BGA748N16

BGA748N16 for 3G/HSPA/LTE Applications Supporting Bands I, II, V and VIII

with Reference Resistor Rref= 8.2 kΩ

Application Note AN237

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RF and Protection Devices

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Previous Revision:

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1 Introduction

1.1 About 3G and 4G Applications

Recently, demand for wireless data service is growing faster than ever before. Starting from the first 3G technology, Universal Mobile Telecommunications System (UMTS), also known as Wideband Code Division Multiple Access (WCDMA) to the 3.5G technologies, High Speed Downlink Packet Access (HSDPA), High Speed Uplink Packet Access (HSUPA), and the combined technology HSPA and HSPA+, the wireless data rate through mobile phone networks increase dramatically. Ever since the rollout of HSDPA networks and flat-rate pricing plans, the wireless industry has seen unprecedented growth in mobile broadband average revenue per user.

Since middle 2009, further enhancements of the HSPA technology, defines a new OFDMA-based technology through the Long Term Evolution (LTE) start to ramp in the market. The ability of LTE to support bandwidths up to 20MHz and to have more spectral efficiency by using better modulation methods like QAM-64, is of particular importance as the demand for higher wireless data speeds continues to grow fast.

Countries all over the world have released various frequencies bands for the 3G and 4G applications. **Table 1** and **Table 2** show the band assignment for the UMTS and LTE bands worldwide.

Table 1 UMTS/WCDMA Band Assignment

Band No.	Uplink Frequencies (TX)	Downlink Frequencies (RX)	Comment
1	1920 - 1980 MHz	2110 - 2170 MHz	
2	1850 - 1910 MHz	1930 - 1990 MHz	
3	1850 - 1915 MHz	1930 - 1995 MHz	
4	1850 - 1920 MHz	1930 - 2000 MHz	
5	1710 - 1785 MHz	1805 - 1880 MHz	
6	1710 - 1755 MHz	2110 - 2155 MHz	
7	824 - 849 MHz	869 - 894 MHz	
8	830 -840 MHz	875 - 885 MHz	
9	2500 - 2570 MHz	2620 - 2690 MHz	
10	880 - 915 MHz	925 - 960 MHz	

Table 2 LTE Band Assignment

Band No.	Uplink Frequency Range	Downlink Frequency Range	Comment
1	1920 - 1980 MHz	2110 - 2170 MHz	
2	1850 - 1910 MHz	1930 - 1990 MHz	
3	1710 - 1785 MHz	1805 - 1880 MHz	
4	1710 - 1755 MHz	2110 - 2155 MHz	
5	824 - 849 MHz	869 - 894 MHz	
7	2500 - 2570 MHz	2620 - 2690 MHz	
8	880 - 915 MHz	925 - 960 MHz	
9	1749.9 - 1784.9 MHz	1844.9 - 1879.9 MHz	
10	1710 - 1770 MHz	2110 - 2170 MHz	
11	1427.9 - 1452.9 MHz	1475.9 - 1500.9 MHz	
12	698 - 716 MHz	728 - 746 MHz	
13	777 - 787 MHz	746 - 756 MHz	
14	788 - 798 MHz	758 - 768 MHz	
17	704 - 716 MHz	734 - 746 MHz	
18	815 - 830 MHz	860 - 875 MHz	
19	830 - 845 MHz	875 - 890 MHz	
20	832 - 862 MHz	791 - 821 MHz	
21	1447.9 - 1462.9 MHz	1495.9 - 1510.9 MHz	
33	1900 -1920 MHz	1900 -1920 MHz	
34	2010 - 2025 MHz	2010 - 2025 MHz	
35	1850 - 1910 MHz	1850 - 1910 MHz	
36	1930 - 1990 MHz	1930 - 1990 MHz	
37	1910 - 1930 MHz	1910 - 1930 MHz	
38	2570 - 2620 MHz	2570 - 2620 MHz	
39	1880 - 1920 MHz	1880 - 1920 MHz	
40	2300 - 2400 MHz	2300 - 2400 MHz	

In order to cover different countries with a unique device, mobile phones and 3G data cards are usually equipped with more than one band. Some typical examples are the triple band combination of band 1, 2 and 5 or quad band combination of band 1, 2, 5 and 8. Since last year, some 700MHz bands are released in the US, so that band combination like 4, 13 and 17 are also well visible in the market.

1.2 Applications

Figure 1 shows an example of the block diagram of the front-end of a 3G modem. A SPnT switch connects on one side the modem antenna and on the other sides several duplexers for different 3G bands. Every duplexer is connected to the transmitting (TX) and receiving (RX) pathes of each band. The external LNA, here for example BGA735N16, 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. It can be 1-, 2-, 3-, or 4-bands. Recently, even mobile devices with 6 bands are under discussion.

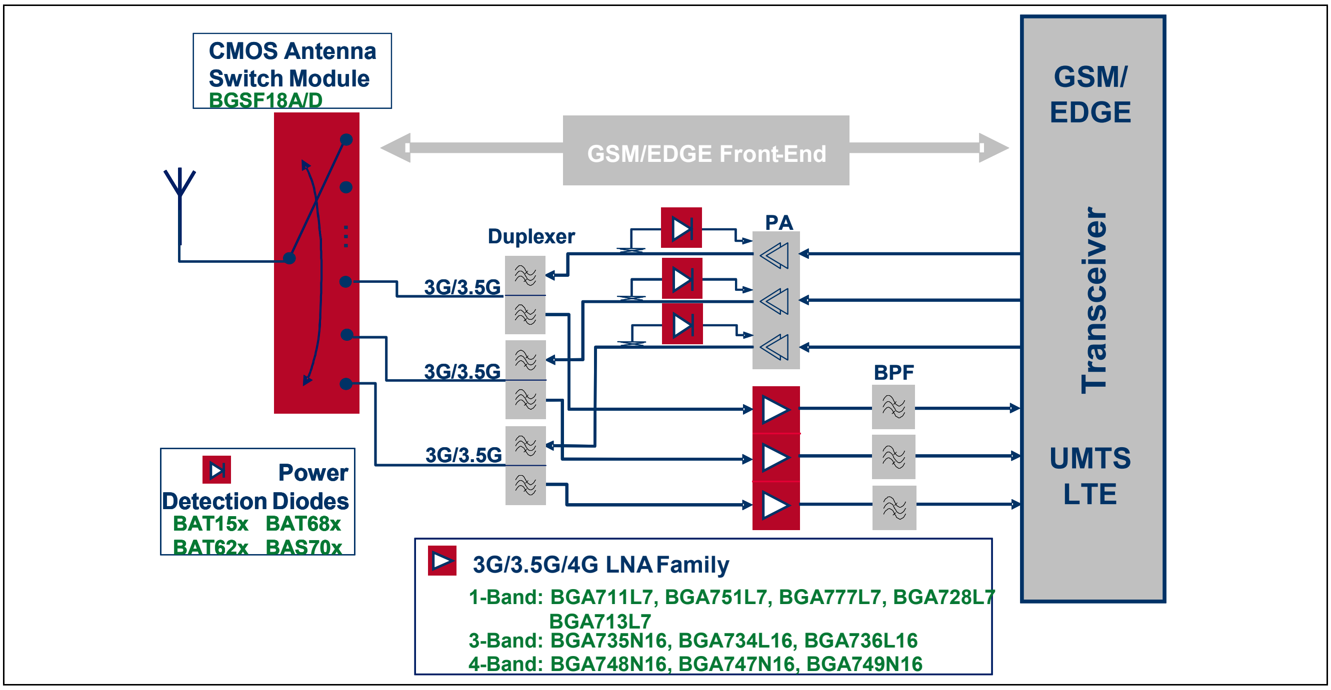

Figure 1 Example of Application Diagram of a 3-band RF front-end for 3G and 4G systems.

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

1.3 Infineon LNAs for 3G and 4G Applications

With the increasing wireless data speed and with the extended link distance of mobile phones and 3G data cards, the requirements on the sensitivity are much higher. Infineon offers different kind of low noise amplifiers (LNAs) to support the customers for mobile phones and data cards of 3G and 4G to improve their system performance to meet the requirements coming from the networks/service providers.

The benefits to use external LNAs in an equipment for 3G and 4G 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 oss in front of the integrated LNA on the transceiver IC increases the system noise figure noticeable. An external LNA physically close to the ANT can help to eliminate the path loss and reduce the system noise figure. Therefore the sensitivity can be improved by several dB.
- 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.

Table 3 shows a list of the MMIC LNA portfolio from Infineon Technologies for the applications of 3G and 4G applications (stand July 2010). Depending on the applications, LNAs with different band combinations are available:

- Single-band LNAs like BGA711L7 for high-band (HB, 1700MHz-2300MHz), BGA777L7 for high-band (2300MHz-2700MHz) or BGA751L7 for low-band (LB, 700-1000MHz) are available. BGA713L7 is designed for the special LTE bands 12, 13, 14, 17, 18, 19 and 20 in the US.
- 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. BGA747N16 can cover 3x high-bands and 1x low-band. All of these quad-bands LNAs can support all designs with 3 to 4 bands.

The broad product portfolio with highest integration and best features in noise figure, switchable gain level and flexible band selection helps designers of mobile phones and data cards to achieve outstanding performance. Therefore Infineon LNAs are widely used by major mobile phone vendors.

Table 3 Infineon Product Portfolio of LNAs for 3G and 4G Applications (Stand July 2010)

Frequency Range	700 MHz – 1 GHz	1400MHz – 2200MHz	2100 MHz – 2700 MHz	Comment
Single-Band LNA				
BGA711L7		x		
BGA751L7	x			
BGA777L7			x	
BGA728L7	x	x		
BGA713L7	x			
Triple Band LNA				
BGA734L16	x	x	x	
BGA735N16	x	x	x	
BGA736N16	x	x	x	
Quad-band LNA				
BGA747N16	x	x	x	
BGA748N16	x	x	x	
BGA749N16	x	x	x	

2 Infineon LNA BGA748N16 for 3G and 4G Applications

This application note focuses on the Infineon's Quad-band LNA BGA748N16 tuned for the band combination of **band I, II, V and VIII**. It presents the performance of BGA748N16 **with an external reference resistor of 8.2 kΩ** which enables the device to work with a current of **6.2 mA** at single supply voltage of 2.8 V. All the measurements are executed with the standard evaluation board presented at the end of this application note.

2.1 Features of BGA748N16

- High gain and low gain modes
- Low noise figure
- Tunable supply current with external Rref
- Standby mode (< 2 µA typ.)
- Output internally matched to 50 Ω for major bands.
- Inputs pre-matched to 50 Ω.
- 2 kV HBM ESD protection
- Low external component count
- Small leadless TSNP-16-1 package (2.3 x 2.3 x 0.39 mm)
- Pb-free (RoHS compliant) device

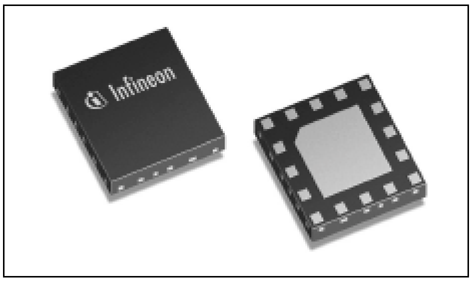

Figure 2 BGA748N16 in TSNP-16 Package

3 Description

Figure 3 shows the internal block diagram of BGA748N16 with the topview of the TSNP-16 and the pin assignment. **Table 4** is the pin assignment of BGA748N16 with the description of their functions accordingly. As shown in the block diagram, BGA748N16 includes 4 LNAs into one device. Each of the LNA can be switched to the high-gain and the low-gain mode. The gain switch can be easily done by switching the VGS pin to Vcc for high-gain mode or 0 V (low-gain mode). Furthermore, the following functions are integrated into BGA748N16:

- Smart active biasing circuit: to enable the circuit performance over temperature and supply voltage variation.
- Output matching circuits for the standard bands (bands 1, 2, 5, 8 in this case)
- Current setting with only one external resistor Rref.
- Band selection with the two pins VEN1 and VEN2 (**Table 5**).
- On/off switch of the whole device with one single pin VON (**Table 6**).
- All the digital control pins VON, VEN1, VEN2 and VGS are CMOS 2.8V logic compliant.
- ESD protection circuit allaround the device for 2kV HBM.

The RF input pins of the LNAs are connected directly with the base of the major SiGe:C RF transistors to achieve the best noise figure performance. In addition, the input and the output matching circuits can be tuned to different bands if required.

