

# AN11595

## BGU8M1UK LTE LNA evaluation board

Rev. 2 — 22 February 2015

Application note

### Document information

Info	Content
<b>Keywords</b>	BGU8M1UK, LTE, LNA
<b>Abstract</b>	This document explains the BGU8M1UK LTE LNA evaluation board
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**Revision history**

Rev	Date	Description
2	20150222	Performance BGU8M1UK for mid + high band added
1	20141106	First publication

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## 1. Introduction

NXP Semiconductors' BGU8M1UK LTE LNA Evaluation Board is designed to evaluate the performance of the LTE LNA using:

- NXP Semiconductors' BGU8M1UK LTE Low Noise Amplifier
- A matching inductor
- A decoupling capacitor

NXP Semiconductors' BGU8M1UK is a low-noise amplifier for LTE receiver applications in a extremely small wafer level chip scale package (WLCSP) 0.65 x 0.44 x 0.2 mm; 6 solder bumps; 0.22 mm bump pitch.

The BGU8M1UK features gain of 16 dB and a noise figure of 0.8 dB at a current consumption of 4.3 mA. Its superior linearity performance removes interference and noise from co-habitation cellular transmitters, while retaining sensitivity. The LNA and components occupy a total area of approximately 4 mm<sup>2</sup>.

In this document, the application diagram, board layout, bill of materials, and typical results are given, as well as some explanations on LTE related performance parameters like input third-order intercept point IIP3, gain compression and noise.

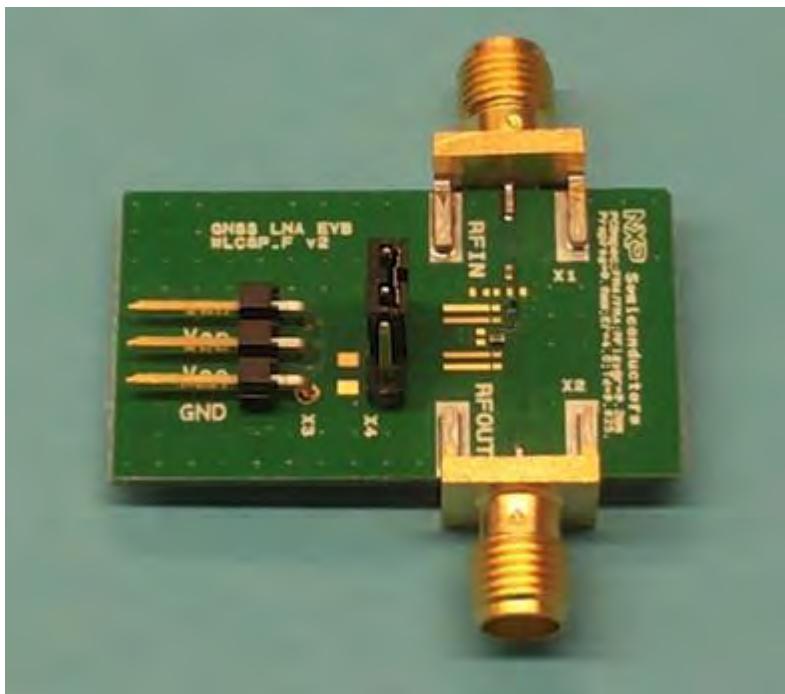


Fig 1. BGU8x1UK LTE LNA evaluation board (used for BGU8L1UK, BGU8M1UK and BGU8H1UK)

## 2. General description

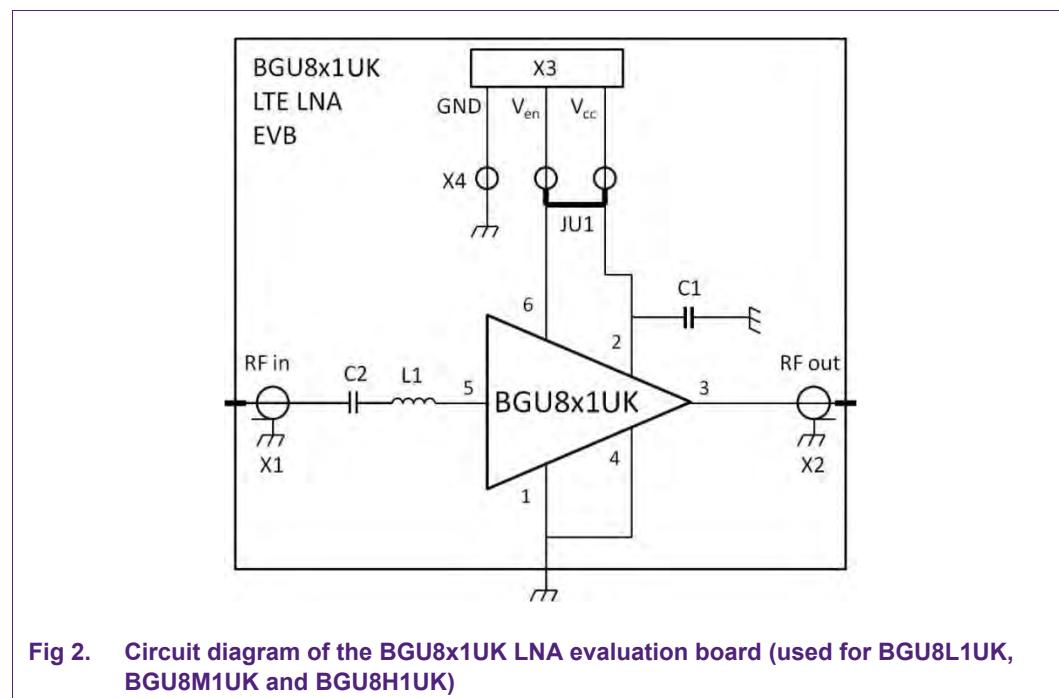
Modern cellular phones have multiple radio systems, so problems like co-habitation are quite common. Since the LTE diversity antenna needs to be placed far from the main antenna to ensure the efficiency of the channel, a low noise amplifier close to the antenna is used to compensate the track-losses (and SAW-filter losses when applicable) on the printed circuit board. A LTE receiver implemented in a mobile phone requires a low current consumption and low Noise Figure. All the different transmit signals that are active in smart phones and tablets can cause problems like inter-modulation and compression. Therefore also a high linearity is required.

## 3. BGU8M1UK LTE LNA evaluation board

The BGU8M1UK LNA evaluation board simplifies the RF evaluation of the BGU8M1UK LTE LNA applied in a LTE 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 BGU8L1UK including the input series inductor (L1) and DC blocking capacitor (C2) as well as a decoupling capacitor (C1) for the supply voltage. The board is supplied with two SMA connectors for input and output connection to RF test equipment. The BGU8M1UK can operate from a 1.5 V to 3.1 V single supply and consumes typical 4.3 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 to Vcc.



