BGA925L6

IMD Performance of BGA925L6 with Different Application Circuits under Specific Test Conditions

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1 BGA925L6 GPS Front-End LNA for High Performance Integrated Solution

1.1 Features

- High gain: 15.8 dB
- High out-of-band input 3rd-order intercept point: +7 dBm
- High input 1dB compression point: -5 dBm
- Low noise figure: 0.65 dB
- Low current consumption: 4.8 mA
- Operating frequency: 1550-1615 MHz
- Supply voltage: 1.5 V to 3.6 V
- Digital on/off switch (1V logic high level)
- Ultra small TSLP-6-2 leadless package
- Package dimensions: 0.70mm x 1.1mm x 0.40mm
- B7HF Silicon Germanium technology
- RF output internally matched to 50 Ω
- Only two external SMD components necessary
- 2 kV HBM ESD protection (including AI-pin)
- Pb-free (RoHS compliant) package

Figure 1 BGA925L6 in TSLP-6-2 Package (0.70mm x 1.1mm x 0.40mm)

1.2 Applications

- Global Positioning System (GPS)
- GLONASS (Russian GNSS)
- Galileo (European GNSS)
- COMPASS (Chinese Beidou Navigation System)

2 Introduction

The BGA925L6 is a front-end Low Noise Amplifier (LNA) for Global Navigation Satellite Systems (GNSS) application. It is based on Infineon Technologies' B7HF Silicon-Germanium (SiGe:C) technology, enabling a cost-effective solution in a ultra small TSLP-6-2 package with ultra low noise figure, high gain, high linearity and low current consumption over a wide range of supply voltages from 3.6 V down to 1.5 V. All these features make BGA925L6 an excellent choice for GNSS LNA as it improves sensitivity, provide greater immunity against out-of-band jammer signals, reduces filtering requirement and hence the overall cost of the GNSS receiver.

The ever growing demand to integrate more and more functionality into one device leads to many challenges when transmitter/receiver has to work simultaneously without degrading the performance of each other. In today's smart-phones a GNSS receiver simultaneously co-exists with transceivers in the GSM/EDGE/UMTS/LTE bands. These 3G/4G transceivers transmit high power in the range of +24 dBm which due to insufficient isolation couple to the GNSS receiver. The cellular signals can mix to produce Intermodulation products exactly in the GNSS receiver frequency band.

In this application note, different application circuits based around BGA925L6 have been considered and compared taking into account their IMD performance under special test cases. BGA925L6 can also be preceded with any external pre-filter by adding necessary components required for optimal performance but in this specific application the SAW filter of Infineon's BGM1033N7 module has been used. Table 3 show different application circuits designed to optimize noise figure, matching and increased rejection of jammer signals. The SAW filter used here has insertion loss of around 1dB and high out-of-band rejection. In special cases an additional notch can be added to suppress a specific jammer. In all the application circuits defined in Table 3, an additional "notch" has been added to suppress LTE band-13 jammer signal since its 2nd harmonic falls into GPS band. The component values for the notch are then fine tuned so as to have optimal noise figure, LTE band-13 rejection, gain and input matching.

The Internal circuit diagram of the BGA925L6 is presented in Figure 2. Table 1 shows the pin assignment of BGA925L6. Table 2 shows the truth table to turn on/off BGA925L6 by applying different voltage to the PON pin.

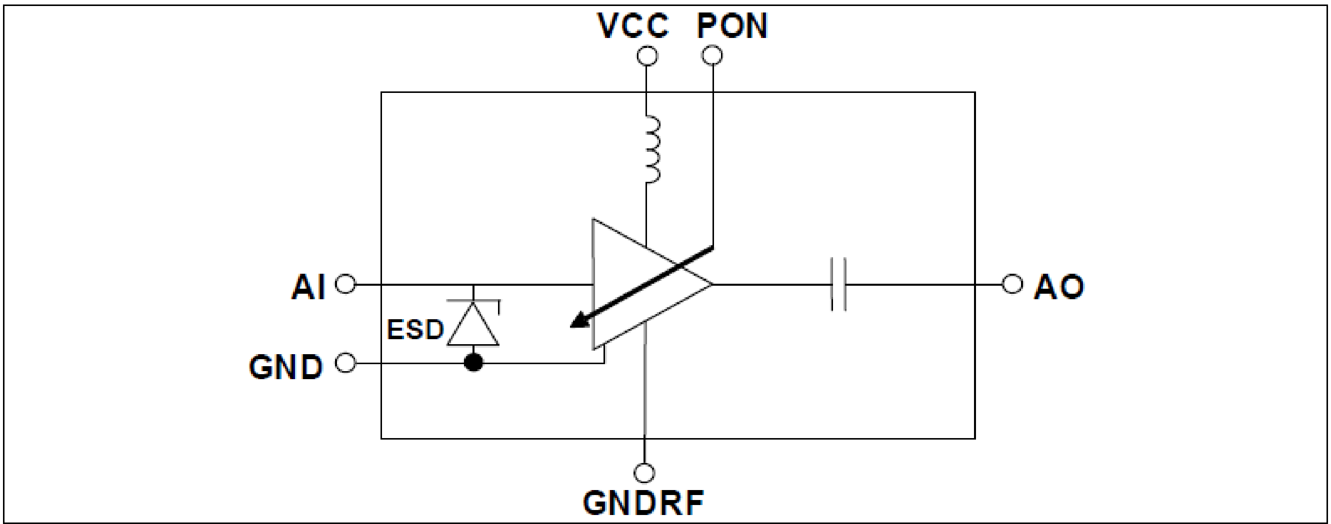


Figure 2 Block diagram of the BGA925L6 for GNSS band 1559-1615MHz applications

Table 1 Pin Definition

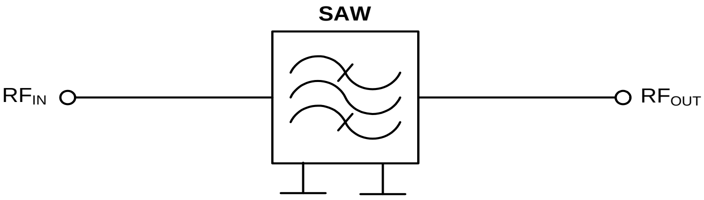
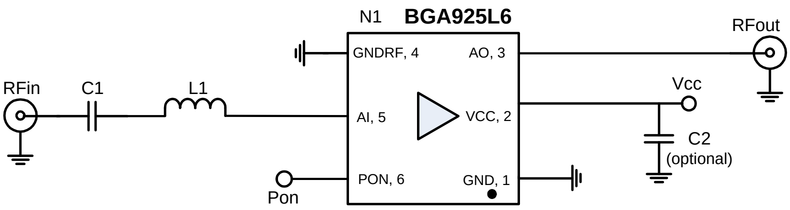
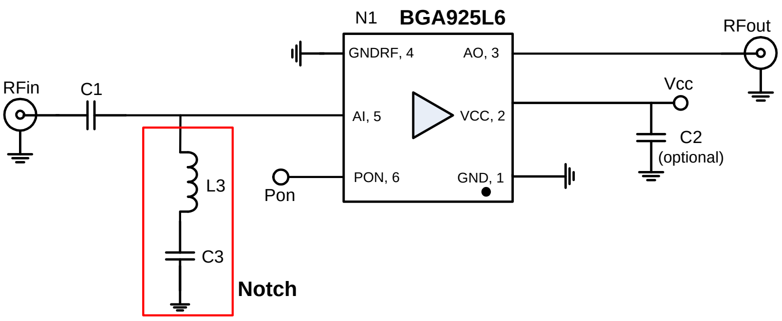
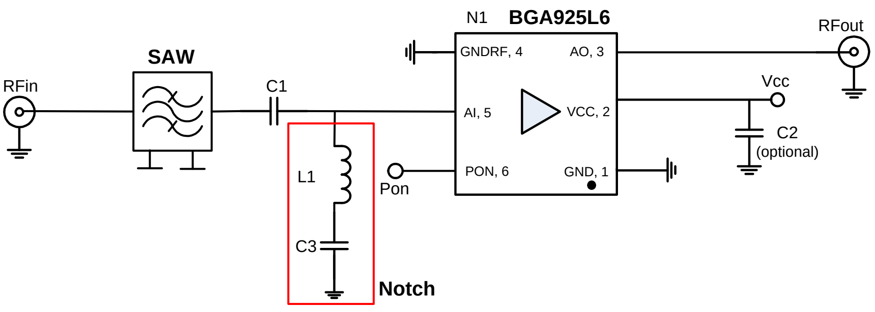
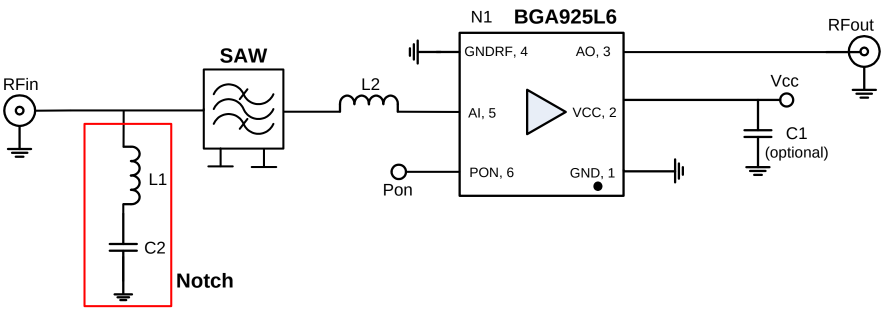
Pin	Symbol	Comment
1	GND	General ground
2	VCC	DC supply
3	AO	LNA output
4	GNDRF	LNA RF ground
5	AI	LNA input
6	PON	Power on control

