



Agilent X-Series Signal Analyzer

This manual provides documentation
for the following analyzers:

PXA Signal Analyzer N9030A

MXA Signal Analyzer N9020A

EXA Signal Analyzer N9010A

CXA Signal Analyzer N9000A

MXE EMI Receiver N9038A

N9069A & W9069A Noise Figure Measurement Application Measurement Guide



Agilent Technologies

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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 pre-amplifier, mixer, and IF amplifier that make up the system. By controlling the noise figure and gain of system components, you can directly control the noise figure of the overall system. Once the noise figure is known, system sensitivity can be easily 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.

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 signal and noise together and does not change the signal-to-noise ratio.

What does the Agilent N9069A/W9069A Noise figure Measurement Application do?

The Noise Figure measurement 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:

- Averaging
- Storage of a results file to internal memory
- Multiple data views; Graph, Meter and Table
- Result types including Noise Figure, Noise Factor, Gain, Y-Factor, Effective Temp, P hot and P cold
- Supports traditional 346x Series Noise Sources
- Supports N4000x Series Smart Noise Sources (SNS)
- Supports external source control using LAN



2 Making Measurements

This chapter begins with instructions common to all measurements, then details features available for Noise Figure measurements. For information specific to individual measurements, see the sections at the page numbers below.

“Making Basic Measurements” on page 12

“Making Frequency Converter Measurements” on page 51

“Advanced Features” on page 94

Setting Up and Making a Measurement

Making the Initial Signal Connection

CAUTION Before connecting a signal to the analyzer, make sure the analyzer can safely accept the signal level provided. The signal level limits are marked next to the RF Input connectors on the front panel.

See the Input Key menu for details on selecting input ports and the AMPTD Y Scale menu for details on setting internal attenuation to prevent overloading the analyzer.

Using Analyzer Mode and Measurement Presets

To set your current measurement mode to a known factory default state, press **Mode Preset**. This initializes the analyzer by returning the mode setup and all of the measurement setups in the mode to the factory default parameters.

To preset the parameters that are specific to an active, selected measurement, press **Meas Setup, Meas Preset**. This returns all the measurement setup parameters to the factory defaults, but only for the currently selected measurement.

The 3 Steps to Set Up and Make Measurements

Once the equipment is configured and the analyzer turned on, measurements can be set up using the following three steps. The sequence starts at the Mode level, is followed by the Measurement level, then finally, the analyzer parameters may be adjusted if needed.

Table 2-1 *The 3 Steps to Set Up and Make a Measurement*

Step	Action	Notes
1. Select and Set Up the Mode	a. Press Mode b. Press Noise Figure . c. Press Mode Preset . d. Press Mode Setup	All licensed, installed modes available are shown under the Mode key. Using Mode Setup , make any required adjustments to the mode settings. These settings will apply to all measurements in the mode.

Table 2-1 *The 3 Steps to Set Up and Make a Measurement*

Step	Action	Notes
2. Set Up the Measurement	a. Press Meas Setup	The measurement begins as soon as all measurement conditions are met. The resulting data is shown on the display or is available for export. Use Meas Setup to make any required adjustment to the selected measurement settings. The settings only apply to this measurement.
3. Select and Set Up a View of the Results	Press View/Display, Layout . Select a display format for the current measurement data.	Graph, Table, and Meter View are available.

Table 2-2 *Main Keys and Functions for Making Measurements*

Step	Primary Key	Setup Keys	Related Keys
1. Select and set up a mode.	Mode	Mode Setup, FREQ Channel	System
2. Select and set up the measurement.	Meas	Meas Setup	Sweep/Control, Restart, Single, Cont
3. Select and set up a view of the results.	View/Display	SPAN X Scale, AMPTD Y Scale	Peak Search, Quick Save, Save, Recall, File, Print

Making Basic Measurements

This section describes how to make basic noise figure measurements, covers the most common measurement related tasks, and uses a basic example to demonstrate measuring the noise figure and gain of a device such as an amplifier, which performs no frequency conversion.

The following topics can be found in this section:

[“Entering Excess Noise Ratio \(ENR\) Data” on page 12](#)

[“Setting the Measurement Frequencies” on page 18](#)

[“Setting the Bandwidth and Averaging” on page 21](#)

[“Calibrating the Analyzer” on page 23](#)

[“Displaying the Measurement Results” on page 31](#)

[“Indicating an Invalid Result” on page 44](#)

[“Example of a Basic Amplifier Measurement” on page 45](#)

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, an Agilent 346B, is a noise source that is powered by a pulsed +28 V supply on the rear panel of the analyzer. These need their ENR data to be entered manually, either by using the Alpha Editor or by transferring the data from the diskette supplied with Agilent noise sources to a USB storage device. See [“Entering ENR Table Data for Noise Sources” on page 13](#) for more information.

The other type of noise source, for example, an Agilent 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.

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 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 Agilent 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. Noise Source parameters and Auto Load ENR criteria can be changed by the user if needed. Press **Meas Setup, ENR, SNS Setup.**

NOTE The 346 Series noise sources from Agilent 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 Agilent 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.

Entering ENR Table Data Manually Enter the ENR data manually as follows:

- Step 1.** Power on the analyzer and wait the recommended time for warmup.
- Step 2.** Press **Mode, Noise Figure**.
- Step 3.** Press **Meas Setup, ENR**.
- Step 4.** Press **Meas Table** or **Cal Table** to select the ENR table for which you wish to enter data.

NOTE To enter common measurement and calibration ENR data, press **Use Meas Table Data for Cal** to underline **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**.

Step 5. Optional Step

Press **Serial #**, enter the noise source serial number using the Alpha Editor or an external USB keyboard, and press **Done**.

Step 6. Optional Step

Press **Model ID**, enter the noise source model number using the Alpha Editor or an external USB keyboard, and press **Done**.

Step 7. Press Edit.

An ENR Table appears on the left side of the display, and a table editing and navigation menu on the right side. See [Figure 2-1](#).

NOTE To clear an existing table, press **Meas Setup, ENR, Meas Table, Clear Table**.

Step 8. Press **Frequency** to move the highlight to the Frequency column. Enter the frequency value 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.

Step 9. Enter the corresponding ENR value of the ENR list. Press dB to terminate.

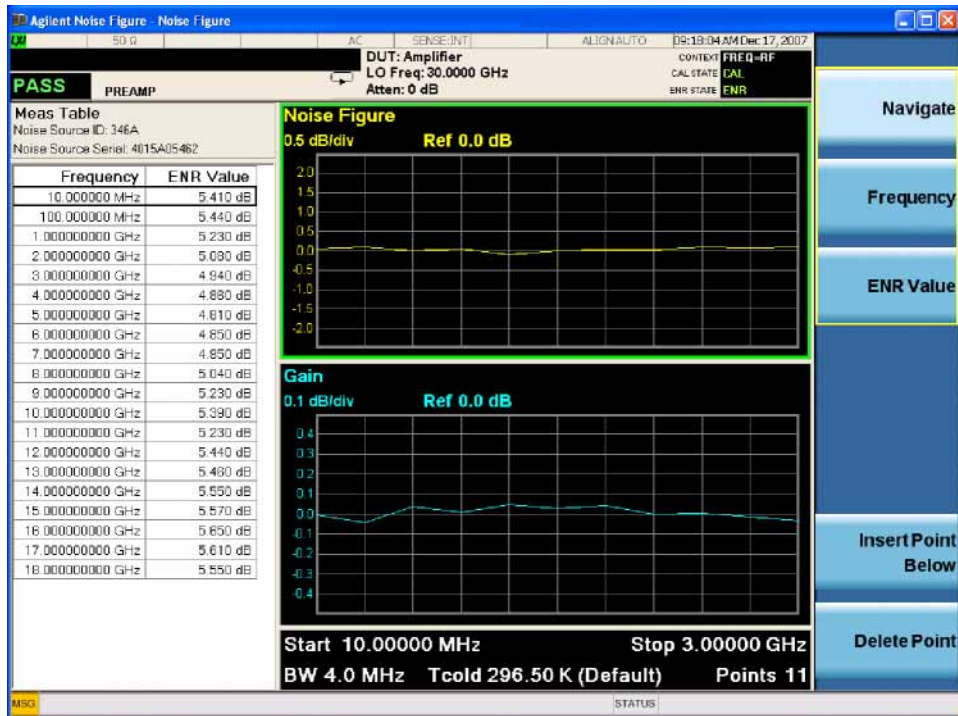
Step 10. Read the note (below) or repeat steps 8 to 9 until all the frequency and ENR values you need are entered.

NOTE 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.

Step 11. After completing the ENR table entries, press **Return** to return to the ENR menu.

Figure 2-1

ENR Table



Step 12. Optional Step

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 15.

NOTE 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:

Step 1. Press **Save, Data, ENR Table** or **Cal Table**.

Step 2. Press **Meas (Common) Table** or **Cal Table, Save As...** and navigate to the location where you want the file to be stored.

Step 3. Press **File Name** to name your file if you do not want to use the default name.

NOTE

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.

Step 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 1. Press **Recall, Data (Import), ENR Table**.

Step 2. Press **ENR Meas/Common Table, Open**.

Step 3. Select the desired file from the list of saved ENR tables and press **Open**.

Entering 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 enter a Spot ENR value:

Step 1. Press **Meas Setup, ENR**.

Step 2. Press **Spot**, Spot ENR.

Step 3. Enter an ENR value using the numeric keys and press **Enter**. The default value is 15.200 dB.

NOTE

If you are using a noise source with a calibrated ENR list and the frequency you want to measure is not a listed ENR value, then you need to interpolate the ENR list to an appropriate value.

To Enable Spot ENR Mode

Step 1. Press **Meas Setup, ENR**.

Step 2. Press **ENR Mode** to underline **Spot**.

Entering a Spot T_{hot} Value When making measurements you can enter a specific Spot T_{hot} value. The Spot T_{hot} value is applied across the whole measurement frequency range.

To enter a Spot T_{hot} value:

Step 1. Press **Meas Setup, ENR, Spot.**

Step 2. Press **Spot T Hot.**

Step 3. Enter a T_{hot} value using the numeric keys and press **Enter**. The default value is 9892.80 K.

To Enable Spot T_{hot} Mode

Step 1. Press **Meas Setup, ENR.**

Step 2. Press **Spot, Spot T Hot.**

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.

Changing the User T_{cold} Value Manually

To change the User T_{cold} value:

Step 1. Press **Meas Setup, ENR.**

Step 2. Press **T Cold, User.**

Step 3. Enter the T_{cold} temperature using the numeric keys on the front panel, and press **Enter**.

Loading the User T_{cold} Value from an SNS To automatically load the SNS T_{cold} value:

Step 1. Make sure that the SNS is properly attached to the analyzer.

Step 2. Press **Meas Setup, ENR.**

Step 3. Press **T Cold, SNS T Cold** to underline On.

Step 4. Press **User T Cold From SNS.**

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 Channel, 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 1. Press **FREQ Channel, Freq Mode**.

Step 2. Press **Swept** to select the Sweep mode.

Step 3. Press **Start Freq**, enter the value using the key pad and terminate it using the unit menu keys

Press **Stop Freq**, enter the value using the key pad and terminate it using the unit menu keys

Or use the **Center Freq** and the **Span** keys to set the desired values.

Step 4. Press **Sweep Points**, enter the number of measurement points using the numeric keys 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:

Step 1. Press **FREQ Channel, Freq Mode**.

Step 2. Press **List** to set the frequency mode to 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, using the **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.

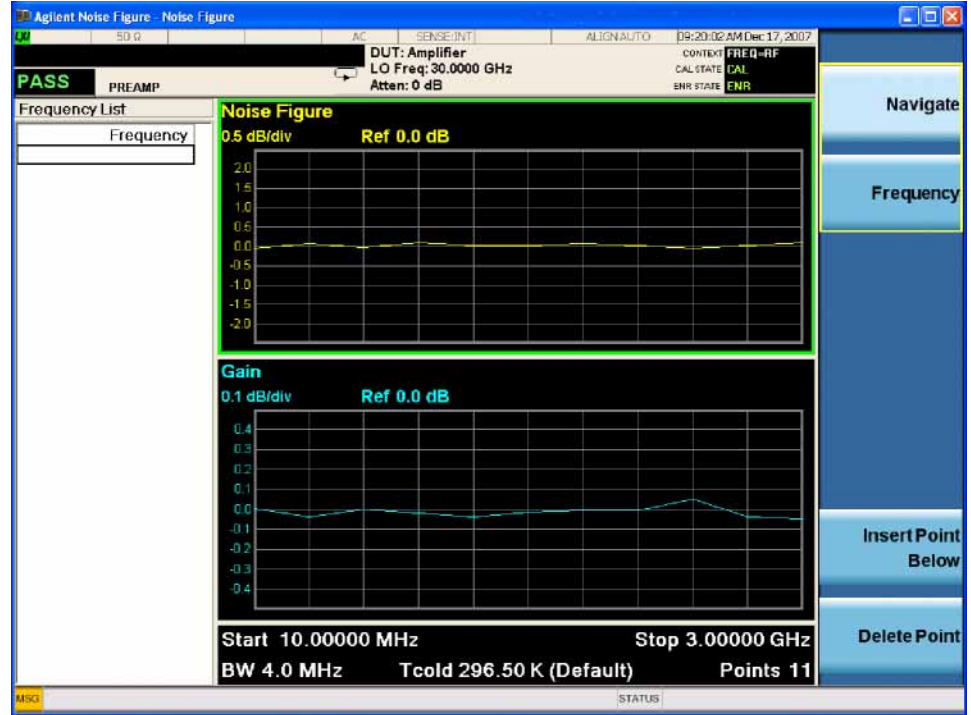
To Create a Frequency List Manually

Step 1. Press **FREQ Channel, Freq Mode, List**.

Step 2. Press **Edit Frequency List, Edit**.

A Frequency List table appears on the left side of the display.

Figure 2-2 An Empty Frequency List



Step 3. Press **Frequency**, enter the frequency value in the table using the numeric keys, and terminate it using the unit menu keys.

NOTE You do not need to enter the frequency values in ascending order, as the analyzer continually sorts the values into ascending order.

Step 4. Read the note below or repeat step 3 until your list is complete.

NOTE 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.

Step 5. Save the Frequency List to the analyzer internal memory.

NOTE If you do not save the frequency list, you may lose the data. This depends on your Power On selection. If **System, Power On, Mode and Input/Output Defaults** is selected, the values from the list that was last in use fills the table.

Editing a Frequency List

Step 1. Press **FREQ Channel, Edit Frequency List, Edit.**

Creating a Frequency List from Sweep Points

You can create a frequency list from the swept mode frequency and points data.

To set the analyzer to use the swept mode data:

Step 1. Press **FREQ Channel, Edit Frequency List.**

Step 2. Press **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.

NOTE

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

To set a fixed frequency:

Step 1. Press **FREQ Channel, Freq Mode, Fixed.**

Step 2. Press **Fixed Freq** and enter the frequency value using the numeric keys and the unit termination menu keys.

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 Value

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, Agilent 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.

Step 1. Press **BW**, **RBW** and select whether the resolution bandwidth is to be set automatically, or to be set manually by you.

Step 2. Enter your resolution bandwidth using the numeric keys and terminate by using the unit termination keys.

Setting Averaging

Increased averaging reduces jitter and provides more accurate measurement results. However, the measurement speed is sacrificed. The maximum number of averages allowed is 10,000, and the default value is 10. The default setting, however, is Off.

Enabling Averaging

Averaging can be enabled by setting the Averaging to On. To disable averaging set Averaging to Off.

Setting the Number of Averages

To set the number of averages you want:

Step 1. Press **Meas Setup**, **Avg Number** to underline **On**.

Step 2. Enter the numeric value you want using the numeric key pad and press **Enter**.

Averaging Mode

The Noise Figure Measurement application uses exponential averaging. With exponential averaging, the first average is done for every point in the sweep, then the second average for every point and so on. This is called “sweep averaging”. After the average number is reached, subsequent averages affect the average total exponentially, that is, if the average number is set to 10, then each subsequent average affects the running average by 1/10th.

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 which 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**, **Apply Calibration** to underline **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”. See [“Indicating an Invalid Result” on page 44](#) for an explanation of these conditions.

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 right corner 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 right corner 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 right corner of the display switches to a yellow `~CAL` message. This would happen, for example, if you change the RBW after calibrating but before measuring.

To Perform a Calibration

- Step 1.** Verify that the correct ENR table is loaded in the analyzer, or input the ENR values of the noise source into the analyzer’s measurement table or calibration table.

See [“Entering ENR Table Data for Noise Sources” on page 13](#) for more details.

- Step 2.** Press **FREQ Channel, Freq Mode** and select the desired mode.
- Step 3.** Press **Start Freq**, enter the numeric value you want using the key pad, and terminate by selecting a unit key.
- Step 4.** Press **Stop Freq**, enter the numeric value you want using the key pad, and terminate by selecting a unit key.
- Step 5.** Press **Points**, enter the numeric value you want using the key pad, and press **Enter**.
- Step 6.** Press **BW, RBW Auto Man** to **Auto**.
- Step 7.** Press **Meas Setup, Average Num On Off** to **On**, enter the numeric value you want using the key pad, and press **Enter**

NOTE

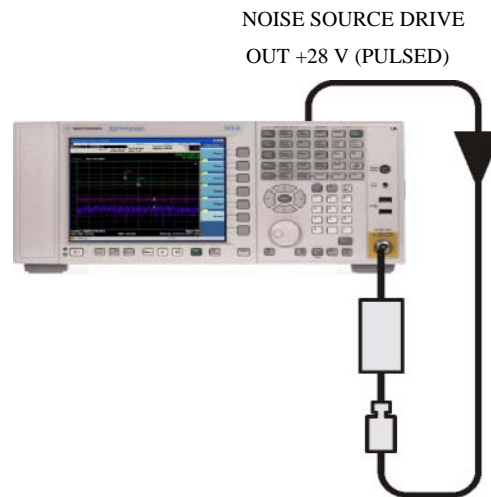
If the analyzer is an MXA/EXA/CXA, go to [step 9](#).

