BGA825L6S

Improving Immunity of BGA825SL6 against Out-Of-Band Jammer for LTE Band-13

Application Note AN304

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RF and Protection Devices

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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: 17.0 dB
- Out-of-band input 3rd-order intercept point: +8 dBm
- Input 1dB compression point: -7 dBm
- Low noise figure: 0.60 dB
- Low current consumption: 4.8 mA
- Operating frequency: 1550 - 1615 MHz
- Supply voltage: 1.5 V to 3.6 V
- Digital on/off switch (1V logic high level)
- Small TSLP-6-3 leadless package (footprint: 0.9 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

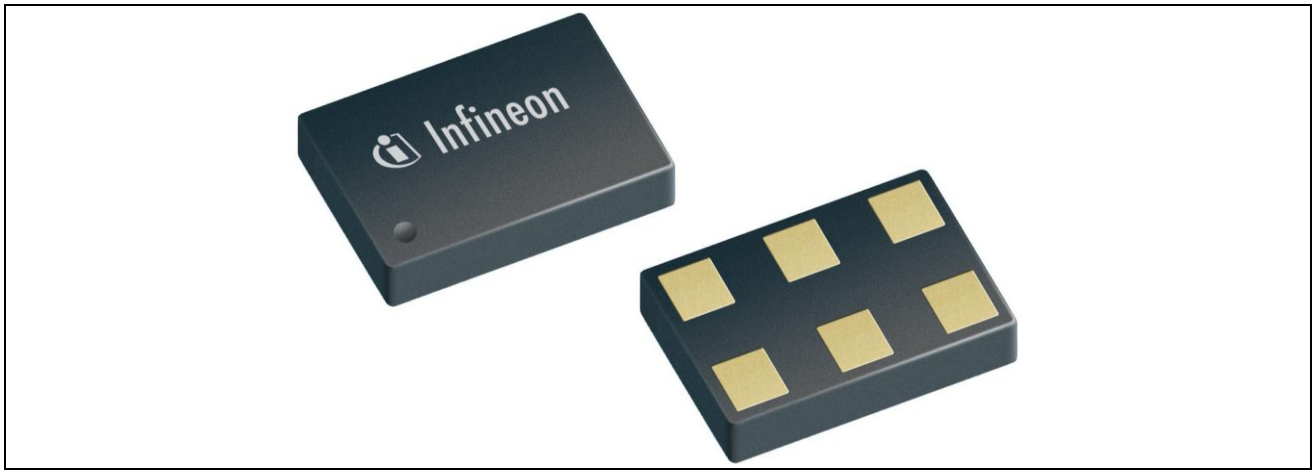

Figure 1 BGA825L6S in TSLP-6-3 Package (0.90mm x 1.1mm x 0.40mm)

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

2 Introduction

The BGA825L6S 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-6-3 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 BGA825L6S 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.

This application note addresses the issue of out-of-band jammers and improving the immunity of BGA825L6S against the jammers. The out-of-band signal considered is LTE Band-13, as the intermodulation product fall into GPS band.

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, LTE Band-13 2nd harmonic falls into GPS band, GSM 827/897 MHz mixes with WLAN 2402/2472 MHz to produce second-order-product at GPS.

The jamming resistance of BGA825L6S against these jammers is improved by increasing the attenuation of the circuit at these specific out-of-band frequencies of band-13 (787MHz). This is achieved by using external SMDs and a SAW filter before BGA825L6S. In some applications where more rejection is required at special frequencies and SAW filter alone cannot provide sufficient attenuation, some external notches can be designed for those frequencies. Figure 3 and figure 4 showing such an application circuit where notches have been designed to attenuate 787MHz (parallel and shunt notch configuration). The component values are fine tuned so as to have optimal noise figure, jammer rejection, gain and input matching.

Introduction

The Internal circuit diagram of the BGA825L6S is presented in Figure 2. Table 1 show the pin assignment of BGA825L6S. Table 2 shows the truth table to turn on/off BGA825L6S by applying different voltage to the PON pin.

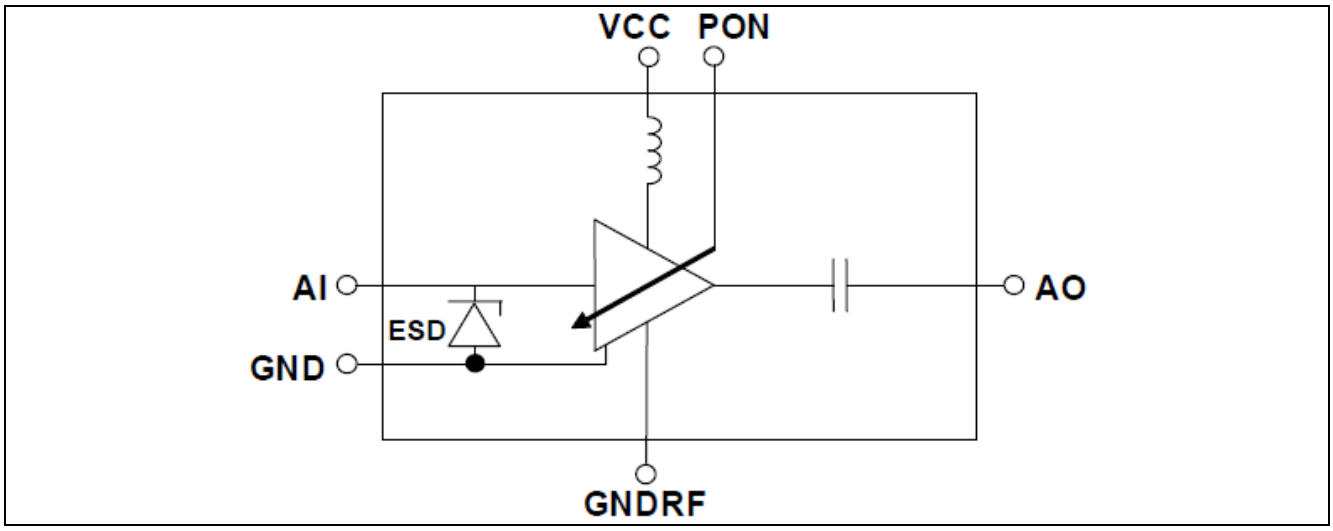

Figure 2 Block diagram of the BGA825L6S for GNSS band 1559-1615MHz applications

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 circuits for improved rejection out-of-band jammers (LTE-Band-13)

3.1 Schematic Diagrams

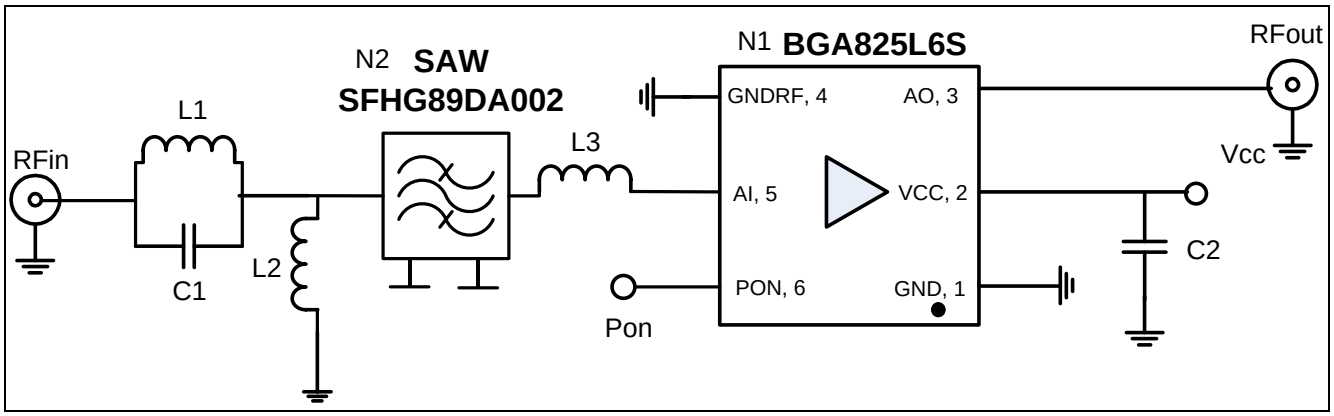

Figure 3 BGA825L6S application circuit 1 including SAW filter matching inductor and Parallel Notch

Table 3 Bill-of-Materials application circuit 1

Symbol	Value	Unit	Package	Manufacturer	Comment
L1	12	nH	03015	LQW04A/Murata	Band- 13 notch
C1	3.3	pF	0201	Various	Band- 13 notch
L2	5.6	nH	03015	LQW04A/Murata	Input matching
L3	7.5	nH	03015	LQW04A/Murata	matching
C2	10	nF	0201	Various	RF bypass
N1	BGA825L6S		TSLP-6-3	Infineon	SiGe:C LNA
N2	SFHG89DAA002			WISOL	SAW Filter

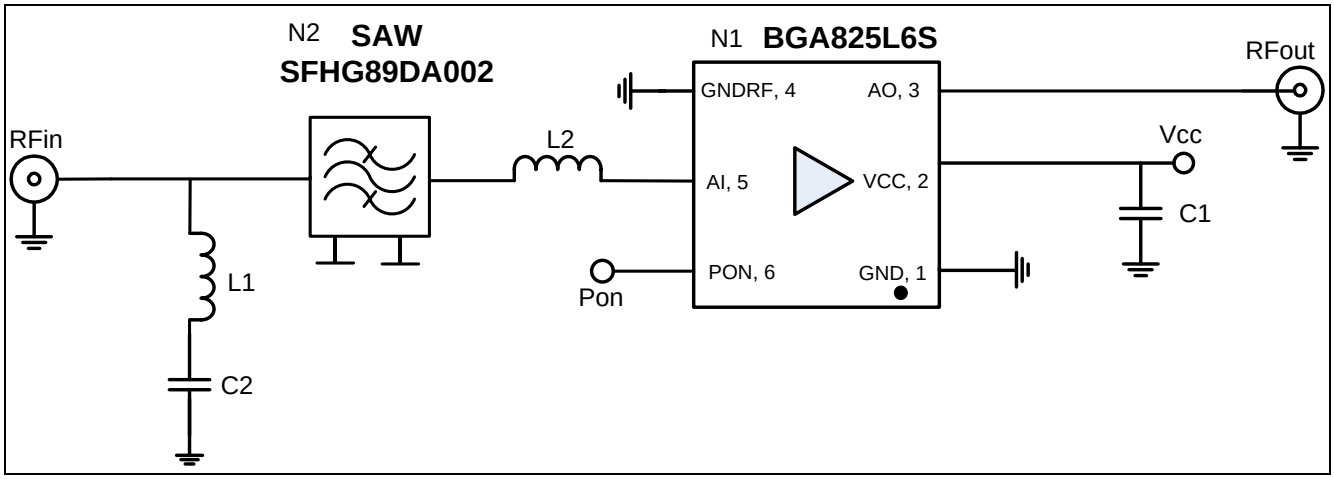

Figure 4 BGA825L6S application circuit 2 including SAW filter and shunt Notch

Table 4 Bill-of-Materials application circuit 2

Symbol	Value	Unit	Package	Manufacturer	Comment
L1	12	nH	03015	LQW04A/Murata	Band- 13 notch
C2	3.3	pF	0201	Various	Band- 13 notch
L2	7.5	nH	03015	LQW04A/Murata	Input matching
C1	10	nF	0201	Various	RF bypass
N1	BGA825L6S		TSLP-6-3	Infineon	SiGe:C LNA
N2	SFHG89DAA002			WISOL	SAW Filter

4 Typical Measurement Results

4.1 Typical Measurement Results of application circuit 1

Table 5 and Table 6 show typical measurement results of the application circuit shown in Figure 3. The values given in this table include losses of the board and the SMA connectors if not otherwise stated.

