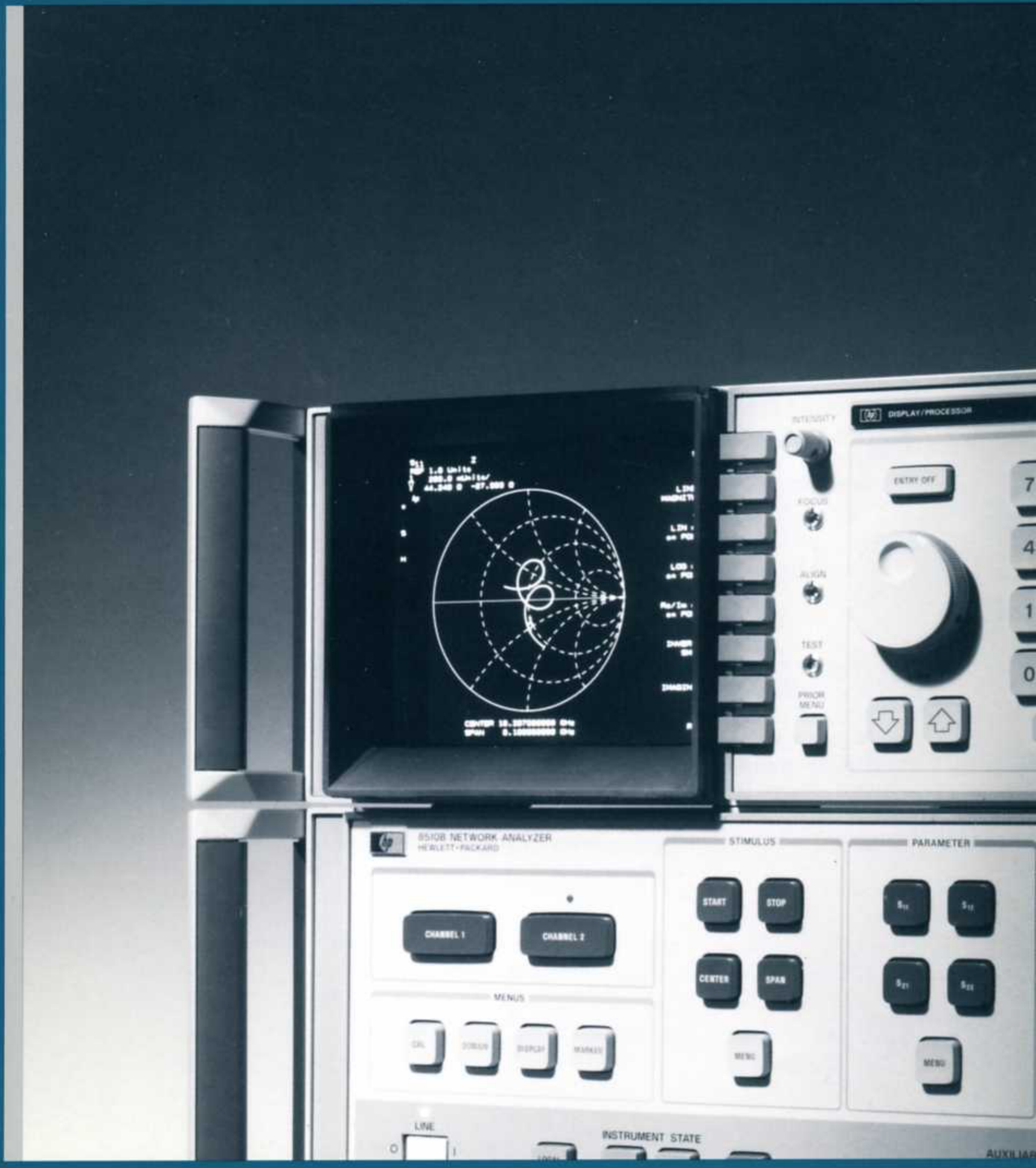
Product Note 8510-10

HEWLETT PACKARD

HP 8510B Introductory Users Guide

An Introduction to Front Panel Operation of the HP 8510B



Contents

Introduction

Providing a tour of the setup, measurement calibration, measurement, display, and data output features and capabilities of the HP 8510 is the objective of this User's Guide. It provides an operator's introduction to the HP 8510B Network Analyzer, showing how the instrument is used to characterize the frequency and time domain performance of network components. Rather than being a formal text on measurement theory and techniques, this guide uses example procedures to illustrate operating sequences in actual measurement situations. This will help you to get started making network measurements using the HP 8510 and to demonstrate the ease with which accurate results can be obtained.

The reader who is fairly new to network analysis will find Chapter 1 helpful. It presents a general procedure for making network measurements using the HP 8510. This procedure is then followed throughout the rest of the guide.

Chapters 2 and 3 illustrate the HP 8510 at work making a variety of reflection and transmission measurements. The examples have been chosen to demonstrate many of the operating modes for the instrument. The example device under test is a bandpass filter, although the examples should help you adapt these techniques to measurement of your particular device.

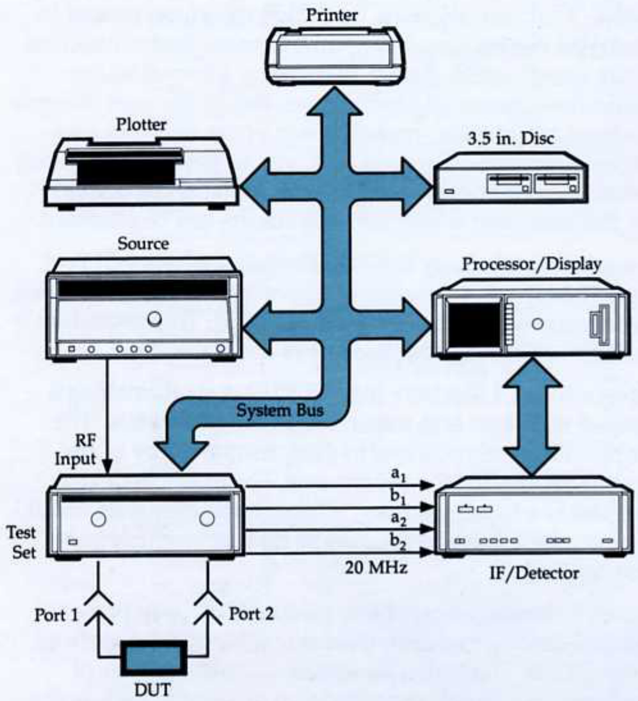
Chapter 4 shows the capability of the HP 8510 to present measured data in the Time Domain, an optional feature of the HP 8510B. This valuable feature permits analysis of impedance and length characteristics of a signal path with respect to time or distance.

It is assumed that the HP 8510 is installed and ready for use. The HP 8510B Operating and Programming Manual has more complete operating information for both manual and automatic measurements. Refer there for further information on any topic not covered in this User's Guide. The HP 8510B Keyword Dictionary provides a very detailed description for each function. Finally, the HP 8510B pocket-size Operating and Programming Quick Reference provides memory aids type information for the user who is familiar with the HP 8510.

Chapter 1
Operating the HP 8510

Getting Acquainted

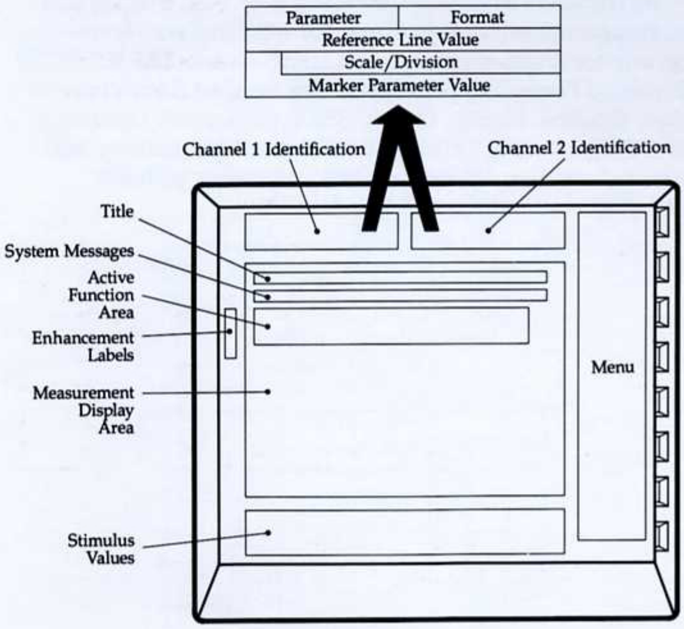
The minimum measurement system consists of the source, the test set, the signal processor, and the display. Together these comprise a complete stimulus/response test system which provides stimulus to the device under test and measures the signal transmitted through the device or reflected from its input. The system then detects and processes the data to provide various displays showing the magnitude and phase of these responses.



The Network Analyzer System. A representative network analyzer system is shown here. It consists of: the sweeper or synthesized sweeper to provide the stimulus; the test set which provides signal separation and the receiver input stage; and the HP 8510 which consists of two instruments, the IF/Detector and the Display/Processor.

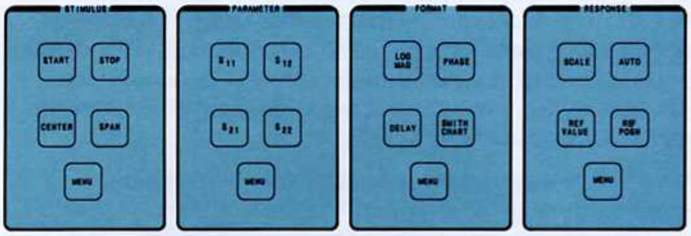
Any HP-IB compatible line printer or graphics plotter may be connected for hardcopy output. Measurement-related data may be stored and loaded using the HP 8510 cartridge tape unit or an external disc mass storage unit.

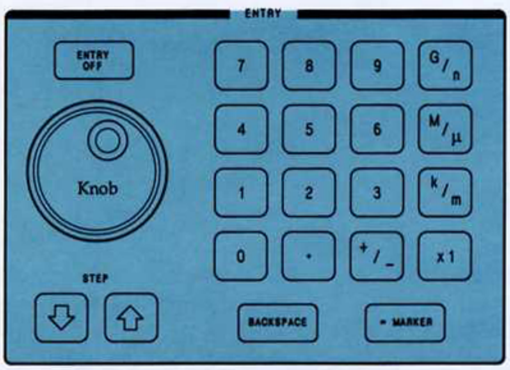
In operation, the front panel keys of the HP 8510 are used to define the measurement conditions and control the measurement process. The HP 8510 controls the system instruments via the system bus. This direct control allows the HP 8510 to take full advantage of the capabilities of the various system instruments. The device to be tested is connected between the test set Port 1 and Port 2. Accuracy enhancement techniques permit measurement calibration at the interface to the device under test, minimizing the effect of systematic measurement errors.



CRT Display. The front panel of the network analyzer is relatively simple. First, there is the CRT which presents the measurement results. This illustration shows the general areas for the measurement trace and for the various annotations which communicate to the operator.

Basic Measurement Functions
S/P/F/R





Basic Measurement Functions — S/P/F/R. Next, there are groups of keys for the measurement setup, measurement calibration, data presentation, and data output functions. The basic measurement and display functions are specified using keys in the STIMULUS, PARAMETER, FORMAT, and RESPONSE blocks.

Active Function. Pressing one of the function keys in these groups either changes the instrument state immediately, such as selecting one of the parameters, or, for keys such as START, makes that function the "active" function and its current value is shown in a specific area of the CRT.

Knob and Numeric Entry. The function value is changed using the ENTRY controls. The knob changes the function value in steps related to the current function value and the speed of the knob. The STEP keys change the active function value by a proportional increment each time the key is pressed. Enter a numeric value using the numeric, the decimal, and the +/- toggle, then pressing the appropriate units key.

