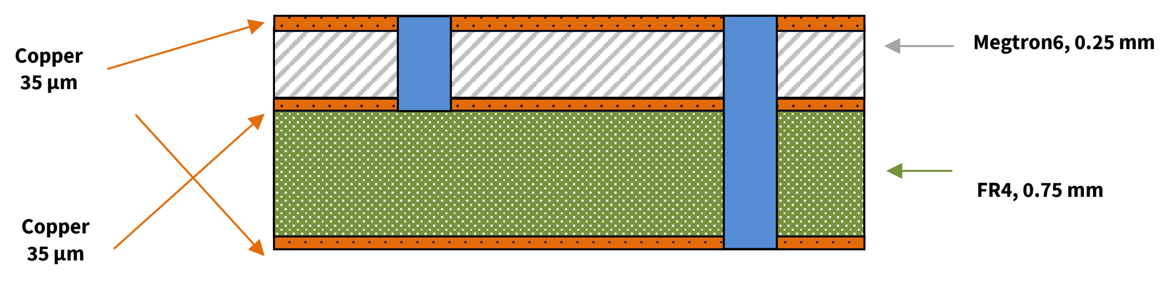

Figure 20 PCB layer information

5 Authors

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

Horson Hao, Staff Application Engineer of Business Unit "Radio Frequency and Sensors"

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

6 Reference

[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/

Revision History

Major changes since the last revision Rev 1.2 2021-03-23

Page or Reference	Description of change
7-9	Updated performance at L2 band
10	Updated BoM for 0201 inch solution and 0402 inch solution separately

Edition 2021-08-27

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference
AN_1903_PL55_1904_153753