BGA123L4 as Low Current Low Noise Amplifier for GNSS Applications

About this document

Scope and purpose

This application note describes Infineon's GNSS MMIC: BGA123L4 as low current Low Noise Amplifier for GNSS applications (1550 – 1615 MHz) with 0402 components for matching.

1. The BGA123L4 is a Silicon Germanium Low Noise Amplifier supporting 1550 – 1615 MHz.
2. The target application is GNSS applications (1550 – 1615 MHz).
3. In this report, the performance of BGA123L4 is measured on a Rogers4003 board. This device is matched with 0402 size external components. Performance deviation, when matched with 0201 components, is also presented.
4. Key performance parameters at 1.8 V, 1575 MHz
   Noise figure = 0.75 dB
   Insertion gain = 18.3 dB
   Input return loss = 9.5 dB
   Output return loss = 14.8 dB
   Inband Input IP3 = -14.5 dBm
5. Key performance parameters at 1.2 V, 1575 MHz
   Noise figure = 0.80 dB
   Insertion gain = 18.0 dB
   Input return loss = 9.3 dB
   Output return loss = 13.8 dB
   Inband Input IP3 = -14.8 dBm

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1) The graphs are 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 fastest growing businesses in the electronic industry. Today, four GNSS systems are in operation: the United States GPS, the Russian GLobal Orbiting Navigation Satellite System (GLONASS), the Chinese BeiDou Navigation Satellite System (BDS), and the European Union Galieo navigation system. Main market segments include the Personal Navigation Devices (PND), GNSS-enabled mobile phones and GNSS-enabled portable devices.

The main challenges for the growing GNSS-enabled mobile phone segment are to achieve high sensitivity and high immunity defined by government regulations against interference of cellular signals for safety and emergency reasons. This means 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 signals.

The main challenges for the GNSS-enabled portable devices are to obtain a long battery operation time, and low Time-To-First Fix (TTFF) to quickly locate the device.

GPS: 1563 – 1587 MHz (L1), 1215 - 1240 MHz (L2), 1164 – 1189 MHz (L5)
Galileo: 1559 – 1591 MHz (E1), 1259 -1299 MHz (E6), 1164 MHz – 1214 MHz (E5)
GLONASS: 1598 - 1609 MHz (G1), 1237 -1254 MHz (G2), 1189 MHz – 1214 MHz (G3)
Beidou: 1559 – 1591 MHz (B1), 1193 – 1221 MHz (B2), 1257 – 1281 MHz(B3)
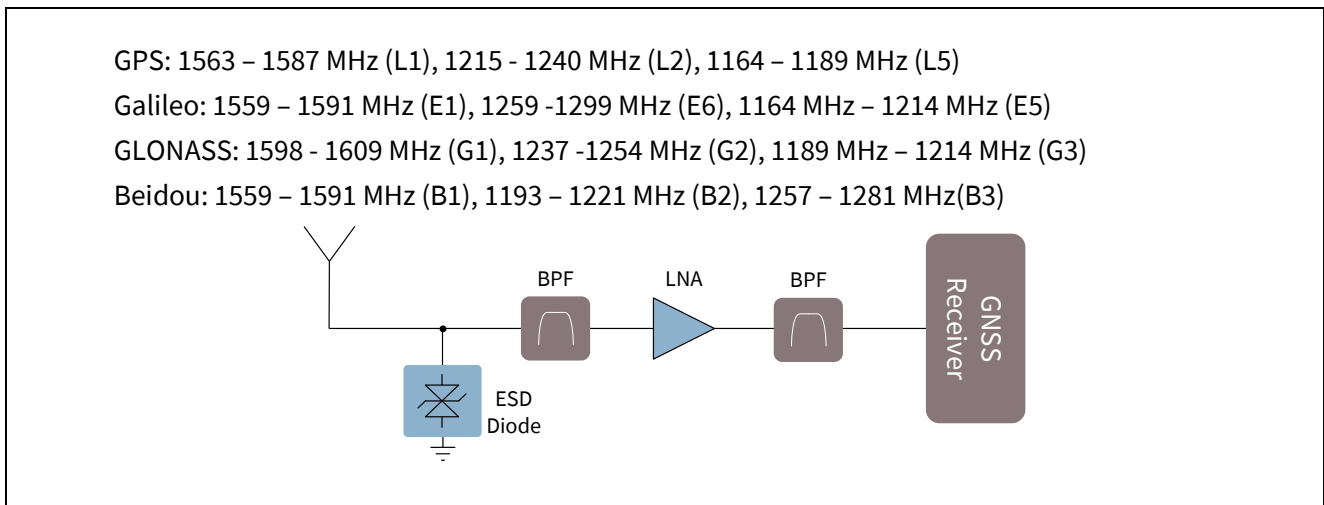
Figure 1   Application Diagram: Receiver Frontend of the Global Navigation Satellite System

1.2 Infineon Product Portfolio for GNSS Applications

Infineon offers a complete product portfolio to all customers designing high-performance flexible RF front-end solutions for all GNSS systems:

- **Low Noise Amplifiers (LNAs):** Infineon offers a wide range of products such as high-performance Monolithic Microwave Integrated Circuits (MMICs) as well as cost effective and high-end RF transistors

- **Transient Voltage Suppression (TVS) Diodes:** Infineon devices can protect GNSS antennas reliably up to 20 kV

Infineon Technologies is among the market leaders in GNSS Low Noise Amplifiers (LNAs) for navigation applications. The GNSS MMIC LNA products offer low Noise Figure (NF), high gain and low power consumption. In addition they are designed with high out-of-band linearity performance to enhance interference immunity.

1.3   Key Features of GNSS Low Noise Amplifiers

Low Noise Figure & 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 NF and high gain is required to boost the sensitivity of the system and Time-To-First Fix (TTFF).

High robustness against coexistence of out-of-band jammer signals

In the presence of very weak GNSS satellite signals, there is no inband intereference signal in the GNSS receiver frontends.

In case of mobile phone systems, GNSS signals coexist with strong jammer signals from other RF applications, e.g. 3G/4G, wireless LAN, etc. The above out-of-band jammer signals can mix to produce intermodulation products in the GNSS receiver frequency band. Compared with the receveid signal level from GNSS satellites, the resulted intermodulation products are significant intreference, LNAs with high robustness against out-of-band intereference signals are required.

Low Current Consumption

Power consumption is an important feature in many GNSS systems that are mainly battery-operated mobile devices. Infineon's LNAs have an integrated power on/off feature which provides for low power consumption and increased stand-by time for GNSS handsets. Moreover, the low current consumption (e.g. 1.1 mA) makes Infineon's LNAs suitable for portable devices such as GNSS enabled wearables and connected IoT devices.

Please visit www.infineon.com for more details on LNA products for navigation in mobile phones and portable devices.

2 BGA123L4 Overview

2.1 Features

• Operating frequencies: 1550 - 1615 MHz

• Ultra low current consumption: 1.1 mA

• Wide supply voltage range: 1.1 V to 3.6 V

• High insertion power gain: 18.2 dB

• Low noise figure: 0.75 dB

• 2 kV HBM ESD protection (including AI pin)

•Ultra small TSLP-4-11 leadless package (footprint: 0.7 x 0.7 x 0.31 mm3)

• RF output internally matched to 50 Ohm

• Only one external SMD component necessary

• Pb-free (RoHS complaint) package
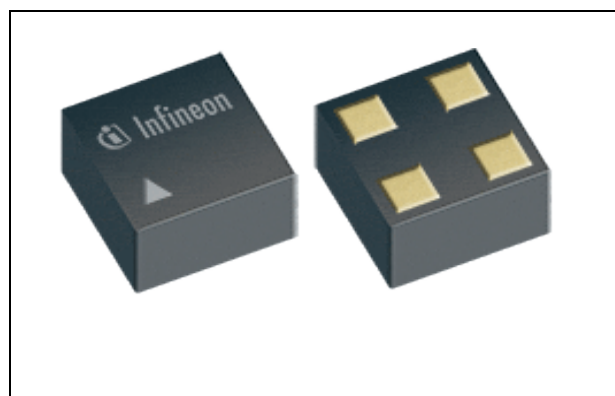
• B7HF Silicon Germanium technology

Figure 2   BGA123L4 in TSLP-4-11

2.2 Key Applications of BGA123L4

BGA123L4 is designed to enhance GNSS signal sensitivity especially in wearables and mobile cellular IoT devices. With 18.2 dB gain and only 0.75 dB noise figure it ensures high system sensitivity. The current needed is only 1.1 mA which means just 1.3 mW power consumption, which is critical to help to conserve batteries. The wide supply voltage range of 1.1 V to 3.6 V ensures flexible design and high compatibility. It supports all GNSS systems including GPS, GLONASS, Beidou and Galileo.

2.3 Description

The BGA123L4 is an ultra low noise amplifier for Global Navigation Satellite Systems (GNSS) which covers all GNSS frequency bands from 1550 MHz to 1615 MHz like GPS, GLONASS, Beidou, Galilieo and others. The LNA provides 18.2 dB gain and 0.75 dB noise figure at a current consumption of only 1.1 mA in the application configuration described in Figure 4. The BGA123L4 is based upon Infineon Technologies´ B7HF Silicon Germanium technology. It operates from 1.1 V to 3.6 V supply voltage.
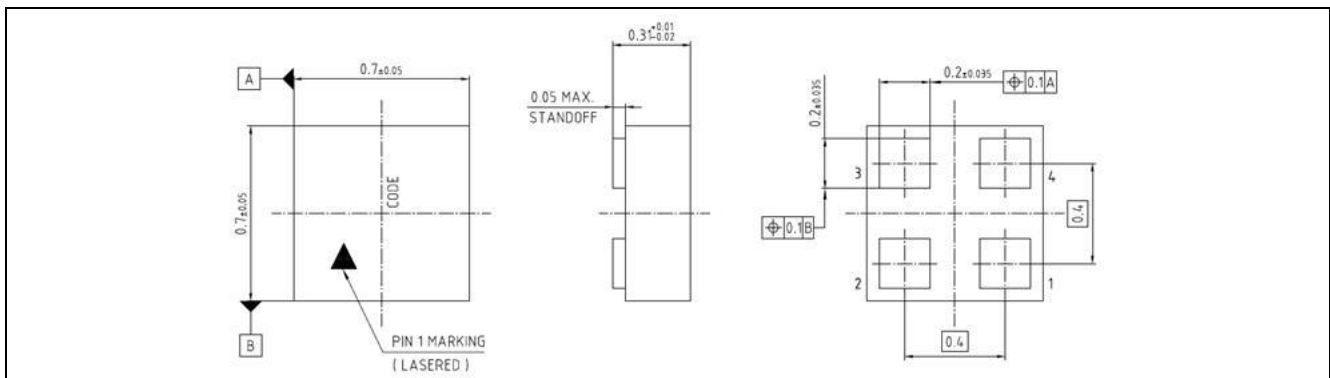

Figure 3   Package and pin connections of BGA123L4

Table 1   Pin Assignment of BGA123L4

Pin No.	Symbol	Function
1	VCC	DC supply
2	AO	LNA output
3	GND	Ground
4	AI	LNA input

Table 2   Mode Selection of BGA123L4

To select the mode for BGA123L4, one option is to control the mode directly via the Vcc pin; an alternative option is to connect the the Vcc pin to the GPIO port. Below table provides the voltage range required at the Vcc pin to set the device to ON mode or OFF mode.