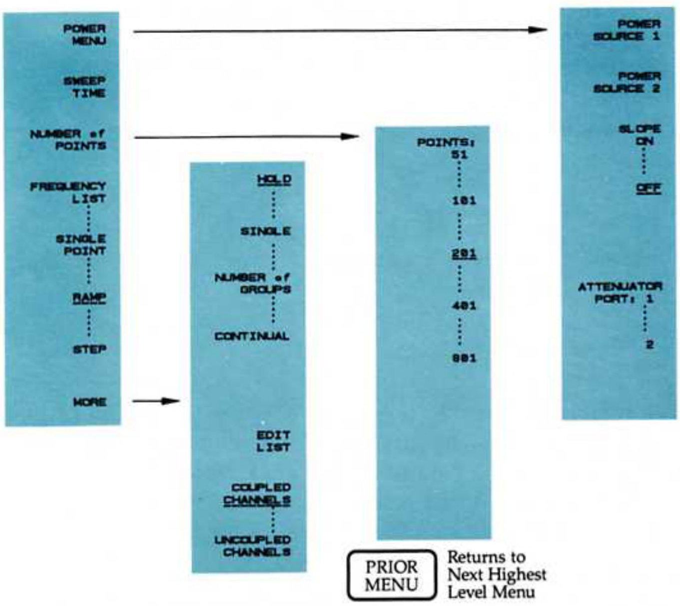
The G/n, M/μ, and k/m keys are general purpose terminators having values of $10^9/10^{-9}$, $10^6/10^{-6}$, and $10^3/10^{-3}$, respectively, and the x1 key is used to specify the basic units for the quantity, for example Hz. To specify the Start frequency of 3 GHz, press START, 3, then G/n. Press ENTRY OFF to clear the active function area.

Entry Area Terminators

Key Name	Frequency	Power	Power Slope	Time	Voltage
G/n	GHz	—	—	ns	—
M/μ	MHz	—	—	μs	μV
k/m	kHz	—	—	ms	mV
x1	Hz	dBm	dB/GHz	s	V

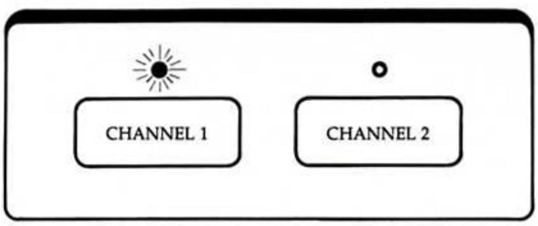
x1 Always Basic Units for Current Active Function

Stimulus Menu Structure



Softkey Menus. Choices in each of these function groups are extended using CRT-displayed "menus". Pressing a MENU key presents a selection of additional function key labels on the CRT. This is called a "softkey menu". Each "menu" lists the possible choices for a particular function, with each choice corresponding to one of the eight "softkeys" located to the right of the CRT. Press the softkey to the right of the function label to activate the function.

Every key, when pressed, either activates the function, possibly changing the state of the system, or presents the next level softkey menu. For example, pressing the MARKER key makes a trace marker the active function and also presents the first level marker menu to allow selection of other marker functions. You may press any key at any time, in any sequence, without fear of damaging the system – although the measurement result may not be meaningful.



Channel Selection. The HP 8510 has two separate, identical measurement channels. To select the channel for display, press CHANNEL 1 or CHANNEL 2. An indicator above the keys lights to indicate the current selected channel.

Turn on System Power

First turn on power to the source, test set, and other peripherals connected to the HP 8510. Now set the LINE switch on the IF/Detector to ON. This switch controls primary line power to both the IF/Detector and the Display/Processor. The LED above the switch will light to show that power is applied. It is necessary to turn on the network analyzer last to allow all other instruments on the 8510 system bus to go through their start-up cycle, then the HP 8510 can gain control.

As soon as power is applied, the network analyzer performs a self-test sequence that tests internal operation as well as operation of the other system instruments. During this sequence you may observe the following messages on the Display/Processor CRT:

- TESTING (may not be visible due to CRT warm-up)
- A diagonal line across the CRT
- LOADING OPERATING SYSTEM
- SYSTEM INITIALIZATION IN PROGRESS
- RECALLING INSTRUMENT STATE

The instrument state at the end of this sequence will vary according to the actual instrument state stored in the HP 8510 Instrument State number 8. This state is very close to the standard Preset state unless it has been changed by the user. However, all properly functioning systems will display the operating system firmware issue in the active function area.

In a typical environment, the system will be ready to make measurements immediately, with about 30 to 90 minutes warmup required to meet all system performance specifications. When you are finished with the system, power can be left applied to the test set and the source (HP 834x source in STANDBY) in order to minimize warmup time.

General Measurement Sequence

Even with its wide range of capabilities, the HP 8510 is easy to operate. Common measurements can be set up with only a few front panel selections. The following sequence is used throughout the HP 8510 user documentation to illustrate the use of the HP 8510 in its various operating modes.

Preset Press this key at any time to return the system to a predefined state.

Connections Set up the measurement configuration for your particular device under test requirements

Controls Set up the network analyzer instrument state in these steps:

- Use the STIMULUS keys to set the desired start and stop points of the frequency sweep.
- Use the PARAMETER keys to select the parameter to be measured and displayed.
- Use the FORMAT keys to select the type of graticule for display of the measured data.
- Use the RESPONSE keys to position the trace for viewing.

Measurement Calibration Use the keys under CAL and connect appropriate calibration standards where the device under test will be connected in order to improve the accuracy of the measurement.

Save Instrument State Use the SAVE keys to store the current control settings in internal non-volatile memory, and the RECALL keys to recall previously saved instrument states.

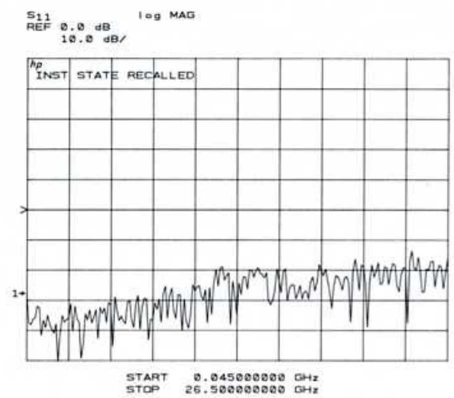
Measurement With error correction on, when the device under test is connected its response will be displayed on the CRT.

Read Values Use the MARKER keys and the knob to position the measurement marker(s) to points of interest on the trace.

Output Results Use the COPY keys to select data output to printer and/or plotter. Use the TAPE/DISC key to direct measurement result and instrument state files to the HP 8510 tape cartridge or to external mass storage.

These steps are discussed in detail in the following paragraphs.

Step 1: PRESET

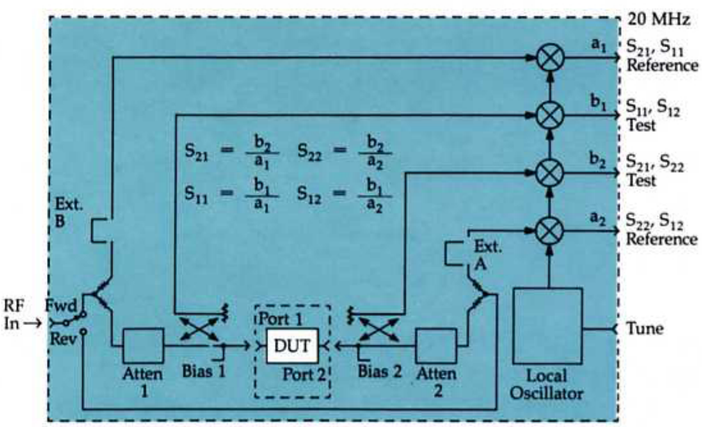


Press the green **PRESET** key on the IF/Detector. About one second later the CRT should appear as shown here, with the current S_{11} measurement displayed in the logarithmic magnitude format. The appearance of the trace will depend on the actual connection to PORT 1 of the test set. Note that an instrument preset is also issued to all instruments connected to the 8510 system bus.

PRESET always initializes all system functions to the same default conditions, except for the frequency range which depends upon the capabilities of the source and test set. A table at the rear of this document shows a partial list of important preset conditions.

Step 2: Test Setup Connections

The point(s) at which the device under test is connected to the test set is called the Reference Plane(s). If cables are used to extend the test set port out to the device under test, the end of the cable is defined as the Port 1 and Port 2 reference plane. All measurements are made with respect to the reference plane(s).



Here is a signal flow diagram of a typical S-Parameter test set. It is called a two-path test set because the stimulus signal can be applied to either test set PORT 1 or PORT 2, thus allowing all four parameters of a two-port test device to be measured without the need to manually disconnect and reverse the device.

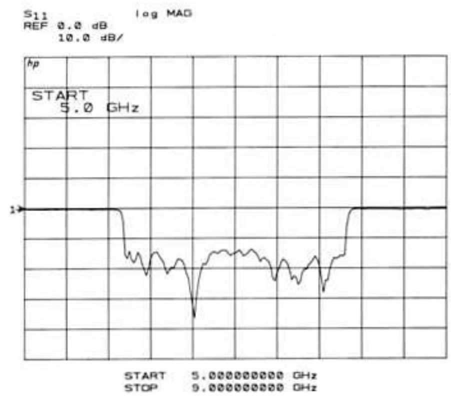
Control of the signal path is accomplished using keys in the **PARAMETER** block. An illustration on the test set front panel shows the signal flowgraph, and lighted indicators show whether the stimulus is incident at Port 1 or Port 2.

Various cables and adapters are used to connect the device to be tested to the network analyzer. If the device is a one-port device, connect the DUT directly to the test port, using an adapter if required. If the device has two or more ports, either use the two test port extension cables and the necessary adapters to achieve a symmetrical setup, as shown here, or connect the DUT directly to Port 1 and use a single cable.

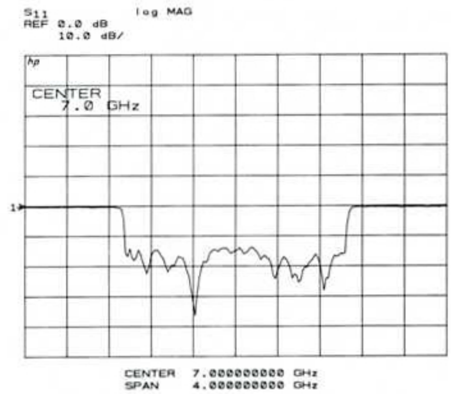
In order to minimize the connect/disconnect cycles on the relatively expensive test set or cable connectors, it is always good practice to use a consumable high quality adapter, or "connector saver". Connect this connector saver to the point at which the test device or adapter for the test device will be connected.

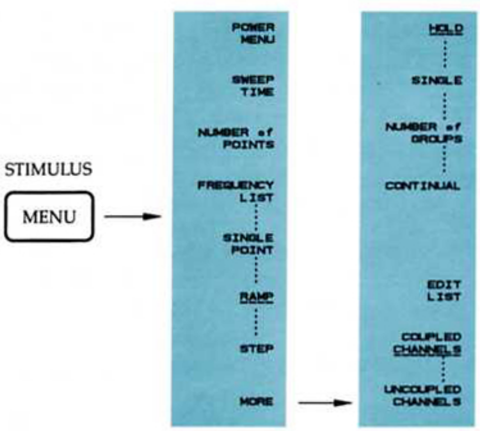
Step 3: System Control Settings

Use the STIMULUS, PARAMETER, FORMAT, and RESPONSE controls to configure the network analyzer for the measurement.



Set Stimulus. Controls in the STIMULUS block and the menus allow you to set the frequency sweep, source power level, sweep time, number of points to be measured, and other related characteristics of the incident signal. The **START** and **STOP** keys and the **CENTER** and **SPAN** keys are used to set the limits of the frequency sweep. Notice that the stimulus annotation at the bottom of the CRT displays the current frequency sweep in terms of Start/Stop or Center/Span depending upon which of the keys has been pressed last.



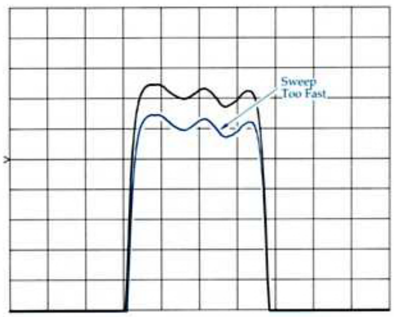


Press the STIMULUS **MENU** key to present the first level Stimulus Menu. Now press the **NUMBER of POINTS** softkey. The Number of Points menu provides selection of the number of points to be measured over the frequency sweep. Press **POINTS: 51, 101, 201, 401,** or **801** depending on the number of points you wish to measure.

