Application Note No. 135

Low Noise Amplifier (LNA) for 2.3 - 2.5 GHz Applications using the SiGe BFP640 Transistor

RF & Protection Devices

Never stop thinking

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Revision History: 2007-12-19, Rev. 1.2

Previous Version: 2003-09-07, Rev. 1.1	
Page	**Subjects (major changes since last revision)**
All	Small changes in figure descriptions

1 Low Noise Amplifier (LNA) for 2.3 - 2.5 GHz Applications using the SiGe BFP640 Transistor

Applications

- 2.3 GHz SDARS, 2.4 GHz (Bluetooth, WiLAN, other 2.4 GHz ISM band applications)

Overview

- Design Goals: Gain = 15 dB, Noise Figure < 1.2 dB, Input / Output Return Loss 10 dB or better, current < 7 mA from a 3.0 V power supply, Output P_{1dB} > -15 dBm min.
- Printed Circuit Board used is Infineon Part Number 640-061603 Rev A. Standard FR4 material is used in a three-layer PCB. Please refer to cross-sectional diagram.
- 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 approximately 35 mm². Total Parts count, including the BFP640 transistor, is 12.
- Achieved 15 dB gain, 0.96 dB Noise Figure at 2400 MHz from a 3.0 V supply, drawing 6.7 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 0.2 dB lower. Amplifier is unconditionally stable from 5 MHz to 6 GHz. Input P_{1dB} ≈ -13.1 dBm @ 2400 MHz. Outstanding Input Third Order Intercept of +11.6 dBm.

PCB Cross - Section Diagram

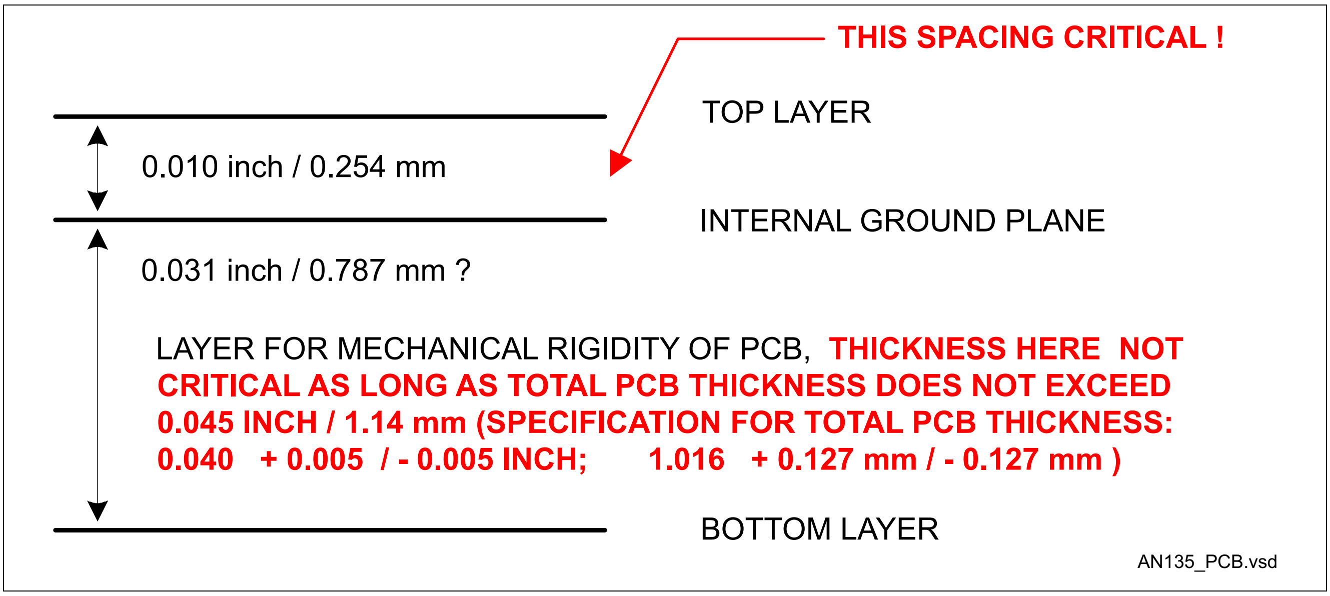


Figure 1 PCB - Cross Sectional Diagram

Summary of LNA Data

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

Table 1 Summary of Results

Parameter	Result	Comments
Frequency Range	2300 - 2500 MHz	Covers SDARS 2.330 GHz band as well as 2.4 GHz ISM band.
DC Current	6.7 mA	
DC Voltage, V_{CC}	3.0 V	
Collector-Emitter Voltage, V_{CE}	2.5 V	BFP640: V_{CEmax} = 4.0 V
Gain	15.8 dB @ 2330 MHz 15.5 dB @ 2400 MHz 15.2 dB @ 2483 MHz	Gain target: 15 dB min.
Noise Figure	0.93 dB @ 2330 MHz 0.96 dB @ 2400 MHz 0.95 dB @ 2483 MHz	See noise figure plots and tabular data, **Figure 3** and **Table 3** (These values do not extract PCB losses, etc. resulting from FR4 board an passives used on PCB - these results are at input SMA connector)
Input P_{1dB}	-11.3 dBm @ 2400 MHz	See input power sweep vs. gain plot, **Figure 7**
Output P_{1dB}	+3.2 dBm @ 2400 MHz	
Input 3rd Order Intercept	+11.6 dB @ 2400 MHz	Two-Tone Test, see **Figure 12** and **Figure 13**
Input Return Loss	10.5 dB @ 2330 MHz 11.5 dB @ 2400 MHz 12.8 dB @ 2483 MHz	
Output Return Loss	16.1 dB @ 2330 MHz 13.3 dB @ 2400 MHz 11.2 dB @ 2483 MHz	
Reverse Isolation	21.9 dB @ 2330 MHz 21.7 dB @ 2400 MHz 21.5 dB @ 2483 MHz	

Bill of Material

Table 2 Bill of Material, Broadband BFP640 UHF Feedback LNA

Reference Designator	Value	Manufacturer	Case Size	Function
C1	8.2 pF	Various	0402	DC blocking, input
C2	1.5 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	8.2 pF	Various	0402	Decoupling (RF short)
C5	5.6 pF	Various	0402	Decoupling (RF short). Also has some influence on stability (using less than 8.2 pF causes output of amplifier to “see” more loss from R1 at lower frequencies → stability improvement).
C6	0.1 µF	Various	0402	Decoupling, low frequency
L1	12 nH	Murata LQP15M series	0402	RF choke at input
L2	3.9 nH	Murata LQP15M series	0402	RF choke + impedance match at output
R1	10 Ω	Various	0402	Stability improvement
R2	51 kΩ	Various	0402	Bring bias current / voltage into base of transistor
R3	68 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	SOT343	BFP640 B7HF 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 2.3 - 2.5 GHz LNA

