# Application Note No. 120

## 1.8 V Low Noise Amplifier for 1575 MHz GPS Applications using the SiGe:C BFP740F Tranistor

RF & Protection Devices

Never stop thinking

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**Application Note No. 120**

**Revision History: 2007-09-03, Rev. 1.2**

**Previous Version: 2005-08-10, Rev. 1.1**

| Page | Subjects (major changes since last revision) |
|---|---|
| All | Document layout change |
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# 1 1.8 V Low Noise Amplifier for 1575 MHz GPS Applications using the SiGe:C BFP740F Tranistor

**Applications**

- 1575.42 MHz GPS

**Overview**

- BFP740F in TSFP-4 package is evaluated for a GPS LNA application. Note TSFP-4 package is only 1.4 x 1.2 x 0.55 mm high.
  Design Goals: Gain = 20 dB min, Noise Figure = 0.8 dB max, Input / Output Return Loss 10 dB or better, current < 10 mA from a 1.8 V power supply
- Printed Circuit Board used is Infineon Part Number 740F-080404 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 BFP740F transistor, is 11.

**Summary of Results**

$T$ = 25 °C, Network Analyzer Source Power ≈ -30 dBm

**Table 1 Summary of Data**

| 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 |
|---|---|---|---|---|---|---|---|---|---|
| 1575.42 | 10.8 | 19.7 | 27.1 | 12.8 | 0.76 | +0.2 | +19.9 | -17.3 | +1.4 |

PCB loss is not extracted, e.g. reference plane of measurement is at PCB input RF SMA connector. If PCB loss were extracted, noise figure result would improve by 0.1-0.2 dB, e.g. NF result would be lower / better.

**PCB Cross - Section Diagram**

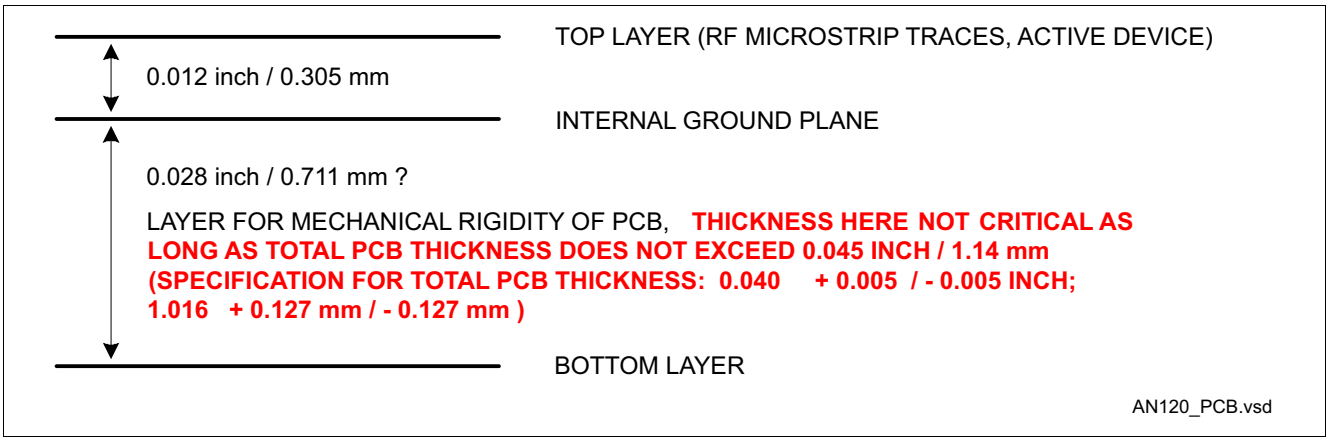



**Figure 1 PCB - Cross Sectional Diagram**

**TSFP-4 package details (dimensions in millimeters)**

Note maximum package height is 0.59 mm / 0.023 inch

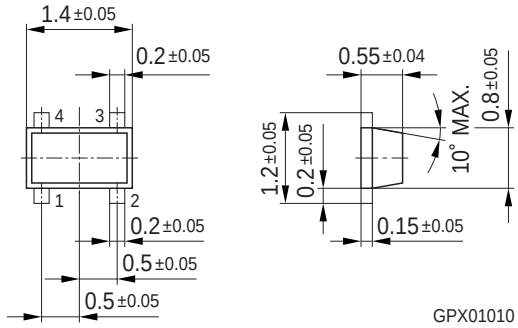



**Figure 2 TSFP-4 package details**

Recommended Soldering Footprint for TSFP-4 given below (dimensions in millimeters). Device package is to be oriented as shown in above drawing (e.g. orient long package dimension horizontally on this footprint).

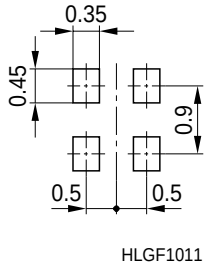



**Figure 3 TSFP-4 package - Soldering Footprint**

## 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 self-resonant frequency makes it slightly inductive, slightly improving input match. |
| C2 | 2.7 pF | Various | 0402 | DC block, output. Also influences output and input impedance match. |
| C3 | 0.1 µF | Various | 0402 | Decoupling, low frequency. Also improves Third-Order Intercept. |
| C4 | 3.3 pF | Various | 0402 | Decoupling at collector; also influence on stability and output match. |
| C5 | 0.1 µF | Various | 0402 | Low frequency decoupling, slightly improves Third Order Intercept. |
| L1 | 9.1 nH | Murata LQP15M series chip inductor | 0402 | RF choke at input, also influences input impedance match |
| L2 | 4.7 nH | Murata LQP15M series chip inductor | 0402 | RF choke + impedance match at output |
| R1 | 10 Ω | Various | 0402 | Improves low frequency stability e.g. K > 1 |
| R2 | 22 kΩ | Various | 0402 | Brings bias current / voltage into base of transistor. |
| R3 | 30 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 | BFP740F B7HFe SiGe:C Ultra-Low Noise HBT 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<br>Pins 1, 5 = Ground<br>Pin 3 = $V_{CC}$<br>Pins 2, 4 = no connection |

