Design guide for RF low-noise transistors in global navigation satellite systems for space applications

HiRel NPN Silicon RF Transistor

About this document

Scope and purpose

This application note provides application circuit design examples with Infineon's HiRel NPN silicon RF transistor for global navigation satellite system (GNSS) low-noise amplifiers (LNA). In this document the transistor-based LNA schematics, PCB layouts, and measurement results are presented. This document is relevant to the following space-qualified devices:

- HiRel BFY650B-12 NPN silicon germanium RF transistor

Intended audience

This document is intended for engineers who design LNAs for GNSS high reliability applications, such as in satellites.

Product features

- For L (GNSS), S, C, and X-frequency bands
- Ideal for low-noise amplifiers and low phase-noise oscillators
- Hermetically sealed microwave package
- Radiation hardened

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1 Introduction

1.1 GNSS receiver front end

Today, GNSS is much more than the global positioning system (GPS). Satellite systems, such as GLONASS, BeiDou, and Galileo, are increasingly providing navigation services. Satellites typically carry both a star tracker instrument and a GNSS receiver unit onboard to gauge their exact location, which they must know at all times.

The signals that propagate through space are significantly attenuated. With such a low signal strength, the signal quality at the satellite depends heavily on the signal amplification of the first stage with a low measure of noise figure (NF) in the receiver chain.

The LNA should be placed as close to the antenna as possible to avoid additional connection loss between the antenna and receiver, resulting in dramatic performance degradation. Having an LNA close to the receiver antenna improves the receiver's sensitivity to weak signals. The power consumption of the amplifier used is also important to note, as it is of crucial importance in the satellite system. Infineon's HiRel silicon bipolar transistors based on SiGe technology offer the best figure-of-merit in terms of gain and power consumption.

The antenna and LNA combination, along with filters, form the radio frequency (RF) front end of the receiver, sometimes referred to as the "active antenna". Depending on the system specification's focus on NF, gain, or out-of-band interference, the sequence of LNA and filters in the GNSS RF front end may be different. The following figure shows two of the most common configurations.

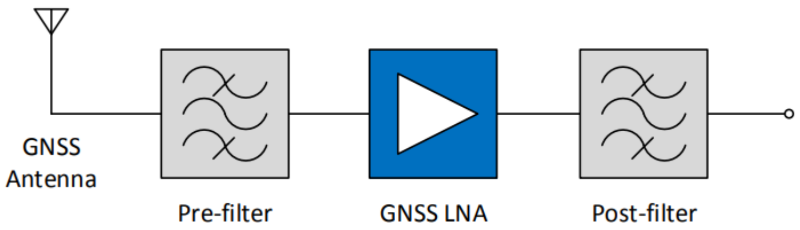

Figure 1 Block diagram example of a GNSS radio front end

1.2 Infineon HiRel NPN silicon RF transistor

With decades of space heritage, Infineon's radiation hardened HiRel microwave transistors are offered in hermetically sealed ceramic packages and used in a wide range of space missions. Application examples include first and second stage LNAs, oscillators, and mixers.

Infineon's HiRel silicon bipolar transistor product range covers different generations of RF microwave transistor technology from bipolar Si to SiGe based devices. RF bipolar transistors with different voltage classes, frequency ranges, and output power are available and based on Infineon's vast microwave bipolar transistor technical knowledge.

With different bipolar transistor types to choose from, Infineon's high reliability microwave bipolar junction transistor devices are available in different quality levels:

- **Professional (P)**: Designed for Engineering Modules and used for breadboards and circuit evaluation
- **ESCC-qualified (ES)**: Fulfills the requirements of the European Space Agency (ESA) for flight modules

Their optimized inner transistor cell structure leads to best-in-class power gain and NF at high frequencies, including GNSS bands.

2 GNSS LNA application circuits

2.1 Performance overview

The following table reports the GNSS LNAs' performance with HiRel NPN Silicon Germanium RF transistor in a measured at 1575 MHz.

