GNSS MMIC LNA: BGA524N6

Low Power Low Noise Amplifier for GNSS Applications in 1550 MHz - 1615 MHz using 0201 Components

Application Note AN420

About this document

Scope and purpose

This technical report describes Infineon's GNSS MMIC LNA: BGA524N6 as Low Noise Amplifer for Global Navigation Satellite System (1550 MHz – 1615 MHz) applications.

1. It presents the BGA524N6's performance at 1550 MHz - 1615 MHz when the DC current consumption is less than 1.7 mA and a 0201 size inductor is used for input matching.
2. The BGA524N6 is a Silicon-Germanium Low Noise Amplifer (LNA).
3. The BGA524N6 serves the Global Navigation Satellite System applications such as GPS, GLONASS, Galileo and Beidou.
4. The LNA's gain, noise figure, matching and linearity performance have been investigated on a FR4 board.
5. Key performance parameters achieved at 1.8 V, 1575.42 MHz
   a. Noise Figure = 1.07 dB
   b. Gain = 16.8 dB
   c. Input P1dB = -12.3 dBm
   d. Input IP3 = -12.8 dBm
   e. Out-of-band Input IP3 = -7.8 dBm

Table of Content

About this document **1**

1 Introduction of Global Navigation Satellite Systems (GNSS) Applications **4**
1.1 Infineon's Product Portfolio for the GNSS Applications 5
1.2 Key Features of Low Noise Amplifiers (LNAs) 5

2 BGA524N6 Overview **6**
2.1 Features 6
2.2 Key Applications of BGA524N6 6
2.3 Description 7

3 Application Circuit and Performance Overview **8**
3.1 Summary of Measurement Results 8
3.2 BGA524N6 as Low Noise Amplifer for GNSS Applications using 0201 Components 10
3.3 Schematics and Bill-of-Materials 11

4 Measurement Graphs **12**

5 Evaluation Board and Layout Information **20**

6 Authors **22**

Revision History **22**

List of Figures[1]

Figure 1 Application Diagram: Receiver Frontend the Global Navigation Satellite System With LNAs and Filter 4
For more information on Infineon's available product portfolio for the GNSS application, please visit Infineon's website at www.infineon.com. 5
Figure 2 BGA524N6 in TSNP-6-1 6
Figure 3 Package and pin connections of BGA524N6 7
Figure 4 Schematics of the BGA524N6 Application Circuit 11
Figure 5 Narrowband Gain of the BGA524N6 LNA for GNSS applications 12
Figure 6 Wideband Gain of BGA524N6 as LNA for GNSS applications 12
Figure 7 Noise Figure of BGA524N6 as LNA for GNSS applications 13
Figure 8 Input matching of BGA524N6 as LNA for GNSS applications 13
Figure 9 Input matching (Smith chart) of BGA524N6 as LNA for GNSS applications 14
Figure 10 Output matching of the BGA524N6 as LNA for GNSS applications 14
Figure 11 Output matching (Smith chart) of BGA524N6 as LNA for GNSS applications 15
Figure 12 Reverse isolation of BGA524N6 as LNA for GNSS applications 15
Figure 13 Stability factor k of BGA524N6 as LNA for GNSS applications 16
Figure 14 Stability factors of the BGA524N6 as LNA for GNSS applications 16
Figure 15 IP1dB of the BGA524N6 as LNA for GNSS applications (1.8 V / 1.5 V, GPS) 17
Figure 16 IP3 of the BGA524N6 as LNA for GNSS applications (1.8 V, GPS) 17
Figure 17 IP3 of the BGA524N6 as LNA for GNSS application (1.5 V, GPS) 18
Figure 18 Out-of-band IP3 of the BGA524N6 as LNA for GNSS applications (1.8 V, GPS) 18
Figure 19 Out-of-band IP3 of the BGA524N6 as LNA for GNSS applications (1.5 V, GPS) 19
Figure 20 Photo Picture of Evaluation Board (overview) <PCB Marking M260814> 20
Figure 21 Photo Picture of Evaluation Board (detailed view) 20
Figure 22 PCB Layer Information 21

List of Tables

Table 1 Pin Assignment of BGA524N6 7
Table 2 Mode Selection of BGA524N6 7
Table 3 Electrical Characteristics (at room temperature) at Vcc =1.8V 8
Table 4 Electrical Characteristics (at room temperature) at Vcc =1.5V 9
Table 5 Bill-of-Materials 11

1) The graphs are generated with the simulation program AWR Microwave Office®.

1 Introduction of Global Navigation Satellite Systems (GNSS) Applications

Global Navigation Satellite Systems (GNSS) are among the fastest growing businesses in the electronic industry. Today, GNSS is much more than the well-known GPS, which was introduced for civilian use more than a decade ago. Nations around the world are working on their own navigation satellite systems for strategic reasons and also to offer improved user experience. Today, three GNSS systems are operational: the United States GPS, the Russian GLONASS and the Chinese Beidou. The Galileo positioning system being developed by the European Union will start first service in 2016[1].

From a civilian usage point, additional systems added to GNSS bring with them the advantages of increased satellite signal reception, increased coverage, higher precision and the facility for additional features such as Search And Rescue (SAR). The most important market segments since 2008 are Personal Navigation Devices (PND) and GNSS enabled mobile phones. The architecture and the performance of the so-called RF front-end is the key contributor to fulfill the strict requirements of the GNSS system, because it consists of the whole line-up between the GNSS antenna and the integrated GNSS chipset. The main challenges for the growing GNSS-enabled mobile phone market are to achieve high sensitivity and high immunity against interference of cellular signals driven by government regulations for safety and emergency reasons, for example, in the US and Japan. This means the reception for GPS/GLONASS signals at very low power levels down to less than -160 dBm in mobile phones in the vicinity of co-existing high power cellular signals. In addition, excellent ESD robustness characteristics and low power consumption for long battery usage duration are mandatory features for portable and mobile phones. Below is an application diagram of the GNSS RF front-end.

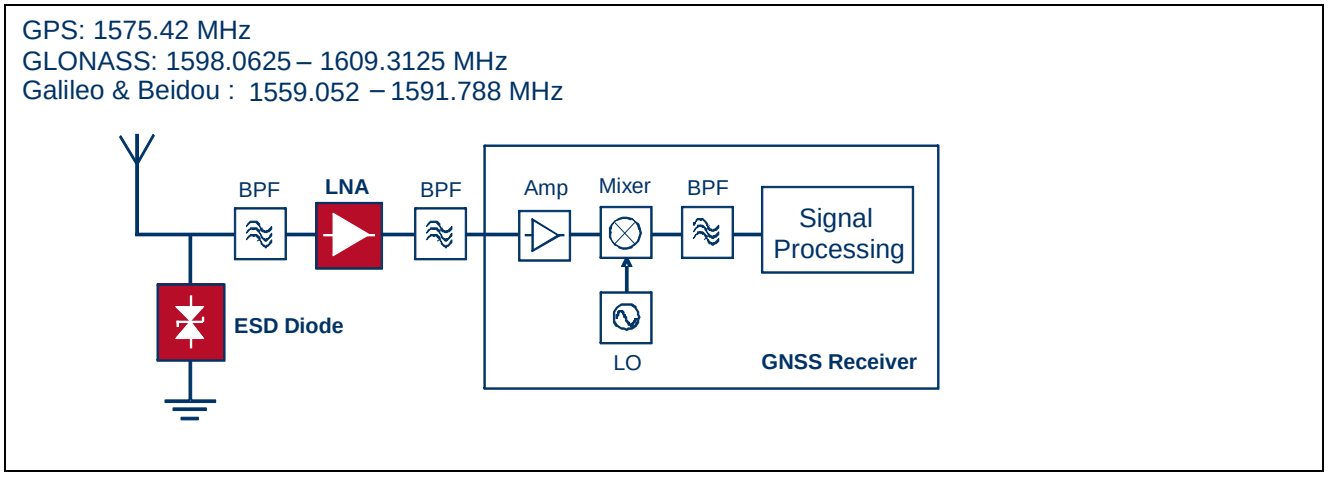

Figure 1 Application Diagram: Receiver Frontend the Global Navigation Satellite System With LNAs and Filter

1.1 Infineon's Product Portfolio for the GNSS Applications

Infineon Technologies is the market leader in GNSS LNAs for navigation applications in PND and cellular products. Infineon Technologies offers a complete product portfolio to all customers designing high performance flexible RF front-end solutions for GNSS:

- **Low Noise Amplifiers (LNA):** consisting of a wide range of products like high performance MMICs as well as cost effective and high end RF transistors
- **Front-End Module (FEM):** Infineon offers GPS/GLONASS FEMs with LNAs and band-pass filter(s) integrated into a single tiny package with well-optimized performance for navigation in mobile phones
- **Transient Voltage Suppression (TVS) Diodes:** protecting GNSS antenna reliably up to 20 kV

For more information on Infineon's available product portfolio for the GNSS application, please visit Infineon's website at **www.infineon.com**.

1.2 Key Features of Low Noise Amplifiers (LNAs)

Low Noise Figure & High Gain: The power levels of satellite signals received by a GPS/GNSS receiver are as low as -160 dBm. This poses a challenge on the sensitivity of the system. An external LNA with low noise figure and high gain is required to boost the sensitivity of the system and Time-To-First Fix (TTFF).

High Linearity: In modern mobile phones, the GNSS signals are co-habited by strong interfering cellular signals. The cellular signals can mix to produce Intermodulation products exactly in the GNSS receiver frequency band. To enhance interference immunity of the GNSS systems, LNAs with high linearity characteristics such as input IP3 and input P1dB are required.

Low Current Consumption: Power consumption is an important feature in GNSS devices which 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 low current consumption (down to 2.5 mA) makes Infineon's LNAs suitable for portable technology like GNSS receivers and mobile phones.

2 BGA524N6 Overview

2.1 Features

- High insertion power gain: 19.6 dB
- Out-of-band input 3rd order intercept point: -4 dBm
- Input 1 dB compression point: -12 dBm
- Low noise figure: 0.55 dB
- Low current consumption: 2.5 mA
- Operating frequencies: 1550 - 1615 MHz
- Supply voltage: 1.5 V to 3.3 V
- Digital on/off switch (1 V logic high level)
- Ultra small TSNP-6-2 leadless package (footprint: 0.7 x 1.1 mm^2)
- B7HF Silicon Germanium technology
- RF output internally matched to 50
- Only 1 external SMD component necessary
- 2 kV HBM ESD protection (including AI-pin)
- Pb-free (RoHS compliant) package

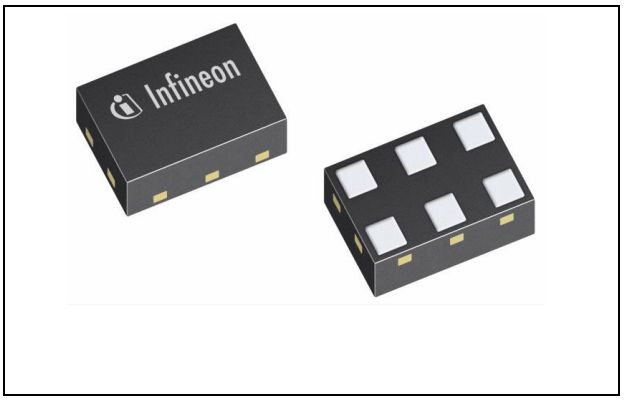

Figure 2 BGA524N6 in TSNP-6-1

2.2 Key Applications of BGA524N6

➢ Ideal for all Global Navigation Satellite Systems (GNSS) applications like

- GPS (US GNSS) working in the L1 band at 1575.42 MHz
- GLONASS (Russian GNSS) working in the L1 band from 1598.0625 MHz to 1605.3125 MHz
- Galileo (European GNSS) working in the E1 band from 1559.052 MHz to 1591.788 MHz
- Beidou (Chinese GNSS) working in E2 band at 1561.098 MHz

2.3 Description

The BGA524N6 is a front-end low noise amplifier for Global Navigation Satellite Systems (GNSS) from 1550 MHz to 1615 MHz like GPS, GLONASS, Galileo, Beidou and others. The LNA provides 19.6 dB gain and 0.55 dB noise figure at a current consumption of 2.5 mA only in the application configuration described in **Chapter 3**. The BGA524N6 is based upon Infineon Technologies B7HF Silicon Germanium technology. It operates from 1.5 V to 3.3 V supply voltage.

