AN11068

BGU8007/BGU7005 Matching Options for Improved LTE Jammer Immunity

Rev. 2 — 30 May 2012 Application Note

Document information

Info	Content
Keywords	LNA, GNSS, GPS, BGU8007, BGU7005
Abstract	This document describes several matching topologies for the BGU8007 and BGU7005 LNAs. These topologies provide additional immunity to 700 MHz LTE band jammers.

Revision history

Rev	Date	Description
2	20120530	Added BGU8007 information, updated matching topology

Contact information

For more information, please visit: http://www.nxp.com

For sales office addresses, please send an email to: salesaddresses@nxp.com

1. Introduction

The BGU8007 and BGU7005 are low-noise amplifiers dedicated for Global Navigation Satellite System (GNSS) receiver applications. They are both offered in plastic leadless 6-pin SOT886 packages. The BGU8007 uses NXP's eighth generation 180 GHz f_T SiGe:C process, has typical gain of 19 dB and typical noise figure of 0.75 dB, and can be operated at collector voltages up to 2.5V. The BGU7005 uses NXP's seventh generation 110 GHz f_T SiGe:C process, has typical gain of 16.5 dB and typical noise figure of 0.85 dB, and can be operated at collector voltages up to 3.1V. Both parts contain a single RF stage and are supplied with an enable function allowing them to be controlled using logic signals. Each MMIC also features temperature-stabilized bias circuitry. Product datasheets and several supporting user manuals are available for the BGU8007 and BGU7005.

- BGU8007 Datasheet: *SiGe:C Low Noise Amplifier MMIC for GPS, GLONASS, and Galileo*
- BGU7005 Datasheet: *SiGe:C Low Noise Amplifier MMIC for GPS, GLONASS, and Galileo*
- User Manual for the BGU8007 GPS LNA Evaluation Board (UM10497)
- User Manual for the BGU7005 GPS LNA evaluation board (UM10380)
- User Manual for the BGU7005 GPS Front End evaluation board (UM10381)
- 2-Tone Test BGU7005 and BGU7007 GPS LNA (UM10453)

In the cases of both the BGU8007 and the BGU7005, only two external components are required to build the baseline application circuits: a decoupling capacitor on the collector feed and a low-cost series inductor for RF input matching. The outputs of the parts are 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 LTE band signals. Although this note deals specifically with the BGU8007 and BGU7005, the techniques presented here are applicable to the entire family of NXP GNSS LNAs.

The baseline input matches provide high gain, low current consumption, high linearity, and lowest noise figure. In the specific case of operating the BGU8007 or BGU7005 in the presence of LTE 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 a gain null in the 700 MHz LTE band. 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 BGU8007 with baseline single element input match and a 3-element jammer immunity input match which creates the 700 MHz gain null.

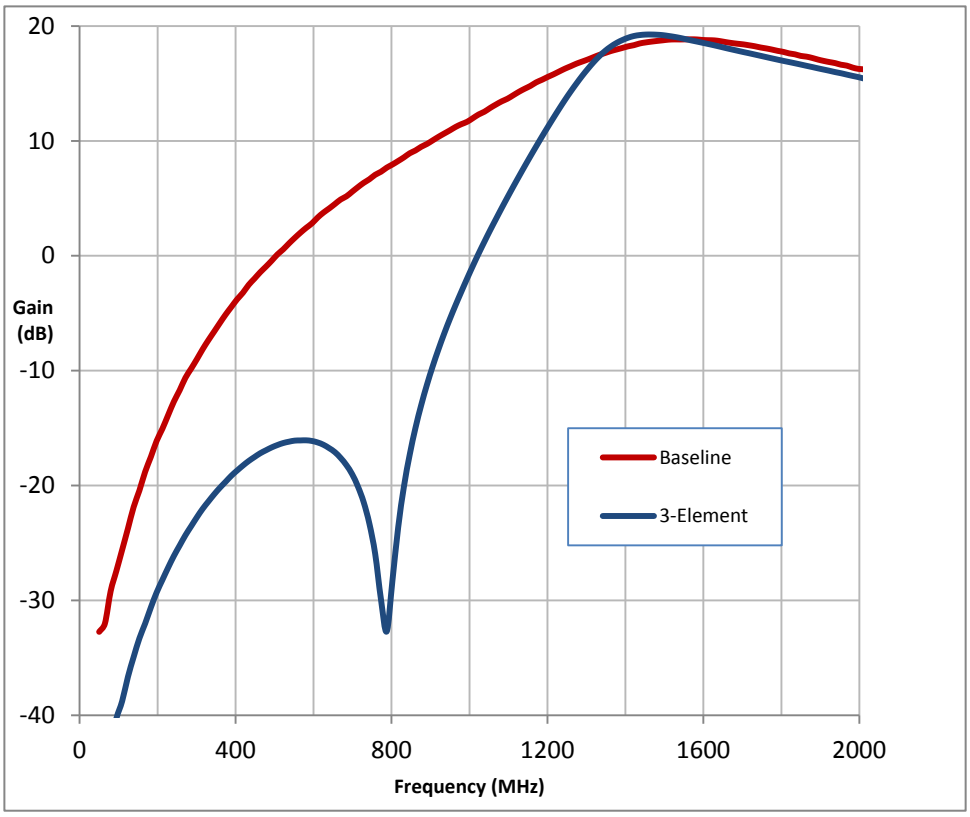


Fig 1. Gain Roll-off Comparison for Baseline and LTE Jammer Immunity Matching Options BGU8007 1.8V

2. Baseline Single Element Match Performance BGU7005

Both the standard BGU8007 and BGU7005 evaluation boards are 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 BGU8007 baseline circuit, while Figure 3 and Table 2 show the BGU7005 baseline circuit. The baseline configuration application board, used for both the BGU8007 and BGU7005, is shown in Figure 4. The broadband gain and input/output return loss are shown in Figures 5 and 6 for the BGU8007 and BGU7005, respectively.

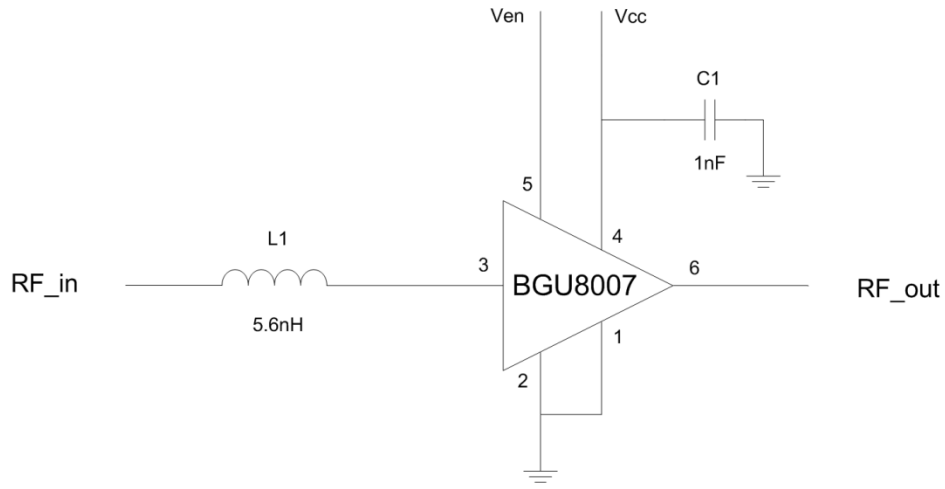


Fig 2. BGU8007 Baseline Schematic

Table 1. List of Components for Baseline Input Match BGU8007

For schematic see Figure 2

Component	Description	Value	Supplier
C1	Decoupling Capacitor	1nF	Various
L1	Input Matching	5.6nH	Murata LQW15
IC1	BGU8007	-	NXP

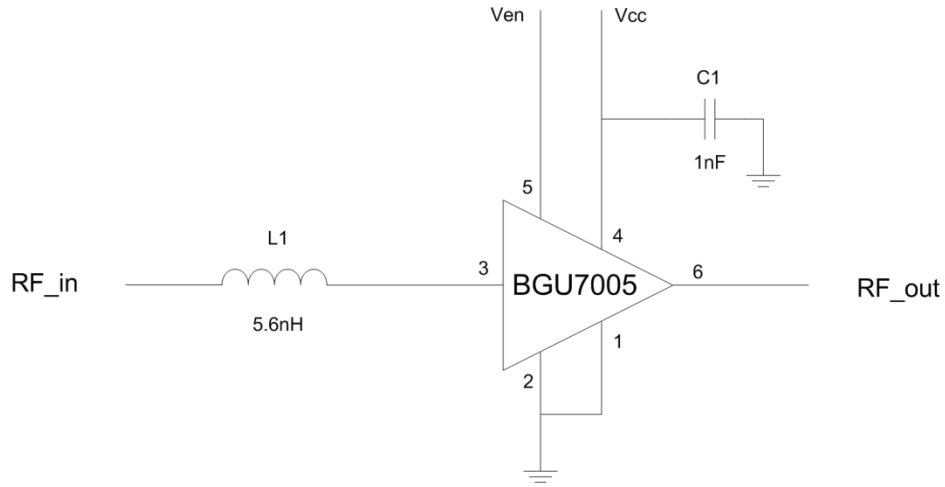


Fig 3. BGU7005 Baseline Schematic

Table 2. List of Components for Baseline Input Match BGU7005

For schematic see Figure 3

Component	Description	Value	Supplier
C1	Decoupling Capacitor	1nF	Various
L1	Input Matching	5.6nH	Murata LQW15
IC1	BGU7005	-	NXP

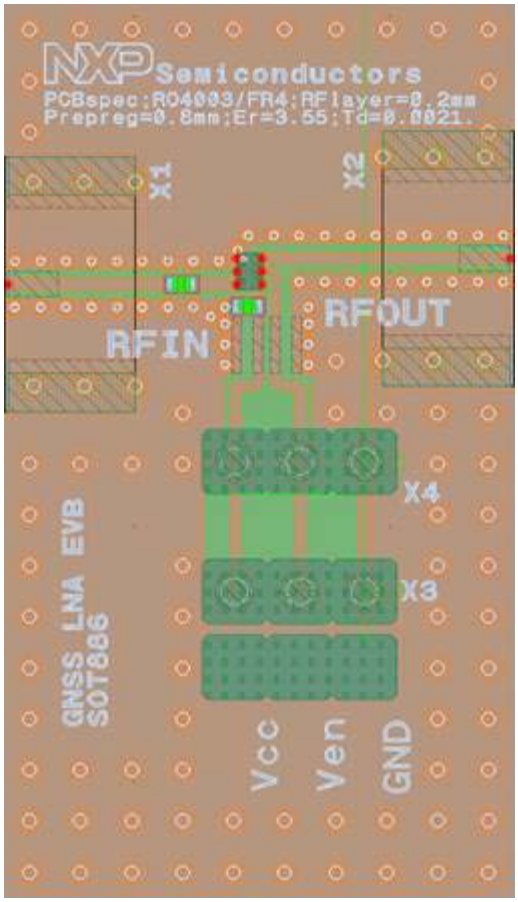
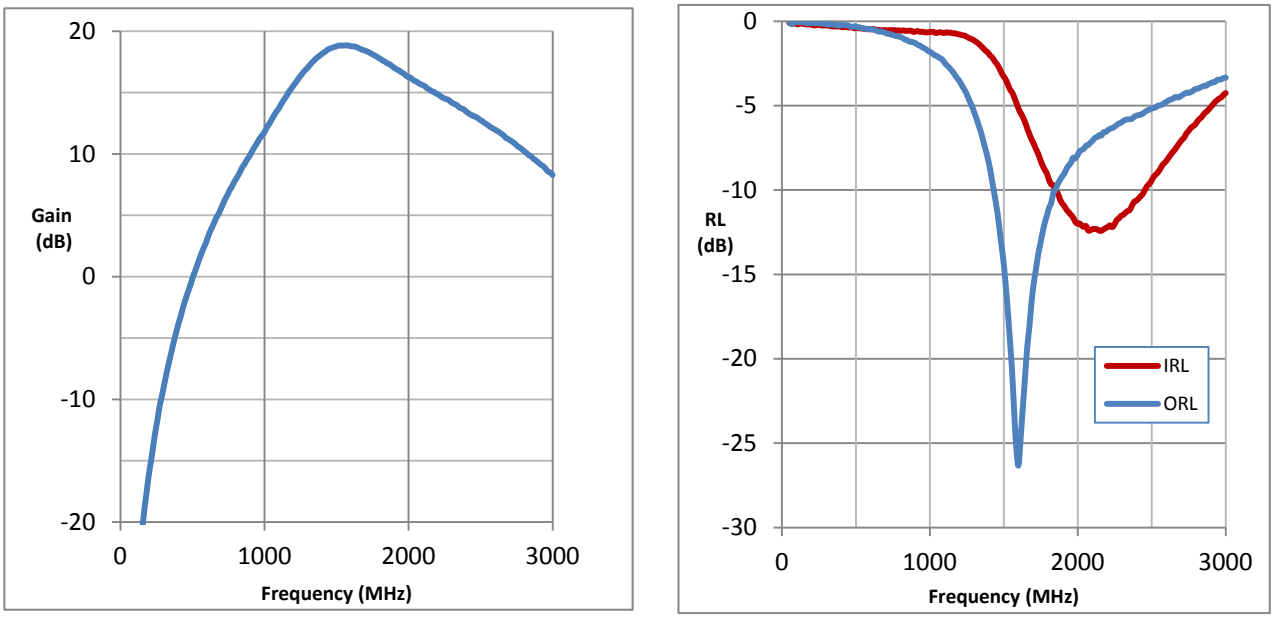