Table 5 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	5.2		mA	
Navigation System	Sys	GPS	GLONASS		
Frequency Range	Freq	1575.42	1598-1606	MHz	
Gain	G	15.5	15	dB	
Noise Figure	NF	1.75	1.74	dB	PCB and SMA losses of 0.1dB substracted
Input Return Loss	RLin	-12.5	-12.8	dB	
Output Return Loss	RLout	-13.6	-20	dB	
Reverse Isolation	IRev	-24.1	-24.2	dB	
Input P1dB	IP1dB	-6.6	-6	dBm	f_{gps} = 1575.42 MHz $f_{GLONASS}$ = 1605.38 MHz
Output P1dB	OP1dB	7.9	8	dBm	
Input IP3 In-band	IIP3	-0.75	-0.35	dBm	
Output IP3 In-band	OIP3	14.75	14.65	dBm	f_{1gps} = 1575 MHz f_{2gps} = 1576MHz $f_{1GLONASS}$ =1602 MHz $f_{2GLONASS}$ =1603 MHz Input power= -30dBm
LTE band-13 2nd Harmonic	H2	-88.1		dBm	f_{IN} = 787.76 MHz P_{IN} = +15 dBm f_{H2} = 1575.52 MHz
Input IP3 out-of-band	$IIP3_{OOB}$	42.9		dBm	f_1 = 1712.7 MHz f_2 = 1850 MHz Input power = +10dBm f_{IIP3} = 1575.4 MHz
Stability	k	>1		--	Unconditionnally Stable

Table 6 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	5.2		mA	
Navigation System	Sys	GPS	GLONASS		
Frequency Range	Freq	1575.42	1598-1606	MHz	
Gain	G	15.8	15.3	dB	
Noise Figure	NF	1.74	1.75	dB	PCB and SMA losses of 0.1dB substracted
Input Return Loss	RLin	-11.5	-12.6	dB	
Output Return Loss	RLout	-12.5	-18.2	dB	
Reverse Isolation	IRev	-24.1	-24.2	dB	
Input P1dB	IP1dB	-4.3	-4.4	dBm	f_{gps} = 1575.42 MHz $f_{GLONASS}$ = 1605.38 MHz
Output P1dB	OP1dB	10.5	9.9	dBm	
Input IP3 In-band	IIP3	-1.1	-0.45	dBm	
Output IP3 In-band	OIP3	14.7	14.85	dBm	f_{1gps} = 1575 MHz f_{2gps} = 1576MHz $f_{1GLONASS}$ =1602 MHz $f_{2GLONASS}$ =1603 MHz Input power= -30dBm
LTE band-13 2nd Harmonic	H2	-88.1		dBm	f_{IN} = 787.76 MHz P_{IN} = +15 dBm f_{H2} = 1575.52 MHz
Input IP3 out-of-band	$IIP3_{OOB}$	45.5		dBm	f_1 = 1712.7 MHz f_2 = 1850 MHz Input power = +10dBm f_{IIP3} = 1575.4 MHz
Stability	k	>1		--	Unconditionnally Stable from 0 to 10GHz

4.2 Typical Measurement Results of application circuit 2

Table 5 and Table 6 show typical measurement results of the application circuit shown in Figure 3. The values given in this table include losses of the board and the SMA connectors if not otherwise stated.

Table 7 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	5.2		mA	
Navigation System	Sys	GPS	GLONASS		
Frequency Range	Freq	1575.42	1598-1606	MHz	
Gain	G	15.8	14.3	dB	
Noise Figure	NF	1.66	1.73	dB	PCB and SMA losses of 0.1dB substracted
Input Return Loss	RLin	-24.9	-6.9	dB	
Output Return Loss	RLout	-17	-18.8	dB	
Reverse Isolation	IRev	-23.6	-24.9	dB	
Input P1dB	IP1dB	-7.2	-7.6	dBm	f_{gps} = 1575.42 MHz $f_{GLONASS}$ = 1605.38 MHz
Output P1dB	OP1dB	23	21.9	dBm	
Input IP3 In-band	IIP3	-0.8	-1.3	dBm	
Output IP3 In-band	OIP3	15	13	dBm	f_{1gps} = 1575 MHz f_{2gps} = 1576MHz $f_{1GLONASS}$ =1602 MHz $f_{2GLONASS}$ =1603 MHz Input power= -30dBm
LTE band-13 2nd Harmonic	H2	-92.1		dBm	f_{IN} = 787.76 MHz P_{IN} = +15 dBm f_{H2} = 1575.52 MHz
Input IP3 out-of-band	$IIP3_{OOB}$	45.4		dBm	f_1 = 1712.7 MHz f_2 = 1850 MHz Input power = +10dBm f_{IIP3} = 1575.4 MHz
Stability	k	>1		--	Unconditionnally Stable from 0 to 10GHz

Table 8 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	5.2		mA	
Navigation System	Sys	GPS	GLONASS		
Frequency Range	Freq	1575.42	1598-1606	MHz	
Gain	G	15.9	14.4	dB	
Noise Figure	NF	1.65	1.75	dB	PCB and SMA losses of 0.1dB substracted
Input Return Loss	RLin	-25.7	-6.8	dB	
Output Return Loss	RLout	-18.5	-20.7	dB	
Reverse Isolation	IRev	-24	-25.3	dB	
Input P1dB	IP1dB	-5.3	-4.4	dBm	f_{gps} = 1575.42 MHz $f_{GLONASS}$ = 1605.38 MHz
Output P1dB	OP1dB	9.6	9	dBm	
Input IP3 In-band	IIP3	-1.05	-0.8	dBm	
Output IP3 In-band	OIP3	14.85	13.6	dBm	f_{1gps} = 1575 MHz f_{2gps} = 1576MHz $f_{1GLONASS}$ =1602 MHz $f_{2GLONASS}$ =1603 MHz Input power= -30dBm
LTE band-13 2nd Harmonic	H2	-92.4		dBm	f_{IN} = 787.76 MHz P_{IN} = +15 dBm f_{H2} = 1575.52 MHz
Input IP3 out-of-band	$IIP3_{OOB}$	47.1		dBm	f_1 = 1712.7 MHz f_2 = 1850 MHz Input power = +10dBm f_{IIP3} = 1575.4 MHz
Stability	k	>1		--	Unconditionnally Stable from 0 to 10GHz

