Application Note No. 027

Using the BGA420 Si MMIC Amplifier for Various UHF Applications from 300 MHz to 2.5 GHz

RF & Protection Devices

Never stop thinking

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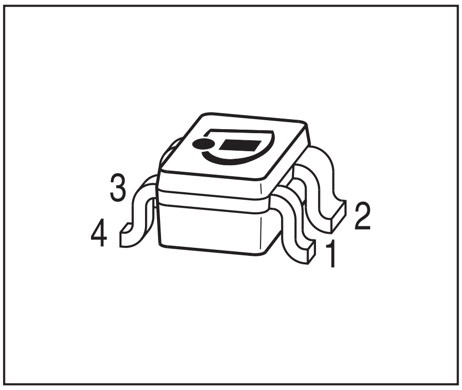
Page	Subjects (major changes since last revision)
All	Document layout change

1 Using the BGA420 Si MMIC Amplifier for Various UHF Applications from 300 MHz to 2.5 GHz

- Fast, Easy-To-Use & Flexible MMIC in standart SOT343 package
- Unconditionally Stable (K>1) cascadable gain block
- High Gain & Low Noise Figure; Outstanding price / performance ratio
- Easy Matching:
  - Broadband 50 Ω output match
  - 50 Ω input match > 1500 MHz, with simple external input matching < 1500 MHz
- Low Power Consumption: 7 mA @ 3 V; 13 mA @ 5 V(2.7-6 V operating range)
- High Reverse isolation (< 28 dB at 1.8 GHz)
- Applications: 315 / 434 MHz Automotive Remote Keyless Entry (RKE) & Tire Pressure Monitoring System (TPMS) receivers; 2nd stage LNA for GPS (1575 MHz); LNAs for FRS / GMRS “Walkie Talkies” (460 MHz); Wireless Security Systems & Garage Door Opener receivers (345 & 390 MHz), LO Buffer Amplifiers, etc.



1 = IN, 2 = GND, 3 = OUT, 4 = +V_D

1.1 Introduction

Infineon Technologies‘ BGA420 Silicon MMIC Amplifier consists of a 25 GHz transition frequency (f_T) transistor with integrated resistive feedback and integrated bias resistors. Fabricated in Infineon‘s mature, well-proven B6HF bipolar process, this MMIC‘s resistive feedback provides a forgiving, broadband impedance match in addition to ensuring unconditional stability (K>1, B_1>0). Since integrated capacitors consume increasing amounts of chip area as capacitance values become larger, DC blocking capacitors are not integrated in order to reduce cost, preserve flexibility and extend usable bandwidth to lower frequencies. The equivalent circut diagram of the BGA420 is given in **Figure 1**. Note the BGA430 has a 50 Ω output match (10 dB return loss or better) over the entire frequency range from below 100 MHz to over 3 GHz, while the input match is 50 Ω for frequencies over ≈ 1500 MHz - so no external input matching is required > 1500 MHz. A simple external input matching network is needed for achieving greater than 10 dB return loss for frequencies below 1500 MHz. The BGA420 does not require an “RF choke” inductor on the power supply pin (pin4). The BGA420‘s ground pin (pin2) is easily identified, being the largest / widest lead on the package. This ground pin should be directly connected to the printed circuit board‘s (PCB‘s) ground plane as directly as possible, with a short ground-return path provided by PCB ground vias placed close to this pin.

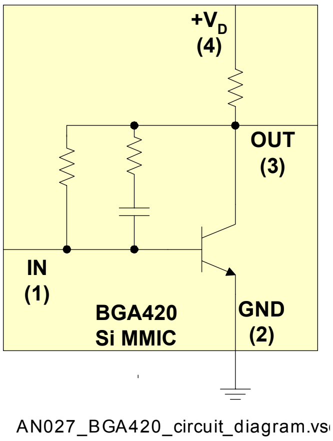


Figure 1 BGA420 Circuit Diagram

1.2 Application Examples

The BGA420 Silicon MMIC is suitable for a wide range of RF / Wireless applications. This application note presents three general circuit topologies. The first circuit ("Configuration #1) uses an external input matching circuit enabling operation in the 300 - 500 MHz range. This implementation uses a total of 5 external chip capacitors and 1 chip coil. Examples of applications in this frequency range include:

1. External Low Noise Amplifiers (LNAs) for improving range / sensitivity of Remote Keyless Entry (RKE) and Tire Pressure Monitoring System (TPMS) receiver RFICs at 315 and 434 MHz
2. LNAs for receivers in wireless security systems (345 MHz) and Garage Door Opener receivers (390 MHz)
3. LNAs or buffer amplifiers used in FRS / GMRS "walkie talkies" in the 460 MHz band.

The 2nd and 3rd circuits shown ("Configuration #2" and "Configuration #3) are general-purpose 900 to 2500 MHz amplifiers. Configuration #2 uses no external input matching to reduce parts count as low as possible, having a total external parts count of 4 capacitors. Configuration #3 adds one external series inductor at the BGA420 input to improve impedance matching. It is worth noting, that the addition of the input series inductor in Configuration #3 does improve input return loss, but there is little improvement in power gain by adding this additional component, and Noise Figure is slightly degraded with the addition of the input matching inductor. Potential applications in this frequency range include:

1. 2nd stage LNAs for Global Positioning System (GPS) receivers st 1575 MHz
2. Amplifiers for 900 MHz and 2.4 GHz ISM band systems
3. Local Oscillator (LO) "buffer" amplifiers. The high reverse isolation of the BGA420 (28 dB typical at 1800 MHz) makes it a good "buffer amplifier".

The printed circuit board (PCB) used for all three circuit configurations is fabricated in standard, low-cost epoxy (FR4) material, and a cross-sectional diagram of the PCB is given in **Figure 2** below. An image of the topside of the PC-Board is given in **Figure 3**. The optional chip coils used in Configurations 1 and 3 are Murata LQP15M series "0402" low-cost inductors. Note that 0402 size components were used to minimize required PCB area; however these same application circuits could also be realized with 0603 or 0201 case size components.

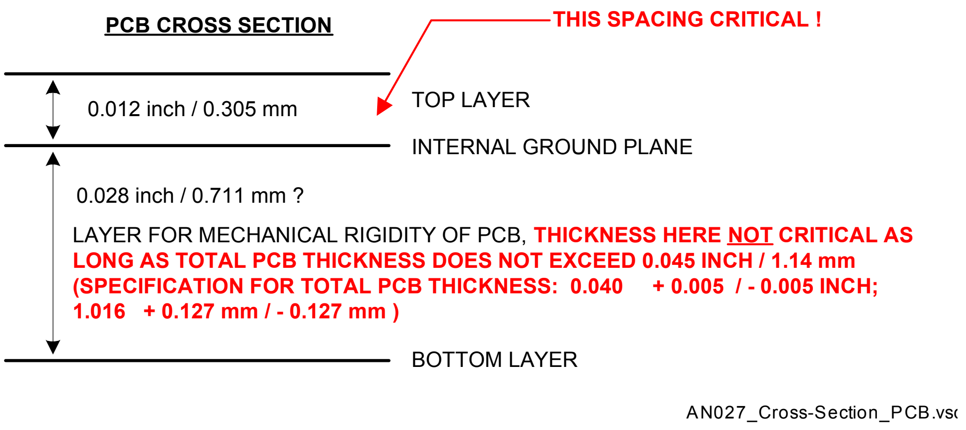


Figure 2 Cross-Section Diagram of Printed Circuit Board, Infineon Part Number 420-031705 Rev A

Figure 3 Image of Top Side of PCB

Figure 4 on the following page gives a schematic diagram and close-up assembly diagram photo of each of the three circuit configurations. The PCB images next to the schematic diagrams are a “zoom” of close-in image showing components placement.

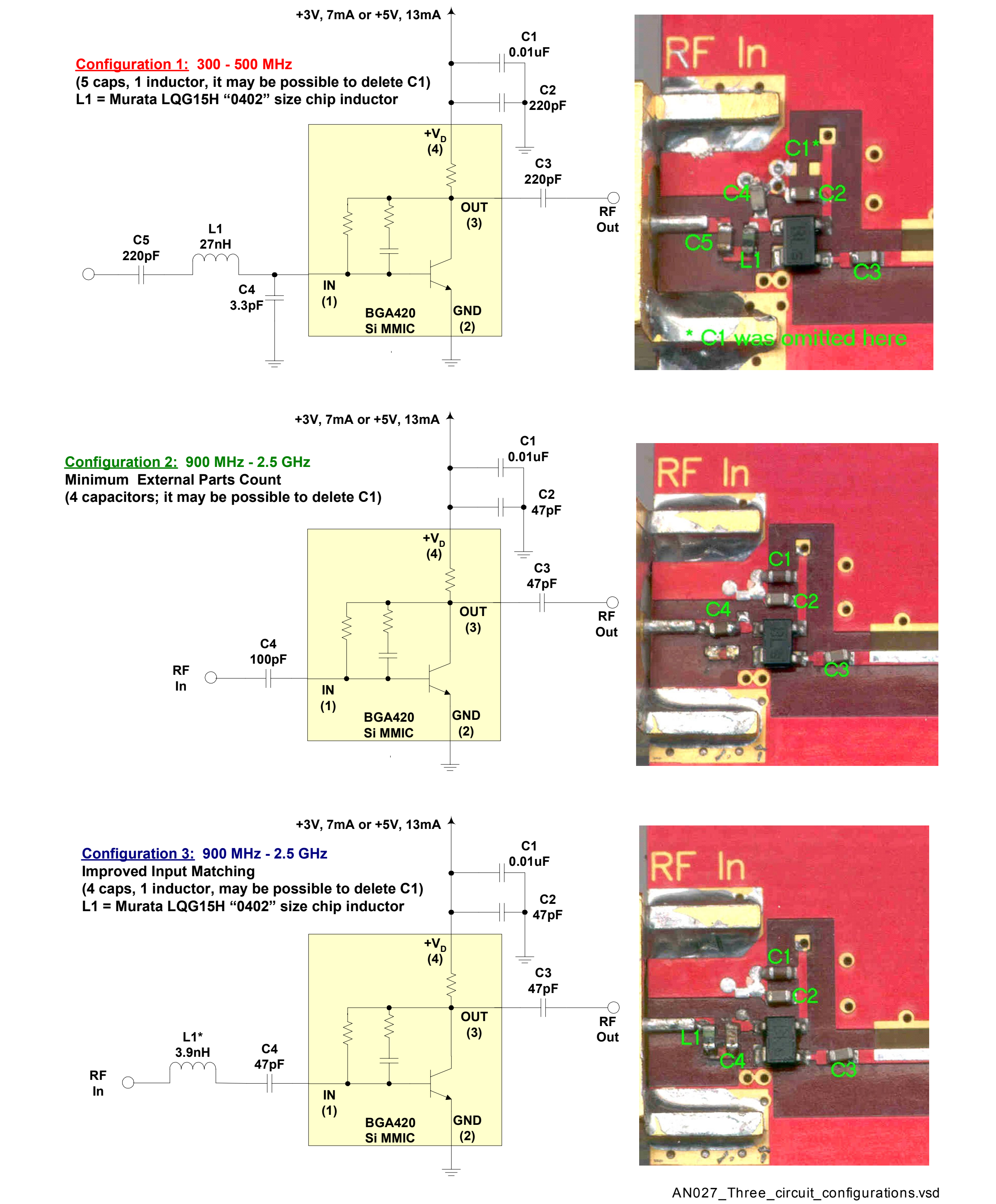


Figure 4 Three circuit configurations presented for BGA420, Configuration 1 is for 300-500 MHz; Configuration 2 is for 900-2500 MHz with minimal parts count; Configuration 3 is for 900-2500 MHz with improved input match

1.3 Summary of Circuit Performance Values

An overview of performance parameters including gain, noise figure, and linearity benchmarks are given in the tables that follow, for each of the three desribed circuit configurations, for both 3.0 V and 5.0 V power supply voltages. Note that all data is taken at T = 25 °C and with network analyzer source power = -30 dBm. Network analyzer "screen shots" of performance data is included in section 4 (appendix) of this applications note.

Table 1 Summary of Data, Configuration # 1, 300 - 500 MHz Application, T = 25 °C

Frequency MHz	V_D Volts	I_D MA	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
315	3.0	7.1	11.5	20.0	31.3	14.6	2.1	-11.9	+8.1	-20.8	-1.8
315	5.0	13.4	16.0	21.7	32.5	16.5	2.5	-7.7	+14.0	-17.3	+3.4
345	3.0	7.1	13.8	20.0	31.4	15.0	2.1				
345	5.0	13.4	18.8	21.6	32.6	16.4	2.6				
390	3.0	7.1	16.1	19.7	31.7	15.0	2.2				
390	5.0	13.4	20.2	21.1	32.9	15.5	2.8				
434	3.0	7.1	14.6	19.3	32.1	14.4	2.3				
434	5.0	13.4	16.6	20.7	33.3	14.3	2.9				

Table 2 Summary of Data, Configuration # 2, 900 - 2500 MHz Application, minimum parts, T = 25 °C

Frequency MHz	V_D Volts	I_D mA	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
900	3.0	7.1	7.2	15.9	33.9	10.9	1.9				
900	5.0	13.4	9.1	16.8	35.2	10.7	2.2				
1575	3.0	7.1	9.4	12.4	29.3	12.3	2.1				
1575	5.0	13.4	10.8	12.8	30.1	11.5	2.5				
1900	3.0	7.1	10.3	11.0	26.9	13.1	2.3	+1.0	+12.0	-11.2	-1.2
1900	5.0	13.4	11.5	11.4	27.4	12.1	2.7	+4.8	+16.2	-6.5	+3.9
2450	3.0	7.1	11.4	9.1	23.6	14.4	2.5				
2450	5.0	13.4	12.5	9.3	24.0	13.1	2.9				

Table 3 Summary of Data, Configuration # 3, 900 - 2500 MHz Application, improved input matching, T = 25 °C

Frequency MHz	V_D Volts	I_D mA	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
900	3.0	7.1	9.3	16.2	33.5	11.2	2.0				
900	5.0	13.4	11.6	16.9	35.0	11.2	2.3				
1575	3.0	7.1	24.8	12.7	28.9	13.4	2.3				
1575	5.0	13.4	25.1	13.0	29.9	12.7	2.7				
1900	3.0	7.1	20.5	11.1	26.6	15.4	2.6	+0.5	+10.7	-11.4	-1.3
1900	5.0	13.4	18.9	11.3	27.4	14.3	3.1	+4.8	+16.1	-7.1	+3.3
2450	3.0	7.1	9.6	8.6	24.1	20.4	3.3				
2450	5.0	13.4	9.7	8.8	24.6	18.0	3.8				

2 Conclusions

The BGA420 is a simple, cost-effective, flexible and easy-to-use MMIC amplifier suitable for a wide range of RF / Wireless applications, from below 100 MHz up to 2.5 GHz. The output of the BGA420 requires no external impedance matching elements and has better than 10 dB return loss over the entire frequency range. The input of the BGA420 has a 50 Ω match for frequencies over 1500 MHz, and needs simple input matching circuits for frequencies under approximately 1500 MHz. This MMIC can be used with power supply voltages from below 3 V up to a maximum of 6 V. Application PC boards like that shown in this Application Note are available from Infineon Techologies. When ordering such PCBs, please be sure to indicate which circuit variant is desired - Configuration #1, Configuration #2, Configuration #3.

3 Appendix - Data Plots

The following section shows network analyzer screen shots, noise figure plots and gain compression plots for the different BGA420 amplifier configuration applications presented in this applications note.

3.1 Configuration #1: 300 -500 MHz Application

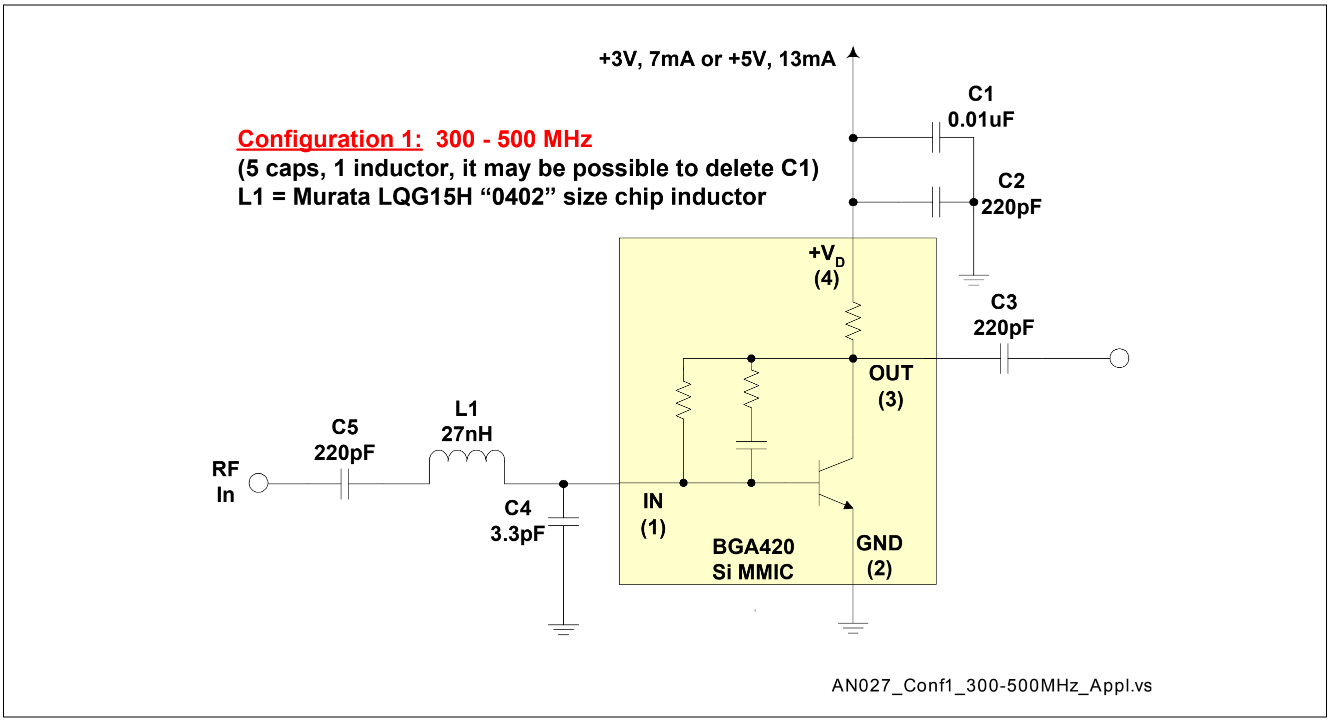


Figure 5 Configuration #1, 300-500 MHz Circuit

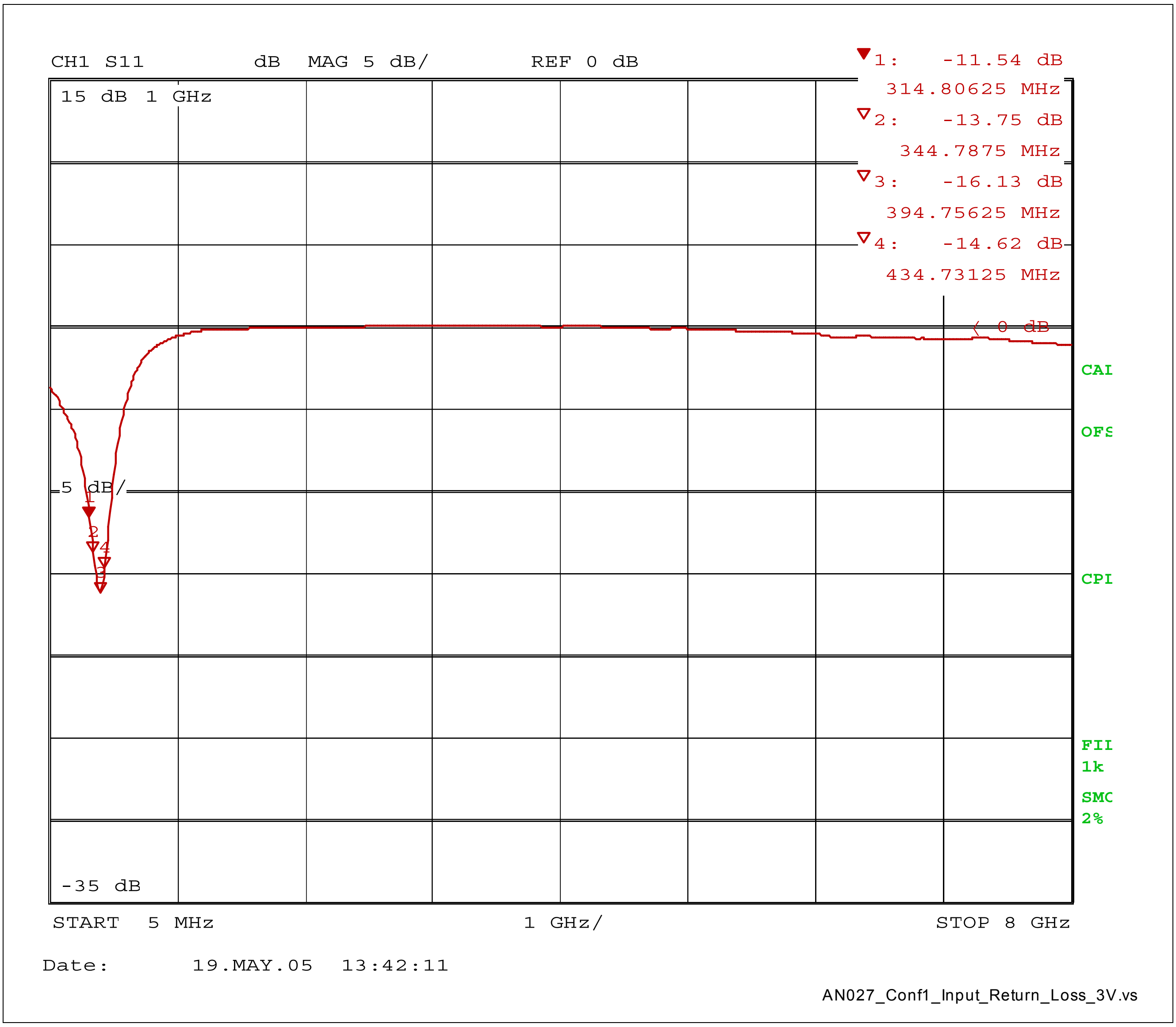


Figure 6 Configuration #1, 300 - 500 MHz Circuit, Input Return Loss, Log Mag, 5 MHz - 8 GHz sweep 3 V, 7.1 mA Condition

