Application Note No. 149

1.8 V, 2.6 mA Low Noise Amplifier for 1575 MHz GPS L1 Frequency with the BFP405 RF Transistor

RF & Protection Devices

Never stop thinking

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Revision History: 2008-02-22, Rev. 1.2

Previous Version: 2005-09-23, Rev. 1.1	
Page	**Subjects (major changes since last revision)**
All	Small changes in figure descriptions

1 1.8 V, 2.6 mA Low Noise Amplifier for 1575 MHz GPS L1 Frequency with the BFP405 RF Transistor

Overview

- The low emitter-area BFP405 RF Transistor in SOT343 package is shown in a low-cost, low-power consumption LNA targeted for systems having a 1.8 V voltage regulator.
- Standard, low-cost "0402" size passives are used. Total PCB area needed is 50 mm²; total parts count, including the BFP405F transistor, is 12 pieces.
- Printed Circuit Board used is Infineon Part Number 640-061603 Rev A. Standard FR4 material is used in a three-layer PCB. See cross-sectional diagram below.
- The amplifier is unconditionally stable from 5 MHz to 8 GHz.

Summary of Results

T = 25 °C, Network Analyzer Source Power ≈ -25 dBm, V_{CC} = 1.8 V, V_{CE} = 1.5 V, I_C = 2.6 mA, Z_S = Z_L = 50 Ω.

Table 1 Summary of Results

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
1575	9.6	15.3	26.6	9.6	1.6	-5	+10.3	-23.0	-8.7

* PCB loss is not extracted, e-g- reference plane of measurement is at PCB input RF SMA connector. If PCB loss were extracted, noise figure would improve by 0.1 - 0.2 dB, e.g. NF result would be lower / better.

