Agilent
PSA Series Spectrum Analyzers
Noise Figure Measurements Personality

Technical Overview with Self-Guided Demonstration, Option 219

The noise figure measurement personality, available on the Agilent PSA Series spectrum analyzers, provides a suite of noise figure and gain measurements including system calibration.

Agilent Technologies

Add Noise Figure and Gain Measurements to Your Set of Test and Development Tools

A key measurement in the development of devices and systems is its noise figure. The overall noise figure of a system is one of the limiting factors in its performance. Making noise figure measurements can be a tedious manual process. But with Agilent's noise figure measurement systems, these measurements can be fast and easy with accurate results. Meet many of your measurement needs with a one-analyzer solution from Agilent.

- Perform system calibration easily and quickly.
- Analyze the device noise figure in several different formats.
- Characterize the noise figure of frequency conversion devices.
- Easily calculate measurement uncertainty.

The Agilent PSA Series offers high performance spectrum analysis up to 50 GHz with powerful one-button measurements, a versatile feature set, and a leading-edge combination of flexibility, speed, accuracy and dynamic range. Expand the PSA to include noise figure measurements with the noise figure measurements personality (Option 219).

The noise figure measurements personality provides noise figure and gain measurements over the frequency range of the PSA with specified measurements over the 10 MHz to 3 GHz range.

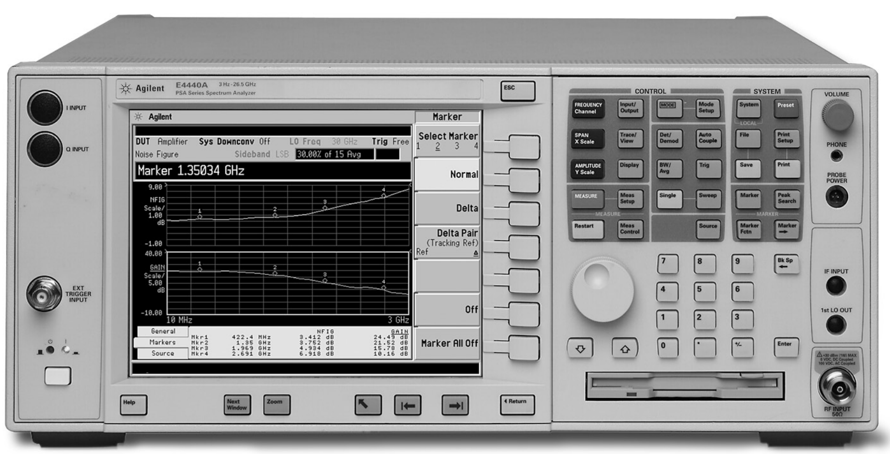
The technical overview includes:

- measurement details
- demonstrations
- PSA Series key specifications for the noise figure personality
- ordering information
- related literature

All demonstrations use the Agilent 346C noise source, mixer, amplifier and 70 MHz band pass filter. The keystrokes surrounded by [] indicate hard keys and while key names surrounded by {} indicate soft keys located on the right edge of the display.

Noise figure measurements:

- entering ENR values
- calibration
- noise figure and gain
- using display features
- measurement uncertainty calculator
- mixer as the DUT
- mixer as part of system



Demonstration preparation

To perform the following demonstrations, the PSA requires these options.

Product type	Model number	Required options
PSA Series spectrum analyzer	E4440A/43A/45A/46A/48A	Option 1DS built-in preamplifier Option 219 noise figure measurement personality
Noise source	346A/346B/346C	

To configure the measurement system, simply connect the noise source (Agilent 346C) to the rear panel connector labeled "noise source drive out + 28 V (pulsed)" using a 1 meter BNC cable (50 Ω).

Noise figure measurement process summary

Measuring the noise figure of a device requires knowledge of the measurement system. Once the noise figure of the measurement instrument is known and the gain of the device under test (DUT) is known, then the noise figure of DUT can be calculated, after which the overall noise figure is measured. Most computing measurement systems, such as the Option 219 measurement personality, can display noise figure in dB. Noise figure measurements are comprised of three steps:

1. Enter the excess noise ratio ENR values in dB of the noise source.
2. Calibrate the measurement personality.
3. Make noise figure measurements.

Entering the ENR table for a noise source

The noise source used for this demonstration is the 346C. This noise source has a calibrated range of 10 MHz to 26.5 GHz. There is a pulsed 28 V source that drives the noise source. When the voltage is on, the output of the noise source is the excess noise value. Once calibration data is entered into the measurement personality, system calibration and DUT measurements can be made. In most cases a common ENR table can be used for calibration and measurements. However, in the case of mixers, for example, the frequency range of the source for measurements may be outside the range for calibration, and therefore two sources are required. There are instances where the calibration ENR table is different from the measurement ENR table. An example would be the analysis of the noise figure of a frequency conversion device (mixer). In this case there is no longer a common table used. Instead, the common table function is turned off. There are two methods of loading the ENR information into the table. The preferred method is to load the values from a disk supplied with the noise source. The second method, which is less desirable, is to enter the excess noise ratio common table manually.

