Application Note No. 137

Low Cost, 3 Volt, +12.5 dBm 2.33 GHz SDARS Active Antenna 2nd Stage Low Noise Amplifier using the Infineon BFP640 SiGe Transistor

RF & Protection Devices

Never stop thinking

Edition 2008-01-10

Published by
Infineon Technologies AG
81726 München, Germany

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

Previous Version: 2004-11-16, Rev. 1.1	
Page	**Subjects (major changes since last revision)**
All	Small changes in figure descriptions

1 Low Cost, 3 Volt, +12.5 dBm 2.33 GHz SDARS Active Antenna 2nd Stage Low Noise Amplifier using the Infineon BFP640 SiGe Transistor

Overview

The Silicon-Germanium BFP640 SiGe Low Noise Transistor is shown in an SDARS active antenna LNA application. The BFP640 is targeted for the 2nd stage in a 3 stage SIRIUS LNA chain. The demo board is standard FR4 material and "0402" case sizes components are used throughout. A total of approximately 45 mm² of PCB area is required, and the total component count, including the BFP640 and all passives, is 12. No inductive emitter degeneration is used in this design for improved high-frequency stability margin (> 10 GHz).

SDARS Active Antenna LNA

2320 - 2332.5 MHz (SIRIUS, 3 Stages)

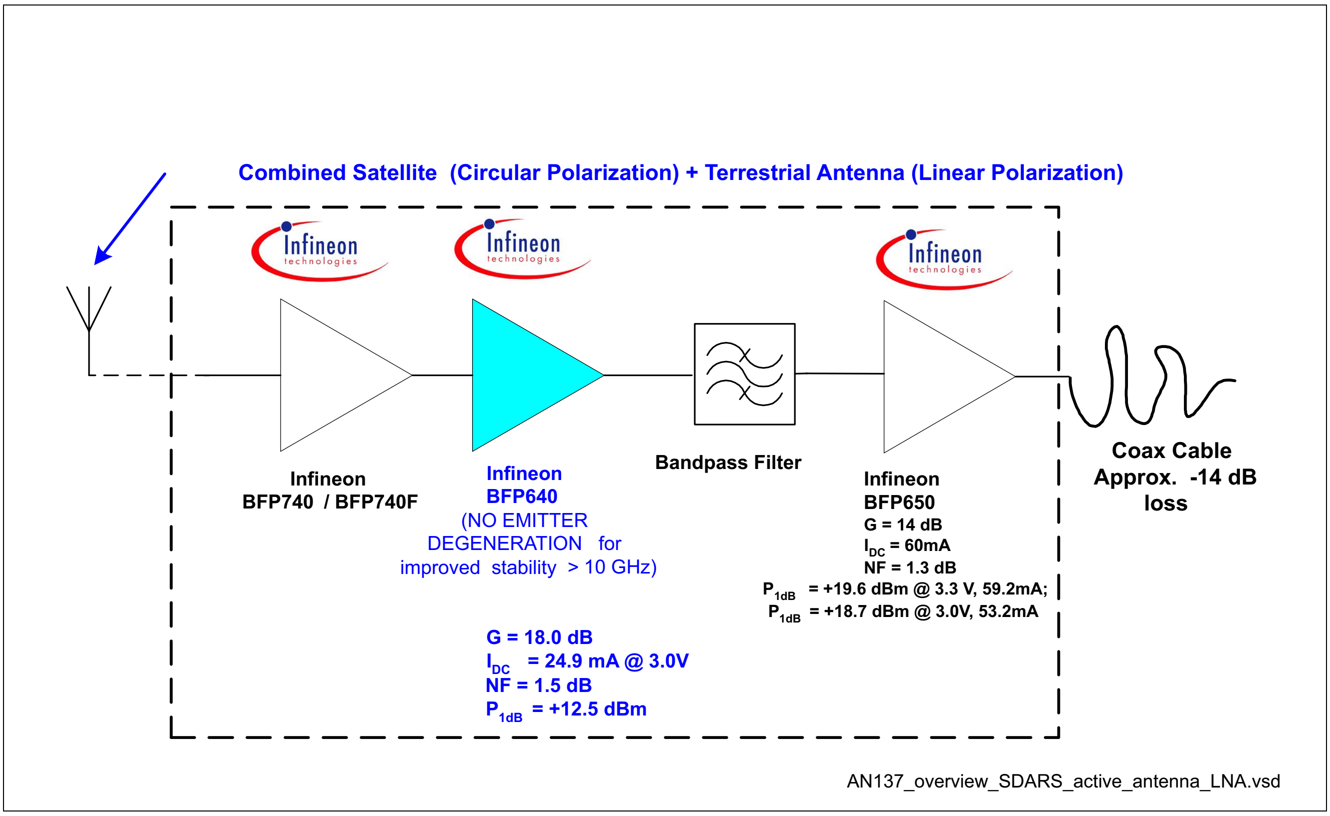


Figure 1 Overview of SDARS Active Antenna LNA

Summary

Achieved 18 dB gain, 1.5 dB Noise Figure over the 2320 - 2345 MHz band, drawing 14.9 mA @ 3.0 volts. Noise figure result does NOT "back out" FR4 PCB losses - if PCB loss at LNA input were extracted, Noise Figure result would be approximately 0.1 - 0.2 dB lower. Amplifier is unconditionally stable from 50 MHz to 20 GHz.
Output P_{1dB} = +12.5 dBm @ 3 V. Input 3rd Order Intercept = +10.0 dBm @ 2332 MHz, Output IP_3 = +28.0 dBm.

