BGA855N6 as LNA for GNSS Applications from 1164 MHz to 1254 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 1164 MHz – 1254 MHz.

The BGA855N6 is a Silicon Germanium Low Noise Amplifier supporting 1164 MHz – 1300 MHz.

1. The target applications of this circuit are GPS L5/Galileo E5/GLONASS L3/Beidou B2/QZSS L5/NavIC L5 bands, as well as GPS L2/QZSS L2C bands in the range of 1164 MHz to 1254 MHz.
2. In this report, the performance of BGA855N6 is investigated on a MEG6 board. This device is matched with 0402 size high Q factor LQW15 inductors. Noise Figure deviation, when matched with 0201 size LQP03T inductors, is also presented.
3. Key performance parameters at 1.8 V, 1176.45 MHz
   Noise figure = 0.65 dB (LQW15 inductors for matching)
   Noise figure = 0.80 dB (LQP03T inductors for matching)
   Insertion gain = 18.0 dB
   Input return loss = 11 dB
   Output return loss = 20 dB
4. Key performance parameters at 1.8 V, 1227.6 MHz
   Noise figure = 0.65 dB (LQW15 inductors for matching)
   Noise figure = 0.85 dB (LQP03T inductors for matching)
   Insertion gain = 17.7 dB
   Input return loss = 12 dB
   Output return loss = 19 dB

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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 Galieo 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 connectivitiy 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.

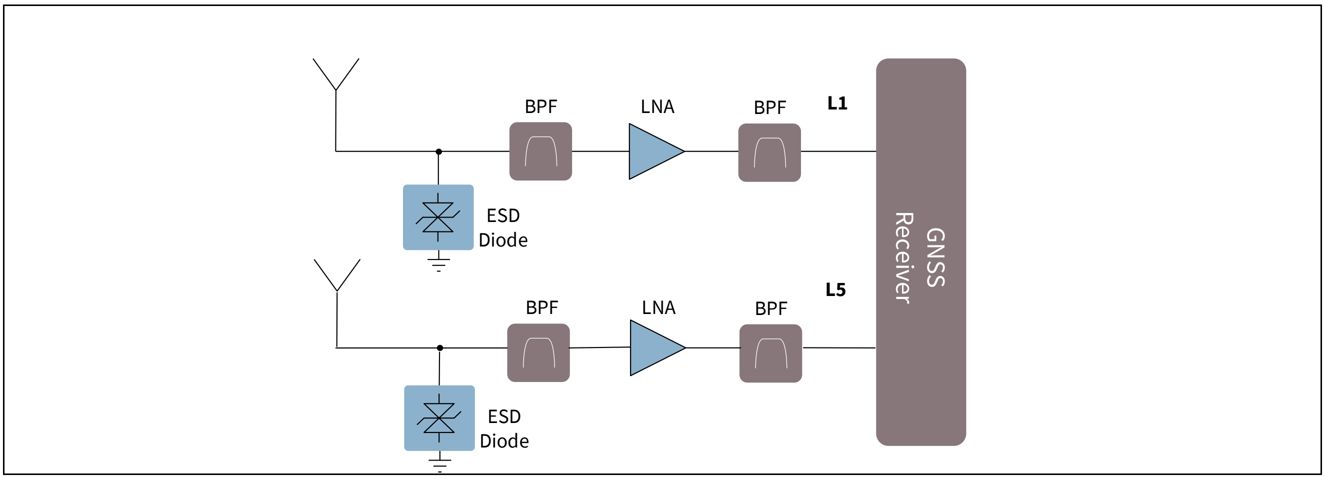

Figure 1 Application Diagram: Receiver Frontend of the Global Navigation Satellite System

1.2 Lower L bands

The GNSS systems have been first operated in the upper L band ranging 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.

The lower L bands include GPS L5 / GLONASS L3 / BDS B2 / Galileo E5 / QZSS L5 / NavIC L5 bands (1164 MHz to 1217 MHz), and GPS L2 / GLONASS L2 / BDS B3 / Galileo E6 / QZSS L2C / QZSS LEX bands (1217 MHz to 1300 MHz).

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 2 illustrates an overview of the frequency allocation of GNSS applications.

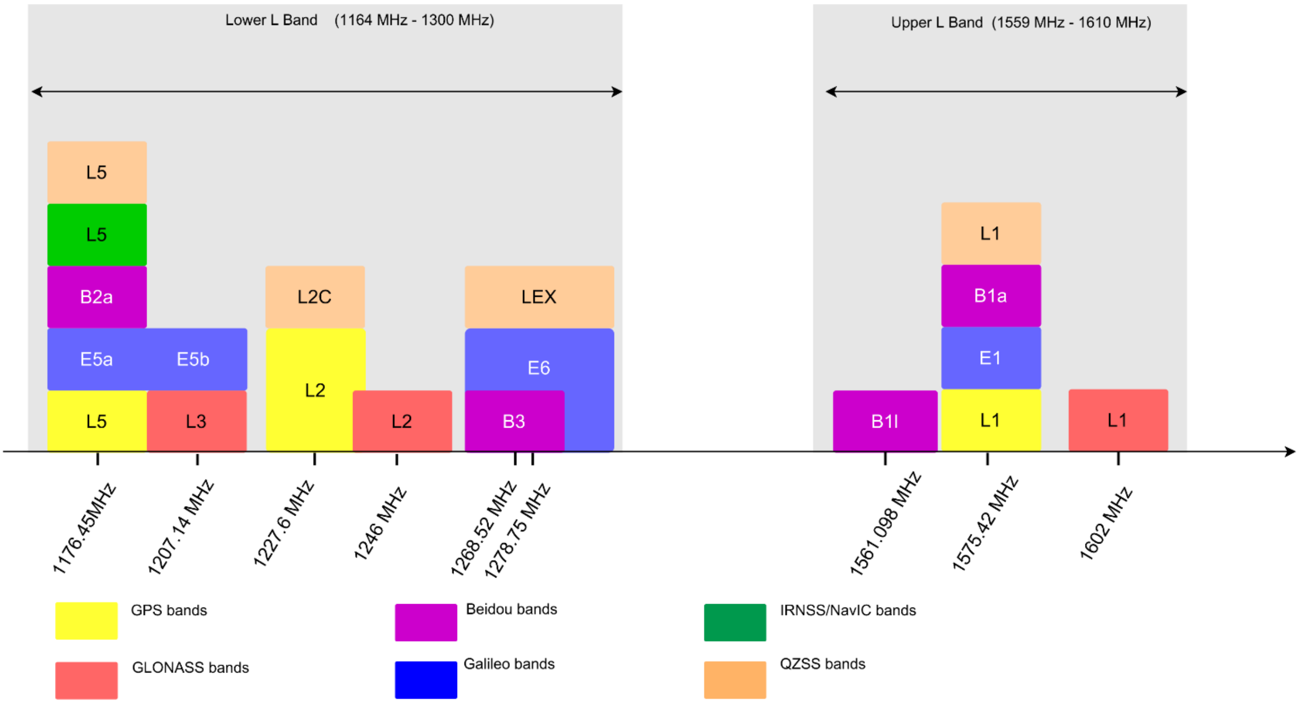

Figure 2 **Frequency allocation GNSS systems, upper L band and lower L band**

1.3 Infineon Product Portfolio for GNSS Applications

Infineon Technologies offers below 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

1.4 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 & 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.