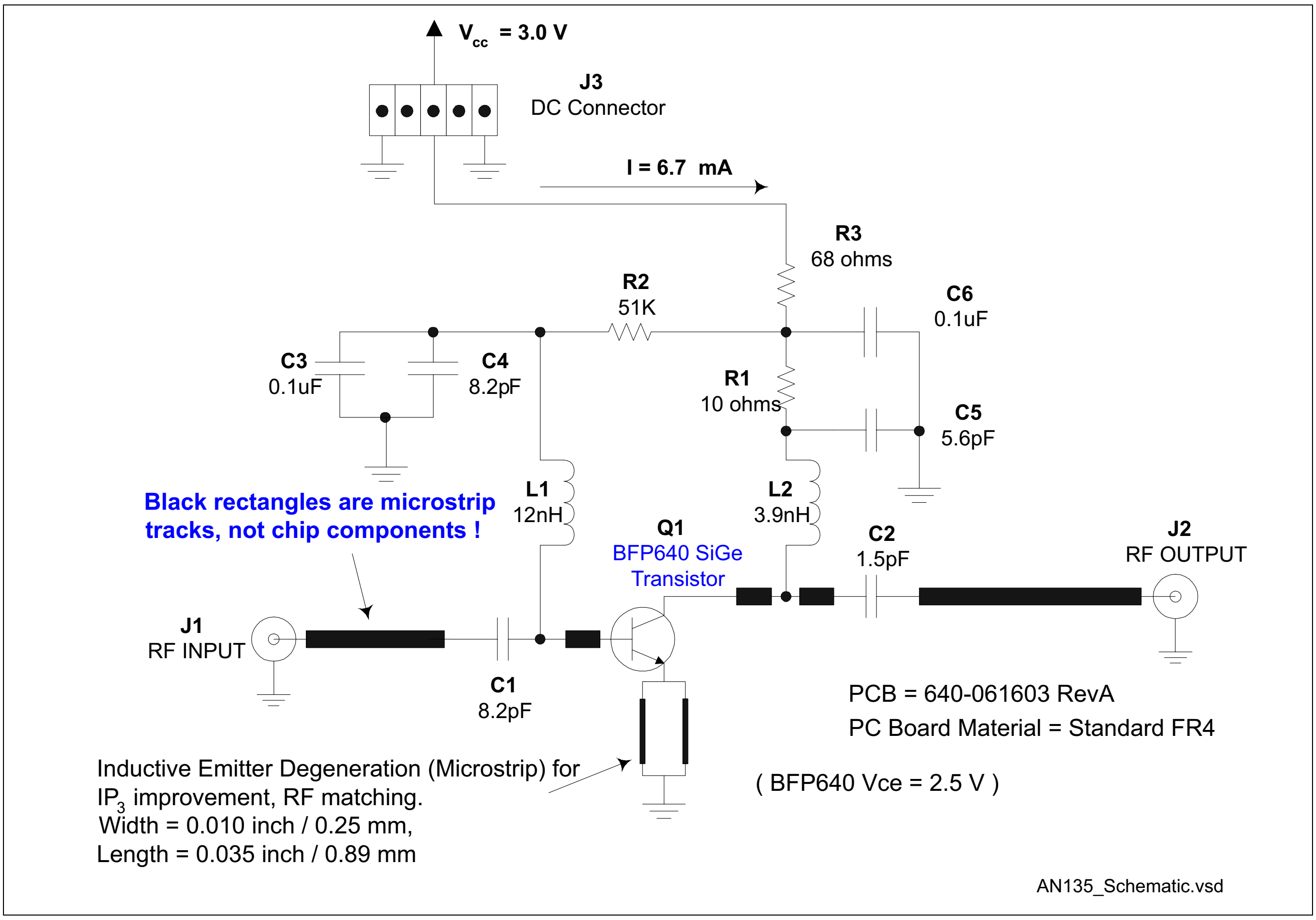


Figure 2 Schematic Diagram

Noise Figure, Plot, Center of Plot (x-axis) is 2400 MHz.

Rohde & Schwarz FSEK3

07 Sep 2003

Noise Figure

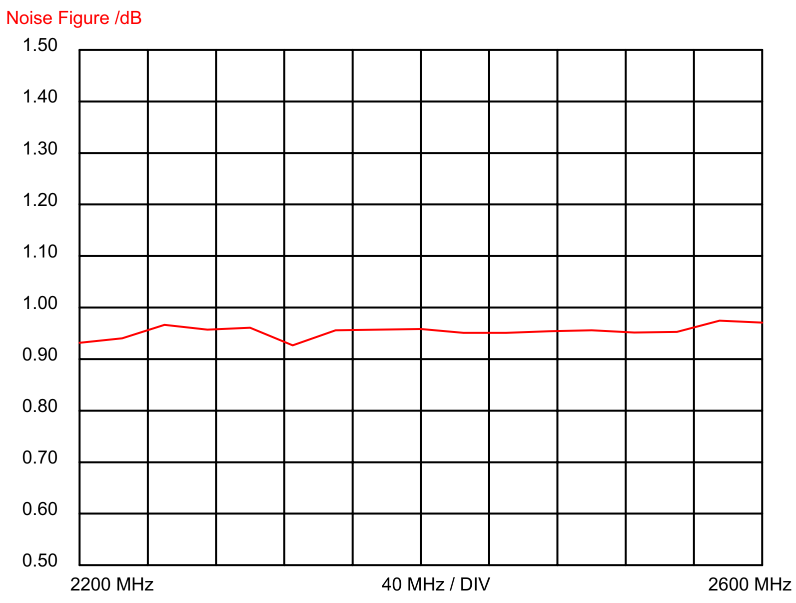
EUT Name:	BFP640 2.3 - 2.5 GHz LNA
Manufacturer:	Infineon Technologies
Operating Conditions:	V = 3.0 V, I = 6.7 mA, T = 25 C
Operator Name:	Gerard Wevers
Test Specification:	LWR # SD 00032 LNA P
Comment:	On PCB 640-061603 Rev A
	07 September 2003

Analyzer

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

Measurement

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



AN135_plot_nf.vsd

Figure 3 Noise Figure

Noise Figure, Tabular Data

From Rohde & Schwarz FSEK3 + FSEB30
System Preamplifier = MITEQ SMC-02

Table 3 Noise Figure

Frequency	Noise Figure
2200 MHz	0.93 dB
2225 MHz	0.94 dB
2250 MHz	0.97 dB
2275 MHz	0.96 dB
2300 MHz	0.96 dB
2325 MHz	0.93 dB
2350 MHz	0.96 dB
2375 MHz	0.96 dB
2400 MHz	0.96 dB
2425 MHz	0.95 dB
2450 MHz	0.95 dB
2475 MHz	0.95 dB
2500 MHz	0.96 dB
2525 MHz	0.95 dB
2550 MHz	0.95 dB
2575 MHz	0.97 dB
2600 MHz	0.97 dB

