

BGA7M1N6

Single-Band LTE LNA

Single Band LTE LNA BGA7M1N6 for  
Broadband Application Supporting  
1800 MHz to 2200 MHz, Using 0201  
Components

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## 1 Introduction

### 1.1 Introduction About 3G and 4G

The mobile technologies for smartphones have seen tremendous growth in recent years. The data rate required from mobile devices has increased significantly over the evolution modern mobile technologies starting from the first 3G/3.5G technologies (UMTS & WCDMA, HSPA & HSPA+) to the recently 4G LTE-Advanced (LTE-A, LTE-B, LTE-C, ... ). LTE-Advanced can support download data rates of up to 1 Gbps and upload data rates up to 500 Mbps.

Advanced technologies such as diversity Multiple Input Multiple Output (MIMO) and Carrier Aggregation (CA) are adopted to achieve such higher data rate requirements. MIMO technology, commonly referred as the diversity path in smartphones, has attracted attention for the significant increase in data throughput and link range without additional bandwidth or increased transmit power. The technology supports scalable channel bandwidth from 1.4 to 20 MHz. The ability of 4G LTE to support bandwidths up to 20 MHz and to have more spectral efficiency by using high order modulation methods like QAM-64 is of particular importance as the demand for higher wireless data rates continues to grow fast. Carrier aggregation used in LTE-Advanced combines up to 5 carriers and widens bandwidths up to 100 MHz to increase the user rates, across FDD and TDD.

Countries all over the world have released various frequency bands for the 4G applications. **Table 1** shows the band assignment for the LTE bands worldwide.

**Table 1**      **LTE Band Assignment**

Band No.	Uplink Frequency Range	Downlink Frequency Range	Comment
1	1920-1980 MHz	2110-2170 MHz	FDD
2	1850-1910 MHz	1930-1990 MHz	FDD
3	1710-1785 MHz	1805-1880 MHz	FDD
4	1710-1755 MHz	2110-2155 MHz	FDD
5	824-849 MHz	869-894 MHz	FDD
6	830-840 MHz	875-885 MHz	FDD
7	2500-2570 MHz	2620-2690 MHz	FDD
8	880-915 MHz	925-960 MHz	FDD
9	1749.9-1784.9 MHz	1844.9-1879.9 MHz	FDD
10	1710-1770 MHz	2110-2170 MHz	FDD

**Table 1      LTE Band Assignment**

<b>Band No.</b>	<b>Uplink Frequency Range</b>	<b>Downlink Frequency Range</b>	<b>Comment</b>
11	1427.9-1452.9 MHz	1475.9-1500.9 MHz	FDD
12	698-716 MHz	728-746 MHz	FDD
13	777-787 MHz	746-756 MHz	FDD
14	788-798 MHz	758-768 MHz	FDD
17	704-716 MHz	734-746 MHz	FDD
18	815-830 MHz	860-875 MHz	FDD
19	830-845 MHz	875-890 MHz	FDD
20	832-862 MHz	791-821 MHz	FDD
21	1447.9-1462.9 MHz	1495.9-1510.9 MHz	FDD
22	3410-3500 MHz	3510-3600 MHz	FDD
23	2000-2020 MHz	2180-2200 MHz	FDD
24	1626.5-1660.5 MHz	1525-1559 MHz	FDD
25	1850-1915 MHz	1930-1995 MHz	FDD
26	814-849 MHz	859-894 MHz	FDD
27	807-824 MHz	852-869 MHz	FDD
28	703-748 MHz	758-803 MHz	FDD
29	N/A	716-728 MHz	FDD
33		1900-1920 MHz	TDD
34		2010-2025 MHz	TDD
35		1850-1910 MHz	TDD
36		1930-1990 MHz	TDD
37		1910-1930 MHz	TDD
38		2570-2620 MHz	TDD
39		1880-1920 MHz	TDD
40		2300-2400 MHz	TDD
41		2496-2690 MHz	TDD
42		3400-3600 MHz	TDD
43		3600-3800 MHz	TDD
44		703-803 MHz	TDD

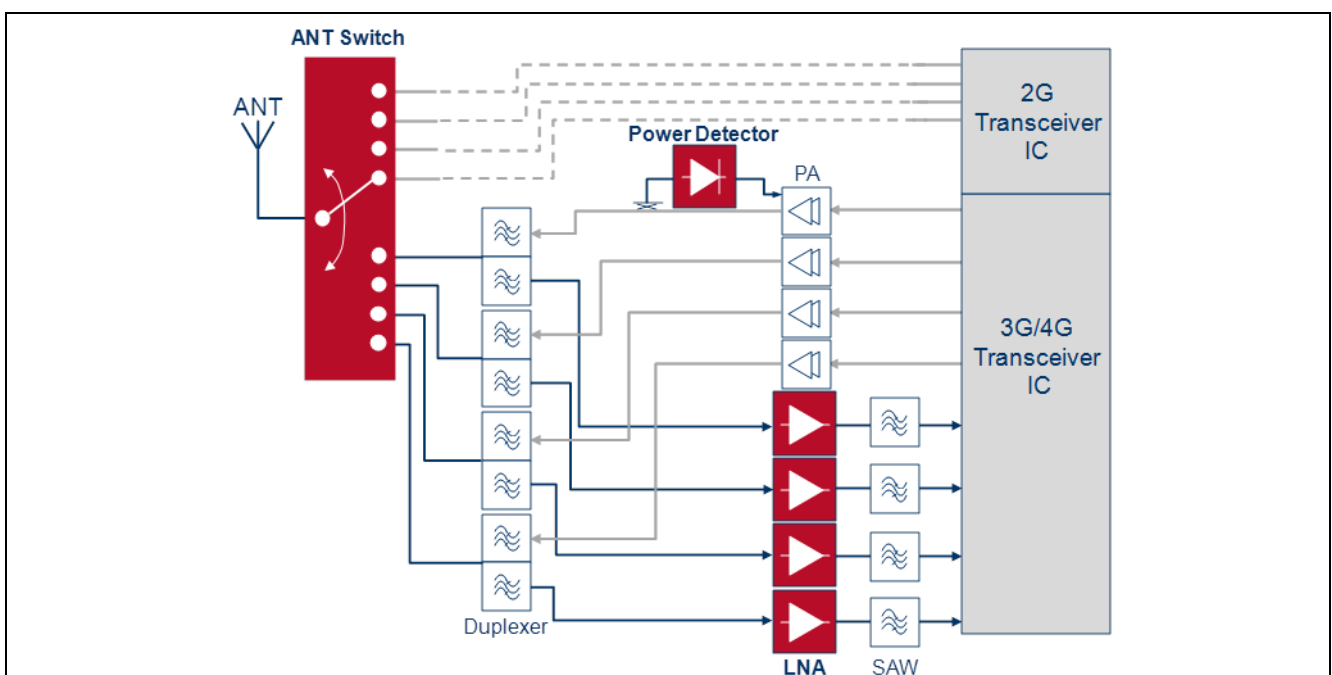
In order to cover all the bands from different countries in a unique device, mobile phones and data cards are usually equipped with several bands. Some typical examples are quad-band FDD systems are the following band combinations: 1/2/5/8, 1/3/5/7 and 3/7/5/17. Besides these FDD-LTE frequency bands, several TD-LTE bands are available around the world. Some of these bands are band-42 in Australia and UK, band-38 in the US and China, and band-40 in India and Australia.

## 1.2 Applications

**Figure 1** shows an example of the simplified block diagram of the RF front-end of a 3G and 4G system. A SPnT switch connects one side the antenna and several duplexers for different 4G bands on the other side. Every duplexer is connected to the transmitting (TX) and receiving (RX) paths of each band. The external LTE LNA BGA7M1N6 of Infineon is placed on the RX path between the duplex and the bandpass SAW filter. The output of the SAW filter is connected to the receiver input of the transceiver IC.

Depending on the number of bands designed in a device, various numbers of LNAs are required in a system. Recently, even mobile devices with 5 modes 13 bands are under discussion. Not only for the main pathes, but also for the diversity pathes, the external LNAs are widely used to boost end user experience while using mobile devices for video and audio streaming.

Besides low noise amplifiers, Infineon Technologies also offers solutions for high power highly linear antenna switches, band switches as well as power detection diodes for power amplifiers.



**Figure 1** Example of Application Diagram of RF Front-End for 3G and 4G Systems.

### 1.3 Infineon LNAs for 3G, 4G LTE and LTE-A Applications

With the increasing wireless data rate and with the extended link distance of mobile phones and 4G data cards, the requirements on the sensitivity are much higher. Infineon offers different kind of low noise amplifiers (LNAs) to support the customers developing 4G LTE and LTE-Advanced mobile phones and data cards to further improve their system performance and to meet the requirements coming from the networks/service providers.

The benefits to use Infineon's high performance LNAs in 4G LTE and LTE-Advanced applications are:

- Flexible design to place the front-end components: due to the size constraint, the modem antenna and the front-end can not be always put close to the transceiver IC. The path loss in front of the integrated LNA on the transceiver IC increases the system noise figure noticeably. An external LNA physically close to the antenna can help to eliminate the path loss and reduce the system noise figure. Therefore the sensitivity can be improved by several dB.
- Support RX carrier aggregation where two LNAs can be tuned on at the same time.
- Boost the sensitivity by reducing the system noise figure: external LNA has lower noise figure than the integrated LNA on the transceiver IC.
- Bug fix to help the transceiver ICs to fulfill the system requirements.
- Increase the dynamic range of the power handling.

Infineon Technologies is the leading company with broad product portfolio to offer high performance SiGe:C bipolar transistor LNAs and MMIC LNAs for various wireless applications by using the industrial standard silicon process. The MMIC LNA portfolio includes:

- New generation single band LTE LNAs like BGA7H1N6 for high-band (HB, 2300-2700 MHz), BGA7M1N6 for mid-band (MB, 1805-2200 MHz) and BGA7L1N6 for low-band (LB, 728-960 MHz) are available.
- New generation LTE LNA Banks are quad-band. Currently there are six different types of these new LTE LNAs which are shown in **Table 2**. Each LNA bank combines four various



bands LNA from the high-band (HB, 2300-2700 MHz), mid-band (MB, 1805-2200 MHz) and low-band (LB, 728-960 MHz). Two of the four LNAs in one LNA bank can be turned on at the same time to support carrier aggregation.

The broad product portfolio with highest integration and best features in noise figure and flexible band selection helps designers to design mobile phones and data cards with outstanding performance. Therefore Infineon LNAs and LNA banks are widely used by mobile phone vendors.

**Table 2 Infineon Product Portfolio of LNAs for 4G LTE and LTE-A Applications**

Frequency Range	728 MHz–960 MHz	1805MHz–2200MHz	2300 MHz–2690 MHz	Comment
<b>Single-Band LNA</b>				
BGA7L1N6	1X			
BGA7M1N6		1X		
BGA7L1N6			1X	
<b>Quad-Band LNA bank</b>				
BGM7MLLH4L12	1X	2X	1X	
BGM7LMHM4L12	1X	2X	1X	
BGM7HHMH4L12		1X	3X	
BGM7MLLM4L12	2X	2X		
BGM7LLHM4L12	2X	1X	1X	
BGM7LLMM4L12	2X	2X		

In addition, the older generation of LTE LNAs are featured with gain switching functions which is often helpful for the cases that string or weak signal environment could happen in the field. **Table 3** shows the available band combinations:

- Single-band LNAs like BGA777L7 / BGA777N7 for high-band (2300-2700 MHz), BGA711L7 / BGA711N7 for mid-band (MB, 1700-2300 MHz) and BGA751L7 / BGA751N7, BGA728L7/BGA728N7, BGA713L7/BGA713N7 for low-band (LB, 700-1000 MHz) are available.

- Dual-band LNA BGA771L16 supports 1x mid-band (MB, 1700-2300 MHz) and 1x low-band (LB, 700-1000 MHz).

- Triple-band LNAs BGA734N16, BGA735N16 and BGA736N16 are available to cover the most bands. All of the three triple-band LNAs can support designs covering 2x high-bands and 1x low-band.

- Both BGA748N16 and BGA749N16 are quad-band LNAs. BGA748N16 can cover 2x high- and 2x low-bands and BGA749N16 can cover 1x high-band and 3x low-bands.

