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HP References in this Manual

This manual may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies. We have made no changes to this manual copy. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A.

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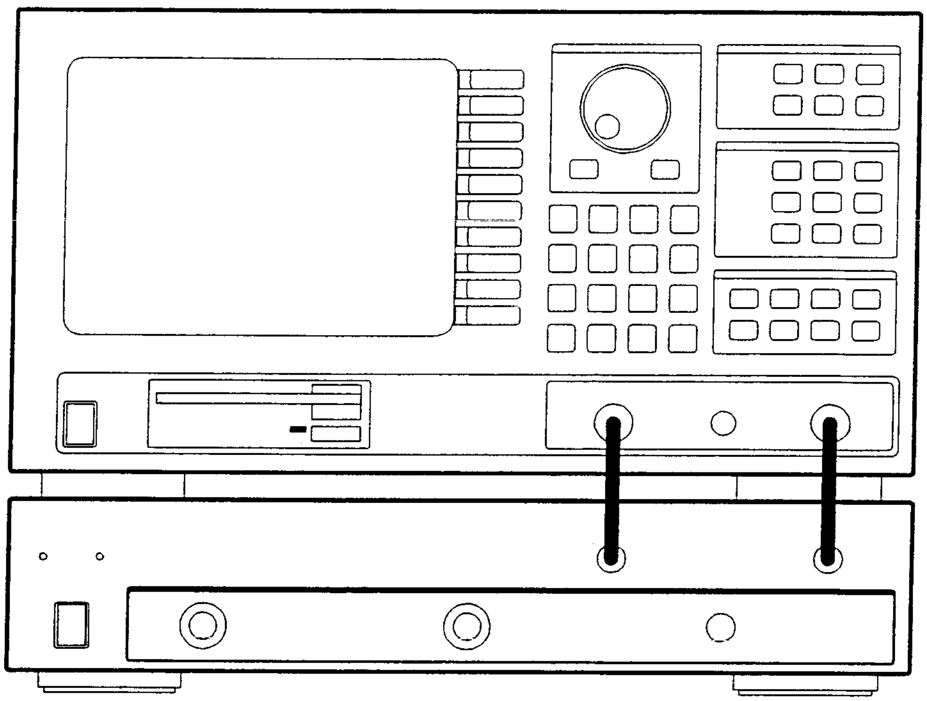
HP 3589A Operator's Guide



For Instruments with Firmwave Revision A.00.00

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Part I

Overview

1

Before You Begin

In this Book

This book is the *HP 3589A Operator's Guide*. It provides a conceptual overview of the HP 3589A Spectrum/Network Analyzer and its companion HP 35689A/B S-Parameter Test Set. This book also contains typical tasks to help you learn how to use your new analyzer. These include both measurement-specific tasks and general tasks.

To Learn About Spectrum Measurements

If you've already used a swept-tuned spectrum analyzer before, you should have no trouble making spectrum measurements (or scalar network measurements) with the HP 3589A. This instrument has many of the same features found in other Hewlett-Packard spectrum analyzers, such as the HP 3585A/3585B and the HP 3588A. If you haven't made spectrum measurements before, be sure to read "Spectrum Analyzer Basics" in chapter 2.

To Learn About Network Measurements

The HP 3589A makes vector network measurements somewhat differently than most other Hewlett-Packard network analyzers. This is because the HP 3589A uses a single receiver instead of two or three receiver channels. This provides cost-effective network measurements (in an implementation known as a *single-channel network measurement*) and eliminates the possibility of a channel-to-channel mismatch that can occur in two- or three-channel network analyzers.

If you are unfamiliar with single-channel network measurements, be sure to read the overview information in chapter 3, "Network Measurements." This also includes information about the HP 35689A/B S-Parameter Test Set—a companion unit that lets you make reflection and transmission measurements for one-port and two-port devices.

To Learn More About the HP 3589A

To get comfortable with your new analyzer, continue reading part I of this book. Afterwards, try some of the tasks shown in part II and part III. You may also need to use other books in the operating manual set. For more information, see "Where to find Additional Information" later in this chapter.

About the Analyzer

The HP 3589A helps solve your measurement problems by combining spectrum and network analysis features in one analyzer. It does this by providing three distinct measurement types, all of which are available for the entire 10 Hz to 150 MHz frequency range.

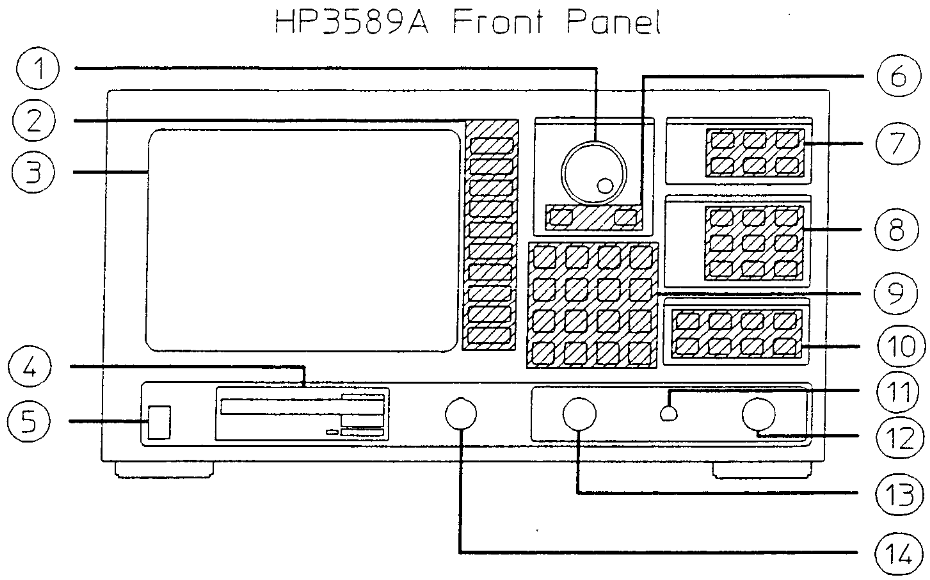
- The *swept spectrum* measurement type lets you measure spectral components for spans up to 150 MHz. But a design that includes a digital resolution bandwidth (RBW) filter allows the HP 3589A to measure these components several times faster than traditional swept-tuned analyzers.
- The *narrowband zoom* measurement type lets you make narrowband measurements much more quickly than swept spectrum measurements by using an implementation of the Fast Fourier Transform. This lets you characterize, for example, a signal and its close-in sidebands. Narrowband zoom measurements are available for spans of 40 kHz or less.
- The *swept network* measurement type lets you characterize one-port and two-port devices. Because the HP 3589A provides vector (rather than scalar) network data, you can characterize both the magnitude and phase response of these devices. And with the addition of the HP 35689A/B test set, you can make S-parameter measurements as well.

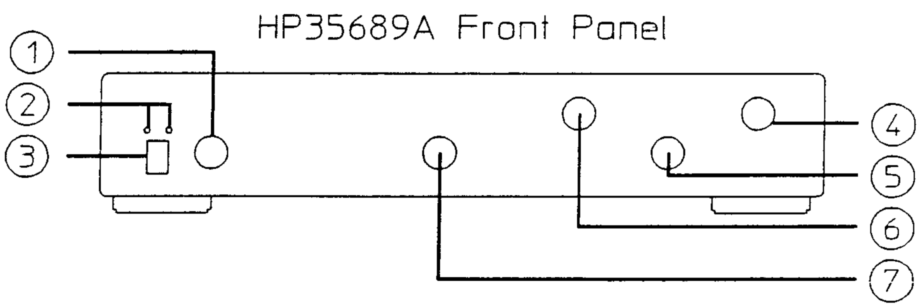
You can also operate the analyzer remotely, via the HP-IB, to make automated measurements—a technique that's particularly useful for repetitive tasks (such as those encountered in production-line testing). However, you aren't restricted to remote operation for automated measurements—you can also use the analyzer's optional HP Instrument BASIC (Option 1C2) to create automated measurement routines *without an external controller or computer.*

Your instrument may also be equipped with the time-gated sweep option (Option 1D6). This extends the analyzer's triggering capability to let you characterize magnetic and optical media and head assemblies from burst signal sources such as video recorders, magnetic and optical disks, and similar devices.

Other options include additional instrument memory (Option 1C1) and a high-stability frequency reference (Option 1D5).

The Analyzer at a Glance





HP 3589A Front Panel

1-The knob's primary purpose is to move a marker along the trace. But you can also use it to change values during numeric entry, move a cursor during text entry, or select a hypertext link in help topics.

2-A softkey's function changes as different menus are displayed. Its current function is determined by the video label to its left, on the analyzer's screen.

3-The analyzer's screen is divided into two main areas. The menu area, a narrow column at the screen's right edge, displays softkey labels. The data area, the remaining portion of the screen, displays traces and other data.

4-Use a 3.5 inch flexible disk (DS,DD) in this disk drive to save your work.

5-The POWER switch turns the analyzer on and off.

6-Use the MARKER hardkeys and their menus to control marker positioning and marker functions, including limit testing.

7-Use the DISPLAY hardkeys and their menus to select and manipulate trace data, and to select display options for that data.

8-Use the MEASUREMENT hardkeys and their menus to control the analyzer's receiver and source, and to specify other measurement parameters.

9-Use the numeric-entry hardkeys to change the value of numeric parameters or to enter characters in text strings.

10-Use the SYSTEM hardkeys and their menus to control various system functions (online help, plotting, presetting, and so on).

11-The PROBE POWER connector provides power for an HP 41800A Active Probe.

12-The INPUT connector routes your test signal or DUT output to the analyzer's receiver. Input impedance is selectable: either 50 ohms or 1 megohm.

13- The SOURCE connector routes the analyzer's source output to your DUT. Output impedance is 50 ohms.

14-The KEYBOARD connector allows you to attach an optional keyboard to the analyzer. The keyboard is most useful for writing and editing HP Instrument BASIC programs.

HP 35689A/B Front Panel

1-The PORT 1 connector is routed to the analyzer's source when the FORWARD indicator is lit. It is routed to the receiver when the REVERSE indicator is lit.

2-The direction indicators show you which port connector is routed to the analyzer's source. The left indicator is lit when the left port is connected, the right indicator is lit when the right port is connected.

3-The POWER switch turns the test set on and off.

4-The OUTPUT connector must be attached to the analyzer's INPUT connector for all measurements made with the test set.

5-The SPECTRUM INPUT connector allows you to make spectrum measurements without disconnecting the test set.

6-The test set's INPUT connector must be attached to the analyzer's SOURCE connector for all measurements made with the test set.

7-The PORT 2 connector is routed to the analyzer's receiver when the FORWARD indicator is lit. It is routed to the source when the REVERSE indicator is lit.

The Optional Keyboard

The HP 3589A analyzer has a connector on the front panel that lets you attach an optional alphanumeric keyboard. The keyboard's primary purpose is to make it easier for you to develop programs with the analyzer's optional HP Instrument BASIC editor. However, the keyboard is also active outside of the editor. When prompts are displayed, you can use it for entering text strings or numbers. When prompts are not displayed, you can use it as an alternative to the front-panel keys:

- Pressing an alpha key (A-Z) is the same as pressing a front-panel hardkey. Front-panel engravings, adjacent to each hardkey, show you which character corresponds to each hardkey.
- Pressing a function key (F1-F10) is the same as pressing the corresponding front-panel softkey.
- Pressing the F12 function key is the same as pressing the [**Help**] hardkey.
- Pressing the Alt, Ctrl, and Del keys simultaneously is the same as pressing the [**Preset**] hardkey.

The HP 3589A supports the following keyboards:

- French (C1405A #ABF).
- German (C1405A #ABD).
- Italian (C1405A #ABZ).
- Spanish (C1405A #ABE).
- Swedish/Finnish (C1405A #ABS).
- U.K. English (C1405A #ABU).
- U.S. English (C1405A #ABA).

You can configure the analyzer to use any of the listed keyboards. Press [**Special Fctn**] [NON-VOL SETUP] [KEYBOARD SETUP], then press the softkey that matches the keyboard you are using. Selecting the softkey that matches your keyboard ensures that the expected character is entered when you press a key. However, it does not localize the display annotation or the online help.

Caution

Only the listed keyboards are approved for use with this product. Hewlett-Packard does not warrant damage or performance loss caused by a nonapproved keyboard.

Firmware Revision

This book should be used with HP 3589A Spectrum/Network Analyzers having the firmware revision shown on the title page. If your analyzer has a significantly different firmware revision number, contact your local HP Sales/Service office to obtain a documentation set that matches your firmware revision.

Firmware revisions are significant *only if the first two digits in the revision number are changed.* For example, A.01.00 indicates a significant change from A.00.00. However, a change to A.00.01 from A.00.00 indicates very minor changes that do not affect the documentation set.

To check the firmware revision date of your instrument, press [**Special Fctn**], [NON-VOL SETUP], and then [VERSION].

Notation Conventions

Hardkeys

Throughout this book, they are printed like this: [**Hardkey**]. Hardkeys are front-panel buttons whose functions are always the same. Hardkeys have a label printed directly on the key itself.

Softkeys

Throughout this book, softkeys are printed like this: [SOFTKEY]. Softkeys are keys whose functions change with the analyzer's current menu selection. A softkey's function is indicated by a video label to the left of the key (at the edge of the analyzer's screen).

Toggle Softkeys

Some softkeys toggle through different settings. Toggle softkeys have a highlighted word in their label that changes with each press of the softkey. Throughout this book, toggle softkeys are described by their appearance after a required key-press. For example, as in "press [SOFTKEY ON / OFF] until ON is highlighted."

Ghosted Softkeys

Occasionally, a softkey may be inactive—this occurs when a softkey is not appropriate for a particular measurement or not available with the current instrument configuration. When this happens, the analyzer "ghosts" the inactive softkey. A ghosted softkey appears less bright than a normal softkey.

For example, if you are making swept network measurements and you don't have the HP 35689A/B test set connected, the [S11], [S21], [S12], and [S22] softkeys are ghosted. This is because S-parameter measurements are possible only when you have an HP 35689A/B test set connected to the analyzer.

Where to find Additional Information

Online Help

The [**Help**] key on the analyzer's front panel provides fast, easy-to-read information about specific instrument controls and features.

Online help is a good way to learn about the analyzer—or to refresh your memory if you don't use the analyzer very often. Online help also has an index that lets you request information by topic name.

Quick Start Guide

Use the *HP 3589A Quick Start Guide* as an introduction to the HP 3589A. If you haven't read this book yet, you should probably do so. The Quick Start Guide is very short, and it's designed to get you comfortable with the analyzer in a very short time.

HP-IB Programmer's Reference

To help you operate the analyzer remotely via HP-IB, see the *HP 3589A HP-IB Programmer's Reference*. Here you'll find a conceptual overview of the HP-IB and how you can use it to control your instrument remotely. There is also a command reference that lists all HP-IB commands. The reference includes a description of each command, its proper syntax, and example statements. Additionally, there are sample programs to help you create your own HP-IB programs.

HP Instrument BASIC

To learn more about using HP Instrument BASIC (a subset of the HP BASIC programming language) with your new analyzer, see *Using HP Instrument BASIC with the HP 3589A*. This shows you how to record and develop programs for the HP 3589A. There are also sample programs to help you get started with HP Instrument BASIC.

For more global information about HP Instrument BASIC, see the *HP Instrument BASIC User's Handbook*. This is a reference for the HP Instrument BASIC language—a language used on the HP 3589A as well as other Hewlett-Packard instruments.

Performance Test Guide.

For specifications, installation instructions, and performance tests, see the *HP 3589A Performance Test Guide*.

Service Guide

For service information, see the *HP 3589A Service Guide*. This manual includes adjustments, replaceable parts, circuit descriptions, and troubleshooting.

Related Information.

For applications information, you can request copies of Hewlett-Packard application notes from your local HP Sales and Service Office. For a more general overview of spectrum/network measurements, a good source of information is *Spectrum and Network Measurements* by Robert A. Witte (Prentice Hall, Englewood Cliffs, New Jersey, 1991).

Need Assistance?

If you need assistance, contact your nearest Hewlett-Packard Sales and Service Office listed in the HP Catalog, or contact your nearest regional office listed at the back of this guide. If you are contacting Hewlett-Packard about a problem with your HP 3589A Spectrum/Network Analyzer, please provide the following information:

- Model number: HP 3589A
- Serial number:
- Firmware version:
- Options :
- Date the problem was first encountered:
- Circumstances in which the problem was encountered:
- Can you reproduce the problem?
- What effect does this problem have on you?

2

Spectrum Measurements

There are three measurement types available with the HP 3589A Spectrum/Network Analyzer—*swept spectrum, narrowband zoom, and swept network measurements.* This chapter explains swept spectrum measurements and narrowband zoom measurements.

Although this chapter focuses on concepts common to spectrum measurements, most of the concepts (such as *resolution bandwidth*, *display resolution*, and *manual sweep*) are also important for network measurements. A few concepts (such as *bandwidth coupling*, *video filtering*, and *oversweep*) are not. However, you should be familiar with spectrum measurements before making network measurements—so even if you use the HP 3589A exclusively for network measurements, make sure you review the material in this chapter.

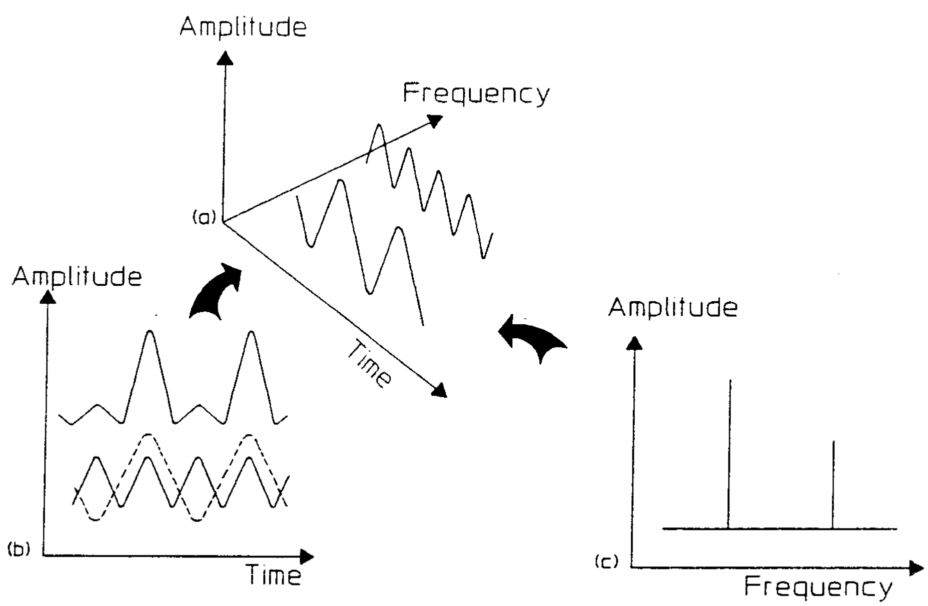
Spectrum Basics

If you are already familiar with spectrum analyzers, you might want to go directly to the next section, "Swept Spectrum Overview."

Time Domain versus Frequency Domain

Time-domain displays show a parameter (usually amplitude) versus *time*. This is the traditional way of looking at a signal—an oscilloscope, for example, displays signals in the time domain. In contrast, frequency-domain displays show a parameter (usually amplitude) versus *frequency*. A spectrum analyzer takes an analog input signal and converts it to the frequency domain—the resulting spectrum measurement shows the energy of each frequency component at each point along the frequency spectrum.

The relationship between Time and Frequency Domains



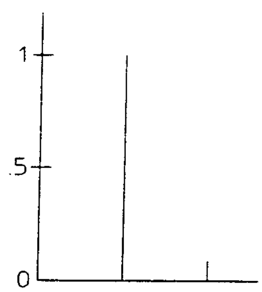
Now look at the nearby illustration. Notice the difference between the time-domain and frequency-domain displays of the same input signal.

Many signals not visible in the time domain (such as noise and distortion products) are clearly visible in the frequency domain. Because spectrum displays show frequency components distributed along the frequency axis, it's possible to view many different signals at the same time. This is why the spectrum analyzer is such a useful tool for looking at complex signals—it lets you easily measure (and compare) the frequency and amplitude of individual components.

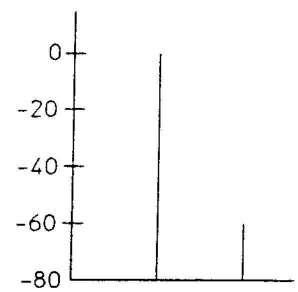
Linear versus Logarithmic Amplitude Axis

Time-domain displays usually have a linear x-axis and a linear y-axis (think of an oscilloscope). However, frequency-domain displays usually use a *logarithmic* y-axis (the amplitude axis) to show both small signals and large signals.

Let's look at the spectrum of a sine wave. Because the amplitude of any harmonic is small relative to the fundamental frequency, it's nearly impossible to view a harmonic on the same display as the fundamental unless the y-axis scale is logarithmic. That's why most measurements made with spectrum analyzers use a logarithmic amplitude scale—a scale based on decibels. And since the dB scale is by definition logarithmic, there's no need to use logarithmically-spaced graticule lines.



(a) Linear Amplitude Scale



(b) Logarithmic Amplitude Scale

The Frequency Span

Full-span measurements let you view the entire available frequency spectrum on one display. With the HP 3589A, for example, full-span measurements extend from 10 Hz to 150 MHz (information below 10 Hz can be displayed, but is not guaranteed to be accurate).

You can also select any number of different spans and position these spans where you want by specifying their start or center frequencies. This process of viewing smaller spans is sometimes called "zooming." You can control the frequency span examined by specifying a center frequency and a span size. Alternatively, you can specify a start and a stop frequency to define a particular frequency span. Alternatively, you may wish to view smaller slices of the frequency spectrum.

Spectrum Measurements and Scalar Network Measurements

In its simplest form, a spectrum analyzer has a single input channel and thus can be used only to examine a signal source. However, spectrum analyzers often include a *tracking source*—a sinusoidal output with a frequency that follows the analyzer's swept-tuned (or manually-tuned) frequency. This lets you make amplitude versus frequency measurements to characterize networks such as filters and amplifiers.

Usually, you can only make *scalar* network measurements with a spectrum analyzer equipped with a tracking source. Scalar network measurements do not reveal phase information. *Vector* measurements, on the other hand, reveal both amplitude and phase information. To learn more about network measurements, see chapter 3, "Network Measurements."

Swept Spectrum

When you select the swept spectrum measurement type, the HP 3589A Spectrum Analyzer functions as a traditional triple-conversion, swept-tuned spectrum analyzer, with a specified frequency range extends from 10 Hz to 150 MHz. If you've used a swept-tuned spectrum analyzer already, you should have no trouble making measurements with the HP 3589A. And even if you haven't used a spectrum analyzer before, you'll find the HP 3589A quite easy to learn. In either case, you might want to step through some of the sample measurement tasks outlined in the *HP 3589A Operator's Guide.*

Resolution Bandwidth and Video Bandwidth

Resolution Bandwidth

Resolution bandwidth—often called RBW—determines the analyzer's frequency resolution. It also affects how fast the analyzer makes a measurement, since resolution bandwidth affects the analyzer's sweep time. Normally, resolution bandwidth is adjusted automatically as you select different frequency spans.

Because resolution bandwidth also affects sweep time, manually selecting a narrower resolution bandwidth can slow down a measurement more than necessary. Selecting a resolution bandwidth that is too wide, on the other hand, may not provide adequate resolution and can obscure spectral components that are close together. *Resolution bandwidth is one of the most important parameter settings in a swept-tuned spectrum analyzer.*

Video Bandwidth

Video filtering is another feature common to many swept-tuned spectrum analyzers (it is not used for network measurements). A video filter is a variable bandwidth low-pass filter placed between the analyzer's detector and the display. The amount of video filtering is determined by the video bandwidth—often called VBW. For the HP 3589A, video filtering is normally off. The range of available video bandwidth varies, depending on the current resolution bandwidth setting.

It's important to understand the difference between resolution bandwidth and video bandwidth. Narrowing resolution bandwidth reduces noise in a measurement. In contrast, video filtering does not reduce noise—instead, it simply reduces the variation in the noise level, and smooths the noise floor. Video filtering—like resolution bandwidth—also affects the analyzer's sweep time. Using a narrow video bandwidth slows down a measurement considerably.

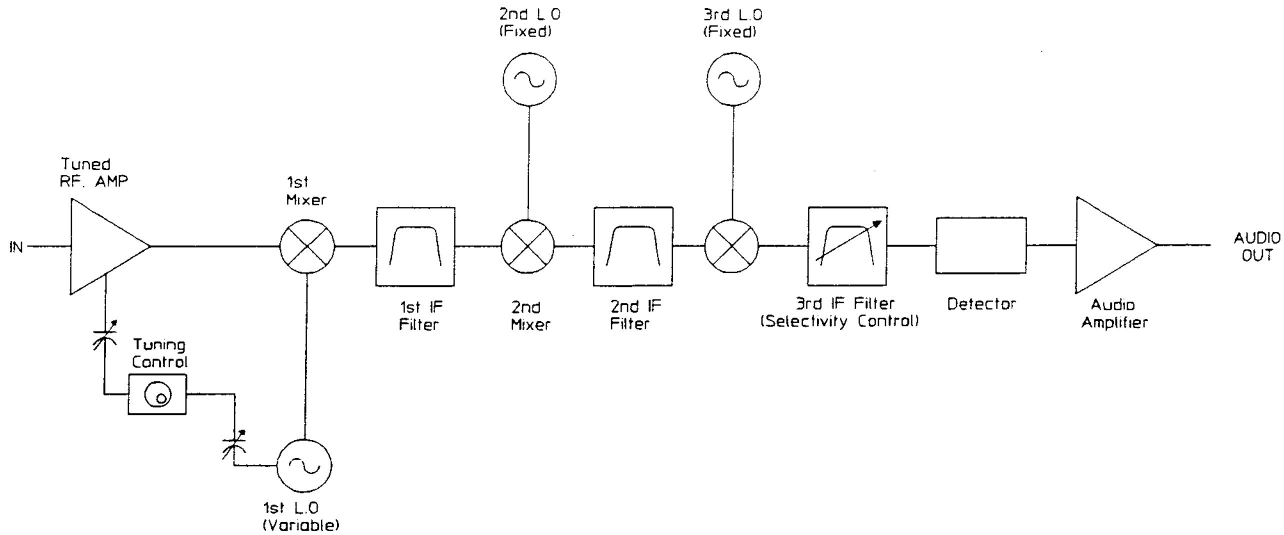
How are Resolution Bandwidth and Video Bandwidth Related?

Understanding resolution bandwidth and video bandwidth is often easier if we compare a swept-tuned spectrum analyzer to a general-coverage communications radio receiver. Both devices, at the block level, are actually quite similar. Consider the following:

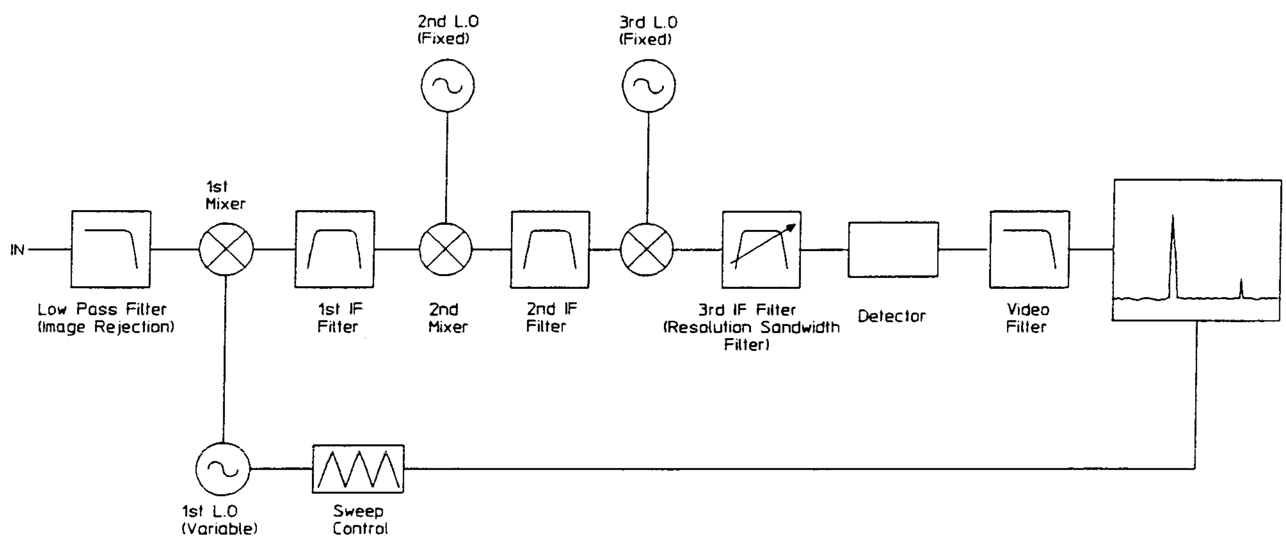
- The front-end of a swept-tuned spectrum analyzer and a communications radio receiver are nearly identical. Both are superheterodyne devices that use local oscillators and multiple mixing stages to convert the signals of interest down to intermediate frequencies, where fixed-tuned filters can more easily provide good frequency resolution. And like many communications radio receivers, swept-tuned spectrum analyzers use multiple conversion (several IF stages) to more easily reject image frequencies. Both devices can also vary the bandwidth of the final IF filter to control selectivity. In fact, it's only after the detector stage that the circuit diagrams for a typical spectrum analyzer and a radio receiver begin to look quite different.

- Both devices have variable local oscillators to examine frequencies of interest. In the spectrum analyzer, the local oscillator usually sweeps across a range of frequencies (this eventually translates to a visual sweep between the start and stop frequencies of the spectrum you're examining). In the radio receiver, the local oscillator can also be varied, but is set to a single frequency while listening to a particular broadcast station.

- Both devices use a detector after the final IF stage to recover the incoming signal. In a spectrum analyzer, the detected signal is converted to a dc value (representing its amplitude) and then sent to the display-driver circuitry—where you can view the signal on a CRT display. In a radio receiver, the detected signal is demodulated (to recover its original ac modulation) and then sent to an audio amplifier and then to headphones or a loudspeaker that you can use to monitor the signal.



Typical Superheterodyne Communications Radio Receiver



Typical Swept-tuned Spectrum Analyzer

In the spectrum analyzer, resolution bandwidth is determined by the bandwidth of the analyzer's final IF filter. Video bandwidth (not used for network measurements) is determined by the amount of low-pass filtering used between the spectrum analyzer's detector and the display. In the radio receiver, the resolution bandwidth is analogous to the various settings available for the final IF bandwidth filter (usually called a "selectivity" adjustment). The video filter is analogous to a variable filter placed between the radio receiver's detector and the audio amplifier (though in fact, few radios actually have such a filter).

In the spectrum analyzer, narrowing the resolution bandwidth lowers the noise floor because there is less noise power within the bandwidth of a narrower filter. This occurs because noise is equally distributed across the frequency spectrum, and so the noise floor is lowered as you progressively restrict the range of frequencies fed to the detector circuit. The trade-off is a reduced information bandwidth (the range of frequencies examined at any given time). For a radio receiver, reduced IF bandwidth limits the audio bandwidth of the detected signal, producing poorer-quality audio, but offers greater selectivity and provides a signal with less noise.

In the spectrum analyzer, narrowing the video bandwidth simply reduces the variance in the noise level (if the output of the spectrum analyzer was an analog meter, using video filtering would be equivalent to dampening the meter movement). This smooths the noise level—and in some cases, can reveal low-level signals that might otherwise be obscured. In the radio receiver, video filtering would be analogous to using a low-pass filter before the output amplifier to attenuate the higher frequencies (a "noise filter" or "noise limiter").

Some spectrum analyzers (such as the HP 3589A) are equipped with a "video averaging" feature. This lets you average successive traces. Because both video filtering and video averaging both smooth the noise floor, the results of an averaged measurement without video filtering are often similar to a single trace with video filtering.