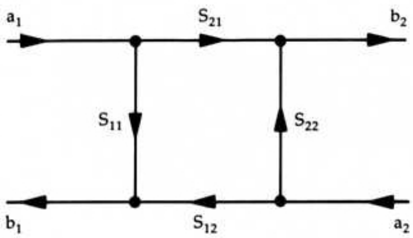
The **RAMP** and **STEP** softkeys select the sweep mode. **RAMP** can be used with any source, and **STEP** may be used when the source is a synthesized sweeper such as the HP 8340 series instruments.

Preset always selects Ramp sweep, in which the source is swept from the lowest frequency to the highest frequency in a continuous sweep. Measured data is sampled at the selected frequency points without stopping the sweep.

The Step sweep mode is used when maximum frequency accuracy and repeatability are required. The tradeoff is measurement speed. In the Step mode the synthesized sweeper is phase locked at each frequency point before the measured data is read.



Sweep time is an important consideration for testing narrowband devices. Preset always selects the fastest sweep time appropriate for the HP 8510 data acquisition process. The optimum sweep time for a particular measurement is as fast as possible while allowing time for the device under test to respond. A practical method for determining this optimum sweep time is to connect the device under test then slow the sweep as necessary until the device response does not change. Too fast a sweep time will be indicated by smoothing of narrow responses. Press STIMULUS **MENU** then the **SWEEP TIME** softkey and use the knob or **STEP** keys to adjust the sweep time.



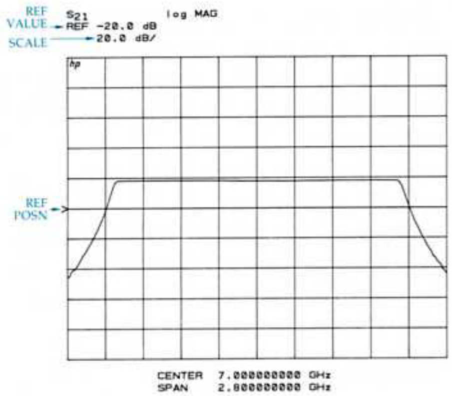
Select Parameter. Keys in the PARAMETER block allow you to select the S-parameter to be measured and displayed. Recall that S-parameters are always defined as a ratio and they are represented by the notation S_{outin} where $_{out}$ represents the emerging signal and $_{in}$ represents the incident signal. Therefore, S_{11} is the ratio of the signal emerging from port 1 to the signal incident at port 1, or as shown in the signal flow diagram, the ratio b_1/a_1. After Preset, Channel 1 displays S_{11} and Channel 2 displays S_{21}, if selected.

Select Format for Display. Twelve different display formats provide a comprehensive selection of useful presentations. The keys in the FORMAT block and displayed by FORMAT **MENU** also select the marker units shown by the active stimulus marker. This list shows the trace values and marker units for each of the standard format selections. Examples of how these formats are used for various reflection and transmission measurements are discussed in later chapters.

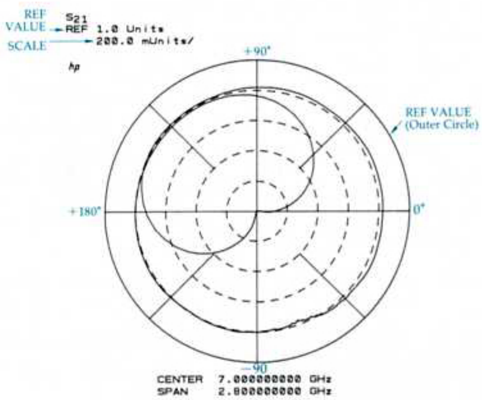
FORMAT	MARKER Basic Units
LOG MAG	dB
PHASE	degrees
DELAY	seconds
SMITH CHART	$R \pm jX$
SWR	
LINEAR MAGNITUDE	ρ (reflection)
	τ (transmission)
LIN mkr on POLAR	$\rho \angle \varnothing°$
	$\tau \angle \theta°$
LOG mkr on POLAR	$dB \angle \varnothing°$
Re/Im mkr on POLAR	$x \pm jy$
INVERTED SMITH	$G \pm jB$
REAL	x
IMAGINARY	jy (unitless)

Notice that the Parameter and Format keys are associated such that when a parameter is selected, the measurement is displayed in the format last selected for that parameter.

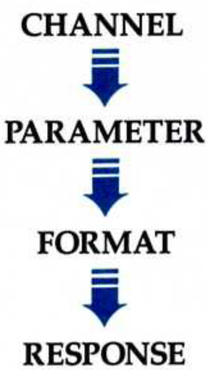
For example, press S_{11} then **SMITH**. This measurement can show the actual complex impedance of the device under test. Now select S_{21} and **DELAY**, a measurement of the transit time for the stimulus signal. Switching between the parameters with each parameter keeping its preferred format is accomplished without additional keystrokes. This may seem like a minor feature but it is an example of how the HP 8510 is designed to provide maximum convenience to the user.



Position Response for Viewing. Press AUTO to automatically scale the selected format for display of the complete measurement trace. The SCALE, REF VALUE, and REF POSN along with the ENTRY block control the display presentation. The trace is always positioned on the graticule according to its value with respect to the value of the graticule reference position line. For Cartesian displays such as LOG MAG and DELAY the reference position can be any horizontal line.



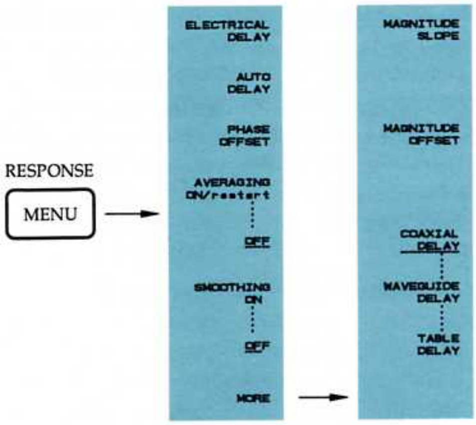
For Polar formats, such as LOG mkr on POLAR and LIN mkr on POLAR, the reference position is the outer circle for magnitude and zero degrees for phase. For consistency, the SMITH format uses Polar conventions.

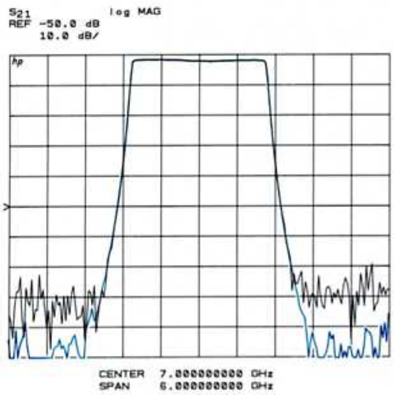


This diagram shows that the HP 8510 internal memory provides what is called the "P/F/R Limited Instrument State". Functionally, this feature allows you to select the response settings most appropriate for viewing the parameter in each format, then switch between the different formats. This extends the previous example showing linkage of the Parameter and Format keys to separate, independent recall of the last presentation used for each channel. As an example of this, select

CHANNEL 1, S_{11}, LOG MAG, AUTO.
CHANNEL 2, S_{11}, MARKER, REF VALUE, = MARKER, SCALE, 0.1, x1.

Switch between Channel 1 and Channel 2 and between parameters and formats on both channels to learn about this Channel/P/F/R association. Of course, all settings are saved when you use the save instrument state function.





Averaging. Probably the most frequently used feature to improve the data presentation is averaging. Press RESPONSE **MENU**, then **AVERAGING ON/restart**. The active function is now the averaging factor applied to the measurement.

Averaging is used to extend the effective dynamic range of the measurement and thus improve accuracy and resolution. Although averaging is performed on the digitized data by the HP 8510 central processing unit, it operates like a variable bandwidth IF filter to reduce the effect of random noise and other time variant errors on the displayed trace.

In the Ramp sweep mode, averaging is accomplished on a sweep-by-sweep basis by averaging the newly acquired data with the current displayed data using the weighted exponential running average technique. Using this process, the new data has relatively little effect on the existing data and n+1 sweeps, where n is the averaging factor, are required to produce fully averaged data. The proper procedure is, then, if you select an averaging factor of 16, allow 17 sweeps until using the data. You may use the Number of Groups function on the Stimulus menu to keep track of the sweeps by pressing STIMULUS **MENU**, **NUMBER of GROUPS**, then **17**, **x1**. When the H annotation appears on the screen the data is ready.

In the Step sweep mode, each data point is averaged as it is measured by taking n+1 measurements of that point. Thus, for Step sweep, only one sweep is required to produce fully averaged data.

Step 4: Perform Measurement Calibration

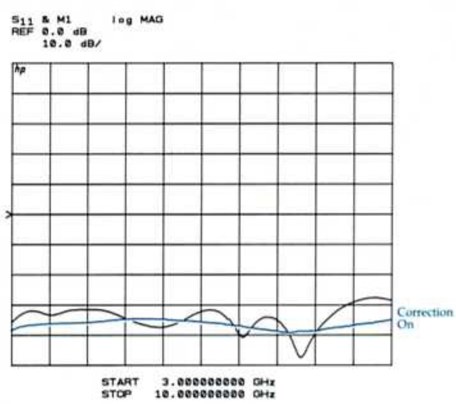
Accuracy in network measurements is greatly influenced by factors external to the network analyzer frequency conversion and signal processing steps. Parts of the measurement setup such as interconnecting cables and test sets, (as well as the instrument itself) all introduce variations in magnitude and phase that can distort the actual performance of the DUT. Because the magnitude and phase of the error is unknown, each error is assumed to have a cumulative effect of increasing the uncertainty of the measured data.

Errors that are repeatable and have effects that can be predicted are called "systematic" errors. The measurement calibration step seeks to remove the effects of these systematic errors from the measurement of the device under test. There are three categories of these systematic errors:

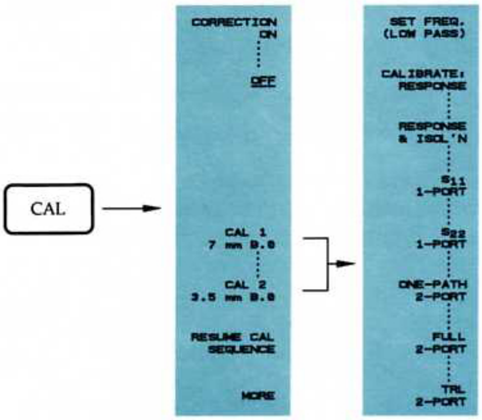
- Frequency Response (Tracking)
- Leakages
- Mismatches

The HP 8510 can use any of several methods to measure and compensate for these test system imperfections. Each method removes one or more of the systematic errors using a specific error model. In the process of measurement calibration the user connects and measures one or more precisely known standards at the point at which the test device will be connected. In principle, the difference between the precisely known response of each calibration standard and the actual measured response is used to determine the magnitude and phase value of one of the errors. Later, when the device under test is connected, the effects of these errors are mathematically removed and the device response is displayed with much reduced measurement uncertainty.

The accuracy of error-corrected measurements are depends on the quality of the standards used for calibration. This is one of the HP 8510 calibration kits containing standards for measurement calibration at a 7mm reference plane. Since the calibration standards are very precise, great accuracy enhancement is achieved.



These are examples of measurements of a 1-Port device made without accuracy enhancement and with complete accuracy enhancement. The first measurement uses no error correction and includes the effects of all systematic errors. The second example shows results of the same measurement with frequency response, directivity, and source mismatch errors reduced by accuracy enhancement.



To perform any of the measurement calibration procedures, first set all of the STIMULUS characteristics such as the frequency range over which the DUT is to be measured, the number of points, source power, and others, then proceed with the measurement calibration sequence. If the DUT must be measured using different STIMULUS settings, then the measurement calibration procedure must be performed again for the new stimulus settings.