Scanned Image of PC Board

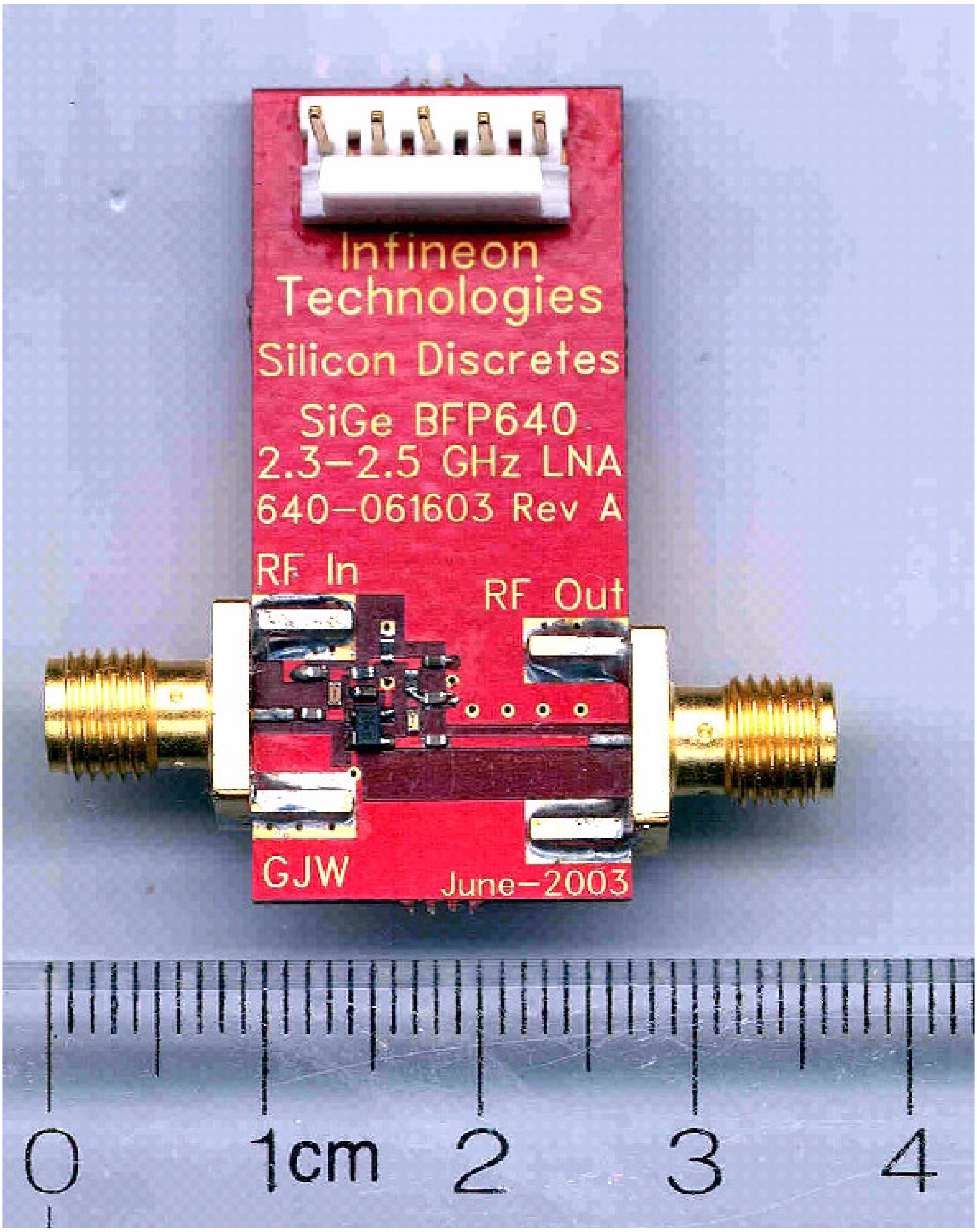


Figure 4 Image of PC Board

Scanned Image of PC Board, Close-In Shot.

