Application Note No. 142

Low Cost, Low Current Broadband UHF Low Noise Amplifier with the ESD-Hardened BFP540ESD RF Transistor draws 3 mA

RF & Protection Devices

Never stop thinking

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Revision History: 2008-02-15, Rev. 1.2

Previous Version: 2006-03-07, Rev. 1.1	
Page	**Subjects (major changes since last revision)**
All	Small changes in figure descriptions

1 Low Cost, Low Current Broadband UHF Low Noise Amplifier with the ESD-Hardened BFP540ESD RF Transistor draws 3 mA

Applications

- External LNA for 315 / 434 MHz extended-range automotive Remote Keyless Entry (RKE) / Tire Pressure Monitoring System (TPMS) receivers, 900 MHz ISM band, 345 MHz Wireless Security Systems, 390 MHz garage door opener receivers, 288 - 418 MHz HomeLink™ Wireless products.

Overview

The ESD-hardened BFP540ESD RF Transistor, capable of sustaining 1000 V Electro Static Discharge (ESD) pulses per the Human Body Model (HBM) is unique in terms of combining high RF performance with ESD-robustness:

- Transit frequency f_T = 34 GHz
- Maximum Stable Gain MSG of 21 dB @ 1.8 GHz
- Minimum Noise Figure F_{min} = 0.9 dB @ 1.8 GHz

Features

- Low current: 3.3 mA @ 5 V; 3 V operation possible with resistor value change
- Low Noise Figure: 1.5 dB Noise figure at 315 / 434 MHz
- Gain: 14.6 dB @ 315 MHz
- Low cost design on 2-layer FR4 PCB material with no chip coils; total parts count = 10; PCB area ≈ 50 mm²
- Unconditionally Stable: K>1, B_1>0 from 5 MHz to 6 GHz

BFP540ESD is shown in a low cost, low current (3 mA) broadband resistive-feedback UHF LNA. The amplifier runs from a 5 V supply, but could use 3 V with simple resistor value changes. Broadband design permits use of the LNA from < 100 MHz to > 1 GHz with no component changes required, and the good input / output match over this entire frequency range eases integration with other system blocks, e.g. bandpass filters. Only resistors and capacitors are required (0402 case size). PCB area 50 ≈ mm². Please refer to schematic diagram (**Figure 2**). A PCB originally designed for the smaller TSFP-4 package was employed for this demo; so the larger SOT343 package used by the BFP540ESD was made to fit the PCB footprint as well as possible.

Summary of Results

T = 25 °C, network analyzer source power = -30 dBm, V_{CC} = 5.0 V, I = 3.3 mA, z = 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
105	11.2	15.0	21.0	15.2	1.5	---	---	---	---
315	11.2	14.6	21.1	14.5	1.5	-13.2	+1.5	-21.5	-7.9
390	---	---	---	---	---	---	---	---	---
434	11.4	14.2	21.3	13.8	1.5	---	---	---	---
915	11.9	12.1	21.4	11.8	1.6	---	---	-19.6	-8.5