## Schematic Diagram for 1575 MHz GPS LNA

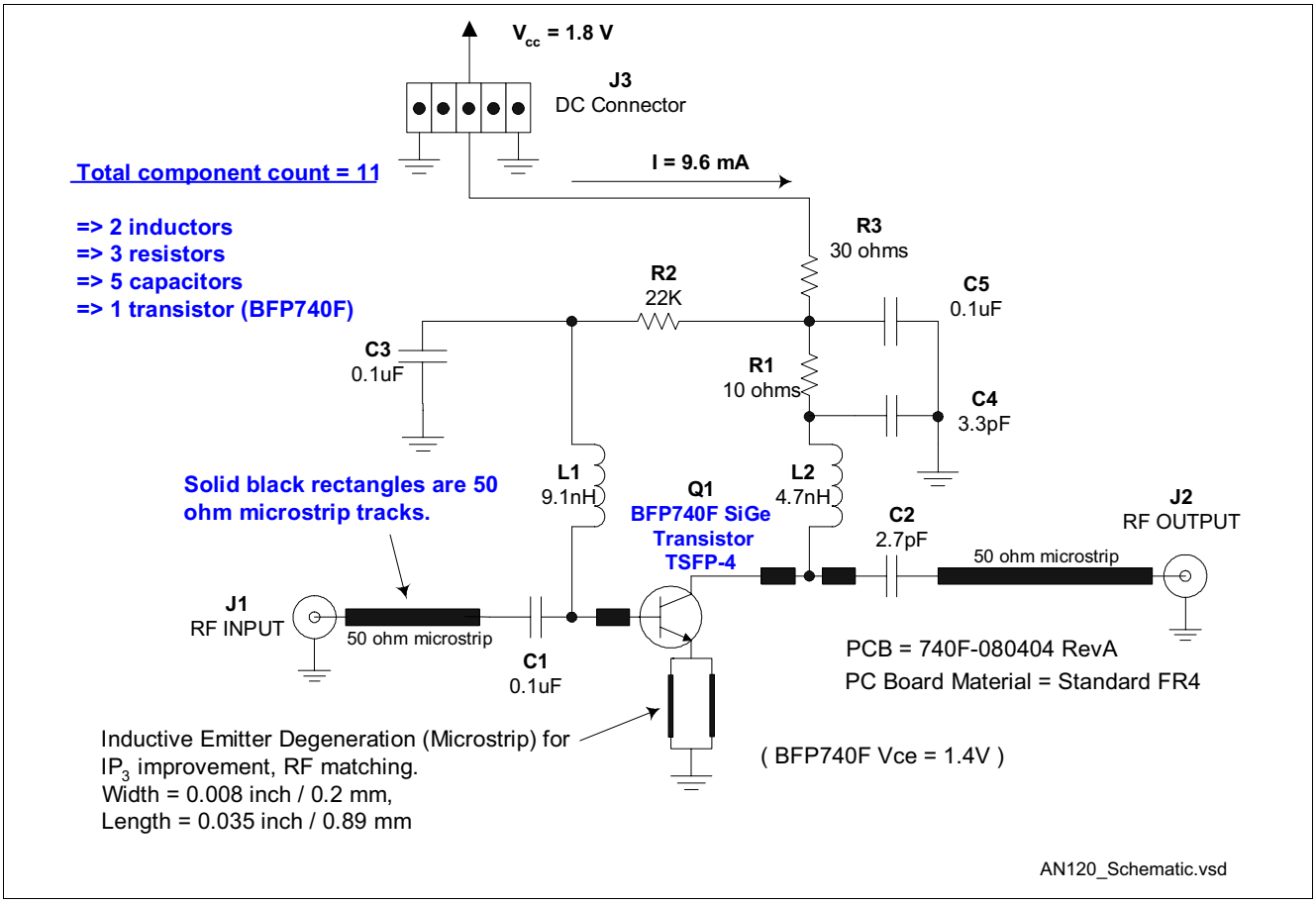



**Figure 4 Schematic Diagram**

**Noise Figure, Plot, Center of Plot (x-axis) is 1575 MHz.**

Rohde & Schwarz FSEK3

11 Aug 2005

Noise Figure

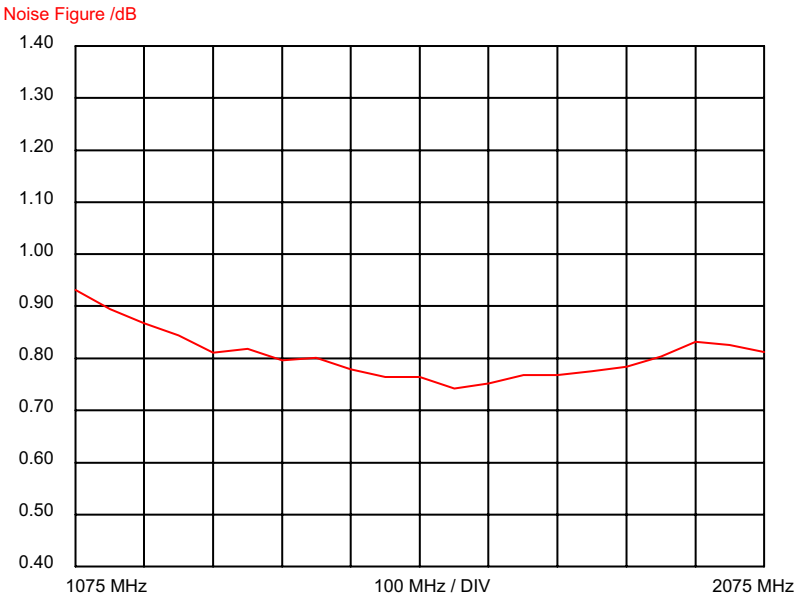
| | |
|---|---|
| EUT Name: | BFP740F GPS "L1" (1575.42 MHz) Low Noise Amplifier |
| Manufacturer: | Infineon Technologies AG |
| Operating Conditions: | V cc = 1.8 V, I = 9.6mA, Vce = 1.4 V |
| Operator Name: | Gerard Wevers |
| Test Specification: | LWR SD00086 LNA P |
| Comment: | On PCB 740F-080404 Rev A<br>10 August 2005 |

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 |




AN120_plot_nf.vsd

**Figure 5 Noise Figure**

**Noise Figure, Tabular Data**

From Rhode & Schwarz FSEK3 + FSEM30 + System Preamplifier

**Table 3 Noise Figure**

| Frequency | Noise Figure |
|---|---|
| 1075 MHz | 0.93 dB |
| 1125 MHz | 0.89 dB |
| 1175 MHz | 0.87 dB |
| 1225 MHz | 0.84 dB |
| 1275 MHz | 0.81 dB |
| 1325 MHz | 0.82 dB |
| 1375 MHz | 0.80 dB |
| 1425 MHz | 0.80 dB |
| 1475 MHz | 0.78 dB |
| 1525 MHz | 0.76 dB |
| 1575 MHz | 0.76 dB |
| 1625 MHz | 0.74 dB |
| 1675 MHz | 0.75 dB |
| 1725 MHz | 0.77 dB |
| 1775 MHz | 0.77 dB |
| 1825 MHz | 0.78 dB |
| 1875 MHz | 0.78 dB |
| 1925 MHz | 0.80 dB |
| 1975 MHz | 0.83 dB |
| 2025 MHz | 0.83 dB |
| 2075 MHz | 0.81 dB |

