Application Note No. 170

BFR740L3RH SiGe:C Ultra Low Noise RF Transistor in 5 – 6 GHz LNA Application with 14 dB Gain, 1.3 dB Noise Figure & < 100 nanosecond Turn-On / Turn-Off Time

TSLP-3-9 Pb-Free / Halogen Free Transistor Package

(For 802.11a & 802.11n “MIMO” Wireless LAN Applications)

RF & Protection Devices

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Application Note No. 170

Revision History: 2008-12-03, Rev 1.0
2009-05-11, Rev 1.1

Previous Version:	
Page	**Subjects (major changes since last revision)**
7	**Value of C2 in Bill Of Material corrected (1.0 => 1.2pF)**

Trademarks

SIEGET® is a registered trademark of Infineon Technologies AG.

Additional Information:

More details about Infineon RF Transistors may be found at www.infineon.com/RF

Direct link to RF Transistor Datasheets / Specifications: www.infineon.com/rf.specs

For S-Parameters, Noise Parameters, SPICE models: www.infineon.com/rf.models

For Application Notes: www.infineon.com/rf.appnotes

1 BFR740L3RH SiGe:C Ultra Low Noise RF Transistor in 5 – 6 GHz LNA Application with 14 dB Gain, 1.3 dB Noise Figure & < 100 nanosecond Turn-On / Turn-Off Time

Overview

- Infineon Technologies **BFR740L3RH** is a high gain, ultra low noise Silicon-Germanium-Carbon (SiGe:C) HBT device suitable for a wide range of Low Noise Amplifier (LNA) applications.

- The circuit shown in this document is targeted for 802.11a & 802.11n "MIMO" applications in the Wireless Local Area Network (WLAN) market, particularly for Access Points (AP's) which require external LNA's to fulfill high-sensitivity / low Bit Error Rate (BER) / long range requirements. LNA's for this application must be able to switch on / off within about 1 microsecond, or 1000 nanoseconds. Charge storage (capacitance) used in the circuit is minimized to reduce turn-on / turn-off times. Trade-off for reduced capacitance values is a reduction in Third Order Intercept (IP_3) performance. **Amplifier is Unconditionally Stable (μ_1 > 1.0) from 10 MHz – 12 GHz.**

- External parts count (not including BFR740L3RH transistor) = 12; 6 capacitors, 3 resistors, & 3 chip inductors. All passives are '0402' case size. **BFR740L3RH leadless transistor package is RoHS – compliant, free of any Halogen-compounds,** and is 1 x 0.6 x 0.31mm in size.

2 Summary Of Performance Data

(T=25 °C, network analyzer source power ≈ -25 dBm, V_{CC} = 3.0 V, V_{CE} = 2.2 V, I_C=12.9 mA, Z_S=Z_L=50 Ω)

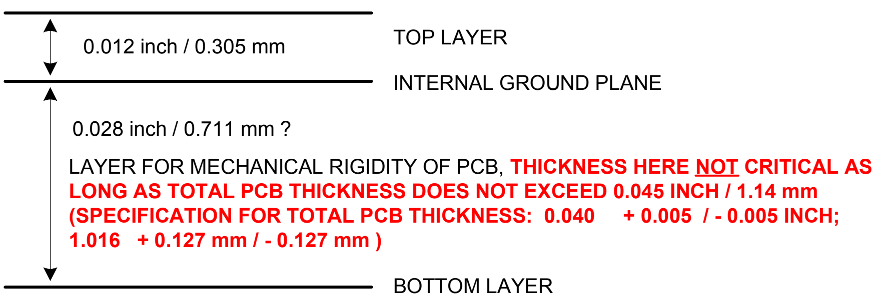
Frequency MHz	dB[s11]^2	dB[s21]^2	dB[s12]^2	dB[s22]^2	* NF dB	** IIP_3 dBm	** OIP_3 dBm	IP_{1dB} dBm	OP_{1dB} dBm
5150	- 13.2	**14.6**	-20.7	-12.8	**1.3**	---	---	---	---
5470	-19.5	**14.3**	-20.3	-12.7	**1.3**	+4.1	+18.4	-5.2	+8.1
5825	-18.0	**13.9**	-20.0	-16.0	**1.4**	---	---	---	---
2500	- 2.9	**0.9**	- 44.1	- 0.6	**---**	---	---	---	---

*** does not extract PCB loss. If PCB loss (at input) were extracted, noise figure would be ~ 0.2 dB lower.**
Note: reverse isolation (dB[s12]^2) when DC power to LNA is OFF = -11.5 dB @ 5470 MHz. See page 18.

3 Details of PC Board Construction

PC board is fabricated from standard, low-cost "FR4" glass-epoxy material. A cross-section diagram of the PC board is given below.

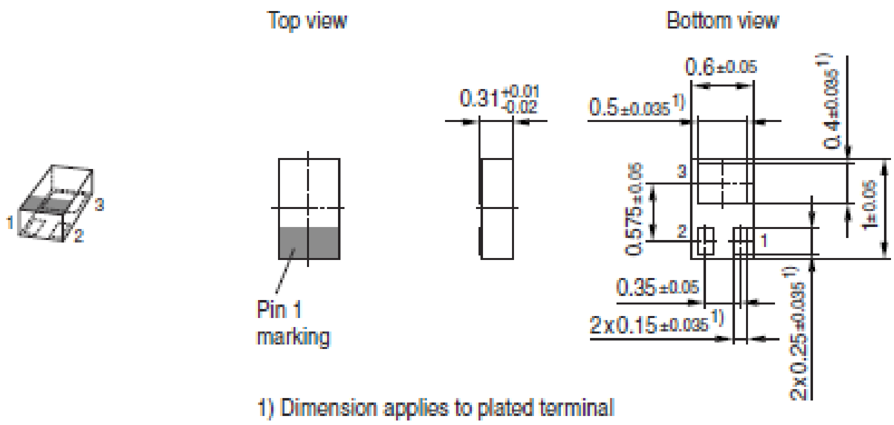
PCB CROSS SECTION



4 TSLP-3-9 Package Outline & Footprint. Dimensions in millimeters (mm). Note this package does not contain any Halogen compounds in addition to being RoHS – compliant.

TSLP-3-9 (–) – Low Height

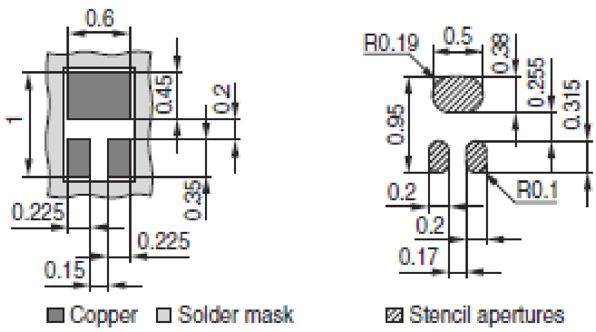
Package Outline



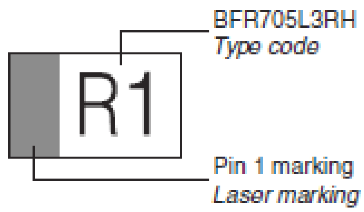
1) Dimension applies to plated terminal

Foot Print

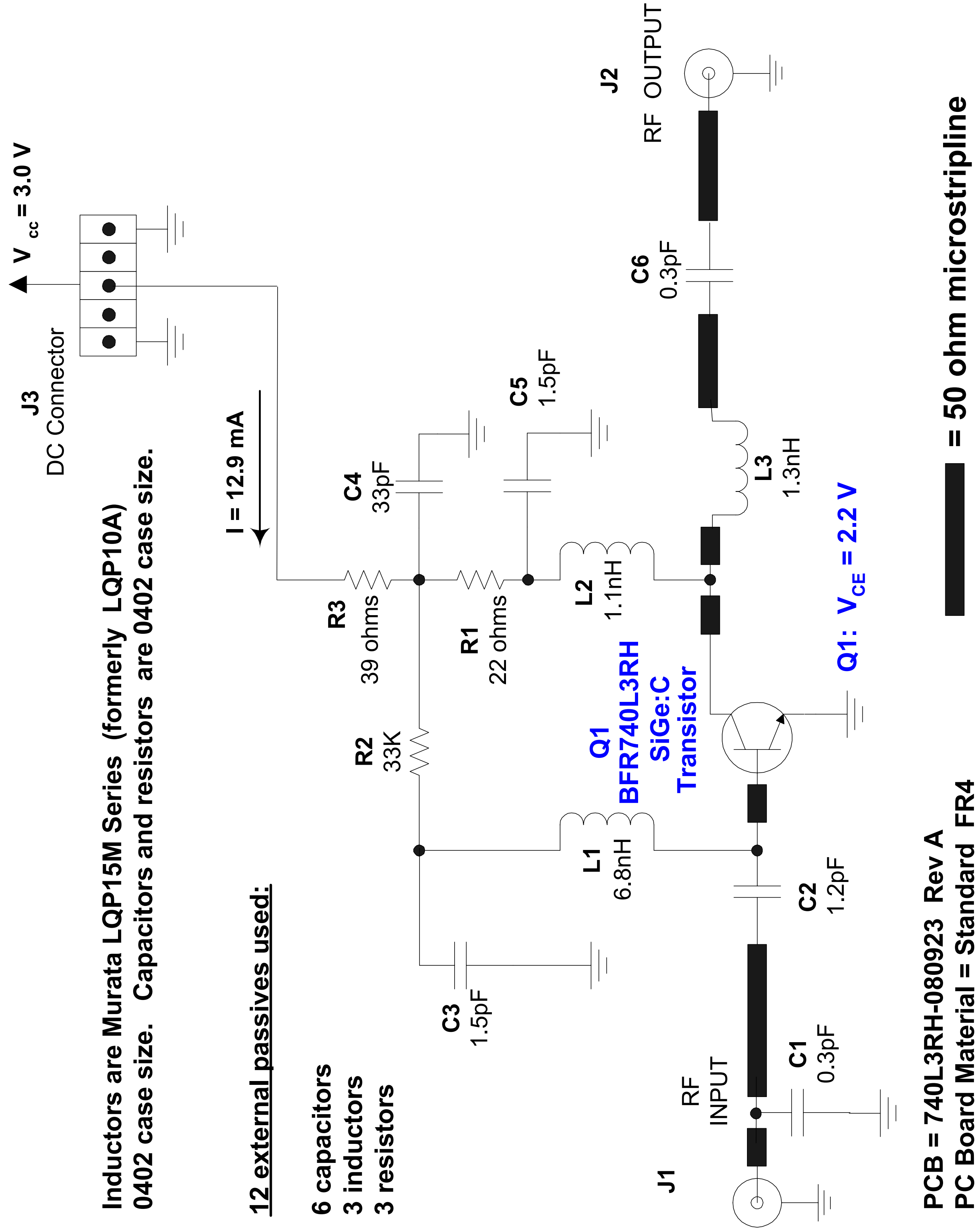
For board assembly information please refer to Infineon website "Packages"