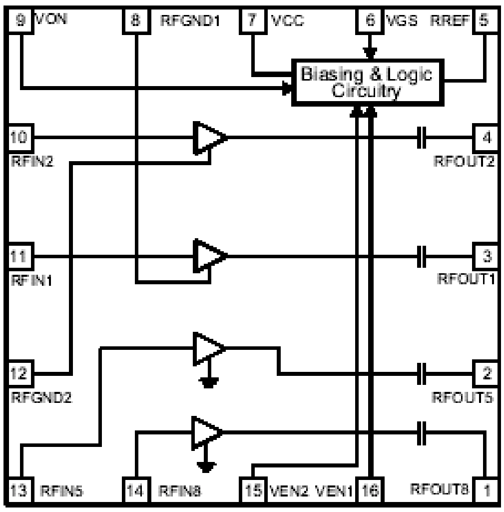

Figure 3 Block diagram and pin assignment of BGA748N16 (topview)

Table 4 Pin Assignment of BGA748N16

Pin No.	Symbol	Function
0	GND	Ground Package Paddle;ground connection for band V and band VIII
1	RFOUT8	LNA output UMTS band VIII
2	RFOUT5	LNA output UMTS band V
3	RFOUT1	LNA output UMTS band I
4	RFOUT2	LNA output UMTS band II
5	RREF	Bias current reference resistor (High gain mode)
6	VGS	Gain step control voltage
7	VCC	Supply voltage
8	RFGND1	LNA emitter ground UMTS band I
9	VON	Power on control voltage
10	RFIN2	LNA input UMTS band II
11	RFIN1	LNA input UMTS band I
12	RFGND2	LNA emitter ground UMTS band II
13	RFIN5	LNA input UMTS band V
14	RFIN8	LNA input UMTS band VIII
15	VEN2	Band select control voltage
16	VEN1	Band select control voltage

Table 5 Band selection Truth table(Vcc=2.8V)

Pin control	Band I	Band II	Band V	Band VIII	Stand-by
VEN1	H	H	H	L	L
VEN2	H	L	L	L	L
VON	H	H	H	H	L

Table 6 Gain control Truth table(Vcc=2.8V)

Pin control	High Gain	Low Gain
VGS	H	L

4 Application Information

Figure 4 shows the application circuit of BGA748N16 for bands I, II, V and VIII. **Table 7** describes the bill-of-materials for this application circuit.

4.1 Schematics

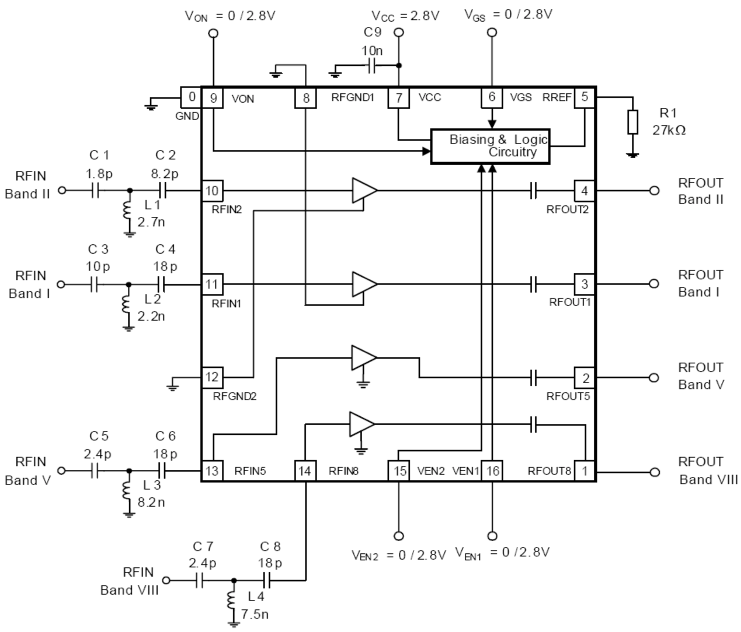

Figure 4 Schematics of the application circuit of BGA748N16 for bands I, II, V and VIII

Table 7 Bill-of-Materials

Symbol	Value	Unit	Size	Manufacturer	Comment
C1	1.8	pF	0402	Various	Input matching band II
C2	8.2	pF	0402	Various	Input matching /DC block Band II
C3	10	pF	0402	Various	Input matching band I
C4	18	pF	0402	Various	Input matching band I
C5	2.4	pF	0402	Various	Input matching band V
C6	18	pF	0402	Various	Input matching band V
C7	2.4	pF	0402	Various	Input matching band VIII
C8	18	pF	0402	Various	Input matching band VIII
C9	10	nF	0402	Various	HF to ground
L1	2.7	nH	0402	Murata LQW series	Input matching band II
L2	2.2	nH	0402	Murata LQW series	Input matching band I
L3	8.2	nH	0402	Murata LQW series	Input matching band V
L4	7.5	nH	0402	Murata LQW series	Input matching band VIII
R1	27	KΩ	0402	Various	Bias settings
Q1	BGA748N16		TSNP16-1		Infineon SiGe:C MMIC quad-band LNA

5 Typical Measurement Results

5.1 Results of Band I

Table 8 Electrical Characteristics (at room temperature) of Band I

Band I, VGS=0V for low gain mode, VGS=2.8V for high gain mode

Parameter	Symbol	Value		Unit	Comment/Test Condition
Frequency Range	Freq	2110...2170		MHz	
DC Supply Voltage	Vcc	2.8		V	
Gain Mode	-	High Gain	Low Gain		
DC Current	Icc	6.2	0.8	mA	
Gain	G	18.5	-8.2	dB	
Noise Figure	NF	1.4	8.4	dB	SMA and PCB losses of 0.1dB excluded
Input Return Loss	RLin	10.6	14.6	dB	
Output Return Loss	RLout	20.4	9.9	dB	
Reverse Isolation	IRev	36.3	8.2	dB	Pin=-30dBm
Input P1dB	IP1dB	-10.6	3.9	dBm	Measured @2140MHz
Output P1dB	OP1dB	6.9	-5.3	dBm	
Input IP3	IIP3	-3.9	16	dBm	
Output IP3	OIP3	14.6	7.8	dBm	*f*1=2140MHz; f2=2140MHz Pin=-30dBm high gain mode Pin=-20dBm Low gain mode
Stability	k	>1		--	Unconditionnally stably from DC to 10 GHz

5.2 Results of Band II

Table 9 Electrical Characteristics (at room temperature) of Band II

Band II, VGS=0V for low gain mode, VGS=2.8V for high gain mode

Parameter	Symbol	Value		Unit	Comment/Test Condition
Frequency Range	Freq	1930...1990		MHz	
DC Supply Voltage	Vcc	2.8		V	
Gain Mode	-	High Gain	Low Gain		
DC Current	Icc	5.7	0.8	mA	
Gain	G	17.4	-8.4	dB	
Noise Figure	NF	1.4	8.4	dB	SMA and PCB losses of 0.1dB excluded
Input Return Loss	RLin	13.0	20.2	dB	
Output Return Loss	RLout	12.9	22.8	dB	
Reverse Isolation	IRev	35.5	8.4	dB	Pin=-30dBm
Input P1dB	IP1dB	-9	3.9	dBm	Measured @1960MHz
Output P1dB	OP1dB	7.4	-5.5	dBm	
Input IP3	IIP3	-4.3	16.9	dBm	
Output IP3	OIP3	13.1	8.5	dBm	*f*1=1960MHz; f2=1961MHz Pin=-30dBm high gain mode Pin=-20dBm Low gain mode
Stability	K	>1		--	Unconditionnally stably from DC to 10 GHz

5.3 Results of Band V

Table 10 Electrical Characteristics (at room temperature) of Band V

Band V, VGS = 2.8 V for low gain mode, VGS = 0 V for high gain mode

Parameter	Symbol	Value		Unit	Comment/Test Condition
Frequency Range	Freq	869...894		MHz	
DC Supply Voltage	Vcc	2.8		V	
Gain Mode	-	High Gain	Low Gain		
DC Current	Icc	5.3	0.8	mA	
Gain	G	17.0	-8.3	dB	
Noise Figure	NF	1.4	8.4	dB	SMA and PCB losses of 0.1dB excluded
Input Return Loss	RLin	11.5	12.6	dB	
Output Return Loss	RLout	17.9	11.1	dB	
Reverse Isolation	IRev	37.5	8.2	dB	Pin=-30dBm
Input P1dB	IP1dB	-8.3	0.9	dBm	Measured @880MHz
Output P1dB	OP1dB	7.7	-8.5	dBm	
Input IP3	IIP3	-5	13.2	dBm	
Output IP3	OIP3	12.0	4.9	dBm	*f*1=880MHz; f2=881MHz Pin=-30dBm high gain mode Pin=-20dBm Low gain mode
Stability	k	>1		--	Unconditionnally stably from DC to 10 GHz

5.4 Results of Band VIII

Table 11 Electrical Characteristics (at room temperature) of Band VIII

Band VIII, VGS = 0V for low gain mode, VGS = 2.8V for high gain mode

Parameter	Symbol	Value		Unit	Comment/Test Condition
Frequency Range	Freq	925...960		MHz	
DC Supply Voltage	Vcc	2.8		V	
Gain Mode	-	High Gain	Low Gain		
DC Current	Icc	5.3	0.8	mA	
Gain	G	17.0	-8.2	dB	
Noise Figure	NF	1.4	8.4	dB	SMA and PCB losses of 0.1dB excluded
Input Return Loss	RLin	12.6	9.5	dB	
Output Return Loss	RLout	14.5	10.9	dB	
Reverse Isolation	IRev	35.7	8.2	dB	Pin=-30dBm
Input P1dB	IP1dB	-10.0	2.8	dBm	Measured @940MHz
Output P1dB	OP1dB	6.0	-6.4	dBm	
Input IP3	IIP3	-4.5	12.2	dBm	
Output IP3	OIP3	12.5	4.0	dBm	*f*1=940MHz; *f*2=941MHz Pin=-30dBm high gain mode Pin=-20dBm Low gain mode
Stability	k	>1		--	Unconditionnally stably from DC to 10 GHz

6 Measured Graphs

6.1 Graphs of Band I

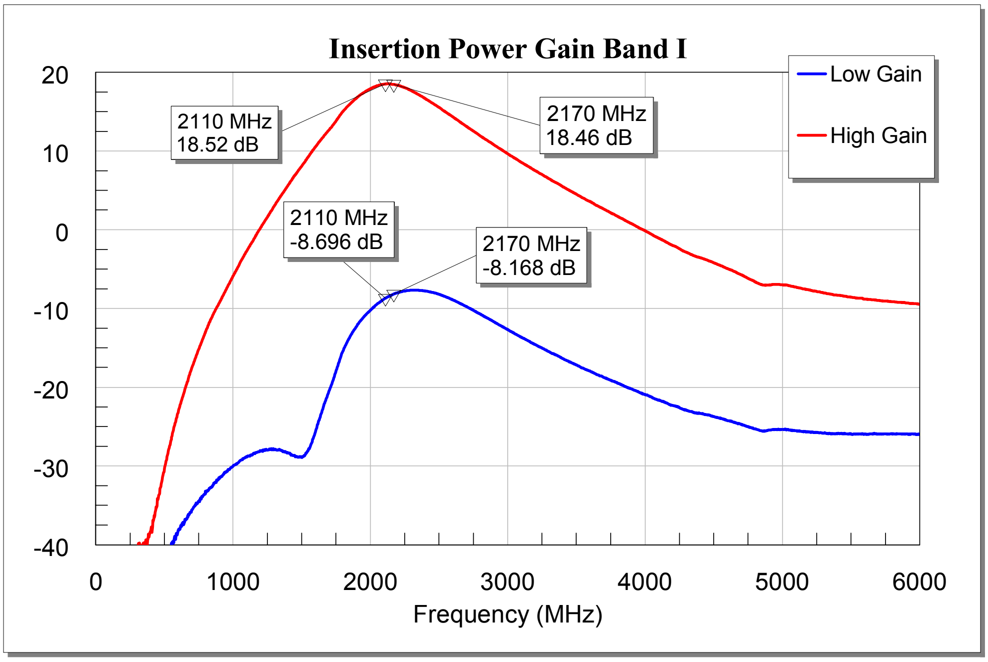

Figure 5 Measured Power Gain of BGA748N16 in Band I with Rref= 8.2 kΩ

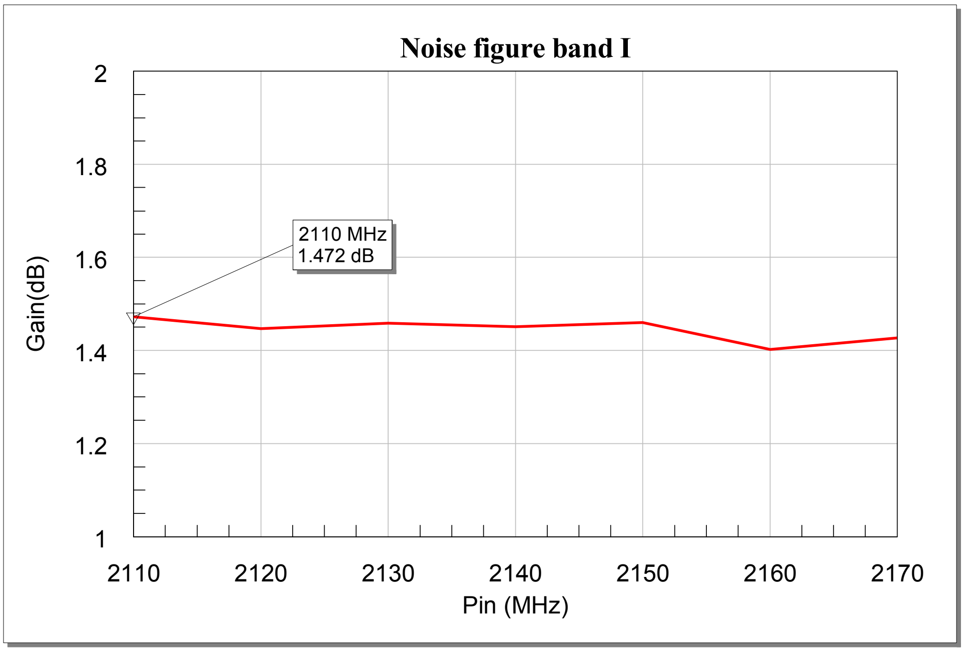

Figure 6 Measured Noise Figure of BGA748N16 in Band I with Rref= 8.2 kΩ (in high gain mode)