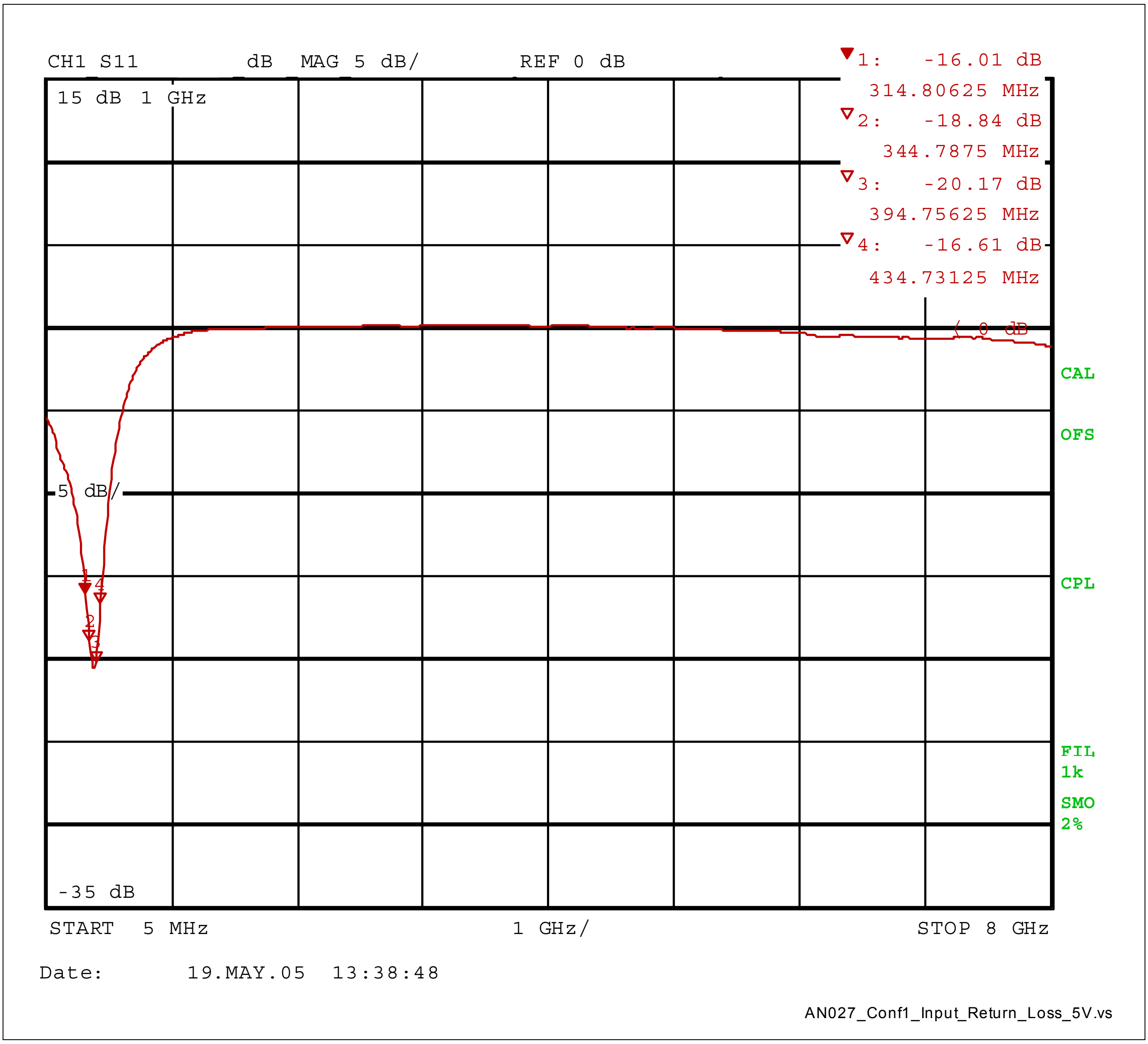


Figure 7 Configuration #1, 300 - 500 MHz Circuit, Input Return Loss, Log Mag, 5 MHz - 8 GHz sweep 5 V, 13.4 mA Condition

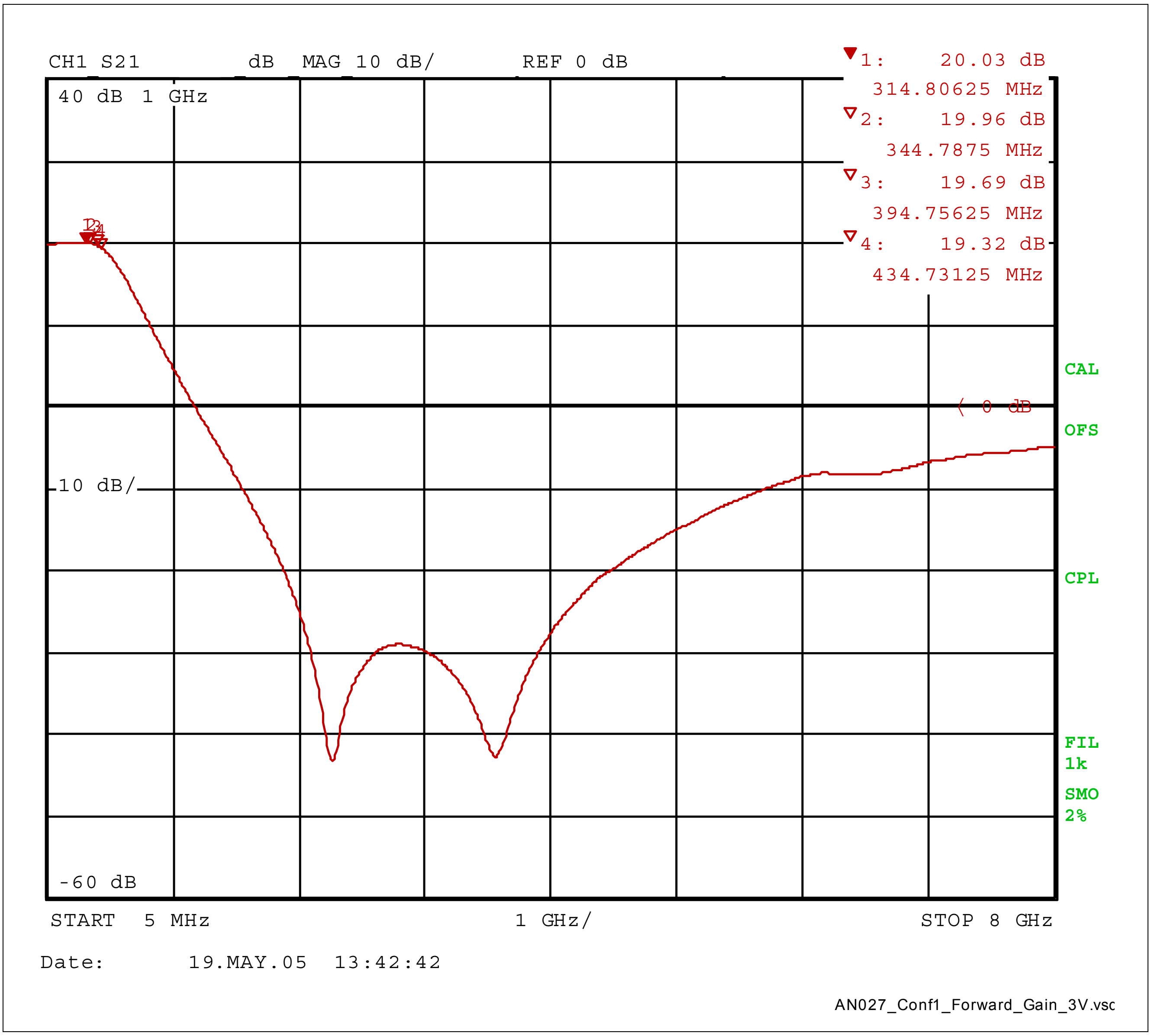


Figure 8 Configuration #1, 300 - 500 MHz Circuit, Forward Gain, Log Mag, 5 MHz - 8 GHz sweep 3 V, 7.1 mA Condition

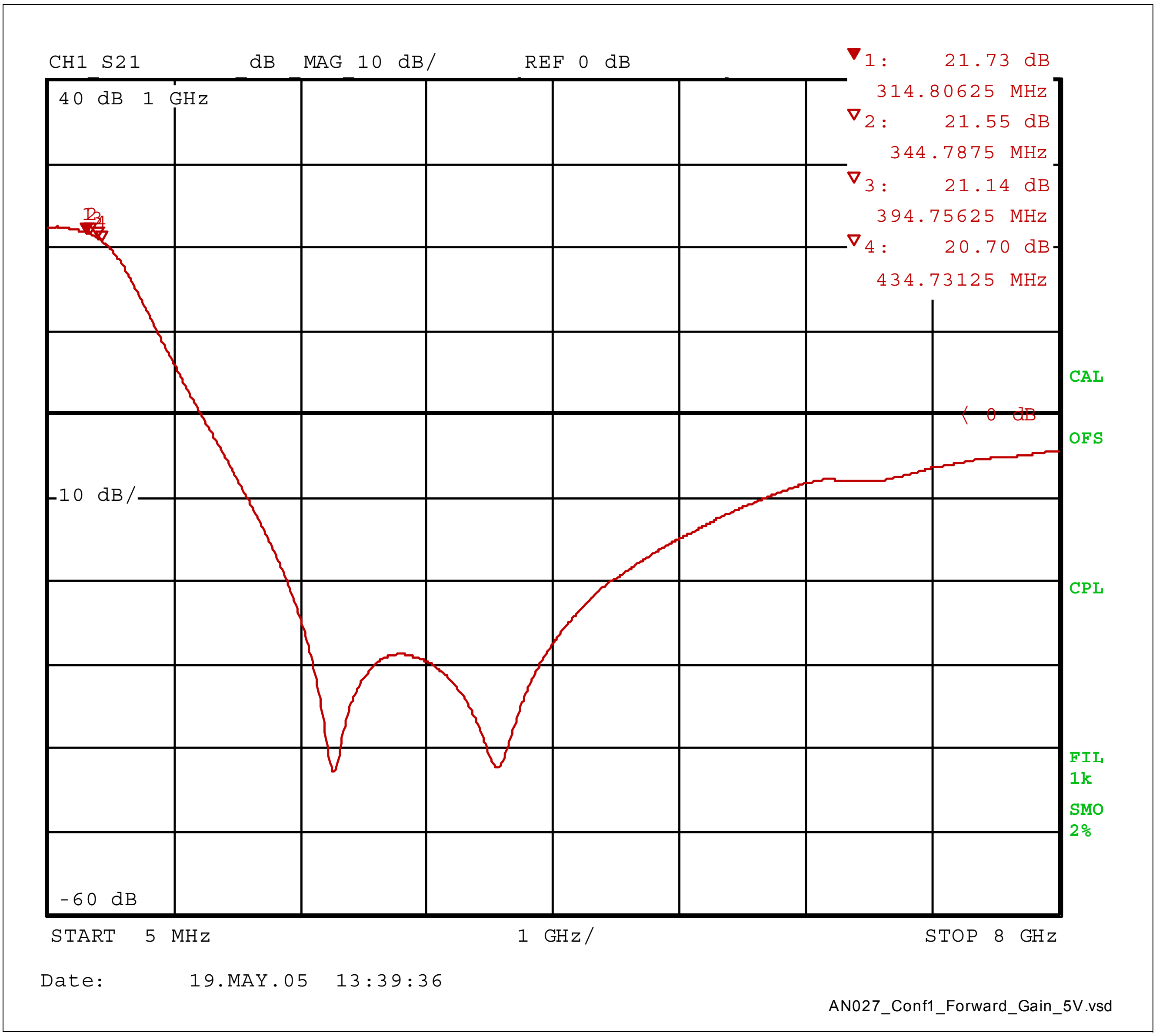


Figure 9 **Configuration #1, 300 - 500 MHz Circuit, Forward Gain, Log Mag, 5 MHz - 8 GHz sweep 5 V, 13.4 mA Condition**

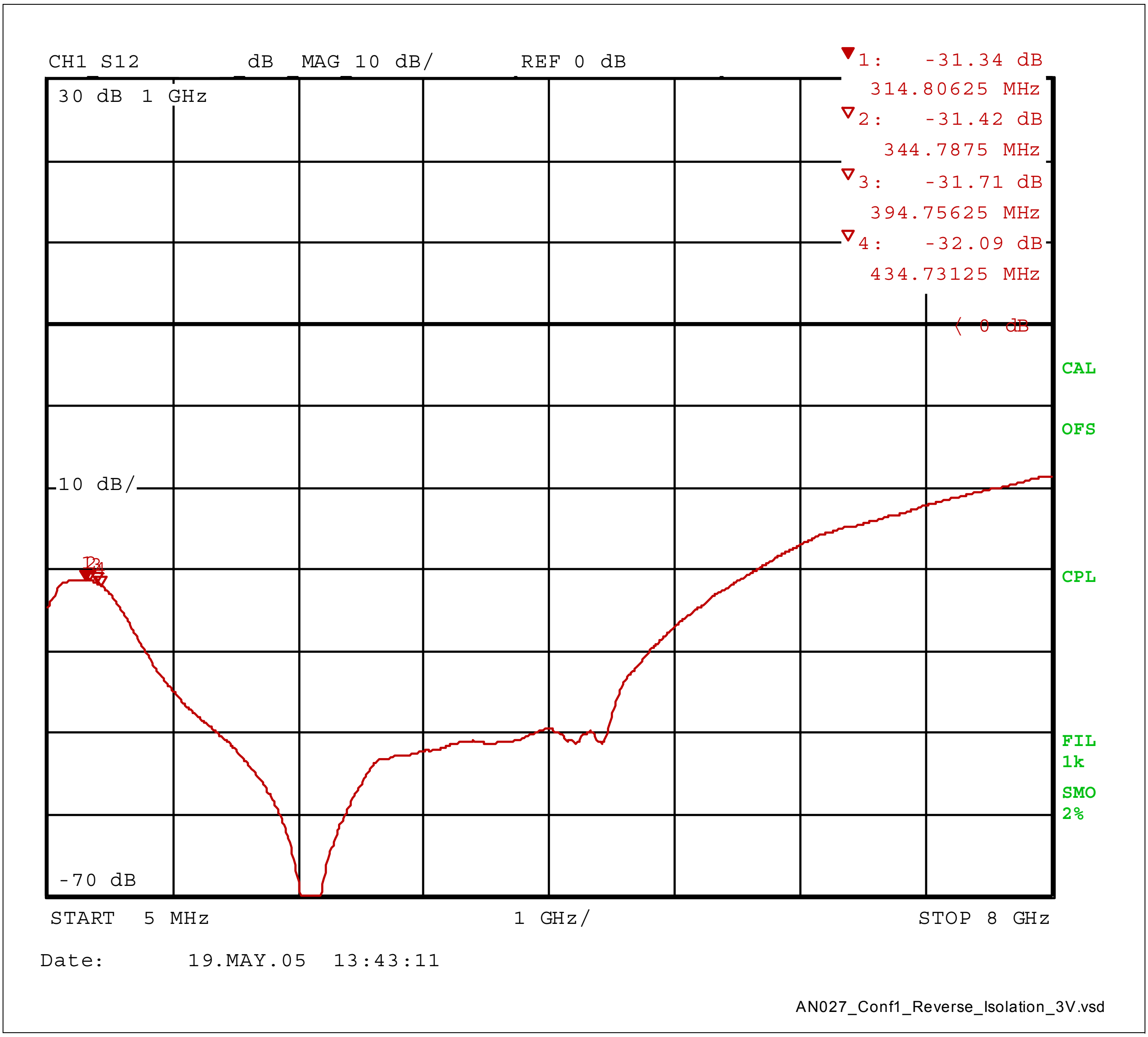


Figure 10 Configuration #1, 300 - 500 MHz Circuit, Reverse Isolation, Log Mag, 5 MHz - 8 GHz sweep 3 V, 7.1 mA Condition

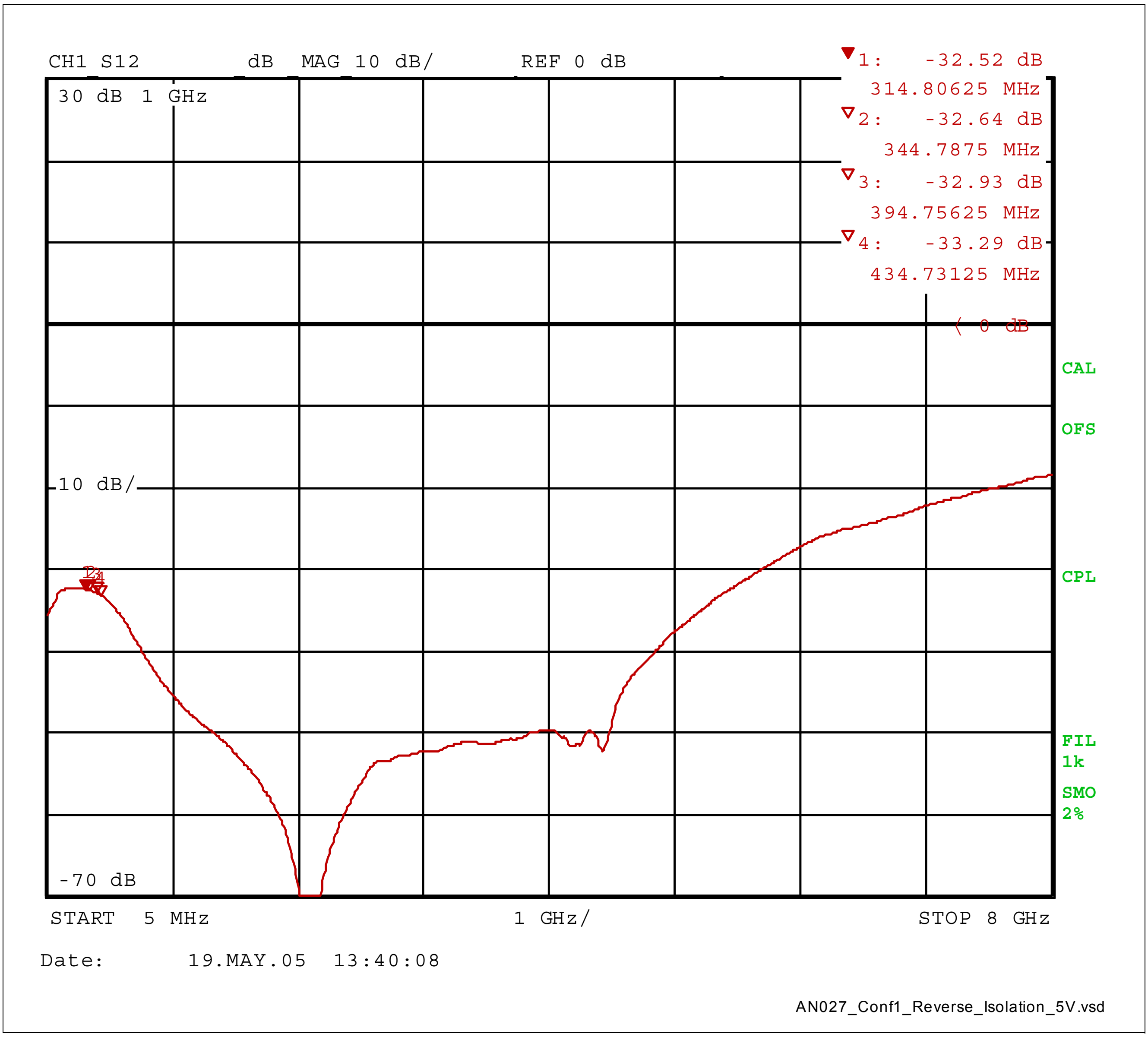


Figure 11 Configuration #1, 300 - 500 MHz Circuit, Recerse Isolation, Log Mag, 5 MHz - 8 GHz sweep 5 V, 13.4 mA Condition

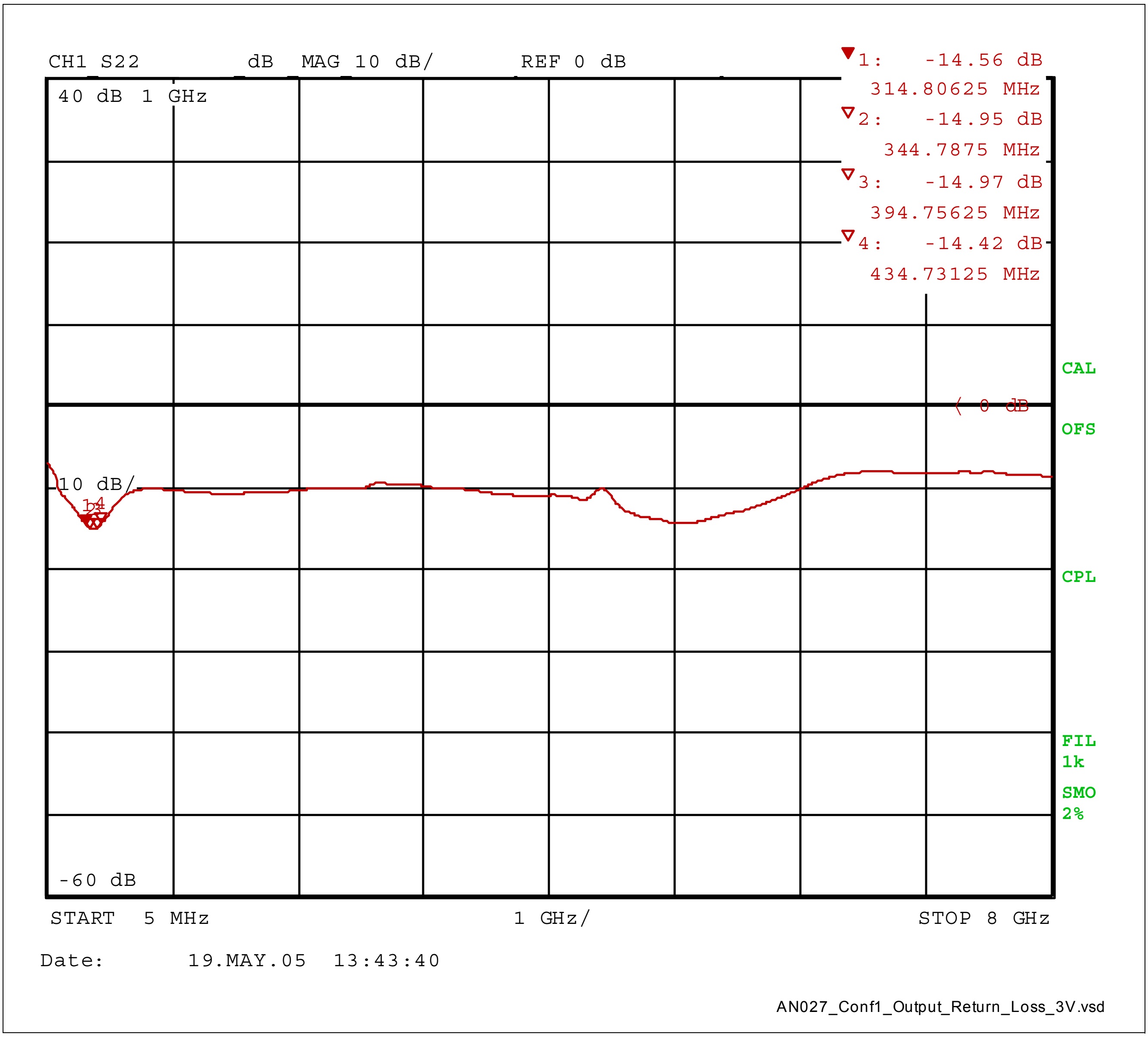


Figure 12 Configuration #1, 300 - 500 MHz Circuit, Output Return Loss, Log Mag, 5 MHz - 8 GHz sweep 3 V, 7.1 mA Condition