5 Measured Graphs for GPS and GLONASS bands

5.1 Measured Graphs for application circuit 1

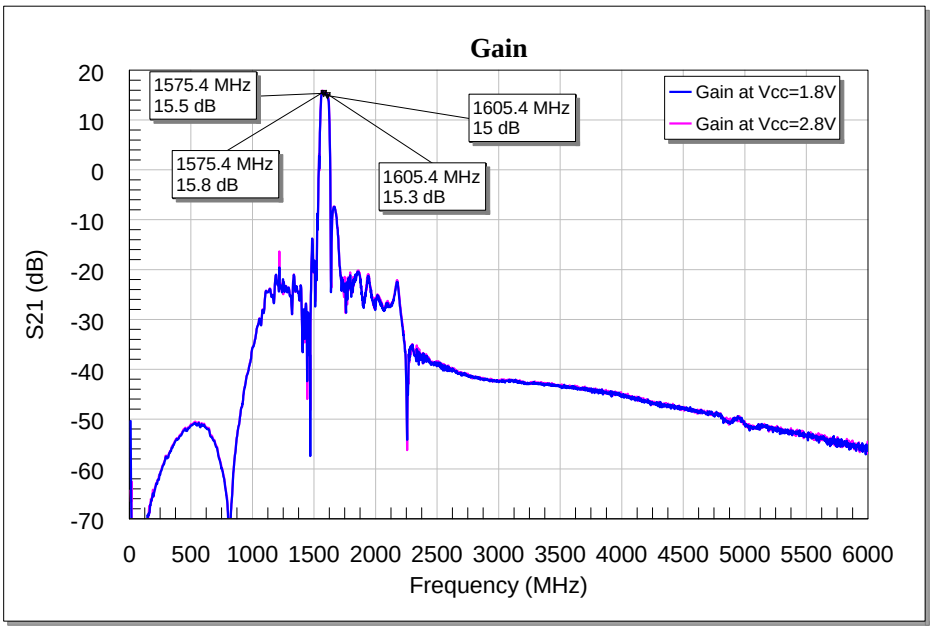

Figure 5 Power gain of BGA825L6S for GPS and GLONASS bands

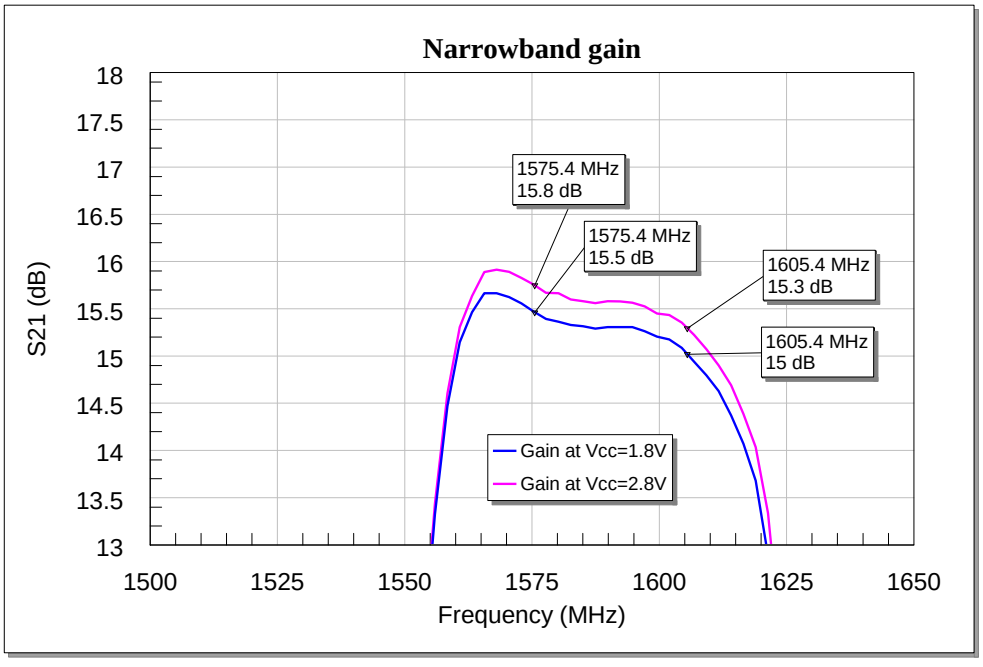

Figure 6 Narrowband power gain of BGA825L6S for GPS and GLONASS bands

Measured Graphs for GPS and GLONASS bands

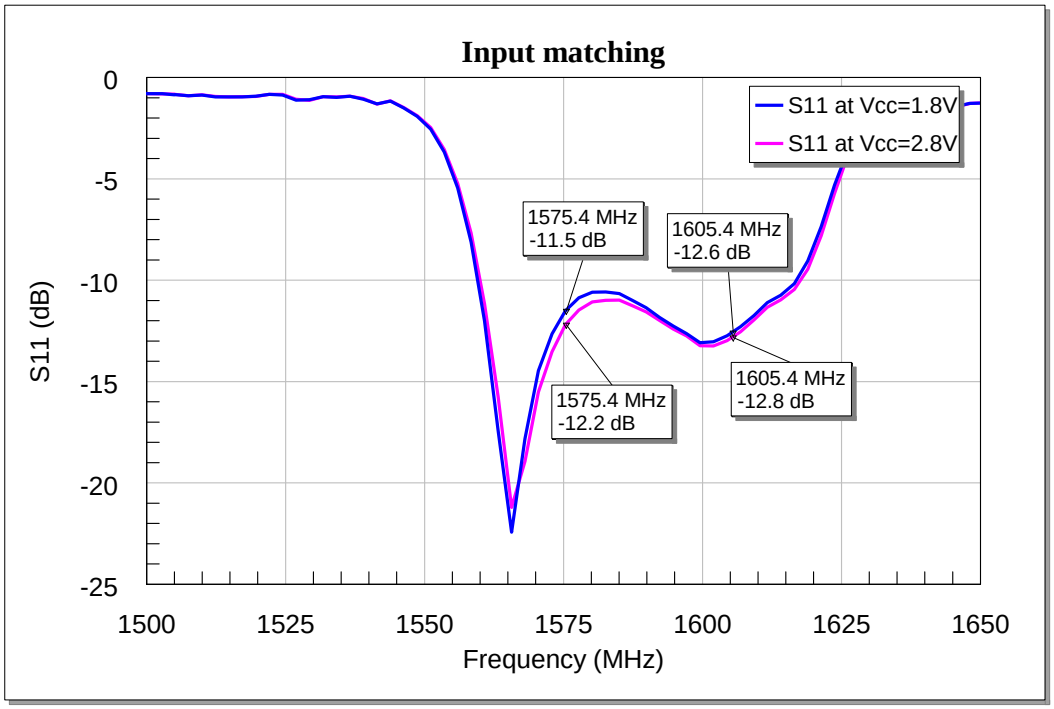

Figure 7 Input matching of BGA825L6S for GPS and GLONASS bands

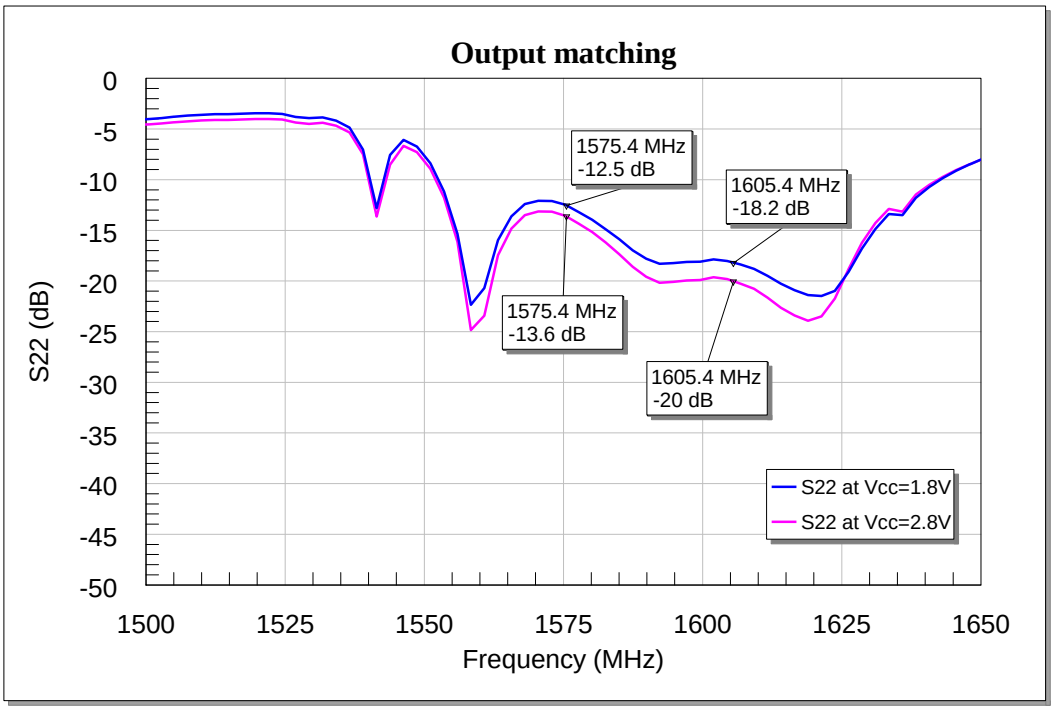

Figure 8 Output matching of BGA825L6S for GPS and GLONASS bands

Measured Graphs for GPS and GLONASS bands

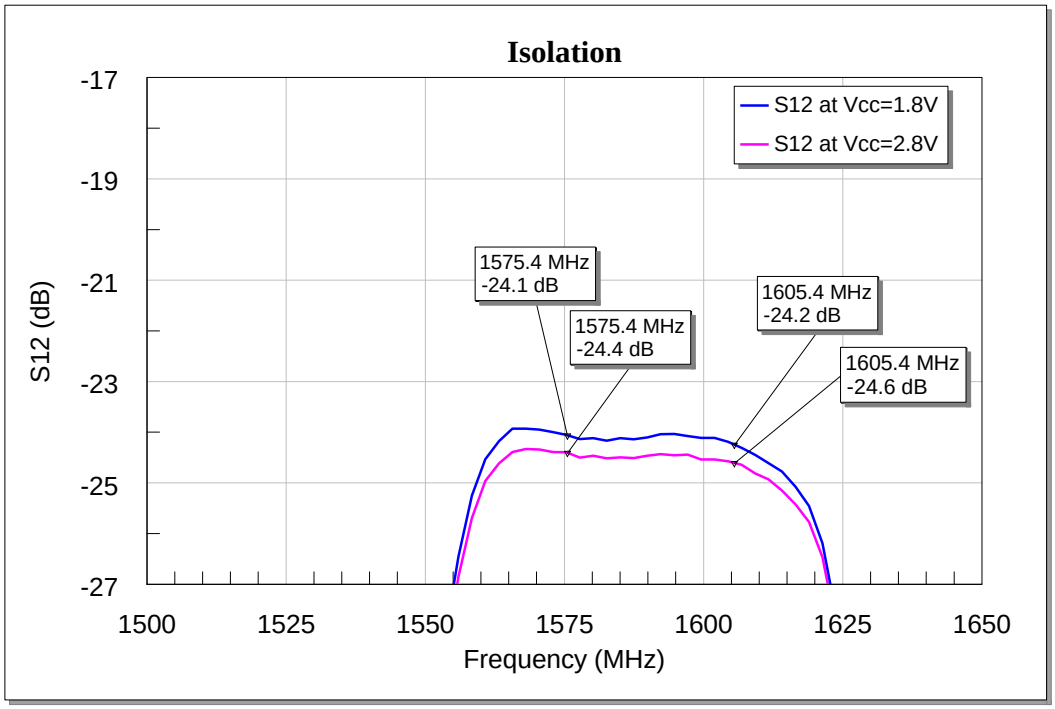

Figure 9 Reverse isolation of BGA825L6S for GPS and GLONASS bands

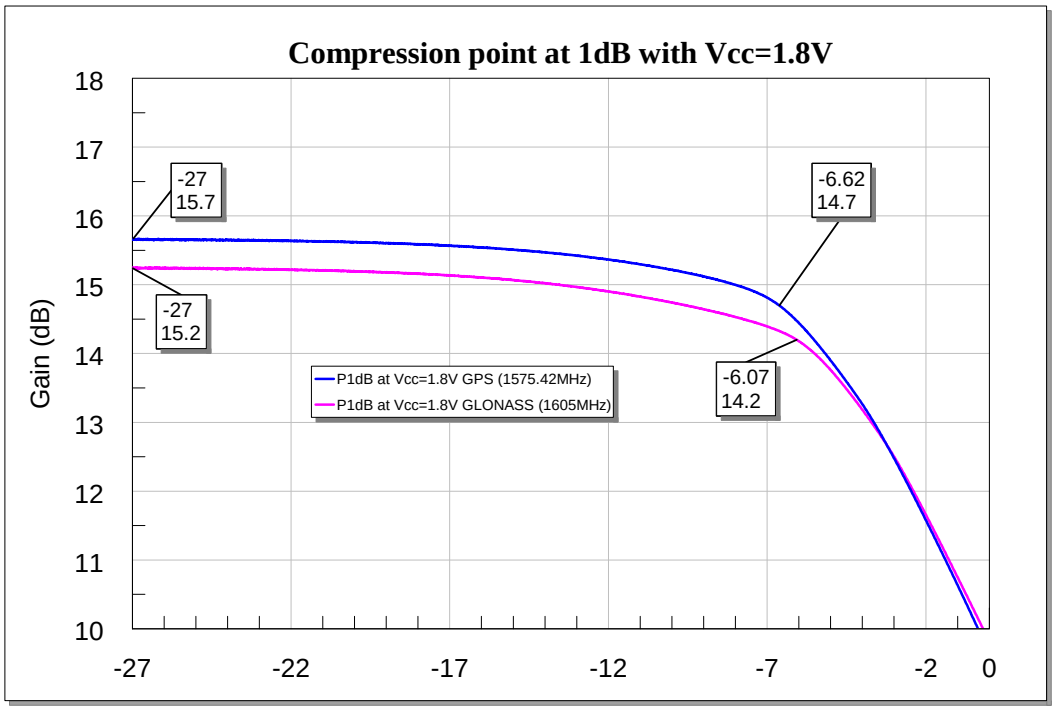

Figure 10 Input 1 dB compression point of BGA825L6S at supply voltage of 1.8V GPS and GLONASS bands

Measured Graphs for GPS and GLONASS bands

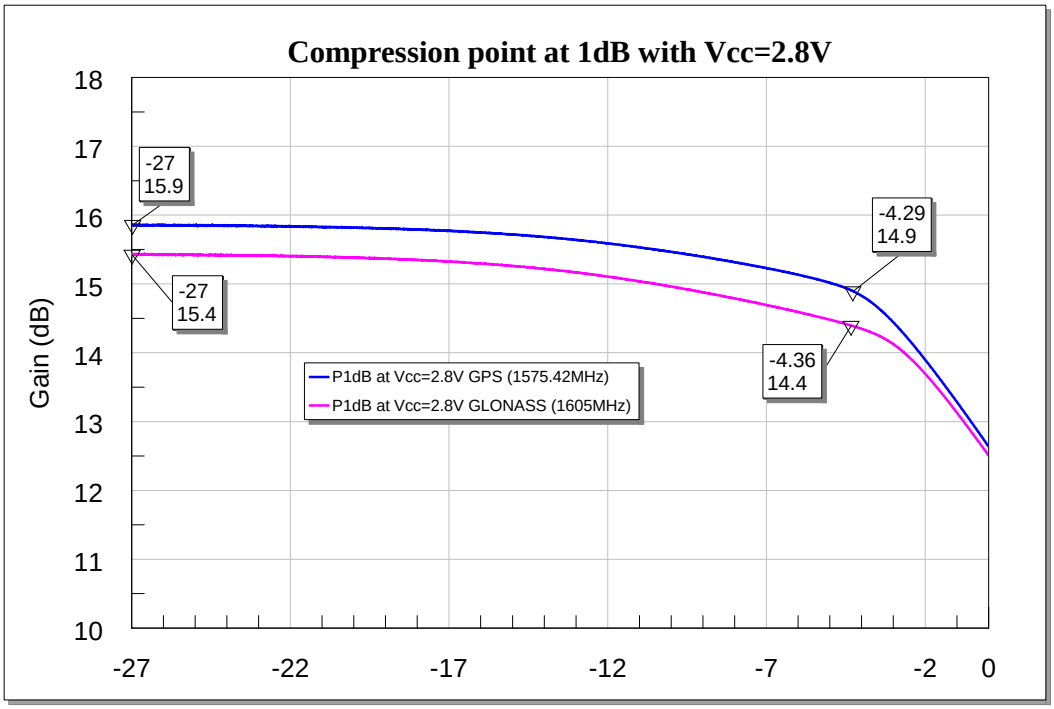

Figure 11 Input 1 dB compression point of BGA825L6S at supply voltage of 2.8V forGPS and GLONASS bands

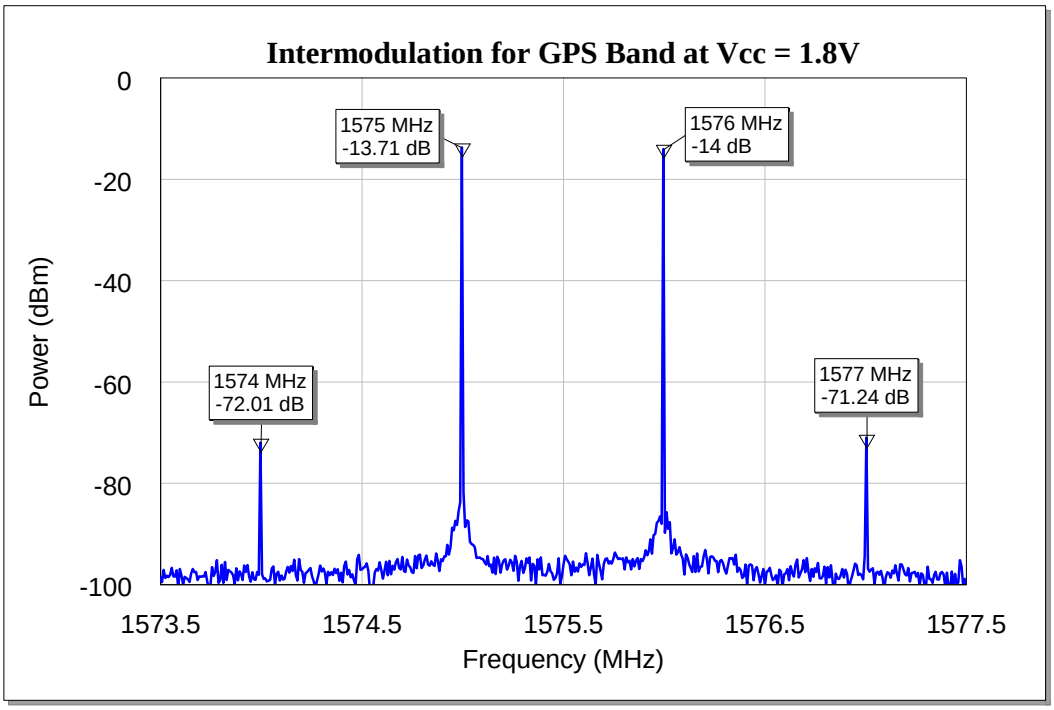

Figure 12 Carrier and intermodulation products of BGA825L6S for GPS band at Vcc=1.8V