This exercise illustrates the different methods of entering excess noise ratio numbers.

Instructions	Keystrokes
Enable the noise figure measurement personality.	[Preset] [Mode] ({More} if necessary) {Noise Figure}
Enter the ENR numbers from disk.	[File] {Load} {Type} {More} {ENR Meas/Common Table} {Load Now}
You may also enter ENR values manually. Add excess noise ratio (ENR) serial number and model number.	{Meas Setup} {ENR} {Meas & Cal Table} [Return] {Serial #} Use the numeric pad and alpha editor to enter the serial number. If the serial number already exists, you will be prompted to choose whether or not you want to load the data. If not, press {Model ID} and enter the model number using the alpha editor and numeric key pad.
Adding ENR values versus frequency.	{Index} [1] {Frequency} [10] {MHz} {ENR Value} [13.14] {dB} Repeat the process for index 2 and so on.
Saving the calibration data to a floppy or the internal memory of the PSA.	[File] {Save} {Dir Select} Use up/down arrows to select drive A for the floppy, then press {Dir Select}. Press {Name} and use the Alpha Editor to name the file (8 characters max). When finished entering the name, press [Return] and {Save Now}.

Calibration of the noise figure measurement personality

In order to make accurate measurements, the personality must first be calibrated. Calibration is required because the NF of the measurement system has to be known before a DUT can be measured. The measured instrument noise figure is then removed from the total noise figure measurement so that only the DUT noise figure and gain is displayed.

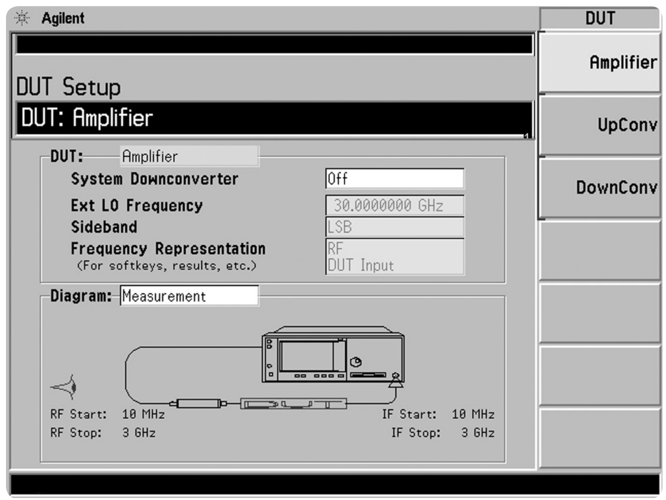
Following is the calibration process:

1. Select the frequency range.
2. Set the number of points and set the number of averages.
3. If the device under test does not have gain or if the gain is low, turn on the built-in preamplifier before calibration.

Perform a system calibration.

Instructions	Keystrokes
Connect the noise source to the PSA with a BNC cable to the source driver on the rear panel.	Connect BNC cable between 346 series noise source and the rear panel connector labeled Noise Source Drive Out +28 V (Pulsed).
Set the start frequency.	[Frequency] {Start Freq} [10] {MHz}
Set the stop frequency.	{Stop Freq} [3] {GHz}
Set the number of points at which to measure.	{Points} [30] [Enter]
Set the averaging function to 15 averages.	[Meas Setup] {Avg Number On} [15] [enter]
Calibrate the measurement personality.	[Meas Setup] {Calibrate} {Calibrate}

Figure 1.
DUT set up

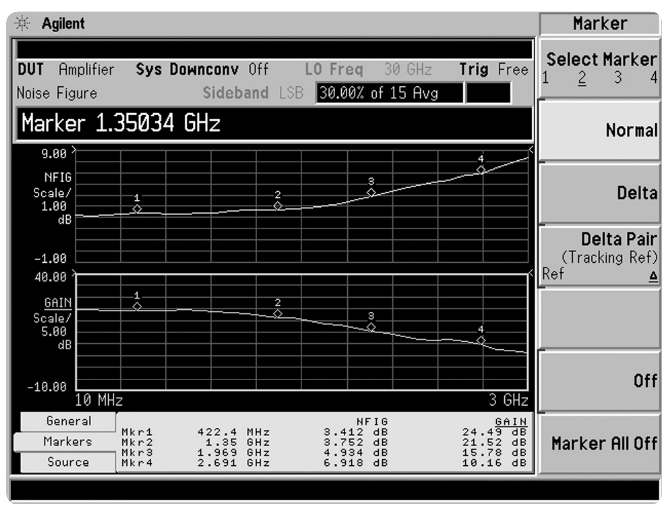


Noise figure and gain measurements

Now that the measurement personality is calibrated with the noise source connected directly to the input, it is a simple matter to make noise figure and gain measurements on a device.