Video averaging with the HP 3589A Spectrum Analyzer is an rms exponential average and is actually a better approximation of noise than video filtering. Also, if you need to smooth the noise floor, video-averaged measurements are faster than a single video-filtered trace, since a series of averaged measurements will reveal a complete frequency span much faster than the slower progression of a single, video-filtered trace.

Bandwidth Coupling

The automatic adjustment of resolution bandwidth, sweep time, and video bandwidth for different frequency spans is called "bandwidth coupling." It is an important feature and one common to most swept-tuned spectrum analyzers. Keep in mind that bandwidth coupling is used only when making spectrum measurements—*it is not used for network measurements.*

Consider that if you select a 100 kHz to 150 MHz span (a large span) the analyzer automatically selects a resolution bandwidth of 17 kHz. If you select a 100 kHz to 200 kHz span (a much smaller span) the analyzer automatically selects a resolution bandwidth of 580 Hz.

Video bandwidth works the same way. If you've turned on video filtering, the analyzer automatically selects an appropriate level of video filtering. For example, if you select a 100 kHz to 150 MHz span, the analyzer selects a video bandwidth of 26 kHz. When you select a 100 kHz to 200 kHz span, the analyzer selects a video bandwidth of 900 Hz.

For most measurement situations, bandwidth coupling provides the best compromise between frequency resolution and speed. And for most measurements, bandwidth coupling is generally preferable since it greatly simplifies your measurement setup.

Changing Bandwidth Coupling

You can easily override the current resolution bandwidth or video bandwidth selection by manually entering a setting of your own. For example, you can specify a different resolution bandwidth setting (anywhere from a maximum of 17 kHz to a minimum of about 1 Hz).

If you override a current resolution bandwidth or video bandwidth setting, the analyzer remembers the adjustment you made and uses this adjustment when calculating appropriate resolution or video bandwidths for different spans. For example, if you changed to a narrower resolution bandwidth than the default RBW (the one selected automatically), the analyzer maintains a narrower-than-normal resolution bandwidth for subsequent spans.

Turning Off Bandwidth Coupling

When you turn off bandwidth coupling, you must manually set appropriate resolution bandwidth and video bandwidth settings to make useful measurements. Keep in mind that when bandwidth coupling is off, you must be careful not to use too fast a sweep time for the current combination of resolution bandwidth and frequency span. If you do so, the UNCAL status indicator appears. This indicates an uncalibrated sweep—this reminds you that the analyzer is sweeping too fast to ensure an accurate measurement.

Sweep Time

Sweep time is the time required for the analyzer to complete one full sweep on the display. Normally, sweep time is adjusted automatically. The analyzer selects an appropriate sweep time, based on the frequency span and the resolution bandwidth you have selected.

You can also set the sweep time manually. If you select a sweep time that's too fast for the current frequency span and resolution bandwidth settings, the UNCAL status message appears in the lower right hand corner of the display. This indicates that the analyzer is sweeping too fast to make an accurate measurement.

On some spectrum analyzers, sweep time is called "scan time." Also, sweep time is sometimes expressed as "sweep speed" or "sweep rate"— expressed either in hertz/second or time/graticule division.

Note

When the analyzer's peak detector is on, increasing the sweep time can cause apparent increases in the noise floor level—assuming you hold the span and resolution bandwidth constant. With longer sweep times, the analyzer spends more time detecting peaks for a given display point. This increases the chance that a larger peak will be detected, if the frequencies represented by the display point contain only noise energy.

To learn more about the peak detector and its function, see "The Peak Detector" sidebar later in this chapter.

Oversweep

Unlike traditional swept-tuned spectrum analyzers that use analog IF (intermediate frequency) filters, the HP 3589A uses digital IF filters. These digital filters settle in a more predictable way than comparable analog filters. This means the analyzer can make faster measurements—particularly at narrow resolution bandwidths—than spectrum analyzers with analog IF filters.

The inherent predictability of digital IF filters allows the HP 3589A to use a built-in correction algorithm when making spectrum measurements to "oversweep" its digital filters—yet still maintain both amplitude and frequency accuracy. This allows the analyzer to sweep even faster (up to four times faster than conventional swept-tuned analyzers for comparable measurements).

Oversweep is useful for most spectrum measurements. It is automatically enabled when you turn on the analyzer. However, slightly inaccurate results may be occur when measuring the spectra of non-stationary signals—so it sometimes is better to turn off oversweep.

When making swept spectrum measurements, oversweep is disabled if you turn on the analyzer's source (this prevents slight measurement inaccuracies). In addition, *oversweep is not available for swept network measurements.*

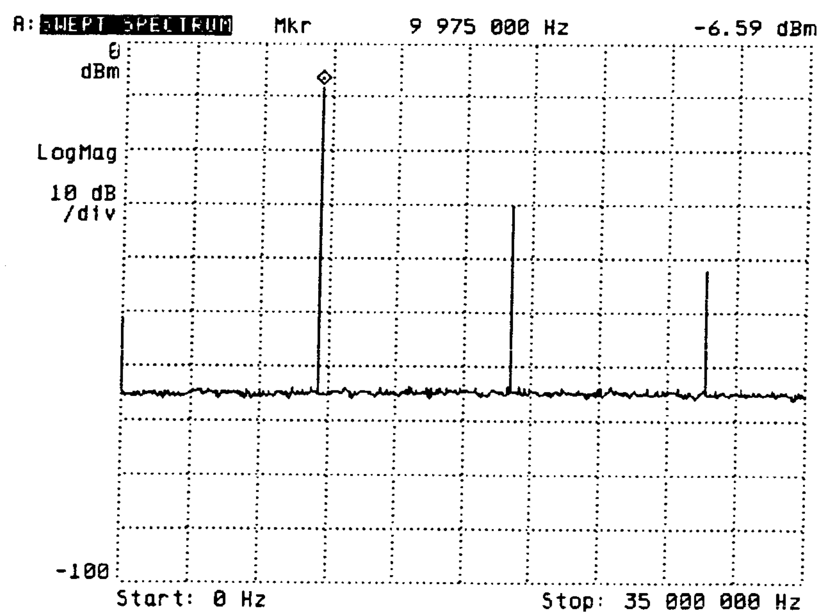
Local Oscillator Feedthrough

When viewing frequency spans that start at 0 Hz (or very close to 0 Hz), a spectral line is usually visible at the extreme left of the analyzer's display. This is the local oscillator feedthrough—sometimes called "zero response." The energy measured here, in the first few display points, is not due to the input signal. Rather, it is energy measured from the analyzer's own local oscillator.

As the analyzer sweeps from 0 Hz, the action of the variable local oscillator and its associated mixer effectively "tune" the analyzer's input to 0 Hz. When the analyzer is tuned to 0 Hz (and only at 0 Hz), the local oscillator is running at the same frequency as the mixer's IF frequency. At this point, some of the local oscillator signal feeds through the first mixer stage. As a result, this energy passes through the first IF filter and subsequently into the detector stage. This creates a response on the analyzer's display even though no input signal is present.

Local oscillator feedthrough is common to all swept-tuned spectrum and network analyzers. Local oscillator feedthrough diminishes as you view spectra with start frequencies increasingly greater than 0 Hz. Local oscillator feedthrough is also noticeable when making network measurements, particularly when using logarithmic sweeps that start near 0 Hz (we'll talk more about this in the next chapter).

In the HP 3589A, the input is ac-coupled, so the "zero response" is contributed solely by the local oscillator feedthrough—not a combination of dc offset and local oscillator feedthrough if the analyzer had a dc-coupled input.



Peak Detecting and Display Resolution

What is a peak detector and why is one needed?

The measurement results that you view on the HP 3589A's CRT screen are actually made up of 401 evenly-spaced discrete points. For swept spectrum measurements, these 401 points represent the continuous range of frequencies that the analyzer evaluates during each frequency sweep – extending from the currently-selected start frequency to the currently-selected stop frequency. For narrowband zoom measurements, these 401 points are the results obtained from the analyzer's FFT algorithm (see "Narrowband Zoom Measurements" later in this chapter). The analyzer always uses 401 points to represent measurement data, regardless of selected frequency span or measurement type.

During swept spectrum measurements, the analyzer evaluates all frequencies within its displayed frequency span but is only able to display 401 points. During a swept measurement, the analyzer's peak detector looks for a peak between two display point frequencies and transfers the amplitude of this peak to a nearby display point. This ensures that all measured spectral peaks are visible.

For narrowband zoom measurements, peak detection isn't needed. All frequencies within a Narrowband zoom measurement span are evaluated, due to the nature of the FFT algorithm. To learn more about Narrowband zoom measurements, see "Narrowband Zoom Measurements" later in this chapter. Additionally, peak detection is not used for swept network measurements, as it would degrade the accuracy of these measurements.

Digital Storage

All spectrum analyzers require some form of display storage to retain, on a CRT screen, the relatively slow-moving results of a swept spectrum measurement. Early spectrum analyzers used CRTs with long-persistence phosphors (or storage meshes behind the CRT face) to maintain a visible trace throughout an entire frequency sweep. Modern spectrum analyzers use digital technology to convert the analog output from an analyzer's video detector to binary numbers in an internal memory. These values are then displayed on the analyzer's CRT screen.

Although digital storage requires a display with a finite number of display points, there are tremendous advantages to digitizing measurement results. Many functions, such as trace math, were unobtainable with older spectrum analyzers. Digitizing measurement results also makes it easy to save and recall traces and to transfer measurement data to other instruments (for example, over the HP-IB).

The 401-point Display

As we mentioned earlier, the analyzer always displays measurement data with a 401-point resolution – even though the analyzer does evaluate all frequencies within its displayed frequency span. The peak detector, in effect, compensates for the limited display resolution.

To better understand the concept of display resolution, move the main marker from display point to display point. Notice how the marker jumps to each point – you cannot put the marker between points. As you move the marker, also notice how the marker readout steps through a series of discrete frequencies that corresponds to each display point.

For each frequency span, the analyzer assigns a discrete frequency value to each display point by dividing the current frequency span by 400. The analyzer then uses the specified start frequency to calculate nominal frequency values for each of the remaining 400 points.

When the peak detector finds a spectral peak between the nominal frequencies that define a pair of display points, it transfers the amplitude of this peak to a nearby display point. The analyzer moves any peak detected between two display points to the leftmost display point for each pair of display points.

The Relationship between Frequency Resolution and Display Resolution

For swept spectrum measurements, your ability to resolve two closely-spaced components – that is, the analyzer's ability to place each component on its own display point – may be limited by the display resolution. However, the maximum resolution obtainable is actually determined by the resolution bandwidth you've selected. As you select increasingly narrower spans, the display resolution improves until the point where you reach the maximum resolution available with the current resolution bandwidth setting.

For narrowband zoom measurements, the analyzer's frequency resolution is determined by the combination of frequency span and the zoom type (high-accuracy or high-resolution). As you narrow your measurement span, your frequency resolution increases.

Resolution limited by current resolution bandwidth setting: If the resolution bandwidth is insufficient to reveal two closely-spaced components, the peak detector simply sees these two components as a single frequency and displays them on a single display point. The amplitude of the two components is combined, though it varies from sweep to sweep as the phase relationship between the two components changes.

Resolution limited by current display resolution: If the display resolution is insufficient to reveal two closely-spaced components – but the current resolution bandwidth setting does provide enough resolution to distinguish two separate components – the peak detector takes the larger of the two components and places it on a single display point. However, were you to narrow the span enough – keeping the resolution bandwidth constant – you would be able to view two discrete frequency components as the display resolution improved.

When should you turn off the peak detector?

The peak detector is normally on (it defaults to on when you turn on the analyzer). You should use the peak detector for all spectrum measurements – if you don't, you won't be able to see spectral peaks that occur between the display point frequencies.

You may want to turn off the peak detector when making certain types of noise measurements – though when you use the analyzer's noise marker, the peak detector is automatically disabled for the duration of the noise marker calculation. By the way, the peak detector is automatically disabled when making swept network measurements so you don't have to turn it off for these measurements.

The Peak Detector and the noise floor

Since the analyzer keeps positive peaks and rejects negative peaks when the peak detector is on, the average level of random noise appears to increase. This effect is more pronounced for longer sweep times. When the analyzer spends more time sweeping, there is an increased probability that it will detect more positive excursions of the noise. You can use the analyzer's noise level function to measure the true energy of the noise floor (the peak detector is disabled while analyzer calculates the noise level).

Manual Sweep

For swept spectrum measurements, sweep times can be very long for small spans—particularly when using a narrow resolution bandwidth. You can use *manual sweep* to disable the analyzer's automatic sweep. Manual sweep lets you tune the analyzer to a discrete frequency. For both spectrum and network measurements, this lets you measure the amplitude of discrete frequencies without waiting for the analyzer to sweep through an entire span—a considerable advantage when using both a narrow resolution bandwidth and a narrow video bandwidth. And using manual sweep with network measurements can tell you if you are sweeping to fast for your device-under-test (we'll explain this further in the next chapter, "Network Measurements").

Manual sweep is also useful when making automated measurements. Using manual sweep dramatically reduces measurement time since it's much faster to transfer amplitude data for a single frequency over the HP-IB rather than sending data for the entire 401-point display.

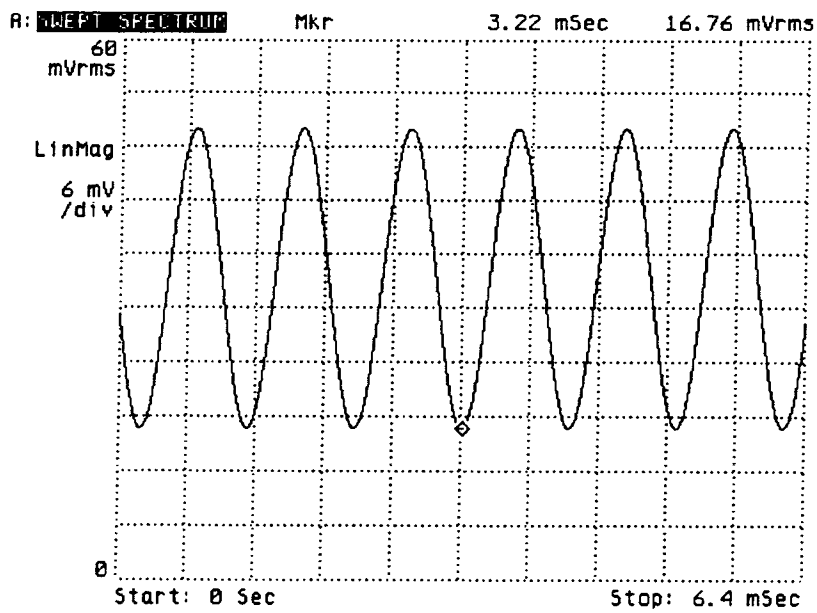
Zero Span

In Zero Span mode, the analyzer's local oscillator remains at a single frequency—in other words, the analyzer acts as a fixed-tuned receiver. This is similar to manual sweep mode. But unlike manual sweep mode (in which you examine a signal at a only one display point), zero span lets you examine a signal on all 401 display points.

Zero Span Displays Time - Domain Data

Zero Span is the only measurement type where measurement data is shown in the *time domain*, not the frequency domain. When looking at a zero span trace, the vertical axis still represents amplitude, but the horizontal axis represents time. This lets you view the amplitude of a test signal versus time. Here are a few applications:

- **Observing the amplitude modulation of a carrier frequency.**
- **Checking the long-term amplitude stability of a test signal.**
- **Adjusting a filter or other network to pass (or stop) a particular frequency.**
- **Adjusting the frequency of a test signal to match a frequency reference (by adjusting the beat frequency to 0 Hz).**



Note

Zero span is available only when the analyzer is making swept spectrum or swept network measurements. It is not available when making narrowband zoom measurements.

Special Considerations for Zero Span

For successful measurements in zero span mode, keep in mind the following characteristics:

- *Narrow resolution bandwidth settings can make it difficult to locate a test signal.* If there are no other signals near your test signal, use the maximum resolution bandwidth (17 kHz). Otherwise, you may have difficulty finding your test signal—particularly if you haven't set the center frequency to exactly the same frequency as your test signal. Because the analyzer functions as a fixed-tuned receiver in zero span, the analyzer's "tuning" is too sharp with a narrow resolution bandwidth to detect a test signal that isn't exactly at the specified center frequency.

- Narrow resolution bandwidth settings provide selectivity to exclude closely-spaced signals. If you carefully set the center frequency, you can use a narrow resolution bandwidth to exclude signals that are close to the frequency of your test signal.

For modulated signals, use a resolution bandwidth setting wide enough to reveal the modulation.
If you're using zero span to view amplitude modulation of a carrier frequency, make sure you've adjusted the resolution bandwidth setting wide enough to include the modulated signal. Modulation frequencies greater than one-half the current resolution bandwidth may not be visible—these frequencies are attenuated more than 3 dB and therefore fall outside the passband of the resolution bandwidth filter.

- *Select appropriate trace type.* If you want to measure amplitude in dBm, use the logarithmic magnitude trace type. If you want to measure amplitude in volts, use the linear magnitude trace type. When viewing modulation waveforms use linear magnitude trace type—the logarithmic magnitude scale distorts the shape of the displayed modulation trace.

- Use manual trigger arming to freeze the zero span trace. When viewing modulation waveforms in zero span, you can use manual trigger arming to freeze the trace. This makes it easier to examine the display since the analyzer does not make another measurement until you press [**ARM**].

Narrowband Zoom Measurements

The HP 3589A's narrowband zoom capability uses digital signal processing to provide extremely narrow resolution bandwidths for spans of 40 kHz and less—down to 0.0045 Hz, in fact. You can use narrowband zoom for many applications, including the following:

- uncovering power line interference
- tracking down mechanically-coupled disturbances, such as microphonics
- examining low-level modulation
- studying crowded frequency spectra
- performing more complete noise and spur measurements

Introducing Narrowband Zoom

If you've used a swept-tuned spectrum analyzer before, you already know that measurements of small frequency spans are very time-consuming. Traditionally, swept-tuned analyzers have required very long sweep times for small frequency spans, due to the narrow resolution bandwidths required to provide adequate frequency resolution. The narrower the resolution bandwidth, the more time it takes for the resolution bandwidth filters to settle. In fact, a swept-tuned analyzer's sweep time is inversely proportional to the square of the resolution bandwidth. As you choose increasingly narrower resolution bandwidths (for example, when trying to resolve close-in sidebands) the time it takes to make a measurement *increases exponentially*. This characteristic is common to all conventional swept-tuned spectrum analyzers.

However, the HP 3589A Spectrum Analyzer can make narrow band measurements very quickly with narrowband zoom. This lets you make measurements for small spans (40 kHz and less) much faster than you can with a swept spectrum measurement. For narrowband zoom measurements, the analyzer uses an FFT (Fast Fourier Transform—an implementation of the Discrete Fourier Transform) to convert the input data from the time domain to the frequency domain. The result is measurement capability more than thirty times faster than conventional swept-only analyzers.

Narrowband zoom is ideal for narrowband analysis of close-in sidebands. And it's easy to do. First set the analyzer's center frequency to the carrier frequency you want to examine. Then change the measurement type to narrowband zoom.

High-Accuracy Zoom versus High-Resolution Zoom

When making narrowband zoom measurements, you can select a high-accuracy zoom or a high-resolution zoom. The default selection is high-accuracy zoom.

If you need to measure the absolute or relative amplitude of a spectral component with great accuracy —for example, when using a fixed sine stimulus—use high-accuracy zoom. If it's more important to measure a component's frequency, use high-resolution zoom.

Generally, high-resolution zoom offers greater resolution than the high-accuracy zoom. However, the shape factor of the filters used does affect the detection of very small signals if a much larger signal is present. So for looking at close-in sidebands, you may find that you get better resolution using *high-accuracy zoom*, rather than high-resolution zoom.

3

Network Measurements

There are three measurement types available with the HP 3589A Spectrum/Network Analyzer—*swept spectrum, narrowband zoom, and swept network measurements.* This chapter explains swept network measurements.

Network Basics

This section explains basic concepts of network measurements. Many of these concepts apply directly to the HP 3589A Spectrum/Network Analyzer. Other concepts—such as the configuration of two-channel and three-channel network analyzers—do not apply directly to the HP 3589A but are still important to understand.

The HP 3589A is both a spectrum analyzer and a single-channel network analyzer. Even if you have already used a network analyzer before, you might want to read this section since it introduces the concept of a single-channel network analyzer. This is important if you have not used a single-channel network analyzer before.

What is a Network Analyzer?

Like a spectrum analyzer, a network analyzer displays measurement results in the frequency domain. There are several types of swept network analyzers, including two-channel, three-channel, and single-channel network analyzers (the HP 3589A is a single-channel network analyzer). Most of these analyzers can make similar measurements. The significant differences are measurement speed for a given measurement, ease of setup, and cost and complexity of the analyzer itself.

For accurate results, the device-under-test should not change its characteristics for the duration of the network measurement. Keep in mind that measurement duration includes not only the time it takes the network analyzer to sweep from the start frequency to the stop frequency, but the additional time it takes to calibrate a measurement (calibration for a network measurement is very important; we'll explain calibration with the HP 3589A Spectrum/Network Analyzer later in this chapter).

How Does It Work?

A simplified view of a network analyzer is a device that

- provides a source signal at a required frequency,
- measures the amplitude (and usually phase) of this signal before it is affected by the device-under-test,
- then compares this signal after it is affected by the device-under-test (in theory, the ratio of these two values is the response of the network).

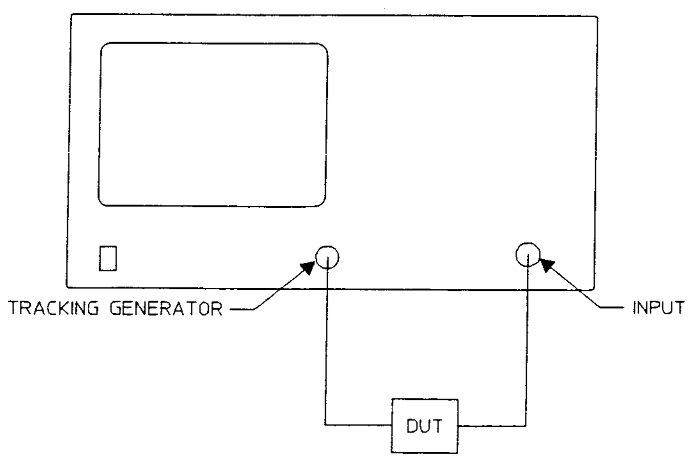
Scalar Network Measurements

The simplest type of network measurement are *scalar* network measurements. Scalar network measurements do not reveal phase information and thus only reveal the amplitude versus frequency response of a network (such as a filter or amplifier). Scalar network measurements are often made with a spectrum analyzer that contains a *tracking source*—a sinusoidal output with a frequency that follows the analyzer's swept-tuned (or manually-tuned) frequency. This provides a way to measure the transfer function of a device-under-test.

Normalization and calibration are important parts of any network measurement. *Normalization* involves the removal of system errors when measuring the device-under-test. However, normalization cannot remove effects caused by the interaction of the device-under-test with the test system. *Calibration*, on the other hand, can remove the effects of interaction but is only available with more sophisticated network analyzers.

For scalar network measurements with a spectrum analyzer and tracking generator, normalization is somewhat limited—in this case, it simply ensures amplitude accuracy by removing the flatness error of the tracking generator from the measurement results. This is done by substituting the device-under-test with a through-connector to make a reference measurement, then using the reference measurement to remove the flatness error. This is typically done either by dividing the measurement trace by the reference trace (if the data is linear) or by subtracting the reference trace from the measurement trace (if the data is logarithmic).

To characterize both amplitude and phase performance of a test device, you need to use an analyzer that makes *vector* measurements. In its simplest form, a *network analyzer* can characterize both the amplitude and phase response of a device-under-test. More sophisticated network analyzers can make additional measurements such as reflection, group delay, impedance, and S-parameters (we'll discuss these measurements in a few moments). Each measurement can also be calibrated to ensure more accurate measurements.



Vector Network Measurements

Traditional vector network analyzers have a source and multiple inputs (often called *receivers*). Two-channel network analyzers have two receivers while three-channel network analyzers have three. In addition, a phase detector is included to determine the phase difference between the stimulus signal and the response signal.

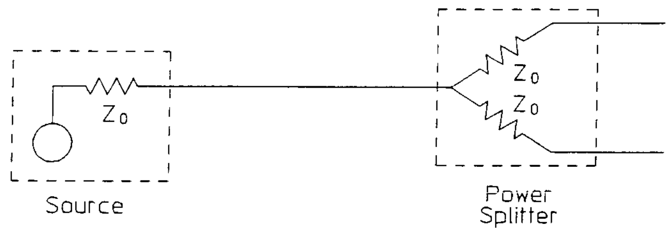
Traditionally, network analyzers have used multiple receivers to provide simultaneous determination of several network parameters. One receiver is used as a reference channel to which the amplitude and phase response of other channels are compared. By using the appropriate combination of power splitters and directional couplers, many different type of network measurements are available.

One type of measurement is a *ratio* measurement. A ratio measurement is the characterization of amplitude and phase response of a device-under-test by comparing its input to its output. Other network measurements include transmission and reflection in both forward and reverse directions, known as *S-parameters* ("scattering" parameters).

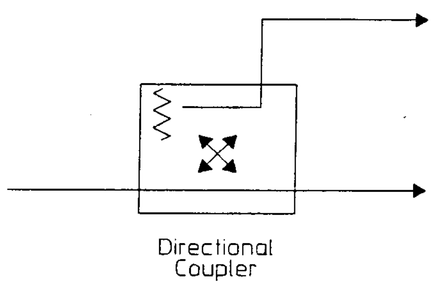
For good performance, network analyzers with multiple receiver channels must have carefully designed receivers. Each receiver must have similar gain and phase—any mismatch degrades the accuracy of the network measurements made with the analyzer. Single-channel network analyzers have only one receiver and thus do not have this constraint (we'll discuss these analyzers in a few moments).

Power Splitters and Directional Couplers

Many network measurements require a two-way power splitter. A two-way power splitter contains three precision resistors, each carefully matched to the impedance of the source and receiver channels (typically 50 ohms or 75 ohms). This ensures that both the reference receiver and the device-under-test are fed signals with the same amplitude and phase.

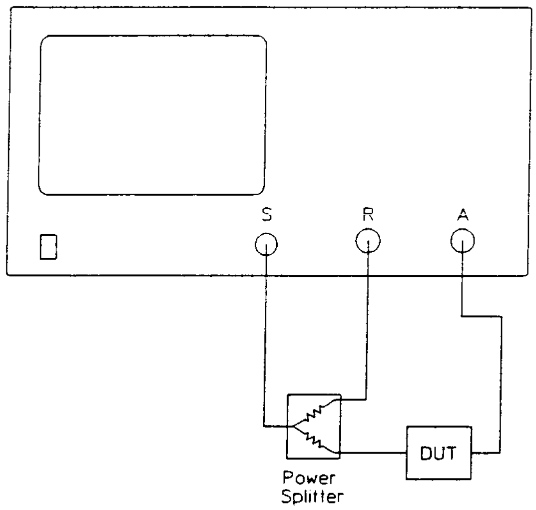


A directional coupler (for example, a directional bridge) is a special device that can sense the direction of energy flowing within a transmission line. Directional couplers are used to determine how much power is transmitted to a device-under-test and how much power is reflected from the device-under-test. Transmission and reflection measurements are useful ways to characterize the performance of many networks.

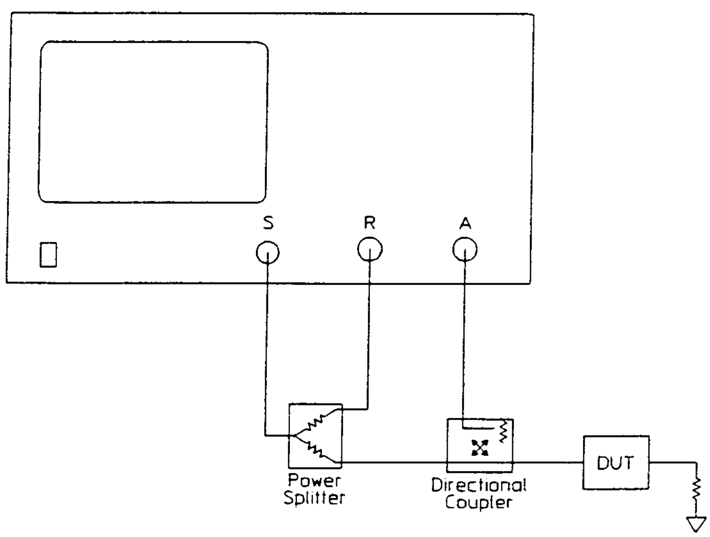


Two-Channel Network Analyzers

A typical two-channel network analyzer has a source and two receiver channels. This type of analyzer is often used with a power splitter and directional coupler to make ratio and reflection/transmission measurements. To make a ratio measurement, a two-channel network analyzer is configured like this:



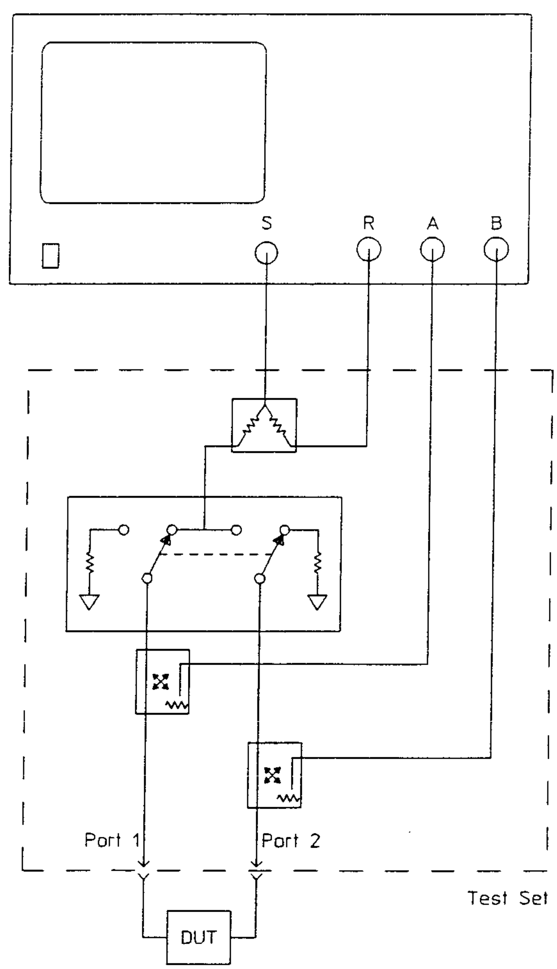
To make a reflection measurement, a two-channel network analyzer is configured like this (note that the unused port of the device is terminated with the appropriate load impedance):



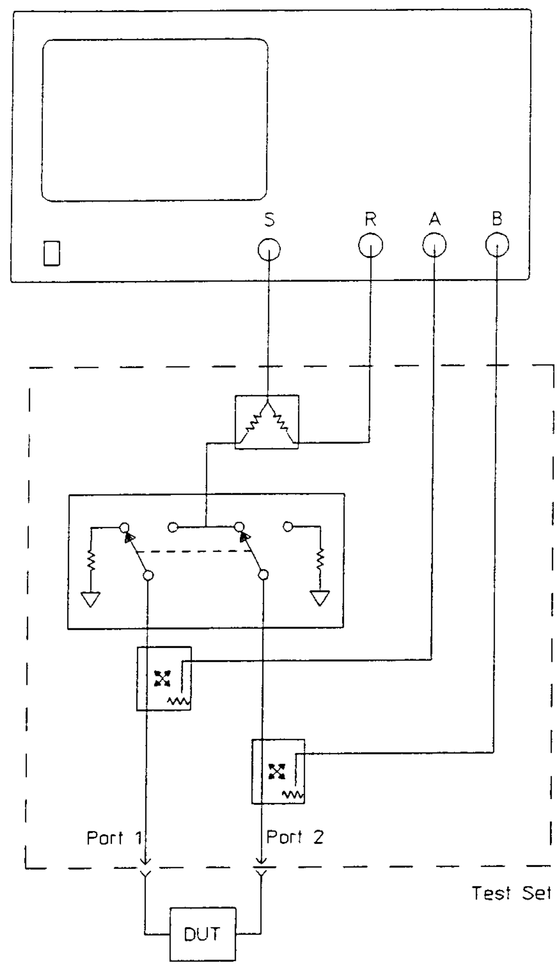
Three-Channel Network Analyzers

A typical three-channel network analyzer has a source and three receiver channels. This type of analyzer is often used with a companion S-parameter test set that contains a power splitter, directional couplers, and switching relays. Three-channel analyzers are generally more expensive than two-channel analyzer but can make S-parameter measurements much faster by automatically selecting the appropriate combination of directional couplers.

