# GNSS MMIC LNA: BGA524N6

# Low Noise Amplifer for GPS L2 Band at 1227.6 MHz using 0201 Components

Application Note AN418

## About this document

### Scope and purpose

This application note describes Infineon's GNSS MMIC LNA: BGA524N6 as Low Noise Amplifer for Global Navigation Satellite System L2 Band (1227. 6 MHz) application.

1. This application note presents the BGA524N6's performance at 1227.6 MHz.
2. The BGA524N6 is a Silicon-Germanium Low Noise Amplifer serving the Global Navigation Systems such as GPS, GLONASS, Galileo and Beidou.
3. We have investigated the BGA524N6's gain, noise figure, matching and linearity performance on a FR4 board.
4. Key performance parameters achieved at 1.8V, 1227.6 MHz
   a. Noise Figure = 1.0 dB
   b. Gain = 17.9 dB
   c. Input P1dB = - 14.9 dBm
   d. Input IP3 = -12.6 dBm

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

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# 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 offering service by 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.

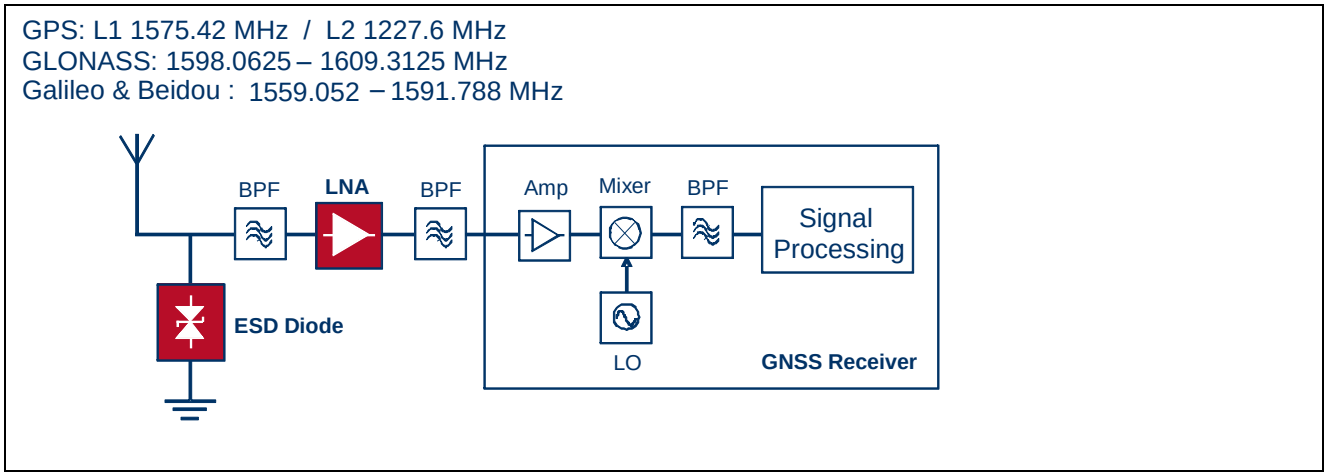


**Figure 1 Application Diagram: Receiver Frontend the Global Navigation Satellite System With LNAs and Filter**

## 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

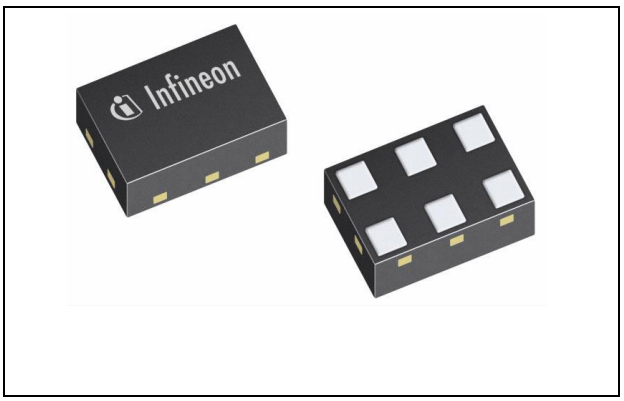


**Figure 2 BGA524N6 in TSNP-6-1**

## 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.

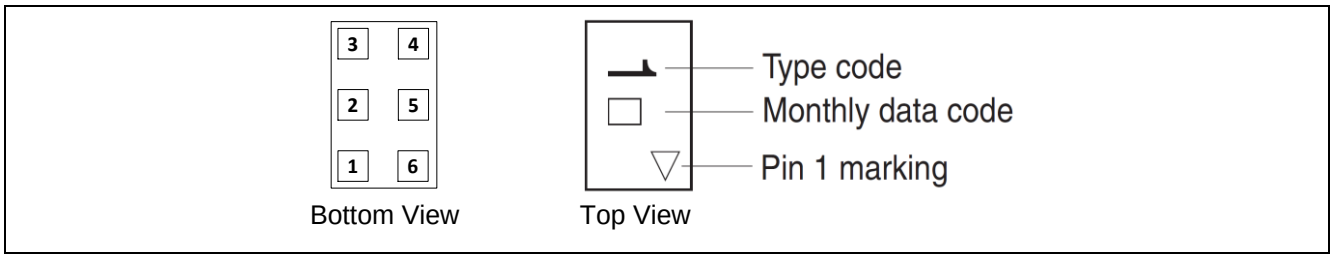


**Figure 3 Package and pin connections of BGA524N6**

**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** 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 Noise Amplifer for GPS L2 Band Application**
**PCB Marking:** **M161214** V5.0
**EVB Order No.:** **AN418**

## 3.1 Summary of Measurement Results

The performance of BGA524N6 for GPS L2 band (1227.6 MHz) application 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 | 2.5 | mA | |
| Frequency Range | Freq | 1227.6 | MHz | |
| Gain | G | 17.9 | dB | |
| Noise Figure | NF | 1.0 | dB | Loss of input line of 0.06 dB is deembeded |
| Input Return Loss | RLin | 15.2 | dB | |
| Output Return Loss | RLout | 14.6 | dB | |
| Reverse Isolation | IRev | 37.2 | dB | |
| Input P1dB | IP1dB | -14.9 | dBm | |
| Output P1dB | OP1dB | 2.0 | dBm | |
| Input IP3 | IIP3 | -12.6 | dBm | $f_1$ = 1227.6 MHz, $f_2$ = 1228.6 MHz; Pin = -30 dBm |
| Output IP3 | OIP3 | 5.3 | dBm | |
| Stability | k | >1 | | Unconditionnally stable from 0 to 10GHz |

**Table 4 Electrical Characteristics (at room temperature) at Vcc =2.8V**

| Parameter | Symbol | Value | Unit | Comment / Test Condition |
|---|---|---|---|---|
| DC Voltage | Vcc | 2.8 | V | |
| DC Current | Icc | 2.5 | mA | |
| Frequency Range | Freq | 1227.6 | MHz | |
| Gain | G | 17.8 | dB | |
| Noise Figure | NF | 1.0 | dB | Loss of input line of 0.06dB is deembeded |
| Input Return Loss | RLin | 15.6 | dB | |
| Output Return Loss | RLout | 16.2 | dB | |
| Reverse Isolation | IRev | 36.7 | dB | |
| Input P1dB | IP1dB | -14.2 | dBm | |
| Output P1dB | OP1dB | 2.6 | dBm | |
| Input IP3 | IIP3 | -12.5 | dBm | $f_1$ = 1227.6 MHz, $f_2$ = 1228.6 MHz; Pin = -30 dBm |
| Output IP3 | OIP3 | 5.3 | dBm | |
| Stability | k | >1 | -- | Unconditionnally stable from 0 to 10GHz |

## 3.2 BGA524N6 as Low Noise Amplifer for GPS L2 Band Application Using 0201 Components

This application note presents the BGA524N6 LNA performance at GPS L2 Band with 1.8 V and 2.8 V power supply. The LNA 524N6 features a current consumption of 2.5 mA at both voltage conditions.

At 1.8 V, 1227.6 MHz, the BGA524N6 LNA obtains gain of 17.9 dB and Noise Figure of 1.0 dB. The input return loss is 15.2 dB and output return loss is 14.6 dB. It reach the input 1 dB compression point at – 14.9 dBm. Using two tones of -30 dBm spacing 1 MHz , the input third-order intercept point (IIP3) is -12.6 dBm at 1227.6 MHz.

At 2.8 V, 1227.6 MHz, the BGA524N6 LNA obtains gain of 17.8 dB and Noise Figure of 1.0 dB. The input return loss is 15.6 dB and output return loss is 16.2 dB. It reaches the input 1 dB compression point at – 14.2 dBm. Using two tones of -30 dBm spacing 1 MHz , the input third-order intercept point (IIP3) is -12.5 dBm at 1227.6 MHz.

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 GPS L2 Band Application is presented in **Figure 4** and its bill-of-materials is shown in **Table 5**.