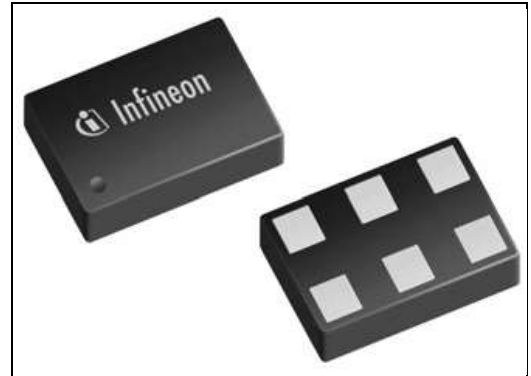
**Table 3 Infineon Product Portfolio of LNAs for 3G and 4G Applications**

Frequency Range	700-1000 MHz	1700-2200 MHz	2100-2700 MHz	Comment
<b>Single-Band LNA</b>				
BGA711N7/L7		1X		
BGA751N7/L7	1X			
BGA777N7/L7			1X	
BGA728L7/N7	1X			
BGA713L7/N7	1X			
<b>Dual-Band LNA</b>				
BGA771L16	1X	1X		
<b>Triple-Band LNA</b>				
BGA734L16	1X	1X	1X	
BGA735N16	1X	1X	1X	
BGA736N16	1X	1X	1X	
<b>Quad-band LNA</b>				
BGA748N16	2X	1X	1X	
BGA749N16	3X		1X	

## 2 BGA7M1N6 Overview

### 2.1 Features

- Insertion power gain: 13.0 dB
- Low noise figure: 0.60 dB
- Low current consumption: 4.4 mA
- Operating frequencies: 1805-2200 MHz
- Supply voltage: 1.5 V to 3.6 V
- Digital on/off switch (1 V logic high level)
- Ultra small TSNP-6-2 leadless package (footprint: 0.7x1.1mm<sup>2</sup>)
- B7HF Silicon Germanium technology
- RF output internally matched to 50 Ω
- Only 1 external SMD component necessary
- 2 kV HBM ESD protection (including AI-pin)
- Pb-free (RoHS compliant) package



**Figure 2 BGA7M1N6 in TSNP-6-2**



### 2.2 Description

The BGA7M1N6 is a front-end low noise amplifier for LTE applications, which covers a wide frequency range from 1805 MHz to 2200 MHz. The LNA provides 13.0 dB gain and 0.60 dB noise figure at a current consumption of 4.9 mA in the application configuration described in **Chapter 3**. The BGA7M1N6 is based upon Infineon Technologies' B7HF Silicon Germanium technology. It operates from 1.5 V to 3.6 V supply voltage.

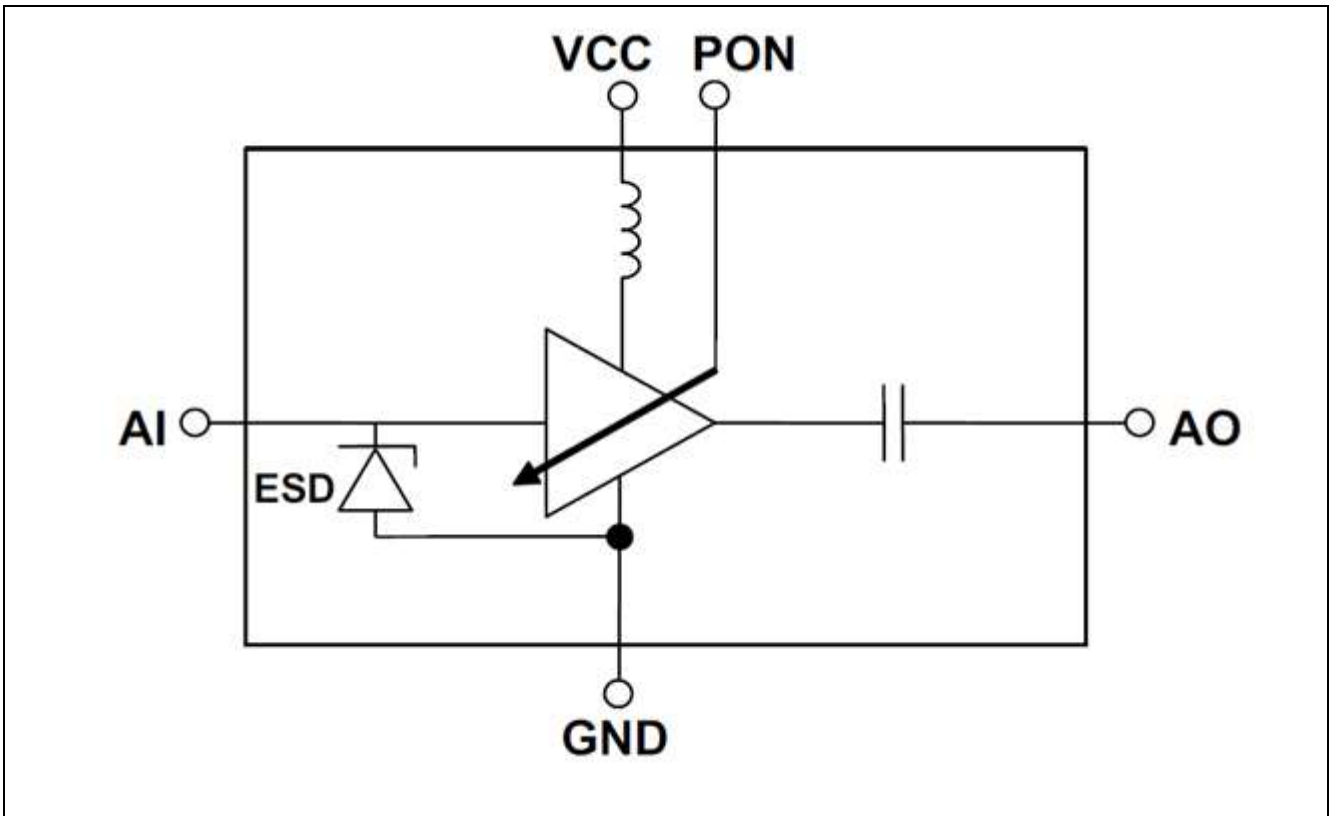


Figure 3 Equivalent Circuit of BGA7M1N6

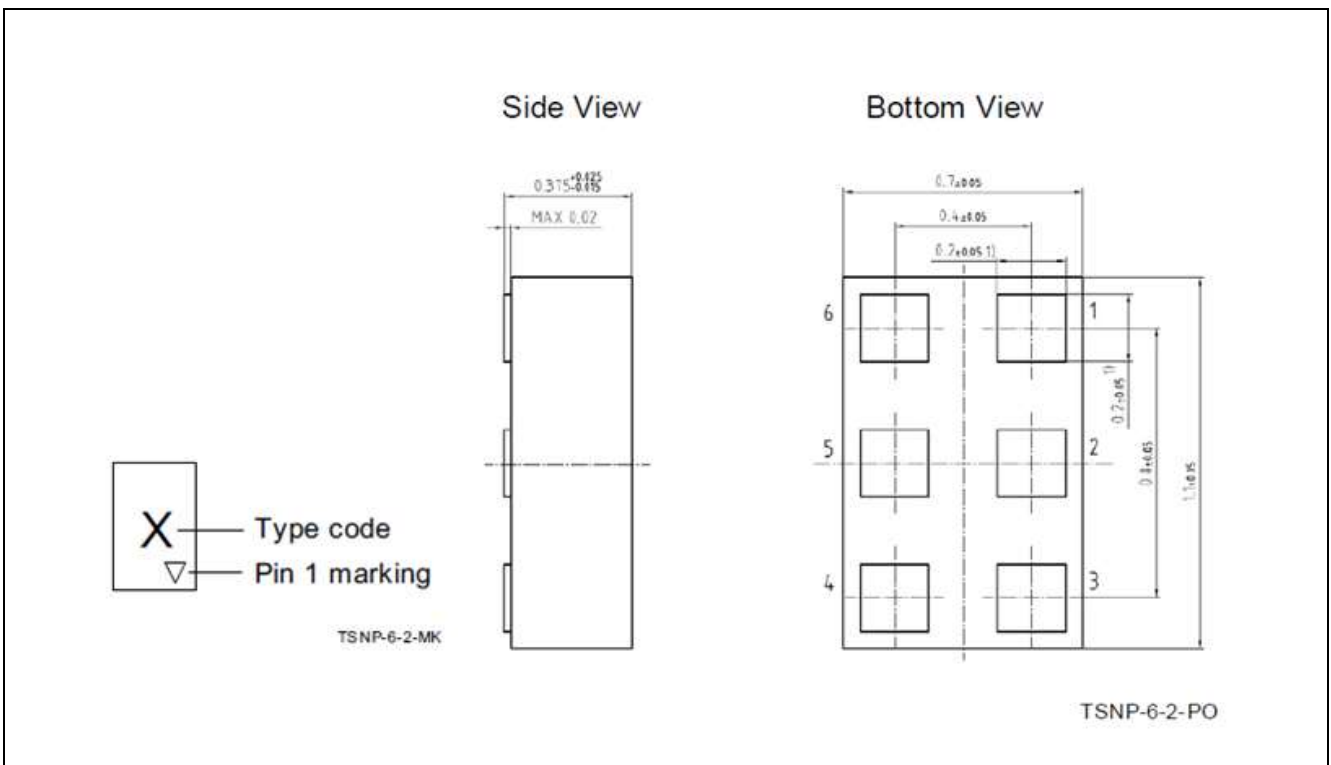
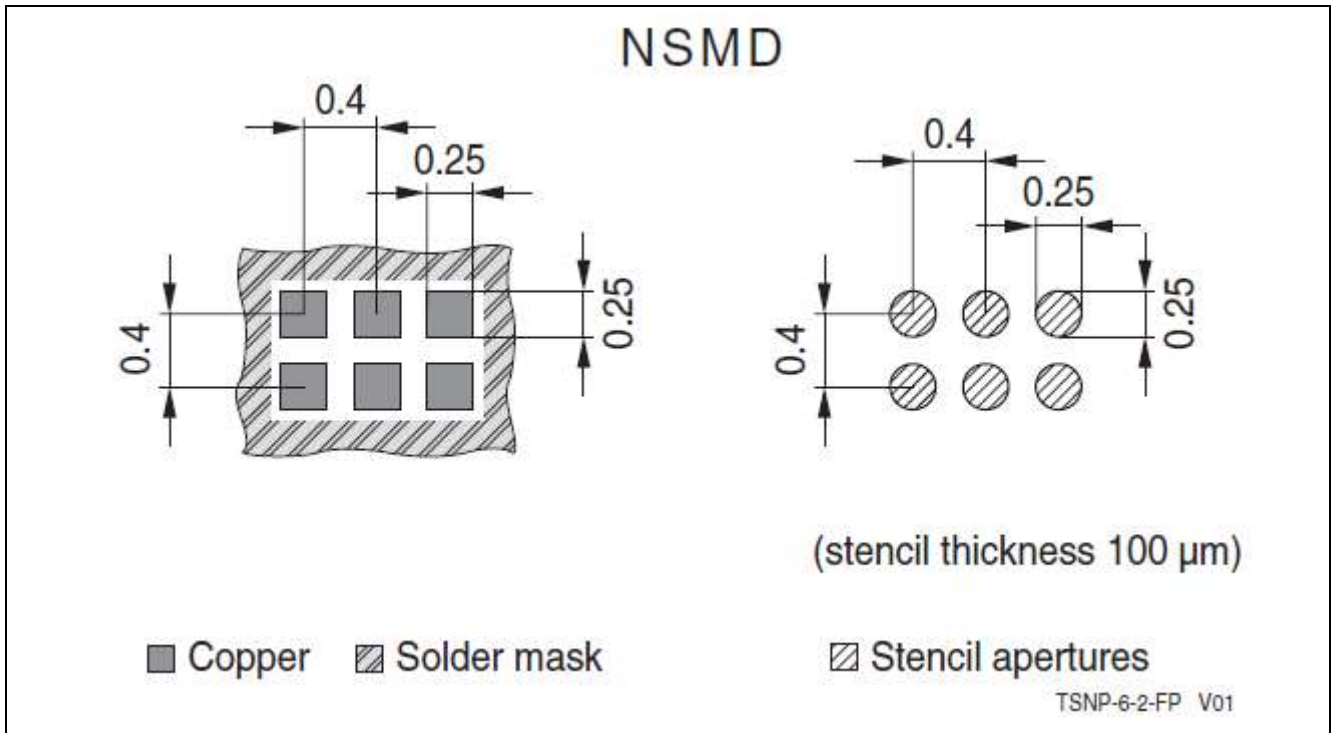


Figure 4 Package and Pin Connections of BGA7M1N6 (TSNP-6-2)



**Figure 5 Footprint Recommendation of BGA7M1N6 (TSNP-6-2)**

**Table 4 Pin Assignment of BGA7M1N6**

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

### 3 Application Circuit and Performance Overview

**Device:** BGA7M1N6

**Application:** Single Band LTE LNA BGA7M1N6 for Broadband Application Supporting 1800 MHz to 2200 MHz, Using 0201 Components

**PCB Marking:** BGA7x1N6 V1.0

#### 3.1 Summary of Measurement Results

**Table 5 Electrical Characteristics at Room Temperature ( $T_A = 25\text{ °C}$ ) for 1.8 V Supply  
 1800 MHz to 2200 MHz,  $V_{CC} = 1.8\text{ V}$ ,  $V_{EN} = 1.8\text{ V}$ ,**

