AN11185

Low Noise Fast Turn ON/OFF 2.4-2.5GHz WiFi LNA with BFU768F

Rev. 1 — 9 October 2012 Application note

Document information

Info	Content
Keywords	BFU768F, 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	20121009	Initial publication

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1. Introduction

The BFU768F 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 BFU768F is one of a series of transistors made in SiGe:C.

BFU710F, BFU730F and BFU790F are the other types. BFU710F, BFU730F are intended for ultra low current applications. The 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

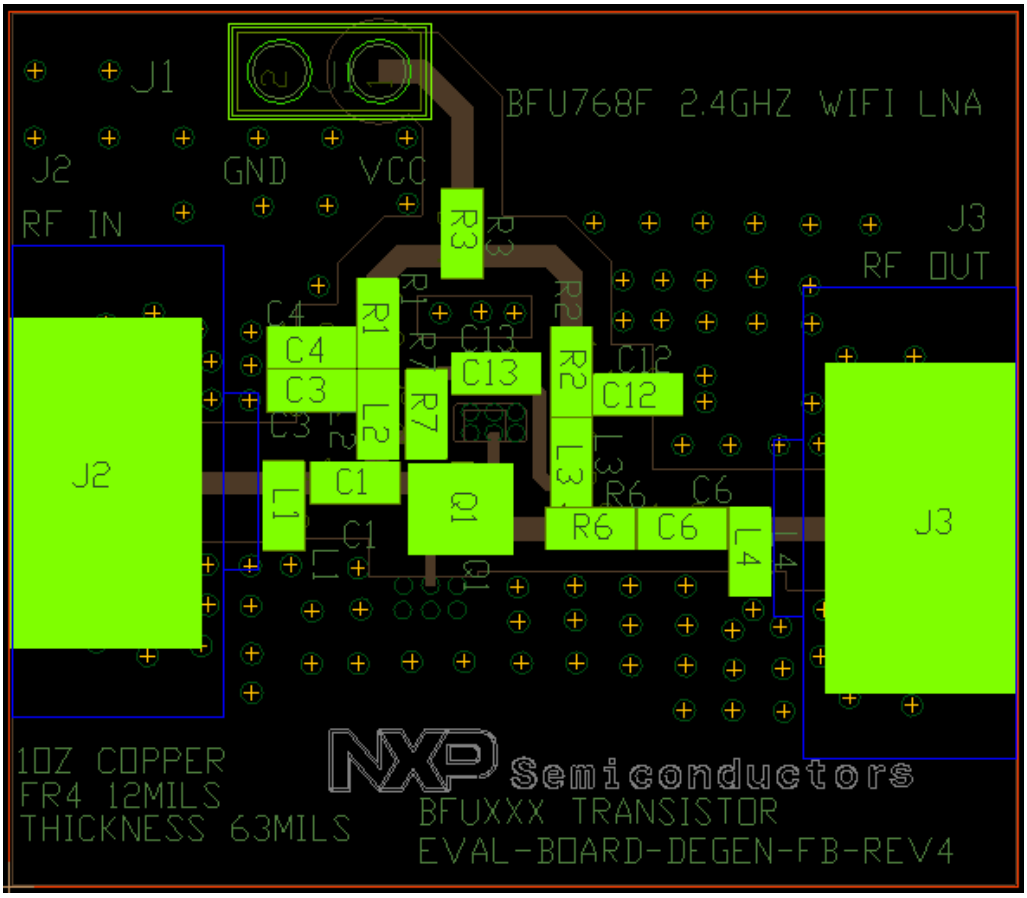


Fig 1. BFUXXX Universal Demo Board/BFU768F 2.4-2.5GHz WiFi LNA EVB Demo Board

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 BFU768F 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

3. Design and Simulation

The 2.4-2.5 GHz WiFi LNA consists of one stage BFU768F 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 14.9dB @2.4GHz with good Noise Figure of 1dB.

With only 10.8mA it also shows a high input P1 dB compression of –11dBm@2.4GHz, as well as high input IP3 of -1dBm.

The LNA has super fast Turn ON and OFF time with 172nS and 41nS respectively.

