VNA400 40 MHz – 40 GHz
Two Port Vector Network Analyzer
Product Manual

Signal Hound VNA400 Product Manual

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Contents

1 Overview

The VNA400 is a USB-powered 40 MHz to 40 GHz, full two-port Vector Network Analyzer, where incident and reflected signals on both ports are simultaneously sampled. With excellent dynamic range and fast sweeps, the VNA400 is optimized for testing two-port devices, such as filters, amplifiers, and attenuators, as well as one port devices like antennas or VSWR testing. The VNA400 is powered from a Thunderbolt 3/4 port or USB-C port rated at 15 watts or higher and draws less than 15 watts.

1.1 Applications

The VNA400 can be used to make linear S-parameter measurements on a variety of devices, from amplifiers with up to 30 dB of gain, to attenuators or isolation testing of 110 dB or more. The VNA400's combination of fast measurements at high dynamic range are useful for antenna testing, attenuator testing, and filter adjustments. One port measurements are useful for impedance matching, and time domain can help locate the source of reflection. The output power is controlled in 1 dB steps, and cannot be set above +3 dBm, so it is not optimized for testing amplifier gain compression or passive diode testing. A wide variety of calibration kits are supported for Short-Open-Load-Thru (SOLT), and Short-Open-Load-Reciprocal (SOLR) calibrations.

Each port includes a DC blocking capacitor, but some amplifier testing will require an external bias tee.

1.2 Software and Installation

Install the latest version of the Signal Hound VNA software and driver from SignalHound.com.

1.3 Front Panel

The front panel has two, 2.92mm male NMD connectors for port 1 and port 2, as well as two status LEDs, one per port. Front panel D-rings are optional.

1.3.1 LED States

BOTH LEDs OFF – the VNA400 is not powered

Port One RED – Port one is actively transmitting

Port Two RED – Port two is actively transmitting

Both Ports GREEN – the VNA is in standby / warmup mode

1.4 Rear Panel

The rear panel has the USB-C connector for power and data, the fan's air inlets, and the SMA-F 10 MHz time base input.

- The USB-C connector for power and data
- The fan's air inlets on either side. Do not block the air inlets
- The 10 MHz time base input (0 to +13 dBm recommended)

1.5 Connecting the VNA400

Using the provided cable, connect the VNA400 to your PC or laptop's Thunderbolt 3 / 4 port. If your system has a USB-C port, it will not power the VNA unless it is rated for ≥ 15-watt power delivery. Gently tighten both thumb screws evenly. Cables longer than 1 meter, or cables not rated to at least 5 amps, are not recommended. Once connected and powered on, you may launch the VNA software or wait 45 minutes for warmup, then launch the software. The VNA may be used without a 45-minute warmup, but accuracy and repeatability will be significantly worse.

Optionally, connect a 10 MHz external reference for best frequency accuracy, where 1 part per million accuracy is insufficient.

Some computers may take several seconds to recognize the device and negotiate power. This is normal.

1.6 Calibrating the VNA400

The VNA400 should be completely warmed up before you begin the calibration process, as the slight gain and phase drift across temperature will negatively affect your measurement accuracy and repeatability. This typically takes about 45 minutes. At room temperature, the VNA will typically settle between 46 and 48 °C. The temperature at time of calibration is saved, and when that calibration is later loaded, the VNA400 will attempt to regulate its fan speed to match this temperature. A torque wrench is recommended for best connector repeatability. See the VNA software guide for additional information on step-by-step calibration.

The VNA supports both Short-Open-Load-Thru (SOLT) calibrations, as well as Short-Open-Load-Reciprocal (SOLR) calibrations. Please note the VNA uses slightly different internal settings when optimizing for these calibrations, so it must be selected before beginning the calibration.

For best results, warm up the VNA and apply your stimulus settings, including number of points, power, and IF bandwidth before starting the 1 or 2-port calibration.

If you are using time domain, ensure that your start and stop frequencies are even multiples of your frequency step.

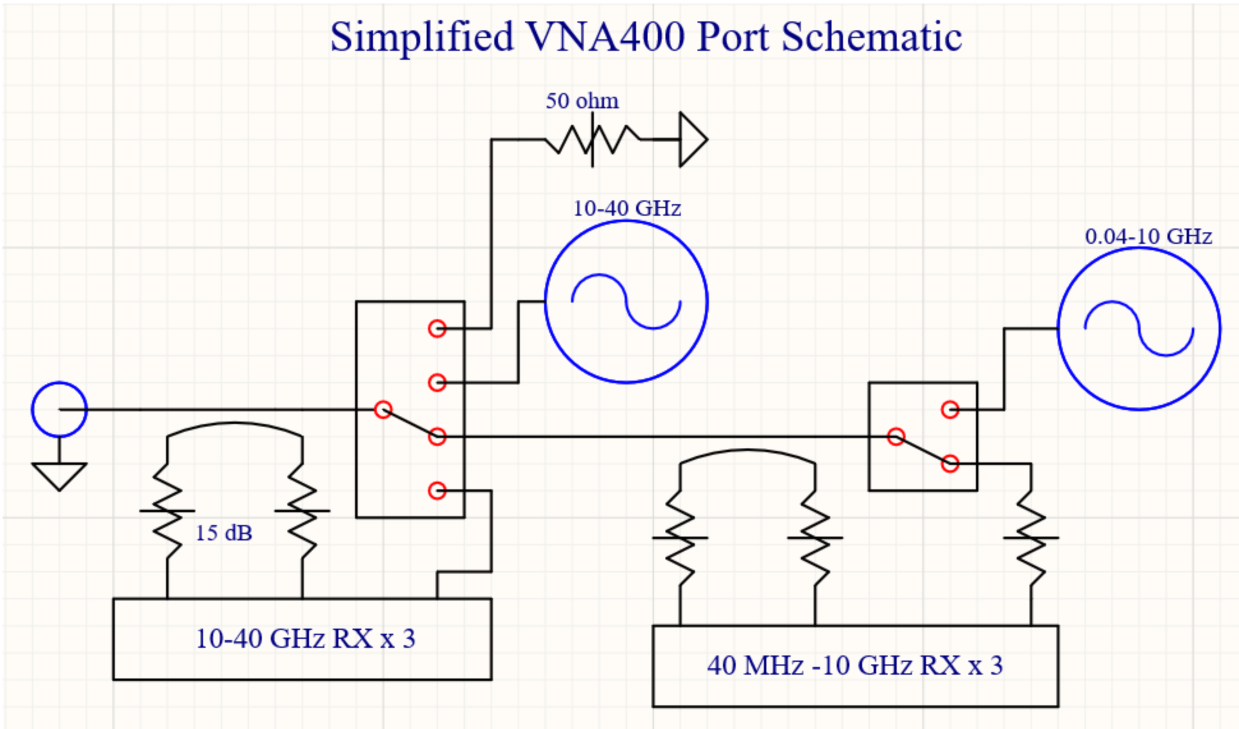
1.6.1 Connector Care

2.92 mm connectors can be worn or damaged if they are allowed to rotate during engagement or disengagement. Connectors should be clean and in good condition. Align them carefully, do not cross-thread, and rotate only the (male) connector nut until finger tight. Then, holding the opposite (female) connector stationary, tighten with a torque wrench, typically to 8 inch-pounds for stainless steel connectors (both 2.92mm and NMD).