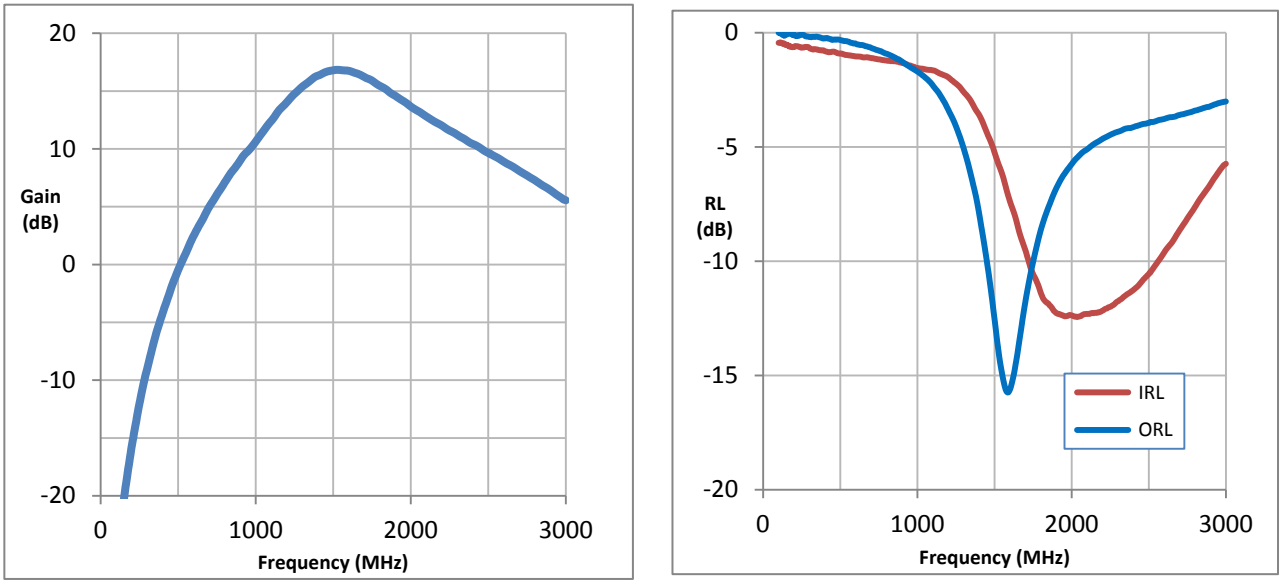
Fig 4. BGU8007/BGU7005 Baseline Board Layout



a. Gain vs. Frequency

b. Input and Output Return Loss vs. Frequency

Fig 5. Gain and Return Loss vs. Frequency Baseline Match BGU8007



a. Gain vs. Frequency

b. Input and Output Return Loss vs. Frequency

Fig 6. Gain and Return Loss vs. Frequency Baseline Match BGU7005

One method to judge the linearity of an LNA under jamming conditions is an out-of-band second-order spurious product measurement. 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, two incident 700MHz LTE band signals 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 787.4 MHz and 788.0 MHz are applied to the input of the LNAs, producing a 2nd order spurious in the GNSS band.

$$787.4\ \text{MHz} + 788.0\ \text{MHz} = 1575.4\ \text{MHz}$$

Figure 7 below shows the measured results of this two-tone test for the baseline BGU8007 input match. The level of the 2nd order spurious product and the output level of the f_1 fundamental product are plotted as a function of single tone input power. Figure 8 shows the same information for the BGU7005 in its baseline configuration.

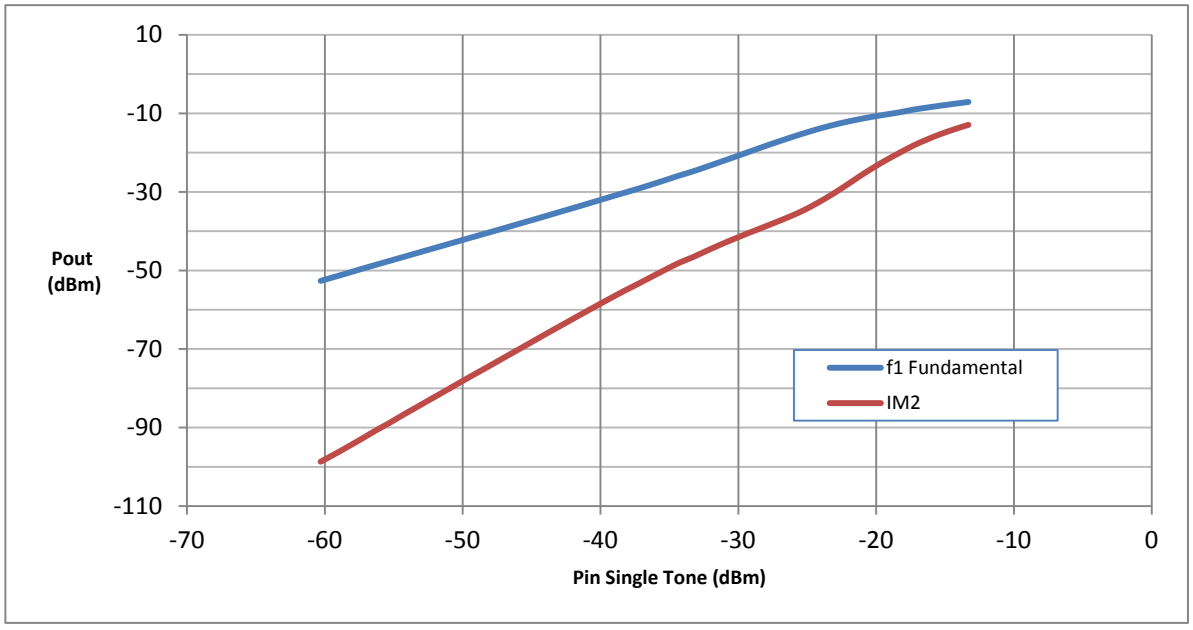


Fig 7. Two Tone Test Results (f_1 = 787.4 MHz, f_2 = 788 MHz, f_{spur} = 1575.4 MHz) Baseline Match BGU8007 1.8V

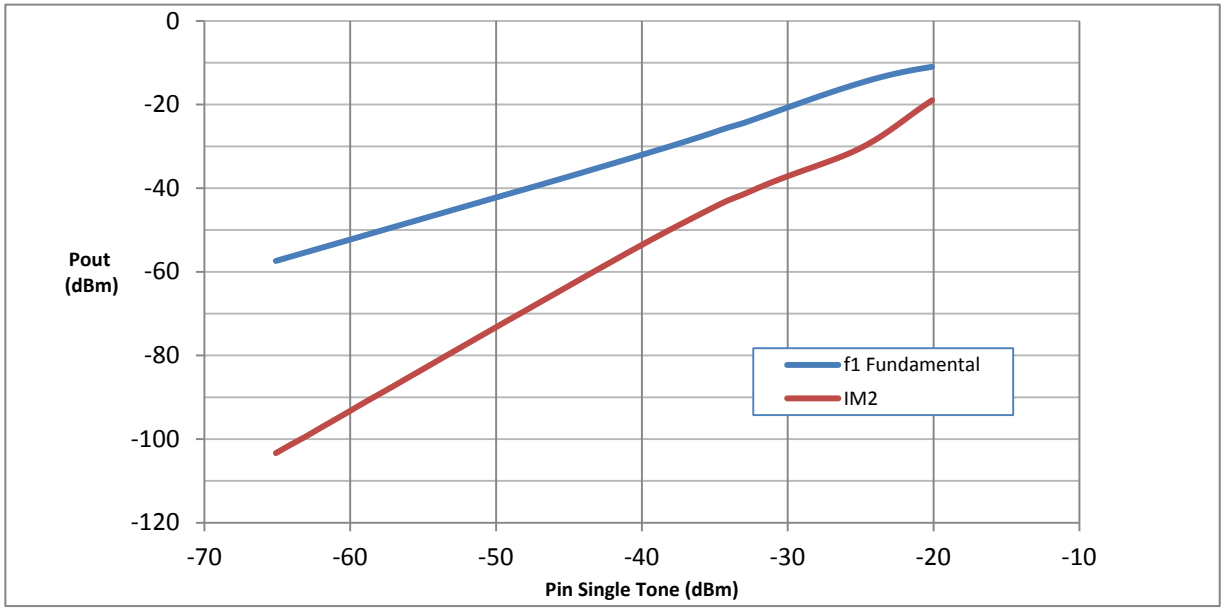
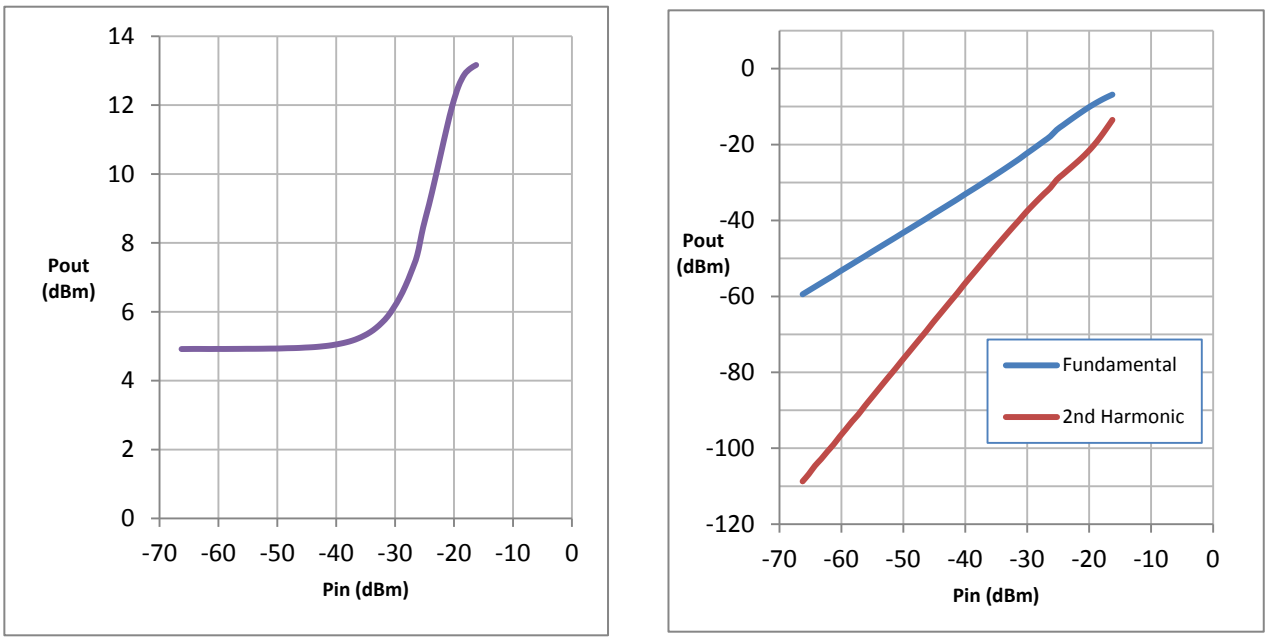


Fig 8. Two Tone Test Results (f_1 = 787.4 MHz, f_2 = 788 MHz, fspur = 1575.4 MHz) Baseline Match BGU7005 1.8V

Another important consideration is the level of the 2nd order harmonic product, which is generated by the device at twice the frequency of an incident tone.