Disconnect the noise source from the input and connect the DUT to the input and connect the noise source to the DUT as shown in Figure 1. The noise figure and gain of the device under test is shown in Figure 2.

Figure 2.
Typical noise figure and gain graph



Using the display features

The noise figure measurement personality has many features to help you interpret and analyze noise figure measurements.

Select and Zoom Active Window:
This feature allows you to highlight a window and then enlarge it for closer analysis.

This exercise illustrates the use of the display features.

Instructions	Keystrokes
Highlight the window of interest.	Press [Next Window] until the window you want is highlighted.
Enlarge the window for closer analysis.	[Zoom]
Switch to another window (Figures 3 and 4).	[Next Window]

Figure 3.
Noise figure full screen

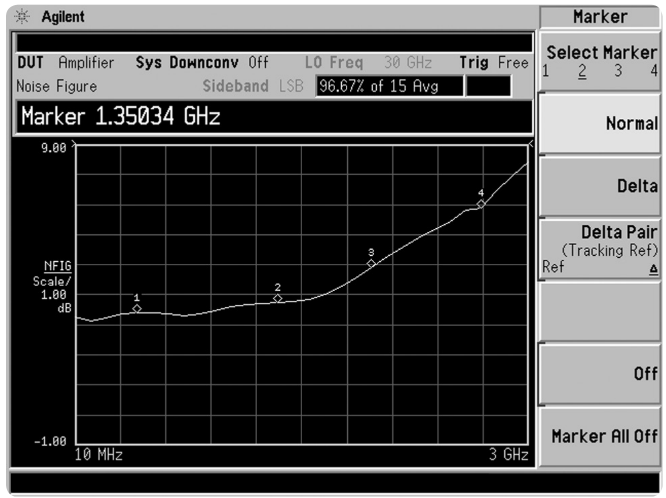
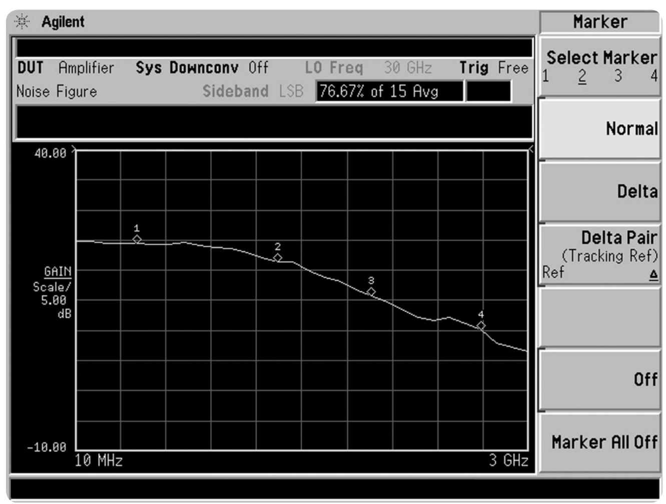


Figure 4.
Device gain full screen



General, markers and source tabs

There are three tabs available at the bottom of the screen. These tabs are accessed using the left and right arrow keys. The General tab shows information about BW, number of points, Tcold value, loss, attenuator setting and internal preamplifier setting. The Marker tab gives the frequency, noise figure and gain of each of the markers. The Source tab includes information about the noise source including serial number and model identification.

Instructions	**Keystrokes**
View the tabs at the bottom of display (Figures 5, 6, and 7).	Use the Right and Left Tab keys at the bottom of the front panel to scroll through the tabs.

Figure 5.
General information display

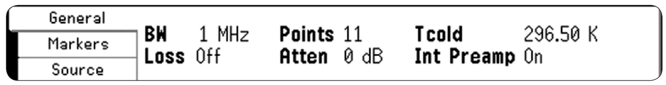


Figure 6.
Noise source information

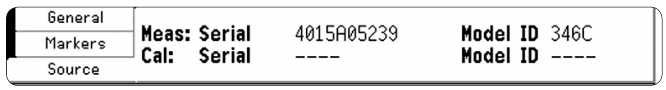
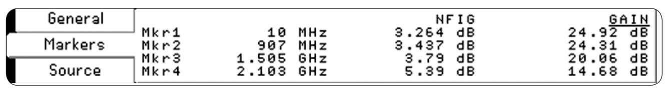