### 3.2 PCB Layout

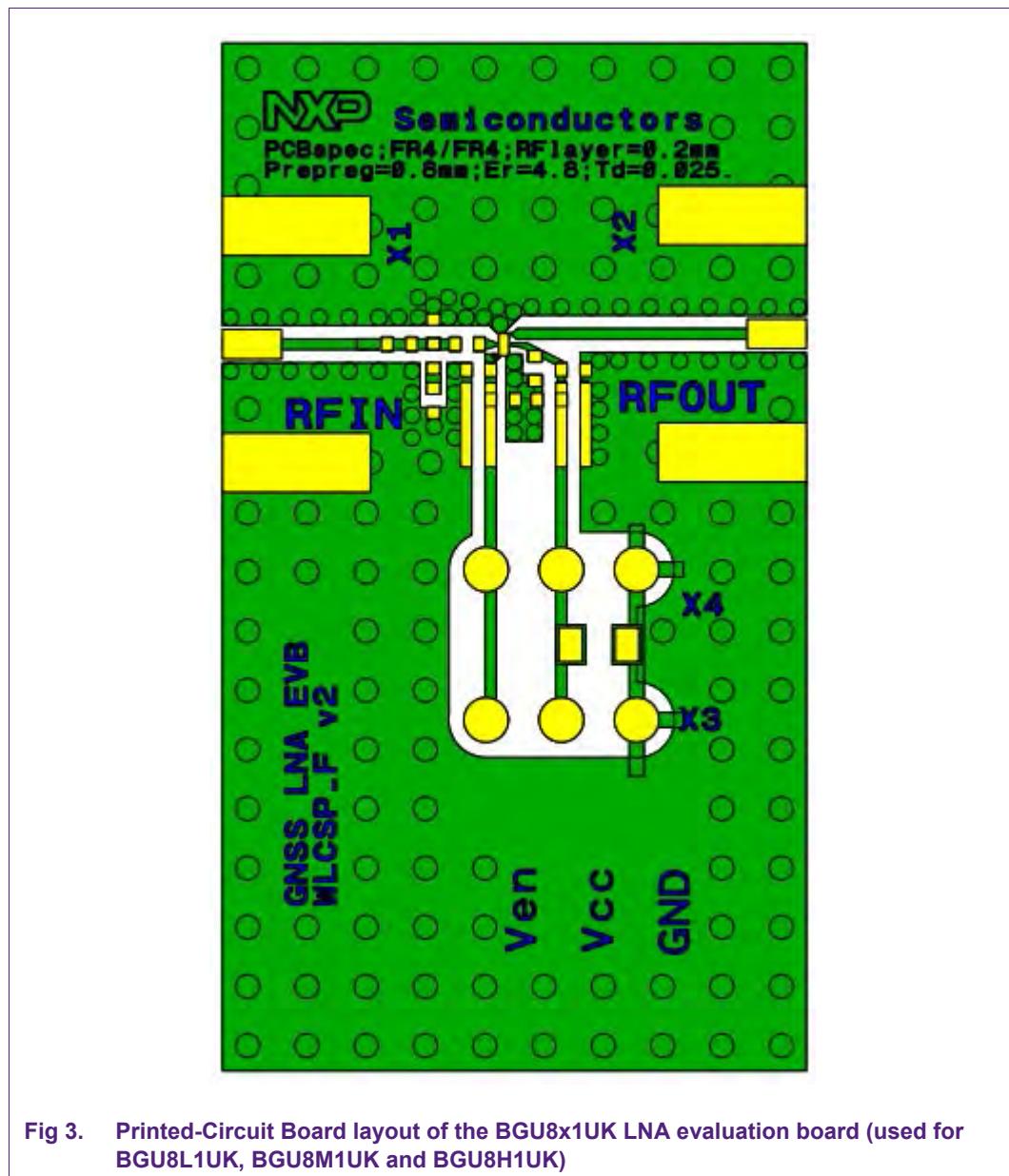
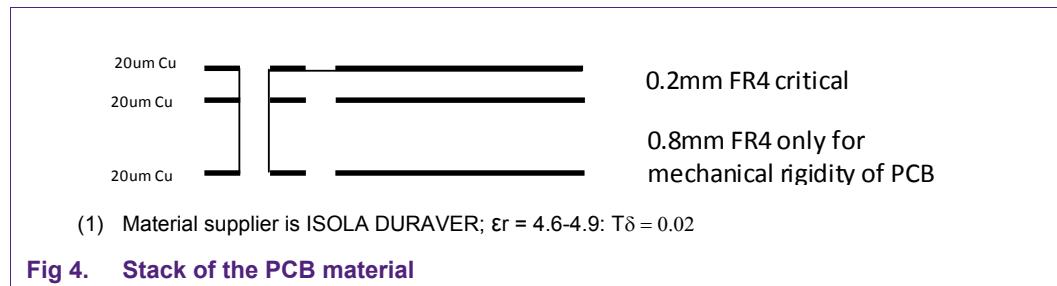


Fig 3. Printed-Circuit Board layout of the BGU8x1UK LNA evaluation board (used for BGU8L1UK, BGU8M1UK and BGU8H1UK)

A good PCB layout is an essential part of an RF circuit design. The LNA evaluation board of the BGU8M1UK can serve as a guideline for laying out a board using the BGU8M1UK. 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. An option can be to skip the input series capacitor (C2) when a SAW filter is used in front of

the LNA, since most of the SAW filters will block the DC-current. 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.



**Fig 4. Stack of the PCB material**

## 4. Bill of materials

Table 1. BOM of the BGU8M1UK LTE LNA evaluation board

Designator	Description	Footprint	Value	Supplier Name/type	Comment
E	BGU8M1UK	0.65 x 0.44 x 0.2mm <sup>3</sup> , 0.22mm pitch		NXP	WLCSP
PCB		20 x 35mm		BGU8M1UK LTE LNA EV Kit	
C1	Capacitor	0402	1uF	Murata GRM1555	Decoupling
C2	Capacitor	0402	1nF	Murata GRM1555	DC block
L1	Inductor	0402	4.7nH	Murata LQW15	Input 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				

### 4.1 BGU8M1UK

NXP Semiconductors' BGU8M1UK LTE low noise amplifier is designed for the LTE 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 BGU8M1UK. The BGU8M1UK is also equipped with an enable function that allows it to be controlled via a logic signal. In disabled mode it consumes less than 1  $\mu$ A.

The output of the BGU8M1UK is internally matched between 1805 MHz and 2200 MHz, whereas only one series inductor at the input is needed to achieve the best RF performance. The output is AC coupled via an integrated capacitor.

It requires only three external components to build a LTE LNA having the following advantages:

- Low noise
- System optimized gain
- High linearity under jamming
- 0.65 x 0.44 x 0.2, 0.22mm pitch: WLCSP
- Low current consumption
- Short power settling time

### 4.2 Series inductor

The evaluation board is supplied with Murata LQW15 series inductor of 4.7 nH. This is a wire wound type of inductor with high quality factor (Q) and low series resistance (Rs). 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  $R_s$  the noise performance will degrade.

