BGA915N7

Highly Linear and Low Noise Amplifer for Global Navigation Satellite Systems-GPS/GLONASS/Galileo/COMPASS from 1550 MHz to 1615 MHz Applications (with low-Q Inductors)

Application Note AN253

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RF and Protection Devices

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Application Note AN253

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Page	Subjects (major changes since last revision)
1	Title updated

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Last Trademarks Update 2011-02-24

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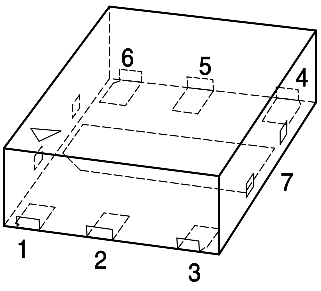
1 BGA915N7 GPS Front-End LNA for High Performance Integrated Solution

1.1 Features

- High gain: 15.5 dB
- High out-of-band input 3rd-order intercept point: +10 dBm
- High input 1dB compression point: -5 dBm
- Low noise figure: 0.7 dB
- Low current consumption: 4.4 mA
- Operating frequency: 1550-1615 MHz
- Supply voltage: 1.5 V to 3.6 V
- Digital on/off switch (1V logic high level)
- Very small TSNP-7-6 leadless package
- B7HF Silicon Germanium technology
- RF output internally matched to 50 Ω
- Only three external SMD components necessary
- 2 kV HBM ESD protection (including AI-pin)
- Pb-free (RoHS compliant) package



TSNP-7-6

Figure 1 BGA915N7 in TSNP-7-6 Package (1.40mm x 1.26mm x 0.38mm)

1.2 Applications

- Global Positioning System (GPS)
- GLONASS (Russian GNSS)
- Galileo (European GNSS)
- COMPASS (Chinese Beidou Navigation System)

2 Introduction

The BGA915N7 is a front-end Low Noise Amplifier (LNA) for Global Navigation Satellite Systems (GNSS) applications. It is based on Infineon Technologies' B7HF Silicon-Germanium (SiGe:C) technology, enabling a cost-effective solution in a very small TSNP-7-6 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. 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 and also improved coverage area. Noise figure of the LNA defines the overall noise figure of the GNSS receiver system. This is where BGA915N7 excels by providing noise figure as low as 0.7 dB and high gain of 15.5 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 1712.5 MHz mixes with UMTS 1850 MHz to produce third-order-product exactly at GPS 1575 MHz. To quantify the effect, BGA915N7 shows out-of-band input IP3 at GPS of +10 dBm as a result of frequency mixing between GSM 1713 MHz and UMTS 1851 MHz with power levels of -20 dBm. BGA915N7 has a high in-band input 3rd order intercept point (IIP3) of +0.2 dBm, so that it is especially suitable for the GPS function in mobile phones.

BGA915N7 also offers sufficient rejection at 787.76MHz, which is band-13 of upcoming LTE and whose 2^{nd} harmonic is at GPS frequency, to meet specifications of 2^{nd} harmonic of band-13 without any additional circuitry. BGA915N7 has input referred band-13 second harmonic level of -60.8 dBm when the input signal of 787.76 MHz at -25 dBm is applied.

The output of the BGA915N7 is internally matched to 50 Ω, and a DC blocking capacitor is integrated on-chip, thus no external component is required at the output. Depending on the application, three or four external components on the input side are required.

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 consumption (4.4 mA) makes the device suitable for portable technology like GNSS receivers and mobiles phones.

The Internal circuit diagram of the BGA915N7 is presented in Figure 2. Table 1 show the pin assignment of BGA915N7. Table 2 shows the truth table to turn on/off BGA915N7 by applying different voltage to the PON pin.

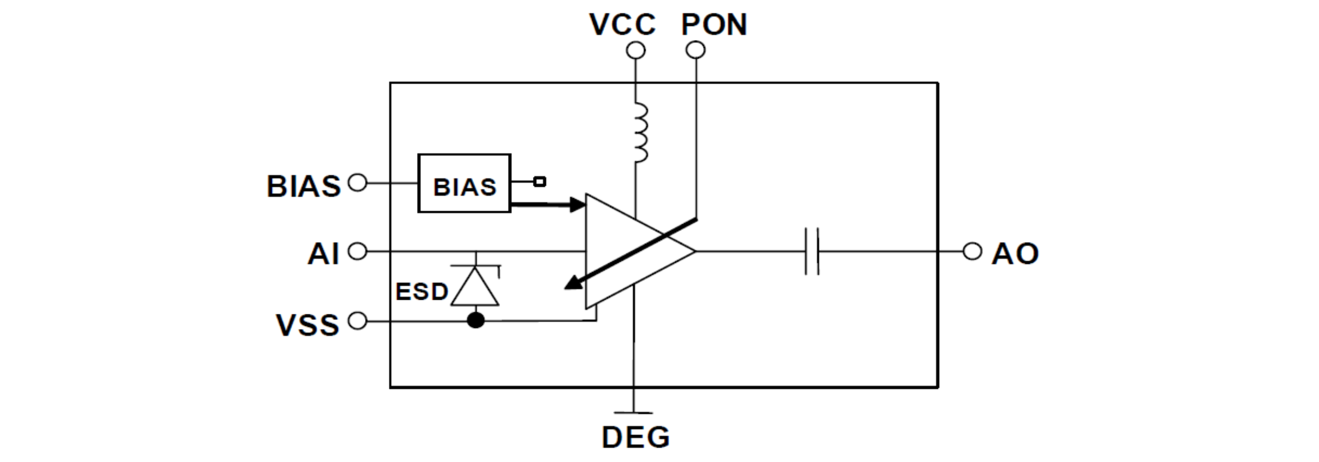


Figure 2 Block diagram of the BGA915N7 for GNSS High Bands 1559-1615MHz applications

Table 1 Pin Definition

Pin	Symbol	Comment
1	DEG	Emitter degneration
2	AI	Amplifier Input
3	BIAS	Collector to Base bias
4	AO	Amplifier Output
5	VCC	Voltage supply
6	PON	Power On/Off mode
7	VSS	Grounding

Table 2 Switching Mode

Mode	Symbol	ON/OFF Control Voltage	
		Min	Max
On	PON, on	1.0V	VCC
Off	PON, off	0	0.4