Table 1 Summary of measurement results for the 6 GHz to 7 GHz band WLAN LNA

Parameter	Symbol	Value	Unit	Notes
Device	–	BFY650B-12	–	–
Bias voltage	V_{CC}	3	V	–
Bias current	I_{CC}	14.5	mA	–
Frequency	f	1575	GHz	–
Gain	G	12.2	dB	–
NF	NF	1.07	dB	PCB and SMA loss subtracted: 0.15 dB
Input return loss	RL_{in}	10.5	dB	–
Output return loss	RL_{out}	11.7	dB	–
Reverse isolation	ISO_{rev}	26.3	dB	–
Output 1 dB compression point	OP_{1dB}	2.3	dBm	Measured at 1.575 GHz
Output third-order intercept point	OIP_3	11.5	dBm	Input power: -30 dBm Tone 1: 1575 MHz Tone 2: 1576 MHz
Stability	K	>1	–	Measured from 10 MHz to 14 GHz

2.2 Schematic

The following figure shows the general schematic of the GNSS LNAs with Infineon's space-grade NPN Silicon RF transistor BFY650B-12. In the schematic, the resistor R1 serves as the DC negative feedback to stabilize the biasing point, while R2 stands for transistor base bias. The circuit input matching is achieved by the network of the capacitor C1 and the inductor L1, L2. The network of L3 and C4 match the transistor to the output port. In general, R3 and R4 stabilize the circuit, whose firmness is measured up to 13 GHz.