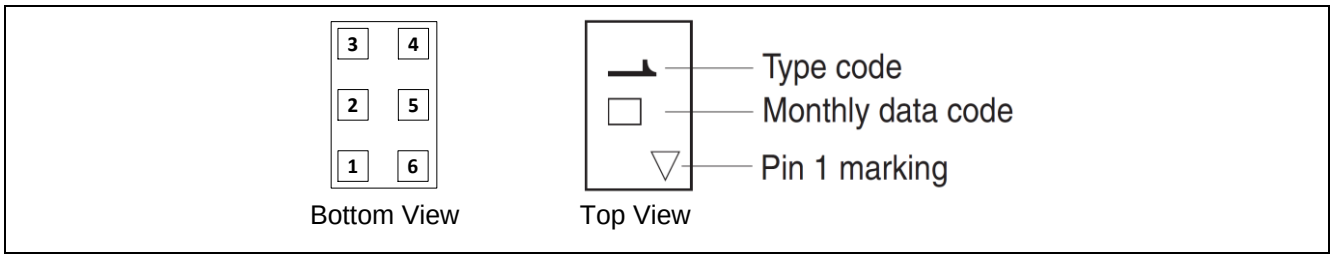

Figure 3 Package and pin connections of BGA524N6

Table 1 Pin Assignment of BGA524N6

Pin No.	Symbol	Function
1	GND	Ground
2	VCC	DC supply
3	AO	LNA output
4	GND	Ground
5	AI	LNA input
6	PON	Power on control

Table 2 Mode Selection of BGA524N6

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

Please visit the product page of **BGA524N6 (Link)** for more information.

3 Application Circuit and Performance Overview

In this chapter the performance of the application circuit, the schematic and bill-on-materials are presented.

Device: **BGA524N6**
Application: **Low Power LNA for GNSS Applications using 0201 Components**
PCB Marking: **M260814** V2.1
EVB Order No.: **AN420**

3.1 Summary of Measurement Results

Ther performance of BGA524N6 for Beidou/Galilieo/GPS/GLONASS applications is summarized in the following tables.

Table 3 Electrical Characteristics (at room temperature) at Vcc =1.8V

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	1.8			V	V_{PON} = Vcc
DC Current	Icc	1.62			mA	
System	Sys	Beidou	GPS Galileo	GLONASS		
Frequency Range	Freq	1559-1563	1575.42 1559-1591	1598-1609	MHz	f_{Beidou} = 1561.098 MHz $f_{GPS\ /\ Galileo}$ = 1575.42 MHz $f_{GLONASS}$ = 1602 MHz
Gain	G	16.8	16.8	16.7	dB	
Noise Figure	NF	1.06	1.07	1.08	dB	Loss of input line of 0.07 dB is deembeded
Input Return Loss	RLin	9.3	9.3	9.4	dB	
Output Return Loss	RLout	16.3	20.3	31.1	dB	
Reverse Isolation	IRev	37.3	37.4	37.7	dB	
Input P1dB	IP1dB	-12.4	-12.3	-12.6	dBm	
Output P1dB	OP1dB	3.4	3.5	3.1	dBm	
Input IP3	IIP3	-	-12.8	-	dBm	$f_{1Galileo/GPS}$ = 1575.42 MHz, $f_{2Galileo/GPS}$ = 1576.42 MHz; Pin = -30 dBm
Output IP3	OIP3	-	4.0	-	dBm	
Input IP3 (Out-of-band)	IIP3_oob	-7.8			--	f1 = 1712.7 MHz; f2 = 1850 MHz, Pin =-20dBm
Stability	k	>1				Unconditionnally stable from 0 to 10GHz

Table 4 Electrical Characteristics (at room temperature) at Vcc =1.5V

Parameter	Symbol	Value			Unit	Comment / Test Condition
DC Voltage	Vcc	1.5			V	
DC Current	Icc	1.69			mA	
System	Sys	Beidou	GPS Galileo	GLONASS		
Frequency Range	Freq	1559-1563	1575.42 1559-1591	1598-1609	MHz	f_{Beidou} = 1561.098 MHz $f_{GPS\ /\ Galileo}$ = 1575.42 MHz $f_{GLONASS}$ = 1602 MHz
Gain	G	16.7	16.7	16.5		
Noise Figure	NF	1.06	1.07	1.08	dB	Loss of input line of 0.07dB is deembeded
Input Return Loss	RLin	9.1	9.2	9.2	dB	
Output Return Loss	RLout	17.6	22.3	27.5	dB	
Reverse Isolation	IRev	37.4	37.2	37.7	dB	
Input P1dB	IP1dB	-15.0	-14.9	-15.2	dBm	
Output P1dB	OP1dB	0.7	0.8	0.3	dBm	
Input IP3	IIP3	-	-13.0	-	dBm	$f_{1Galileo/GPS}$ = 1575.42 MHz, $f_{2Galileo/GPS}$ = 1576.42 MHz; Pin = -30 dBm
Output IP3	OIP3	-	3.7	-	dBm	
Input IP3 (Out-of-band)	IIP3_oob	-7.6			--	f1 = 1712.7 MHz; f2 = 1850 MHz, Pin =-20dBm
Stability	k	>1			--	Unconditionnally stable from 0 to 10GHz

3.2 BGA524N6 as Low Noise Amplifer for GNSS Applications using 0201 Components

This technical report presents the BGA524N6 LNA performance at 1550 MHz – 1615 MHz with 1.8 V and 1.5 V supply voltages. The circuit includes a resistor at input side to reduce the current consumption to less than 1.7 mA at both voltage conditions.

At 1.8 V, 1575.42 MHz, the BGA524N6 LNA obtains gain of 16.8 dB and noise figure of less than 1.1 dB. The input return loss is 9.3 dB and output return loss is 20.3 dB. It reachs the input 1 dB compression point (IP1dB) at -12.3 dBm. Using two tones of -30 dBm spacing 1 MHz , the input third-order intercept point (IIP3) is 3.5 dBm. Using two tones of -20 dBm at 1712.7 MHz and 1850 MHz, the out-of-band input third-order intercept point (IIP3_oob) is -7.8 dBm for GPS application.

At 1.5 V, 1575.42 MHz, the BGA524N6 LNA obtains gain of 16.7 dB and noise figure of less than 1.1 dB. The input return loss is 9.2 dB and output return loss is 22.3 dB. It reachs the input 1 dB compression point (I P1dB) at -14.9 dBm. Using two tones of -30 dBm spacing 1 MHz , the input third-order intercept point (IIP3) is 3.7 dBm. Using two tones of -20 dBm at 1712.7 MHz and 1850 MHz, the out-of-band input third-order intercept point (IIP3_oob) is -7.6 dBm for GPS application.

The circuit is unconditionablelly stable up to 10 GHz. Above performance are measured on a FR4 board.

3.3 Schematics and Bill-of-Materials

Ther schematic of BGA524N6 for GNSS applications is presented in **Figure 4** and its bill-of-materials is shown in **Table 5**.

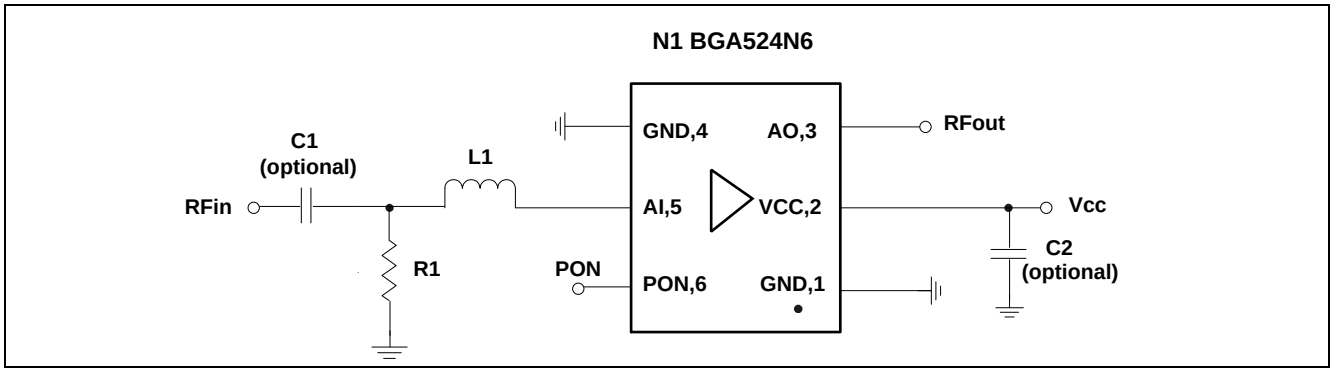

Figure 4 Schematics of the BGA524N6 Application Circuit

Table 5 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1 (optional)	>=1	nF	0201	Various	DC block
C2 (optional)	>10	nF	0201	Various	RF bypass
L1	8.2	nH	0201	Murata LQP03T series	Input matching
R1	56	kOhm	0201	Various	Current reduction
N1	BGA524N6		TSNP-6-2	Infineon	SiGe LNA

Note: DC block function is NOT integrated at input of BGA524N6. The DC block capacitor C1 is not necessary if the DC block function on the RF input line can be ensured by the previous stage.

Note: The RF bypass capacitor C2 at the DC power supply pin filters out the power supply noise and stabilize the DC supply. The RF bypass capacitor C2 is not necessary if a clean and stable DC supply can be ensured.

4 Measurement Graphs

The performance of the BGA524N6 application circuit is presented with the following graphs.

