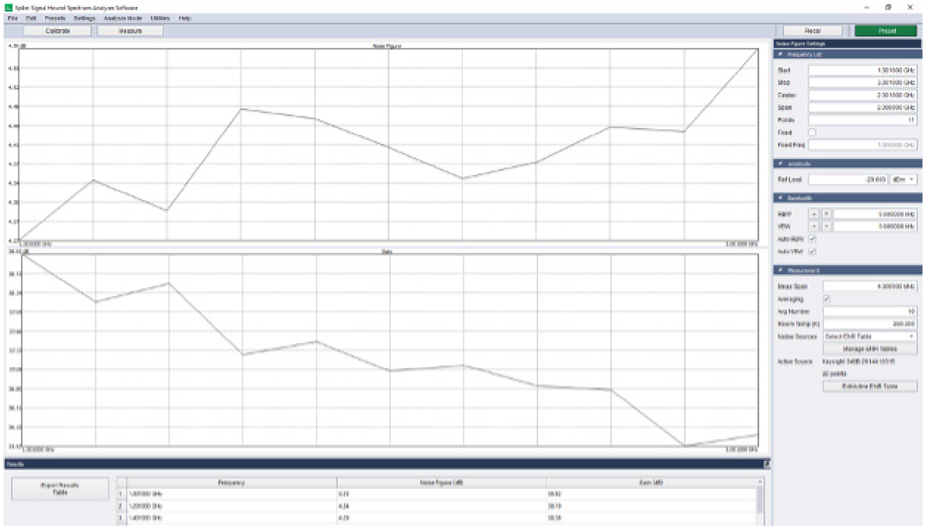
# Feature Overview-

## Noise Figure Analysis Mode in Spike™

### Key features of Spike's Noise Figure analysis module —

- Characterize the noise contributions of electrical components in a signal chain
- Save multiple calibrated ENR noise sources for selection in future test sessions
- View measurement results in the Noise Figure and Gain plots, export data for analysis at a later date



# Contents

# Overview

Our Spike™ spectrum analyzer software now includes a Noise Figure analysis mode. This new analysis mode enables Noise Figure and Gain measurements to be performed on devices that pass an RF signal through them, such as amplifiers, mixers, attenuators, and filters. As always, at Signal Hound we are proud to offer this as part of our free software package that comes with all our spectrum analyzers.

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In the modern communications landscape, receiving systems are often expected to process very weak signals, and therefore must be increasingly sensitive. Noise is one of the primary challenges. When noise levels rise higher than signal level, errors are produced.

Using Gain to raise signal level increases noise equally, thereby retaining the same signal-to-noise ratio, which does not solve the problem. Amplifying the signal may not be feasible due to fiscal, regulatory, or design limitations. The remaining viable strategy is to reduce noise in the receiver. Keeping noise levels low thus becomes a central consideration.

All electrical components produce noise. A complex system, such as a receiver, represents the cumulative noise of its components. Noise Figure is one of the most useful metrics for characterizing the noise contributions of both components and the system as a whole. In practice, devices can be reliably differentiated by comparing this key parameter.

# What is Noise Figure?

Noise Figure is a measure of the noise a device contributes to a signal, expressed as the degradation in signal-to-noise ratio (SNR) as the signal passes through the device. In basic form, Noise Figure (NF) is the ratio of SNR at input to SNR at output:

$$NF = \frac{S_{in}/N_{in}}{S_{out}/N_{out}}$$

# Measurement Methodology

Since DUT noise and noise from instruments measuring the DUT are indistinguishable, the DUT's noise contribution cannot be measured directly in one step. Instead, a subtractive method is used to isolate it: the measurement system's noise is subtracted from the noise produced by the DUT and the measurement system combined.

The first step is called the calibration step. The second step is the DUT measurement step. In each scenario, power measurements are taken with the noise source in both an ON and OFF state.

Since data from the calibration step is stored in memory for the current configuration, the measurement step may be repeated multiple times each time the noise source is calibrated.

