# Product Note 8340-7

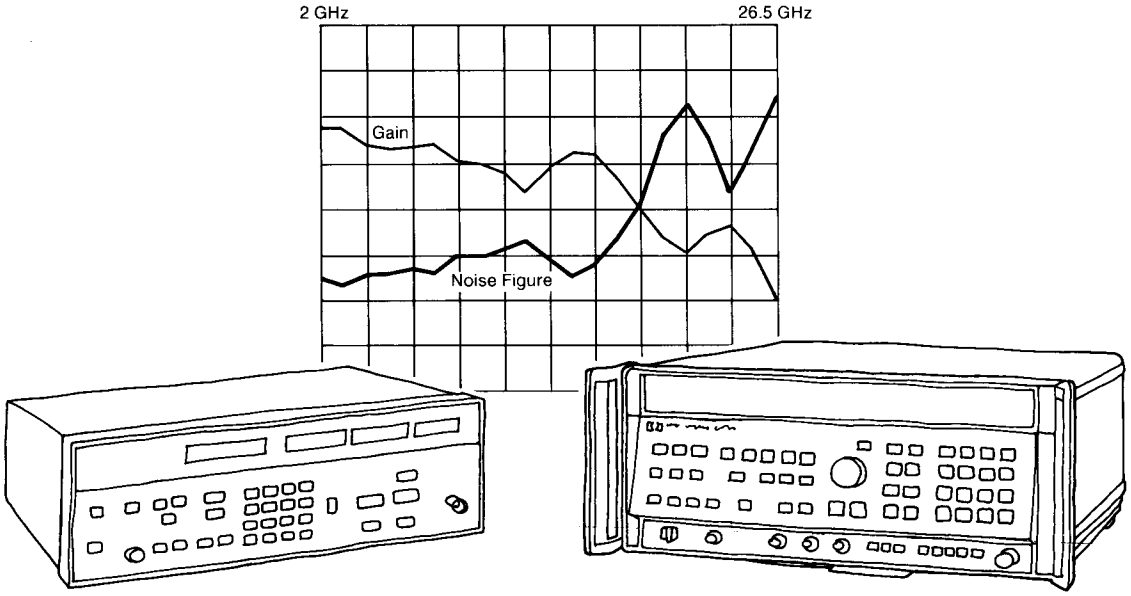
HEWLETT PACKARD

BDSV



## Synthesizer Applications

Microwave noise figure measurements using the HP 8340 or 8341 synthesized sweeper with the HP 8970A noise figure meter




HP 8970
Noise Figure Meter

HP 8340/8341
Synthesized Sweeper

# Introduction

The HP 8340 and 8341 Synthesized Sweepers are versatile microwave sources that deliver the combined capabilities of a synthesized signal generator and a sweep oscillator. The HP 8340 and 8341 also make an outstanding local oscillator for microwave noise figure measurements. Functioning as the LO, the HP 8340 and 8341 can extend the HP 8970A Noise Figure Meter input frequency range (10 MHz to 1.5 GHz) to cover the 1.5 to 26.5 GHz frequency range.

The HP 8970A microprocessor-controlled Noise Figure Meter, in addition to performing tedious calculations and error correction, programs the HP 8340 or 8341 via the Hewlett-Packard Interface Bus (HP-IB)* over the frequency range of interest without the use of an external controller, thus making an easy to set up and easy to run microwave noise figure measurement system.

The purpose of this product note is to describe the operation of the HP 8340 or 8341 Synthesized Sweeper as an external LO with the HP 8970A Noise Figure Meter. This document does not intend to supersede the Product Note HP 8970A-1 but to be a complement dedicated to the HP 8340 and 8341. All specific noise figure information is found in the Product Note HP 8970A-1 or the references listed in Appendix A.

**Notes**

In this product note, the terms "RF" and "microwave" are used here with this specific meaning: "RF" refers to measurements made in the frequency range of the HP 8970A: 10-1500 MHz, "microwave" refers to measurements above 1500 MHz.

The measurement examples in this product note show frequency coverage to 26.5 GHz. This capability is available with the 10 MHz to 26.5 GHz HP 8340 and HP 346C noise source and an appropriate 26.5 GHz mixer. An 18 GHz system can be configured using the 10 MHz to 20 GHz HP 8341 and the HP 346B noise source and the HP HMXR 5001 mixer.

*HP-IB is Hewlett-Packard's hardware, software, documentation and support for IEEE-488 and IEC 625, worldwide standards for interfacing instruments.

# Equipment Setup

A typical setup for microwave noise figure measurements using an HP 8970A Noise Figure Meter and an HP 8340 or 8341 as an LO source is shown in Figure 1. The broadband noise signal from the HP 346C Noise Source goes through the Device Under Test (DUT) and is then down converted in the HP HMXR-5001 mixer (or equivalent) to a value in the RF input range of the HP 8970A (10-1500 MHz).

