AN11912

BGU8103 [GPS1301M] GNSS L2-band LNA evaluation board

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Document information

Info	Content
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Abstract	This document explains the BGU8103 [GPS1301M] GNSS L2-band LNA evaluation board
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Contact information	For more information, please visit: http://www.nxp.com

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1. Introduction

NXP Semiconductors BGU8103, called GPS1301M according new naming convention, Global Navigation Satellite System (GNSS) LNA L2-band Evaluation Board is designed to evaluate the performance of the GNSS LNA using:

- NXP Semiconductors GPS1301M GNSS Low Noise Amplifier
- A matching inductor
- A decoupling capacitor

NXP Semiconductors GPS1301M is a low-noise amplifier for wearable GNSS receiver applications in a plastic, leadless 6 pin, extremely thin small outline SOT1232 at 1.1 x 0.7 x 0.37mm, 0.4mm pitch. The GPS1301M features gain of 17.5 dB and a noise figure of 0.80 dB at the L1-band (~1575MHz) with an extremely low current consumption of 1.2 mA. Its sufficient linearity performance removes interference and noise from co-habitation cellular transmitters, while retaining sensitivity. The LNA components occupy a total area of approximately 2.5 mm^2.

In this document, the application diagram, board layout, bill of materials, and typical results are given for the GPS1301M EVB tuned for the GNSS L2-band, as well as some explanations on GNSS related performance parameters like out-of-band input third-order intercept point O_IIP3, gain compression under jamming and noise under jamming.

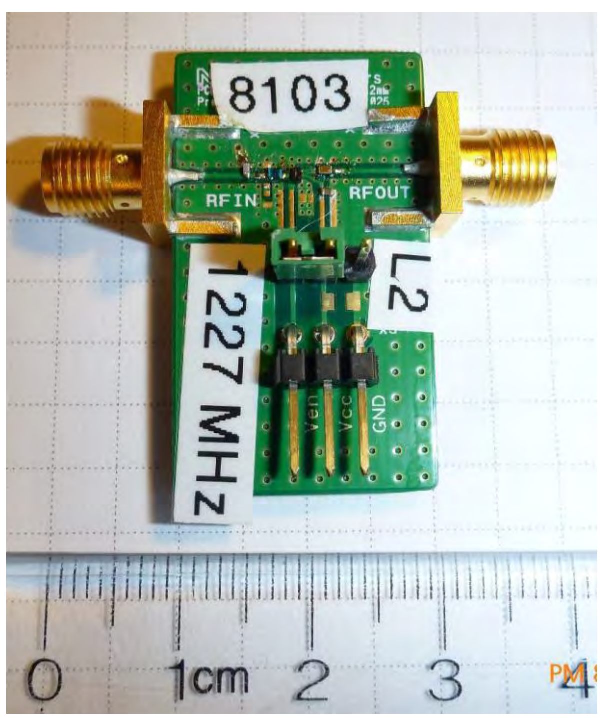


Fig 1. GPS1301M GNSS LNA evaluation board tuned for the GNSS L2-band

2. General description

Modern wearable applications like smartwatches suffer less from strong radio signals in the direct neighborhood, so problems like co-habitation are not likely to occur and linearity performance of a GNSS receiver may be reduced. To maximize battery life, the power consumption of a GNSS receiver implemented in a wearable application should be as low as possible.

Since the GNSS receiver needs to receive signals with an average power level of -130 dBm, sensitivity is very important. Currently there are several GNSS chipsets on the market that can be implemented in wearable applications. Although many of these GNSS ICs do have integrated LNA front ends, the noise performance, and as a result the system sensitivity, is not always adequate. The GNSS receiver sensitivity is a measure how accurate the coordinates are calculated. The GNSS signal reception can be improved by a GNSS LNA, which improves the sensitivity by amplifying the wanted GNSS signal with a low-noise amplifier.

3. GPS1301M GNSS LNA L2-band evaluation board

The GPS1301M L2-band LNA evaluation board simplifies the RF evaluation of the GPS1301M GNSS LNA applied in a GNSS front-end, often used in mobile cell phones. The evaluation board enables testing of the device RF performance and requires no additional support circuitry. The board is fully assembled with the GPS1301M including the matching components required to tune the GPS1301M for the L2-band (~1230MHz) and decoupling capacitor.

The matching of this board is optimized for the L2-band (~1230MHz). This board can also be used to check the performance at the L5-band (~1180MHz).

The board is supplied with two SMA connectors for input and output connection to RF test equipment. The GPS1301M can operate from a 1.5 V to 3.1 V single supply and consumes typical 1.2 mA.

3.1 Application Circuit

The circuit diagram of the evaluation board is shown in Fig 2. With jumper JU1 the enable input can be connected either to Vcc or GND.

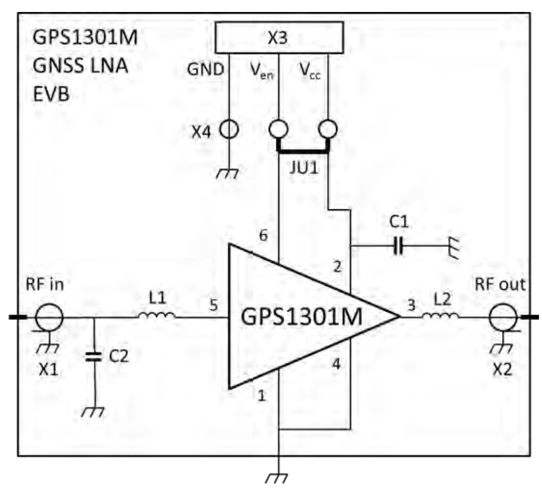


Fig 2. Circuit diagram of the GPS1301M LNA evaluation board tuned for the GNSS L2-band

