AN11357

BGU8009 Matching Options for 850 MHz / 2400 MHz Jammer Immunity

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Document information

Info	Content
Keywords	LNA, GNSS, GPS, BGU8009, WLAN, GSM-850, GSM-900
Abstract	This document describes an alternative input matching option for the BGU8009 GNSS LNA. This option provides additional immunity to GSM-850/900 and 2.4 GHZ Wireless LAN jammers.

Revision history

Rev	Date	Description
01	20130527	First publication

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1. Introduction

The BGU8009 is a Low Noise Amplifier (LNA) dedicated for Global Navigation Satellite System (GNSS) receiver applications. It is offered in a plastic leadless 6-pin SOT886 package. The BGU8009 uses NXP's eighth generation 180 GHz f_T SiGe:C process. Under small signal conditions it has typical gain of 17.8 dB and typical noise figure of 0.65 dB, and can be operated at supply voltages up to 3.1V. The part contains a single RF stage and is supplied with an enable function allowing it to be controlled using logic signals. It also features temperature-stabilized bias circuitry. A product datasheet as well as an application note detailing the features of the BGU8009 evaluation board are available.

- BGU8009 Datasheet: *SiGe:C Low Noise Amplifier MMIC for GPS, GLONASS, Galileo, and Compass*
- Application Note BGU8009 GNSS LNA Evaluation Board (AN11288)

In the case of the baseline matching scenario for the BGU8009, only two external components are required: a decoupling capacitor on the collector feed and a low-cost series inductor for RF input matching. The output of the part is internally matched for GNSS frequencies. This application note will outline additional options for modifying the input match to provide increased immunity for the LNA in the presence of GSM-850/900 and 2.4 GHz Wireless LAN (WLAN) signals. For example, a 2410 MHz WLAN signal and an 835 MHz GSM-850 signal will cause a 1575 MHz 2nd order intermodulation product (IM2) to be generated in an active device such as an LNA. Another possible case is a 2465 MHz WLAN signal and an 890 MHz GSM-900 signal. Although this note deals specifically with the BGU8009, the techniques presented here are applicable to the entire family of NXP GNSS LNAs.

The baseline input match provides high gain, low current consumption, high linearity, and lowest noise figure. In the specific case of operating the BGU8009 in the presence of GSM and WLAN band jammers, the input match can be modified to provide additional immunity to these signals. The basic premise is to add additional low cost components to the input match in order to provide gain nulls in the 800 and 2400 MHz bands. This technique can potentially reduce or alleviate the need for relatively high cost filtering in the system.

Figure 1 below shows the broadband gain performance of the BGU8009 with baseline single element input match and a 5-element jammer immunity input match which creates the gain nulls.

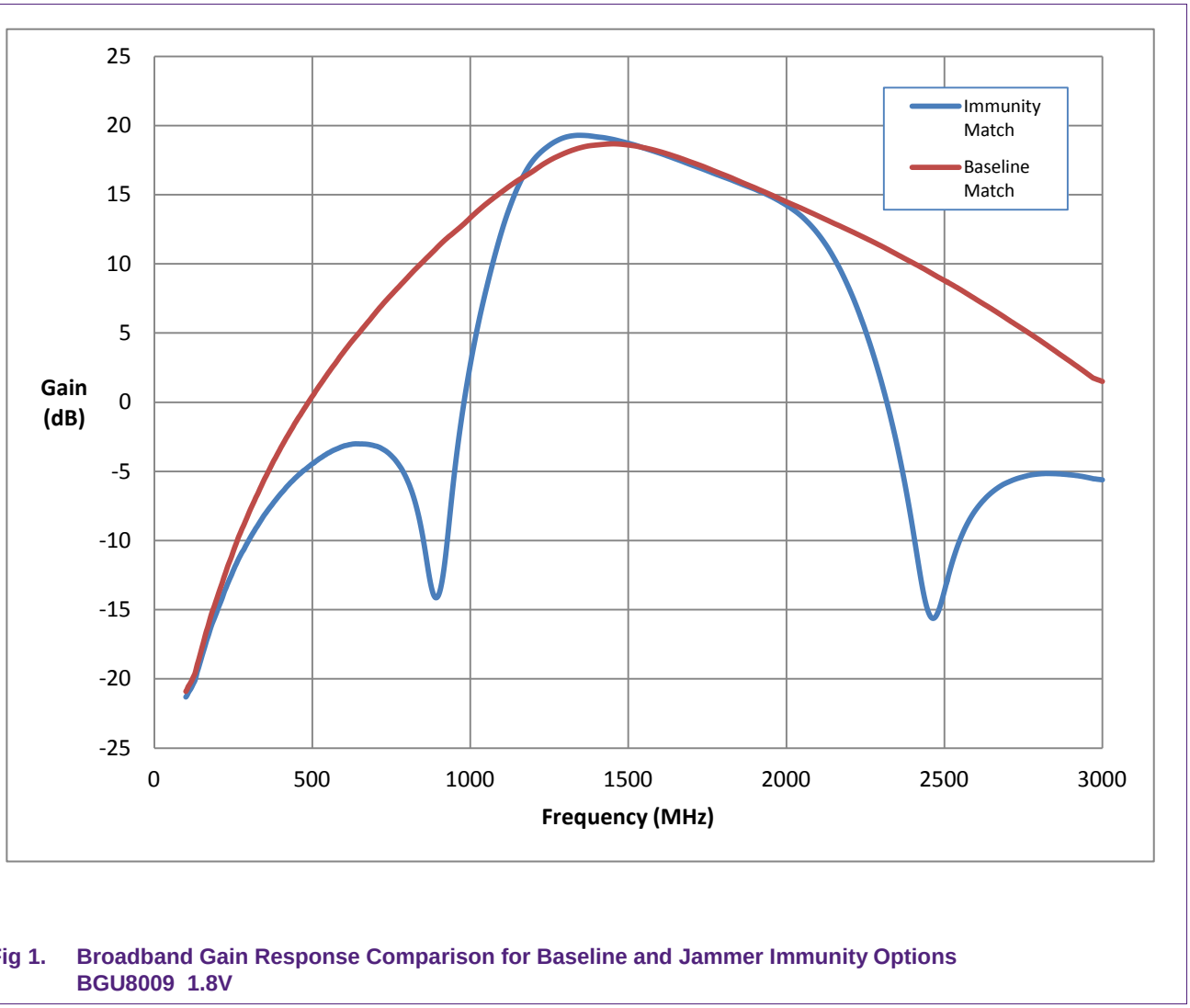


Fig 1. Broadband Gain Response Comparison for Baseline and Jammer Immunity Options BGU8009 1.8V

2. Baseline Single Element Match Performance BGU8009

The standard BGU8009 evaluation board is supplied with a Murata LQW15 series inductor (0402 size) in the input match. This type of high quality factor (Q) inductor is recommended in order to provide best noise performance. Figure 2 and Table 1 below show the schematic and bill of materials for the BGU8009 baseline circuit. The broadband gain and input/output return loss are shown in Figure 3.

