
**HP 8719C
HP 8720C
HP 8722A
Network Analyzers**

User's Guide

50 MHz to 13.5, 20, or 40 GHz

This document is intended to provide an introduction to the operation of the HP 8719C, HP 8720C, and HP 8722A network analyzers. It demonstrates many of the features and capabilities of the analyzers, providing actual operating sequences for common network measurements.

How to Use This Guide

To gain the most benefit from this guide, it is suggested that you proceed sequentially through the chapters. Each chapter builds upon the information presented in previous chapters. Once a specific measurement is stored in one of the internal registers (let's say, register 1), feel free to try out some of the other softkeys/features available. Selecting **[RECALL]** *[RECALL REG1]* will restore the previous measurement and allow you to continue with the measurement examples. An appendix is also included to provide more detailed information on additional topics.

To simplify the execution of the measurements, the keys to be selected are bracketed, capitalized and usually presented flush-right within the column. Front panel "hardkeys" are in bold and will be followed by one or more softkeys in *italics*. For example, **[CAL]** *[CALIBRATE MENU] [FULL 2-PORT]*, accesses the two-port calibration softkey menu. Sets of key sequences will often be preceded by a paragraph of text describing their function and providing any special instructions.

The equipment that is used in this guide is listed below. Notice that the bandpass filter used in almost every example, is provided with the analyzer to simplify configuring the measurements. The HP 8722A analyzer will also be shipped with two 2.4 to 3.5 mm adapters. When using 2.4 mm cables, such as the HP 85133E/F test port cables with the HP 8722A analyzer, use the adapters to convert the 3.5 mm bandpass filter to a 2.4 mm test device.

Equipment Used in this Guide¹

Description	HP Part/Model No.
Bandpass Filter (included with analyzer)	HP P/N 0955-0446
3.5 mm Calibration Kit	HP 85052B/D
3.5 mm Test Port Cables	HP 85131E/F
SMA (1 ft) Semi-Rigid Cable	HP P/N 08340-20123
With HP 8722A:	
2.4 to 3.5 mm Adapters (included with analyzer)	
2.4 mm Calibration Kit	HP 85056A/D/K
2.4 mm Test Port Cables	HP 85133E/F
3.5 mm Test Port Cables	HP 85134E/F

¹Other equipment may be substituted, but may require modifying the procedure.

Table of Contents

Chapter 1	Front Panel Tour	4
	General Measurement Sequence	
Chapter 2	Transmission Measurements	6
	Insertion Loss and Gain	
	3 dB Bandwidth	
	Passband Flatness	
	Out-of-band Rejection	
	Measuring Phase Response	
	Insertion Phase	
	Electrical Length	
	Phase Distortion	
	Deviation from Linear Phase	
	Group Delay	
Chapter 3	Reflection Measurements	12
	Return Loss	
	Reflection Coefficient	
	SWR	
	Simultaneous Magnitude/Phase Measurements	
	Impedance (using Smith charts)	
	Admittance	
Chapter 4	Time Domain Measurements	15
	Time Domain Reflection Measurements	
	Gating Time Domain Responses	
Chapter 5	Limit Lines for Device Evaluation	18
Appendix		19
	Calibration Tutorial	
	Optimizing Dynamic Range	
	Selecting Power Level	
	Reducing the Noise Floor	
	IF Bandwidth	
	Averaging	
	Creating a Frequency List	
	Setting Up External Peripherals	
	Using Dual-Channel Display	
	Uncoupled Channels	
	Function Index	

Chapter One

Front Panel Tour

Measurement
formation
channel
S-parameter
meas. type

Display
Settings

- scale
- ref position

Active
Entry Area

Active
Marker
Value

Marker
Statistics

- mean
- standard deviation
- peak-to-peak ripple
- shape factor

Response

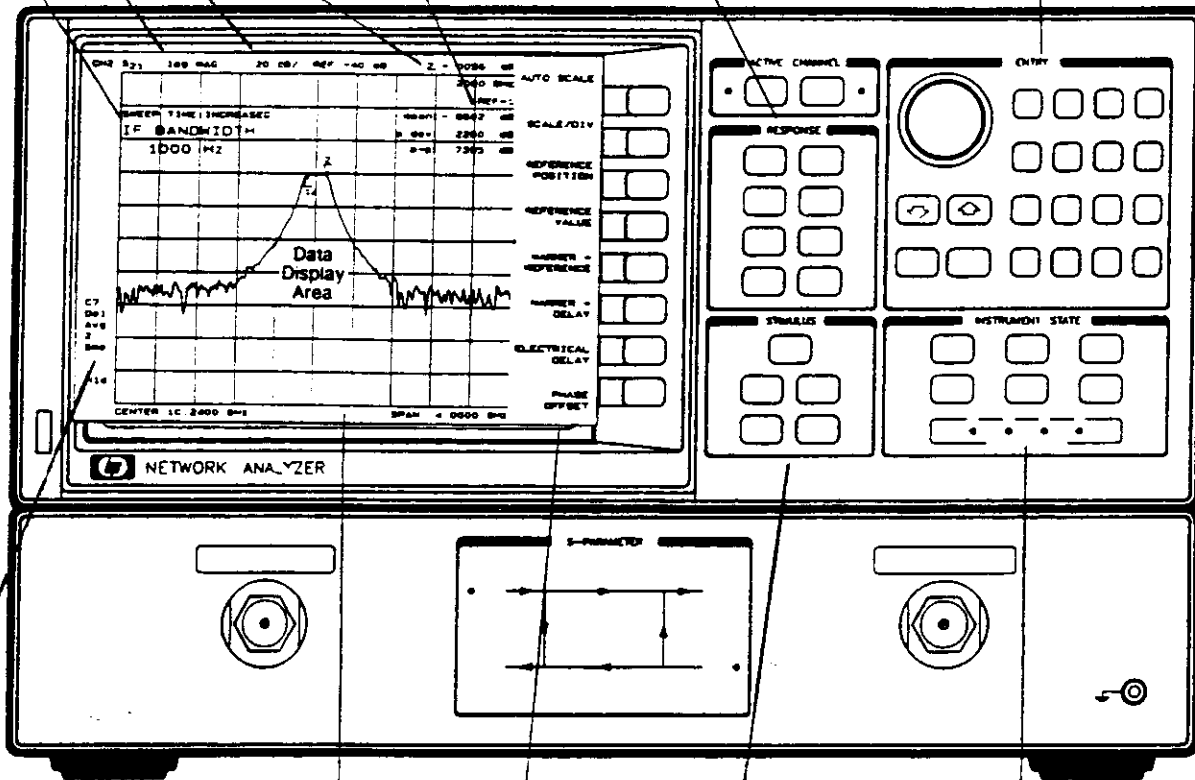
- [MEAS] meas. parameters
- [FORMAT] meas. format
- [SCALE REF] adjust display
- [DISPLAY] define traces
- [AVG] avg, smoothing, IF BW
- [CAL] setup calibration
- [MKR] single, delta markers
- [MKR FCTN] marker functions

Data Entry

Use the numeric keys with the appropriate terminator, the knob or step keys to enter a chosen parameter.

Data Entry Terminators

Key	G/n	M/u	k/m	x1
Freq	GHz	MHz	kHz	Hz
Power	-	-	-	dB(m)
Time	ns	us	ms	s



Units Notations
Parameter changed
Cal is on
Cal is may be invalid
2-port cal is on
2-port cal may be invalid
freeze trace
sweep indicator
waiting for ext. trigger
averaging is on
smoothing is on
electrical delay is on
gating is on
power meter cal on
test set hold

Frequency/ Time
Settings

Softkey Labels

Stimulus Functions
Defines and controls
source parameters.

Instrument State

This section provides control of channel-independent system functions.
[SYSTEM] access limit line, service, and time domain menus.
[LOCAL] define controller modes
[COPY] access printing and plotting functions
[SAVE] store or clear registers
[RECALL] recall measurement or factory preset
[USER PRESET] return the analyzer to a factory-defined or user-defined state

General Measurement Sequence

Factory preset conditions:

Sweep span	0.05 to 13.51 GHz (HP 8719C) 0.05 to 20.05 GHz (HP 8720C) 0.05 to 40.05 GHz (HP 8722A)
Power level	+10 dBm -20 dBm (HP 8722A)
No. of trace points	201
Sweep time	auto, 100 ms
Channel 1	S11, On
Channel 2	S21, Off
Format	Log Mag
Scale	10 dB/div
Reference value	0 dB

Even with the analyzer's wide range of capabilities, common measurements are easily set up with relatively few front panel selections. This section describes a general approach for performing network measurements. The following sequence is used throughout this document to illustrate the use of the analyzer in its various operating modes.

Preset

The factory preset returns the instrument to a known state, as shown in the table. The analyzer also has the capability of storing a user-defined preset. To define a user-preset condition, set up the desired measurement parameters and select [SAVE] [SAVE PRESETS]. Once defined, the analyzer will return to the specified measurement conditions every time [USER PRESET] is selected; then the factory preset can only be recalled by selecting [RECALL] [RECALL FAC PRESET].