**Scanned Image of PC Board**

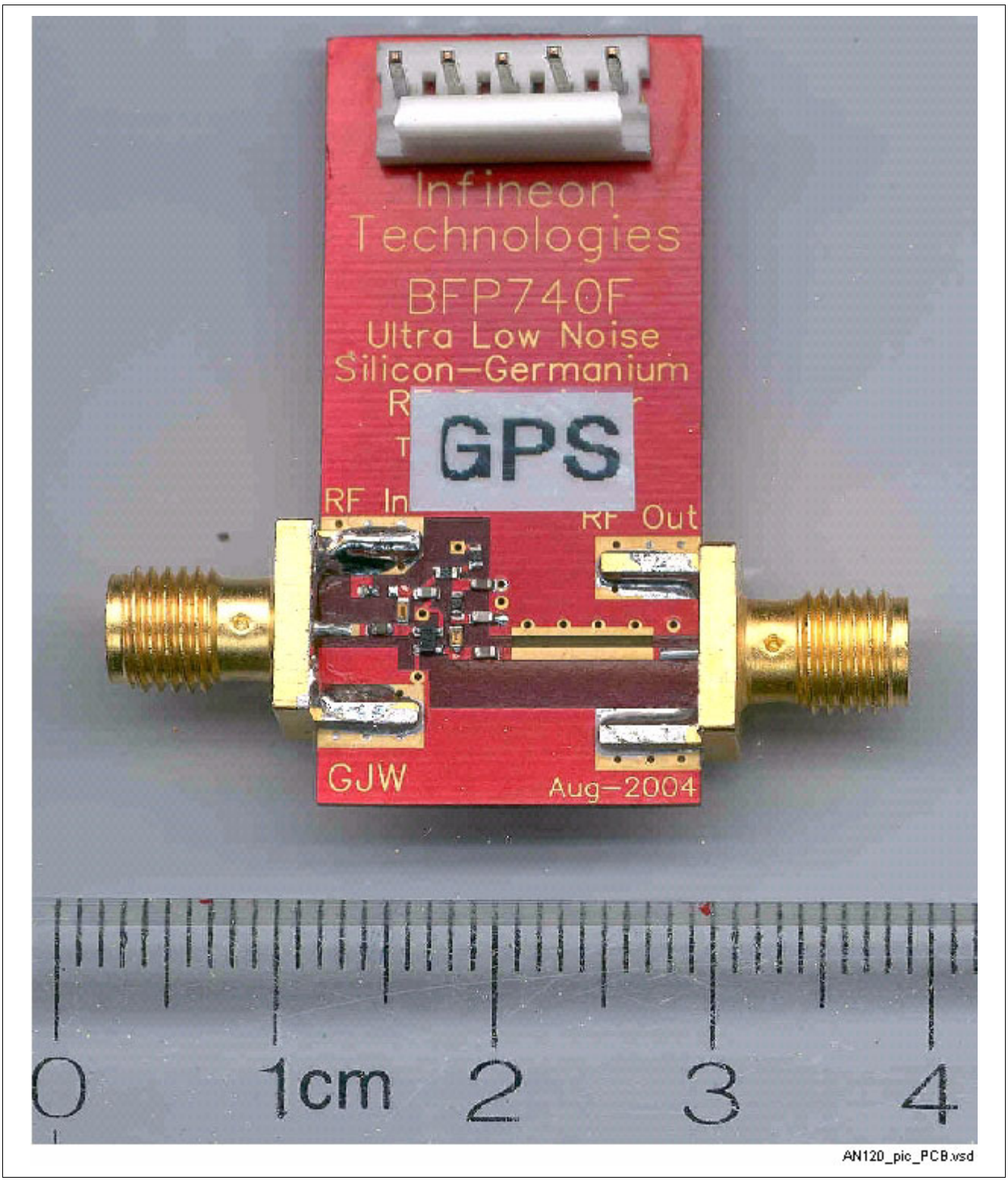



**Figure 6 Image of PC Board**

**Scanned Image of PC Board, Close-In Shot**

Total PCB area used is approximately 40 mm²

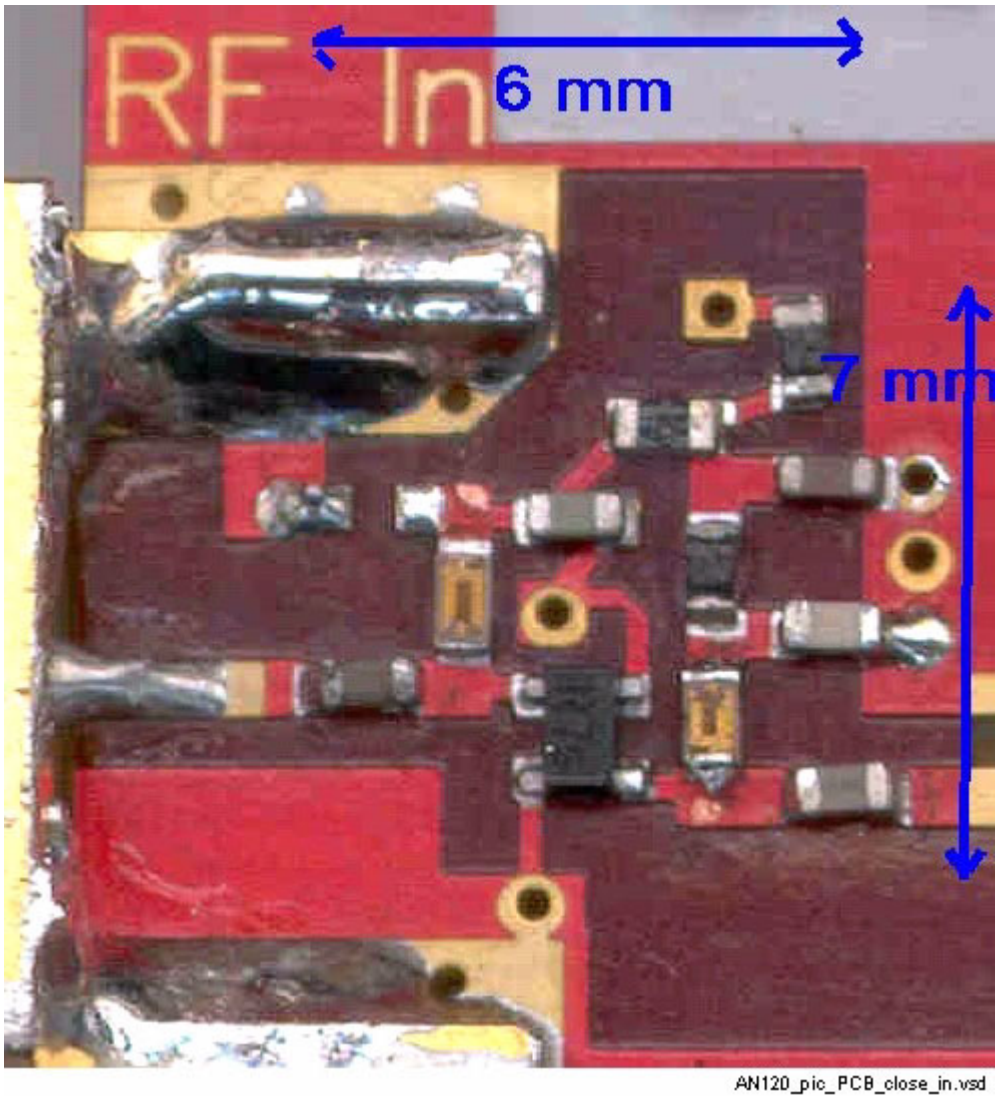



**Figure 7 Image of PC Board, Close-In Shot**

### Amplifier Stability

$T$ = 25 °C, $V_{CC}$ = 1.8 V, $V_{CE}$ = 1.4 V, $I$ = 9.6 mA

Stability Factor "K" is shown below from "screen shot" taken from Rohde and Schwarz ZVC network analyzer. ZVC Vector Network Analyzer calculates and plots K in real time, from measured S parameters.Note that minimum K value is 0.974 at 1.1 GHz, which is ≈ 1, for practical purposes; the amplifier is unconditionally stable over 5 MHz to 8 GHz range.