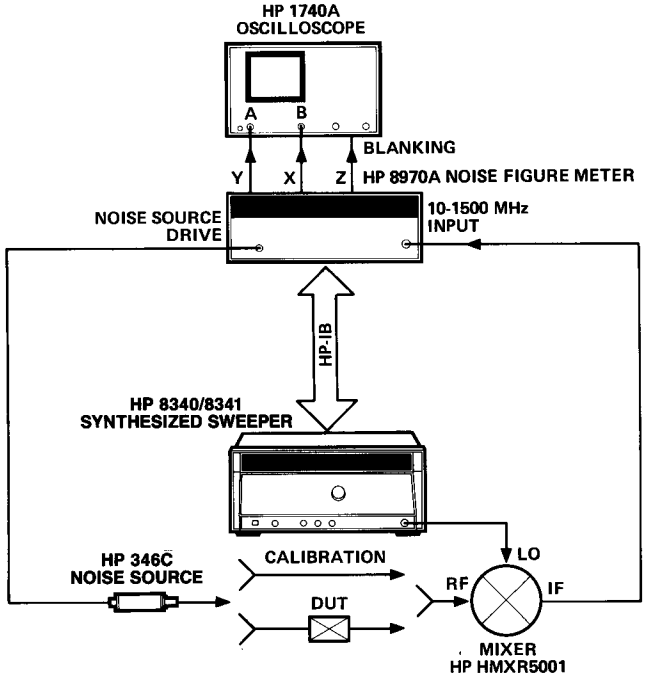



*Figure 1. Mode 1.1—Amplifier measurement setup with "swept LO, fixed IF."*

# HP 8970A Noise Figure Meter

The noise measurement concept is not discussed in this note. Refer to Appendix A for more information on noise figure.

The HP 8970A Noise Figure Meter is a very sensitive, tunable automatic receiver. It's capability is greatly enhanced by a microprocessor used for calculations and error correction purposes. Features of the HP 8970A include its ability to store and compensate for Excess Noise Ratio (ENR) variations versus frequency, reduce the second stage effect and correct the difference between the cold temperature $T_c$ (ambient) and 290K. The HP 8970A also displays the gain and the noise figure (with a resolution of 0.01 dB) and jitter which can be reduced with the smoothing function.

Microwave noise figure measurements are accomplished using a powerful set of "special functions" built into the HP 8970A. In particular these functions allow the user to set the various measurement modes and parameters as well as set up and control the HP 8340 or 8341 via the HP-IB. The special function codes are listed on pull-out card #1 of the HP 8970A. A special function is selected by typing in the function code on the front panel keyboard. For example, the function 40.1 SP displays the external LO source HP-IB address.

Press [4] [0] [.] [1] [SP]

When the HP 8970A is switched on or PRESET key is pressed, most of the functions are placed in a default state. Each default function is written in green on pull-out card #1.

Mode 1.0 is the default mode. This is the "RF" mode or internal mode. Noise figure and gain measurements are made from 10-1500 MHz without any external instruments required.

For "microwave" measurements (1.5-18 GHz), some form of down conversion to the 10 to 1500 MHz band of the HP 8970A is needed. Four possibilities exist depending on the type of component to be measured and the local oscillator (LO) frequency range. This note describes the operation of these four microwave modes with the HP 8340 or 8341 used as an LO. The items to be measured with the HP 8970A can be divided into two groups: one for devices without frequency conversion like amplifiers, and a second for devices with frequency conversion like mixers or receivers. For each type of DUT, either a "swept LO, fixed IF" or "swept IF, fixed LO" technique can be used. Each of these modes is selected with the special functions 1.1 through 1.4. The choices are summarized in the following table.

| Device | Devices without frequency conversion | Devices with frequency conversion |
|---|---|---|
| examples | amplifiers | mixers<br>receivers |
| swept LO—fixed IF | [1] [.] [1] | [1] [.] [3] |
| swept IF—fixed LO | [1] [.] [2] | [1] [.] [4] |

With each of these modes, the frequency of the HP 8340 or 8341 LO is set from the HP 8970A. The special function 41.0 allows the HP 8970A to act as an HP-IB controller and programs the HP 8340 or 8341 as an LO in CW mode to coordinate the sweep of the LO with the noise figure measurement.

The term "swept LO, fixed IF" refers to step-by-step CW sweep on the HP 8340 or 8341, with the frequency increments and a fixed intermediate frequency (IF) set on the HP 8970A. The term "swept IF, fixed LO" refers to step-by-step IF sweep on the HP 8970A and a fixed LO frequency set on the HP 8340 or 8341 from the HP 8970A.

For every mode, the measurement is made after the calibration procedure. During calibration, the noise source is connected directly to the measurement system. For measurement, the DUT is inserted between the noise source and the measurement system. The measurement setup varies from the setup described in Figure 1 depending on the type of the DUT to be tested.

For DUT's without frequency conversion (e.g. amplifiers), the HP 8340 or 8341 is connected to the mixer LO input during the calibration and is a part of the measurement system. In the frequency down conversion process, the input of the HP 8970A (IF output of the mixer) receives the converted noise from the noise source and the noise added by the DUT, plus a part of the broadband noise from the HP 8340 or 8341 synthesized LO. In this case the broadband noise added by the LO can be calibrated out as a part of the second stage correction in the HP 8970A.

For DUT's with frequency conversion (e.g. mixers, receivers), the HP 8340 or 8341 LO is not connected during calibration and becomes a part of the DUT. Thus, a second stage correction for the broadband noise floor of the LO is not possible.

A "swept LO, fixed IF" technique can be used either for double sideband (DSB) or single sideband (SSB) measurements. But a "swept IF, fixed LO" technique is always a SSB measurement for devices without frequency conversion (e.g. amplifiers) and usually, but not always, a SSB measurement for devices with frequency conversion (e.g. mixers, receivers).

# HP 8340 or 8341 Synthesized Sweeper

The HP 8340 or 8341 is used as a local oscillator with a mixer to down convert the measuring frequency into the input frequency band of the HP 8970A. The allowable frequency range of the DUT is determined from the following equation:

$$F_{meas} = F_{LO} \pm F_{IF}$$

$F_{IF}$ is limited to the HP 8970A frequency range. To measure a broadband device, a broadband local oscillator is required.