3.2 PCB Layout

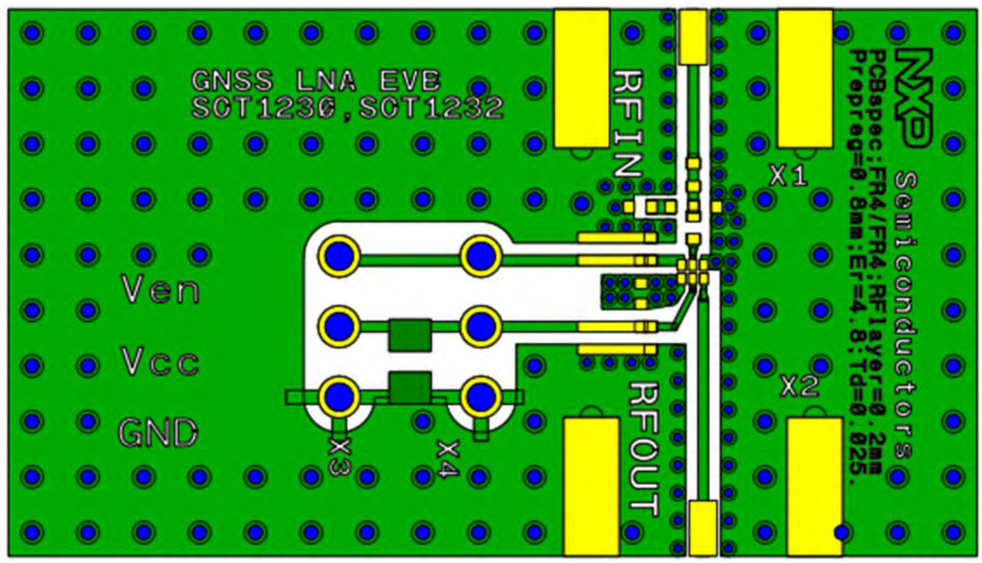
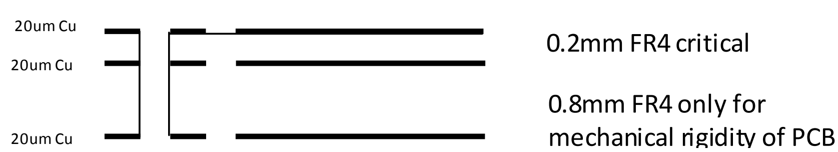


Fig 3. Printed-Circuit Board layout of the GPS1301M LNA evaluation board

A good PCB layout is an essential part of an RF circuit design. The LNA evaluation board of the GPS1301M can serve as a guideline for laying out a board using the GPS1301M. Use controlled impedance lines for all high frequency inputs and outputs. Bypass Vcc with decoupling capacitors, preferably located as close as possible to the device. For long bias lines it may be necessary to add decoupling capacitors along the line further away from the device. Proper grounding of the GND pins is also essential for good RF performance. Either connect the GND pins directly to the ground plane or through vias, or do both, which is recommended. The material that has been used for the evaluation board is FR4 using the stack shown in Fig 4.



(1) Material supplier is ISOLA DURAVER; εr = 4.6-4.9: $T\delta = 0.02$

Fig 4. Stack of the PCB material

3.3 Bill of materials

Table 1. BOM of the GPS1301M GNSS LNA evaluation board tuned for the GNSS L2-band

Designator	Description	Footprint	Value	Supplier Name/type	Comment
	GPS1301M	1.1 x 0.7 x 0.37mm^3, 0.4mm pitch		NXP	SOT1232
PCB		20 x 35mm		GPS1301M GNSS LNA EV Kit	
C1	Capacitor	0402	1 nF	Murata GRM1555	Decoupling
C2	Capacitor	0402	1.5 pF	Murata GRM1555	Input matching
L1	Inductor	0402	22 nH	Murata LQW15	Input matching
L2	Inductor	0402	12 nH	Murata LQP15	Output matching
X1, X2	SMA RD connector	-	-	Johnson, End launch SMA 142-0701-841	RF input/ RF output
X3	DC header	-	-	Molex, PCB header, Right Angle, 1 row, 3 way 90121-0763	Bias connector
X4	JUMPER Stage	-	-	Molex, PCB header, Vertical, 1 row, 3 way 90120-0763	Connect Ven to Vcc or separate Ven voltage
JU1	JUMPER				

3.4 GPS1301M product description

NXP Semiconductors' GPS1301M GNSS low noise amplifier is designed for the GNSS frequency band. The integrated biasing circuit is temperature stabilized, which keeps the current constant over temperature. It also enables the superior linearity performance of the GPS1301M. The GPS1301M is also equipped with an enable function that allows it to be controlled via a logic signal. In disabled mode it consumes less than1 µA.

The output of the GPS1301M is internally matched for 1575.42 MHz whereas only one series inductor at the input is needed to achieve the best RF performance. Both the input and output are AC coupled via an integrated capacitor.

It requires only two external components to build a GNSS LNA having the following advantages:

- Low noise
- System optimized gain
- High linearity under jamming
- 1.1 x 0.7 x 0.37, 0.4mm pitch: SOT1232
- Low current consumption
- Short power settling time

3.5 Series inductor

The evaluation board is supplied with Murata LQW15 series inductor of 22 nH at the input. This is a wire wound type of inductor with high quality factor (Q) and low series resistance (Rs) (see Table 2). This type of inductor is recommended in order to achieve the best noise performance. High Q inductors from other suppliers can be used. If it is decided to use other low cost inductors with lower Q and higher Rs the noise performance will degrade.

