Application Note No. 129

Low Noise Amplifier for 2.3 to 2.5 GHz Applications using the SiGe BFP640F Transistor

Small Signal Discretes

Never stop thinking

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Application Note No. 129

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Previous Version: 2005-08-19, Rev. 1.1	
Page	**Subjects (major changes since last revision)**
All	Small changes in figure descriptions

1 Low Noise Amplifier for 2.3 to 2.5 GHz Applications using the SiGe BFP640F Transistor

Applications

- 2.4 GHz ISM band (Blue Tooth, Cordless Phone, Wireless LAN, ZigBee, etc.)
- 2.33 GHz “SDARS” Satellite Radio (e.g. “XM Radio”)

Overview

- BFP640F in TSFP-4 package is evaluated for 2.3 - 2.5 GHz LNA application. Note TSFP-4 package is only 1.4 x 1.2 x 0.55 mm high. Printed Circuit Board used is Infineon Part Number 640F-021904 Rev A. Standard FR4 material is used in a three-layer PCB. Please refer to cross-sectional diagram below.
- 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 8 GHz.
- Total PCB area used for the single LNA stage is < 40 mm². Total Parts count, including the BFP640 transistor, is 12.

Target Specifications

- Design Goals: Gain = 15 dB min, Noise Figure < 1.0 dB, Input / Output Return Loss 10 dB or better, current < 7 mA from a 3.0 V power supply.

Summary of Results

T = 25 °C, V_{CC} = 3.0 V, I_C = 6.3 mA, V_{CE} = 2.5 V, network analyzer source power ≅ -30 dBm

Table 1 Summary of Results

Frequency MHz	dB $[S_{11}]^2$	dB $[S_{21}]^2$	dB $[S_{12}]^2$	dB $[S_{22}]^2$	$NF^{(1)}$ dB	IIP_3 (2) dBm	OIP_3 (2) dBm	IP_{1dB} dBm	OP_{1dB} dBm
2330	10.3	15.7	21.0	17.9	0.9	---	---	---	---
2400	11.1	15.5	20.7	16.8	0.9	+0.1	+29.6	-11.1	+3.4
2500	12.5	15.1	20.5	14.4	0.9	---	---	---	---

(1) Note that PCB loss is not extracted. If PCB loss were extracted, NF would be 0.1 to 0.2 dB lower.
(2) Outstanding Third-Order Intercept Performance

PCB Cross - Section Diagram

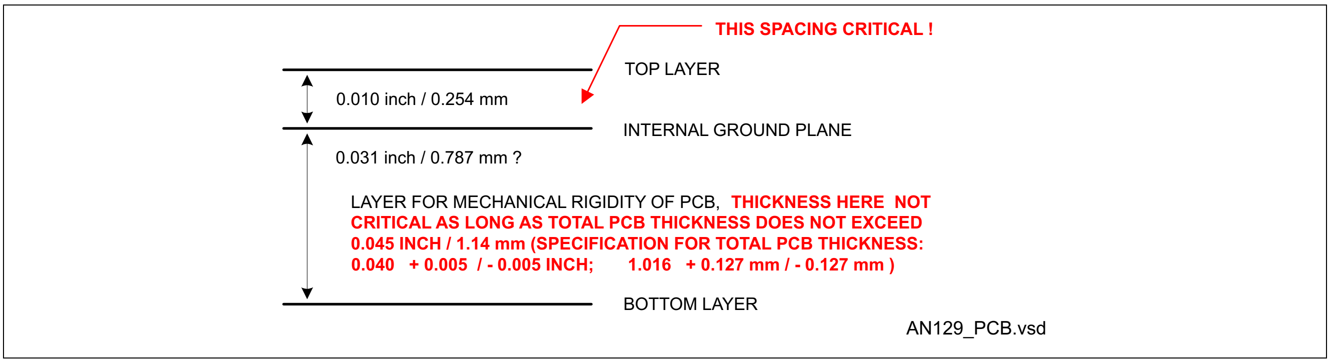


Figure 1 PCB - Cross Sectional Diagram

TSFP-4 Package Details

(Dimensions in Millimeters). Note maximum package height is 0.59 mm / 0.023 inch.

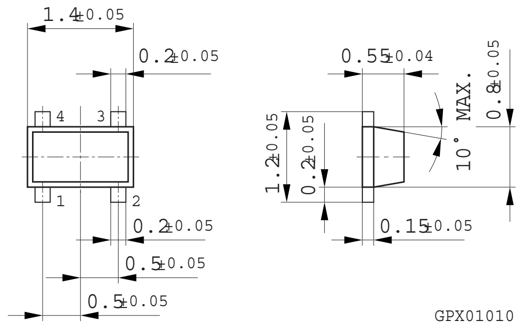


Figure 2 Package Details of TSFP-4

Recommended Soldering Footprint for TSFP-4 (dimensions in millimeters).

Device package is to be oriented as shown in above drawing (e.g. orient long package dimension horizontally on this footprint).

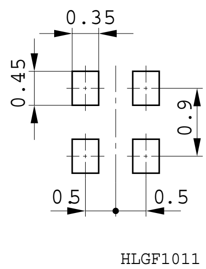


Figure 3 Package Footprint of TSFP-4

Bill of Material

Table 2 Bill of Material

Reference Designator	Value	Manufacturer	Case Size	Function
C1	33 pF	Various	0402	DC blocking, input. Also, using cap above serf-resonance makes it slightly inductive, slightly improving input match.
C2	1.2 pF	Various	0402	DC block, output. also influences output and input impedance match.
C3	0.022 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 influence on output match and stability.
C6	0.022 µF	Various	0402	Decoupling, low frequency.
L1	12 nH	Murata LQG 15HN series low cost inductor	0402	RF choke at input.
L2	3.9 nH	Murata LQG 15HN series low cost inductor	0402	RF Choke + impedance match at output.
R1	10 Ω	Various	0402	Stability improvement.
R2	43 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	TSFP-4	BFP640F 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 2300 - 2500 MHz LNA

