AN11147

Low Noise Fast Turn ON/OFF 2.4-2.5GHz WiFi LNA with BFU730F

Rev. 1 — 15 October 2012 **Application note**

Document information

Info	Content
Keywords	BFU730F, 2.4-2.5GHz LNA, WiFi (WLAN)
Abstract	This document provides circuit simulation, schematic, layout, BOM and typical EVB performance for a 2.4-2.5GHz WiFi (WLAN) LNA

Revision history

Rev	Date	Description
v.1	15 October 2012	First publication

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1. Introduction

The BFU730F is a discrete HBT that is produced using NXP Semiconductors' advanced 110 GHz fT SiGe:C BiCmos process. SiGe:C is a normal silicon germanium process with the addition of Carbon in the base layer of the NPN transistor. The presence of carbon in the base layer suppresses the boron diffusion during wafer processing. This allows a steeper and narrower SiGe HBT base and a heavier doped base. As a result, lower base resistance, lower noise and higher cut off frequency can be achieved.

The BFU730F is one of a series of transistors made in SiGe:C.

BFU710F, BFU760F and BFU790F are the other types. BFU710F is intended for ultra low current applications. The BFU760F and BFU790F are high current types and are intended for application where linearity is key.

New 6th & 7th Generation Wideband transistors from NXP offer best RF noise figure / gain tradeoff at 12GHz drawing lowest current which means best signal reception at low power, enabling products to be more sensitive in noisy environments and friendlier to the environment.

Key Benefits:

- Application up to 18 GHz and higher
- Broad choice of parts for the perfect fit in the application
- Lowest current consumption meaning greener products
- SOT343F package for high performance and easy manufacturing

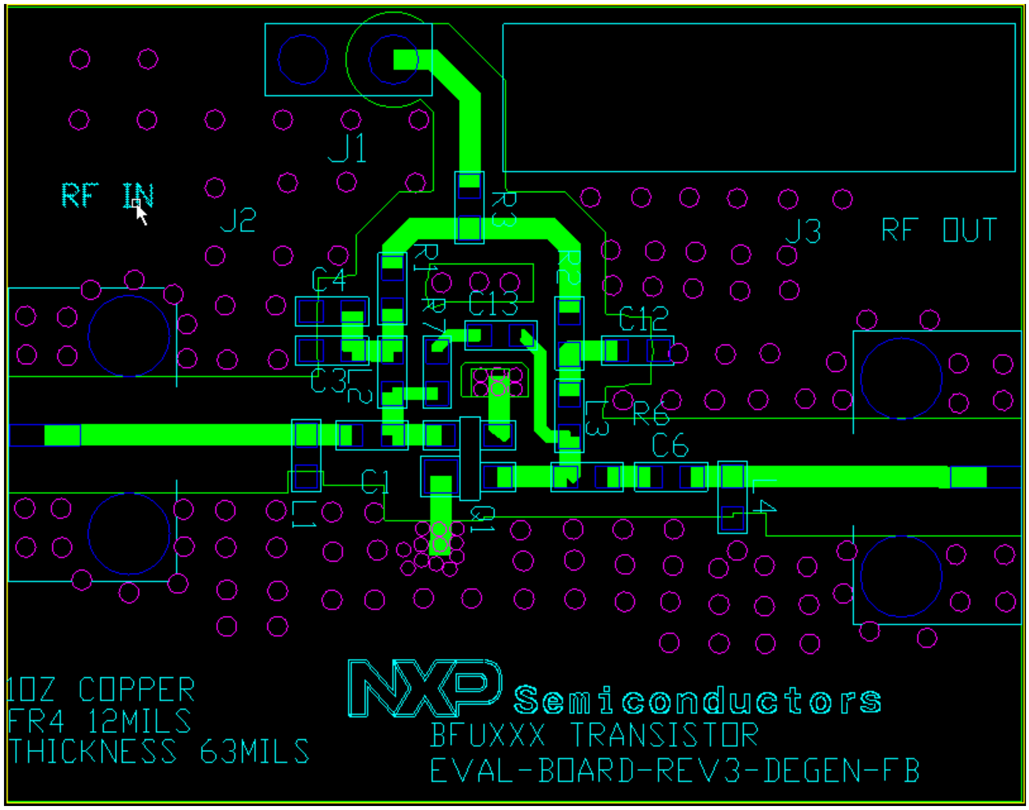


Fig 1. BFUXXX Universal Demo Board/BFU730F 2.4-2.5GHz WiFi LNA EVB Demo Board

2. Requirements and design of the 2.4-2.5GHz WiFi LNA

The circuit shown in this application note is intended to demonstrate the performance of the BFU730F in a 2.4-2.5 GHz LNA for e.g. 802.11a/b/g & 802.11n “MIMO” WiFi (WLAN) applications.

Key requirements for this application are:

- Frequency Band 2.4 – 2.5GHz
- Gain
- Input/output Match
- Linearity
- NF
- Turn ON/OFF Time

Table 1. 2.4-2.5GHz WiFi LNA Design Target Spec

Target specification for 2.4– 2.5GHz WiFi LNA

VCC	Icc	NF	Gain	IP1dB	IIP3	IRL	ORL	Turn ON/OFF Time
3.0	10	<2	>15 but < 20dB	>-14	>-4	>10	>10	<500
V	mA	dB	dB	dBm	dBm	dB	dB	nS

3. Design and Simulation

The 2.4-2.5 GHz WiFi LNA consists of one stage BFU730F amplifier. For this amplifier the minimum number of external components is used for low cost purpose:

- 1 multilayer chip inductor, lower cost comparing to wirewound type
- 4 resistors, low cost part
- 5 capacitors, low cost part

The design has been simulated using Agilent’s Advanced Design System (ADS), and the simulation results are given in the following figures.

The LNA shows excellent match at input/output with greater than 10dB return loss and gain of 17dB @2.4GHz with good Noise Figure of 1.08 dB.

With only 10.8mA it also shows a high input P1 dB compression of –12dBm@2.4GHz, as well as high input IP3 of -1.8dBm.

