BGA524N6 as Low Noise Amplifier for GNSS Applications with LTE B13/B14 Rejection

About this document

Scope and purpose

This application note describes Infineon's GNSS MMIC: BGA524N6 as a Low-Noise Amplifier (LNA) for GNSS applications (1550 to 1615 MHz) with LTE B13/B14 rejection using 0201 size components for matching.

1. The BGA524N6 is a silicon germanium LNA supporting 1550 to 1615 MHz.
2. The target application is GNSS applications (1550 to 1615 MHz).
3. In this report, the performance of BGA524N6 for LTE B13/B14 rejection is measured on a FR4 board. This device is matched with 0201 size external components. For comparision purposes, the Noise Figure (NF) with 0402 size LQW15 inductor component in the circuit is also presented.
4. Key performance parameters at 1.8 V, 1575 MHz
   NF with LQP03T inductor = 1.05 dB
   NF with LQW15 inductor = 0.95 dB
   Insertion gain = 19.1 dB
   Insertion gain at 787 MHz = -37 dB
   Input return loss = 11.5 dB
   Output return loss = 17.2 dB
   Out-of-band output IM3 = -48.1 dBm
5. Key performance parameters at 2.8 V, 1575 MHz
   NF with LQP03T inductor = 1.05 dB
   NF with LQW15 inductor = 0.95 dB
   Insertion gain = 19.0 dB
   Insertion gain at 787 MHz = -37 dB
   Input return loss = 11.5 dB
   Output return loss = 17.4 dB
   Out-of-band output IM3 = -49.2 dBm

Table of contents

List of figures[1]

List of tables

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 (PNDs), 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: 1574 – 1576 MHz (L1), 1226 - 1229 MHz (L2), 1166 – 1186 MHz (L5)
Galileo: 1573 – 1577 MHz (E1), 1166 MHz – 1217 MHz (E5), 1258 -1299 MHz (E6)
GLONASS: 1597 - 1609 MHz (G1), 1237 -1254 MHz (G2), 1189 MHz – 1214 MHz (G3)
Beidou: 1559 – 1563 MHz (B1), 1175 – 1209 MHz(B2), 1266 – 1270 MHz (B3)
QZSS: 1574 – 1576 MHz (L1), 1226 - 1229 MHz (L2), 1166 – 1186 MHz (L5), 1258 -1299 MHz (L6)
IRNSS: 1166 – 1188 MHz (L5), 2484 - 2500 MHz (S)

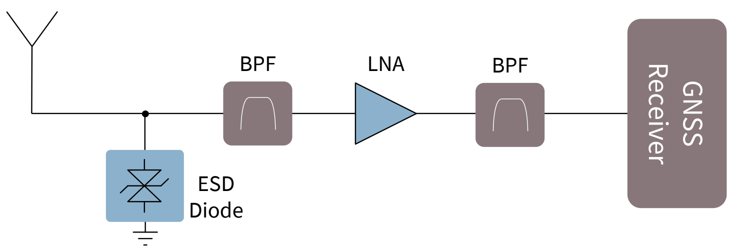

Figure 1 Application diagram: receiver front-end of the Global Navigation Satellite System

1.1.1 LTE band 13/band 14 interference

The second harmonic of LTE band 13 and band 14 (777 MHz/788 MHz) is located in the GNSS band at 1574 MHz/1576 MHz. Figure 2 shows the interference measurement of LTE band 13 with the GNSS band of 1575 MHz.

Considering a worst-case isolation of 15 dB between both the antennas, jammer frequency f_{LTE} = 787.76 MHz, the power of the LTE band 13 jammer is -32 dBm at the input of GNSS LNA. After inserting a band 13 rejection filter at the LNA input, the second harmonic at f_{H2} = 1575.52 MHz will be reduced to -110 dBm at the LNA output.

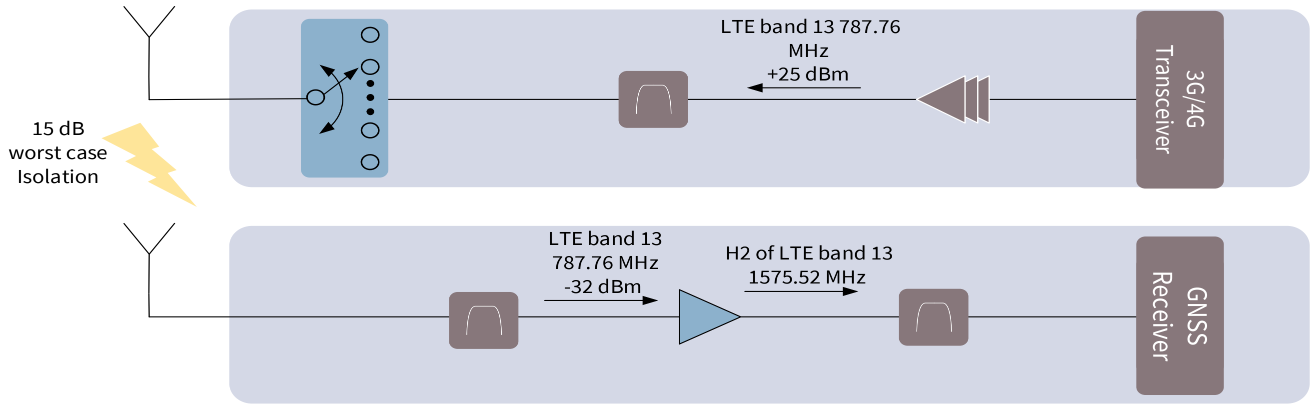

Figure 2 Block diagram for the LTE band 13 second harmonic interference

1.1.2 Out-of-band interference

Because GNSS and cellular systems co-exist in a compact area in a mobile phone, coupling from the cellular transmitter to the GNSS receive path results in the intermixing of other high-frequency signals in GNSS FE devices; for example, intermodulation between LTE band 2 and band 3 signals, intermodulation between LTE band 5 and WLAN 2.4 GHz signals, etc.

In the example below, the LTE band 3 signal ($f1_{IN}$) and LTE band 2 signal ($f2_{IN}$) produce third-order intermodulation products at GPS frequencies. This effect desensitizes the GPS receiver and decreases its performance. When $f1_{IN}$ = 1712.7 MHz and power $P1_{IN}$ = -25 dBm, and $f2_{IN}$ = 1850 MHz and power $P2_{IN}$ = -25 dBm are used, the third-order intermodulation product, $2 \times f1_{IN} - f2_{IN}$, is located at 1575.4 MHz. This signal is referred to as Out-of-band Output IM3 (OoB OIM3). The Out-of-Band Input IM3 (OoB IIM3) can be calculated as:

$$OoB\ IIM3 = OoB\ OIM3 - Gain\ at\ 1575.4\ MHz$$

As an example, if the OoB OIM3 of the device at 1575.4 MHz is -48.1 dBm and the gain of the amplifier at 1575.4 MHz is 19.1 dB, then the OoB IIM3 is calculated as:

$$OoB\ IIM3 = -48.1 - 19.1 = -67.2\ \text{dBm}$$

1.2 Infineon product portfolio for GNSS applications

Infineon offers the following 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.

1.3 Key features of GNSS low-noise amplifiers

Infineon Technologies is among the market leaders in GNSS LNAs for navigation applications. The GNSS MMIC LNA products offer the following features:

Low Noise Figure & High Gain

The power levels of satellite signals received by a GNSS receiver are as low as -130 dBm. An external LNA with exceptionally low NF and good gain helps to boost the signal-to-noise ratio of the system. The existing LNA portfolio includes devices with various gain levels to tailor to customer's RF systems.

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 recent development has focused on low current (e.g. 1.1 mA) and low supply voltage (1.2 V), making the 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.

BGA524N6 overview

1.4 Features

- Operating frequencies: 1550 to 1615 MHz
- Ultra-low current consumption: 2.5 mA
- Wide supply voltage range: 1.5 to 3.3 V
- High insertion power gain: 19.6 dB
- Low NF: 0.55 dB
- 2 kV HBM ESD protection (including AI pin)
- Ultra-small TSNP-6-2 leadless package (footprint: 0.7 x 1.1 mm^2)
- RF output internally matched to 50 Ω
- Only one external SMD component necessary
- Pb-free (RoHS compliant) package
- B7HF silicon germanium technology

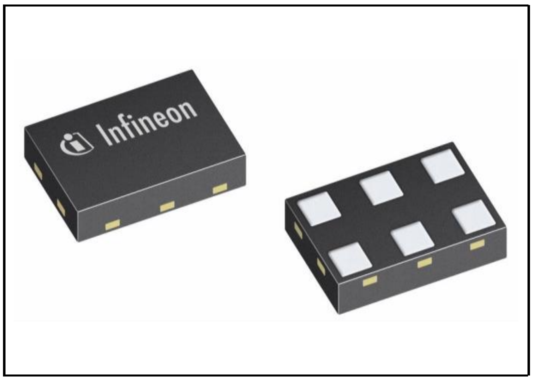

Figure 3 BGA524N6N6 in TSNP-6-2

1.5 Key applications of BGA524N6

BGA524N6 is designed to enhance GNSS signal sensitivity, especially in wearables and mobile cellular IoT devices. With 19.6 dB gain and only 0.55 dB NF it ensures high system sensitivity. The current needed is only 2.5 mA, which is critical to help to conserve batteries. The wide supply voltage range of 1.5 to 3.3 V ensures flexible design and high compatibility. It supports all GNSS systems including GPS, GLONASS, BeiDou and Galileo.

1.6 Description

The BGA524N6 is an ultra-low-noise amplifier for Global Navigation Satellite Systems (GNSSs), which covers all GNSS frequency bands from 1550 to 1615 MHz, such as GPS, GLONASS, BeiDou, Galilieo and others. The LNA provides 19.6 dB gain and 0.55 dB NF at a current consumption of only 2.5 mA in the application configuration described in Figure 5. The BGA524N6 is based on Infineon Technologies' B7HF silicon germanium technology. It operates from 1.5 to 3.3 V supply voltage.