To make forward transmission and forward reflection measurements, a three-channel network analyzer is configured like this:



To make reverse transmission and reverse reflection measurements, a three-channel network analyzer is configured like this:



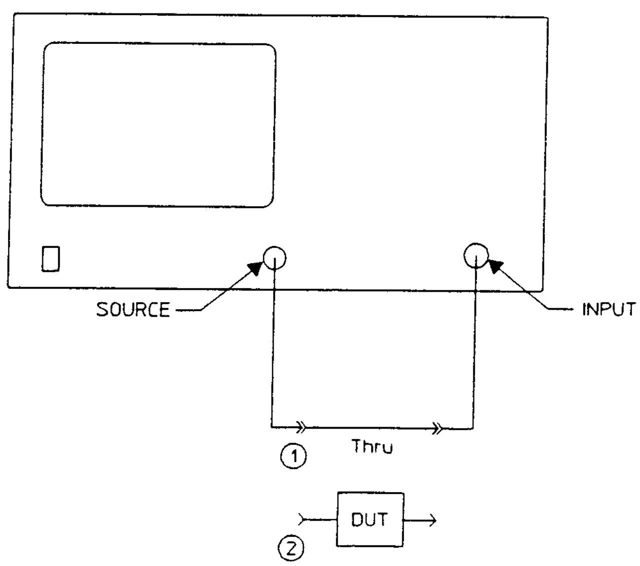
Single-Channel Network Analyzers

In more recent network analyzers, the source frequency and the local-oscillator frequency are synthesized from a common reference frequency. This allows for accurate (and repeatable) amplitude and phase control of the various signals inside the network analyzer. Because the source signal is phase-locked to an internal reference, *each sweep can be exactly the same as the previous sweep*—a concept that is particularly important for single-channel network measurements. In fact, without this accuracy, good single-channel network measurements would not be possible.

The single-channel network analyzer has one source and one receiver channel (the HP 3589A is an example of this type of network analyzer). Because it uses a single receiver instead of two or three closely-matched receiver channels, a single-channel network analyzer is less expensive and eliminates the possibility of a channel-to-channel mismatch that can occur in two- or three-channel network analyzers. The trade-off however, is that measurements with a single-channel network analyzer may require additional time to set up and calibrate for comparable measurement situations.

To make a typical network measurement with a single-channel network analyzer (a forward transmission measurement, for example), you first connect the source to the receiver with a though-connector in place of the device-under-test and make a reference measurement. Then using the same cabling, you replace the through-connector with the device-under-test and make a second measurement. The measured transmission is the result of the current measurement divided by the stored reference measurement.

Because the reference measurement and the actual measurement are not done at the same time, the accuracy of a single-channel network measurement can be degraded if excessive time elapses between the reference measurement and the measurement of the device-under-test. Additionally, temperature changes that occur between the two measurements can also affect accuracy.



Swept Network Measurement

The HP 3589A makes vector network measurements somewhat differently than most other Hewlett-Packard network analyzers. This is because the HP 3589A uses a single receiver instead of two or three receiver channels. This provides cost-effective network measurements (in an implementation known as a *single-channel network measurement*) and eliminates the possibility of a channel-to-channel mismatch that can occur in two- or three-channel network analyzers. If you are unfamiliar with single-channel network measurements, be sure you have read "Single-Channel Network Measurements" earlier in this chapter.

Introducing the HP 35689A/B S-Parameter Test Set

As we mentioned earlier, network analyzers are often used with a companion S-parameter test set. A typical test set contains a power splitter, directional couplers, and switching relays. A test set extends the measurement capability of a network analyzer and lets the analyzer make S-parameter measurements much faster by automatically selecting the appropriate combination of directional couplers.

Two test sets are available for the HP 3589A Spectrum/Network Analyzer. The HP 35689A S-Parameter Test Set is designed for measuring 50-ohm devices while the HP 35689B is designed for 75-ohm devices. Both test sets have a separate spectrum input to let you make spectrum measurements without disconnecting the test set.

Note

The HP 35689A/B contains directional couplers that are optimized for operation above 100 kHz. Although you can make network measurements with start frequencies lower than 100 kHz, the analyzer's performance is not specified below 100 kHz when using the HP 35689A/B test set.

Network Measurements Without a Test Set

To make S-parameter measurements, you need to use an HP 35689A/B S-Parameter Test Set. However, you can still make some swept network measurements without the test set. You can make normalized transmission and normalized reflection measurements (in the forward direction only).

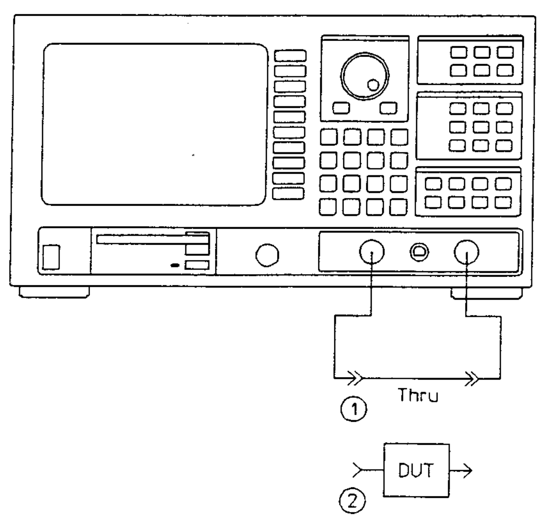
Note

Without an S-parameter test set, the HP 3589A makes forward transmission and reflection measurements only. To make reverse measurements, you can make forward measurements with the device-under-test reversed.

Normalized Transmission

Normalized transmission measurements without the S-parameter test set are a two-part process. First, you insert a through-connector in place of the device-under-test to make a reference measurement. Then you replace the through-connector with the device-under-test.

You can also do a "quick normalization" procedure if you don't want to disconnect the device-under-test and replace it with a through connector. During a quick normalization, the analyzer connects the source channel to the input channel internally. However, quick normalization *does not* remove the effects of cables and connectors between the analyzer and the device-under-test. For this reason, measurements made with quick normalization are somewhat less accurate.



Normalized Reflection

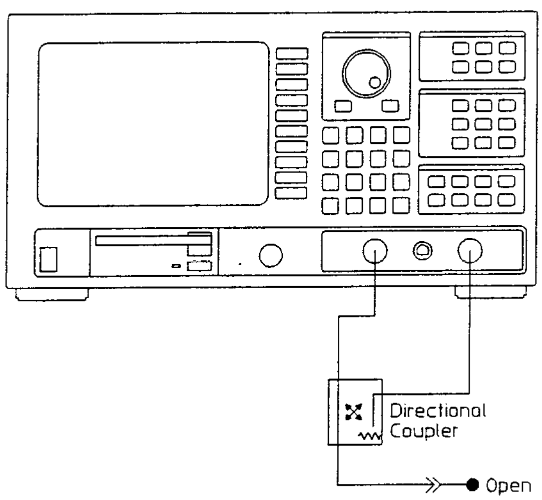
Normalized reflection measurements without the S-parameter test set are a two-part process. You have the option of normalizing with an open termination or with a shorted termination. Both configurations require an external directional coupler. If you are testing a two-port device, you must terminate the device-under-test with an appropriate load.

You can use normalized reflection measurements to measure the following:

- Normalized reflection coefficient
- Normalized VSWR
- Normalized impedance

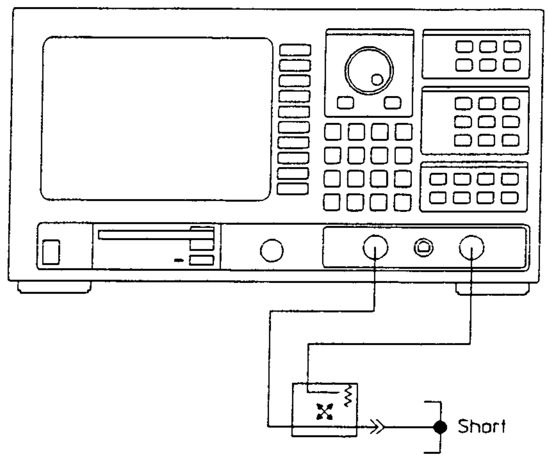
Normalizing with an Open Termination

For this configuration, you connect an open termination across the output of the directional coupler to make a reference measurement. Then you remove the open termination and replace it with the device-under-test to make the reflection measurement.



Normalizing with a Shorted Termination

For this configuration, you first connect a shorted termination across the output of the directional coupler to make a reference measurement. Then you remove the shorted termination and replace it with the device-under-test to make the reflection measurement.



Normalization

To ensure accuracy, you should normalize before each measurement if you have changed any settings in the MEASUREMENT group (such as span or resolution bandwidth) that affect normalization. For both normalized transmission and reflection measurements, the COR? message appears if a measurement parameter has changed since the last normalization.

If you don't use the HP 35689A/B test set with the analyzer, you can only make normalized measurements. Although this is adequate for many network measurements, you will need a test set to make fully-calibrated S-parameter measurements.

Normalization is easier to do than calibration, but does not take into account the interaction between a network analyzer and the device-under-test. Normalization is a process that simply measures amplitude and phase errors within a test system (with the device-under-test removed) and then removes these errors after measuring the device-under test.

Network Measurements with the Test Set

Two test sets are available for the HP 3589A Spectrum/Network Analyzer. The HP 35689A S-Parameter Test Set is designed for measuring 50-ohm devices while the HP 35689B is designed for 75-ohm devices. Both test sets have a separate spectrum input to let you make spectrum measurements without disconnecting the test set.

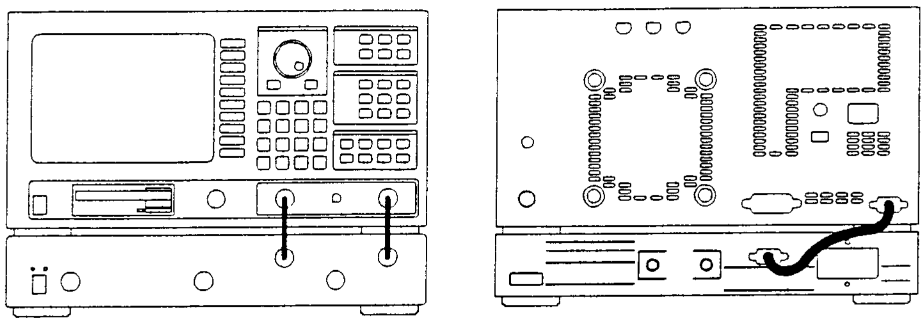
With a test set, you can make the following measurements:

- Normalized transmission
- Normalized reflection
- S_{11} (forward reflection)
- S_{21} (forward transmission)
- S_{12} (reverse transmission)
- S_{22} (reverse reflection)

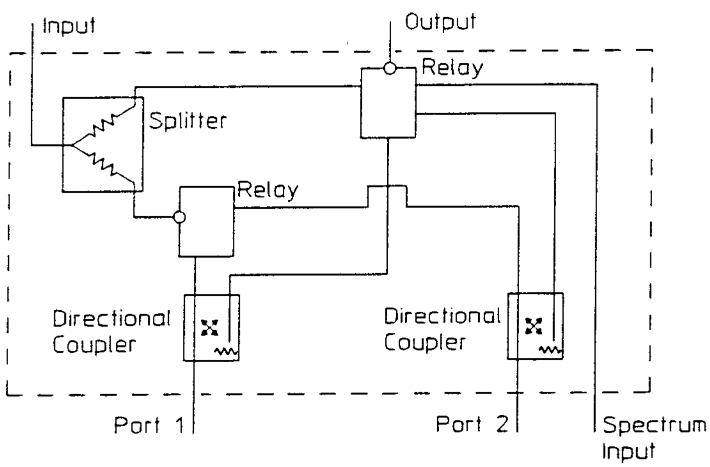
Note

The HP 35689A/B contains directional couplers that are optimized for operation above 100 kHz. Although you can make network measurements with start frequencies lower than 100 kHz, the analyzer's performance is not specified below 100 kHz when using the HP 35689A/B test set.

The test set is connected to the analyzer like this:



The following illustration is a simplified diagram of the HP 35689A/B S-Parameter Test Set. Although unused paths are always terminated, these terminations are not shown in this diagram.



Normalization and Calibration with the HP 35689A/B S-Parameter Test Set

To ensure accuracy, you should normalize or calibrate before each measurement if you have changed any settings in the MEASUREMENT group that affect measurement accuracy—settings such as span, resolution bandwidth, or source level).

Normalization is easier to do than calibration, but does not take into account the interaction between a network analyzer and the device-under-test. Normalization is a process that simply measures amplitude and phase errors within a test system (with the device-under-test removed) and then removes these errors after measuring the device-under test.

Calibration, on the other hand, is a process that compensates for interaction between a network analyzer and the device-under-test. To calibrate for transmission measurements, the HP 3589A needs a two-step process—one step to evaluate the measurement system without the device-under-test and another step with the device-under-test in place (to measure the exact power applied to the input of the device). To calibrate for reflection measurements, the analyzer needs a four-step process—three steps with the appropriate port open, shorted, and terminated, and another step with the device-under-test in place (to measure the exact power applied to the input of the device).

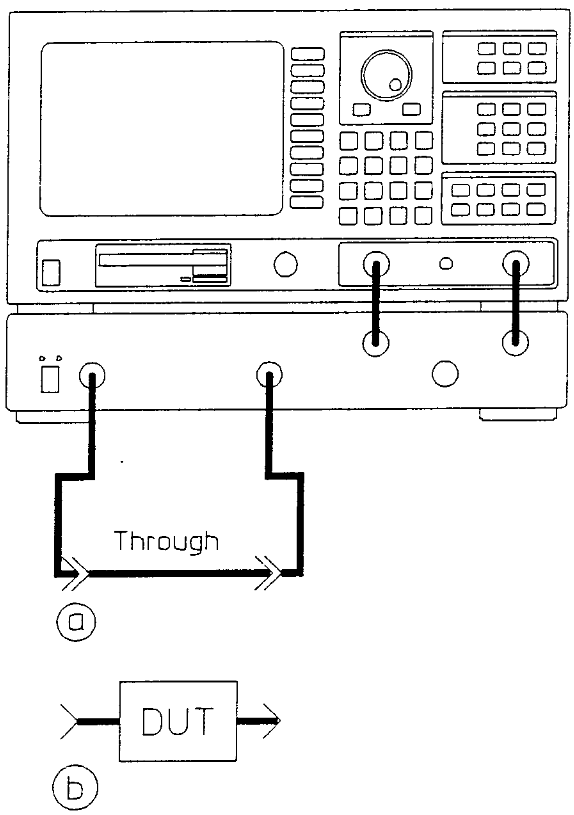
To summarize, you should know that

- for both normalized transmission and reflection measurements, the COR? message appears if a measurement parameter has changed since the last normalization.
- for S-parameter measurements, the COR? message appears if a measurement parameter has changed since the last time you calibrated.

Normalized Transmission with the Test Set

Normalized transmission measurements are similar to those without the test set. First, you insert a through connector in place of the device-under-test to make a reference measurement. Then you replace the through connector with the device-under-test.

You can also do a "quick normalization" procedure if you don't want to disconnect the device-under-test and replace it with a through connector. During a quick normalization, the analyzer makes a through connection inside the test set. However, quick normalization *does not* remove the effects of cables and connectors between the analyzer and the device-under-test. For this reason, measurements made with quick normalization are somewhat less accurate.



Normalized Reflection with the Test Set

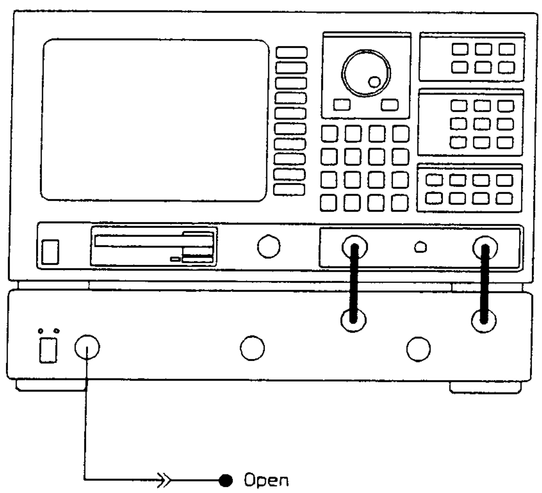
Normalized reflection measurements are similar to those without the test set. You have the option of normalizing with an open termination or with a shorted termination. Because the test set contains a directional coupler, you don't need to use an external coupler. If you are testing a two-port device, you must terminate the device-under-test with an appropriate load.

You can use normalized reflection measurements to measure the following:

- Normalized reflection coefficient
- Normalized VSWR
- Normalized impedance

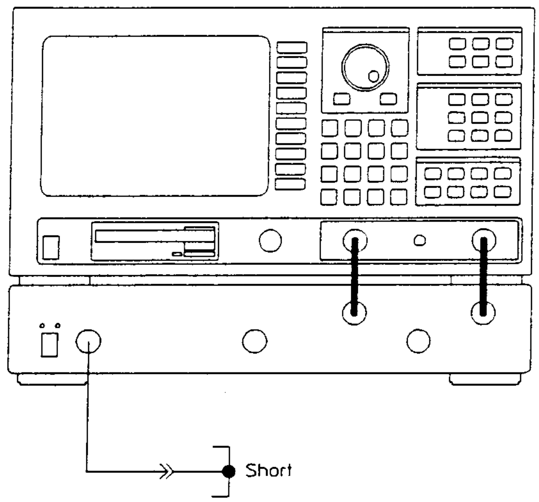
Normalizing with an Open Termination

For this configuration, you connect an open termination across the output of Port 1 to make a reference measurement. Then you remove the open termination and replace it with the device-under-test to make the reflection measurement.



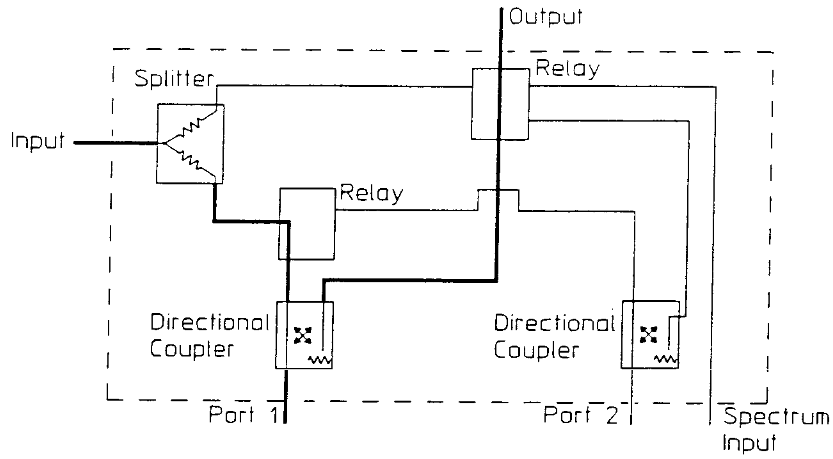
Normalizing with a Shorted Termination

For this configuration, you first connect a shorted termination across Port 1 to make a reference measurement. Then you remove the shorted termination and replace it with the device-under-test to make the reflection measurement.



Forward Reflection (S_{11})

To make a forward reflection measurement (S_{11}), the analyzer and test set are configured like this:

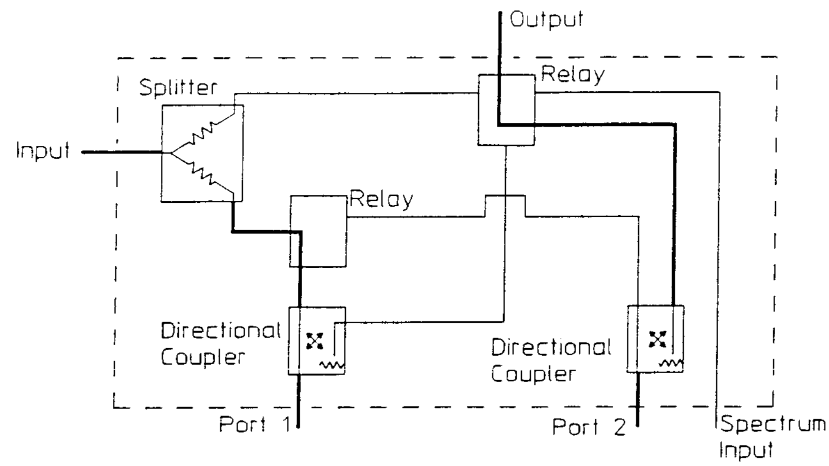


Before making a forward reflection measurement, you should first calibrate by doing the following:

- calibrate with Port 1 open
- calibrate with Port 1 shorted
- calibrate with Port 1 terminated with the reference impedance
- make a reference measurement with the device-under-test in place

Forward Transmission (S_{21})

To make a forward transmission measurement (S_{21}), the analyzer and test set are configured like this:

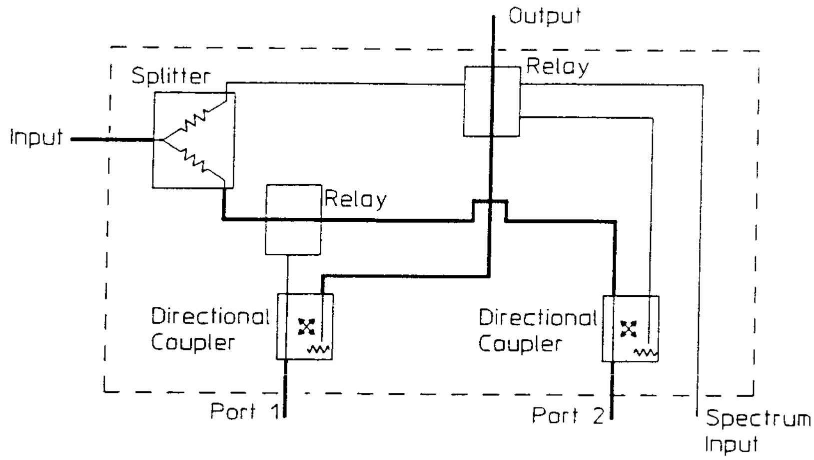


Before making a forward transmission measurement, you should first calibrate by doing the following:

- calibrate with a through connector between Port 1 and Port 2
- make a reference measurement with the device-under-test

Reverse Transmission (S_{12})

To make a reverse transmission measurement (S_{12}), the analyzer and test set are configured like this:

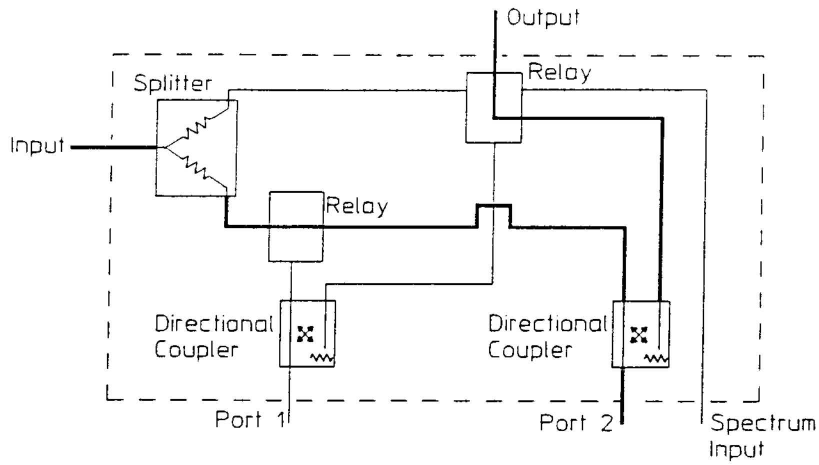


Before making a reverse transmission measurement, you should first calibrate by doing the following:

- calibrate with a through connector between Port 1 and Port 2
- make a reference measurement with the device-under-test in place

Reverse Reflection (S_{22})

To make a reverse reflection measurement (S_{22}), the analyzer and test set are configured like this:



Before making a reverse reflection measurement, you should first calibrate by doing the following:

- calibrate with Port 2 open
- calibrate with Port 2 shorted
- calibrate with Port 2 terminated with the reference impedance
- make a reference measurement with the device-under-test in place

4

Gated Sweep

Your analyzer may be equipped with the gated sweep feature (Option 1D6). This chapter provides a brief overview of the sweep gating feature and some of the reasons why it is useful.

What is Sweep Gating?

Sweep gating (Option 1D6) adds the capability to pause and continue the analyzer's internal data collection process to let you view the spectrum of an interrupted RF signal without displaying unwanted spectral components. With sweep gating, you can measure non-steady state signals by having the analyzer time-gate a part of the input signal and display a spectrum containing only the time-gated parts of the input signal. In other words, it's now possible to make measurements of a signal with a *duration that is less than the analyzer's sweep time.*

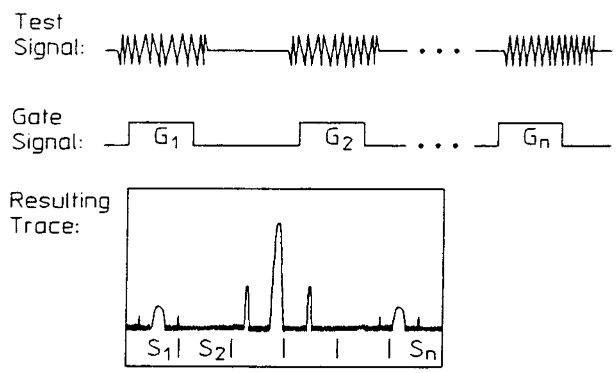
Sweep gating is often used to analyze burst signals from devices such as videotape recorders or computer disk drives. Figure 4-1 shows a typical spectrum from this type of burst signal using a conventional sweep mode. Figure 4-2 shows the same spectrum using sweep gating.

Sweep gating is available for both the swept spectrum and swept network measurement types. You can also use gated sweep with manual sweep and zero span modes.

How Does it Work?

When sweep gating is on, the analyzer collects and updates the display data only during a specified data collection time, called the *gate time*. The analyzer only sweeps during the gate allowing it to measure portions of a signal that are separated in time while ignoring interfering portions of the same signal.

During the gated sweeping, a complete sweep between the start and stop frequencies is built up from several shorter sweeping segments. Each segment is measured during a time gate. In the following illustration, the number of gates (n) is equal to sweep time divided by gate length. Gates are labelled G and sweep segments are labelled S.

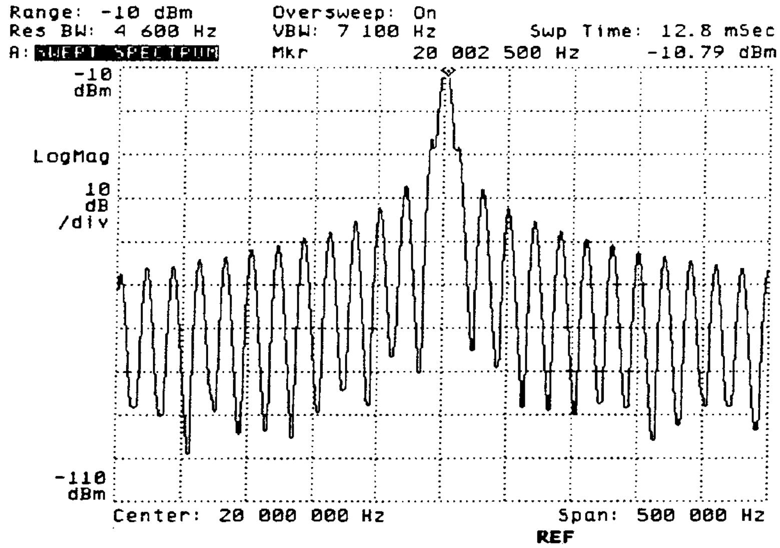


You control sweep gating by defining the following parameters:

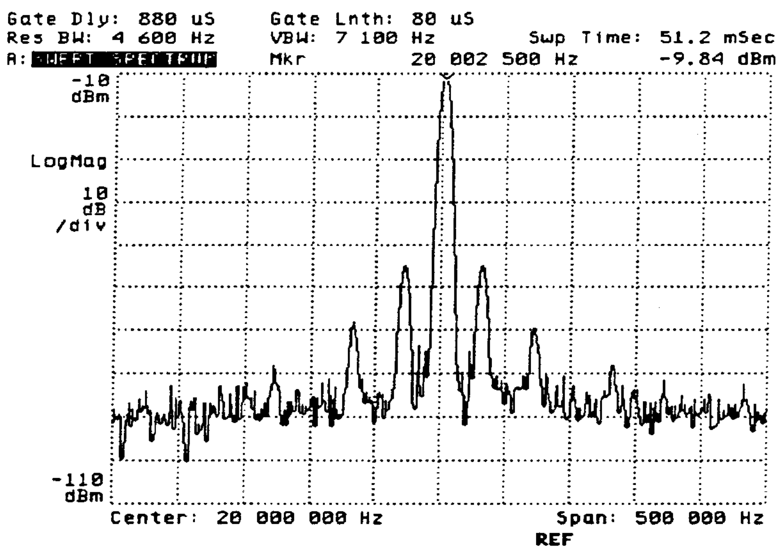
- Gated trigger mode (edge or level)
- Gated trigger polarity (positive or negative)
- Gate length (for edge triggering only)
- Gate delay (automatic or manual)

To successfully use sweep gating, a suitable TTL-level trigger signal must accompany the signal you want to measure. The trigger signal should occur at a consistent point relative to the signal you want to measure. The relationship between the trigger signal, gate length, and gate delay is very important—you must understand this relationship before you can make good gated sweep measurements.

Bust Spectrum Without Sweep Gating



Burst Spectrum With Sweep Gating

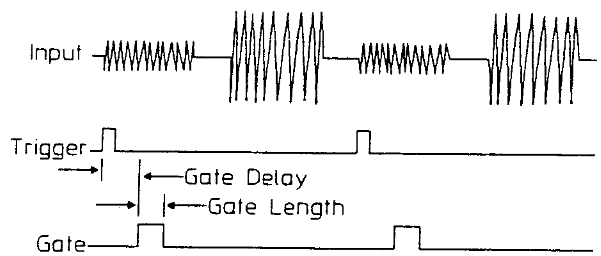


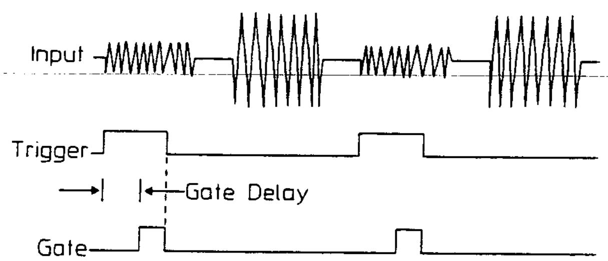
Important Concepts

Trigger Mode

There are two trigger modes for sweep gating—*edge mode* and *level mode*. Edge mode is generally easier to use because it requires a simpler trigger signal. If you use the edge trigger, you only have to define the start time of a gated sweep (since the *gate length* determines the duration of the measurement). If you use the level trigger, the trigger signal must define both the start time and the stop time.

