Application Note No. 138

Dual-Band (L1 + L2) GPS Low Noise Amplifier using the SiGe BFP640 HBT RF Transistor

RF & Protection Devices

Never stop thinking

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Revision History: 2008-01-10, Rev. 1.2

Previous Version: 2005-08-09, Rev. 1.1

Page	Subjects (major changes since last revision)
All	Small changes in figure descriptions

1 Dual-Band (L1 + L2) GPS Low Noise Amplifier using the SiGe BFP640 HBT RF Transistor

Applications

- GPS Low Noise Amplifiers (LNAs) for 3 V systems, where reception of both L1 (1575.42 MHz) and L2 (1227.6 MHz) GPS signals is required.

Overview

The Infineon BFP640 SiGe Heterojunction Bipolar Transistor in SOT343 package is shown in a low-cost LNA circuit suitable for dual band GPS applications operating from a 3 V power supply. PC board is fabricated from standard, low-cost, commercial grade glass-epoxy material ("FR4"). 0402 case-size passive components are used.

Target Specifications

Gain @ 1227.6 MHz => >18 dB; Gain @ 1575.42 MHz => > 17 dB; OP_{1dB} > +3 dBm; Noise Figure (NF) < 3 dB; V_{CC} = 3.0 Volts, I < 15 mA.

Remarks

(T = 25 °C)

- Amplifier is unconditionally stable from 5 MHz - 8 GHz (K>1). See plot on Page 7
- 19.9 dB gain at 1227.6 MHz, 18.5 dB gain at 1575.42 MHz
- Noise Figure = 1.1 dB for both L1 and L2 frequencies[1)]
- 9.1 mA current consumption at 3.0 V
- Output P_{1dB} meets target at 1575 MHz, but is slightly low at 1227 MHz. OP_{1dB} can be improved by increasing current; do this by reducing value of resistor R2 (see **Figure 2**)

Summary of Results

Table 1 Summary of Results, T = 25 °C

Frequency (MHz)	dB[s11]²	dB[s21]²	dB[s12]²	dB[s22]²	NF[1)] dB	IIP_3 dBm	OIP_3 dBm	IP_{1dB} dBm	OP_{1dB} dBm
1227.6	11.3	19.9	27.6	18.9	1.1	---	---	-17.6	+1.3
1575.4	17.2	18.5	25.6	11.3	1.1	+5.7	+24.2	-14.4	+3.1

Cross Sectional Diagram of PC Board

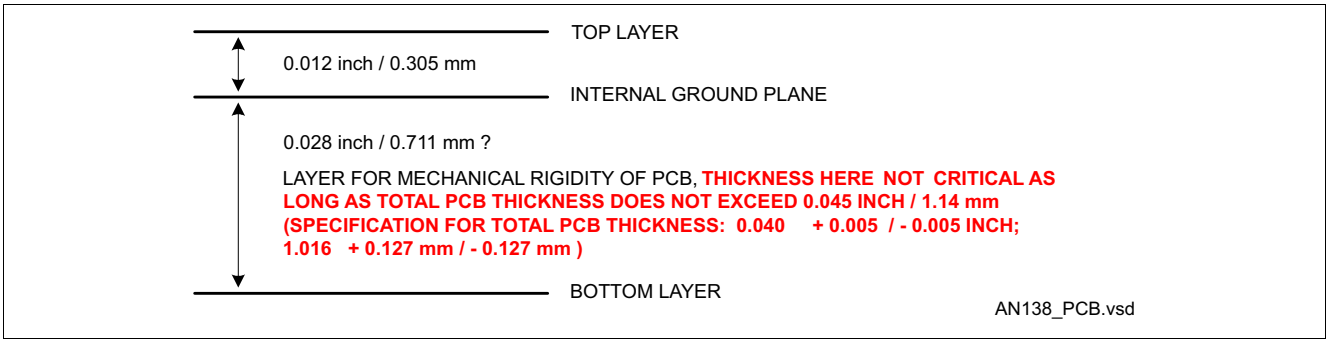


Figure 1 PCB - Cross Sectional Diagram

1) Note that PCB loss is not extracted. If PCB loss were extracted, NF would be 0.1 to 0.2 dB lower

