BGA824N6 as Low Noise Amplifier for GPS L2 / GPS L5 and other Lower L band GNSS Applications

About this document

Scope and purpose

This application note describes Infineon's GNSS MMIC: BGA824N6 as a Low Noise Amplifier (LNA) for GPS L2/GLONASS G2/Galieo E6 bands (1215 to 1254 MHz) and GPS L5/GLONASS G3 /Galieo E5 bands (1164 to 1214 MHz) applications. The performances with both 0201 inch and 0402 inch components for matching have been investigated.

1. The BGA824N6 is a silicon germanium LNA supporting 1550 to 1615 MHz.
2. The target applications are GPS L2/GLONASS G2/Galieo E6 bands (1215 to 1254 MHz) and GPS L5/GLONASS G3/Galieo E5 bands (1164 to 1214 MHz) applications.
3. In this report, the performance of BGA824N6 is measured on an FR4 board. Two external components are added at the LNA output side to retune the device to L2 and L5 bands. This device is matched with 0201 size or 0402 size external components.
4. Key performance parameters at 1.8 V, 1214 MHz:

   Noise Figure = 0.90 dB (LQP03 inductor, 0201 inch components)

   Noise Figure = 0.70 dB (LQW15 inductor, 0402 inch components)

   Insertion gain = 17.6 dB

   Input return loss = 17.4 dB

   Output return loss = 18.0 dB

   Input P1dB = -11.6 dBm

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

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1 Introduction of Global Navigation Satellite Systems (GNSSs)

1.1 Global Navigation Satellite Systems (GNSSs)

GNSSs are among the fastest growing applications in the electronic industry. Today, four GNNSs 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 Galileo navigation system. Among the above systems, BDS and Galileo are expected to be fully operational by 2020. Main market segments include Personal Navigation Devices (PNDs) and GNSS-enabled cell phones and wearables.

The main challenges for the growing GNSS-enabled cell phone market 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 (e.g. down to -130 dBm) in cell phones in the vicinity of coexisting high-power cellular signals. In addition, cell phones must have low power consumption to ensure long battery usage time.

GPS: 1563 to 1587 MHz (L1), 1215 to 1240 MHz (L2), 1164 to 1189 MHz (L5)
Galileo: 1559 to 1591 MHz (E1), 1259 to 1299 MHz (E6), 1164 to 1214 MHz (E5)
GLONASS: 1598 to 1609 MHz (G1), 1237 to 1254 MHz (G2), 1189 to 1214 MHz (G3)
BeiDou: 1559 to 1591 MHz (B1), 1193 to 1221 MHz (B2), 1257 to 1281 MHz (B3)

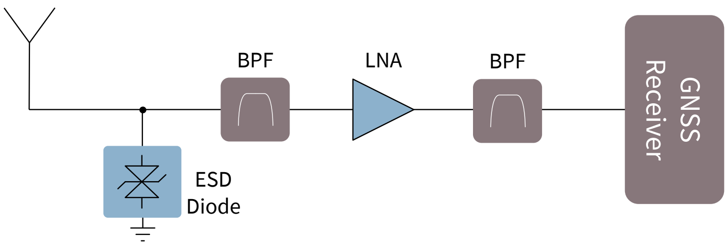

Figure 1 Application diagram: receiver front-end of the GNSS with LNAs and filter

1.2 Lower L bands (1164 to 1254 MHz) for the GNSSs

The GPS L5 band centers on 1176.45 MHz, and its frequency ranges from 1164 to 1189 MHz. It 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 Galileo E5 band ranges from 1164 to 1214 MHz. The GLONASS G3 band ranges from 1189 to 1214 MHz.

The GPS L2 band centers on 1227.6 MHz, and its frequency ranges from 1215 to 1240 MHz. The Galileo E6 band ranges from 1259 to 1299 MHz. The GLONASS G2 band ranges from 1237 to 1254 MHz.

1.3 Infineon product portfolio for GNSS applications

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

- **LNAs:** Infineon offers a wide range of high-performance products such as Monolithic Microwave Integrated Circuits (MMICs) as well as discrete RF transistors.
- **Transient Voltage Suppression (TVS) diodes:** Infineon devices can protect GNSS antennas reliably up to 20 kV.

1.4 Key features of GNSS LNAs

Infineon's GNSS MMIC LNA products offer the following features:

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

High linearity

In cell phones, GNSS signals often coexist with strong interfering cellular signals. The cellular signals can mix to produce intermodulation products in the GNSS receiver frequency band. To enhance interference immunity of the GNNSs, LNAs with high linearity characteristics are required. Some Infineon GNSS LNAs are designed with high in-band and out-of-band linearity performance to enhance interference immunity.

Low current consumption

Power consumption is an important feature in many GNNSs that are mainly battery operated. 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. 1.05 mA) makes Infineon's LNAs suitable for portable technology such as GNSS-enabled wearable devices.

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

2 BGA824N6 overview

2.1 Features

- High insertion power gain: 17.0 dB
- Out-of-band input third-order intercept point: +7 dBm
- Input 1 dB compression point: -6 dBm
- Low NF: 0.55 dB
- Low current consumption: 3.8 mA
- Operating frequencies: 1550 to 1615 MHz
- Supply voltage: 1.5 to 3.3 V
- Digital on/off switch (1 V logic high level)
- Ultra-small TSNP-6-2 leadless package (footprint: 0.7 × 1.1 mm^2)
- B7HF silicon germanium technology
- RF output internally matched to 50 Ω
- Only one external SMD component necessary
- 2 kV HBM ESD protection (including AI-pin)
- Pb-free (RoHS compliant) package

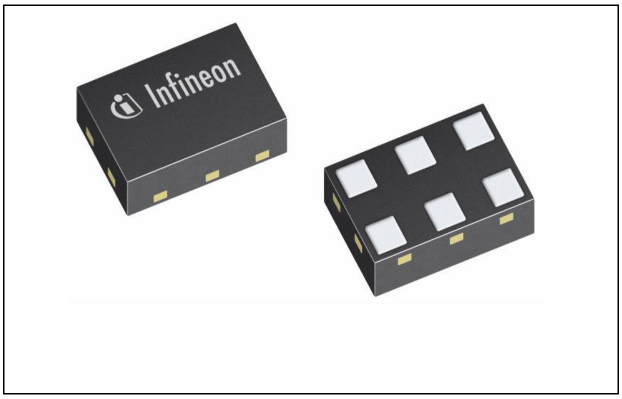

Figure 2 BGA824N6 in TSNP-6-2

2.2 Key applications of BGA824N6

Ideal for all GNSSs, such as GPS, GLONASS, BeiDou, Galileo, IRNSS, QZSS and others.

2.3 Description

The BGA824N6 is a front-end LNA for GNSSs from 1550 to 1615 MHz, such as GPS, GLONASS, BeiDou, Galileo, IRNSS, QZSS and others. The LNA provides 17.0 dB gain and 0.55 dB NF at a current consumption of 3.8 mA only in the application configuration described in Chapter 3. The BGA824N6 is based on Infineon Technologies' B7HF silicon germanium technology. It operates from 1.5 to 3.6 V supply voltage.

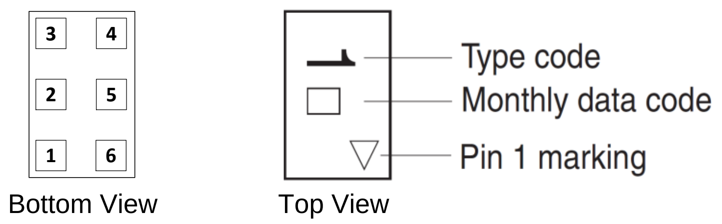

Figure 3 Package and pin connections of BGA824N6

Table 1 Pin assignment of BGA824N6

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

Table 2 Mode selection of BGA824N6

LNA mode	Symbol	ON/OFF control voltage at PON pin	
		Min.	Max.
ON	PON, on	1.0 V	V_{CC}
OFF	PON, off	0 V	0.4 V

Please visit the product page of BGA824N6 for more information.