## 5. Required Equipment

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

- ✓ DC Power Supply op to 30 mA at 1.5 V to 3.1 V
- ✓ Two RF signal generators capable of generating RF signals at the LTE operating frequency of 1805 MHz to 2200 MHz.
- ✓ An RF spectrum analyzer that covers at least the operating frequency of 1805 MHz to 2200 MHz as well as a few of the harmonics. Up to 6 GHz should be sufficient.
- ✓ 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 (can also be done with a RF spectrum analyzer)
- ✓ Directional coupler
- ✓ Proper RF cables

## 6. Connections and setup

The BGU8M1UK LTE LNA evaluation board is fully assembled and tested (see Fig 5). 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 BGU8M1UK.
2. Jumper JU1 is connected between the  $V_{cc}$  terminal of the evaluation board and the  $V_{en}$  pin of the BGU8M1UK.
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 approximately -40 dBm output power at center frequency of the wanted LTE-band and set the spectrum analyzer at the same center frequency and a reference level of 0 dBm.
4. Turn on the DC power supply and it should read approximately 4..5 mA.
5. Enable the RF output of the generator: The spectrum analyzer displays a tone around -24 dBm.
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, P1dB and IP3 (see Fig 6).
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 (see Fig 7).

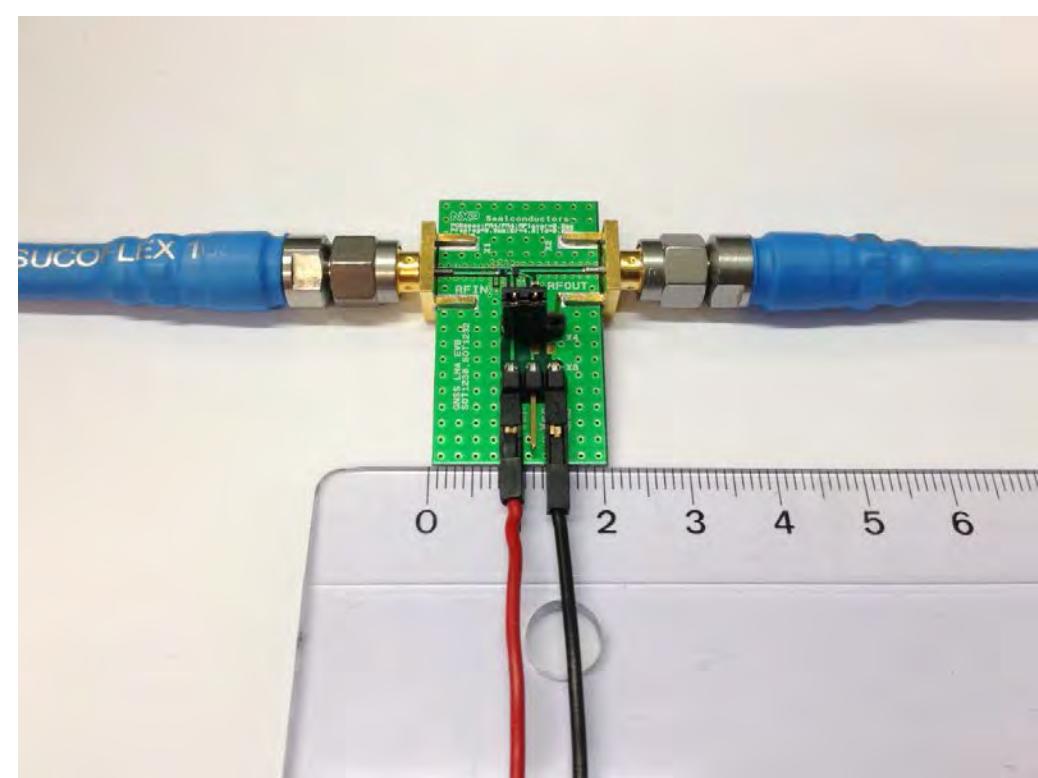


Fig 5. Evaluation board including its connections

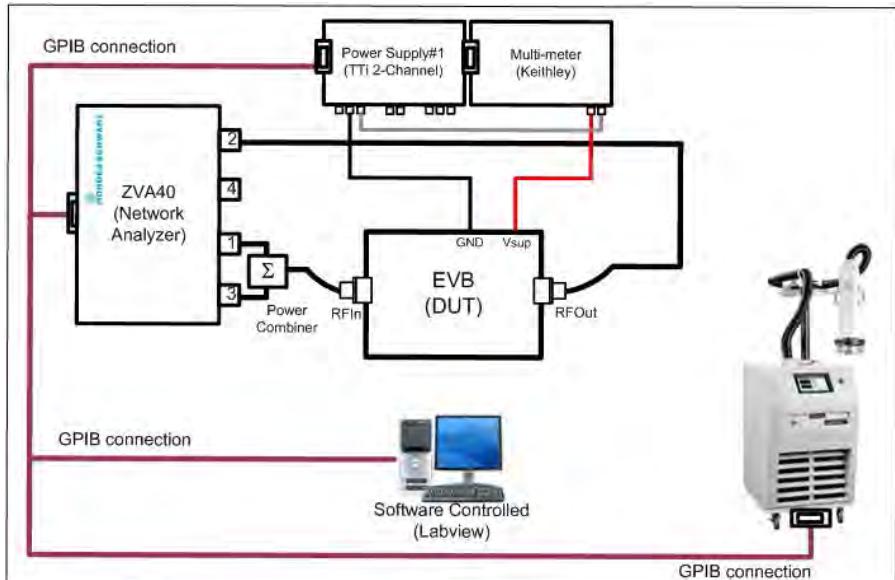


Fig 6. 2-Tone Setup for 50Ω LNA board tests (S-Parameters, P1dB and 2-Tone-tests)

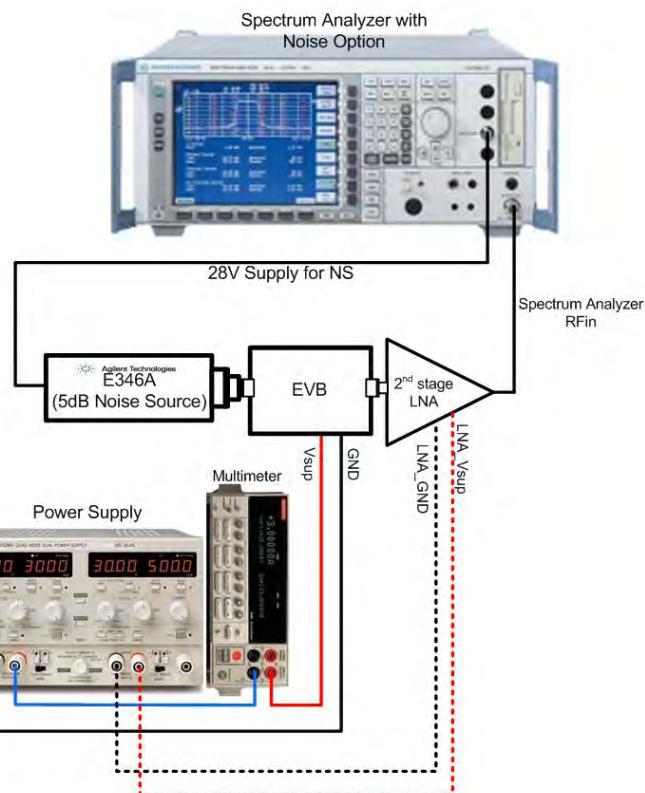


Fig 7. Setup diagram for 50Ω LNA-board NF-Measurements.