## The Y-Factor Method

From these measurements, the Y factor method is used to calculate Noise Figure. Its computations are carried out in terms of noise temperature (T) in linear scale.

Noise temperature, or effective thermal noise, takes advantage of the fact that any type of random noise, regardless of whether it is thermal in origin, can be expressed as the equivalent amount of thermal noise that would be generated at a physical temperature.

Y factor is defined as the linear ratio of noise power level (N) when the noise source is ON and OFF:

$$Y = \frac{N_{ON}}{N_{OFF}}$$

Gain is also computed from these direct measurements of the calibration system (cal), which is the noise source and spectrum analyzer only, and the measurement system (meas), which adds the DUT into the signal chain:

$$G_{dut} = \frac{N_{meas}^{ON} - N_{meas}^{OFF}}{N_{cal}^{ON} - N_{cal}^{OFF}}$$

Expressed in linear terms, Noise Figure is called noise factor (F). Using equations to derive noise temperature from Y factor, noise factor from noise temperature, and the noise factor of a two-stage system from the noise factors of its stages, the noise factor of the DUT can be written as:

$$F_{dut} = F_{meas} - \frac{F_{cal} - 1}{G_{dut}}$$

Finally, converting back to logarithmic scale, Noise Figure is expressed in dB:

$$NF = 10 \log_{10} F$$

*NOTE: For a complete derivation of Noise Figure from direct measurements, see the Spike User Manual, Section 4.12.1.2: The Y Factor Method: https://signalhound.com/sigdownloads/Spike/Spike-User-Manual.pdf.*

# Plots

Noise figure analysis mode contains two plots, one for Noise Figure and one for Gain. Each plot shows the measurement for each test frequency defined in the frequency list.

The plots are shown as continuous lines to better visualize the results across test frequencies. However, markers can be placed on the plots and moved discreetly from point to point, for precise feedback.

## Noise Figure Plot

The Noise Figure plot displays the calculated Noise Figure at each test frequency.

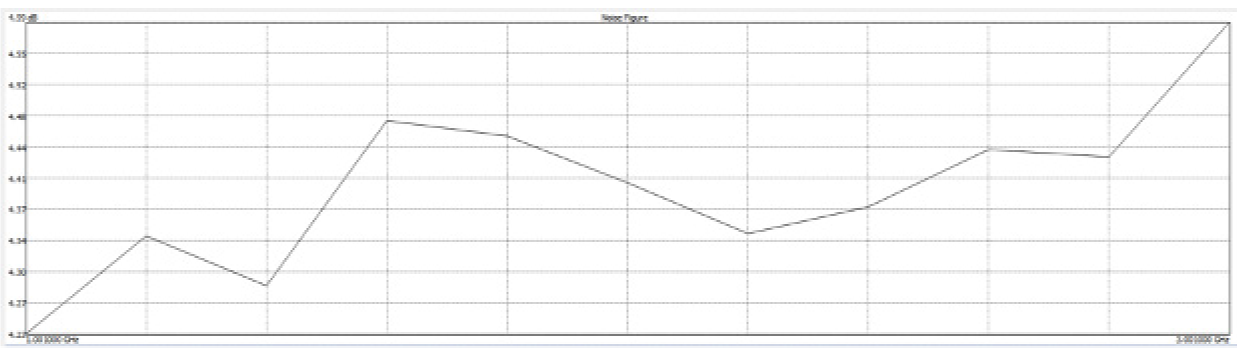


Figure 2: Noise Figure plot in Noise Figure analysis mode.

## Gain Plot

The Gain plot displays the calculated Gain at each test frequency.