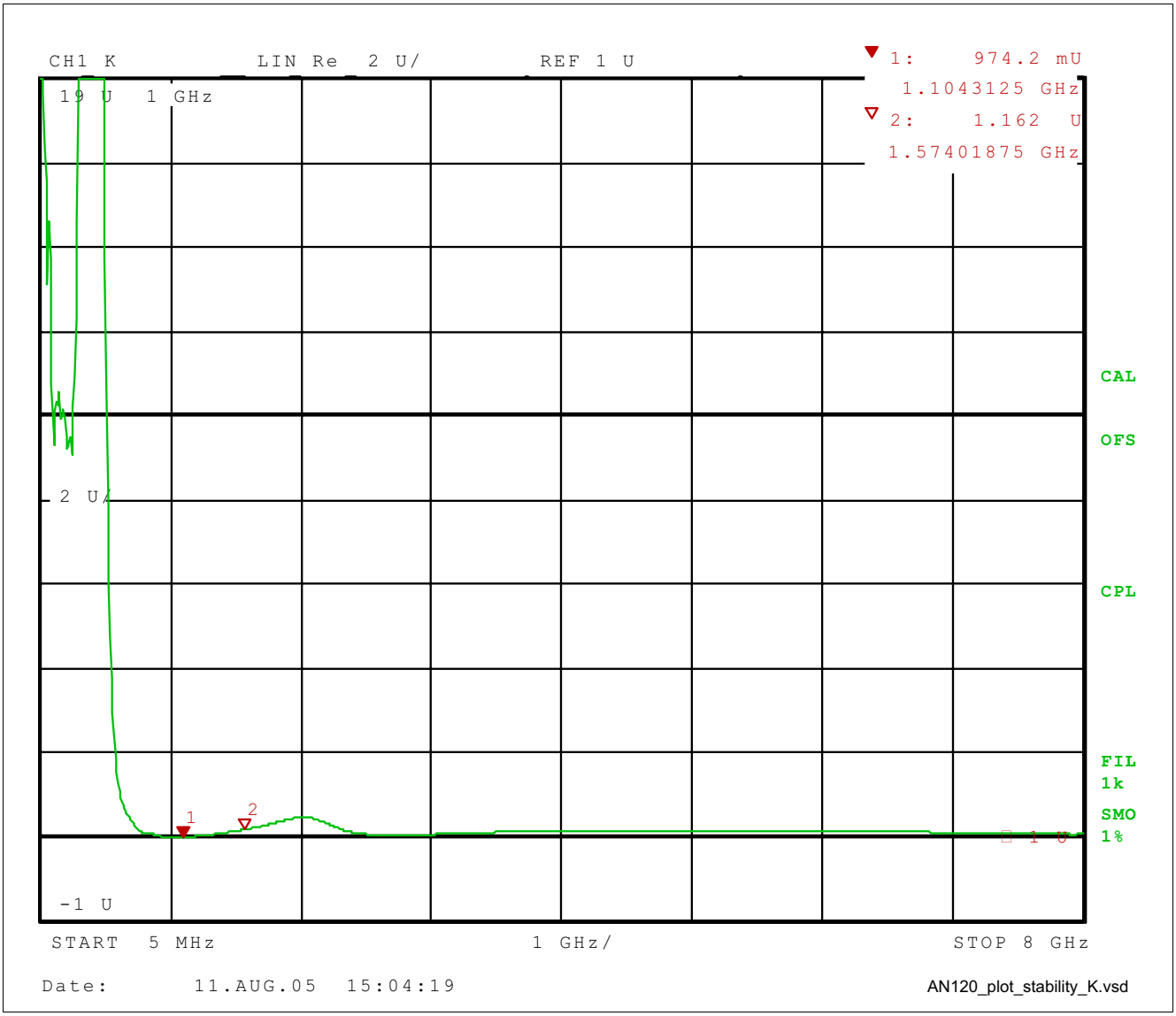



**Figure 8 Plot of Stability K(f)**

**Gain Compression at 1575 MHz**

$T$ = 25 °C, $V_{CC}$ = 1.8 V, $V_{CE}$ = 1.4 V, $I$ = 9.6 mA

Amplifier is checked for 1 dB compression point. An Aglient power meter was used to ensure accurate power levels are measured (as opposed to using Vector Network Analyzer in “Power Sweep” mode).

Output $P_{1dB}$ ≅ +1.4 dBm; Input $P_{1dB}$ = +1.4 dBm - (Gain - 1 dB) = +1.4 dBm - 18.7 dB = -17.3 dBm

**Table 4 Gain Compression (1575 MHz)**

| $P_{OUT}$, dBm | Gain, dBm |
|---|---|
| -10.0 | 19.7 |
| -9.0 | 19.7 |
| -8.0 | 19.7 |
| -7.0 | 19.6 |
| -6.0 | 19.6 |
| -5.0 | 19.6 |
| -4.0 | 19.6 |
| -3.0 | 19.5 |
| -2.0 | 19.4 |
| -1.0 | 19.3 |
| 0.0 | 19.2 |
| +1.0 | 18.9 |
| +2.0 | 18.5 |
| +3.0 | 17.6 |