Table 2. Series Inductor options

Type	Murata	Size 0201	Size 0402	Size 0603	Comment
Multilayer Non-Magnetic Core	LQG		15H NF↑↑	18H NF↑	
Film	LQP	03T NF↑↑	15M NF↑		
Wirewound Non-Magnetic Core	LQW		15A **Default**	18A NF↓	Lowest NF

4. Typical LNA evaluation board results

Table 3 gives the measured performance of the GPS1301M LNA EVB.

Table 3. Typical results measured on the evaluation Board
Operating Temperature = 25 °C

Parameter	Symbol	LNA EVB	LNA EVB	LNA EVB	LNA EVB	Unit	Remarks
Supply Voltage	V_{CC}	1.5	1.8	2.8	3.1	V	
Supply Current	I_{CC}	1.1	1.2	1.2	1.2	mA	
Noise Figure	NF @ 1180 MHz	1.2	1.2	1.2	1.2	dB	[1]
	NF @ 1230 MHz	1.3	1.3	1.3	1.3	dB	
Power Gain	G_p @ 1180 MHz	15.5	15.7	16.0	16.0	dB	
	G_p @ 1230 MHz	15.2	15.4	15.7	15.8	dB	
Input Return Loss	RL_{in} @ 1180 MHz	13.0	13.6	13.9	14.0	dB	
	RL_{in} @ 1230 MHz	10.2	11.2	12.7	12.9	dB	
Output Return Loss	RL_{out} @ 1180 MHz	9.2	9.2	9.4	9.3	dB	
	RL_{out} @ 1230 MHz	7.7	7.8	7.8	7.8	dB	
Reverse Isolation	ISO_{rev} @ 1180 MHz	35.6	35.7	35.5	35.5	dB	
	ISO_{rev} @ 1230 MHz	36.4	36.4	36.1	36.1	dB	
Input 1dB Gain Compression	P_i1dB @ 1175 MHz	-18.9	-17.3	-14.2	-13.5	dBm	
	P_i1dB @ 1230 MHz	-18.3	-16.6	-13.6	-13.0	dBm	
Output 1dB Gain Compression	P_o1dB @ 1175 MHz	-4.4	-2.6	0.8	1.5	dBm	
	P_o1dB @ 1230 MHz	-3.8	-2.2	1.1	1.8	dBm	
Input third order intercept point	IIP3 @ 1170 MHz	-16.2	-16.3	-16.2	-16.2	dBm	
	IIP3 @ 1225 MHz	-15.9	-16.1	-15.9	-15.9	dBm	
Output third order intercept point	OIP3 @ 1170 MHz	-0.7	-0.6	-0.2	-0.2	dBm	
	OIP3 @ 1225 MHz	-0.7	-0.7	-0.2	-0.1	dBm	
Power settling time	T_{on}	<2	< 2	< 2	< 2	µs	
	T_{off}	<1	< 1	< 1	< 1	µs	

[1] The noise figure and gain figures are measured at the SMA connectors of the evaluation board. The losses of the connectors and the PCB of approximately 0.05 dB are not subtracted. Measured at T_{anb} = 25 °C.

At the average power levels of –130 dBm that have to be received by a GNSS receiver, the system will not have in-band intermodulation problems caused by the GNSS-signal itself. Strong out-of-band cell phone TX jammers however can cause linearity problems, and result in third-order intermodulation products in the GNSS frequency band. In the next paragraphs the effects of these Jammer-signals on the Noise and Gain performance of the GPS1301M are described. The effect of these Jammers on the In-band and Out-of-Band Third-Order Intercept points are described in more detail in a separate User Manual: UM10453: 2-Tone Test BGU7005 and BGU7007 GNSS LNA.

4.1 In-band 1dB gain compression due to jammers

As stated before, signal levels in the GNSS frequency band of -130dBm average will not cause linearity problems in the GNSS band itself. This of course is also valid for the 1dB gain compression in-band. The 1dB compression point at 1225 MHz caused by cell phone TX jammers however is important.

Measurements have been carried out using the setup shown in Fig 5.

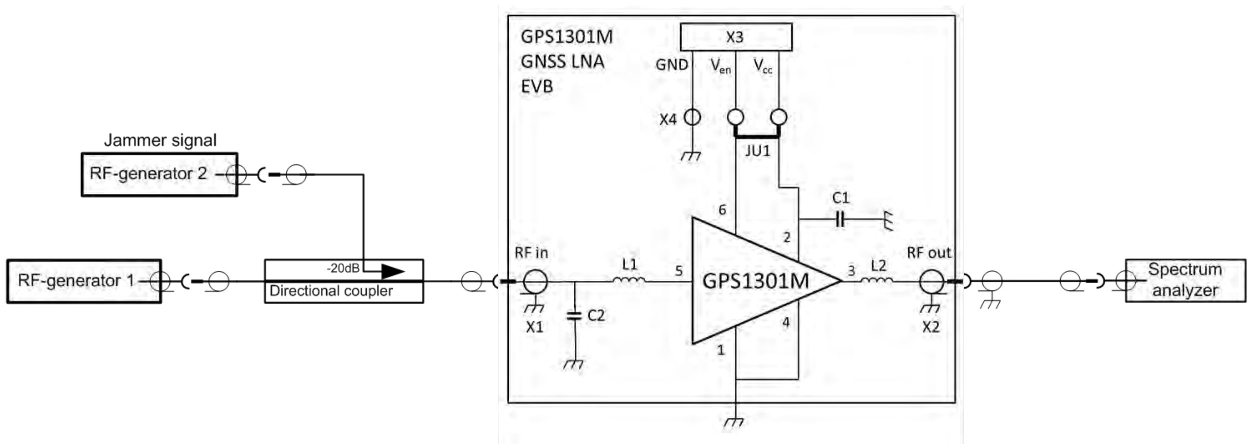
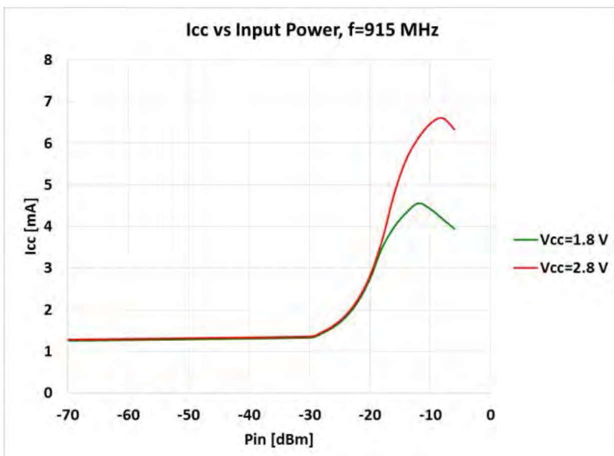