3 Application circuit and performance overview

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

Device: BGA824N6

Application: GPSS L2 / L5 band and other Lower L band applications

PCB marking: 161214

EVB order no.: AN542

3.1 Summary of measurement results

The performance of BGA824N6 for 1164 MHz – 1254 MHz is summarized in the following table. The performance is measured based on 0201 inch size components for matching, unless otherwise specified.

Table 3 Electrical characteristics at 1.8 V (at room temperature)

Parameter	Symbol	Value			Unit	Comment/Test condition
Frequency range	Freq	1164	1214	1254	MHz	
DC voltage	V_{CC}	1.8			V	
DC current	I_{CC}	4.1			mA	
Gain	G	17.4	17.6	17.3	dB	
Noise Figure[1]	NF	0.90	0.90	0.90	dB	Loss of input line of 0.1 dB is de-embedded, [1]LQP03TN 0201 inch inductor for matching
Noise Figure[2]	NF	0.70	0.70	0.70	dB	Loss of input line of 0.1 dB is de-embedded, [2]LQW15 0402 inch inductor for matching
Input return loss	RL_{in}	11.3	17.4	24.9	dB	
Output return loss	RL_{out}	15.3	18.1	12.2	dB	
Reverse isolation	I_{Rev}	26.3	25.5	25.4	dB	
Input P1dB	I_{P1dB}	-12.8	-11.6	-10.6	dBm	
Output P1dB	O_{P1dB}	3.6	5	5.7	dBm	
Input IP3	I_{IP3}	-6.3	-5.2		dBm	Power at input: -30 dBm f1 = 1176.5 MHz, f2 = 1177.5 MHz f1 = 1227.6 MHz, f2 = 1228.6 MHz
Output IP3	O_{IP3}	11.2	12.3		dBm	
Out-of-band IM3 input referred	Oob IIM3	-86.5			dBm	Power at input: -25 dBm f1 = 1850 MHz, f2 = 2485 MHz,

Table 3 Electrical characteristics at 1.8 V (at room temperature)

Parameter	Symbol	Value	Unit	Comment/Test condition
Out-of-band IM3 input referred	Oob IIM3	-68.9	dBm	measured at 1215 MHz
Stability	K	> 1	–	Measured up to 8 GHz

Table 4 Electrical characteristics at 2.8 V (at room temperature)

Parameter	Symbol	Value			Unit	Comment/Test condition
Frequency range	Freq	1164	1214	1254	MHz	
DC voltage	V_{CC}	2.8			V	
DC current	I_{CC}	4.2			mA	
Gain	G	17.4	17.6	17.4	dB	
Noise Figure[1]	NF	0.95	0.95	0.95	dB	Loss of input line of 0.1 dB is de-embedded, [1]LQP03TN 0201 inductor for matching
Noise Figure[2]	NF	0.75	0.75	0.75	dB	Loss of input line of 0.1 dB is de-embedded, [2]LQW15 0402 inductor for matching
Input return loss	RL_{in}	11.6	17.8	26.2	dB	
Output return loss	RL_{out}	14.3	17.8	12.2	dB	
Reverse isolation	I_{Rev}	26.8	26.0	25.8	dB	
Input P1dB	I_{P1dB}	-10.3	-9.1	-8.1	dBm	
Output P1dB	O_{P1dB}	6.1	7.5	8.3	dBm	
Input IP3	I_{IP3}	-5.8	-4.9		dBm	Power at input: -30 dBm f1 = 1176.5 MHz, f2 = 1177.5 MHz f1 = 1227.6 MHz, f2 = 1228.6 MHz
Output IP3	O_{IP3}	11.7	12.6		dBm	
Out-of-band IM3 input referred	Oob IIM3	-86.6			dBm	Power at input: -25 dBm f1 = 1850 MHz, f2 = 2485 MHz, measured at 1215 MHz
Out-of-band IM3 output referred	Oob OIM3	-69.0			dBm	
Stability	K	> 1			–	Measured up to 8 GHz

3.2 Schematics and BOM

The schematic of BGA824N6 for GNSS band L2/G2/E6/L5/G3/E5 applications is presented in **Figure 4**, and its BOM is shown in Table 5.

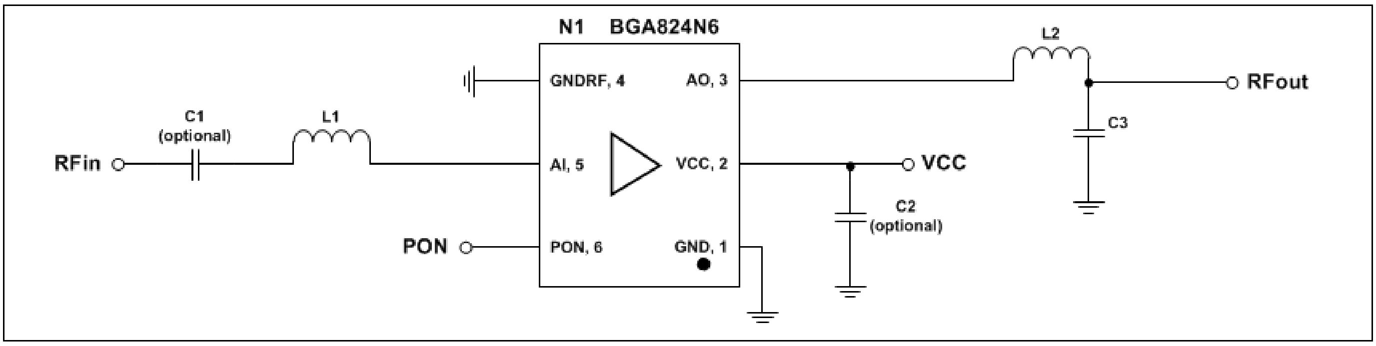

Figure 4 Schematics of the BGA824N6 application circuit

Table 5 BOM

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	>= 1	nF	0201	Various	DC block
C2	>= 1	nF	0201	Various	RF bypass
C3	3.9	pF	0201 (0402)	Various	Output matching
L1	12	nH	0201 (0402)	Murata LQP03TN Murata LQW15	Input matching
L2	3.9	nH	0201 (0402)	Murata LQP03TN Murata LQW15	Output matching
N1	BGA824N6	TSNP-6-2		Infineon Technologies	SiGe LNA

Note: *1) DC block function is NOT integrated at the input of BGA824N6. 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.*

Note: *2) 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.*

Note: *3) for comparision purposes, the impact of using 0402 inch high Q Murata inductor and 0402 inch capacitors for matching is also investigated; please refer to Tables 3 and 4 for the performance results.*

4 Measurement graphs

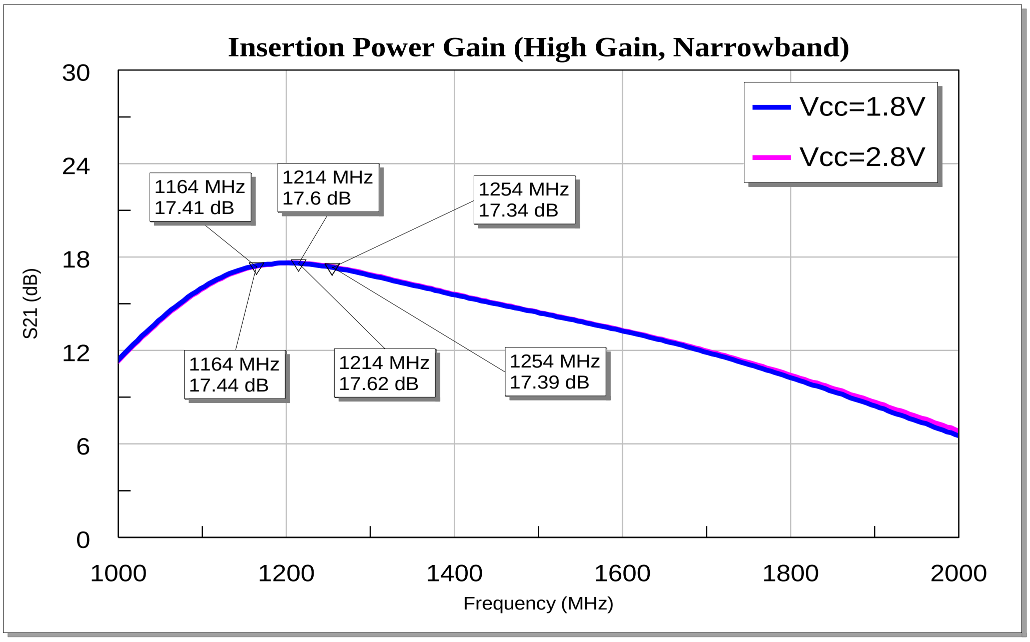

Figure 5 Insertion power gain (narrowband) of BGA824N6 for L2/G2 and L5/G3 applications

