BGA525N6 as dualband multi-mode LNA for GNSS Applications with High Q 0201 inch inductors for matching

About this document

Scope and purpose

This application note describes Infineon's GNSS MMIC: BGA525N6 as a low-noise amplifier (LNA) for GNSS applications in the frequency range of 1160 MHz - 1210 MHz and 1560 MHz - 1610 MHz.

The BGA525N6 is a dualband silicon germanium (SiGe) LNA supporting the main GNSS bands both in lower L bands and upper L bands

1. The target applications of this circuit are GPS L1/Galileo E1/GLONASS L1/BeiDou B1/QZSS L1 bands, GPS L2/QZSS L2C and GPS L5/Galileo E5/GLONASS L3/BeiDou B2/QZSS L5/NavIC L5 bands.

2. In this report, the performance of BGA525N6 is investigated on a Megtron 6 board with option for SMA connectors or K connectors. This device is matched with 0201 size high Q-factor LQP03HQ inductors. The 3 different operating modes featuring high gain, middle gain (standard) and low power consumption (power saving) are all presented. Compared with the performance with high Q 0402 LQW inductors for matching as presented in application note AN656, the gain is slightly lower and noise figure slightly higher. Three matching inductor solutions are investigated for each mode.

3. Key performance of a typical sample at V_{CC} = 1.8 V, with 10 nH LQP03HQ inductors for matching:

L1 band 1575 MHz	L5 band 1176 MHz
High Gain Mode	High Gain Mode
I_{CC} = 3.5 mA	I_{CC} = 3.5 mA
Insertion gain = 18.2 dB	Insertion gain = 19.0 dB
Noise figure = 0.90 dB	Noise figure = 0.85 dB
Out-of-band IIP3 = -7 dBm	Out-of-band IIP3 = -2 dBm
Standard Mode	Standard Mode
I_{CC} = 2.2 mA	I_{CC} = 2.2 mA
Insertion gain = 16.7 dB	Insertion gain = 17.4 dB
Noise figure = 0.95 dB	Noise figure = 0.90 dB
Out-of-band IIP3 = -6 dBm	Out-of-band IIP3 = -2 dBm
Power saving Mode	Power saving Mode
I_{CC} =1.4 mA	I_{CC} = 1.4 mA
Insertion gain = 14.7 dB	Insertion gain = 15.0 dB
Noise figure = 1.05 dB	Noise figure = 1.05 dB
Out-of-band IIP3 = -6 dBm	Out-of-band IIP3 = -7 dBm

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1 Introduction and product overview

1.1 Global Navigation Satellite Systems

Global Navigation Satellite Systems (GNSS) are among the most commonly used services in the electronics industry. Today, the following GNSS systems are in operation: GPS, GLONASS, Beidou, Galileo, QZSS and IRNSS or NavIC. Main market segments include GNSS-enabled cell phones, GNSS modules for industrial, consumer and automotive application and GNSS-enabled wearable devices.

The upper L band in the range of 1560 MHz to 1610 MHz has been the main band for global navigation services. The lower L band in the range of 1160 MHz to 1300 MHz enables high precision navigation. It increases the navigation accuracy and quality by reducing the multipath effect in urban environment, as well as offers safety-of-life signal in emergency situation.

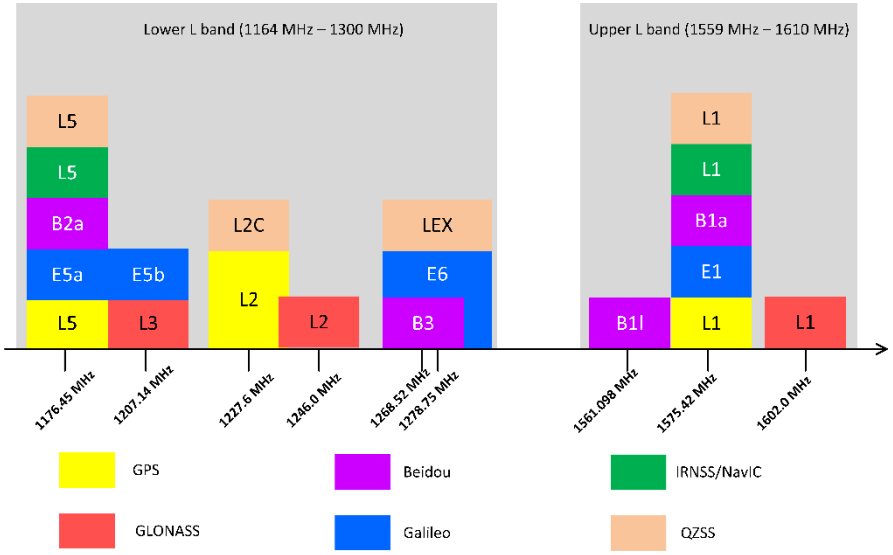

Figure 1 Frequency allocation for GNSSs, upper L band and lower L band

1.2 Key challenges for modern GNSS reception

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

1.2.1 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.

1.2.2 Out-of-band interference

Often GNSS and other wireless communication functions coexist in a compact area. Coupling from other wireless RF systems result in intermixing of high-frequency signals into GNSS RF receive path, 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 are major interference signals for GNSS RF Frontends.

1.3 BGA525N6 overview

- Operation frequencies: 1164 MHz to 1615 MHz
- Multi-operating modes for different applications
- Broadband design allowing simultaneous operation of L1, L2 and L5 bands
- Wide supply voltage range: 1.1 V to 3.3 V
- Insertion power gain up to 19.5 dB
- Noise figure down to 0.70 dB
- 2 kV HBM ESD protection (including AI pin)
- Ultra-small and RoHS/WEEE-compliant package

RoHS Halogen-Free Lead-Free Green

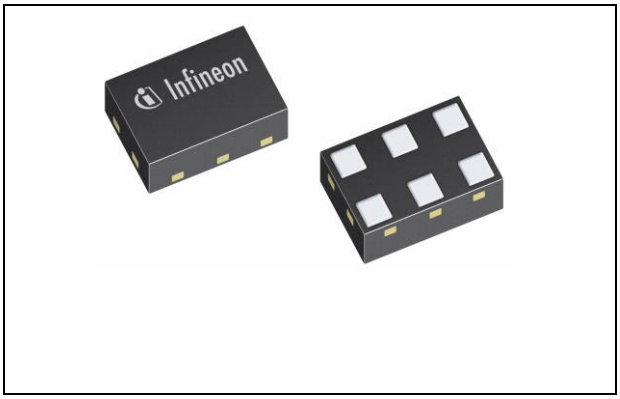

Figure 3 BGA525N6 in TSNP-6-2

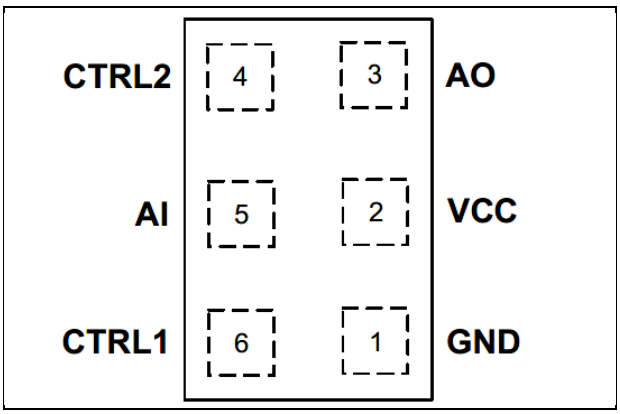

Figure 2 BGA525N6 pin configuration (transparent top view)

Table 1 Pin assignment

Pin no.	Symbol	Function
1	GND	Ground
2	VCC	DC supply
3	AO	LNA output
4	CTRL2	Control pin 2
5	AI	LNA input
6	CTRL1	Control pin 1

2 Application circuit and performance overview

In this chapter the performance of the application circuit, the schematics and bill of materials (BOM) are presented.

