HP 8510
NETWORK ANALYZER SYSTEM
OPERATING AND PROGRAMMING MANUAL

System Firmware
Revision A.02.00

1400 FOUNTAINGROVE PARKWAY SANTA ROSA, CA 95401 U.S.A.

Manual Part Number 08510-90005 Printed January 1985
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HEWLETT PACKARD

SERIAL NUMBERS

This manual applies to HP 8510 network analyzers and test sets with these serial number prefixes:

HP 85101A	2332	2427	HP 8511A	2345
	2438	2452	HP 8512A	2336
HP 85102A	2402	2420	HP 8513A	2345
	2446		HP 8514A	2343
			HP 8515A	2345

FIRMWARE AND SOFTWARE REVISIONS

This manual covers these revisions of the software and firmware supplied with the HP 8510 system:

Part Number		Revision
85101-10001	system firmware	A.02.00
85101-10002	system firmware, with Option 010	A.02.00
85101-10003	adjustments and diagnostic	1.0
85101-10006	circuit modeling program, boot disc	1.0
85101-10007	circuit modeling program, program disc	1.0
08510-10001	adjustments	1.0
08510-10006	performance tests HP 8510A/8511A	1.0
08510-10002	performance tests HP 8510A/8512A	2.0
08510-10003	performance tests HP 8510A/8513A	2.0
08510-10004	performance tests HP 8510A/8514A	2.0
08510-10005	performance tests HP 8510A/8515A	2.0

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MANUAL UPDATE RECORD HP 8510 OPERATING AND PROGRAMMING MANUAL

HP 8510 Manual Changes supplements are identified in the lower left-hand corner of the cover sheet with a date and, in some instances, by serial number prefix information as well.

Whenever your copy of the HP 8510 Operating and Programming Manual is updated, put this page behind the title page. This will make it clear when the manual was last updated.

HP 8510 Operating and Programming Manual

√ **UPDATED 3 March 1986**

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HP 85013A Basic Measurements Application Pac. This software application pac offers a choice between two calibration error models and computes group delay from the corrected S_{21} phase data. The Eight Term Error Model is comparable to using the HP 8510 internal one port calibration procedure for S_{11} and S_{22} measurements and the HP 8510 frequency response calibration for S_{21} and S_{12} measurements. The Twelve Term error model is comparable to using the HP 8510 internal two port calibration procedure. Up to 401 related (Start/Stop/Step) or unrelated (individual CW) frequency points can be measured. The calibration procedure used is similar to the procedure used with the HP 8409-series automatic network analyzer.

HP 85014A Active Device Measurements Application Pac. This software application pac provides these capabilities that are especially useful in measuring active devices at RF and microwave frequencies: calibration and real-time de-embedding of packaged devices using the HP 85041A transistor test fixture; safe and oscillation-free automatic (or manual) biasing of bipolar and field effect transistors using the HP 8717B transistor bias supply; automatic listing and plotting of S, H, Y, and Z, parameters, amplifier summary data, and termination summary data; and storage and retrieval of S-parameter data in formats suitable for Computer Aided Design (CAD) applications.

TIME DOMAIN OPTION 010

HP 85012A Time Domain Software Package. This software package upgrades HP 8510 network analyzer systems to full Option 010 time domain capability. It replaces the existing operating system firmware with firmware that includes the time domain capability.

When the program has been installed, fully error-corrected transmission and reflection measurements can be made in terms not only of frequency but also of time. Frequency domain measurements are converted mathematically to the time domain, using the high-speed internal computer of the HP 8510 and Chirp Z Fast Fourier Transform techniques. In addition, systems with time domain capability can be used with an HP series 200/300 computer to run the Circuit Modeling Program described later in this HP 8510 Operating and Programming manual.

HP 8510 NETWORK ANALYZER SYSTEM DOCUMENTATION

This Operating and Programming manual is part of the seven-volume HP 8510 network analyzer system manual set, HP Part Number 08510-90001. Operating and Programming is Section III of the system manual and appears in Volume 1. A duplicate of this information is also supplied as a separate volume in each seven-volume set. This duplicate copy of Operating and Programming is designed to be kept with the instrument even when it is not practical to keep the whole manual set nearby.

Each volume in the HP 8510 network analyzer system manual consists of a separate three-ring binder containing one or more sections of the manual, as follows. The first five volumes are numbered. The sixth volume (not numbered) is a duplicate of the Operating and Programming material. The seventh (also not numbered) is the HP 8510 Keyword Dictionary.

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VI Replaceable Parts
VII Backdating
VIII Service

VOLUME 5

VIII Service (continued)

Operating and Programming (duplicate)

Keyword Dictionary

REPLACEMENT PAGE - ALL SERIALS
Revised 2 December 1985

Volume 3 (Accessories) in the seven-volume manual set is shipped empty, containing only tabs. It is designed as a convenient single place to keep the manuals for system calibration and verification kits, cables, the system rack, etc.

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Two sections of the manual, Installation and Operating and Programming, are also available separately, if extra copies of these are wanted. The individual part numbers are given below. In addition, the first three volumes of the manual are available as a partial manual set, providing complete information except for Service. Part numbers are as follows:

Complete Manual, 7 volumes	08510-90001
Installation Manual	08510-90010
Operating and Programming Manual	08510-90005
Partial Manual Set (Vols. 1, 2, 3)	08510-90020
HP 8510 Keyword Dictionary	08510-90007
HP 8510 Quick Reference (pocket-sized)	08510-90012

Two manual options are available at the time the system order is placed. Option 910 provides a complete extra copy of the seven-volume manual set. Option 914 deletes the service material and consists of five volumes: Volumes 1, 2, and 3, the duplicate Operating and Programming manual, and the HP 8510 Keyword Dictionary.

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MANUAL	DESCRIPTION	HP PART NUMBER
8340A	Synthesized Sweeper	08340-90239
8341A	Synthesized Sweeper	08341-90001
8350B	Sweep Oscillator	08350-90034
85013A	Basic Measurement Application Pac	85013-90001
85014A	Active Device Measurements Application Pac	85014-90001
85041A	Transistor Test Fixture	85041-90001
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85132A/B	7mm Test Port Return Cables	85132-90001
11590B	Bias Tee	11590-90001
11612A	Bias Network	11612-90001
11635A	Bias Network	11635-90001
11667B	Power Splitter	11667-90037

Manuals are also available for HP 8350B sweep oscillator RF plug-ins. Among the RF plug-ins used in HP 8510/HP 8350B applications are HP models 83595A and 83592A/B/C.

For information on HP computer products, including printers and plotters, suitable for use in HP 8510 applications, please contact your nearest Hewlett-Packard Sales/Support Office.

GENERAL INTRODUCTION

This HP 8510 network analyzer system Operating and Programming manual is a complete guide to operating the HP 8510 network analyzer system. It is designed to be self-contained and easy to use, and to be useful for beginning and advanced users alike.

Among its principal features are these:

- a complete table of contents, designed to show the overall organization of the manual and to provide easy access to all of the topics covered; a complete list of illustrations and tables is also included, to make it easy to find particular examples or lists quickly;
- individual tables of contents at the beginning of each part of the manual, introducing each part and reducing the need to refer back to the general table of contents; lists of illustrations and tables are also included;
- an Introductory Measurement Sequence, a self-contained, step-by-step tutorial explaining how to perform a simple, complete sequence measuring the transmission and reflection characteristics of a two-port coaxial device; the tutorial can be carried out without reference to the rest of the manual, or it can be skipped entirely, as all of the subjects treated briefly in the tutorial are discussed in detail later in the manual;
- an Introduction to Programming for HP 8510 network analyzer systems using an HP 200/300 series computer as the system controller;
- a discussion of the HP 8510 Circuit Modeling Program, a software program for HP 200/300 series computers and HP 8510 systems equipped with time domain Option 010; the Circuit Modeling Program is particularly valuable in explaining the time domain functions of the HP 8510 system;
- Reference Data, including a complete pictorial representation of the menus and sub-menus used in the HP 8510 network analyzer system menu structure; these menus are also annotated with HP-IB programming mnemonics;
- a complete General Index at the end of the manual.

Sample calibration and measurement sequences appear throughout the manual, as do CRT displays and menu diagrams. Background discussions of such topics as error correction models and parameter definitions are also included, as separate modules within the manual. For complete details, see the General Contents.

Tabs labeled Application Pacs, Advanced Applications, and General Application Information are also included as a convenience. Behind them can be placed the manuals for such software products as the HP 85013A Basic Measurement Application Pac, Application Notes on specialized uses of the HP 8510 system, and other operating material. Only the tabs are included, and they can be removed and discarded if desired. The HP 8510 Operating and Programming manual is complete without them.

RELATION TO OTHER PARTS OF THE HP 8510 NETWORK ANALYZER SYSTEM MANUAL

This Operating and Programming manual is part of the seven-volume HP 8510 network analyzer system manual. It supports day-to-day general purpose use of the HP 8510 network analyzer system, including systems with time domain Option 010. But it assumes that the system has already been installed and has passed all performance tests required to meet the published HP 8510 system specifications with the source and test set(s) being used. These other subjects are covered in other parts of the HP 8510 system manual.

- Installation, including instrument interconnections and environmental requirements, is covered in the Installation section of the HP 8510 system manual, Volume 1 of the seven-volume manual set. The information in the Installation section is duplicated in the separate HP 8510 system Installation Manual.
- Specifications for the available configurations of the HP 8510 system appear in the General Information section of the HP 8510 system manual, Volume 1 of the seven-volume manual set. Performance Tests for the available configurations appear in the separate section with this title in Volume 2.
- Service, including service of HP 8510 system test sets, is covered in Volumes 4 and 5 of the seven-volume manual set. Adjustments required after service are covered in Volume 2.

Operating and Service information on sources used in the HP 8510 system is not covered in the HP 8510 system manual except insofar as system problems may be traceable to the source. Detailed information appears in the individual Operating and Service manuals for those instruments.

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INTRODUCTION

The HP 8510 network analyzer system is an advanced and sophisticated measuring instrument designed to make microwave measurements of many kinds. But the basic principles of its operation are fairly simple. The information in this part of the HP 8510 system manual is designed to help you get the most from your HP 8510 system by explaining some of the basic principles of its operation and the equipment that should be used with it. Actual measurements are described in the next section of this manual, as an Introductory Measurement Sequence.

In the present section, the HP 8510 network analyzer system is described and a typical measurement is explained in terms of a system block diagram. Digital microprocessing of the data, sources compatible with the HP 8510 system, and the HP 8510 system test sets are also described using block diagrams.

Extremely accurate and complex measurements are possible with the HP 8510 system, and for this reason accessories such as cables, attenuators, extension lines, adapters, and calibration and verification kits are unusually important. Accessories which should be used with the HP 8510 system are listed and discussed after the system, its sources, and its test sets, have been described.

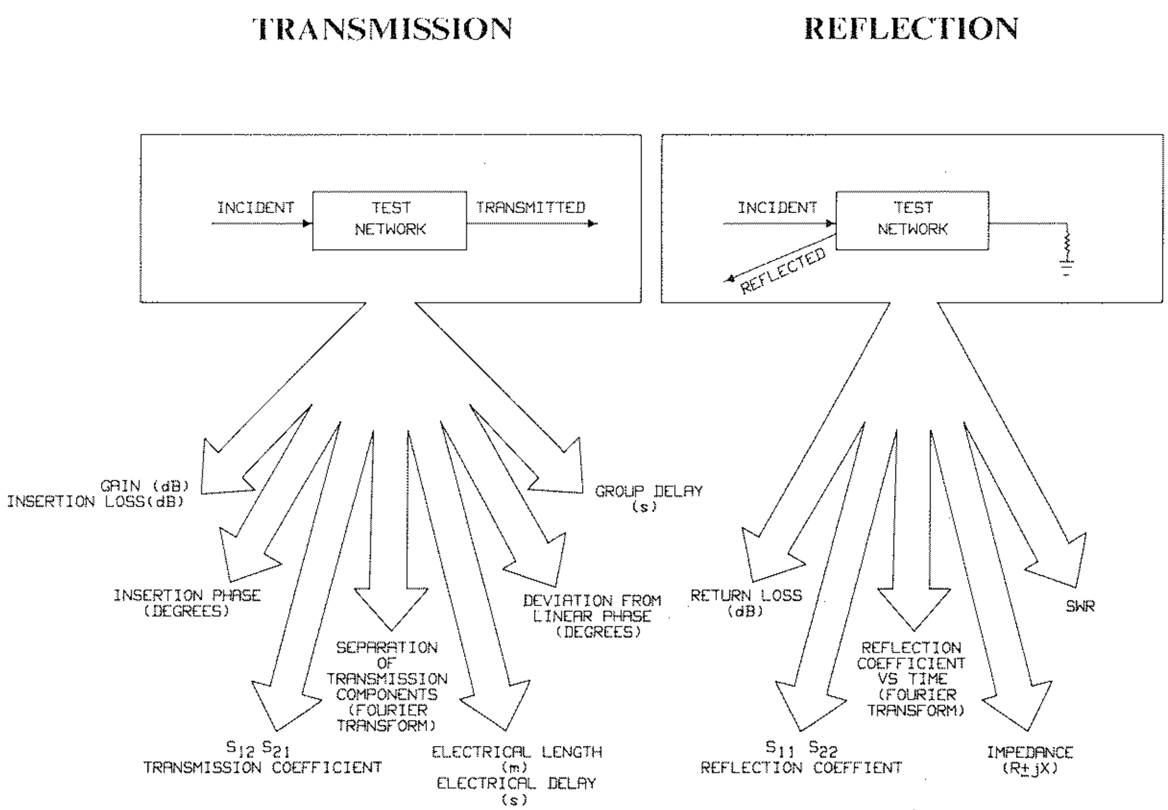
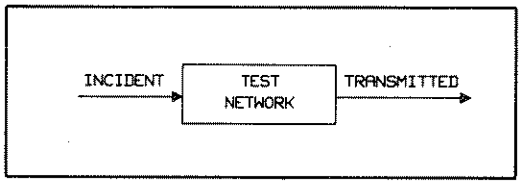


Figure 1. Transmission and Reflection Measurements

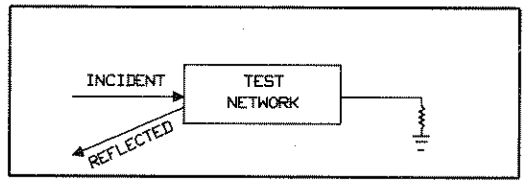
BASIC PRINCIPLES

Vector network analyzers such as the HP 8510 network analyzer system measure the magnitude and phase characteristics of linear networks such as filters, amplifiers, attenuators, and antennas. As with all network analyzers, two kinds of measurements are made: reflection measurements and transmission measurements. An incident signal generated by an RF source is compared with the signal transmitted through the device or reflected from its input.

TRANSMISSION



REFLECTION



Transmission measurements are made by comparing the transmitted signal to the incident signal. This results in measurement data on transmission characteristics of the network such as:

Insertion Loss or Gain,
Transmission Coefficient,
Electrical Delay,
from which Electrical Length can be obtained,
Deviation from Linear Phase,
Group Delay.

Reflection measurements are made by comparing the reflected signal to the incident signal. This results in measurement data on reflection characteristics of the device such as:

Return Loss,
Standing Wave Ratio (SWR),
Reflection Coefficient,
Impedance.

Mathematical analysis of transmission and reflection data on the swept response of the network also makes it possible to determine the position and magnitude of impedance changes with respect to a reference plane. This analysis, called time domain analysis, is done using Fourier Transform principles and is possible on HP 8510 network analyzer systems equipped with time domain Option 010.

HP 8510 NETWORK ANALYZER SYSTEM

The HP 8510 network analyzer system has four essential parts:

a source,

a test set,

a signal detector and analog-to-digital converter, and

a digital microprocessor and display.

The source provides the RF signal. The test set separates this signal into an incident signal sent to the device-under-test and a reference signal against which the transmitted and reflected signals are later compared. It also receives transmitted and reflected signals from the device-under-test. The signal detector and analog-to-digital converter takes all of these signals and converts them to digital information for high-speed processing. The digital microprocessor controls the system, analyzes the digitized signals, corrects errors, and displays the results in a variety of formats.

In the HP 8510 network analyzer system, these essential parts are individual HP instruments configured together make up the HP 8510 system:

HP 834x-series synthesized sweeper,

or

HP 835x-series sweep oscillator with an appropriate
HP 835xx-series plug-in,

HP 851x-series test set;

HP 85102A IF detector;

HP 85101A display/processor.

Additional system components can include hardcopy output devices such as a printer and/or a plotter, and an HP series 200 computer serving as an external controller for programmed operation.

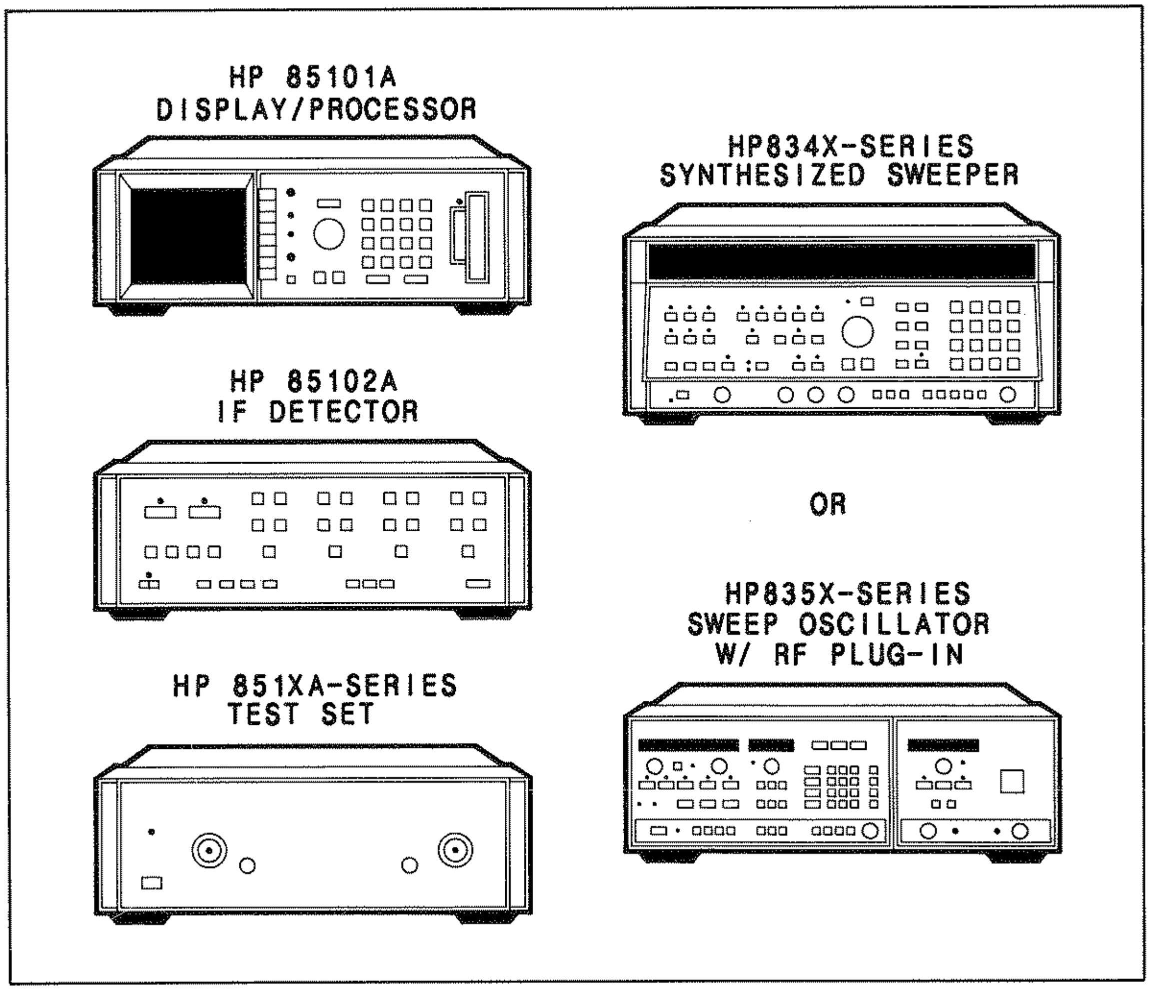


Figure 2. HP 8510 Network Analyzer System

SYSTEM BLOCK DIAGRAM

A simplified block diagram of the HP 8510 network analyzer system is shown in Figure 3.

As Figure 3 shows, the HP 8510 network analyzer is a high performance vector receiver with four inputs, two independent measurement channels, and an internal microcomputer to automate measurement and data processing operations. A special System Bus provides fast digital communication between the instruments that make up the system, allowing the network analyzer to make full use of the source and test set capabilities. This interface also provides direct data transfer to the hardcopy device for neat, permanent records of the measurement display.

During a typical measurement with the source operating in the ramp sweep mode, the source is swept from the lower to the higher measurement frequency in a linear ramp. Signal separation components in the test set apply a portion of the incident signal and the responses from the device under test to the first frequency conversion stage.

Digital communication between the receiver and the test set pretunes the 65 to 300 MHz voltage-tuned local oscillator (VTO) so that one of its harmonics mixes with the stimulus to produce a first IF frequency close to 20 MHz. Fine tuning is accomplished by comparing the IF frequency with the internal 20 MHz crystal reference and sweeping the local oscillator to track the stimulus frequency.

When the local oscillator reaches its upper frequency limit, the sweep is stopped, the local oscillator is retuned, phase lock is reestablished, and the sweep is continued. Since the first local oscillator frequency is selected algorithmically from the known stimulus frequency, the measurement is free from harmonic skip.

The second frequency conversion produces an IF frequency of 100 kHz for application to the detection and data processing elements of the receiver. Because the frequency conversions are phase coherent and the IF signal paths are carefully matched, magnitude and phase relationships between the input signals are maintained throughout the frequency conversion and detection steps. Automatic, fully calibrated autoranging IF gain steps maintain the IF signal at optimum levels for detection over a wide dynamic range.

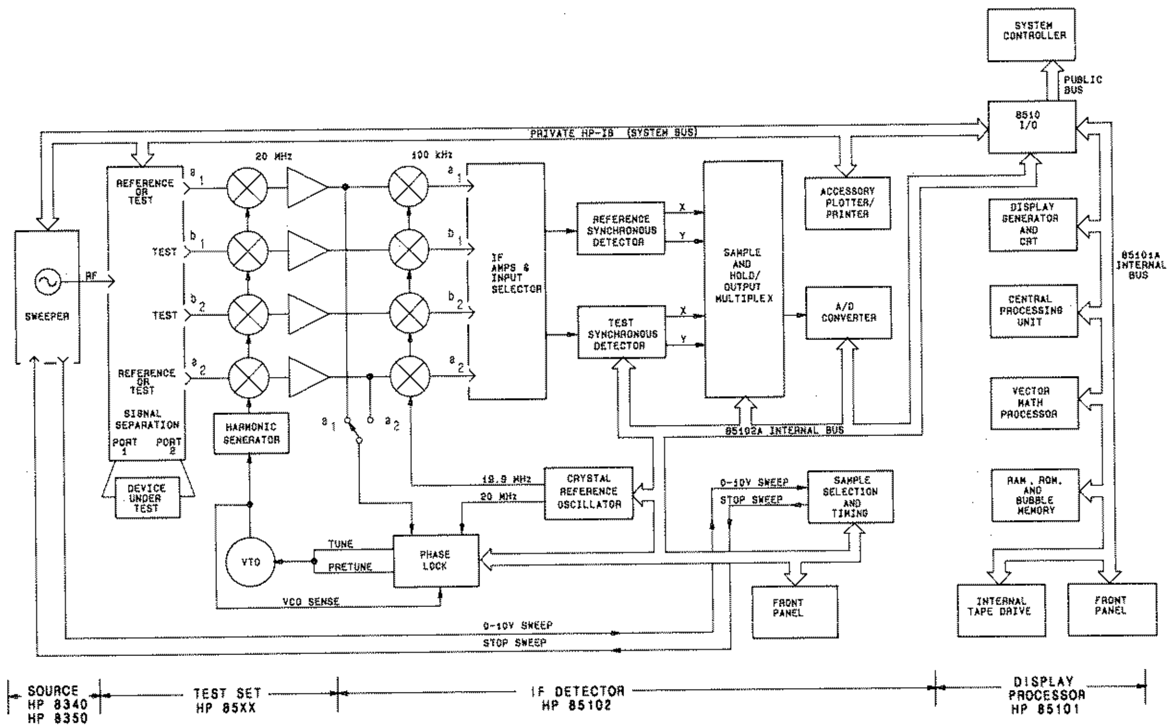


Figure 3. Simplified Block Diagram

The reference detector channel can use either input a_1 or a_2 as the reference signal. The test detector can use any of the inputs as the test signal. During the sweep, the selected inputs are sampled up to 401 times, with sample timing accomplished by sensing the 0 to 10 volt sweep output from the source. With 401 points selected, at each positive 0.025 volt change in the sweep voltage all selected inputs are sampled and applied to the reference and test synchronous detectors.

