Keysight X-Series Signal Analyzers

This manual provides documentation for the following models:

N9040B UXA

N9030B PXA

N9020B MXA

N9010B EXA

N9000B CXA

N8973B NFA

N8974B NFA

N8975B NFA

N8976B NFA

N9069C
Noise Figure
Measurement
Guide

KEYSIGHT TECHNOLOGIES

Notices

Trademark Acknowledgments

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1 Introduction to Noise Figure

Modern receiving systems must often process very weak signals, but the noise added by the system components tends to obscure those very weak signals. Sensitivity, bit error ratio (BER) and noise figure are system parameters that characterize the ability to process low-level signals. Of these parameters, noise figure is unique in that it is suitable not only for characterizing the entire system, but also the system components such as the preamplifier, mixer, and IF amplifier that make up the system. By controlling the noise figure and gain of the system components, you can directly control the noise figure of the overall system. Once the noise figure is known, system sensitivity can be estimated from the system bandwidth. Noise figure is often the key parameter that differentiates one system from another, one amplifier from another, and one transistor from another.

The noise figure of a network is defined to be the ratio of the signal-to-noise power ratio at the input to the signal-to-noise power ratio at the output.

Noise figure is independent of the modulation format and of the fidelity of modulators and demodulators. Noise figure is a more general concept than noise-quieting used to indicate the sensitivity of FM receivers or BER used in digital communication.

Noise figure should be thought of as separate from gain. Once noise is added to the signal, subsequent gain amplifies the signal and noise together and does not change the signal-to-noise ratio.

How does the Noise Figure Measurement Work?

The noise figure measurement is usually made on 2-port devices to see the decrease of the signal-to-noise ratio as the signal goes through the DUT. The N9069C Noise Figure Measurement Application uses the Y-factor method to calculate the noise figure. This section briefly explains how a complete Y-factor measurement is made. You can refer to Application Note 57-2: Noise Figure Measurement Accuracy - The Y-Factor Method for more detailed information.

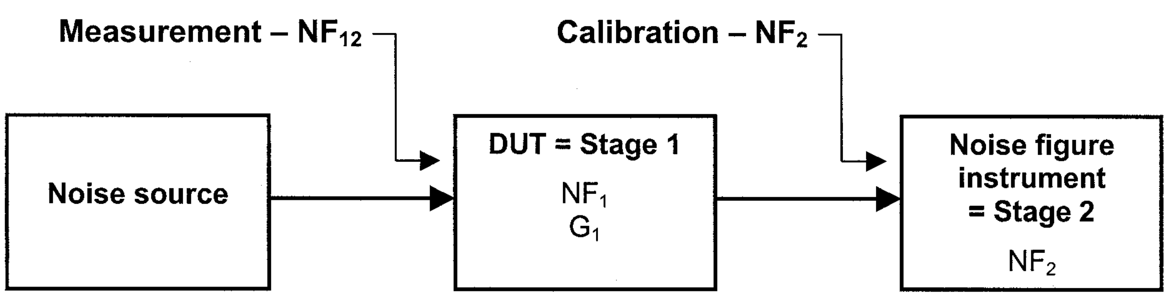
The test system can be seen as a two-stage system as shown in the following figure. The DUT is stage 1 and the instrument connected to the DUT is stage 2. The noise figure of the DUT can be calculated using the following equation.

Equation 1-1

$$F_1 = F_{12} - [(F_2 - 1)/G_1]$$

This equation is the basis for the noise figure measurement. The noise figure and gain of the DUT are measured in the process.

Figure 1-1 Noise Figure Measurement Using a Two-Stage System



Noise Source

The Y-factor method uses a noise source to provide stimulus to the DUT input. The noise source has two known levels of noise with a pre-calibrated Excess Noise Ratio (ENR). The noise from the noise source is broadband.

Equation 1-2

$$ENR = (T_S^{ON} - T_S^{OFF})/T_0$$

T_s^{ON} and T_s^{OFF} are the noise temperatures of the noise source in its ON and OFF states. T_0 is the reference temperature of 290 K.

Y-factor Measurement

The complete Y-factor measurement of the DUT noise figure and gain consists of two steps, calibration and measurement, as shown in Figure 1-2. The analyzer measures the noise power corresponding to the noise source On and noise source Off in certain bandwidth at different frequencies. A total of four measurements are taken in the process.

Process

1. A calibration (Figure 1-2) is done without the DUT in place to measure the instrument itself. The noise source is usually connected directly to the input of the instrument.

   In calibration, the analyzer makes two measurements with the noise source ON and OFF respectively.

   Note that if the ENR of the noise source is much smaller than the instrument noise figure (for example, ENR 6 dB, instrument noise figure 30 dB), the CAL will not work well. In this case, it is recommended to use a USB preamplifier and/or the internal preamplifier, to reduce the instrument noise figure. If the preamplifier can *not* be used for some other concerns, you can use a noise source with a higher ENR.

2. A measurement is done with the DUT inserted and the test system consists of the DUT (stage 1) followed by the instrument (stage 2). The analyzer makes another two measurements with the noise source ON and OFF respectively.

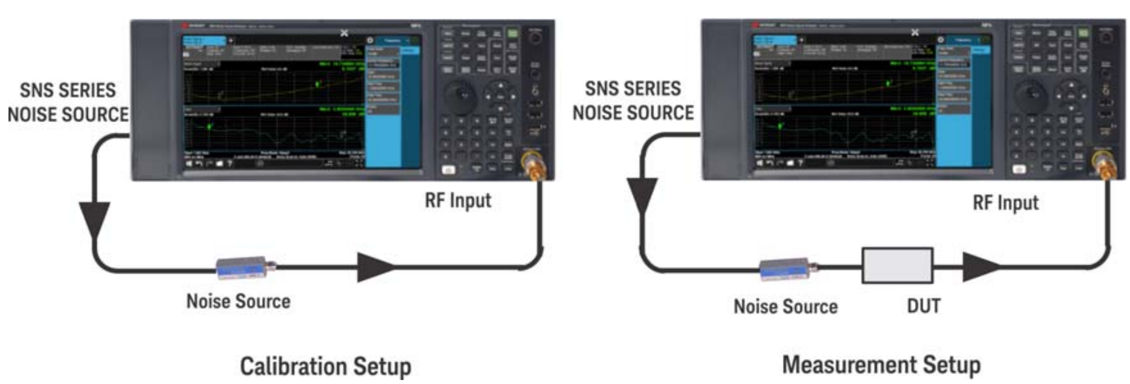
   In the measurement, if the DUT has gain, the measurement with the noise source ON is the largest signal case in the four measurements. In some high-gain cases, especially with an external preamplifier, there is a risk of overloading the instrument that must be addressed.

With these four measurements in the two stages, the analyzer can calculate the noise figure and gain of the DUT. The DUT discussed above is assumed to have two ports, input and output.

If the DUT is frequency translating, the ENR values of the noise source used in the calibration and measurement are for different frequency ranges. See “Making Frequency Converting DUT Measurements” on page 20 for more details.

If the frequency range of the DUT is beyond the frequency range of the analyzer, a system down-converter is needed. See “Measurements with a System Downconverter” on page 28 for more details.

Figure 1-2 Y factor Noise Figure Measurement Requires Two Steps: Calibration and Measurement of the DUT



What does the Keysight N9069C Noise Figure Measurement Application Do?

The noise figure measurement application enables you to make a number of individual noise figure measurements over the range of frequencies specified by the frequency parameters. After each frequency point has been measured, the results are displayed.

The measurement includes the following functionality:

- Layout data views: Graph, Meter and Table
- Result types including Noise Figure, Noise Factor, Gain, Y-Factor, Effective Temp, P_{hot} and P_{cold}
- DUT type including amplifier, downconverter, upconverter, and multi-stage converter
- Supports traditional 346x Series Noise Sources
- Supports N4000x Series Smart Noise Sources (SNS)
- Supports U7227-Series USB Preamplifier
- Supports external source control for simulated LOs using LAN, USB and GPIB
- Multiple DUT set up and calibration (up to 12 DUT's)
- Built in noise figure uncertainty calculator with adjustable noise source match spec style and match distribution

2 Making Noise Figure Measurements

This chapter introduces how to use U7227-Series USB Preamplifiers in noise figure measurements, gives two measurement examples on basic measurements and frequency converter measurements respectively, and then talks about the procedure to calculate measurement uncertainty for noise figure measurements. The following topics are covered in this chapter:

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Making Basic Measurements

This section describes how to make basic noise figure measurements, using an example of a basic amplifier measurement, which performs no frequency conversion.

Basic Amplifier Measurement

Noise figure measurements are made by measuring the output power of the DUT for two different input noise power levels. The high and low power inputs come from a calibrated noise source. The noise source is switched on and off in rapid succession. High power input to the analyzer uses the noise power generated when the noise source is switched on, and low power input uses the noise power generated at ambient temperature with the noise source switched off.

This section uses a low noise amplifier with a frequency range of 100 kHz to 500 MHz as the DUT and the Keysight SNS Series noise source N4002A to show how a basic noise figure measurement and various basic operations are performed. The specifications of interest to the example are listed in the following table.

Table 2-1 The Example DUT Specifications

Frequency Range	Minimum Gain	Total Gain range	Typical Noise Figure
100 kHz to 500 MHz	20 dB	± 0.5 dB	2.9 dB

This example sets a frequency range of interest of 200 MHz to 400 MHz. The purpose of the measurement is to verify the specified table results are as stated over the frequency range of interest.

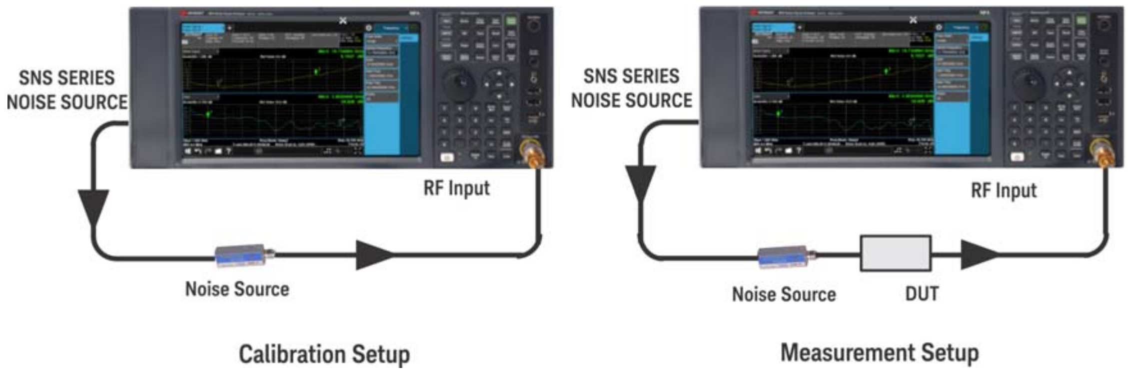
To make noise figure measurements, there are generally two steps:

1. **Calibrate the analyzer to measure the noise figure contributed by the signal analyzer. The calibration used in this example is User Cal. Two types of calibration are available: User Cal and Internal Cal. See “User Cal vs. Internal Cal” on page 59 for more information.**
2. **Make the measurement with the DUT.**

Figure 2-1 on page 15 shows the system connections for calibration and measurement. If you are using the Keysight 346x noise source, connect the NOISE SOURCE DRIVE OUT +28 V (PULSED) port from the rear panel of the signal analyzer to the noise source instead.

NOTE If the DUT has a low or negative gain, it is recommended to use the USB preamplifier together with the signal analyzer to get more accurate results. For more details, refer to “Using the U7227-Series USB Preamplifiers in Noise Figure Measurements” on page 37.

Figure 2-1 System Connections for The Two Steps in Noise Figure Measurement



When you are making measurements, follow the procedure and change the values to meet your needs.

Calibrating the Analyzer

Connect the noise source and the signal analyzer following the calibration setup in Figure 2-1. Then follow the procedure below.

NOTE You may need to use adapters to connect the noise source output to the analyzer input during calibration. The connectors you use need to be included in the measurement if possible. If you remove these connectors for the calibration, you need to apply Loss Compensation to compensate for any loss caused by the connector's removal if you need improved accuracy. "Using Loss Compensation" on page 78 has an explanation of this.

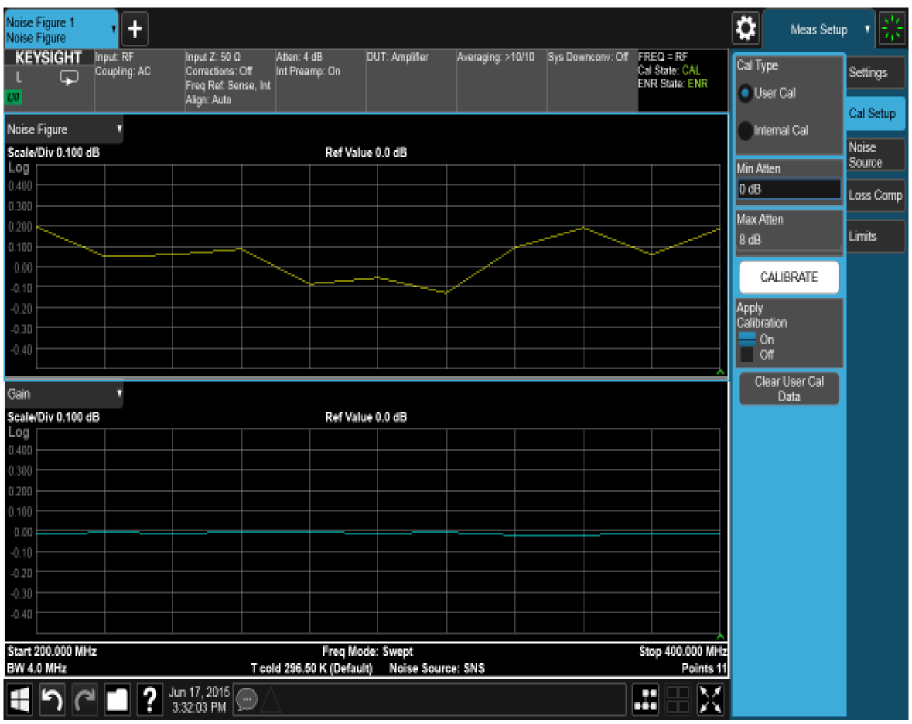
Calibration

Step	Action	Notes
1. Turn the instrument on	– Press the power key	To obtain optimum measurement accuracy, it is recommended the analyzer warm up for 30 minutes.
2. Select the mode and measurement	– Press **MODE/MEAS**, **Noise Figure**, **OK**	
3. Preset the mode	– Press **Mode Preset**	
NOTE	If you have a U7227-Series USB Preamplifier, see "Guide for Using U7227-Series USB Preamplifier and the Internal Preamplifier inside X-Series Signal Analyzer" on page 41 to find the proper system configurations for your test case, and turn on the internal preamplifier, set the internal attenuation range for calibration, and set the internal attenuation for the measurement if needed.	

Step	Action	Notes
4. Configure the amplitude parameters	– Press **AMPTD**, select the **Signal Path** tab, select **On** from the Internal **Preamp** drop down list. – Press **MEAS SETUP**, select the **Cal Setup** tab, **User Cal**, and set the **Min Atten** and **Max Atten** values. – Press **AMPTD**, select the **Attenuation** tab and set the value used in the measurement stage.	When you enter the Noise Figure Mode, the internal preamplifier automatically turns on.If an external U7227 Preamplifier is connected, the internal preamplifier turns off to avoid overloads. The attenuation value used in the measurement should be in the range of Min Atten and Max Atten values.
5. Configure the frequency parameters of the measurement	– Press **FREQ, Freq Mode**, and select **Swept**. – Press **Start Freq**, and enter **200 MHz**. – Press **Stop Freq**, and enter **400**, **MHz**. – Press, **Points**, and enter **11**.	
6. Select the ENR Mode	– Press **MEAS SETUP, ENR**. – In the ENR dialog, toggle **ENR Mode** to **Table**.	
7. Configure the ENR table	– Toggle **Use Meas Table Data for Cal** to **On**.	
8. View ENR values **NOTE** ENR values are retained in the analyzer memory until a different SNS is plugged in or the ENR table is manually edited.	– Press **Edit Meas Table**, to view the ENR values automatically loaded from the SNS noise source into the instrument.	If you are using other noise sources, for example, the Keysight 346B noise source, you need to enter the ENR values manually. For more information about entering the ENR data, refer to "Entering Excess Noise Ratio (ENR) Data" on page 64.
9. Set averaging	– Press **MEAS SETUP**, **Avg/Hold Num** and enter **10**. – Press **Averaging** and toggle to **On**.	

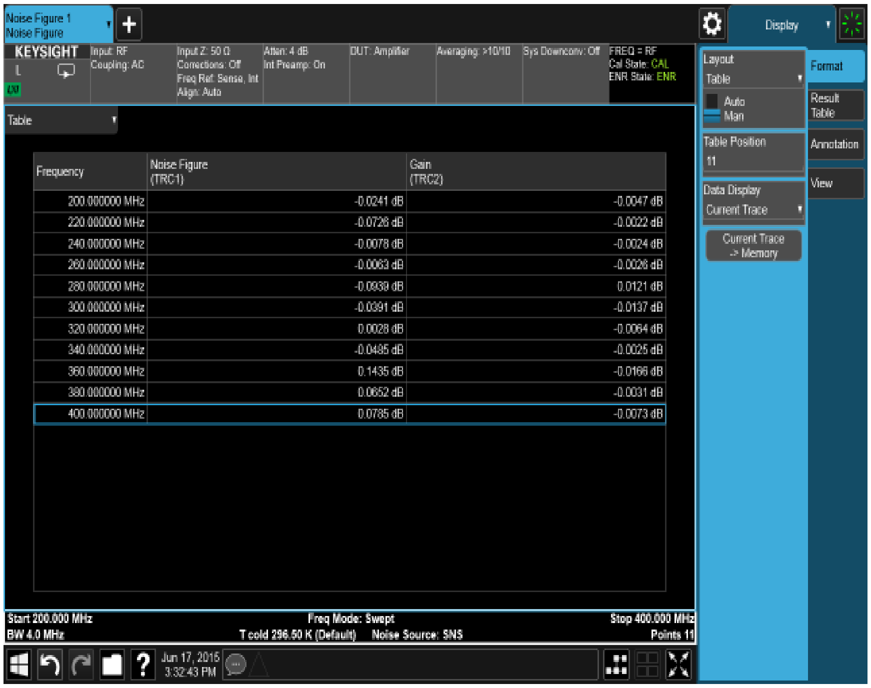
Step	Action	Notes
10. Set the BW	– Press **BW**, toggle the **Res BW** to **Auto**.	
11. Set the attenuation	– Press **MEAS SETUP**, select the **Cal Setup** tab, change the **Min Atten** and **Max Atten** values if required.	This example uses the default minimum and maximum input attenuation. See “Selecting the Input Attenuation Range” on page 75 for more details.
12. Perform a calibration	– Press **CALIBRATE**.	You will be asked to confirm the calibration. See the following figure for results after calibration.

With the calibration completed and no device under test inserted, both gain and noise figure are near 0 dB. This shows that the analyzer has removed the noise contribution from the measurement system.



Step	Action	Notes
13. View the results in a table	– Press **Display** and select **Table** from the **Layout** drop down list.	A result similar to the following graphic is now displayed. The expectation is approximately 0 dB of noise figure and gain. It may be better to view these results using the table layout mode

Step	Action	Notes



NOTE

If any input frequencies are in high band, that is above 3.6 GHz, the Calibrate process will optimize the preselector at these frequencies and use these preselector adjust values in the calibration acquisition results and when acquiring the measurement results. This reduces the error corrected results since the preselector is set at the same place for acquiring the calibration and measurement results. The Optimize Preselector function (**Meas Setup**, **Optimize Preselector**) allows the adjusted values to be collected again without the calibration acquisition results.

NOTE

If you do not have either a High Band Preamp, or an external preamp and you are calibrating above 3.6 GHz, the calibration data will vary significantly. Measurements made with this calibration data might be valid, but only if the device you are testing has a high gain. If this is not the case, the measurement accuracy will be poor.

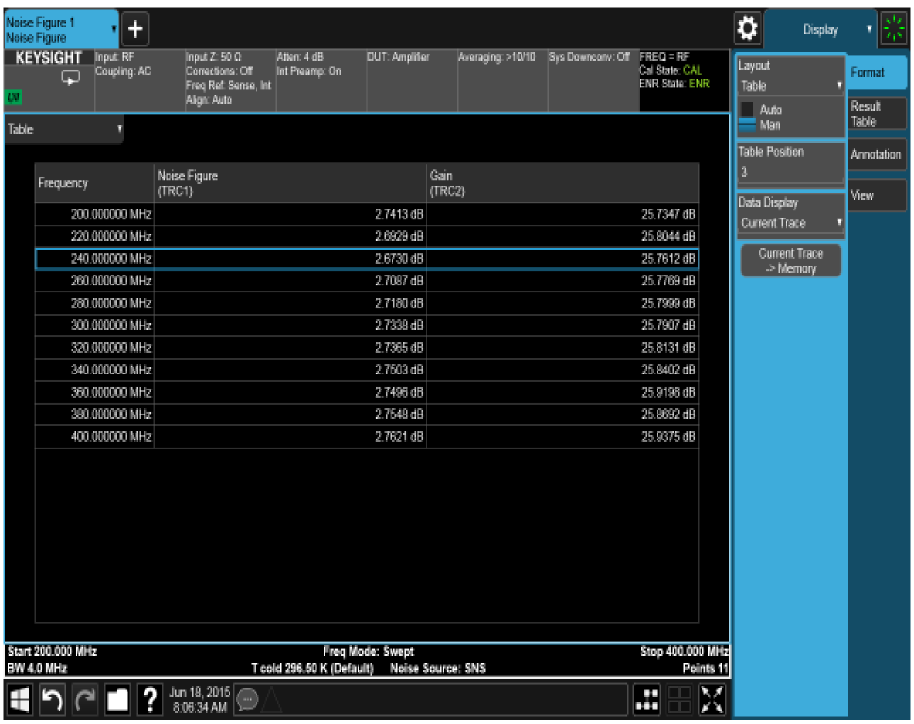
When using external preamplifiers or high-gain DUTs, ensure that neither the external preamp (or the high-gain DUT) nor the internal preamp go into compression as this will affect the accuracy of your measurements. If you suspect that one or another of the preamplifiers is going into compression, use attenuation prior to that preamplifier to prevent compression. The analyzer’s internal attenuator will only affect compression occurring in the internal preamplifier. It will not have any effect on any compression occurring in the external preamplifier.