1.6.2 Electrostatic Discharge (ESD)

ESD can damage the solid-state switches and mixers inside the VNA400. This is especially important when using antennas, or other testing where the RF signal path is exposed to static discharge. Observe ESD precautions when using the VNA400.

2 Architecture



The signal path for each port consists of:

- RF connector
- High frequency forward and reverse directional couplers
- Source – load switch
    - 50-ohm load
    - High frequency source path
    - High frequency, high sensitivity receiver
    - Low frequency subsystem
        - Low frequency bidirectional bridge
        - Low frequency source path
        - Low frequency, high sensitivity receiver and termination

2.1 RF Sources

The high frequency (> 10 GHz) source output power is typically -30 to -3 dBm, but maximum power rolls off to about -13 dBm, beginning around 26.5 GHz. Above 10 GHz, a x4 frequency multiplier is used, which generates some subharmonics.

The low frequency (< 10 GHz) source output power is typically -27 to +3 dBm, but maximum power rolls off to about -3 dBm at 10 GHz, beginning around 8 GHz.

Separate sources are used for port 1 and port 2. A separate shared local oscillator (LO) is routed to both ports. All oscillators use fractional-N PLLs.

When SOLR calibrations are used, the receiving port's inactive source is used instead of the 50-ohm load to preserve reciprocity.

2.2 Receivers

The VNA400 uses a dynamic range enhanced 4 receiver architecture. A total of 12 mixers, two active per port for any given measurement, along with a four-channel simultaneous sampling ADC, downconvert and digitize the 1 MHz intermediate frequency (IF). For frequencies where there is a fractional-N spur at a 1 MHz offset, a slightly different IF frequency is used.

Maximum sweep speed is reached using a measurement bandwidth of 20 kHz or higher. For most applications this is the 20kHz recommended maximum bandwidth.

When insertion loss is above ~35 dB, the ports are considered isolated well enough to use the high sensitivity downconverters. This significantly decreases trace noise for high insertion loss regions of 2-port measurements. This also means that when a 2-port calibration is active, each point in the sweep is measured 4 times (once per port per gain range), resulting in slower sweeps.

There is typically about 6-8 dB of headroom for the receivers at maximum power, and about 30-36 dB at minimum power. Cables and filters should generally be tested at maximum power for the best dynamic range. Amplifiers should be tested at minimum power, or at least (peak gain) of attenuation when possible. Calibrations should be run using the exact stimulus settings (power, frequency range, number of points, IF bandwidth) that you plan on using for your device under test. Amplifiers with > 30 dB gain should not be tested without attenuation, and caution should be exercised when testing amplifiers capable of over +20 dBm output power, as this can damage the VNA.

Care should also be taken when connecting an amplifier with several volts of DC bias, as the power surge may damage the VNA input. This may be avoided by connecting the unpowered amplifier to the powered, idle VNA, then applying power to the amplifier.

Higher gain amplifiers can be measured by adding external attenuators to the ports either before or after calibration. Adding up to 6 dB of attenuation to each port before calibration allows full 2-port measurements of up to 40 dB of gain, but adds noise to the return loss measurements. Adding a previously measured external attenuator after calibration allows higher gain measurements but does not allow simultaneous S11 and S22 measurements.

2.3 Fans

There are two fans in the VNA400. These will generally be on above 0°C, at a low speed. When you save or load a calibration, the fans will increase or decrease speed to attempt to maintain the temperature at time of calibration.

The fans are powered from the USB voltage. There is a slightly higher power consumption below 10 GHz than above 10 GHz, resulting in a slightly lower USB voltage below 10 GHz, reducing the fan speed slightly in this region. For slow sweeps spanning 10 GHz, this effect may be audible, but it is normal behavior. The fan speed may be manually reduced if desired in the software, but for maximum accuracy, the default behavior is to maintain internal temperature at time of calibration.

The VNA400 has vents for the fan on the sides and bottom. For best performance do not block these vents.

3 Preliminary Specifications

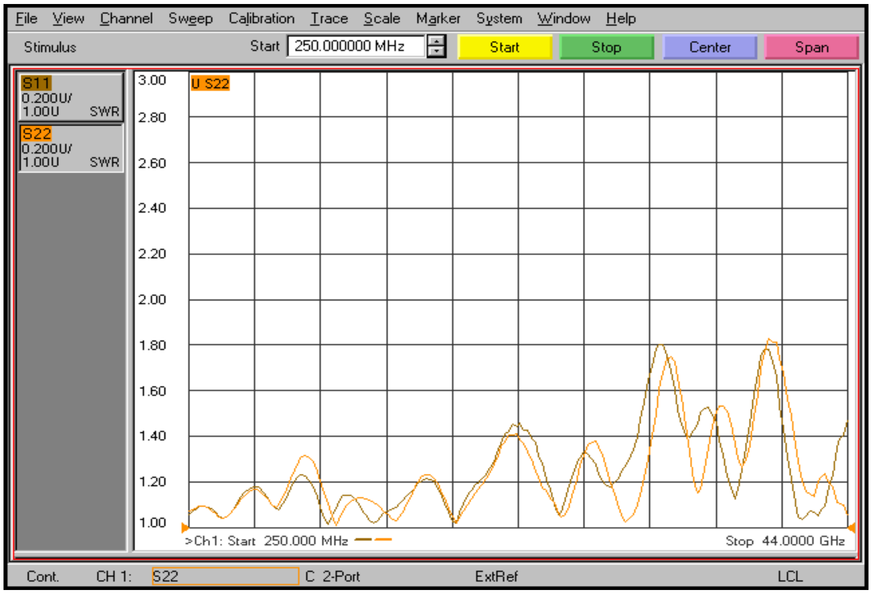
Frequency Range	40 MHz to 40 GHz
Frequency Resolution	< 1 Hz
Internal Timebase Accuracy	±1.0 part per million
Port 1/2 Connector	50Ω nominal, 2.92mm male NMD
VSWR to internal load	<1.3 50 MHz to 12 GHz typical
	<1.5 12 GHz to 26.5 GHz typical
	<2.0 26.5 GHz to 40 GHz typical
Port 1/2 Input Protection	±16 VDC, +20 dBm peak RF input power
	ESD: 1.0 kV HBM (typical)
Measurement Bandwidth	10 Hz – 100 kHz
Measurement Points	1 – 64001
Measurement Speed	500 µs per point typical at 30 kHz BW
Maximum Source Power	< 8 GHz: +3 dBm typ
	8 GHz – 36 GHz: -3 dBm typ
	36 – 40 GHz: -10 dBm typ
Minimum Source Power	-27 dBm typ
Non-harmonic Spurious	< 10 GHz: < -30 dBc
	≥ 10 GHz: < -13 dBc
Source Power Accuracy	< 10 GHz: ± 2.5 dB, 10 dB steps
	≥ 10 GHz: ± 3.0 dB, 10 dB steps
Source Power Resolution	1 dB
RMS Trace Noise	< 0.004 dB, 1 kHz BW, max power, S21 thru
	< 0.0015 dB typical
Corrected System Performance	Data-based 8770CK SOLT, tested with beadless airline
Directivity	< 24 GHz: < -42 dB typ. ≥ 24 GHz: < -39 dB typ.
Source Match	< 24 GHz: < -37 dB typ. ≥ 24 GHz: < -34 dB typ.
Load Match	< 24 GHz: < -42 dB typ. ≥ 24 GHz: < -40 dB typ.
Transmission Tracking	< 24 GHz: ± 0.03 dB typ. ≥ 24 GHz: ± 0.12 dB typ.
Uncorrected Error Terms	< 24 GHz: < -10 dB, < -14 dB typical
(directivity, source match, load match)	≥ 24 GHz: < -4 dB, < -8 dB typical

