# Design guide for RF low-noise transistor in UWB applications

## RF bipolar transistor

## About this document

### Scope and purpose

This application note provides application circuit design examples with Infineon's low-noise silicon germanium: carbon (SiGe:C) transistors for ultra wideband (UWB) low-noise amplifiers (LNAs). In this document, the transistor-based LNA schematics, PCB layouts and measurement results are presented. This document is relevant to the following low-noise transistor:

- BGB707L7ESD Low-noise transistor for UWB

### Intended audience

This document is intended for engineers who need to design LNAs for UWB applications.

## Table of contents

# 1 Introduction

## 1.1 UWB receiver

UWB is a rapidly emerging technology with uniquely attractive features that invite significant advances in wireless communication, network, radar, imaging and positioning systems. In 2002, the US Federal Communications Commission (FCC) proposed an enormous “new bandwidth” covering 3.6 to 10.1 GHz at the noise floor, where UWB radio overlaying coexistent RF systems can operate using low-power ultra-short information-bearing pulses.

UWB radios come with unique advantages, which include improved ability to penetrate obstacles, ultra-high precision ranging at the centimeter level, the potential for very high data rates along with a proportionate increase in user capacity, and potentially small size and processing power. IEEE 802.15.4 (2015) standard incorporates a UWB PHY into a personal area network standard and allows for power-efficient, high-data-rate communications together with accurate location estimation. The allocated frequency bands for UWB are 3.1 to 10.6 GHz in North America, 6 to 8.5 GHz in Europe, and 3.4 to 4.8 GHz, 7.25 to 10.25 GHz in Japan.

UWB radio characterizes transmission systems with instantaneous spectral occupancy of more than 500 MHz or a fractional bandwidth of more than 20 percent. Especially for wireless communications, the FCC-regulated power level is very low (below -41.3 dBm), which allows UWB technology to overlay GPS and IEEE 802.11 wireless local area networks (WLANs) that coexist in the 3.6 to 10.1 GHz band. To receive such low signal strength for a quiet broadband signal depends strongly on the first-stage signal amplification with a low measure of noise figure (NF) in the receiver. Broadband LNA can be built easily using an Infineon RF transistor with few external components. The Infineon RF LNA provides very low NF and high gain for wide bandwidth.

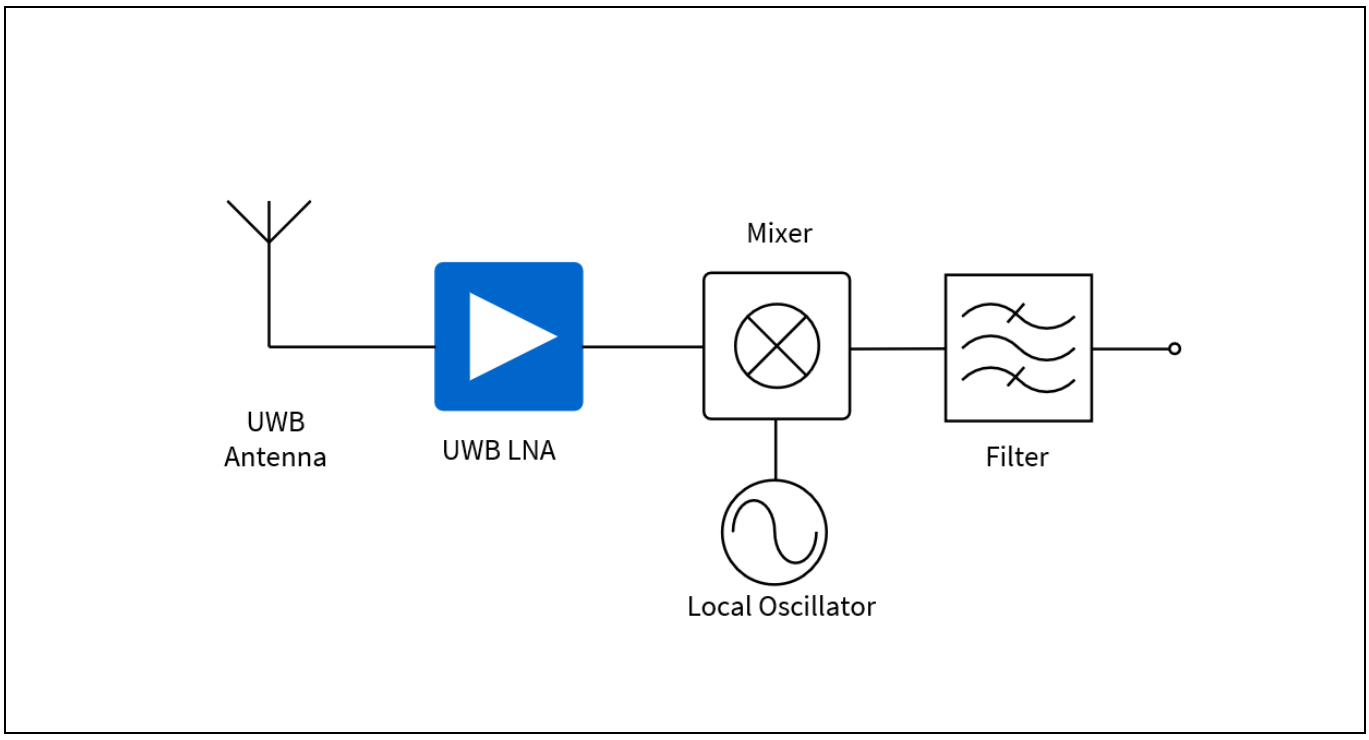


**Figure 1 A block diagram example of the simplified UWB receiver system**

## 1.2 Infineon RF transistors family

Infineon provides high-performance RF transistors targeting UWB LNA applications. Infineon's reliable high-volume RF transistors offer exceptionally low NF, high gain and high linearity at low power consumption levels for RF applications. The BGB707L7ESD is a SiGe:C low-noise monolithic microwave integrated circuit (MMIC) with integrated ESD protection and active biasing. The device is as flexible as discrete transistors and features high gain, reduced power consumption and very low distortion for a very wide range of applications.

# 2 UWB LNA circuit with BGB707L7ESD for 3.5 to 6.5 GHz frequency

## 2.1 Performance overview

The following table shows the UWB LNA performance with RF low-noise MMIC BGB707L7ESD at 3500, 5000 and 6500 MHz.

**Table 1 Summary of measurement results for the UWB LNA with BGB707L7ESD transistor**

| Parameter | Symbol | Value | | | Unit | Notes |
|---|---|---|---|---|---|---|
| Device | | BGB707L7ESD | | | | |
| Bias voltage | $V_{CC}$ | 3.3 | | | V | |
| Bias current | $I_{CC}$ | 9.7 | | | mA | |
| Frequency | f | 3500 | 5000 | 6500 | MHz | |
| Gain | G | 17.5 | 15.7 | 14.6 | dB | |
| NF | NF | 1.04 | 1.09 | 1.14 | dB | PCB and SMA connector losses subtracted: 0.15 dB |
| Input return loss | $RL_{in}$ | 5.5 | 8.9 | 9.1 | dB | |
| Output return loss | $RL_{out}$ | 7.6 | 8.3 | 9.4 | dB | |
| Reverse isolation | $ISO_{rev}$ | 28.2 | 25.6 | 24.3 | dB | |
| Output 1 dB compression point | $OP_{1dB}$ | 1.5 | 5.9 | 7.5 | dBm | |
| Stability | K | More than 1 | | | | Measured from 10 MHz to 15 GHz |

## 2.2 Schematic

The following figure shows the general schematic of the UWB LNA with low-noise MMIC BGB707L7ESD. In the circuit, the resistor R1 sets up the biasing current. The resistors R2 and R3 stabilize the circuit, whose stability is measured up to 15 GHz. The circuit input matching is achieved by the network of capacitors C1, C2 and the inductor L1. The network of L2, C4, C5 and C6 matches the transistor to the output port. The capacitor C3 serves as the RF bypass.