LNA Mode	ON/OFF Control Voltage at Vcc pin	
	Min	Max
ON	1.1 V	3.6 V
OFF	0 V	0.4 V

Please visit the product page of BGA123L4 for more information.

3 Application Circuit and Performance Overview

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

Device: BGA123L4

Application: GNSS Applications

PCB Marking: GL05

EVB Order No.: AN551

3.1 Summary of Measurement Results

The performance of BGA123L4 for GNSS applications is summarized in the following table.

Table 3 **Electrical Characteristics at 1.8 V (at room temperature)**

Parameter	Symbol	Value			Unit	Comment/Test Condition
Frequency Range	Freq	1550	1575	1615	MHz	
DC Voltage	Vcc		1.8		V	
DC Current	Icc		1.10		mA	
Gain	G	18.2	18.3	18.3	dB	
Noise Figure[1][4]	NF	0.80	0.75	0.80	dB	LQW15 inductor for matching, Loss of input line of 0.08 dB is deembedded[1,2]
Noise Figure[2][4]	NF	0.80	0.75	0.80	dB	LQP03T inductor for matching, loss of input line of 0.08 dB is deembedded[1,2]
Input Return Loss	RLin	9.2	9.5	9.7	dB	
Output Return Loss	RLout	12.6	14.8	15.1	dB	
Reverse Isolation	IRev	37.0	37.7	38.6	dB	
Input P1dB	IP1dB	-14.0	-14.1	-14.5	dBm	
Output P1dB	OP1dB	3.2	3.2	2.8	dBm	
Input IP3	IIP3		-14.5		dBm	Power @ Input: -30 dBm f1 = 1575 MHz, f2 = 1576 MHz
Output IP3	OIP3		3.8		dBm	
Out-of-band IM3 input referred[3]	Oob_IIM3		-68.5		dBm	Power @ Input: -25 dBm f1 =1712.7 MHz f2= 1850 MHz
Out-of-band IM3 output referred	Oob_OIM3		-50.2		dBm	
Stability	k		>1		--	Measured up to 8 GHz

Application Circuit and Performance Overview

Table 4   Electrical Characteristics at 1.2 V (at room temperature)

Parameter	Symbol	Value			Unit	Comment/Test Condition
Frequency Range	Freq	1550	1575	1615	MHz	
DC Voltage	Vcc	1.2			V	
DC Current	Icc	1.05			mA	
Gain	G	17.9	18.0	18.0	dB	
Noise Figure[1] [4]	NF	0.80	0.80	0.80	dB	LQW15 inductor for matching, Loss of input line of 0.08 dB is deembedded[1,2]
Noise Figure[1)2] [4]	NF	0.80	0.80	0.80	dB	LQP03T inductor for matching, loss of input line of 0.08 dB is deembedded[1,2]
Input Return Loss	RLin	9.0	9.3	9.5	dB	
Output Return Loss	RLout	11.7	13.8	14.0	dB	
Reverse Isolation	IRev	37.5	37.7	38.5	dB	
Input P1dB	IP1dB	-16.8	-17.0	-17.5	dBm	
Output P1dB	OP1dB	0.1	0.0	-0.5	dBm	
Input IP3	IIP3	-14.8			dBm	Power @ Input: -30 dBm f1 = 1575 MHz, f2 = 1576 MHz
Output IP3	OIP3	3.2			dBm	
Out-of-band Input IM3 input referred[3]	Oob_IIM3	-64.3			dBm	Power @ Input: -25 dBm f1 =1712.7 MHz f2= 1850 MHz
Out-of-band Output IM3 output referred	Oob_OIM3	-46.3			dBm	
Stability	k	>1			--	Measured up to 8 GHz

3.2 Schematics and Bill-of-Materials

The schematic of BGA123L4 for GNSS applications is presented in Table 5 and its bill-of-materials is shown in Table 5.
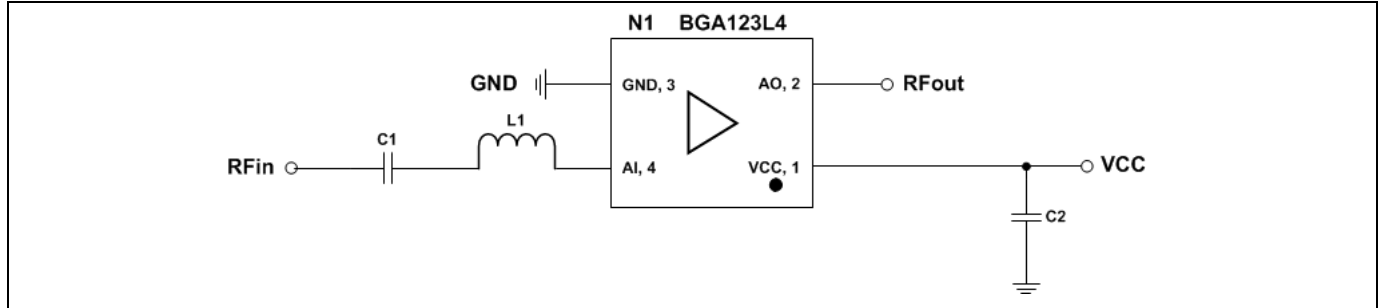
Table 5   Schematics of the BGA123L4 Application Circuit

Table 6   Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	1	nF	0402/0201	Various	DC block
C2	>=1	nF	0402/0201	Various	RF bypass
L1	10	nH	0402/0201	Murata LQW15 / Murata LQP03TN	Input Matching
N1	BGA123L4	TSLP-4-11		Infineon Technologies	SiGe LNA

Note: DC block function is NOT integrated at input of BGA123L4. The DC block might be realized with pre-filter in GNSS applications.

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

Measurement Graphs

4 Measurement Graphs
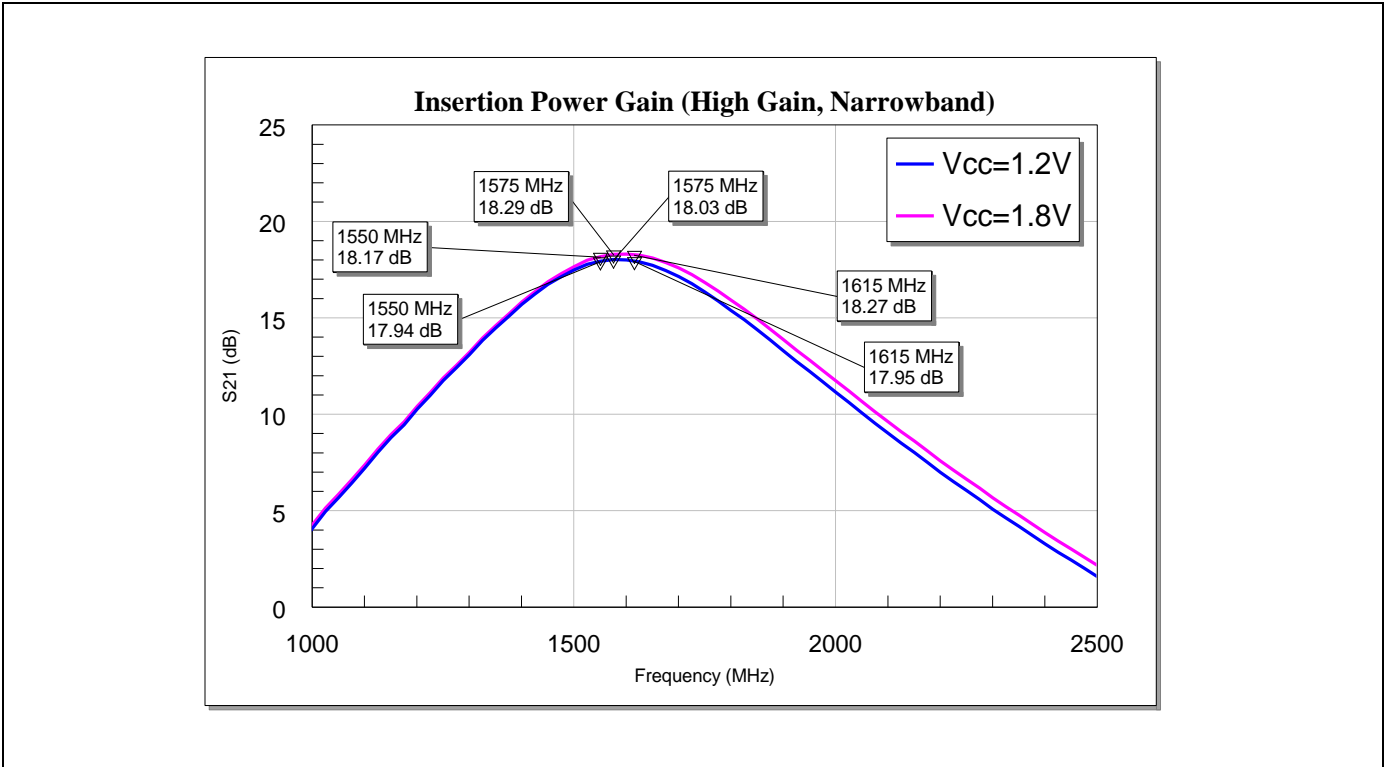
Figure 4 **Insertion Power Gain (Narrowband) of BGA123L4 for GNSS Applications**
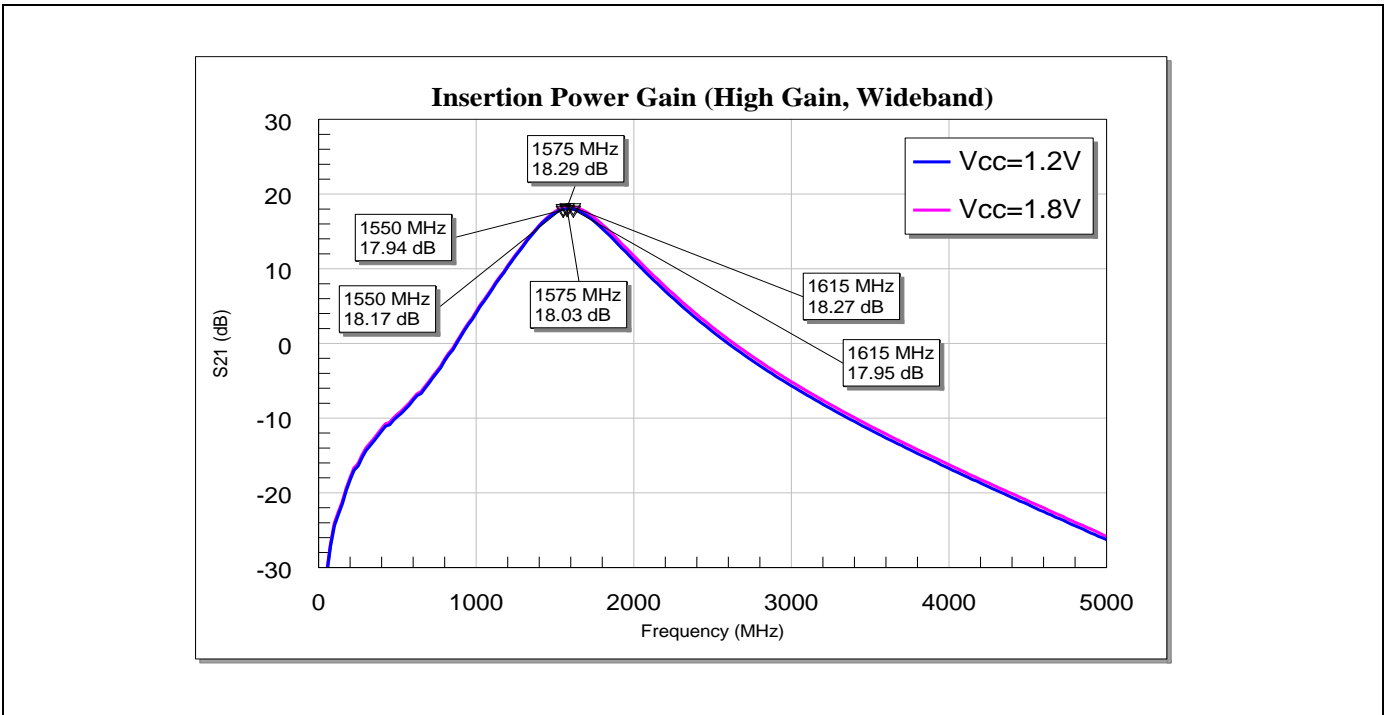
Figure 5 **Insertion Power Gain (Wideband) of BGA123L4 for GNSS Applications**