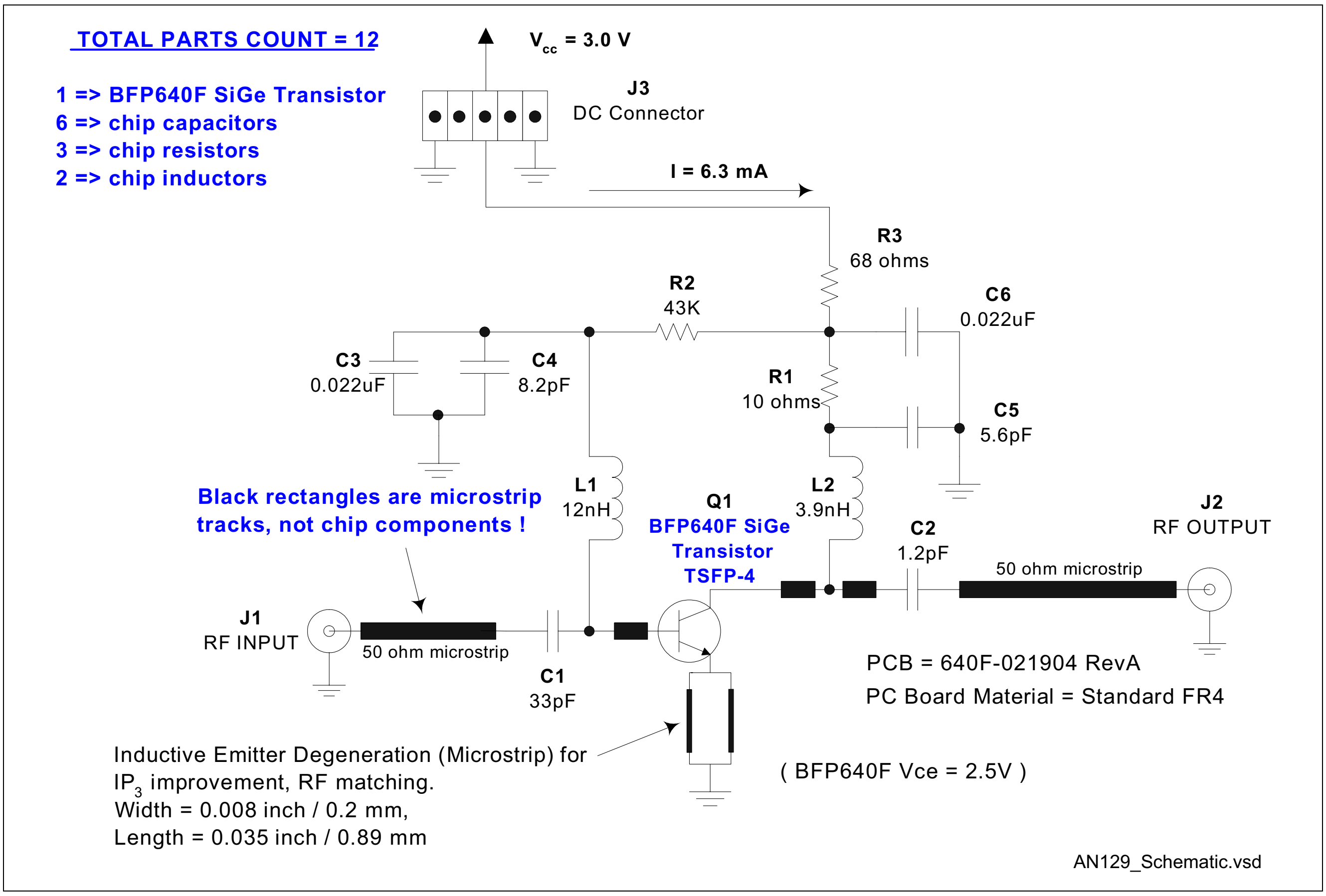


Figure 4 Schematic Diagram

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

Rohde & Schwarz FSEK3

24 Aug 2005

Noise Figure

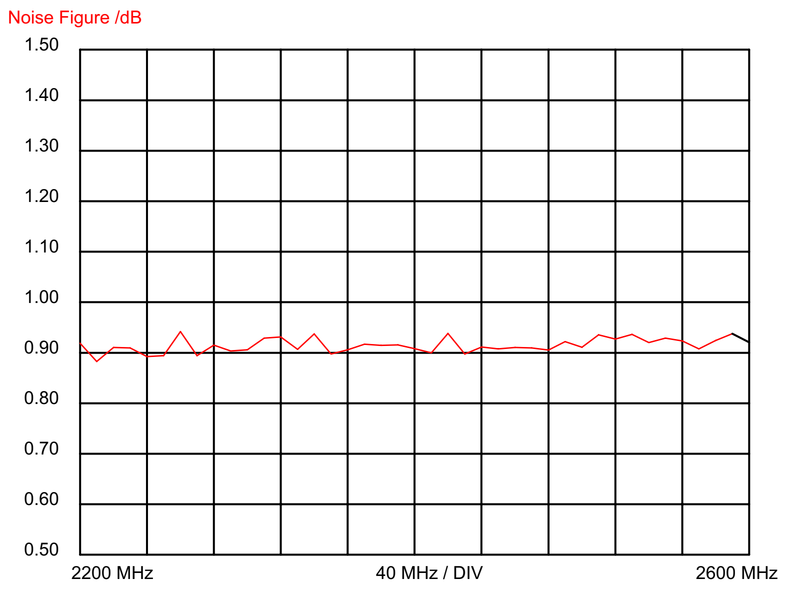
EUT Name:	BFP640F LNA, 2.3 to 2.5 GHz
Manufacturer:	Infineon Technologies
Operating Conditions:	V = 3.0 V, I = 6.3 mA, T = 25 C
Operator Name:	Gerard Wevers
Test Specification:	
Comment:	
	24 August 2005

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



AN129_plot_nf.vsd

Figure 5 Noise Figure

Noise Figure, Tabular Data

Table 3 Noise Figure

Frequency	Noise Figure
2200 MHz	0.92 dB
2210 MHz	0.88 dB
2220 MHz	0.91 dB
2230 MHz	0.91 dB
2240 MHz	0.89 dB
2250 MHz	0.89 dB
2260 MHz	0.94 dB
2270 MHz	0.89 dB
2280 MHz	0.91 dB
2290 MHz	0.90 dB
2300 MHz	0.91 dB
2310 MHz	0.93 dB
2320 MHz	0.93 dB
2330 MHz	0.91 dB
2340 MHz	0.94 dB
2350 MHz	0.90 dB
2360 MHz	0.91 dB
2370 MHz	0.92 dB
2380 MHz	0.91 dB
2390 MHz	0.92 dB
2400 MHz	0.91 dB
2410 MHz	0.90 dB
2420 MHz	0.94 dB
2430 MHz	0.90 dB
2440 MHz	0.91 dB
2450 MHz	0.91 dB
2460 MHz	0.91 dB
2470 MHz	0.91 dB
2480 MHz	0.91 dB
2490 MHz	0.92 dB
2500 MHz	0.91 dB
2510 MHz	0.94 dB
2520 MHz	0.93 dB
2530 MHz	0.94 dB
2540 MHz	0.92 dB
2550 MHz	0.93 dB
2560 MHz	0.92 dB
2570 MHz	0.91 dB
2580 MHz	0.92 dB

Table 3 Noise Figure (cont'd)