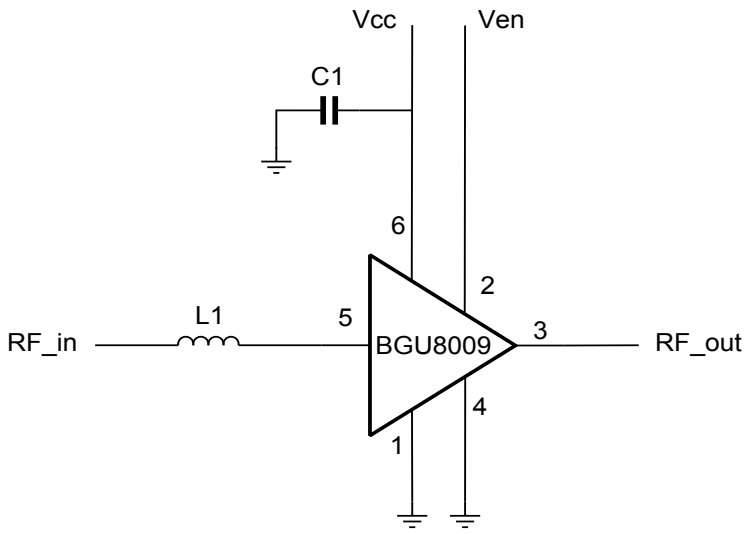
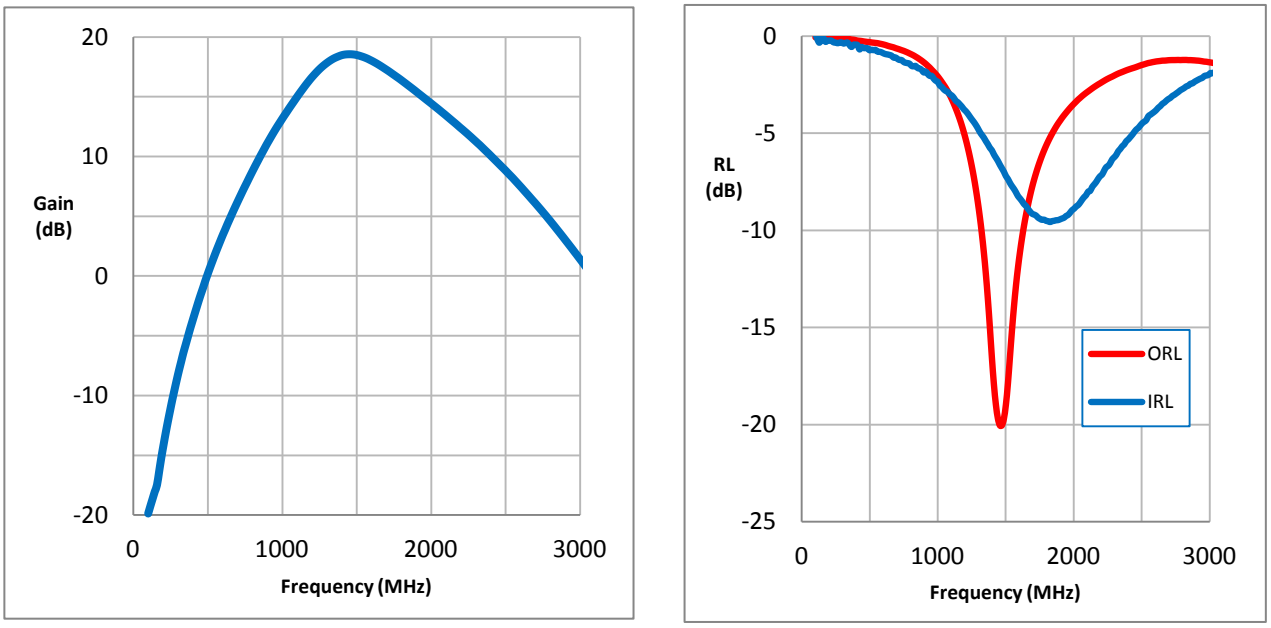


Fig 2. BGU8009 Baseline Schematic

Table 1. List of Components for Baseline Input Match BGU8009

For schematic see Figure 2

Component	Description	Value	Supplier
C1	Decoupling Capacitor	1nF	Various
L1	Input Matching	5.6nH	Murata LQW15
IC	BGU8009	-	NXP



a. Gain

b. Input and Output Return Loss

Fig 3. Gain and Return Loss vs. Frequency Baseline Match BGU8009

At average power levels received by a GNSS receiver under normal conditions, the system will not have in-band intermodulation problems caused by the GNSS signal itself. Strong out-of-band transmit frequency jammers can cause linearity problems, however. For example, an incident 870 MHz signal along with a 2445 MHz signal can cause a 2nd order spurious product which falls in the GNSS band to be produced in the LNA.

$$f_{spur} = f_1 - f_2 \sim \text{GNSS band}$$

Specific to this application note, two input signals of equal amplitude at 2445 MHz and 870 MHz are applied to the input of the LNA, producing a 2nd order spurious in the GNSS band.

$$2445\ \text{MHz} - 870\ \text{MHz} = 1575\ \text{MHz}$$

Figure 4 below shows the measured results of this two-tone test for the baseline BGU8009 input match. The level of the 2nd order spurious product and the output level of the f_1 and f_2 fundamental products are plotted as a function of single tone input power (note that Pin1 = Pin2 for the plot).