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 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

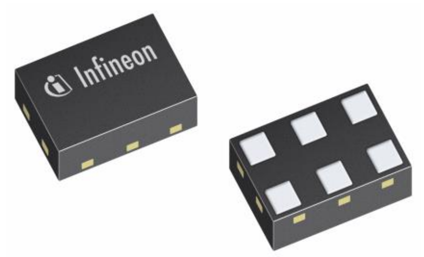

Figure 3 BGA855N6 in TSNP-6-10

2.2 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

- G2/G3 Glonass Signals

- B2/B3 Beidou Signals

- L2C/L5/LEX QZSS Signals

- L5 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 – 1254 MHz

PCB Marking: BGA855N6 V1.0

EVB Order No.: EVAL BGA855N6 AN580

3.1 Summary of Measurement Results

The performance of BGA855N6 for GNSS Lower L band 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	1207.14	1176.45	1227.6	MHz	B2/E5b, E5a/L5 , L2 center frequencies
DC Voltage	Vcc	1.8			V	
DC Current	Icc	4.9			mA	
Gain	G	17.8	18.0	17.7	dB	
Noise Figure[1)]	NF	0.65	0.65	0.65	dB	LQW15 inductor for matching, loss of input line of 0.05 dB is deembedded[1)]
Noise Figure[2)]	NF	0.80	0.80	0.80	dB	LQP03TN inductor for matching, loss of input line of 0.05 dB is deembedded[2)]
Input Return Loss	RLin	12	11	12	dB	
Output Return Loss	RLout	20	20	19	dB	
Reverse Isolation	IRev	22	22	22	dB	
Input IP3	IIP3	-1[3)]		0[4)]	dBm	Power @ Input: -30 dBm f1 =1176 MHz f2= 1177 MHz[3)] f1 =1227 MHz f2= 1228 MHz[4)]
Input P1dB	IP1dB	-12[5)]		-11[6)]	dBm	f=1176MHz[5)] ; f=1227MHz[6)]
Out-of-band Input IP3[3)]	Oob_IIP3	7	5	8	dBm	Power @ Input: -20 dBm f1 =1850 MHz f2= 2493 MHz Oob_IM3 measured at 1207 MHz
Out-of-band Output IM3	Oob_OIM3	-69	-67	-71	dBm	f1 =1785 MHz f2= 2401 MHz Oob_IM3 measured at 1169 MHz f1 =1856 MHz f2= 2485 MHz Oob_IM3 measured at 1227 MHz
Out-of-band Input IP2	Oob_IIP2	24			dBm	Power @ Input: -20 dBm
Out-of-band Output IM2	Oob_OIM2	-46			dBm	f1 =2550 MHz f2= 3726 MHz Oob_IM2 measured at 1176 MHz

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

Parameter	Symbol	Value	Unit	Comment/Test Condition
Stability	k	>1	--	Measured up to 10 GHz

3) If Pin = -20 dBm, the OoB IIP3 level will be identical to Pin = - 25 dBm.

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

Parameter	Symbol	Value			Unit	Comment/Test Condition
Frequency Range	Freq	1207.14	1176.45	1227.6	MHz	B2/E5b, E5a/L5 , L2 center frequencies
DC Voltage	Vcc	2.8			V	
DC Current	Icc	5.2			mA	
Gain	G	18.0	18.1	17.9	dB	
Noise Figure[1)]	NF	0.65	0.65	0.65	dB	LQW15 inductor for matching, loss of input line of 0.05 dB is deembedded[1)]
Noise Figure[2)]	NF	0.80	0.80	0.85	dB	LQP03TN inductor for matching, loss of input line of 0.05 dB is deembedded[2)]
Input Return Loss	RLin	13	12	13	dB	
Output Return Loss	RLout	20	19	19	dB	
Reverse Isolation	IRev	23	23	22	dB	
Input IP3	IIP3	0[3)]		2[4)]	dBm	Power @ Input: -30 dBm f1 =1176 MHz f2= 1177 MHz[3)] f1 =1227 MHz f2= 1228 MHz[4)]
Input P1dB	IP1dB	-10[5)]		-8[6)]	dBm	f=1176MHz[5)] ; f=1227MHz[6)]
Out-of-band Input IP3	Oob_IIP3	7	6	7	dBm	Power @ Input: -20 dBm f1 =1850 MHz f2= 2493 MHz Oob_IM3 measured at 1207 MHz f1 =1785 MHz f2= 2401 MHz
Out-of-band Output IM3	Oob_OIM3	-70	-68	-72	dBm	Oob_IM3 measured at 1169 MHz f1 =1856 MHz f2= 2485 MHz Oob_IM3 measured at 1227 MHz
Out-of-band Input IP2	Oob_IIP2	25			dBm	Power @ Input: -20 dBm f1 =2550 MHz f2= 3726 MHz
Out-of-band Output IM2	Oob_OIM2	-47			dBm	Oob_IM2 measured at 1176 MHz
Stability	k	>1			--	Measured up to 10 GHz

3) If Pin = -20 dBm, the OoB IIP3 level will be identical to Pin = - 25 dBm.

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

Parameter	Symbol	Value	Unit	Comment/Test Condition

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

Parameter	Symbol	Value			Unit	Comment/Test Condition
Frequency Range	Freq	1207.14	1176.45	1227.6	MHz	B2/E5b, E5a/L5 , L2 center frequencies
DC Voltage	Vcc	1.2			V	
DC Current	Icc	4.1			mA	
Gain	G	17.6	17.7	17.5	dB	
Noise Figure[1)]	NF	0.60	0.60	0.60	dB	LQW15 inductor for matching, loss of input line of 0.05 dB is deembedded[1)]
Noise Figure[2)]	NF	0.80	0.80	0.80	dB	LQP03TN inductor for matching, loss of input line of 0.05 dB is deembedded[2)]
Input Return Loss	RLin	10	10	10	dB	
Output Return Loss	RLout	20	21	19	dB	
Reverse Isolation	IRev	21	22	21	dB	
Input IP3	IIP3	-3[3)]		-2[4)]	dBm	Power @ Input: -30 dBm f1 =1176 MHz f2= 1177 MHz[3)] f1 =1227 MHz f2= 1228 MHz[4)]
Input P1dB	IP1dB	-16[5)]		-14[6)]	dBm	f=1176MHz[1)] ; f=1227MHz[2)]
Out-of-band Input IP3	Oob_IIP3	6	4	7	dBm	Power @ Input: -20 dBm f1 =1850 MHz f2= 2493 MHz Oob_IM3 measured at 1207 MHz f1 =1785 MHz f2= 2401 MHz Oob_IM3 measured at 1169 MHz f1 =1856 MHz f2= 2485 MHz Oob_IM3 measured at 1227 MHz
Out-of-band Output IM3	Oob_OIM3	-69	-66	-71	dBm	
Out-of-band Input IP2	Oob_IIP2	23			dBm	Power @ Input: -20 dBm f1 =2550 MHz f2= 3726 MHz Oob_IM2 measured at 1176 MHz
Out-of-band Output IM2	Oob_OIM2	-45			dBm	
Stability	k	>1			--	Measured up to 10 GHz

3) If Pin = -20 dBm, the OoB IIP3 level will be identical to Pin = - 25 dBm.

3.2 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.