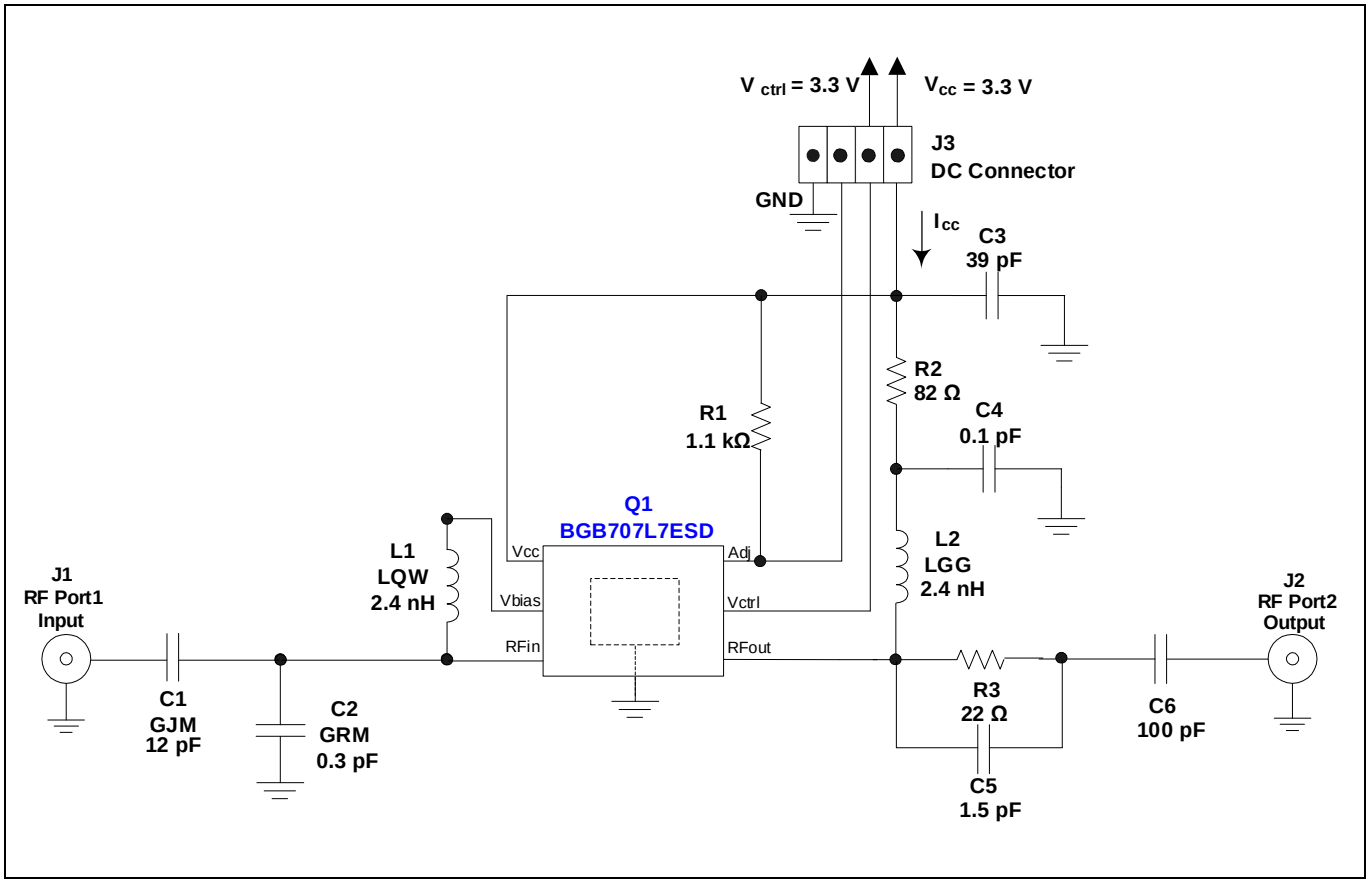


**Figure 2 Schematic of the UWB LNA with BGB707L7ESD transistor**

## 2.3 Bill of materials

**Table 2 Bill of materials of the UWB LNA with BGB707L7ESD transistor**

| Symbol | Value | Unit | Package | Manufacturer | Comment |
|---|---|---|---|---|---|
| Q1 | BGB707L7ESD | | TSLP-7-1 | Infineon Technologies | SiGe:C MMIC LNA |
| C1 | 12 | pF | 0402 | Murata GJM | Input matching and DC block |
| C2 | 0.3 | pF | 0402 | Murata GRM | Input matching |
| C3 | 39 | pF | 0402 | Various | RF bypass |
| C4 | 0.1 | pF | 0402 | Murata GRM | Output matching |
| C5 | 1.5 | pF | 0402 | Murata GRM | Output matching |
| C6 | 100 | pF | 0402 | Various | Output matching and DC block |
| L1 | 2.4 | nH | 0402 | Murata LQW | DC feed and input matching |
| L2 | 2.4 | nH | 0402 | Murata LQG | DC feed and output matching |
| R1 | 1.1 | kΩ | 0402 | Various | Base bias |
| R2 | 82 | Ω | 0402 | Various | Stability improvement |
| R3 | 22 | Ω | 0402 | Various | Stability improvement |

## 2.4 Evaluation board and layout information

The UWB LNA evaluation board with BGB707L7ESD transistor:

- PCB material: Rogers RO4003C
- PCB marking: BGB7 family V3.1 M141017

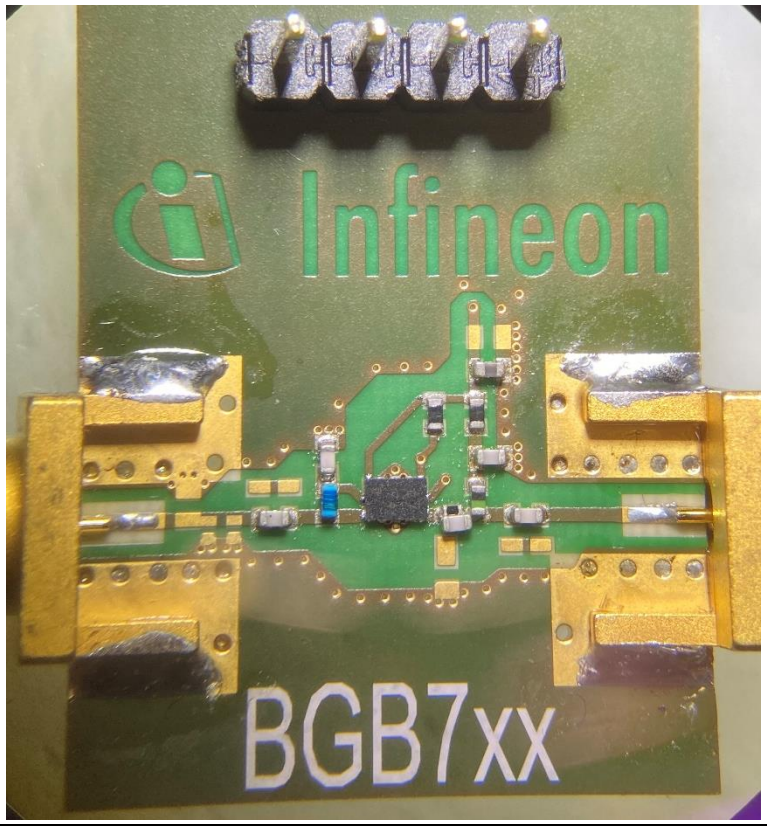


**Figure 3 PCB layout and photo of the BGB707L7ESD UWB LNA evaluation board**

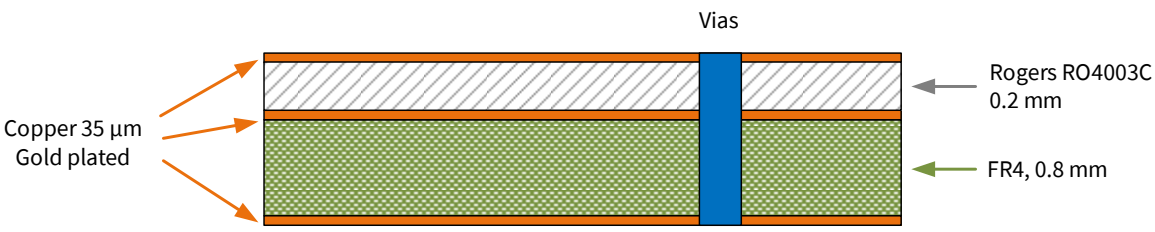


**Figure 4 PCB stack information for the evaluation board**

## 2.5 Measurement results of the UWB LNA with BGB707L7ESD transistor

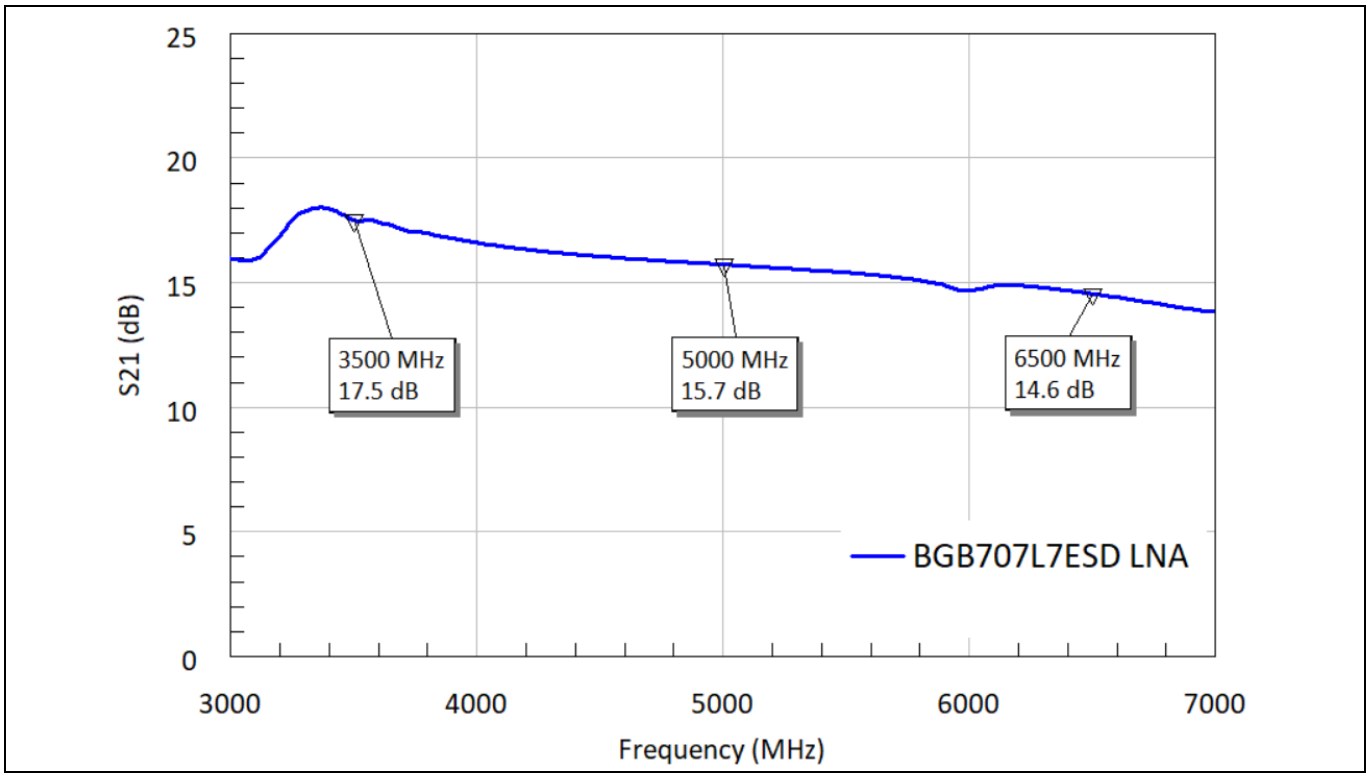


**Figure 5 Small-signal gain of the UWB LNA with BGB707L7ESD transistor**

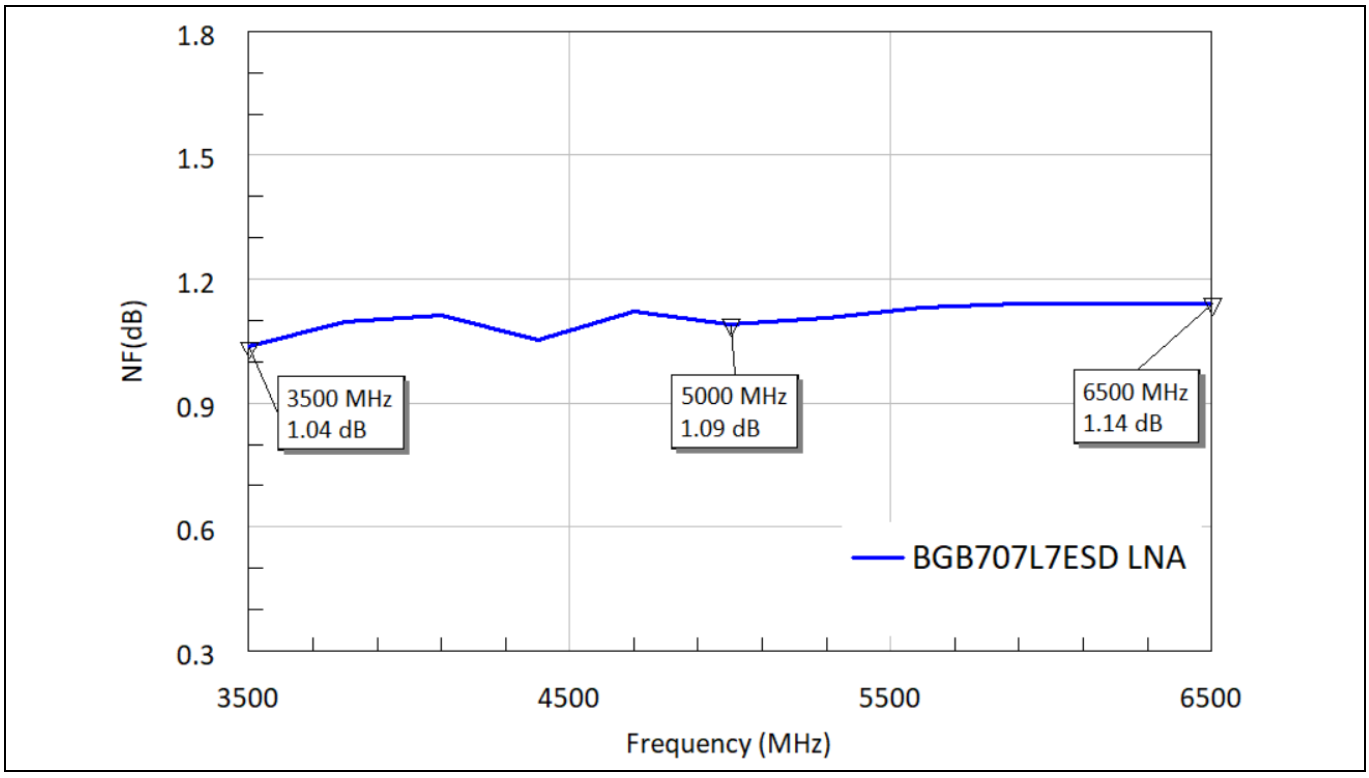


**Figure 6 NF measurement of the UWB LNA with BGB707L7ESD transistor**

*Note: The graphs are generated with the AWR electronic design automation (EDA) software Microwave Office®.*