Table 2 Switching Mode

Mode	Symbol	ON/OFF Control Voltage	
		Min	Max
On	PON, on	1.0V	VCC
Off	PON, off	0	0.4

3 Application Circuits

Table 3 Schematic diagram of various application circuits based around BGA925L6

Application Circuit	Remarks
	**SAW** filter from BGM1033 is used in all the measurements where it is specified. IL @ 1575 MHz = 0.94 dB IL @ 787 MHz = 20 dB
	**AN265** is the standard application circuit for BGA925L6. C1 = 1 nF (0201) C2 = 10 nF (0201) L1 = 5.6 nH (LQP series - 0201) N1 = BGA925L6 (LNA)
	**TR1067** is the application which deals with the improvement of band-13 2nd harmonic. C1 = 2.7 pF (0201) C2 = 10 nF (0201) C3 = 6.8 pF (0201) L3 = 5.6 nH (LQG series – 0402) N1 = BGA925L6 (LNA)
	**SAW Notch LNA** is the application which is designed to improve LTE band-13 2nd harmonic and also suppress other out-of-band jammers using pre-SAW filter. C1 = 2.7 pF (0201) C2 = 10 nF (0201) C3 = 6.8 pF (0201) L1 = 5.6 nH (LQG series – 0402) N1 = BGA925L6 (LNA)
	**Notch SAW LNA** application circuit is designed to improve the immunity against LTE band-13 jammers and also other out-of-band signals by using a pre-SAW filter. C1 = 10 nF (0201) C2 = 4.7 pF (0201) L1 = 8.2 nH (LQG series – 0402) L2 = 6.8 nH (LQG series – 0402) N1 = BGA925L6 (LNA)

4 Typical Measurement Results

Table 4 to Table 7 show typical measurement result of the application circuits shown in Table 3. The values given in this table include losses of the board and the SMA connectors if not otherwise stated.

Table 4 Electrical Characteristics (at room temperature), Vcc = Vpon = 1.8 V

Parameter	Symbol	Value				Unit
DC Voltage	Vcc	1.8				V
Frequency Range	Freq	1575				MHz
Application Circuit		**AN265**	**TR1067**	**SAW Notch LNA**	**Notch SAW LNA**	
DC Current	Icc	4.8	4.8	4.8	4.8	mA
Gain	G	15.6	15.2	14.7	15.0	dB
Noise Figure	NF	0.73	0.95	1.69	1.83	dB
Input Return Loss	RLin	12.6	9.5	13.9	17.9	dB
Output Return Loss	RLout	23.4	15.6	15.7	21.8	dB
Reverse Isolation	IRev	21.8	22.4	23.4	22.6	dB
Input P1dB f_{gps} = 1575 MHz	IP1dB	-8.1	-9.5	-9.5	-7.1	dBm
Output P1dB	OP1dB	6.5	4.6	4.2	6.9	dBm
Stability	k	>1			--	--

Table 5 Electrical Characteristics (at room temperature), Vcc = Vpon = 2.8 V

Parameter	Symbol	Value				Unit
DC Voltage	Vcc	2.8				V
Frequency Range	Freq	1575				MHz
Application Circuit		**AN265**	**TR1067**	**SAW Notch LNA**	**Notch SAW LNA**	
DC Current	Icc	5.0	5.0	5.0	5.0	mA
Gain	G	15.6	15.3	14.8	15.0	dB
Noise Figure	NF	0.73	0.96	1.7	1.84	dB
Input Return Loss	RLin	12.6	9.5	13.5	16.4	dB
Output Return Loss	RLout	23.4	14.3	14.2	19.4	dB
Reverse Isolation	IRev	21.8	22.9	23.1	24.0	dB
Input P1dB f_{gps} = 1575 MHz	IP1dB	-7.1	-9.5	-9.3	-6.2	dBm
Output P1dB	OP1dB	6.5	4.7	4.5	7.8	dBm
Stability	k	>1			--	--

Table 6 IMD comparison of different Application Circuits at Vcc=1.8V

	AN265[a]	TR1067 [a]	SAW[b]	SAW Notch LNA[b]	Notch SAW LNA[b]	Test Conditions
LTE Band-13 2nd Harmonic Level [dBm]	-31.4	-104.3	-84.6	-68.5	-93.9	**a**: f_{IN} = 787.76 MHz, P_{IN} = -25 dBm **b**: f_{IN} = 787.76 MHz, P_{IN} = +15 dBm
In-band Output IP3 [dBm]	16.8	10.0		10.8	12.5	**a/b**: f_1 = 1575.5 MHz, P_1 = -30 dBm; f_2 = 1576.5 MHz, P_2 = -30 dBm
Out-of-band Output IM3 @ 1575.4 MHz [dBm]	-120.7	-120.8	-95.5	-83.0	-79.1	**a**: f_1 = 1712.7 MHz, P_1 = -41 dBm; f_2 = 1850 MHz, P_2 = -41.5 dBm **b**: f_1 = 1712.7 MHz, P_1 = +10 dBm; f_2 = 1850 MHz, P_2 = +10 dBm
Out-of-band Output IM2 @ 1575.4 MHz [dBm]	-17.4	-83.5	-69.2	-53.3	-78.3	**a**: f_1 = 787.4 MHz, P_1 = -20 dBm; f_2 = 788 MHz, P_2 = -20 dBm **b**: f_1 = 787.4 MHz, P_1 = +20 dBm; f_2 = 788 MHz, P_2 = +20 dBm
Out-of-band Output IM2 @ 1575.4 MHz [dBm]	-41.2	-66.8	-40.1	-24.5	-23.2	**a**: f_1 = 824.6 MHz, P_1 = -17 dBm; f_2 = 2400 MHz, P_2 = -40 dBm **b**: f_1 = 824.6 MHz, P_1 = +23 dBm; f_2 = 2400 MHz, P_2 = 0 dBm

Table 7 IMD comparison of different Application Circuits at Vcc=2.8V

	AN265[a]	TR1067 [a]	SAW[b]	SAW Notch LNA[b]	Notch SAW LNA[b]	Test Conditions
LTE Band-13 2nd Harmonic Level [dBm]	-31.7	-104.7	-84.6	-68.5	-93.8	**a**: f_{IN} = 787.76 MHz, P_{IN} = -25 dBm **b**: f_{IN} = 787.76 MHz, P_{IN} = +15 dBm
In-band Output IP3 [dBm]	17.5	10.1		10.9	12.5	**a/b**: f_1 = 1575.5 MHz, P_1 = -30 dBm; f_2 = 1576.5 MHz, P_2 = -30 dBm
Out-of-band Output IM3 @ 1575.4 MHz [dBm]	-119.7	-119.8	-95.5	-83.2	-79.0	**a**: f_1 = 1712.7 MHz, P_1 = -41 dBm; f_2 = 1850 MHz, P_2 = -41.5 dBm **b**: f_1 = 1712.7 MHz, P_1 = +10 dBm; f_2 = 1850 MHz, P_2 = +10 dBm
Out-of-band Output IM2 @ 1575.4 MHz [dBm]	-17.5	-83.7	-69.2	-53.3	-78.7	**a**: f_1 = 787.4 MHz, P_1 = -20 dBm; f_2 = 788 MHz, P_2 = -20 dBm **b**: f_1 = 787.4 MHz, P_1 = +20 dBm; f_2 = 788 MHz, P_2 = +20 dBm
Out-of-band Output IM2 @ 1575.4 MHz [dBm]	-41.2	-66.9	-40.1	-24.5	-23.1	**a**: f_1 = 824.6 MHz, P_1 = -17 dBm; f_2 = 2400 MHz, P_2 = -40 dBm **b**: f_1 = 824.6 MHz, P_1 = +23 dBm; f_2 = 2400 MHz, P_2 = 0 dBm

