Application Note No. 150

A 900 MHz Low Noise Amplifier Using the BFR360F Transistor in TSFP-3 Package

RF & Protection Devices

Never stop thinking

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

Previous Version: 2003-01-24, Rev. 1.1

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

1 A 900 MHz Low Noise Amplifier Using the BFR360F Transistor in TSFP-3 Package

Overview

- The low-cost, high performance BFR360F in the ultra-small TSFP-3 package is evaluated to show the feasibility of a 1 dB Noise Figure LNA for 900 MHz ISM band applications.
- The Printed Circuit Board Used is PCB 640-052402 Revision C, originally designed for a two-stage 5 - 6 GHz LNA application. Standard FR4 material is used.
- Low-cost, standard SMT passive components are used throughout, in "0402" case size.
- Total PCB area used for the single LNA stage is approximately 50 mm². Note that further reduction in PCB area is possible.
- Achieved > 15 dB gain, 1.1 dB Noise Figure at 915 MHz, on 3.0 V supply, drawing 5.7 mA. Note noise figure result does NOT "back out" FR4 PCB losses - if the PCB loss at LNA input were extracted, Noise Figure Results would be approximately 0.1 dB lower.

PCB Cross - Section Diagram

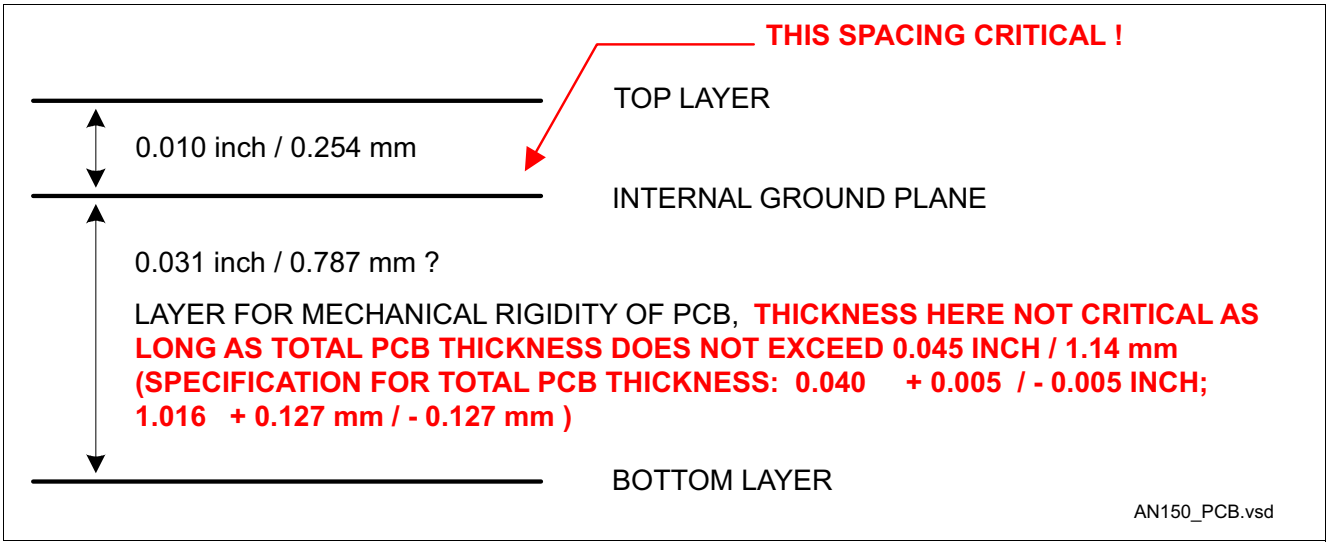


Figure 1 PCB - Cross Sectional Diagram

Summary of Data

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

Table 1 Summary of Results

Parameter	Result	Comments
Frequency Range	902 - 928 MHz	ISM band, but LNA usable down to approx. 850 MHz.
DC Current	5.7 mA	
DC Voltage, V_{CC}	3.0 V	
Collector-Emitter Voltage, V_{CE}	≅ 2.74 V	BFP640: V_{CEmax} = 4.0 V
Gain	15.3 dB @ 902 MHz 15.4 dB @ 915 MHz 15.6 dB @ 928 MHz	
Noise Figure	1.1 dB @ 902 MHz 1.1 dB @ 915 MHz 1.1 dB @ 928 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}	-17.0 dBm @ 915 MHz	See input power sweep vs. gain plot, **Figure 7**.
Input 3rd Order Intercept	+11.6 dB @ 2400 MHz	Please see **Figure 15**.
Input Return Loss	11.1 dB @ 902 MHz 10.2 dB @ 915 MHz 10.2 dB @ 928 MHz	
Output Return Loss	10.7 dB @ 902 MHz 10.8 dB @ 915 MHz 10.4 dB @ 928 MHz	
Reverse Isolation	24.0 dB @ 902 MHz 23.7 dB @ 915 MHz 23.3 dB @ 928 MHz	

Bill of Material

Table 2 Bill of Material

Reference Designator	Value	Manufacturer	Case Size	Function
C1	0.1 µF	Various	0402	DC blocking, input (also using cap above SRF gives it slight inductive characteristic for input match).
C2	5.6 pF	Various	0402	DC blocking and output matching.
C4, C5	47 pF	Various	0402	Output RF ground.
C3, C6	0.1 µF	Various	0402	Low frequency ground at base (Input 3rd Order Intercept improvement), low frequency decoupling / blocking.
L1	18 nH	Murata LQG15H low cost chip inductor	0402	RF choke to DC bias on base of Q1, some positive influence on input blocking.
L2	8.2 nH	Murata LQG15H low cost chip inductor	0402	RF choke to collector of Q1, also influences output match.
R1	36 Ω	Various	0402	Influence on RF stability and output match.
R2	43 kΩ	Various	0402	DC bias for base of Q1
R3	10 Ω	Various	0402	Provides some DC feedback for bias compensation (beta variation, temperature, etc.).
Q1	-	Infineon Technologies	TSFP-3	BFR360F Transistor, f_T = 14 GHz
J1, J3	-	Johnson 142-0701-841	-	RF input / output connectors
J4	-	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