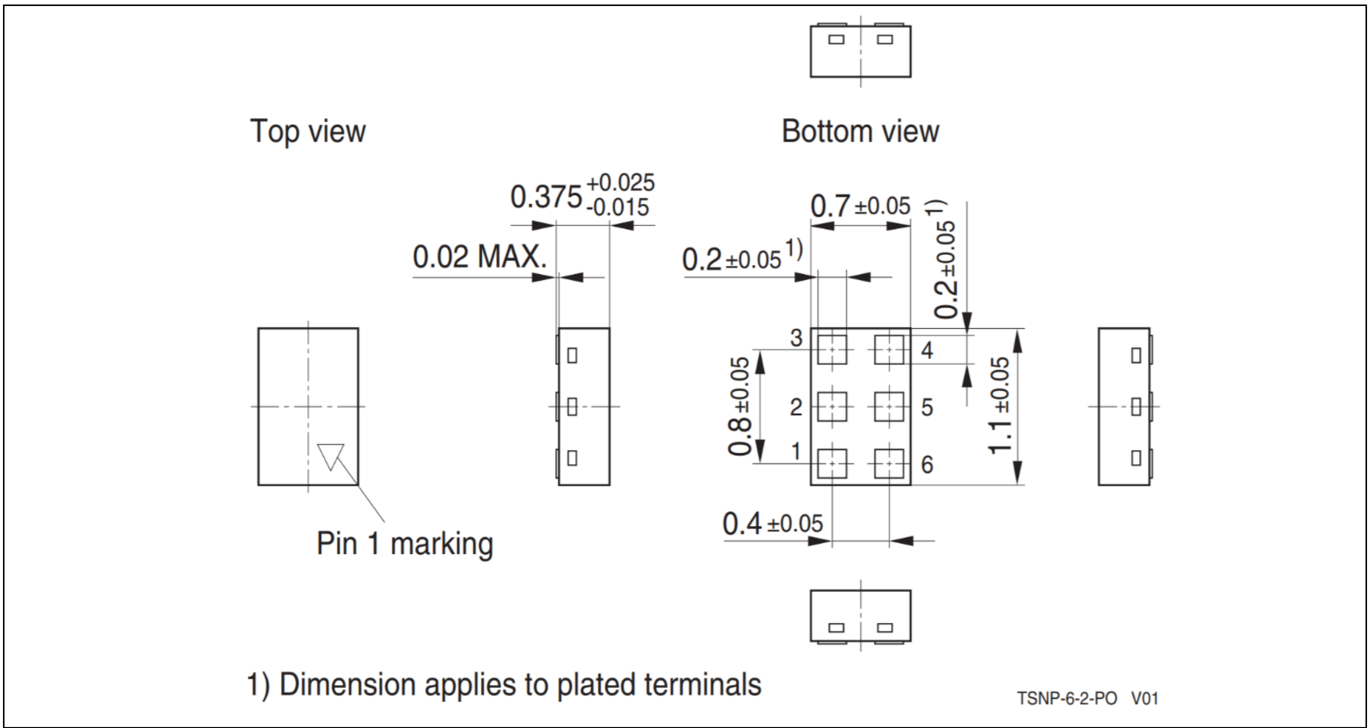

Figure 4 Package and pin connections of BGA524N6

Table 1 Pin assignment of BGA524N6

Pin no.	Symbol	Function
1	GND	Ground
2	VCC	DC supply
3	AO	LNA output
4	GND	Ground
5	AI	LNA input
6	PON	Power on control

2 Application circuit and performance overview

In this chapter the performance of the application circuit, the schematic and Bill of Materials are presented.

Device:	**BGA524N6**
Application:	**LNA for GNSS applications with LTE B13/B14 rejection**
PCB marking:	**M110705**
EVB order no.:	**AN575**

2.1 Summary of measurement results

The performance of BGA524N6N6 for GNSS applications is summarized in the following table.

Table 2 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	V_{CC}	1.8			V	
DC current	I_{CC}	2.6			mA	
Gain	G	19.1	19.1	18.9	dB	
Gain at 787 MHz	G_B13	-37			dB	
Noise Figure[1)]	NF	1.10	1.05	1.05	dB	LQP03T inductor for matching, loss of input line of 0.05 dB is de-embedded[1)]
Noise Figure[2)]	NF	0.95	0.95	0.95	dB	LQW15 inductor for matching, loss of input line of 0.05 dB is de-embedded[2)]
Input return loss	RL_{in}	12.6	11.5	10.1	dB	
Output return loss	RL_{out}	11.8	17.2	24.8	dB	
Reverse isolation	I_{Rev}	37.7	37.6	37.9	dB	
Input P1dB	IP1dB		-15.2		dBm	
Output P1dB	OP1dB		3.9		dBm	
LTE band 13 second harmonic input referred	B13 IHD2	-68.3			dBm	Power at input: -25 dBm f = 787.7 MHz, HD2 measured at 1575.4 MHz
LTE band 13 second harmonic output referred	B13 OHD2	-49.2			dBm	
Input IP3	IIP3	-12.1			dBm	Power at input: -30 dBm f1 = 1575 MHz, f2 = 1576 MHz
Output IP3	OIP3	6.9			dBm	
Out-of-Band Input IM3[3)]	OoB_IIM3	-67.2			dBm	Power at input: -25 dBm f1 = 1712.7 MHz, f2 = 1850 MHz OoB_IM3 measured at 1575.4 MHz
Out-of-Band Output IM3	OoB_OIM3	-48.1			dBm	
Stability	K	> 1			–	Measured up to 10 GHz

Table 3 Electrical characteristics at 2.8 V (at room temperature)

Parameter	Symbol	Value			Unit	Comment/test condition
Frequency range	Freq	1550	1575	1615	MHz	
DC voltage	V_{CC}	2.8			V	
DC current	I_{CC}	2.7			mA	
Gain	G	19.2	19.0	18.9	dB	
Gain at 787 MHz	G_B13	-37			dB	
Noise Figure[1)]	NF	1.10	1.05	1.05	dB	LQP03T inductor for matching, loss of input line of 0.05 dB is de-embedded[1)]
Noise Figure[2)]	NF	0.95	0.95	0.90	dB	LQW15 inductor for matching, loss of input line of 0.05 dB is de-embedded[2)]
Input return loss	RL_{in}	12.7	11.5	10.1	dB	
Output return loss	RL_{out}	11.9	17.4	24.9	dB	
Reverse isolation	I_{Rev}	37.6	37.6	37.8	dB	
Input P1dB	IP1dB		-11.5		dBm	
Output P1dB	OP1dB		7.6		dBm	
LTE band 13 second harmonic input referred	B13 IHD2	-68.3			dBm	Power at input: -25 dBm f = 787.7 MHz, measure HD2 at 1575.4 MHz
LTE band 13 second harmonic output referred	B13 OHD2	-49.2			dBm	
Input IP3	IIP3	-12.1			dBm	Power at input: -30 dBm f1 = 1575 MHz, f2 = 1576 MHz
Output IP3	OIP3	7.0			dBm	
Out-of-Band Input IM3[3)]	OoB_IIM3	-68.2			dBm	Power at input: -25 dBm f1 = 1712.7 MHz, f2 = 1850 MHz OoB_IM3 measured at 1575.4 MHz
Out-of-Band Output IM3	OoB_OIM3	-49.2			dBm	
Stability	K	> 1			–	Measured up to 10 GHz

3) Out-of-band Input IMx = IM level output referred – Gain @ the measured frequency

2.2 Schematic and BOM

The schematic of BGA524N6 for GNSS applications is presented in Figure 5 and its BOM is shown in Error! Reference source not found..

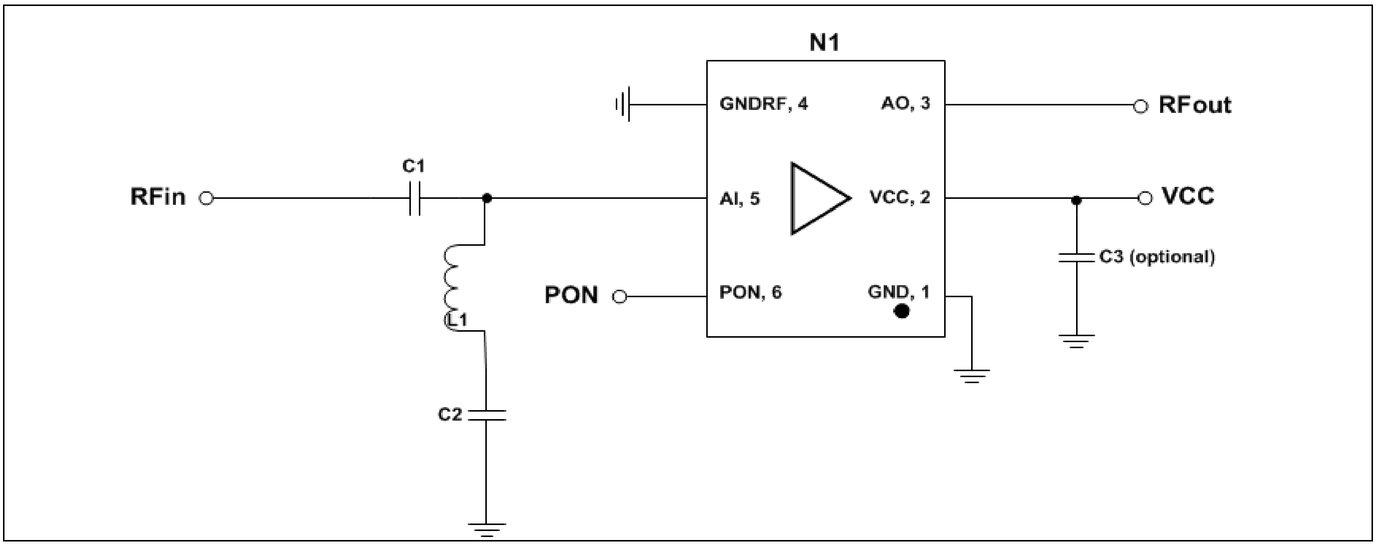

Figure 5 Schematic of the BGA524N6 application circuit

Table 4 BOM

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	1.5[1)]/1.6[2)]	pF	0201	Various	Input matching
C2	6.8	pF	0201	Various	B13/B14 notch filter
C3	Greater than or equal to 1	nF	0201	Various	RF bypass
L1	6.2	nH	0201/0402	Murata LQP03T/ Murata LQW15	B13/B14 notch filter
N1	BGA524N6	TSNP-6-2		Infineon Technologies	SiGe LNA

Note: 1) C1 = 1.5 pF used for matching when LQW15 inductor is used as a filter component

2) C1 = 1.6 pF used for matching when LQP03T inductor is used as a filter component

3) Measurements have been presented using 0201 components

Note: DC block function is NOT integrated at the input of BGA524N6. The DC block might be realized with pre-filter in GNSS applications.