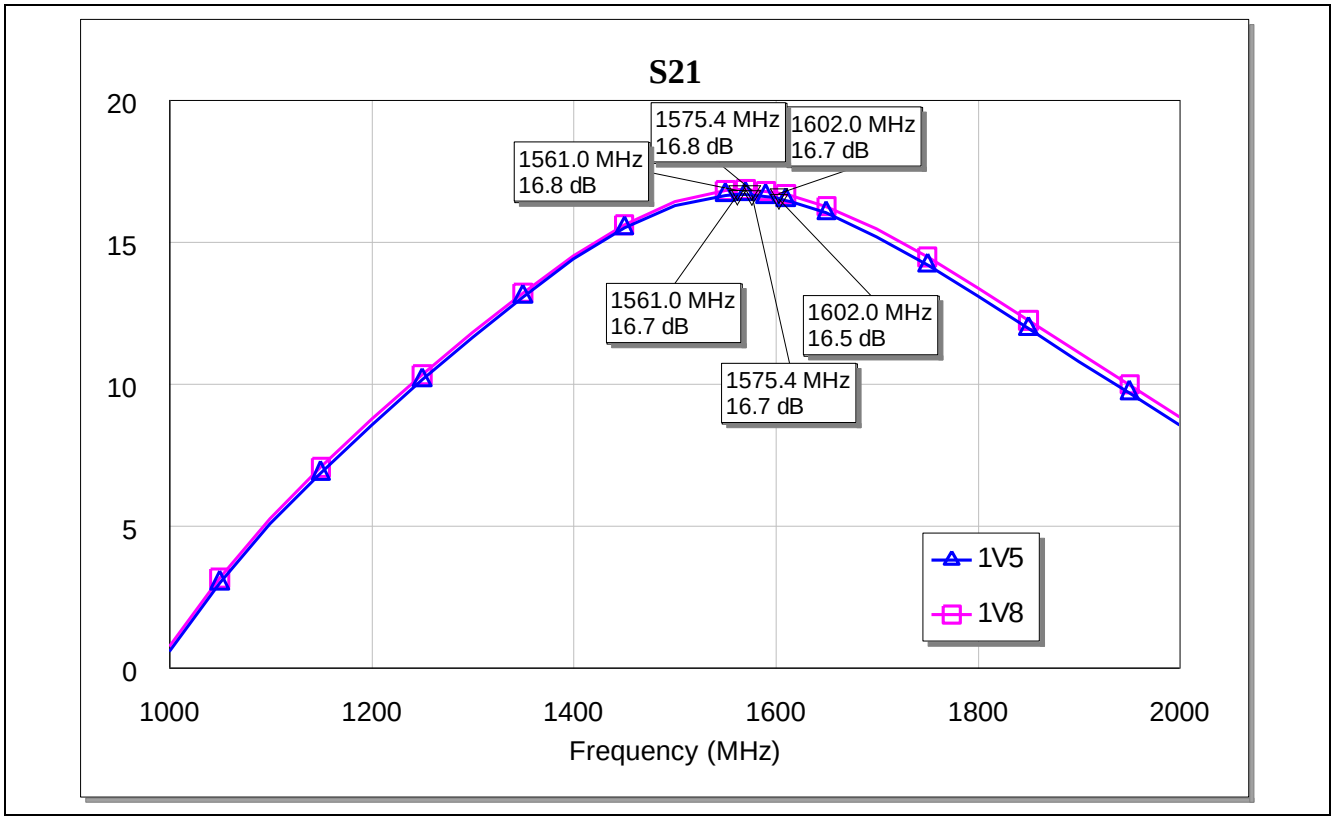

Figure 5 Narrowband Gain of the BGA524N6 LNA for GNSS applications

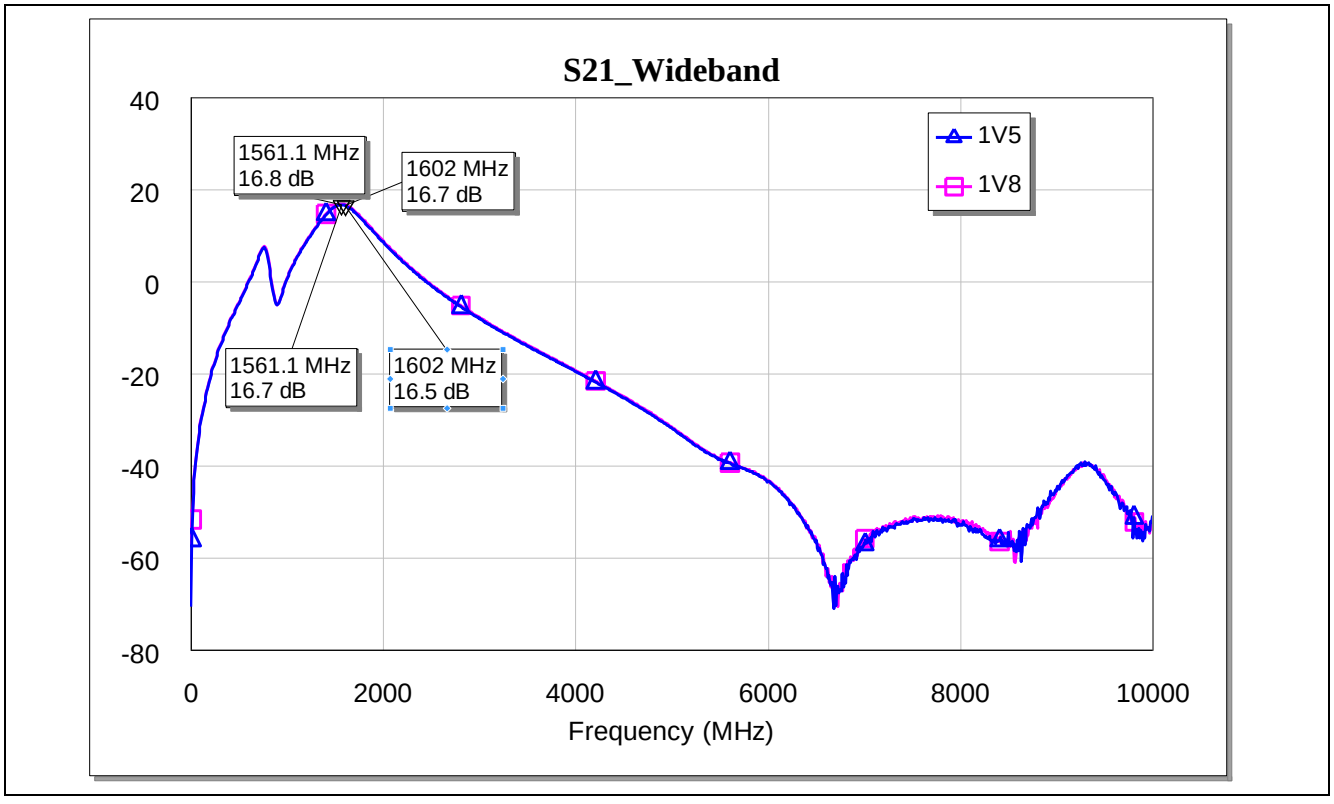

Figure 6 Wideband Gain of BGA524N6 as LNA for GNSS applications

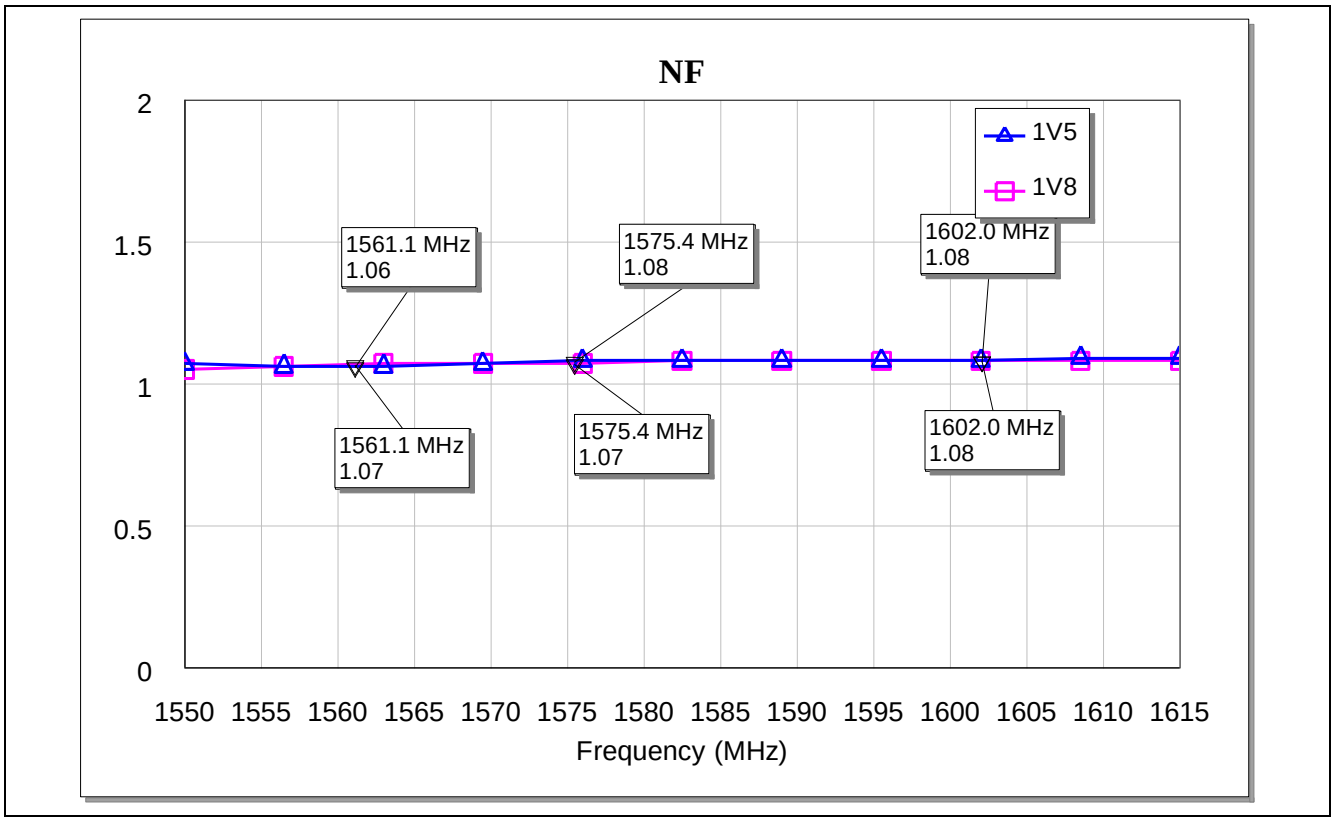

Figure 7 Noise Figure of BGA524N6 as LNA for GNSS applications