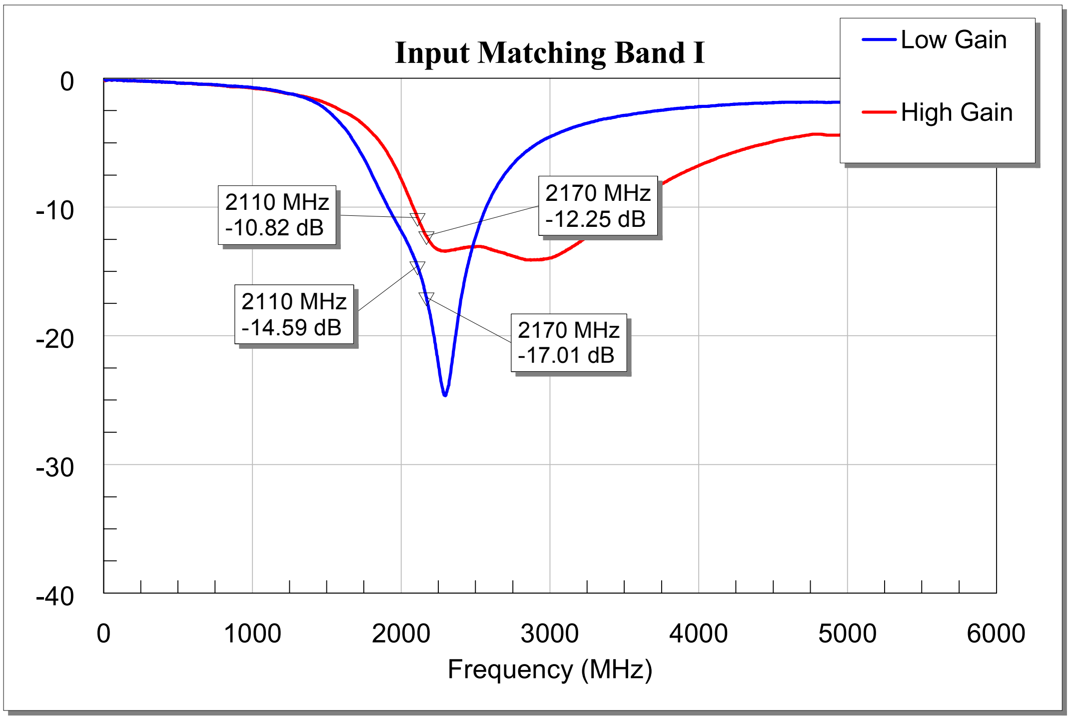

Figure 7 Measured input insertion loss of BGA748N16 in Band I with Rref= 8.2 kΩ

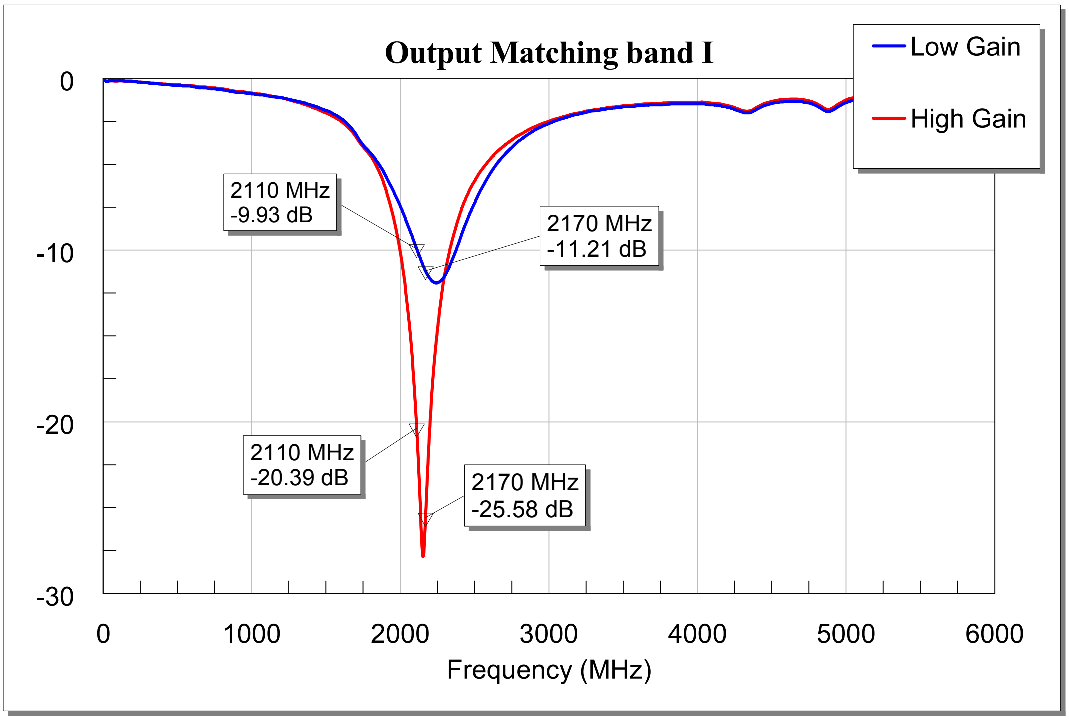

Figure 8 Measured output insertion loss of BGA748N16 in Band I with Rref= 8.2 kΩ

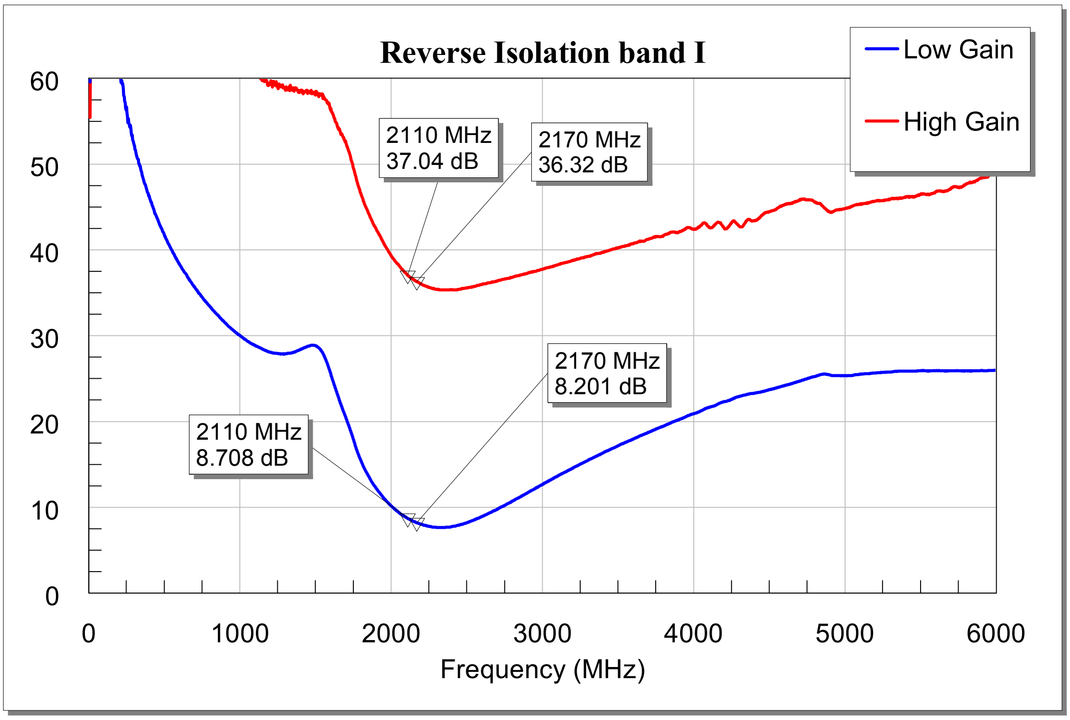

Figure 9 Measured reverse isolation of BGA748N16 in Band I with Rref= 8.2 kΩ

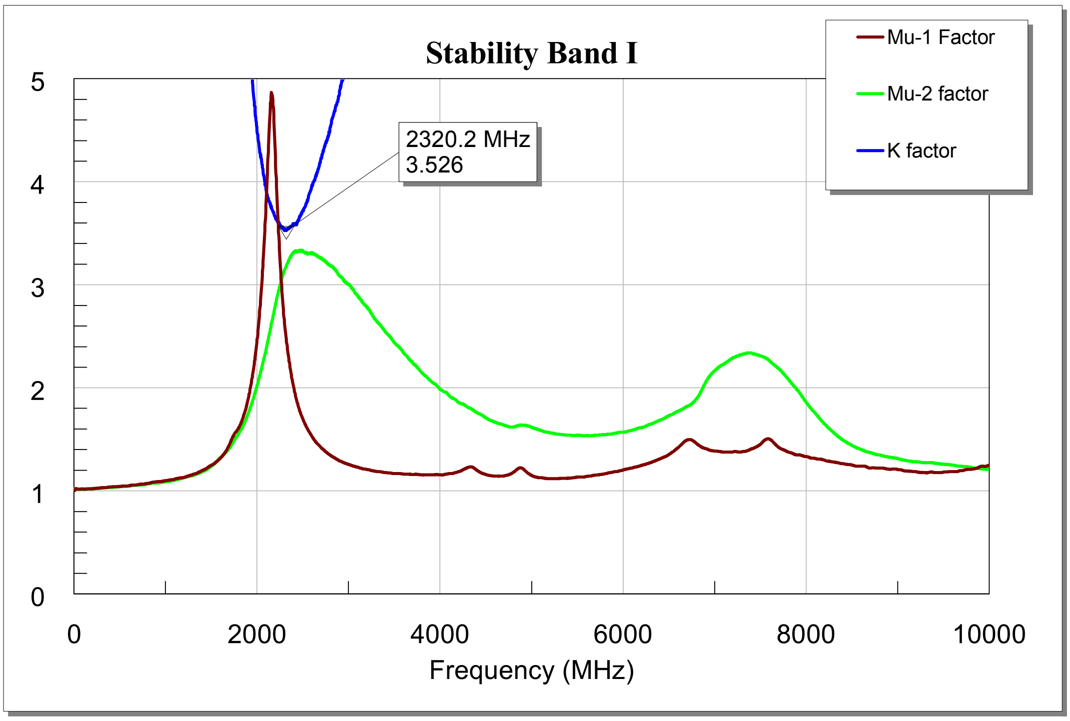

Figure 10 Measured stability factor of BGA748N16 in Band I with Rref= 8.2 kΩ

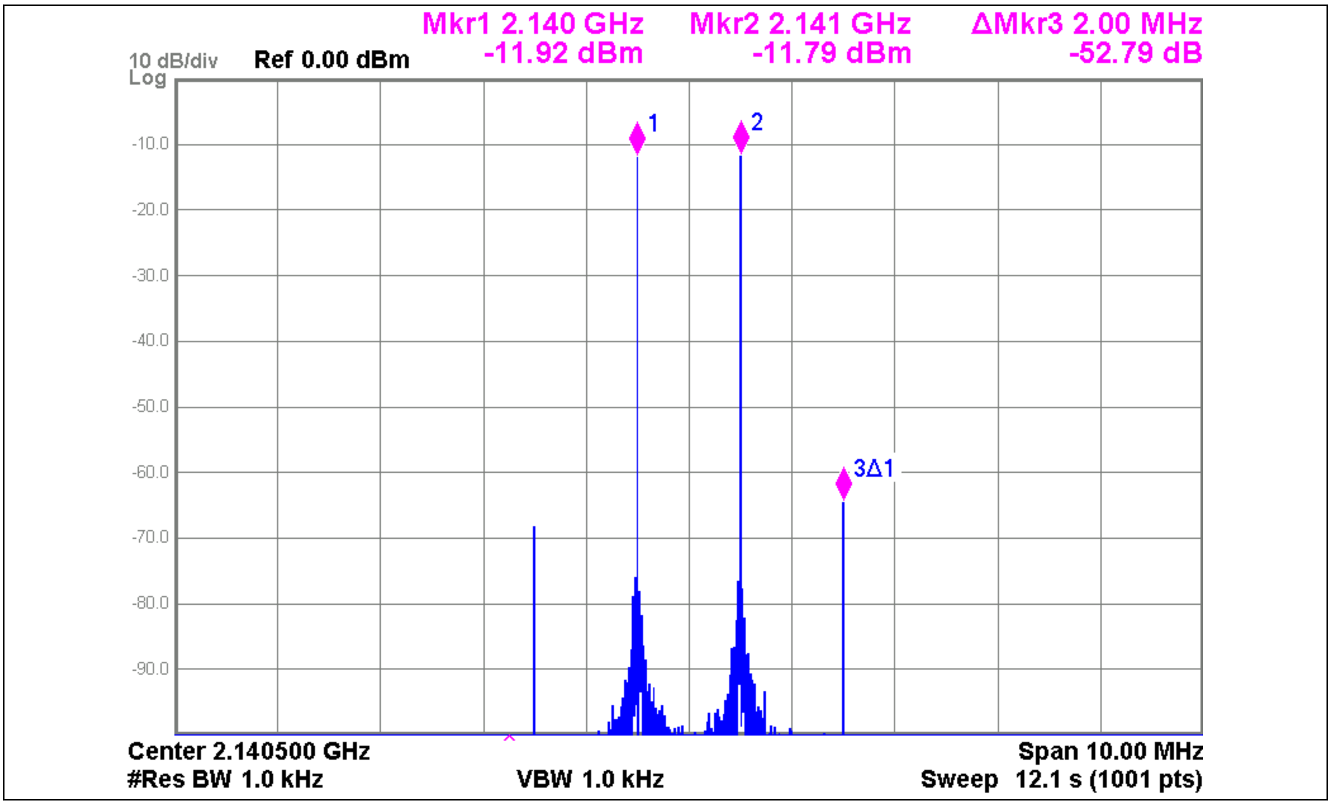