Figure 7.
Marker information



Scale and reference level values

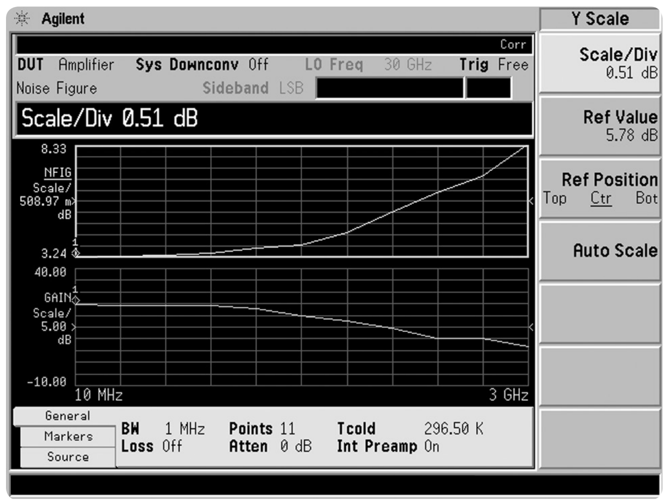
The scale in dB per division and the reference values can be adjusted to give an optimized view of the measured results. The scale per division can be adjusted in 0.1 dB steps from 0 to 20 dB. The reference level can be placed at the top of the graph, in the center or at the bottom. The reference level is adjustable in 0.1 dB steps from –100 dB to +100 dB.

Use the Auto Scale feature to give the broadest view of the measured trace. The lowest point will be placed at the bottom of the graph and the highest value at the top of the graph.

Perform display scaling.

Instructions	Keystrokes
Set the scale of the graphical view.	Press [Amplitude] [Next Window] to highlight the graph to be changed. Press {Scale/Div} and enter the new value [1.5] and press {dB}.
Set the reference value and the position of the reference.	Press [Amplitude], then [Next Window] to highlight the graph to be changed. Press {Ref Value} and enter [18] and press {dB}. Move the position of the Ref Value by pressing {Ref Position Ctr}.
Expand the trace to fit the graph for a better view of the measurement using the Auto Scale function as shown in Figure 8.	Press [Amplitude] use [Next Window] to highlight the graph to be expanded then press {Auto Scale}.

Figure 8. Display of noise figure after auto-scaling



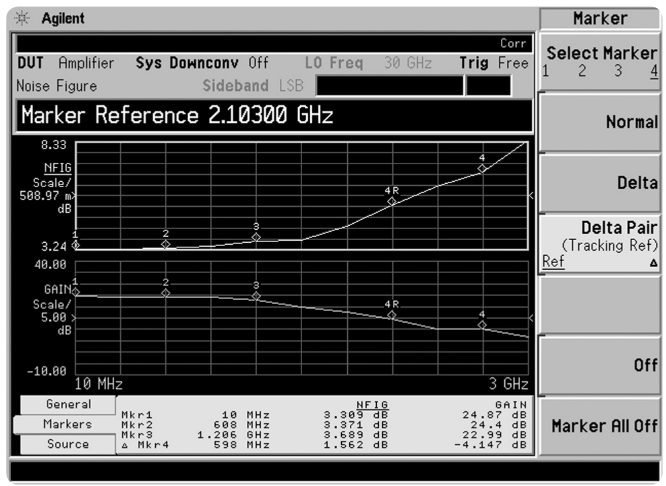
Markers

A total of four normal markers can be placed on the graphical display. The placement of the markers is limited to the calibration points. If there are 11 calibration points then the markers can be placed on each of the vertical graticule lines. Each of the normal markers can be changed to delta markers. For example, marker 2 will change to marker 2 and 2R where 2R is the reference and 2 would be the delta.

This exercise illustrates the use of markers.

Instructions	Keystrokes
The marker function operates the same as the standard E4440A series PSA.	To turn marker on, press [Marker].
Turn on marker 2. Active delta marker 2.	Press {Select Marker 2} and press {Normal}. First place the marker to a reference point using knob or up/down arrows. Press {Delta}.
The marker table under the graphical display reflects the delta marker information (Figure 9).	Move the marker relative to the reference marker.
Switch between displaying the absolute frequency of the delta marker and the reference marker frequency.	Press {Delta Pair}. Note the change in frequency above the graphical display.