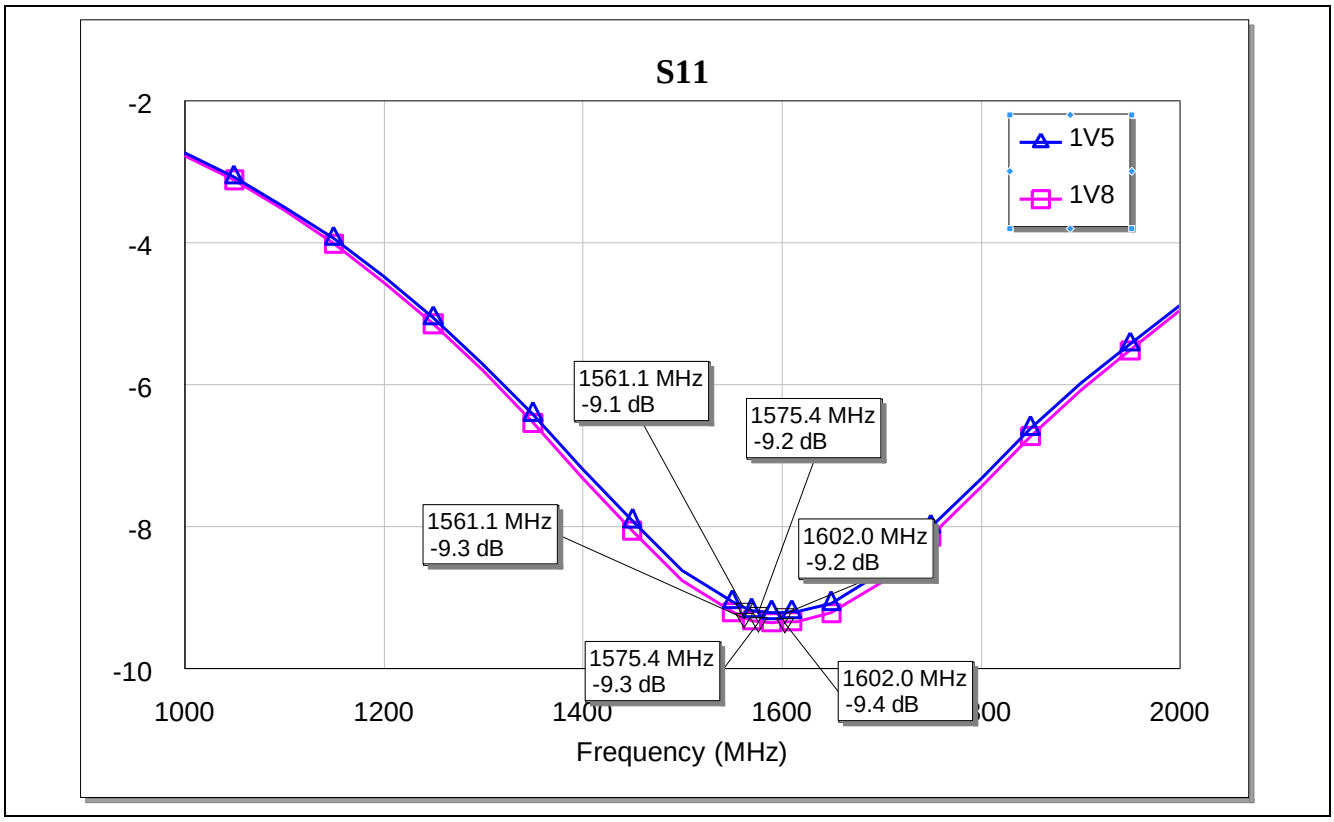

Figure 8 Input matching of BGA524N6 as LNA for GNSS applications

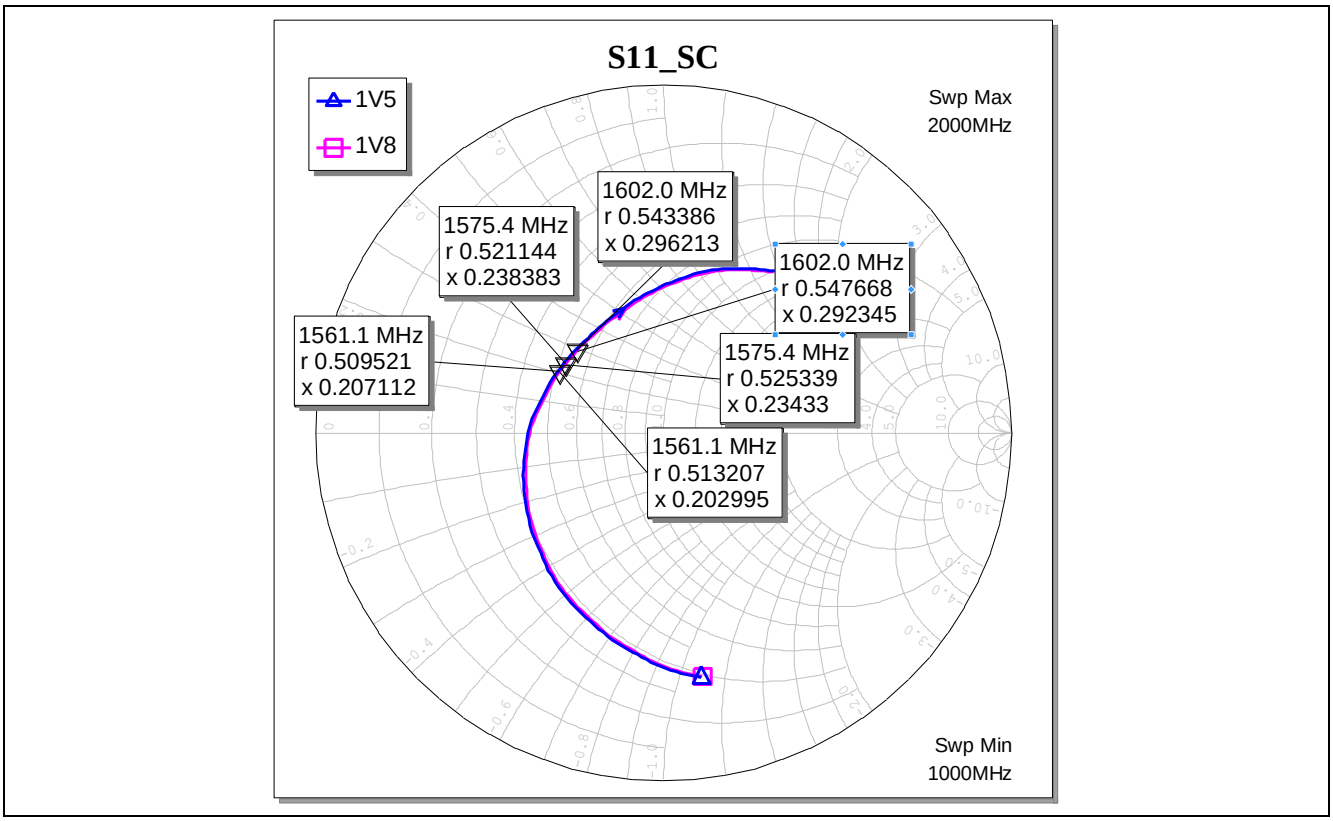

Figure 9 Input matching (Smith chart) of BGA524N6 as LNA for GNSS applications

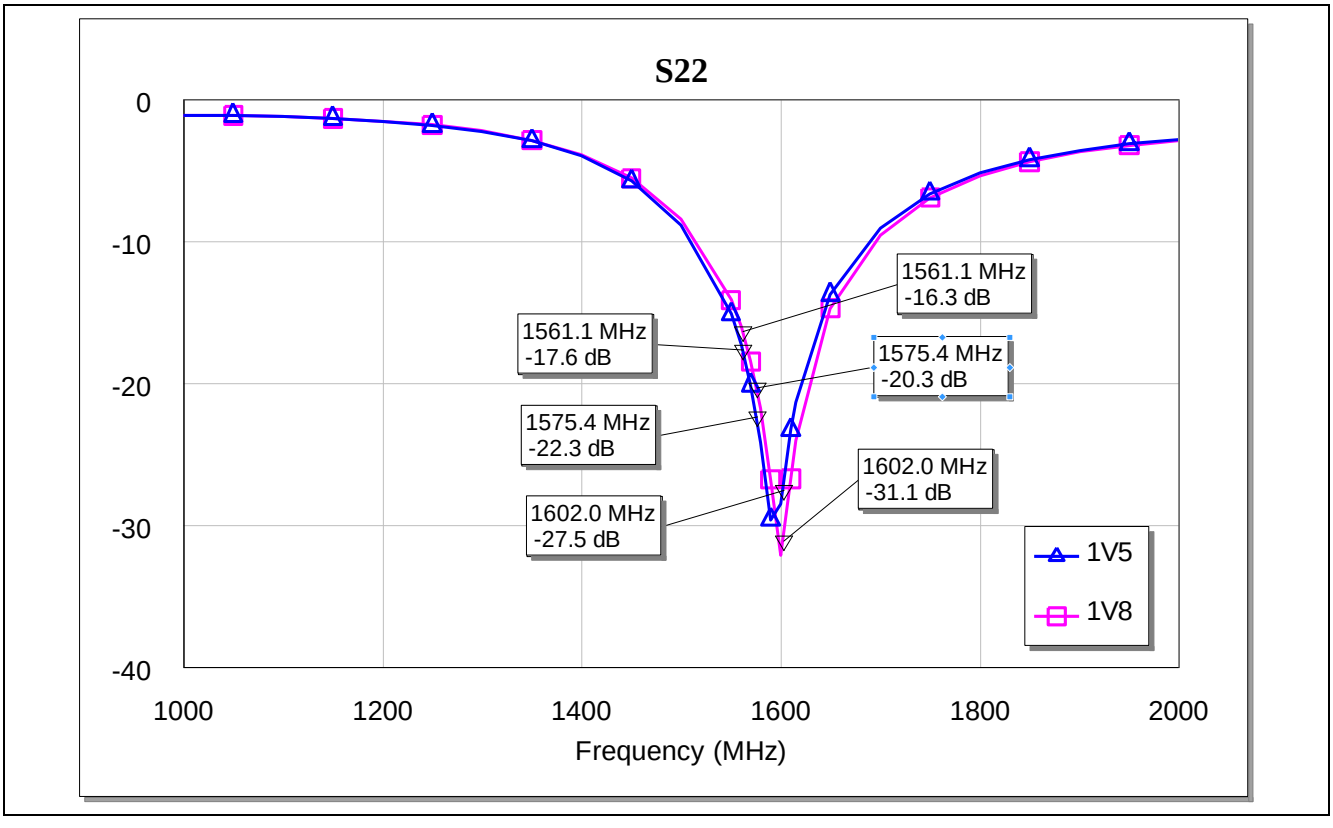

Figure 10 Output matching of the BGA524N6 as LNA for GNSS applications