PCB Cross - Section Diagram

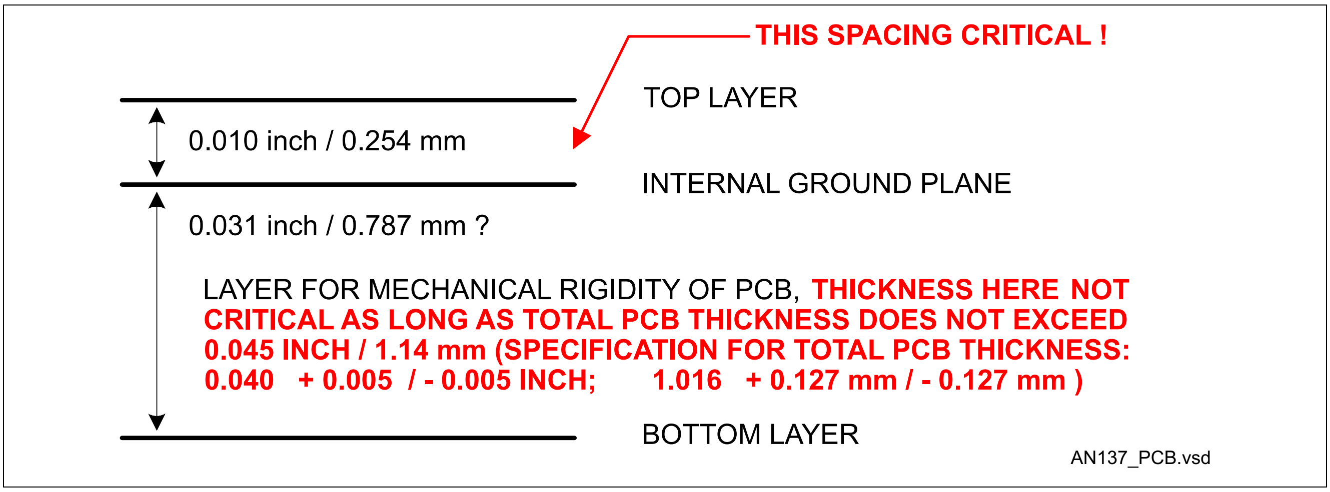


Figure 2 PCB - Cross Sectional Diagram

Schematic Diagram

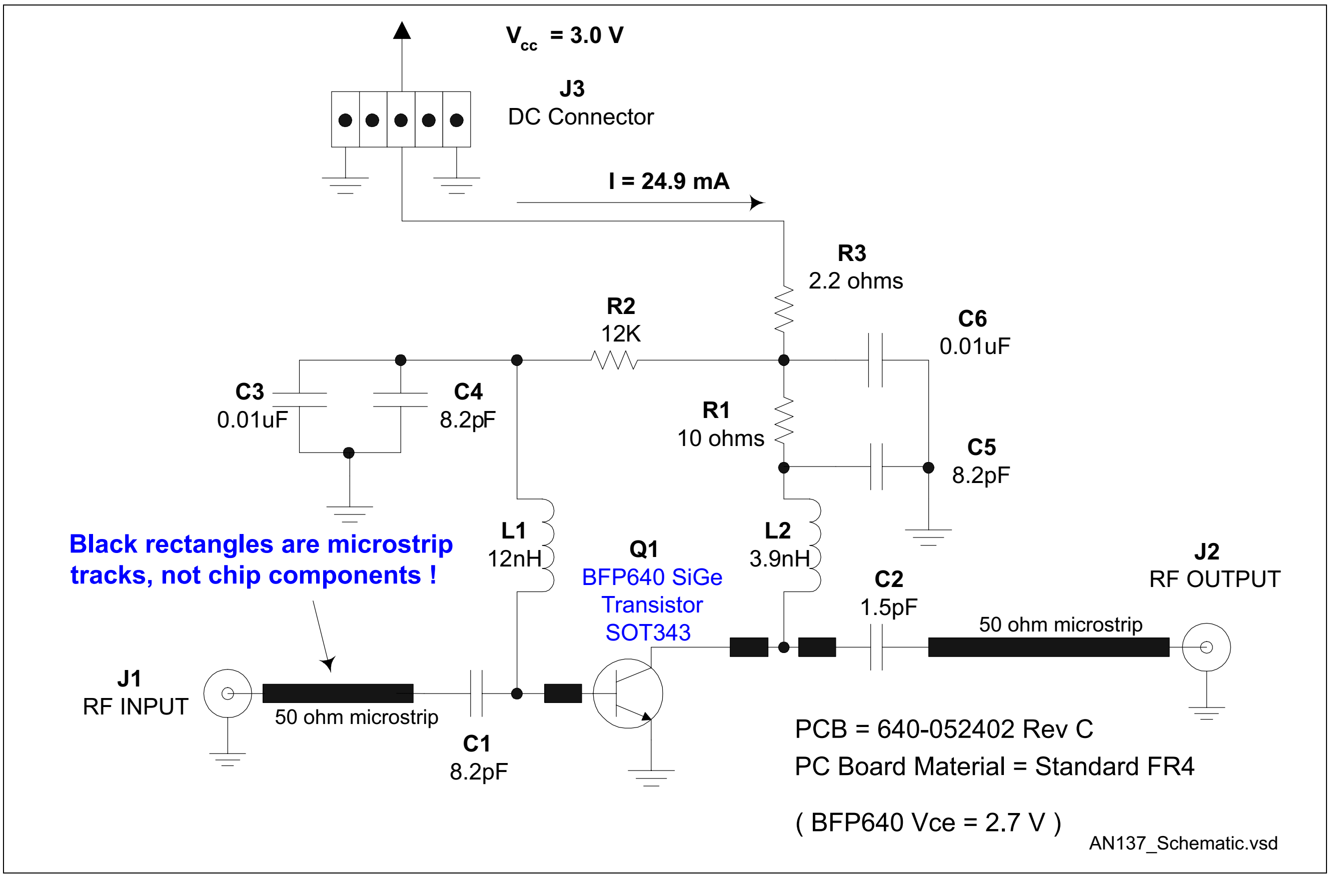


Figure 3 Schematic Diagram

Summary of Data

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

Table 1 Summary of Data

Parameter	Result	Comments
Frequency Range	Under 2320 - over 2345 MHz	Covers both XM Radio and SIRIUS frequency bands.
DC Current	24.9 mA @ 3.0 V	Note power supply voltage is measured directly across PCB supply line and ground, to eliminate voltage drop across wire harness.
Gain	18.0 dB @ 2320 MHz 18.0 dB @ 2332.5 MHz 17.9 dB @ 2345 MHz	
Noise Figure	1.5 dB @ 2320 MHz 1.5 dB @ 2332.5 MHz 1.4 dB @ 2345 MHz	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}	-4.5 dBm @ 3.0 V	Measured @ 2332.5 MHz. See **Figure 8**.
Output P_{1dB}	+12.5 dBm @ 3.0 V	See **Figure 8**.
Power Added Efficiency (PAE) at 1 dB Compression Point	23.4% @ 3.0 V	PAE = $(P_{OUT} - P_{IN}) / (V_{CC} \times I_C)$
Input 3rd Order Intercept	+10.0 dBm @ 2332 MHz	Measured at 3.3 V, see **Figure 16** and **Figure 17**.
Output 3rd Order Intercept	+28.0 dBm @ 2332 MHz	Measured at 3.3 V, see **Figure 16** and **Figure 17**.
Input Return Loss	15.0 dB @ 2320 MHz 15.2 dB @ 2332.5 MHz 15.4 dB @ 2345 MHz	
Output Return Loss	10.4 dB @ 2320 MHz 10.3 dB @ 2332.5 MHz 10.2 dB @ 2345 MHz	
Reverse Isolation	23.8 dB @ 2320 MHz 23.8 dB @ 2332.5 MHz 23.7 dB @ 2345 MHz	

Noise Figure, Plot, 2232.5 MHz to 2432.5 MHz, Center of Plot (x-axis) is 2332.5 MHz.

Rohde & Schwarz FSEK3 — 16 Nov 2004

Noise Figure / Rauschmessung

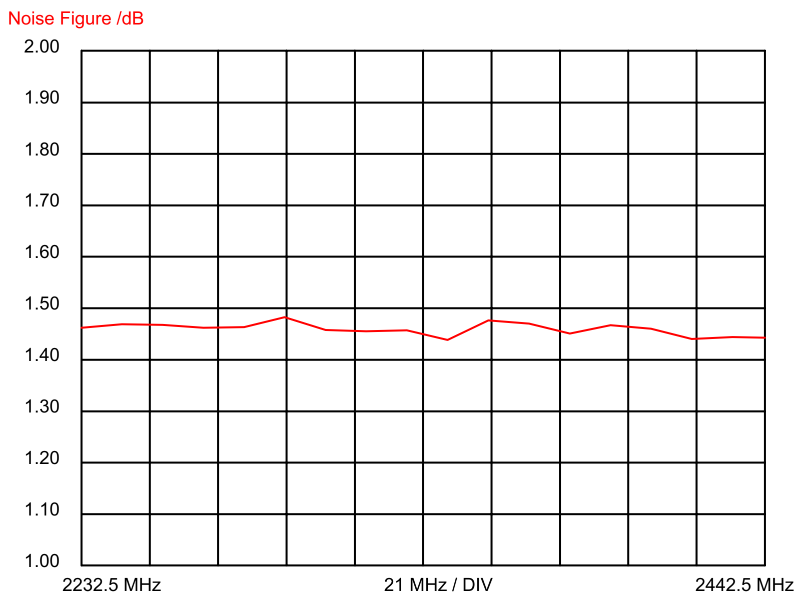
EUT Name:	BFP640 2.33 GHz SDARS Active Antenna LNA 2nd Stage
Manufacturer:	Infineon Technologies
Operating Conditions:	V = 3.0 V, I = 24.9 mA, T = 25 C
Operator Name:	Gerard Wevers
Test Specification:	LWR_SD00058_LNA_P NO INDUCTIVE EMITTER DEGENERATION
Comment:	PCB = 640-052402 Rev A 16 November 2004