Making the Measurement

Step	Action	Notes
1. Make the measurement	– Insert the DUT between the noise source and the signal analyzer following the measurement setup in Figure 2-1.	After the DUT and noise source are connected, the measurement result appears on the analyzer's display. If it does not, press **Restart**. A result similar to the following figure is displayed. Refer to "Displaying the Measurement Results" on page 82 for more details about viewing measurement results.

The results show the DUT has an average noise figure of 2.72 dB, an average gain of 25.82 dB and a minimum gain of 25.735 dB. The device under test therefore meets its manufacturer's specification over the frequency range of interest.

Figure 2-2 Typical Tabulated Results after Measurement



Step	Action	Notes
2. View the results in a graphical format	– Press **Display**, **Layout, and select Graph** from the drop down menu. – Toggle **Overlaid/Combined** To On.	A graphical result that has the current two (noise figure and gain) traces is displayed.

Making Frequency Converter Measurements

This chapter describes how to make noise figure measurements involving frequency converters. Frequency converters are necessary when:

– The frequency conversion is part of the DUT. For example, the DUT is a mixer or a receiver.

– The frequency conversion is part of the measurement test setup. The DUT is to be measured at a higher frequency than the analyzer's frequency range covers, hence an external Block Downconverter and local oscillator are added to the measurement test setup to convert this higher frequency to a frequency within the analyzer's range.

The noise figure measurement application can support multiple frequency conversions, in the DUT (including multi-stage converter) and/or as an added System Downconverter, which configures the analyzer as a frequency range extender. Refer to "Accounting for Frequency Conversion" on page 50 for details about what needs to be considered carefully in the frequency converter measurements.

Making Frequency Converting DUT Measurements

An example is provided on the following pages using the analyzer to make a noise figure measurement on a downconverter, which is upper sideband. The specifications for the DUT are listed in Table 2-2 on page 22. The LO is set to sweep in a frequency range and the IF is fixed at 60 MHz frequency.

The calibration of the measurement system is similar to a basic calibration, the noise source is connected directly to the RF input of the analyzer and a calibration is made. The DUT is then placed between the noise source and the analyzer, and a corrected measurement is made. The DUT performs frequency conversion in the measurement setup. However, there is no frequency conversion in the calibration setup, as is shown in Figure 2-3 on page 21. The purpose of the calibration setup is to allow the analyzer to measure its own noise figure and sensitivity with the noise source. The calibration must be performed across the frequency range to which the analyzer will tune when performing the measurement.

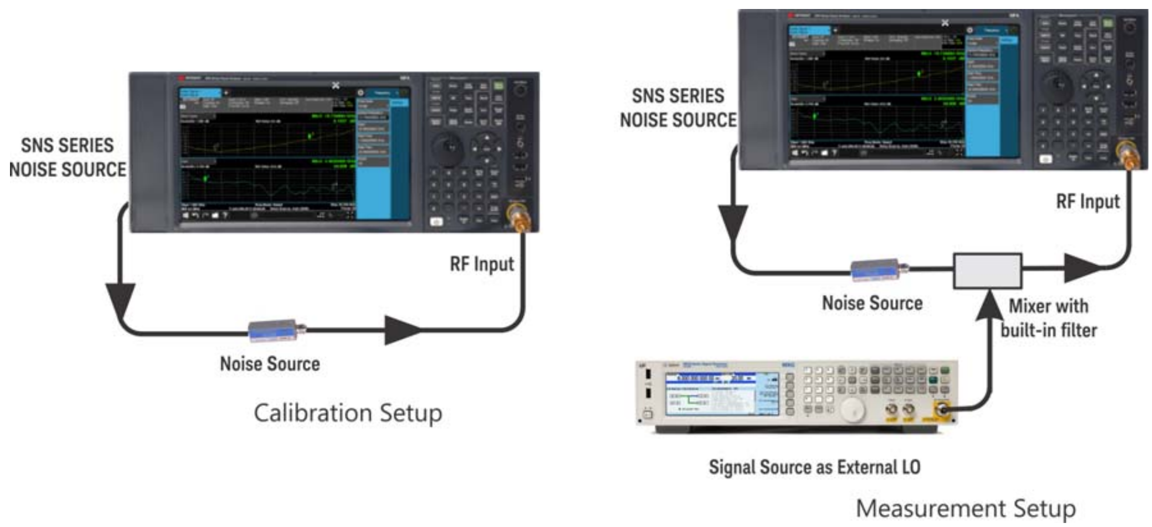
NOTE If the DUT has a low or negative gain, it is recommended to use a USB preamplifier together with the signal analyzer to get more accurate results. For more details, refer to "Using the U7227-Series USB Preamplifiers in Noise Figure Measurements" on page 37.

NOTE The RF input section on the X-Series analyzers has a built-in 3.6 GHz Low Pass Filter. This filter needs to be accounted for when planning the filter requirements during calibration and measurement when working in low band <3.6 GHz.

For both calibration and the measurement, a noise source, such as the Keysight 346C, or the Keysight N4002A SNS, must be connected to the noise source drive connector on the back of the X-Series analyzer. In this section, a Keysight SNS series noise source is used as an example.

External LO control is used to control a signal generator to supply an LO at a frequency range of 3.14 GHz to 3.64 GHz, and the frequency reference of the signal generator may be connected to the EXT REF IN on the rear panel of the X-Series analyzer. This locks the LO and the analyzer together for greater measurement accuracy.

Figure 2-3 X-Series Frequency Converting DUT Measurement



For these measurements, you can access the DUT Setup dialog (**MEAS SETUP**, **DUT Setup & Calibration**):

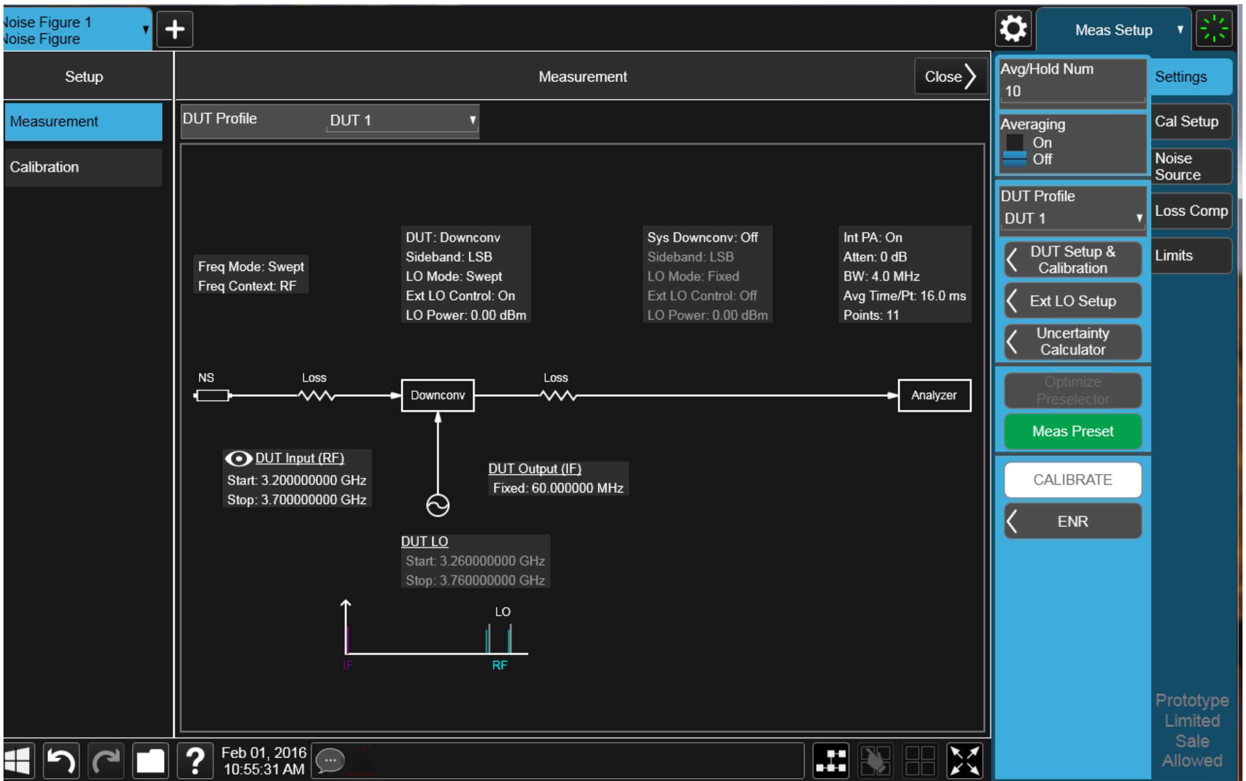


Table 2-2 DUT Setup Table

Freq Mode	**Swept**
Frequency Context	**RF** This determines whether you specify the measurement frequencies at the DUT input (**RF**) or at the analyzer’s input (**IF**). See “Freq Context” on page 62.
DUT	**Downconv**
Sideband	**USB** See “Sideband (both for DUT and system downconverter)” on page 63.
LO Mode	**Swept**
Ext LO Control	**On**
System Downconverter	**Off**

Table 2-2 DUT Setup Table

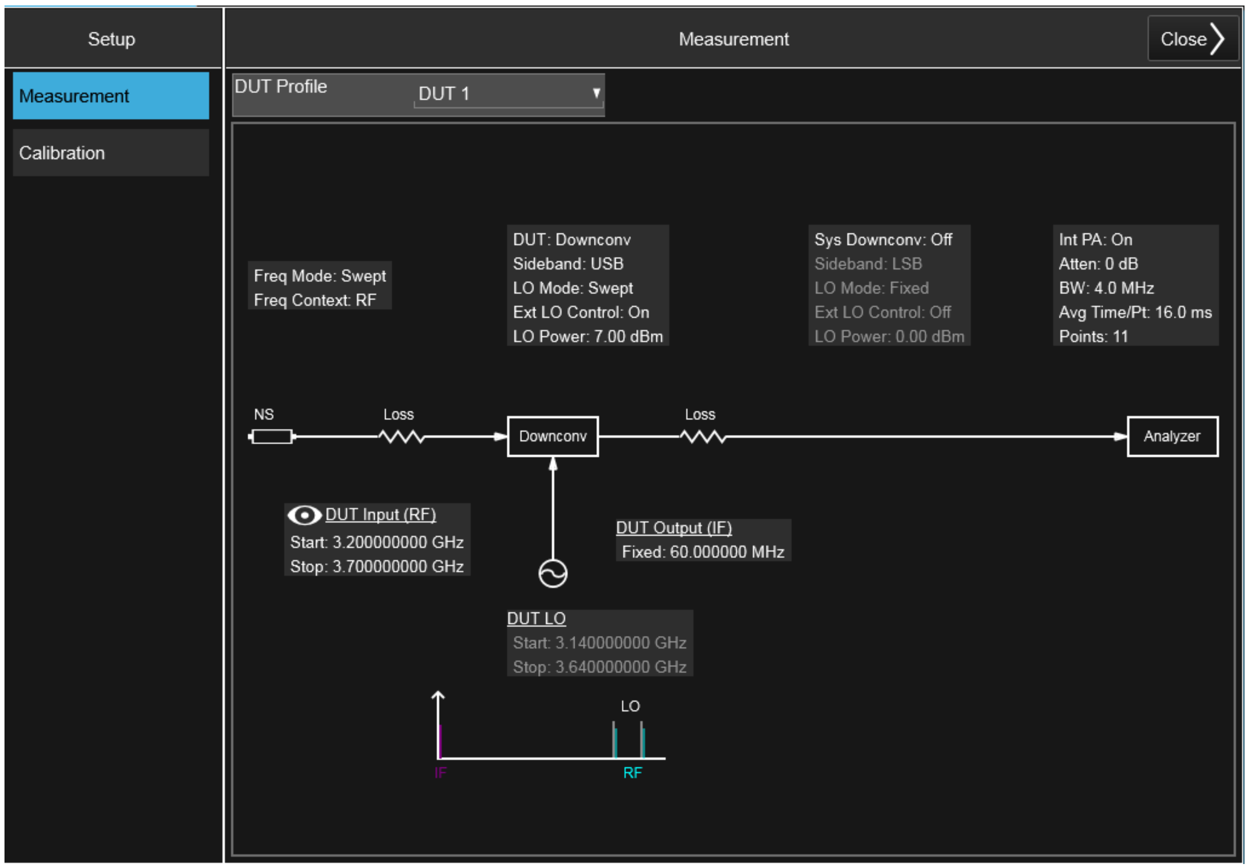
Diagram	**Calibration** or **Measurement**. This does not affect the measurement or calibration, but indicates how the noise source, the DUT and the analyzer should be set up. The blue 'eye' icon acts as a visual reminder of the **Frequency Context** setting you have selected.
DUT Input (RF)	Start: 3.2 GHz
DUT Input (RF)	Stop:3.7 GHz
DUT Out (IF)	Fixed: 60 MHz

Initial Setup Procedure

Follow the overview procedure of the initial setup.

Step	Action	Notes
1. Turn the instrument on	– Press the power key	To obtain optimum measurement accuracy, it is recommended the analyzer warm up for 30 minutes.
2. Select the mode and measurement	– Press **MODE/MEAS**, **Noise Figure**, **OK**	
3. Preset the mode	– Press **Mode Preset**	
4. Configure the ENR	– Press **MEAS SETUP, ENR.** – Toggle **ENR Mode** to **Table** – Toggle **Use Meas Table Data for Cal** to **On.**	
5. View ENR data	– Press **Edit Meas Table** to view the ENR values automatically loaded from the SNS noise source into the instrument. – Press **Close**.	If you are using other noise sources, for example, the Keysight 346B noise source, you need to enter the ENR values manually. For more information about entering the ENR data, refer to "Entering Excess Noise Ratio (ENR) Data" on page 64. Note that for calibration and for making measurements, the ENR data for different frequency ranges are used.

Step	Action	Notes
6. Configure Ext LO Setup	– Press **Ext LO Setup**. – – In the **LAN** box of the dialog, enter the **IP Address** and press **Done**. – Press **Add Specified IP Address**. – Press **Select Highlighted Source as DUT LO**.	For more information about setting an external LO, see "Setting up External LO Control" on page 77.
7. Configure DUT LO Setup	– On the Select dialog, press **Ext LO Setup**. – Press **DUT LO Setup**. – In the **LO Settings** area of the dialog, enter the following values: **LO Power; 7.0 dBm** **Min Freq; 250 kHz** **Max Freq; 6 GHz**. – Press **DUT Setup & Calibration**.	This sets the minimum and maximum values of the signal generator.
8. Configure the DUT Setup	– Set the parameters as listed in Table 2-2.	After setting all parameters, the DUT Setup screen will look like the following figure. Refer to "DUT Setup Form" on page 61 to see detailed information about each parameters in the DUT setup form.



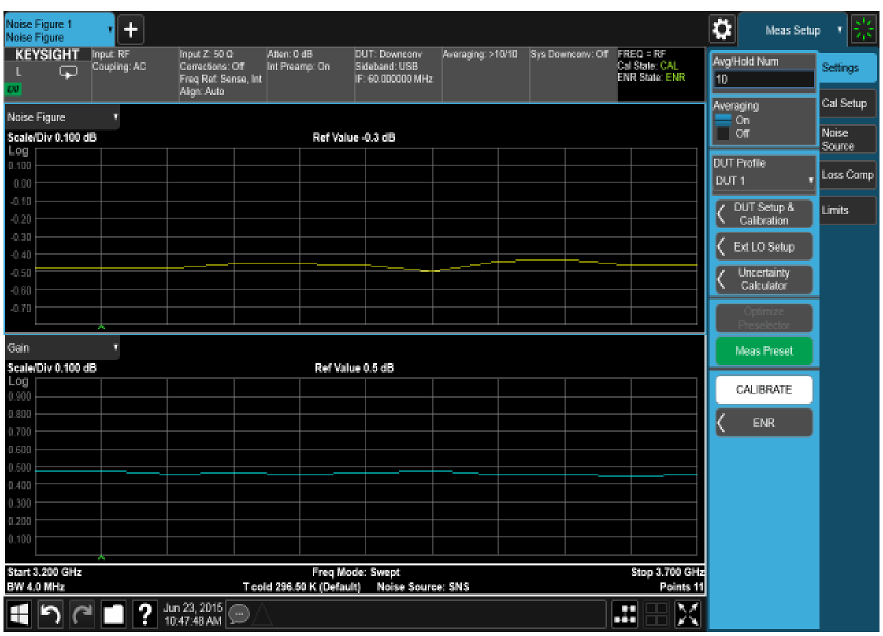
Step	Action	Notes
9. Set Averaging	– Press **MEAS SETUP, Avg/Hold Num, 10.** – Toggle **Averaging** to **On**.	
10. Turn on the Internal Preamp	– Press **AMPTD**, **Signal Path**, **Internal Preamp** to **On**.	**NOTE** ENR values are retained in the analyzer memory until a different SNS is plugged in or the ENR table is manually edited.

Calibration of the Measurement Setup

Calibration of the setup for a noise figure measurement is specific to the frequency you have set. If you change the frequency after calibration, you will have to recalibrate the measurement.

Connect the noise source and analyzer for calibration (See Figure 2-3). Note that you need to connect any After DUT filtering prior to calibration.

Step	Action	Notes
1. Configure the system calibration	– Connect the calibration system as shown in Figure 2-3 on page 21.	If you have U7227-Series USB Preamplifier, see "Guide for Using U7227-Series USB Preamplifier and the Internal Preamplifier inside X-Series Signal Analyzer" on page 41 to find the proper system configurations for your test case, and turn on the internal preamplifier, set the internal attenuation range for calibration, and set the internal attenuation for the measurement if needed.
2. Configure the amplitude parameters	– Press **AMPTD**, select the **Attenuation** tab and set the value used in the measurement stage. – Press **MEAS SETUP**, select the **Cal Setup** tab, **User Cal**, and set the **Min Atten** and **Max Atten** values.	The attenuation value used in the measurement should be in the range of Min Atten and Max Atten values.
3. Perform a calibration	– Press **CALIBRATE**.	You will be asked to confirm the calibration. See the following figure for results after calibration. When calibration is complete the measurement system is calibrated at the mixer output. The red `UNCAL` text changes to green `CAL` text in the top right side of the display.



Making the Corrected Noise Figure and Gain Measurement

A measurement corrected for the noise contributed by the analyzer is made. Insert the DUT into the system as shown in Figure 2-3 on page 21. A graphic display of noise figure and gain is shown in Figure 2-4. Press **View/Display**, **Table** to display the table view, see Figure 2-5.

Figure 2-4 Corrected Measurement Results (Graph View)

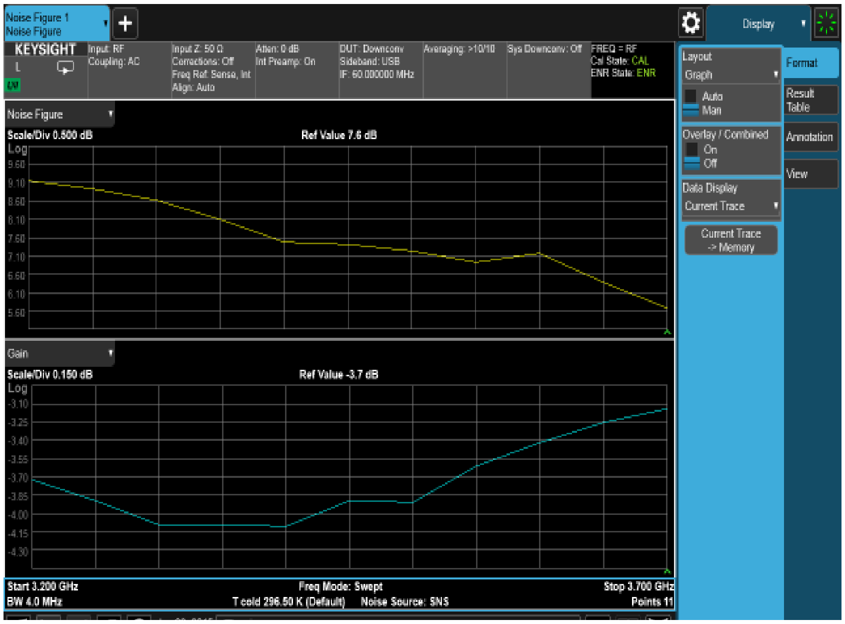
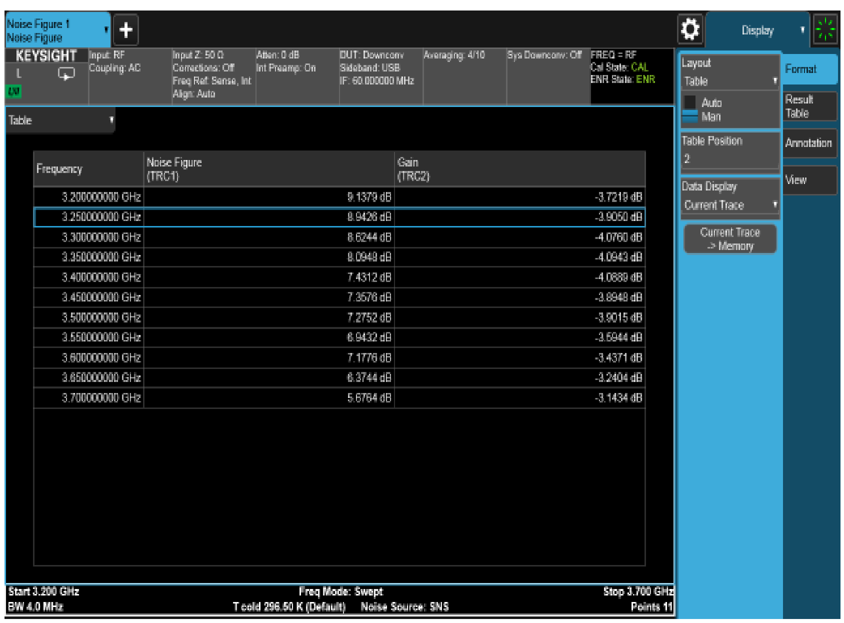


Figure 2-5 Corrected Measurement Results (Table View)



Frequency	Noise Figure (TRC1)	Gain (TRC2)
3.200000000 GHz	9.1379 dB	-3.7219 dB
3.250000000 GHz	8.9426 dB	-3.9050 dB
3.300000000 GHz	8.6244 dB	-4.0760 dB
3.350000000 GHz	8.0949 dB	-4.0943 dB
3.400000000 GHz	7.4312 dB	-4.0889 dB
3.450000000 GHz	7.3576 dB	-3.8948 dB
3.500000000 GHz	7.2752 dB	-3.9015 dB
3.550000000 GHz	6.9432 dB	-3.5944 dB
3.600000000 GHz	7.1776 dB	-3.4371 dB
3.650000000 GHz	6.3744 dB	-3.2404 dB
3.700000000 GHz	5.6764 dB	-3.1434 dB

NOTE Once you have successfully made the measurement you may want to save the setup for future measurements. Press **Save**, **State**, **Save To File**.