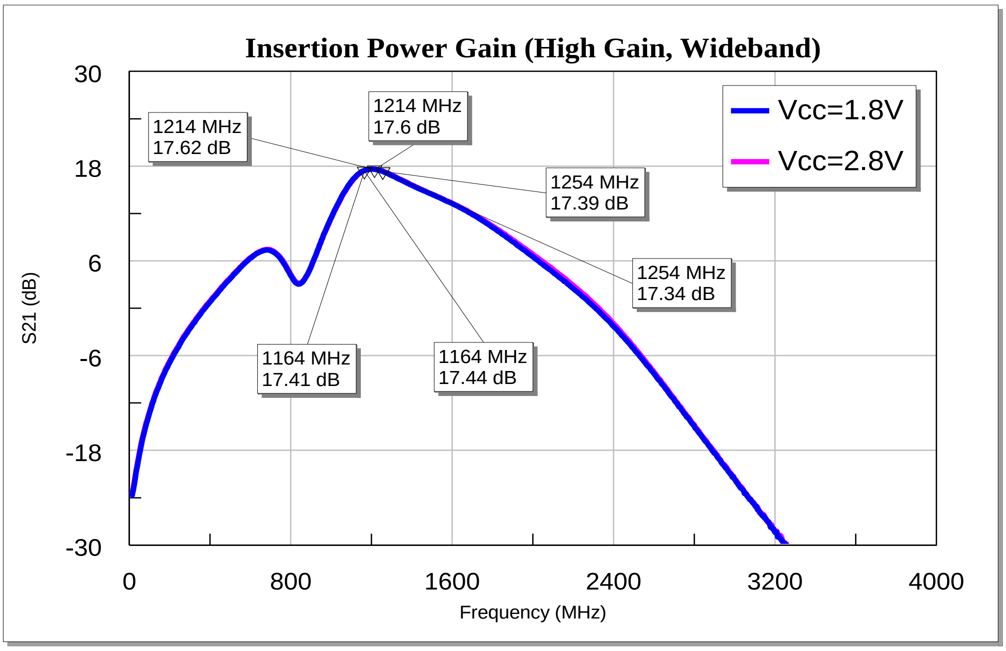

Figure 6 Insertion power gain (wideband) of BGA824N6 for L2/G2 and L5/G3 applications

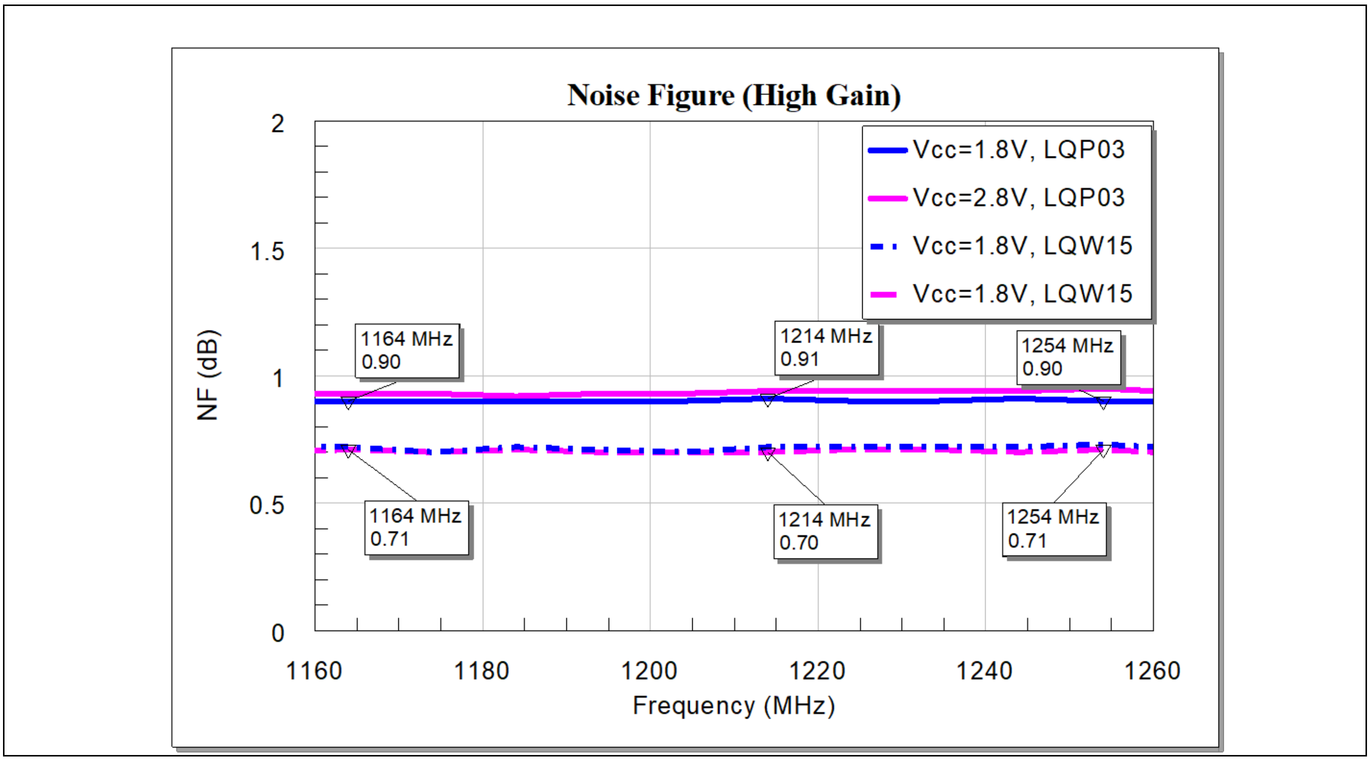

Figure 7 NF of BGA824N6 for GPS L2, L5 and other Applications (incl. 0402 components and 0201 components)