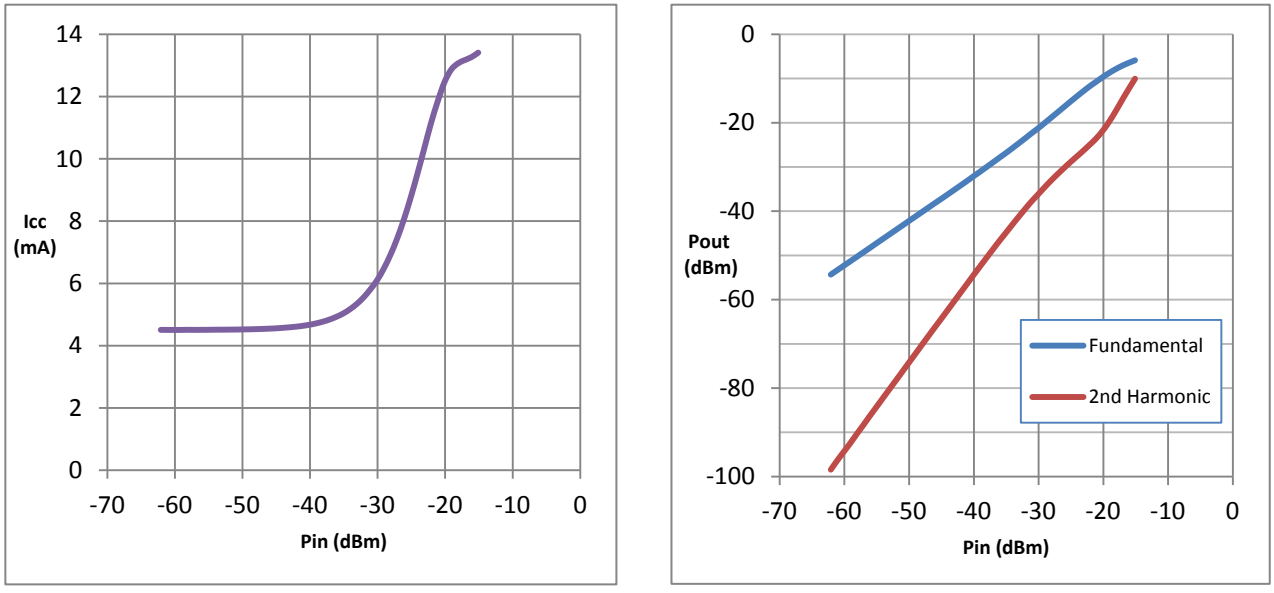
f_{harm} (2nd order) = $2f_1$ ~ GNSS band

Again specific to this note, an input frequency of 788 MHz produces a 2nd order harmonic in the GNSS band, at 1576 MHz. Figure 9 shows the level of the 2nd order harmonic as a function of input power of the 788 MHz tone, as well as collector current as a function of input power, for the BGU8007. Figure 10 provides the same information for the BGU7005.



a. Current vs Pin b. Pout vs. Pin

Fig 9. Single Tone Test Results f_1 = 788 MHz Baseline Match BGU8007 1.8V



a. Current vs. Pin b. Pout vs. Pin

Fig 10. Single Tone Test Results f_1 = 788 MHz Baseline Match BGU7005 1.8V

Figures 11 and 12 show the GNSS-band noise figure for a BGU8007 and BGU7005 sample, respectively. Note that these data are with no jammer signals present, and also include printed circuit board and SMA connector losses.

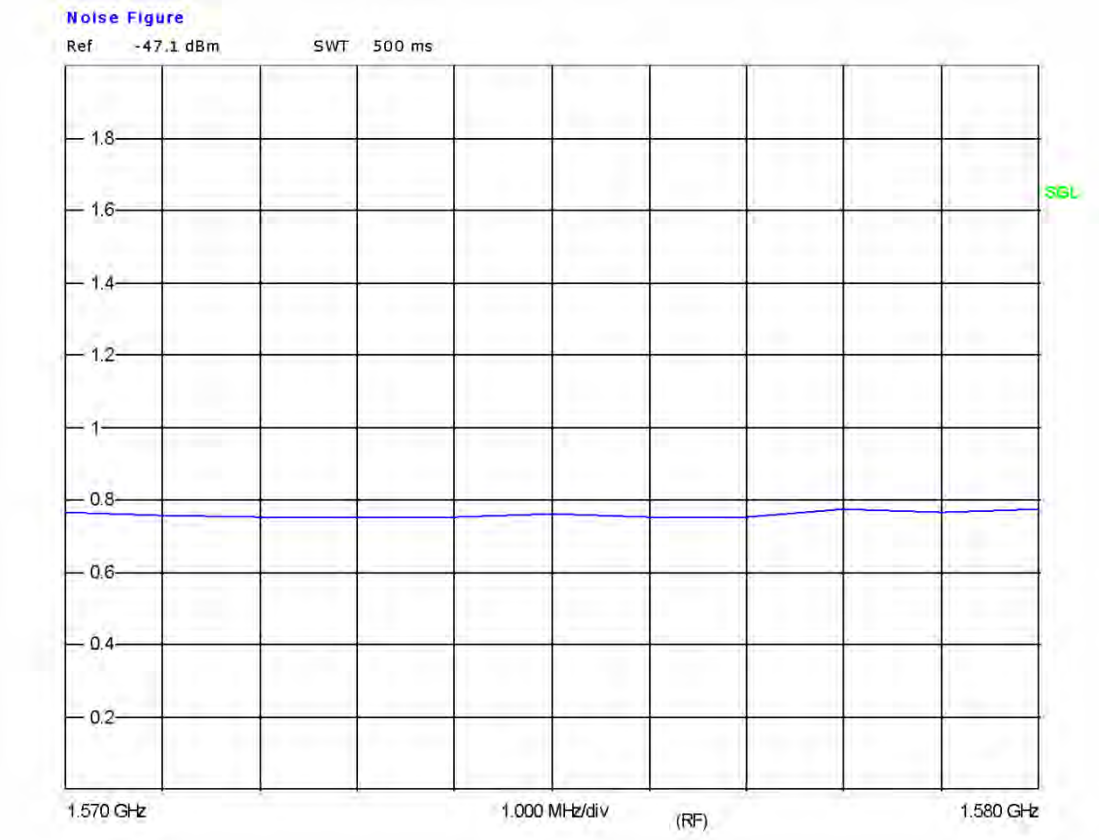


Fig 11. BGU8007 Baseline Match 1.8V

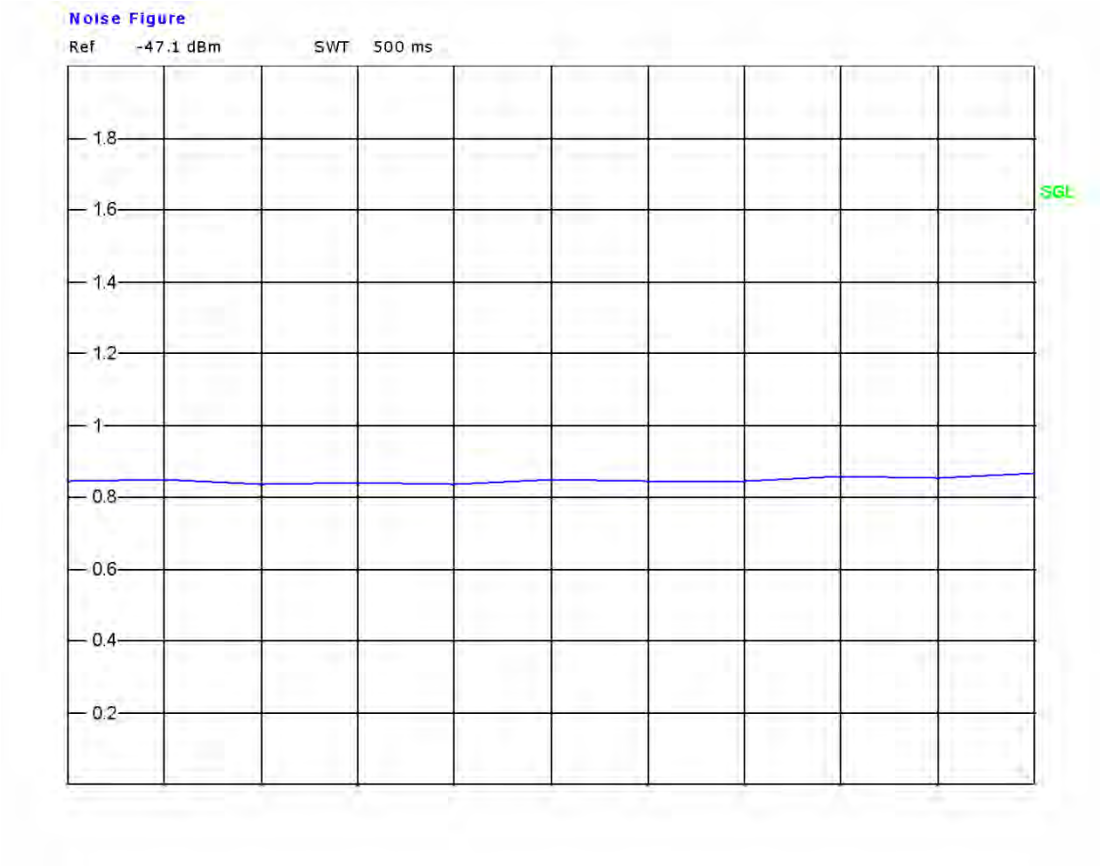


Fig 12. BGU7005 Baseline Match 1.8V

3. Input Match for LTE Jammer Immunity

To increase immunity to LTE band signals, the input match can be modified to a three-element topology, providing a gain null in the response of the LNA circuit at 700 MHz LTE band frequencies. The additional elements are a low cost chip capacitor and low cost chip inductor. See Figure 13 and Table 3 for schematic and bill of materials for the BGU8007, and Figure 14 and Table 4 for the BGU7005. Figure 15 shows the updated application board, with the location of the L1-C2 network.

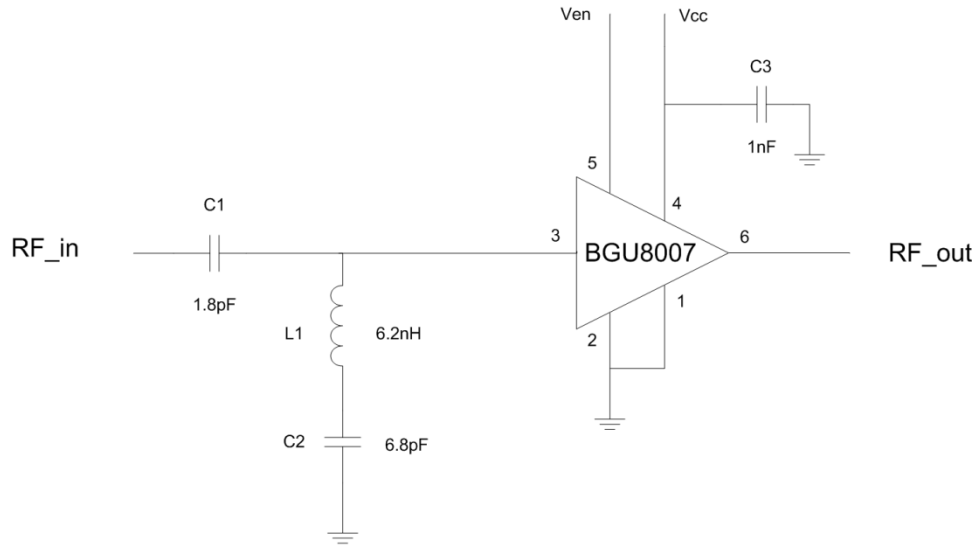


Fig 13. BGU8007 LTE Jammer Immunity Match Schematic

Table 3. List of Components for LTE Jammer Immunity Input Match BGU8007

For schematic see Figure 13

Component	Description	Value	Supplier
C1	Input Matching	1.8pF	Murata GJM15
L1	Input Matching	6.2nH	Murata LQW15
C2	Input Matching	6.8pF	Murata GRM15
C3	Decoupling Capacitor	1nF	Various
IC1	BGU8007	-	NXP

