BGA725L6

High-Gain Low Noise Amplifier for Global Navigation Satellite Systems (GNSS) from 1550 MHz to 1615 MHz Applications using 0201 components

Application Note AN280

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RF and Protection Devices

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Revision History: 2012-06-08

Previous Revision: None

Page	Subjects (major changes since last revision)

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1 SiGe Low Noise Amplifier for Global Navigation Satellite Systems (GNSS)

1.1 Features

- High insertion power gain: 20.0 dB
- Out-of-band input 3rd-order intercept point: -2 dBm
- Input 1dB compression point: -15 dBm
- Low noise figure: 0.65 dB
- Low current consumption: 3.6 mA
- Operating frequency: 1550 - 1615 MHz
- Supply voltage: 1.5 V to 3.6 V
- Digital on/off switch (1V logic high level)
- Ultra small TSLP-6-2 leadless package (footprint: 0.7 x 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 1 BGA725L6 in TSLP-6-2 Package (0.70mm x 1.1mm x 0.40mm)

1.2 Applications

- GPS (Global Positioning System) working in the L1 band at 1575.42 MHz
- GLONASS (Russian GNSS) working in the L1 band from 1598.06 MHz to 1605.38 MHz
- Galileo (European GNSS) working in the E2-L1-E1 band from 1559 MHz to 1592 MHz
- COMPASS (Chinese Beidou Navigation System) working in E2 band at 1561.10 MHz and E1 band at 1589.74 MHz

2 Introduction

The BGA725L6 is a front-end Low Noise Amplifier (LNA) for Global Navigation Satellite Systems (GNSS) application. It is based on Infineon Technologies' B7HF Silicon-Germanium (SiGe) technology, enabling a cost-effective solution in a ultra small TSLP-6-2 package with ultra low noise figure, high gain, high linearity and low current consumption over a wide range of supply voltages from 3.6 V down to 1.5 V. All these features make BGA725L6 an excellent choice for GNSS LNA as it improves sensitivity, provide greater immunity against out-of-band jammer signals, reduces filtering requirement and hence the overall cost of the GNSS receiver.

The GNSS satellites are at an orbit altitude of more than 20,000 km away from earth's surface and transmit power in the range of +47 dBm. After taking losses (atmospheric, antenna etc.) into account, the received signal strength at the GNSS device input is very low in the range of -130 dBm. The ability of the GNSS device to receive such a low signal strength and provide meaningful information to the end-user depends strongly on the noise figure of the GNSS receive chain. This ability which is called receiver sensitivity can be improved by using a low-noise amplifier with low noise figure and high gain at the input of the receiver chain. The improved sensitivity results in a shorter Time-To-First-Fix (TTFF), which is the time required for a GNSS receiver to acquire satellite signals and navigation data, and calculate a position. Noise figure of the LNA defines the overall noise figure of the GNSS receiver system. This is where BGA725L6 excels by providing noise figure as low as 0.65 dB and high gain of 20.0 dB, thereby improving the receiver sensitivity significantly.

The ever growing demand to integrate more and more functionality into one device leads to many challenges when transmitter/receiver has to work simultaneously without degrading the performance of each other. In today's smart-phones a GNSS receiver simultaneously co-exists with transceivers in the GSM/EDGE/UMTS/LTE bands. These 3G/4G transceivers transmit high power in the range of +24 dBm which due to insufficient isolation couple to the GNSS receiver. The cellular signals can mix to produce Intermodulation products exactly in the GNSS receiver frequency band. For example, GSM 1712.7 MHz mixes with UMTS 1850 MHz to produce third-order-product exactly at GPS. To quantify the effect, BGA725L6 shows out-of-band input IP3 at GPS of +2.9 dBm as a result of frequency mixing between GSM 1712.7 MHz and UMTS 1850 MHz with power levels of -20 dBm. BGA725L6 has a high out-of-band input 3rd order intercept point (IIP3) of +2.9 dBm, so that it is especially suitable for the GPS function in mobile phones.

BGA725L6 also offers sufficient rejection at 787.76MHz, which is band-13 of upcoming LTE and whose 2nd harmonic is at GPS frequency, to meet specifications of 2nd harmonic of band-13 without any additional circuitry. BGA725L6 has input referred band-13 second harmonic level of -44.7 dBm when the input signal of 787.76 MHz at -25 dBm is applied.

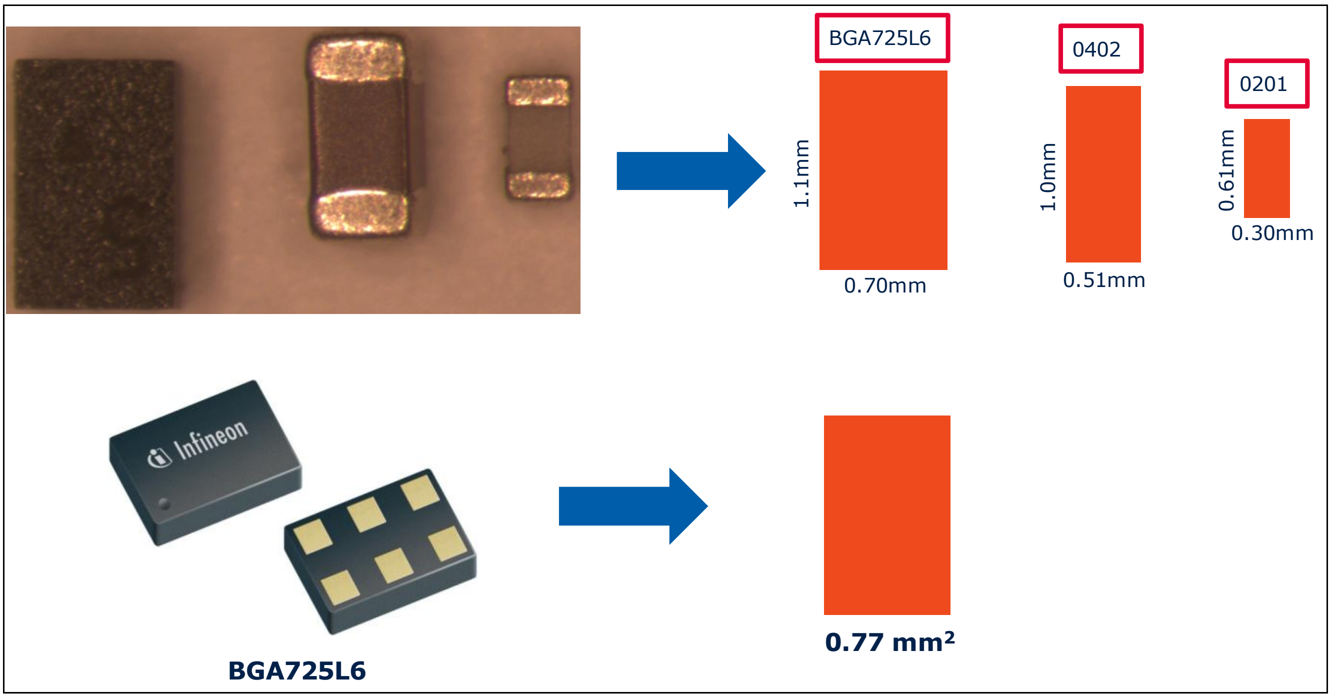

Figure 2 BGA725L6 package size in comparison with 0402 and 0201 components

As the industry inclines toward assembly miniaturization and also surface mount technology matures, there is a desire to have smaller and thinner components. This is especially the case with portable electronics where higher circuit density allows device design flexibility and also optimum use of the limited space available. BGA725L6 has ultra small package with dimensions of 0.70mm x 1.1mm x 0.40mm and it requires only two components at its input, the capacitor at the input has to be used if a DC block is required and the inductor provides input matching. The DC block at input is optional as it is usually provided by the pre-filter before the LNA in many GPS applications. All the device manufacturers implement very good power supply filtering on their boards so that the RF bypass capacitor mentioned in this application circuit may not be needed in the end. The minimal number of external SMD components reduces the application bill of materials and the PCB area thus making it an ideal solution for compact and cost-effective GNSS LNA. The output of the BGA725L6 is internally matched to 50 Ω, and a DC blocking capacitor is integrated on-chip, thus no external component is required at the output.