Figure 11 Measured input IP3 of BGA748N16 in middle of Band I with Rref= 8.2 kΩ (in high gain mode)

6.2 Graphs of Band II

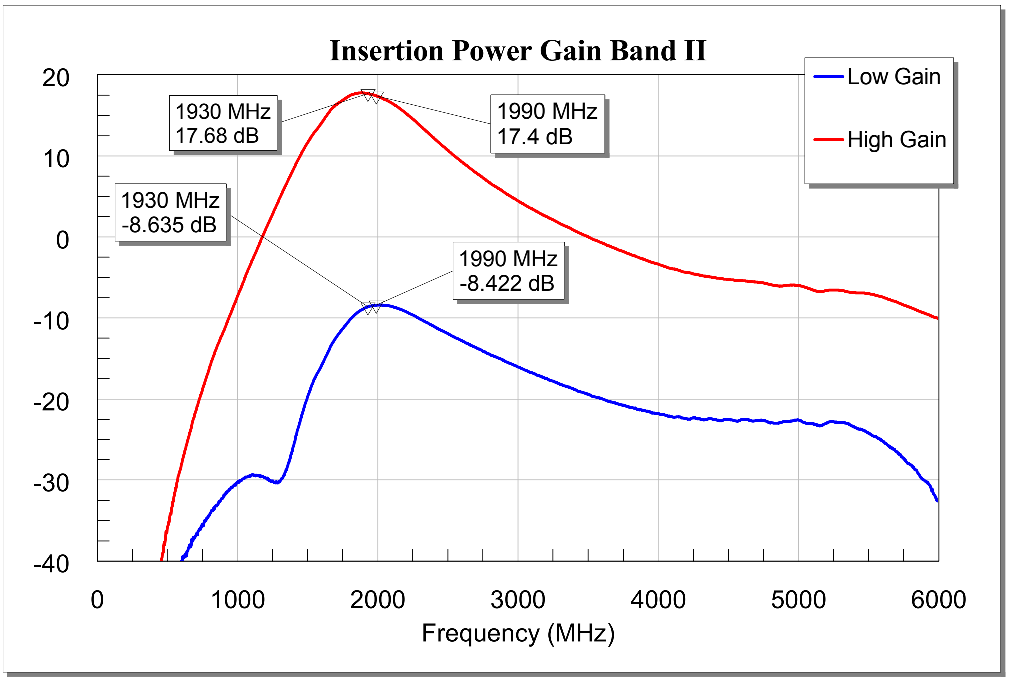

Figure 12 Measured Power Gain of BGA748N16 in Band II with Rref= 8.2 kΩ

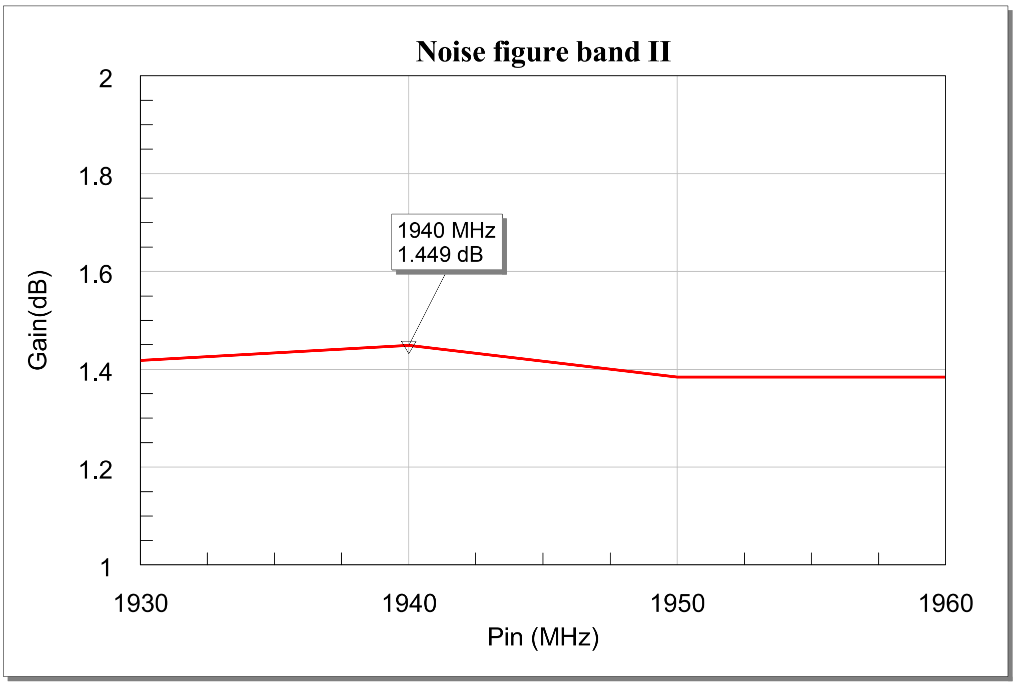

Figure 13 Measured Noise Figure of BGA748N16 in Band II with Rref= 8.2 kΩ (in high gain mode)

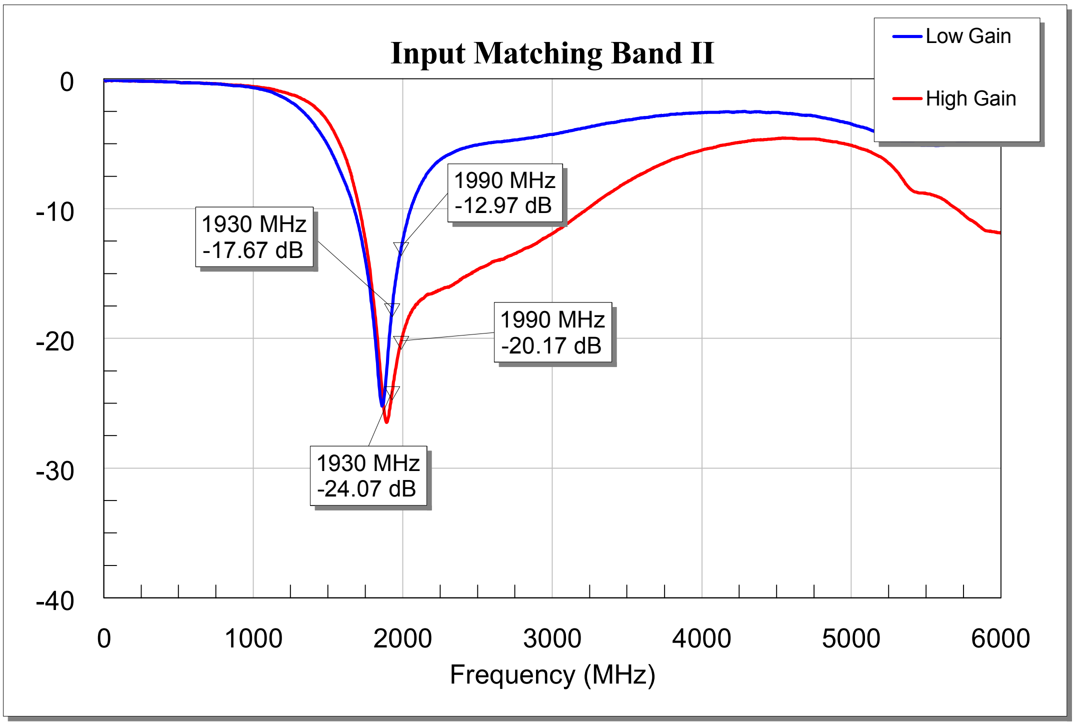

Figure 14 Measured input insertion loss of BGA748N16 in Band II with Rref= 8.2 kΩ

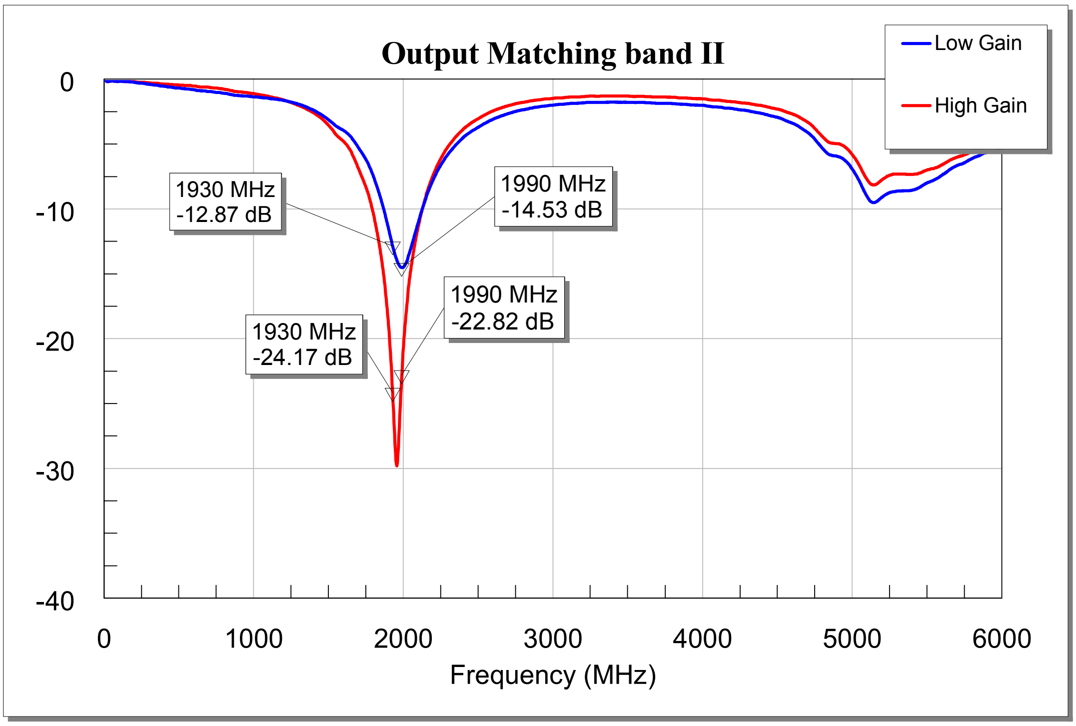

Figure 15 Measured output insertion loss of BGA748N16 in Band II with Rref= 8.2 kΩ