The gated-sweep triggering modes are best understood if you compare three key signals in the time domain. The following illustrations show you how to set up the same gate for each of the two modes:

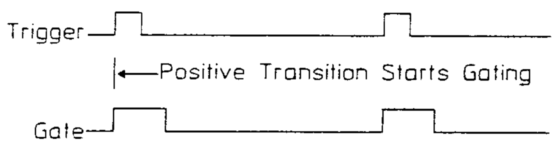




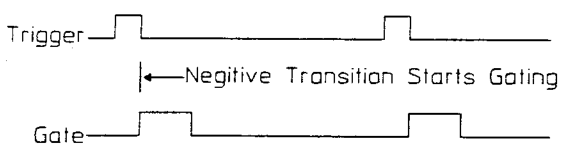
Trigger Polarity

You can select either positive or negative trigger polarity (these apply to both edge-mode and level-mode triggers). You should know that trigger polarity's effect on gating depends on the trigger mode. The first two timing diagrams show you how trigger polarity affects edge-mode gating. The second two show you how it affects level-mode gating. (Both diagrams assume that gate delay is 0.)

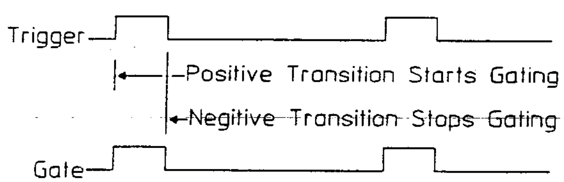
Edge-Mode Gating, Positive Trigger



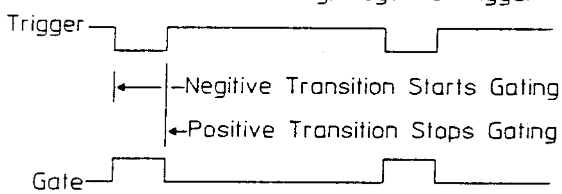
Edge-Mode Gating, Negative Trigger



Level-Mode Gating, Positive Trigger



Level-Mode Gating, Negative Trigger



Gate Delay

Keep in mind that the analyzer does not begin collecting data immediately after the trigger signal changes state—rather, there is a slight delay, called *gate delay*. Gate delay determines the time interval between the arrival of a gate trigger and the start of gating. You can specify automatic or manual gate delay.

Manual Gate Delay

If you use manual gate delay, you can specify your own values (with a minimum delay of 0 seconds). You can increase the manual gate delay to better synchronize the trigger signal with a particular signal you want to measure. For example, you may elect to use a longer gate delay if the signal you want to measure occurs quite a bit after the trigger signal.

You should know that:

- The minimum gate delay is 0 seconds.
- When edge-mode triggering is selected, the increment between available gate delays is 10 microseconds for the six widest resolution bandwidths (RBWs): 17 kHz to 580 Hz. Below 580 Hz, the increment doubles for successively smaller RBWs.
- When level-mode triggering is selected, the increment between available gate delays equals the minimum gate length for the current RBW.

Automatic Gate Delay

For automatic gate delay, the analyzer uses the minimum "safe" delay interval. The minimum safe delay ensures that a gated measurement's noise floor will be unaffected by any signal present at the receiver before triggering.

Trigger Latency

A variable delay, called *trigger latency*, is added to the gate delay when you specify a manual gate delay. The trigger latency for each gate trigger is a random value between 0 Sec and some maximum. The maximum is different in each of the following cases:

- When edge-mode triggering is selected for swept spectrum measurements, maximum latency is 10 uSec for the six widest resolution bandwidths (RBWs): 17 kHz to 580 Hz. Below 580 Hz, maximum latency doubles for successively smaller RBWs.
- When level-mode triggering is selected for swept spectrum measurements or when either triggering mode is selected for swept network measurements, maximum latency equals the minimum gate length for the current RBW.

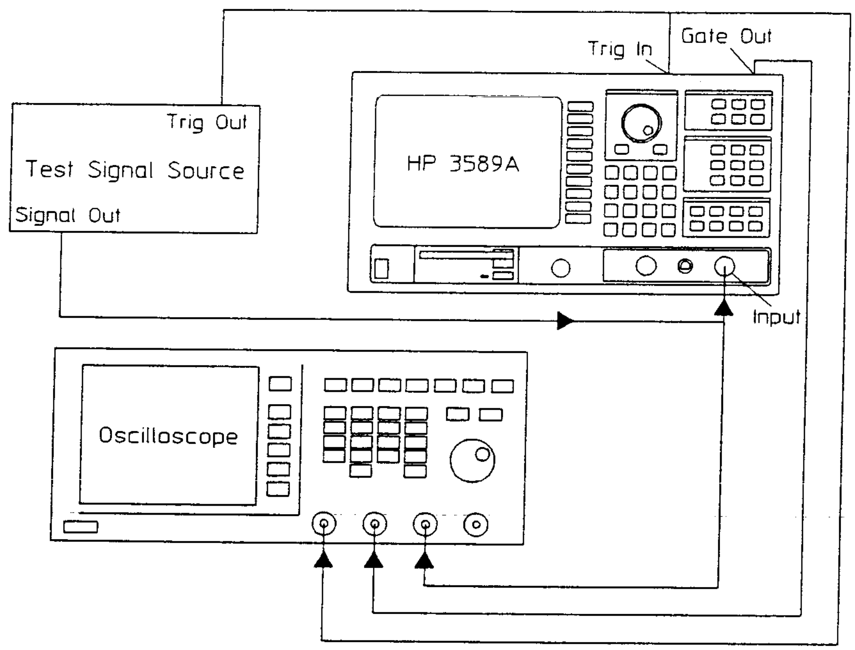
Trigger Holdoff

The sweep-gating circuitry requires a short amount of time to reset between the end of a gate and the arrival of another trigger signal. This time, called trigger holdoff, is related to the gate delay:

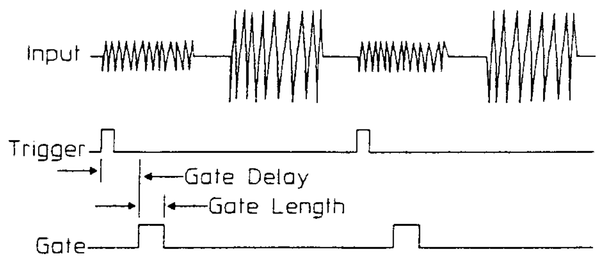
- For automatic gate delay, the trigger holdoff is approximately equal to the automatic gate delay.
- For manual gate delay, where the delay is *less* than 2 times the suggested automatic gate delay, trigger holdoff is approximately equal to the to manual gate delay.
- For manual gate delay, where the delay is *more* than 2 times the suggested automatic gate delay, trigger holdoff is approximately equal to 2 times the automatic gate delay.

Using an Oscilloscope to Set Up Gated Measurements

Gated sweep measurements are often easier if you include an oscilloscope in your measurement setup. The oscilloscope helps you position the gate over the correct portion of your test signal. The basic setup should look something like this:



The following illustration shows you example oscilloscope waveforms of the three key signals. Notice that you can re-position the gate by adjusting the values of gate delay and gate length.



Note

The preceding illustration applies only to edge-mode triggering with positive trigger polarity.

Part II

Measurement Tasks

5

Making Spectrum Measurements

To measure a wideband spectrum

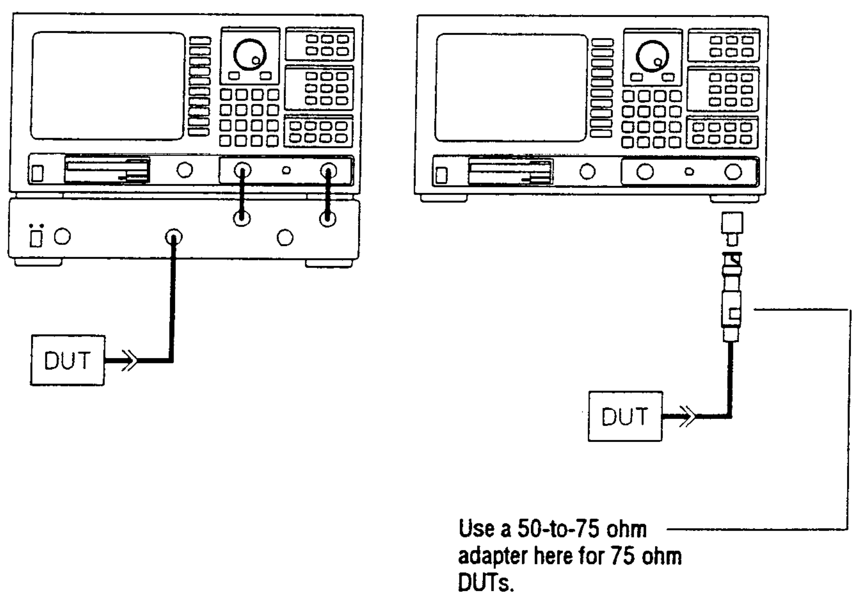
You can measure a wideband spectrum either with or without the HP 35689A/B S-Parameter Test Set. The setup illustration shows you both options. However, since the test set's performance is not specified below 100 kHz, you should *not* use it for measurements that include lower frequencies.

1 Initialize the analyzer.
Press [**Preset**].

2 Connect your DUT (as shown in the illustration).

3 Specify the measurement parameters.
Press [**Freq**] [CENTER] <num> <unit>, then press [SPAN] <num> <unit>.
If you are *not* using the test set, press [**Range/Input**], then press [50 OHMS] or [75 OHMS] to match your DUT impedance.

See "To select a 75 ohm adapter" in chapter 8, for more information on 75 ohm measurements.

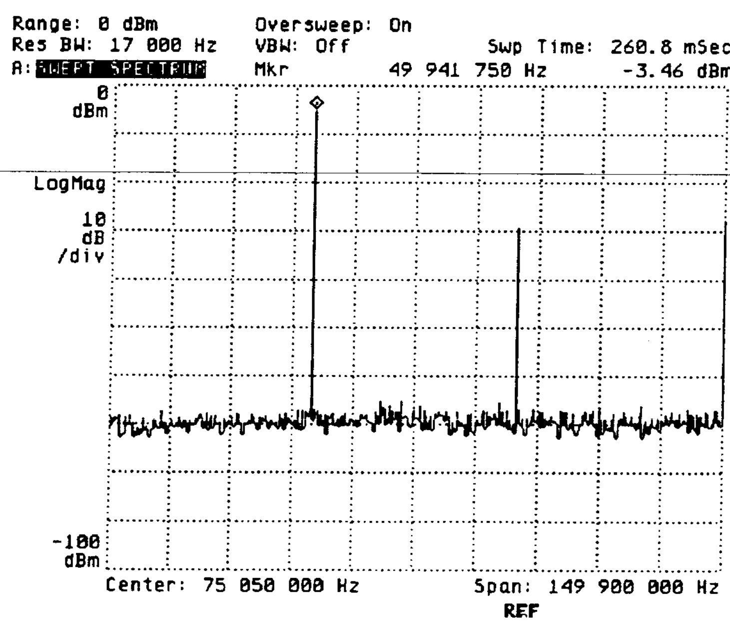


4 Measure the DUT.
Press [**Meas Restart**].

5 Configure the display.
Press [**Scale**] [AUTO SCALE].

When you press [**Preset**], the analyzer does several things to simplify your wideband spectrum measurement:

- It selects the measurement type you need by selecting the [SWEPT SPECTRUM] softkey. With this softkey selected, the HP 3589A functions as a traditional swept-tuned spectrum analyzer.
- It checks for the presence or absence of a test set and sets the state of the [TEST SET IN/OUT] softkey to match. This ensures that the analyzer will measure your DUT at the proper connector: the test set's SPECTRUM INPUT connector if the test set is present; the analyzer's INPUT connector if the test set is absent.
- It sets the [AUTORANGE ON/OFF] softkey to ON. When autoranging is on, the analyzer continuously monitors the level of your test signal and selects the best range setting for that signal.



To measure a narrowband spectrum

You can measure a narrowband spectrum either with or without the HP 35689A/B S-Parameter Test Set. The setup illustration shows you both options. However, since the test set's performance is not specified below 100 kHz, you should *not* use it for measurements that include lower frequencies.

1 Initialize the analyzer.

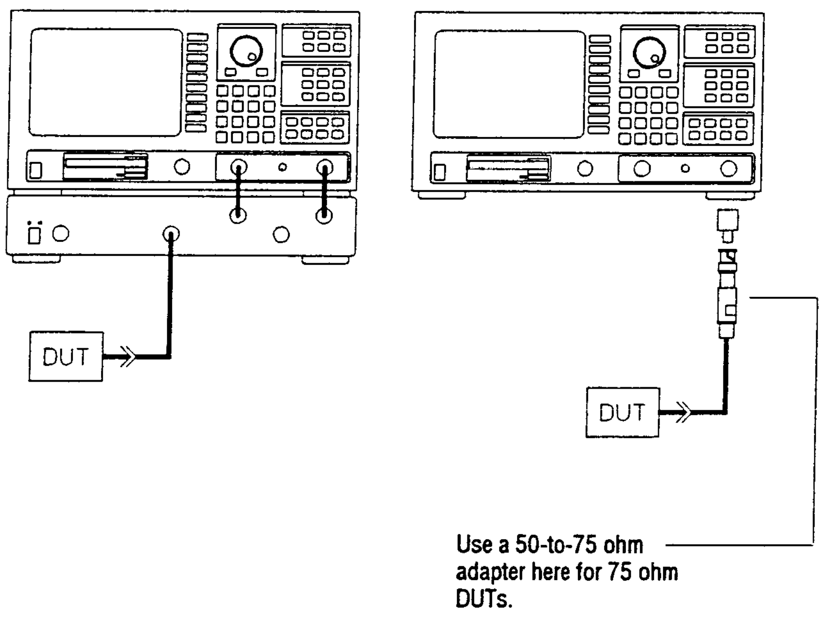
Press [**Preset**].
Press [**Meas Type**] [NARROW BAND ZOOM].

2 Connect your DUT (as shown in the illustration).

3 Specify the measurement parameters.

Press [**Freq**] [CENTER] <num> <unit>, then press [SPAN] <num> <unit>.
If you are *not* using the test set, press [**Range/Input**], then press [50 OHMS] or [75 OHMS] to match your DUT impedance.

See "To select a 75 ohm adapter" in chapter 8, for more information on 75 ohm measurements.



4 Measure the DUT.
Press [**Meas Restart**].

5 Configure the display.
Press [**Scale**] [AUTO SCALE].

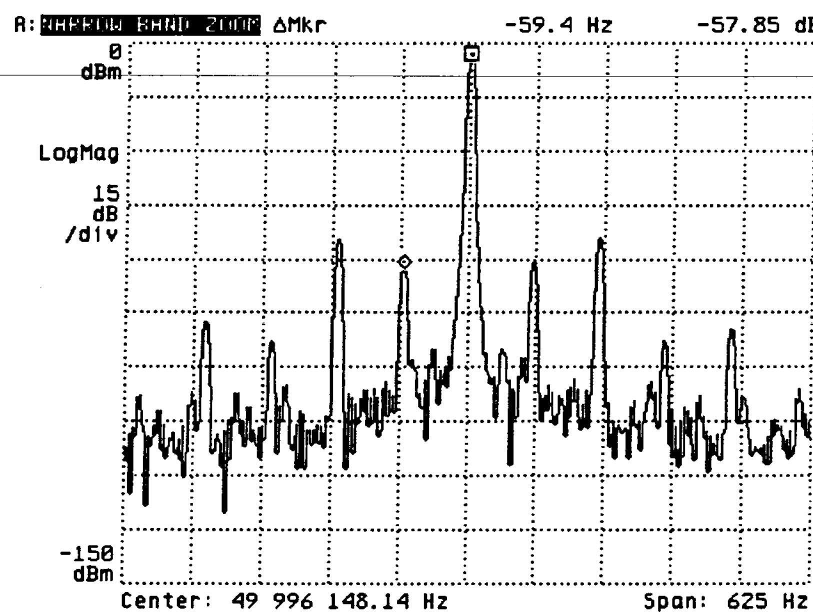
The only difference between this task and the previous task, "To measure a wideband spectrum," is your selection of the narrowband zoom measurement type in step 1. This difference gives you a big advantage: measurement times are much shorter than they would be for comparable swept spectrum measurements.

Along with the advantage come some restrictions on the frequency span. When [NARROW BAND ZOOM] is selected, the [SPAN] softkey is limited to 16 discrete values. The values range from 1.22 Hz to 40 kHz and are derived from the following formula:

$$\frac{40,000}{2^n}$$

The range of integer values for n is 0 through 15.

If the span restrictions are unacceptable for a given narrowband measurement, you can always select the swept spectrum measurement type: just press [**Meas Type**] [SWEPT SPECTRUM]. Measurements will be slower, but spans will be much less restricted.

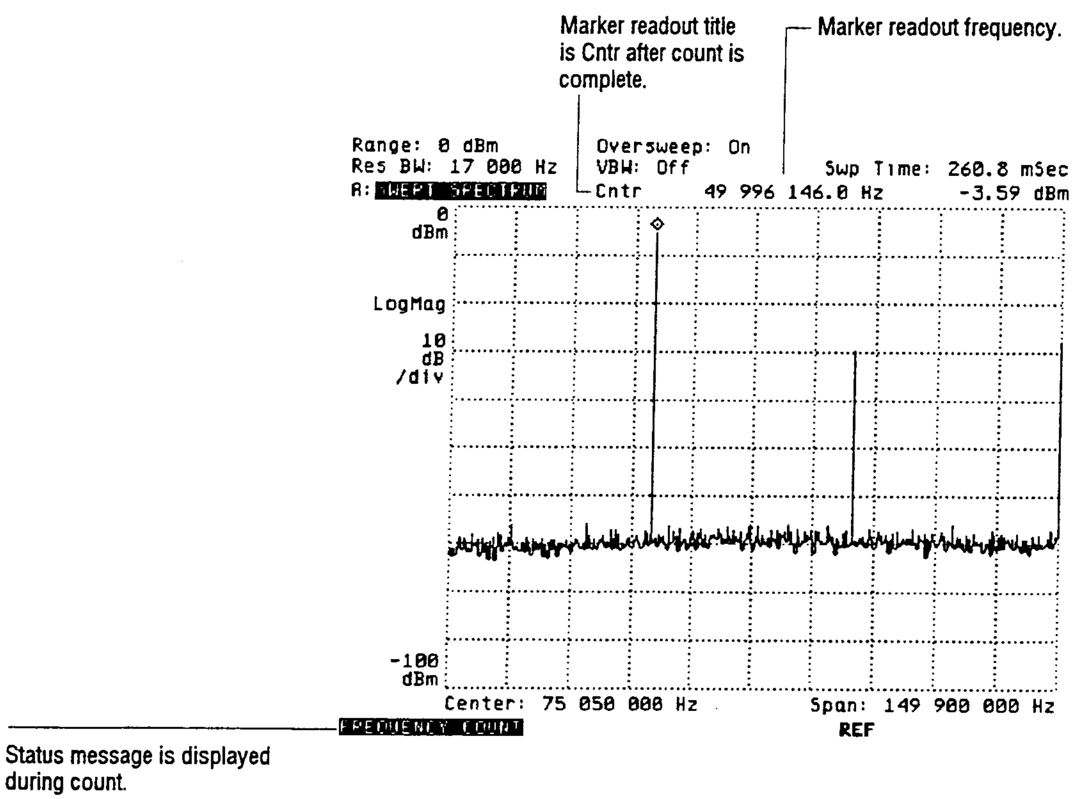


To measure signal frequency

1. Complete the task "To measure a wideband spectrum."
2. Turn the knob or use the marker search keys (located under the [**Marker**] hardkey) to place the marker on the component you want to measure.
3. Press [**Marker Fctn**], then press [FREQ CNTR ON/OFF] to highlight ON.
4. Read the marker readout's frequency after the title changes from Mkr to Cntr.

The analyzer's frequency counter determines the frequency of the largest signal component at the main marker's current position. If you move the marker after the analyzer completes a count, the marker readout title changes back to Mkr until a count is completed at the new marker position.

The frequency counter is also available for narrowband zoom measurements.



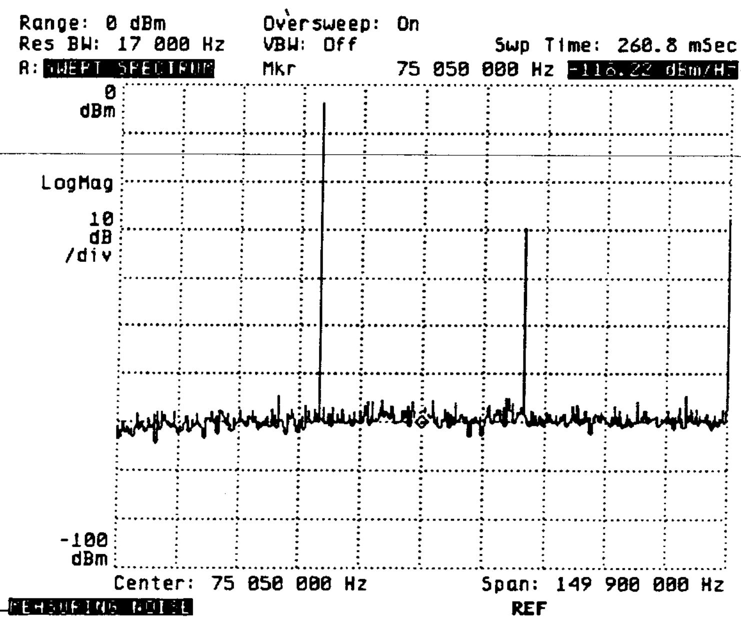
To measure noise (single point)

1 Complete the task "To measure a wideband spectrum."
2 Turn the knob to place the marker on a relatively flat portion of the noise floor.
3 Press [**Marker Fctn**], then press [NOISE LVL ON/OFF] to highlight ON.
4 Read the marker readout's amplitude after it is highlighted.

The analyzer's noise level marker measures noise spectral density (normalized to a 1 Hz bandwidth) at the main marker's current position. If you move the marker after the analyzer completes a noise measurement, the amplitude readout is not highlighted again until a noise measurement is completed at the new marker position.

For more information on noise measurements, display help for the [NOISE LVL ON/OFF] softkey.

Marker amplitude readout is highlighted after noise measurement.



Status message is displayed during noise measurement.

To measure noise (whole trace)

1 Complete the task "To measure a wideband spectrum."

2 Press [**Math**] [DEFINE F1] [INPUT] [/] [SQRT(NBW)] [ENTER].

3 Press [**Trace Data**] [FUNCTION (F1-F5)] [F1].

4 Press [**Meas Type**], then press [PEAK DET ON/OFF] to highlight OFF.

5 Press [**Sweep**], then press [OVERSWEEP ON/OFF] to highlight OFF.

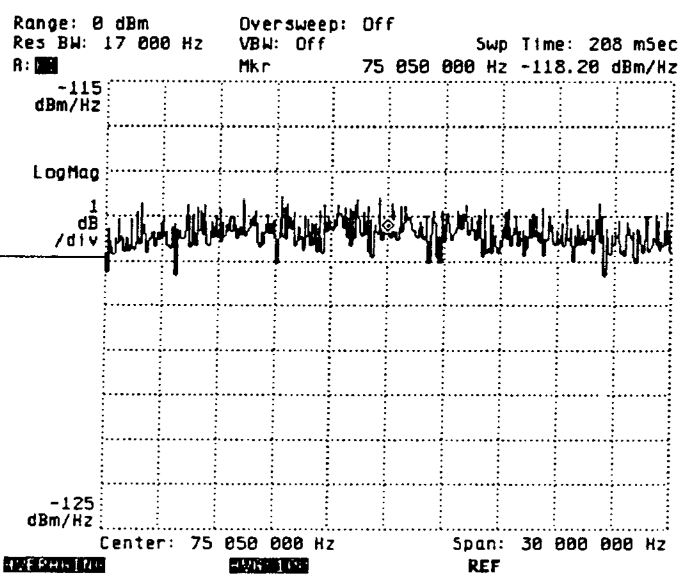
6 Press [**Scale**] [AUTO SCALE]

7 Press [**Avg/Pk Hld**] [AVERAGE] [NUMBER AVERAGES] 100 [ENTER].

The math function you create in step 2 normalizes your trace data to a 1 Hz bandwidth. The resulting trace displays the noise spectral density of your test signal. For accurate results, the trace should contain no discrete components, and noise should be random, and the number of averages should be fairly large.

The analyzer's peak detector and oversweep corrections increase the noise amplitude by several dB, so you must turn them off while displaying noise spectral density. However, most swept spectrum measurements require the peak detector for accurate results, so you must turn it back on before you start another task. You should also turn the oversweep corrections back on if you want shorter measurement times.

The amplitude unit is dBm/Hz.



The trace should contain no discrete components, even when the peak detector is ON.

To measure harmonic distortion

1 Complete the task "To measure a wideband spectrum."

2 Turn the knob or press [**Marker**] [MKR TO PEAK] to place the main marker on the fundamental frequency.

3 Press [**Marker**] [ZERO OFFSET] to place the offset marker on the fundamental frequency.

4 Turn the knob or press [**Marker**] [MORE MKR SEARCH] [NXT RIGHT PEAK] to move the main marker to successive harmonics.

5 Record each harmonic's amplitude offset from the fundamental frequency (as displayed in the marker readout).

To calculate total harmonic distortion (THD), you must first convert the harmonics' dB offsets to V^2 values, sum the V^2 values, and convert the sum back to dB. You can use the following formulas:

$10^{(h/10)} = v$

$v_1 + v_2 + \ldots v_n = s$

$10 \times \log(s) = d$

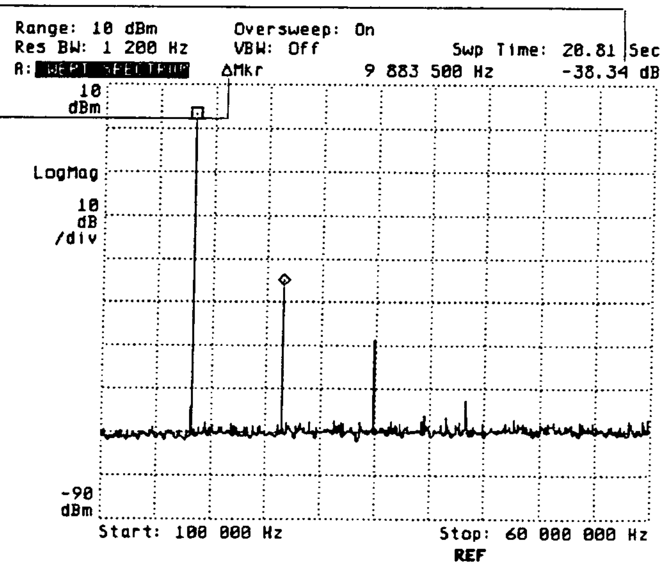
where **h** is a harmonic's dB offset
v is the V^2 value of the offset
s is the sum of the V^2 values
d is the sum converted back to dB

You can then calculate THD by inserting the value of **d** in the following formula:

$$\%THD = 100 \times 10^{(d/20)}$$

Amplitude offset is displayed here.

The delta symbol indicates that the marker readout is relative the offset marker's position.



6

Making Network Transmission Measurements

To measure normalized transmission

You can measure normalized transmission either with or without the HP 35689A/B S-Parameter Test Set. The setup illustration shows you both options.

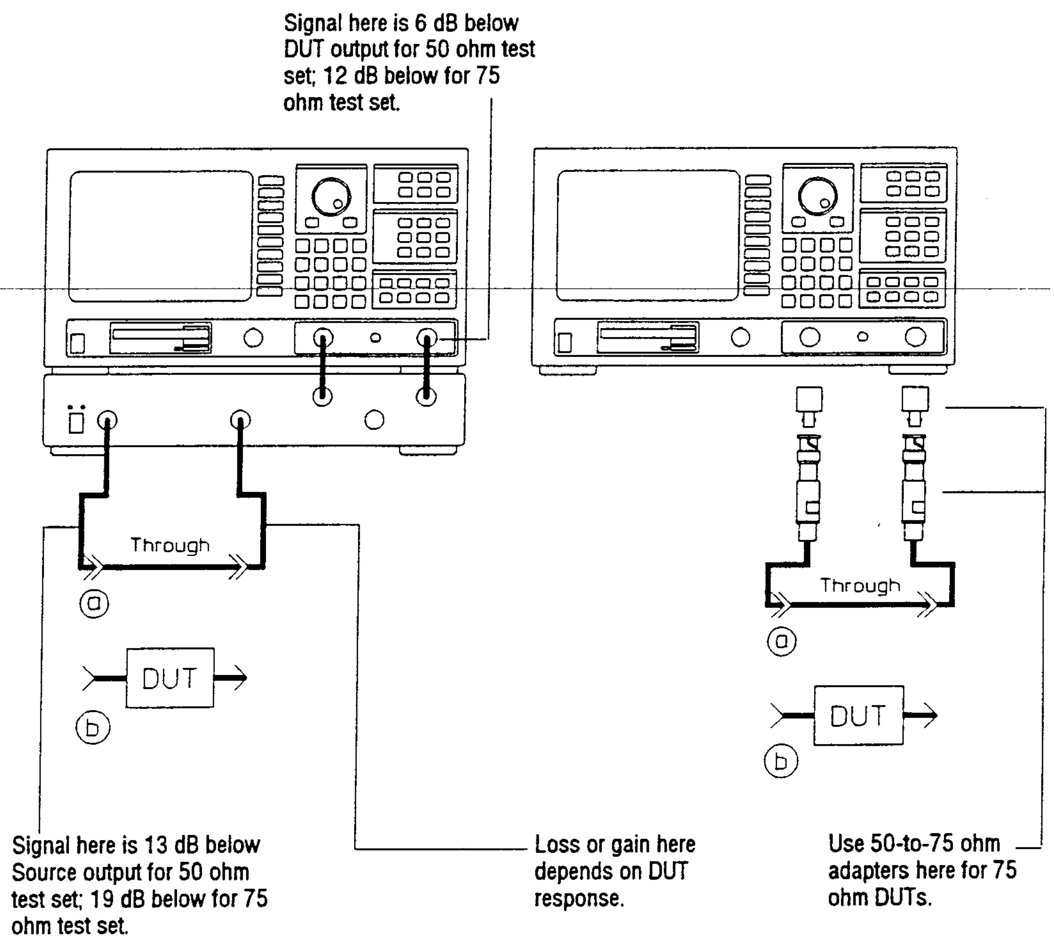
1 Initialize the analyzer.

Press [**Preset**].
Press [**Meas Type**] [SWEPT NETWORK].

2 Specify the measurement parameters.

Press [**Freq**] [START] <num> <unit>, then press [STOP] <num> <unit>.
If you are *not* using the test set, press [**Range/Input**], then press [50 OHMS] or [75 OHMS] to match your DUT impedance.
Press [**Range/Input**] [RANGE] <num> <unit>.
Press [**Source**] [SOURCE AMPLITUDE] <num> <unit>.

See "To select a 75 ohm adapter" for more information on 75 ohm measurements.



3 Calibrate your measurement.

Insert a through connection between the PORT 1 and PORT 2 cables.
Press [**Meas Type**] [MEAS CALIBRATE] [XMSN NORM (THRU)].