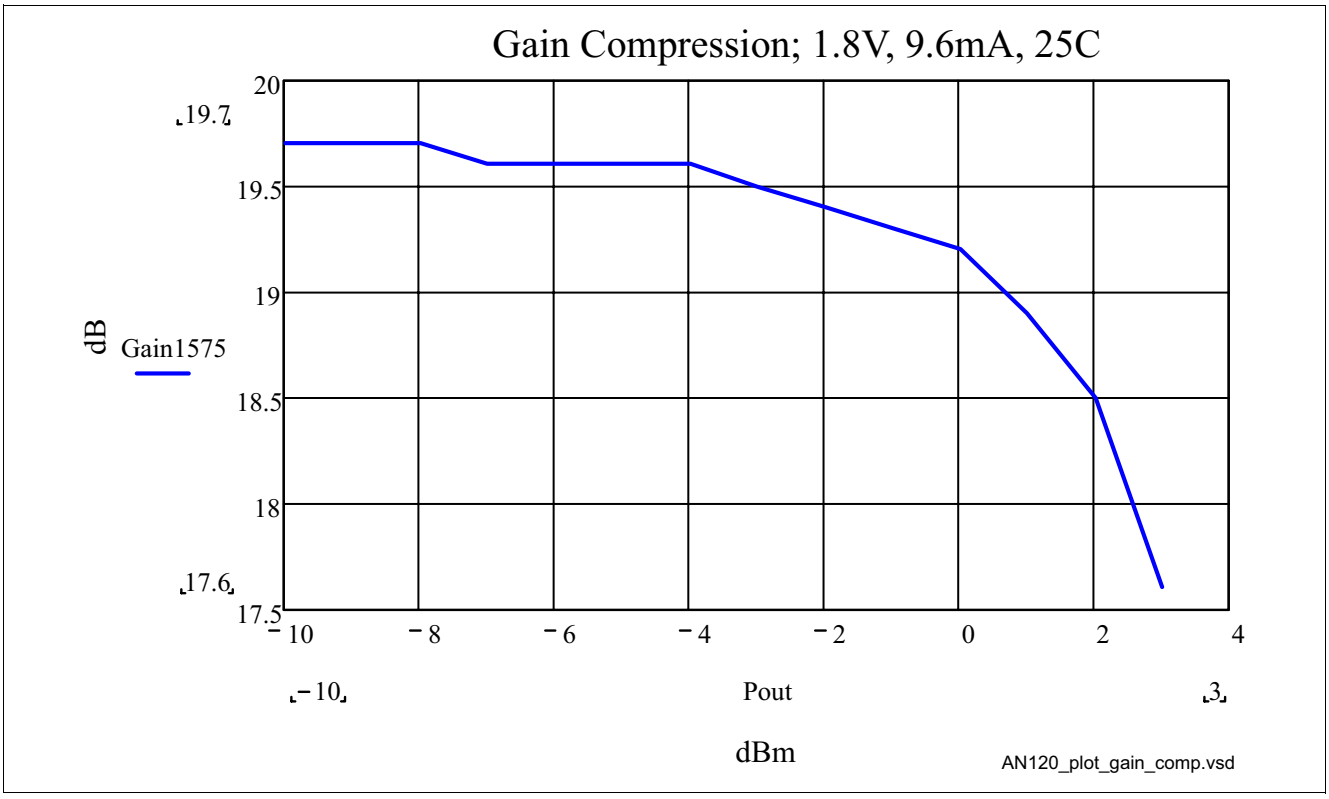



**Figure 9 Plot of Gain Compression @ 1575 MHz**

Please Note - all plots are taken from Rhode and Schwarz ZVC Network Analyzer, $T$ = 25 °C, source power ≈ -30 dBm

