

# Application Note No. 134

Low-Current Low Noise Amplifier (LNA) for 1575  
MHz Global Positioning Satellite (GPS)  
Applications using the SiGe BFP640 Transistor

RF & Protection Devices



Never stop thinking

**Edition 2007-12-12**

**Published by  
Infineon Technologies AG  
81726 München, Germany**

**© Infineon Technologies AG 2009.  
All Rights Reserved.**

#### **LEGAL DISCLAIMER**

THE INFORMATION GIVEN IN THIS APPLICATION NOTE IS GIVEN AS A HINT FOR THE IMPLEMENTATION OF THE INFINEON TECHNOLOGIES COMPONENT ONLY AND SHALL NOT BE REGARDED AS ANY DESCRIPTION OR WARRANTY OF A CERTAIN FUNCTIONALITY, CONDITION OR QUALITY OF THE INFINEON TECHNOLOGIES COMPONENT. THE RECIPIENT OF THIS APPLICATION NOTE MUST VERIFY ANY FUNCTION DESCRIBED HEREIN IN THE REAL APPLICATION. INFINEON TECHNOLOGIES HEREBY DISCLAIMS ANY AND ALL WARRANTIES AND LIABILITIES OF ANY KIND (INCLUDING WITHOUT LIMITATION WARRANTIES OF NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS OF ANY THIRD PARTY) WITH RESPECT TO ANY AND ALL INFORMATION GIVEN IN THIS APPLICATION NOTE.

#### **Information**

For further information on technology, delivery terms and conditions and prices please contact your nearest Infineon Technologies Office ([www.infineon.com](http://www.infineon.com)).

#### **Warnings**

Due to technical requirements components may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies Office.

Infineon Technologies Components may only be used in life-support devices or systems with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system, or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body, or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.

---

**Application Note No. 134**

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

**Previous Version: 2003-08-28, Rev. 1.1**

<b>Page</b>	<b>Subjects (major changes since last revision)</b>
All	Small changes in figure descriptions

# 1 Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning Satellite (GPS) Applications using the SiGe BFP640 Transistor

## Overview

- BFP640 is investigated for use as an LNA for 1575 MHz GPS.
- Design Goals: Gain = 16 dB min, Noise Figure < 0.6 dB, Input / Output Return Loss 10 dB or better, current 4 mA from a 3.0 V power supply, Input  $P_{1dB} > -14.8$  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 mm<sup>2</sup>. Total Parts count, including the BFP640 transistor, is 13.
- Achieved 15 dB gain, 0.95 dB Noise Figure at 1575 MHz from a 3.0 V supply, drawing 4.9 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  $P_{1dB} \approx -18.7$  dBm.

## PCB Cross - Section Diagram

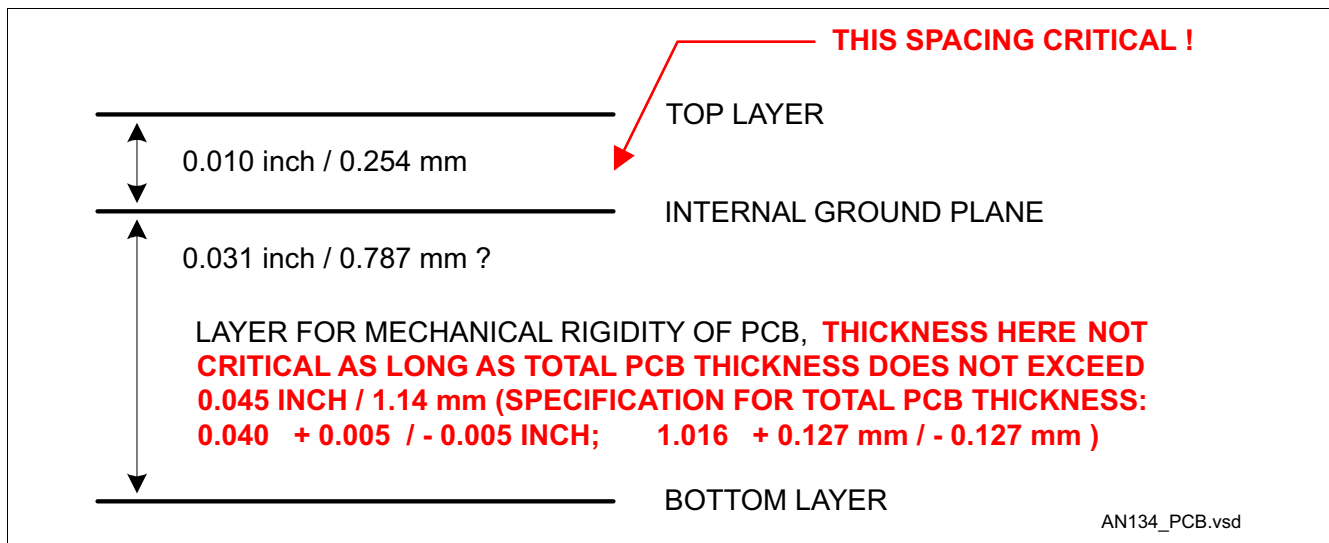


Figure 1 PCB - Cross Sectional Diagram

## Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

## Summary of LNA Data

$T = 25\text{ }^{\circ}\text{C}$ , Network analyzer source power = -25 dBm

Table 1 Summary of LNA Data

Parameter	Result	Comments
Frequency Range	1575.42 MHz	
DC Current	4.9 mA	Target: 4 mA max.
DC Voltage, $V_{CC}$	3.0 V	
Collector-Emitter Voltage, $V_{CE}$	2.4 V	BFP640: $V_{CEmax} = 4.0\text{ V}$
Gain	15.2 dB @ 1575.42 MHz	Gain target: 16 dB min.
Noise Figure	0.95 dB @ 1575.42 MHz	See noise figure plots and tabular data, <a href="#">Figure 3</a> and <a href="#">Table 3</a> (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 $P_{1dB}$	-18.7 dBm @ 1575.42 MHz	Target: -14.8 dBm. See input power sweep vs. gain plot, <a href="#">Figure 7</a>
Output $P_{1dB}$	-4.5 dBm @ 1575.42 MHz	
Input 3 <sup>rd</sup> Order Intercept	-1.1 dBm @ 1575.42 MHz	Target: +2 dBm min. See pages <a href="#">Figure 15</a> and <a href="#">Figure 16</a> .
Input Return Loss	9.3 dB @ 1575.42 MHz	10 dB min.
Output Return Loss	10.0 dB @ 1575.42 MHz	10 dB min.
Reverse Isolation	26.8 dB @ 1575.42 MHz	

## Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

## Bill of Material

Table 2 Bill of Material, Broadband BFP640 UHF Feedback LNA

Reference Designator	Value	Manufacturer	Case Size	Function
C1	22 pF	Various	0402	DC blocking, input
C2	3.3 pF	Various	0402	DC block, output. Also influences output and input impedance match.
C3	0.1 $\mu$ F	Various	0402	Decoupling, low frequency. Also improves Third-Order Intercept.
C4	22 pF	Various	0402	Decoupling (RF short)
C5	12 pF	Various	0402	Decoupling (RF short). Also has some influence on stability (using less than 22 pF causes output of amplifier to "see" more loss from R1 at lower frequencies $\rightarrow$ stability improvement).
C6	0.1 $\mu$ F	Various	0402	Decoupling, low frequency
L1	22 nH	Murata LQP15M series low-cost inductor	0402	RF choke at input
L2	6.8 nH	Murata LQP15M series low-cost inductor	0402	RF choke + impedance match at output
L3	1.5 nH	Murata LQP15M series low-cost inductor	0402	Input impedance match.
R1	43 $\Omega$	Various	0402	Stability improvement
R2	56 k $\Omega$	Various	0402	Bring bias current / voltage into base of transistor
R3	82 $\Omega$	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

Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

Schematic Diagram for 1575 MHz LNA

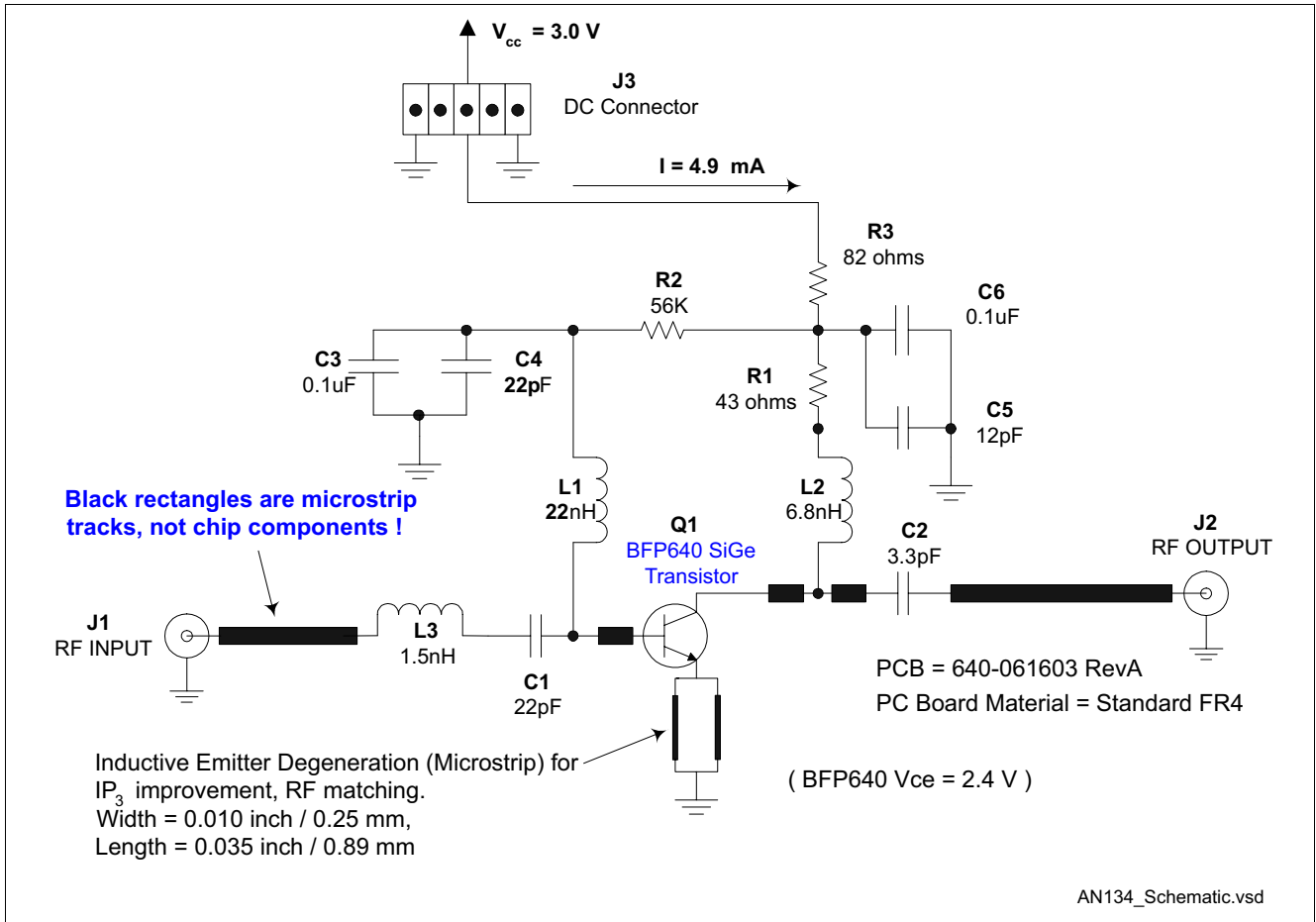


Figure 2 Schematic Diagram

Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

Noise Figure, Plot, Center of Plot (x-axis) is 1575.4 MHz.

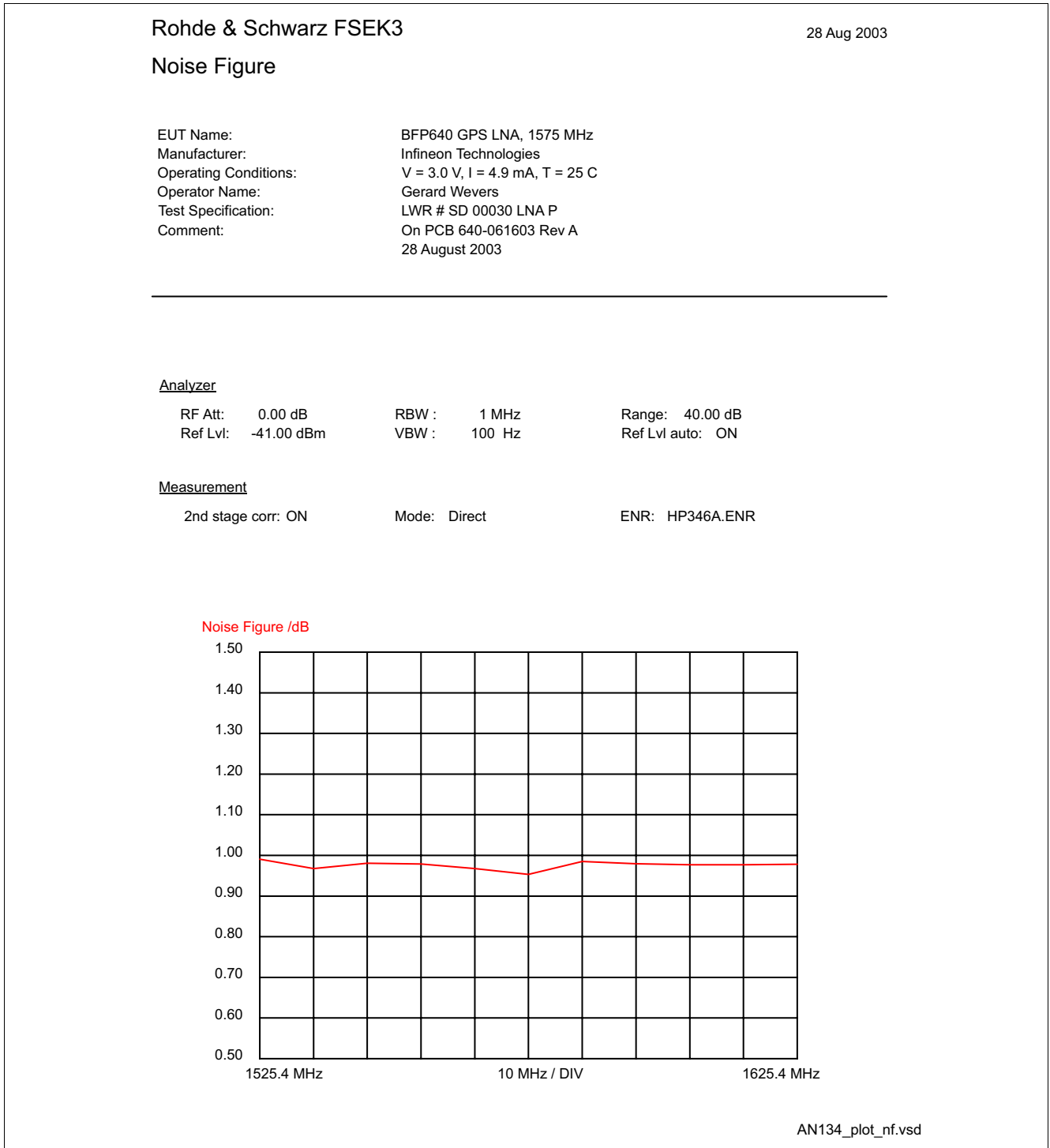


Figure 3 Noise Figure



---

**Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning****Noise Figure, Tabular Data**

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

**Table 3    Noise Figure**

<b>Frequency</b>	<b>Noise Figure</b>
1525.4 MHz	0.99 dB
1535.4 MHz	0.97 dB
1545.4 MHz	0.98 dB
1555.4 MHz	0.98 dB
1565.4 MHz	0.97 dB
1575.4 MHz	0.95 dB
1585.4 MHz	0.99 dB
1595.4 MHz	0.98 dB
1605.4 MHz	0.98 dB
1615.4 MHz	0.98 dB
1625.4 MHz	0.98 dB

Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

Scanned Image of PC Board

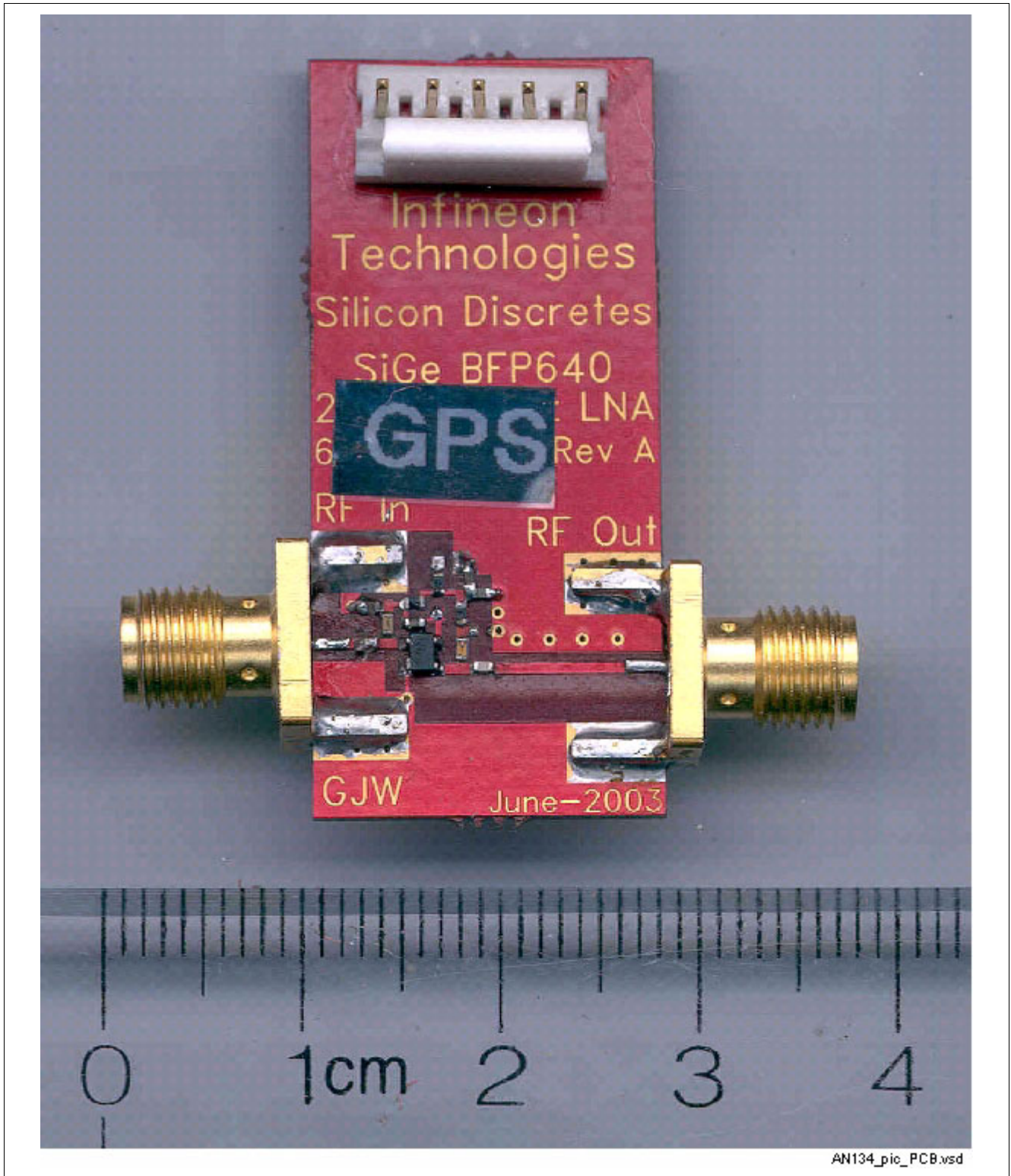


Figure 4 Image of PC Board

Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

Scanned Image of PC Board, Close-In Shot.