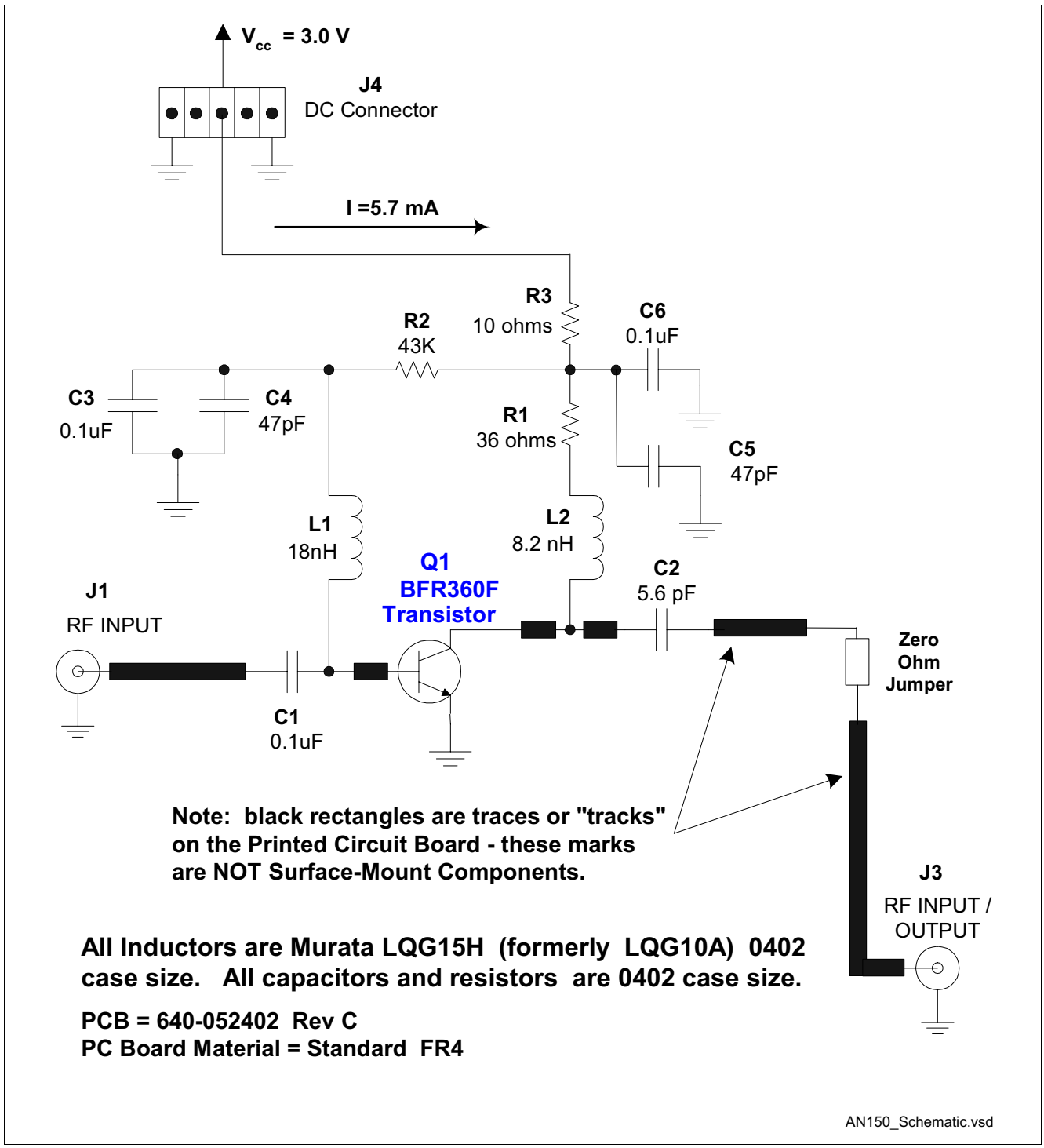


Figure 2 Schematic Diagram

Noise Figure, Plot. Center of Plot (x-axis) is 915 MHz.

Rohde & Schwarz FSEK3

25 Jan 2003

Noise Figure

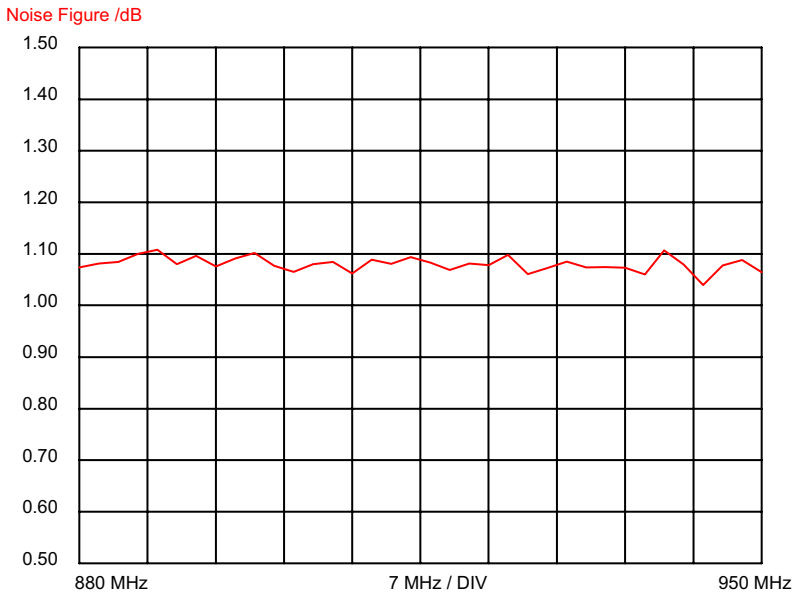
EUT Name:	BFR360F Low Noise Amplifier, 900 MHz ISM Band
Manufacturer:	Infineon Technologies
Operating Conditions:	V = 3.0 V, I = 5.7 mA, T = 25 C
Operator Name:	Gerard Wevers
Test Specification:	900 MHz ISM
Comment:	On BFP640 PCB 640-052402 Rev C 24 Jan 2003

Analyzer

RF Att:	0.00 dB	RBW :	1 MHz	Range:	40.00 dB
Ref Lvl:	-44.00 dBm	VBW :	100 Hz	Ref Lvl auto:	ON

Measurement

2nd stage corr: ON	Mode: Direct	ENR: HP346A.ENR



AN150_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
880 MHz	1.07 dB
882 MHz	1.08 dB
884 MHz	1.08 dB
886 MHz	1.10 dB
888 MHz	1.11 dB
890 MHz	1.08 dB
892 MHz	1.10 dB
894 MHz	1.08 dB
896 MHz	1.09 dB
898 MHz	1.10 dB
900 MHz	1.08 dB
902 MHz	1.07 dB
904 MHz	1.08 dB
906 MHz	1.08 dB
908 MHz	1.06 dB
910 MHz	1.09 dB
912 MHz	1.08 dB
914 MHz	1.09 dB
916 MHz	1.08 dB
918 MHz	1.07 dB
920 MHz	1.08 dB
922 MHz	1.08 dB
924 MHz	1.10 dB
926 MHz	1.06 dB
928 MHz	1.07 dB
930 MHz	1.09 dB
932 MHz	1.07 dB
934 MHz	1.07 dB
936 MHz	1.07 dB
938 MHz	1.06 dB
940 MHz	1.11 dB
942 MHz	1.08 dB
944 MHz	1.04 dB
946 MHz	1.08 dB
948 MHz	1.09 dB
950 MHz	1.06 dB