Frequency	**Noise Figure**
2590 MHz	0.94 dB
2600 MHz	0.92 dB

Scanned Image of PC Board

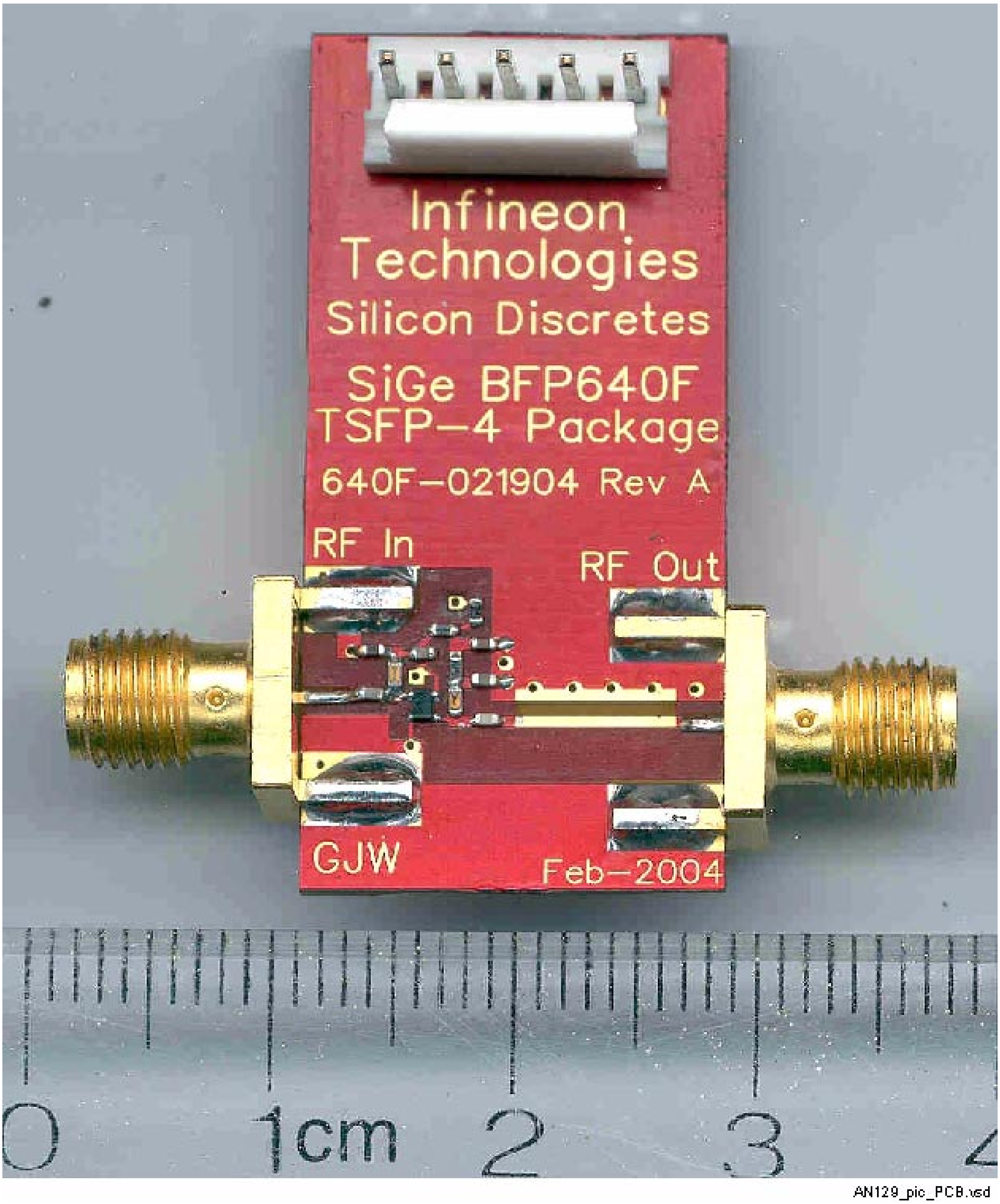


Figure 6 Image of PC Board

Scanned Image of PC Board, Close-In Shot. Total PCB area.

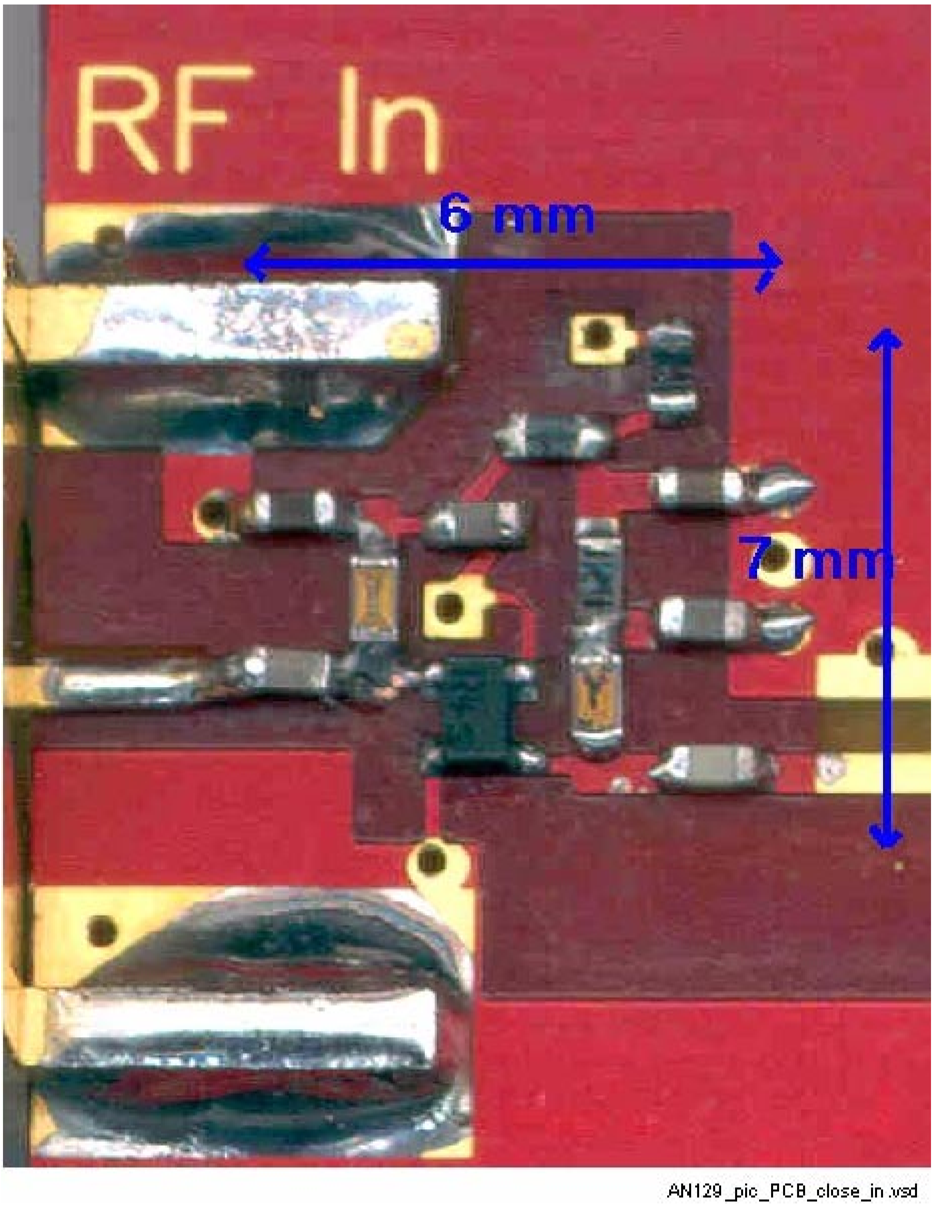


Figure 7 Image of PC Board, Close-In Shot

Gain Compression at 2400 MHz, V_{CC} = 3.0 V, I = 6.3 mA, V_{CE} = 2.5 V

Amplifier is checked for output1 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 $P_{1dB} \cong$ +3.4 dBm
Input $P_{1dB} \cong$ +3.4 dBm - (Gain - 1 dB) = +0.8 dBm - 14.5 dB = -11.1 dBm

Table 4 Gain Compression at 2400 MHz

P_{in}, dBm	P_{out}, dBm
-5.0	15.5
-4.0	15.5
-3.0	15.5
-2.0	15.4
-1.0	15.4
0.0	15.3
+1.0	15.2
+2.0	15.1
+3.0	14.8
+4.0	14.1
+5.0	13.0