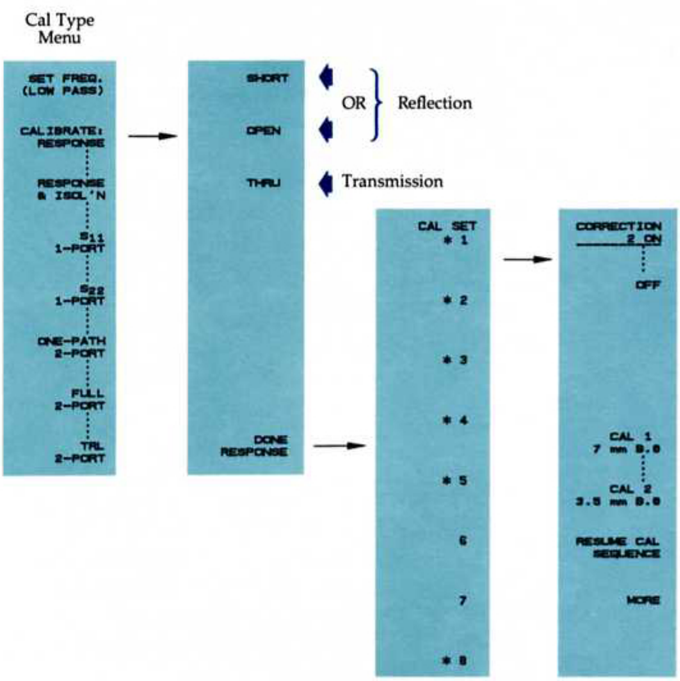
Now select the parameter to be measured. Press CAL, select either CAL 1 or CAL 2 (depending upon the test port connector type). This will cause the Cal Type menu to be displayed. This menu allows choice of several different calibration techniques and accuracy enhancement error models. Three of these choices are discussed in the following paragraphs, starting with the simplest (frequency response) and ending with the most complete (full 2-port).

Frequency Response Reflection or Transmission Calibration

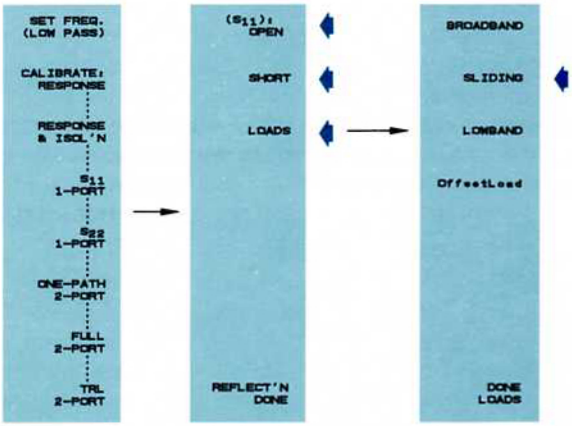
- Simple Procedure
- Requires only a "thru" for transmission measurements
- Requires a short circuit or open circuit for reflection measurements

The frequency response calibration removes the magnitude and phase frequency response errors of the selected signal path by normalizing the response of the device under test to the ideal response of the selected calibration standard. For S_{21} and S_{12} measurements, the thru connection is substituted for the DUT to establish a 0 dB and 0 degrees reference. The thru connection is accomplished by connecting together the points at which the DUT will be connected. For S_{11} and S_{22} measurements, either a short circuit or an open circuit is connected to the point at which the DUT will be connected, to establish the reference response.

To perform the frequency response calibration, first select the parameter to be measured, then press CALIBRATE: RESPONSE. Now connect the calibration standard, a thru for transmission or a short or an open for reflection, and press the softkey naming the calibration standard used. After the standard is measured, press DONE RESPONSE. Now select the calibration error coefficient register to store the correction factors by pressing CAL SET 1. Correction is turned on and the corrected response is shown.



Cal Type



1-Port Reflection Calibration

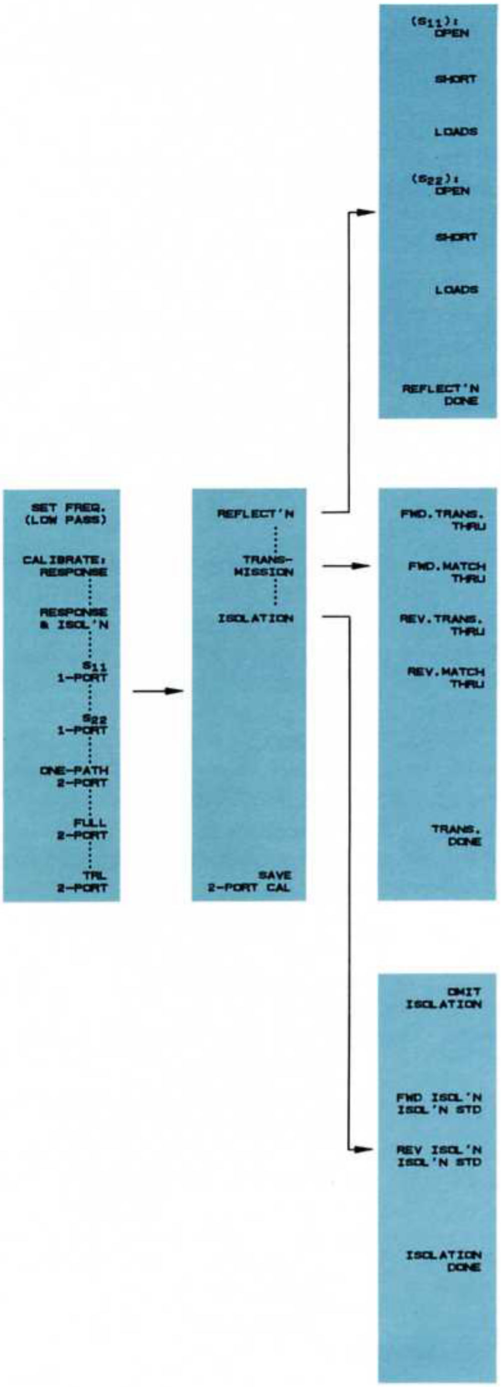
- More accurate than the frequency response calibration
- Requires three terminations (open, short, load)
- Good choice for measurements of small or large reflections.

This calibration routine removes all three of the systematic error terms for a reflection measurement of a one-port DUT. These are Directivity, Source Match and Reflection Signal Path Frequency Response. It is best applied to measurement of a one-port device because it does not remove the mismatch effects seen from the output port of a 2-port DUT. These output mismatch effects are negligible if either the reflected signal is large or the DUT greatly attenuates the mismatch signals seen from the output port.

To perform the one-port reflection calibration, select **CALIBRATE: S_{11} 1-PORT** or **CALIBRATE: S_{22} 1-PORT** (depending upon if the DUT is to be connected to Port 1 or Port 2). The correct parameter for the cal type is selected automatically. Connect the open circuit and press **OPEN**. Connect the short circuit and press **SHORT**.

Now press **LOADS** to display the Loads Standard Selection menu. For best results when measuring above 2 GHz, a sliding type load is generally the more accurate means to measure the directivity error. For this example, connect a high quality (small reflection) fixed load at the port and select **BROADBAND**, then when the load has been measured, press **LOADS DONE**.

Press **SAVE 1-PORT CAL**. The error coefficients are computed and the Cal Set Selection menu is displayed. Press one of the cal set keys to store the error coefficients and turn correction on.



2-Port Calibration

- Most accurate for measurement of 2-Port DUT
- Measures 12 error terms
- Best applied using S-Parameter Test Set

This is the most complete calibration procedure for measurement of transmission and reflection characteristics of 2-port devices. Twelve systematic errors are quantified, six for the forward S-parameters and six for the reverse parameters. These are: Directivity, Source Match and Frequency Response for both Port 1 and Port 2 reflection signal paths; and Isolation (crosstalk), Load Match, and Frequency Response for the forward and reverse transmission signal paths. In order to accomplish error correction for a two-port DUT, all four DUT S-parameters must be measured.

The HP 8510B offers two calibration choices to achieve 2-Port error correction: **FULL 2-PORT** and **TRL 2-PORT**. Both of these calibration types use all 12 error terms and use the same accuracy enhancement mathematics to correct the measured data. The difference between them is the technique used to quantify the error terms. The FULL 2-PORT calibration uses Opens, Shorts, and Loads at each port in exactly the same way as the 1-Port calibration to measure reflection error terms, a thru to measure transmission tracking and load match, and an open transmission signal path to measure isolation. Since this calibration is the most commonly used and the standards are readily available, it is the procedure described in detail here.

The TRL 2-PORT calibration type uses multiple measurments of the thru connection, identical reflection standards at each port, and a transmission line of appropriate length and impedance to measure the error terms. If proper standards are available, this is the preferred technique due to fewer connections required and the potential for more accurate characterization of the error terms. More details of this new calibration procedure are contained in other documentation supplied with the HP 8510 system.

Select **FULL 2-PORT** from the Cal Type selection menu, then press **REFLECT'N**. The correct parameter for the calibration step is selected automatically. Proceed by connecting the calibration standards at Port 1 and pressing the **(S_{11}): OPEN, SHORT,** and **LOADS** keys as for the 1-Port calibration discussed above. Now connect the calibration standards at Port 2 and press the **(S_{22}): OPEN, SHORT,** and **LOADS** keys in turn. When all standards are measured, select **REFLECT'N DONE**.

Next select **TRANSMISSION**, connect the thru, and press each of the **FWD. TRANS.**, the **FWD. MATCH**, the **REV. TRANS.**, and the **REV. MATCH** softkeys in turn, then press **TRANS. DONE**.

On the Isolation menu, choose **OMIT ISOLATION** except when you are measuring devices with very high insertion loss. For high dynamic range measurements, connect loads to Port 1 and Port 2, choose an averaging factor of 10 or greater (use **RESUME CAL** on the Cal Menu) and select **FWD. ISOL'N** then **REV. ISOL'N**.

What is a Cal Set?

A cal set contains the error coefficients for each frequency measured during the calibration sequence. After correction is turned on, the measurement at each frequency is used with the error coefficient(s) for that frequency in the error model equation to obtain and plot the corrected value.

- **Parameter(s)**
- **Frequency Range**
- **Number of Points**
- **Source Power**
- **Sweep Time**
- **Power Slope**
- **Ramp/Step/Single Point**
- **Trim Sweep**

Along with the error coefficients, a cal set also contains a subset of the complete instrument state that includes important instrument settings used for the calibration. The contents of this "Cal Set Limited Instrument State" are listed here.

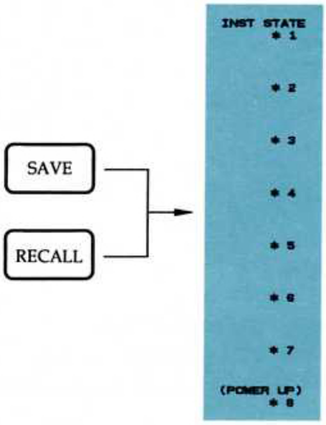
If one of the instrument settings in the cal set limited instrument state is changed, the HP 8510 either displays a caution message and turns correction off, or simply displays a caution message. Note that some instrument changes to the instrument state make the cal set invalid, such as changing the frequency range or number of points. Other changes do not cause correction to be turned off but leave it to the user to decide whether or not the corrected data remains valid.

Also note that turning on correction automatically recalls the cal set limited instrument state, placing the HP 8510 in the same configuration as during the measurement calibration. To see this feature operate, change the Start and Stop frequencies for the current cal set. The message is displayed and correction is turned off. Now press CAL, CORRECTION ON, then specify the previous cal set. Note that the sweep frequencies are changed back to those which apply to the specific cal set. This feature makes it possible to calibrate several different frequency ranges, then when measuring the device, change frequency ranges by simply selecting a different cal set.

CAL SET RULES

Parameter(s)	Will not turn on if parameter not included. Turns off if new parameter selection not included.
Frequency Range Number of Points	Turns correction off if changed.
Source Power Sweep Time Power Slope Ramp/Step/Single Point Trim Sweep	CAUTION: CORRECTION MAY BE INVALID. Displayed if changed.