The LNA has super fast Turn ON and OFF time with 138nS and 35nS respectively.

The designed LNA is unconditionally stable at 10 MHz-26 GHz.

3.1 BFU730F 2.4-2.5GHz WiFi LNA Simulation

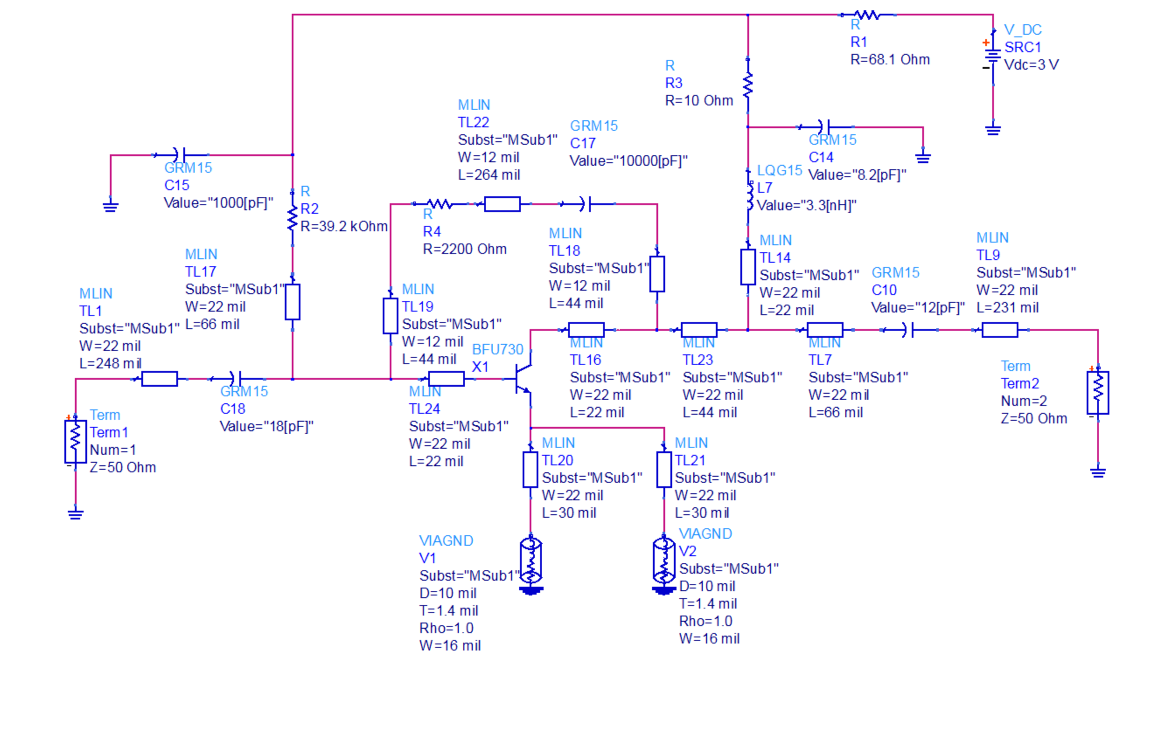


Fig 2. BFU730F 2.4-2.5GHz WiFi LNA Simulation: Circuit

3.2 BFU730F 2.4-2.5GHz WiFi LNA Simulation Result

3.2.1 Gain and Match in 2.4-2.5GHz Band

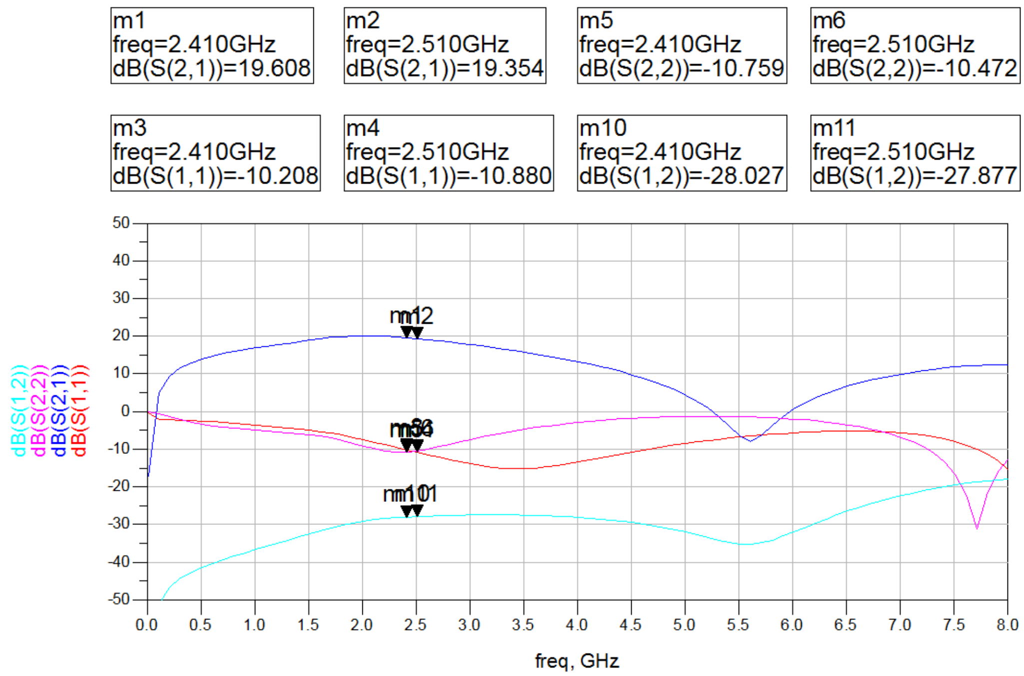


Fig 3. BFU730F 2.4-2.5GHz WiFi LNA Simulation: Gain and Match

3.2.2 Noise Figure in 2.4-2.5GHz Band

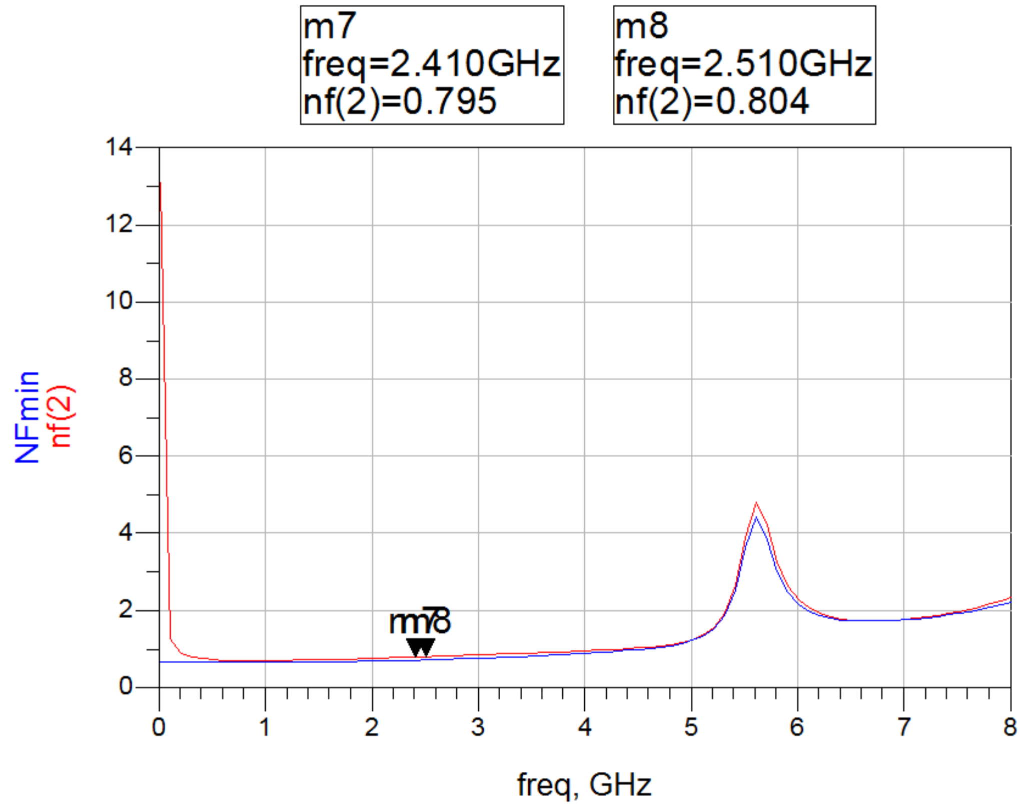


Fig 4. BFU730F 2.4-2.5GHz WiFi LNA Simulation: Noise Figure