Measurement Graphs
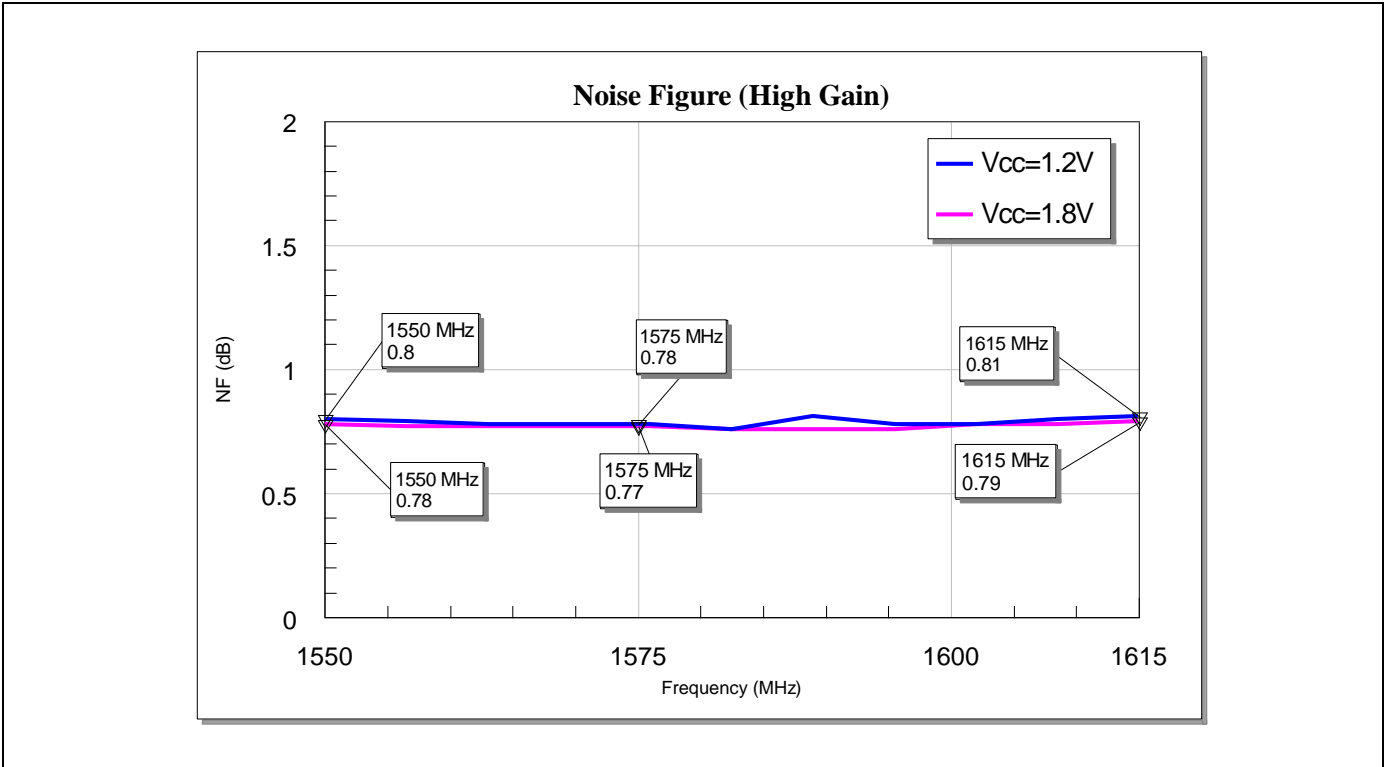
Figure 6   Noise Figure of BGA123L4 for GNSS Applications (SMA and Connector Losses Deembedded)
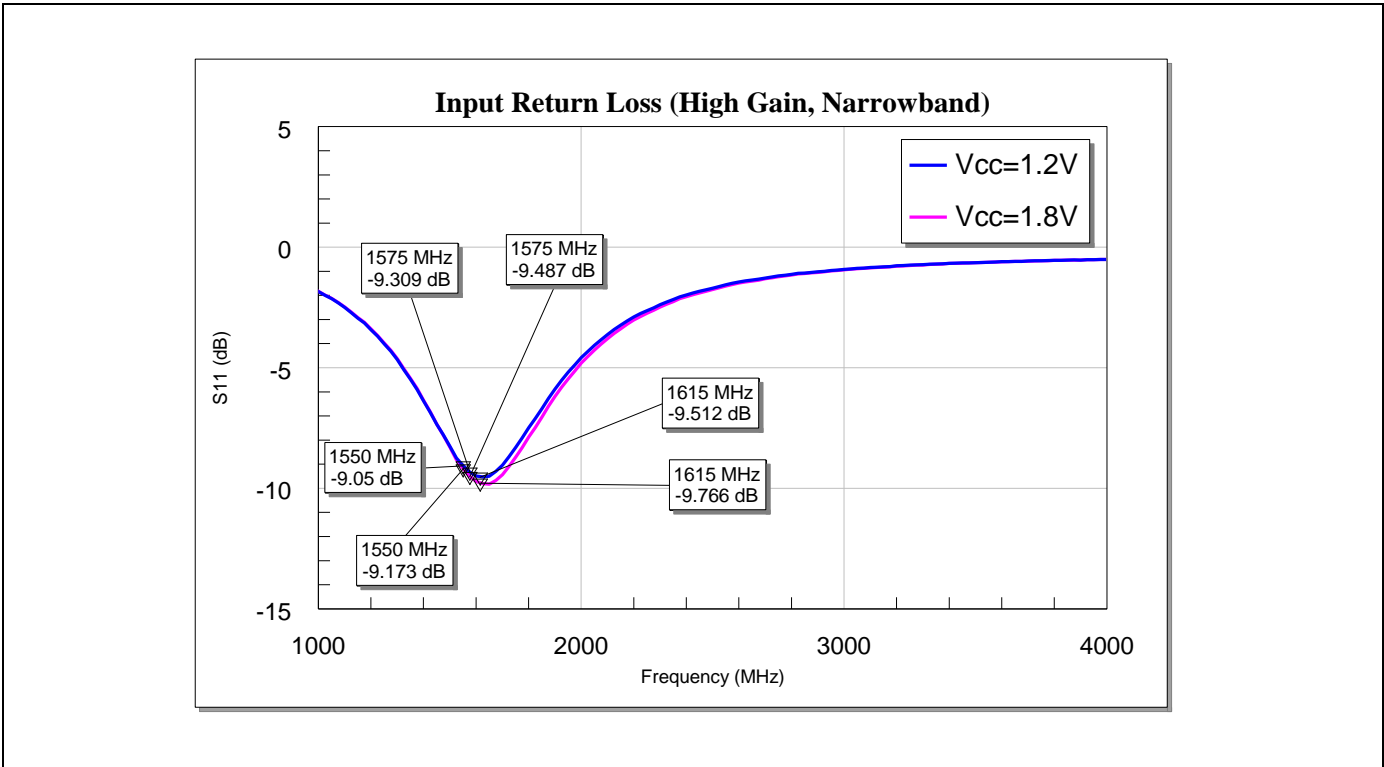
Figure 7   Input Return Loss of BGA123L4 for GNSS Applications