Dynamic Range, 100 Hz BW	0.1 - 2 GHz: -124 dB (-132 dB typ)
(max power to noise floor)	2 - 8 GHz: -110 dB (-125 dB typ)
	40 - 100 MHz and 8 - 10.1 GHz: -95 dB (-110 dB typ)
	10.1 - 32 GHz: -110 dB (-117 dB typ)
	32 – 40 GHz: -95 dB (-110 dB typ to 38 GHz)
Stability over Temperature	±0.02 dB/°C typical, S21 thru
Time Base Input	SMA, 10 MHz, 0 to +15 dBm recommended
System Requirements	Windows 10 or newer / Ubuntu 18 or newer
Power Requirements	Powered from PC / Laptop Thunderbolt 3 / 4 port or USB-C port featuring ≥15W power delivery
	5V, 3A max, 12W typical.
Environmental	-20°C to +50°C (-4°F to +122°F), 5-95% RH
Size and Weight	11.2” x 6.8” x 1.5”, 4.5 lbs.
Recommended Calibration Interval	1 year

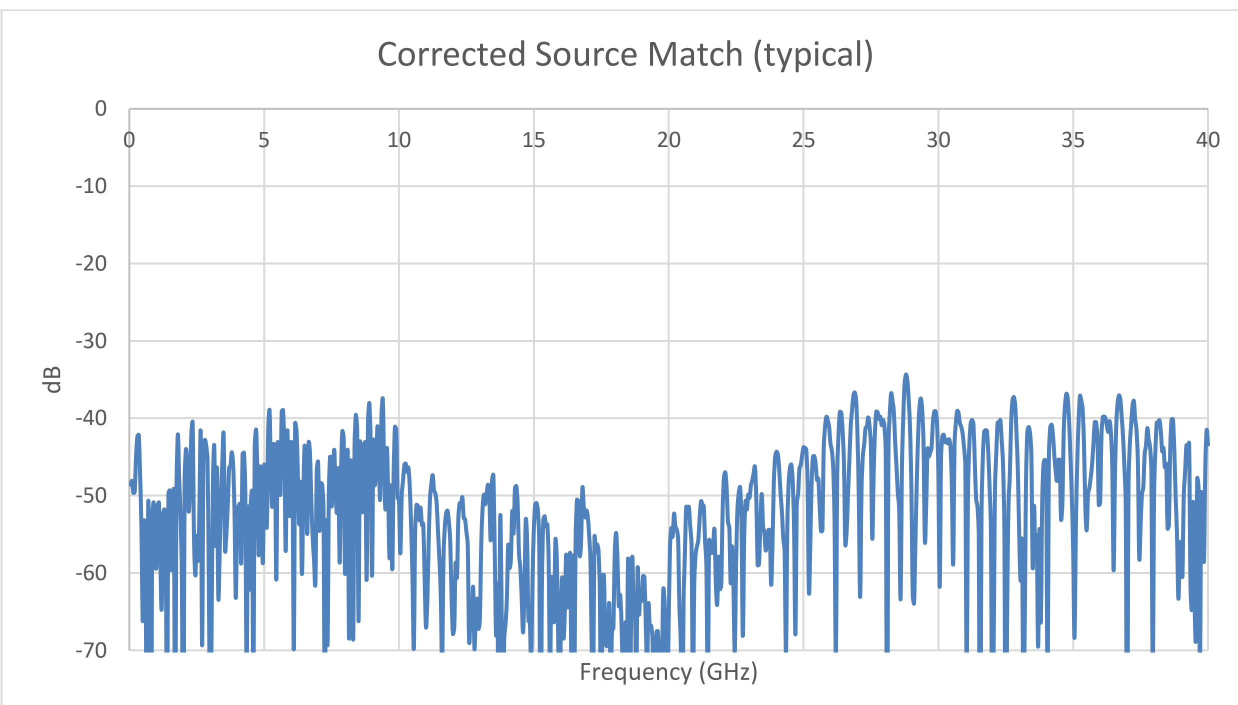
4 Typical Performance Plots

Corrected measurements using 2.92mm Maury 8770CK calibration kit + beadless airline