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

3.1 BFU768F 2.4-2.5GHz WiFi LNA Simulation

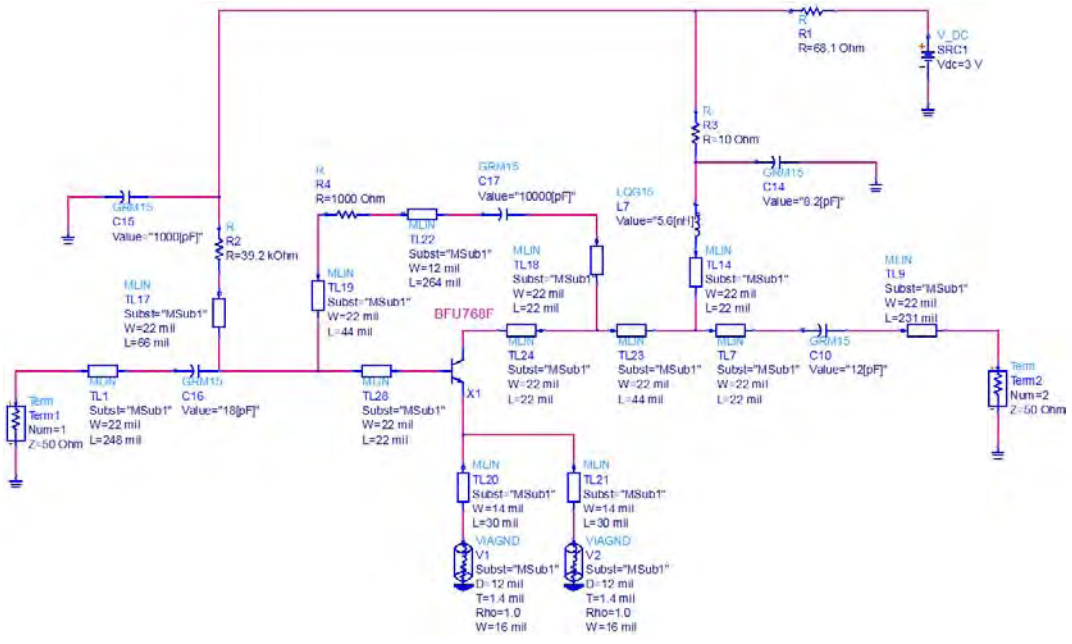


Fig 2. BFU768F 2.4-2.5GHz WiFi LNA Simulation: Circuit

3.2 BFU768 2.4-2.5GHz WiFi LNA Simulation Result

3.2.1 Gain and Match in 2.4-2.5GHz Band

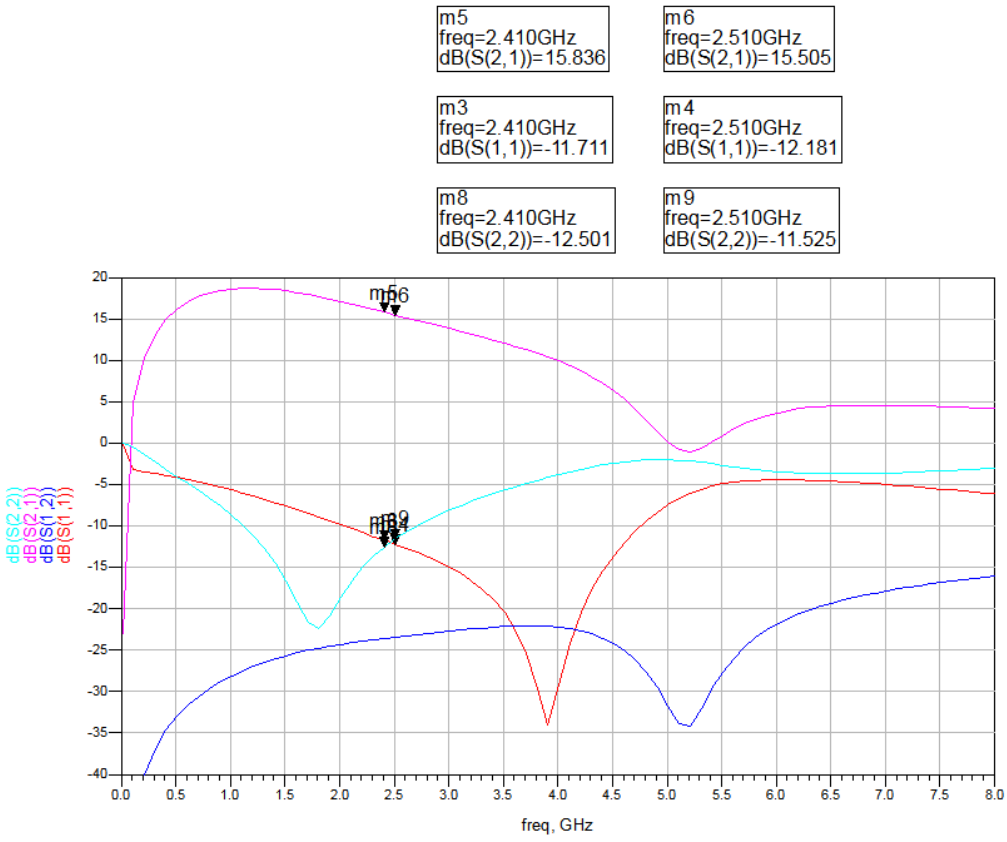


Fig 3. BFU768F 2.4-2.5GHz WiFi LNA Simulation: Gain and Match

3.2.2 Noise Figure in 2.4-2.5GHz Band

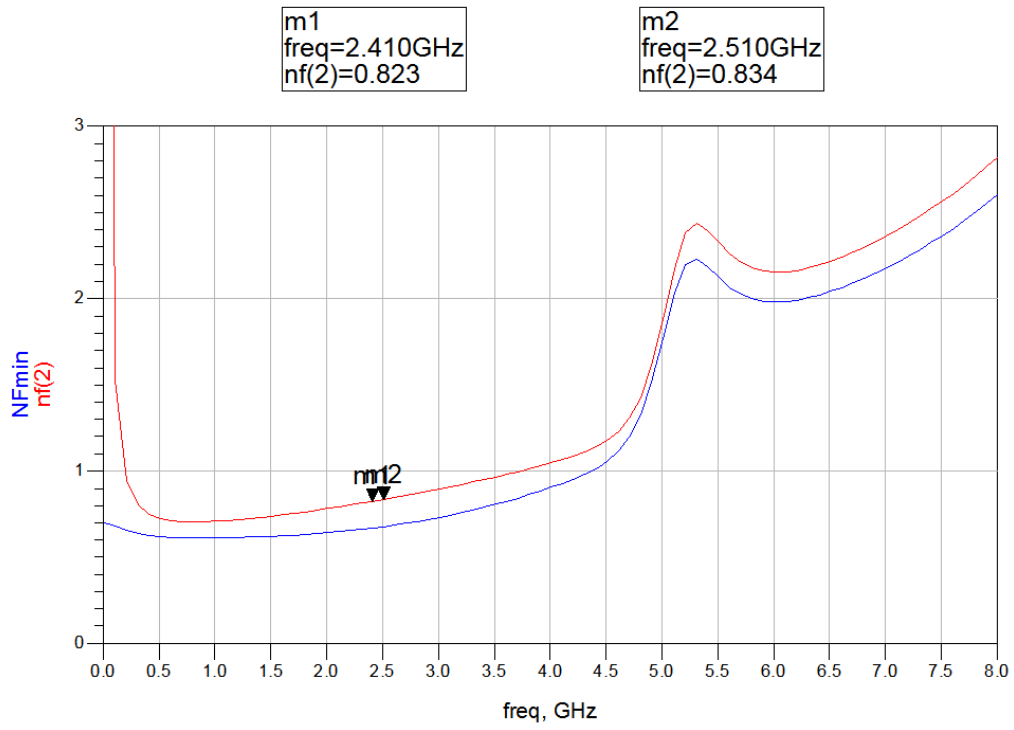


Fig 4. BFU768F 2.4-2.5GHz WiFi LNA Simulation: Noise Figure

3.2.3 Stability

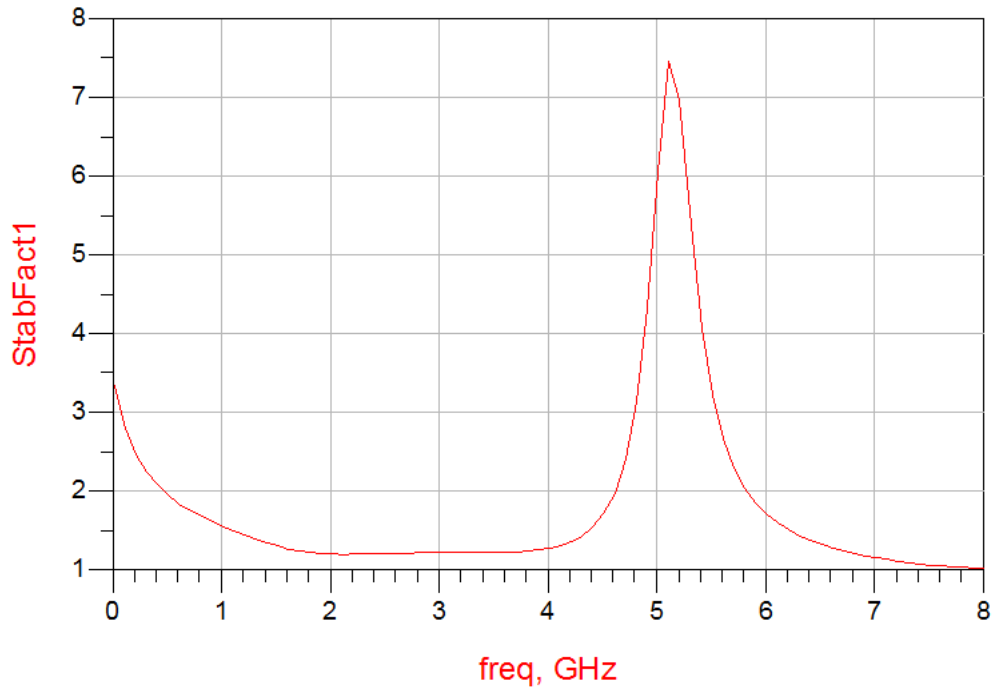


Fig 5. BFU768F 2.4-2.5GHz WiFi LNA Simulation: Stability

4. Application Board

The 2.4-2.5GHz WiFi LNA evaluation board simplifies the evaluation of the BFU768F application. The evaluation board enables testing of the device performance and requires no additional support circuitry. The board is fully assembled with the BFU768F 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