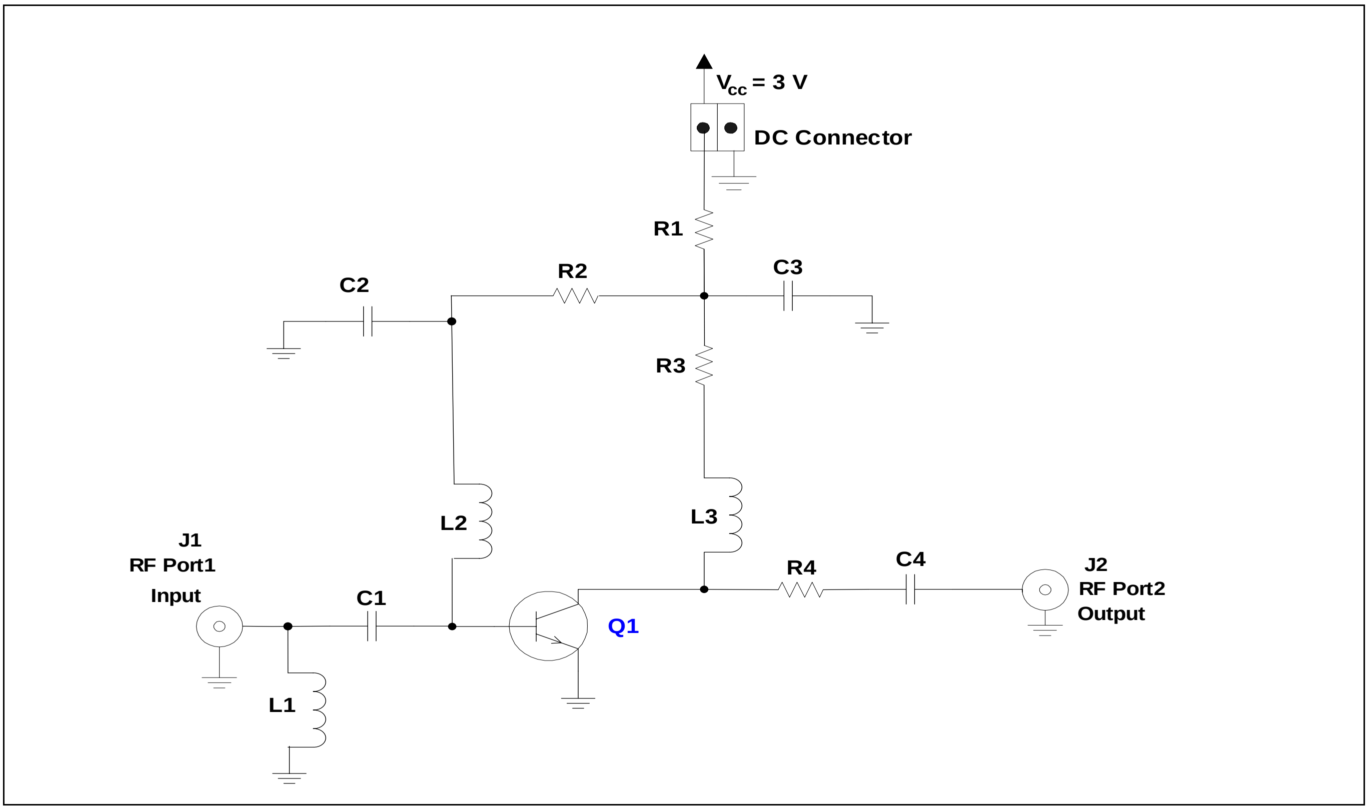

Figure 2 GNSS LNA's schematic with BFY650 HiRel transistor

2.3 Bill of materials

Table 2 BOM of the GNSS LNA

Symbol	Value	Package/size	Manufacturer	Notes
Q1	BFY650B-12	Micro-X	Infineon	
C1	6.8 pF	0402	Various	Input matching and DC blocking
C2	47 pF	0402	Various	RF decoupling
C3	33 pF	0402	Various	RF decoupling
C4	6.8 pF	0402	Various	Output matching and DC blocking
R1	30 Ω	0402	Various	DC bias and DC negative feedback
R2	33 kΩ	0402	Various	DC biasing for transistor base
R3	30 Ω	0402	Various	Low-frequency stability improvement
R4	20 Ω	0402	Various	Low-frequency stability improvement
L1	3 nH	0402	Murata	Input matching
L2	56 nH	0402	Murata	RF choke and input matching
L3	2.2 nH	0402	Murata	RF choke and output matching

2.4 Evaluation boards and layout information

The evaluation boards for GNSS LNAs:

- PCB material: FR4
- PCB marking:
  - Micro-X LNA

The detailed description of the PCB stack and photos of the GNSSS LNAs' evaluation boards and are shown in the following figures.

