Application Note No. 112

Wideband LNA for 200 MHz to 6 GHz applications with BFR740L3RH

RF & Protection Devices

Never stop thinking

Edition 2007-08-14

Published by
Infineon Technologies AG
81726 München, Germany

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Application Note No. 112

Revision History: 2007-08-14, Rev. 1.2

Previous Version: 2004-10-25, Rev. 1.1	
Page	**Subjects (major changes since last revision)**
All	Small changes in figure descriptions

1 Wideband LNA for 200 MHz to 6 GHz applications with BFR740L3RH

Applications

- 900 MHz ISM Band, Satellite TV LNB IF Amplifiers (950 - 2150 MHz), 1575 MHz GPS, 2.4 GHz ISM Band (802.11 b/g WLAN, Cordless, etc.), "SDARS" Satellite - based Radio (2.33 and 2.6 GHz), 5 - 6 GHz WLAN (802.11a), 5 GHz Cordless Phones, etc.

Overview

- A Wideband, Feedback Low Noise Amplifier (LNA) for 200 MHz to 6 GHz, using the Ultra Low Noise BFR740L3RH RF Transistor in TSLP-3-9 Leadless Package with a height of only 0.32 mm.
- The Silicon-Germanium BFR740L3RH B7HFe Ultra-Low-Noise RF Transistor is shown in a simple, low-cost general-purpose wideband LNA application. “0201” case size passive components are used to reduce occupied PCB area.
- The BFR740L3RH TSLP-3-9 package is only 1 x 0.6 x 0.4 mm, and is suitable for use in modules. The complete amplifier only uses 16 mm² of PCB area.

Principal Advantages

- The remarkable gain-bandwidth product & extremely low noise figure of the BFR740L3RH opens up entirely new possibilities for the RF circuit designer. In this case, simple resistive feedback is used to create a forgiving, low-parts-count, easy-to-use broadband LNA with gain & noise performance on par with traditional, more troublesome, narrow-band LNA designs. Use of feedback yields 1) good wideband impedance match & 2) stabilizes the amplifier over the entire 5 MHz to 6 GHz range.
- Achieved ≅ 19.5 to 10.0 dB gain, 1.1 to 1.7 dB Noise Figure from under 200 MHz to 6 GHz, from 3.0 V supply drawing 11.8 mA. Noise figure result does NOT "back out" FR4 PCB losses - if PCB loss at LNA input were extracted, Noise Figure result would be approximately 0.1 - 0.2 dB lower. Amplifier is unconditionally stable from 5 MHz to 6 GHz. Input 3rd Order Intercept = +0.9 dBm @ 2400 MHz.

PC Board Cross Sectional Diagram

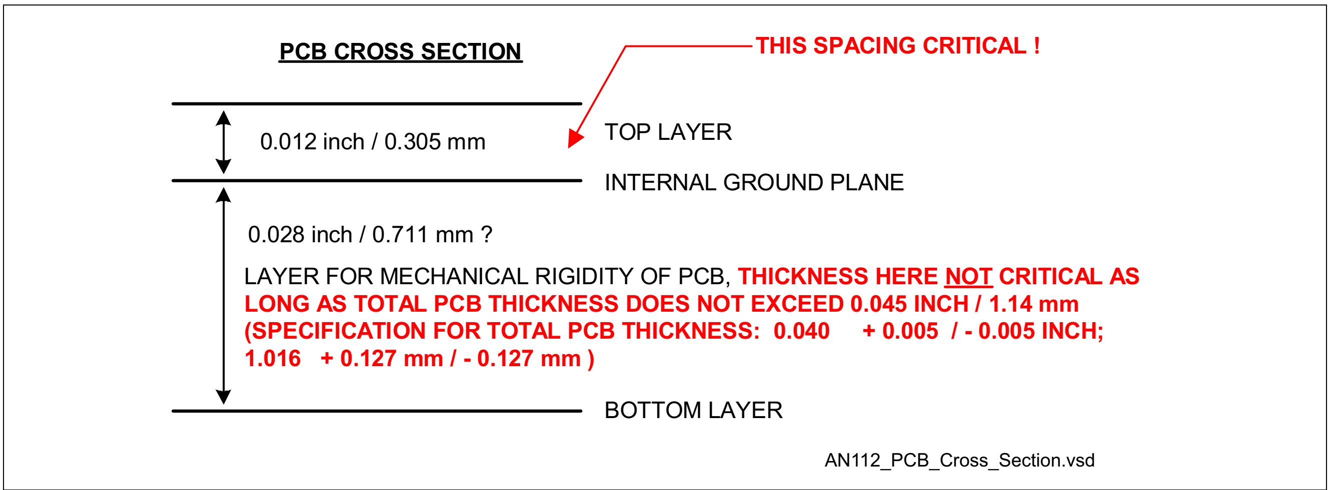


Figure 1 PC Board Cross Sectional Diagram

Summary of Data

(T = 25°C) Network analyzer source power = -30 dBm

Table 1 Summary of Data

Parameter	Result	Comments
Frequency Range	Under 200 MHz to over 6 GHz	Wideband forgiving design e.g. "universal LNA"
DC Current	11.8 mA @ 3.0 V	Note power supply voltage is measured directly across PCB supply line and ground, to eliminate voltage drop across wire harness!
DC Voltage, V_{CC}	3.0 V	
Gain	18.7 dB @ 315 MHz 19.5 dB @ 950 MHz 18.1 dB @ 1575 MHz 15.9 dB @ 2400 MHz 10.5 dB @ 5150 MHz	315 MHz: Remote Keyless Entry 950 MHz: Cellular, 900 MHz ISM, etc. 1575 MHz: GPS 2400 MHz: 2.4 GHz ISM, WLAN, etc. 5150 MHz: 802.11a WLAN
Noise Figure	1.3 dB @ 315 MHz 1.1 dB @ 950 MHz 1.1 dB @ 1575 MHz 1.2 dB@ 2400 MHz 1.5 dB @ 5150 MHz	See Noise Figure plots and tabular data, pages 7 - 11. These values do NOT extract PCB losses, etc. resulting from FR4 board and passives used on PCB - these results are at input SMA connector
Input P_{1dB}	-9.6 dBm @ 2400 MHz	See Page 15
Output P_{1dB}	+6.3 dBm @ 2400 MHz	See Page 15
Input 3rd Order Interception	+0.9 dBm @ 2400 MHz	See pages 22 & 23 Note IP3 can be improved by 8 to 10 dB by adding charge storage to base, coupled in with an RF choke. Requires the addition of 1 more chip coil.
Output 3rd Order Interception	+16.8 dBm @ 2400 MHz	See Pages 22 & 23
Input Return Loss	7.7 dB @ 315 MHz 13.1 dB @ 950 MHz 15.1 dB @ 1575 MHz 17.2 dB@ 2400 MHz 20.3 dB @ 5150 MHz	Needs more optimization at low frequencies.
Output Return Loss	5.0 dB @ 315 MHz 9.6 dB @ 950 MHz 12.0 dB @ 1575 MHz 11.4 dB @ 2400 MHz 10.2 dB @ 5150 MHz	Needs more works at low frequencies
Reserve Isolation	26.3 dB @ 315 MHz 23.3 dB @ 950 MHz 21.8 dB @ 1575 MHz 20.1 dB@ 2400 MHz 15.8 dB @ 5150 MHz	

Schematic Diagram

Total Parts Count = 10, including BFR740L3RH Ultra Low Noise SiGe Transistor.
Note simple, forgiving, low-cost configuration.