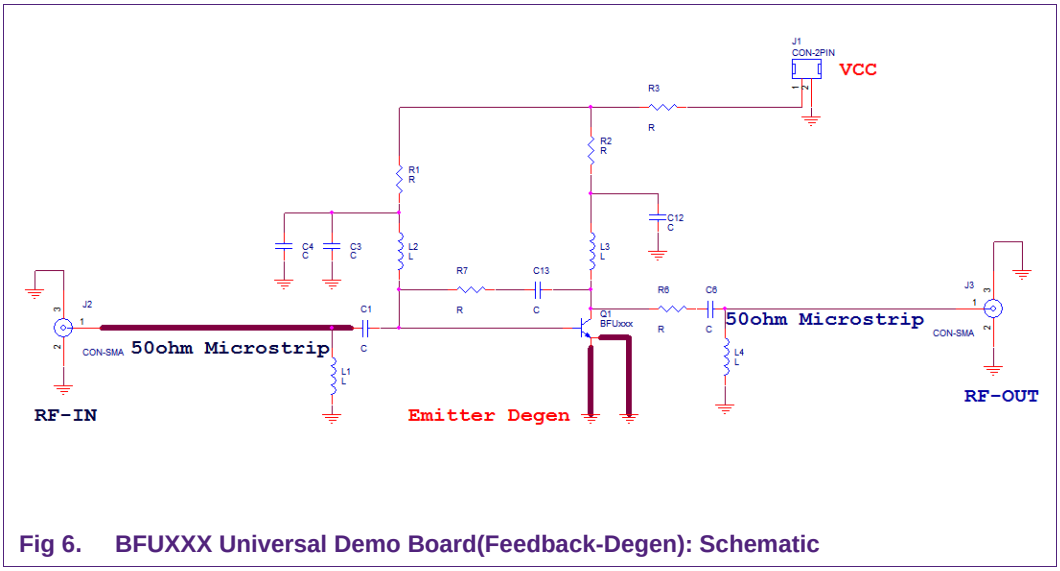


Fig 6. BFUXXX Universal Demo Board(Feedback-Degen): Schematic

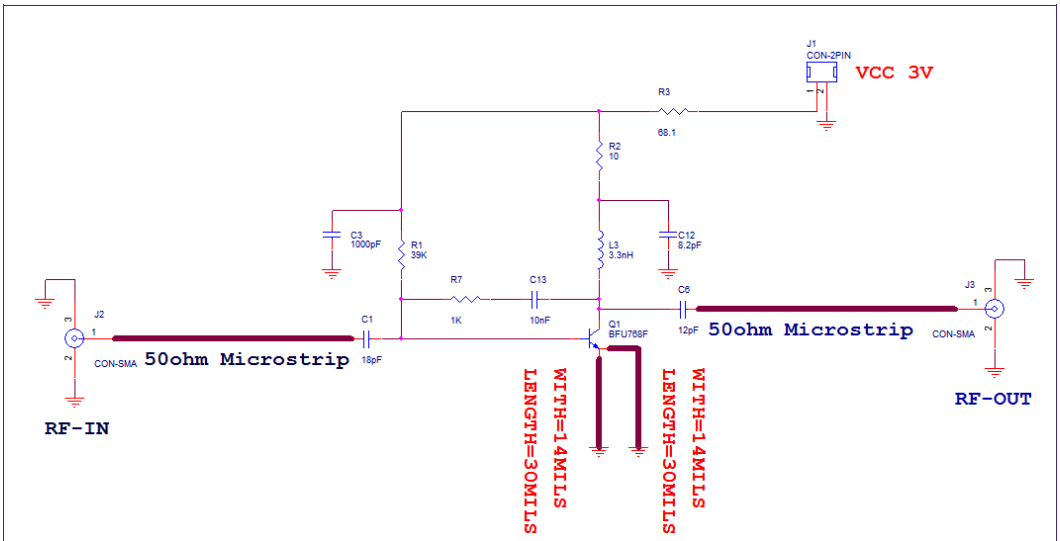


Fig 7. BFU768F 2.4-2.5GHz WiFi LNA: Schematic

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: 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 1. BFU768F 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	Value	Vendor
1	1	C1	GRM1555C1H180JZ01D	18pF	Murata
2	1	C3	GRM1555C1H102JA01	1000pF	Murata
3	1	C6	GRM1555C1H120JZ01D	12pF	Murata
4	1	C12	GRM1555C1H8R2DZ01D	8.2pF	Murata
5	1	C13	GRM155R71C103KA01D	10nF	Murata
6	1	J1	90120-0762	CON-2PIN	Molex
7	2	J2,J3	142-0701-841	CON-SMA	Johanson
8	1	L3	LQG15HS3N3S02D	3.3nH	Murata
9	1	Q1	BFU768F	BFU768F	NXP SEMICONDUCTORS
10	1	R1	ERJ-2RKF3902X	39K	Panasonic - ECG
11	1	R2	ERJ-2RKF10R0X	10	Panasonic - ECG
12	1	R3	ERJ-2RKF68R1X	68.1	Panasonic - ECG
13	1	R7	ERJ-2RKF1001X	1K	Panasonic - ECG