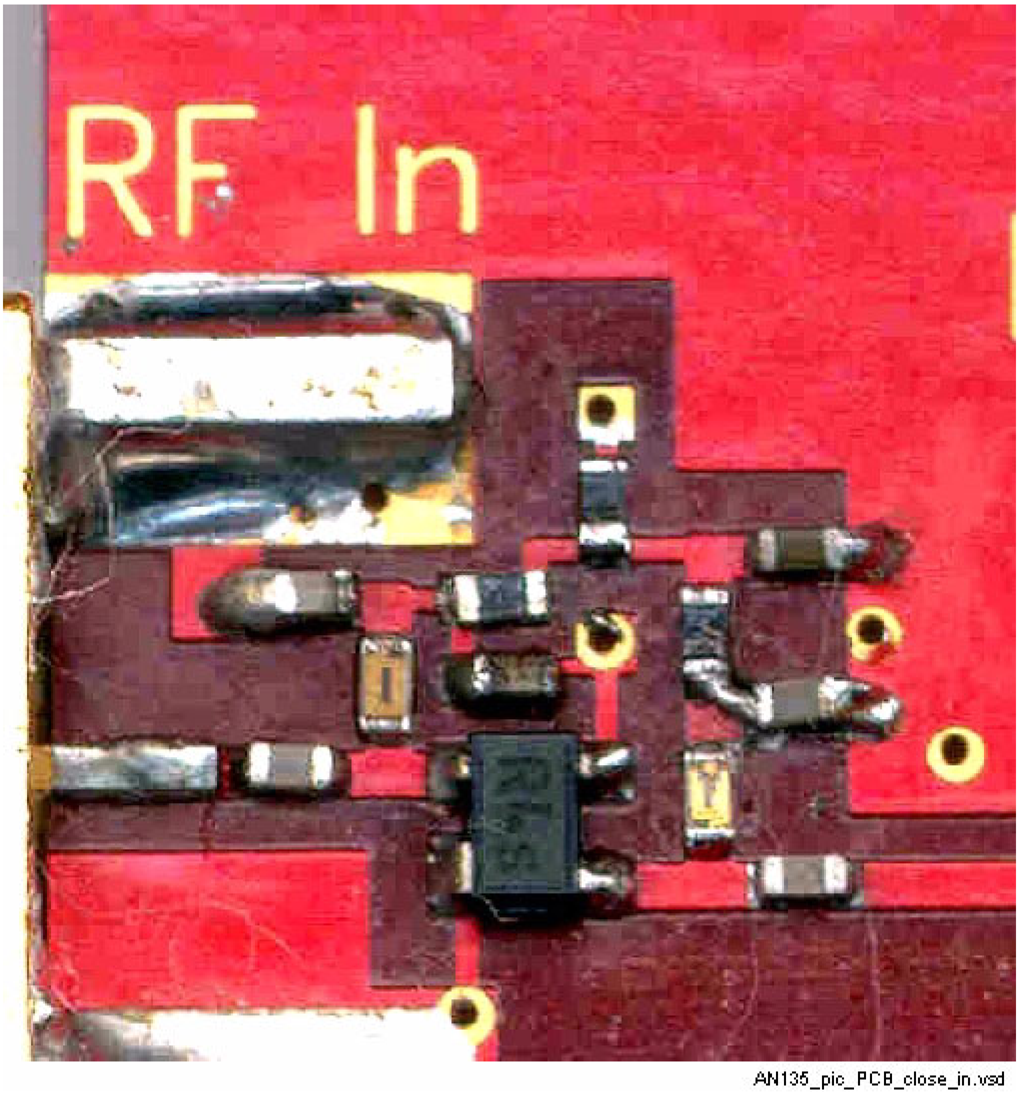


Figure 5 Image of PC Board, Close-In Shot

Stability Factor “K” and Stability Measure “B1”

Note that if K > 1 and B1 > 0, the amplifier is unconditionally stable. Measured LNA s-parameters were taken on a Network Analyzer and then imported into GENESYS simulation package, which calculates and plots K and B1.

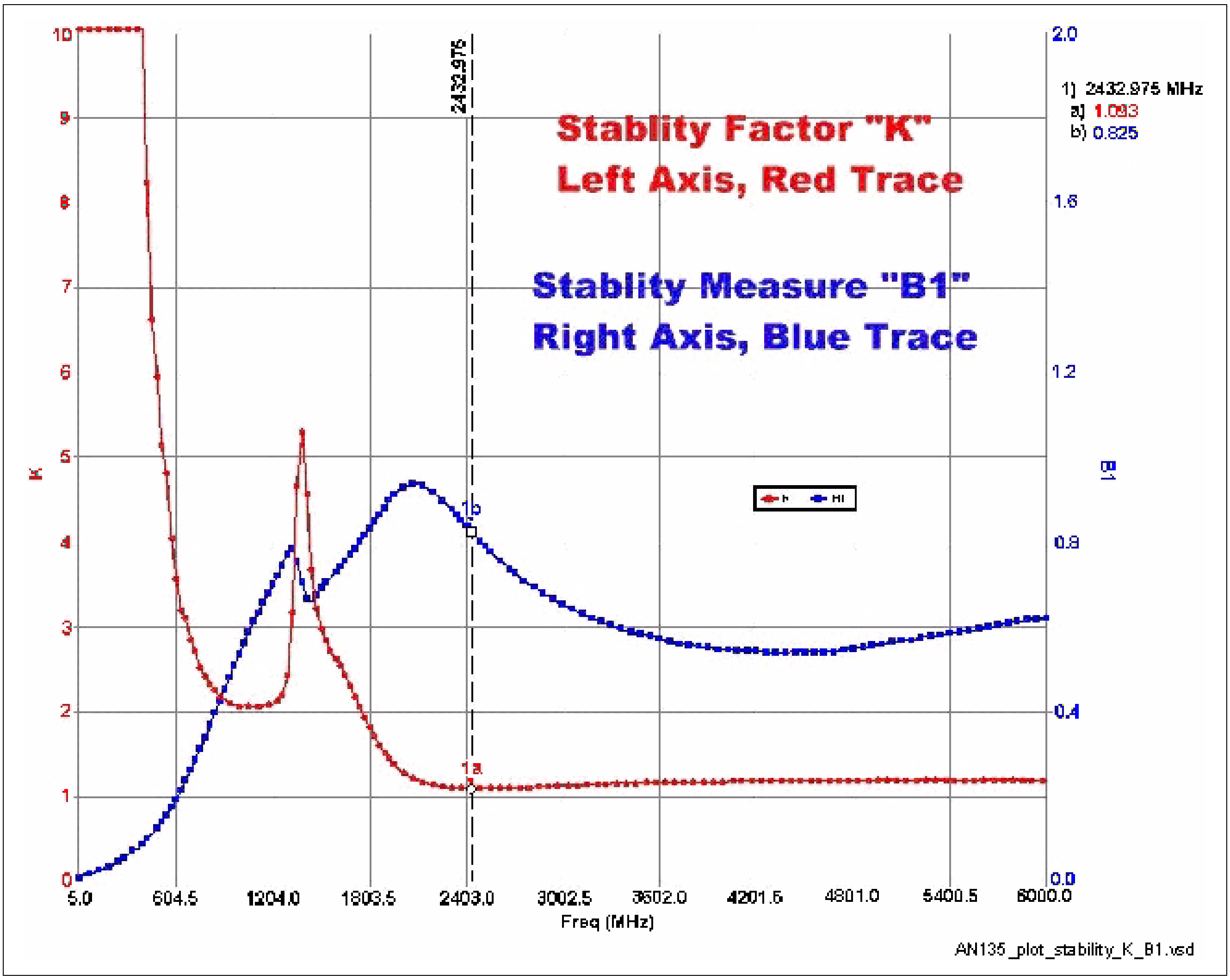


Figure 6 Plot of K(f) and B1(f)

Power Sweep at 2400 MHz (CW)