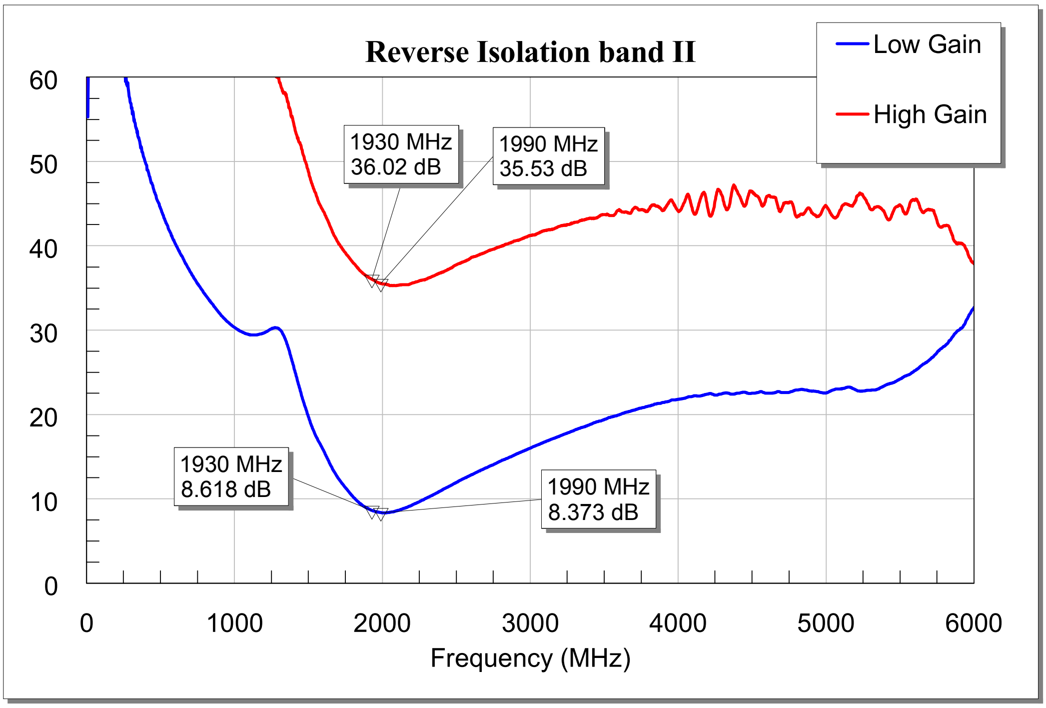

Figure 16 Measured reverse isolation of BGA748N16 in Band II with Rref= 8.2 kΩ

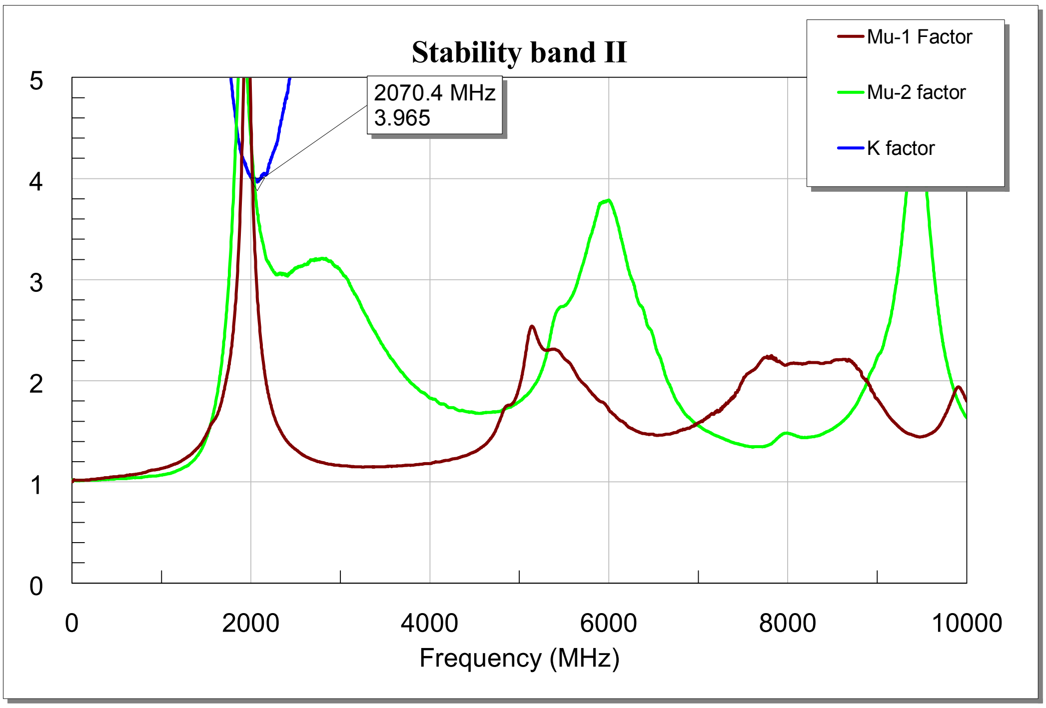

Figure 17 Measured stability factor of BGA748N16 in Band II with Rref= 8.2 kΩ

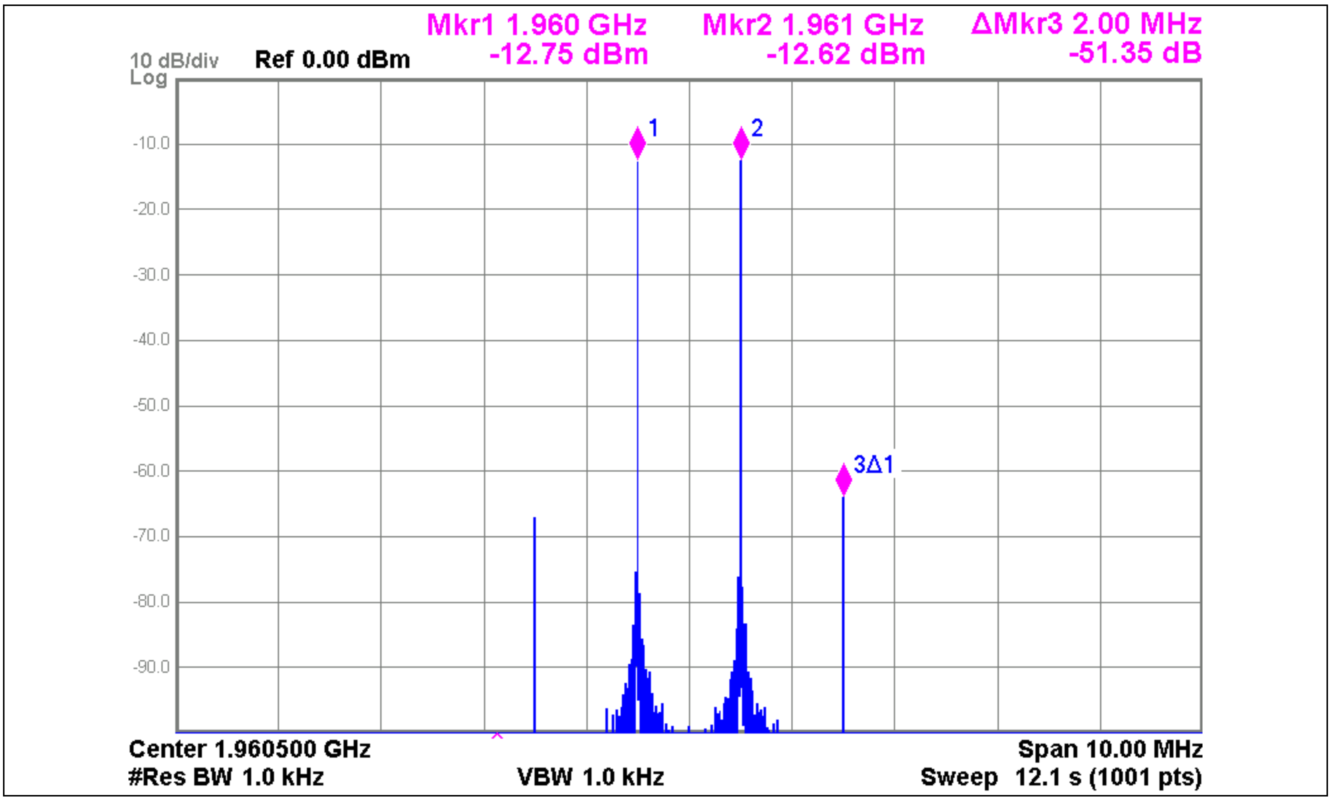

Figure 18 Measured input IP3 of BGA748N16 in middle of Band II with Rref= 8.2 kΩ (in high gain mode)

6.3 Graphs of Band V

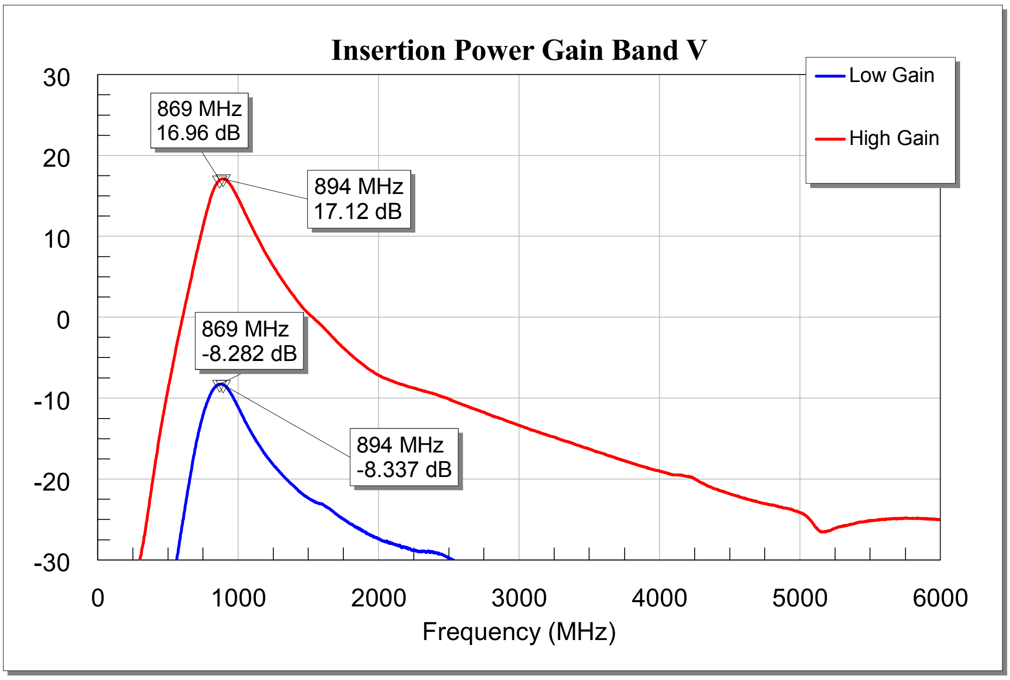

Figure 19 Measured Power Gain of BGA748N16 in Band V with Rref= 8.2 kΩ (in high gain mode)

