AN11068

BGU7005 matching options for improved LTE jammer immunity

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Document information

Info	Content
Keywords	LNA, GNSS, GPS, BGU7005
Abstract	Describes several matching topologies for the BGU7005 LNA. These topologies provide additional immunity to 700 MHz LTE band jammers.

Revision history

Rev	Date	Description
1	20110719	initial version

Contact information

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1. Introduction

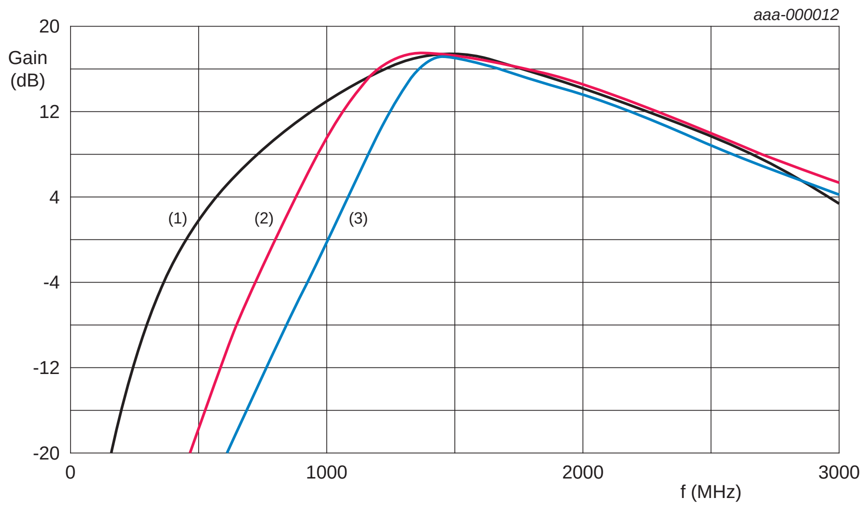
The BGU7005 is a Low-Noise Amplifier (LNA) intended for Global Navigation Satellite System (GNSS) receiver applications. It is manufactured using NXP Semiconductors' advanced 110 GHz SiGe:C process and is offered in a plastic leadless 6-pin SOT886 package. The IC contains an RF stage which is supplied with an enable function allowing it to be controlled by a logic signal. The integrated biasing circuit is temperature stabilized and can operate from a 1.5 V to 2.85 V single supply, typically drawing less than 5 mA. The BGU7005 has a product datasheet and several supporting user manuals which are listed below.

- BGU7005 datasheet: SiGe:C LNA MMIC for GPS
- 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)

Only two external components are required to build the baseline BGU7005 application circuit: a decoupling capacitor on the collector feed and a low-cost series inductor for RF input matching. The IC's output is internally matched for GNSS frequencies. This application note outlines additional options for modifying the input match to provide increased immunity for the LNA in the presence of LTE band signals.

The baseline match of the BGU7005 provides high gain, low current consumption, high linearity, and best noise figure. In the specific case of operating the 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 one or two additional low-cost components to the input match in order to provide faster gain roll-off below GNSS bands. This technique can potentially reduce or alleviate the need for relatively high-cost filtering in the system.

Figure 1 shows the broadband gain performance of the BGU7005 with its baseline 1-element, 2-element, and 3-element input match. As can be seen, adding additional elements decreases the gain of the circuit in the 700 MHz LTE band, resulting in increased jammer immunity.



(1) 1 element.

(2) 2 element.

(3) 3 element.

Fig 1. Gain roll-off comparison for one-, two-, and three-element matching options

2. Baseline single-element performance match

The standard BGU7005 evaluation board is supplied with a Murata LQG15 series inductor (0402 size). This type of high quality factor (Q) inductor is recommended in order to provide best noise performance. Figure 2 and Table 1 show the schematic and bill of materials for the BGU7005 baseline circuit. The broadband gain and input/output return loss are shown in Figure 3.