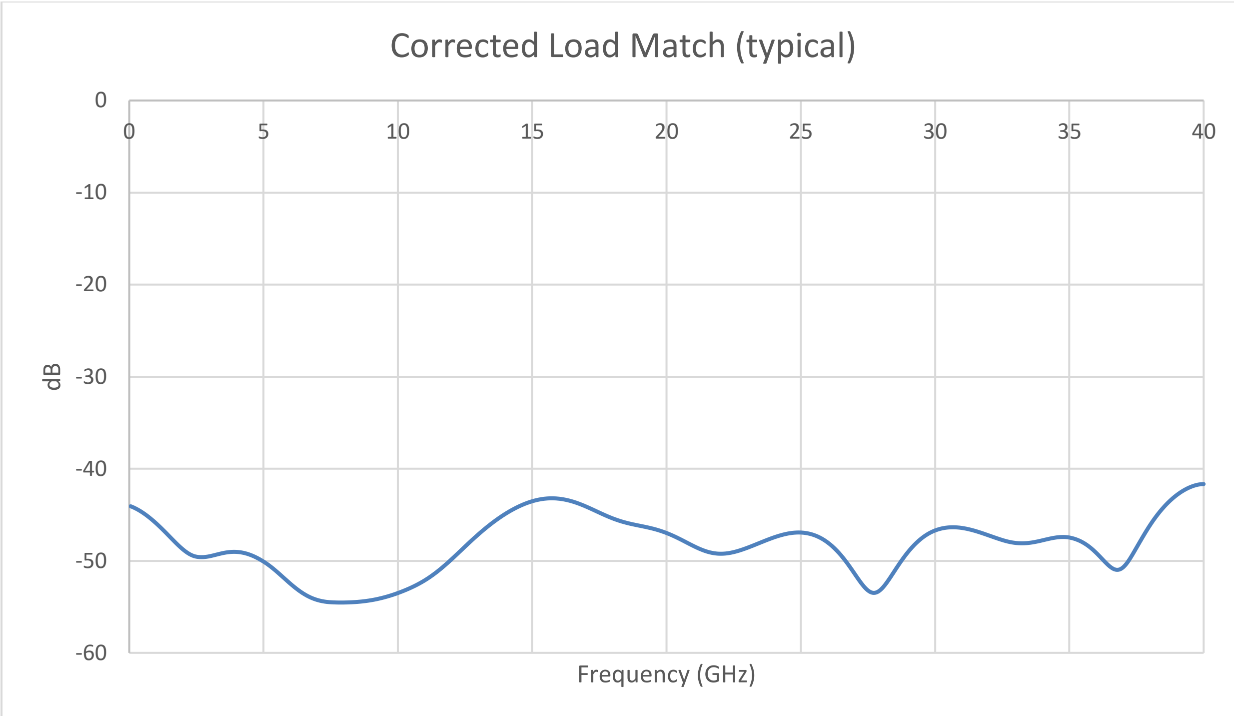
4.1 Typical VSWR to internal load

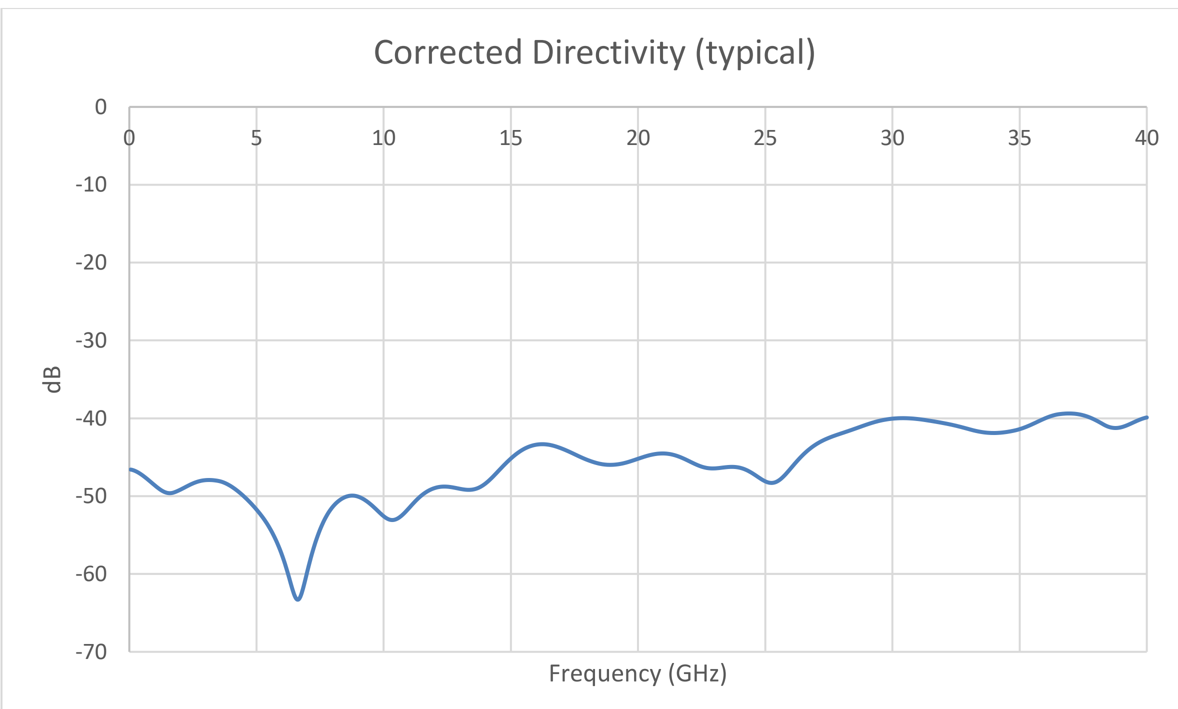


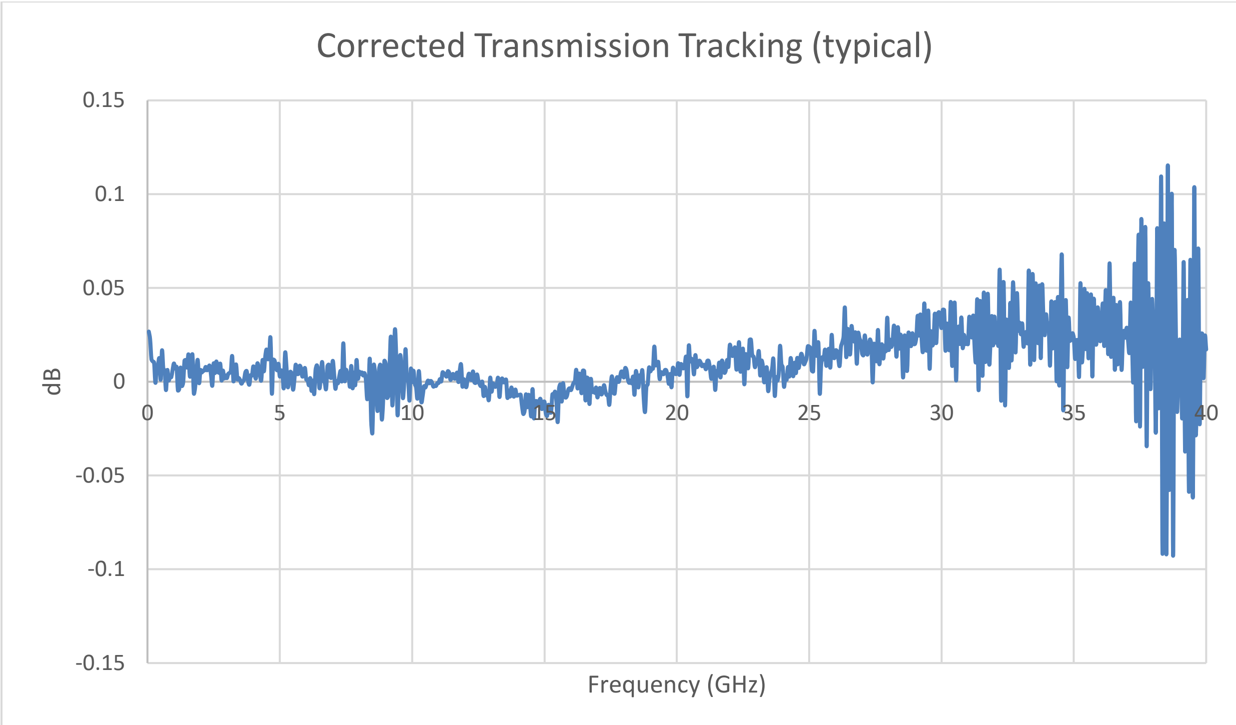
4.2 Typical Corrected Performance

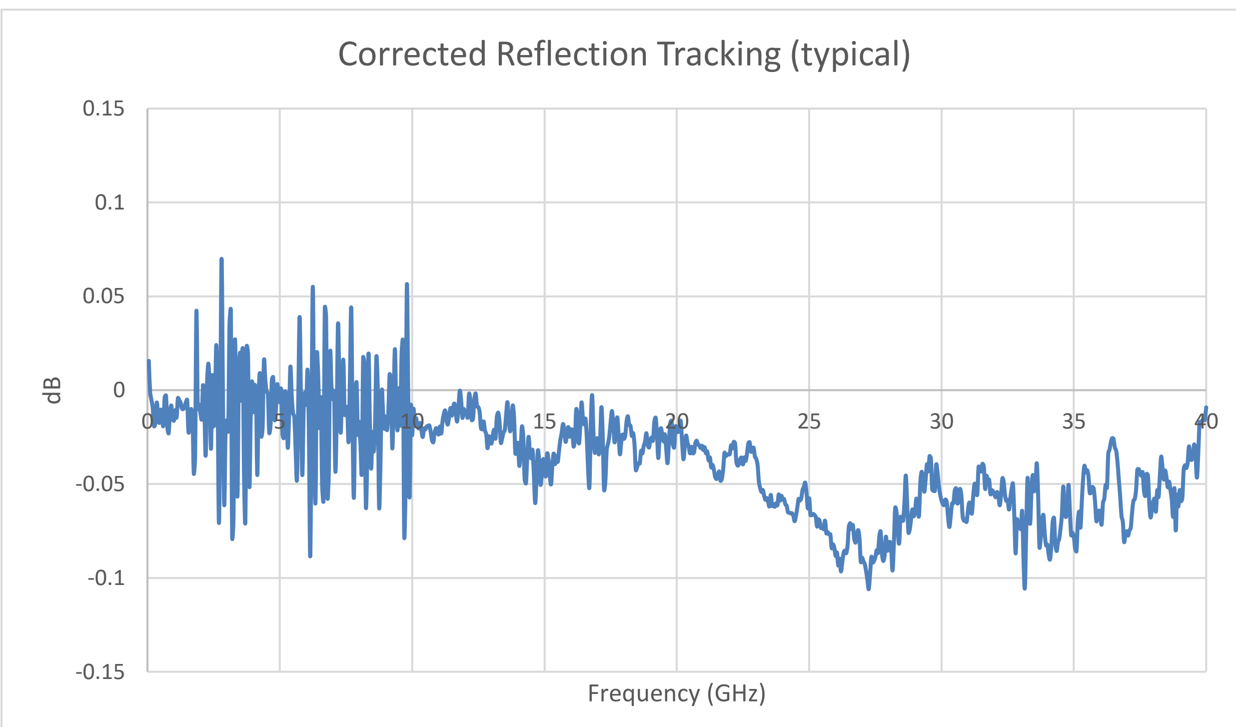