Measurement Graphs
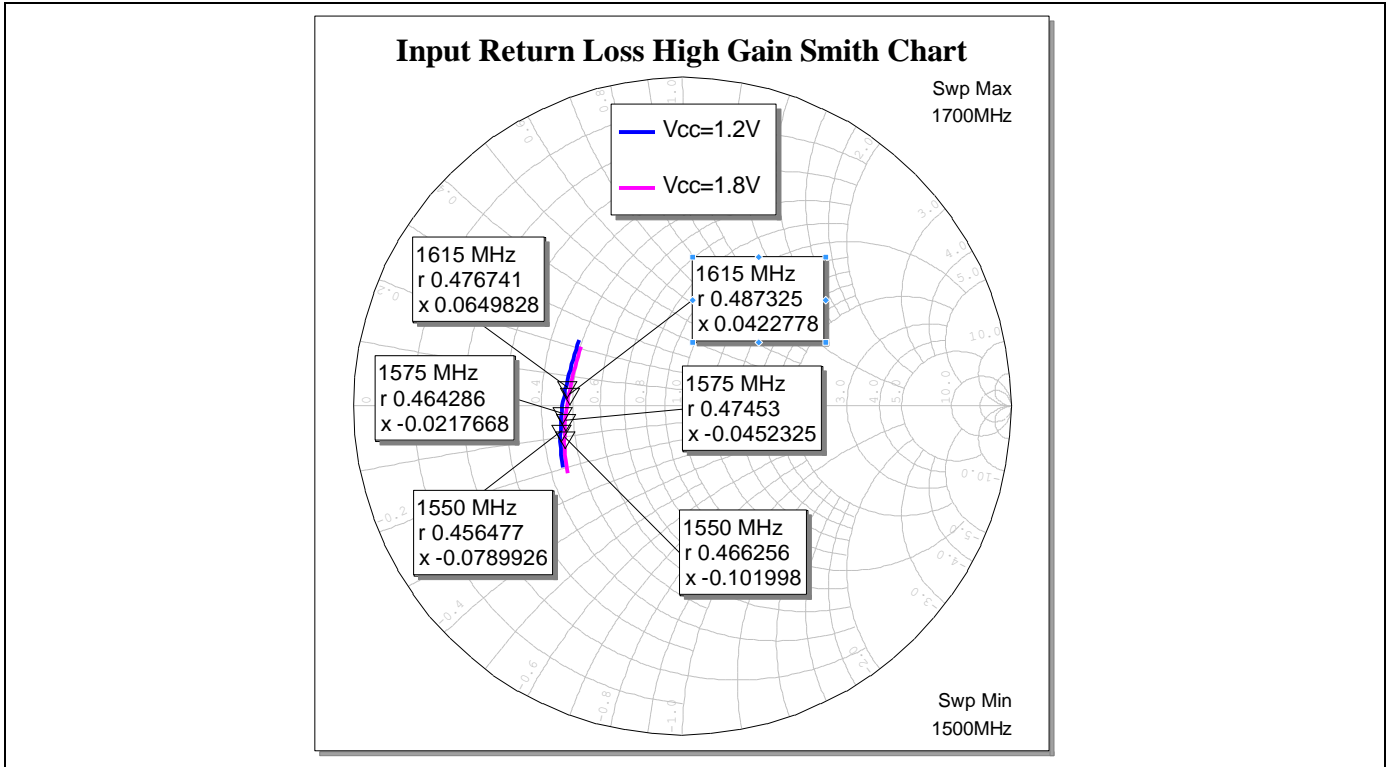
Figure 8   Input Return Loss (Smith Chart) of BGA123L4 for GNSS Applications
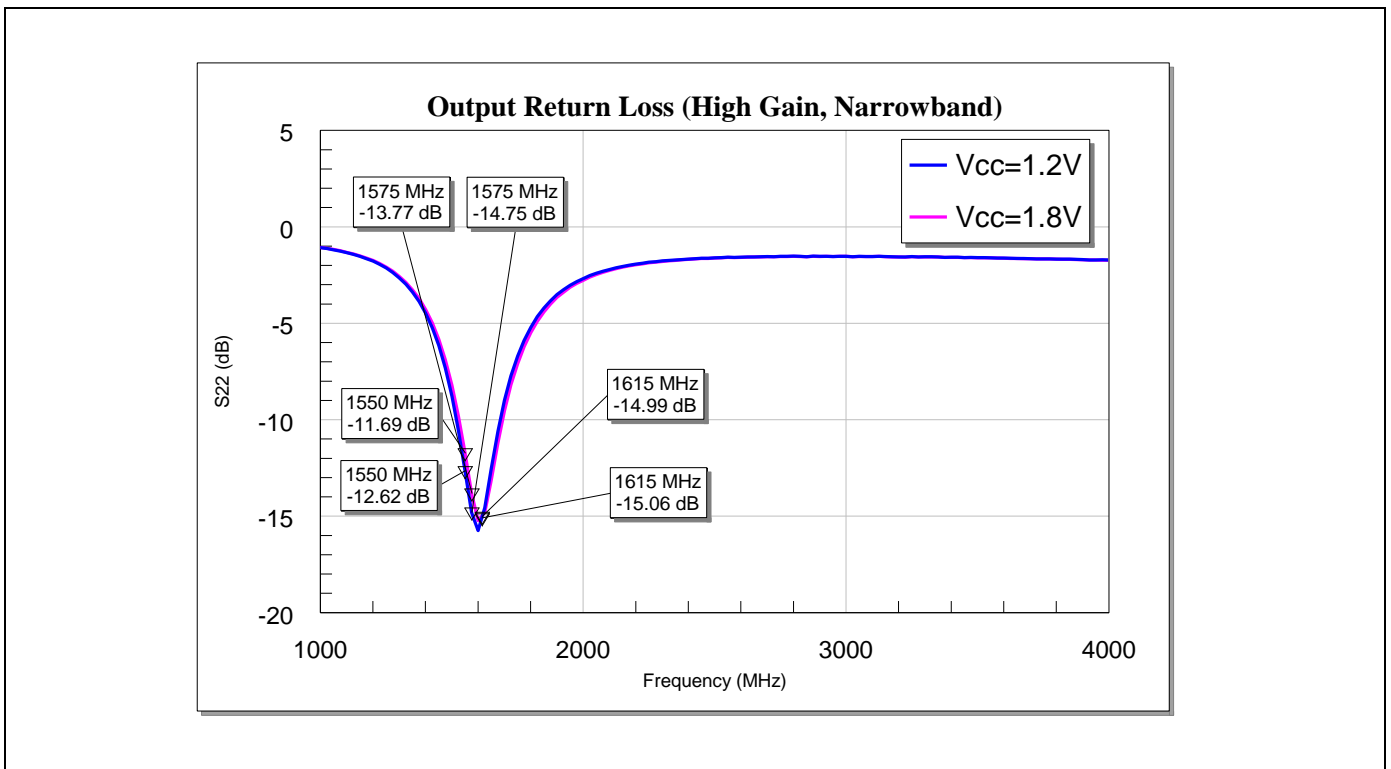
Figure 9   Output Return Loss of BGA123L4 for GNSS Applications

Measurement Graphs
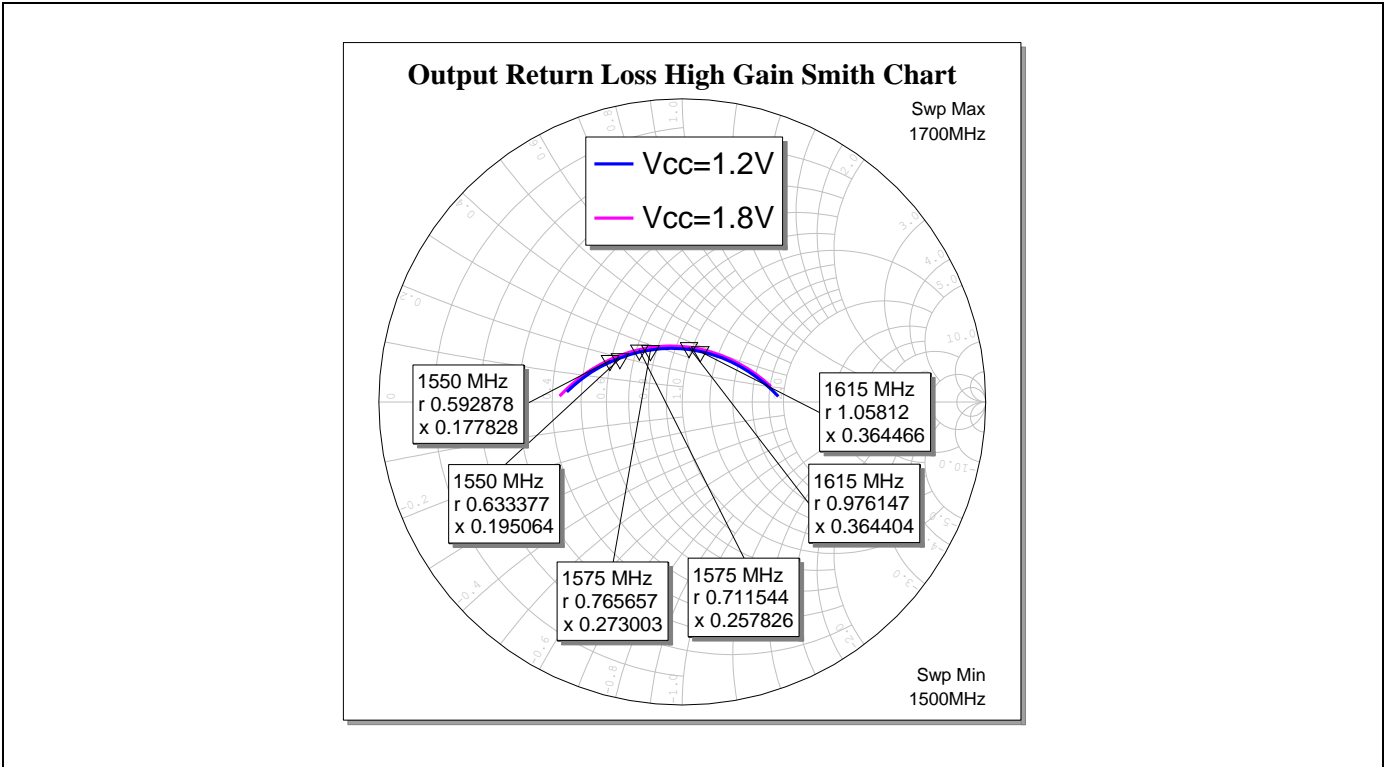
Figure 10   Output Return Loss (Smith Chart) of BGA123L4 for GNSS Applications
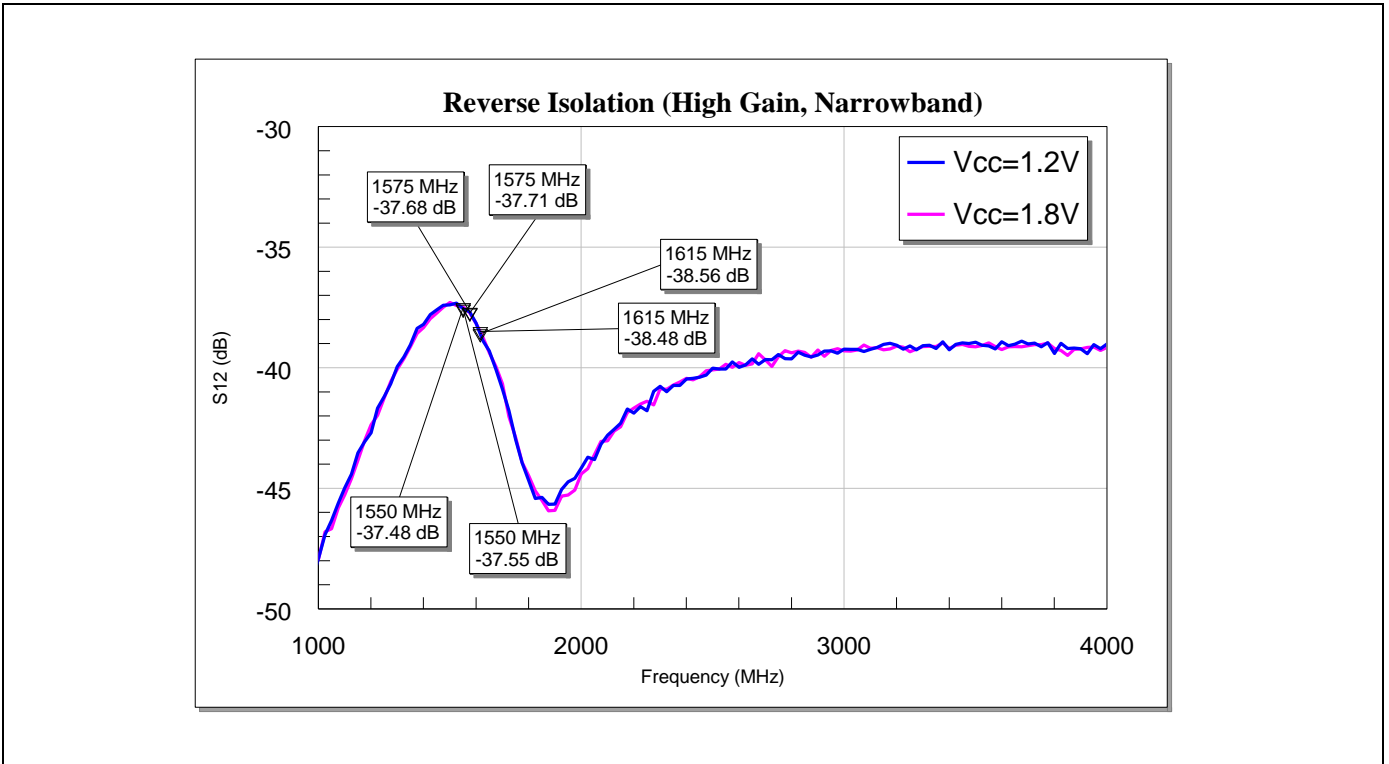
Figure 11   Reverse Isolation of BGA123L4 for GNSS Applications

