Application Note No. 117

Low Noise Amplifier (LNA) for 1575 MHz (GPS) Applications using the Ultra-Low Noise SiGe:C BFP740F Transistor

RF & Protection Devices

Never stop thinking

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Revision History: 2007-11-16, Rev. 1.3

Previous Version: 2007-08-30, Rev. 1.2

Page	Subjects (major changes since last revision)
	Tittle change

1 Low Noise Amplifier (LNA) for 1575 MHz (GPS) Applications using the Ultra-Low Noise SiGe:C BFP740F Transistor

Overview

- BFP740F in TSFP-4 package is evaluated for a 1575 MHz GPS LNA application. Note TSFP-4 package is only 1.4 x 1.2 x 0.55 mm high. Design Goals: Gain = 17 dB min, Noise Figure = 0.8 dB max, Input / Output Return Loss 10 dB or better, current < 8 mA from a 3.0 V power supply.
- Printed Circuit Board used is Infineon Part Number 740F-0080404 Rev A. Standard FR4 material is used in a three-layer PCB. Please refer to cross-sectional diagram below.
- Low-cost, standard "0402" case-size SMT passive components are used throughout. Please refer to schematic and Bill Of Material. The LNA is unconditionally stable from 5 MHz to 6 GHz.
- Total PCB area used for the single LNA stage is < 40 mm². Total Parts count, including the BFP740 transistor, is 12.

Achieved ≅ 20 dB gain, 0.67 dB Noise Figure at 1575 MHz from 3.0 V supply drawing 8.2 mA. Note noise figure result does NOT "back out" FR4 PCB losses - if the PCB loss at LNA input were extracted, Noise Figure result would be approximately 0.1 dB lower. Input P_{1dB} ≈ -18 dBm @ 1575 MHz. Input Third Order Intercept of -1.7 dBm @ 1575 MHz. Further work will be done to optimize input match (presently amplifier has 9.0 dB input return loss).

PCB Cross - Section Diagram

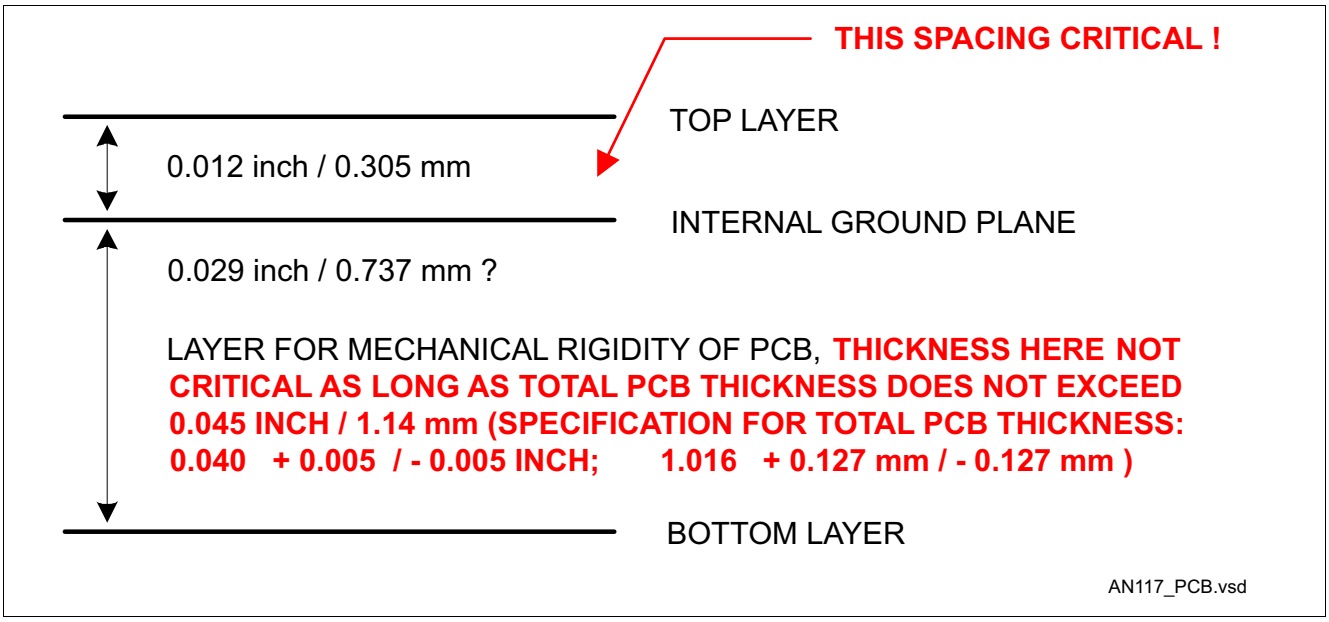


Figure 1 PCB - Cross Sectional Diagram

TSFP-4 package details (dimensions in millimeters). Note maximum package height is 0.59 mm / 0.023 inch.

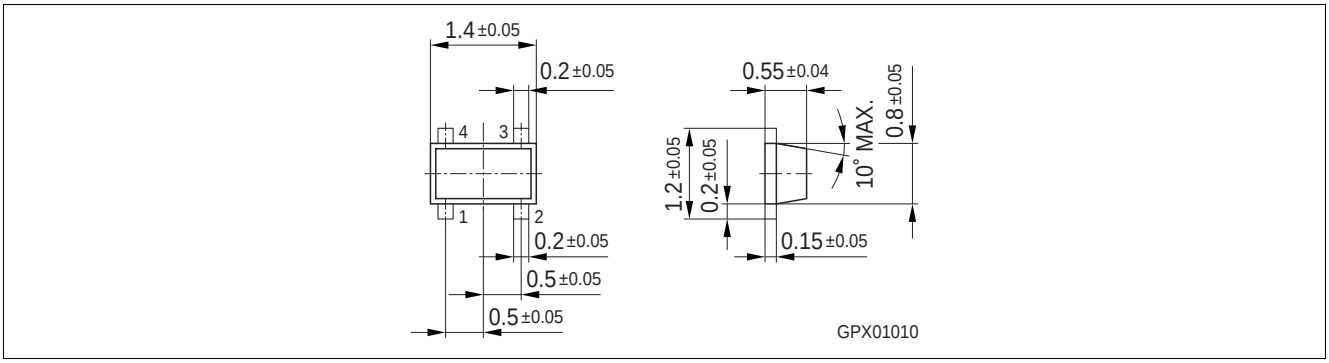


Figure 2 TSFP-4 package details

Recommended Soldering Footprint for TSFP-4 (dimensions in millimeters). Device package is to be oriented as shown in above drawing (e.g. orient long package dimension horizontally on this footprint).