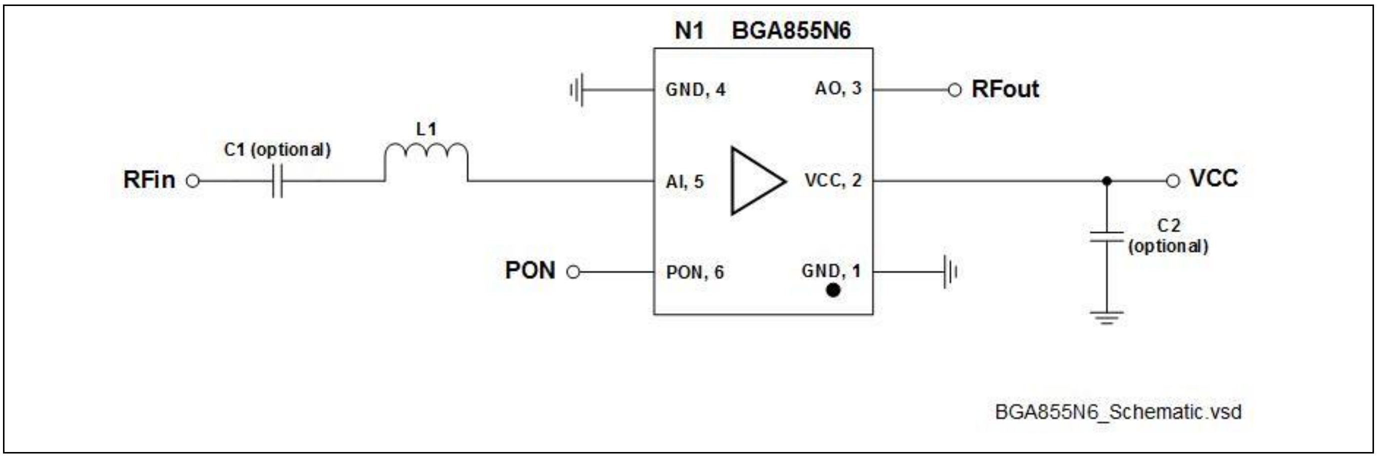

Figure 4 Schematics of the BGA855N6 Application Circuit

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	11	nH	0402/0201	Murata LQW15 / Murata LQP03TN	Input Matching
N1	BGA855N6	TSNP-6-10		Infineon Technologies	SiGe LNA

Note: DC block function is NOT integrated at input of BGA855N6. It is necessary to prevent DC signal conncted to or flowing into RF input pin.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 C2 is not necessary if a clean and stable DC supply can be ensured.

4 Measurement Graphs

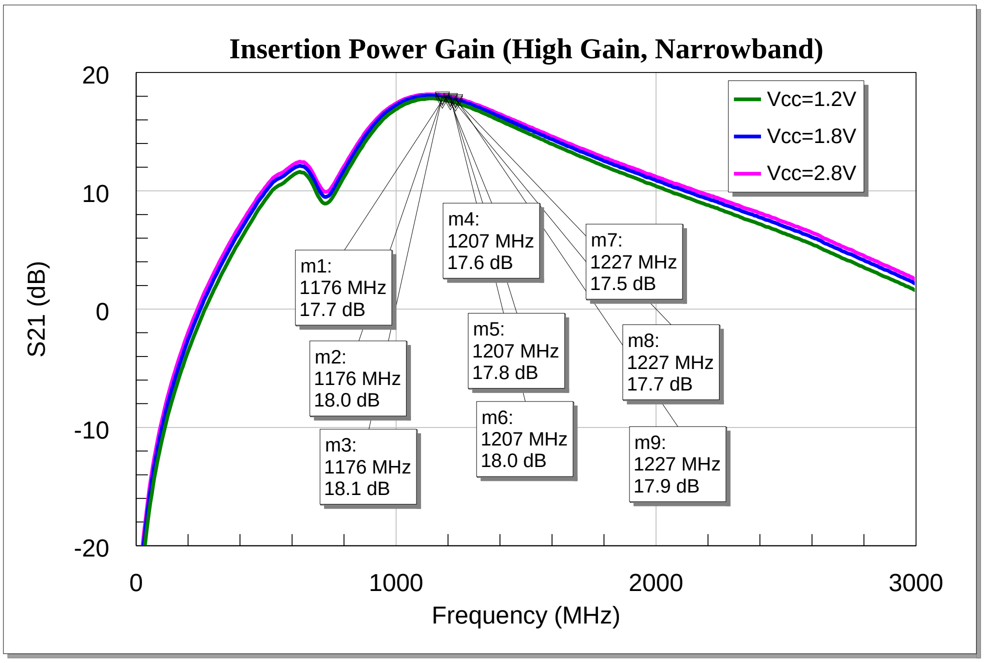

Figure 5 Insertion Power Gain (Narrowband)

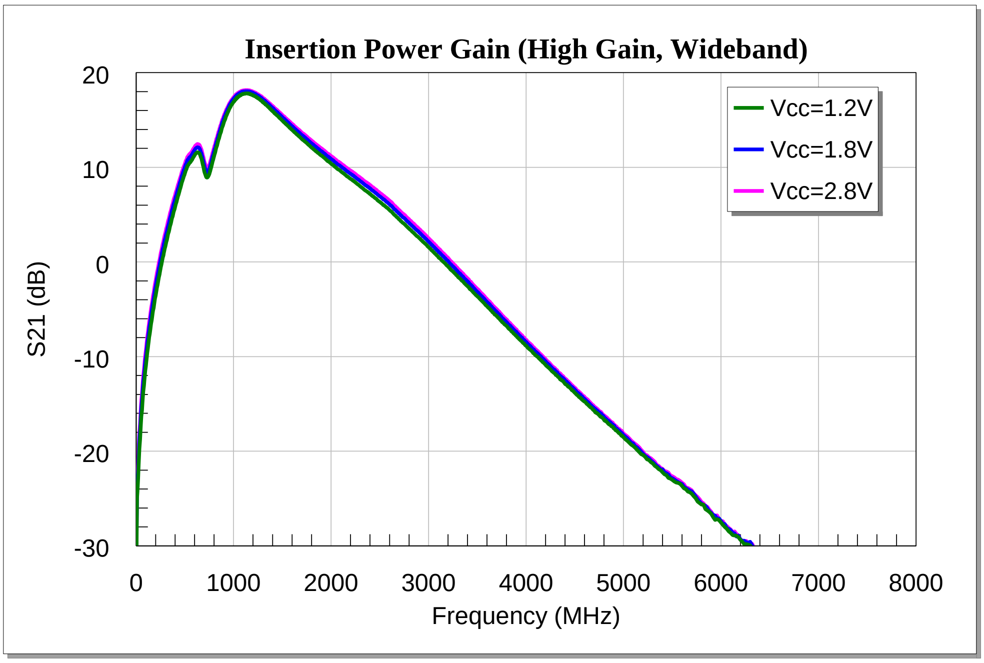

Figure 6 Insertion Power Gain (Wideband)

Measurement Graphs

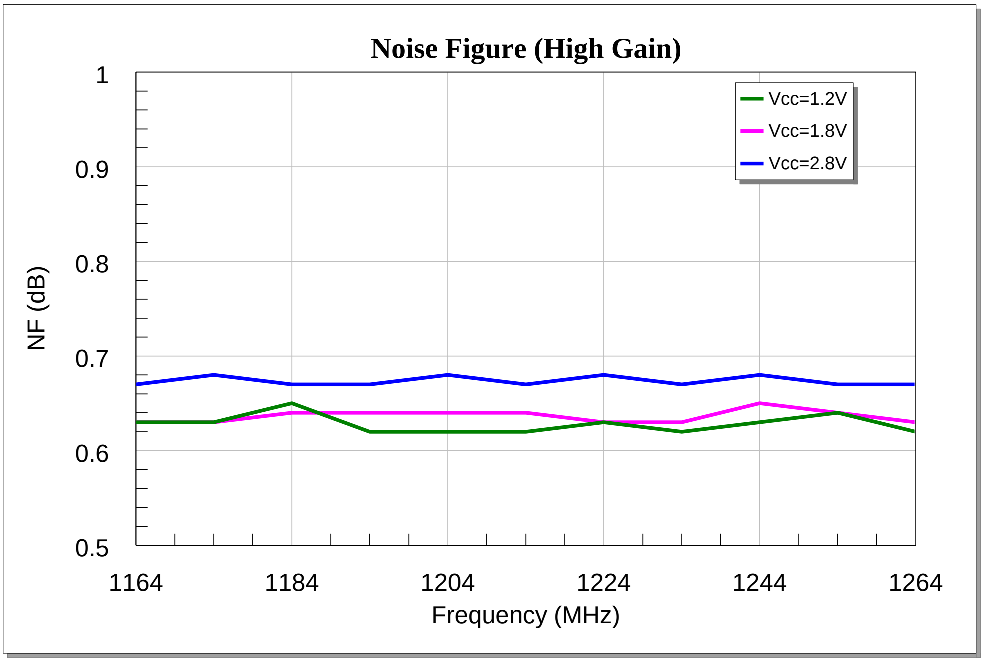

Figure 7 Noise Figure (SMA and Connector Losses Deembedded, LQW15 inductors for matching)