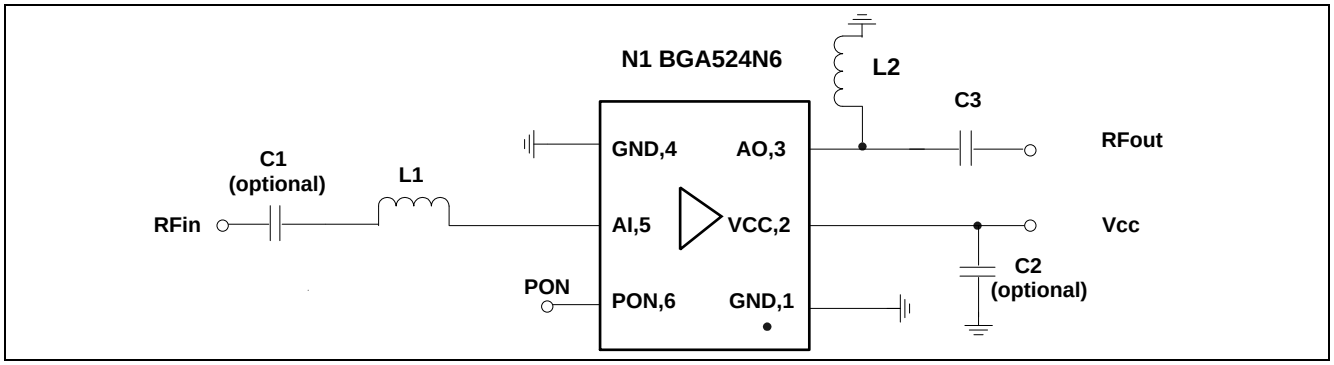


**Figure 4 Schematics of the BGA524N6 Application Circuit**

**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 |
| C3 | 6.8 | pF | 0201 | Various | Output matching |
| L1 | 12 | nH | 0201 | Murata LQP03T series | Input matching |
| L2 | 2.7 | nH | 0201 | Murata LQP03T series | Output matching |
| 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.