Step 5. Save Instrument State



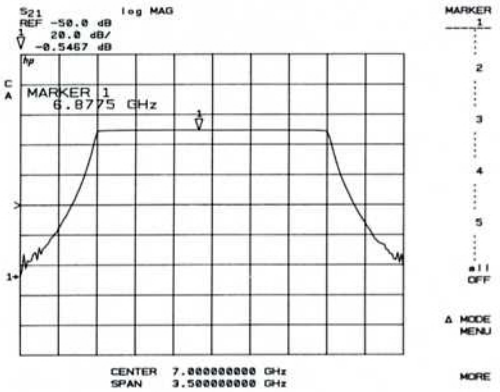
Press SAVE, then select one of the eight instrument state registers to save the current instrument state. All control settings, including the P/F/R limited instrument state for each channel, are saved. Please note that the contents of the cal set are not saved, only the reference to any cal sets that are turned on.

Press RECALL, then select one of the eight instrument state registers to recall a previously saved instrument state. If the recalled instrument state was saved with cal sets turned on, then the HP 8510 will attempt to turn on the cal sets so that corrected measurements are displayed. If the current instrument state is different from the cal set limited instrument state, then correction will not be turned on.

Step 6. Measure Device Under Test

After the test setup is calibrated, connect the device under test and make your measurements. Chapters 2 and 3 give examples of various reflection and transmission measurements.

Step 7. Read Measured Value



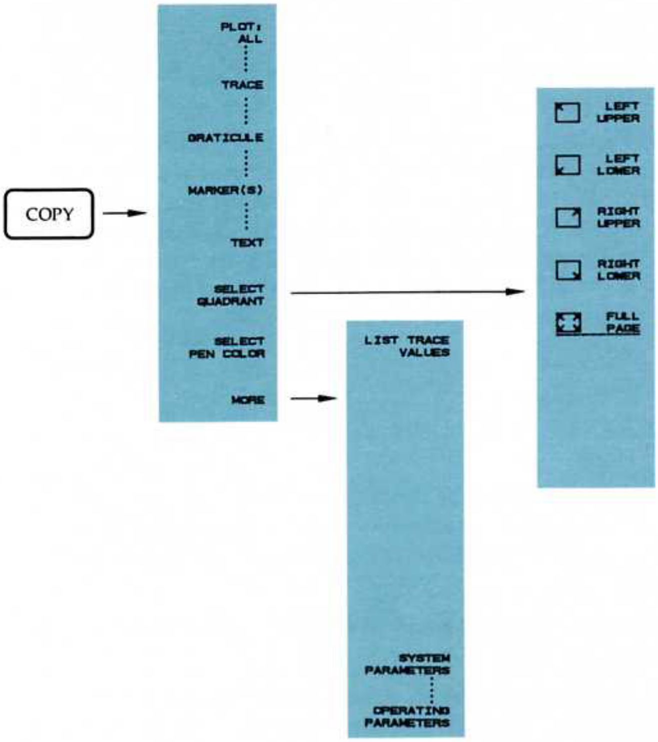
Use the measurement markers to read the trace value at any point on the trace.

The measurement markers are controlled using the MARKER key, the Marker menu structure, and the knob or numeric entries. Pressing the MARKER hardkey turns on one of the markers (actually the last selected marker or, after Preset, Marker 1) and also displays the Marker menu.

The current stimulus value for the marker is displayed in the active entry area of the CRT, and the trace value, in the units of the current format is displayed in the Channel Identification area of the CRT directly under the scale/division annotation.

Note that the Marker menu has softkeys for each of the five measurement markers. The current active marker number is underlined. When you turn on another marker, it becomes the active marker, the previous marker inverts but does not disappear from the screen. To clear the markers from the trace, press ALL OFF.

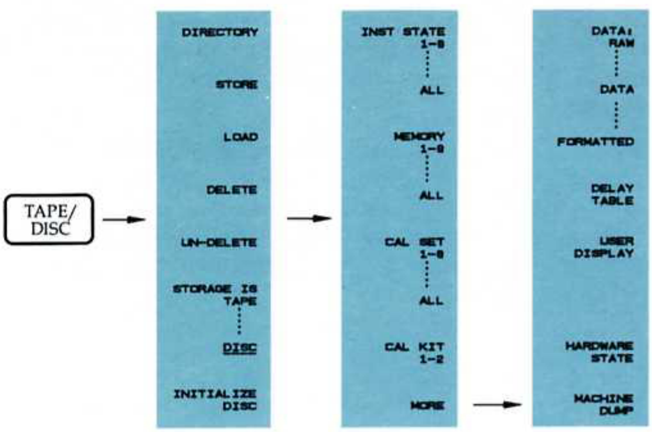
Step 8. Output Measurement Results



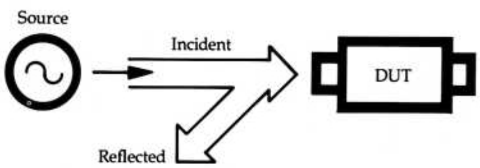
Measurement results can be output to a digital plotter, as a printed tabular list to a printer, to disc-type mass storage on the system bus, or to the HP 8510 front panel cartridge tape.

Output to Plotter. To output the current CRT presentation to a plotter, press COPY then PLOT: ALL. The complete CRT presentation except for the menu will be plotted. Press SELECT QUADRANT to select output of the plot to a specific quadrant of the page, or use the full page.

Output to Printer. The trace value at each measurement frequency for the current parameter in units of the current selected format is output in tabular form as shown here. You may want to switch to 51 points before you try this feature. Press COPY, MORE, LIST TRACE VALUES.



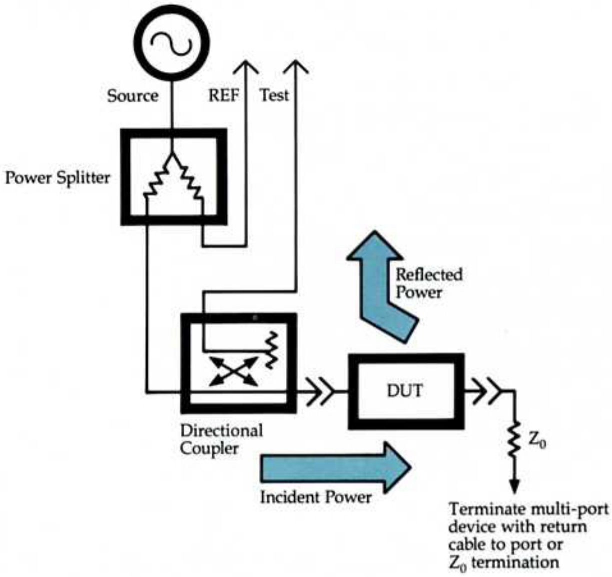
The TAPE/DISC hardkey is used to select output to a disc-type mass storage device on the 8510 system bus or the 8510 tape cartridge. Press TAPE/DISC then select either USE TAPE or USE DISC to select the output device, press STORE and specify the type of file to be recorded, then specify the file to receive the data. To load previously recorded data from storage into HP 8510 memory, press LOAD then specify the file type and file.



Chapter 2
Reflection Measurements

The next three chapters of this User's Guide demonstrate the many kinds of network measurements that can be made with the HP 8510B. For each example a complete measurement setup is given, following the same general measurement sequence described in Chapter 1. The examples used represent typical network measurements using an S-parameter test set. The DUT used in most of these examples is a bandpass filter. For simplicity while learning the instrument, connect 7mm adapters to your device and consider the adapters as part of the device.

The following paragraphs describe reflection measurements of Return Loss, SWR, Reflection Coefficient, and Impedance.



Basic Setup. Reflection measurements require a directional device, such as a directional coupler or directional bridge, in the measurement setup. This signal separator provides a sample of the power traveling in one direction only. For reflection measurements it is connected as shown here allowing the power reflected from the device to be separated and measured independently of the incident power. The ratio of these two signals, the incident and the reflected, is the reflection coefficient of the DUT, or, when expressed in decibels, the Return Loss.

Multi-Port Devices. Reflection measurements involve only one port of a test device. When the device has more than one port, care must be taken to terminate the unused port(s) in their characteristic impedance. If this is not done, reflections off of the unused ports may appear at the test port causing measurement errors. With the S-parameter test set, measurement port 2 provides this termination

Measuring Return Loss

The signal reflected from the device is most often measured as a ratio with the incident signal and can be expressed as return loss or reflection coefficient. These measurements are mathematically expressed as:

$$\text{reflection coefficient} = \text{reflected/incident} = \Gamma = \rho\angle\varphi^\circ$$

(linear magnitude ratio and angle)

$$\text{Return Loss} = 20\log\rho$$

$$\text{SWR} = (1+\rho)/(1\text{-}\rho)$$

Thus, the reflection coefficient consists of a linear magnitude ratio and the angle of the reflected signal, Return Loss is the difference in dB between the reflected and the incident signal, and SWR is a computed value.

Setup

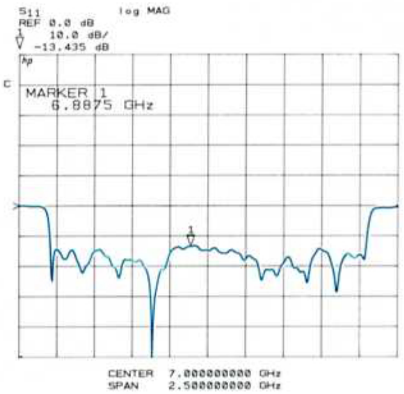
Stimulus **START/STOP** and
NUMBER of POINTS as required
Parameter S_{11}
Format **LOG MAG**
Response as required

Calibrate

CAL, CAL 1, CALIBRATE: RESPONSE,
Connect Short at Port 1.
SHORT, DONE RESPONSE, CAL SET 1.

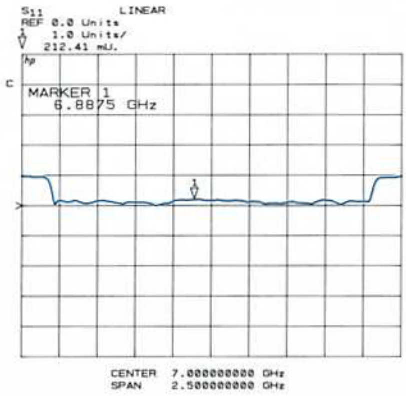
Measurement

Select **LOG MAG** to view the return loss and select **PHASE** to view the phase of the reflected signal. Select FORMAT **MENU, LINEAR MAGNITUDE** to view the reflection coefficient magnitude in linear units, and select **SWR** to view the standing wave ratio.



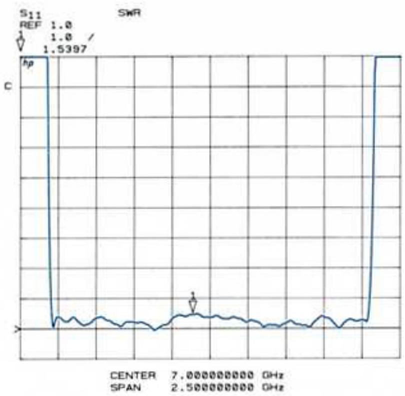
This figure shows the return loss of a filter in the **LOG MAG** format. A typical filter has a good match (large numerical) in the filter passband and a poor match (near 0 dB) outside the passband. A large numerical value for return loss, for example −40 dB, corresponds to a small reflected signal (the reflected signal is 40 dB below the incident signal) just as a large value for insertion loss corresponds to a small transmitted signal.

Measuring Reflection Coefficient Magnitude



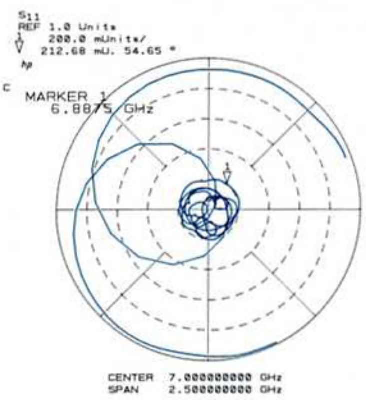
This figure shows the reflected signal viewed using the LINEAR MAGNITUDE cartesian format. In this format a reflection coefficient of 1.00 means that 100 percent of the signal is reflected. Inside the passband a value of 0.7 means that 70 percent of the signal is reflected.

