SP145 Spectrum Analyzer
Product Manual

Signal Hound SP145 User Manual

Published 2/14/2024

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Contents

1 Overview

This document outlines the operation and functionality of the SP145 Signal Hound spectrum analyzer. This document will help you understand the capabilities, performance specifications, and features of your SP145.

The SP145 is a real-time high-speed spectrum analyzer communicating with your PC over a USB-C Super Speed link. It has 40 MHz of real-time bandwidth, tunes from 100 kHz to 14.5 GHz, and sweeps up to 200 GHz/s. The built-in GPS can be used to discipline the time base, as well as provide time stamping and location information.

The SP145 uses a low IF architecture. It collects 245.76 million analog samples per second and processes them in the FPGA to 61.44 million corrected I/Q samples per second, which it streams to the PC.

2 Preparation

2.1 Initial Inspection

Check your package for shipping damage before opening. Your box should contain a Thunderbolt 3 / USB-C locking cable, a Signal Hound SP145, and optionally an external power supply.

2.2 Software Installation

See the Spike Software manual for installation instructions. You must have administrative privileges to install the software. During installation, the SP145 device drivers will also be installed.

It is recommended to install the application folder in the default location.

2.2.1 Software Requirements

Supported Operating Systems

- Windows 10/11 – 64-bit
- Ubuntu Linux – 64-bit

Minimum System Requirements

- Processor –Intel 5th gen quad core i-series processors***
- 8 GB RAM - 1 GB for the SP145 software
- Super-speed USB-C supporting 5V 2A power delivery, or external 5V power supply

Recommended System Requirements

- Windows 10 64-bit or Ubuntu Linux 18.04 64-bit
- Processor –Intel 5th gen quad core i-series processors***
- 8 GB RAM - 1 GB for the SP145 software
- Connectivity
    - Thunderbolt 3/4 port (recommended)
    - Super-speed USB-C supporting 5V 2A power delivery.
    - External 5V power supply
- OpenGL 3.0 capable graphics processor**

(* We do not recommend running the SP145 in a virtual machine (i.e. Parallels/VMWare/etc.))
*(** Certain display features are accelerated with this functionality, but it is not required.)*
*(***Our software is optimized for Intel CPUs. We recommend them exclusively.)*
(† Early USB 3.0 controllers from Renesas and ASMedia do not function well with our SP145. Native USB 3.0 hardware is used to refer to Intel's USB 3.0 controllers found on 3rd generation or newer i-series processors.)

2.3 Connecting Your Signal Hound

With the software and SP145 drivers installed, you are ready to connect your device. Plug the USB-C cable into your PCs USB-C or Thunderbolt 3 port, and then plug the USB 3.0 C connection into the SP145 device. Your PC may take a few seconds to recognize the device and install any last drivers. Wait for this process to complete before launching the Spike software.

2.3.1 Using external power

When using external power, plug in the 5V 2A external power supply before connecting the USB-C. To power down, unplug the USB cable before the external power. This will prevent the SP145 from drawing excess power from the USB cable.

2.4 The SP145 Front and Rear Panels

The **front panel** has 3 SMA connectors:

1. The 50Ω SMA RF Input is in the center. Do not exceed +20 dBm or damage may occur.
2. Trigger / GPIO
3. GPS Antenna

Additionally, a READY/BUSY LED is on the front panel. It flashes from green to orange when it is active. Green indicates the device is ready, and the LED turns off when the device is in low power mode.

The **rear panel** has three connectors:

1. 10 MHz Reference input (SMA). Use a clean 10 MHz reference sine wave or square wave between 0 and +20 dBm.

2. A USB-C connector.

3. External power input. Do not use external power if USB power is available. When using external power, it is recommended to only use the power supply from Signal Hound, a 5V, 2.5A supply with a positive center and an 11 mm barrel.

If a USB-C cable other than the included cable is used between the PC and the SP145, it must be rated for 3 amps and at least 5 Gbps and be no longer than 2 meters.

The SP145 is a real-time spectrum analyzer. This means the device is capable of continuously streaming with no time gaps. Having no time gaps is critical for measurements and tests requiring high probability of intercept (POI).