Typical Performance Plots | Typical Corrected Performance

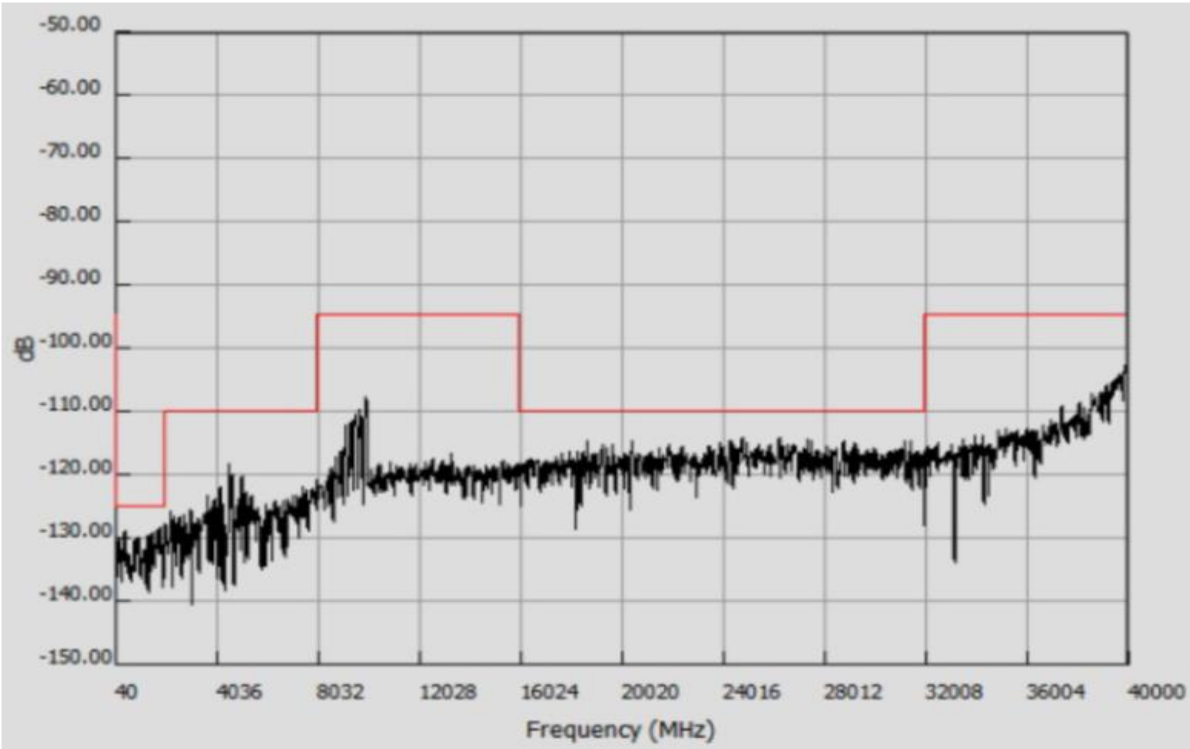


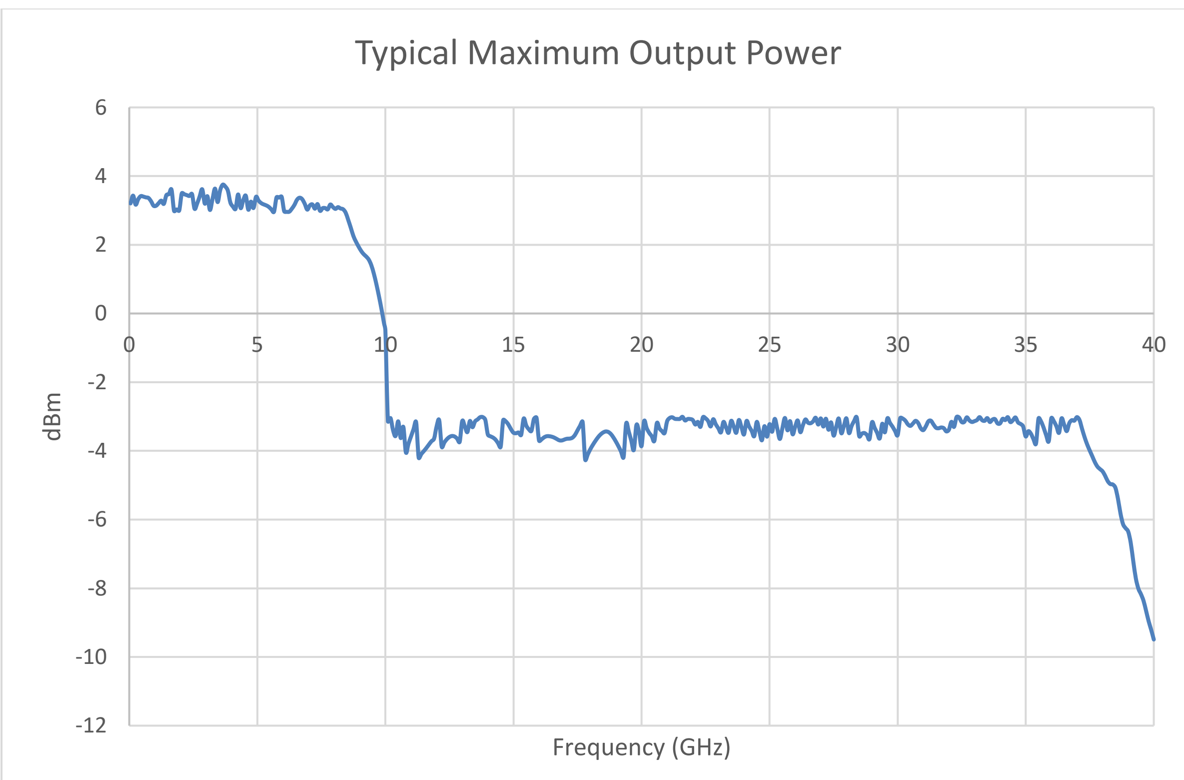


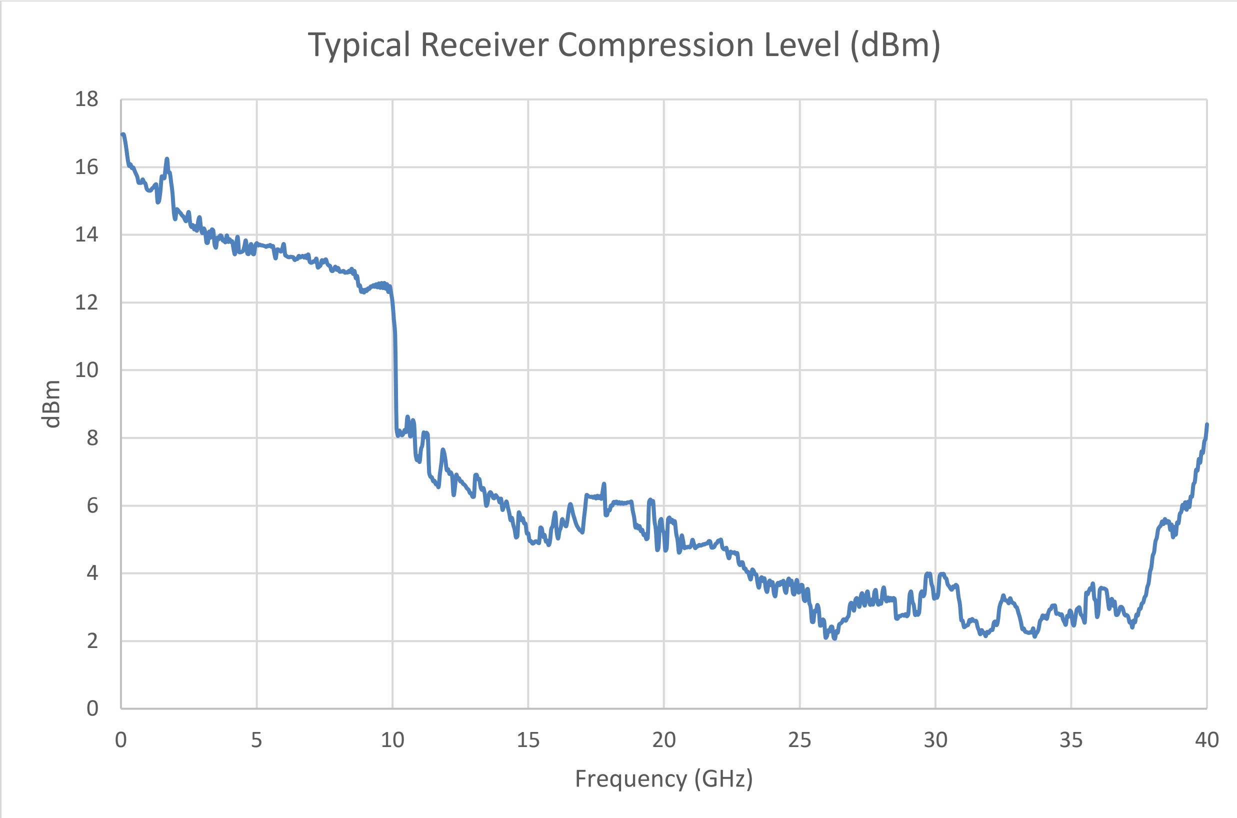

Corrected Transmission Tracking (typical)
dB