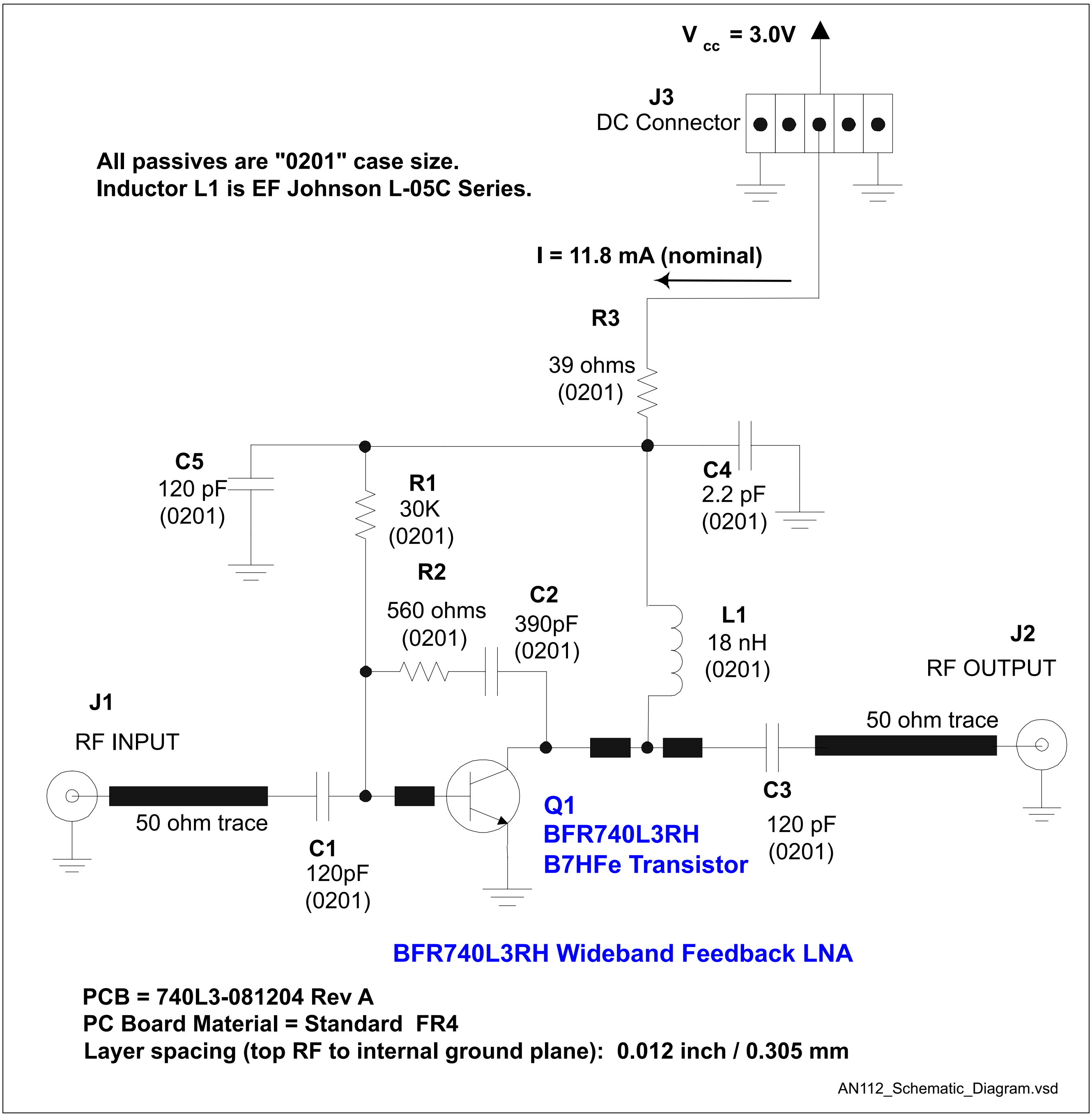


Figure 2 Schematic Diagram

Noise Figure, Plot, 100 MHz to 4 GHz. Center of Plot (x-axis) is 2050 MHz.

Rohde & Schwarz FSEK3

25 Oct 2004

Noise Figure

100 MHz – 4 GHz

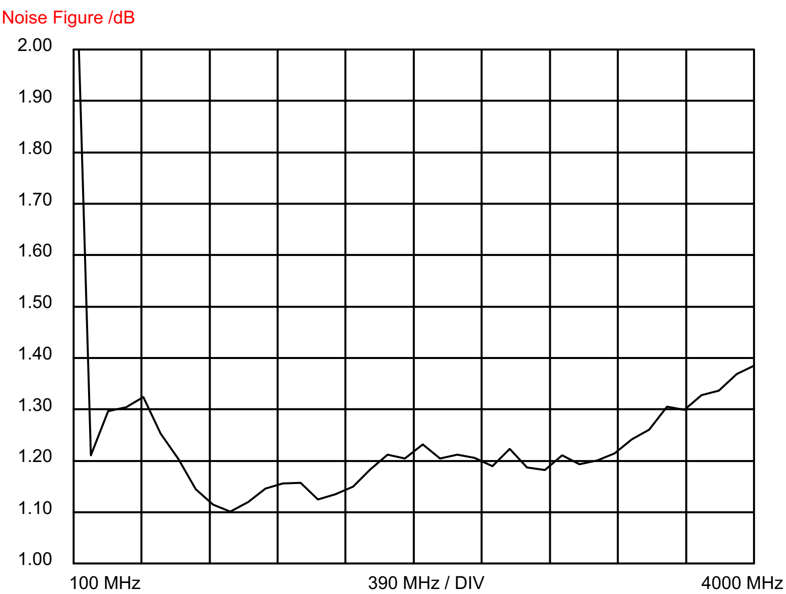
EUT Name:	BFR740L3 Wideband Feedback Low Noise Amplifier
Manufacturer:	Infineon Technologies
Operating Conditions:	V = 3.0 V, I = 11.8 mA, T = 25 C
Operator Name:	Gerard Wevers
Test Specification:	TSLP-3-4 Package for transistor, "0201"case size passives
Comment:	PCB = 740L3-081204 Rev A 25 October 2004

Analyzer

RF Att:	0.00 dB	RBW :	1 MHz	Range:	40.00 dB
Ref Lvl:	-41.00 dBm	VBW :	100 Hz	Ref Lvl auto:	ON

Measurement

2nd stage corr: ON   Mode: Direct   ENR: HP346A.ENR



AN112_Noise_Figure_100M-4G.vsd

Figure 3 Noise Figure (100 MHz - 4 GHz)

Noise Figure, Tabular Data

100 MHz to 4 GHz
From Rhode & Schwarz FSEK3 + FSEM30
System Preamplifier = MITEQ SMC-02

Table 2 Noise Figure @ 25 °C, 3.0 V, 11.8 mA

Frequency	Noise Figure
100 MHz	2.26 dB
200 MHz	1.21 dB
300 MHz	1.30 dB
400 MHz	1.30 dB
500 MHz	1.32 dB
600 MHz	1.25 dB
700 MHz	1.20 dB
800 MHz	1.15 dB
900 MHz	1.12 dB
1000 MHz	1.10 dB
1100 MHz	1.12 dB
1200 MHz	1.15 dB
1300 MHz	1.16 dB
1400 MHz	1.16 dB
1500 MHz	1.12 dB
1600 MHz	1.13 dB
1700 MHz	1.15 dB
1800 MHz	1.18 dB
1900 MHz	1.21 dB
2000 MHz	1.20 dB
2100 MHz	1.23 dB
2200 MHz	1.20 dB
2300 MHz	1.21 dB
2400 MHz	1.21 dB
2500 MHz	1.19 dB
2600 MHz	1.22 dB
2700 MHz	1.19 dB
2800 MHz	1.18 dB
2900 MHz	1.21 dB
3000 MHz	1.19 dB
3100 MHz	1.20 dB
3200 MHz	1.21 dB
3300 MHz	1.24 dB
3400 MHz	1.26 dB
3500 MHz	1.31 dB
3600 MHz	1.30 dB

Table 2 Noise Figure @ 25 °C, 3.0 V, 11.8 mA (cont'd)

Frequency	Noise Figure
3700 MHz	1.33 dB
3800 MHz	1.34 dB
3900 MHz	1.37 dB
4000 MHz	1.39 dB

Noise Figure, Plot, 4 GHz - 7 GHz. Center of Plot (x-axis) is 5500Mz.