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

PCB Cross Sectional Diagram

Note standard low-cost FR4 material is used

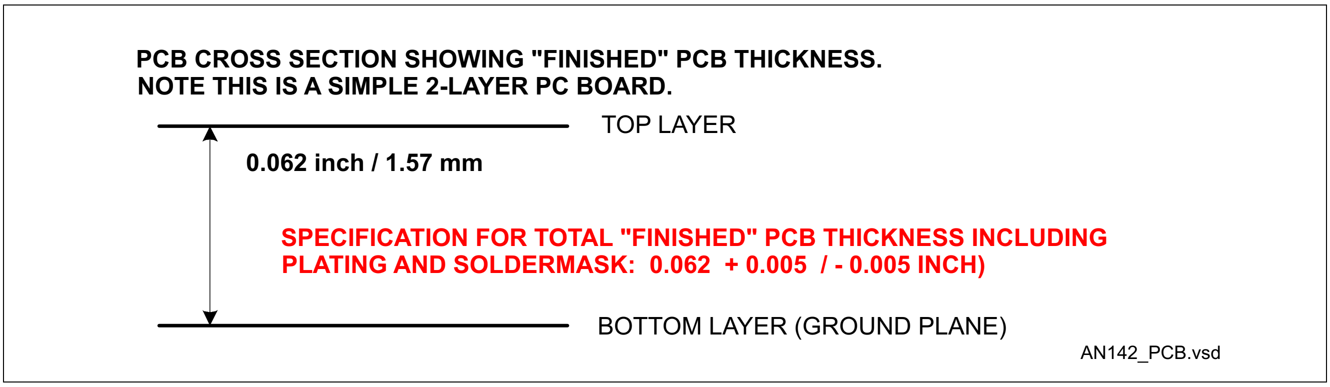


Figure 1 PCB - Cross Sectional Diagram

Schematic Diagram

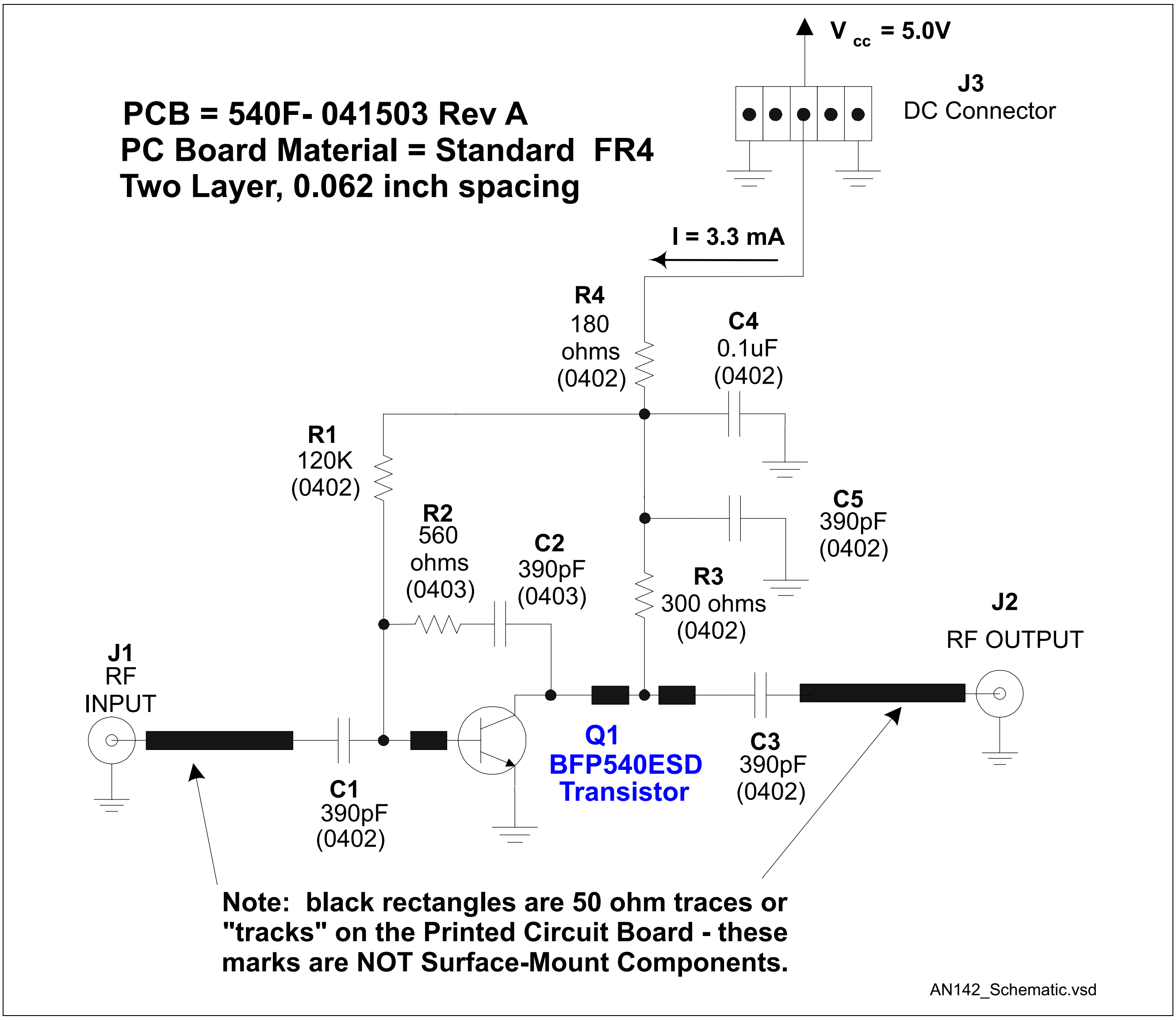


Figure 2 Schematic Diagram

Noise Figure, Plot, 100 MHz to 950 MHz, Center of Plot (x-axis) is 525 MHz.

Rohde & Schwarz FSEK3

09 Mar 2006

Noise Figure

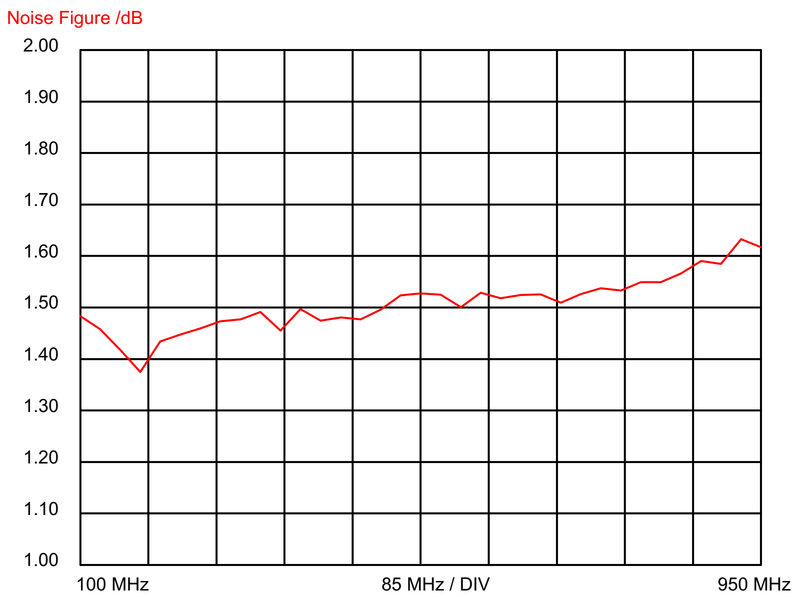
EUT Name:	BFP540ESD Wideband Feedback LNA
Manufacturer:	Infineon Technologies
Operating Conditions:	V = 5.0 V, I = 3.3 mA, T = 25 C
Operator Name:	Gerard Wevers
Test Specification:	900 MHz ISM
Comment:	on PCB 540F-041503 Rev A 9 March 2006

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: HP346AN



AN142_plot_nf.vsd

Figure 3 Noise Figure

Noise Figure, Tabular Data

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

Table 2 Noise Figure

Frequency	Noise Figure
100 MHz	1.48 dB
125 MHz	1.46 dB
150 MHz	1.42 dB
175 MHz	1.37 dB
200 MHz	1.43 dB
225 MHz	1.45 dB
250 MHz	1.46 dB
275 MHz	1.47 dB
300 MHz	1.48 dB
325 MHz	1.49 dB
350 MHz	1.46 dB
375 MHz	1.50 dB
400 MHz	1.47 dB
425 MHz	1.48 dB
450 MHz	1.48 dB
475 MHz	1.50 dB
500 MHz	1.52 dB
525 MHz	1.53 dB
550 MHz	1.52 dB
575 MHz	1.50 dB
600 MHz	1.53 dB
625 MHz	1.52 dB
650 MHz	1.52 dB
675 MHz	1.53 dB
700 MHz	1.51 dB
725 MHz	1.53 dB
750 MHz	1.54 dB
775 MHz	1.53 dB
800 MHz	1.55 dB
825 MHz	1.55 dB
850 MHz	1.57 dB
875 MHz	1.59 dB
900 MHz	1.58 dB
925 MHz	1.63 dB
950 MHz	1.62 dB