5 Measured Graphs for different application circuits of BGA925L6

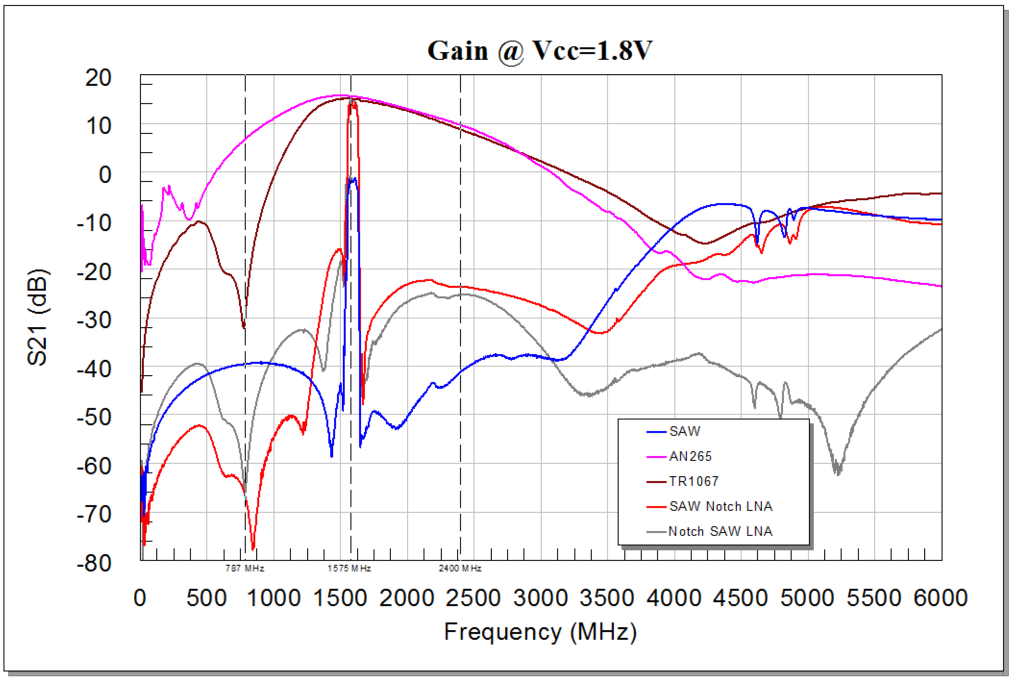


Figure 3 Wideband power gain of different application circuits at supply voltage of 1.8V

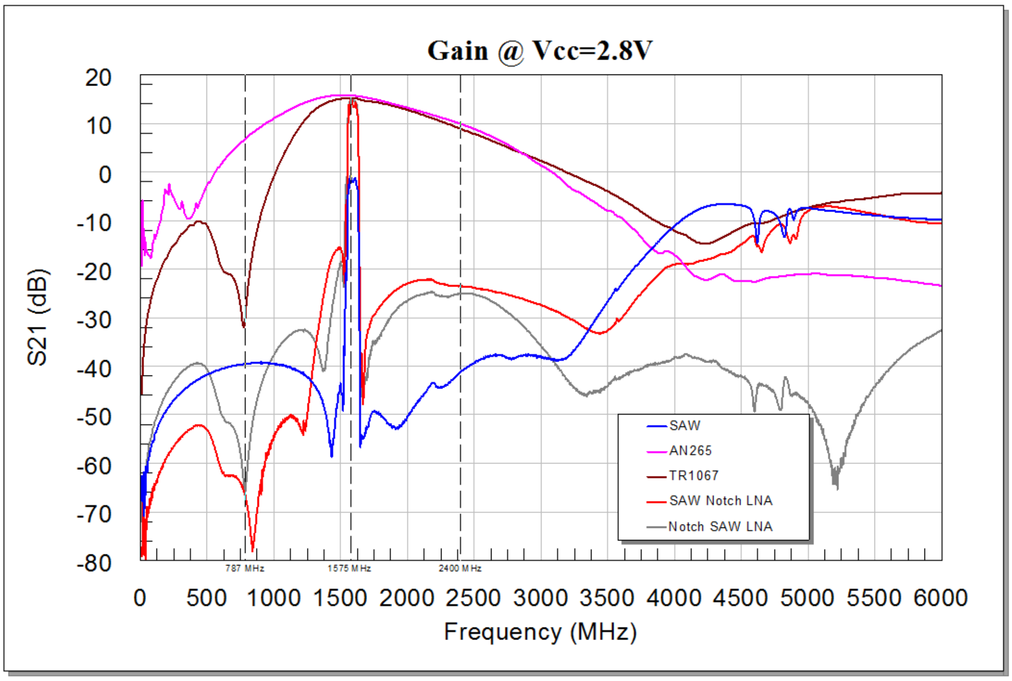


Figure 4 Wideband power gain of different application circuits at supply voltage of 2.8V

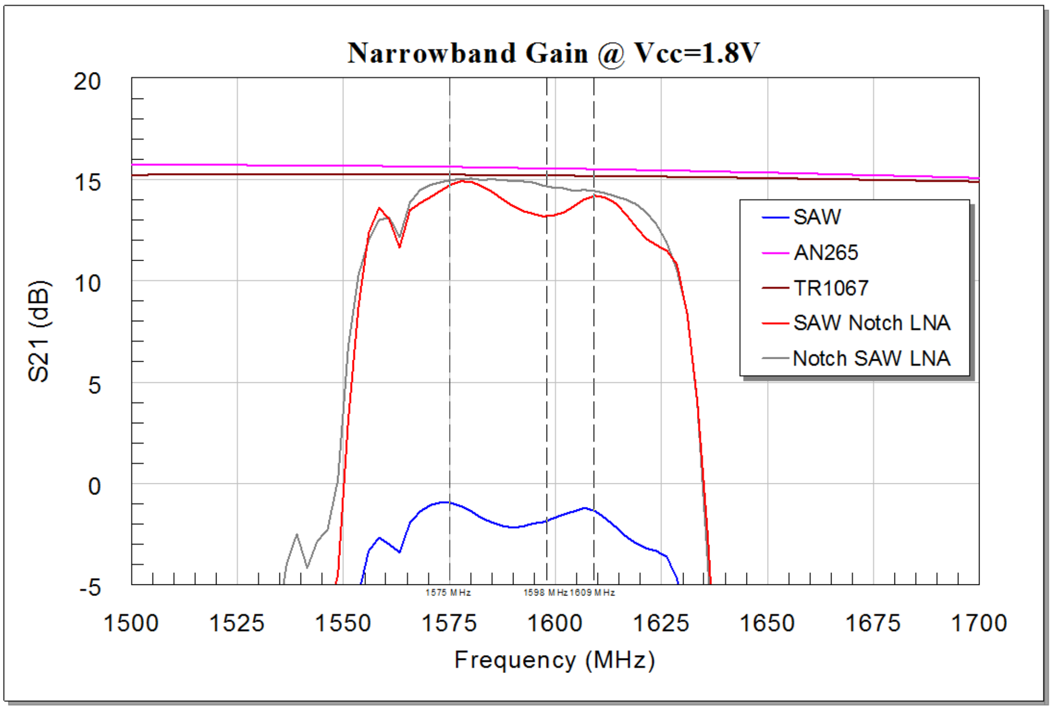


Figure 5 Narrowband power gain of different application circuits at supply voltage of 1.8V