Measuring SWR



This figure shows the reflection measurement in terms of standing wave ratio, a unitless ratio. SWR equal to one means that none of the incident signal is reflected.

Measuring S-Parameters



The S-parameters are measured in exactly the same way as described above. An S-parameter is always a complex coefficient consisting of a linear magnitude ratio and a phase angle, defined with the DUT embedded in a known characteristic impedance, usually 50 ohms. These figures show the reflection measurement viewed using the LIN mkr on POLAR format. The marker reads out the S-parameter directly.

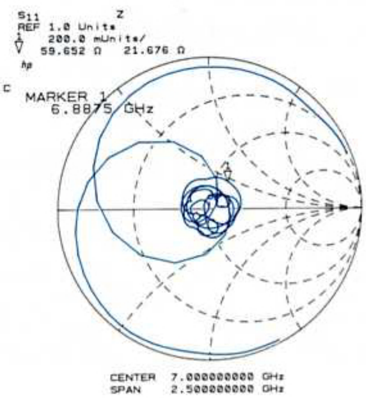
The center of the circle represents a reflection coefficient magnitude of zero, no reflected signal, meaning that the device input exhibits a perfect match and all energy is transferred into the device. The outermost circle represents unity reflection, meaning that all incident energy is reflected. The radial lines show phase angle with the 3 o'clock position corresponding to 0 degrees, that is the reflected signal has the exact same phase angle as the incident signal.

Measuring Impedance

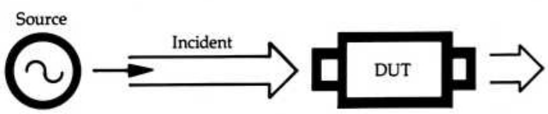
The amount of power reflected from a device is directly related to the impedances of the device under test and the impedance of the port which delivers the incident energy. In fact, each value of the reflection coefficient uniquely defines a device impedance; $\Gamma = 0$ only occurs when the device and the test set impedance are exactly the same. The ideal short circuit has a reflection coefficient of $1\angle \pm 180°$. Every other value for Γ also corresponds uniquely to a complex device impedance according to the equation:

$$Z_n = (1 + \Gamma) / (1 - \Gamma)$$

where Z_n is the device impedance normalized to (i.e. divided by) the measuring system characteristic impedance. After Preset, the system characteristic impedance, Z_0, is set to 50 ohms. Thus, the center of the Smith chart is 50 ohms. When you select **SMITH CHART**, the current system Z_0 is the center of the chart and the marker reads the impedance data in $R \pm jX$ format where R is the resistive component of the impedance and jX is the reactive component of the impedance.



This display shows the complex impedance of the DUT. Select **MARKER**, then use the knob to read the complex impedance at any point on the trace. Note that the marker annotation tells that the complex impedance is capacitive in the bottom half of the chart and inductive in the top half of the chart.



Chapter 3
Transmission Measurements

The reflection measurements discussed in Chapter 2 are only part of the network measurements picture. Measuring the transmission insertion loss and phase characteristics completes the device characterization, and provides a basis for computing parameters such as electrical length and group delay.

The following paragraphs describe transmission measurements of insertion loss, insertion phase, electrical length and group delay.

Measuring Insertion Loss and Gain

Insertion Loss and Gain are ratios of the output signal to the input signal. When set up as shown below, the results can be read directly in decibels.

Setup

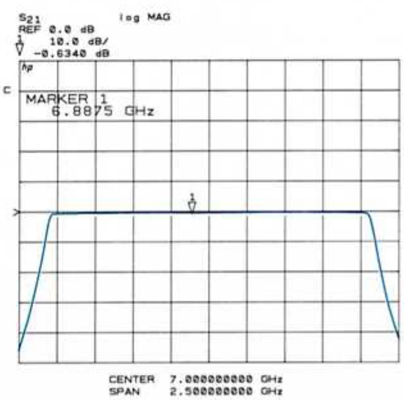
Stimulus START/STOP and
NUMBER of POINTS as required
Parameter S_{21}
Format LOG MAG
Response REF POSN, 10, x1

Calibrate

CAL, CAL 1, CALIBRATE: RESPONSE,
Connect Thru
THRU, DONE RESPONSE, CAL SET 1.

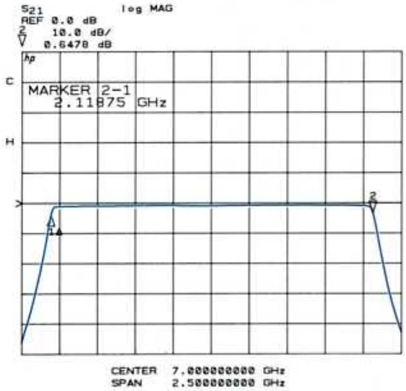
Measurement

Connect test device
MARKER, then position measurement marker to read magnitude ratio.



Calibration for insertion loss and gain sets the magnitude ratio to zero dB at all frequency points with the thru connection. After connecting the test device, a negative measured value indicates loss; a positive measured value indicates gain. This figure shows the insertion loss of a bandpass filter.

3 dB Bandwidth

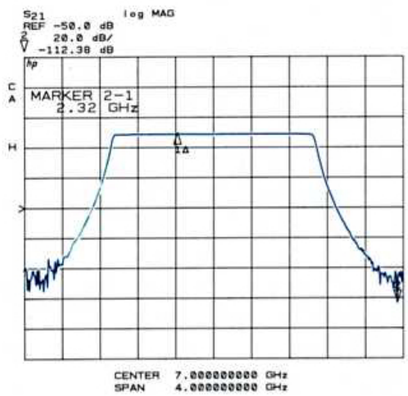


The marker search functions can be used to read the 3 dB bandwidth as follows:

STIMULUS MENU, MORE, HOLD.
MARKER,
MARKER 1, MORE, MARKER to MAXIMUM,
PRIOR MENU,
MARKER 2, MORE, MARKER to MAXIMUM,
PRIOR MENU,
Δ MODE MENU, Δ REF=1, MORE,
TARGET VALUE, −3, x1, MARKER to TARGET,
PRIOR MENU,
MARKER 1, MORE, SEARCH LEFT, PRIOR MENU,
MARKER 2.

The markers are now at the −3 dB frequencies and the 3 dB bandwidth is displayed in the active function area.

Out-of-Band Rejection

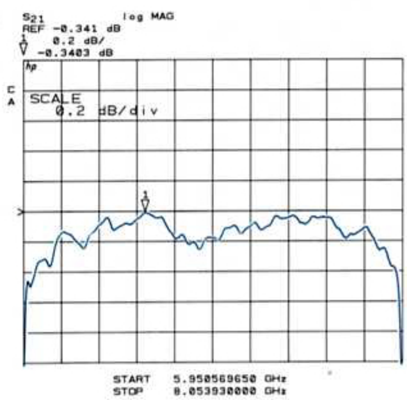


The wide dynamic range of the HP 8510B allows it to measure stopband rejection over 100 dB below the passband response. Maximum dynamic range requires proper selection of input power level.

MARKER, MARKER 1, MORE, MARKER to MAXIMUM,
PRIOR MENU,
Δ MODE MENU, Δ REF = 1,
MARKER 2, MORE, MARKER to MINIMUM.

The marker automatically moves to the minimum point on the trace.

Passband Flatness

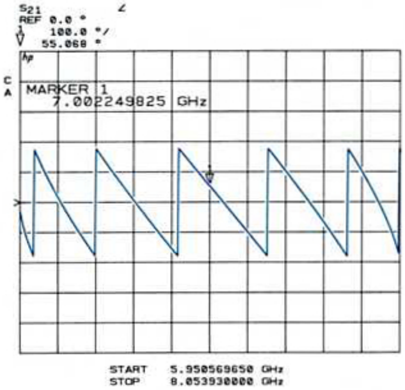


To measure passband flatness at high resolution, select:

MARKER, MORE, MARKER to MAXIMUM,
REF POSN, 5, x1,
REF VALUE, = MARKER, SCALE, 0.01, x1.

The trace is moved to the center graticule then the scale/division is set to view the passband flatness at high resolution.

Measuring Insertion Phase



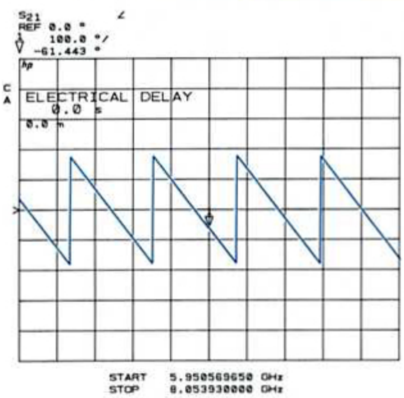
The ratio measurement can also provide information about the phase shift, or insertion phase, of a network.

Since measurement calibration for any parameter applies to all format selections for that parameter, unless the frequency range is changed, this measurement can be made using the previous calibration.

Calibration for insertion phase sets the phase to zero degrees at all frequency points with the thru connection. After connecting the test device, select **PHASE** to display the relative phase shift between the output signal and the input signal.

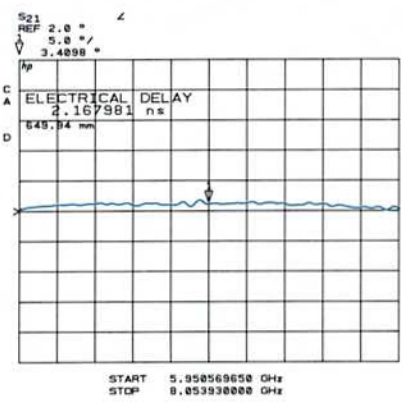
This figure shows the insertion phase of a bandpass filter. The HP 8510 phase measurement range is −180 degrees to +180 degrees, and the vertical trace represents the transition between these values. Thus, the trace between any two of these transition lines represents 360 degrees of phase shift.

Measuring Electrical Length



The HP 8510 electronically implements a function similar to the mechanical "line stretcher" of earlier analyzers. This feature simulates a variable length lossless transmission line, which is effectively added to or removed from the reference signal path to compensate for electrical length in the test signal path.

This feature can be used to easily determine the electrical length of the test device. After measurement calibration, insert the test device, a cable in this example, and select PHASE. Now press **RESPONSE MENU**, and press **ELECTRICAL DELAY**.



Now use the knob or numeric entry to add electrical delay with the objective of flattening the trace to zero degrees at all frequency points. When the phase trace is flat, the active function shows the electrical length of the test device relative to the speed of light in free space.

Thus, the physical length of the device is related to this value by the propagation velocity in the medium of the device.

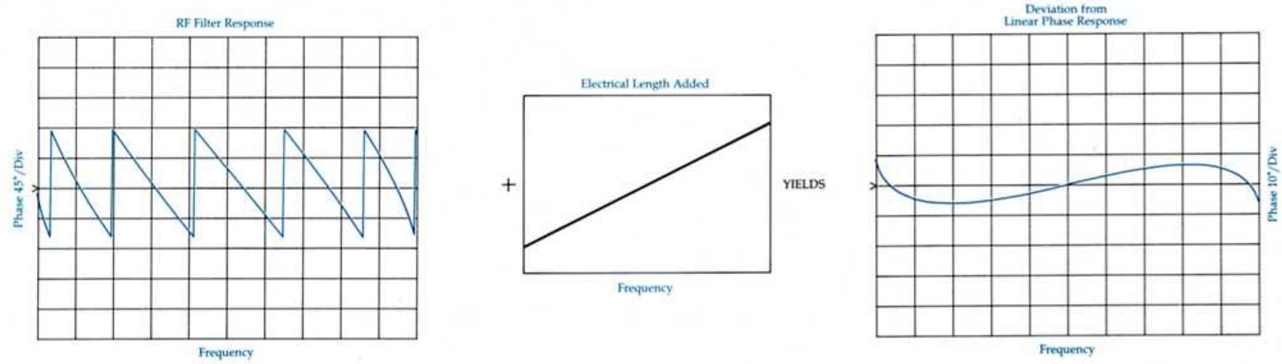
Measuring Phase Distortion

For many networks, the amount of insertion phase is not nearly as important as the linearity of the phase shift over a frequency range of special interest, such as the passband of a filter. The HP 8510 can measure this linearity and express it in two different ways: directly, as deviation from linear phase, or as group delay, a derived value.