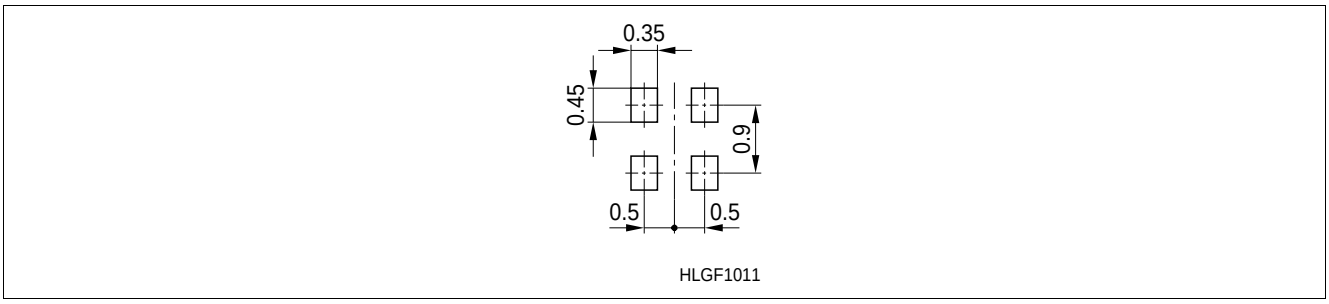


Figure 3 TSFP-4 package - Soldering Footprint

Summary of LNA Data

T = 25 °C, network analyzer source power = -25 dBm

Table 1 Summary of LNA Data

Parameter	Result	Comments
Frequency Range	1575.42 MHz	GPS “L1” carrier frequency
DC Current	8.2 mA @ 3.0 V	
DC Voltage, V_{CC}	3.0 V	
Collector-Emitter Voltage, V_{CE}	2.7 V	
Gain	19.8 dB @ 1575 MHz	
Noise Figure	0.67 dB @ 1575 MHz	See noise figure plots an tabular data. 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}	-18.0 dBm @ 1575 MHz	
Output P_{1dB}	+0.8 dBm @ 1575 MHz	
Input 3rd Order Intercept	-1.7 dBm @ 1575 MHz	Two tones, 1574 & 1575 MHz, -24 dBm each tone. See **Figure 13**.
Input Return Loss	9.0 dB @ 1575 MHz	
Output Return Loss	14.4 dB @ 1575 MHz	
Reverse Isolation	28.7 dB @ 1575 MHz	

Bill of Material

T = 25 °C, network analyzer source power = -25 dBm

Table 2 Bill of Material

Reference Designator	Value	Manufacturer	Case Size	Function
C1	47 pF	Various	0402	DC blocking, input. Also, using cap above self-resonance makes it slightly inductive, slightly improving input match.
C2	2.2 pF	Various	0402	DC block, output. Also influences output and input impedance match.
C3	0.1 µF	Various	0402	Decoupling, low frequency. Also improves Third-Order Intercept.
C4	15 pF	Various	0402	Decoupling (RF Short)
C5	2.2 Pf	Various	0402	Decoupling (RF Short). Also has influence on output match and stability.
C6	0.1 µF	Various	0402	Decoupling, low frequency.
L1	10 nH	Murata LQG15HN series low cost inductor	0402	RF choke at input
L2	4.3 nH	Murata LQG15HN series inductor	0402	RF choke + impedance match at output

Table 2 Bill of Material (cont'd)

Reference Designator	Value	Manufacturer	Case Size	Function
R1	10 Ω	Various	0402	Stability improvement
R2	56 kΩ	Various	0402	Brings bias current / voltage into base of transistor.
R3	30 Ω	Various	0402	Provides some negative feedback for Dc bias / DC operating point to compensate for variations in transistor Dc current gain, temperature variations, etc.
Q1	-	Infineon Technologies	TSFP-4	BFP740F B7HFe Ultra-Low Noise RF Transistor
J1, J2	-	Johnson 142-0701-841	-	RF input / output connectors
J3	-	Amp 5 pin header MTA-100 series 640456-5 (standard pin plating) or 641215-5 (gold plated pins)	-	DC connector Pins 1, 5 = Ground Pin 3 = V_{CC} Pins 2, 4 = no connection