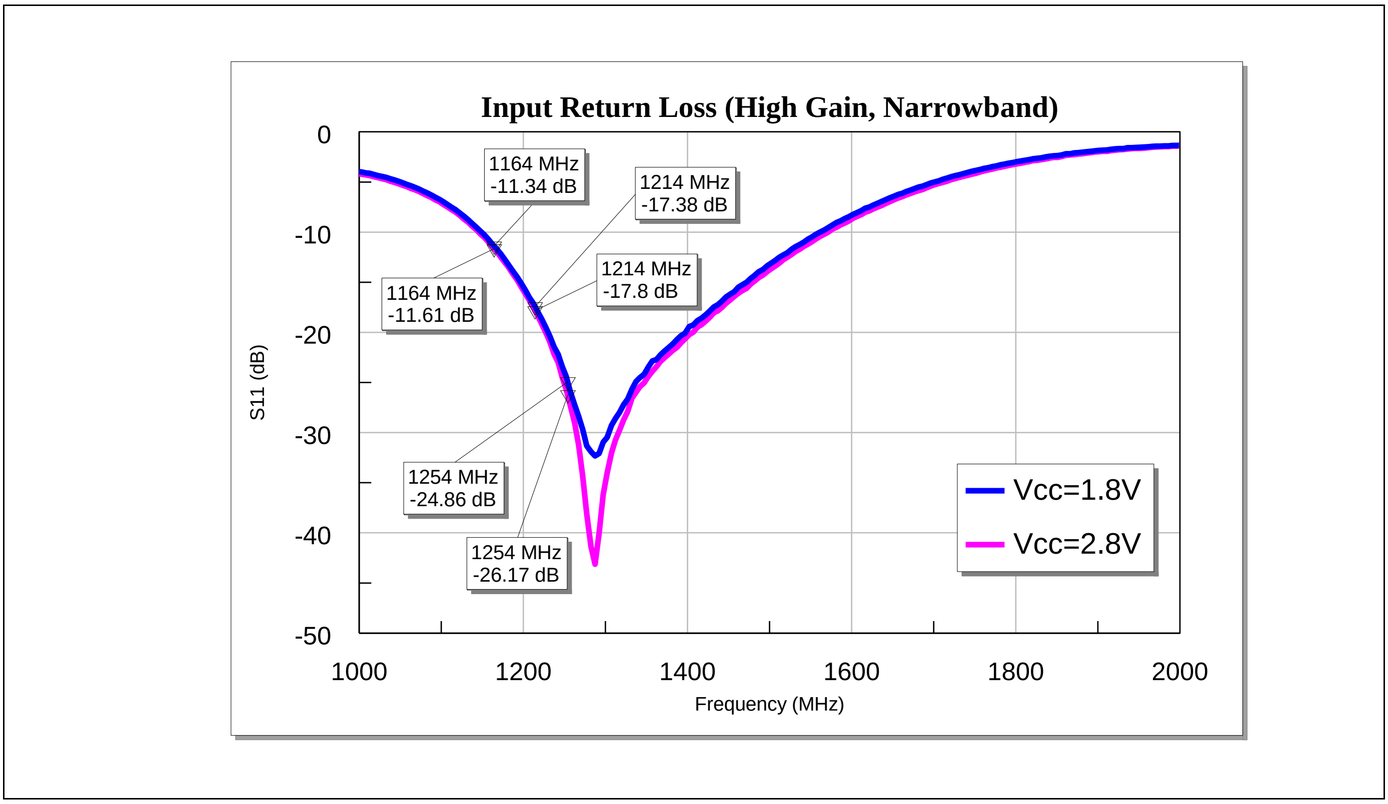

Figure 8 Input return loss (narrowband) of BGA824N6 for GPS L2, L5 and other Applications

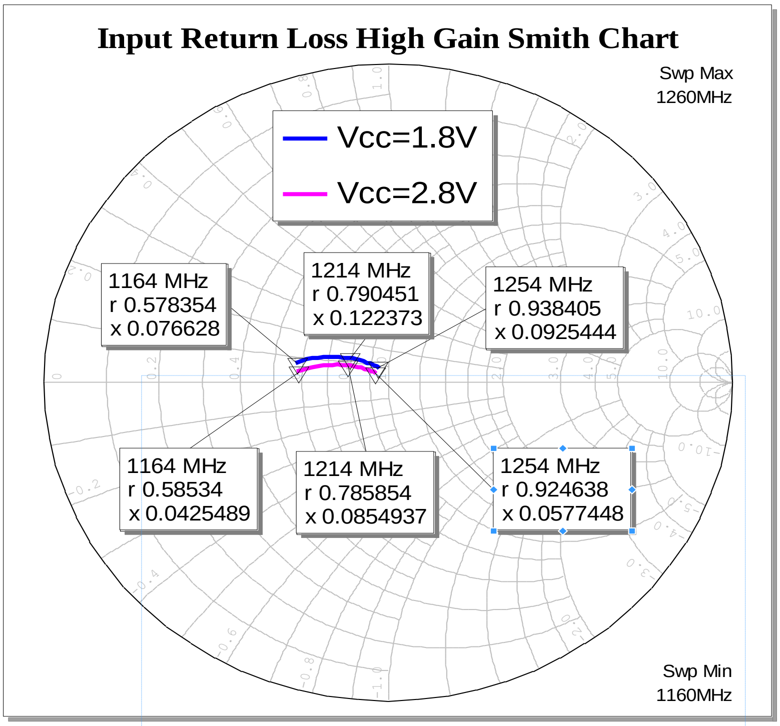

Figure 9 Input return loss (Smith chart) of BGA824N6 for GPS L2, L5 and other Applications

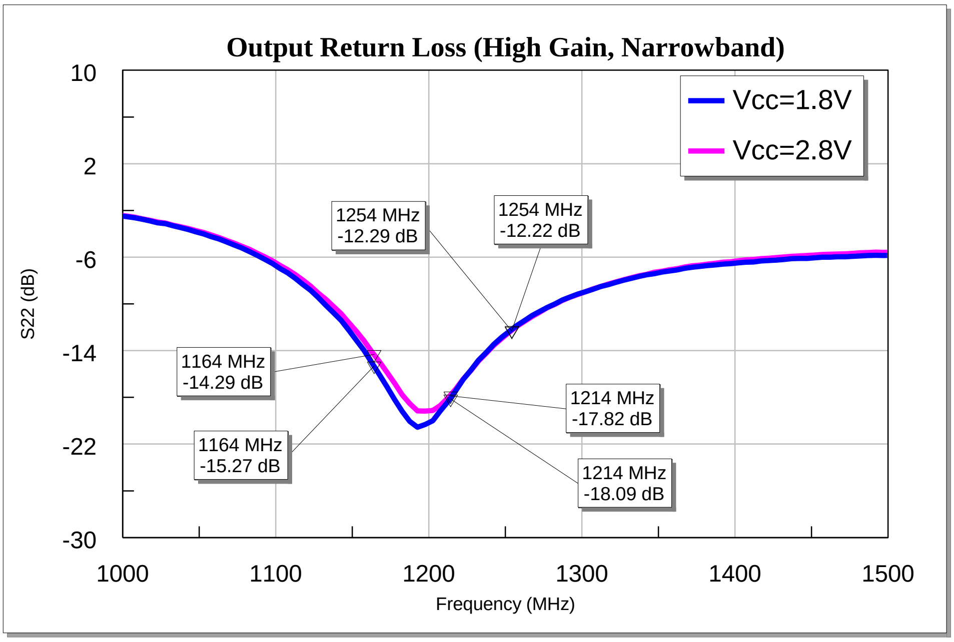

Figure 10 Output return loss (narrowband) of BGA824N6 for GPS L2, L5 and other Applications

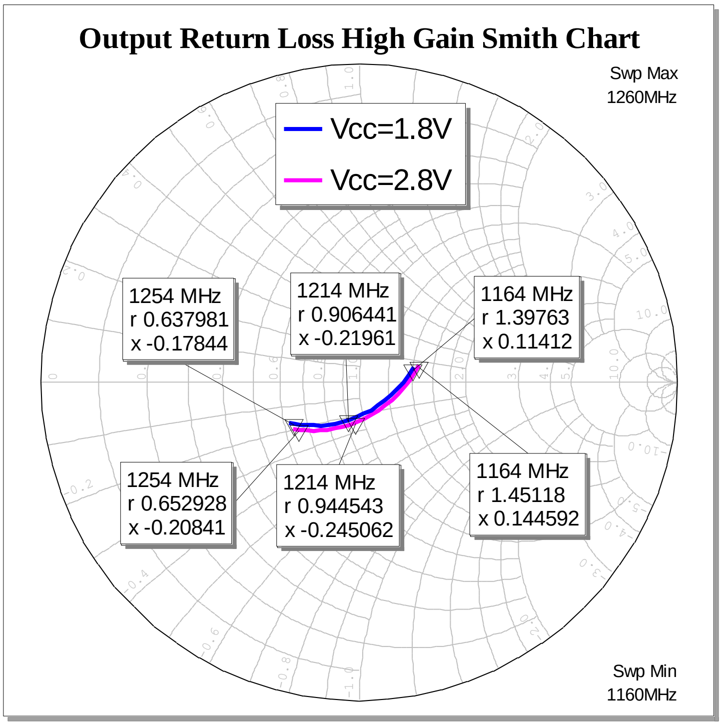

Figure 11 Output return loss (Smith chart) of BGA824N6 for GPS L2, L5 and other Applications