If the analyzer is a PXA, an Internal Cal is provided to perform the analyzer calibration without changing the connection. This is only used when the noise source is directly connected to the RF Input of the analyzer and no other test fixtures are required. Go to [step 8](#) for Internal Cal. In other cases, go to [step 9](#). Note that the uncertainty of the Internal Cal will be larger than User Cal. If you need the most accurate data, use the User Cal and follow the [step 9](#).

- Step 8.** Connect the noise source and the DUT to the analyzer input. See [Figure 2-3](#). Choose the calibration type to be Internal Cal by pressing **Meas Setup, Cal Setup, Internal Cal**. Then go to [step 11](#).

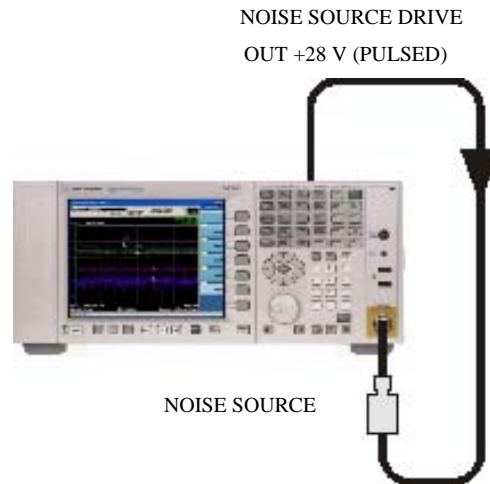
Figure 2-3

X-Series Calibration - Internal Cal



Step 9. Connect the noise source output directly to the analyzer input, as shown in [Figure 2-4](#).

Figure 2-4 X-Series Calibration - User Cal



NOTE

You may need to use adaptors to connect the noise source output to the analyzer input during calibration. The connectors you use need to be included in the measurement. 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 96](#) has an explanation of this.

Step 10. If required, select an input attenuator range by pressing **Meas Setup**, **Cal Setup**, **User Cal** (to activate the key), **User Cal**. The User Cal menu contains the keys that enable you to set the minimum and maximum input attenuation.

See [“Selecting the Input Attenuation Range” on page 28](#) for more details on input attenuation.

Step 11. Press **Meas Setup**, **Calibrate Now**, press **Enter** or select **OK** to start the calibration.

The analyzer performs the calibration, displaying a progress bar while this is happening.

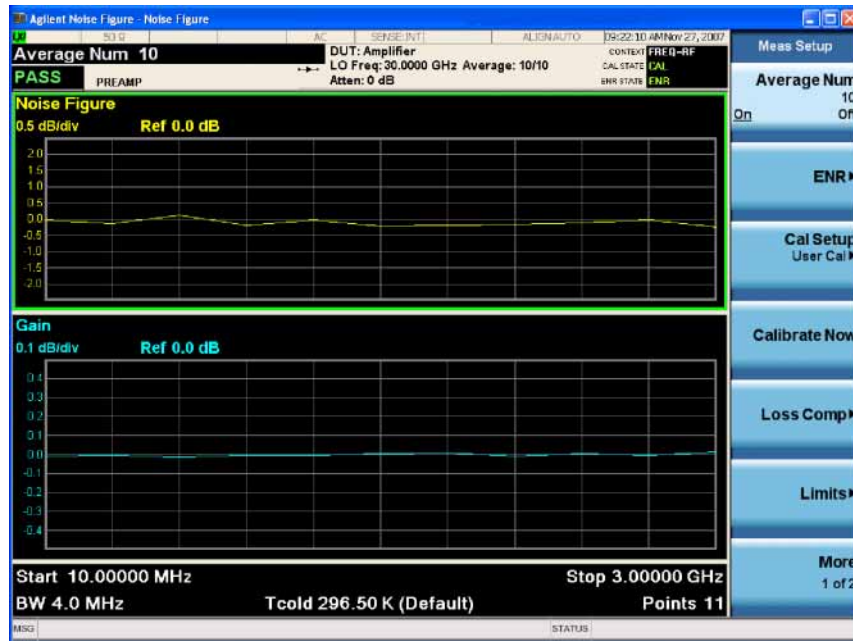
When the calibration is finished the CAL STATE on the right corner of the screen changes from a red UNCAL to a green CAL annotation.

NOTE

In PXA, MXA, and EXA, if any input frequencies are in high band, that is above 3.6 GHz, the Calibrate Now 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, More, Optimize Preselector**) allows the adjust values to be collected again without the calibration acquisition results.

Figure 2-5



NOTE If you do not have either a High Band Preamp, or an external preamp and you are calibrating above 3.6 GHz using a PXA, MXA or EXA, 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.

NOTE When using external preamps 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 other of the preamps is going into compression, use attenuation prior to that preamp to prevent compression. The analyzer's internal attenuator will only affect compression occurring in the internal preamp. It will not have any effect on any compression occurring in the external preamp.

Selecting the Input Attenuation Range

The Noise Figure Measurement Application has a default input attenuation calibration range of:

PXA	0 dB to 8 dB, and a step size of 4 dB
MXA	0 dB to 8 dB, and a step size of 4 dB
EXA	0 dB to 10 dB, and a step size of 10 dB
CXA	0 dB to 8 dB, and a step size of 4 dB

PXA, MXA, and EXA:

See “CXA:” on page 30.

The disadvantage of wide ranges of attenuator calibration is the number of calibration sweeps, and hence, 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 -56 dBm in low band (0 to 3.6 GHz), or greater than -61 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 X-Series analyzers at each frequency range is shown in [Table 2-3 on page 29](#). To check for overdriving of the analyzer, that is, compression occurring at the preamp stage, set the attenuation (**AMPTD Y Scale, Attenuation**) 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 by more than 0.5 dB, attenuation is required. Repeat this process until you have found the lowest level of attenuation that gives you a stable noise figure result, and use this attenuation level for your measurements.

Table 2-3 Power Detection and Ranging on X-Series Signal Analyzers^a

Frequency	Attenuation Setting	Maximum Input Power for High Accuracy	Approximate DUT Characteristics
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
3.6 GHz to 26.5 GHz ^c (MXA Only)	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 (EXA Only)	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. EXA does not have a high band preamp, so 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 the table (above) assume a 5 dB ENR noise source and that the preamp is On.
- 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 $10 \times \log(3.59 \times 10^9 / 100 \times 10^6)$, 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:

- Step 1.** Press **Meas Setup**, **Cal Setup**, **User Cal** (to activate the key), **User Cal**, and select the attenuation range you want using the **Min Atten** and **Max Atten** keys. Use [Table 2-3 on page 29](#) as a guide to what range you require
- Step 2.** Press **dB** to terminate the attenuator range entry.

Setting the Input Attenuation used for Measurement

The attenuators cannot autorange. Hence, when making a measurement you must manually set the input attenuation to avoid overdriving the analyzer. To set the input attenuation:

- Step 1.** Press **AMPTD Y Scale**, **Attenuation** and enter the desired measurement attenuation using the numeric keys.

NOTE

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

- Step 2.** Press **dB** to complete the attenuation setting.

CXA:

See [“PXA, MXA, and EXA:” on page 28](#).

The disadvantage of wide ranges of attenuator calibration is the number of calibration sweeps, and hence, 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. The maximum noise power handling capability of the CXA is more limited than in other X-Series analyzers. If the DUT output noise is excessive, large signal overload errors in the analyzer can create noise figure and gain measurement errors. These errors are negligible when the DUT has a sum of gain and effective input noise of 48 dB or less. When it is more, additional RF attenuation should be used. In this expression, “effective input noise” is the power sum of the noise figure of the DUT and the ENR of the noise source. For example, if the ENR is 6 dB and the NF is 6 dB, the effective input noise is 9 dB.

To check for overdriving of the analyzer, that is, compression occurring at the preamp stage, set the attenuation (**AMPTD Y Scale**, **Attenuation**) 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 by more than 0.5 dB, attenuation is required. Repeat this process until you have found the lowest level of attenuation that gives you a stable noise figure result, and use this attenuation level for your measurements.

To select the input attenuation calibration range:

- Step 1.** Press **Meas Setup**, **Cal Setup**, **User Cal** (to activate the key), **User Cal**, and select the attenuation range you want using the **Min Atten** and **Max Atten** keys. Use [Table 2-3 on page 29](#) as a guide to what range you require
- Step 2.** Press **dB** to terminate the attenuator range entry.

Setting the Input Attenuation used for Measurement

The attenuators cannot autorange. Hence, when making a measurement you must manually set the input attenuation to avoid overdriving the analyzer. To set the input attenuation:

- Step 1.** Press **AMPTD Y Scale**, **Attenuation** and enter the desired measurement attenuation using the numeric keys.

NOTE

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

- Step 2.** Press **dB** to complete the attenuation setting.

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 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 display 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:

Step 1. Press **View/Display, Layout**.

Step 2. Select **Graph, Table, or Meter** to select the display mode you want.

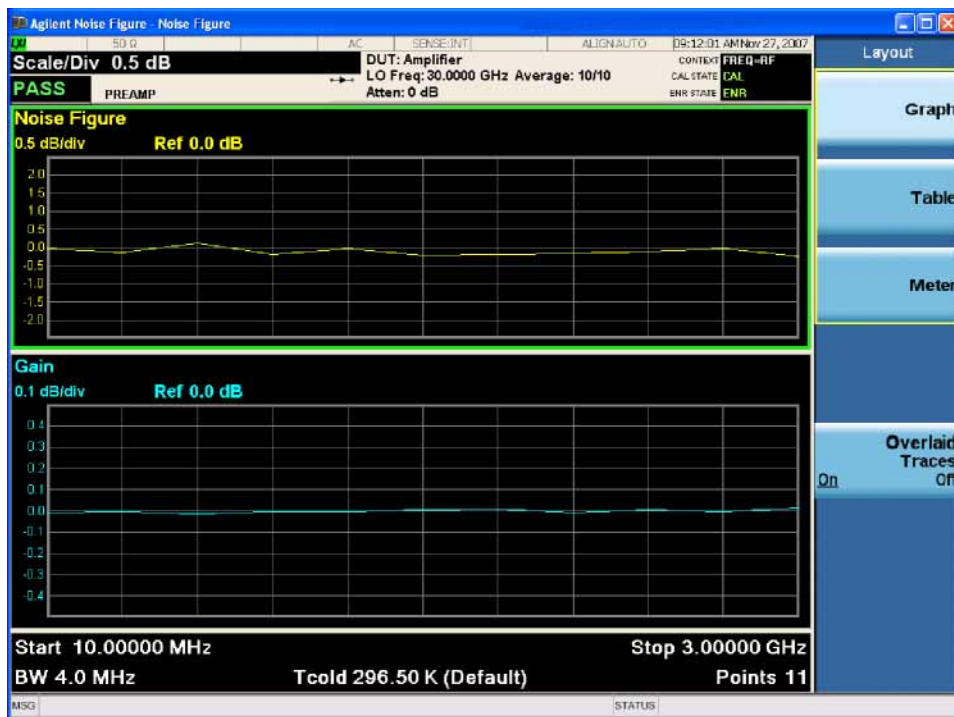
Navigating Around the Display

Active Graph

The active graph is highlighted by a green border. Noise Figure is the active graph by default.

Figure 2-6

Dual-graph Display



Changing the Active Graph

To change the active graph, press the **Next Window** key



below the display. This key allows you to set the upper or lower graph as the active graph.

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 1. Press **Trace/Detector**.

Step 2. Press **Selected Trace** to underline 1, and select the result that you want to display by pressing **Data (Result Type)**. These results will be displayed in the upper display window when View/Display, Layout is set to Graph.

Step 3. Press **Selected Trace** to underline 2, and select the result type that you want to display **Data (Result Type)**. These results will be displayed in the lower display window when View/Display, Layout is set to Graph.

NOTE

If you press the **AMPTD Y Scale** key while View/Display, Layout is set to Graph, the scale menu keys for the active measurement are shown.

Graphical Features

Viewing a Single Graph

While in graph format mode, you can press the **Zoom** key, located below the display,



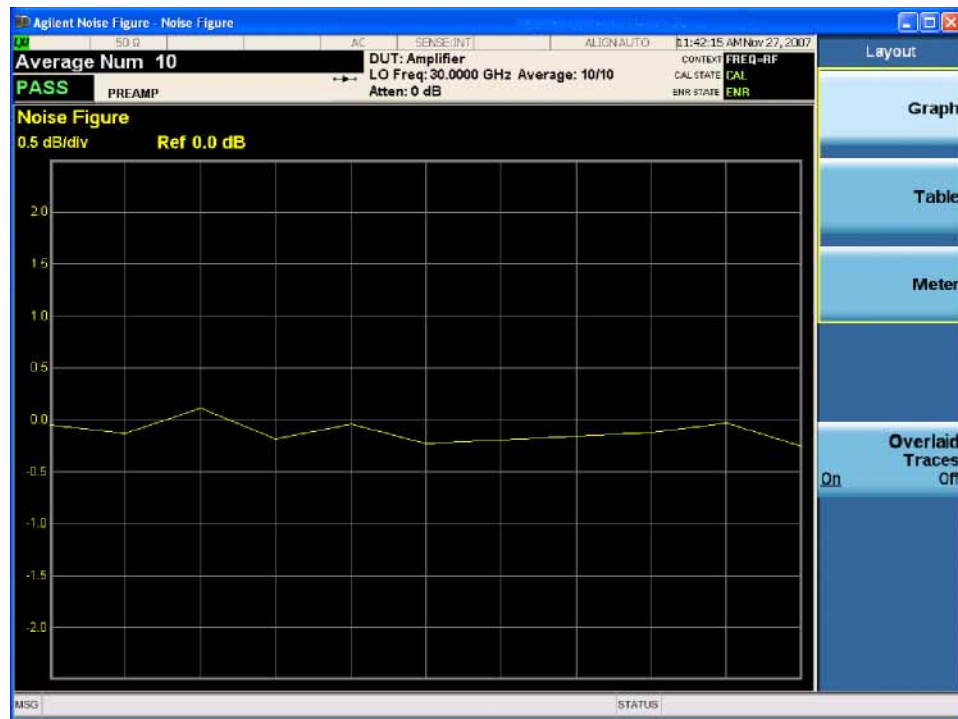
and the active graph fills the display as a single graph, as shown in [Figure 2-7](#). Pressing the Zoom key again returns the display to dual-graph.

NOTE

Expanding the graph to a single window with this key results in a loss of the start and stop frequency information at the bottom of the screen. If you want to see this information as well as enlarge the graph, you can do so using a USB mouse. Connect the mouse to one of the USB ports, navigate to the divider line between the two graphs, and drag this line to enlarge the desired graph and retain the frequency information.

Figure 2-7

Displaying a Single Graph



NOTE

When in single graph mode, pressing the **Next Window** key



displays the other single graph.

Turning the Graticule On and Off

When **Graticule** is set to **On**, the graticule divisions are displayed on the screen. This is the default setting. When **Graticule** is set to **Off**, the graticule lines are not displayed on the screen.

To turn the graticule on or off:

- Step 1.** Press **View/Display, Display**.
- Step 2.** Press **Graticule** to select **Off** or **On** as required.

Figure 2-8 Typical Graph with Graticule Switched Off



Turning the Measurement Bar Annotation On or Off

When **Meas Bar** is set to **On**, the measurement bar annotation is displayed. This is the default setting. When **Annotation** is set to **Off**, the annotation is not displayed.

To turn the annotation on or off:

- Step 1.** Press **View/Display, Display**.
- Step 2.** Press **Annotation, Meas Bar** and select **On** or **Off** as required.

NOTE Follow the preceding steps substituting Screen, Trace, or Active Function to toggle their annotation on or off. The default settings are:

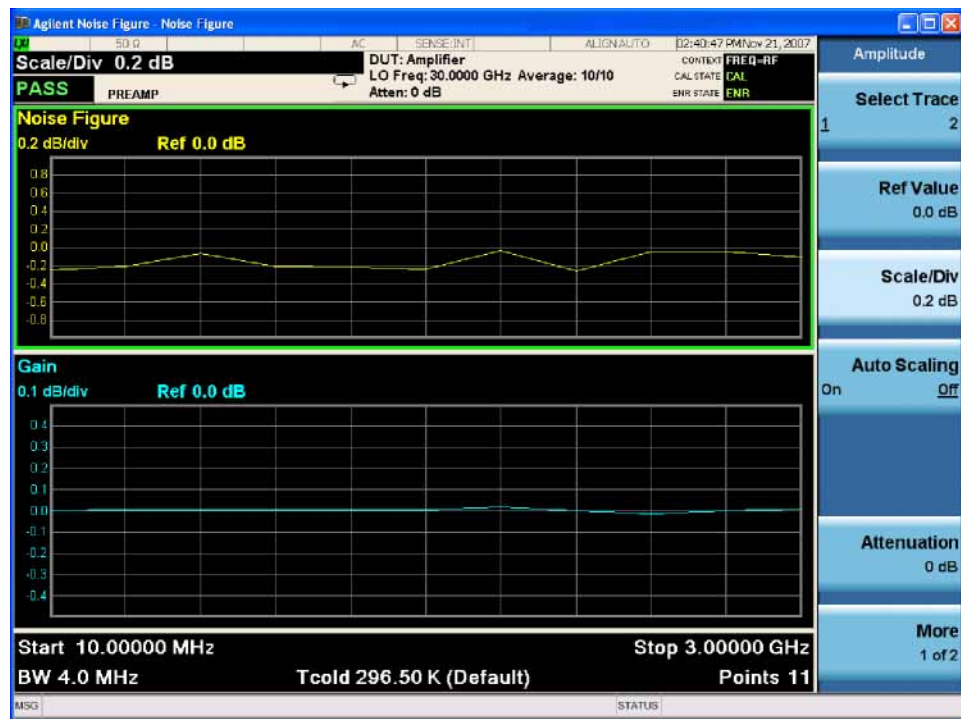
- Screen On
- Trace Off
- Active Function On

Setting the Scaling

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

Press the **AMPTD Y Scale** key to display the Y Scale menu. You can set the scale for the measurement display manually, or press the **Auto Scaling** key. Setting **Auto Scaling** to **On** selects the optimum values for **Ref Value** and **Scale/Div**.