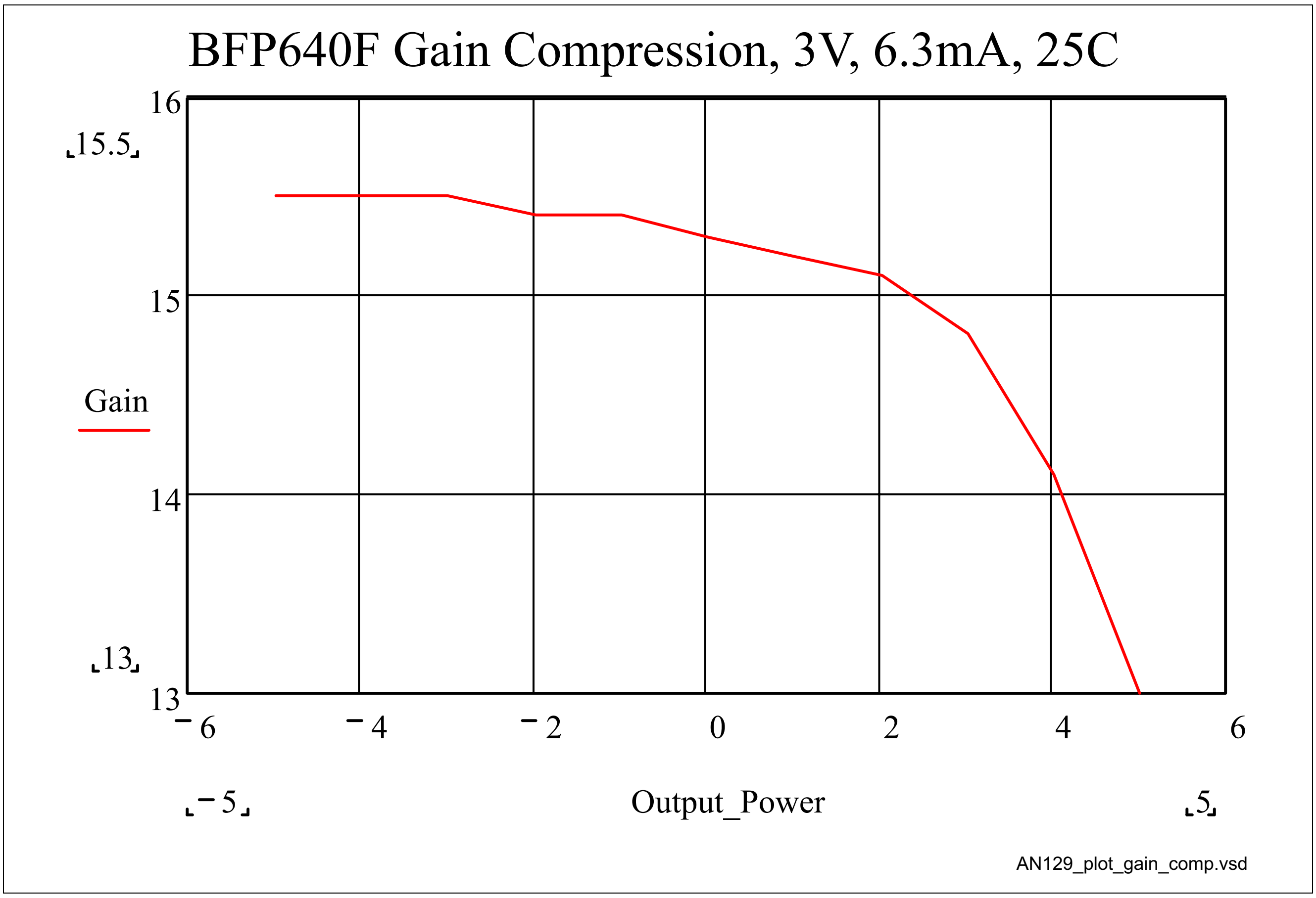


Figure 8 Plot of Gain Compression at 2400 MHz

PLEASE NOTE - All Network Analyzer screen-shots are from Rohde and Schwarz ZVC Network Analyzer, T = 25 °C, source power ≈ -30 dBm

Amplifier Stability, Stability Factor “K”

Rohde and Schwarz ZVC Network Analyzer calculates and plots Stability Factor "K" in real time, from 5 MHz to 8 GHz. Note minimum K value is near 1.05 at 2.5 GHz. Amplifier is unconditionally Stable from 5 MHz to 8 GHz.

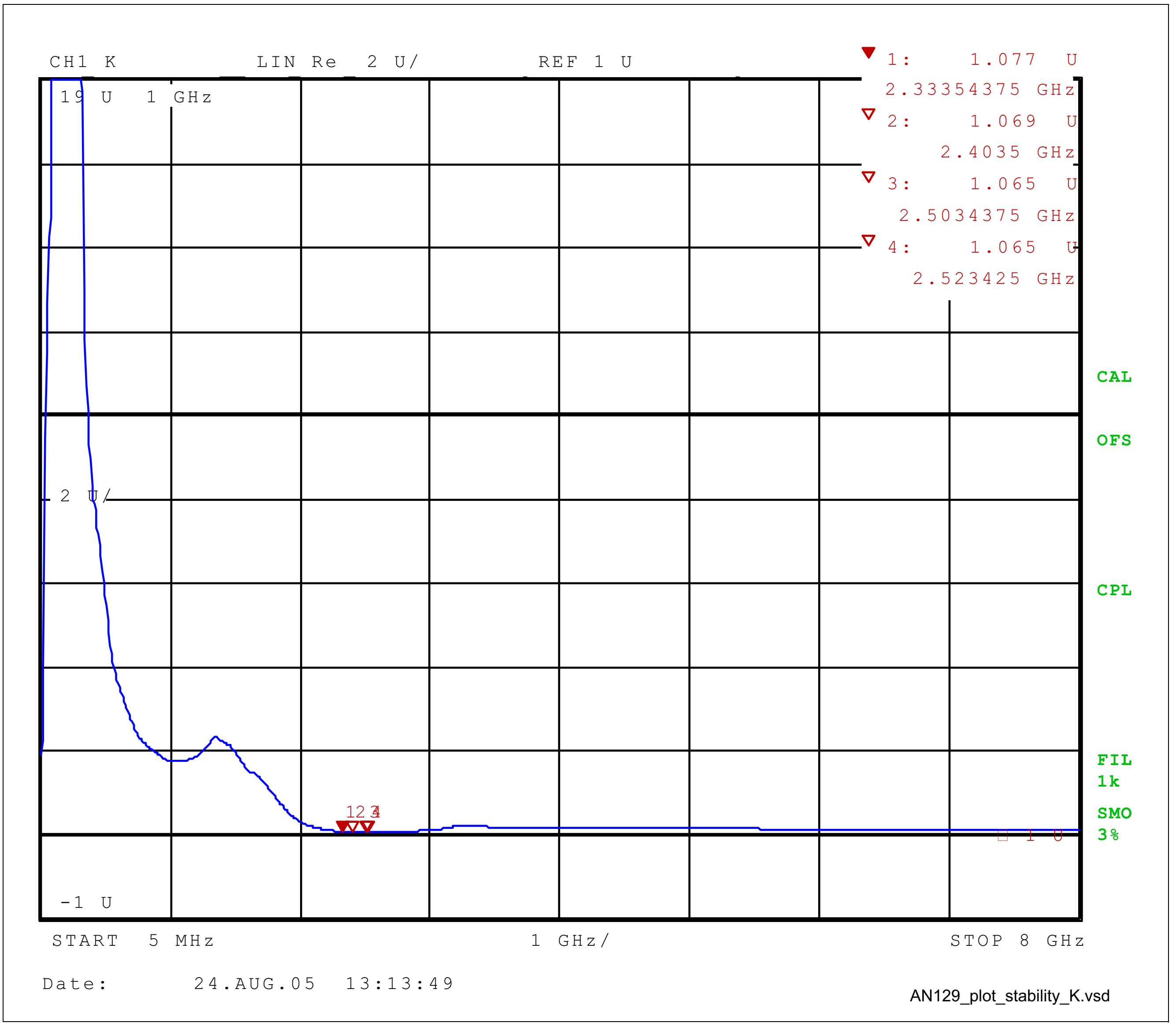


Figure 9 Plot of K(f)