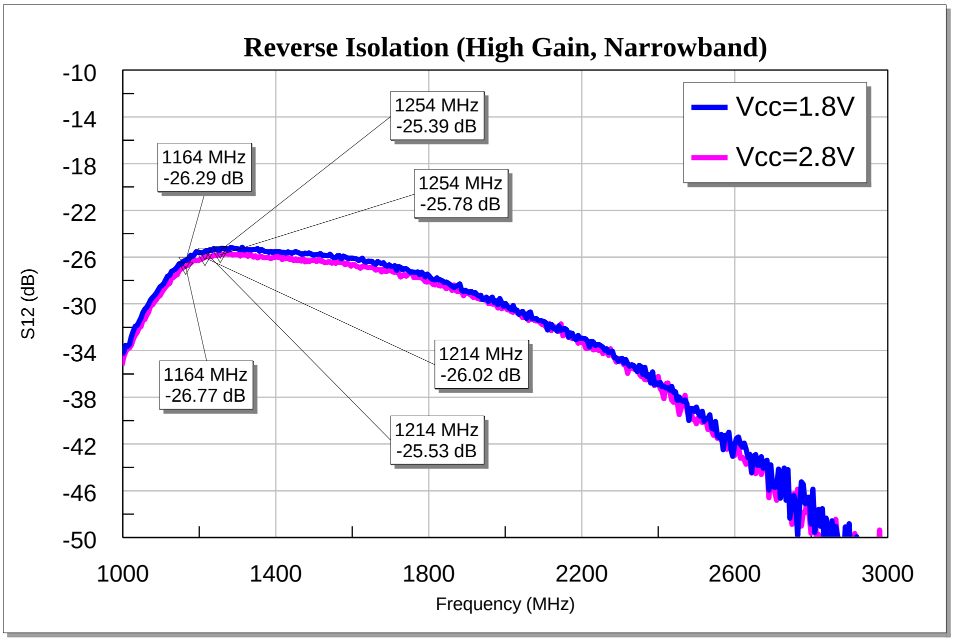

Figure 12 Reverse isolation (narrowband) of BGA824N6 for GPS L2, L5 and other Applications

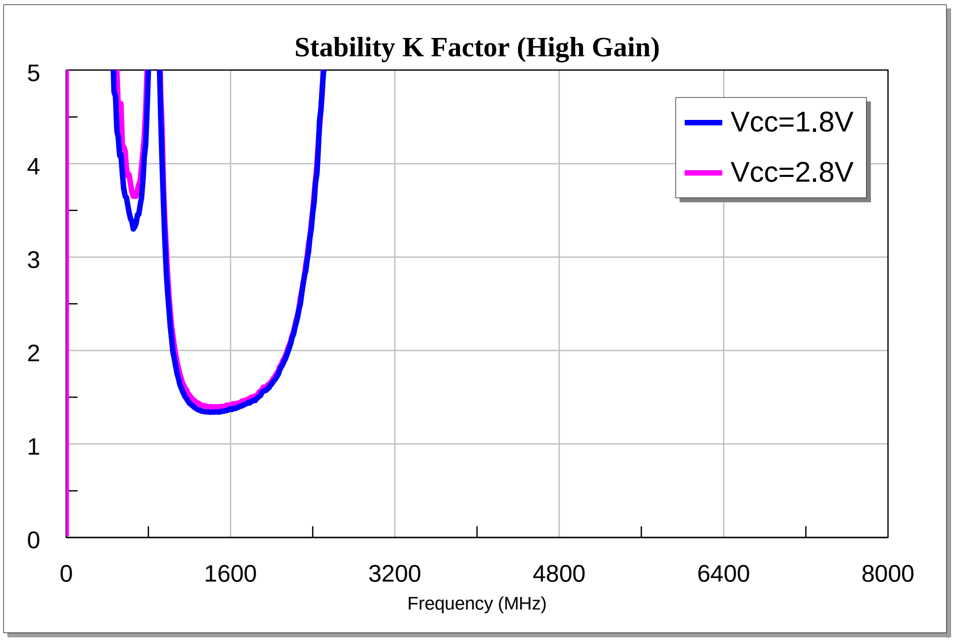

Figure 13 Stability K-factor of BGA824N6 for GPS L2, L5 and other Applications

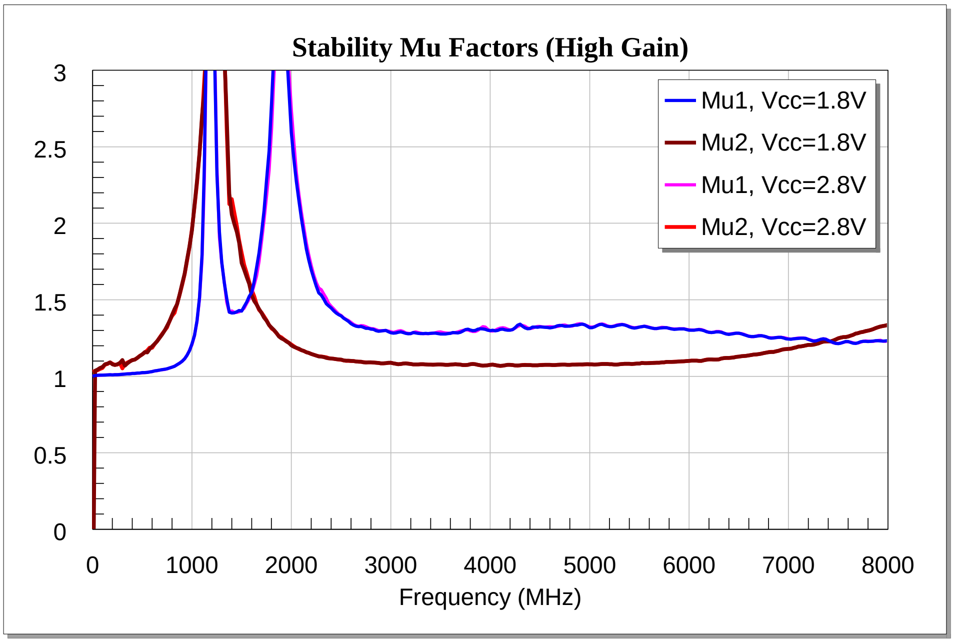

Figure 14 Stability Mufactors of BGA824N6 for GPS L2, L5 and other Applications

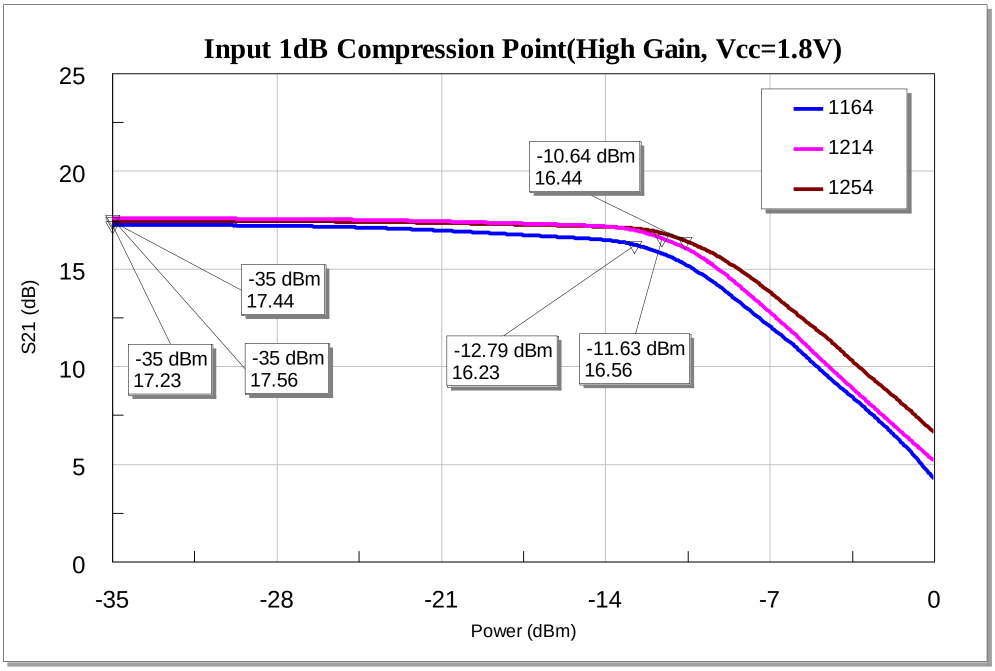

Figure 15 Input 1 dB compression point (1.8 V) of BGA824N6 for GPS L2, L5 and other Applications