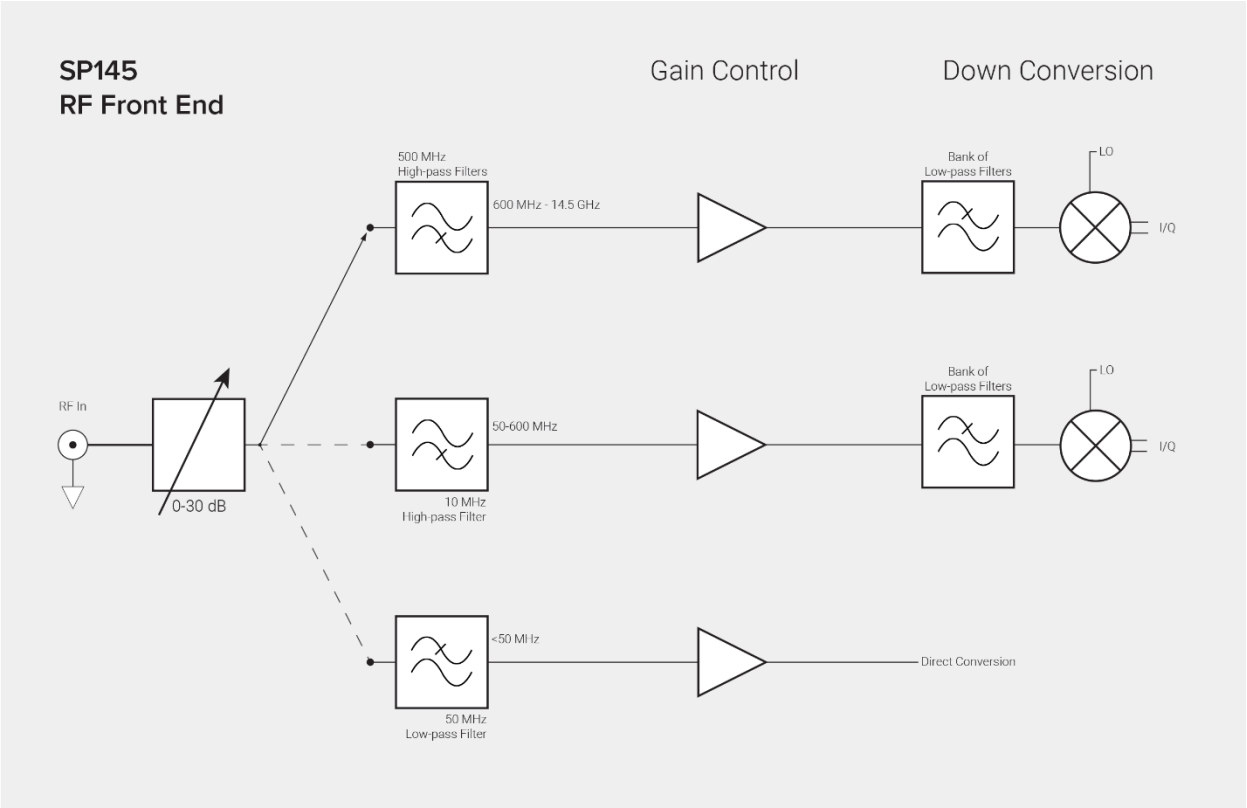
The SP145 offers multiple modes of operation, available in both our Spike software and API. See the Spike software manual and SP145 API manuals for more information.

The SP145 is designed to operate in moderate RF environments. A severe RF environment, such as nearby kilowatt transmitters, may cause interruptions to the SP145's connection to the PC.

3 Understanding the SP145 Hardware

The SP145 is a hybrid direct conversion – low IF spectrum analyzer. The SP145 uses a local oscillator, quadrature mixers, analog and digital filters and decimators to convert a portion of the input spectrum into streaming I/Q data.

3.1 Front End Architecture



3.2 Description

All signals initially pass through a digital step attenuator. This provides 0-30 dB of attenuation. When the RF input level exceeds -20 dBm, attenuation is required to make accurate measurements and avoid compression.

Below 40 MHz, the SP145 is a direct conversion system. A high linearity differential amplifier directly drives the ADC.