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	1.8			V	
DC Current	Icc	4.5			mA	
Frequency Range	Freq	1805	1990	2170	MHz	
Gain	G	12.8	12.7	12	dB	
Noise Figure	NF	0.91	0.94	1.03	dB	Loss of SMA and line of 0.1 dB is subtracted
Input Return Loss	RLin	12.1	13.8	9.7	dB	
Output Return Loss	RLout	8.6	16	23	dB	
Reverse Isolation	IRev	21	19.8	19.3	dB	
Input P1dB	IP1dB	-5.2	-4.2	-2.6	dBm	
Output P1dB	OP1dB	6.6	7.5	8.4	dBm	
Input IP3	IIP3	2.7	4.4	7	dBm	Power @ Input: -30 dBm $f_1 = 1805\text{ MHz}$ , $f_2 = 1806\text{ MHz}$
Output IP3	OIP3	15.5	17.1	19	dBm	$f_1 = 1989\text{ MHz}$ , $f_2 = 1990\text{ MHz}$ $f_1 = 2169\text{ MHz}$ , $f_2 = 2170\text{ MHz}$
Stability	k	>1			--	Measured up to 10 GHz

**Table 6 Electrical Characteristics at Room Temperature ( $T_A = 25\text{ °C}$ ) for 2.8 V Supply  
 1800 MHz to 2200 MHz,  $V_{CC} = 2.8\text{ V}$ ,  $V_{EN} = 2.8\text{ V}$ ,**

Parameter	Symbol	Value			Unit	Comment/Test Condition
DC Voltage	Vcc	2.8			V	
DC Current	Icc	4.6			mA	
Frequency Range	Freq	1805	1990	2170	MHz	
Gain	G	12.9	12.8	12.1	dB	
Noise Figure	NF	0.92	0.95	1.04	dB	Loss of SMA and line of 0.1 dB is subtracted
Input Return Loss	RLin	12.4	15	10.4	dB	
Output Return Loss	RLout	8	14.8	26.5	dB	
Reverse Isolation	IRev	21.5	20.2	19.7	dB	
Input P1dB	IP1dB	-1.6	-0.7	0.8	dBm	
Output P1dB	OP1dB	10.3	11.1	11.9	dBm	
Input IP3	IIP3	3.9	5.6	8.3	dBm	Power @ Input: -30 dBm $f_1 = 1805\text{ MHz}$ , $f_2 = 1806\text{ MHz}$ $f_1 = 1989\text{ MHz}$ , $f_2 = 1990\text{ MHz}$ $f_1 = 2169\text{ MHz}$ , $f_2 = 2170\text{ MHz}$
Output IP3	OIP3	16.8	18.4	20.4	dBm	
Stability	k	>1			--	Measured up to 10 GHz

### **3.2 BGA7M1N6 as LTE LNA for 1800 MHz to 2200 MHz**

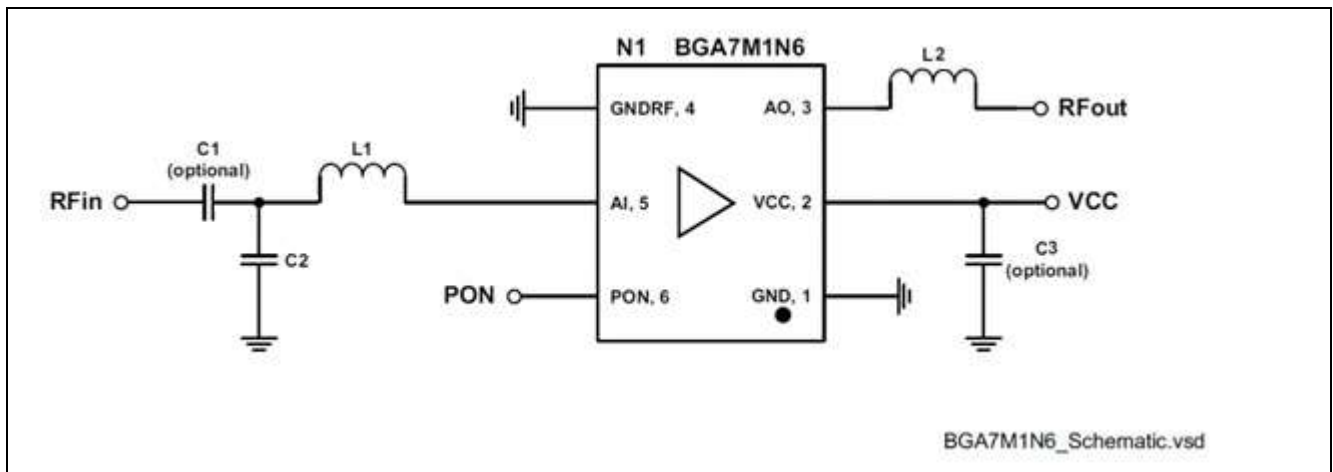
This application note focuses on the Infineon's Single-band LTE LNA BGA7M1N6 for broad band applicatuions covering the frequency range from 1800 MHz to 2200 MHz. It presents the performance of BGA7M1N6 with 1.8 V/2.8 V power supply and the operating current of 4.5 mA.

The application circuit requires only three 0201 passive component. The component values are fine tuned for optimal noise figure, gain, input and output matching. It has a gain of 12.8 dB. The circuit achieves input return loss better than 10.4 dB, as well as output return loss better than 8 dB. At room temperature the noise figure is less than 1.05 dB (SMA and PCB losses are subtracted) for the whole frequencey.

Furthermore, the circuit is measured unconditionally stable till 10 GHz. For the frequency 2170 MHz, using two tones spacing of 1 MHz, the output third order intercept point, OIP3 reaches 20.4 dBm. Input P1dB of the BGA7M1N6 LNA is about 0.8 dBm at 2270 MHz. All the measurements are done with the standard evaluation board presented at the end of this application note.



### 3.3 Schematics and Bill-of-Materials

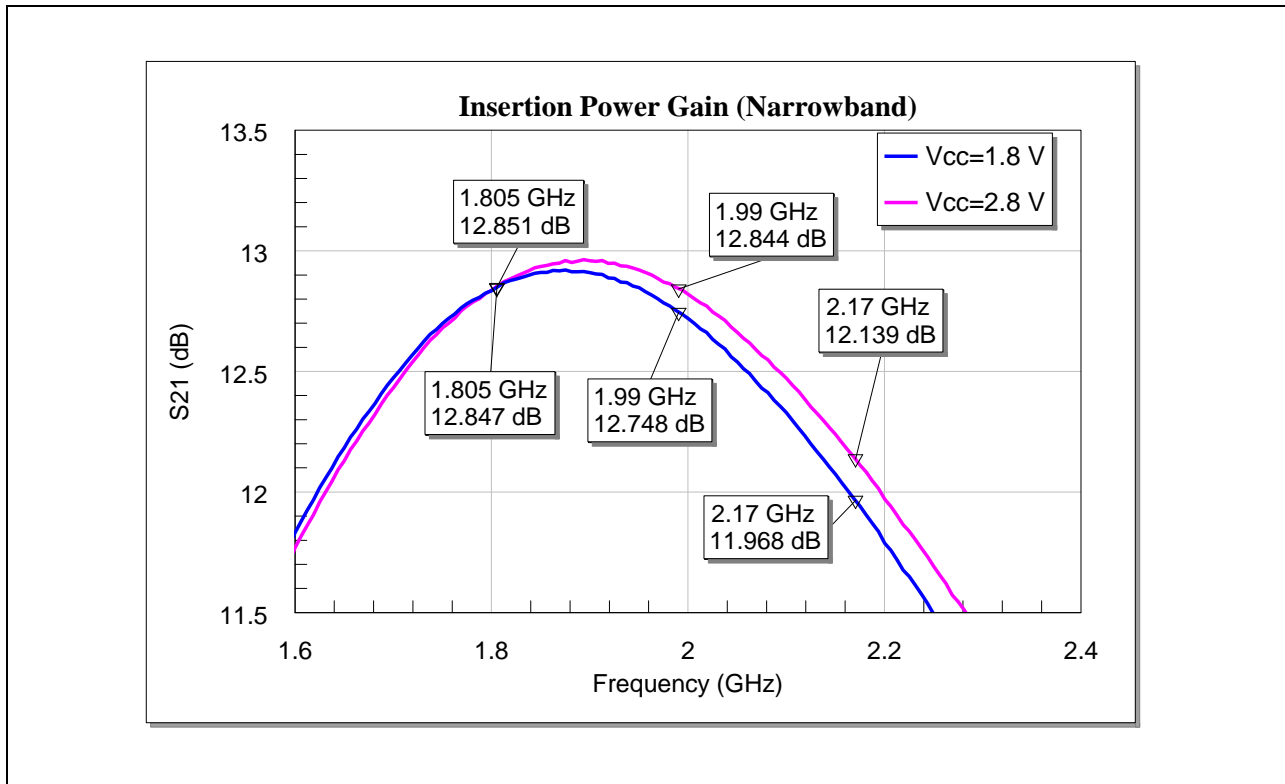


**Figure 6 Schematics of the BGA7M1N6 Application Circuit**

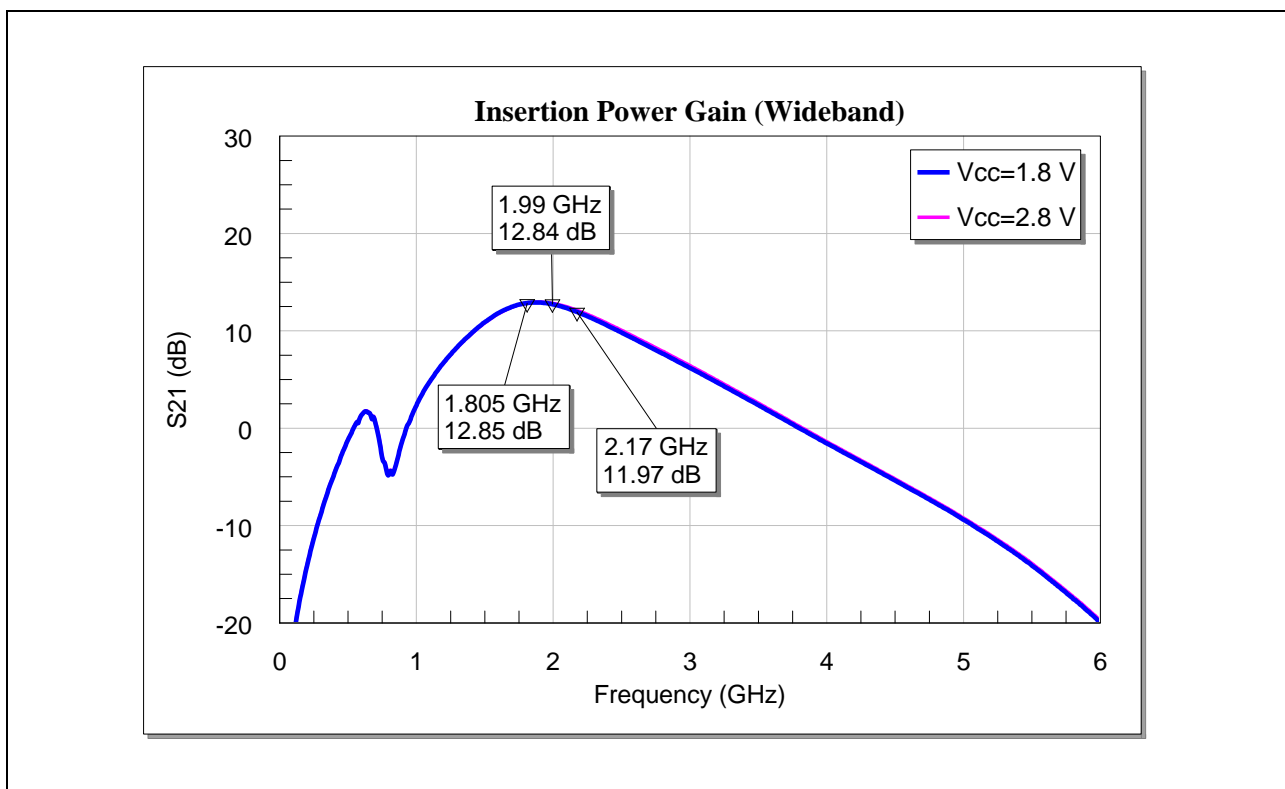
**Table 7 Bill-of-Materials**

Symbol	Value	Unit	Size	Manufacturer	Comment
C1 (optional)	1	nF	0201	Various	DC block
C2	0.6	pF	0201	Murata GJM series	Input matching
C3 (optional)	100	nF	0201	Various	RF to ground
L1	5.6	nH	0201	Murata LQP series	Input matching
L2	1	nH	0201	Murata LQP series	Output matching
N1	BGA7M1N6	TSNP-6-2		Infineon	SiGe LNA