Scanned Image of PC Board

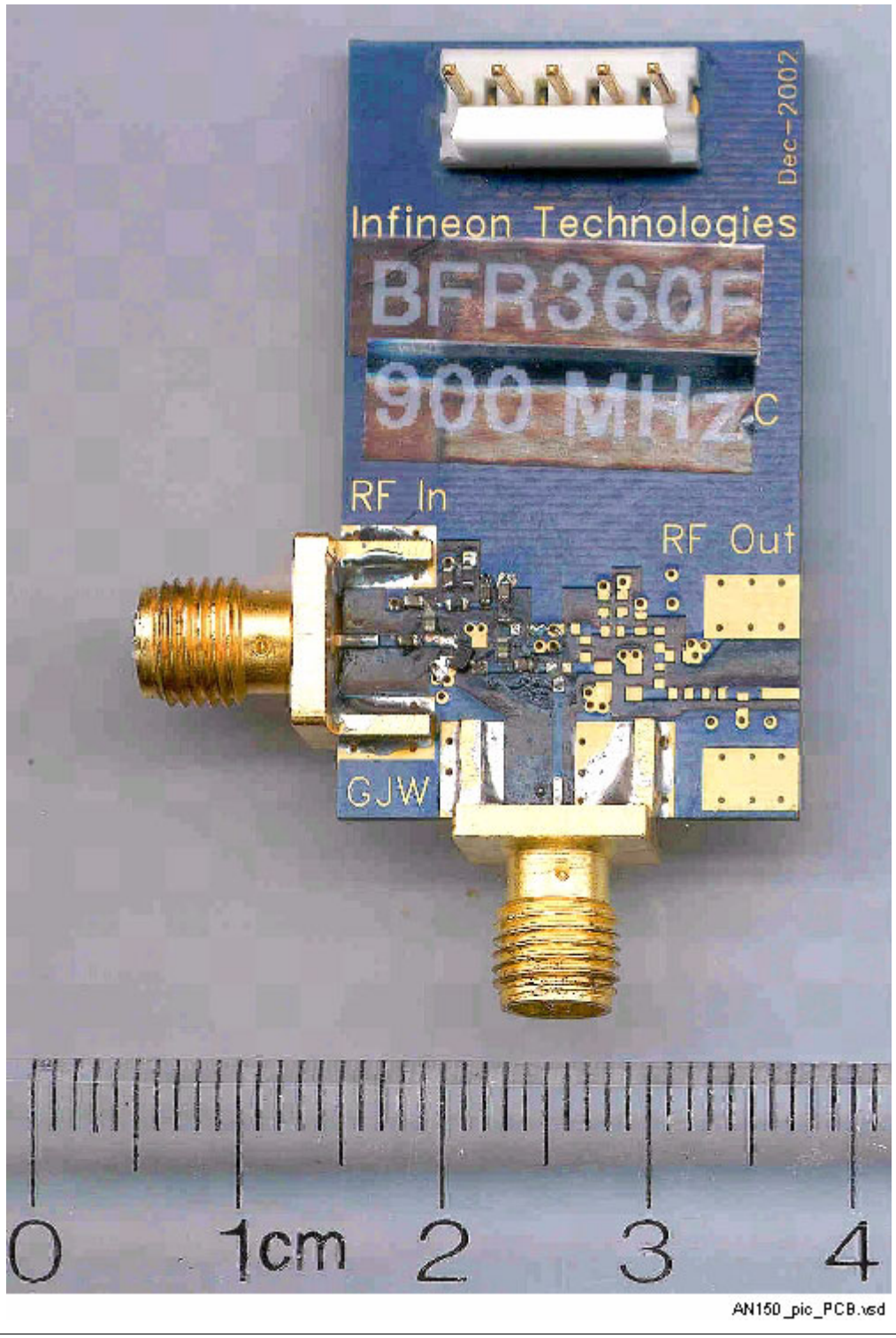


Figure 4 Image of PC Board

Scanned Image of PC Board, Close-In Shot.

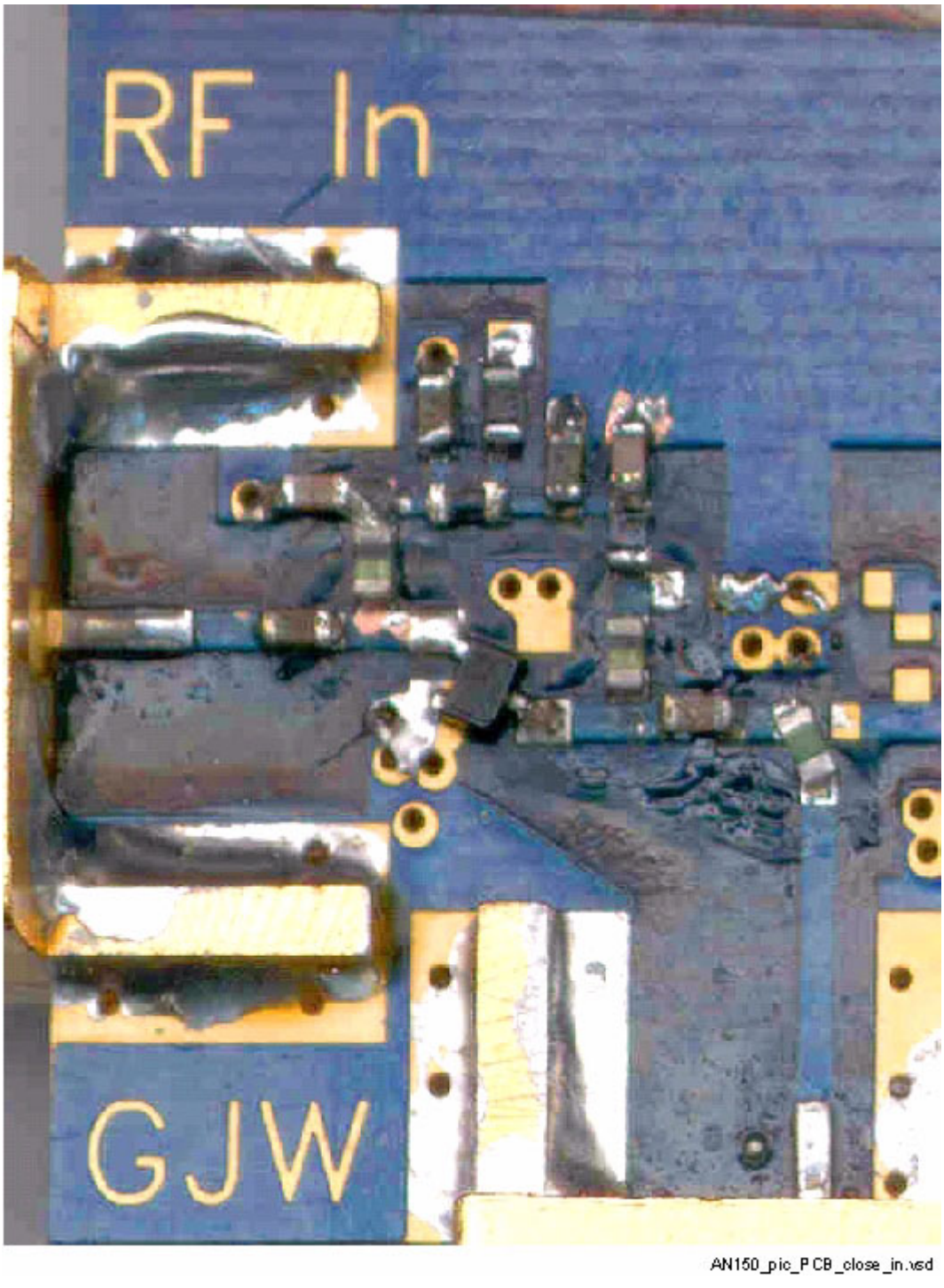


Figure 5 Image of PC Board, Close-In Shot

Stability Factor K and Stability Measure B_1

Note that if K > 1 and B_1 > 0, the amplifier is unconditionally stable. Measured LNA s-parameters were taken on a Network Analyzer & then imported into GENESYS simulation package, which calculates and plots K and B_1.