To eliminate a "user preset," [SAVE]/[CLEAR REGISTER]/[CLEAR PRESETS] must be selected. Then the factory preset will be recalled every time [USER PRESET] is selected.

Setup

Measurement: Select a measurement parameter.

Format: Choose a display format.

Stimulus: Select the source parameters to meet the test requirements of the device under test (DUT).

Calibrate and Save

Calibrate the test system and store the data. System components such as test port cables, adapters, and components within the instrument itself, introduce systematic errors that can mask the actual performance of the DUT. A calibration should be performed at the measurement plane (the point where the DUT is connected to the test system). Calibrations use error-correction algorithms to improve measurement accuracy by removing the effects of repeatable systematic errors in the test system. Refer to *Calibration* in the appendix for more information on calibration types and their uses.

Connect and Measure

Connect the DUT with a single cable or cable set (see page 6), and adjust the display (scale) of the measurement data as desired.

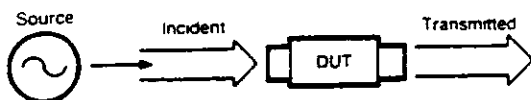
Store/Output Results

Store the results to a disk or output to a printer/plotter. See individual examples for different storage formats and *Setting Up External Peripherals* in the appendix.

Chapter Two Transmission Measurements

This chapter demonstrates how to make common transmission measurements. Modify the instrument setups shown to suit your particular needs.

Insertion Loss and Gain



Insertion loss and gain are the logarithmic ratios of transmitted-to-incident voltage through a two-port test device. Both measurements can be made with the same setup and calibration with the exception of gain measurements which may require lower input power levels to the test device. Select the keys on the right side of the column to setup the measurement. Notice that when a factory preset is performed, maximum output power (+10 or -20 dBm with the HP 8722A) is automatically selected.

Preset (factory)

[USER PRESET]

Setup

Measurement:

[MEAS]/Trans: FWD S21/

Format:

[FORMAT]/LOG MAG/

Stimulus:

[CENTER] 10.24 [G/n]

[SPAN] 4 [G/n]

[MENU]/POWER/[RANGE 1 -10 TO +10] 10 [x1]

[MENU]/NUMBER of POINTS/ 401 [x1]

CH1 S21 log MAG 10 dB/ REF 0 dB

The following information should now be displayed at the top of your screen.

Calibrate and Save

Since the test device has SMA connectors, the HP 85052B/D 3.5 mm cal kit should be used and selected.

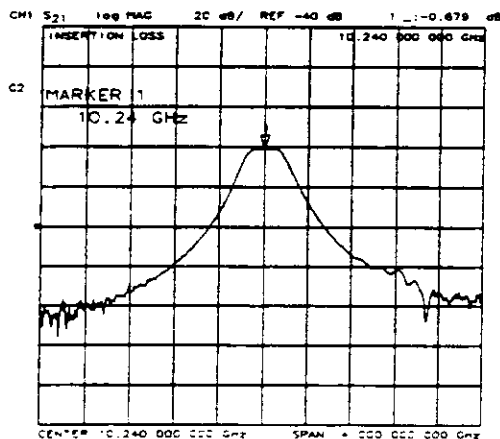
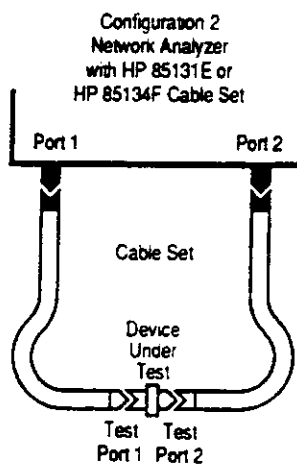
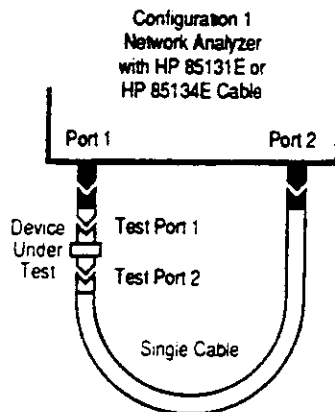
[CAL]/CAL KIT/[3.5 mm]/[RETURN]

To achieve the greatest accuracy, a full two-port calibration sequence is provided. Make sure that all cables and adapters included in the measurement are attached to the test set's measurement ports, so that their associated errors can be removed. Connect each calibration standard (open, short, and load), at the point where the DUT is attached to the test system, in the sequence presented below. Once a standard is attached, select the appropriate softkey, and the analyzer will underline it when the measurement is complete. Repeat this sequence until each standard has been measured at each test port.

[CALIBRATE MENU]/[FULL 2-PORT]
[REFLECTION]

Attach each standard to test port 1 and select its softkey

[S11: OPEN],[SHORT]
[LOADS]/[BROADBAND]/[DONE: LOADS]



Attach each standard to test port 2 and select its softkey

[S22: OPEN],[SHORT]
[LOADS][BROADBAND][DONE: LOADS]
[REFLECT'N DONE]

Connect thru (attach test ports to each other)

[TRANSMISSION]
[DO BOTH FWD + REV]

Complete and save the calibration

[ISOLATION][OMIT ISOLATION]
[DONE 2-PORT CAL]
[SAVE REG 1]

Upon completion of a two-port calibration "C2" will appear on the left side of your display. If the calibration is compromised by changing stimulus settings, the calibration will be turned off ("C2" disappears) or "C2?" may appear cautioning that something has changed that may affect the calibration data.

Connect and Measure

Following a two-port calibration, connect the test device (using either configuration) and select [MEAS] or [MEASURE RESTART] to update the forward and reverse S-parameter data. To maximize the life of the internal electro-mechanical switch, it is assumed that the reverse parameters do not change appreciably, thus only the forward parameters are measured from sweep-to-sweep. When a new device is measured, or data changes significantly, it is recommended to remeasure all four S-parameters by selecting the [MEAS] key.

Adjust the display (scale) of the measurement data as desired. Set the marker in the center of the display (passband) to measure insertion loss. The marker value is displayed in the upper right corner of the CRT. The front panel knob may also be used to move the marker along the trace. The analyzer should now display the complete transmission response of the bandpass filter, as shown in the adjacent figure.

Update S-parameter data

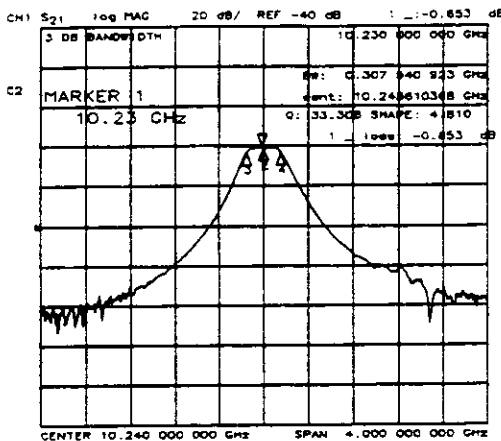
[MEAS]
[SCALE REF][AUTO SCALE]
[MKR]/[MARKER 1] 10.24 [G/n]

Read insertion loss from marker value

Store/Output Results: Plotting

Before proceeding, make sure the analyzer and plotter are properly set up (see appendix). Selecting [COPY] then [PLOT], will plot everything currently displayed, except for the softkey menu. The [DEFINE PLOT] softkey gives users the option of plotting only specific parameters (i.e., [PLOT DATA] ..). Plots can also be customized by adding a descriptive title, selecting the plotter pens, or positioning up to four plots per page.

3 dB Bandwidth

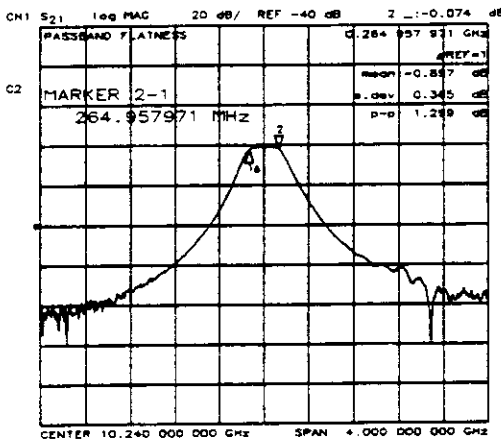


The marker search function can quickly locate a specific amplitude on a trace or a specific bandwidth (i.e., 3 dB or 6 dB). In this example, marker 1 is moved to the highest point on the trace and established as the reference. Then, the -3 dB bandwidth, Q, and shape factor are determined relative to marker 1.

[MKR]/[MARKER 1]
[MKR FCTN]/[SEARCH: MAX]
[BANDWIDTH MENU]
[BANDWIDTH VALUE] -3 [x1]
[BW MEASURE ON off]

When finished, turn the markers off, [MKR]/[all OFF].

Passband Flatness



The following procedure illustrates how to determine passband ripple using the delta marker and marker statistics functions. Use the front panel knob to move marker 1 to the left edge and marker 2 to the right edge of the passband, respectively.