Rohde & Schwarz FSEK3

25 Oct 2004

Noise Figure

4 GHz – 7 GHz

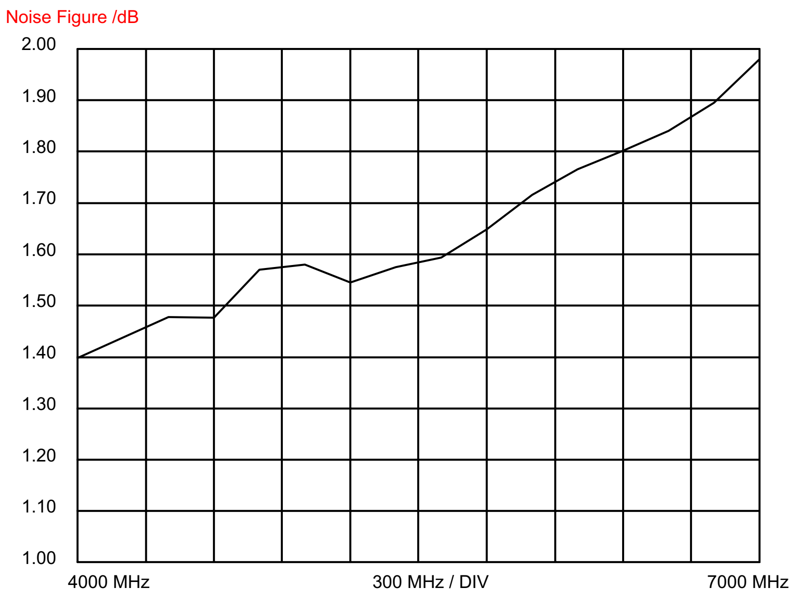
EUT Name:	BFR740L3 Wideband Feedback Low Noise Amplifier
Manufacturer:	Infineon Technologies
Operating Conditions:	V = 3.0 V, I = 11.8 mA, T = 25 C
Operator Name:	Gerard Wevers
Test Specification:	TSLP-3-4 Package for transistor, "0201"case size passives
Comment:	PCB = 740L3-081204 Rev A 25 October 2004

Analyzer

RF Att:	0.00 dB	RBW :	1 MHz	Range:	40.00 dB
Ref Lvl:	-34.00 dBm	VBW :	100 Hz	Ref Lvl auto:	ON

Measurement

2nd stage corr:	ON	Mode:	Direct	ENR:	HP346A.ENR



AN112_Noise_Figure_4G-7G.vsd

Figure 4 Noise Figure (4 GHz - 7 GHz)

Noise Figure, Tabular Data

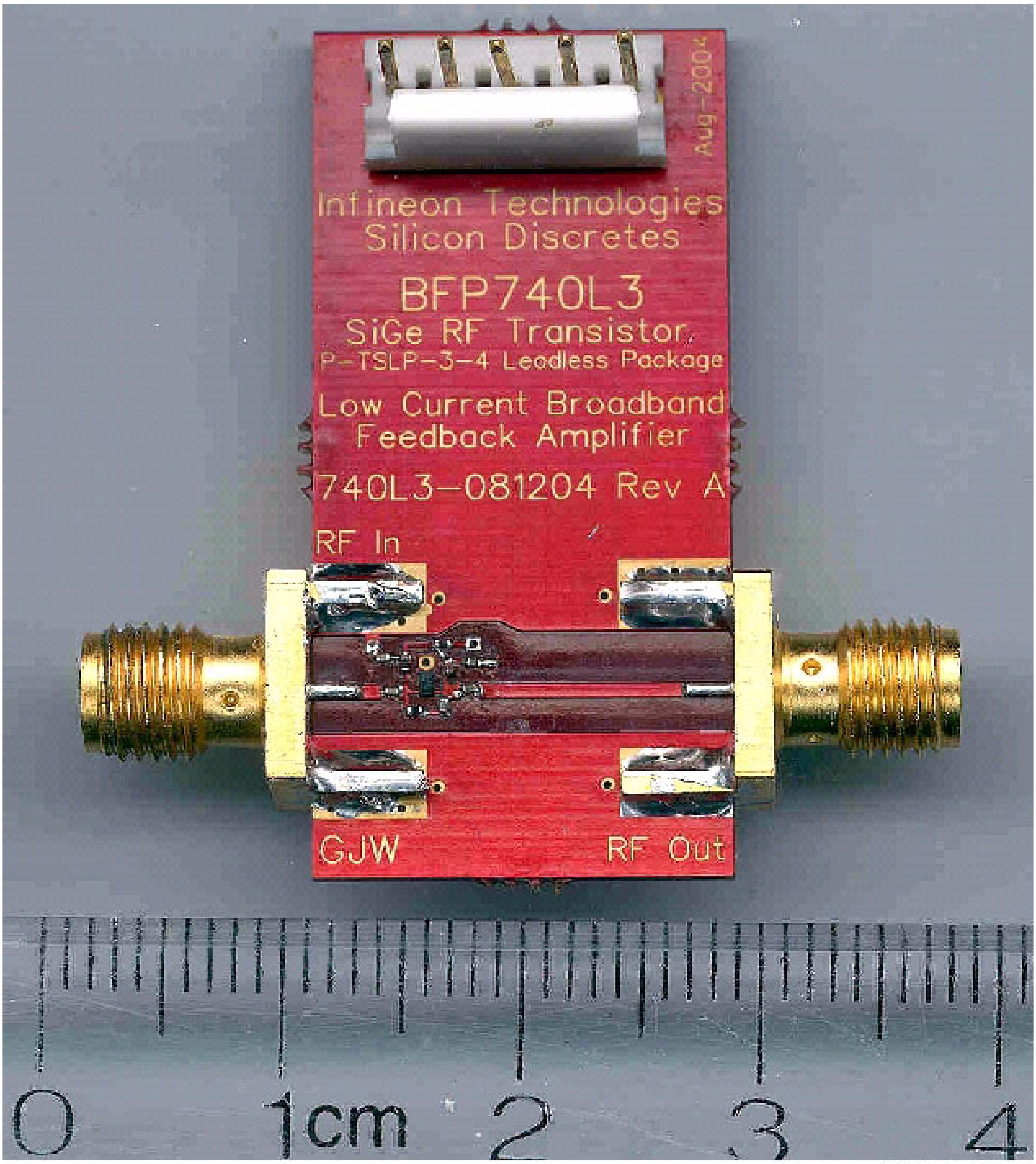
4 GHz to 7 GHz
From Rhode & Schwarz FSEK3 + FSEM30
System Preamplifier = MITEQ AFS-040000800-10-ULN

Table 3 Noise Figure @ 25 °C, 3.0 V, 11.8 mA

Frequency	Noise Figure
4000 MHz	1.40 dB
4200 MHz	1.44 dB
4400 MHz	1.48 dB
4600 MHz	1.48 dB
4800 MHz	1.57 dB
5000 MHz	1.58 dB
5200 MHz	1.54 dB
5400 MHz	1.58 dB
5600 MHz	1.59 dB
5800 MHz	1.65 dB
6000 MHz	1.72 dB
6200 MHz	1.77 dB
6400 MHz	1.80 dB
6600 MHz	1.84 dB
6800 MHz	1.90 dB
7000 MHz	1.98 dB

Scanned Image of PC Board

Note: text on PCB should read “BFR740L3RH” not “BFP740L3”



AN112_pic_PCB.vsd

Figure 5 Image of PC Board

Scanned Image of PC Board, Close-In Shot

Note: Use of ”0201” case size components.