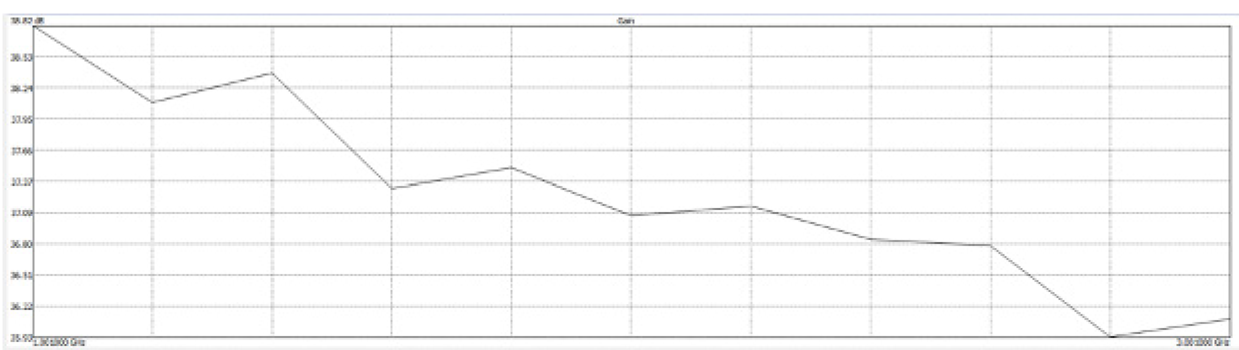


Figure 3: Gain Plot in Noise Figure analysis mode.

# Measurement Walk-Through

The following steps demonstrate the making of a basic noise figure measurement:

## Required Equipment

- **A Signal Hound SM or BB Series Spectrum Analyzer**

    - An SM200A, SM200B, SM200C, or BB60C spectrum analyzer from Signal Hound will work with Noise Figure analysis mode.

      See our spectrum analyzers at https://signalhound.com/products.

- **Spike Spectrum Analyzer Software (from Signal Hound)**

    - Spike Software requires a PC equipped with Windows 7, 8, or 10 operating system, either 32 or 64-bit. For Signal Hound's SM or BB series real-time spectrum analyzers, an Intel Desktop quad-core i5/i7 processor model number 3000 series or later is required. Additionally, a minimum of 4 GB of RAM is required, with 8 GB of RAM being recommended. Spike Software typically requires less than 1 GB of available hard disk space.

      Download for free at https://signalhound.com/spike.

- **A Noise Source**

    - A noise source with calibrated ENR values at specific frequencies, such as a Keysight 346B, along with a power source that can be turned on and off, is necessary for Noise Figure measurements.


Figure 4: Keysight 346B Noise Source.

- **A Device Under Test (DUT)**

    - Of course, you will need a device to test! This can be any system or component that receives and outputs an RF signal. For example, a TekBox TBWA2 40 dB Wideband Amplifier, included with our EMC Near-field Probe Set, available at https://signalhound.com/products/emc-near-field-probe-set-40-db-wideband-amplifier.


Figure 5: TekBox TBWA2 40 dB Wideband Amplifier.

# The Measurement Process

## 1. Define Test Frequency List

Noise Figure mode takes measurements at a set of discrete frequency points. Define the list of test frequencies using the *Frequency List* section of the *Noise Figure Settings* control panel.

## 2. Configure Measurement Settings

Set the parameters that will affect each measurement in the *Amplitude, Bandwidth*, and *Measurement* sections of the control panel. In addition to *Ref Level, RBW,* and *VBW, Meas Span* is the span of each sweep, *Averaging* determines if multiple sweeps will be averaged, *Avg Number* is the number of sweeps averaged at each frequency, and *Room Temp* is the ambient temperature of the room, in Kelvin, which defaults to 290 K.

## 3. Enter and Activate ENR Table for Noise Source

A table of ENR values is a part of the spec of a noise source, and is often printed on the device. This table must be manually entered into the software to obtain accurate measurements.

To enter an ENR table, click the *Manage ENR Tables* button in the *Measurement* section of the control panel to bring up the table manager. Then, click *Add Noise Source,* name the source, click *Edit Points,* and enter each (frequency, ENR) pair in the table editor.