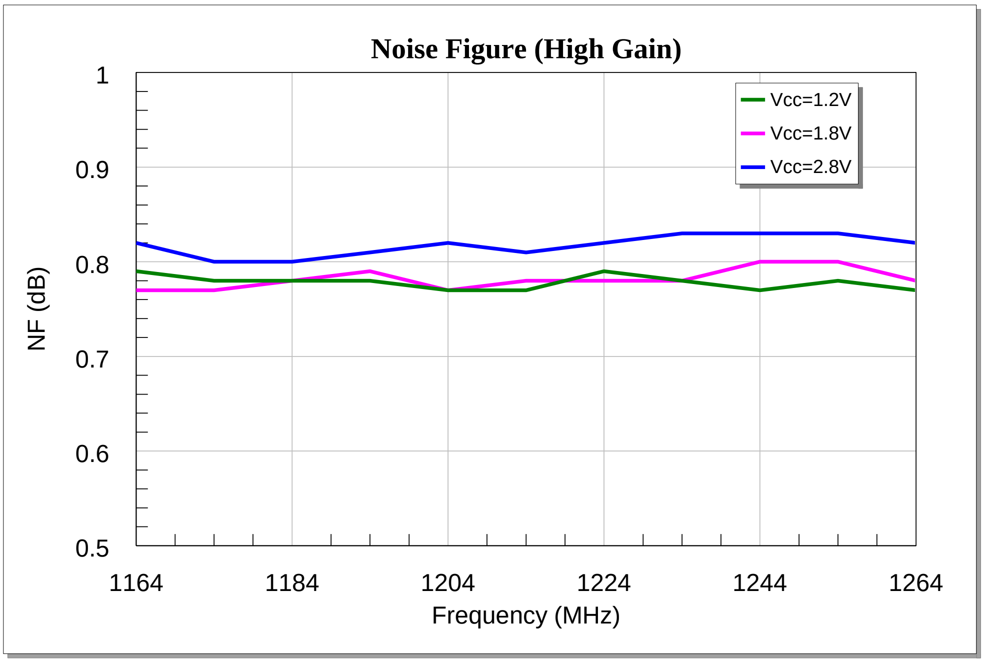

Figure 8 Noise Figure (SMA and Connector Losses Deembedded, LQP03T inductors for matching)