Total PCB area used ≅ 16.3 mm²

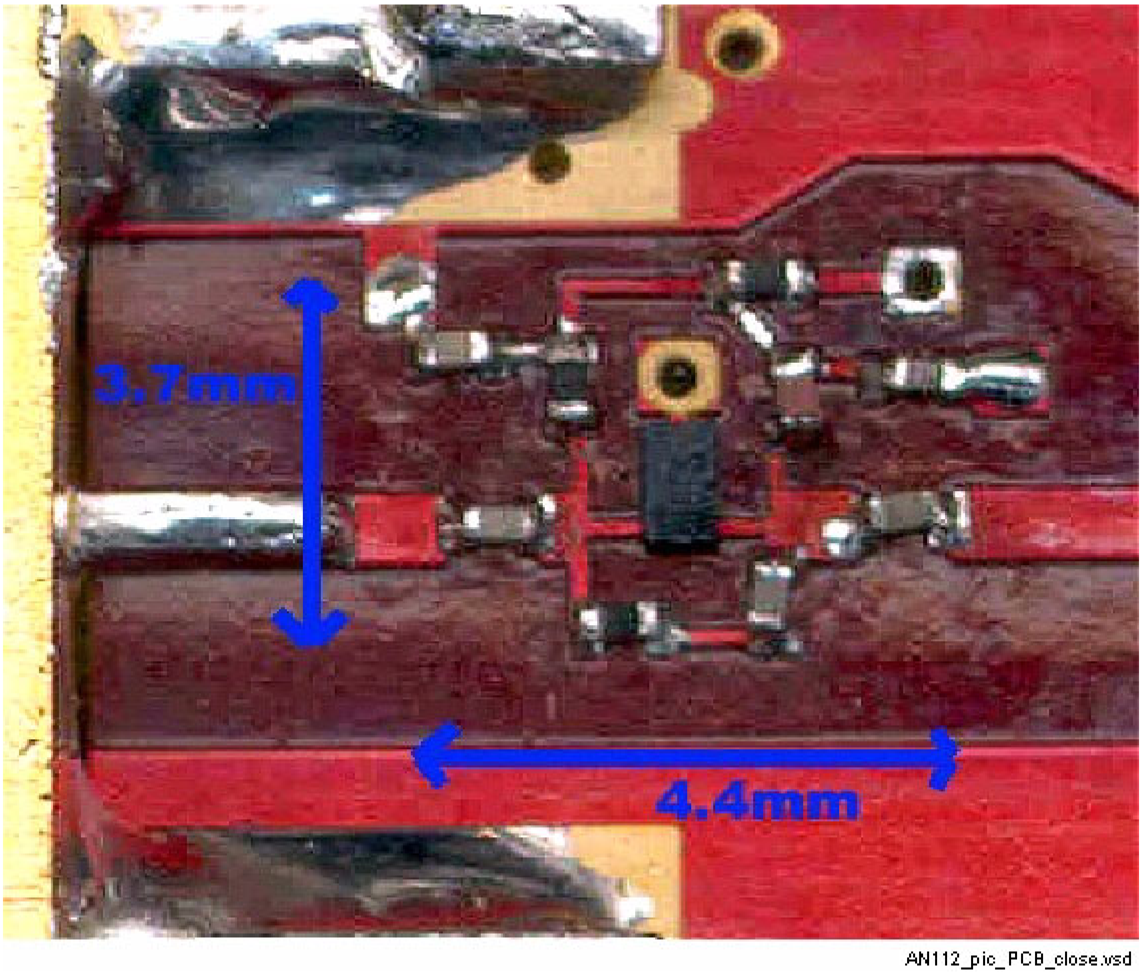


Figure 6 Image of PC Board, Close-In Shot

Plots of Stability Factor "K" and Stability Measure "B_1" from 5 MHz to 6 GHz

Plots are generated from real, measured S parameters taken from the demo PC board, NOT a simulation.
S parameters are exported from Network Analyzer, then imported into Eagleware GENESYS software, which calculates and plots K and B_1.
Note: K>1 and B_1 > 0, showing unconditional stability.

K is trace in red color (bottom trace) and is assigned to left vertical axis at bottom of page.
Note: minimum K value is 1.04

B_1 is trace in blue color (top trace) and is assigned to right vertical axis.

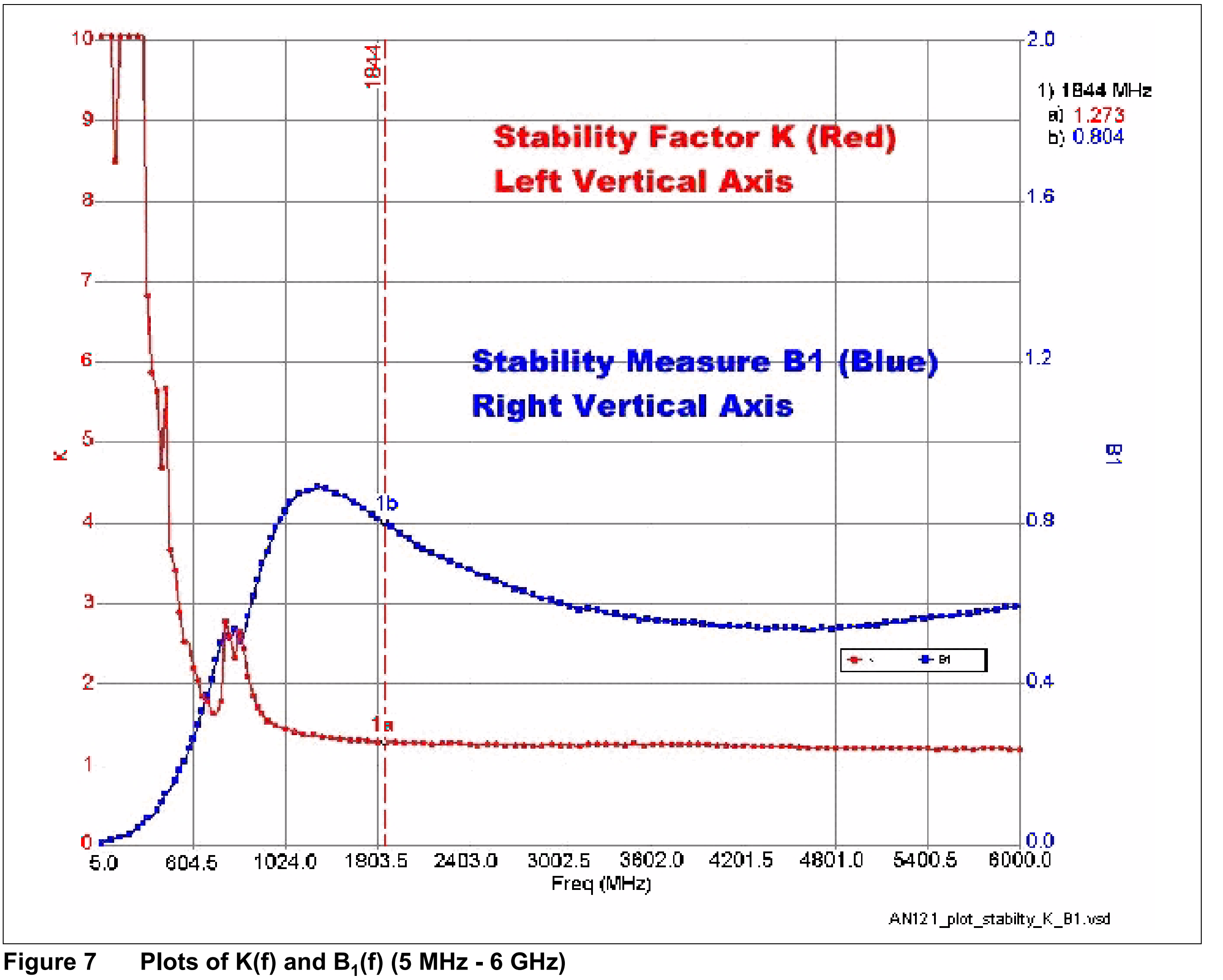


Figure 7 Plots of K(f) and B_1(f) (5 MHz - 6 GHz)

Amplifier Gain Compression Test

Network Analyzer is set to "CW" mode - e.g. set to a single frequency, with power sweep. Input power is swept from -35 dBm to -7 dBm at 2400 MHz. Amplifier hits Input 1dB compression point (IP_{1dB}) at -9.6 dBm input power. The compression point could be increased by increasing BFR740L3RH current. DC current is set to 11.8 mA however BFR740L3RH can safely handle up to 50 mA.