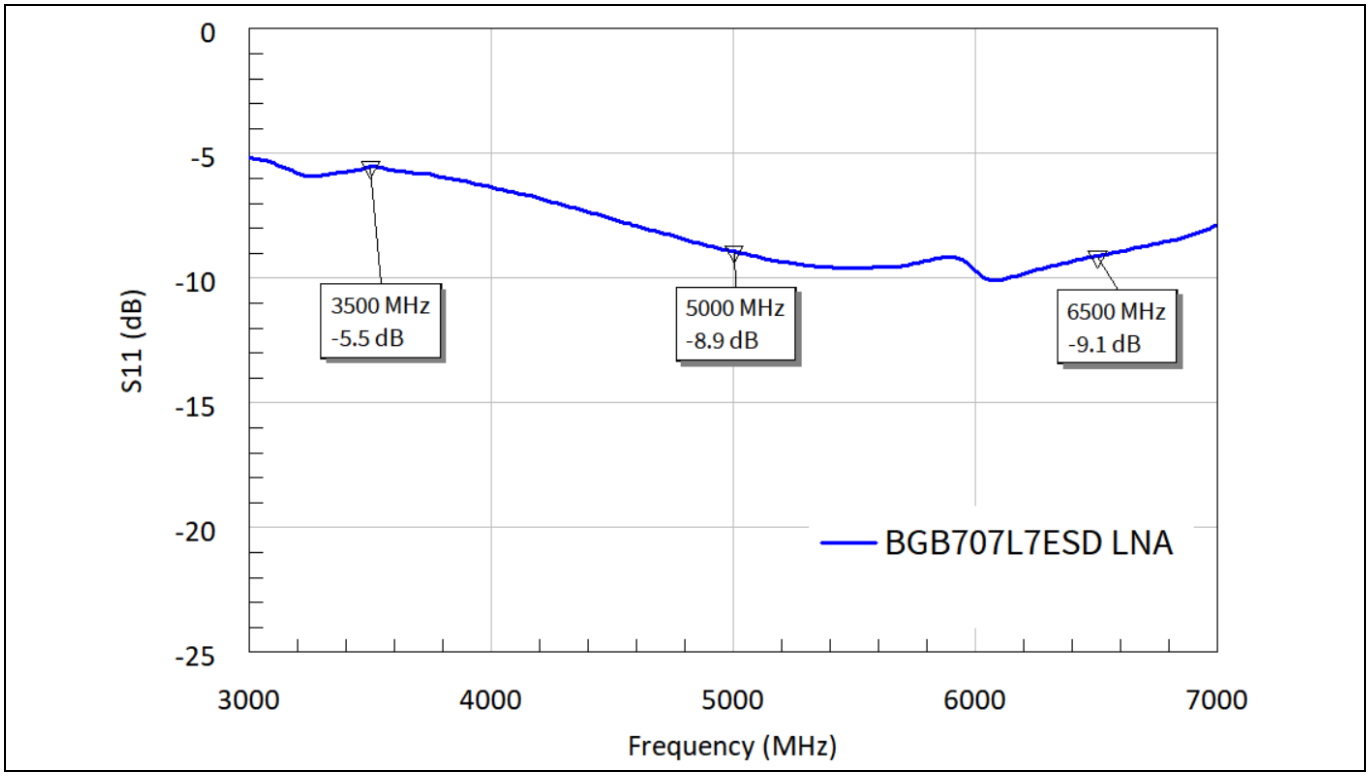


**Figure 7 Input return loss of the UWB LNA with BGB707L7ESD transistor**

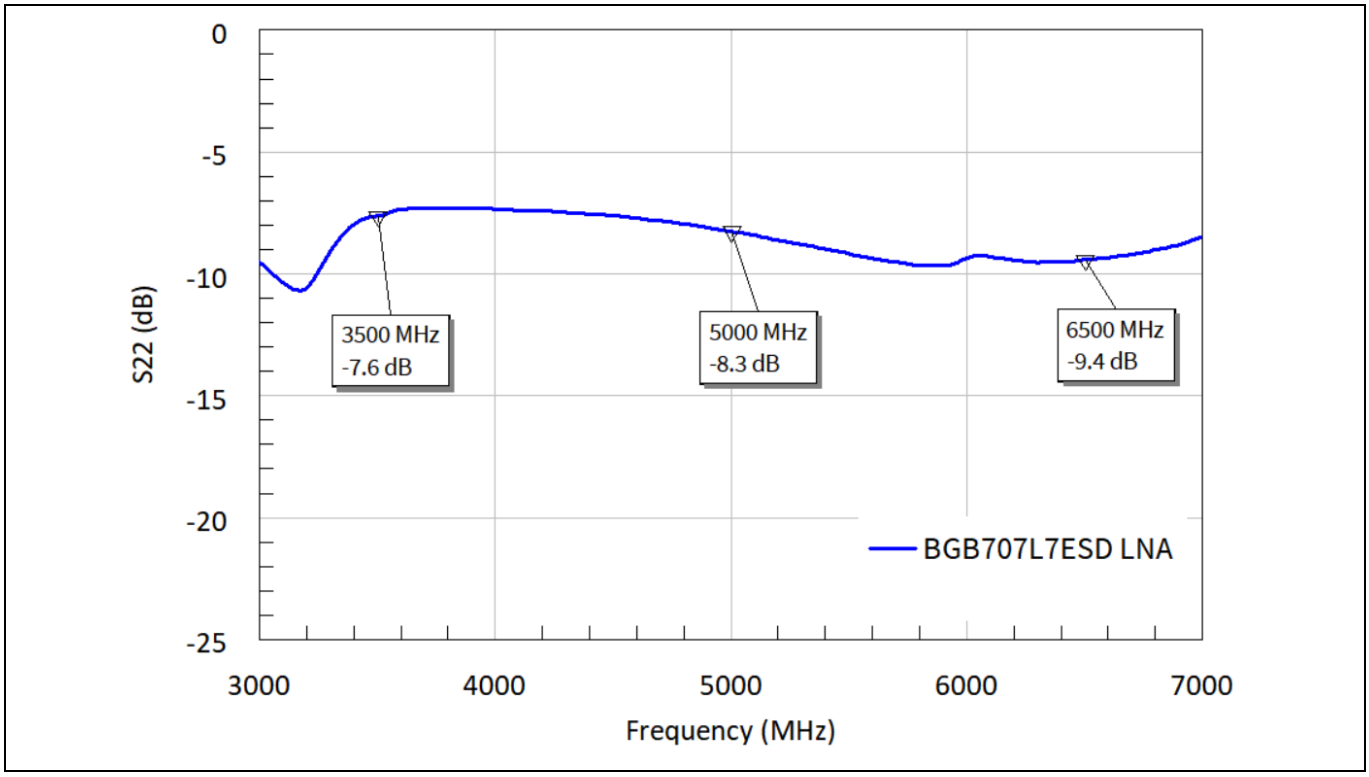


**Figure 8 Output return loss of the UWB LNA with BGB707L7ESD transistor**

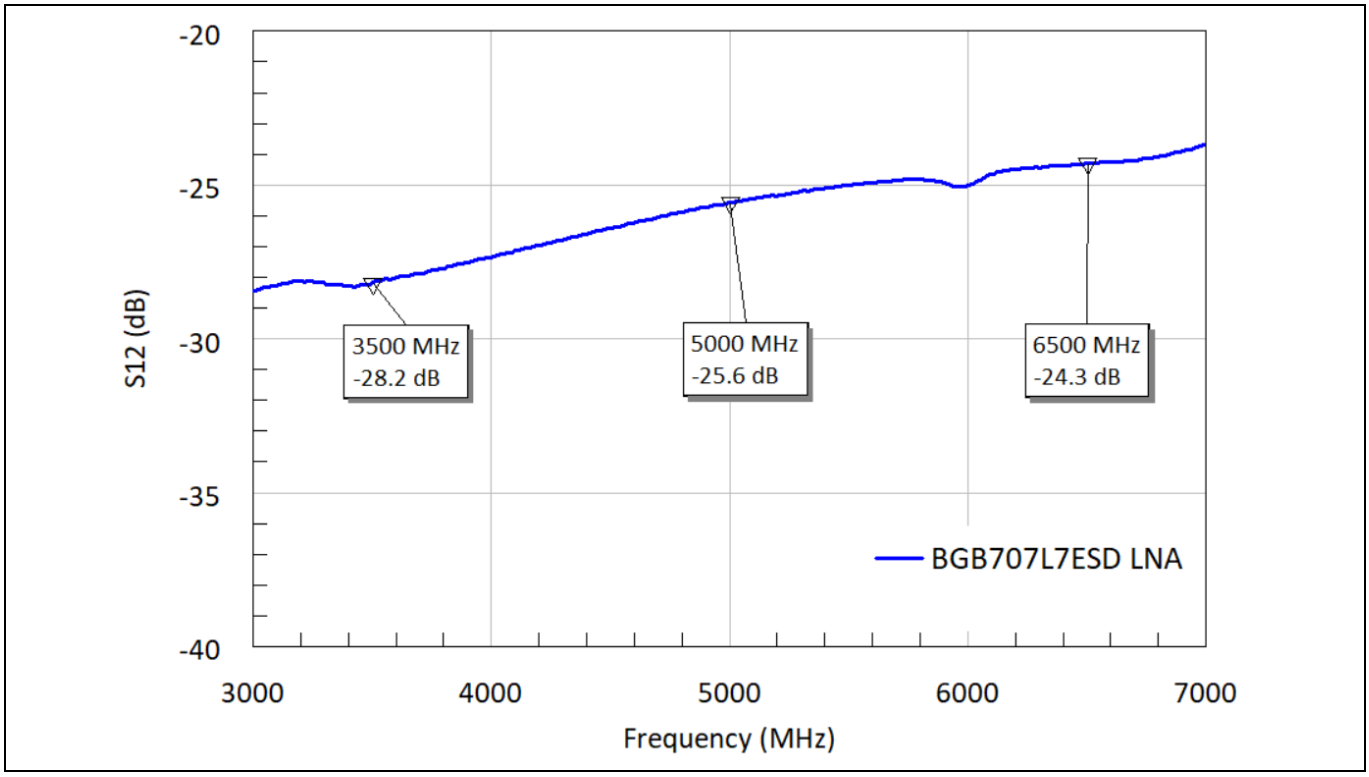


**Figure 9 Reverse isolation of the UWB LNA with BGB707L7ESD transistor**

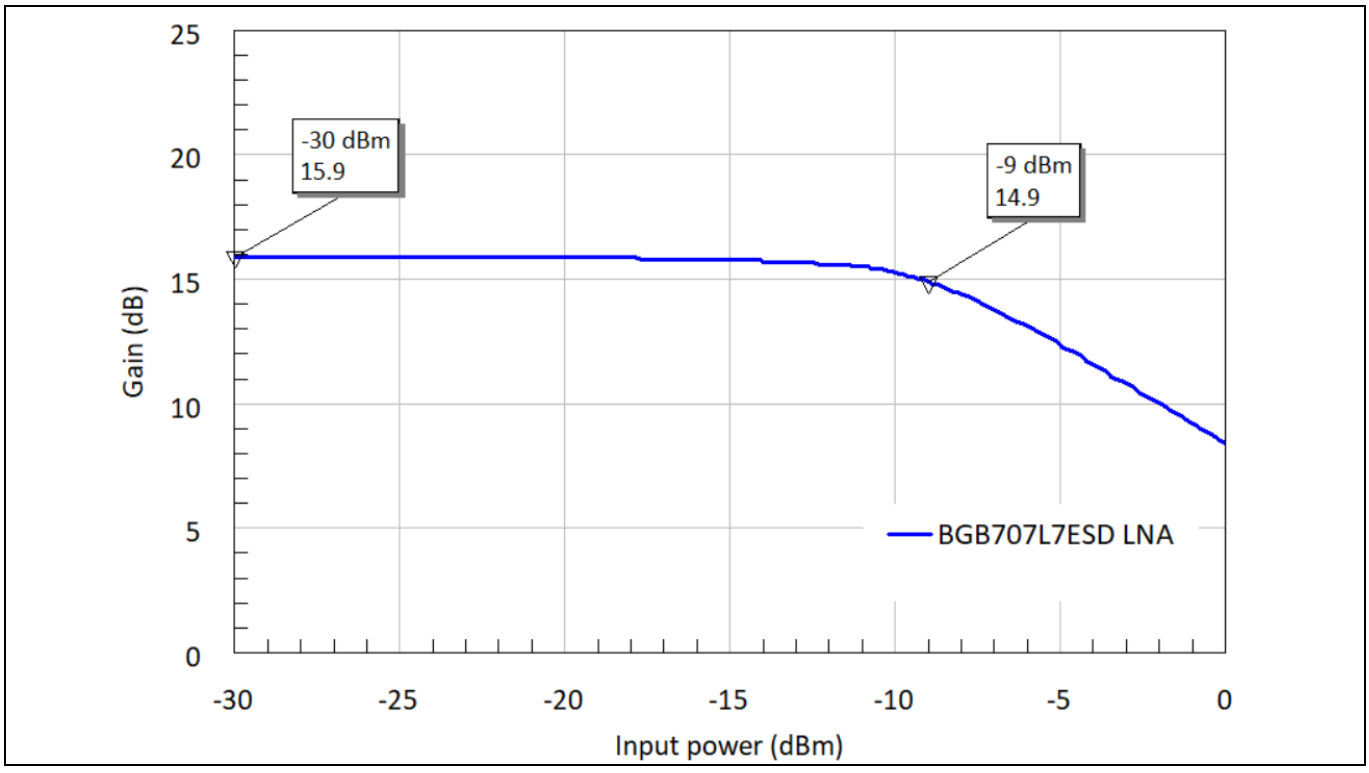


**Figure 10 Input 1 dB compression point of the UWB LNA with BGB707L7ESD transistor at 5 GHz**

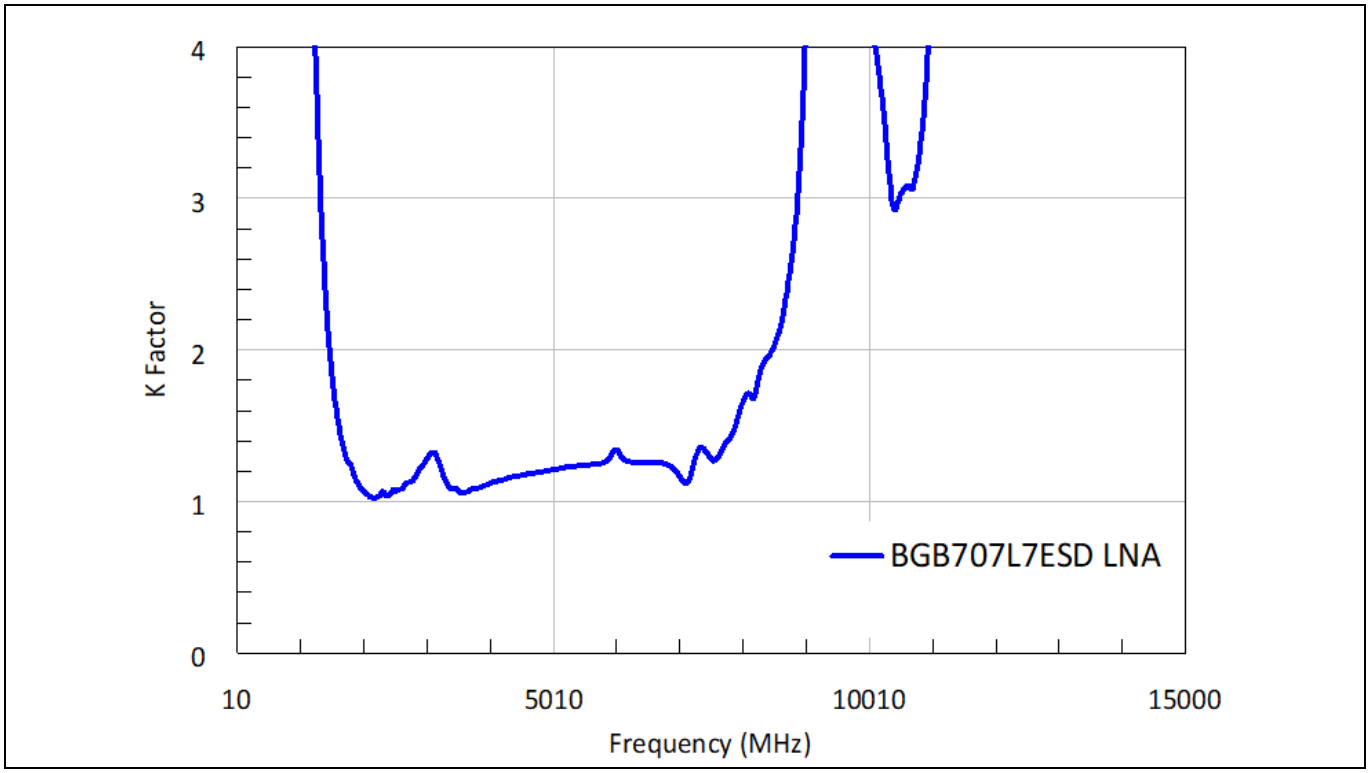


**Figure 11 K-factor measurement of the UWB LNA with BGB707L7ESD transistor**

# 3 UWB LNA circuit with BGB707L7ESD for 6.5 to 8 GHz frequency

## 3.1 Performance overview

The following table shows the UWB LNA performance with RF low-noise MMIC BGB707L7ESD at 6500, 7000, 7500 and 8000 MHz.

**Table 3 Summary of measurement results for the UWB LNA with BGB707L7ESD transistor**

| Parameter | Symbol | Value | | | | Unit | Notes |
|---|---|---|---|---|---|---|---|
| Device | | BGB707L7ESD | | | | | |
| Bias voltage | $V_{CC}$ | 3.3 | | | | V | |
| Bias current | $I_{CC}$ | 9.7 | | | | mA | |
| Frequency | f | 6500 | 7000 | 7500 | 8000 | MHz | |
| Gain | G | 13.8 | 13.4 | 12.8 | 12.2 | dB | |
| NF | NF | 1.23 | 1.09 | 1.04 | 1.11 | dB | PCB and SMA connector losses subtracted: 0.15 dB |
| Input return loss | $RL_{in}$ | 12.4 | 9 | 6.5 | 5.1 | dB | |
| Output return loss | $RL_{out}$ | 11.6 | 15.4 | 18.3 | 15.4 | dB | |
| Reverse isolation | $ISO_{rev}$ | 27 | 26.3 | 26.1 | 26.2 | dB | |
| Output 1 dB compression point | $OP_{1dB}$ | 6.2 | 5.7 | 5.9 | 6.9 | dBm | |