4 Measure the DUT.

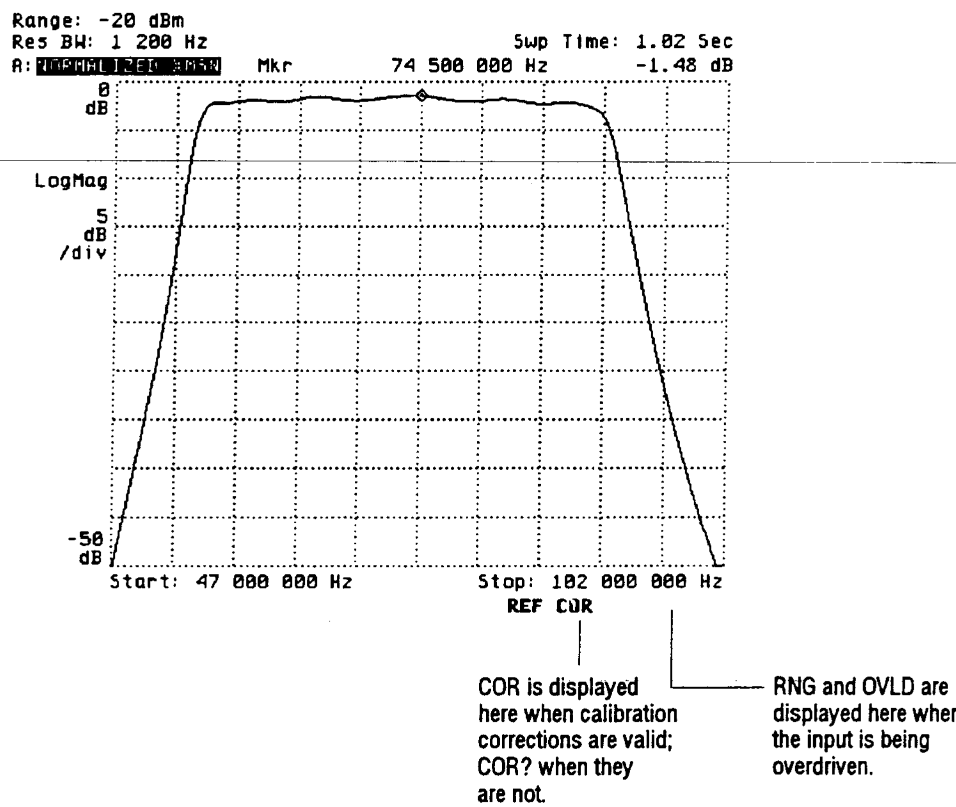
After the analyzer completes one sweep, replace the through connection with your DUT.
Press [**Meas Restart**].

5 Configure the display.

Press [**Scale**] [AUTO SCALE].

You need to watch for three indicators at the bottom of the screen when you measure normalized transmission: RNG, OVLD, and COR. If RNG or OVLD come on during steps 3 or 4, the analyzer's input is being overdriven and your results will be compromised. To correct the problem, select a higher input range or a lower source amplitude in step 2.

COR is displayed when you have successfully calibrated your measurement. It tells you that the correction data is valid for the current setup. COR is changed to COR? when the correction data is no longer valid. You will see this change if you specify new measurement parameters *after* you calibrate the measurement.



To measure S21

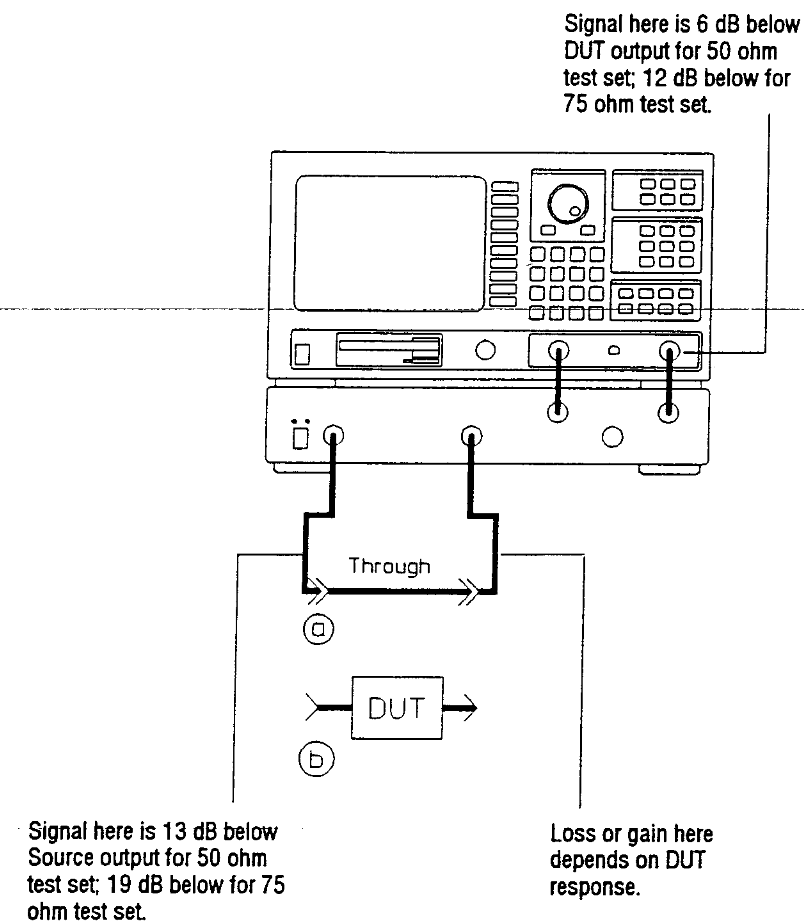
The S21 measurement is similar to the normalized transmission measurement, but it allows you to remove more of the system errors from your measurement setup. The S21 measurement requires an S-parameter test set. Use the HP 35689A to measure 50 ohm devices; use the HP 35689B to measure 75 ohm devices.

1 Initialize the analyzer.

Press [**Preset**].
Press [**Meas Type**] [SWEPT NETWORK].

2 Specify the measurement parameters.

Press [**Freq**] [START] <num> <unit>, then press [STOP] <num> <unit>.
Press [**Range/Input**] [RANGE] <num> <unit>.
Press [**Source**] [SOURCE AMPLITUDE] <num> <unit>.



3 Calibrate your measurement.

Insert a through connection between the PORT 1 and PORT 2 cables.
Press [**Meas Type**] [MEAS CALIBRATE] [S21 CAL] [PORT 1->2 THRU].

4 Measure the DUT.

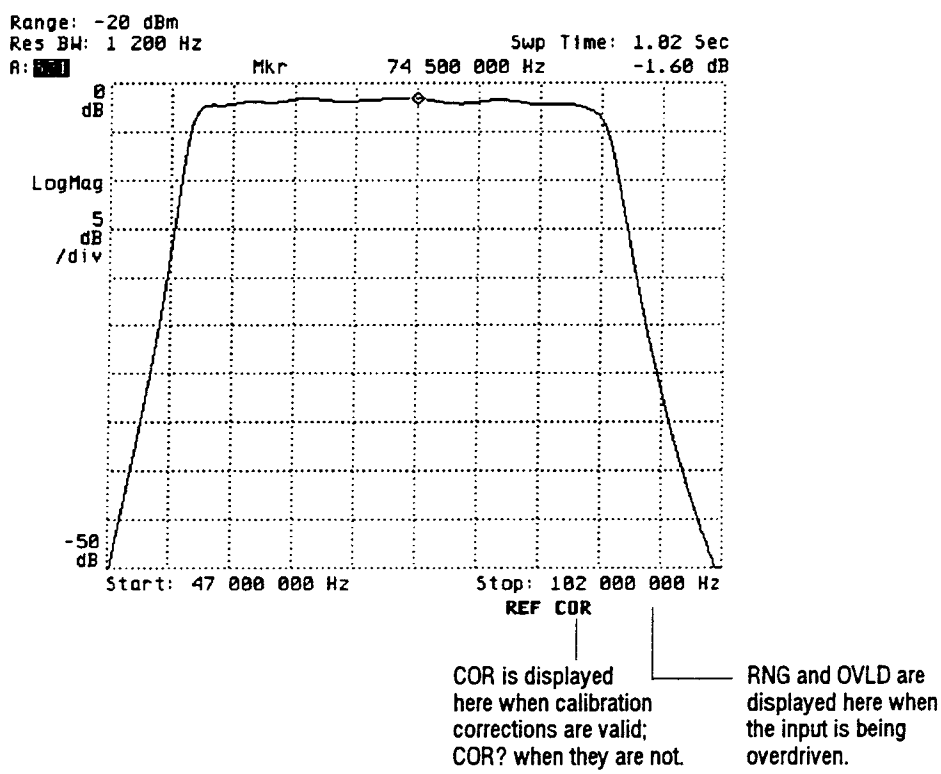
After the analyzer completes two sweeps, replace the through connection with your DUT and press [PORT 1 REF (DUT)].
After the analyzer completes one sweep, press [S21 CAL DONE].
Press [**Meas Restart**].

5 Configure the display.

Press [**Scale**] [AUTO SCALE].

Remember that the HP 3589A is a single-channel analyzer: it doesn't have a separate reference channel for measurements—like S21—that display the ratio of two signals. Instead, the HP 3589A uses a stored reference trace for these measurements. Pressing [PORT 1 REF (DUT)] in step 4 stores a new reference trace. If you change from one DUT to another after calibrating your measurement, you don't need to recalibrate, but you must *always* store a new reference trace for the new DUT.

Review the summary of the previous task—"To measure normalized transmission." It contains important information about the RNG, OVLD, and COR indicators that also applies to this task.



To measure S12

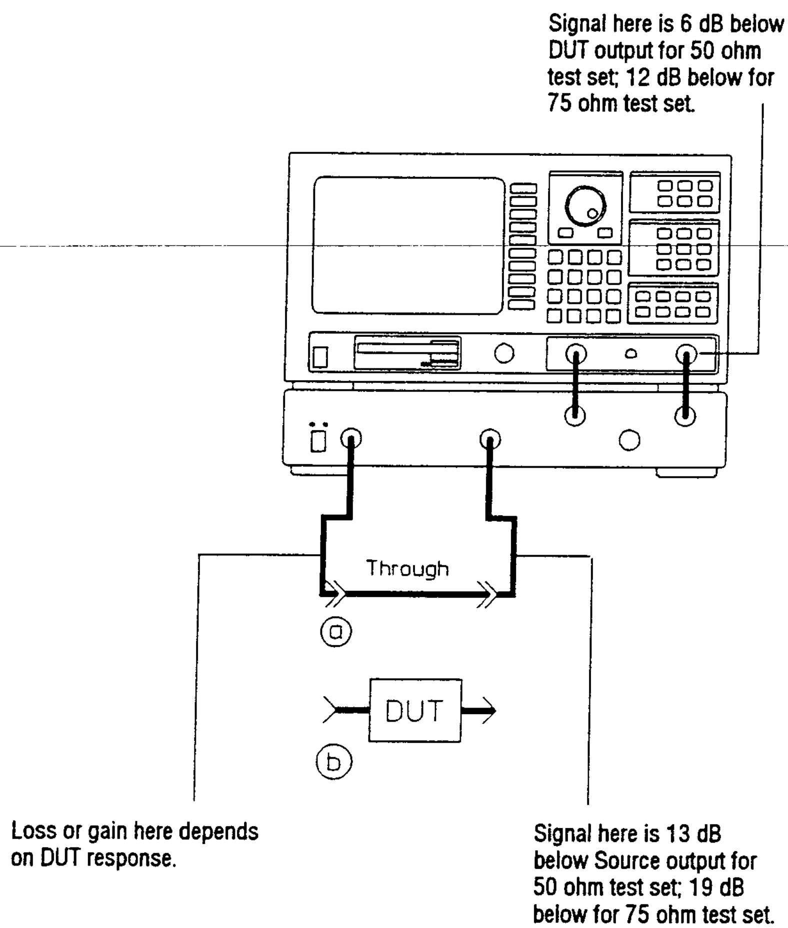
The S_{12} measurement is similar to the S_{21} measurement; both require a test set, and both measure transmission through a device under test (DUT). However, S_{12} supplies a stimulus signal at the test set's PORT 2 and measures the transmitted signal at PORT 1. S_{21} supplies a stimulus signal at the test set's PORT 1 and measures the transmitted signal at PORT 2. The S_{12} measurement is often called reverse transmission.

1 Initialize the analyzer.

Press [**Preset**].
Press [**Meas Type**] [SWEPT NETWORK].

2 Specify the measurement parameters.

Press [**Freq**] [START] <num> <unit>, then press [STOP] <num> <unit>.
Press [**Range/Input**] [RANGE] <num> <unit>.
Press [**Source**] [SOURCE AMPLITUDE] <num> <unit>.



3 Calibrate your measurement.

Insert a through connection between the PORT 1 and PORT 2 cables.
Press [**Meas Type**] [MEAS CALIBRATE] [S12 CAL] [PORT 2->1 THRU].

4 Measure the DUT.

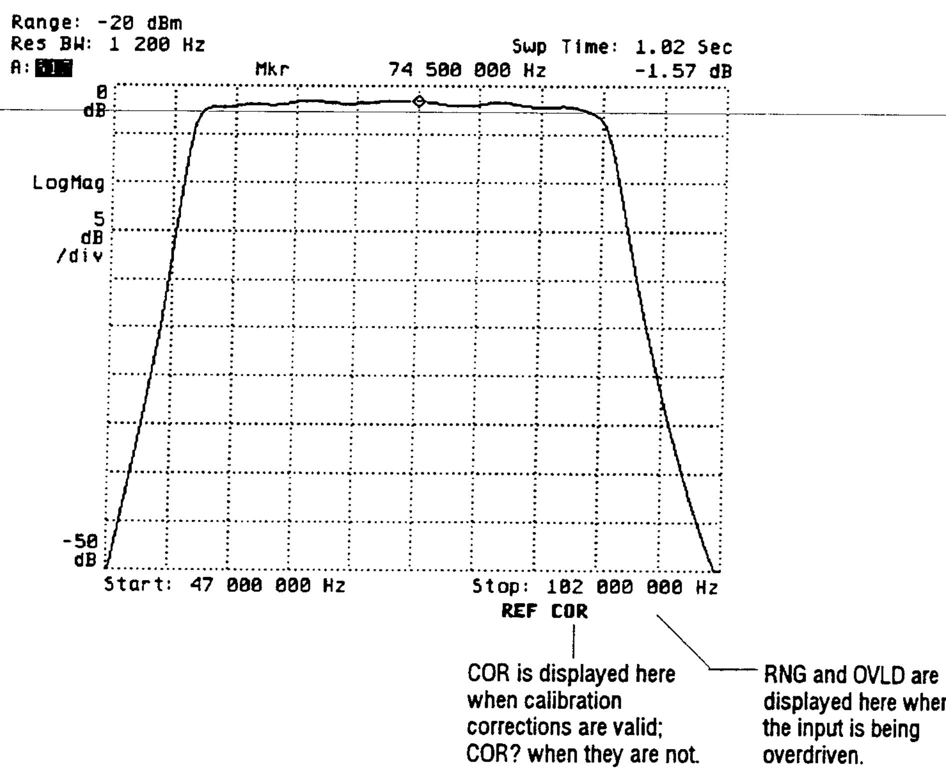
After the analyzer completes two sweeps, replace the through connection with your DUT and press [PORT 2 REF (DUT)].
After the analyzer completes one sweep, press [S12 CAL DONE].
Press [**Meas Restart**].

5 Configure the display.

Press [**Scale**] [AUTO SCALE].

Remember that the HP 3589A is a single-channel analyzer: it doesn't have a separate reference channel for measurements—like S_{12}—that display the ratio of two signals. Instead, the HP 3589A uses a stored reference trace for these measurements. Pressing [PORT 1 REF (DUT)] in step 4 stores a new reference trace. If you change from one DUT to another after calibrating your measurement, you don't need to recalibrate, but you must *always* store a new reference trace for the new DUT.

Review the summary of an earlier task—"To measure normalized transmission." It contains important information about the RNG, OVLD, and COR indicators that also applies to this task.



To measure phase response

1 Complete one of the following tasks: "To measure normalized transmission," "To measure S21," or "To measure S12."

2 Press [**Trace Type**] [PHASE].

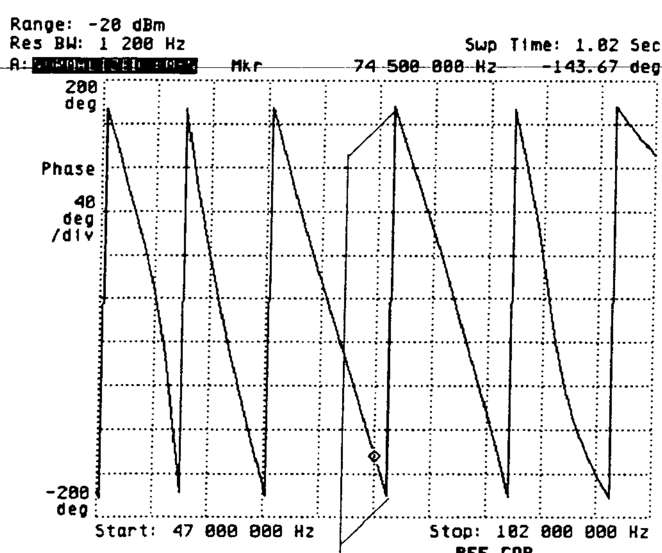
3 If you want to look at unwrapped phase, press [**Scale**] [PHASE SCALING], then press [PH WRAP ON/OFF] to highlight OFF.

4 Press [**Scale**] [AUTO SCALE].

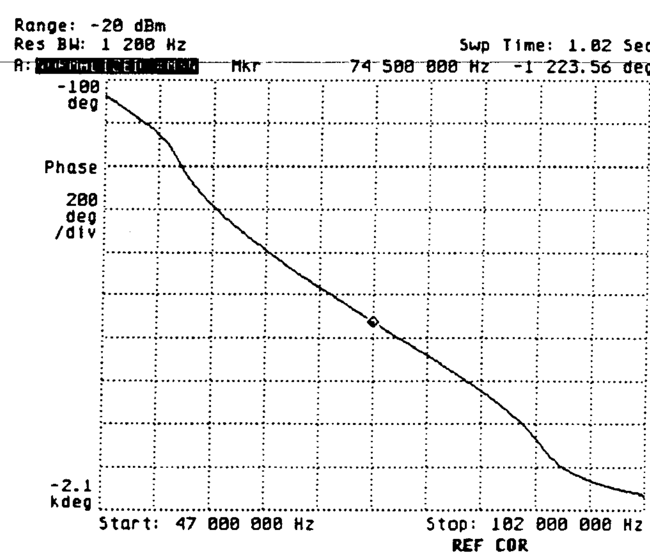
The [PH WRAP ON/OFF] softkey lets you switch between a wrapped and an unwrapped phase display. In a wrapped phase display, all points are displayed within a 360 degree "phase window." You set the upper limit of this window with the [PHASE WRAP REF] softkey. The lower limit is 360 degrees below the upper. Values that fall outside of these limits are automatically forced into the window by adding or subtracting a multiple of 360 degrees.

In an unwrapped phase display, the analyzer displays the actual phase measured at each point on the trace.

Trace displayed with wrapped phase.



Same trace displayed with unwrapped phase.



Phase wraps at +180 and -180 degrees when [PHASE WRAP REF] is set to +180 degrees.

To measure electrical length

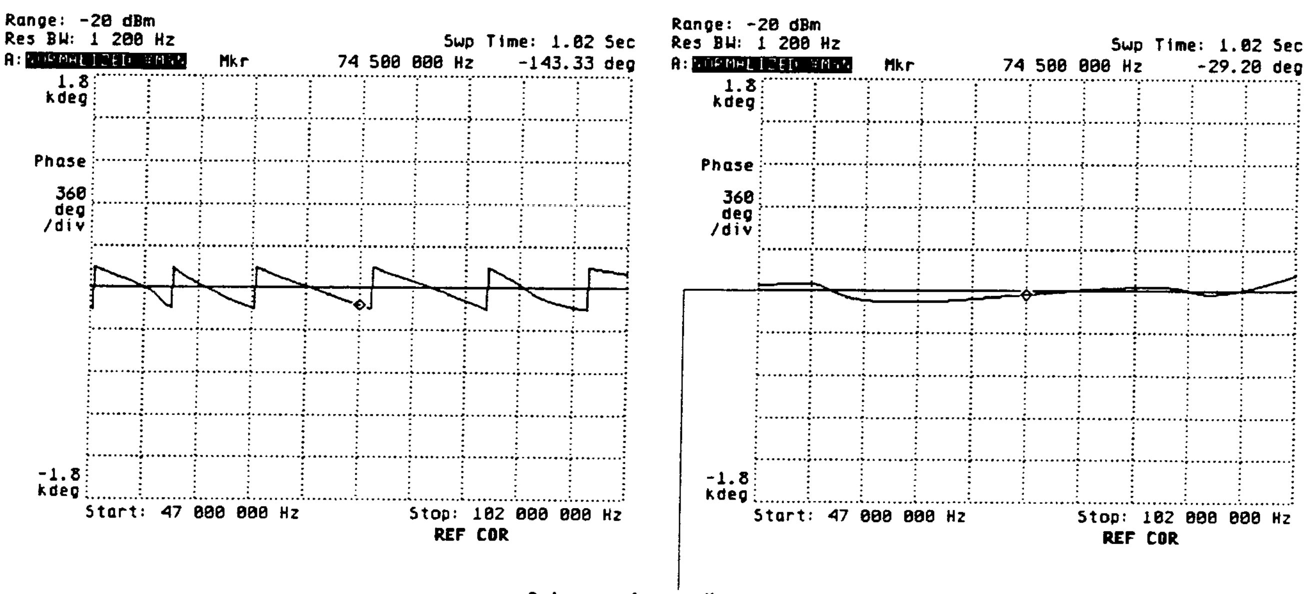
1. Complete the task "To measure phase response."
2. Press [**Scale**] [REF LEVEL POSITION] 50 [PERCENT].
3. Press [REFERENCE LEVEL] 0 [DEGREES], then press [VERTICAL/DIV] 360 [DEGREES].
4. Press [REF LINE ON/OFF] to highlight ON. (This displays the reference line.)
5. Press [**Range/Input**], then press [ELEC LGTH ON/OFF] to highlight ON.
6. Press [ELECTRIC LENGTH] 0 [METER], then turn the knob—while the prompt is still displayed—to flatten the phase response around the reference line.

The electrical length adjustment simulates a length of lossless transmission line. When you enter a positive value, that length of line is added (mathematically) to the signal path. When you enter a negative value, that length of line is subtracted from the signal path. The phase response of your test device is 0 degrees when you subtract a length of line that is equal to the device's electrical length at that frequency.

After you have flattened the response of your phase trace, you can take a closer look at the deviations from the 0 degree reference line by decreasing the value of [VERTICAL/DIV].

Trace before electrical length adjustment.

Same trace after adjustment.



0 degree reference line.

To measure phase distortion

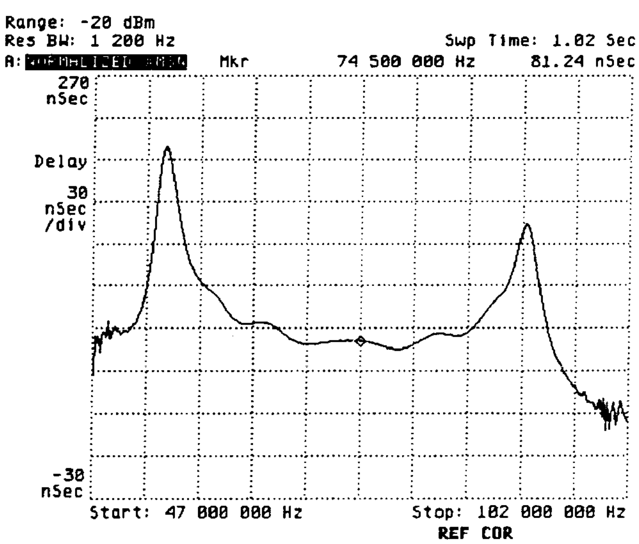
1. Complete one of the following tasks: "To measure normalized transmission," "To measure S21," or "To measure S12."
2. Press [**Trace Type**] [DELAY].
3. Press [DELAY APERTURE], then press one of the % of Span softkeys.
4. Press [**Scale**] [AUTO SCALE].

Group delay is the derivative (or slope) of the phase response. This makes it useful for measuring a device's phase linearity. The formula for group delay is:

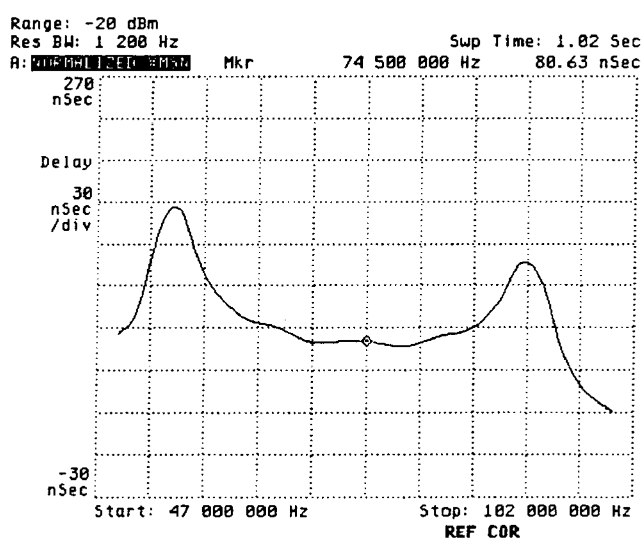
$$-\frac{\Delta(ph)/360}{\Delta(f)}$$

"delta(ph)" is the phase difference (in degrees) of two frequencies separated by delta(f). "delta(f)" is the group-delay aperture (in Hz), which you select by pressing one of the % of Span softkeys. Larger apertures increase the amount of trace smoothing.

Group-delay trace using a 0.5% aperture.



The same trace using a 4% aperture.



7

Making Network Reflection Measurements

To measure normalized reflection

You can measure normalized reflection either with or without the HP 35689A/B S-Parameter Test Set. The setup illustration shows you both options.

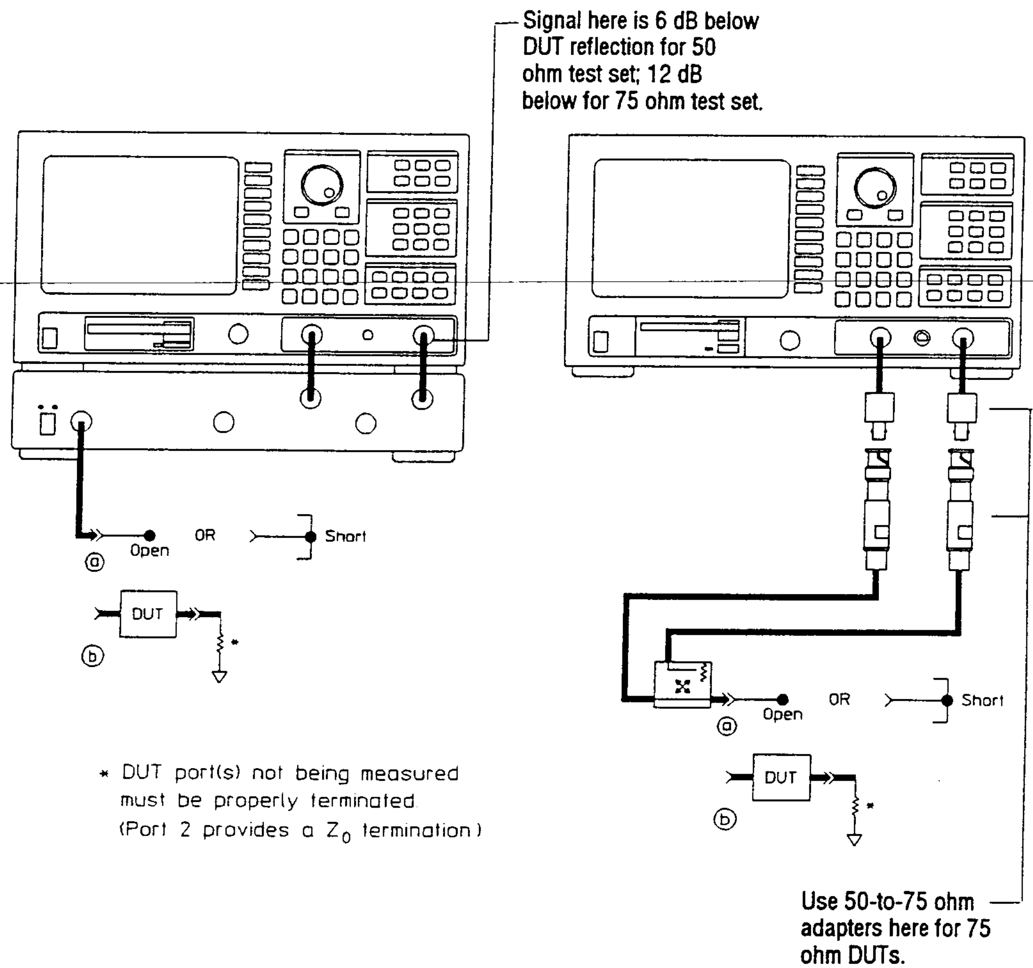
1 Initialize the analyzer.

Press [**Preset**].
Press [**Meas Type**] [SWEPT NETWORK].

2 Specify the measurement parameters.

Press [**Freq**] [START] <num> <unit>, then press [STOP] <num> <unit>.
If you are *not* using the test set, press [**Range/Input**], then press [50 OHMS] or [75 OHMS] to match your DUT impedance.
Press [**Range/Input**] [RANGE] <num> <unit>.
Press [**Source**] [SOURCE AMPLITUDE] <num> <unit>.

See "To select a 75 ohm adapter" for more information on 75 ohm measurements.



3 Calibrate your measurement.

Terminate the PORT 1 cable with a precision open-circuit termination or a precision short-circuit termination.
Press [**Meas Type**] [MEAS CALIBRATE].
If you used an open-circuit termination, press [REFL NORM (OPEN)].
If you used a short-circuit termination, press [REFL NORM (SHORT)].

4 Measure the DUT.

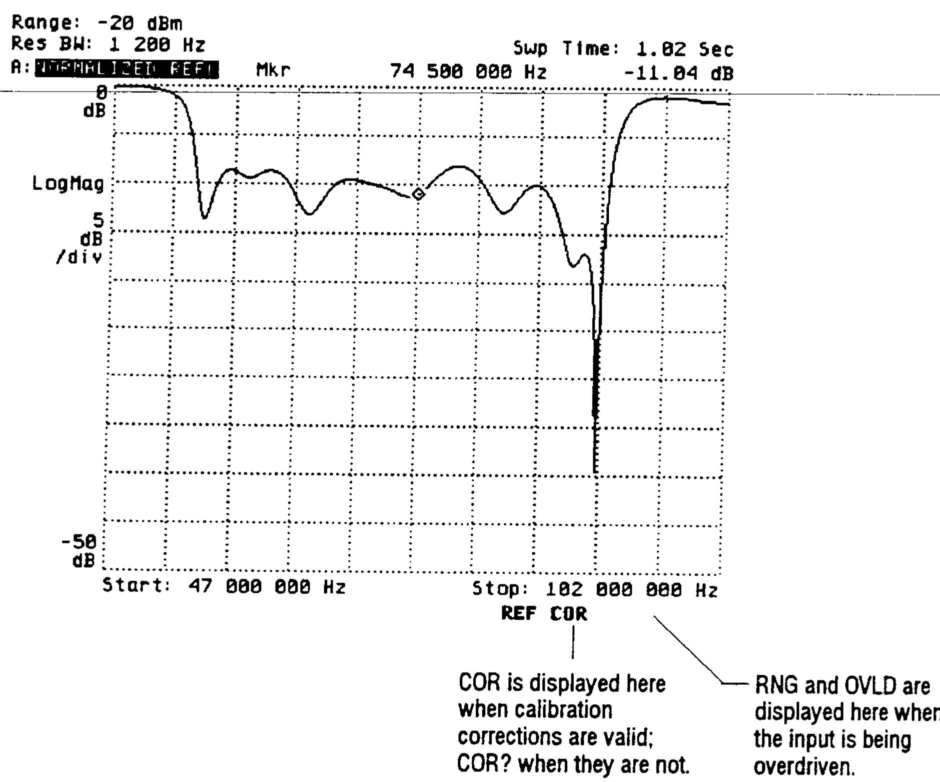
After the analyzer completes one sweep, replace the termination with your DUT.
Press [**Meas Restart**].

5 Configure the display.

Press [**Scale**] [AUTO SCALE].

You need to watch for three indicators at the bottom of the screen when you measure normalized transmission: RNG, OVLD, and COR. If RNG or OVLD come on during steps 3 or 4, the analyzer's input is being overdriven and your results will be compromised. To correct the problem, select a higher input range or a lower source amplitude in step 2.

COR is displayed when you have successfully calibrated your measurement. It tells you that the correction data is valid for the current setup. COR is changed to COR? when the correction data is no longer valid. You will see this change if you specify new measurement parameters *after* you calibrate the measurement.