Schematic Diagram

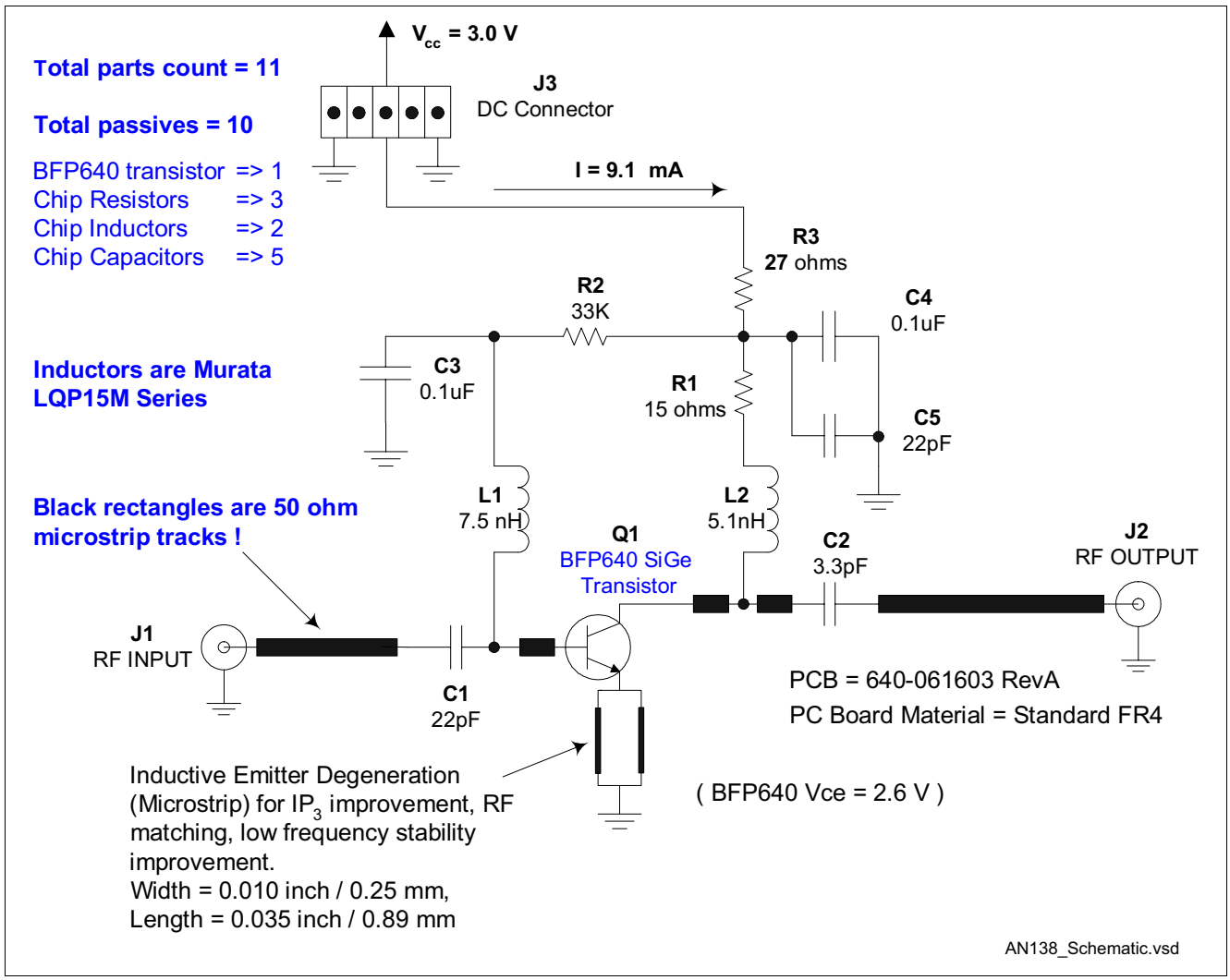


Figure 2 Schematic Diagram

Noise Figure, Plot, 1100 MHz to 1700 MHz, Center of Plot (x-axis) is 1400 MHz.

Rohde & Schwarz FSEK3

08 Aug 2005

Noise Figure

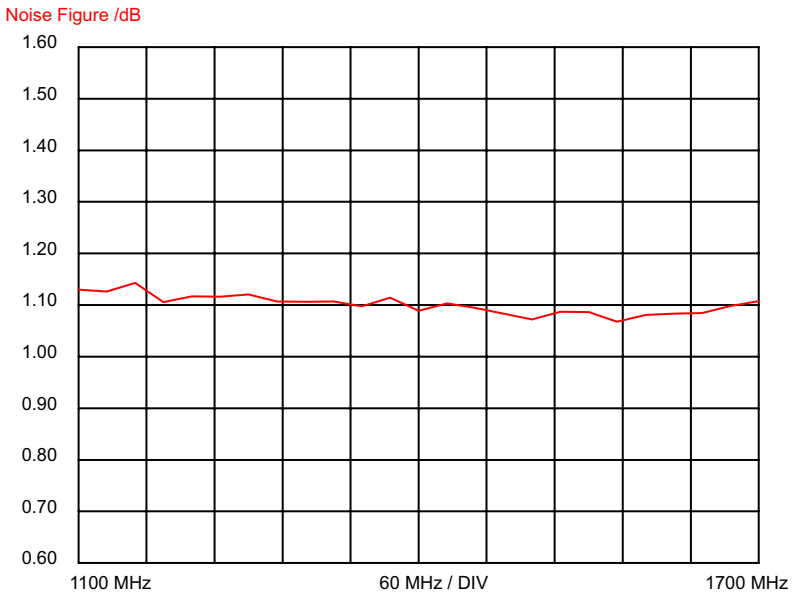
EUT Name:	BFP640 Dual Band GPS LNA (L1 and L2 frequencies)
Manufacturer:	Infineon Technologies AG
Operating Conditions:	V cc = 3.0 V, I = 9.1mA, Vce = 2.6 V
Operator Name:	Gerard Wevers
Test Specification:	LWR SD00085 LNA P
Comment:	On PCB 640-061603 Rev A 8 August 2005

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



AN138_plot_nf.vsd

Figure 3 Noise Figure

Noise Figure, Tabular Data

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

Table 2 Noise Figure

Frequency	Noise Figure
1100 MHz	1.13 dB
1125 MHz	1.13 dB
1150 MHz	1.14 dB
1175 MHz	1.11 dB
1200 MHz	1.12 dB
1225 MHz	1.12 dB
1250 MHz	1.12 dB
1275 MHz	1.11 dB
1300 MHz	1.11 dB
1325 MHz	1.11 dB
1350 MHz	1.10 dB
1375 MHz	1.11 dB
1400 MHz	1.09 dB
1425 MHz	1.10 dB
1450 MHz	1.09 dB
1475 MHz	1.08 dB
1500 MHz	1.07 dB
1525 MHz	1.09 dB
1550 MHz	1.09 dB
1575 MHz	1.07 dB
1600 MHz	1.08 dB
1625 MHz	1.08 dB
1650 MHz	1.08 dB
1675 MHz	1.10 dB
1700 MHz	1.11 dB