The device also integrates an on-chip ESD protection which can resist until 2 kV (referenced to Human Body Model). The integrated power on/off feature provides for low power consumption and increased stand-by time for GNSS handsets. Moreover, the low current consumption (3.6 mA) makes the device suitable for portable technology like GNSS receivers and mobiles phones.

The Internal circuit diagram of the BGA725L6 is presented in Figure 3. Table 1 show the pin assignment of BGA725L6. Table 2 shows the truth table to turn on/off BGA725L6 by applying different voltage to the PON pin.

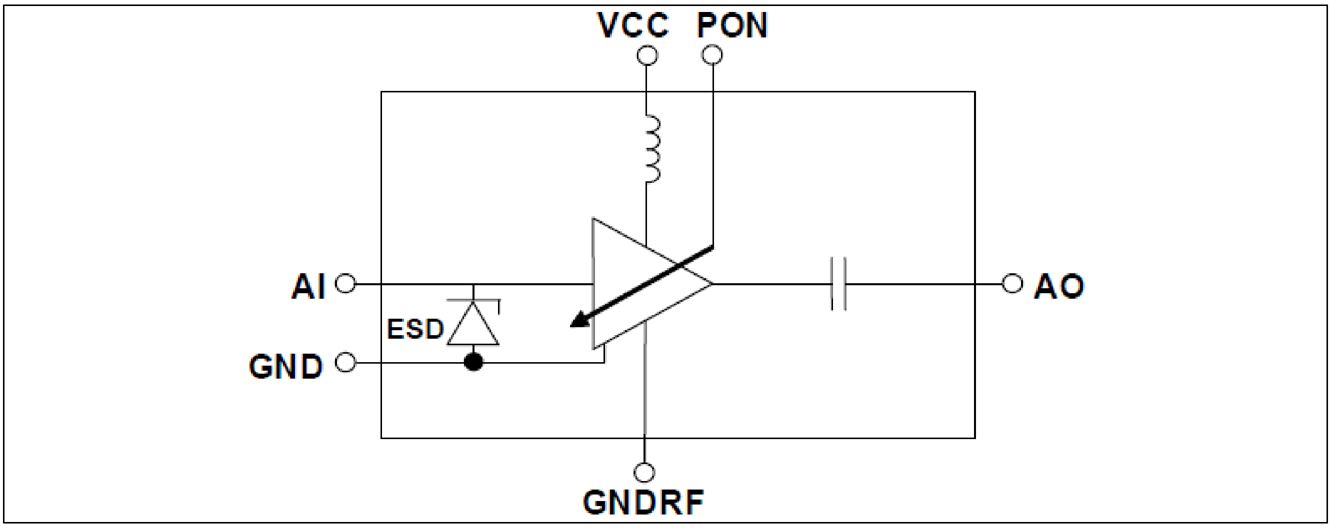

Figure 3 Block diagram of the BGA725L6 for GNSS band 1559-1615MHz applications

Table 1 Pin Definition

Pin	Symbol	Comment
1	GND	General ground
2	VCC	DC supply
3	AO	LNA output
4	GNDRF	LNA RF ground
5	AI	LNA input
6	PON	Power on control

Table 2 Switching Mode

LNA Mode	Symbol	ON/OFF Control Voltage at PON pin	
		Min	Max
ON	PON, on	1.0 V	VCC
OFF	PON, off	0 V	0.4 V

3 Application Circuit

3.1 Schematic Diagram

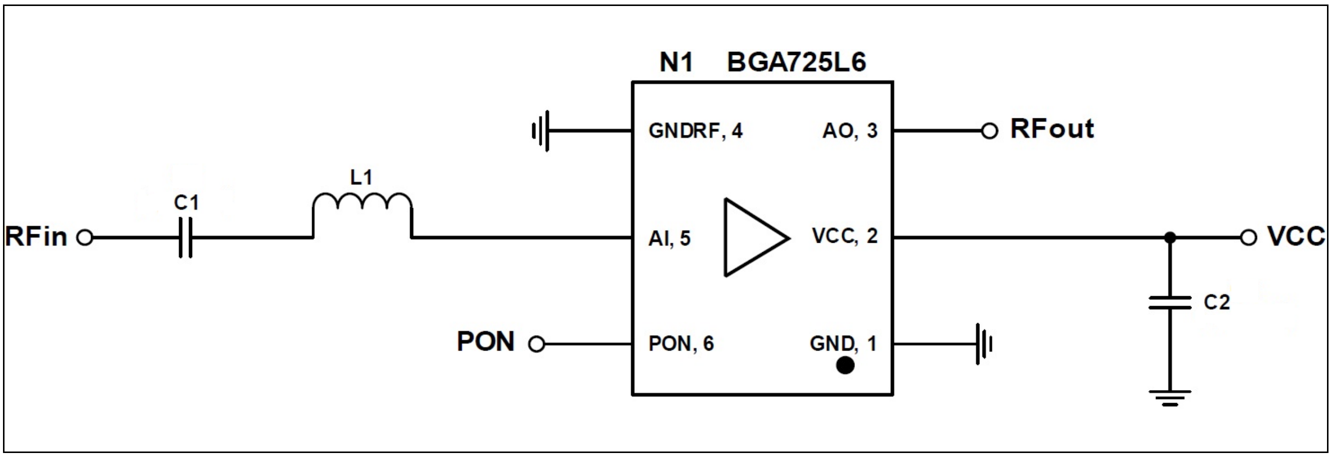

Figure 4 BGA725L6 application circuit

Table 3 Bill-of-Materials

Symbol	Value	Unit	Package	Manufacturer	Comment
C1	1	nF	0201	Various	DC block
C2	10	nF	0201	Various	RF bypass
L1	6.8	nH	0201	Murata LQP series	Input matching
N1	BGA725L6		TSLP-6-2	Infineon	SiGe:C LNA
PCB substrate	FR4				

4 Typical Measurement Results

Table 4 and Table 5 show typical measurement results of the application circuit shown in Figure 4. The values given in this table include losses of the board and the SMA connectors if not otherwise stated.

Table 4 Electrical Characteristics (at room temperature), Vcc = Vpon = 1.8 V

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	1.8			V	
DC Current	Icc	3.8			mA	
Navigation System	Sys	COMPASS/ Galileo	GPS	GLONASS		
Frequency Range	Freq	1559-1593	1575.42	1598-1606	MHz	
Gain	G	19.9	19.9	19.8	dB	
Noise Figure	NF	0.71	0.71	0.71	dB	PCB and SMA losses of 0.07dB substracted
Input Return Loss	RLin	13.9	14.5	15.6	dB	
Output Return Loss	RLout	26.6	35.0	18.6	dB	
Reverse Isolation	IRev	35.2	35.4	36.0	dB	
Input P1dB	IP1dB	-15.4	-15.5	-15.8	dBm	$f_{galileo}$ = 1559 MHz f_{gps} = 1575.42 MHz $f_{GLONASS}$ = 1605.38 MHz
Output P1dB	OP1dB	3.5	3.4	3.0	dBm	
Input IP3 In-band	IIP3	-6.9	-6.9	-7.0	dBm	
Output IP3 In-band	OIP3	13.0	13.0	12.8	dBm	$f_{1gal/gps}$ = 1575 MHz $f_{2gal/gps}$ = 1576MHz $f_{1GLONASS}$ =1602 MHz $f_{2GLONASS}$ =1603 MHz Input power= -30dBm
LTE band-13 2nd Harmonic	H2 – input referred	-44.7			dBm	f_{IN} = 787.76 MHz P_{IN} = -25 dBm f_{H2} = 1575.52 MHz
Input IP3 out-of-band	$IIP3_{OOB}$	-0.5			dBm	f_1 = 1712.7 MHz f_2 = 1850 MHz Input power = -20dBm f_{IIP3} = 1575.4 MHz
Stability	k	>1			--	Unconditionnaly Stable from 0 to 10GHz