Device: BGA525N6

Application: Dualband LNA for GNSS applications in 1160 - 1300 MHz and 1560 - 1610 MHz

PCB marking: BGAxxxN6_Vxx_AE_50um

EVB order no.: EVAL BGA525N6 (AN662)

2.1 Summary of measurement results

The performance is summarized in the following tables. We present performance results based on different matching inductor values, each optimizes for a specific mode. Overall L1 = 11nH supports all three modes, therefore the graphs are presented with this option.

Table 2 Electrical characteristics at TA = 25 °C, L1 = 10nH, 2.8V

Parameter	Symbol	Value						Unit
Frequency	Freq	1575			1176			MHz
DC voltage	V_{CC}	2.8			2.8			V
DC current	I_{CC}	3.6	2.5	1.7	3.6	2.5	1.7	mA
Mode		**HG**	**STD**	**PS**	**HG**	**STD**	**PS**	
Gain	G	18.2	16.7	14.8	19.0	17.4	15.1	dB
Noise figure	NF	0.90	0.95	1.05	0.80	0.90	1.05	dB
Input return loss	RL_{IN}	10	16	20	10	10	8	dB
Output return loss	RL_{OUT}	15	15	15	10	10	10	dB
Reverse isolation	I_{REV}	35	35	36	30	30	30	dB
Input P1dB	IP1dB	-11	-8	-6	-11	-9	-6	dBm
Out-of-band input IP3	Oob_IIP3	-2	-6	-9	-2	-4	-8	dBm, note1
Stability	k	>1			>1			

1. Power at input: -20 dBm, L1 band f_1 = 1713 MHz, f_2 = 1850 MHz, measured at 1574MHz; L5 band f_1 = 1785 MHz, f_2 = 2401 MHz, measured at 1169MHz and f_1 = 1788.5 MHz, f_2 = 2401 MHz, measured at 1176MHz generate same performance, condition 2 presented.

2. For the noise figure calculation, SMA and connector losses of 0.05 dB are subtracted

Table 3 Electrical characteristics at TA = 25 °C, L1 = 10nH, 1.8V

Parameter	Symbol	Value						Unit
Frequency	Freq	1575			1176			MHz
DC voltage	V_{CC}	1.8			1.8			V
DC current	I_{CC}	3.4	2.2	1.5	3.4	2.2	1.5	mA
Mode		**HG**	**STD**	**PS**	**HG**	**STD**	**PS**	
Gain	G	18.2	16.7	14.7	19.0	17.4	15.0	dB
Noise figure	NF	0.90	0.95	1.05	0.85	0.90	1.05	dB
Input return loss	RL_{IN}	10	16	20	10	10	8	dB
Output return loss	RL_{OUT}	15	15	15	10	10	10	dB
Reverse isolation	I_{REV}	35	36	36	30	30	30	dB
Input P1dB	IP1dB	-16	-13	-10	-16	-13	-10	dBm
Out-of-band input IP3	Oob_IIP3	-7	-6	-6	-2	-2	-7	dBm, note1
Stability	k	>1			>1			

Table 4 Electrical characteristics at TA = 25 °C, L1 = 10nH, 1.2V

Parameter	Symbol	Value						Unit
Frequency	Freq	1575			1176			MHz
DC voltage	V_{CC}	1.2			1.2			V
DC current	I_{CC}	3.3	2.2	1.4	3.3	2.2	1.4	mA
Mode		**HG**	**STD**	**PS**	**HG**	**STD**	**PS**	
Gain	G	17.9	16.5	14.3	18.9	17.3	15.0	dB
Noise figure	NF	0.90	0.95	1.10	0.80	0.90	1.05	dB
Input return loss	RL_{IN}	12	17	18	12	11	8	dB
Output return loss	RL_{OUT}	15	14	14	11	10	10	dB
Reverse isolation	I_{REV}	35	36	36	30	30	30	dB
Input P1dB	IP1dB	-18	-13	-8	-19	-17	-15	dBm
Out-of-band input IP3	Oob_IIP3	-8	-6	-5	-2	0	-6	dBm, note1
Stability	k	>1			>1			

1. Power at input: -20 dBm, L1 band f_1 = 1713 MHz, f_2 = 1850 MHz, measured at 1574MHz; L5 band f_1 = 1785 MHz, f_2 = 2401 MHz, measured at 1169MHz and f_1 = 1788.5 MHz, f_2 = 2401 MHz, measured at 1176MHz generate same performance, condition 2 presented.

2. For the noise figure calculation, SMA and connector losses of 0.05 dB are subtracted

Table 5 Electrical characteristics at TA = 25 °C, L1 = 11nH, 2.8V

Parameter	Symbol	Value						Unit
Frequency	Freq	1575			1176			MHz
DC voltage	V_{CC}	2.8			2.8			V
DC current	I_{CC}	3.6	2.5	1.7	3.6	2.5	1.7	mA
Mode		**HG**	**STD**	**PS**	**HG**	**STD**	**PS**	
Gain	G	18.0	16.7	14.7	19.1	17.6	15.4	dB
Noise figure	NF	0.95	1.00	1.10	0.85	0.90	1.05	dB
Input return loss	RL_{IN}	10	13	15	11	11	9	dB
Output return loss	RL_{OUT}	17	16	15	10	10	10	dB
Reverse isolation	I_{REV}	36	36	37	33	33	33	dB
Input P1dB	IP1dB	-11	-8	-6	-11	-9	-6	dBm
Out-of-band input IP3	Oob_IIP3	-2	-6	-9	-2	-4	-8	dBm, note1
Stability	k	>1			>1			

Table 6 Electrical characteristics at TA = 25 °C, L1 = 11nH, 1.8V

Parameter	Symbol	Value						Unit
Frequency	Freq	1575			1176			MHz
DC voltage	V_{CC}	1.8			1.8			V
DC current	I_{CC}	3.4	2.2	1.5	3.4	2.2	1.5	mA
Mode		**HG**	**STD**	**PS**	**HG**	**STD**	**PS**	
Gain	G	18.0	16.6	14.5	19.1	17.6	15.3	dB
Noise figure	NF	0.95	1.00	1.10	0.85	0.90	1.05	dB
Input return loss	RL_{IN}	10	14	15	12	12	9	dB
Output return loss	RL_{OUT}	17	16	15	10	10	10	dB
Reverse isolation	I_{REV}	36	36	37	33	33	33	dB
Input P1dB	IP1dB	-16	-13	-10	-16	-13	-10	dBm
Out-of-band input IP3	Oob_IIP3	-7	-6	-6	-2	-2	-7	dBm, note1
Stability	k	>1			>1			

1. Power at input: -20 dBm, L1 band f_1 = 1713 MHz, f_2 = 1850 MHz, measured at 1574MHz; L5 band f_1 = 1785 MHz, f_2 = 2401 MHz, measured at 1169MHz and f_1 = 1788.5 MHz, f_2 = 2401 MHz, measured at 1176MHz generate same performance, condition 2 presented.
2. For the noise figure calculation, SMA and connector losses of 0.05 dB are subtracted

Table 7 Electrical characteristics at TA = 25 °C, L1 = 11nH, 1.2V

Parameter	Symbol	Value						Unit
Frequency	Freq	1575			1176			MHz
DC voltage	V_{CC}	1.2			1.2			V
DC current	I_{CC}	3.3	2.2	1.4	3.3	2.2	1.4	mA
Mode		**HG**	**STD**	**PS**	**HG**	**STD**	**PS**	
Gain	G	17.7	16.3	14.2	19.0	17.5	15.3	dB
Noise figure	NF	1.00	1.00	1.15	0.85	0.90	1.05	dB
Input return loss	RL_{IN}	11	13	13	13	13	10	dB
Output return loss	RL_{OUT}	16	15	14	10	10	10	dB
Reverse isolation	I_{REV}	36	36	37	33	33	33	dB
Input P1dB	IP1dB	-18	-13	-8	-19	-17	-15	dBm
Out-of-band input IP3	Oob_IIP3	-8	-6	-5	-2	0	-6	dBm, note1
Stability	k	>1			>1			