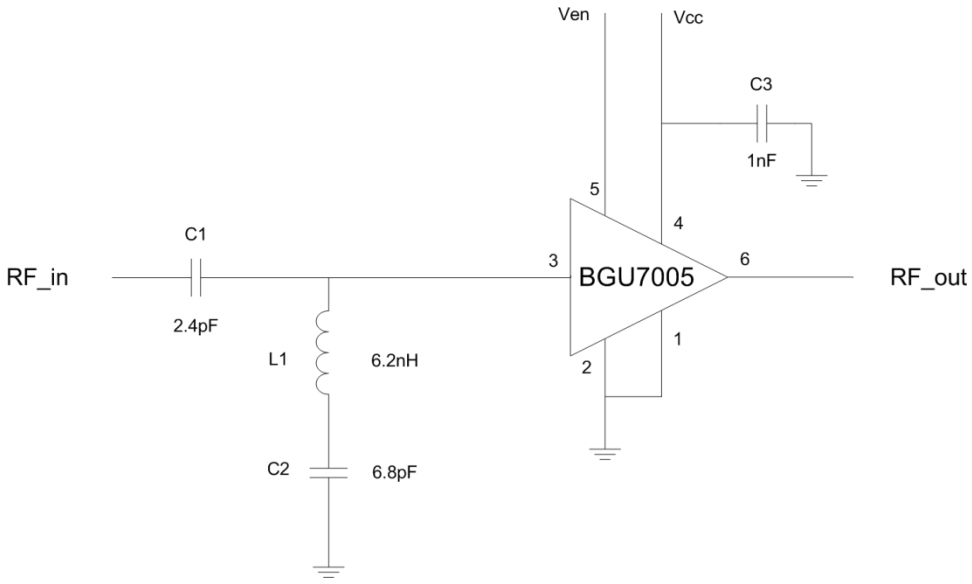


Fig 14. BGU7005 LTE Jammer Immunity Match Schematic

Table 4. List of Components for LTE Jammer Immunity Input Match BGU7005

For schematic see Figure 14

Component	Description	Value	Supplier
C1	Input Matching	2.4pF	Murata GJM15
L1	Input Matching	6.2nH	Murata LQW15
C2	Input Matching	6.8pF	Murata GRM15
C3	Decoupling Capacitor	1nF	Various
IC1	BGU7005	-	NXP

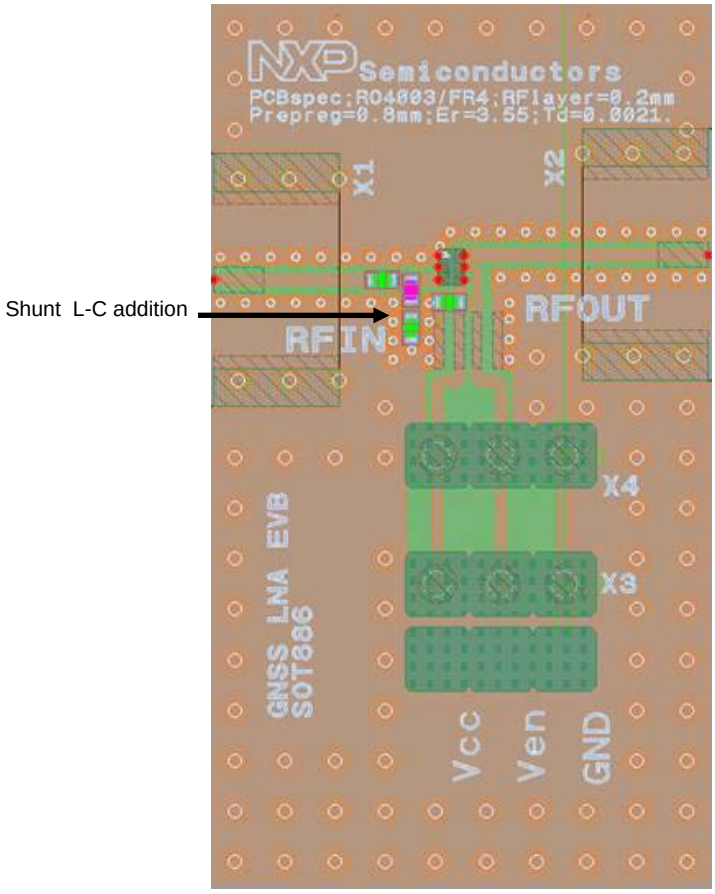
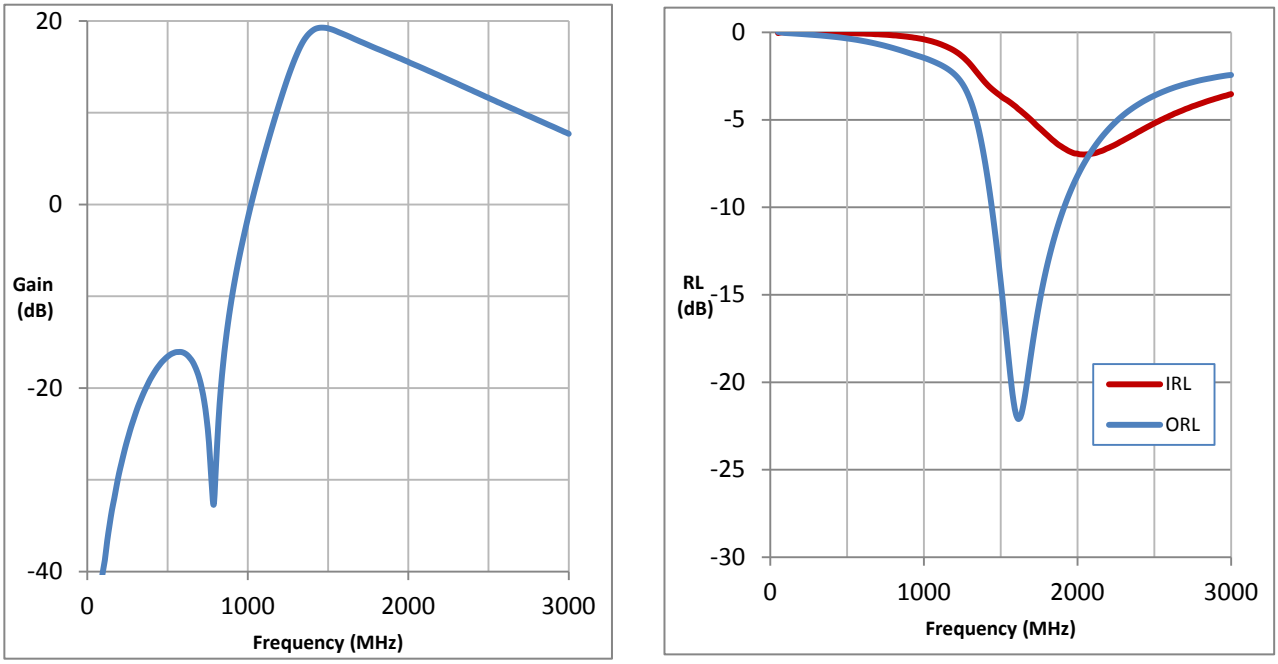


Fig 15. BGU8007/BGU7005 LTE Jammer Immunity Board Layout

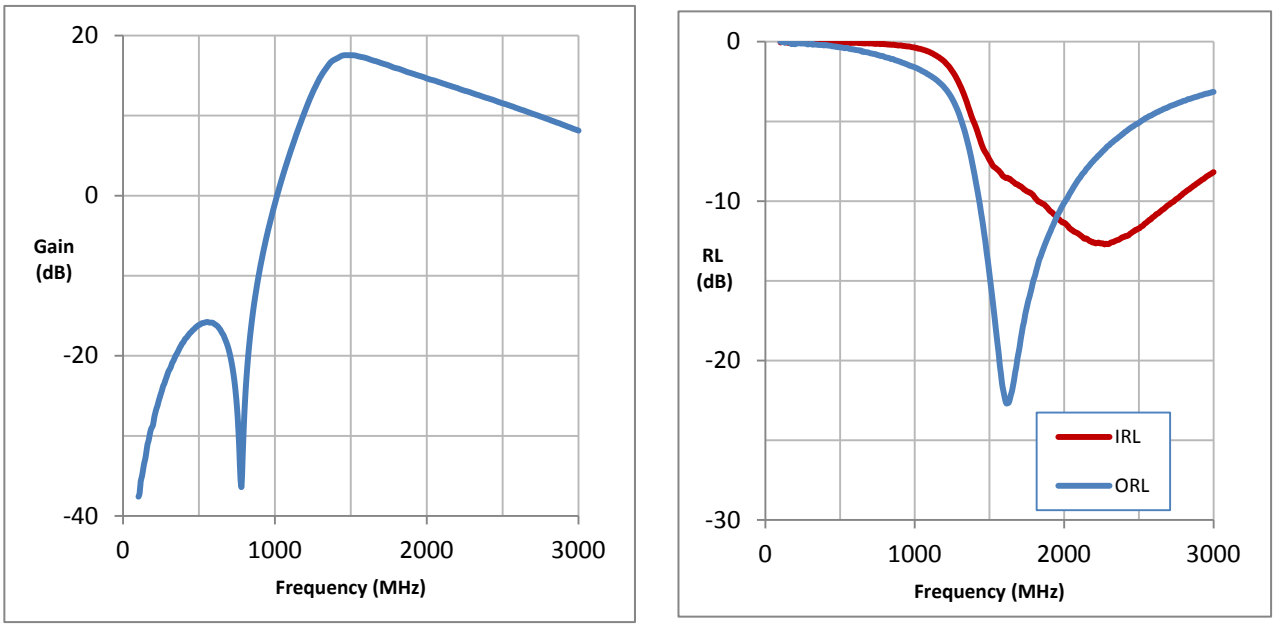
As can be seen in Figures 16 and 17 for the BGU8007 and BGU7005, respectively, the input match provides a gain null around 780 MHz. The gain null serves to reduce the level of 2nd order distortion in the GNSS band.



a. Gain vs. Frequency

b. Input and Output Return Loss vs. Frequency

Fig 16. Gain and Return Loss vs. Frequency LTE Jammer Immunity Match BGU8007 1.8V



a. Gain vs. Frequency

b. Input and Output Return Loss vs. Frequency

Fig 17. Gain and Return Loss vs. Frequency LTE Jammer Immunity Match BGU7005 1.8V

Figure 18 shows the test results for the two-tone test using the three-element jammer immunity match for the BGU8007. Compared to the baseline case, the level of the 2nd order spurious product is greatly reduced and the part remains at the quiescent current level for much higher input power levels. For instance, for a single tone input power of -30 dBm, the 2nd order spurious product is measured as -104 dBm, compared to -42 dBm for the baseline configuration. Figure 19 shows the test results for the BGU7005.

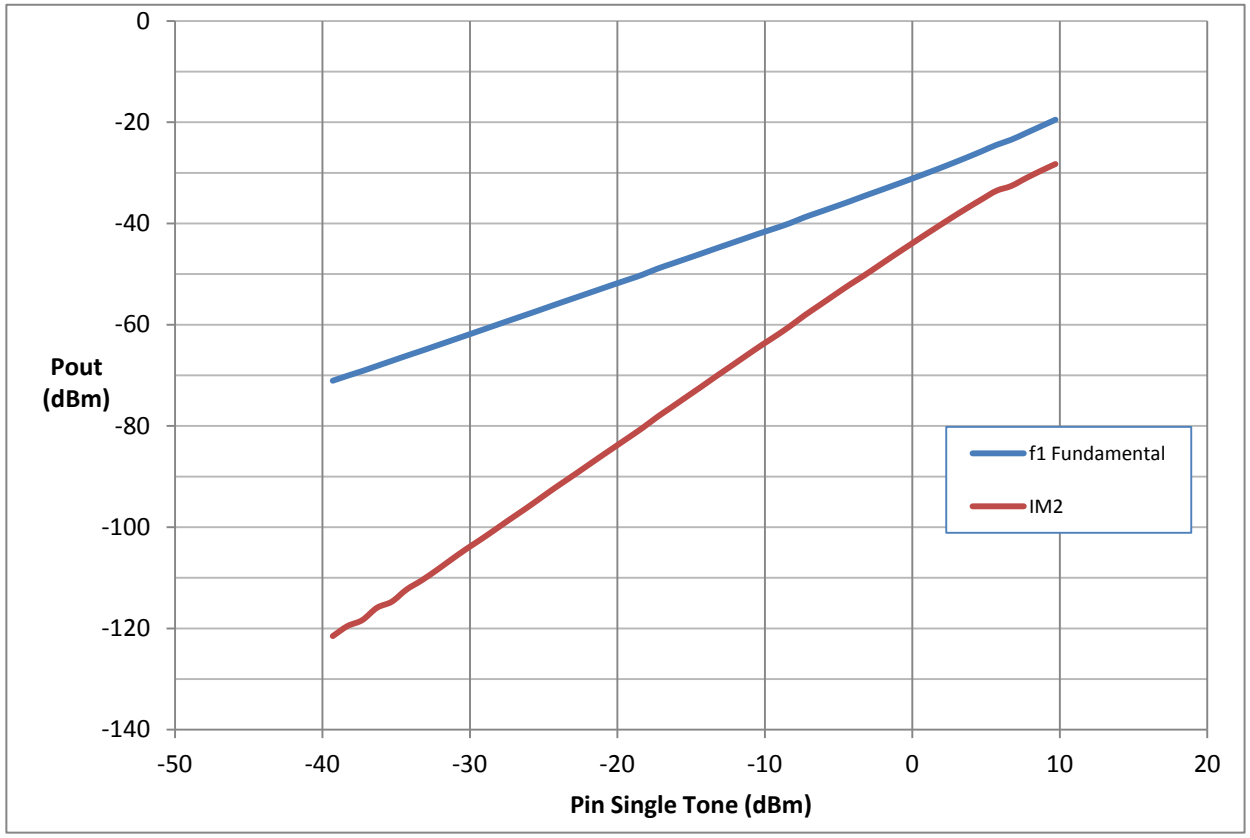


Fig 18. Two-Tone Test Results (f_1 = 787.4 MHz, f_2 = 788 MHz, f_{spur} = 1575. MHz) LTE Jammer Immunity Match BGU8007 1.8V