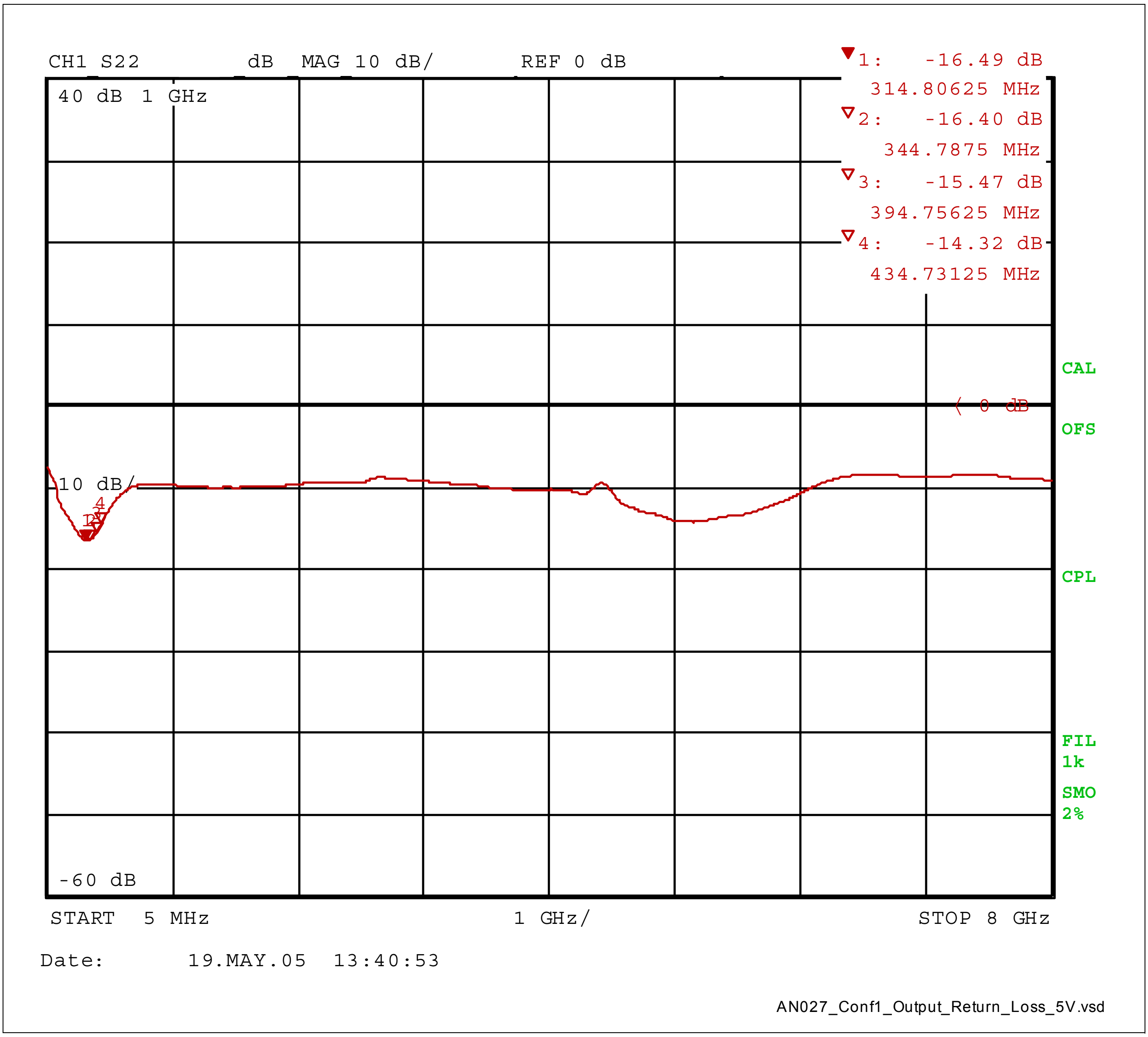


Figure 13 Configuration #1, 300 - 500 MHz Circuit, Output Return Loss, Log Mag, 5 MHz - 8 GHz sweep 5 V, 13.4 mA Condition

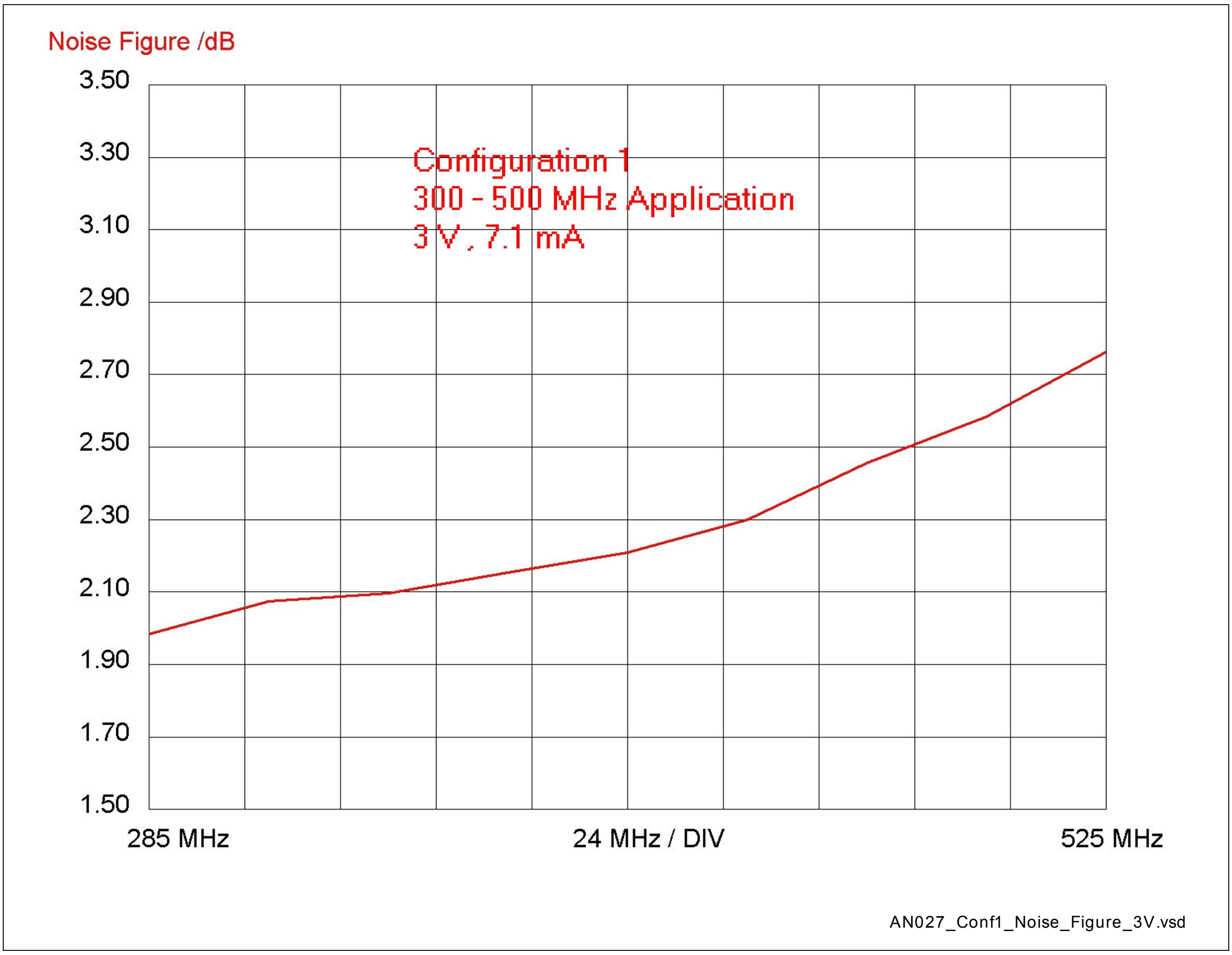


Figure 14 Configuration #1, 300 - 500 MHz Circuit, Noise Figure, 285-525 MHz sweep (Center of plot = 405 MHz) 3 V, 7.1 mA Condition

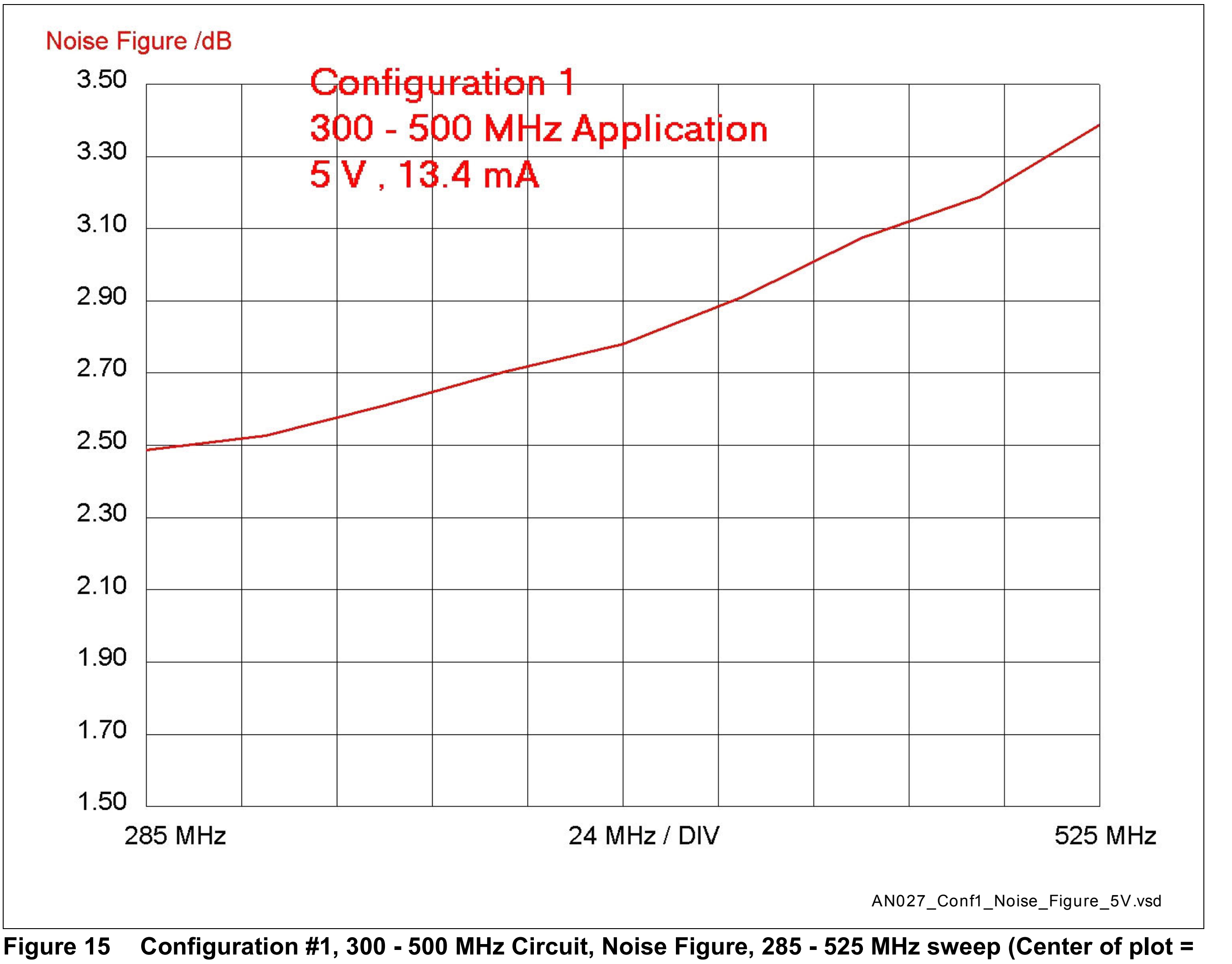


Figure 15 **Configuration #1, 300 - 500 MHz Circuit, Noise Figure, 285 - 525 MHz sweep (Center of plot = 405 MHz) 5 V, 13.4 mA Condition**

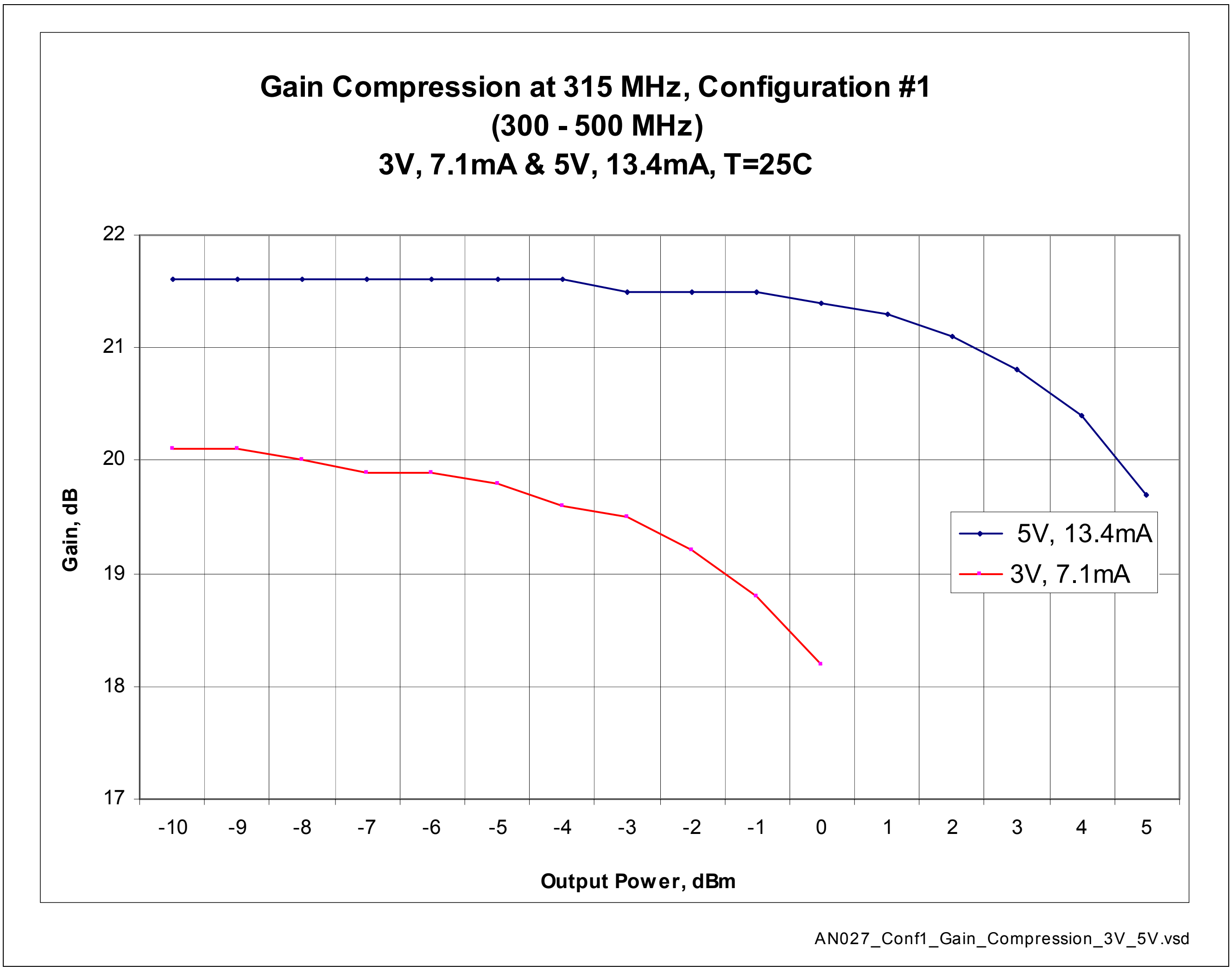


Figure 16 Configuration #1, 300 - 500 MHz Circuit, Gain Compression at 315 MHz 3V, 7.1 mA and 5 V, 13.4 mA

3 V, 7.1 mA: OP_{1dB} = -1.8 dBm; IP_{1dB} = 1.8 dBm - (20 - 1) = -20.8 dBm

5 V, 13.4 mA: OP_{1dB} = +3.4 dBm; IP_{1dB} = +3.4 dBm - (21.7 - 1) = -17.3 dBm

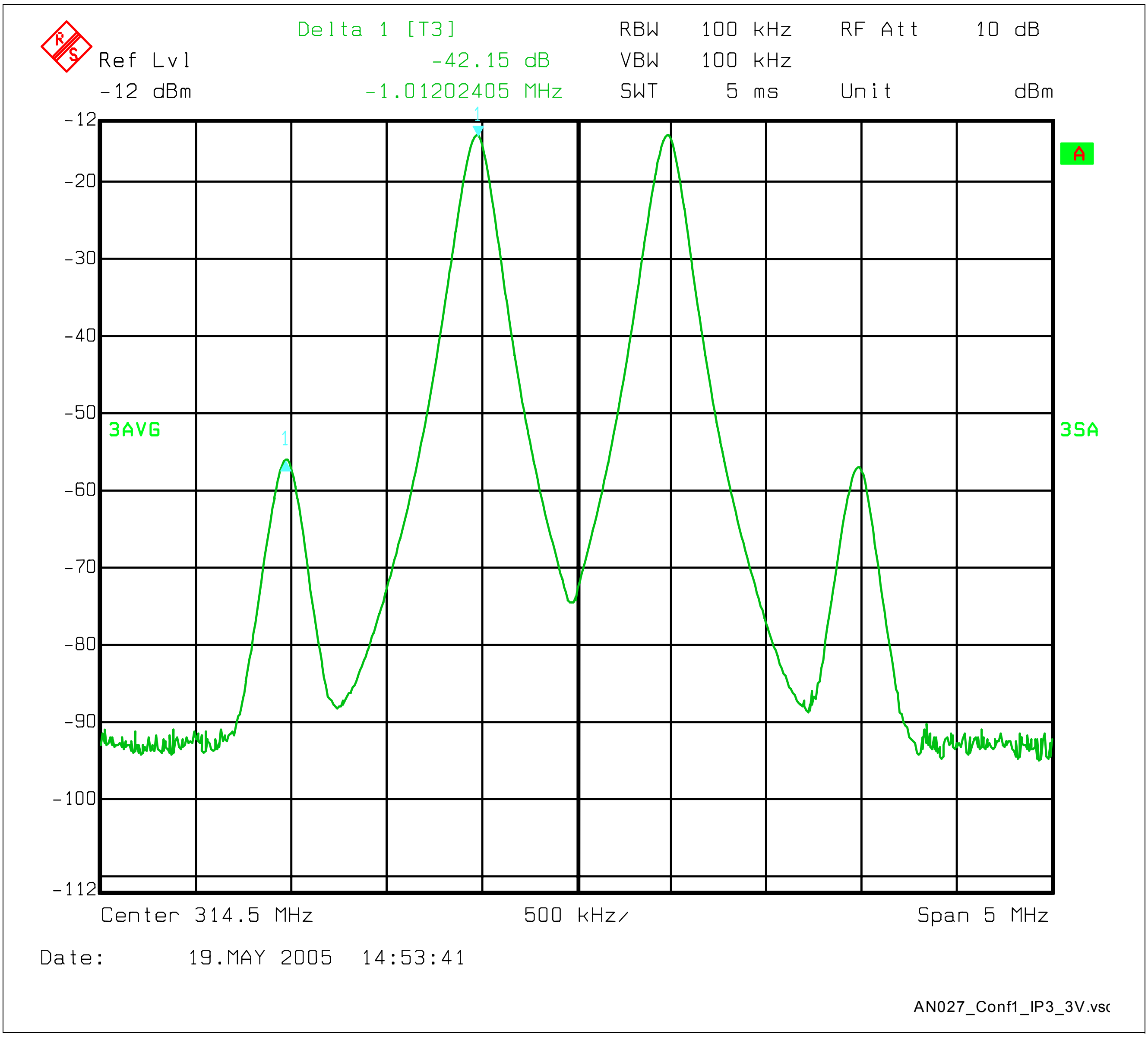


Figure 17 Configuration #1, 300 - 500 MHz Circuit, Third Order Intercept (IP_3) 3 V, 7.1 mA condition