Marking Layout (Example)



5 Schematic Diagram

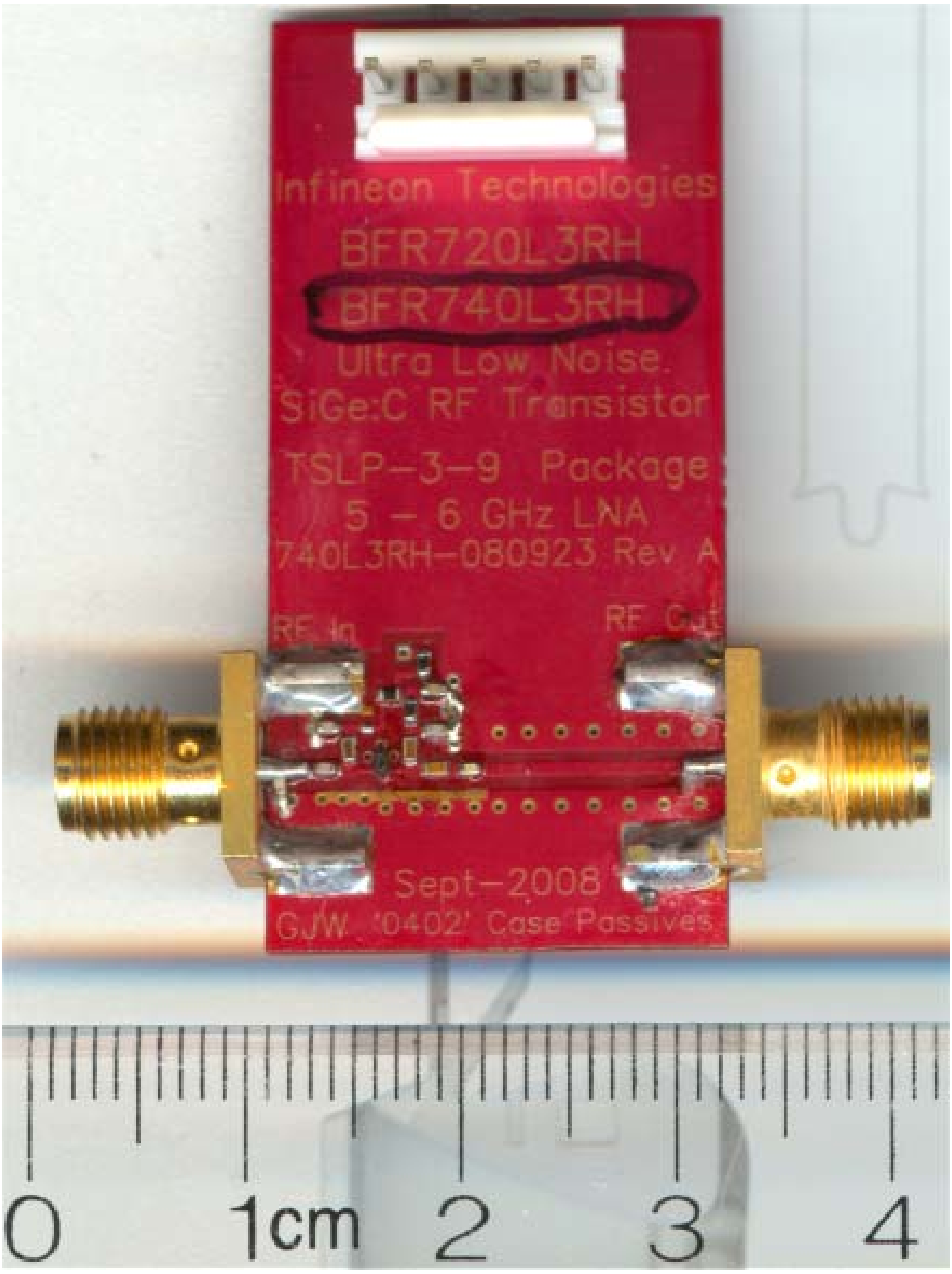


6 Bill Of Material (BOM)

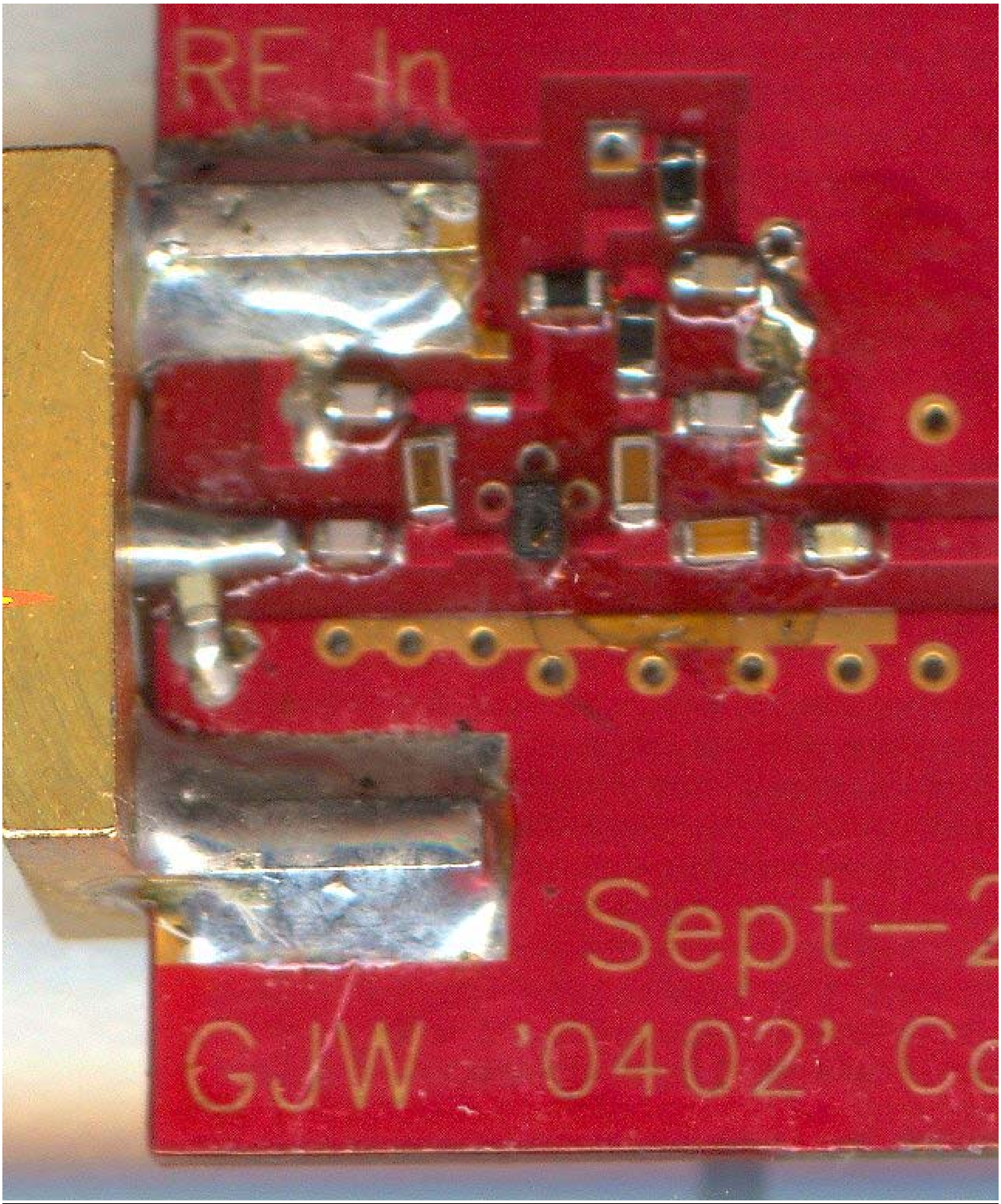
Reference Designator	Value	Description / Part #	Manufacturer	Function
C1	0.3pF	0.3pF, 50V, COG ‘0402’ case size capacitor Murata GRM1555C1HR30BZ01D or equivalent	Murata, AVX, etc.	Input Match
C2	1.2pF	‘0402’ chip capacitor	Various	Input DC block, Input Matching
C3	1.5pF	‘0402’ chip capacitor	Various	RF decoupling / blocking cap
C4	33pF	‘0402’ chip capacitor	Various	RF decoupling / blocking cap
C5	1.5pF	‘0402’ chip capacitor	Various	RF decoupling / blocking cap
C6	0.3pF	0.3pF, 50V, COG ‘0402’ case size capacitor Murata GRM1555C1HR30BZ01D or equivalent	Murata, AVX, etc.	Output DC block and output matching. Also influences input match.
L1	6.8nH	6.8nH ‘0402’ case size chip inductor Murata LQP15M Series or equivalent	Murata	RF Choke at LNA input (for DC bias to base).
L2	1.1nH	1.1nH ‘0402’ case size chip inductor Murata LQP15M series or equivalent	Murata	RF ‘Choke’ at LNA output, for DC bias to collector. Also influences matching and stability.
L3	1.3nH	1.3nH ‘0402’ case size chip inductor Murata LQP15M series or equivalent	Murata	Output matching; also influences input match.
R1	22Ω	‘0402’ chip resistor	Various	For RF stability improvement.
R2	33kΩ	‘0402’ chip resistor	Various	DC biasing (base).
R3	39Ω	‘0402’ chip resistor	Various	DC biasing (provides DC negative feedback to stabilize DC operating point over temperature variation, transistor h_{FE} variation, etc.)
Q1	**---**	**BFR740L3RH SiGe:C Low Noise RF Transistor, TSLP-3-9 package**	**Infineon Technologies**	**LNA active device.**
J1, J2		RF Edge Mount SMA Female Connector, 142-0701-841	Emerson / Johnson	Input, Output RF connector
J3		MTA-100 Series 5 pin connector 640456-5	Tyco (AMP)	5 Pin DC connector header
---		PC Board, Part # 740L3RH-080923 Rev A	Infineon Technologies	Printed Circuit Board