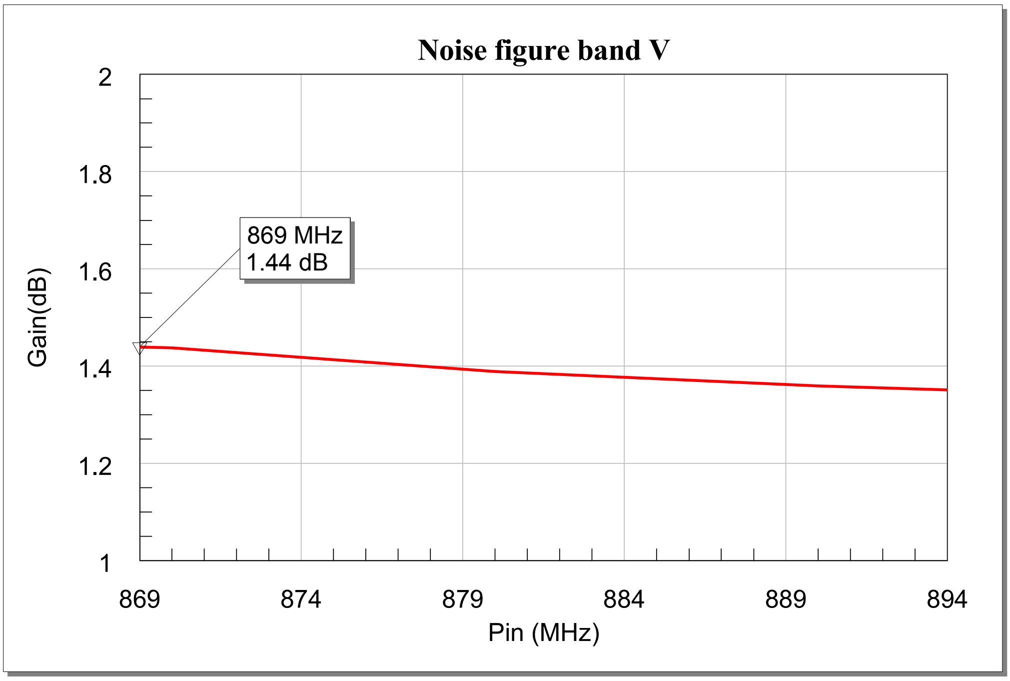

Figure 20 Measured Noise Figure of BGA748N16 in Band V with Rref= 8.2 kΩ

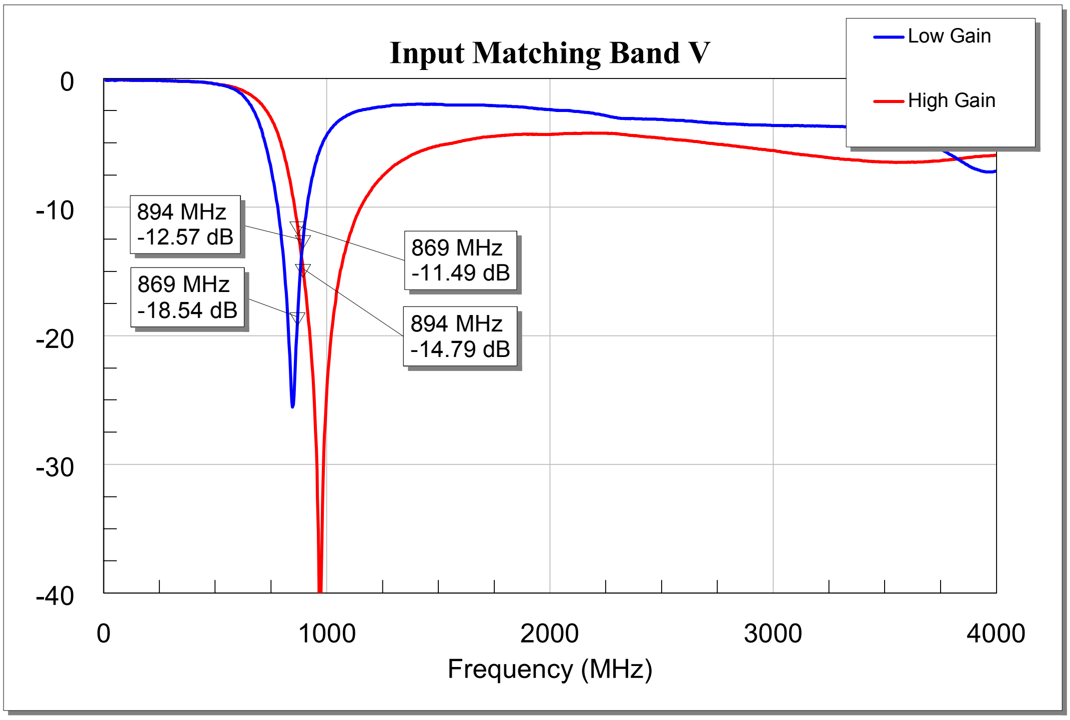

Figure 21 Measured input insertion loss of BGA748N16 in Band V with Rref= 8.2 kΩ

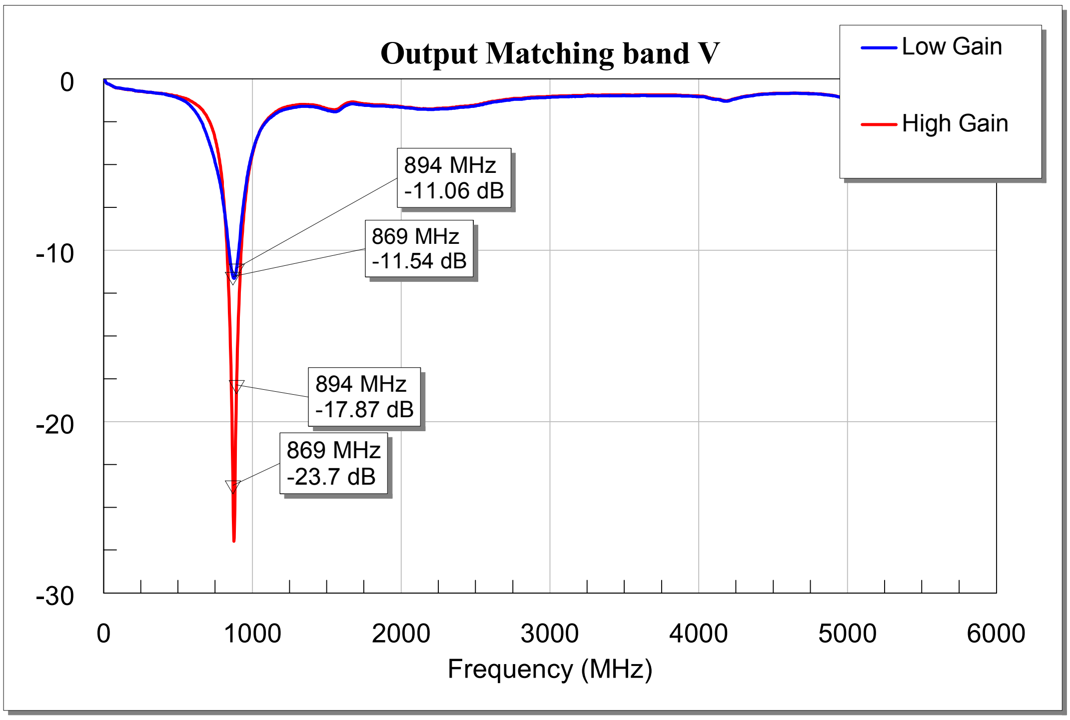

Figure 22 Measured output insertion loss of BGA748N16 in Band V with Rref= 8.2 kΩ

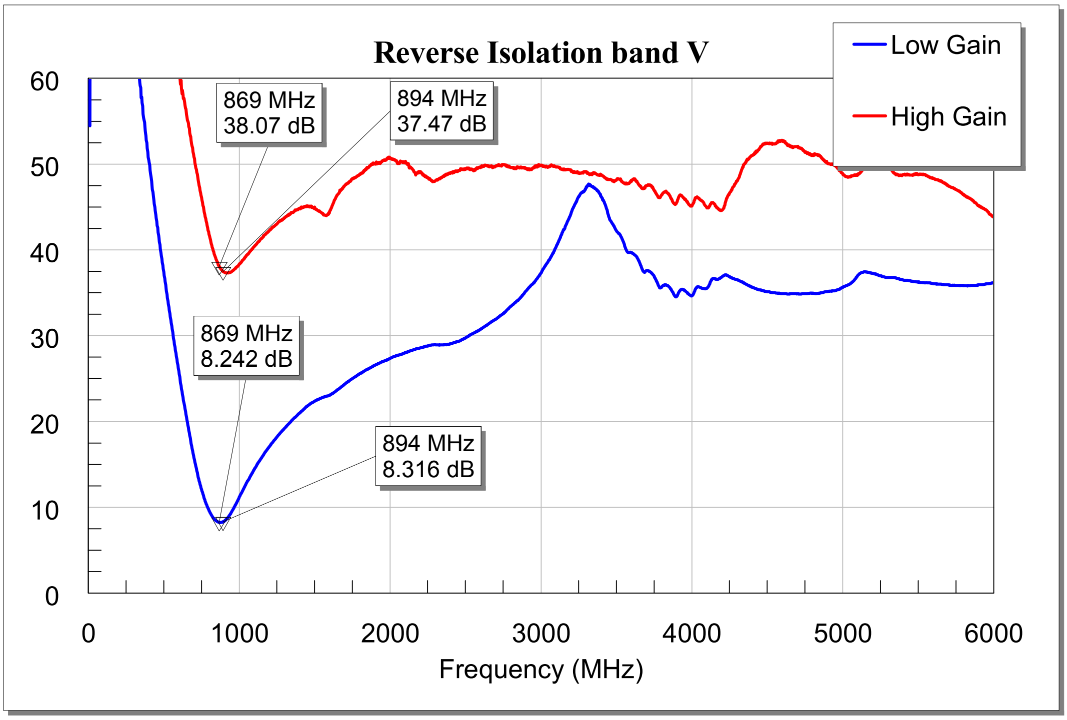

Figure 23 Measured reverse isolation of BGA748N16 in Band V with Rref= 8.2 kΩ

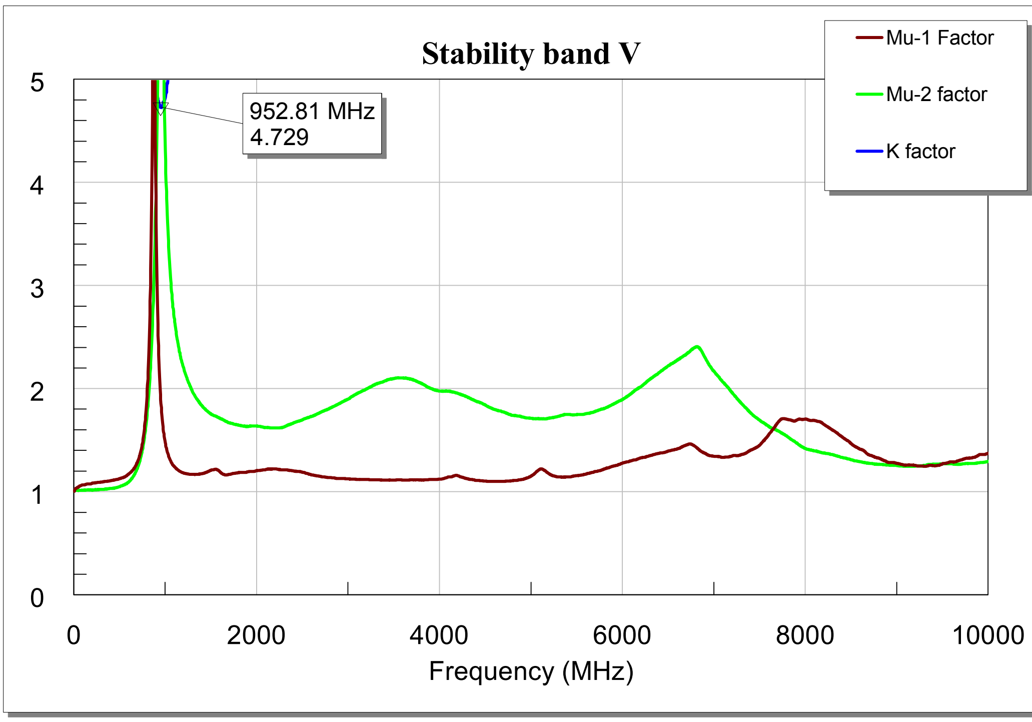

Figure 24 Measured stability factor of BGA748N16 in Band V with Rref= 8.2 kΩ

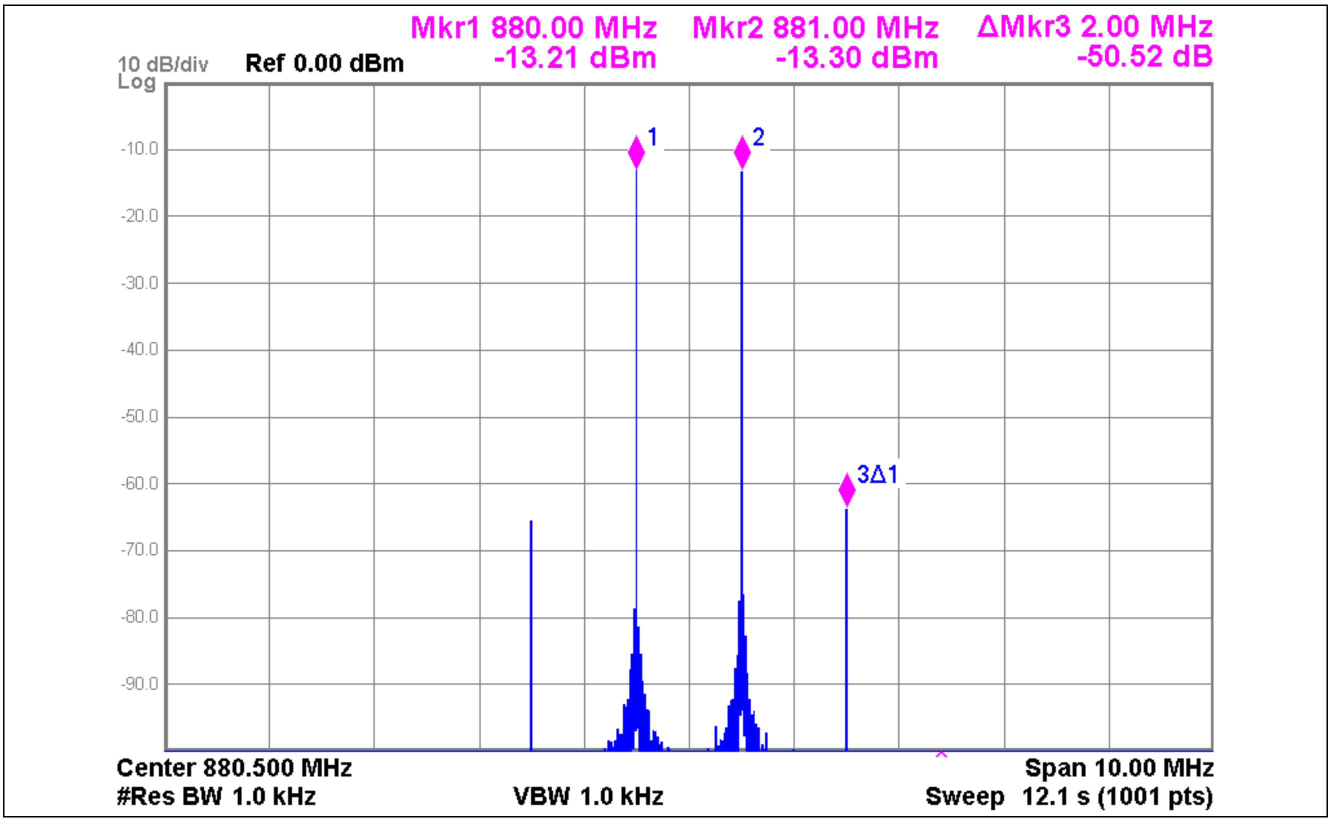

Figure 25 Measured input IP3 of BGA748N16 in middle of Band V with Rref= 8.2 kΩ (in high gain mode)