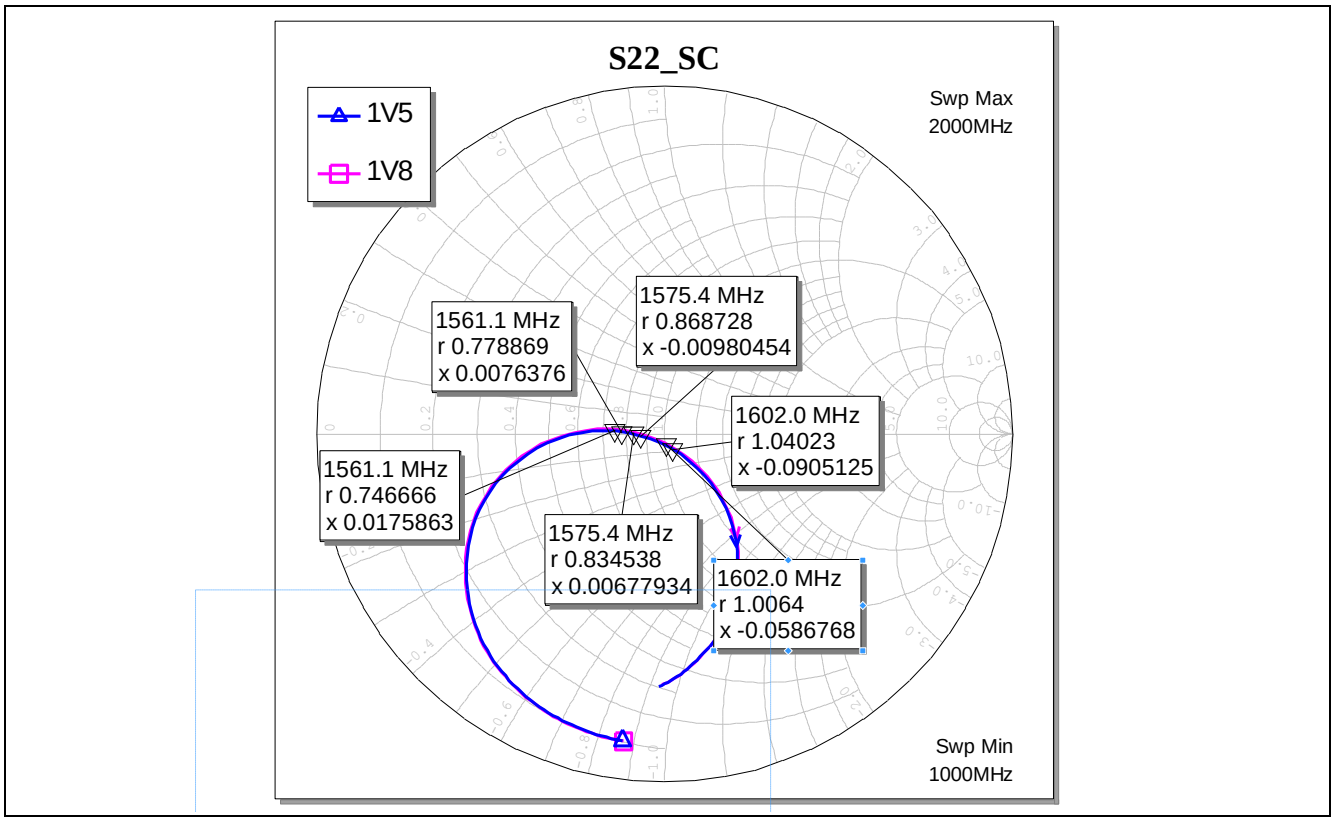

Figure 11 Output matching (Smith chart) of BGA524N6 as LNA for GNSS applications

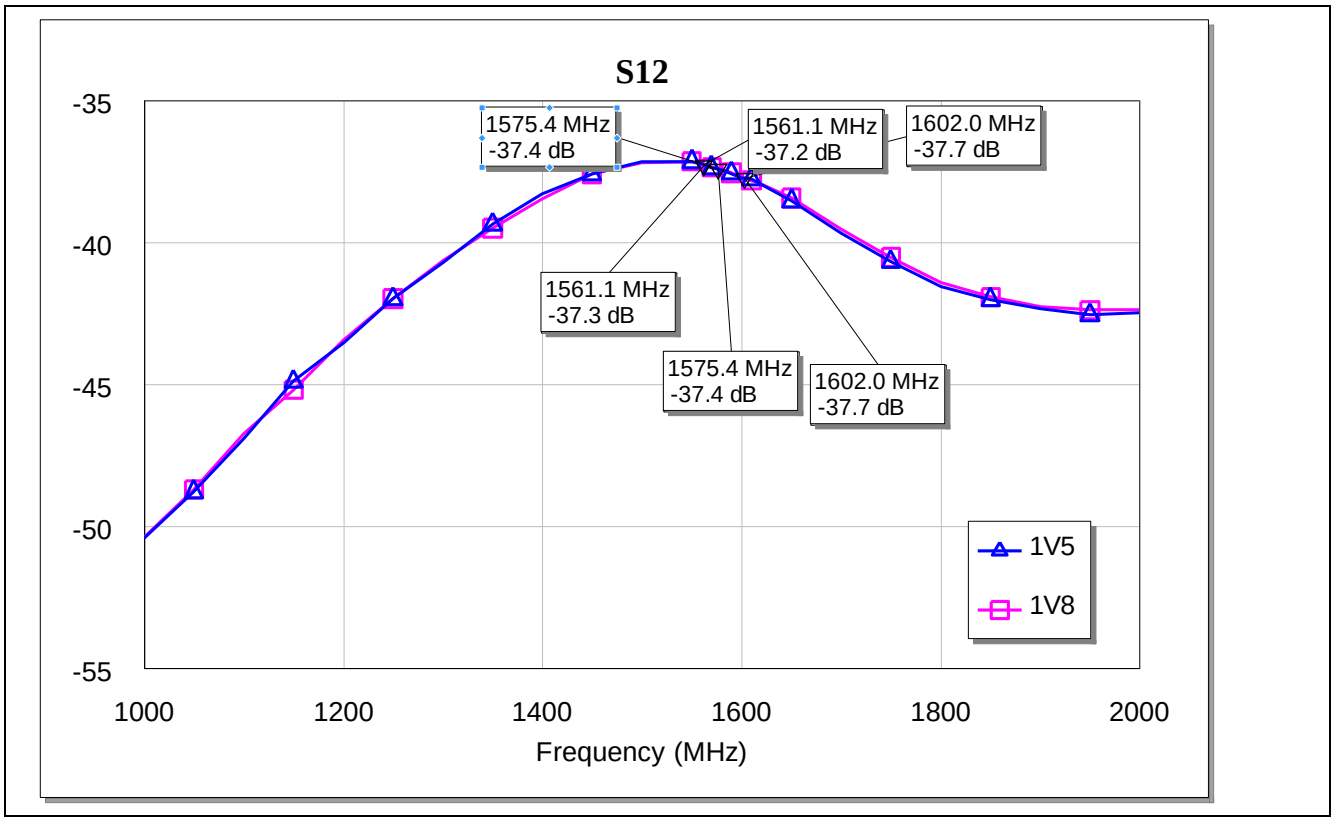

Figure 12 Reverse isolation of BGA524N6 as LNA for GNSS applications

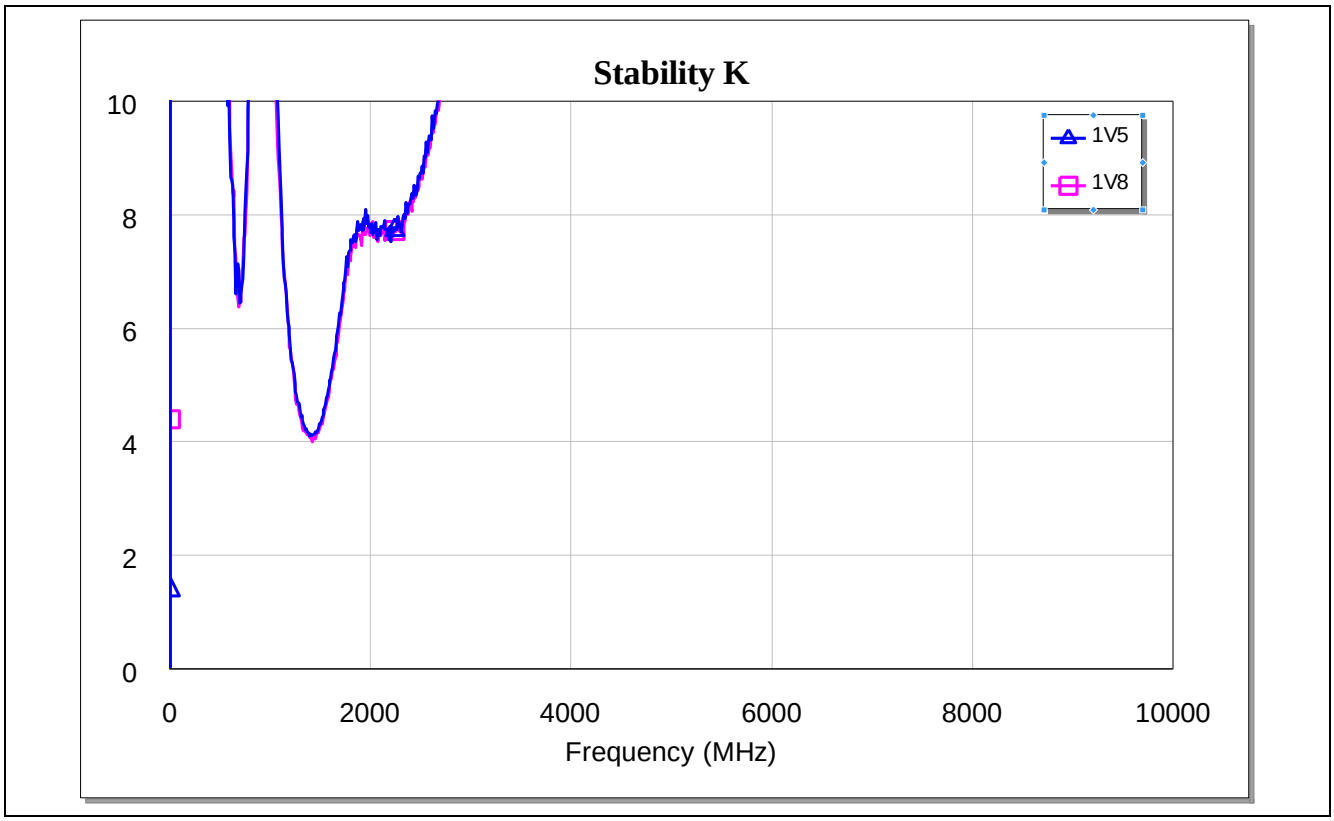

Figure 13 Stability factor k of BGA524N6 as LNA for GNSS applications