Above 40 MHz, the SP145 is a low IF architecture, using quadrature mixers and temperature-compensated correction factors to cancel the image response. A bank of low pass and high pass filters help suppress spurious mixer responses.

3.3 Scalloping Loss

An FFT-based spectrum analyzer uses digital resolution bandwidths rather than discrete analog filters. Moving from analog to digital introduces some new terms important to measurement accuracy, like FFT bins, window functions, spectral leakage and scalloping loss. To sum up, an FFT produces an array of discrete frequency bins and their associated amplitude. Real-world signals rarely line up exactly with a single frequency bin, which can result in some ugly behavior unless a window function is used. Many different window functions are available, with various strengths and weaknesses.

For the SP145, swept modes default to a flat top window, which offers excellent amplitude flatness and therefore very little scalloping loss, in exchange for a wider resolution bandwidth and longer processing time. Most RBWs used by the SP145 are from flat top windows, so scalloping loss is negligible.

In real-time mode a Nuttall window function is used, which has a narrower bandwidth to reduce processing time and level out impulse response. However, when a signal falls halfway between two “bins,” the energy is split between adjacent bins such that the reported “peak” amplitude may be lower by as much as 0.8 dB.

To get an accurate CW reading using “Marker peak”, flat top RBW shape in swept mode is recommended.

In either mode, the “channel power” utility, which integrates the power across any channel bandwidth you specify, also eliminates this scalloping loss, giving you a full accuracy amplitude reading even in real-time mode.

3.4 Dynamic Range

Dynamic range has many definitions, but one common definition in spectrum analysis is intermodulation-free dynamic range (IMFDR), 2/3(TOI – DANL), normalized to a 1 Hz RBW.

At 1 GHz, 0 dBm reference level, the TOI is typically +30 dBm, and DANL is typically -146 dBm (1 Hz RBW). Typical dynamic range a 1 GHz, 2/3 (TOI – DANL) > 110 dB.

The front-end attenuator is the sole source of gain control before the mixers, and as reference level changes, both TOI and DANL change by roughly the same amount, keeping dynamic range fairly constant.

3.5 Protecting the SP145 RF Input

The SP145's input attenuator and front-end switches can be damaged by ESD above 1.5 kV HBM and has a damage level just above +20 dBm peak (not RMS). Some common events which may lead to front end damage include:

1) Applying more than +20 dBm peak power, such as an antenna exposed to a radar pulse.

2) ESD from a passive antenna, either from discharge to an antenna element, or from connecting a large antenna or cable which has built up a static charge.

3) Long term exposure to frequencies below 1 MHz and above +12 dBm may cause attenuator damage.

For any application which may expose the SP145 to front end damage, including connecting to antennas or power amplifiers, a coaxial limiter is required to protect the input. Above 10 GHz, an external preamplifier should be used, both to improve the noise figure and reduce LO leakage to the antenna.

A limiter will protect against overpowering the input, typically raising the damage level above 2 watts, as well as offering significant protection against ESD.

Generally, the performance at low input signal levels is just the insertion loss of the limiter, but at high signal levels there will be some nonlinearity and the resulting intermodulation products. A typical limiter will have an IP3 around +30 dBm, so for input signals below -10 dBm there should be little to no effect on linearity.

4 Troubleshooting

If you experience a problem with your device, please contact us at support@signalhound.com.

5 Calibration and Adjustment

Calibration software is available for the SP145, but requires specialized equipment normally only found in calibration labs. Contact Signal Hound for more information regarding calibration software and required equipment, or to schedule a calibration.

6 SP145 Preliminary Specifications

The following preliminary specifications are based on being in the preset condition, using internal time base, video processing set for average and power, plus VBW, sweep, gain, and attenuation in the default auto mode. Preliminary specifications are subject to change without notice.