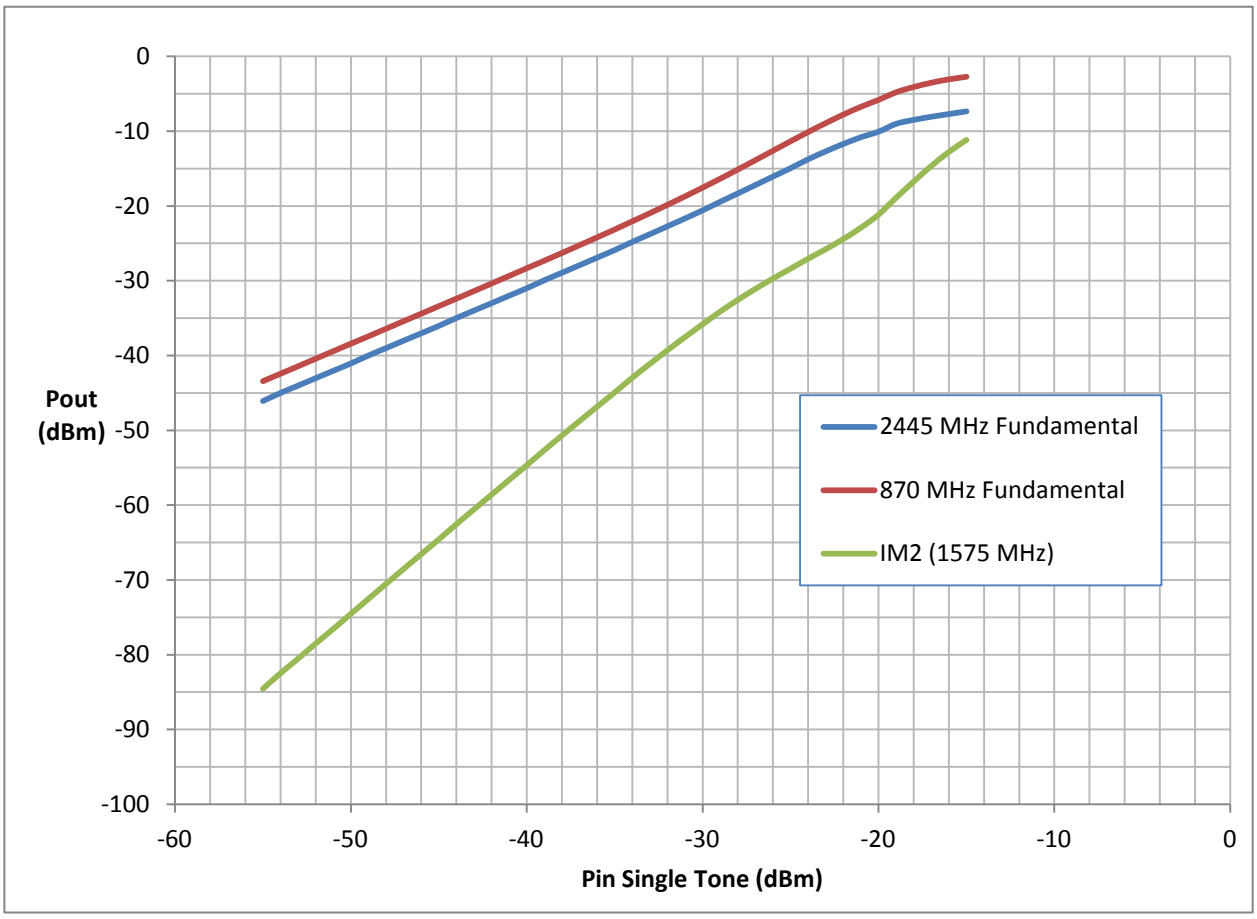


Fig 4. Two Tone Test Results (f_1 = 870 MHz, f_2 = 2445 MHz, f_{spur} = 1575 MHz) Baseline Match BGU8009 1.8V

Figure 5 below shows the current draw of the BGU8009, again as a function of single tone input power (Pin1 = Pin2).

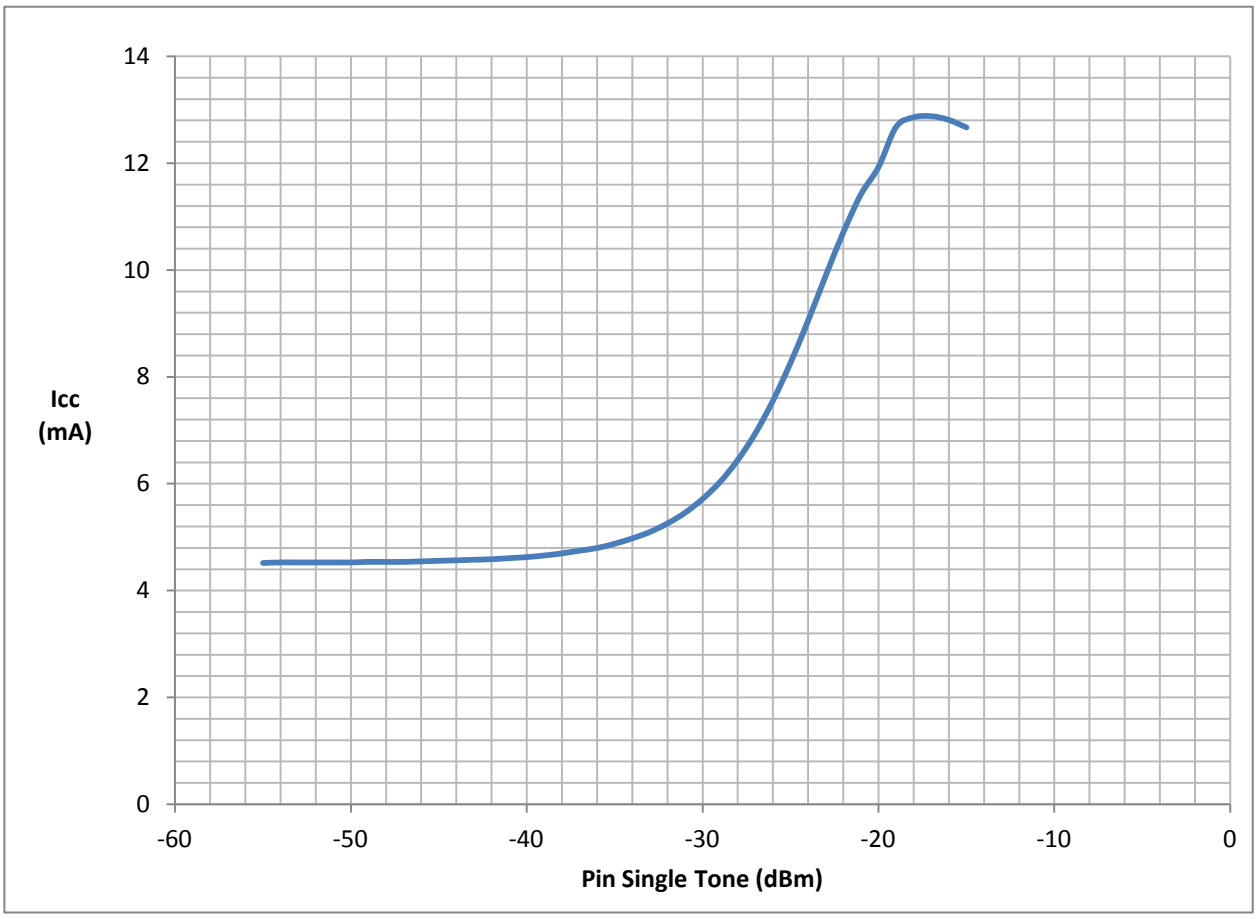


Fig 5. Two Tone Test Results (f_1 = 870 MHz, f_2 = 2445 MHz) Baseline Match BGU8009 1.8V