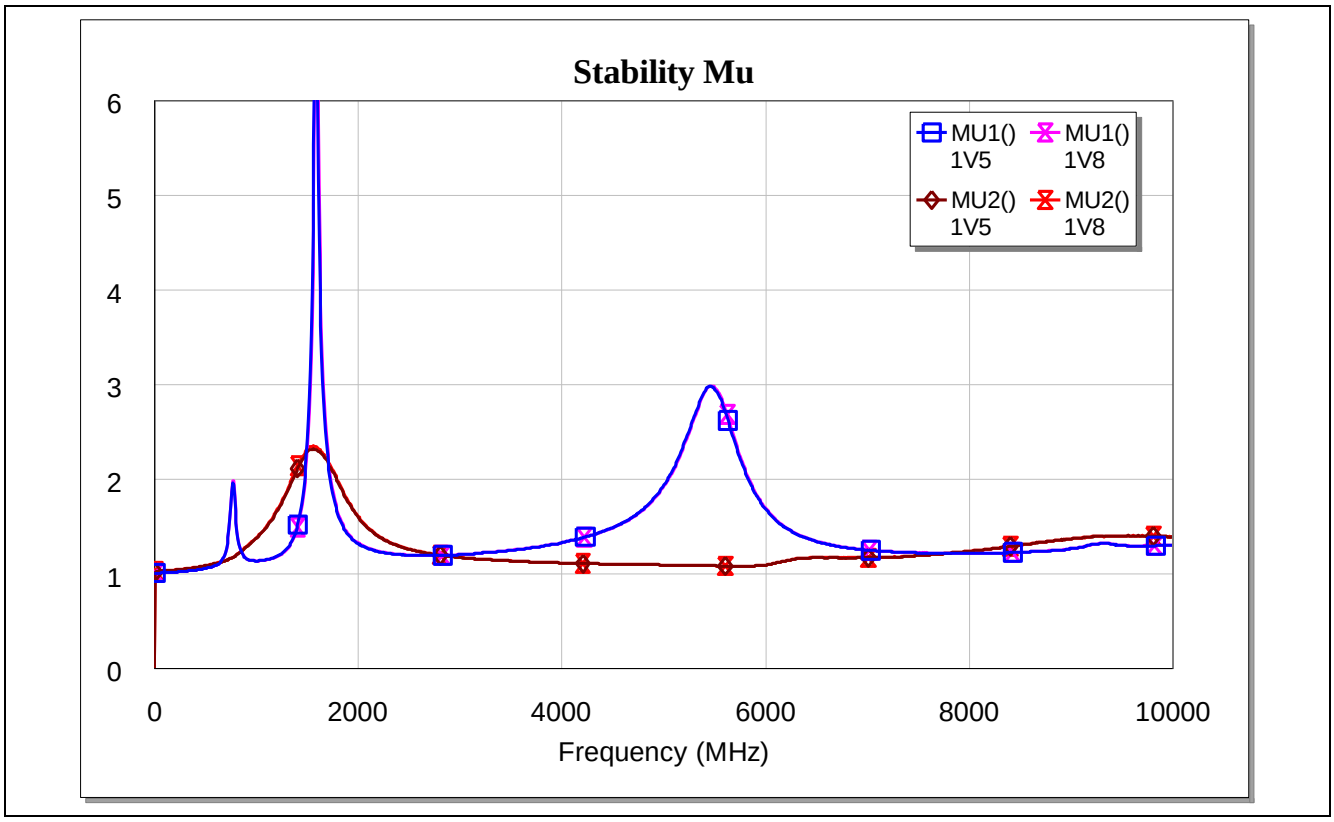

Figure 14 Stability factors of the BGA524N6 as LNA for GNSS applications

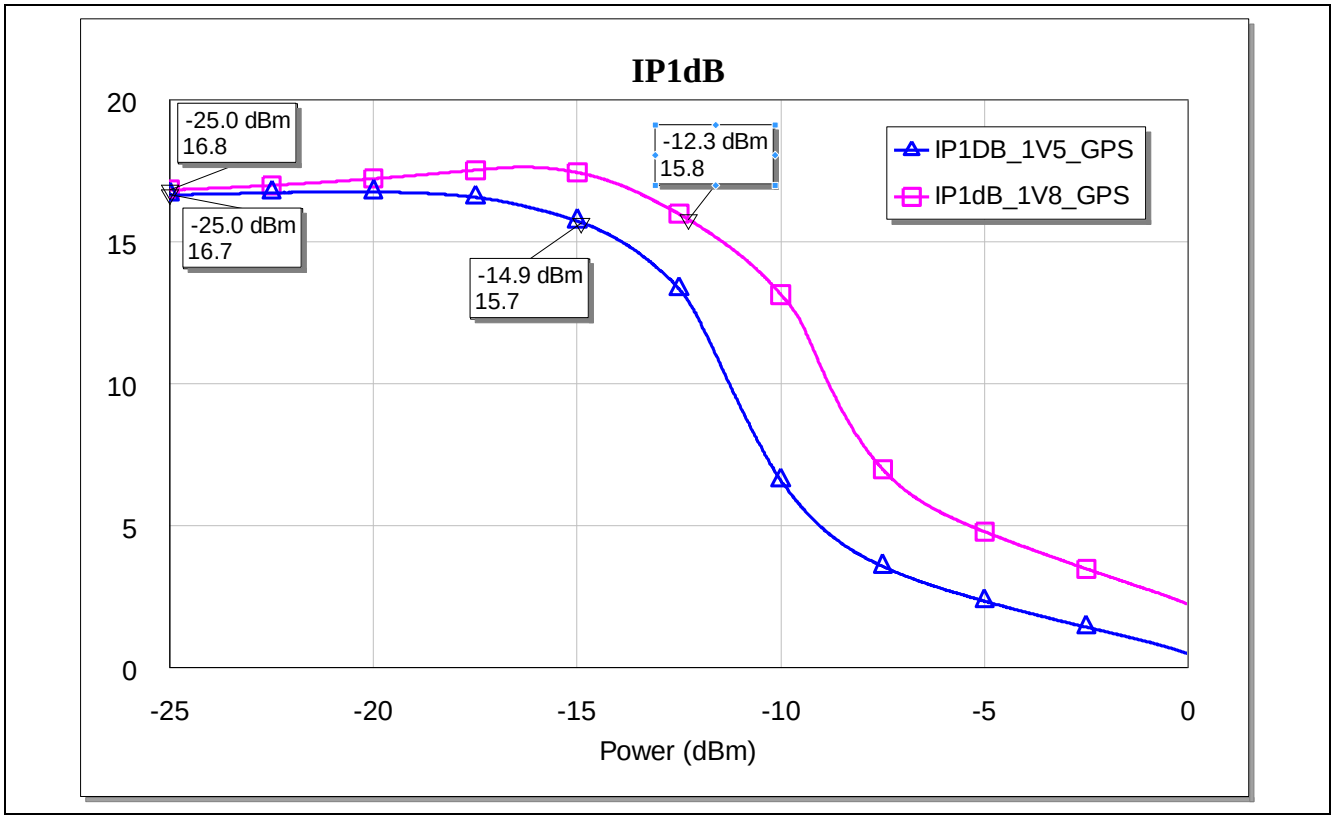

Figure 15 IP1dB of the BGA524N6 as LNA for GNSS applications (1.8 V / 1.5 V, GPS)

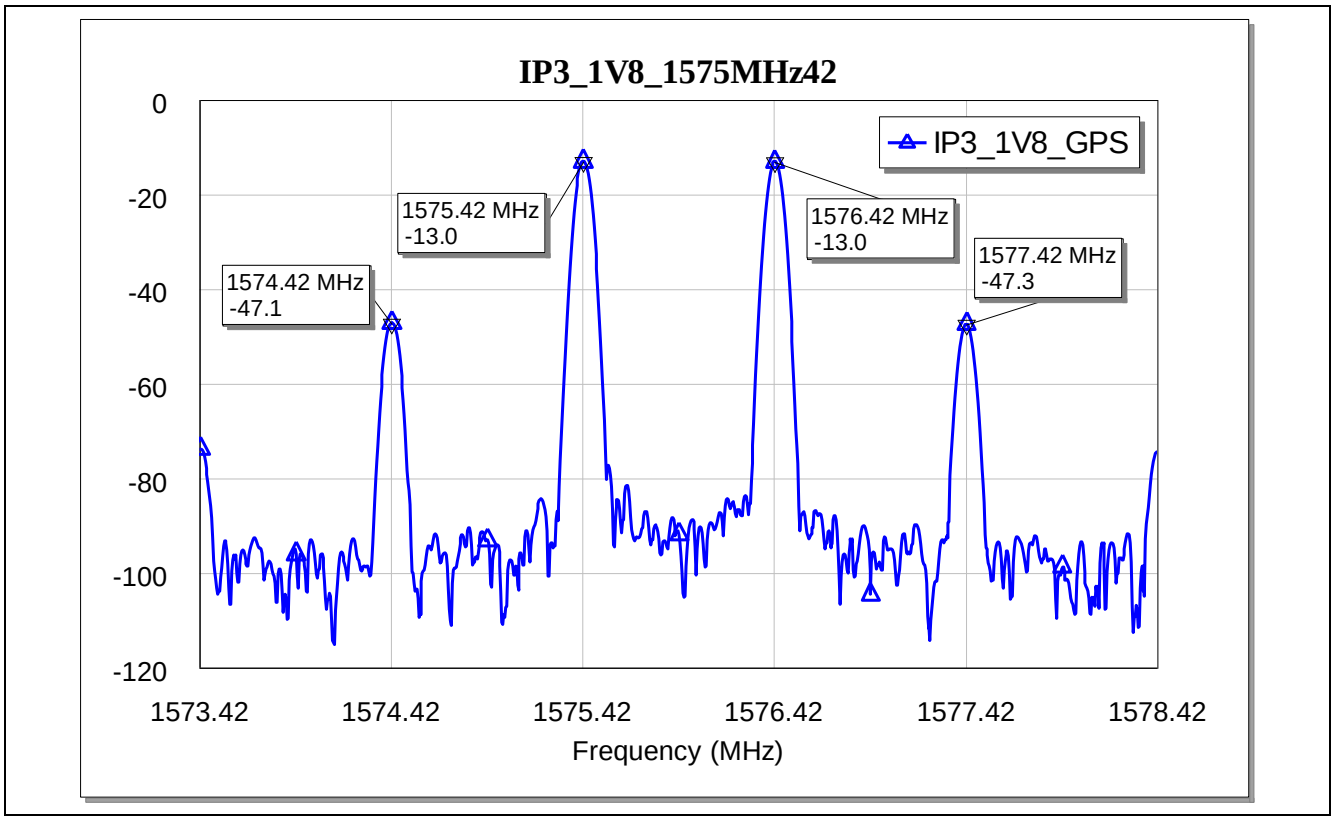

Figure 16 IP3 of the BGA524N6 as LNA for GNSS applications (1.8 V, GPS)