Table 8 Electrical characteristics at TA = 25 °C, L1 = 12nH, 2.8V

Parameter	Symbol	Value						Unit
Frequency	Freq	1575			1176			MHz
DC voltage	V_{CC}	2.8			2.8			V
DC current	I_{CC}	3.6	2.5	1.7	3.6	2.5	1.7	mA
Mode		**HG**	**STD**	**PS**	**HG**	**STD**	**PS**	
Gain	G	17.8	16.4	14.3	19.1	17.7	15.5	dB
Noise figure	NF	1.05	1.10	1.20	0.85	0.90	1.00	dB
Input return loss	RL_{IN}	9	11	12	12	14	11	dB
Output return loss	RL_{OUT}	16	17	16	12	10	10	dB
Reverse isolation	I_{REV}	35	36	36	30	30	30	dB
Input P1dB	IP1dB	-11	-8	-6	-11	-9	-6	dBm
Out-of-band input IP3	Oob_IIP3	-2	-6	-9	0	-3	-6	dBm, note1
Stability	k	>1			>1			

1. Power at input: -20 dBm, L1 band f_1 = 1713 MHz, f_2 = 1850 MHz, measured at 1574MHz; L5 band f_1 = 1785 MHz, f_2 = 2401 MHz, measured at 1169MHz and f_1 = 1788.5 MHz, f_2 = 2401 MHz, measured at 1176MHz generate same performance, condition 2 presented.

2. For the noise figure calculation, SMA and connector losses of 0.05 dB are subtracted

Table 9 Electrical characteristics at TA = 25 °C, L1 = 12nH, 1.8V

Parameter	Symbol	Value						Unit
Frequency	Freq	1575			1176			MHz
DC voltage	V_{CC}	1.8			1.8			V
DC current	I_{CC}	3.4	2.2	1.5	3.4	2.2	1.5	mA
Mode		**HG**	**STD**	**PS**	**HG**	**STD**	**PS**	
Gain	G	17.7	16.3	14.1	19.2	17.7	15.6	dB
Noise figure	NF	1.05	1.10	1.20	0.85	0.90	1.00	dB
Input return loss	RL_{IN}	10	12	11	13	14	11	dB
Output return loss	RL_{OUT}	15	14	15	11	11	10	dB
Reverse isolation	I_{REV}	35	36	36	30	30	30	dB
Input P1dB	IP1dB	-16	-13	-10	-16	-13	-10	dBm
Out-of-band input IP3	Oob_IIP3	-7	-5	-6	3	-2	-6	dBm, note1
Stability	k	>1			>1			

Table 10 Electrical characteristics at TA = 25 °C, L1 = 12nH, 1.2V

Parameter	Symbol	Value						Unit
Frequency	Freq	1575			1176			MHz
DC voltage	V_{CC}	1.2			1.2			V
DC current	I_{CC}	3.3	2.2	1.4	3.3	2.2	1.4	mA
Mode		**HG**	**STD**	**PS**	**HG**	**STD**	**PS**	
Gain	G	17.4	16.0	13.7	19.1	17.6	15.5	dB
Noise figure	NF	1.10	1.10	1.25	0.90	0.90	1.05	dB
Input return loss	RL_{IN}	10	11	10	16	15	12	dB
Output return loss	RL_{OUT}	17	14	15	11	11	11	dB
Reverse isolation	I_{REV}	35	36	36	30	30	30	dB
Input P1dB	IP1dB	-18	-13	-8	-19	-17	-15	dBm
Out-of-band input IP3	Oob_IIP3	-8	-6	-5	-1	3	-5	dBm, note1
Stability	k	>1			>1			

1. Power at input: -20 dBm, L1 band f_1 = 1713 MHz, f_2 = 1850 MHz, measured at 1574MHz; L5 band f_1 = 1785 MHz, f_2 = 2401 MHz, measured at 1169MHz and f_1 = 1788.5 MHz, f_2 = 2401 MHz, measured at 1176MHz generate same performance, condition 2 presented.
2. For the noise figure calculation, SMA and connector losses of 0.05 dB are subtracted

2.2 Schematics and bill of materials

The schematic is shown in Figure 4 and its Bill of Materials is shown in below table.

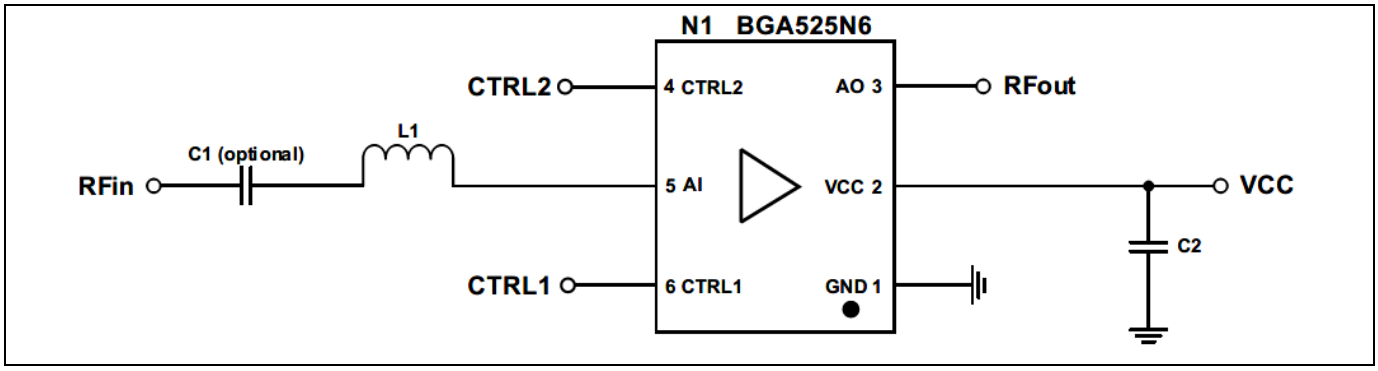

Figure 4 Schematic of the BGA525N6 application circuit

Table 11 Bill of Materials (BOM)

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	1	nF	0201	Various	DC block[1) 3)]
C2	1 56	nF pF	0201	Various	RF bypass[2)]
L1	10 11 12	nH	0201	Murata LQP03HQ	Input matching 10 nH, for HG/STD modes 11nH, for HG/STD/PS modes 12nH, for PS mode
N1	BGA525N6		TSNP-6-2	Infineon Technologies	SiGe LNA

1) DC block function is NOT integrated at the input pin. DC block capacitor C1 is not necessary if the DC block function on the RF input line can be ensured by the previous stage. For reducing switching time, lower DC block cap value is recommended. C1 = 100 pF enables less than 3 µs switching time.
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. In this app note, the value of 1 nF is used for C2.
3) The value of C1 may be changed to 100 pF resulting in a faster switching time OFF-to-ON.
4) for comparision purpose, the performance data of all three modes are presented for each matcing inductor value

Table 12 Gain Mode Selection Truth Table

V_{CTR1}	V_{CTR2}	Operation Mode
Low	High	High gain (HG)
High	Low	Standard (STD)
High	High	Low power (LP)
Low	Low	OFF

1) High and Low Vctrl level could be set to Vcc level and GND level respectively for mode switch. For detailed min and max range of High and Low, please refer to datasheet.

3 Measurement graphs

For simplicity purpose, the measurement graphs with L1 11nH at 1.8V are presented.