NOTE

If the measurement includes the insertion loss of any filter that was not calibrated out at the calibration step, it can be removed by pressing **MEAS SETUP**, **Loss Comp** tab, **Loss (Before DUT** or **After DUT**), **Loss Comp Mode**, **Fixed** on the analyzer and entering the insertion loss value for the device.

You can also do table loss and create distinct frequency/amplitude values.

Making Multi-stage Converter Measurements

The multi-stage converter measurement is similar to the measurement procedure as described above. However, with a multi-stage converter measurement, there is no fixed relationship between the RF and IF frequency. You need to enter the RF and IF frequencies according to the input and output of the DUT.

In multi-stage converters, there might be more than one LO used. The noise figure measurement application can control only one of them.

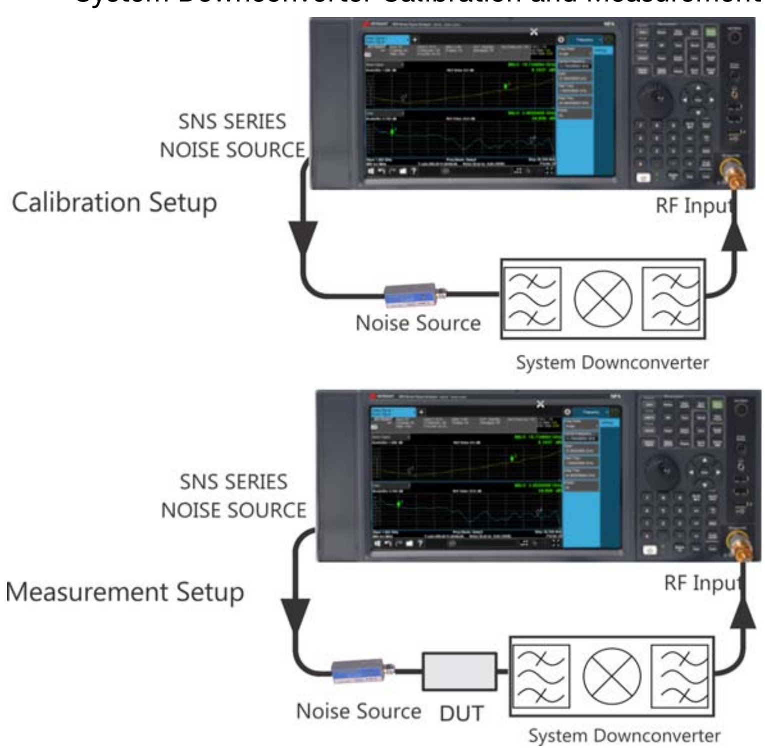
Measurements with a System Downconverter

A system downconverter can be thought of as a frequency extender for the analyzer, to allow measurements to be made on DUTs at frequencies that the analyzer does not cover.

NOTE

This measurement discussion uses an unspecified external downconverter. So there are no warranted specifications or characteristics provided for the measurement system.

Figure 2-6 System Downconverter Calibration and Measurement



A system downconverter is part of the measurement system, and is present in both the calibration setup and the measurement setup. See Figure 2-6. During calibration the noise performance of both the analyzer and the system downconverter are measured. Because of this, when corrected measurements are performed, the results then apply to the DUT only. If there are no more frequency conversions in the DUT, ENR data for the same frequency range is used for both calibration and measurements.

The analyzer can be used in much more complex systems, with multiple frequency conversions between the DUT and the noise source. However, the control of such systems is application-specific. You need to perform frequency calculations to suit that particular system, account for the effects of any DSB conversions, determine filter requirements, and calculate the appropriate ENR values for calibration and the measurement.

To connect the analyzer and make your measurements:

Step	Notes
1. Turn the analyzer on.	
2. Press **MODE/MEAS**, **Noise Figure**, **OK, Mode Preset** to return the analyzer to a known state.	
3. Enter the ENR values into the analyzer if required.	See "Entering Excess Noise Ratio (ENR) Data" on page 64 for the procedures to do this.
4. Refer to "Setting up External LO Control" on page 77 to set up the LO control for the system downconverter and DUT as required.	Note that you need to use an external LO control to control another signal generator as the LO if the LO Freq Mode for either DUT or the system downconverter is set to Swept.
5. Press **MEAS SETUP**, **DUT Setup & Calibration**, and set the DUT Setup form as required.	Refer to "DUT Setup Form" on page 61 to see the detailed information for each parameters in the DUT setup form.
6. Press **MEAS SETUP**, **Avg/Hold Num**, **10**, toggle **Averaging** to **On**.	Setting averaging here reduces jitter and provides more accurate measurement results. See "Setting Averaging" on page 74 for more details.
7. Configure the measurement connection to calibration setup as shown in Figure 2-6 and press **MEAS SETUP**, **CALIBRATE** to perform calibration.	
8. Change the measurement connections to the measurement setup as shown in Figure 2-6 and make the corrected measurements.	

Measurement Modes with a DSB System Downconverter

The noise source generates broadband noise. In a DSB system downconverter calibration setup, noise input from both the USB and LSB sidebands will be converted to the same IF, as shown in Figure 2-7. The DSB system downconverter measurements have implicit linear averaging of the DUT characteristics. The same ENR values are used for both the USB and LSB frequencies, and are taken from the average frequencies of the USB and the LSB. This corresponds to the LO frequency. Results returned are the average of the two sideband powers.

The benefits of a DSB measurement are minimal filter requirements, and wide frequency coverage. In the DSB measurement, the usual aim is to choose as low an IF as possible, to minimize the separation between the sidebands, and thus get the optimum resolution possible.

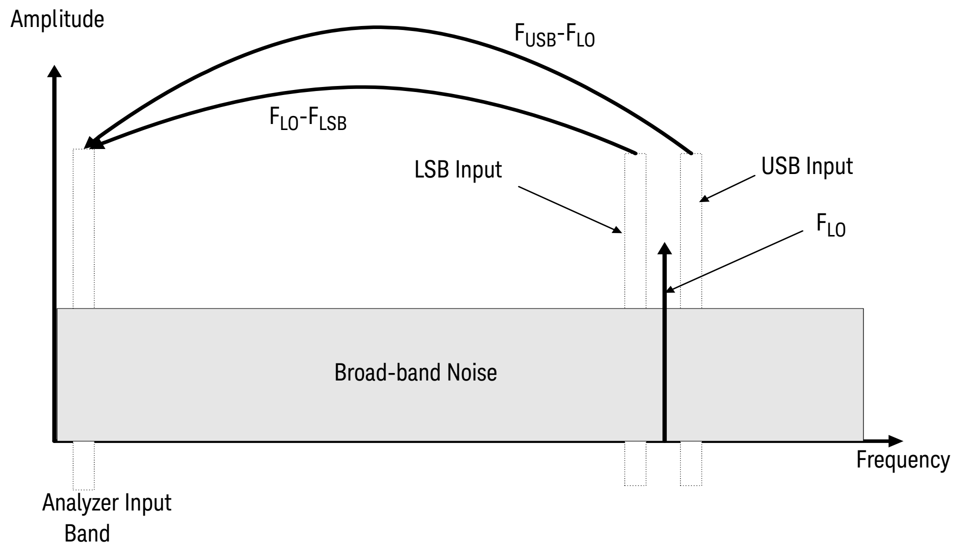
NOTE

When making Double Sideband (DSB) measurements, it is important that the IF is much lower in frequency than the LO frequency. This is because the ENR values in the ENR table can only be applied to one frequency or, in the case of a swept measurement, to one set of frequencies. The ENR values can not be applied simultaneously to both the upper sideband and to the lower sideband. The ENR values are therefore applied to the midpoint between the upper sideband and the lower sideband, and this equates to the LO frequency.

Consequently, the higher the IF frequency is in comparison to the LO frequency, the further apart the upper and lower sidebands will be. The further these upper and lower sidebands are from the LO frequency, the less accurate the ENR value will be.

It is recommended for greatest accuracy that the IF frequency be no greater than 1% of the LO frequency when making double sideband measurements. When making a swept measurement, no frequency in the swept frequency band should exceed 1% of the LO frequency.

Figure 2-7 DSB System Downconverter Measurements



– If the DUT bandwidth is greater than the LSB-USB separation, a system downconverter can operate in USB, LSB, or DSB mode, and the same circumstances occur in both the calibration and the measurements, hence DSB sideband power addition corrections are not needed. Corrected measurements cancel any sideband summation effects.

NOTE

For this case, the prerequisites of using the DSB system downconverter is that the noise source ENR, gain, and DUT frequency response in the LSB-USB area are constant. To verify this, you can experiment with different IFs to see if the frequency variation errors are a problem. If the noise figure values change significantly with the choice of IF, then the SSB system downconverter is recommended.

– If the DUT bandwidth is less than the LSB-USB separation and a DSB system downconverter is still used, the calibration setup will operate in DSB mode while the measurement setup will actually operate in SSB mode, influenced by the DUT’s selectivity. For this case, a gain correction factor is needed due to the DSB calibration and SSB measurement. Normally, a 3 dB after DUT loss compensation should be set by pressing **Meas Setup**, **Loss Comp** tab, **Loss**, **After DUT**, **Loss Comp Mode**, **Fixed**, **Fixed Loss, 3**, **dB**.

For microwave measurements, above 3.6 GHz, the analyzer's input filter will reject LO leakage from the downconverter, otherwise a filter is needed between the system downconverter and the analyzer. Also, considerations about mixer LO harmonic modes apply.

Measurement Modes with an SSB System Downconverter

The analyzer can perform frequency calculations for DSB, LSB, or USB system downconverter conversions. The filtering requirements will be measurement-specific.

Figure 2-8 shows how filtering makes an LSB measurement, and Figure 2-9 shows a USB downconversion measurement.

Figure 2-8 LSB System Downconverter Measurements

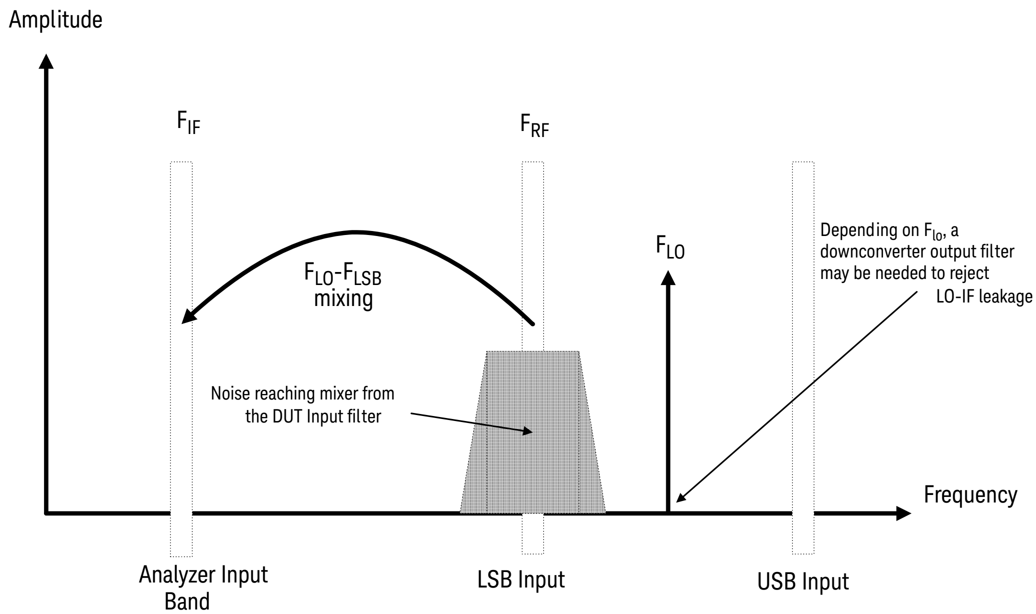
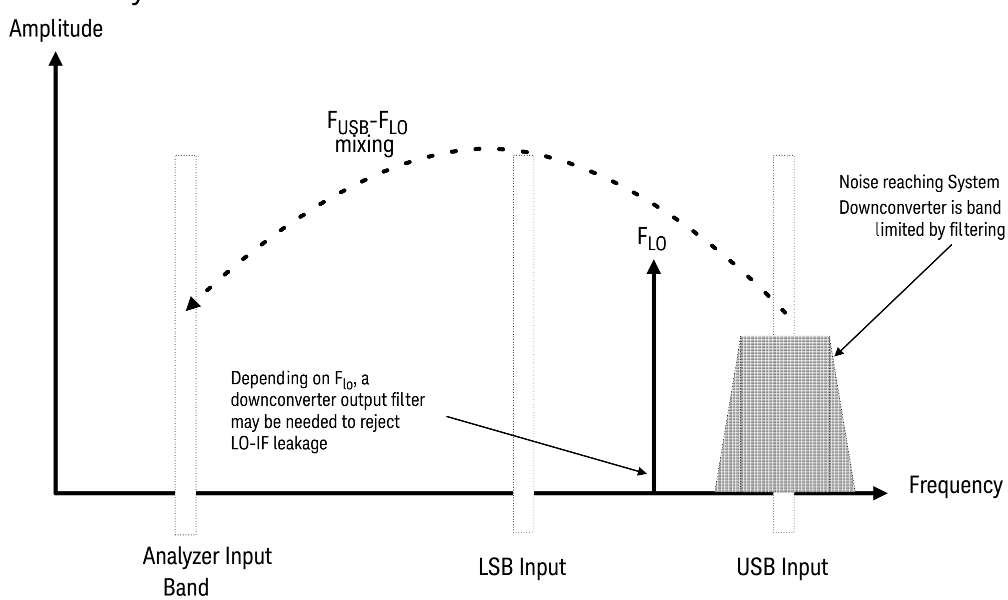


Figure 2-9 USB System Downconverter Measurements



Ideally, choose a high IF for the conversion to separate the USB and LSB bands, thus simplifying the filter requirements.

The filter needed to make SSB measurement could be part of the DUT, or a measurement-specific filter must be obtained and applied at the input to the system downconverter.

The bandwidth of the SSB filter limits the maximum frequency range over which a measurement can be swept. Therefore, SSB measurements are not suited to very wideband DUTs.

Filtering is needed to select the wanted sideband. A swept noise figure measurement is then possible even if the LO cannot be swept.

Calculating Measurement Uncertainty

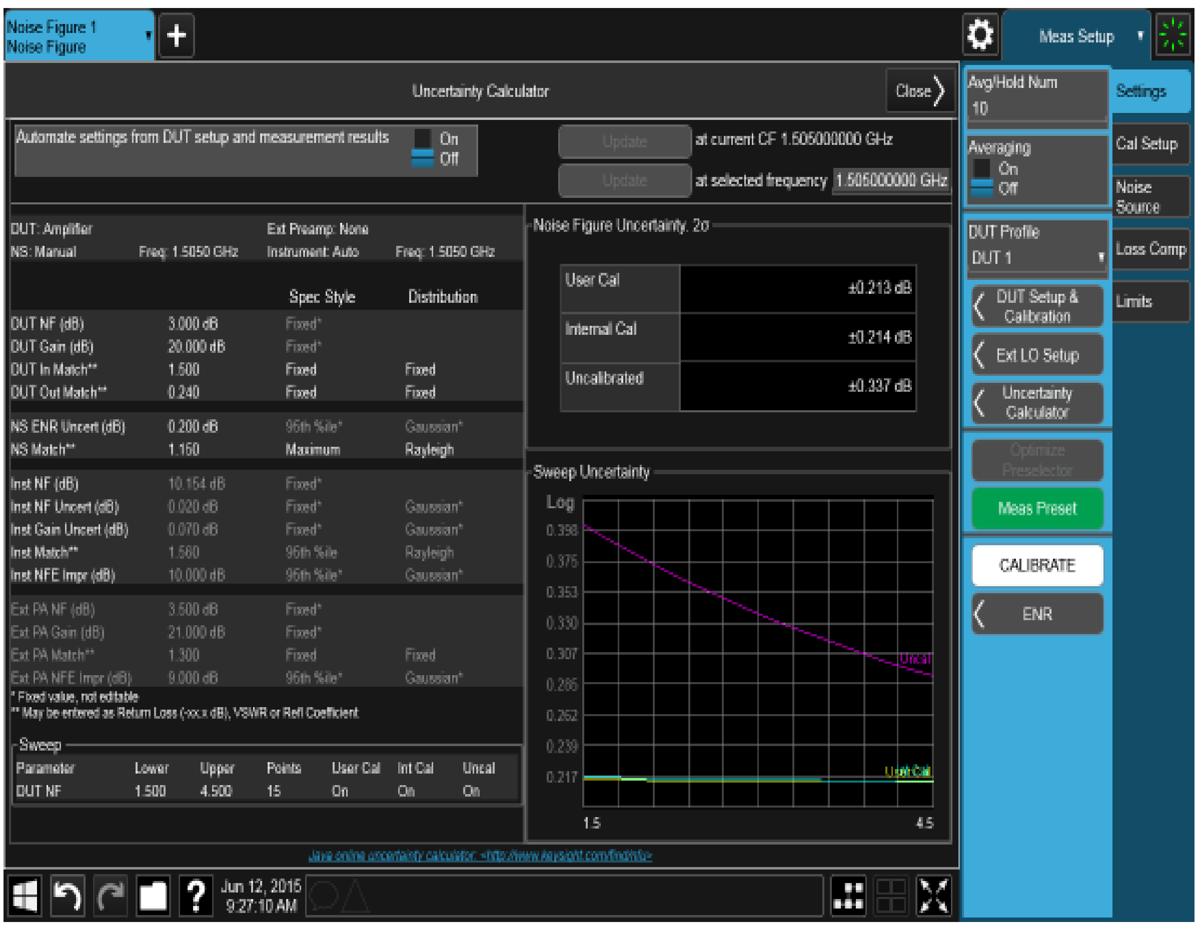
Measurement uncertainty is a key parameter for noise figure measurements, especially for a DUT with extremely low noise figure. During the product design and manufacturing period, it is necessary to have a solid understanding of how a number of variables affect the overall measurement uncertainty. These contributors include the analyzer itself, the noise source, and the DUT.

The Noise Figure Measurement Application provides a measurement uncertainty calculator to calculate the RSS (root sum square) measurement uncertainty. Once you measure or identify the various device characteristics, they can be entered into the analyzer and the RSS uncertainty will be calculated.

Refer to Application Note 57-2, Keysight part number 5952-3706E, for more information about calculating noise figure uncertainties. The online version and excel version of the Noise Figure Uncertainty Calculator can be found at the website below:

http://www.keysight.com/find/nfu

Figure 2-10 Measurement Uncertainty Calculator



The following procedure takes the measurement results on the amplifier in "Making Basic Measurements" on page 14 section as an example, to calculate the measurement uncertainty.

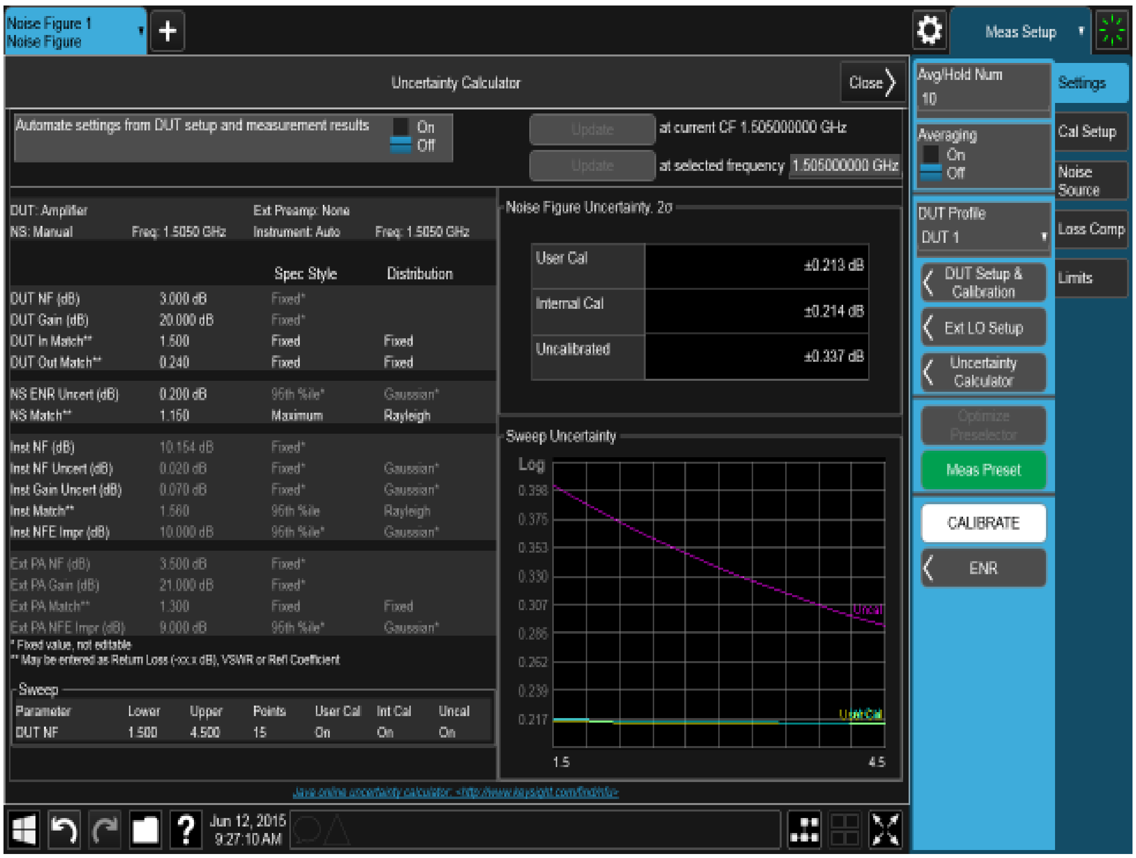
Step	Notes
1. Press **MEAS SETUP**, **Uncertainty Calculator**.	Perform this step after the corrected measurement results are obtained.
2. On the Measurement Uncertainty Calculator dialog, toggle the **Automate settings from DUT Setup and measurement results** setting to On.	This will automatically fill the parameters required for the measurement uncertainty calculation from the instrument and measurement results. Once the setting is set to On, – the noise source type is set to **Auto (SNS)** if an SNS is connected. – the instrument type is set to **Auto**. – the Ext Preamp type is set to **Auto** if an U7227-Series USB Preamplifier is connected. Then the parameters for these devices will be loaded from the instrument automatically. You can also change these types to **Manual** and enter the corresponding parameters manually.
3. If you are using a Keysight SNS noise type, go to step 4 directly. If you are using a Keysight 346x series noise source, choose the model number you are using from the **NS:** drop-down list. For other noise sources, choose **Manual** in the **Noise Source** type list and enter **NS ENR Uncert (dB)** and **NS Match** values manually.	
4. Enter the **DUT In Match** and **DUT Out Match** values and choose the spec style and distribution.	The values for DUT match can be either read from the data sheet or measured. They can be entered as return loss (-XX.X dB), VSWR, or reflection coefficient. It is recommended that the spec style is set to Fixed.
5. Click the **Update at current CF** button to show the measurement uncertainty for the current measurement results. The following figure shows the uncertainty calculator screen.	If you need to calculate measurement uncertainty for other frequency points, enter the frequency value in the box near the **Update at selected frequency** button, and click the **Update at selected frequency** button to display the results for that frequency.