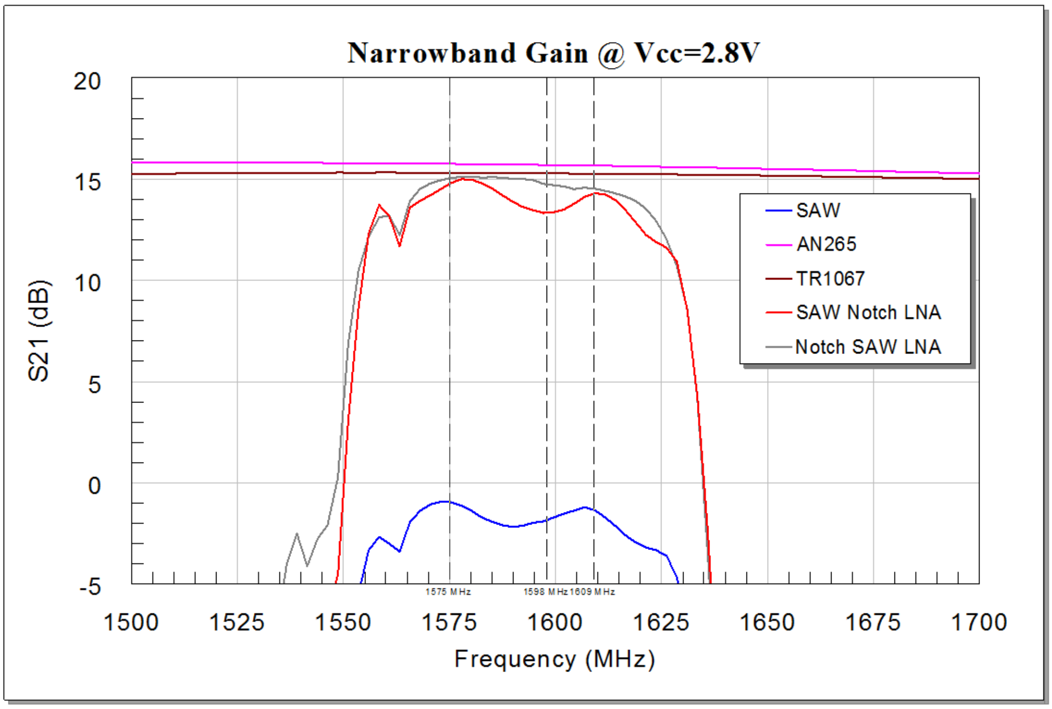


Figure 6 Narrowband power gain of different application circuits at supply voltage of 2.8V

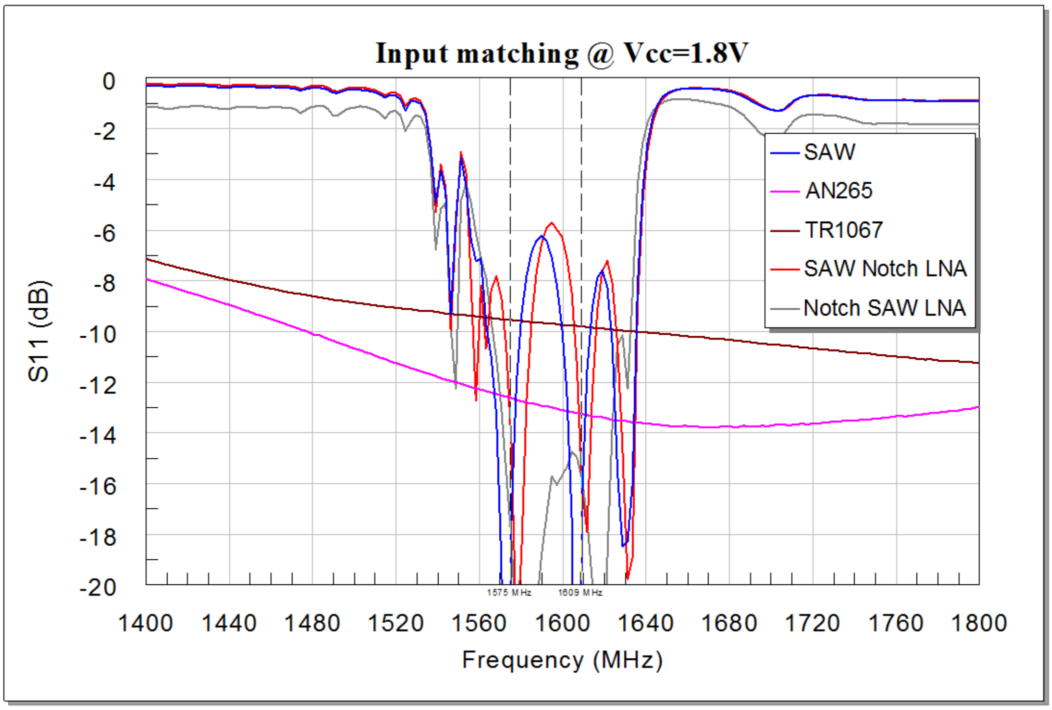


Figure 7 Input matching of different application circuits at supply voltage of 1.8V

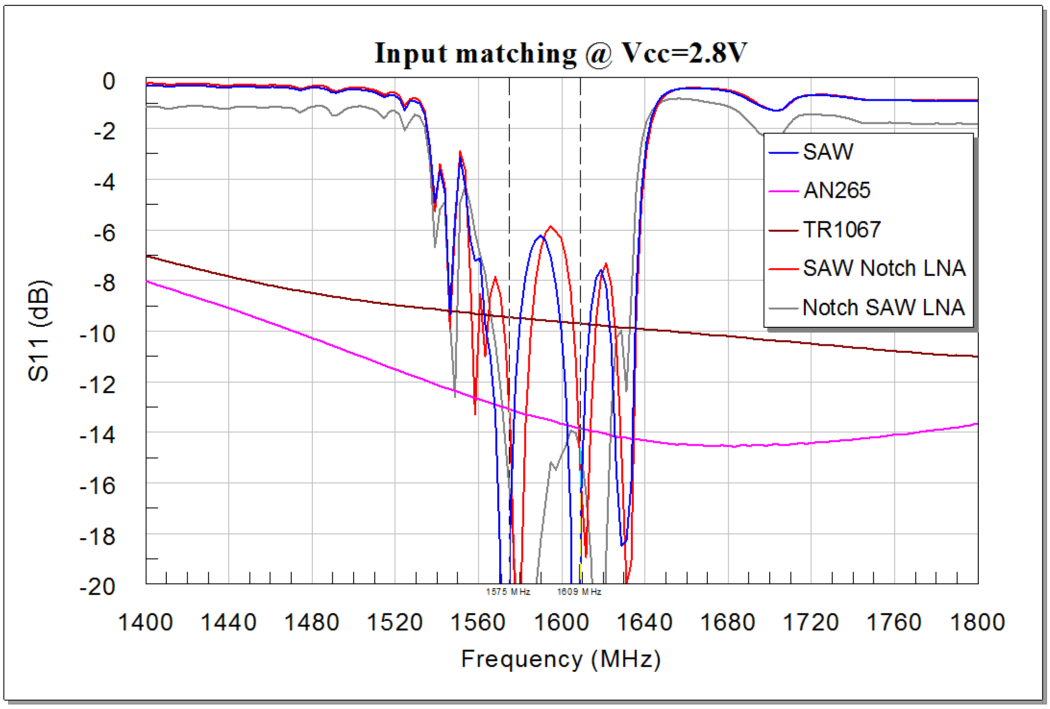


Figure 8 Input matching of different application circuits at supply voltage of 2.8V