3 Application Circuit

3.1 Schematic Diagram

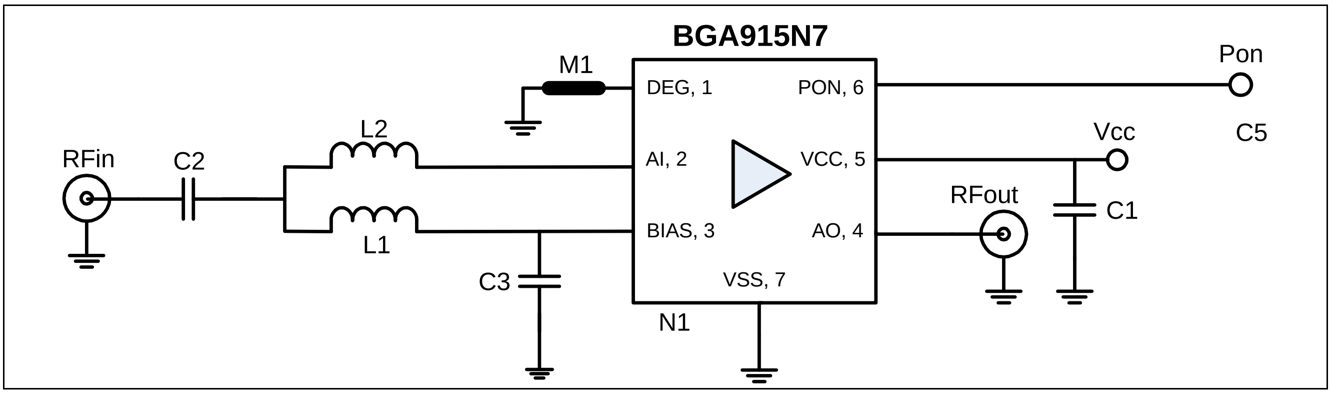


Figure 3 BGA915N7 application circuit[1]

Table 3 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	0.22	µF	0402	Various	RF bypass for low frequencies
C2	33	pF	0402	various	DC block
C3	15	pF	0402	various	Input matching
L1	5.1	nH	0402	Murata LQG	Bias feed/Input matching
L2	1.8	nH	0402	Murata LQG	Input matching
N1	BGA915N7		TSNP-7-6	Infineon Technologies	SiGe:C MMIC LNA
M1[2]	~ 0.55	nH			Microstrip line

[1] This application circuit is implemented using low-Q inductors and FR4 substrate. For application with high-Q inductors please refer to application note AN251

[2] Total board inductance = inductance of the microstrip line (~500pH) + inductance of via (~50pH)
Please refer to application note AN258 for more details on “realization of small inductor values on a PCB by using microstriplines”.

4 Typical Measurement Results

Table 4 and Table 5 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 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	4.3			mA	
Frequency System	Sys	Galileo/COMPASS	GPS	GLONASS		
Frequency Range	Freq	1559-1593	1575	1602-1615	MHz	
Gain	G	15.8	15.7	15.5	dB	
Noise Figure	NF	0.84	0.85	0.83	dB	PCB and SMA connectors losses of 0.07dB substracted
Input Return Loss	RLin	8.8	8.9	9.2	dB	
Output Return Loss	RLout	17.4	18.2	19.0	dB	
Reverse Isolation	IRev	20.0	20.0	19.8	dB	
Input P1dB	IP1dB	-7.0	-6.9	-6.6	dBm	$f_{galileo}$ = 1559 MHz f_{gps} = 1575 MHz $f_{GLONASS}$ = 1615 MHz
Output P1dB	OP1dB	7.8	7.8	7.9	dBm	
LTE band-13 2nd Harmonic	H2 – input referred		-60.5		dBm	f_{IN} = 787.76 MHz P_{IN} = -25 dBm
Input IP3 In-band	IIP3	0.0	0.0	0.5	dBm	$f_{1gal/gps}$ = 1575 MHz $f_{2gal/gps}$ = 1576MHz $f_{1GLONASS}$ =1609 MHz $f_{2GLONASS}$ =1610 MHz Input power= -30dBm
Output IP3 In-band	OIP3	15.5	15.5	15.9	dBm	
Input IP3 out-of-band	IIP3o		14.2		dBm	f_1 = 1713 MHz f_2 = 1851 MHz Input power= -20dBm
Stability	k	>1			--	Unconditionally 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	4.5			mA	
Frequency System	Sys	Galileo/COMPASS	GPS	Glonass		
Frequency Range	Freq	1559-1593	1575	1602-1615	MHz	
Gain	G	15.8	15.8	15.6	dB	
Noise Figure	NF	0.86	0.85	0.84	dB	PCB and SMA connectors losses of 0.07dB substracted
Input Return Loss	RLin	9.3	9.4	9.7	dB	
Output Return Loss	RLout	16.7	17.6	19.4	dB	
Reverse Isolation	IRev	20.4	20.4	20.2	dB	
Input P1dB	IP1dB	-4.3	-4.1	-3.8	dBm	$f_{galileo}$ = 1559 MHz f_{gps} = 1575 MHz $f_{GLONASS}$ = 1615 MHz
Output P1dB	OP1dB	10.5	10.7	10.8	dBm	
LTE band-13 2nd Harmonic	H2 – input referred		-60.8		dBm	f_{IN} = 787.76 MHz P_{IN} = -25 dBm
Input IP3 In-band	IIP3	0.2	0.2	0.8	dBm	$f_{1gal/gps}$ = 1575 MHz $f_{2gal/gps}$ = 1576MHz $f_{1GLONASS}$ =1609 MHz $f_{2GLONASS}$ =1610 MHz Input power= -30dBm
Output IP3 In-band	OIP3	16.0	16.0	16.4	dBm	
Input IP3 out-of-band	IIP3o		10.3		dBm	f_1 = 1713 MHz f_2 = 1851 MHz Input power= -20dBm
Stability	k	>1			--	Unconditionnally Stable from 0 to 10GHz