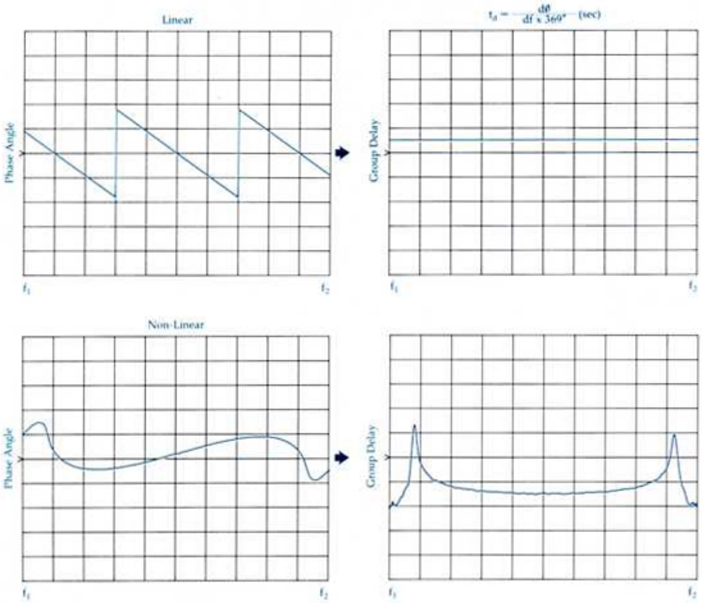
Deviation from Linear Phase. Measuring deviation from linear phase is an alternative made possible by the range of the electronic line stretcher. Insertion phase consists of two components, linear and non-linear. Deviation from linear phase is a measure of the non-linear component of insertion phase. By compensating for the linear insertion phase, using the electrical delay controls, the deviation from linear phase over the frequency sweep can be measured directly.

Compared to group delay, deviation from linear phase is a fundamental measurement because delay is the derivative of phase change with frequency. Also, greater phase sensitivity allows a greater dynamic range than group delay measurements, and deviation from linear phase will produce greater detail in areas where the phase response changes rapidly over a small frequency range.

This figure shows how introducing linear insertion phase using electrical delay allows determination of non-linear insertion phase. You may change the scale/division to view the phase response at very high resolution.



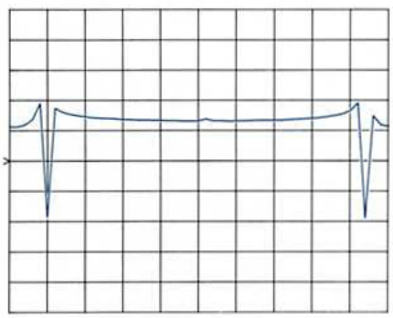
If the network exhibits large phase changes with frequency, reduce the sweep and recalibrate before making the measurement. This measurement shows the phase response between the 3 dB points. Even if the network must be specified in terms of group delay, the deviation from linear phase measurement serves as a good check of the actual phase response. Using the dual channel capability, press STIMULUS MENU, DUAL CHANNEL, SPLIT, then compare deviation from linear phase with the group delay measurement described next.



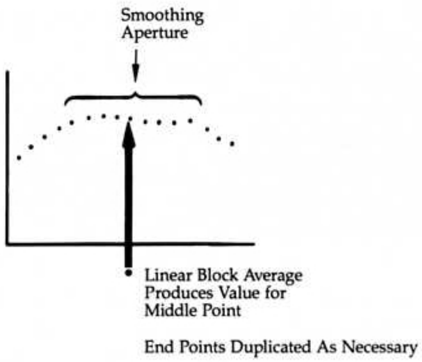
Group Delay. The phase linearity of many devices is specified in terms of group or envelope delay. This is especially true of telecommunications components and systems. After calibration, select **DELAY** to view the group delay of the DUT.

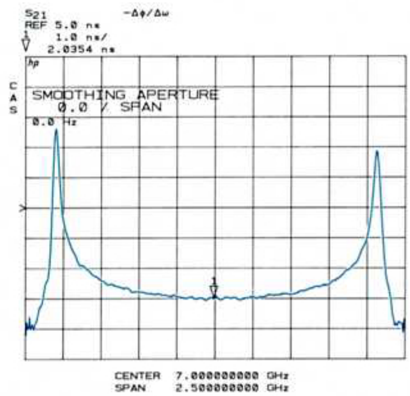
A device with no phase distortion presents a linear phase characteristic. The group delay will thus appear as a flat line. This figure shows that the group delay varies as a function of frequency when the test device exhibits deviation from linear phase.

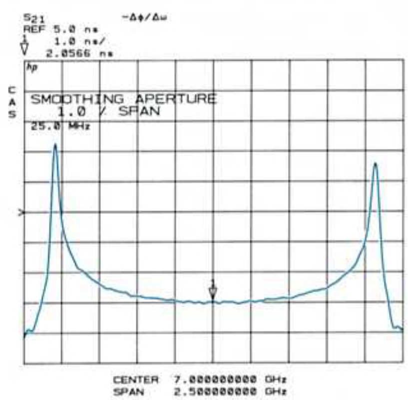
Thus, group delay is the transit time through the DUT as a function of frequency. Mathematically it is the derivative of the phase response with respect to frequency, where $\Delta\varphi$ is the difference in phase at two frequencies separated by Δf. The quantity Δf is commonly called the "aperture" of the measurement.



The minimum aperture is the frequency step between the phase measurements and you must choose this aperture when you set the frequency range and number of points so that there is no more that 180 degrees of phase shift between any of the frequency points. If there is more than 180 degrees of phase shift, the group delay trace will show a sudden discontinuity.

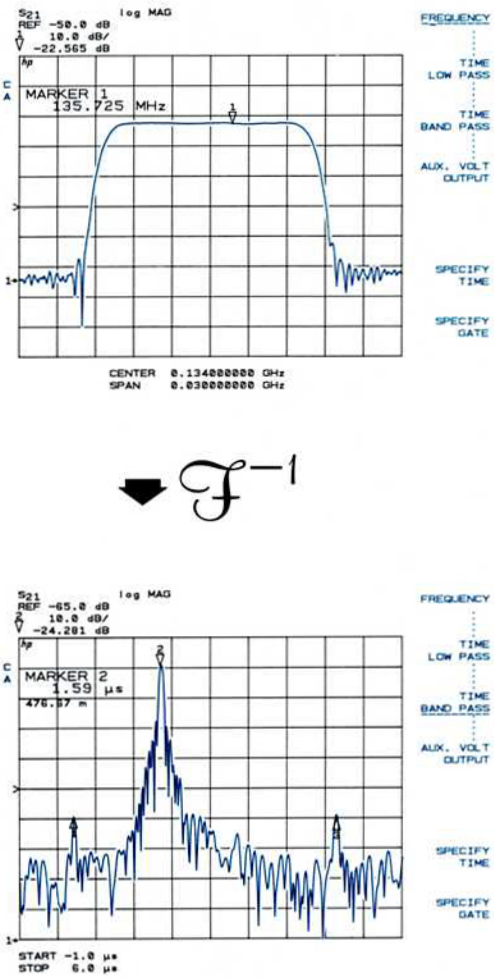






After selecting the minimum aperture, you may increase the effective aperture of the measurement using the smoothing function. Press RESPONSE **MENU**, then **SMOOTHING**, then use the knob or numeric entry to set the effective aperture. Note that increasing the aperture smooths the group delay trace as the aperture is increased, removing fine grain variations form the response. This is why, when comparing group delay measurements, the aperture must be specified.

Chapter 4
Time Domain Measurements



The HP 8510 with optional Time Domain analysis capability can display the time domain response of the DUT. Time domain analysis is useful for isolating a problem in the DUT in time or in distance. Time and distance are related by the speed of light and the relative velocity of propagation in the medium of the DUT. The HP 8510 measures the transmission or reflection frequency response of the DUT and uses an inverse Fourier transform to convert the data to the time domain.

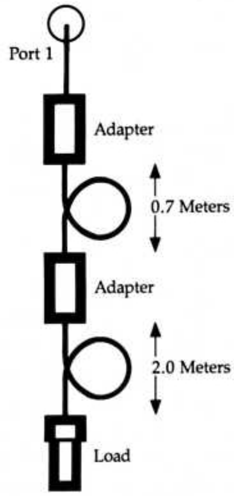
To begin familiarizing yourself with the time domain controls, press the **DOMAIN** hardkey and look at the Domain menu. The two keys of interest here are the **TIME LOW PASS** key and the **TIME BAND PASS** key. These keys select two different time domain modes and there are several considerations for use of each mode, but the simple guideline is to use **TIME LOW PASS** for devices which have DC responses (or at least down to about 100 MHz), and use **TIME BAND PASS** for devices which are band limited. For example, when measuring a coaxial cable, the Low Pass mode is probably the best choice. When measuring a filter, the Band Pass mode is probably better. If you use Time Low Pass for a device which does not have sufficient low end frequency response, the measurement will be very noisy.

Since the frequency domain data is used to develop the time domain response, the first step is to perform an appropriate measurement calibration.

If you are using Time Low Pass, press the **SET FREQ LOW PASS** key (on the Cal menu, and also appears after pressing **TIME LOW PASS**) before beginning the calibration–this sets the start and stop frequencies to meet the special requirements of the Time Low Pass mode.

As examples, we first use time domain analysis to locate points of reflection (e.g. at connectors and bends along a transmission line), then to separate the individual transmission paths (e.g. main path, leakage and triple travel path) through a surface acoustic wave (SAW) filter.

Reflection Measurements



The time domain response of a reflection measurement is often compared with the familiar time domain reflectometry (TDR) measurements. Like the TDR measurement, it measures the size of the reflections versus time (or distance). Unlike the TDR, the HP 8510 time domain capability allows you to choose the frequency range over which you would like to make the measurement, and it can measure devices which do not have a DC response. Also, with its "Gating" capability, the HP 8510 time domain lets you perform "what if" analysis by mathematically removing selected reflections and seeing the effect back in the frequency domain.

The test device is a pair of test cables, connected by one or two adapters to make things interesting, as shown in the figure. Terminate the end of the cable with a fixed load. Proceed as follows to measure this device.

Setup

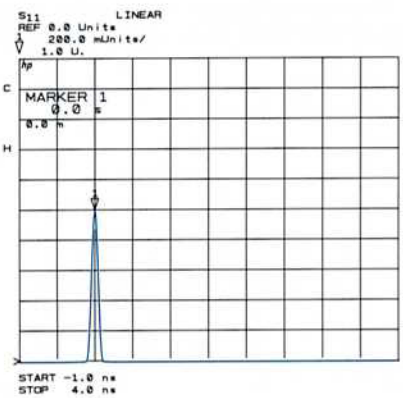
Stimulus START/STOP and
NUMBER of POINTS as required
Parameter S_{11}
Format LOG MAG
Response as required

Calibrate

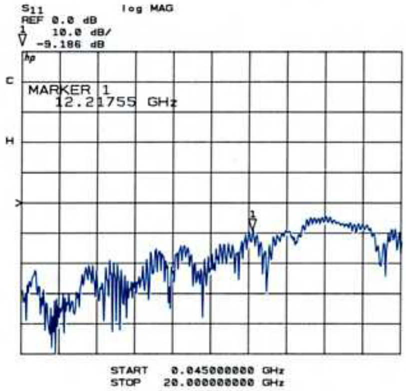
CAL, CAL 1, CALIBRATE: RESPONSE,
Connect Short at Port 1.
SHORT, DONE RESPONSE, CAL SET 1.