Figure 6 shows the GNSS-band noise figure for a typical BGU8009 sample. Note that these data are with no jammer signals present, and also include printed circuit board and SMA connector losses. De-embedding the PCB and connector will result in a NF which is 0.05 dB lower.

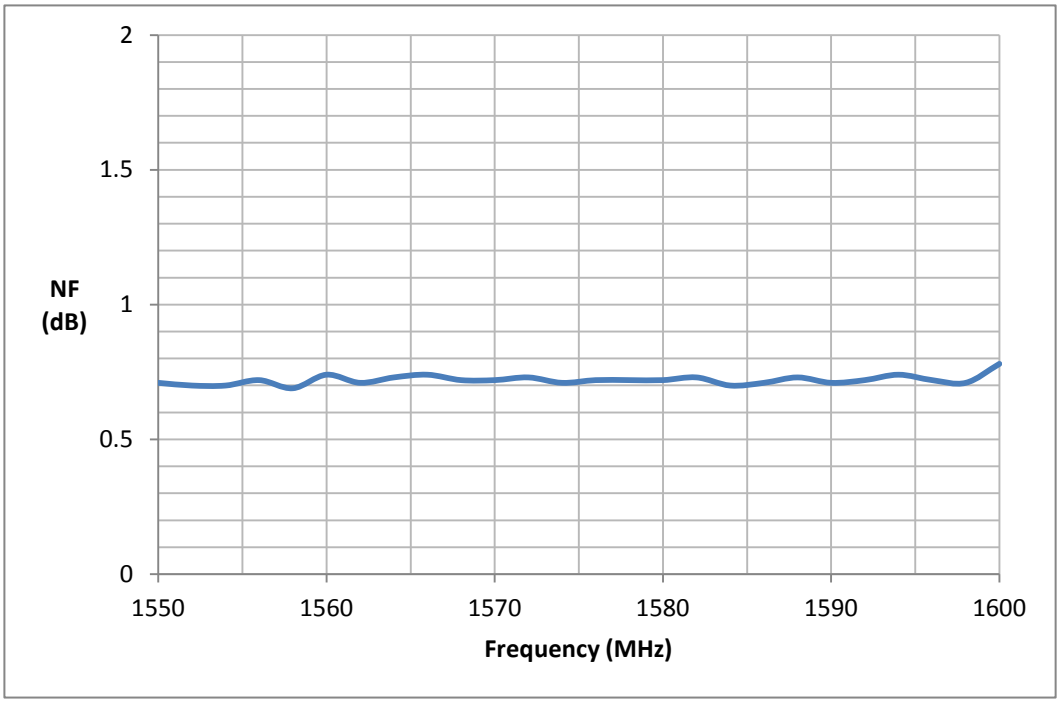


Fig 6. Noise Figure Baseline Match BGU8009 1.8V

3. Input Match for 800 MHz / 2400 MHz Jammer Immunity

To increase immunity to GSM-800 and 2.4 GHz WLAN signals, the input match can be modified to include a dual notch topology, providing gain nulls in the broadband response. The additional elements are low cost chip capacitors and low cost chip inductors. See Figure 7 and Table 2 for the schematic and bill of materials for the BGU8009 jammer immunity configuration.