The synchronous detectors develop the real (X) and imaginary (Y) parts of the signal. The X,Y pairs are sequentially converted to digital values and read by the Central Processing Unit (CPU). Then digital techniques are used that practically eliminate drift, offsets, and cicrularity errors as sources of measurement uncertainty.

POST-DETECTION DIGITAL SIGNAL PROCESSING

Post-detection digital signal processing (Figure 4) proceeds under control of the CPU, a microprocessor equipped with 256 kBytes of RAM, 256 kBytes of magnetic bubble memory, and 26 kBytes of ROM.

The CPU takes advantage of multi-tasking software architecture and several distributed processors to provide a very fast display update rate. It accepts the digitized real and imaginary data and corrects gain and quadrature errors before the reference and test pairs are ratioed and stored in the raw data array. If averaging is on, the incoming data is averaged with the existing data as it is stored.

While the data acquisition software is continually filling the raw data array, the data processing software is processing the data for the two independent display channels.

If error correction is turned on, the raw data and error coefficients from the selected calibration coefficient set are used in appropriate computations by a dedicated vector math processor. Next, phase offsets commanded by the electrical delay and reference plane extension are added to the data. If a time domain presentation is selected, the corrected data is converted from the frequency domain to the time domain using the inverse Fourier Chirp Z transform technique and stored into the corrected data arrays.

The memory arrays are filled from the corrected data array under control of the user with trace data for use in vector computations with the current corrected data. If trace math is selected, vector multiplication, division, addition, or subtraction is performed. The resulting data are formatted according to the FORMAT selection, point-to-point smoothing is applied, if selected, and stored into the formatted data arrays. The traces are now scaled, and output to the display memory where the trace data is combined with various CRT annotation data. A dedicated display processor asynchronously converts the formatted data and annotations for display at a flicker-free rate on the vector-writing CRT.

When the operating system detects a front panel button push, it executes the command immediately (as when a parameter change is made), or it makes the selected function the active function and awaits input from the knob, numeric pad, or STEP keys (as when there is a scale/division change), or it presents a softkey menu. Selecting some functions aborts the data processing operation. For example, **MEASUREMENT RESTART** restarts all measurement related functions to the beginning of the data acquisition group (a group is that number of sweeps needed to make the measurement completely; how may sweeps are taken thus depends on the measurement); **PRESET** initializes the system to a pre-defined state.

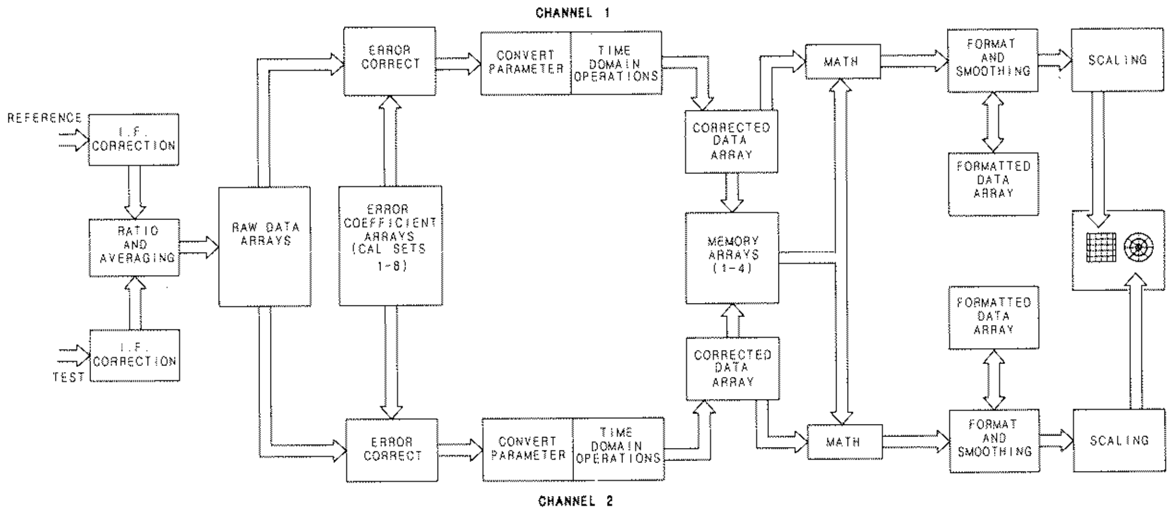


Figure 4. Post-Detection Digital Signal Processing

SOURCES

The RF source in an HP 8510 network analyzer system can be either an HP 834x-series synthesized sweeper or HP 835x-series sweep oscillator with an HP 835xx-series plug-in (Figures 5 and 6). These sources have the correct analog interface signals and full compatibility with the digital 8510 System Bus. If an HP 835x-series sweep oscillator is used, both the sweep oscillator and the plug-in may need to be retrofitted with certain later revisions of the firmware to be compatible with the HP 8510 system. Consult your Hewlett-Packard representative if you need more information on compatibility questions.

The 8510 system bus allows the network analyzer to act as the system controller by managing the source using standard HP-IB protocol. Capabilities added by the system bus include alternate sweep, in which a different frequency range may be selected for each measurement channel, and control of necessary source functions using the HP 8510 front panel controls.

Both types of sources can operate in the Ramp Sweep mode, in which the network analyzer directs the source to sweep in a linear ramp over the selected frequency range. HP 834x-series instruments provide better performance in this Ramp Sweep mode than do HP 835x-series instruments, because of the "Lock-and-Roll" tuning technique used in the HP 834x series. In this "Lock and Roll" technique, the first frequency of the sweep is set with synthesizer accuracy and a linear analog sweep proceeds to the stop frequency. For sweep widths less than 5 MHz, fully locked synthesizer performance is obtained over the complete sweep. Instruments in the HP 835x series are open-loop YIG-tuned sources.

The HP 8340A can also operate in the Step Sweep mode. In this mode, synthesizer-class frequency accuracy and repeatability is obtained by phase-locking the source at each of the up to 401 frequency steps over the selected frequency range. This mode provides the highest accuracy although at a reduced measurement speed.

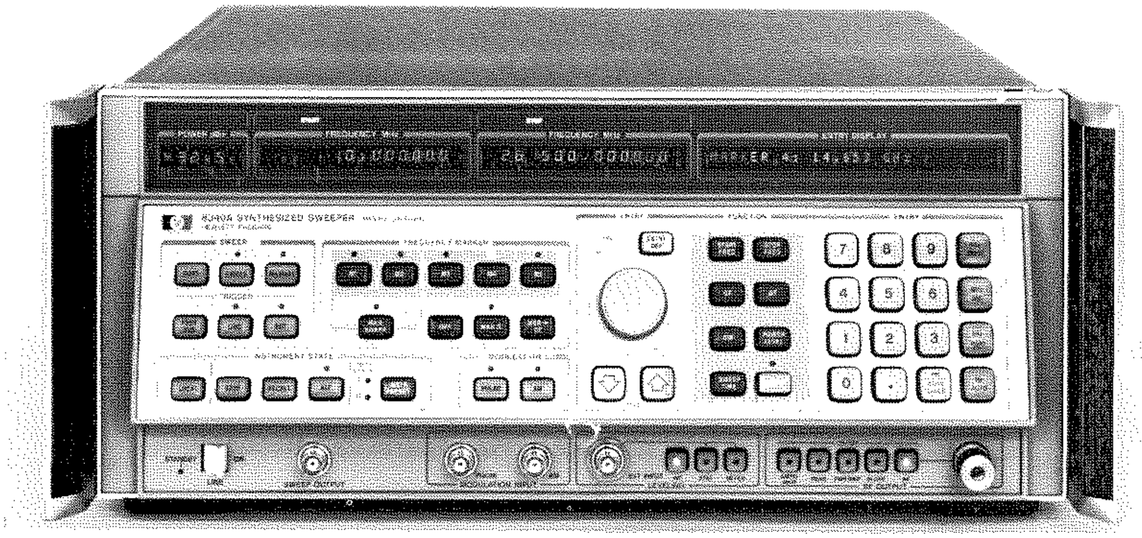


Figure 5. HP 834x-Series Synthesized Sweeper

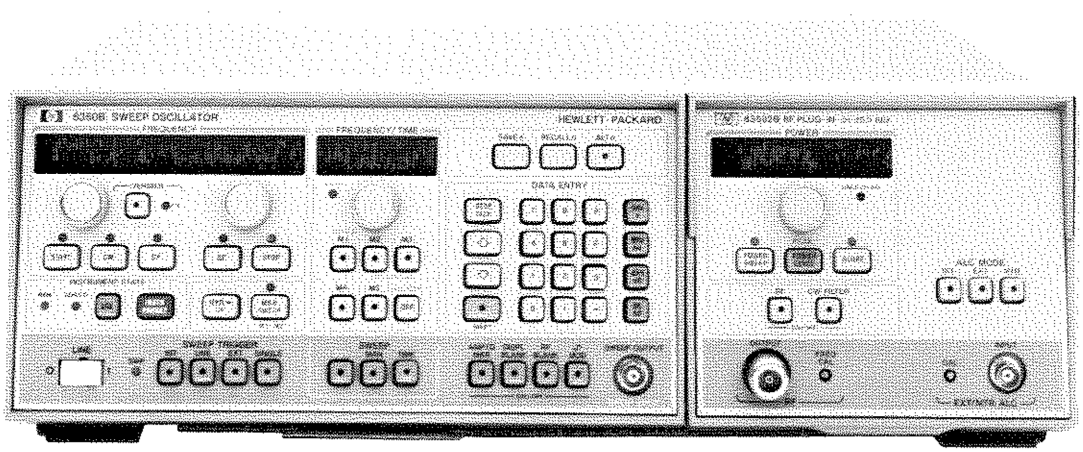


Figure 6. HP 835x-Series Sweep Oscillator with HP 835xx Plug-In

TEST SETS

The HP 851x-series test sets in the HP 8510 network analyzer system have three main functions. They provide:

the input/output ports to connect the device-under-test;

signal separation to separate the reference and test signals;

and RF to 20 MHz conversion.

(The HP 8511A frequency converter differs slightly in that it does not have signal separation devices, thus allowing custom configurations.) The frequency converter is fully integrated into the signal separation path to provide optimum performance. Taking the test-to-reference-signal ratio in S-parameter test sets after electronic switching eliminates signal path selection repeatability errors. Parameter selection is controlled from the network analyzer front panel.

Table 1. HP 851x-Series Test Sets

Test Set Model Number, Type	Test/Input Port Connector	Frequency Range
HP 8511A Frequency Converter	3.5mm (f)	0.045 - 26.5 GHz
HP 8512A Reflection/ Transmission	7mm	0.500 - 18.0 GHz
HP 8513A Reflection/ Transmission	3.5mm (m)	0.045 - 26.5 GHz
HP 8514A S-Parameter	7mm	0.500 - 18.0 GHz
HP 8515A S-Parameter	3.5mm (m)	0.045 - 26.5 GHz

NOTE - HP 8512 and HP 8514 test sets are usable to 0.045 GHz, although with degraded performance specifications.

Reflection/Transmission Test Sets. The HP 8512A and HP 8513A reflection/transmission test sets (Figure 7) provide automatic selection of S_{11} or S_{21}. Fully error-corrected measurements for one-port devices can be made using the 1-Port calibration procedure. The comprehensive One-Path 2-Port calibration procedure provides full error correction for two-port devices if the device-under-test is manually reversed. The HP 8512A test set must use a 20 dB attenuator at the device end of the transmission return cable; the HP 8513A test set must use a 10 dB attenuator at the device end of the transmission return cable.

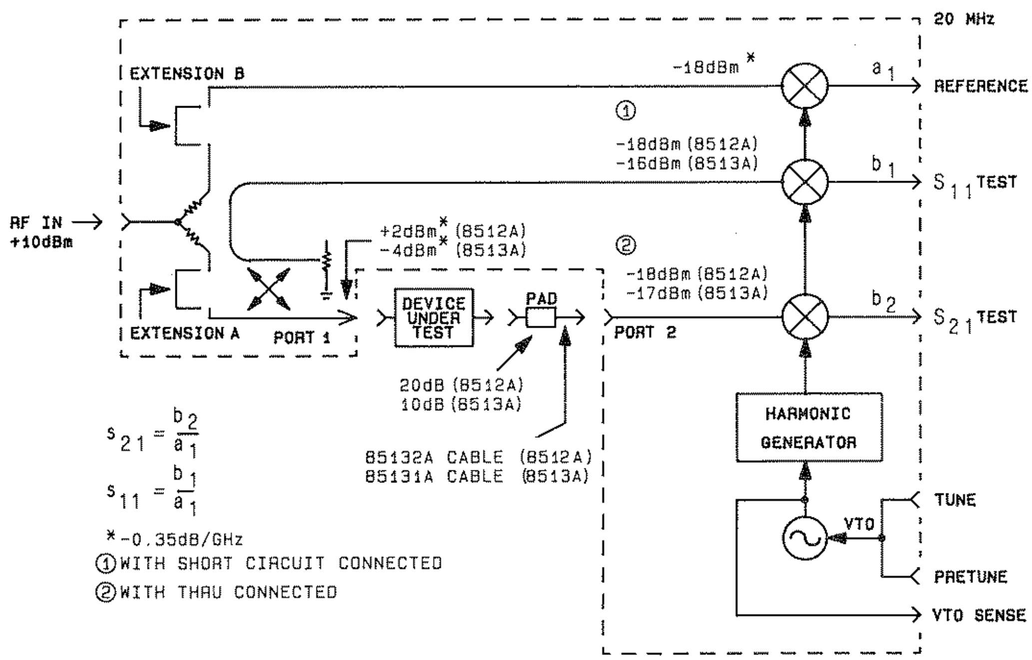


Figure 7. Reflection/Transmission Test Sets Signal Flow

S-Parameter Test Sets. The HP 8514A and HP 8515A S-parameter test sets (Figure 8) provide automatic selection of S_{11}, S_{21}, S_{12}, and S_{22}. The stimulus is automatically switched for forward and reverse measurements, allowing fully error corrected measurements for one-port devices and for two-port devices without the need manually to reverse the device-under-test. Bias input and sense connections are provided to allow testing active devices. Internal 0 to 90 dB, 10 dB step attenuators are provided to control the incident stimulus level at the device-under-test input, without causing a change in the reference signal level.

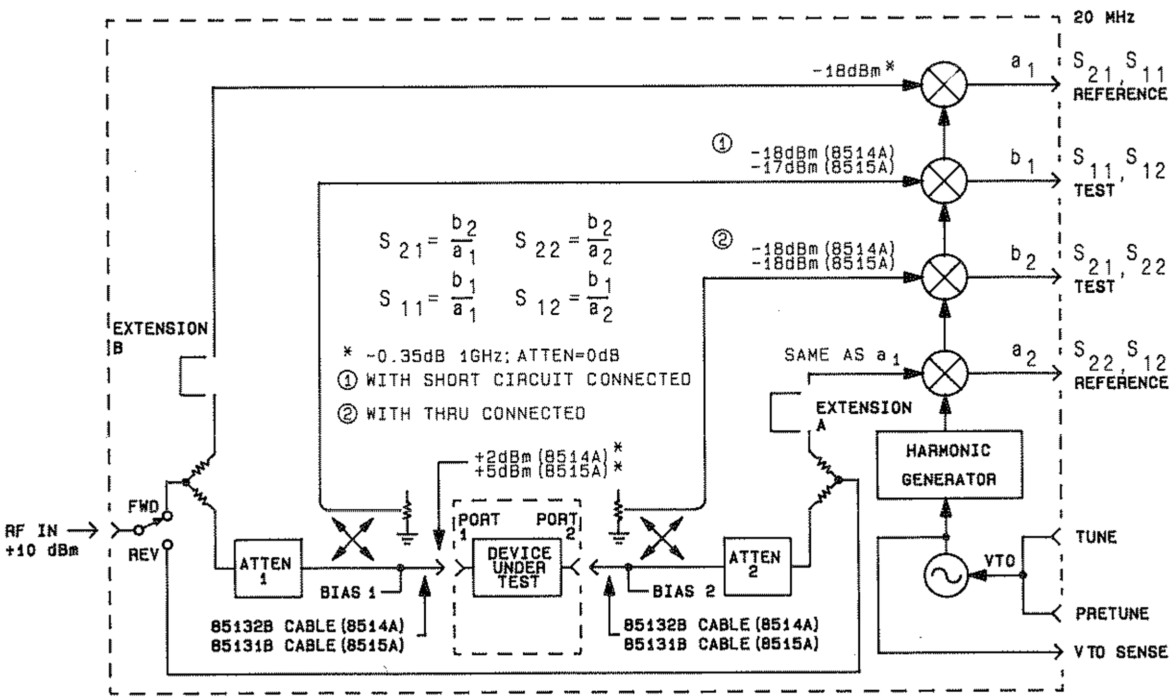


Figure 8. S-Parameter Test Sets Signal Flow

Custom Test Sets. To configure signal separation of your own design, use the HP 8511A frequency converter (Figure 9). If your test setup does not follow the conventions of the reflection/transmission or S-parameter test set, use the REDEFINE PARAMETER sequence of the HP 8510 system to select appropriate reference and test inputs to be used for the measurement.

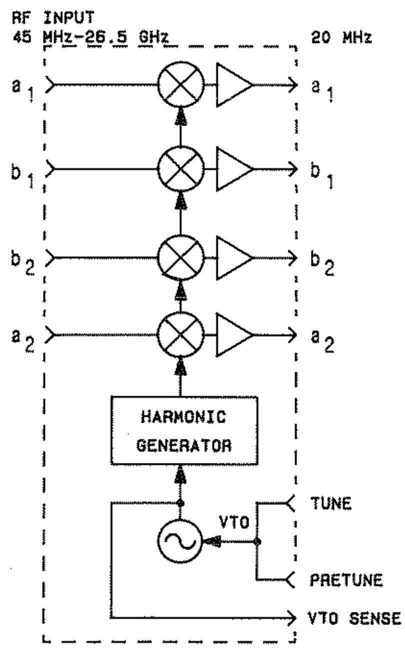


Figure 9. HP 8511A Frequency Converter

TEST PORT RETURN CABLES, ATTENUATORS

High quality cables, attenuators, adapters, and other accessories are essential if one is to achieve accurate, repeatable measurements. Worn or unstable cables and connectors will increase measurement errors due to directivity, mismatch, and frequency response effects. Check cables and connectors regularly and replace them whenever necessary.

Test port return cables used with an HP 8510 network analyzer system must be durable and stable, and care is required to avoid damaging them. Cables can be destroyed by excessive (less than 5-inch radius) bends. Even with careful use, cables do wear out eventually, and for this reason all cables should be treated as consumable items to be replaced as often as necessary. The most important characteristic of all cables is minimum magnitude and phase change between movements (flexures) of the cable. Replace a cable when large magnitude and/or phase changes occur when the cable is moved.

The cables recommended below, in good condition, must be used for detailed performance verification of the HP 8510 system. These cable sets have low insertion loss, good electrical match, and high return loss, and they are stable in use. For other applications, any high quality cable set can be used.

Recommended cables and (when required) 20 or 10 dB attenuators for the test set configurations that can be used in an HP 8510 network analyzer system are:

Table 2. Recommended Cables and Attenuators

Test Set Model Number	Test Port Connector	Return Cables, Attenuators
HP 8512A	7 mm	HP 85132A, 8492A-020
HP 8513A	3.5 mm (m)	HP 85131A, 8493C-010
HP 8514A	7 mm	HP 85132B (2 in set)
HP 8515A	3.5 mm (m)	HP 85131B (2 in set)

EXTENSION LINES

External reference-signal-path extension lines on the test set rear panels are used to balance the reference and test signal path lengths according to the port 1 and port 2 connections to the test device. These extension lines (and the signal paths they apply to) depend on the test set and are as follows. The standard lengths described in the next several paragraphs balance the cable configurations already listed in Table 2.

TEST SET	LABEL	SIGNAL PATH
Reflection-Transmission Test Sets		
HP 8512A	EXTENSION A	b_1, b_2
	EXTENSION B	a_1
HP 8513A	EXTENSION A	a_1
	EXTENSION B	b_1, b_2
S-Parameter Test Sets		
HP 8514A	EXTENSION A	a_1
	EXTENSION B	a_2
HP 8515A	EXTENSION A	a_1
	EXTENSION B	a_2

Reflection/Transmission Test Sets: HP 8512A, HP 8513A. When using a standard test setup (HP 83132A or HP 85131A cable and attenuator) with a device-under-test connected directly to Port 1, use the short extensions, HP part number 08512-20019. On these test sets, one of the lines is in the test signal path, and this fact makes it possible to add bias tees, step or fixed attenuators, amplifiers, isolators, or other devices.

S-Parameter Test Sets: HP 8514A, HP 8515A. When using a standard test setup with the device-under-test connected at the ends of the HP 85131B or HP 85132B test port return cables, use the long extensions, HP part number 08414-20013. When connecting the device-under-test directly at Port 1 and using a single HP 85131A or HP 85132A cable, use the short extension lines, HP part number 08512-20019.

Extension Lines may be changed to other lengths of high quality cable (low insertion loss, high return loss, stable in use) in order to balance electrical lengths in other configurations. Signal path balance is less important when using the HP 8340 synthesized sweeper, particularly in the Step sweep mode.

ADAPTERS

If adapters must be used to connect the devices under test, use only high-quality adapters such as those supplied in the HP 85052A (3.5mm) and the HP 85054A (Type-N) calibration kits. Keep the mating surfaces clean, inspect all connectors visually before every use, and use connector gages to verify that the mating tolerances are within specifications. Always use a torque wrench, set to the correct torque, when tightening or removing connections.

Test sets which have 3.5mm connectors on the test ports (e.g. HP 8513A, HP 8515A) can be used with test port return cables which have 7mm connectors by using the adapters in the HP 85130A special 3.5mm-to-7mm adapter set. These adapters provide a rugged interface for attaching the 7mm test port return cables.

For best results, these HP 85130A adapters (not the adapters in the HP 85052A 3.5mm calibration kit) should be used if 7mm calibration or verification devices are used for calibration or performance verification of a 3.5mm test set (e.g. HP 8513A or HP 8515A). The adapters in the calibration kit are suitable only in the opposite case, when 3.5mm devices are used with a 7mm test set.