Fig 5. 1dB Gain compression under jamming measurement setup (LNA evaluation board)

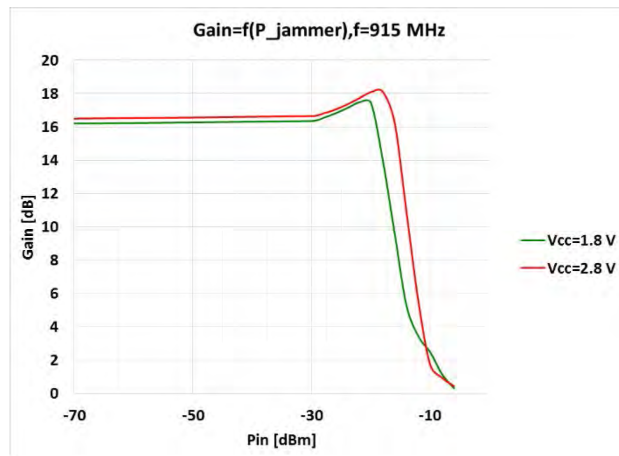
The gain of the DUT was measured between port RFin and RFout of the EVB at the GNSS frequency 1225 MHz, while simultaneously a jammer power signal was swept at the 20dB attenuated input port of the Directional Coupler. Please note that the drive power of the jammer is 20 dB lower at the input of the DUT caused by the directional coupler.

The figures below show the supply-current (Icc) and gain compression curves with 915, 1463, 1695, 1850 and 2350 MHz jammers (input jammer power at LNA-board, taking into account the approx. 20 dB attenuation of the directional coupler and RF-cable from Jammer-Generator to the directional coupler).
The gain drops 1dB with approximately -18 dBm input jamming power at 915 MHz and at -15 dBm @1463 MHz (Vcc=1.8V) (Fig 7 and Fig 9). With an 1850MHz jamming signal, the 1dB gain compression occurs around -11 dBm input power level (Fig 11).