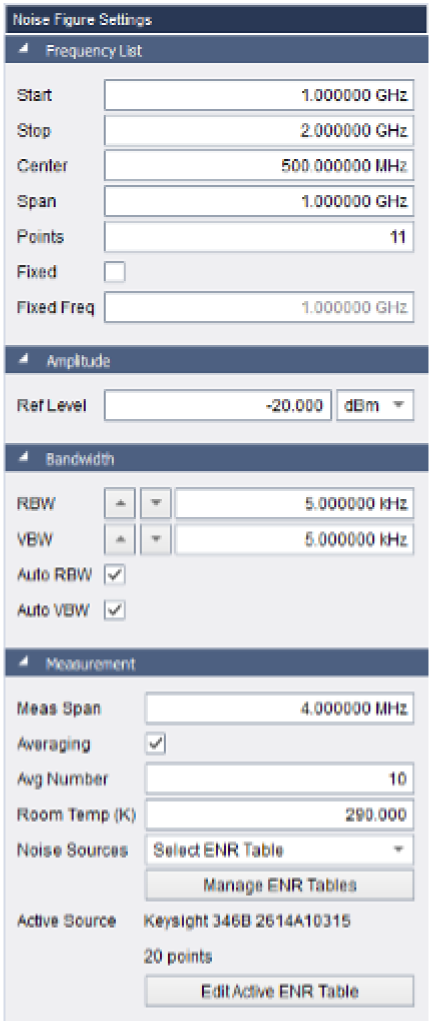


Figure 6: Noise Figure Settings control panel.

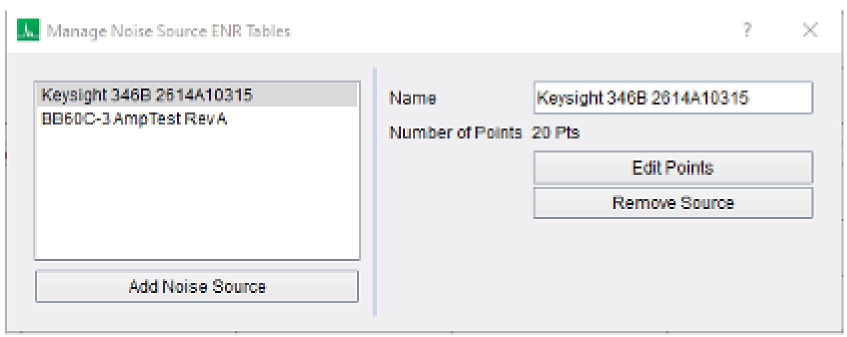


Figure 7: ENR Table Manager.

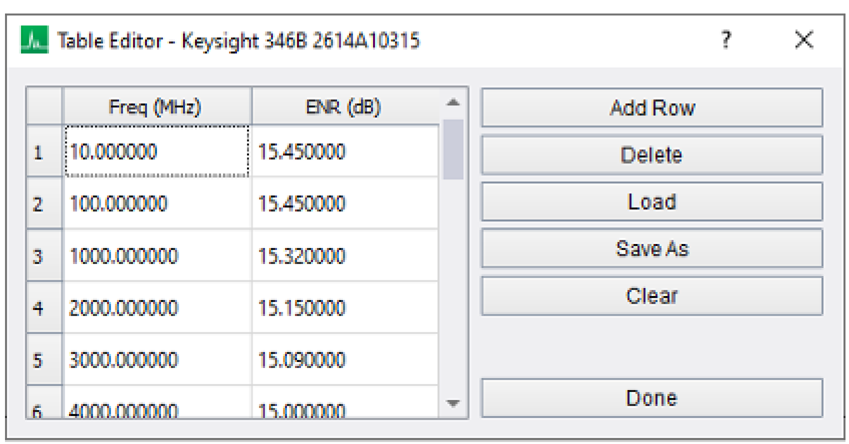


Figure 8: ENR Table Editor.

Finally, activate the table by selecting it from the Noise Sources dropdown.

Alternatively, the unnamed active table can be quickly edited using the Edit Active ENR Table button.