4.3 Typical Application Board Test Result

4.3.1 S-Parameter – Gain and Match (On State)

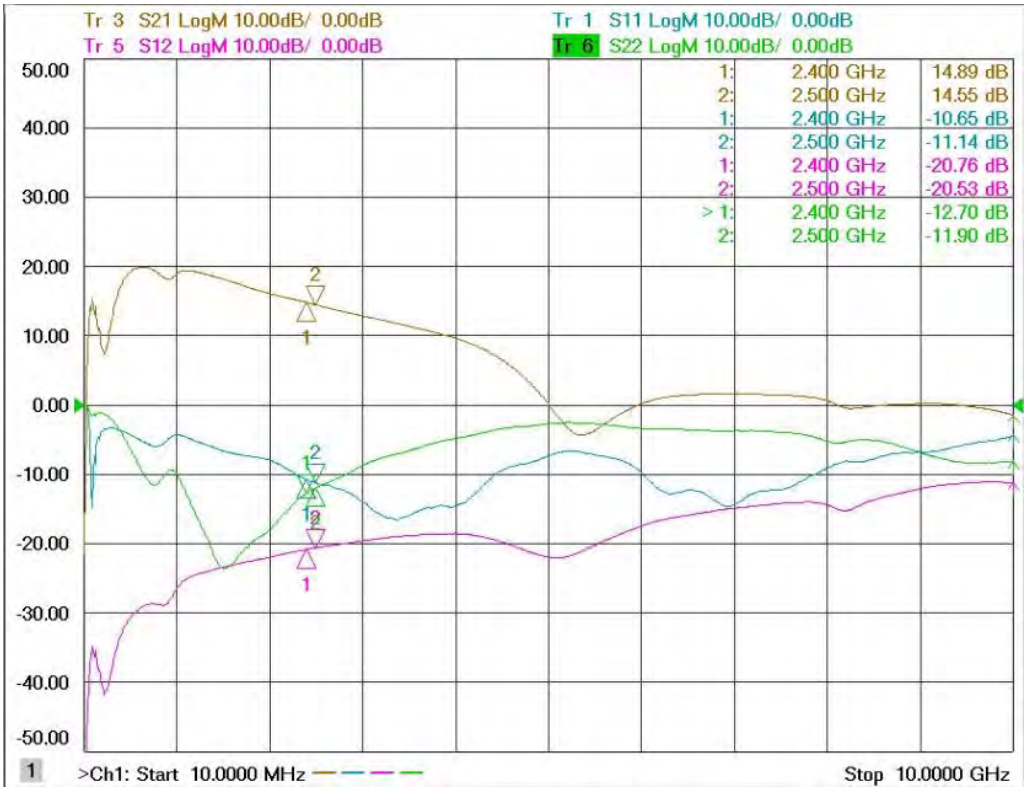


Fig 8. BFU768F 2.4-2.5GHz WiFi LNA: S-Parameter

4.3.2 S-Parameter – Gain and Match (Off State)