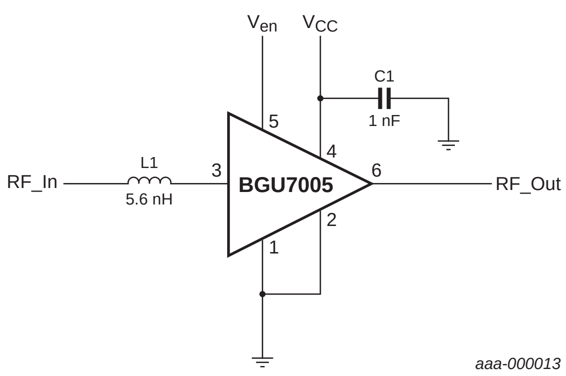
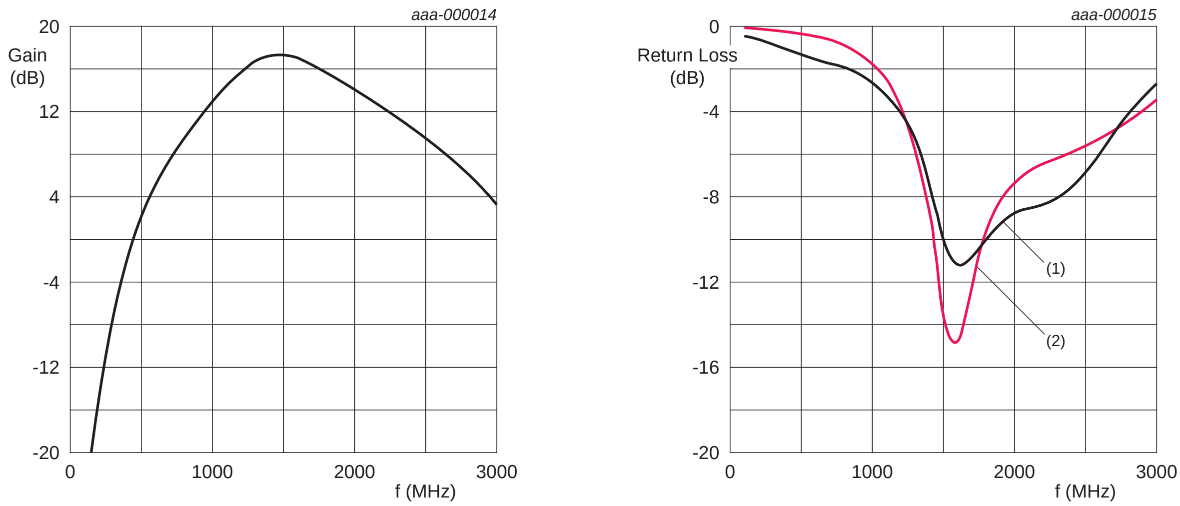


Fig 2. Baseline schematic

Table 1. List of components for single-element input match

Component	Description	Value	Supplier
C1	decoupling capacitor	1 nF	various
L1	input matching	5.6 nH	Murata LQG15
IC1	BGU7005	-	NXP



(1) Input R_L.

(2) Output R_L.

a. Gain as a function of frequency

b. Return loss as a function of frequency

Fig 3. Gain and return loss as a function of frequency, single-element match; V_{CC} = 2.85 V

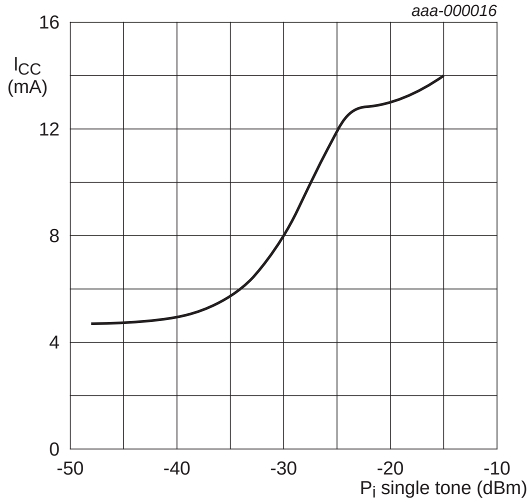
One method to judge the linearity of an LNA under jamming conditions is an out-of-band second-order spurious product measurement. At average power levels received by a GNSS receiver under normal conditions, the system will not have in-band intermodulation problems caused by the GNSS signal itself. Strong out-of-band transmit frequency jammers can cause linearity problems, however. For example, two incident 700 MHz LTE band signals can cause a second-order spurious product which falls in the GNSS band to be produced in the LNA.