| Stability | K | More than 1 | | | | | Measured from 10 MHz to 15 GHz |

## 3.2 Schematic

The following figure shows the general schematic of the UWB LNA with low-noise MMIC BGB707L7ESD. In the circuit, the resistor R1 sets up the biasing current. The resistors R2 and R3 stabilize the circuit, whose stability is measured up to 15 GHz. The circuit input matching is achieved by the network of capacitors C1, C2 and the inductor L1. The network of L2, C3, C5, and C6 matches the transistor to the output port. The capacitors C2 and C4 serve as the RF bypass.

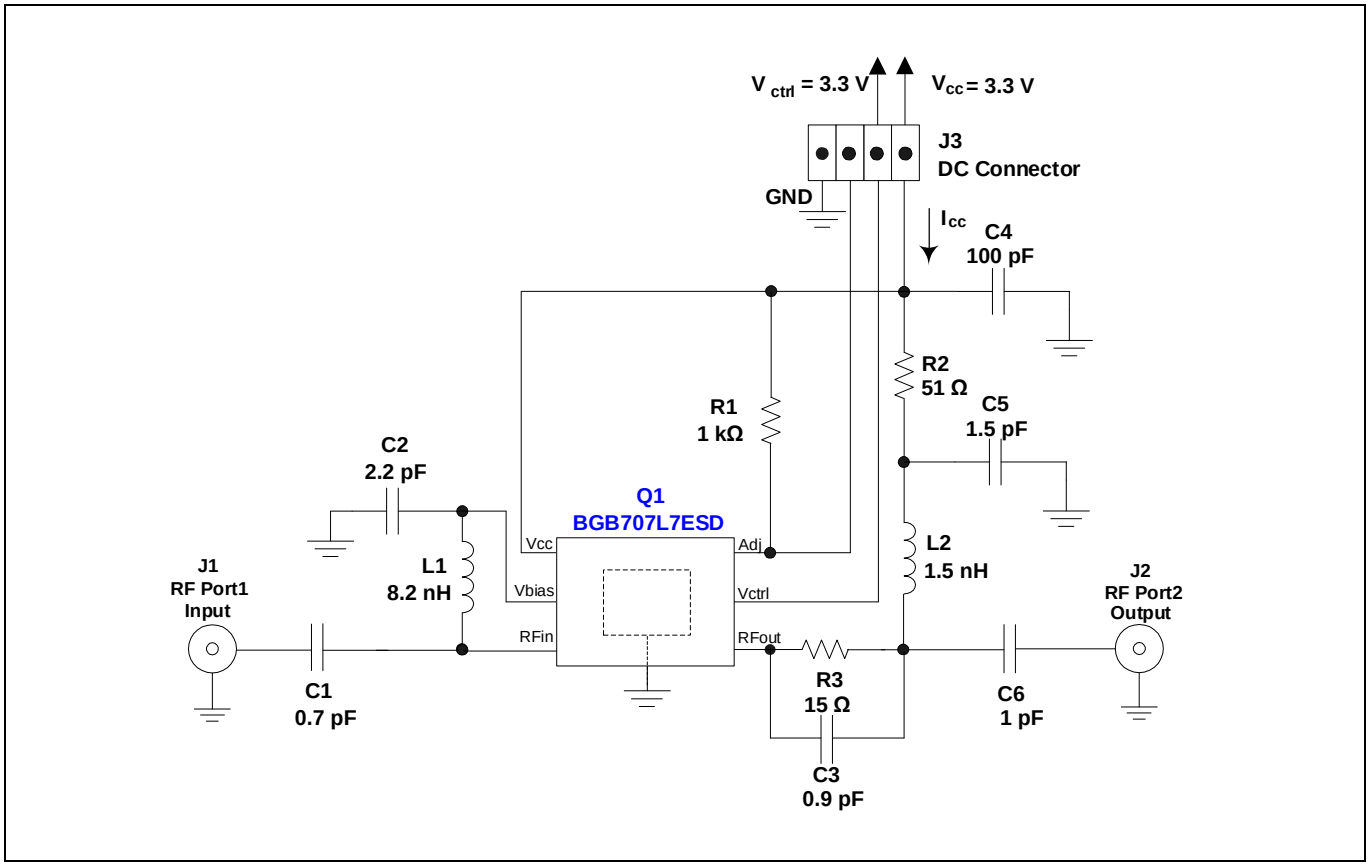


**Figure 12 Schematic of the UWB LNA with BGB707L7ESD transistor**

## 3.3 Bill of materials

**Table 4 Bill of materials of the UWB LNA with BGB707L7ESD transistor**

| Symbol | Value | Unit | Package | Manufacturer | Comment |
|---|---|---|---|---|---|
| Q1 | BGB707L7ESD | | TSLP-7-1 | Infineon Technologies | SiGe:C MMIC LNA |
| C1 | 0.7 | pF | 0402 | Various | Input matching and DC block |
| C2 | 2.2 | pF | 0402 | Various | RF bypass |
| C3 | 0.9 | pF | 0402 | Various | Output matching |
| C4 | 100 | pF | 0402 | Various | RF bypass |
| C5 | 1.5 | pF | 0402 | Various | Low-frequency stability improvement |
| C6 | 1 | pF | 0402 | Various | Output matching and DC block |
| L1 | 8.2 | nH | 0402 | Murata LQW | DC feed and input matching |
| L2 | 1.5 | nH | 0402 | Murata LQG | DC feed and output matching |
| R1 | 1 | kΩ | 0402 | Various | Base bias |
| R2 | 51 | Ω | 0402 | Various | Low-frequency stability improvement |
| R3 | 15 | Ω | 0201 | Various | High-frequency stability improvement |