Figure 9.
Display of markers and delta markers



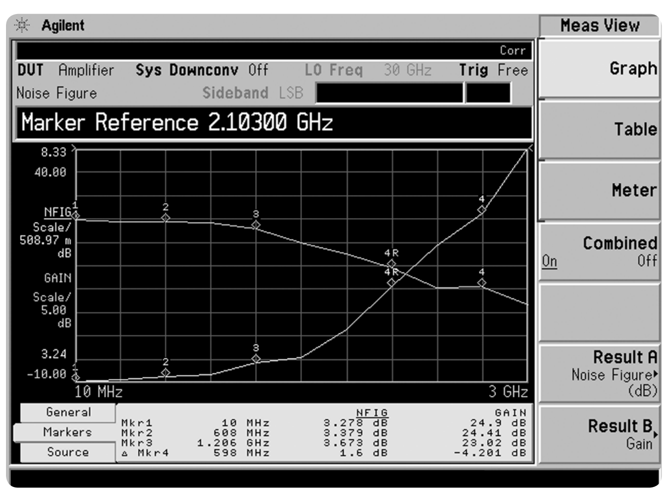
Change format of the active window

The default view of the window is the graphical mode with noise figure in the top and gain in the bottom. The two graphs can be combined to display both traces on one graph. There are two other views available table mode and meter mode.

Illustrating more of the display features.

Instructions	Keystrokes
To combine both traces on one graph, see Figure 10.	[Trace/View] {Combined on}
Activate the table mode.	[Trace/View] {Table}
Activate the meter mode.	[Trace/View] {Meter}

Figure 10.
Full screen of the combined mode



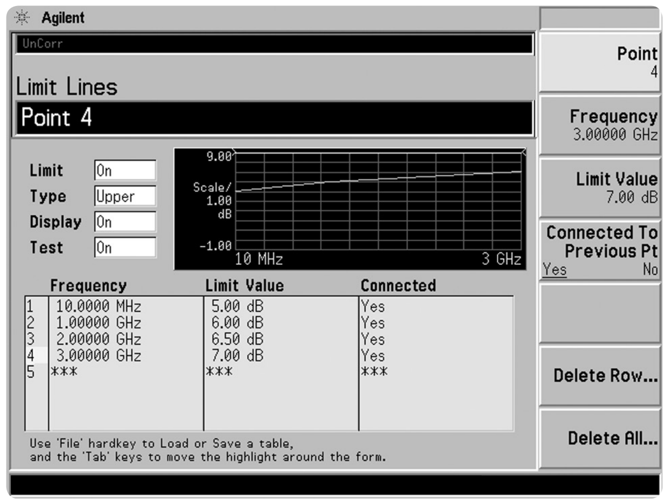
Creating limit lines

Up to four limit lines can be set, two for the upper graph and two for the lower graph. The limit lines for the upper graph are designated with up arrows, and the limit lines for the lower graph are designated with down arrows. The limit lines can be designated as upper limit or lower limit and each can have a test pass/fail indicator.

This exercise develops limit lines.

Instructions	Keystrokes
Open the limit line editor. Select upper limit for the upper graph and turn on the limit test.	[Display] {Limits} {Limit Line 1} {Edit...} Use right/left tab keys under display to highlight "Limit". Press {On}, tab to Type, press {Upper}, Display {On}, Test {On}.
Insert limit values for 10 MHz, 1, 2 and 3 GHz (Figure 11).	Use right/left tab keys to highlight point 1. {Frequency} [10] {MHz} {Limit Value} [5] {dB} {Connected Yes} {Point 2} {Enter} {Frequency} [1] {GHz} {Limit Value} [6] {dB} {Connected Yes} {Point 3} {Frequency} [2] {GHz} {Limit Value} [6.5] {dB} {Connected Yes} {Point 4} {Frequency} [3] {GHz} {Limit Value} [7] {dB} {Connected Yes}

Figure 11.
Display of limit line



Noise figure uncertainty calculator

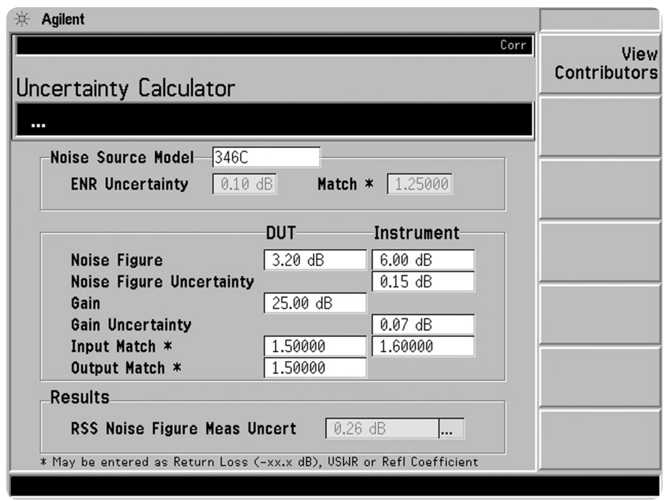
When making a noise figure measurement, there are many aspects of the measurement setup that can affect the uncertainty of that measurement. The instrument uncertainty is one element of measurement uncertainty where the instrument itself adds to the measurement uncertainty; this is the instrument uncertainty we read in the specifications. Other factors like the noise source and the system mismatch also add to the measurement uncertainty. A measurement uncertainty calculator is used to incorporate all of these factors to determine the total measurement uncertainty.