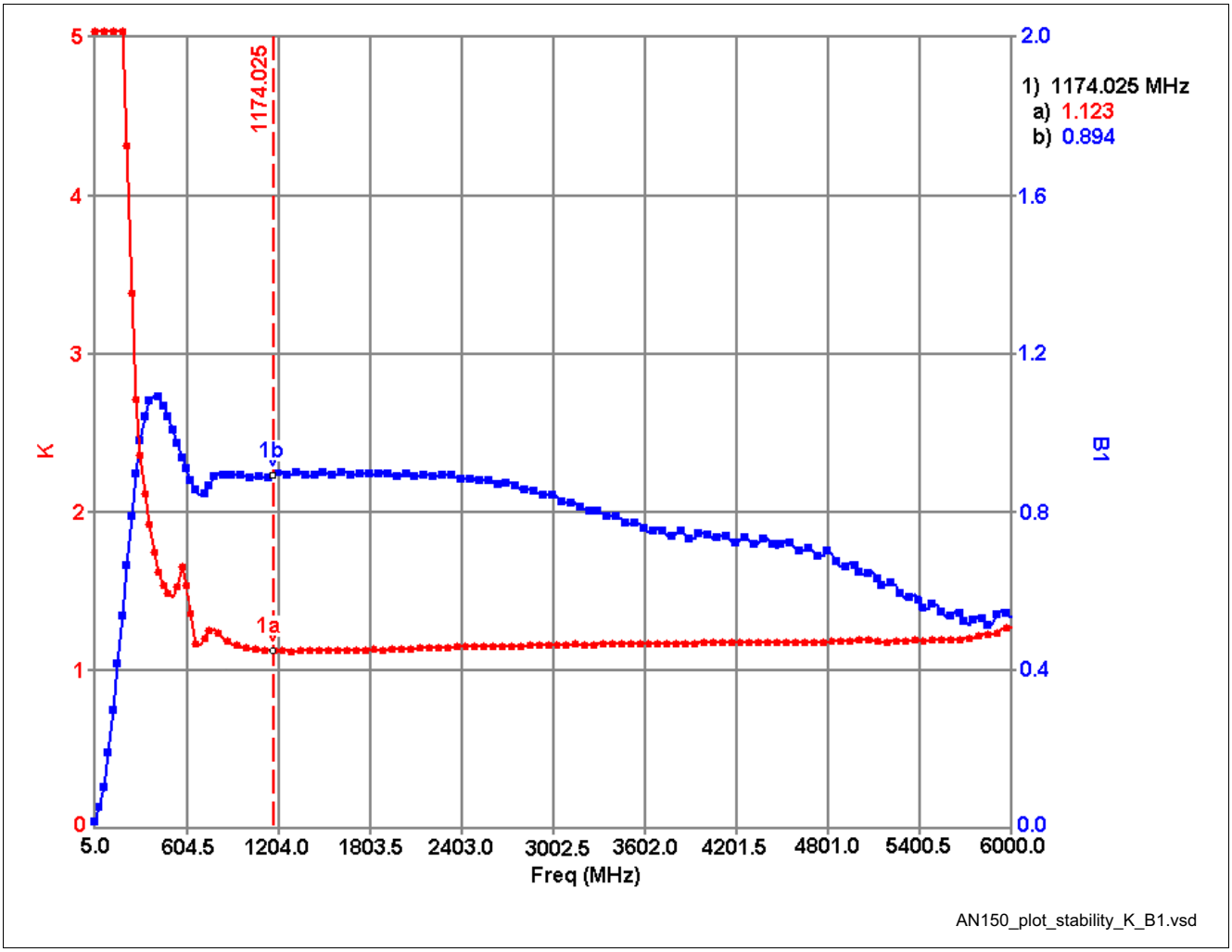


Figure 6 Plot of K(f) and B_1(f)

Power Sweep at 915 MHz (CW)