Frequency range	100 kHz to 14.5 GHz
Streaming Digitized I/Q	Up to 40MHz of streaming I/Q bandwidth
Resolution Bandwidths (RBW)	1 Hz to 1 MHz
Internal Timebase Accuracy	±1 ppm per year. <±1 ppm typical over temperature. ±1 ppb typical when locked to GPS
Sweep Speed (RBW ≥70 kHz)	200 GHz/sec typical
Amplitude (RBW ≤100 kHz)	Absolute Accuracy: ±2.0 dB (Flat top window) Range:+10dBm to Displayed Average Noise Level (DANL)
RF Input VSWR	< 1.3:1 typical below 10 GHz (≥10 dB attenuation) < 2:1 typical above 10 GHz (≥10 dB attenuation)
LO Leakage at RF Input	Below 5 GHz: < -80 dBm 5-10 GHz: < -47 dBm 10-12.2 GHz: < -37 dBm 12.2-14.5 GHz: < -27 dBm

Displayed Average Noise Level (DANL)*

Frequency	dBm/Hz	typical
0.1-50 MHz	-158	-161
50-1000 MHz	-164	-169
1-4.5 GHz	-163	-168
4.5-12 GHz	-161	-167
12-14.5 GHz	-157	-162

Residual Responses*	<-103 dBm (ref Level ≤ -20 dBm, 0 dB Attenuation)

Spurious Mixer Responses* -40dBc
(any ref level from 0dBm to -30dBm, in 5dB increments, input signal 12 dB below ref level, and ≤30kHz RBW)

IP2 *

Frequency	Input IP2	typical
0.1 - 500 MHz	+35 dBm	+40 dBm
0.5 – 13 GHz	+20 dBm	+30 dBm
13 - 14.5 GHz	+18 dBm	+28 dBm

IP3 *

Frequency	Input IP3	typical
0.1 – 2800 MHz	+25 dBm	+30 dBm
2.8 – 5.3 GHz	+19 dBm	+24 dBm
5.3 - 14.5 GHz	+17 dBm	+22 dBm

SSB Phase Noise at 1 GHz Center Frequency*

Offset Frequency	dBc/Hz
10 Hz	-60
100 Hz	-80
1 kHz	-100
10 kHz	-120
100 kHz	-120
1 MHz	-135

Synchronization GPS enables ± 40ns (typical) streaming I/Q timestamping accuracy

Operating Temperature 32°F to 113°F (0°C to +45°C) Standard

-22°F to 140°F (-30°C to +60°C) for Option-1

Weight Net, 1.10 lbs. (0.50 kg)

Size 7.45” x 4.51” x 1.81” (189mm x 115mm x 46mm)

Power 5 VDC, 10 watt maximum, USB-C or external power

Control and Communication USB 3.x

**DANL, Residual Responses, Spurious Mixer Responses, and Phase Noise specifications apply only at 20°C to 25°C. IP2 and IP3 tested at 0 dBm reference level, equivalent to "preamplifier off" state*

*** IP2 and IP3 typical performance specifications can be found in the Appendix: Typical Performance Characteristics of the SP145.*

7 Warranty and Disclaimer

7.1 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.

7.2 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.

7.3 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.

7.4 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.

7.5 Certification

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

7.6 Credit Notice

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Intel® and Core™ are trademarks or registered trademarks of the Intel Corp. in the USA and/or other countries.