Scanned Image of PC Board

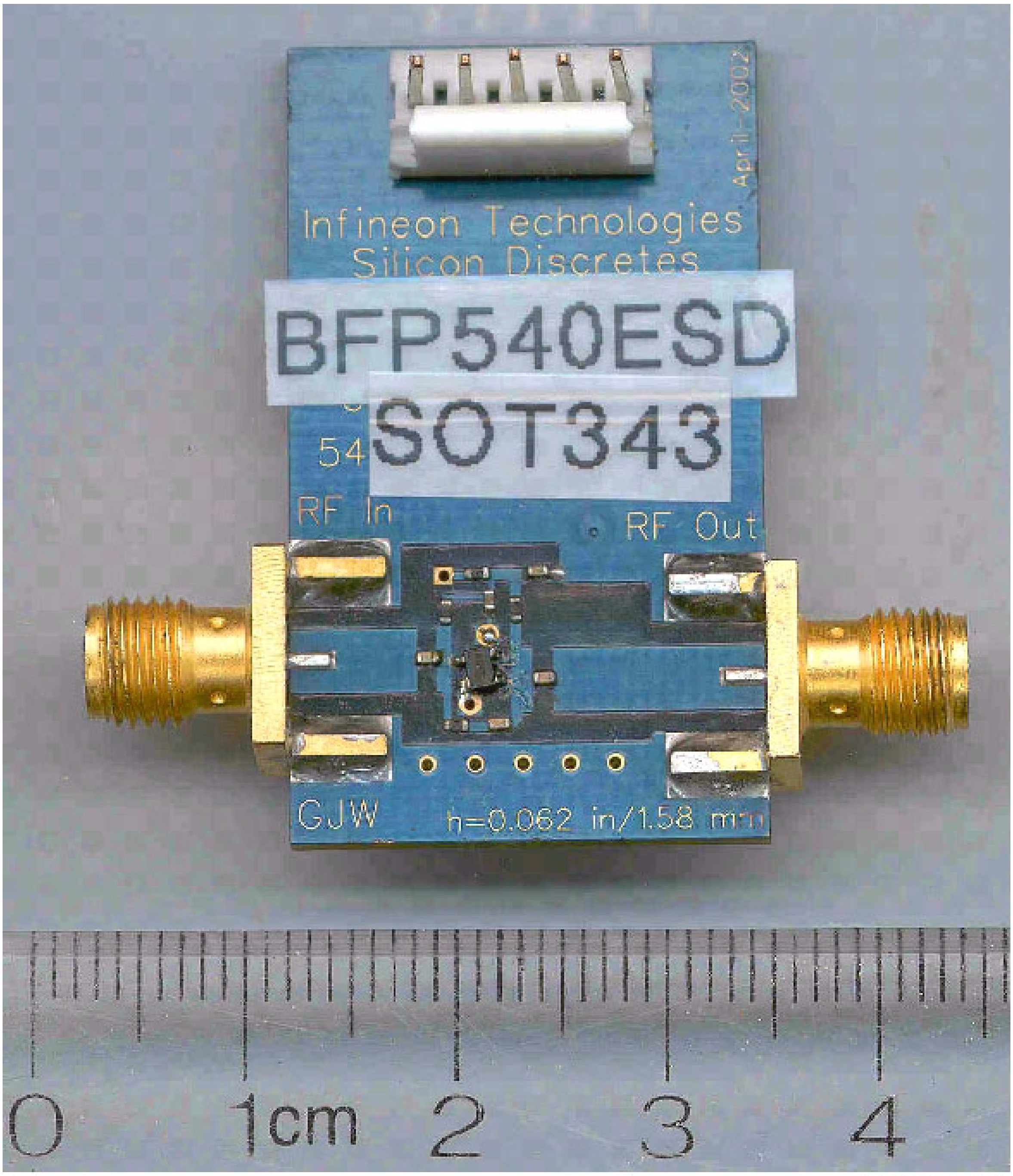


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Figure 4 Image of PC Board

Scanned Image of PC Board, Close-In Shot.

Note BFP540ESD in SOT343 package is kloodged into PCB footprint originally designed for smaller TSFP-4 package.

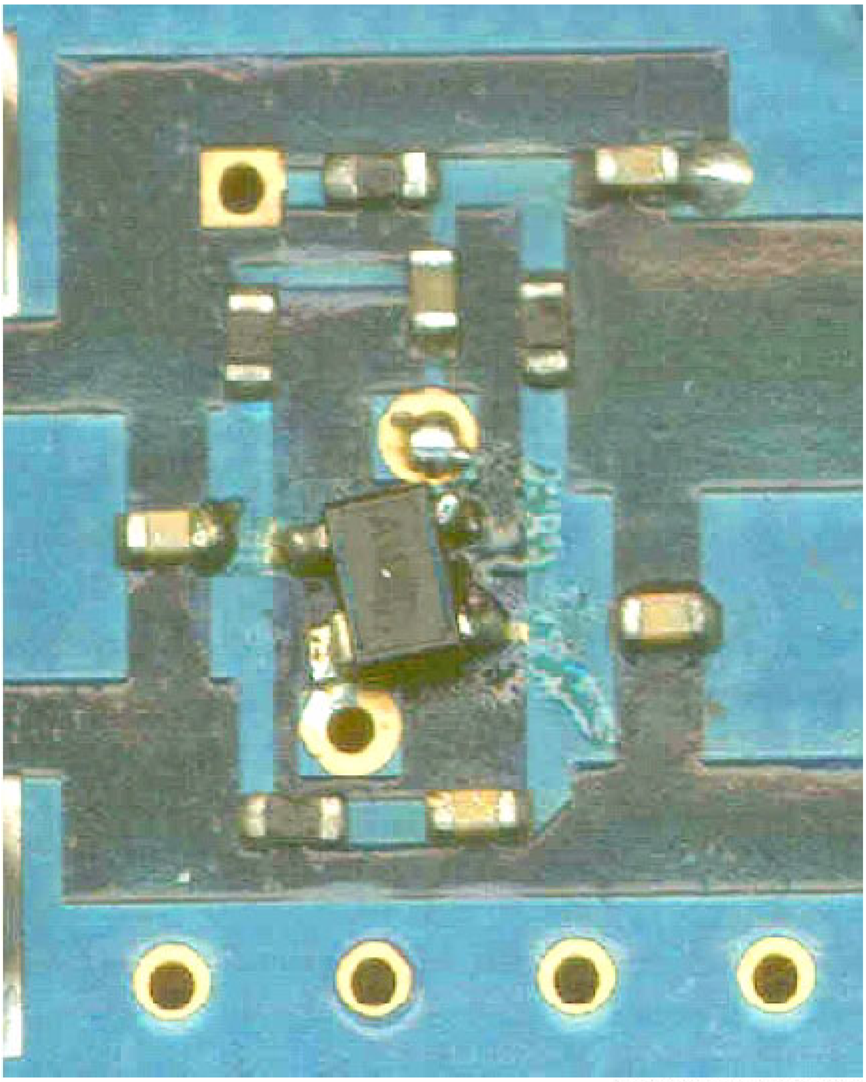

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Figure 5 Image of PC Board, Close-In Shot

Gain Compression Test, 315 MHz

Amplifier is checked for 1 dB compression point at V_{CC} = 5.0 V, I_C = 3.3 mA, T = 25 °C). An Agilent power meter was used to ensure accurate power levels are measured (as opposed to using Vector Network Analyzer in "Power Sweep" mode).