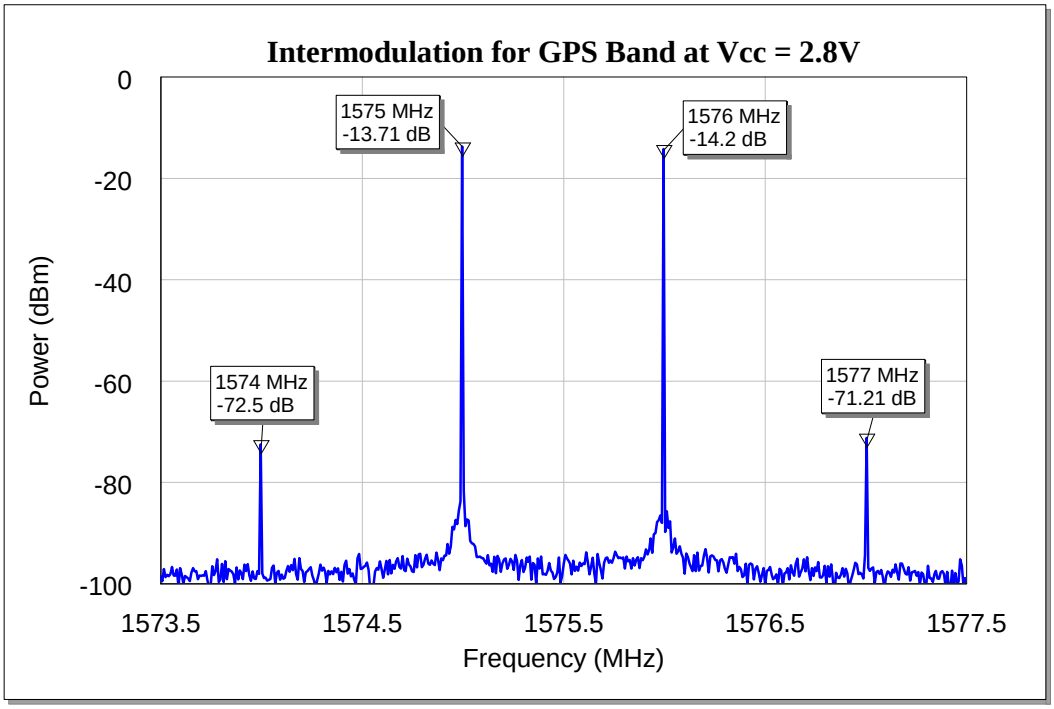

Figure 13 Carrier and intermodulation products of BGA825L6S for GPS band at Vcc=2.8V

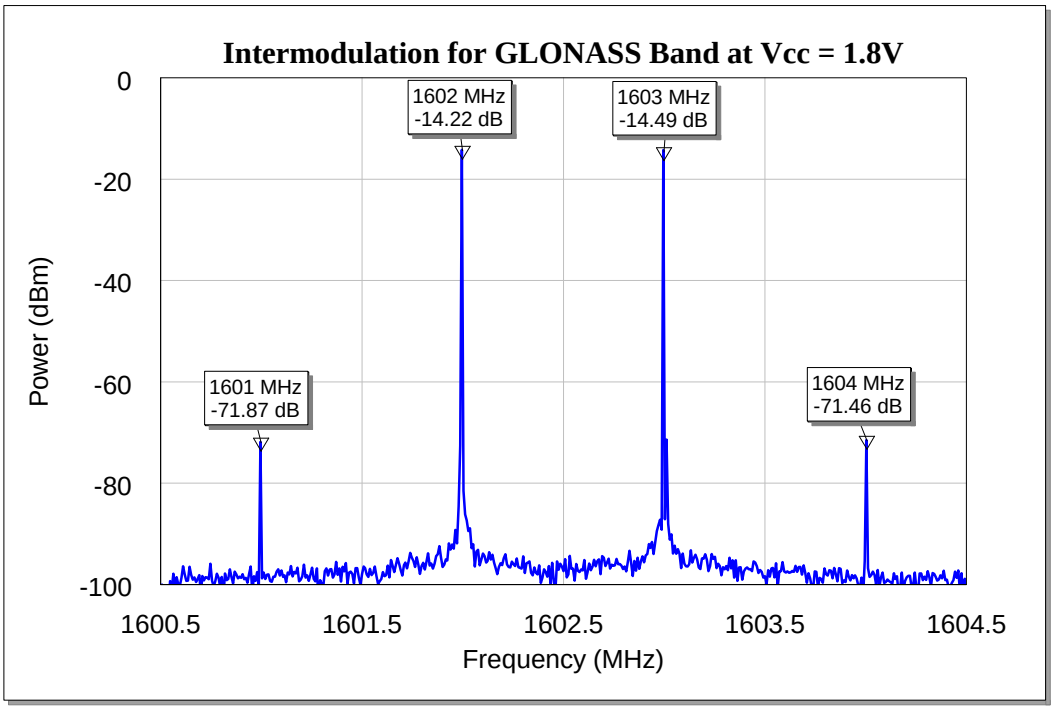

Figure 14 Carrier and intermodulation products of BGA825L6S for GLONASS band at Vcc=1.8V

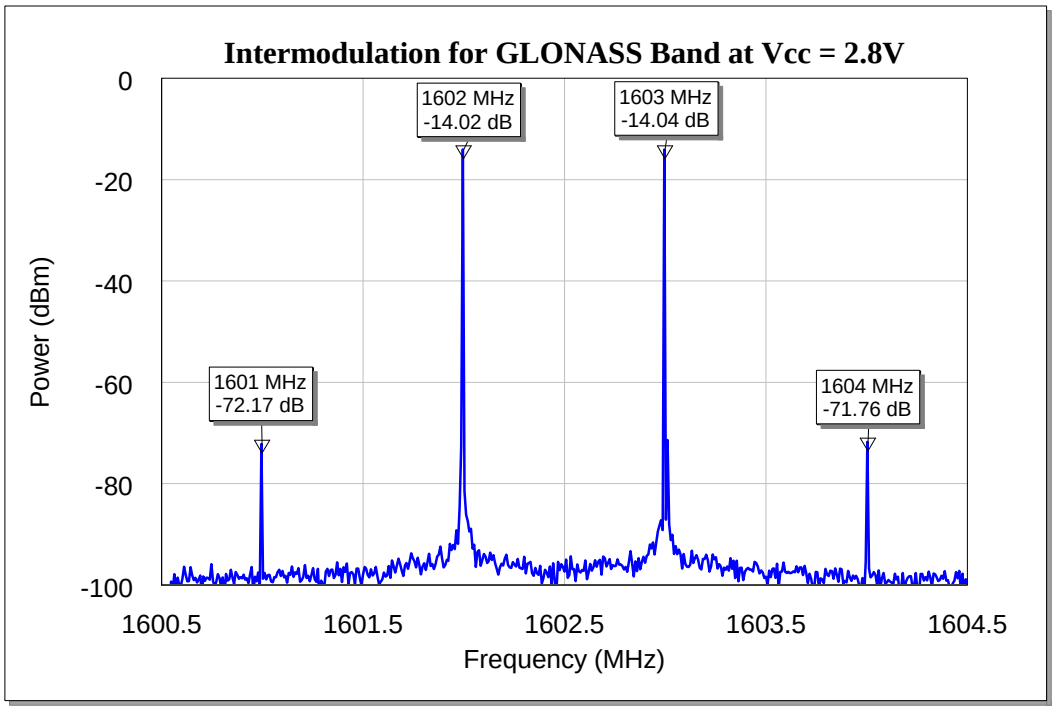

Figure 15 Carrier and intermodulation products of BGA825L6S for GLONASS band at Vcc=2.8V