5 Measured Graphs for Galileo, GPS and GLONASS bands

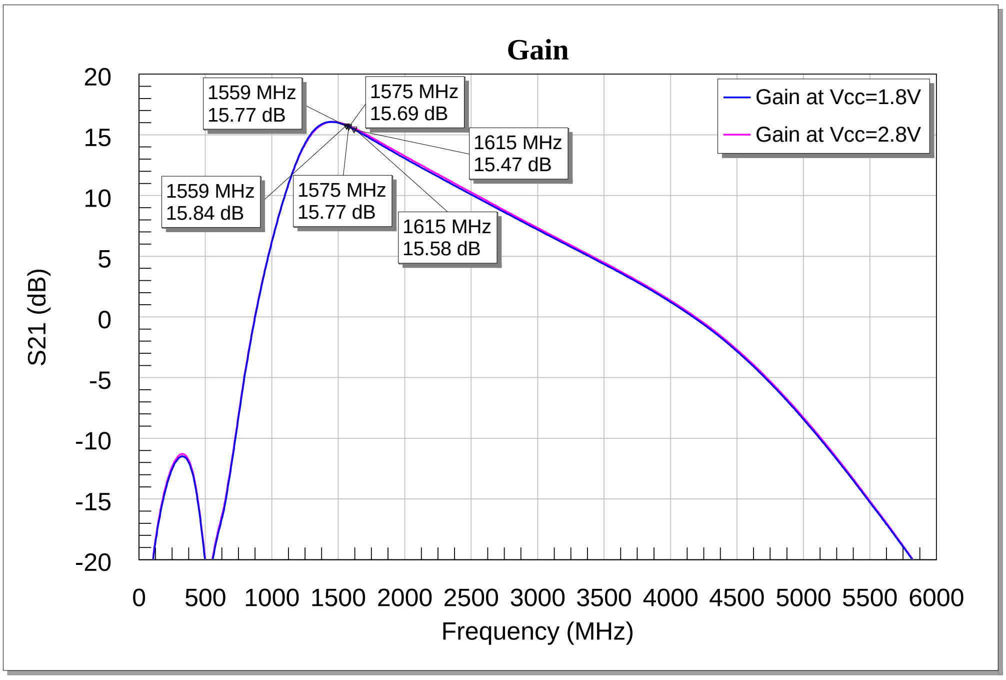


Figure 4 Power gain of BGA915N7 for Galileo, GPS and GLONASS bands

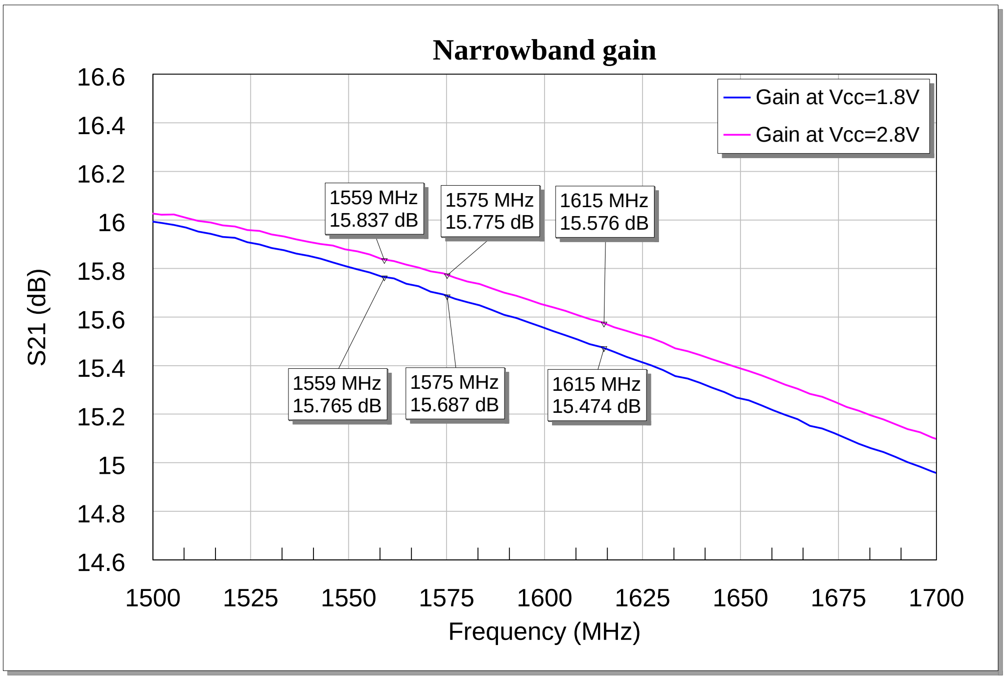


Figure 5 Narrowband power gain of BGA915N7 for Galileo, GPS and GLONASS bands

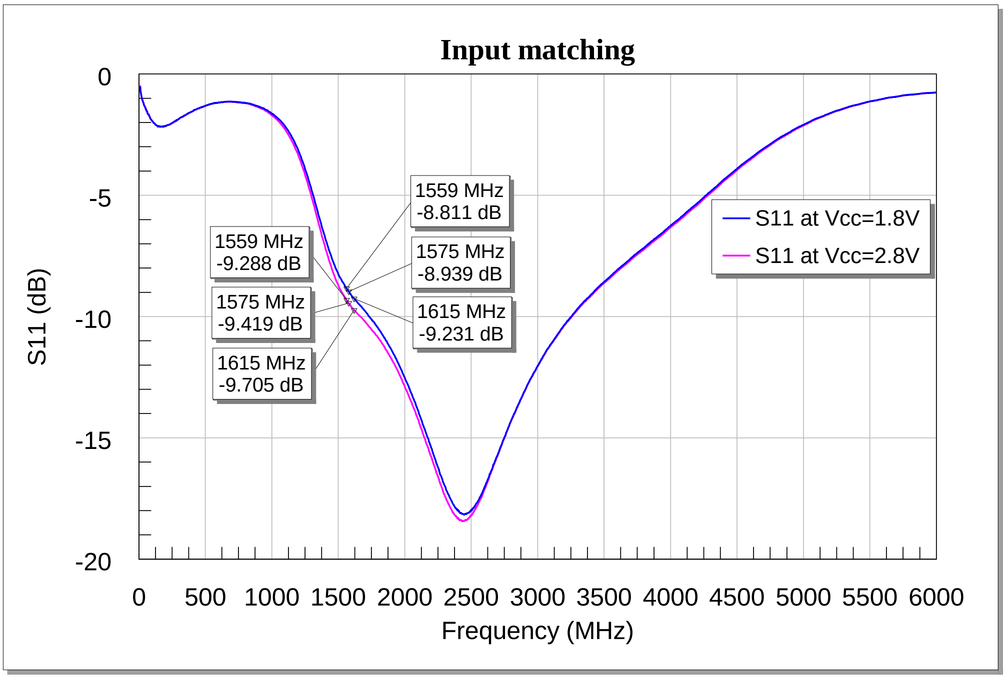


Figure 6 Input matching of BGA915N7 for Galileo, GPS and GLONASS bands

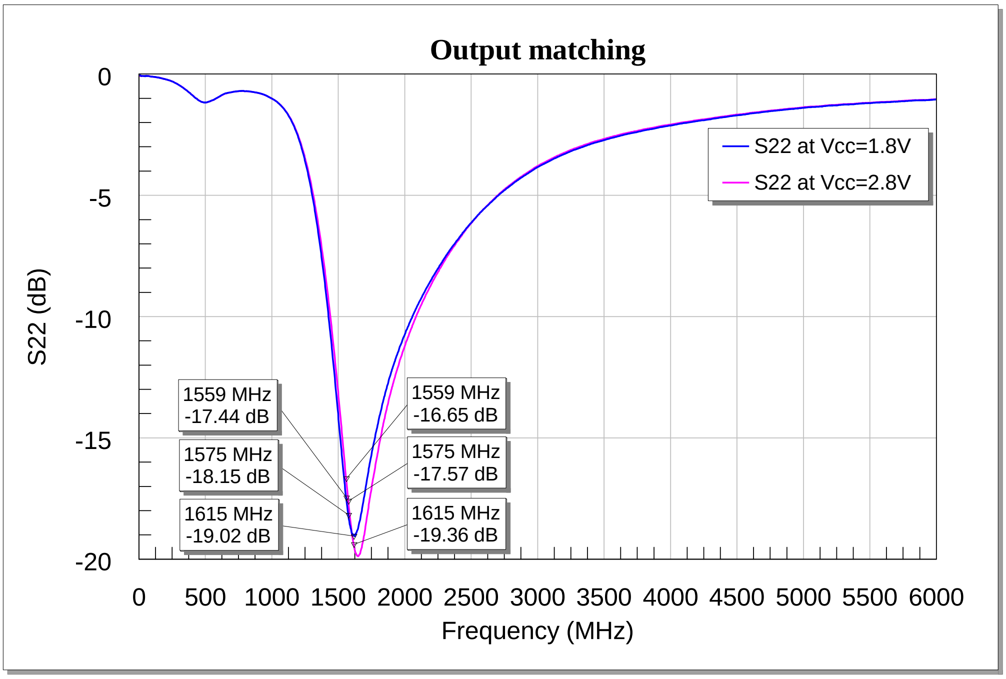