Measurement Graphs

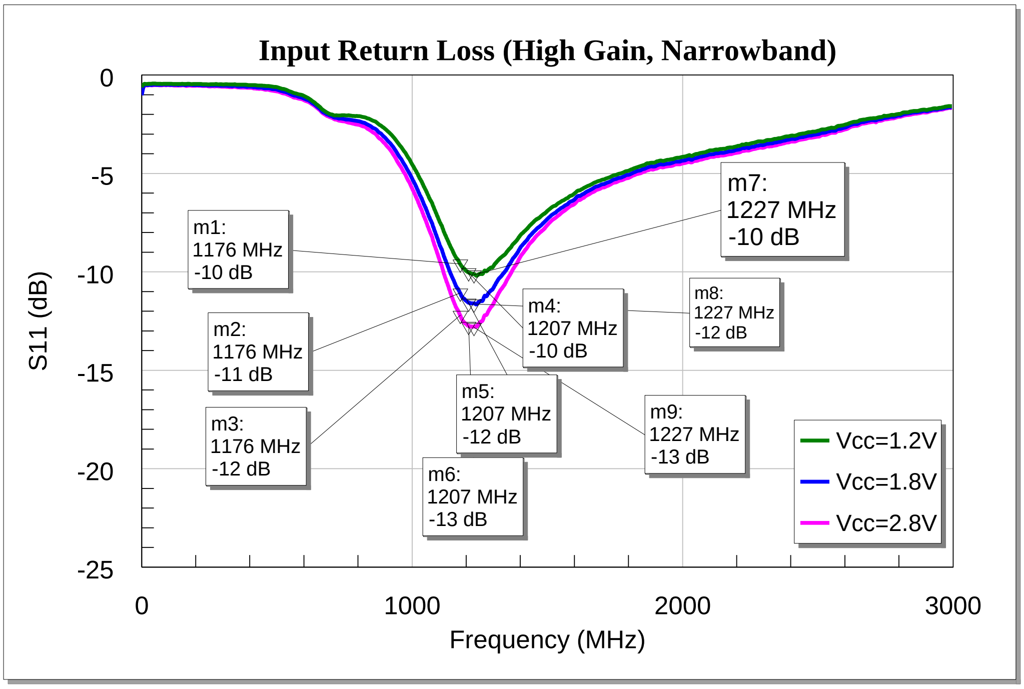

Figure 9 **Input Return Loss**

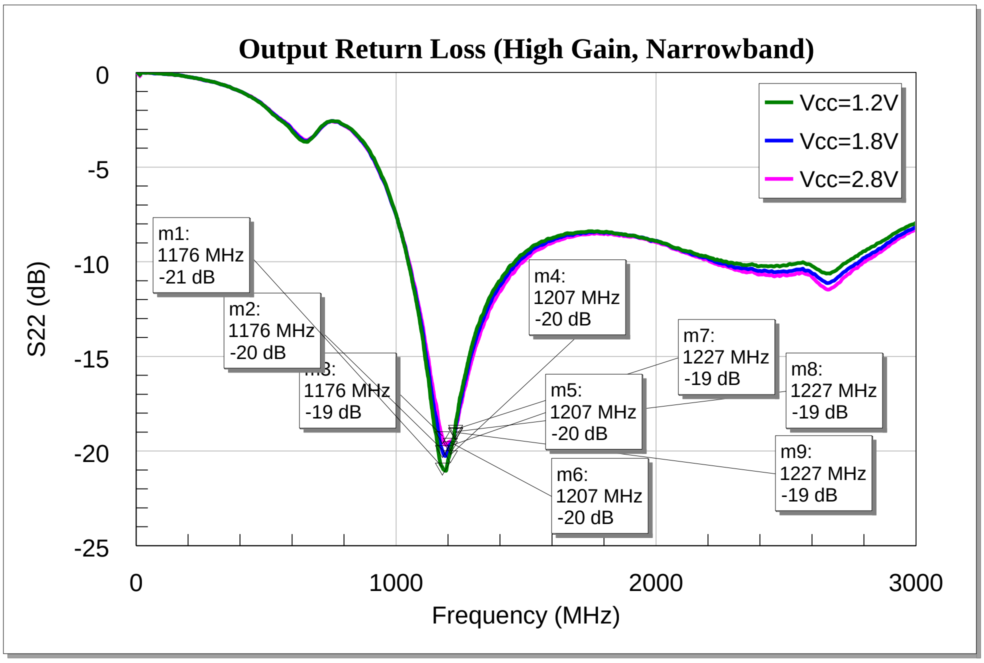

Figure 10 **Output Return Loss**

Measurement Graphs

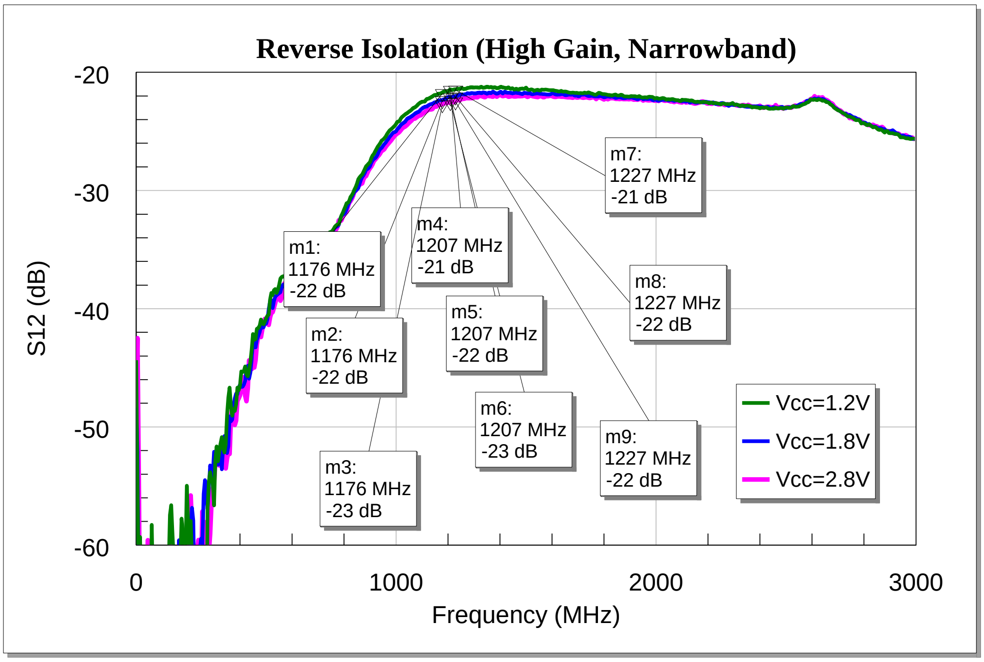

Figure 11 **Reverse Isolation**

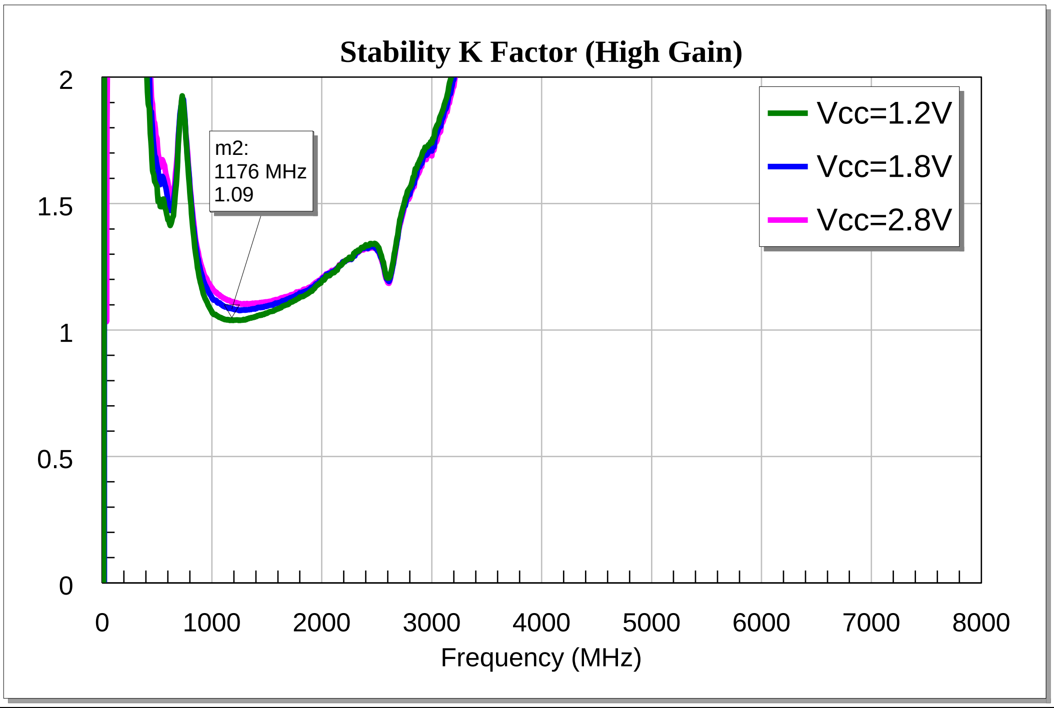

Figure 12 **Stability K-factors**

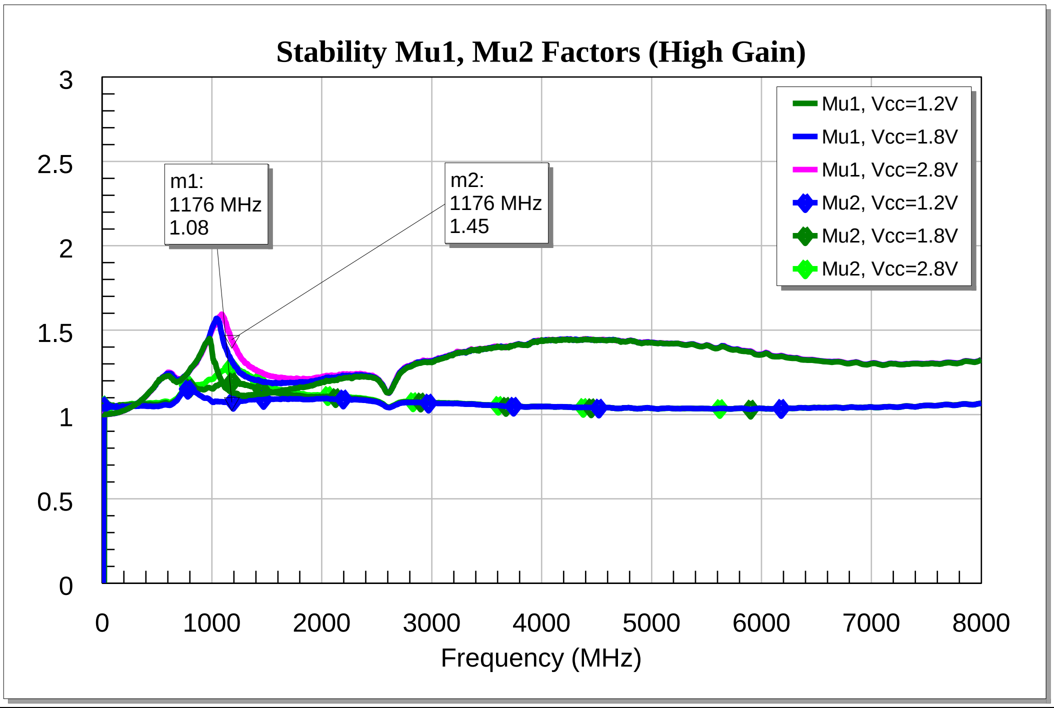