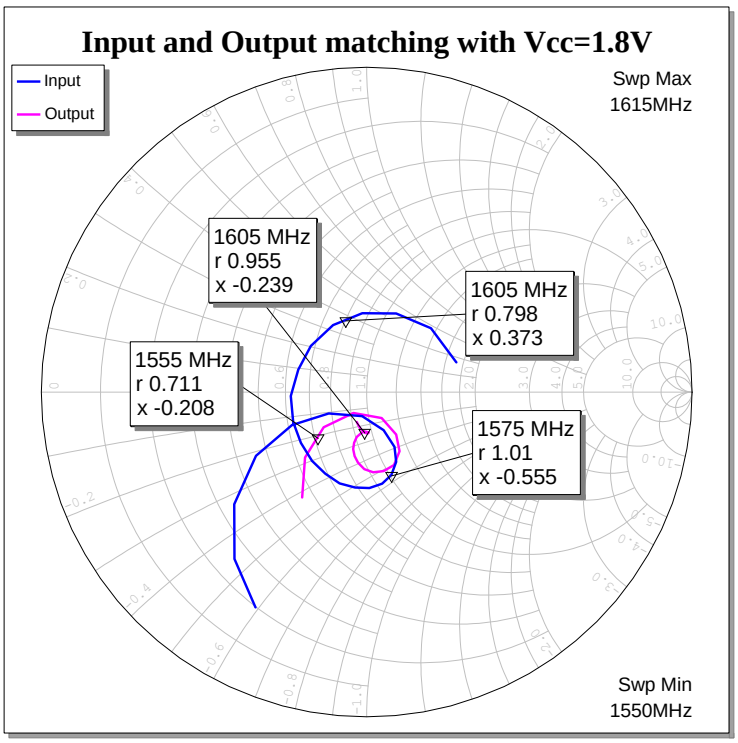

Figure 16 Input and output matching for GPS and GLONASS bands with Vcc=1.8V

Measured Graphs for GPS and GLONASS bands

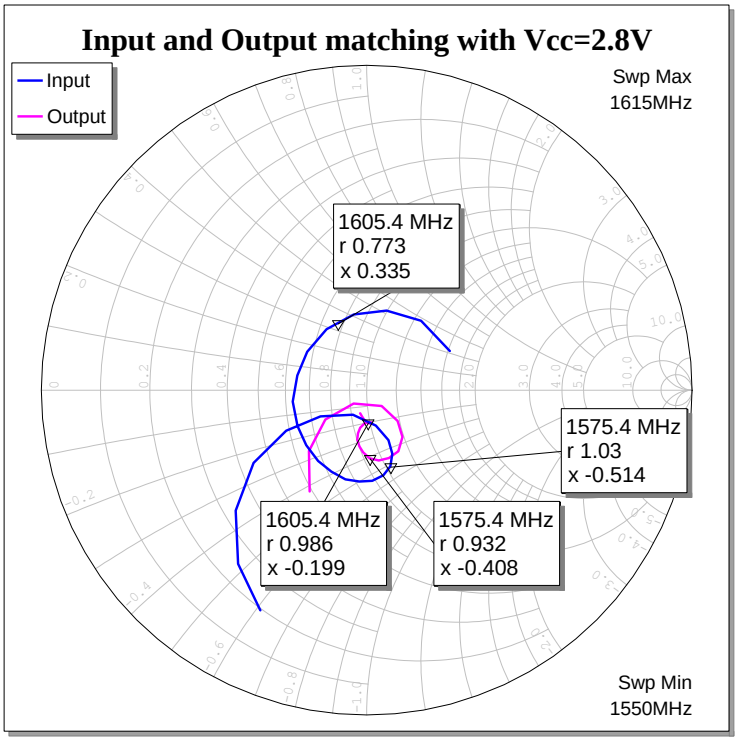

Figure 17 Input and output matching for GPS and GLONASS bands with Vcc=2.8V

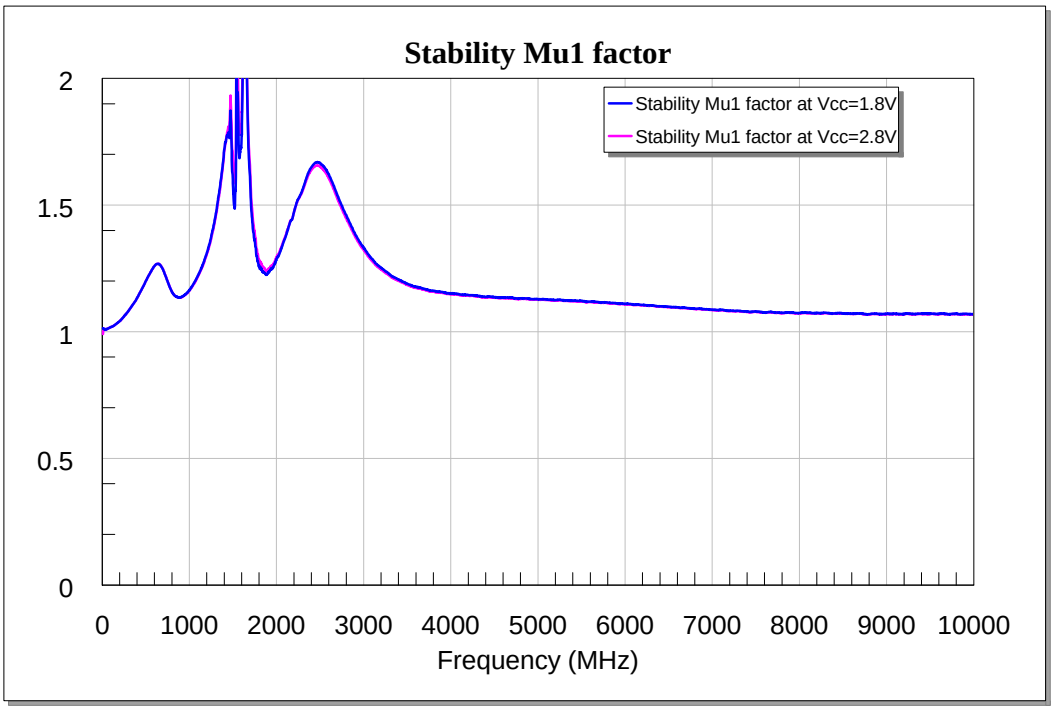

Figure 18 Stability factor µ1 of BGA825L6S upto 10GHz

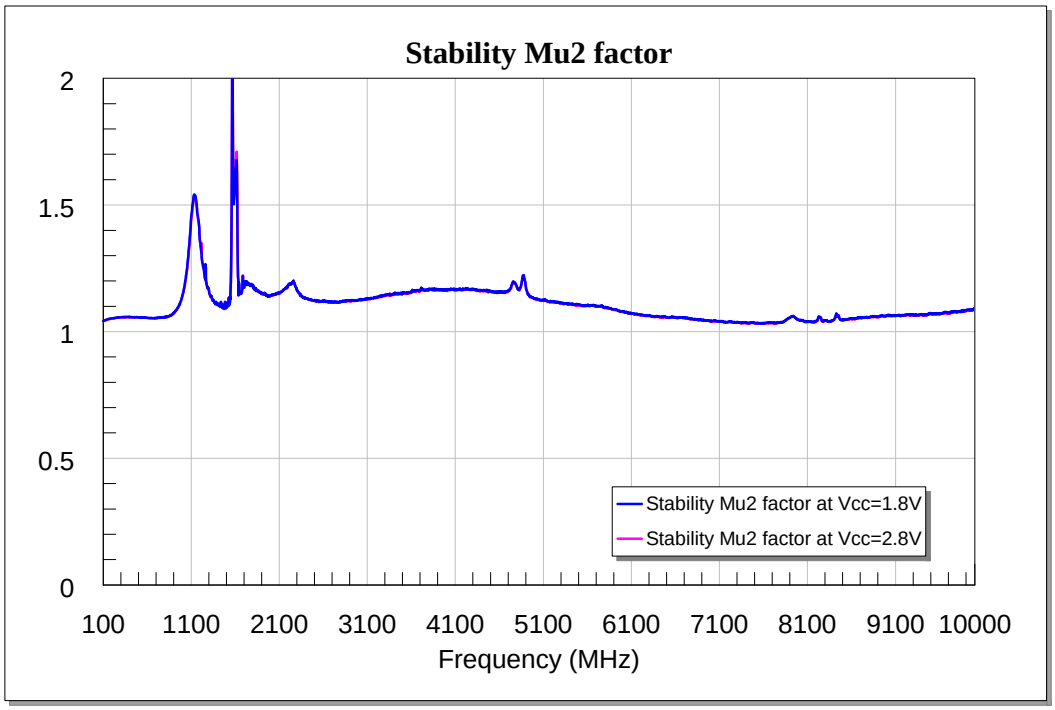

Figure 19 Stability factor µ2 of BGA825L6S upto 10GHz

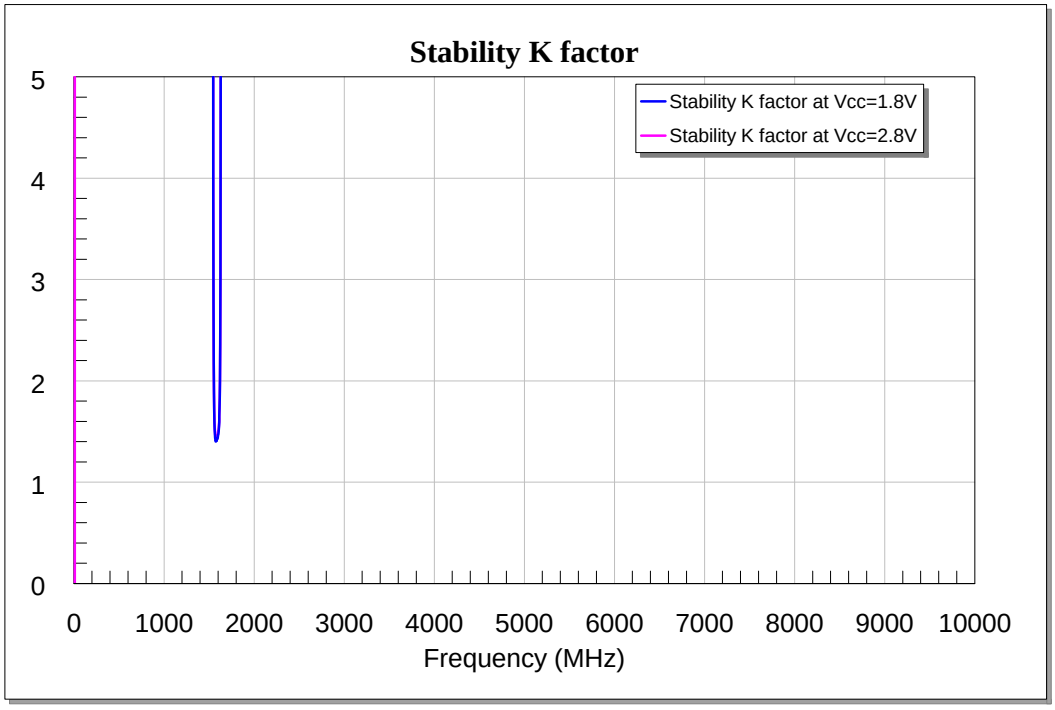

Figure 20 Stability factor k of BGA825L6S upto 10GHz

5.2 Measured Graphs for application circuit 2

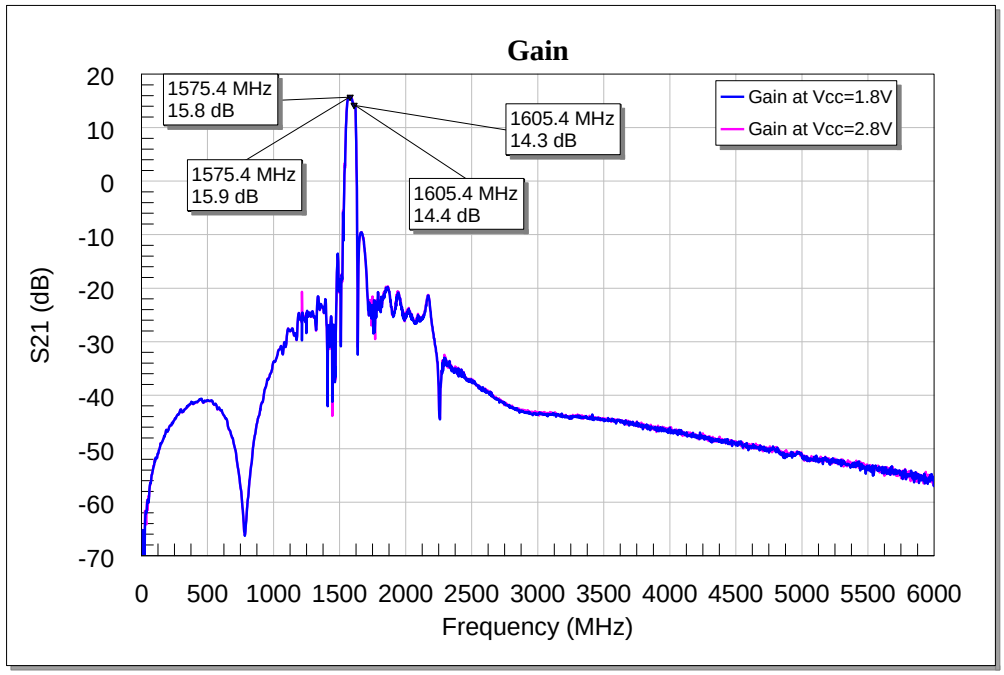

Figure 21 Power gain of BGA825L6S for GPS and GLONASS bands

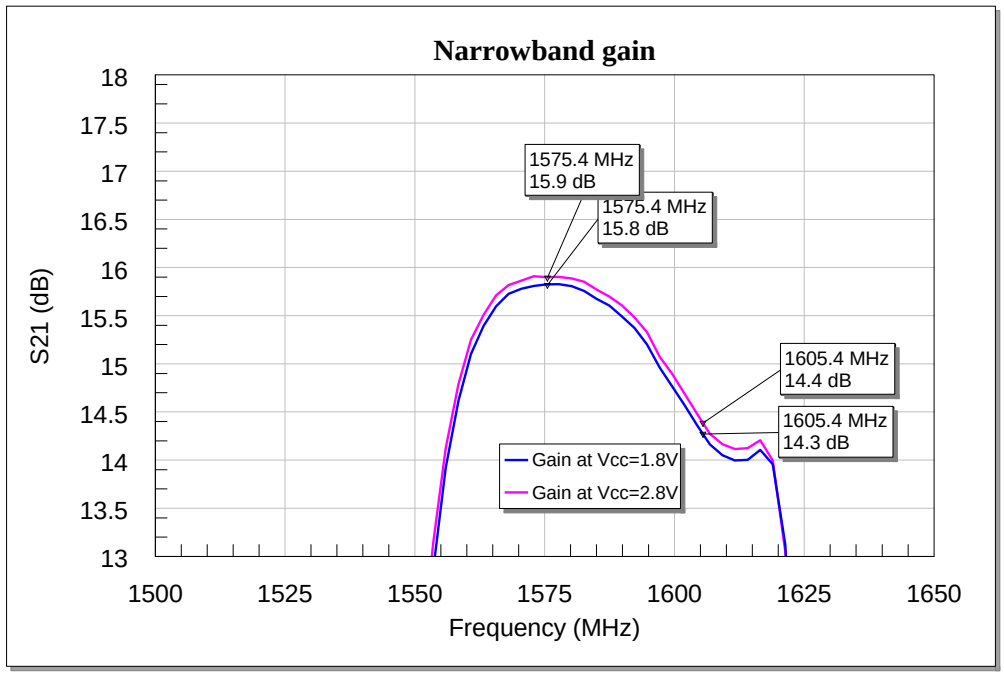