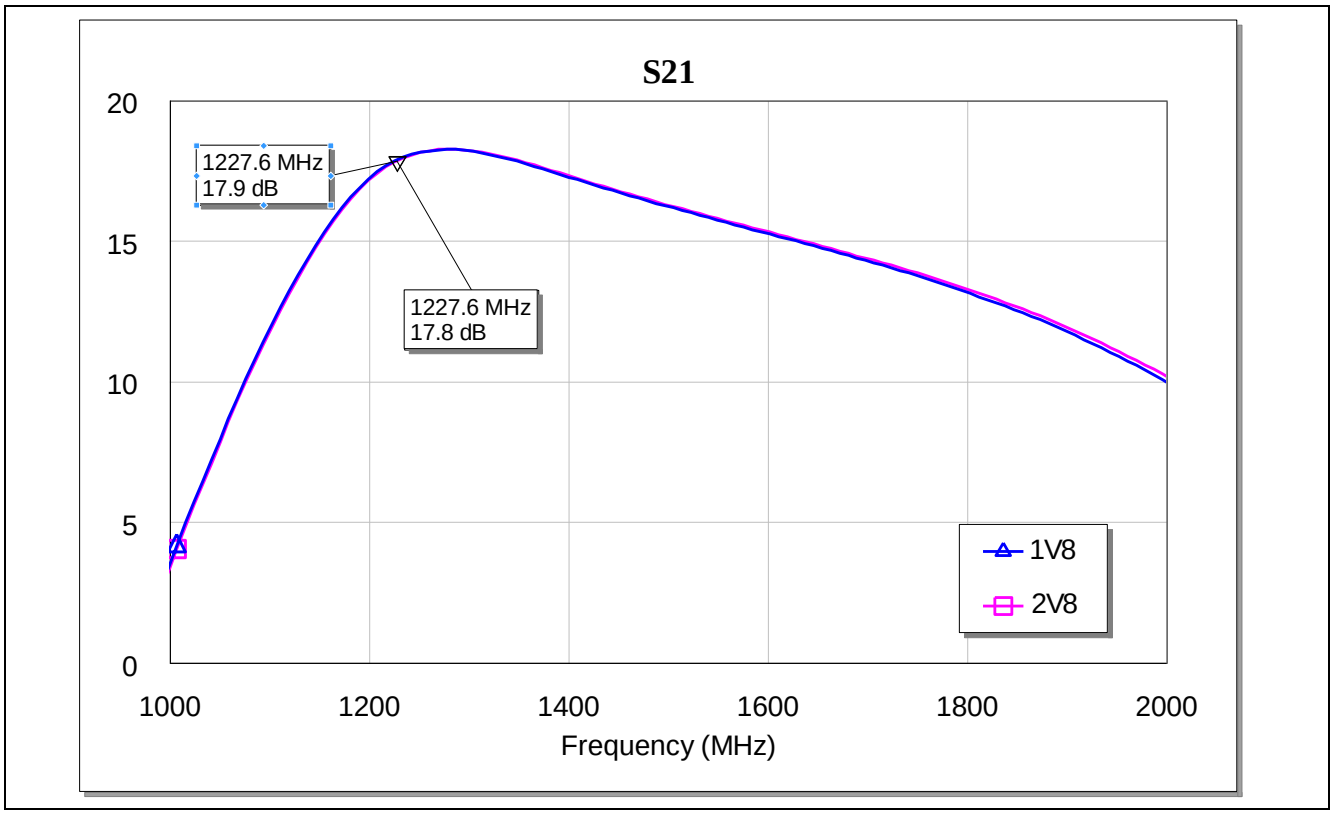


**Figure 5 Narrowband Gain of the BGA524N6 LNA for GPS L2 Band Application**

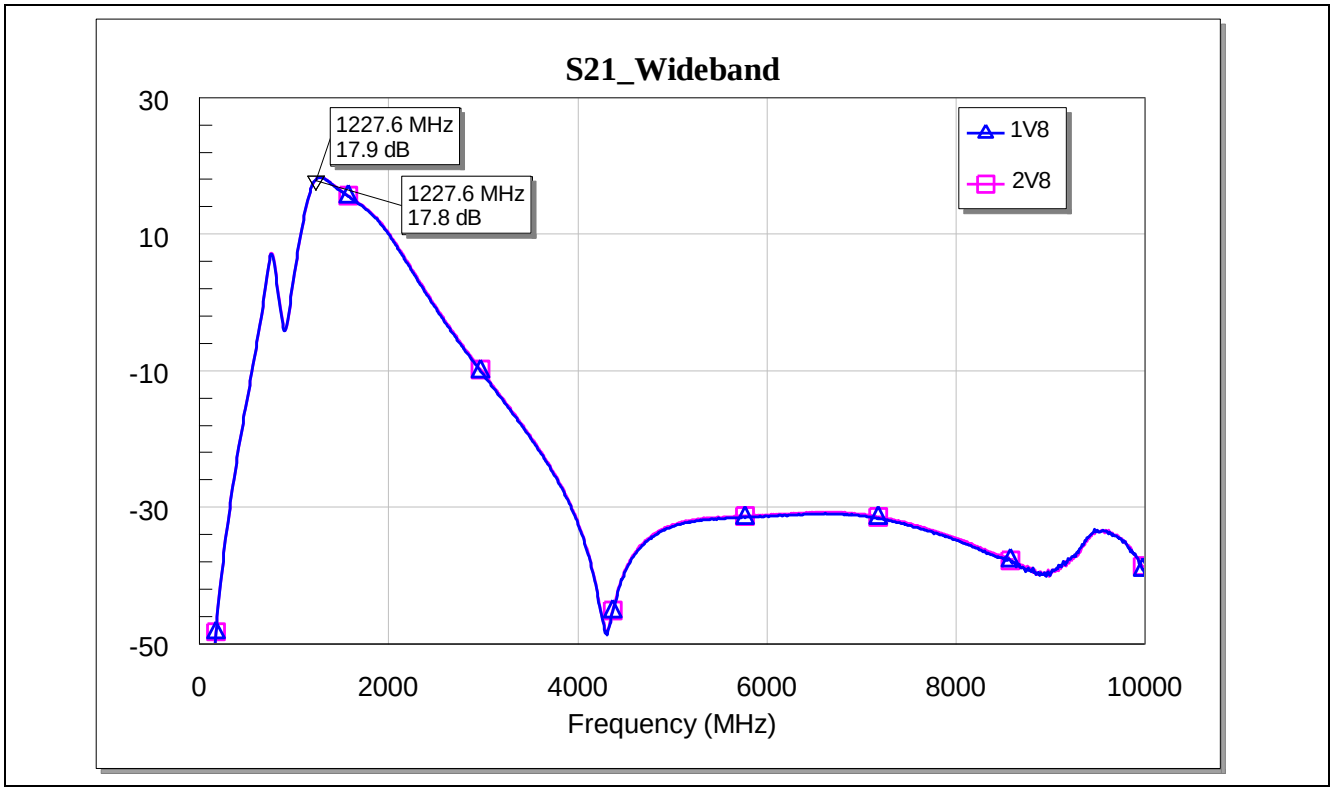


**Figure 6 Wideband Gain of BGA524N6 as LNA for GPS L2 Band Application**

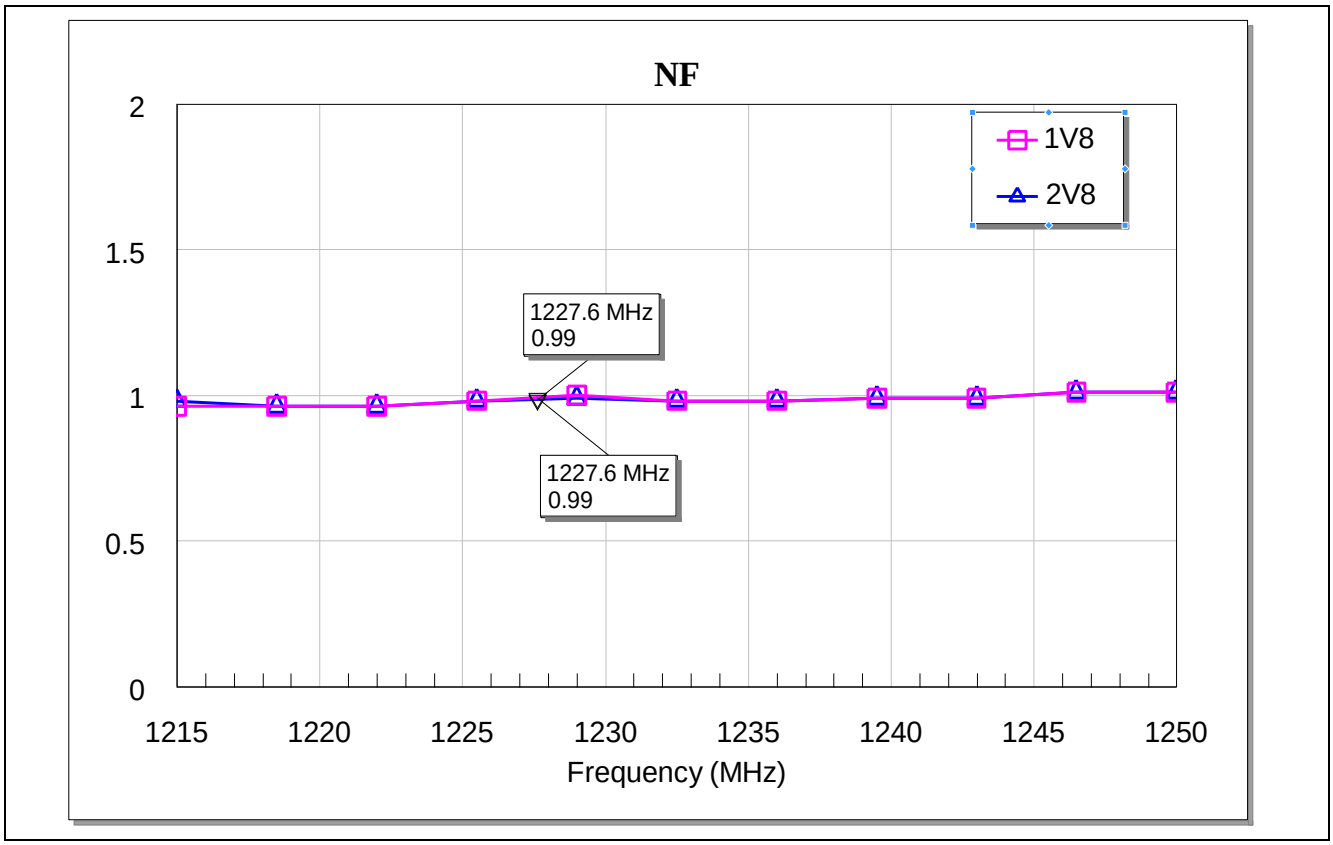


**Figure 7 Noise Figure of BGA524N6 as LNA for GPS L2 Band Application**

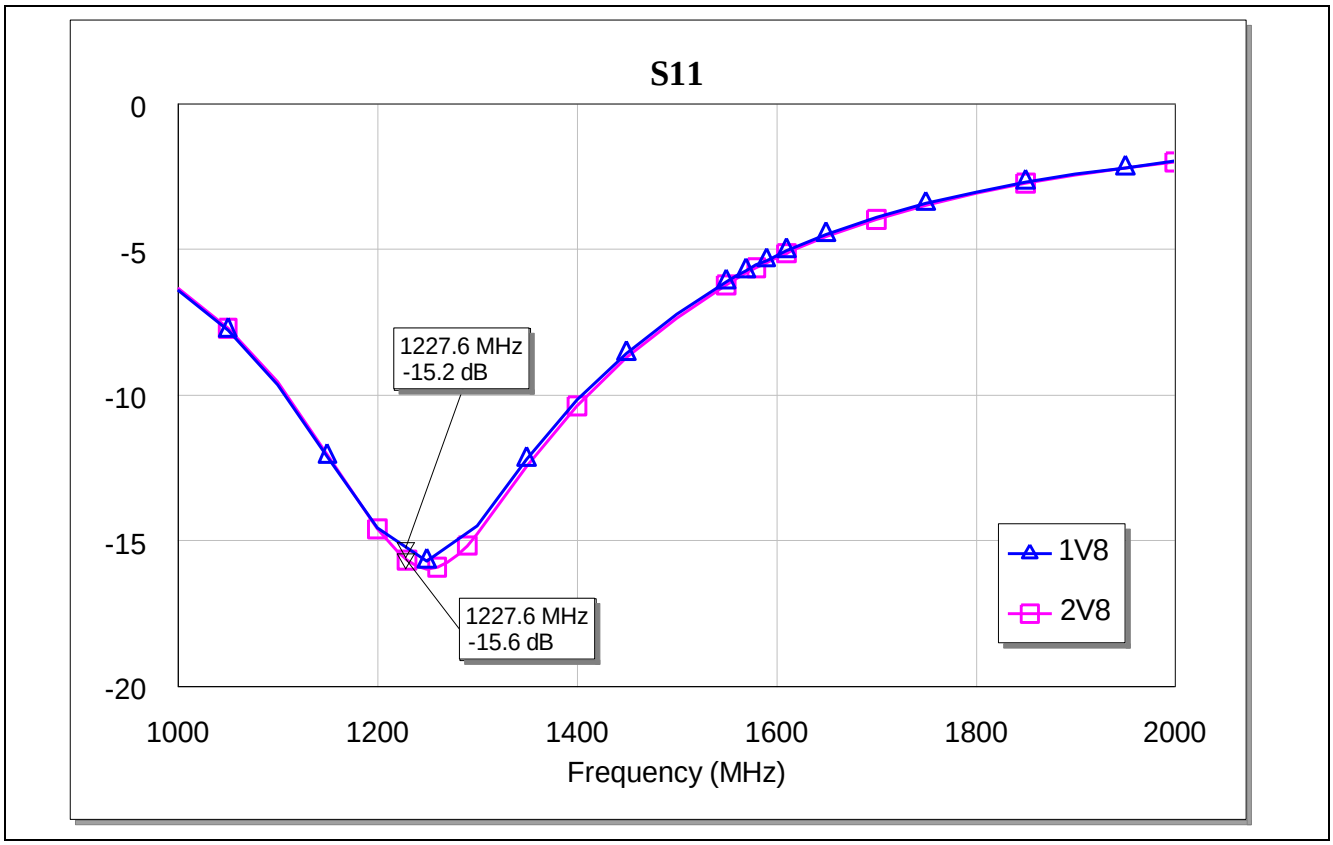