PCB Cross - Section Diagram

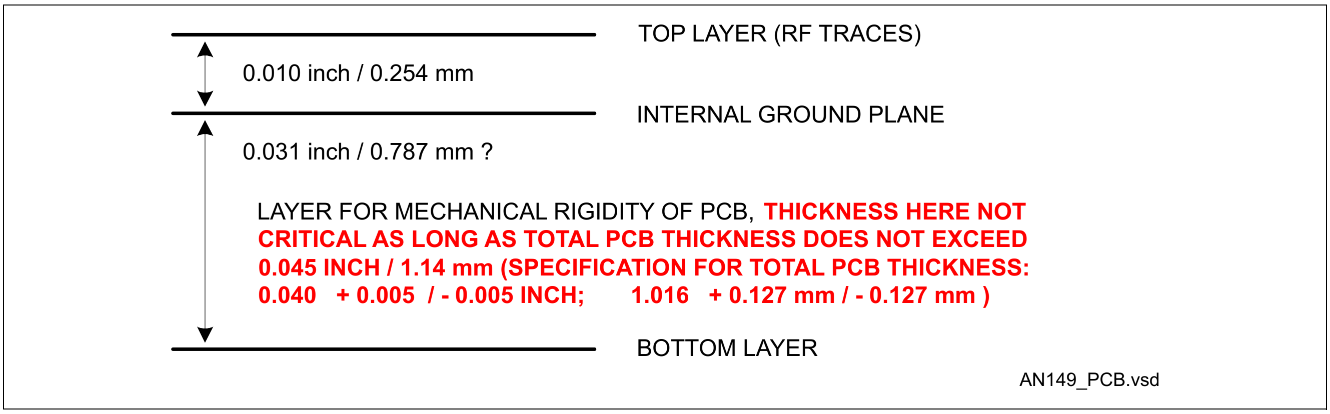


Figure 1 PCB - Cross Sectional Diagram

Schematic Diagram

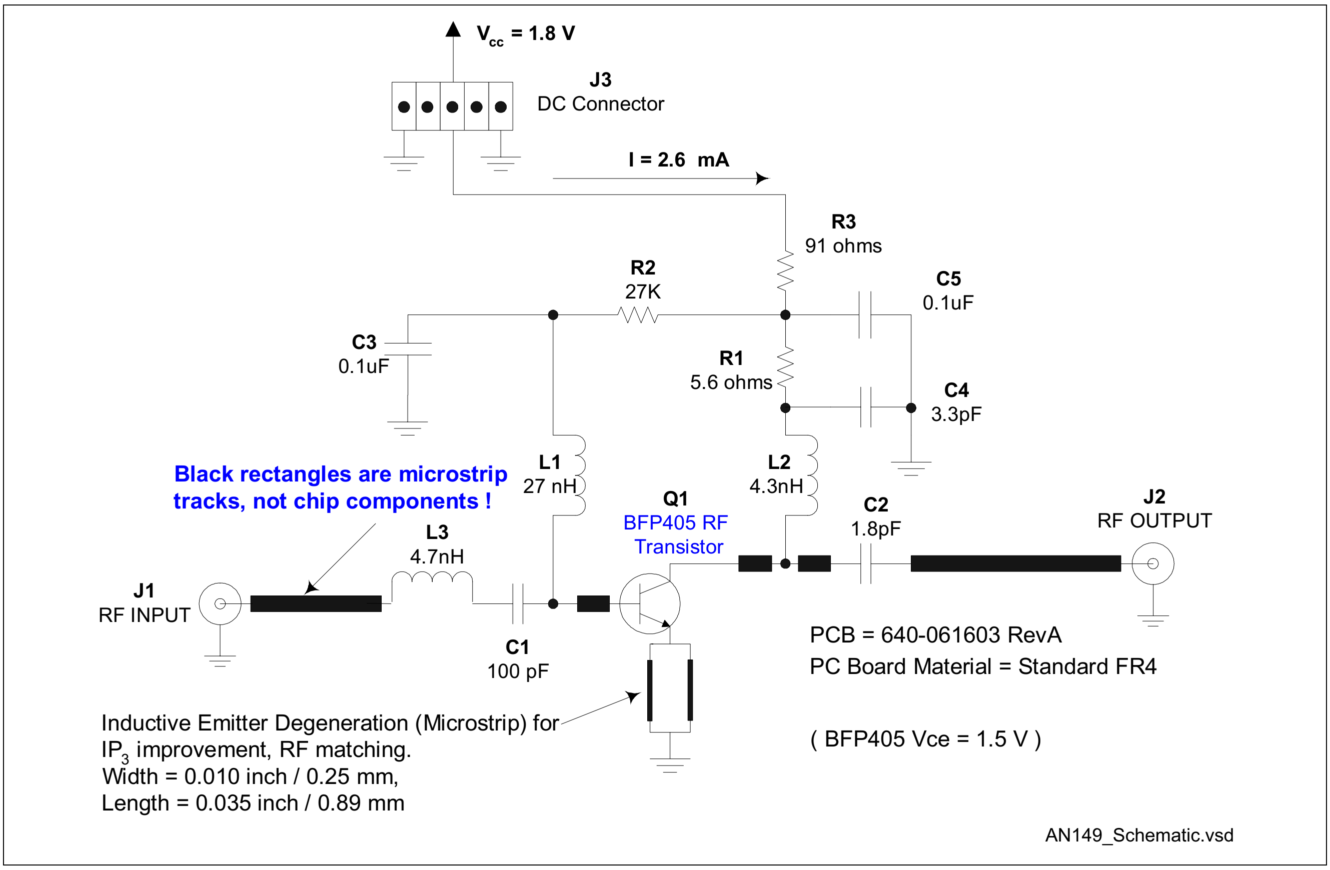


Figure 2 Schematic Diagram

Bill of Material

Table 2 Bill of Material

Designator	Value	Manufacturer	Case Size	Function
C1	100 pF	Various	0402	DC blocking, input. Using above SRF also provides some net inductance.
C2	1.8 pF	Various	0402	DC block, output. Also influences output and input match.
C3	0.1 µF	Various	0402	Decoupling, low frequency. Also improves Third Order Intercept.
C4	3.3 pF	Various	0402	Decoupling, high frequency. Also influences stability and output match.
C5	0.1 µF	Various	0402	Low frequency decoupling.
L1	27 nH	Murata LQP15M series	0402	RF choke at input, bring in DC bias to base.
L2	4.3 nH	Murata LQP15M series	0402	RF choke at output, influences matching.
L3	4.7 nH	Murata LQP15M series	0402	Input impedance matching.
R1	5.6 Ω	Various	0402	RF stability aid.
R2	27 kΩ	Various	0402	Sets DC operating point (DC bias).
R3	91 Ω	Various	0402	Sets DC operating point and provides some negative DC feedback to stabilize DC operating point over lot-to-lot variations in device DC current gain, also helps to stabilize DC operating point over temperature.
Q1	-	Infineon Technologies	SOT343	BFP405 RF Transistor, B6HF process
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

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

Rohde & Schwarz FSEK3 23 Sep 2005

Noise Figure

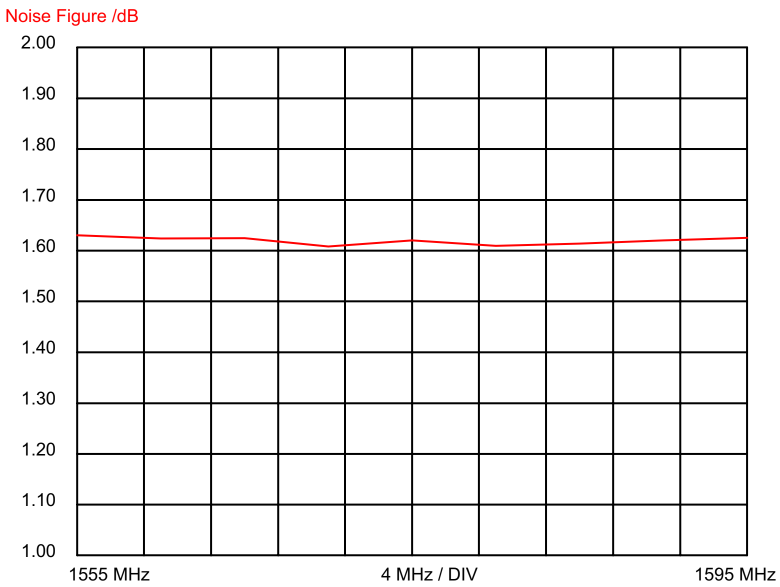
EUT Name:	BFP405 Low Voltage, Low Current LNA
Manufacturer:	Infineon Technologies
Operating Conditions:	V=1.8 V, Vce = 1.5V, I=2.6mA, T=25 C
Operator Name:	Gerard Wevers
Test Specification:	LWR SD 00092 LNA P
Comment:	on PCB 540F-061603 Rev A 23 Sept 2005

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



AN149_plot_nf.vsd

Figure 3 Noise Figure

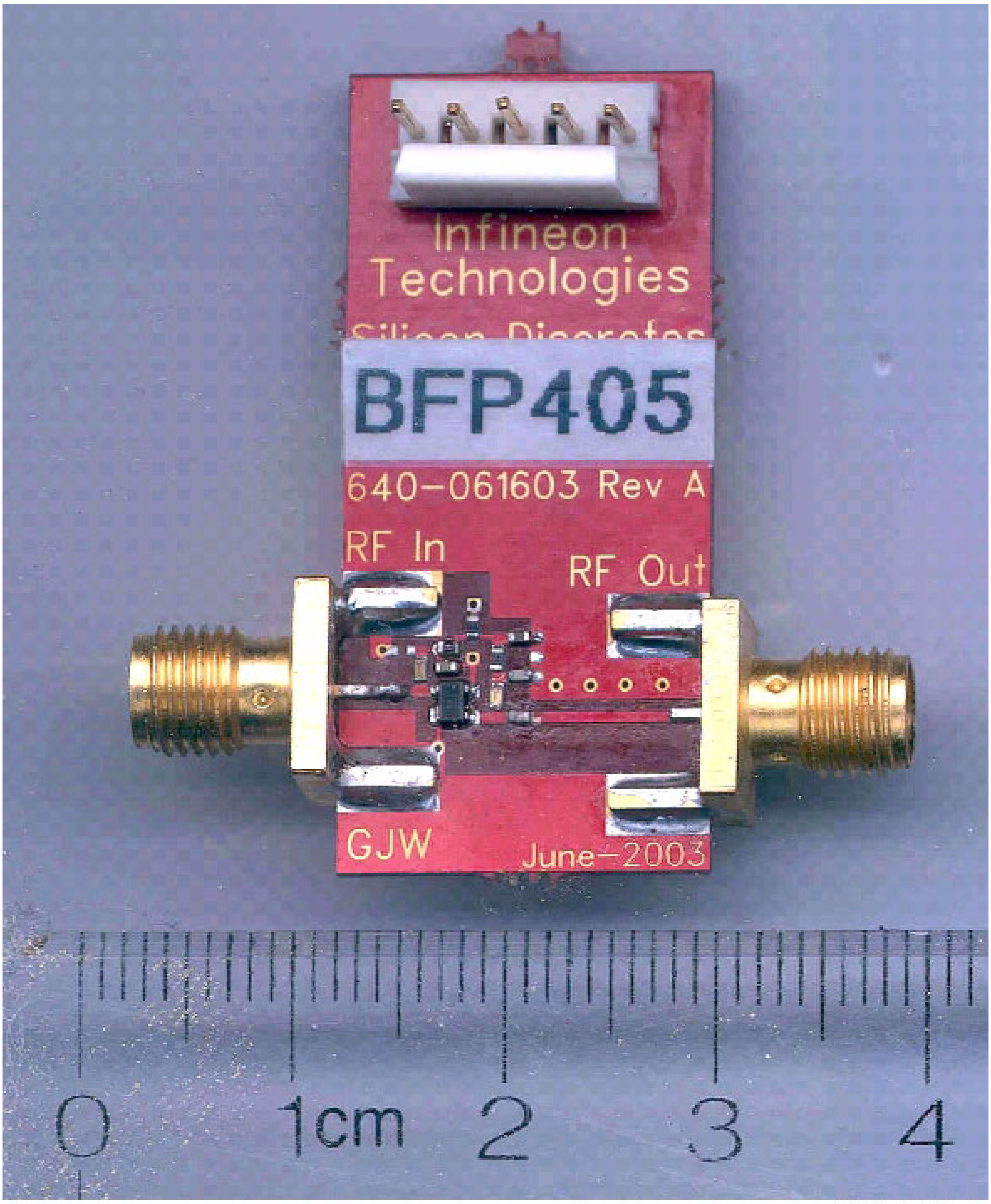
Noise Figure, Tabular Data

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

Table 3 Noise Figure

Frequency	Noise Figure
1555 MHz	1.63 dB
1560 MHz	1.62 dB
1565 MHz	1.62 dB
1570 MHz	1.61 dB
1575 MHz	1.62 dB
1580 MHz	1.61 dB
1585 MHz	1.61 dB
1590 MHz	1.62 dB
1595 MHz	1.63 dB

Scanned Image of PC Board



AN149_pic_PCB.vsd

Figure 4 Image of PC Board

Scanned Image of PC Board, Close-In Shot.