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



AN137_plot_nf.vsd

Figure 4 Noise Figure

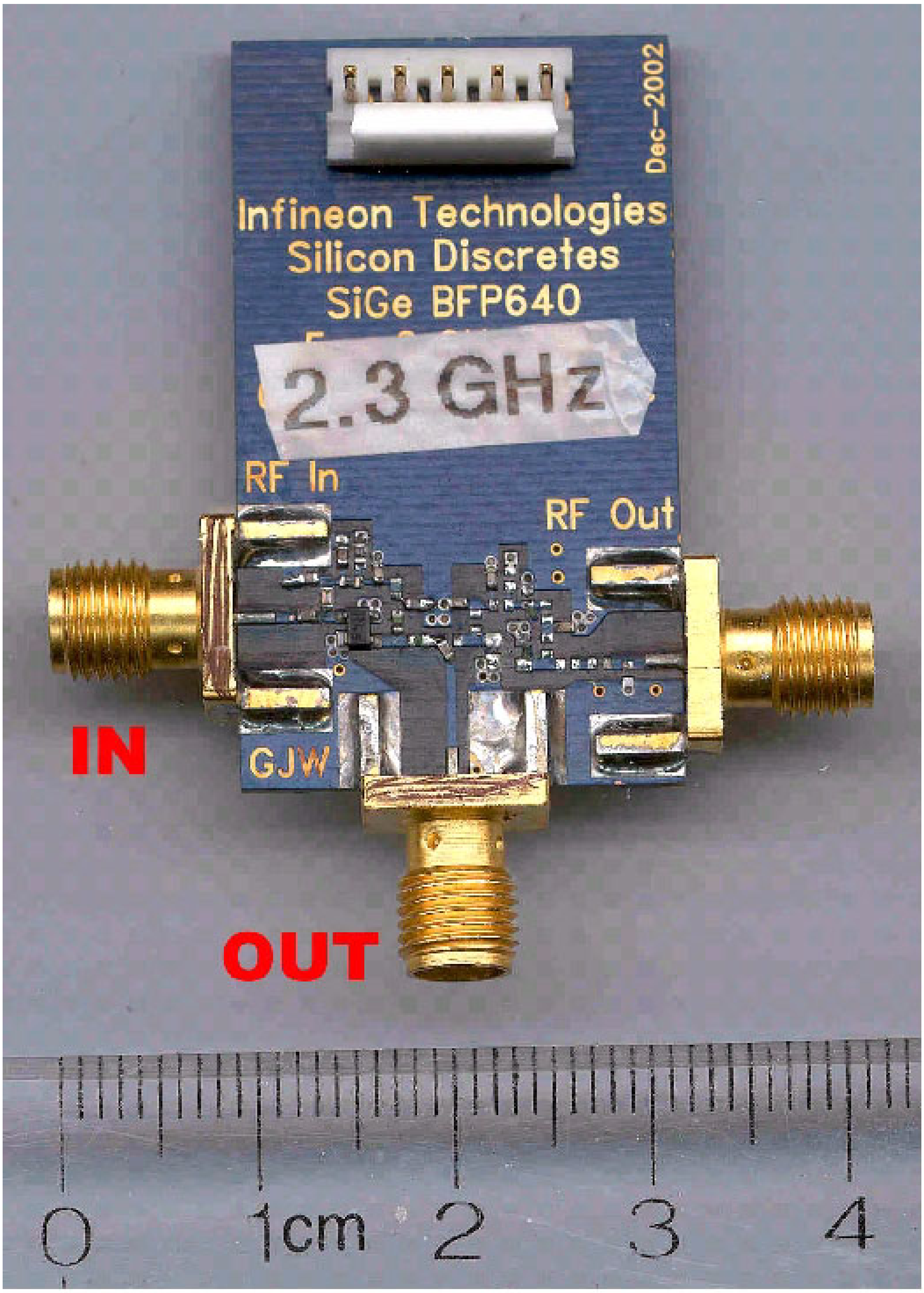
Noise Figure, Tabular Data

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

Table 2 Noise Figure

Frequency	Noise Figure
2232.5 MHz	1.46 dB
2245 MHz	1.47 dB
2257.5 MHz	1.47 dB
2270 MHz	1.46 dB
2282.5 MHz	1.46 dB
2295 MHz	1.48 dB
2307.5 MHz	1.46 dB
2320 MHz	1.46 dB
2332.5 MHz	1.46 dB
2345 MHz	1.44 dB
2357.5 MHz	1.48 dB
2370 MHz	1.47 dB
2382.5 MHz	1.45 dB
2395 MHz	1.47 dB
2407.5 MHz	1.46 dB
2420 MHz	1.44 dB
2432.5 MHz	1.44 dB
2442.5 MHz	1.44 dB

Scanned Image of PC Board

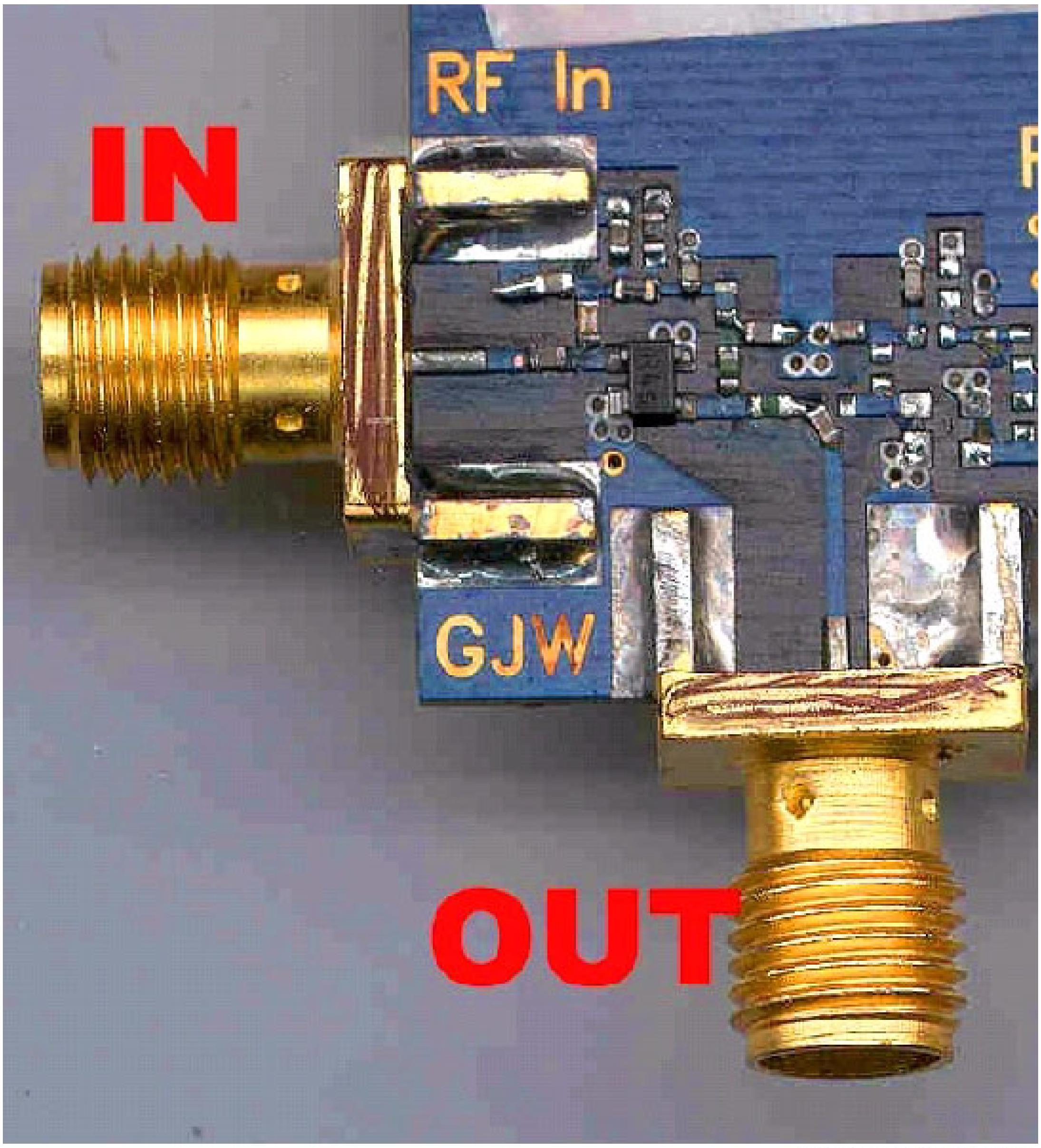


AN137_pic_PCB.vsd

Figure 5 Image of PC Board

Scanned Image of PC Board, Close-In Shot.

Total PCB area used ≅ 41 mm²



AN137_pic_PCB_close_in.vsd

Figure 6 Image of PC Board, Close-In Shot

Stability Factor "K" and Stability Measure "B_1" (50 Hz - 20.050 GHz)

Plots are generated from real, measured S parameters taken from the demo PC board, NOT a simulation. S parameters are exported from Agilent 8720 ES Network Analyzer, then imported into Eagleware GENESYS software, which calculates and plots K and B_1. Note K > 1 and B_1 > 0, showing unconditional stability.

K is trace in red color (bottom trace) and is assigned to left vertical axis at bottom of page. Note K > 1.

B_1 is trace is blue in color (top trace) and is assigned to right vertical.