3.2.3 Stability

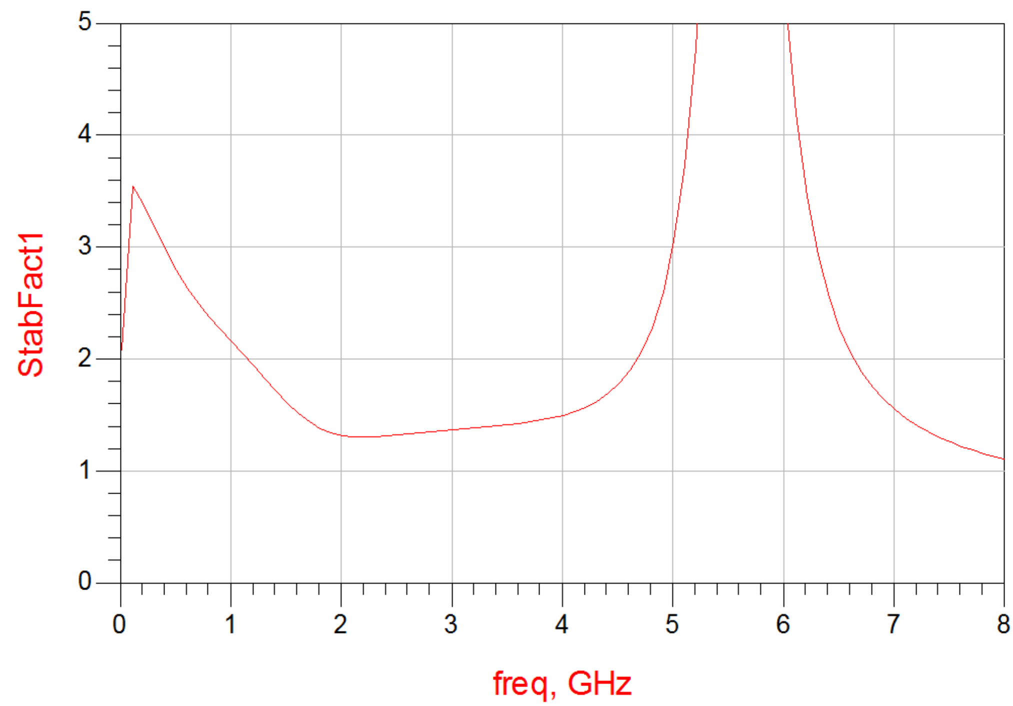


Fig 5. BFU730F 2.4-2.5GHz WiFi LNA Simulation: Stability

4. Application Board

The 2.4-2.5GHz WiFi LNA evaluation board simplifies the evaluation of the BFU730F application. The evaluation board enables testing of the device performance and requires no additional support circuitry. The board is fully assembled with the BFU730F transistor, including input and output matching components, to optimize performance.

The board is supplied with two SMA connectors for input and output connection to RF test equipment.