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

3 Measurement graphs

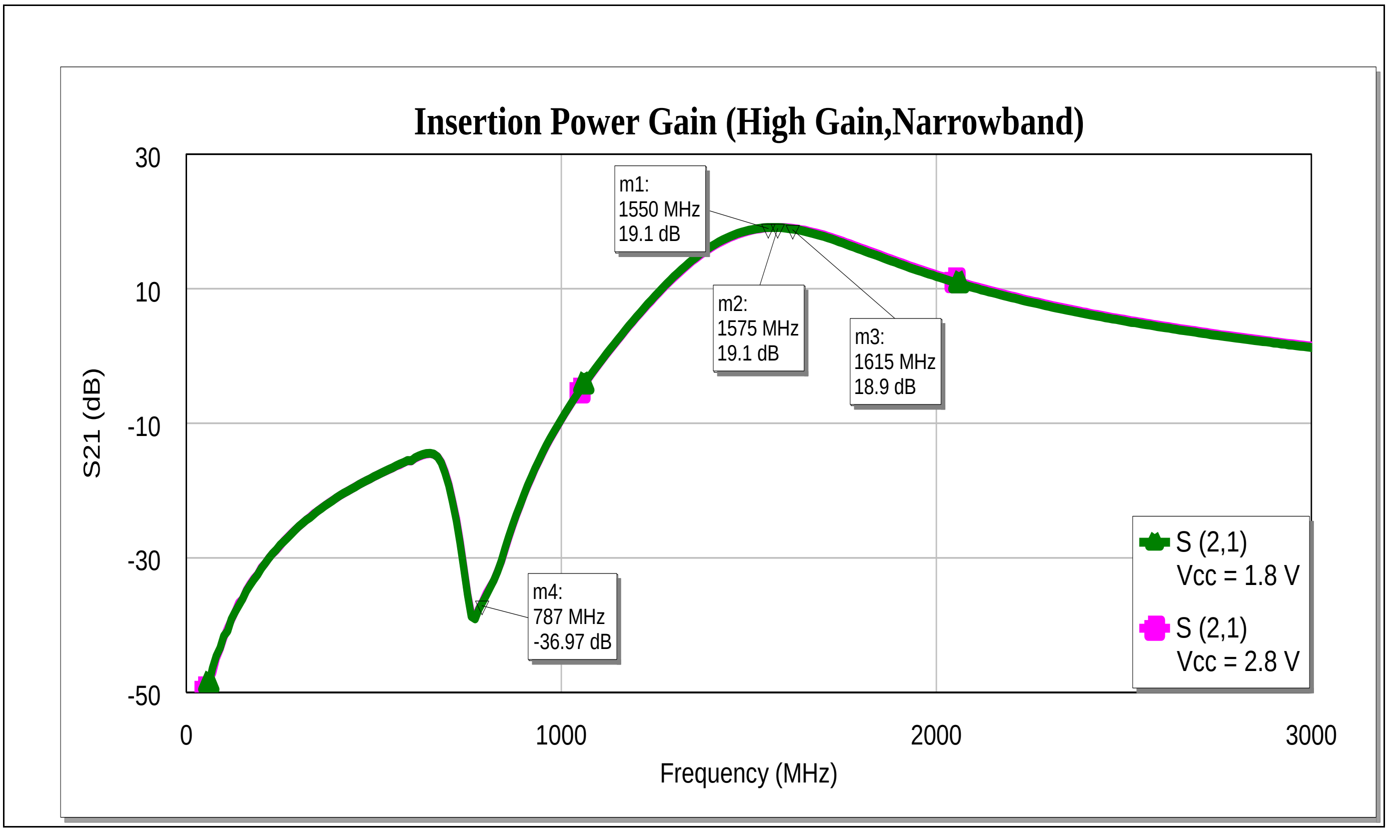

Figure 6 Insertion power gain (narrowband) of BGA524N6 for GNSS applications

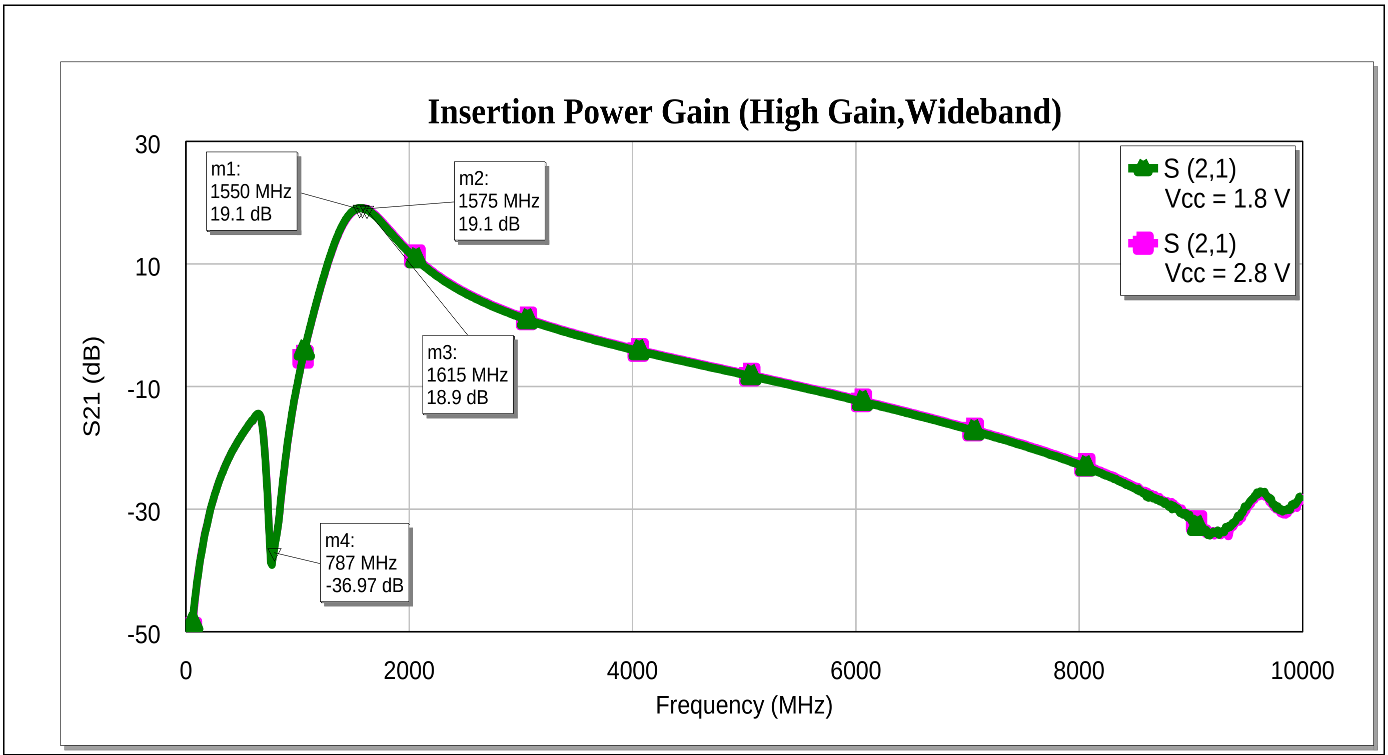

Figure 7 Insertion power gain (wideband) of BGA524N6 for GNSS applications

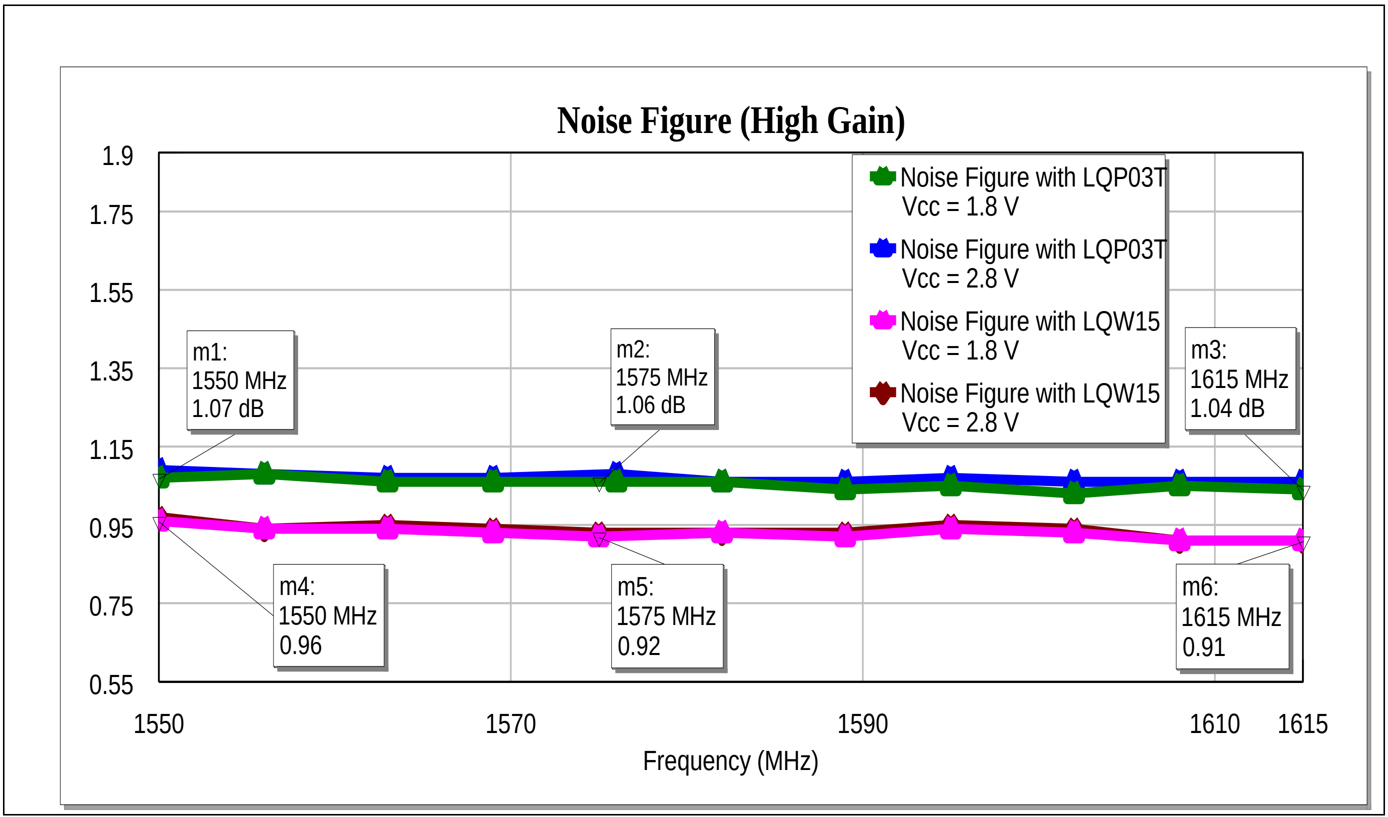

Figure 8 NF of BGA524N6 for GNSS applications (without SMA and connector losses)