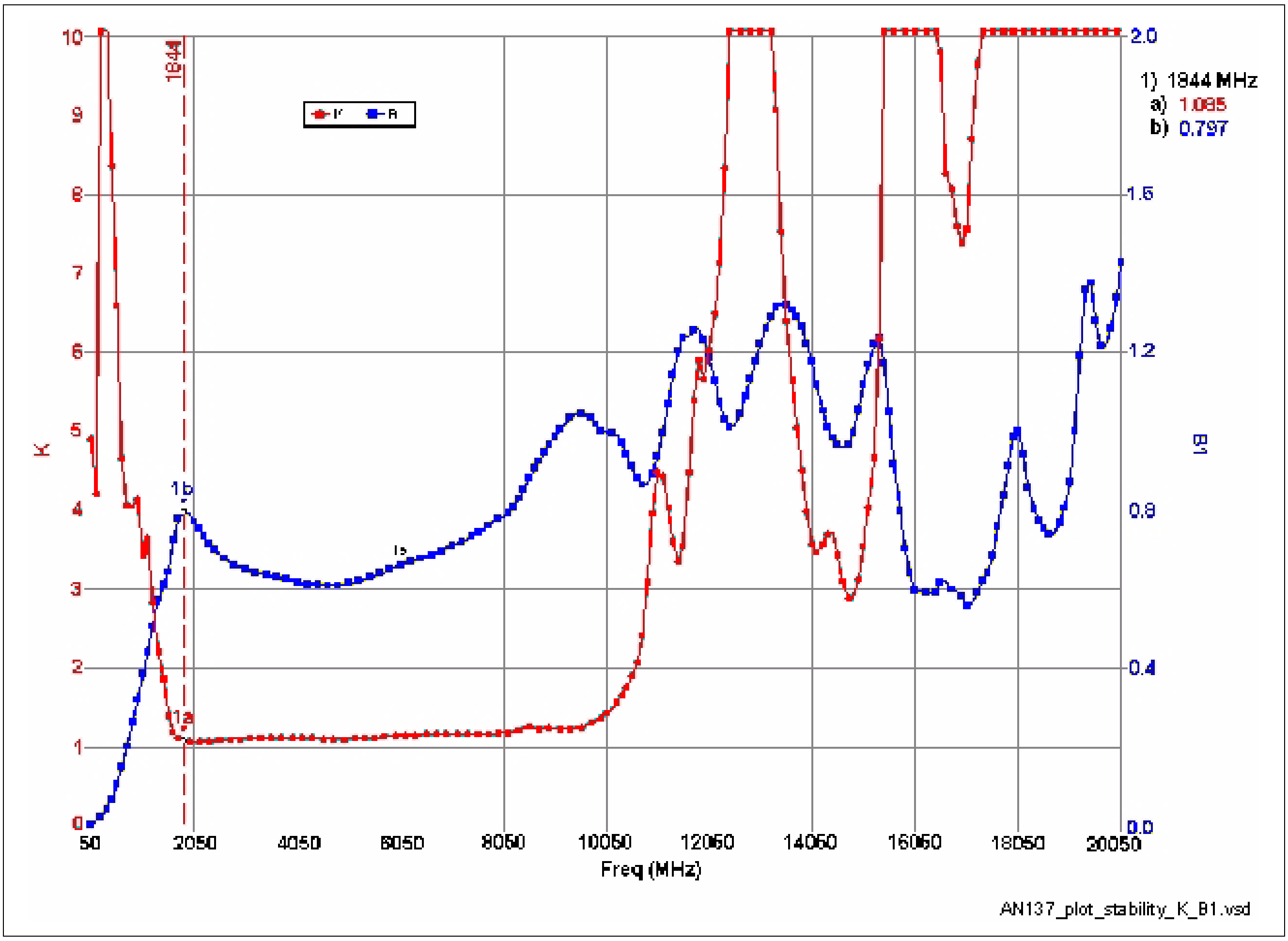


Figure 7 Plot of K(f) and B_1(f)

Gain Compression Test

V_{CC} = 3.0 Volts

Network Analyzer is set to "CW" mode - e.g. set to a single frequency, with power sweep. Input power is swept from -25 dBm to +3 dBm at 2332.5 MHz. Amplifier hits Input 1 dB compression point (IP_{1dB}) at - 4.5 dBm input power. Output P_{1dB} = - 4.5 dBm + 17 dB gain at P_{1dB} point => +12.5 dBm, or 17.8 mW.