Total PCB area is approximately 50 mm².

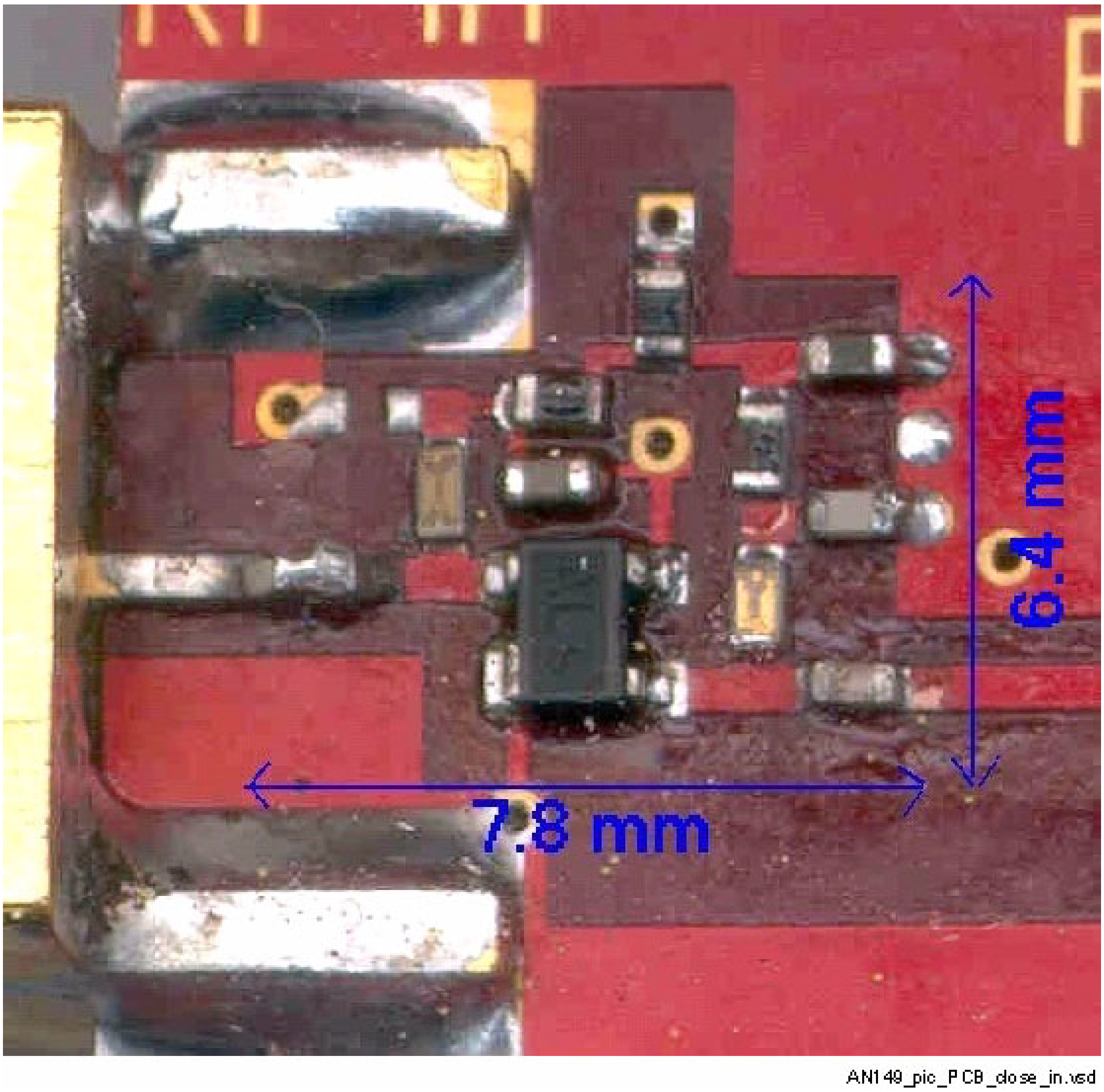
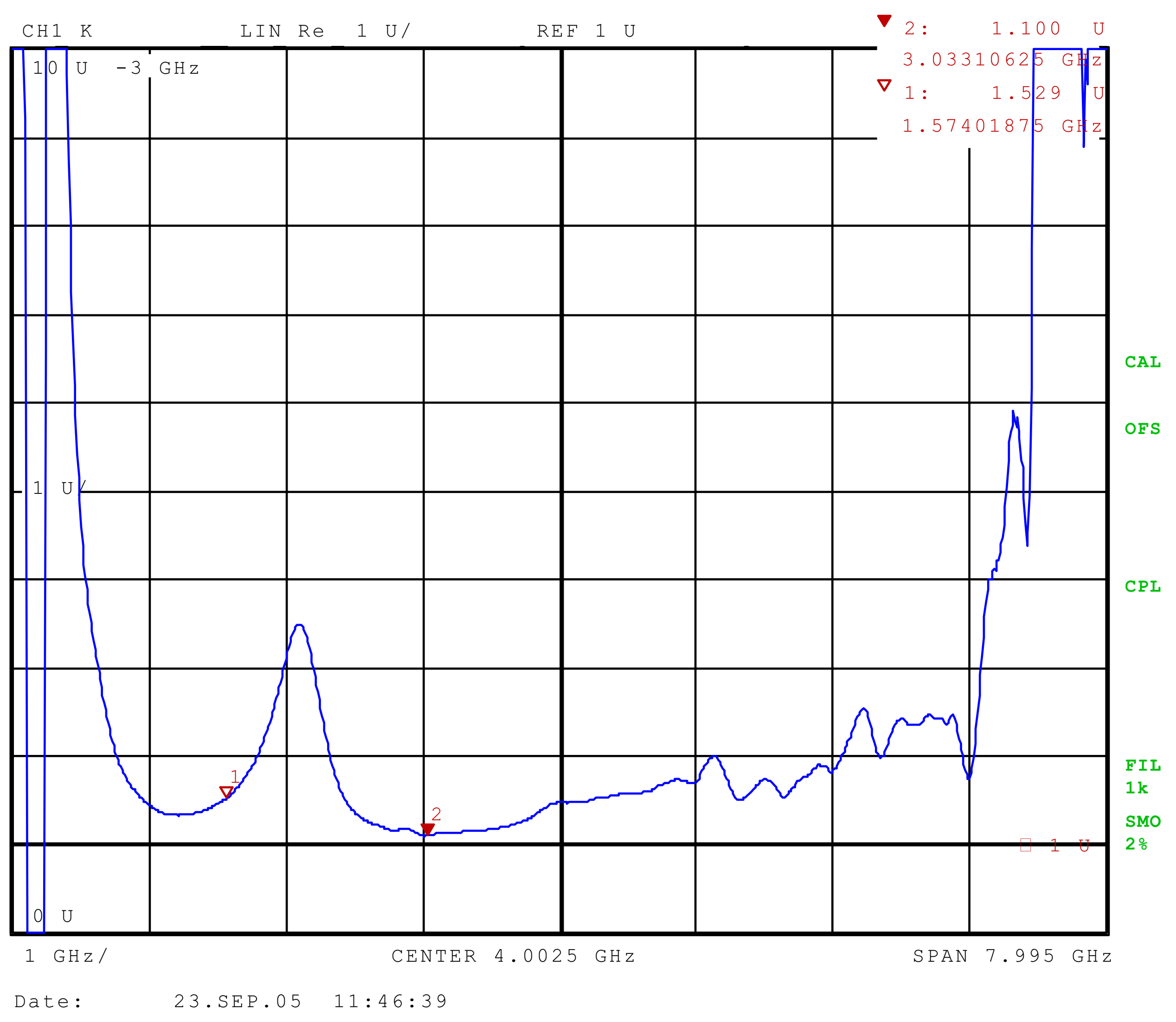