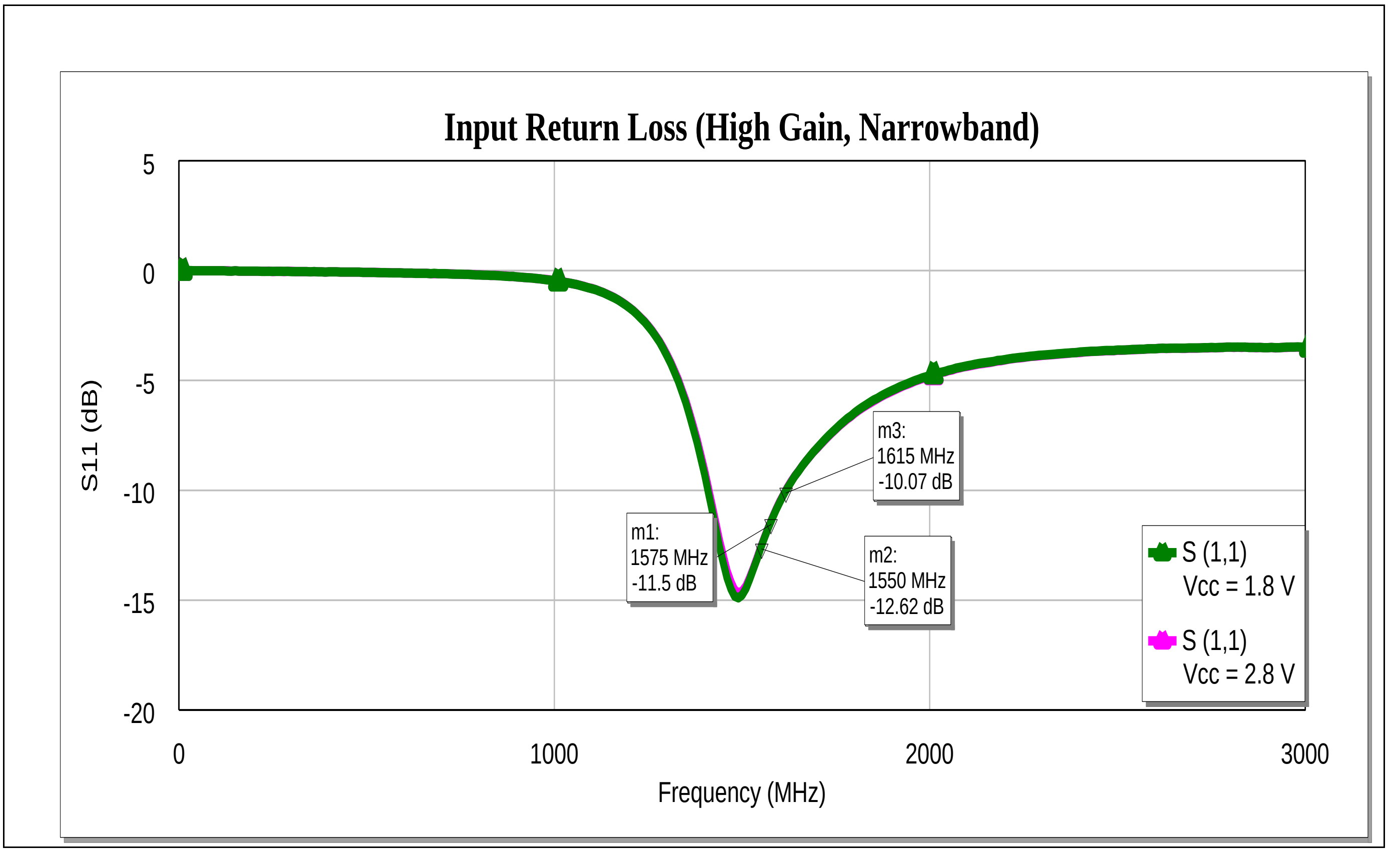

Figure 9 Input return loss of BGA524N6 for GNSS applications

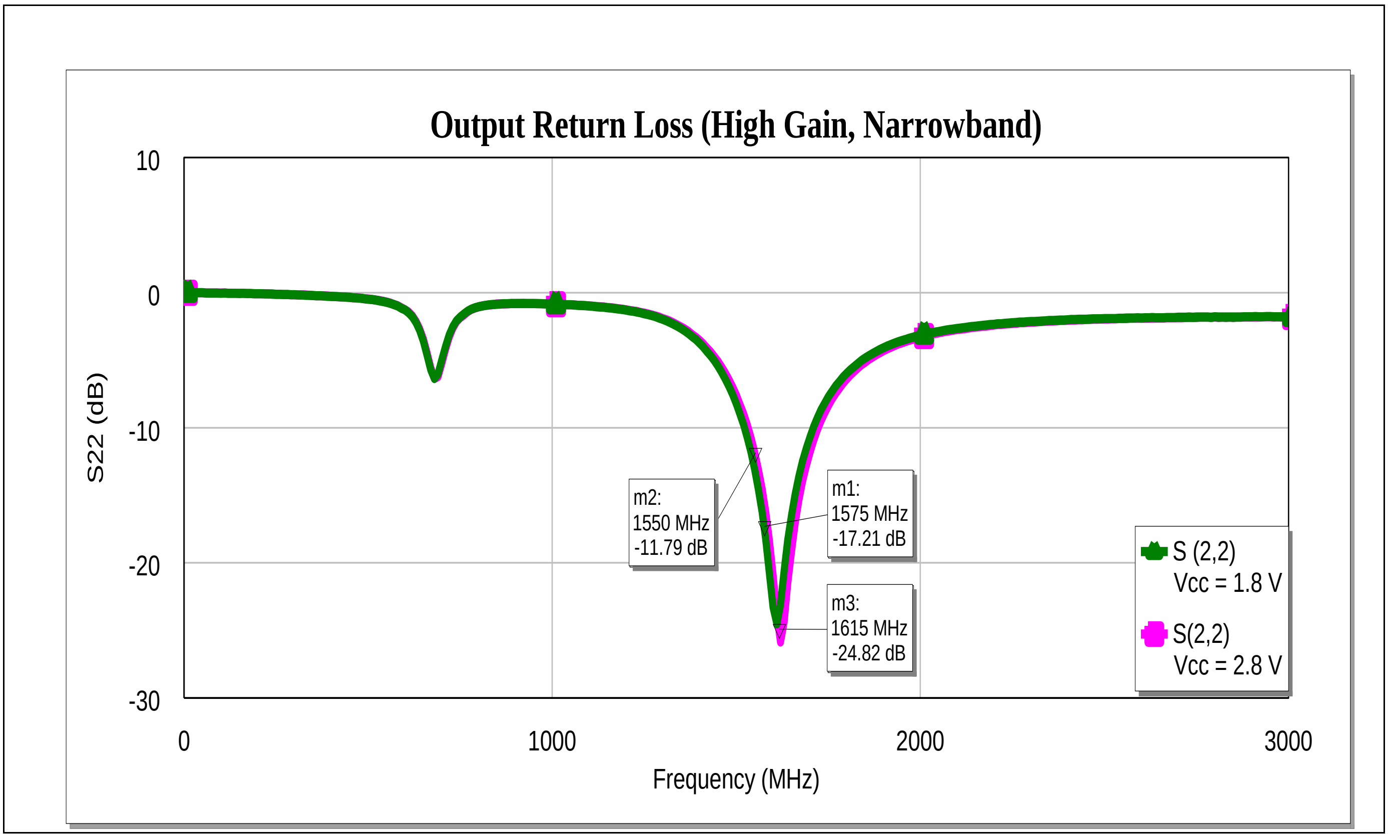

Figure 10 Output return loss of BGA524N6 for GNSS applications

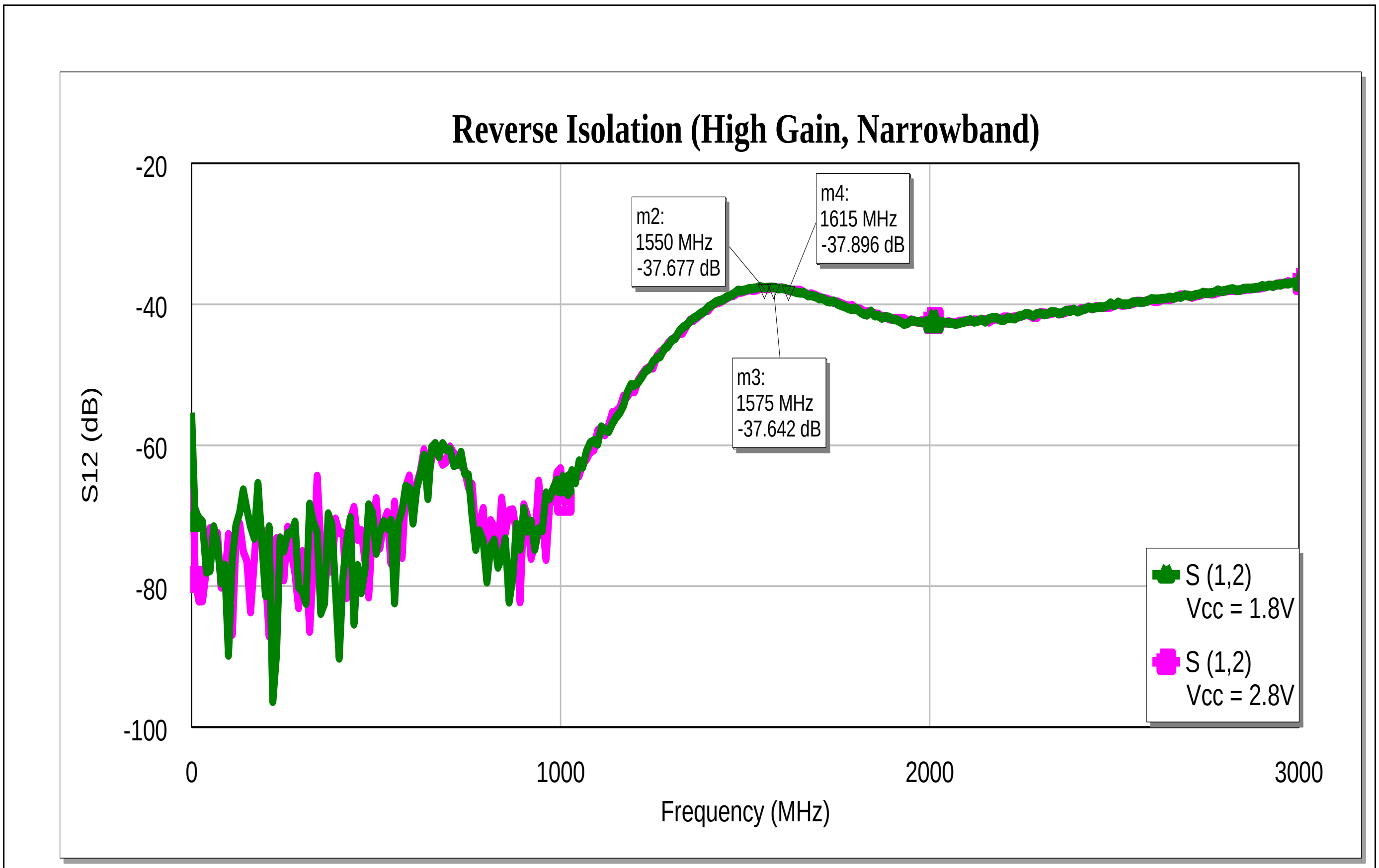

Figure 11 Reverse isolation of BGA524N6 for GNSS applications