Source Power (Input) Swept from -25 to 0 dBm

Input $P_{1dB} \cong$ -11.3 dBm

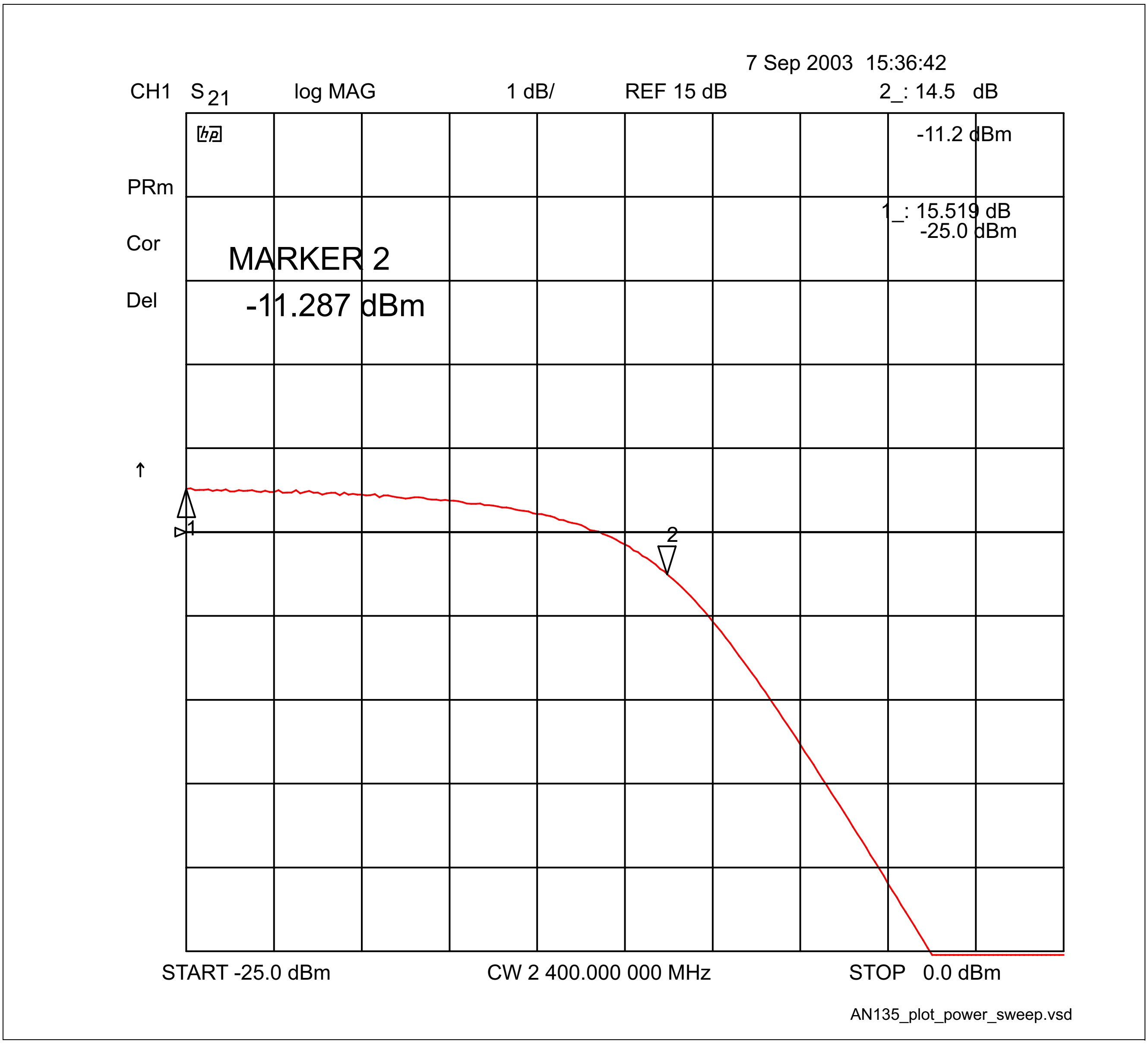


Figure 7 Plot of Power Sweep at 2400 MHz

Input Return Loss, Log Mag

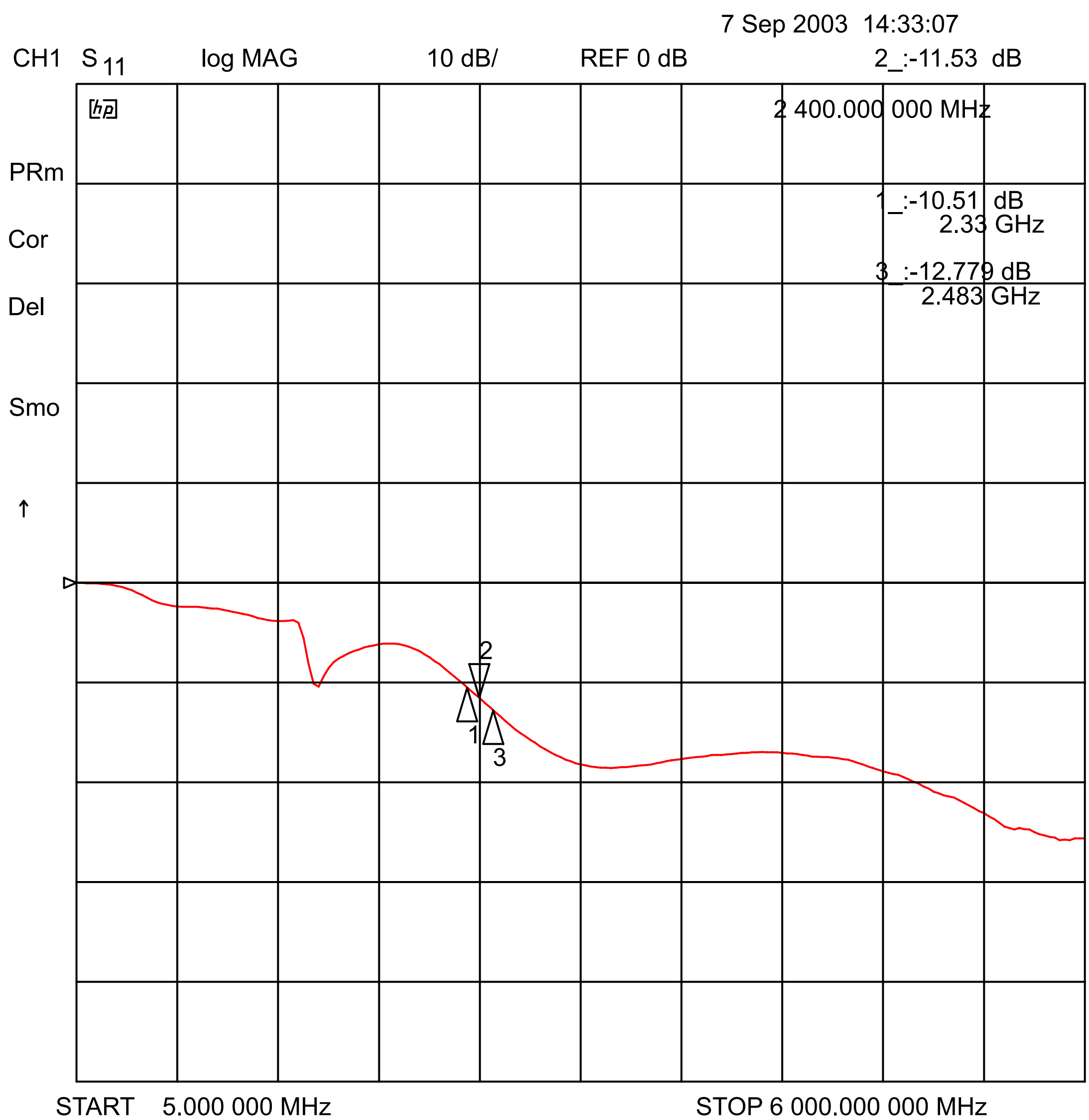