To measure S_{11}

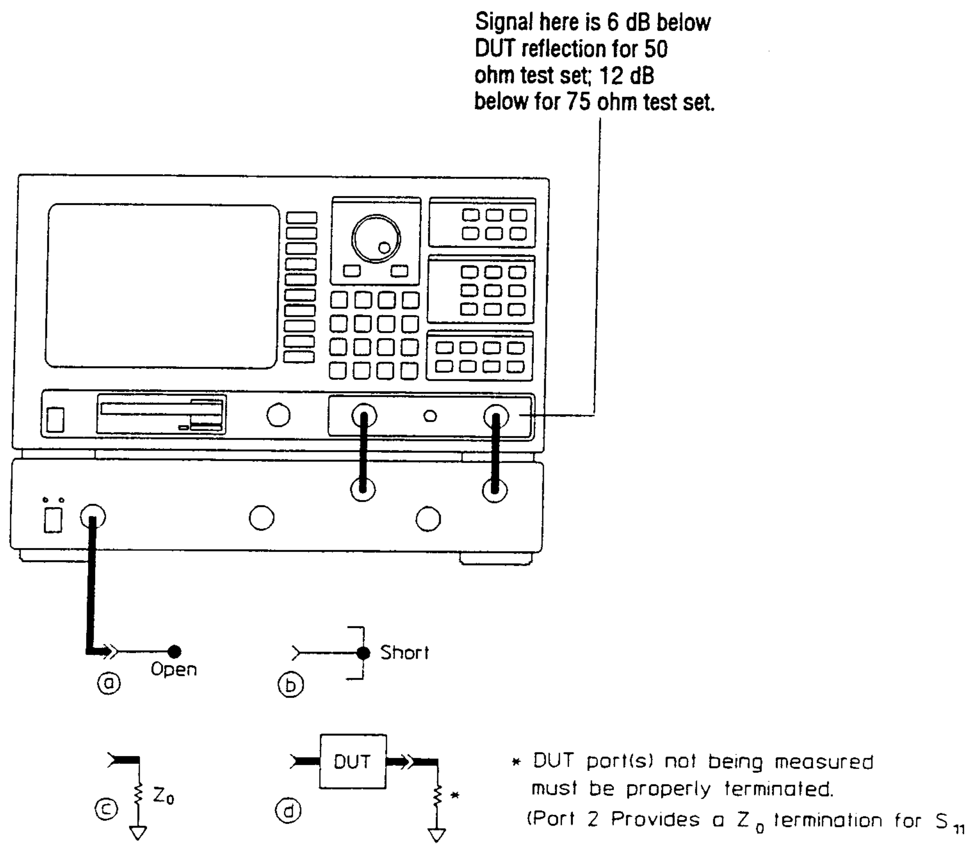
The S_{11} measurement is similar to the normalized reflection measurement, but it allows you to remove more of the system errors from your measurement setup. The S_{11} measurement requires an S-parameter test set. Use the HP 35689A to measure 50 ohm devices; use the HP 35689B to measure 75 ohm devices.

1 Initialize the analyzer.

Press [**Preset**].
Press [**Meas Type**] [SWEPT NETWORK].

2 Specify the measurement parameters.

Press [**Freq**] [START] <num> <unit>, then press [STOP] <num> <unit>.
Press [**Range/Input**] [RANGE] <num> <unit>.
Press [**Source**] [SOURCE AMPLITUDE] <num> <unit>.



3 Calibrate your measurement.

Terminate the PORT 1 cable with a precision open-circuit termination.
Press [**Meas Type**] [MEAS CALIBRATE] [S11 CAL] [PORT 1 OPEN].
After the analyzer completes two sweeps, replace the open-circuit with a precision short-circuit termination and press [PORT 1 SHORT].
After the analyzer completes two sweeps, replace the short-circuit with a precision Z_0 termination—50 ohms for the HP 35689A, 75 ohms for the HP 35689B—and press [PORT 1 TERM].

4 Measure the DUT.

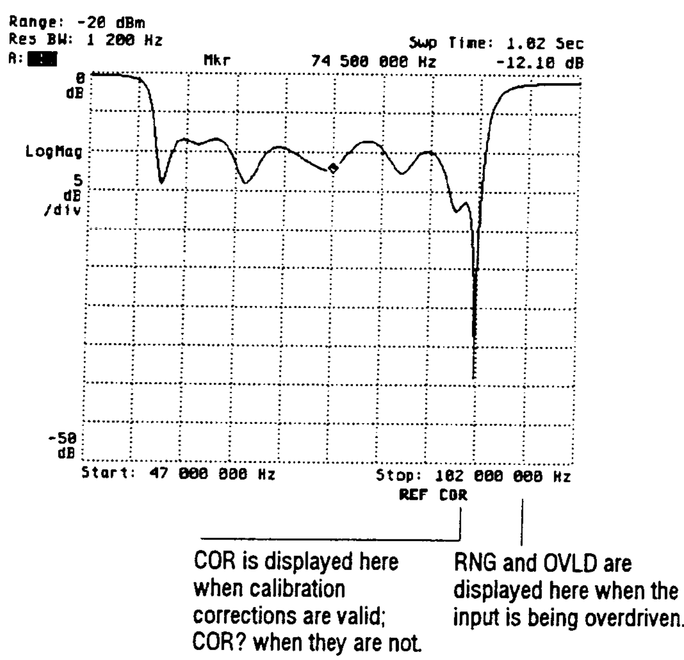
After the analyzer completes two sweeps, replace the Z_0 termination with your DUT and press [PORT 1 REF (DUT)].
After the analyzer completes one sweep, press [S11 CAL DONE].
Press [**Meas Restart**].

5 Configure the display.

Press [**Scale**] [AUTO SCALE].

Remember that the HP 3589A is a single-channel analyzer: it doesn't have a separate reference channel for measurements—like S_{11}—that display the ratio of two signals. Instead, the HP 3589A uses a stored reference trace for these measurements. Pressing [PORT 1 REF (DUT)] in step 4 stores a new reference trace. If you change from one DUT to another after calibrating your measurement, you don't need to recalibrate, but you must *always* store a new reference trace for the new DUT.

Review the summary of the previous task—"To measure normalized reflection." It contains important information about the RNG, OVLD, and COR indicators that also applies to this task.



To measure S_{22}

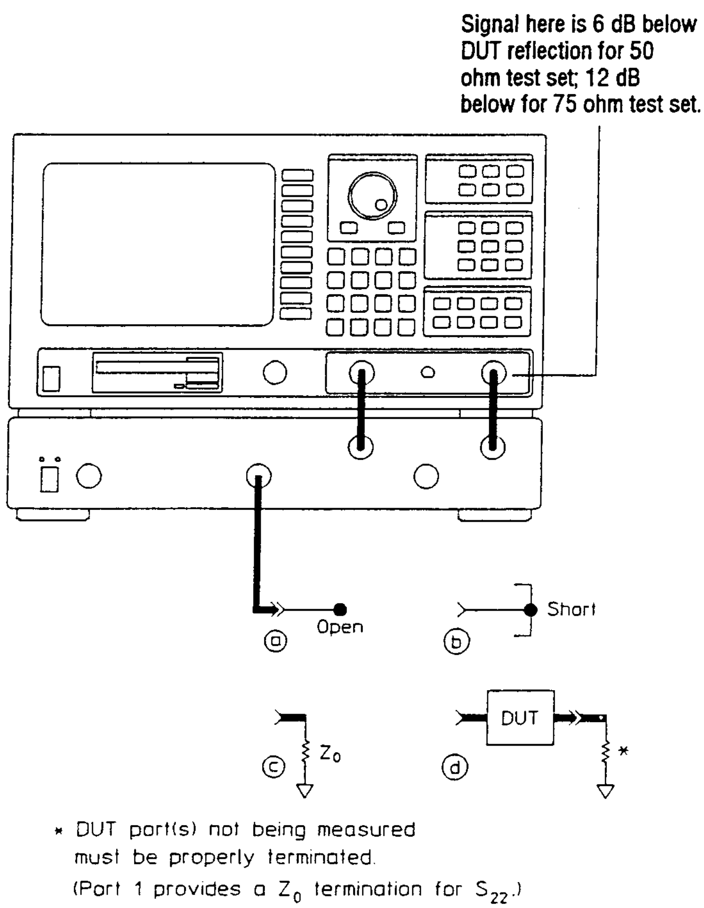
The S_{22} measurement is similar to the S_{11} measurement; both require a test set, and both measure reflection from a device under test (DUT). However, S_{22} supplies a stimulus signal and measures reflection via the test set's PORT 2. S_{11} supplies a stimulus signal and measures reflection via the test set's PORT 1. When you are measuring a two-port device, S_{22} is often called reverse reflection.

1 Initialize the analyzer.

Press [**Preset**].
Press [**Meas Type**] [SWEPT NETWORK].

2 Specify the measurement parameters.

Press [**Freq**] [START] <num> <unit>, then press [STOP] <num> <unit>.
Press [**Range/Input**] [RANGE] <num> <unit>.
Press [**Source**] [SOURCE AMPLITUDE] <num> <unit>.



3 Calibrate your measurement.

Terminate the PORT 2 cable with a precision open-circuit termination.
Press [**Meas Type**] [MEAS CALIBRATE] [S22 CAL] [PORT 2 OPEN].
After the analyzer completes two sweeps, replace the open-circuit with a precision short-circuit termination and press [PORT 2 SHORT].
After the analyzer completes two sweeps, replace the short-circuit with a precision Z_0 termination—50 ohms for the HP 35689A, 75 ohms for the HP 35689B—and press [PORT 2 TERM].

4 Measure the DUT.

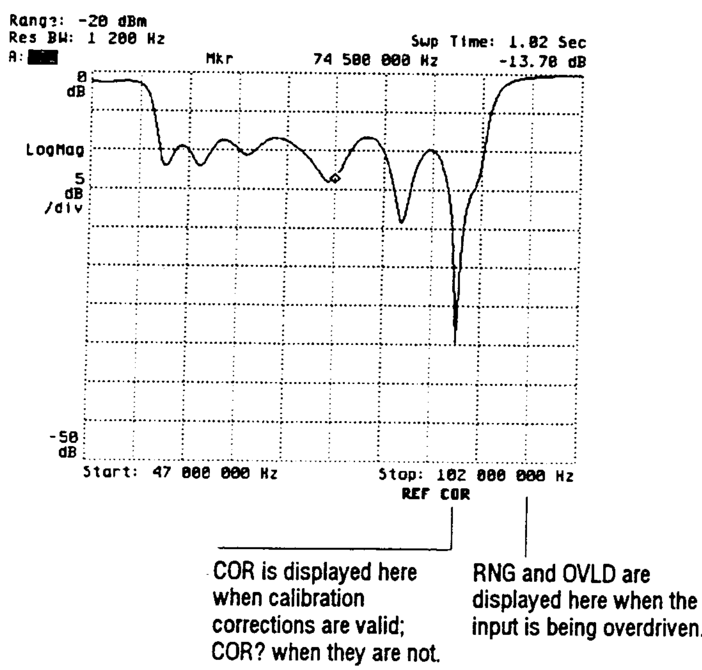
After the analyzer completes two sweeps, replace the Z_0 termination with your DUT and press [PORT 2 REF (DUT)].
After the analyzer completes one sweep, press [S22 CAL DONE].
Press [**Meas Restart**].

5 Configure the display.

Press [**Scale**] [AUTO SCALE].

Remember that the HP 3589A is a single-channel analyzer: it doesn't have a separate reference channel for measurements—like S_{22}—that display the ratio of two signals. Instead, the HP 3589A uses a stored reference trace for these measurements. Pressing [PORT 2 REF (DUT)] in step 4 stores a new reference trace. If you change from one DUT to another after calibrating your measurement, you don't need to recalibrate, but you must *always* store a new reference trace for the new DUT.

Review the summary of an earlier task—"To measure normalized reflection." It contains important information about the RNG, OVLD, and COR indicators that also applies to this task.



To measure reflection coefficient

1 Complete one of the following tasks: "To measure normalized reflection," "To measure S11," or "To measure S22."

2 Press [**Trace Type**] [LINEAR MAGNITUDE].

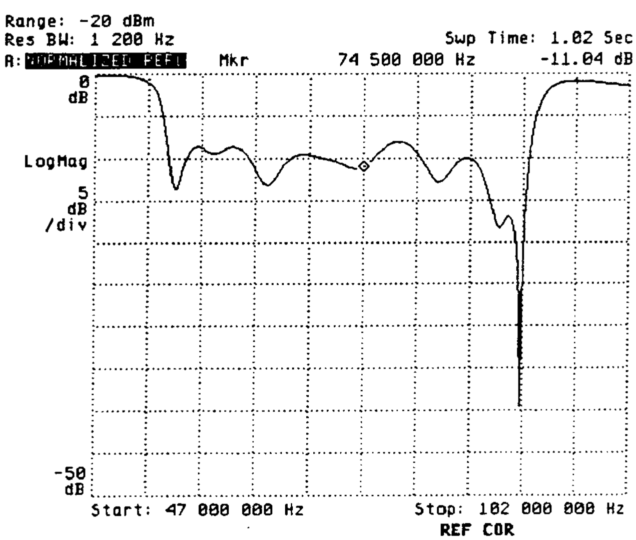
3 Press [**Scale**] [AUTO SCALE].

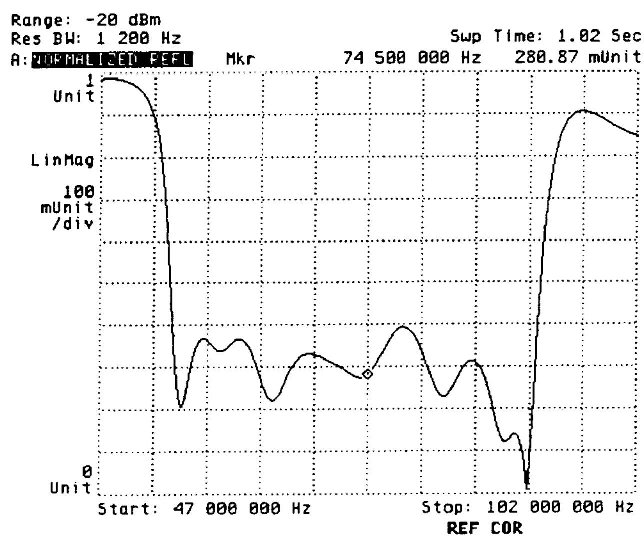
All of the measurements listed in step 1 use the default trace type: log magnitude. When you display the results of a reflection measurement using log magnitude on the y-axis, you are displaying the return loss of the device under test (DUT). When you display the same results using linear magnitude on the y-axis, you are displaying the DUT's reflection coefficient.

The range of y-axis values for return loss is from 0.0 dB (100% reflection) to $-\infty$ dB (no reflection). The range of values for reflection coefficient is from 1.0 (100% reflection) to 0.0 (no reflection).

Return loss is displayed using log magnitude on the y-axis.

Reflection coefficient is displayed using linear magnitude on the y-axis.





To measure impedance

1 Complete the task "To measure normalized reflection."

2 Press [**Trace Data**] [NETWORK FUNCTION] [NORM IMPEDANCE].

3 Press [**Format**] [UPPER/LOWER].

4 Press [**Trace Type**] [REAL], then press [**Scale**] [AUTO SCALE].

5 Press [**Active Trace**] to activate trace B.

6 Press [**Trace Data**] [NETWORK FUNCTION] [NORM IMPEDANCE].

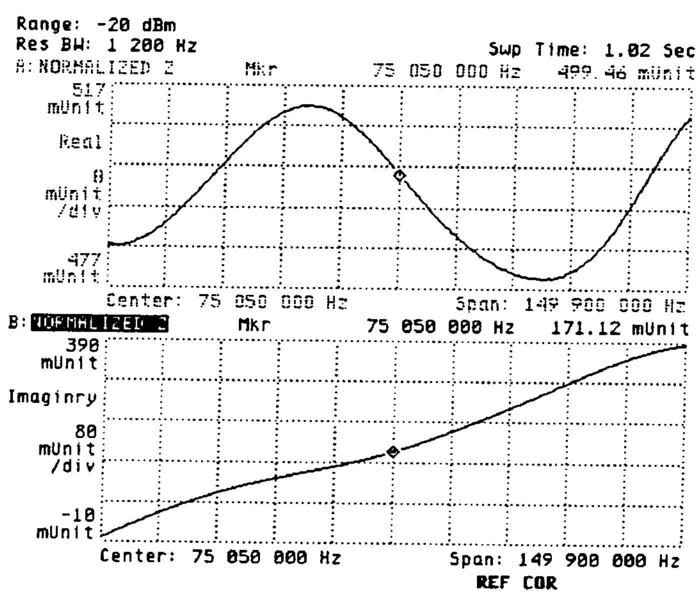
7 Press [**Trace Type**] [IMAGINARY], then press [**Scale**] [AUTO SCALE].

A device's reflection coefficient is directly related to the impedances of the device and the measurement system. As a result, the analyzer can determine device impedance once you have measured the reflection coefficient. It uses the following formula to derive the normalized impedance trace:.

$$Z_n = \frac{1 + \text{REFL\_COEF}}{1 - \text{REFL\_COEF}}$$

Z_n is the device impedance (Z_L) normalized to the measurement system's characteristic impedance (Z_0)—either 50 or 75 ohms. REFL_COEF is the trace displayed when you press [**Trace Data**] [NETWORK FUNCTION] [NORM REFL COEF].

Both real and imaginary parts of a normalized impedance trace are displayed.



8

Measurement Enhancements

This chapter describes some techniques you can use to enhance your measurement results. The summary at the end of each task tells you whether it applies to spectrum measurements, network measurements, or both.

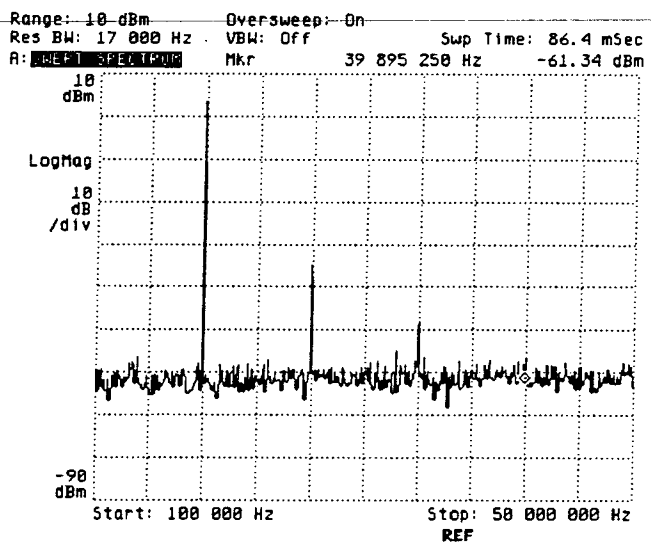
To lower the noise floor

1. Press the [**Res BW**] hardkey.
2. If the swept spectrum measurement type is selected, press the [RES BW] softkey, then press the down-arrow hardkey.
   or
   If the narrowband zoom measurement type is selected, press the [HI RES ZOOM] softkey.

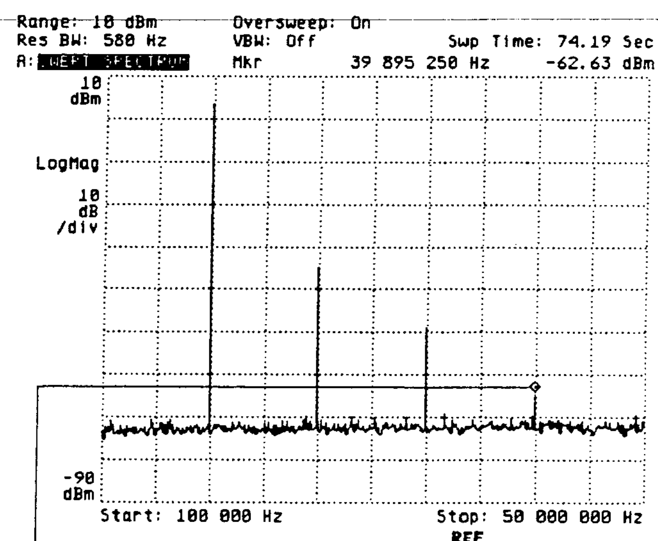
Low-level spectral components can be hidden by the noise floor during both types of spectrum measurements. You can reveal these components by limiting the amount of noise energy that's detected during a measurement. Use narrower resolution bandwidths to limit noise during swept spectrum measurements. Use the high-resolution zoom type to limit noise during narrowband zoom measurements.

There's a penalty for using narrower resolution bandwidths during swept spectrum measurements. The analyzer must use longer sweep times to provide calibrated results. You can select a resolution bandwidth that provides the best compromise between a shorter sweep time and a lower noise floor for each measurement situation.

Signal measured with a wide Res BW setting.



Same signal measured with a narrower Res BW setting.



Low-level component is revealed.

To reduce noise variance

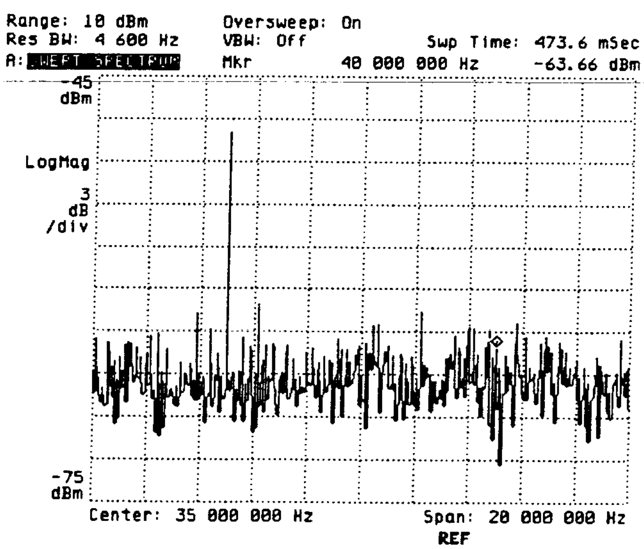
1 Press [**Avg/Pk Hld**] [AVERAGE].

2 Press [NUMBER AVERAGES], then type the number of measurements you want to combine and press [ENTER].

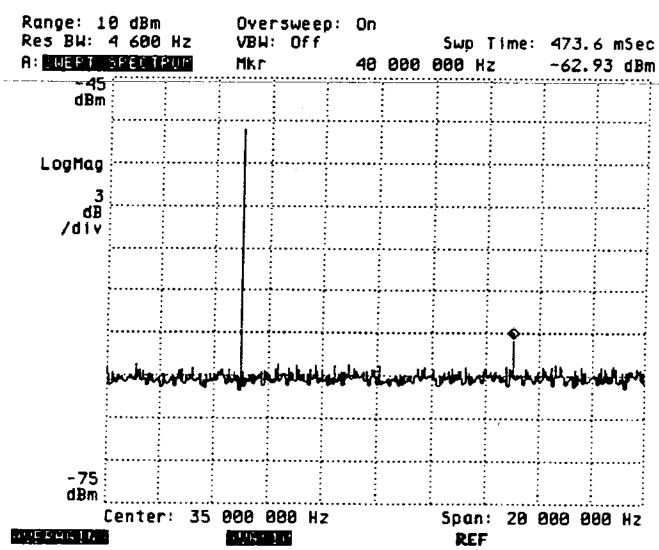
Noise variance can reduce the accuracy of spectrum and network measurements. When you enable averaging, the analyzer combines the results of several measurements—the number you specify with [NUMBER AVERAGES]—to reduce variance. The analyzer uses rms (power) averaging for spectrum measurements, and vector averaging for network measurements.

Averaging is available for all three of the analyzer's measurement types, but an additional function is available to reduce noise variance for swept spectrum measurements: video filtering. The softkeys that control video filtering are available under the [**Res BW**] hardkey. For more information, display online help for the video filtering softkeys.

Single measurement, unaveraged.



Ten measurements, combined by averaging.



To increase frequency resolution

1 Press [**Freq**] [SPAN], then press the down-arrow hardkey one or more times.

2 Press the [**Res BW**] hardkey.

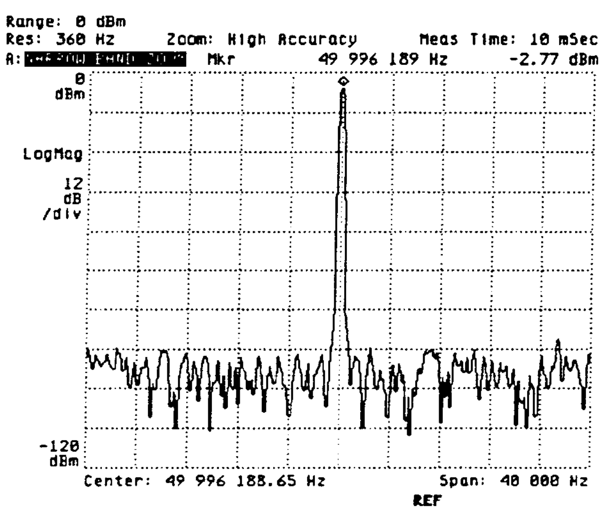
3 If the swept spectrum measurement type is selected, press the [RES BW] softkey, then press the down-arrow hardkey.
or
If the narrowband zoom measurement type is selected, press the [HI RES ZOOM] softkey.

Frequency resolution is a function of two factors for both types of spectrum measurements. For swept spectrum measurements, it's a function of frequency span and resolution bandwidth. For narrowband zoom measurements, it's a function of span and zoom type.

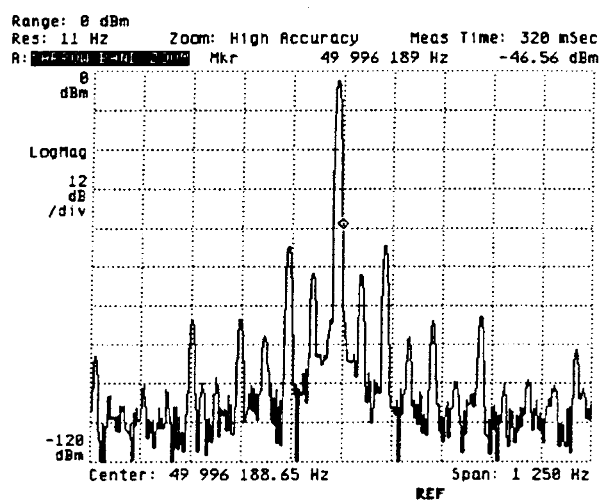
Span determines the frequency granularity of the analyzer's display. In the HP 3589A, swept spectrum and narrowband zoom traces are composed of 401 points that are equally spaced along the display's x-axis. Each point represents not just a single frequency, but a range of frequencies equal to 1/400th of the current span. The display cannot resolve two components that are represented by the same point.

Even if you select a span that provides adequate frequency granularity to resolve two components on the display, they will not appear as distinct responses unless the analyzer's receiver is also able to resolve them. Resolution bandwidth and zoom type determine the receiver's ability to resolve two components.

Signal measured at a wide span. Components appear as a single response.



Same signal measured at a narrower span. Components are separated.

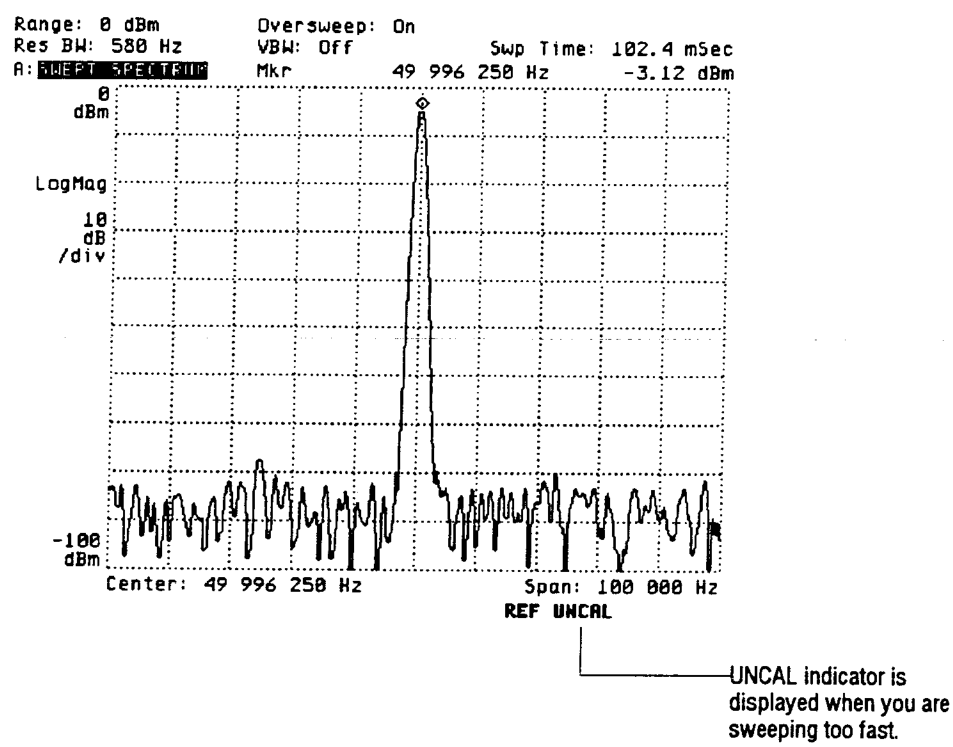


To optimize spectrum sweep time

1 At any time during a swept spectrum measurement, press [**Sweep**] [SWEEP TIME], then press the down-arrow hardkey until the UNCAL indicator is first displayed at the bottom of the screen.

2 Press the up-arrow hardkey one time to turn off the UNCAL indicator.

The analyzer displays the UNCAL indicator at the bottom of the screen when you select a sweep time that's too short to provide calibrated results for swept spectrum measurements. But for a given setup, the analyzer allows shorter sweep times if oversweeping is enabled. You can enable oversweeping by pressing [**Sweep**], and then pressing [OVERSWEEP ON/OFF] to highlight ON.



To optimize network sweep time

1 Complete a network measurement task through the step where you specify the measurement parameters, then connect your device under test (if you haven't already done so).

2 Press [**Scale**] [AUTO SCALE].

3 Turn the knob to place the main marker on the steepest part of the trace.

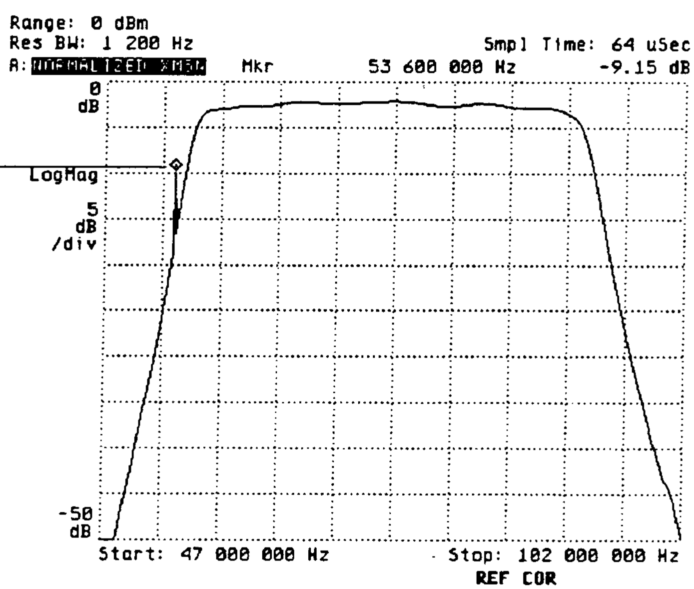
4 Press [**Sweep**] [MANUAL FREQ] [**Marker Value**], then press [SWEEP AUTO/MAN] several times to toggle between AUTO and MAN.

5 If the marker's y-axis position changes significantly when you toggle [SWEEP AUTO/MAN], you are sweeping too fast. Press [SWEEP TIME] and the up-arrow hardkey to increase the sweep time.
or
If the marker's y-axis position doesn't change significantly when you toggle [SWEEP AUTO/MAN], you may be able to sweep faster. Press [SWEEP TIME] and the down-arrow hardkey to decrease the sweep time.