Step	Notes

6. The noise figure measurement uncertainty of the current measurement result is displayed in **the Noise Figure Uncertainty. 2σ** and **Sweep Uncertainty** areas. Three types of measurement uncertainty are provided; User Cal, Internal Cal, and Uncalibrated. For more information about user cal and internal cal, you can refer to “User Cal vs. Internal Cal” on page 59.

– The **Noise Figure Uncertainty. 2σ** area shows uncertainty results for the current settings.

– The **Sweep Uncertainty** area shows sweeping uncertainty results for a parameter that can be set in the **Sweep** area. You can see the impact of different parameters to the uncertainty results through this display.

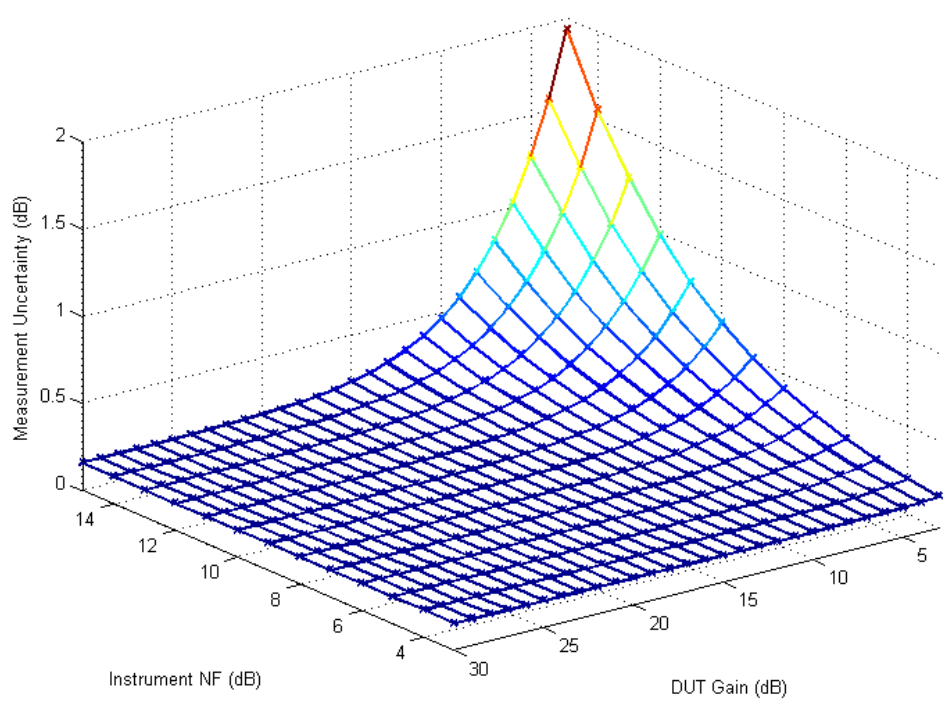


7. (Optional) In the **Sweep** area, select another sweep parameter, and set the ranges by entering the **Lower** and **Upper** values.

Using the U7227-Series USB Preamplifiers in Noise Figure Measurements

The U7227-Series USB Preamplifiers turn the X-Series Noise Figure Analyzers into better noise figure analyzers by reducing the overall instrument noise figure. Reducing instrument noise figure is necessary when the device under test (DUT) is lossy or has low gain. This is because the instrument noise figure contributes more to the final measurement uncertainty when the gain of the DUT is low. Figure 2-11 shows how the measurement uncertainty of a typical noise figure measurement depends on the DUT gain and instrument noise figure. The data is derived using the Uncertainty Calculator in the N9069C noise figure measurement application. It can be seen that the measurement uncertainty increases when the DUT gain is low and instrument noise figure is high. In optimal noise figure measurements, these regions should be avoided.

Figure 2-11 3-D Plot of Measurement Uncertainty versus DUT Gain and Instrument Noise Figure (DUT Noise Figure: 3 dB)



This section first introduces how to connect the U7227-Series USB Preamplifier to the signal analyzer and then provides a rough guide about using the USB preamplifier and the internal preamplifier inside the signal analyzer.

“Initial Connection to the Signal Analyzer” on page 38

“Guide for Using U7227-Series USB Preamplifier and the Internal Preamplifier inside X-Series Signal Analyzer” on page 41

Initial Connection to the Signal Analyzer

The U7227-Series USB Preamplifier is powered via a USB connection from the signal analyzer. To connect it to the analyzer, follow the steps below.

CAUTION

Before connecting a signal to the input port of the U7227-Series USB Preamplifier, make sure the USB preamplifier can safely accept the signal level provided. The signal level limits are marked next to the Input connectors of the USB preamplifier.

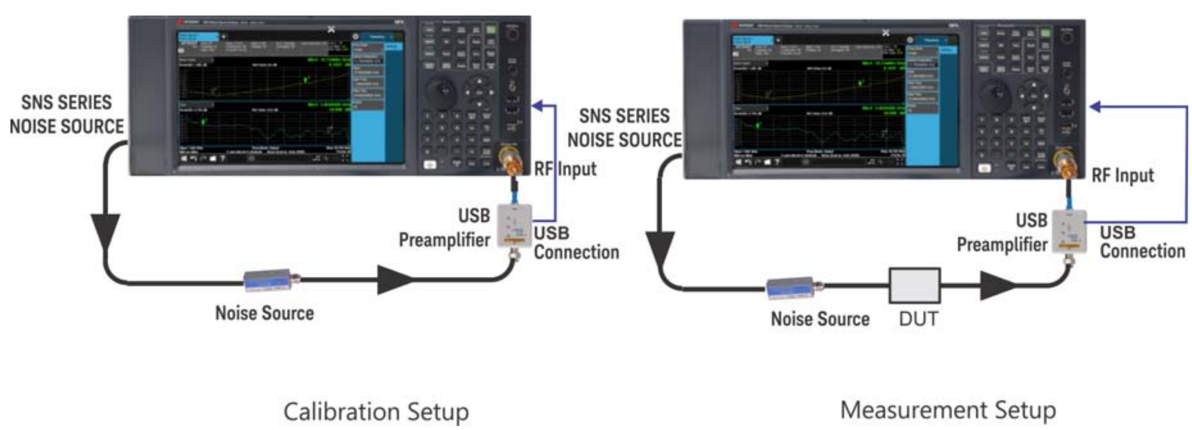
1. Connect the Output port of the USB preamplifier to the RF Input port of the signal analyzer.
2. Connect the USB port (Type-A) of the USB preamplifier to the USB port (Type-A) of the signal analyzer either in the front panel or in the rear panel using a USB cable. You can “hot plug” the USB preamplifier into the analyzer’s USB port at any time.

NOTE

The USB connections of the U7227-Series USB Preamplifier and the keyboard to the signal analyzer must be separated from each other; for example, the USB preamplifier connects through the front panel while the keyboard connects through the back panel.

Figure 2-12 shows the U7227-Series USB Preamplifier connection in the two stages of the noise figure measurement. While the USB preamplifier is plugged into one of the analyzer’s USB ports, the analyzer will consider it to be in the RF input signal path and will apply the gain settings and other calibration data of the USB preamplifier to the measurements. Therefore, adding preamplifier correction data is not necessary.

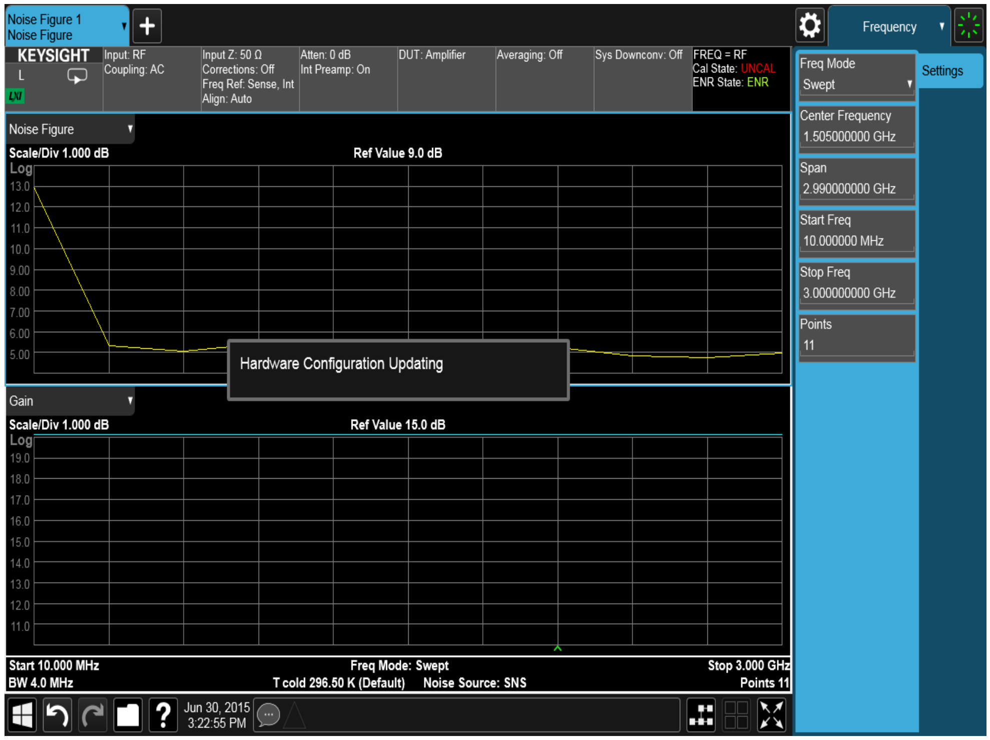
Figure 2-12 U7227-Series USB Preamplifier and Analyzer Connection in the Two Stages of Noise Figure Measurement



In the noise figure measurement application, the signal analyzer will respond in the following manner when the USB cable of the U7227-Series USB Preamplifier is plugged into one of the analyzer’s ports:

1. The sweep will pause momentarily while the “Hardware Configuration Updating” message appears on the signal analyzer display. See Figure 2-13.

Figure 2-13 “Hardware Configuration Updating” Message



2. The USB preamplifier’s calibration data, such as gain, noise figure, and S-parameters, will be automatically downloaded into the analyzer.

NOTE The USB preamplifier’s RF output cable, connector loss, and frequency response are accounted for in the data that is automatically downloaded into the analyzer’s memory. The calibration data is not user accessible.

3. The “Ready” LED is lit on the USB preamplifier.

4. The USB preamplifier’s model and serial number will be displayed. See Figure 2-14.

Figure 2-14 Signal Analyzer Display after USB Preamplifier is Ready For Use

5. The USB preamplifier is ready for use.

NOTE

When the instrument is in the Noise Figure mode and the external U7227 Series USB preamplifier is plugged in, the internal preamplifier will turn off to avoid compression. The user can turn it on at any point (**Amplitude, Signal Path, Internal Preamps, On**)

Guide for Using U7227-Series USB Preamplifier and the Internal Preamplifier inside X-Series Signal Analyzer

This section provides a rough guide for using the U7227-Series USB Preamplifier, the internal preamplifier, and the internal attenuator together to make accurate noise figure measurements.

Amplitude Concerns in the Noise Figure Test System

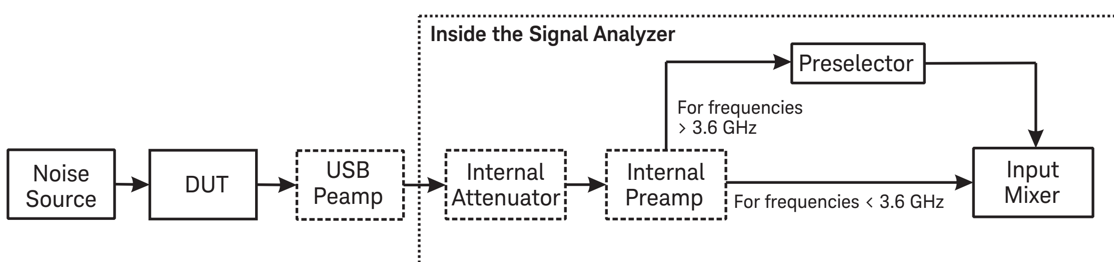
Before talking about the guide, let us look at some signal amplitude concerns in the test system. Figure 2-15 shows all the possible blocks in the signal path of the noise signal in the noise figure measurement. The blocks with dotted lines indicate that you can choose whether to use them or not. The USB preamplifier, the internal preamplifier and input mixer inside the signal analyzer are non-linear components and have a limit on the largest signal that can be processed. The power limits of the noise signal are for the following places:

– before the USB preamplifier
– before the internal preamplifier
– before the input mixer

To make an accurate noise figure measurement, the noise power should be below the maximum allowable power at all these three places. You can refer to the technical overview of the U7227-Series USB Preamplifier and the specification guide of the X-Series signal analyzer to check the maximum allowable powers. For power levels before the internal preamplifier and before the input mixer, the internal attenuator inside the signal analyzer can be applied to reduce the power level. But at the same time, the instrument noise figure will increase with using the internal attenuator.

The rough guide for the noise figure test system configuration in the following section is based on the noise power calculation before the non-linear components. For more details about noise power calculation in different stages of the test system, refer to “Calculating the Noise Power into Different Stages of the Noise Figure Measurement System” on page 85.

Figure 2-15 Blocks in the Signal Path of the Noise Signal in the Noise Figure Measurement



Rough Guide for the Noise Figure Test System Configuration

To configure the test system for accurate noise figure measurements, the first priority is to make the instrument noise figure (USB preamplifier + signal analyzer) as low as possible. To reduce the instrument noise figure, the USB preamplifier and internal preamplifier should be used whenever possible. If an overload or compression exists in the test system, removing or turning off the preamplifier (USB preamplifier or internal preamplifier) or adding internal attenuation can eliminate the problem. On the signal analyzer,

– To turn on/off the internal preamplifier, press **AMPTD**, **Signal Path** tab, **Internal Preamp**, **On/Off**.

– To set the internal attenuator, press **AMPTD**, **Attenuation** tab, and set the attenuation.

Figure 2-16 and Figure 2-17 show the supported DUT characteristics (noise figure and gain) of different system configurations for different frequency ranges up to 26.5 GHz. The X-axis is for the DUT noise figure, the Y-axis is for DUT gain. This rough guide is based on the noise power calculation before the non-linear components. For more details about noise power calculation in different stages of the test system, refer to “Calculating the Noise Power into Different Stages of the Noise Figure Measurement System” on page 85.

Before using Figure 2-16 and Figure 2-17 to find a proper test system configuration, you need to pay attenuation to the following points:

– The DUT reference bandwidth used to calculate the noise power is 3.59 GHz, which is the worst case for the lower band (10 MHz to 3.6 GHz). To maintain consistency between the lower band and higher band, the same DUT reference bandwidth is used in the calculation for frequency ranges above 3.6 GHz. Then the reference bandwidths (Ref BW) for both below 3.6 GHz and above 3.6 GHz are both 3.59 GHz.

  If the DUT has a narrower bandwidth, the DUT characteristics can be increased accordingly. For example, if the DUT has a bandwidth of 100 MHz, the supported DUT gain can be increased by a factor of

  $10 \times \log(3.59 \times 10^9 / 100 \times 10^6)$, that is by 15.6 dB.

– The noise figure and gain for the U7227C USB Preamplifier are used in the calculation. If you are using the U7227A or U7227F, the supported DUT characteristics should be different.

– A 6 dB ENR noise source is used in the calculation. If you are using a noise source with higher ENR, the supported DUT gain will be lower.

– For different instruments and for a wide frequency range, the data for the USB preamplifier and the X-Series signal analyzer differs considerably, the most precise data is used in most cases.

Below is the procedure for using Figure 2-16 and Figure 2-17 to find the proper system configuration. See “Examples for Using the Guide to Find the Test System Configuration” on page 46 for examples of using this procedure.

1. Check the DUT and get the rough data for the DUT bandwidth (BW), noise figure (NF), and gain.
2. Calculate the bandwidth adjust factor (AF) using the following equation.

   $AF = 10 \times \log(Ref\_BW / \mathrm{DUT\_BW}) = 10 \times \log(3.59 \times 10^9 / \mathrm{DUT\_BW})$[1]

   Then subtract the AF from the DUT Gain. The resultant value is called DUT_Gain_Modified.

   $$DUT\_Gain\_Modified = DUT\_Gain - AF$$

3. Use the DUT_NF and DUT_Gain_Modified values to search in Figure 2-16 or Figure 2-17 from bottom to top and find an approximate place for them.
4. Find the corresponding system configuration. If the system configuration includes the internal attenuation, do the following to find the proper attenuation level:
   a. Set the attenuation to 0 dB and note the noise figure of your DUT.
   b. Increase the attenuation by one step (4 dB). If the noise figure changes too much, such as 0.3 dB, this attenuation is required for accurate measurement.
   c. Repeat step (b) until you find the proper value.

NOTE As in the calculation of the supported DUT characteristics in Figure 2-16 and Figure 2-17, the most precise data is used in most cases, it is recommended to try the system configuration below the one you find using DUT_NF and DUT_Gain_Modified first.

1. The Ref BW is the bandwidth used in Figure 2-16 or Figure 2-17 to calculate the noise power, which is 3.59 GHz.

Figure 2-16 Supported DUT Characteristics and Recommended Test System Configuration for Frequency Ranges below 3.6 GHz