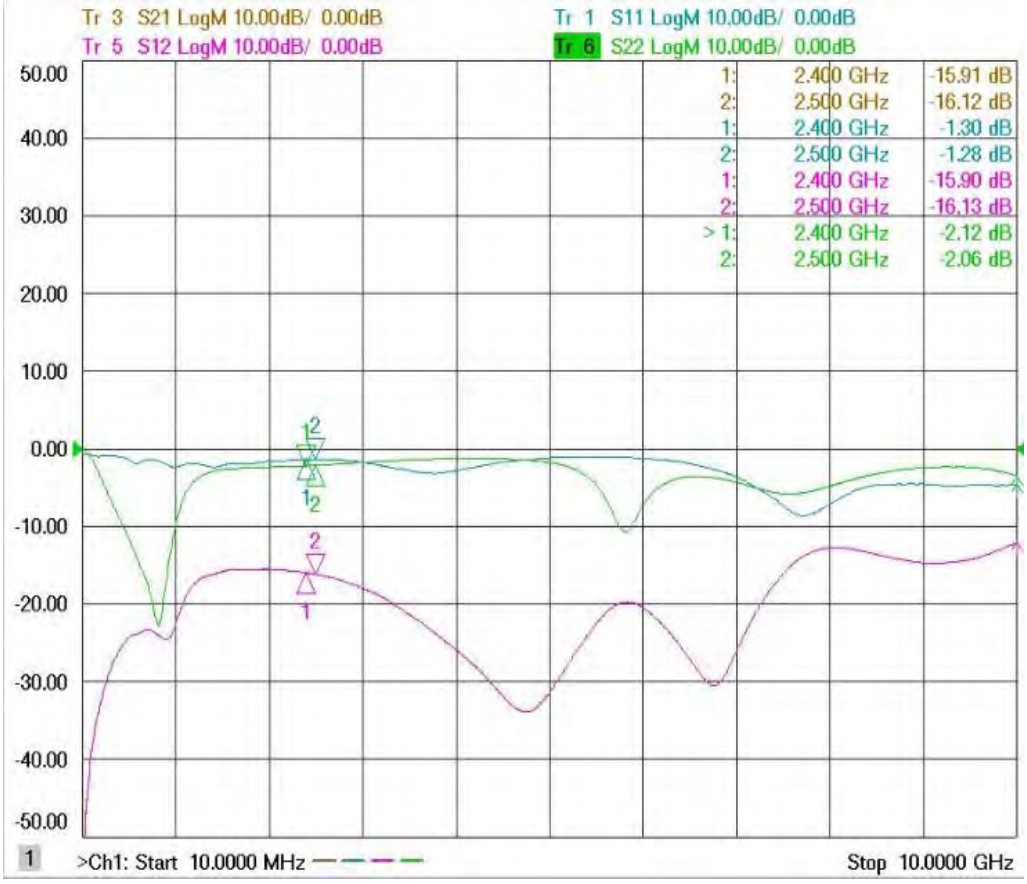


Fig 9. BFU768F 2.4-2.5GHz WiFi LNA: S-Parameter

4.3.3 P1dB

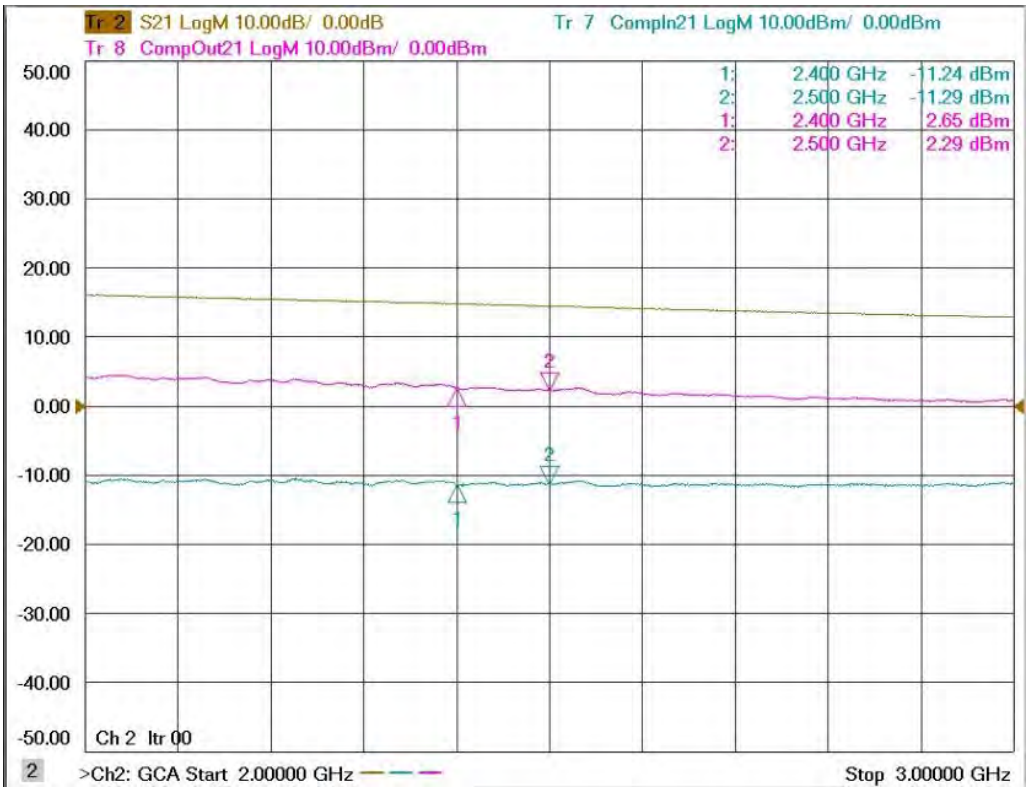
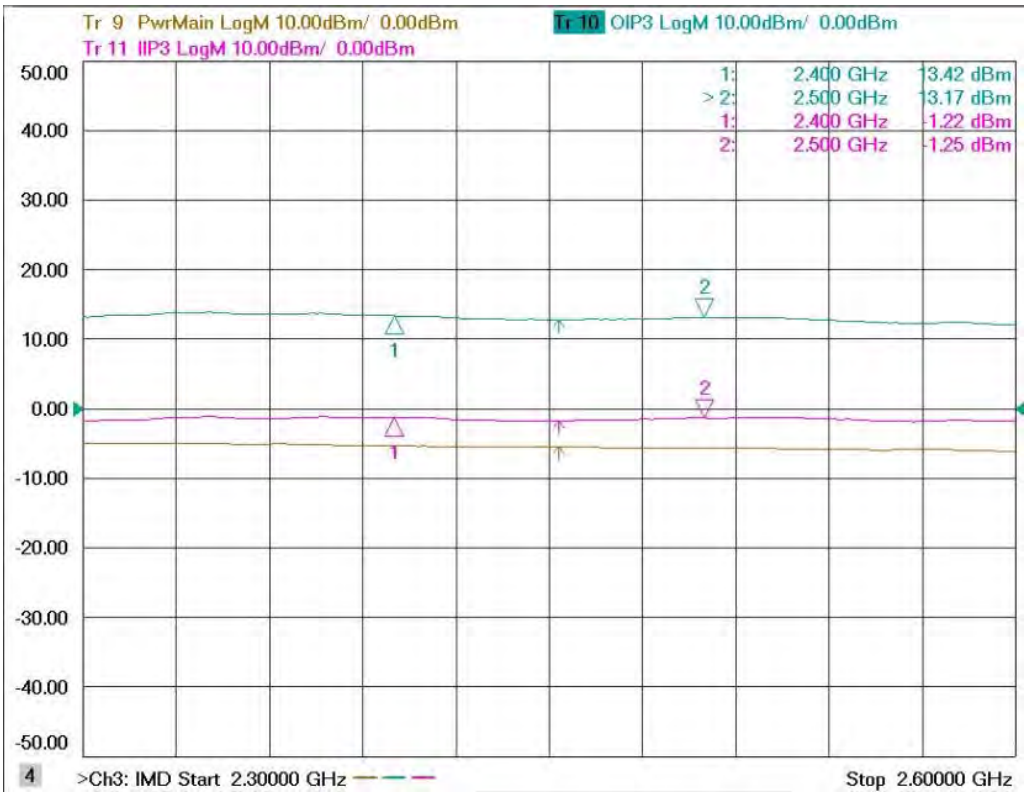