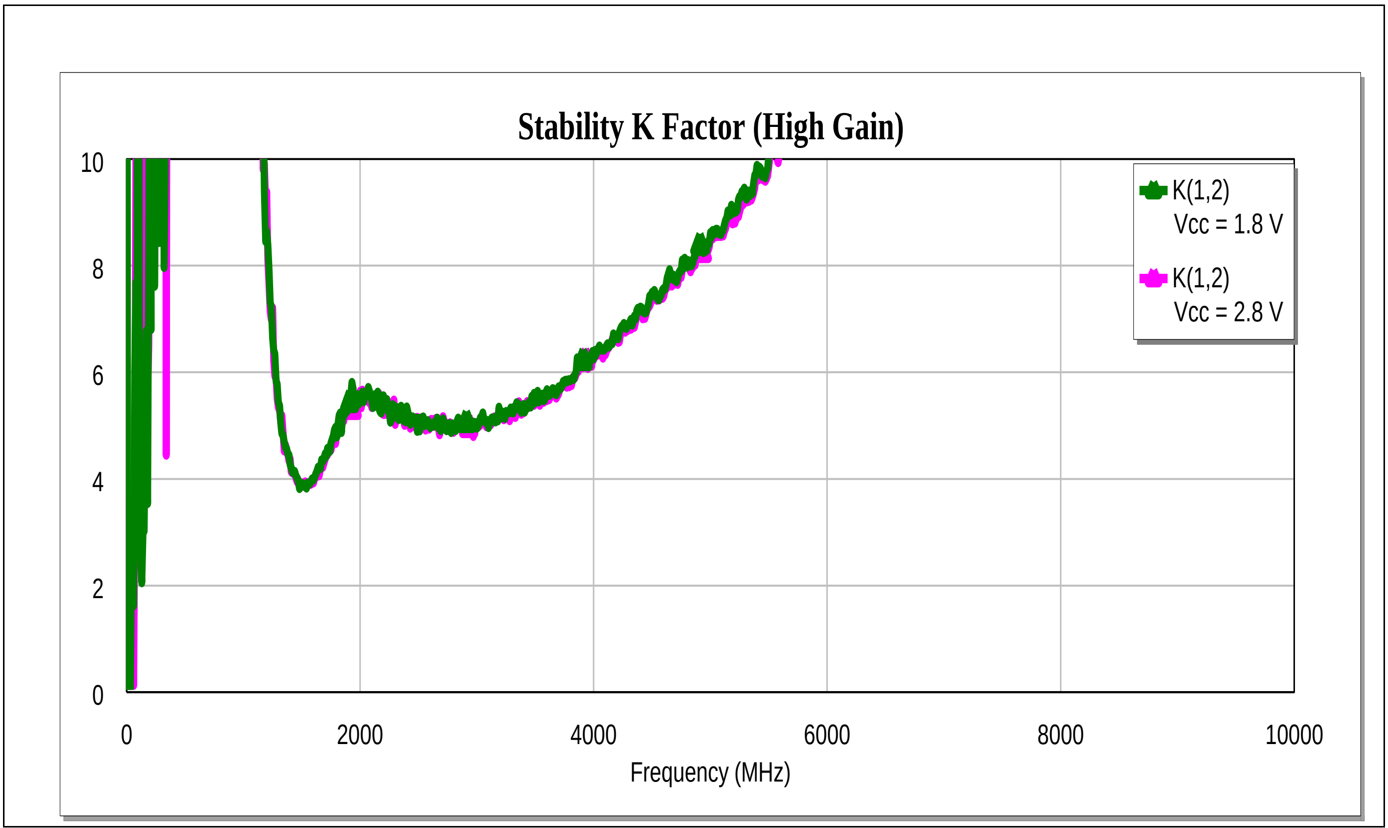

Figure 12 Stability K-factor of BGA524N6 for GNSS applications

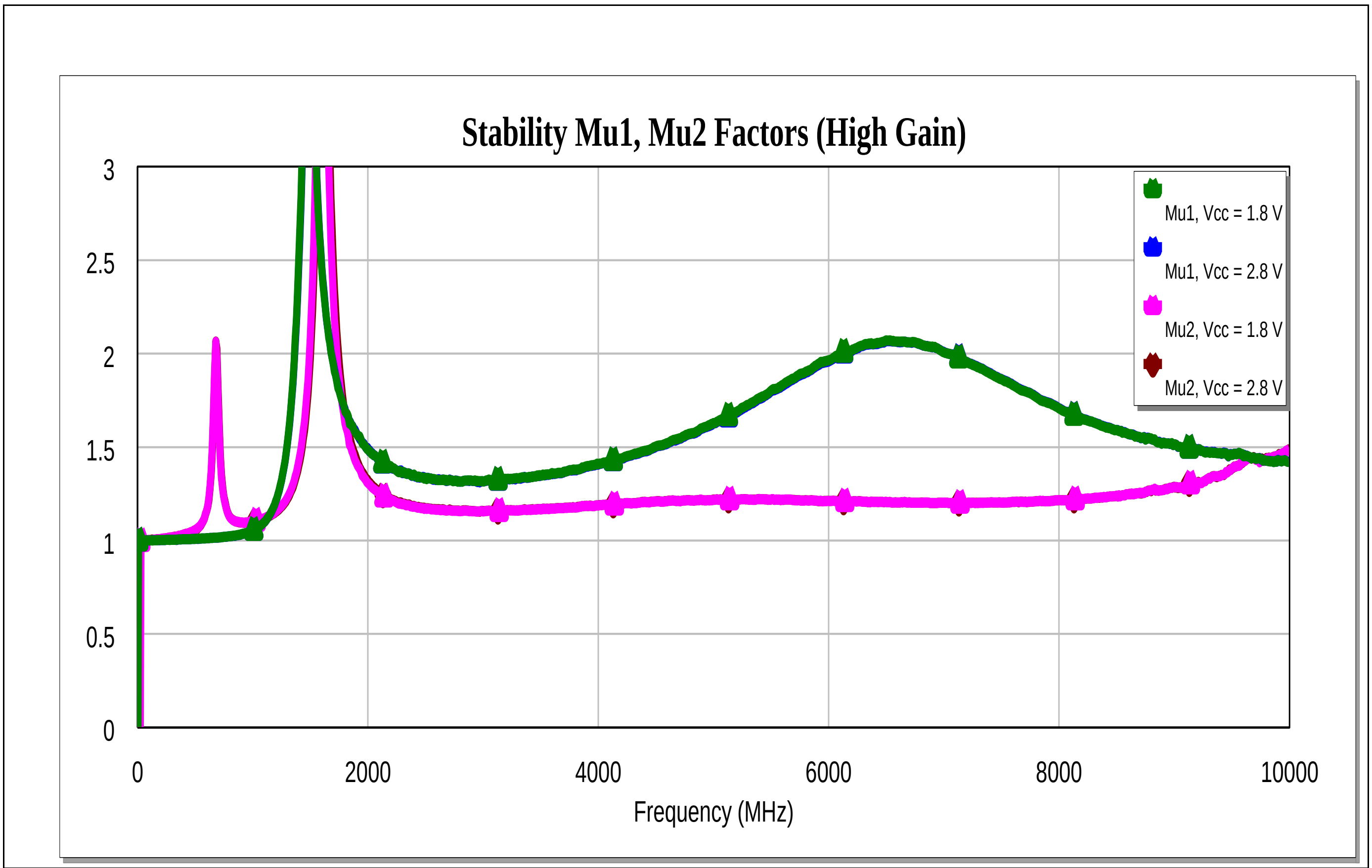

Figure 13 Stability Mu1-factor, Mu2-factor of BGA524N6 for GNSS applications

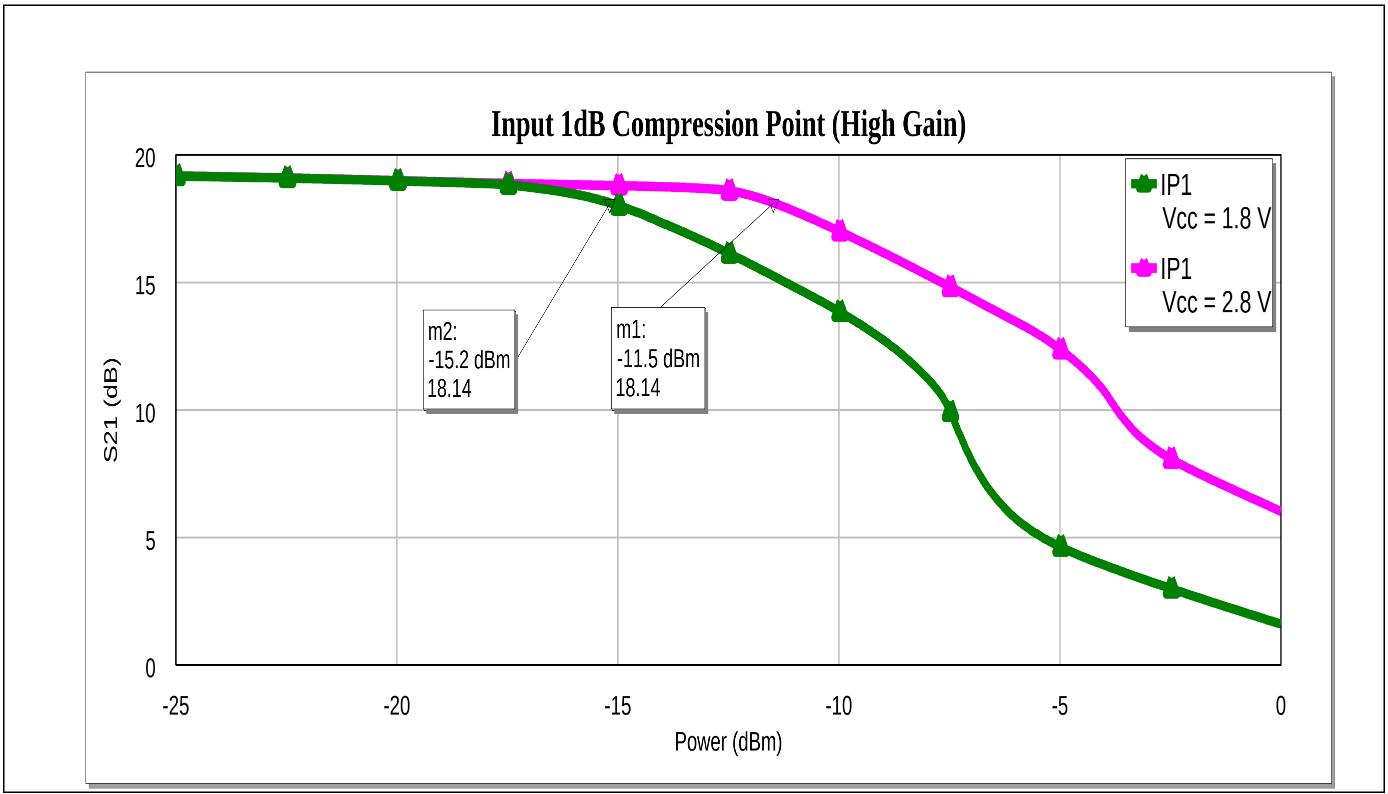