4.1 Application Circuit Schematic

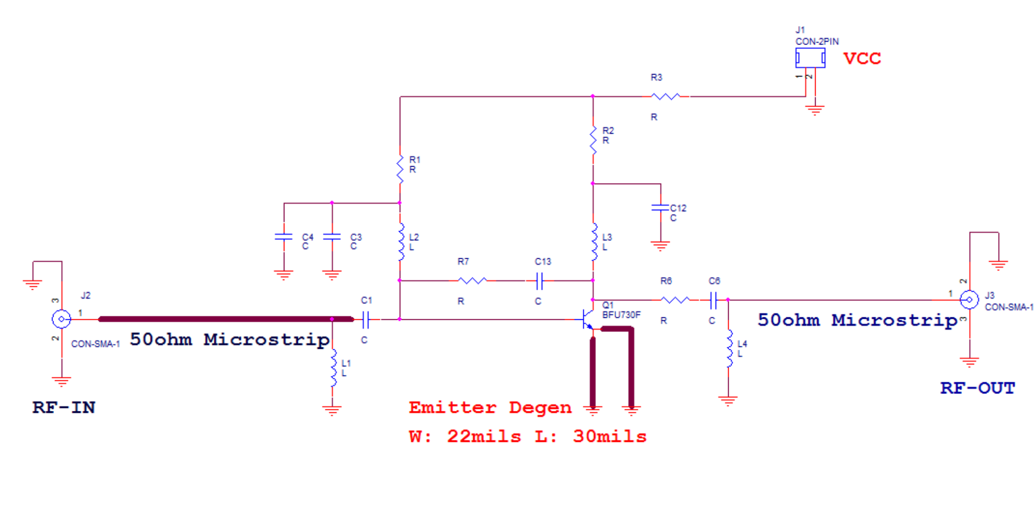


Fig 6. BFUXXX Universal Demo Board(w/De-gen & Feedback): Schematic

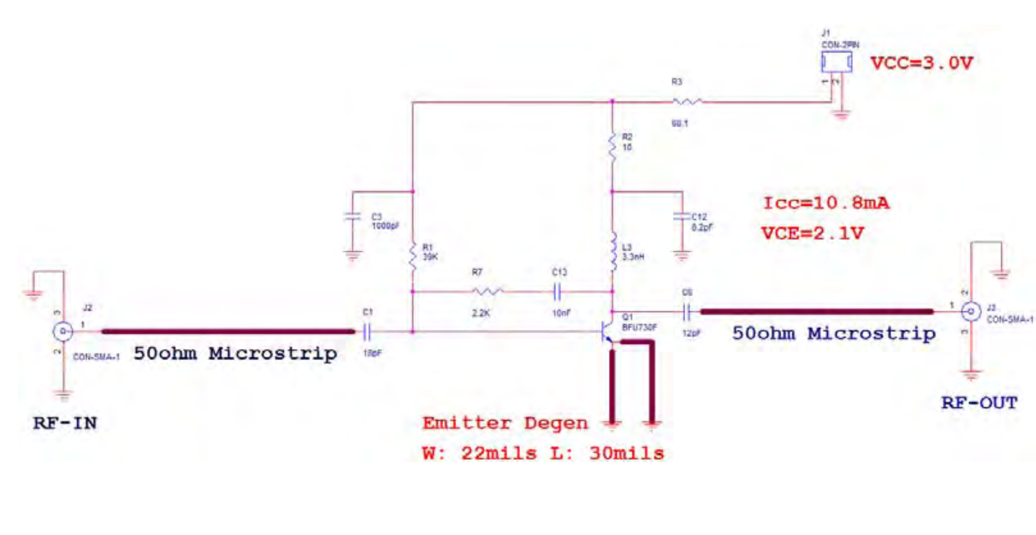


Fig 7. BFU730F 2.4-2.5GHz WiFi LNA: Schematic

Note: Figure 6 is the schematic for BFUXXX universal demo board, some assembly changes are made to accommodate this simplified low cost design, the revised schematic is shown in figure 7, and the changes are as following:

1. L1, L2, L4, C4, R6: not populated
2. Move R1 (39K) to L2 location, short two solder pads of R1 or put a 0 ohm jumper
3. Short two solder pads of R6 or put a 0 ohm jumper

4.2 Application Board Bill-Of-Material

Table 2. BFU730F 2.4-2.5GHz WiFi LNA Part List

Customer can choose their preferred vendor but should be aware that the performance could be affected.

Item	Quantity	Reference	Part Number	Vendor	Value
1	1	C1	GRM1555C1H180JZ01D	Murata	18pF
2	1	C3	GRM1555C1H102JA01	Murata	1000pF
3	1	C6	GRM1555C1H120JZ01D	Murata	12pF
4	1	C12	GRM1885C1H8R2DZ01D	Murata	8.2pF
5	1	C13	GRM155R71C103KA01D	Murata	10nF
6	1	J1	90120-0762	Molex	CON-2PIN
7	2	J2,J3	901-10110	Amphenol	CON-SMA-1
8	1	L3	LQG15HS3N3S02D	Murata	3.3nH
9	1	Q1	BFU730F	NXP SEMICONDUCTORS	BFU730F
10	1	R1	ERJ-2GEJ393X	Panasonic - ECG	39K
11	1	R2	ERJ-2RKF10R0X	Panasonic - ECG	10
12	1	R3	ERJ-2RKF68R1X	Panasonic - ECG	68.1
13	1	R7	ERJ-2RKF2201X	Panasonic - ECG	2.2K