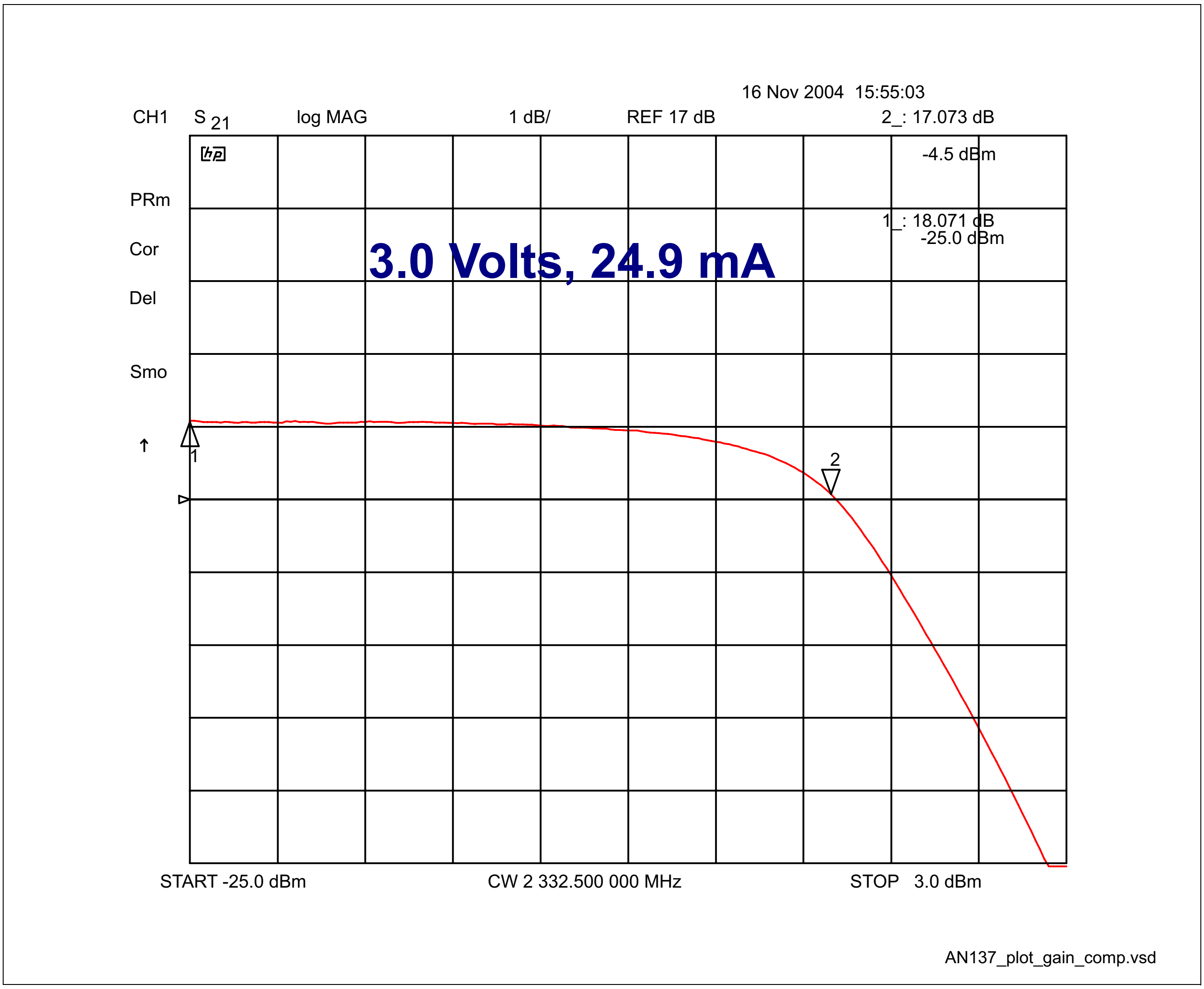


Figure 8 Plot of Gain Compression Test

Input Return Loss, Log Mag

5 MHz - 6 GHz

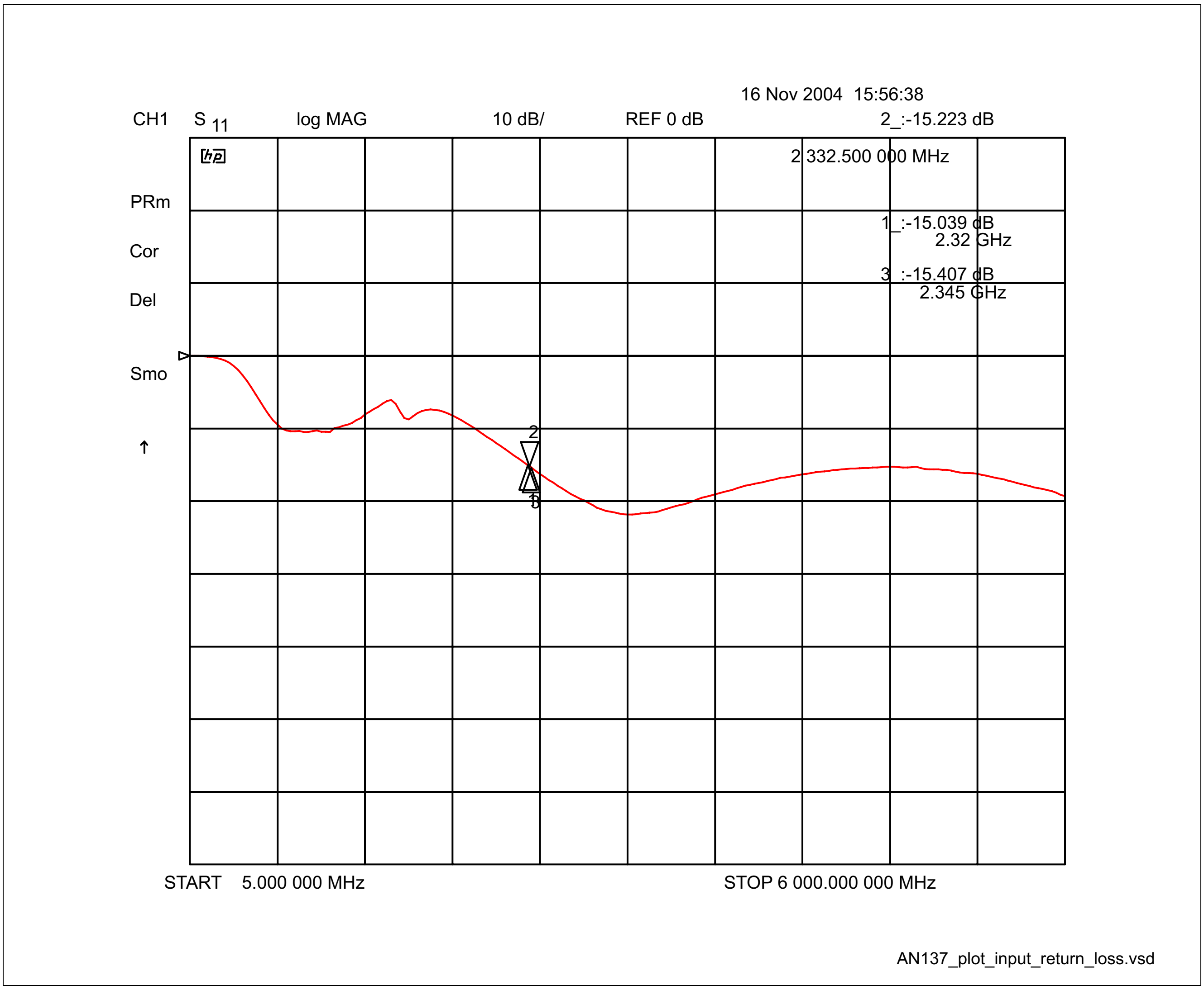


Figure 9 Plot of Input Return Loss

Input Return Loss, Smith Chart

Reference Plane = Input SMA Connector on PC Board
5 MHz - 6 GHz