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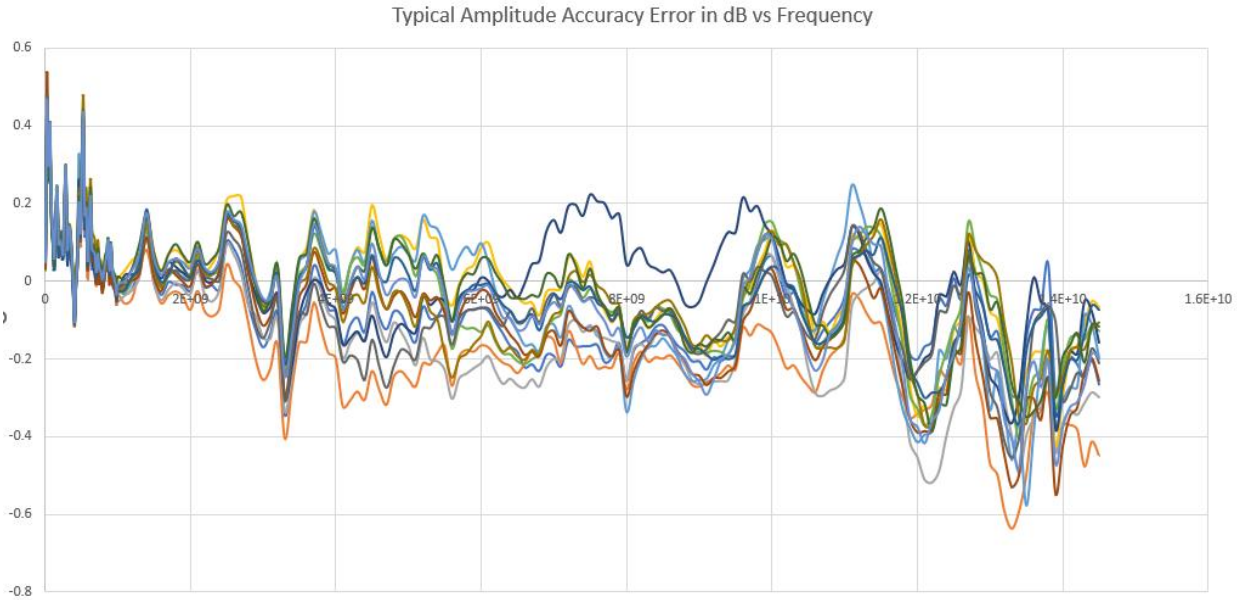