Figure 13 Stability Mu1-factor, Mu2-factor

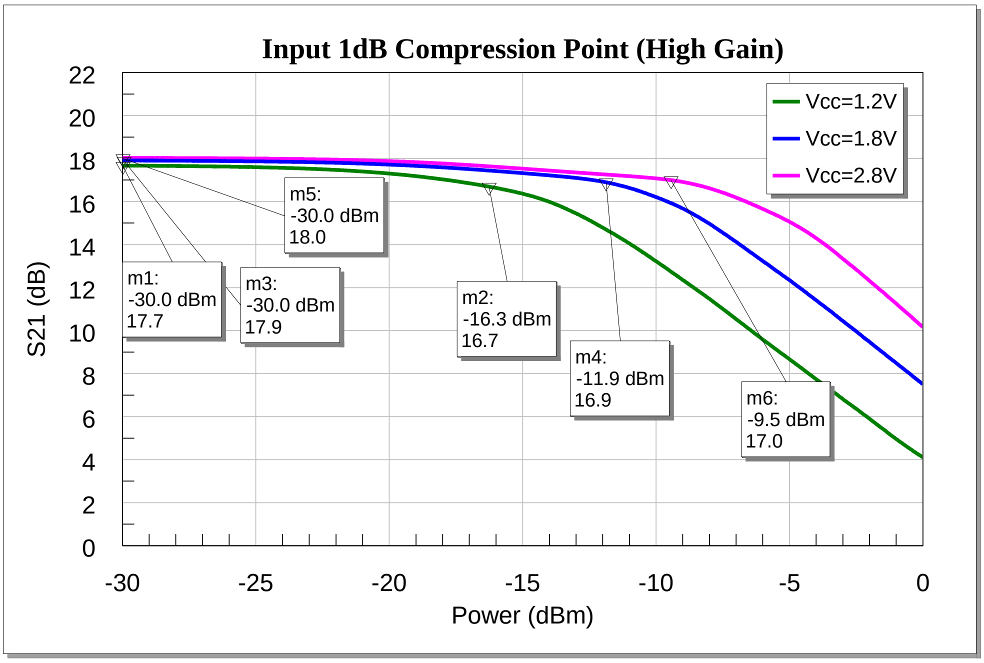

Figure 14 Input 1dB Compression Point (1176MHz)

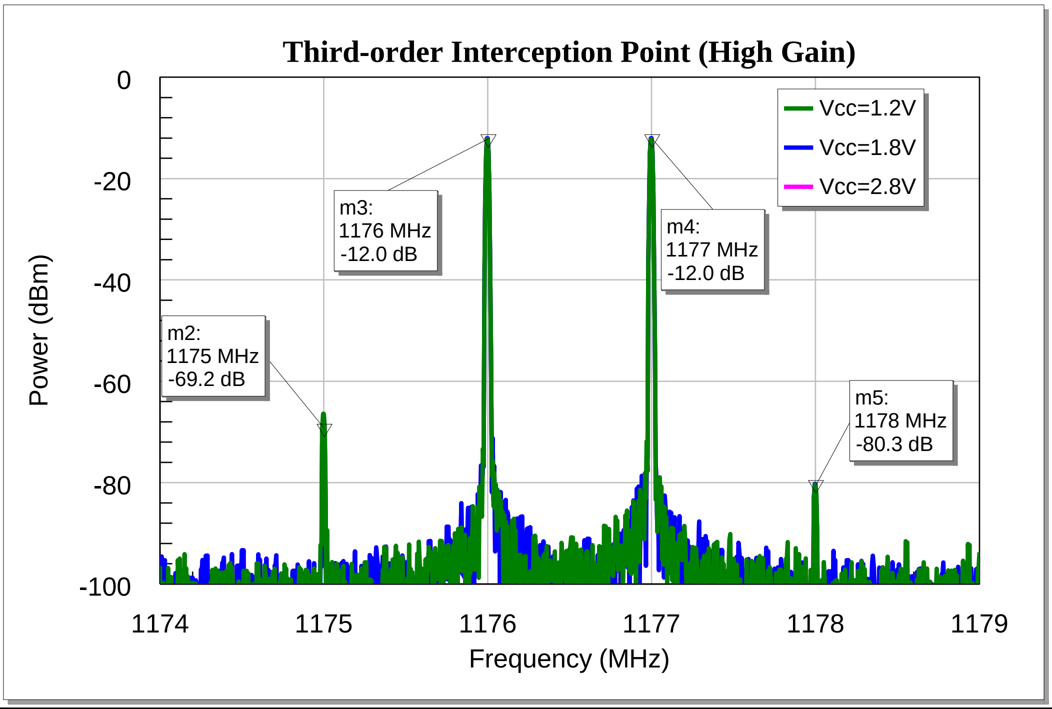

Figure 15 **Inband Third-order Intermodulation Point (1176 MHz, output referred)**

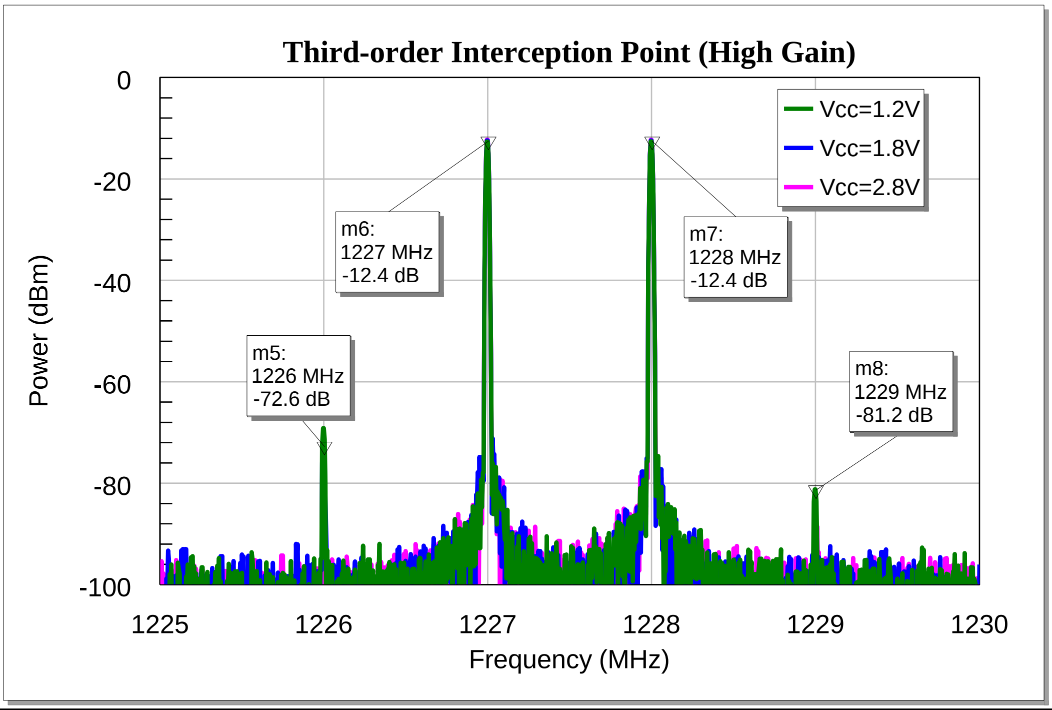

Figure 16 **Inband Third-order Intermodulation Point (1227 MHz, output referred)**