Figure 8 Plot of Input Return Loss

Forward Gain, Wide Sweep

5 MHz - 6 GHz

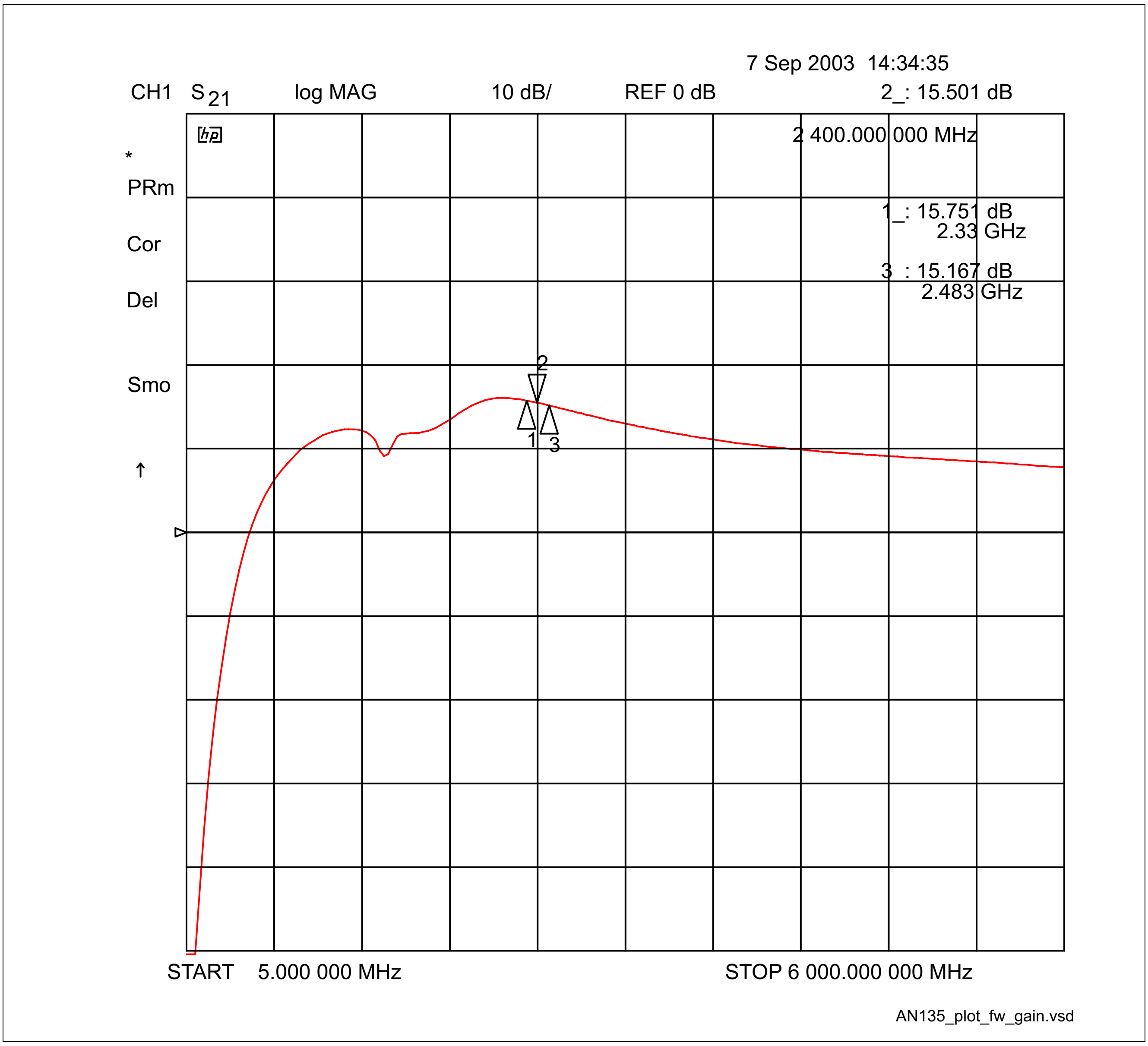


Figure 9 Plot of Forward Gain

Reverse Isolation

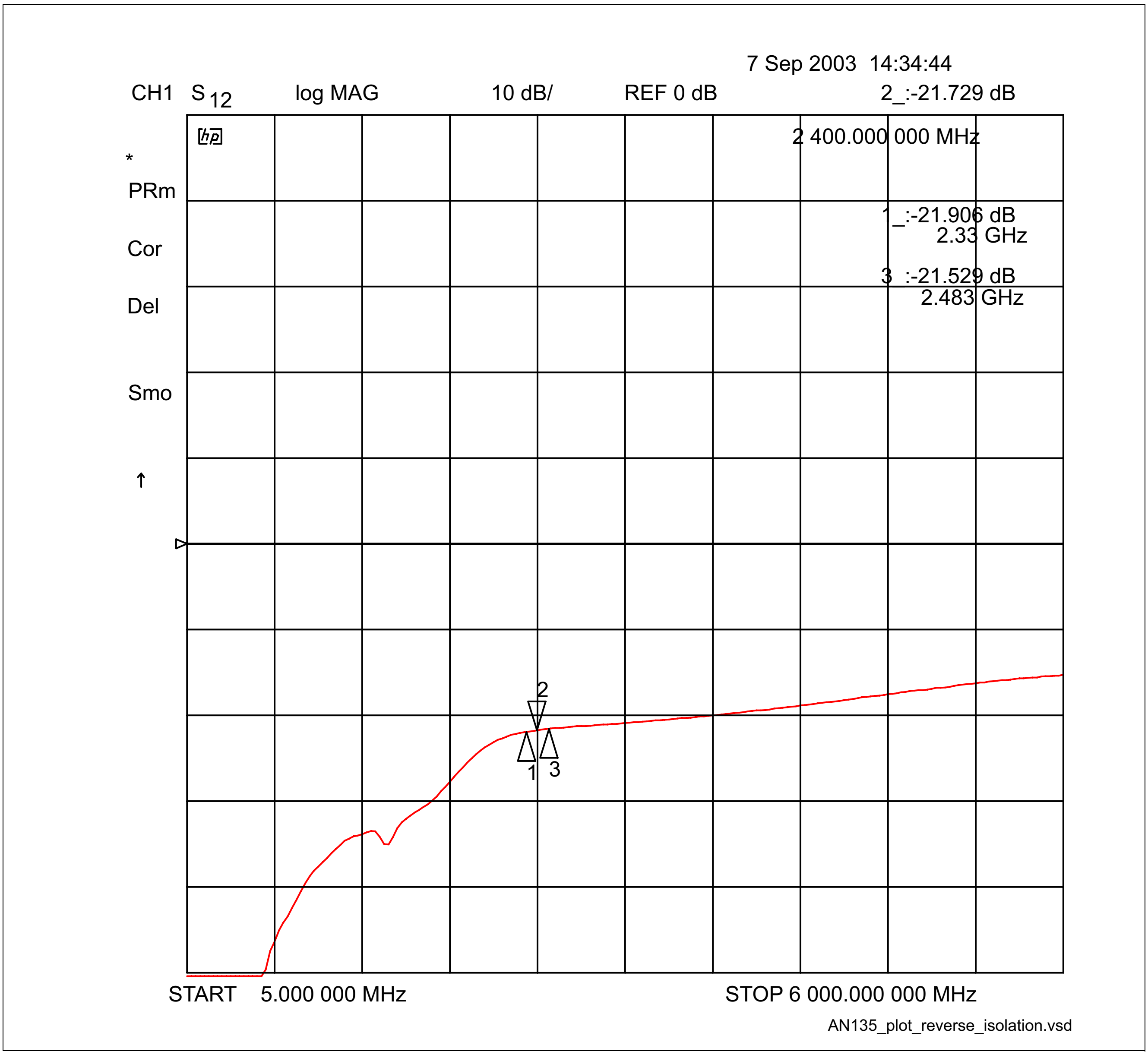


Figure 10 Plot of Reverse Isolation