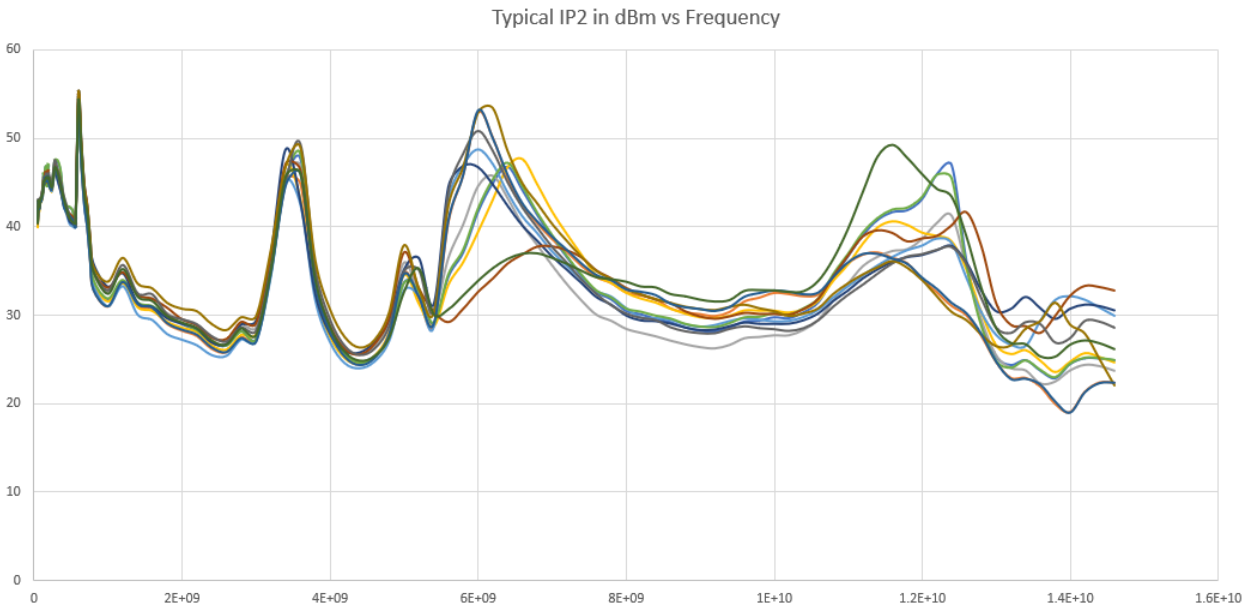
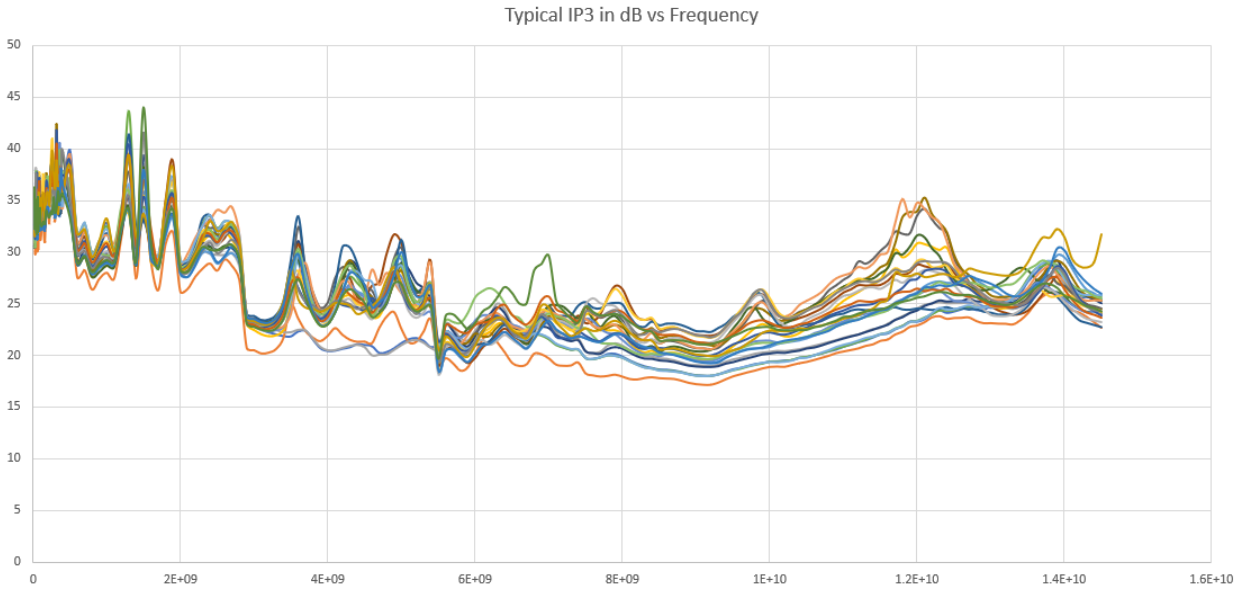
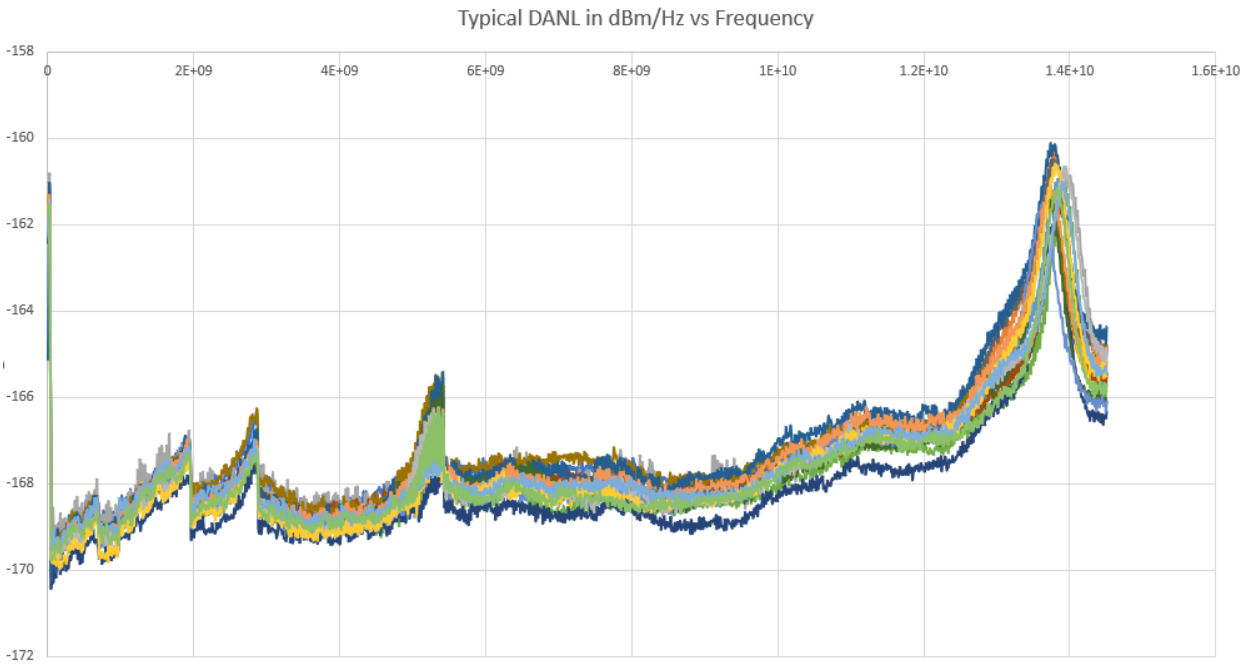
8 Appendix