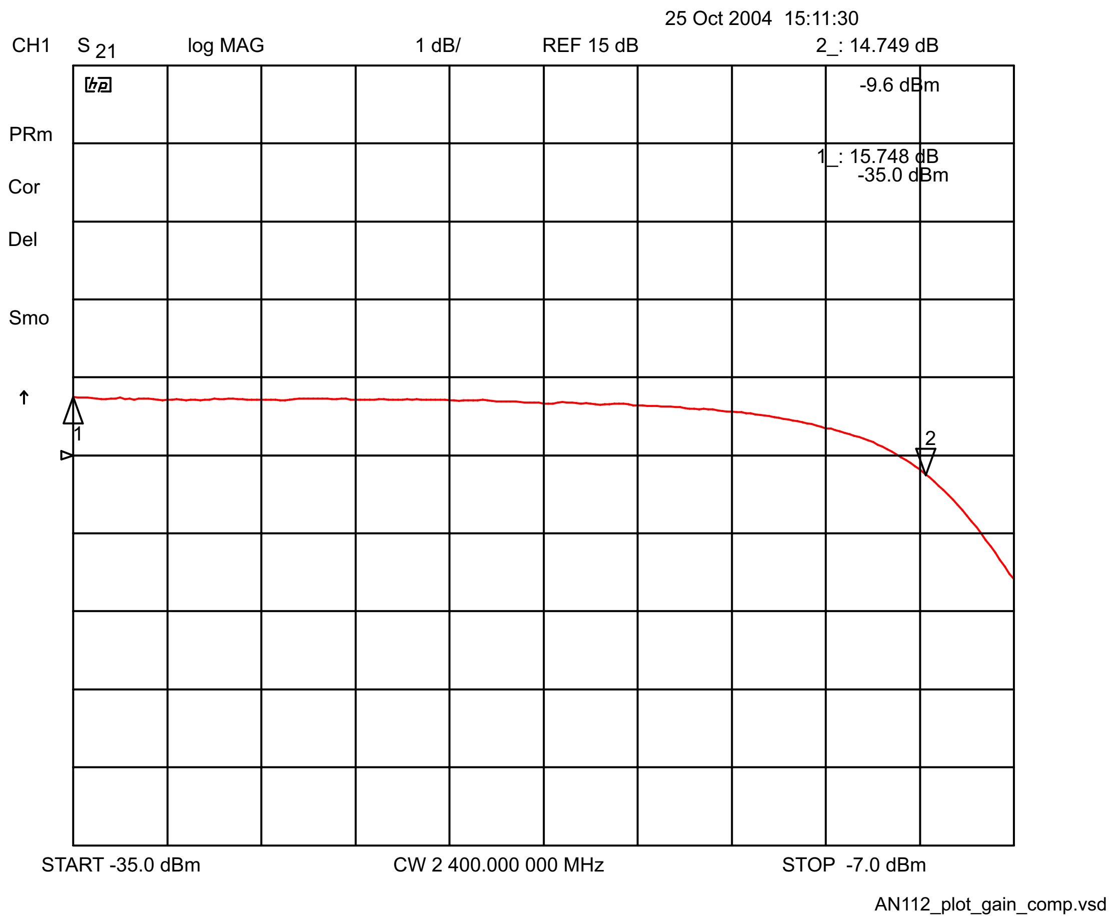


Figure 8 Plot of Amplifier Gain Compression Test

Input Return Loss, Log Mag

5 MHz to 6 GHz

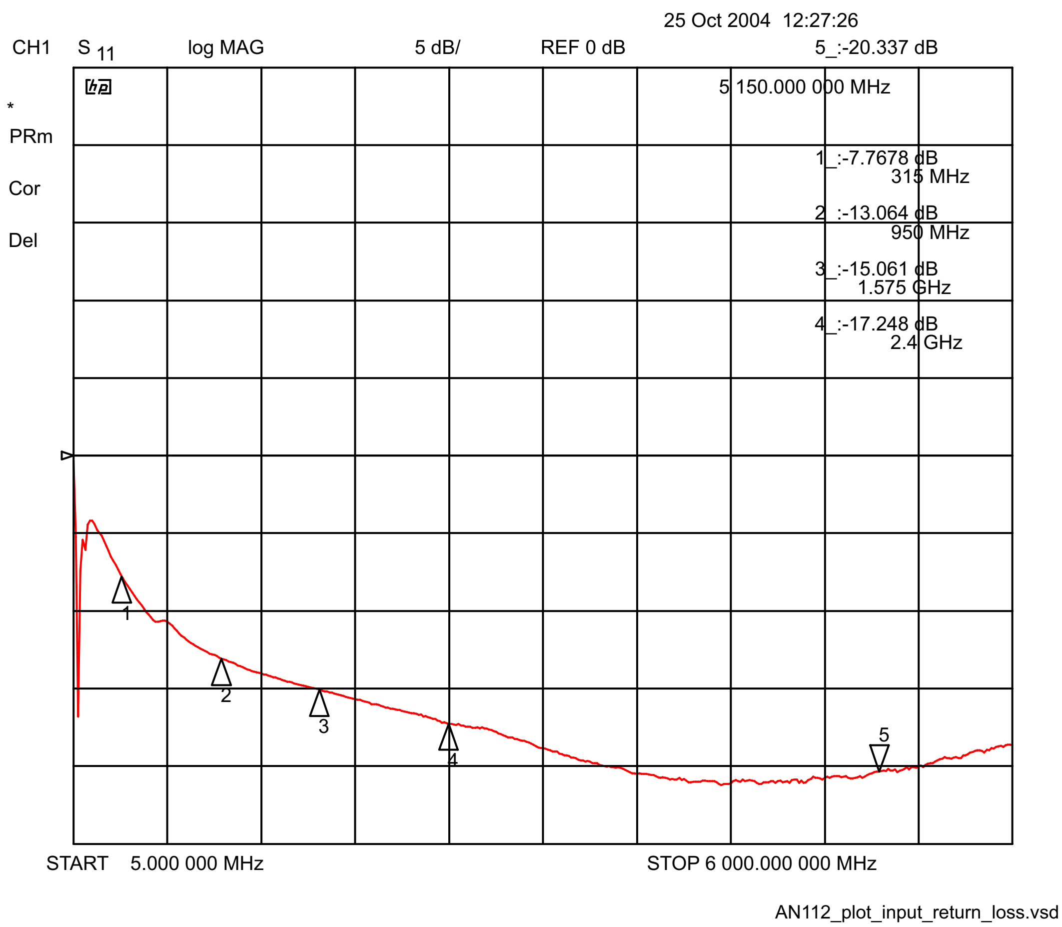


Figure 9 Plot of Input Return Loss (5 MHz - 6 GHz)