Scanned Image of PC Board

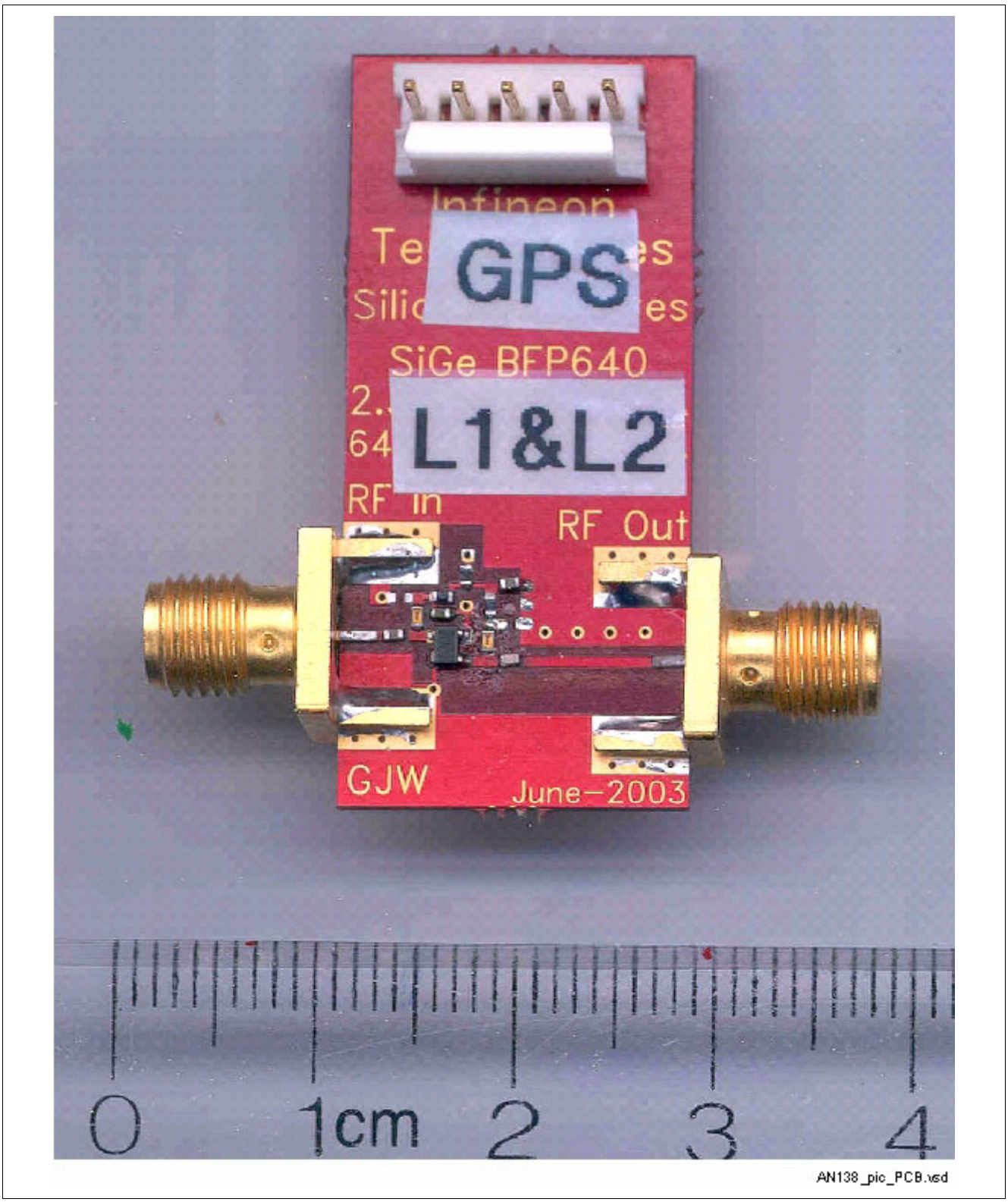


Figure 4 Image of PC Board

Scanned Image of PC Board, Close-In Shot.

Total PCB area used ≅ 50 mm²

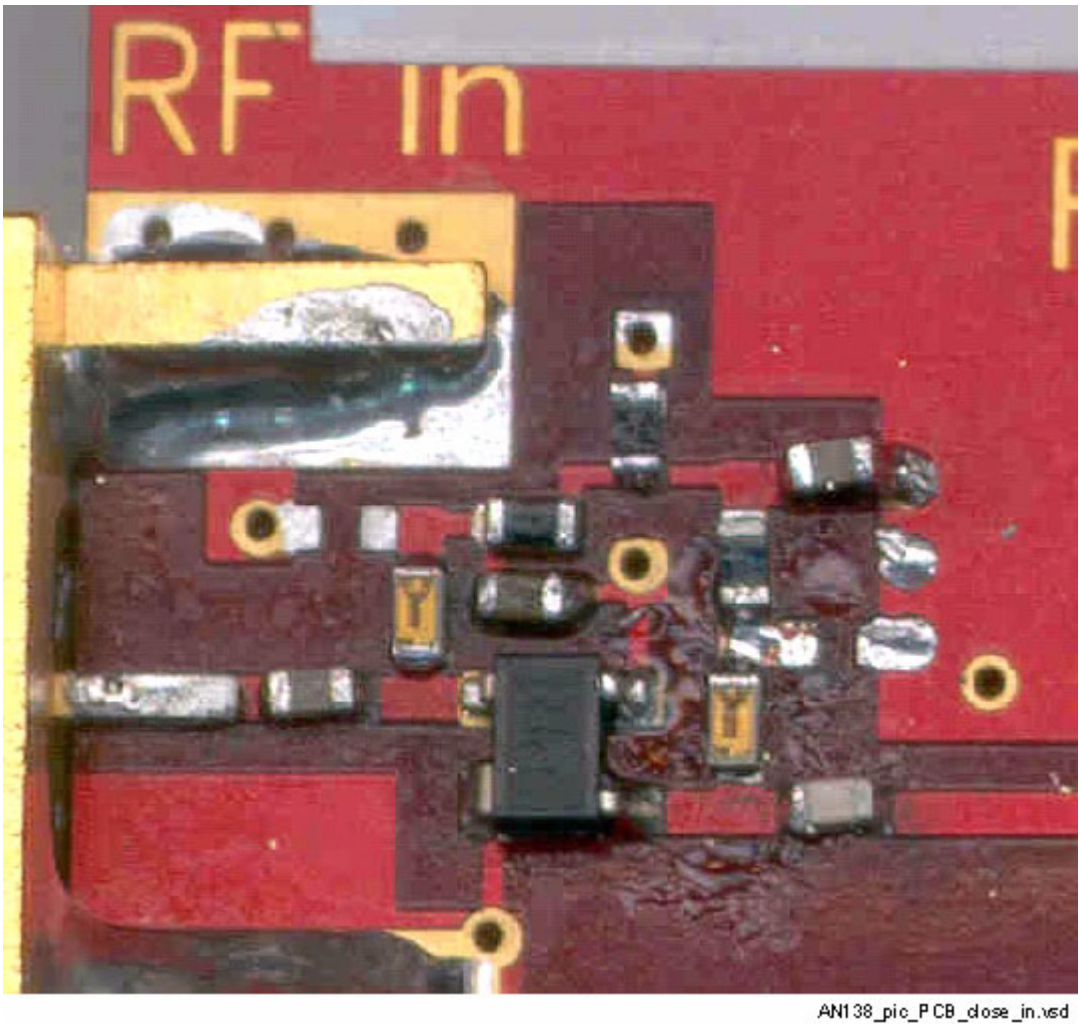


Figure 5 Image of PC Board, Close-In Shot

Stability

Rohde and Schwarz ZVC Network Analyzer calculates and plots Stability Factor "K" in real time, from 5 MHz to 8 GHz. Note K>1 from 5 MHz to 8 GHz; minimum K value is approximately 1.1 at ≈ 6.6 GHz. Amplifier is Unconditionally Stable over 5 MHz - 8 GHz frequency range.