Figure 22 Narrowband power gain of BGA825L6S for GPS and GLONASS bands

Measured Graphs for GPS and GLONASS bands

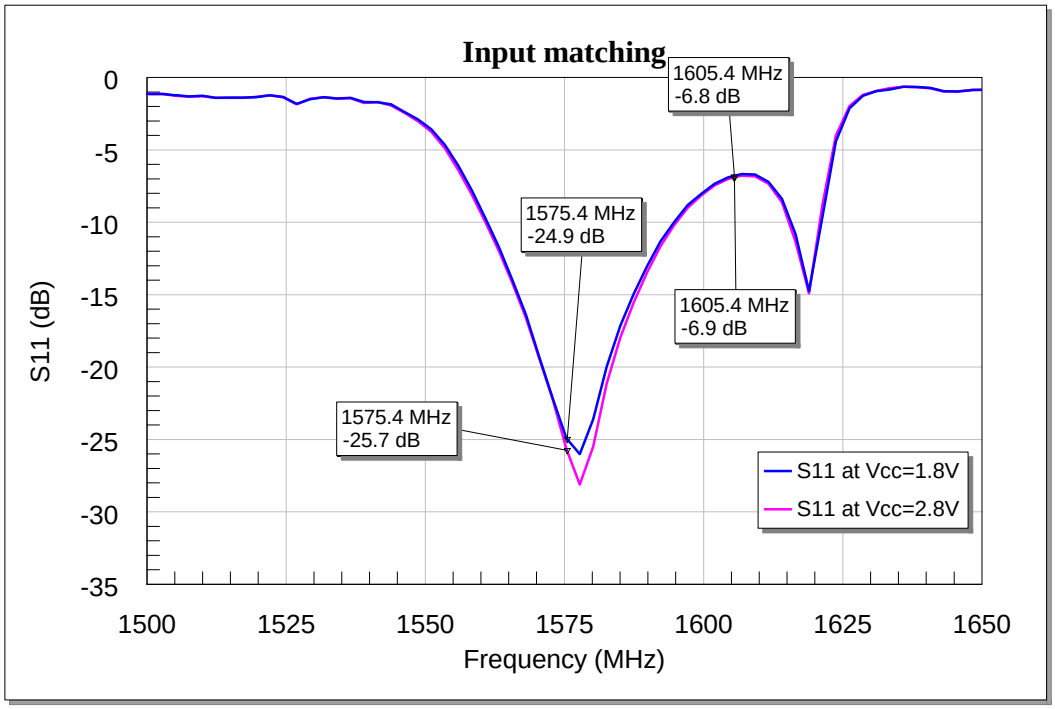

Figure 23 Input matching of BGA825L6S for GPS and GLONASS bands

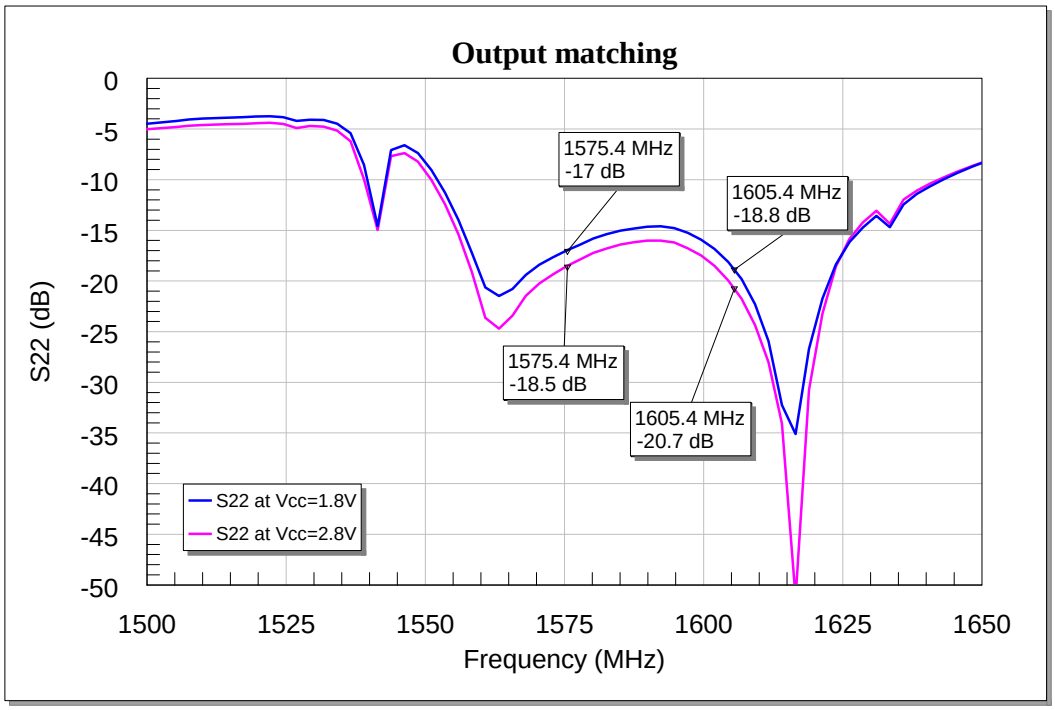

Figure 24 Output matching of BGA825L6S for GPS and GLONASS bands

Measured Graphs for GPS and GLONASS bands

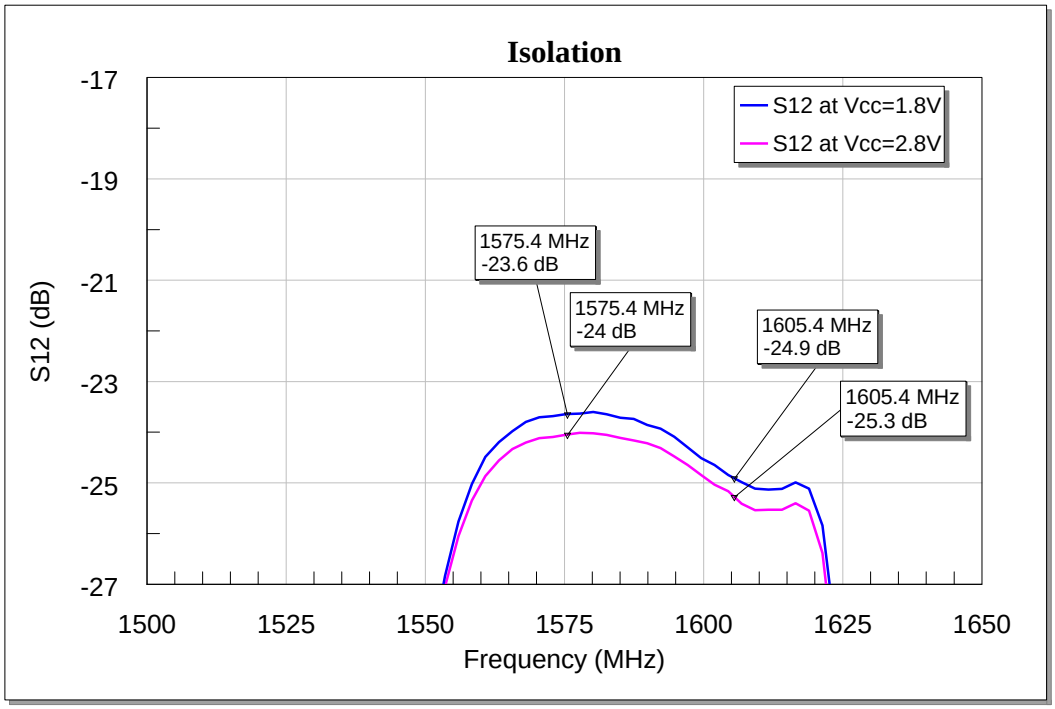

Figure 25 Reverse isolation of BGA825L6S for GPS and GLONASS bands

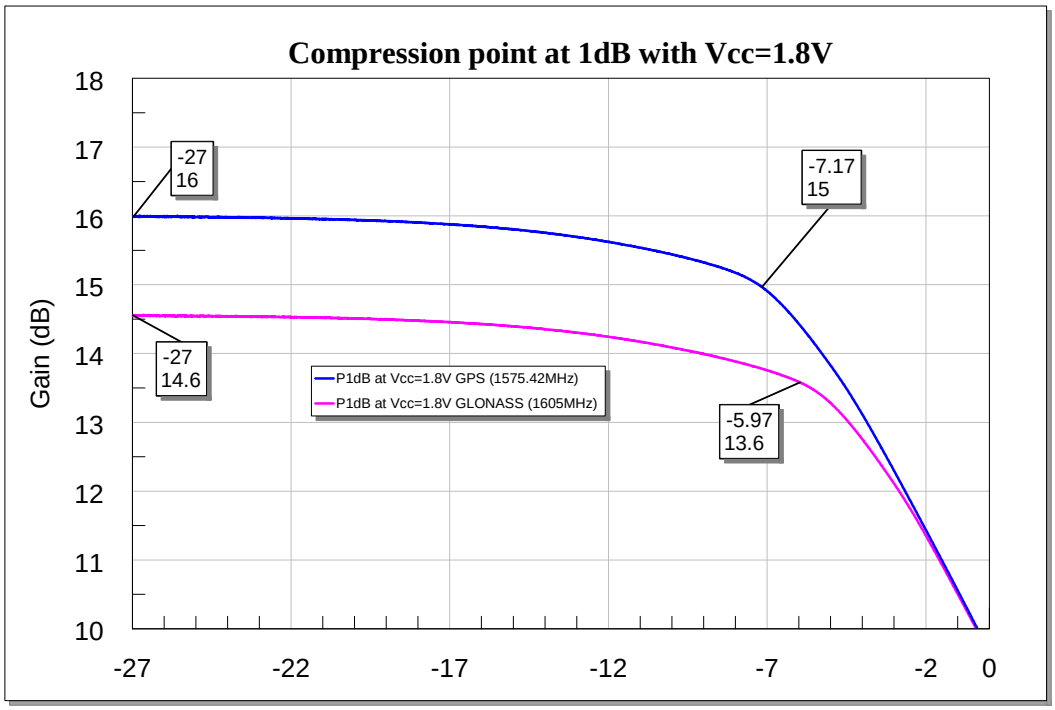

Figure 26 Input 1 dB compression point of BGA825L6S at supply voltage of 1.8V GPS and GLONASS bands

Measured Graphs for GPS and GLONASS bands

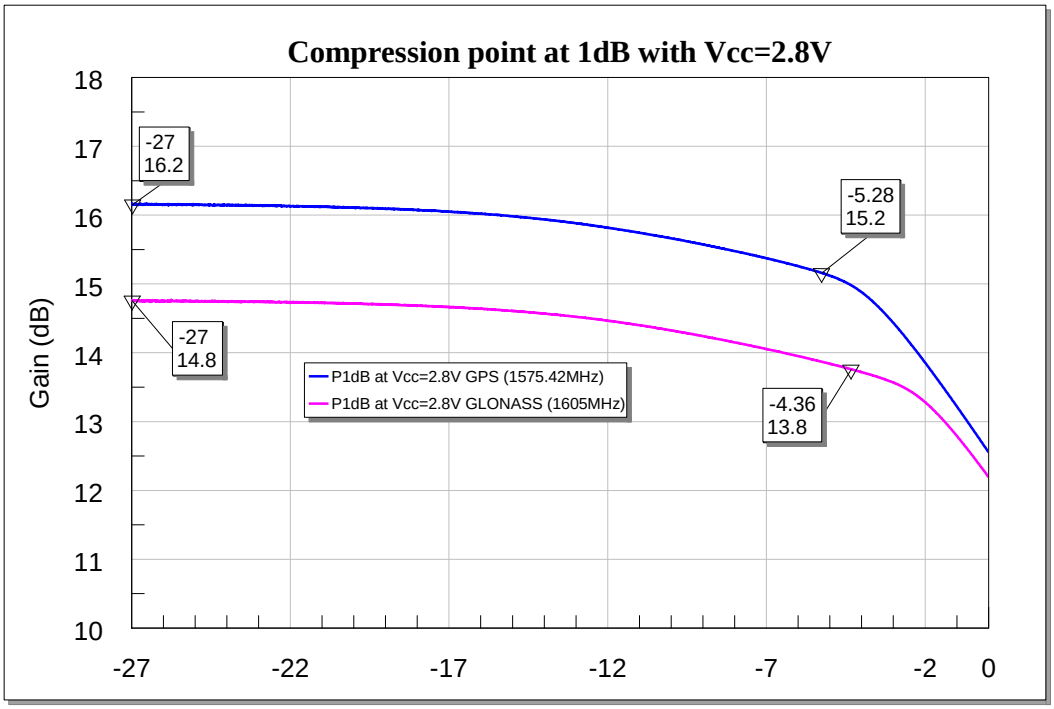

Figure 27 Input 1 dB compression point of BGA825L6S at supply voltage of 2.8V for GPS and GLONASS bands