Input $P_{1dB} \cong$ -21.5 dBm; Output P_{1dB} = -21.5 dBm + (Gain - 1 dB) = -21.5 dBm + 13.6 dB = -7.9 dBm

Table 3 Gain Compression at 315 MHz

P_{OUT}, dBm	Gain, dB
-33	14.6
-32	14.6
-31	14.6
-30	14.6
-29	14.5
-28	14.5
-27	14.4
-26	14.3
-25	14.2
-24	14.1
-23	13.9
-22	13.7
-21	13.5
-20	13.2
-19	12.9

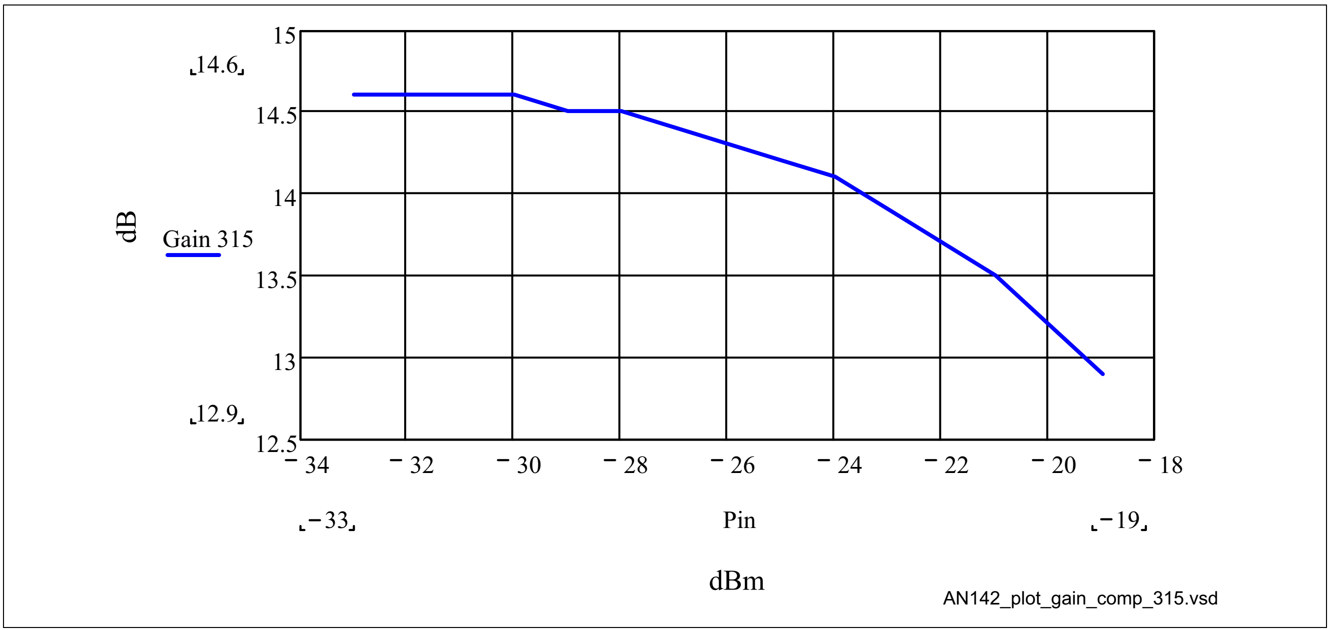

Figure 6 Plot of gain compression @ 315 MHz, 5 V, 3.3 mA, 25 °C

Gain Compression Test, 915 MHz

Amplifier is checked for 1 dB compression point at V_{CC} = 5.0 V, I_C = 3.3 mA, T = 25 °C). An Agilent power meter was used to ensure accurate power levels are measured (as opposed to using Vector Network Analyzer in "Power Sweep" mode).

Input $P_{1dB} \cong$ -19.6 dBm; Output P_{1dB} = -19.6 dBm + (Gain - 1 dB) = -19.6 dBm + 11.1 dB = -8.5 dBm

Table 4 Gain Compression at 915 MHz

P_{OUT}, dBm	Gain, dB
-33	12.1
-32	12.1
-31	12.1
-30	12.1
-29	12.0
-28	12.0
-27	12.0
-26	11.9
-25	11.9
-24	11.8
-23	11.7
-22	11.6
-21	11.4
-20	11.2
-19	10.9