Schematic Diagram for 1575 MHz GPS LNA

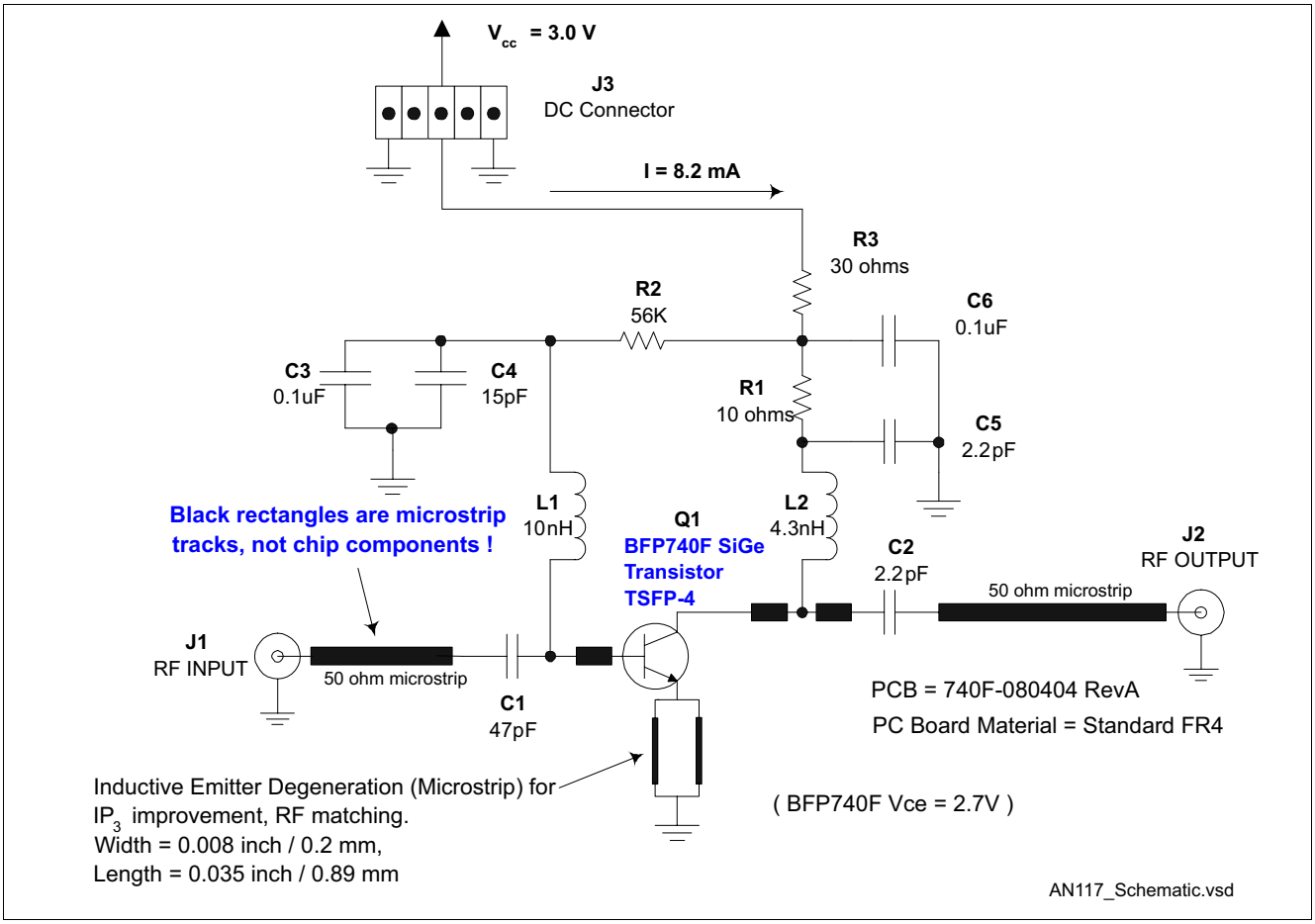


Figure 4 Schematic Diagram

Noise Figure, Plot. Center of Plot (x-axis) is 1575 MHz.

Rohde & Schwarz FSEK3

20 Aug 2004

BFP740F Engineering sample - first results - Noise Figure

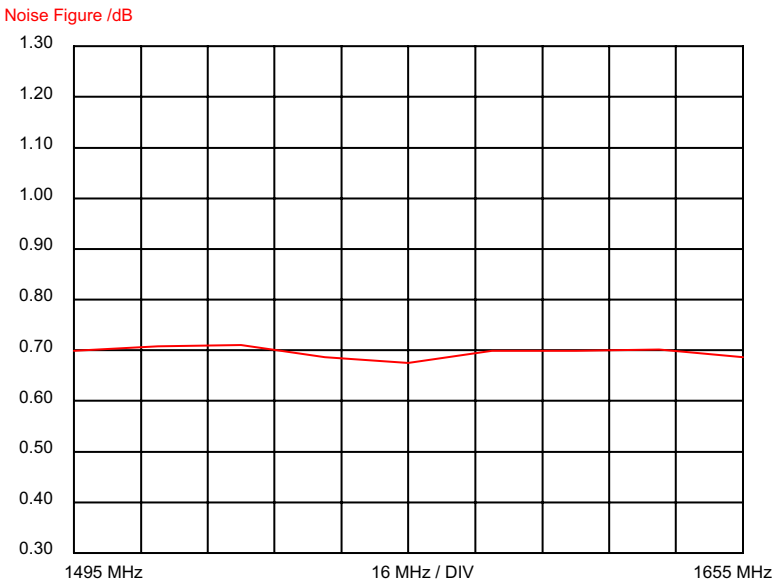
EUT Name:	New PCB 740F-080404 Rev A
Manufacturer:	Infineon Technologies
Operating Conditions:	Vcc = 3.0 V, Vce = 2.7 V, Ic = 8.2 mA
Operator Name:	Gerard Wevers
Test Specification:	LWR_SD00051_LNA_P
Comment:	
	19 Aug 2004

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



AN117_plot_nf.vsd

Figure 5 Noise Figure

Noise Figure, Tabular Data

From Rhode & Schwarz FSEK3 + FSEM30
System Preamplifier = MITEQ SMC-02

Table 3 Noise Figure

Frequency	Noise Figure
1495 MHz	0.70 dB
1515 MHz	0.71 dB
1535 MHz	0.71 dB
1555 MHz	0.69 dB
1575 MHz	0.67 dB
1595 MHz	0.70 dB
1615 MHz	0.70 dB
1635 MHz	0.70 dB
1655 MHz	0.69 dB