[MKR]/[MARKER 1]
Position marker 1
[ΔMODE MENU]/[ΔREF=1]/[2]
Position marker 2
[MKR FCTN]/[MKR MODE MENU]
[STATISTICS ON off]

The statistics function illustrates the DUT's performance between the active and reference markers (2 and 1, respectively), providing measurement data on mean insertion loss, standard deviation and peak-to-peak ripple. All this information is presented in the upper right region of the display. If reference markers are not set up, statistics are calculated for the entire trace. Upon completion of the measurement turn off the statistics function and the markers, [STATISTICS on OFF], [MKR]/[all OFF].

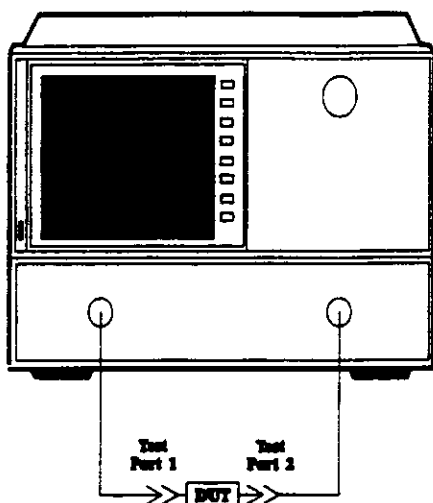
Out-of-Band Rejection

The analyzer's wide dynamic range allows it to measure stopband rejection over 100 dB below the passband response (> 70 dB on HP 8722A). Obtaining the maximum dynamic range requires proper selection of the test port power level, IF bandwidth, and averaging factor; these topics are discussed in the *Optimizing Dynamic Range* section of the appendix.

Don't hesitate to try out some of the other marker functions before moving on. When finished, return to the original setup by recalling register 1.

[RECALL]/[RECALL REG1]

Measuring Phase Response



To completely characterize a device, phase performance must also be determined. The analyzer can provide information on insertion phase (phase shift), electrical delay and phase distortion.

Since the phase response of the passband of the filter is the primary concern, the following measurement requires a narrower frequency span. The frequency subset feature is used to reduce the frequency span without invalidating the two-port calibration performed at the beginning of this chapter. The feature actually uses the original calibration data points that are within the reduced span, so although the system is still calibrated, only 41 of the original 401 calibration points are used. Note, a higher resolution phase measurement can be achieved by recalibrating the system at the narrower span.

Recall Cal [RECALL]/RECALL REG1/

Adjust Setup

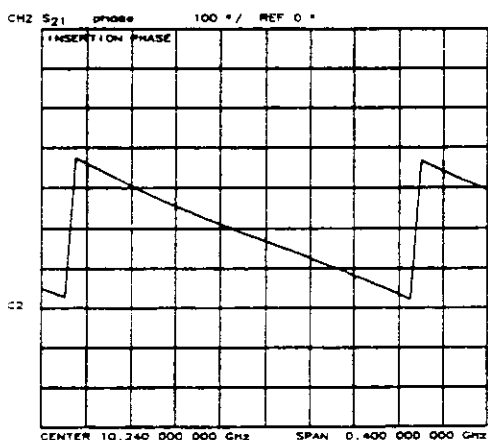
Measurement: [CH 2]
[MEAS]/Trans: FWD S21/
Format: [FORMAT]/PHASE/
Stimulus: [CAL]/FRQ SUBSET ON off/
[CENTER] 10.24 [G/n]
[SPAN] 400 [M/u]

Save

Save the instrument configuration and calibration in register 2.

[SAVE] [SAVE REG2/]

Insertion Phase



Connect and Measure

Connect the test device with a single cable or a cable set and scale the display as desired.

Update S-parameter data

[MEAS]
[SCALE REF]/[AUTO SCALE/]

The analyzer's display should exhibit a trace similar to that shown. The analyzer measures and displays phase over the range of -180° to $+180^\circ$. As phase changes beyond these values, a sharp 360° transition occurs in the display data.

Store/Output Results: Printing

Before proceeding, make sure the analyzer and printer are properly set up (see appendix). Selecting [COPY] then [PRINT], will print everything currently displayed, except for the softkey menu.

Electrical Length

The linearly changing phase seen in the previous figure is primarily due to the DUT's electrical length. Since the analyzer can simulate a variable length lossless transmission line, the user can determine the DUT's electrical length (delay), by adding electrical length until the phase shift has been reduced to a flat line.

Use marker functions to add delay and reduce the phase shift displayed; make sure the reference value is set to 0°. Fine-tune the measurement until the best flat line is achieved, then read the electrical length from the CRT's active entry area. It represents the electrical length of the DUT relative to the speed of light in free space. The physical length of the DUT is related to this value by the propagation velocity of its medium.

[MKR FCTN]/[MARKER -> MENU]

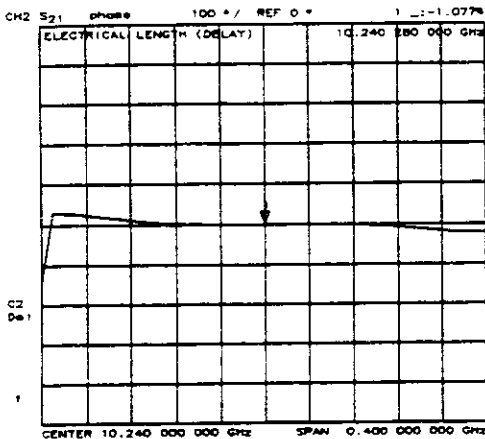
Position marker in passband center

[MARKER -> DELAY]

[SCALE REF]/[REFERENCE VALUE] 0 [x1]

[ELECTRICAL DELAY]

Rotate knob until best flat line is achieved; then read the electrical delay from the active entry area.



Phase Distortion

For many devices, the amount of insertion phase is not nearly as important as the linearity of the phase shift over a range of frequencies. The analyzer can measure this linearity and express it in two different ways: as deviation from linear phase or as group delay.

Deviation From Linear Phase

The ripple seen in the electrical length measurement above, is due to the deviation from linear phase through the device. It can easily be measured by increasing the scale resolution and using the markers to directly measure the maximum deviation from linear phase as shown in the figure.

[SCALE REF]/[AUTO SCALE]

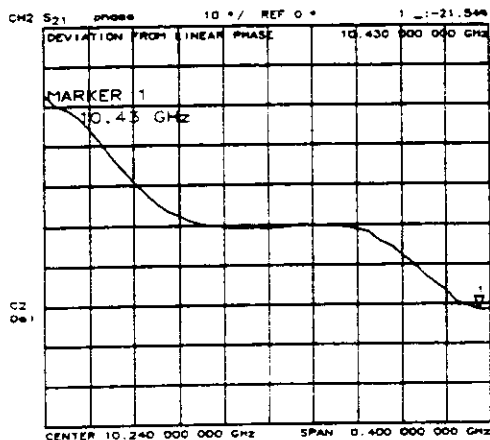
[MKR FCTN]/[SEARCH: MAX]

[MIN]

Upon completion of the phase linearity measurement, return the electrical delay to 0.

[SCALE REF]

[ELECTRICAL DELAY] 0 [x1]



Group Delay

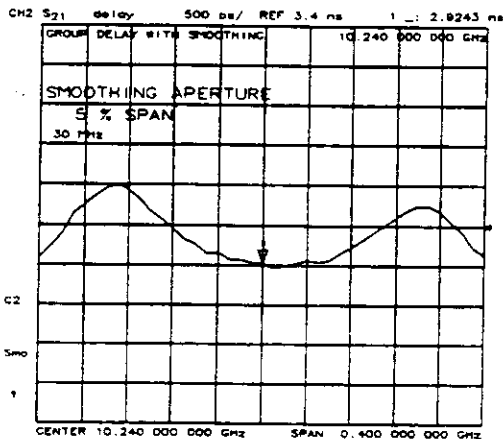
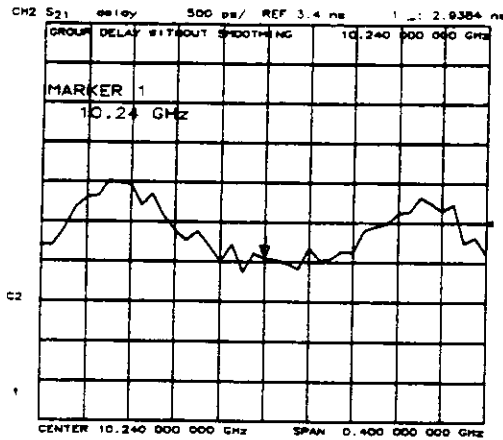
The phase linearity of many devices is specified in terms of group or envelope delay. This is especially true of telecommunications components and systems where phase distortion is critical.