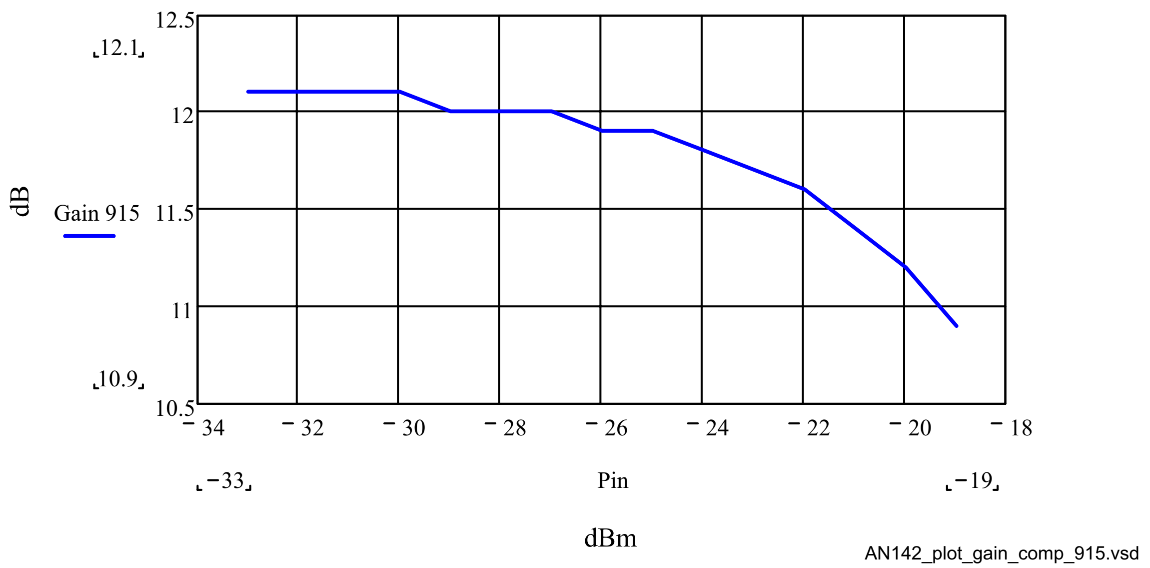

Figure 7 Plot of gain compression @ 915 MHz, 5 V, 3.3 mA, 25 °C

Input Return Loss, Log Mag

5 MHz - 8 GHz

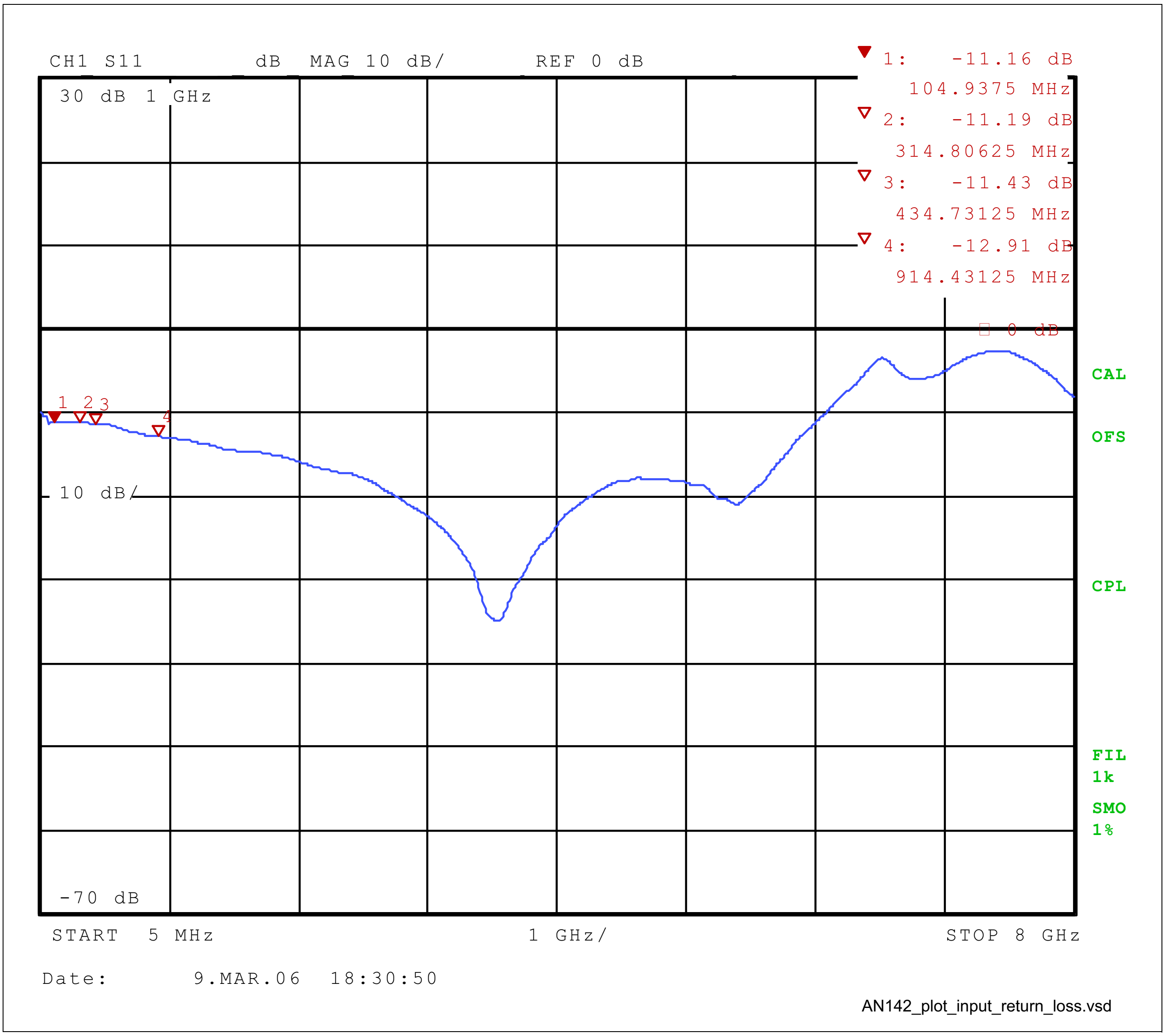

Figure 8 Plot of Input Return Loss

Input Return Loss, Smith Chart