Source Power (Input) swept from -25 to 0 dBm

Input P_{1dB} ≅ -17.0 dBm

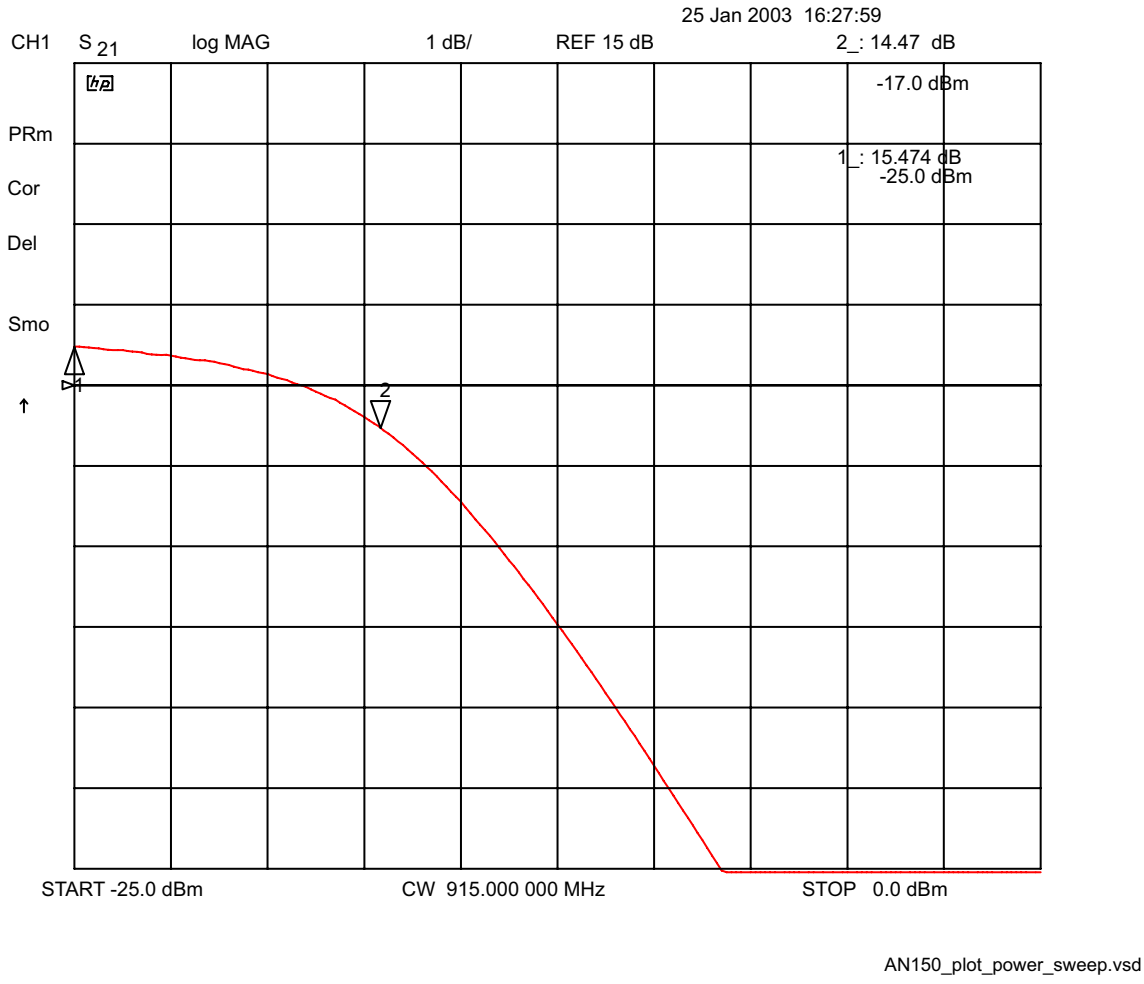


Figure 7 Plot of Power Sweep

Input Return Loss, Log Mag

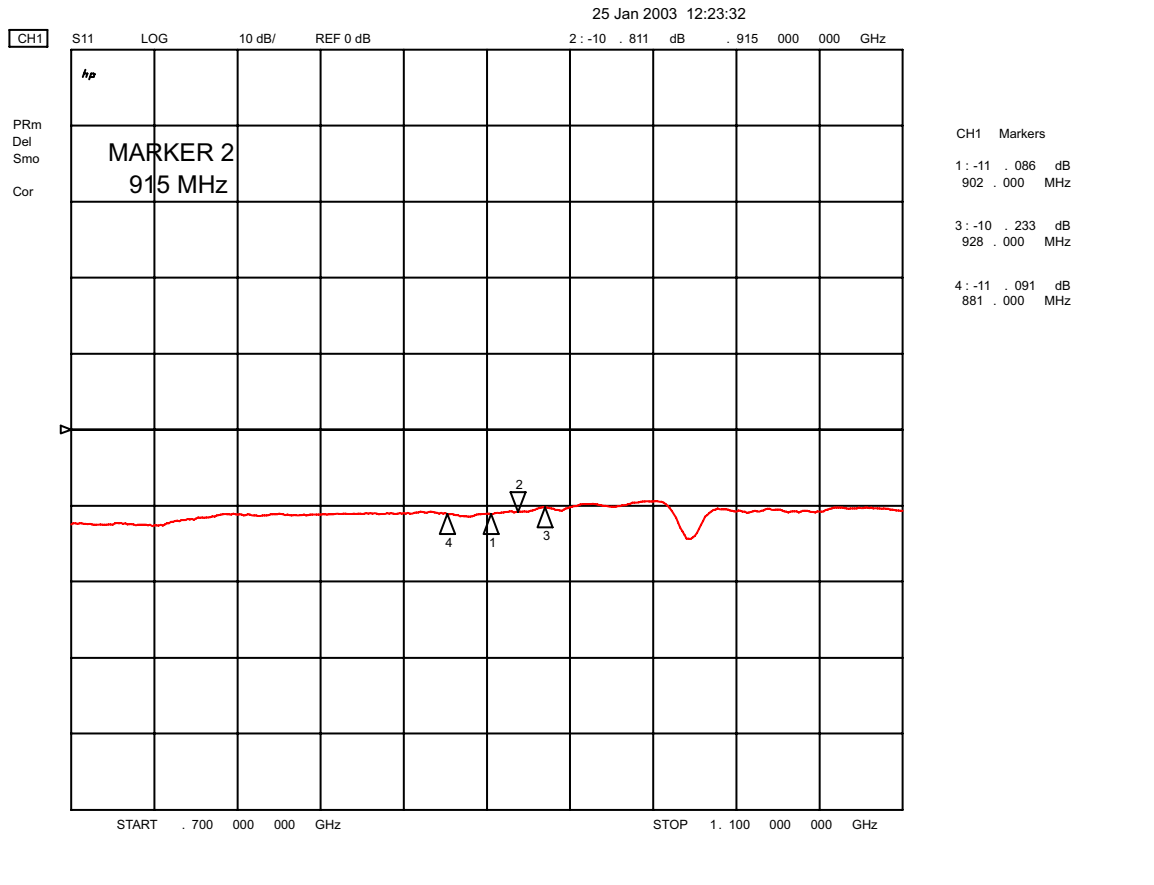


Figure 8 Plot of Input Return Loss

Input Return Loss, Smith Chart

Reference Plane = PCB Input SMA Connector