Figure 5 Image of PC Board, Close-In Shot

Amplifier Stability

T = 25 °C, V_{CC} = 1.8 V, V_{CE} = 1.5 V, I = 2.6 mA.

Stability Factor "K" is shown below from "screen shot" taken from Rohde and Schwarz ZVC network analyzer. ZVC Vector Network Analyzer calculates and plots K in real time, from measured S parameters. Note that K>1 from 5 MHz to 8 GHz; amplifier is unconditionally stable over this range.



AN149_plot_stability_K.vsd

Figure 6 **Plot of K(f)**

Gain Compression at 1575 MHz, T = 25 °C

Amplifier is checked for 1 dB compression point. An Agilent power meter was used to ensure accurate power levels are measured (as opposed to using Vector Network Analyzer in "Power Sweep" mode).

Output $P_{1dB} \cong$ -8.7 dBm; Input $P_{1dB} \cong$ -8.7 dBm -(Gain - 1 dB) = -8.7 dBm - 14.3 dB = -23.0 dBm

Table 4 Gain Compression at 1575 MHz

P_{OUT}, dBm	Gain, dB
-15.0	15.3
-14.0	15.3
-13.0	15.2
-12.0	15.1
-11.0	15.0
-10.0	14.8
-9.0	14.4
-8.0	14.0
-7.0	13.2

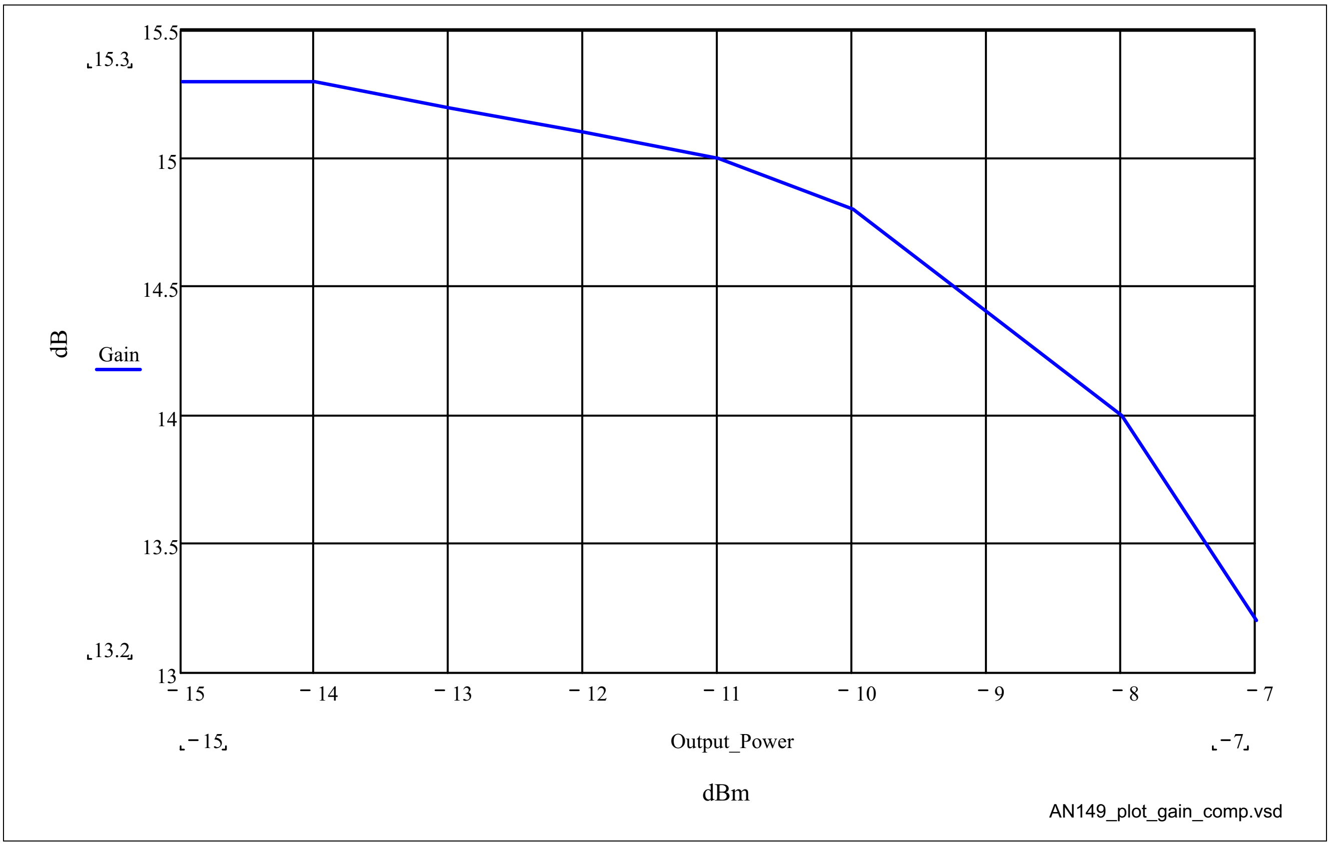


Figure 7 Plot of BFP405 Gain Compression, 1575.4 MHz

Please Note - all plots are taken from Rohde and Schwarz ZVC Network Analyzer
T = 25 °C, source power ≈ -30 dBm.