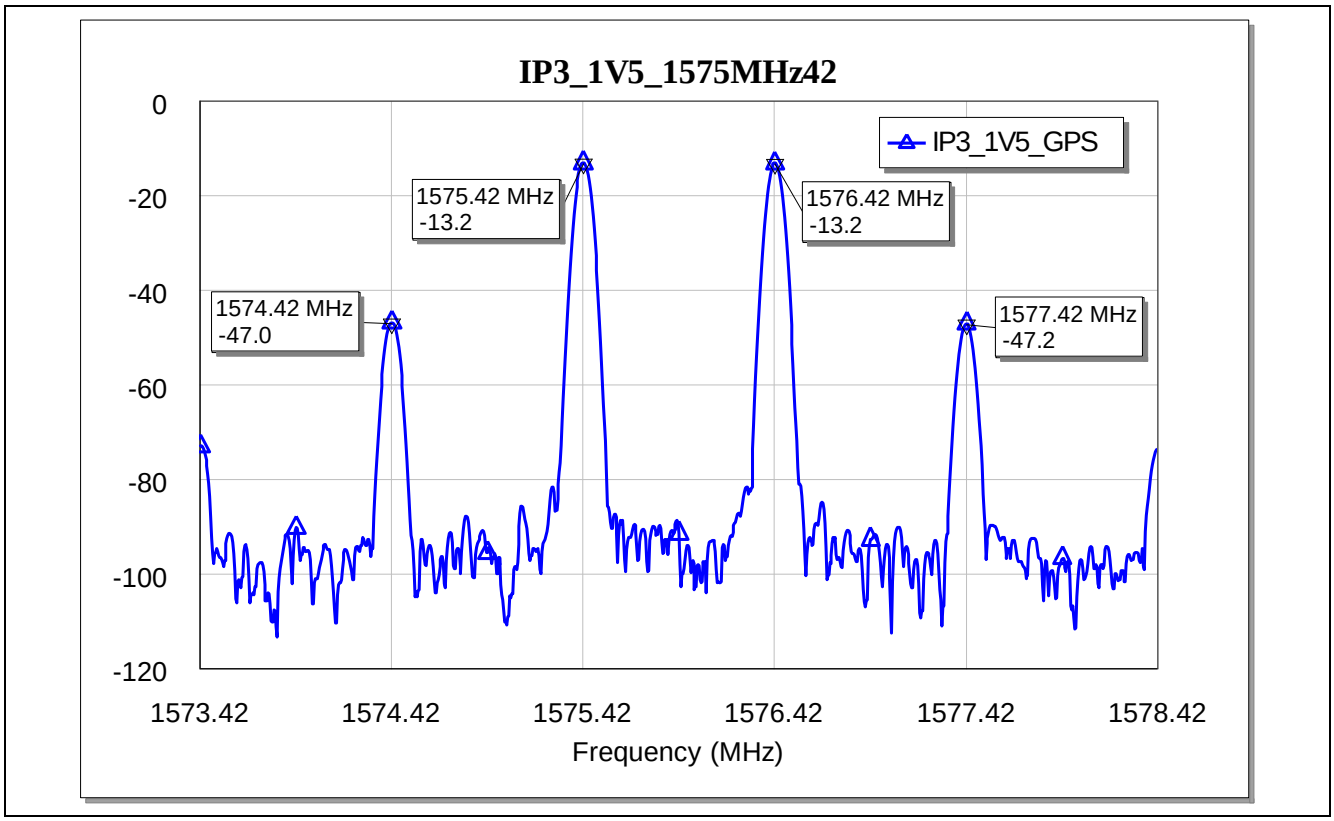

Figure 17 IP3 of the BGA524N6 as LNA for GNSS application (1.5 V, GPS)

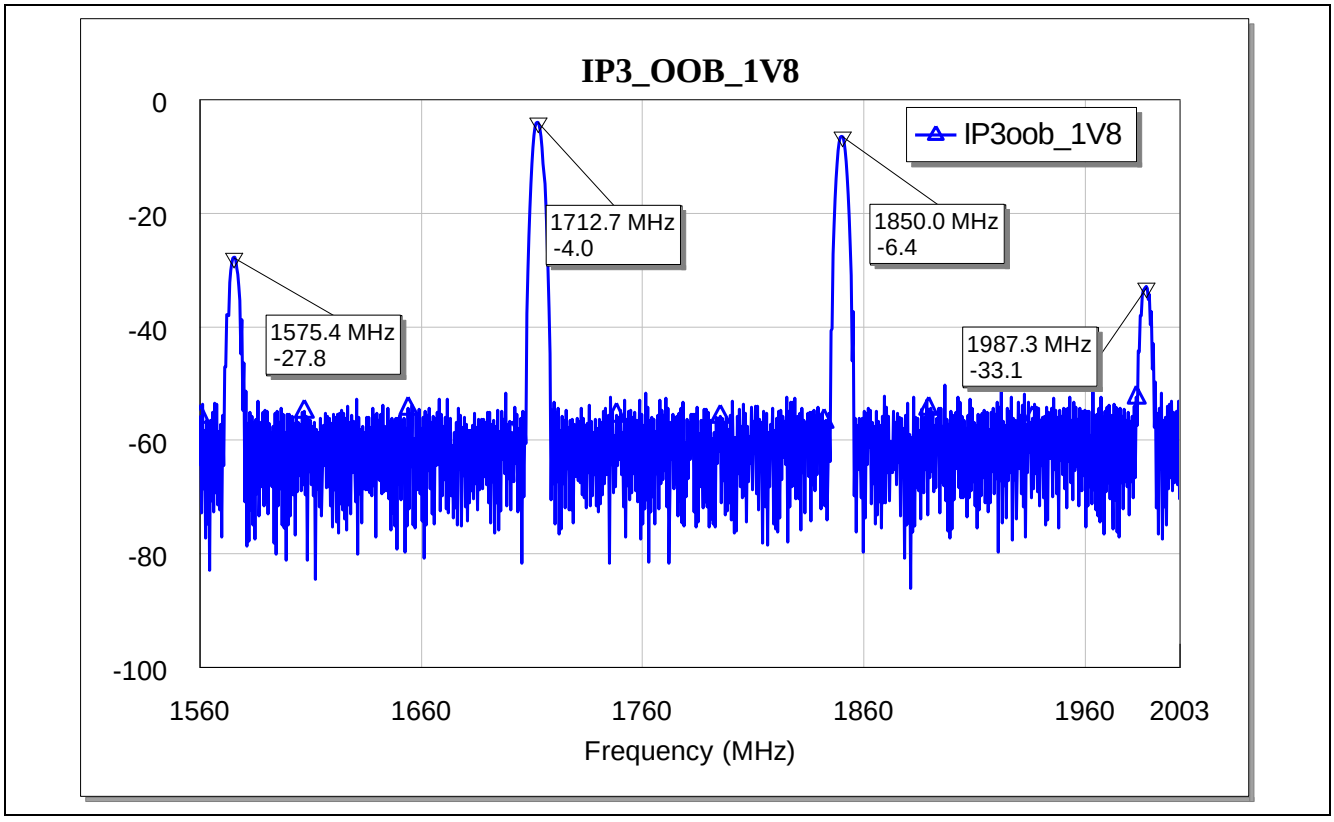

Figure 18 Out-of-band IP3 of the BGA524N6 as LNA for GNSS applications (1.8 V, GPS)

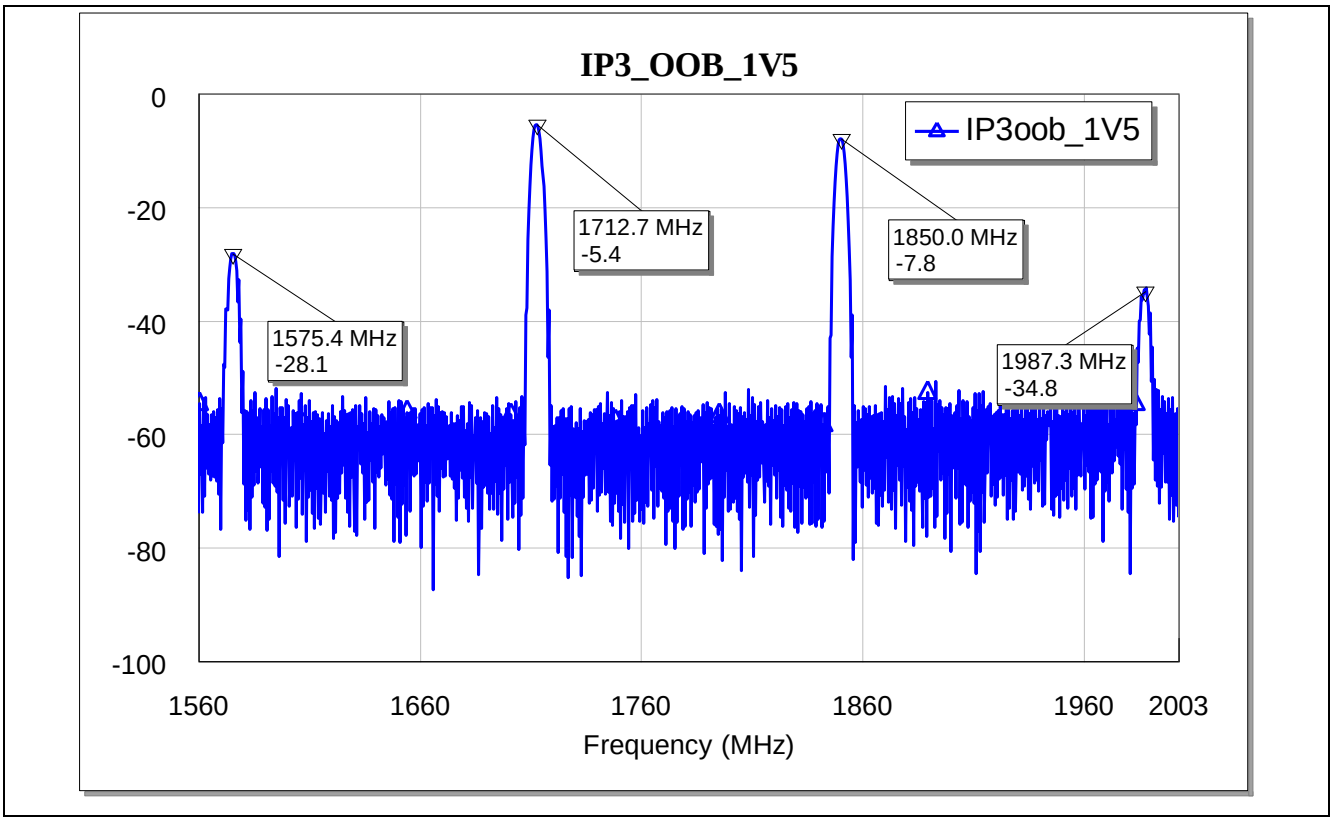

Figure 19 Out-of-band IP3 of the BGA524N6 as LNA for GNSS applications (1.5 V, GPS)