4.3 Typical Application Board Test Result

4.3.1 S-Parameter – Gain and Match

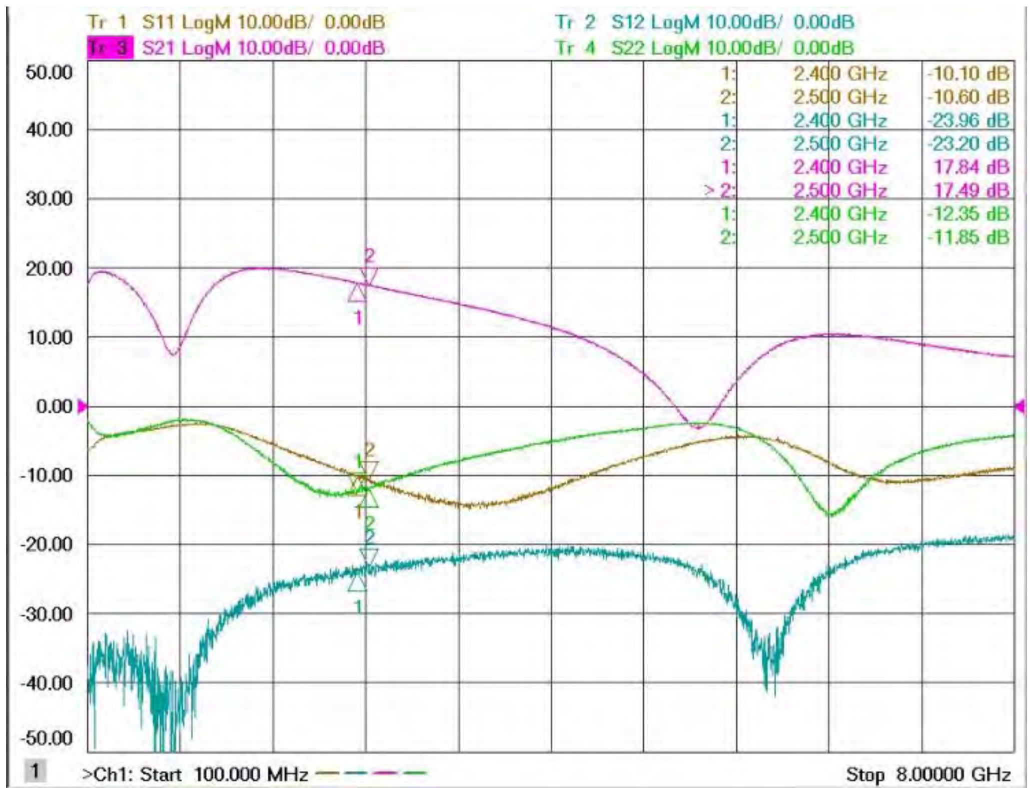


Fig 8. BFU730F 2.4-2.5GHz WiFi LNA: S-Parameter

4.3.2 P1dB

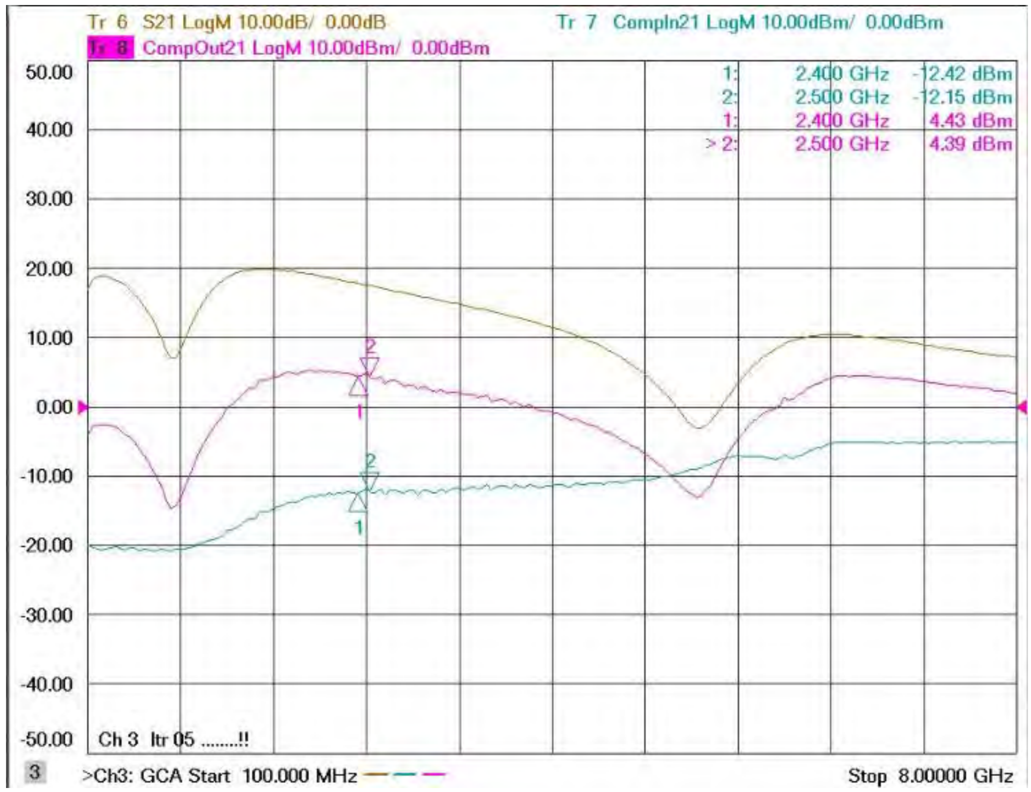
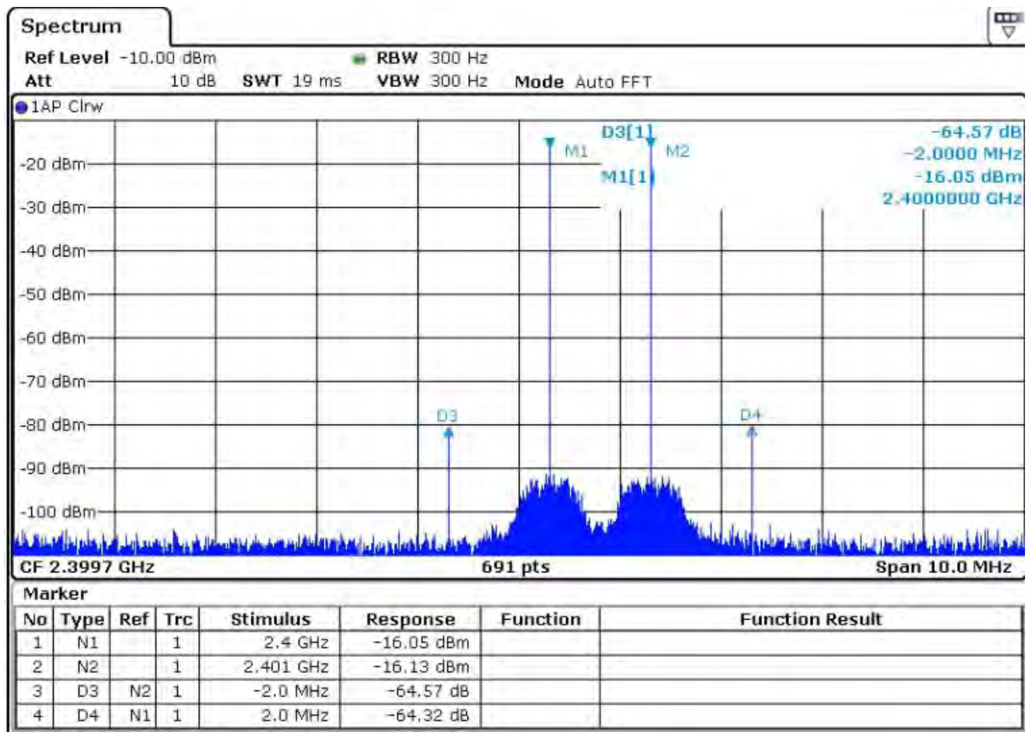