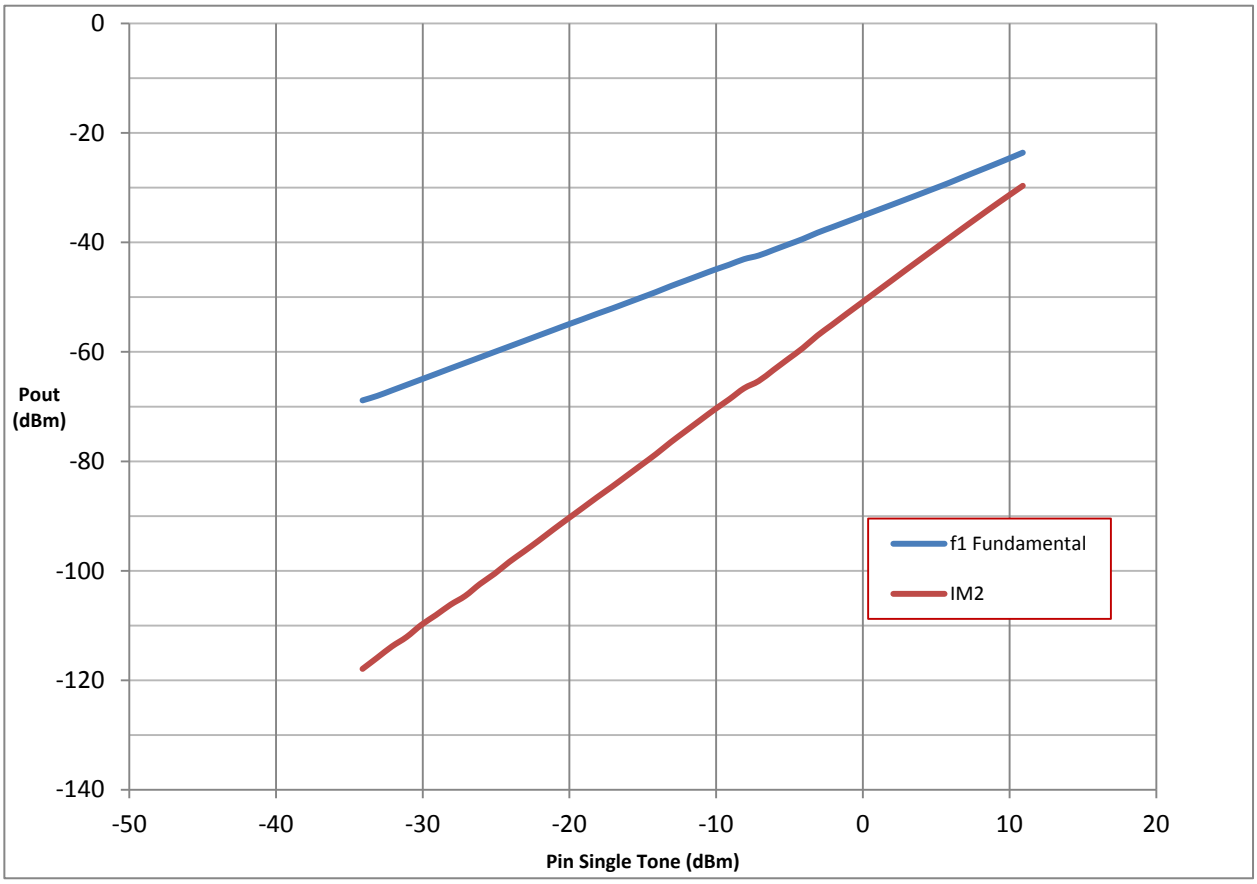
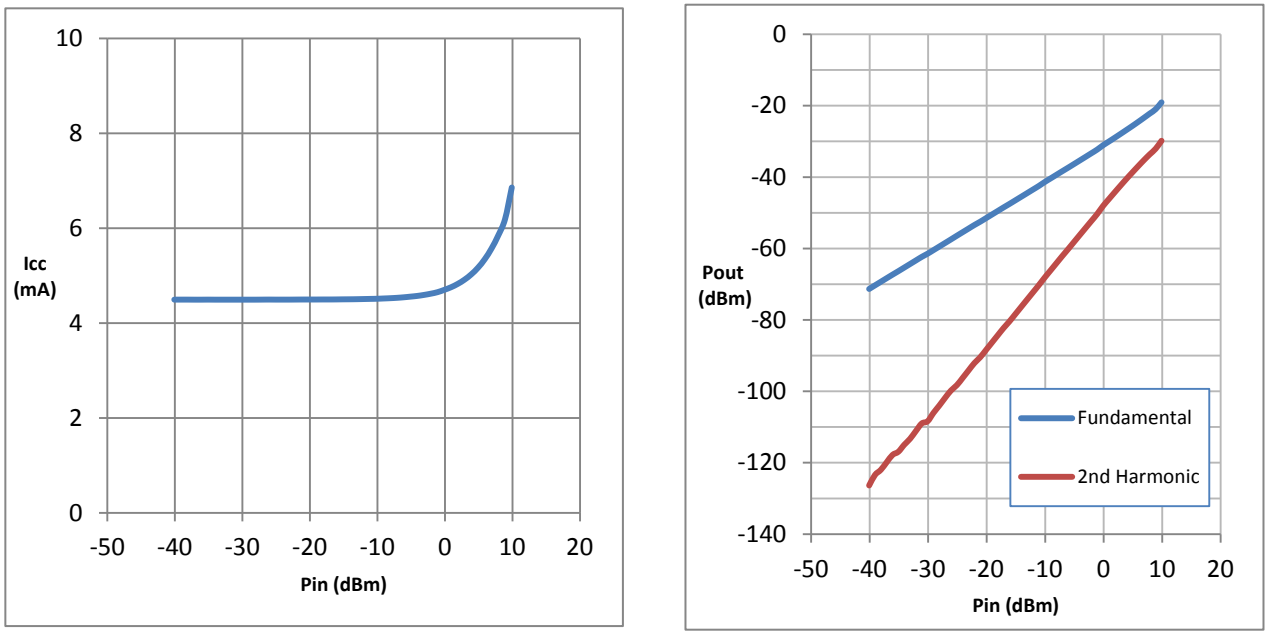


Fig 19. Two-Tone Test Results (f_1 = 787.4 MHz, f_2 = 788 MHz, f_{spur} = 1575.4 MHz) LTE Jammer Immunity Match BGU7005 1.8V

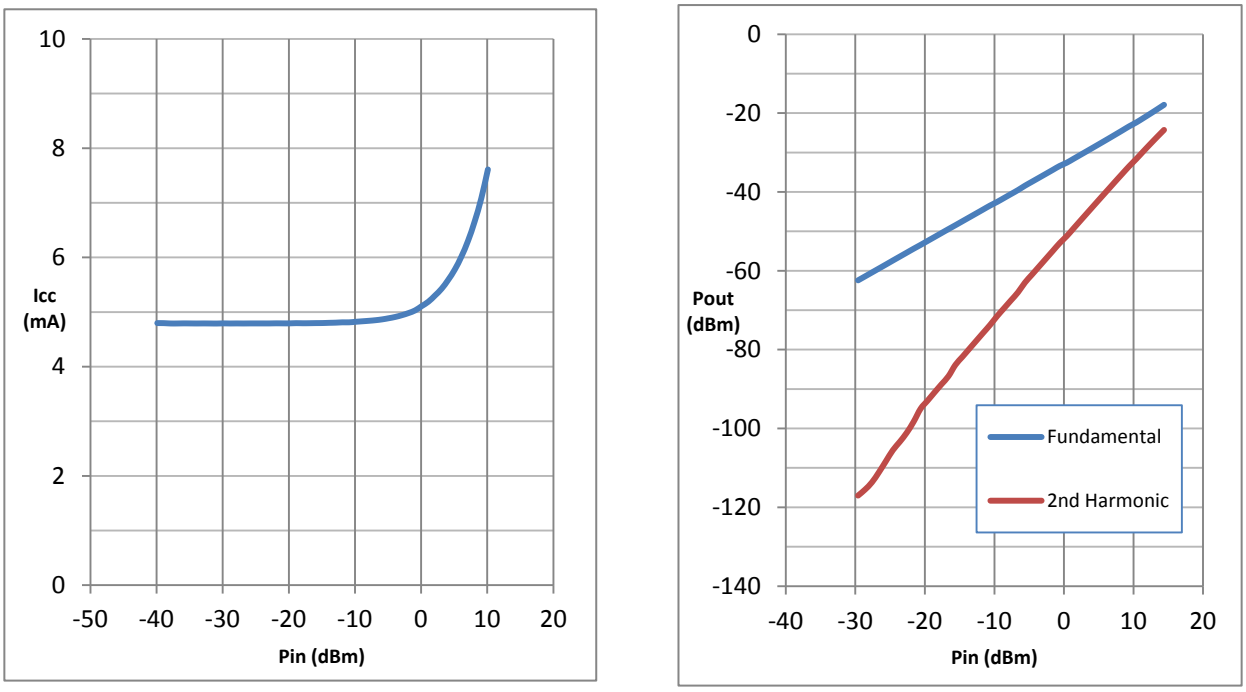
Figure 20 shows the 2nd harmonic level as well as the collector current draw as a function of 788 MHz input power (single tone input) for the BGU8007 with the jammer immunity match. As with the 2nd order spurious product from the two-tone test, the 2nd order harmonic product from the single tone test is drastically reduced compared to the baseline case. For -30 dBm input power, the 2nd order harmonic is measured as -108 dBm compared to -38 dBm for the baseline. Figure 21 shows the 2nd harmonic plot for the BGU7005. Also note from the figures that the 788 MHz input power must be greater than 0 dBm for the current draw of the devices to move appreciably above their quiescent levels.



a. Current vs. Pin

b. Pout vs. Pin

Fig 20. Single Tone Test Results f_1 = 788 MHz LTE Jammer Immunity Match BGU8007 1.8V



a. Current vs. Pin

b. Pout vs. Pin

Fig 21. Single Tone Test Results f_1 = 788 MHz LTE Jammer Immunity Match BGU7005 1.8V

Finally, Figure 22 shows the noise figure for a BGU8007 sample with the 3-element LTE jammer immunity match. There is some slight degradation in noise figure due to additional components on the input of the MMIC. Figure 23 shows the NF result for a BGU7005 sample. As with the baseline case, these noise figure data include board and connector losses, and are taken with no jammer present.