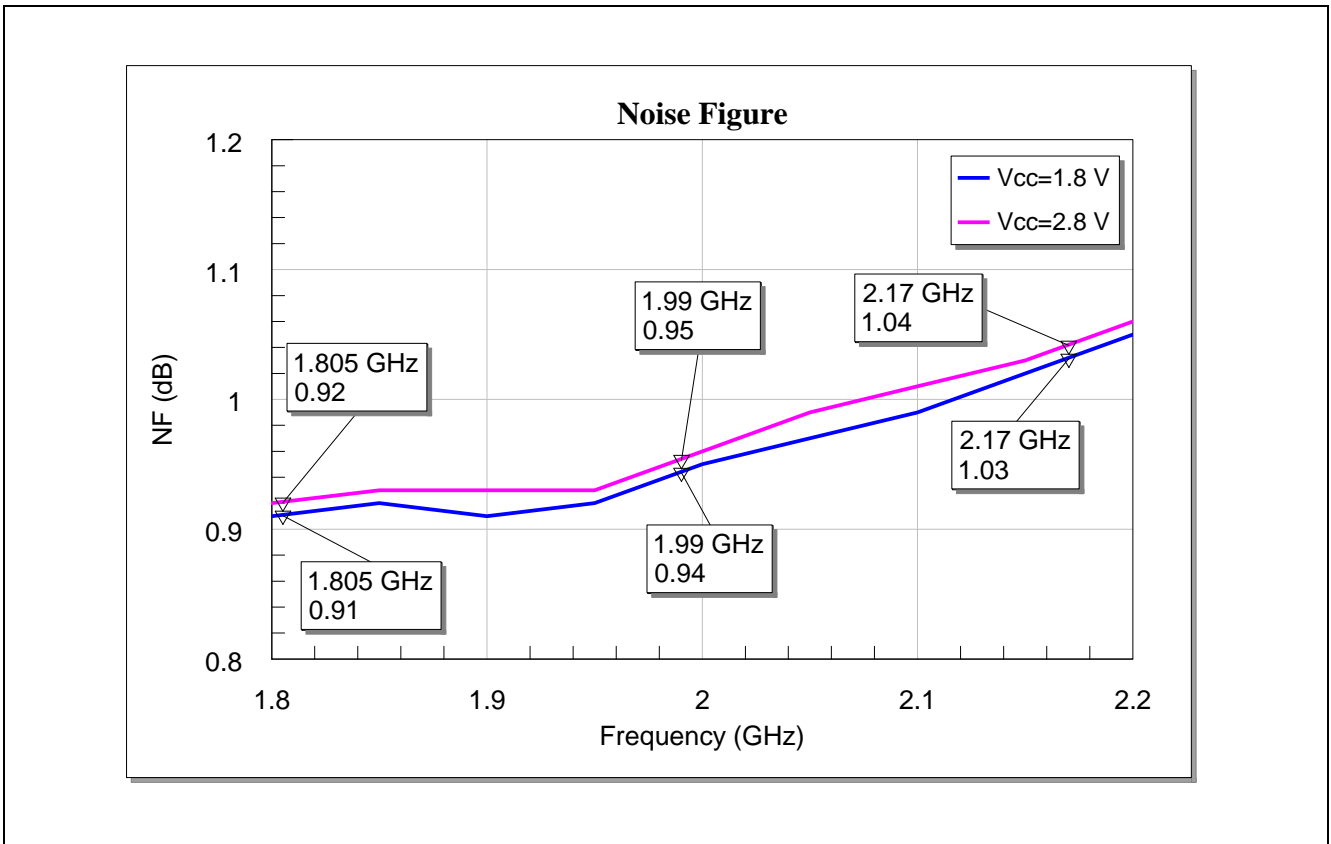
## 4 Measurement Graphs



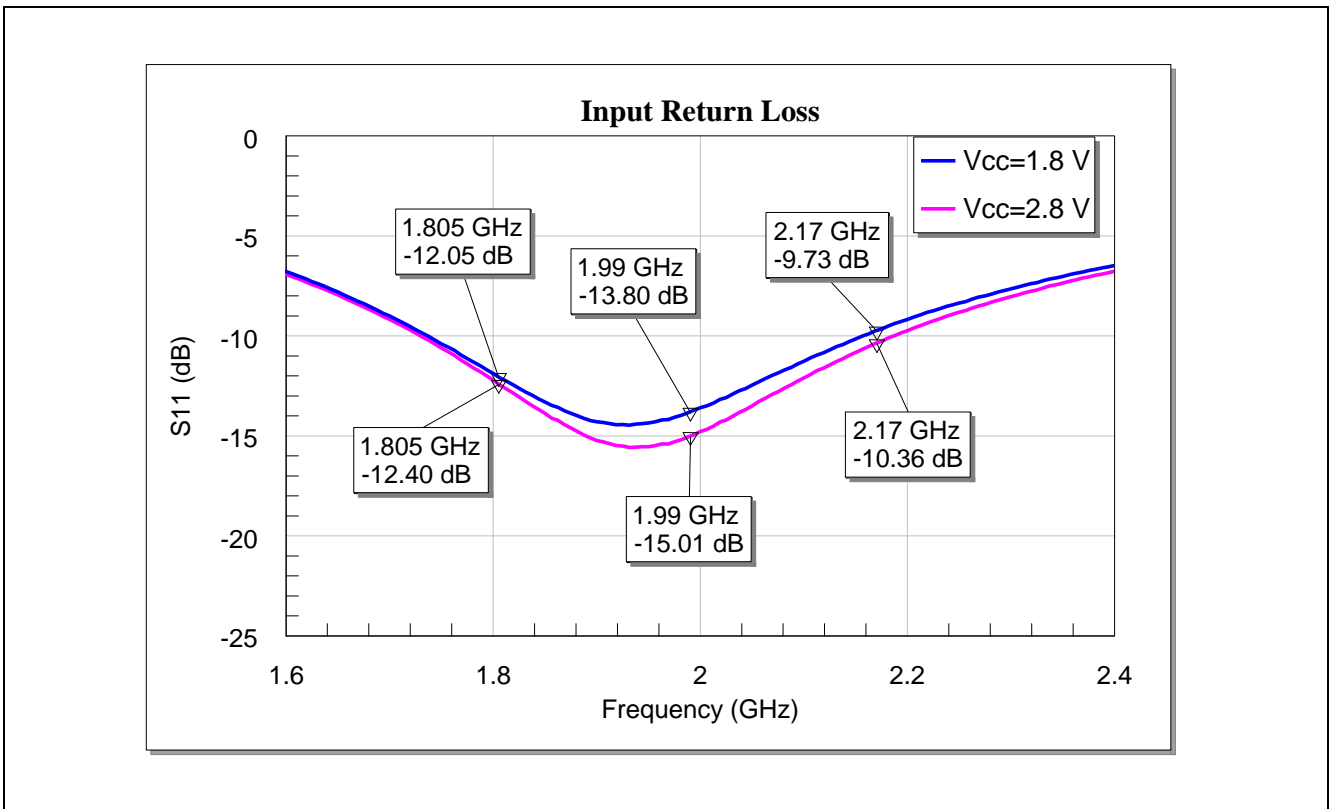
**Figure 7** Insertion Power Gain (Narrowband) of the BGA7M1N6 Covering from 1800 MHz to 2200 MHz



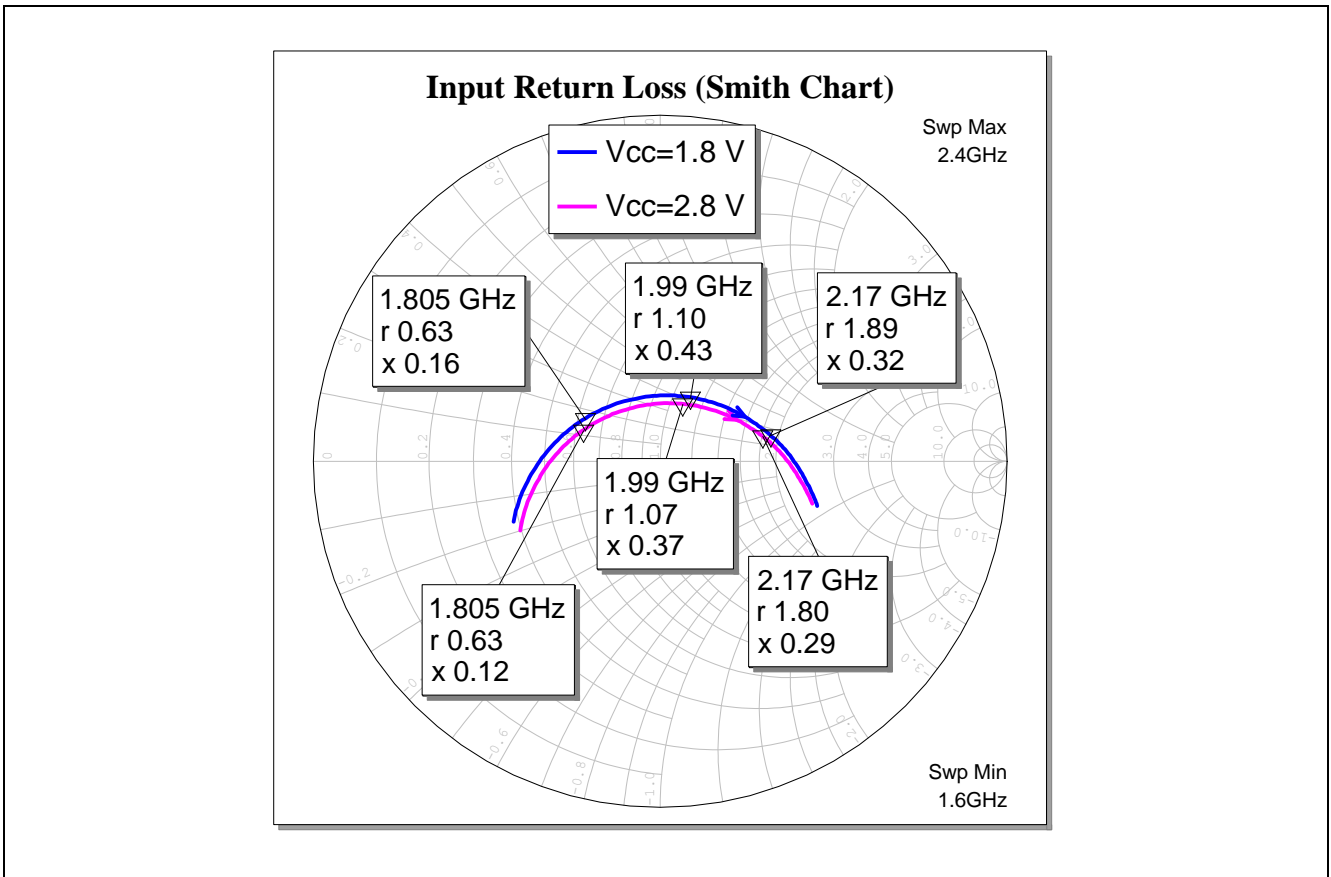
**Figure 8** Insertion Power Gain (Wideband) of the BGA7M1N6 Covering from 1800 MHz to 2200 MHz



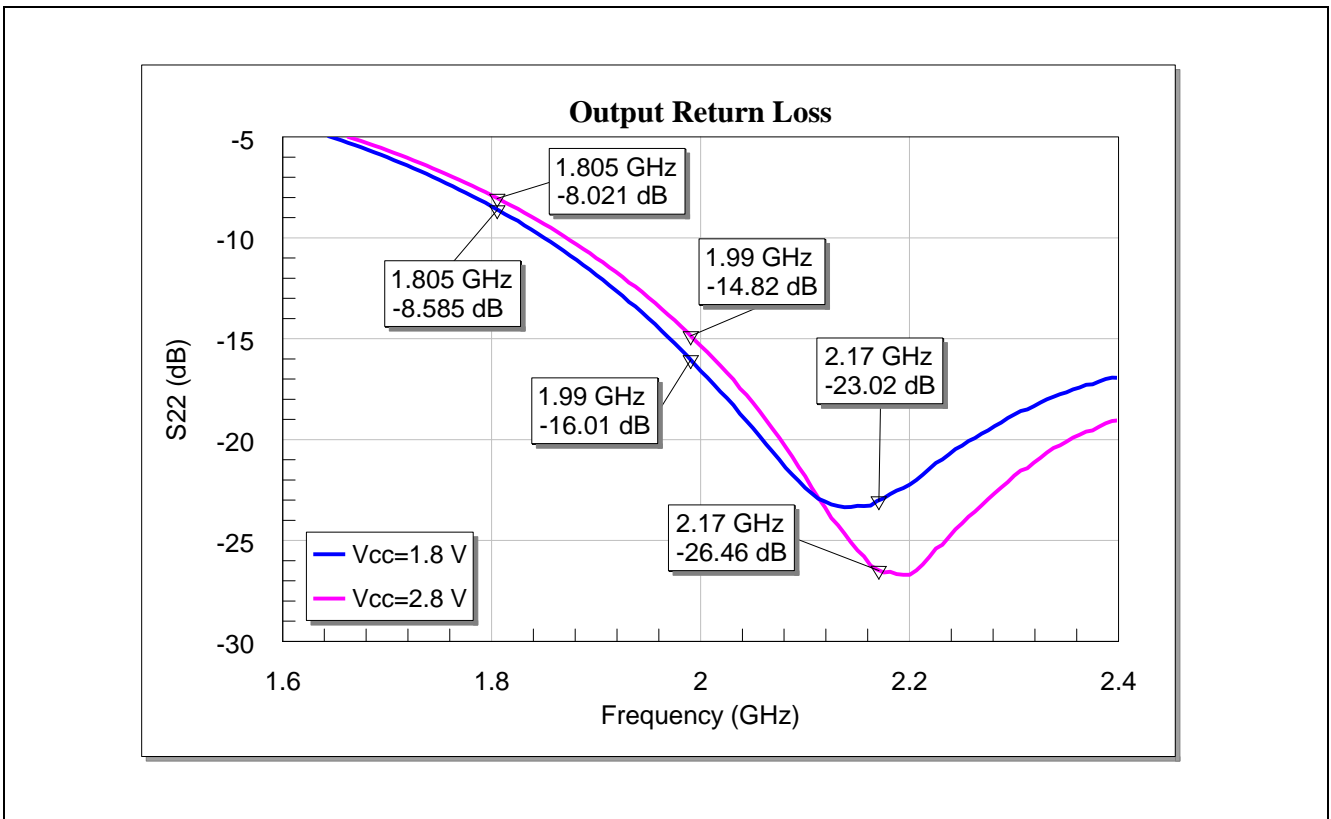
**Figure 9** Noise Figure of the BGA7M1N6 Covering from 1800 MHz to 2200 MHz