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

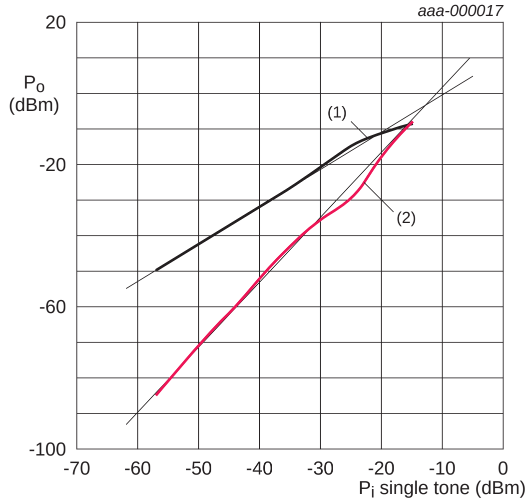
Specific to this application note, two input signals of equal amplitude at 787.4 MHz and 788.0 MHz are applied to the input of the BGU7005 producing a 2nd-order spurious frequency in the GNSS band.

787.4 MHz + 788.0 MHz = 1575.4 MHz

Figure 4 shows the measured results of this two-tone test for the baseline BGU7005 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 input power.



a. Supply current as a function of input power



(1) P_o (f_1).

(2) IM2 ($f1 = f_2$).

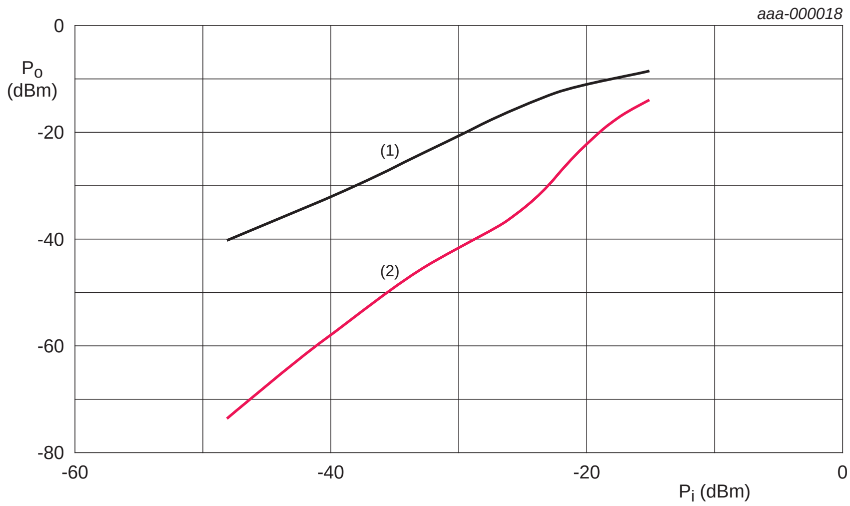
b. Output power as a function of input power

Fig 4. Two-tone test results (f_1 = 787.4 MHz, f_2 = 788 MHz, f_{spur} = 1575.4 MHz) single-element match; V_{CC} = 2.85 V

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 5 shows the level of the 2nd-order harmonic as a function of the input power of the 788 MHz tone.



(1) Fundamental (788 MHz).

(2) Second harmonic (1576 MHz).

Fig 5. Single-tone test results, f_1 = 788 MHz, single-element match; V_{CC} = 2.85 V

3. Two-element input match for LTE jammer immunity

The input match can be modified to a high-pass topology by adding one additional element, a low-cost 0402-size chip capacitor. This “series-C shunt-L” topology decreases the gain of the BGU7005 circuit in the 700 MHz LTE-band, resulting in increased immunity to a signal residing in this band; see Figure 6 and Table 2 for the modified schematic and bill of materials.