**Figure 8 Input matching of BGA524N6 as LNA for GPS L2 Band Application**

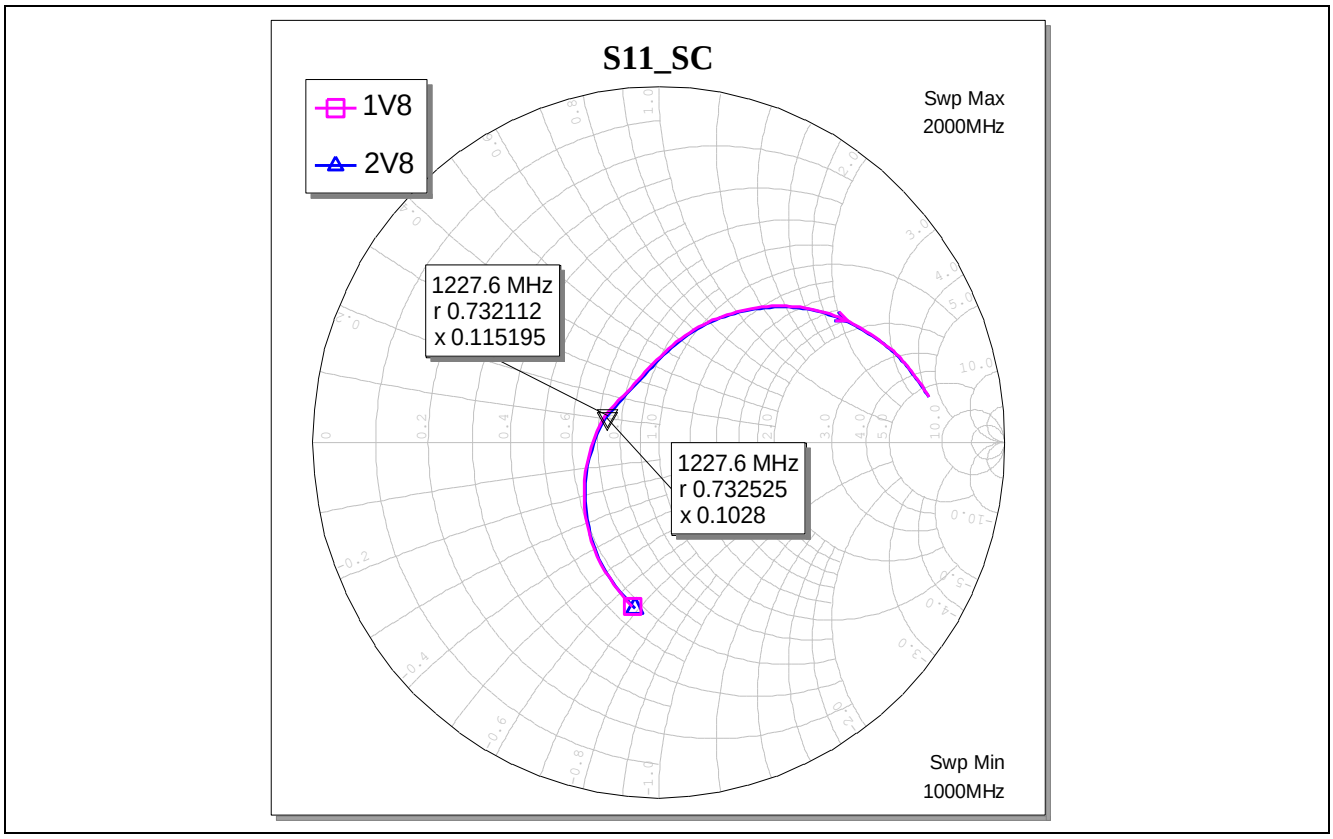


**Figure 9 Input matching (Smith chart) of BGA524N6 as LNA for GPS L2 Band Application**

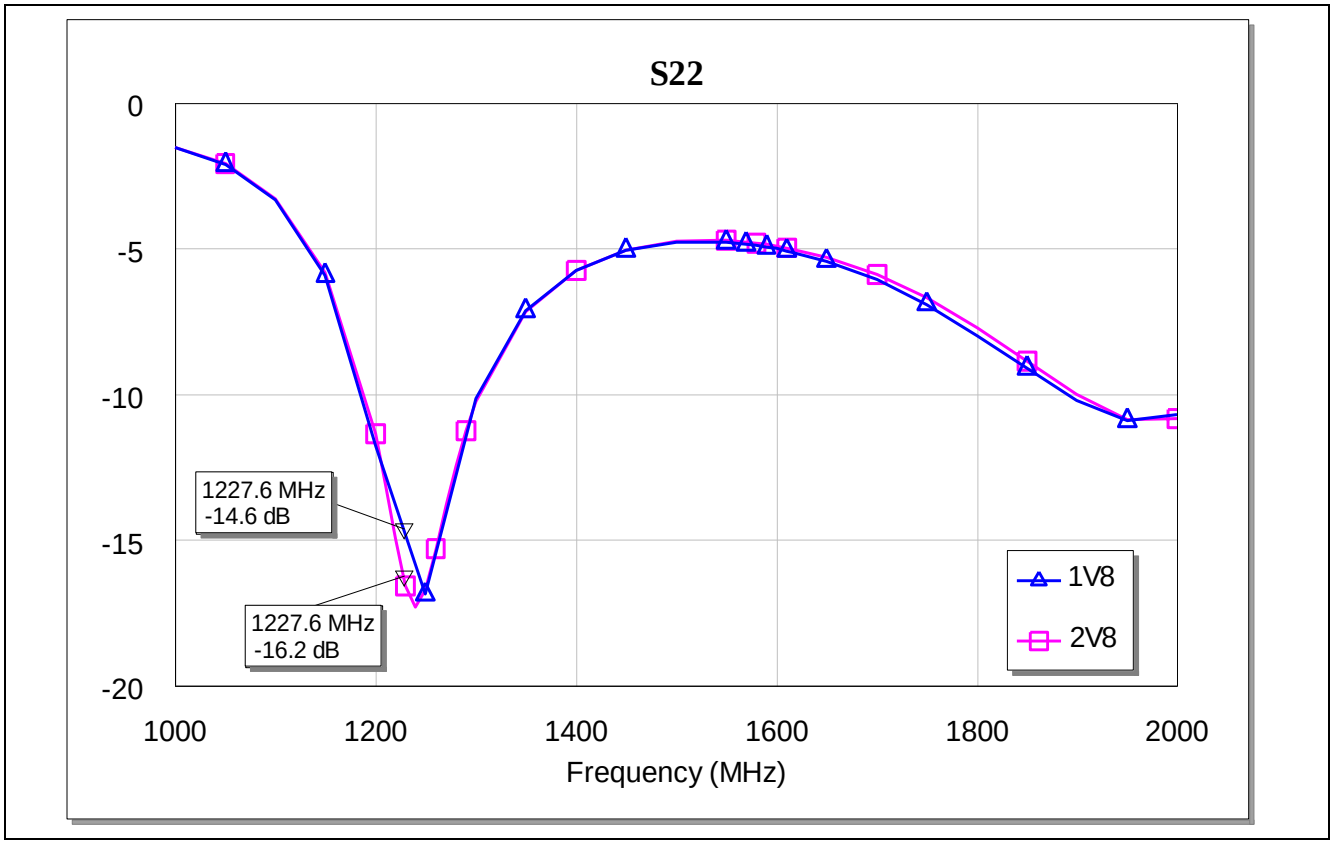


**Figure 10 Output matching of the BGA524N6 as LNA for GPS L2 Band Application**

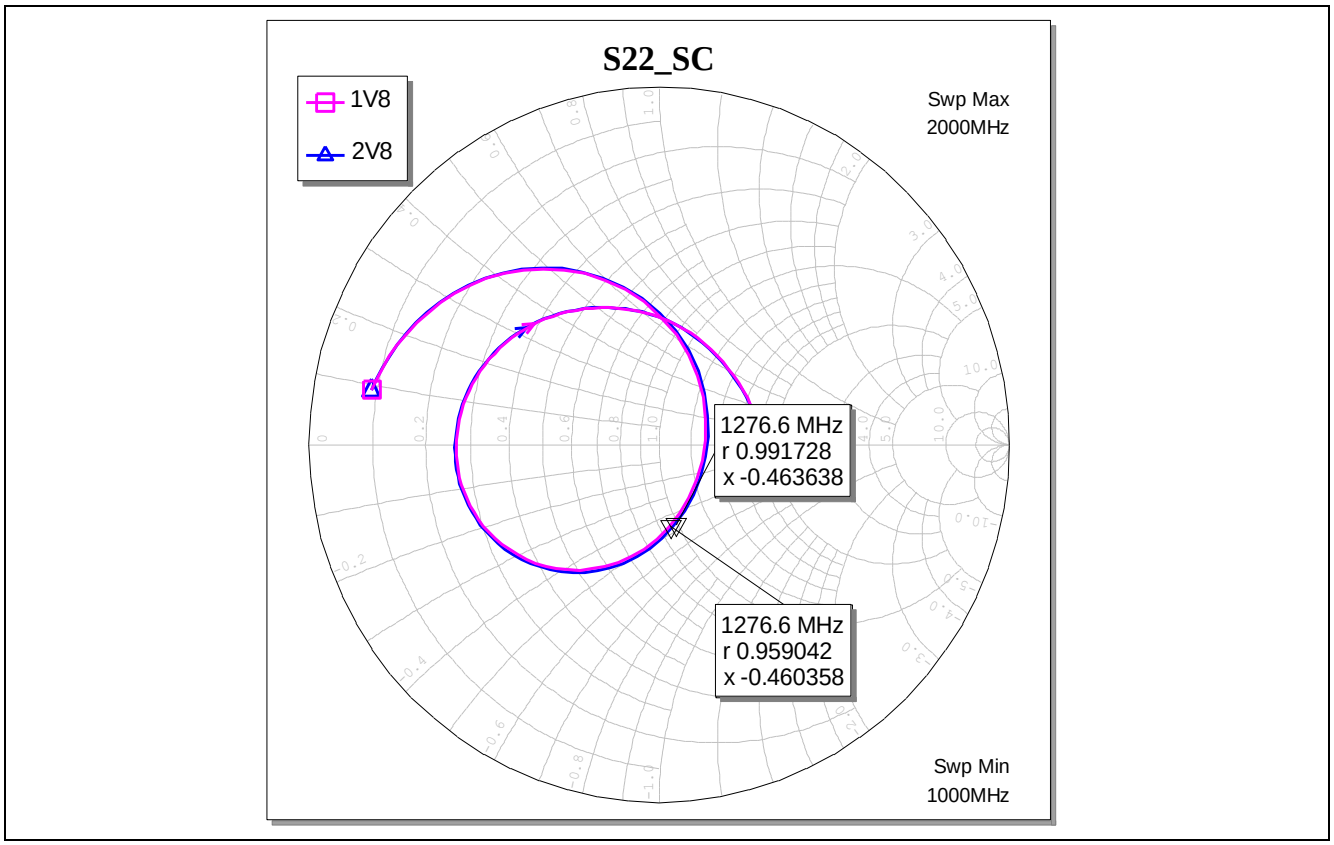