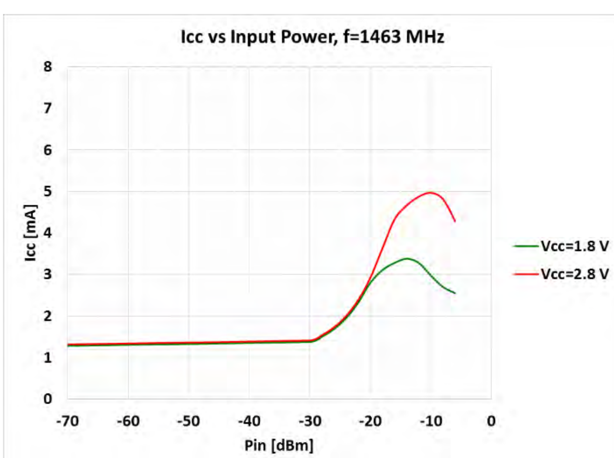
Pin 1225 MHz = -45 dBm

Fig 6. Icc versus jammer power at 915 MHz



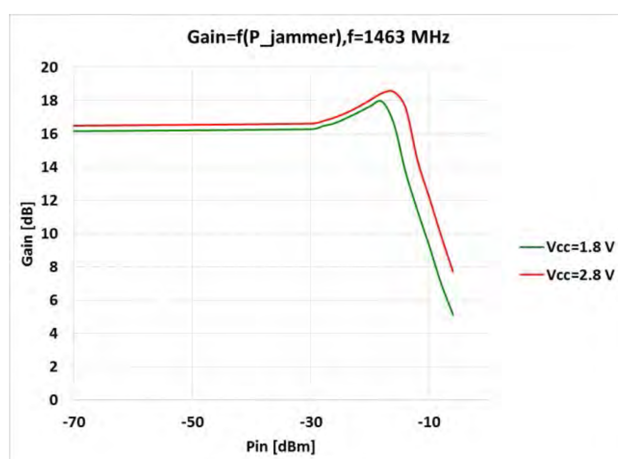
Pin 1225 MHz = -45 dBm

Fig 7. Gain versus jammer power at 915 MHz



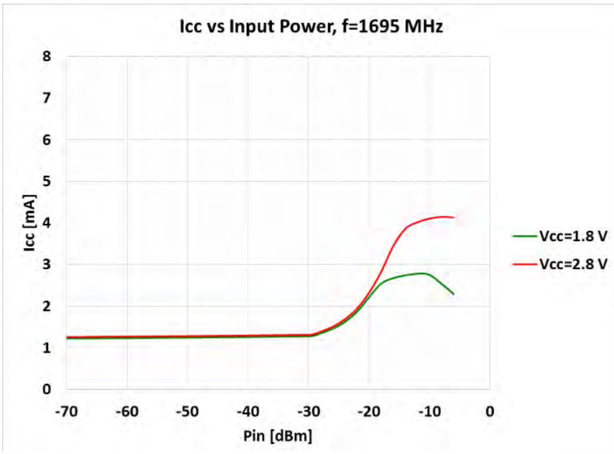
Pin 1225 MHz = -45 dBm

Fig 8. Icc versus jammer power at 1463 MHz



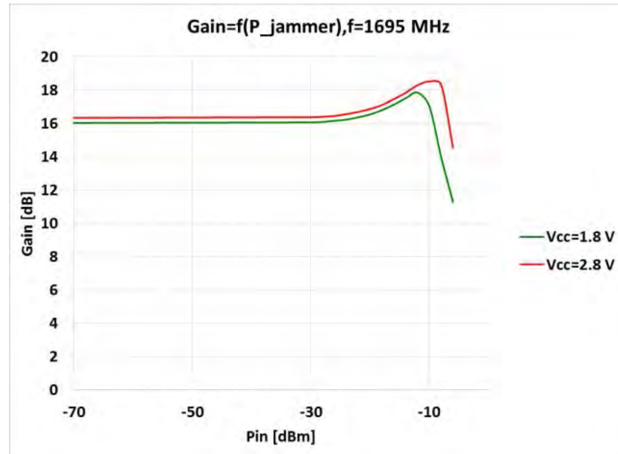
Pin 1225 MHz = -45 dBm

Fig 9. Gain versus jammer power at 1463 MHz



Pin 1225 MHz = -45 dBm

Fig 10. Icc versus jammer power at 1695 MHz

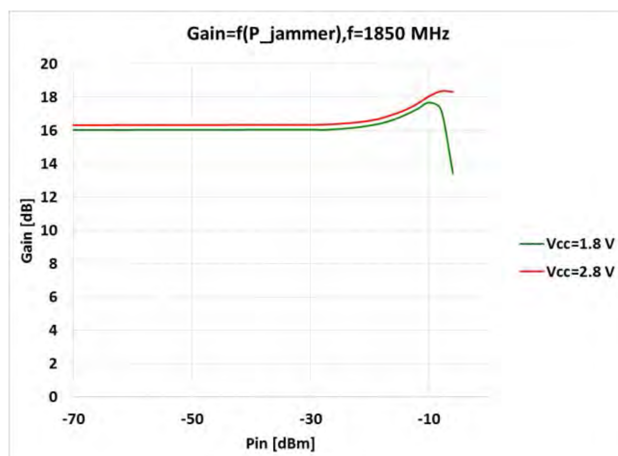


Pin 1225 MHz = -45 dBm

Fig 11. Gain versus jammer power at 1695 MHz

Pin 1225 MHz = -45 dBm

Fig 12. Icc versus jammer power at 1850 MHz

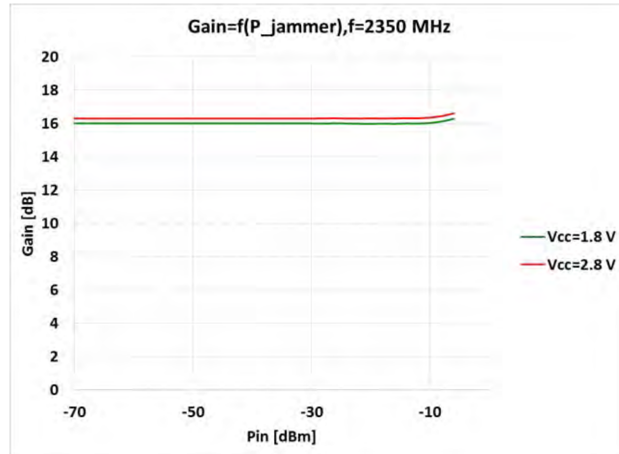


Pin 1225 MHz = -45 dBm

Fig 13. Gain versus jammer power at 1850 MHz

Pin 1225 MHz = -45 dBm

Fig 14. Icc versus jammer power at 2350 MHz



Pin 1225 MHz = -45 dBm

Fig 15. Gain versus jammer power at 2350 MHz

4.2 Noise figure as function of jammer power

Noise figure under jamming conditions is a measure of how the LNA behaves when e.g. a GSM TX interfering signal is at the input of the GNSS antenna. To measure this behavior the setup shown in Fig 16 is used.

The jammer signal is coupled via a directional coupler to the DUT: this is to avoid the jammer signal damaging the noise source. The GNSS BPF is needed to avoid driving the second-stage LNA in saturation.