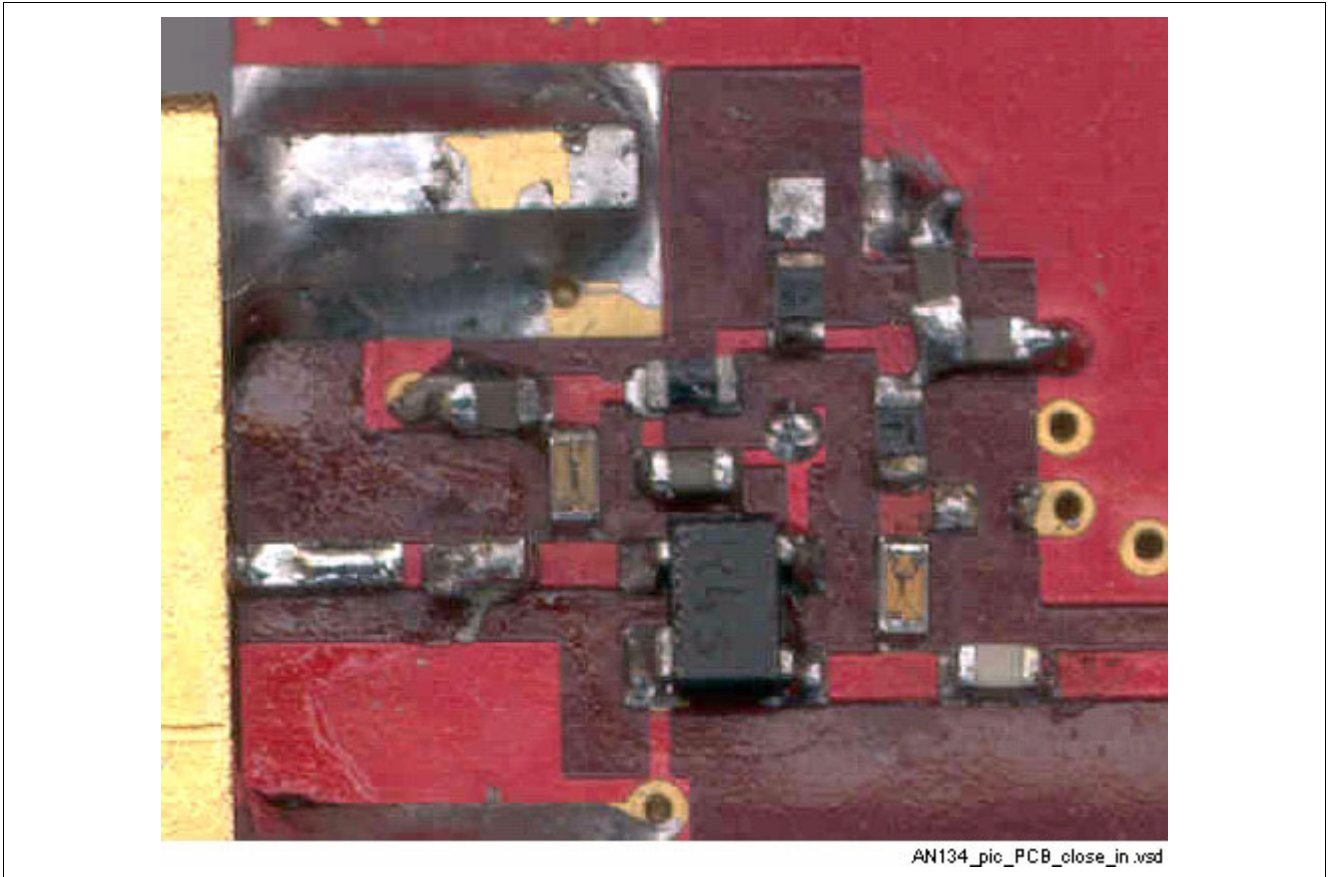


Figure 5 Image of PC Board, Close-In Shot

Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

**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.

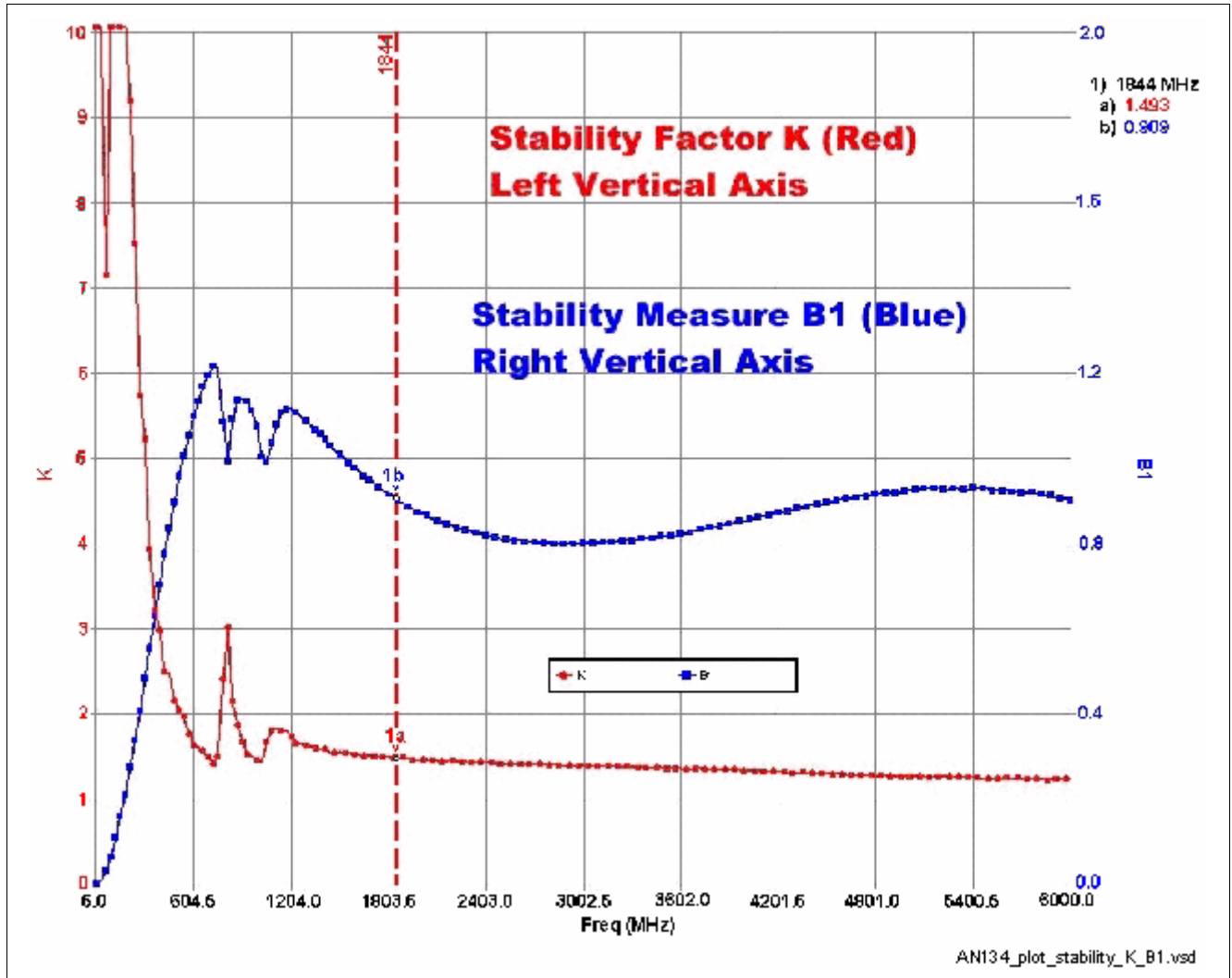


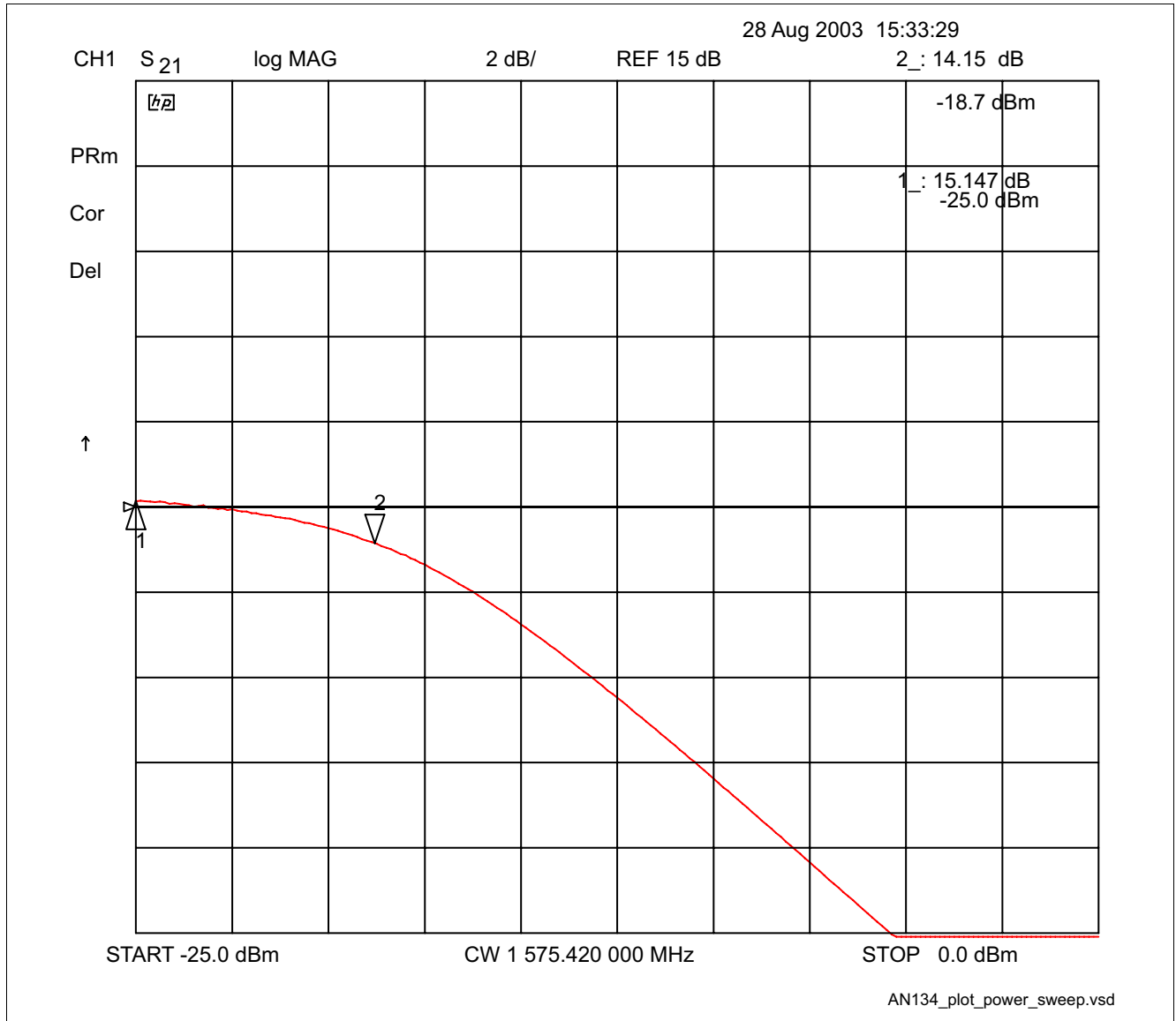
Figure 6 Plot of K(f) and B1(f)

Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

**Power Sweep at 1575 MHz (CW)**

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

Input  $P_{1dB} \cong -18.7$  dBm



**Figure 7 Plot of Power Sweep at 1575 MHz**

Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

Input Return Loss, Log Mag

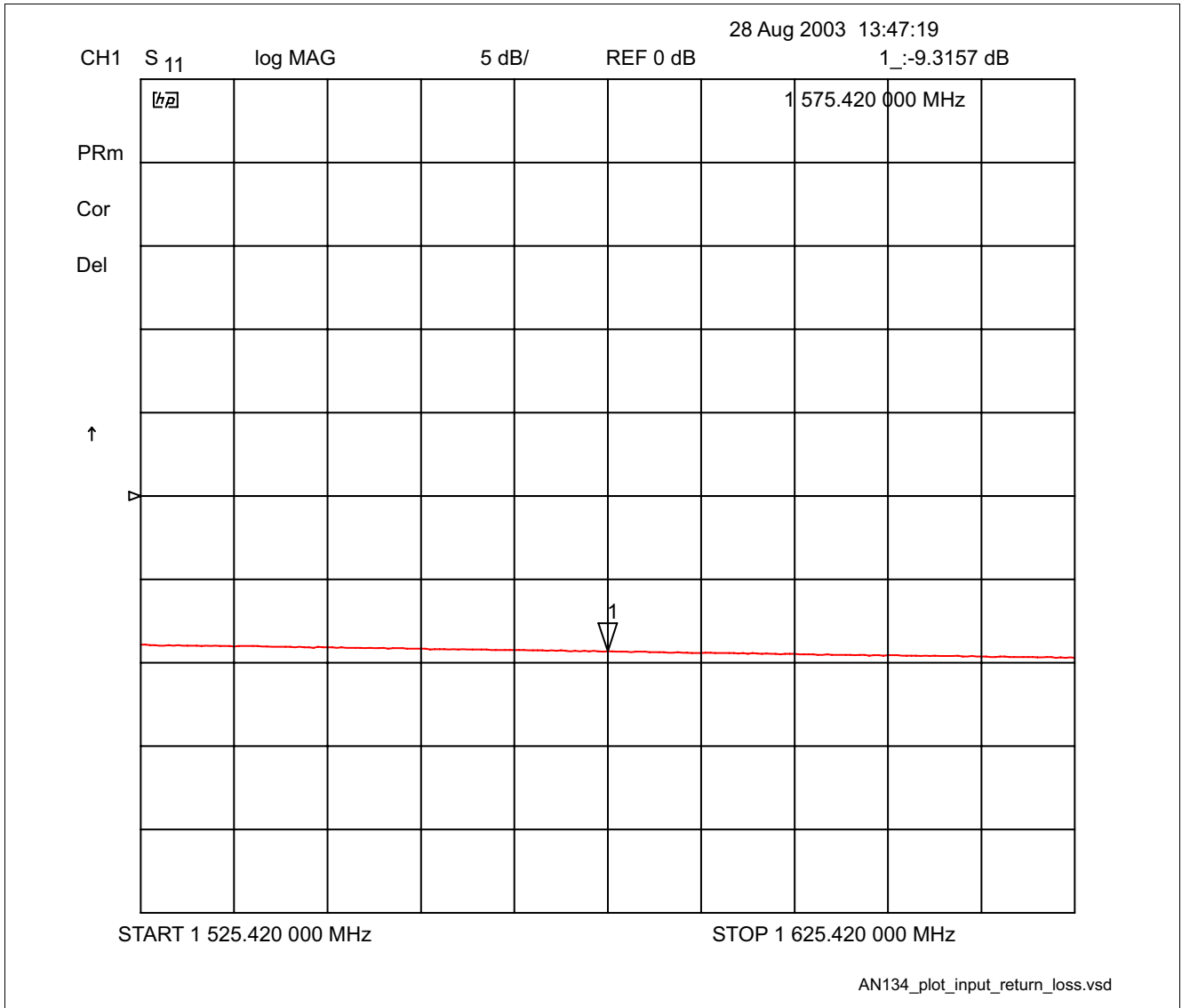


Figure 8 Plot of Input Return Loss

Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

Input Return Loss, Smith Chart