Table 5 Electrical Characteristics (at room temperature), Vcc = Vpon = 2.8 V

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	2.8			V	
DC Current	Icc	3.9			mA	
Navigation System	Sys	COMPASS/ Galileo	GPS	GLONASS		
Frequency Range	Freq	1559-1593	1575.42	1598-1606	MHz	
Gain	G	19.9	19.9	19.9	dB	
Noise Figure	NF	0.72	0.70	0.73	dB	PCB and SMA losses of 0.07dB substracted
Input Return Loss	RLin	13.7	14.3	15.5	dB	
Output Return Loss	RLout	21.9	33.4	21.7	dB	
Reverse Isolation	IRev	35.2	35.3	35.7	dB	
Input P1dB	IP1dB	-14.8	-14.7	-14.6	dBm	$f_{galileo}$ = 1559 MHz f_{gps} = 1575.42 MHz $f_{GLONASS}$ = 1605.38 MHz
Output P1dB	OP1dB	4.1	4.2	4.3	dBm	
Input IP3 In-band	IIP3	-5.8	-5.8	-5.9	dBm	
Output IP3 In-band	OIP3	14.1	14.1	14.0	dBm	$f_{1gal/gps}$ = 1575 MHz $f_{2gal/gps}$ = 1576MHz $f_{1GLONASS}$ =1602 MHz $f_{2GLONASS}$ =1603 MHz Input power= -30dBm
LTE band-13 2nd Harmonic	H2 – input referred	-44.7			dBm	f_{IN} = 787.76 MHz P_{IN} = -25 dBm f_{H2} = 1575.52 MHz
Input IP3 out-of-band	$IIP3_{OOB}$	2.9			dBm	f_1 = 1712.7 MHz f_2 = 1850 MHz Input power = -20dBm f_{IIP3} = 1575.4 MHz
Stability	k	>1			--	Unconditionally Stable from 0 to 10GHz

5 Measured Graphs for COMPASS/Galileo, GPS and GLONASS bands

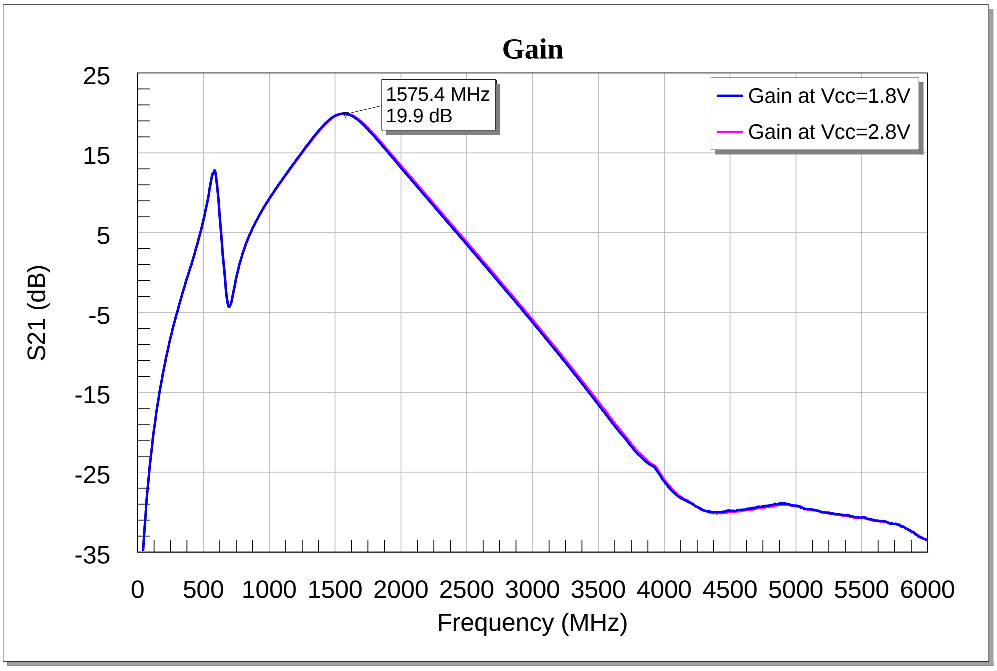

Figure 5 Power gain of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands

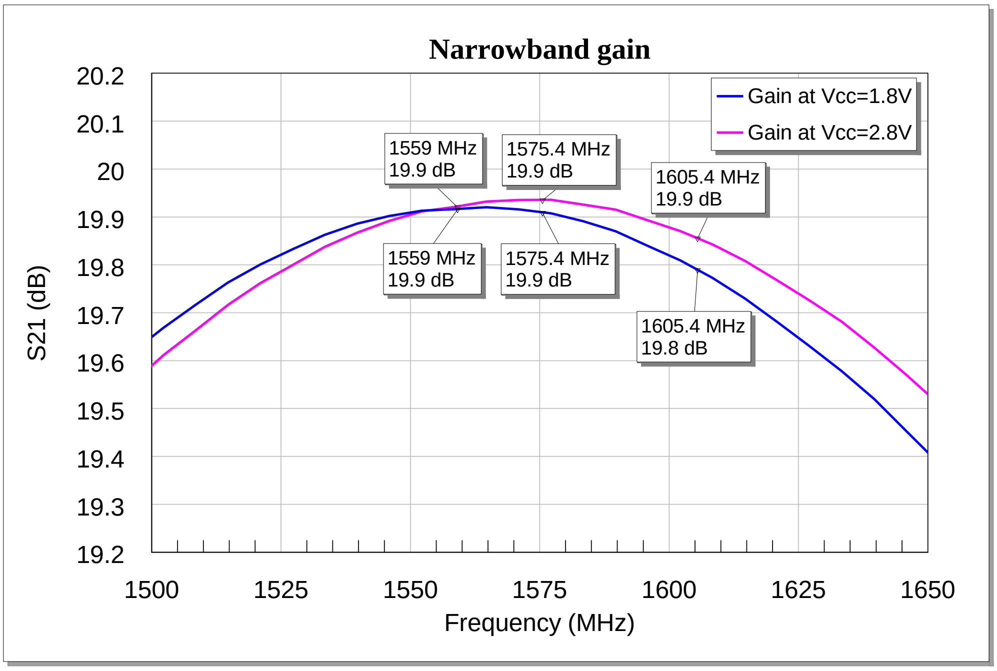

Figure 6 Narrowband power gain of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands

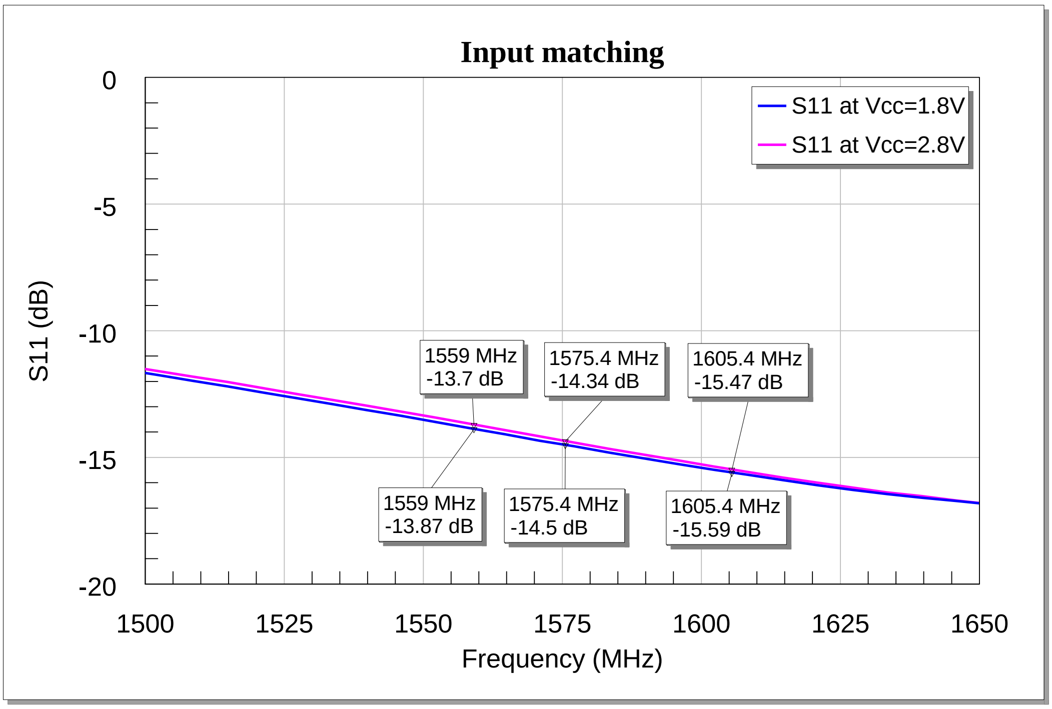

Figure 7 Input matching of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands

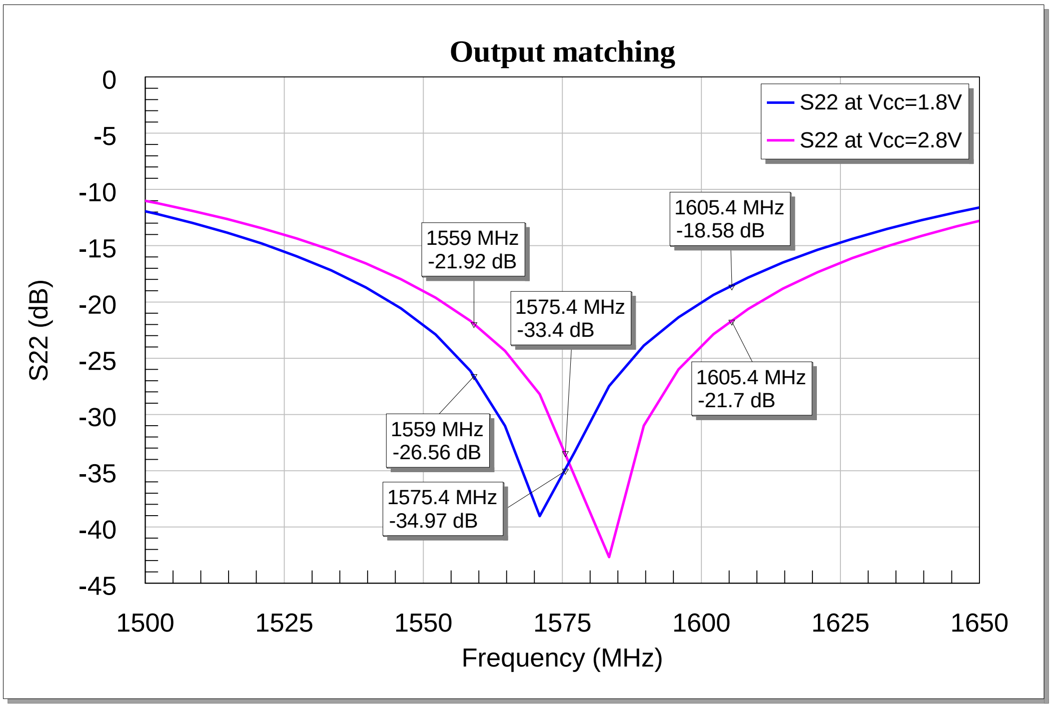

Figure 8 Output matching of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands

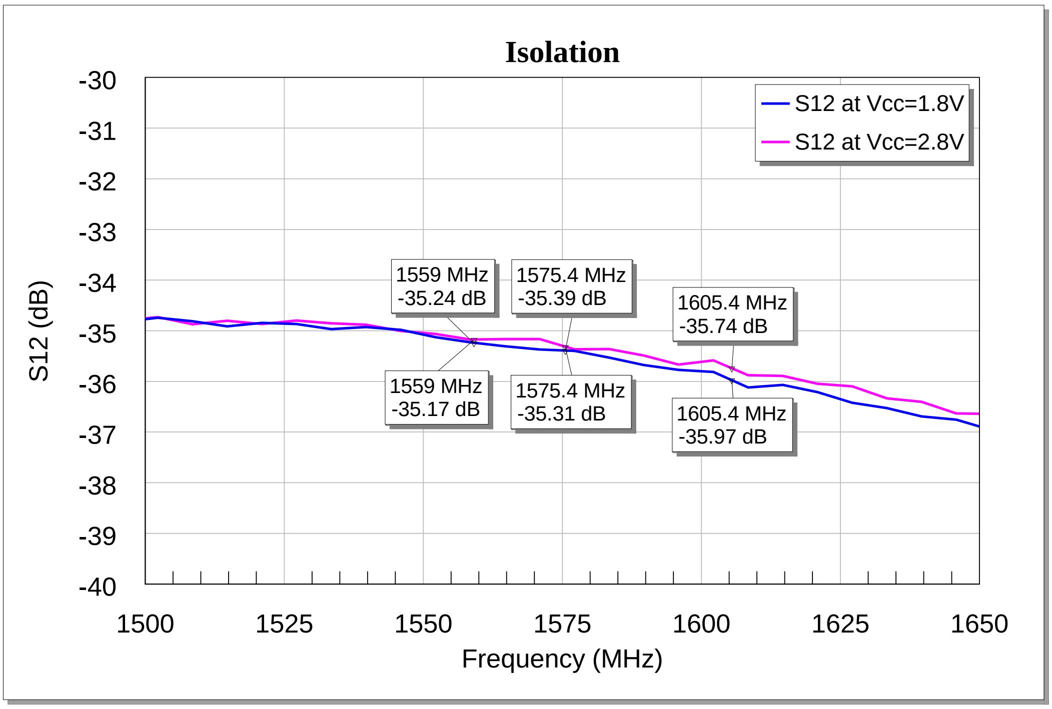

Figure 9 Reverse isolation of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands

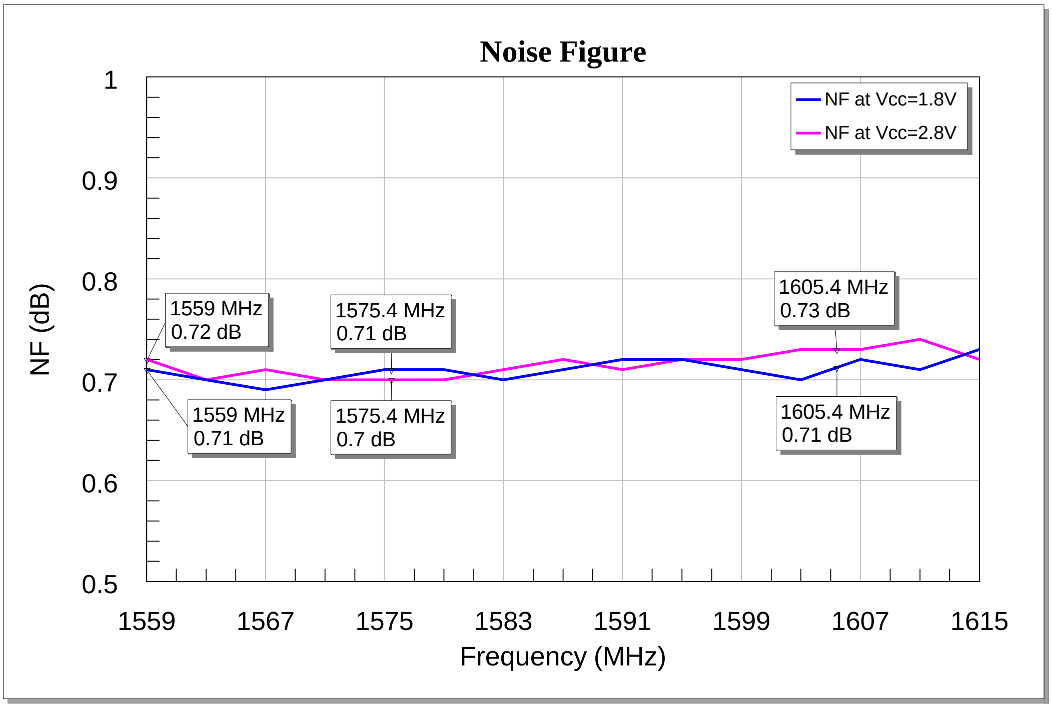

Figure 10 Noise figure of BGA725L6 for COMPASS, Galileo, GPS and GLONASS bands

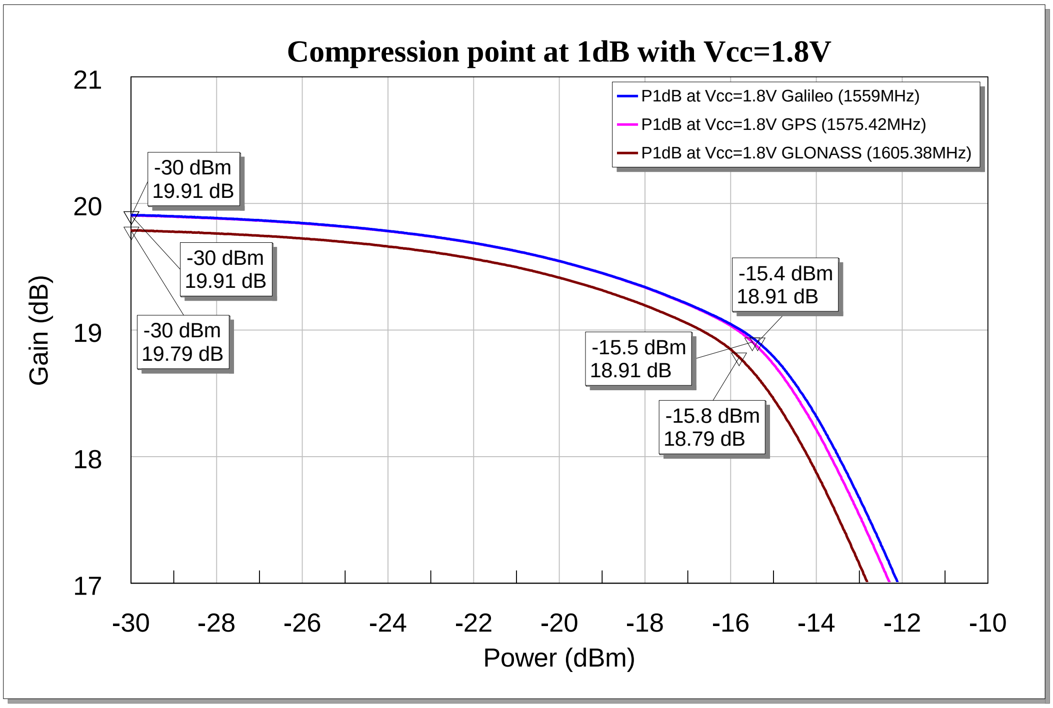

Figure 11 Input 1 dB compression point of BGA725L6 at supply voltage of 1.8V for COMPASS, Galileo, GPS and GLONASS bands

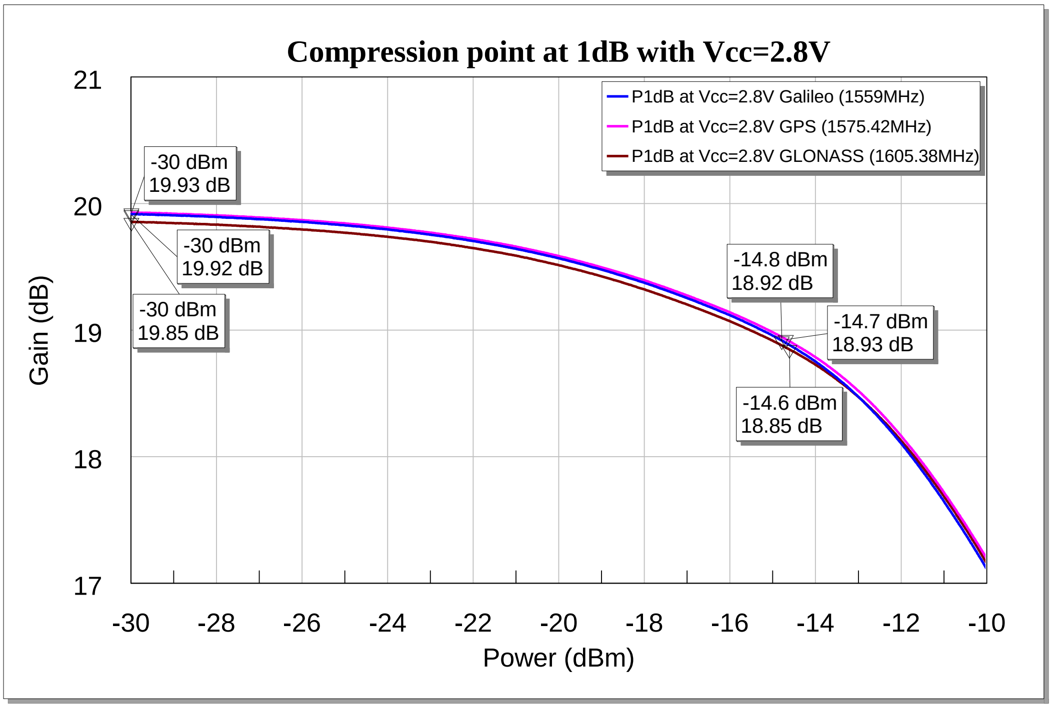

Figure 12 Input 1 dB compression point of BGA725L6 at supply voltage of 2.8V for COMPASS, Galileo, GPS and GLONASS bands

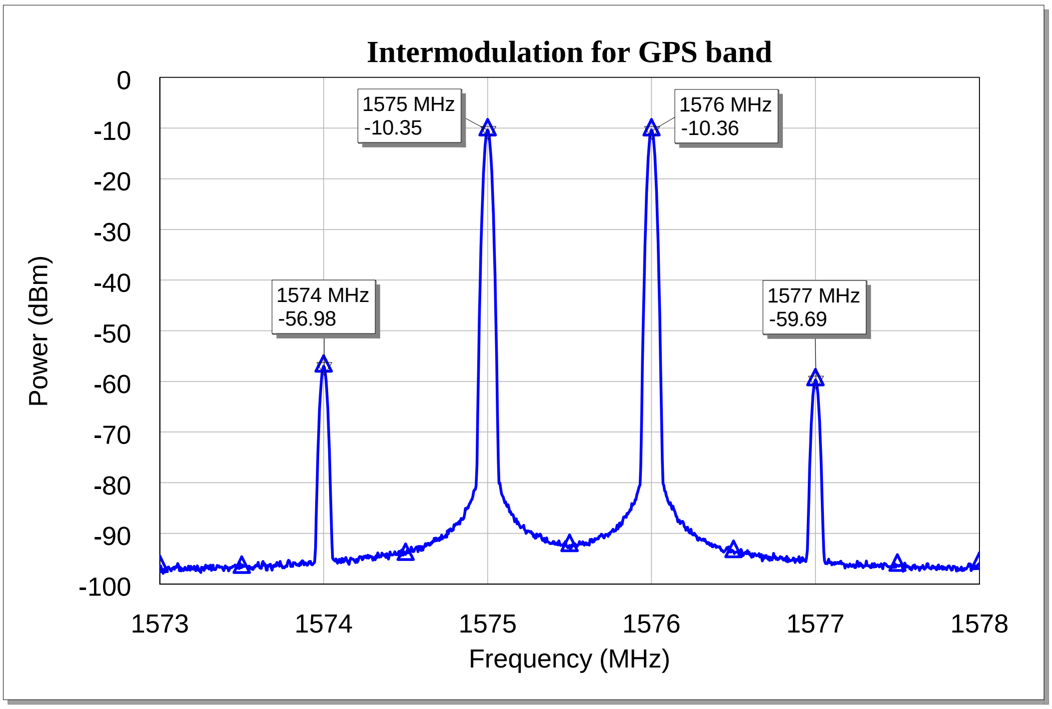

Figure 13 Carrier and intermodulation products of BGA725L6 for GPS band at Vcc=1.8V