**Figure 11 Output matching (Smith chart) of BGA524N6 as LNA for GPS L2 Band Application**

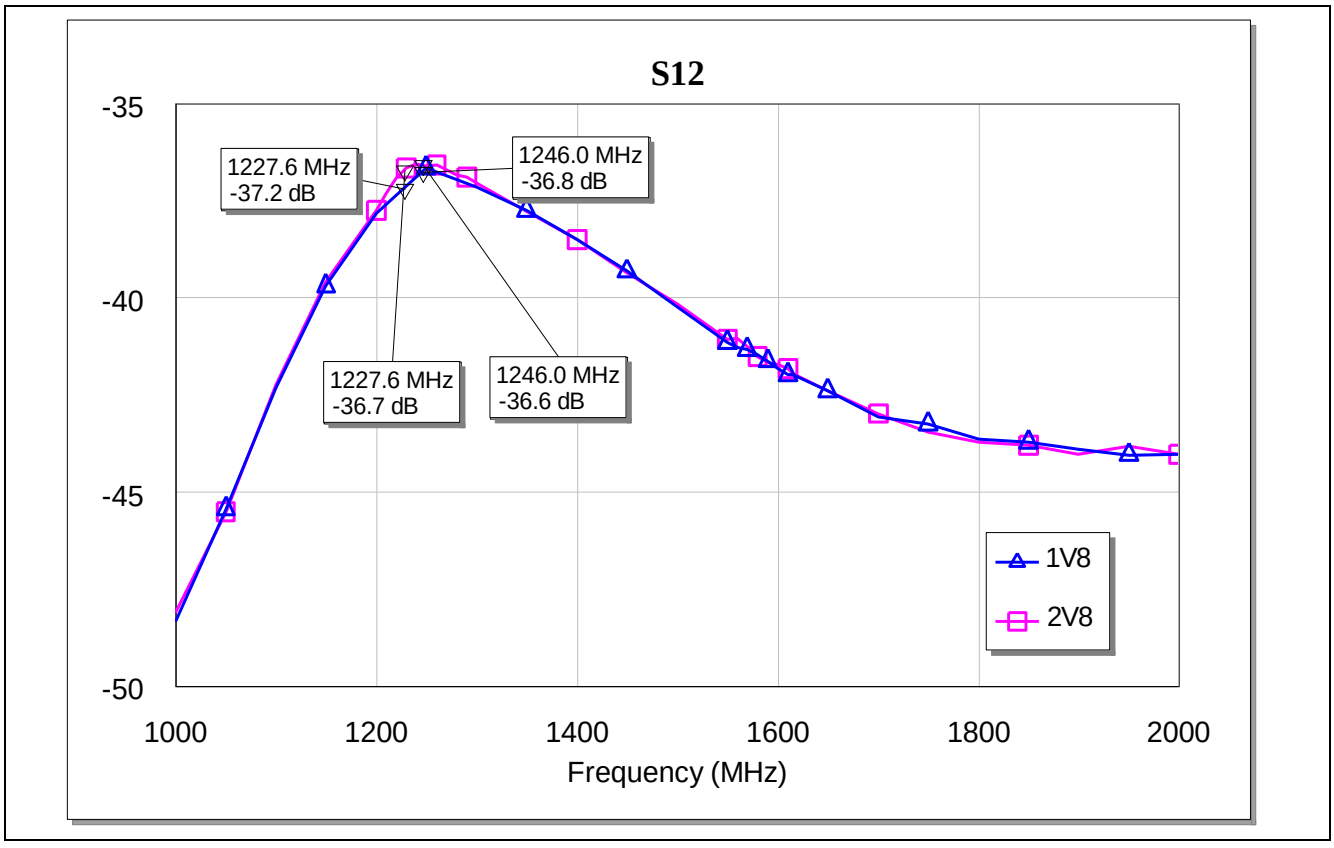


**Figure 12 Reverse isolation of BGA524N6 as LNA for GPS L2 Band Application**

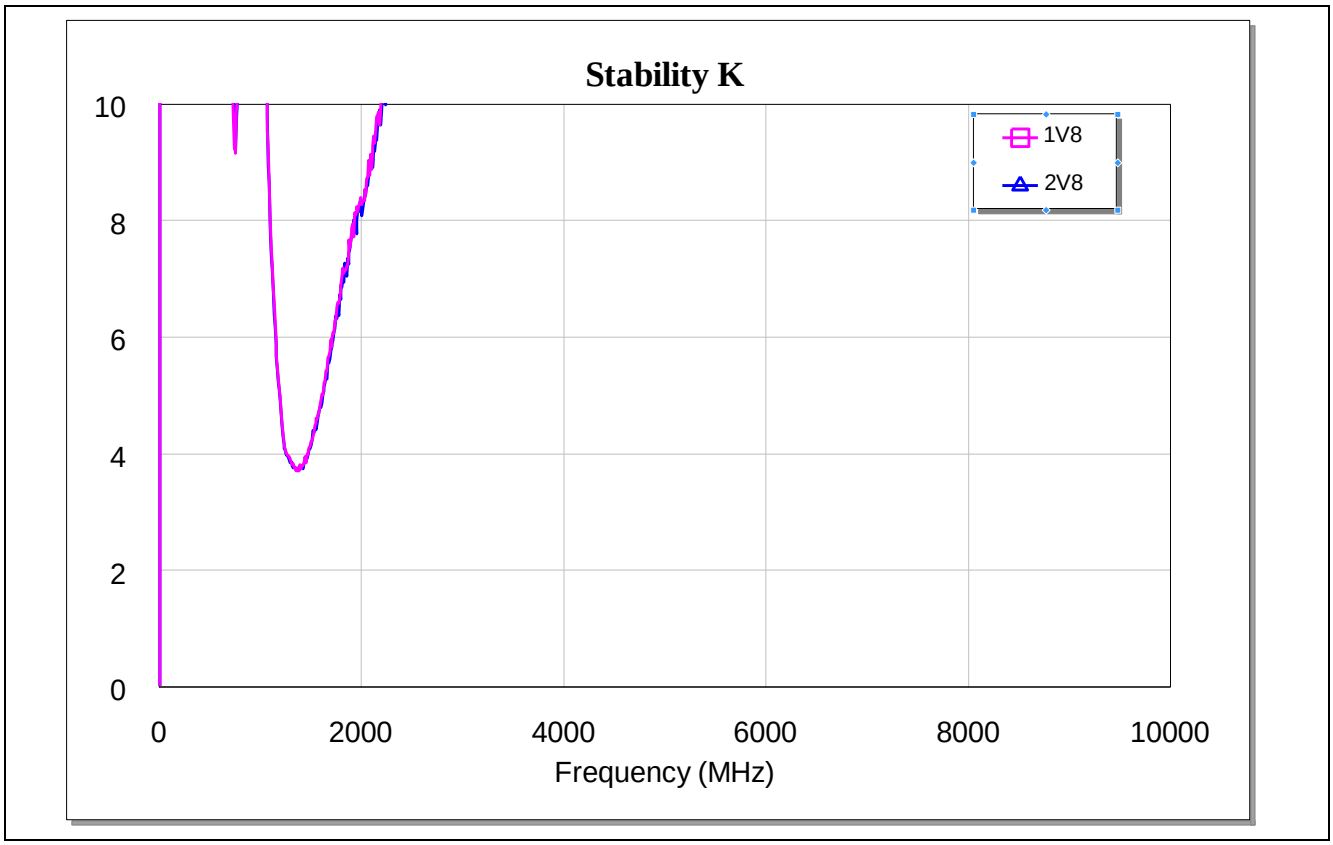


**Figure 13 Stability factor k of BGA524N6 as LNA for GPS L2 Band Application**

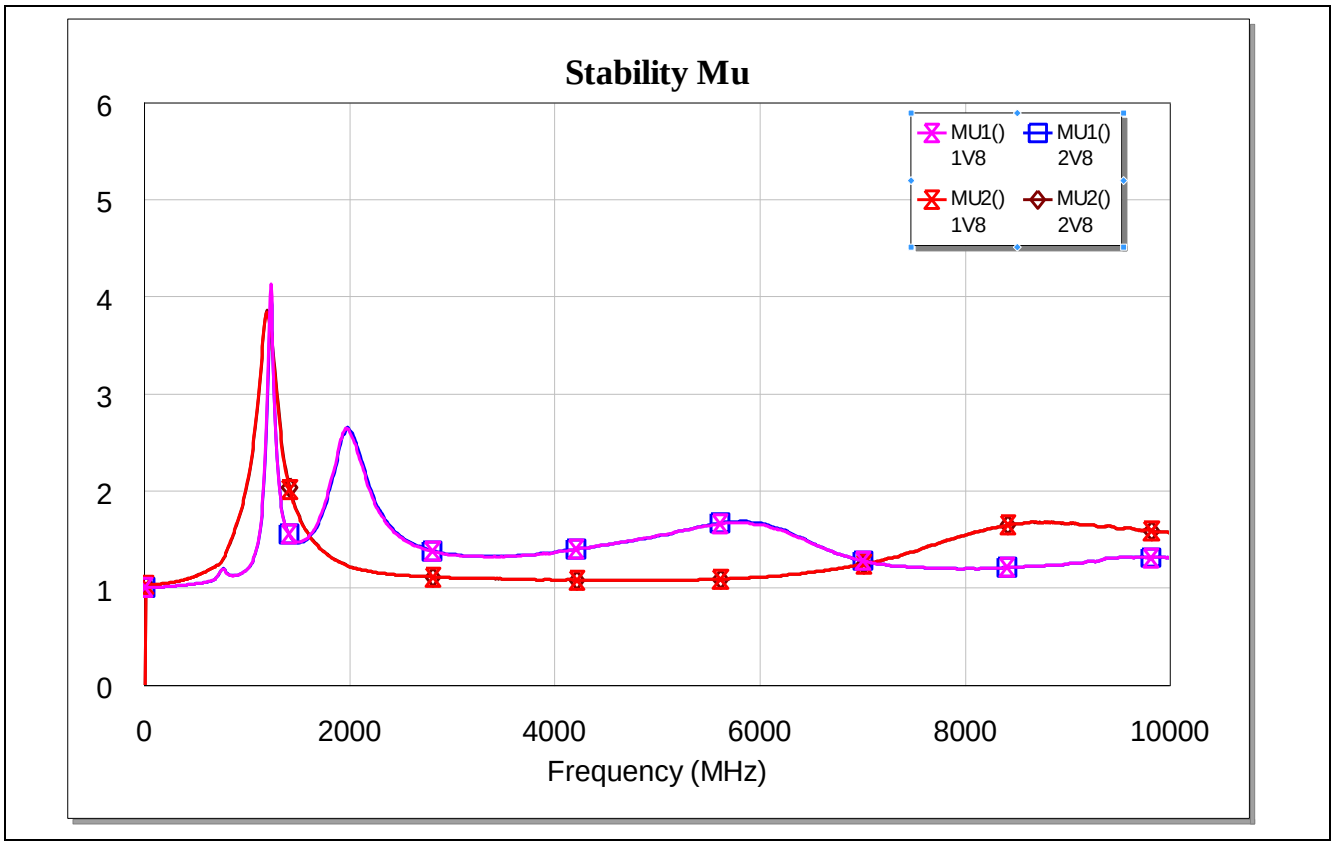