7 Scanned Images of PC Board

View of Entire PC Board



Close-In View of LNA Section



8 Noise Figure Measurement Data

Noise Figure Plot, from Rohde and Schwarz FSEK3 + FSEM30

Rohde & Schwarz FSEK3 02 Dec 2008

Noise Figure Measurement

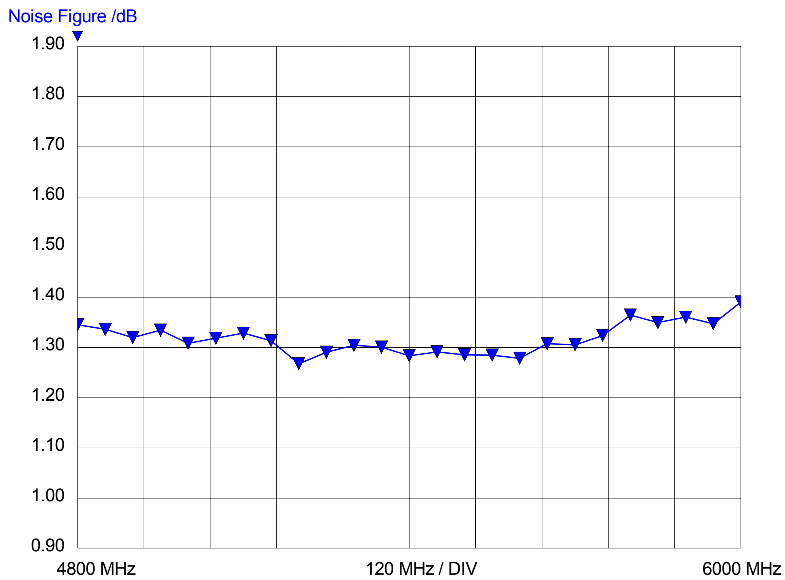
EUT Name:	BFR740L3RH 5 - 6 GHz LNA, Fast Switching / Fast Turn ON-OFF Time
Manufacturer:	Infineon Technologies
Operating Conditions:	T=25 C, V = 3.0V, Vce = 2.2V, I = 12.9mA
Operator Name:	Gerard Wevers
Test Specification:	WLAN 802.11n, 802.11n
Comment:	PCB = 740L3RH-080923 Rev A; Preamp = MITEQ AFS3-04000800-10-ULN 2 December 2008

Analyzer

RF Att:	0.00 dB	RBW :	1 MHz	Range:	30.00 dB
Ref Lvl:	-45.00 dBm	VBW :	100 Hz	Ref Lvl auto:	ON

Measurement

2nd stage corr:	ON	Mode:	Direct	ENR:	346A_1.ENR



Noise Figure, Tabular Data

Taken With Rohde & Schwarz FSEM30 + FSEK3
System Preamplifier = MITEQ 4 – 8 GHz LNA

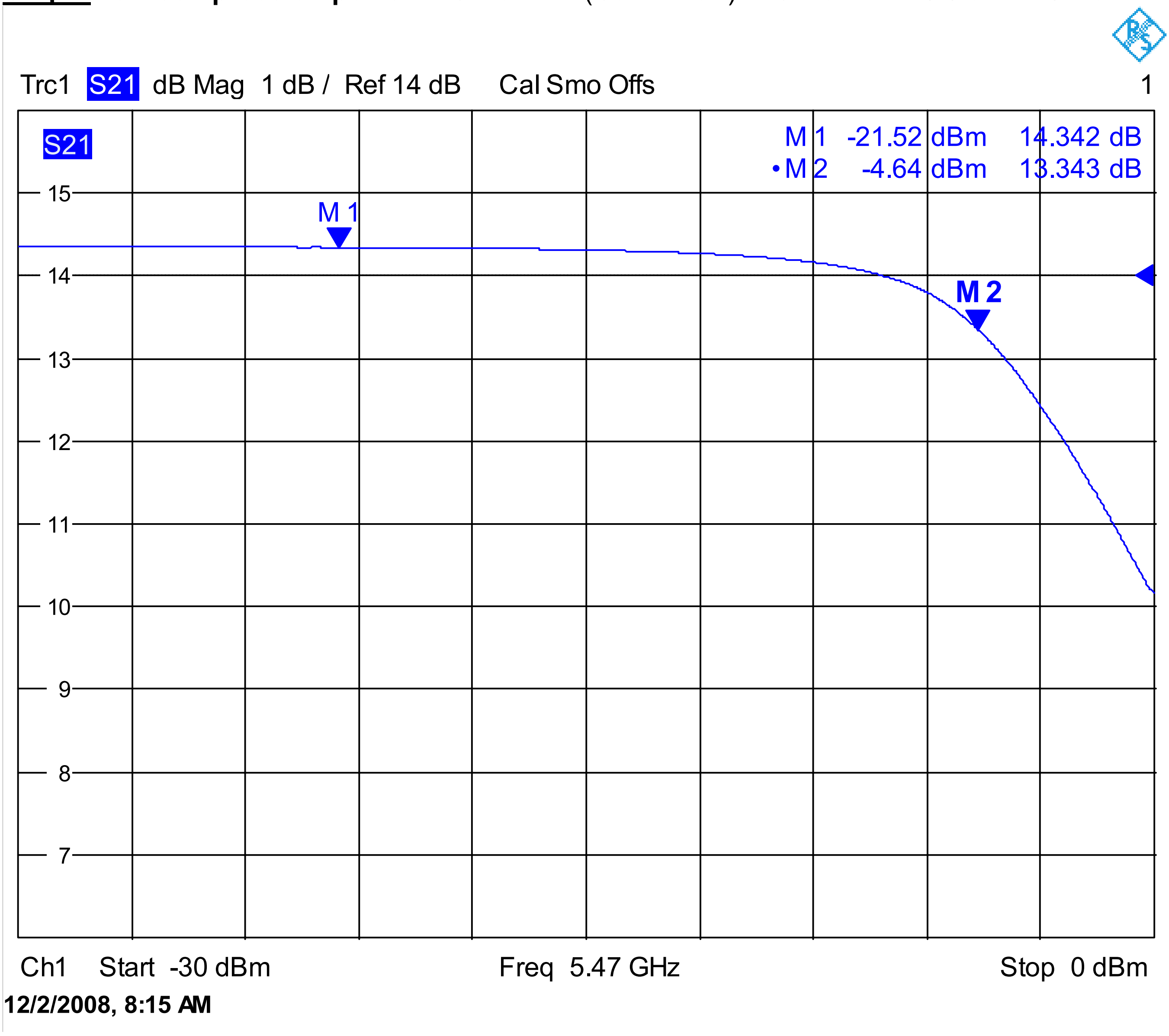
Frequency	Nf	Temp
4800 MHz	1.35 dB	105.3 K
4850 MHz	1.34 dB	104.5 K
4900 MHz	1.32 dB	103 K
4950 MHz	1.33 dB	104.3 K
5000 MHz	1.31 dB	102 K
5050 MHz	1.32 dB	102.9 K
5100 MHz	1.33 dB	103.8 K
5150 MHz	1.31 dB	102.4 K
5200 MHz	1.27 dB	98.3 K
5250 MHz	1.29 dB	100.4 K
5300 MHz	1.30 dB	101.6 K
5350 MHz	1.30 dB	101.3 K
5400 MHz	1.28 dB	99.7 K
5450 MHz	1.29 dB	100.4 K
5500 MHz	1.29 dB	99.9 K
5550 MHz	1.28 dB	99.8 K
5600 MHz	1.28 dB	99.3 K
5650 MHz	1.31 dB	101.9 K
5700 MHz	1.31 dB	101.7 K
5750 MHz	1.32 dB	103.3 K
5800 MHz	1.36 dB	107.1 K
5850 MHz	1.35 dB	105.7 K
5900 MHz	1.36 dB	106.7 K
5950 MHz	1.35 dB	105.5 K
6000 MHz	1.39 dB	109.5 K

9 Amplifier Compression Point Measurement

Gain Compression at 5470 MHz, V_{CC} = +3.0 V, I = 12.9mA, V_{CE} = 2.2V, T = 25°C:
Rohde & Schwarz ZVB20 Vector Network Analyzer is set up to sweep input power to LNA at a fixed frequency of 5470 MHz. X-axis of VNA screen-shot below shows input power to LNA being swept from –30 to 0 dBm. ZVB20 Port 1 output power is checked / verified against HP E4419A power meter; ZVB20 output power is ≅ 0.6 dB lower than indicated on ZVB20 due to test cable loss. Therefore, a 0.6 dB offset is needed.