Input Return Loss, Log Mag

5 MHz - 8 GHz Sweep

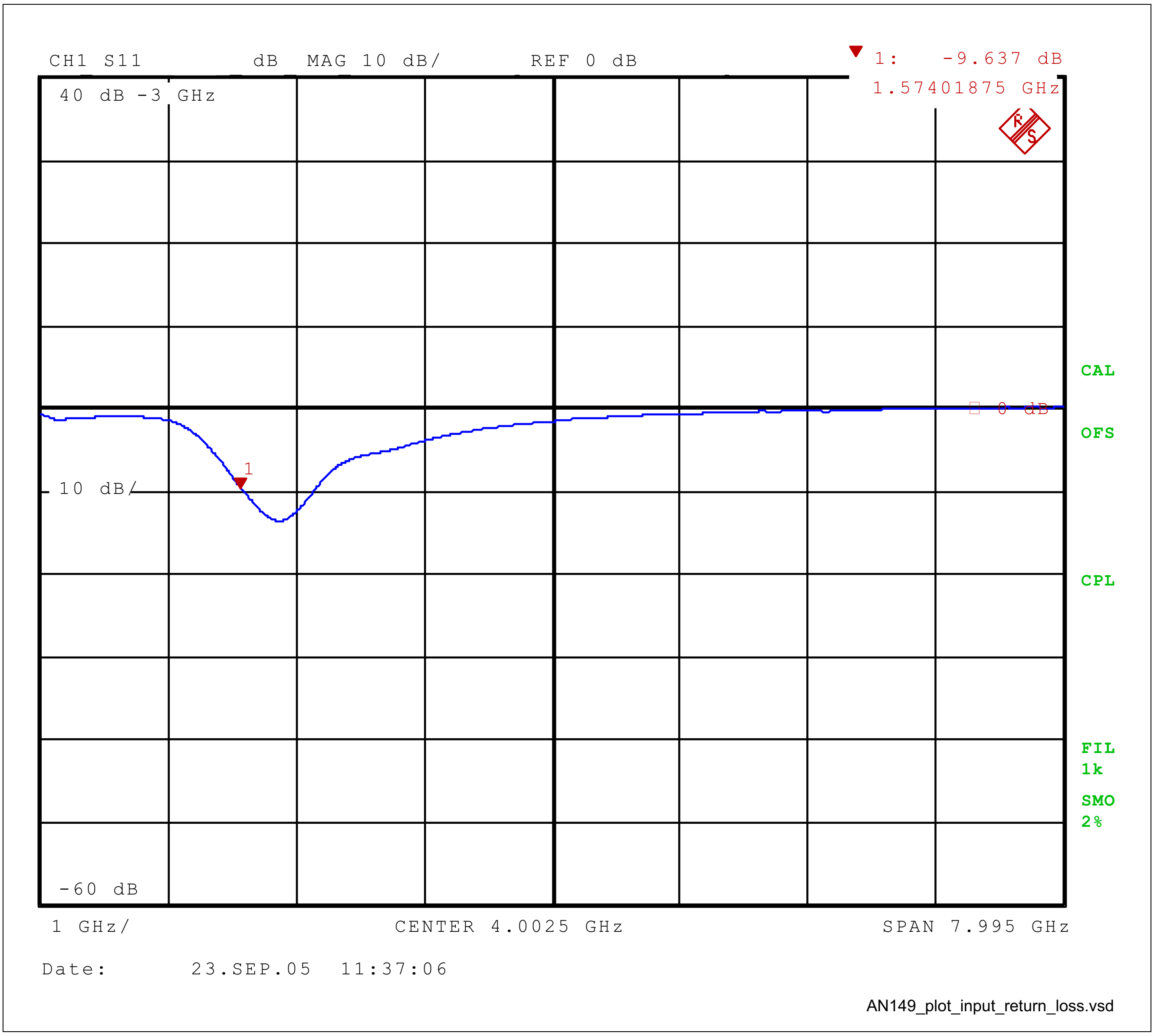


Figure 8 Plot of Input Return Loss

Input Return Loss, Smith Chart

Reference Plane = Input SMA Connector on PC Board
5 MHz - 8 GHz Sweep

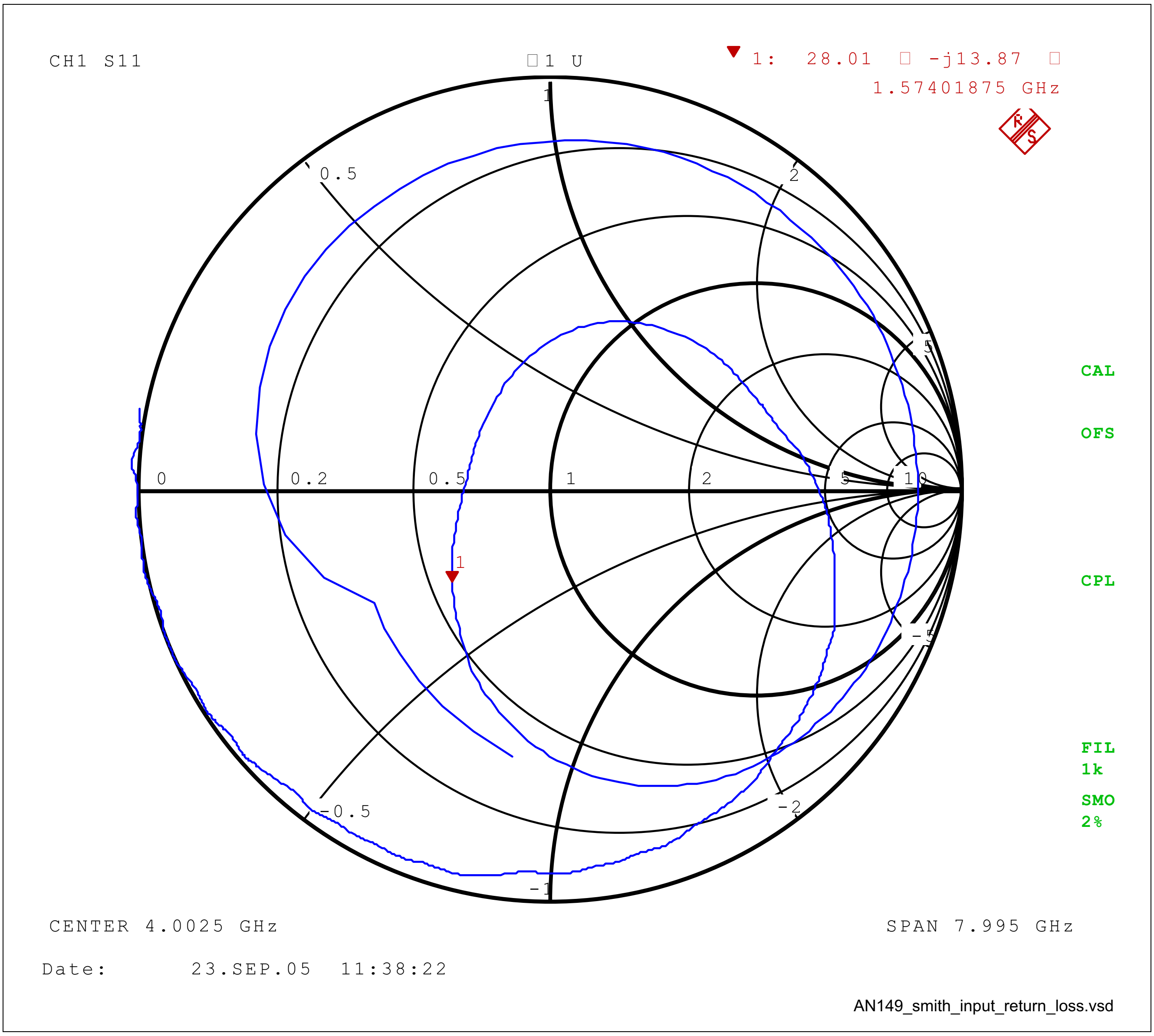