Group delay is a measure of transit time through the DUT as a function of frequency. It is approximated by: $-\Delta\phi/(\Delta f)(360)$, where $\Delta\phi$ is the phase difference between two adjacent frequencies Δf . The quantity Δf is commonly referred to as the aperture. The minimum aperture is equal to the analyzer's frequency span divided by the number of points minus one (4 GHz/400 points). To measure group delay correctly, the phase difference at a specific aperture must be less than 180° , satisfying the following relationship:

$$\text{approximate DUT delay} < \frac{\text{number of points} - 1}{2(\text{frequency span})}$$

The smoothing function can be used to increase the effective group delay aperture without changing the frequency span. It increases the number of points over which group delay is calculated, allowing variation of apertures from minimum (no smoothing) to 20% of the frequency span. Since increasing the aperture removes fine grain variations from the response (see figures), group delay apertures must be specified when comparing measurements.

The following sequence measures the group delay at the center of the passband. The smoothing aperture will be displayed in the active entry area and the group delay as a marker value. Note the trace distortion at high apertures.



[FORMAT]/DELAY/
[SCALE REF]/AUTO SCALE/
[MKR] 10.24 [G/n]
[AVG]/SMOOTHING ON off/
[SMOOTHING APERTURE] 0 [x1]

Rotate front panel knob and note changes

In addition to smoothing, group delay measurements can also benefit from the noise reduction techniques discussed in the *Optimizing Dynamic Range* section of the appendix.

Chapter Three Reflection Measurements

This chapter demonstrates how to make reflection measurements. Return loss, reflection coefficient and SWR (standing wave ratio) are the different measurement formats commonly used to exhibit the magnitude of the signal reflected from the DUT. These measurements are mathematically defined as:

Reflection coefficient: $V_{\text{reflected}}/V_{\text{incident}} = \Gamma = \rho/\phi$
Return loss (dB): $-20\log \rho$
SWR: $(1 + \rho)/(1 - \rho)$

Polar and Smith chart display formats are also included to provide information on phase as well as magnitude. Modify the instrument setups shown to suit your particular needs.

Since reflection measurements involve only one port of a test device, it is critical that all unused ports are properly terminated, or measurement errors will result. Multiport devices must be terminated with a 50 ohm load or a 50 ohm test port cable.

Return Loss

Return loss is the logarithmic ratio of reflected-to-incident voltage for the test device, as shown in the equation above. A large return loss indicates that only a small portion of the incident signal is being reflected from the DUT. Return loss can range from infinity (no reflection) to 0 dB (complete reflection).

The following sequence sets up reflection measurements using the two-port calibration performed in chapter 2. Although the complete setup is presented, only the "measurement" parameters actually need adjustment.

Recall Cal

[RECALL]/RECALL REG1/

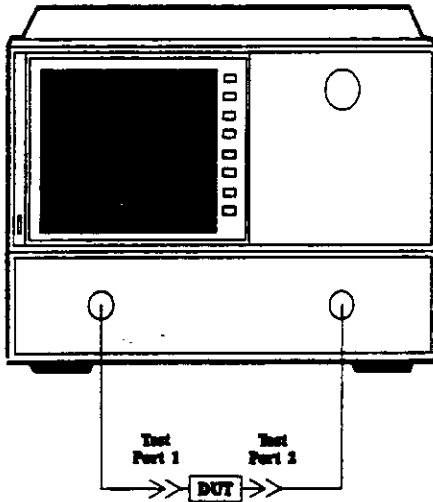
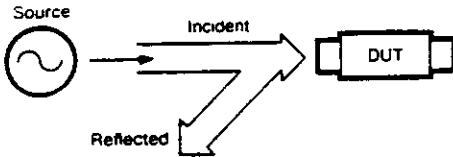
Adjust Setup

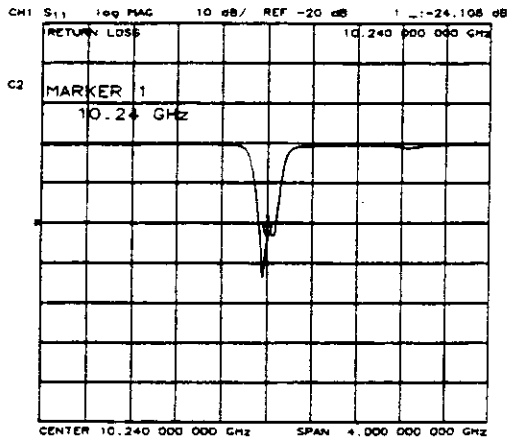
Measurement: [MEAS]/Ref: FWD S11/
 Format: [FORMAT]/LOG MAG/
 Stimulus: [CENTER] 10.24 [G/n]
 [SPAN] 4 [G/n]
 [MENU]/POWER/[RANGE 1 -10 TO +10] 10 [x1]
 (-20 dBm with HP 8722A)

Calibrate and Save

Use or perform the two-port calibration provided in chapter 2. For more information on calibration types and their uses, refer to the *Calibration* section of the appendix. Save the setup in register 3.

[SAVE]/SAVE REG3/





Connect and Measure

Connect the test device with a single cable or a cable set and scale the data. Use the marker to determine the return loss of the passband. This filter exhibits the desired response for a bandpass filter, with high return loss (20 to 30 dB) in the passband indicating good match between the filter and the test system, and high reflection (<0.5 dB return loss) in the reject band.

Update S-parameter data

[MEAS]
[SCALE REF]/[AUTO SCALE]
[MKR] 10.24 [G/n]

Move marker where desired with knob

Store Results

When the calibration is active, the following sequence will initialize the disk and store everything necessary to recreate the data displayed (without the DUT). Before proceeding, make sure the analyzer and disk drive are properly set up, see *Setting Up External Peripherals* in the appendix.

[SAVE]/[STORE TO DISK]
[DEFINE, INIT, PURGE]
[INITIALIZE DISK]/[INIT DISK? YES]
[RAW ARRAY ON off]/[RETURN]
[STORE FILE1]/[RETURN]

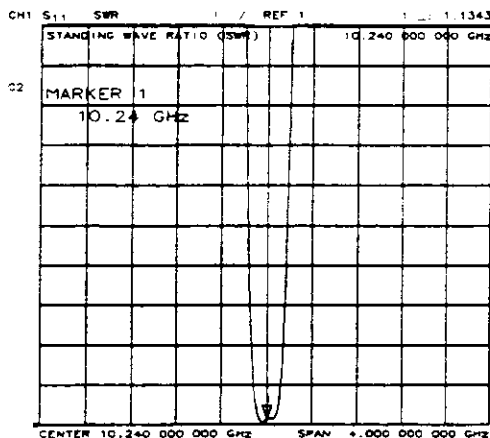
Reflection Coefficient

Selecting the [LIN MAG] format will display " ρ ", the magnitude of the signal reflected from a test device. A $\rho=1$ indicates full reflection while a $\rho=0$ indicates a perfect impedance match or no reflection.

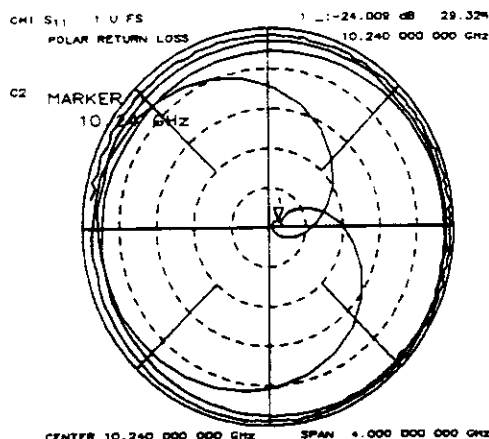
[FORMAT]/[LIN MAG]

SWR

The Standing Wave Ratio (SWR) is the ratio of maximum to minimum standing wave voltage. To display the reflection measurement as SWR, select the [FORMAT]/[SWR]. SWR varies between 1 and infinity, where 1 represents no reflection and infinity represents 100% reflection.



Simultaneous Magnitude/Phase Measurements



Magnitude measurements only supply part of the information necessary to fully characterize a device. Selecting a polar format displays the reflection coefficient in terms of magnitude and phase (ρ/ϕ) simultaneously. The concentric circles are scaled in units of linear magnitude from 0 at the center (no reflection) to 1 at the outer circle (total reflection). Phase is indicated by radial lines where 0° corresponds to the right side of the horizontal axis and $\pm 180^\circ$ corresponds to the left side of the horizontal axis. Use the markers to obtain accurate measurements of frequency, magnitude, and phase.

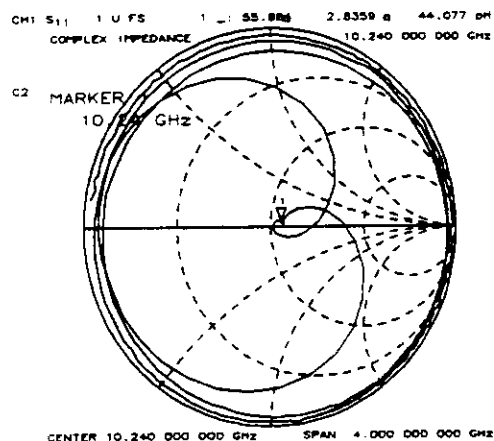
[FORMAT]/POLAR/
[MKR] 10.24 [G/n]

Move marker with knob to measure different points

When a return loss measurement is desired in a polar format, the magnitude must be displayed in a logarithmic form.