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0
5
10
15
20
25
30
35
40
Frequency (GHz)

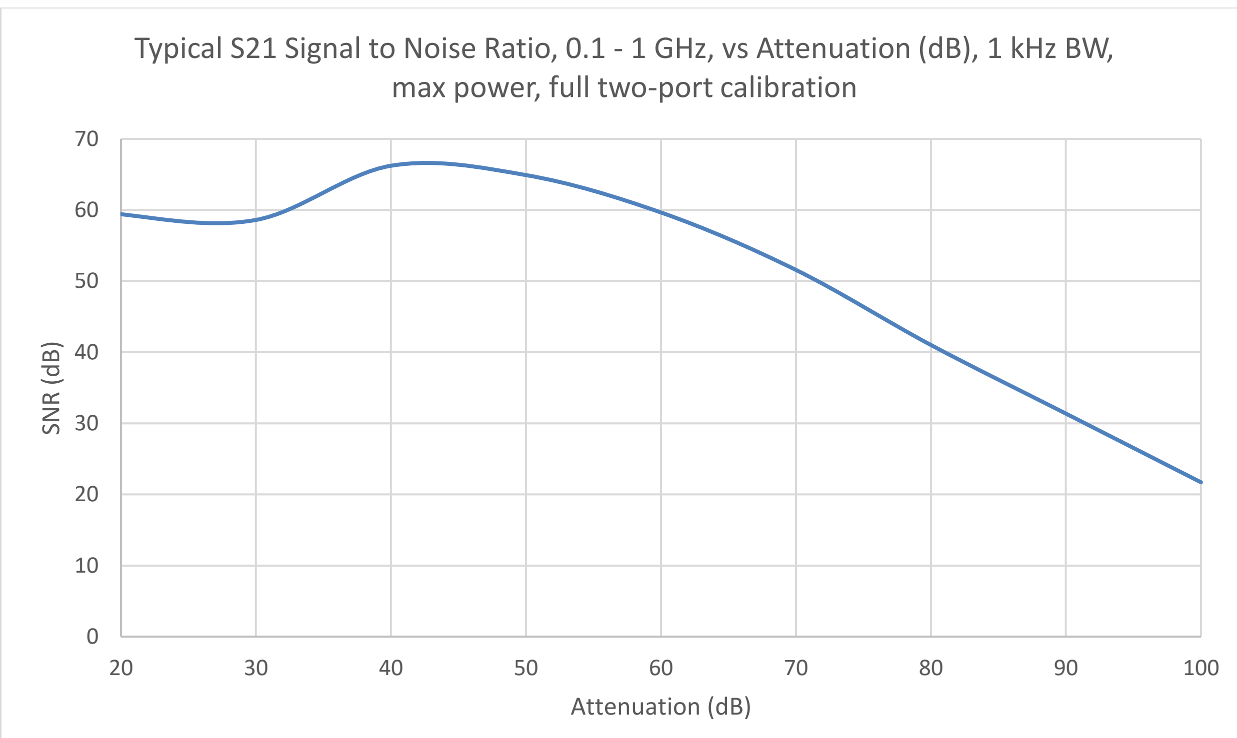

Corrected Reflection Tracking (typical)
dB
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0
5
10
15
20
25
30
35
40
Frequency (GHz)