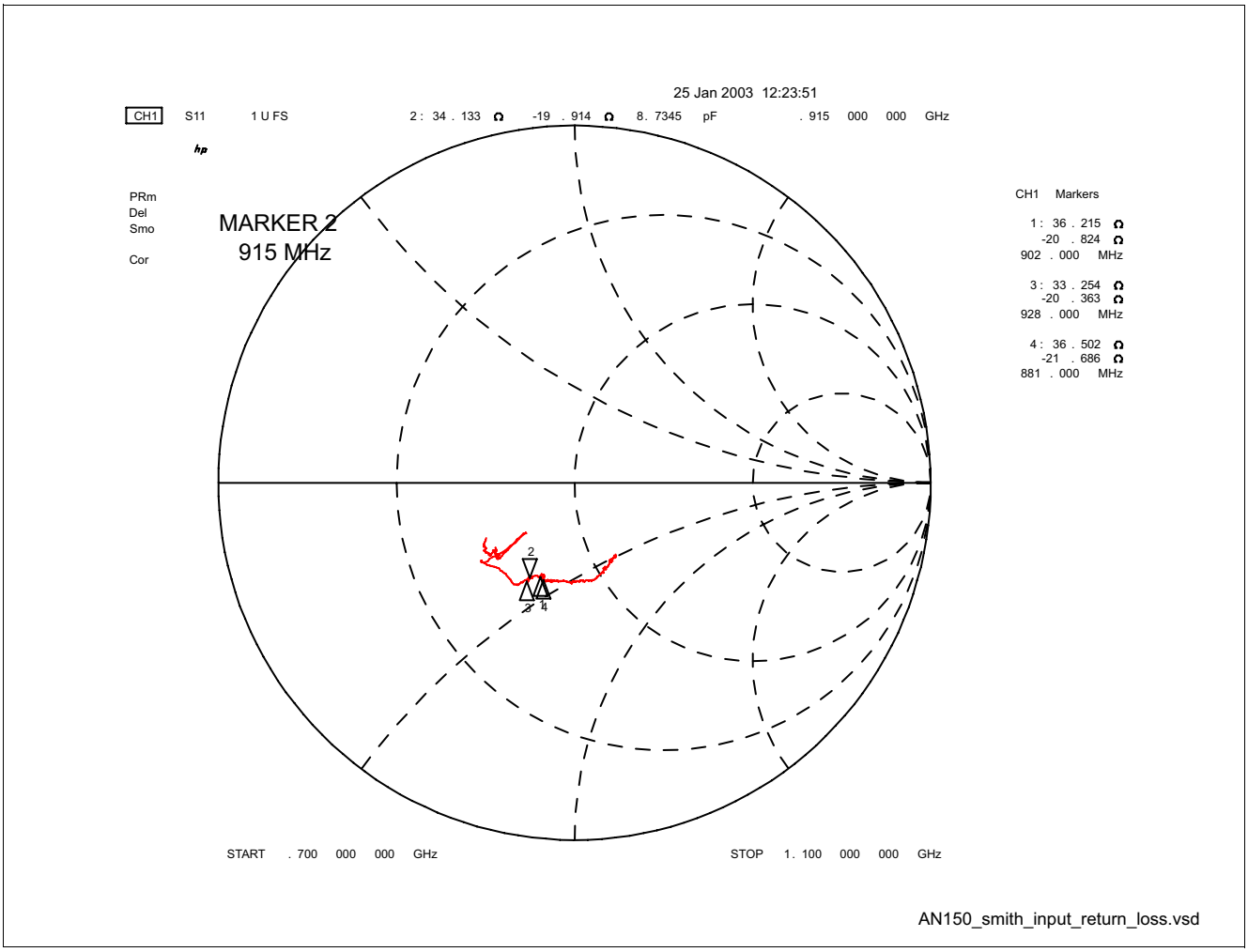


Figure 9 Smith Chart of Input Return Loss

Forward Gain

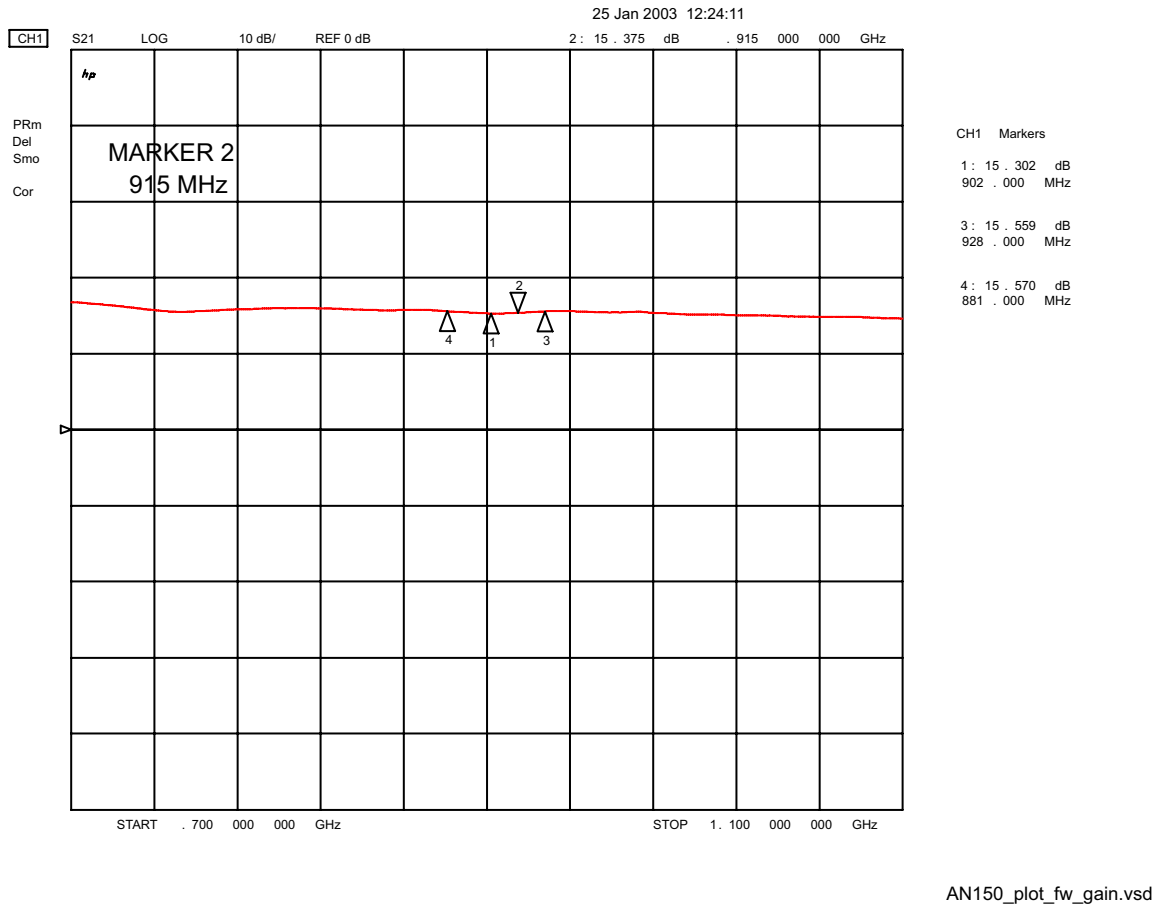


Figure 10 Plot of Forward Gain

Forward Gain, Wide Span

50 MHz - 18 GHz

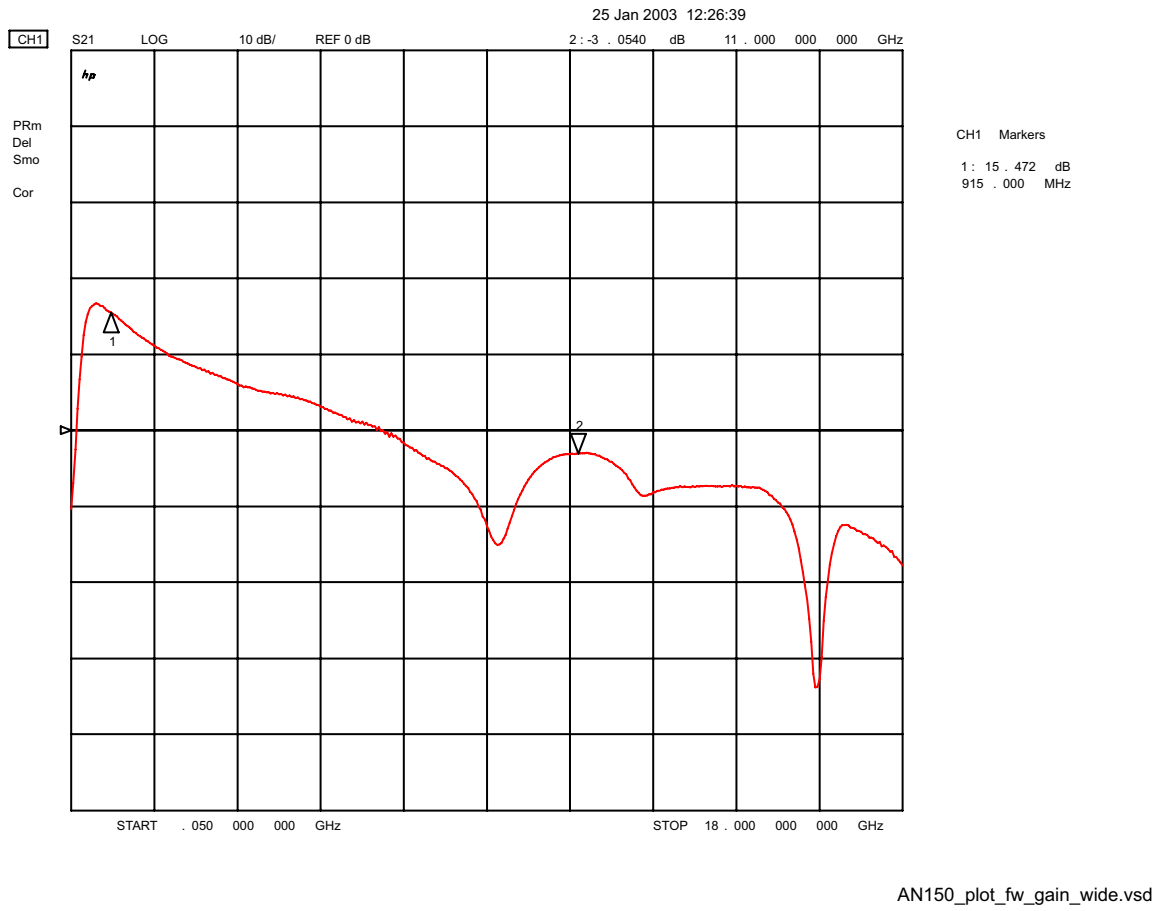


Figure 11 Plot of Forward Gain, Wide Span