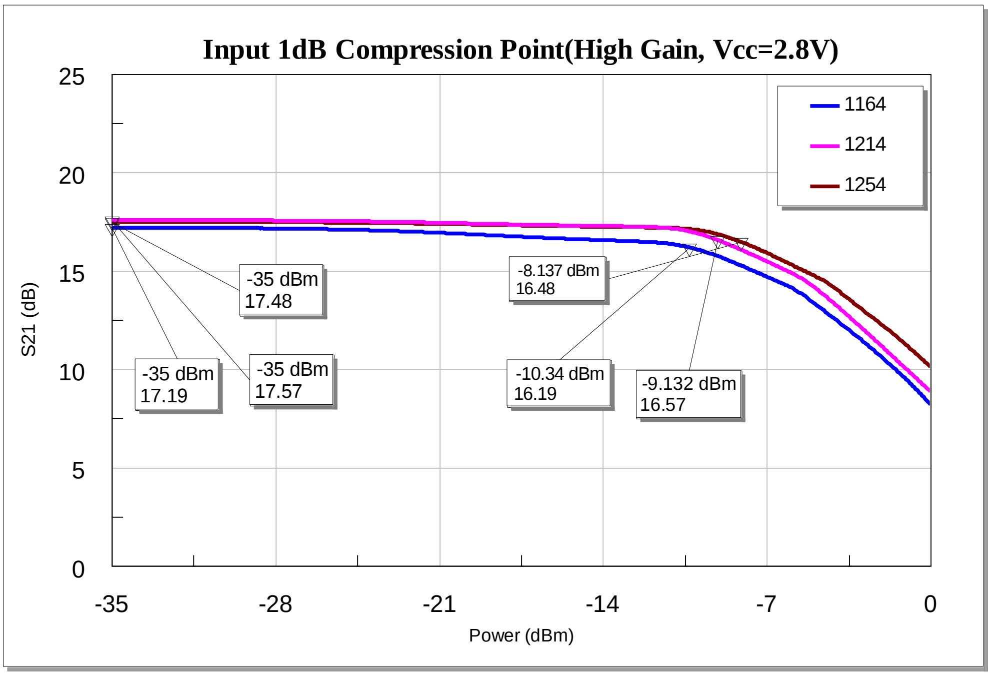

Figure 16 Input 1 dB compression point (2.8 V) of BGA824N6 for GPS L2, L5 and other Applications

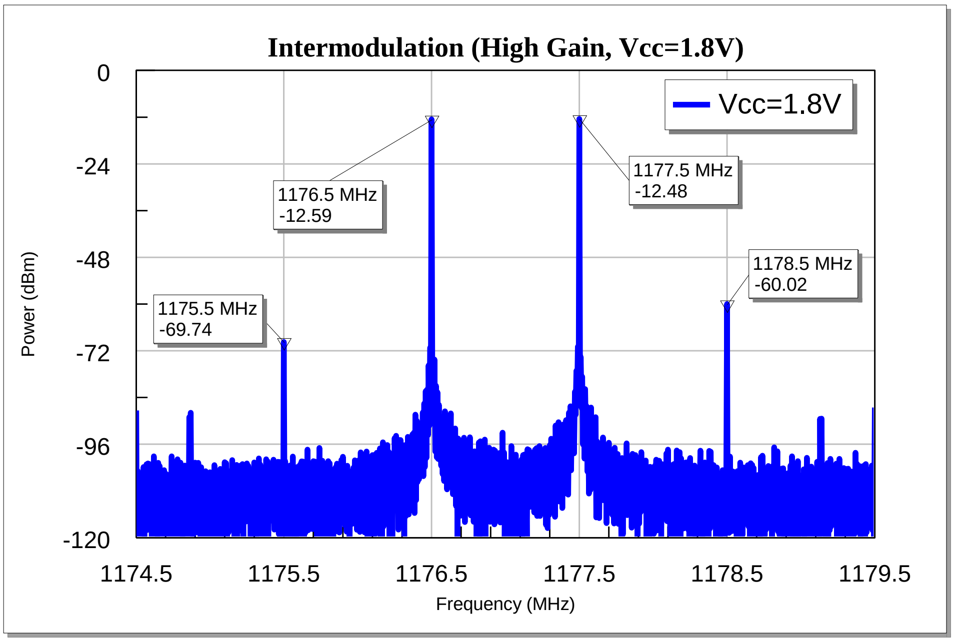

Figure 17 Third-order interception point (h1.8 V) of BGA824N6 for GPS L2, L5 and other Applications

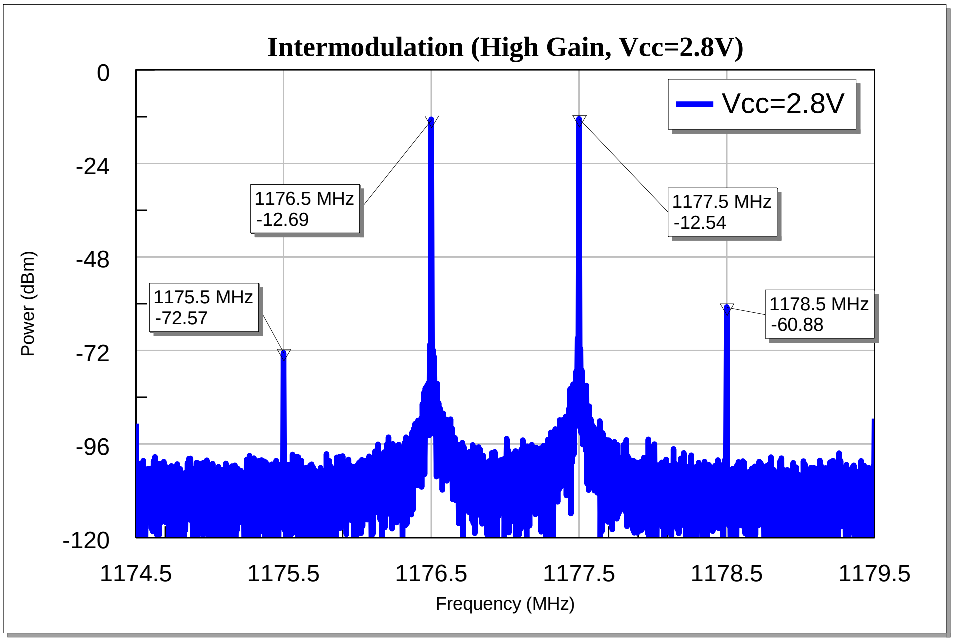

Figure 18 Third-order interception point (2.8 V) of BGA824N6 for GPS L2, L5 and other Applications

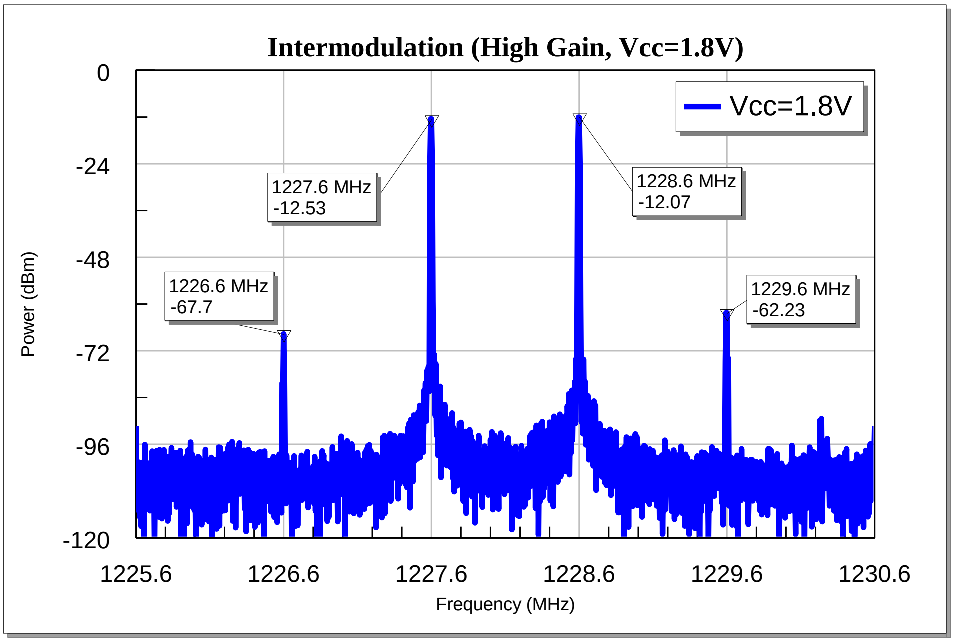

Figure 19 Third-order interception point (1.8 V) of BGA824N6 for GPS L2, L5 and other Applications