Input Return Loss, Smith Chart

Reference Plane = Input SMA Connector on PC Board
5 MHz to 6 GHz

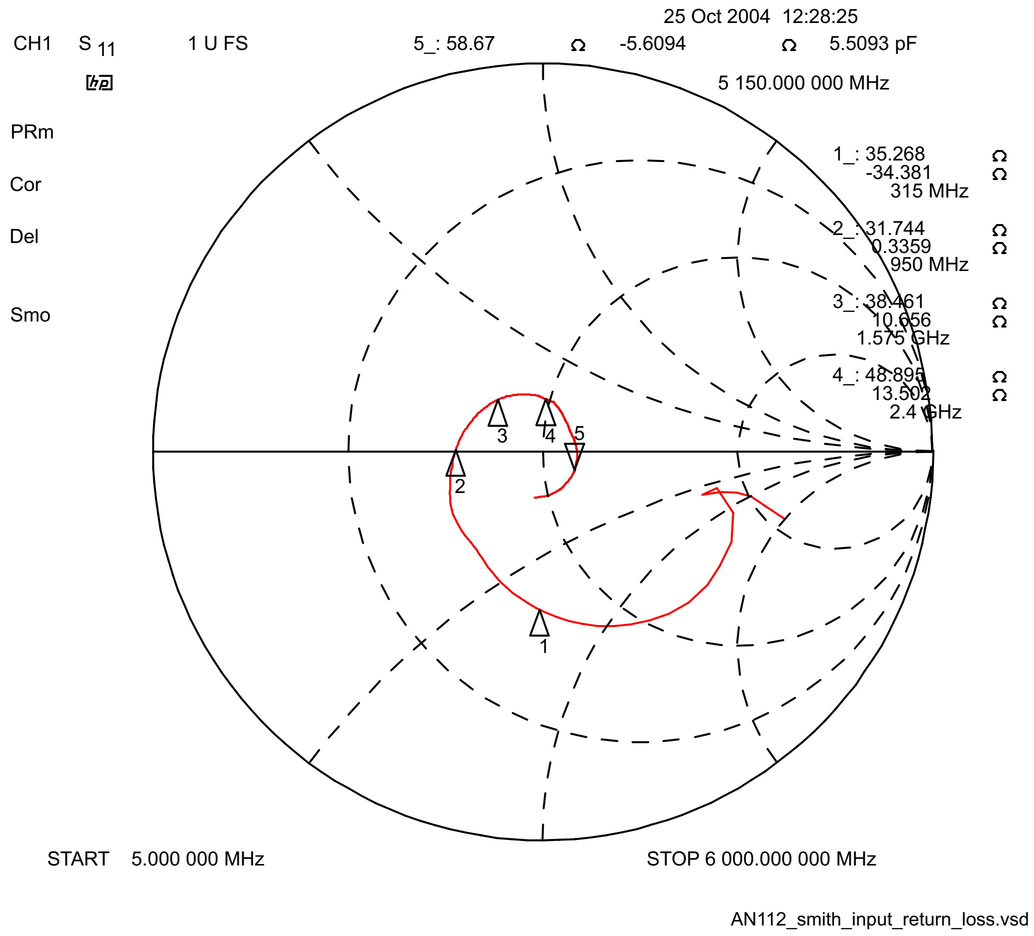


Figure 10 Smith Chart of Input Return Loss (5 MHz - 6 GHz)

Forward Gain, Wide Sweep

5 MHz to 6 GHz

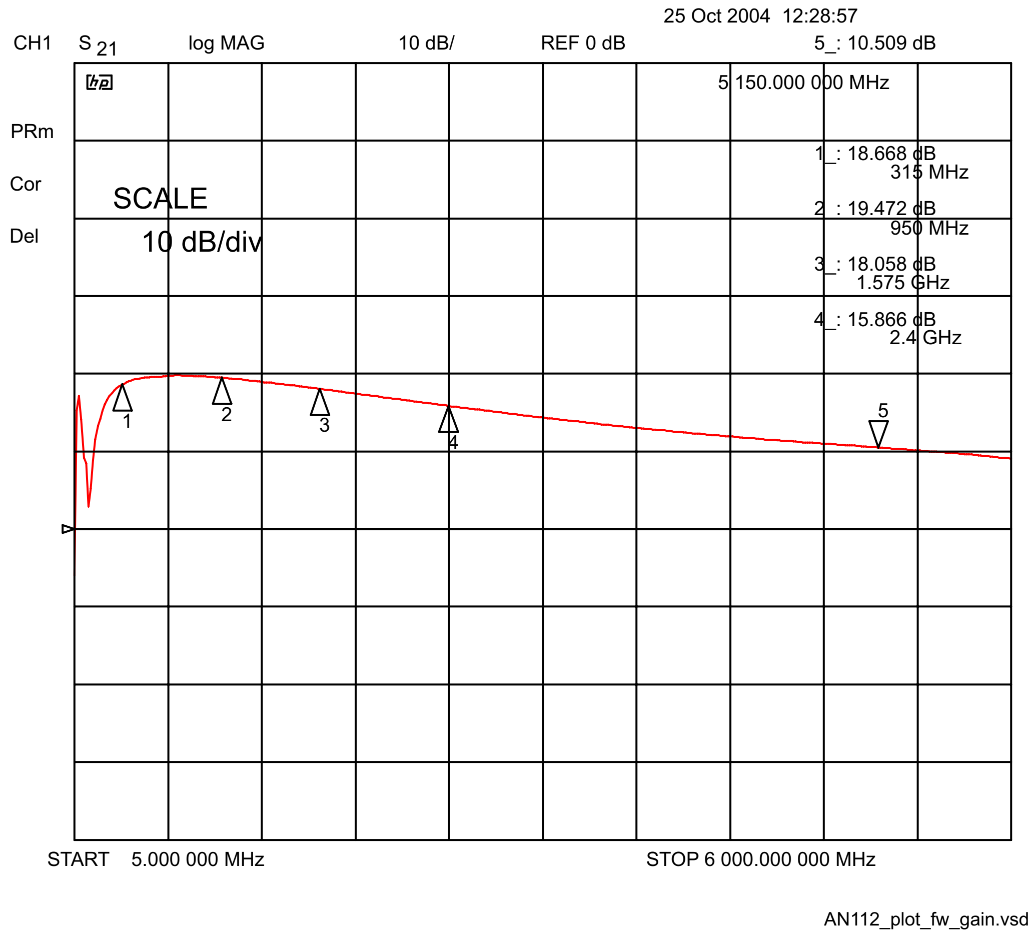


Figure 11 Plot of Forward Gain(5 MHz - 6 GHz)

Reverse Isolation

5 MHz to 6 GHz

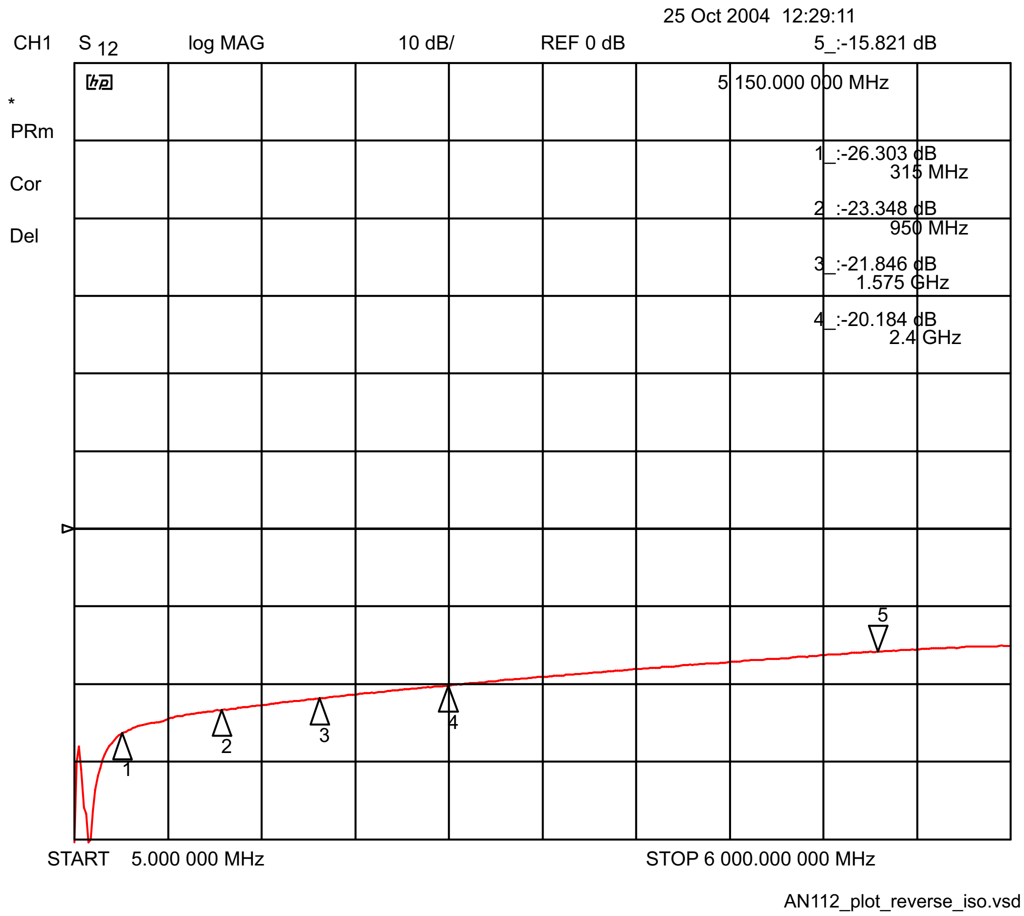


Figure 12 Plot of Reverse Isolation (5 MHz - 6 GHz)