CALIBRATION KITS

Use only the highest quality calibration standards: devices which have a known response and are stable in use. Only if the calibration devices used have an accuracy equal to or greater than those in the HP 85050A (7mm) and HP 85052A (3.5mm) calibration kits will they provide the calibration and error correction accuracy needed to achieve full, specified measurement accuracy with the HP 8510 network analyzer system.

Also be aware that calibration standards, like all devices, can become worn and unstable with use. When a calibration device is no longer stable and repeatable, or shows signs of connector damage or wear, it must be replaced. Detailed handling and storage instructions appear in the calibration kit operating and service manuals.

Characteristics for the standards in the HP 85050A (7mm), HP 85052A (3.5mm) and HP 85054A (Type-N) calibration kits are loaded from the tape cartridge supplied with the calibration kits. Characteristics can also be defined by the user. Each calibration kit is supplied with a data cartridge on which is stored the nominal characteristics for each of the calibration devices in the kit.

The HP 85050A 7mm calibration kit consists of open and short circuit terminations, fixed and sliding loads, a 7mm connector gage, gage calibration block and aligning pin, extra precision 6-slot center collets, a center collet extractor, a 7mm connector torque wrench, and the device data cartridge. Option 010 adds a 30 cm beadless airline, which is used for time domain applications.

The HP 85052A 3.5mm calibration kit consists of male and female open and short circuit terminations, fixed and sliding loads, 7mm-to-3.5mm adapters, matched 3.5mm-to-3.5mm adapters, a 3.5mm connector torque wrench, 3.5mm connector gages and gage calibration block, and the device data cartridge. Option 010 adds a 15cm beadless airline, which is used for time domain applications.

The HP 85054A Type-N Calibration Kit consists of male and female Type-N open and short circuit terminations, fixed and sliding loads, 7mm-to-Type-N adapters, and the device data cartridge .

When other calibration kits are used, nominal characteristics of the standards can be defined by the user from the front panel of the HP 8510, using the MODIFY CAL KIT sequence described in Measurement Calibration part of this manual. After the calibration kit standards are defined, the data can be recorded on tape then loaded from tape whenever required.

VERIFICATION KITS

Performance verification standards are used to determine that the system can be calibrated and produce good measurement results. Devices in the verification kits are precision devices which should be treated with care and used only in specific situations, not on a day-to-day basis. These devices have been characterized on a standards-class network analyzer by experienced factory personnel. If you use proper calibration and measurement techniques, your measurement results should be comparable to the data supplied with the devices, within the system specifications.

Only verification devices which have an accuracy equal to or greater than those in the HP 85051A (7mm) and HP 85053A (3.5mm) verification kits can be used to verify HP 8510 network analyzer system specifications.

The HP 85051A (7mm) and HP 85053A (3.5mm) verification kits both include fixed attenuators (20 dB and 50 dB for 7mm, 20 dB and 40 dB for 3.5mm) and beadless and stepped two-port airline mismatch standards. Data for the devices includes a device data sheet which lists fully error-corrected data and measurement uncertainty data on all devices in the kit at various specified frequencies. This measurement uncertainty includes both the uncertainty of the HP factory measurement system and the specified uncertainty of the user's system.

The device data sheet with the HP 85051A 7mm verification kit lists data at 20 frequencies, 19 of them within the specified range of the HP 8512A and HP 8514A test sets. The device data sheet with the HP 85053A 3.5mm verification kit lists data at 18 frequencies. The data cartridge contains formatted trace data on the devices before they were shipped from the factory, as measured on a standards-class HP 8510 network analyzer system. The formatted trace data contains information for 201 frequencies.

To verify system performance using these standards, perform standard 7mm or 3.5mm two-port calibration and measurement procedures, present corrected response of standard device, then read the marker at the specified frequency points and compare your measured data with the standard data supplied with the devices. Refer to the Performance Tests section of the HP 8510 system manual for detailed system performance verification instructions.

INTRODUCTORY MEASUREMENT SEQUENCE

ILLUSTRATIONS

INTRODUCTION

This part of the HP 8510 network analyzer system manual offers a brief, self-contained, step-by-step tutorial designed to acquaint you with some of the main features of the HP 8510 system. It is not designed for reference, nor does it provide detailed explanation of any of the steps performed. All of the subjects treated briefly here are discussed later in this manual or in the manuals supplied with HP 8510 system calibration and verification kits. The aim of this material is strictly tutorial.

The tutorial describes a simple, complete sequence measuring the transmission and reflection characteristics of a two-port coaxial device such as a bandpass filter. It also reviews important points on cleaning and gaging connectors and on making connections discussed in detail in the calibration and verification kit manuals. Figures 15-a through 15-k summarize the sequence and show the CRT displays you can expect to see.

The steps in this sequence assume that the system has already been installed and is ready for operation. If it is not, follow the steps in the Installation section of the HP 8510 system manual.

INTRODUCTORY MEASUREMENT SEQUENCE

The HP 8510 introductory measurement sequence described here has three main parts: setting up the measurement, including inspection and cleaning of the connectors, system calibration, and measurement of the device-under-test. A brief overview of the front panel controls and a review of connection procedures is also included.

Besides the HP 8510 network analyzer and a two-port device of known characteristics to be measured, you will need the calibration kit for the system: the HP 85050A 7mm calibration kit, the HP 85052A 3.5mm calibration kit, or the HP 85054A Type-N calibration kit. These kits contain the calibration devices, connector gages, and a torque wrench for making connections.

You will also need materials for inspecting and cleaning the connectors. These additional items are shown in Figure 11; part numbers are given in later in this part of the manual, in the discussion of cleaning connectors, and in the HP 8510 system calibration and verification kit manuals.

The correct test port return cable(s) and attenuators for each test set are also required. These are listed in Table 2 of this manual and in the description of the measurement setup for this introductory measurement sequence.

FRONT PANEL

The front panel of HP 8510 network analyzer system is shown in Figure 10. It consists of the HP 85101A display/processor and, below it, the HP 85102A IF/detector.

The CRT displays measurement data and menus which offer selections of measurements and measurement parameters. Eight softkeys to the right of the CRT are used to make choices from the menus. In the ENTRY area to the right of the softkeys, the knob, step, numeric and units keys are used to enter numerical values, to change the value of the active function, and to position the marker on the data trace.

Below these controls, sixteen dark gray function keys are arranged in four blocks: STIMULUS, PARAMETER, FORMAT, DISPLAY. These keys control the four basic measurement and display functions of the HP 8510 network analyzer system. To the left of these four function blocks are keys allowing you to choose the measurement channel for display or front panel control and, in the MENUS block, keys allowing you to display four specialized menus. At the very bottom are other operating and menu keys, the LINE power switch, the green instrument **PRESET** key, and the measurement RESTART key.

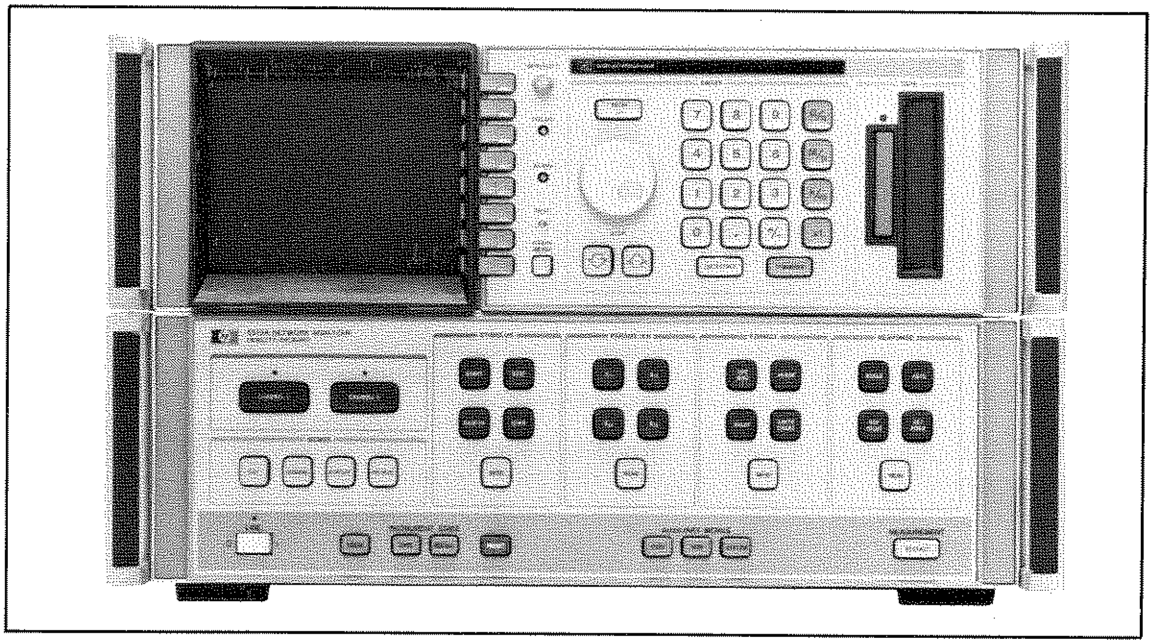


Figure 10. HP 8510 Network Analyzer Front Panel

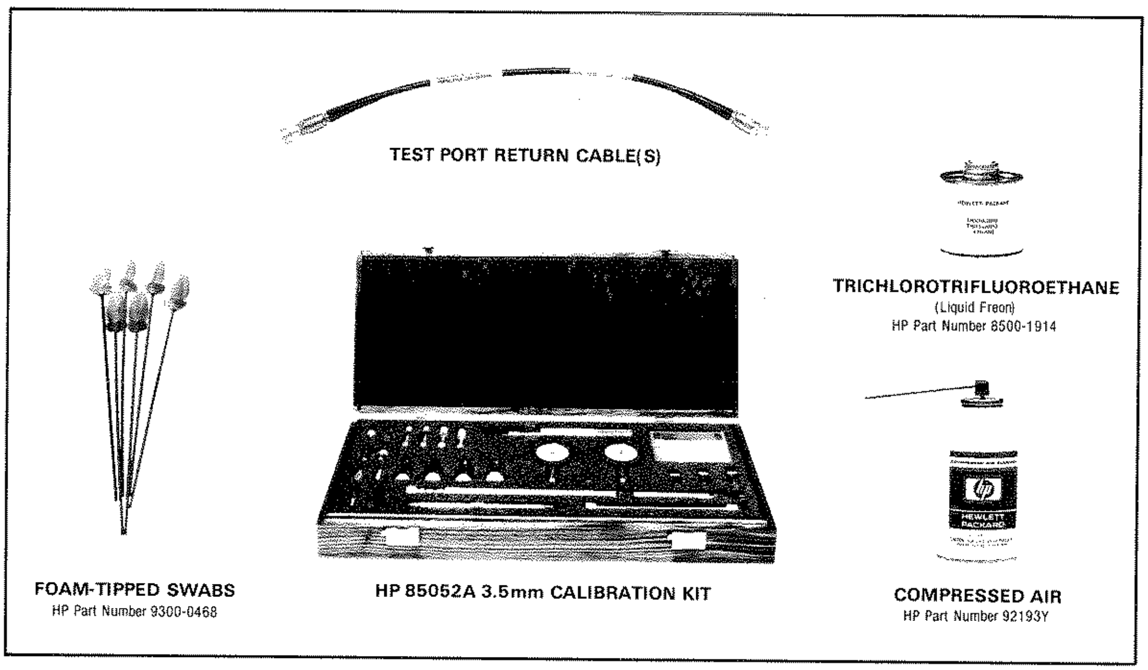


Figure 11. Equipment Required

MEASUREMENT SETUP

The measurement setup used in this introductory measurement sequence is shown in Figure 12. With reflection/transmission test sets, calibration and device measurements are done at Port 1 with an attenuator pad and a single test port return cable completing the connection to Port 2. With the HP 8512A reflection/transmission test set (7mm) use the HP 8492A-020 20 dB attenuator pad and the HP 85132A test port return cable. With the HP 8513A reflection/transmission test set (3.5mm) use the HP 8493C-010 10 dB attenuator pad and the HP 85131A test port return cable.

With S-parameter test sets, calibration and device measurements are done using a matched set of two test port return cables. With the HP 8514A S-parameter test set (7mm) use the HP 85132B cable set. With the HP 8515A S-parameter test set (3.5mm) use the HP 85131B cable set.

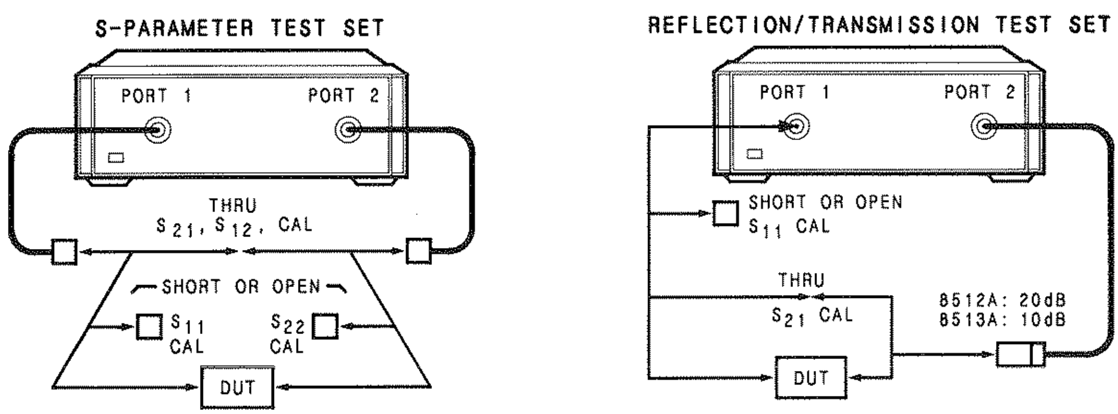


Figure 12. Measurement Setup

CLEANING AND GAGING CONNECTORS, MAKING CONNECTIONS

Accuracy and repeatability in microwave measurements requires care and skill, especially in making connections. Not only will a bad connection or connector produce bad data, it is very likely to damage your equipment, requiring replacement of the parts or time-consuming and costly repairs. Moreover, work at Hewlett-Packard on connector repeatability has shown clearly that it is essential to inspect and clean all connectors before every use if accurate measurements are to be made. Dirt and contamination on connectors is the most important single source of measurement problems.

Therefore make it part of your routine, before performing any calibrations or making measurements, to satisfy yourself:

> that all connectors are undamaged and clean;
>
> that the mechanical dimensions of the connectors, as checked with a connector gage, are within mechanical specifications; and
>
> that all connections have been made in a way that assures consistent and repeatable mechanical (and therefore electrical) contact between the connector mating surfaces.

Detailed information on inspecting and cleaning connectors, and on making connections, appears in the HP 85050A, HP 85052A and HP 85054A calibration kit manuals and is summarized in the HP 85051A and HP 85053A verification kit manuals. The main points are worth reviewing briefly here.

Visual Inspection. Always begin by making a careful visual inspection of all connectors, including the test set connectors, to make sure that they are undamaged and clean.

Use an illuminated magnifying glass and examine the connectors first for such obvious problems as deformed threads, contamination, or corrosion. Then concentrate on the mating surfaces of each connector. Look for burrs, scratches, rounded shoulders, misalignment, or any other signs of wear or damage.

Also make sure that the surfaces are clean, free of dust and any solvent residues. Dirt or damage visible with a 4-power magnifying glass is always enough to cause degraded electrical performance and possible connector damage. All such connectors should be repaired or discarded immediately.

Figure 13. Inspecting and Cleaning Connectors

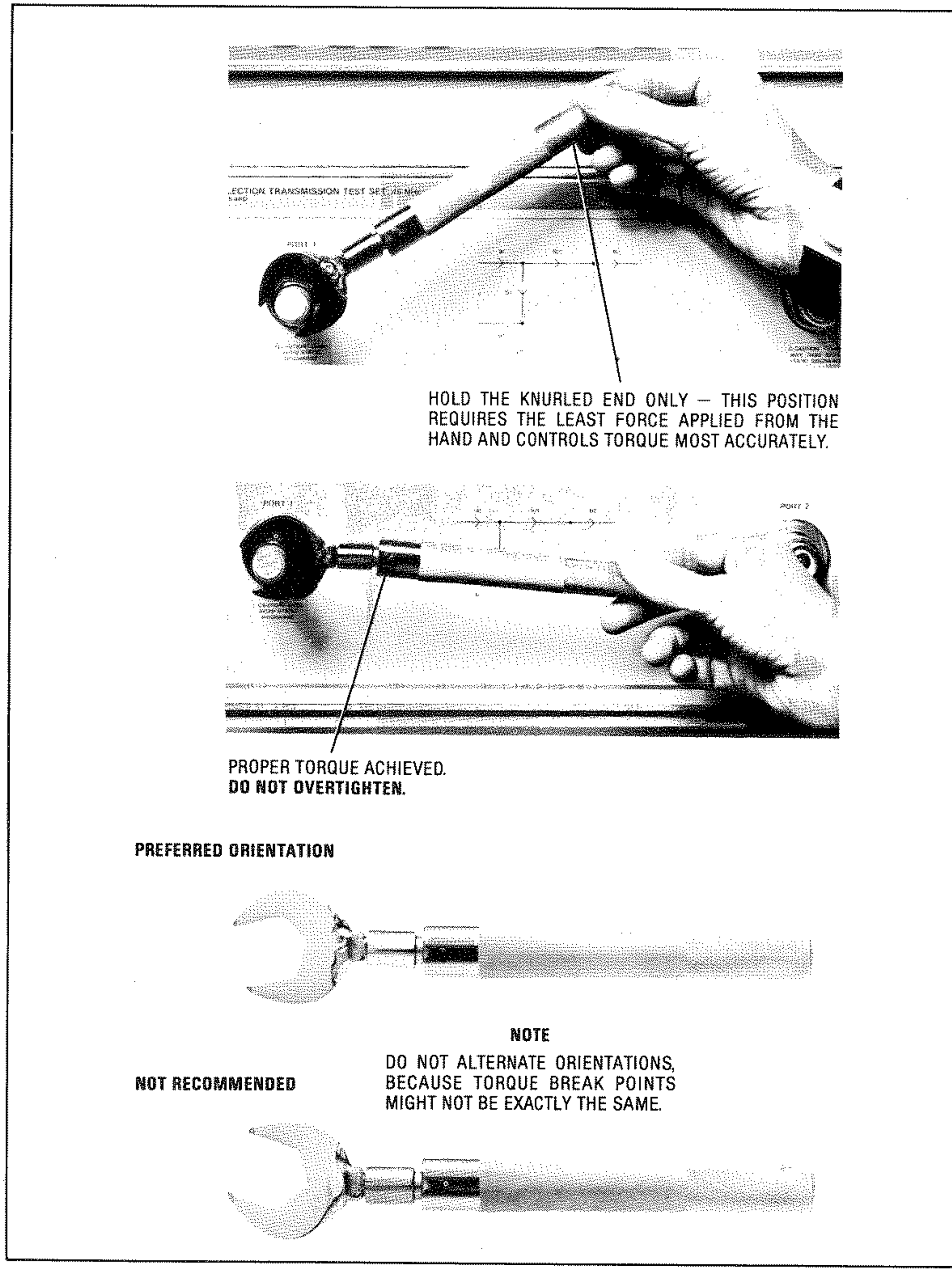


Figure 14. Using a Torque Wrench

Cleaning. Dust or dirt on the connector surfaces can be brushed or wiped away using a plastic foam swab or low-pressure, clean compressed air. Compressed air in a small pressurized can is available as HP part number 92193Y; plastic foam swabs are available as HP part number 9300-0468.

When inspecting or cleaning the connectors on the test set, be sure to ground yourself and your equipment before touching any center conductor. Wear a grounded wrist strap and grasp the outer shell of the test port briefly before touching the connector. This will prevent electrostatic discharge (ESD) that can severely damage the sensitive sampler circuit diodes in the test set.

If necessary, liquid Freon (trichlorotrifluoroethane) can be used sparingly as a cleaning solvent. Trichlorotrifluoroethane, HP part number 8500-1914, is the only cleaning solvent Hewlett-Packard recommends for cleaning connnectors. Other forms of the solvent often contain additives that can damage plastic interior support beads or leave residues. Using the solvent in liquid rather than spray form is preferable because the liquid can be applied much more selectively. If a spray must be used, spray the cleaning swab only, not the connector.

When you are satisfied that all connectors are clean and undamaged, check the mechanical dimensions of the connectors with a connector gage.

Mechanical Inspection. Mechanical inspection of microwave connectors consists of using a precision connector gage (or gages) to check the mechanical dimensions of all connectors, including those on the test set. Connector dimensions must be within very precise mechanical tolerances in order to assure that perfect mating will occur between the connector surfaces, thus resulting in a good electrical match and avoiding damage to the connectors themselves.

The critical dimension to measure is the recession of the center conductor behind the outer conductor mating plane. This dimension differs according to connector type and whether the connector is on the test set or a device or cable. Dimensions are given in the manuals supplied with the devices.

In general, *no protrusion* of the shoulder of the center conductor in front of the outer conductor mating plane is allowable, although some protrusion of the spring-loaded center conductor collet on precision 7mm connectors after assembly is allowed. The maximum allowable *recession* of the center conductor shoulder is given in the individual calibration and verification kit manuals, and with the manuals supplied with cables.

First zero the gage(s) using the gage calibration block supplied with the gage itself. Then insert the gage carefully into the connector and read the amount of recession (or protrusion) of the center conductor from the graduated dial. Discard or mark and send away for repair any connector that is not within allowable tolerances. *Such a connector will damage any other connector it is mated to even on the very first connection.*

Connection Techniques. When all connectors have been inspected visually and mechanically, you are ready to make connections. The important points to remember in making connections are these:

> to check all connector and thread alignments carefully before tightening the connector nuts;
>
> to make the initial connection only finger tight;
>
> for the most demanding measurements (40 dB or more return loss, for example) to rotate the device backward 10 to 20 degrees to eliminate air wedges; type-N connectors are an exception, and should not be rotated; and
>
> to use a torque wrench for all final connections, to avoid overtightening.

Support the cables and all devices being used, to avoid putting vertical or lateral force on any connectors. Avoid bending the cables any more than is necessary, and do not straighten them when finished making measurements. Leave the cables formed as they were when last used, even for storage. Straightening the cables creates much more stress and fatigue than the minor bending required in making connections and disconnections for measurements.

In disconnecting devices and cables, take care not to rock or bend any connections. Doing so can damage connectors permanently due to misalignment or even breakage.

MEASUREMENT SEQUENCE

Turn On Power. Turn on ac power to the system rack (if used). Then turn on the power to the instruments in the HP 8510 system in the following order. Note that the network analyzer should be turned on last (using the LINE switch), in order for the network analyzer to gain control of the instruments connected to the 8510 system bus.

- SOURCE: HP 834x or HP 835x
- TEST SET: HP 851x
- SYSTEM PERIPHERALS: PLOTTER (if used),
  PRINTER (if used)
- NETWORK ANALYZER: LINE switch, front panel.

Power to both the display/processor and the IF detector is controlled by the LINE switch on the front panel of the IF detector if the line switch on the rear panel of the display/processor is set to SYSTEM CONTROLLED. If the display/ processor does not turn on, check the position of this rear-panel switch first.

When power is turned on, the network analyzer goes through its initalization and self-test routines and then is set to the instrument state stored in Instrument State Register 8. This is the Standard Power On State, unless changed by using the INSTRUMENT STATE **SAVE 8** sequence.

When measurements are complete, power can be left applied to the test set and the source (HP 8340 in Standby) to minimize warmup time; or power can be turned off to all of the instruments, individually or by turning off power to the system rack (if used).

Press Network Analyzer PRESET. Press the green **PRESET** key on the HP 8510 network analyzer front panel. This sets the system to its Standard Preset State. A partial list of standard preset conditions for the HP 8510 system is given in Table 3.