Output Return Loss, Log Mag

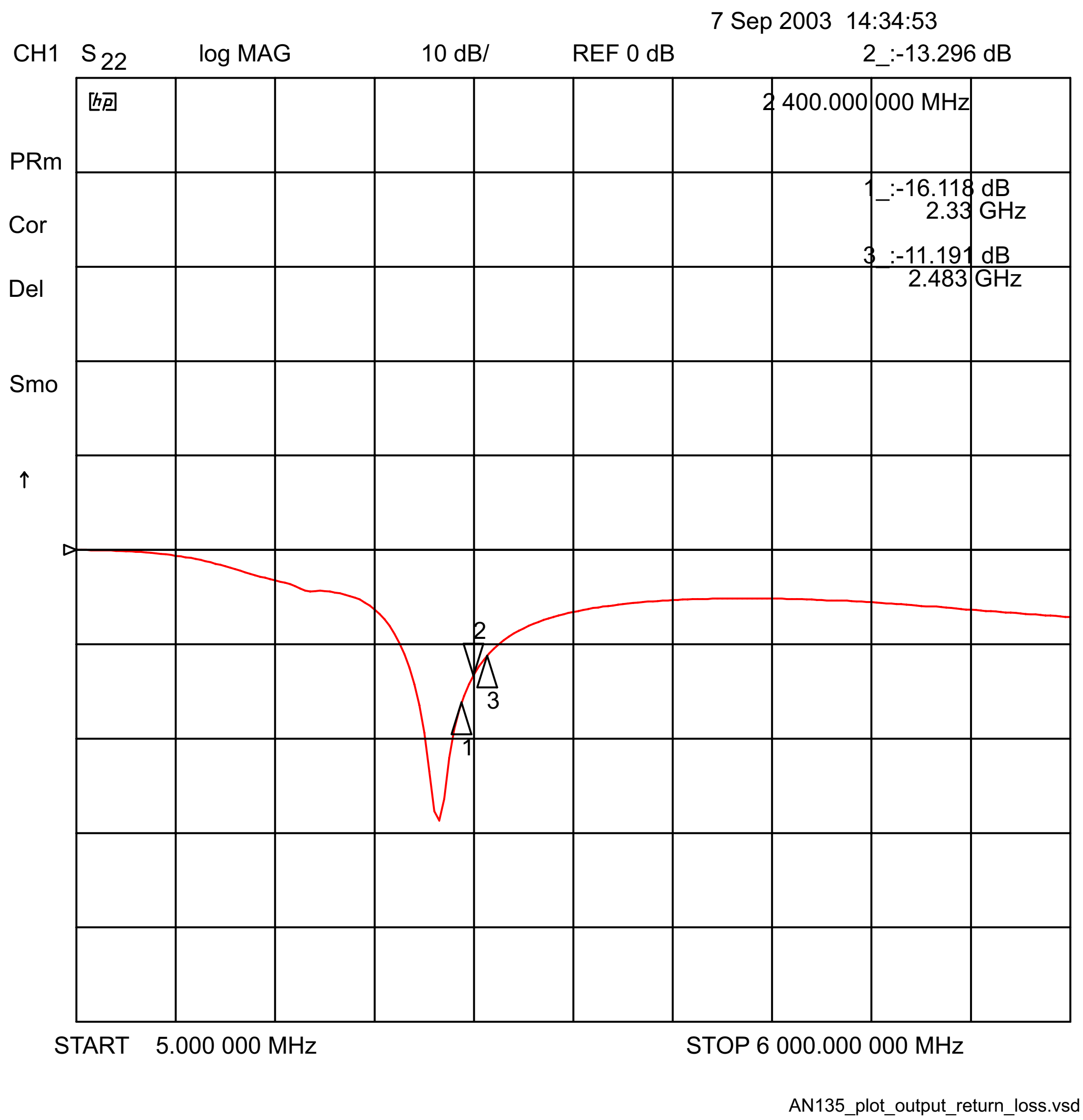


Figure 11 Plot of Output Return Loss

Two-Tone Test, 2400 MHz

Input Stimulus for Amplifier Two-Tone Test.

f_1 = 2400 MHz, f_2 = 2401 MHz, -17 dBm each tone.