[MKR FCTN]/MKR MODE MENU/
[POLAR MKR MENU]/[LOG MKR]

Impedance



The amount of power reflected from a device is directly related to the impedances of both the device and the measuring system. In fact each value of the reflection coefficient (ρ) uniquely defines a device impedance; $\rho=0$ only occurs when the device and measurement system impedance are exactly the same. A short circuit has a reflection coefficient of $\rho=1/180^\circ$.

Choosing the Smith chart format provides a plot of the complex impedance of the test device as a function of frequency; both the resistive (R) and reactive (X) components ($R \pm jX$) are displayed.

[FORMAT]/SMITH CHART/
[MKR] 10.24 [G/n]

Move marker with knob to measure different points

Frequency information is available in this format only with an active marker. Markers are also used to display the resistance, reactance, and the effective capacitance or inductance of a specific measurement point (see the adjacent figure).

Admittance

When admittance information is desired, changing the markers on a Smith chart to the $[G \pm jB \text{ MKR}]$ format inverts the display and provides admittance data in Siemens units (equivalent to mhos).

[MKR FCTN]/MKR MODE MENU/
[SMITH MKR MENU]/[G \pm jB MKR]

CH1 S11 1 U FS 1: 55.9...0 +2.5...0 37...pH
10.240 000 000 GHz

CH1 S11 1 U FS 1: 17.9...mS -850...μS 18...nH
10.240 000 000 GHz

Chapter Four

Time Domain Measurements

Time domain (Option 010) analysis uses the inverse Fourier transform of frequency domain data, to isolate responses in time and distance. Time and distance are related by the relative velocity factor of the DUT - the rate at which a signal propagates through a medium relative to the speed of light. Time domain analysis is valuable for identifying:

- * the location of transmission path discontinuities (faults)
- * the location and nature of impedance changes,
- * multiple signal paths

In addition, the gating feature of time domain analysis allows users to selectively remove undesirable portions of the time domain response, and view the resulting response in the frequency domain. Thus, gating can significantly reduce the effects of system components which may be obscuring the frequency response of the desired device or component. For example, gating can remove the effects of:

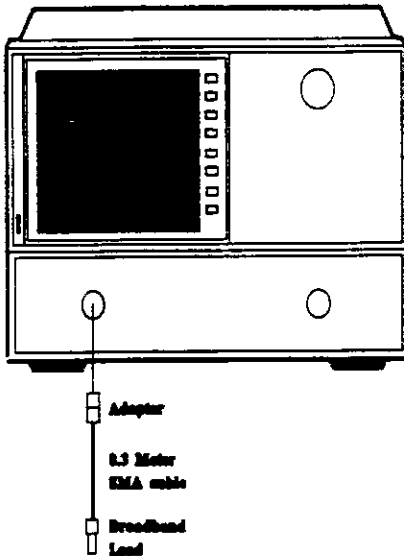
- * connectors and adapters in reflection measurements
- * multiple paths in transmission measurements

The frequency span and the number of points selected, will determine the resolution and the range (or distance) that can be measured. Resolution is the minimum distance between two responses which still allows them to be uniquely identified. Higher resolution is achieved as the frequency span increases. The range on the other hand, is inversely proportional to the frequency span: $range = (number\ of\ points - 1) / (frequency\ span)$. Thus the user has to trade off resolution for range and determine which is more important for a measurement.

There are two primary modes of time domain operation: low-pass and bandpass. Low-pass mode simulates the magnitude data provided by TDR (time domain reflectometer) measurements. Low-pass mode provides impedance information (bandpass mode does not) and the highest resolution, but requires frequency domain data that is harmonically related and extends to DC. Bandpass mode is most useful for band-limited devices (i.e., waveguide), and can have an arbitrary frequency range and number of data points.

The following example illustrates a time domain measurement of a semi-rigid cable (.3m), using the low-pass impulse mode. Since the measurement is performed at port 1, and a broadband frequency sweep is desired for greater resolution, a one-port calibration is required.

Time Domain Reflection Measurements



The **[SET FREQ LOW PASS]** softkey automatically adjusts the start and stop frequencies, so that the stop frequency is a harmonic multiple of the start:

$$frequency_{stop} = (frequency_{start}) \times (number\ of\ points).$$
 Notice that the full span of the analyzer has harmonically related frequencies (i.e., 0.05 GHz x 401 pts. = 20.05 GHz). If you require more information on time domain analysis and its measurement modes, refer to chapter nine in the reference section of the manual. Although the complete setup is provided, only the format and the number of points will have to be set, the rest of the keystrokes are already set by the factory preset.

Preset (factory)

[USER PRESET]

Setup

Measurement:

[MEAS]/Ref: FWD S11/

Format:

[FORMAT]/LIN MAG/

Stimulus:

[START] 50 [M/u]

[STOP] 20.05 [G/n]

[MENU]/NUMBER of POINTS/ 401 [x1]

Calibrate and Save

In turn, connect each of the calibration standards (open, short, and load) at the port 1 connector and select the appropriate softkey. The standard's softkey label will be underlined upon completion of the measurement.

[CAL]/CAL KIT/[3.5 mm]/[RETURN]

[CALIBRATE MENU]/[SET FREQ LOW PASS]

[S11 1-PORT]

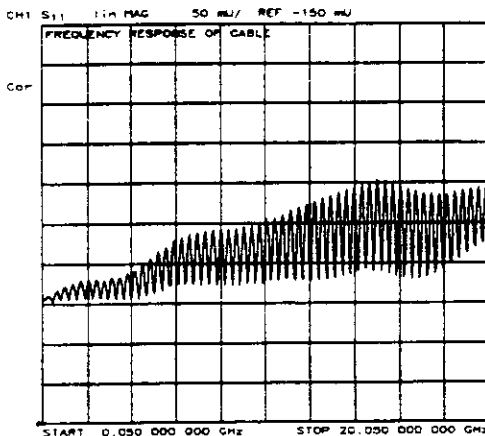
Connect standards to port 1

[S11: OPEN],[SHORT]

[LOADS]/[BROADBAND]/[DONE: LOADS]

[DONE 1-PORT CAL]

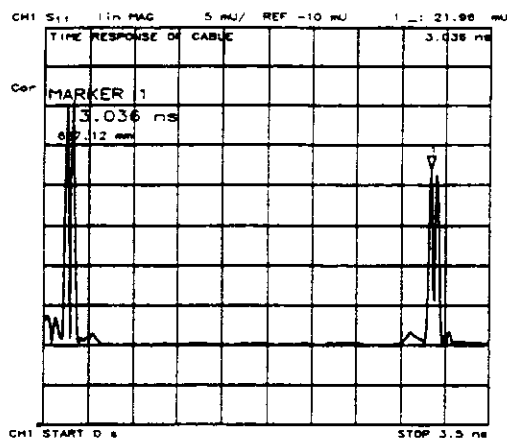
[SAVE REG 4]



Connect and Measure

Connect the semi-rigid cable to the test system as shown, with an adapter and a terminating load. Use **[SCALE REF]/[AUTO SCALE]** to adjust the display. The resulting measurement shows the frequency response of the cable, in terms of the reflection coefficient. Notice, the complex ripple pattern from multiple reflections in the DUT.

To determine physical length rather than electrical length in time domain, the velocity factor must be adjusted to reflect the relative velocity of the signal through the medium under test. Polyethylene dielectric cables have a velocity factor around 0.66, while teflon dielectric cable's velocity factor is around 0.7.



Also, a time span should be established that will display the entire length of the cable, within the range limitations $[(\text{number of points} - 1)/(\text{frequency span})]$ previously discussed. Since, reflection measurements measure the round trip time and distance to and from the test system components, the analyzer will display twice the actual time and distance.

$$\text{Minimum } T_{\text{round trip}} = \frac{2 \times L_{\text{cable}}}{\text{velocity factor} \times C} = \frac{.6\text{m}}{.7 \times .3\text{m/ns}} = 2.85 \text{ ns}$$

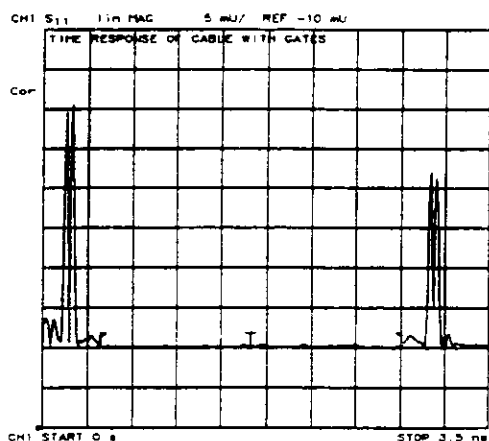
[CAL]/[MORE]
[VELOCITY FACTOR] .7 [x1], [RETURN]
[SYSTEM]/[TRANSFORM MENU]
[LOW PASS IMPULSE]/[TRANSFORM ON off]
[START] 0 [x1], [STOP] 3.5 [G/n]
[SCALE REF]/[AUTO SCALE]
[MKR] 2.85 [G/n]

Use front panel knob to move marker to first peak, read time and distance from active entry area

Store/Output Results

Store the results to a disk or output to a printer/plotter.