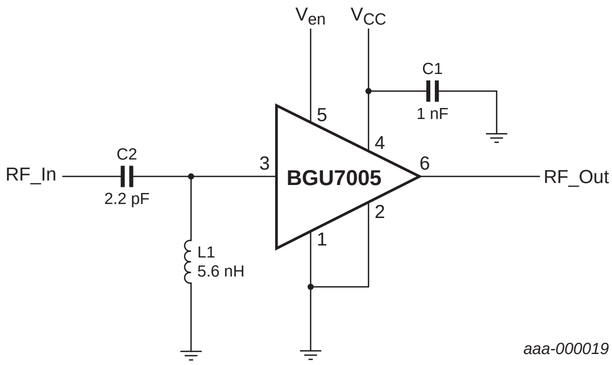
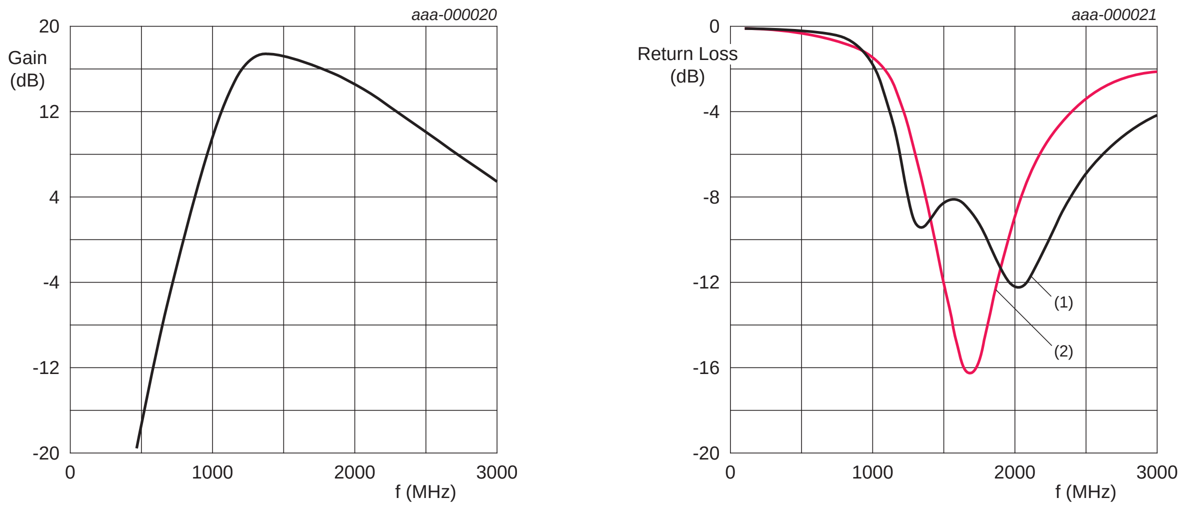


Fig 6. Two-element match schematic

Table 2. List of components for two-element input match

Component	Description	Value	Supplier
C1	decoupling capacitor	1 nF	various
L1	input matching	5.6 nH	Murata LQG15
C2	input matching	2.2 pF	Murata GRM15
IC1	BGU7005	-	NXP

As discussed in the introduction, the additional matching component steepens the gain roll-off below the GNSS band. Figure 7 shows the broadband gain response, plus the input and output return loss of the part for the two-element input match case.



(1) Input R_L.

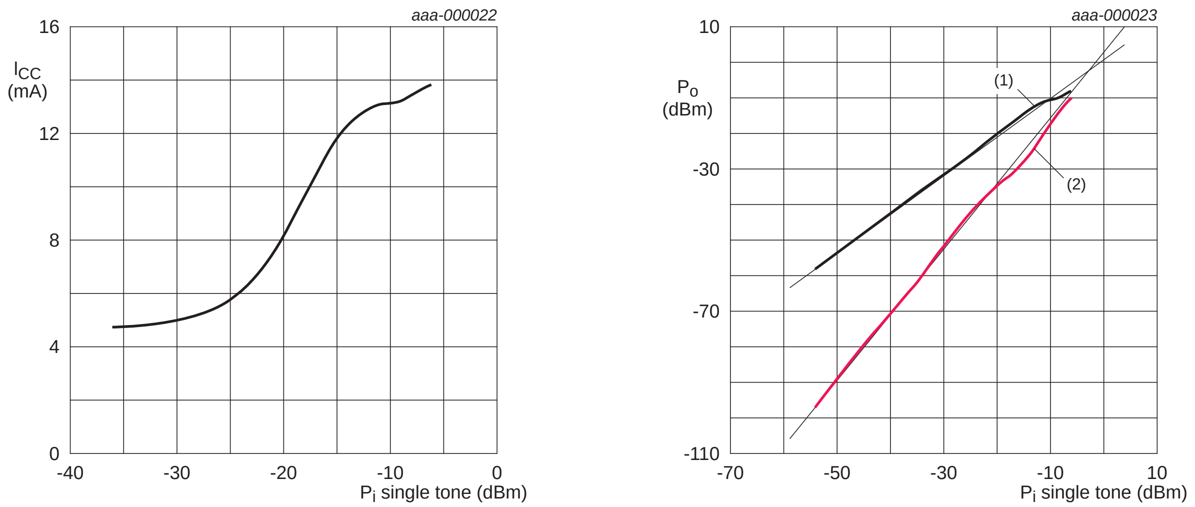
(2) Output R_L.