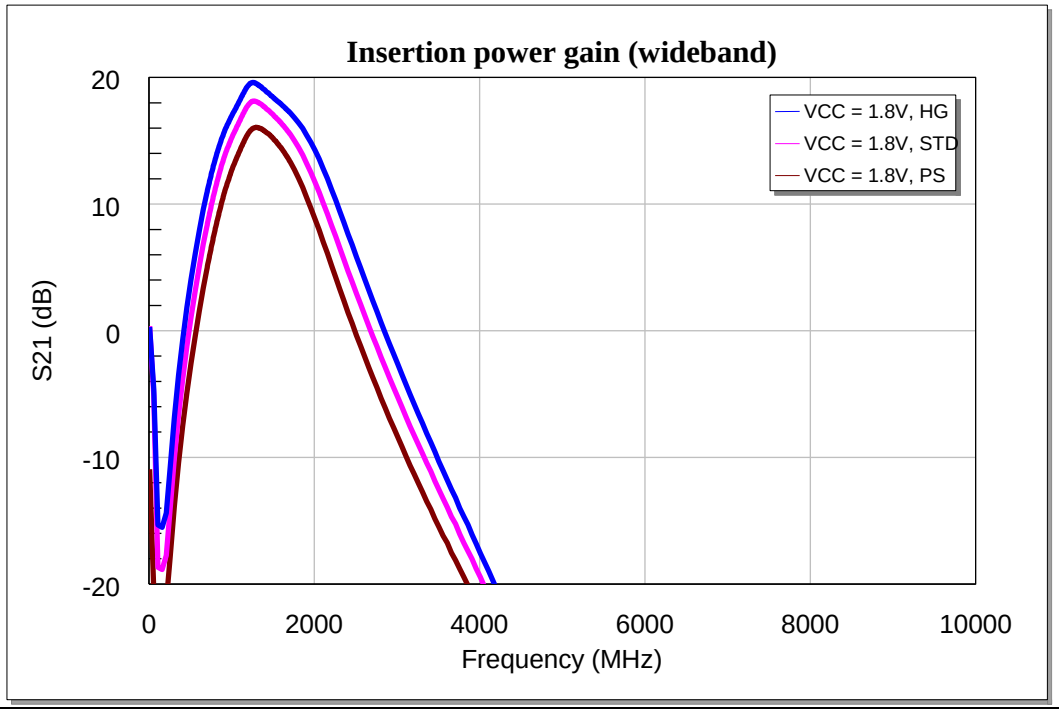

Figure 5 Insertion power gain (wideband)

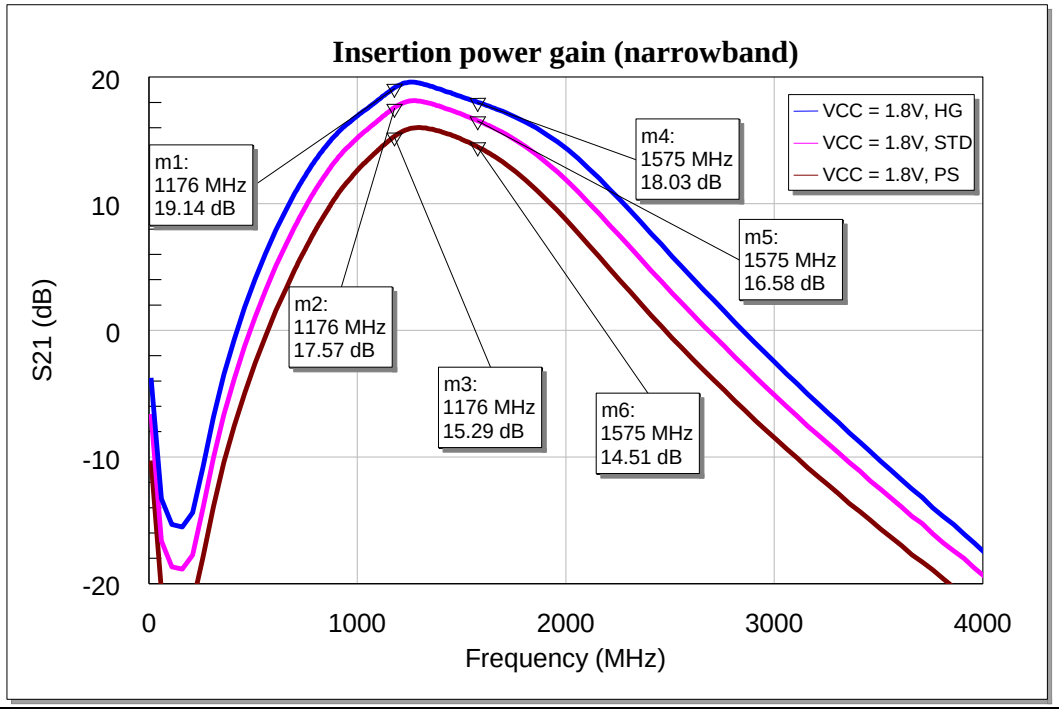

Figure 6 Insertion power gain (narrowband)

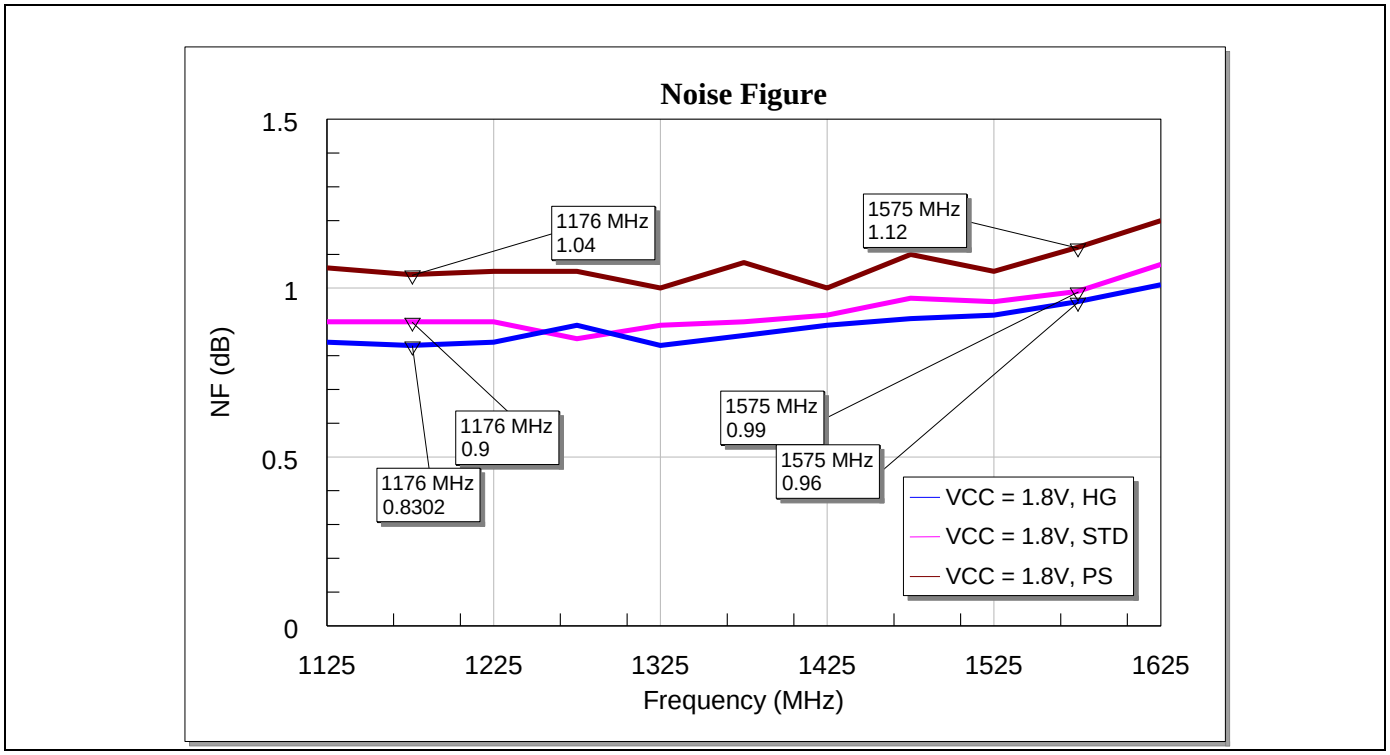

Figure 7 Noise figure (SMA and connector losses deembedded)