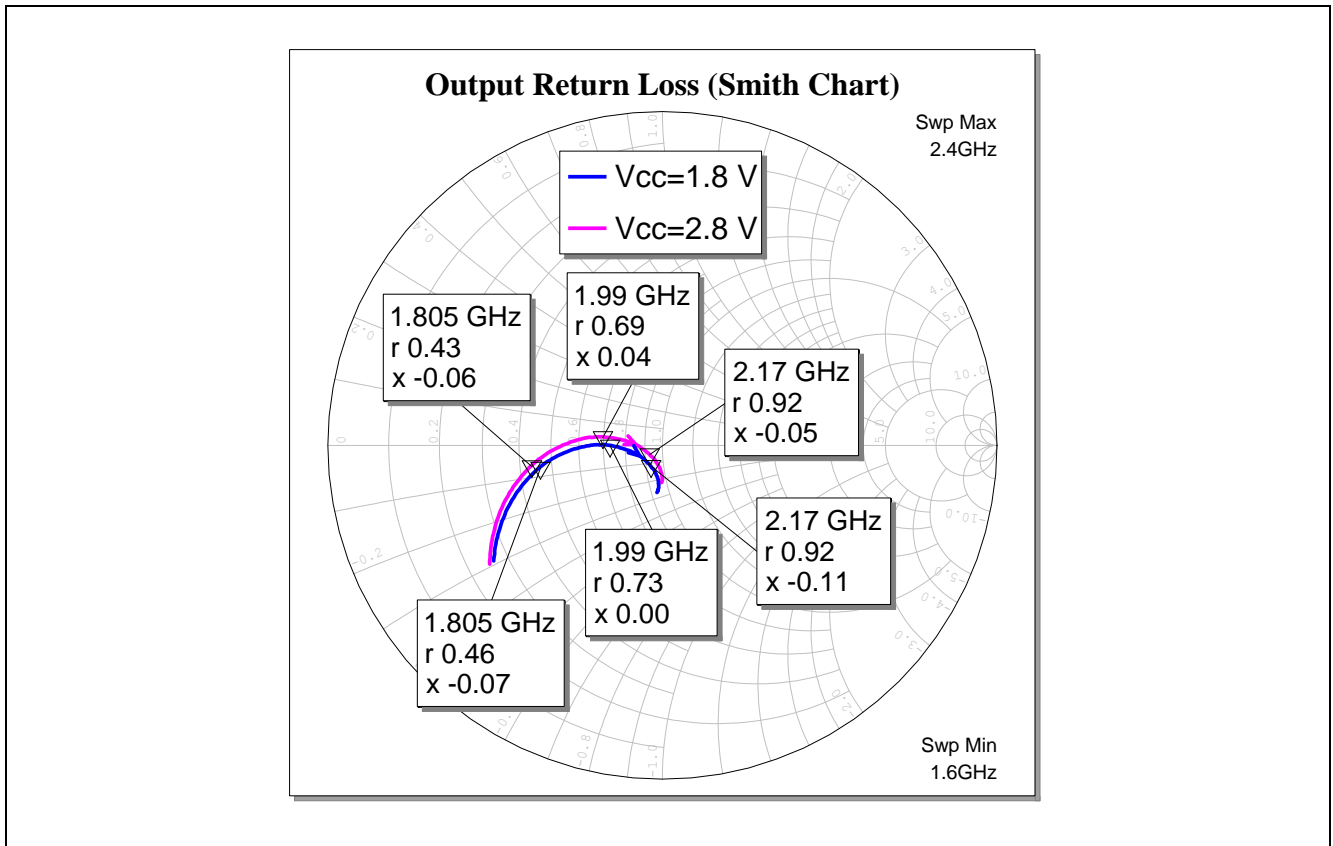
**Figure 10** Input Matching of the BGA7M1N6 Covering from 1800 MHz to 2200 MHz



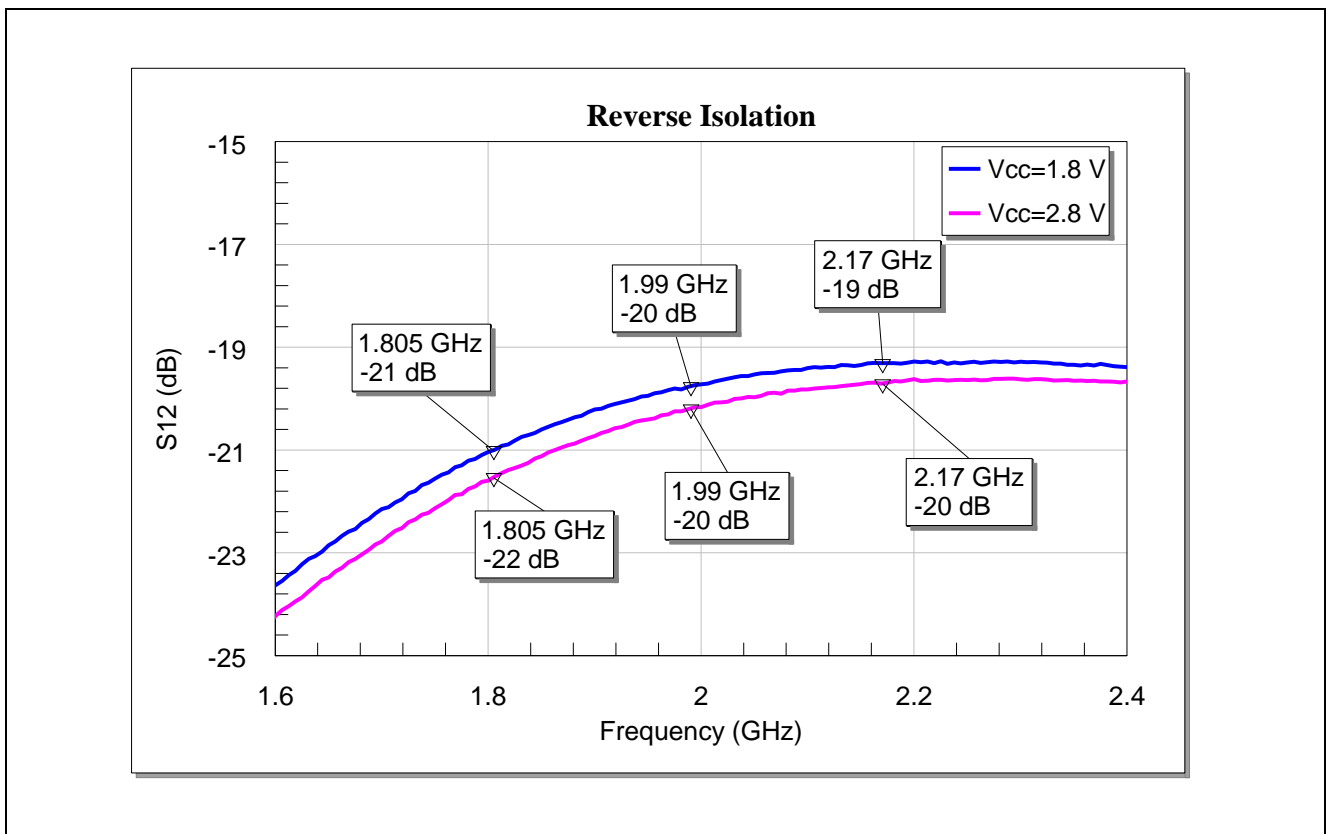
**Figure 11 Input Matching (Smith Chart) of the BGA7M1N6 Covering from 1800 MHz to 2200 MHz**



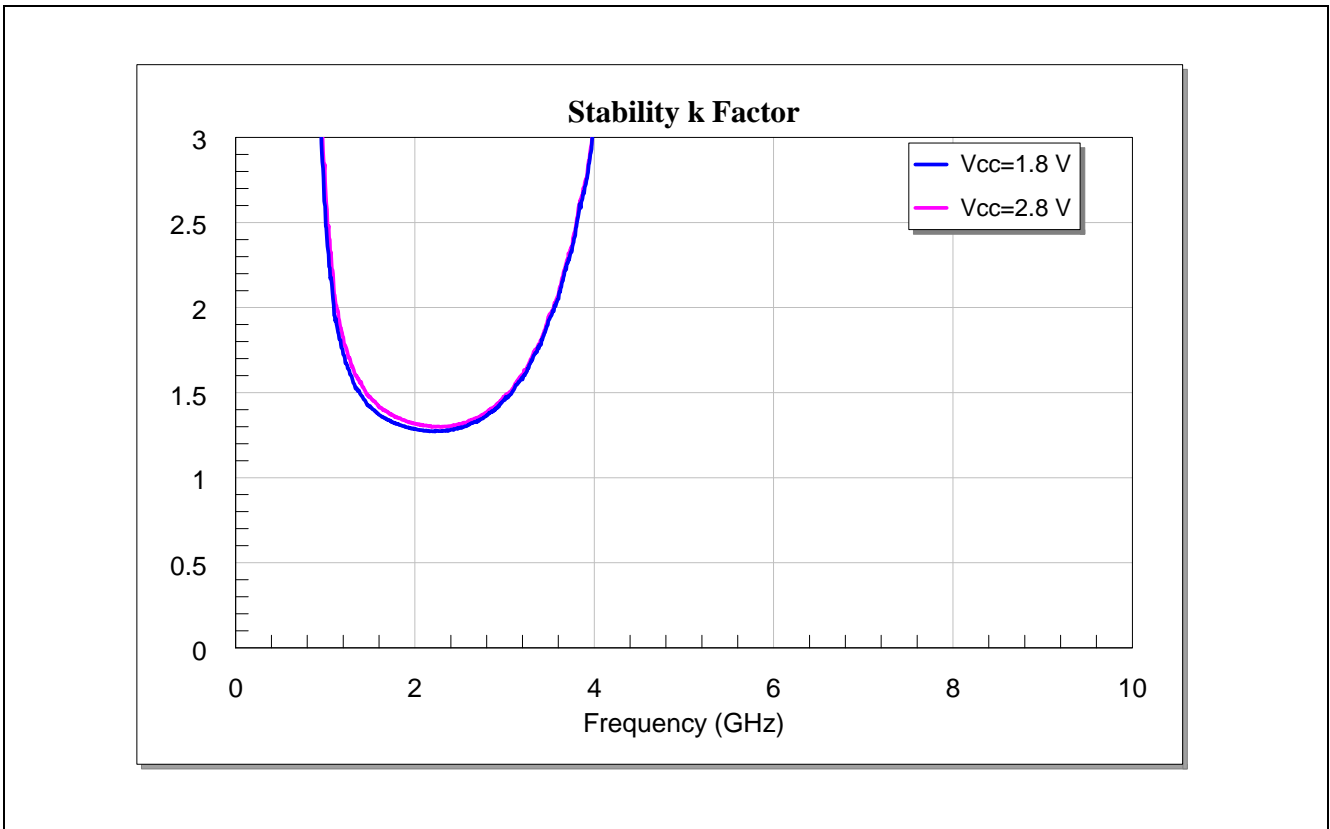
**Figure 12 Output Matching of the BGA7M1N6 Covering from 1800 MHz to 2200 MHz**