**Figure 14 Stability factors µ1, µ2 of the BGA524N6 as LNA for GPS L2 Band Application**

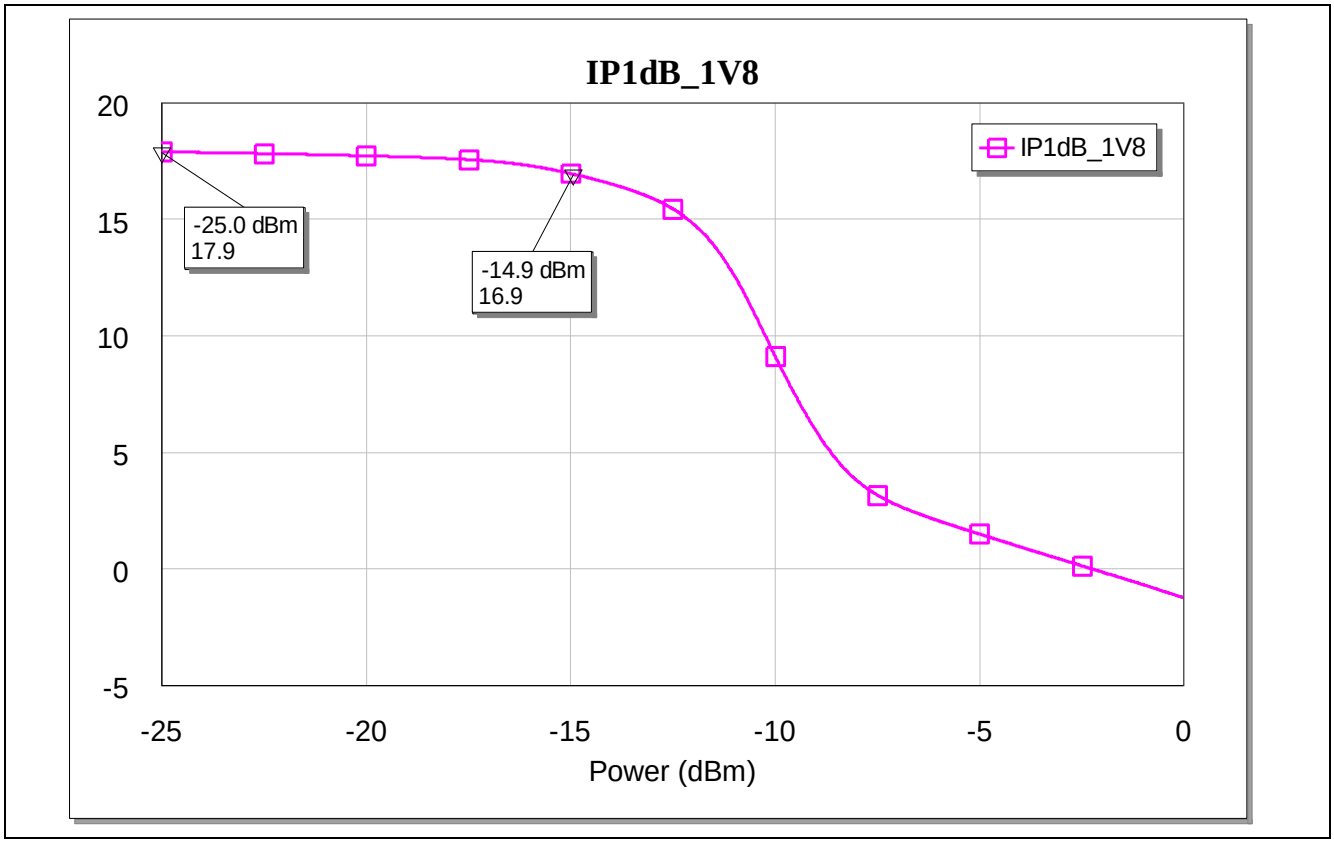


**Figure 15 IP1dB of the BGA524N6 as LNA for GPS L2 Band Application (1.8V)**

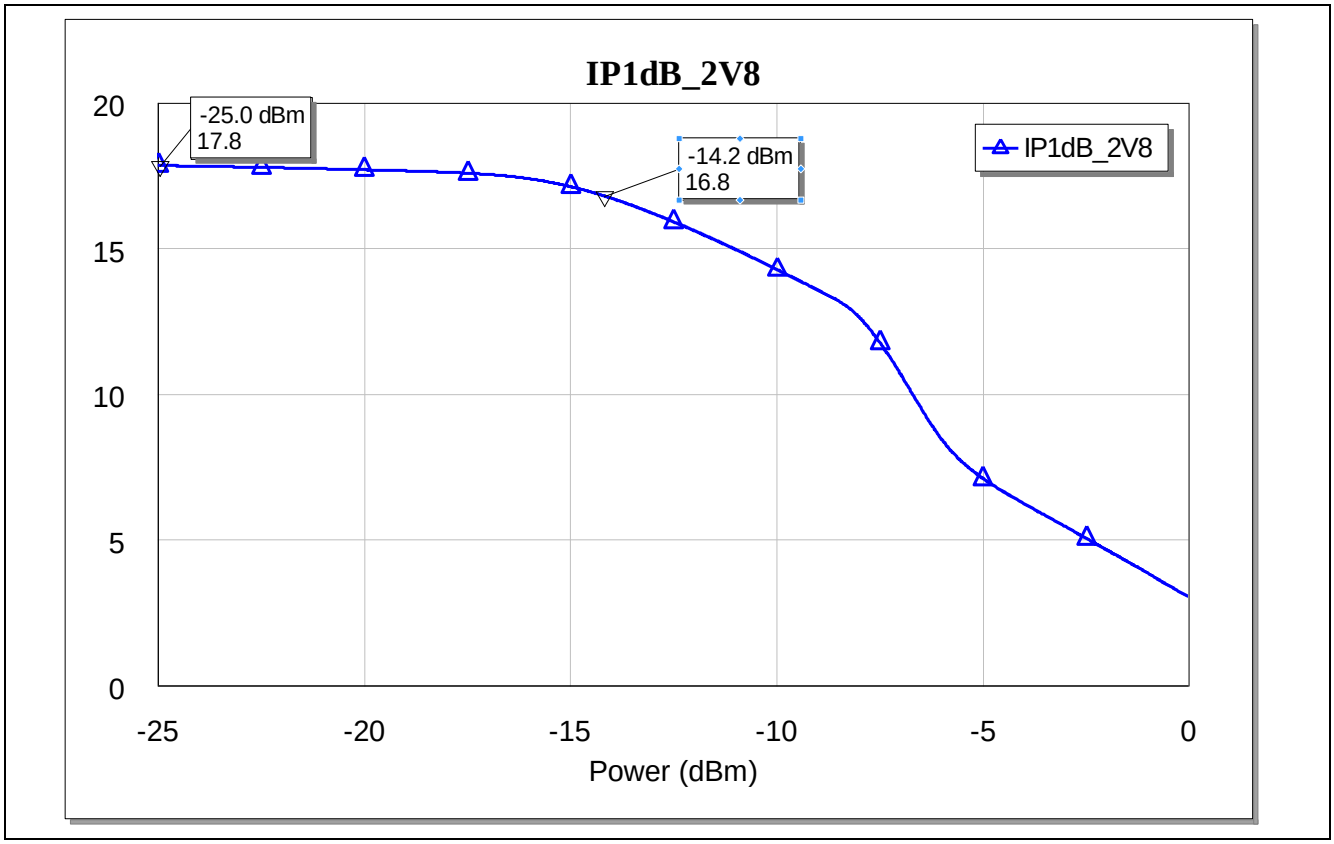


**Figure 16 IP1dB of the BGA524N6 as LNA for GPS L2 Band Application (2.8V)**

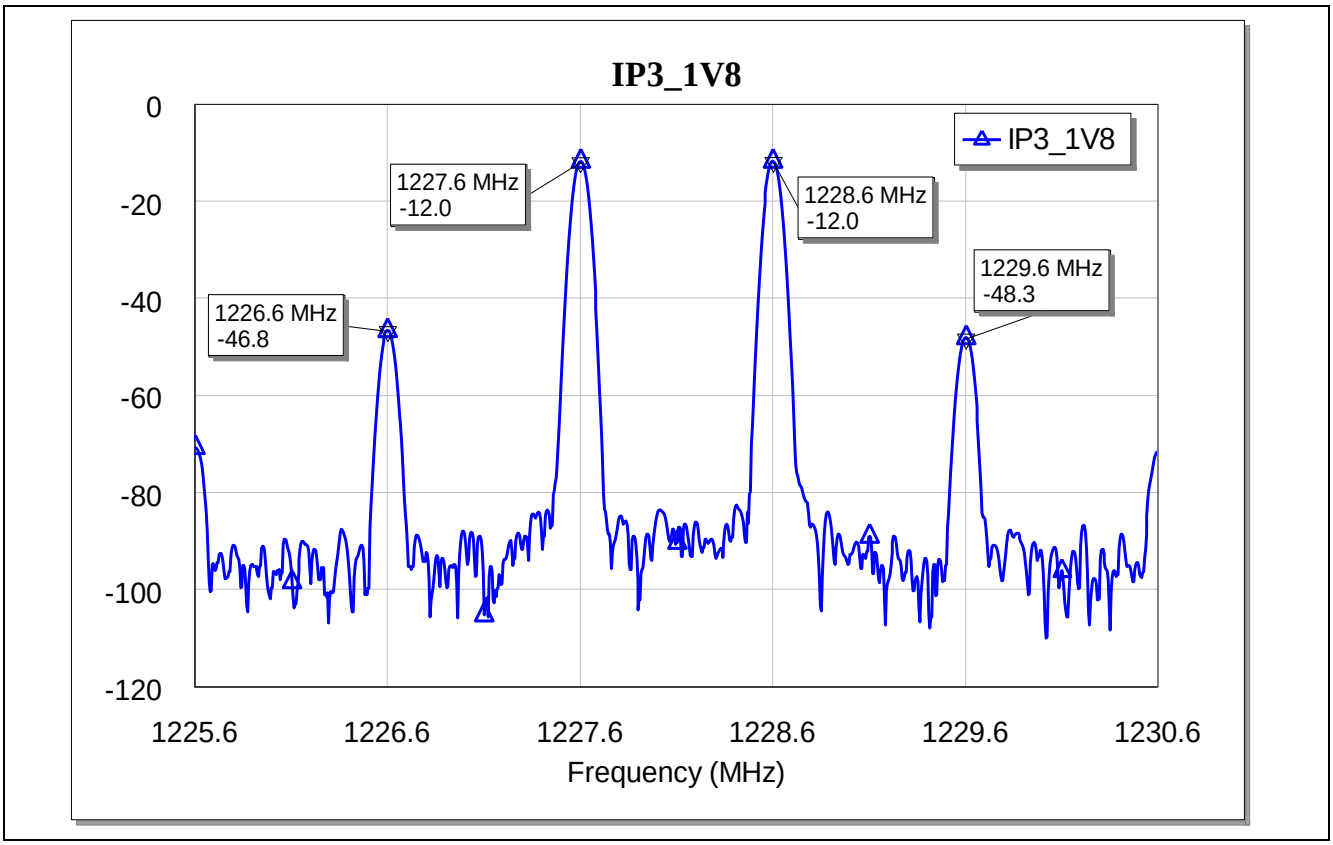


**Figure 17 IP3 of the BGA524N6 as LNA for GPS L2 Band Application (1.8V)**

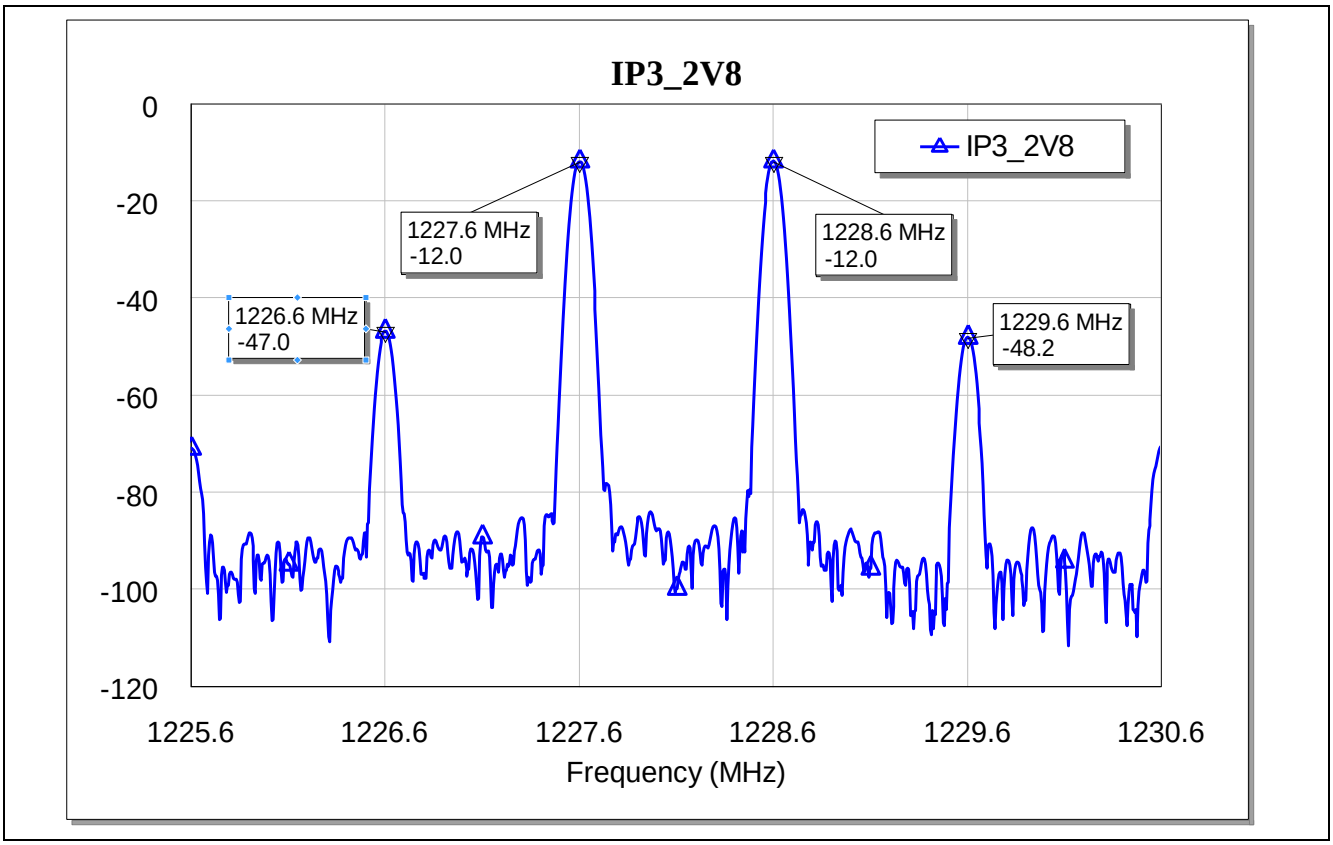