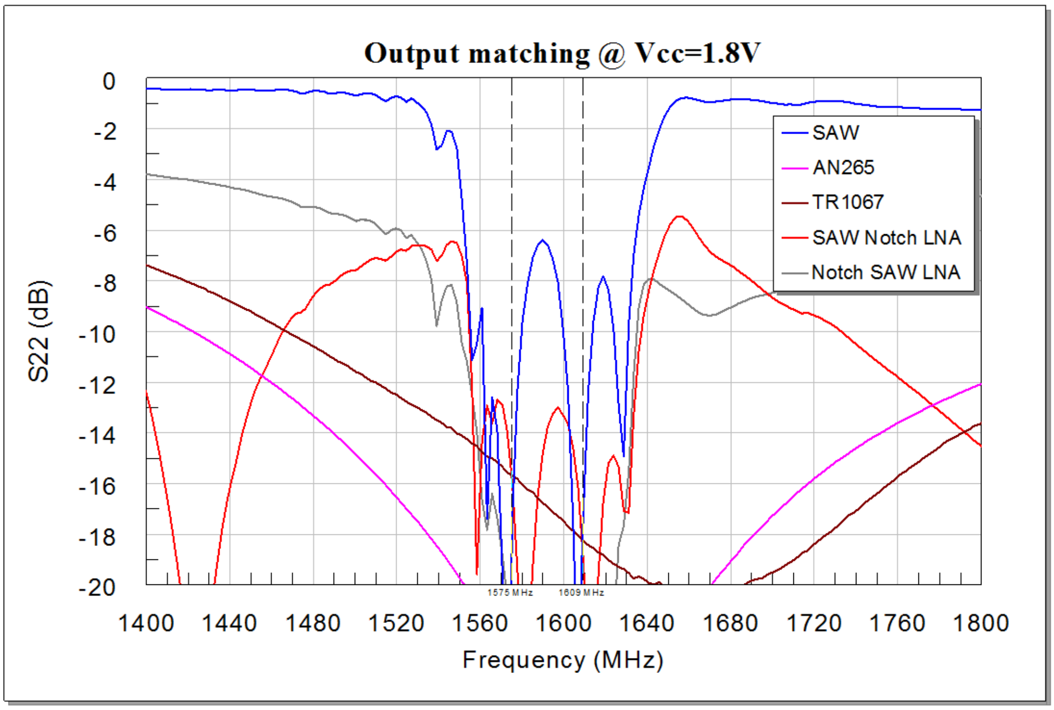


Figure 9 Output matching of different application circuits at supply voltage of 1.8V

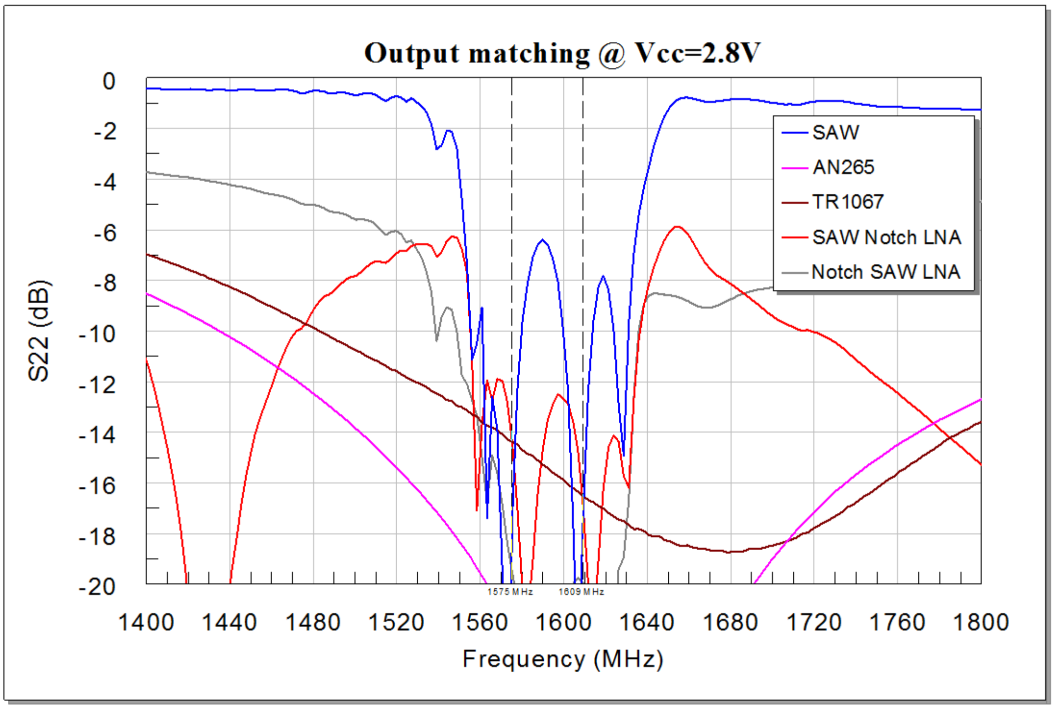


Figure 10 Output matching of different application circuits at supply voltage of 2.8V

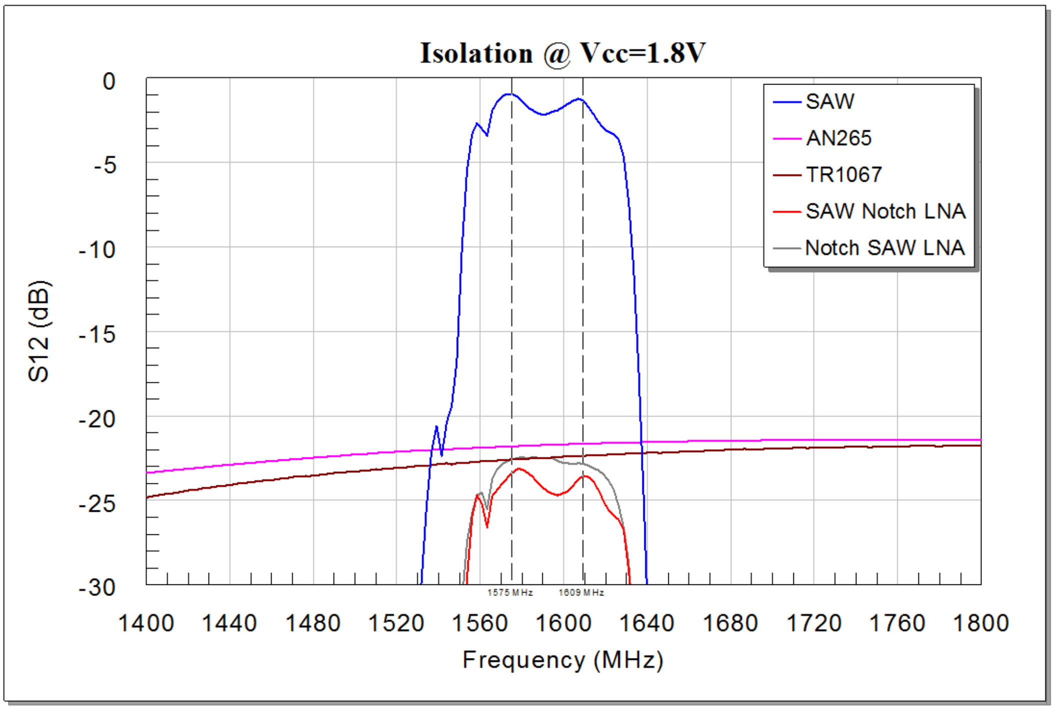


Figure 11 Reverse isolation of different application circuits at supply voltage of 1.8V

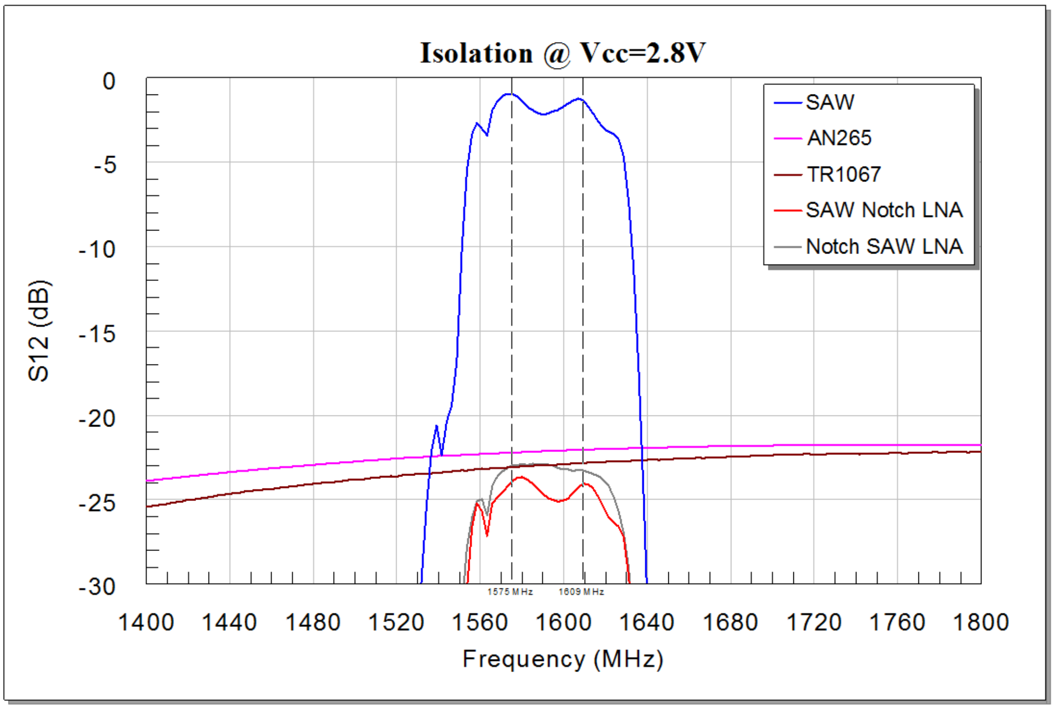


Figure 12 Reverse isolation of different application circuits at supply voltage of 2.8V