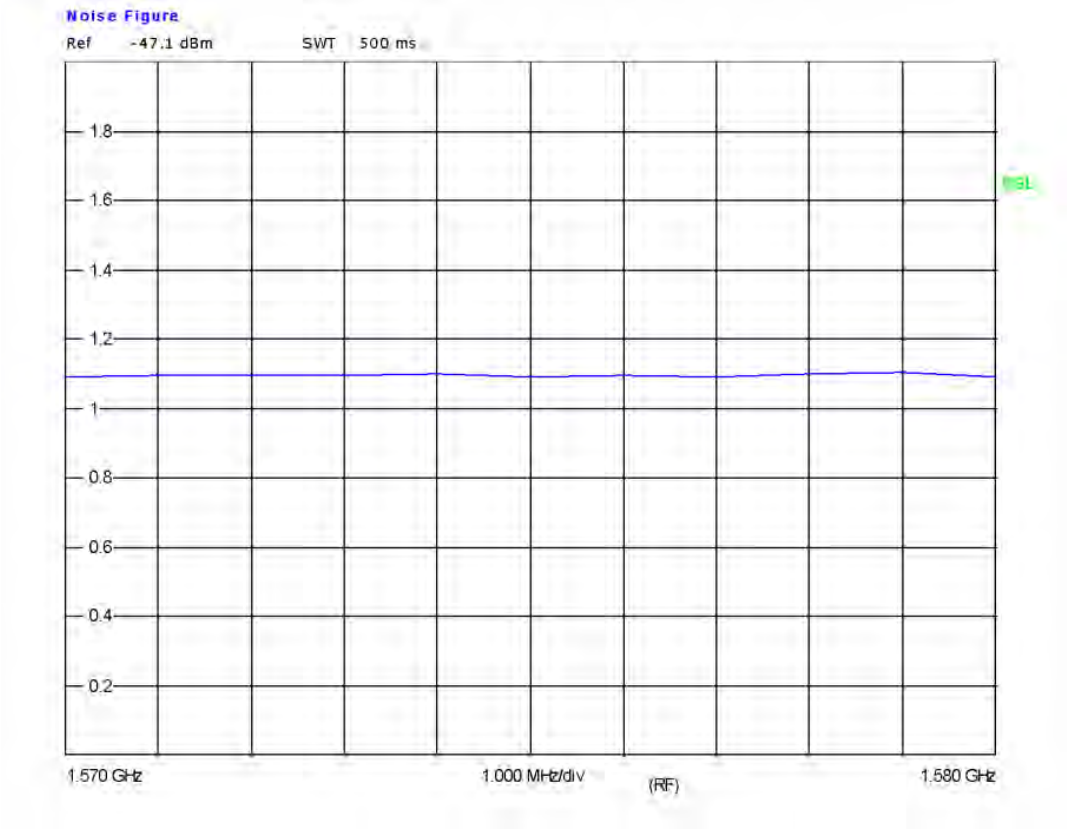


Fig 22. BGU8007 LTE Jammer Immunity Match 1.8V

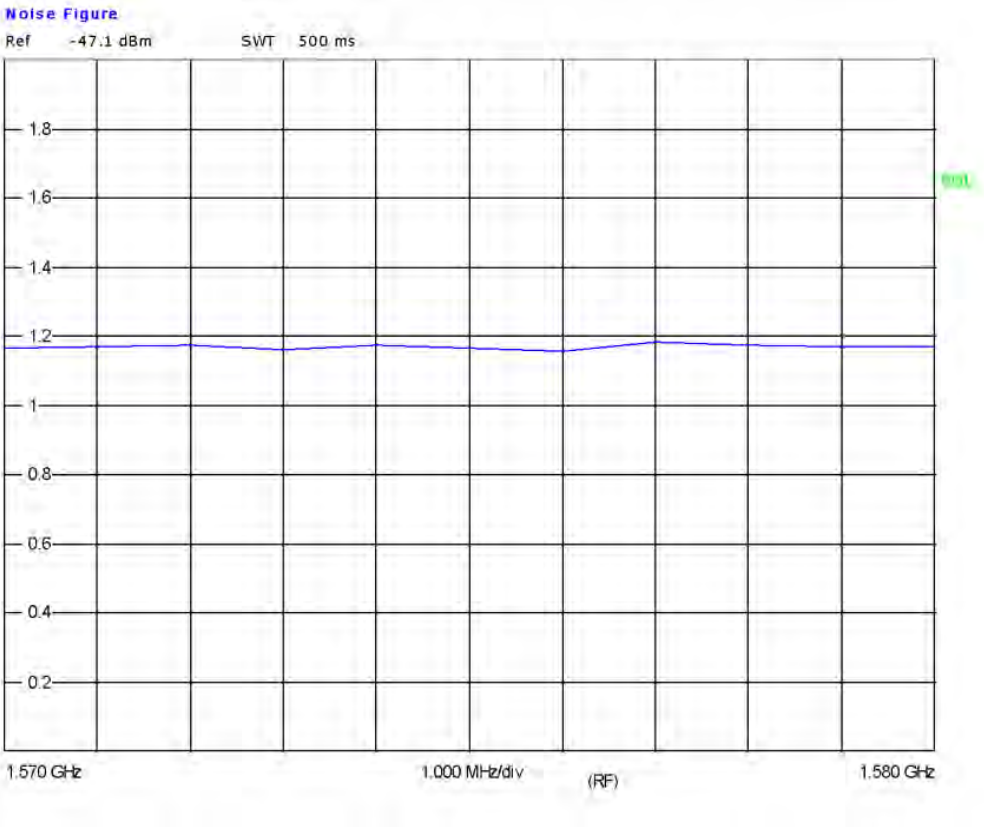


Fig 23. BGU7005 LTE Jammer Immunity Match 1.8V

4. Two-element Compromise Input Match

The 3-element matching option outlined in Section 3 provides the best-case performance in cases where 2nd order distortion performance of a 700 MHz band jammer(s) is paramount, whereas the baseline match provides the simplest solution and lowest noise figure. In cases where component count or board space is critical, yet 700 MHz 2nd order distortion performance is still a concern, the input match can be modified to a 2-element high-pass topology. This “series-C shunt-L” topology decreases the gain of the LNA circuit in the 700 MHz LTE-band, but not as much as the 3-element jammer immunity solution. Please see Figure 24 and Table 5 for the 2-element compromise match schematic and bill of materials for the BGU8007. Figure 25 and Table 6 show the schematic and bill of materials for the BGU7005.

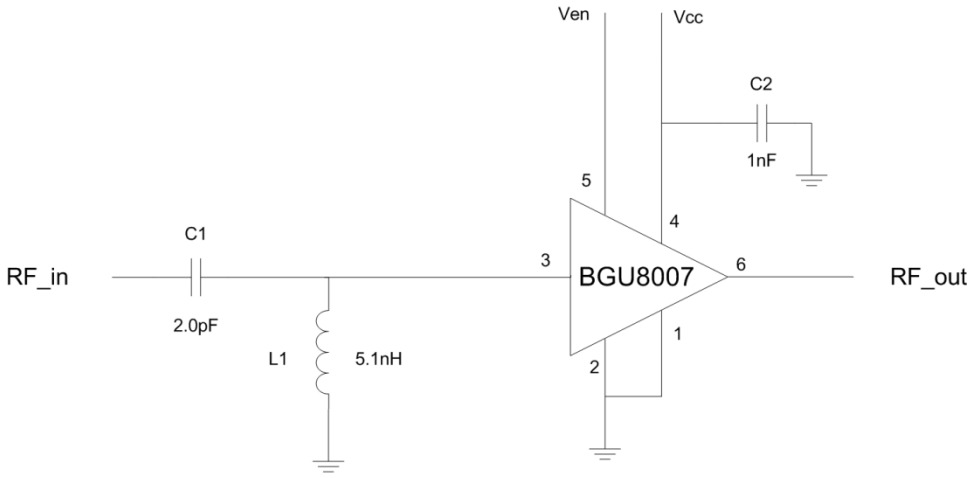


Fig 24. BGU8007 Two-element Match Schematic

Table 5. List of Components for Two Element Input Match BGU8007

For schematic see Figure 24

Component	Description	Value	Supplier
C1	Input Matching	2.0pF	Murata GJM15
L1	Input Matching	5.1nH	Murata LQW15
C2	Decoupling Capacitor	1nF	Various
IC1	BGU8007	-	NXP

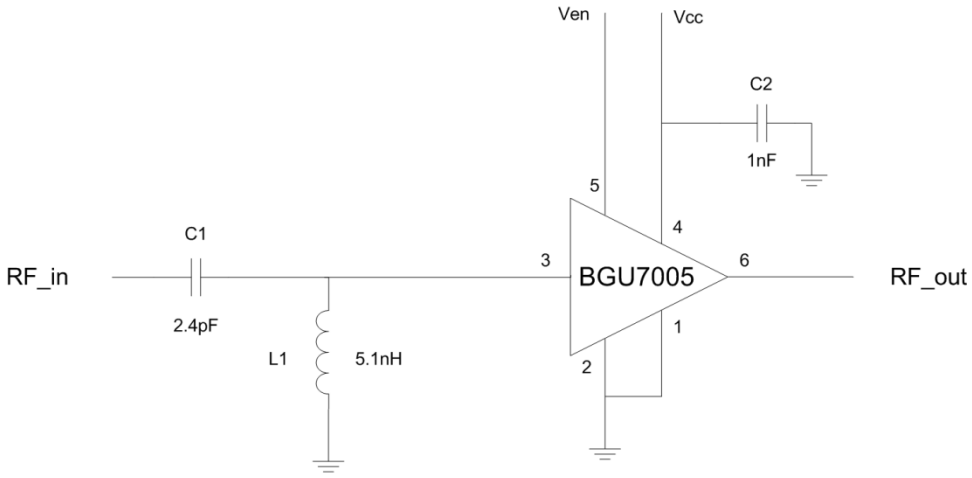


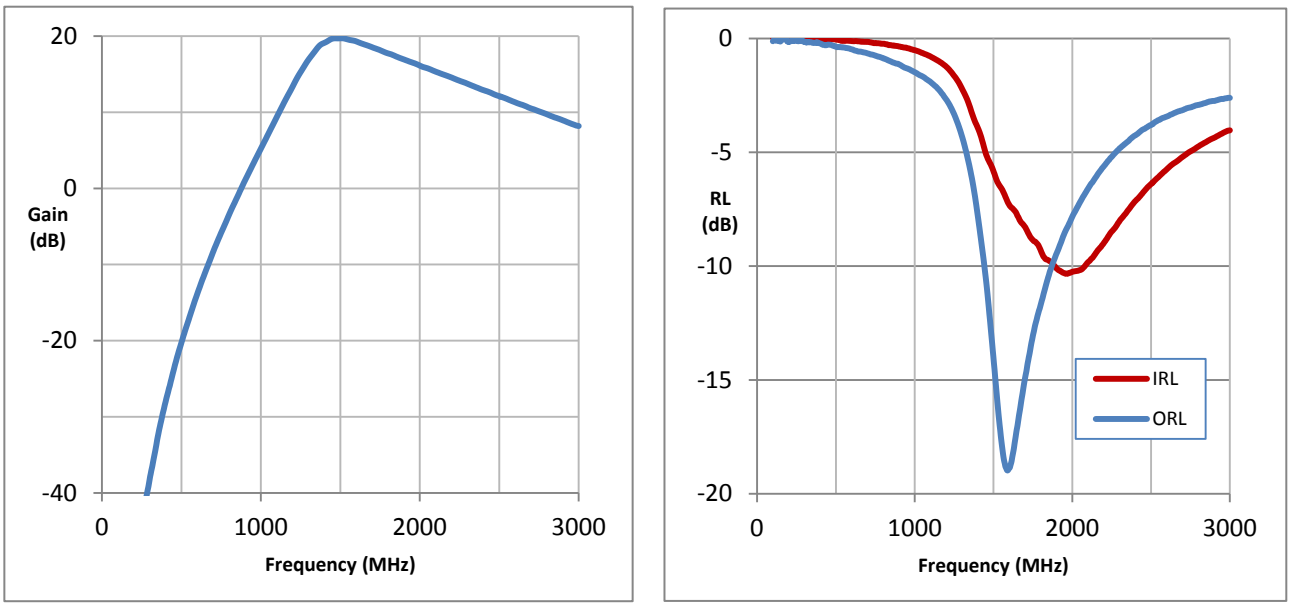
Fig 25. BGU7005 Two-element Match Schematic

Table 6. List of Components for Two Element Input Match BGU7005

For schematic see Figure 25

Component	Description	Value	Supplier
C1	Input Matching	2.4pF	Murata GJM15
L1	Input Matching	5.1nH	Murata LQW15
C2	Decoupling Capacitor	1nF	Various
IC1	BGU7005	-	NXP