Scanned Image of PC Board

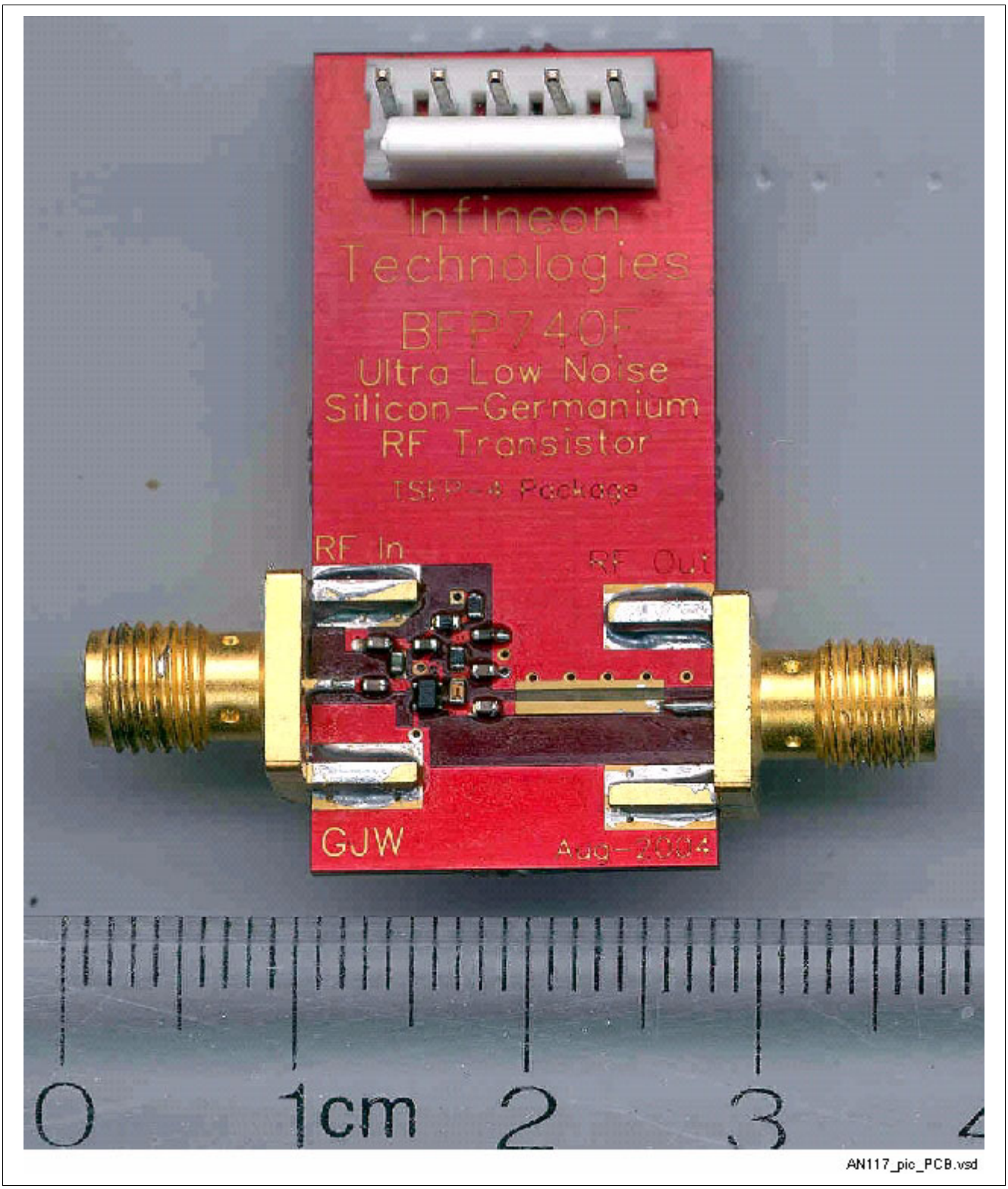


Figure 6 Image of PC Board

Scanned Image of PC Board, Close-In Shot

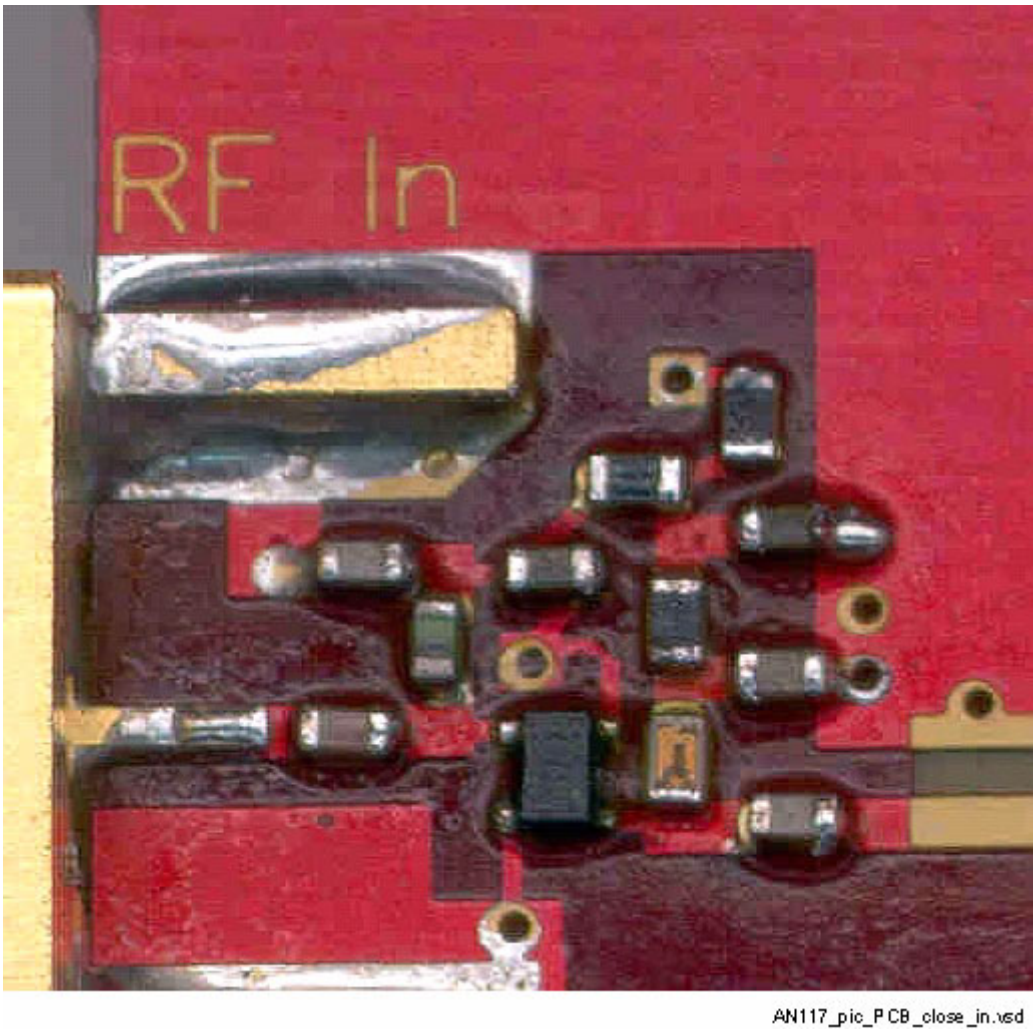


Figure 7 Image of PC Board, Close-In Shot