**Input Return Loss, Log Mag**

5 MHz to 8 GHz Sweep

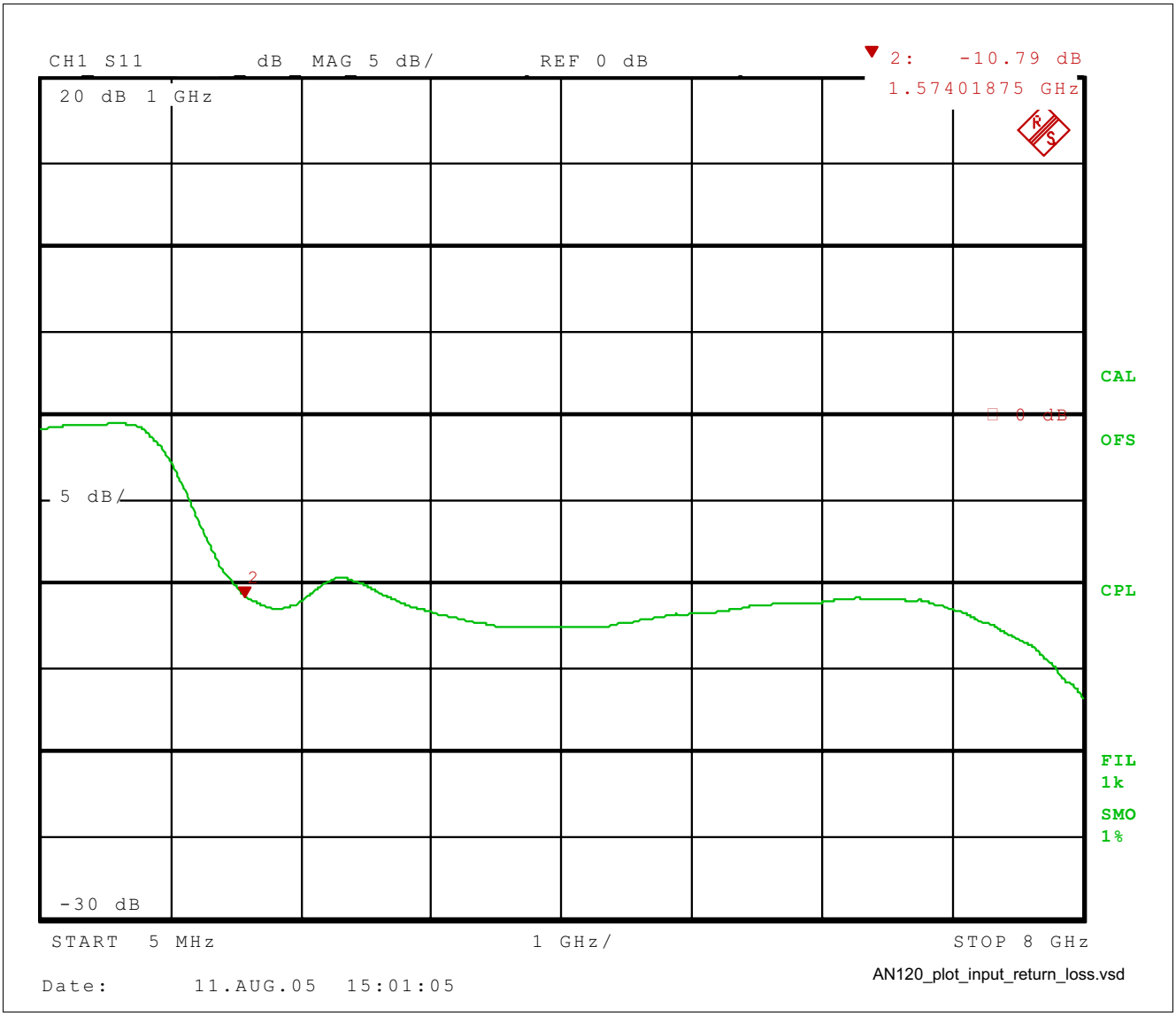



**Figure 10 Plot of Input Return Loss**

**Input Return Loss, Smith Chart**

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

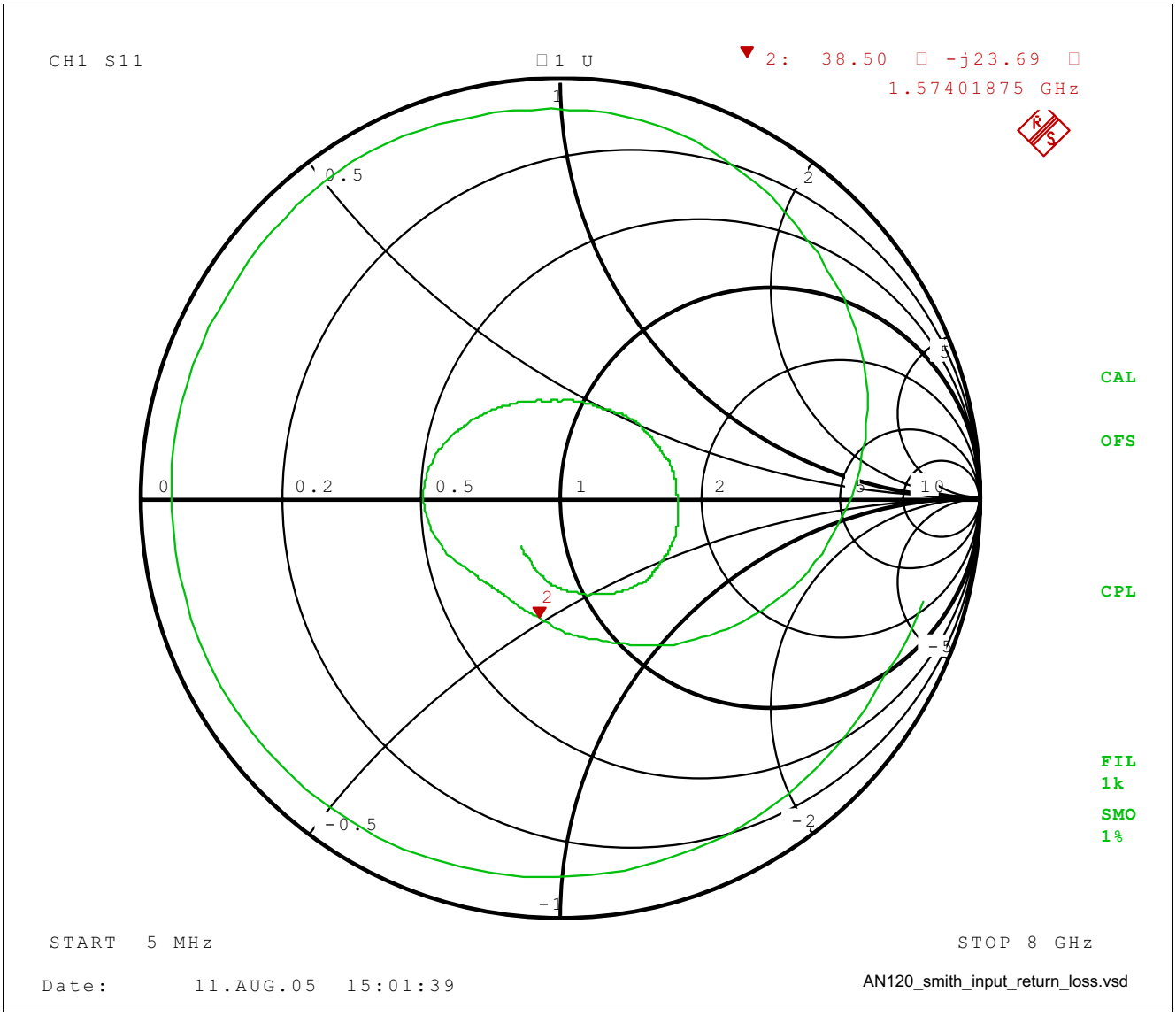



**Figure 11 Smith Chart of Input Return Loss**

**Forward Gain**

5 MHz to 8 GHz Sweep

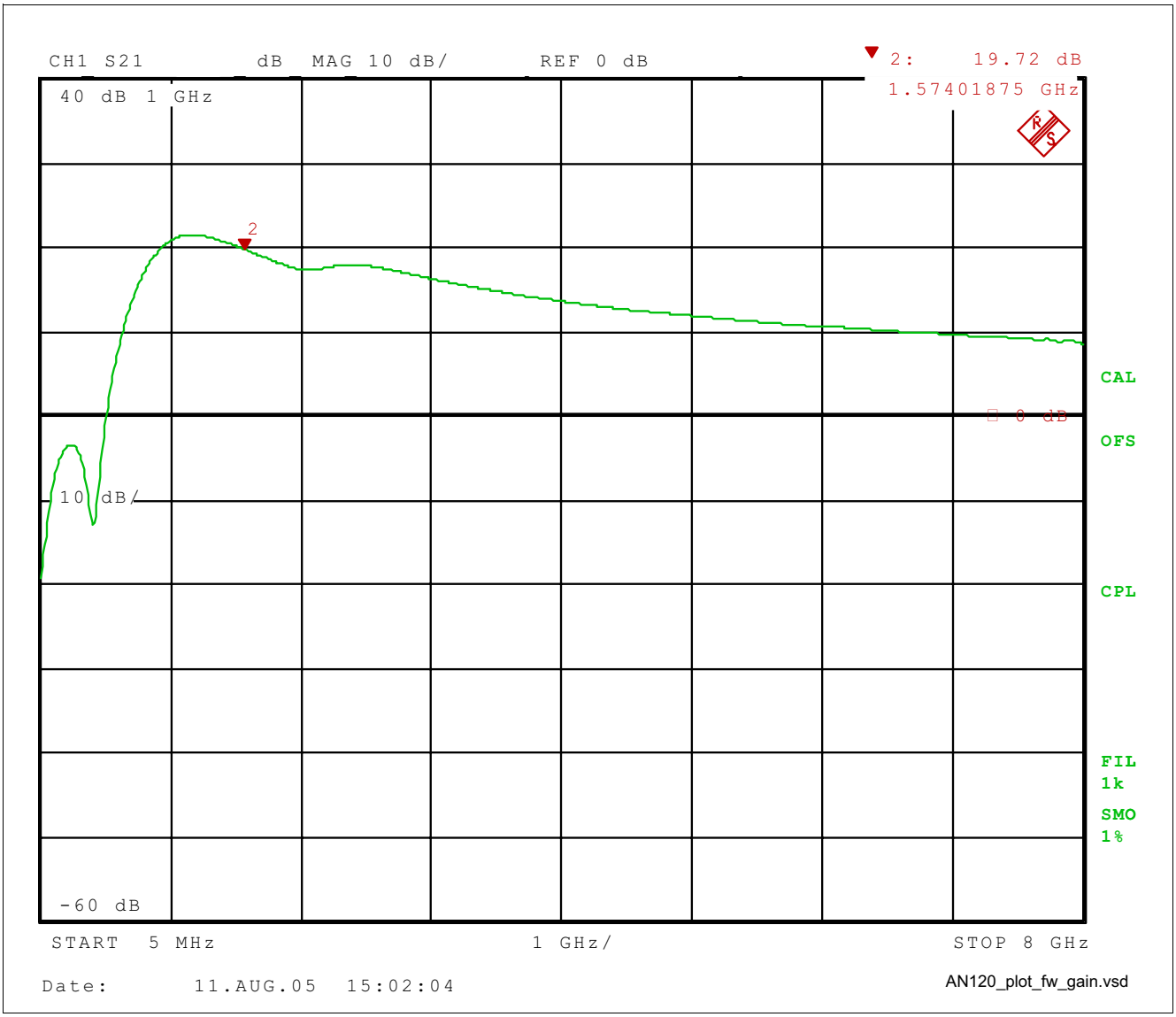