The noise figure measurement personality, Option 219, has a built-in uncertainty calculator. To calculate the overall measurement uncertainty, simply choose the default noise source (346C for example), enter the input and output match of the device under test and the gain/noise figure of the DUT from the measurement display and the value of the uncertainty will be calculated. There are some default values for the instrument (PSA) already entered.

Use the built-in uncertainty calculator.

Instructions	Keystrokes
Select uncertainty calculator.	[Mode Setup] {Uncertainty Calculator}.
Choose 346C as default source.	Use right/left tab keys to highlight "Noise Source Model" box. Press {346C}.
Enter the noise figure and gain values from the measurements graph or marker table.	Use tab keys to highlight "DUT Noise Figure" and enter [3.2] {dB}. (To view the marker table, press [Return] and to return to the calculator press {Uncertainty Calculator}). Then highlight "DUT Gain" and enter [25] {dB}.
The input and output match of the DUT is determined from the specifications sheet or measured using a network analyzer.	Highlight "DUT Input Match" and enter [1.5]. Highlight "DUT Output Match" and enter [1.5]. The measurement uncertainty is then calculated and the results is display at the bottom of the form (Figure 12).

Figure 12. Uncertainty calculator display



Noise figure measurements using a mixer as the DUT

When a down conversion is included in the noise figure measurement, for example measuring the noise figure of a mixer, there are some additional setups to consider. For this example let us use a mixer as a down-converter with an IF at 70MHz, LO at 1GHZ and both RF sidebands are used, 930 and 1070 MHz (DSB):

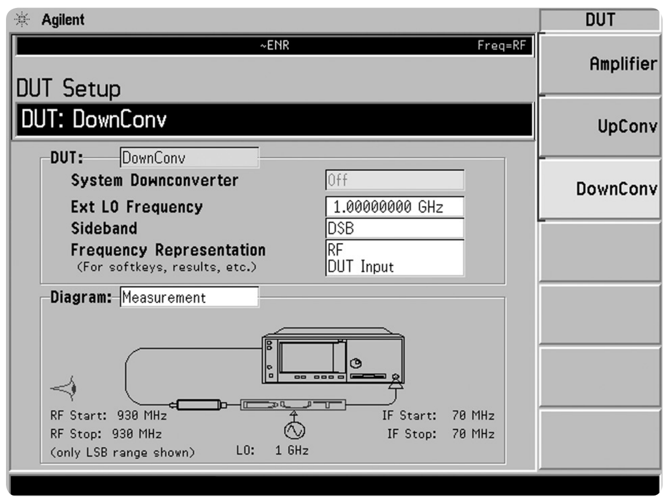
- The measurement, as well as calibration, is made at the IF frequency.
- When an IF frequency is chosen, it is a good idea to keep the frequency as low as possible in order to avoid large differences in ENR values between the upper and lower sidebands when using DSB mode. This is because it is the ENR value at the LO that is used in the measurement (compromise since it is centered between the two sidebands)
- Since this device has some loss, it is recommended that the internal preamp be used.
- Compensate for two sidebands by selecting double side band. Any

  broadband noise in the LO will directly affect results. This can be solved by either a high pass or low pass filter at the LO port that removes the noise at the IF frequency. Place an IF filter at the input of the spectrum analyzer to remove LO feed through. Usually mixers have around 20 dB of isolation between the LO-IF port so the high powered LO will seriously affect results.

Perform measurements on mixers.

Instructions	Keystrokes
Set up the PSA for down conversion measurements. It is recommended that the internal preamp be used when measuring devices that have low gain.	{Meas Setup} {Int Preamp On} [Mode Setup] {DUT Setup...} {Down Conv}
Set up the source for +7 dBm at 1 GHz.	On E4438C press [Frequency] [1] {GHz} [Amplitude] [7] {dBm} [RF On].
Set up the LO frequency (Figure 13).	Scroll to "Ext LO frequency" using tab keys then enter [1] {GHz}. Tab to "sideband" and choose "DBS".
Set up the fixed IF frequency.	[Frequency] {Freq Mode} {Fixed} {Fixed Frequency} [70] {MHz}
Calibration: connect the noise source to the input of the PSA.	[Meas Setup] {Calibrate} {Calibrate}
Measure the DUT: Connect the mixer IF (I) port to the PSA, the LO (L) port to the signal source and the RF (R) to the noise source.	To add more averaging, press [Meas Setup] then {Avg Number On).