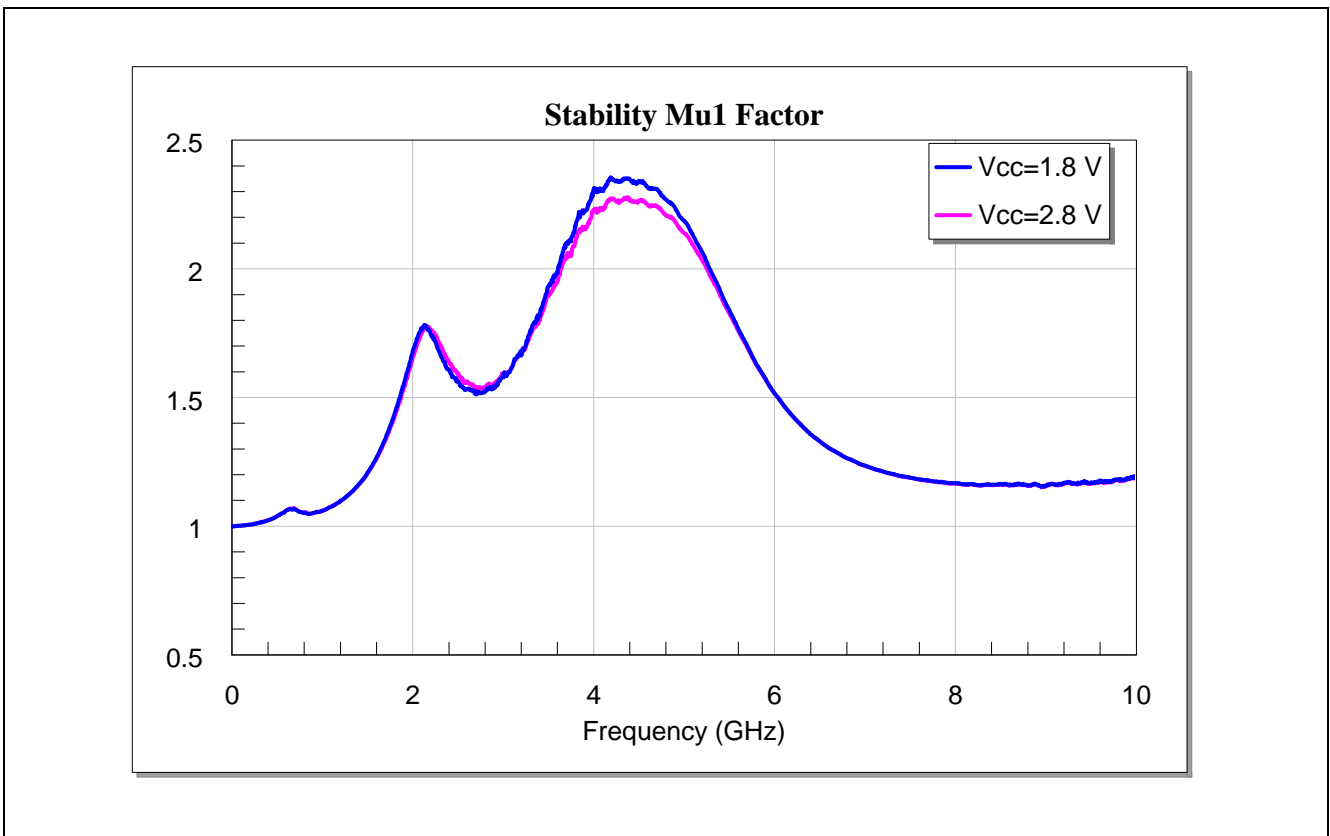
**Figure 13 Output Matching (Smith Chart) of the BGA7M1N6 Covering from 1800 MHz to 2200 MHz**



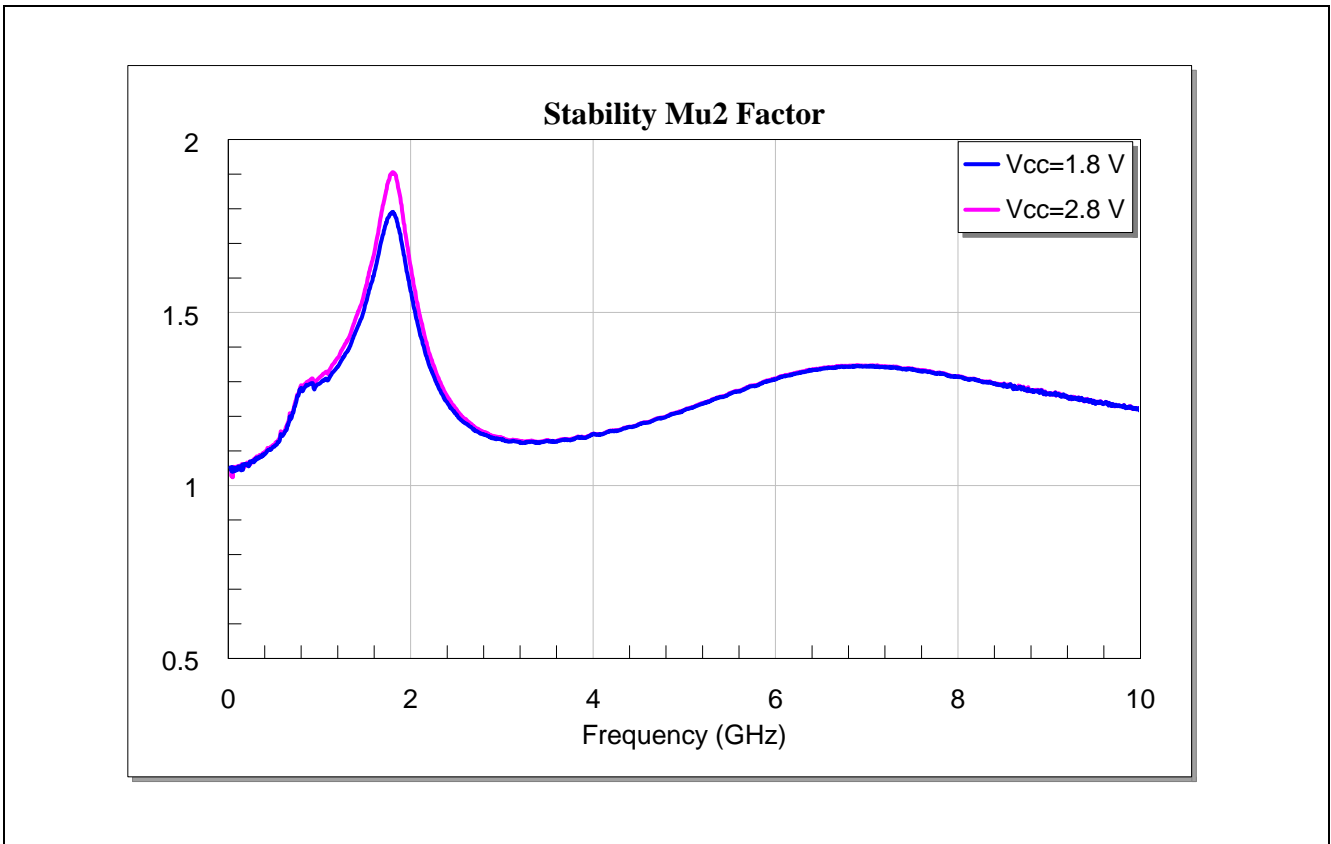
**Figure 14 Reverse Isolation of the BGA7M1N6 Covering from 1800 MHz to 2200 MHz**



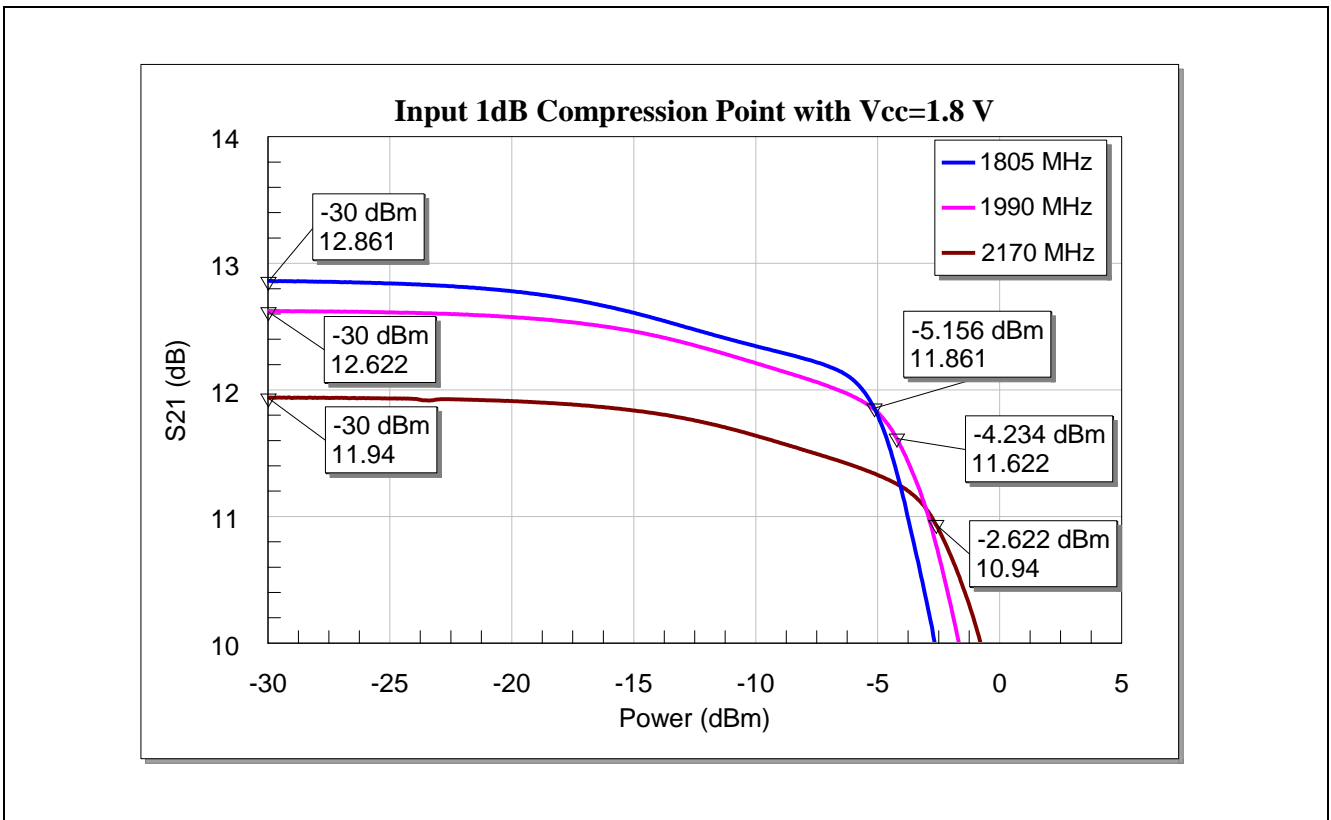
**Figure 15** Stability K-factor of the BGA7M1N6 Covering from 1800 MHz to 2200 MHz



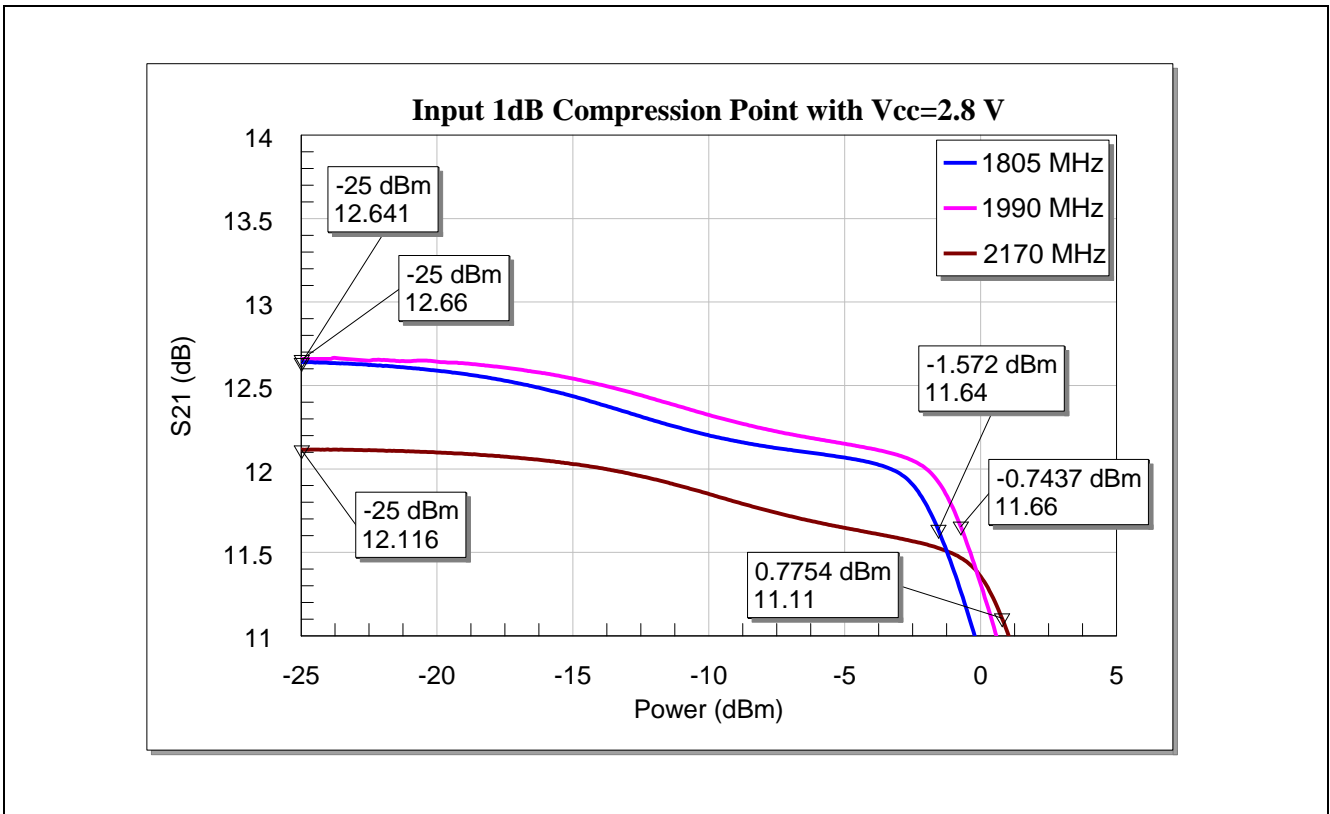
**Figure 16** Stability Mu1-factor of the BGA7M1N6 Covering from 1800 MHz to 2200 MHz