Fig 9. BFU730F 2.4-2.5GHz WiFi LNA: P1dB

4.3.3 Linearity/IP3



No	Type	Ref	Trc	Stimulus	Response	Function	Function Result
1	N1		1	2.4 GHz	-16.05 dBm		
2	N2		1	2.401 GHz	-16.13 dBm		
3	D3	N2	1	-2.0 MHz	-64.57 dB		
4	D4	N1	1	2.0 MHz	-64.32 dB		

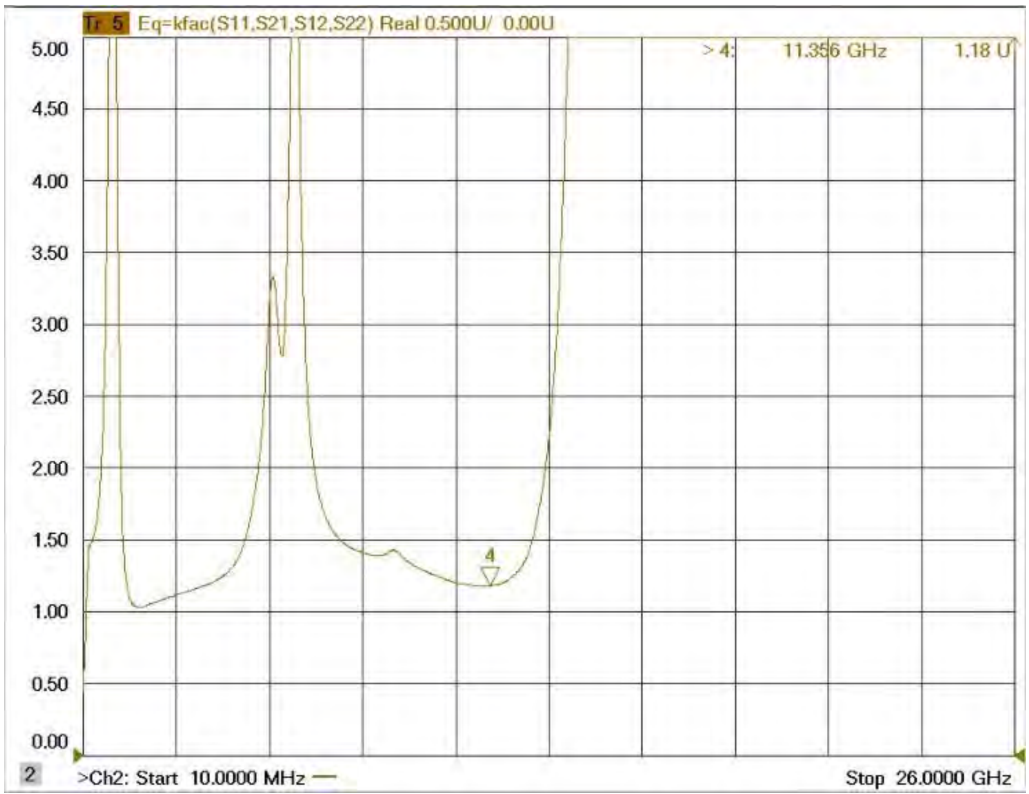
Two tones: f1: 2.4GHz, f2: 2.401GHz, -30dBm each tone, tone spacing: 1MHz

OIP3 = 64/2 + (-16) = 16dBm

IIP3 = OIP3- Gain = 16-17.8 = -1.8dBm

Fig 10. BFU730F 2.4-2.5GHz WiFi LNA: IP3

4.3.4 Stability



K Factor

Fig 11. BFU730F 2.4-2.5GHz WiFi LNA: Stability

4.3.5 Noise Figure Measurement

A network analyzer is used to measure the input loss between the input of RF connector (J2) to the first matching component (C1) of the device. For input loss measurement the first match component is removed and the pad at the input connector (J2) side is shorted to ground as illustrated in Figure 12.

The measured return loss is approximately 0.28dB across the band, therefore 0.14dB input loss must be de-embedded to get the LNA noise figure.

The Noise figure data in the graphic below is the noise figure after de-embedding the connector and input loss.