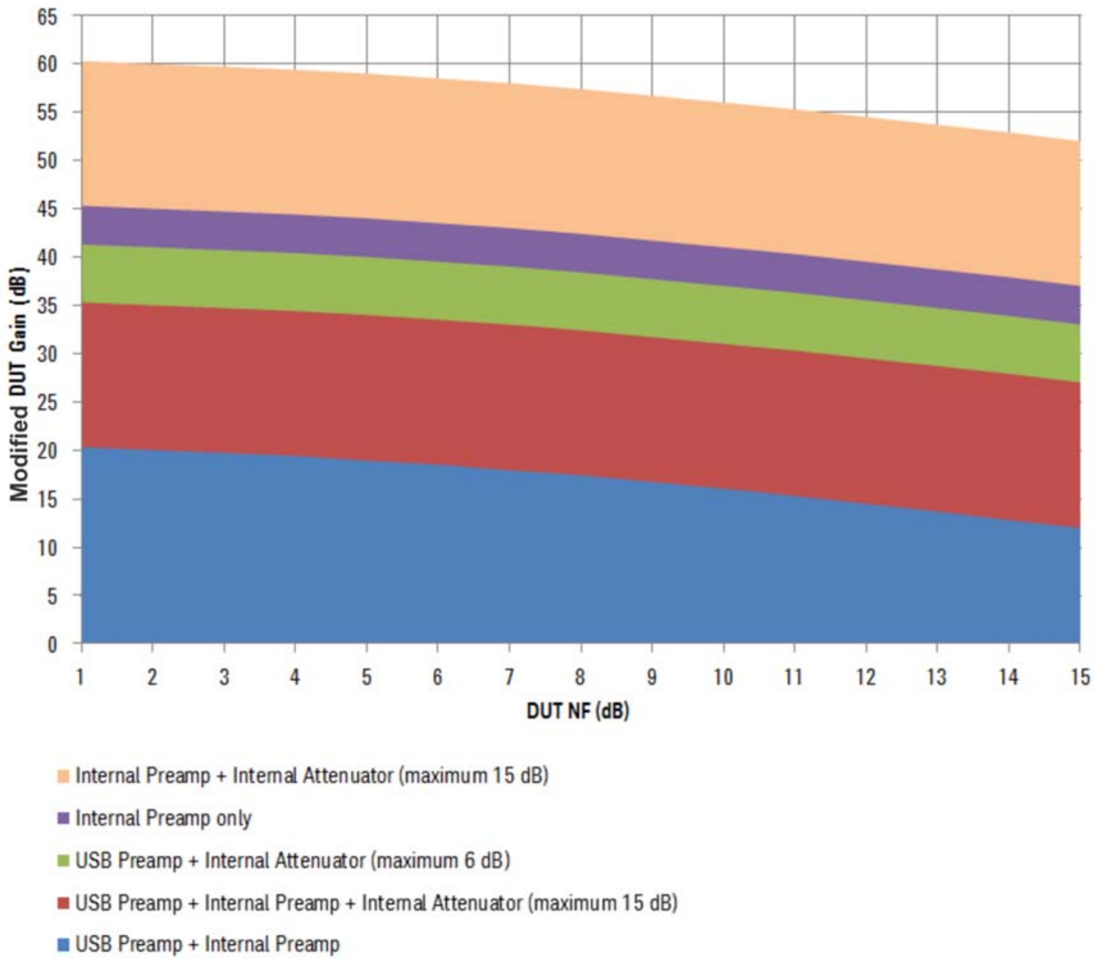
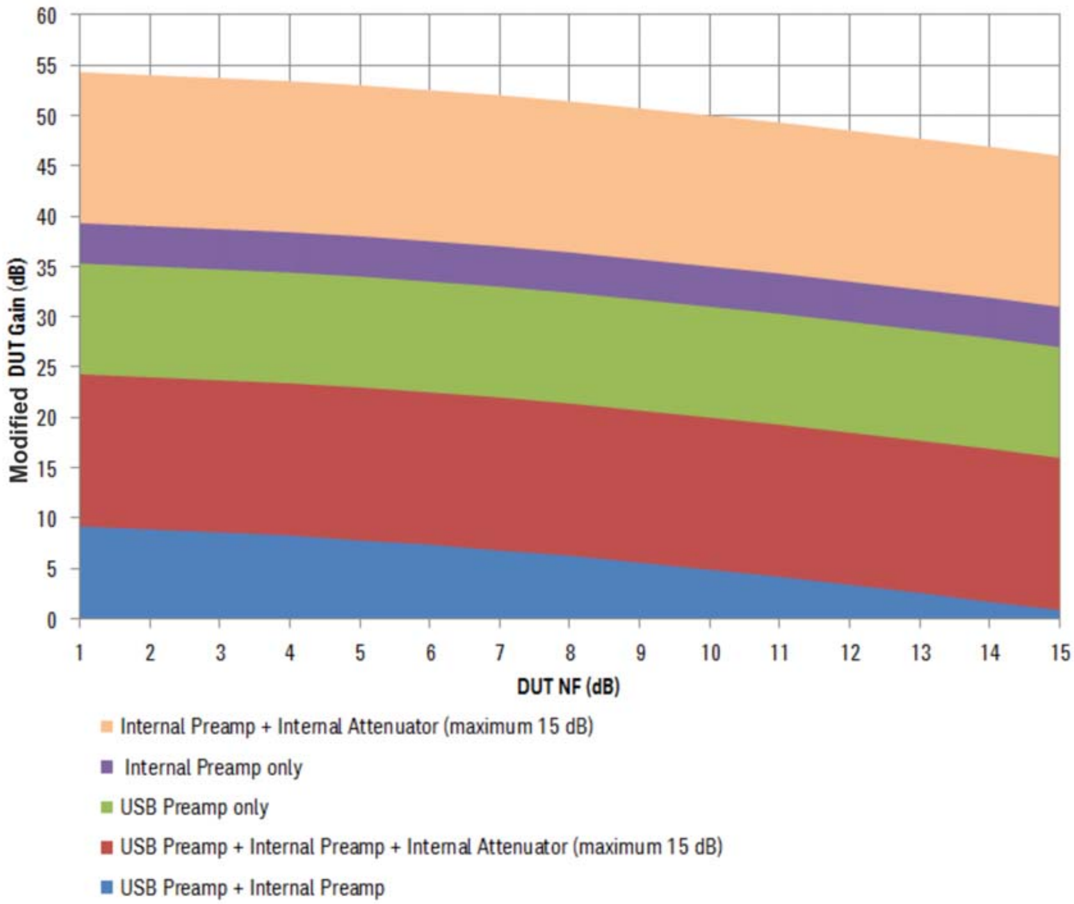


Figure 2-17 Supported DUT Characteristics and Recommended Test System Configuration for Frequency Ranges above 3.6 GHz



NOTE

For frequency ranges above 3.6 GHz, if no preamplifier is used in the signal analyzer, the major noise power concern will be the noise power before the mixer. In this case, the input noise outside the preselector bandwidth (less than 80 MHz) will be filtered. This may affect the supported DUT characteristics.

Figure 2-16 and Figure 2-17 provide a rough guide for frequency ranges up to 26.5 GHz. For the frequency ranges above, the U7227F USB Preamplifier used together with the X-Series can support up to 50 GHz. The calculation method for frequency ranges above 26.5 GHz is similar to the “3.6 GHz to 26.5 GHz” frequency range. The supported DUT gain will decrease because of the increase of the noise figure and gain for both the USB preamplifier and the internal preamplifier. Refer to Table 2-3 and Table 2-4.

Table 2-3 Noise Figure and Gain Specification of the U7227-Series USB Preamplifier[a]

Specification	U7227A	U7227C	U7227F
Frequency	10 MHz to 4 GHz	100 MHz to 26.5 GHz	2 to 50 GHz
Gain (dB)[b]	> 16 (10 to 100 MHz) > 0.5 F + 17 (100 MHz to 4 GHz)	> 0.26F +16.1 (100 MHz to 26.5 GHz)	> 0.23F + 16.5 (2 to 50 GHz)
Noise Figure	< 5.5 dB (10 to 100 MHz) < 5 dB (10 MHz to 4 GHz)	< 6 dB (100 MHz to 4 GHz) < 5 dB (4 to 6 GHz) < 4 dB (6 to 18 GHz) < 5 dB (18 to 26.5 GHz)	< 10 dB (2 to 4 GHz) < 8 dB (4 to 40 GHz) < 9 dB (40 to 44 GHz) < 10 dB (44 to 50 GHz)

a. Specifications are tested and measured on an operating temperature of 23 °C.
b. "F" signifies frequency in GHz.

Table 2-4 Noise Figure and Gain Specification of the NFA X-Series Noise Figure Analyzer

Spec (nominal)	NFA X-Series Noise Figure Analyzer
Gain (dB) (.Max)	20 dB (100 kHz to 3.6 GHz) 35 dB (3.6 to 26.5 GHz) 40 dB (26.5 to 40 GHz)
Noise Figure	13 to 14.5 dB (100 kHz to 3.6 GHz) 9 dB (3.6 to 8.4 GHz) 10 dB (11 to 18 GHz) (DANL+176.24 dB) (>13.6 GHz)

Examples for Using the Guide to Find the Test System Configuration

This section gives an example of using the “Rough Guide for the Noise Figure Test System Configuration” on page 42 to find a proper test system configuration

DUT with Frequency Ranges below 3.6 GHz

The DUT characteristic is as below:

DUT NF: 5 dB

DUT gain: 30 dB

Frequency range: 1 to 2 GHz

The DUT bandwidth is:

$$\text{DUT\_BW} = 1 \times 10^9 \text{ Hz}$$

The bandwidth adjust factor is:

$$AF = 10 \times \log(3.59 \times 10^9 / (\text{DUT\_BW})) = 5.55 \text{ dB}$$

The modified DUT gain is:

$$DUT\_Gain\_Modified = DUT\_Gain - AF = 24.45 \text{ dB}$$

Use DUT NF and DUT Gain Modified values to search in Figure 2-16 from bottom to top. The test system configuration should be USB Preamp + Internal Preamp + Internal Attenuator.

DUT with Frequency Ranges above 3.6 GHz

The DUT characteristic is as below:

DUT NF: 4 dB

DUT gain: 25 dB

Frequency range: 3 to 10 GHz

The DUT bandwidth is:

$$DUT\_BW = 7 \times 10^{9} \text{ Hz}$$

The bandwidth adjust factor is:

$$AF = 10 \times \log(3.59 \times 10^{9} / (DUT\_BW)) = -2.9 \text{ dB}$$

The modified DUT gain is:

$$DUT\_Gain\_Modified = DUT\_Gain - AF = 27.9 \text{ dB}$$

Use DUT NF and DUT Gain Modified values to search in Figure 2-17 from bottom to top. The test system configuration should be USB Preamp only.

3 Measurement Related Tasks and Concepts

This chapter provides more details about measurement tasks and concepts related to the noise figure measurements, which are described in three sections as below. Also included is a simple comparison of three instruments and some further information.

NOTE For fundamentals of noise figure and the Y-factor method, you can refer to application note 57-1 and 57-2 as listed in "Further Information" on page 87.

KEYSIGHT TECHNOLOGIES

Setting the Measurement System

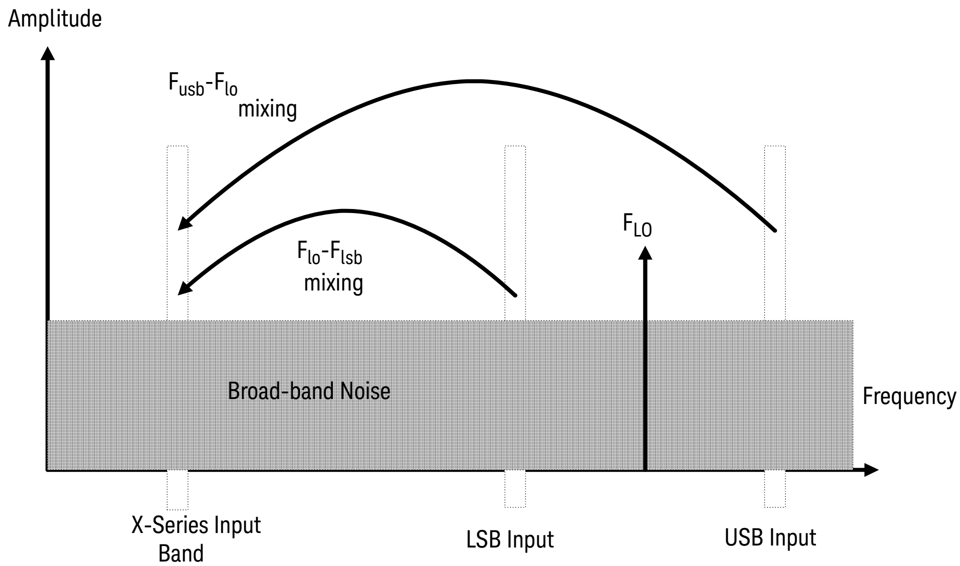
Accounting for Frequency Conversion

If noise figure measurement includes frequency conversions, the following points will need to be carefully considered.

Sidebands and Images

For any measurement involving frequency conversion, you need to consider the exact frequency ranges involved, and make decisions about the filtering requirements for the specific measurement. For example, there may be several different methods of measuring a mixer, and the method chosen may be set by the choice of available filters.

Figure 3-1 Sidebands and Images with Downconversion



Simple, ideal, mixers output signals on both the sum and difference of their RF and LO frequencies. Hence, for a fixed output frequency and a fixed LO frequency, there are two different input frequencies that are converted to the output frequency. This is shown in Figure 3-1.

The noise sources used in noise figure measurements are broad-band. When using a downconverter, there is a probability that noise will be presented to a simple mixer in both the upper and lower input frequency bands that are converted into the same IF output band to which the analyzer is tuned. The analyzer receives mixer-created noise from the two frequency bands which are superimposed. The noise is random, and the two power levels combine by simple addition. Similarly, the analyzer receives noise-source-created noise from the two frequency bands combined as added power. Any measurement where two mixing products are combined like this is usually termed Double-Sideband, DSB.

It is conventional to call the higher frequency band of an image pair the Upper-Sideband, USB, and the lower frequency band of an image pair the Lower-Sideband, LSB.

Non-ideal mixers exhibit some unwanted behaviors:

- Some of the input signal leaks directly to the output.
- Some of the LO signal, and its harmonics, leak directly to the output.
- Mixing products are created between the input signal and the harmonics of the LO.

There are other unwanted products involving input signal harmonics, but these tend to be less troublesome than those above, provided the mixer is operated at a level within its linear range.

Signal Leakage

Direct signal leakage of an input signal through to a mixer's output can occur, because the noise sources cover a broad frequency range. Signal leakage is not normally a problem unless the noise source has a large variation in ENR, or the mixer's RF-to-IF leakage is high.

LO Leakage

The LO power is normally greater than the largest input signal that a mixer is intended to operate with. The LO power leaking from the mixer's output is at a high level compared to the signal levels involved in the noise figure measurement. Hence, LO leakage needs to be considered when measuring noise figure of a frequency converting DUT.

When working in low band < 3.6 GHz, if the LO frequency is low enough to be passed by the input filter of the analyzer's RF section (a 3.6 GHz Low Pass Filter), the LO leakage can prevent successful measurement of the DUT noise figure. Desensitization by LO leakage can be avoided by adding a filter between the DUT and the analyzer to remove the LO frequency component.

Low pass filters with cutoffs at low frequencies, may exhibit spurious resonances and leakage at low microwave frequencies. It may be necessary to use a pair of lowpass filters, one microwave, one RF, to assure a stopband attenuation over a wide frequency range.

LO Harmonics

Many mixers are operated by sinusoidal LO signals. LO harmonics can be formed in the mixer at significantly high levels. It is common for the specified LO input level for a diode mixer to be chosen to operate the diodes between saturation and off conditions, thereby making the mixer act as a switch. LO harmonic derived products from industry standard double-balanced mixers may be similar in level to what they would have been with a square-wave LO signal. Instead of just being sensitive at one pair of frequencies $[F_{LO} \pm F_{IF}]$, the mixer input is sensitive at a series of pairs:

Equation 3-1

$$[F_{LO} \pm F_{IF}] + [\mathbf{2}F_{LO} \pm F_{IF}] + [\mathbf{3}F_{LO} \pm F_{IF}] + [\mathbf{4}F_{LO} \pm F_{IF}] + [\mathbf{5}F_{LO} \pm F_{IF}] + \ldots$$

Filtering is needed to eliminate the noise input to the DUT at these higher order frequencies. However, their frequencies may be great enough that the mixer attenuates them, making them insignificant.

Single Sideband Measurements

Most mixer applications involve single sideband (SSB) mixing - either LSB or USB. Therefore, it is ideal to make noise figure measurements on a mixer in the circumstances in which it is used. Making an SSB measurement requires suitable filters to remove the unwanted image, any LO leakage, and other unwanted mixer products. This may require filters that are not readily available, or that are expensive, and a DSB measurement may be chosen as a compromise when measuring a downconverter or using the System Downconverter. There is no general guidance on what filtering is needed. Each case needs individual consideration.

Items to be considered are:

- Decide the frequency ranges that must be covered; Input, LO, and Output.
- Calculate the frequency range that the unwanted image will cover.
- Calculate the frequency range that the LO harmonic modes will cover.
- Choose a filter to go between the noise source and the DUT, that will pass the wanted input band and stop the unwanted input bands.
- Consider the LO frequency range (and harmonics), and whether or not a filter is needed to protect the analyzer input from being desensitized by LO leakage in the 0 - 4.6 GHz range.
- Choose a filter, if necessary, to go between the DUT and the analyzer.

If any of these ranges conflict, making the filter requirements impossible, the measurement could be split into a group of smaller ranges, with different filters for each.

If the DUT is a complicated mixer, it may already contain filters to operate the mixer in single sideband mode over the frequency range of interest. A mixer in its final application exhibits the same problems that make noise figure measurements difficult, hence the application will need similar filtering to that needed during noise figure measurement.

Figure 3-2 Single Sideband Mixer Measurements

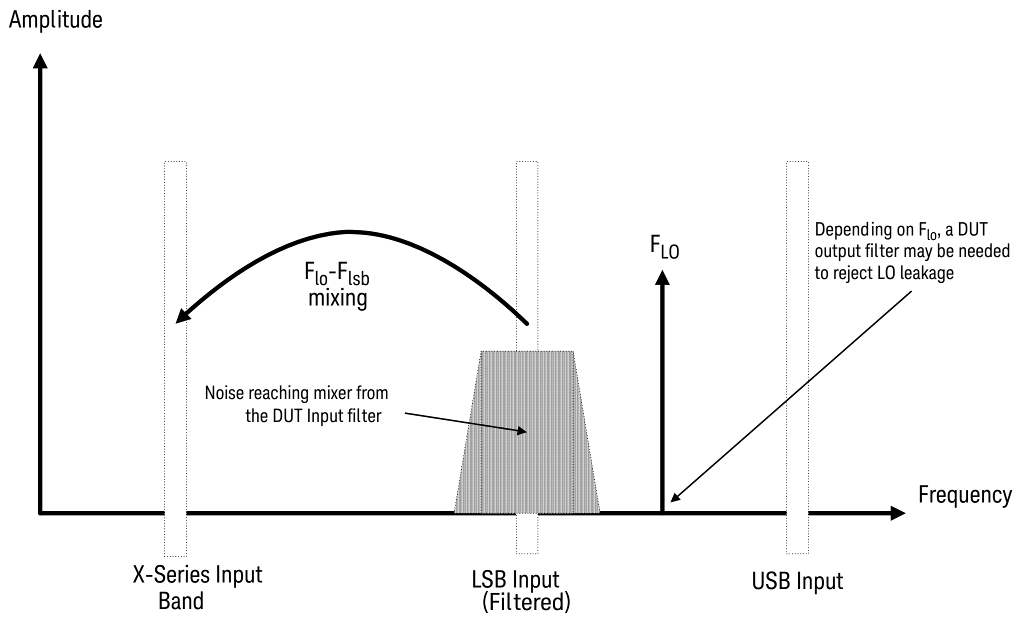


Figure 3-2 shows an SSB mixer measurement (Downconverter, LSB) where a filter makes it single sideband. If the IF frequency is lowered, the analyzer is tuned to a lower frequency, and the USB and LSB bands will move closer to the LO frequency. This makes filtering more difficult. If the IF is lowered further, a point is reached where filtering is not possible and SSB measurements cannot be made. The width of the filter limits where the LO or IF frequencies sweep to make a measurement.

The analyzer performs frequency calculations and controls the frequency for a variety of mixer modes. However, you have to determine the filter requirements, and provide those filters in the measurement setup.

'Downconverter' means that the output frequency, (IF) is lower than the input, (RF).

'Upconverter' means that the output frequency, (IF) is higher than the input (RF).

NOTE **This is the convention used in this analyzer. Some engineering terms use reversed terms for upconverters.**

The analyzer can handle SSB mixer measurements in modes defined by the following combinational choices:

– **DUT**: **Upconverter, Downconverter**, or **Amplifier** with **System Downconverter On**.

– **Sideband**: **LSB** or **USB**.

Double Sideband Measurements

Double Sideband (DSB) measurements can only be made when the DUT is a downconverter, or when the system downconverter is On. DSB techniques can be useful when making noise figure measurements under the following conditions:

– When adequate filters for image-free SSB measurements are not available

– When frequency ranges have to be covered that make SSB filters impractical or impossible

DSB measurements do not eliminate the need for filtering. However, they can greatly simplify the filtering needed. This benefit is achieved by effectively averaging the LSB and USB results and averaging the ENR values. This results in a loss of frequency resolution and accuracy.

Figure 3-3 Double Sideband Measurements

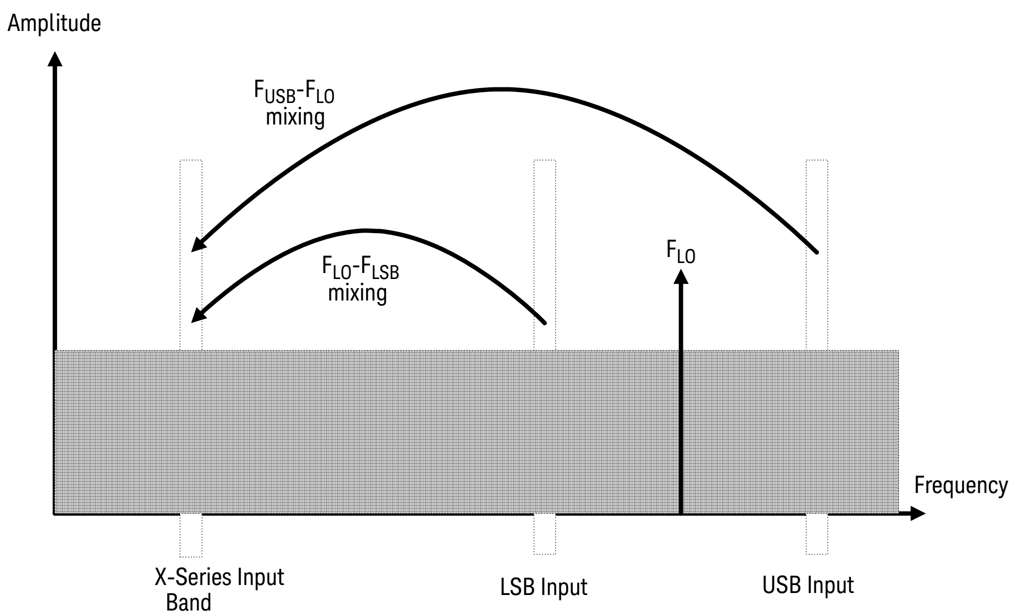


Figure 3-3 shows a double sideband, downconversion, mixing. Noise from two separated RF bands are mixed into the IF band, where the power addition takes place.

DSB measurements are made with the noise from a pair of separate bands, symmetrically arranged about the LO frequency. The IF value should be low, ideally no larger than 1% of the LO frequency. As the two sidebands, the USB and the LSB, are generated at frequencies equal to $F_{LO} \pm F_{IF}$, this technique maintains the two bands close together. This is necessary because the assumption is made that the variations in the noise source ENR, gain and noise figure are constant between the two bands. ENR values are applied to the mid-point between the upper and lower sidebands, and this equates to the frequency of the LO.

Figure 3-3 shows that noise from two bands are combined during the measurement, while during calibration, when the DUT was not connected, only one band (at the IF frequency) was used.

If the assumptions about the parameters being flat over the frequency between the two sidebands are valid, your results will show a doubling in power (3 dB increase) in the noise level during the measurement of any downconverting DUT. There is also a doubling of measured power when using the system downconverter, but compensation is not required because the calibration power is also doubled.

This 3 dB increase in measured power with downconverting DUTs can be corrected using the Loss Compensation Setup screen (**MEAS SETUP**, **Loss Comp** tab). Set **Loss Comp Mode** to **Fixed**, enter a **Fixed Value** of –3 dB, and set **Temperature** to the noise source's cold temperature. The DSB power addition occurs for both the **Hot** and **Cold** noise from the noise source, and the noise created in the input of the DUT. A temperature value can be assigned to this loss using the Before DUT Temperature. Using the **Cold** temperature of the noise source (often assumed to be 290 Kelvin) corrects for this, and the analyzer will give calibrated results comparable to those that would have been given by an SSB measurement.

DSB measurements are not appropriate for making measurements where DUT performance, or noise source ENR, have significant variation over the frequency range $[F_{LO} \pm F_{IF}]$.