Figure 14 Input 1dB compression point of BGA524N6 for GNSS applications

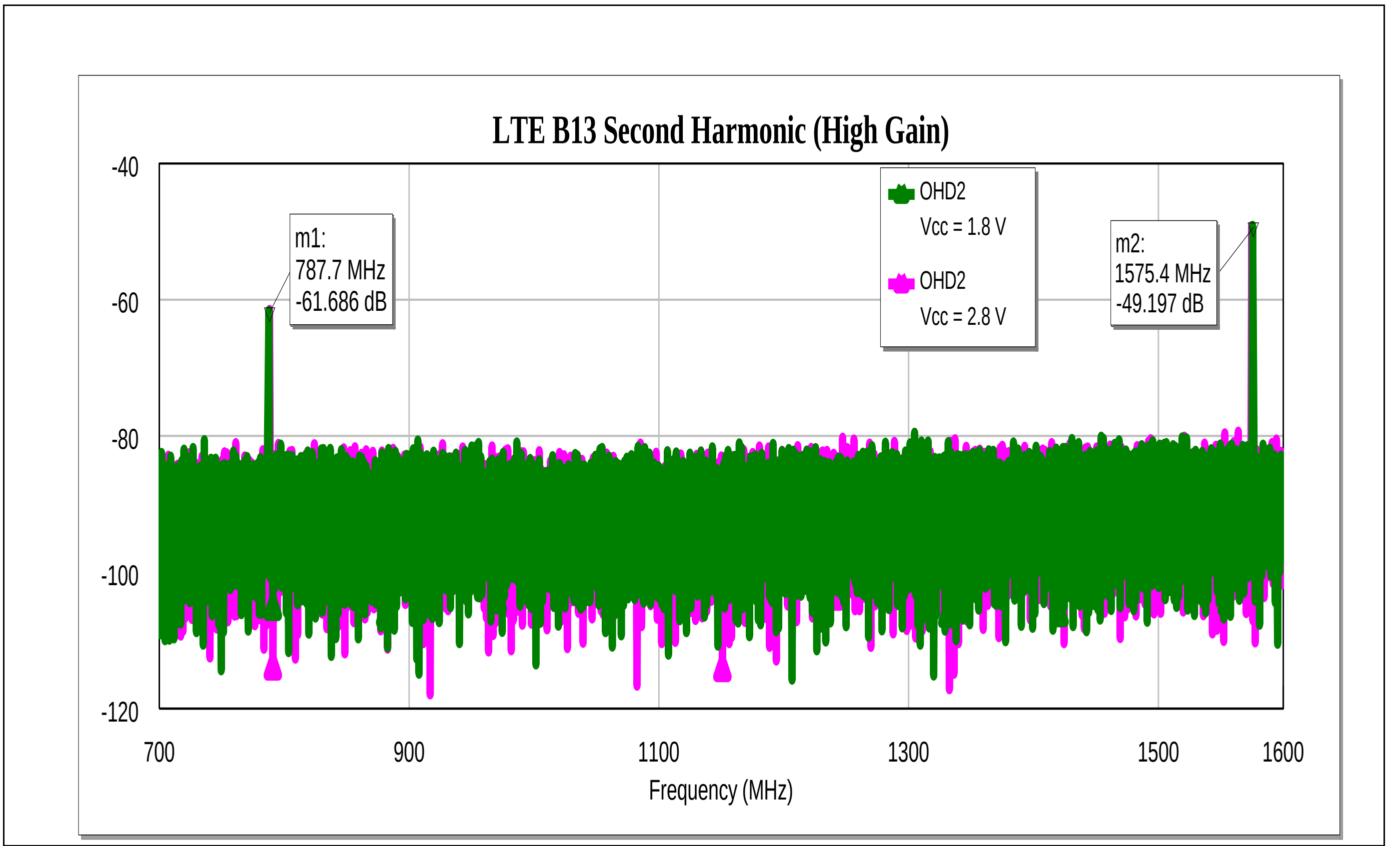

Figure 15 Second harmonic of LTE band 13 of BGA524N6 for GNSS applications

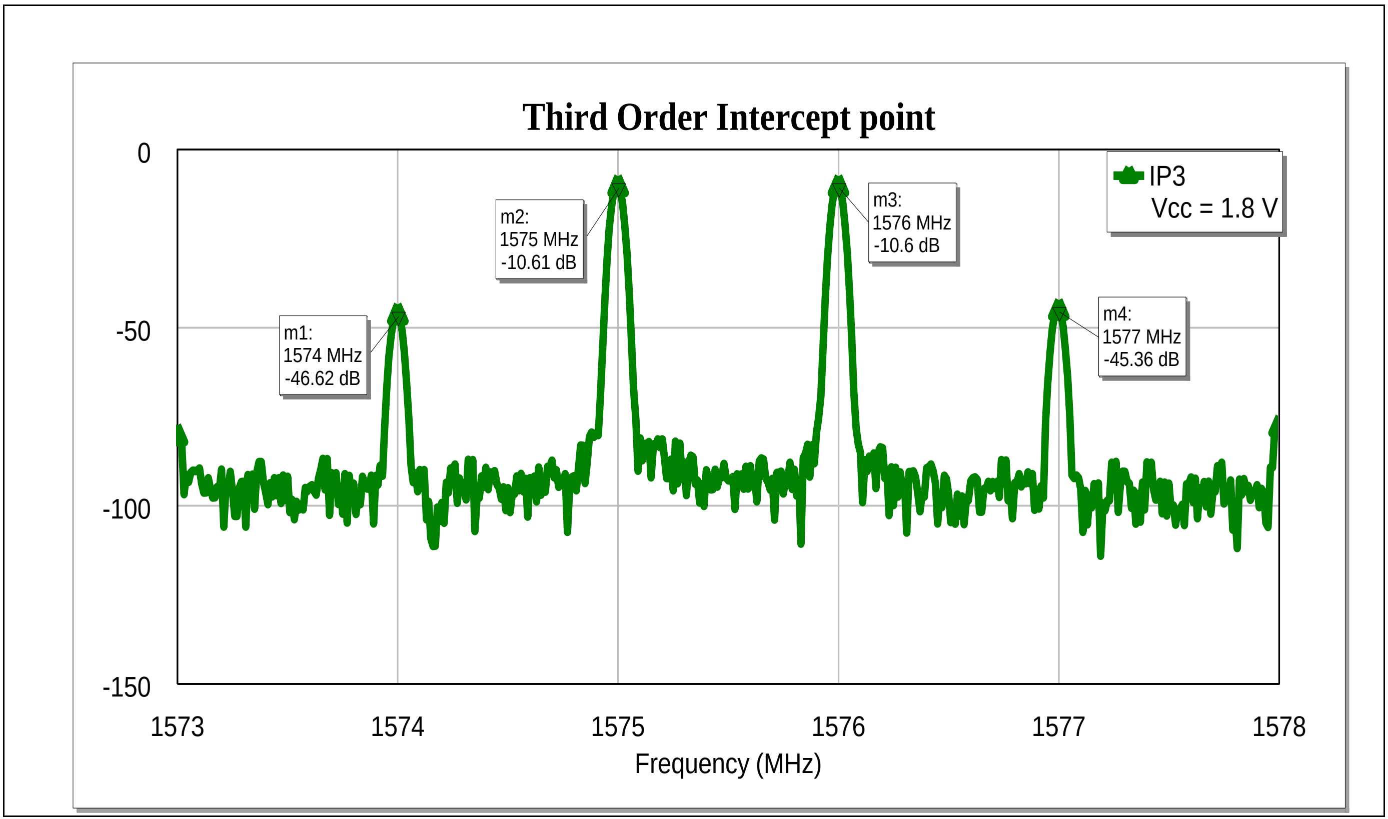

Figure 16 Third-order interception point (1.8 V) of BGA524N6 for GNSS applications