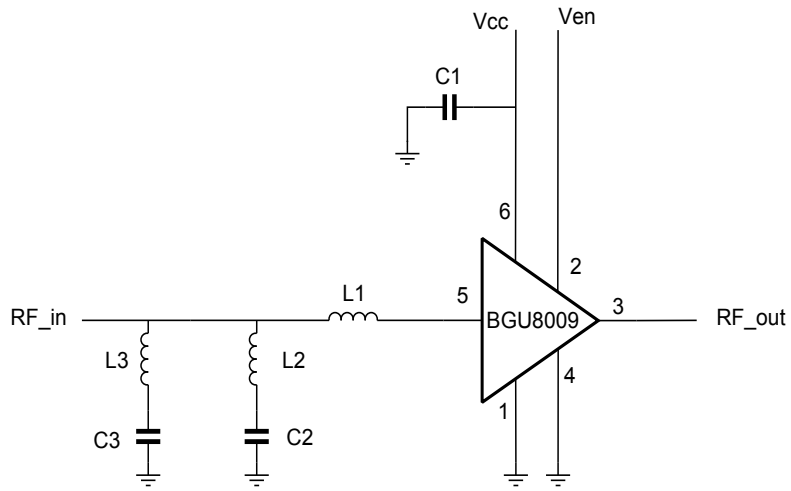


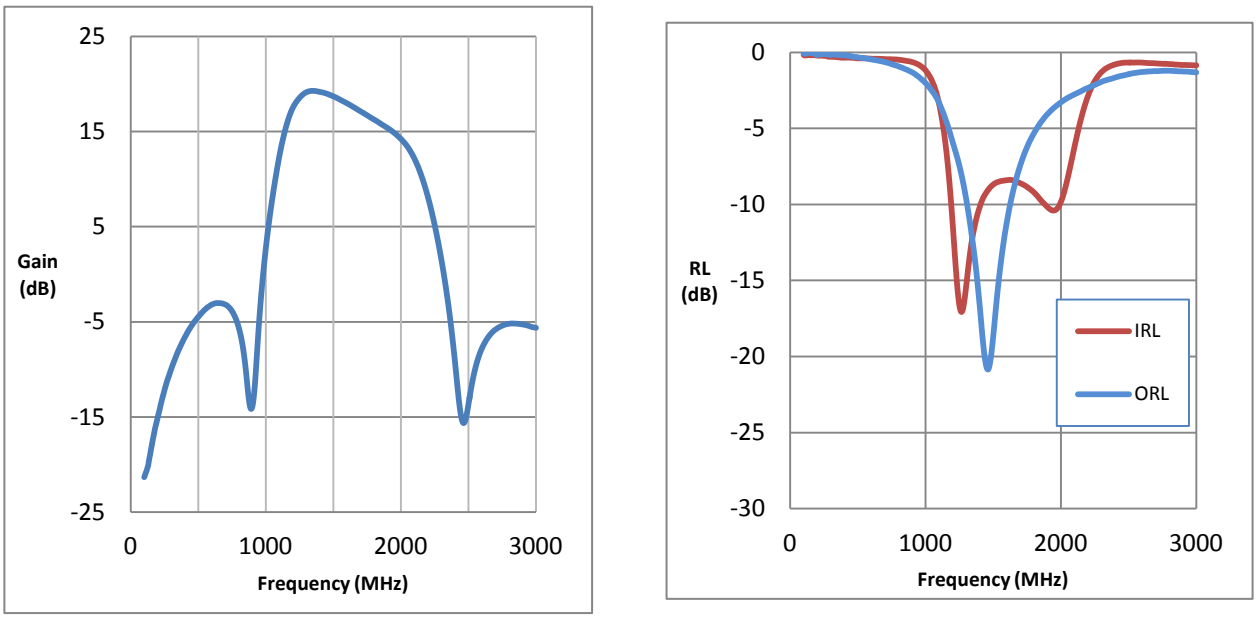
Fig 7. BGU8009 Jammer Immunity Match Schematic

Table 2. List of Components for Jammer Immunity Input Match BGU8009

For schematic see Figure 7

Component	Description	Value	Supplier
C1	Decoupling Capacitor	1nF	Various
L1	Input Matching	5.6 nH	Murata LQW15
L2	Notch	6.2 nH	Murata LQG15
L3	Notch	3.0 nH	Murata LQG15
C2	Notch	4.7 pF	Murata GRM15
C3	Notch	1.0 pF	Murata GRM15
IC	BGU8009	-	NXP

As can be seen in Figure 8, the jammer immunity matching topology creates gain nulls in the 870 MHz and 2445 MHz frequency regions. The gain nulls serve to reduce the level of 2nd order intermodulation distortion in the GNSS band.



a. Gain vs. Frequency

b. Input and Output Return Loss vs. Frequency

Fig 8. Gain and Return Loss vs. Frequency Jammer Immunity Match BGU8009 1.8V

Figures 9 and 10 below show the two-tone test results with the jammer immunity match. The fundamental tones are again 870 MHz and 2445 MHz, and the results are plotted as a function of single tone input power (Pin1 = Pin2).

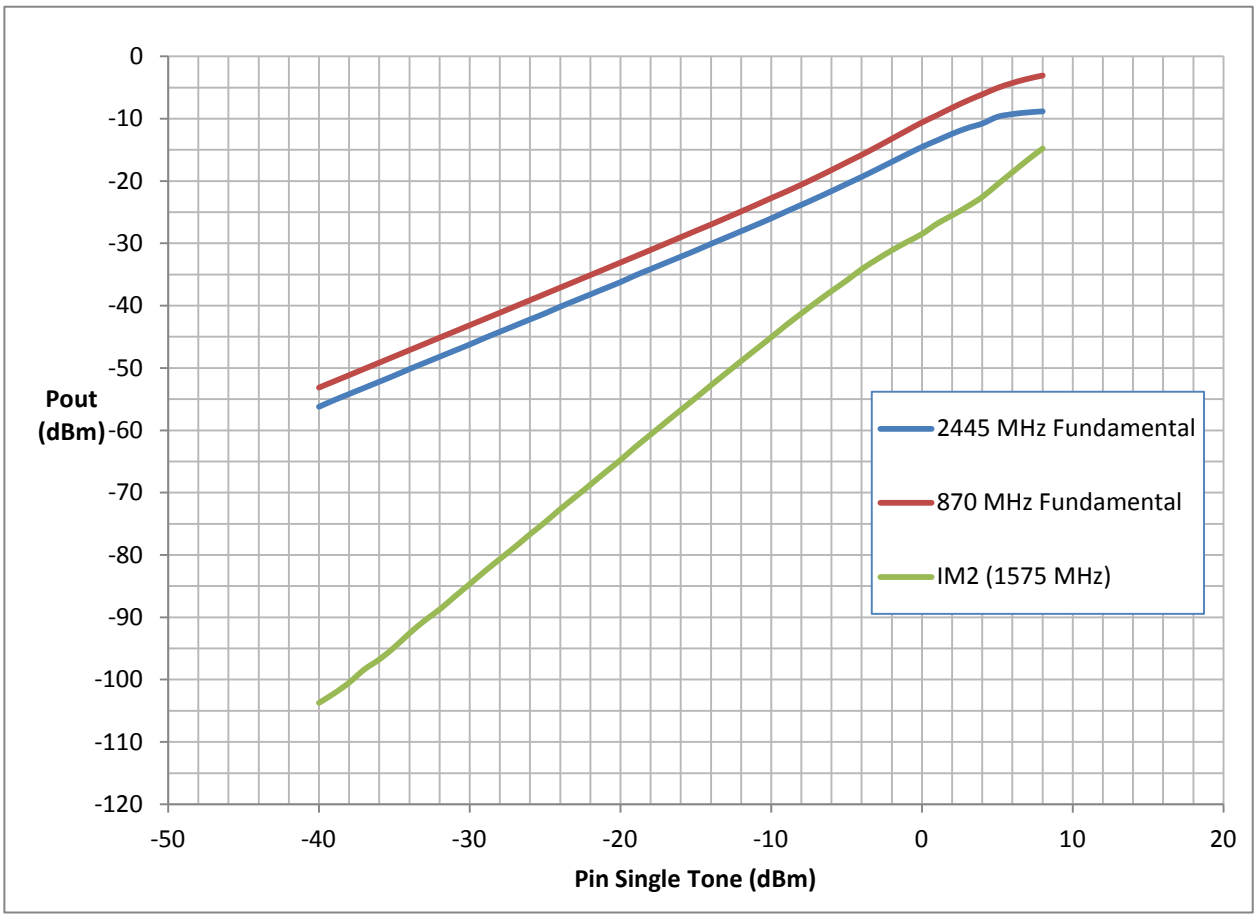


Fig 9. Two-Tone Test Results (f_1 = 870 MHz, f_2 = 2445 MHz, f_{spur} = 1575 MHz) Jammer Immunity Match BGU8009 1.8V