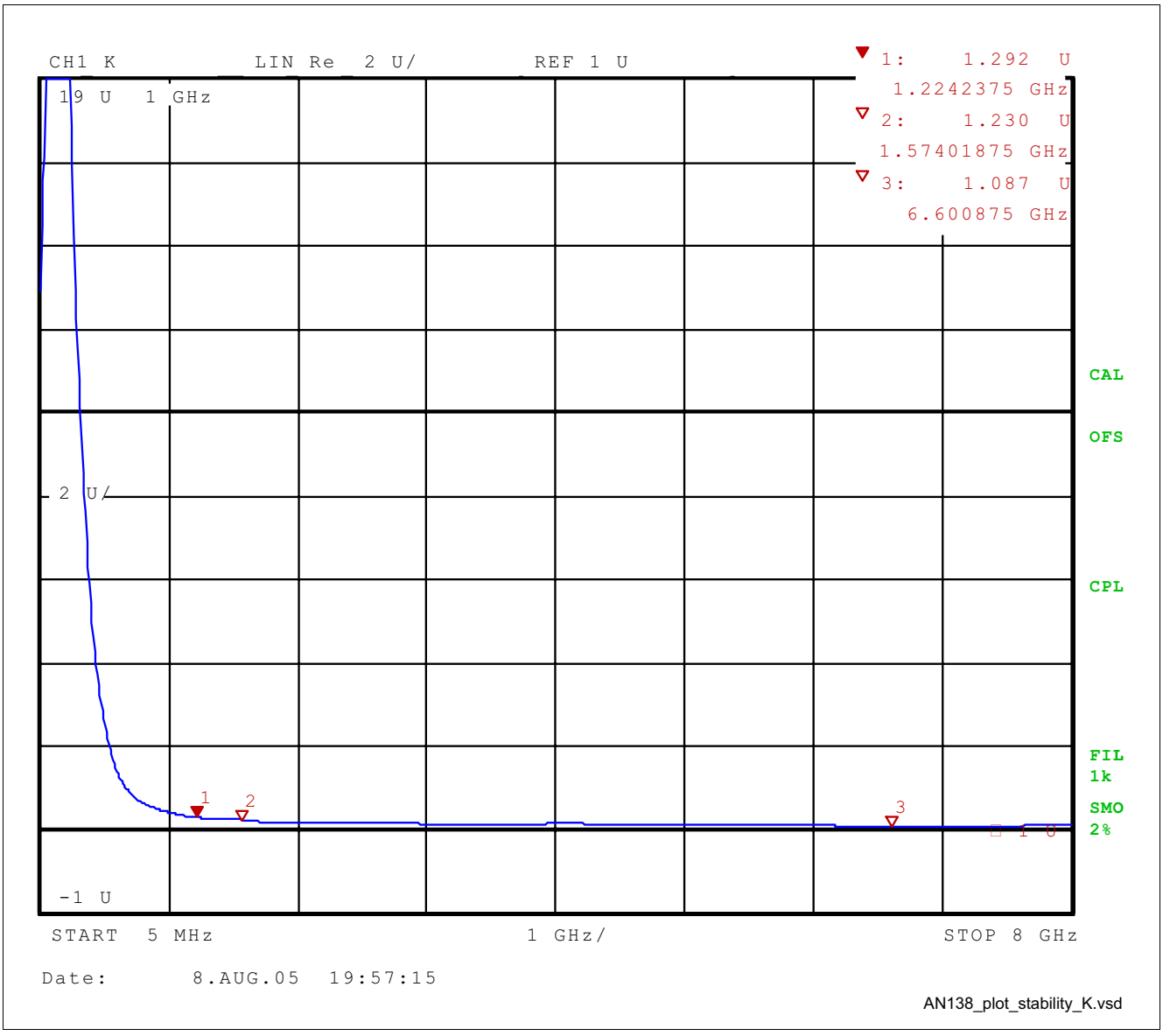


Figure 6 Plot of K(f)

Gain Compression at 1227 MHz and 1575 MHz

Amplifier is checked for output 1 dB compression point at V_{CC} = 3 V, I = 9.1 mA (with V_{CE} = 2.6 V). An Agilent power meter was used to ensure accurate power levels are measured (as opposed to using Vector Network Analyzer in "Power Sweep" mode).

1227 MHz:
Output $P_{1dB} \cong$ + 1.3 dBm; Input P_{1dB} = +1.3 dBm - (Gain - 1 dB) = +1.3 dBm - 18.9 dB = -17.6 dBm

1575 MHz:
Output $P_{1dB} \cong$ + 3.1 dBm; Input P_{1dB} = +3.1 dBm - (Gain - 1 dB) = +1.3 dBm - 17.5 dB = -14.4 dBm

Table 3 Gain Compression

P_{OUT}, dBm	Gain @ 1227 MHz, dB	Gain @ 1575 MHz, dB
-10.0	19.9	18.5
-9.0	19.9	18.5
-8.0	19.9	18.5
-7.0	19.8	18.5
-6.0	19.8	18.4
-5.0	19.8	18.4
-4.0	19.7	18.4
-3.0	19.7	18.4
-2.0	19.6	18.3
-1.0	19.5	18.3
0.0	19.4	18.2
+1.0	19.1	18.1
+2.0	18.6	17.9
+3.0	17.7	17.5
+4.0	16.3	16.7