a. Gain as a function of frequency

b. Return loss as a function of frequency

Fig 7. Gain and return loss as a function of frequency, two-element match; V_{CC} = 2.85 V

Figure 8 shows the test results for the two-tone test using the two-element match. The level of the GNSS-band 2nd-order spurious product is reduced compared to the baseline case. More specifically, for an input level of –30 dBm, the level of the 2nd-order spurious product is decreased by 16 dB (–52 dBm compared to –36 dBm for the single element case). Note that the IC's current draw remains at the quiescent level for significantly higher power levels due to the lower gain at LTE band frequencies.



(1) P_o (f_1).

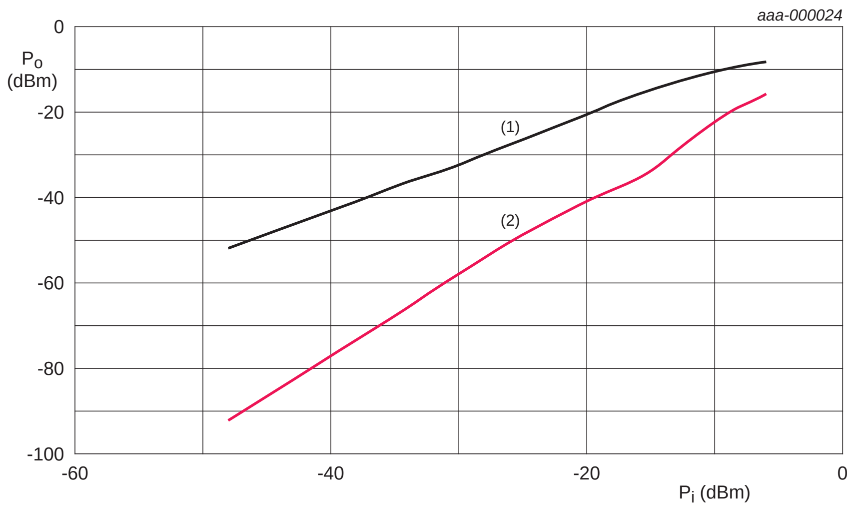
(2) IM2 (f_1 = f_2).

a. Supply current as a function of input power

b. Output power as a function of input power

Fig 8. Two-tone test results (f_1 = 787.4 MHz, f_2 = 788 MHz, f_{spur} = 1575.4 MHz), two-element match; V_{CC} = 2.85 V

Figure 9 shows the 2nd-harmonic level as a function of 788 MHz input power for the two element match. As with the spurious product, the level of the 2nd-order harmonic is greatly reduced compared to the baseline case. At –30 dBm input, the 2nd-order harmonic level is decreased by 16 dB (–58 dBm compared to –42 dBm for the single-element case).



(1) Fundamental (788 MHz).

(2) Second harmonic (1576 MHz).

Fig 9. Single-tone test results, f_1 = 788 MHz, two-element match; V_{CC} = 2.85 V

4. Three-element input match for LTE jammer immunity

To further increase immunity to LTE-band signals, the input match can be modified to a three-element topology, providing faster gain roll-off at frequencies below GNSS bands. The additional element is another low-cost chip capacitor; see Figure 10 and Table 3 for schematic and bill of materials.