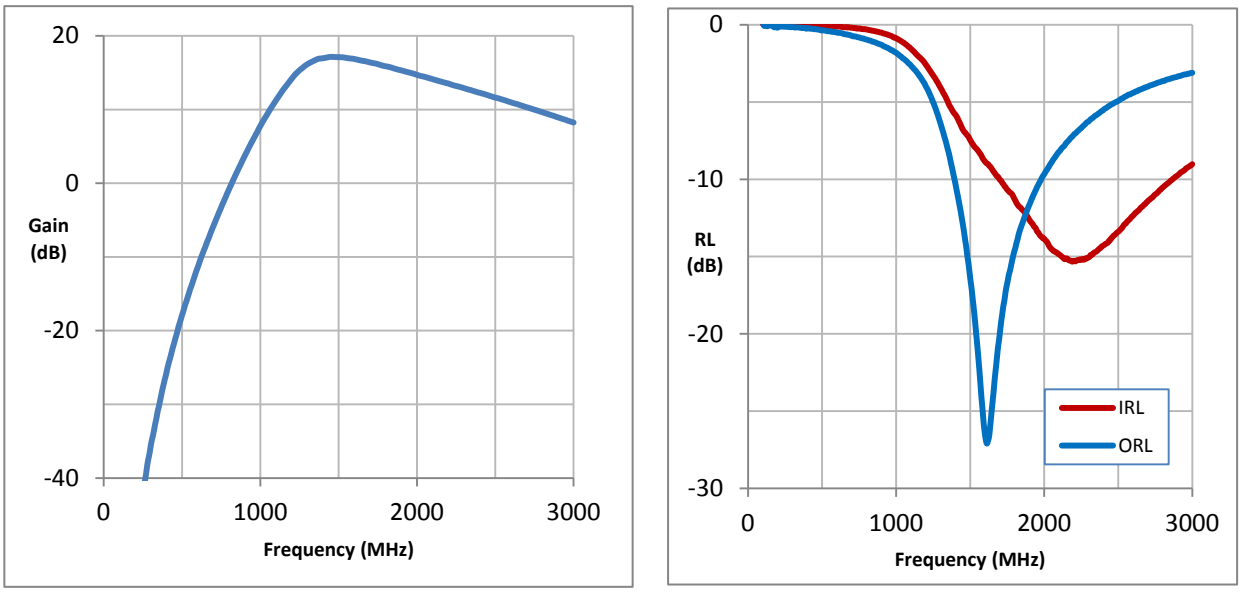
This alternative steepens the gain roll-off below the GNSS band but does not provide a gain null. Figures 26 and 27 show the broadband gain response, plus the input and output return loss of the part for the two-element input match case for the BGU8007 and BGU7005, respectively.



a. Gain vs. Frequency

b. Input and Output Return Loss vs. Frequency

Fig 26. Gain and Return Loss vs. Frequency Two-Element Match BGU8007 1.8V



a. Gain vs. Frequency

b. Input and Output Return Loss vs Frequency

Fig 27. Gain and Return Loss vs. Frequency Two-Element Match BGU7005 1.8V

Figures 28 through 31 show the test results for the two-tone and single-tone tests using the two-element match for both the BGU8007 and BGU7005. The second order distortion products are reduced compared to the baseline case, but not as much as with the 3-element jammer immunity match. For instance, the 2nd order harmonic product for the BGU8007 single-tone test case is measured as -53 dBm compared to -38 dBm for the baseline.

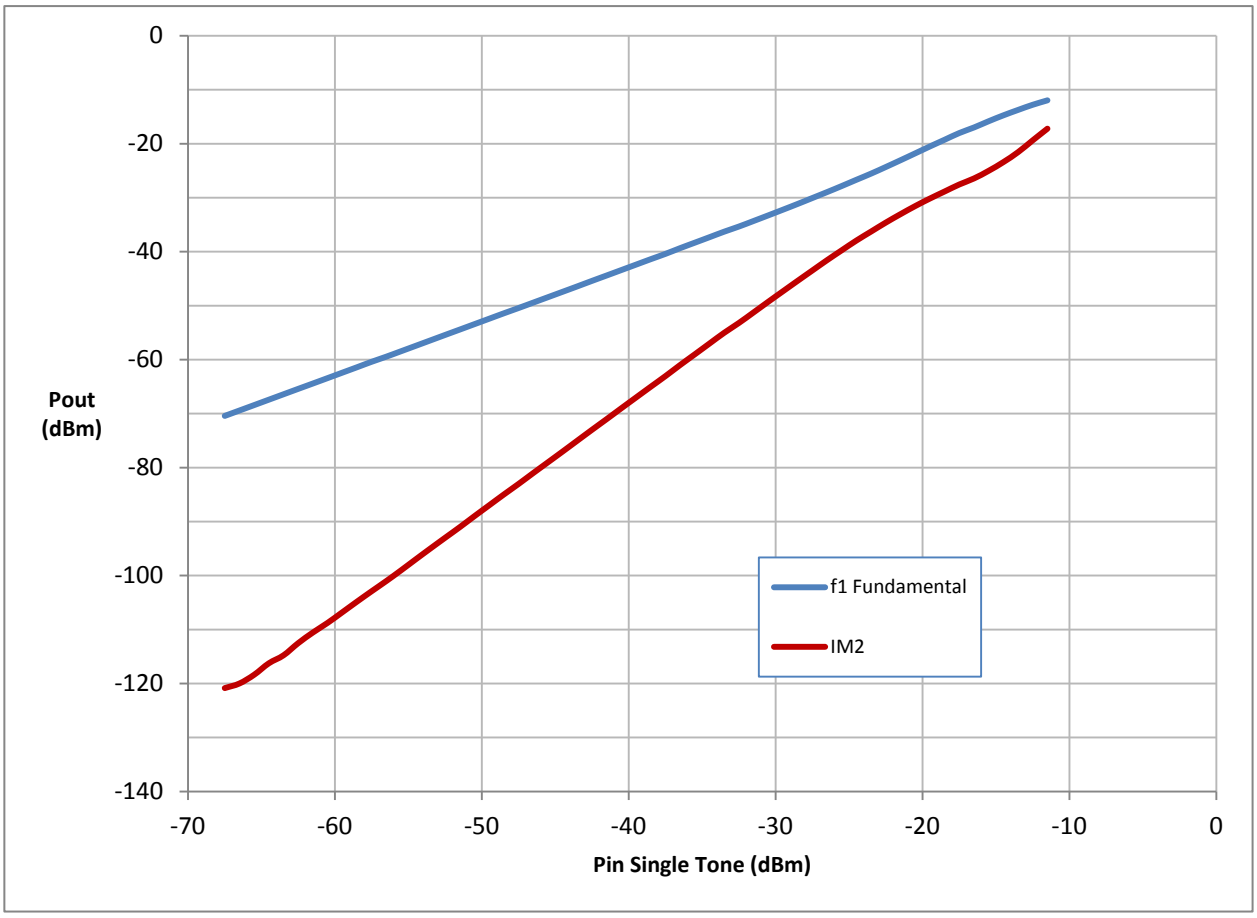


Fig 28. Two Tone Test Results (f_1 = 787.4 MHz, f_2 = 788 MHz, f_{spur} = 1575.4 MHz) 2-element Match BGU8007 1.8V

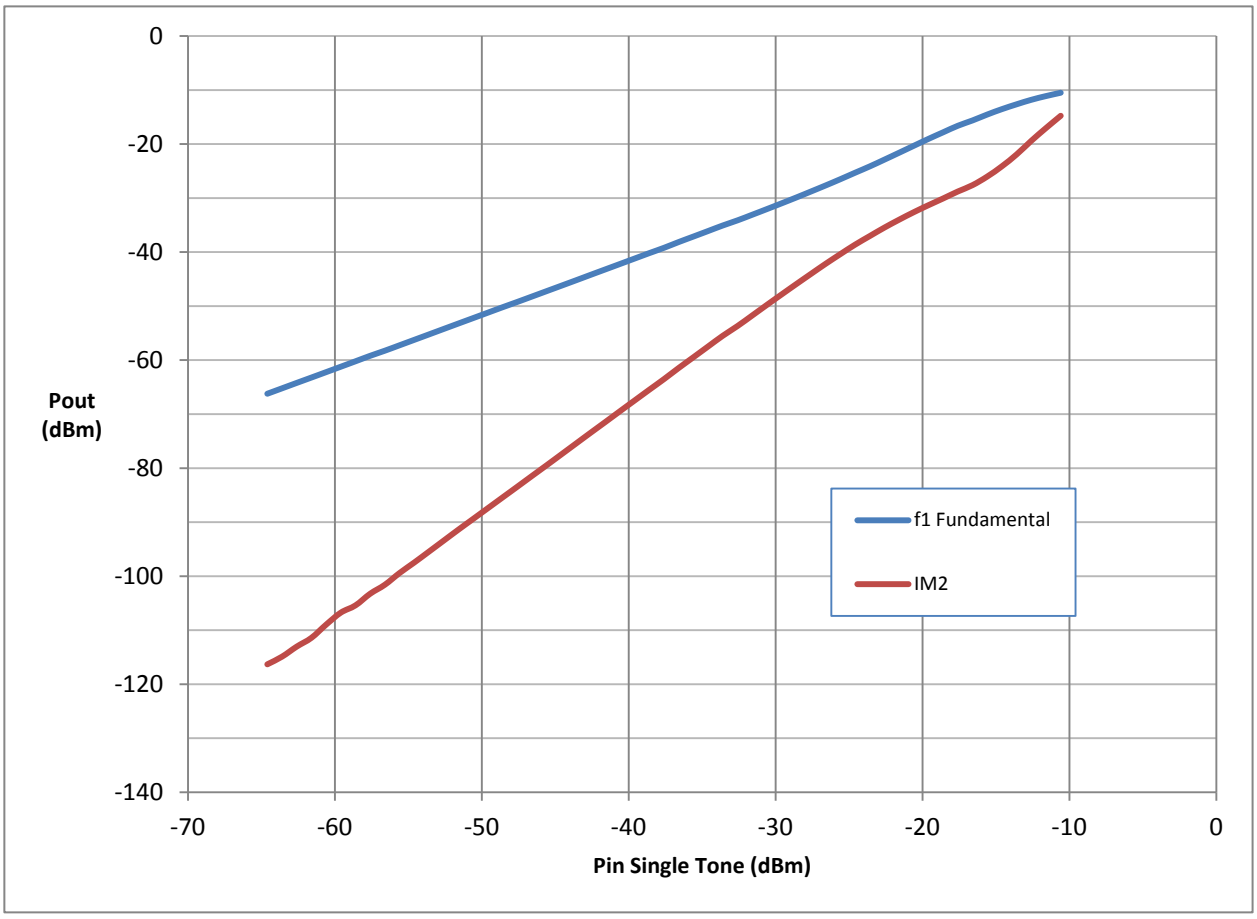
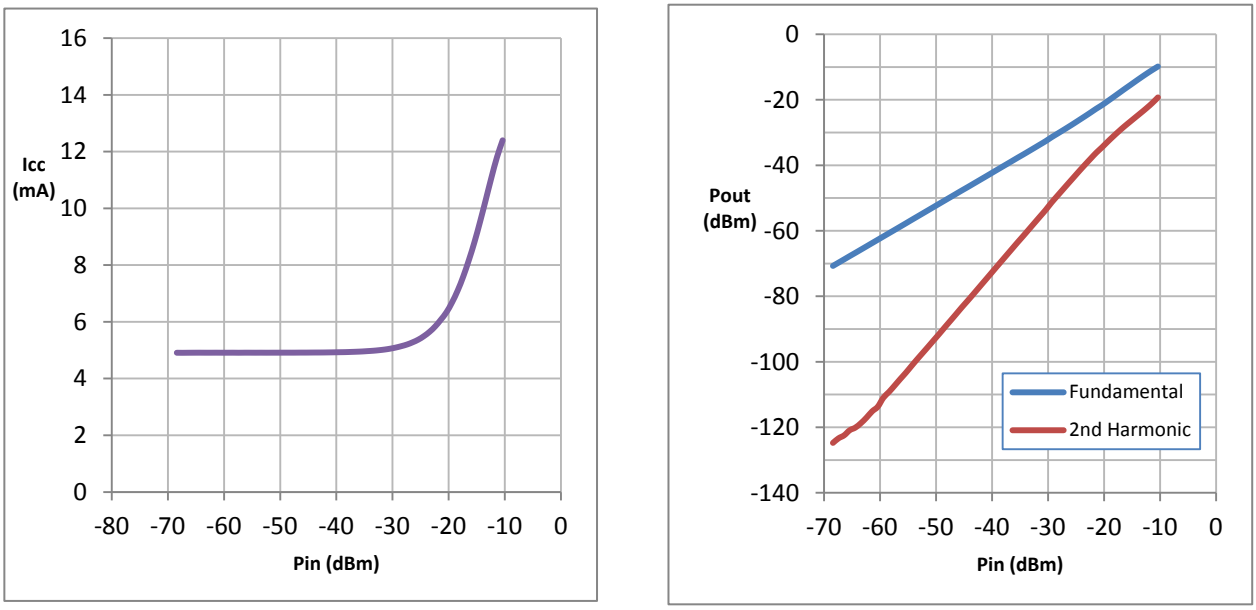