6.4 Graphs of Band VIII

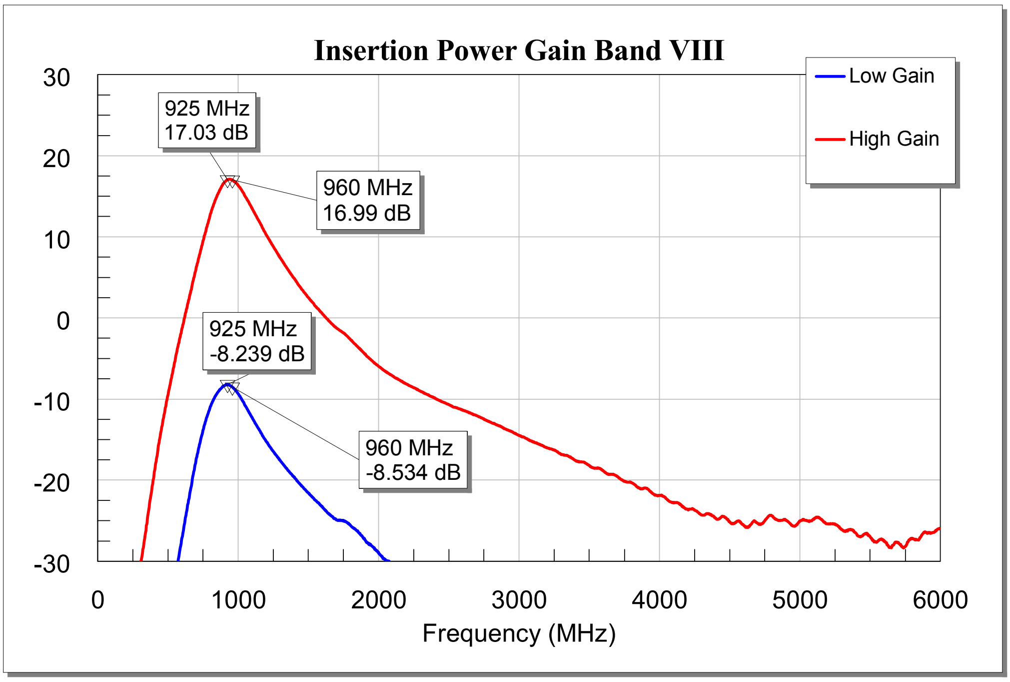

Figure 26 Measured Power Gain of BGA748N16 in Band VIII with Rref= 8.2 kΩ (in high gain mode)

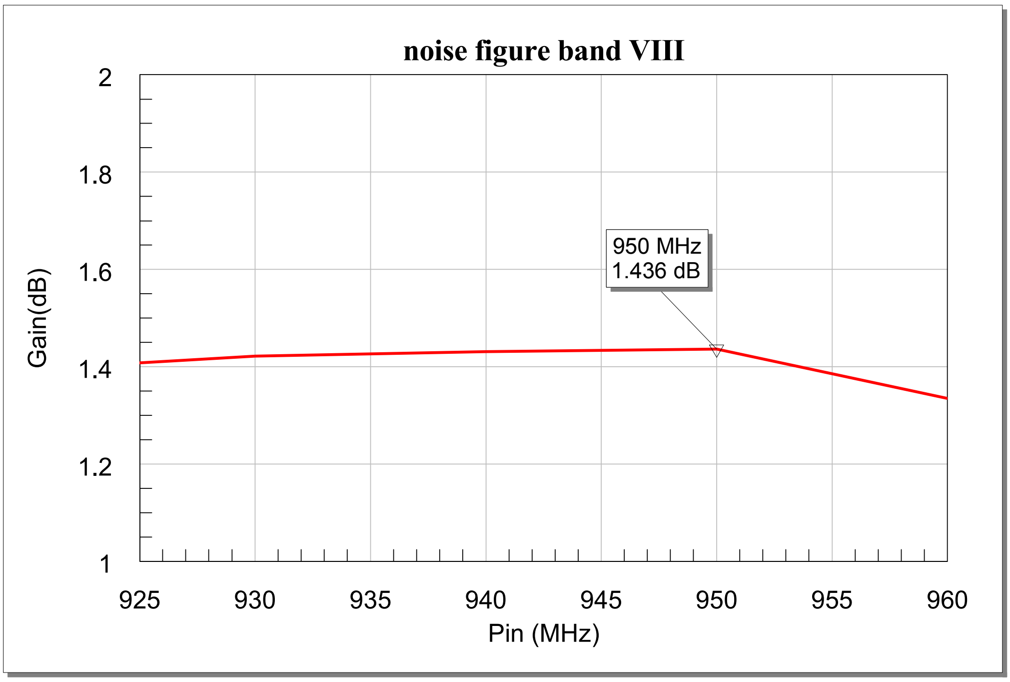

Figure 27 Measured Noise Figure of BGA748N16 in Band VIII with Rref= 8.2 kΩ

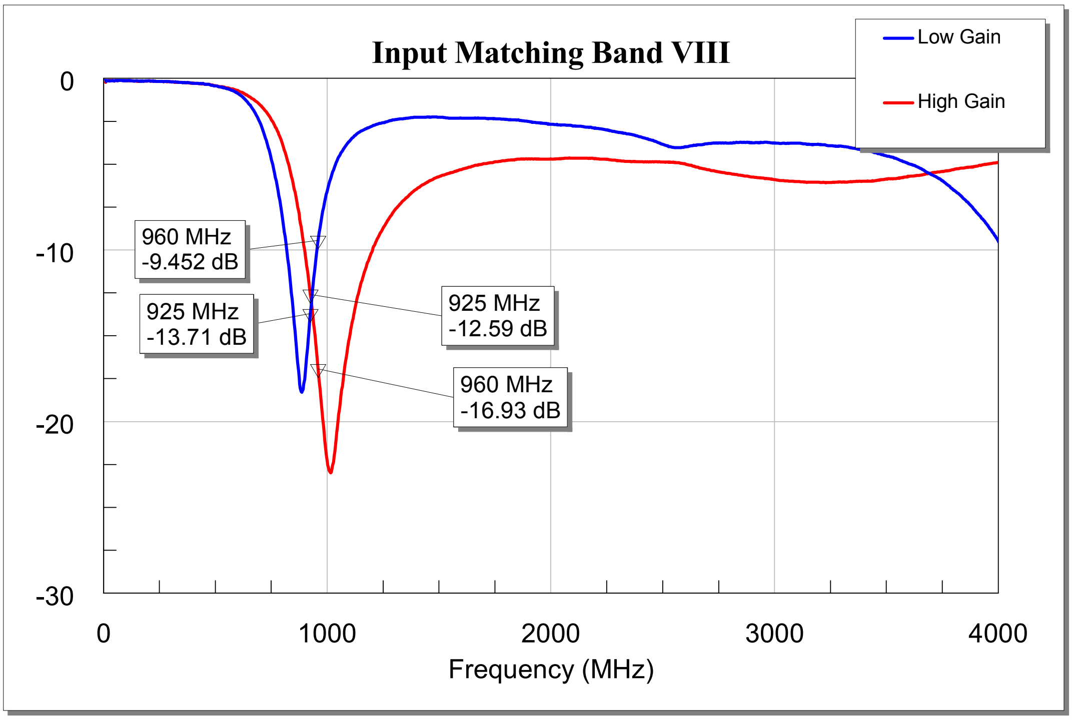

Figure 28 Measured input insertion loss of BGA748N16 in Band VIII with Rref= 8.2 kΩ

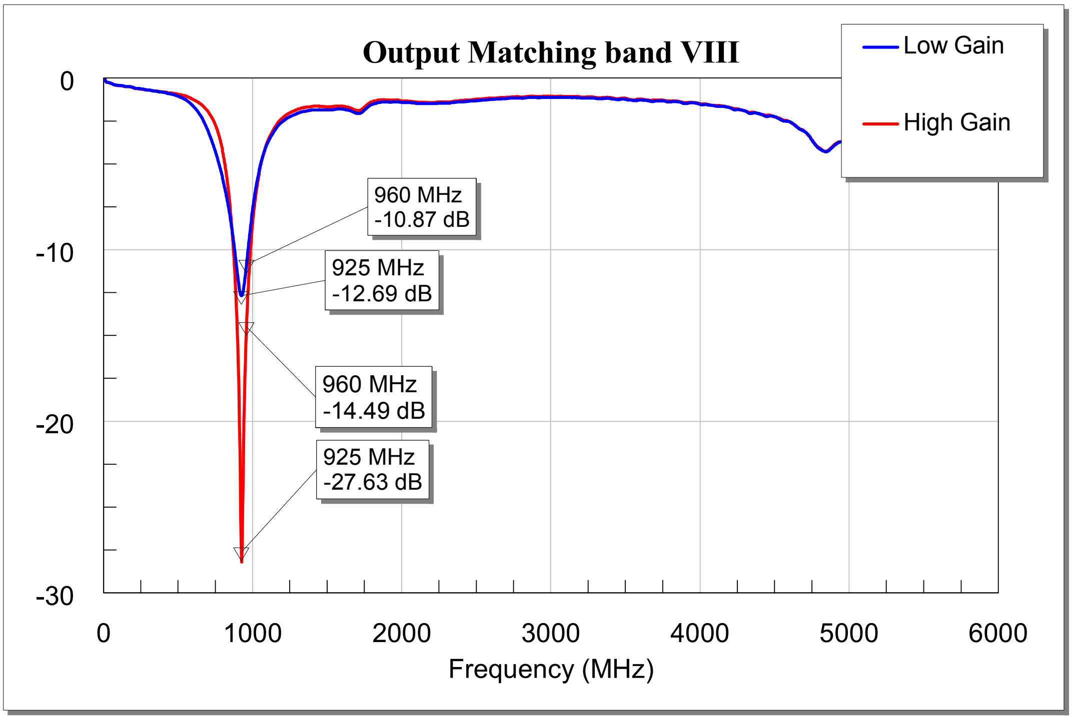

Figure 29 Measured output insertion loss of BGA748N16 in Band VIII with Rref= 8.2 kΩ