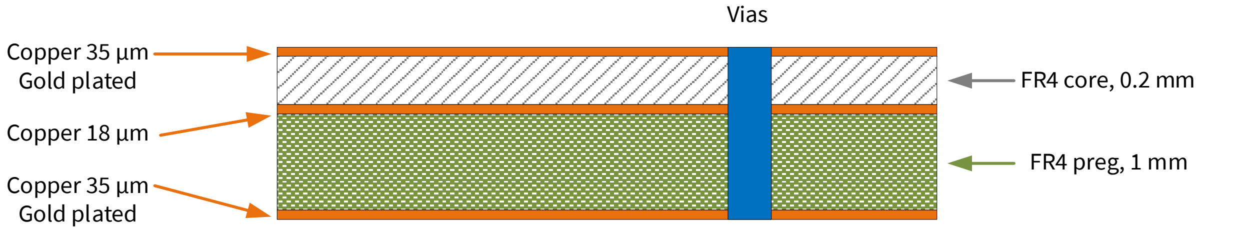

Figure 3 **PCB stack information for the evaluation board**

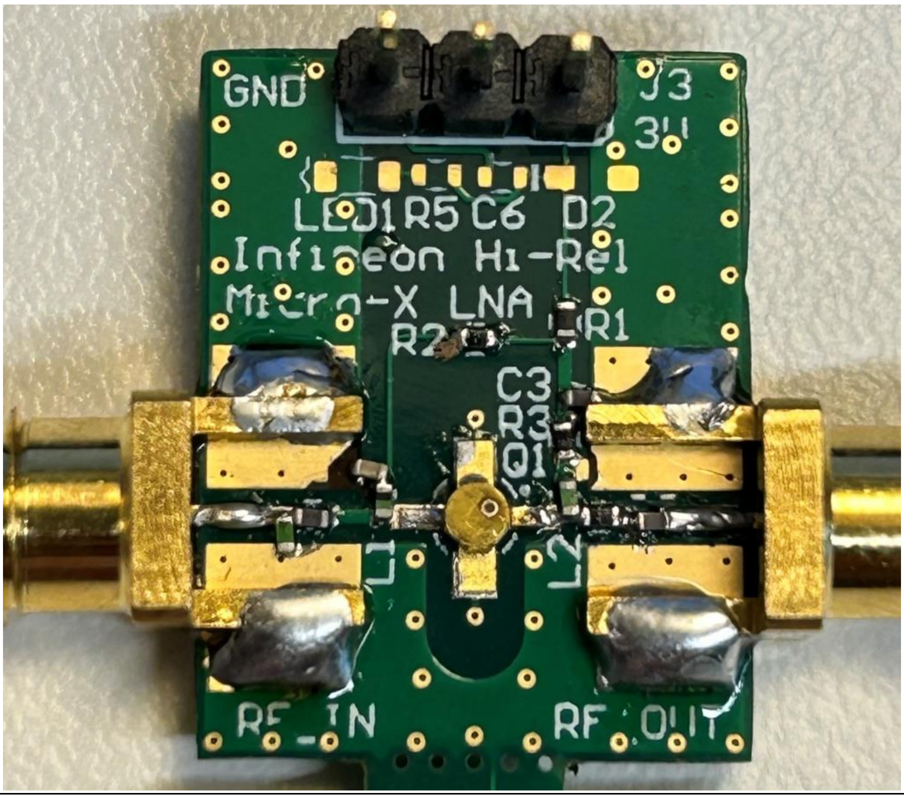

Figure 4 **Photograph of the evaluation board with the marking Micro-X LNA**

2.5 Measurement results of the GNSS LNA