Fig 10. BFU768F 2.4-2.5GHz WiFi LNA: P1dB

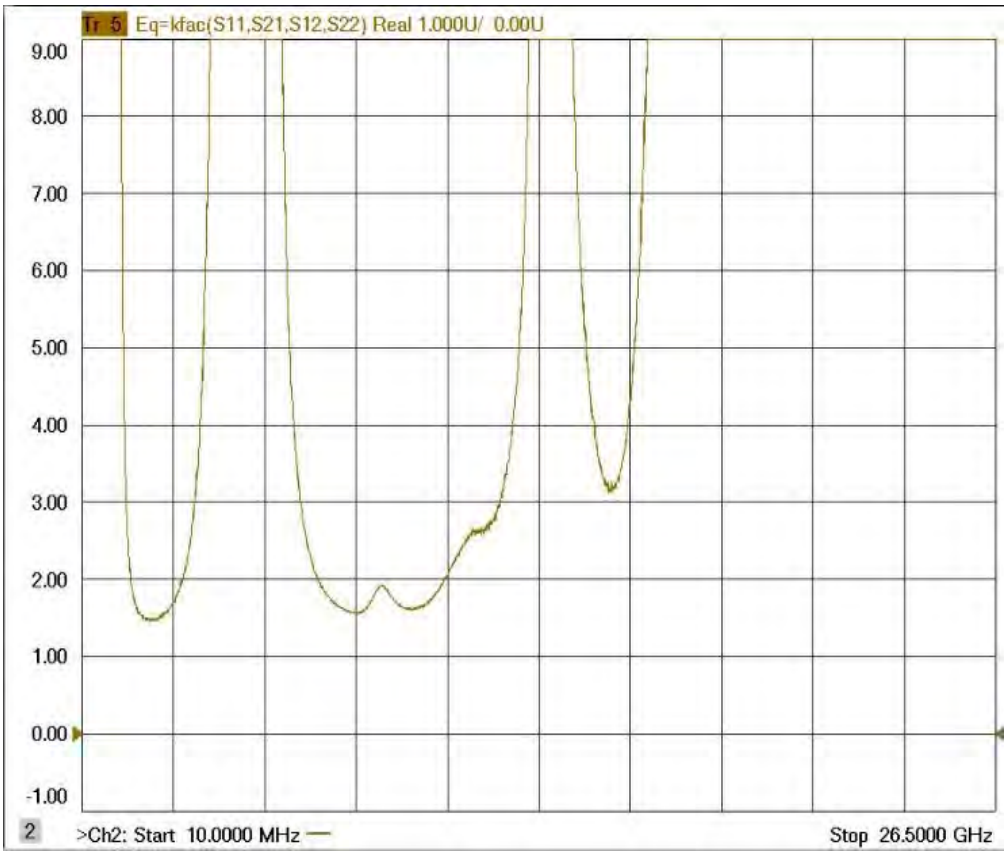
4.3.4 Linearity/IP3



Two Tone Spacing: 1MHz

Fig 11. BFU768F 2.4-2.5GHz WiFi LNA: IP3

4.3.5 Stability



K Factor

Fig 12. BFU768F 2.4-2.5GHz WiFi LNA: Stability

4.3.6 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.