Reverse Isolation

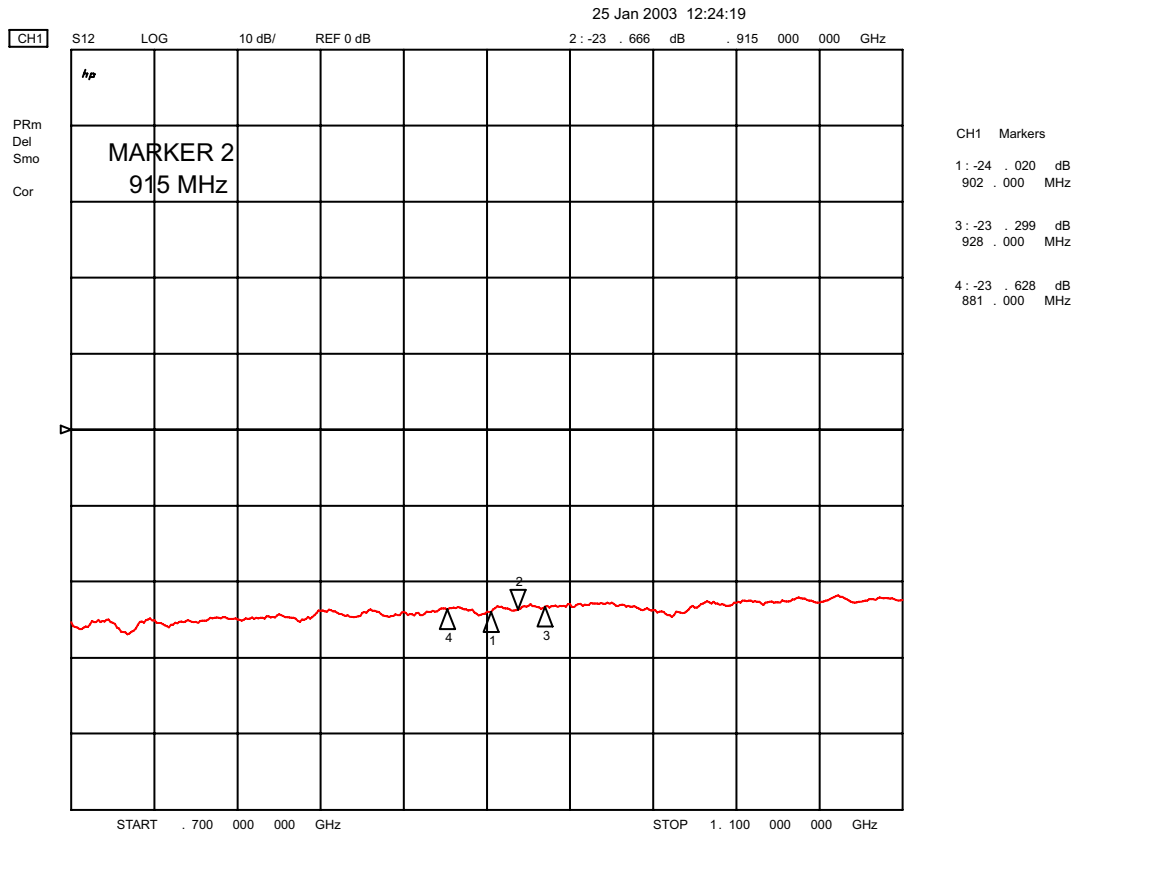


Figure 12 Plot of Reverse Isolation

Output Return Loss, Log Mag

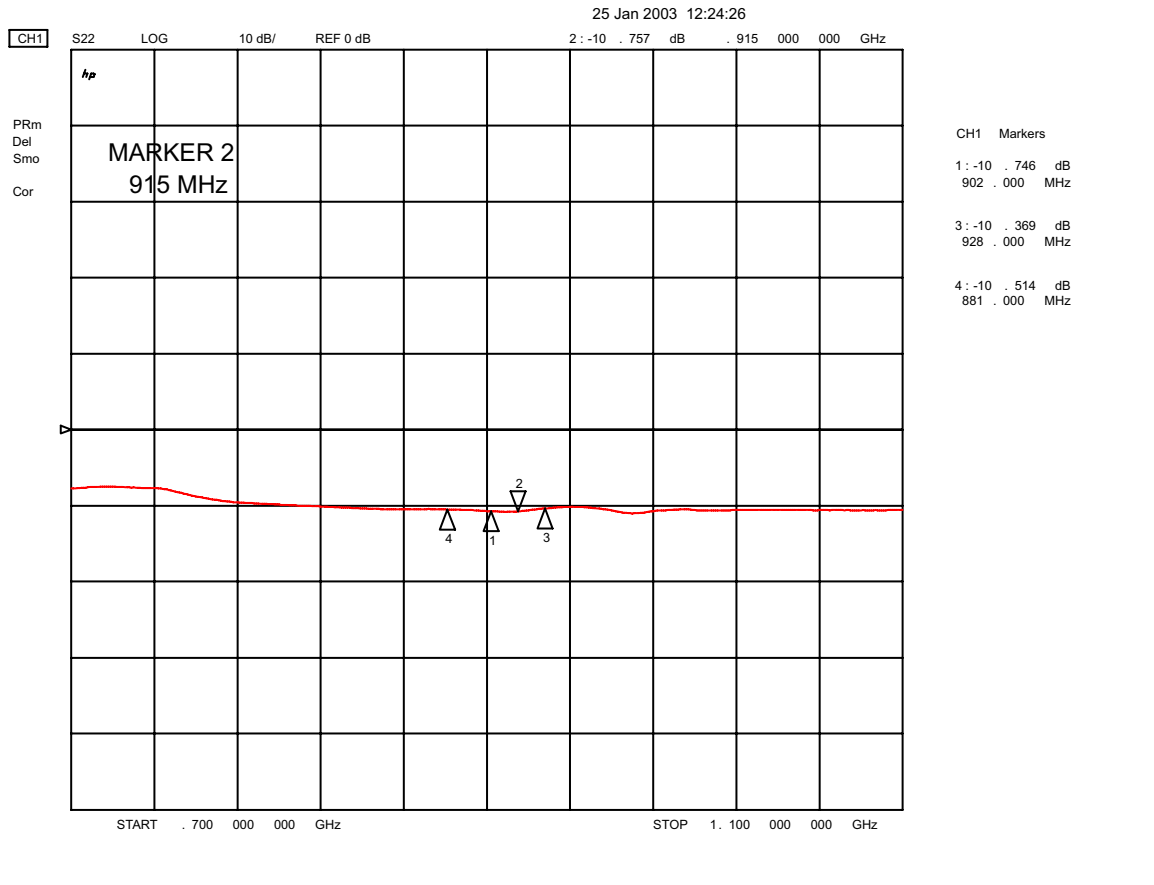


Figure 13 Plot of Output Return Loss

Output Return Loss, Smith Chart

Reference Plane = PCB Output SMA Connector