## 7. Evaluation Board Tests

### 7.1 S-Parameters

The measured S-Parameters and stability factor K are given in the figures below. For the measurements, a BGU8M1UK-LNA EVB is used ((see Fig 5). Measurements have been carried out using the setup shown in Fig 6.

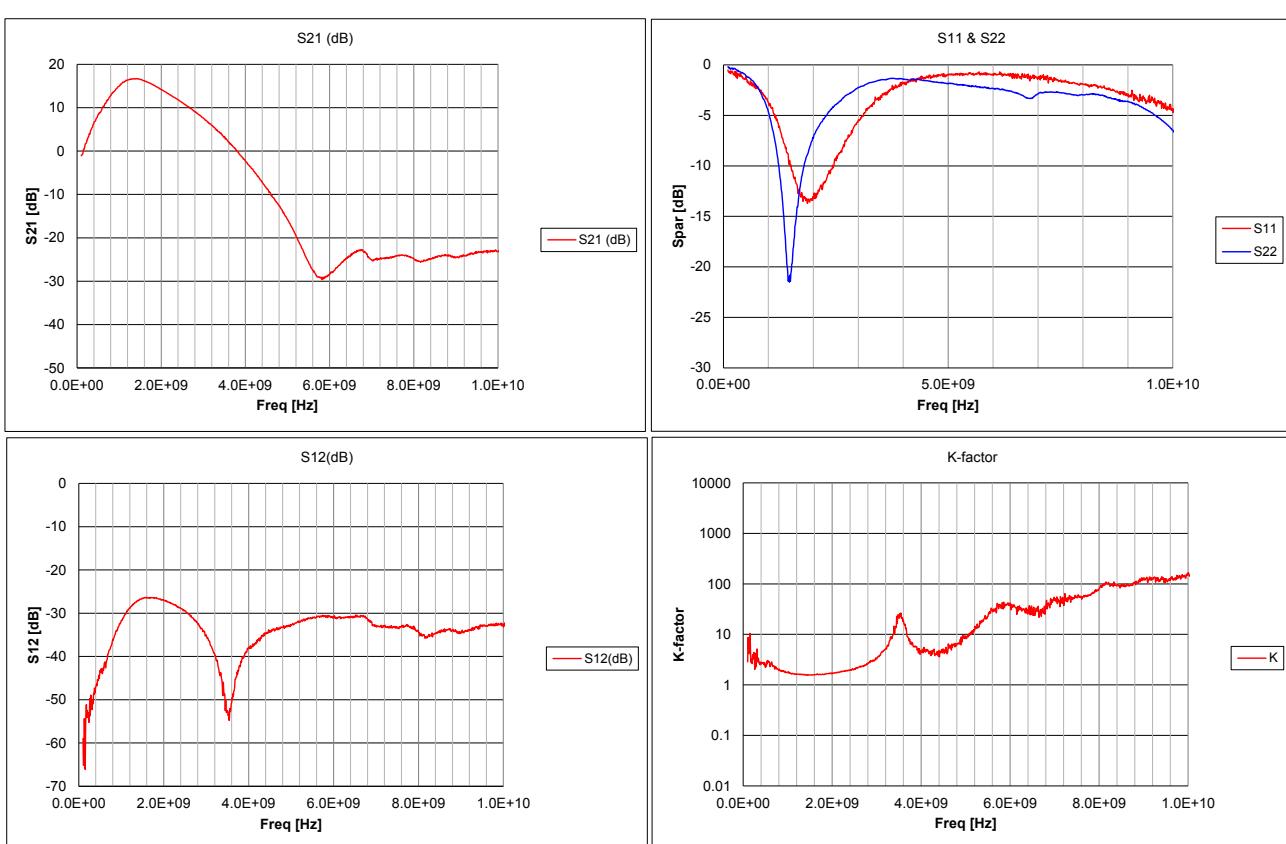


Fig 8. BGU8M1UK S-Parameters (typical values). Vcc=2.8V, Pin=-45dBm.

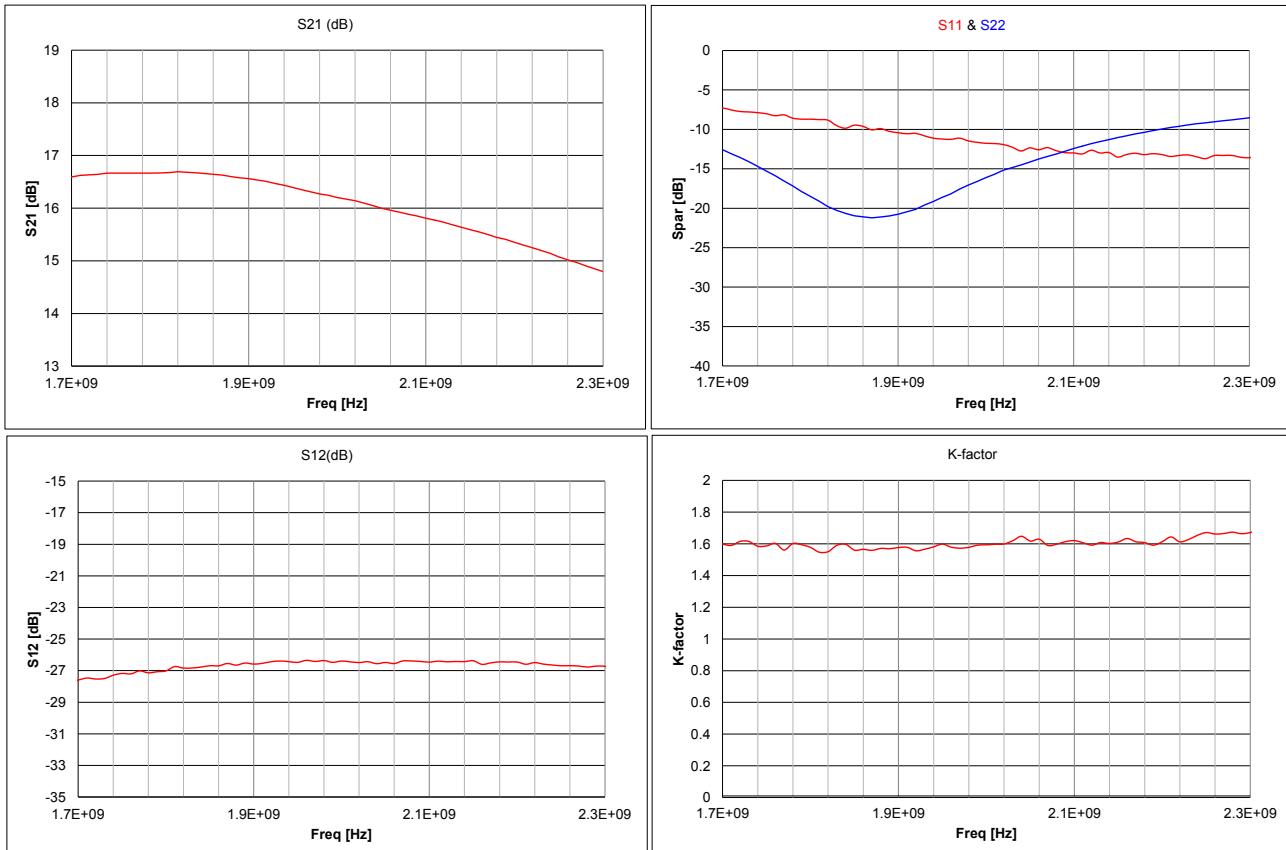


Fig 9. BGU8M1UK S-Parameters (typical values). Vcc=2.8V, Pin=-45dBm (freq. range zoomed in).