Reference Plane = PCB Input SMA Connector

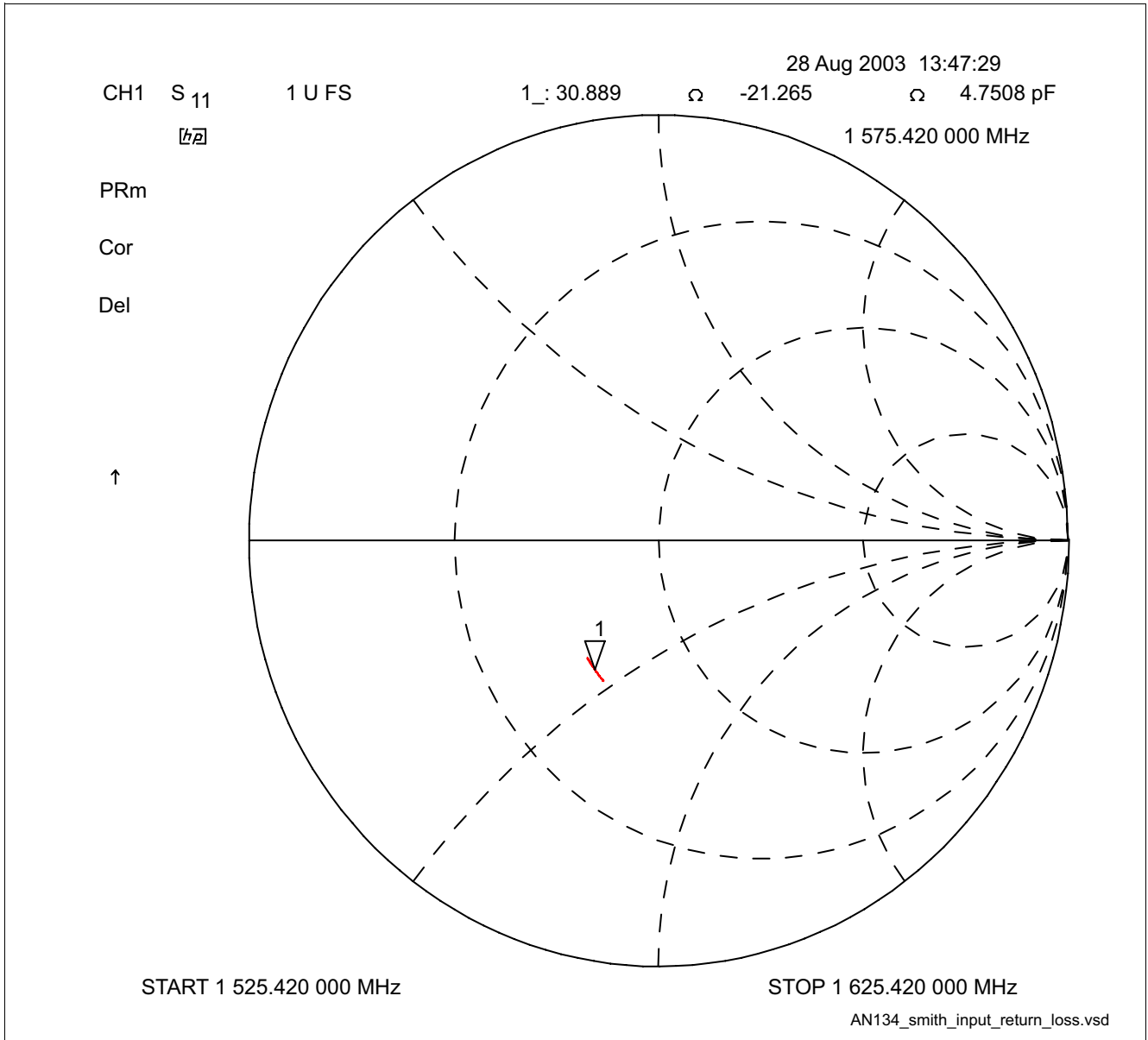


Figure 9 Smith Chart of Input Return Loss

Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

Forward Gain, Wide Sweep

5 MHz - 6 GHz

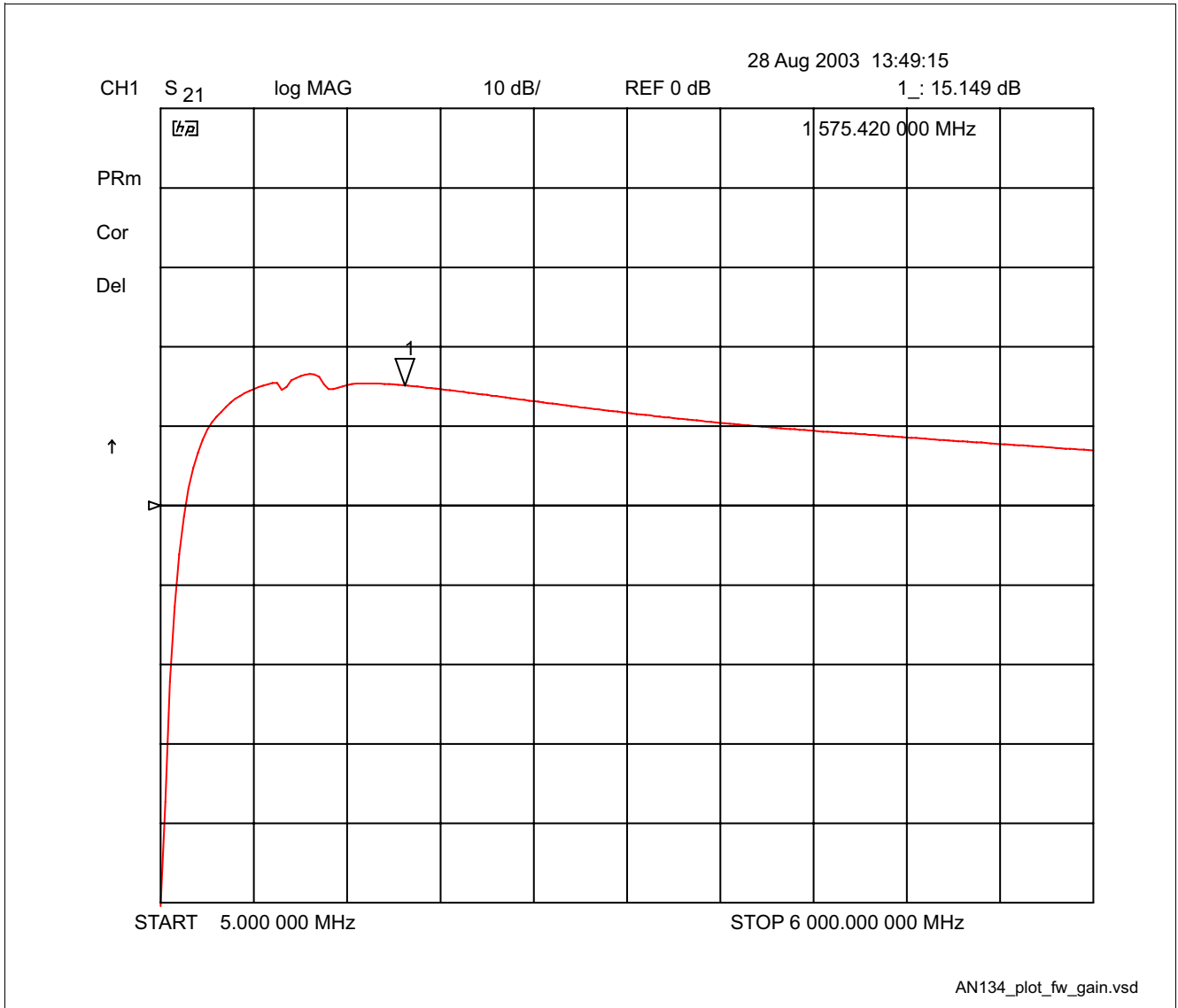


Figure 10 Plot of Forward Gain (wide sweep)



Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

Forward Gain, Narrow Sweep

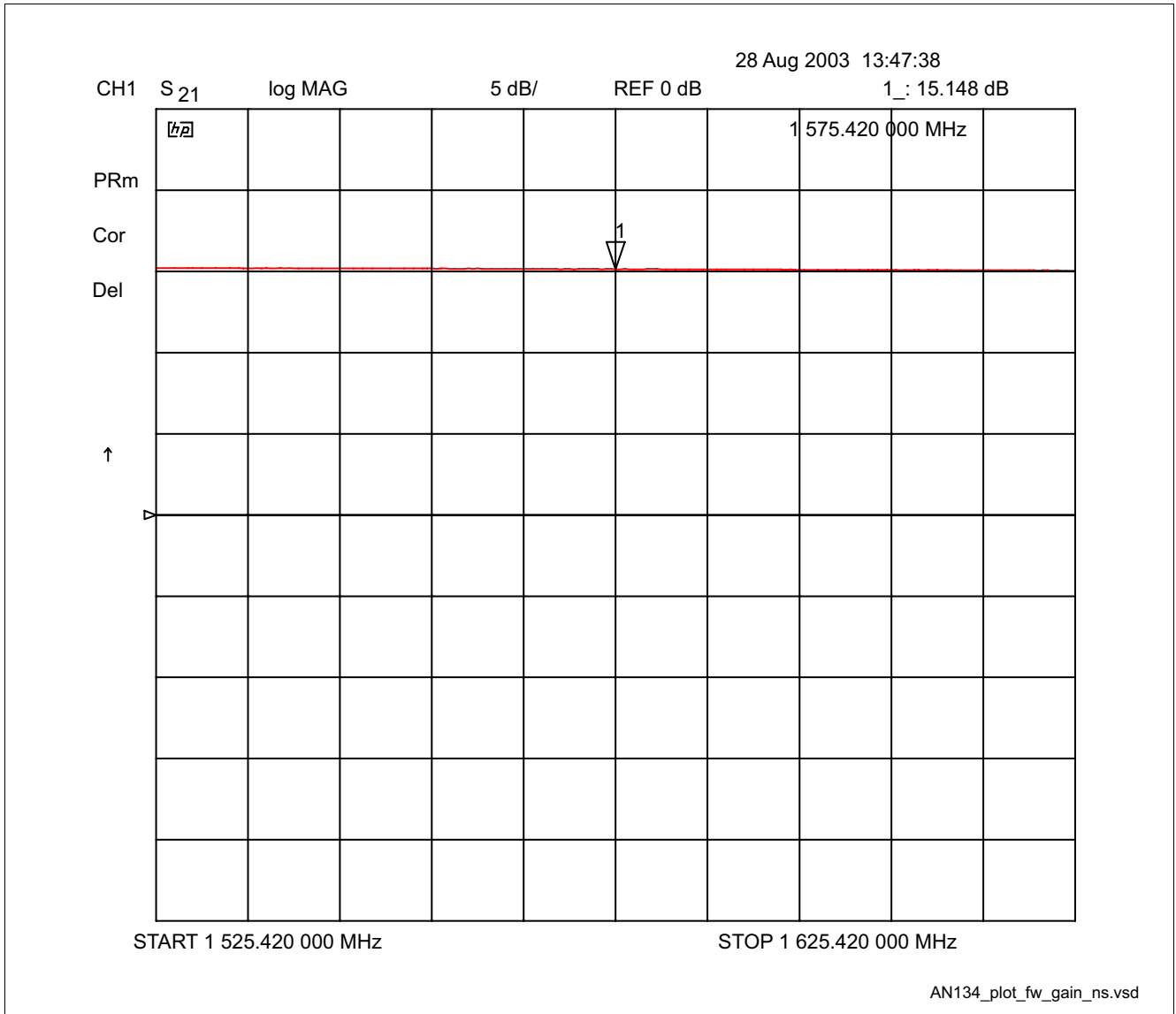


Figure 11 Plot of Forward Gain (narrow sweep)

Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

Reverse Isolation

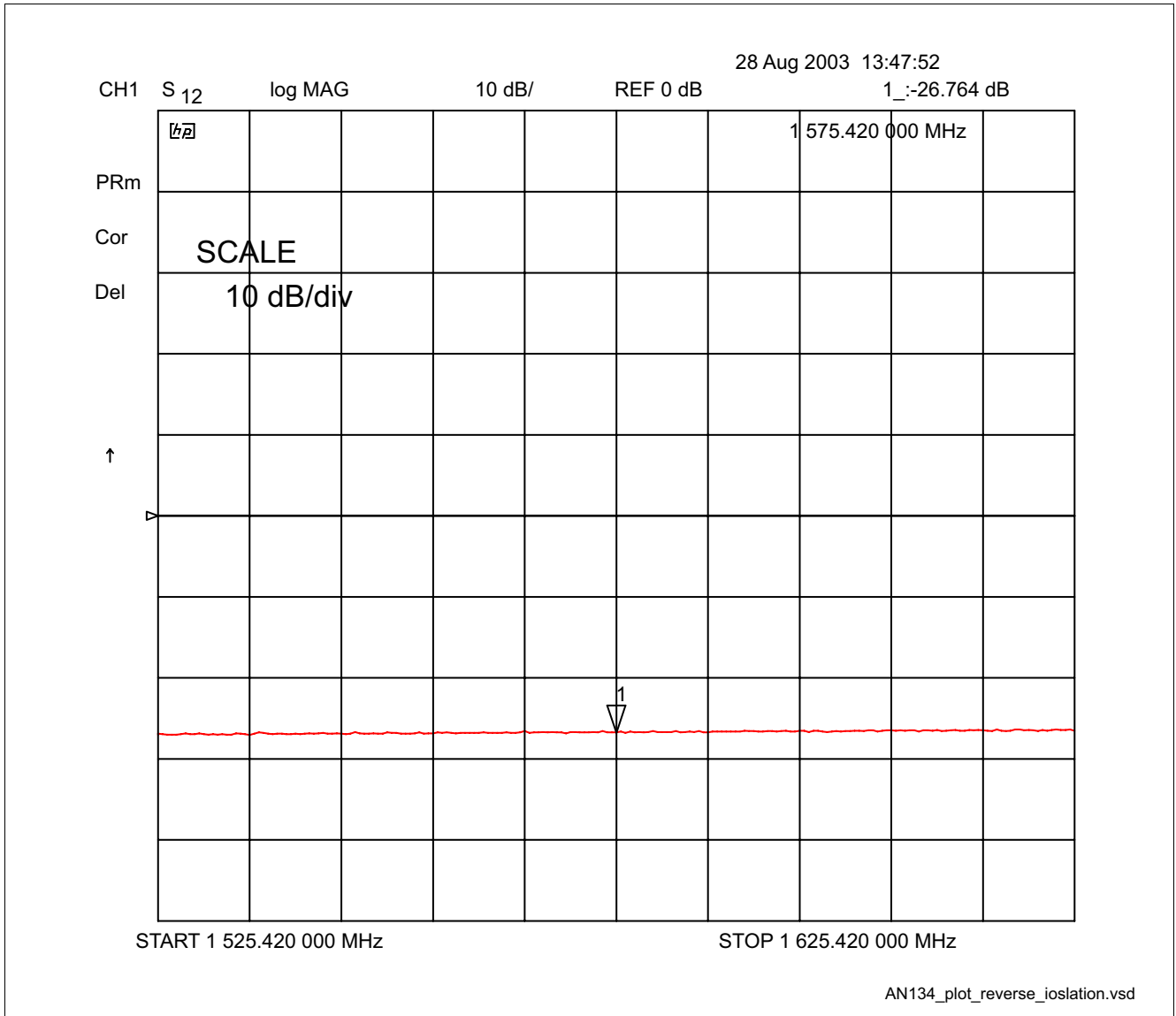


Figure 12 Plot of Reverse Isolation

Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

Output Return Loss, Log Mag

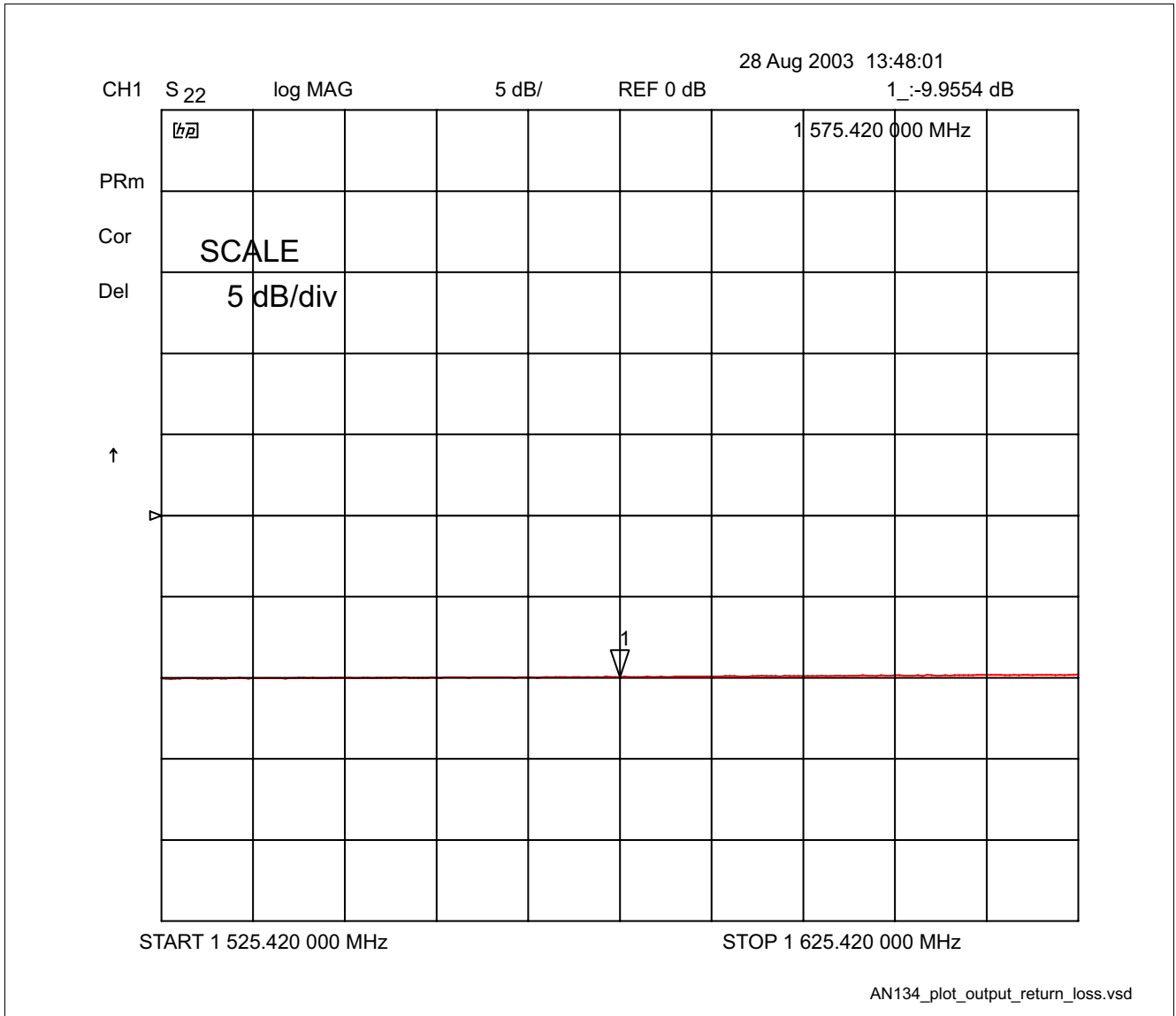


Figure 13 Plot of Output Return Loss

Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

Output Return Loss, Smith Chart

Reference Plane = PCB Output SMA Connector

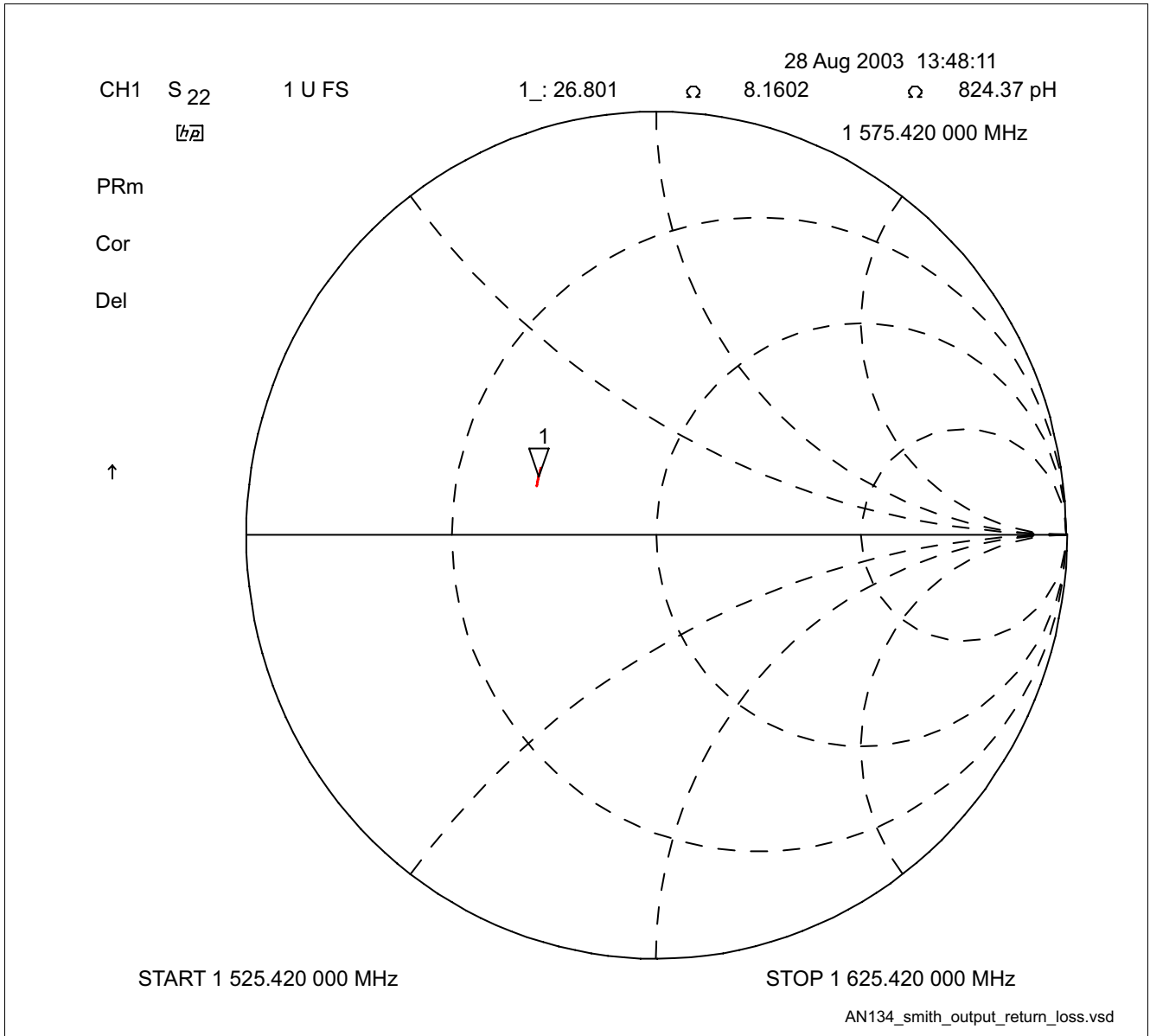


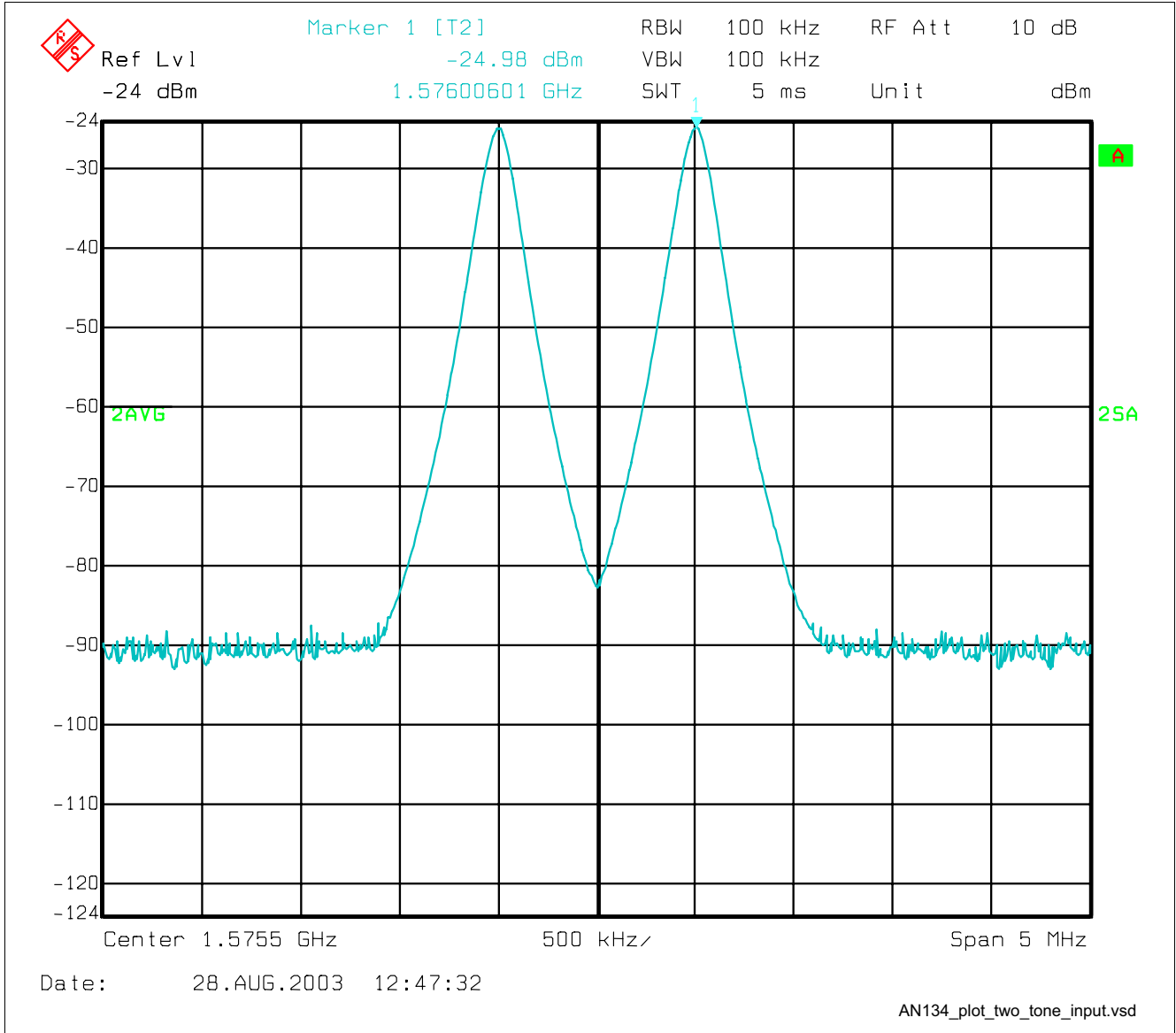
Figure 14 Smith Chart of Output Return Loss

Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

**Two-Tone Test, 1575 MHz**

Input Stimulus for Amplifier Two-Tone Test.

$f_1 = 1575 \text{ MHz}$ ,  $f_2 = 1576 \text{ MHz}$ ,  $-25 \text{ dBm}$  each tone.



**Figure 15 Two-Tone Test, LNA Response @ 1575 MHz**

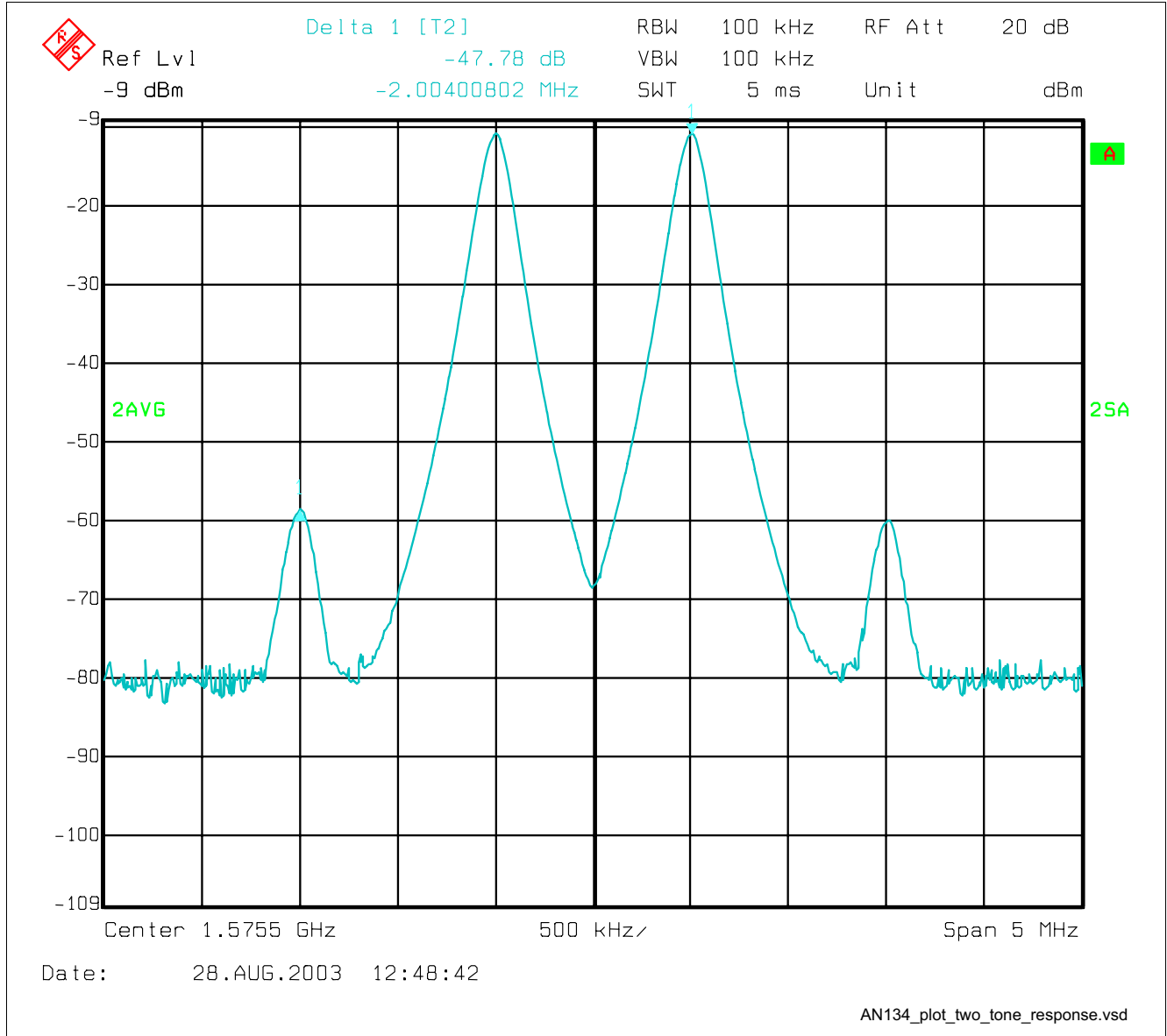
Low-Current Low Noise Amplifier (LNA) for 1575 MHz Global Positioning

**Two-Tone Test, 1575 MHz**

LNA Response to Two-Tone Test.

Input  $IP_3 = -25 + (47.8 / 2) = -1.1$  dBm

Output  $IP_3 = -1.1$  dBm + 15.2 dB gain = +14.1 dBm



**Figure 16 Two-Tone Test, LNA Response @ 1575 MHz**