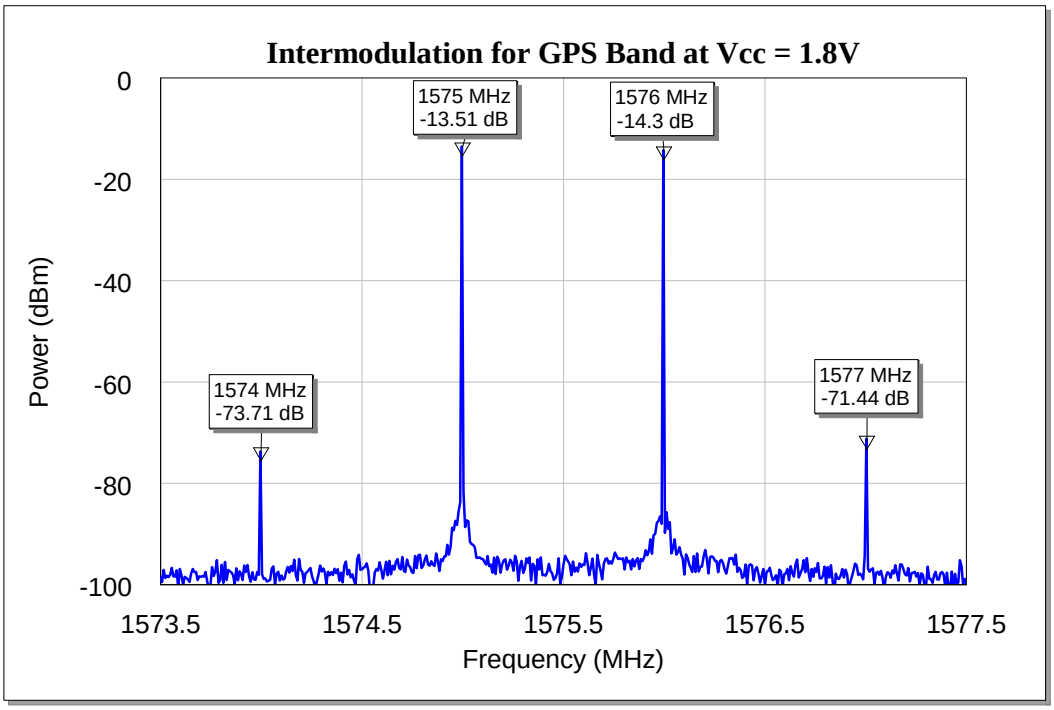

Figure 28 Carrier and intermodulation products of BGA825L6S for GPS band at Vcc=1.8V

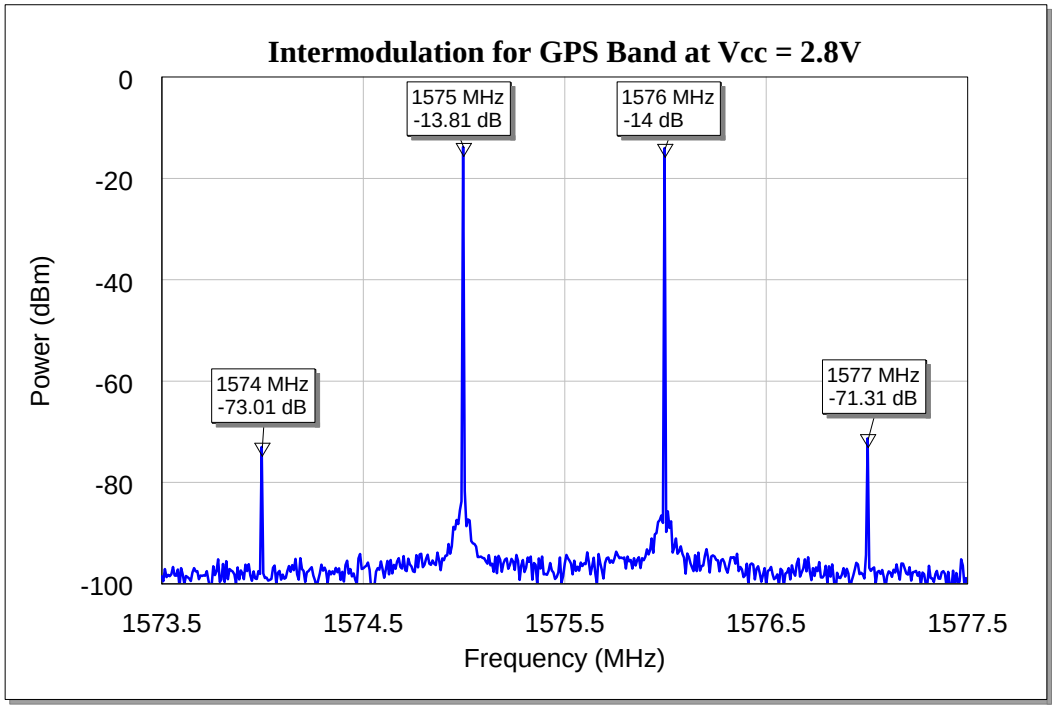

Figure 29 Carrier and intermodulation products of BGA825L6S for GPS band at Vcc=2.8V

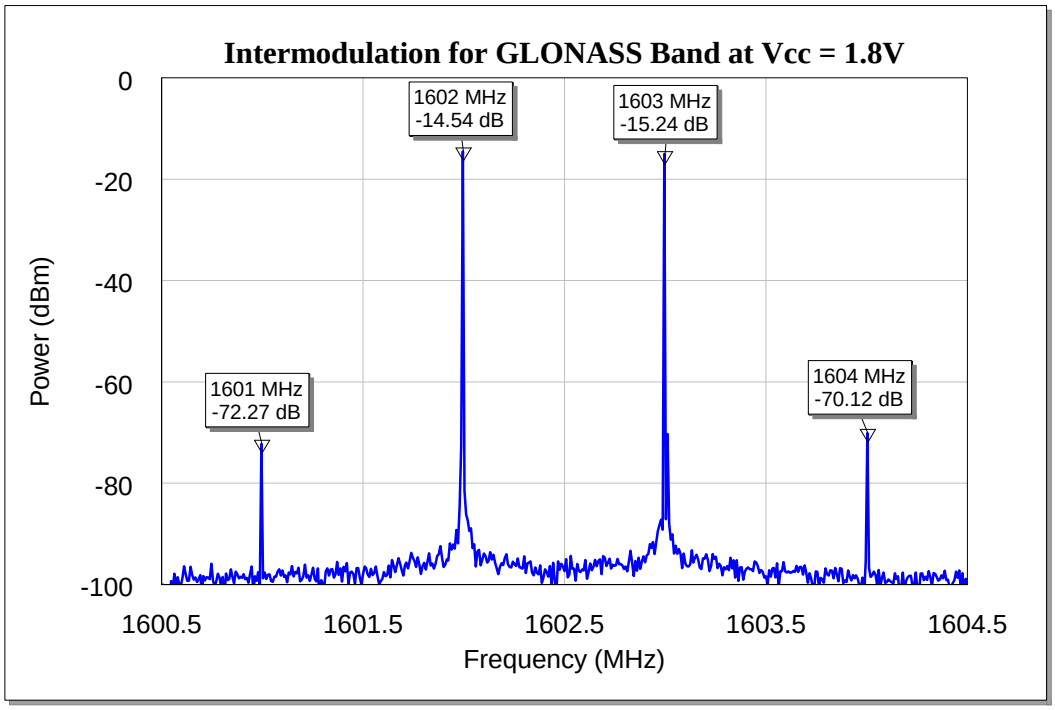

Figure 30 Carrier and intermodulation products of BGA825L6S for GLONASS band at Vcc=1.8V

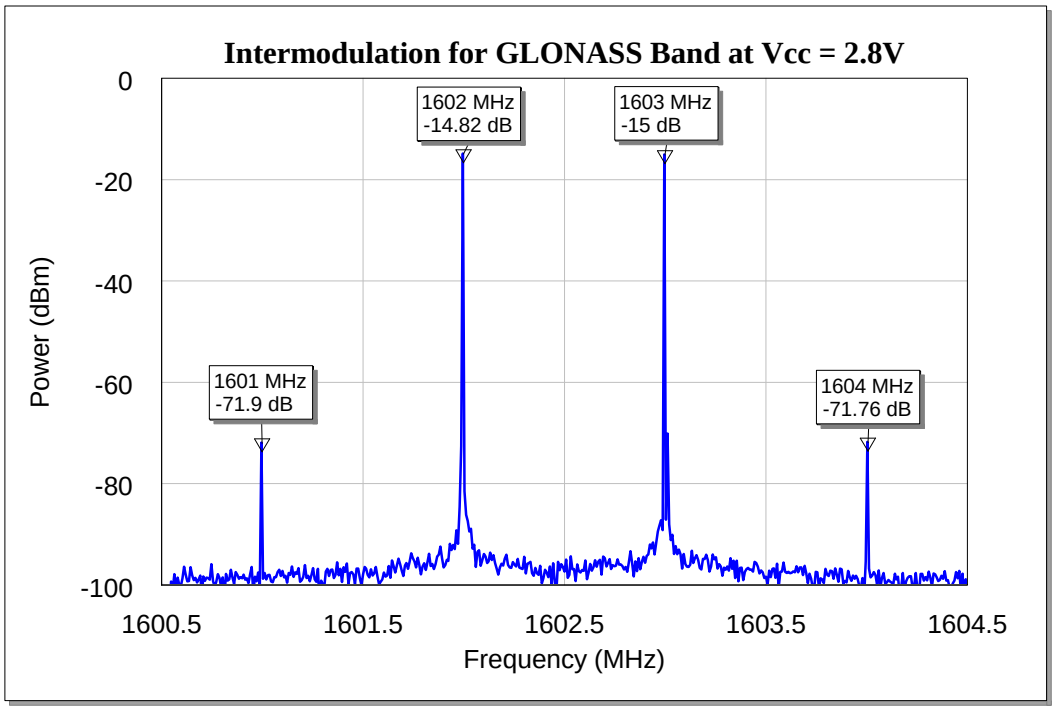

Figure 31 Carrier and intermodulation products of BGA825L6S for GLONASS band at Vcc=2.8V