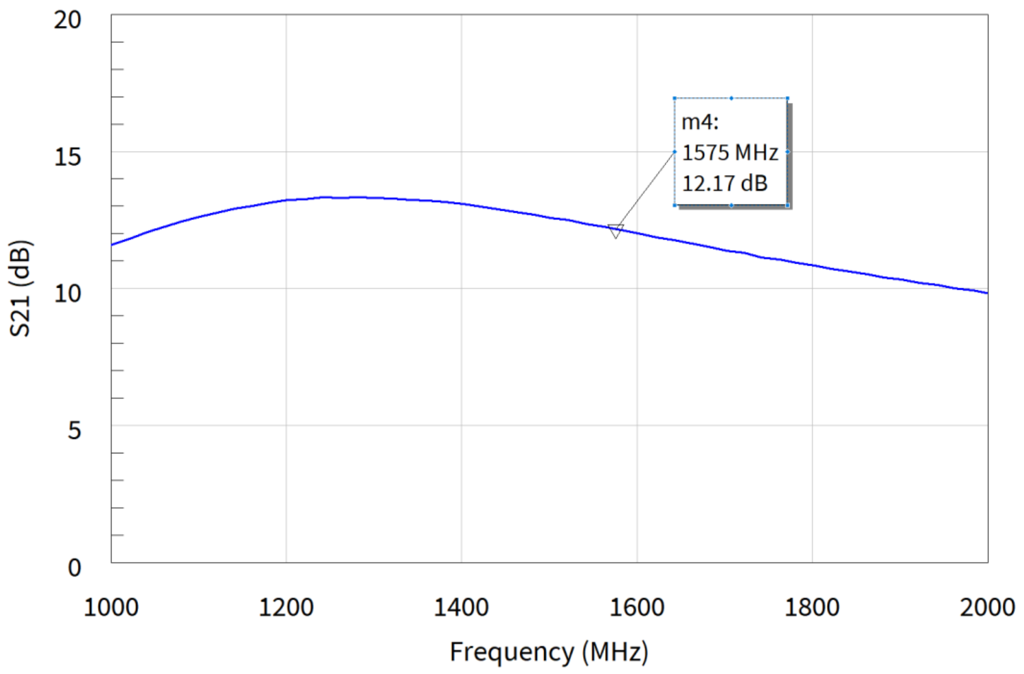

Figure 5 Small signal gain of the GNSS LNA

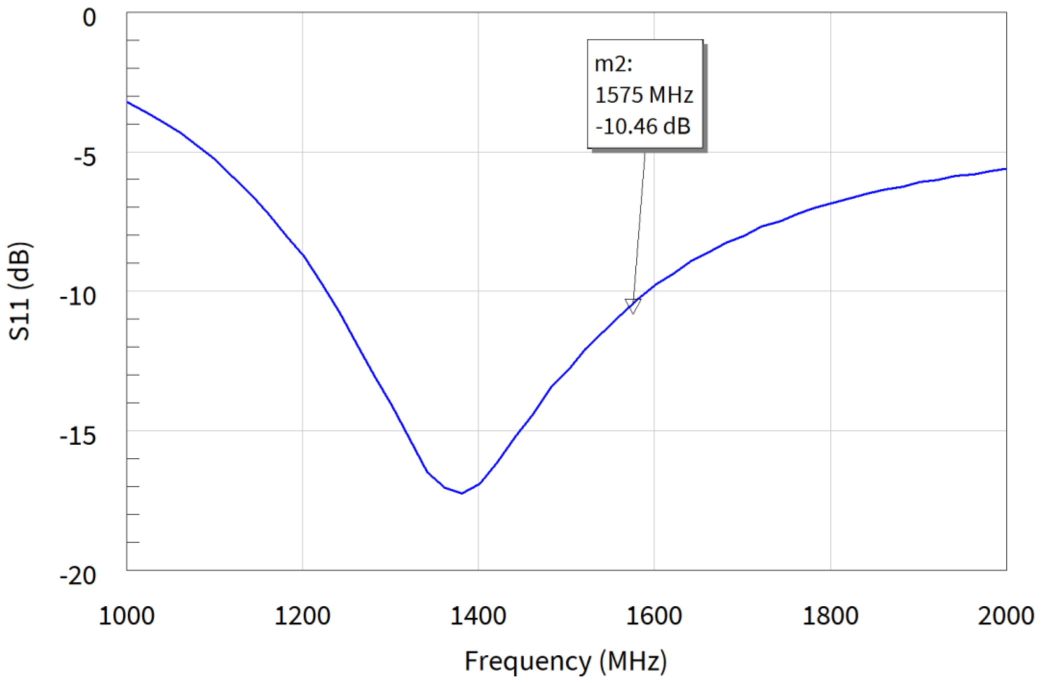

Figure 6 Input return loss S11 of the GNSS LNAs with transistors

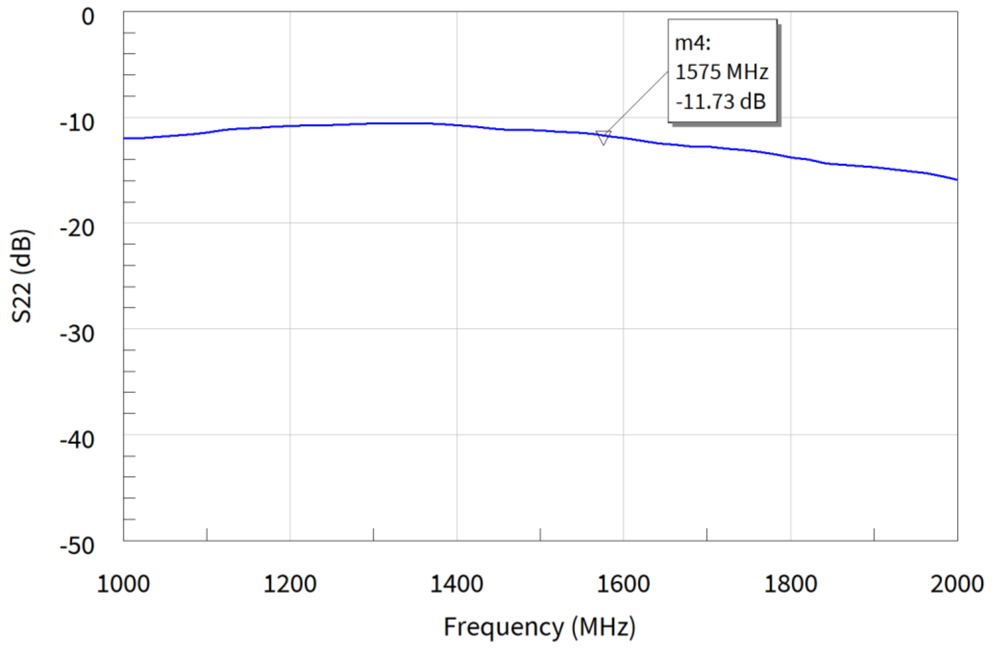