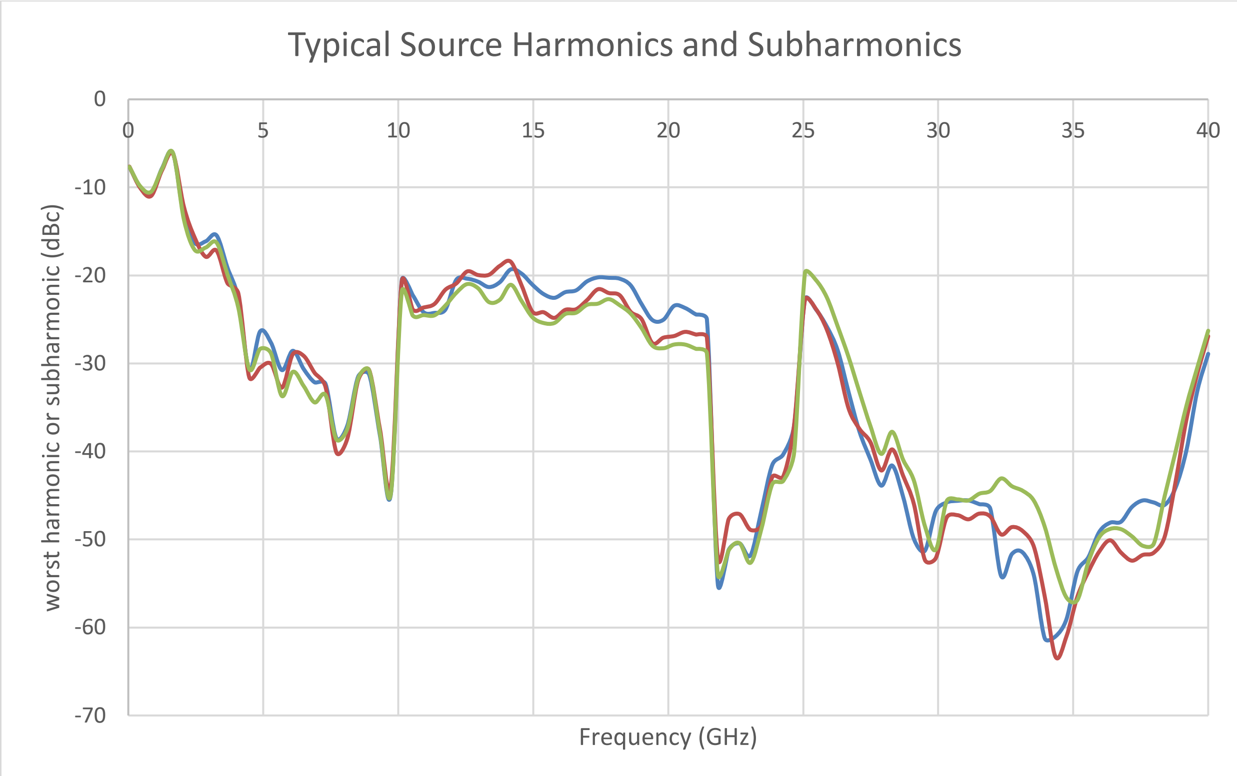
4.3 Typical Dynamic Range (100 Hz BW, max power, isolation off)