The HP 8340 and 8341 is outstanding as an LO for noise figure measurements made with the HP 8970A above 1.5 GHz. Its synthesized frequency accuracy and stability make it ideal for microwave tuned receiver testing and mixer LO driving. The typical microwave LO drive power for this applications ranges from +7 to +10 dBm. The HP 8340 and 8341 specifies > +9 dBm and typically provides +11 dBm from 1.5 GHz to 20 GHz. The broadband noise floor of the LO source should typically be −140 dBm in a 1 Hz bandwidth at 30 MHz from the carrier. The HP 8340 and 8341 meet these requirements for frequencies above 2.4 GHz. For frequencies below 2.4 GHz some special considerations may be required.

The broadband noise floor on the standard unit is higher below 2.4 GHz than above 2.4 GHz, and can become the limiting factor depending on the type of DUT and the ability of the mixer to reject the LO noise. For noise figure applications it is suggested that an HP 8340 or 8341 with option H89 be ordered. This special option reduces the noise floor below 2.4 GHz to a level that can be used directly in any mode of the HP 8970A noise figure meter. This option can also be retrofit. For details contact your local HP sales office.

If the synthesizer to be used in the noise figure configuration is not equipped with option H89, there are alternate ways to compensate for the broadband noise below 2.4 GHz. These are documented in the "MEASUREMENT EXAMPLES" section.

## HP 8970A CONTROL OF THE HP 8340 OR 8341

The HP 8970A has the capability to become a controller and to program the external LO via the HP-IB using special functions.

Press [4] [.] [1] [SP]

to enable the noise figure meter to control an external local oscillator via the HP-IB.

On the HP 8970A pull-out card #1, Special Function 41.0 enables the HP 8970A to control the HP 8350 Sweep Oscillator as an external LO. The HP-IB codes for controlling the HP 8350 in a CW mode are the same for the HP 8340 or 8341. To inform the HP 8970A to send the proper HP-IB codes to the HP 8340 or 8341,

Press [4] [1] [.] [0] [SP]

Place the HP 8970A in a mode that programs the HP 8340 or 8341 by pressing

[1] [.] [1] [SP]

This is the swept LO, fixed IF mode.

Note that the "TALK" light on the HP 8970A is now lit and the HP 8340 or 8341 is now in REMOTE mode. If the HP 8340 or 8341 is not in REMOTE mode, an error "E42" appears on the right display of the HP 8970A (see pull-out card #2 for error listing). Check over the connection of the HP-IB cable and also check the HP-IB address as follows:

On the HP 8970A, the assumed external LO source address code is 19.

Press [4] [0] [.] [1] [SP]

to check the LO address code. If 19 is not displayed on the HP 8970A

Press [1] [9] [ENTER] on the HP 8970A.

On the HP 8340 or 8341, press the SHIFT then LOCAL keys to display the HP 8340 or 8341 HP-IB address code. If 19 is not in the "Entry" display

Press [1] [9] [Hz] on the HP 8340 or 8341

## HP 8340 OR 8341 POWER LEVEL ADJUSTMENT

The user must adjust the power level to a value between +7 to +10 dBm. Note that most double balanced mixers require an LO drive around 7 dBm to minimize the noise figure of the mixer. A slightly smaller LO drive signal like 5 dBm degrades the noise figure of the mixer, but usually not enough to be important if second stage correction is used.

The HP 8340 or 8341 power level can be set manually via the front panel or programmed using special function 42.0 on the HP 8970A to send an Auxiliary Command to the HP 8340 or 8341. This function allows the user to enter ten ASCII characters under their decimal equivalent according to the HP 8970A front panel key sequence shown below.

Press [4] [.] [0] [SP]

to stop any further HP-IB commands from being sent to the HP 8340 or 8341. This step is necessary for smooth HP-IB interaction after HP-IB command modifications.

Press [4] [2] [.] [0] [SP]

to access the Auxilliary Command Register.

Then press

[8] [0] [ENTER] for P (Power)

[7] [6] [ENTER] for L (Level)

[4] [8] [ENTER] for 0 (dBm)

[5] [5] [ENTER] for 7 (dBm)

Press FREQUENCY
to exit Special Function 42.0 and return to normal front panel operation.

Press [4] [.] [1]

to send the new power setting (+7 dBm in this case) to the HP 8340 or 8341 and restore HP 8970A HP-IB control of the HP 8340 or 8341.

When the power setting of the HP 8340 or 8341 needs to be modified, it is not necessary to re-enter the full sequence. Press 4.0 SP and then 42.0 SP. The value 80 will appear in the frequency display. If, for instance, the power level must be changed to +8 dBm, press the ENTER key twice without changing the data. The number 76 then 48 will appear. Press 48 ENTER (for ASCII 0) and 56 ENTER (for ASCII 8). After completing the rest of the key sequence (from FREQUENCY on) the HP 8340 or 8341 output power will change to +8 dBm. All these characters may be stored with the front panel configuration of the HP 8970A in the STORE/RECALL registers, so the total measurement setup (both HP 8970A and HP 8340 or 8341) can be recalled with one keystroke.