Figure 7 Output matching of BGA915N7 for Galileo, GPS and GLONASS bands

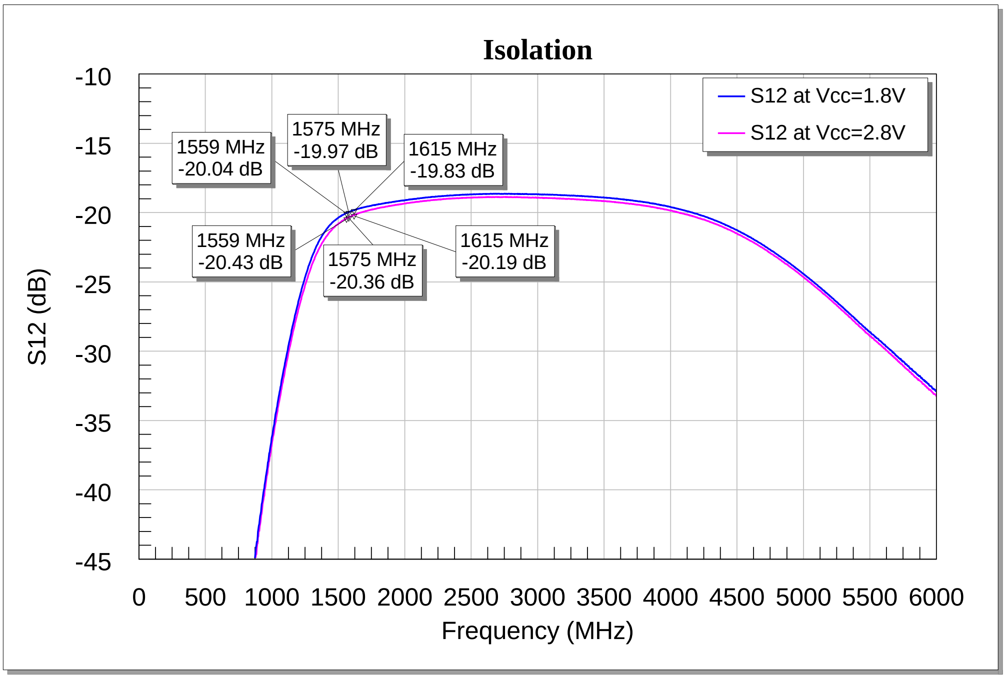


Figure 8 Reverse isolation of BGA915N7 for Galileo, GPS and GLONASS bands

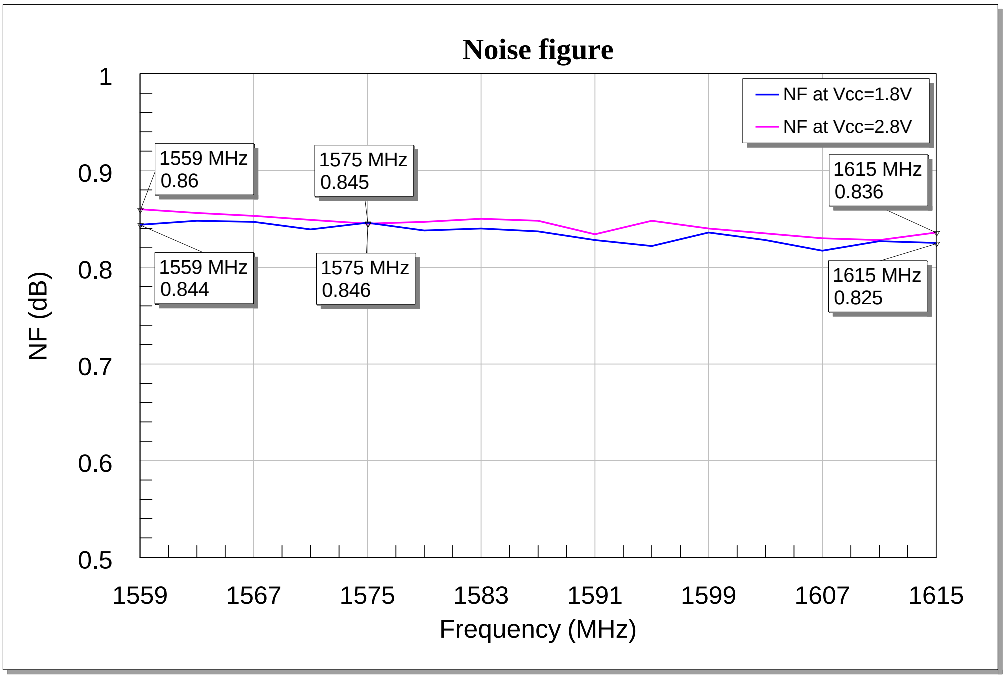


Figure 9 Noise figure of BGA915N7 for Galileo, GPS and GLONASS bands

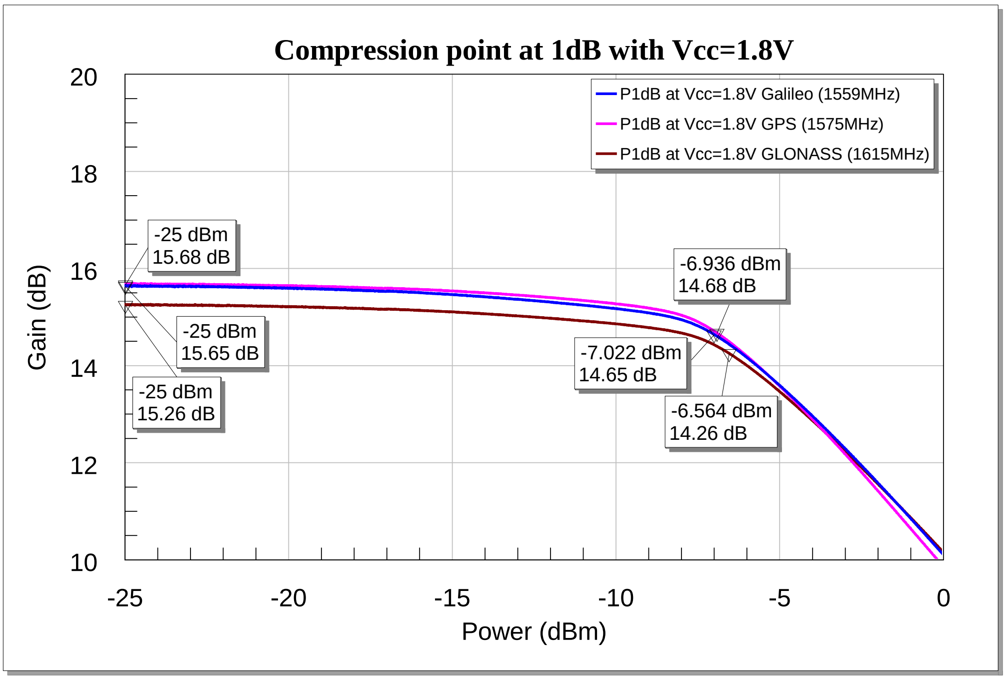


Figure 10 Input 1 dB compression point of BGA915N7 at supply voltage of 1.8V for Galileo, GPS and GLONASS bands