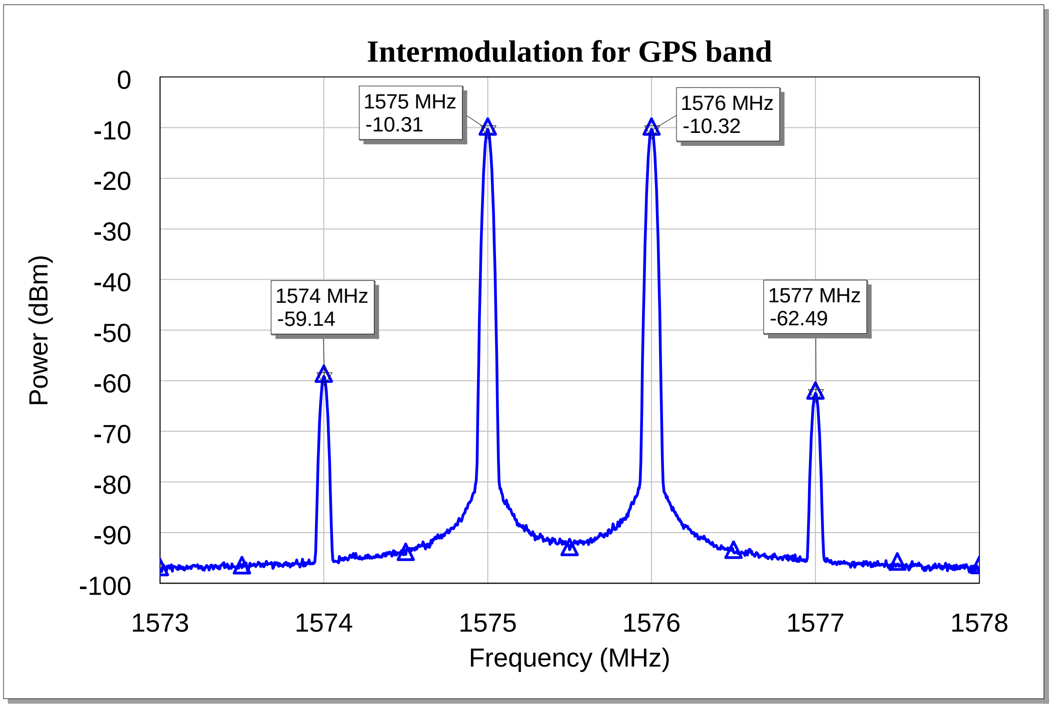

Figure 14 Carrier and intermodulation products of BGA725L6 for GPS band at Vcc=2.8V

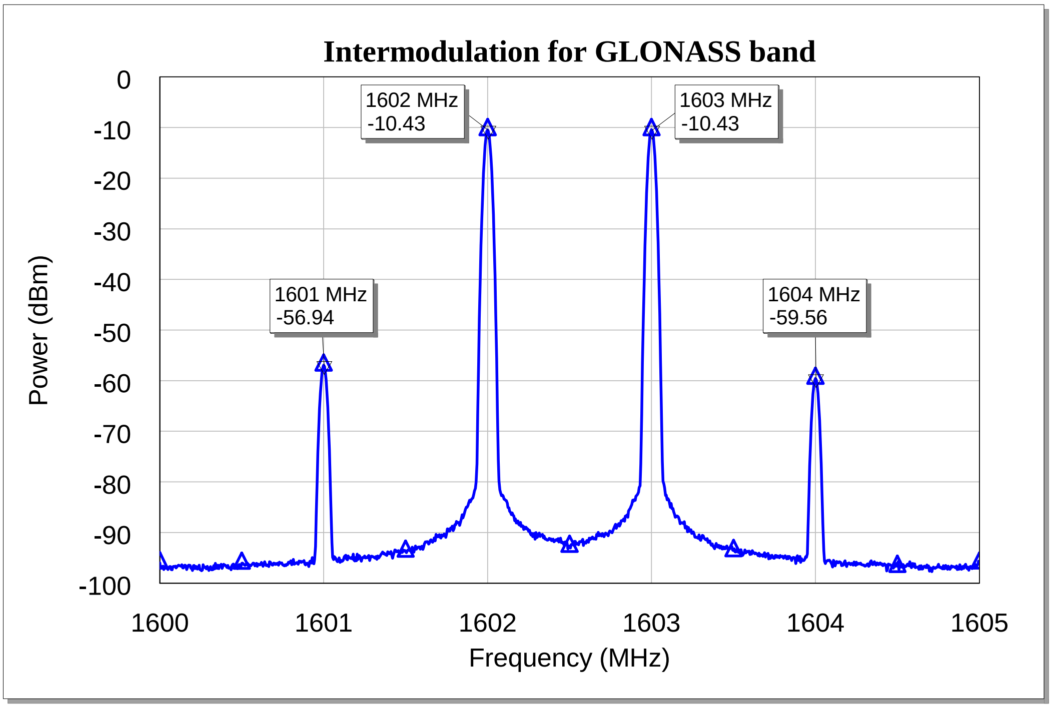

Figure 15 Carrier and intermodulation products of BGA725L6 for GLONASS band at Vcc=1.8V

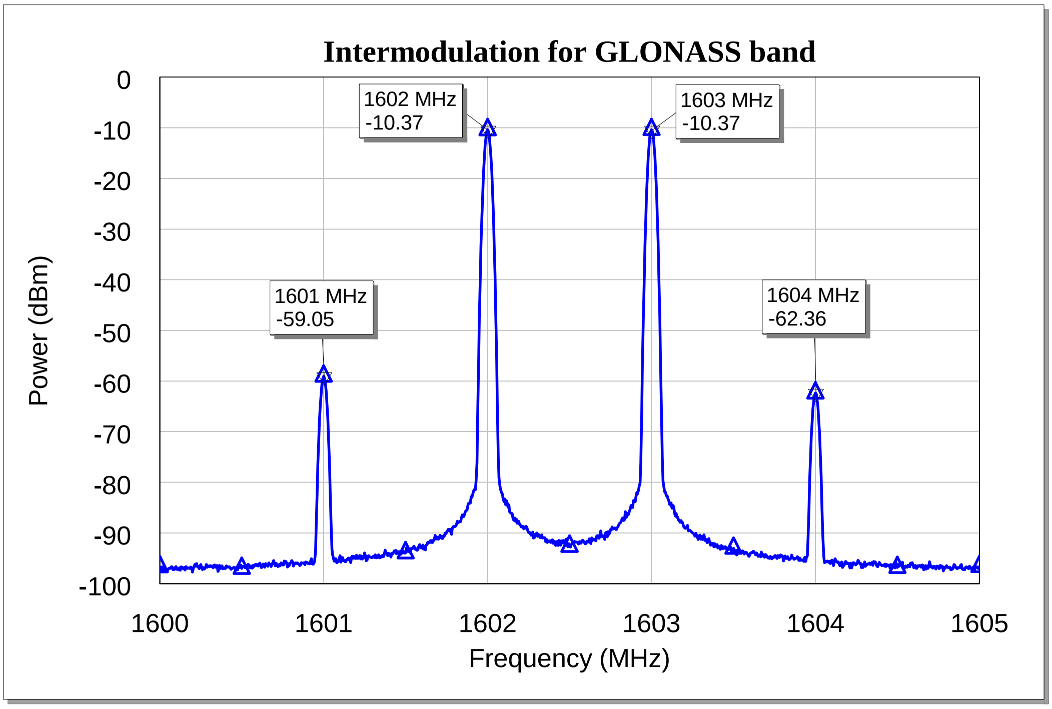

Figure 16 Carrier and intermodulation products of BGA725L6 for GLONASS band at Vcc=2.8V