Power Sweep at 1575 MHz (CW)

Source Power (Input) swept from -35 to -7 dBm
Input P_{1dB} ≅ -18.0 dBm

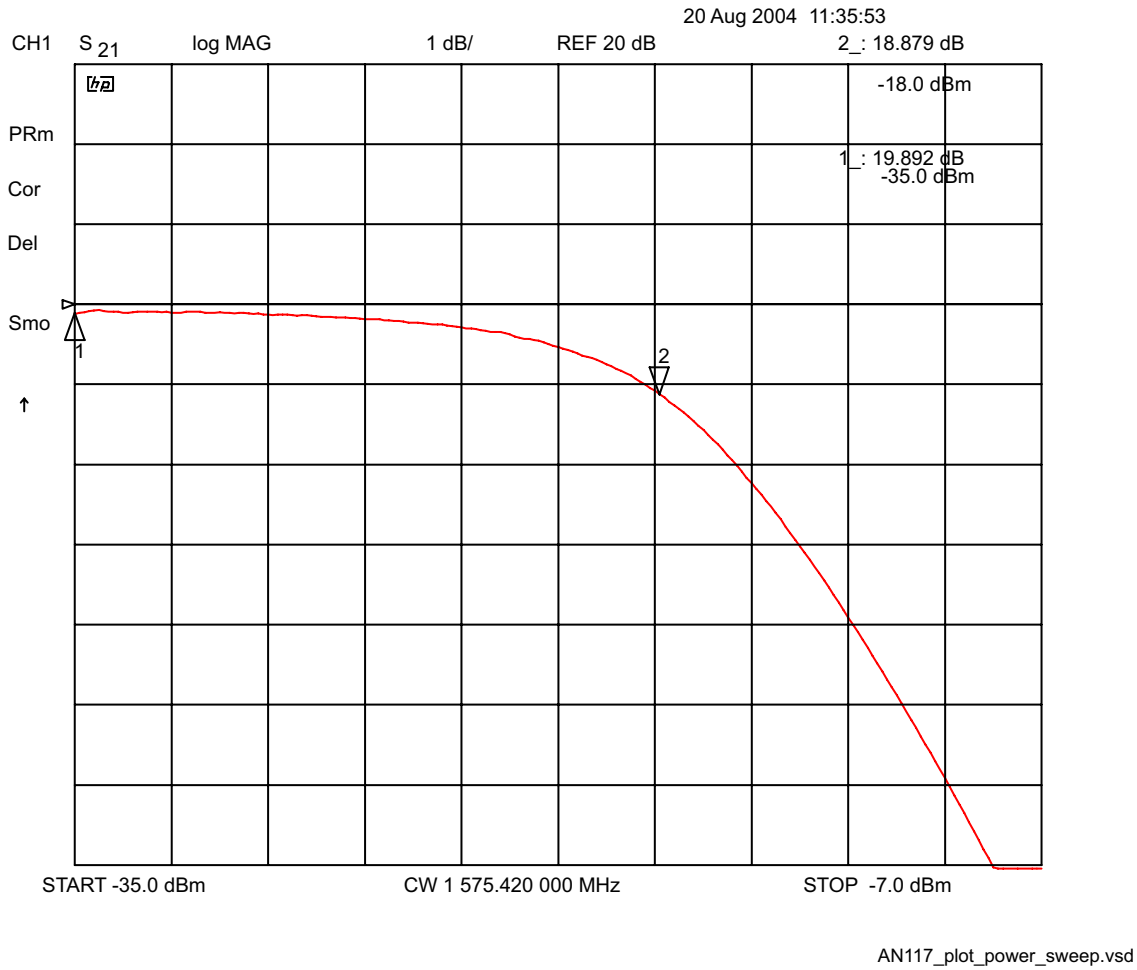


Figure 8 Plot of Power Sweep (1575 MHz)