## 7.2 S-Parameters and NF performance in the min-high band

The BGU8M1UK can also be used for the LTE mid-high band (between 1.8 and 2.7GHz) with some reduced gain performance beyond 2.2GHz (compared with the BGU8H1UK, which is especially designed for the high band). The input inductor L1 (see Fig 2) is not modified. The measured S-Parameters and NF-performance are given in the figures below.

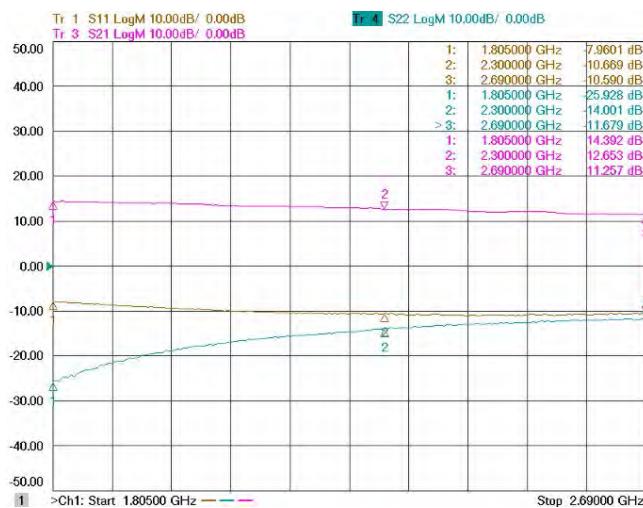


Fig 10. BGU8M1UK S-Parameters for the mid-high band between 1.8GHz and 2.7GHz (typical values). Vcc=2.8V, Pin=-45dBm.

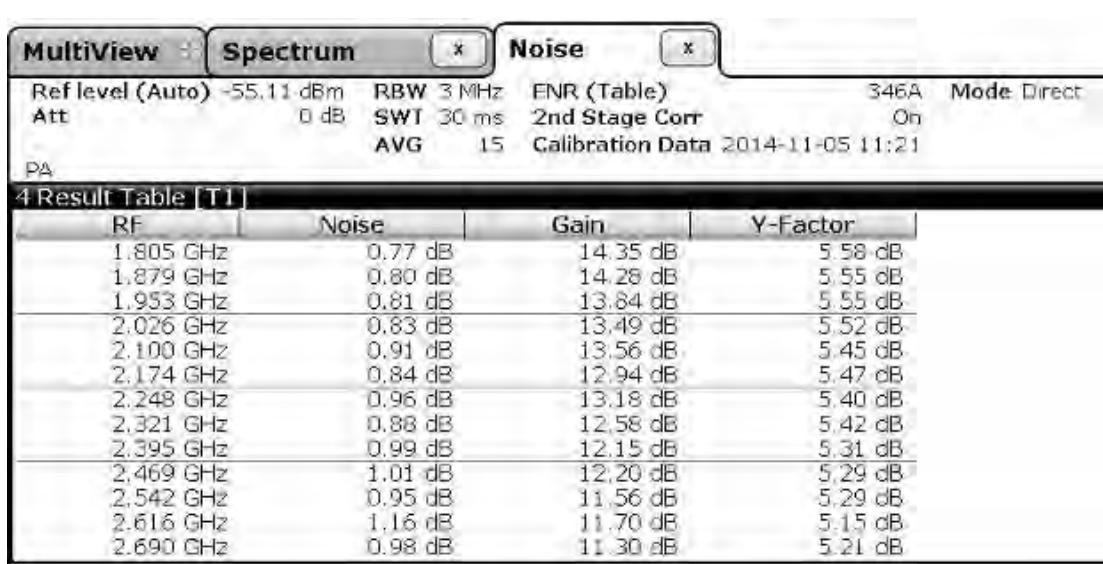


Fig 11. BGU8M1UK NF results for the min-high band between 1.8GHz and 2.7GHz (typical values). Vcc=2.8V.

### 7.3 1dB gain compression

Strong in-band cell phone TX jammers can cause linearity problems and result in third-order intermodulation products in the LTE frequency band. In this chapter the effects of these strong signals is shown. For the measurements, a BGU8M1UK-LNA EVB is used ((see Fig 5). Measurements have been carried out using the setup shown in Fig 6

The gain as function of input power of the DUT was measured between port RFin and RFout of the EVB at the LTE center frequencies.

The figures below show the gain compression curves at LNA-board.

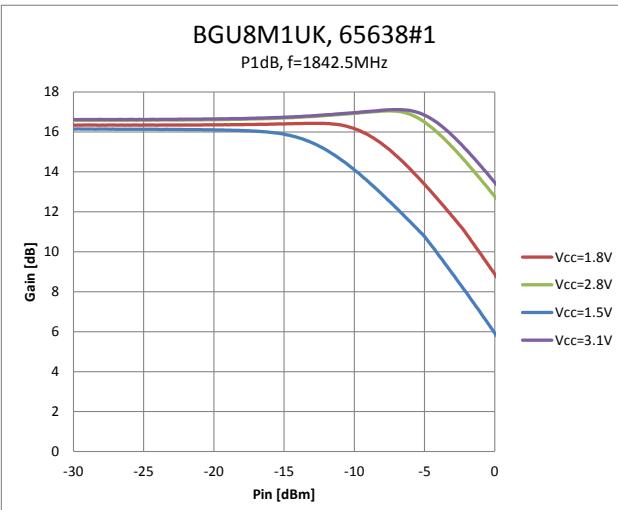


Fig 12. Gain versus inp. power, f=1842.5MHz (band 3)

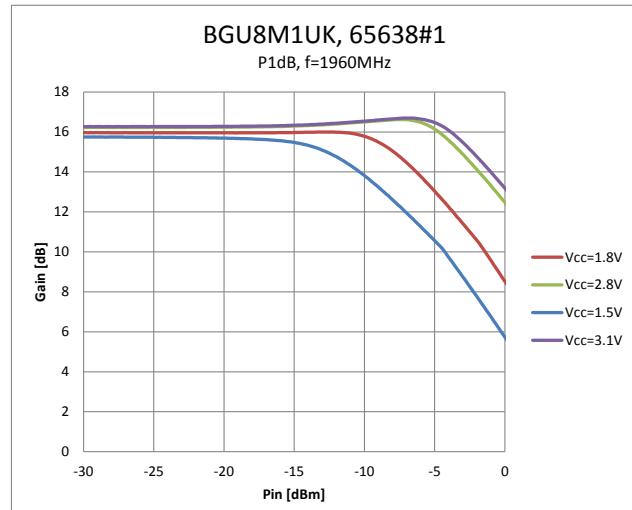


Fig 13. Gain versus input power, f=1960MHz (band 2)