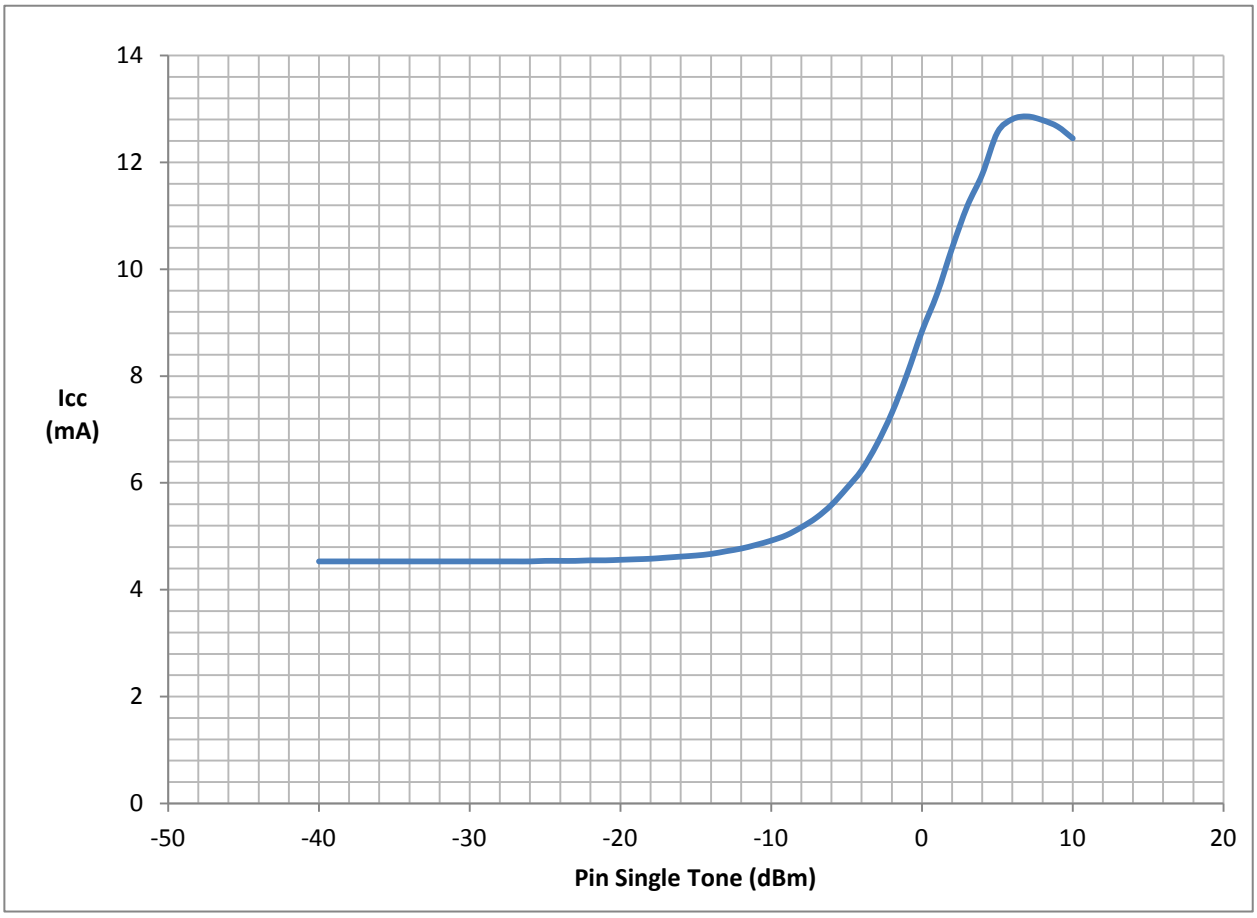


Fig 10. Two Tone Test Results (f_1 = 870 MHz, f_2 = 2445 MHz) Jammer Immunity Match BGU8009 1.8V

Figure 11 below shows a direct comparison of 1575 MHz IM2 distortion level at the output of the LNA as a function of single tone input power. The jammer immunity match results in a suppression of approximately 49 dB for the 1575 MHz IM2 product.

In terms of input 2nd order intercept point, or IIP2, the 49 dB suppression of the IM2 product corresponds to a 49 dB increase in IIP2 level:

$$IIP2 = P1in + P2in - IIM2$$

where IIM2 is the input-referred IM2 level, and all power levels are in dBm. So, for the baseline case for -30 dBm input power level per tone,