Figure 13. Setup for measuring a mixer



Measurements using a mixer as part of the system

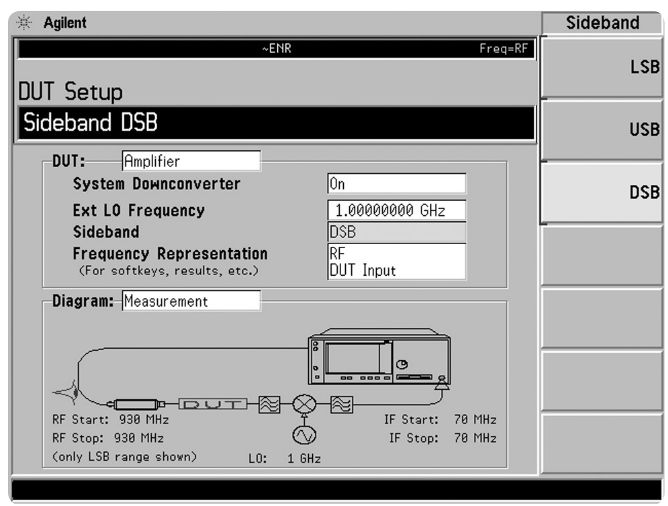
In this application the mixer is part of the noise figure measurement system. The diagram below shows the DUT and the mixer as the down converter. The DUT in this case is an amplifier. When using a mixer as part of the measurement system, calibration is performed with the mixer in the path. As in the illustration above, 70 MHz is used as the IF and a band pass filter is added to the IF out of the mixer. Choose the LO frequency to be 70 MHz above the desired RF and then calibrate and then insert the device under test. In this case, the device is tested at one frequency.

In this measurement, there is no input filter to limit the noise input to the upper sideband even though the LSB was selected. The noise from the upper sideband and lower sideband will give a noise figure higher than expected (3 dB).

Perform measurements with a mixer as part of the system.

Instructions	Keystrokes
Setup for the calibration process.	Connect the noise source to the R port of the mixer, the signal source to the L port and the 70 MHz BPF to the I port. Connect the other end of the 70 MHz BPF to the input of the SA.
Analyzer setup - this assumes that the ENR factors are loaded in the PSA (Figure 14).	[Mode Setup] {DUT Setup} {Amplifier} Using the tab keys under the display, highlight system downconverter and press {On}, move to "LO" and enter [1] {GHz}. Move to "Sideband" and select {LBS}. Move to "Frequency Representation" and select "RF DUT Input".
Set up the SA frequency.	[Frequency] {Freq Mode} {Fixed} {Fixed Freq 930 MHz}. Set the source to 1 GHz and +7 dBm. [RF On]
Start the calibration process.	[Meas Setup] {Calibrate} {Calibrate}
Place the DUT in the system between the noise source and the RF port.	No key presses required; the noise figure and gain is indicated in the box below the display.

Figure 14. Setup using a mixer as part of the system



Noise figure measurement personality (200 kHz to 26.5 GHz)

Noise figure

Frequency range 200 kHz to 10 MHz	(With internal preamp 1DS)	
	Meas. range	Instr. uncertainty
ENR	(nominal)	(nominal)
4 to 7 dB	0 to 20 dB	±0.05 dB
12 to 17 dB	0 to 30 dB	±0.05 dB
20 to 30 dB	0 to 35 dB	±0.10 dB

Frequency range 10 MHz to 3 GHz	(With internal preamp 1DS and 1 MHz RBW)	
ENR	Meas. range	Instr. uncertainty
4 to 7dB	0 to 20 dB	±0.05 dB
12 to 17 dB	0 to 30 dB	±0.05 dB
20 to 22 dB	0 to 35 dB	±0.10 dB

Frequency range 3 GHz to 26.5 GHz[1]	(With RBW of 1 MHz)
	Measurement uncertainty
ENR ~ 15 dB	±0.3 dB (nominal)

Gain

Frequency range 200 kHz to 10 MHz	(With internal preamp 1DS)	
	Meas. range	Instr. uncertainty
ENR	(nominal)	(nominal)
4 to 7 dB	–20 to 40 dB	±0.17 dB
12 to 17 dB	–20 to 40 dB	±0.17 dB
20 to 30 dB	–20 to 40 dB	±0.17 dB

Frequency range 10 MHz to 3 GHz	(With internal preamp 1DS and 1 MHz RBW)	
ENR	Meas. range	Instr. uncertainty
4 to 7dB	–20 to 40 dB	±0.17 dB
12 to 17 dB	–20 to 40 dB	±0.17 dB
20 to 22 dB	–20 to 40 dB	±0.17 dB

Frequency range 3 GHz to 26.5 GHz	(With RBW of 1 MHz)
	Measurement uncertainty
ENR ~ 15 dB	±1.0 dB (nominal)

1. Performance above 3 GHz depends on the gain of the DUT and whether or not a preamplifier is used. Please refer to the *Noise Figure Guide*, literature number E4440-90195, for details.