Input Return Loss, Log Mag

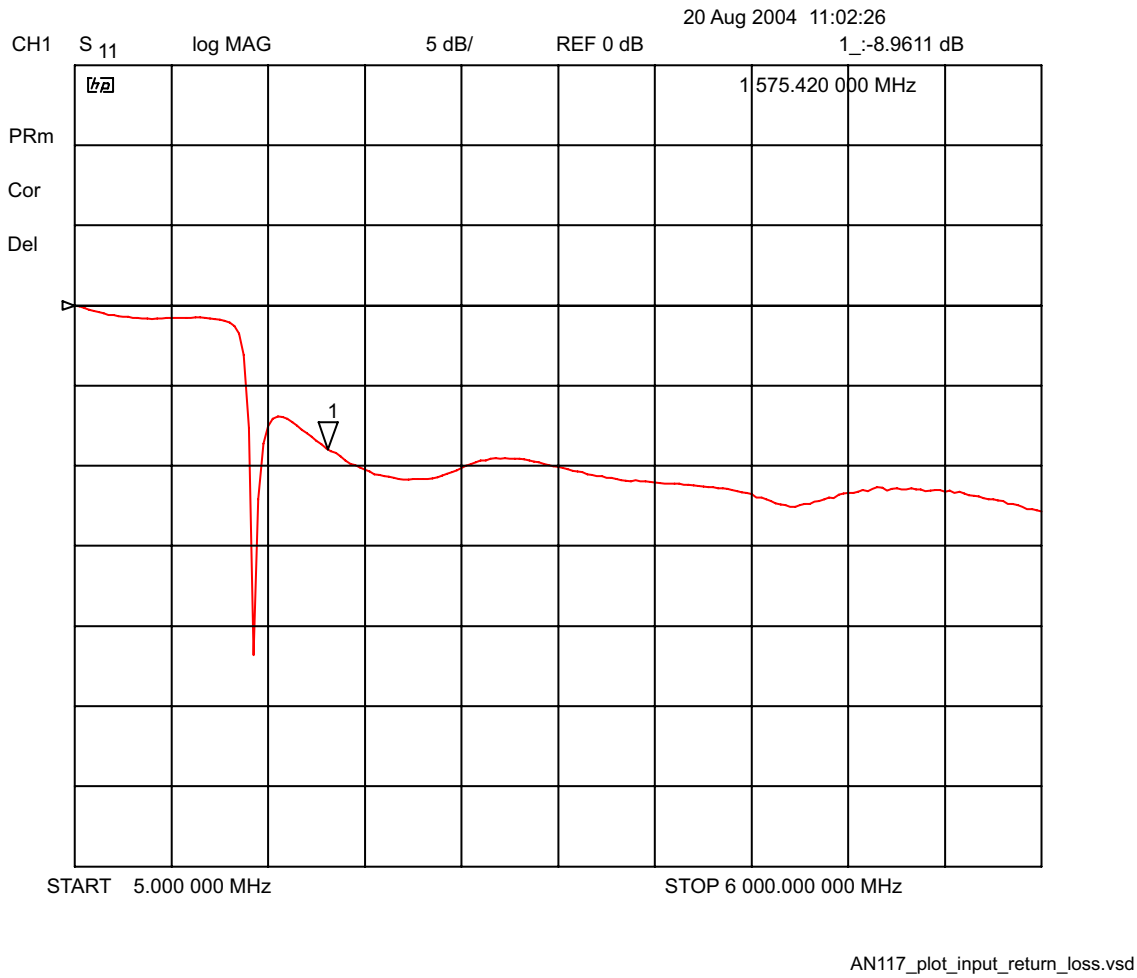


Figure 9 Plot of Input Return Loss

Forward Gain, wide Sweep

(5 MHz - 6 GHz)