Figure 2-9 Typical Noise Figure Displayed on a Graph



NOTE If limit line **Display** is set to **On**, and Auto Scaling is enabled or the scale is changed, the limit lines may no longer appear in the display.

Setting Noise Figure Scale

NOTE The following can also be applied to other result types.

Press **AMPTD Y Scale**, **Scale/Div** and change the value using the front-panel knob or the numeric keys. Values entered using the numeric keys can be terminated by pressing the appropriate termination key.

NOTE

Instead of setting the **Scale/Div** manually, you can let the analyzer choose a suitable value that will cause the measurement trace to be displayed over the full range of the display window. To do this, set the **Auto Scaling** key to **On**.

Setting the Reference Value

Step 1. Press **AMPTD Y Scale**.

Step 2. Press **Ref Value** and change the value using the front-panel knob or the numeric keys. Values entered using the numeric keys can be terminated by pressing the appropriate termination key.

Working with Markers

NOTE

The marker functionality only applies when you are working in graph format.

The function of the Marker keys enable you to measure the frequency and measurement results by placing a diamond-shaped marker at a point on the trace. The measurement results displayed depend on the result type selected.

The analyzer has 4 markers, The markers can be coupled to both the lower graph trace and upper graph trace.

Each marker can be enabled as a normal or delta marker. The active marker's frequency is displayed in the active function area, and at the top of the active window.

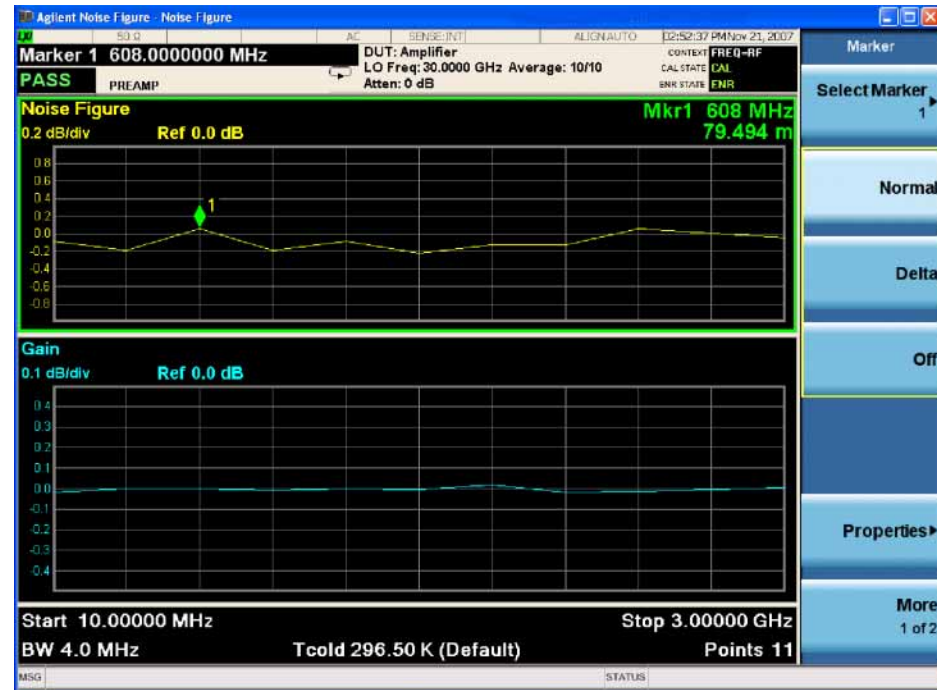
Selecting Markers To select a marker:

Step 1. Press **Marker**, Select Marker. Marker 1 is selected by default. If you wish to select marker 2, 3, or 4, press **Select Marker**.

Step 2. Press **Normal** or **Delta** to select your type of marker(s).

Figure 2-10

A Normal State Marker



A marker is placed on trace 1. Turn the knob or use the up- and down-arrow keys to place the markers at the point on the trace you want to measure, or use the numeric keys to enter the frequency of interest. The marker frequency and marker result are displayed in the active function area.

NOTE

It is possible to place a marker at an interpolated position on the graphs by manually entering the frequency point using the numeric keypad or external keyboard.

Marker Trace

You can assign a specific marker to one of the traces

Press **Marker**, **Properties**, **Select Marker**, **1**, **2**, **3**, or **4**, **Marker Trace**, **Trace 1** or **Trace 2**.

To Turn an Active Marker Off

To turn an active marker off, press the **Off** key. This also removes the marker annotation from the top of the active window, and the marker frequency from the active function area.

To Switch All the Markers Off

To switch all the markers off press **Marker**, **More**, **All Markers Off**. This turns off all the markers and associated annotation.

Changing the Marker States

To Use Delta Markers

The **Delta** key places a reference marker at the current position of the active marker. The delta markers enable you to measure the difference between the reference marker and the delta marker position on the trace. Turn the knob to place the delta marker to the point on the trace you want to measure. The delta marker has its

frequency and measurement result value differences annotated relative to the reference marker on the marker tab at the bottom of the screen. The delta marker has its actual frequency value displayed in the active function area. See [Figure 2-11](#) on page 40.

Figure 2-11

The Delta Marker State Enabled



To activate a Delta marker:

- Step 1.** Press **Marker**, Select Marker.
- Step 2.** Press the key to select the marker of interest.
- Step 3.** Press **Delta** and use the front-panel knob to move the Delta marker from the reference marker. The annotation on the top of the active window displays the difference between the reference marker and the delta marker. The frequency of the delta marker is displayed in the active function area at the top of the screen.

Searching with Markers

The **Peak Search** key accesses a further menu which allows you to place an active marker on the minimum or maximum points of a trace or find the next peak to the right or left when using a Normal marker.

When using Delta markers, you can search for the Minimum Peak to Maximum Peak on the trace. You can set these to repeat continuously when you toggle the **Continuous Peak Search** key to **On**.

It should be noted that the Search function operates on the active trace. The active trace is always indicated by a green border surrounding the graph. See [Figure 2-12](#) on page 41.

Searching for Min or Max Point You need to have activated a Normal marker to perform a minimum or maximum search.

Figure 2-12 Typical Trace Showing Maximum Point Found



To search for the maximum point:

- Step 1.** Press **Peak Search, More, Peak Criteria.**
- Step 2.** Press **Max.**

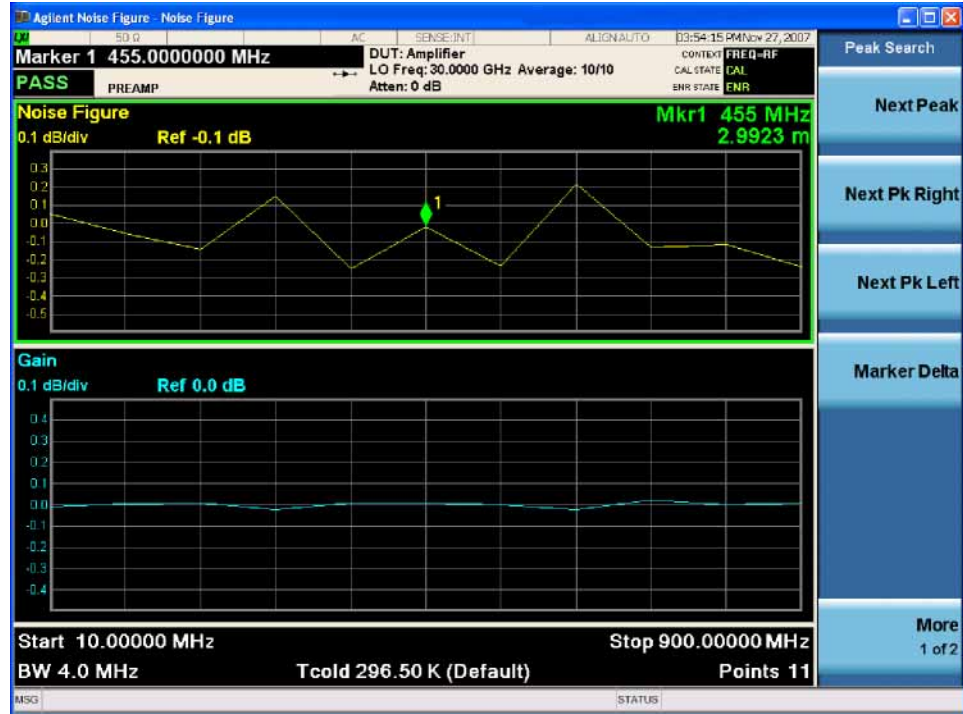
If you want to continuously find the maximum point on the trace, press **Peak Search, More,** and toggle **Continuous Peak Search** to **On.**

Making Measurements

Making Basic Measurements

Searching for the Next Peak

Step 1. Press **Peak Search** and use the front-panel knob to position the marker on the peak of interest.

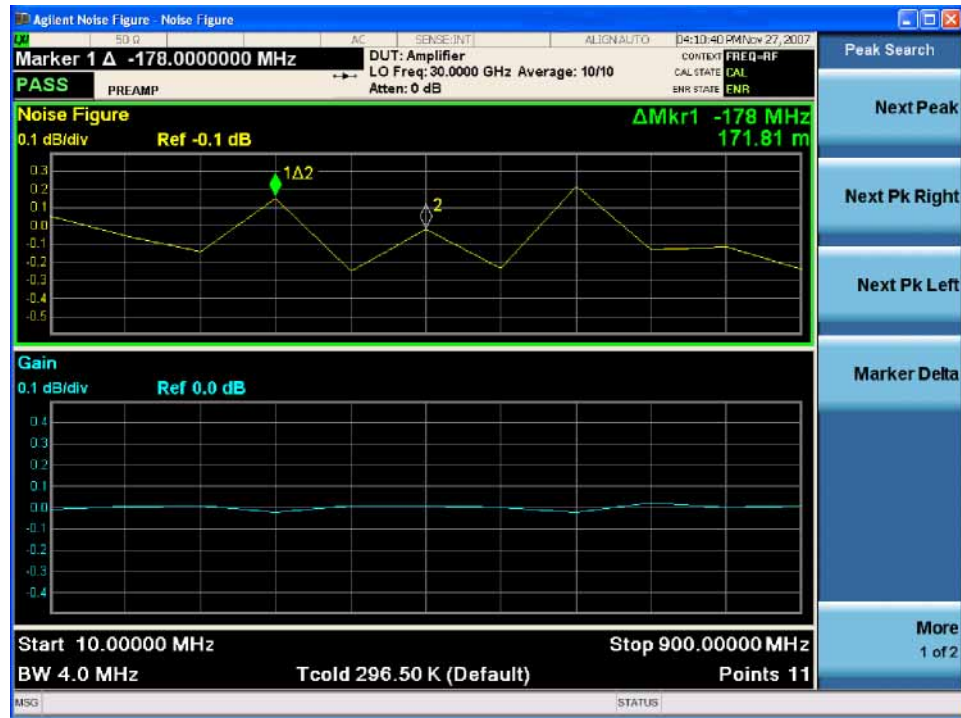


Step 2. Press **Marker Delta, Next Pk Right**.



The marker is now positioned on the peak point in the section of the trace between the current position and the right edge of the screen.

Step 3. Press Next Pk Left.



The marker is now positioned on the peak point in the section of the trace between the current position and the left edge of the screen.

Searching for Peak to Peak Points You need to have activated Delta markers to perform a Peak to Peak search.

Step 1. Press Peak Search, Peak Criteria, Pk To Pk.

Step 2. Press Pk-Pk Search.

The markers are now on the maximum and minimum points of the trace. See [Figure 2-13 on page 44](#).

Figure 2-13 Peak to Peak



If you want to continuously find the maximum and minimum points on the trace, toggle **Continuous Peak Search** to **On**.

The annotation displays the difference between the two points.

Indicating an Invalid Result

When an invalid result is detected while in graph display format, the graph is drawn at the top of the screen for the current measurement point and a special marker indicator is displayed. Also in table and meter formats the same special indicators are used to display an invalid result.

Several invalid result conditions may exist simultaneously. These conditions are ranked in order of severity and only the most severe condition present is displayed.

The ranking order is:

Table 2-4 Ranking Order of Invalid Result Conditions

Ranking Order	Invalid Result Condition	Marker Indicator
1	Hot power \leq cold power	“==”
2	Calibrated calculation not possible	“xx”
3	Measurement result calculation invalid	“--”

The ranked order 2 only occurs if a corrected measurement is requested and either:

- The input range used at this measurement point is not calibrated.
- The input range is calibrated, but the calibration data is invalid at this point.

Example of a 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 DUT to show how a basic noise figure measurement and various basic operations are performed. The DUT used is a low noise amplifier with a usable frequency range of 20 MHz to 3.0 GHz. The specifications of interest to the example are listed in [Table 2-5](#).

Table 2-5

The Example DUT Specifications

Frequency Range	Typical Gain	Minimum Gain	Typical Noise Figure
20 MHz to 3 GHz	20 dB	14 dB	4.8 dB

The example sets a frequency range of interest of 1.0 GHz to 2.0 GHz. The purpose of the measurement is to verify the specified table results are as stated over the frequency range of interest.

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

NOTE

For these basic measurements, confirm the analyzer measurement mode is in the default setting, press **Mode Preset**. This status is displayed above the graphs in the Settings Panel of the Measurement Bar as follows:

- **DUT:** Amplifier
 - **LO Freq:** 30.000 GHz
 - **Atten:** 0 dB
-

Calibrating the Analyzer

The first step is to calibrate the analyzer to obtain the corrected measurement you wish to make.

Step 1. Turn the instrument on and wait for the power-up process to complete.

NOTE

To obtain optimum measurement accuracy, it is recommended the analyzer warm up for 30 minutes.

Step 2. Press **System, Power On**, and press the green **Restore Power On Defaults** key to return the analyzer to its factory-default state.

Step 3. Press **Mode, Noise Figure**.

Step 4. Press **Mode Preset**.

Step 5. Press **Meas Setup, ENR**, and toggle **ENR Mode** to **Table**.

Step 6. Press **Use Meas Table Data for Cal** and toggle to **On**.

Step 7. Press **Meas Table, Edit** and enter the ENR values of the noise source.

In this example, a 346B noise source is used which has the following Frequency/ENR pairs up to 2 GHz:

Table 2-6 Example Noise Source ENR/Frequency values

Frequency (GHz)	ENR (dB)
.01	15.13
.10	15.39
1.0	15.21
2.0	15.02

Step 8. Press **FREQ Channel** and set the frequency parameters of the measurement:

- Press **Freq Mode, Swept**.
- Press **Start Freq, 10, MHz**.
- Press **Stop Freq, 900, MHz**.
- Press, **Points, 15, Enter**.

Step 9. Press **Meas Setup, Average Num On Off** to **On, 5, Enter**.

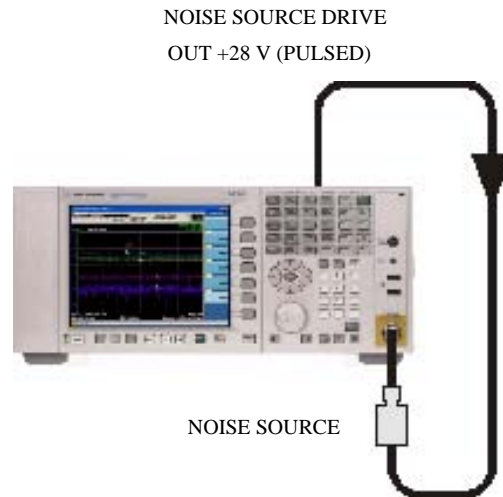
Step 10. Press **BW, RBW Auto Man** to **Auto, 4, MHz**.

Step 11. Press **Meas Setup, Cal Setup, User Cal, User Cal** to change the minimum and maximum input attenuation, if required.

This example uses the default minimum input attenuation of **0 dB**, and the default maximum input attenuation of **10 dB**.

Step 12. Connect the noise source drive from the rear panel of the analyzer to the noise source.

Figure 2-14 Calibration Setup with Normal Noise Source



Step 13. Connect the noise source output to the **RF INPUT 50 Ω** port as shown in [Figure 2-14](#).

Step 14. Press **Meas Setup, Calibrate Now** to calibrate the analyzer.

A graph similar to [Figure 2-15](#) is now displayed.

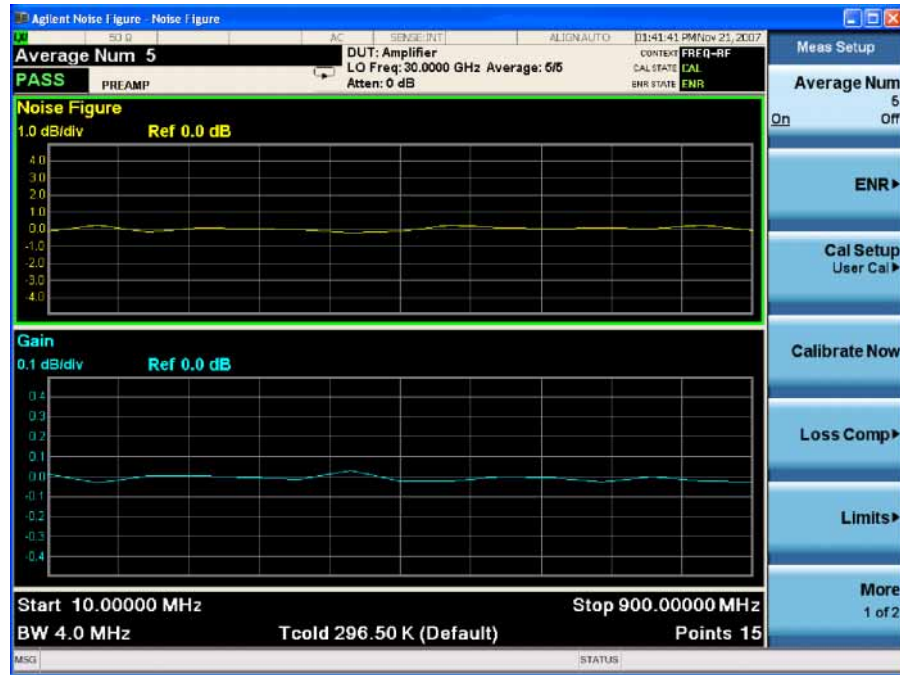
With calibration completed and no device under test inserted, both gain and noise figure with Apply Calibration set to On are near 0 dB. This shows that the analyzer has removed the noise contribution from the measurement system. Since the input is noise, which is random in its nature, there is some variation above and below zero.