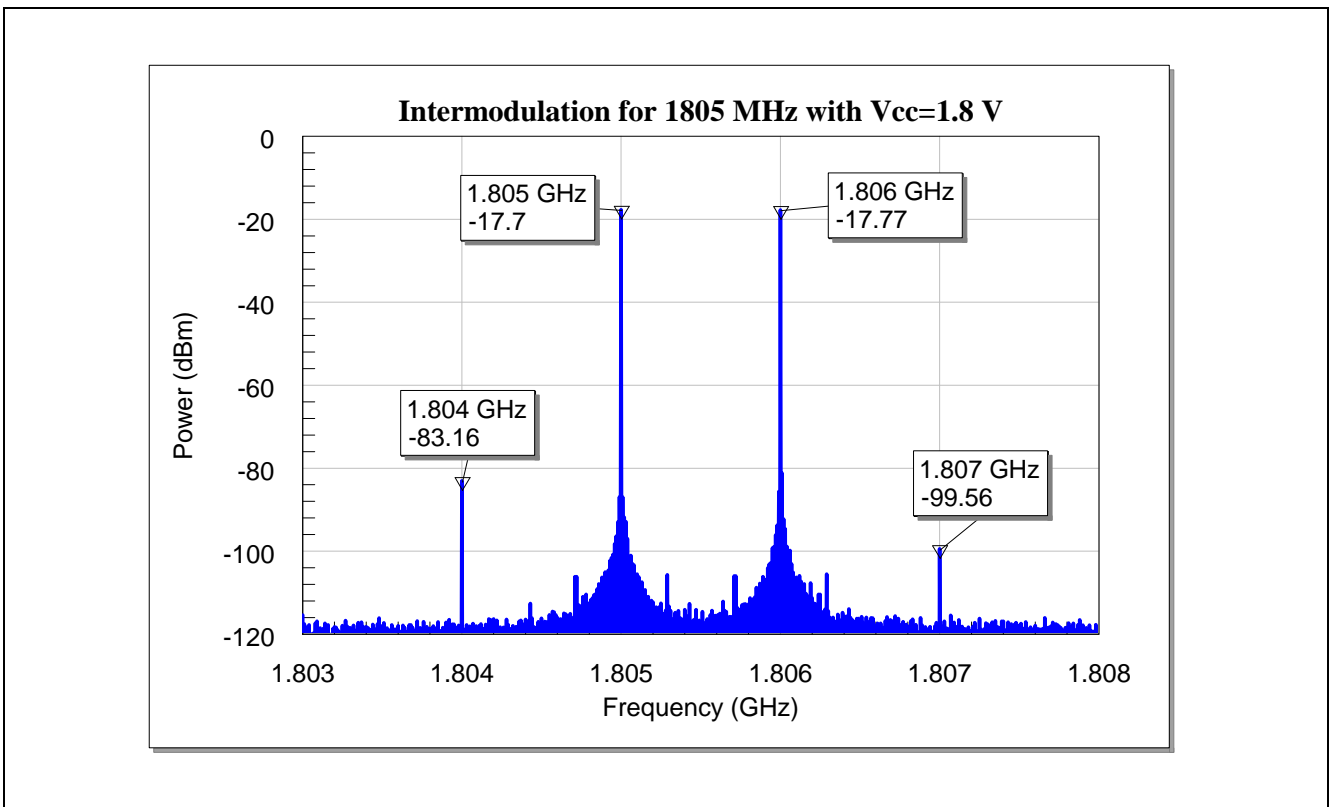
**Figure 17** Stability Mu2-factor of the BGA7M1N6 Covering from 1800 MHz to 2200 MHz