Refer to this shortened ASCII table if another power level must be entered.

| ASCII | Decimal | ASCII | Decimal |
|---|---|---|---|
| 0 | 48 | 5 | 53 |
| 1 | 49 | 6 | 54 |
| 2 | 50 | 7 | 55 |
| 3 | 51 | 8 | 56 |
| 4 | 52 | 9 | 57 |

# Noise source

The HP 346C Noise Source allows microwave noise figure measurements up to 26.5 GHz. Each HP 346C Noise Source is delivered with a calibration list of accurate ENR data versus frequency. These data points are also plotted on the body of the HP 346C. They are entered in the HP 8970A to enhance the noise figure measurement accuracy.

The procedure to enter these data points is described in the Product Note HP 8970A-1, but can be summarized as follows:

1. Press the ENR key on HP 8970A.
2. The "MHz" unit LED will be flashing, permitting a frequency to be entered. If a new frequency must be entered, type in the value in MHz, then press the ENTER key. Or press only the ENTER key to keep the same frequency.
3. The "dB" unit LED will be flashing, permitting a new ENR value entry. Then press the ENTER key.
4. Enter the next frequency and the next ENR value.

If a mistake is made before ENTER, press the NOISE FIGURE key and enter the proper number.

## OSCILLOSCOPE ADJUSTMENT

When making a swept measurement (swept LO or swept IF), the sweep can be too fast to read gain and noise figure for each frequency point. So, the HP 8970A stores these data in a RAM, and they are then converted into an analog signal to be displayed on an oscilloscope screen.

Any oscilloscope having an "A vs B" (or "y vs x") function or an external sweep input can be used. The B (or x) axis represents the frequency domain. On the A (or y) axis, noise figure and gain are displayed together or separately depending on the special function chosen (section 7.X SP shown on the pull-out card #1). When displayed together, the noise figure trace can be adjusted to be brighter than the gain trace with a screw driver adjustment on the rear panel of the HP 8970A.

The display of the oscilloscope should be adjusted for a full screen display. This is done easily by using an oscilloscope test pattern.

Press [7] [.] [1] [SP]

and adjust the A and B channel sensitivities (0 to + 6V from min to max scale on both channels) and position for a full screen dynamic range of the HP 8970A. To return to the noise figure and gain display,

Press [7] [SP]

# Measurement Examples

As mentioned earlier, the four "microwaves" measurement modes of the HP 8970A are divided into two groups, one for devices without frequency conversion and one for devices with frequency conversion. The following sections present measurement examples using these four modes and discuss the choice between double sideband (DSB) or single sideband (SSB) selection as a function of the DUT, the HP 8970A measurement mode and the HP 8340 or 8341 frequency range.

# Devices without frequency conversion

## DOUBLE SIDEBAND AMPLIFIER MEASUREMENT

Mode 1.1 swept LO on HP 8340 or 8341
fixed IF on HP 8970A

The typical setup for this mode is shown in Figure 1. The IF frequency is kept fixed and the local oscillator is swept over the frequency range of interest.

In the range from 1.5 to 2.4 GHz, an HP 8340/41 with option H89 operates in the standard configurations described. When using a standard HP 8340/41 in the 1.5 to 2.4 GHz range, there are two possible solutions to decrease the broadband noise floor. First, the power level of the LO can be adjusted to between +5 and +6 dBm to reduce the broadband noise floor. The HP 8970A can then remove the broadband noise with its second stage effect correction capability.

The second possible solution is to insert a band-pass filter centered on the fixed IF value between the IF port of the mixer and RF input of the HP 8970A. This filter must be as selective as possible to reject most of the broadband noise from the HP 8340 or 8341 LO. The bandwidth of this filter must be at least 4 MHz. But, if in this lower frequency range, the broadband noise of the LO source limits the measurement accuracy, an alternate measurement from 1.5 to 2.4 GHz can be made using the swept IF technique that is discussed in the next section (mode 1.2).

## HP 8970A LO CONTROL

First press the PRESET key and select the "swept LO — fixed IF" measurement mode on the HP 8970A by pressing

[1] [.] [1] [SP]

Then use 4.1 SP and 41.0 SP as described in the HP 8340 or 8341 section to control the HP 8340 or 8341 LO frequency from the HP 8970A. To verify that the HP 8970A is properly controlling the HP 8340 or 8341, check that the "TALK" LED on HP 8970A and "REMOTE" LED on HP 8340 or 8341 are lit.

## SET THE START AND STOP FREQUENCIES

To enter the start and stop frequencies on the HP 8970A that define the frequency range in which the LO is swept, press the START and STOP keys on the HP 8970A and enter the frequency values in MHz, terminating each entry with the ENTER key. To enter the frequency step size, press the STEP SIZE key, type the value in MHz, then press the ENTER key. Note that the start, stop and step size frequencies, when the mode 1.1 is initiated are automatically set to these default values: 2 GHz, 26.5 GHz and 20 MHz. If the start frequency must be set below 2 GHz, an error "E32" is displayed on the HP 8970A. This error means that the entered value is out of the preprogrammed frequency range assumed for the swept LO. But the lower limit can be changed with 42.3 SP. The upper limit can also be changed with 42.4 SP. But if the HP 346C Noise Source (0.01-26.5 GHz) is used, there is no need to change the 26.5 GHz upper limit.

## IF SETTING

In mode 1.1, the IF is a fixed frequency. Its default value is 30 MHz when the mode 1.1 is initiated. Any other value can be entered in the 10 to 1500 MHz range. This range is limited by the mixer IF frequency response (10 to 1000 MHz on the HMXR 5001 Mixer).