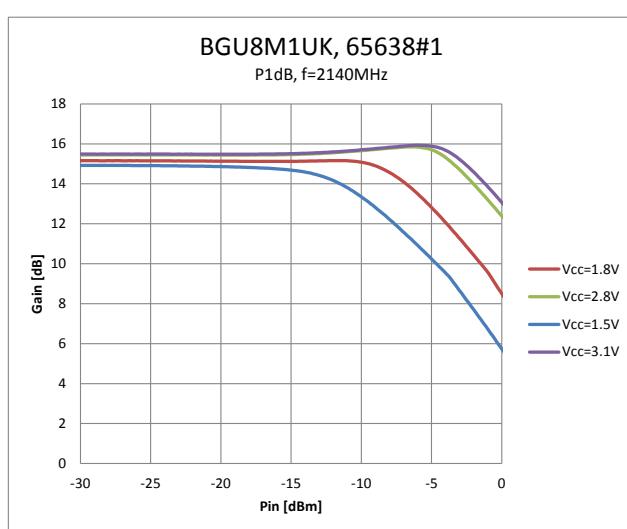
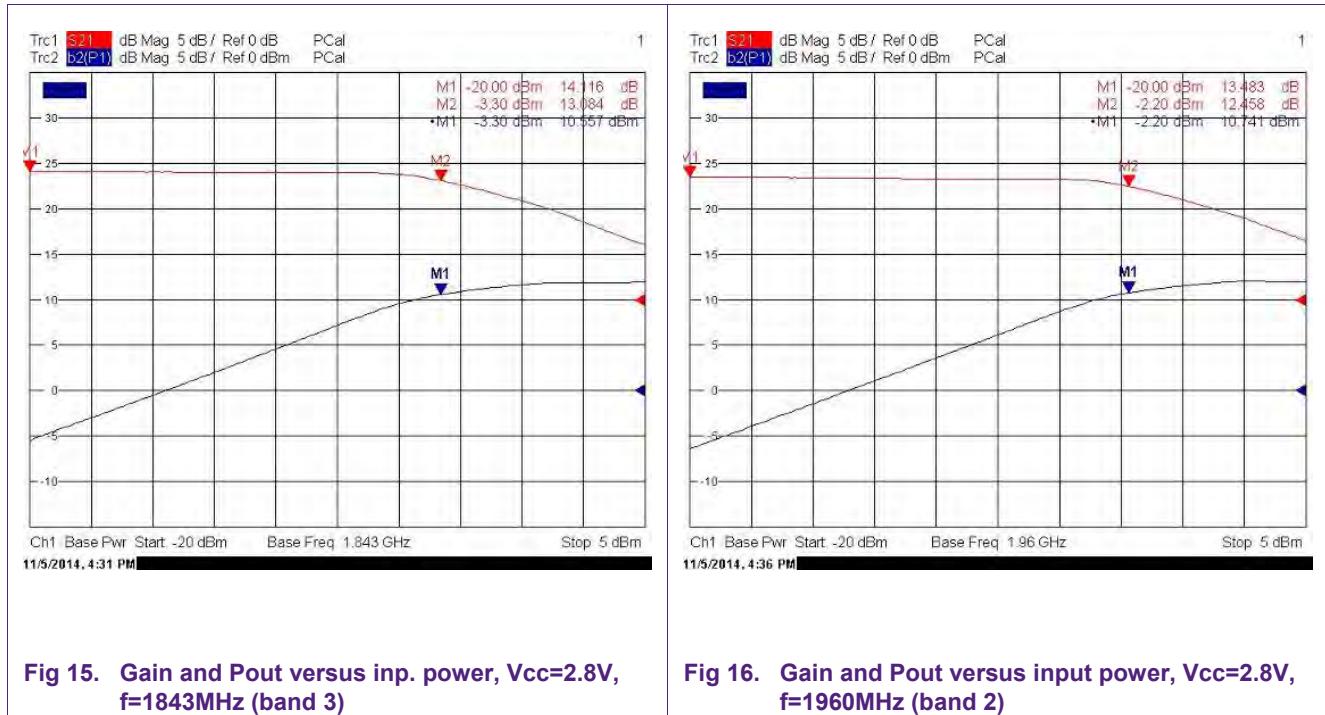


Fig 14. Gain versus input power, f=2140MHz (band 1)

## 7.1 1dB gain compression in the mid-high band

The BGU8M1UK can also be used for the LTE mid-high band (between 1.8 and 2.7GHz) with some reduced gain performance beyond 2.2GHz (compared with the BGU8H1UK, which is especially designed for the high band). The input inductor L1 (see Fig 2) is not modified. The measured Gain and Pout-curves are given in the figures below.