**Figure 18 IP3 of the BGA524N6 as LNA for GPS L2 Band Application (2.8V)**

# 5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: **M161214 V5.0**

PCB material: **FR4**

$\varepsilon_r$ of PCB material: **4.8**

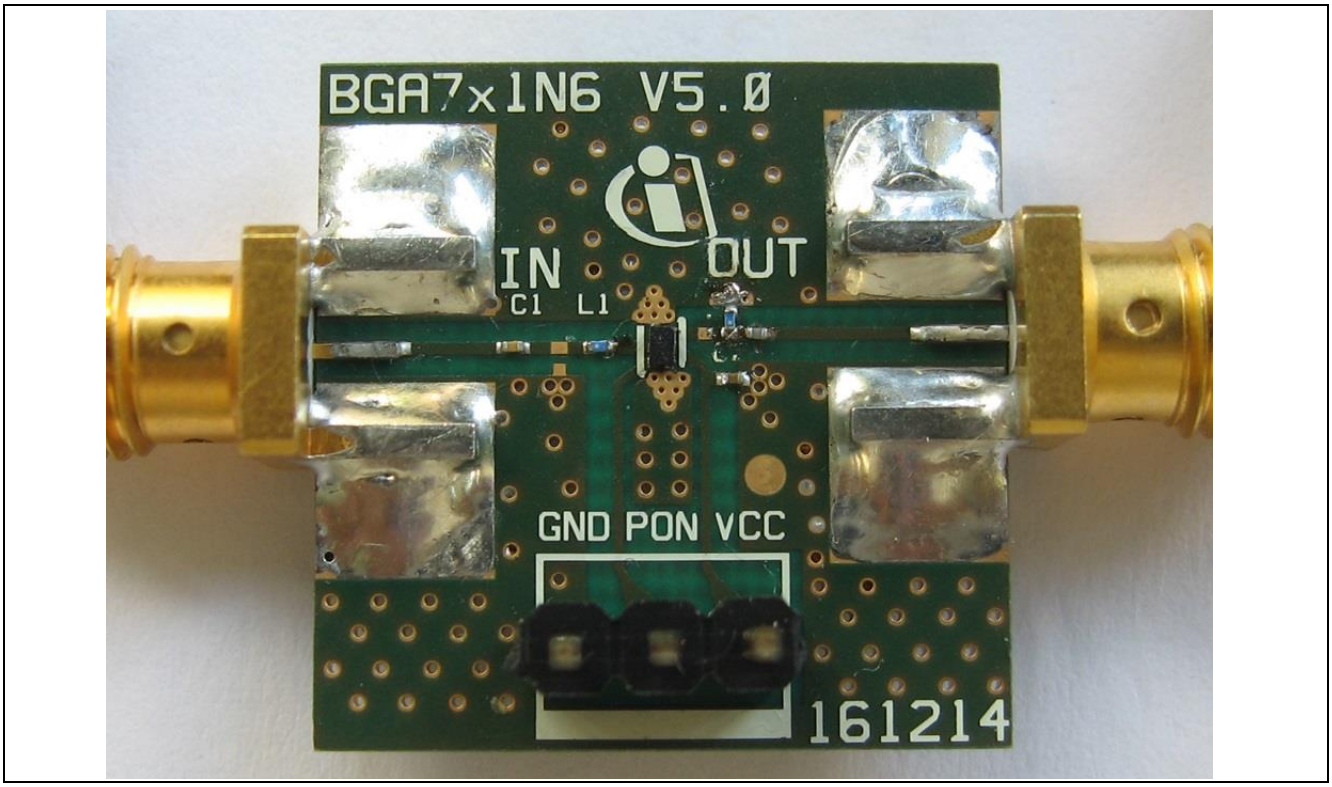


**Figure 19 Photo Picture of Evaluation Board (overview) <PCB Marking M161214 V5.0 >**

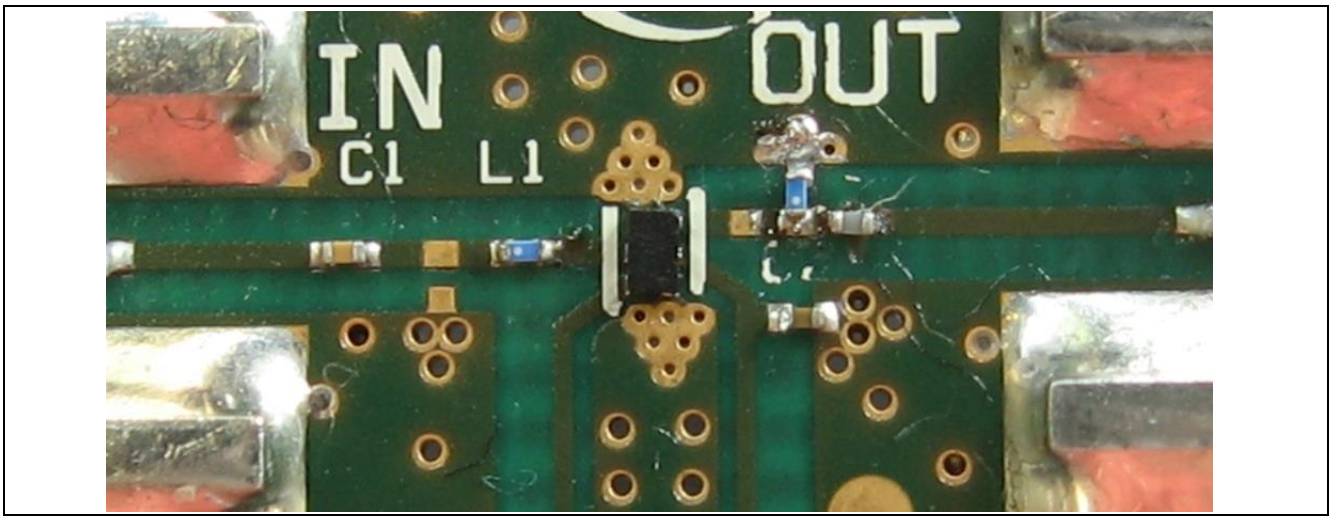