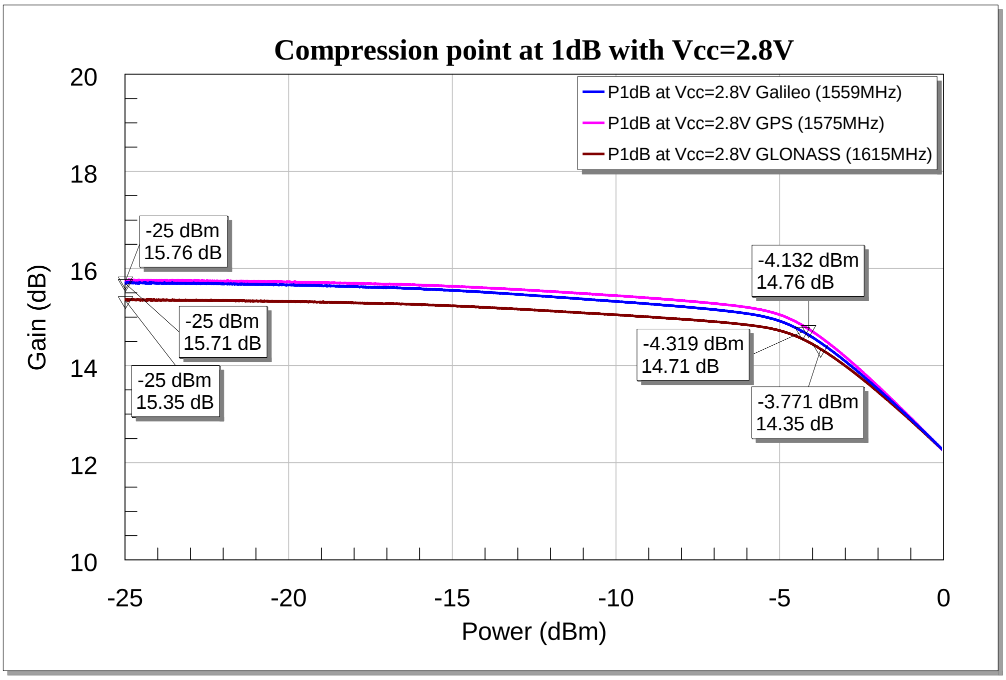


Figure 11 Input 1 dB compression point of BGA915N7 at supply voltage of 2.8V for Galileo, GPS and GLONASS bands

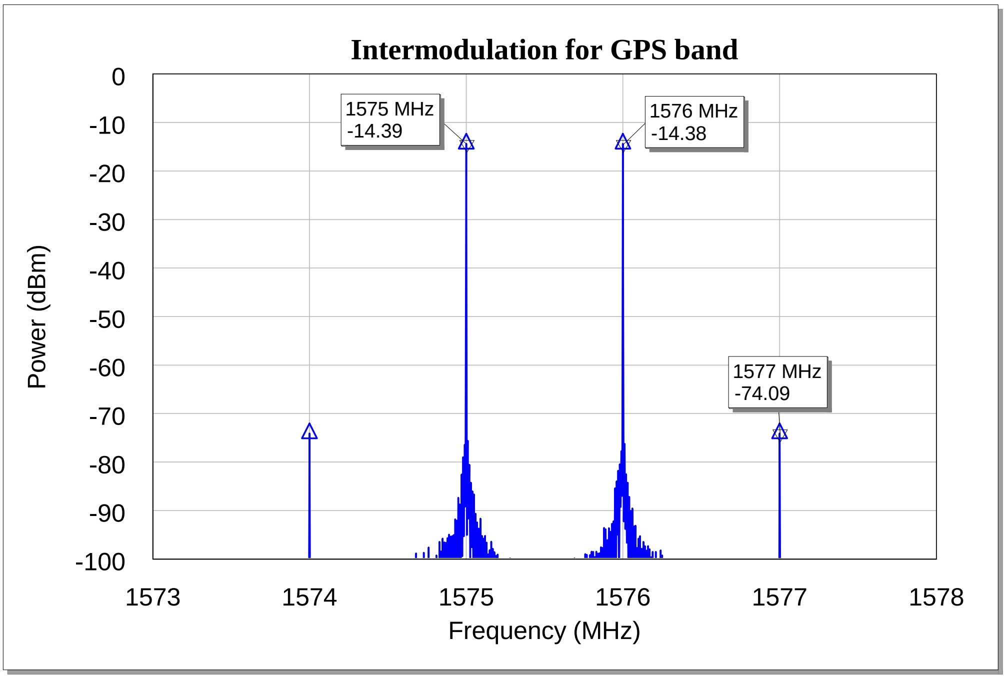


Figure 12 Carrier and intermodulation products of BGA915N7 for GPS band at Vcc=1.8V

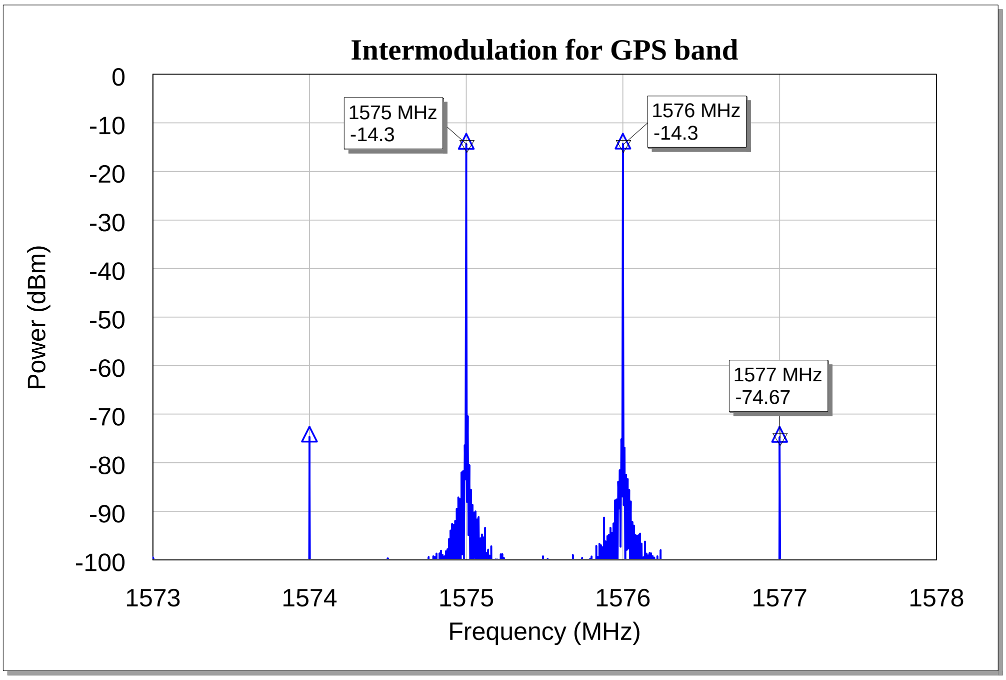


Figure 13 Carrier and intermodulation products of BGA915N7 for GPS band at Vcc=2.8V