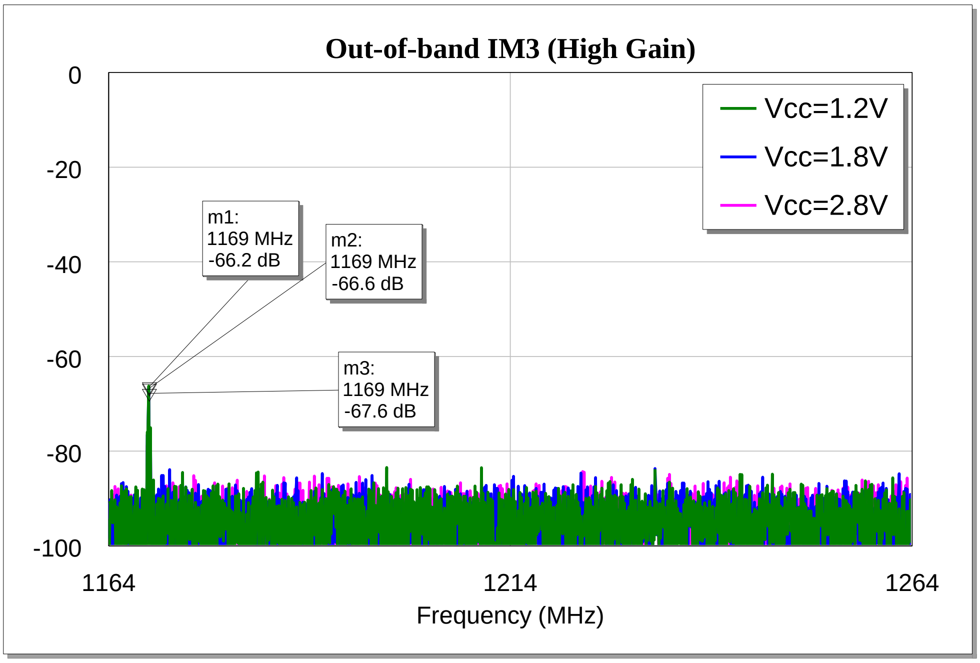

Figure 17 Out-of-band Third-order Intermodulation Point (L5 band, Output referred)

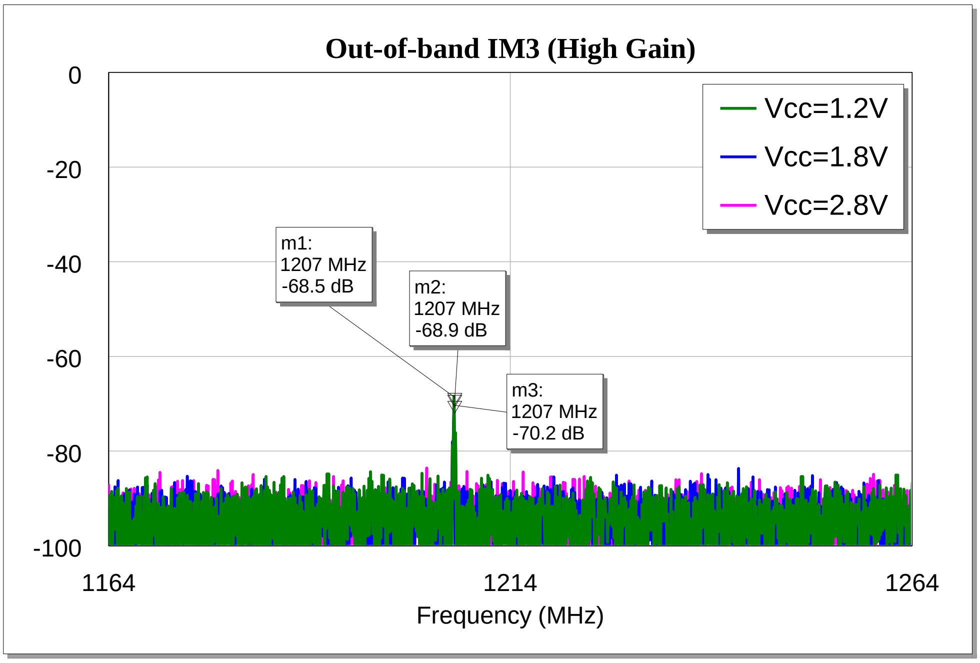

Figure 18 Out-of-band Third-order Intermodulation Point (E5 band, output referred)

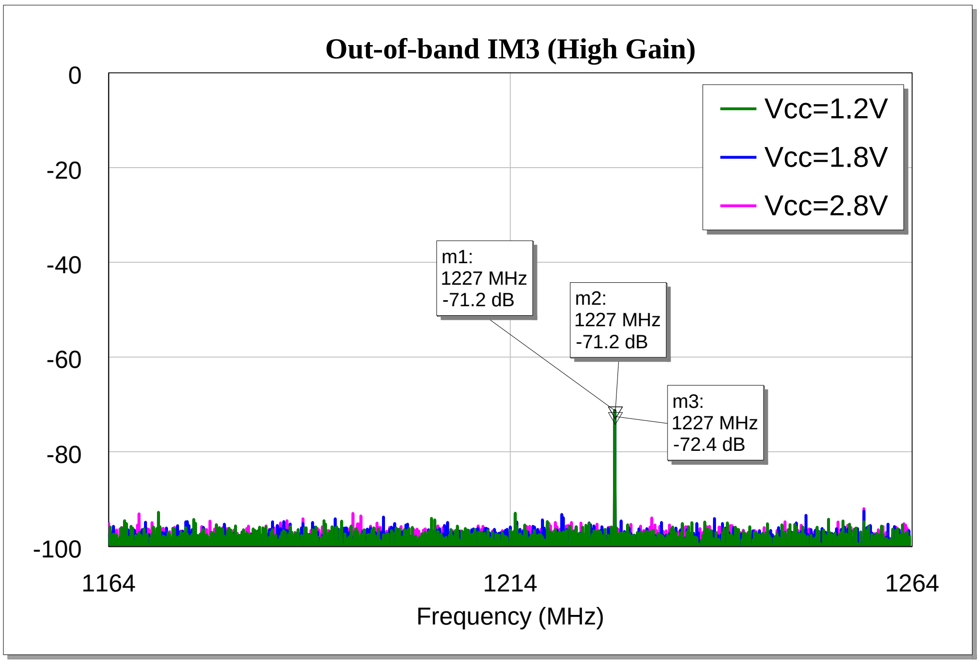

Figure 19 Out-of-band Third-order Intermodulation Point (L2 band, output referred)