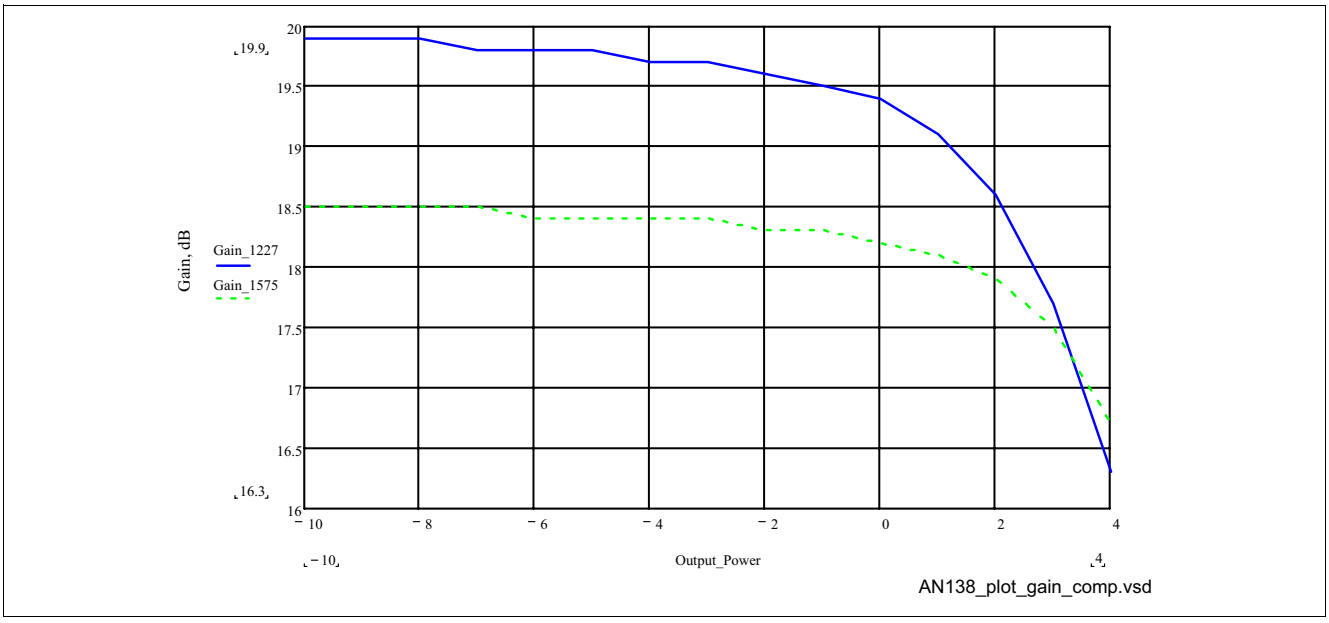


Figure 7 Plot of Gain Compression, Output Power in dB

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

Input Return Loss, Log Mag

5 MHz - 8 GHz Sweep

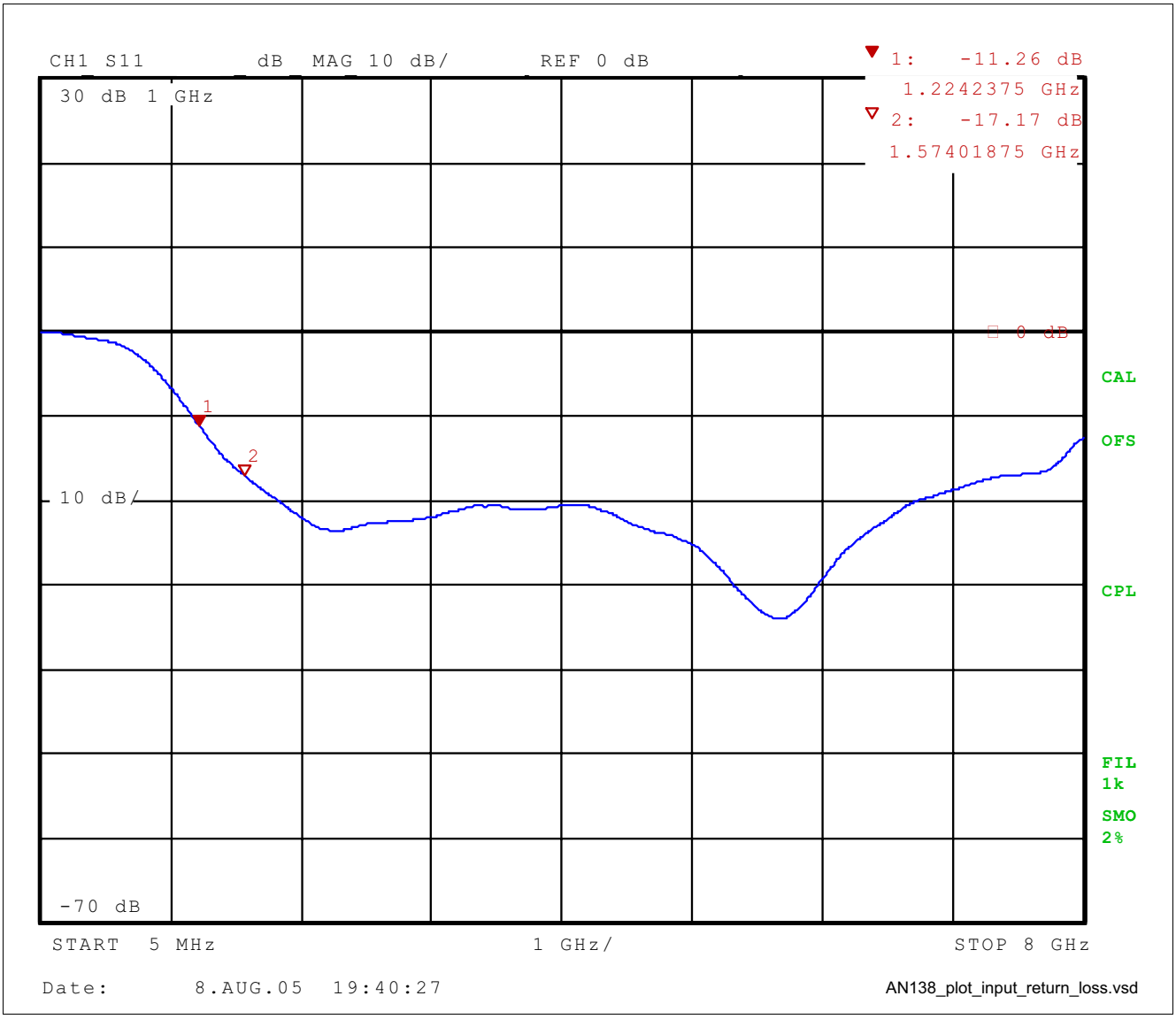


Figure 8 Plot of Input Return Loss

Input Return Loss, Smith Chart

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