Reference Plane = Input SMA RF Connector
5 MHz - 8 GHz

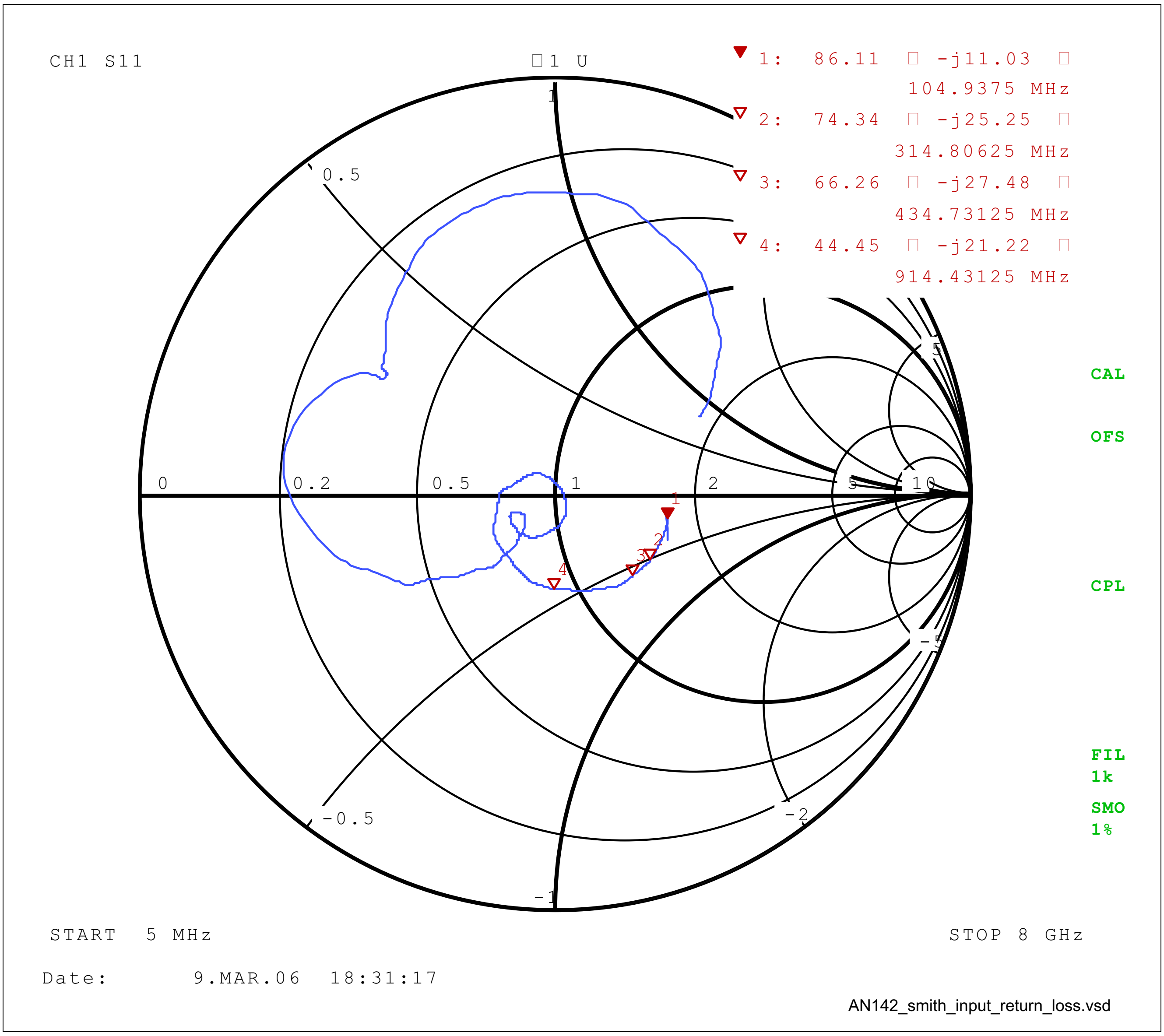

Figure 9 Smith Chart of Input Return Loss

Forward Gain, Wide Sweep

5 MHz - 8 GHz

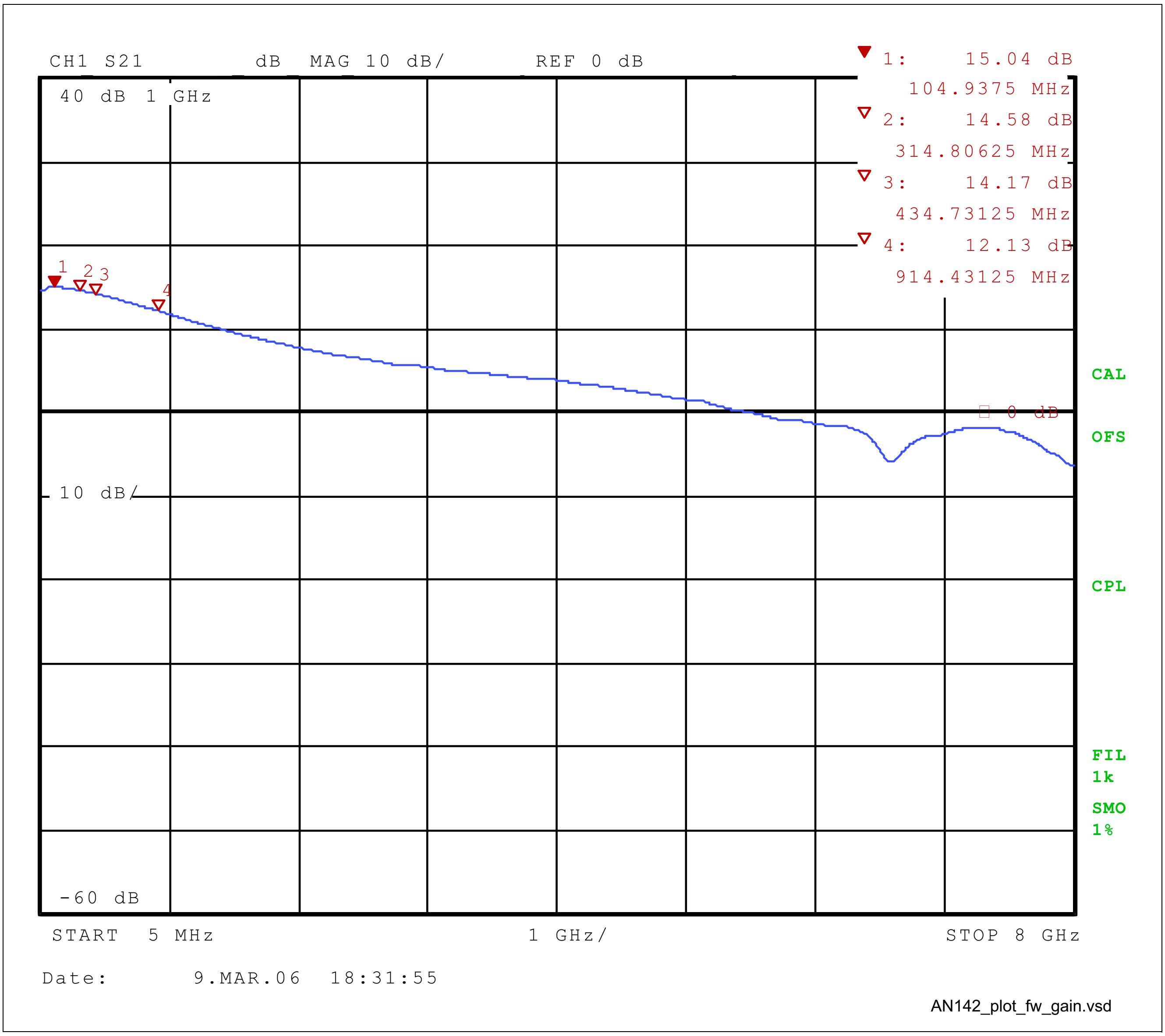

Figure 10 Plot of Forward Gain

Reverse Isolation