Measurement Graphs
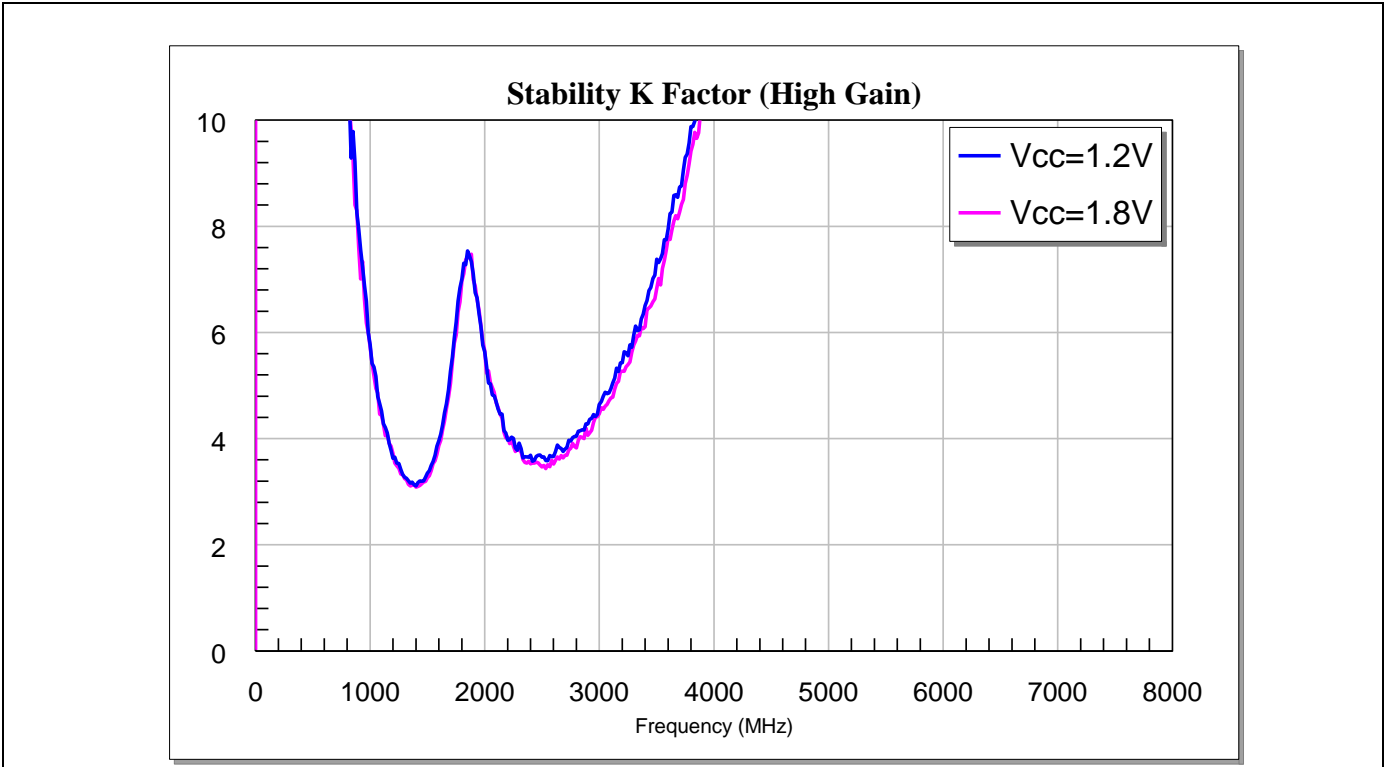
Figure 12   Stability K-factor of BGA123L4 for GNSS Applications
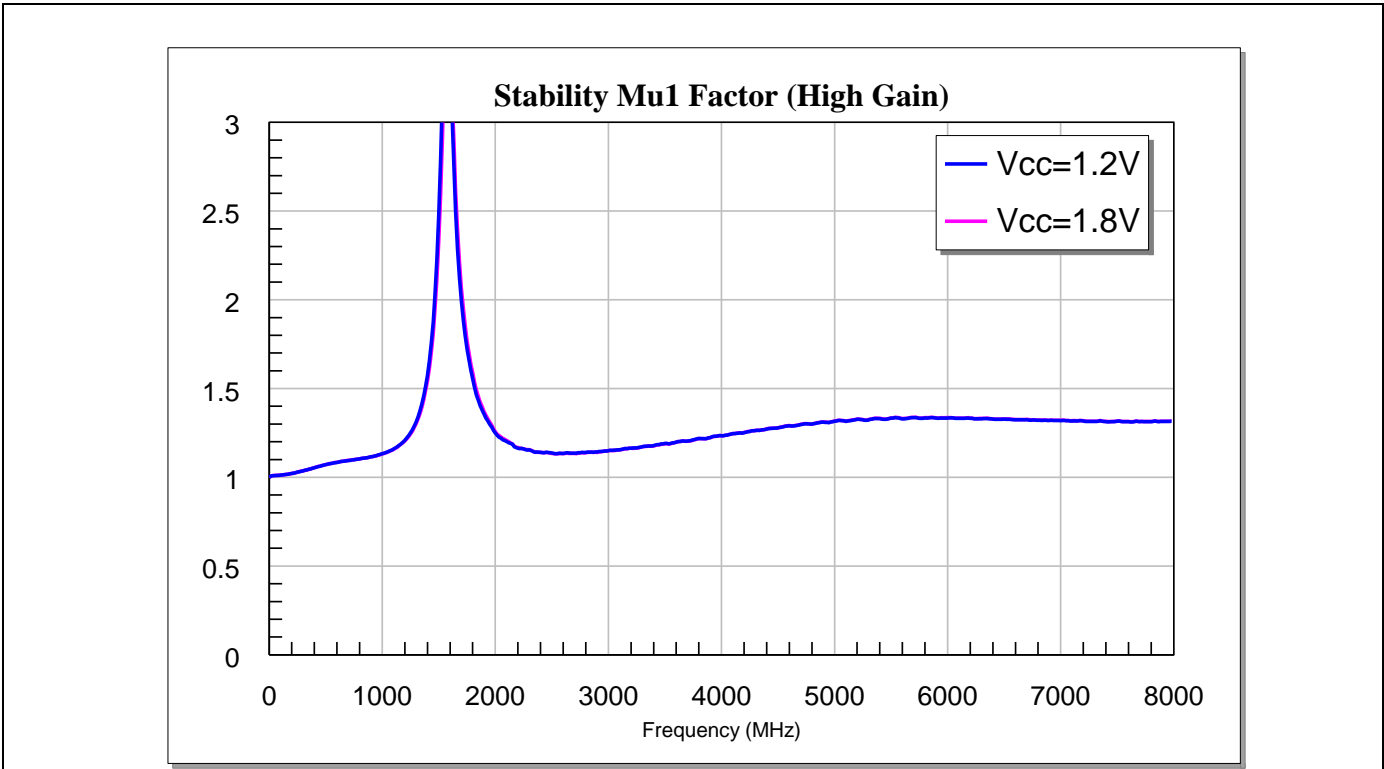
Figure 13   Stability Mu1-factor of BGA123L4 for GNSS Applications