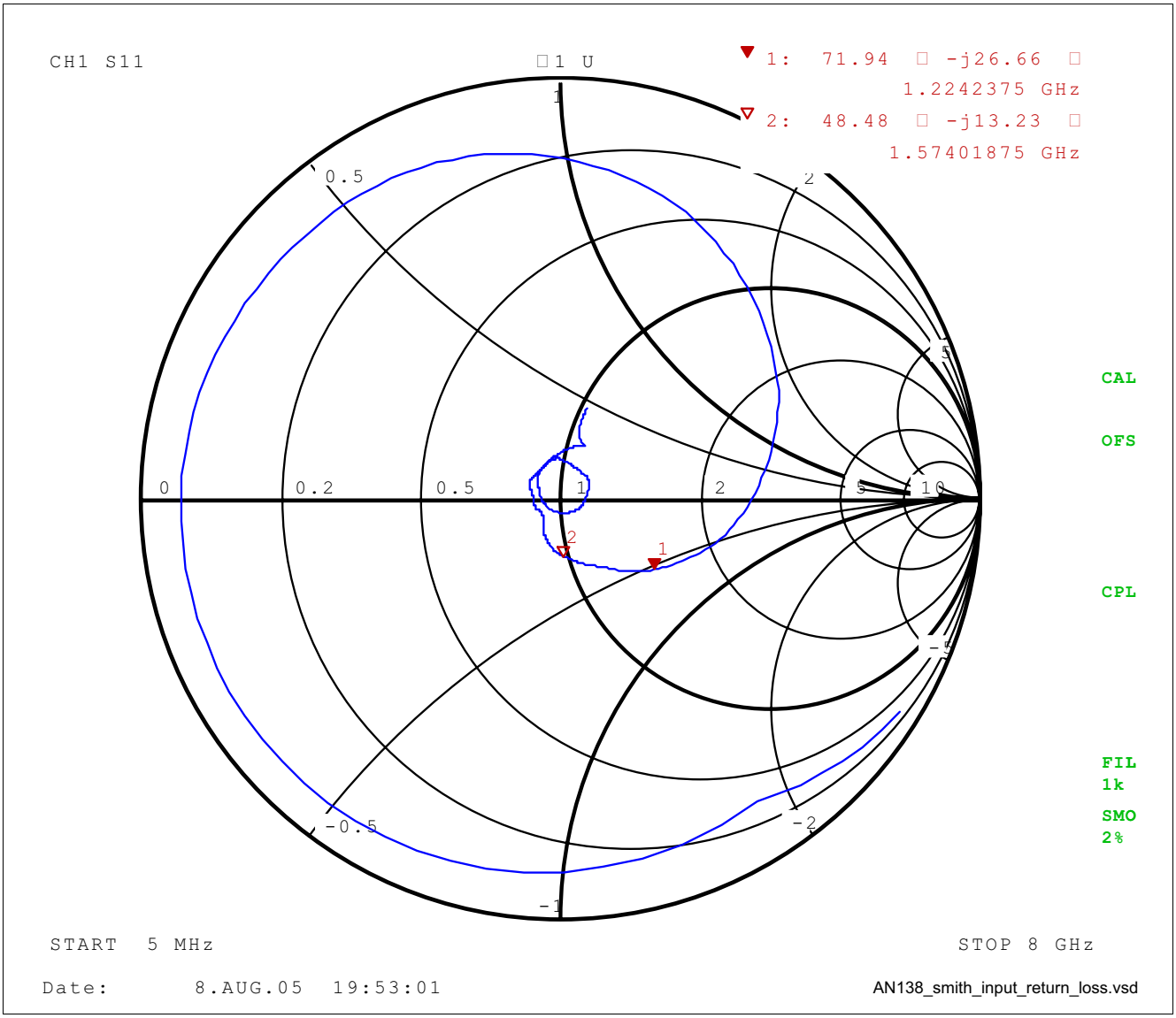


Figure 9 Smith Chart of Input Return Loss

Forward Gain

5 MHz - 8 GHz Sweep

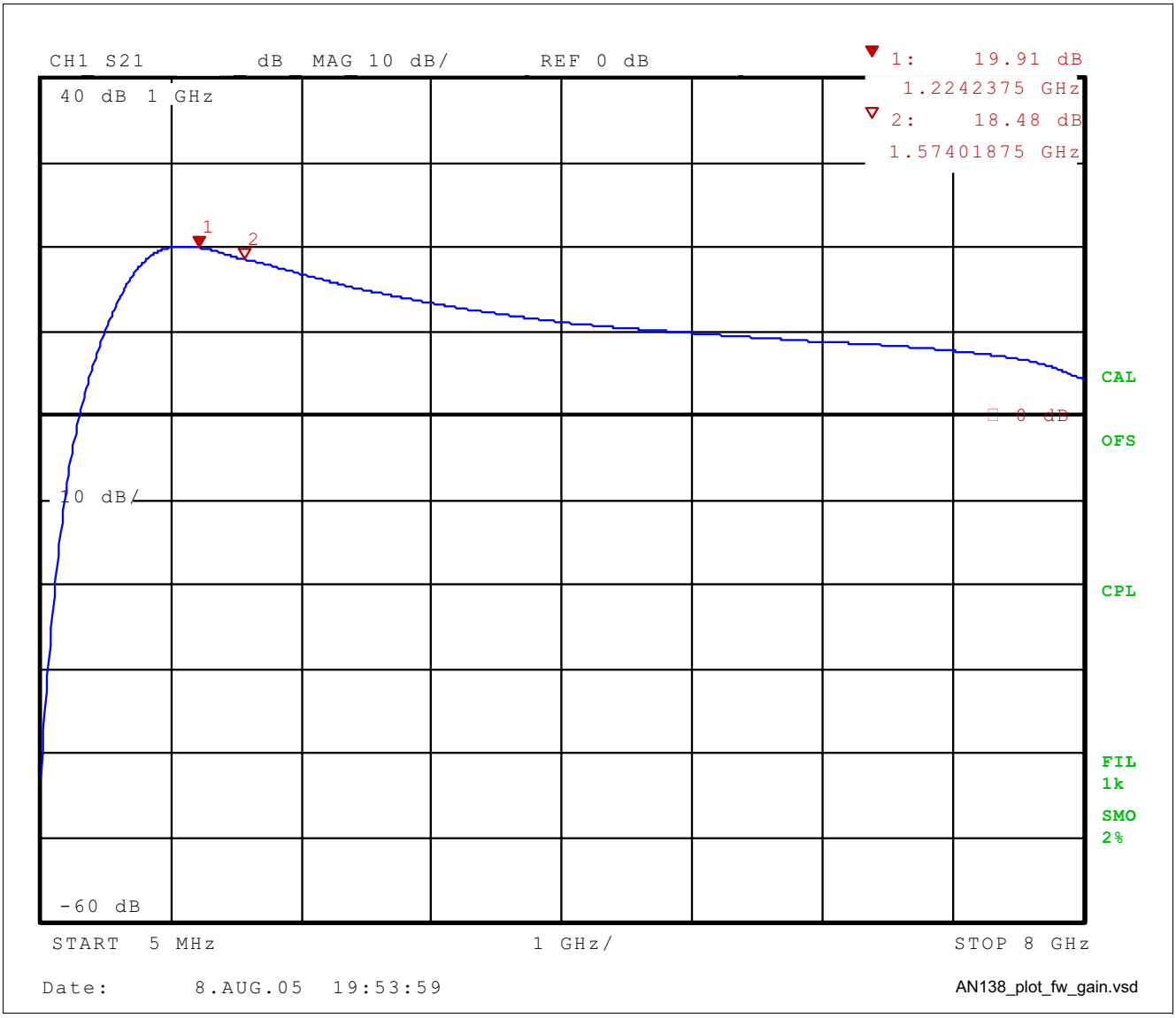


Figure 10 Plot of Forward Gain

Reverse Isolation

5 MHz - 8 GHz Sweep

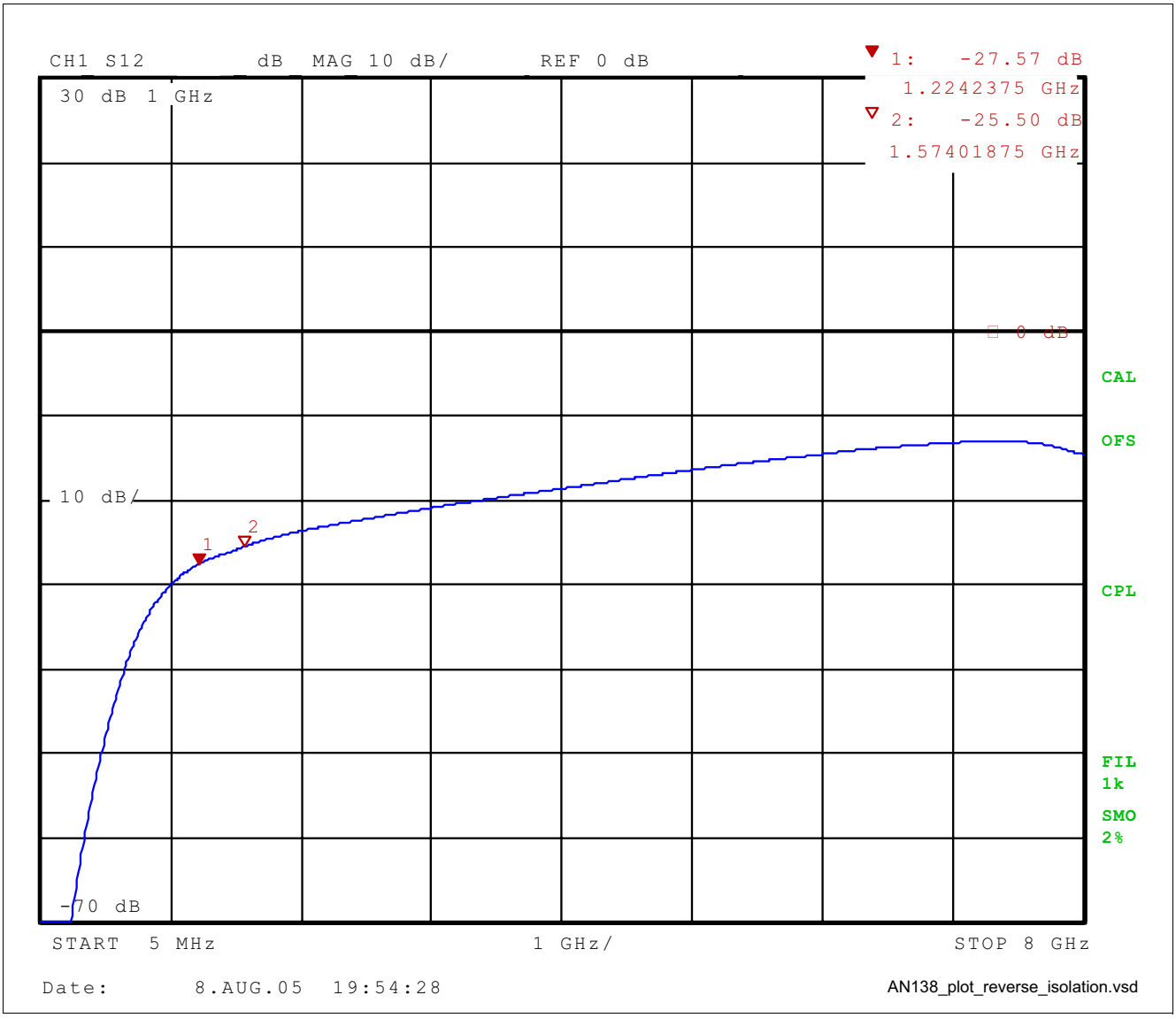


Figure 11 Plot of Reverse Isolation