Input Return Loss, Log Mag

5 MHz to 8 GHz Sweep

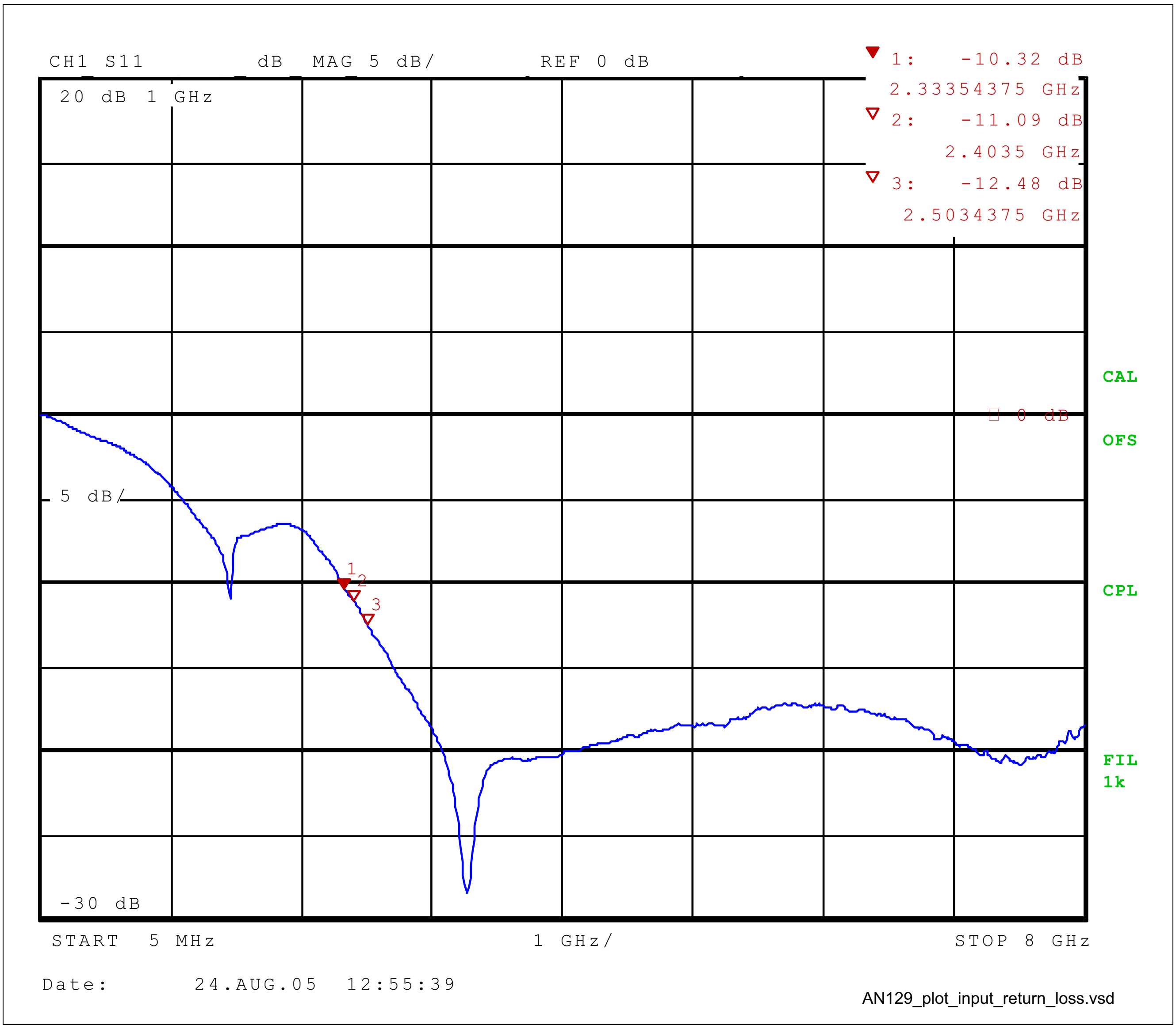


Figure 10 Plot of Input Return Loss

Input Return Loss, Smith Chart

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

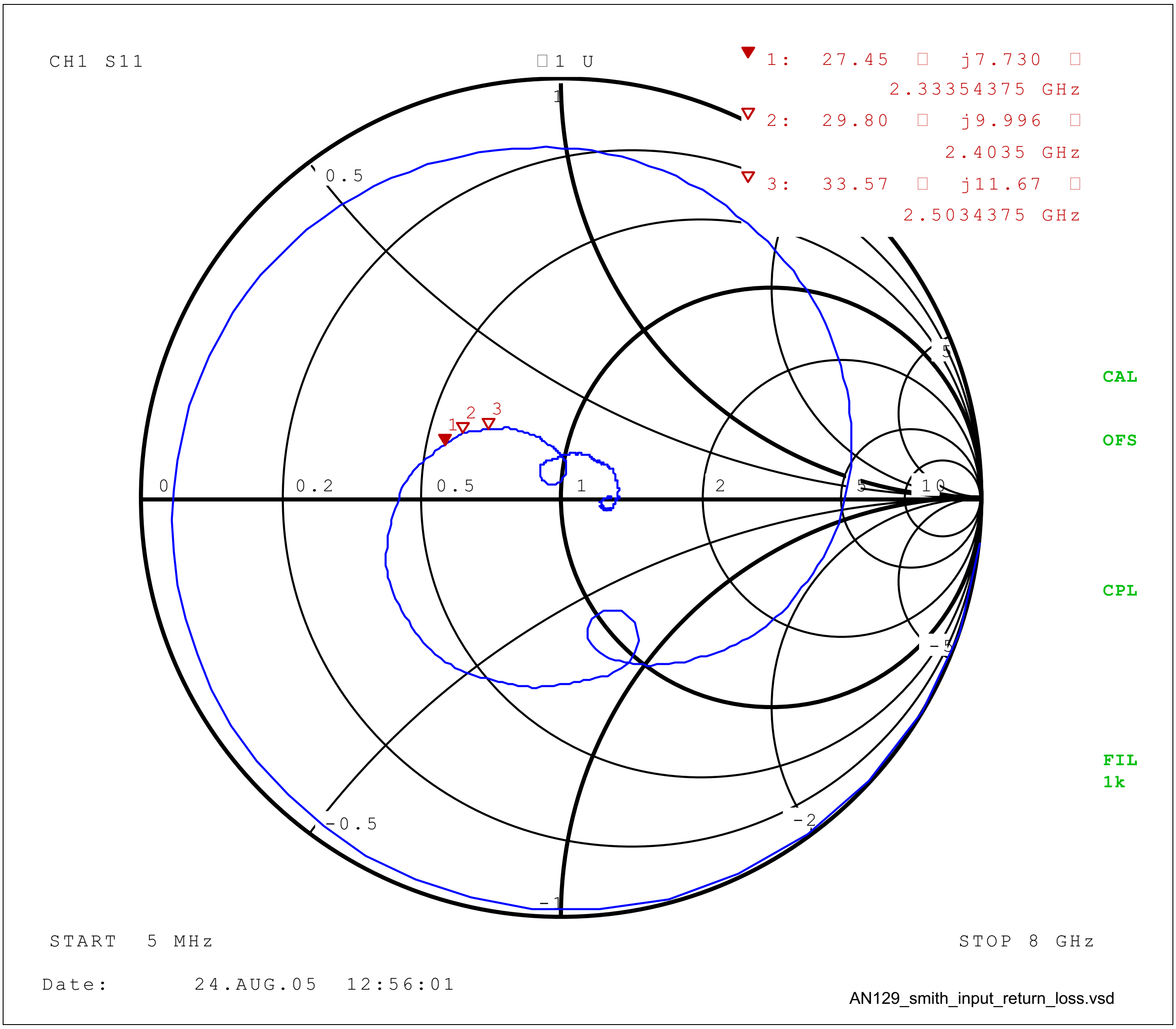


Figure 11 Smith Chart of Input Return Loss