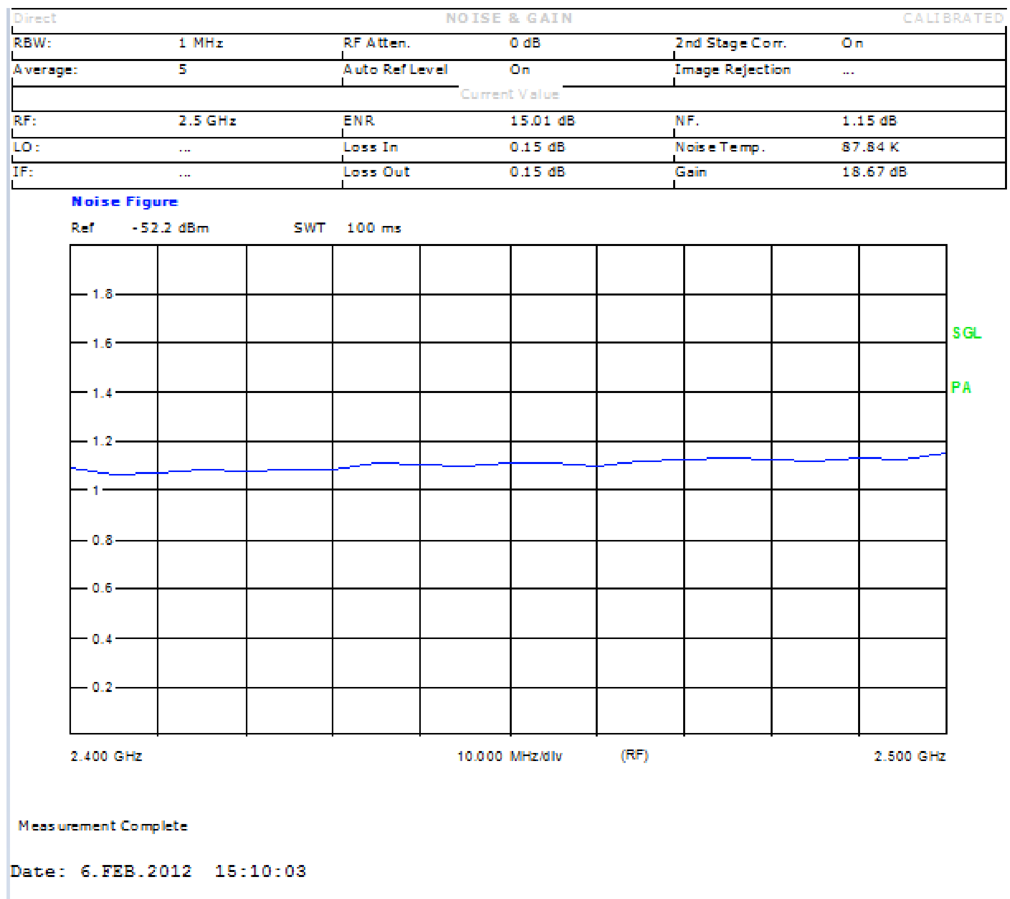


Fig 12. BFU730F 2.4-2.5GHz WiFi LNA: Noise Figure

4.3.6 LNA Turn ON/OFF Time

The following diagram shows the setup to test LNA Turn ON and Turn OFF time. The LNA Turn ON and Turn OFF time are mainly determined by the R-C time constant of the biasing circuitries: on the Base bias path the $\tau 1 = R3*C3$ and on the Base-Collector Feedback path $\tau 2 \sim= (R2+R3)*C12$, on the Collector bias path $\tau 3 \sim= (R2+R3)*C12$.

Due to much larger value of C3 obviously $\tau 2$ path will be the faster charge path on the base of the transistor hence lead to a faster Turn On time comparing with circuit topology that has no feedback.

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 -25dBm at 2.4GHz and increase its level until the output DC on the oscilloscope is at 25mV on 5mV/division, the signal generator RF output level is approximately -12dBm.

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.

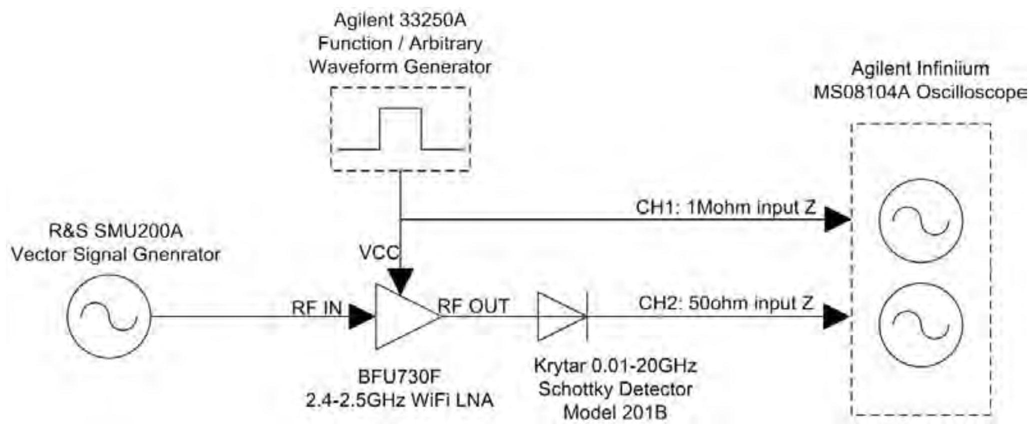
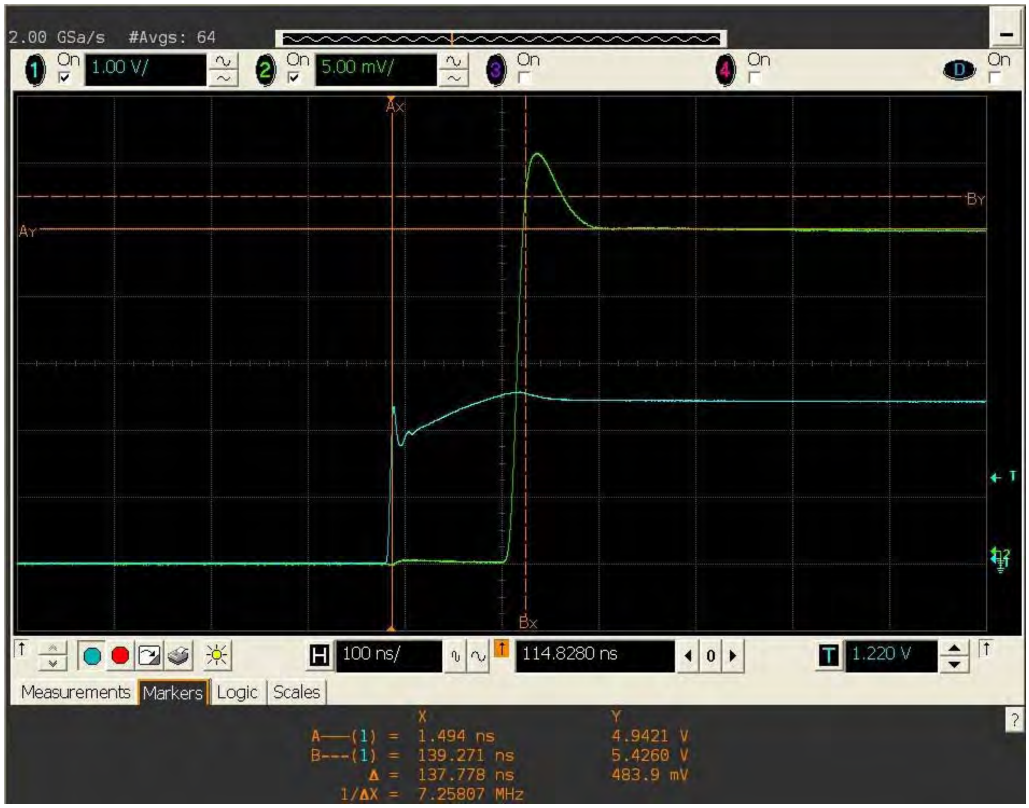