Figure 9 Smith Chart of Input Return Loss

Forward Gain

5 MHz - 8 GHz Sweep

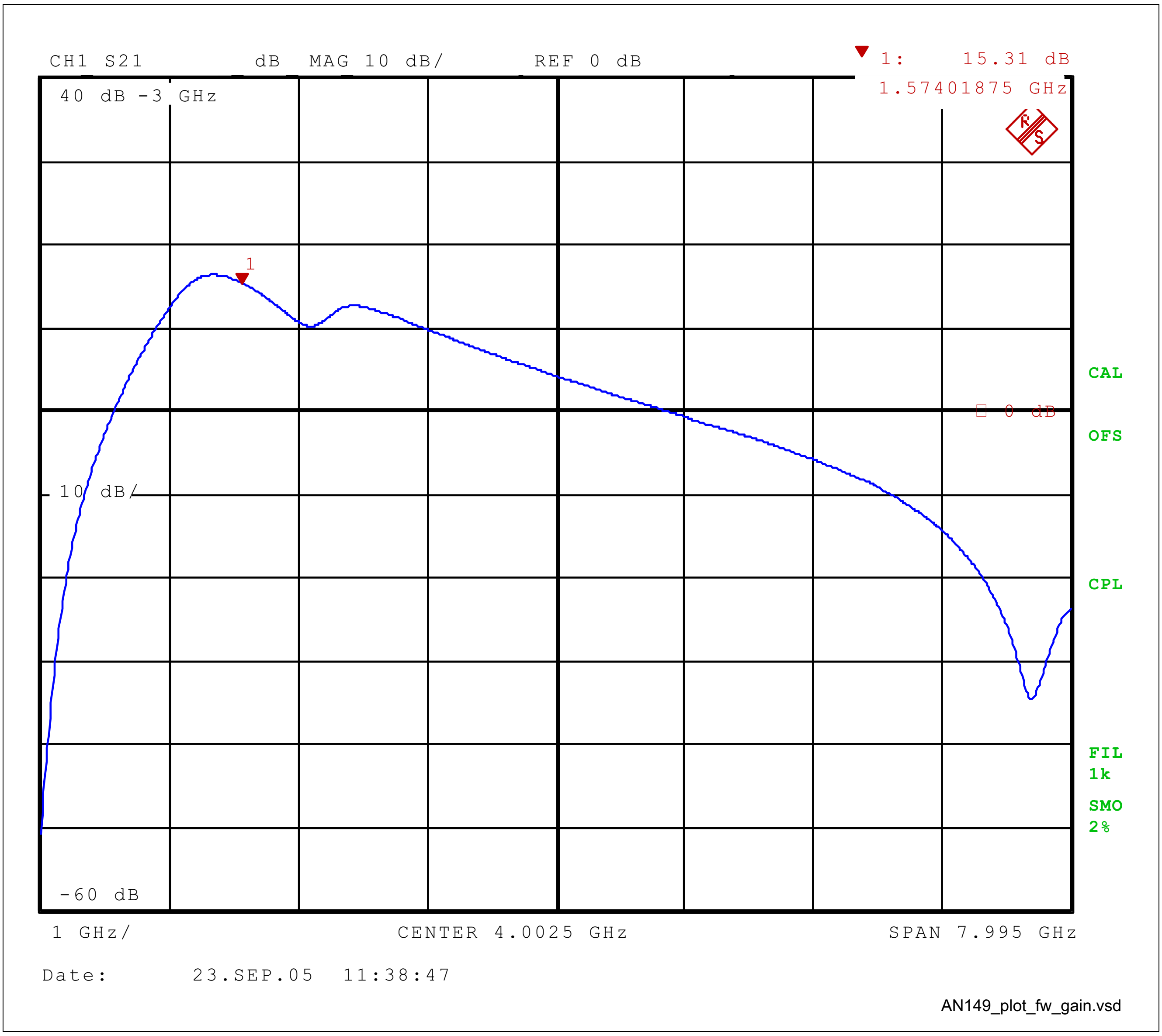


Figure 10 Plot of Forward Gain

Reverse Isolation

5 MHz - 8 GHz

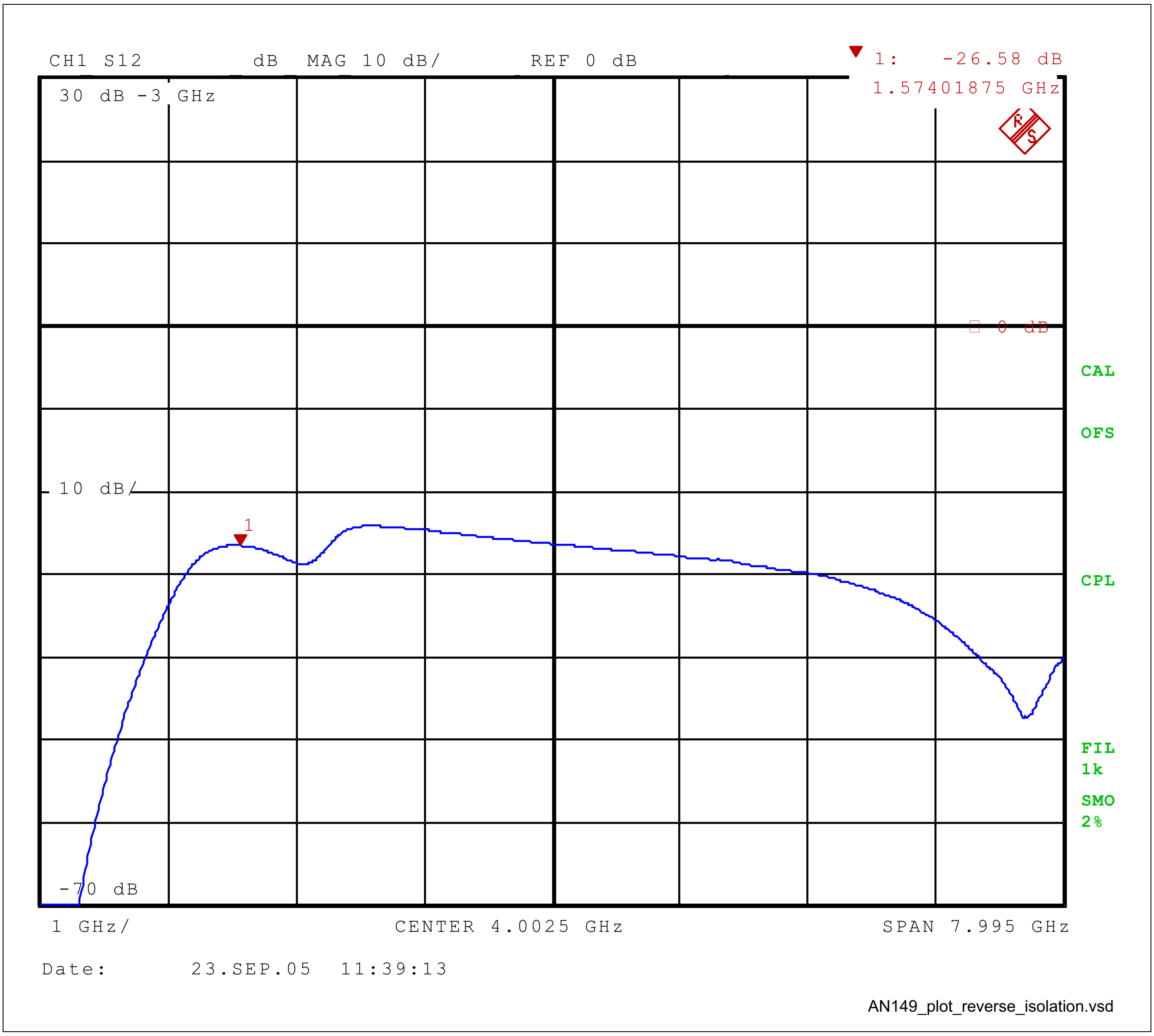


Figure 11 Plot of Reverse Isolation

Output Return Loss, Log Mag