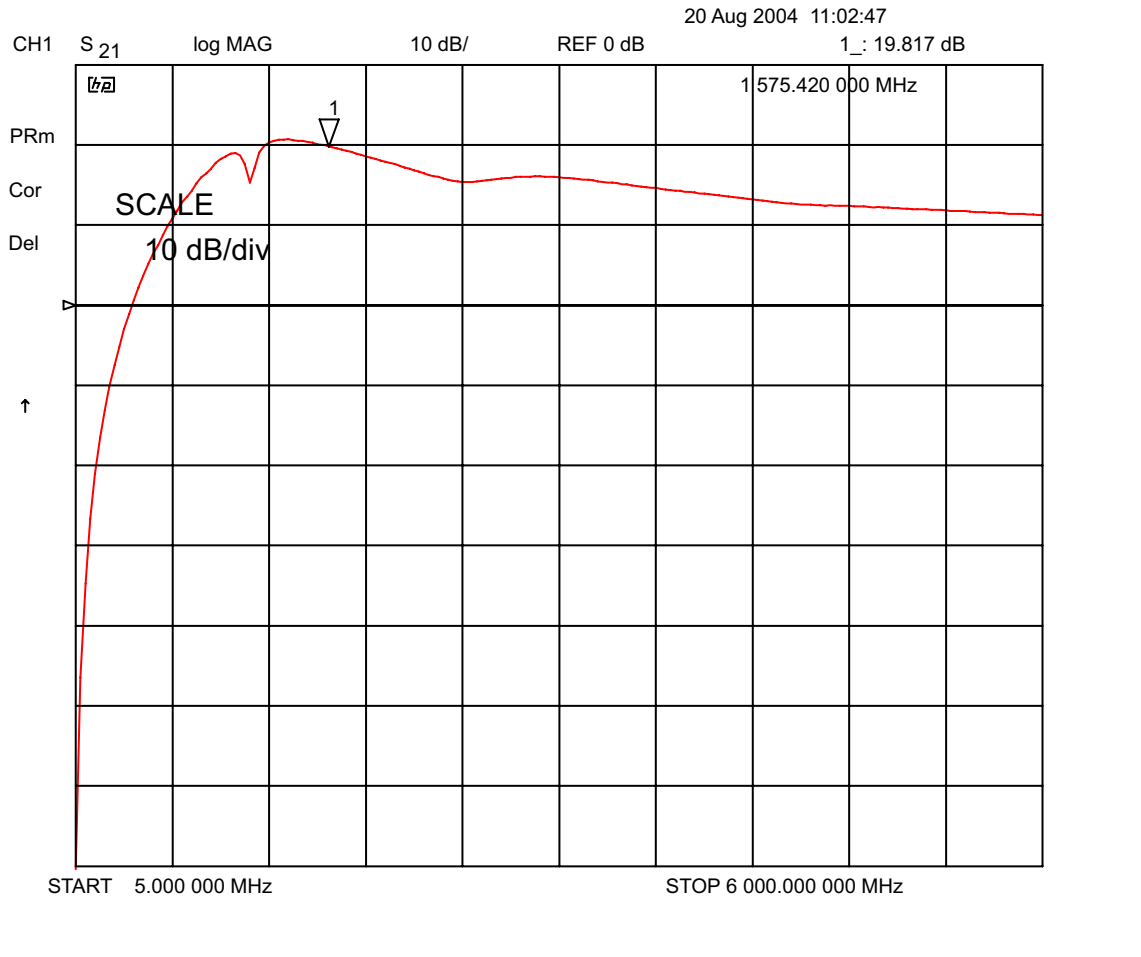


Figure 10 Plot of Forward Gain

Reverse Isolation

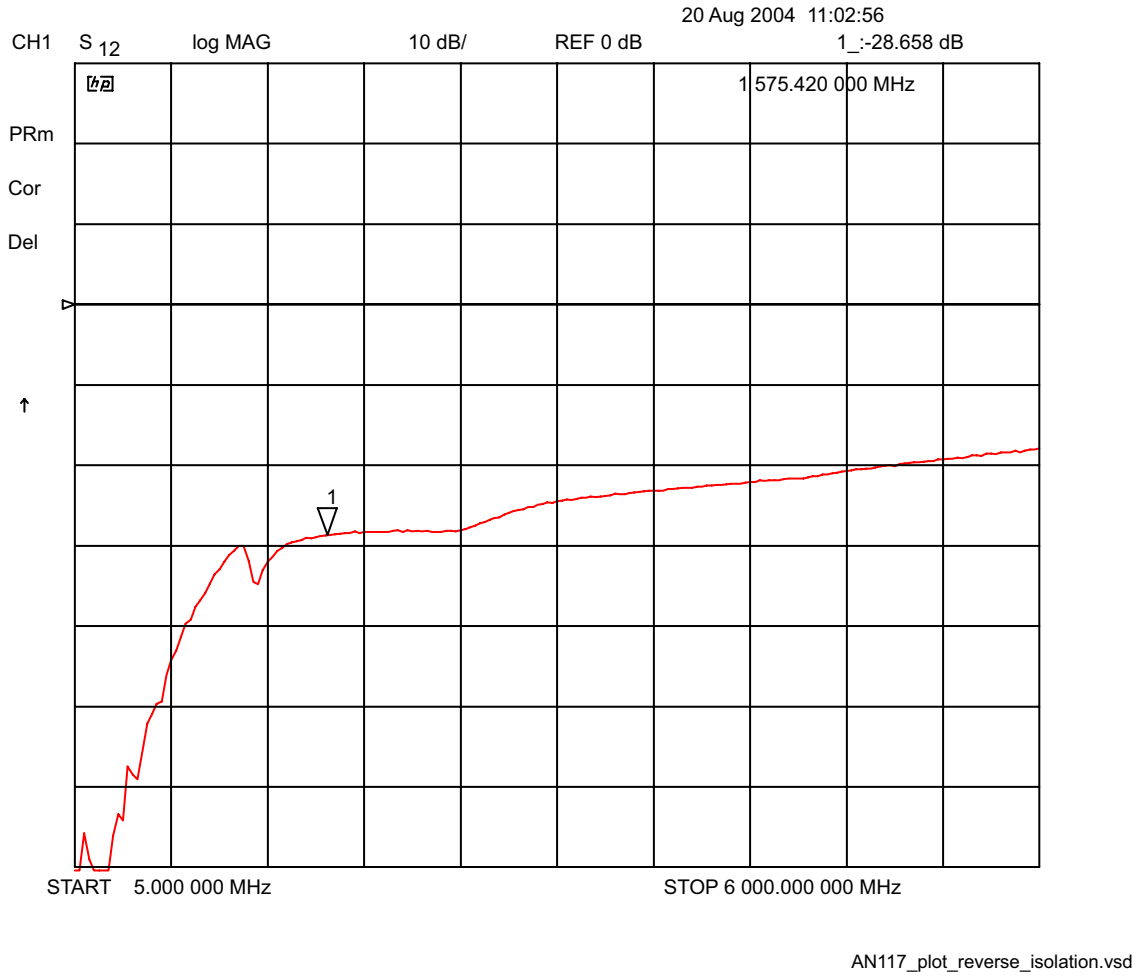


Figure 11 Plot of Reverse Isolation

Output Return Loss, Log Mag

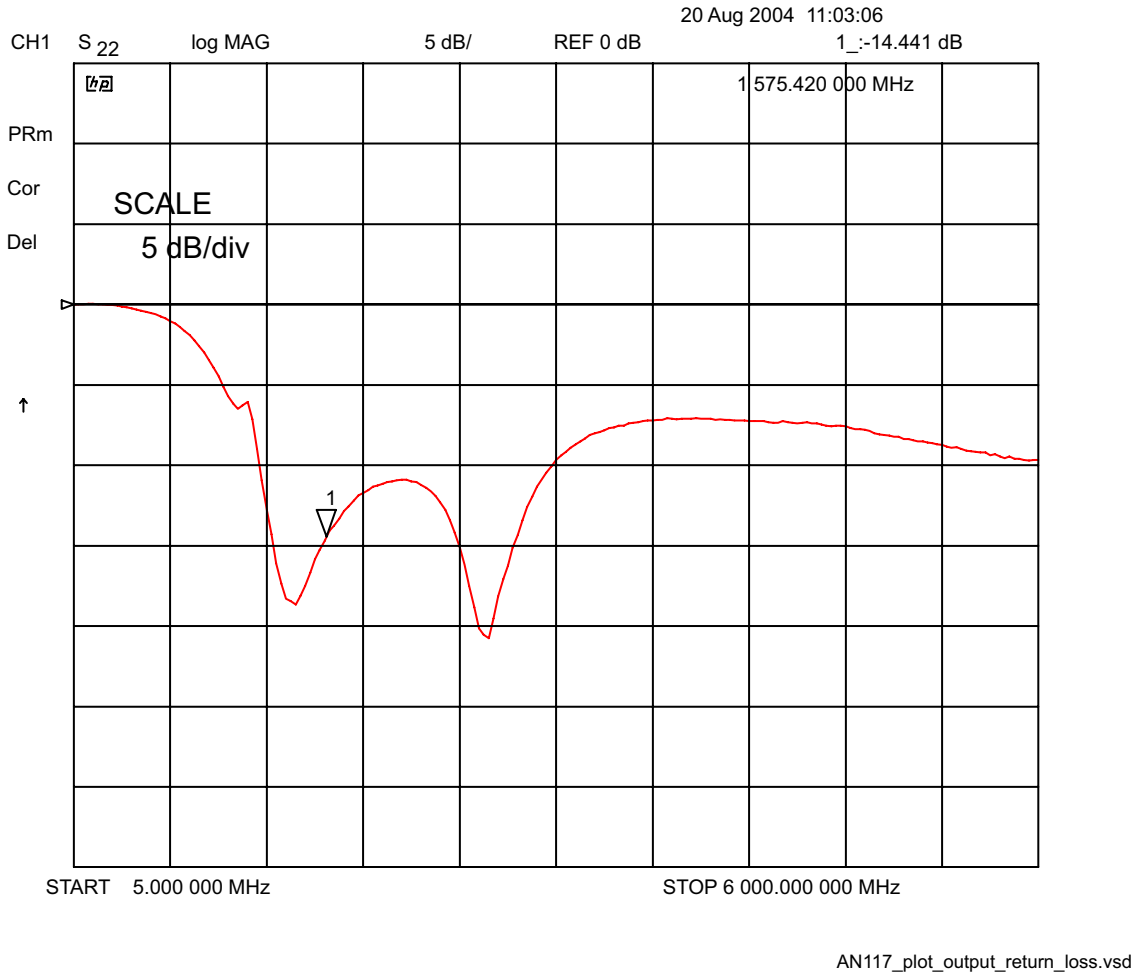


Figure 12 Plot of Output Return Loss