NOTE

For EXA instruments: 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 enough gain and noise figure. Otherwise, the measurement accuracy will be poor.

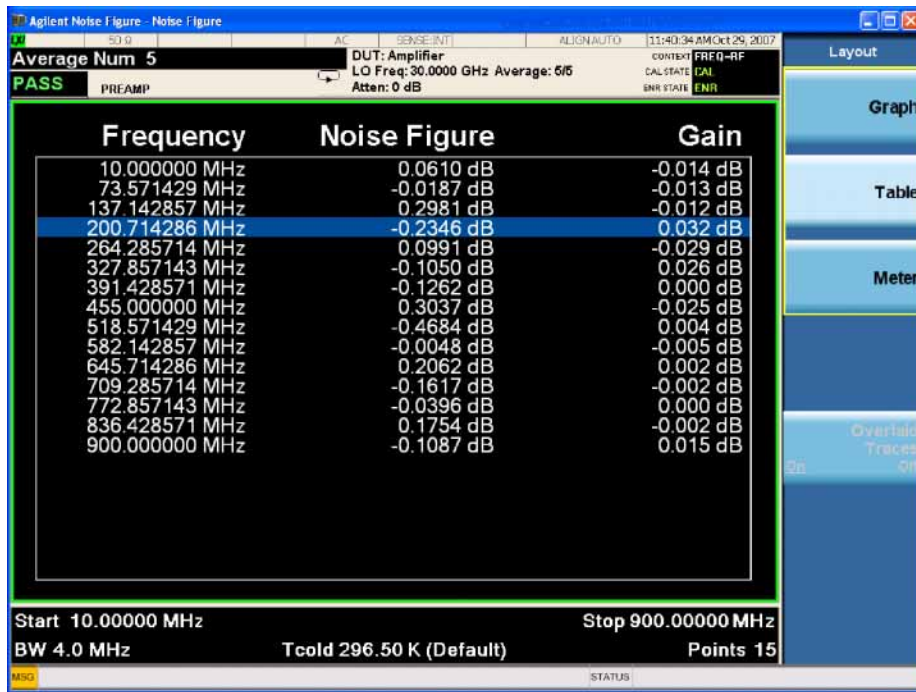
Making Measurements
Making Basic Measurements

Figure 2-15 Typical Graph after Calibration is Complete



Press **View/Display, Layout**, and select **Table**. A result similar to Figure 2-16 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.

Figure 2-16 Typical Tabulated Results after Calibration



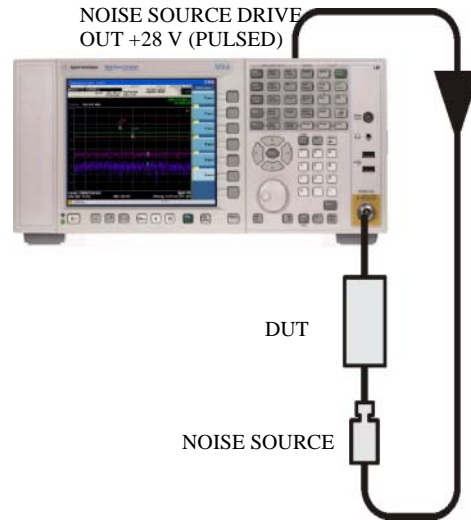
Making Measurements

To make noise figure measurements once calibration is complete:

- Step 1.** Disconnect the noise source from the 50Ω input of the analyzer
- Step 2.** Connect the DUT to the 50Ω input of the analyzer.
- Step 3.** Connect the noise source output to the DUT input as shown in [Figure 2-17](#).

Figure 2-17

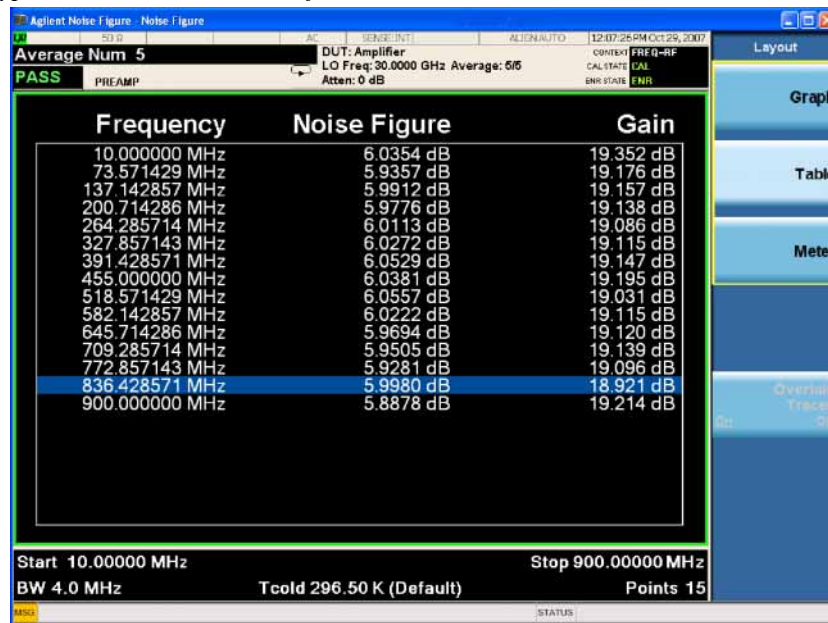
Connecting the DUT to Make a Measurement



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 [Figure 2-18](#) is now displayed.

Figure 2-18

Typical Tabulated Results after Measurement



Step 4. Press **View/Display, Layout** and select **Table**. A graphical result similar to [Figure 2-18](#) is now displayed.

The results shown in [Figure 2-16](#) and [Figure 2-18](#) show the DUT has an average noise figure of 5.4 dB, an average gain of 19.2 dB and a minimum gain of 19.006 dB. The device under test therefore meets its manufacturer's specification over the frequency range of interest.

Step 5. Press **View/Display, Layout, Graph** then turn **Overlaid Traces** On. A graphical result which has the current two (noise figure and gain) traces is displayed.

The name of each trace is located on the right side of the trace. The graph annotation uses the same color as its trace.

If you turn on the marker, the current marker point's frequency, the two trace's marked amplitude result will be shown on the top of the display. It will only show the noise figure readout if you turn the Marker Compatibility under Mode Setup, Advanced to be Off.

Further Information on Noise Figure Measurements

Agilent 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
- *Application Note 57-2*
Noise Figure Measurement Accuracy - the Y-Factor Method
- *Application Note 57-3*
10 Hints for Making Successful Noise Figure Measurements

All three application notes are available from the Agilent website.

Making Frequency Converter Measurements

This chapter describes how to make measurements outside the frequency range of the X-Series signal analyzers.

This section covers:

“Overview of Frequency Converter Measurements” on page 52

“Comparison of the 8970B, the NFA Analyzer, and the X-Series Noise Figure Measurement Application” on page 64

“Choosing and Setting Up the Local Oscillator” on page 65

“Connecting the System” on page 67

“Measuring a Frequency Converting DUT” on page 76

“Making Frequency Converting DUT Measurements” on page 76

“Measurements with a System Downconverter” on page 86

“Frequency Restrictions” on page 92

Overview of Frequency Converter Measurements

Noise figure measurements involving 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 set-up. The DUT is to be measured at a higher frequency than the analyzer's frequency range covers, hence an external mixer and local oscillator are added to the measurement test set-up to convert this higher frequency to a frequency within the analyzer's range.

The Noise Figure measurement application can make a single frequency conversion, either in the DUT, or as an added **System Downconverter**, which configures the analyzer as a frequency range extender.

Configuring extended frequency measurements involves the following steps:

Step 1. Press **Mode Setup, DUT Setup...**, and select the type of DUT being measured. See “[DUT Setup Form Parameters](#)” on page 53 for more details.

Step 2. Navigate in the DUT Setup form and set the following parameters for the measurement.

- **System Downconverter**
- **Sideband**

NOTE

When measuring Downconverter noise, or an amplifier type DUT with the System Downconverter, you can measure upper sideband (USB), lower sideband (LSB), or double sideband (DSB).

- **LO Freq Mode**
- **Ext LO Control**
- **Ext LO Power**
- **Freq Mode**
- **Frequency Context**
- **Diagram**

Step 3. Press **FREQ Channel** and set the measurement frequency range and number of points.

Step 4. Press **BW** and set the resolution bandwidth.

For more details on configuring measurements, including calibration, see “[Making Basic Measurements](#)” on page 12.

DUT Setup Form

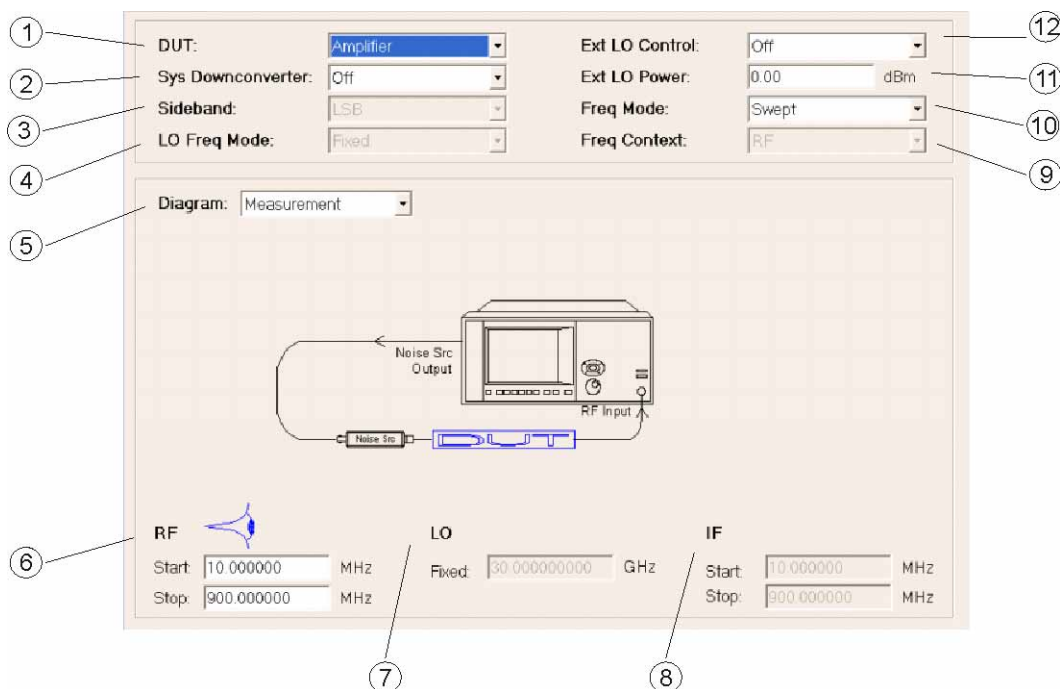


Table 2-7 DUT Setup Form Parameters

Item		Description	
#	Name	Available Selections	
1	DUT	Amplifier	A device that performs no internal frequency conversion. To measure the noise figure of an amplifier at a frequency outside the range of the analyzer using a system downconverter, set DUT to Amplifier , and set System Downconverter to On . 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 upconversion. It cannot be used in conjunction with a system downconverter.
		Upconv	A device that performs internal frequency downconversion. It cannot be used in conjunction with a system downconverter.
2	Sys Downconverter	On/Off	When measuring an amplifier type DUT, this allows you to specify whether or not the system downconverter is to be used in the measurement. NOTE: This is only applicable when the DUT type is an Amplifier. The system downconverter cannot be used with Upconverters or Downconverters.

Table 2-7 DUT Setup Form Parameters

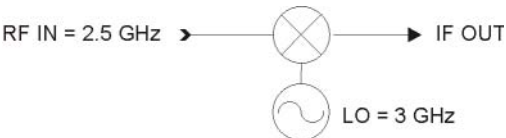
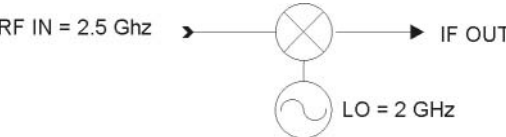
Item			Description
#	Name	Available Selections	
3	Sideband	LSB	<p>Lower Sideband – the RF input frequency is < the LO frequency. For example:</p> 
		USB	<p>Upper Sideband – the RF input frequency is > the LO frequency. For example:</p> 
		DSB	<p>Double Sideband – both upper and lower sidebands.</p> <p>NOTE: Available when DUT is a Downconverter, or when the DUT is an Amplifier + System Downconverter is on (unavailable when off).</p> <p>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 specifying frequencies at the analyzer input, that is, with an IF Frequency Context, or when making Upper Side Band (USB) or Lower Sideband (LSB) measurements, there is no ambiguity.</p> <p>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.</p> <p>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.</p> <p>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.</p>

Table 2-7 *DUT Setup Form Parameters*

Item			Description
#	Name	Available Selections	
4	LO Freq Mode	Fixed	External LO frequency is constant.
		Swept	External LO frequency changes between sweep points.
5	Diagram	Calibration	Selects a calibration diagram to be displayed. The diagram represents the connections you need to make to perform the calibration using the current settings.
		Measurement	Selects a measurement diagram to be displayed. The diagram represents the connections you need to make to perform the measurement using the current settings.
6	RF (Freq)	Start/Stop/Fixed	<p>The RF Start, Stop and Fixed frequencies can be changed when the Frequency Context (9) is RF. The Fixed frequency menu appears only when the LO Freq Mode is Fixed, and the Freq Mode is set to Fixed. If the LO Freq Mode is swept, the Fixed frequency parameter selection will be disabled.</p> <p>The RF Start, Stop and Fixed frequency boxes near the bottom of the DUT Setup Form are disabled when:</p> <ul style="list-style-type: none"> – the DUT setup requires a frequency conversion (down, up, system downconverter), the LO is fixed and the context is set to IF. –the DUT setup requires a frequency conversion (down, up, system downconverter), the LO is swept and the context is set to LO.
7	LO (Freq)	Start/Stop/Fixed	<p>The LO Start, Stop and Fixed frequencies can be changed when the Frequency Context is LO.</p> <p>When the LO Freq Mode is fixed, the Start and Stop LO frequencies are disabled and hidden, and the Fixed frequency parameter is enabled and displayed to allow changing the LO frequency.</p> <p>When the LO Freq Mode is swept, the Start and Stop frequencies are enabled and displayed, and the Fixed frequency parameter is disabled and hidden.</p>

Table 2-7 DUT Setup Form Parameters

Item			Description
#	Name	Available Selections	
8	IF (Freq)	Start/Stop/Fixed	<p>The IF Start, Stop and Fixed frequencies can be changed when the Frequency Context is IF and the LO Freq Mode is Fixed. The Start and Stop frequencies are only available when the context is IF</p> <p>When the DUT setup requires a frequency conversion (down, up, system downconverter) and the LO Freq Mode is Fixed, the IF Start and Stop frequency parameters are enabled and displayed and the IF Fixed frequency is disabled and hidden</p> <p>When the DUT setup requires a frequency conversion (down, up, system downconverter) and the LO Freq Mode is Swept, the IF Start and Stop frequency parameters are disabled and hidden and the Fixed frequency is enabled and displayed.</p>
9	Freq Context	RF	<p>Frequencies are displayed as they are before they enter the DUT and before any frequency conversion takes place. In the case of system downconverters, this means before the downconverter. In the case of DSB measurements, the RF frequencies represented are only that of the LSB Start and Stop range. If a frequency conversion is being performed, the RF frequencies are not the ones being measured at the analyzer RF input port.</p> <p>The IF Start and Stop frequencies are also displayed on the setup diagram. These are calculated from the specified RF Start and Stop frequencies, and the external LO frequency.</p>
		IF	<p>Frequencies are displayed as they are when they leave the DUT and enter the analyzer after the frequency conversion takes place. These are the frequencies that the analyzer is physically measuring. In the case of a system downconverter, this means after the downconverter.</p> <p>The RF Start and Stop frequencies are also displayed on the setup diagram. These are calculated from the specified IF Start and IF Stop frequencies, and the external LO frequency.</p>
		LO	<p>Frequencies at the external LO are displayed. These are not the frequencies that the analyzer is physically measuring. 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.</p>

Table 2-7 DUT Setup Form Parameters

Item			Description
#	Name	Available Selections	
10	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. Start Freq, Stop Freq, Center Freq, and Span parameters are coupled. NOTE: When the FREQ Channel key is selected while in this mode, the Fixed frequency parameter is unavailable (grayed).
		Fixed	A single frequency (supplied by the Fixed Freq parameter) is measured. NOTE: When the FREQ Channel key is selected while in this mode, the Start/Stop/Center Freq, and Points parameters are unavailable (grayed).
		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 file, or by entering the data manually into the frequency list. Duplicate frequencies are allowed. If the Frequency Context changes, the list values are recalculated to satisfy the new context. NOTE: When the FREQ Channel key is selected while in this mode, the Start/Stop/Center/Fixed Freq, and Points parameters are unavailable (grayed).
11	External LO Power	-100 dBm to 100 dBm	Allows you to set the LO drive level into the frequency converter device.
12	External LO Control	On/Off	Allows you to toggle the external LO control on and off through a LAN interface.

Frequency Downconverting DUT

In this mode, the DUT contains a frequency downconverting device, for example, a mixer or receiver.