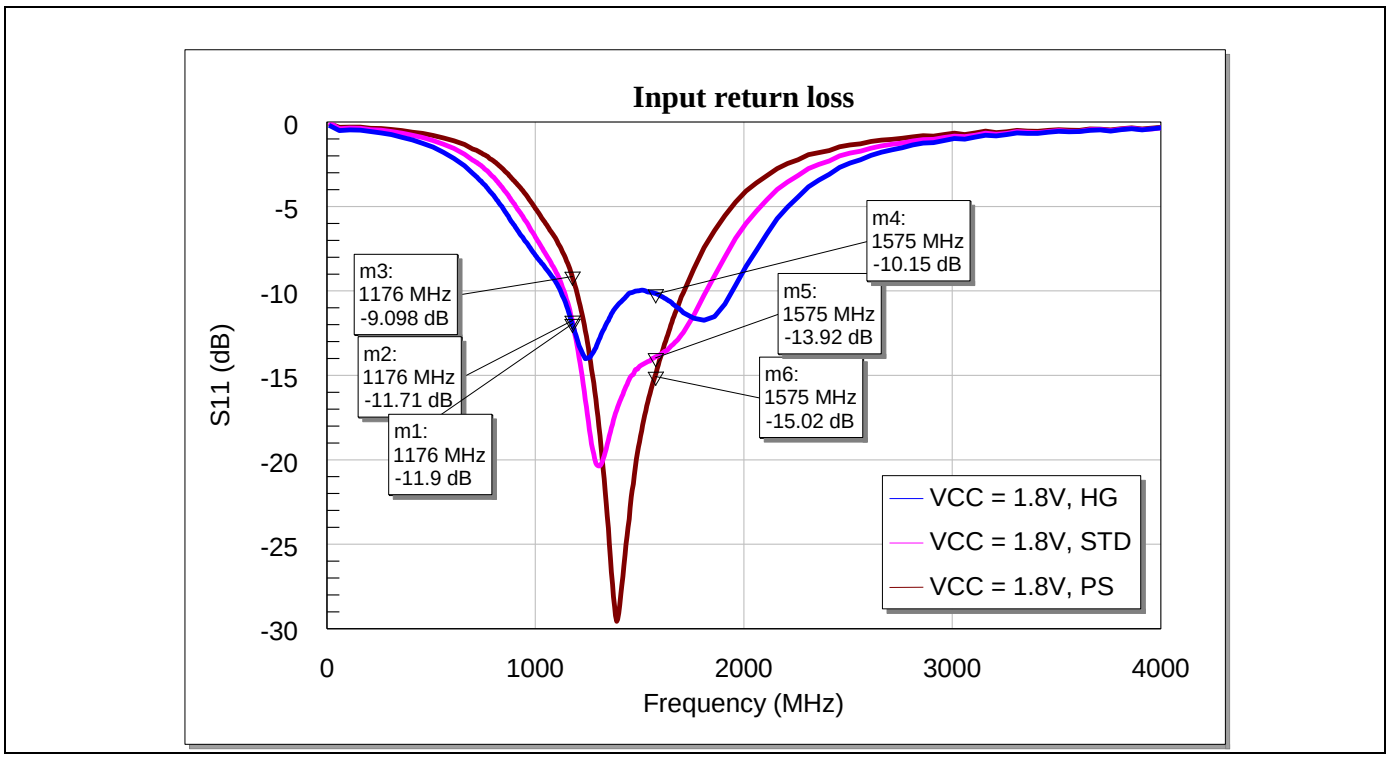

Figure 8 Input return loss

Measurement graphs

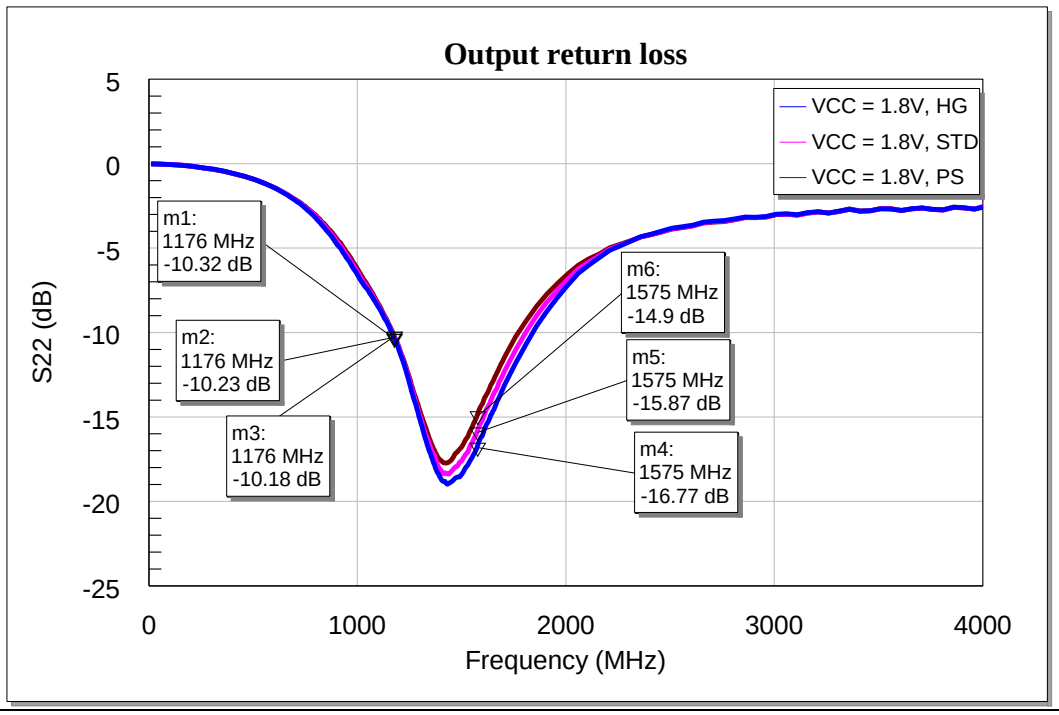

Figure 9 Output return loss

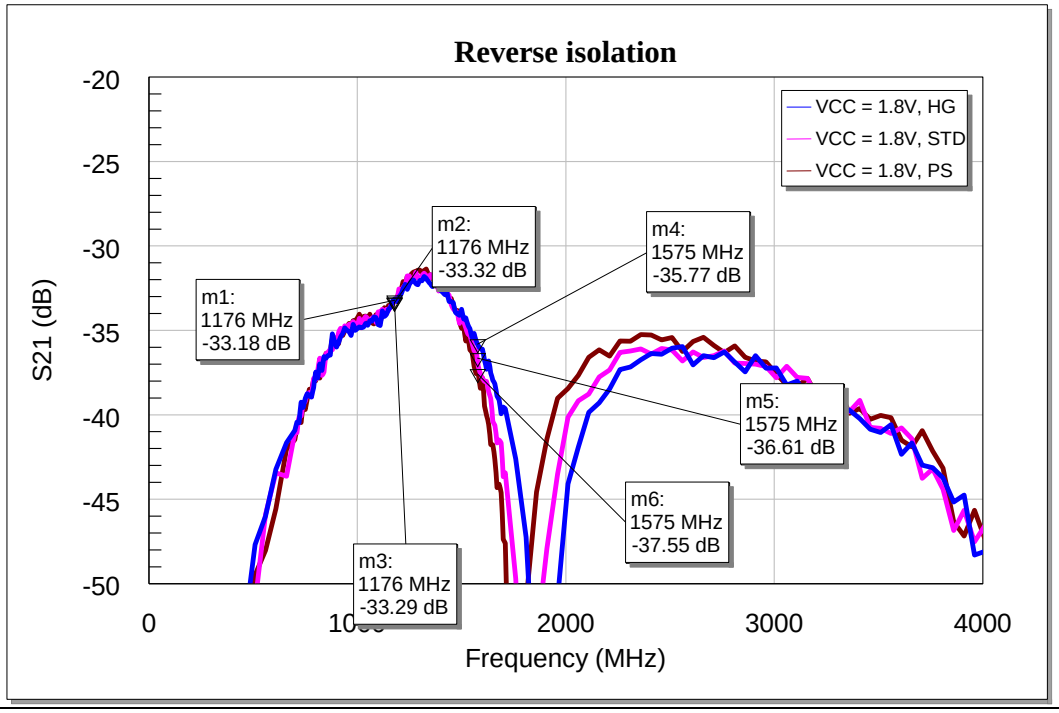

Figure 10 Reverse isolation

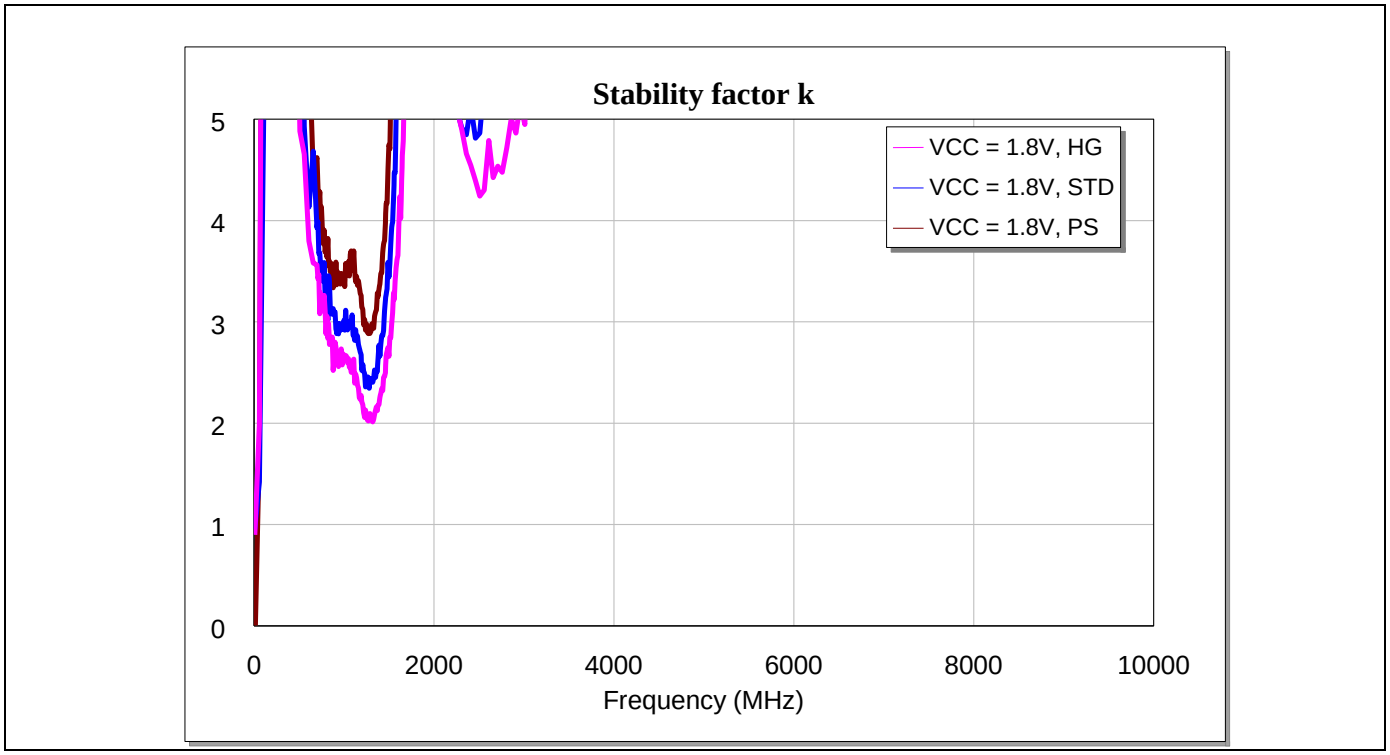

Figure 11 Stability k-factor