Measurement Graphs
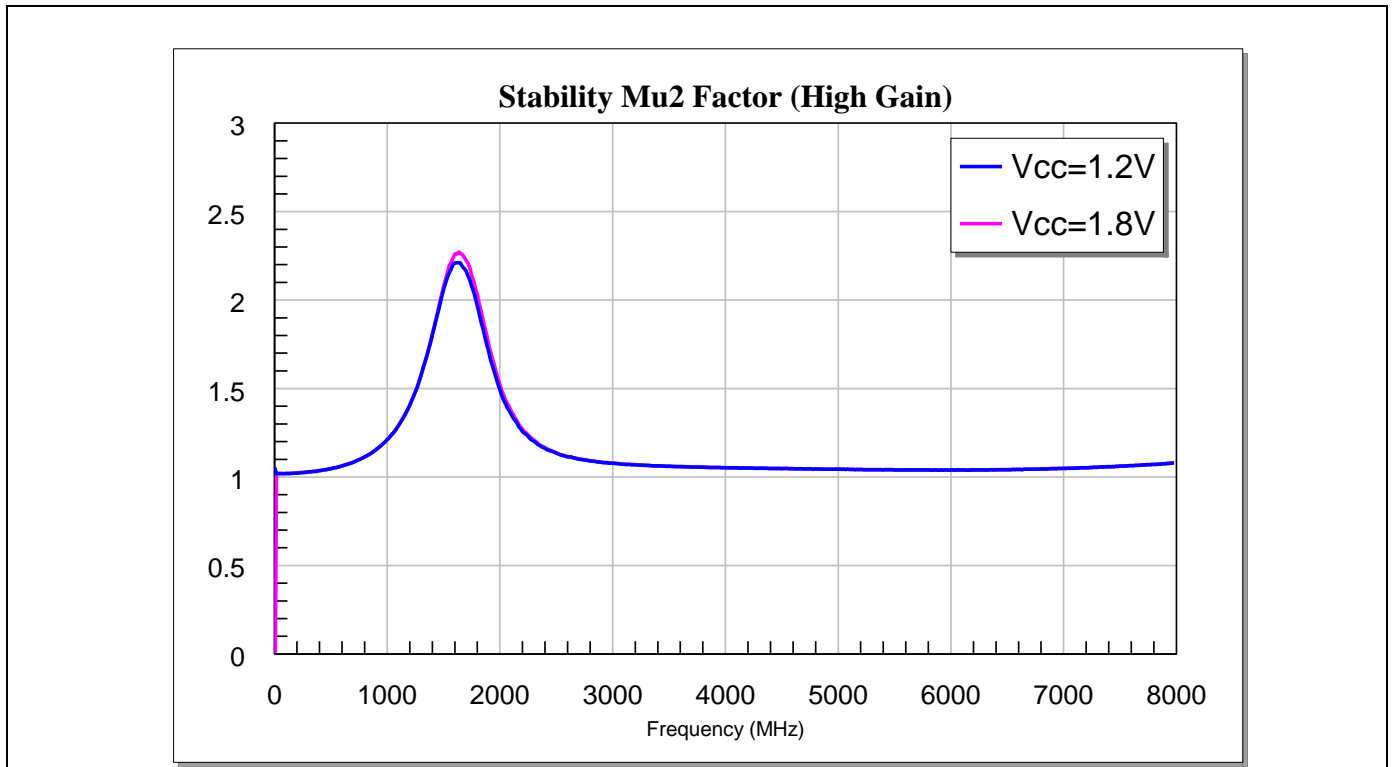
Figure 14   Stability Mu2-factor of BGA123L4 for GNSS Applications
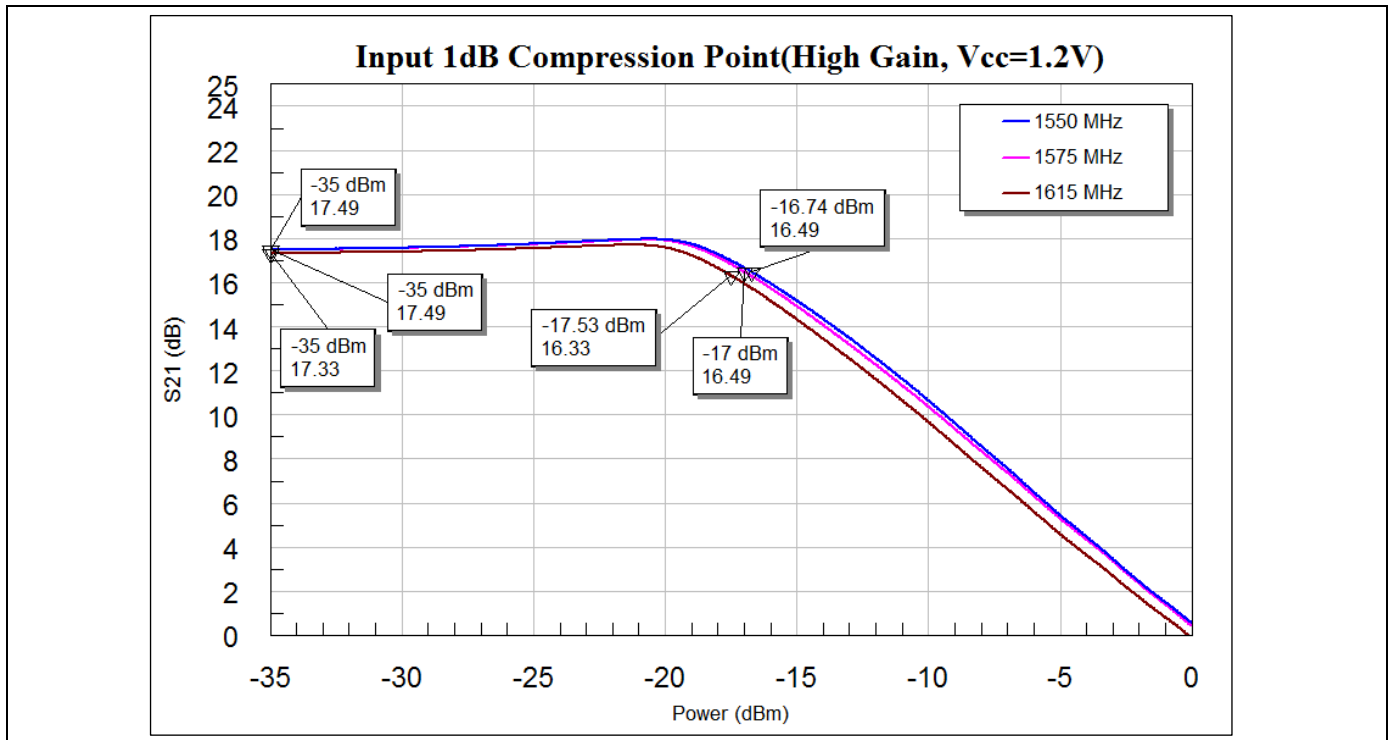
Figure 15   Input 1dB Compression Point (1.2V) of BGA123L4 for GNSS Applications

Measurement Graphs
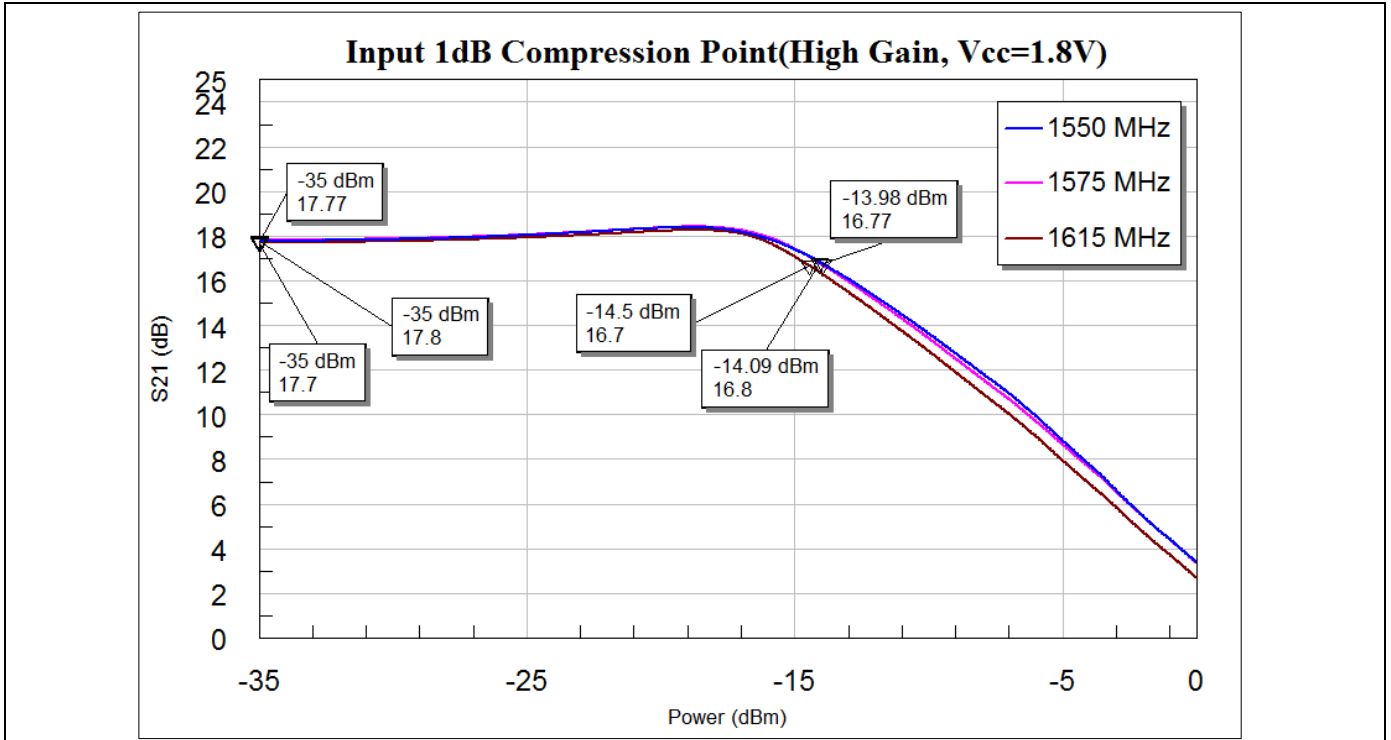
Figure 16   Input 1dB Compression Point (1.8V) of BGA123L4 for GNSS Applications
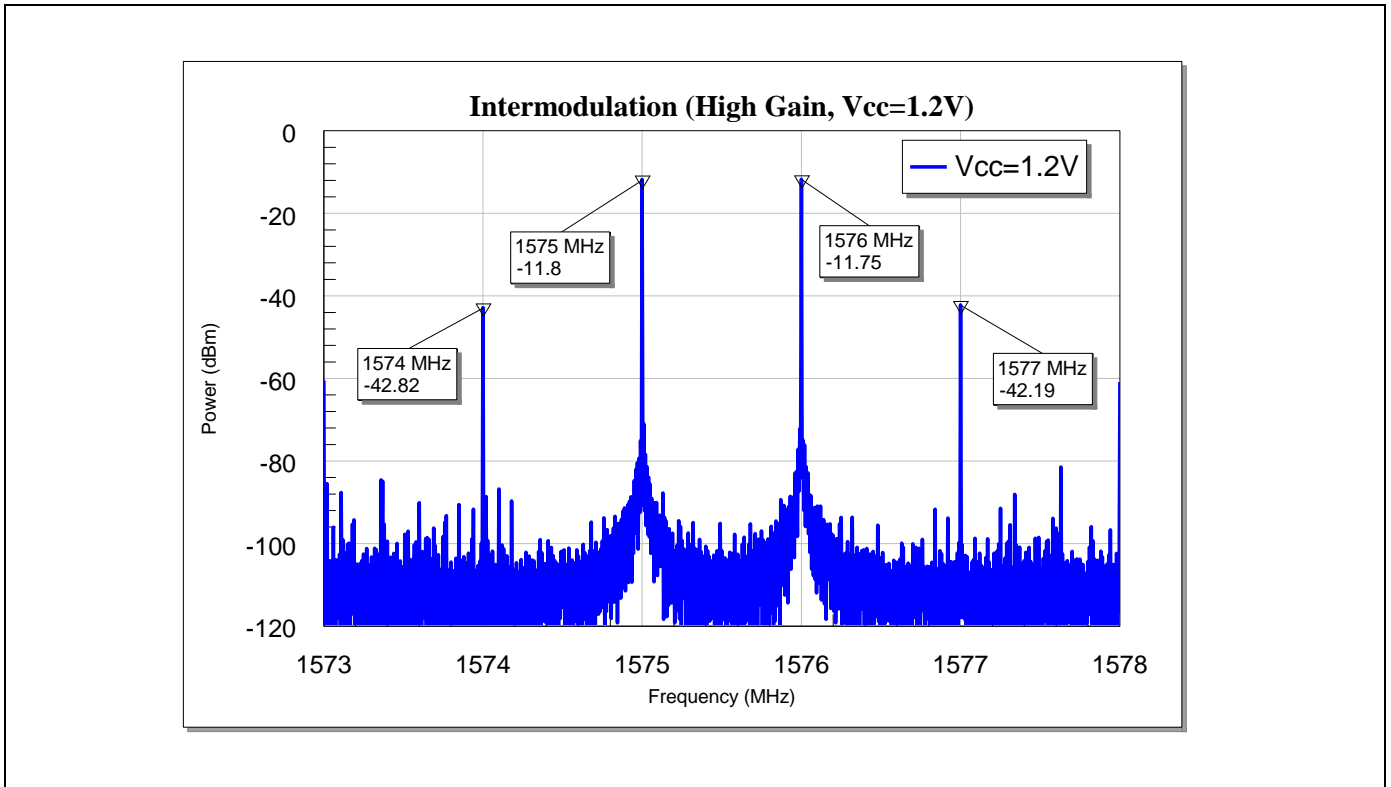
Figure 17   Third-order Interception Point (1.2V) of BGA123L4 for GNSS Applications (Output referred)