Input: f_1= 314 MHz, f_2 = 315 MHz, -33 dBm each tone

Input IP_3 = -33 dBm + (42.2 dB / 2) = -11.9 dBm

Output IP_3 = -11.9 dBm + 20.0 dB gain = +8.1 dBm

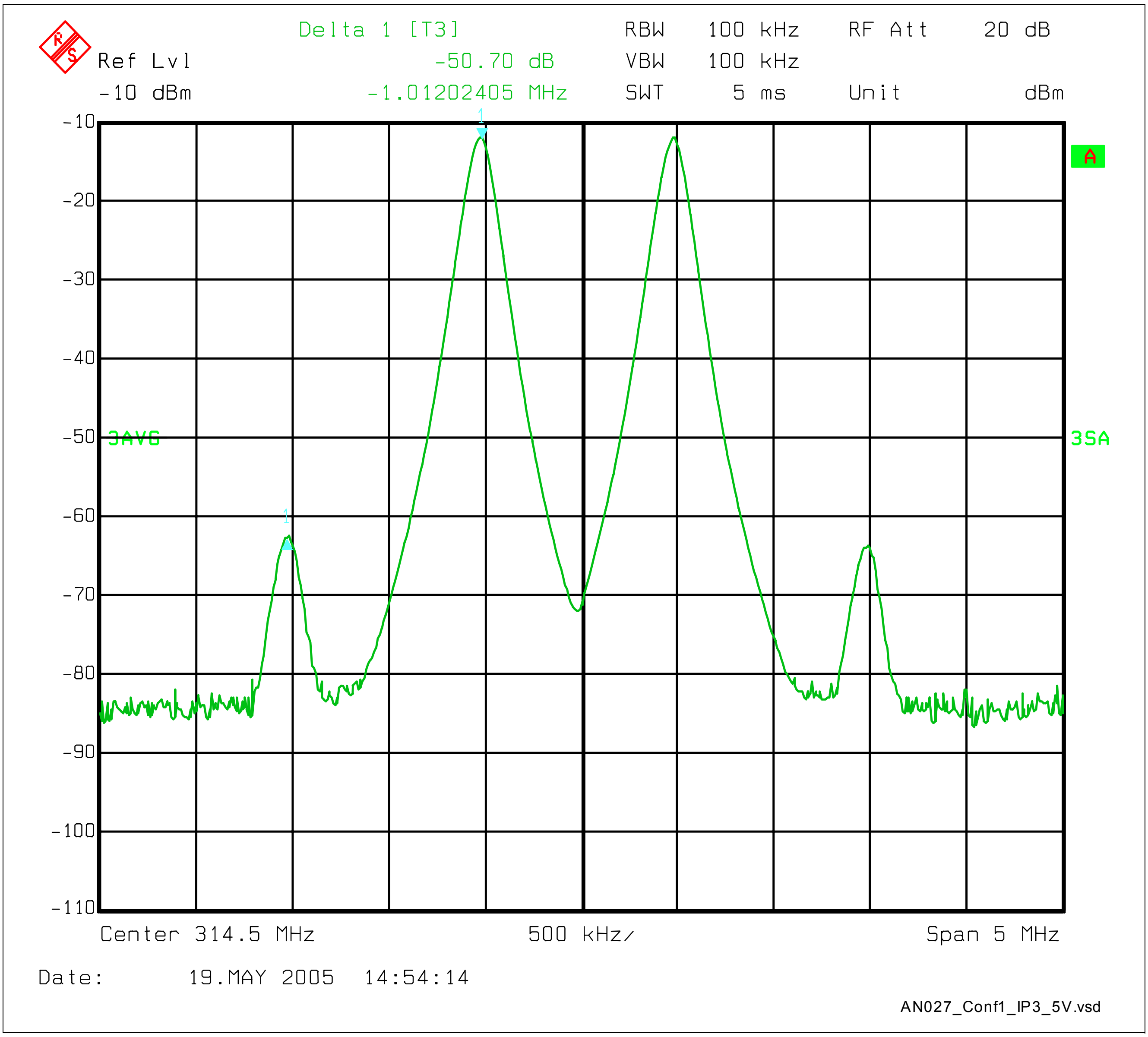


Figure 18 Configuration #1, 300 - 500 MHz Circuit, Third Order Intercept (IP_3) 5 V, 13.4 mA condition

Input: f_1= 314 MHz, f_2 = 315 MHz, -33 dBm each tone

Input IP_3 = -33 dBm + (50.7 dB / 2) = -7.7 dBm

Output IP_3 = -7.7 dBm + 21.7 dB gain = +14.0 dBm

3.2 Configuration #2: 900 MHz - 2.5 GHz, minimum part count

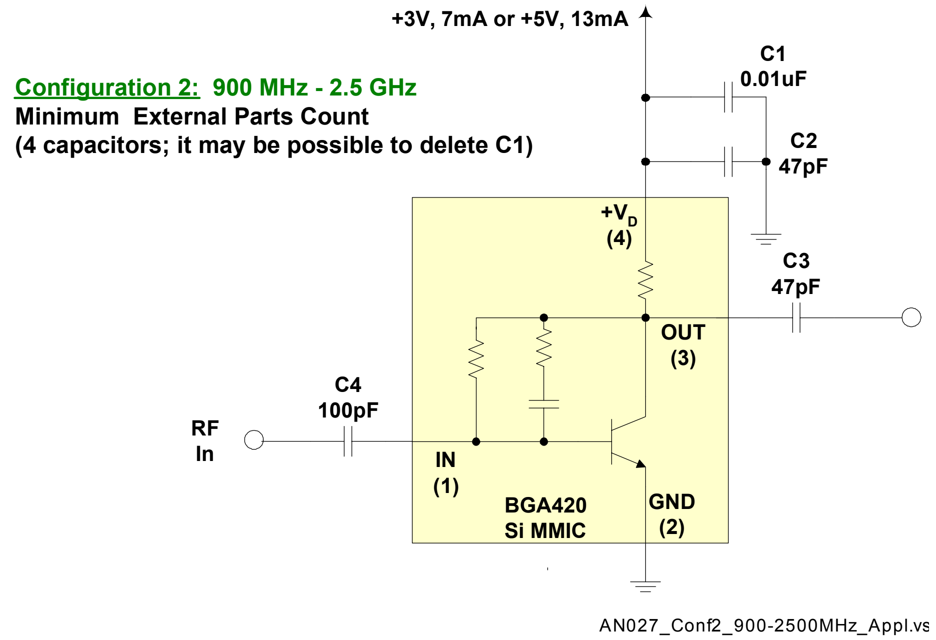


Figure 19 Configuration #2, 900 MHz - 2.5 GHz, Minimum Parts Count

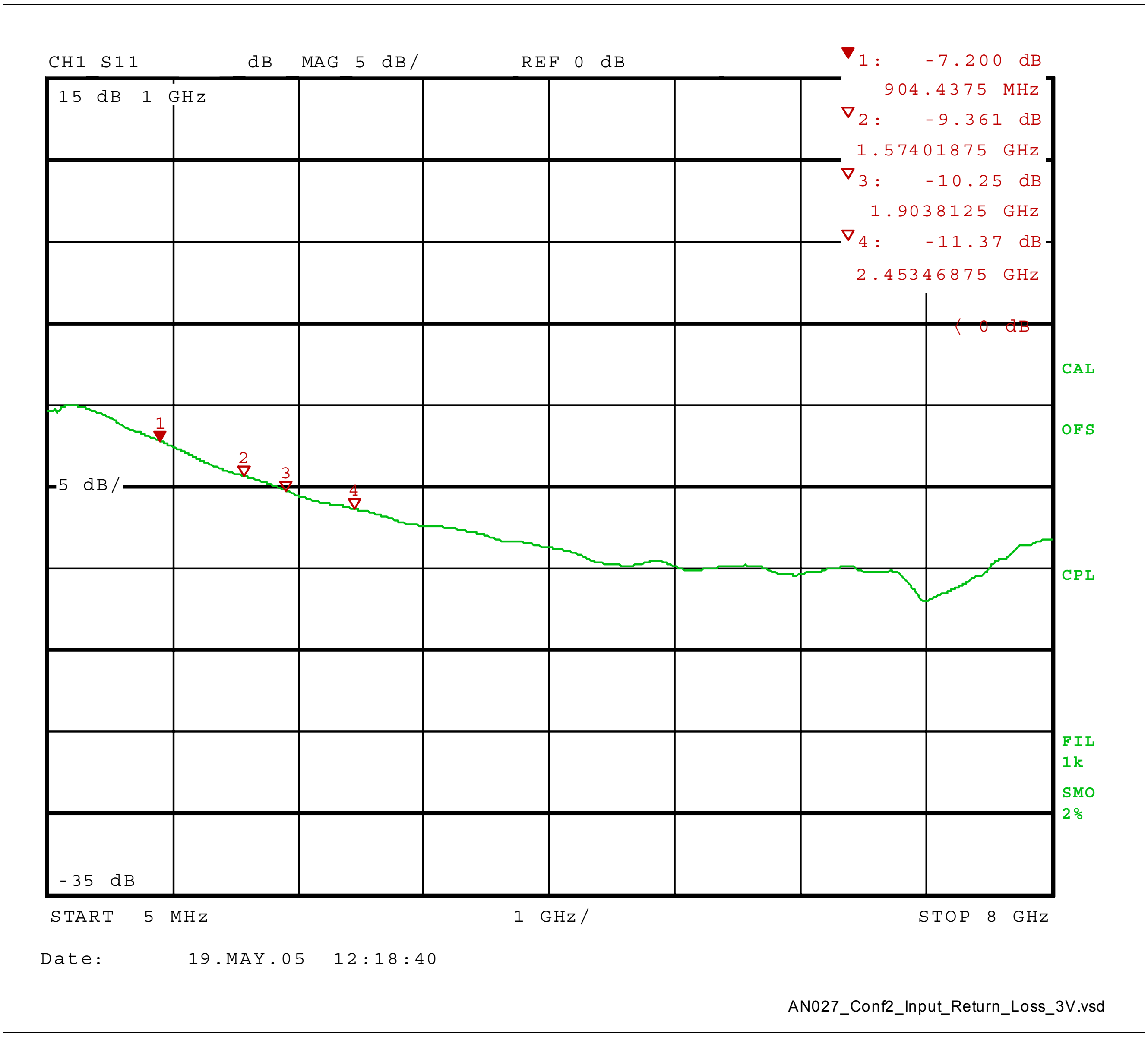


Figure 20 Configuration #2, 900 MHz - 2.5 GHz Minimum Parts Count, Input Return Loss, Log Mag, 5 MHz - 8 GHz sweep 3 V, 7.1 mA Condition

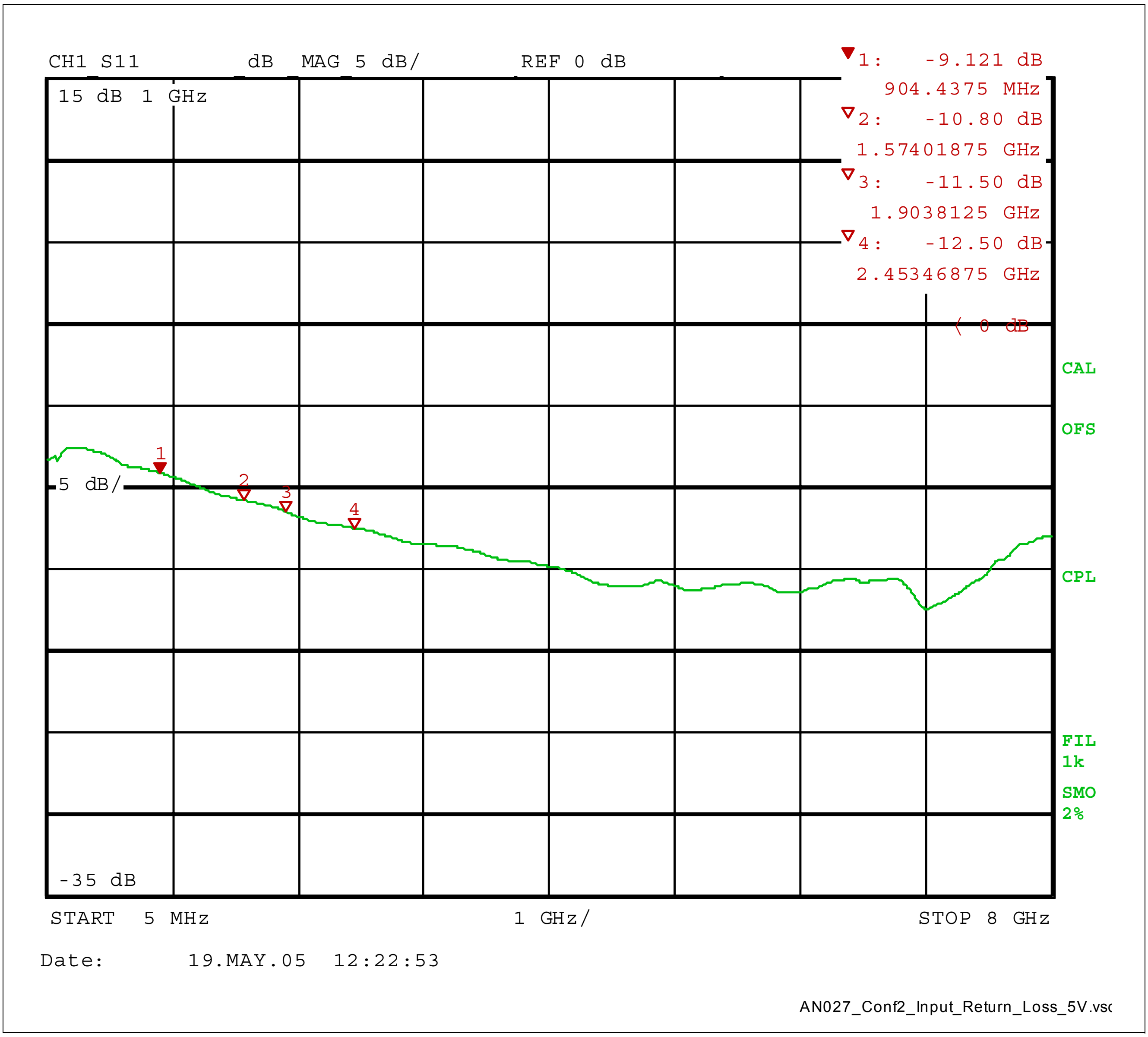


Figure 21 **Configuration #2, 900 MHz - 2.5 GHz, Minimum Parts Count, Input Return Loss, Log Mag, 5 MHz - 8 GHz sweep 5 V, 13.4 mA Condition**

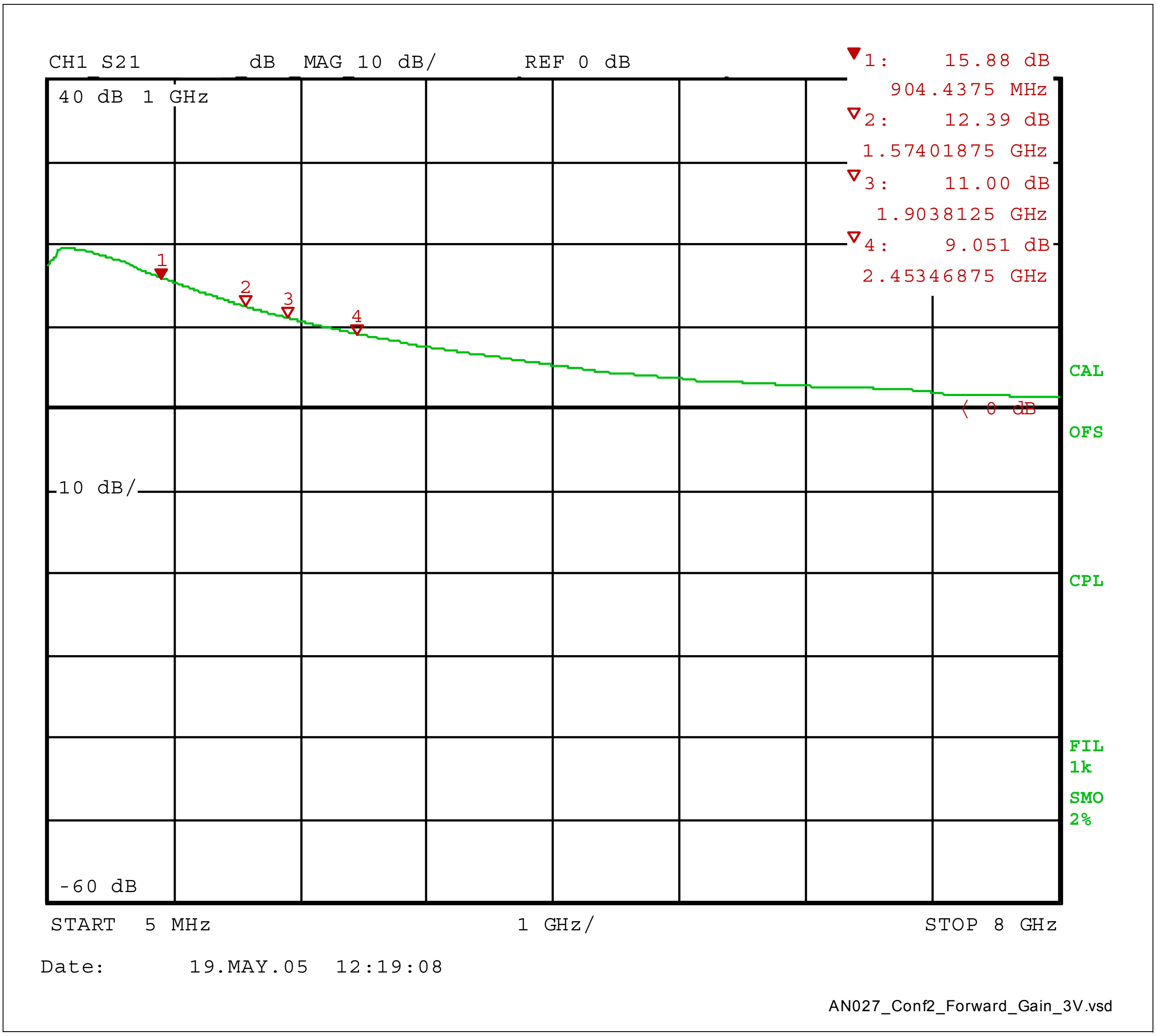


Figure 22 **Configuration #2, 900 - 2.5 GHz, Minimum Parts Count, Forward Gain, Log Mag, 5 MHz - 8 GHz sweep 3 V, 7.1 mA Condition**

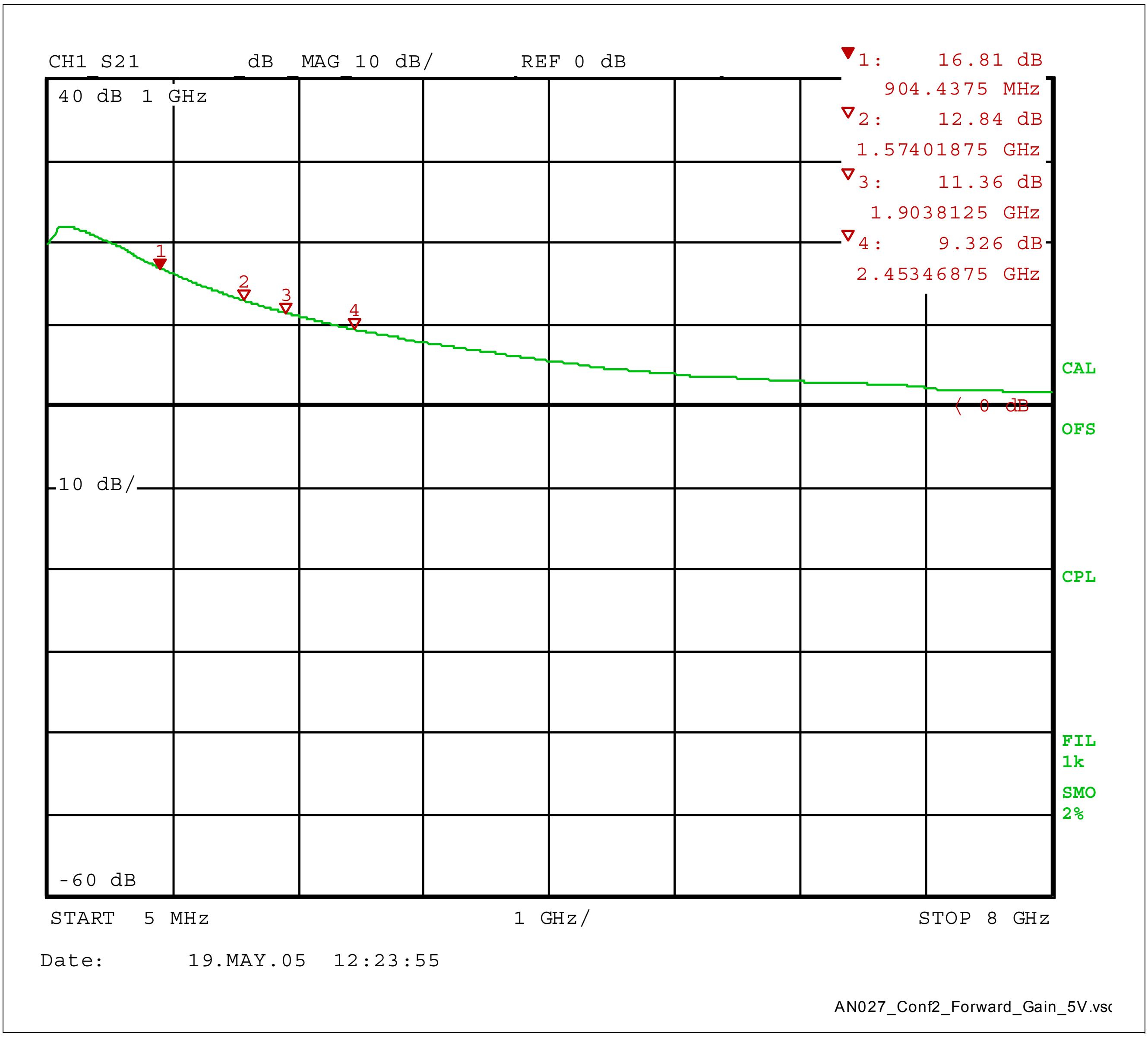


Figure 23 Configuration #2, 900 MHz - 2.5 GHz, Minimum Parts Count, Forward Gain, Log Mag, 5 MHz - 8 GHz sweep 5 V, 13.4 mA Condition