**Figure 12 Plot of Forward Gain**

**Reverse Isolation**

5 MHz to 8 GHz

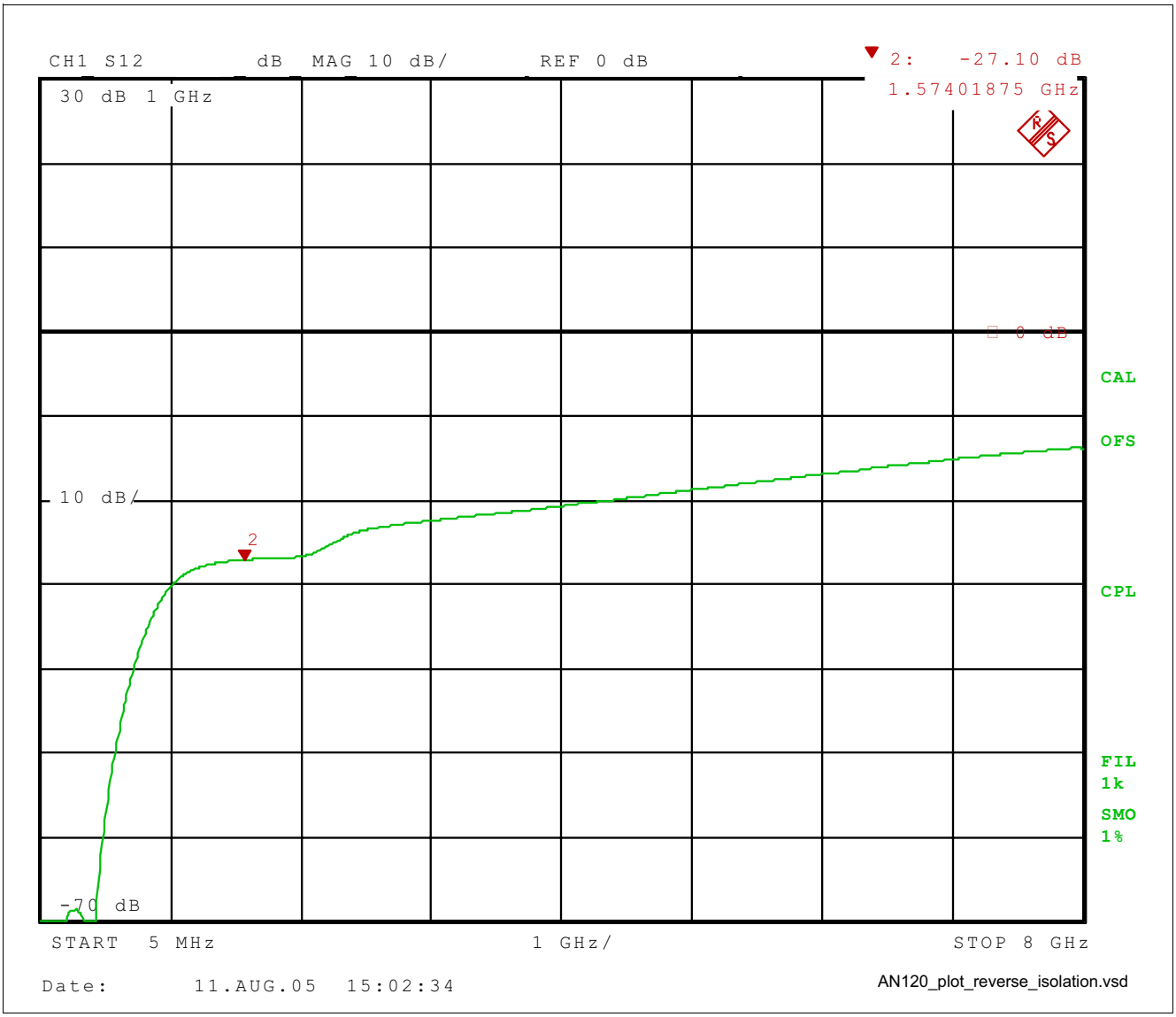



**Figure 13 Plot of Reverse Isolation**

**Output Return Loss, Log Mag**

5 MHz to 8 GHz

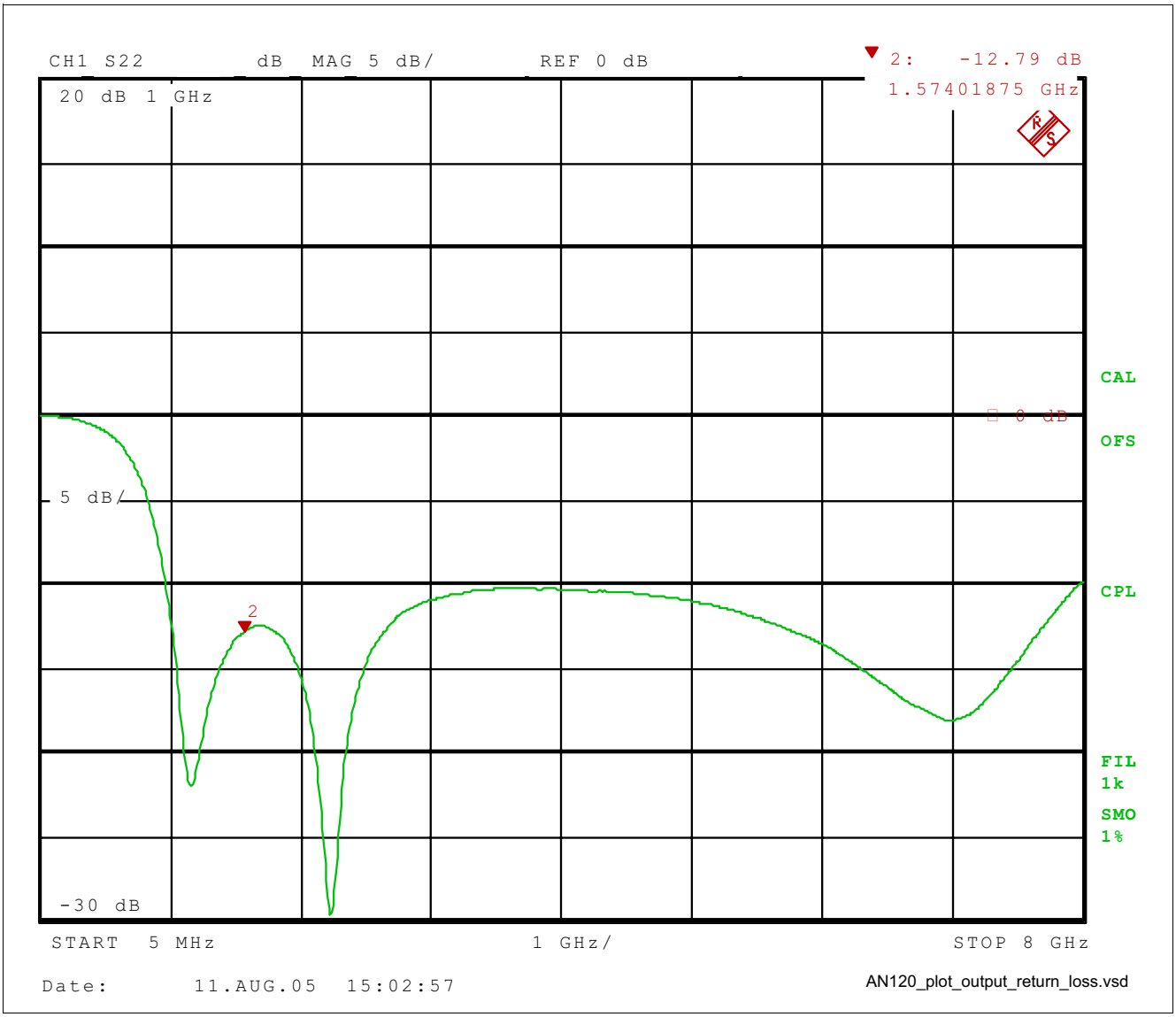



**Figure 14 Plot of Output Return Loss**

**Output Return Loss, Smith Chart**

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