Forward Gain

5 MHz to8 GHz Sweep

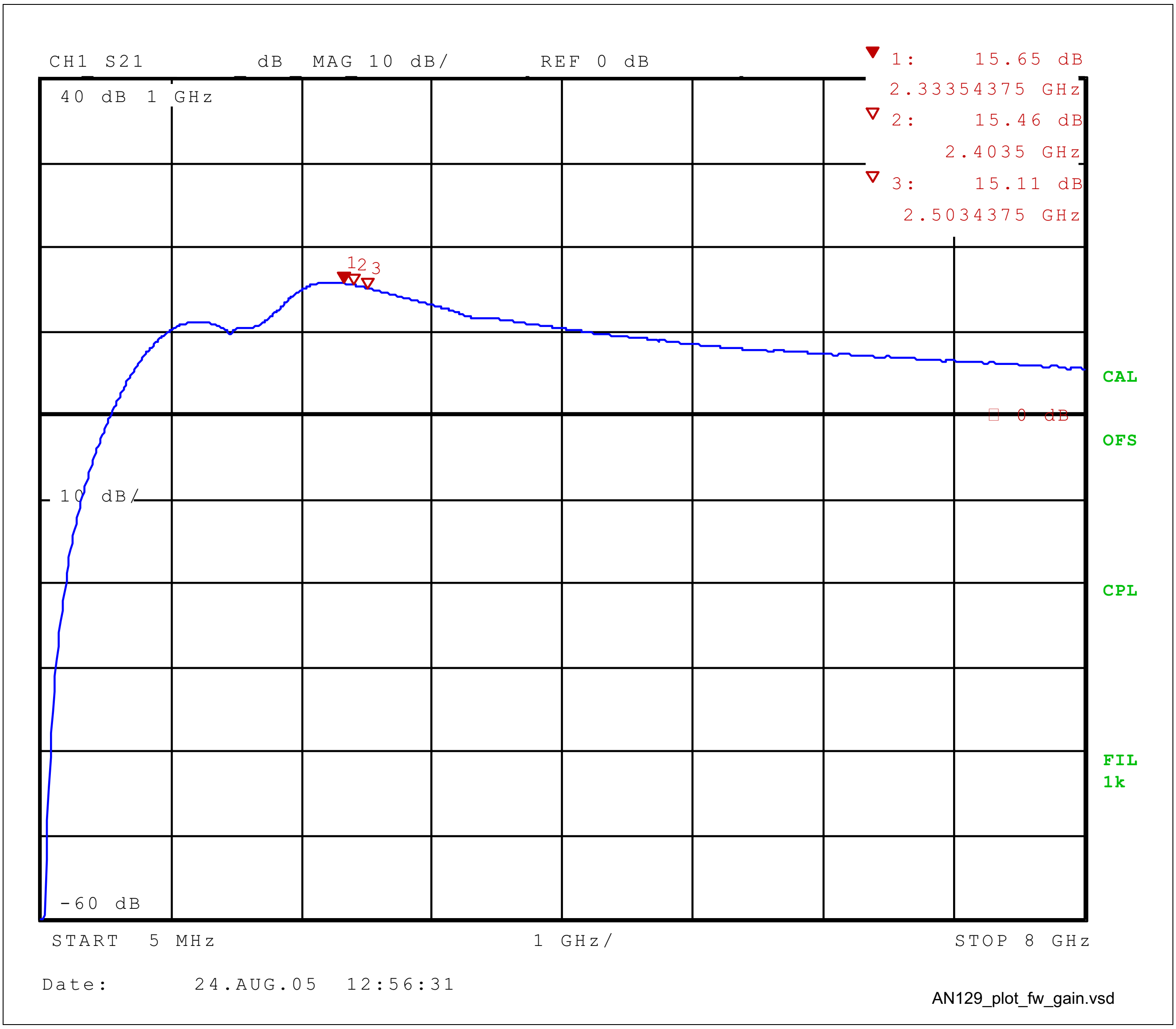


Figure 12 Plot of Forward Gain

Reverse Isolation

5 MHz to 8 GHz

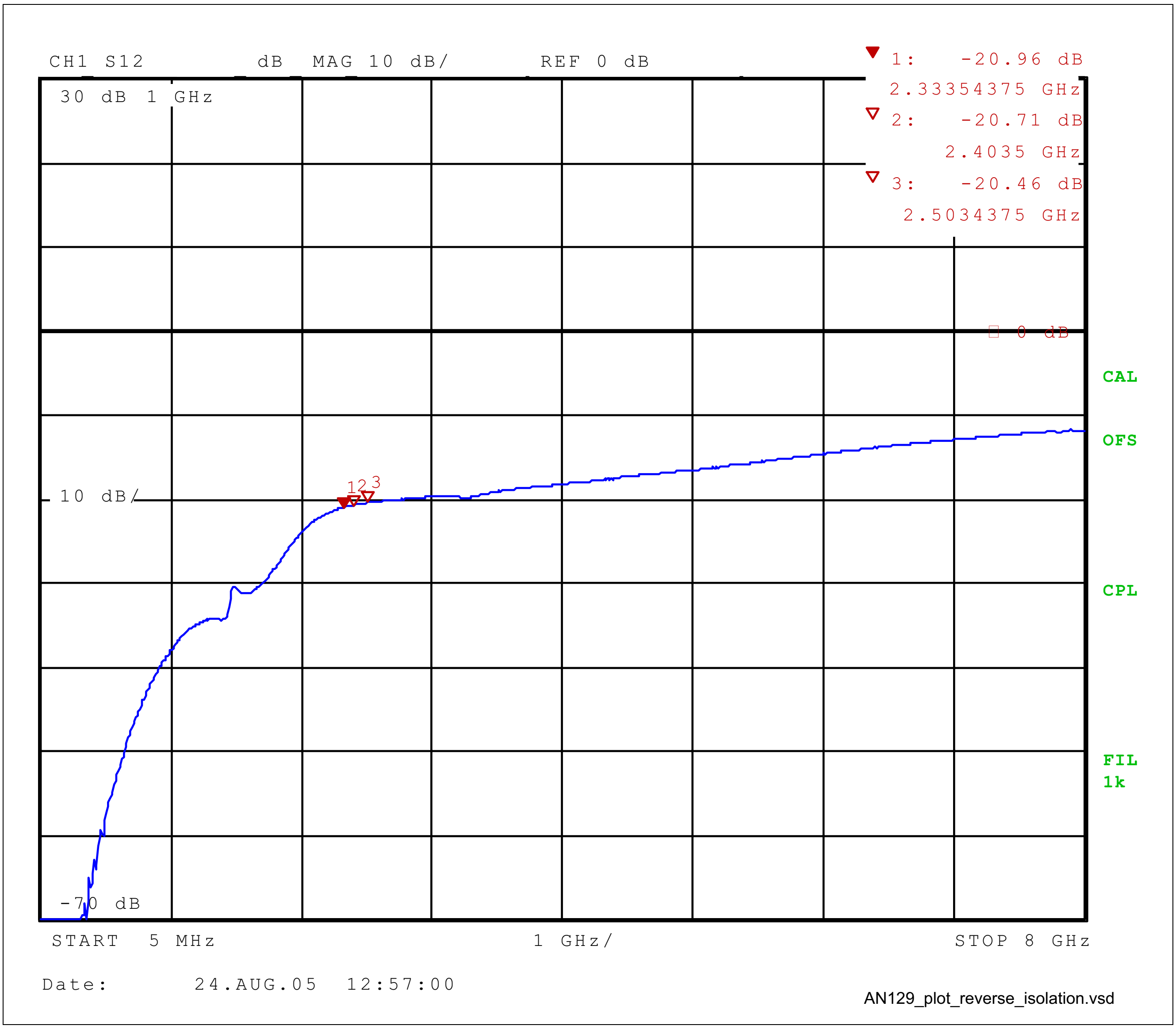


Figure 13 Plot of Reverse Isolation

Output Return Loss, Log Mag

5 MHz to 8 GHz