5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: **M260814 V2.1**

PCB material: **FR4**

ε_r of PCB material: **4.8**

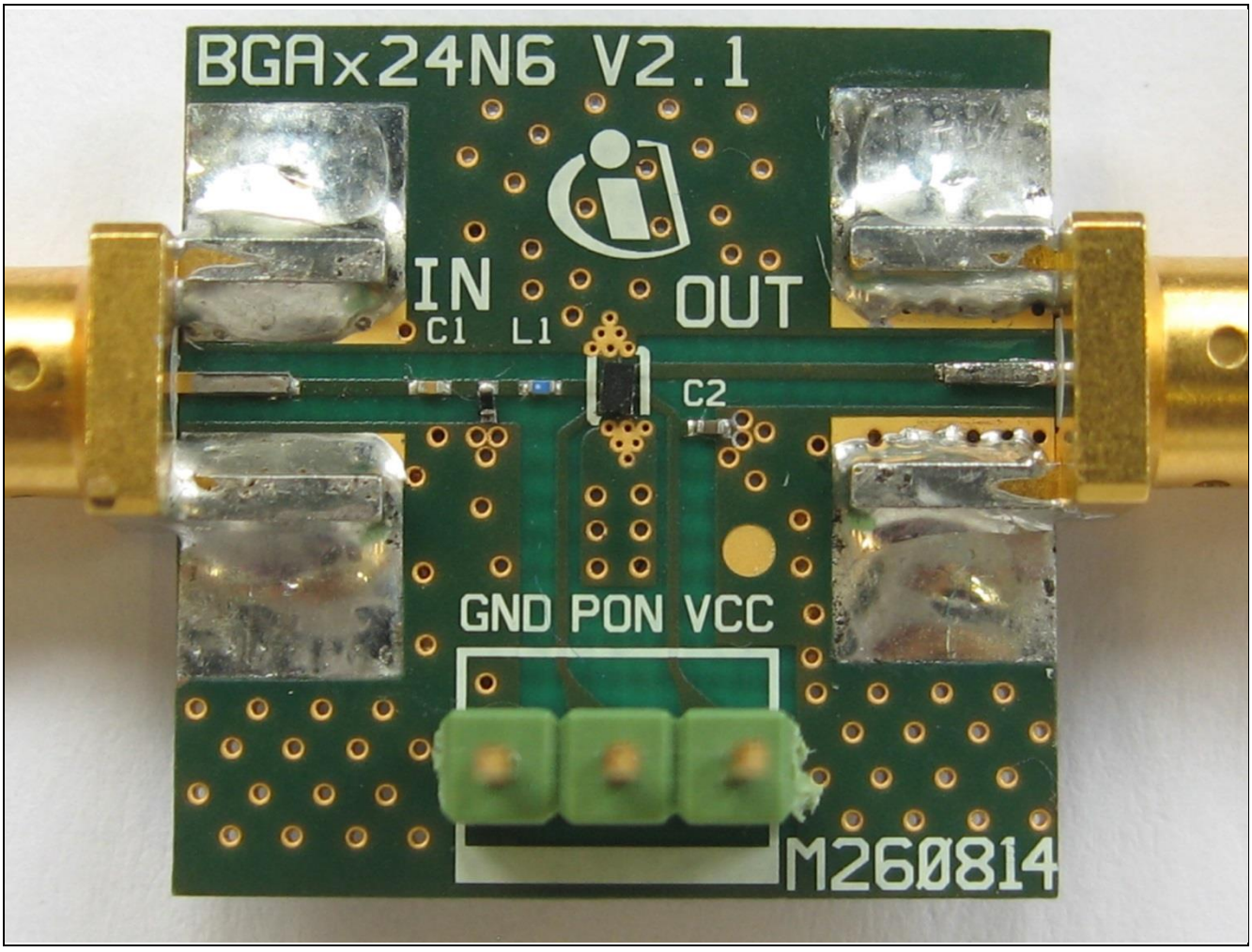

Figure 20 Photo Picture of Evaluation Board (overview) <PCB Marking M260814 V2.1>

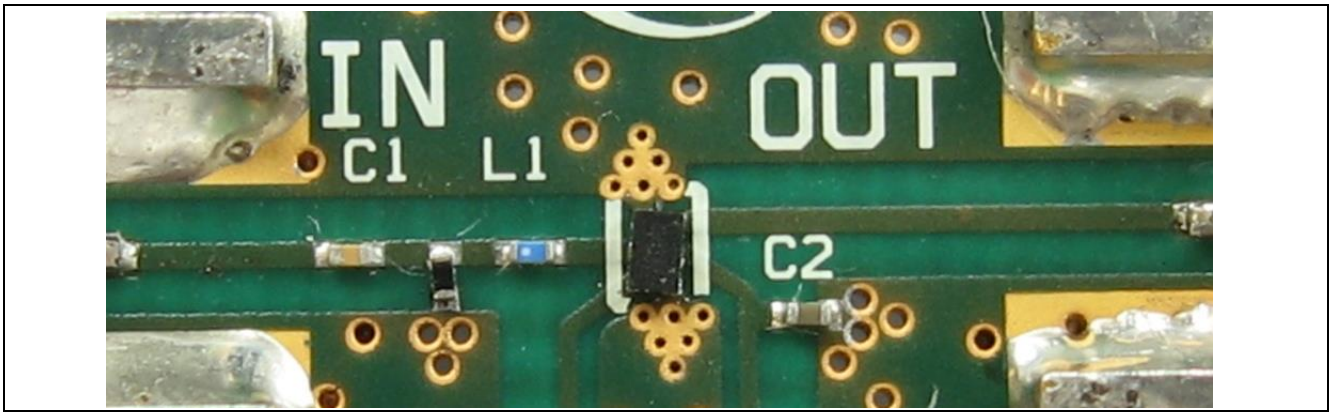

Figure 21 Photo Picture of Evaluation Board (detailed view)

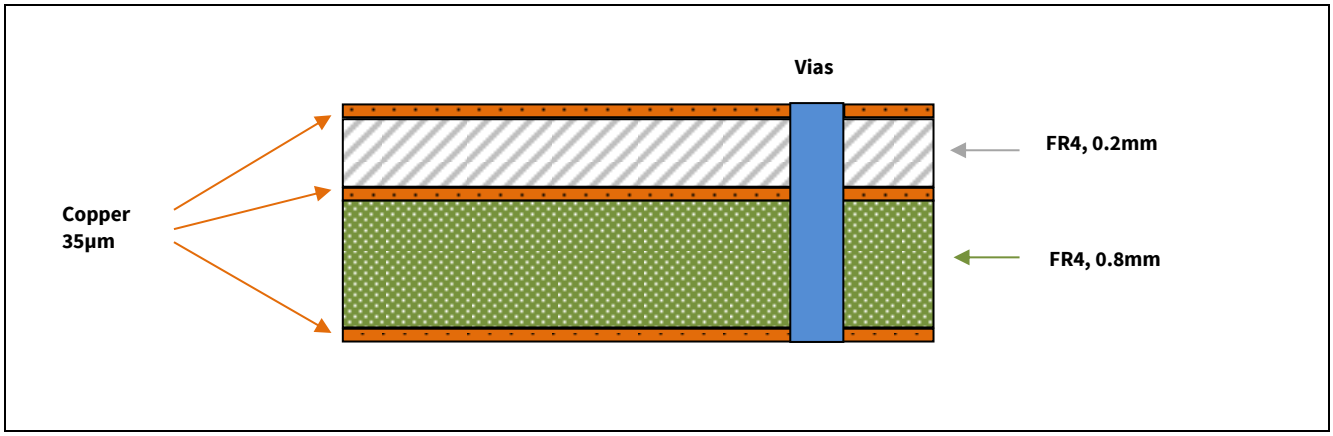

Figure 22 PCB Layer Information

6 Authors

Moakhkhrul Islam, Application Engineer of Business Unit “Radio Frequency and Sensors”
Xiang Li, Application Engineer of Business Unit “Radio Frequency and Sensors”

7 References

[1] http://europa.eu/rapid/press-release_IP-15-4717_en.htm

Revision History

Major changes since the last revision

Page or Reference	Description of change
all	V1.0 First release of document

Trademarks of Infineon Technologies AG

AURIX™, C166™, CanPAK™, CIPOS™, CIPURSE™, CoolGaN™, CoolMOS™, CoolSET™, CoolSiC™, CORECONTROL™, CROSSAVE™, DAVE™, DI-POL™, DrBLADE™, EasyPIM™, EconoBRIDGE™, EconoDUAL™, EconoPACK™, EconoPIM™, EiceDRIVER™, eupec™, FCOS™, HITFET™, HybridPACK™, ISOFACE™, IsoPACK™, i-Wafer™, MIPAQ™, ModSTACK™, my-d™, NovalithIC™, OmniTune™, OPTIGA™, OptiMOS™, ORIGA™, POWERCODE™, PRIMARION™, PrimePACK™, PrimeSTACK™, PROFET™, PRO-SIL™, RASIC™, REAL3™, ReverSave™, SatRIC™, SIEGET™, SIPMOS™, SmartLEWIS™, SOLID FLASH™, SPOC™, TEMPFET™, thinQ!™, TRENCHSTOP™, TriCore™.

Other Trademarks

Advance Design System™ (ADS) of Agilent Technologies, AMBA™, ARM™, MULTI-ICE™, KEIL™, PRIMECELL™, REALVIEW™, THUMB™, µVision™ of ARM Limited, UK. ANSI™ of American National Standards Institute. AUTOSAR™ of AUTOSAR development partnership. Bluetooth™ of Bluetooth SIG Inc. CAT-iq™ of DECT Forum. COLOSSUS™, FirstGPS™ of Trimble Navigation Ltd. EMV™ of EMVCo, LLC (Visa Holdings Inc.). EPCOS™ of Epcos AG. FLEXGO™ of Microsoft Corporation. HYPERTERMINAL™ of Hilgraeve Incorporated. MCS™ of Intel Corp. IEC™ of Commission Electrotechnique Internationale. IrDA™ of Infrared Data Association Corporation. ISO™ of INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. MATLAB™ of MathWorks, Inc. MAXIM™ of Maxim Integrated Products, Inc. MICROTEC™, NUCLEUS™ of Mentor Graphics Corporation. MIPI™ of MIPI Alliance, Inc. MIPS™ of MIPS Technologies, Inc., USA. muRata™ of MURATA MANUFACTURING CO., MICROWAVE OFFICE™ (MWO) of Applied Wave Research Inc., OmniVision™ of OmniVision Technologies, Inc. Openwave™ of Openwave Systems Inc. RED HAT™ of Red Hat, Inc. RFMD™ of RF Micro Devices, Inc. SIRIUS™ of Sirius Satellite Radio Inc. SOLARIS™ of Sun Microsystems, Inc. SPANSION™ of Spansion LLC Ltd. Symbian™ of Symbian Software Limited. TAIYO YUDEN™ of Taiyo Yuden Co. TEAKLITE™ of CEVA, Inc. TEKTRONIX™ of Tektronix Inc. TOKO™ of TOKO KABUSHIKI KAISHA TA. UNIX™ of X/Open Company Limited. VERILOG™, PALLADIUM™ of Cadence Design Systems, Inc. VLYNQ™ of Texas Instruments Incorporated. VXWORKS™, WIND RIVER™ of WIND RIVER SYSTEMS, INC. ZETEX™ of Diodes Zetex Limited.

Last Trademarks Update 2014-07-17

www.infineon.com

Edition 2015-06-02

Published by

Infineon Technologies AG

81726 Munich, Germany

© 2015 Infineon Technologies AG. All Rights Reserved.

Do you have a question about any aspect of this document?

Email: erratum@infineon.com

Document reference

AN_201506_PL32_004

Legal Disclaimer

THE INFORMATION GIVEN IN THIS APPLICATION NOTE (INCLUDING BUT NOT LIMITED TO CONTENTS OF REFERENCED WEBSITES) IS GIVEN AS A HINT FOR THE IMPLEMENTATION OF THE INFINEON TECHNOLOGIES COMPONENT ONLY AND SHALL NOT BE REGARDED AS ANY DESCRIPTION OR WARRANTY OF A CERTAIN FUNCTIONALITY, CONDITION OR QUALITY OF THE INFINEON TECHNOLOGIES COMPONENT. THE RECIPIENT OF THIS APPLICATION NOTE MUST VERIFY ANY FUNCTION DESCRIBED HEREIN IN THE REAL APPLICATION. INFINEON TECHNOLOGIES HEREBY DISCLAIMS ANY AND ALL WARRANTIES AND LIABILITIES OF ANY KIND (INCLUDING WITHOUT LIMITATION WARRANTIES OF NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS OF ANY THIRD PARTY) WITH RESPECT TO ANY AND ALL INFORMATION GIVEN IN THIS APPLICATION NOTE.

Information

For further information on technology, delivery terms and conditions and prices, please contact the nearest Infineon Technologies Office (**www.infineon.com**).

Warnings

Due to technical requirements, components may contain dangerous substances. For information on the types in question, please contact the nearest Infineon Technologies Office. Infineon Technologies components may be used in life-support devices or systems only with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.