5 MHz - 8 GHz

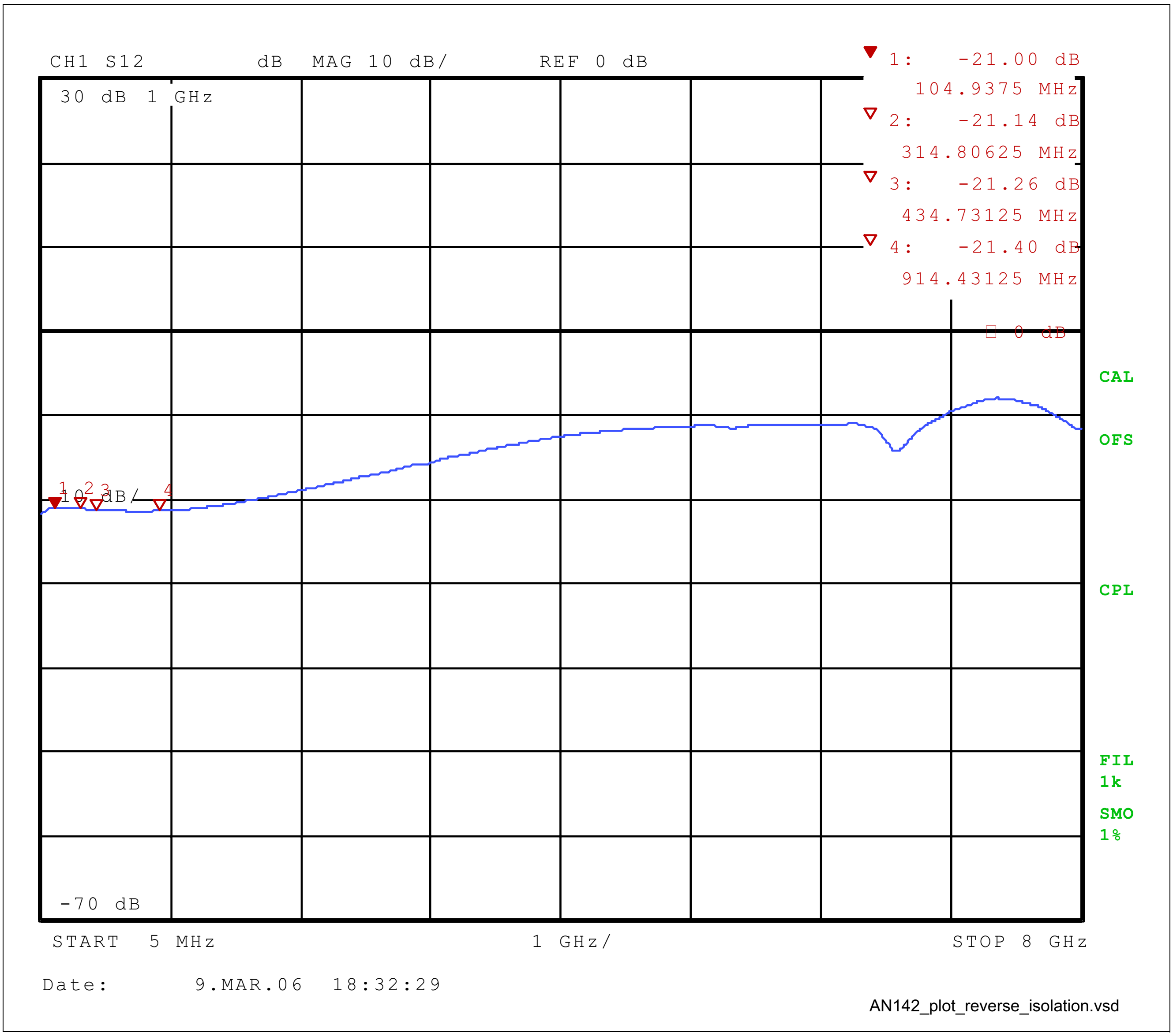

Figure 11 Plot of Reverse Isolation

Output Return Loss, Log Mag

5 MHz - 8 GHz

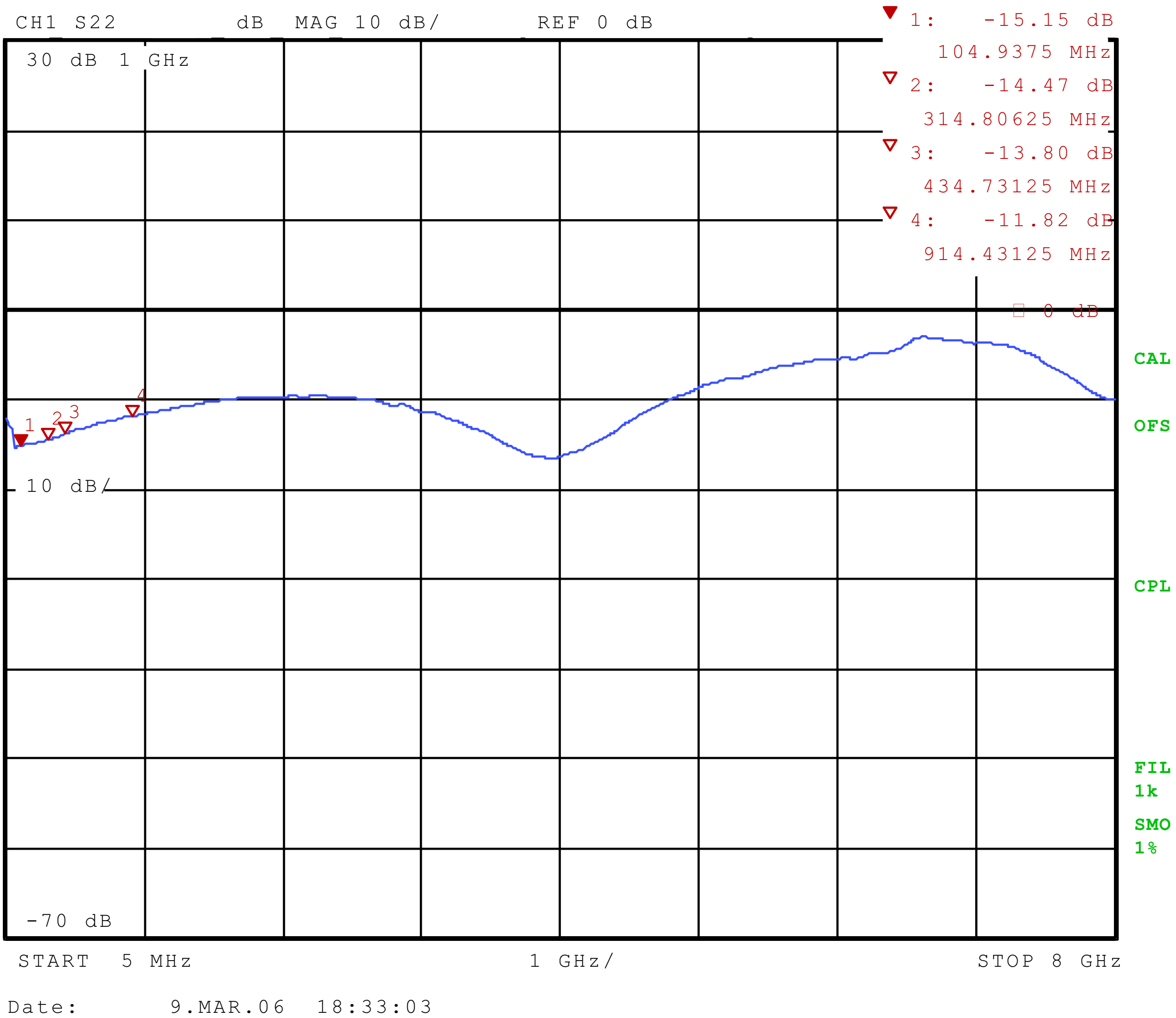

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Figure 12 Plot of Output Return Loss