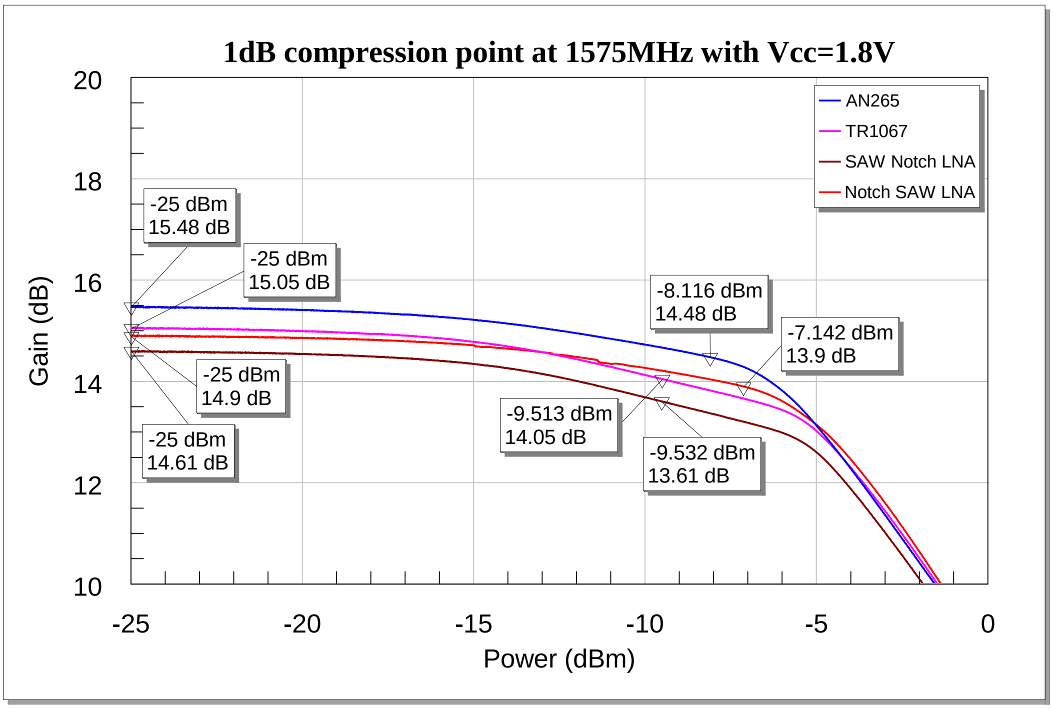


Figure 13 Input 1dB compression point of different application circuits at supply voltage of 1.8V

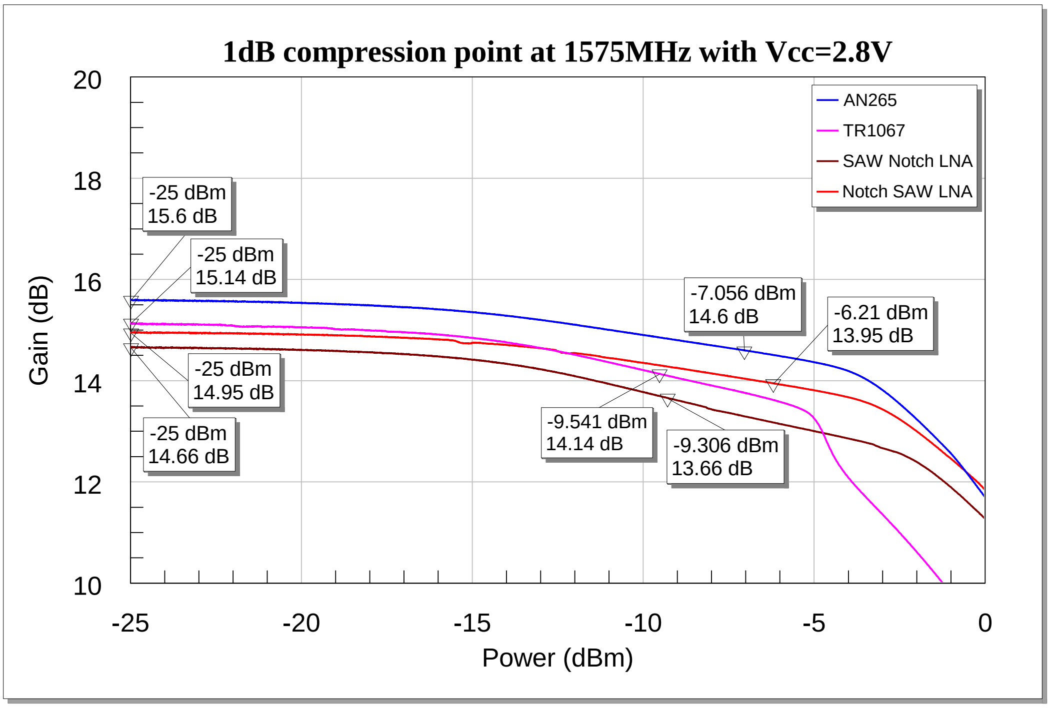


Figure 14 Input 1dB compression point of different application circuits at supply voltage of 2.8V

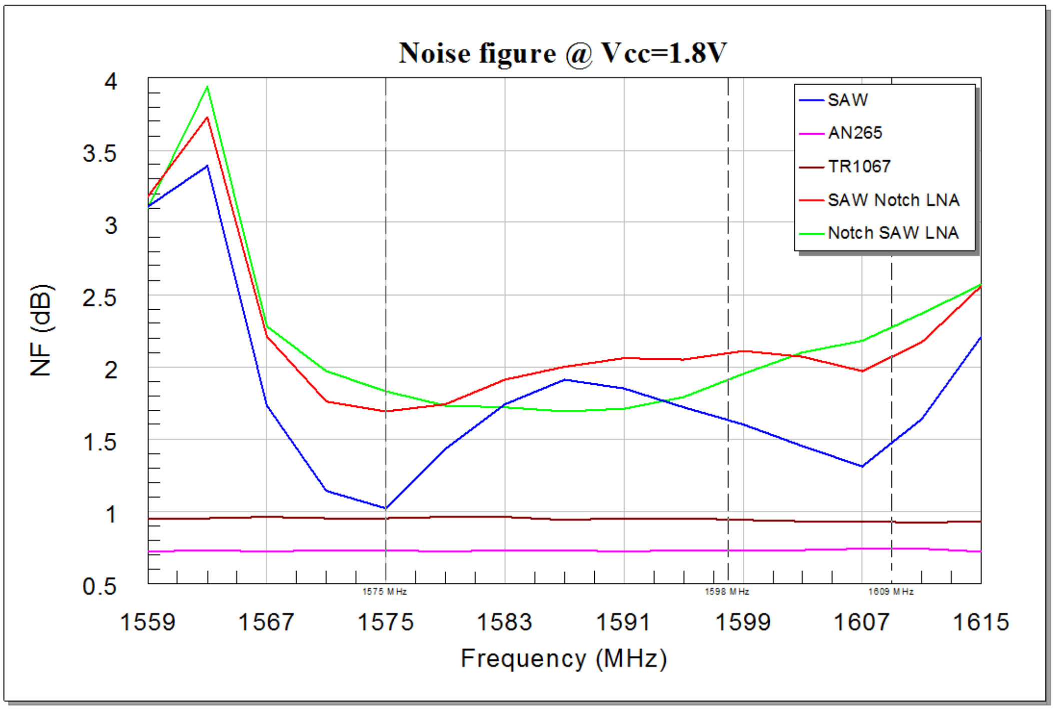


Figure 15 Noise figure of different application circuits at supply voltage of 1.8V