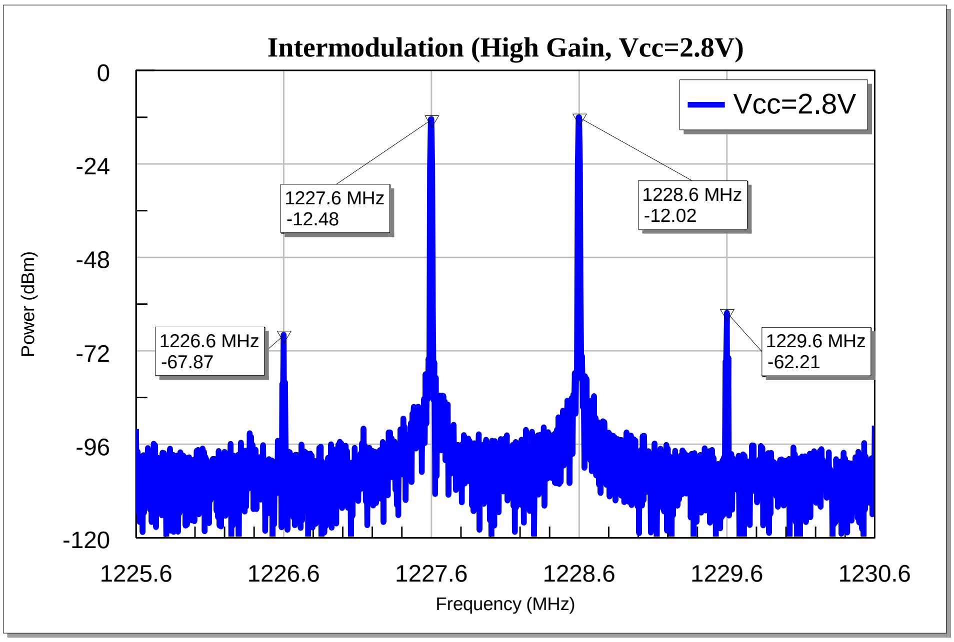

Figure 20 Third-order interception point (2.8 V) of BGA824N6 for GPS L2, L5 and other Applications

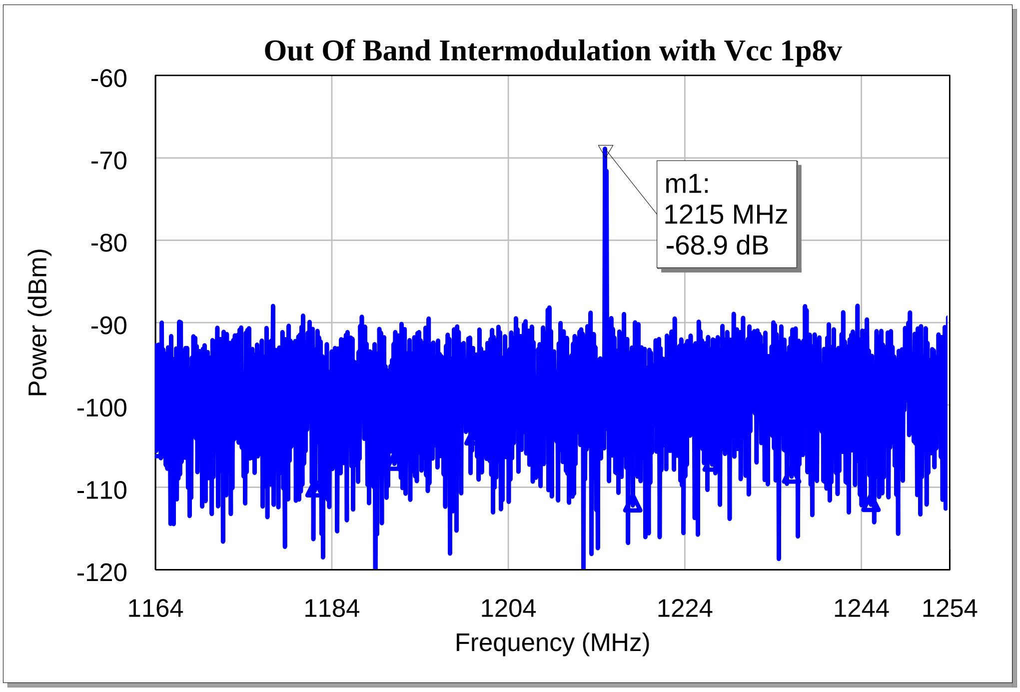

Figure 21 Out-of-band Third-order interception point (1.8 V) of BGA824N6 for for GPS L2, L5 and other Applications

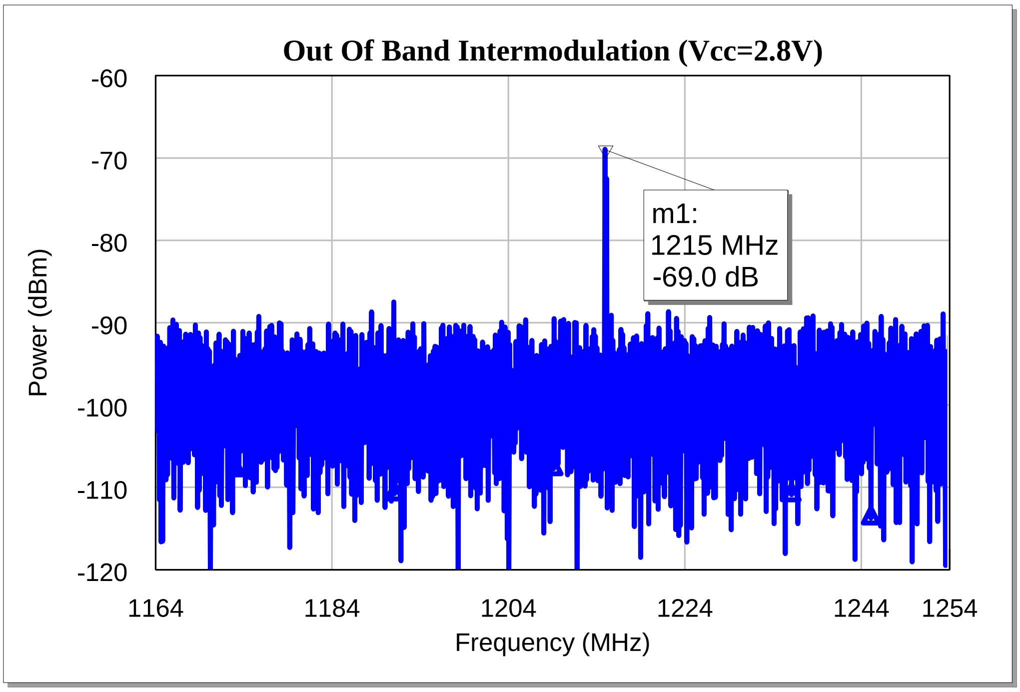

Figure 22 Out-of-band Third-order interception point (2.8 V) of BGA824N6 for for GPS L2, L5 and other Applications

5 Evaluation board and layout information

In this application note, the following PCB is used:

PCB marking: **161214**

PCB material: **FR4**

ε_r of PCB material: **4.8**

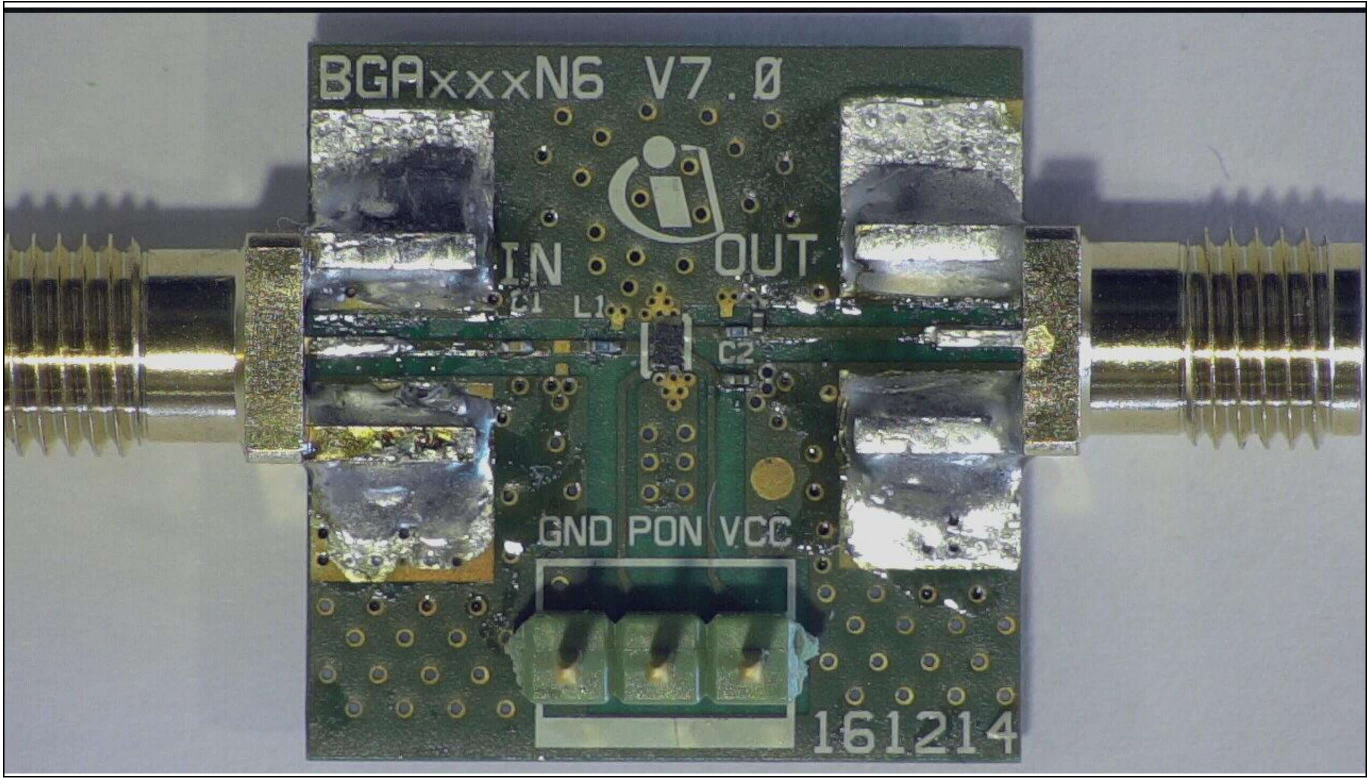

Figure 23 Photo of evaluation board (overview)

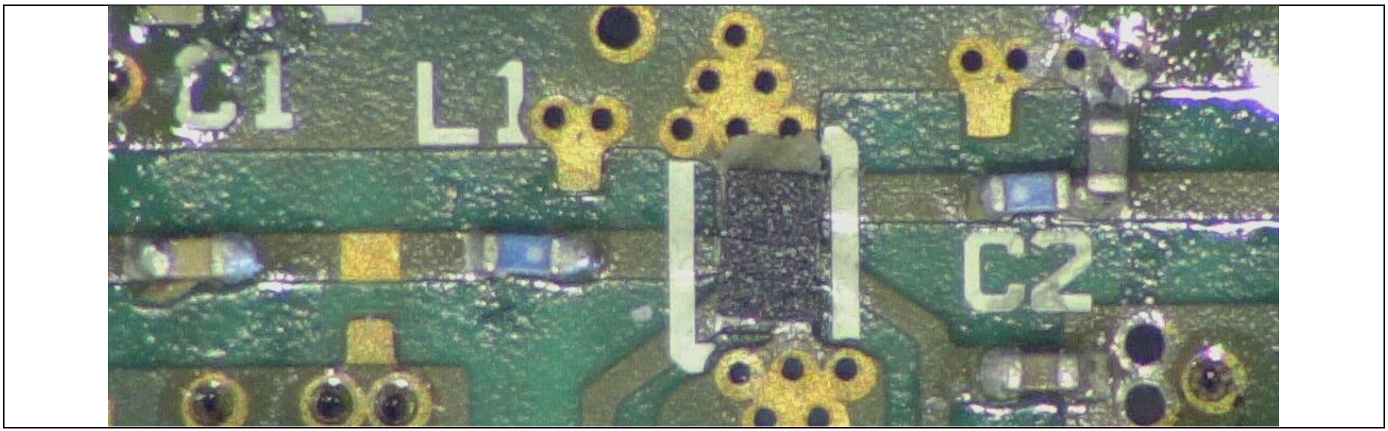

Figure 24 Photo of evaluation board (detailed view)

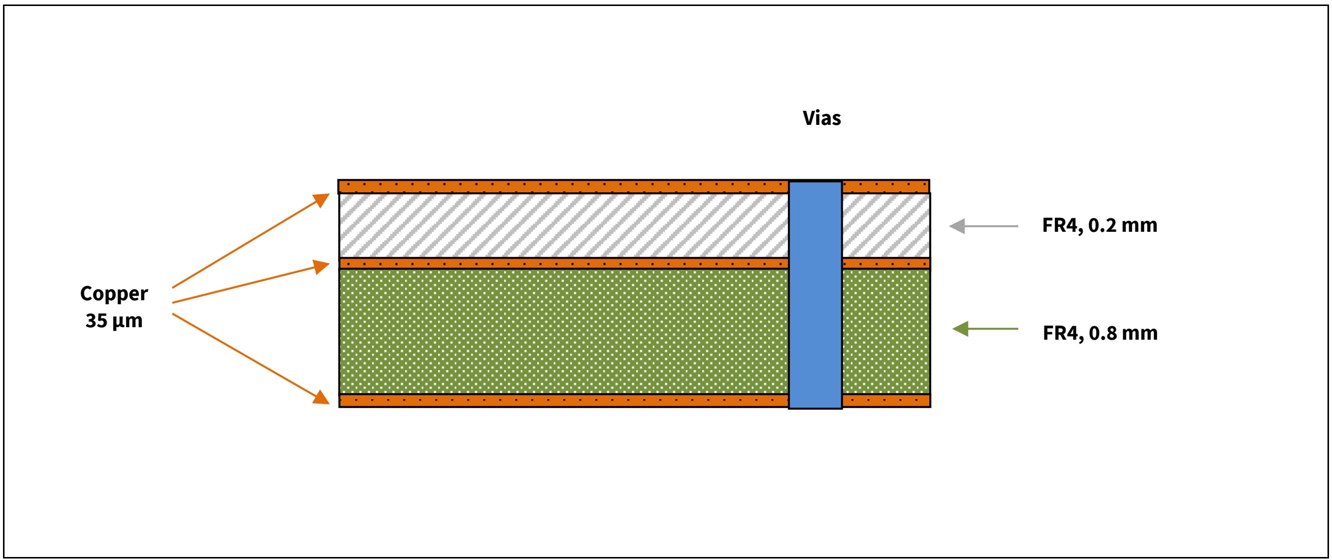

Figure 25 PCB layer information

6 Authors

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

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

7 References

[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

8 Revision history

Major changes since the last revision, Rev. 1.1 2018-10-02

Page or reference	Description of change
1, 8, 9,10,11	Added the performance data with 0402 size LQW15 inductors for matching, updated out-of-band IM3 values
9,11	Corrected the SMA and line loss, and the NF values
12	Updated BOM to include 0402 size components
14	Updated noise figure graph
21	Updated out-of-band IM3 graph

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