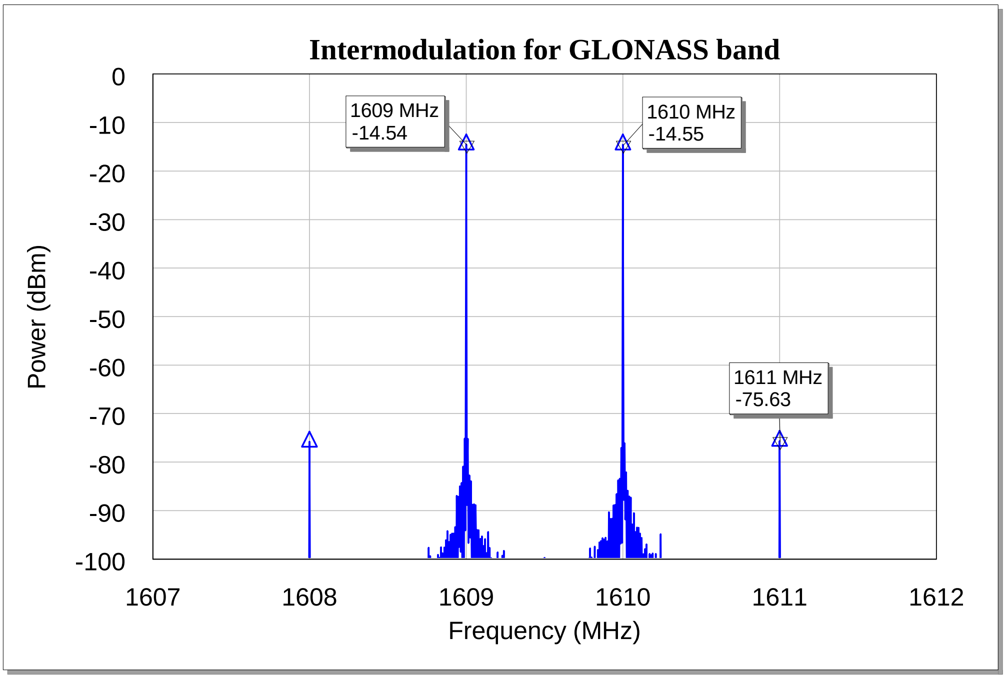


Figure 14 **Carrier and intermodulation products of BGA915N7 for GLONASS band at Vcc=1.8V**

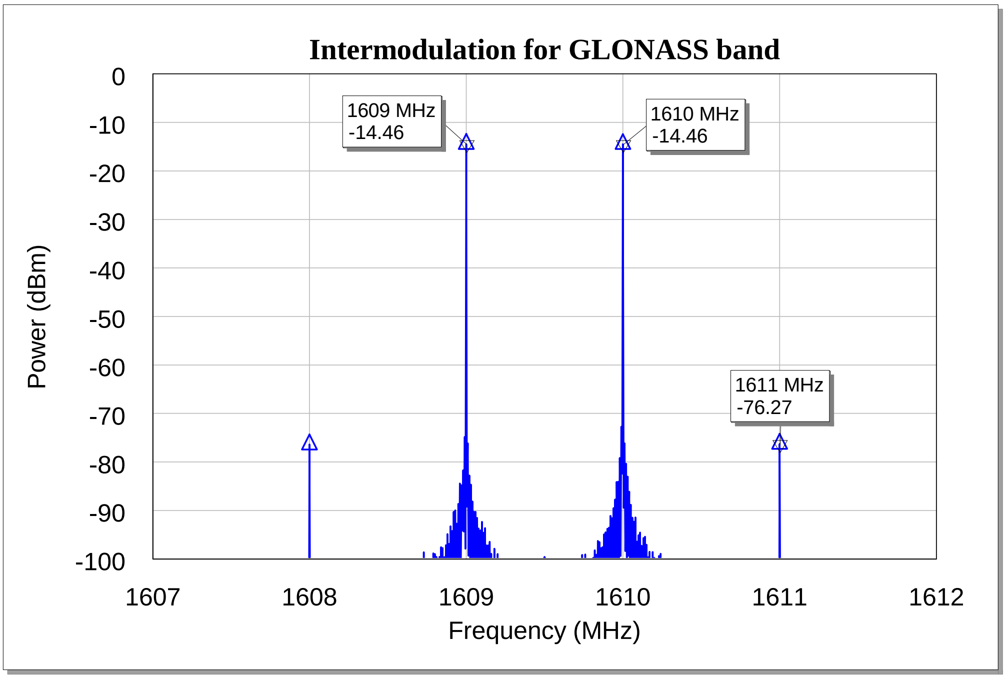


Figure 15 **Carrier and intermodulation products of BGA915N7 for GLONASS band at Vcc=2.8V**