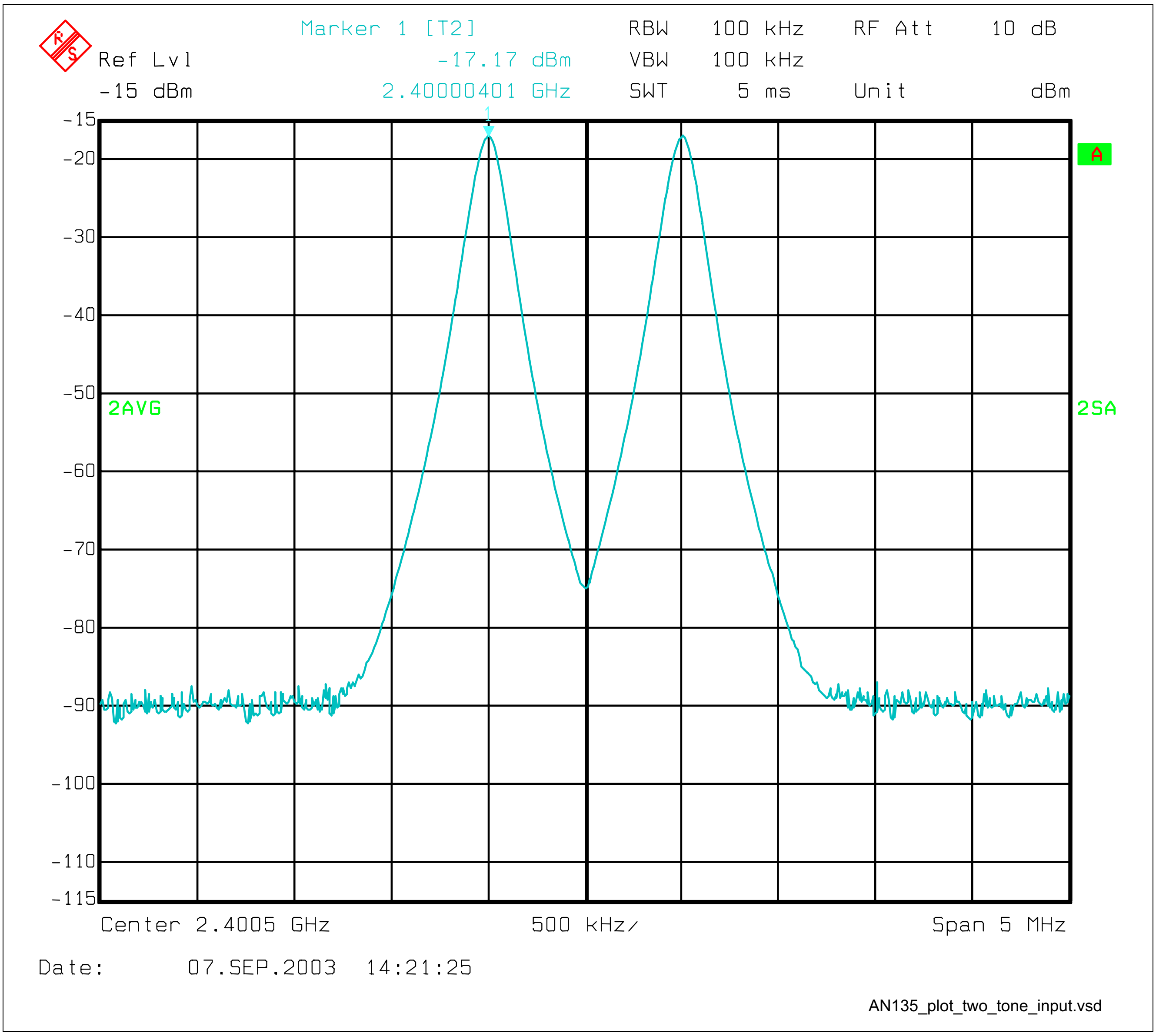


Figure 12 Tow-Tone Test, Input Stimulus @ 2400 MHz

Two-Tone Test, 2400 MHz

LNA Response to Two-Tone Test.

Input IP_3 = -17 + (57.1 / 2) = +11.6 dBm
Output IP_3 = +11.6 dBm + 15.5 dB gain = +27.1 dBm

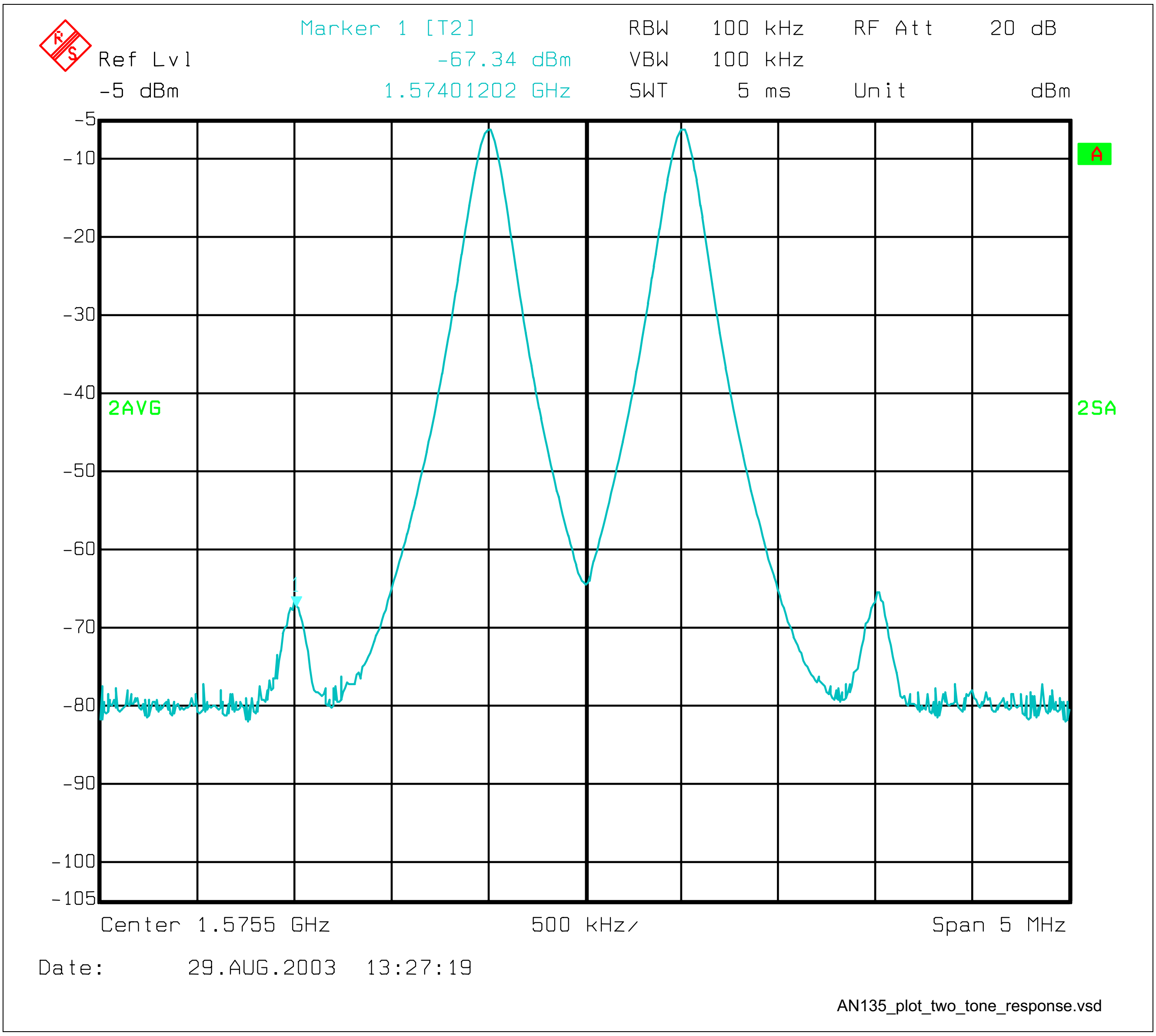


Figure 13 Tow-Tone Test, LNA Response @ 2400 MHz