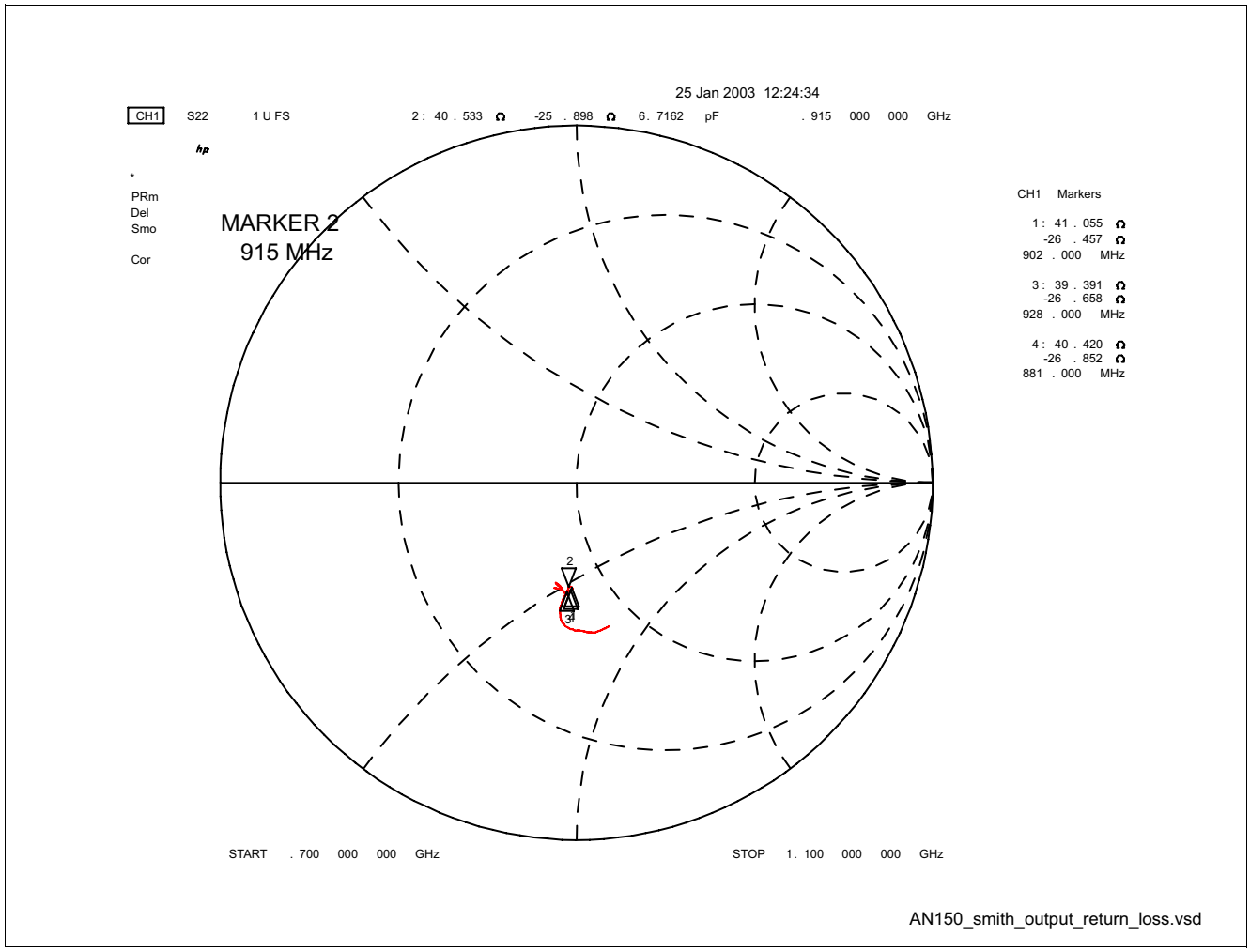


Figure 14 Smith Chart of Output Return Loss

LNA Output Response to Two-Tone Test

Input stimulus: f_1 = 914 MHz, f_2 = 915 MHz, -25 dBm each tone.

Input IP_3 = -25 + (50.7 / 2) = -0.4 dBm

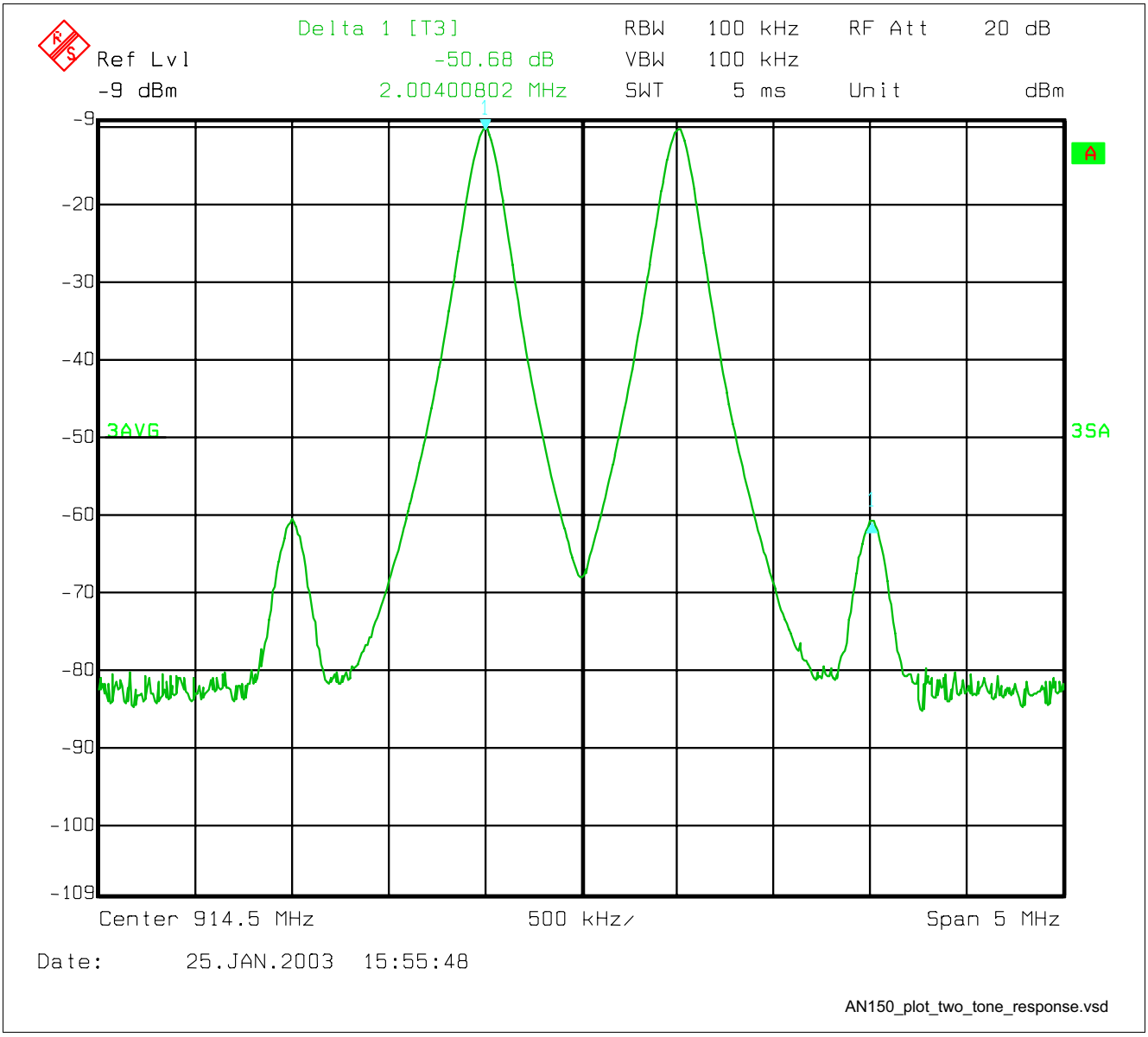


Figure 15 Tow-Tone Test, LNA Response