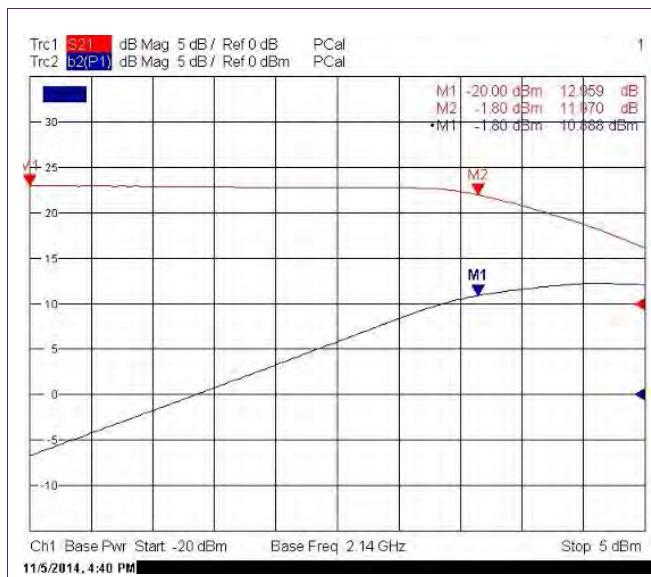


Fig 17. Gain and Pout versus inp. power, Vcc=2.8V, f=2140MHz

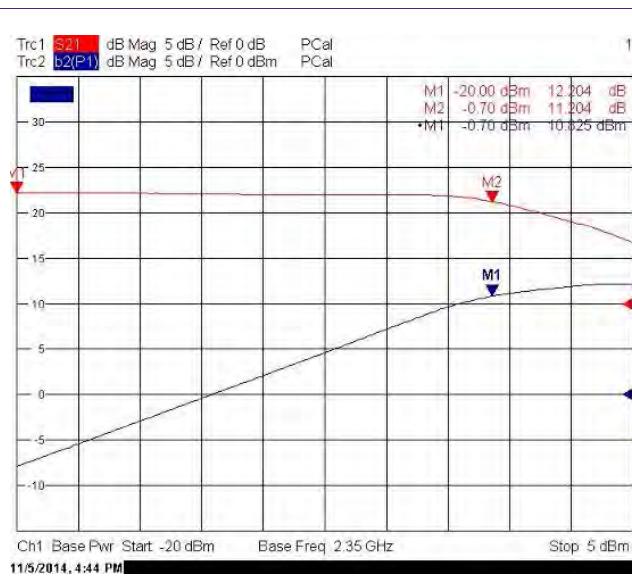


Fig 18. Gain and Pout versus input power, Vcc=2.8V, f=2350MHz

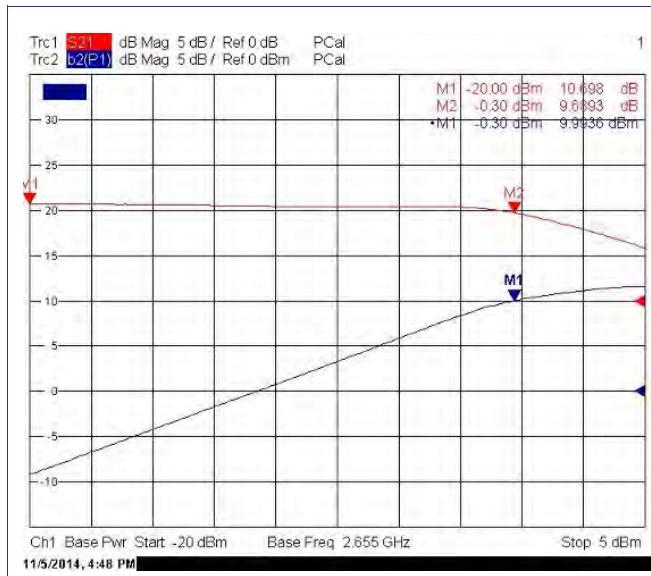


Fig 19. Gain and Pout versus inp. power, Vcc=2.8V, f=2655MHz

## 7.2 2-Tone Test, IP3

The figures below show the spectra of the DUT caused by a 2-Tone input signal around the centre of the LTE-bands. For the measurements, a BGU8M1UK-LNA EVB is used (see Fig 5). Measurements have been carried out using the setup shown in Fig 6.

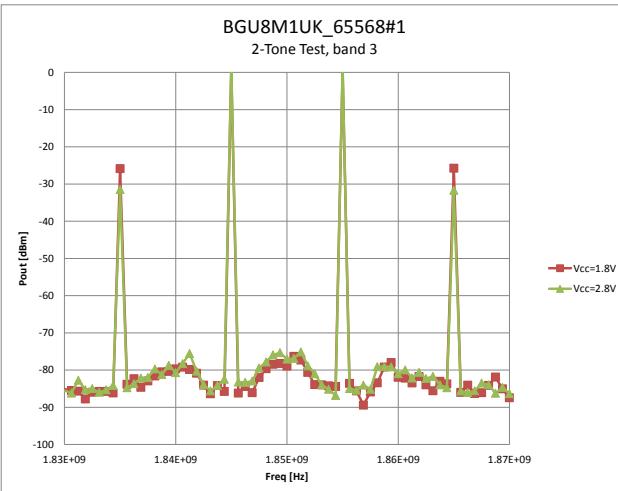


Fig 20. 2-Tone output spectrum, Pin=-15dBm, band 3

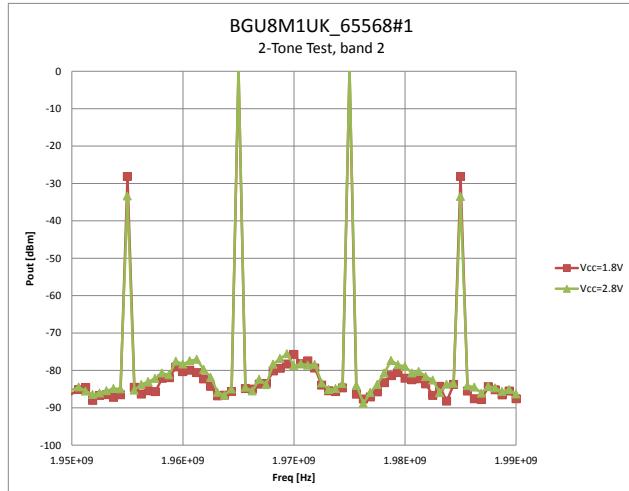


Fig 21. 2-Tone output spectrum, Pin=-15dBm, band 2

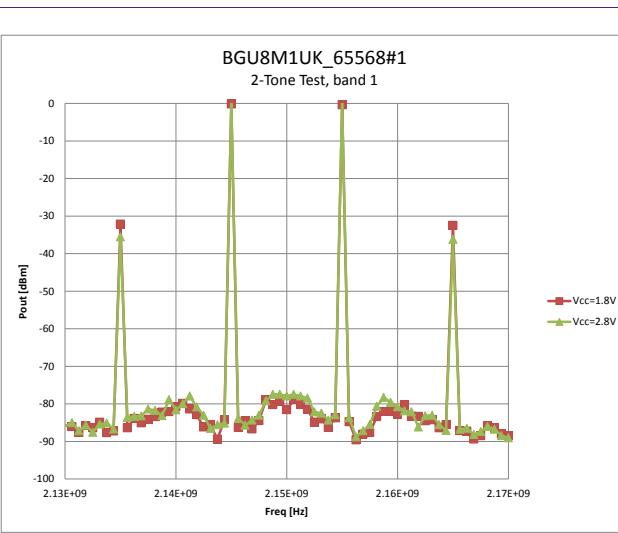


Fig 22. 2-Tone output spectrum, Pin=-15dBm, band 1

### 7.3 Enable Timing Test

The following diagram shows the setup to test LNA Turn ON and Turn OFF time.

Set the waveform generator to square mode and the output amplitude at 3Vrms with high output impedance. The waveform generator has adequate output current to drive the LNA therefore no extra DC power supply is required which simplifies the test setup.

Set the RF signal generator output level to -20dBm between 1805 MHz and 2200 MHz and increase its level until the output DC on the oscilloscope is at 5mV on 1mV/division, the signal generator RF output level is approximately -3dBm.

It is very important to keep the cables as short as possible at input and output of the LNA so the propagation delay difference on cables between the two channels is minimized.

It is also critical to set the oscilloscope input impedance to 50ohm on channel 2 so the diode detector can discharge quickly to avoid a false result on the Turn OFF time testing.