LNA response to two-tone test

Input Stimulus for Amplifier Two-Tone Test
f_1 = 1574 MHz, f_2 = 1575 MHz, -24 dBm each tone
Input IP_3 = -24 + (44.6 / 2) = -1.7 dBm
Output IP_3 = -1.7 dBm + 19.8 dB gain = +18.1 dBm

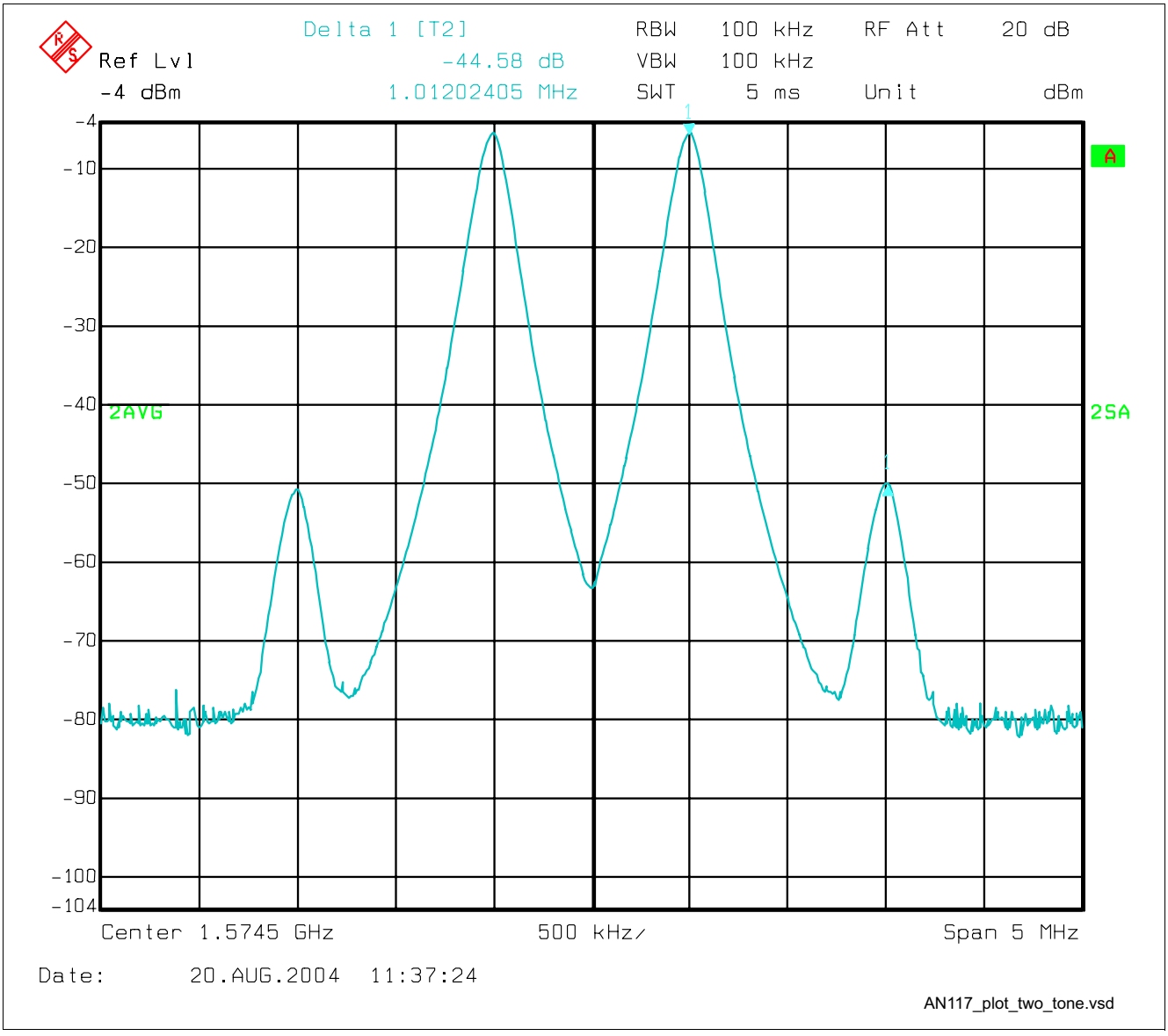


Figure 13 Tow-Tone Test (LNA Response)