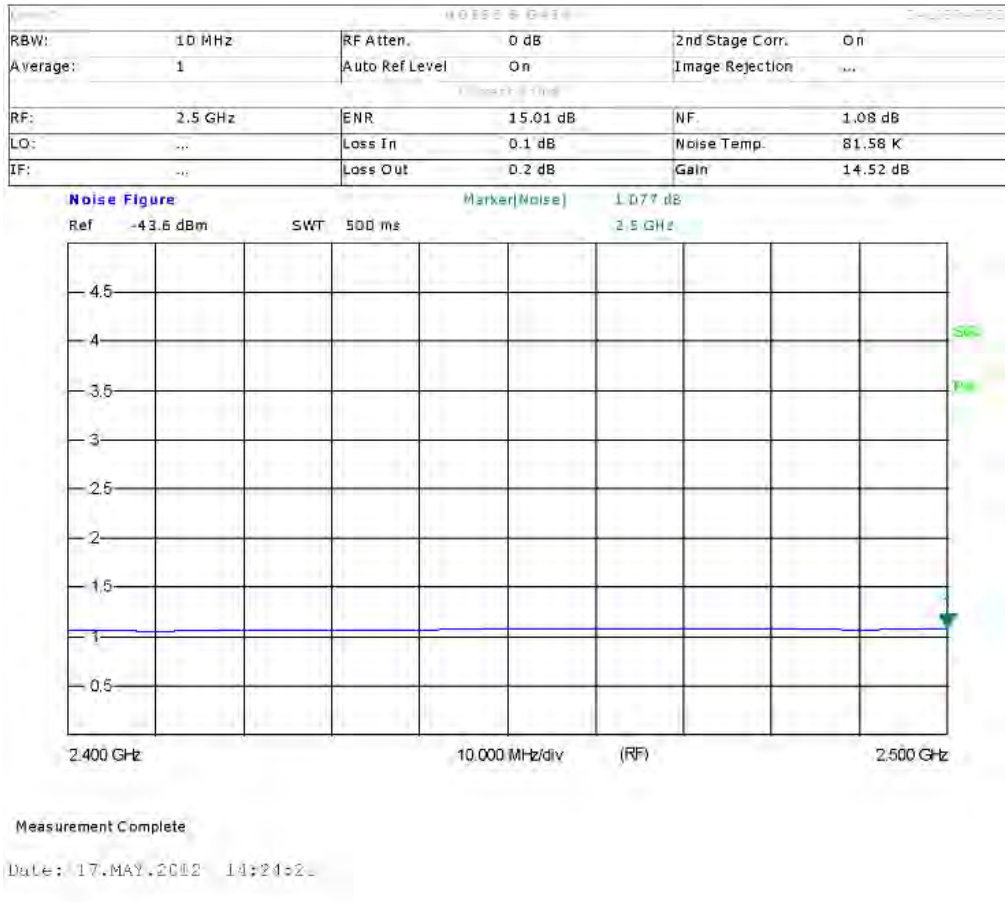


Fig 13. BFU768F 2.4-2.5GHz WiFi LNA: Noise Figure

4.3.7 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 τ1 = R3*C3 and on the Base-Collector Feedback path τ2~= (R2+R3)*C12, on the Collector bias path τ3~= (R2+R3)*C12.

Due to much larger value of C3 obviously τ2 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.

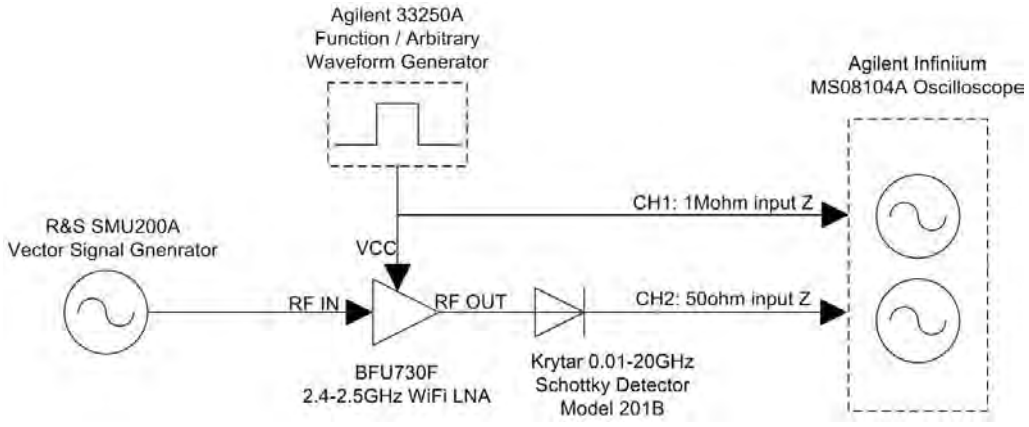
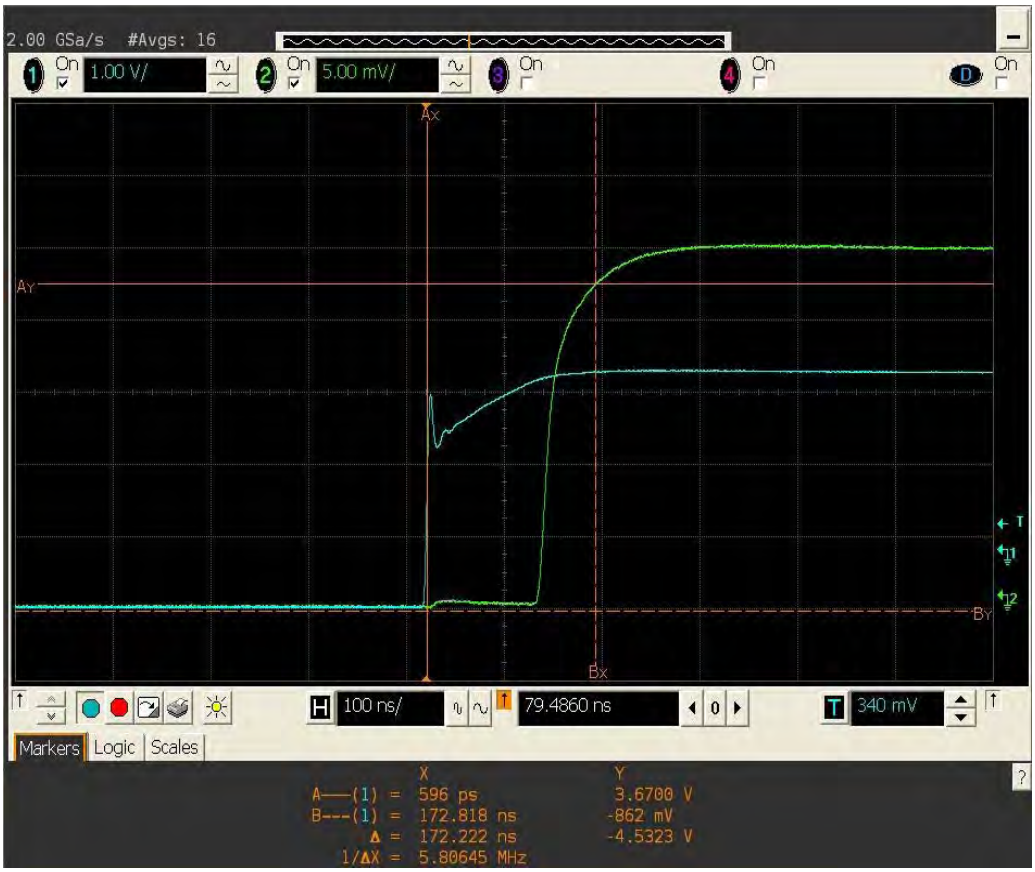