Figure 7 **Output return loss measurement of the GNSS LNA transistors**

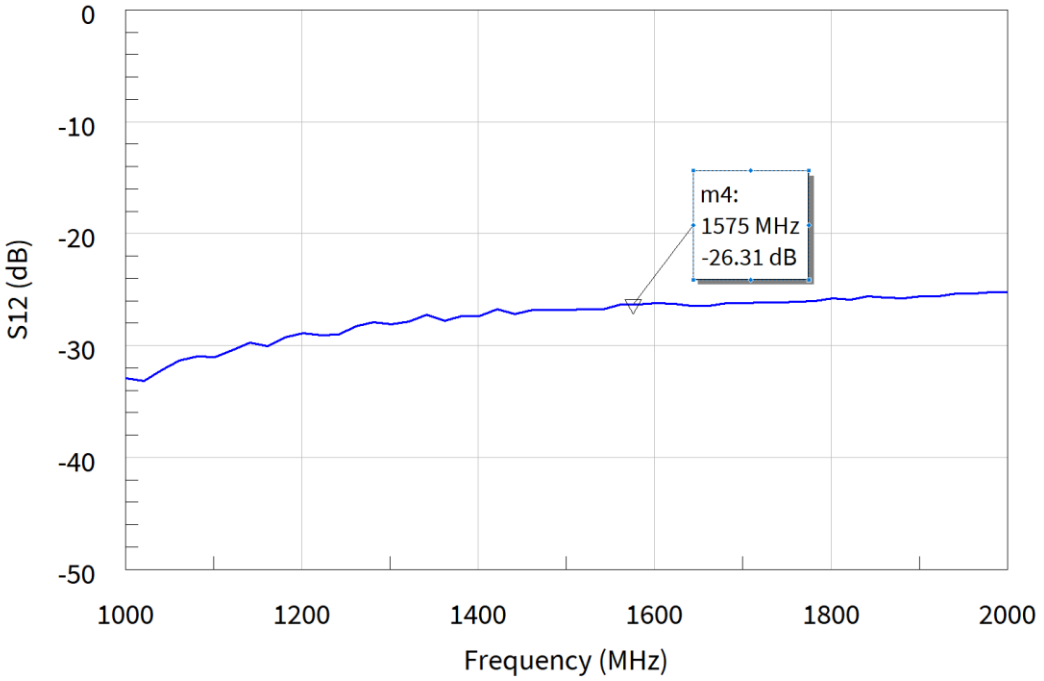

Figure 8 **Reverse isolation measurement of the GNSS LNAs with transistors**

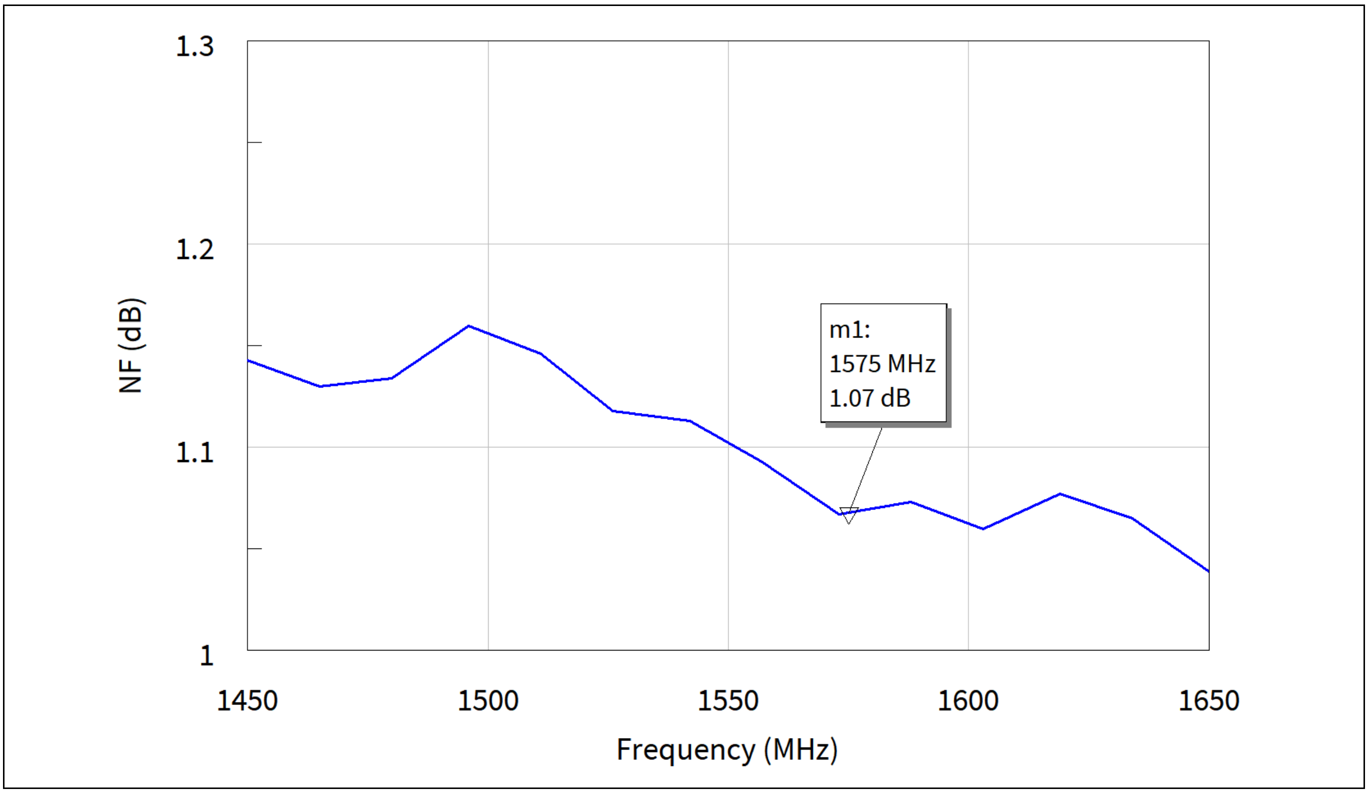