5 MHz - 8 GHz

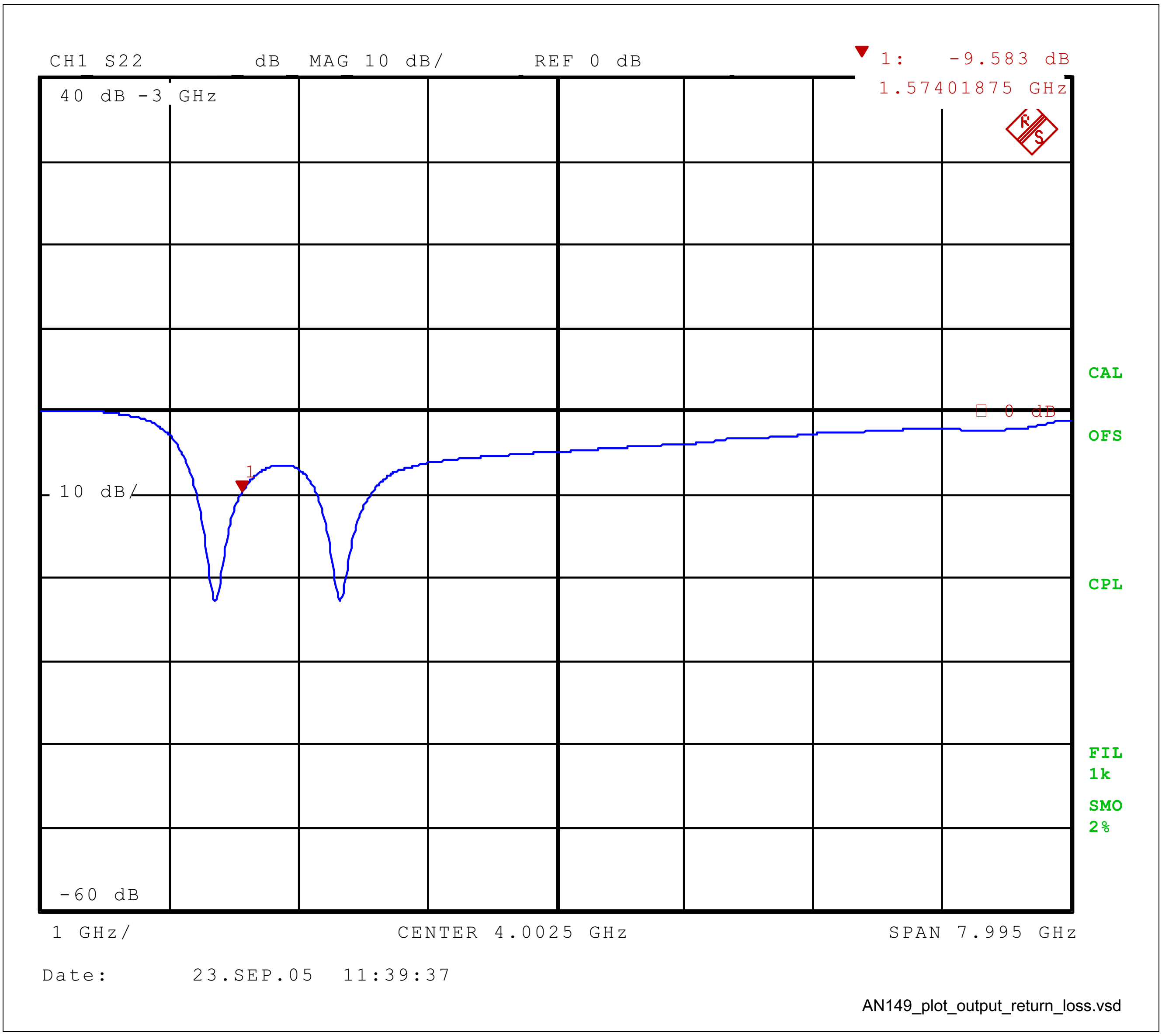


Figure 12 Plot of Output Return Loss

Output Return Loss, Smith Chart

Reference Plane = Output SMA Connector on PC Board
5 MHz - 8 GHz Sweep

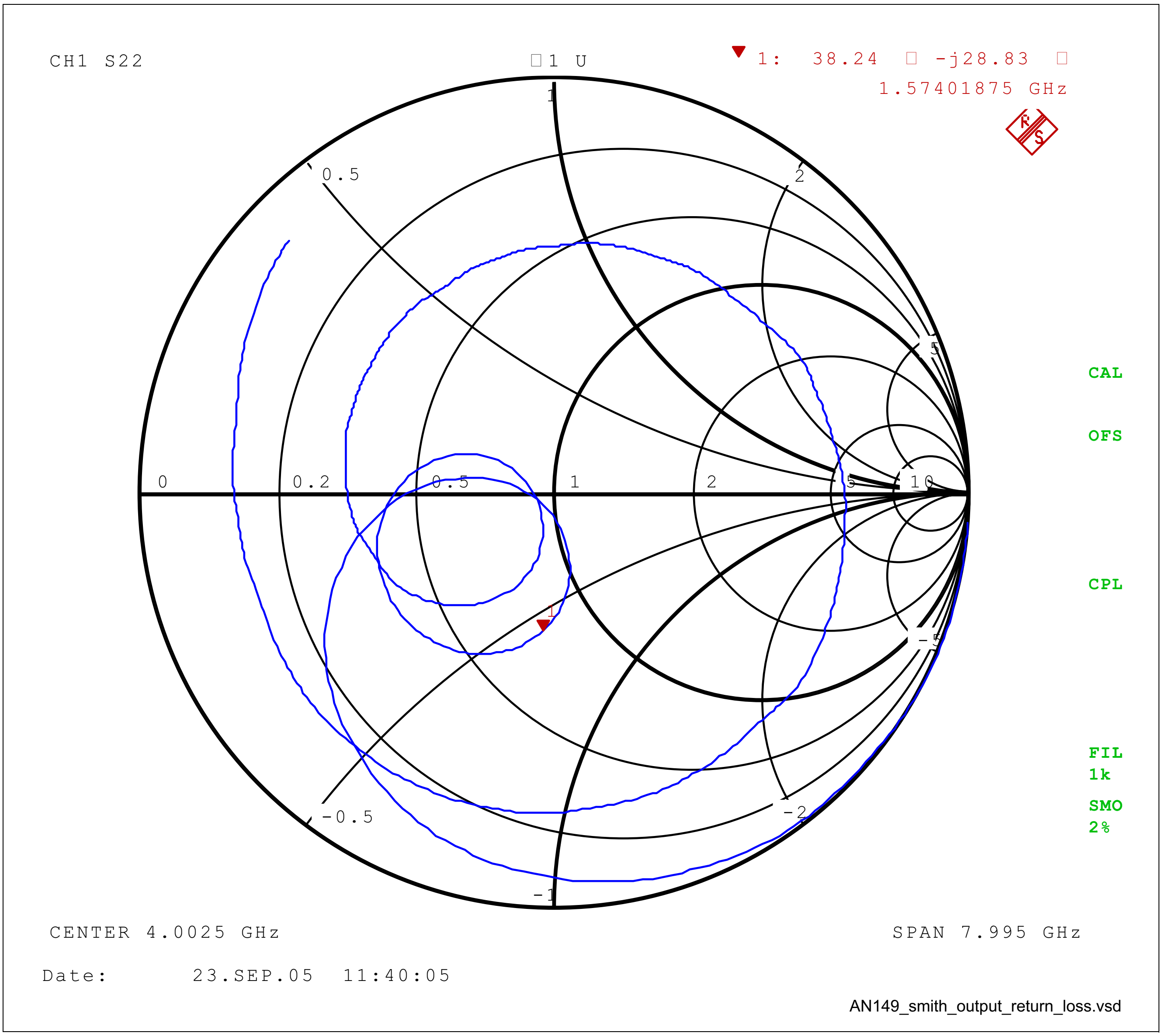


Figure 13 Smith Chart of Output Return Loss