## 4. Measurement

Noise Figure mode is not a continuous measurement as it involves manual steps. To begin the calibration process, press the Calibrate button in the global toolbar in the upper left of Spike. If a calibration has already been performed for this configuration, press the Measure button to begin measuring the DUT.

Pop-up dialog boxes will guide you through the process below.

## 5. Calibration

Connect the noise source directly to the Signal Hound spectrum analyzer. Then, follow the prompts to turn power to the noise source On and Off.

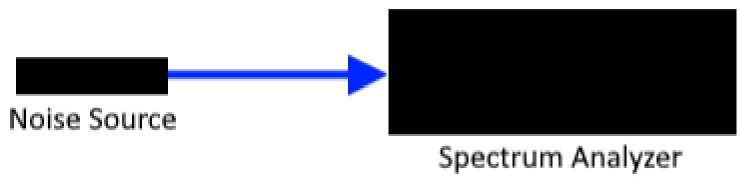


Figure 9: Diagram of calibration step setup.


Figure 10: Keysight 346B noise source connected to Signal Hound SM200A spectrum analyzer in calibration step.

## 6. DUT Measurement

Insert the DUT in the signal chain between the noise source and the spectrum analyzer. Then, follow the prompts to turn power to the noise source Off and On.

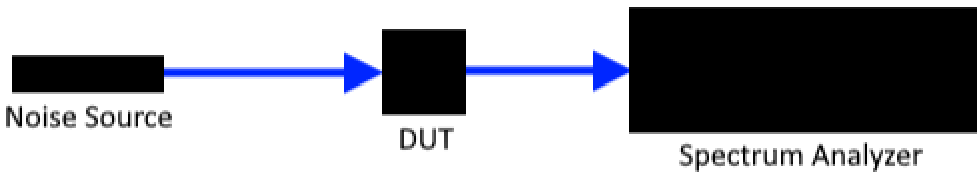


Figure 11: Diagram of DUT measurement step setup.


Figure 12: Keysight 346B noise source connected to TekBox TBWA 40 dB Wideband Amplifier (DUT) connected to Signal Hound SM200A spectrum analyzer in DUT measurement step.

## 7. View Results

Noise Figure and Gain calculations at each frequency are shown in the Noise Figure and Gain plots, and the Results table.