Set Stimulus, Parameter, Format, Response. Now use the function keys in the STIMULUS, PARAMETER, FORMAT, and RESPONSE function blocks and the knob, step, and numeric and units keys in the ENTRY block to choose the type of measurement and display desired.

STIMULUS. To set the start and stop points of the frequency sweep, first press the START key in the STIMULUS function block. Then use the knob, step, numeric and units keys in the ENTRY block to select the start frequency. Then press the STOP key in the STIMULUS function block and do the same to select the stop frequency. Selections appear below the graticule (grid) and in the Active Function area of the CRT display as you make them. For example, **START 0.5 G/n STOP 18 G/n** sets the start frequency to 0.5 GHz and the stop frequency to 18 GHz.

PARAMETER. To select the parameter to be measured, use the keys in the PARAMETER function block. Selections appear in the upper left-hand corner of the CRT display.

The Standard Preset State initializes Channel 1 to measure S_{11}, Channel 2 to measure S_{21}, and selects the single channel display mode. Thus, after the green **PRESET** key is pressed, pressing **CHANNEL 1** displays S_{11} and pressing **CHANNEL 2** displays S_{21}. The LED indicators above the channel buttons indicate which channel is currently selected. Any parameter can be displayed using either channel.

FORMAT. To select the type of graticule (grid) used in the display of the measured data, use the keys in the FORMAT function block.

The Standard Preset State initializes Channel 1 and Channel 2 to display power ratio versus frequency using the **LOG MAG** graticule. Any format can be selected for the display of any parameter.

RESPONSE. To position the trace on the CRT, use the keys in the RESPONSE function block. Select the channel, then press the RESPONSE key representing the value you wish to change. Then use the knob, step keys, or the numeric and **x1** unit keys to change the value.

Pressing the **AUTO** key automatically selects a scale/division value that displays the entire trace and a value for the reference position that positions the trace on the CRT.

MEASUREMENT CALIBRATION

The HP 8510 introductory measurement sequence described here assumes that the standard HP 85050A 7mm calibration kit is defined as Cal Kit 1. If parameters from a different Cal Kit have been defined and installed, some of the key labels relating to calibration standard selection may be different, but the general sequence will be similar.

If a different Cal Kit has been defined, the standard definition can be restored by inserting the appropriate calibration kit device characteristics data cartridge, then using the **TAPE**, **LOAD**, **CAL KIT 1-2**, **CAL KIT 1** sequence. (The same procedure can be used to load any other definition if desired.) Instructions for doing this appear later in this manual, under the heading Storing Calibration Data.

If the test set used is the HP 8513A or HP 8515A, both of which have 3.5mm test port connectors, whenever the instruction appears in the following sequence to press the softkey **CAL 1 7mm**, instead press the softkey **CAL 2 3.5mm.** The standard HP 85052A 3.5mm calibration kit is defined as Cal Kit 2.

After calibration, the measurements in this introductory measurement sequence can be made in any order. Disconnect the devices used in one measurement before going on to the next.

Calibration Setup

Calibration Setup. Begin measurement calibration by connecting the test port return cable(s) to the test port(s) of the test set. Then, if a reflection/transmission (HP 8512A, HP 8513A) test set is being used, connect the correct attenuator pad to the end of the cable. Details are shown in Figure 12.

Then connect the other end of the attenuator to Port 1 of the test set (reflection/ transmission test sets) or connect the two cables together (S-parameter test sets). Use a torque wrench in making all final connections.

Calibration PRESET. Return the system to its Standard Preset State by pressing the green **PRESET** key on the front panel.

Set Stimulus. Using the STIMULUS function block, set the start frequency to 0.5 GHz and the stop frequency to 18.0 GHz. (With some test sets, these values are selected automatically as part of the Standard Preset State.) Figure 15-a shows how the CRT display should appear.

The Standard Preset State selects the Ramp Sweep mode and a sweep time of 100 milliseconds/sweep, and this is usually acceptable. If distortion appears in the trace, a slower sweep time (200 milliseconds, for example) can be selected.

To change the sweep time, press the STIMULUS block **MENU** key, then the softkey labeled **SWEEP TIME**. Use the ENTRY block controls to set the new sweep time. Enter the value, then press either the **x1** key, if the value is in seconds, or the **k/m** key if the value is in milliseconds. For more information on sweep times see the Main Function Blocks part of this manual, under the heading Sweep Time.

Calibration Setup

- Prepare Measurement Setup.
  See Figure 12.
- Press green **PRESET** key.
- Use STIMULUS controls to set
  start frequency to 0.5 GHz,
  stop frequency to 18.0 GHz.

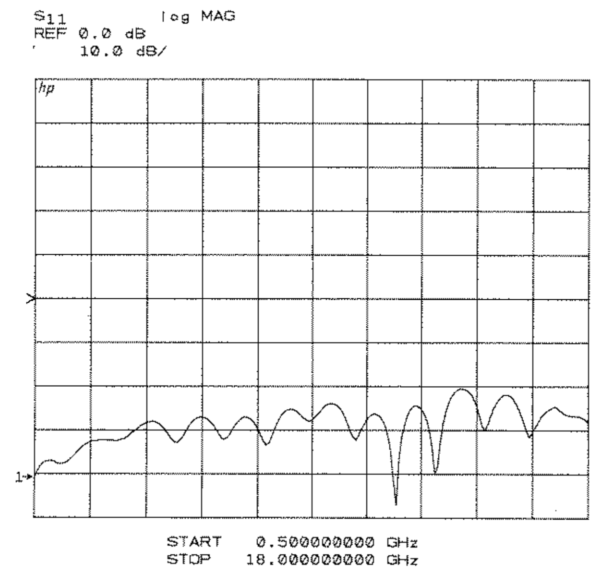


Figure 15-a. Thru Connection:
PRESET, ENTRY OFF

Reflection Frequency Response Calibration

Reflection Frequency Response Calibration: S_{11} Calibration. Press **CHANNEL 1**. Then, in the PARAMETER function block, select S_{11}.

In the MENUS block press **CAL** to present the Cal Menu. When the menu appears, press the softkey **CAL 1 7mm**. This will bring the Cal Type Menu onto the CRT. Press the softkey **CALIBRATE: RESPONSE** to present the Frequency Response Cal Menu.

Now connect the shielded open circuit calibration device to PORT 1. If an S-Parameter test set is being used, connect the device to the end of the cable attached to PORT 1 of the test set, not to the test port directly. Use a torque wrench in making the final connection.

Channel 1 (Figure 15-b) now displays the uncorrected reflection signal path frequency response. When the trace is stable, indicating that the shielded open circuit is properly connected, press **OPEN** to measure the reflection signal path frequency response.

Save Calibration. When the message WAIT--MEASURING CAL STANDARD disappears, press **DONE: RESPONSE** to indicate that the frequency response calibration is complete, then press **CAL SET 1** to store the calibration data. The Cal Menu will reappear with **CORRECTION ON** selected. Press **PHASE.**

At this point the displayed trace (Figure 15-c) represents the current measurement trace of the shielded open circuit response (0 dB Return Loss, with some phase shift due to the reactive response of the shielded open circuit; the calibration process has removed the reflection frequency response errors of the system). The network analyzer can measure reflection, corrected for the system reflection signal path frequency response, in either domain using any format.

Reflection Frequency Response Calibration

S_{11} Calibration

- Connect Shielded Open Circuit at Port 1.
- Observe Reflection Signal Path Frequency Response.
- Press **CAL, CAL 1 7 mm , CALIBRATE: RESPONSE.**
- When trace is correct, press **OPEN.**
  When message WAIT--MEASURING CAL STANDARD disappears, press **DONE: RESPONSE.**

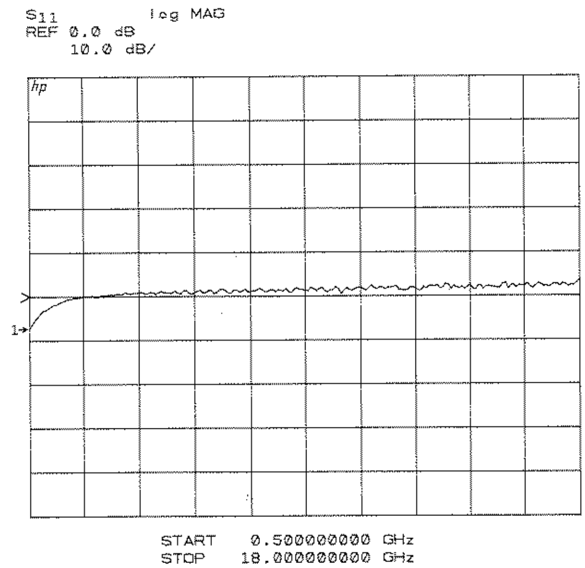


Figure 15-b. Open Circuit Connected

Save Calibration

- Press **CAL SET 1.**
  (Calibration saved as Cal Set 1; **CORRECTION ON** selected; trace should be flat at 0 dB.)
- Press **PHASE.**
  (Trace should be Typical Shielded Open Circuit Phase Response.)

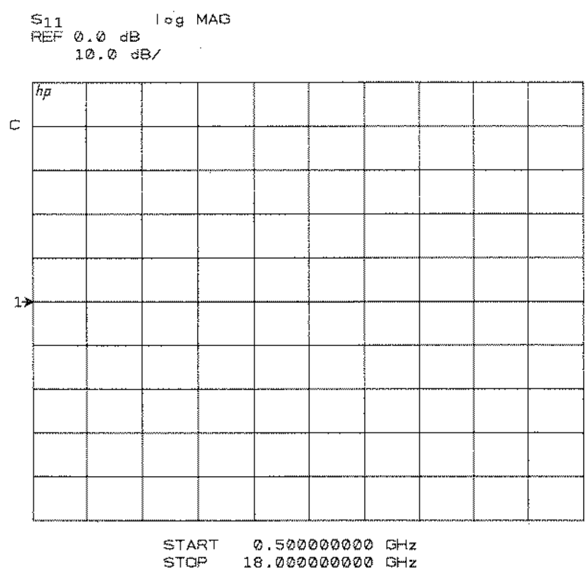


Figure 15-c. Calibration Saved:
CORRECTION ON, S_{11}, LOG MAG

Transmission Frequency Response Calibration

Transmission Frequency Response Calibration: S_{21} Calibration. Press CHANNEL 2. Then, in the PARAMETER function block, select S_{21}.

In the MENUS block press **CAL** to present the Cal Menu. When the menu appears, press the softkey **CAL 1 7 mm.** This will bring the Cal Type Menu onto the CRT. Press the softkey **CALIBRATE: RESPONSE** to present the Frequency Response Cal Menu.

Now make a thru connection by connecting together the points at which the two-port device will be connected. If a reflection/transmission test set is being used, connect the attenuator directly to Port 1 of the test set. If an S-Parameter test set is being used, connect the two cables together. Use a torque wrench in making the final connections.

Channel 2 (Figure 15-d) now displays the uncorrected transmission signal path frequency response. When the trace is stable, indicating that the thru is properly connected, press **THRU** to measure the transmission signal path frequency response.

Save Calibration. When the message WAIT--MEASURING CAL STANDARD disappears, press **DONE: RESPONSE** to indicate that the frequency response calibration is complete, then press **CAL SET 2** to store the calibration data. The Cal Menu will reappear with **CORRECTION ON** selected. Press **PHASE.**

At this point the displayed trace (Figure 15-e) represents the thru response (0 dB Insertion Loss, with 0 degrees phase shift for the 7mm Thru; the calibration process has removed the reflection frequency response errors of the system). The network analyzer can now measure transmission characteristics, corrected for the system transmission signal path frequency response, in either domain using any format.

Transmission Frequency Response Calibration

S_{21} Calibration

- Connect PORT 2 to PORT 1 (Thru).
- Press **CHANNEL 2.** Observe Transmission Signal Path Frequency Response.
- Press **CAL**, **CAL 1 7 mm**, **CALIBRATE: RESPONSE.**
- When trace is correct, press **THRU.** When message WAIT--MEASURING CAL STANDARD disappears, press **DONE: RESPONSE.**

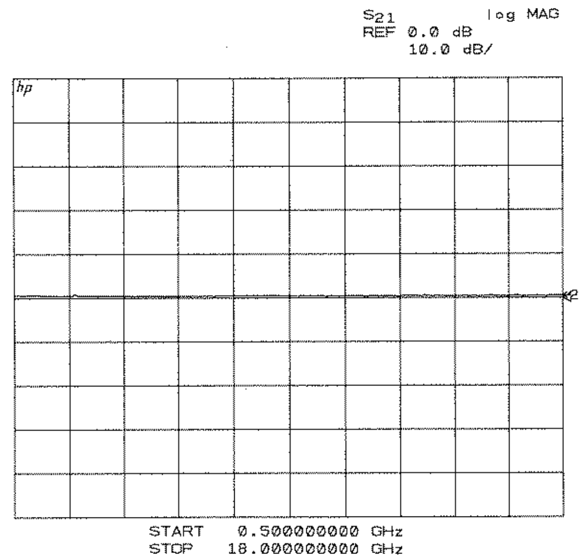


Figure 15-d. Thru Connection

Save Calibration

- Press **CAL SET 2.** (Calibration saved as Cal Set 2; **CORRECTION ON** selected; trace should be flat at 0 dB.)
- Press **PHASE.** (Trace should be flat at 0 degrees.)

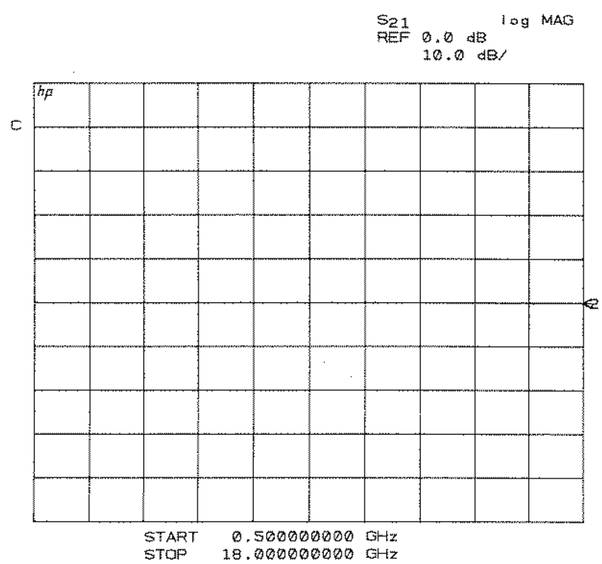


Figure 15-e. Calibration Saved:
CORRECTION ON, S_{21}, LOG MAG

MEASUREMENTS

Connect the Device Under Test. If a reflection/transmission test set is being used, disconnect the attenuator from Port 1 and connect the device you will be testing (DUT) in its place. Do not disconnect the attenuator from the cable or the cable from Port 2, and bend the cable as little as possible. Use a torque wrench in making the final connections.

If an S-parameter test set is being used, disconnect the two cables from one another and connect the device between them. Do not disconnect either cable from its test port, and bend the cables as little as possible. Use a torque wrench in making the final connections.

Read Trace Values: Return Loss and Phase Angle. To read the return loss of the device-under-test, select **CHANNEL 1**, S_{11}, and **LOG MAG**. Then press **MARKER**. Use the knob to position the marker to any point on the trace.

The measured return loss magnitude and frequency values at the marker position are displayed above the graticule (grid) on the CRT. Figure 15-f shows how the display will now appear.

To read the measured phase angle press **PHASE**.

To position the trace automatically for viewing, press **AUTO**.

Read Trace Values: Insertion Loss and Phase Angle. To read the insertion loss of the device-under-test, select **CHANNEL 2**, S_{21}, and **LOG MAG**. Then press **MARKER**. Use the knob to position the marker to any point on the trace.

The measured insertion loss magnitude and frequency values at the marker position are displayed above the graticule (grid) on the CRT. Figure 15-g shows how the display will now appear.

To read the measured phase angle press **PHASE**.

To position the trace automatically for viewing, press **AUTO**.

Read Trace Values: Return and Insertion Loss and Phase Angle

- Connect Device Under Test.

- Press **CHANNEL 1, LOG MAG.**
- Press **MARKER.**
- Use knob to position Marker on trace; read Return Loss dB.
- Press **PHASE.**
- Use knob to position Marker on trace; read reflection phase angle degrees.

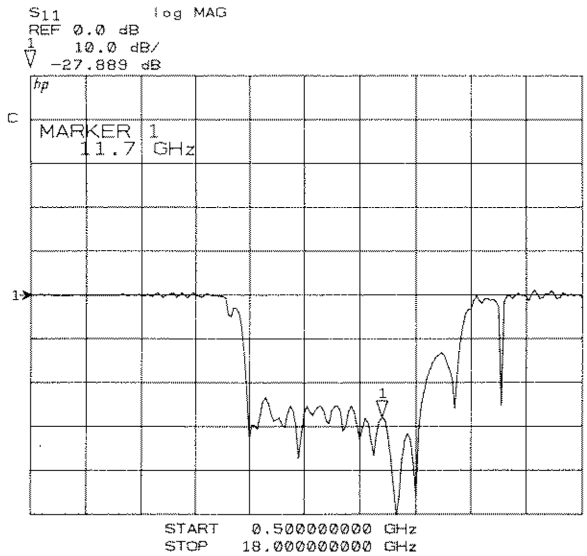


Figure 15-f. Device-Under Test Return Loss: S_{11}, LOG MAG.

- Press **CHANNEL 2, LOG MAG.**
- Use knob to position Marker on trace; read Insertion Loss dB.
- Press **PHASE.**
- Use knob to position Marker on trace; read insertion phase angle degrees.

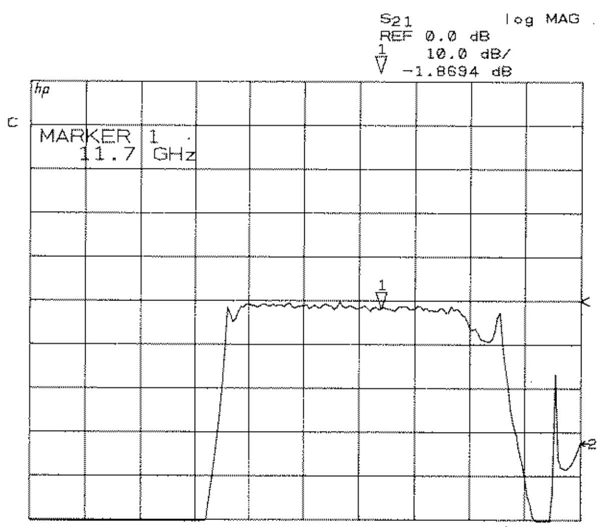


Figure 15-g. Device-Under Test Insertion Loss: S_{21}, LOG MAG.

Read Time Domain Trace Value. If your HP 8510 system is equipped with Option 010, Time Domain, you can now make the following additional measurements illustrating time domain measurements. Figures 15-h through 15-k show the results you can expect.

Disconnect the device-under test and connect the short circuit device at Port 1 of the test set. If an S-parameter test set is being used, connect the short circuit device at the end of the cable attached to Port 1.

Select **CHANNEL 1**, then S_{11}. Now press **DOMAIN** to present the Time Domain Menu. When the menu appears, press **TIME BAND PASS**. The Time Band Pass Mode provides a time domain presentation suitable for limited bandwidth test devices.

Position the marker to the peak of the response by pressing **MARKER**, **MORE**, **MARKER to MAXIMUM**. The measured time value should be 0 seconds, meaning that the short circuit is connected to Port 1 at the same point at which reflection measurement calibration was performed. See Figure 15-h.

Remove the short circuit, install an airline (a 20cm airline is used in this example) at Port 1, and install the short circuit at the end of the airline. Installing the airline requires special care: follow the procedures described in the HP 85050A or HP 85052A calibration kit manuals exactly. If an S-parameter test set is being used, make these connections at the end of the cable attached to Port 1.

The peak response (Figure 15-i) should move away from 0 seconds, out to approximately 1.35 nanoseconds. This indicates that the short circuit is displaced that amount from the point at which the reflection measurement calibration was performed. The peak response value represents twice the actual electrical propagation delay of the airline because the signal travels its length twice: to the short circuit, then back again to the Port 1 measurement plane.

Read Time Domain Reflection Trace Value

- Press **CHANNEL 1.**
- Connect Short Circuit at Port 1.
- Press **DOMAIN, TIME BAND PASS.**
- Position Marker to peak at 0 seconds.

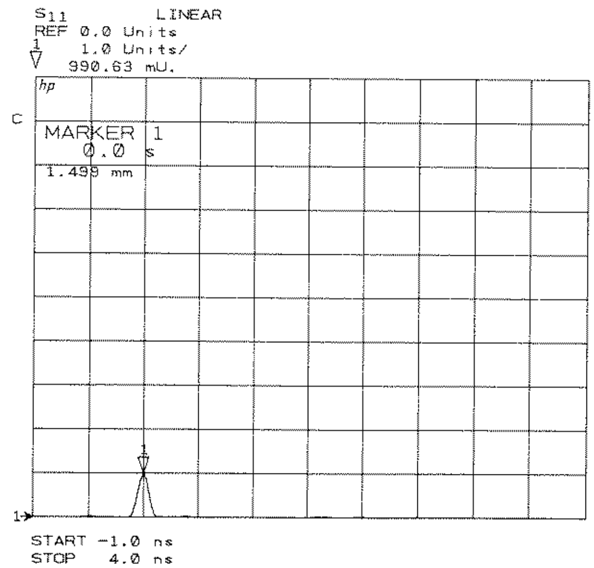


Figure 15-h. Time Domain Short: S_{11}, TIME BAND PASS.

- Connect Airline to Port 1, Short Circuit to Airline.
- Position Marker to peak response. Delay is twice electrical length of Airline.

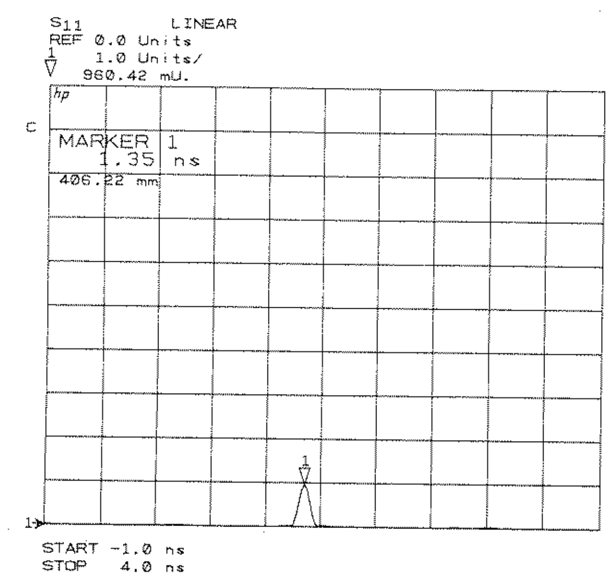


Figure 15-i. Time Domain Airline and Short Circuit

Now make a thru connection. Disconnect the short circuit and the airline. If a reflection/transmission test set is being used, connect the attenuator directly to Port 1 of the test set. If an S-Parameter test set is being used, connect the two cables together. Select **CHANNEL 2, S_{21}**. Press **DOMAIN**, then press **TIME BAND PASS**.

Position the marker to the peak of the response. The measured time value should be 0 seconds, meaning that the transmission return cable is connected to the same point at which transmission measurement calibration was performed. See Figure 15-j.

Finally, insert the airline. If a reflection/transmission test set is being used, disconnect the attenuator from Port 1 and connect the airline in its place. Do not disconnect the attenuator from the cable or the cable from Port 2, and bend the cable as little as possible.

If an S-parameter test set is being used, disconnect the two cables from one another and connect the airline between them. Do not disconnect either cable from its test port, and bend the cables as little as possible.