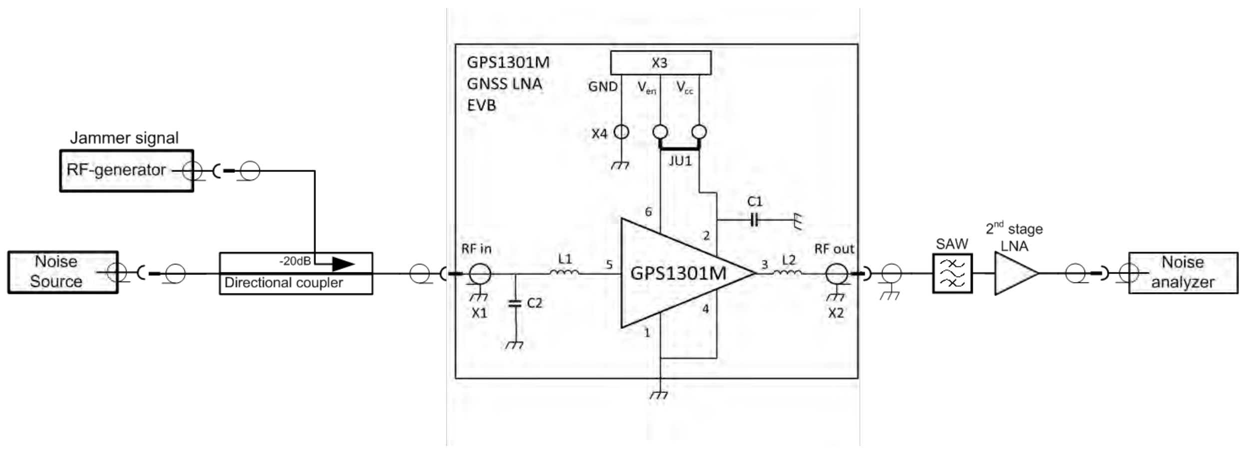


Fig 16. Noise under jamming measurement setup (LNA evaluation board)

With the results of these measurements and the specification of the SAW filter, the jammer power levels that cause noise increase can be calculated.

As can be seen in Fig 17, with a 915 MHz jammer the NF of the LNA starts to increase at P_{jam} = -25 dBm (input jammer power at LNA-board, taking into account the approx. 20 dB attenuation of the directional coupler and RF-cable from Jammer-Generator to the directional coupler). For the 3400 MHz jammer the NF of the LNA starts to increase at P_{jam} = -12 dBm (see Fig 23).