Amplifier Response to Two Tone Test

Input stimulus: f_1 = 1575 MHz, f_2 = 1576 MHz, -30 dBm each tone.

Input IP_3 = -30 + (50.0 / 2) = -5.0 dBm
Output IP_3 = -5.0 dBm + 15.3 dB gain = +10.3 dBm

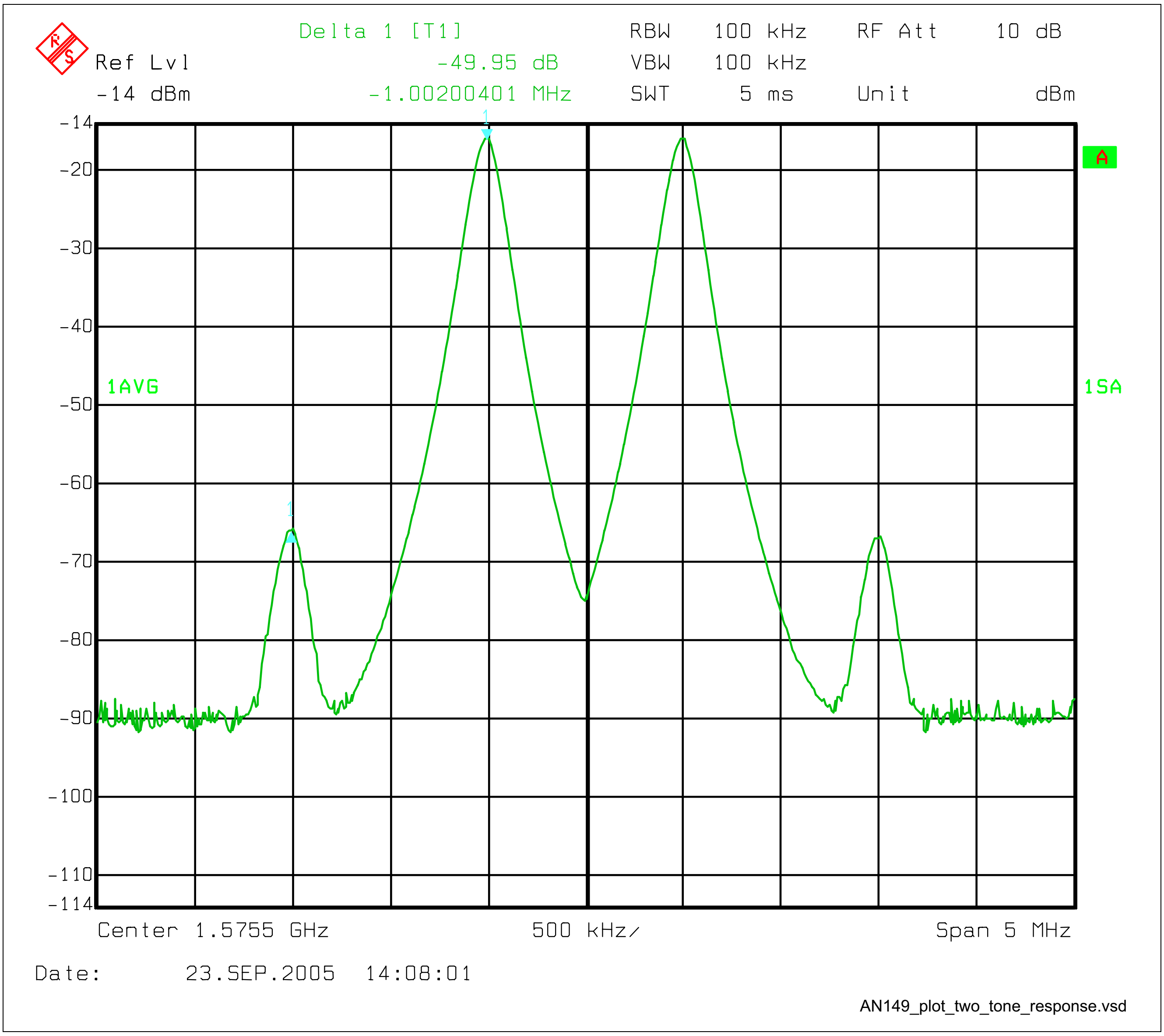


Figure 14 Tow-Tone Test, LNA Response