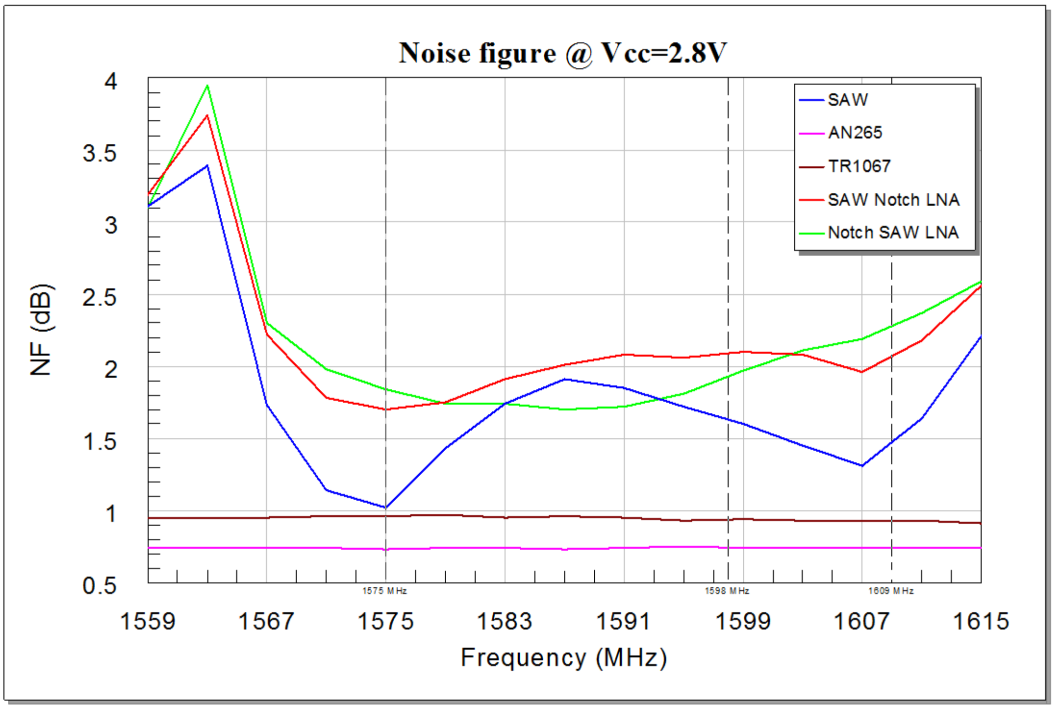


Figure 16 Noise figure of different application circuits at supply voltage of 2.8V

6 Miscellaneous Measured Graphs

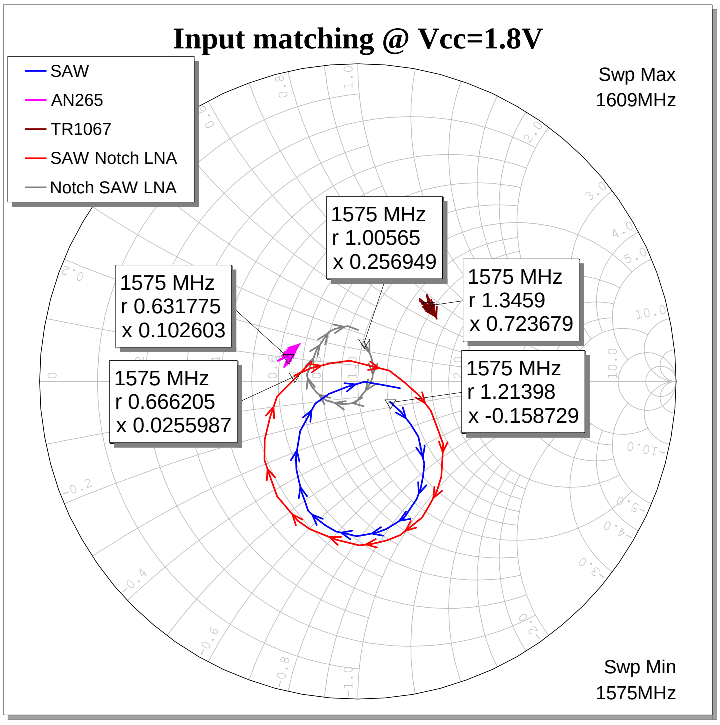


Figure 17 Input matching of different application circuits at supply voltage of 1.8V

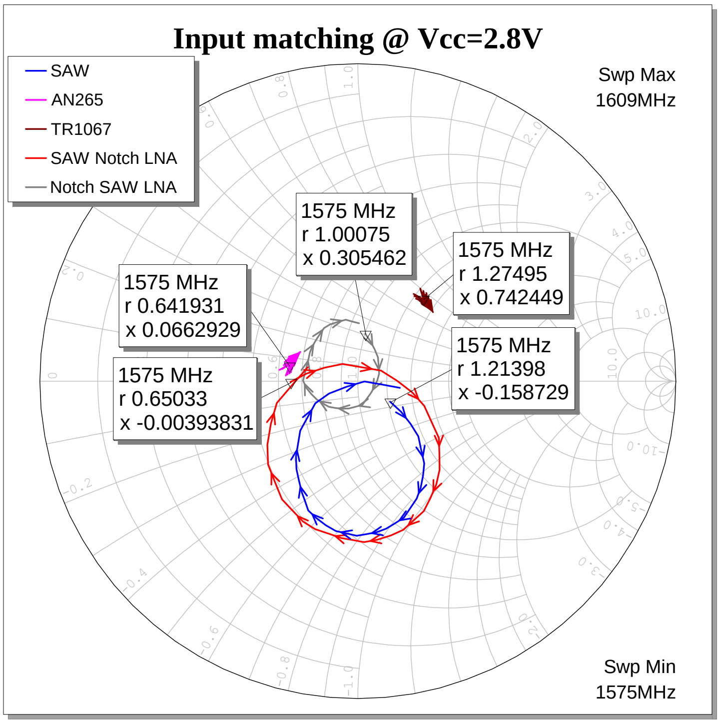


Figure 18 Input matching of different application circuits at supply voltage of 2.8V

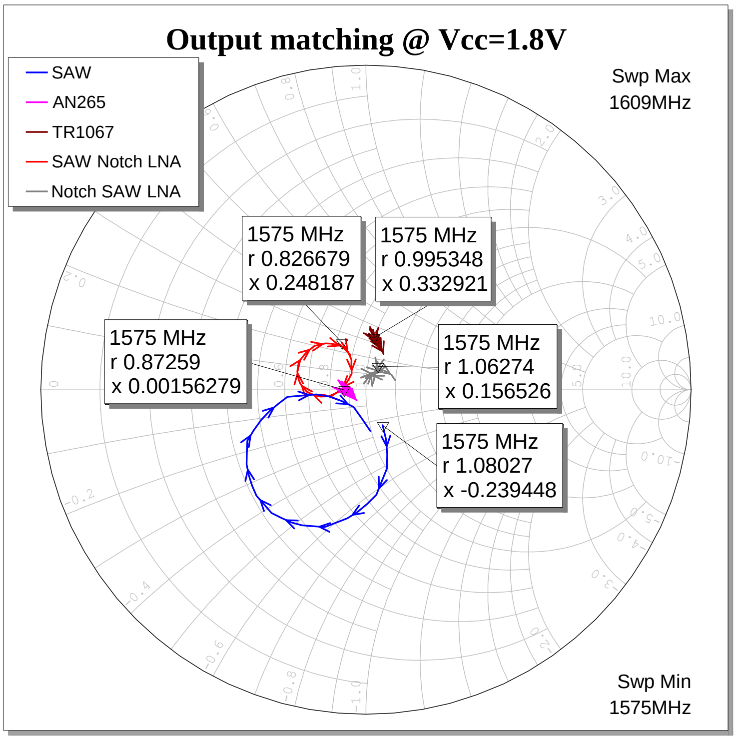


Figure 19 Output matching of different application circuits at supply voltage of 1.8V