Figure 9 NF measurement of GNSS LNA

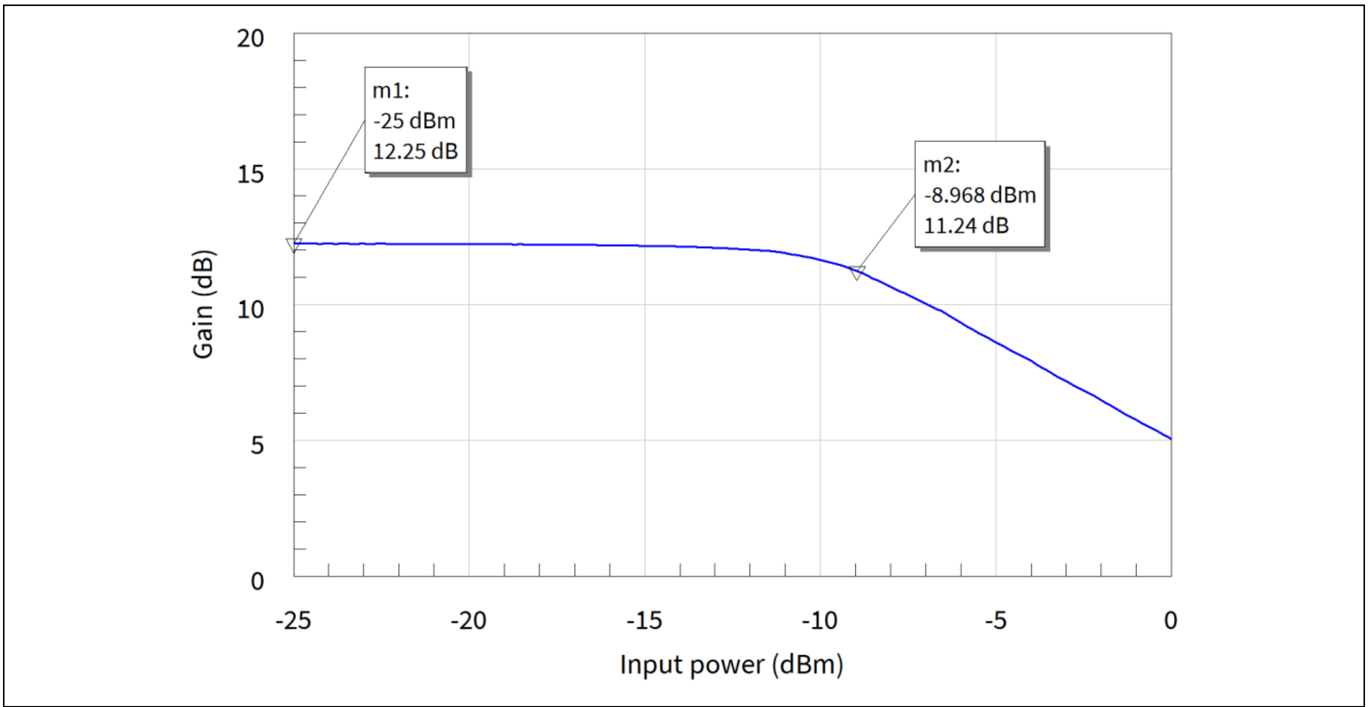

Figure 10 Input 1 dB compression point measurement at 1575 Mhz

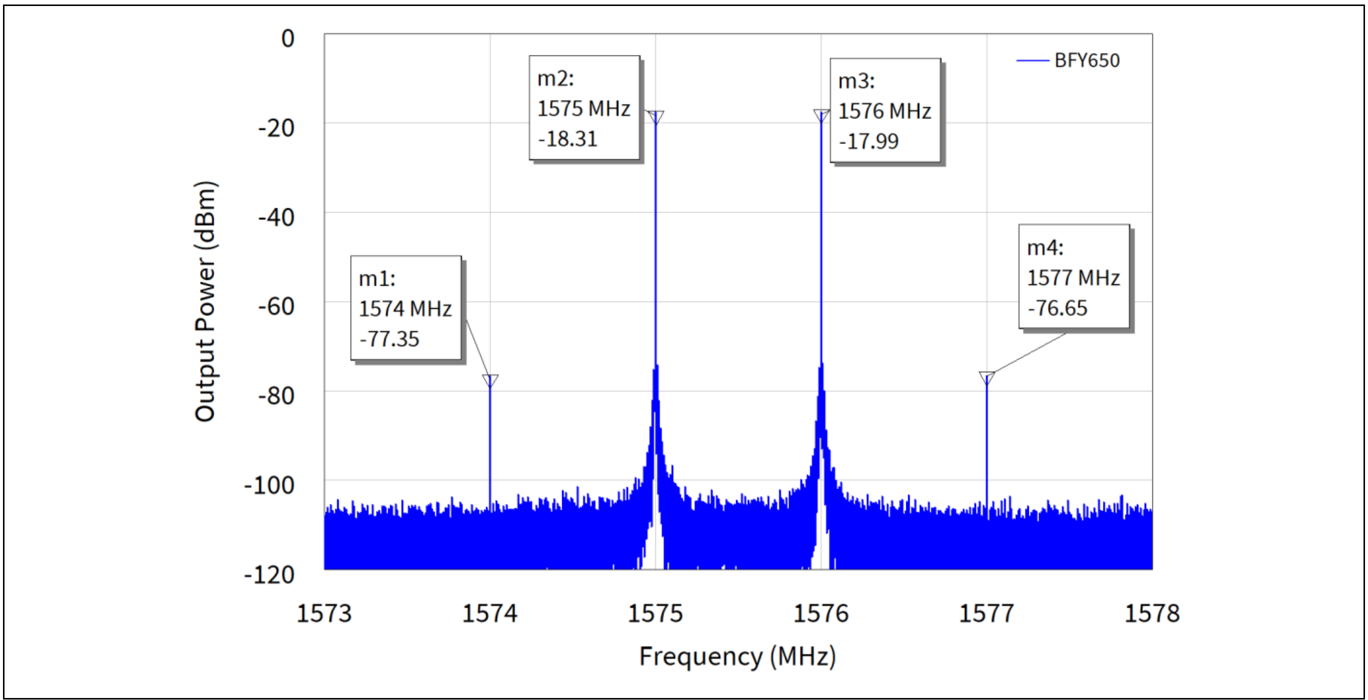

Figure 11 Output IMD_3 measurement of the 1575 MHz band GNSS LNA