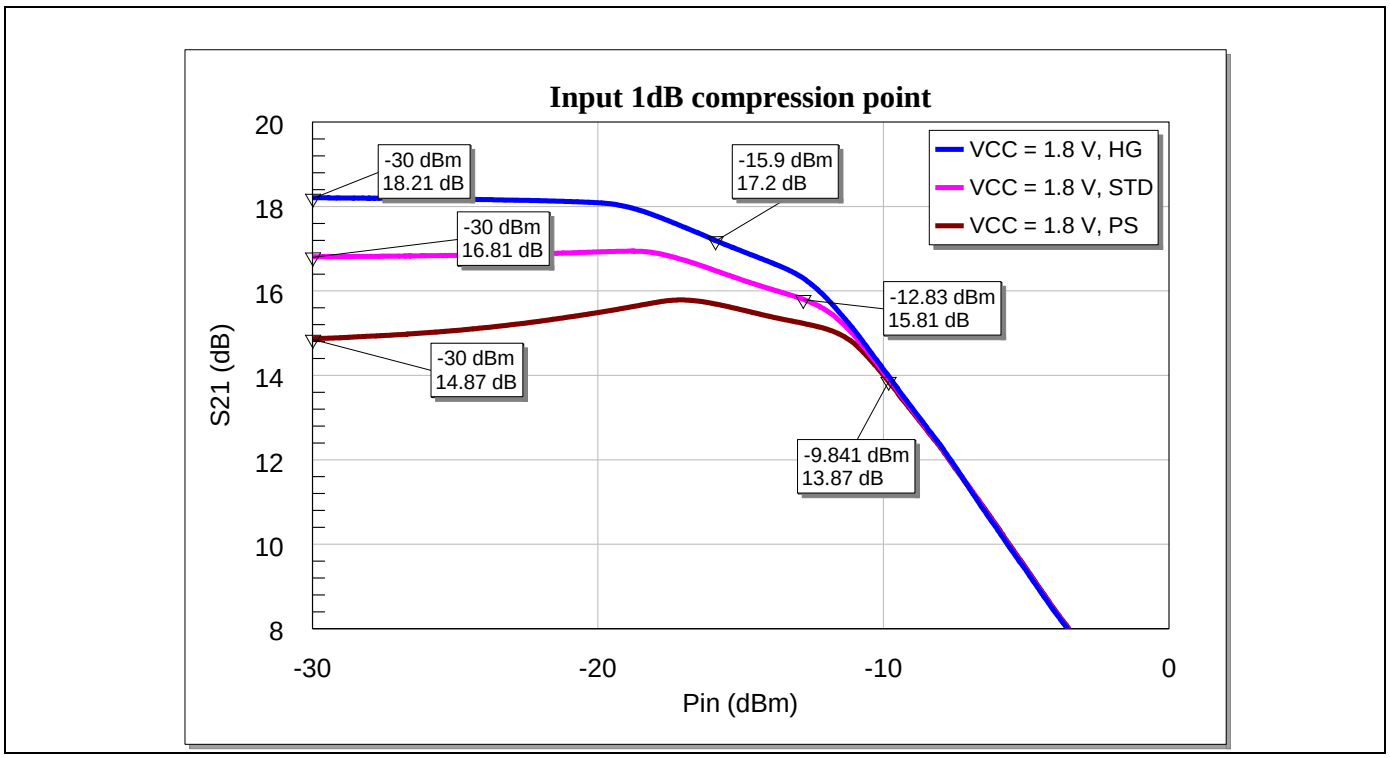

Figure 12 Input 1 dB compression point at 1575 MHz

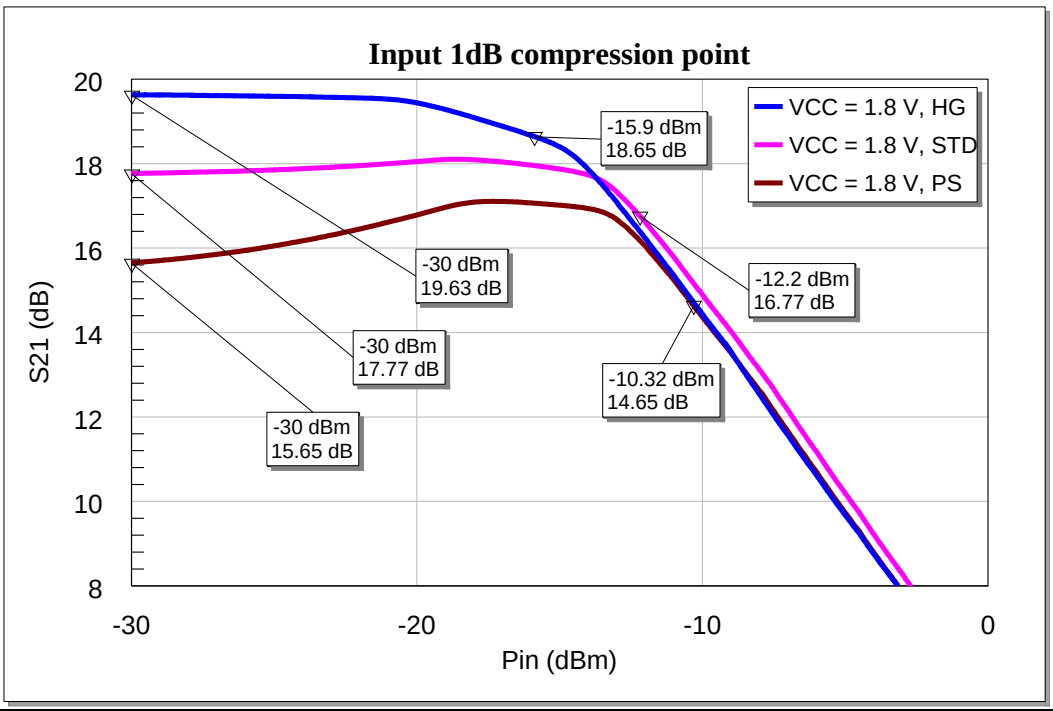

Figure 13 Input 1dB compression point at 1176 MHz

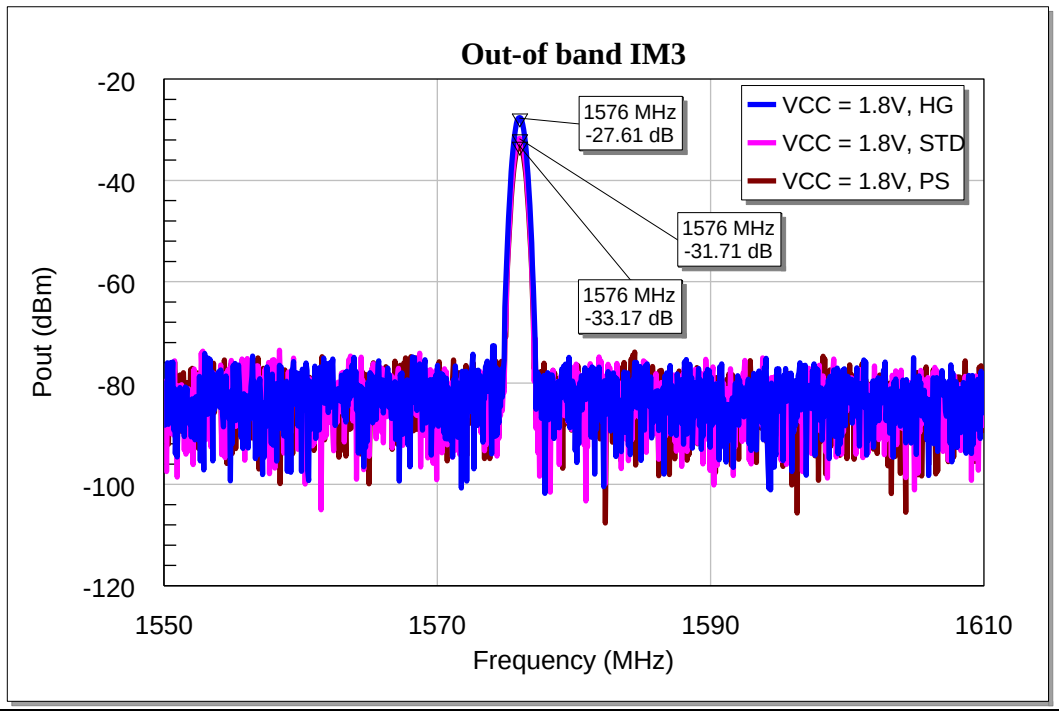

Figure 14 OoB third-order intermodulation point (f1 = 1717 MHz, f2 = 1850 MHz, L1 band, output referred)