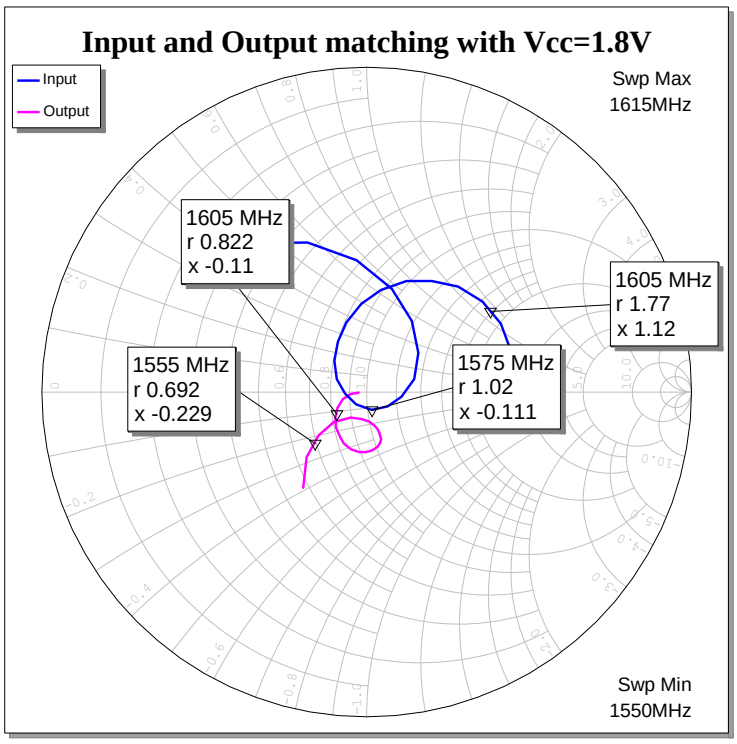

Figure 32 Input and output matching for GPS and GLONASS bands with Vcc=1.8V

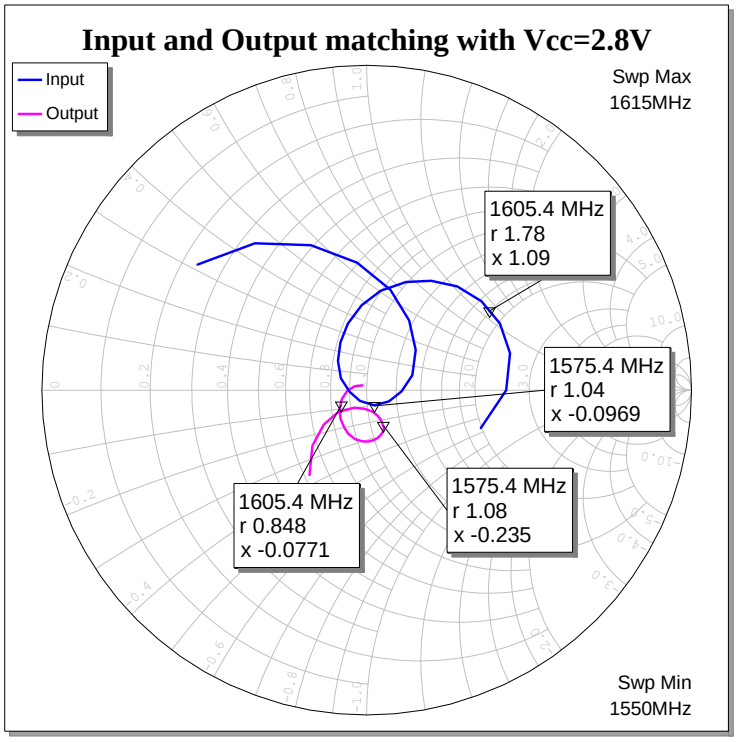

Figure 33 Input and output matching for GPS and GLONASS bands with Vcc=2.8V

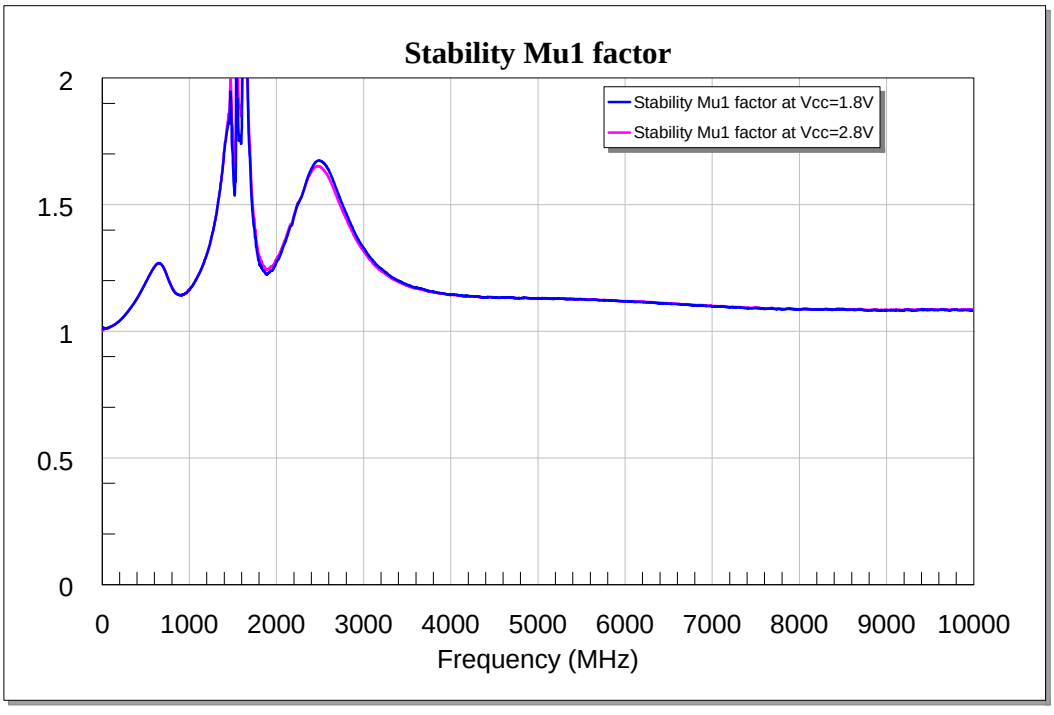

Figure 34 Stability factor µ1 of BGA825L6S upto 10GHz

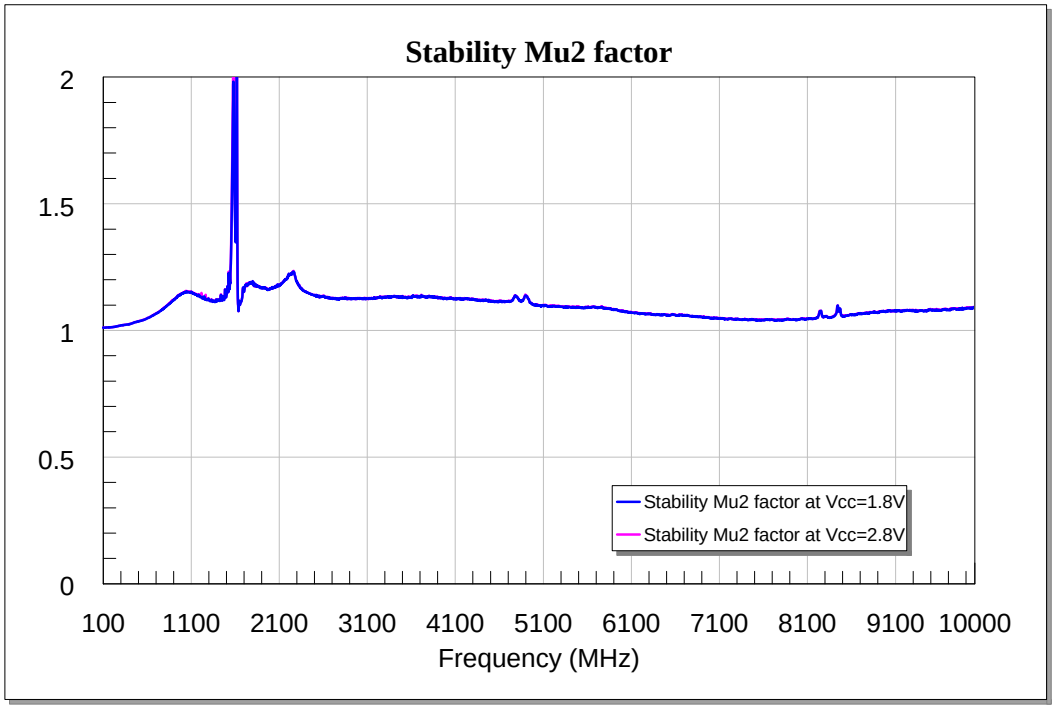

Figure 35 Stability factor µ2 of BGA825L6S upto 10GHz

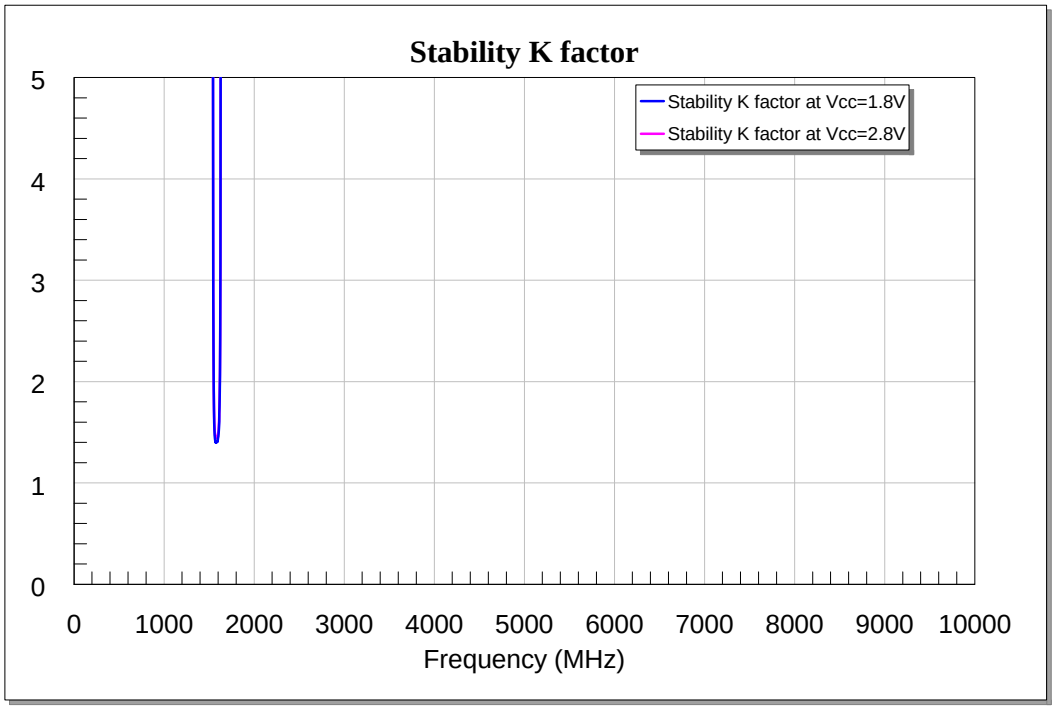

Figure 36 Stability factor k of BGA825L6S upto 10GHz

6 Evaluation Board

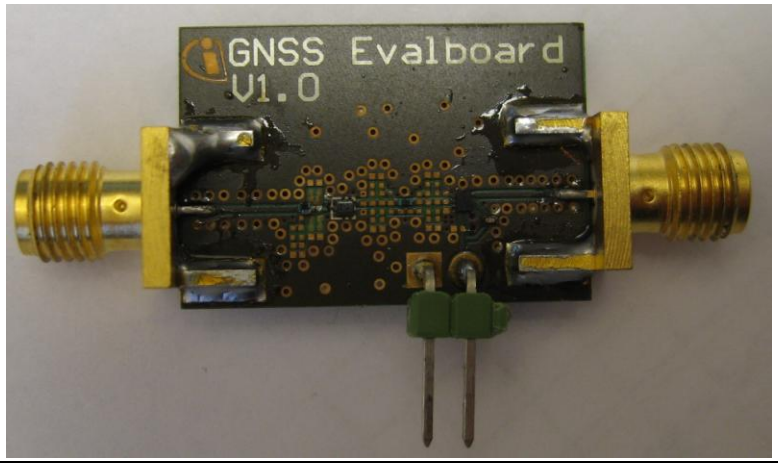

Figure 37 Populated PCB picture of BGA825L6S application circuit 1

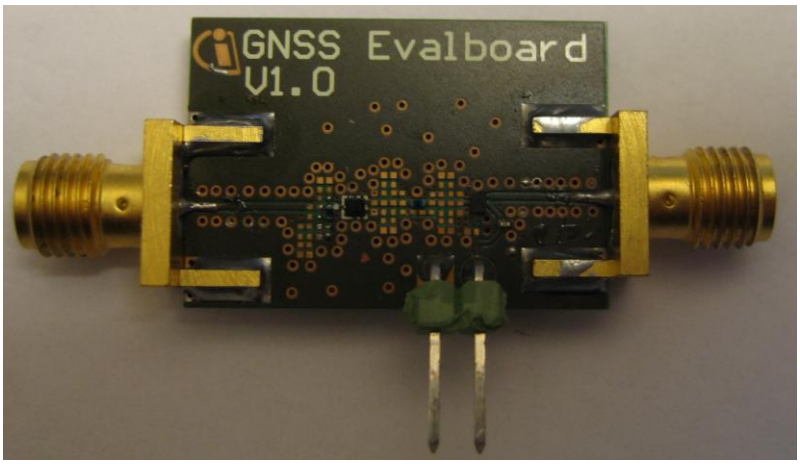

Figure 38 Populated PCB picture of BGA825L6S application circuit 2

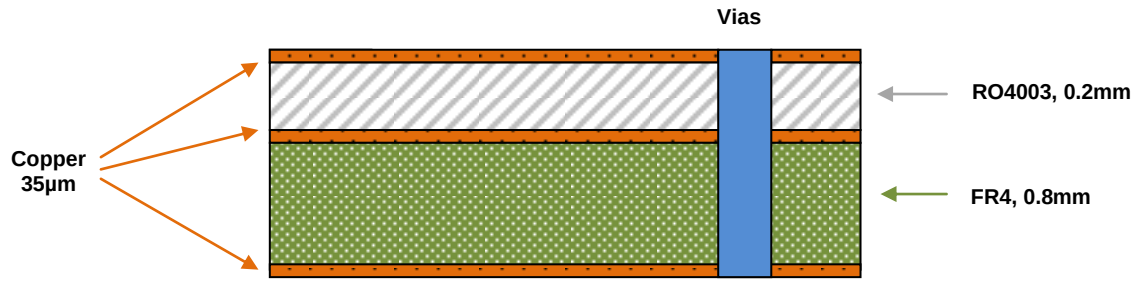

Figure 39 PCB layer stack

7 Authors

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