DSB measurements need care to determine their filtering needs.

NOTE

When making a Double Side Band (**DSB**) measurement with **RF** Frequency Context, the frequencies you specify as the RF Start and Stop frequencies refer to the Lower Side Band (**LSB**) only.

LO Leakage (with specific DSB information)

LO leakage is a problem when working in the 200 kHz to 3.6 GHz range. It can be avoided by tuning the LO to frequencies greater than 3.6 GHz. Above 3.6 GHz, the analyzer's input filter progressively attenuates the LO signal. For a DSB downconverter measurement with the LO frequency below about 3.6 GHz, a lowpass filter will be needed. The cutoff frequency must be chosen to pass the IF frequency of the measurement. The amount of attenuation over the LO frequency range has to be sufficient to reduce the LO leakage down to the broad-band (10.0 MHz - 3 GHz) noise level presented to the analyzer input.

With most DSB Downconverter measurements, the IF is made low, with respect to, the RF and LO frequencies, so filter needs are not complex.

NOTE

Low pass filters with cutoffs at low frequencies, may exhibit spurious resonances and leakage at low microwave frequencies. It may be necessary to use a pair of lowpass filters, one microwave, one RF, to assure a stopband attenuation over a wide frequency range.

LO Harmonics (with specific DSB information)

Many mixers have product pairs associated with harmonics of the LO. Depending on the mixer, these could be at a sufficient level to distort the measured noise figure results. To avoid this insert an input filter between the noise source and the DUT. A highpass filter may also be needed in this location if signal leakage is a problem.

There is no general guidance on what filtering is needed. Each case needs individual consideration:

1. Decide the frequency ranges that have to be covered; Input, LO, and Output.
2. Calculate the frequency range that the LO harmonic modes will cover.
3. If LO harmonic related products are a problem, choose a filter to go between the noise source and the DUT, that will pass the wanted input band and stop the LO harmonic modes. If the frequency ranges are wide, the measurement may have to be split into frequency ranges with different filters for each.
4. Consider the LO frequency (and harmonics). Is a filter needed to protect the analyzer input being desensitized by LO leakage in the 0 to 4.6 GHz range?
5. Choose a filter, if necessary, to go between the DUT and the analyzer.

The analyzer can handle DSB mixer measurements when using a **Downconverter**, or when the **System Downconverter** is **On**.

Choosing and Setting Up the Local Oscillator

Selecting a Local Oscillator for Extended Frequency measurements with the X-Series

Because of reciprocal mixing, noise components in the LO are converted into the IF band applied to the analyzer. This converted LO noise causes the measured noise figure to be higher than the noise figure of the mixer.

If the mixer is to be used with a particular LO in its final application, its noise figure should be measured with the same LO. The measurement then gives the noise figure for the combination of the extended frequency device and the LO in the final system.

For testing of extended frequency measurements, the LO must have a low noise floor over frequencies equal to the LO ± IF. It is also important that the LO has low broad-band noise because any noise at the IF frequency will pass through to the IF and distort the results.

Effect of high level LO spurious signals and noise on mixer measurements with low L-to-I rejection.

The spurious level of the LO also has to be low. At frequencies where there is a high spurious signal, the noise figure measured will have a peak at that IF. For example, ideally the LO's noise, including spurious, needs to be below –90 dBm. If a mixer has higher isolation, then the noise of the LO can be higher since the mixer will be better able to reject the LO's noise.

This is especially necessary if the mixer has a poor balance, or LO to IF isolation. With low isolation, the mixer is more likely to pass the LO noise through and thus increase the measured noise figure.

NOTE **L-to-I rejection is the mixer's ability to reject the fundamental, harmonics and spurious signals of the LO, and not allow them to pass through to the IF output.**

Selecting a Local Oscillator

Here are several criteria that must be met when choosing the LO:

– It should have a frequency appropriate to the DUT's frequency range, IF range, and sideband chosen.
– It should have sufficient power to drive mixers (typically, +7 dBm).
– It should have excellent frequency accuracy and repeatability (typically, the same as the analyzer you are using.)

The last point, frequency accuracy, deserves further comment. There are three frequency-dependent components in a noise figure measurement that must all be aligned to make an accurate measurement at the IF. The need for frequency accuracy is the main reason for recommending a synthesized source for the LO, such as a Keysight E8257D Analog Signal Generator with Option UNX.

NOTE **Measurement requirements will dictate what type of signal generator is needed.**

Other LOs may be used, but should be tested to determine that their noise is sufficiently low, as LO noise can cause an increase in noise figure for the mixer/LO combination, and calibration of the system may not be possible. A broad-band, high gain amplifier at the LO output usually generates unacceptable noise. This is almost always the case when a heterodyne-type sweep oscillator or signal generator is used.

Calibrating the Analyzer

To compensate for the noise contribution of the analyzer and associated cabling in the measurement path, a calibration is necessary. The calibration measures the analyzer's noise contribution with no device under test (DUT) in place. This correction is often referred to as the second stage calibration. The correction is then applied to the measurement with the DUT in place.

To perform a calibration you need to enter the ENR values and set up the frequency range, number of measurement points, the bandwidth, the averaging, and measurement mode to be used during the measurement.

NOTE

If you alter the frequency range after you have calibrated the analyzer, it changes the analyzer's status to either the uncalibrated (a red `UNCAL` indicator) or the interpolated (`a yellow ~ENR` indicator) calibrated state. Before you can make another measurement to the specified accuracy, you must either recalibrate the analyzer, or recall a previously saved state file in which the calibration data has been saved.

Corrected Measurements

You can make corrected measurements only at frequencies that are covered by the current calibration. Attempting to make corrected measurements at frequencies less than the lowest calibration frequency or greater than the highest calibration frequency will generate an error and invalidate the calibration.

To proceed you must either:

– perform a calibration over the desired measurement frequency range

– change the measurement frequency to one covered by the existing calibration

– perform uncalibrated measurements

  Uncorrected measurements actually measure the noise figure of the analyzer and any associated components in the input path. This can be useful if you wish to use the Uncertainty Calculator.

NOTE

If you perform a measurement outside the calibrated range of the analyzer, **Apply Calibration** is automatically set to **Off** and a message is displayed stating `User Cal:Cal invalidated`. If you then change your measurement frequency back to a frequency within the calibrated range, the previous error message will be replaced by a message stating `User Cal:Cal valid`. Apply Cal from MEAS SETUP menu. Press **MEAS SETUP**, **Cal Setup** tab, **Apply Calibration** to **On** to make a corrected measurement.

When to Perform Calibration

To make corrected measurements, you must calibrate the analyzer whenever:

– You power cycle the analyzer

– You preset the analyzer

– You select a measurement frequency or frequency range outside the currently calibrated range

– There is a large temperature variation since the last calibration

– The input signal level can no longer be measured using one of the calibrated input attenuator ranges

– When an invalid result is detected and the condition is indicated by a “xx”.

Interpolated Results

When the location of the measurement points is changed without exceeding the range of frequencies being measured, interpolation between calibration points is used and a new calibration is not required.

The locations of the measurement points, that is, the frequencies at which measurements are made, change whenever the start frequency, the stop frequency, or the number of sweep points is changed.

Calibration Indicator

Whenever anything within the analyzer changes to invalidate the current calibration, the `CAL STATE` displays `UNCAL` in red at the top of the display. If the analyzer has been successfully calibrated for the current frequency and measurement settings, the `CAL STATE` displays `CAL` in green text at the top of the display.

Interpolated Calibration

Whenever anything within the analyzer changes to force the current calibration to interpolate the calibration data, the `CAL STATE` green `CAL` message at the top of the display switches to a yellow `~CAL` message. This would happen, for example, if you change the RBW after calibrating but before measuring.

User Cal vs. Internal Cal

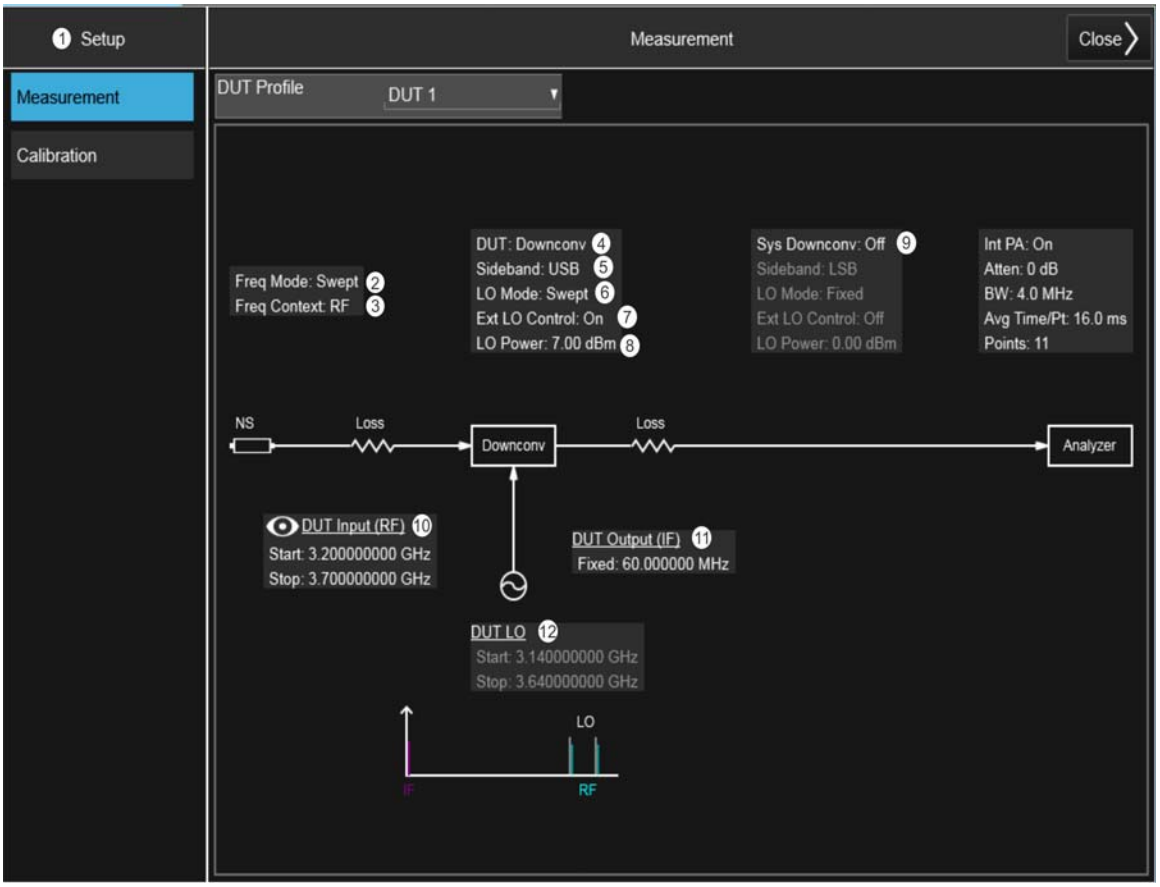
User Cal is the most commonly used calibration method. For the X-Series used with the USB Preamp there is another calibration method available, Internal Cal. See Table 3-1 for a comparison between User Cal and Internal Cal.

Table 3-1 User Cal vs. Internal Cal

Items	User Cal	Internal Cal
System connection and setting procedure	User Cal needs a different system connection. To perform User Cal, you need to connect the noise source directly to the signal analyzer first, without the DUT, as shown in Figure 2-1 on page 15. And then on the instrument, 1. Press **MEAS SETUP**, **Cal Setup**, **User Cal**. 2. Press **CALIBRATE**.	Internal Cal does NOT need the special system connection. Just connect the noise source, DUT, and signal analyzer as desired, and perform the Internal Cal. On the instrument, press **MEAS SETUP**, **Cal Setup**, **Internal Cal**.
Calibration Theory	In User Cal, the instrument measures the P_{cold} and P_{hot} values directly and stores them in the instrument.	Internal Cal uses the internal cal files stored in the instrument and USB preamp. The information contained there allows the instrument to calculate the P_{cold} and P_{hot} values.
When to perform calibration?	For cases described in "When to Perform Calibration" on page 59, you need to change the system connection to the calibration setup and perform the User Cal again.	Internal Cal takes most of the cases of "When to Perform Calibration" on page 59 into account inside the instrument. So you don't need to make an Internal Cal again and again for most cases. However, if the ambient temperature is significantly changed, it is recommended to perform the Characterize Noise Floor operation on the signal analyzer by pressing **System**, **Alignments**, **Advanced**, **Characterize Noise Floor**.
Advantage	Accurate calibration results	Simple system connection without a mechanical connection change for calibration.
Recommended use cases	Choose User Cal when – you are very concerned about getting accurate data. – the DUT is not connected to the noise source and signal analyzer directly, but via some test fixtures or automated test equipment.	Choose Internal Cal when – you are very concerned about measurement speed.

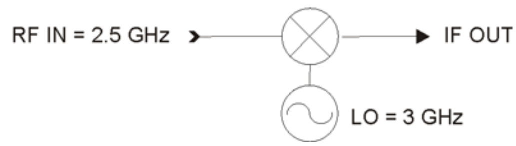
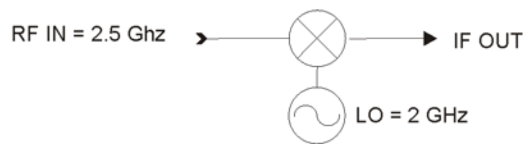
Setting the Signal Analyzer to Make a Measurement

DUT Setup Form



Item			Description
#	Name	Available Selections	
1	Setup	Calibration	Selects the calibration diagram to be displayed. The diagram represents the connections you need to make to perform the calibration using the current settings.
		Measurement	Selects the measurement diagram to be displayed. The diagram represents the connections you need to make to perform the measurement using the current settings.

Item			Description
#	Name	Available Selections	
2	Freq Mode	Swept	Points are linearly distributed between the Start and Stop Frequency, where the number of points is determined by the Points parameter under the Sweep/Control menu. The Start Freq, Stop Freq, Center Freq, and Span parameters are coupled.
		Fixed	A single frequency (supplied by the Fixed Freq parameter) is measured.
		List	A user-specified list of frequencies is measured. The list of frequencies can be supplied using the respective SCPI commands, loading the frequency list from a file, or by entering the data manually into the frequency list. Duplicate frequencies are not allowed. If the Frequency Context changes, the list values are recalculated to satisfy the new context.
3	Freq Context	RF	RF refers to the frequency or frequency range before the DUT. In the case of DSB measurements for a downconverter, the RF frequencies represented are only that of the LSB Start and Stop range. If RF is selected as Freq Context, the measurement results will be displayed with the frequency of the RF frequency settings. If there are frequency conversions in the measurement system, the frequencies displayed in the measurement results are different from the input frequency of the analyzer.
		IF	IF refers to the frequency or frequency range after the DUT. If a system downconverter is not used, the IF frequency will be the input frequency of the signal analyzer. In the case of a system downconverter, IF means before the system downconverter. Then the input frequency of the signal analyzer will be determined by the IF frequency and the system downconverter LO, or the system downconverter IF. If IF is selected as Freq Context, the measurement results will be displayed with the frequency of the IF frequency settings. If a system downconverter is used, the frequencies displayed in the measurement results are different from the input frequency of the analyzer.
		LO	LO refers to the frequency or frequency range of the DUT LO. These are not the frequencies that the analyzer is physically measuring. If LO is selected as Freq Context, the measurement results will be displayed with the frequency of the LO frequency settings. This context lets you review the LO frequencies required to program the external LO or those set by the analyzer when using an external source control.
4	DUT	Amplifier	A device that performs no internal frequency conversion. **NOTE** The Amplifier DUT is for any DUT that does not perform frequency conversion and includes amplifiers, filters, attenuators and so forth.
		Downconv	A device that performs internal frequency downconversion.
		Upconv	A device that performs internal frequency upconversion.
		Converter (Multi-Stage)	A device that performs multi-stage frequency conversions.

Item			Description
#	Name	Available Selections	
5	Sideband (both for DUT and system downconverter)	LSB	Lower Sideband – the RF input frequency is < the LO frequency. For example(downconverter): 
		USB	Upper Sideband – the RF input frequency is > the LO frequency. For example (downconverter): 
		DSB	Double Sideband – both upper and lower sidebands. **NOTE** Available when the DUT is a Downconverter, or System Downconverter is set to on. **NOTE** When making a Double Side Band (**DSB)** measurement with **RF** Frequency Context, the frequencies you specify as the RF Start and Stop frequencies refer to the Lower Side Band (**LSB)** only. When making Double Sideband (**DSB**) measurements, it is important that the IF frequency is much smaller than the LO frequency. This is because the ENR values in the ENR table can only be applied to one frequency, which is the LO frequency. The ENR values cannot be applied simultaneously to both the upper sideband and to the lower sideband. The ENR values are therefore applied to the midpoint between the upper sideband and the lower sideband, and this equates to the LO frequency. Consequently, the higher the IF frequency is in comparison to the LO frequency, the further apart the upper and lower sidebands will be. The further these upper and lower sidebands are from the LO frequency, the less accurate the ENR value be. It is recommended for greatest accuracy that the IF be no greater than 1% of the LO frequency when making double sideband measurements. When making a swept measurement, no frequency in the swept frequency band should exceed 1% of the LO frequency.
6	LO Freq Mode	Fixed	The External LO frequency is constant.
		Swept	The External LO frequency changes between sweep points. **NOTE** When LO Freq Mode is set to Swept, an external LO control on a separate signal source is needed.

Item			Description
#	Name	Available Selections	
7	External LO Control	On/Off	Allows you to toggle the external LO control on and off through LAN, USB, or GPIB interface.
8	LO Power		Allows you to set the LO power level in dBm units.
10	DUT Input (RF)	Start/Stop	Allows you to set the RF start and stop frequencies. RF here refers to the frequency or frequency range before the DUT.
12	DUT LO	Start/Stop	Allows you to set the LO star and stop frequency. LO here refers to the frequency or frequency range of the DUT LO.
11	DUT Output (IF)	Fixed	Allows you to set the IF fixed frequency. IF here refers to the frequency or frequency range after the DUT.
9	Sys Downconv	IF	Allows you to set the tuned frequency of the system downconverter output when the LO Frequency mode of the system downconverter is set to Swept. This will be the input frequency of the signal analyzer.
		LO	Allows you to set the external LO frequency of the system downconverter when the LO Freq Mode of the system downconverter is set to Fixed. The input frequency of the signal analyzer can be calculated by subtracting the System Downconv LO from the DUT Output (IF).
		On/Off	Allows you to specify whether or not the system downconverter is to be used in the measurement.

Entering Excess Noise Ratio (ENR) Data

You can enter ENR data under Meas Setup for the noise source you are using as a table of values or as a single spot value. The values held in the table can be used for measurements at a range of frequencies as well as at a fixed frequency.

The single spot value is used either for measurements at a single frequency, or for measurements across a range of frequencies that is narrow enough such that the ENR value does not change significantly across that range.

There are two types of noise source. The first type, for example, a Keysight 346B, is a noise source that is powered by a pulsed +28 V supply on the rear panel of the analyzer. These noise sources need their ENR data to be entered manually, either by using the Alpha Editor or by transferring the data from the diskette supplied with the Keysight noise sources to a USB storage device. See “Entering ENR Table Data for Noise Sources” on page 65 for more information.

The other type of noise source, for example, a Keysight N4000A, is known as a SNS Noise Source. These SNS Series Noise Sources connect directly to the analyzer SNS connector on the rear panel and their ENR data is downloaded automatically into the analyzer.

The tasks related to “entering ENR data” in this section are listed below:

“Selecting a Common ENR Table” on page 65

"Entering ENR Table Data for Noise Sources" on page 65

"Saving an ENR Table" on page 68

"Entering ENR Data from Internal Storage" on page 69

"Using a Spot ENR Value" on page 69

"Setting the Tcold Value" on page 69

Selecting a Common ENR Table

You can use the same ENR table for calibration and for making measurements, or you can use separate Measurement ENR (Meas Table) and Calibration ENR (Cal Table) tables. You need separate measurement and calibration tables when separate noise sources are used for DUT measurements and for calibration. An example of this is when you are using frequency converters, and the calibration range is different than the measurement range.

NOTE ENR tables can contain up to 501 frequency points.

To use the same ENR table for calibration and measurement:

Press **MEAS SETUP**, **ENR**, **Use Meas Table Data for Cal** to **On**.

When the Use Meas Table Data for Cal is turned on, the ENR data for both the measurement and calibration is sourced from a combined ENR table. When it is turned off, the measurement and calibration ENR data is sourced from separate tables.

Entering ENR Table Data for Noise Sources

You can enter ENR data in the form of an ENR table in the following ways:

- You can manually input the required frequencies and corresponding ENR values.
- You can load the ENR data from a USB storage device on which the data has been previously stored. (The diskette supplied with every Keysight 346 Series noise source contains the ENR data for that particular noise source. The information on the diskette can be transferred to a USB storage device, which will enable you to load the data or store it in the analyzer's memory.)
- You can load the ENR data from the internal analyzer memory, where the data has been previously stored.

– When in noise figure mode, SNS ENR data by default will load automatically when the SNS is connected to the analyzer.

NOTE

The 346 Series noise sources from Keysight Technologies have the ENR values printed on a label that is affixed to the body of the device. These ENR values are also provided in the form of a calibration report, and on a diskette which is supplied with all Keysight 346x Series noise sources. The values printed on the noise source itself are only shown to two decimal places. The values stored on a diskette are correct to three decimal places.

To enter the ENR data manually, do the following:

Table 3-2

Step	Notes
1. Power on the analyzer and wait the recommended time for warmup.	
2. Press **MODE/MEAS**, **Noise Figure, OK**.	
3. Press **MEAS SETUP**, **ENR**.	