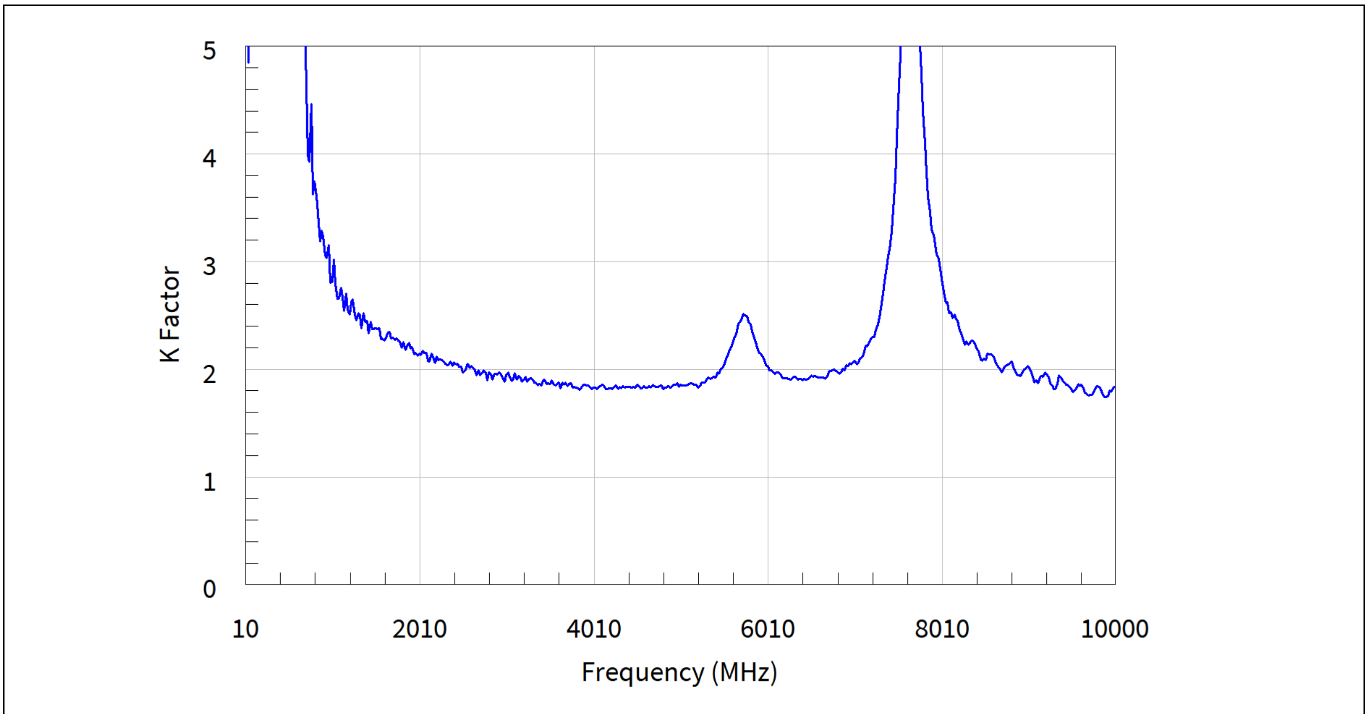

Figure 12 Stability K-factor plots of the 6 GHz to 7 GHz band WLAN LNAs

Revision history

Document revision	Date	Description of changes
V 1.0	2024-12-18	Initial release

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