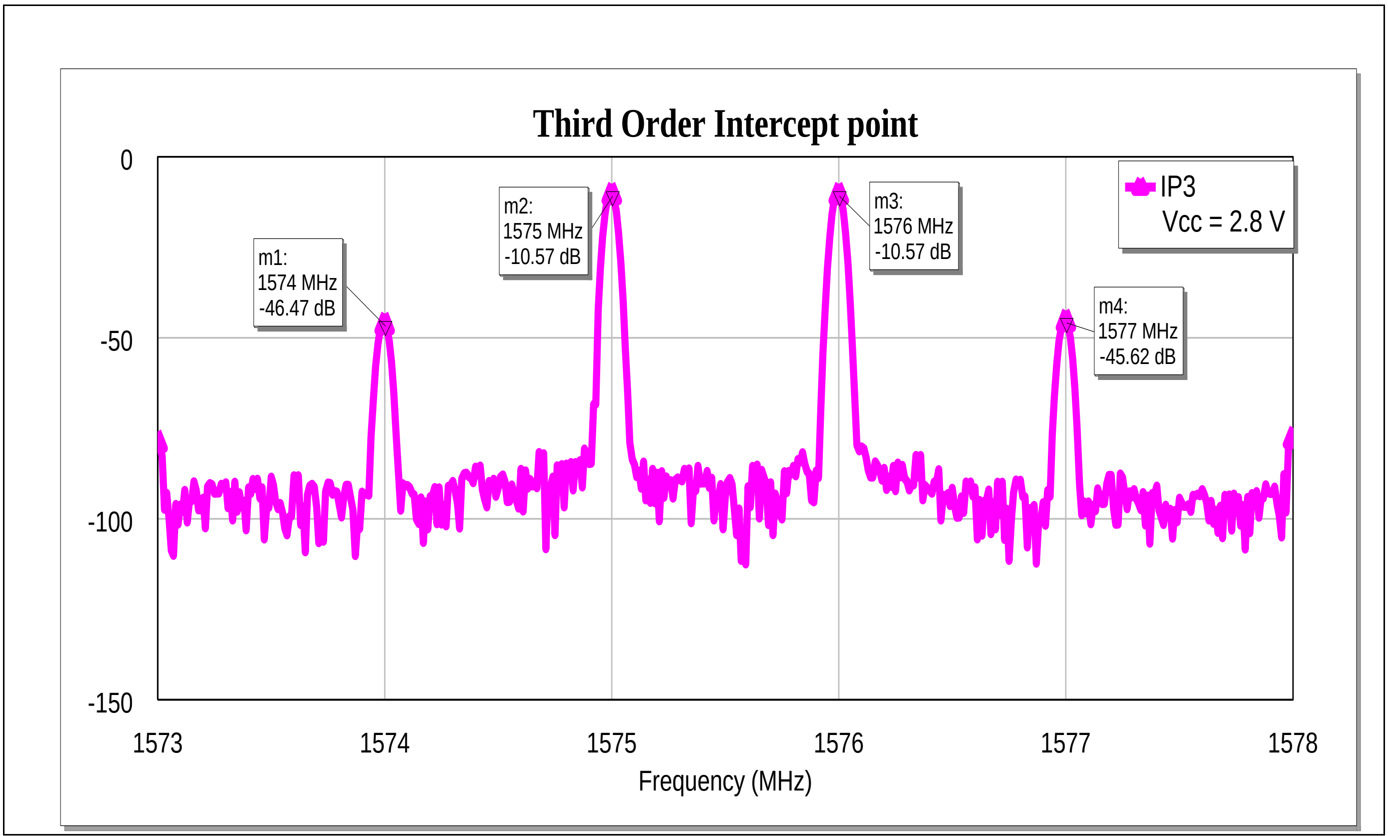

Figure 17 Third-order interception point (2.8 V) of BGA524N6 for GNSS applications

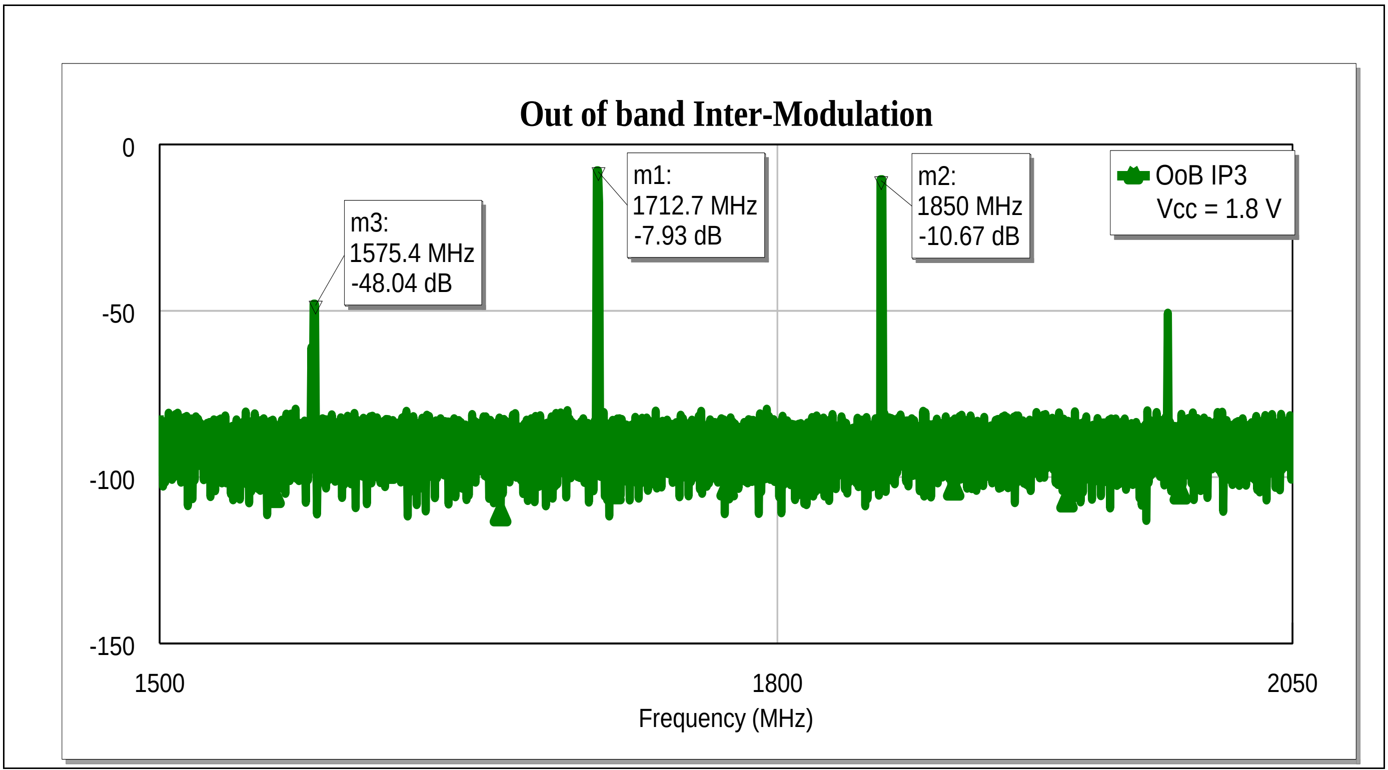

Figure 18 Out-of-band interception point (1.8 V) of BGA524N6 for GNSS applications

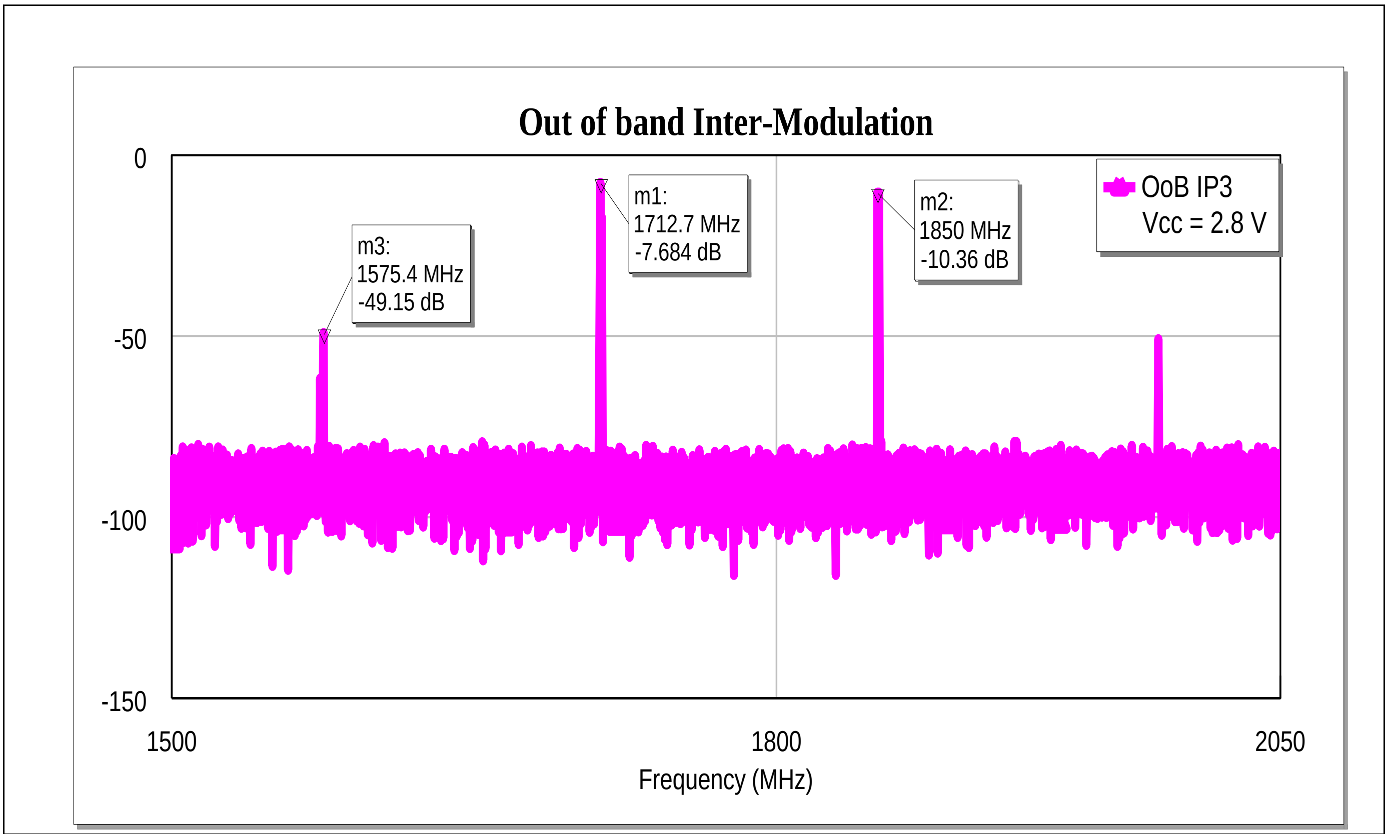

Figure 19 Out-of-band third-order interception point (2.8 V) of BGA524N6 for GNSS applications