The peak response (Figure 15-k) should move away from 0 nanoseconds, out to approximately 675 picoseconds, indicating that the transmission return port is displaced that amount from the point at which transmission calibration was performed. This value represents the actual electrical propagation delay of the airline.

Read Time Domain Transmission Trace Value

- Press **CHANNEL 2.**
- Connect Thru.
- Press **DOMAIN, TIME BAND PASS.**
- Position Marker to peak at 0 seconds.

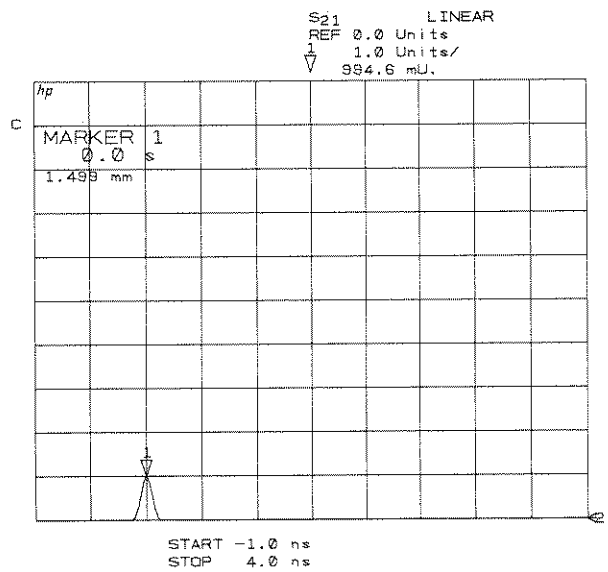


Figure 15-j. Time Domain Thru: S_{21}, TIME BAND PASS.

- Insert Airline.
- Position Marker to peak response. Delay is electrical length of airline.

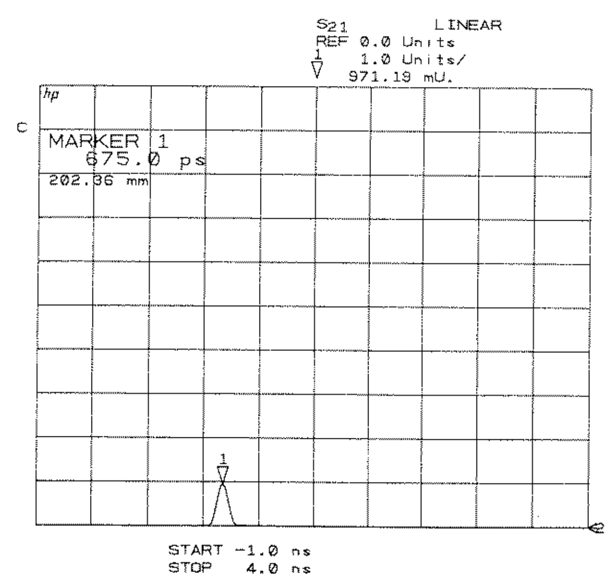


Figure 15-k. Time Domain Airline and Thru Connection

NOTES

NOTES

NOTES

GENERAL OPERATIONS

ILLUSTRATIONS

TABLES

INTRODUCTION

This part of the HP 8510 network analyzer system manual explains several important aspects of general system operations. System interconnections are covered in detail in the Installation section of the HP 8510 manual. The present section begins by describing the HP 8510 power-on, self-test and initialization sequences and gives the standard HP-IB addresses of the components of the system.

The Standard Preset State and the power-up instrument state are also described. These are sets of conditions defining such measurement details as the channel being displayed, the stimulus, parameter, format, and response settings, and the display format. Instructions are given for changing the power-up instrument state. Instructions are also given for loading the operating system firmware.

INSTRUMENT INTERCONNECTIONS

Set up and cable the system components as outlined in the Installation section of the HP 8510 system manual. That section also contains detailed information on instrument power requirements and operating conditions.

POWER-ON SEQUENCE

Power should be applied to the instruments in the HP 8510 system in the following order. Note that the HP 8510 network analyzer itself should be turned on last, in order for it to gain control of the instruments connected to the 8510 system bus.

- SOURCE: HP 834x or HP 835x
- TEST SET: HP 851x
- SYSTEM PERIPHERALS: PLOTTER (if used),
  PRINTER (if used)
- NETWORK ANALYZER: LINE switch, front panel.

If an external controller is used as part of the HP 8510 system, the above power-on steps should precede turning on the power to the controller peripherals and the controller itself:

- CONTROLLER PERIPHERALS
- CONTROLLER

Power to both the display/processor and the IF detector is controlled by the LINE switch on the front panel of the IF detector if the line switch on the rear panel of the display/processor is set to SYSTEM CONTROLLED. If the display/processor does not turn on, check the position of this rear-panel switch first.

When power is turned on, the network analyzer goes through its initalization and self-test routines and then is set to the instrument state stored in Instrument State Register 8. This is the Standard Preset State, unless changed by using the INSTRUMENT STATE SAVE 8 sequence.

When measurements are complete, power can be left applied to the test set and the source (HP 8340 in Standby) to minimize warmup time; or power can be turned off to all of the instruments, individually or by turning off power to the system rack (if used).

SELF-TEST AND INITIALIZATION

The HP 8510 self-test and initialization sequence occurs automatically when the system is turned on. This sequence tests the various buses and circuits in the HP 85101A display/processor. If the system passes all of the tests in the sequence, the operating system is loaded automatically and measurements can begin.

CRT display prompts and events during self-test and initialization are as follows.

TESTING appears on the CRT for approximately one second. Owing to CRT warmup time this message may not always be visible.

When the TESTING prompt disappears, a diagonal line appears momentarily on the CRT, running from the lower left-hand corner continuously to the upper-right hand corner of the display. This indicates that the display is operating correctly.

SYSTEM INITIALIZATION IN PROGRESS is now displayed in the upper left-hand corner of the CRT.

> This indicates that the system has completed the self-test sequence successfully. It is now loading the operating system from bubble memory into RAM, using the program in the self-test ROM.

Loading takes about 20 seconds, after which the display will go blank for about two seconds. Then the prompt SYSTEM INITIALIZATION IN PROGRESS will reappear.

> This indicates that the Self-Test ROM has turned over control to the program stored in RAM and that the initialization process is continuing.

RECALLING INSTRUMENT STATE will appear below the system initialization message, and after about 2 seconds the CRT will display a graticule (grid) and be in the Power Up State.

> This is the power-up state of the HP 8510 system, and the appearance of the graticule and trace indicates that self-test and initialization are both now complete and that the internal measurement program is now running.

HP-IB ADDRESSES

Figure 16 shows the instrument interconnections and the HP-IB system bus address assignments in the HP 8510 network analyzer system. The 8510 system bus expects the HP-IB addresses of the source, test set, printer, and plotter be as given in Figure 16. These are the standard addresses.

To check Instrument Addresses, press the front-panel key labeled **LOCAL** to present the Address Menu, then check each address against the list in Figure 16. If you find that the instrument addresses are different, change them to the correct addresses.

Standard HP-IB Addresses, HP 8510 System Bus

8510 HP-IB Address	16
System Bus Address	17
Source Address	19
Test Set Address	20
Plotter Address	05
Printer Address	01
HP-IB	7

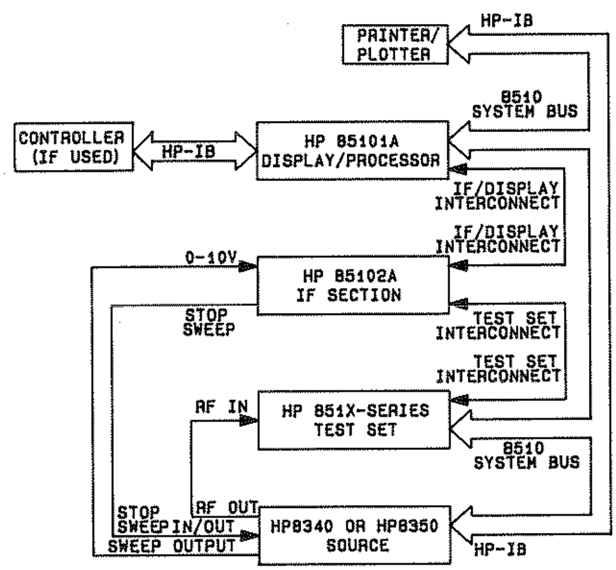


Figure 16. System Interconnections and HP-IB Addresses

INSTRUMENT PRESET STATE

When the self-test and initialization sequence has been completed, the network analyzer system is automatically set to the instrument state stored in Instrument State Register 8. This Power-Up instrument state is set at the factory, it differs from the Standard Preset State only in frequencies, and it can be changed by changing Instrument State 8 using the sequence described below.

A partial list of the Standard Preset State conditions for the HP 8510 system is given in Table 3. These preset conditions cannot be changed, but the power-up instrument state (Instrument State 8), recalled after the power-up self-test and initialization sequence is complete, can be changed. This is sometimes convenient if a certain instrument state is desired when power is turned on.

To change the power-up instrument state use the front panel keys and the knob, step, and numeric keys in the ENTRY block to define the power-on instrument state desired instead of the Standard Preset State.

When you have finished defining the new instrument state, press the front-panel key labeled SAVE. This will bring the Save Menu onto the CRT display. (This menu is the same as the Instrument State Selection Menu accessible from the Tape Menu.) Press the softkey labeled (POWER UP) 8 to save into Instrument State Register 8 the instrument state you have just defined. This state will now be recalled whenever power is turned on.

Table 3. Standard Preset State

INSTRUMENT STATE
Selected Channel = 1, No Menu Displayed
SAVE/RECALL Instrument States 1-8 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 = 0 s,
TRIM SWEEP = 0,
CAL SETS 1-8 = Not Changed.

DOMAIN
FREQUENCY DOMAIN.
GATE OFF.

DISPLAY
SINGLE CHANNEL, DATA,
Trace Memories 1-4 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.

NOTE - FURTHER INFORMATION ON PRESET AND DEFAULT CONDITIONS APPEARS IN THE INDIVIDUAL SECTIONS COVERING EACH FUNCTION.

LOADING OPERATING SYSTEM FIRMWARE

The HP 8510 network analyzer system is shipped with the operating system firmware already installed in non-volatile bubble memory. To install new operating system firmware, for example to upgrade the system to Option 010 time domain capability or to install revised firmware, follow the procedure given here and summarized in Table 4.

The operating system firmware is recorded on a magnetic tape cartridge, HP part number 85101-10001 or HP part number 85101-10002 (includes Option 010 time domain).

First disable the write-protect feature on the operating system firmware tape cartridge by moving the RECORD tab fully in the direction of the arrow. Then insert the cartridge into the tape drive of the HP 8510 display/processor. Press the Auxiliary Menus key labeled **SYSTEM**. Menu choices will appear on the CRT display.

Press the softkey labeled **SERVICE FUNCTIONS** to display the next menu. When the menu appears, press the softkey labeled **TEST MENU**.

In addition to the menu, this prompt will appear: **ENTER SELECTION THEN PRESS =MARKER**. Using the entry keys on the front panel of the HP 8510, first enter **19**, then press **=MARKER.** Selection **19** is the **LOAD PROGRAM TAPE** command, and when it is followed by **=MARKER** it causes the operating system firmware to be loaded into the HP 8510 operating system.

Loading takes about 3 minutes, and you will find that during loading the tape drive starts and stops often. This is normal. Loading has been completed when the graticule appears again on the CRT display.

When the graticule appears, cycle the power once by turning the line switch on the HP 8510 front panel off and then on.

Remove the tape cartridge and write-protect it by sliding the RECORD tab back to its original position or by removing the tab.

To verify that the firmware has been loaded correctly, begin any measurement sequence. For example, if the operating system firmware includes Option 010 time domain, press the **DOMAIN** Menu key, then the softkey **TIME BAND PASS**. Then press the **AUTO** Response key. If the firmware has been loaded correctly, the CRT display will show time on the horizontal axis and linear magnitude on the vertical axis.

NOTE - It is strongly recommended that you make a backup tape of the operating system firmware. Instructions are given later in this manual in the discussion of printer, plotter, and tape operations.

Table 4. Loading Operating System Firmware

Disable the tape cartridge write-protect feature by moving the RECORD tab fully in the direction of the arrow on the tape cartridge.

Insert the operating system tape cartridge into the tape drive receptacle on the display/processor front panel.

Press:	SYSTEM
Then:	SERVICE FUNCTIONS
Then:	TEST MENU
Enter:	**19**
Then press:	=MARKER

Wait while the program is loaded. Loading takes about 3 minutes.

Loading is complete when the graticule reappears on the CRT.

Cycle the power once by turning the line switch on the HP 8510 front panel off and then on.

Remove the tape cartridge and slide the RECORD tab back to its original position.

Loading can be checked by initiating any measurement operation.

Make a backup tape of the operating system firmware.

Error Messages During Operating System Loading. WRITE PROTECT ERROR. This error message indicates that the write protect feature on the system firmware cartridge has not been disabled. Remove the cartridge and disable the write protect feature by moving the RECORD tab fully in the direction of the arrow. Then begin the loading sequence again.

ID ERROR. This error message appears if a cartridge is inserted into any system other than the original system to which it has been keyed. As it is installed for the first time, the program automatically keys itself uniquely to the display/processor of the HP 8510 system in which it is installed and cannot be used in any other system. This message also appears if a tape which is not an HP 8510 system program tape is inserted.

If this message appears, remove the cartridge and check that it is the correct cartridge for the system being used. Original cartridges are labeled with the serial number of the HP 8510 system display/processor in which they have been installed. Insert the correct cartridge and begin the loading sequence again. To prevent confusion among backup cartridges, it is a good idea to mark backup cartridges in the same way as original cartridges, with the display/processor serial number.

OPTIONAL FUNCTION NOT INSTALLED. This message indicates that time domain measurements cannot be made with the system. If the operating system firmware you have installed does include Option 010 time domain, remove the cartridge and repeat the loading procedure.

FRONT PANEL OPERATIONS

ILLUSTRATIONS

INTRODUCTION

This part of the HP 8510 network analyzer system manual explains how to use the front-panel keys and controls. It explains these controls and features: channel selections, the CRT and its labels, the ENTRY block, the four INSTRUMENT STATE keys, and the measurement RESTART key. It gives an introduction to the four basic measurement function blocks, and it also explains the system of softkeys and menus used in the HP 8510 network analyzer system.

Detailed information on the four basic measurement function blocks (STIMULUS, PARAMETER, FORMAT, and RESPONSE) appears in the next part of this manual, in the section titled Main Function Blocks. Complete graphical presentation of the HP 8510 menu structure, including programming mnemonics, appears in the section of this manual titled Reference Data.

Measurement procedures, including measurement calibration, are covered separately later in this manual.

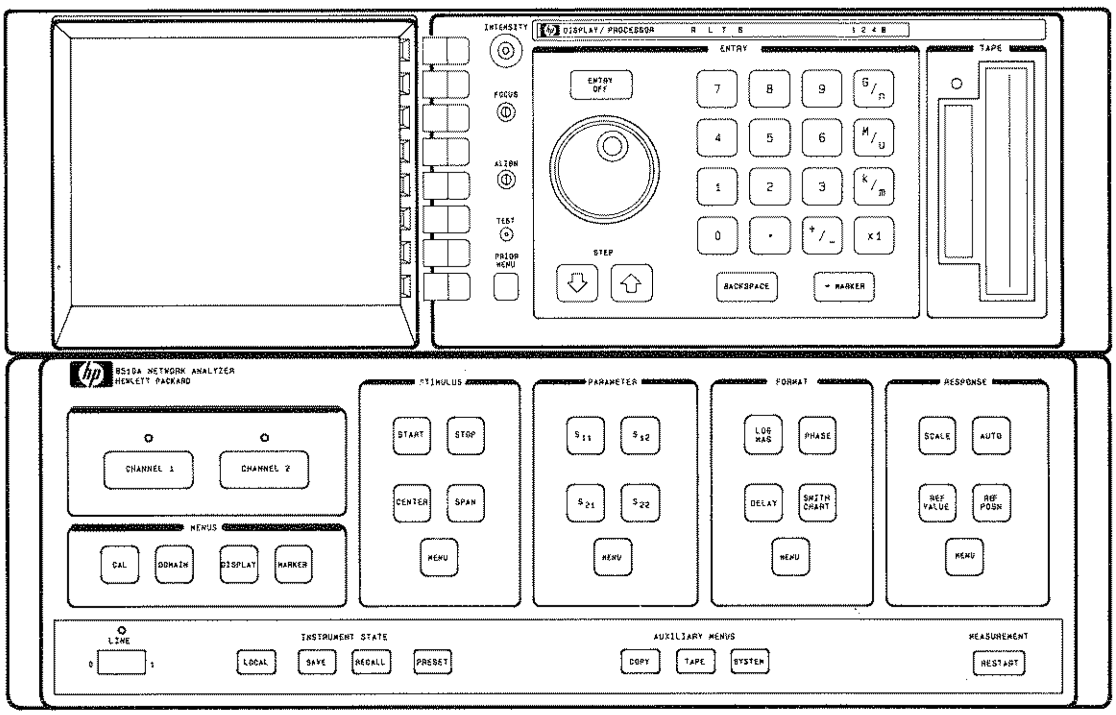


Figure 17. Front Panel Controls

FRONT PANEL OPERATIONS

Figure 17 shows the front-panel controls of the HP 8510 network analyzer system. Controls are grouped in various labeled blocks on the front panels of the HP 85101A display/processor and the HP 85102A IF detector. No front-panel controls exist on the test set except its line switch, and the source is controlled by the HP 8510 system, via the 8510 system bus, not independently from its own front panel.

CHANNEL SELECTIONS

To select the active display channel when a single channel display mode is desired, press **CHANNEL 1** or **CHANNEL 2**. The light above the key indicates the choice that has been made.

When a dual channel display mode has been selected, pressing **CHANNEL 1** or **CHANNEL 2** selects the channel which is controlled by the front panel. That channel becomes the active channel.

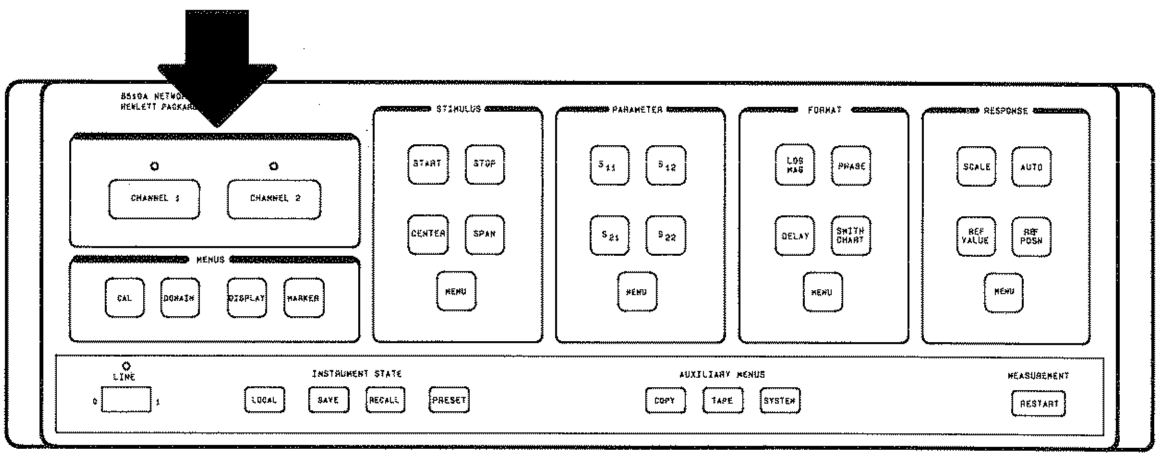


Figure 18. Channel Selection Keys

Channel 1 and Channel 2 have identical capabilities and, for most functions, are completely independent. Further information on capabilities that are and are not independent appears in the discussion titled Alternate Sweep in the next section of this manual.

CRT DISPLAY

Figure 19 shows the HP 8510 CRT display.

Parameter and Format information appears at the top of the display. This is given for Channel 1 and/or Channel 2, depending on the display mode selected. The parameter being displayed and the format of the display are given. Also given is the value of the reference line, the scale/division, and (if the marker has been turned on) the value at the current marker position.

Stimulus values appear at the bottom of the display. Depending on the selections made, these values are the start and stop or center and span frequencies (or time values) in the measurement currently being displayed.

CRT annotation for cartesian displays includes Trace labels (**1** for Channel 1, on the left of the graticule, **2** for Channel 2, on the right), and Reference Line Position symbols (> for Channel 1 and < for Channel 2).

The Active Function area of the CRT display identifies the current active function for the selected channel. Pressing **ENTRY OFF** clears this area.

Enhancement Labels to the left of the Active Function area indicate that certain functions which may affect the measurement have been selected. These labels are:

C = correction on	A = averaging on
S = smoothing on	G = time domain gating on
D = electrical delay on	O = IF overload
H = hold	* = measurement not completed

The Title area provides a space to enter up to 50 characters of information about the measurement or to label calibration standards, calibration kits, and redefined parameters. To create or change a title, press the front-panel key labeled **SYSTEM** in the AUXILIARY MENUS block, and then press the softkey labeled **TITLE**. This will bring the Title Menu and the existing title onto the display.

To delete the whole title, press the softkey labeled **ERASE TITLE** or use the **BACKSPACE** key in the ENTRY block. To enter a character, position the ↑ symbol below the character by turning the knob, then press **SELECT LETTER**. The character will now appear as the last character in the title area. Repeat this process to write the rest of the title.

When you have finished creating or changing the title, press the softkey labeled **TITLE DONE**. Pressing **PRESET** replaces any existing title with the characters **hp**.

System Messages such as prompts, error messages, and procedural advisories appear immediately below the Channel 1 identification labels. If an error which affects the measurement occurs, an error message is displayed and a beep signals the operator to look at the message.

Menus appear on the right of the display, beside the eight softkeys used to make selections from them.