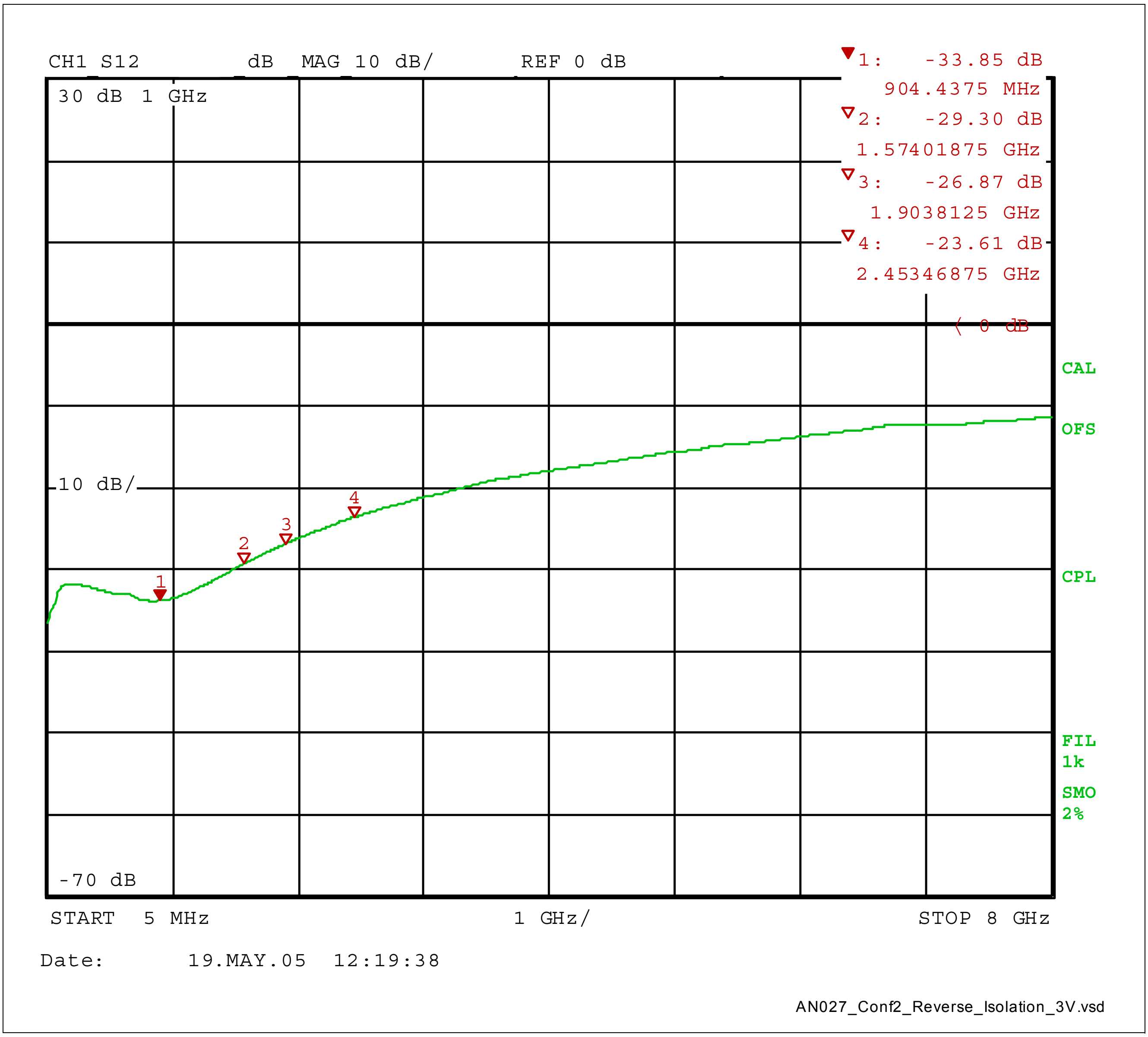


Figure 24 **Configuration #2, 900 MHz - 2.5 GHz, Minimum Parts Count, Reverse Isolation, Log Mag, 5 MHz - 8 GHz sweep 3 V, 7.1 mA Condition**

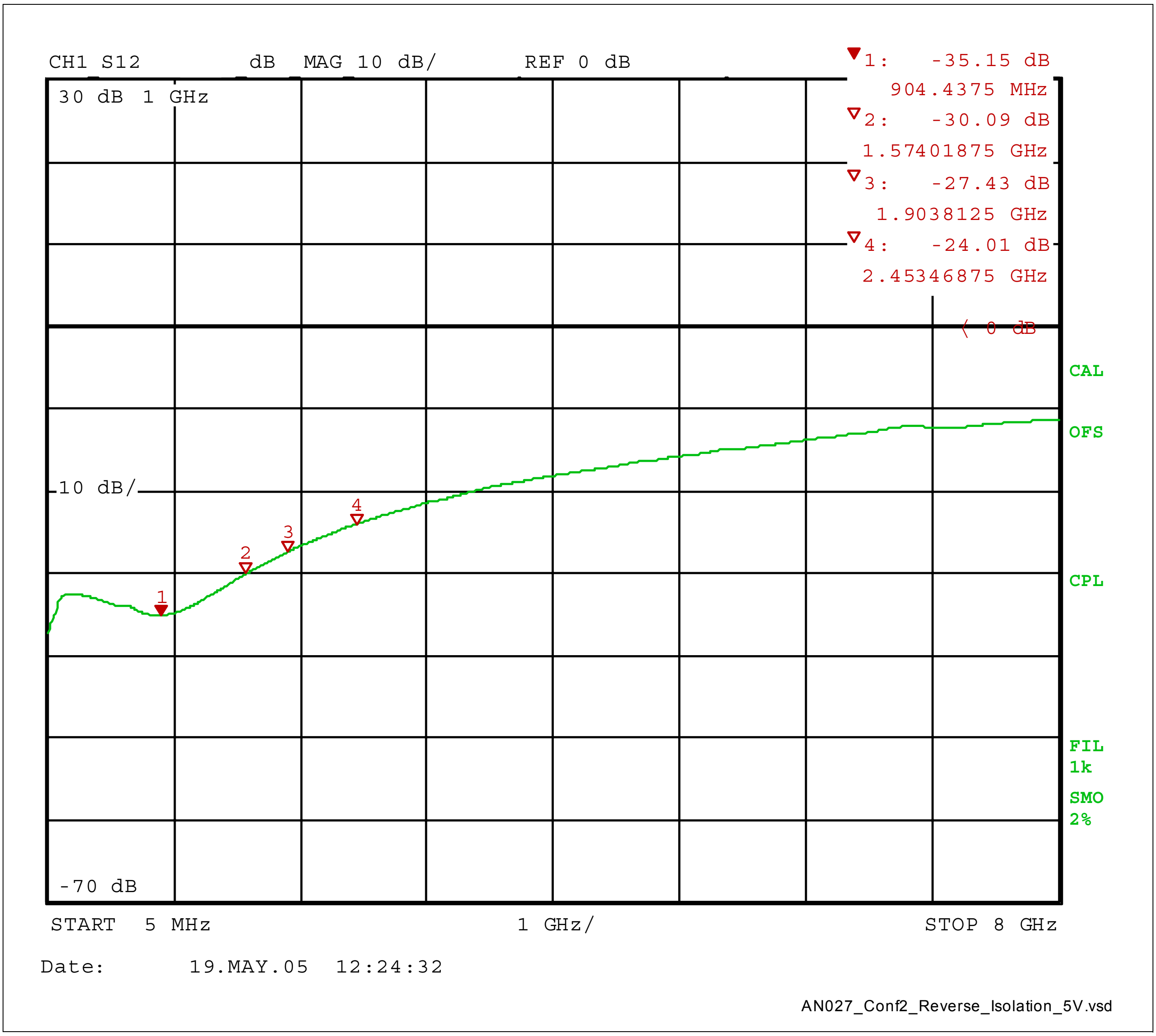


Figure 25 Configuration #2, 900 MHz - 2.5 GHz, Minimum Parts Count, Recerse Isolation, Log Mag, 5 MHz - 8 GHz sweep 5 V, 13.4 mA Condition

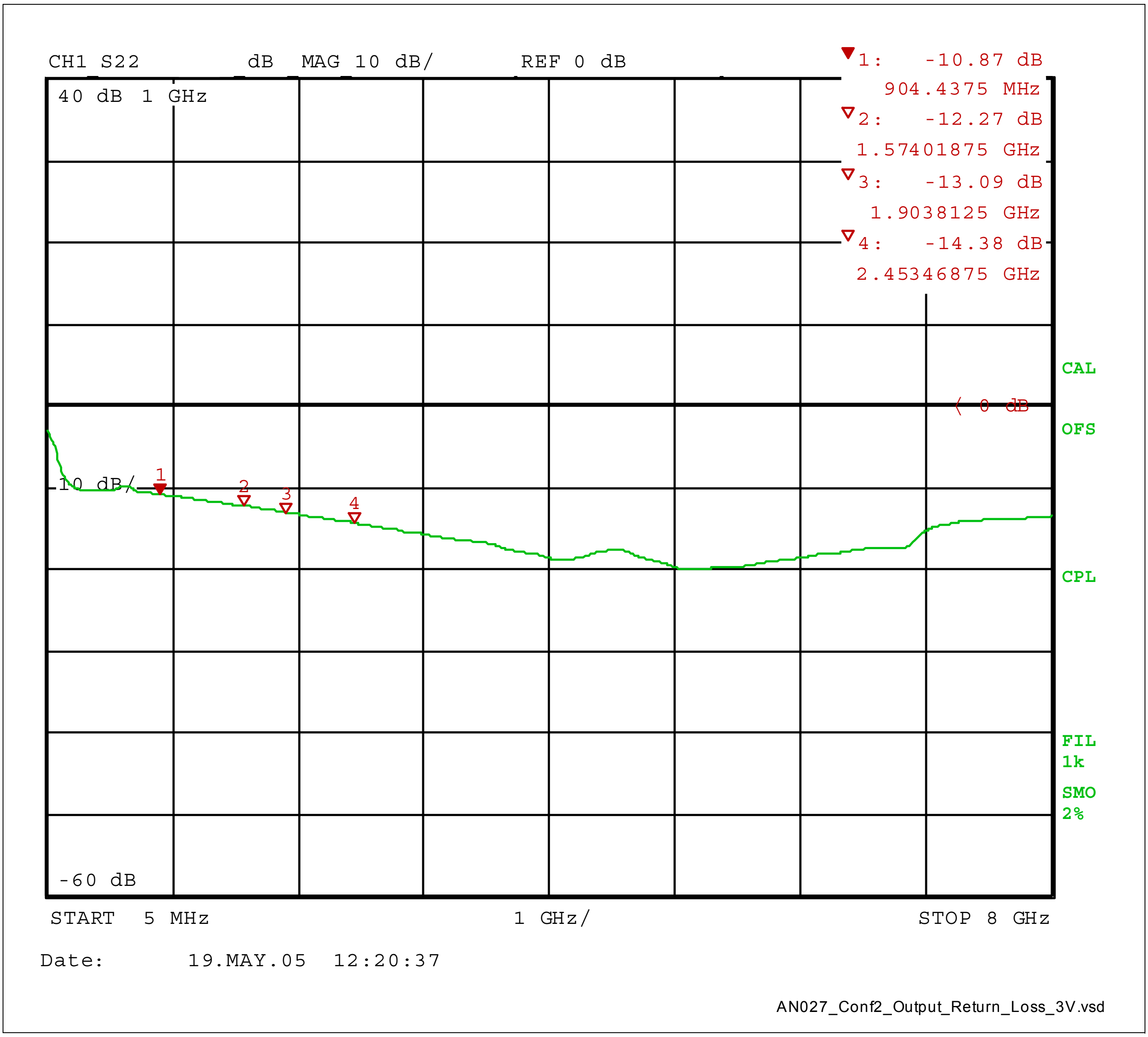


Figure 26 Configuration #2, 900 MHz - 2.5 GHz, Output Return Loss, Log Mag, 5 MHz - 8 GHz sweep 3 V, 7.1 mA Condition

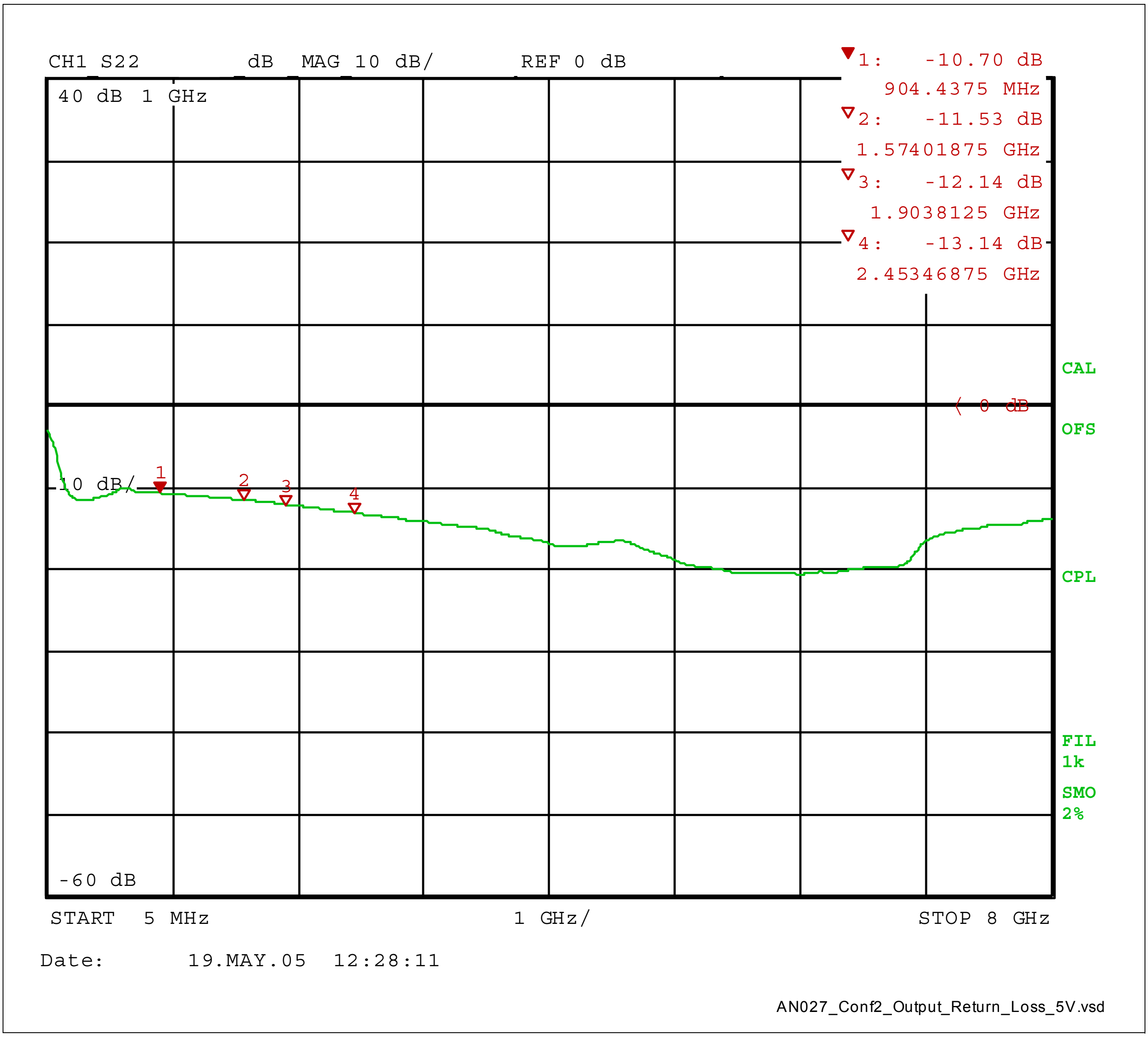


Figure 27 Configuration #2, 900 MHz - 2.5 GHz, Minimum Part Count, Output Return Loss, Log Mag, 5 MHz - 8 GHz sweep 5 V, 13.4 mA Condition

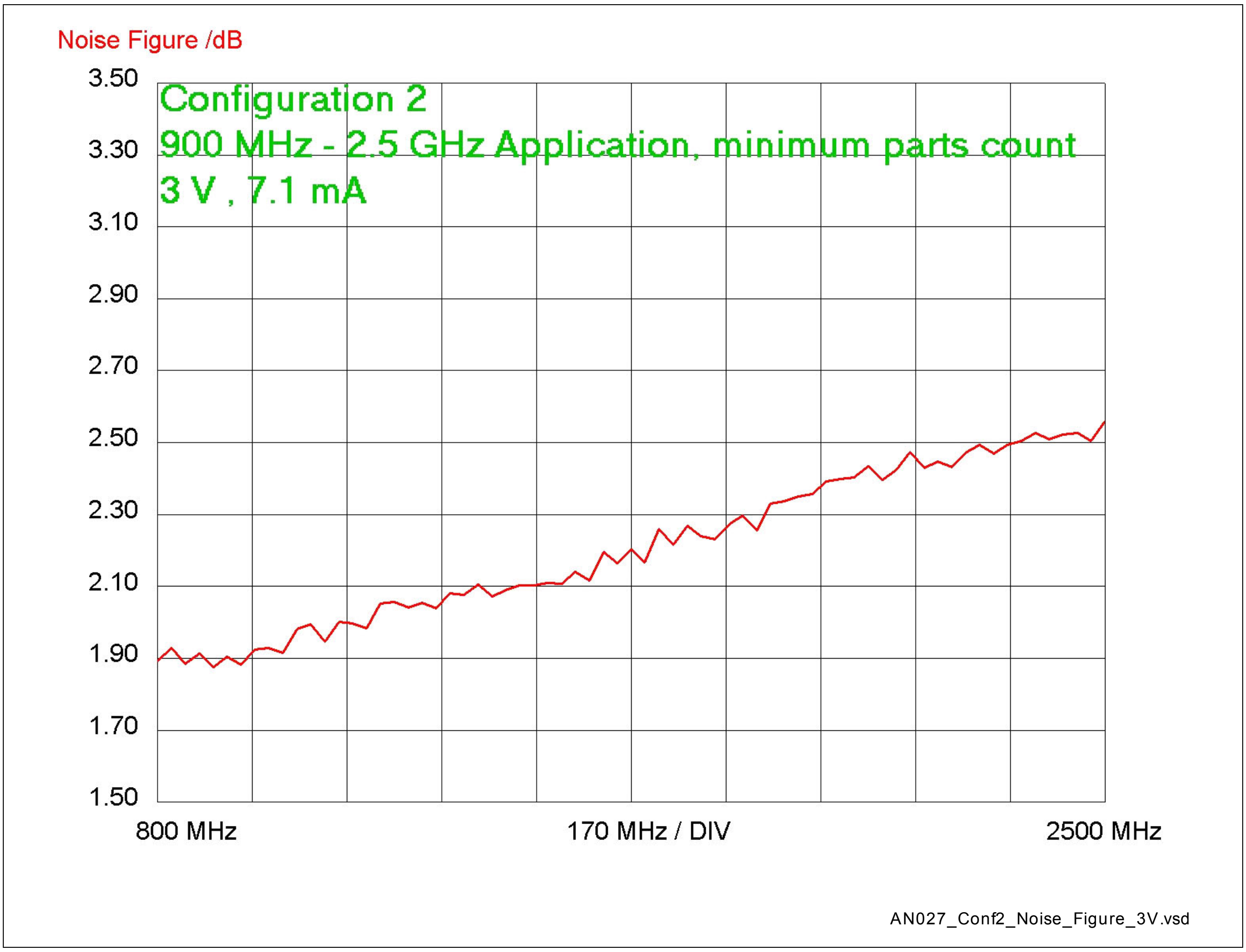


Figure 28 **Configuration #2, 900 MHz - 2.5 GHz, Minimum Parts Count, Noise Figure, 800 - 2500 MHz sweep (Center of plot = 1650 MHz) 3 V, 7.1 mA Condition**

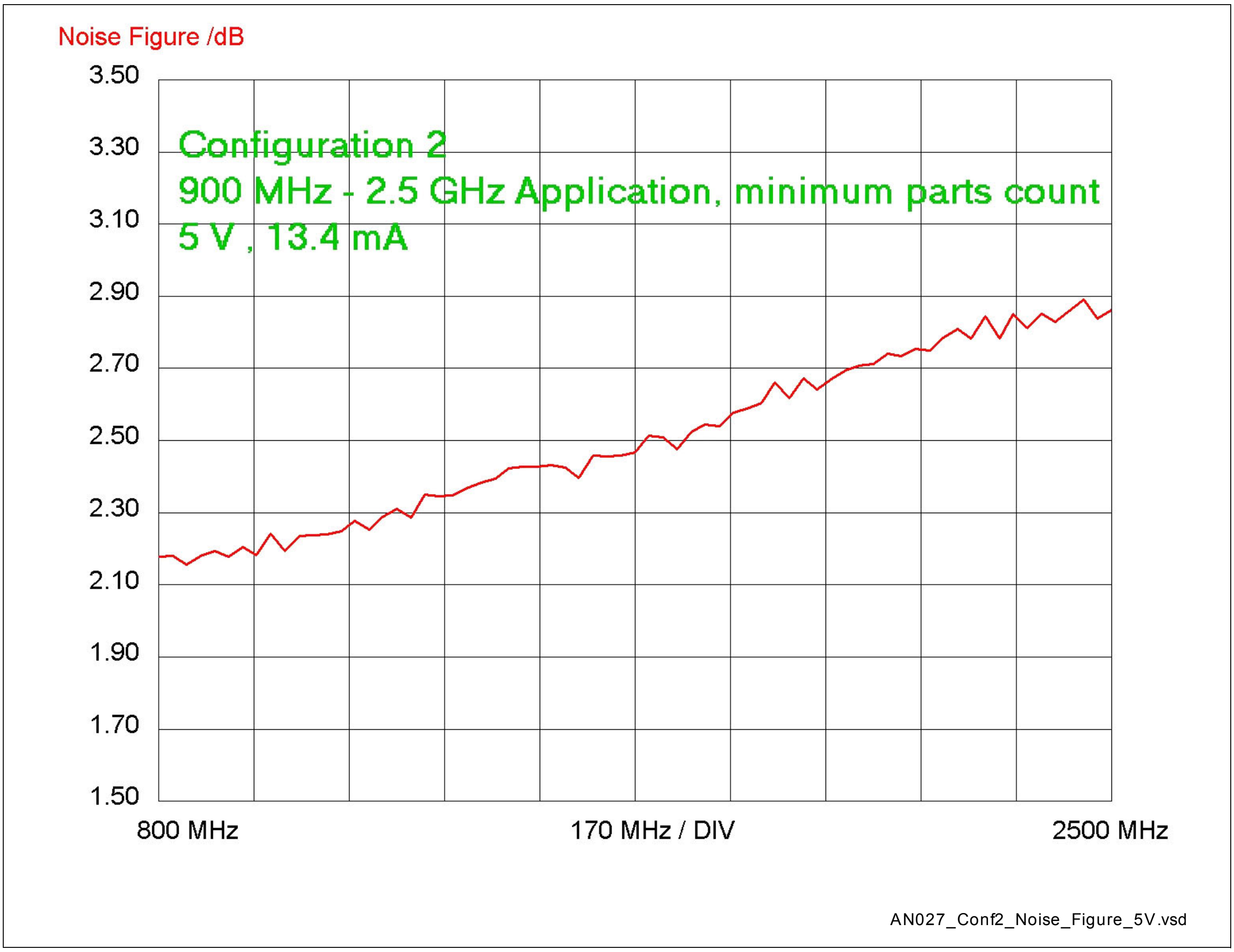


Figure 29 **Configuration #2, 900 MHz - 2.5 GHz, Minimum Parts Count, Noise Figure, 800 - 2500 MHz sweep (Center of plot = 1650 MHz) 5 V, 13.4 mA Condition**