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: **BGA855N6 V1.0**

PCB material: **Megtron6**

ε_r of PCB material: **3.7**

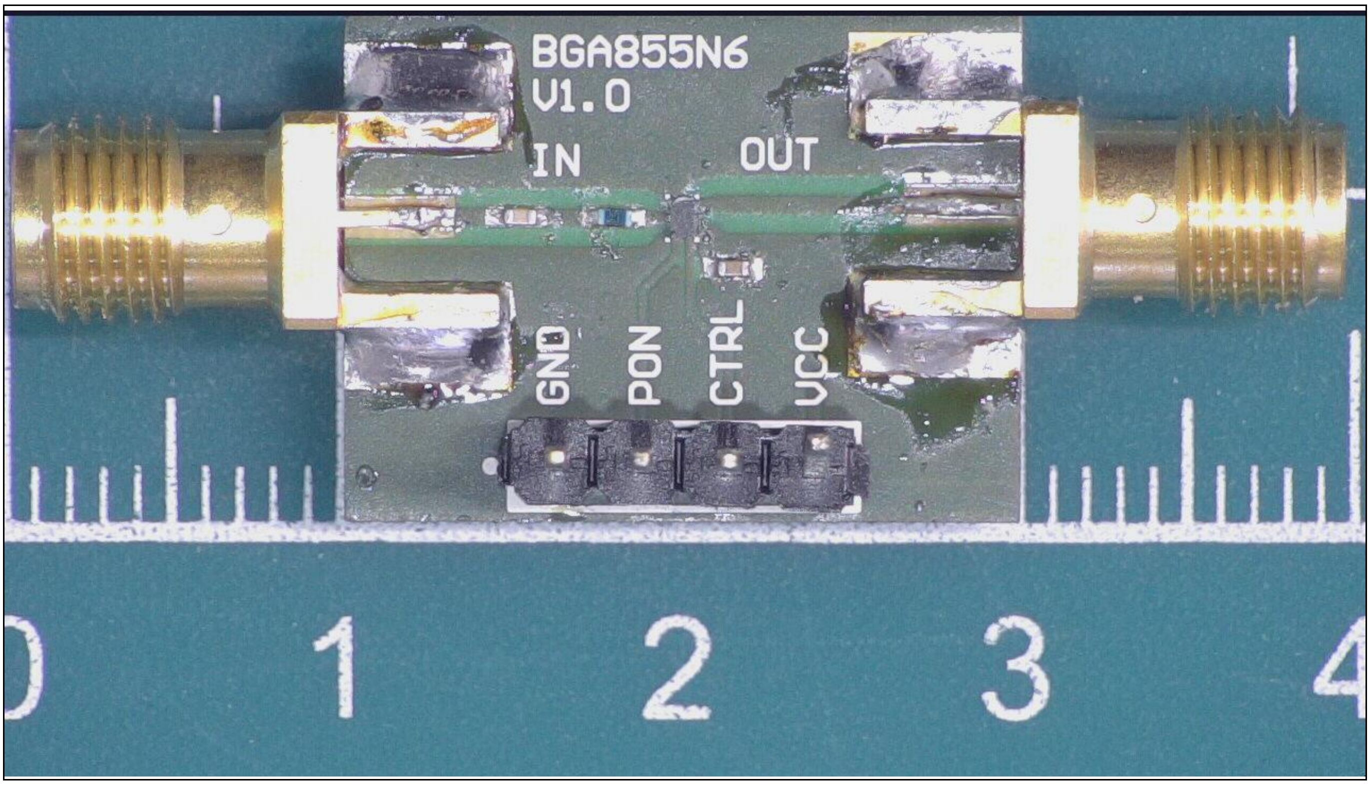

Figure 20 Photo Picture of Evaluation Board (overview)

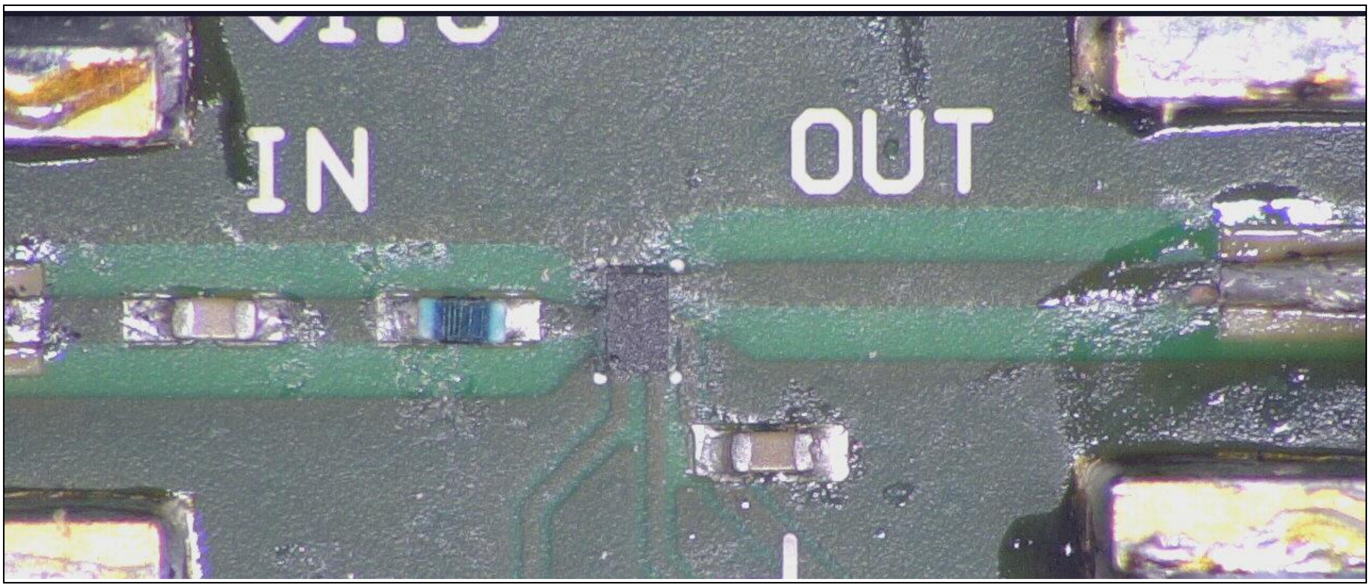

Figure 21 Photo Picture of Evaluation Board (detailed view)

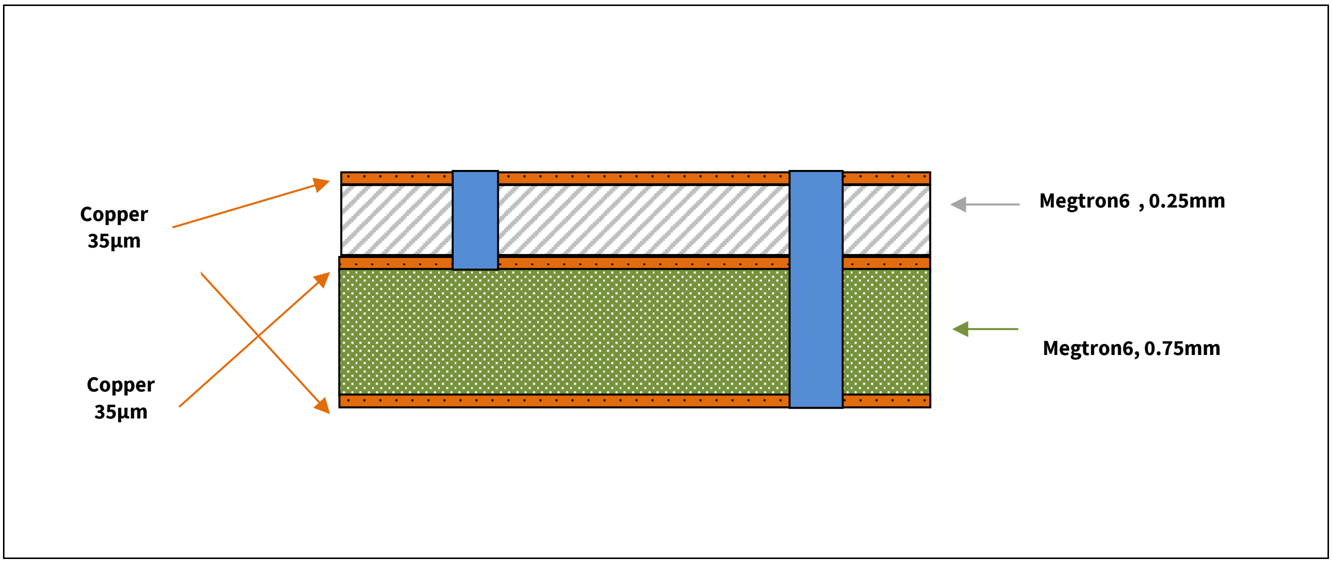

Figure 22 PCB Layer Information

6 Authors

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

7 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 1.1 2019-11-06

Page or Reference	Description of change
Page 8 onwards	Updated the measurement frequency of 1176MHz., 1227MHz for IIP3 into the performance table and graphs, updated reporting conditions and graphs for OoB IIP3
Page 8 onwards	Inserted IM2 results for 1176MHz

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