Figure 3-4 ENR Dialog

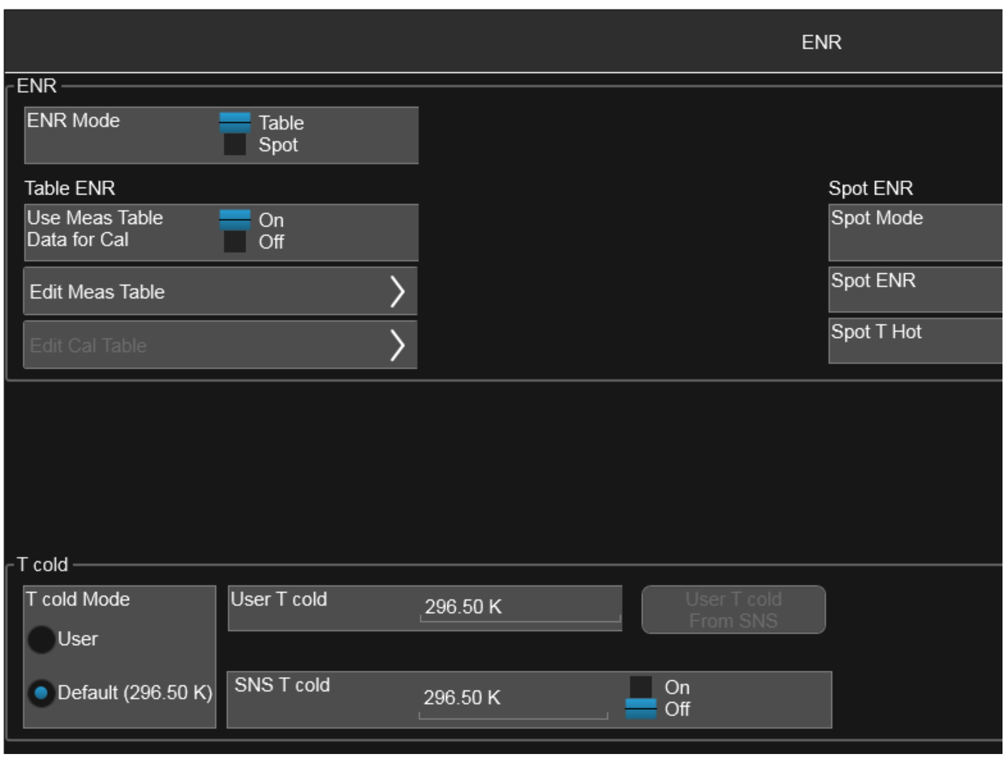
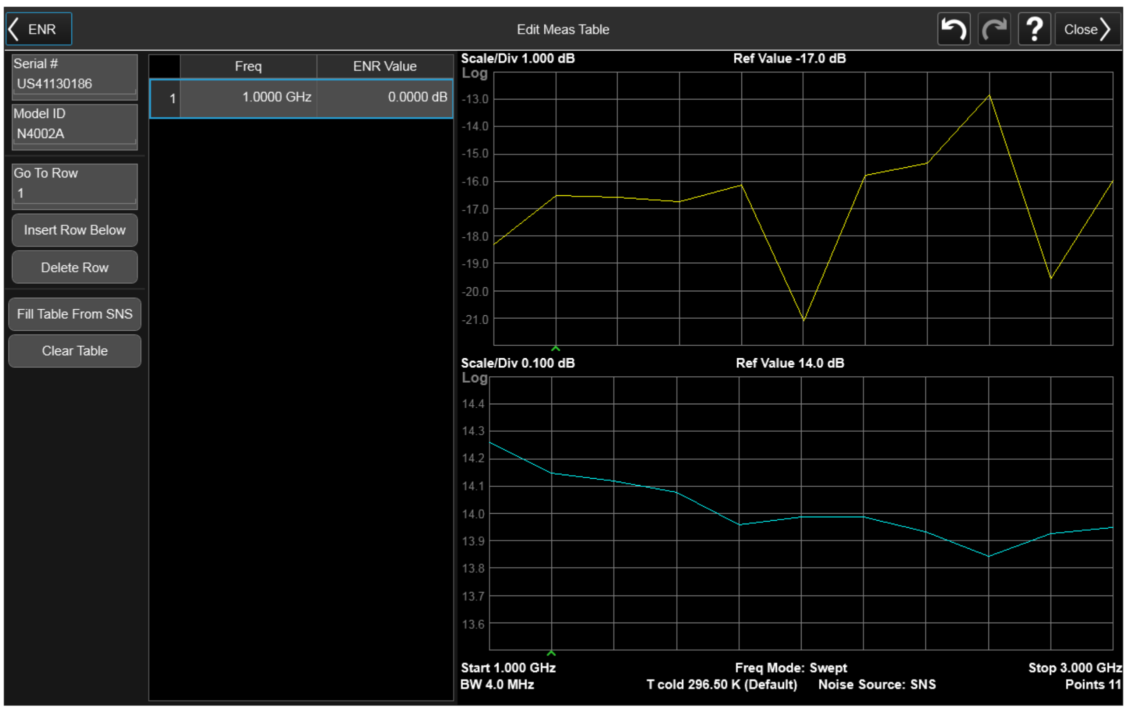


Table 3-2

Step	Notes
4. Press **Edit Meas Table** to access the ENR table for which you wish to enter data. An ENR Table appears with a table editing and navigation menu on the left side. See the following figure. To clear an existing table, press **Clear Table**.	To enter common measurement and calibration ENR data, press **Use Meas Table Data for Cal** to **On**. The measurement table data is automatically used for the calibration data. To enter either measurement ENR data or calibration ENR data, make sure that **Use Meas Table Data for Cal** is set to **Off**, and then select your table by pressing either **Meas Table** or **Cal Table**.

Figure 3-5 ENR Table



Step	Notes
5. (Optional) Press **Serial #**, enter the noise source serial number using the on screen keyboard or an external USB keyboard, and press **Done**.	
6. (Optional) Press **Model ID**, enter the noise source model number using the on screen keyboard or an external USB keyboard, and press **Done**.	
7. Press **Go To Row** to move the highlight to the Frequency/ENR column. Enter the values in the table using the numeric keys and terminate it using the unit menu keys.	You can insert the frequencies into the ENR Table entry in any order, as the analyzer automatically sorts the frequency list into ascending order.

Table 3-2

Step	Notes
8. Repeat step 7 until all the frequency and ENR values you need are entered.	The ENR Table data is stored in comma separated value (.csv) format. It is sometimes more convenient to use a text editor to edit or enter this data rather than to enter the data manually using the analyzer. Start by saving at least one ENR value to memory and then edit or add to the saved file.
9. After completing the ENR table entries, press **<ENR** to return to the ENR menu.	
10. (Optional) Once you have completed entering the ENR data, you can save the ENR table using the **Save** key. For details on saving files, see "Saving an ENR Table" on page 68.	ENR table data survives a power cycle and preset. You need to save ENR data if you wish to recall it easily. When results are needed at frequencies between those entered in the ENR tables, a linearly interpolated value is automatically used at those frequencies.

Saving an ENR Table

You can save an ENR table to the analyzer's internal memory:

Table 3-3

Step	Notes
1. Press **Save**, **ENR Table, Save As...**	
2. Press **Meas (Common) Table** or **Cal Table**, and navigate to the location where you want the file to be stored.	
3. Press the box next to **File Name** to name your file if you do not want to use the default name.	Although the file extension is shown in the default filename, you must not include the file extension when specifying your own filename. The file extension is determined by the type of file you tell the analyzer you are saving. It is added automatically to the filename you specify.
4. Press **Save**.	

Entering ENR Data from Internal Storage

If the noise source you are using has its ENR data previously stored on internal memory, you can load this ENR data into the analyzer as follows:

Step	Notes
1. Press **Recall**, **ENR Table**.	
2. Press **Meas (Common) Table**, **Cal Table, Recall From...**.	
3. Select the desired file from the list of saved ENR tables and press **Recall**.	

Using a Spot ENR Value

A Spot ENR value can be applied across the whole measurement frequency range, or when making a measurement in fixed frequency mode, you can enter a specific spot ENR value corresponding to the fixed frequency.

To enable Spot ENR mode and enter a Spot ENR value:

Step	Notes
1. Press **MEAS SETUP**, **ENR**.	
2. Press **ENR Mode** to select **Spot**.	
3. In the Spot ENR box, press **Spot Mode** to select **ENR**.	
4. Enter an ENR value. The default value is 15.200 dB.	Instead of entering a Spot ENR value, you can also use a Spot T_{hot} value by pressing **Spot T Hot** and entering a specific Spot T_{hot} value. Then The Spot value is applied across the whole measurement frequency range.

Setting the T_{cold} Value

When making measurements in different ambient temperature conditions you can change the T_{cold} value manually.

The default temperature value is set at 296.50 K (23.25° C or 73.85° F). The **T cold** key is set to **Default** to confirm this default temperature.

To change the User T_{cold} value manually, press **MEAS SETUP**, **ENR**, **TCold Mode** to **User**, **User T Cold**, and then enter the T_{cold} temperature, and press **K**.

To automatically load the SNS T_{cold} value, first make sure that the SNS is properly attached to the analyzer, then on the analyzer, press **MEAS SETUP**, **ENR**, **TCold Mode** to **Default,** and toggle **SNS T Cold** to **On**.

Setting the Measurement Frequencies

Before you set the frequencies you want to measure, you need to select a frequency mode. Three frequency modes are available when you press **FREQ**, **Freq Mode**:

– **Swept** – points are linearly distributed between the start and stop frequencies, where the number of points is determined by the Points parameter. The start frequency, stop frequency, center frequency, and span parameters are coupled.The **Fixed Freq** key is unavailable in Swept mode.

– **Fixed** – a single frequency is measured. The start frequency, stop frequency, center frequency, and span parameters are unavailable in Fixed mode.

– **List** – a user-specified list of frequencies is measured. the list of frequencies can be supplied using the respective SCPI commands, loading the frequency list from a file, or by entering the data manually into the frequency list.The start frequency, stop frequency, center frequency, span, and sweep points parameters are unavailable in List mode.

Using Swept Frequency Mode

In swept frequency mode, you set the start and stop frequencies (or equivalent center and span frequencies) over which the sweep is made. You also need to set the number of measurement points. These measurement points are equally spaced over the frequency span. The maximum number of points is 501 and the default number of points is 11.

NOTE If you change the span after a calibration, and the calibration has been made over a narrower frequency range, the calibration will become invalid. The Cal States are reported as follows:

UNCAL (red)– calibration is invalid

CAL (green)– calibration is valid

~CAL (yellow)– calibration is interpolated or adjusted for changes

To make a measurement over a specific frequency range:

Step	Notes
1. Press **FREQ**, **Freq Mode**.	
2. Select the Sweep mode.	
3. Press **Start Freq**, enter the value and terminate it using the unit menu Press **Stop Freq**, enter the value and terminate it using the unit menu	You can also use the **Center Freq** and the **Span** selections to set the desired values.
4. Press **Points**, enter the number of measurement points and press **Enter**.	

Using List Frequency Mode

List frequency mode allows you to enter the frequency points where measurements are made. This allows you to specify measurement points, for example, in areas of interest that would otherwise have less coverage in the sweep mode.

Frequency lists are limited to 501 entries.

To set the analyzer to use the data in the frequency list table, press **FREQ**, **Freq Mode**, **List**.

You can create a frequency list in the following ways:

– Manually, by specifying each individual point.

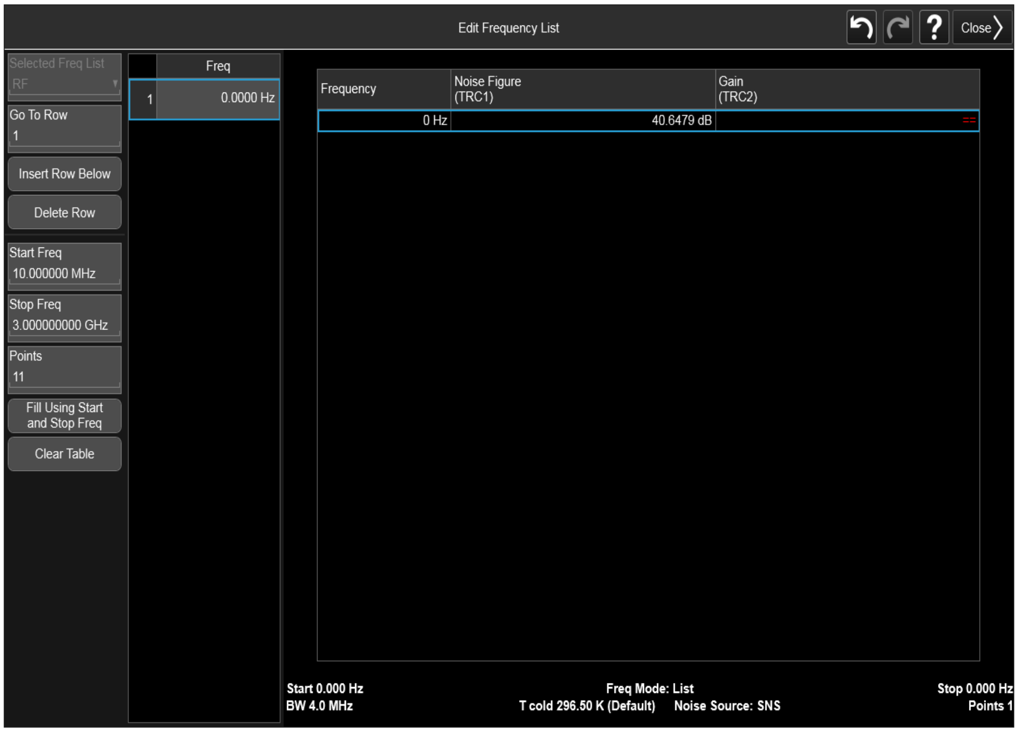
– From the sweep points, by specifying the measurement frequency range and setting the analyzer to generate equally spaced points within that range, press **Edit Freq List**, enter the start and stop frequencies, press **Fill Using Start and Stop Freq** key. This list of frequencies can be edited later if required.

– Loading a list from the internal memory where the data has been previously stored.

To creating a frequency list manually,

Step	Notes
1. Press **FREQ**, **Freq Mode**, **List**.	
2. Press **Edit Freq List**, **Edit**. A Frequency List table appears.	

Step	Notes
Figure 3-6 An Empty Frequency List	



Step	Notes
3. Press Insert Row Below.	
4. Press the highlighted row under **Freq**, enter the frequency value in the table and terminate it using the unit menu.	You do not need to enter the frequency values in ascending order, as the analyzer continually sorts the values into ascending order.
5. Repeat step 3 and 4 until your list is complete.	The frequency data is stored in comma separated value (.csv) format. It is sometimes more convenient to use a text editor to edit or enter this data rather than to enter the data manually using the analyzer. Start by saving at least one value to memory, and then edit or add to the saved file.
6. Save the Frequency List to the analyzer internal memory.	If you do not save the frequency list, you may lose the data.

NOTE

To create a frequency list from sweep points, press **FREQ**, **Edit Frequency List**, **Fill Using Start and Stop Freq**. This clears the current frequency list and fills the list with the frequencies generated by the swept frequency mode. This results in the same frequency list as setting **Frequency Mode** to **Swept**. You can use this list as a starting point, and then edit the frequencies as required.

Using Fixed Frequency Mode

The fixed frequency mode is used when you want to make a measurement at a single frequency.

To set a fixed frequency, press **FREQ**, **Freq Mode**, **Fixed**, then press **Fixed Freq** and enter the frequency value using the numeric keys and the unit termination menu.

NOTE

If you have not entered the noise source ENR data that you intend using for the fixed frequency mode measurement, you may specify a spot ENR value and set the ENR mode to Spot.

Setting the Bandwidth and Averaging

Effect of Bandwidth and Averaging on Speed, Jitter, and Measurement Accuracy

Jitter is a natural occurrence when measuring noise. To reduce jitter you must increase the number of averages or increase the measurement bandwidth.

If the bandwidth is reduced, you need to increase the number of averages to maintain the same uncertainty.

The greater the number of averages chosen, the more accurate the measurement, as this reduces jitter on the measurement. However, this must be considered against how long it takes to complete the measurement.

There is therefore a trade off between speed and the accuracy and uncertainty of a measurement.

Selecting the Resolution Bandwidth (RBW) Value

To set the RBW value, press **BW**, **RBW** and select whether the resolution bandwidth is to be set automatically, or to be set manually by you.

When the resolution bandwidth is set to Auto (default setting), the bandwidth is set automatically, and is dependent on the measurement frequency.

At measurement frequencies of 8 MHz or above, the resolution bandwidth is set automatically to 4 MHz.

At measurement frequencies less than 8 MHz, the resolution bandwidth is set automatically to approximately one third of the measurement frequency.

When the resolution bandwidth is set to manual (Man), you can manually specify the resolution bandwidth from a minimum of 1 Hz to a maximum of 8 MHz. The lower the resolution bandwidth setting, the longer the measurement will take. With a resolution bandwidth setting of 1 Hz, each measurement point may take up to 6000 seconds.

CAUTION

Do not switch to DC Coupling if your input signal contains a DC component. You risk permanently damaging your analyzer's front end components if you do this.

NOTE

For greater accuracy in your noise figure measurements, Keysight recommends that you use DC Coupling for measurement frequencies below 10 MHz, and AC coupling for frequencies greater than 20 MHz. When setting your analyzer to DC Coupled, make sure you do not have a DC component being fed into the analyzer input as you may damage your analyzer. Press the **Input/Output**, **RF Input**, then the **RF Coupling** key to set your analyzer to AC or DC Coupled. The RF Coupling setting is AC by default.

Setting Averaging

Increased averaging reduces jitter and provides more accurate measurement results. However, the measurement speed is sacrificed.

To reduce variance, there are two ways. One is to increase the Avg Time/Pt under the Sweep/Control menu. Another is to set the Average Num value under the Meas Setup menu.

Avg Time/Pt is the measurement duration for each of the two states (noise source on and noise source off) that occur at each frequency point. Therefore, for one result trace, the time required is the multiplication of 2 times the number of frequency points and the Avg Time/Pt value. Longer settings of Avg Time/Pt reduce the variance of the results, but slows the throughput. To set the point average time, press **Sweep/Control**, **Avg Time/Pt**, and set the average time for each point.

The Avg/Hold Num value under the Meas Setup menu is to set the number of traces that will be averaged. Press **MEAS SETUP**, **Averaging** to **On** and then enter the average number. The Noise Figure Measurement Application uses exponential averaging.

Compared to increasing the Avg Time/Pt, setting the Avg/Hold Num number will require more time to achieve a given variance, as the overhead time (for switching the noise source on and off) at each point is experienced during each sweep. Thus increasing Avg Time/Pt is more efficient while a shorter Avg Time/Pt with a higher Avg/Hold Num number gives more interactive results, with an earlier first view of the results.

Selecting the Input Attenuation Range

The noise figure measurement application has a default input attenuation calibration range of 0 dB to 8 dB, and a step size of 4 dB.

The disadvantage of wide ranges of attenuator calibration is the number of calibration sweeps, and the time the calibration routine takes. The advantage of wider ranges is freedom from needing to repeat the calibration when using a higher output power DUT.

In the Noise Figure Measurement Application, the attenuators do not autorange. There is therefore a risk of overdriving the analyzer. If the input signal power level is greater than –26 dBm in low band (0 to 3.6 GHz), or greater than –31 dBm in high band (above 3.6 GHz), the preamp can go into compression and the accuracy of your results will be adversely affected. In most cases, 0 dB attenuation is adequate.

A guide to the input power that can be handled by the X-Series analyzers at each frequency range is shown in Table 3-4 on page 75. To check for overdriving of the analyzer, that is, compression occurring at the preamp stage, set the attenuation (**AMPTD**, **Attenuation** tab) to 0 dB and note the noise figure of your DUT. Now increase the attenuation by one step (4 dB) by pressing the up-arrow key. If your noise figure changes too much, such as 0.3 dB, attenuation is required for accurate measurements. The error will decline to 40% as large with each additional 4 dB step of attenuation and then the remaining error with higher attenuation is about two-thirds as large as the change in NF observed. When you choose increased attenuation to avoid compression errors, you also get increased uncertainty due to the imperfectly calibrated noise of the analyzer relative to the noise of the DUT. Usually, any noise level that is large enough to cause compression is so large that it makes the analyzer noise an insignificant contributor of uncertainty.

Table 3-4 Power Detection and Ranging on X-Series Signal Analyzers

Frequency	**Attenuation Setting**	**Maximum Input Power for High Accuracy**	**Approximate DUT Characteristics**[a]
10 MHz to 3.6 GHz	0 dB	–26 dBm	Over the full bandwidth[b], a DUT with NF = 5 dB and Gain < 44 dB, or NF = 15 dB and Gain < 37 dB
	4 dB	–22 dBm	Gains 4 dB higher than the 0 dB attenuation case
	8 dB	–18 dBm	Gains 8 dB higher than the 0 dB attenuation case
	12 dB	–14 dBm	Gains 12 dB higher than the 0 dB attenuation case

Table 3-4 Power Detection and Ranging on X-Series Signal Analyzers

Frequency	Attenuation Setting	Maximum Input Power for High Accuracy	Approximate DUT Characteristics[a]
3.6 GHz to 26.5 GHz[c] (Analyzers with microwave preamplifiers)	0 dB	–31 dBm	A wide bandwidth DUT with NF = 5 dB and Gain <39 dB, or NF = 15 dB and Gain < 32 dB
	4 dB	–27 dBm	Gains 4 dB higher than the 0 dB attenuation case
	8 dB	–23 dBm	Gains 8 dB higher than the 0 dB attenuation case
	12 dB	–19 dBm	Gains 12 dB higher than the 0 dB attenuation case
3.6 GHz to 26.5 GHz[c] (Analyzers without preamplifiers)	0 dB	–14 dBm	A DUT with 80 MHz bandwidth, NF=10 dB and Gain up to 63 dB can be accommodated when using a 17 dB ENR noise source. With wider bandwidths, even more output noise can be accommodated. When no preamplifier is used in the analyzer, the input noise outside the preselector bandwidth (nominally 40 to 80 MHz) gets reflected without causing nonlinearities in the analyzer input stages.

a. The figures given in this table assume a 5 dB ENR noise source.
b. If the DUT has a narrower bandwidth than the 10 MHz to 3.6 GHz specified here, the DUT characteristics can be increased accordingly for bandwidths down to 12 MHz. For example, if the DUT has a bandwidth of 100 MHz, the DUT characteristics can be increased by a factor of 10 x log(3.59 x 109/100 x 106), that is by 15.6 dB. In this example with an attenuation setting of 0 dB, the Gain of a DUT with a 15 dB noise figure can be increased from 37 dB to 52.6 dB. For bandwidths narrower than 12 MHz, the allowable power does not increase further than it does at 12 MHz.
c. In the 3.6 – 26.5 GHz frequency range, the situation is considerably more complicated than in the low band case and footnote. The ability of the preamp to handle large signals is poorest at 3.6 GHz, the frequency for which the example in the table applies. The ability to handle large signals increases linearly with frequency, increasing about 11 dB at 26 GHz. Also, the allowable gain of the DUT does still increase as its bandwidth decreases, but only down to bandwidths of about 70 MHz.