Input 1 dB compression point = - 4.6 dBm – 0.6 dB offset = **- 5.2 dBm**

Output 1dB compression point = - 5.2 dBm + (Gain – 1dB) = -5.2 dBm + 13.3 dB = **+8.1 dBm**



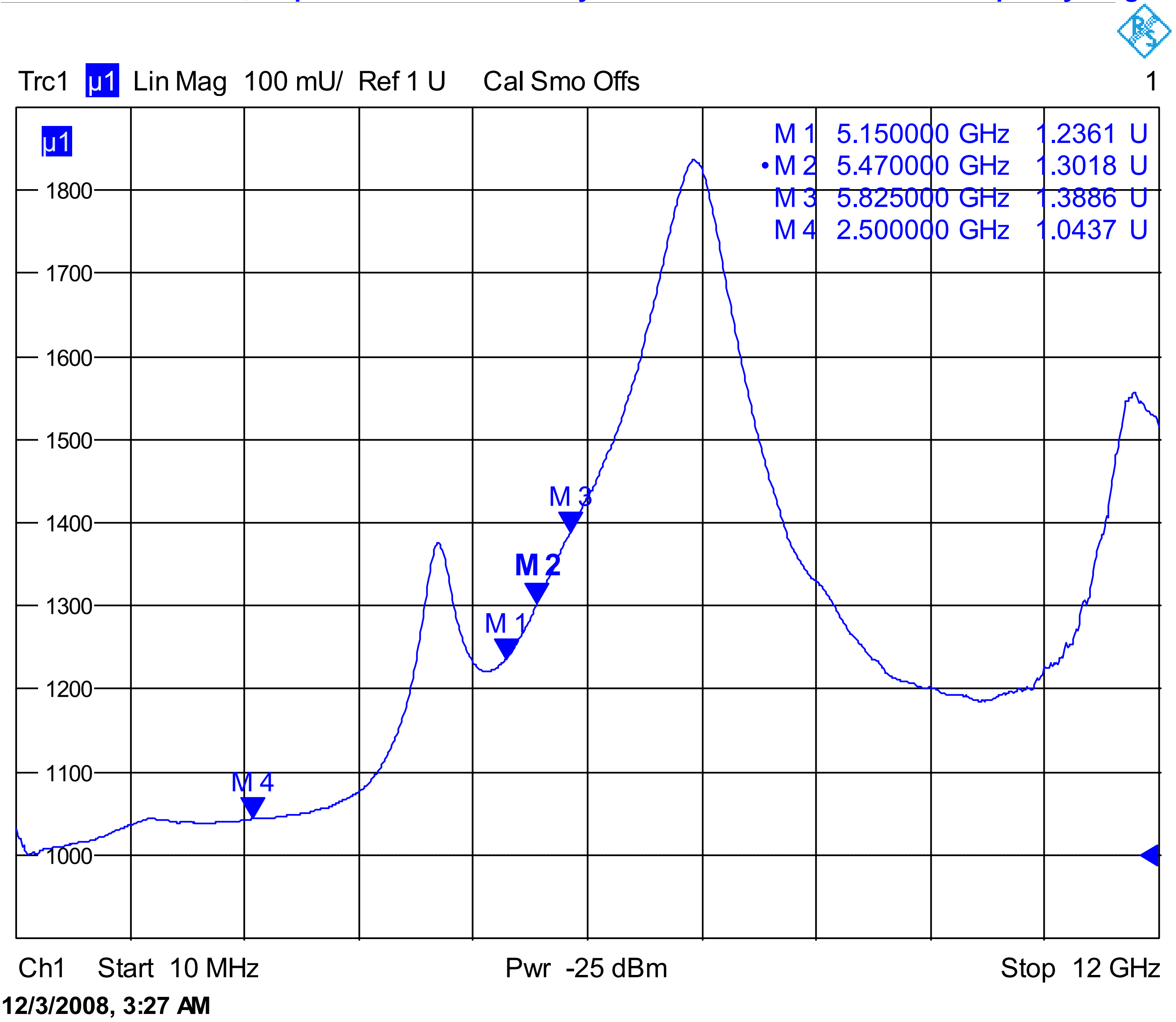
10 Amplifier Stability, Gain, Return Loss and Reverse Isolation Plots

Amplifier Stability - Plot of Stability Factor "μ_1" :

Rohde and Schwarz ZVB Network Analyzer Calculates and plots stability factor **"μ_1"** of the BFP740F amplifier in real time. Stability Factor μ_1 is defined as follows [1]:

$$\mu_1 = \frac{1 - |S_{11}|^2}{|S_{22} - S_{11}^* \det(\mathbf{S})| + |S_{21}S_{12}|}$$

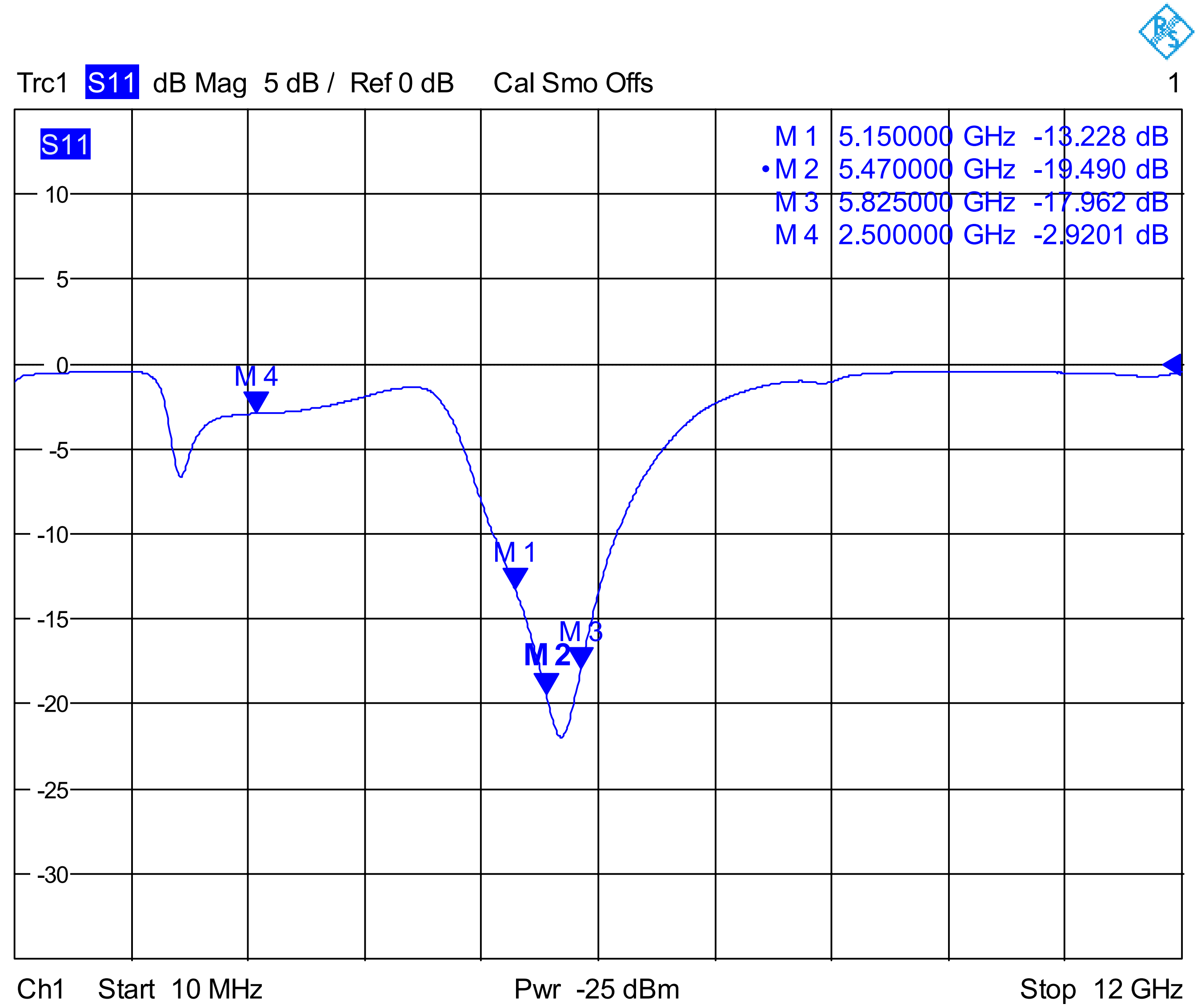
The necessary and sufficient condition for Unconditional Stability is μ_1 > 1.0. In the plot, μ_1 **>** 1.0 over 10 MHz – 12 GHz; **amplifier is Unconditionally Stable over 10 MHz – 12 GHz frequency range.**