Measurement Graphs
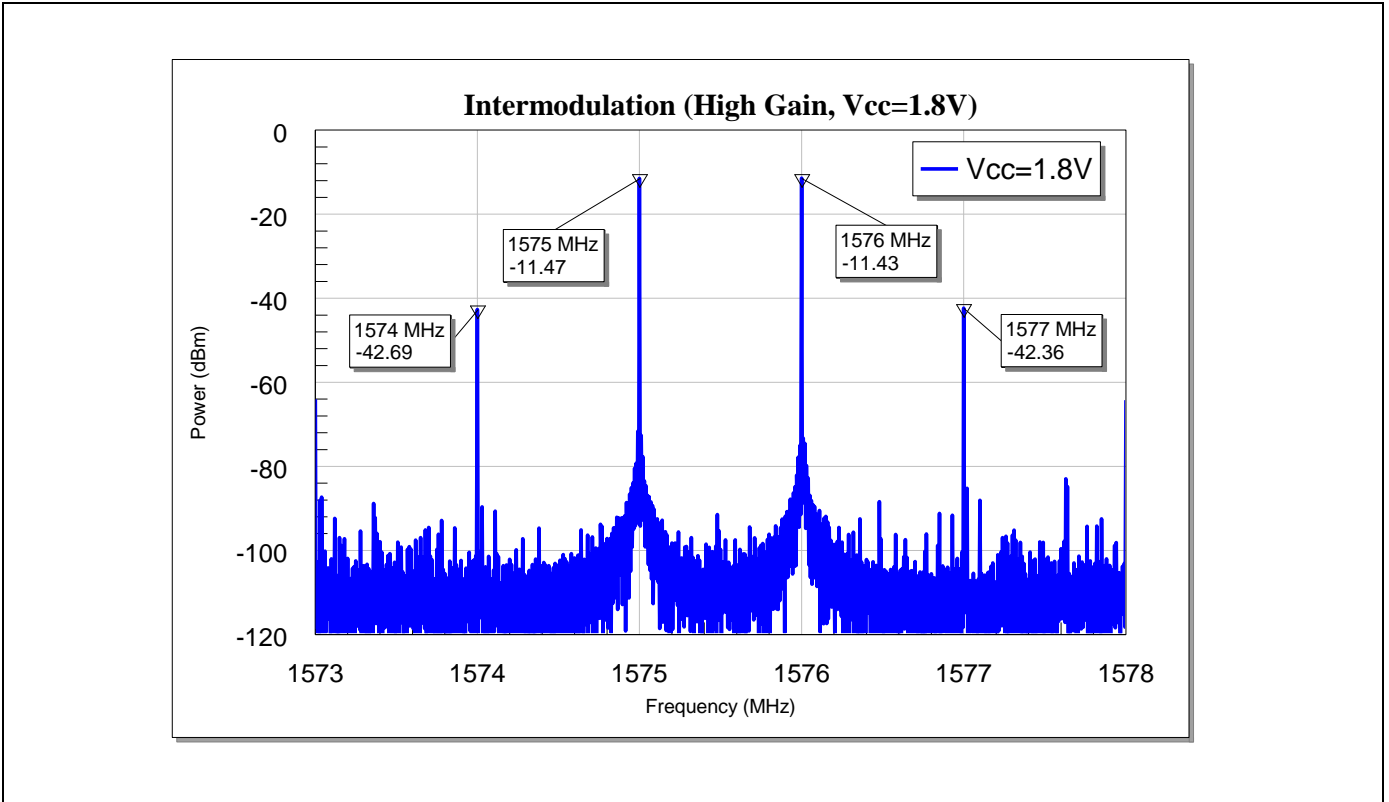
Figure 18   Third-order Interception Point (1.8V) of BGA123L4 for GNSS Applications (Output referred)
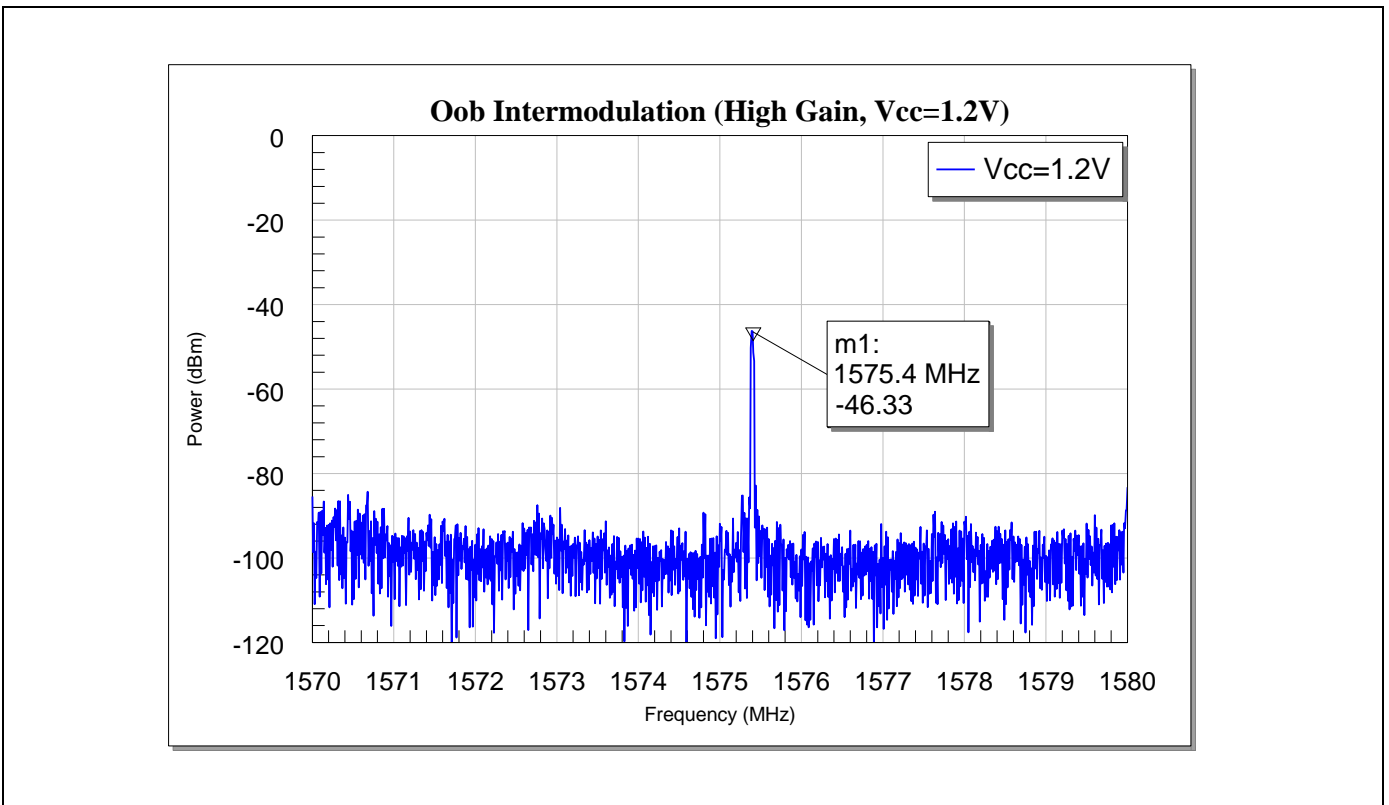
Figure 19   Out-of-band Third-order Intermodulation (1.2V) of BGA123L4 for GNSS Applications (Output referred)