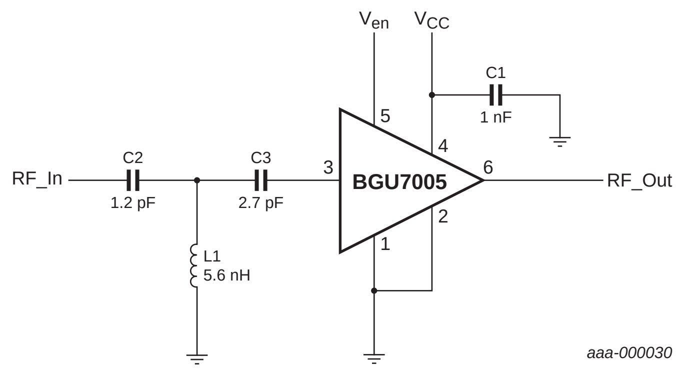
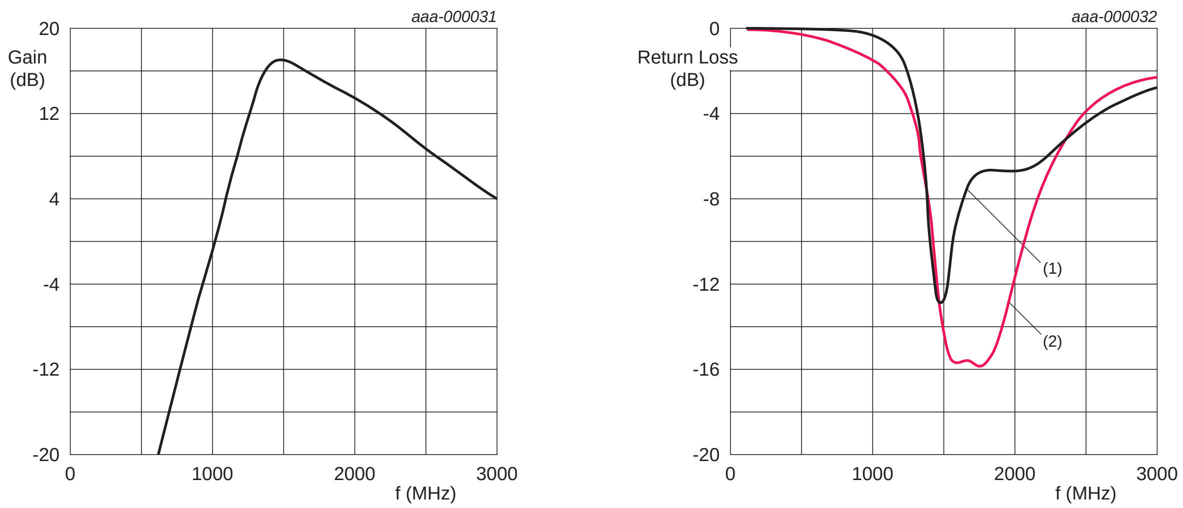


Fig 10. Three-element match schematic

Table 3. List of components for three-element input match

Component	Description	Value	Supplier
C1	decoupling capacitor	1 nF	various
L1	input matching	5.6 nH	Murata LQG15
C2	input matching	1.2 pF	Murata GRM15
C3	input matching	2.7 pF	Murata GRM15
IC1	BGU7005	-	NXP

Figure 11 shows that the gain roll-off has increased below the GNSS band.



(1) Input R_L.

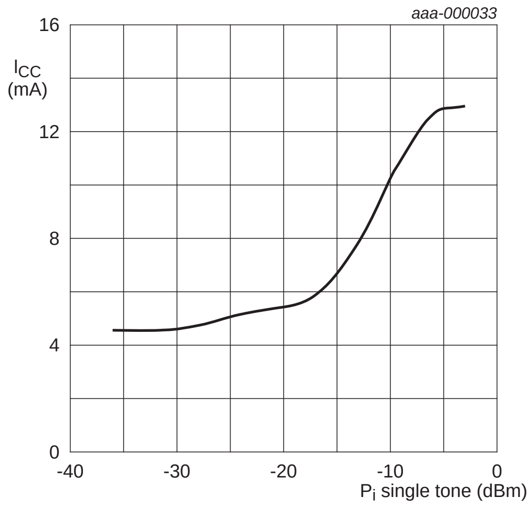
(2) Output R_L.

a. Gain as a function of frequency

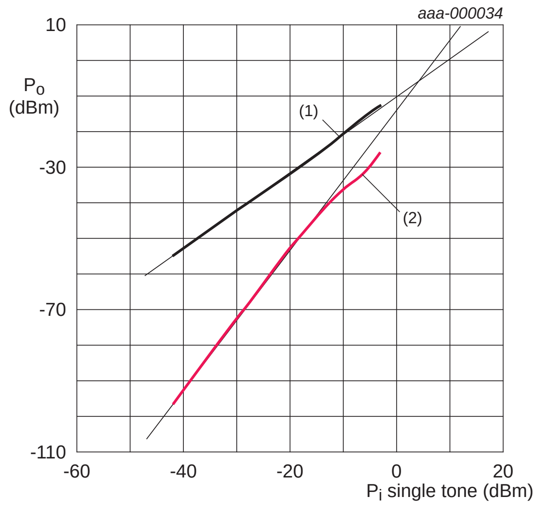
b. Return loss as a function of frequency