**Figure 18** Input 1dB Compression Point of the BGA7M1N6 Covering from 1800 MHz to 2200 MHz with Vcc=1.8 V

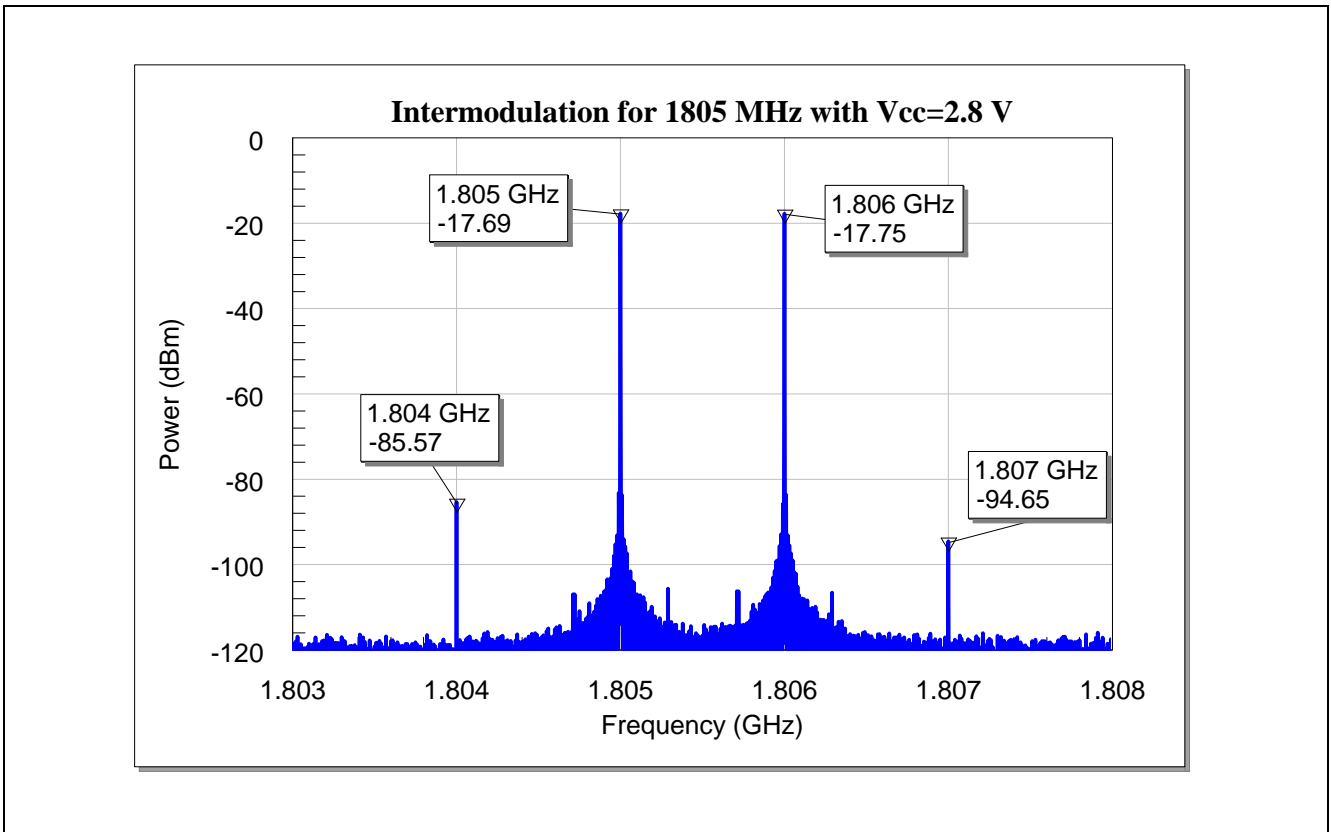


**Figure 19** Input 1dB Compression Point of the BGA7M1N6 Covering from 1800 MHz to 2200 MHz with Vcc=2.8 V

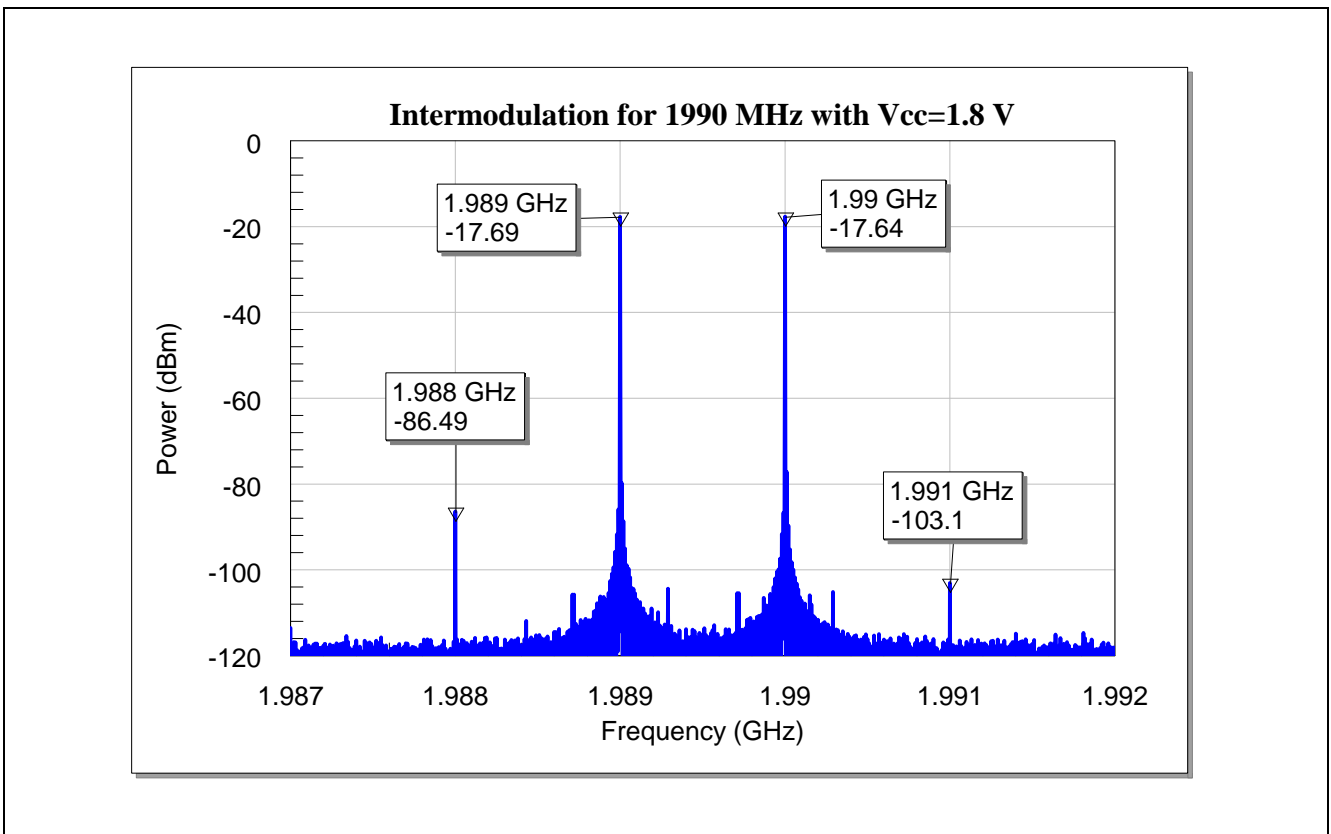


**Figure 20** Input 3<sup>rd</sup> Intercept Point of the BGA7M1N6 at 1805 MHz with Vcc=1.8 V

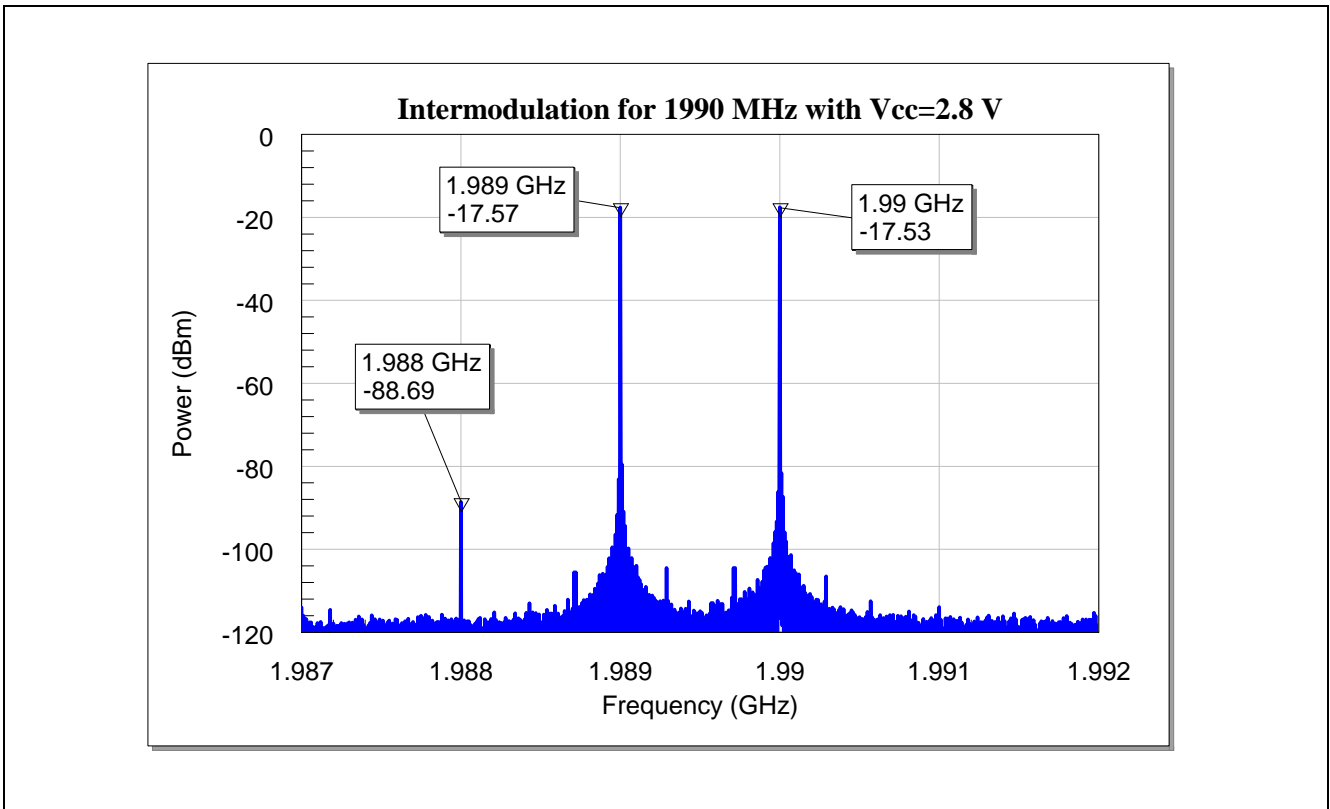




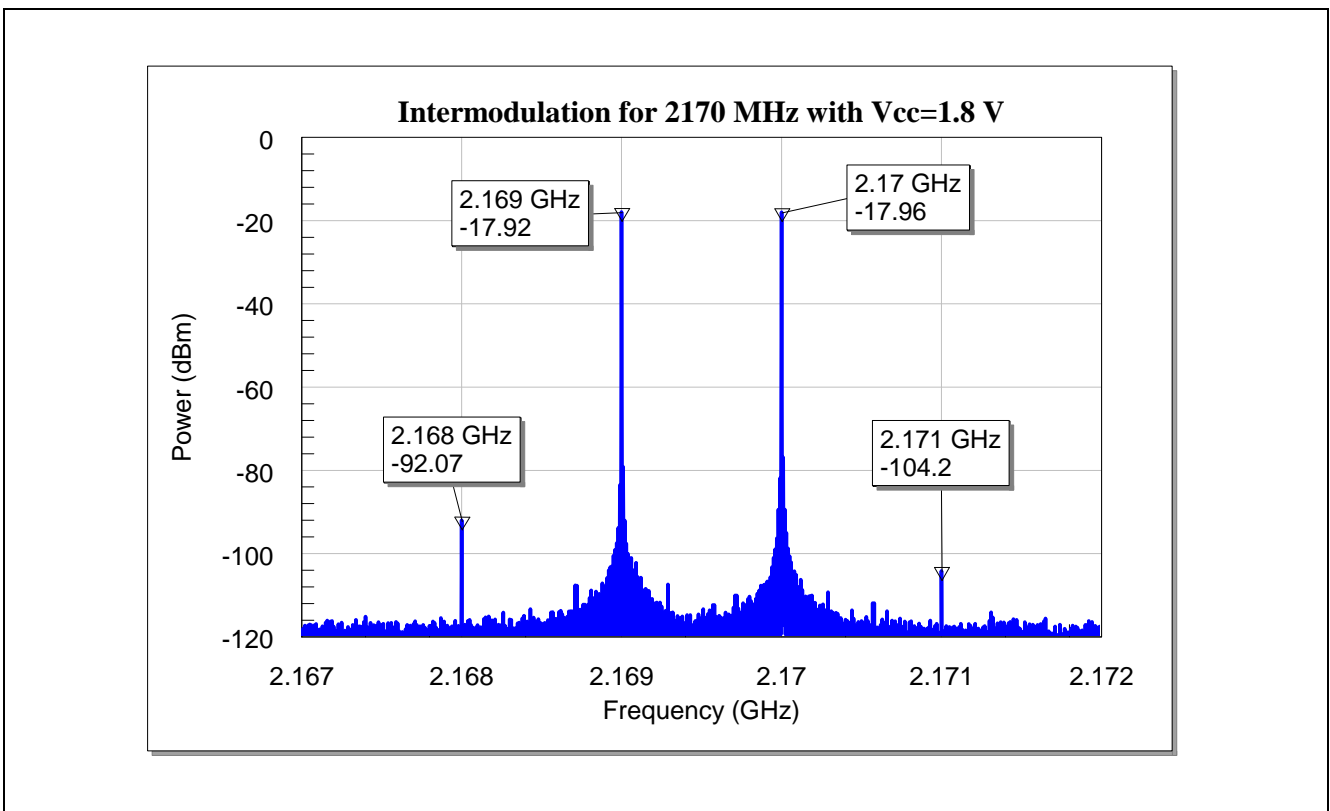
**Figure 21** Input 3<sup>rd</sup> Intercept Point of the BGA7M1N6 at 1805 MHz with Vcc=2.8 V



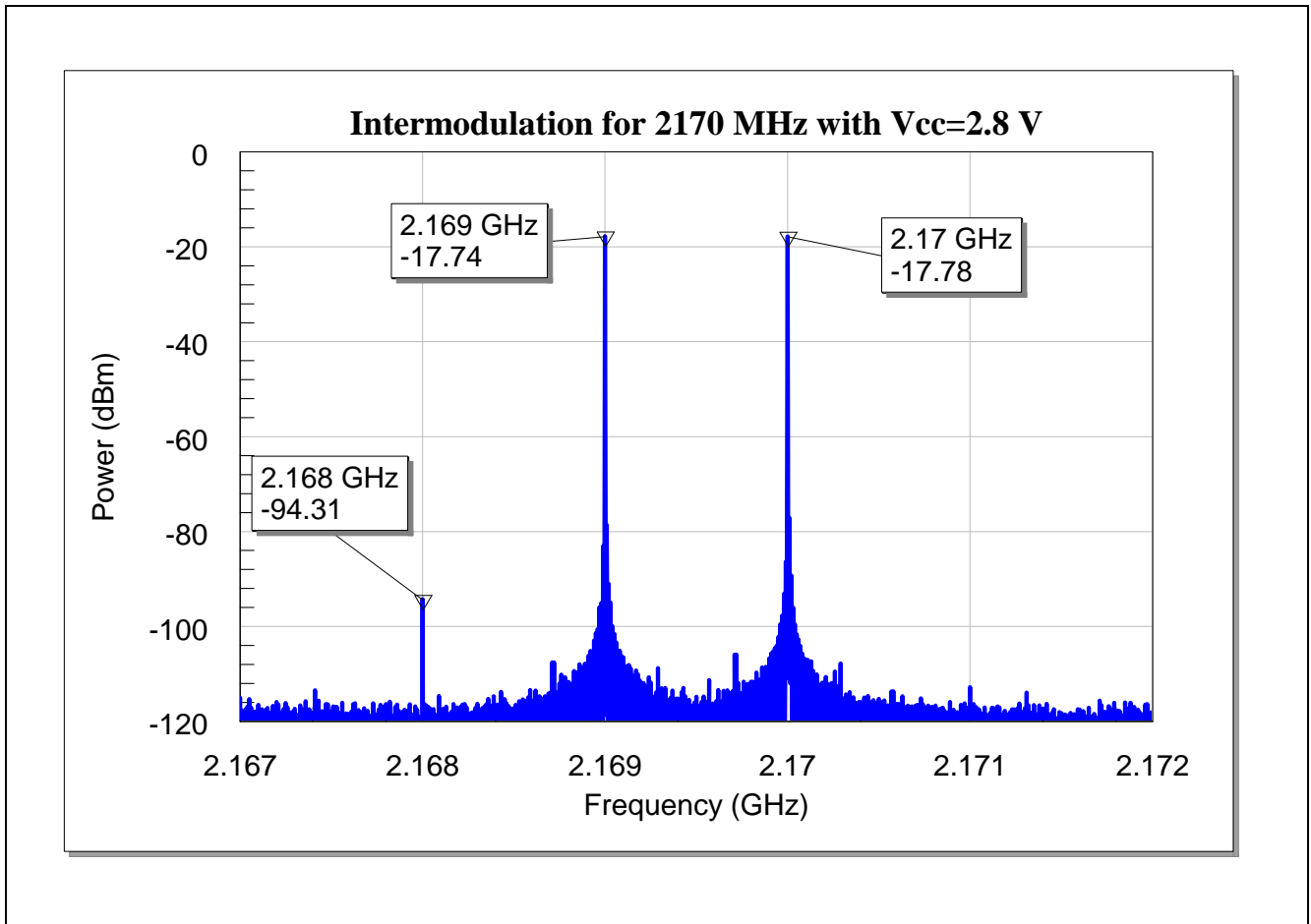
**Figure 22** Input 3<sup>rd</sup> Intercept Point of the BGA7M1N6 at 1990 MHz with Vcc=1.8 V



**Figure 23** Input 3<sup>rd</sup> Intercept Point of the BGA7M1N6 at 1990 MHz with Vcc=2.8 V



**Figure 24** Input 3<sup>rd</sup> Intercept Point of the BGA7M1N6 at 2170 MHz with Vcc=1.8 V



**Figure 25** Input 3<sup>rd</sup> Intercept Point of the BGA7M1N6 at 2170 MHz with Vcc=2.8 V

## 5 Evaluation Board and Layout Information

In this application note, the following PCB is used:

PCB Marking: BGA7x1N6 V1.0

PCB material: FR4

$\epsilon_r$  of PCB material: 4.3



Figure 26 Picture of Evaluation Board (overview)

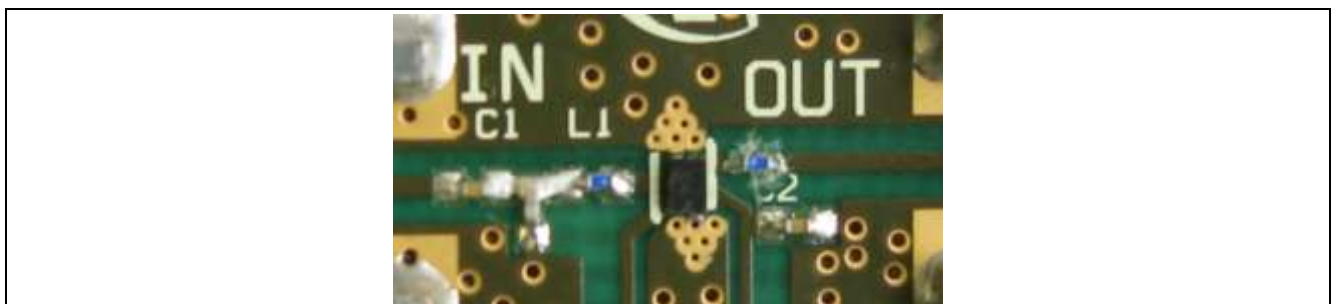


Figure 27 Picture of Evaluation Board (detailed view)

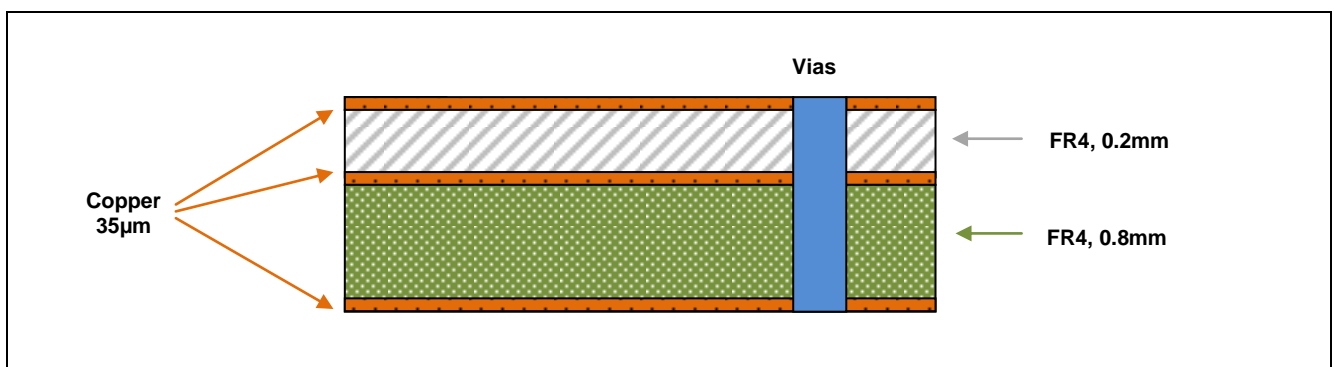


Figure 28 PCB Layer Stack

## **6 Authors**

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## **7 Remark**

The graphs are generated with the simulation software AWR Microwave Office®.

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