6 Miscellaneous Measured Graphs

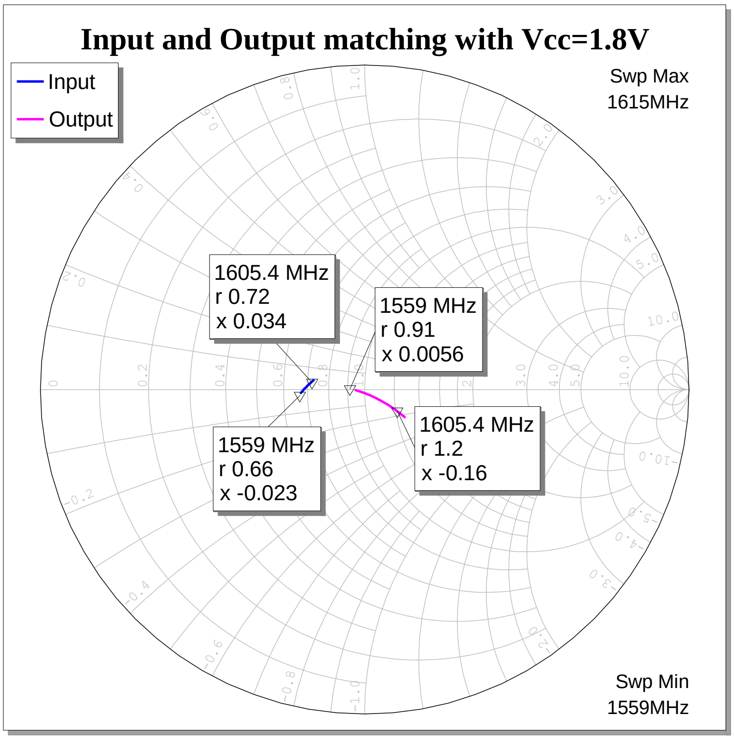

Figure 17 Input and output matching for COMPASS, Galileo, GPS and GLONASS bands with Vcc=1.8V

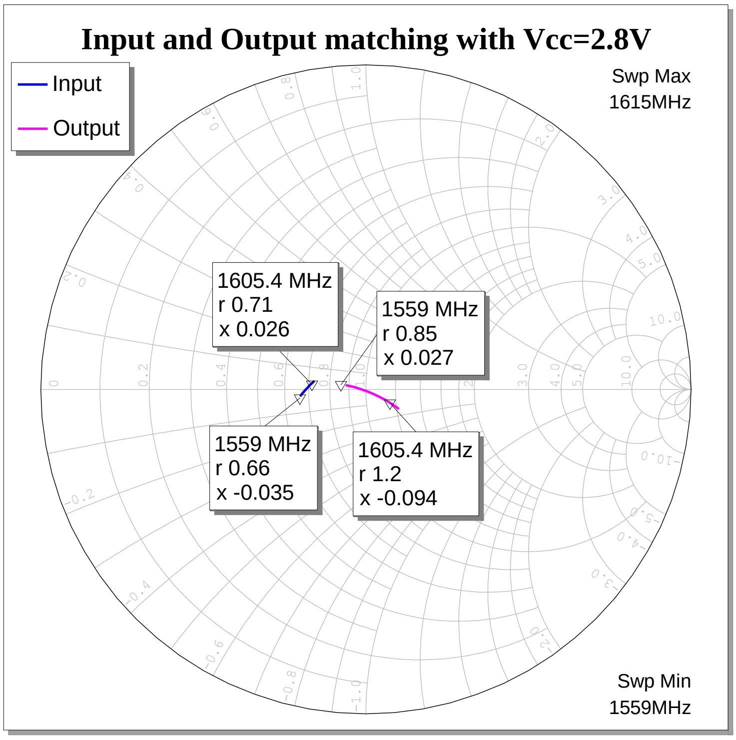

Figure 18 Input and output matching for COMPASS, Galileo, GPS and GLONASS bands with Vcc=2.8V