Gating Time Domain Responses



Gating is a powerful tool, providing the flexibility to selectively remove undesirable responses from time and frequency domain measurements. Use gating to evaluate the performance of individual components of the DUT.

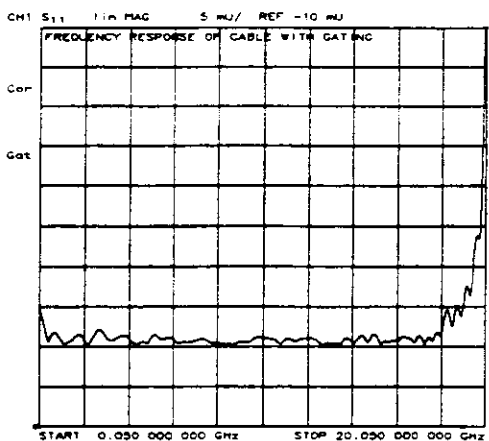
To demonstrate the effects of gating, the following sequence eliminates the responses from the semi-rigid cable's connectors. Enter the gate's start and stop cursors by rotating the front panel knob or through direct entry on the numeric keypad. The start and stop cursors should be at the end of the input connector's response and at the beginning of the connector-load response, respectively (see figure).

[MKR]/[all OFF]
[SYSTEM]/[TRANSFORM MENU]
[SPECIFY GATE]/[GATE: START]

Position cursor with knob

[STOP]

Position cursor with knob



Turning the gate on and transform off provides a frequency domain display which represents the response of the cable without the connectors. As expected, the measurement exhibits a much smoother and lower magnitude ripple pattern. Now, reflection coefficient and impedance of just the cable can be determined. When measuring a cable as shown, reduce measurement uncertainty by using high-quality connectors.

[GATE ON]/[RETURN]
[TRANSFORM MENU on OFF]
[SCALE REF]/[AUTO SCALE]

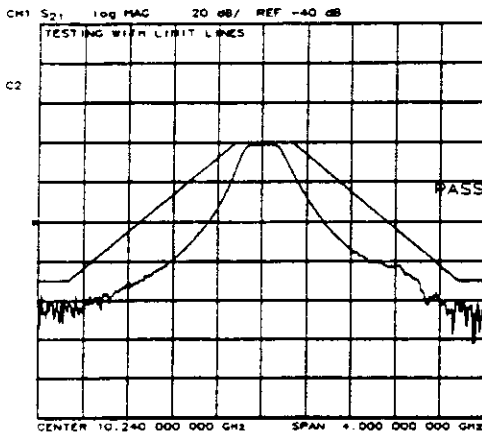
Chapter Five

Limit Lines for Device Evaluation

Limit testing is a time-saving feature that compares measurement data to user-defined specifications. Depending on the results of the comparison, the DUT will either pass or fail. Limit testing allows you to objectively evaluate the performance of your device, and can ensure that all test devices are aligned and tested to the same specifications at each measurement station.

Limit testing is implemented by creating any combination of flat, sloping, and single point limit lines on the CRT. This section describes how to create limit lines for the transmission response of the bandpass filter provided with the analyzer. If you performed the transmission measurement in chapter one, select **[RECALL]/[REG1]** to retrieve the setup and calibration. If chapter one was skipped, step through the setup and calibration sequence on pages six and seven.

The following sequence enters the first segment displayed in the adjacent figure. Each limit line segment must specify the stimulus value (start frequency), the test limits (upper and lower), and the limit type. Since only an upper test limit is desired, the lower limit is set to -200 dB to ensure that it will not impact the measurement.



```
[SCALE REF]/[AUTO SCALE]
[SYSTEM]/[LIMIT MENU]/[LIMIT LINE ON off]
[EDIT LIMIT LINE]/[ADD]
[STIMULUS VALUE] 8 [G/n]
[UPPER LIMIT] -70 [x1],[LOWER LIMIT] -200 [x1]
[DONE]/[LIMIT TYPE]/[FLAT LINE]/[RETURN]
```

A line should now be displayed just above the noise floor. Notice, that only the start frequency is specified and the segment continues across the screen. To terminate a segment, another segment or a single point must be specified. In the following table the second segment's frequency and test limit (9 GHz/-70 dB) terminates the first segment. The subsequent entries will complete the limit line entries depicted in the figure. When **[ADD]** is selected a replica of the previous segment will appear as a new segment. Change only the necessary parameters, then select **[DONE]** to access the limit type menu. The table below abbreviates the flat and sloped line types as FL and SL respectively.

	Stimulus	Upper	Lower	Type
2	[ADD] 8.5 [G/n]	-70 [x1]	-200 [x1] [DONE]	SL [RETURN]
3	[ADD] 10 [G/n]	0 [x1]	-200 [x1] [DONE]	FL [RETURN]
4	[ADD] 10.5 [G/n]	0 [x1]	-200 [x1] [DONE]	SL [RETURN]
5	[ADD] 12 [G/n]	-70 [x1]	-200 [x1] [DONE]	FL [RETURN]

Appendix

Calibration Tutorial

The calibration step effectively characterizes and removes the effects of repeatable measurement variations (or systematic errors) such as:

- * Frequency Response (Tracking)
- * Leakages (Directivity and Crosstalk) and
- * Mismatch (Load Match and Source Match)

The analyzer offers several calibrations techniques that can compensate for one or more of these test imperfections. The following table provides a summary of these techniques and their applications.

Calibration	Application	Errors Removed	Measurement Sequence
Full 2-Port <i>Cal Time:</i> <i>about 5 min.</i>	<ul style="list-style-type: none"> * Most accurate for 2-port devices * All measurement applications 	Reflection errors (ports 1 and 2): Directivity Source Impedance Match Frequency Response Transmission errors (forward and reverse): Load Impedance Match Frequency Response	[CAL]/[CALIBRATE MENU] [FULL 2-PORT]/[REFLECTION] Connect each standard to port 1 [S11]/[OPEN],[SHORT],[LOAD] ¹ [BROADBAND]/[DONE: LOADS] Connect each standard to port 2 [S22]/[OPEN],[SHORT],[LOAD] [BROADBAND]/[DONE: LOADS] [TRANSMISSION] Connect thru [DO BOTH FWD + REV] [ISOLATION]/[OMIT ISOLATION]
The isolation calibration should be omitted unless it is really necessary - if needed, use the following sequence			
Isolation 10 to 20 dB of the noise floor	<ul style="list-style-type: none"> * May be used when signal is within 10 to 20 dB of the noise floor * Useful for high loss/isolation devices, such as some filters and switches. Try optimizing the dynamic range first 	Leakage Crosstalk (forward and reverse)	[AVG]/[AVERAGING FACTOR] 16 [x1] [AVERAGING ON] Connect 50 ohm loads to ports 1 & 2 [CAL]/[RESUME CAL SEQUENCE] [ISOLATION] [FWD ISOL'N ISOL'N STD] [REV ISOL'N ISOL'N STD] [AVG]/[AVERAGING OFF] [CAL]/[RESUME CAL SEQUENCE] [ISOLATION DONE] [DONE 2-PORT CAL],[SAVE REG1] [MEAS]
Finish 2-port calibration			
One-Port Reflection <i>Cal Time:</i> <i>about 2 min</i>	<ul style="list-style-type: none"> * Most accurate for 1-port devices. * Reflection measurements. 	Directivity Source Impedance Match Frequency Response	[CAL]/[CALIBRATE MENU] [S11 1-PORT] or [S22 1-PORT] Connect each standard to the port [Sxx]/[OPEN],[SHORT],[LOADS] [BROADBAND]/[DONE: LOADS] [DONE 1-PORT CAL]
Frequency Response <i>Cal Time:</i> <i>about 1 min.</i>	<ul style="list-style-type: none"> * Use when high accuracy is not needed. * Transmission measurements. * Reflection measurements. * Useful for well matched, high insertion loss devices. 	Frequency Response	[CAL]/[CALIBRATE MENU] [RESPONSE] Reflection: connect one standard to port [OPEN] or [SHORT] - short is preferred Transmission: connect thru [THRU] [DONE RESPONSE]

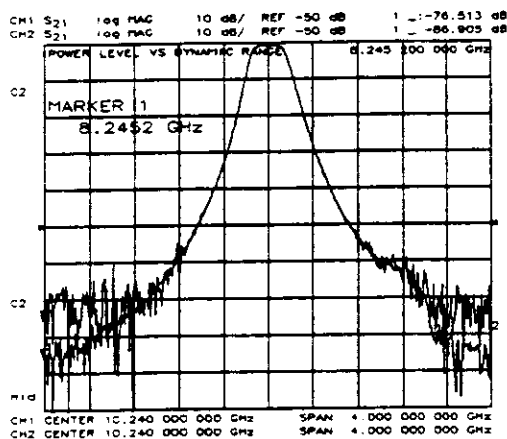
¹Criteria for load selection: For greatest accuracy at frequencies <3 GHz choose lowband; at frequencies >3 choose sliding load; for full span use both. Broadband loads are convenient, have very good accuracy and are simpler to use (have no frequency restrictions).