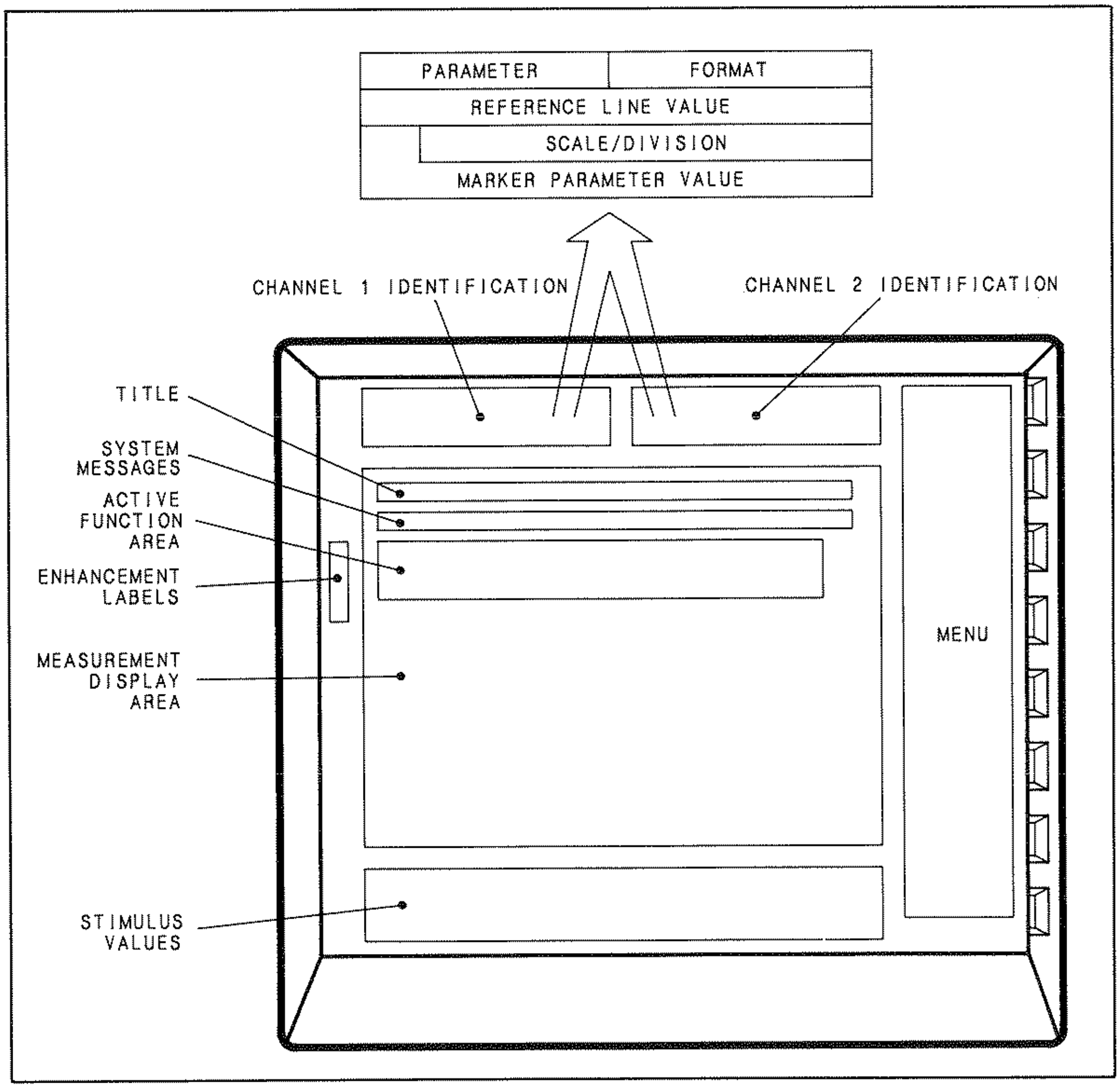


Figure 19. CRT Display

STIMULUS / PARAMETER / FORMAT / RESPONSE

Keys in the four main function blocks control the four basic measurement functions in the HP 8510 system: Set Stimulus, Select Parameter, Select Format, and Present Response for Measurement. In general, these controls are independent for Channel 1 and Channel 2. Pressing the MENU key in the block displays the first-level menu for that function.

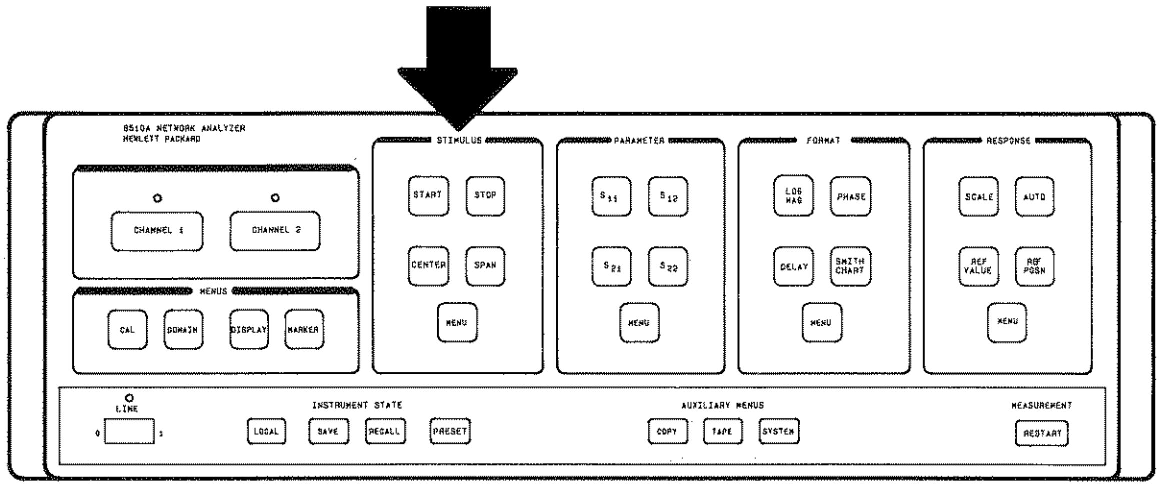


Figure 20. Main Function Blocks

In the PARAMETER function block, pressing any parameter key not only selects that parameter but also recalls a limited instrument state which includes the last selected display format, response settings, and whether correction was last On or Off. This makes it easy to switch between displays of different parameters without having to re-specify the format each time. This limited instrument state is independent for Channel 1 and Channel 2.

For example, you might want to display S_{11} and S_{22} on a Smith Chart; electrical delay for S_{21}; and phase for S_{12}. To set this up, press S_{11} then **SMITH CHART**; S_{21} then **DELAY**; S_{12} then **PHASE**; and finally S_{22} then **SMITH CHART**. Now, each time you select a parameter, the format you have selected for that parameter will be recalled.

If Correction On was last selected for that parameter, the last Cal Set turned on for that parameter is applied to the measurement.

Pressing a FORMAT key recalls the RESPONSE settings last selected for that combination of parameter and format. For example, you can select S_{11}, **LOG MAG** for viewing at 10 dB/division and S_{11}, **PHASE** for viewing at 5 degrees/division.

More detailed information on the four basic measurement function blocks appears in the next part of this manual, in the section titled Main Function Blocks.

ENTRY Block

In the ENTRY block, the knob, the numeric and units keys, and the STEP keys are used to enter and specify values and to move the marker on the trace. The +/- sign can be entered before or after the numeric. Units must be specified after the numeric is entered: **G/n** = Giga/nano; **M/µ** = Mega/micro; **k/m** = kilo/milli; **x1** = basic units (dB, dBm, degree, second, Hz, volts). Specifying the units enters the value. Use the **BACKSPACE** key to correct errors during entry.

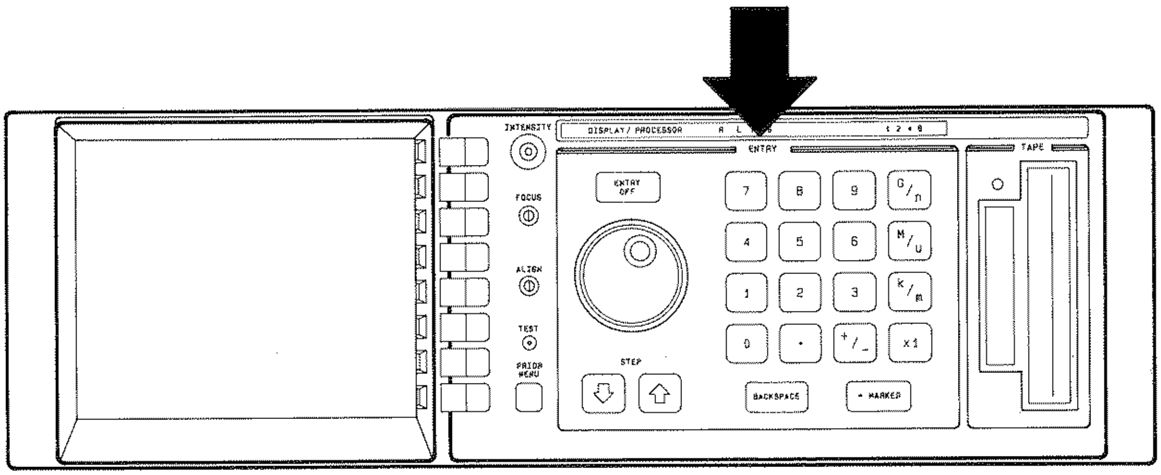


Figure 21. ENTRY Block

The **STEP** keys increase or decrease the value of the current active function. The size of the step increment is determined by the current state of the network analyzer and cannot be changed by the operator.

The **=MARKER** key is used in function entry, in the manner explained in the discussion of the RESPONSE function block later in this manual.

INSTRUMENT STATE KEYS

The four INSTRUMENT STATE keys near the bottom of the HP 8510 front panel are used to save and recall instrument states, to select the Standard Preset instrument state, and to return control of the network analyzer to the front panel if an external controller is being used.

Pressing **SAVE** brings the Instrument State Select Menu onto the CRT display. Pressing the softkey beside a number (**1**, **2**, **3**, **4**, **5**, **6**, **7**, or **8**) saves the current complete state of the network analyzer, including the controlled functions of the source and the test set, in the corresponding storage register (1 through 8). The contents of calibration and trace memories being used are not saved, only the current reference to that memory.

Pressing **RECALL** brings the same menu onto the display. To recall an instrument state saved earlier, press the corresponding softkey.

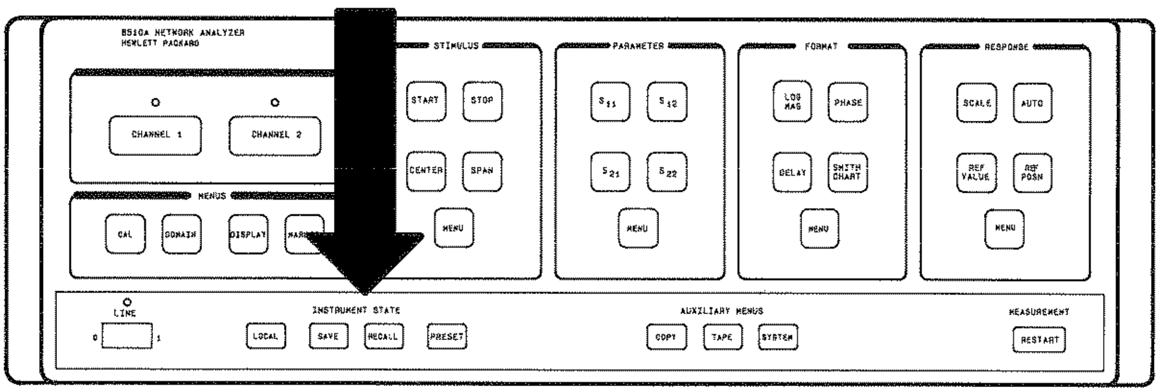


Figure 22. INSTRUMENT STATE Block

Pressing the green **PRESET** key sets the system to Standard Preset State listed in Table 3.

Pressing **LOCAL** returns control of the system to the HP 8510 front panel and displays the Address Menu. This key is used only when an external controller is being used to control the system through the HP 8510 HP-IB connector and when Local Lockout is not commanded.

MEASUREMENT RESTART

The Measurement RESTART key at the bottom right-hand corner of the HP 85102 IF/detector front panel restarts the measurement, including the current group of sweeps, and restarts averaging.

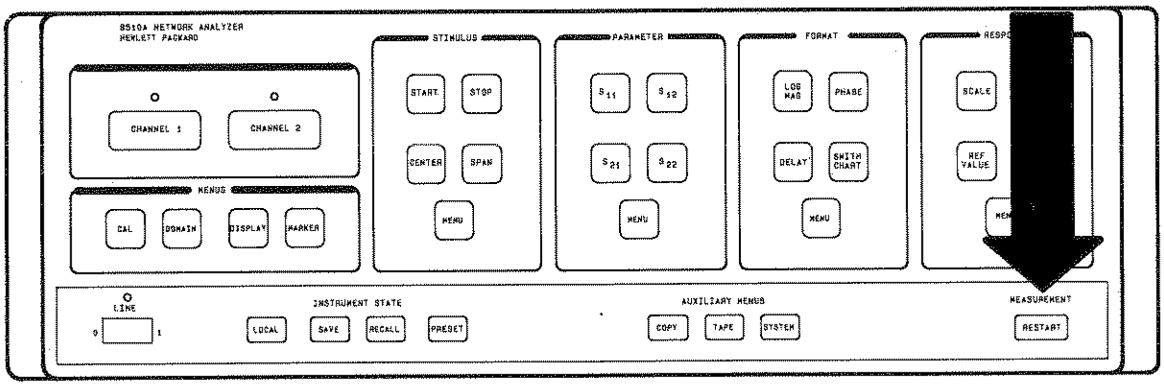


Figure 23. Measurement RESTART Key

Measurement RESTART is performed automatically whenever a parameter is changed and in most other instances when the machine state has been changed in a way that could affect the measured value.

MENUS

From an operator's standpoint, one of the most important features of the HP 8510 network analyzer system is its extensive series of menus and sub-menus. Operations of many kinds can be selected, modified, and recalled using front-panel keys and the eight softkeys to the right of the CRT display to make choices from menus displayed on the CRT. Using the HP 8510 network analyzer system to its fullest extent depends very much on taking full advantage of this series of menus.

Various front-panel keys are used to bring menus onto the CRT display of the HP 8510 system:

> Keys labeled **MENU** exist in each of the four main function blocks: **STIMULUS**, **PARAMETER**, **FORMAT**, and **RESPONSE**. Press the **MENU** key in any function block to bring onto the CRT menus for that function which make it possible to specify and change details of the measurements.
>
> Keys labeled **CAL**, **DOMAIN**, **DISPLAY**, and **MARKER** exist in the front-panel block labeled **MENUS**. These keys bring onto the CRT menus for calibrating the HP 8510 system and for choosing from among many different measurement and display modes.
>
> Keys labeled **COPY**, **TAPE**, and **SYSTEM** in the front-panel area labeled **AUXILIARY MENUS** bring onto the CRT menus for choosing input and output operations according to the particular measurements being made.
>
> Keys labeled **SAVE** and **RECALL** in the front-panel area labeled **INSTRUMENT STATE** bring onto the CRT menus which allow for storing and recalling various instrument states. The **LOCAL** key in the same front-panel area brings onto the CRT a menu showing all internal and external interface bus addresses.

Pressing any of these front panel keys brings onto the CRT display one of the thirteen first-level menus in the HP 8510 system (Figure 24).

On the menu display, the value or choice currently being used in system operation is underlined. Mutually exclusive choices are connected by dots. (In the menus associated with calibration, all standards which have been defined will be underlined; and although they are connected by dots, these standard choices are mutually exclusive only in the sense that standards must be measured one at a time.)

Pressing the softkey beside a label either executes the function or presents another menu. If the choice selected requires an input, the current value is displayed as the active function and a prompt will appear on the CRT when the softkey is pressed. Use the knob, step, numeric, units and =MARKER keys in the ENTRY block to enter the values desired.

Press the front-panel key labeled **PRIOR MENU** to return to the menu previously displayed. If the current menu is a first-level menu, pressing this key clears the menu area of the CRT display. The menu area is also cleared when the **PRESET** key is pressed.

EXAMPLE: USING MENUS

Press the front-panel key labeled **PRESET** to clear the CRT display.

Press the **MENU** key in the **STIMULUS** block to display the first-level Stimulus Menu. The **STIMULUS** block controls the source in the HP 8510 system, and this first-level menu offers seven choices, including **MORE**. Pressing the softkey beside **MORE** brings the continuation of the Stimulus Menu onto the display, offering six more choices.

(1) Suppose first that you want to check or change the number of points per sweep.

Press the softkey beside the menu label **NUMBER of POINTS**. Doing so will display the second-level Number of Points Menu.

The current number of points per sweep will be underlined on the display. To change the number of points per sweep, press the softkey beside the menu label showing the new number of points you desire. This new value will now be underlined.

Press the front-panel key labeled **PRIOR MENU** (or the MENU key in the **STIMULUS** block) to bring the first-level Stimulus Menu onto the CRT display again.

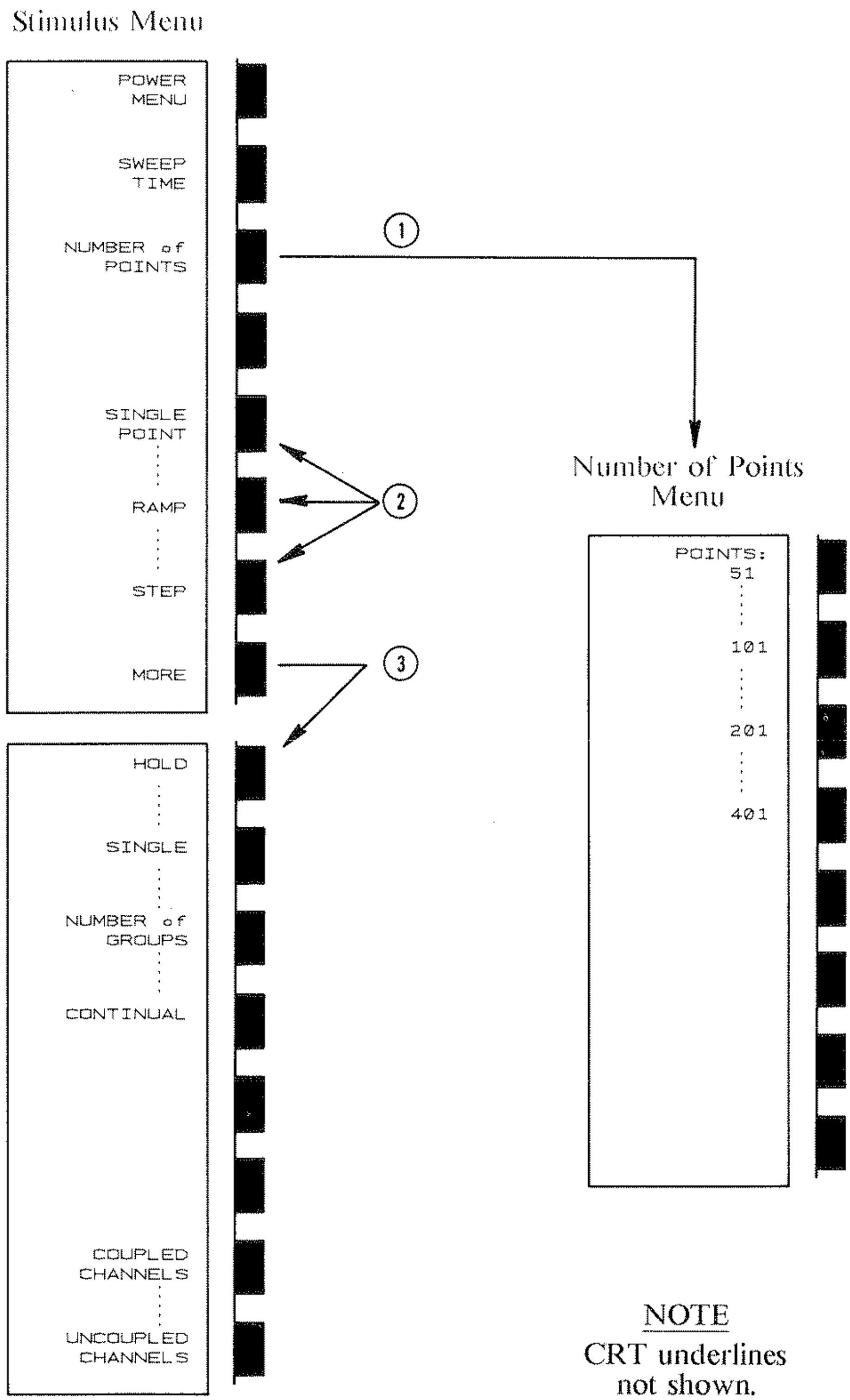
(2) Next, suppose that you want the source to operate in the **RAMP** mode. In this case, the choices of mode appear on the first-level menu, connected by dots indicating that the choices are mutually exclusive.

Press the softkey beside **RAMP**. This will cause the source to operate in the RAMP mode. This mode label will be underlined on the CRT display, indicating that it is now the current choice.

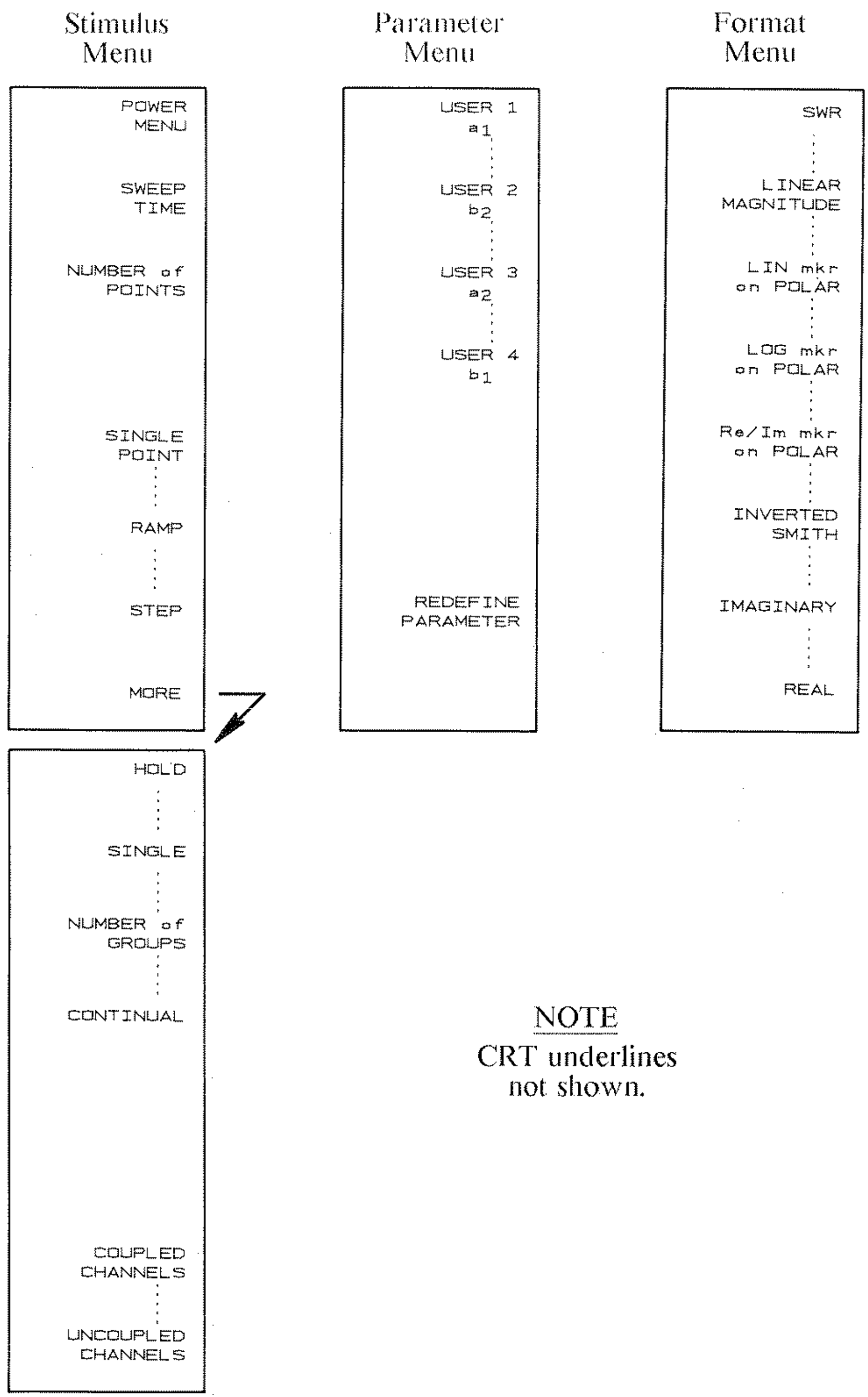
(3) Finally, suppose that you want to stop updating the trace displayed on the CRT display with every new sweep, in other words to HOLD the current trace without updating.

This choice does not appear on the Stimulus Menu as it is first displayed. Therefore press the softkey beside **MORE** to display the continuation of the Stimulus Menu.

To hold the present trace, press the softkey beside **HOLD**. On the menu this choice will now be underlined. To undo the choice, press one of the three other softkeys (linked by dots) below **HOLD**. Press the front-panel key labeled **PRIOR MENU** to bring the first-level **STIMULUS** menu onto the CRT display. Press **PRIOR MENU** again to clear the menu area of the display.



NOTE
CRT underlines not shown.



NOTE
CRT underlines not shown.