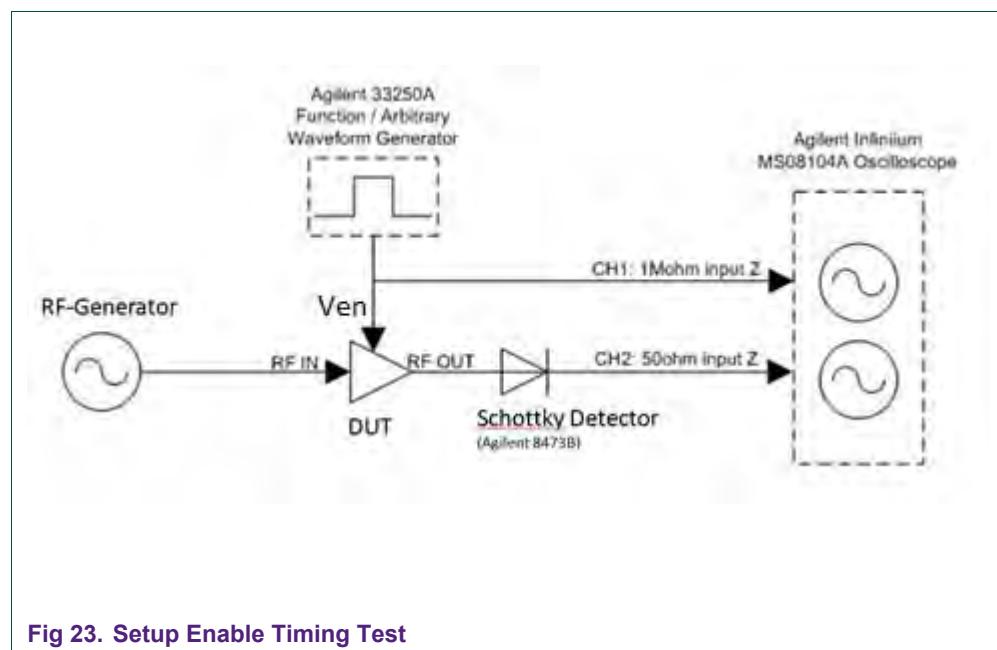


Fig 23. Setup Enable Timing Test

The series capacitor will influence the Ton/Toff switching time. When the default value C2=1nF is used, Ton will approximately be 9us. By reducing C2 to 100pF, Ton is reduced to approximately 4 $\mu$ s (see Fig 24 and Fig 25).

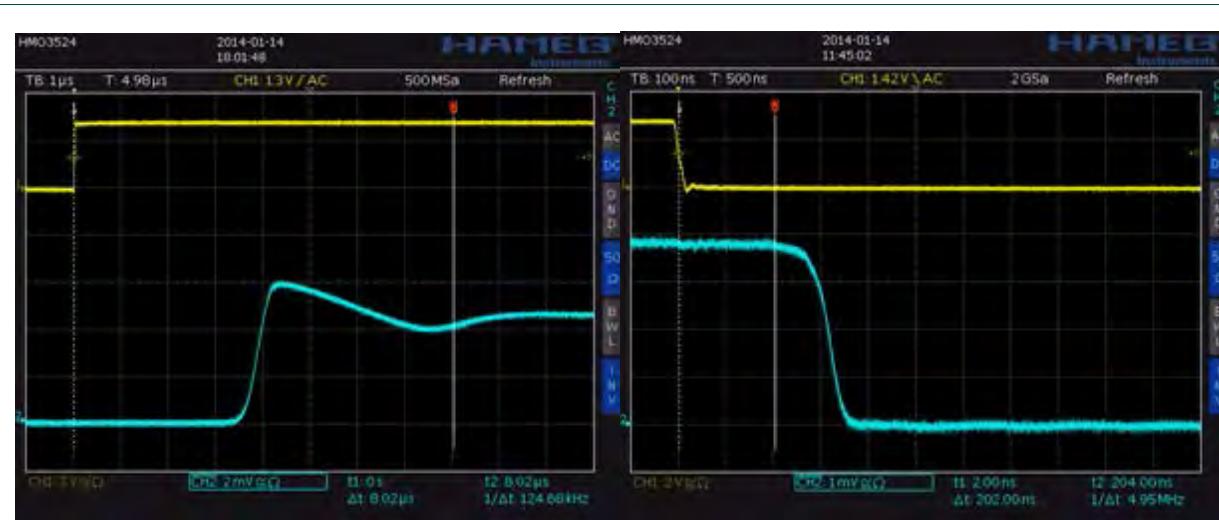


Fig 24. Results Enable Timing Test. Series capacitor C2=1nF. Ton~9μs (left) and Toff~200ns (right).



Fig 25. Results Enable Timing Test. Series capacitor C2=100pF. Ton~4μs (left).

## 8. Typical LNA evaluation board results

Table 2. Typical results measured on the evaluation Board.

		Typical LNA evaluation board results Temp = 25 °C						
Parameter	Symbol						Unit	Notes
		Freq. [MHz]						
Supply Voltage	<b>V<sub>cc</sub></b>	1.5	1.8	2.8	3.1		V	
Supply Current	<b>I<sub>cc</sub></b>	3.9	4.0	4.3	4.4		mA	
Noise Figure	1840 <b>NF</b>	0.80	0.80	0.80	0.80		dB	
	1960	0.80	0.80	0.80	0.80			[1]
	2140	0.90	0.90	0.90	0.90			
Power Gain	1840 <b>G<sub>p</sub></b>	16.0	16.0	16.0	16.5		dB	
	1960	15.5	15.5	16.0	16.0			
	2140	15.0	15.0	15.5	15.5			
Input Return Loss	1840 <b>R<sub>Lin</sub></b>	8.5	8.5	9.5	9.5		dB	
	1960	9.5	10.0	11.0	11.0			
	2140	10.5	11.5	13.0	13.0			
Output Return Loss	1840 <b>R<sub>Lout</sub></b>	15.0	15.0	15.0	15.0		dB	
	1960	15.0	15.0	15.0	15.0			
	2140	11.0	11.0	11.0	11.0			
Reverse Isolation	1840 <b>IS<sub>orev</sub></b>	25	25	25	25		dB	
	1960	25	25	25	25			
	2140	25	25	25	25			
Input 1dB Gain Compression	1840 <b>P<sub>i1dB</sub></b>	-12.0	-8.0	-4.0	-3.0		dBm	
	1960	-12.0	-8.0	-4.0	-3.0			
	2140	-11.0	-7.0	-3.0	-2.0			
Output 1dB Gain Compression	1840 <b>P<sub>o1dB</sub></b>	3.0	7.0	11.0	12.5		dBm	
	1960	2.5	6.5	11.0	12.0			
	2140	3.0	7.0	11.5	12.5			
Input third order intercept point	1840 <b>IIP<sub>3</sub></b>	-5.0	-1.0	1.0	2.0		dBm	[2]
	1960	-5.0	0.0	2.0	2.0			
	2140	-4.0	0.0	3.0	3.0			
Output third order intercept point	1840 <b>OIP<sub>3</sub></b>	11.0	15.0	17.0	18.5		dBm	[2]
	1960	10.5	15.5	18.0	18.0			
	2140	11.0	15.0	18.5	18.5			
Power settling time	<b>T<sub>on</sub></b>	4	4	4	4		μs	
	<b>T<sub>off</sub></b>	1	1	1	1		μs	

[1] Including PCB losses

[2]  $f = f_{center\_band}$ ;  $\Delta f = 1\text{MHz}$

$\text{Pin}_f_1 = \text{Pin}_f_2 = -15\text{ dBm}$

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