Optimizing Dynamic Range

Network analyzers are often used to simultaneously measure two signals that are widely separated in amplitude. Testing the attenuation of a filter requires measurement of both its transmitted and rejected signals, which may differ by 60 dB or more. System dynamic range is the difference between the measurement port's output power and the analyzer's noise floor. To optimize system dynamic range:

- * choose the optimum input power for the DUT, and
- * reduce the analyzer's noise floor

Selecting Power Level



The analyzer is capable of providing +10 to -65 dBm (in 20 dB power ranges) at the output port; the HP 8722A offers -20 to -65 dBm in 10 dB power ranges. Selecting a higher port power level provides greater usable dynamic range. When choosing the appropriate power level the user must ensure that the test device is not overdriven (active devices only) and that the resulting output signal is within the measurement range of the analyzer. The analyzer can measure signals from +10 to <-100 dBm.

The accompanying figure illustrates how available dynamic range is affected by test port power levels. The input power levels are -10 dBm on trace 1 and +10 dBm on trace 2. As you can see, the additional 20 dB input power provides approximately 20 dB of improvement in dynamic range. Measuring signals below -85 dBm requires lowering the noise floor.

Reducing the Noise Floor

There are several approaches available to reduce the noise floor. Each method offers its own contributions and limitations. The following table summarizes these issues for each method.

Method	Contributions (+)/Limitations (-)
Reduce IF Bandwidth	<ul style="list-style-type: none"> + Filters unwanted responses better than averaging + Generally faster than averaging + Better than averaging for 2-port error corrected measurements + Easiest when programming over HP-IB + Better for frequency list or log sweep measurements - Sweep time is automatically increased as the bandwidth is narrowed - Changing IF bandwidth after calibration may impact measurement accuracy
Averaging	<ul style="list-style-type: none"> + Filters out very low frequency noise better than reducing IF bandwidth + Doesn't impact measurement accuracy if applied after calibration - Takes many sweeps to complete the measurement
Isolation Calibration	<ul style="list-style-type: none"> + Removes crosstalk from the measurement + Doesn't affect accuracy - More difficult to implement

IF Bandwidth

The receiver IF bandwidth is selectable from 3 kHz to 10 Hz. Each tenfold reduction in IF bandwidth lowers the noise floor approximately 10 dB. With a 10 Hz bandwidth, a noise floor of -100 dBm can be achieved.

[AVG]/[IF BW] 30 [x1]

Averaging

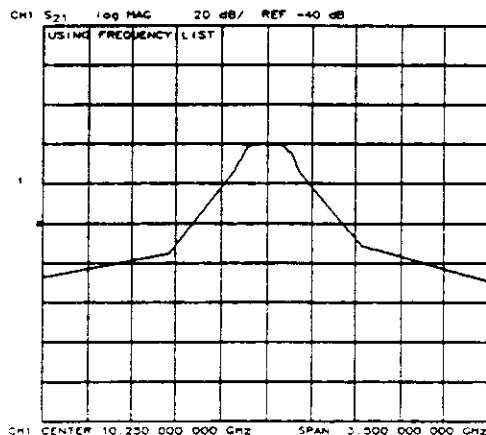
Averaging reduces random noise, by applying weighted vector averaging to successive traces. Doubling the average factor (the number of averages), reduces the noise floor by approximately 3 dB. When averaging is on, each successive sweep reduces the noise level until the sweep count reaches the averaging factor value. Also, "Avg" is displayed in the status notations area of the CRT, and the sweep count is displayed directly below. Users must be careful to make adjustments to the test device only after averaging has been completed. To average 64 successive traces, select the following keys:

[AVG]/[AVERAGING FACTOR] 64 [x1]
[AVERAGING ON]

Creating a Frequency List

The frequency list feature can be used to specify arbitrary measurement frequencies. By testing only the points you need, measurement time is reduced and throughput is maximized. To setup a list the user must specify sweep segments. These segments may contain a single point or a frequency span with a fixed number of points or step size. As many as 1,601 measurement frequencies may be contained in up to 30 segments.

The following frequency list, provides some information about the filter's stopband, while focusing on the pass-band with 101 measurement points. Note: the user may choose to only view a specific segment or the entire list. This example displays the complete list, as shown in the figure.



[MENU]/[SWEEP TYPE MENU]
[EDIT LIST]/[ADD]/[CW] 8.5 [G/n]/[DONE]
[ADD]/[CW] 9.5 [G/n]/[DONE]
[ADD]/[START] 10 [G/n]/[STOP] 10.5 [G/n]
[NUMBER of POINTS] 101 [x1]/[DONE]
[ADD]/[CW] 11 [G/n]/[DONE]
[ADD]/[CW] 12 [G/n]/[DONE]/[DONE]
[LIST FREQ]/[ALL SEGS SWEEP]/[RETURN]

As with any other measurement, the system should be calibrated and saved, as previously shown.

Setting Up External Peripherals

Factory-set peripheral addresses

Device	Decimal Address
Plotter	1
Printer	5
Disk (drive)	0

To store and output measurement results on a plotter, printer, or disk drive, the analyzer must be the system controller (when no other controller i.e. computer, is on the system bus). Also, the appropriate HP-IB addresses must be set up on the peripherals.

[LOCAL]/SYSTEM CONTROLLER/
[SET ADDRESSES]/[ADDRESS: device name]

The table displays the factory-set addresses for several peripherals. Refer to the peripheral's manual to verify the setting (most addresses are set with switches). To change an address, select the device softkey and enter a new number on the keypad followed by [x1].

Using Dual-Channel Display

In some cases, it is useful to be able to view more than one measured parameter at a time. For example, simultaneous insertion loss and return loss measurements are useful when adjusting the impedance match of a device for maximum power transfer. Such measurements are easily achieved using the dual-channel display feature.

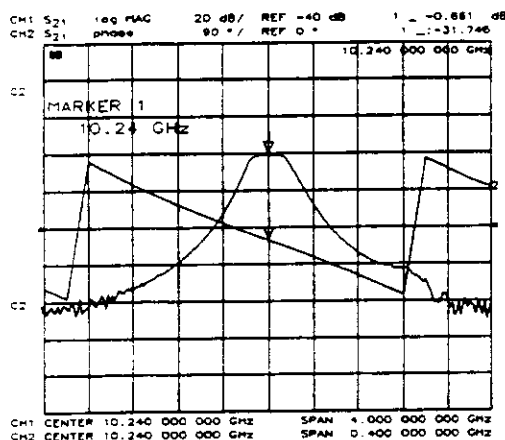
To activate the dual channel feature, select [DISPLAY] [DUAL CHAN ON off]. You will notice that each channel is displayed separately on a split screen. To display the channels on the same graticule, select [MORE] [SPLIT DISP on OFF].

Uncoupled Channels

There are times when a user would like to test and compare the response of a device at different stimulus related measurement parameters, such as power or frequency. When dual-channel mode is active, selecting [MENU] [COUPLED CH on OFF] causes the analyzer to alternate between two sets of stimulus values.

The following sequence recalls the transmission measurement performed in chapter 2, then uncouples the channels and sets a phase measurement with a reduced frequency span on channel 2. Now the filter can be easily tuned for optimal transmission and phase performance.

[RECALL]/RECALL REG1/
[MENU]/COUPLED CH on OFF/
[DISPLAY]/DUAL CHAN on off/
[MORE]/[SPLIT DISP on OFF]
[CH 2]/[SCALE REF]/[AUTO SCALE]
[CAL]/FREQ SUBSET ON off],[SPAN] 400 [M/u]
[FORMAT]/PHASE],[MKR] 10.24 [G/n]



Function Index

A

Address, set: [LOCAL]
 Adjust colors/intensity: [DISPLAY]/[MORE]/[ADJUST DISPLAY]
 Admittance, measure: [FORMAT]/[SMITH CHART]/[MKR FCTN]/[MKR MODE MENU]/[G + jB]

Aperture, smoothing: [AVG]

Arbitrary sweep (frequency list): [MENU]/[SWEEP TYPE MENU]/[EDIT LIST]

ASCII format, storing: [SAVE]/[STORE TO DISK]/[DEFINE, INIT, PURGE]/[DISK FILE FORMAT]

Auto scale: [SCALE REF]

Average sweeps: [AVG]/[AVERAGING ON off]

Averages, set: [AVG]/[AVERAGING FACTOR]

B

Bandpass mode (time domain): [SYSTEM]/[TRANSFORM MENU]

Bandwidth, 3 dB: [MKR FCTN]/[BANDWIDTH MENU]

Bandwidth, IF: [AVG]/[IF BW]