Note that in mode 1.1 as described to this point, the HP 8970A normally measures a double sideband (DSB) noise figure unless a particular sideband is selected with 2.1 SP or 2.2 SP. In DSB, an average between the two spot measurements at $f_{LO} - f_{IF}$ and $f_{LO} + f_{IF}$ is made, thus, the frequency resolution is twice the IF. Therefore, the higher the IF, the larger the measurement error due to the averaging effect when the noise figure of the DUT varies rapidly versus frequency. For these devices, the smallest IF (consistent with close-in LO noise) or a single sideband (SSB) measurement at a large IF is recommended (see next section).

If the IF value must be changed from 30 MHz

Press [3] [SP]

Then type the IF value in MHz and press the ENTER key.

## CALIBRATION

To compensate for the second stage noise contribution, the system is calibrated with the noise source, the HP 8340 or 8341 local oscillator and the mixer in place. The calibration setup is set by connecting the noise source directly to the RF input of the mixer, by-passing the DUT (see figure 1). The response of the system over the swept range is stored in an HP 8970A calibration memory. This memory size allows 81 spot frequency measurements to be stored. When the CALIBRATE key is pressed, an error "E31" can occur if the total number of frequency steps exceed 81. If this occurs, re-enter a larger step size.

Press [CALIBRATE] on the HP 8970A.

The calibration LED remains lit during the calibration, and the HP 8970A front panel is locked out. Pressing the CALIBRATE key again will abort the calibration and reactivate the front panel. The HP 8340 or 8341 LO source is swept three times for each of the three most sensitive RF attentuator settings of the HP 8970A.

The smoothing function is recommended for calibration to reduce jitter that comes from the nature of the noise itself. The smoothing factor, changed with the INCREASE and DECREASE keys on the HP 8970A front panel, is the number of measurements averaged at each frequency point.

When the calibration is completed (the calibration LED goes out), press the NOISE FIGURE AND GAIN key on HP 8970A. The noise figure and gain should display values around 0, although noise figure jitter of ±00.4 dB is not unusual for this case of 0 dB noise figure and gain. This large jitter is because the measurement is totally of second stage noise figure. The HP 8970A corrects for the second stage and the result is the difference between two large numbers of the same size. This jitter can be reduced by increasing the smoothing factor during the calibration.

## MEASUREMENT

Connect the Device Under Test between the HP 346C Noise Source and the RF input of the mixer. The system is now ready to start the measurement of the DUT. Press the AUTO key on the HP 8970A to start the measurement.

The HP 8340 or 8341, controlled by the noise figure meter, continuously sweeps step-by-step from the start frequency to the stop frequency. Check the noise figure and gain readouts to determine the maximum and minimum values and verify both parameters variations on the oscilloscope screen. If some values are off screen or if the variations do not match the scale, new limits for noise figure and gain can be entered using the special functions 8.X SP shown on pull-out card #1. After pressing the PRESET key, the default ranges are: 0 to 8 dB for noise figure and 0 to 40 for gain.

Every time a key is pressed on the HP 8970A, the automatic sweep is aborted. Exceptions to aborting the sweep are the smoothing INCREASE or DECREASE keys and NOISE FIGURE or NOISE FIGURE AND GAIN keys as well as the LOCAL and SP keys. It is necessary to press the AUTO key to continue the sweep after it has been interrupted.

When measuring with NOISE FIGURE AND GAIN function, if the frequency boundaries (start or stop) cannot be extended without recalibrating, an error "E20" or "E21" is shown on the right display of the HP 8970A. A new calibration must be made for noise figure and gain correction in the new frequency limits before a new measurement can be made.

For calibration, the frequency step size was limited to 81 points. For measurement, the number of steps can be higher than 81. The HP 8970A microprocessor interpolates between the two closest calibration points. However, proper operation of the oscilloscope display is limited to 256 points.

If the measurement setup must be repeated, the complete HP 8970A front panel configuration may be stored in one of the 10 STORE/RECALL registers to be recalled later. NOISE FIGURE, NOISE FIGURE AND GAIN functions and the smoothing factor cannot be recalled. When recalled, the HP 8340 or 8341 will be automatically set back in REMOTE mode. Calibration data is not saved with the STORE key nor is it destroyed by using the RECALL key. Calibration data remains until the HP 8970A is turned off or until a new calibration is started.

When a stored configuration is recalled from the STORE/RECALL memory, the function mode is not displayed. To remember which mode was selected, 50.1 SP can be used. The second digit displayed on the frequency display is the function number. For more detailed information, refer to pull-out card #2.

## SINGLE SIDEBAND AMPLIFIER MEASUREMENT

There are two applications that use the single sideband technique to overcome limitations of the measurement system. First, this technique is useful when using a standard HP 8340 or 8341 (without option H89) to overcome the broadband noise floor across the 1.5 to 2.4 GHz range. In the case of an excess LO noise floor it is necessary to use a single sideband technique and filter out the unwanted sideband using a low pass filter. Second, the single sideband technique is also used when the DUT response, such as that of a tuner, varies rapidly with frequency. A single sideband technique also avoids the measurement error in the fine grain variation due to the the averaging effect of the double sideband measurement. In this case, either the "swept LO, fixed IF" or the "swept IF, fixed LO" technique may be used at any frequency between 1.5 and 26.5 GHz as long as the appropriate low pass filter is available (see Appendix B). The typical setup differs from the previous one only by inserting the low-pass filter between the DUT and the RF input of the mixer (see Figure 2). It is important that the filter is placed after the DUT so that the filter is a part of the measurement system. The DUT is once again inserted between the noise source and the measurement system. If the filter were placed ahead of the DUT, some of the DUT added noise may be in the unwanted sideband and would create a measurement error.