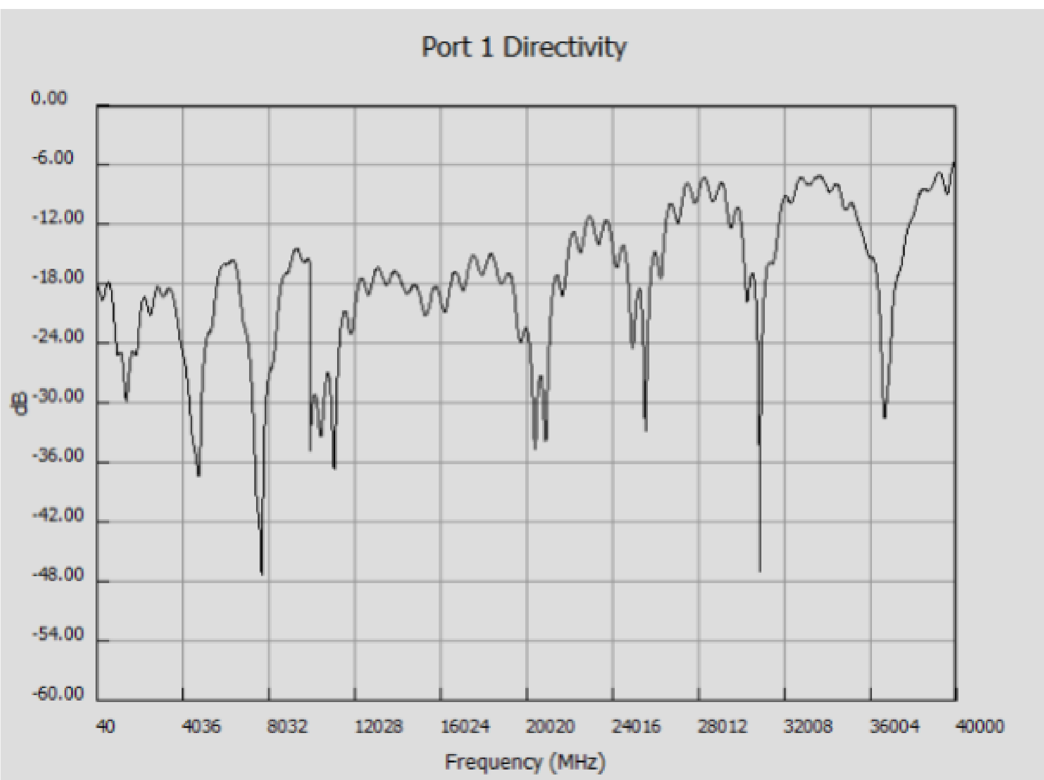


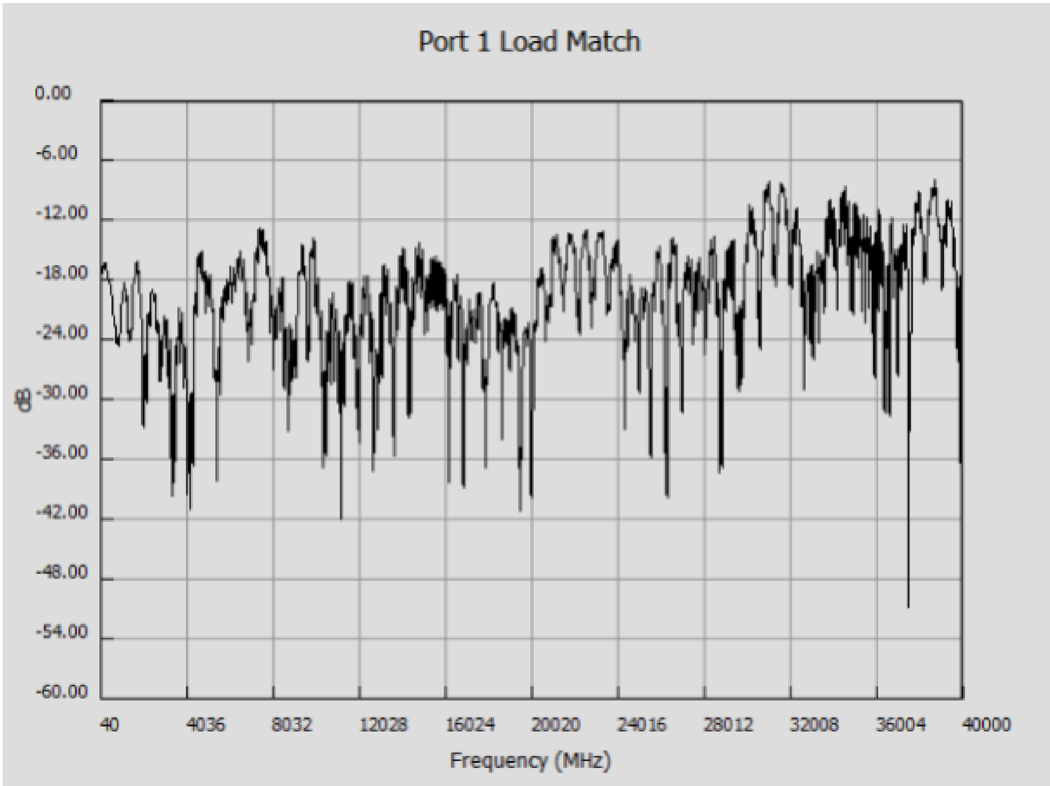

Typical Receiver Compression Level (dBm)
dBm
0
2
4
6
8
10
12
14
16
18
0
5
10
15
20
25
30
35
40
Frequency (GHz)

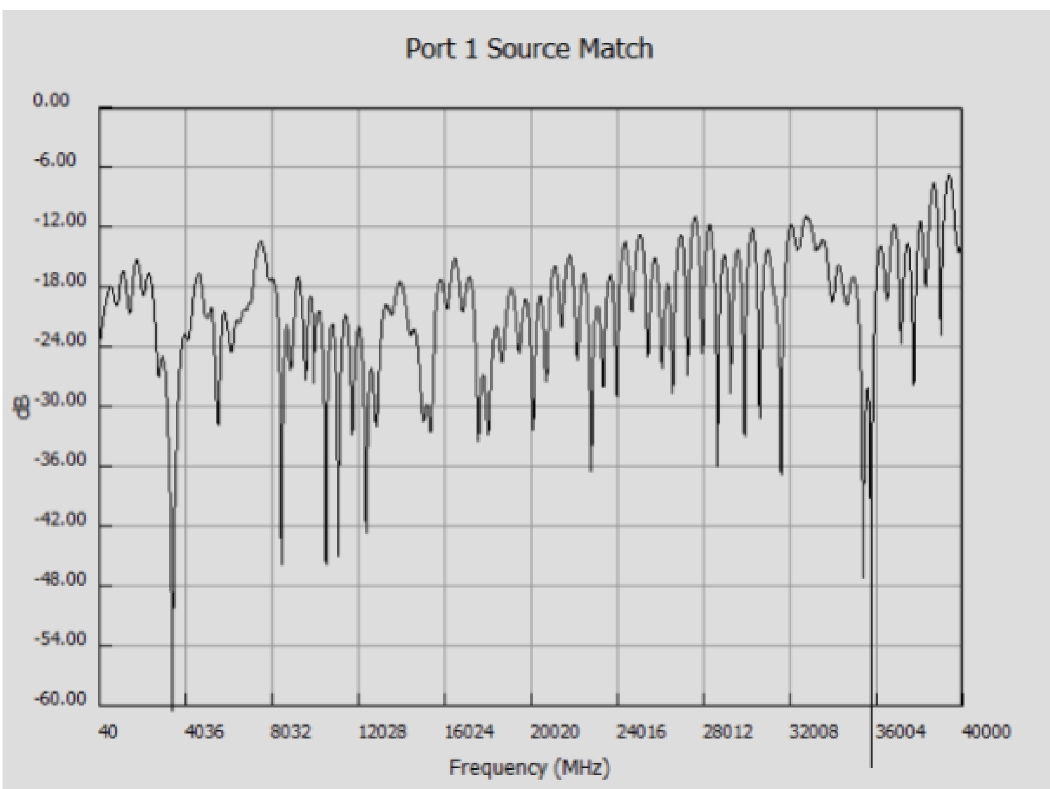

Typical S21 Signal to Noise Ratio, 0.1 - 1 GHz, vs Attenuation (dB), 1 kHz BW, max power, full two-port calibration
SNR (dB)
0
10
20
30
40
50
60
70
20
30
40
50
60
70
80
90
100
Attenuation (dB)



4.4 Typical Uncorrected Performance




Port 1 Load Match
0.00
-6.00
-12.00
-18.00
-24.00
-30.00
-36.00
-42.00
-48.00
-54.00
-60.00
dB
40
4036
8032
12028
16024
20020
24016
28012
32008
36004
40000
Frequency (MHz)


Port 1 Source Match
0.00
-6.00
-12.00
-18.00
-24.00
-30.00
-36.00
-42.00
-48.00
-54.00
-60.00
dB
40
4036
8032
12028
16024
20020
24016
28012
32008
36004
40000
Frequency (MHz)

5 Warranty and Disclaimer

5.1 Warranty

The information contained in this manual is subject to change without notice. Signal Hound makes no warranty of any kind with regard to this material, including, but not limited to, the implied warranties or merchantability and fitness for a particular purpose. Signal Hound shall not be liable for errors contained herein or for incidental or consequential damages in connection with the furnishing, performance, or use of this material. This Signal Hound product has a warranty against defects in material and workmanship for a period of two years from date of shipment. During the warranty period, Signal Hound will, at its option, either repair or replace products that prove to be defective.

5.2 Warranty Service

For warranty service or repair, this product must be returned to Signal Hound. The Buyer shall pay shipping charges to Signal Hound and Signal Hound shall pay UPS Ground, or equivalent, shipping charges to return the product to the Buyer. However, the Buyer shall pay all shipping charges, duties, and taxes, to and from Signal Hound, for products returned from another country.

5.3 Limitation of Warranty

The foregoing warranty shall not apply to defects resulting from improper use by the Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product. No other warranty is expressed or implied. Signal Hound specifically disclaims the implied warranties or merchantability and fitness for a particular purpose.

5.4 Exclusive Remedies

The remedies provided herein are the Buyer’s sole and exclusive remedies. Signal Hound shall not be liable for any direct, indirect, special, incidental, or consequential damages, whether based on contract, tort, or any other legal theory.

5.5 Certification

Signal Hound certifies that, at the time of shipment, this product conformed to its published specifications.