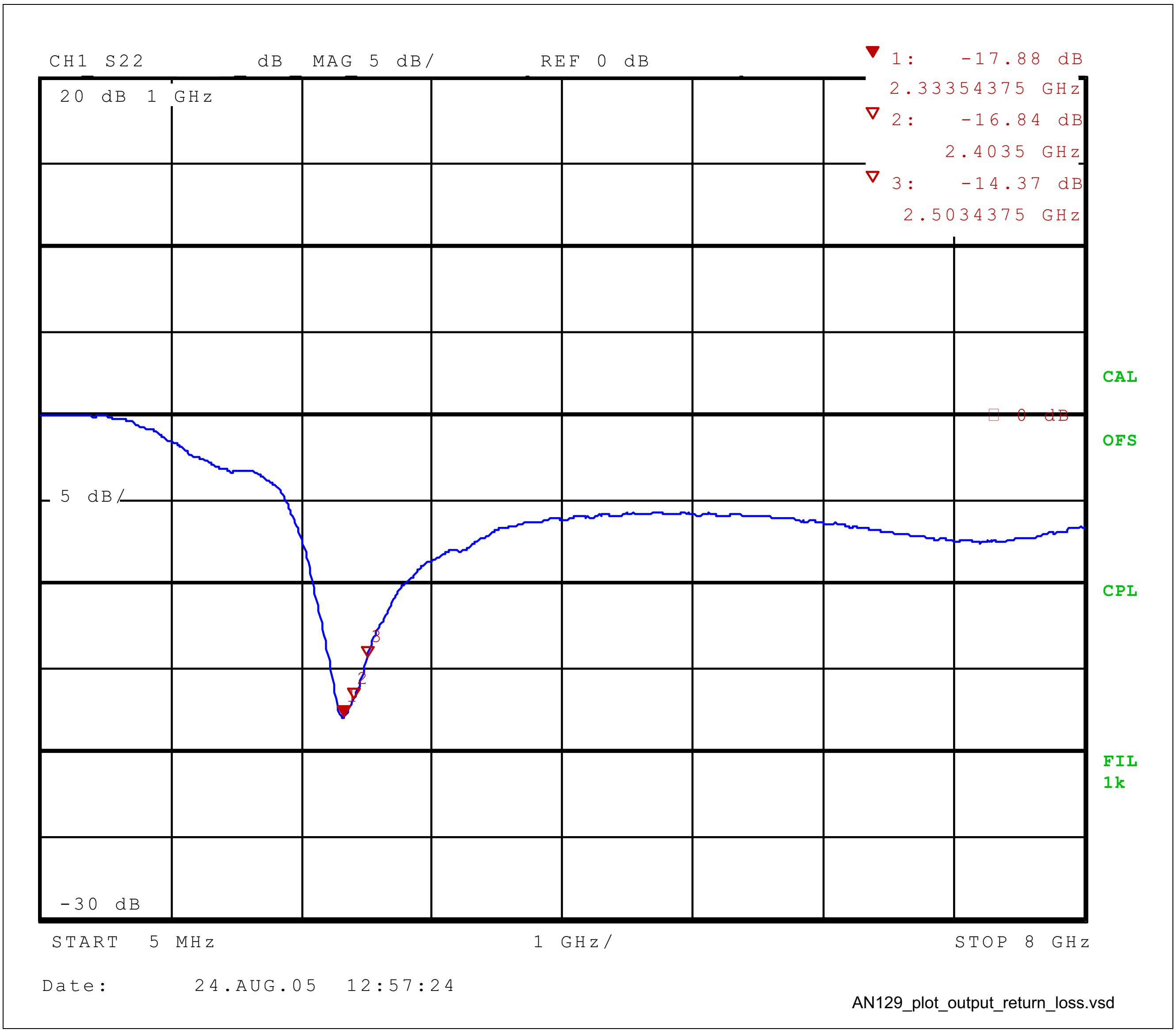


Figure 14 Plot of Output Return Loss

Output Return Loss, Smith Chart

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

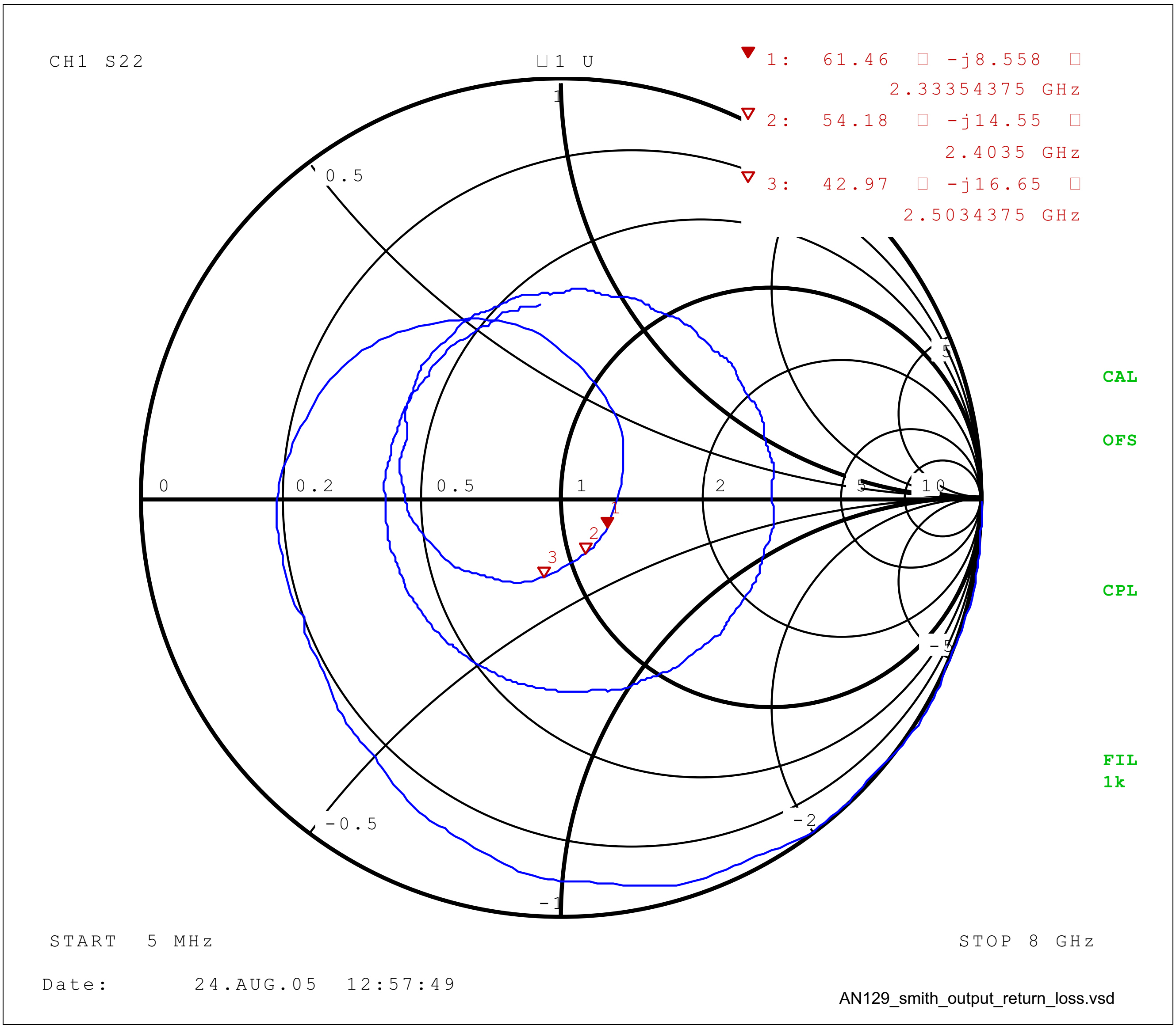


Figure 15 Smith Chart of Output Return Loss

Two-Tone Test, 2400 MHz