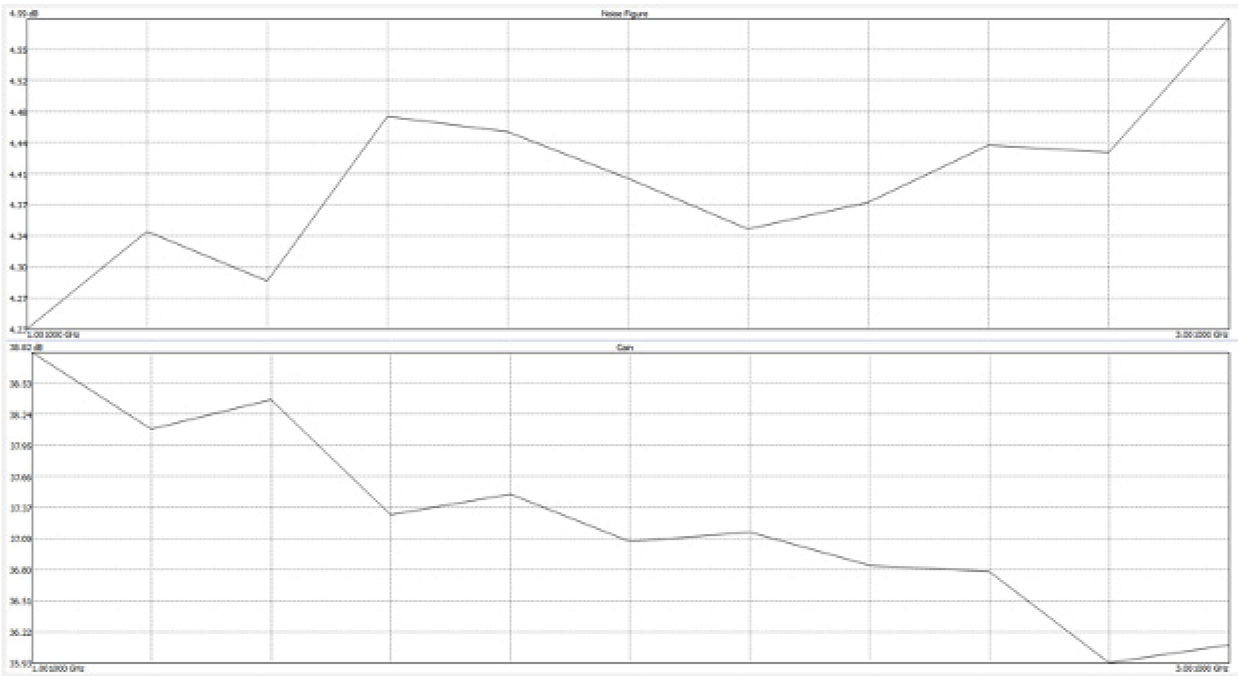


Figure 13: Noise Figure and Gain plots.

Results

Export Results Table

| | Frequency | Noise Figure (dB) | Gain (dB) |
|---|---|---|---|
| 1 | 1.001000 GHz | 4.23 | 38.82 |
| 2 | 1.201000 GHz | 4.34 | 38.10 |
| 3 | 1.401000 GHz | 4.29 | 38.38 |
| 4 | 1.601000 GHz | 4.47 | 37.31 |
| 5 | 1.801000 GHz | 4.46 | 37.50 |
| 6 | 2.001000 GHz | 4.40 | 37.08 |

Figure 14: Noise Figure mode Results table.

# Noise Figure Spectrum Analyzer Key Parameters

| SIGNAL HOUND SPECTRUM ANALYZER | BB60C  | SM200B  |
|---|---|---|
| **Price** | $3,160 USD | $13,510 USD |
| **Frequency Range** | 9 kHz - 6 GHz | 100 kHz - 20 GHz |
| **Maximum (ENR + Gain)** | 40 dB | 60 dB |
| **Noise Source Control** | Manual | Manual |
| **Maximum Averaging** | 1000 Sweeps | 1000 Sweeps |
| **Maximum Test Frequencies** | 1001 | 1001 |
| **Minimum Test Frequency Resolution** | 10 kHz | 10 kHz |
| **Measurement Span** | 100 kHz - 10 MHz | 100 kHz - 10 MHz |
| **Defined Room Temperature** | 0.01 - 375 K | 0.01 - 375 K |

# Conclusion

Signal Hound's new Noise Figure analysis mode makes it easy to take noise figure and gain measurements, which can be critical differentiating factors for a wide range of RF components and systems.

With flexible definition of the test frequency list, fine-tuned control over the configuration of each measurement – including span, RBW, VBW, reference level, number of sweeps to average, and room temperature – and simple management of ENR tables so each of your noise sources need be entered only once (or can even be loaded and saved to CSV files), a simple, guided measurement process, cached calibration data, and intuitively displayed, easily exportable results—Spike's new analysis mode performs noise figure measurements quickly and accurately.

## Further Reading

Learn more about Spike's available analysis modes at signalhound.com/spike.

# About Signal Hound

Signal Hound designs and builds powerful, affordable spectrum analyzers and signal generators for engineers and RF professionals around the globe. Whether you're needing EMC precompliance capabilities in a small two-person shop or spectrum monitoring on a national scale, our test equipment is designed with you in mind. Accurate and powerful enough for mission-critical RF analysis, priced at a point accessible to most, and supported by a talented group of engineers committed to what they do – we truly believe that our devices offer unrivaled value in the test equipment industry.

In business since 1996 and selling our own line of Signal Hound test equipment since 2010, we've built the foundation of our company on years of test equipment repair, service, hardware and software development, and manufacturing experience. Signal Hound is a small company with big goals – and an even bigger commitment to providing our customers with an outstanding experience when purchasing and using our products.

Signal Hound®