[1]. "Fundamentals of Vector Network Analysis", Michael Hiebel, 4th edition 2008, pages 175 – 177, ISBN 978-3-939837-06-0

Input Return Loss, Log Mag

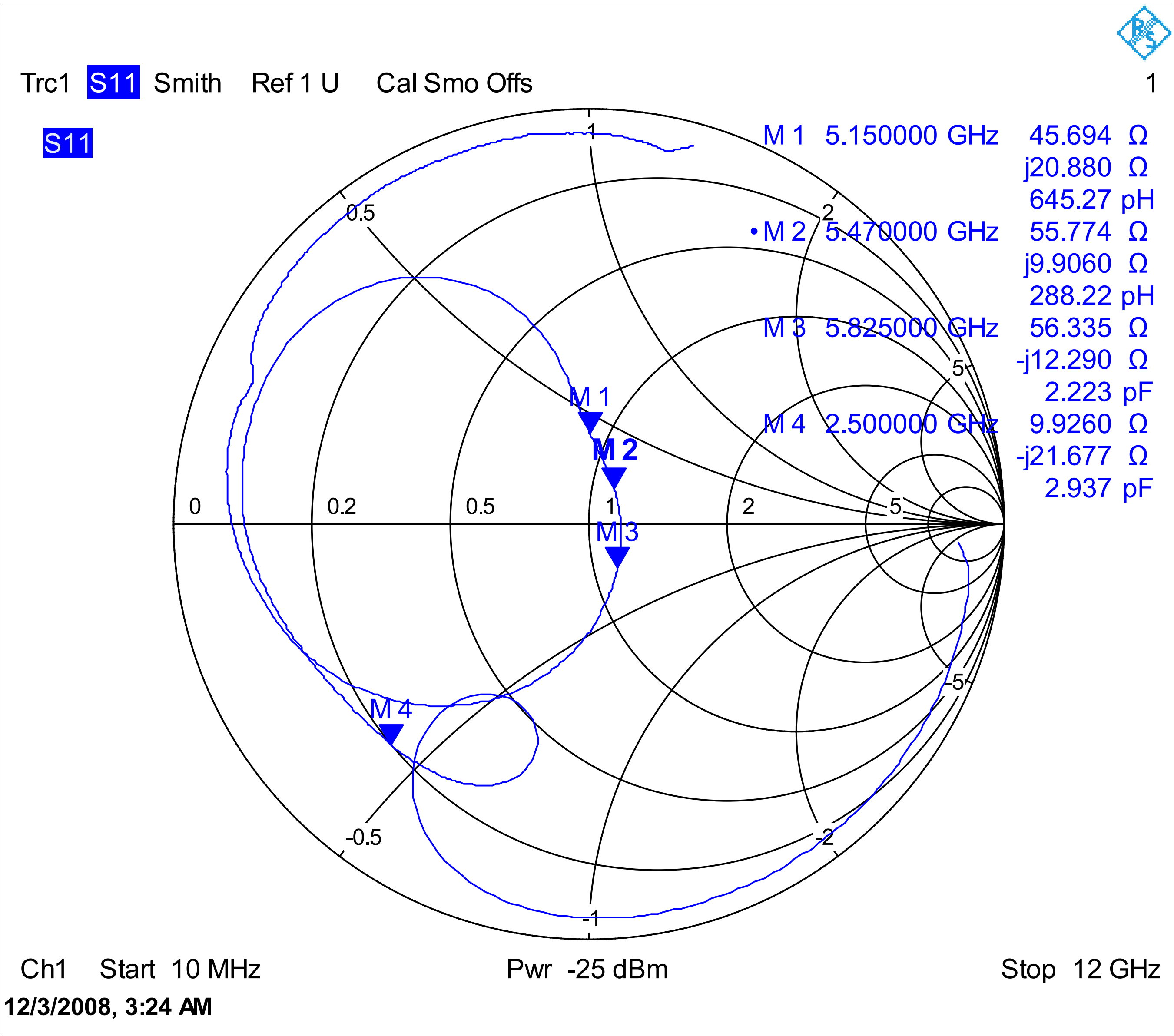
10 MHz – 12 GHz Sweep



12/3/2008, 3:23 AM

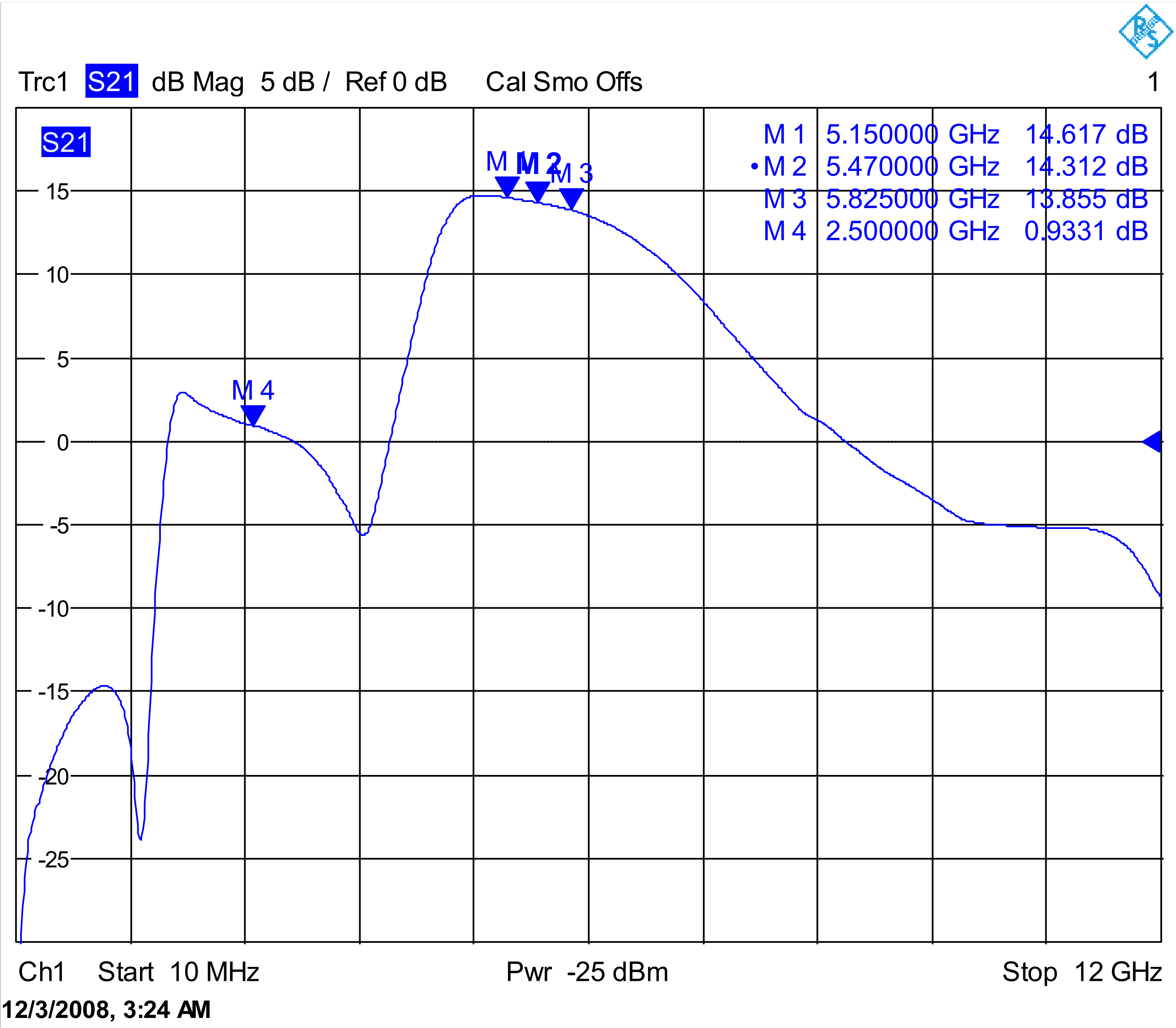
Input Return Loss, Smith Chart

Reference Plane = Input SMA Connector on PC Board