## 3.4 Evaluation board and layout information

The UWB LNA evaluation board with BGB707L7ESD transistor:

- PCB material: Rogers RO4003C
- PCB marking: BGB7 family V3.1 M141017

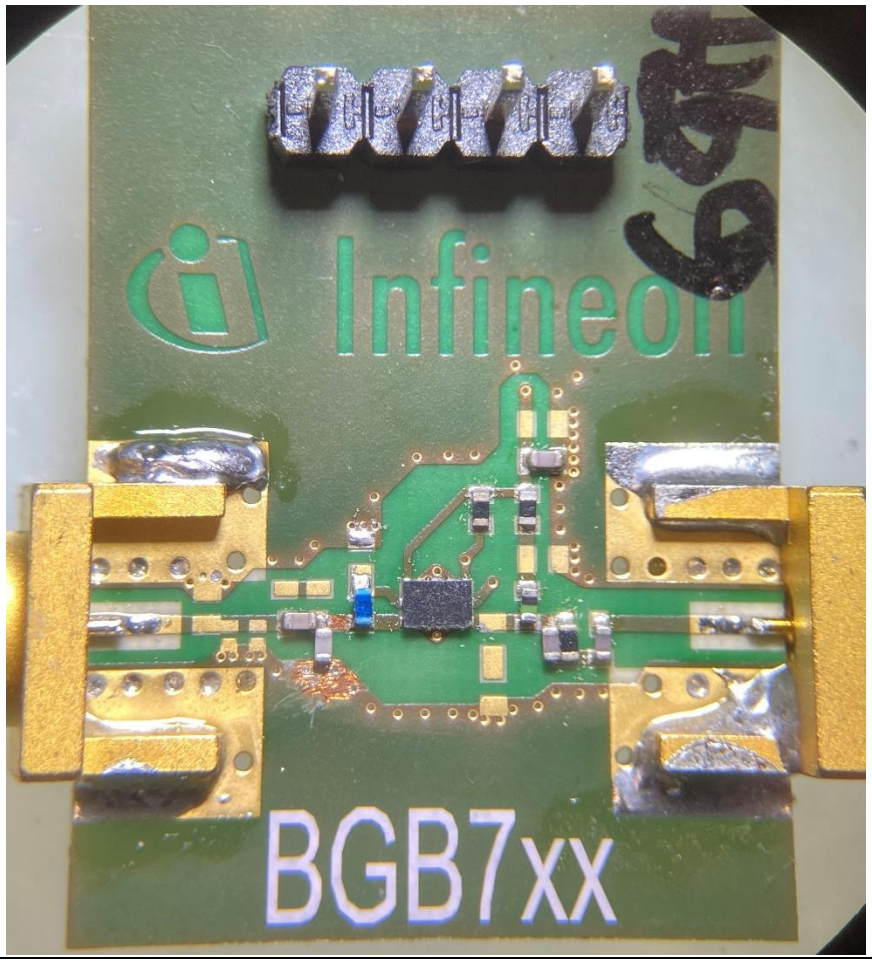


**Figure 13 PCB layout and photo of the BGB707L7ESD UWB LNA evaluation board**

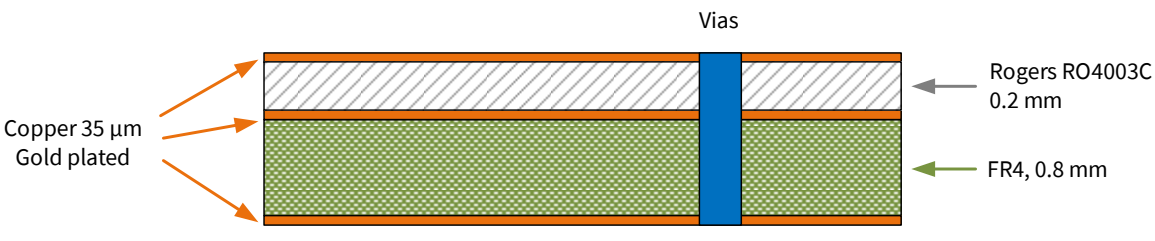


**Figure 14 PCB stack information for the evaluation board**

## 3.5 Measurement results of the UWB LNA with BGB707L7ESD transistor

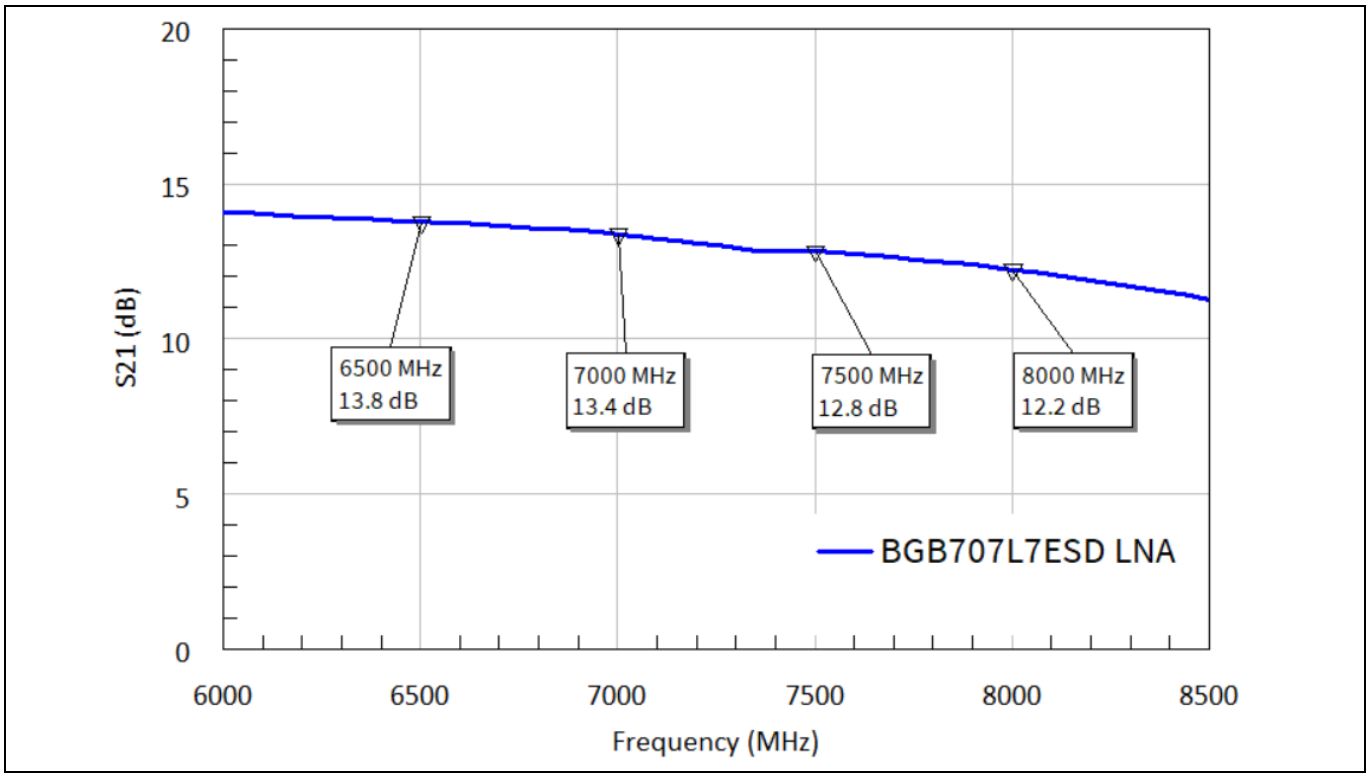