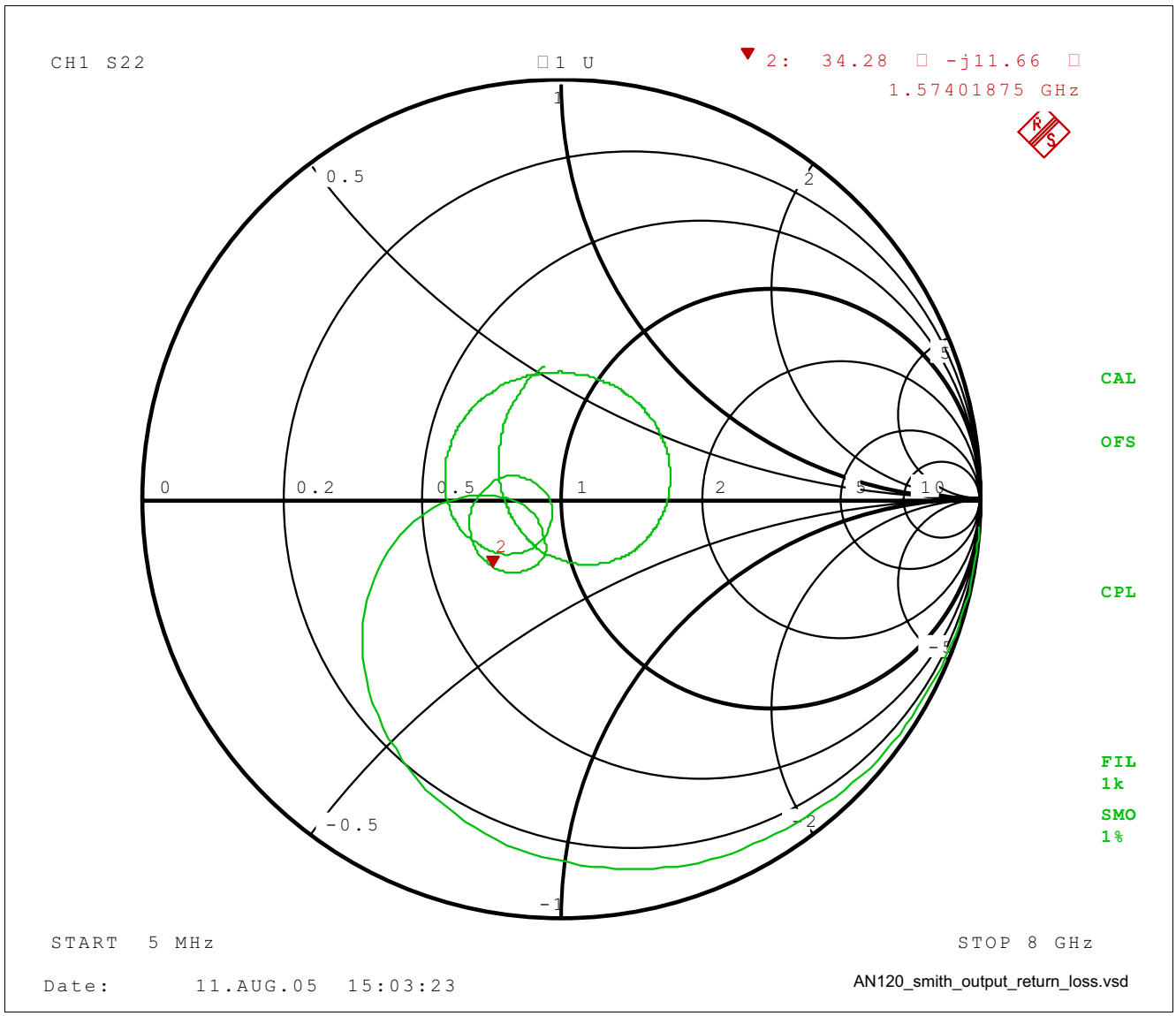



**Figure 15 Smith Chart of Output Return Loss**

### LNA Response to Two-Tone Test

Input Stimulus: $f_1$ = 1574 MHz, $f_2$ = 1575 MHz, -25 dBm each tone.
Input $IP_3$ = -25 + (50.3/2) = +0.2 dBm
Output $IP_3$ = +0.2 dBm + 19.7 dB gain = +19.9 dBm

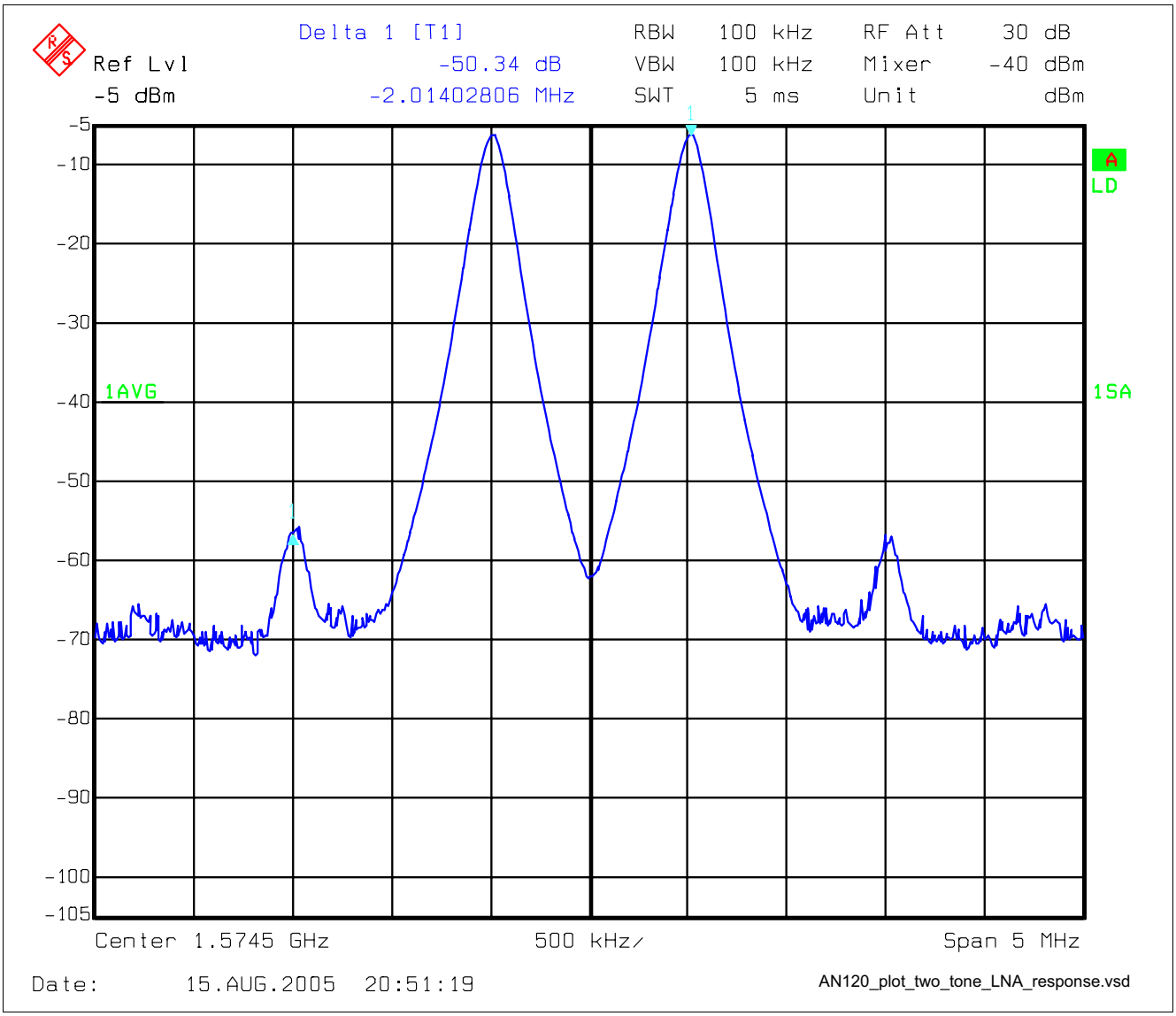



**Figure 16 Tow-Tone Test, LNA Response (1575 MHz)**