Output Return Loss, Log Mag

5 MHz - 8 GHz Sweep

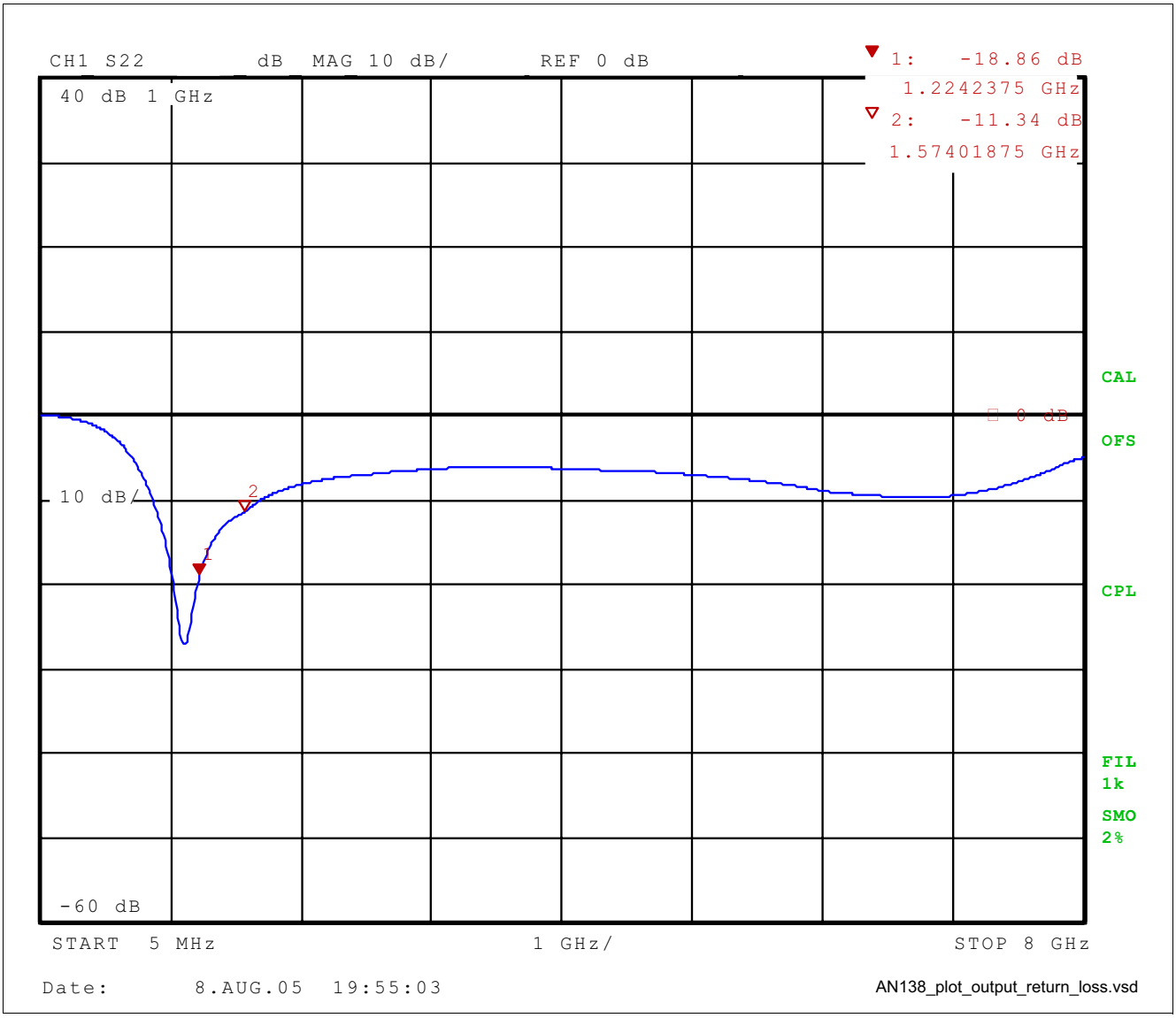


Figure 12 Plot of Output Return Loss

Output Return Loss, Smith Chart

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

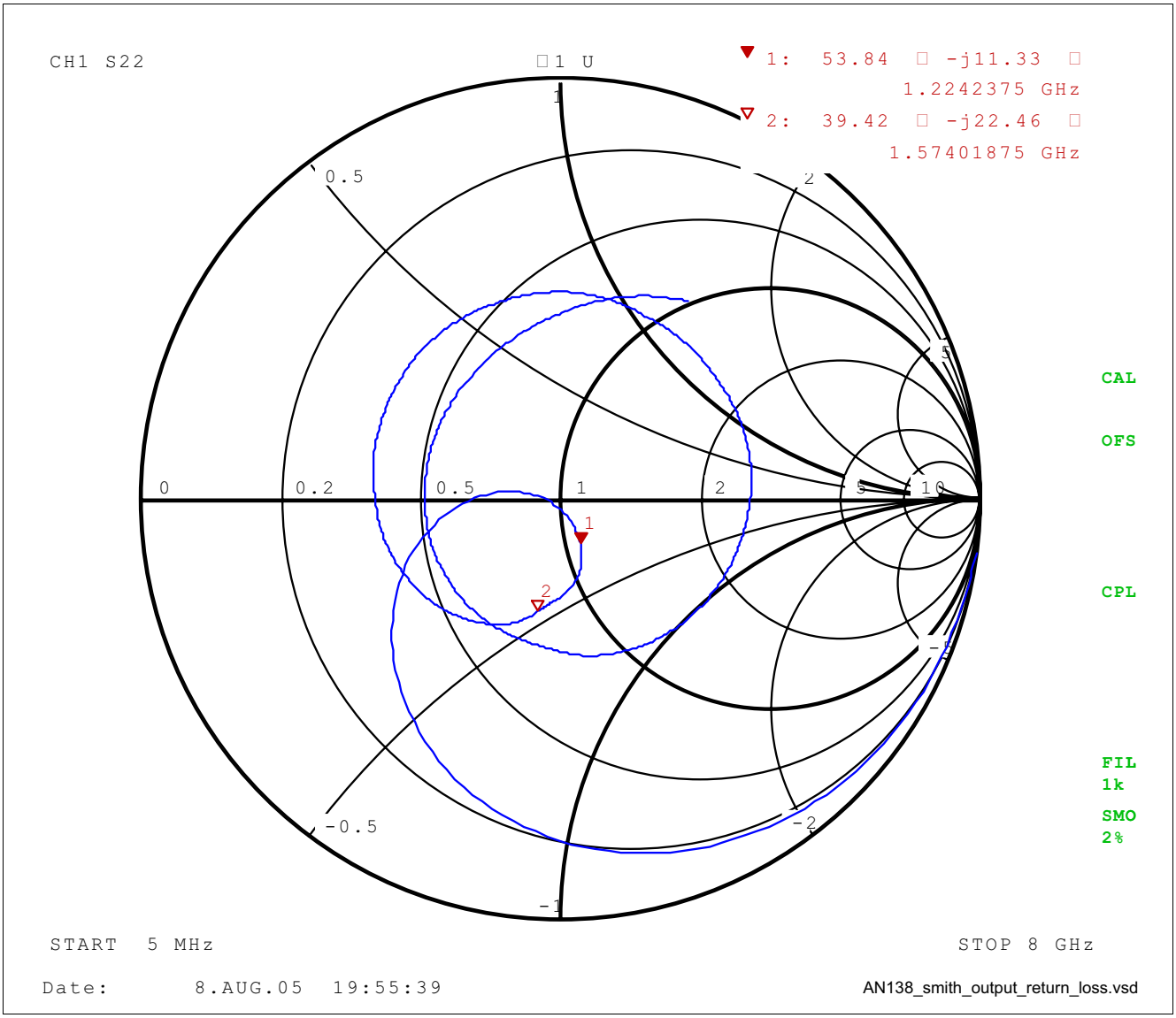


Figure 13 Smith Chart of Output Return Loss

Two-Tone Test, 1575 MHz