Beep done/warn: [DISPLAY]/[MORE]

Binary format, storing: [SAVE]/[STORE TO DISK]/[DEFINE, INIT, PURGE]/[DISK FILE FORMAT]

Blank, frequency: [DISPLAY]/[MORE]

C

Cal kit, modify: [CAL]/[CAL KIT]

Calibration, on off: [CAL]/[CORRECTION ON OFF]

Calibration, setup: [CAL]/[CALIBRATE MENU]

Characteristic impedance, set: [CAL]/[MORE]

Clear (storage) register: [SAVE]/[CLEAR REGISTER]

Color, adjust: [DISPLAY]/[ADJUST DISPLAY]

Continuous markers: [MKR FCTN]/[MARKER MODE MENU]

Control system, functions: [LOCAL]

Convert data, Z/Y formats: [MEAS]/[CONVERSION]

Couple channels: [MENU]

Couple markers: [MKR FCTN]/[MARKER MODE MENU]

Crosstalk, eliminate (w/isolation cal): [CAL]/[CALIBRATE MENU]/[RESPONSE & ISOL 'N] or [FULL 2-PORT]

CW freq, meas. vs time: [MENU]/[CW FREQ]

D

Data, display: [DISPLAY]

Define plot: [COPY]/[CONFIGURE PLOT]

Define sweep: [MENU]/[SWEEP TYPE MENU]

Delay, aperture: [AVG]/[SMOOTHING APERTURE]

Delay, electrical: [FORMAT]/[PHASE]/[SCALE REF]/[ELECTRICAL DELAY]

Delay, group: [FORMAT]/[DELAY]

Delta markers: [MKR]/[Δ MODE MENU]

Demodulation (time domain): [SYSTEM]/[TRANSFORM MENU]/[WINDOW]

Discrete markers: [MKR FCTN]/[MKR MODE MENU]

Disk (drive), address: [LOCAL]/[SET ADDRESSES]

Disk, load from: [RECALL]

Disk, setup: [SAVE]/[STORE TO DISK]/[DEFINE, INIT, PURGE]

Disk, store to: [SAVE]

Display, adjust: [DISPLAY]/[MORE]

Display HP-IB commands: [LOCAL]/[HP-IB DIAG ON off]

Display, setup trace: [DISPLAY]

Display, simultaneous traces: [DISPLAY]/[DUAL CHAN ON off]/[MORE]/[SPLIT DISP on OFF]

Dual channel display: [DISPLAY]

E

Electrical delay (length): [FORMAT]/[PHASE]/[SCALE REF]/[ELECTRICAL DELAY]

Error correction, applying: [CAL]/[CALIBRATE MENU]

External Trigger: [MENU]/[TRIGGER MENU]

F

Fixed marker offset: [MKR]/[Δ MODE MENU]/[FIXED MARKER POSITION]

Focus: [DISPLAY]/[MORE]/[ADJUST DISPLAY]

Format disk: [SAVE]/[STORE TO DISK]/[DEFINE, INIT, PURGE]/[INITIALIZE DISK]

Frequency blank: [DISPLAY]/[MORE]

Frequency list: [MENU]/[SWEEP TYPE MENU]

Frequency subset: [CAL]

Freeze trace: [MENU]/[TRIGGER MENU]/[HOLD]

G

Gate (time domain), setup: [SYSTEM]/[TRANSFORM MENU]/[SPECIFY GATE]

Group delay: [FORMAT]/[DELAY]

H

HP-IB, addresses: [LOCAL]/[SET ADDRESSES]

HP-IB, control: [LOCAL]/[SYSTEM CONTROLLER]

Hold: [MENU]/[TRIGGER MENU]

I

IF bandwidth: [AVG]

Impedance, system: [CAL]/[MORE]

Impulse mode (time domain): [SYSTEM]/[TRANSFORM MENU]/[LOW PASS IMPULSE]

Initialize disk: [SAVE]/[STORE TO DISK]/[DEFINE, INIT, PURGE]

Intensity, adjust: [DISPLAY]/[MORE]/[ADJUST DISPLAY]

Invert Smith chart (admittance): [FORMAT]/[SMITH CHART]/[MKR FCTN]/[MKR MODE MENU]/[G + jB]

L

Limit lines: [SYSTEM]/[LIMIT MENU]

Line stretcher (simulate): [SCALE REF]/[ELECTRICAL DELAY]

Linear magnitude format: [FORMAT]

Linear frequency sweep: [MENU]/[SWEEP TYPE MENU]

List current operating parameters: [COPY]/[OP PARAM]

List frequency: [MENU]/[SWEEP TYPE MENU]

List (trace) values, display: [COPY]

Log frequency sweep: [MENU]/[SWEEP TYPE MENU]

Log magnitude format: [FORMAT]

Low pass frequency, set: [CAL]/[CALIBRATE MENU]

Low pass mode (time domain): [SYSTEM]/[TRANSFORM MENU]

M
Marker, delta: [MKR]
Marker, equals: [MKR FCTN]/[MARKER -> MENU]
Marker, offset: [MKR]/[Δ MODE MENU]/[FIXED MARKER POSITION]
Marker search functions: [MKR FCTN]
Marker statistics: [MKR FCTN]/[MKR MODE MENU]
Marker track (search value): [MKR FCTN]/[TRACKING ON off]
Marker zero: [MKR]
Match, load: [FORMAT]/[SWR]
Max, locate: [MKR FCTN]
Measurement, restart: [MEAS]
Memory, display: [DISPLAY]
Min, locate: [MKR FCTN]
Modify cal kit: [CAL]/[CAL KIT]
Modify colors: [DISPLAY]/[MORE]/[ADJUST DISPLAY]
N
Number of groups (triggered): [MENU]/[TRIGGER MENU]
Number of points (per sweep): [MENU]
O
Operating parameters, display list: [COPY]/[OP PARAM]
Operation, set manual/remote: [LOCAL]
Output power: [MENU]
P
Pass (system) control: [LOCAL]
Pens, plotter: [COPY]/[CONFIGURE PLOT]
Phase, measure: [FORMAT]
Plot: [COPY]
Plot, configure pens/lines: [COPY]/[CONFIGURE PLOT]
Plot, define: [COPY]/[DEFINE PLOT]
Plot setup, default: [COPY]/[PRINT/PLOT SETUPS]
Points, set number: [MENU]
Polar markers: [MKR FCTN]/[MKR MODE MENU]
Polar, format: [FORMAT]
Port extensions: [CAL]/[MORE]
Power, output: [MENU]
Preset, factory (w/active user preset): [RECALL]/[RECALL FAC PRESET]
Preset, re-establish factory: [SAVE]/[CLEAR REGISTER]/[CLEAR PRESETS]
Preset, store user: [SAVE]/[SAVE PRESETS]
Print: [COPY]
Print, define: [COPY]/[PRINT/PLOT SETUPS]
R
Real, format: [FORMAT]
Recall default colors: [DISPLAY]/[MORE]/[ADJUST DISPLAY]
Reference, adjust: [SCALE REF]
Reflection, measure: [MEAS]
Resume cal sequence: [CAL]
S
Search functions (marker): [MKR FCTN]
Secure system, eliminate freq. info.:
[DISPLAY]/[MORE]/[FREQUENCY BLANK]
Set addresses: [LOCAL]
Set freq. low pass: [CAL]/[CALIBRATE MENU]
Set Z0: [CAL]/[MORE]
Scale data (best fit): [SCALE REF]/[AUTO SCALE]
Shape gate: [SYSTEM]/[TRANSFORM MENU]/[SPECIFY GATE]
Single sweep: [MENU]/[TRIGGER MENU]
Smith chart: [FORMAT]
Smith chart markers: [MKR FCTN]/[MKR MODE MENU]
Smoothing: [AVG]
Smoothing, percent: [AVG]/[SMOOTHING APERTURE]
Split display: [DISPLAY]/[DUAL CHAN ON off]/[MORE]
Statistics: [MKR FCTN]/[MKR MODE MENU]
Stimulus, couple: [MENU]/[COUPLED CH ON off]
Sweep functions: [MENU]
SWR: [FORMAT]
System control functions: [LOCAL]
T
Table, list sweep: [MENU]/[SWEEP TYPE MENU]
Talker/listener, system control mode: [LOCAL]
Target, search value: [MKR FCTN]
Time domain functions: [SYSTEM]/[TRANSFORM MENU]
Title (display): [DISPLAY]/[MORE]
Trace functions: [DISPLAY]
Trace markers: [MKR FCTN]
Tracking, marker: [MKR FCTN]
Transform, Fourier: [SYSTEM]
Transmission, measure: [MEAS]
Trigger, functions: [MENU]
U
Uncoupled markers: [MKR FCTN]/[MKR MODE MENU]
User preset, set: [SAVE]/[SAVE PRESETS]
User preset, remove: [SAVE]/[CLEAR REGISTER]/[CLEAR PRESETS]
V
Velocity factor: [CAL]/[MORE]
W
Window, set: [SYSTEM]/[TRANSFORM MENU]