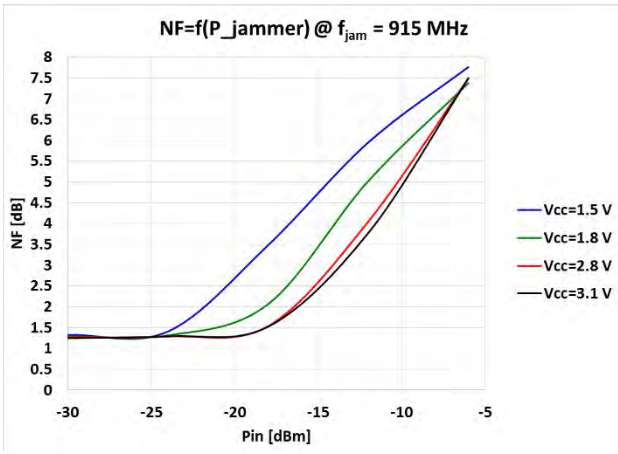


Fig 17. NF versus jammer power at 915 MHz

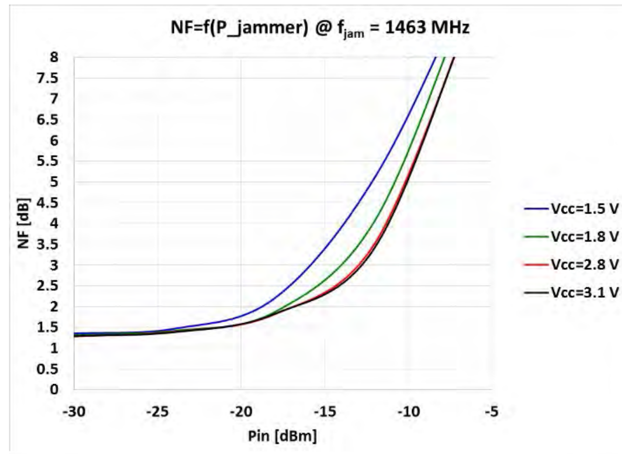


Fig 18. NF versus jammer power at 1463 MHz

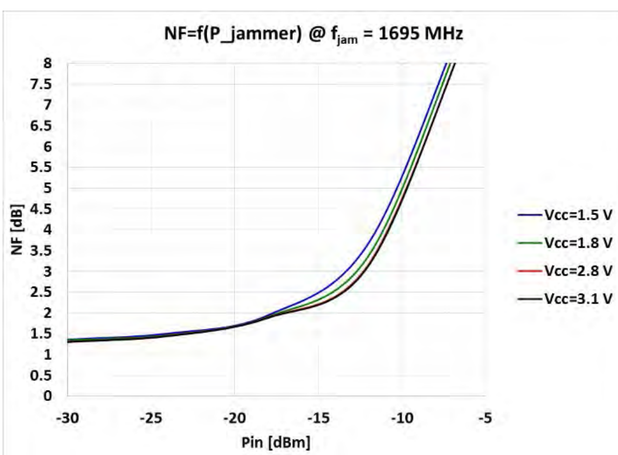


Fig 19. NF versus jammer power at 1695 MHz

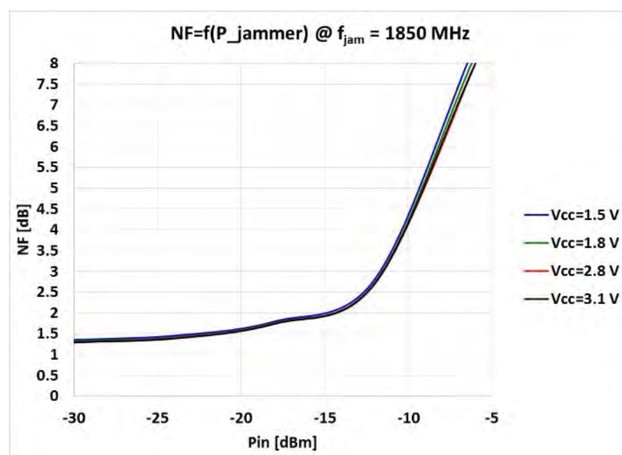


Fig 20. NF versus jammer power at 1850 MHz

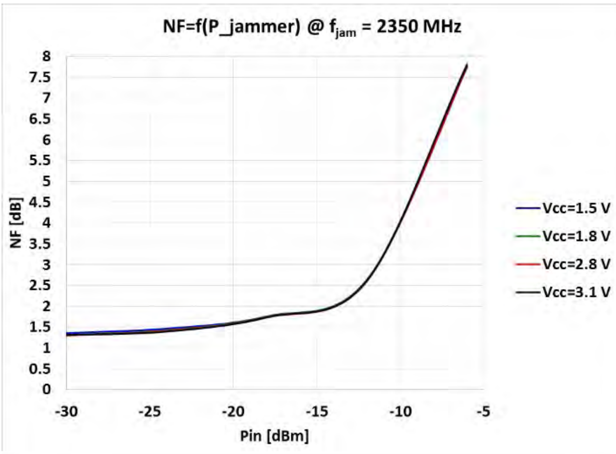


Fig 21. NF versus jammer power at 2350 MHz

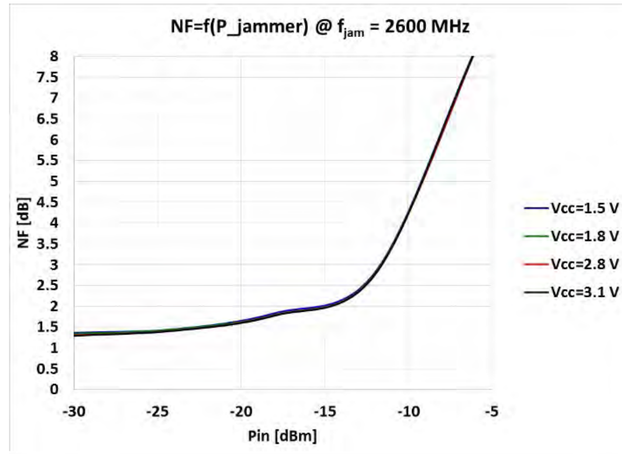


Fig 22. NF versus jammer power at 2600 MHz

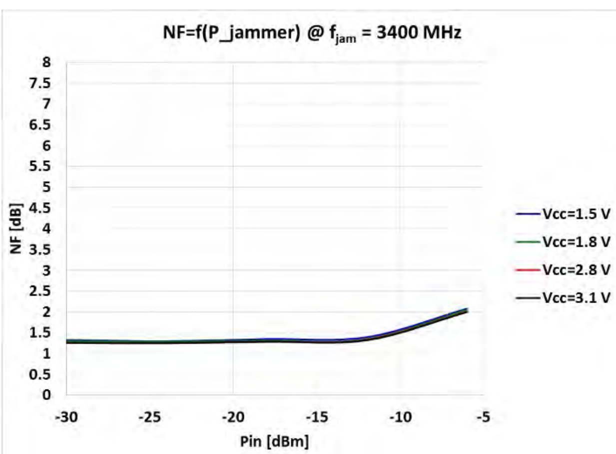


Fig 23. NF versus jammer power at 3400 MHz

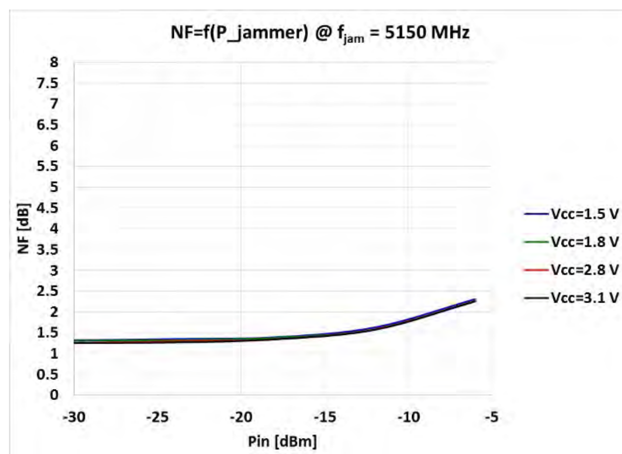
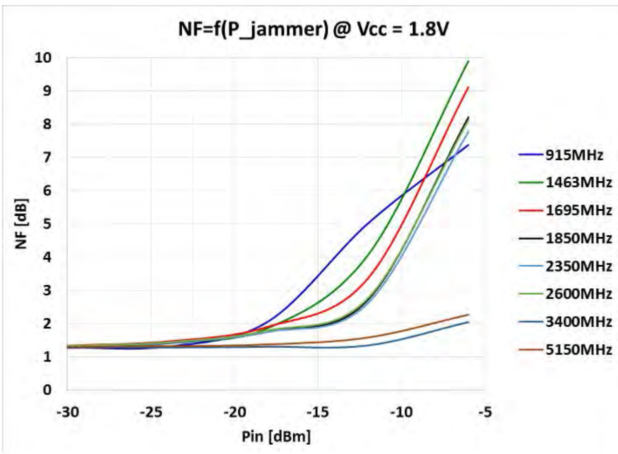


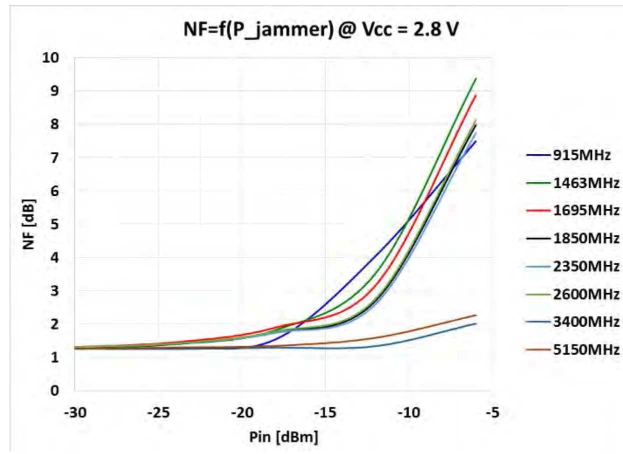
Fig 24. NF versus jammer power at 5150 MHz

The figures below show the noise figure (NF) related to the jamming frequency at different voltage supplies. The influence of the jammer decreases as the frequency separation between the L2-band and the jammer increases.