6 Miscellaneous Measured Graphs

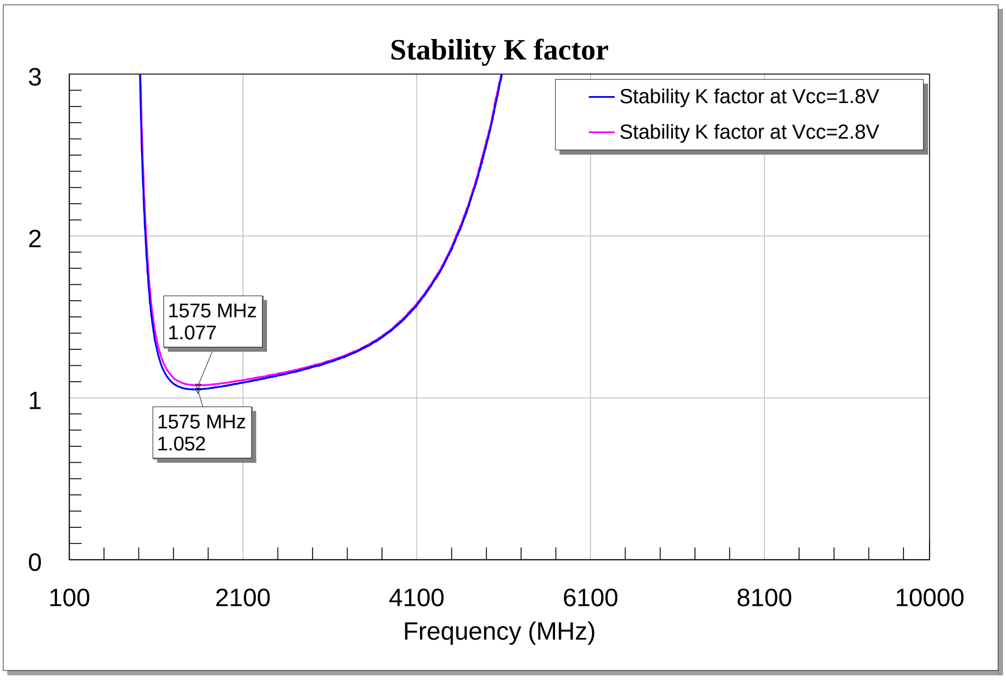


Figure 16 Stability factor k of BGA915N7 upto 10GHz

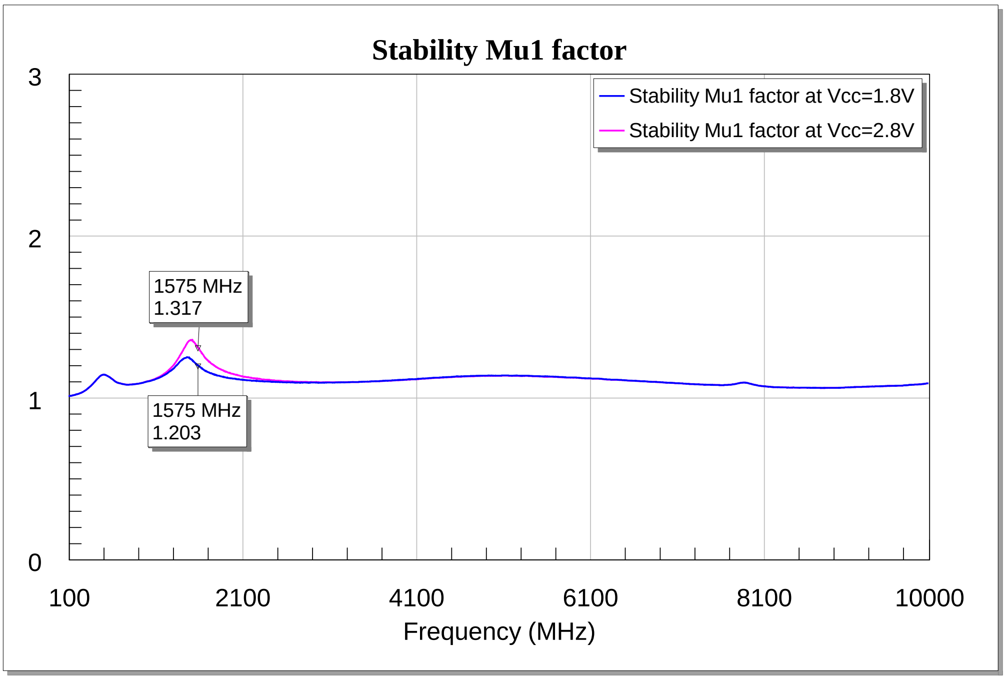


Figure 17 Stability factor µ1 of BGA915N7 upto 10GHz

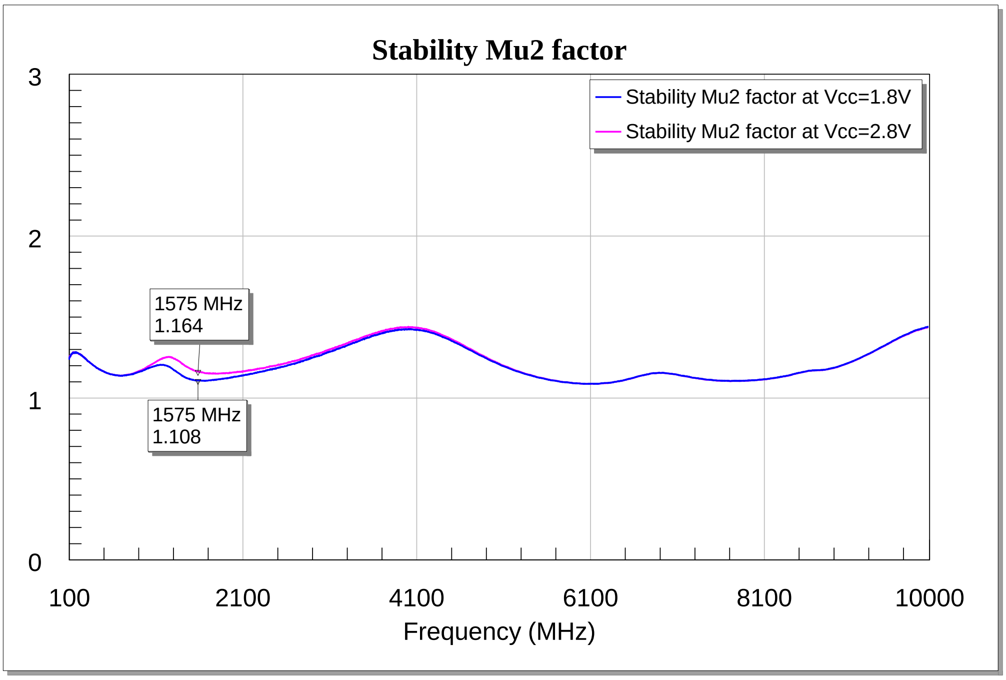


Figure 18 Stability factor μ2 of BGA915N7 upto 10GHz

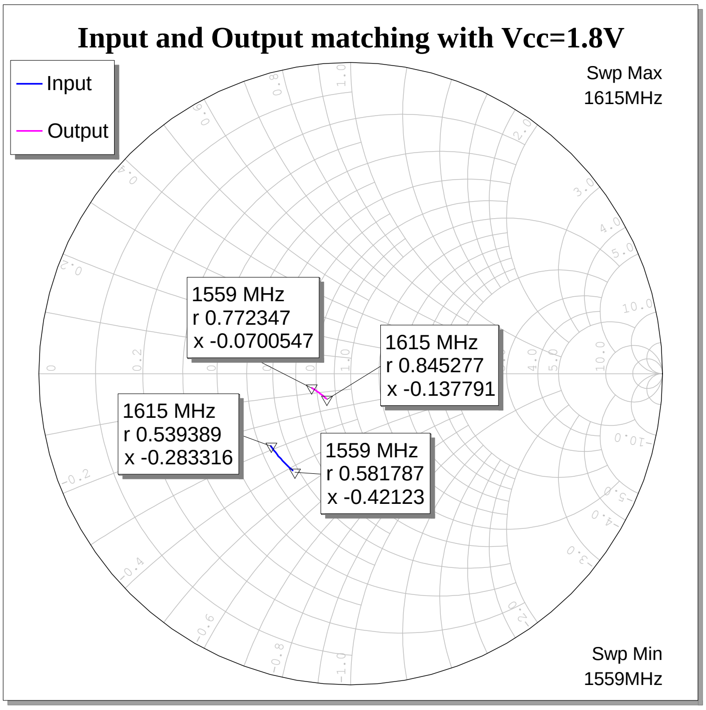


Figure 19 Input and output matching for Galileo, GPS and GLONASS bands with Vcc=1.8V