NOTE

For frequency downconverting DUT measurements, the following requirements apply:

- LSB: $FLO > FRF$
- USB: $FRF > FLO$
- DSB: $FLO > FRF$

Variable IF Fixed LO (equivalent to Mode 1.4 on an 8970B Noise Figure Meter)

In this measurement, the external Local Oscillator (LO) remains locked at one frequency and the Noise Figure measurement application does the sweeping.

This is an overview of the set up for this type of measurement. See [“Frequency Restrictions” on page 92](#). For greater detail see [“Measuring a Frequency Converting DUT” on page 76](#).

Press **Mode Setup, DUT Setup...** to access the DUT Setup form. Set the values on the DUT Setup form as shown in the following table.

Table 2-8

DUT	DownConv
System Downconverter	Off
Sideband	LSB, USB or DSB. See “Sideband” on page 54 .
LO Freq Mode	Select Fixed.
Frequency Context	IF or RF. This determines whether you specify the measurement frequencies at the DUT input (RF) or at the analyzer’s input (IF). See Frequency Context (below) for a more detailed description. See “Freq Context” on page 56
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 eyeball icon acts as a visual reminder of the Frequency Context setting you have selected.
LO Freq	Enter a frequency value.

NOTE Filtering is needed to remove the unwanted sideband when making single-sideband measurements (LSB or USB). Filtering is also needed to filter out any LO leakage in the IF path. Ideally any filters should be included in the calibration path. However, if they are not in the path, you can use Loss Compensation (**Meas Setup, Loss Comp**) to account for any additional error.

Variable IF Swept LO (equivalent to Mode 1.4 on an 8970B Noise Figure Meter)

This is an overview of the set up for this type of measurement. See [“Frequency Restrictions” on page 92](#). For greater detail see [“Measuring a Frequency Converting DUT” on page 76](#).

Press **Mode Setup, DUT Setup...** to access the DUT Setup form. Set the values on the DUT Setup form as shown in the following table.

Table 2-9

DUT	DownConv
System Downconverter	Off
Sideband	LSB, USB or DSB. See “Sideband” on page 54 .
LO Freq Mode	Select Swept.
Frequency Context	IF or 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 56 .
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 physically connected. The blue eyeball icon acts as a visual reminder of the Frequency Context setting you have selected.
LO Freq	Enter a frequency value.

NOTE Filtering is needed to remove the unwanted sideband when making single-sideband measurements (LSB or USB). Filtering is also needed to filter out any LO leakage in the IF path. Ideally any filters should be included in the calibration path. However, if they are not in the path, you can use Loss Compensation (**Meas Setup, Loss Comp**) to account for any additional error.

Frequency Upconverting DUT

In this mode, the DUT contains a frequency upconverting device, for example, or a transmitter module.

NOTE

Filtering is needed to remove the unwanted sideband when making single-sideband measurements. Filtering is also needed to filter out any LO leakage in the IF path. Ideally any filters should be included in the calibration path. However, if they are not in the path, you can enter Loss Compensation (**Meas Setup, Loss Comp**) to account for any additional error.

Setup for Variable IF Fixed LO (equivalent to Mode 1.4 with SUM Sideband on an 8970B Noise Figure Meter)

In this measurement, the external Local Oscillator (LO) remains locked at one frequency and the Noise Figure measurement application does the sweeping.

This is an overview of the set up for this type of measurement. For further details on frequency restrictions, see “[Frequency Restrictions](#)” on page 92.

For an example of this measurement, see “[Making Frequency Converting DUT Measurements](#)” on page 76. This shows you how to make an LSB measurement. However, you need to change the settings and apply the appropriate filtering.

Press **Mode Setup, DUT Setup...** to access the DUT Setup form. Set the values on the DUT Setup form as shown in the following table.

Table 2-10

DUT	UpConv
System Downconverter	Off
Sideband	LSB or USB See“ Sideband ” on page 54.
LO Freq Mode	Select Fixed.
Frequency Context	IF or 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 56.
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 eyeball icon acts as a visual reminder of the Frequency Context setting you have selected.
LO Freq	Enter a frequency value.

Setup for Variable IF Swept LO (equivalent to Mode 1.4 with SUM Sideband on an 8970B Noise Figure Meter)

This is an overview of the set up for this type of measurement. For further details on frequency restrictions, see [“Frequency Restrictions” on page 92](#).

For an example of this measurement, see [“Making Frequency Converting DUT Measurements” on page 76](#). This shows you how to make an LSB measurement. However, you need to change the settings and apply the appropriate filtering.

Press **Mode Setup, DUT Setup...** to access the DUT Setup form. Set the values on the DUT Setup form as shown in the following table.

Table 2-11

DUT	UpConv
System Downconverter	Off
Sideband	LSB or USB See “Sideband” on page 54 .
LO Freq Mode	Select Swept.
Frequency Context	IF or 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 56 .
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 eyeball icon acts as a visual reminder of the Frequency Context setting you have selected.
LO Freq	Enter Start and Stop frequency values.

System Downconverter

In these examples, the DUT is a non-frequency converting device, for example an amplifier or filter, and its frequency range is higher than the frequency range of the analyzer. Frequency downconversion is required within the measurement system, using a System Downconverter external to the DUT, to convert the signal of interest to be within the frequency range of the analyzer.

In this measurement, the external Local Oscillator (LO) remains locked at one frequency and the Noise Figure measurement application does the sweeping.

NOTE

Filtering is needed to remove the unwanted sideband when making single-sideband measurements. Filtering is also needed to filter out any LO leakage in the IF path. Ideally any filters should be included in the calibration path. However, if they are not in the path, you can use Loss Compensation (**Meas Setup, Loss Comp**) to account for any additional error.

Variable IF Fixed LO (equivalent to Mode 1.2 on an 8970B Noise Figure Meter)

This is an overview of the set up for this type of measurement. See [“Frequency Restrictions” on page 92](#) for the restrictions applicable to this measurement. See [“Measurements with a System Downconverter” on page 86](#) for an example of this type of measurement. You will need to change the settings and apply the appropriate filtering.

Press **Mode Setup, DUT Setup...** to access the DUT Setup form. Set the values on the DUT Setup form as shown in the following table.

Table 2-12

DUT	Amplifier
Sys Downconverter	On
Sideband	LSB, USB or DSB See “Sideband” on page 54 .
LO Freq Mode	Select Fixed.
Frequency Context	IF or 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 56 .
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 eyeball icon acts as a visual reminder of the Frequency Context setting you have selected.

Table 2-12

LO Freq	Enter a frequency value.
----------------	--------------------------

Setup for Variable IF Swept LO (equivalent to Mode 1.2 on an 8970B Noise Figure Meter)

This is an overview of the set up for this type of measurement. See [“Frequency Restrictions” on page 92](#) for the restrictions applicable to this measurement. See [“Measurements with a System Downconverter” on page 86](#) for an example of this type of measurement. You will need to change the settings and apply the appropriate filtering.

Press **Mode Setup, DUT Setup...** to access the DUT Setup form. Set the values on the DUT Setup form as shown in the following table.

Table 2-13

DUT	Amplifier
System Downconverter	On
Sideband	LSB, USB or DSB See “Sideband” on page 54 .
LO Freq Mode	Select Swept.
Frequency Context	IF or 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 56 .
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 eyeball icon acts as a visual reminder of the Frequency Context setting you have selected.
LO Freq	Enter Start and Stop frequency values.

Comparison of the 8970B, the NFA Analyzer, and the X-Series Noise Figure Measurement Application

Table 2-14 shows the relationship between the 8970B Noise Figure Analyzer, the NFA Series, and the X-Series Noise Figure Measurement application.

Table 2-14

8970B / NFA / X-Series Measurement Cross Reference

8970B	NFA Series	X-Series
Mode 1.1: Swept LO	DUT = Amplifier, System Downconverter ON, LO Mode: Variable	DUT = Amplifier, System Downconverter ON, LO Freq Mode: Variable
Mode 1.2: Fixed LO	DUT = Amplifier, System Downconverter ON, LO Mode: Fixed	DUT = Amplifier, System Downconverter ON, LO Freq Mode: Fixed
Mode 1.3: Swept LO	DUT = Downconv, LO Mode: Variable	DUT = Downconv, LO Freq Mode: Variable
Mode 1.4: Fixed LO	DUT = Downconv, LO Mode: Fixed	DUT = Downconv, LO Freq Mode: Fixed
Mode 1.3 with SUM Sideband: Swept LO	DUT = Upconv, LO Mode: Variable, Mode Setup: USB	DUT = Upconv, LO Freq Mode: Variable, Sideband = USB
Mode 1.4 with SUM Sideband: Fixed LO	DUT = Upconv, LO Mode: Fixed, Mode Setup: USB	DUT = Upconv, LO Freq Mode: Fixed, Sideband = USB

NOTE

LO Freq Mode is unavailable (grayed out) when the Freq Mode is Fixed. Change Freq Mode to Swept or List to change the LO Freq Mode.

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 extended frequency device and LO in the final system.

For testing of extended frequency measurements, the LO must have a low noise floor over frequencies equal to the $LO \pm IF$. 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 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:

1. It should have a frequency appropriate to the DUT's frequency range, IF range, and sideband chosen.
2. It should have sufficient power to drive mixers (typically, $+7$ dBm).
3. 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 an Agilent 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.

NOTE When making Double Sideband (**DSB**) measurements, it is important that the IF is much smaller 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 will the ENR value be.

Another potential source of error is the frequency response of the DUT. If the frequency response varies over the measurement range, from lower to upper frequency, the noise figure results only represent an average value.

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.

Connecting the System

Figure 2-19 shows the connection diagrams you use to calibrate the analyzer, and after calibration, to measure a DUT, whether it is a downconverter, an upconverter, amplifier, or a filter. This general diagram does not show where to place a filter to remove any unwanted sideband or input noise for any specific DUT.

Setting Up the Analyzer for Noise Figure Measurements

You can connect the 10 MHz timebase references, thus locking the analyzer and the LO to the same frequency reference.

- Step 1.** To connect the 10 MHz reference output from the LO to a X-Series analyzer, you need to ensure that an external reference is selected.

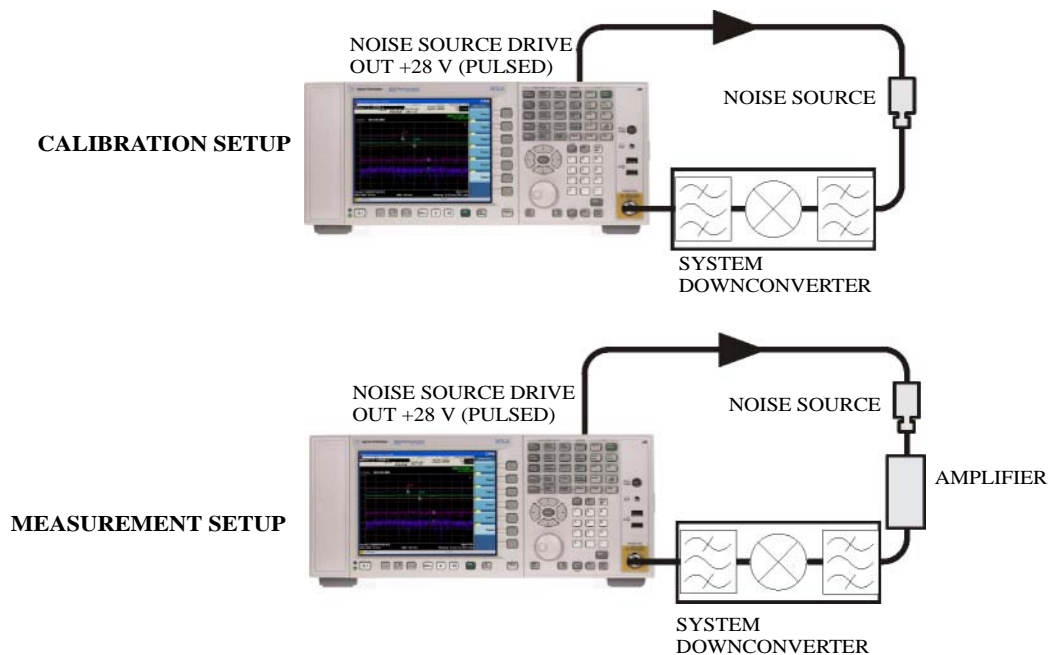
Press **Input/Output, More, Freq Ref In, External**, and ensure that the **External Ref Freq** is set to **10 MHz**.

- Step 2.** Connect the **10 MHz Ref Out** of the LO to the **EXT REF IN** of the analyzer.

To connect the analyzer and make your measurements:

Figure 2-19

Setting Up System Downconverter Measurements



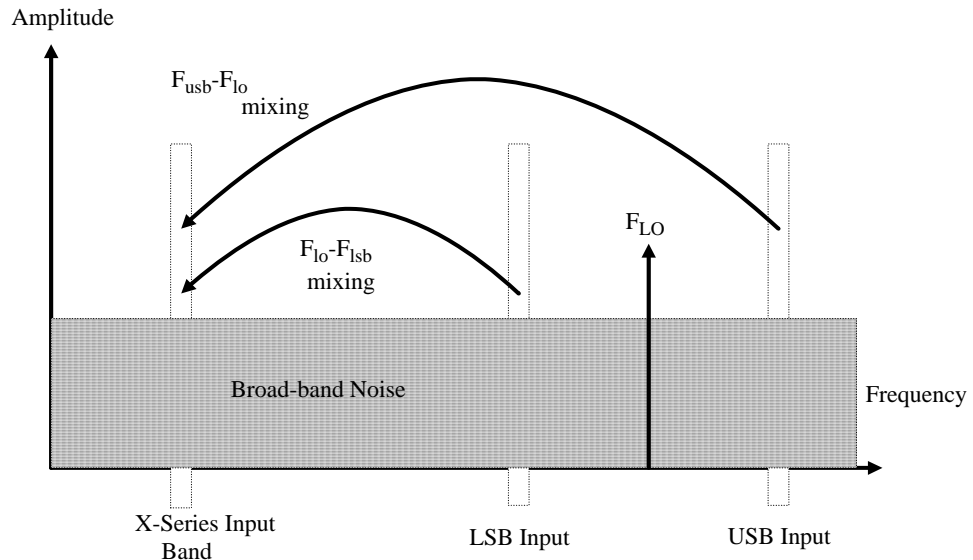
- Step 1.** Turn the analyzer on.
- Step 2.** Press **Mode, Noise Figure, Mode Preset** to return the analyzer to a known state.
- Step 3.** Enter the ENR values in to the analyzer if required. See [“Entering Excess Noise Ratio \(ENR\) Data”](#) on page 12 for the procedures to do this.
- Step 4.** Follow the procedure documented in [“To Perform a Calibration”](#) on page 24.
- Step 5.** Configure the measurement setup shown in Figure 2-19 and measure the DUT.

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 2-20

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 2-20](#).

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 hence 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:

1. Some of the input signal leaks directly to the output.
2. Some of the LO signal, and its harmonics, leak directly to the output.

3. 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, in order 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, hence 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 2-1

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

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:

1. Decide the frequency ranges that must be covered; Input, LO, and Output.
2. Calculate the frequency range that the unwanted image will cover.
3. Calculate the frequency range that the LO harmonic modes will cover.
4. 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.
5. 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.
6. 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 2-21 Single Sideband Mixer Measurements

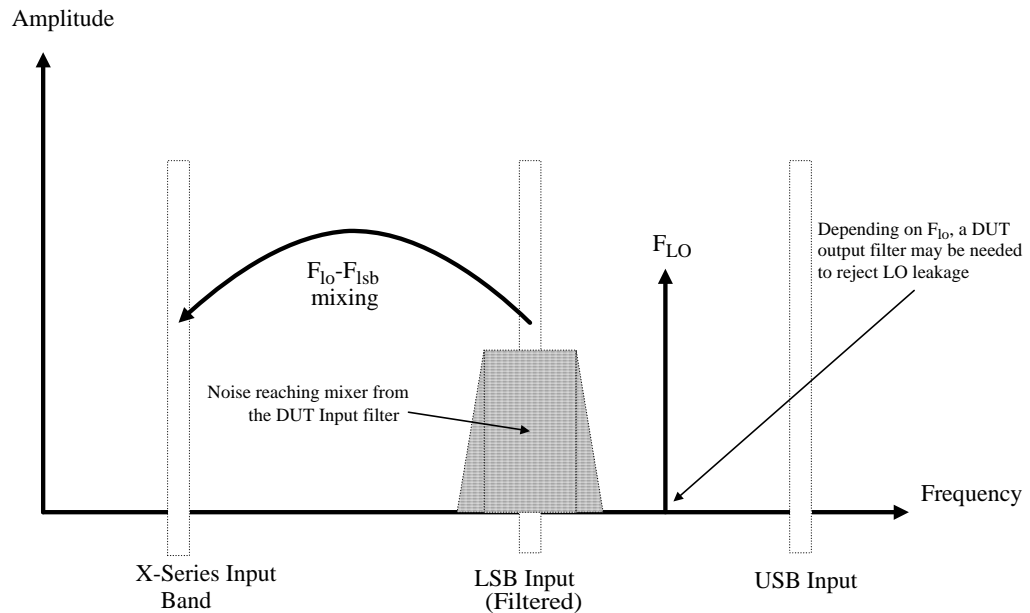


Figure 2-21 shows an SSB mixer measurement (Downconverter, LSB) where a filter makes it single sideband. If the IF frequency is lowered, the analyzer is tuned to a lower frequency, and the USB and LSB bands will move closer to the LO frequency. This makes filtering more difficult. If the IF is lowered 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 DUT is an amplifier and 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 2-22

Double Sideband Measurements

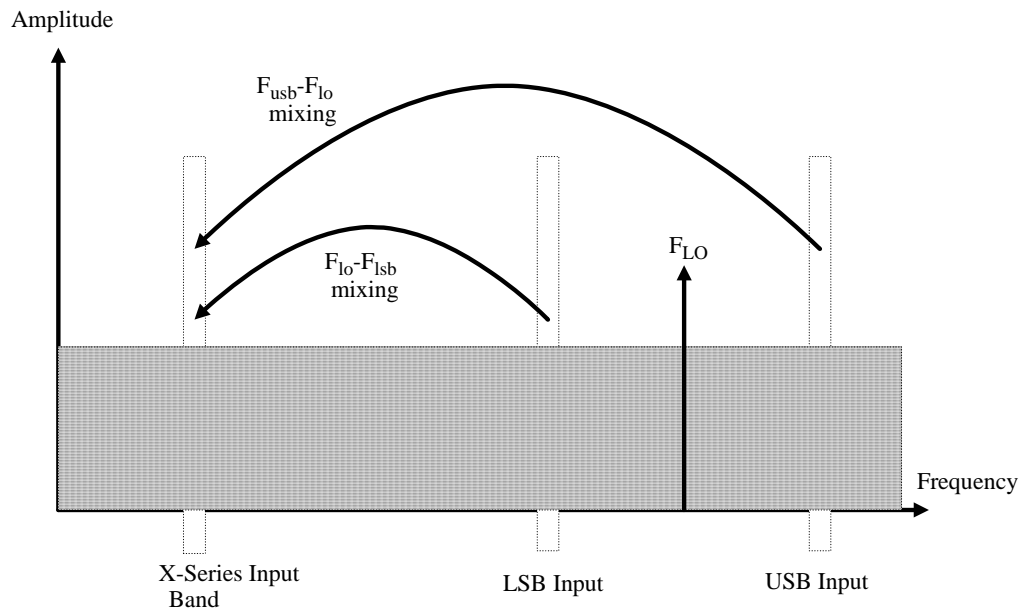


Figure 2-22 shows a double sideband, downconversion, mixing. Noise from two separated RF bands are mixed into the IF band, where the power addition takes place.