**Figure 15 Small-signal gain of the UWB LNA with BGB707L7ESD transistor**

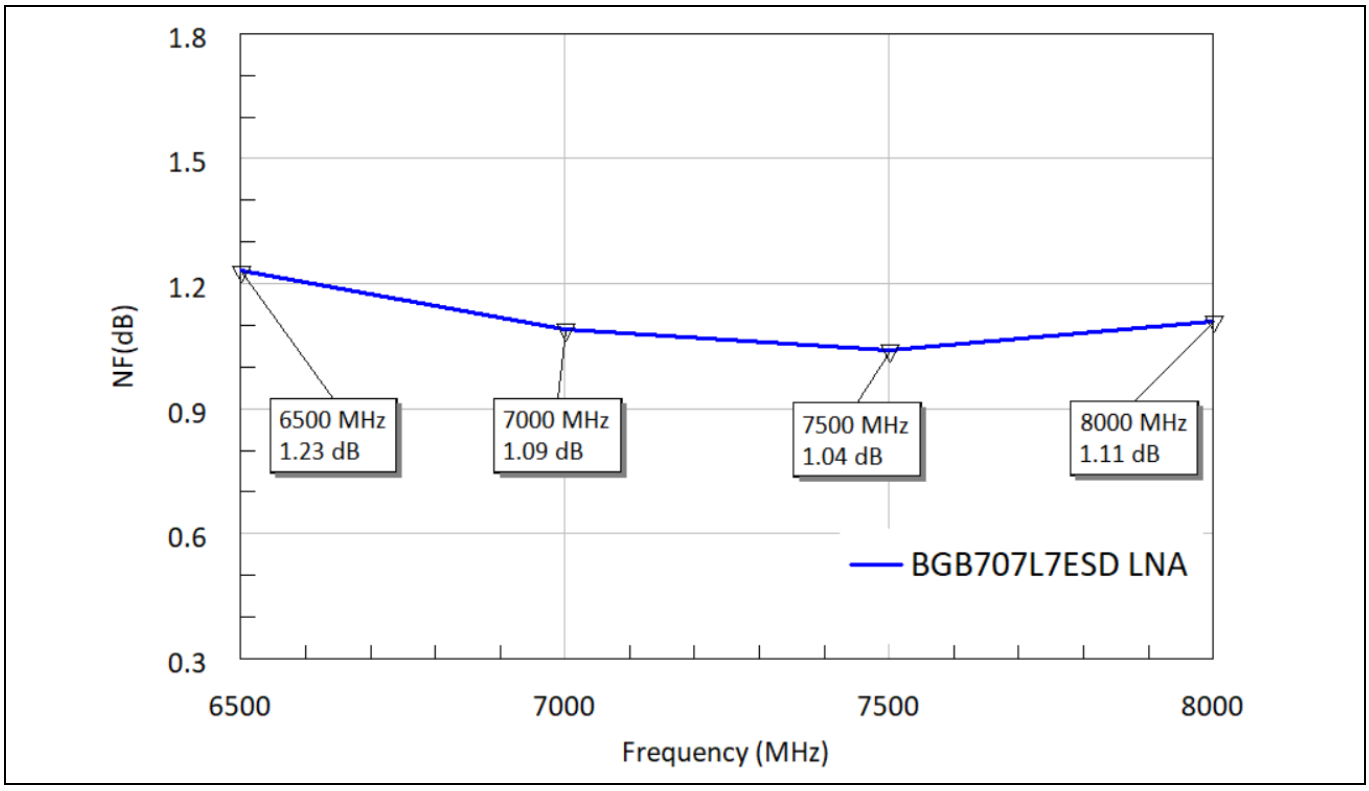


**Figure 16 NF measurement of the UWB LNA with BGB707L7ESD transistor**

*Note: The graphs are generated with the AWR EDA software Microwave Office®.*

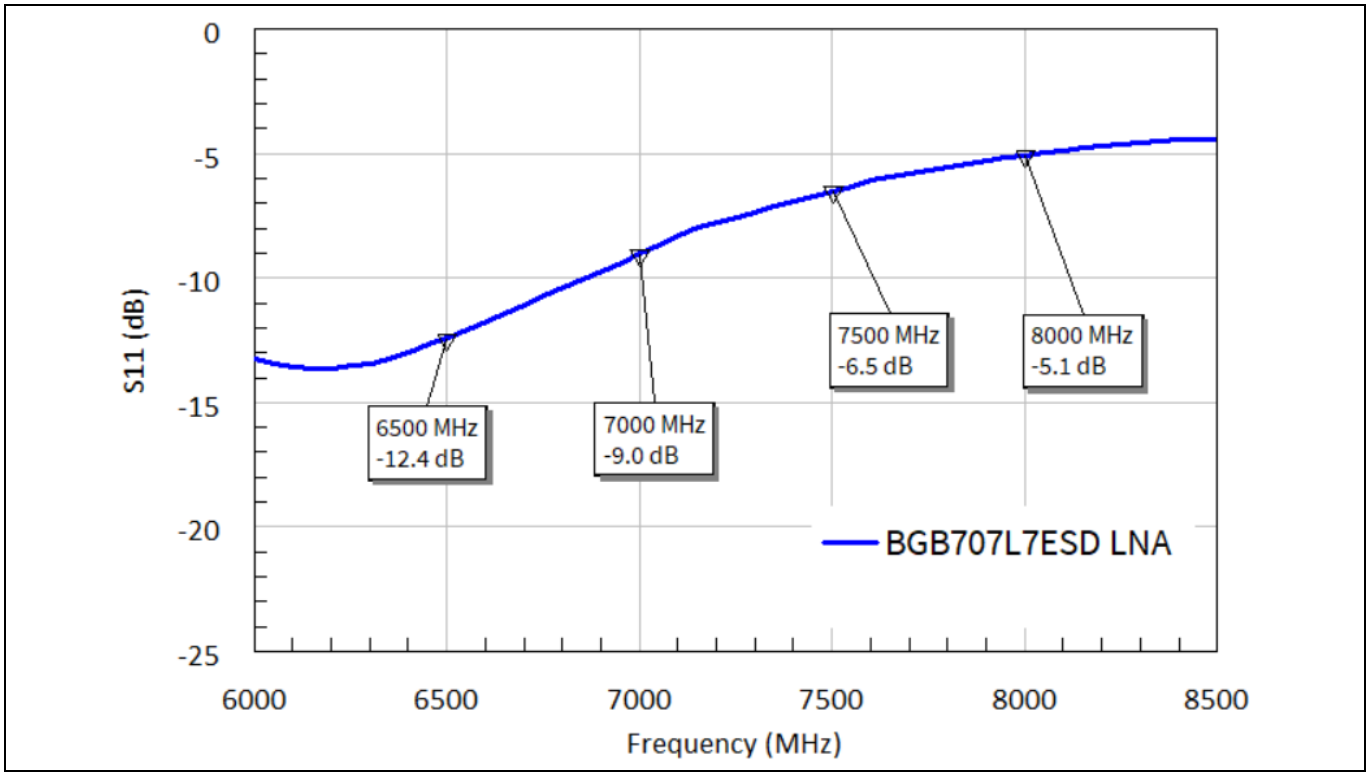


**Figure 17 Input return loss of the UWB LNA with BGB707L7ESD transistor**

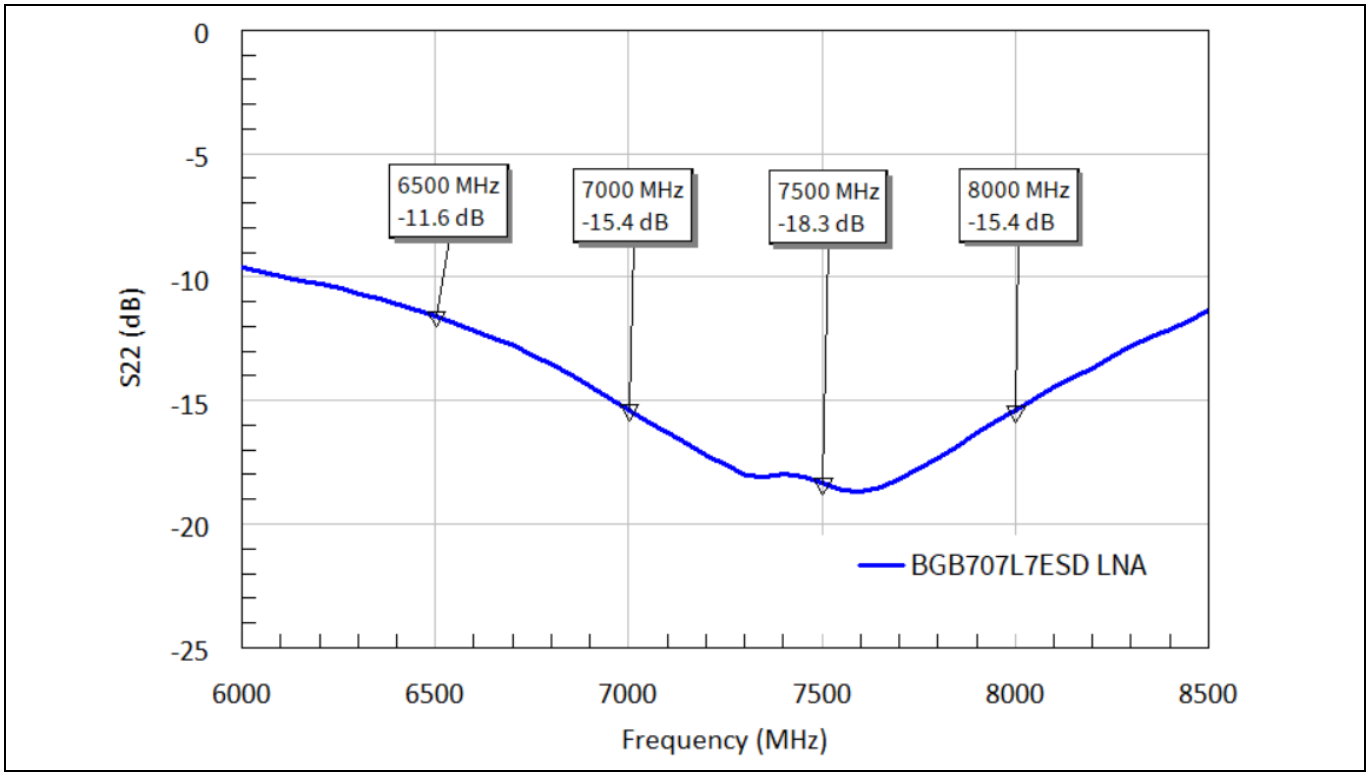


**Figure 18 Output return loss of the UWB LNA with BGB707L7ESD transistor**

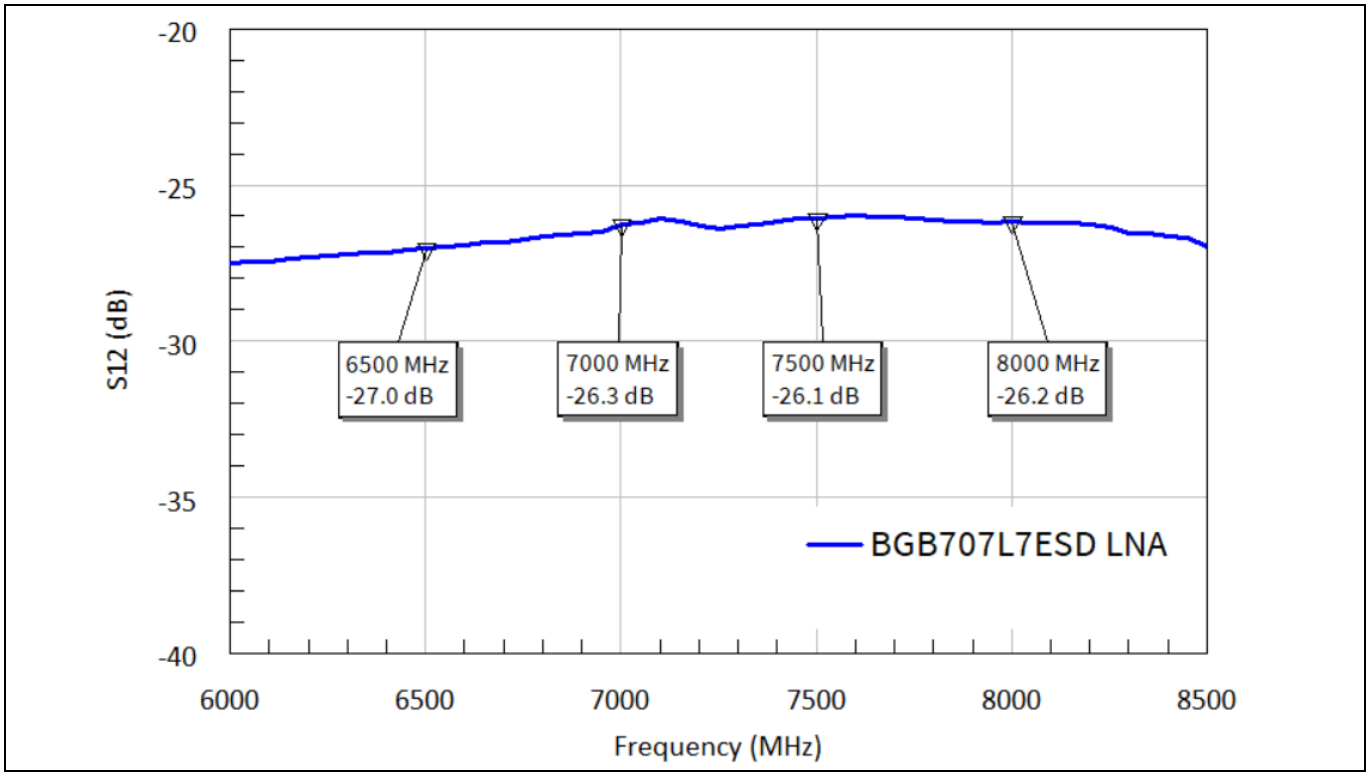