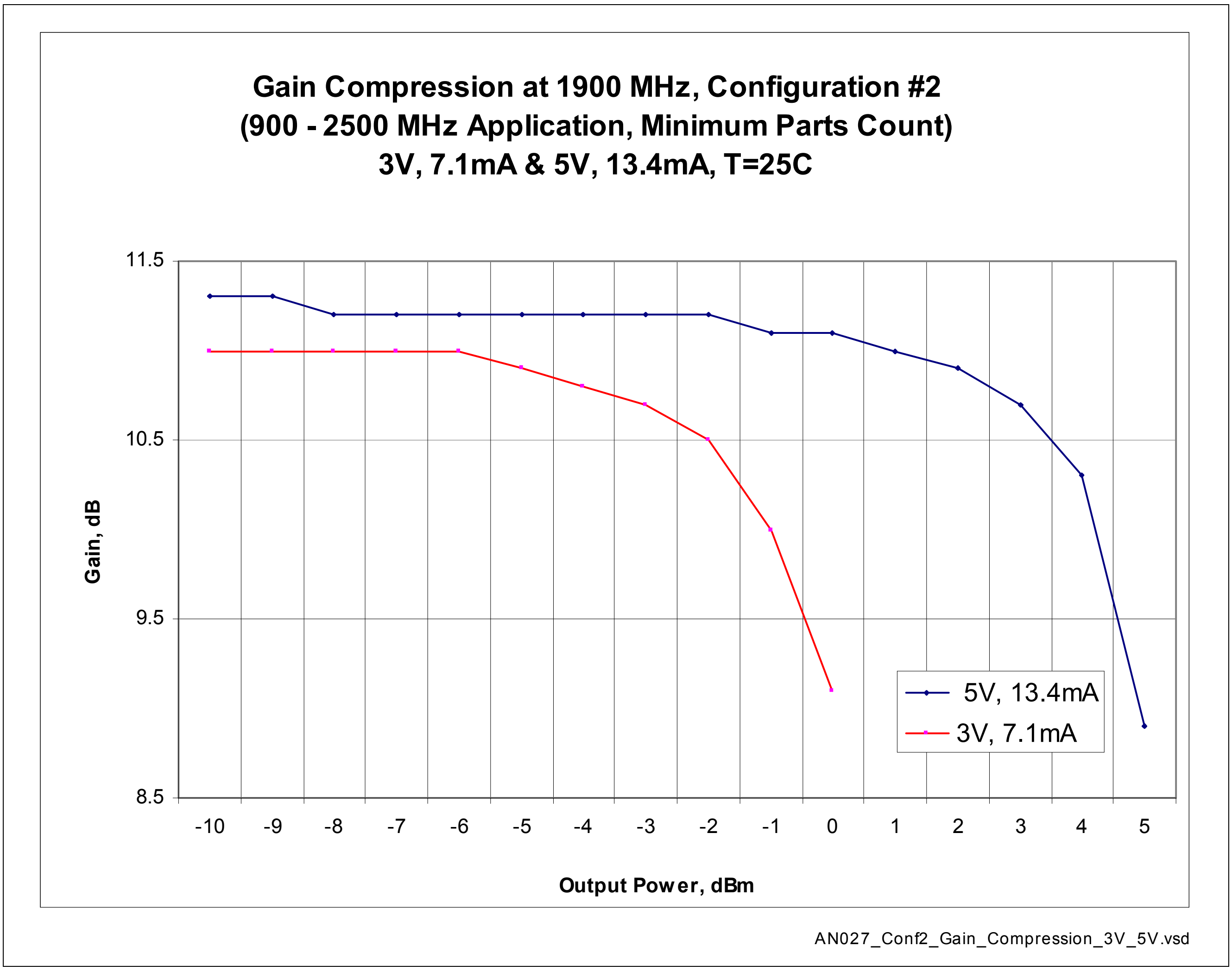


Figure 30 Configuration #2, 900 MHz - 2.5 GHz Circuit, Minimum Parts Count, Gain Compression at 315 MHz 3 V, 7.1 mA and 5 V, 13.4 mA

3 V, 7.1 mA: OP_{1dB} = -1.2 dBm; IP_{1dB} = -1.2 dBm - (11.0 - 1) = -11.2 dBm

5 V, 13.4 mA: OP_{1dB} = +3.9 dBm; IP_{1dB} = +3.9 dBm - (11.4 - 1) = -6.5 dBm

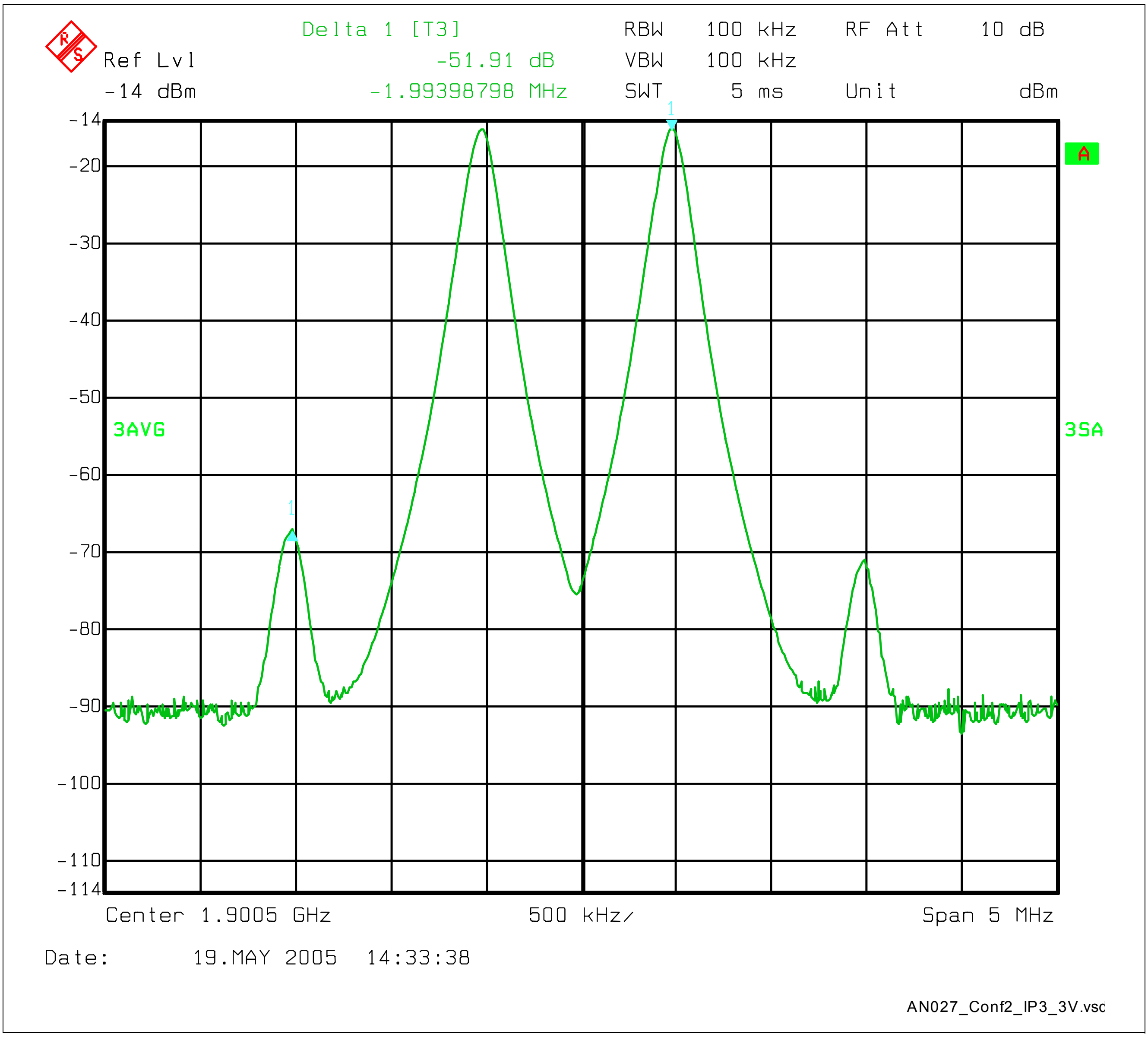


Figure 31 Configuration #2, 900 MHz- 2.5 GHz, Minimum Parts Count, Third Order Intercept (IP_3) 3 V, 7.1 mA condition

Input: f_1= 1900 MHz, f_2 = 1901 MHz, -25 dBm each tone

Input IP_3 = -25 dBm + (51.9 dB / 2) = +1.0 dBm

Output IP_3 = +1 dBm + 11.0 dB gain = +12.0 dBm

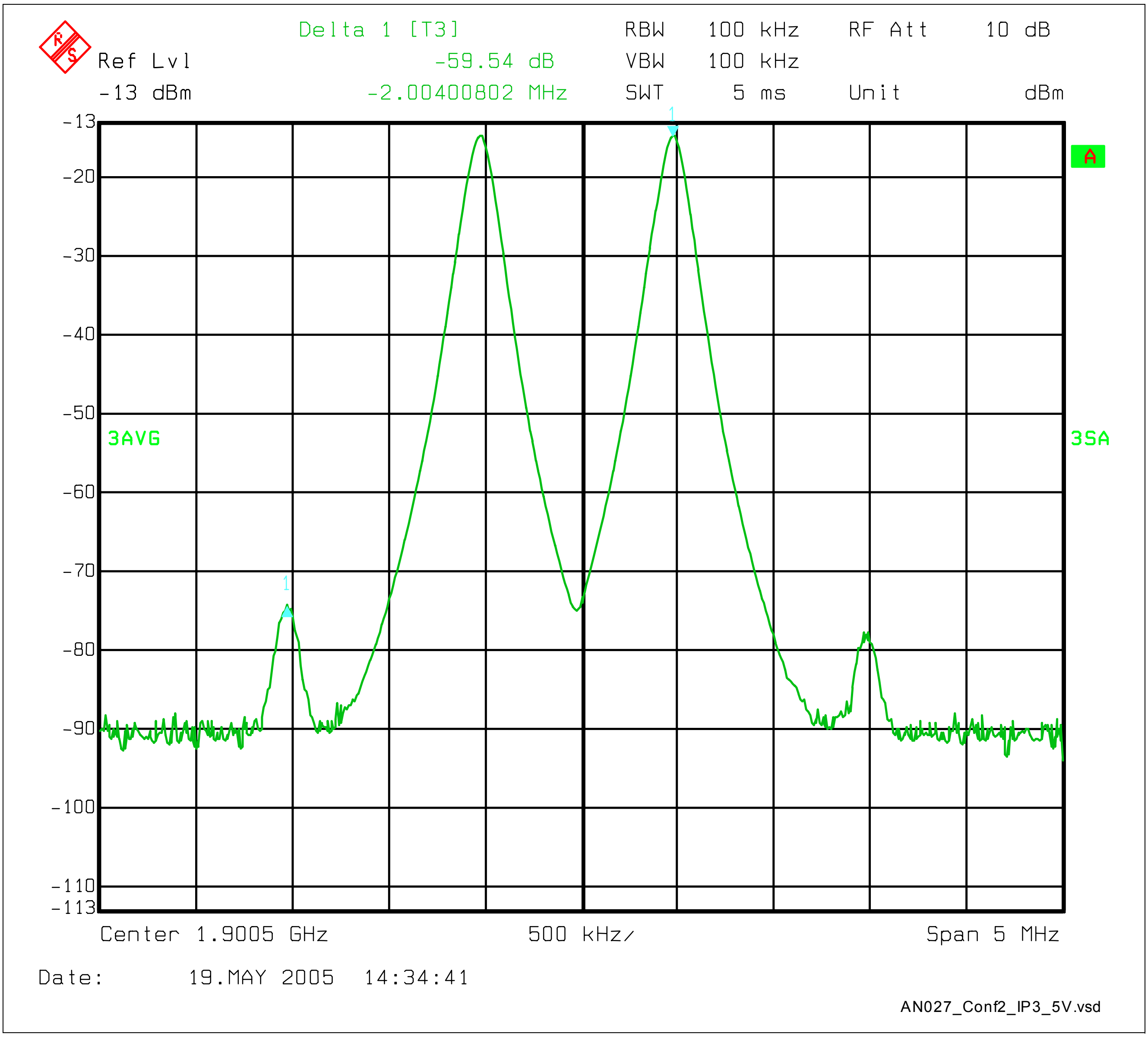


Figure 32 Configuration #2, 900 MHz - 2.5 GHz, Minimum Parts Count, Third Order Intercept (IP_3) 5 V, 13.4 mA condition

Input: f_1= 1900 MHz, f_2 = 1901 MHz, -25 dBm each tone

Input IP_3 = -25 dBm + (59.5 dB / 2) = +4.8 dBm

Output IP_3 = +4.8 dBm + 11.4 dB gain = +16.2 dBm

3.3 Configuration #3: 900 MHz - 2.5 GHz, improved input match

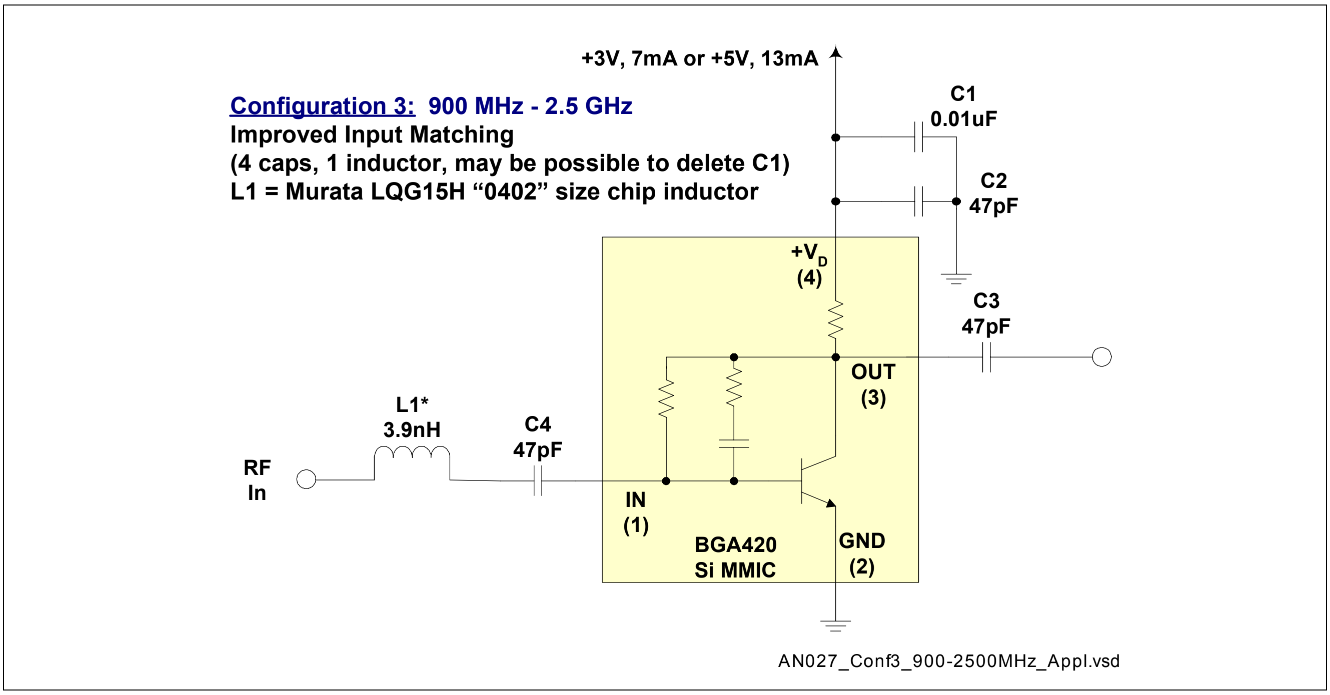


Figure 33 Configuration #3, 900 MHz - 2.5 GHz, Improved Input Matching

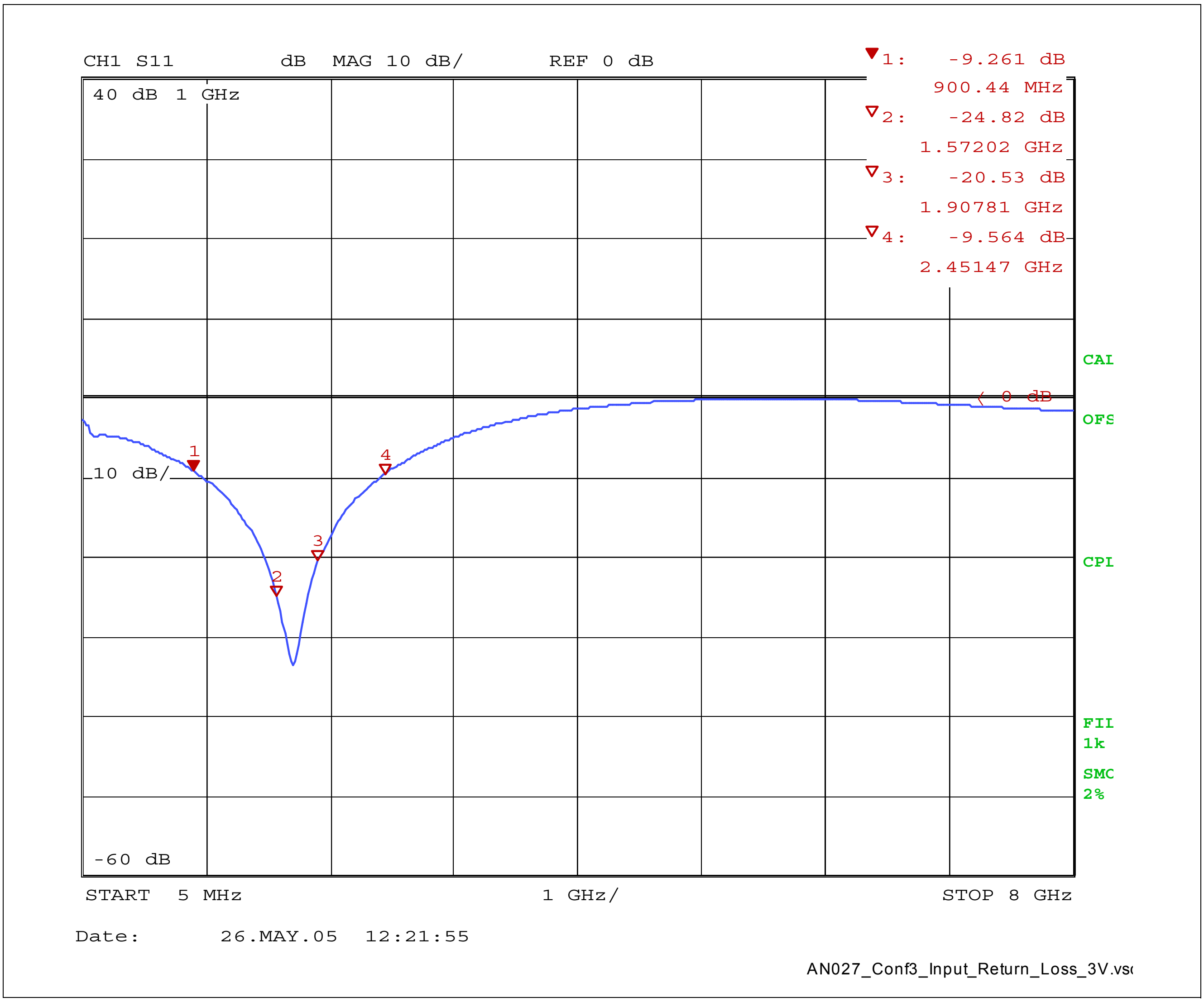


Figure 34 **Configuration #3, 900 MHz - 2.5 GHz Circuit, Improved Input Matching, Input Return Loss, Log Mag, 5 MHz - 8 GHz sweep 3 V, 7.1 mA Condition**

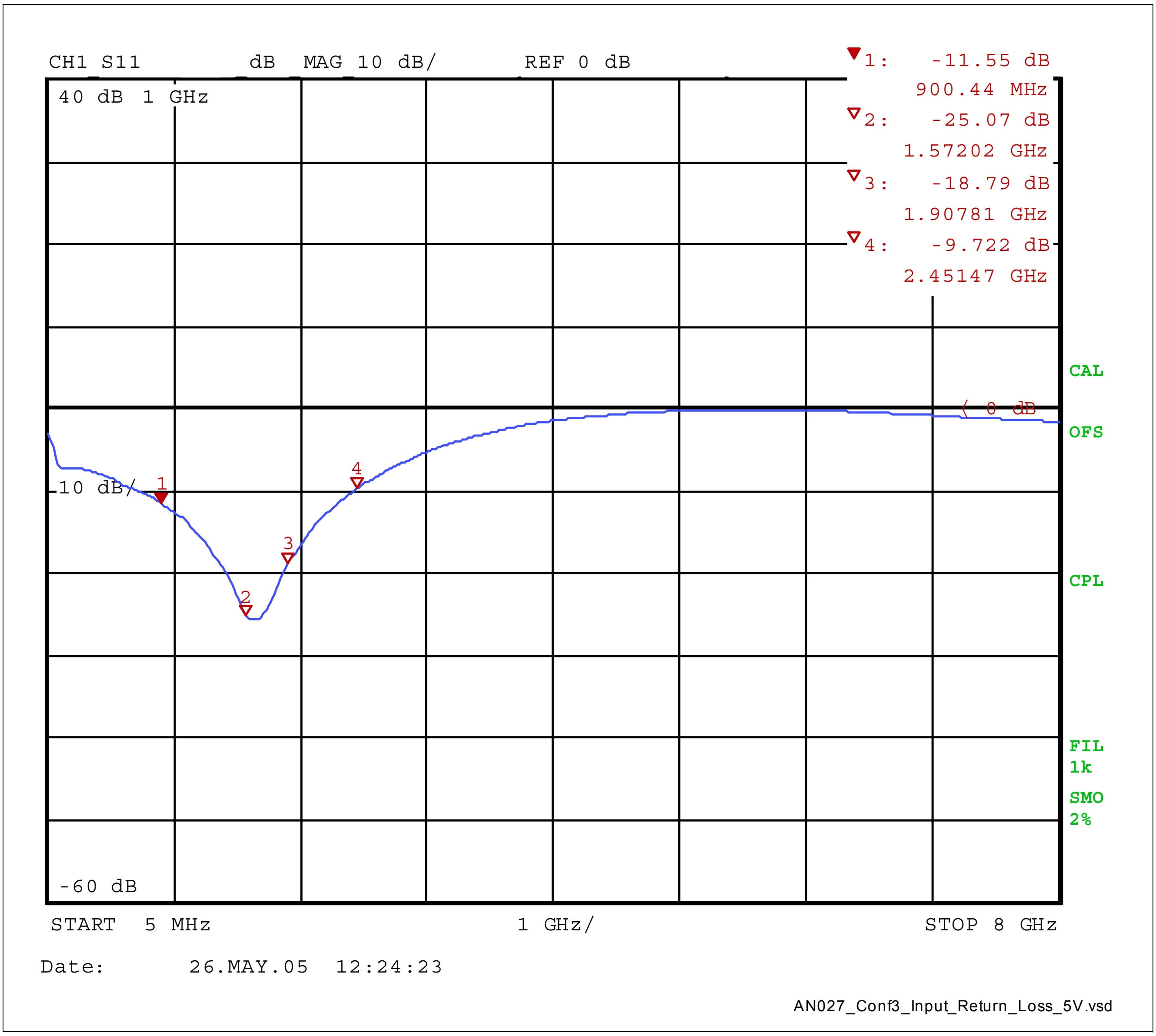


Figure 35 **Configuration #3, 900 MHz - 2.5 GHz Circuit, Improved Input Matching, Input Return Loss, Log Mag, 5 MHz - 8 GHz sweep 5 V, 13.4 mA Condition**