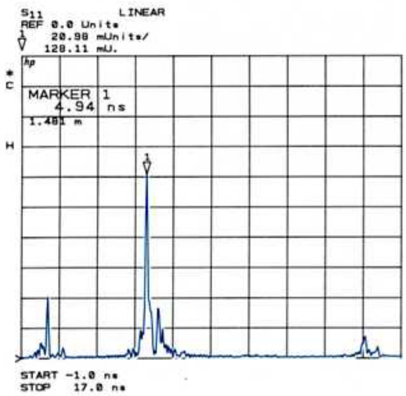
Measurement

The Time Low Pass impulse mode is most similar to the TDR presentation but we are using the Time Band Pass mode in this example because it is simpler. Refer to the Time Domain Measurements section of the HP 8510 Operating and Programming manual for a complete description of all of the time domain operating modes and features.



After calibration, with the short circuit still connected, press DOMAIN, then TIME BAND PASS. Measurement calibration with a short circuit sets the reference plane, the point at which the short was connected, to a reflection coefficient of 1 and ±180 degrees at zero seconds. The time domain response should show a response of 1.00 at zero seconds.





Now connect the cables. These figures show the frequency domain response and the time domain response of the cables under test. The complex ripple pattern in the frequency domain is caused by reflections from the adapters interacting with each other. By transforming this data to the time domain, you can determine the magnitude of the reflections versus distance along the cable.

As an experiment, loosen the adapters connecting the two cables and observe the responses. You can change the start and stop time using the STIMULUS **START** and **STOP** controls. Please note that as you switch between the time and frequency domains, the Format and Response settings are preserved.

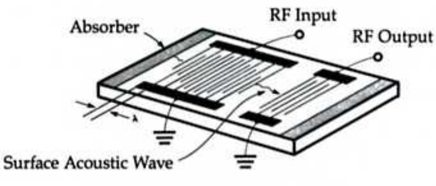
A good rule of thumb is that the energy travels about 1 foot per nanosecond, or 0.3 meter per nanosecond, in free space. Since most cables have a relative velocity of about 2/3 the propagation velocity in free space, and since you are measuring the round trip distance, from the test port to the reflection and back to the test port, you can figure about 3 nanoseconds per foot, or 10 nanoseconds per meter as the propagation velocity in the cable. Thus, to view an entire cable of about four feet in length, enter a stop time of about 40 nanoseconds (**START**, **4**, **G/n**).

Transmission Measurements

In this example, we will measure the transmission response of a SAW filter. We will use the Time Band Pass mode, not because it is simpler, but because the DUT is band limited.

Setup

Stimulus **START/STOP** and
NUMBER of POINTS as required
Parameter S_{21}
Format **LOG MAG**
Response

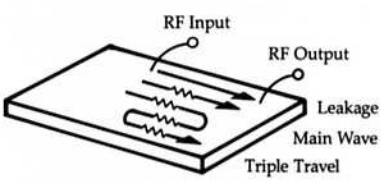


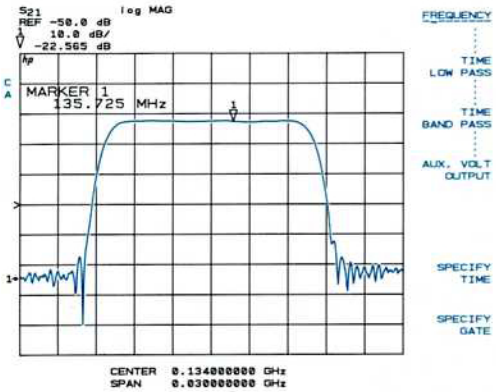
Calibrate

CAL, CAL 1, CALIBRATE: RESPONSE,
Connect Thru (connect Port 1 and Port 2 together)
THRU, DONE RESPONSE, CAL SET 1.

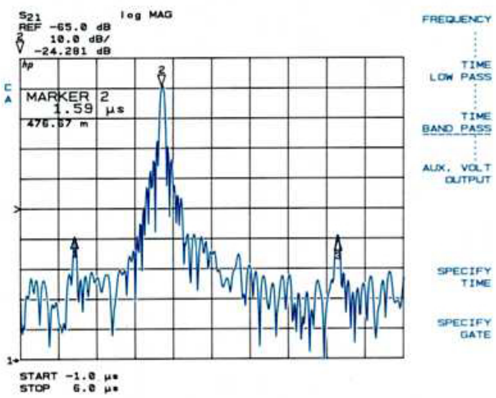
Measurement

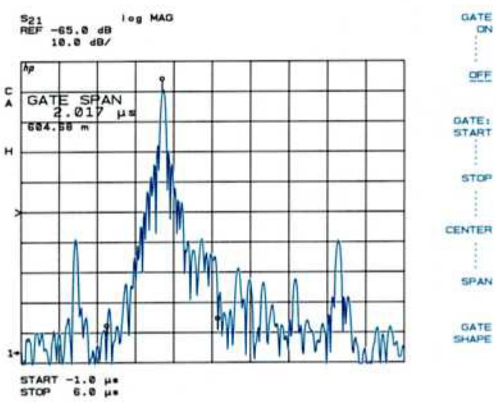
After calibration, with the thru still connected, press **DOMAIN**, then **TIME BAND PASS**. Measurement calibration with a thru sets the reference plane, the point connecting Port 1 and Port 2, to a transmission coefficient of 1 and 0 degrees at zero seconds. The time domain response should show a response of 1.00 at zero seconds.



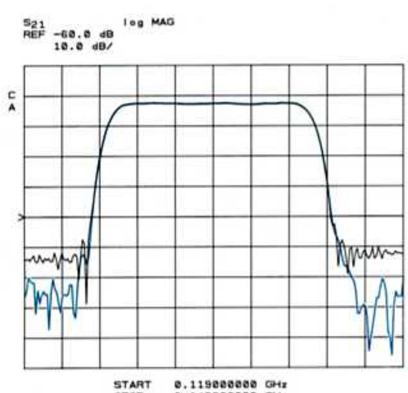


Now connect the SAW filter. These figures show the frequency domain response and the time domain response of this device. Note the three components of the transmission time domain response: RF leakage, at near zero time, the main travel path through the device (about 1.6 microseconds), and the "triple travel" path (about 4.5 microseconds travel time). Each of these signal paths is illustrated in the drawing.





Time Domain Gating. Time domain analysis also lets you remove individual parts of the time domain response to see the effect of potential design changes. We do this by mathematically "gating" out the undesired responses. In this example we see the effect of removing the leakage and triple travel responses using the gating feature. On the Domain menu, press **SPECIFY GATE**, then press **GATE CENTER** and use the knob to center the gate on the main path response. Now turn on gating by pressing **GATE ON**. Only the responses inside the gate are retained. Return to the frequency domain and see that this design change would yield better out-of-band rejection for this device.



Standard Preset State

Instrument State
Selected Channel = 1, no menu displayed
SAVE/RECALL Instrument States 1 through 8 not changed

Stimulus
Maximum sweep range of source and test set
NUMBER OF POINTS = 201
Source power = +10 dBm
Test set attenuation = 0 dB
SWEEP TIME = 100 ms
RAMP SWEEP, CONTINUAL
Coupled channels

Parameter
Channel 1 = S_{11}
Channel 2 = S_{21}

Format
Channel 1 = LOG MAG
Channel 2 = LOG MAG

Response
SCALE = 10 dB/division
REF VALUE = 0 dB
REF POSN = 5
ELECTRICAL DELAY = 0 seconds
AVERAGING = OFF
SMOOTHING = OFF
PHASE OFFSET = 0 degrees

Cal
CORRECTION OFF
Z_0 = 50 ohms
PORT EXTENSIONS 1 and 2 = 0s
TRIM SWEEP = 0
CAL SETS 1 through 8 = not changed

Domain
FREQUENCY DOMAIN
GATE OFF

Display
SINGLE CHANNEL, DATA
Trace Memories 1 through 4 not changed

Marker
all OFF
Δ OFF

System
HP-IB addresses not changed
CRT ON
IF GAIN = AUTO

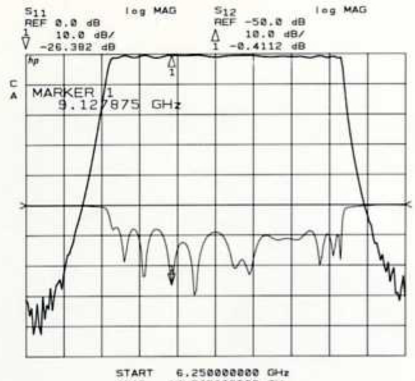
Copy
PLOT ALL = FULL PAGE
Channel 1 = Pen 1
Channel 2 = Pen 2


INTENSITY
DISPLAY/PROCESSOR
ENTRY
TAPE
ENTRY OFF
7
8
9
G/n
FOCUS
4
5
6
M/μ
ALIGN
1
2
3
k/m
TEST
STEP
0
.
+/-
x1
PRIOR MENU
BACKSPACE
=MARKER
STIMULUS
PARAMETER
FORMAT
RESPONSE
START
STOP
LOG MAG
PHASE
SCALE
AUTO
CENTER
SPAN
DELAY
SMITH CHART
REF VALUE
REF POSN
MENU
MENU
MENU
MENU
AUXILIARY MENUS
MEASUREMENT
PRESET
COPY
TAPE
SYSTEM
RESTART

Measurement Enhancements

The HP 8510 network analyzer provides many features that add to convenience and accuracy. The following paragraphs describe three of these features.

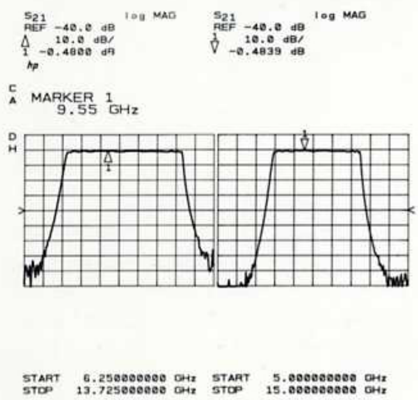
Dual Channel Overlay and Split



The HP 8510 can display two measurements simultaneously. Press the **DISPLAY** hardkey to present the Display menu, then press **DUAL CHANNEL**. Next press either **OVERLAY** or **SPLIT**. Notice that the Channel Identification annotations for both channel 1 and Channel 2 are displayed. To make changes in the control settings of a channel, first select the channel by pressing either **CHANNEL 1** or **CHANNEL 2**, then make the change.

As you make changes to the instrument state using the front panel hardkeys and softkeys, notice that some settings are Coupled, meaning that the setting always applies to both channels. An example of a function that is always coupled is Number of Points, on the Stimulus menu. Other functions are selected independently for each channel so are called Uncoupled functions. An example of a function that is always uncoupled is Averaging, on the Response menu.

Coupled and Uncoupled Channels



There is a subset of the coupled functions which may be uncoupled using the **UNCOUPLED CHANNELS** softkey on the first level Stimulus menu. These are generally stimulus-related. The Start and the Stop values of the frequency sweep are examples of functions which may be uncoupled.

To apply this to your measurement, first select STIMULUS **MENU, UNCOUPLED CHANNELS, DISPLAY, DUAL CHANNEL, SPLIT**. For functions which are now uncoupled, select the Channel, then select the function and change its value. For example, measurement calibration now applies to only the current selected channel (indicator lighted).

Preset always selects Coupled Channels. If you switch from Uncoupled to Coupled, values of the current selected channel are used.

Frequency List

The Frequency List feature can be used to specify arbitrary frequency points for measurement. Pressing the **FREQUENCY LIST** softkey presents a menu structure that allow you to specify unrelated single frequencies or segments. For example, in the application where the same number of points are measured over adjacent octaves, use the following key sequence:

STIMULUS **MENU, MORE, EDIT LIST,**
ADD, START, 2, G/n, STOP, 4, G/n,
STEP SIZE, 100, M/µ, DONE,
ADD, START, 4, G/n, STOP, 8, G/n,
STEP SIZE, 200, M/µ, DONE,
DUPLICATE POINTS, DUPLICATES DELETED, DONE,
FREQUENCY LIST.

Now the analyzer will measure only these frequency points.

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