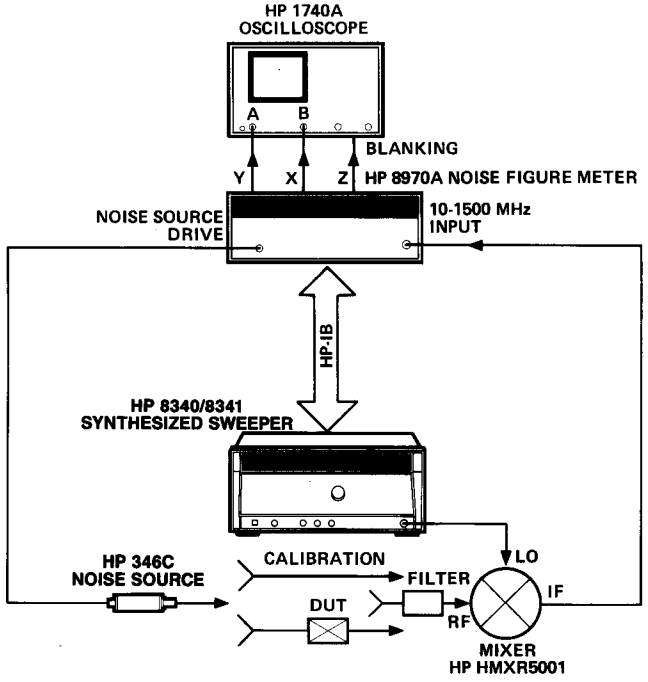



*Figure 2. Single sideband amplifier measurement.*

Mode 1.1 swept LO on HP 8340 or 8341
fixed IF on HP 8970A

In both mode 1.1 and 1.2, convenient measurements depend on a large IF (e.g. 1000 MHz). Then the frequency difference between the lower sideband (LSB) and the upper sideband (USB) is large, being twice the IF (see Figure 3). It is usually not difficult to design a filter to pass the desired sideband and reject the undesired sideband. It is not necessary that the filter rejects the LO frequency. Being at the RF port of the mixer, the filter scarcely affects the LO power. On the other hand, the mixer IF frequency response often limits the highest IF. For example, with the HP HMXR 5001 Mixer, the maximum IF is 1000 MHz.

| SWEPT LO | LSB | USB | FIXED IF |
|---|---|---|---|
| 9800 | 8800 | 10800 | 1000 |
| 10300 | 9300 | 11300 | 1000 |

FREQUENCY IN MHz

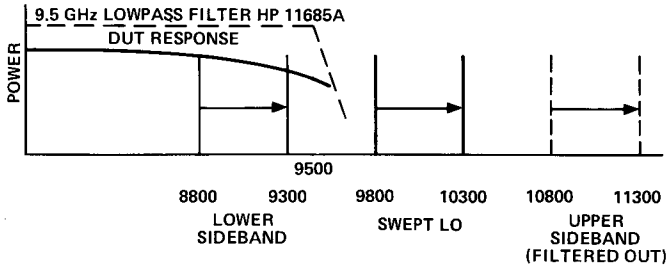



*Figure 3. Mode 1.1—Single sideband amplifier measurement.*

The mode 1.1 (1.1 SP), the external HP 8340 or 8341 LO control (4.1 SP and 41.0 SP) and the start, stop and step size frequencies are set as described in the previous section.

The large IF is entered by pressing

[3] [.] [0] [SP]

[1] [0] [0] [0] [ENTER]

and the appropriate sideband is selected with 2.1 SP (lower sideband) or 2.2 SP (upper sideband).

The filter is a part of the measurement system and is connected for both calibration and measurement.

Mode 1.2. fixed LO on HP 8340 or 8341
swept IF on HP 8970A

A single sideband measurement example using mode 1.2 is illustrated in Figure 4. If the broadband noise floor of the 1.5 to 2.4 GHz frequency range of the HP 8340 or 8341 cannot be adequately compensated by calibrating in mode 1.1 for a DSB measurement, a SSB measurement is required. This example allows the LO frequency to be tuned out of the heterodyne band of the HP 8340 or 8341 where the broadband noise floor is much lower.

| FIXED LO | LSB | USB | SWEPT IF |
|---|---|---|---|
| 2500 | 1500 | 3500 | 1000 |
| 2500 | 2400 | 2600 | 100 |

ALL VALUES IN MHz

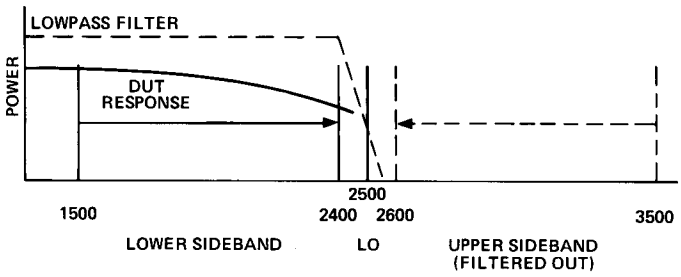



*Figure 4. Mode 1.2—Single sideband amplifier measurement.*

After pressing the PRESET key on HP 8970A the following functions are selected.