Input Stimulus for Amplifier Two-Tone Test.
f_1 = 2400 MHz, f_2 = 2401 MHz, -17 dBm each tone.

Input IP_3 = -17 + (62.1 / 2) = +14.1 dBm
Output IP_3 = +14.1 dBm +15.5 dB gain = +29.6 dBm

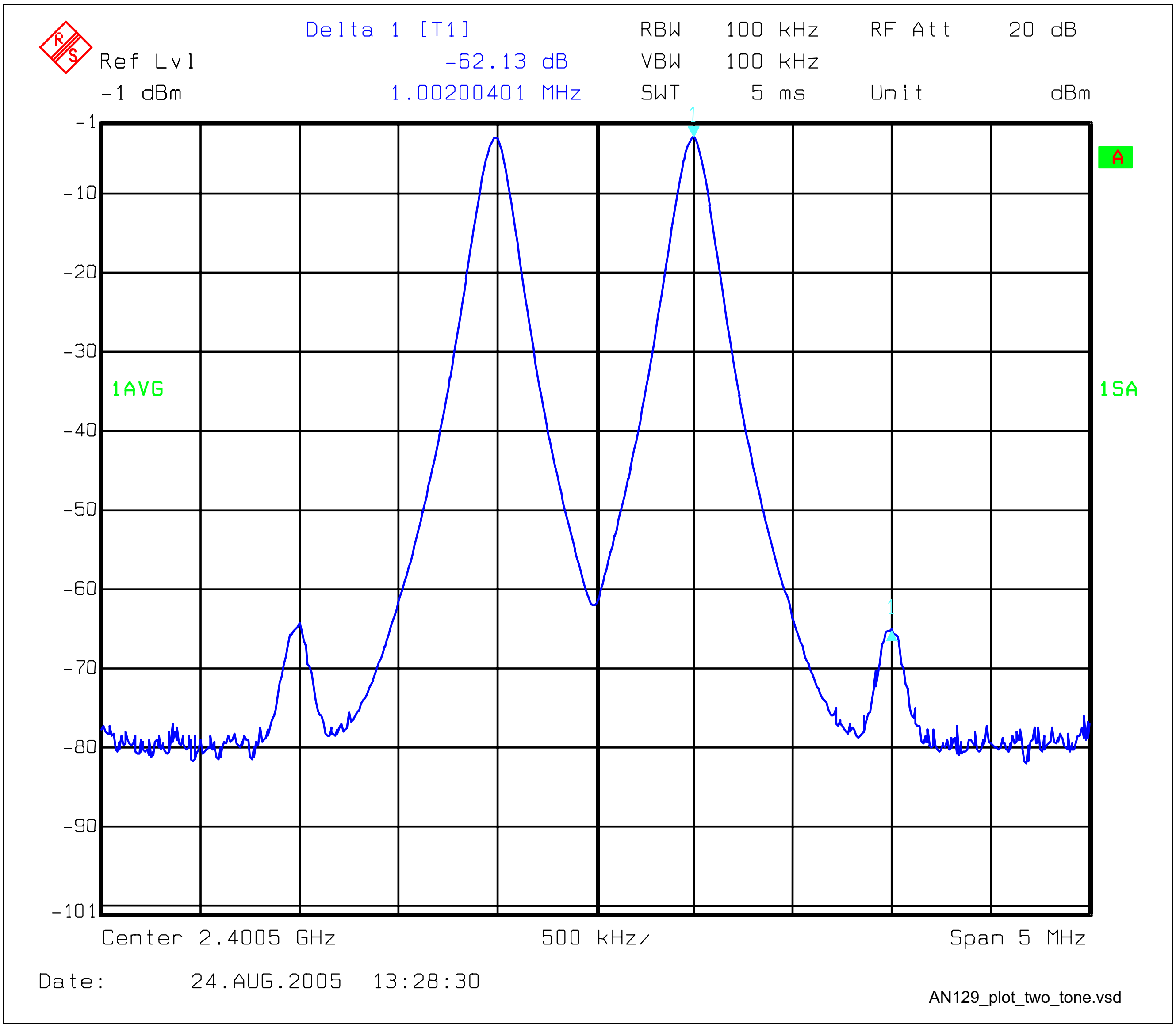


Figure 16 Tow-Tone Test, Input Stimulus @ 2400 MHz