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 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 2-22 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**). Set **Before DUT** 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 4.6 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 4.6 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, in order 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**.

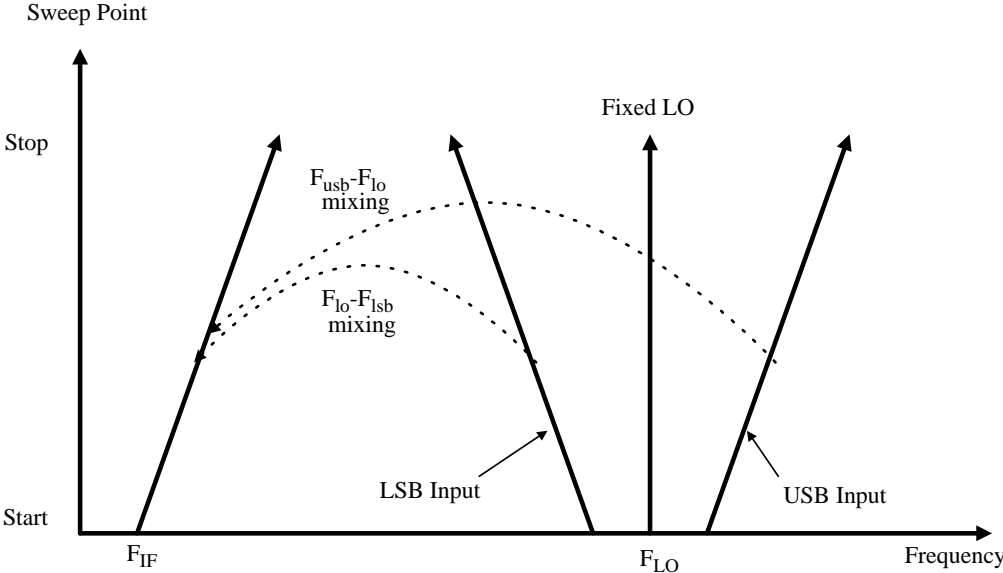
Fixed LO

As the LO frequency is fixed, the two sideband input pairs diverge, so their average remains fixed. This feature can be useful for measuring a complex DUT where the effect of variation of performance of the post-mixer stage over IF frequency is of interest.

Because the LO frequency is held constant, it is the IF frequency at the analyzer input that is swept. [Figure 2-23](#) illustrates this mode.

Figure 2-23

Fixed LO Measurements



Making Frequency Converting DUT Measurements

An example is provided on the following pages using the analyzer to make a fixed frequency measurement. The LO is locked at a specified frequency, and a lower sideband (LSB) measurement of a mixer is made. The example can be modified to make measurements where the IF is swept. Also, from the example, upper and double side band measurements can be made. The changes in the example's procedure are explained in each case.

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.

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.

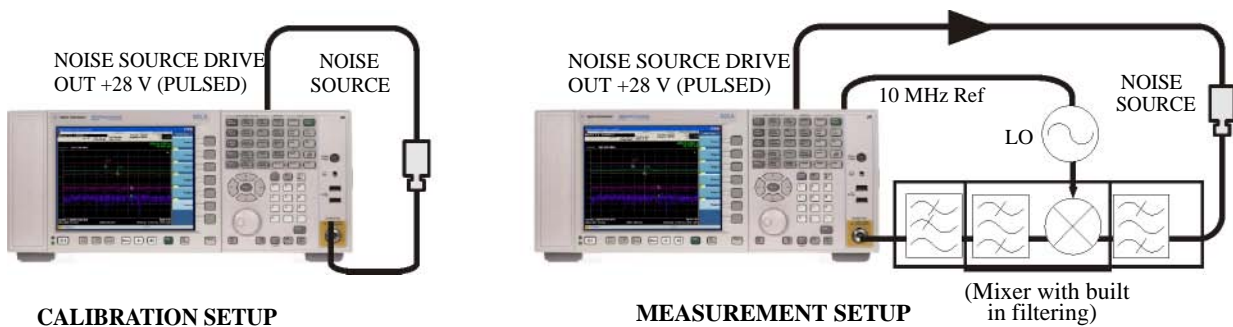
Measuring a Frequency Converting DUT

In this measurement, the DUT performs frequency conversion in the measurement setup. However, there is no frequency conversion in the calibration setup, as is shown in Figure 2-24. The purpose of the calibration setup is to allow the analyzer to measure its own noise figure and sensitivity with the noise source. This must be performed across the frequency range to which the analyzer will tune when performing the measurement.

For both calibration and for measurement, a noise source, such as the Agilent 346C, or SNS, such as the Agilent N4002A, must be connected to the noise source drive connector on the back of a X-Series analyzer.

The LO frequency reference output from the LO may be connected to the **EXT REF IN** on the back of a X-Series analyzer. This locks the LO and the analyzer together for greater measurement accuracy.

Figure 2-24 X-Series Frequency Converting DUT Measurement



For these measurements you must access the **DUT Setup...** screen (**Mode Setup, DUT Setup...**), and set the following parameters:

Table 2-15

DUT	Upconv or Downconv
System Downconverter	Not accessible
LO Freq Mode	Select Fixed.
Sideband	LSB, USB or DSB (Downconverters only) See “Sideband” on page 54.
Frequency Context	IF or 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 56.
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.
LO	Enter a frequency value.

Making Downconverting DUT Measurements using a Fixed LO and Fixed IF (Equivalent to Mode 1.4 on an 8970B Noise Figure Analyzer)

Both double and single sideband measurements may be made in this mode. This measurement may be useful to choose the optimum IF for a mixer or receiver, or to measure how a mixer’s or a receiver’s noise figure and gain vary with IF.

Lower Sideband Measurement

The example lower sideband measurement is made using an X-Series analyzer. A signal generator is used to supply an LO at 970 MHz. Setting the RF frequency of interest to 900 MHz, with the LO of 970 MHz gives an IF of 70 MHz. This also meets with the need to maintain the LO frequency out of the analyzer’s passband.

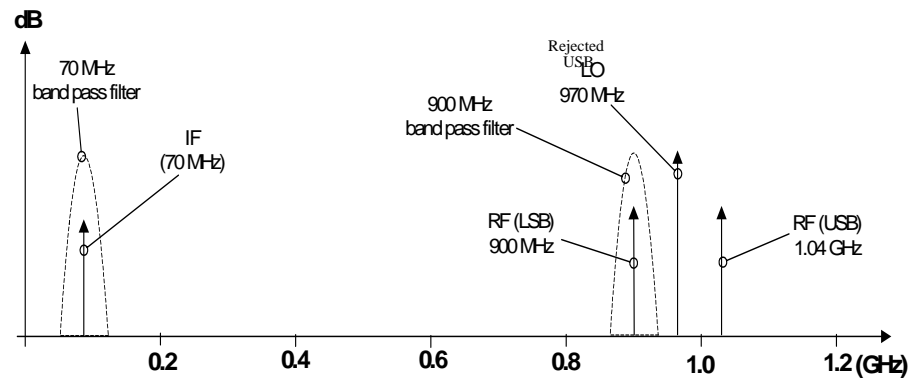
See [Figure 2-25](#).

NOTE

In the example, a 900 MHz Band Pass Filter is used between the noise source and the DUT to remove the upper sideband (see [Figure 2-25](#)).

A 70 MHz Band Pass Filter is used between the DUT and the analyzer to remove all signals except the 70 MHz signal in which we are interested.

Figure 2-25 Fixed LO (970 MHz) and Fixed IF (70 MHz), LSB Spectrum



Initial Setup Procedure

Follow the overview procedure of the initial setup.

- Step 1.** Power on the analyzer and the LO. You need to wait for the recommended warm up time to get accurate measurement results.
- Step 2.** Connect the 10 MHz reference, if required. See “[Connecting the System](#)” on page 67 for more details.
- Step 3.** Load the ENR values for the chosen noise source. See “[Entering Excess Noise Ratio \(ENR\) Data](#)” on page 12 for more details.
- Step 4.** Set up the LO. See “[Choosing and Setting Up the Local Oscillator](#)” on page 65 for more details.
- Step 5.** Connect the system and add filtering where required. [Figure 2-27](#) on page 81 shows the connections.

Setting Up the DUT

- Step 1.** Press **Mode Setup, DUT Setup...** The DUT Setup form is displayed ([Figure 2-26](#)). Set the **DUT** field to **DownConv**. The default **DUT** setting is **Amplifier**.

NOTE

The **Sys Downconverter** field is no longer accessible to you when the DUT is a downconverter.

- Step 2.** Navigate to the **Sideband** field. Select the lower sideband (**LSB**).
- Step 3.** Navigate to the **Freq Mode** field and select **Swept**.
- Step 4.** Navigate to the **Freq Context** field, and select **IF**. This means that we will specify the frequency at the analyzer’s input (70 MHz), and the RF frequency will be calculated by the noise figure measurement application.

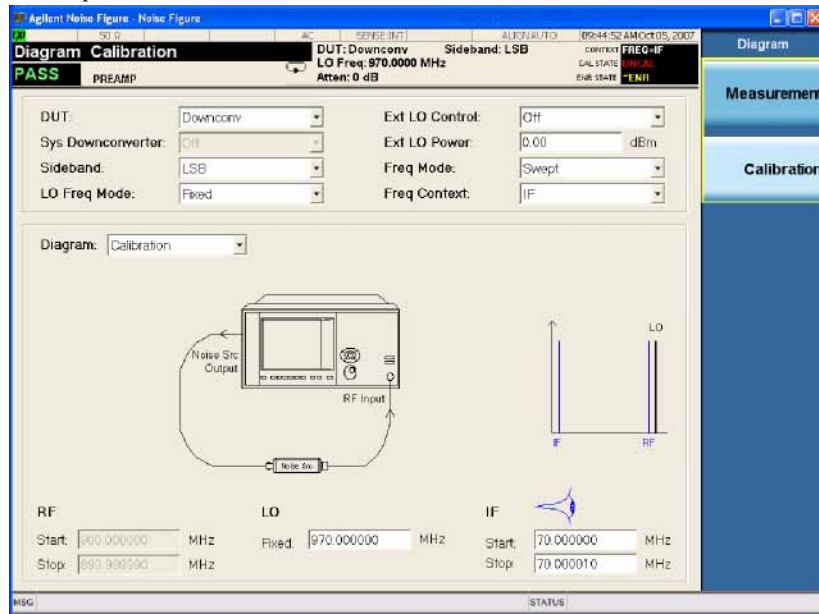
Step 5. Navigate to the **Diagram** field, and select **Calibration**. This will then display the setup diagram for measurement calibration. Check that the system is setup as shown in the diagram.

NOTE

In this example measurement, a 70 MHz bandpass and a 200 MHz low-pass filter have been used between the DUT and the analyzer. These filters have been added at this Calibration stage to remove any errors that they might contribute from the final result.

Figure 2-26

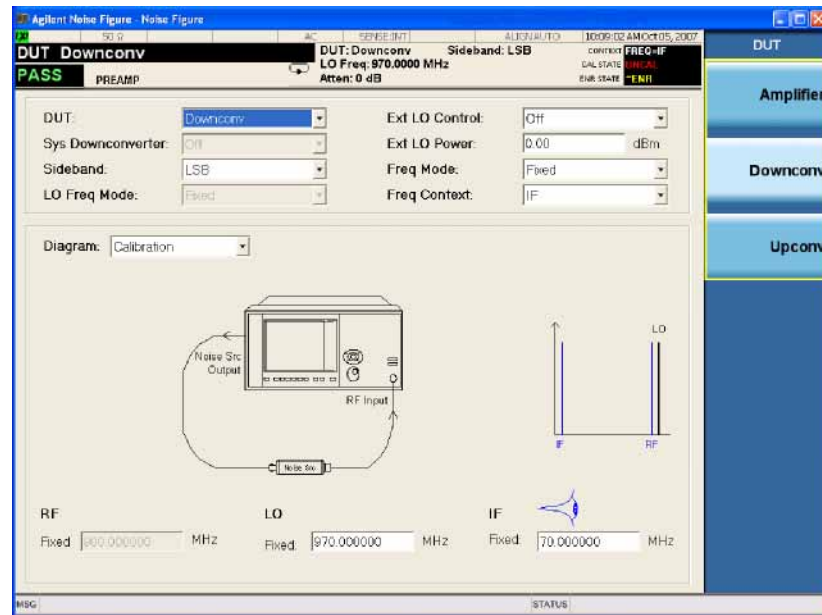
DUT Setup Form



Setting Frequency, and Averaging

- Step 1.** Navigate to the **Freq Mode** field and select **Fixed**.
- Step 2.** Change the **Fixed Freq** to **70 MHz**.

Figure 2-27 DUT Setup Form with Fixed Mode



NOTE

There are two possible frequencies you can enter - the RF frequency (before downconversion) or the IF frequency (after downconversion). In this example, we previously specified that the **Freq Context** was **IF**, so a value of 70 MHz is used.

Step 3. Navigate to the **LO** field and enter the LO frequency of **970 MHz**.

Step 4. Press **Meas Setup, Averaging On Off** to **On, 10, Enter**.

Step 5. Press **AMPTD Y Scale, More 1 of 2**, and verify that the **Internal Preamp** is set to **On**

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.

To connect the noise source and analyzer for calibration. (See [Figure 2-28](#).) Connect any After DUT filtering prior to calibration.

Making Measurements

Making Frequency Converter Measurements

Figure 2-28 X-Series Frequency Converting DUT Calibration and Measurement



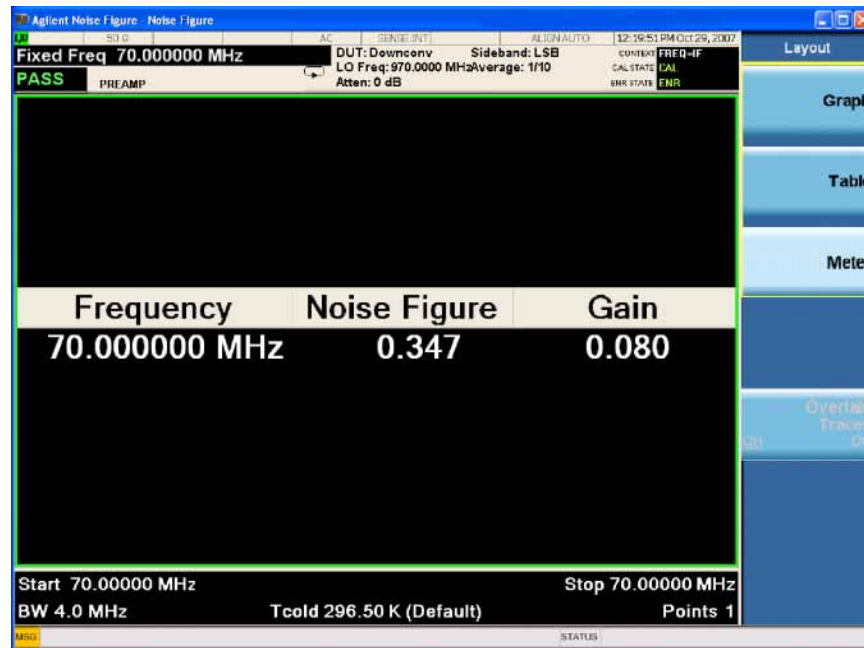
Step 1. Press the **Meas Setup, Calibrate Now**.

You will be asked to confirm the calibration.

When calibration is complete the measurement system is calibrated at the mixer input. The red UNCAL text changes to green CAL text in the top right side of the display.

Step 2. Press the **View/Display, Layout, Meter** to see the calibration results.

Figure 2-29 Typical Calibration Results



NOTE

After calibration the instrument will be close to 0 dB with no DUT inserted. This is because the instrument is now using the ENR value for the RF, while the input is tuned to the IF. When DUT is added, the NFA measures the noise figure of the DUT. If the configuration is arranged to reject one sideband, the SSB result is displayed. If both sidebands are converted by the mixer the DSB result is displayed.

Making the Corrected Noise Figure and Gain Measurement

A measurement corrected for the noise contributed by the analyzer may now be made. Insert the DUT into the system as shown in Figure 2-28. Press the **View/Display** key and the **Meter** key to display the results. A typical display of noise figure and gain (conversion loss) is shown in Figure 2-30.