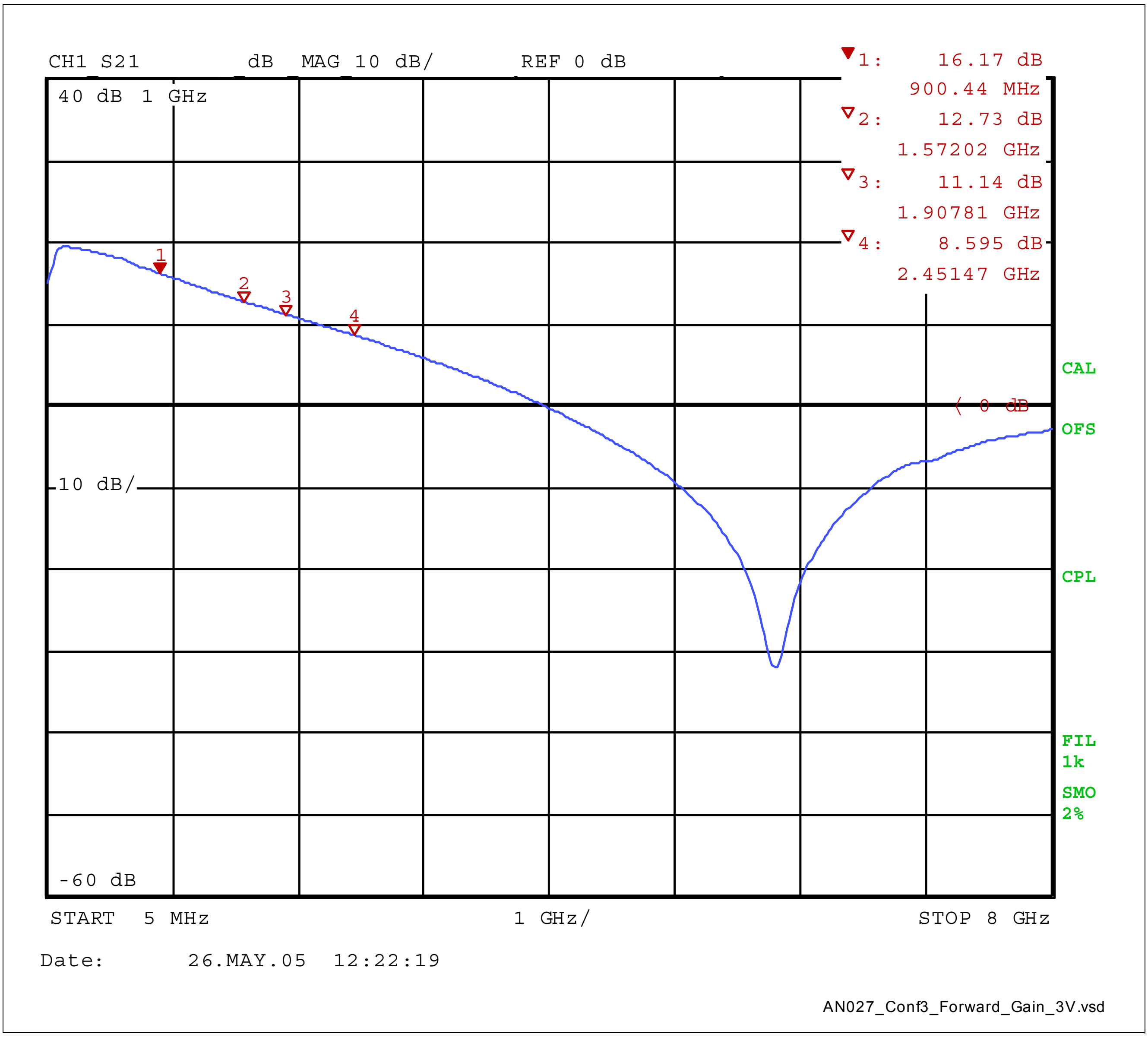


Figure 36 **Configuration #3, 900 MHz - 2.5 GHz Circuit, Improved Input Matching, Forward Gain, Log Mag, 5 MHz - 8 GHz sweep 3 V, 7.1 mA Condition**

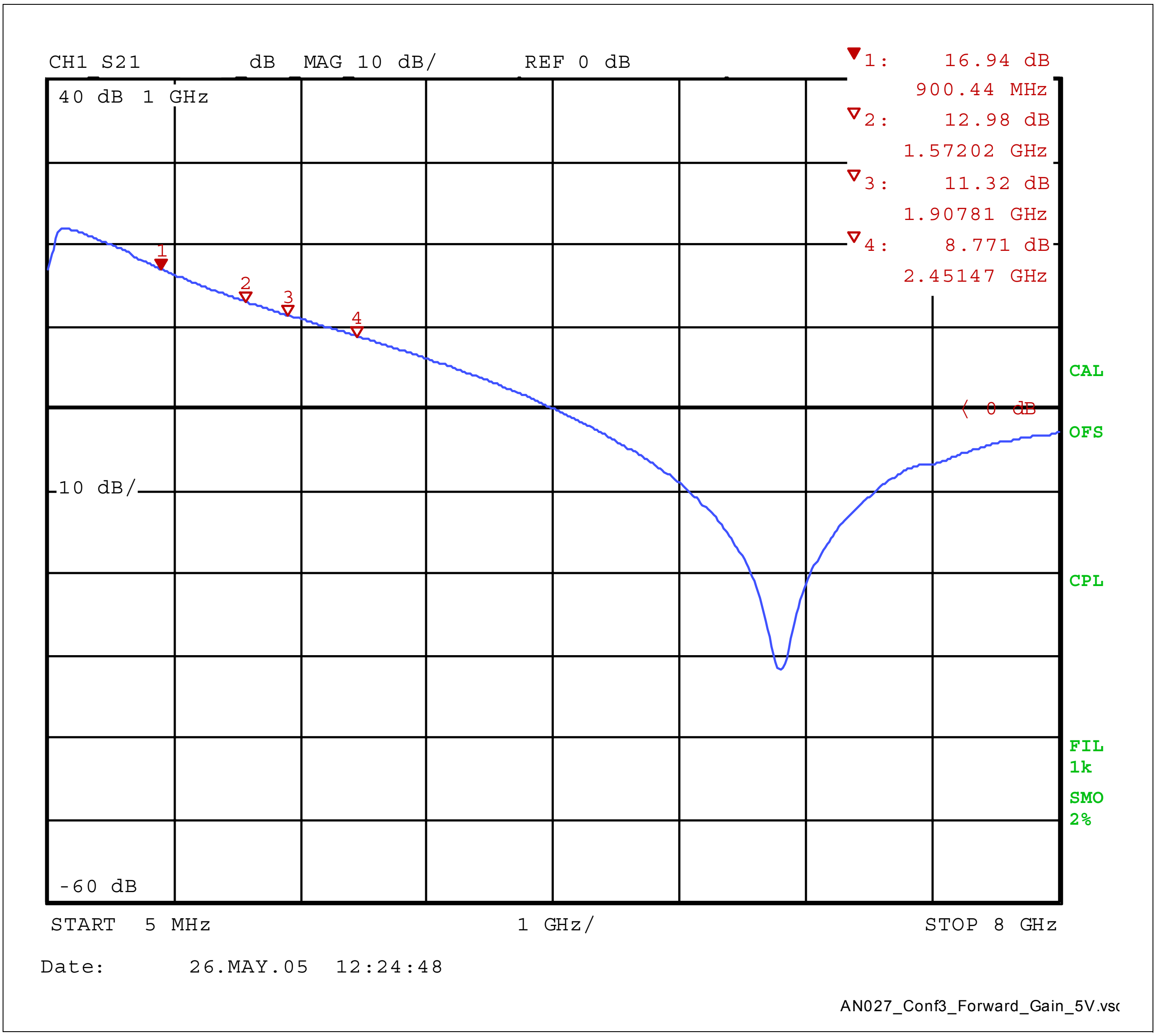


Figure 37 **Configuration #3, 900 MHz - 2.5 GHz Circuit, Improved Input Matching, Forward Gain, Log Mag, 5 MHz - 8 GHz sweep 5 V, 13.4 mA Condition**

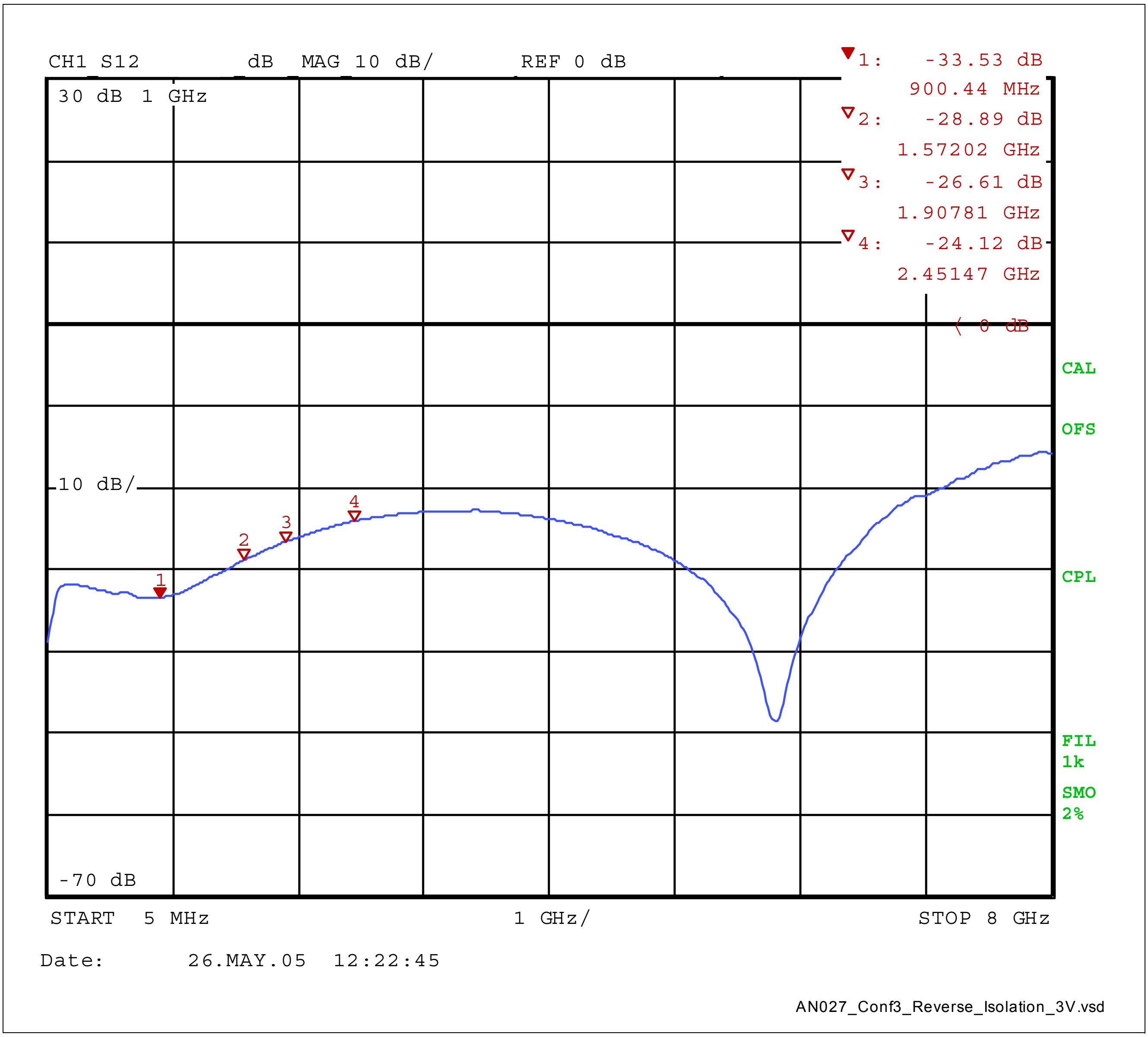


Figure 38 **Configuration #3, 900 MHz - 2.5 GHz Circuit, Improved Input Matching, Reverse Isolation, Log Mag, 5 MHz - 8 GHz sweep 3 V, 7.1 mA Condition**

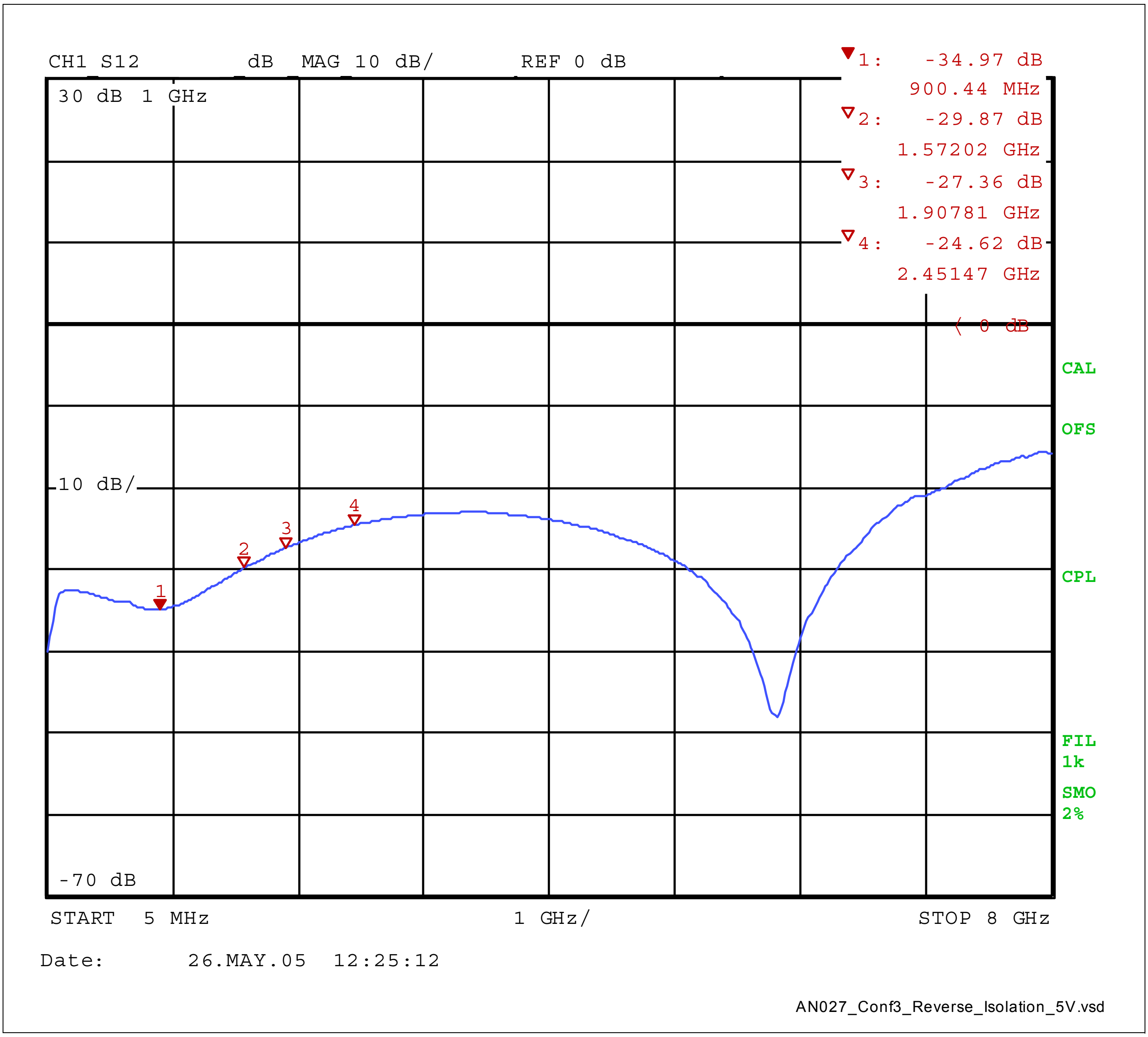


Figure 39 Configuration #3, 900 MHz - 2.5 GHz Circuit, Improved Input Matching, Recerse Isolation, Log Mag, 5 MHz - 8 GHz sweep 5 V, 13.4 mA Condition

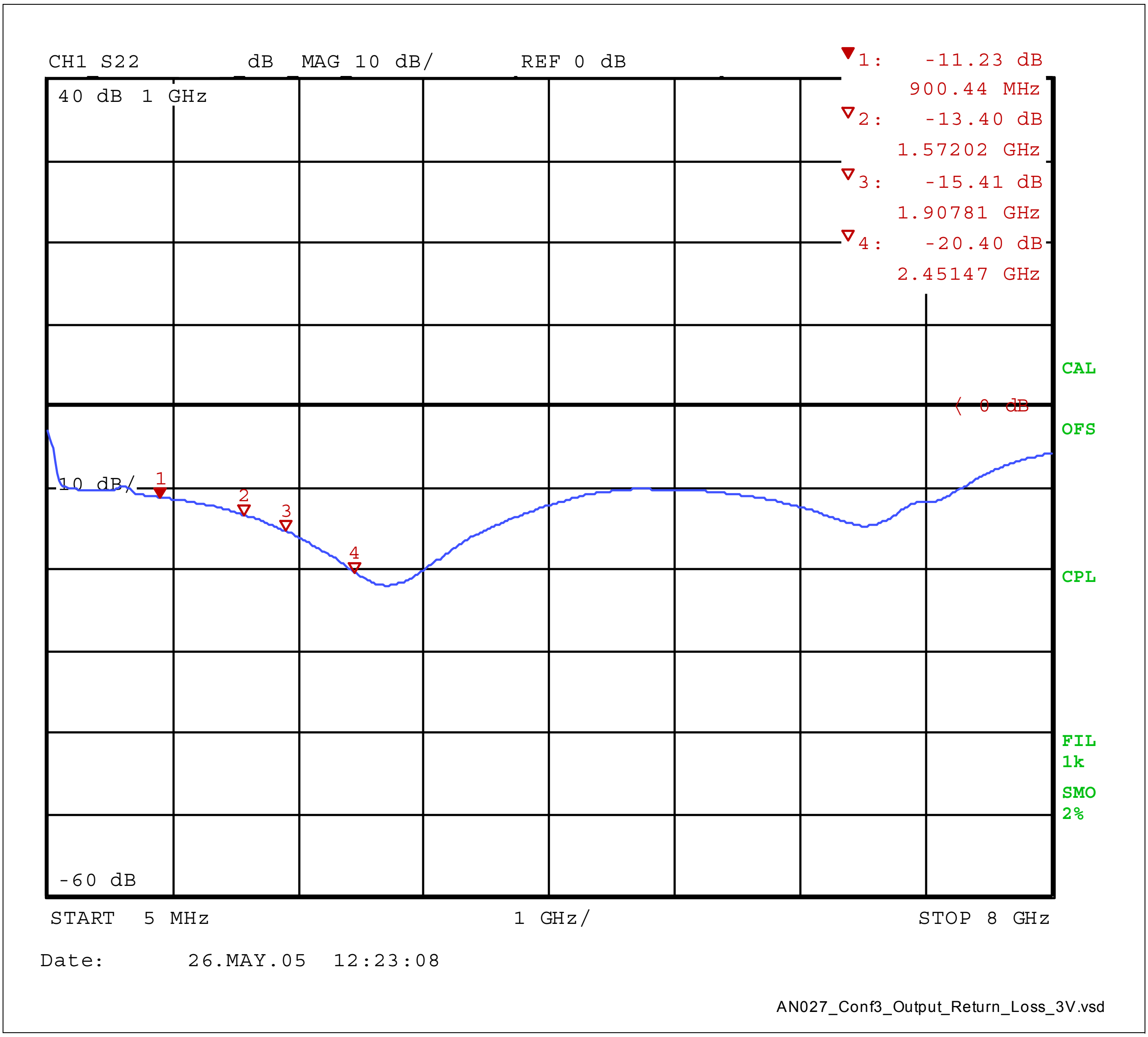


Figure 40 Configuration #3, 900 MHz - 2.5 GHz Circuit, Improved Input Matching Output Return Loss, Log Mag, 5 MHz - 8 GHz sweep 3 V, 7.1 mA Condition