**Figure 20 Photo Picture of Evaluation Board (detailed view)**

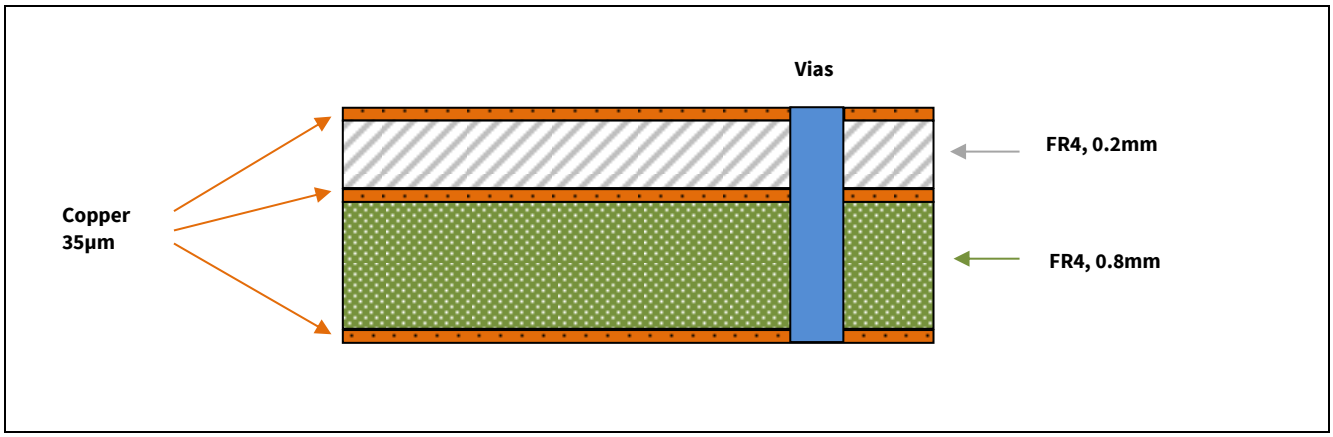


**Figure 21 PCB Layer Information**

# 6 Authors

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

# 7 Reference

[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 |
| | |
| | |
| | |

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