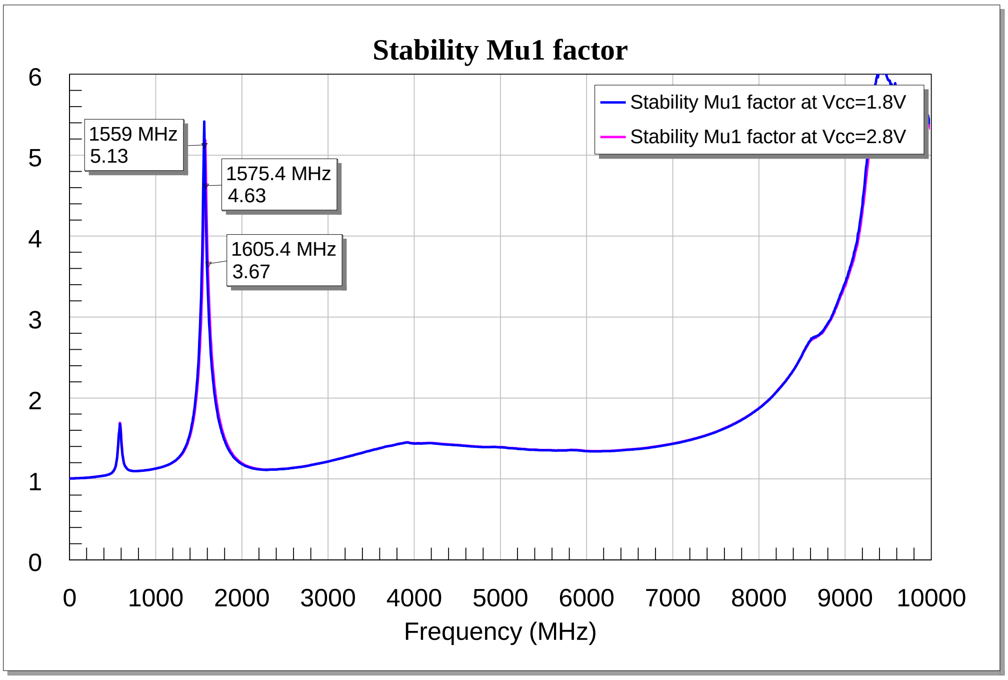

Figure 19 Stability factor µ1 of BGA725L6 upto 10GHz

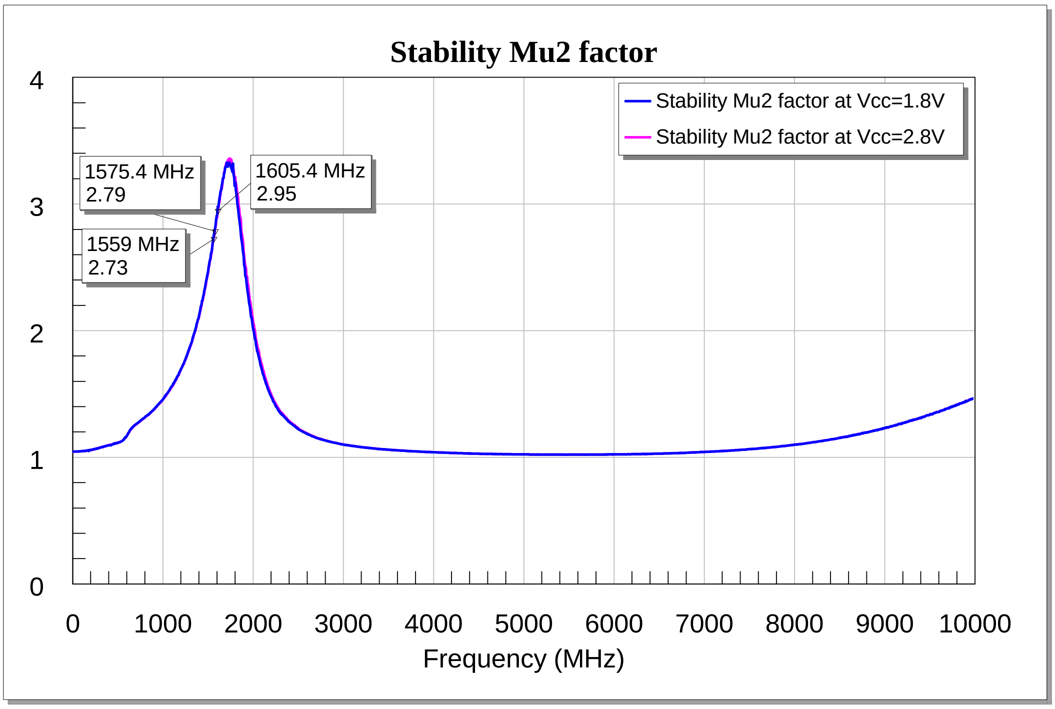

Figure 20 Stability factor µ2 of BGA725L6 upto 10GHz

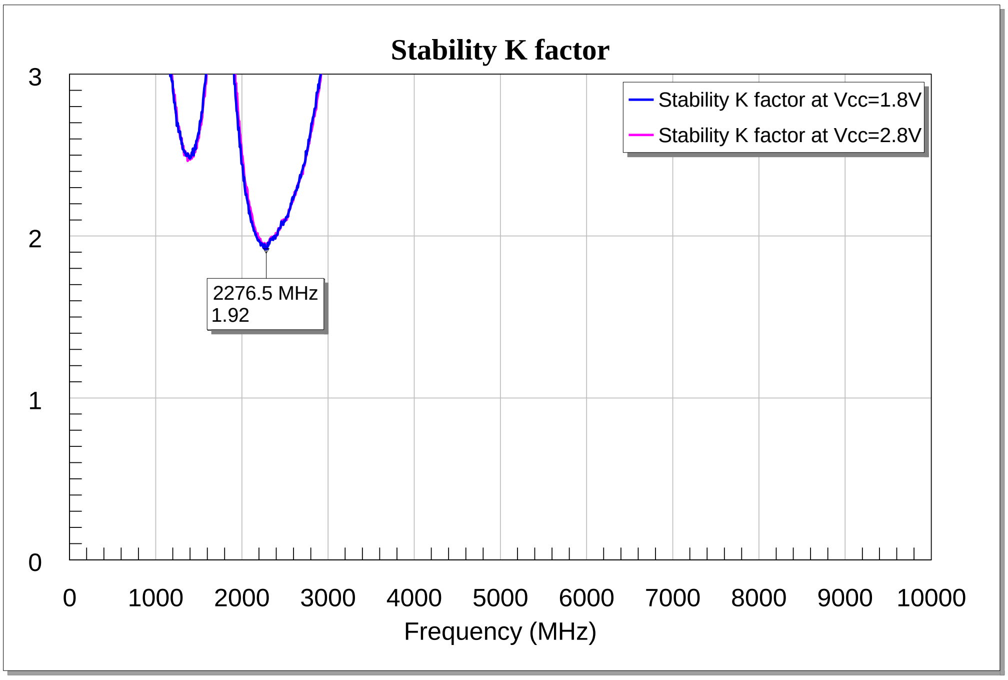

Figure 21 Stability factor k of BGA725L6 upto 10GHz

7 Evaluation Board

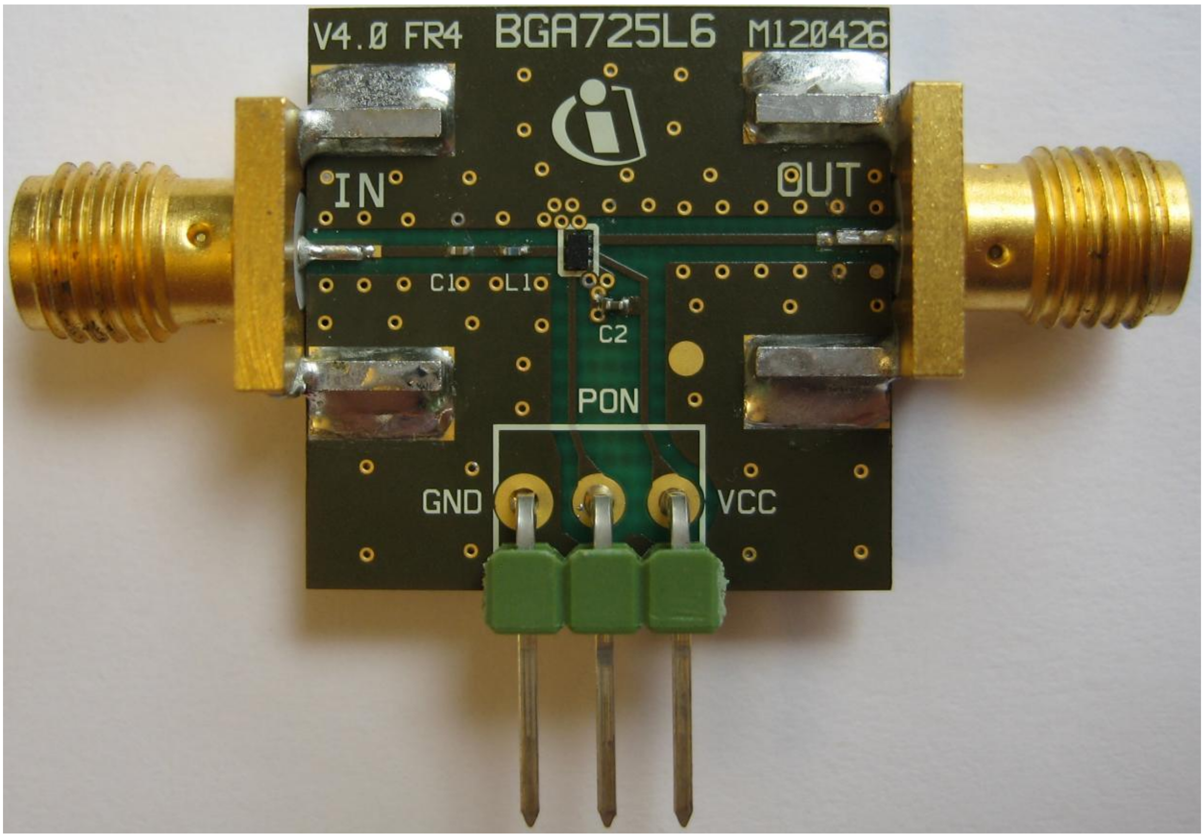

Figure 22 Populated PCB picture of BGA725L6

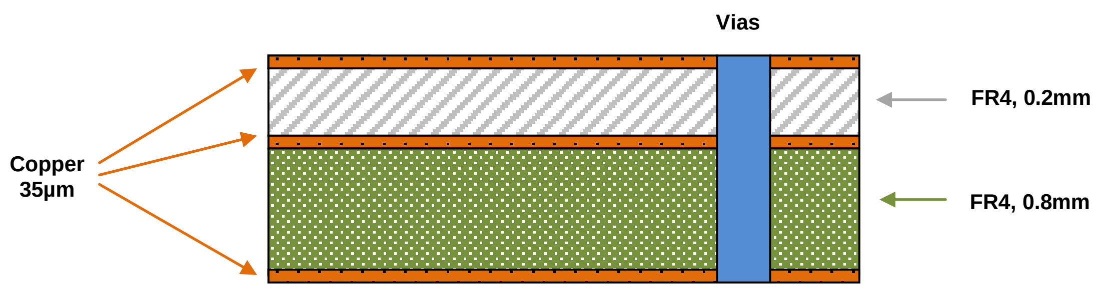

Figure 23 PCB layer stack

8 Authors

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