PSA Series Ordering Information

PSA Series spectrum analyzer

E4443A 3 Hz to 6.7 GHz
E4445A 3 Hz to 13.2 GHz
E4440A 3 Hz to 26.5 GHz
E4447A 3 Hz to 42.98 GHz
E4446A 3 Hz to 44 GHz
E4448A 3 Hz to 50 GHz

Options

To add options to a product,
use the following ordering scheme:
Model E444xA (x = 0, 3, 5, 6, 7 or 8)
Example options E4440A-B7J, E4448A-1DS

Warranty & Service

Standard warranty is three years.

R-51B-001-5C	Warranty Assurance Plan, Return to Agilent, 5 years

Calibration [1]

R-50C-011-3	Calibration Assurance Plan, Return to Agilent, 3 years
R-50C-011-5	Calibration Assurance Plan, Return to Agilent, 5 years
R-50C-016-3	Agilent Calibration + Uncertainties + Guardbanding, 3 years
R-50C-016-5	Agilent Calibration + Uncertainties + Guardbanding, 5 years
AMG	Agilent Calibration + Uncertainties + Guardbanding (accredited calibration)
A6J	ANSI Z540-1-1994 Calibration
R-50C-021-3	ANSI Z540-1-1994 Calibration, 3 years
R-50C-021-5	ANSI Z540-1-1994 Calibration, 5 years
UK6	Commercial calibration certificate with data To be ordered with PSA

Measurement Personalities

E444xA-226	Phase noise	
E444xA-219	Noise figure	Requires 1DS
E444xA-241	Flexible digital modulation analysis	
E444xA-BAF	W-CDMA	Requires B7J
E444xA-210	HSDPA	Requires B7J and BAF
E444xA-202	GSM w/ EDGE	Requires B7J
E444xA-B78	cdma2000	Requires B7J
E444xA-214	1xEV-DV	Requires B7J and B78
E444xA-204	1xEV-DO	Requires B7J
E444xA-BAC	cdmaOne	Requires B7J
E444xA-BAE	NADC, PCD	Requires B7J
E444xA-217	WLAN	Requires 122 or 140
E444xA-211	TD-SCDMA	
E444xA-215	External source control	
E444xA-266	Programming code compatibility suite	

Hardware

E444xA-1DS	100 kHz to 3 GHz built-in preamplifier	
E444xA-B7J	Digital demodulation hardware	
E444xA-122	80 MHz bandwidth digitizer	E4440A/43A/45A only, excludes 140, H70
E444xA-140	40 MHz bandwidth digitizer	E4440A/43A/45A only, excludes 122, H70
E444xA-123	Switchable MW preselector bypass	E4440A/43A/45A only, excludes AYZ
E444xA-124	Y-axis video output	
E444xA-AYZ	External mixing	E4440A/47A/46A/48A only, excludes 123
E4440A-BAB	Replaces type-N input connector with APC 3.5 connector	E4440A only
E444xA-H70	70 MHz IF output	Excludes 122, 140. Not available for E4447A

PC Software

E444xA-230	BenchLink Web Remote Control Software	
E444xA-233	N5530S measuring receiver software & license	Requires B7J, E4443A/45A/40A only
E444xA-235	Wide BW digitizer external calibration wizard	Requires 122 E4443A/45A/40A only

Accessories

E444xA-1CM	Rack mount kit
E444xA-1CN	Front handle kit
E444xA-1CP	Rack mount with handles
E444xA-1CR	Rack slide kit
E444xA-015	6 GHz return loss measurement accessory kit
E444xA-045	Millimeter wave accessory kit
E444xA-0B1	Extra manual set including CD ROM

Recommended noise source

(For Option 219, noise figure measurement)

346A	Noise source, 10 MHz to 18 GHz, nominal ENR 6 dB
346B	Noise source, 10 MHz to 18 GHz, nominal ENR 15 dB
346C	Noise source, 10 MHz to 26.5 GHz

1. Options not available in all countries

Product Literature

Selecting the Right Signal Analyzer for Your Needs, selection guide, literature number 5968-3413E

PSA Series literature

PSA Series, brochure, literature number 5980-1283E
PSA Series, data sheet, literature number 5980-1284E

NFA Series literature

NFA Series Configuration Guide, literature number 5980–0163E
NFA, brochure, literature number 5980–0166E
NFA Series Demonstration guide,literature number 5980–2028E

Application literature

10 Hints for Making Successful Noise Figure Measurements, application note 1341, literature number 5980–0288E
Fundamentals of RF and Microwave Noise Figure Measurements, application note 57-1, literature number 5952–8255E
Noise Figure Measurement Accuracy – The Y Factor Method, application note 57-2, literature number 5952–3706E

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(BP-09-27-13)

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Published in USA, November 25, 2013
5988-7884EN

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