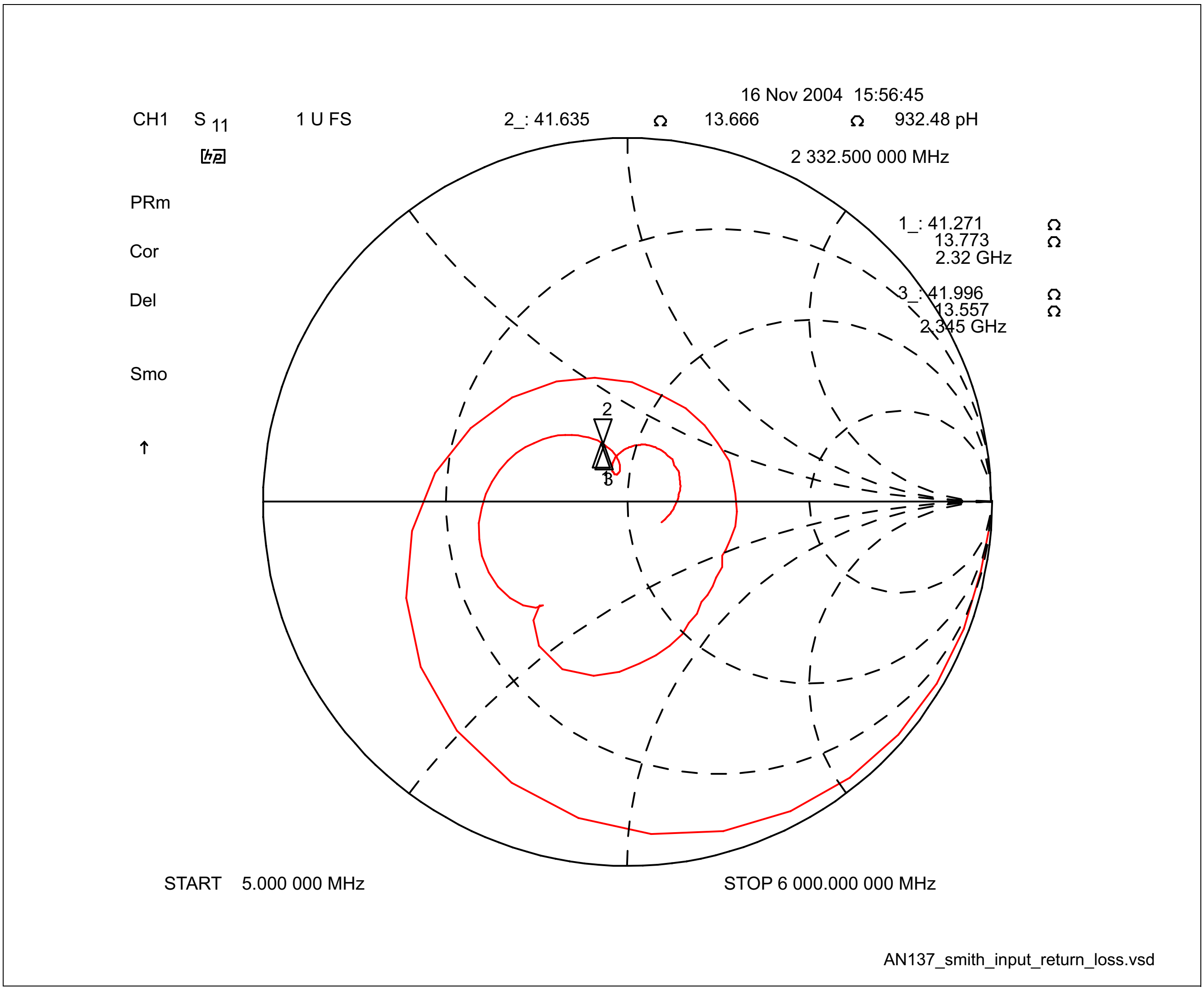


Figure 10 Smith Chart of Input Return Loss

Forward Gain

5 MHz - 6 GHz

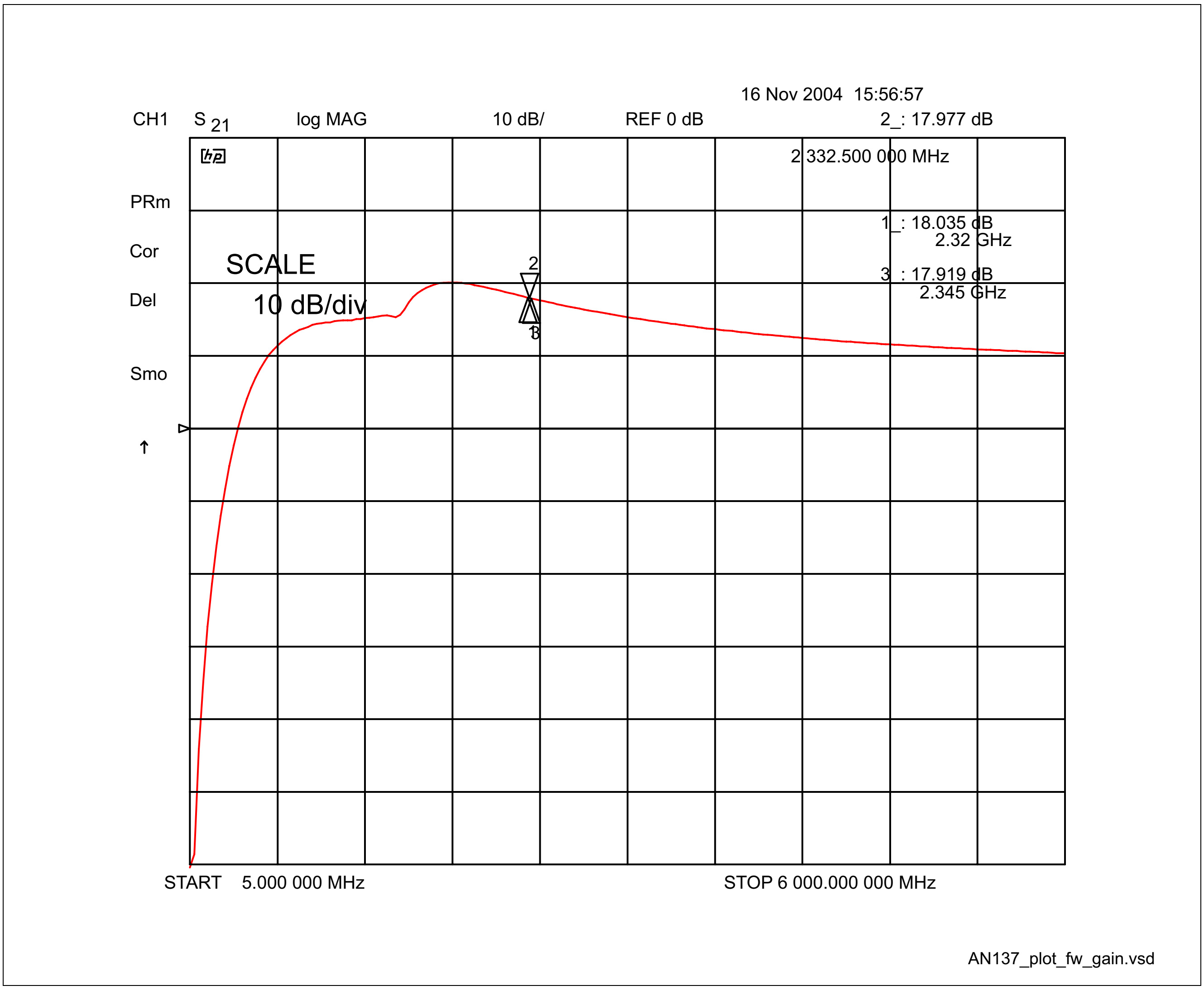
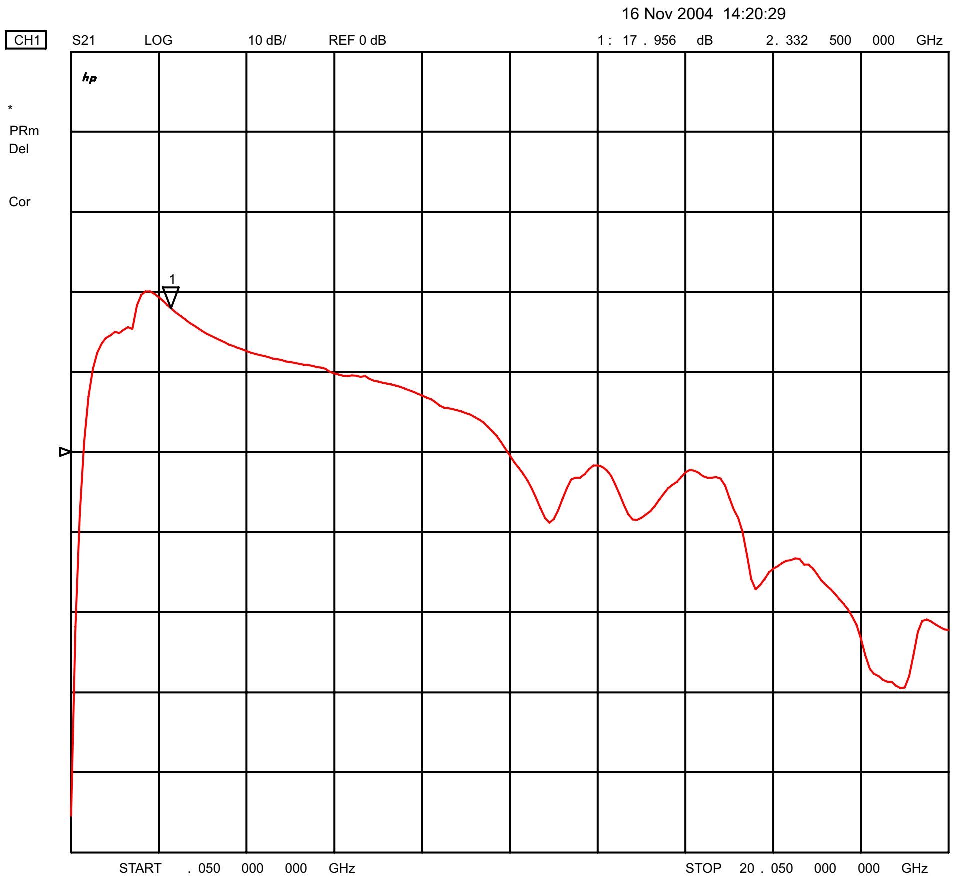


Figure 11 Plot of Forward Gain

Forward Gain, 50 MHz to 20.050 GHz (from Agilent 8720 ES)