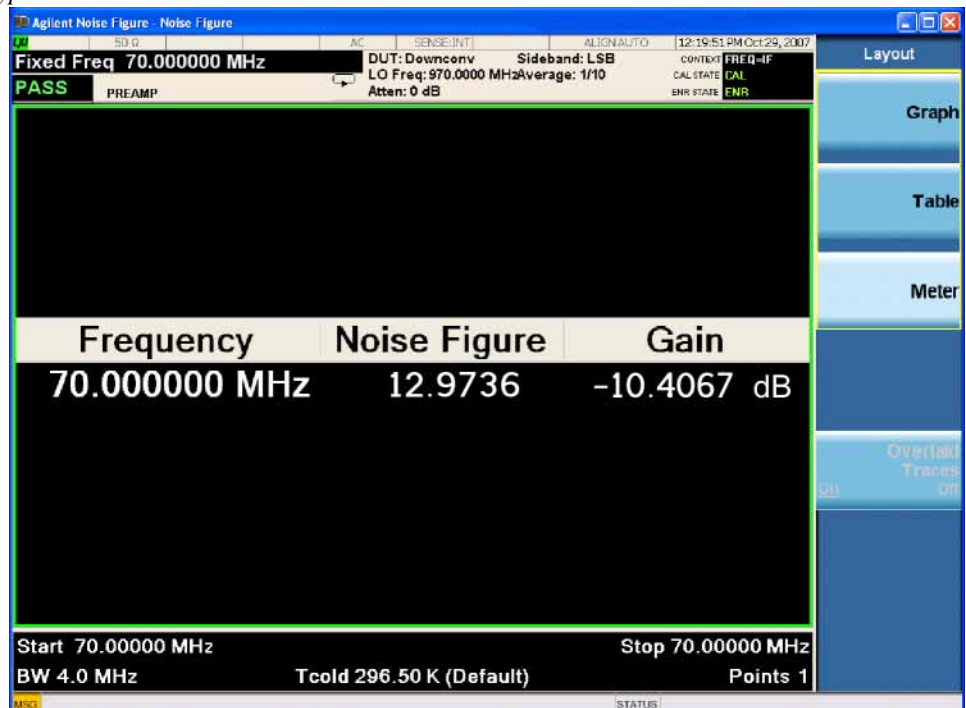
NOTE

The filtering used for this example measurement comprised:

- 900 MHz bandpass filter between the noise source and the DUT
- 70 MHz bandpass and 200 MHz low-pass filters between the DUT and the analyzer

Figure 2-30

Typical Microwave Results



NOTE

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

NOTE

This measurement includes the insertion loss of the 900MHz BPF that was not calibrated out at the calibration step. To remove this from the measurement it can be entered into the Loss Before DUT loss compensation by pressing **Meas Setup, Loss Comp, Before DUT** on the analyzer and entering the insertion loss value for the device.

Upper Sideband Measurement

The upper sideband measurement setup is similar to the LSB measurement procedure described in “[Lower Sideband Measurement](#)” on page 77. However, the filtering requirements will be different because the LSB has to be filtered out. Follow the LSB procedure, and in the **DUT Setup...** form select **USB** in the sideband.

Double Sideband Measurement

The double sideband measurement setup is similar to the LSB measurement procedure described in “[Lower Sideband Measurement](#)” on page 77. Follow the LSB procedure, and in the **DUT Setup...** form select the **DSB** in the sideband.

If the assumptions about the parameters being flat over the frequencies between the two sidebands are valid, your results will show a doubling in power (3 dB increase) in noise level during a DSB measurement. This can be corrected, press **Meas Setup, Loss Comp**. Set **Before DUT** 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. 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.

Making Upconverting DUT Measurements using a Fixed LO and Variable IF (Equivalent to Mode 1.4 with SUM, USB, on an 8970B Noise Figure Meter)

Lower Sideband Measurement

The lower sideband measurement setup is similar to the LSB measurement procedure described in “[Lower Sideband Measurement](#)” on page 77. However, with an upconverting measurement, the RF is the lower frequency, and the IF is the higher frequency to which you will convert. Follow the LSB procedure, and in the **DUT Setup...** form ensure the **LSB** is the sideband is selected, and select **Upconv** instead of **Downconv** as the DUT. The filtering requirements will be different.

Upper Sideband Measurement

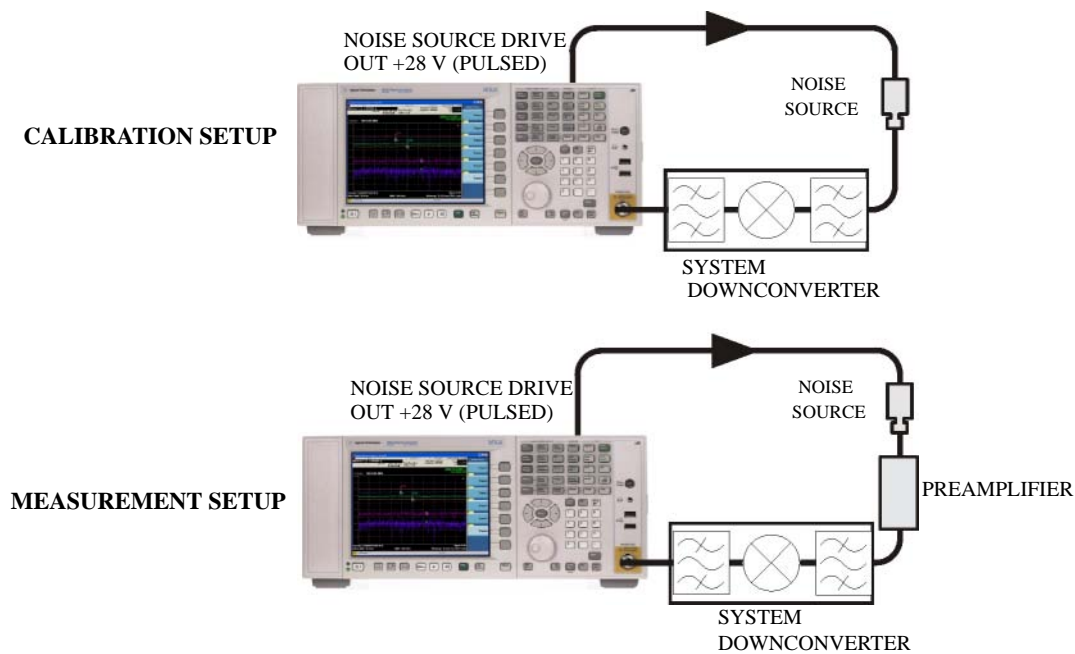
The upper sideband measurement setup is similar to the LSB measurement procedure described in “[Lower Sideband Measurement](#)” on page 77. However, with an upconverting measurement, the RF is the lower frequency, and the IF is the higher frequency to which you will convert. Follow the LSB procedure, and in the **DUT Setup...** form ensure the **LSB** is the sideband is selected, and select **Upconv** instead of **Downconv** as the DUT. The filtering requirements will be different.

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 the analyzer does not cover in its frequency range.

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

Figure 2-31 System Downconverter Calibration and Measurement



A system downconverter is part of the measuring system, and is present in both the calibration setup and the measurement setup. See [Figure 2-31](#). 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. ENR data for the same frequency range is used for both calibration and measurements

The analyzer has the capability to control a single frequency conversion, so system downconverter measurements under the analyzer's control are limited to non-frequency converting DUTs.

The analyzer can be used in much more complex systems, with multiple frequency conversions between the DUT and measurement system. 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 measurement.

USB, LSB or DSB?

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

If the DUT is narrowband and a DSB system downconverter is used, the calibration setup will operate in true DSB mode. However, the measurement setup mode will be influenced by the DUT's selectivity.

The possibilities fit into two groups:

1. The DUT bandwidth is much greater than the LSB-USB separation, so a normal DSB measurement results.
2. The DUT bandwidth is much less than the LSB-USB separation, and the sweep width is less than the USB-LSB separation, so a SSB measurement results. This needs a gain correction factor due to the DSB calibration

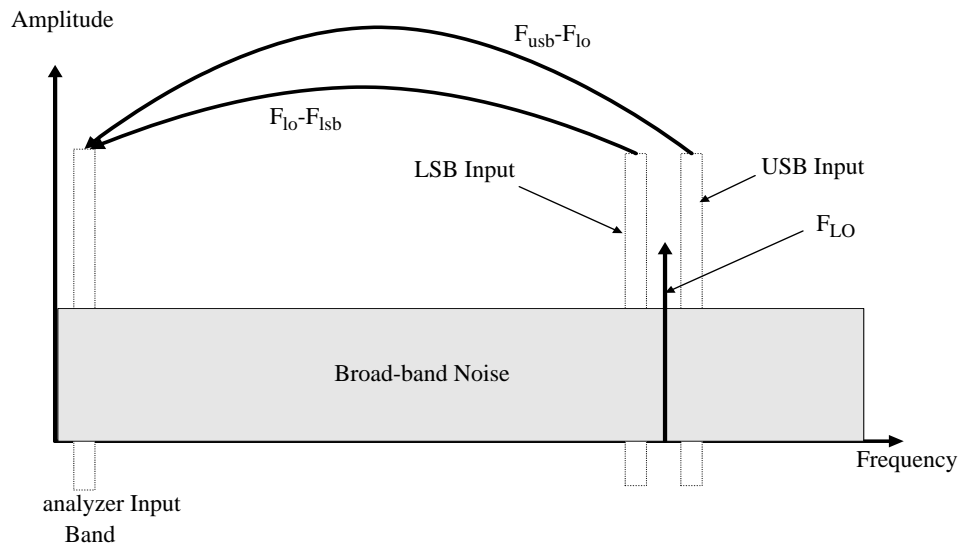
NOTE

There is a third situation and this must be avoided. This is where the DUT selectivity can resolve the individual sidebands of the DSB measurement and the sweep is wide enough to scan the DUT across them. Different parts of the measurement plot are in different modes. USB, LSB and DSB could occur in different places on the same plot, with gradual changes between them, set by the shape of the DUT's frequency response. Variable gain correction would be needed across the plot and the corrections needed would change if adjustments to the DUT changed its shape.

Measurement Modes with a DSB System Downconverter

The benefits of a DSB measurement are minimal filter requirements, and wide frequency coverage. DSB measurements are appropriate for wideband DUTs. Their disadvantages, covered in the “USB, LSB or DSB?” section, make them inappropriate for narrowband DUTs. The usual aim is to choose as low an IF as possible, in order to minimize the separation between the sidebands, and thus get the optimum resolution possible. [Figure 2-32](#) shows this.

Figure 2-32 DSB System Downconverter Measurements



DSB system downconverter measurements have implicit linear averaging of 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.

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 USB, for LSB, or for USB system downconverter conversions.

The filtering requirements will be measurement-specific.

Figure 2-33 shows how filtering makes an LSB measurement, and Figure 2-34 shows a USB downconversion measurement.

Figure 2-33 *LSB System Downconverter Measurements*

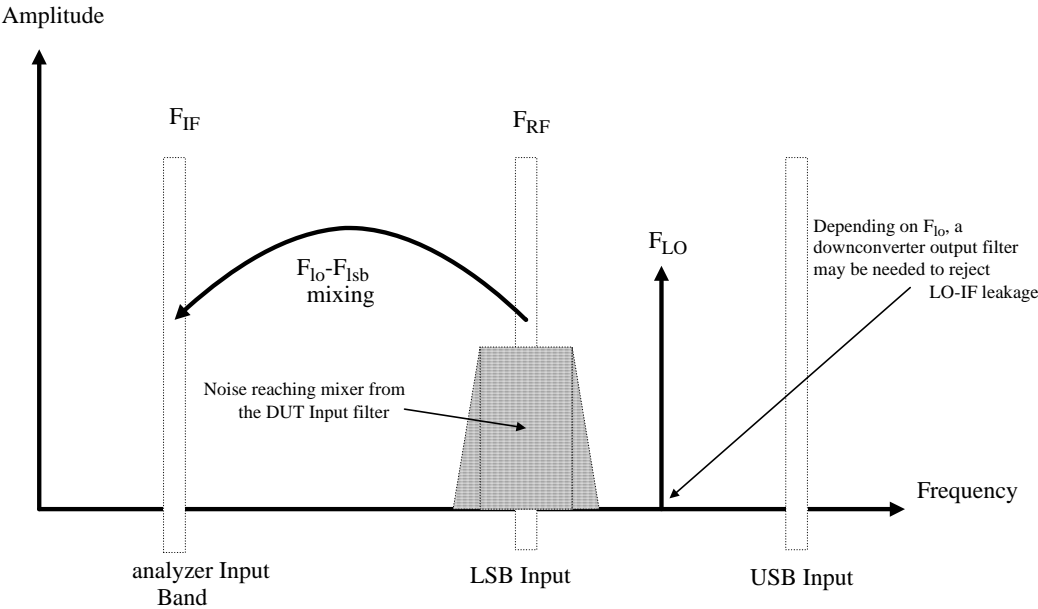
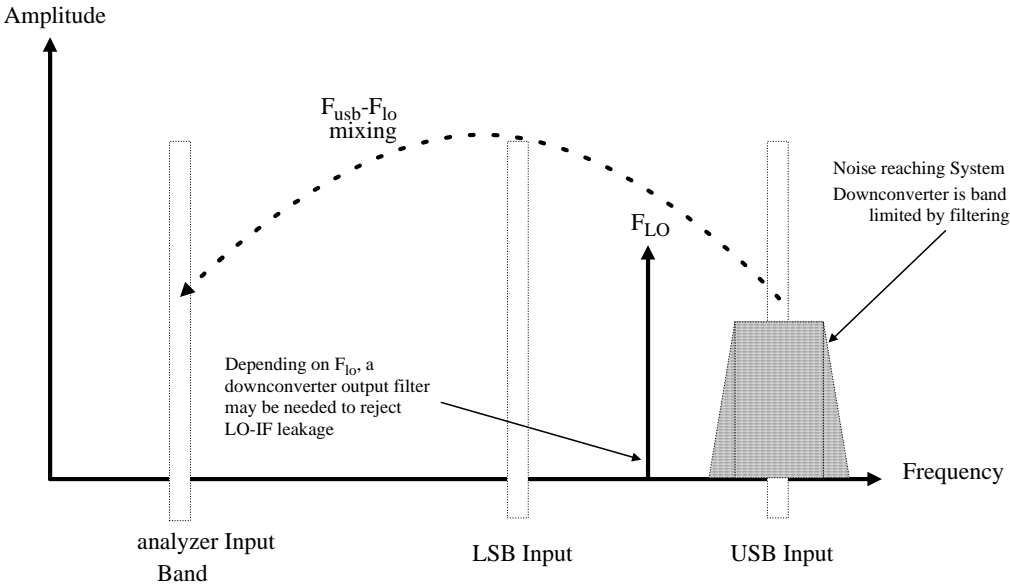


Figure 2-34 *USB System Downconverter Measurements*



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 an 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.

Making Measurements

Making Frequency Converter Measurements

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

FIXED LO, LSB

The main benefit of the fixed LO system downconverter modes is that a programmable synthesized LO is not needed.

Figure 2-35

LSB Measurements

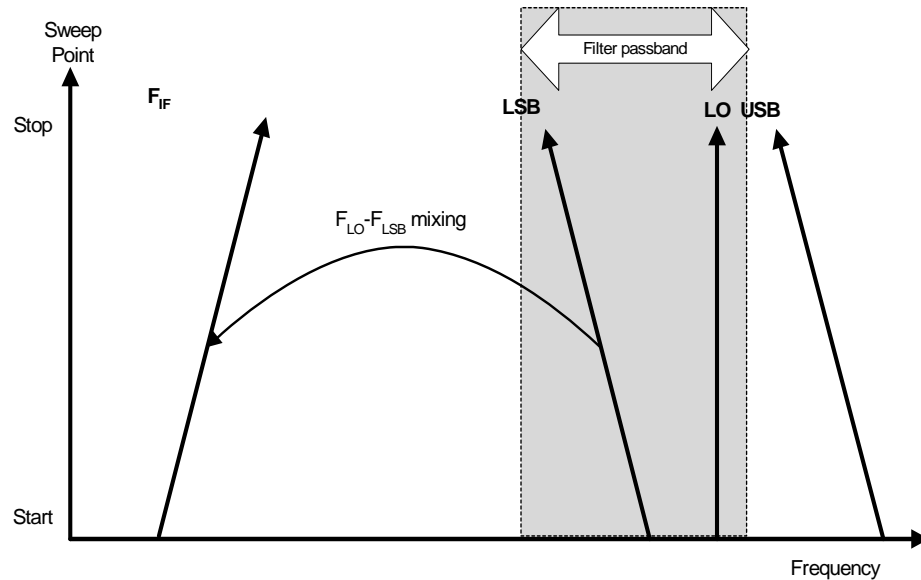


Figure 2-35 shows how the analyzer sweeps its own input frequency so that as the LSB tunes, the frequency increases across the sweep. The filter required is either a lowpass or a bandpass. The maximum sweep width is now limited to the maximum IF, less an allowance for the filter transition band.

FIXED LO, USB

Figure 2-36

USB Measurements

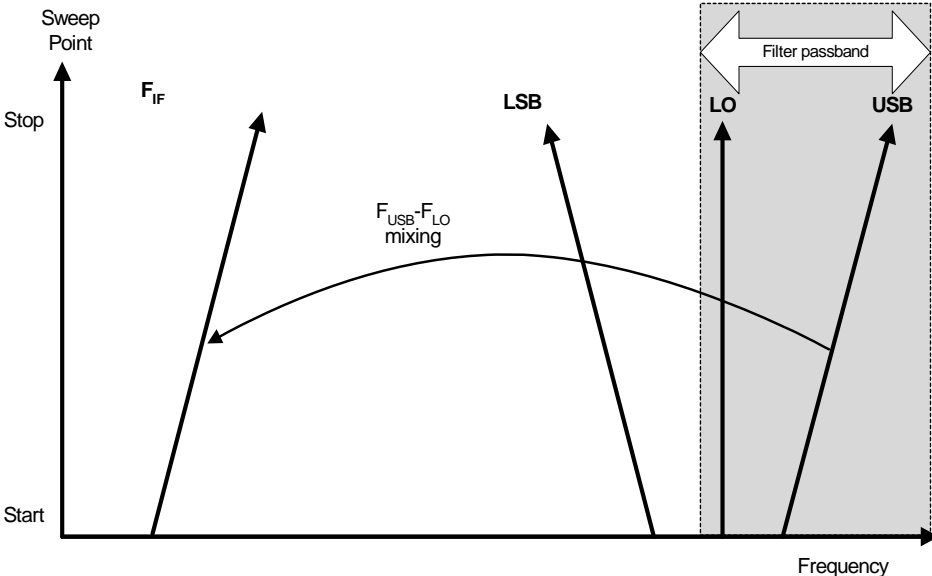


Figure 2-36 shows that as the analyzer is tuned in the normal direction, that is, from a low frequency to a high frequency, the USB and the IF vary with the same phase and rate of change. The filter can be a bandpass or highpass, and the sweep width is again limited to the maximum IF, less an allowance for the filter transition band.