$$IIP2 = (-30) + (-30) - (-36 - Gain[1575MHz]) = -6\,dBm$$

And for the jammer immunity case,

$$IIP2 = (-30) + (-30) - (-85 - Gain[1575MHz]) = 43\,dBm$$

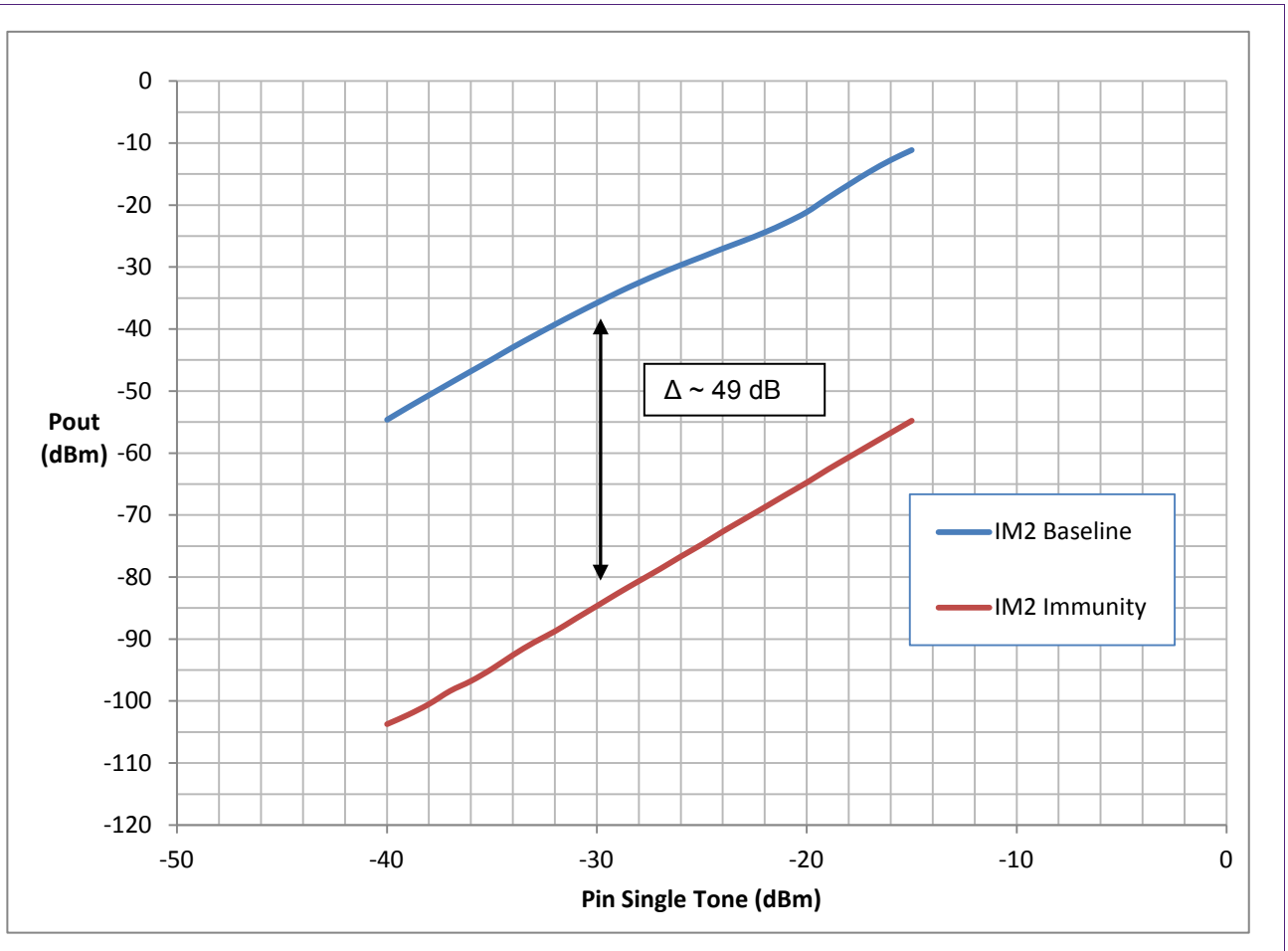


Fig 11. IM2 Comparison Jammer Immunity vs. Baseline BGU8009 1.8V

Figure 12 shows a comparison of the current draw as a function of the input power. As can be seen, with the jammer immunity match there is an approximately 24 dB difference of input power levels needed to reach a given current draw, once the quiescent current of the part is exceeded.

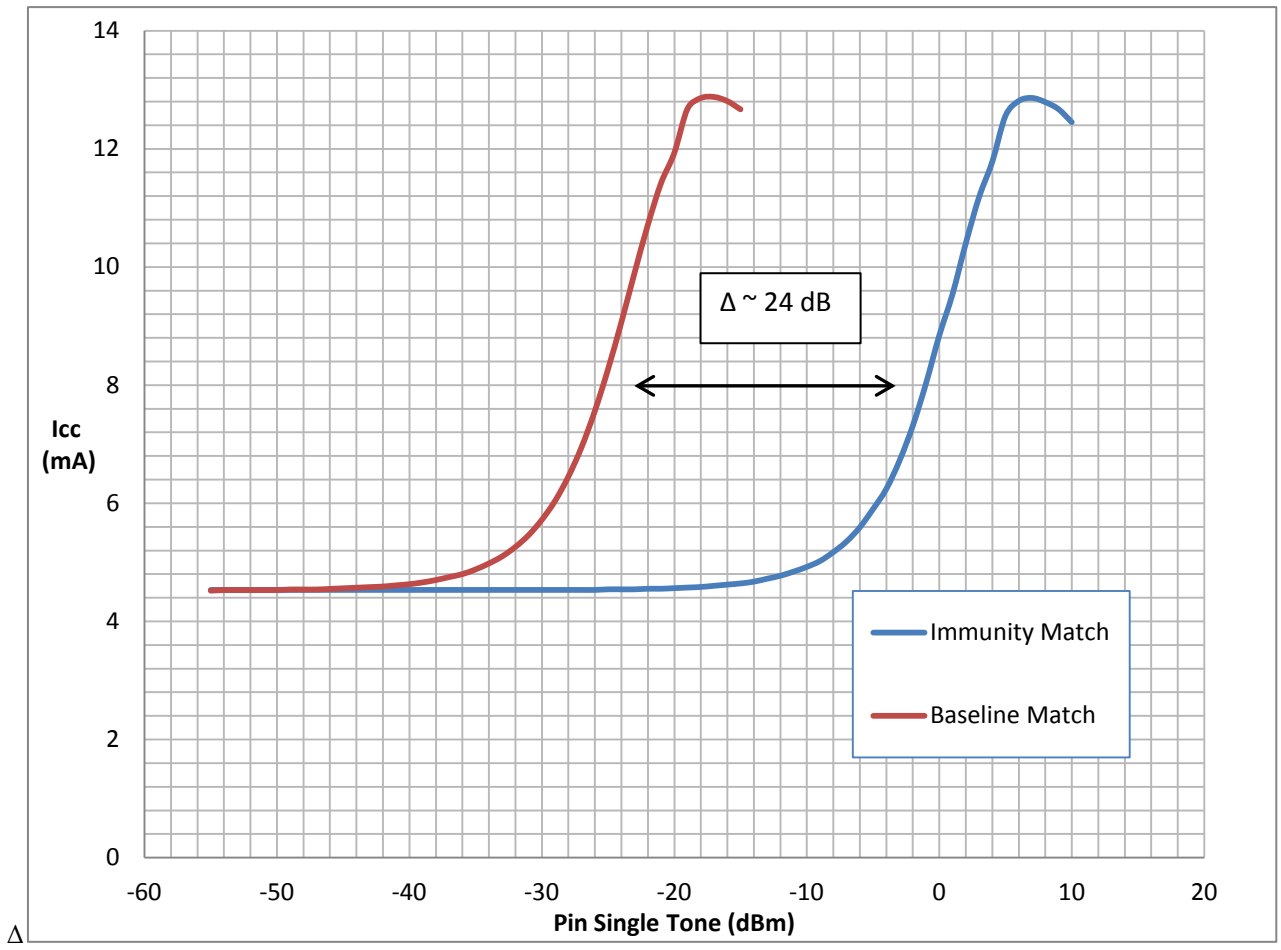


Fig 12. Current Draw Comparison Jammer Immunity vs. Baseline BGU8009 1.8V

Figure 13 shows the NF with the jammer immunity match. The noise figure is degraded by 0.35 dB due to the additional elements at the input of the LNA.