**Figure 19 Reverse isolation of the UWB LNA with BGB707L7ESD transistor**

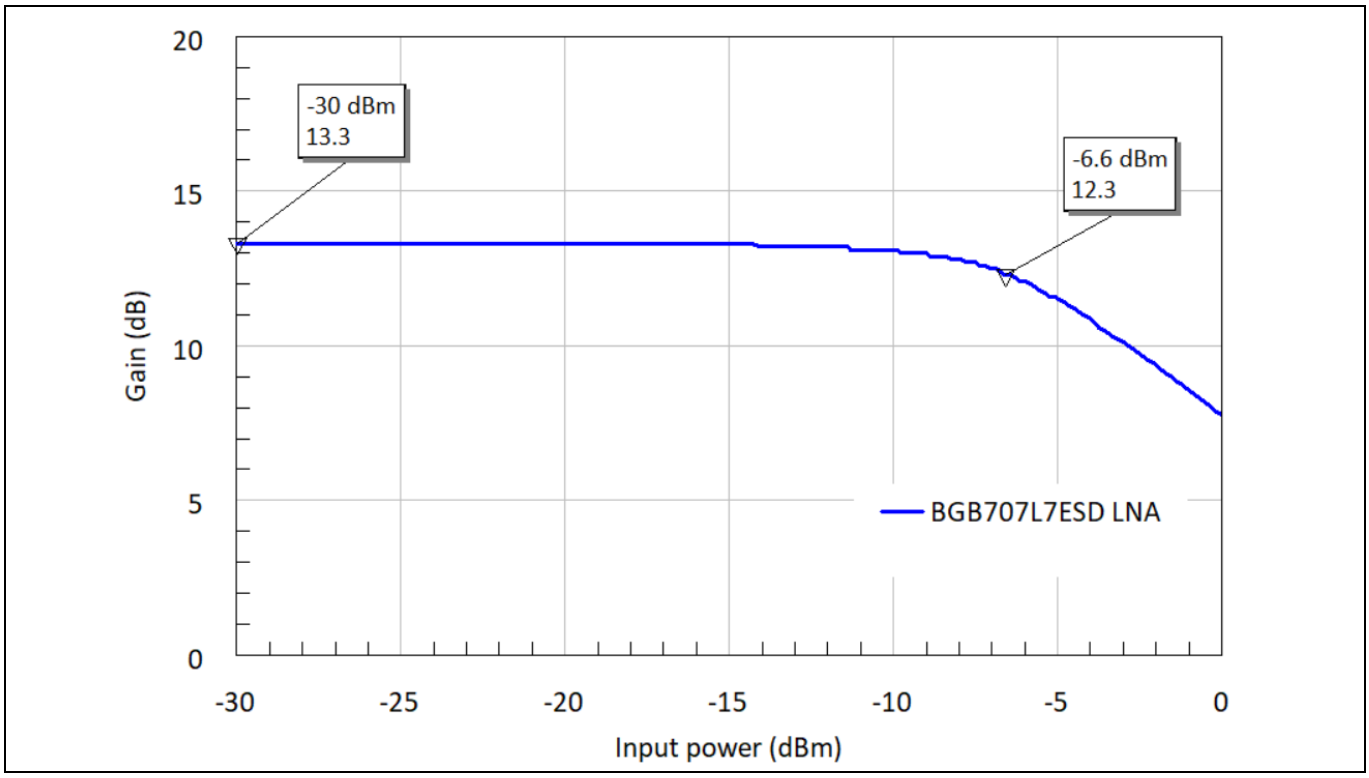


**Figure 20 Input 1 dB compression point of the UWB LNA with BGB707L7ESD transistor at 7 GHz**

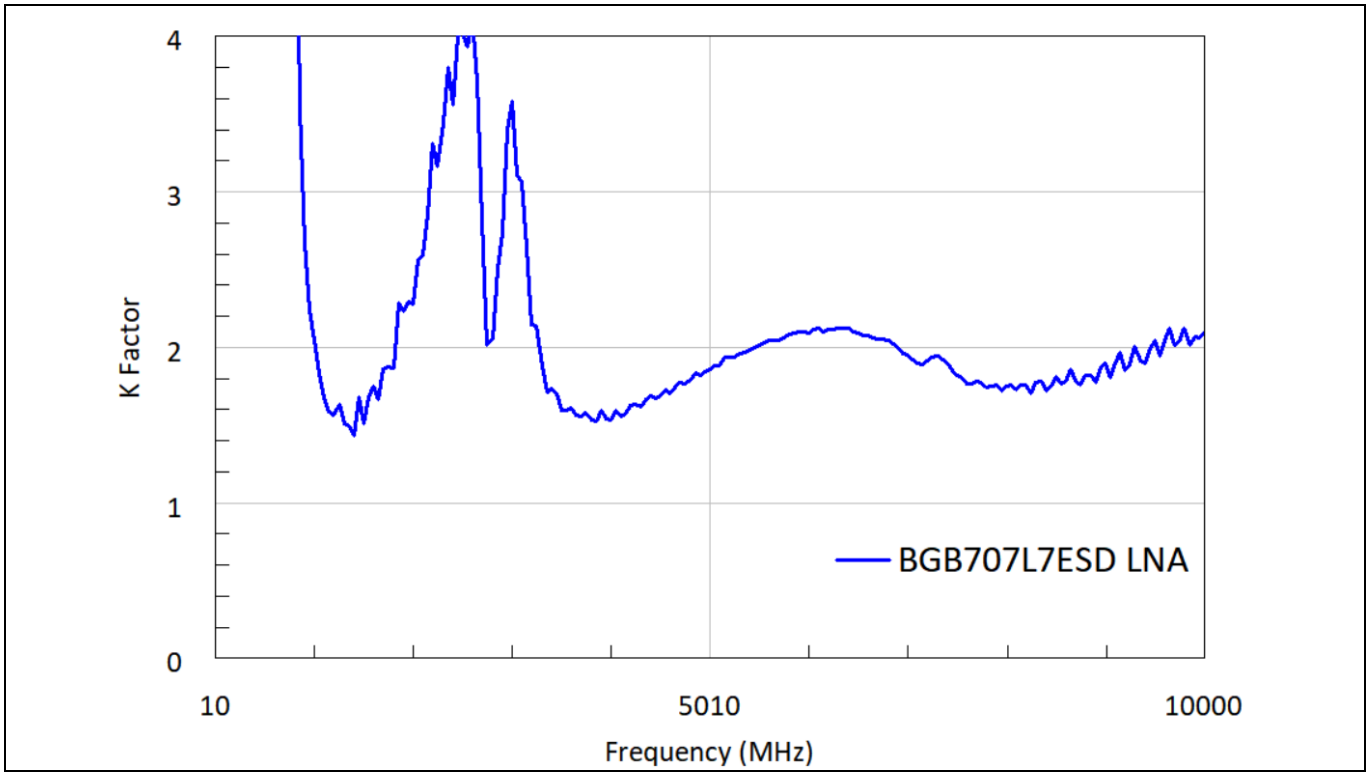


**Figure 21 K-factor measurement of the UWB LNA with BGB707L7ESD transistor**

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# Revision history

| Document version | Date of release | Description of changes |
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