Marker is at 2332.5 MHz



AN137_plot_fw_gain_agilent.vsd

Figure 12 Plot of Forward Gain from Agilent 8720 ES

Reverse Isolation

5 MHz - 6 GHz

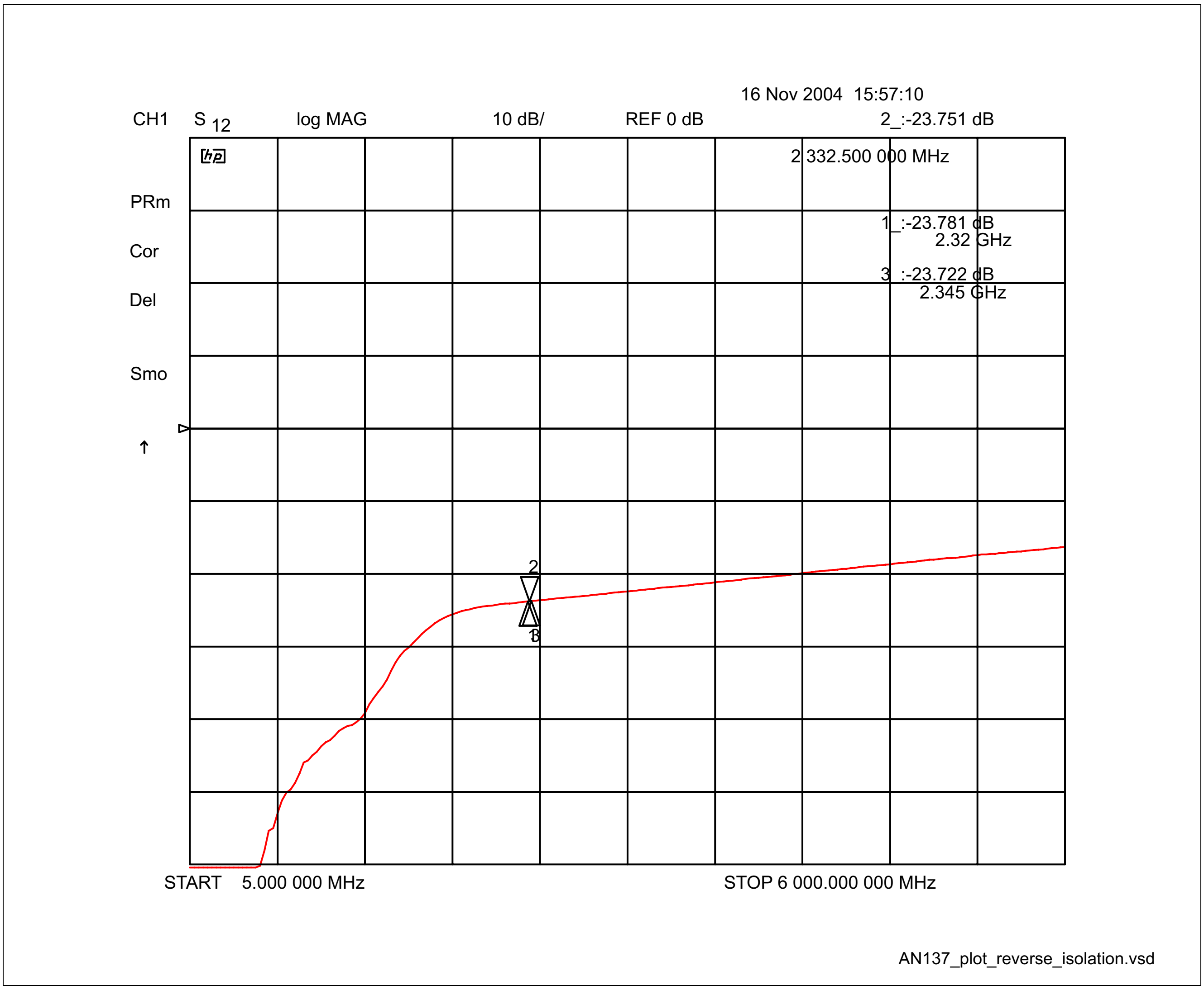


Figure 13 Plot of Reverse Isolation

Output Return Loss, Log Mag

5 MHz - 6 GHz

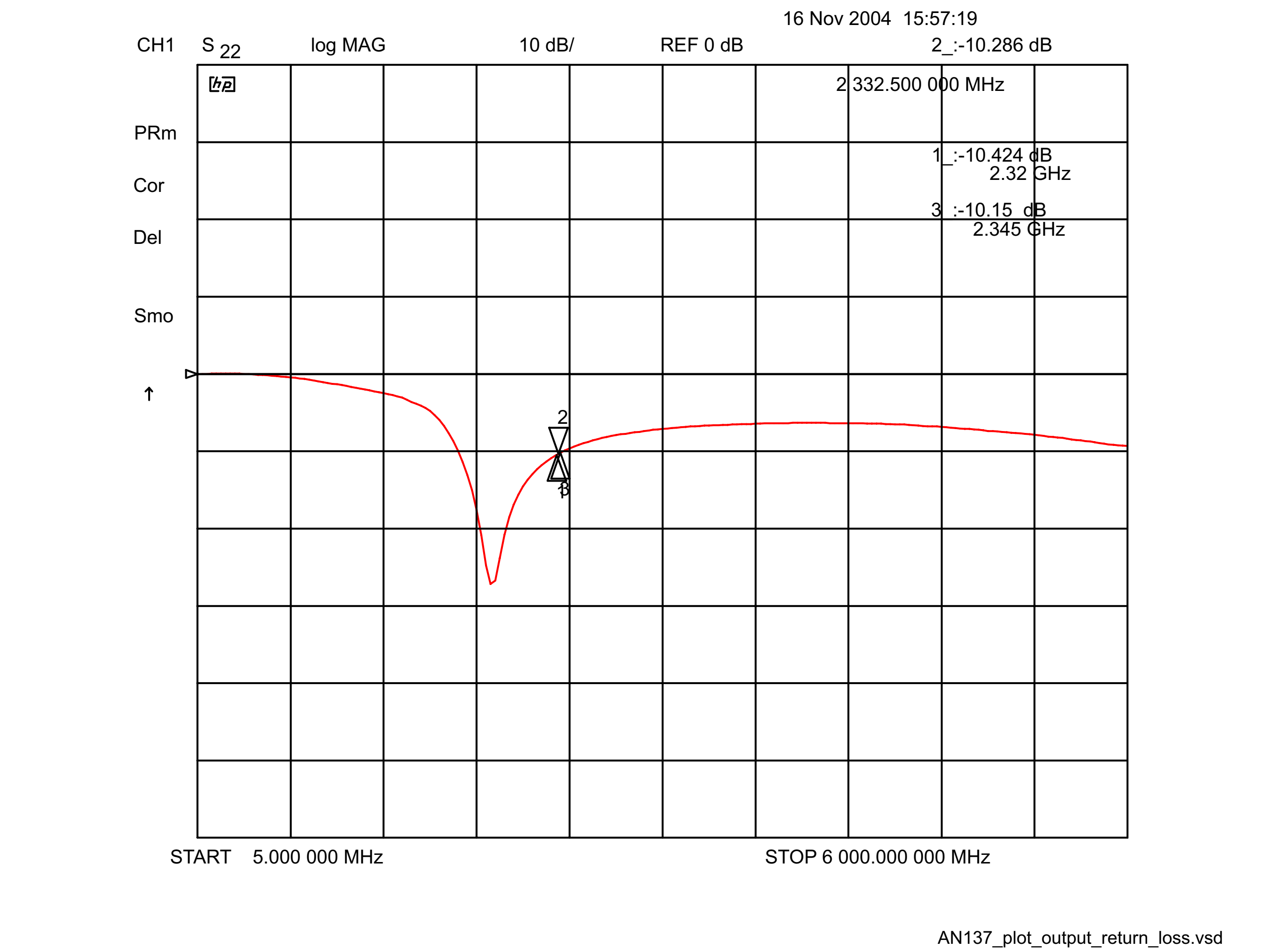


Figure 14 Plot of Output Return Loss

Output Return Loss, Smith Chart

Reference Plane = Output SMA Connector on PC Board
5 MHz - 6 GHz

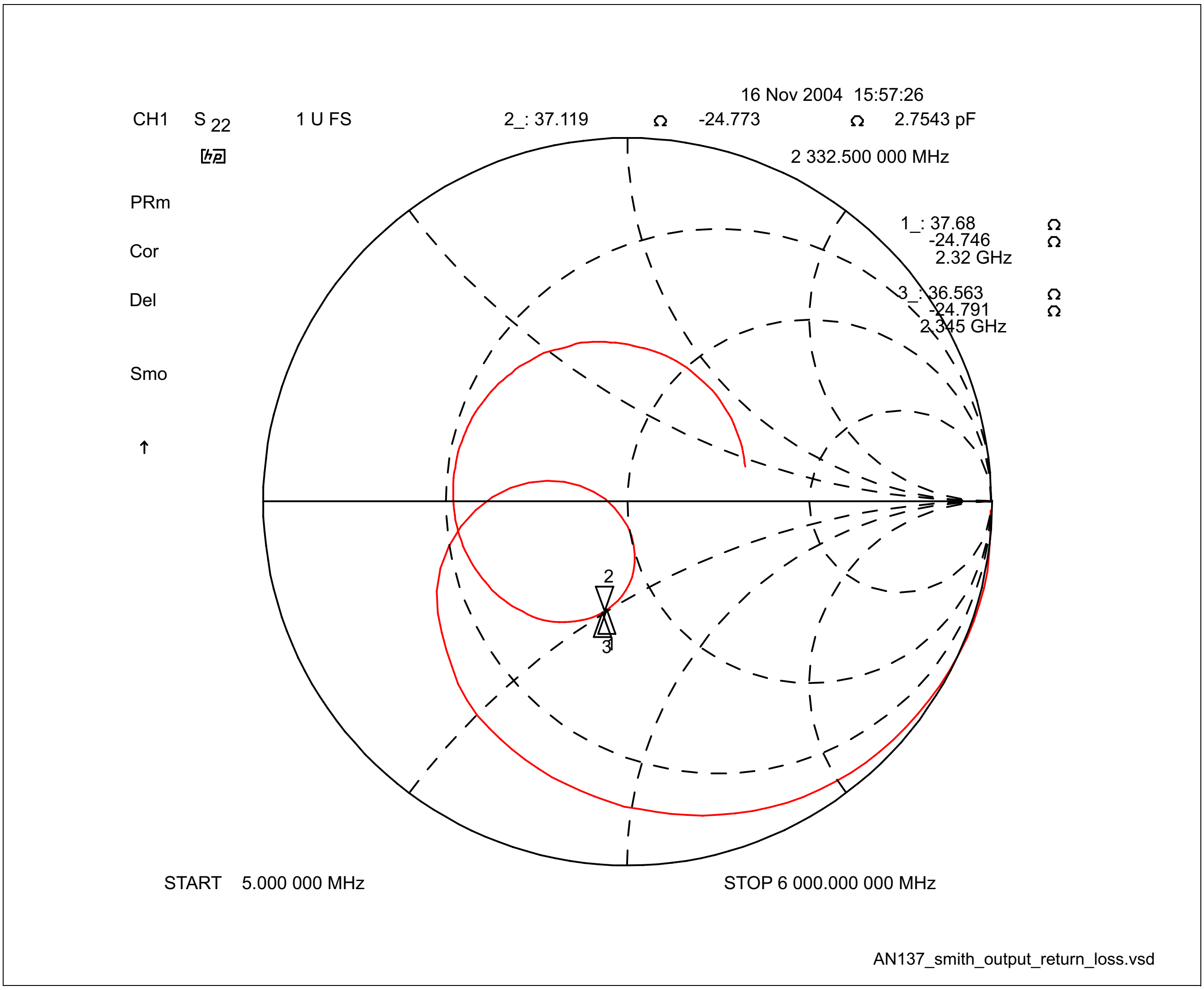


Figure 15 Smith Chart of Output Return Loss

Two-Tone Test, 2332 MHz

Input Stimulus for Amplifier Two-Tone Test.
f_1 = 2332 MHz, f_2 = 2333 MHz, -19 dBm each tone.