Figure 24. First-Level Menus (1 of 4)

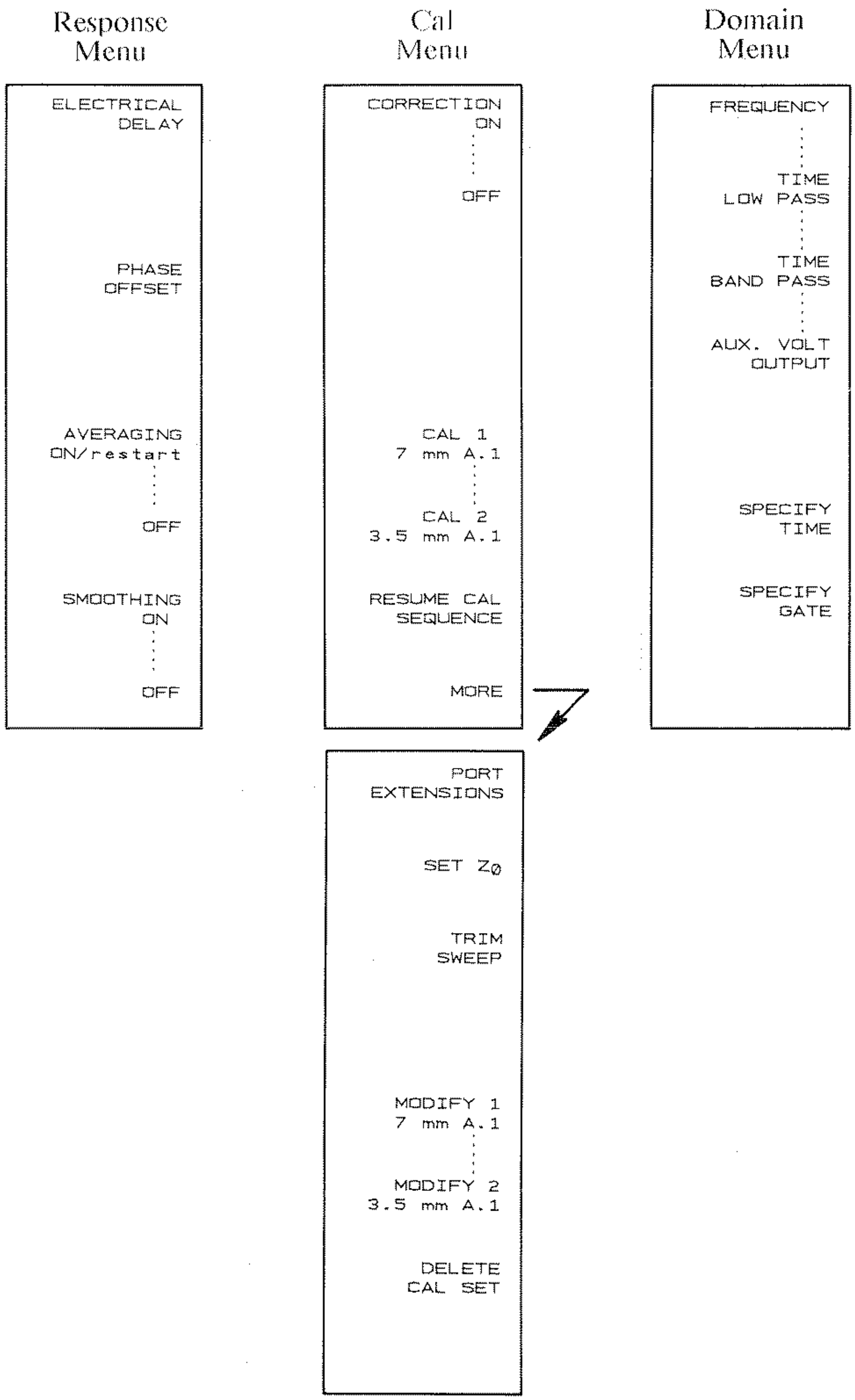


Figure 24. First-Level Menus (2 of 4)

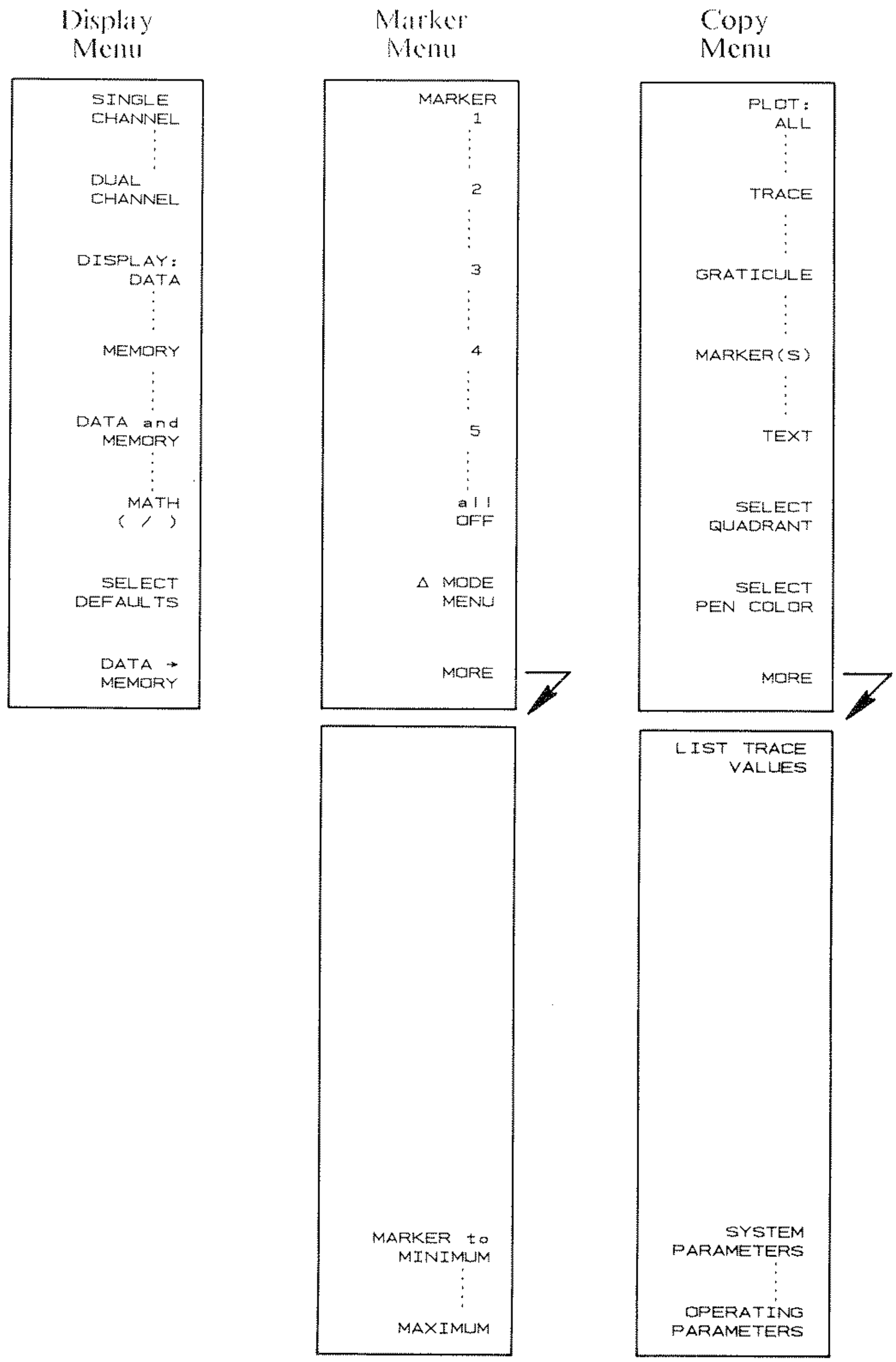


Figure 24. First-Level Menus (3 of 4)

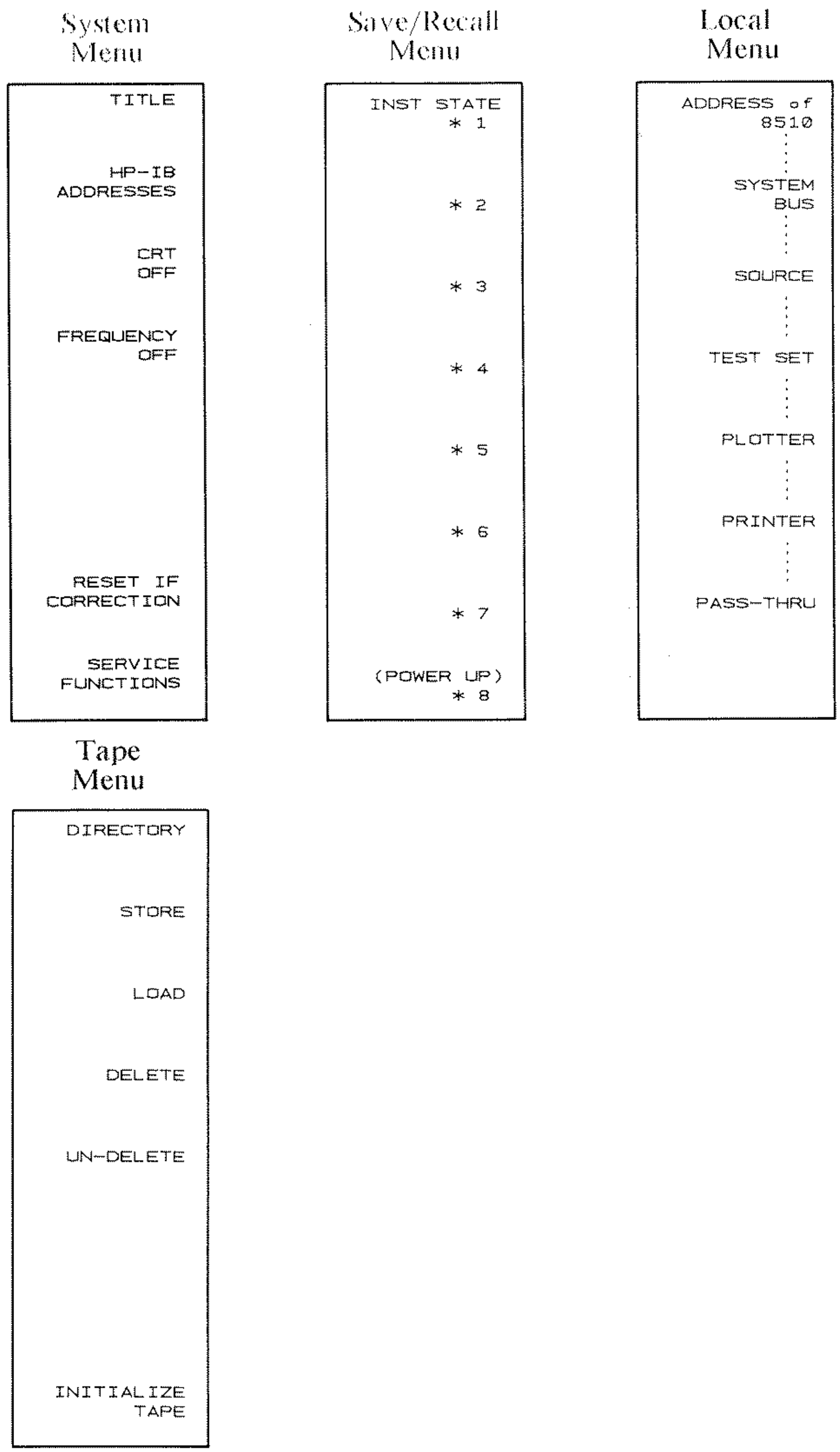


Figure 24. First-Level Menus (4 of 4)

MAIN FUNCTION BLOCKS: STIMULUS PARAMETER FORMAT RESPONSE

ILLUSTRATIONS

TABLES

INTRODUCTION

This part of the HP 8510 network analyzer system manual explains how to use the front-panel keys in the four main function blocks: STIMULUS, PARAMETER, FORMAT, and RESPONSE. It also explains how to use the measurement markers and how to compare current measurements with measurements made earlier and stored in memory.

STIMULUS block keys and the associated Stimulus menus allow complete control of the source in network measurement applications from the HP 8510 front panel, and the menus allow setting of source characteristics such as sweep time, the number of data points taken during the sweep, source RF power level, and S-parameter test set attenuation.

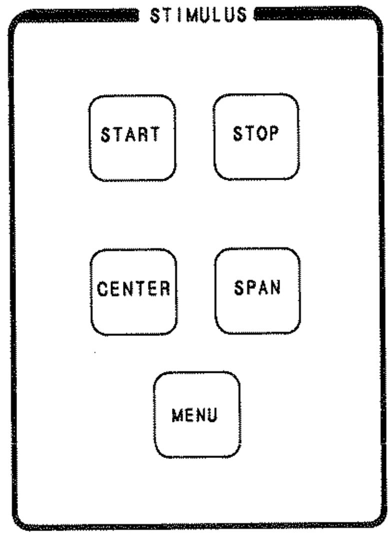
PARAMETER block keys and the associated Parameter menus allow selection of the parameter to be measured. The Redefine Parameter menu makes it possible to change the definitions of the parameters, for example in order to use custom test sets and the HP 8511A frequency converter.

FORMAT block keys and menus allow a wide range of display formats for the measured data.

RESPONSE block keys control such details of the display as the trace position, the scale units per division, and the value of the reference line. Response menus give access to other features in displays of the data such as electrical delay, phase offset, averaging, and smoothing.

Measurement procedures using these keys and menus, including measurement calibration, are covered separately in the next four parts of this manual. The complete HP 8510 menu structure, including programming mnemonics, appears in the section of this manual titled Reference Data.

STIMULUS



STIMULUS block keys and the associated Stimulus menus allow complete control of the source in network measurement applications from the HP 8510 front panel. The menus allow you to set source characteristics such as sweep time, the number of data points taken during the sweep, source RF power level, and S-parameter test set attenuation.

The **START**, **STOP**, **CENTER** and **SPAN** keys are used to set the stimulus spans. The **MENU** key brings the first-level Stimulus Menu onto the CRT display and allows you to select other source characteristics.

SET FREQUENCY SWEEP

To set the frequency sweep, use the **START** and **STOP** keys or the **CENTER** and **SPAN** keys, and the knob, numeric, step, and units keys in the ENTRY block. In the Time Domain mode these keys have the same function except that they set the stimulus sweep in terms of time. Table 5 gives the corresponding units.

Table 5. STIMULUS Units

Key	Frequency	Time	Power	Power Slope
G/n	GHz	nsec	—	—
M/μ	MHz	μsec	—	—
k/m	kHz	msec	—	—
x1	Hz	sec	dB	dB/GHz

To set the start frequency, press the **START** key, then enter the frequency using the knob, step, or numeric keys in the ENTRY block. To correct errors made during entry use the **BACKSPACE** key. Specifying the units enters the value. When you have entered the start frequency, do the same using the **STOP** key to set the stop frequency.

To set the sweep so that it spans a certain frequency range, press the **CENTER** key and enter the center frequency and units. Then press the **SPAN** key and enter the total frequency width and units of the span desired.

The **START**, **STOP**, and **CENTER** keys can be pressed in any order, making it possible to check or to change any of these values by itself.

The range of frequency settings depends on the frequency limits of the source and on the test set being used. The range of time settings allowed is determined by internal network analyzer logic.

In the Instrument PRESET State, the start and stop frequencies are set to the greatest common range of the test set and the source used in the system.

SET SWEEP USING MARKERS

Another way to set the sweep is by using the measurement marker(s).

Use the knob to position the marker anywhere on the trace. Press any of the three keys: **START**, **STOP**, or **CENTER**. Then press the **=MARKER** key in the ENTRY block. The value at the point where the marker is positioned now becomes the new start, stop, or center frequency.

STIMULUS MENU

Pressing the STIMULUS block MENU key brings the first-level Stimulus Menu (Figure 25) onto the CRT display. Choices on this menu allow you to change the settings of the source RF power level, the sweep time, the number of points per sweep, the source mode, the sweep mode, and (if desired) to set different stimulus values for each channel. These choices are explained in the following pages.

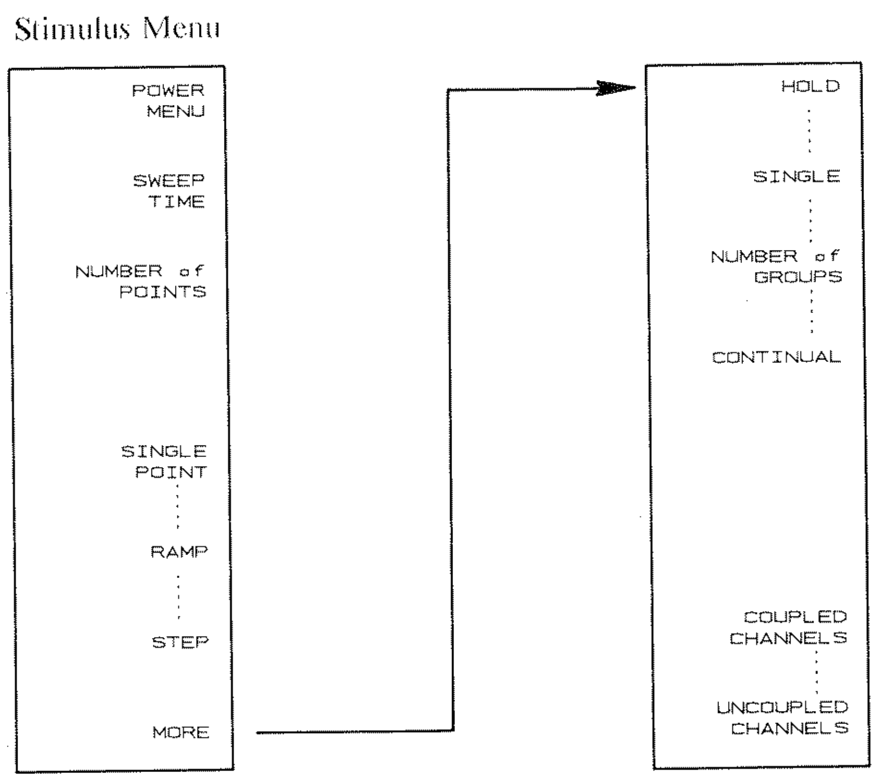


Figure 25. Stimulus Menu

SOURCE POWER LEVEL

In the Standard Preset State, the source RF power level is set to an appropriate value, usually +10 dBm. In most applications this level does not need to be changed, and in changing levels caution should be observed because power levels above +20 dBm may damage the test set. Power levels also depend on the source, in that even though a certain power level may be set, the source may not be able to achieve that power level for all frequencies, especially at higher frequencies. Before changing power levels, consult the specifications for the source and see the discussion of Dynamic Range Considerations later in this part of the manual.

If you have decided to change the source RF power level, use the Source Power Menu (Figure 26):

- Press STIMULUS MENU
  POWER MENU
  POWER
  The current value will appear as the Active Function.

- Use the ENTRY block controls to set the new source power level.
  Pressing the **x1** key sets the source RF power in dBm.

Messages will appear on the CRT if the source power level selected is too low for proper network analyzer operation.

SLOPE ON/OFF

It is also possible to set the amount by which the source RF power level is increased or decreased over the course of the sweep. Generally this is done under special circumstances to preserve dynamic range at higher frequencies by increasing the source RF power at these frequencies. In this way it is possible to compensate for losses in the test setup.

Before using this function read the discussion of Dynamic Range Considerations later in this part of the manual.

Pressing the softkey labeled **SLOPE ON** results in the previously used slope (dB/GHz) being turned on. The first time the function is used the slope is 0.0 dB/Ghz. To re-set the system for normal operation press the softkey labeled **SLOPE OFF**.

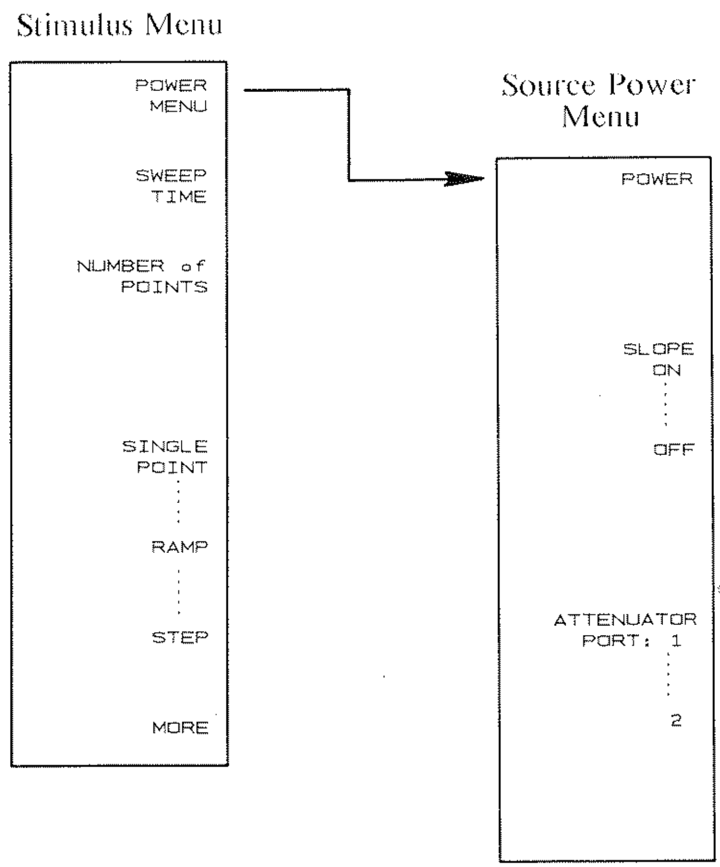


Figure 26. Source Power Menu

ATTENUATOR PORT: 1 . . . 2

Attenuator choices on the Source Power Menu control the internal 0 to 90 dB, 10 dB/step attenuators in S-parameter test sets. These choices do not operate when a refection/transmission test set is used although the display will indicate (falsely) that a change has been made.

Pressing the softkey beside the port label turns on the attenuators affecting that port. This reduces the incident signal level applied to the test port without changing the reference channel signal level.

In the Standard Preset State, both Port 1 and Port 2 attenuators are set to 0 dB.

DYNAMIC RANGE CONSIDERATIONS

The input level at calibration determines the available measurement range without overload or excessive measurement uncertainty. The maximum signal that can be applied to Port 1 or Port 2 of the test set without damage is about +20 dBm. For measurements on passive devices the incident signal level should be as high as the test device characteristics permit without exceeding -10 dBm into any of the first frequency conversion stages. For gain measurements, set the incident signal level to a value at which the expected test device output will not exceed -10 dBm into any of the first frequency converters. Incident signal levels can be measured using the **USER 1** through **USER 4** definitions on the Parameter Menu; see the discussion headed Measuring Power (dBm) in the description of the Parameter function block later in this manual.

Figure 27 shows these dynamic range considerations. Example 1 shows levels at calibration for a passive device with both reference (R) and test (T) inputs near -10 dBm. When calibrated at these levels, the maximum dynamic range is available for insertion loss measurements.

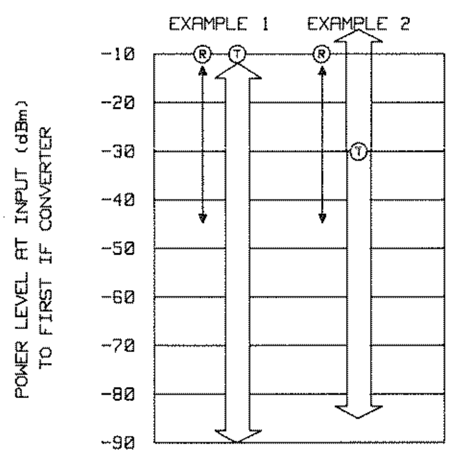


Figure 27. Dynamic Range Considerations

Example 2 shows levels at calibration for an active device with an expected 20 dB of gain. The reference input is set near the top of its range and the test signal is set to produce near -30 dBm with the Thru connected. With an S-parameter test set, reducing the test signal level is accomplished by setting the internal Port 1 attenuator to about 20 dB. At these levels the network analyzer can measure about 20 dB of gain and insertion loss down to the noise floor.