Input Stimulus for Amplifier Two-Tone Test.
f_1 = 1575 MHz, f_2 = 1576 MHz, -25 dBm each tone.
LNA response to two-tone test is below (spectrum analyzer screen-shot).
Input IP_3 = -25 + (61.4 / 2) = +5.7 dBm. Output IP_3 = +5.7 dBm + 18.5 dB gain = +24.2 dBm

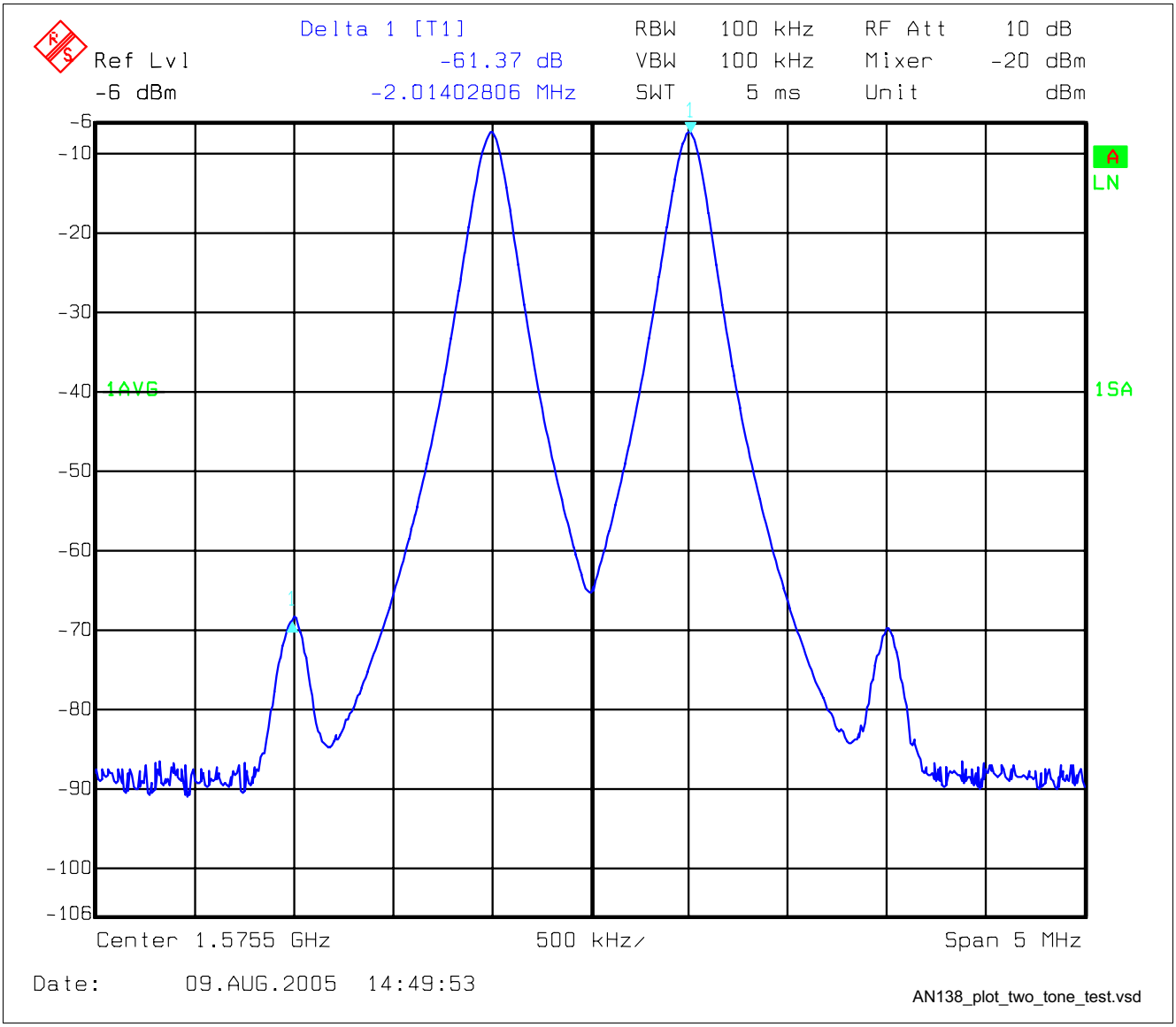


Figure 14 Tow-Tone Test, LNA Response @ 1575 MHz