Press [1] [.] [2] [SP]

to select the mode 1.2 (swept IF, fixed LO)

[2] [.] [1] [SP]

to select the lower sideband ($F_{meas}$ $F_{LO}$)

[3] [.] [1] [SP]

and

[2] [5] [0] [0] [ENTER]

to program the HP 8340 or 8341 at 2500 MHz fixed LO frequency, which is out of the heterodyne band,

Press

[START] [1] [5] [0] [0] [ENTER]

to set the start frequency of the sweep, and press

[STOP] [2] [4] [0] [0] [ENTER]

to set the stop frequency of the sweep. The start and stop frequencies entered are not the sweep limit of the IF but the range at which the DUT is analyzed. In this example, the IF is swept from 1000 MHz to 100 MHz to maintain the relationship $F_{meas} = F_{LO} - F_{IF}$ at each frequency point.

Note that the filter is used for both calibration and measurement. As in mode 1.1, the calibration compensates for system noise, including that of the filter. Now the system consists of LO source, mixer and filter. The calibration is made three times over the swept IF range. For the measurement, insert the DUT between the noise source and the low pass filter and press the NOISE FIGURE AND GAIN key on the HP 8970A to select a noise figure and gain corrected measurement. Then press the AUTO key on the HP 8970A to start the measurement.

# Devices with frequency conversion (e.g. mixers, receivers)

In most cases devices with frequency conversion use only one converted sideband. Although, only one sideband is used for communication, the other sideband is often not rejected and becomes a spurious response; so, the two parameters measured by the HP 8970A, gain (or conversion loss) and noise figure are generally specified in single sideband. Conversion loss is only defined for a single frequency at the output of the DUT. The HP 8970A makes a DSB noise figure measurement if the mixer responds to both sidebands and a SSB measurement if it responds to only one.

The setup for the measurement of devices with frequency conversion is the same as the one described on Figure 1 except the mixer will be the device under test itself or replaced by a frequency conversion device to be tested. In this setup, one of the main differences is the calibration procedure which is made without the mixer and the external LO.

The broadband noise floor of a standard HP 8340 or 8341 (without option H89) is not compensated for as it was in the calibration procedure for measuring a device without frequency conversion. Therefore, for a swept LO technique only units with option H89 are recommended.

Mode 1.3 swept LO on HP 8340 or 8341
fixed IF on HP 8970A

Set up the instruments as shown in Figure 5. Here, the mixer is the DUT.

If the broadband noise floor of the LO mentioned above is too high, a bandpass filter can be inserted between the noise source and the HP 8970A input during calibration and between the DUT output (mixer IF port) and the HP 8970A input, during measurement. This bandpass filter, centered around the IF frequency and having at least 4 MHz bandwidth rejects the broadband noise from the LO. Adjust the power level on the HP 8340 or 8341 manually or automatically using Auxiliary Command 42.0 SP in the range of +7 to +10 dBm. A smaller LO signal level may degrade the noise figure of the mixer. Refer to mixer specifications for proper level adjustment.

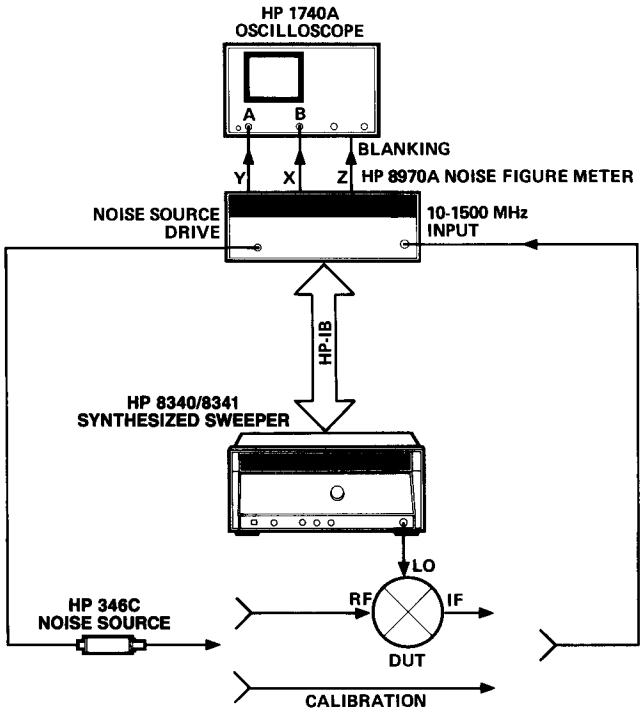



*Figure 5. Mixer measurement setup.*

Preset the HP 8970A, then choose the mode by pressing


Then, press 4.1 SP and 41.0 SP special function to program the HP 8340 or 8341 as an external LO source and select the start, stop and step frequencies as described in mode 1.1.

This swept LO technique measures a DSB noise figure and the IF frequency is minimized to increase the resolution and reduce the error due to fine grain variation. The predetermined 30 MHz IF may be maintained or another value entered using the 3.0 SP special function.

## CALIBRATION

The calibration is made without the external LO and without the mixer (DUT). The HP 346C noise source is directly connected to the HP 8970A input. This setup is calibrated at the fixed IF frequency for three input attenuator settings.

If a bandpass filter centered around the IF is used, it must be installed during the calibration.

## MEASUREMENT

Connect the mixer to be tested and the HP 8340 or 8341 LO as shown in Figure 5. Press the NOISE FIGURE AND GAIN key on the HP 8970A to have a corrected measurement. Press the AUTO key on the HP 8970A to start the measurement.