To select the input attenuation calibration range, press **MEAS SETUP**, **Cal Setup** tab, **User Cal** and select the attenuation range you want using the **Min Atten** and **Max Atten** selections. Use Table 3-4 on page 75 as a guide to what range you require.

Setting the Input Attenuation used for Measurement

The attenuators cannot autorange. When making a measurement you must manually set the input attenuation to avoid overdriving the analyzer.

To set the input attenuation, press **AMPTD, Attenuation** Tab and enter the desired measurement attenuation using the numeric keys.

NOTE The measurement input attenuation must be within the calibrated attenuation range.

Setting up External LO Control

When the frequency converters are included in the measurements, the Noise Figure Measurement Application can help to control the LO of the DUT and/or system downconverter that will be used in the measurement system. If the DUT is a multi-stage converter, only one LO of the DUT can be controlled.

Adding External LO to List

Before setting the external LO control for a DUT or system downconverter, you first need to add the target LO to the external LO list. You can connect to the external LO through USB, GPIB, or LAN. In this example, the external LO is connected through LAN.

Step	Notes
1. Press **MEAS SETUP**, **Ext LO Setup**.	
2. Press **LO Select**.	In this dialog, you can also delete a highlighted external LO, or verify the connection status of an existing external LO by pressing **Delete Highlighted Source** or **Select Highlighted Source as DUT LO**.
3. In the **LAN** box of the dialog, enter the **IP Address** and press **Done**.	
4. Press **Add Specified IP Address**.	(Optional) You can also add the external LO using Connection Expert. Press Run Connection Expert....

Setting up DUT LO or System Downconverter LO

The setting up process for a DUT LO and a system downconverter LO is similar. Below is an example for setting up the DUT LO.

Step	Notes
1. Press **MEAS SETUP**, **Ext LO Setup**.	
2. Press **LO Select**.	
3. In the **LAN** box of the dialog, enter the **IP Address** and press **Done**.	
4. Press **Add Specified IP Address**.	(Optional) You can also add the external LO using Connection Expert. Press Run Connection Expert....

Step	Notes
5. Press **Select Highlighted Source as DUT LO**.	
6. On the Select dialog, press **Ext LO Setup**.	
7. Press **DUT LO Setup**.	.
8. In the **LO Settings** area of the dialog, set the parameters such as LO Power, Min Freq and Max Freq as needed:	The LO frequency in **MEAS SETUP**, **DUT Setup & Calibration...** should be set within the range of Min Freq and Max Freq values.

Using Loss Compensation

You can configure the noise figure measurement application to compensate for losses due to cabling and connectors, and those due to temperature effects that occur in the measurement setup. These can be between the Noise Source and the DUT (**Before DUT**), or between the DUT and the analyzer input (**After DUT**), or both. Loss compensation can be set either by specifying a single, fixed loss value, which gets applied at all frequencies, or using various loss values, specified in a table, applied across the frequency span. In the table mode, linearly interpolated values are used between each table entry.

Any device that causes loss will also generate excess noise, and this excess noise is proportional to the absolute temperature of the device causing the loss. You can compensate for this extra noise by specifying the temperature of the device causing the loss. This temperature dependent compensation is applied at all frequencies.

Examples where Loss Compensation is applied

This is important in cases such as:

– Amplifiers with waveguide input, where a lossy waveguide-to-coax adapter is needed.

– Transistors, where input and output tuners are required.

– Non-50Ω converters (such as TV tuners and amplifiers) where matching pads or transformers are required.

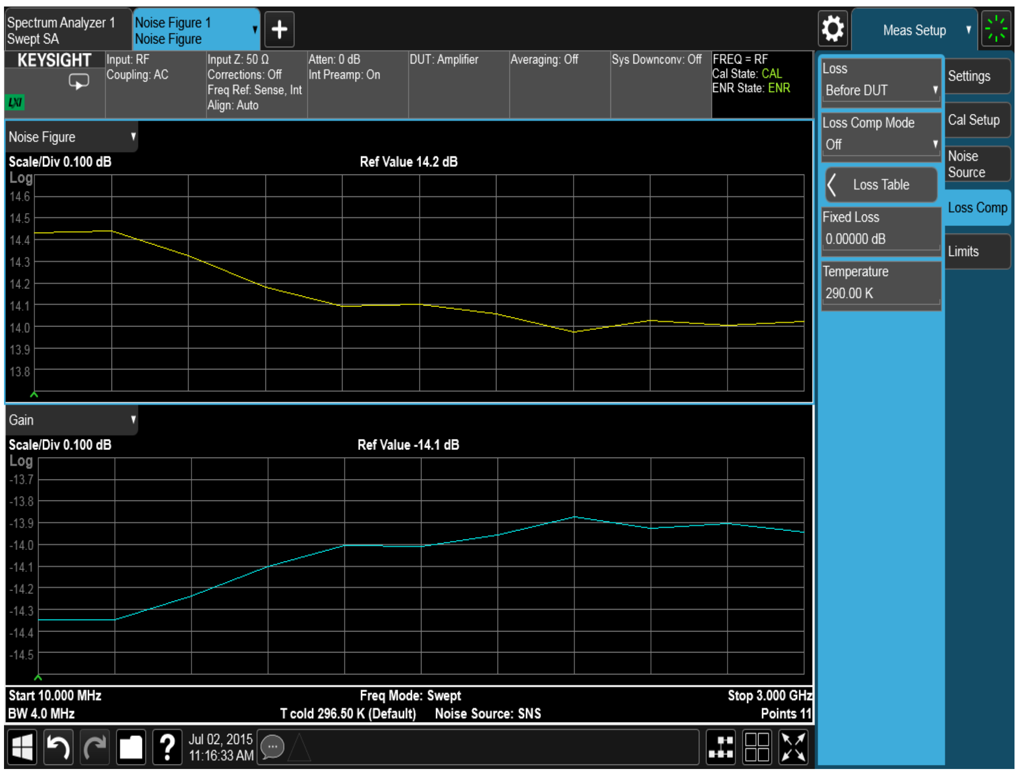
– Compensation for fixed attenuators used to improve SWR.

– Double sideband measurement modification (of receivers and mixers) to approximate single sideband results.

Configuring Fixed Loss Compensation

To configure fixed loss compensation follow the example below:

Step	Notes
1. Press **MEAS SETUP**, **Loss Comp** tab.	
2. Press **Loss, Before DUT** or **After DUT**, **Loss Comp Mode**, **Fixed**.	
3. Press **Fixed Loss** and enter the loss compensation value and press the **dB** termination key.	The lower limit is –100.000 dB, the upper limit is 100.000 dB, and the default is 0.000 dB.



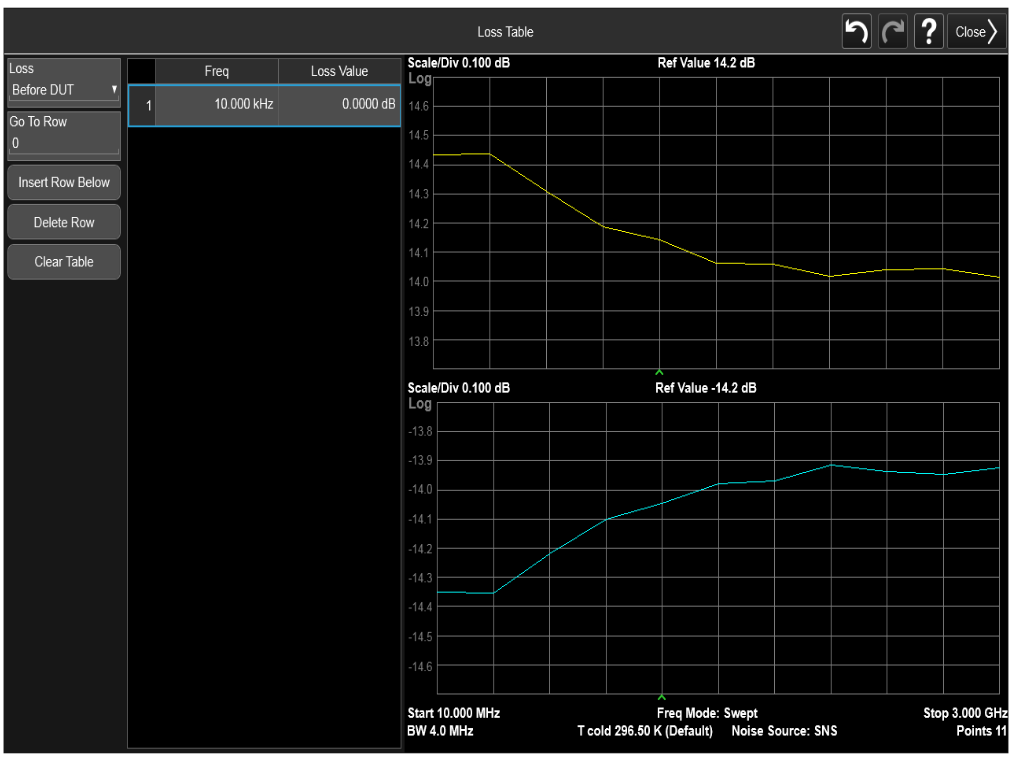
Step	Notes
4. Press **Temperature**, and use the numeric keys or the knob to enter the temperature of the device where the loss is occurring. This will normally be room temperature, which is 290 K.	It is important that you enter the correct temperature. This will give you better accuracy for you measurements.

Creating a Loss Compensation Table

Loss Compensation tables can have a maximum of 501 entries. To create a loss compensation table proceed as follows.

NOTE The Loss Compensation table frequency limits in the **Before DUT Table...** are specified in terms of the DUT's input frequencies and the **After DUT Table...** are specified in terms of the DUT's output frequencies. This is important when making frequency converting DUT measurements or using a system downconverter.

Step	Notes
1. Press **MEAS SETUP**, **Loss Comp** tab.	
2. Press **Before DUT** or **After DUT**, **Loss Table**.	You are presented with a Loss compensation table with one entry. See the following figure.



Step	Notes
3. Press the highlighted row and enter the Loss Frequency value in the table using the numeric keys. Terminate it using the unit menu.	
4. Enter the corresponding Loss Value. and press **dB**.	

Step	Notes
5. Repeat steps 3 to 4 until all the Loss Frequency and Loss Values you need are entered.	You can insert the Loss Frequency and Loss Values in the Loss Compensation Table in any order, as the Noise Figure Measurement Application automatically sorts the table list into ascending frequency order.

NOTE The Loss Compensation Table data is stored in CSV (Comma Separated Value) format. It is sometimes more convenient to use a text editor to edit or enter this data rather than to enter the data manually using the analyzer. Start by saving a table with at least one loss compensation value to memory, and then edit or add to the saved file.

Setting Temperature of Loss

Any device (cables, connectors and so forth) that causes a loss will also generate excess noise. The amount of excess noise so generated is proportional to the absolute temperature of the device causing the loss. You must compensate for this excess noise in the measurement, and this is done by specifying the temperature of the device. To set the temperature of the device causing the loss, proceed as follows:

NOTE The temperature you specify here is used both for **Fixed** loss compensation, and for all frequencies specified in a loss compensation **Table**.

To set the temperature of loss,

Press **MEAS SETUP**, **Loss Comp** tab, **Before DUT** or **After DUT**, **Temperature**, then enter a value using the numeric keypad and press **Enter**. The lower limit is 0.0 K, the upper limit is 29,650,000.0 K. The default is 290.0 K.

Viewing Measurement Results

Displaying the Measurement Results

The analyzer features a color display and a comprehensive set of display features to allow you to analyze the measurement results in detail, or to quickly obtain a pass/fail indication.

The following display features are available:

– Graph, Table, or Meter mode display
– Single or dual-graph display allowing any two available result types to be displayed simultaneously
– Zoom to display only one result graph on the display
– Markers for searching a trace, and for displaying point data more accurately than can be done with a trace alone
– Save the current active trace data to internal memory
– Switch the graticule on or off
– Switch the annotation on the measurement bar, screen, trace, and active function on or off

Selecting the Layout

You can display the measurement results in either:

– Graph format
– Table format
– Meter format

The default view provides a display of noise figure and gain on the dual-graph display. The upper graph is noise figure and the lower graph is gain.

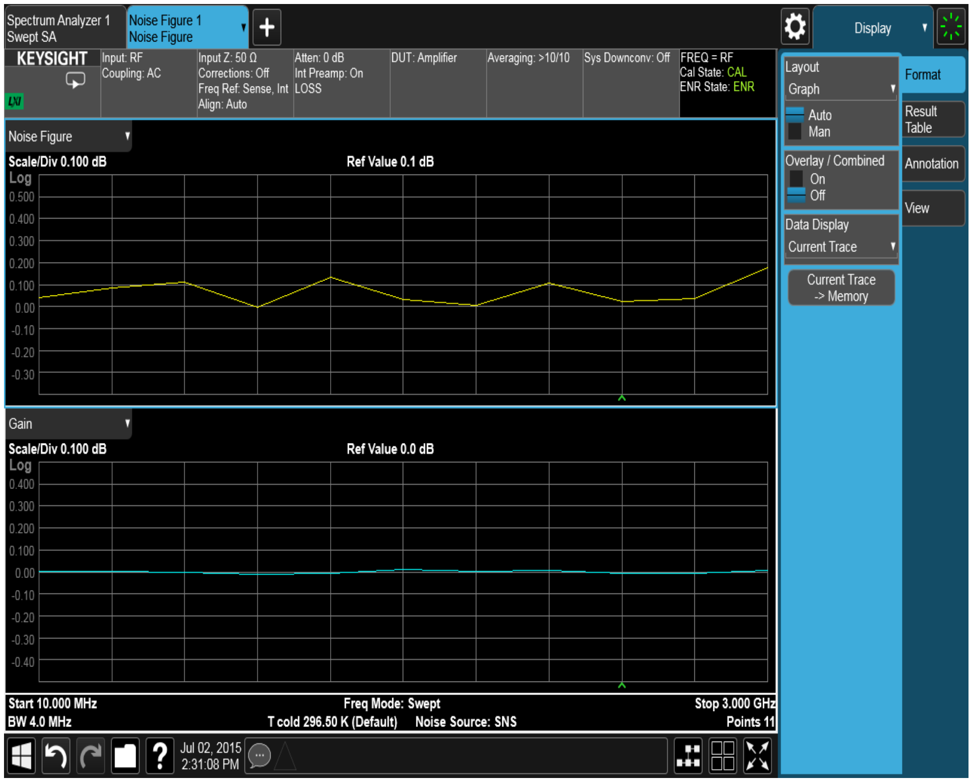
In all formats you can choose two result parameters you want to display.

To set the display format, press **Display**, **Layout** and then select **Graph**, **Table**, or **Meter** to select the display mode you want.

Navigating Around the Display

The active graph is highlighted by a blue border. noise figure is the active graph by default.

Figure 3-7 **Dual-graph Display**



To change the active graph, tap the desired window.

Selecting Result Types to Display

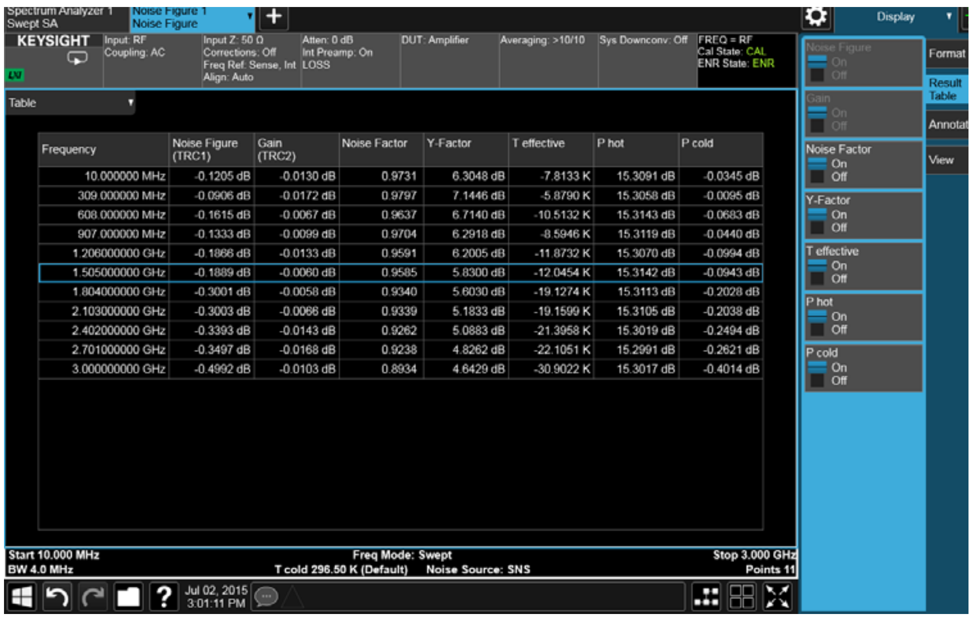
You can choose to display any pair of measurement results in all of the display format modes.

The measurement result types are as follows, with their units in parentheses:

- Noise Figure (dB)
- Noise Factor (linear)
- Gain (dB)
- Y Factor (dB)
- T effective (Kelvin, K)
- P hot (dB)
- P cold (dB)

To specify which measurement results are displayed,

Step	Notes
1. Press **Display, Layout, select Table**.	
2. Press **Results Table** and toggle **On** the result that you want to display.	



Setting the Scaling

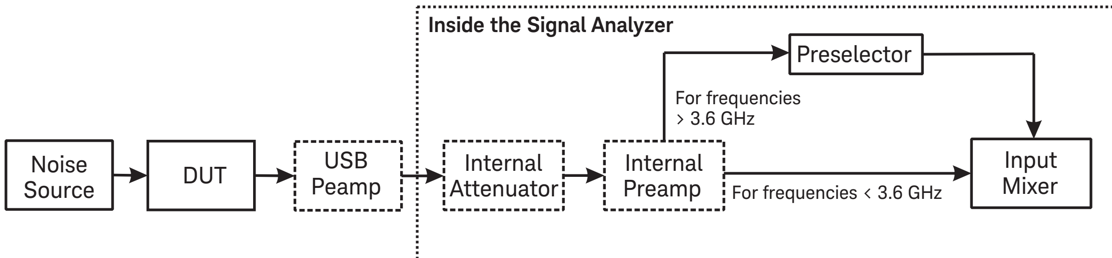
You can set the result’s scale parameters in the active graph.

Press the **AMPTD** to display the **Y Scale tab**. and press **Auto Scaling** to **On**. Setting **Auto Scaling** to **On** selects the optimum values for **Ref Value** and **Scale/Div**.

Calculating the Noise Power into Different Stages of the Noise Figure Measurement System

Figure 3-8 show the possible blocks in the signal path of the noise signal in the noise figure measurement. The blocks with dotted lines indicate that you can choose whether to use them or not. The non-linear components in the signal path include the USB Preamplifier, the internal preamplifier and the input mixer. The input noise power of these components should not exceed the maximum value for the linear range.

Figure 3-8 Blocks in the Signal Path of the Noise Signal in the Noise Figure Measurement



To calculate the noise power in different stages, Equation 3-2 is used:

Equation 3-2

$$P_{noise} = -174 + 10 \times log_{10}(BW) + 10 \times log_{10}(ENR_{linear} + F) + Gain_{dB}$$

in which,

- The unit of P_{noise} is dBm.
- -174 dBm/Hz is the thermal noise per hertz calculated from kT_0.
- BW is the bandwidth of the DUT, for most cases. The unit is Hz. If you are going to calculate the noise power of the input mixer for frequency ranges higher than 3.6 GHz, BW is the bandwidth of the preselector, which is usually below 80 MHz.
- ENR_{linear} is the excess noise ratio of the noise source. Normally, the ENR of a noise source is given in dB.

  $$ENR_{linear} = 10^{(ENR_{dB}/10)}$$

- F is the noise figure in linear terms of a part of the test system, which is from the DUT input to the input point of the noise power under calculation. For example, if you are calculating the noise power of the input mixer for frequency ranges below 3.6 GHz, the F includes the noise figure for the combination of DUT, USB Preamp, internal attenuator, internal preamp.
- $Gain_{dB}$ is the gain of a part of the test system, which is exactly the same part as that is used in F calculation. For example. if you are calculating the noise power of the input mixer for frequency ranges below 3.6 GHz, use the following equation.

$$Gain_{dB} = DUTGain + USBPreampGain + InternalPreampGain - Internal\ Attenuation$$

Calculating the Noise Figure for Noise Power Calculation

To calculate the noise power using Equation 3-2, you need to calculate the noise figure of a part of the test system. This section gives an example of calculating the noise figure of the combination of DUT, USB Preamp, internal attenuator, and internal preamp. It can be seen as 4 stage systems, so the total noise figure F can be calculated using Equation 3-3, in which the F and G are all in linear terms.

Equation 3-3

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3}$$

F_1 and G_1 are the noise figure and Gain of the DUT.

F_2 and G_2 are the noise figure and Gain of the USB Preamp. You can get a rough values from the Keysight USB Preamplifers Technical Overview, 5991-4246EN.

F_3 and G_3 are the noise figure and Gain of the internal attenuator. The noise figure of the internal attenuator is equal to its attenuation.

F_4 is the noise figure of the internal preamp. You can get the rough values from the specification guide of the signal analyzer. Note that the noise figure values from the specification guide is the noise figure of the instrument with the internal preamp turned on. As the internal preamp has high gain, this value is taken as the noise figure of the internal preamp here.

Further Information

Keysight Technologies produces three application notes about noise figures and their measurement. These are:

– Application Note 57-1

  Fundamentals of RF and Microwave Noise Figure Measurements

  http://cp.literature.keysight.com/litweb/pdf/5952-8255E.pdf

– Application Note 57-2

  Noise Figure Measurement Accuracy - the Y-Factor Method

  http://cp.literature.keysight.com/litweb/pdf/5952-3706E.pdf

– Application Note 57-3

  10 Hints for Making Successful Noise Figure Measurements

  http://cp.literature.keysight.com/litweb/5980-0288E.pdf

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