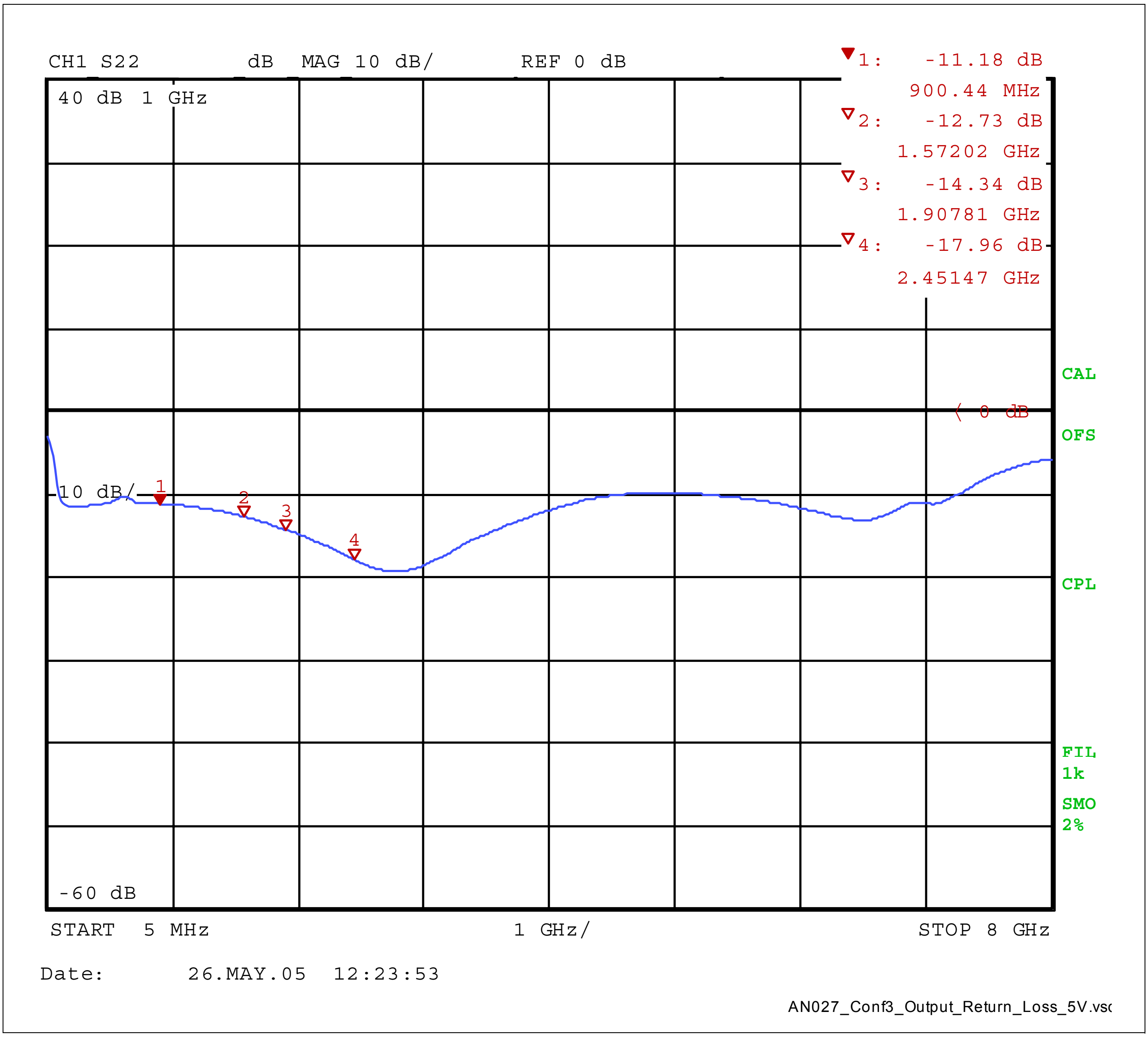


Figure 41 Configuration #3, 900 MHz - 2.5 GHz Circuit, Improved Input Matching, Output Return Loss, Log Mag, 5 MHz - 8 GHz sweep 5 V, 13.4 mA Condition

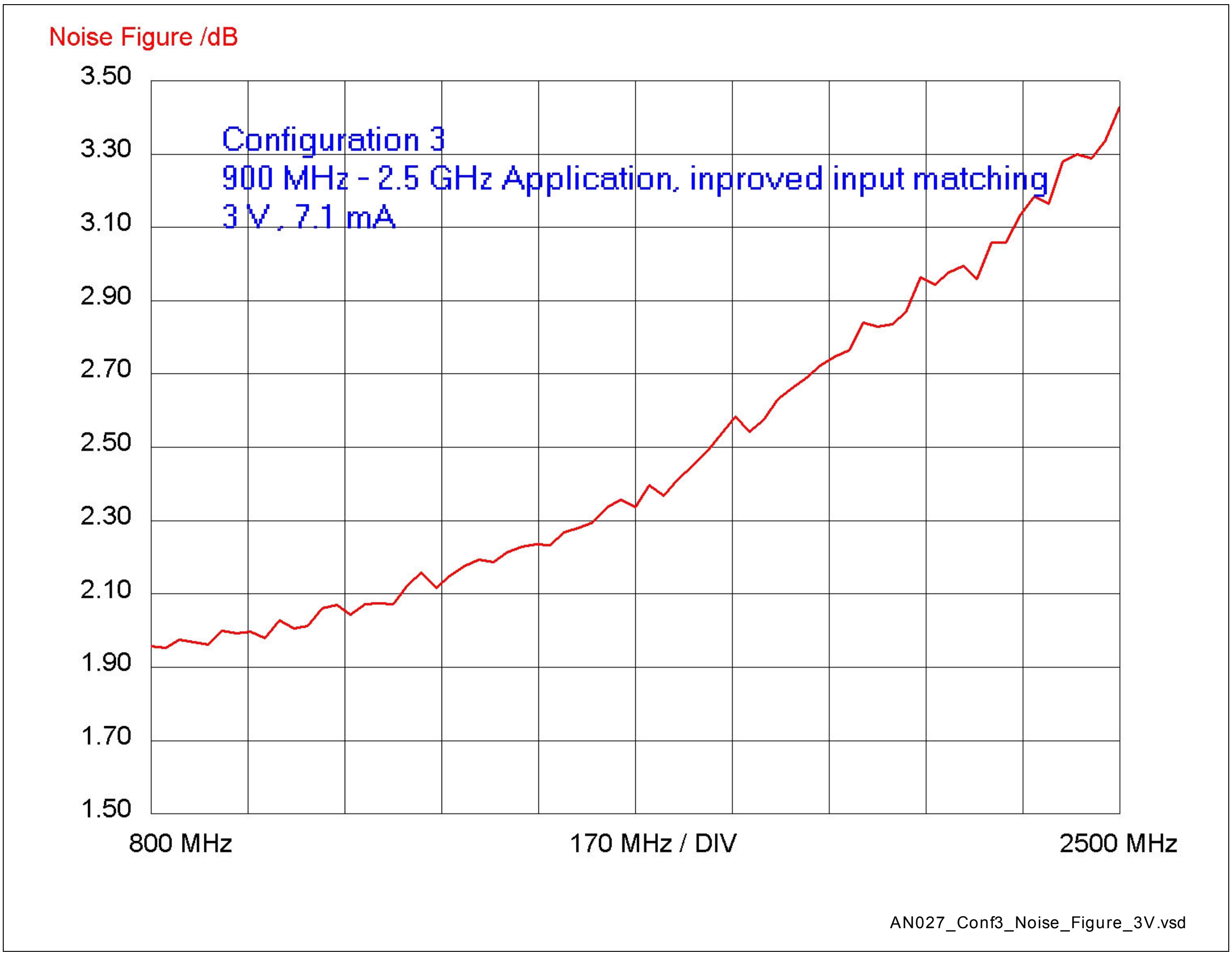


Figure 42 **Configuration #3, 900 MHz - 2.5 GHz Circuit, Improved Input Matching, Noise Figure, 800-2500 MHz sweep (Center of plot = 1650 MHz) 3 V, 7.1 mA Condition**

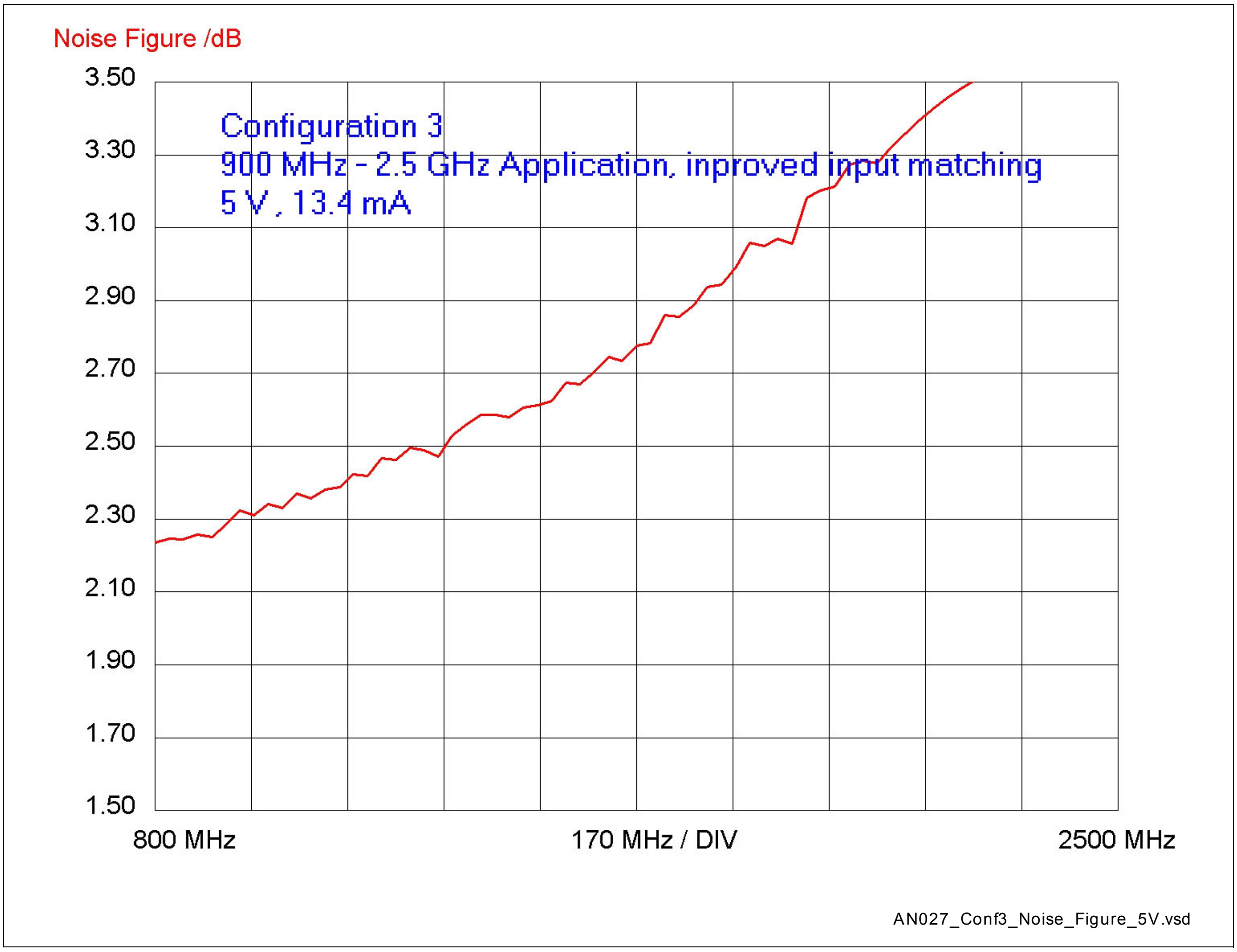


Figure 43 Configuration #3, 900 MHz - 2.5 GHz Circuit, Improved Input Matching, Noise Figure, 800-2500 MHz sweep (Center of plot = 1650 MHz) 5 V, 13.4 mA Condition

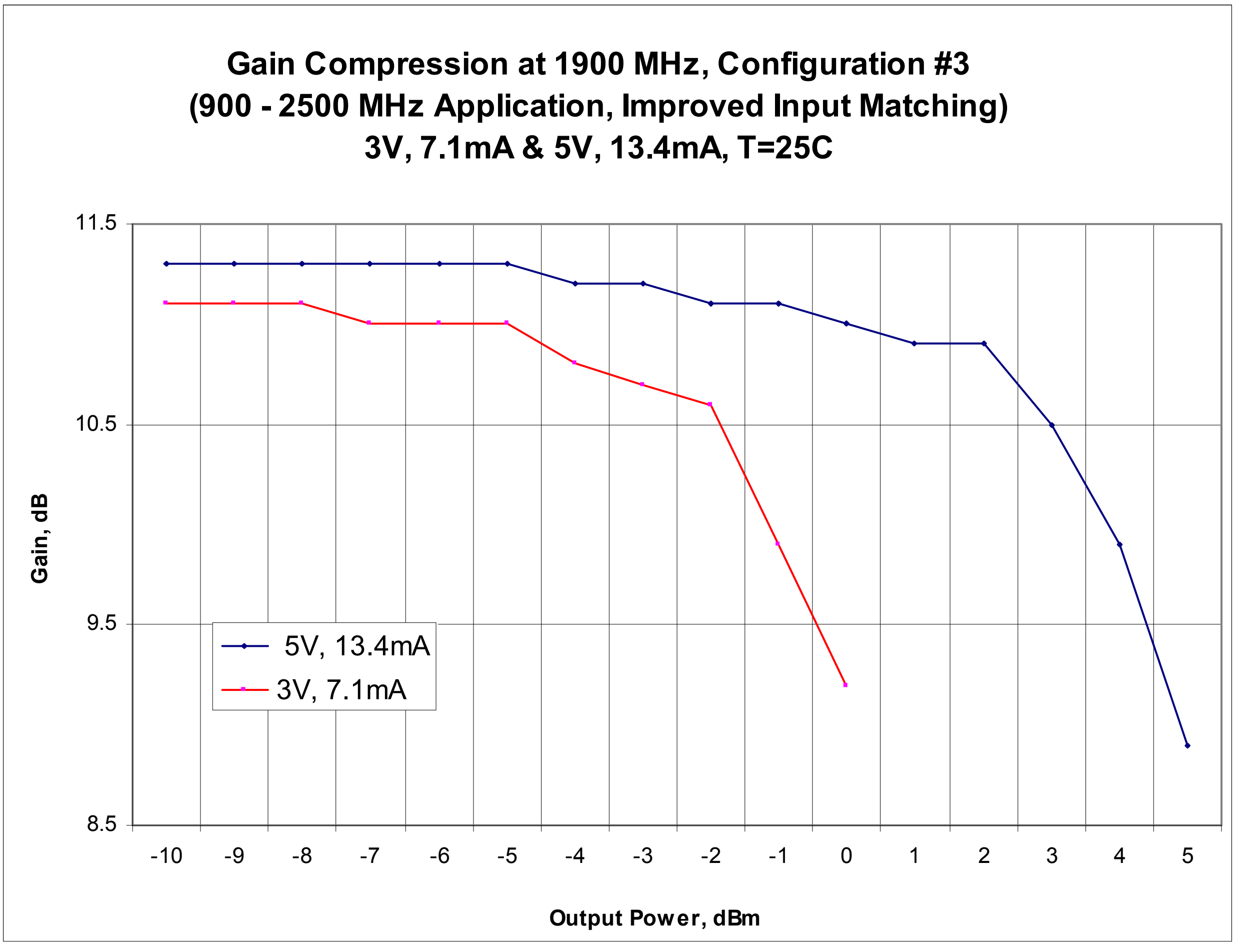


Figure 44 Configuration #3, 900 MHz - 2.5 GHz Circuit, Improved Input Matching, Gain Compression at 1900 MHz 3 V, 7.1 mA and 5 V, 13.4 mA Conditions

3 V, 7.1 mA: OP_{1dB} = -1.3 dBm; IP_{1dB} = -1.3 dBm - (11.1 - 1) = -11.4 dBm

5 V, 13.4 mA: OP_{1dB} = +3.3 dBm; IP_{1dB} = +3.3 dBm - (11.4 - 1) = -7.1 dBm

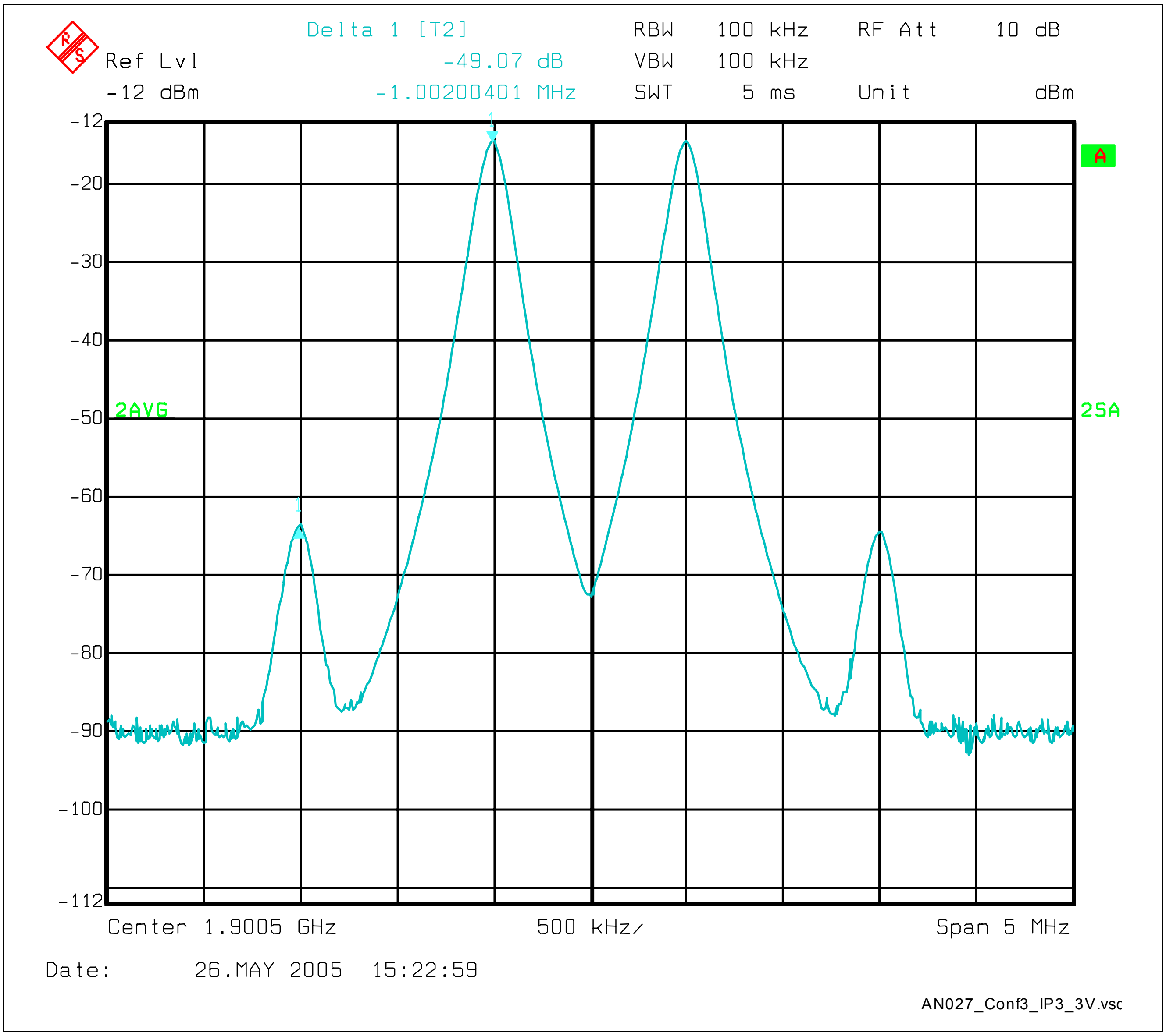


Figure 45 Configuration #3, 900 MHz- 2.5 GHz Circuit, Improved Input Matching, Third Order Intercept (IP_3) 3 V, 7.1 mA condition

Input: f_1= 1900 MHz, f_2 = 1901 MHz, -25 dBm each tone

Input IP_3 = -25 dBm + (49.1 dB / 2) = -0.5 dBm

Output IP_3 = -0.5 dBm + 11.1 dB gain = +10.7 dBm

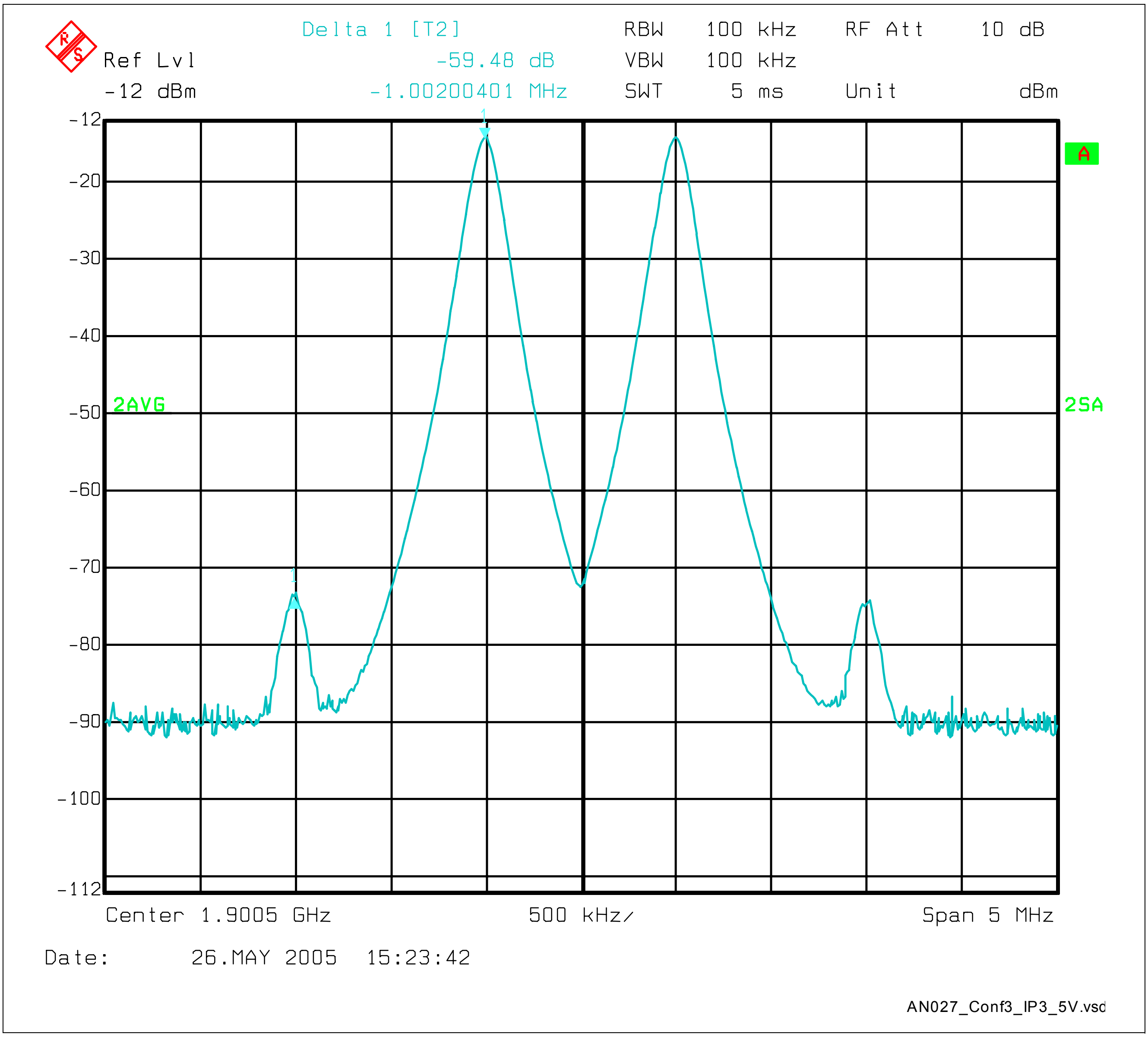


Figure 46 Configuration #3, 900 MHz - 2.5 GHz Circuit, Improved Input Matching, Third Order Intercept (IP_3) 5 V, 13.4 mA condition

Input: f_1= 1900 MHz, f_2 = 1901 MHz, -25 dBm each tone

Input IP_3 = -25 dBm + (59.5 dB / 2) = +4.8 dBm

Output IP_3 = +4.8 dBm + 11.3 dB gain = +16.1 dBm