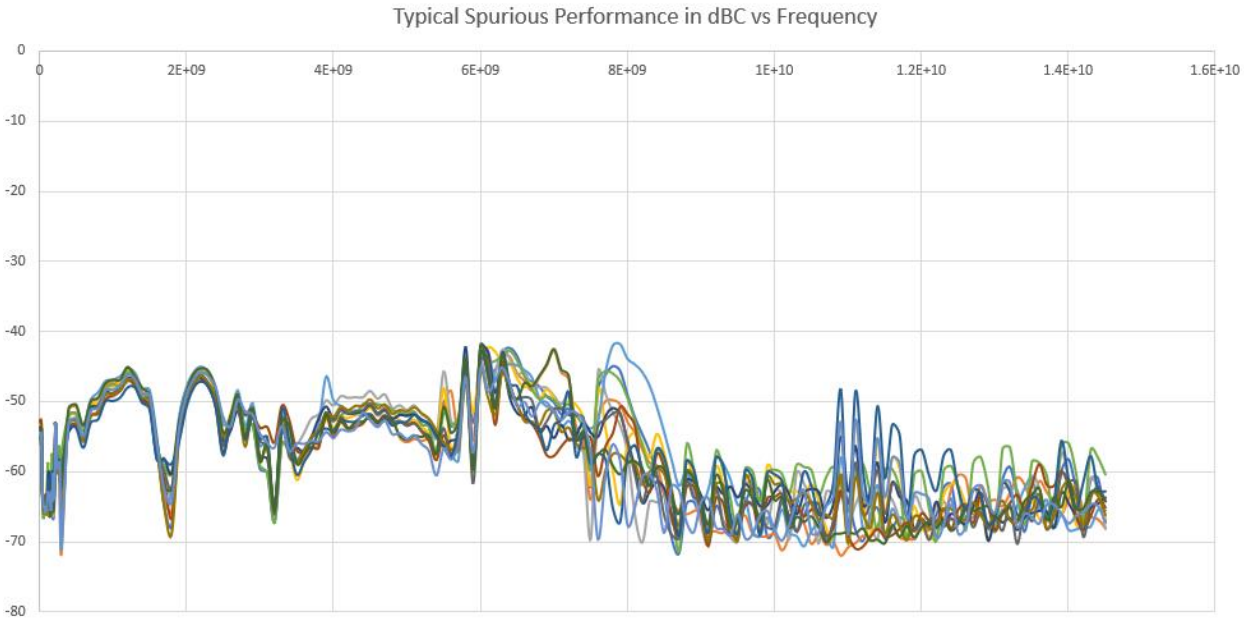
8.1 Typical Performance Characteristics of the SP145




Typical IP2 in dBm vs Frequency
60
50
40
30
20
10
0
0
2E+09
4E+09
6E+09
8E+09
1E+10
1.2E+10
1.4E+10
1.6E+10


Typical IP3 in dB vs Frequency
50
45
40
35
30
25
20
15
10
5
0
0
2E+09
4E+09
6E+09
8E+09
1E+10
1.2E+10
1.4E+10
1.6E+10


Typical DANL in dBm/Hz vs Frequency
-158
-160
-162
-164
-166
-168
-170
-172
0
2E+09
4E+09
6E+09
8E+09
1E+10
1.2E+10
1.4E+10
1.6E+10


Typical Spurious Performance in dBC vs Frequency
0
-10
-20
-30
-40
-50
-60
-70
-80
0
2E+09
4E+09
6E+09
8E+09
1E+10
1.2E+10
1.4E+10
1.6E+10