Frequency Restrictions

To assist you in troubleshooting problems that you may have encountered when setting up these measurement modes, the restrictions that apply to the different types of measurements are detailed on the following pages.

NOTE

The analyzer will only return messages if the frequencies used at the ports of the frequency converter fall outside the valid range that the analyzer can handle. Under such conditions, a valid measurement cannot be performed. Within these limits, it is up to you to specify valid frequencies at all ports for the type of DUT currently selected.

General Recommendations for Noise Figure Measurements

In general, the analyzer will not prevent measurements from being made as long as the IF is in the range the analyzer can measure. The following recommendations apply:

- The IF range is limited to a minimum of 10 kHz, and a maximum of the analyzer’s maximum frequency. This maximum frequency is dependent on the model of analyzer.
- The RF range is from 1 Hz to 325 GHz, depending on the DUT setup.

Table 2-16

DUT Type	Sys Down Converter	LO Type	Sideband	Frequency Restrictions
Amplifier Default Context = RF	Off			
Amplifier Default Context = RF	On	Fixed	LSB	$RF_{START} > IF_{START}$ $LO_{FIXED} > RF_{STOP}$
			USB	$RF_{STOP} > IF_{STOP}$ $RF_{START} > LO_{FIXED}$
			DSB	$RF_{STOP} > IF_{STOP}$ $LO_{FIXED} > RF_{STOP}$

Table 2-16

DUT Type	Sys Down Converter	LO Type	Sideband	Frequency Restrictions
Amplifier Default Context = RF	On	Swept	LSB	$RF_{START} > IF_{FIXED}$ $LO_{START} > RF_{STOP}$
			USB	$RF_{START} > IF_{FIXED}$ $RF_{START} > LO_{STOP}$
			DSB	$RF_{START} > IF_{FIXED}$ $LO_{STOP} > RF_{STOP}$
DownConvert Default Context = IF		Fixed	LSB	$RF_{START} > IF_{START}$ $LO_{FIXED} > RF_{STOP}$
			USB	$RF_{STOP} > IF_{STOP}$ $RF_{START} > LO_{FIXED}$
			DSB	$RF_{STOP} > IF_{STOP}$ $LO_{FIXED} > RF_{STOP}$
DownConvert Default Context = RF		Swept	LSB	$RF_{START} > IF_{FIXED}$ $LO_{START} > RF_{STOP}$
			USB	$RF_{START} > IF_{FIXED}$ $RF_{START} > LO_{STOP}$
			DSB	$RF_{START} > IF_{FIXED}$ $LO_{STOP} > RF_{STOP}$
UpConvert Default Context = IF		Fixed	LSB	$IF_{START} > RF_{START}$ $LO_{FIXED} > IF_{STOP}$
			USB	$IF_{START} > RF_{START}$ $IF_{START} > LO_{FIXED}$
UpConvert Default Context = RF		Swept	LSB	$IF_{FIXED} > RF_{STOP}$ $LO_{START} > IF_{STOP}$
			USB	$IF_{FIXED} > RF_{STOP}$ $IF_{FIXED} > LO_{STOP}$

Advanced Features

This section describes how to use the Limit Lines and Loss Compensation features on your X-Series Analyzer.

This section covers:

- [Setting up Limit Lines](#) and using them for pass/fail testing of the measurements.
- [Using Loss Compensation](#) and using this to correct for system losses in cabling, switches, or connectors and system components.
- [Noise Figure Uncertainty Calculator](#) and how to use it.

Setting up Limit Lines

Limit lines can be set to mark lower or upper boundaries of the active traces and they can also be set to notify you of a failure when a trace passes over a limit line. Two limit lines can be applied to a single trace, for example, allowing an upper and lower boundary limit to be specified. The Noise Figure Measurement application features four independent Limit Lines.

To Change the Limit Line The default limit line setting is **Limit 1**. To change the active indicator, press **Meas Setup, Limits, Select Limit**, and select the desired limit.

Setting the Type of Limit Line You can set the Limit Line to be an upper limit or lower limit and test the trace against this limit line setting.

To set the limit line type, select your Limit Line, then press **Properties**, and set **Type** to **Upper** if you want it to be above the trace or **Lower** if you want it to be below the trace. Each of the four limit line needs to be set up separately.

Enabling Testing Against a Limit Line You can set the Limit Line to test against the trace. If a result fails testing it is reported in the upper left corner of the display. In table mode you also see the reported result failure.

To set the testing of the trace against the limit line, press **Meas Setup, Limits, More, Test Limits** to **On** if you want the result reported or to **Off** if you do not want the result reported. Each of the four limit lines needs to be set up separately.

NOTE

After a failure the LIMITS FAIL: indicator remains displayed until:

- a complete sweep has been performed with the Limit Line test passing at every point
 - you switch **Test Limits** to **Off**
 - you change the limit line type
 - you press **Restart**
-

To Switch All the Limit Lines Off To switch all the Limit Lines off, press **Limits, More 1 of 2, Disable All Limits**. This simultaneously switches off all Limit Lines, regardless of what graph or trace they are associated with.

NOTE When a limit line is switched off the limit line data is not affected.

Creating a Limit Line To set up limit lines, you need to specify the frequencies (X value), the amplitude (Y value). The limit line consists of a table of entries, each of which is a frequency-limit-connected group.

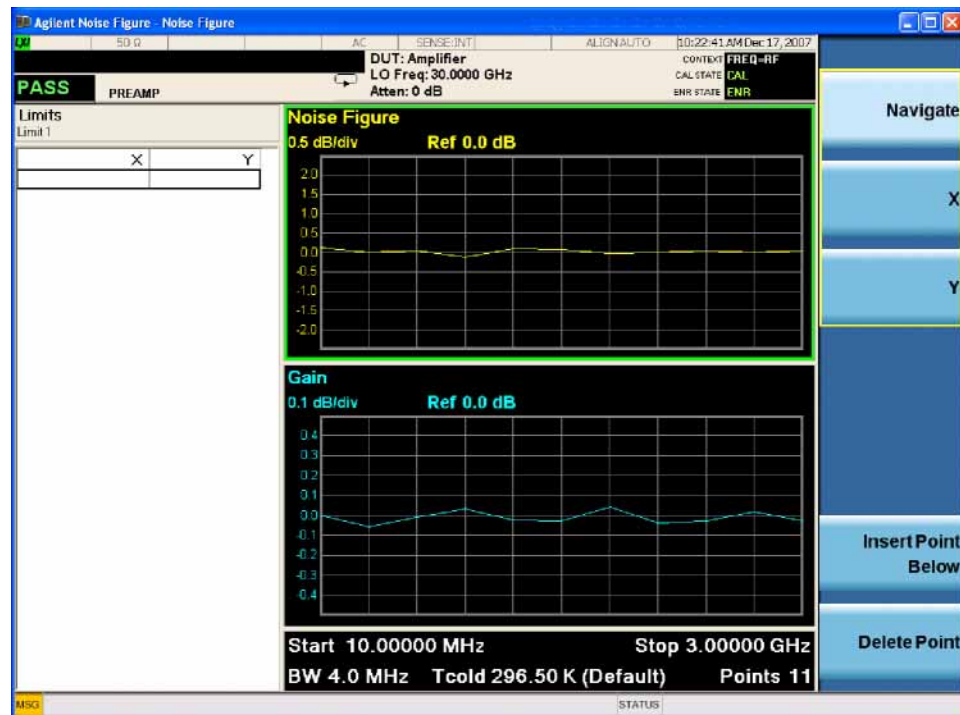
To create a limit line:

Step 1. Press **Meas Setup, Limits, Select Limit**, and select the desired limit.

Step 2. Press the **Edit** key.

You are presented with a Limit Line table with two entries.

Figure 2-37 *Limit Line Table before Limit Lines Values are Added*



Step 3. Press **X**.

Step 4. Navigate to the first Frequency value and enter the frequency using the numeric front panel keys. Press the unit of measurement terminator key.

Step 5. Enter the Limit or Y-axis unit value corresponding to the frequency you just entered. Again, finish by pressing the unit of measure terminator key.

Step 6. Repeat this process until the limit line is defined. Limit line tables can have a maximum of 101 entries.

The limit line is now defined. Press the **Return** key to return to the limit line menu.

NOTE

You can load a previously saved Limit Line table. However, you need to specify which limit line number you want loaded.

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:

1. Amplifiers with waveguide input, where a lossy waveguide-to-coax adapter is needed.
2. Transistors, where input and output tuners are required.
3. Non-50 Ω converters (such as TV tuners and amplifiers) where matching pads or transformers are required.
4. Compensation for fixed attenuators used to improve SWR.
5. 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 1. Press **Meas Setup, Loss Comp.**

Step 2. Press **Before DUT** or **After DUT, Fixed.**

Step 3. Enter the loss compensation value and press the **dB** termination key, see [Figure 2-38](#)

Figure 2-38 Fixed Loss Compensation



The lower limit is -100.000 dB, the upper limit is 100.000 dB, and the default is 0.000 dB.

- Step 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 296.5 K.

NOTE 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 example shows how to enter a Before DUT Table. If you want to enter an After DUT Table follow the procedure, changing the **Before DUT Table** key presses to **After DUT Table** key presses.

NOTE If you want to enter new loss compensation data and there is previous loss compensation data in the Noise Figure Measurement application, you can delete the previous data by pressing the **Clear Table** key.

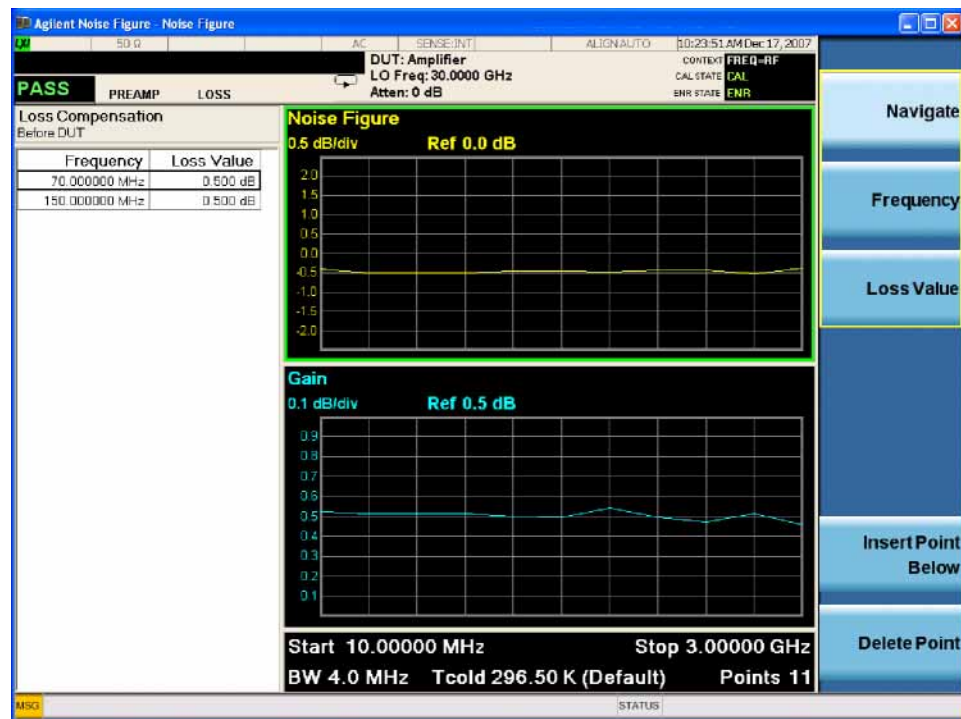
NOTE The Loss Compensation table frequency limits in the **Before DUT Table...** are specified in terms of the DUT's input frequencies and the **After DUT Table...** are specified in terms of the DUT's output frequencies. This is important when making frequency converting DUT measurements or using a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

Step 1. Press **Meas Setup, Loss Comp.**

Step 2. Press **Before DUT** or **After DUT, Table.**

Step 3. Press **Edit.** You are presented with a Loss compensation table with two entries. See [Figure 2-39](#).

Figure 2-39 Loss Compensation Table



Step 4. Press **Frequency** to move to the Frequency column.

Step 5. Enter the Loss Frequency value in the table using the numeric keys. Terminate it using the unit menu keys. The Loss Value column is automatically highlighted.

Step 6. Enter the corresponding Loss Value. and press **dB**.

Step 7. Repeat steps 5 to 6 until all the Loss Frequency and Loss Values you need are entered.

NOTE 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**.

Step 1. Press **Meas Setup, Loss Comp**.

Step 2. Press **Before DUT** or **After DUT, Temperature**.

Step 3. 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.

Noise Figure Uncertainty Calculator

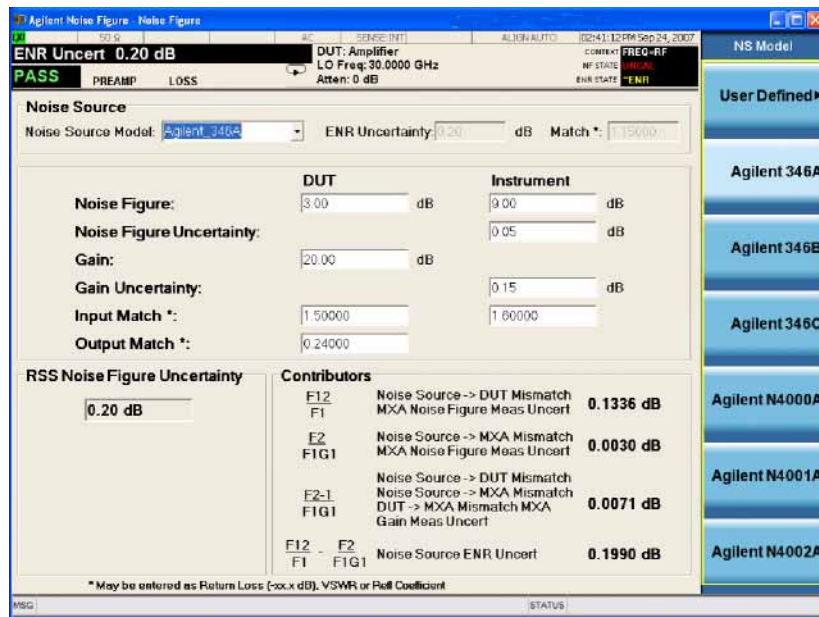
The measurement uncertainty calculator can be used to calculate the RSS (root sum square) measurement uncertainty. Measurement uncertainty is caused by device mismatch and other properties of the noise source, the device under test, and the spectrum analyzer. Once you measure or identify the various device characteristics, they can be entered into the analyzer and it will calculate the RSS uncertainty.

This makes a frequency-independent calculation using one ENR uncertainty value. While it provides a good estimation of the measurement uncertainty, you may want more accuracy. You may want to use more accurate values for ENR, gain and VSWR, or calculate values at a specific frequency of interest or at multiple frequencies. Refer to Application Note 57-2, Agilent part number 5952-3706E, for more information about calculating noise figure uncertainties. This document can be found at:

<http://www.agilent.com/find/nfa>

Figure 2-40

Noise Figure Uncertainty Calculator Screen



Noise Source

Six Agilent Noise Sources are available for selection. If you are not using one of these noise sources, you should select 'User Defined' as the Noise Source if the actual value of the noise source calibration data is available. This allows you to enter the uncertainty of the Excess Noise Ratio (ENR) and the NS Match, which can be from any noise source from any manufacturer. In addition, default values are provided giving typical parameters for noise sources from Agilent Technologies.

DUT	The device under test will be either an amplifier, upconverter, or downconverter. You will have to enter the measured (or documented) values for its noise figure, input match, output match, and gain into the fields in the calculator.
Instrument	Spectrum analyzer default values are provided. These are reasonable defaults for measurements below 3 GHz using the built-in preamp. For more accurate calculations, you will need to input the values that are appropriate for your particular measurement and setup.
RSS Value	The calculator provides the square root of the sum of the squares (RSS) of the various contributions to uncertainty. This is the recommended way to calculate the total measurement uncertainty since each of the contributing factors are random in nature.
System Down Converters	The calculator is designed to calculate uncertainty for a measurement where the DUT is either an amplifier, or a downconverter. It is not designed to calculate the uncertainty when measuring a DUT that is in a measurement setup that includes a system downconverter.

Example Calculation:

- Step 1.** Access the uncertainty calculator by pressing **Mode Setup, Uncertainty Calculator**.
- Step 2.** Suppose that you are testing an amplifier. You must enter the device characteristics into the appropriate DUT fields on the calculator form. Navigate to the required field. Enter the desired value and terminate your entry by pressing one of the units keys (if provided) or the **Enter** key.
- gain = 20 dB
 - noise figure = 3 dB
 - input match = 1.5
 - output match = 0.24
- Step 3.** You can read out the calculated RSS uncertainty from the results field and see the factors that contribute to the total uncertainty. The RSS shown in [Figure 2-40 on page 100](#) is 0.20 dB. This means for the measured value of 3 dB Noise Figure for this DUT, the real Noise Figure could have a value of ± 0.20 dB (that is, 2.80 dB to 3.20 dB).