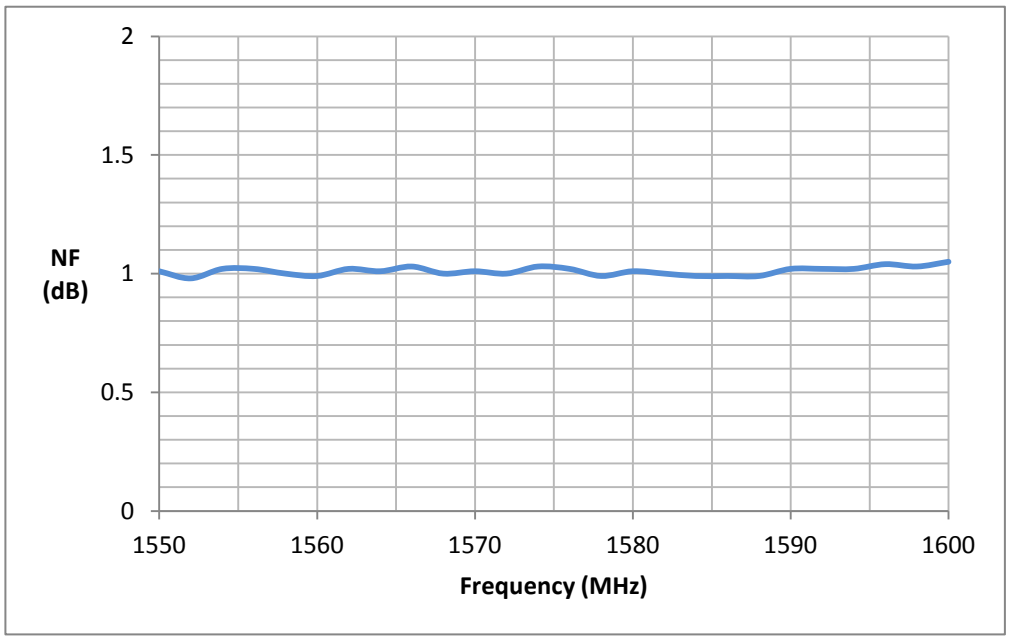


Fig 13. Noise Figure Jammer Immunity Match BGU8009 1.8V

Also note that an LQG15 ceramic inductor can be used as the series inductor in the input match (L1). A lower cost inductor such as this can be used if it is not required to reach absolute best noise figure. Figure 14 below shows a comparison of measured NF with a 5.6 nH LQW15 inductor as L1 and a 5.6 nH LQG15 inductor as L1.

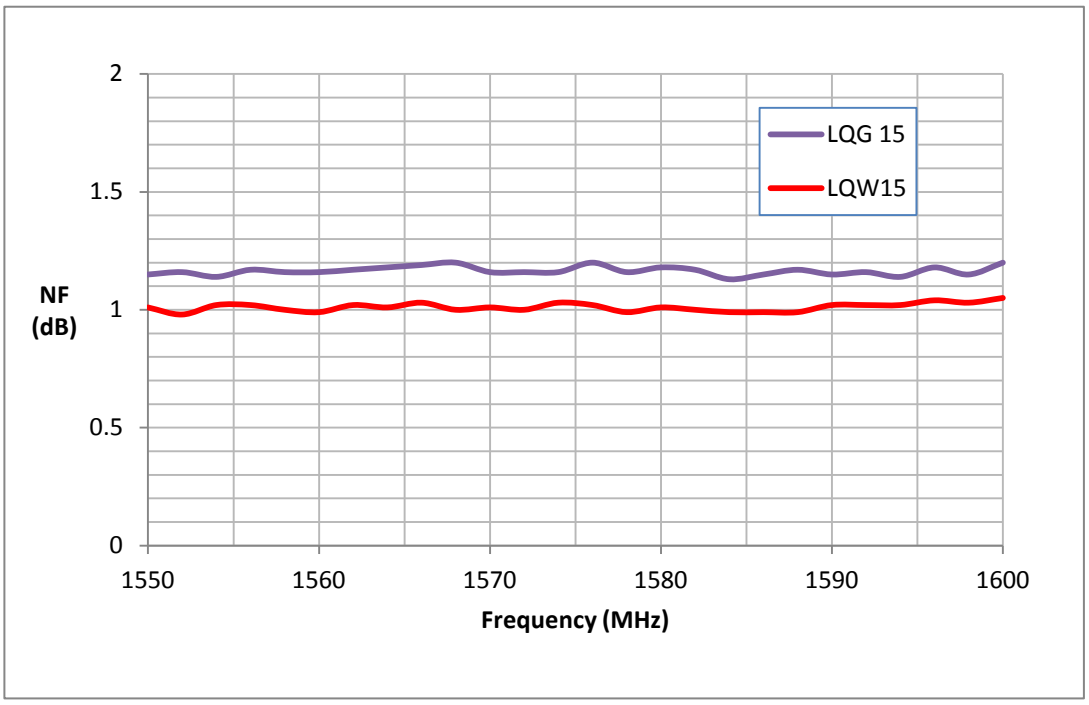


Fig 14. Noise Figure Jammer Immunity Match BGU8009 1.8V LQW15 vs. LQG15 Input Matching Inductor (L1)

4. Conclusion

By changing the input matching topology of NXP's GNSS LNAs, the gain of the circuit in the 800 MHz and 2400 MHz bands can be significantly reduced while leaving the in-band gain essentially unaltered. This can be accomplished with the addition of low cost, readily available lumped element components. This has the effect of increasing the immunity to jamming signals in these bands at the expense of noise figure, which increases slightly due to having additional components at the input of the device. To further quantify, Table 3 below show results for the BGU8009 for the case of 870 MHz and 2445 MHz jamming signals at a level of -30 dBm at the LNA input.

Table 3. LTE Band 2nd Harmonic BGU8009

Vcc = 1.8V IM2 Level for Pin @ -30 dBm / Tone

Matching Option	Gain 870 MHz	Gain 2445 MHz	Gain 1575 MHz	Input Referred IM2 Level	Noise Figure* 1575 MHz
Baseline	10.7 dB	9.5 dB	17.8 dB	-54 dBm	0.70 dB
Jammer Immunity	-12.8 dB	-14.9 dB	17.8 dB	-103 dBm	1.05 dB**

* Includes board and connector losses (0.05 dB)

** Noise Figure degrades by a further 0.15 dB when using an LQG15 series inductor as L1

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