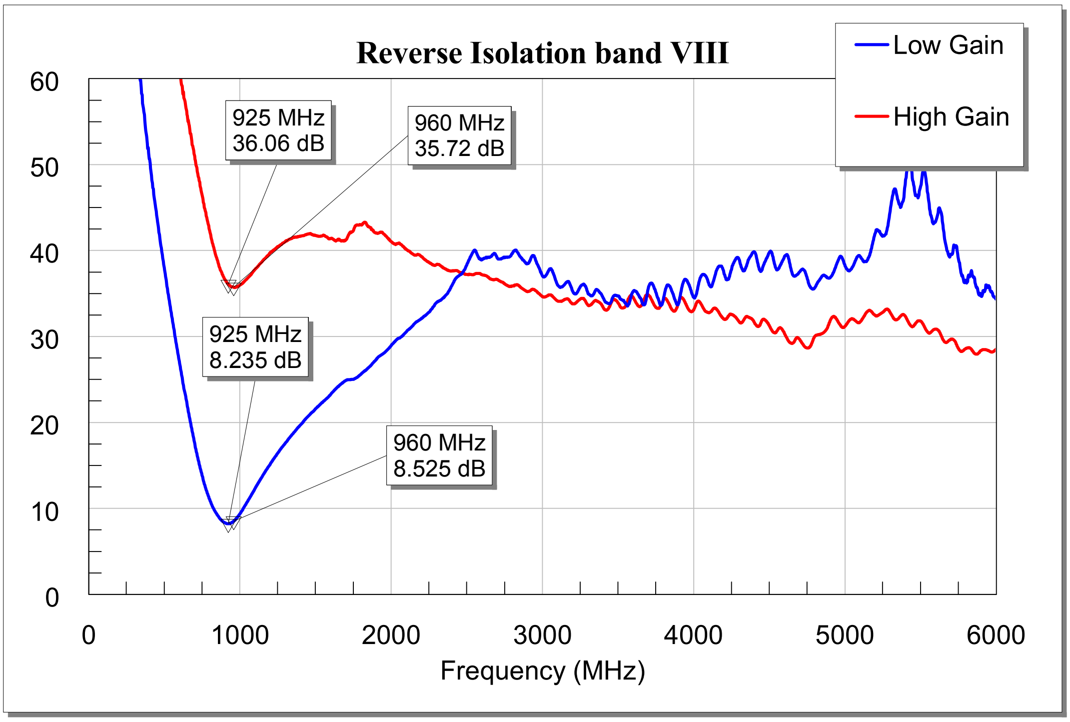

Figure 30 Measured reverse isolation of BGA748N16 in Band VIII with Rref= 8.2 kΩ

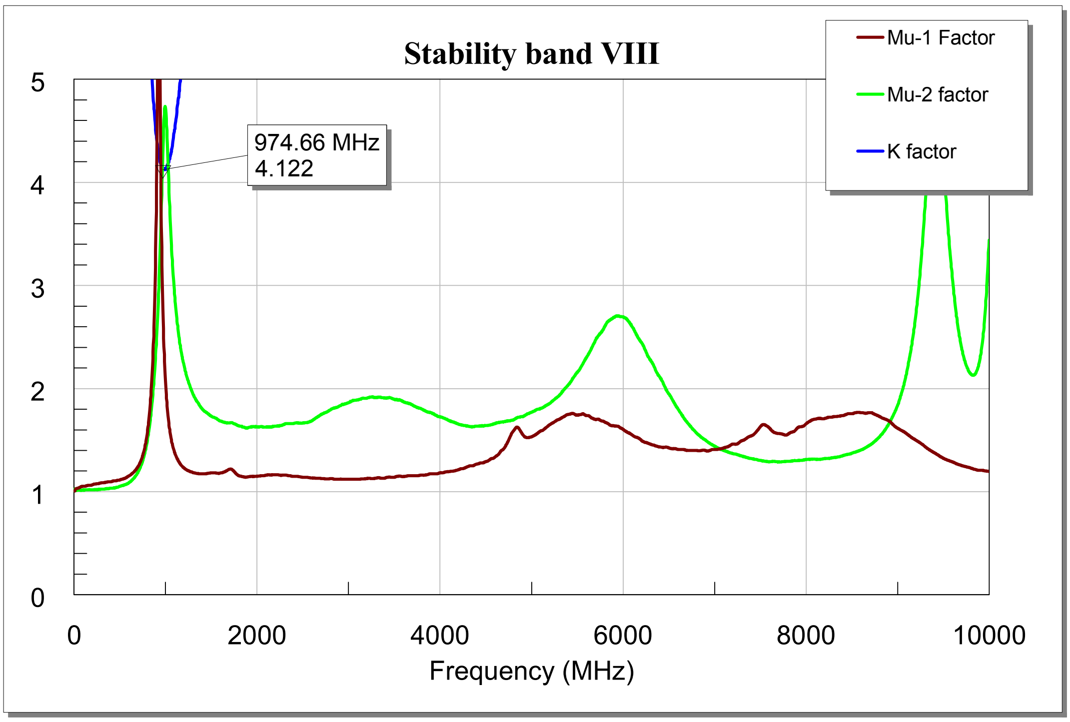

Figure 31 Measured stability factor of BGA748N16 in Band VIII with Rref= 8.2 kΩ

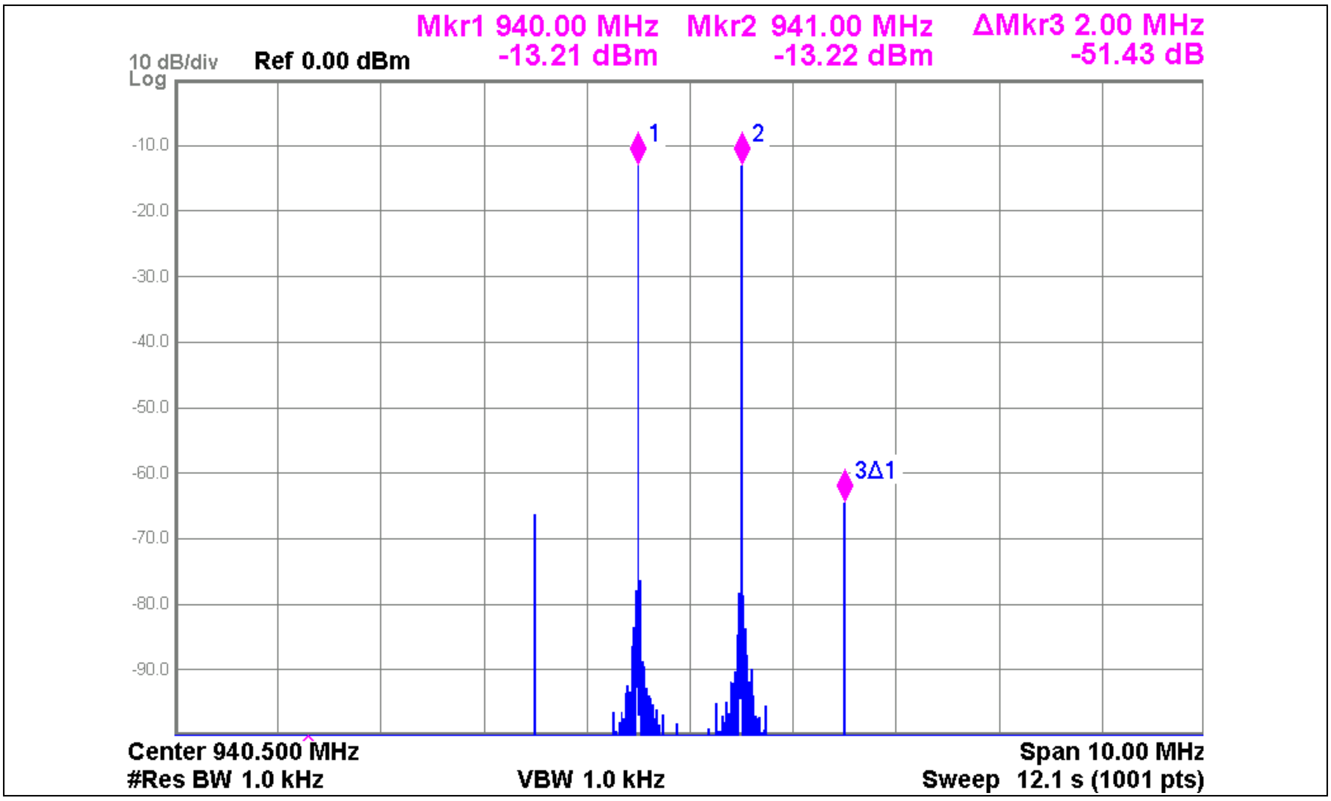

Figure 32 Measured input IP3 of BGA748N16 in middle of Band VIII with Rref= 8.2 kΩ (in high gain mode)

7 Evaluation Board and Layout Information

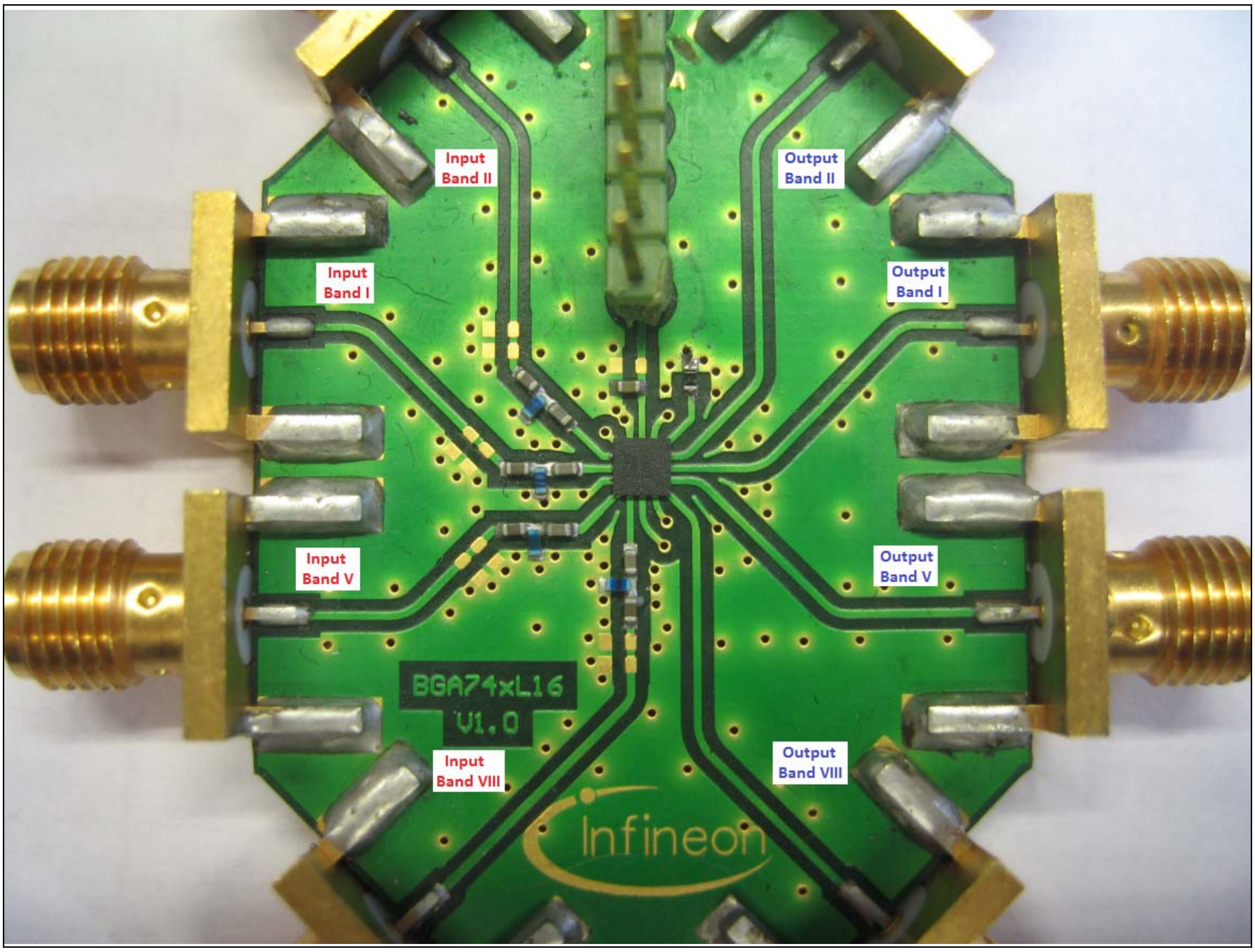

Figure 33 Photo Picture of Evaluation Board of BGA748N16

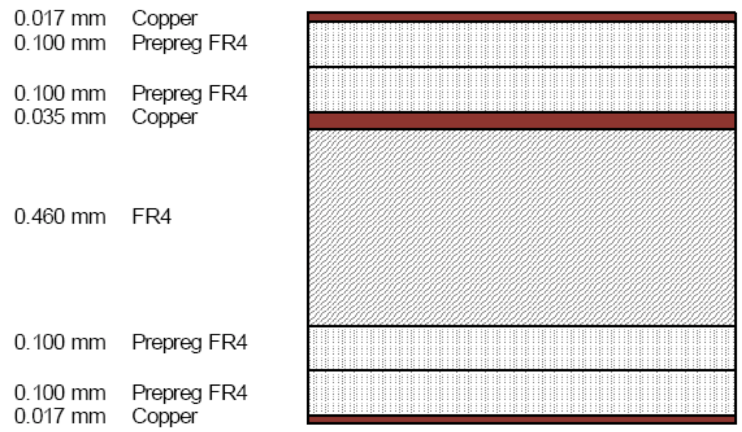

Figure 34 PCB Layer Information of BGA748N16

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