Measurement Graphs
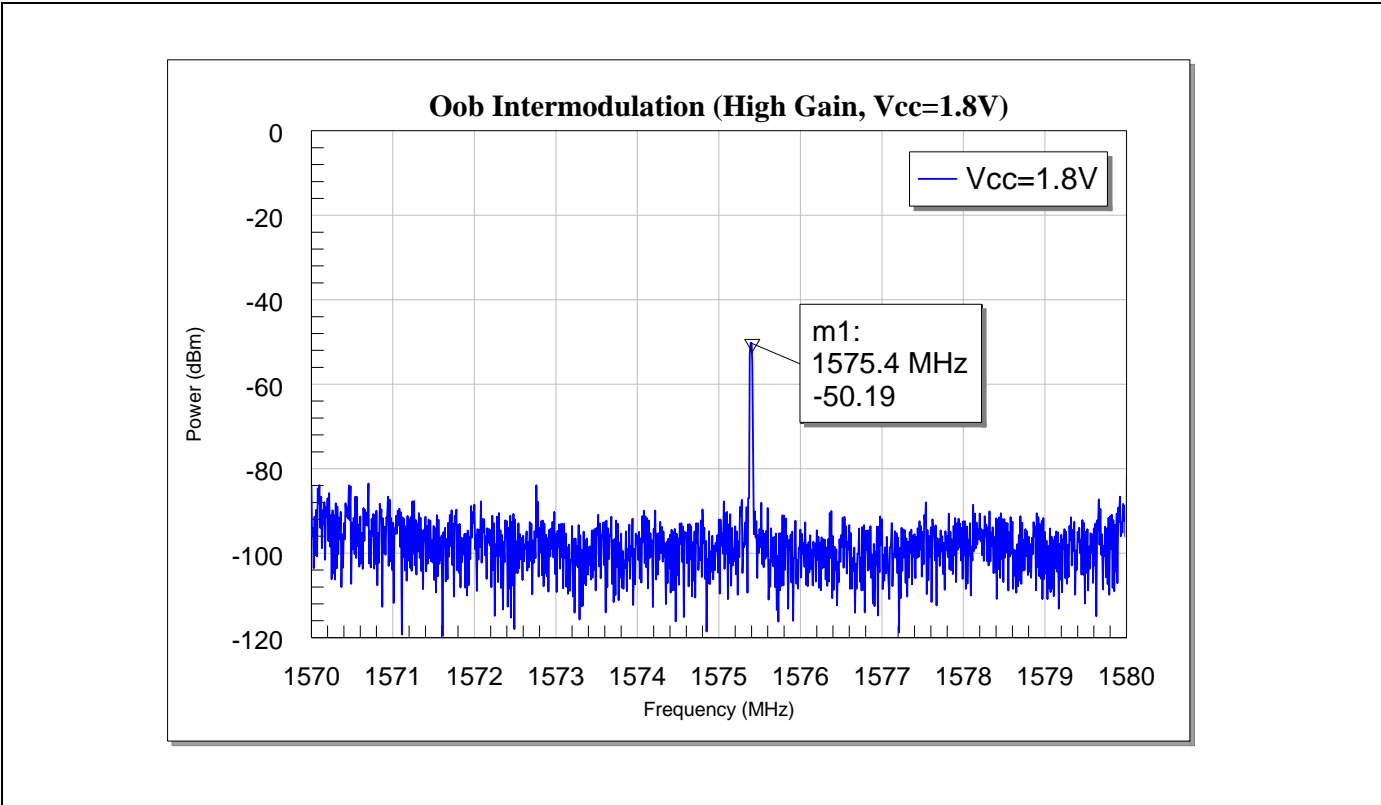
Figure 20   Out-of-band Third-order Intermodulation (1.8V) of BGA123L4 for GNSS Applications (Output referred)

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: **GL05 V1.0**

PCB material: **Rogers 4003**

ε_r of PCB material: **3.6**
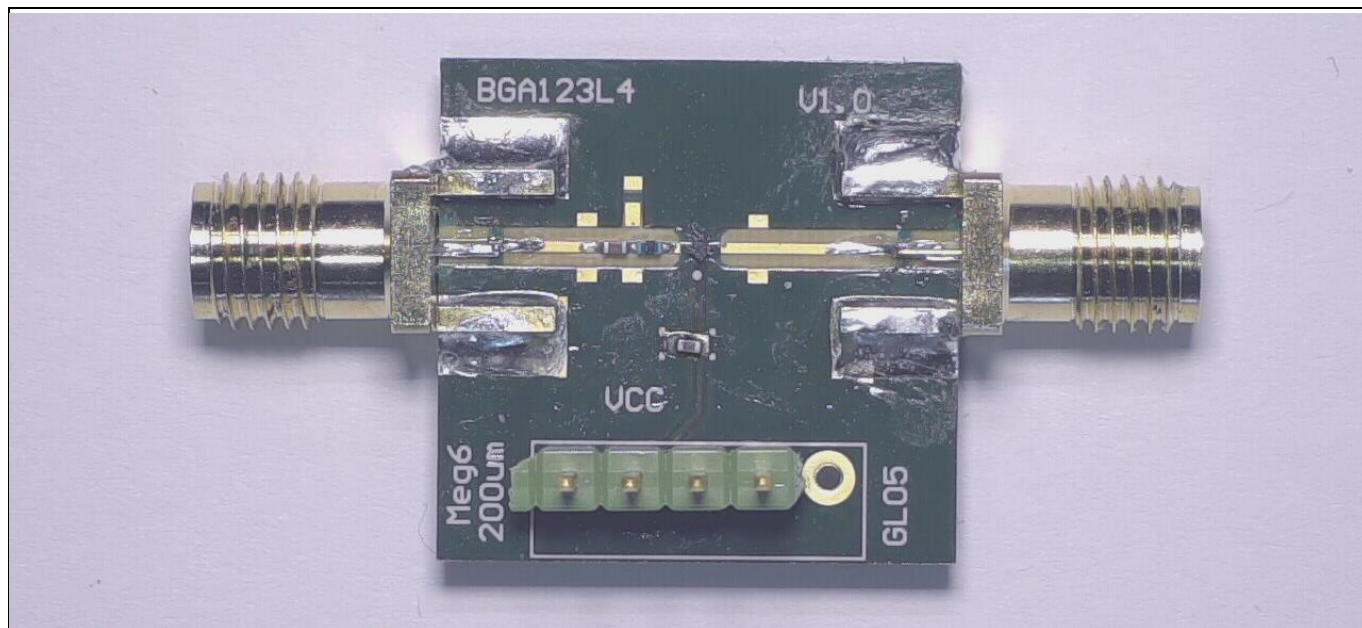
Figure 21   Photo Picture of Evaluation Board (overview)
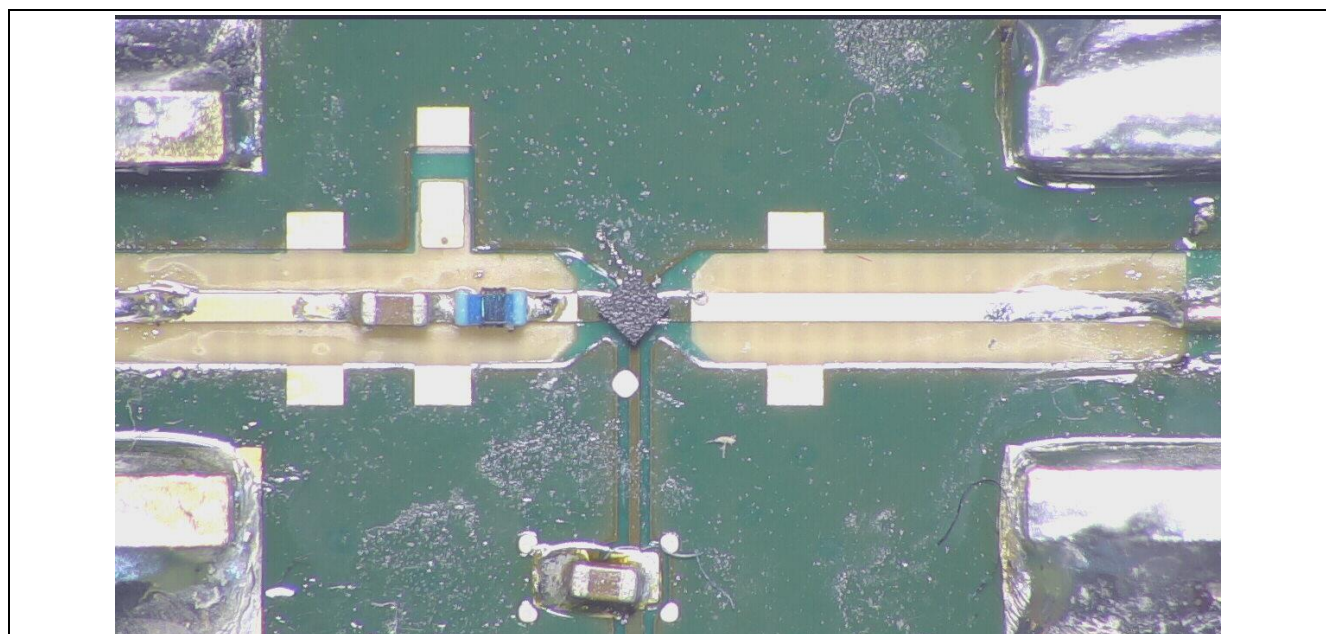
Figure 22   Photo Picture of Evaluation Board (detailed view)

Evaluation Board and Layout Information
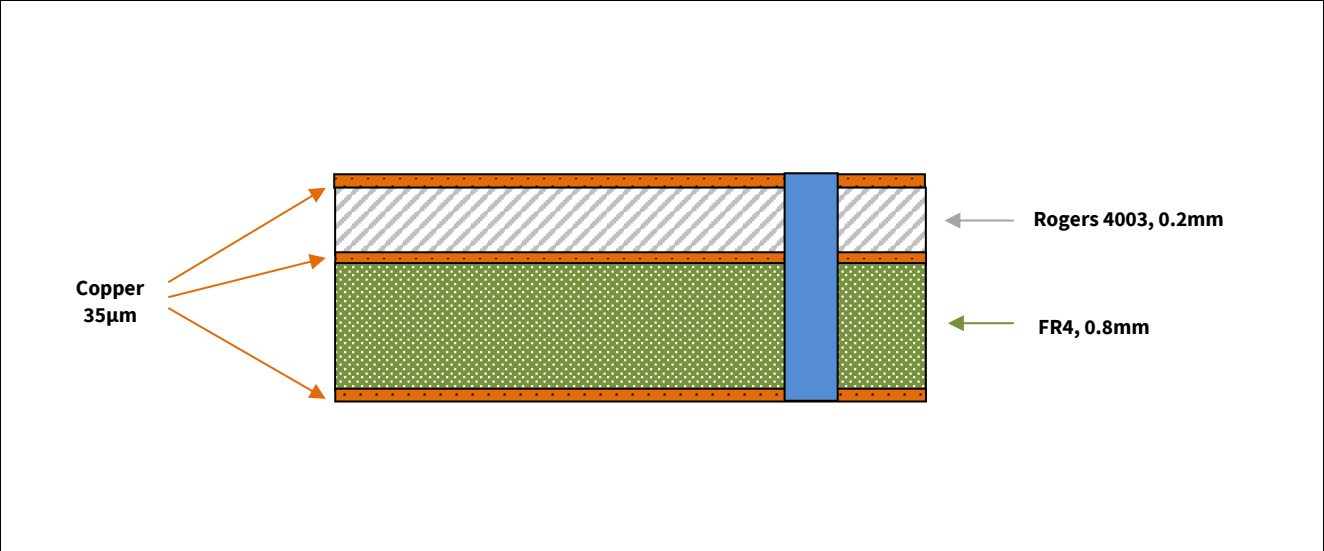
Figure 23   PCB Layer Information

6 Authors

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Ines Ben Hmida, Working Student of Business Unit "Radio Frequency and Sensors"

7 Reference

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

[2]   http://galileognss.eu/wp-content/uploads/2013/09/Galileo-Frequency-bands.jpg

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

[4]   http://rfmw.em.keysight.com/NFUcalc

Revision History

Major changes since the last revision Rev 1.0 2017-12-20

Page or Reference	Description of change
8,9,10	Added Noise Figure when matched with 0201 LQP03TN components
8,9,18,19	Added Out-of-band IM3 measurement results

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