Output Return Loss, Smith Chart

Reference Plane = Output SMA RF Connector
5 MHz - 8 GHz

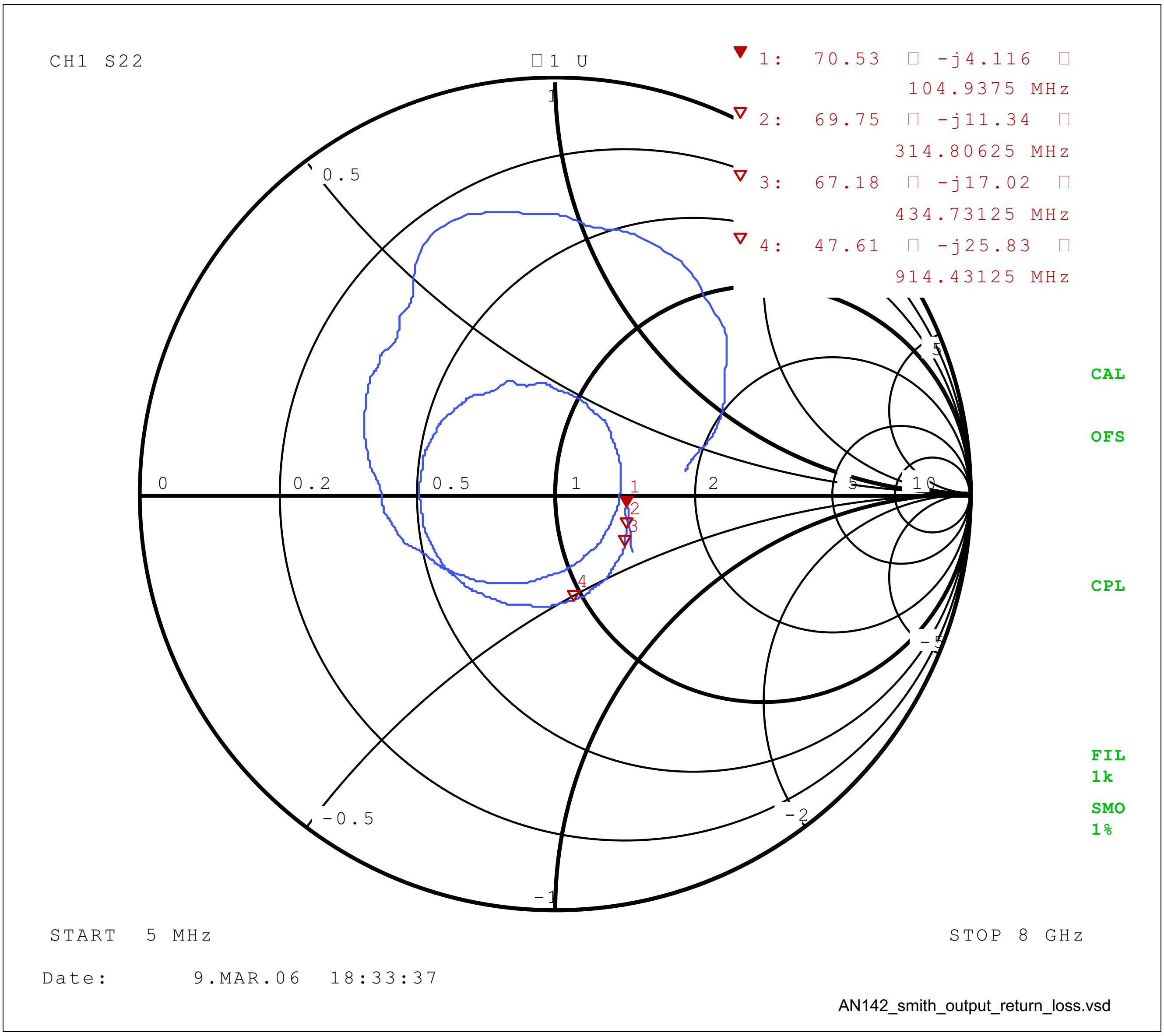

Figure 13 Smith Chart of Output Return Loss

Third Order Intercept Measurement

Input Stimulus for Amplifier Two-Tone Test:
f_1 = 314 MHz, f_2 = 315 MHz, -33 dBm each tone.
(Absolute power level is verified with Agilent Power Meter, not spectrum analyzer)

LNA response to two-tone test (below).

Input IP_3 = -33 + (39.7 / 2) = -13.2 dBm
Output IP_3 = -13.2 dBm + 14.6 dB gain = +1.5 dBm

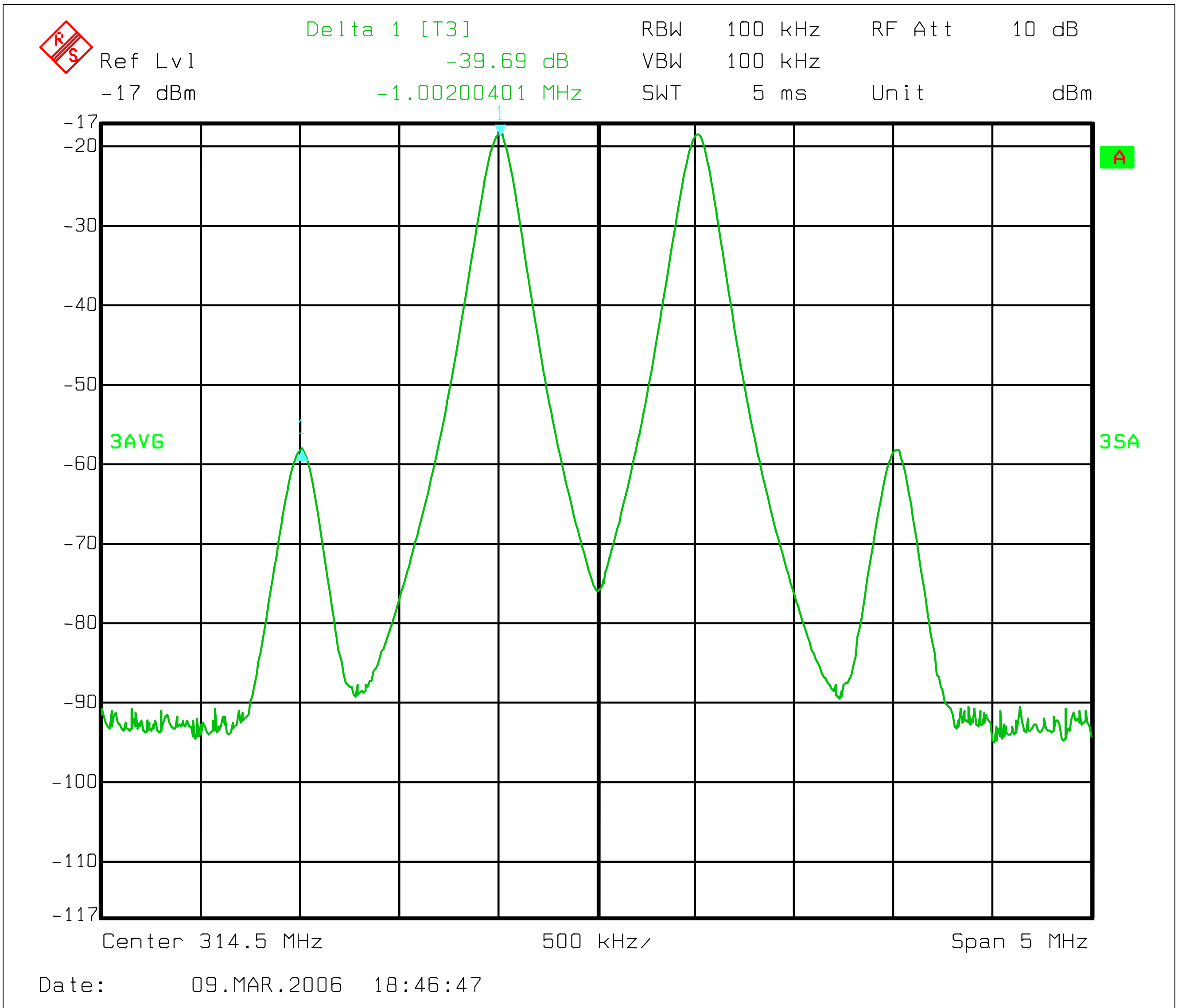

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Figure 14 Tow-Tone Test, LNA Response