Output Return Loss, Log Mag

5 MHz to 6 GHz

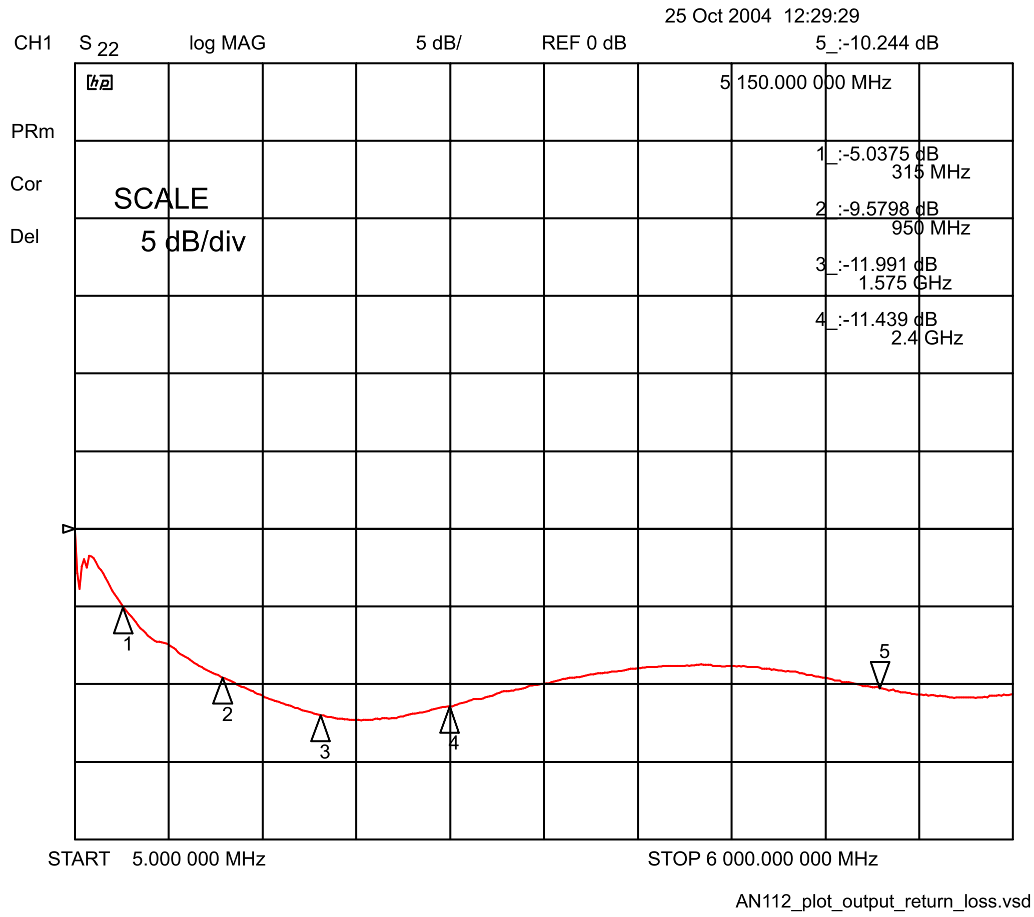


Figure 13 Plot of Output Return Loss (5 MHz - 6 GHz)

Output Return Loss, Smith Chart

Reference Plane = Output SMA Connector on PC Board
5 MHz to 6 GHz

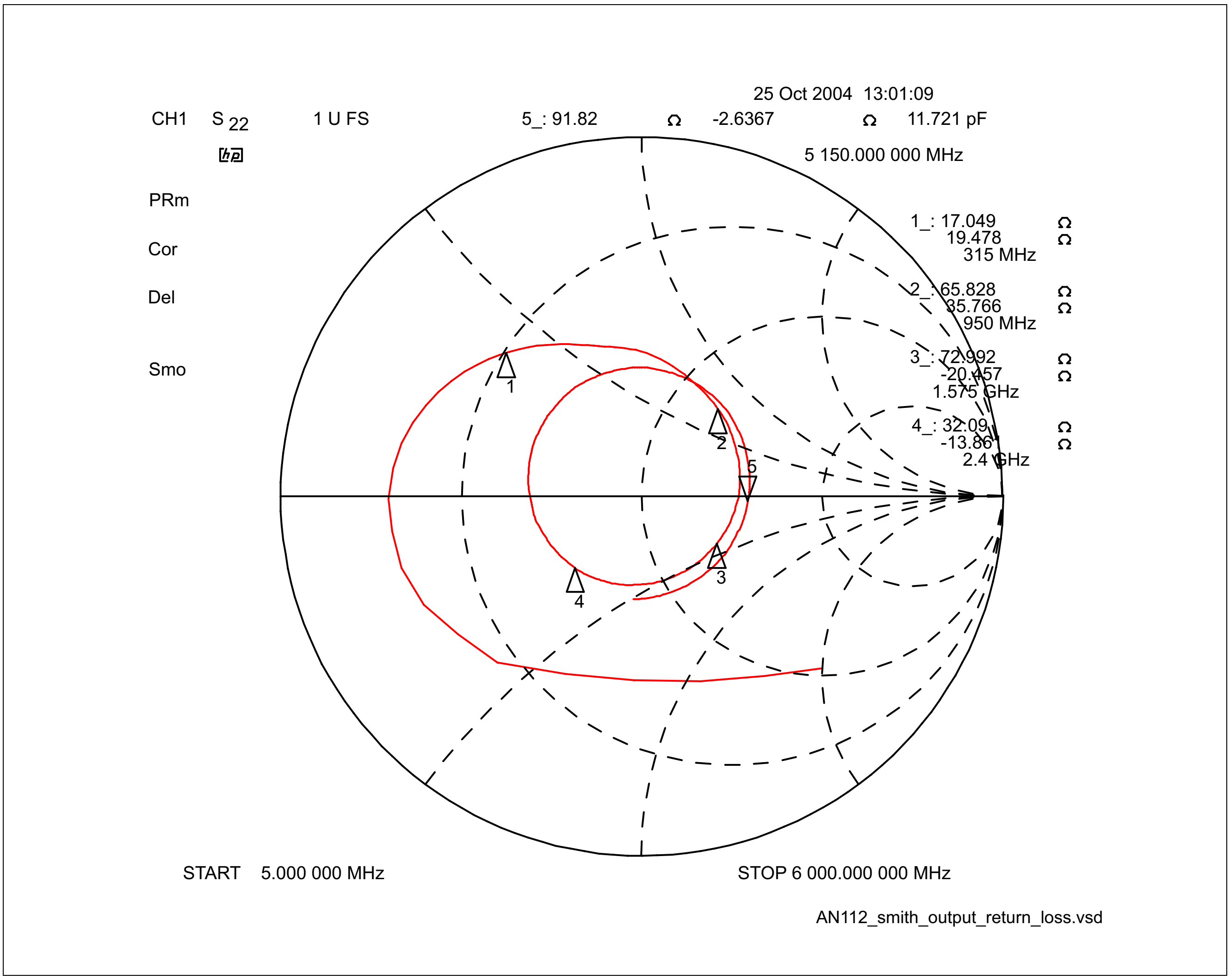


Figure 14 Smith Chart of Output Return Loss (5 MHz - 6 GHz)