10 MHz – 12 GHz Sweep



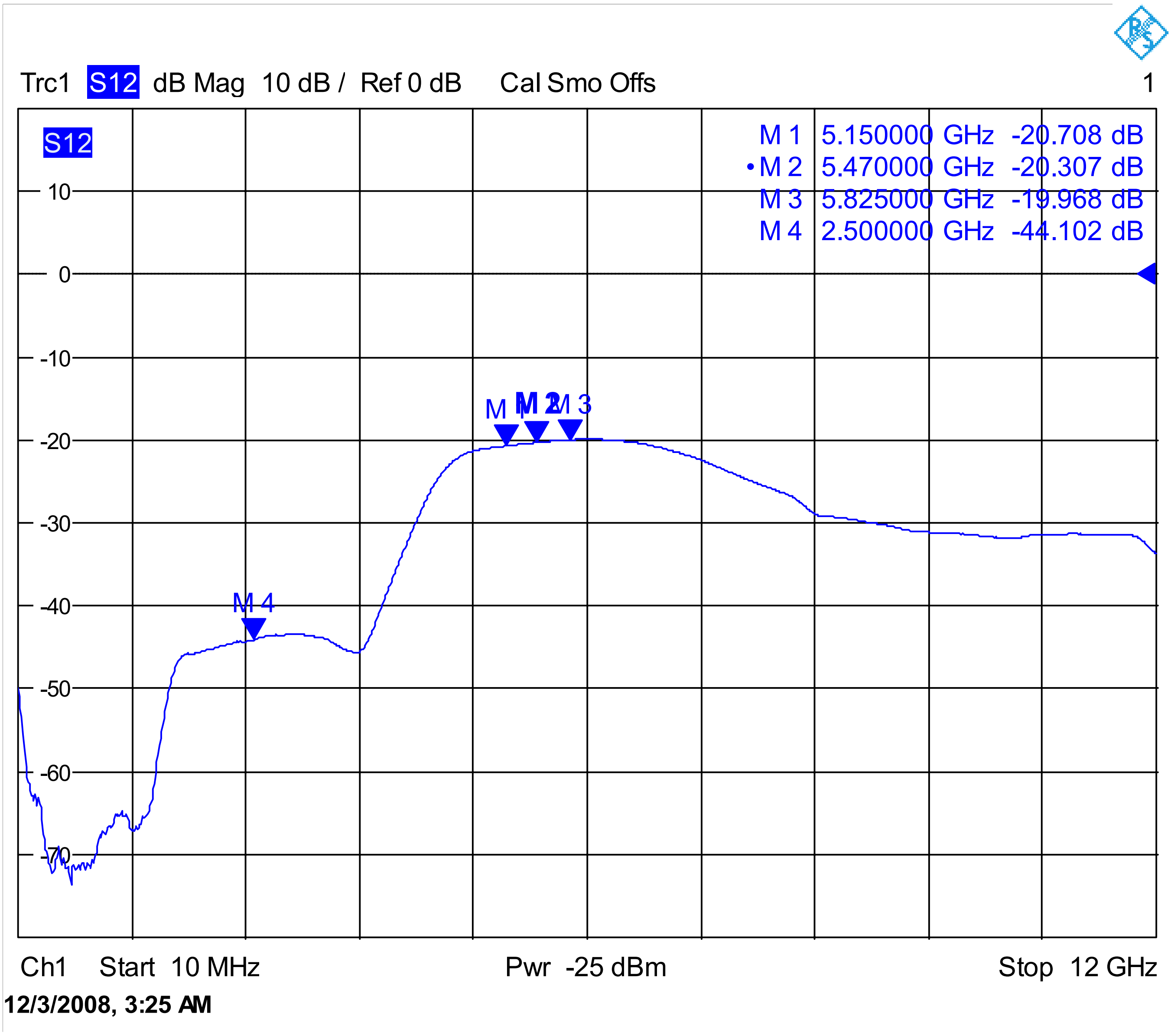
Forward Gain. Input / Output Matching Circuits of LNA reduce gain in 2.4 – 2.5 GHz band.

10 MHz – 12 GHz Sweep



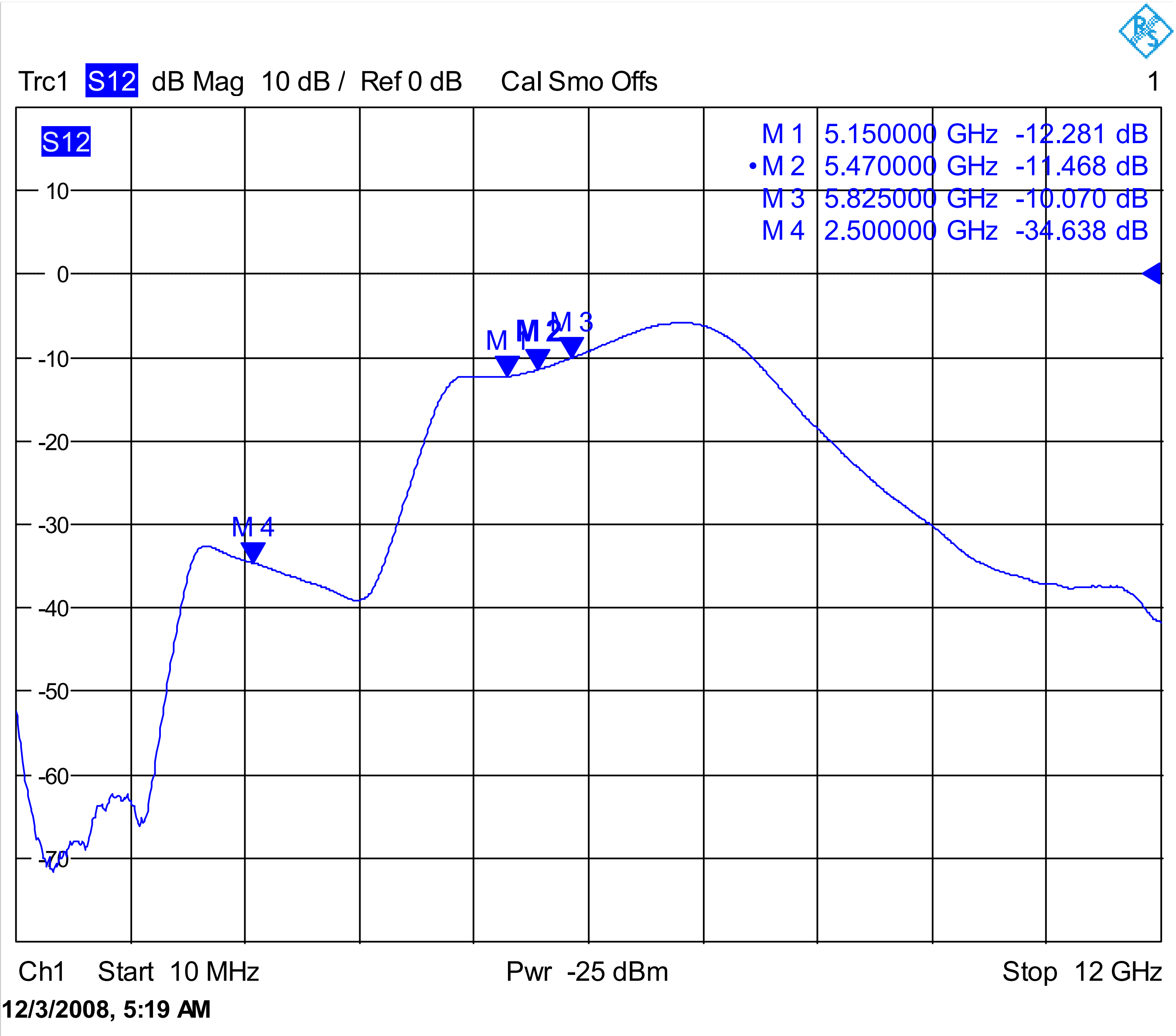
Reverse Isolation

10 MHz – 12 GHz Sweep



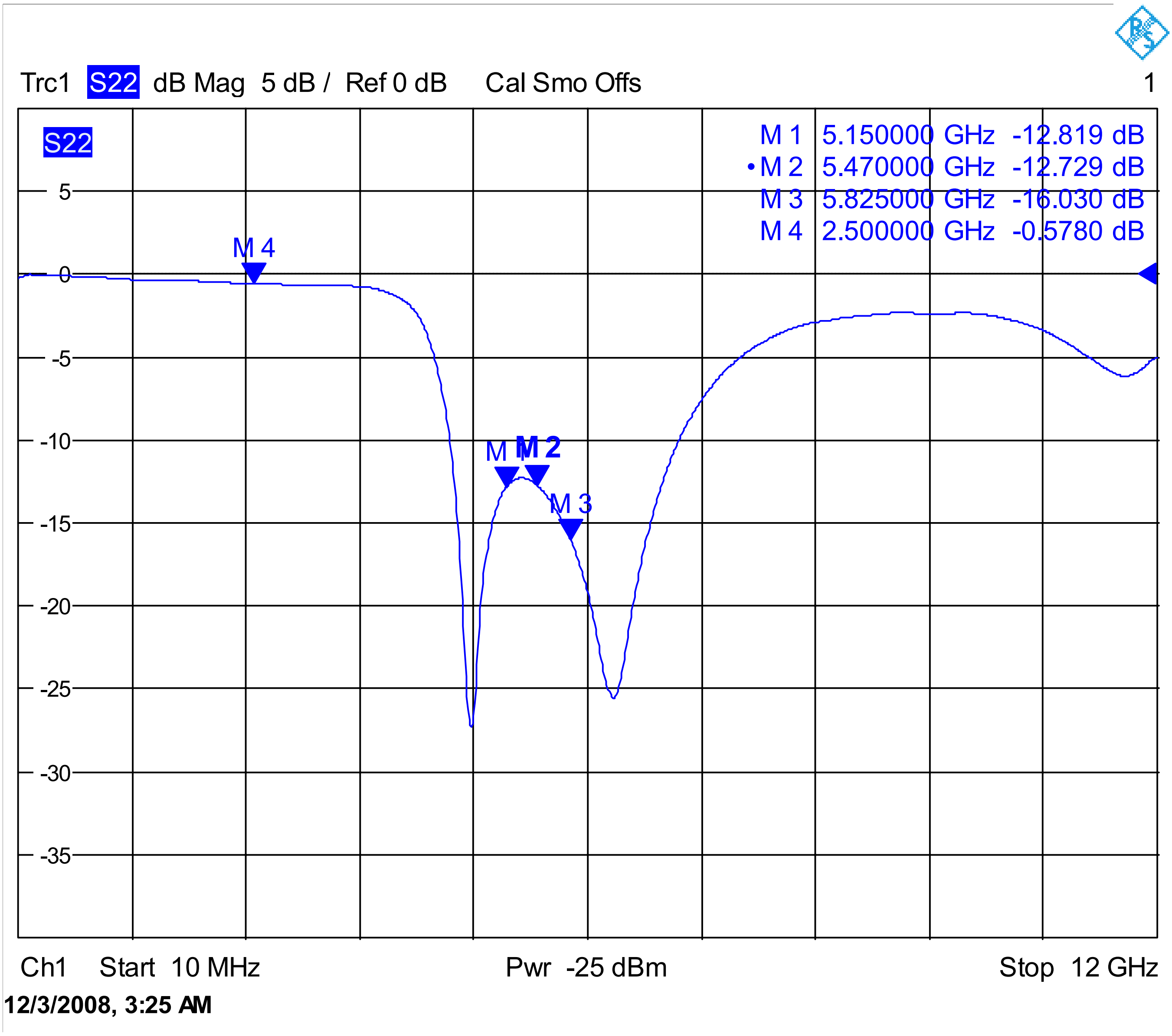
Reverse Isolation, AMPLIFIER DC POWER TURNED OFF.