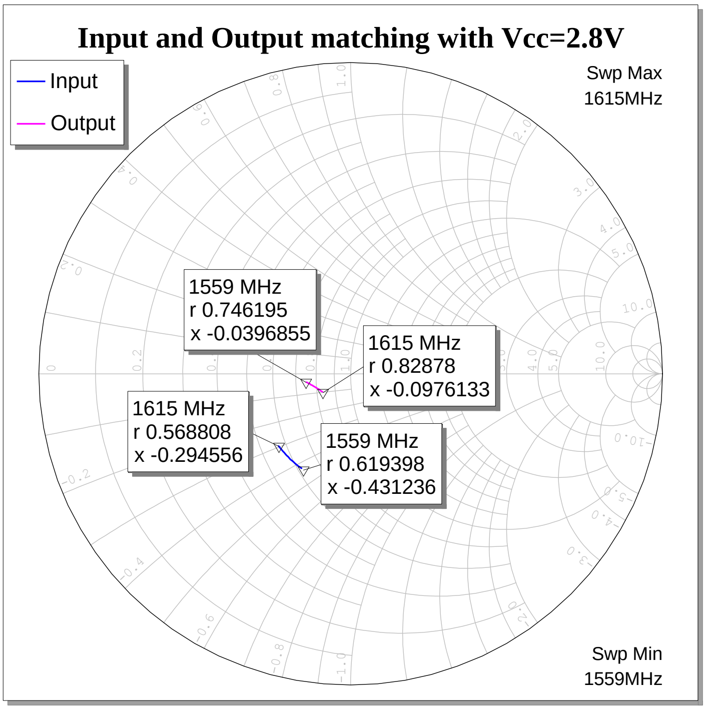


Figure 20 Input and output matching for Galileo, GPS and GLONASS bands with Vcc=2.8V

7 Evaluation Board

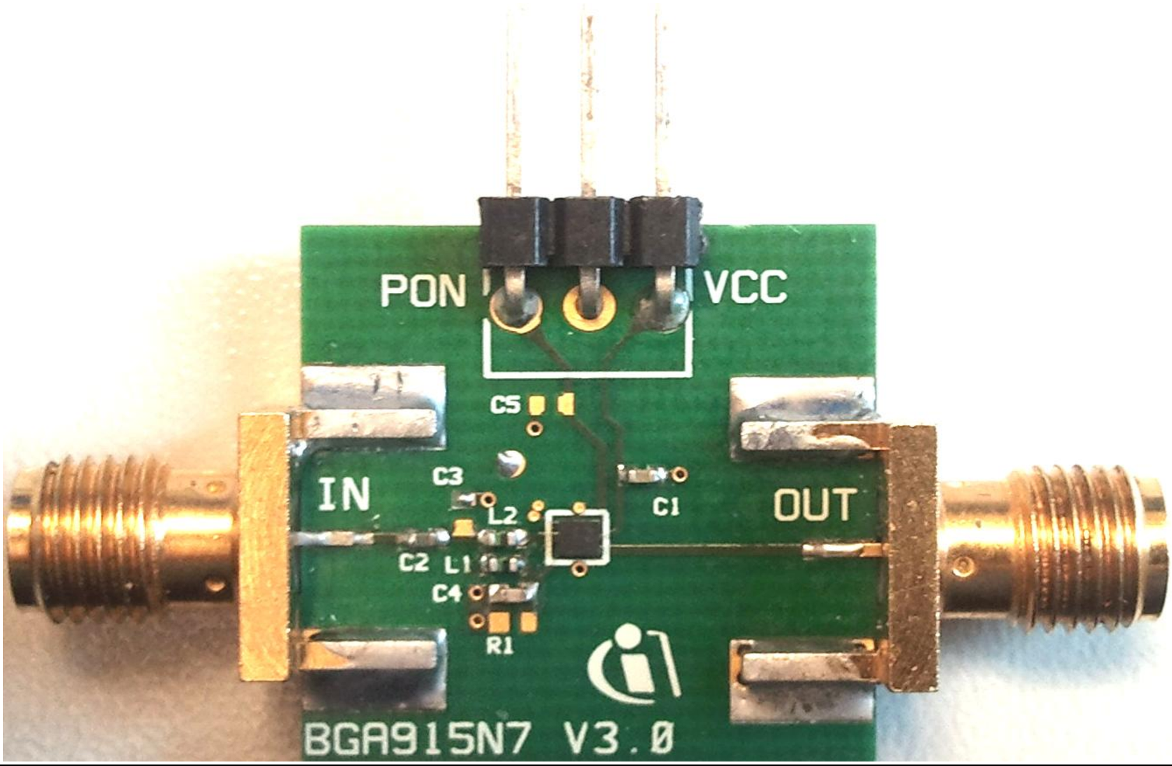


Figure 21 Populated PCB picture of BGA915N7

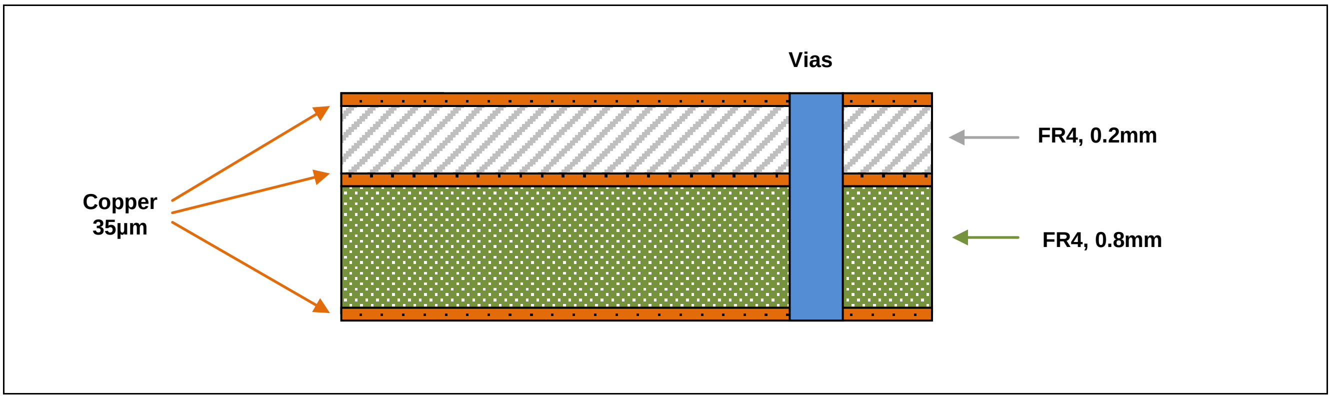


Figure 22 PCB layer stack

8 Authors

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