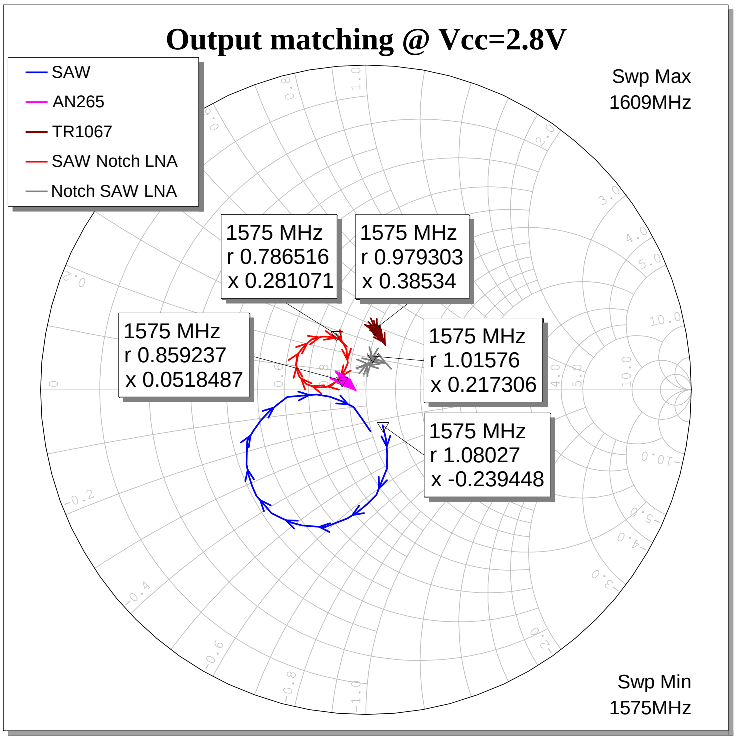
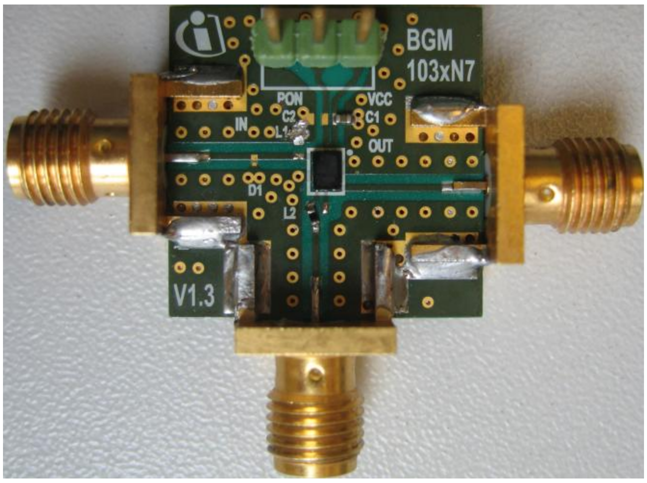
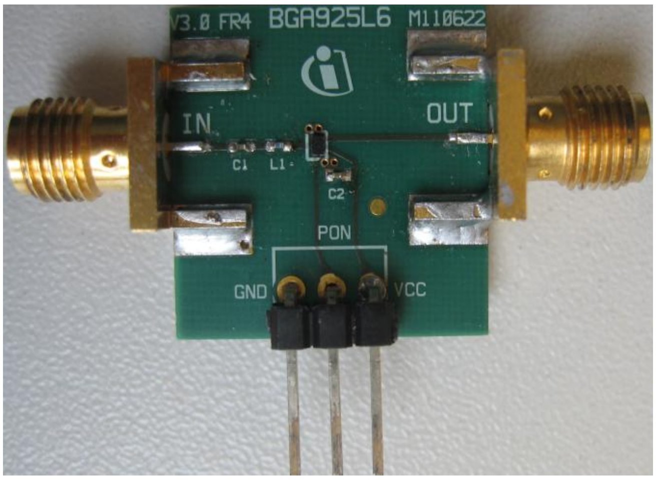
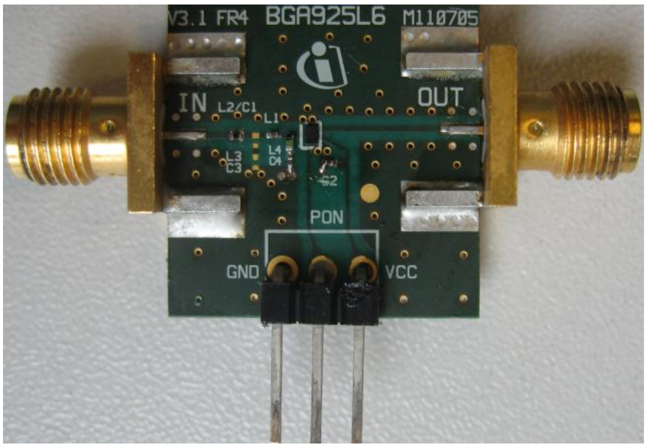
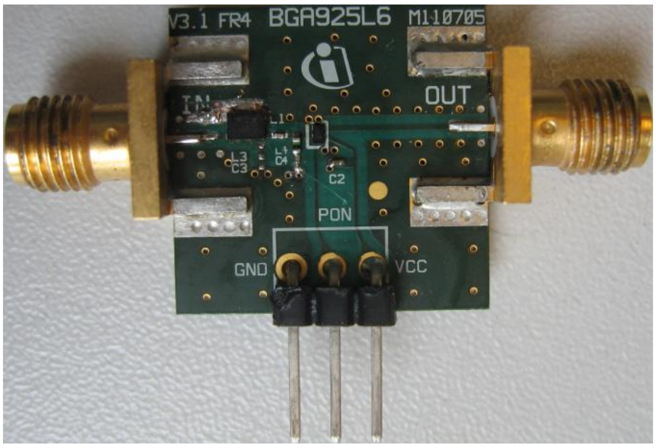
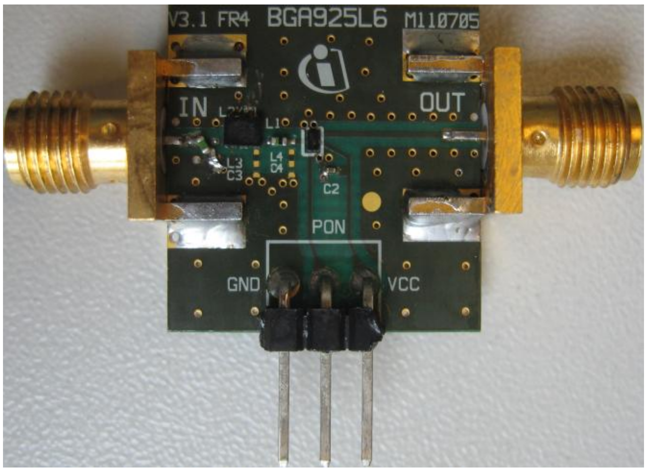
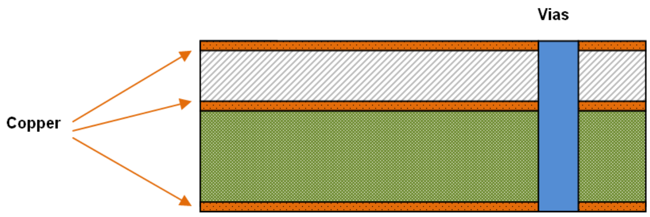


Figure 20 Output matching of different application circuits at supply voltage of 2.8V

7 Evaluation Boards

Table 8 PCBs for different application circuits under consideration

 **SAW** filter (From BGM1033 Module), Rogers	 **AN265** - Standard Application board BGA925L6, FR4
 **TR1067** – BGA925L6 with 787 MHz notch, FR4	 **SAW Notch LNA** – BGA925L6 with SAW filter and Notch, FR4
 **Notch SAW LNA** – BGA925L6 with Notch and SAW filter, FR4	 PCB layer stack

8 Authors

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Dr. Chih-I Lin, Senior Staff Engineer of Business Unit “RF and Protection Devices”.

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