Fig 13. LNA Turn ON and Turn OFF time test setup

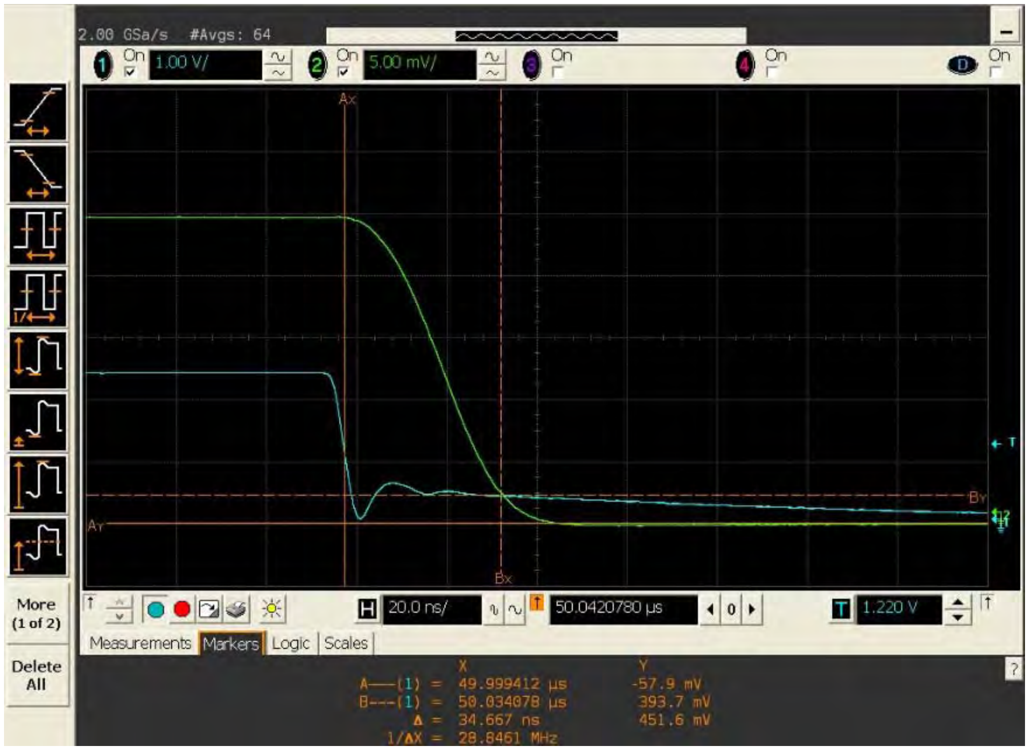
4.3.6.1 LNA Turn ON Time



3.0Vrms, 100KHz and 50% duty cycle pulse applied on VCC pin, measured from 50% of input pulse to 90% of max. output power

Fig 14. BFU730F 2.4-2.5GHz WiFi LNA: Turn ON time

4.3.6.2 LNA Turn OFF Time



3.0Vrms, 100KHz and 50% duty cycle pulse applied on VCC pin, measured from 50% of input pulse to 10% of max. output power

Fig 15. BFU730F 2.4-2.5GHz WiFi LNA: Turn OFF time

4.3.7 Summary Of the Typical Evaluation Board Test Result

Table 3. Typical results measured on the BFU730F 2.4-2.5GHz WiFi LNA Evaluation Board

Operating frequency 2.4-2.5GHz, testing at 2.4GHz and 2.5GHz unless otherwise specified, Temp = 25°C.

Parameter		Symbol	Value	Unit
Supply Voltage		Vcc	3.0	V
Supply Current		Icc	10.8	mA
Noise Figure	@2.4GHz	NF	1.09	dB
	@2.5GHz	NF	1.08	dB
Power Gain	@2.4GHz	Gp	17.8	dB
	@2.5GHz	Gp	17.5	dB
Input Return Loss	@2.4GHz	IRL	10.1	dB
	@2.5GHz	IRL	10.6	dB
Output Return Loss	@2.4GHz	ORL	12.4	dB
	@2.5GHz	ORL	11.9	dB
Reverse Isolation	@2.4GHz	ISLrev	23.9	dB

Parameter		Symbol	Value	Unit
	@2.5GHz	ISLrev	23.2	dB
Input 1dB Gain Compression Point	@2.4GHz	Pi1dB	-12.4	dBm
	@2.5GHz	Pi1dB	-12.2	dBm
Output 1dB Gain Compression Point	@2.4GHz	PL1dB	4.4	dBm
	@2.5GHz	PL1dB	4.4	dBm
Input Third Order Intercept Point Two Tones: f1: 2.4GHz, f2: 2.401GHz, power: -30dBm	@2.4GHz	IIP3	-1.8	dBm
Output Third Order Intercept Point Two Tones: f1: 2.4GHz, f2: 2.401GHz, power: -30dBm	@2.4GHz	OIP3	16.5	dBm
Stability (0- 26GHz)		K	>1	
LNA Turn ON/OFF Time		Ton	138	nS
		Toff	35	nS

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