6 Repeat steps 4 and 5 until you have selected the shortest sweep that doesn't change the marker position when you toggle [SWEEP AUTO/MAN].

The response of your device under test (DUT) determines how fast you can sweep through the specified frequency band and still get accurate measurement results. When you sweep too fast the DUT response is skewed upward in frequency.

Marker is raised above its autosweep position when [SWEEP AUTO/MAN] is toggled to MAN, indicating that the DUT is being swept too fast.

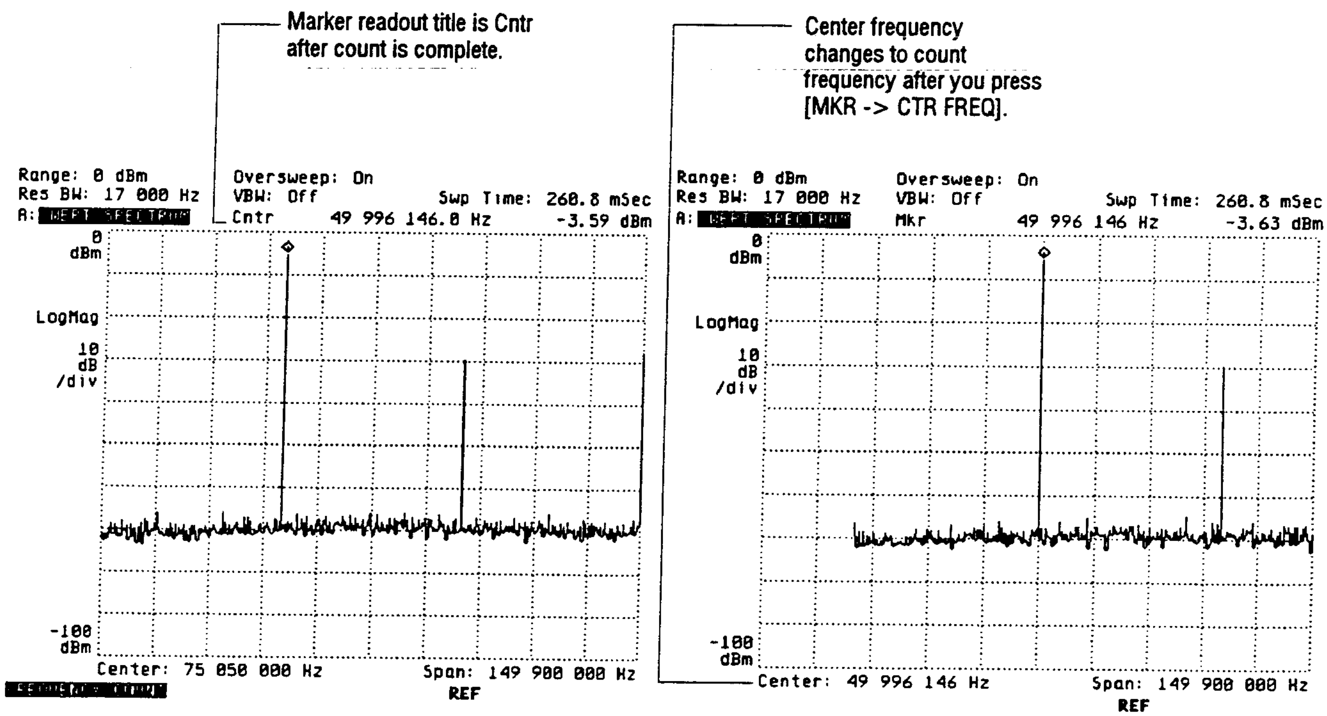


To center a signal component

1. Complete the task "To measure a wideband spectrum."
2. Turn the knob or use the marker search keys (located under the [**Marker**] hardkey) to place the marker on the component you want to center.
3. Press [**Marker Fctn**], then press [FREQ CNTR ON/OFF] to highlight ON.
4. After the marker readout's title changes from Mkr to Cntr, press [**Marker**] [MKR -> CTR FREQ].
5. Press [**Marker Fctn**], then press [FREQ CNTR ON/OFF] to highlight OFF.

You will sometimes want to survey a test signal at a very wide frequency span and then narrow the span around an interesting component. Narrowing the span is very easy if the component is placed precisely at the center of the span; you just press [**Freq**] [SPAN] and then press the down-arrow hardkey several times. This task uses the frequency counter and [MKR -> CTR FREQ] to place a signal component precisely at the center of the current span.

If you use [MKR -> CTR FREQ] without the frequency counter, the signal component may be placed slightly off-center. This displacement from center is exaggerated as you narrow the span, forcing you to adjust the center frequency to keep the component within the span.



To select a 75 ohm adapter

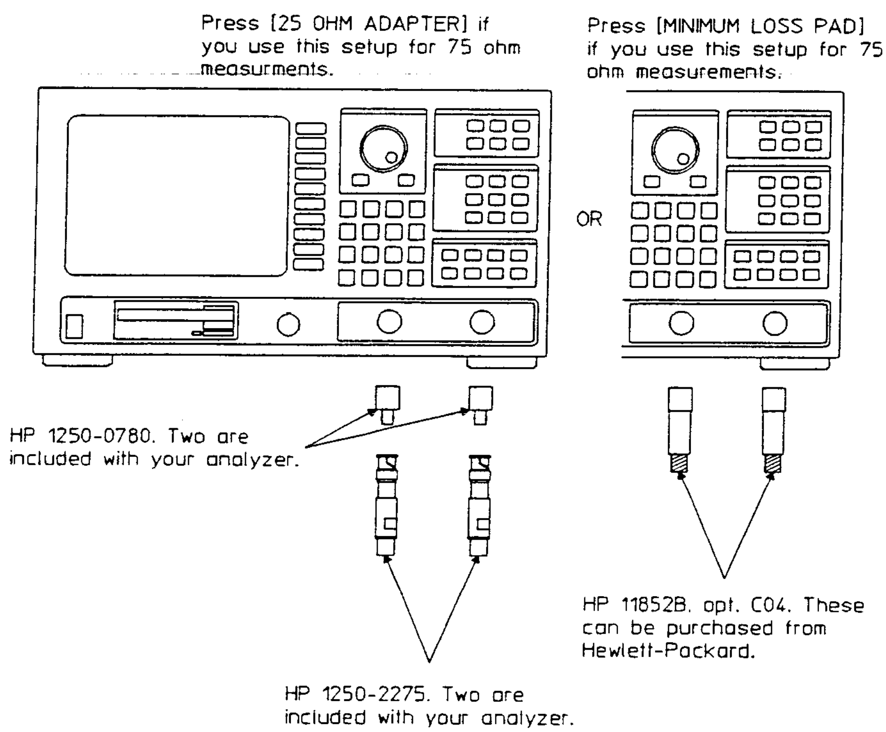
1 Press [**Special Fctn**] [NON-VOL SETUP] [75 OHM SETUP].

2 Press [25 OHM ADAPTER] or [MINIMUM LOSS PAD] to match the adapter you will use for 75 ohm measurements.

When you make measurements without an HP 35689A/B S-Parameter Test Set, you must specify the impedances of the analyzer's SOURCE and INPUT connectors. (You specify these impedances under the [**Source**] and [**Range/Input**] hardkeys.) If you specify 75 ohm impedances, the analyzer automatically adjusts the actual output amplitude and the displayed input amplitude to correct for losses through 50-to-75 ohm adapters. The amplitude adjustments depend on your selection in step 2:

- Press [25 OHM ADAPTER] if you will use an N-to-BNC adapter followed by a 25 ohm BNC adapter barrel on each connector.
- Press [MINIMUM LOSS PAD] if you will use a 50-to-75 ohm minimum loss pad on each connector.

Be careful when you are using both 50 and 75 ohm Type-N connectors. The diameter of the 50 ohm center pin is about twice that of the 75 ohm center pin. You can damage a 75 ohm female connector by attaching it to a 50 ohm male connector.



Part III

General Tasks

9

Using Online Help

This chapter shows you how to use the analyzer's online help system, which provides fast access to the operating information you need. Each task describes one of the three ways you can access information in the system:

- pressing a hardkey or softkey
- selecting a topic from the help index
- selecting a hypertext "link" to a related topic

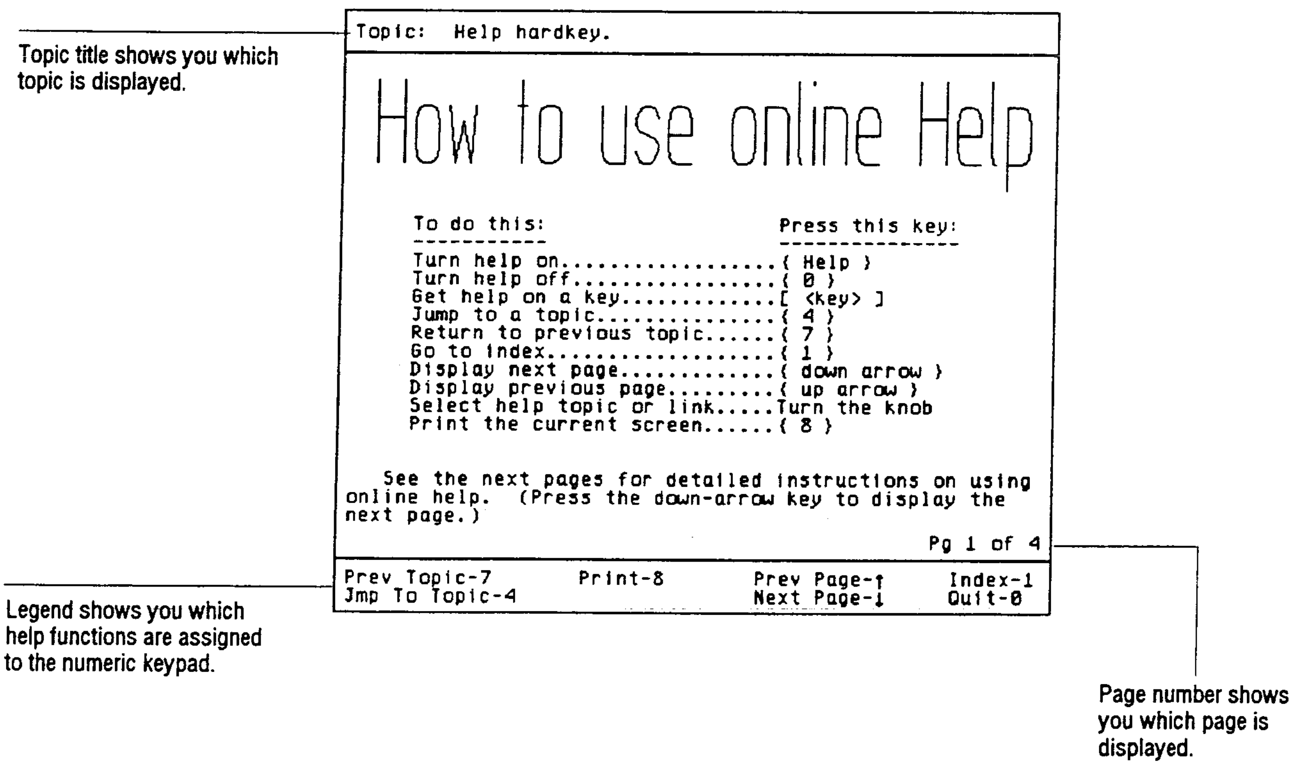
To display help for a key

1. Press [**Help**] to enter the online help system.
2. Press any hardkey or softkey—except [**Preset**].
3. Press the down-arrow or up-arrow hardkey to page through the topic.
4. Repeat steps 2 and 3 for each key you want help on.
5. Press [**0**] on the numeric keypad to quit online help.

The first time you press [**Help**], take just a few moments to read the help overview. It's only four pages long, and it includes descriptions of advanced help features—like the index and cross-reference "links"—that can help you locate the information you need more quickly.

Pressing [**Preset**] always returns the analyzer to its preset state. If you press any other key when help is enabled, the analyzer displays a help topic describing the key's function. For help on the preset state, select "Preset hardkey" from the help index.

When you quit help, the analyzer restores the menu that was displayed before you enabled help.

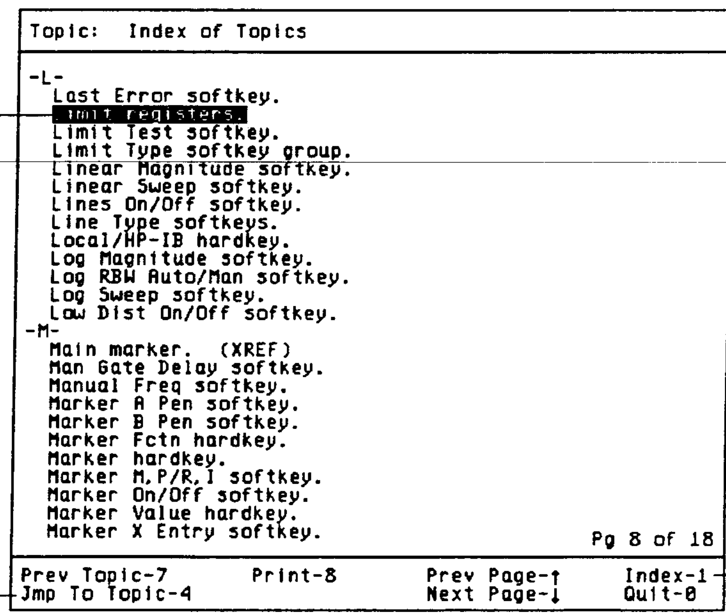


To select a topic from the help index

1. Press [**Help**] to enter the online help system.
2. Press [**1**] on the numeric keypad to display the index.
3. Press the down-arrow or up-arrow hardkey to page through the index.
4. Turn the knob to select the topic you want help on.
5. Press [**4**] to display the topic.
6. Press [**0**] on the numeric keypad to quit online help.

The help index contains an alphabetical listing of all help topics. Most topics listed in the index describe the hardkeys and softkeys, but some are of a more general nature. These more general topics are only available via the index or "links" from related topics.

Some index entries provide cross-references to the available help topics. These entries end with "(XREF)." The name of an XREF entry does not match the name of the topic it displays.



Selected topic is highlighted.

[4] displays the highlighted topic.

[1] displays the index.

To display a related help topic

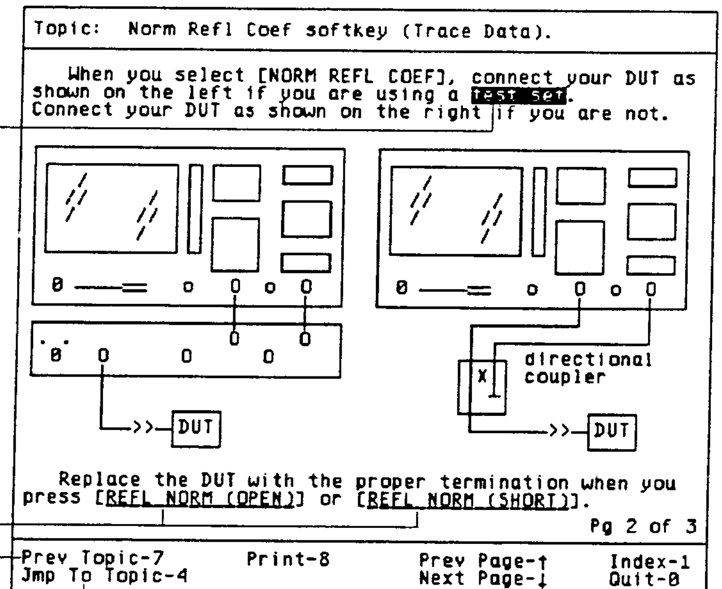
1 Turn the knob to select a "link" in the current help topic.

2 Press [**4**] to display the related topic.

3 Press [**7**] to return to the original topic.

On a given screen full of help text, there may be several special words (or phrases) that are linked to related topics. Most of these words are underlined to identify them as links, but one is highlighted to identify it as the currently-selected link. The knob allows you to select a different link by moving the highlighting from one link to the next. Once you've selected the link you want, press [**4**] to display the related topic.

You can follow links through as many as 20 topics and still return to the original topic. Just press [**7**] one time for each link you followed, and you'll return to the original via all of the related topics you displayed.



The selected link is identified by highlighting.

Links are identified by underlining.

[7] returns you to the previous topic.

[4] displays the related topic.

10

Saving Your Work

This chapter shows you how to save your work on the analyzer's file system. It also shows you how to perform some additional disk operations.

To select the default disk

1 Press [**Disk Util**] [DEFAULT DISK].
or
Press [**Save/Recall**] [DEFAULT DISK].

2 Press [NON-VOL RAM DISK], [VOLATILE RAM DISK], or [INTERNAL DISK].

Your default disk selection tells the analyzer which disk to use when it is saving and recalling files. You can use online help to learn more about these options, but here's a quick summary:

- [NON-VOL RAM DISK] selects a portion of the analyzer's battery-backed RAM. This "disk" only holds 63 kilobytes of data, but the data is not lost when you turn off the analyzer.
- [VOLATILE RAM DISK] selects a portion of RAM that is *not* battery-backed. Data on this "disk" is lost when you turn off the analyzer, but it has two advantages: you can format it to hold much more data than the non-volatile RAM disk, and file operations are much faster than on the internal disk.
- [INTERNAL DISK] selects the analyzer's internal disk drive. This drive stores data on 3.5-inch flexible disks (double-sided, double-density). The disks can be formatted to hold up to 788 kilobytes of data. For more information, see "To format a flexible disk" later in this manual.

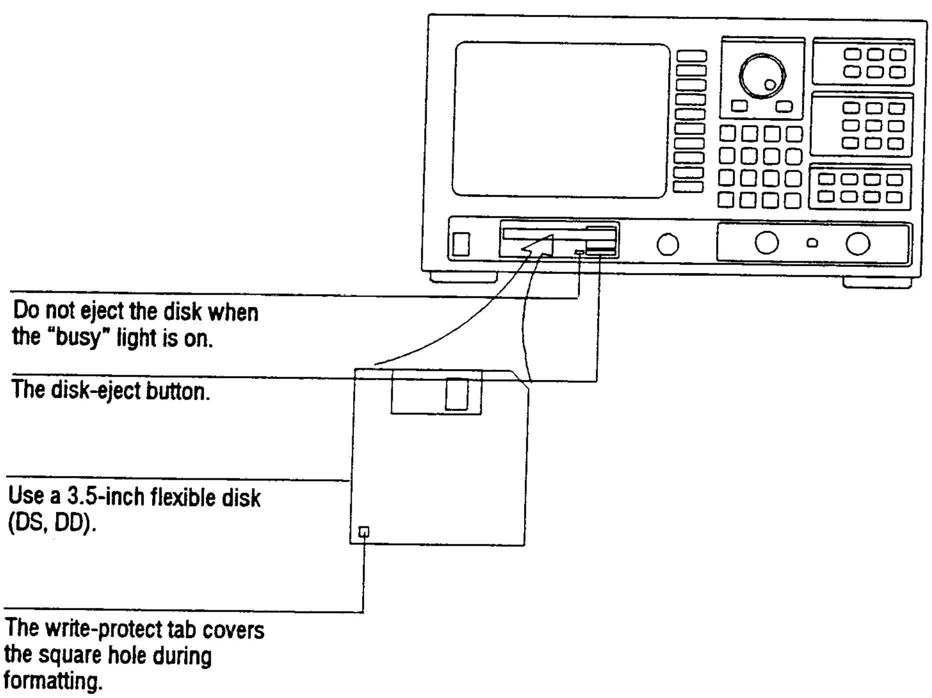
To format a flexible disk

1 Insert a 3.5-inch flexible disk into the analyzer's internal disk drive.
2 Press [**Disk Util**] [DEFAULT DISK] [INTERNAL DISK].
3 Press [**Disk Util**] [FORMAT DISK] [FORMAT OPTION] 0 [ENTER].
4 Press [INTRLEAVE FACTOR] 1 [ENTER].
5 Press [PERFORM FORMAT] [ENTER].

CAUTION You can damage both the disk and the drive if you attempt to eject a disk when the "FORMAT DISK In Progress" message is displayed or when the disk's "busy" light is on.

You must format a 3.5-inch flexible disk before you can use it to store HP 3589A data. Use a double-sided, double-density disk that is *not* write-protected. (See the illustration.) The analyzer takes about one and a half minutes to format a disk and is unavailable for other tasks during that time.

For information on formatting the RAM disks, display online help for the [FORMAT OPTION] softkey.



To save a trace to a file

1 Press [**Active Trace**] if the trace you want to save is not currently active.

2 Press [**Save/Recall**] [SAVE TRACE] [INTO FILE].

3 Type a file name, then press [ENTER].

After you've entered a file name, the analyzer saves the active trace to a file on the default disk. For more information on typing a file name and selecting the default disk, see "To type a text string" and "To select the default disk" earlier in this manual.

To save other data to a file

1 Press [**Save/Recall**].

2 Press the SAVE softkey that matches the type of data you want to save. (If the SAVE softkey you need is not displayed, press [SAVE MORE] for more options.)

3 Type a file name, then press [ENTER].

After you press[ENTER], the analyzer saves the specified data to the default disk. You can save the following types of data:

- traces
- instrument states
- limit definitions
- user-math definitions
- HP Instrument BASIC programs

For more information on saving any of these data types, display online help for the matching SAVE softkey.

To recall a trace from a file

1 Press [**Save/Recall**], then press [CATALOG ON/OFF] to highlight ON.

2 Turn the knob to highlight the file you want to recall.

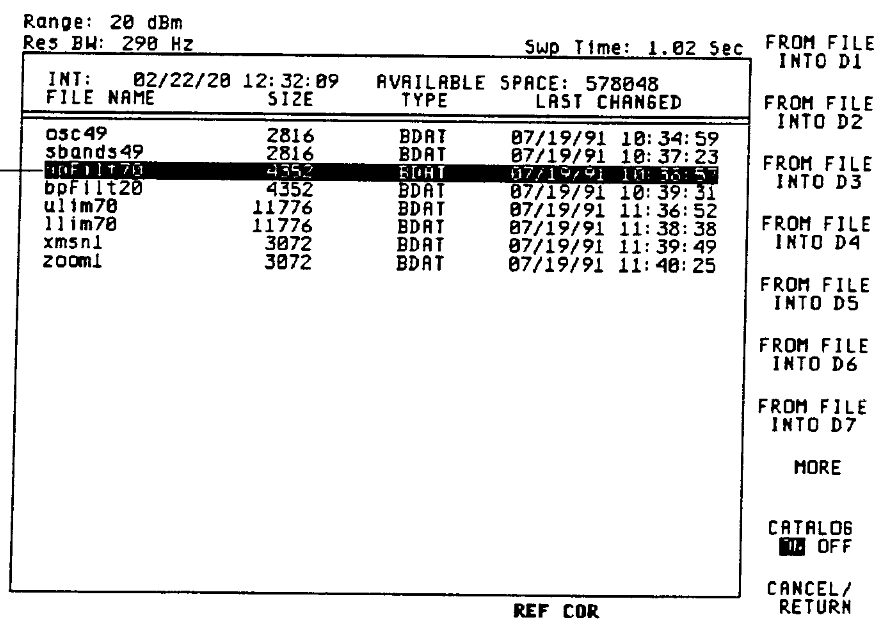
3 Press [RECALL TRACE] [FROM FILE INTO D1] [ENTER].

4 Press [**Active Trace**] if the trace you want to replace is not currently active.

5 Press [TRACE DATA] [DATA REGISTERS] [D1].

It's generally easier to recall a trace if you display the disk catalog and highlight the trace file first. When you do this, the prompt that's displayed when you press [FROM FILE INTO D1] already contains the correct file name. You only need to press [ENTER] to recall the file. If you don't display the catalog first, you will need to type the correct file name into the prompt before you press [ENTER].

The analyzer always recalls a trace into a data register. Steps 4 and 5 allow you to view the recalled trace by selecting the contents of that register for display.



The analyzer recalls the highlighted trace file into the specified data register.

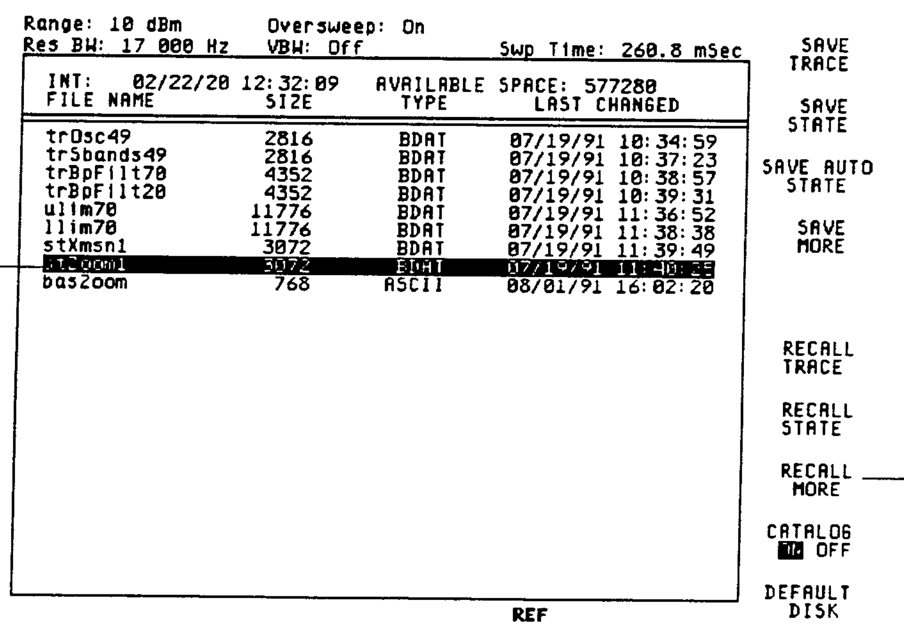
To recall other data from a file

1. Press [**Save/Recall**], then press [CATALOG ON/OFF] to highlight ON.
2. Turn the knob to highlight the file you want to recall.
3. Press the RECALL softkey that matches the type of data you want to recall. (If the RECALL softkey you need is not displayed, press [RECALL MORE] for more options.)
4. Press [ENTER].

The highlighted file is only recalled if its data type matches the RECALL softkey you press. For example, a highlighted state file is recalled when you press [RECALL STATE] [ENTER], but not when you press [RECALL PROGRAM] [ENTER].

It's generally easier to recall a file if you display the disk catalog and highlight the file first. When you do this, the prompt that's displayed when you press a RECALL softkey already contains the correct file name. You only need to press [ENTER] to recall the file. If you don't display the catalog first, you will need to type the file name into the prompt before pressing [ENTER].

Press [RECALL MORE] to display additional RECALL softkeys.



The highlighted file is only recalled if its data type matches the RECALL softkey you pressed.

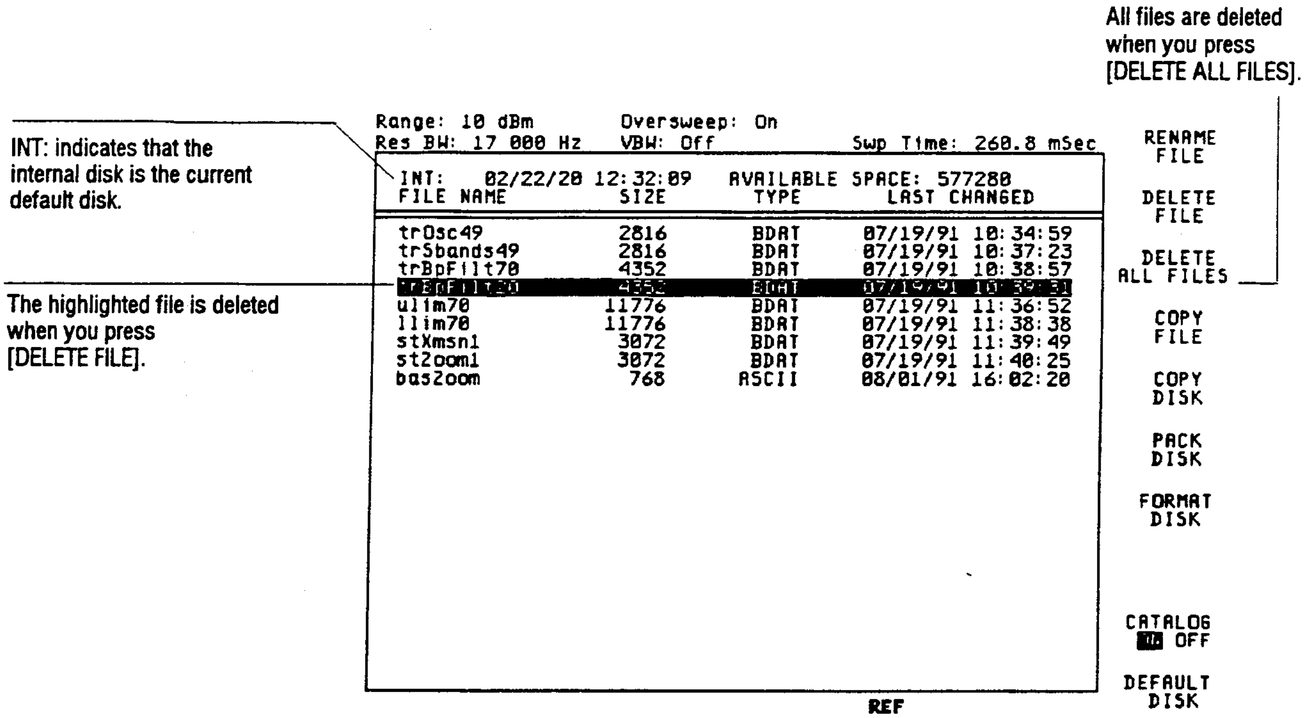
To delete a file

1 Press [**Disk Util**], then press [CATALOG ON/OFF] to highlight ON.

2 Turn the knob to highlight the file you want to delete.

3 Press [DELETE FILE] [ENTER].

When you press [ENTER], the highlighted file is deleted from the default disk. If you want to delete all files at once, press [DELETE ALL FILES] [ENTER] in step 3.



To copy a file

1 Press [**Disk Util**], then press [CATALOG ON/OFF] to highlight ON.
2 Turn the knob to highlight the file you want to copy.
3 Press [COPY FILE] [SOURCE FILENAME] [ENTER].
4 Press [DESTIN FILENAME], then type a file name for the new copy—preceded by a disk specifier if you are copying to another disk—and press [ENTER].
5 Press [PERFORM FILE COPY].

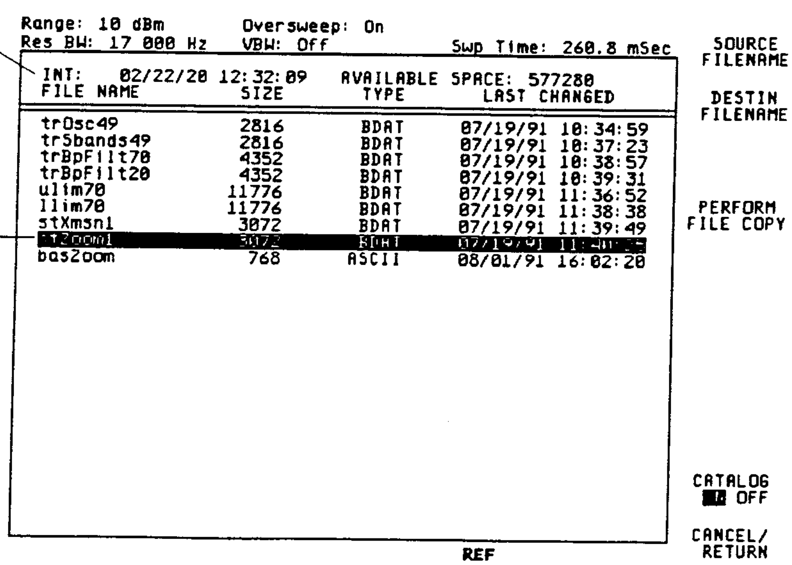
The analyzer's file system recognizes three disk specifiers—one for each of its disks:

- **NVRAM:** specifies the nonvolatile RAM disk.
- **RAM:** specifies the volatile RAM disk.
- **INT:** specifies the internal, 3.5 inch disk drive.