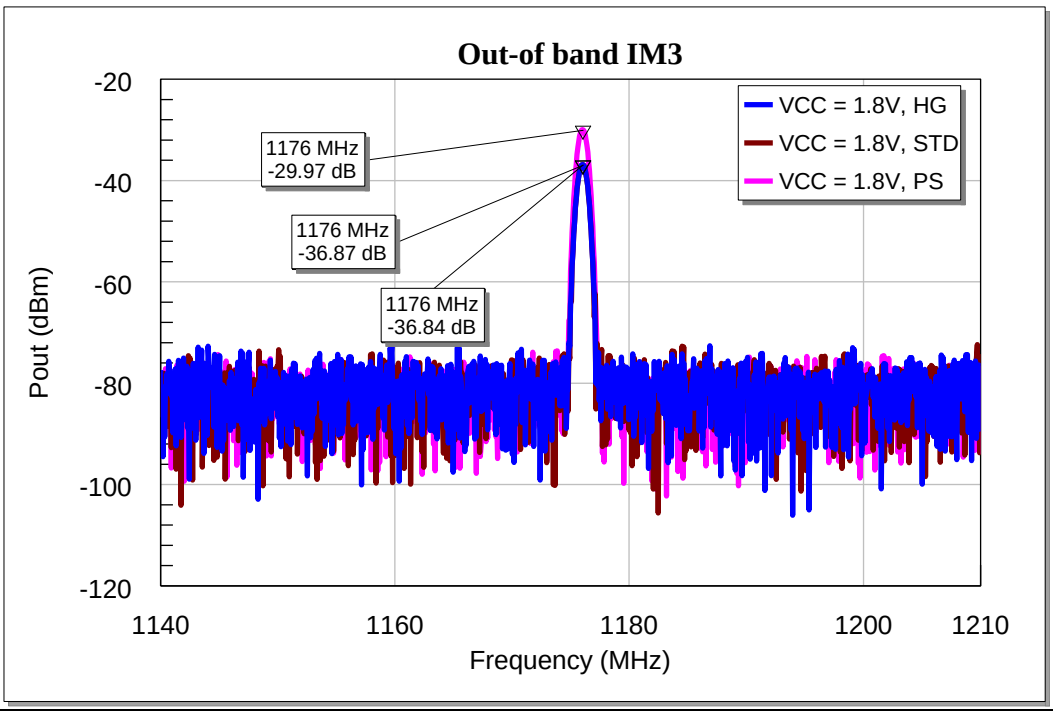

Figure 15 **OoB third-order intermodulation point (f1 = 1788.5 MHz, f2 = 2401 MHz, L5 band, output referred)**

4 Evaluation board and layout information

In this application note, the following PCB is used:

PCB marking: BGAxxxN6_vxx (SMA connector) /TSNP6a V2.1 (K connector)