Fig 11. Gain and return loss as a function of frequency, three-element match; V_{CC} = 2.85 V

Figure 12 shows the test results for the two-tone test using the three-element match. Compared to the two-element case, the level of the 2nd-order spurious product is reduced and the part remains at the quiescent current level for higher input power levels. Specifically for –30 dBm input, the 2nd-order spurious product is measured as –72 dBm, compared to –52 dBm for the 2-element case.



a. Supply current as a function of input power



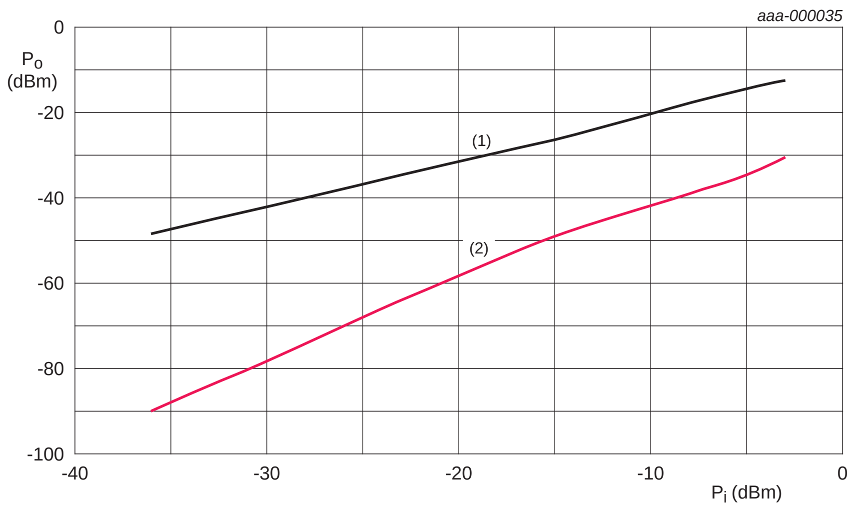
(1) P_o (f_1).

(2) IM2 (f1 = f_2).

b. Output power as a function of input power

Fig 12. Two-tone test results (f_1 = 787.4 MHz, f_2 = 788 MHz, f_{spur} = 1575.4 MHz), three-element match; V_{CC} = 2.85 V

Figure 13 shows the 2nd-harmonic level as a function of 788 MHz input power for the three-element match. As can be seen, for a given input power the level of the 2nd-order harmonic product is significantly reduced compared to the 2-element case. At –30 dBm input power, the 2nd-order harmonic is measured 20 dB lower than the 2-element case (–78 dBm compared to –58 dBm for the 2-element).



(1) Fundamental (788 MHz).

(2) Second harmonic (1576 MHz).

Fig 13. Single-tone test results, f_1 = 788 MHz, three-element match; V_{CC} = 2.85 V

5. Conclusion

By using a high-pass matching topology at the BGU7005 input, the gain of the circuit in the 700 MHz LTE band can be significantly reduced while leaving the in-band gain virtually unaltered. This can be accomplished with the addition of one or two low-cost, readily available ceramic chip capacitors. This has the effect of increasing the immunity of the BGU7005 to jamming signals in this band at the expense of noise figure, which increases due to the additional components at the device input. To further quantify, Table 4 below shows the results of the baseline single-element match, the 2-element match, and the 3-element match for the case of a 788 MHz jamming signal at a level of –25 dBm at the BGU7005 circuit input.

Table 4. LTE band second harmonic

Matching option	Gain at 788 MHz (dB)	Gain at 1576 MHz (dB)	Output power second harmonic (dBm)	Input reference level (dBm)	Noise figure at 1576 MHz (dB)
Single element	9.3	17.2	–32.1	–49.3	0.85
Two element	–0.3	16.9	–43.1	–60	1.05
Three element	–10.4	16.7	–64.7	–81.4	1.35

6. Abbreviations

Table 5. Abbreviations

Acronym	Description
GPS	Global Positioning System
IM2	Second-order InterModulation
LTE	Long-Term Evolution
MMIC	Monolithic Microwave Integrated Circuit

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