Fig 14. LNA Turn ON and Turn OFF time test setup

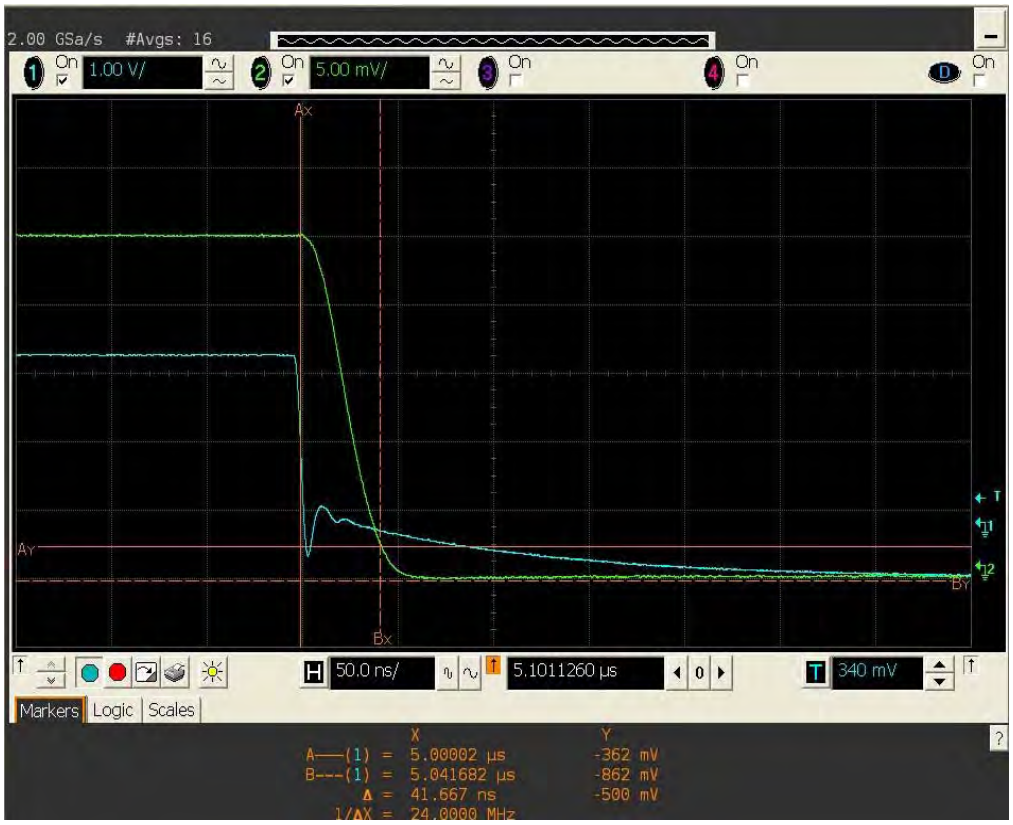
4.3.7.1 LNA Turn ON Time



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 15. BFU768F 2.4-2.5GHz WiFi LNA: Turn ON time

4.3.7.2 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 16. BFU768F 2.4-2.5GHz WiFi LNA: Turn OFF time

4.3.8 Summary Of the Typical Evaluation Board Test Result

Table 2. Typical results measured on the BFU768F 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	1.08	dB
	@2.5GHz	NF	1.05	dB
Power Gain	@2.4GHz	Gp	14.8	dB
	@2.5GHz	Gp	14.5	dB
Input Return Loss	@2.4GHz	IRL	10.6	dB
	@2.5GHz	IRL	11.2	dB
Output Return Loss	@2.4GHz	ORL	12.7	dB

Parameter		Symbol	Value	Unit
	@2.5GHz	ORL	11.9	dB
Reverse Isolation	@2.4GHz	ISLrev	20.7	dB
	@2.5GHz	ISLrev	20.5	dB
Input 1dB Gain Compression Point	@2.4GHz	Pi1dB	-11.2	dBm
	@2.5GHz	Pi1dB	-11.3	dBm
Output 1dB Gain Compression Point	@2.4GHz	PL1dB	2.7	dBm
	@2.5GHz	PL1dB	2.3	dBm
Input Third Order Intercept Point Two Tones: f1: 2.4GHz, f2: 2.401GHz, power: -30dBm	@2.4GHz	IIP3	-1.2	dBm
Output Third Order Intercept Point Two Tones: f1: 2.4GHz, f2: 2.401GHz, power: -30dBm	@2.4GHz	OIP3	13.4	dBm
Stability (0- 26GHz)		K	>1	
LNA Turn ON/OFF Time		Ton	172	nS
		Toff	41	nS

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