PCB material: **Megtron 6**

Er: 3.3

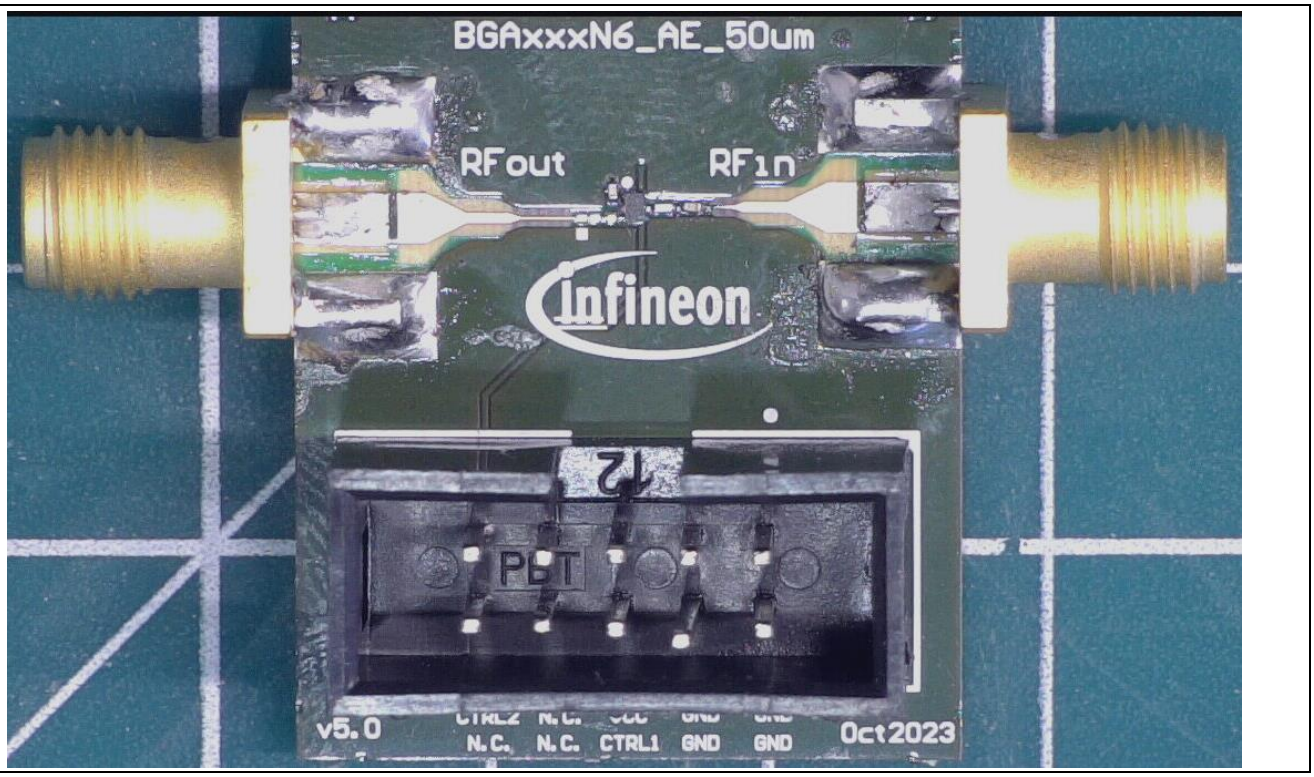

Figure 16 Evaluation board with SMA connector (example)

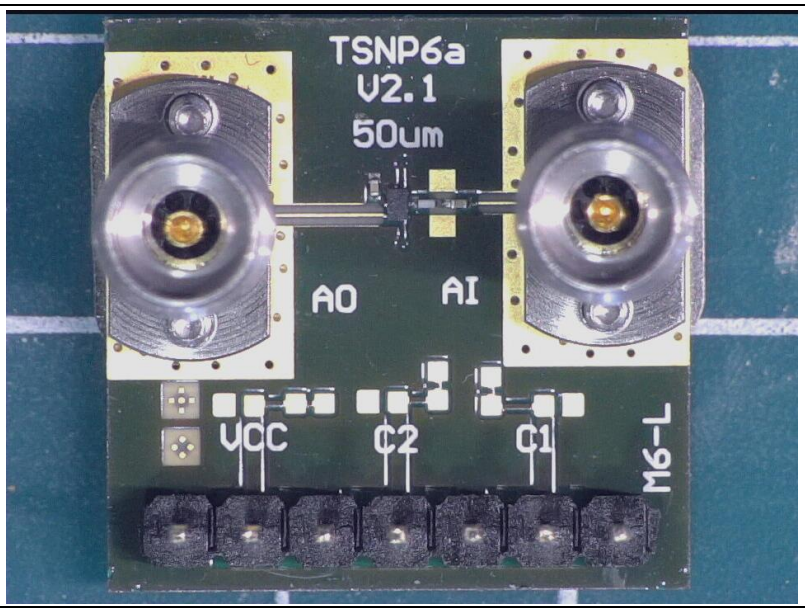

Figure 17 Evaluation board with K connector

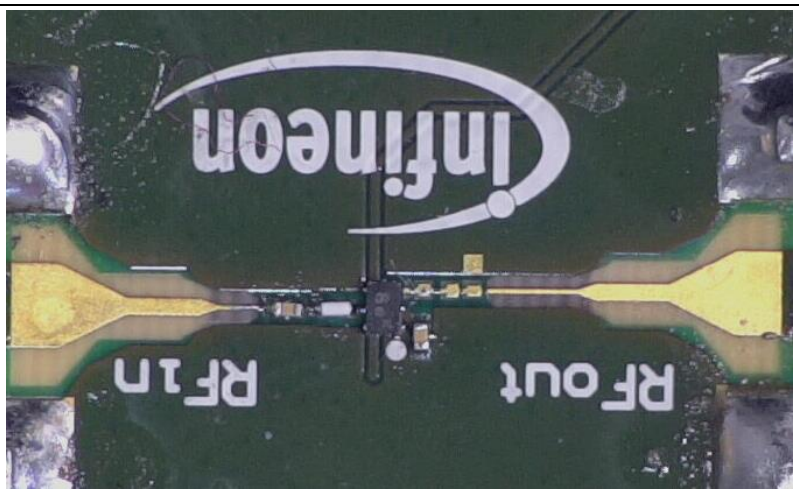

Figure 18 Evaluation board (detailed view)

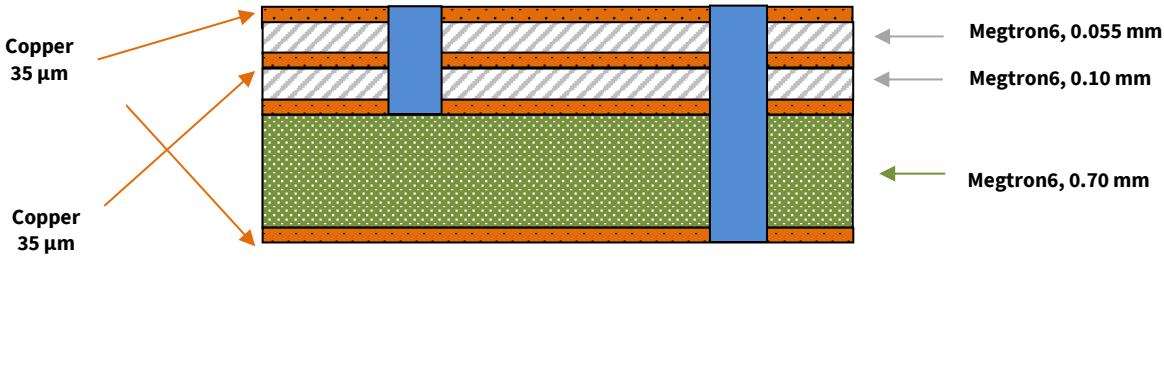

Figure 19 PCB layer information

5 Authors

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Revision history

Major changes since the last revision Rev 1.1 2024-01-24

Page or reference	Description of change
4	GNSS spectrum to include IRNSS L1 band
10	Description of RF bypass capacitor
20-21	EVB pictures and PCB description

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