10 MHz – 12 GHz Sweep



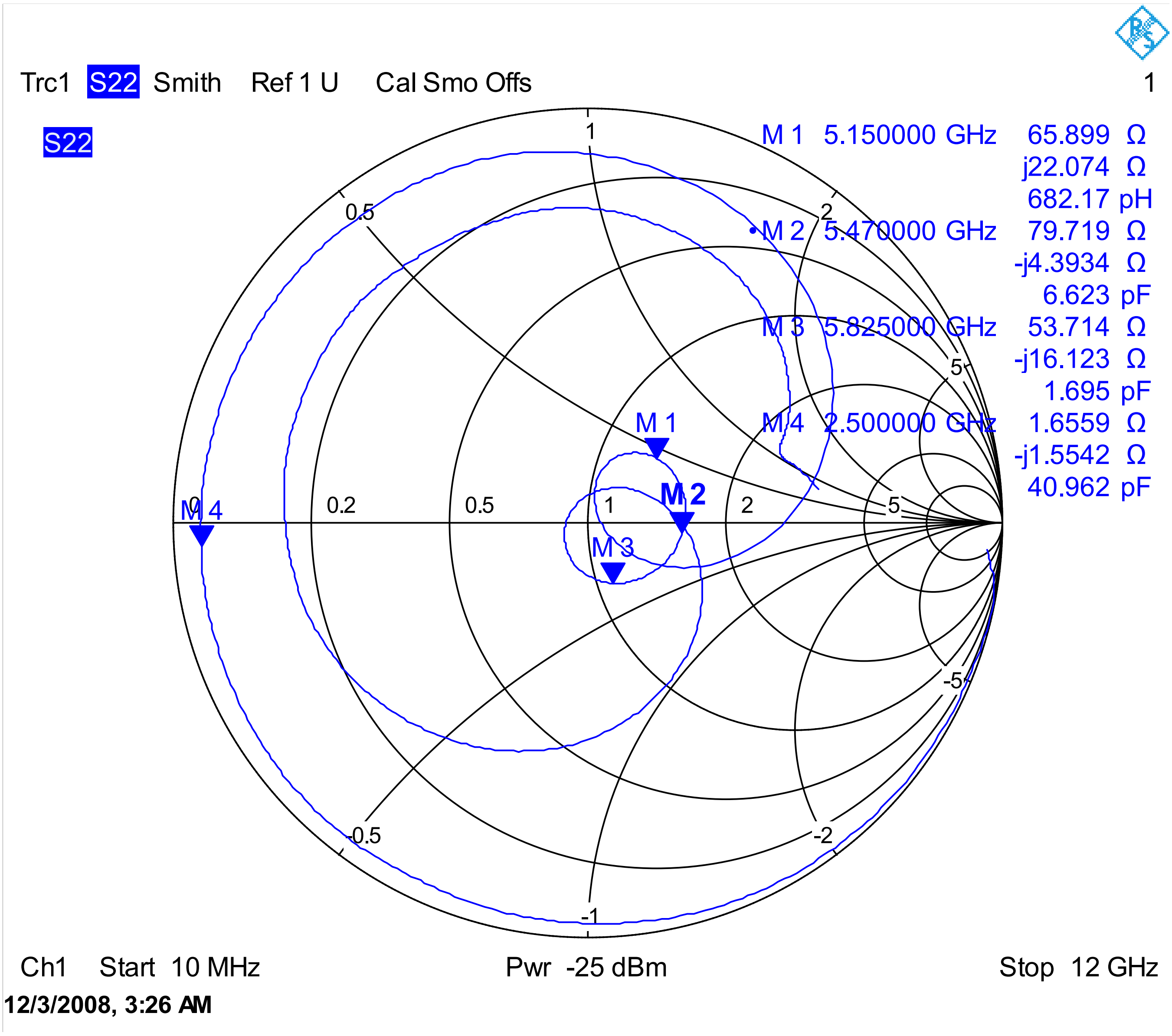
Output Return Loss, Log Mag

10 MHz to 12 GHz Sweep



Output Return Loss, Smith Chart

Reference Plane = Output SMA Connector on PC Board
10 MHz to 12 GHz Sweep

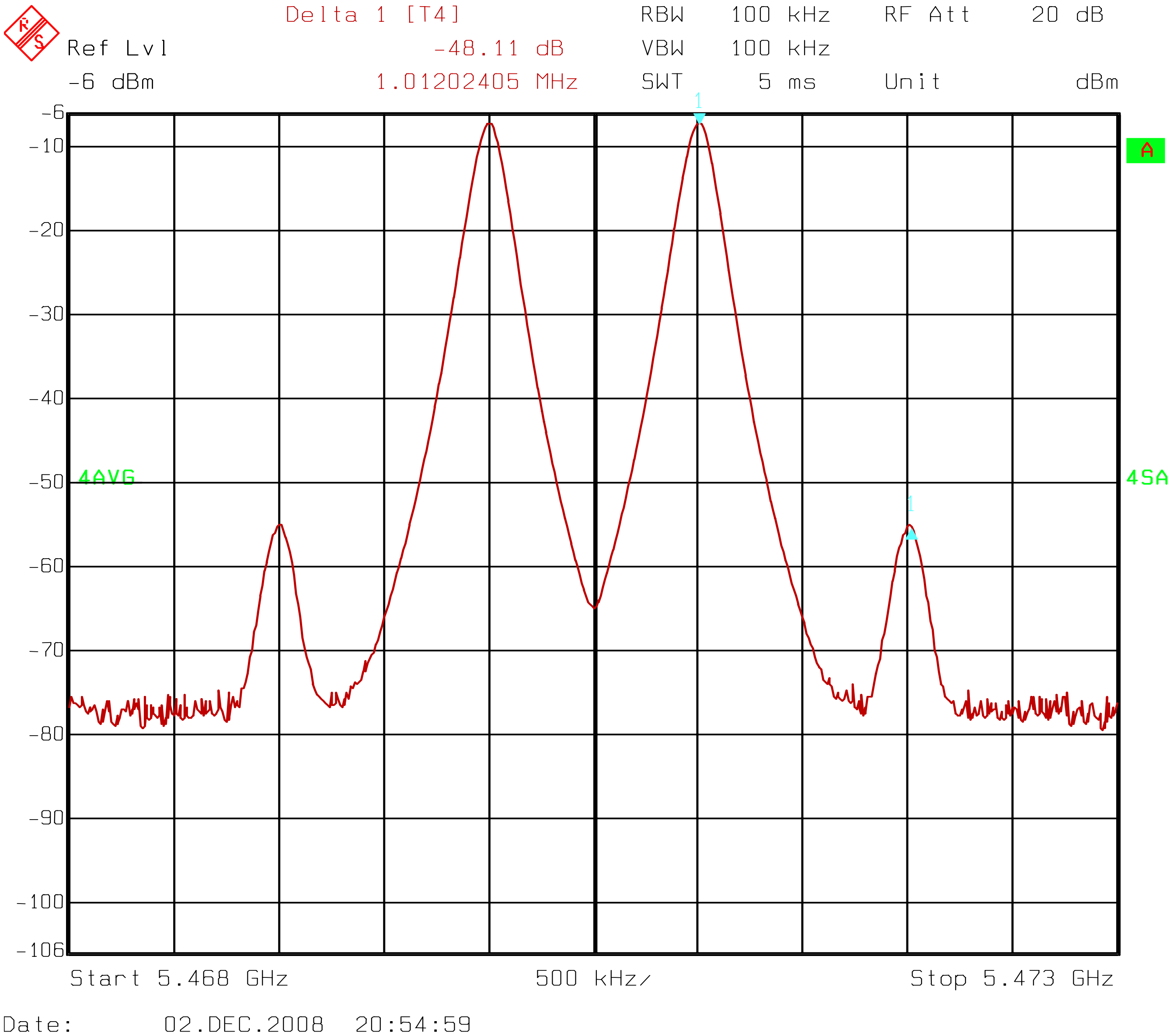


11 Amplifier Third Order Intercept (TOI) Measurement

In-Band Third Order Intercept (IIP$_3$) Test.