Pin 1225 MHz = -30 dBm

Fig 25. Gain versus jammer frequency at Vcc = 1.8 V



Pin 1225 MHz = -30 dBm

Fig 26. Gain versus jammer frequency at Vcc = 2.8 V

5. Required Equipment

In order to measure the evaluation board the following is necessary:

- ✓ DC Power Supply up to 30 mA at 1.5 V to 3.1 V
- ✓ Two RF signal generators capable of generating RF signals at the operating frequency of 1225 MHz, as well as the jammer frequencies 915 MHz upto 5150 MHz
- ✓ An RF spectrum analyzer that covers at least the operating frequency of 1225 MHz as well as a few of the harmonics. Up to 6 GHz should be sufficient. “Optional” a version with the capability of measuring noise figure is convenient
- ✓ Amp meter to measure the supply current (optional)
- ✓ A network analyzer for measuring gain, return loss and reverse isolation
- ✓ Noise figure analyzer and noise source
- ✓ Directional coupler
- ✓ Proper RF cables

6. Connections and setup

The GPS1301M GNSS LNA evaluation board is fully assembled and tested. Please follow the steps below for a step-by-step guide to operate the LNA evaluation board and testing the device functions.

1. Connect the DC power supply to the V_{cc} and GND terminals. Set the power supply to the desired supply voltage, between 1.5 V and 3.1 V, but never exceed 3.1 V as it might damage the GPS1301M.
2. Jumper JU1 is connected between the V_{cc} terminal of the evaluation board and the V_{en} pin of the GPS1301M.
3. Connect the RF signal generator and the spectrum analyzer to the RF input and the RF output of the evaluation board, respectively. Do not turn on the RF output of the signal generator yet, set it to -45 dBm output power at 1225 MHz, set the spectrum analyzer at 1225 MHz center frequency and a reference level of 0 dBm.
4. Turn on the DC power supply and it should read approximately 1.2 mA.
5. Enable the RF output of the generator: The spectrum analyzer displays a tone around –29.3 dBm at 1225 MHz.
6. Instead of using a signal generator and spectrum analyzer one can also use a network analyzer in order to measure gain as well as in- and output return loss.
7. For noise figure evaluation, either a noise figure analyzer or a spectrum analyzer with noise option can be used. The use of a 5 dB noise source, like the Agilent 364B is recommended. When measuring the noise figure of the evaluation board, any kind of adaptors, cables etc. between the noise source and the evaluation board should be minimized, since this affects the noise figure.

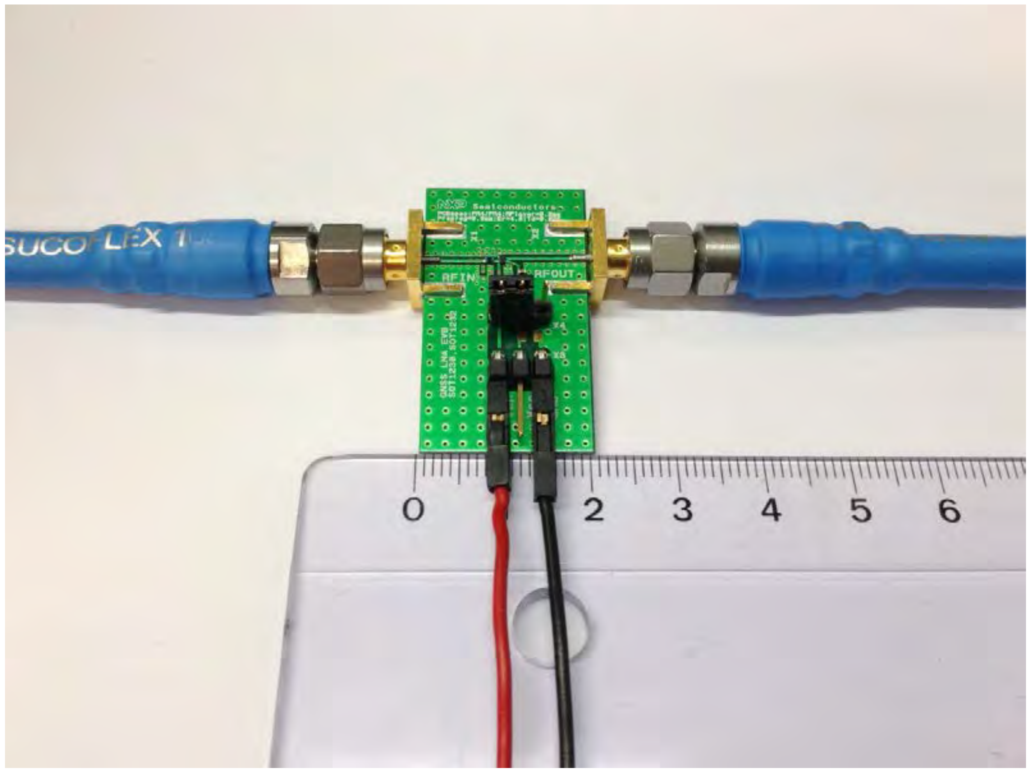


Fig 27. Evaluation board including its connections

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