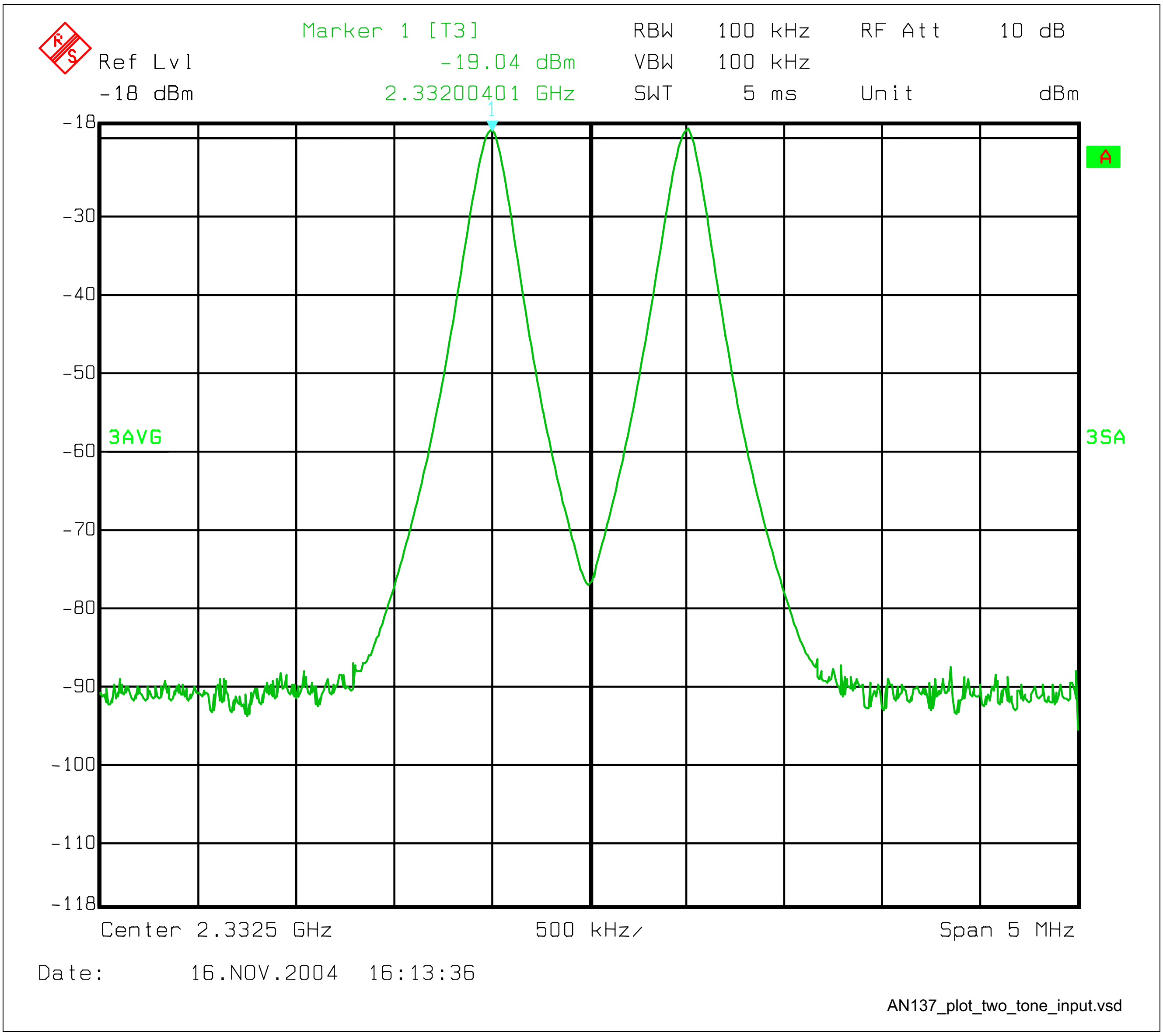


Figure 16 Tow-Tone Test, Input Stimulus @ 2332 MHz

Two-Tone Test, 2332 MHz

LNA Response to Two-Tone Test.

Input IP_3 = -19 + (58.0 / 2) = +10.0 dBm
Output IP_3 = +10.0 dBm + 18.0 dB gain = +28.0 dBm

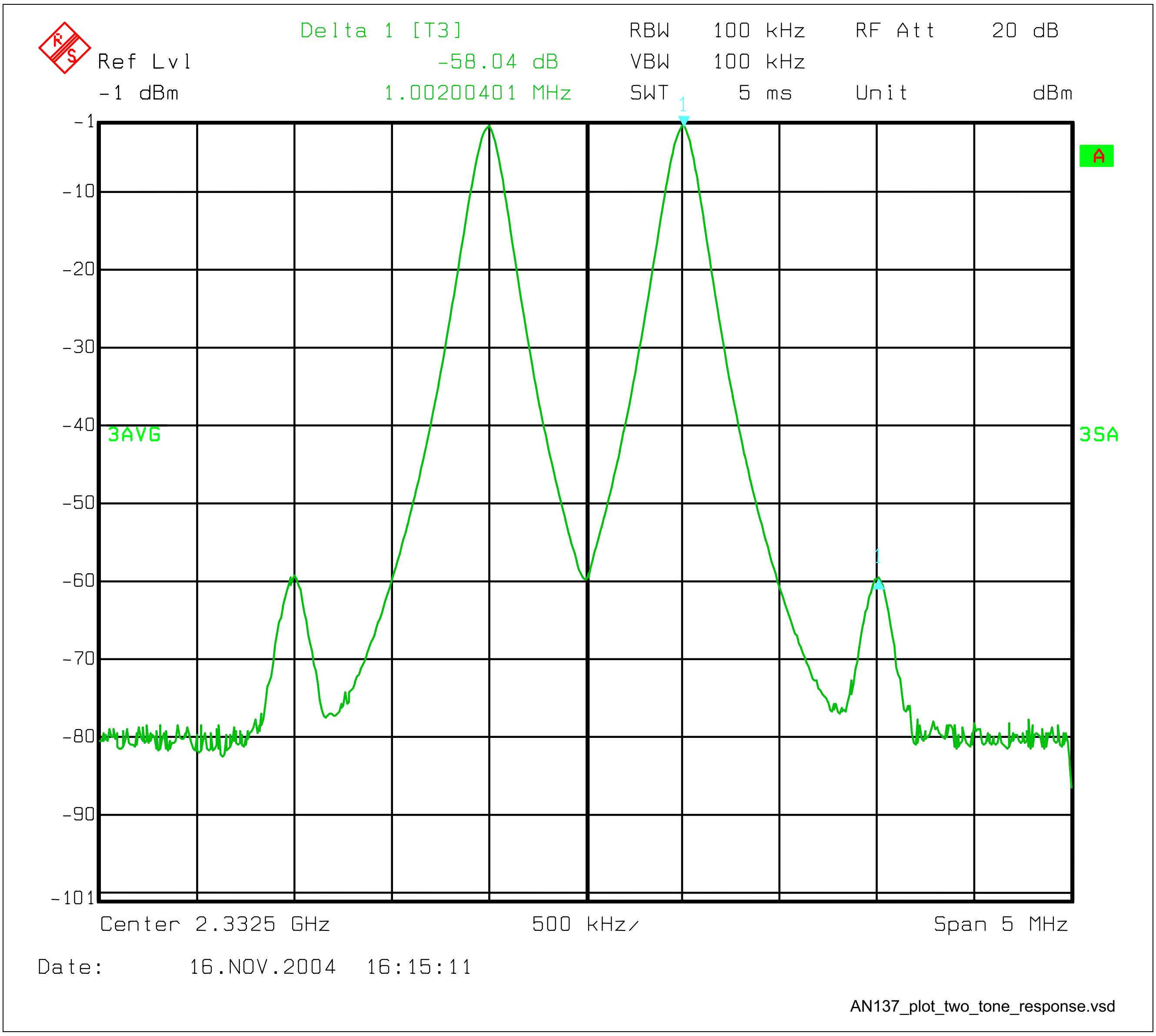


Figure 17 Tow-Tone Test, LNA Response @ 2332 MHz