These disk specifiers allow you to copy a file from the default disk to one of the other two disks. For example, suppose you wanted to copy the file **stZoom1** from the internal disk drive (currently selected as the default disk) to the nonvolatile RAM disk. After pressing [DESTIN FILENAME] in step 3, you would turn the knob to place the cursor at the beginning of **stZoom1**, and then type **NVRAM:**. When you pressed [ENTER] and [PERFORM FILE COPY], a new copy of **stZoom1** would be created on the nonvolatile RAM disk.

INT: indicates that the internal disk is the current default disk.

The highlighted file is displayed automatically in the [SOURCE FILENAME] and [DESTIN FILENAME] prompts.



To recover unusable disk space

- Press [**Disk Util**] [PACK DISK] [ENTER].

When you delete files from a LIF-formatted disk, you sometimes leave spaces that are too small to be used for new files. [PACK DISK] recovers these unusable spaces by shifting the remaining files forward on the disk until the files are directly adjacent to each other. As files are shifted forward, the spaces between files are effectively shifted to a large block of usable space at the end of the disk.

11

Plotting and Printing

This chapter shows you how to plot and print screen contents. It also shows you how to set up an HP-IB plotter or printer.

To set up your plotter

1 Connect the HP-IB ports of your plotter and analyzer with an HP-IB cable.

2 Turn on the plotter.

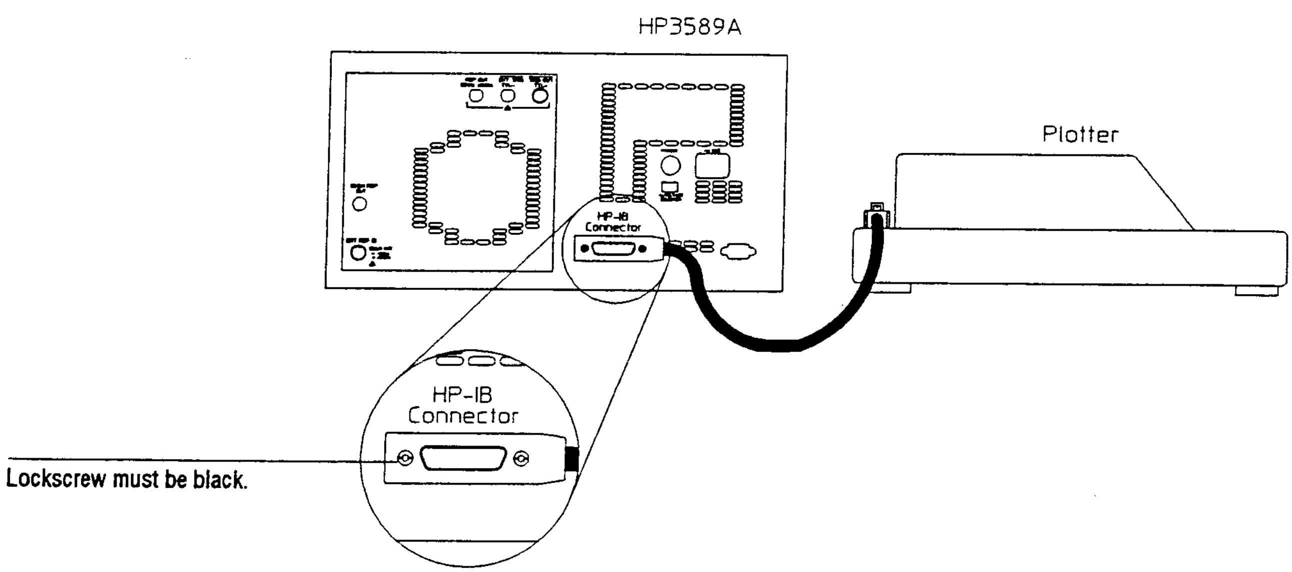
3 Determine the plotter's HP-IB address.

4 On the analyzer, press [**Local/HP-IB**] [PERIPHERL ADDRESSES] [PLOTTER ADDRESS] <num> [ENTER].

CAUTION

The analyzer's HP-IB mounting studs are metric-threaded, so you should *only* use cables with metric-threaded lockscrews. Metric-threaded lockscrews are black, while English-threaded lockscrews are silver.

Refer to your plotter's documentation if you don't know how to turn it on or determine its HP-IB address. When you determine the address, write it down; this is the value you will substitute for <num> in step 4.



To plot screen contents

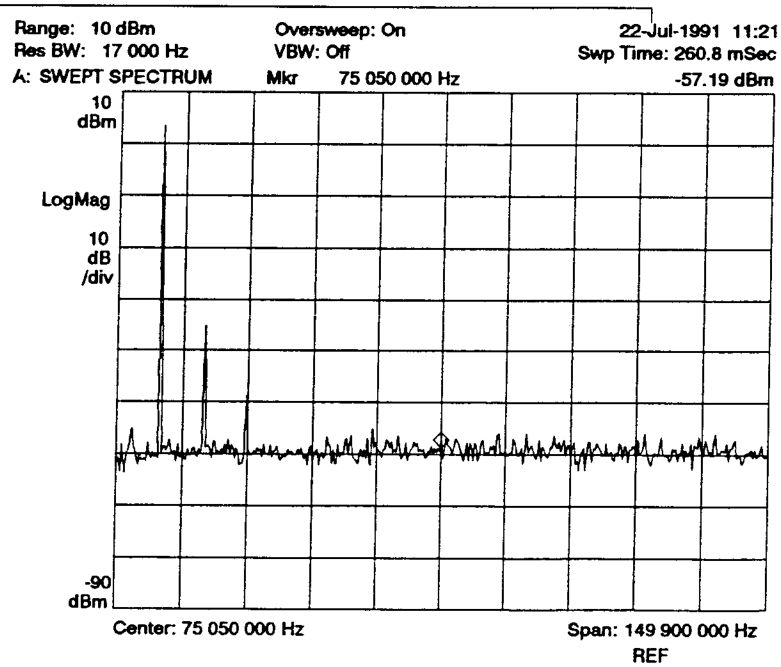
1. Set up your plotter if you haven't already.
2. Press [**Local/HP-IB**] [SYSTEM CONTROLLR].
3. Press [**Plot/Print**] [PLOT ALL].

All of the screen's contents, except the softkey labels, are plotted when you complete this task. However, you can also plot selected portions of the screen by replacing [PLOT ALL] with one of the following softkeys in step 3:

- [PLOT TRACE] plots just the trace.
- [PLOT MARKER] plots the main marker and its coordinates.
- [PLOT OFFST MKR] plots the offset marker and its coordinates.
- [PLOT GRATICULE] plots just the graticule.

The analyzer is only able to initiate plotting if it is attached to an HP-IB plotter and designated as the system controller. If you haven't already set up your plotter, see "To set up your plotter" earlier in this chapter.

Plot of screen contents always includes the current date and time.



To reassign plotter pens

1 Press [**Plot/Print**] [DEFINE PLOT] [DEFINE PLOT PENS].

2 Press the softkey that matches plot component whose pen assignment you want to change.

3 Type the carousel number of the pen you want to use for the selected plot component, then press [ENTER].

You can return to the analyzer's default pen assignments at any time by pressing [DEFAULT PENS] in the Define Plot Pens menu.

To modify the plotting speed

1 Press [**Plot/Print**] [DEFINE PLOT] [PLOT SPEED].
2 Press [SLOW 10 (cm/S)], [FAST 50 (cm/S)], or [USER DEFINED].
3 If you pressed [USER DEFINED] in the previous step, press [USER PLOT SPEED], then type a speed your plotter can accept (using a unit of cm/S) and press [ENTER].

Check your plotter documentation to determine the range of supported plotting speeds.

To set up your printer

1 Connect the HP-IB ports of your printer and analyzer with an HP-IB cable.

2 Turn on the printer.

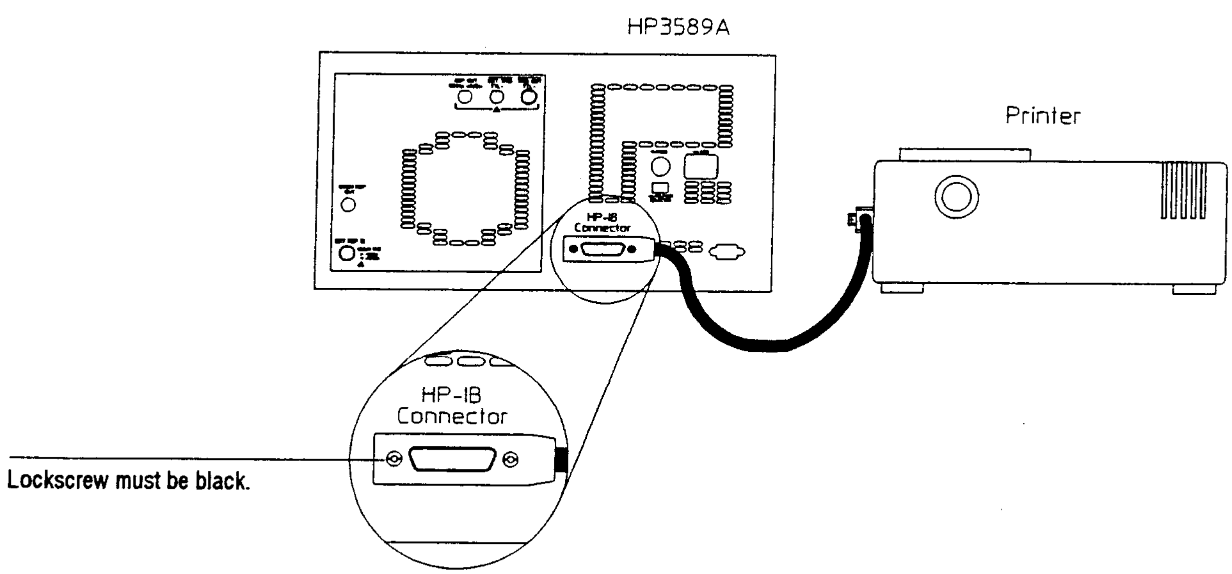
3 Determine the printer's HP-IB address.

4 On the analyzer, press [**Local/HP-IB**] [PERIPHERL ADDRESSES] [PRINTER ADDRESS] <num> [ENTER].

CAUTION

The analyzer's HP-IB mounting studs are metric-threaded, so you should *only* use cables with metric-threaded lockscrews. Metric-threaded lockscrews are black, while English-threaded lockscrews are silver.

Refer to your printer's documentation if you don't know how to turn it on or determine its HP-IB address. When you determine the address, write it down; this is the value you will substitute for <num> in step 4.



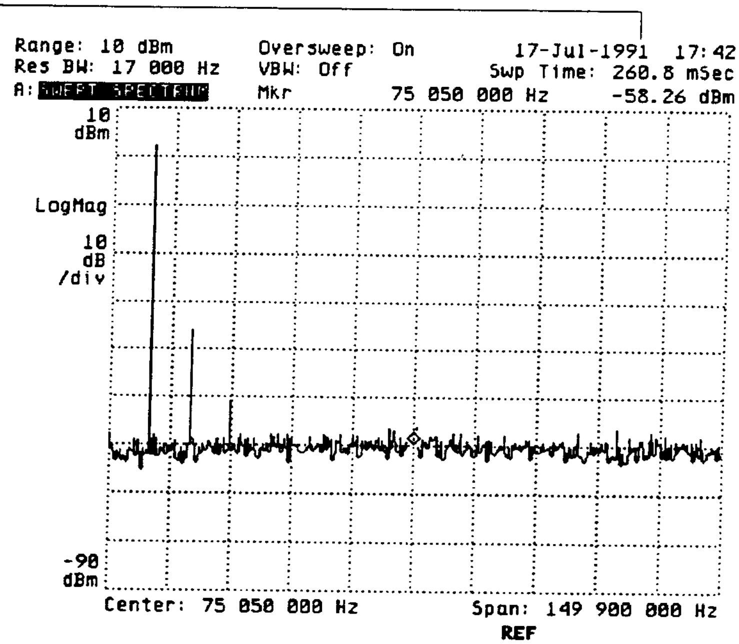
To print screen contents

1 Set up your printer if you haven't already.

2 Press [**Local/HP-IB**] [SYSTEM CONTROLLR].

3 Press [**Plot/Print**] [PRINT ALL].

The analyzer is only able to initiate printing if it is attached to an HP-IB printer and designated as the system controller. If you haven't already set up your printer, see "To set up your printer" earlier in this chapter. All of the screen's contents, except the softkey labels, are printed when you complete this task.



Print of screen contents always includes the current date and time.

12

Limit Testing

This chapter shows you how to use the analyzer's limit-testing functions. The functions allow you to define a set of limits and then test measurement results against those limits.

To draw a limit

1 Press [**Marker Fctn**] [LIMIT TEST], then press [DEFINE UPPER LIM] or [DEFINE LOWER LIM].

2 Turn the knob to place the limit marker at the beginning of your limit line. (Press [MOVE MKR HORIZNTAL] and [MOVE MKR VERTICAL] to control the knob's effect on the marker.)

3 Press [START SEGMENT].

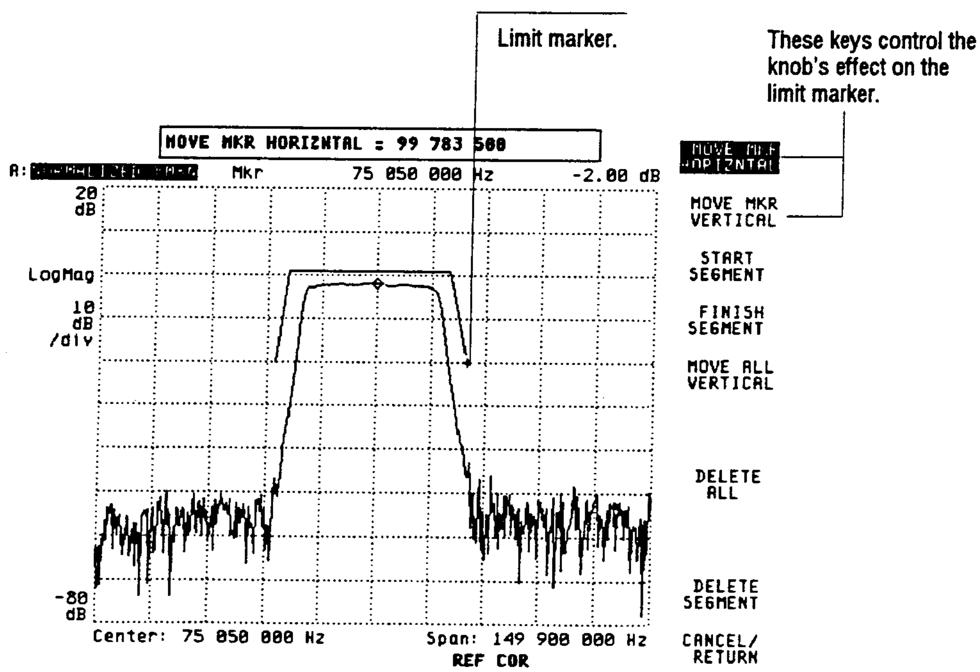
4 Turn the knob to place the limit marker at the end of your limit line.

5 Press [FINISH SEGMENT].

6 Press [**Marker Fctn**] or some other hardkey to exit the Define Lim menu.

This task, as written, shows you how to create a single-segment limit line. However, you can modify the task to create a multi-segment line. Just repeat steps 4 and 5 several times before completing step 6.

The limit you create is stored in the active trace's upper or lower limit register—depending on which key you press in step 1. You can evaluate a trace against the limit by enabling limit testing, as shown in a later task, "To enable limit testing."



To delete a limit segment

1 Press [**Marker Fctn**] [LIMIT TEST], then press [DEFINE UPPER LIM] or [DEFINE LOWER LIM].

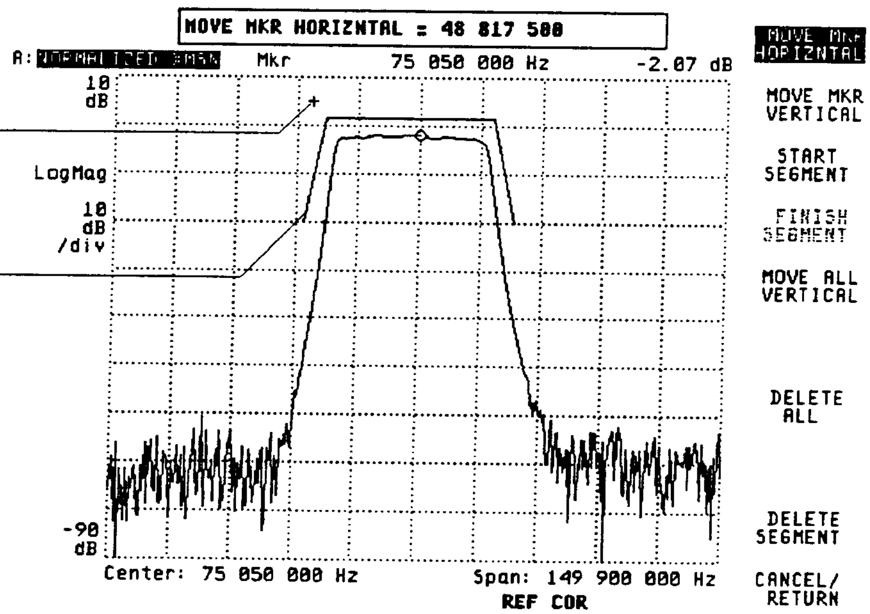
2 Press [MOVE MKR HORIZNTAL], then turn the knob to align the limit marker horizontally with the segment you want to delete.

3 Press [DELETE SEGMENT].

After you finish drawing a limit, you may sometimes decide that a particular segment should be redrawn. To do this, you can delete the segment as described in this task, and then redraw the segment as described in "To draw a limit." If you decide that the entire limit should be redrawn, you can press [DELETE ALL] [CONFIRM DELETE] in step 3, and then redraw the all segments as described in "To draw a limit."

Limit marker.

This segment will be deleted because it is horizontally aligned with the limit marker.



To convert a trace to a limit

1 Press [**Active Trace**] if the trace you want to convert is not currently active.

2 Press [**Save/Recall**] [SAVE TRACE] [INTO FILE], then type a file name and press [ENTER].

3 Press [**Save/Recall**] [RECALL MORE], then press [RECALL UPPER LIM] or [RECALL LOWER LIM].

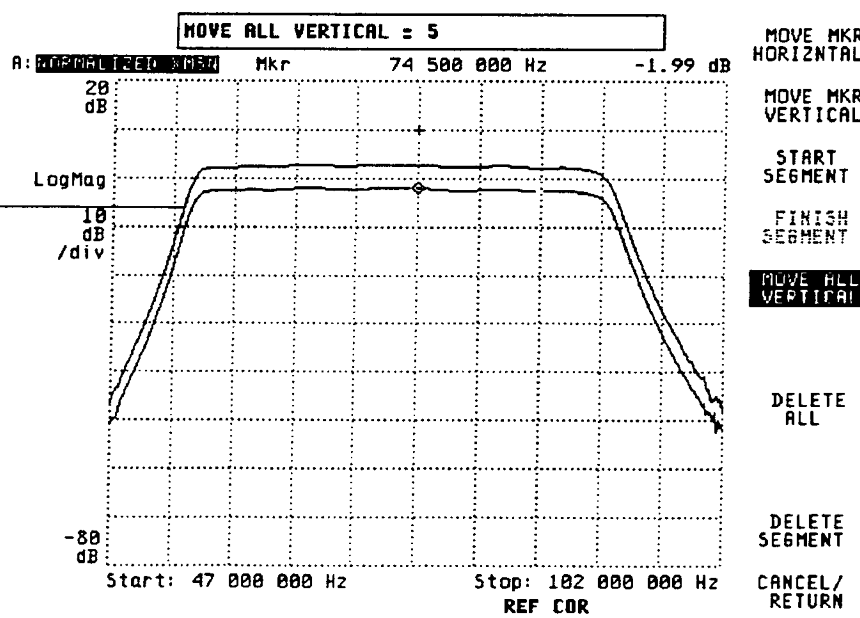
4 Type the same file name you used to save the trace, then press [ENTER].

5 Press [**Marker Fctn**] [LIMIT TEST], then press [LINES ON/OFF] to highlight ON.

The analyzer can convert any trace file into a limit. This allows you to create a reference trace by measuring a standard device and then test the performance of other devices against that trace.

When you convert a trace to a limit, you will probably want to shift the new limit vertically to allow for some deviation from the reference trace. After you determine how much deviation you can allow, press either [DEFINE UPPER LIM] or [DEFINE LOWER LIM] (to match the limit you recalled), then press [MOVE ALL VERTICAL] and turn the knob to shift the limit.

Use [MOVE ALL VERTICAL] and the knob to move the recalled limit up or down.



Trace recalled as an upper limit.

To enable limit testing

1 Press [**Marker Fctn**] [LIMIT TEST], then press [TEST EVAL ON/OFF] to highlight ON.

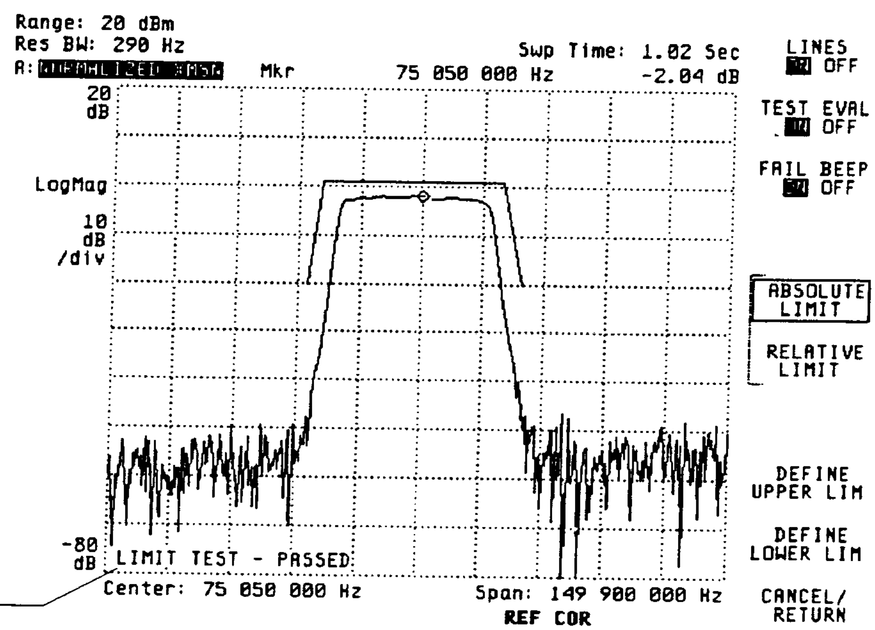
2 If you want the analyzer to display the limits during testing, press [LINES ON/OFF] to highlight ON.

3 If you want the analyzer to beep when your trace fails the limit test, press [FAIL BEEP ON/OFF] to highlight ON.

Limit testing allows the analyzer to evaluate a trace against the contents of an upper and a lower limit register. You can load the registers by drawing limits or by recalling previously defined limits from files (using the Recall Lim softkeys under the [**Save/Recall**] hardkey).

When limit testing is enabled, the trace is evaluated each time it is updated—at the end of a measurement. If any point on the trace falls above an upper limit or below a lower limit, the trace fails the test. The results of the test are displayed in the lower-left corner of the trace area.

[BEEPER ON/OFF], located under the [**Special Fctn**] hardkey, must also be set to ON if you want the analyzer to beep when your trace fails a limit test.



Test results are displayed in the lower-left corner of the trace.

To save a limit

1 Press [**Save/Recall**] [SAVE MORE], then press [SAVE UPPER LIM] or [SAVE LOWER LIM].

2 Type a file name in the text prompt and press [ENTER].

The analyzer has four limit registers: one upper and one lower limit register for each of the two traces. Each register holds a complete limit. The contents of these registers are not altered when you press [**Preset**], but they are lost when you turn off the analyzer. If you create limits that you want to reuse, it's best to save them to a flexible disk so they won't be lost.

13

HP Instrument BASIC

This chapter introduces you to the analyzer's HP Instrument BASIC features, which are available under the [**BASIC**] hardkey when you order option 1C2. You can use HP Instrument BASIC for a wide range of applications—from simple recording and playback of measurement sequences (*keystroke recording*) to sophisticated remote-control operation of other instruments, computers, and peripherals. To learn more, see *Using HP Instrument BASIC with the HP 3589A.*

To clear the program buffer

1 Press [**BASIC**] [UTILITIES] [SCRATCH]

2 Press [SCRATCH] [PERFORM SCRATCH].

It's a good idea to clear the analyzer's program buffer before you create a new program using HP Instrument BASIC's keystroke recording feature. If you don't clear the buffer, the recorded key-presses will be inserted in the existing program.

To record key-presses

1 Press [**BASIC**] [ENABLE RECORDING].

2 Press the keys you want to record.

3 Press [**BASIC**] to end recording.

When you record a measurement sequence with HP Instrument BASIC, the analyzer converts key-presses to equivalent HP-IB commands. The commands are then inserted into BASIC program lines in the analyzer's program buffer.

Your recorded program will produce more consistent results if the first key you press in step 2 is [**Preset**]. [**Preset**] eliminates many unknowns by returning most analyzer parameters to their default states.

Another key to press for consistent results is [**Meas Restart**]. Most measurement sequences you record will include a section that sets up the measurement followed by a section that displays and reads values from the resulting trace data. You press [**Meas Restart**] between sections to ensure that valid trace data is available before the program displays and reads values from that data.

Recorded BASIC program is displayed and ready to be edited when you press [BASIC] [EDIT].

HP-IB commands equivalent to your key-presses are enclosed in quotes.

```
1 ASSIGN @Hp3589a TO 800
2 OUTPUT @Hp3589a;"SYST:PRES"
3 OUTPUT @Hp3589a;"ABOR; :INIT:CONT ON; *WAI"
4 OUTPUT @Hp3589a;"MARK1:MAX"
5 OUTPUT @Hp3589a;"MARK1:FUNC:FCO ON"
6 OUTPUT @Hp3589a;"ABOR; :INIT:CONT ON; *WAI"
7 OUTPUT @Hp3589a;"FREQ:CENT (MARK1:X:FCO?);:MARK1:X
8 OUTPUT @Hp3589a;"MARK1:FUNC:FCO OFF"
9 OUTPUT @Hp3589a;"INST:SEL FFT"
10 OUTPUT @Hp3589a;"FREQ:SPAN 625 Hz"
11 OUTPUT @Hp3589a;"ABOR; :INIT:CONT ON; *WAI"
12 OUTPUT @Hp3589a;"DISP1:Y:AUTO ONCE"
13 OUTPUT @Hp3589a;"AVER ON; :AVER:TYPE RMS"
14 END
```

ENTER

INSERT SPACE

INSERT LINE

DELETE LINE

RECALL LINE

DELETE CHARACTER

TYPING UTILITIES

GOTO LINE

END EDIT

To insert keystrokes in an existing program

1 Press [**BASIC**] [EDIT].

2 Turn the knob to place the cursor at the insertion point.

3 Press [END EDIT] [ENABLE RECORDING].

4 Press the keys you want to record.

5 Press [**BASIC**] to end recording.

If your program is not already loaded in the analyzer's program buffer, see "To load a program." If your program is stored on one of the analyzer's disks, you will need to load it into the buffer before running it.

```
1 ASSIGN @Hp3589a TO 800
2 OUTPUT @Hp3589a;"SYST:PRES"
3 OUTPUT @Hp3589a;"ABOR; :INIT:CONT ON; *WAI"
4 OUTPUT @Hp3589a;"MARK1:MAX"
5 OUTPUT @Hp3589a;"MARK1:FUNC:FCO ON"
6 OUTPUT @Hp3589a;"ABOR; :INIT:CONT ON; *WAI"
7 OUTPUT @Hp3589a;"FREQ:CENT (MARK1:X:FCO?);:MARK1:X
8 OUTPUT @Hp3589a;"MARK1:FUNC:FCO OFF"
9 OUTPUT @Hp3589a;"INST:SEL FFT"
10 OUTPUT @Hp3589a;"FREQ:SPAN 625 Hz"
11 OUTPUT @Hp3589a;"ABOR; :INIT:CONT ON; *WAI"
12 OUTPUT @Hp3589a;"DISP1:Y:AUTO ONCE"
13 OUTPUT @Hp3589a;"AVER ON; :AVER:TYPE RMS"
14 END
```

Recorded key-presses are inserted before this line.

ENTER
INSERT SPACE
INSERT LINE
DELETE LINE
RECALL LINE
DELETE CHARACTER
TYPING UTILITIES
GOTO LINE
END EDIT

To save a program

1 Press [**Save/Recall**] [SAVE MORE] [SAVE PROGRAM].

2 Type a file name in the text prompt and press [ENTER].

When you create a new HP Instrument BASIC program, use [SAVE PROGRAM] to save it for the first time. Saving a program with this softkey protects you from accidently overwriting a file with the same name. Then to save changes you make while editing the program, use [RESAVE PROGRAM].

To load a program

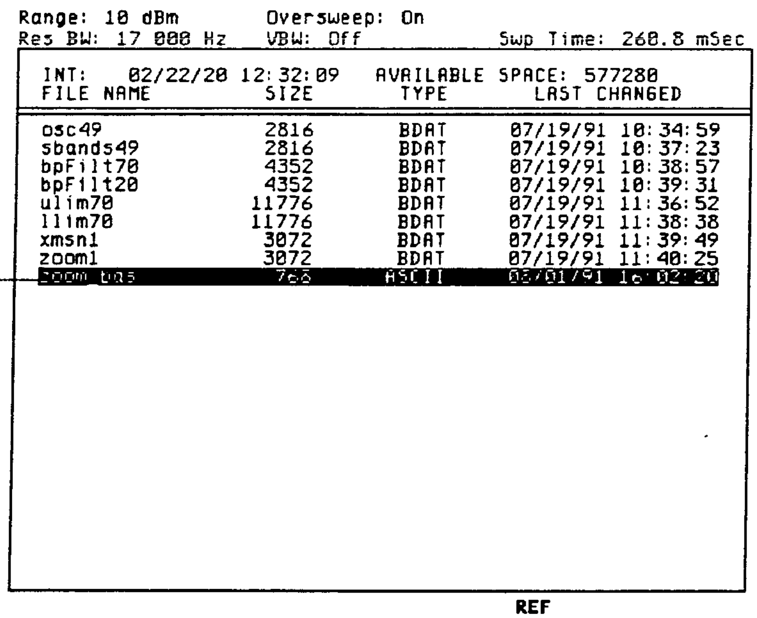
1 Press [**Save/Recall**], then press [CATALOG ON/OFF] to highlight ON.

2 Turn the knob to highlight the file you want to recall.

3 Press [RECALL MORE] [RECALL PROGRAM] [ENTER].

Before you can run or edit an HP Instrument BASIC program, you must load it into the analyzer's program buffer. Recorded programs are automatically placed in this buffer, but programs stored on one of the analyzer's disks must be recalled to the buffer.

The highlighted program is loaded into the program buffer.



To run a program

- Press [**BASIC**][RUN].

This task runs the program currently loaded in the analyzer's program buffer. If your program is stored on one of the analyzer's disks, you will need to load it into the buffer before running it.

Once your program is running, you can stop it by pressing one of three keys:

- Press [**BASIC**] to PAUSE the program.
- Press [**Local/HP-IB**] to STOP the program.
- Press [**Preset**] to STOP the program and preset the analyzer.

See *Using HP Instrument BASIC with the HP 3589A* for more information on pausing and stopping a program.

To print a program

1 Press [**Local/HP-IB**] [SYSTEM CONTROLLR].

2 Press [**BASIC**] [PRINT PROGRAM].

This task prints the contents of the analyzer's program buffer to an attached HP-IB printer. If your program doesn't print, check to see if your printer was set up properly (see "To set up your printer").

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