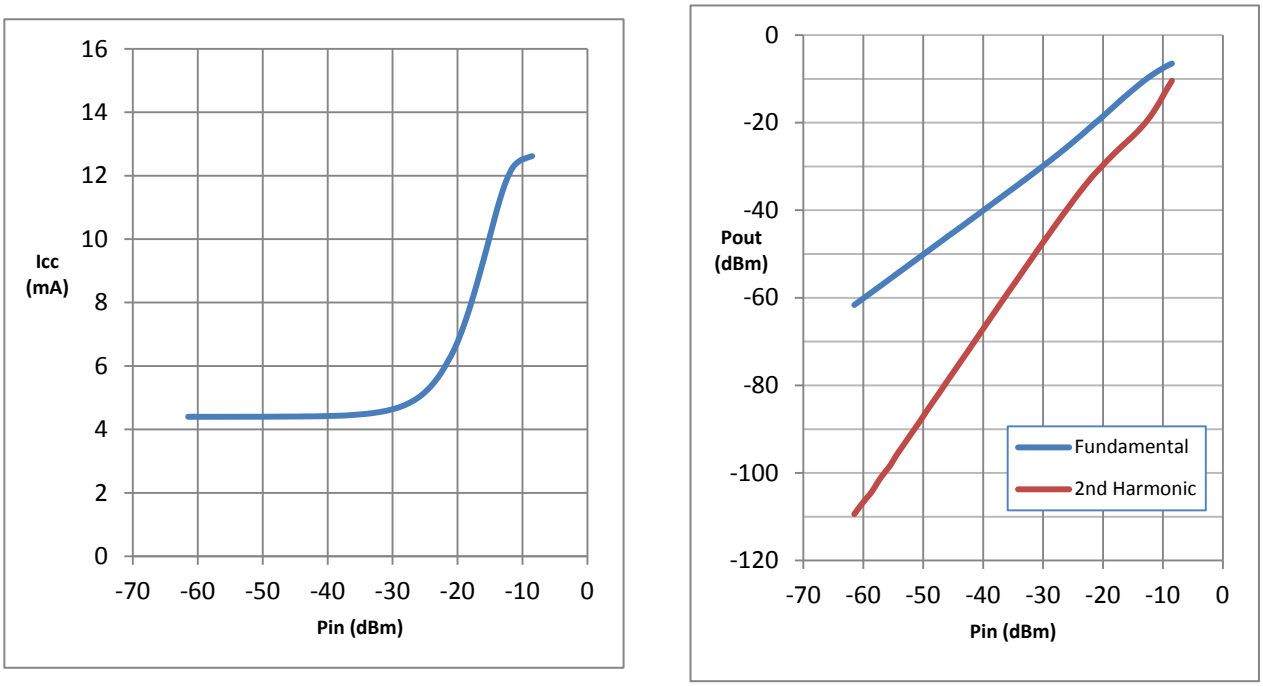
Fig 29. Two Tone Test Results (f_1 = 787.4 MHz, f_2 = 788 MHz, f_{spur} = 1575.4 MHz) 2-element Match BGU7005 1.8V



a. Current vs. Pin

b. Pout vs. Pin

Fig 30. Single Tone Test Results f_1 = 788 MHz 2-element Match BGU8007 1.8V



a. Current vs. Pin

b. Pout vs. Pin

Fig 31. Single Tone Test Results f_1 = 788 MHz 2-element Match BGU7005 1.8V

Figures 32 and 33 show the GNSS-band noise figure for the BGU8007 and BGU7005 with the 2-element compromise input match.

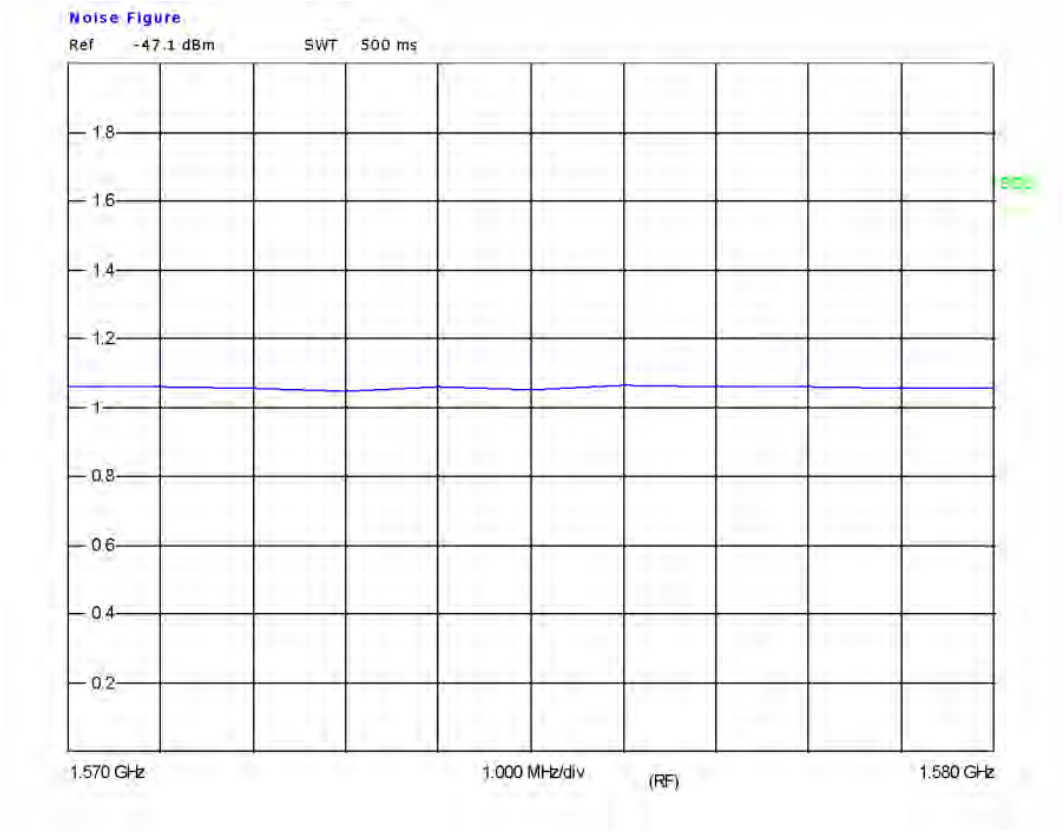


Fig 32. BGU8007 2-element Match 1.8V

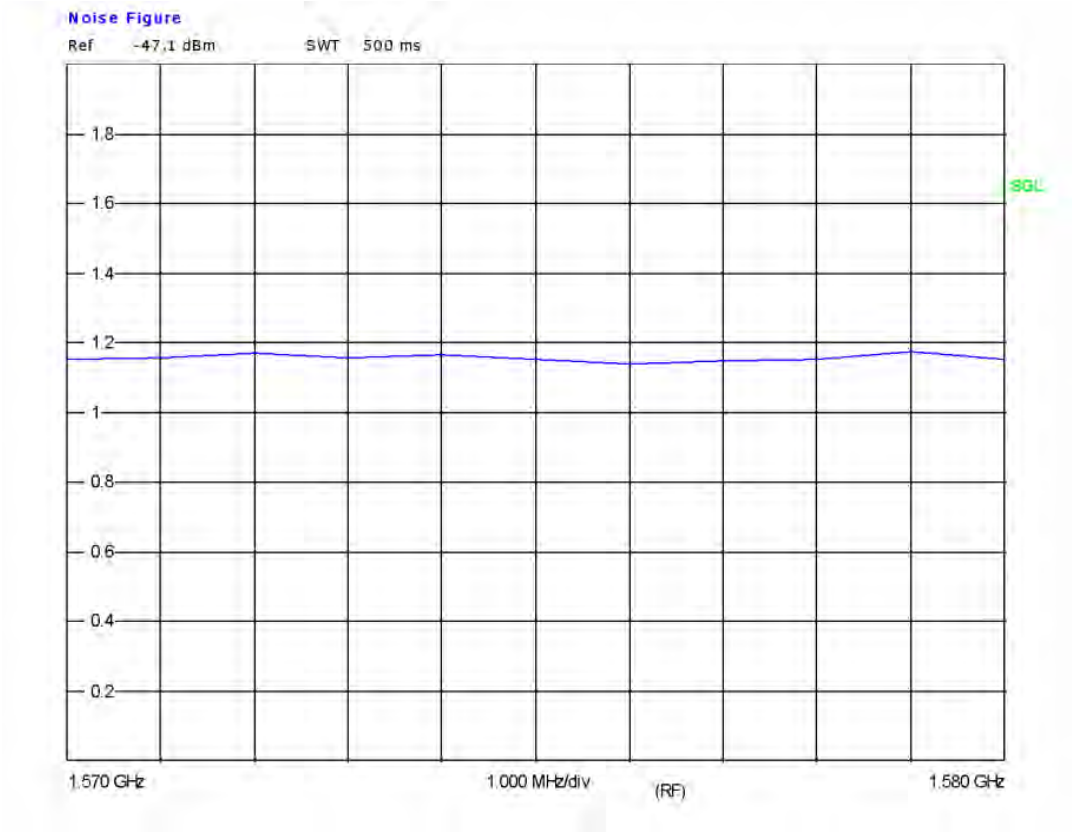


Fig 33. BGU7005 2-element Match 1.8V

5. Conclusion

By changing the input matching topology of NXP's GNSS LNAs, the gain of the circuit in the 700 MHz LTE band can be significantly reduced while leaving the in-band gain nearly unaltered. This can be accomplished with the addition of one or two low cost, readily available lumped element components. This has the effect of increasing the immunity to jamming signals in this band, at the expense of noise figure, which increases slightly due to having additional components at the input of the device. To further quantify, Tables 7 and 8 below show results for the BGU8007 and BGU7005, respectively, for the case of a 788 MHz jamming signal at a level of -25 dBm at the LNA input. Finally, note that while the 7th generation BGU7005 and 8th generation BGU8007 are presented here as examples, these techniques are applicable to the entire family of NXP GNSS LNAs.

Table 7. LTE Band 2nd Harmonic BGU8007

Vcc = 1.8V 2nd Order Harmonic Level for Pin = -25 dBm 788 MHz

Matching Option	Gain 788 MHz	Gain 1576 MHz	Input Referred 2nd Harmonic Level	Noise Figure* 1576 MHz
Baseline	7.7 dB	19.0 dB	-48 dBm	0.75 dB
LTE Jammer Immunity	-33 dB	19.7 dB	-119 dBm	1.10 dB
Two-Element Compromise	-4.0 dB	19.2 dB	-61 dBm	1.05 dB

Table 8. LTE Band 2nd Harmonic BGU7005

Vcc = 1.8V 2nd Order Harmonic Level for Pin = -25 dBm 788 MHz

Matching Option	Gain 788 MHz	Gain 1576 MHz	Input Referred 2nd Harmonic Level	Noise Figure* 1576 MHz
Baseline	9.0 dB	16.5 dB	-46 dBm	0.85 dB
LTE Jammer Immunity	-32 dB	17.4 dB	-122 dBm	1.15 dB
Two-Element Compromise	-2.4 dB	16.9 dB	-60 dBm	1.15 dB

* Includes board and connector losses, no jammer present

6. Legal information

6.1 Definitions

Draft — The document is a draft version only. The content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included herein and shall have no liability for the consequences of use of such information.

6.2 Disclaimers

Limited warranty and liability — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information.

In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Terms and conditions of commercial sale of NXP Semiconductors.

Right to make changes — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

Suitability for use — NXP Semiconductors products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of an NXP Semiconductors product can reasonably be expected to result in personal injury, death or severe property or environmental damage. NXP Semiconductors accepts no liability for inclusion and/or use of NXP Semiconductors products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

Applications — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

Export control — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from national authorities.

Evaluation products — This product is provided on an "as is" and "with all faults" basis for evaluation purposes only. NXP Semiconductors, its affiliates and their suppliers expressly disclaim all warranties, whether express, implied or statutory, including but not limited to the implied warranties of non-infringement, merchantability and fitness for a particular purpose. The entire risk as to the quality, or arising out of the use or performance, of this product remains with customer.

In no event shall NXP Semiconductors, its affiliates or their suppliers be liable to customer for any special, indirect, consequential, punitive or incidental damages (including without limitation damages for loss of business, business interruption, loss of use, loss of data or information, and the like) arising out the use of or inability to use the product, whether or not based on tort (including negligence), strict liability, breach of contract, breach of warranty or any other theory, even if advised of the possibility of such damages.

Notwithstanding any damages that customer might incur for any reason whatsoever (including without limitation, all damages referenced above and all direct or general damages), the entire liability of NXP Semiconductors, its affiliates and their suppliers and customer's exclusive remedy for all of the foregoing shall be limited to actual damages incurred by customer based on reasonable reliance up to the greater of the amount actually paid by customer for the product or five dollars (US$5.00). The foregoing limitations, exclusions and disclaimers shall apply to the maximum extent permitted by applicable law, even if any remedy fails of its essential purpose.

6.3 Trademarks

Notice: All referenced brands, product names, service names and trademarks are property of their respective owners.

7. List of figures

8. List of tables

9. Contents

For more information, visit: http://www.nxp.com
For sales office addresses, please send an email to: salesaddresses@nxp.com

Date of release: 30 May 2012
Document identifier: AN11068