4 Evaluation board and layout Information

In this application note, the following PCB is used:

PCB marking: **M110705**

PCB material: **FR 4**

ε_r of PCB material: **4.3**

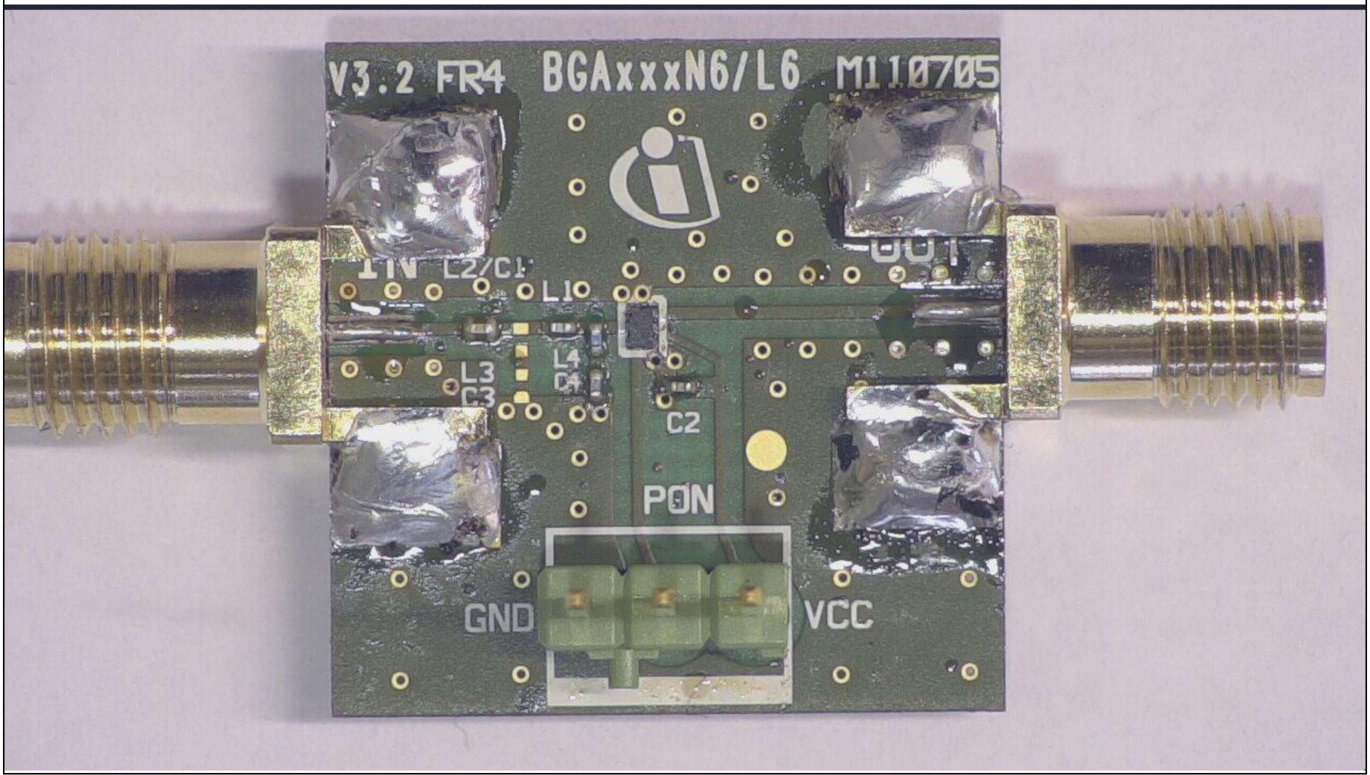

Figure 20 Photo of evaluation board (overview)

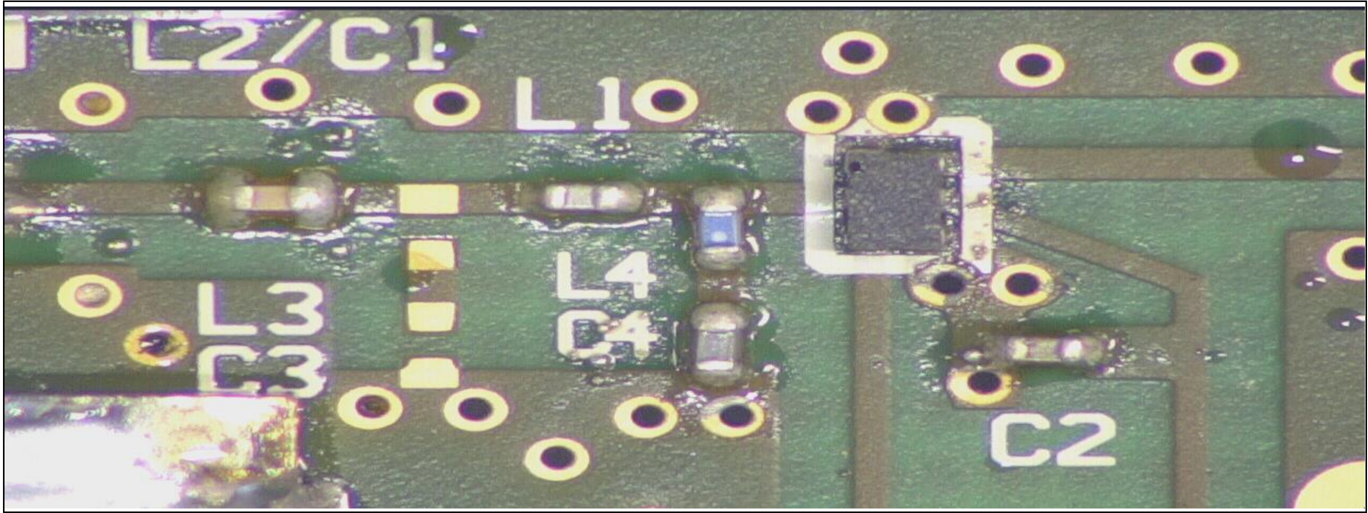

Figure 21 Photo of evaluation board (detailed view)

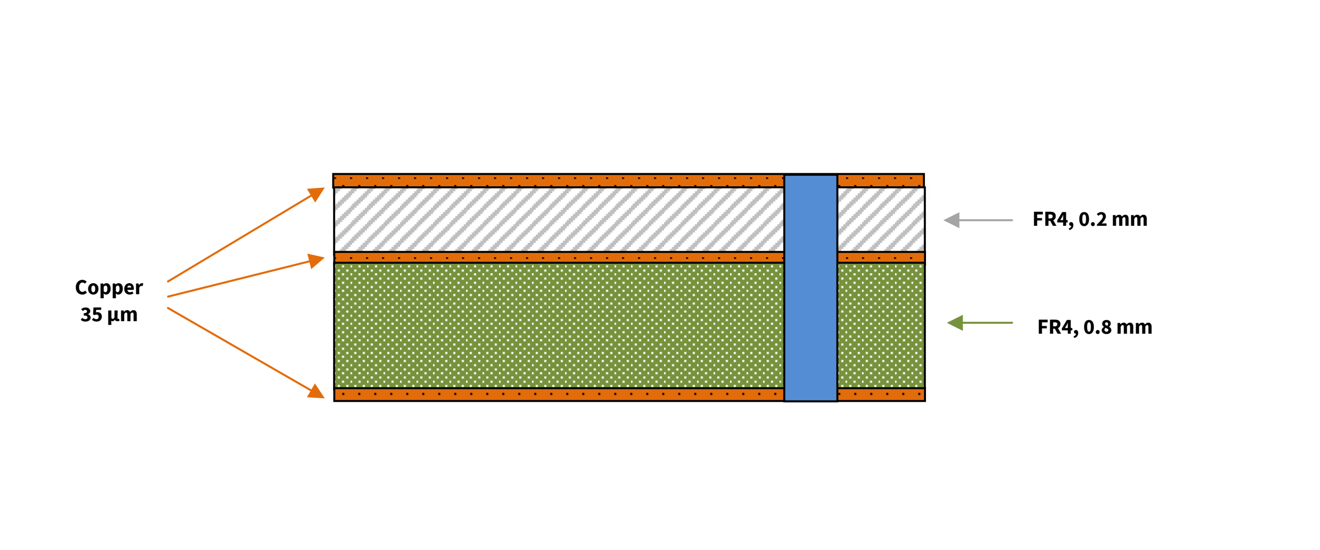

Figure 22 PCB layer information

5 Authors

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

Adeel Ahmed, Working Student of Business Unit “Radio Frequency and Sensors”

6 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] https://www.infineon.com/dgdl/AN267.pdf?folderId=db3a304313b8b5a60113d4239297042f&fileId=db3a3043327f13e30132a509789d4359

Revision history

Major changes since the last revision Rev 1.0 from 2019-2-22

Page or reference	Description of change
4	Updated GNSS frequency allocations in Fig 1

Edition 2019-08-29

Published by

Infineon Technologies AG

81726 Munich, Germany

Do you have a question about this document?

Email: erratum@infineon.com

Document reference
AN_1902_PL55_1902_102406