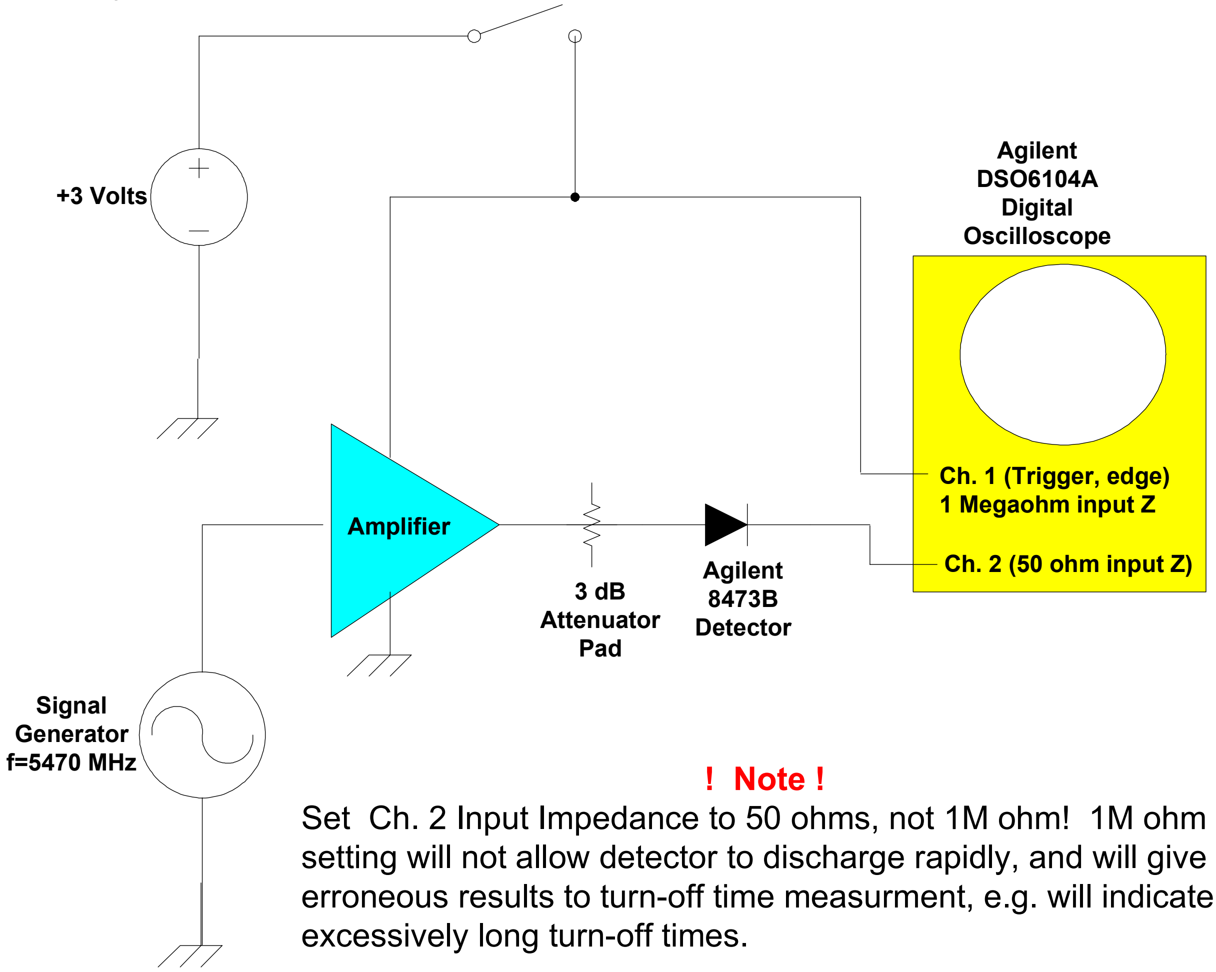
Input Stimulus: f$_1$=5470 MHz, f$_2$=5471 MHz, -20 dBm each tone.

Input IP$_3$ = -20 + (48.1 / 2) = +4.1 dBm. Output IP$_3$ = +4.1 dBm + 14.3 dB gain = +18.4 dBm.



12 Amplifier Turn-On / Turn-Off Time Measurements

The amplifier is tested for turn-on / turn-off time. See diagram below. The RF signal generator runs continuously at a power level sufficient to drive the output of the LNA to approximately 0 dBm when the LNA has DC power ON.



! Note !

Set Ch. 2 Input Impedance to 50 ohms, not 1M ohm! 1M ohm setting will not allow detector to discharge rapidly, and will give erroneous results to turn-off time measurment, e.g. will indicate excessively long turn-off times.

1. **Signal Generator set such that output power of BFP740F LNA is approx. 0 dBm when LNA is powered ON**

2. **Channel 1 of oscilloscope monitors input power supply voltage to Amplifier (+3.0 volts when ON, ~ 0 volts when OFF)**

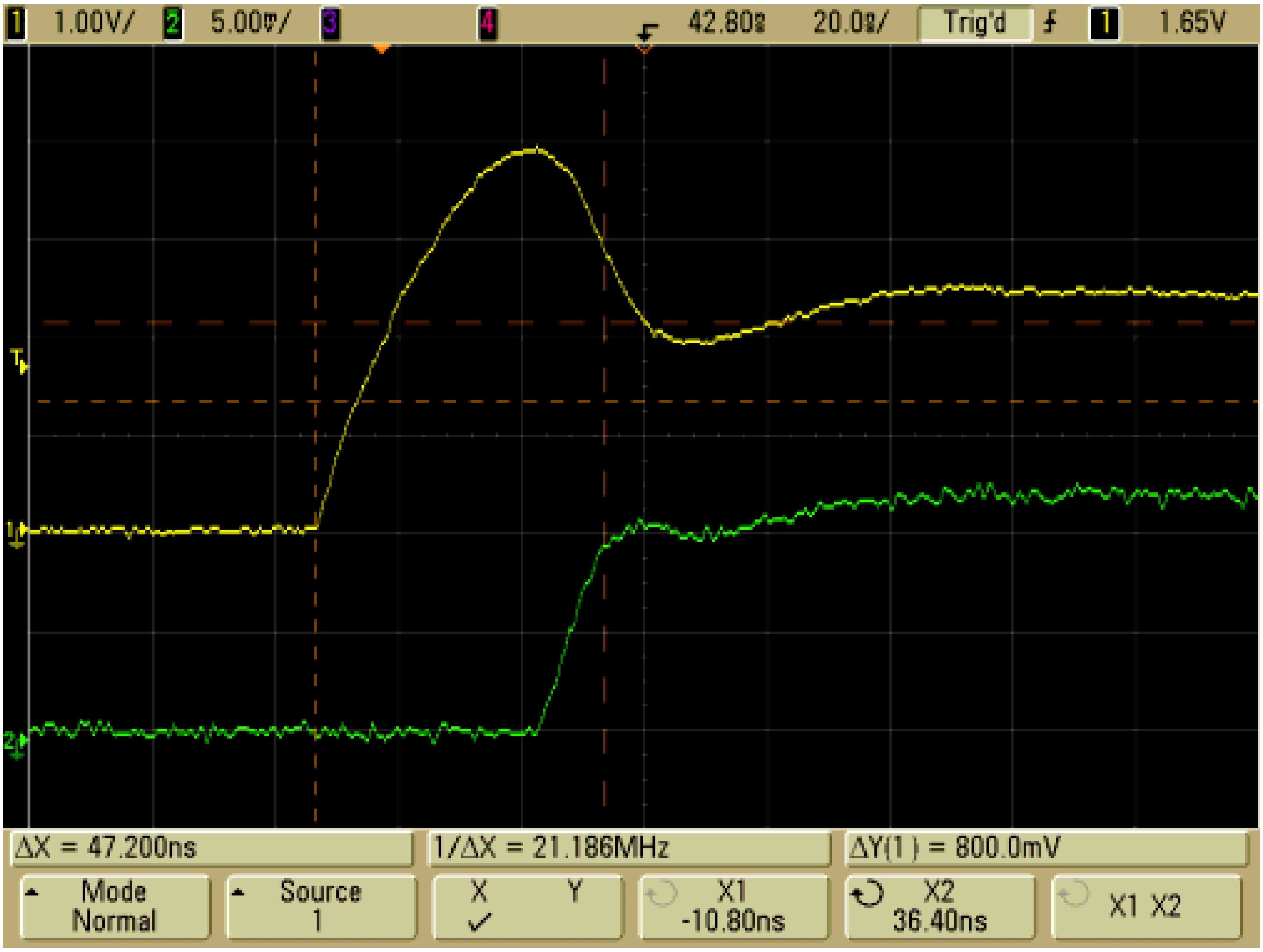
3. **Channel 2 of oscilloscope monitors rectified RF output of Amplifier**

4. **To make measurement of turn-on time, turn power supply OFF, reset o'scope, setup trigger to trigger on rising edge of Ch.1**

5. **To make measurement of turn-off time, turn power supply ON, reset o'scope, setup trigger to trigger on falling edge of Ch. 1**

a) Turn On Time:

Refer to oscilloscope screen-shot below. Upper trace (yellow, Channel 1) is the DC power supply turn-on step waveform whereas the lower trace (green, Channel 2) is the rectified RF output signal of the LNA stage. **Amplifier turn-on time is aproximately 50 nanoseconds, or 0.05microseconds.** Main source of time delay in the LNA turn-on and turn-off events are the R-C time constants formed by (R3 * C4), [(R2+R3) * C3], etc. Charge storage has been minimized in this circuit so as to speed up turn on and turn off times. (Refer to Schematic diagram on page 6).



b) Turn-Off Time:

Rectified RF output signal (lower green trace) takes **approximately ~ 30 nanoseconds, or ~0.03 microseconds** to settle out after power supply is turned off. **Note that input impedance of digital oscilloscope which senses RF Detector Diode output is set to 50 ohms, rather than 1 Megaohm, to permit RF Detector Diode to rapidly discharge after Amplifier is turned off.**

If input impedance of oscilloscope is set to 1 Megaohm, the RF Detector will have to discharge through this 1 Megaohm impedance, giving excessively long results for turn-off times.