Input Stimulus for Amplifier Two-Tone Test

f_1 = 2400 MHz, f_2 = 2401 MHz, -20 dBm each tone

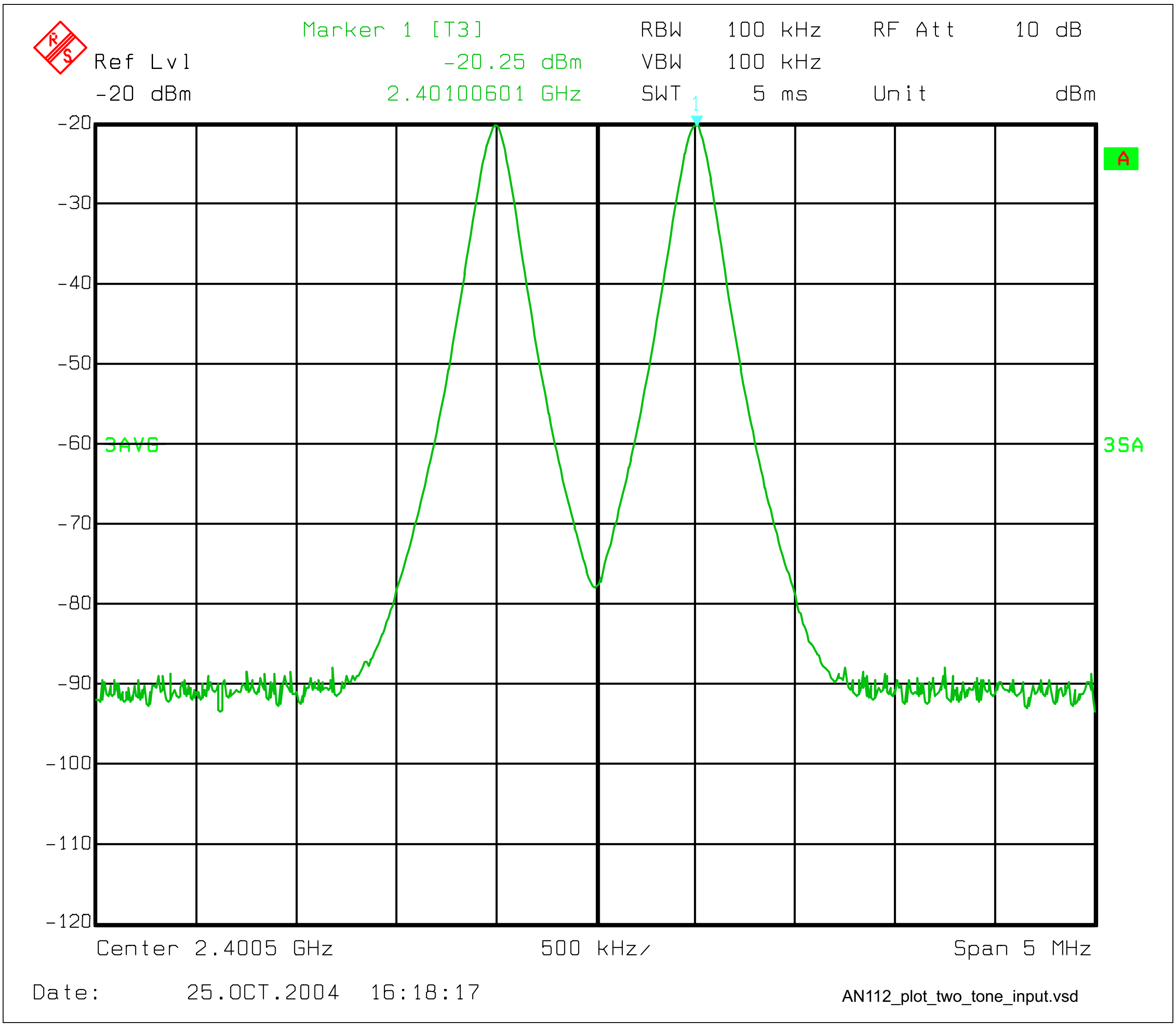


Figure 15 Input Stimulus for Amplifier Tow-Tone Test

LNA Response to Two-Tone Test

Input IP_3 = -20 + (41.7 / 2) = +0.9 dBm
Output IP_3 = +0.9 dBm + 15.9 dB gain = +16.8 dBm.

NOTE: THIRD ORDER INTERCEPT COULD BE IMPROVED BY 8 - 10 dB BY USING CHARGE STORAGE OFF OF BASE OF TRANSISTOR. THIS APPROACH WOULD REQUIRE THE ADDITION OF ONE MORE INDUCTOR TO THE CIRCUIT.

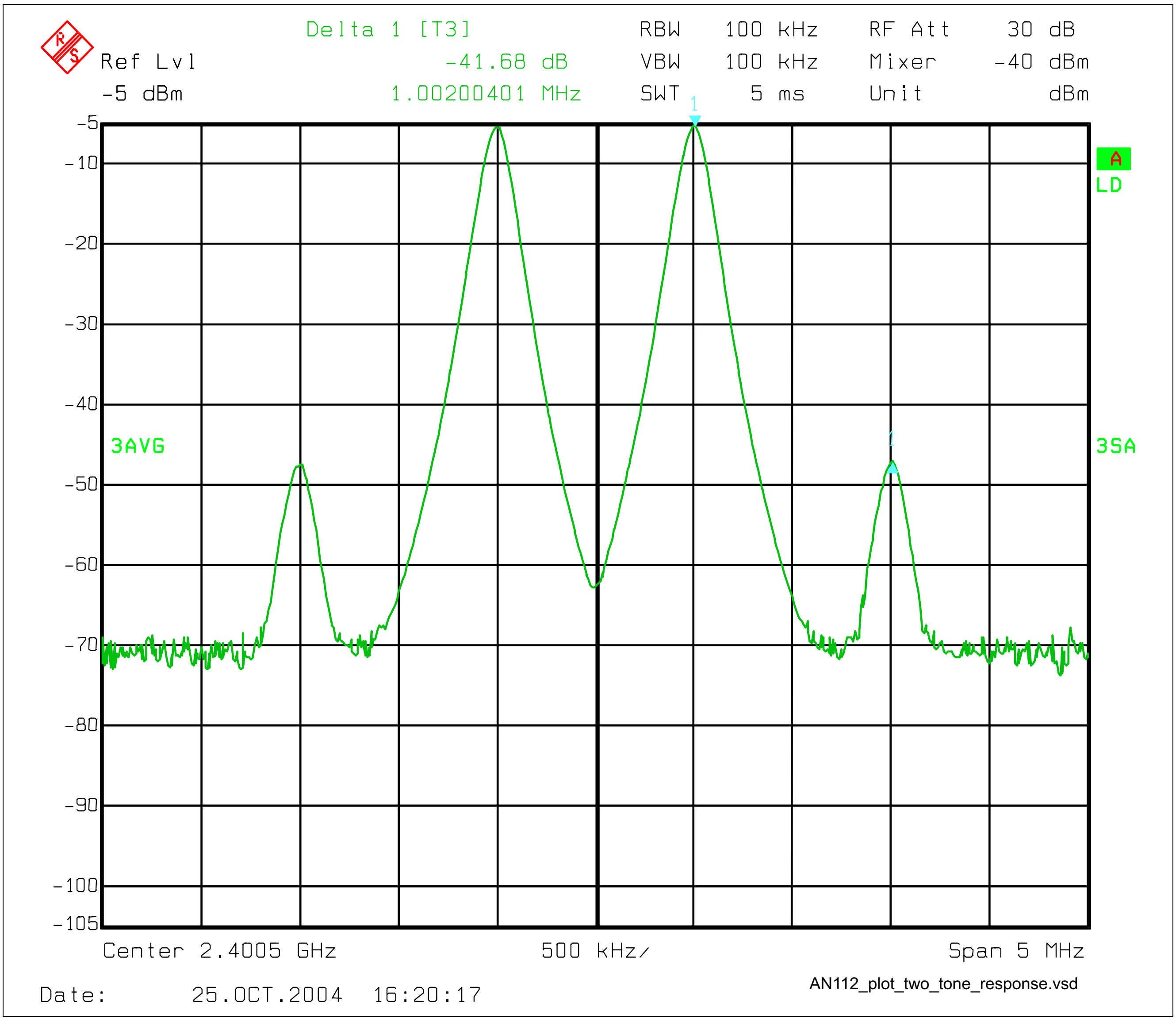


Figure 16 LNA Response to Tow-Tone Test