Note the display on the oscilloscope. Adjust the scale for noise figure if necessary. Note the gain trace is on the bottom of the screen. In fact the HP 8970A is not measuring a gain but a conversion loss. So, enter the following to change the "gain" scale

Press [8] [.] [4] [SP]

[0] [ENTER]

Then [8] [.] [3] [SP]

[–] [8] [ENTER]

As mentioned above the noise figure and the conversion loss of a mixer are specified in single sideband. But, this setup is making a double sideband measurement and a correction is necessary. The HP 8970A actually measures the change in "gain x bandwidth" between calibration and measurement. The calibration is made at a fixed frequency in a 4 MHz single bandwidth. During the measurement, noise power from both sidebands is measured by the HP 8970A resulting in an 8 MHz equivalent bandwidth. Then a 3 dB correction must be made manually or automatically using the 34.X SP.

Press [3] [4] [.] [1] [SP]

to enable the automatic loss compensation. A fictitious negative loss at 290K must be entered to compensate for both conversion loss and noise figure.

Press [3] [4] [.] [2] [SP]

[–] [3] [ENTER]

Then enter the temperature at which the compensation must be made.

Press [3] [4] [.] [3] [SP]

Then [2] [9] [0] [ENTER]

To compensate the conversion loss

Press [3] [4] [.] [4] [SP]

Then [–] [3] [ENTER]

These automatic compensations are turned off by pressing

[3] [4] [SP] [PRESET]

or [0] [SP]

Note this 3 dB correction makes the assumption that the conversion loss and the noise figure are the same in each sideband. To avoid any major error, a small IF frequency is suggested.

Mode 1.4 fixed LO on HP 8340 or 8341
swept IF on HP 8970A

Both double and single sideband measurements may be made in mode 1.4, unlike mode 1.2. In mode 1.2, the measurement must be SSB because the DUT is an amplifier (e.g. IF has no real meaning, except for the frequency resolution). The measurement frequency is the average between $F_{LO} + F_{IF}$ and $F_{LO} - F_{IF}$. This average is always $F_{LO}$ regardless of $F_{IF}$. Thus the DSB measurement in mode 1.2 is meaningless and not allowed.

In mode 1.4, however, IF does have meaning and DSB measurement is useful. This example examines the noise figure of the HP HMXR 5001 mixer with the LO at 4 GHz and the IF going from 10 to 1000 MHz. The measurement setup is the same as the one described in Figure 5. Press the PRESET key on the HP 8970A, then select the "swept IF, fixed LO" mode (mode 1.4) by pressing

[1] [.] [4] [SP]

The default start and step size frequencies are respectively 10 MHz, 1500 MHz and 20 MHz. Change only the stop frequencies by pressing

Stop [1] [0] [0] [0] [ENTER]

then set the LO fixed frequency to 4 GHz by pressing

[3] [.] [1] [SP]

[4] [0] [0] [0] [ENTER]

## CALIBRATION

For calibration, connect the HP 346C noise source directly to the HP 8970A input. Then press the CALIBRATE key on the HP 8970A. The HP 8970A sweeps from 10 to 1000 MHz on three RF attenuator settings.

## MEASUREMENT

To make the measurement of the HP HMXR 5001 mixer (simulated receiver in this case with a mixer/LO source combination), connect the noise source to the RF input of the simulated receiver.

Then start the measurement pressing the AUTO key or the SINGLE key on the HP 8970A.

Note the results on the oscilloscope. This measurement is useful to determine the optimum IF frequency of the mixer (or the receiver) to determine how noise figure and gain vary with IF. Note that for the HP HMXR 5001 the noise figure is degraded at high IF frequencies.

# Appendix A

## Noise figure measurement references


1. RADAR HANDBOOK
   Merrill Skolnik
   McGraw Hill 1970
2. INFORMATION TRANSMISSION, MODULATION, AND NOISE
   Mischa Schwartz
   McGraw Hill 1959
3. ELECTRONIC COMMUNICATIONS SYSTEMS
   George Kennedy
   McGraw Hill 1970
4. ELECTRONICS ENGINEER HANDBOOK
   Donald Fink, Editor-in-Chief
   McGraw Hill 1975
5. TECHNICAL NOTES ON MIXER — THEORY AND TECHNOLOGY
   Watkins Johnson Co.
   Part 1 Vol. 8. no. 2
   Part 2 Vol. 8. no. 3

Hewlett-Packard Application Notes:

8970A-1 Product Note
AN 57-1 Fundamentals of RF and Microwave Noise Figure Measurement


# Appendix B

This is a list of the HP Low Pass Filters which can be used for SSB measurements.

| MODEL NUMBER | CUT-OFF FREQUENCY |
|---|---|
| 360C | 2.2 GHz |
| 11870A | 2.6 GHz |
| 11688A* | 2.8 GHz |
| 360D | 4.1 GHz |
| 11689A* | 4.4 GHz |
| 11684A* | 6.8 GHz |
| 11685A* | 9.5 GHz |
| 11686A* | 13.9 GHz |

*These filters are contained in the HP 11678A Low Pass Filter Kit.

For more information,
call your local HP sales office listed
in the telephone directory white pages.
Or write to Hewlett-Packard:

**United States:**
Hewlett-Packard
P.O. Box 10301
Palo Alto, CA 94303-0890

**Europe:**
Hewlett-Packard S.A.
P.O. Box 529
1180 AM Amstelveen, the Netherlands

**Canada:**
Hewlett-Packard Ltd.
6877 Goreway Drive
Mississauga, Ontario L4V 1M8

**Japan:**
Yokogawa-Hewlett-Packard Ltd.
3-29-21, Takaido-Higashi
Suginami-ku, Tokyo 168

**Elsewhere in the world:**
Hewlett-Packard Intercontinental
3495 Deer Creek Road
Palo Alto, CA 94304

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