Maximum input to the reference or test first frequency conversion stage without gain compression is -10 dBm up to 18 GHz (-15 dBm, 18 to 26.5 GHz). The reference input requires at least -45 dBm to maintain phase lock. Messages NO IF FOUND (RF input too low) and IF OVERLOAD (RF input too high) appear if the input range is exceeded.

NUMBER OF POINTS

In the Standard Preset State, the network analyzer selects 201 points per sweep, producing 200 equally spaced frequency intervals.

With broadband sweeps, responses that are narrow with respect to the frequency interval may not be accurately represented. For example, with a 10 GHz sweep width, the frequency resolution is:

Number of Points	Frequency Resolution (approx. 10 GHz span)
51	200 MHz
101	100 MHz
201	50 MHz
401	25 MHz

This means that with 51 points selected, responses that are narrower than 200 MHz will not be represented accurately using a 10 GHz sweep width. Figure 28 shows the effect of changing the number of points from 51 to 401 in such a measurement.

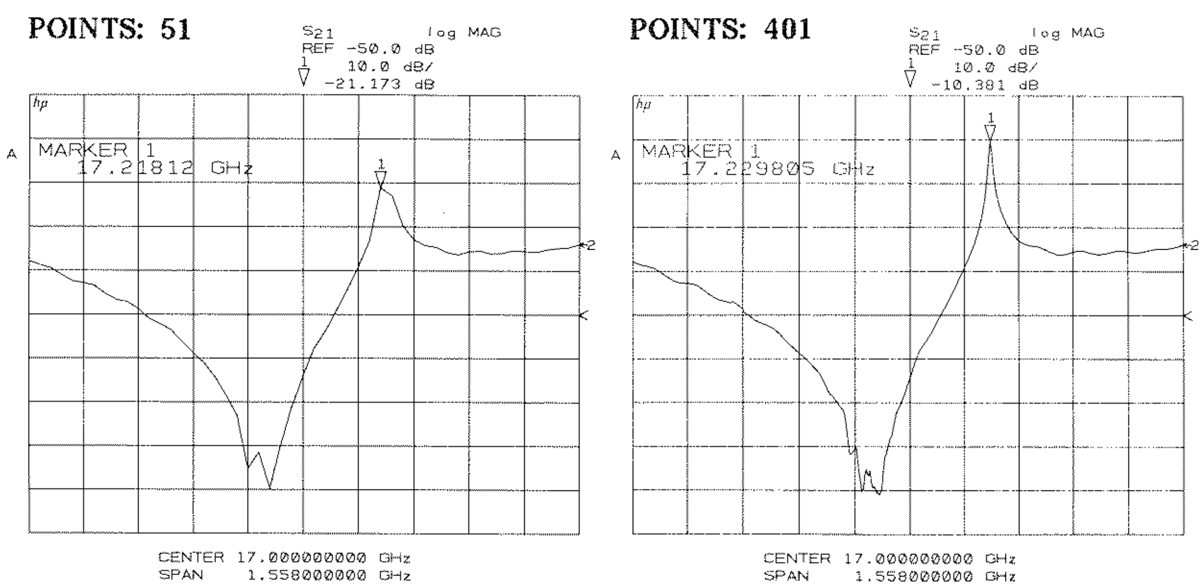


Figure 28. Narrowband Responses

To change the number of points:

- Press STIMULUS MENU
  NUMBER of POINTS
  This will bring the Number of Points Menu onto the CRT.
  The current value will be underlined.
- Use the corresponding softkey to select **51**, **101**, **201**, or **401**.

Selecting the number of points for one channel automatically selects the same number of points for the other channel. If correction or trace math is turned on when the number of points is changed, correction and trace math is turned off.

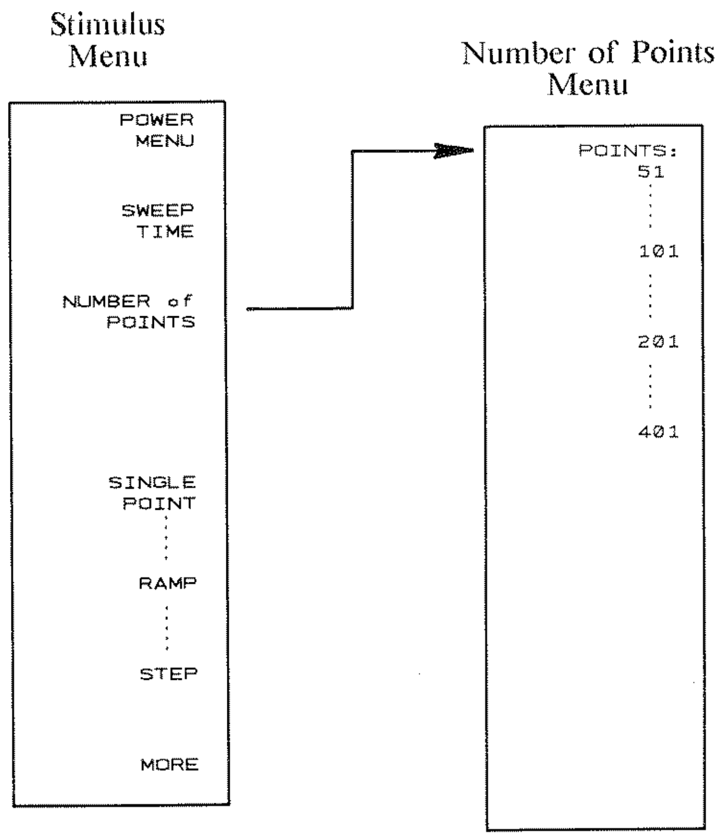


Figure 29. Number of Points Menu

SOURCE MODES

Three source mode selections are available on the Stimulus Menu:

RAMP, in which the source is swept in a continuous analog sweep from the lower to upper frequency and the data is sampled without stopping the sweep; this mode is available with HP 835x and HP 834x sources;

STEP, in which the source is tuned and phase-locked to each of the 51, 101, 201, or 401 frequency sample points; this mode is available only with HP 834x sources;

SINGLE POINT, which sets the source to the center frequency of the sweep already selected in the Ramp or Step sweep mode. All points on the trace are now replicas of the first; only the first point is new data.

To select another frequency in the single point mode, use the STIMULUS block keys and the knob, step, or numeric keys in the ENTRY block. Press START, STOP, CENTER, or SPAN: the annotation C.W. will now appear in the active entry area. Now enter the new frequency desired.

To select the source mode:

- Press STIMULUS MENU
  The current source mode will be underlined.
- Use the corresponding softkey to select the source mode:
  RAMP, **STEP**, or **SINGLE POINT**.

RAMP Mode, HP 835x Sources. Selects standard analog sweep with open loop YIG oscillator tuning accuracy and repeatability.

RAMP Mode, HP 834x Sources. Selects standard analog sweep. With greater than 5 MHz sweep width, the source is phase-locked at the start frequency, then swept with open loop YIG Oscillator tuning accuracy and repeatability. The source is phase-locked at all frequencies for less than 5 MHz sweep widths.

STEP Mode, HP 834x Sources Only. Phase-locked at each data point. The time to measure at each frequency step increases at averaging factors above about 500. Compared with a ramp sweep, taking one sweep in the Step sweep mode takes about the same time as about 100 sweeps in the Ramp mode. To change the elapsed time of the sweep, change the number of points or the averaging factor or both.

SWEEP TIME

In the Ramp Sweep mode, the Standard Preset State selects a sweep time of 100 msec/sweep, and this is usually acceptable. Sometimes, however, an excessively fast sweep time can distort the response of the device under test; and for sweeps of a very wide frequency range a sweep time of at least 200 msec/sweep is recommended. The example on the next page illustrates the effects of sweep time and the changes that can be made in it.

The **SWEEP TIME** choice on the Stimulus Menu allows you to change the sweep time so that the sweep is as fast as possible without being so fast that a distorted measurement response appears from the device under test.

To change the sweep time:

- Press STIMULUS **MENU**
  SWEEP TIME
  The current value will appear as the Active Function.

- Use the ENTRY block controls to set the new sweep time.
  x1 key = seconds **k/m** key = milliseconds

Distortion of the trace or an error message indicates that the sweep is too fast.

In the Step Sweep mode, the sweep time setting adjusts the duration of the dwell time that elapses between the time when phase-lock occurs at the new frequency point and the time when the data is read. The length of this dwell time is given by the equation:

Dwell Time (ms) = Sweep Time (ms)/ Number of Points

This dwell time allows the device to respond to the new frequency. Select the shortest possible dwell time (the fastest possible sweep time) that does not result in distortion of the trace.

EXAMPLE: EFFECTS OF SWEEP TIME

A good way to see the effects of changing sweep times is to measure a device whose response changes rapidly with frequency: for example, a narrow-bandwidth device such as a crystal filter or an electrically long device such as a long cable.

Set up the measurement and notice the appearance of the trace at the Standard Preset sweep time of 100 milliseconds/sweep. Store this trace in memory. Then use the Stimulus Menu to set a slower sweep time, for example 110 milliseconds/sweep. Compare the new trace to the original. Store this new trace and change the sweep time again.

Change the sweep time by the same amount each time, and eventually you will reach a setting at which slowing the sweep still further causes no more changes in the trace. This is the optimum sweep time for that device.

Details of storing and comparing traces are given later in this part of the manual under the heading Comparison Measurements.

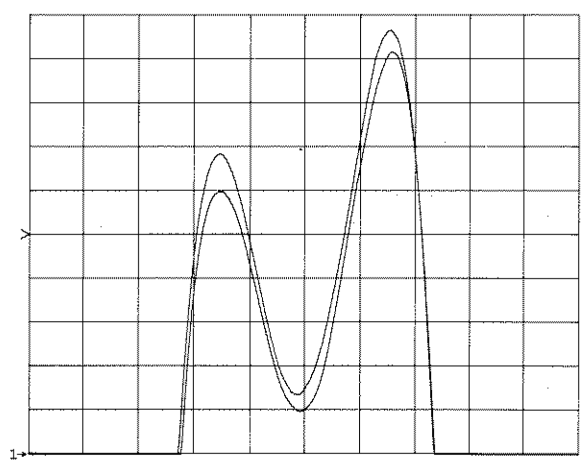


Figure 30. Effects of Sweep Time

HOLD / SINGLE / NUMBER OF GROUPS / CONTINUAL

The Standard Preset condition selects the **CONTINUAL** sweep mode, in which the network analyzer continually executes the sweeps required to produce a measurement. In this mode, the trace is continually updated.

Three other choices as to the nature of the trace being displayed are available on the continuation of the Stimulus Menu. Press the STIMULUS **MENU** key, then the softkey **MORE**, to bring these choices onto the CRT display:

- **HOLD** stops updating the trace. Most processing functions can be changed while in this mode unless they require that additional groups of sweeps be taken.
- **SINGLE** first executes a measurement restart. A single sweep is taken, and then **HOLD** is selected automatically.
- **NUMBER of GROUPS**, followed by a numeric entry and **x1** from the ENTRY block, first executes measurement restart. The specified number of groups of sweeps is taken. Then **HOLD** is selected automatically.

A group consists of a certain number of sweeps that must be taken in order to make one complete measurement; how many sweeps make up a group thus depends on the calibration model being used and other details of the measurement.

The **NUMBER of GROUPS** softkey is used with keys in the ENTRY block to require that a certain number of groups be measured before the trace is held. Regardless of source mode, only one group of sweeps needs to be taken.

If averaging has been selected, the number of groups needed depends on the averaging factor selected and the source mode.

When the source is operating in the Ramp mode, the number of groups measured must be greater than the averaging factor; if it is not, incomplete averaging will occur. Thus, to present an averaged trace when the source is operating in the Ramp mode, enter n + 1 (or more) as the number of groups to be measured.

For example, if the averaging factor is 128, enter 129 as the number of groups. The network analyzer will then execute 129 groups of sweeps. **HOLD** will then be selected, displaying the averaged trace.

When the source is operating in the Step sweep or Single Point mode, data is averaged n times at each data point. Thus, to present an averaged trace when the source is operating in the Step sweep or Single Point mode, enter 1 as the number of groups to be measured.

ALTERNATE SWEEP

The Standard Preset condition selects the **COUPLED CHANNELS** mode. In this mode, all stimulus functions are identical for both channels.

Selecting **UNCOUPLED CHANNELS** makes it possible to set some stimulus functions independently for each channel. This is known as the Alternate Sweep mode, and these functions are:

FREQUENCY, TIME, or VOLTAGE: START, STOP, CENTER, SPAN
GATE: START, STOP, CENTER, SPAN

SOURCE POWER	POWER SLOPE
SWEEP TIME	SWEEP TRIM
CORRECTION ON/OFF	CAL SET

Many other functions can be set differently for the two channels even when **COUPLED CHANNELS** is selected. Among these are Averaging, Smoothing, and the display of the frequency domain on one channel and the time domain on the other channel.

Some functions are always coupled and cannot be set independently. Among these functions are:

SWEEP MODE: RAMP, STEP, SINGLE POINT
NUMBER of POINTS
NUMBER of GROUPS
IF GAIN: REFERENCE and TEST
MARKER: ACTIVE and REFERENCE

To determine if any given function is coupled or uncoupled, make it the Active Function. Press Channel 1, change the function value, and then press Channel 2. If the Active Function value shown for Channel 2 has also changed, the two channels are coupled. Otherwise the two channels are uncoupled and can be set independently.

In dual display modes, separate stimulus values for each channel are displayed below the graticule area (Figure 31). These stimulus values can be changed independently. Choose the channel to be changed by pressing the Channel 1 or Channel 2 front-panel key. Then set the STIMULUS values for that channel in the usual way. Do the same for the other channel in order to change its stimulus values also.

To set both channels again to the same stimulus values, press Channel 1 or Channel 2, whichever has the values desired for both channels. Then press **COUPLED CHANNELS.** Both channels will now have the same stimulus values.

To set different stimulus functions for Channel 1 and Channel 2:

- Press **STIMULUS MENU**
  MORE
  UNCOUPLED CHANNELS
- Press **CHANNEL 1**
  Set the start/stop or center/span frequencies for Channel 1 using the STIMULUS front-panel keys.
- Press **CHANNEL 2**
  Set the start/stop or center/span frequencies for Channel 2 using the STIMULUS front-panel keys.
- Press **DISPLAY**
  DUAL CHANNEL
  OVERLAY or **SPLIT**

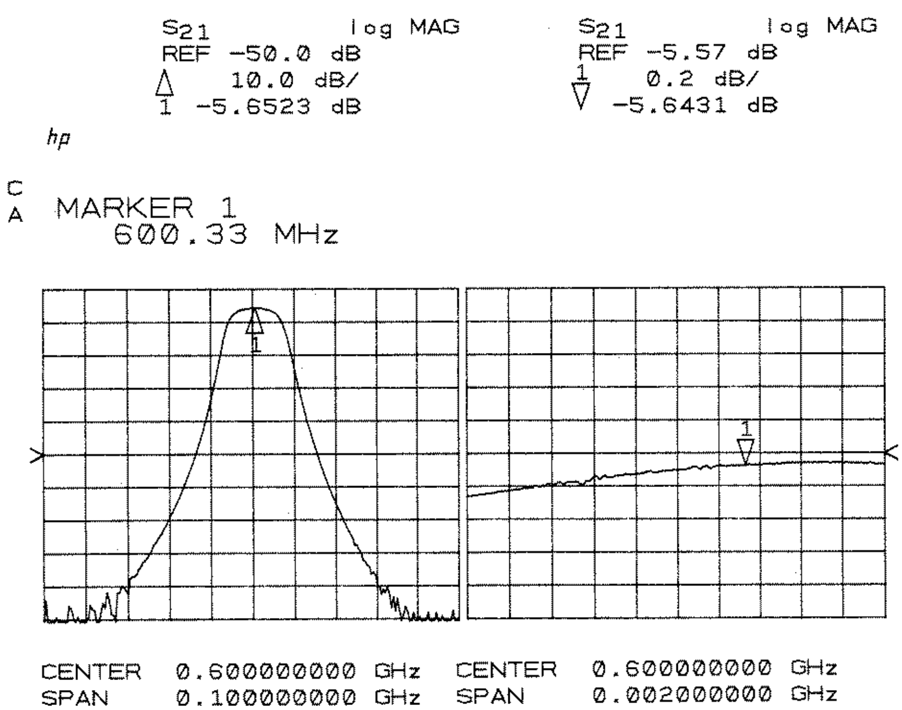
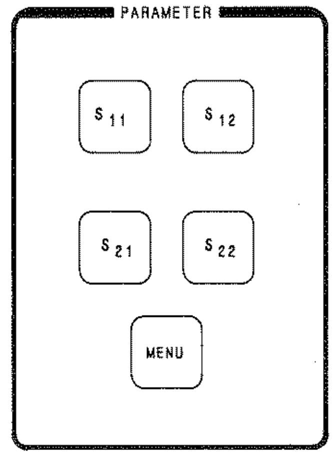


Figure 31. Alternate Sweep: DUAL CHANNEL, SPLIT

PARAMETER



PARAMETER block keys are used to select the parameter to be measured. The Parameter and Redefine Parameter menus make it possible to measure the approximate signal levels in the test set and to change parameter definitions in order to use the HP 8511A frequency converter or to use the HP 8510 system in special measurement applications.

The S_{11}, S_{21}, S_{12}, and S_{22} keys are used to select the parameter to be measured. These selections correspond to the signal flow diagram on the front panel of the test set. When a parameter is selected, test set switching is done automatically to choose the correct reference and test signal paths for that parameter.

Because the 1-Port and 2-Port calibration models include automatic parameter selection, only the four basic S-parameters can be used in these calibrations. In frequency response calibrations both standard and user parameter definitions can be used.

The **MENU** key brings the first-level Parameter Menu onto the CRT display in order to change or redefine parameters.

Pressing the green **PRESET** on the HP 8510 front panel restores all parameter definitions to their standard values.

In addition to explaining the controls and features in the PARAMETER block, this section also offers a basic discussion defining S-parameters and explaining the important conventions used to identify them.

PARAMETER MENU

Pressing the PARAMETER MENU key brings the first-level Parameter Menu onto the CRT display. This menu and the associated Redefine Parameter menu can be used to change the definitions of the four basic S-parameters, to redefine the four user parameters, and to measure the signal levels in the test set. Redefining parameters makes it possible to use custom test sets built around the HP 8511A frequency converter and to use the HP 8510 system in special measurement applications.

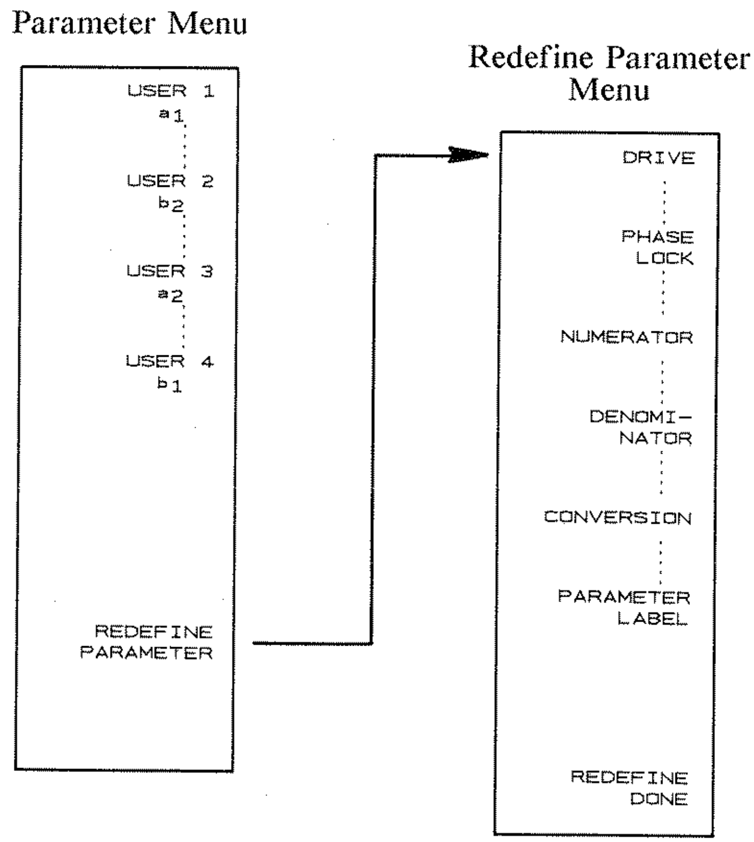


Figure 33. Parameter and Redefine Parameter Menus

REDEFINING PARAMETERS

Table 6 lists the standard parameter definitions selected when the **PRESET** key is pressed on the HP 8510 system front panel and an S-parameter test set responds on the 8510 system bus. If a reflection/transmission test set (or no test set) responds, these standard definitions are set so that $S_{22} = S_{11}$ and $S_{12} = S_{21}$.

Ports and nodes are identified on the front panel of the test set. In all cases the notation used is the same as on the test set block diagrams (Figures 7 through 9) and in the discussion of Definitions and Conventions later in this section of the manual.

Table 6. Standard PARAMETER *Definitions*

	PARAMETERS							
	BASIC				USER			
	S_{11}	S_{21}	S_{12}	S_{22}	a_1	b_2	a_2	b_1
DRIVE PORT	1	1	2	2	1	1	1	1
PHASE LOCK	a_1	a_1	a_2	a_2	a_1	a_1	a_1	a_1
NUMERATOR	b_1	b_2	b_1	b_2	a_1	b_2	a_2	b_1
DENOMINATOR	a_1	a_1	a_2	a_2	<--NO RATIO-->			
CONVERSION	S	S	S	S	S	S	S	S

Note: For Reflection/Transmission Test Sets, or no test set, $S_{22} = S_{11}$ and $S_{12} = S_{21}$.

To redefine one of the basic S-parameters (S_{11}, S_{21}, S_{12}, S_{22}):

- Press PARAMETER MENU
- Press the front-panel key in the PARAMETER block that corresponds to the parameter to be redefined: S_{11}, S_{21}, S_{12}, S_{22}.
- Press **REDEFINE PARAMETER.**
  This will bring the Redefine Parameter Menu onto the CRT.
- Use the corresponding softkeys to choose the drive port, phase lock, numerator, denominator, and conversion definitions to be used in the new definition of the parameter:

  > Press the softkey corresponding to the item on the Redefine Parameter menu to be redefined. This will bring a menu of the available choices onto the CRT, and the current selection will be underlined. Press the softkey corresponding to the new definition.

  Changes are executed immediately when the softkey corresponding to the new definition is pressed. The Redefine Parameter menu also reappears on the CRT, allowing further changes.
- When the parameter has been redefined, press **REDEFINE DONE** to save the instrument state that has now been defined.

Pressing **PRESET** restores the standard S-parameter definitions given in Table 6. Recalling an instrument state also recalls these standard definitions: in other words, redefined S-parameters cannot be recalled as part of an instrument state.

To define a user parameter:

- Press PARAMETER MENU
  This will bring the Parameter Menu onto the CRT.

- Press the softkey that corresponds to the number that you wish this user parameter to have: **USER 1**, **USER 2**, **USER 3**, or **USER 4**. Your choice will now be underlined.

- Press **REDEFINE PARAMETER**.
  This will bring the Redefine Parameter Menu onto the CRT.

- Use the corresponding softkeys to define the drive port, phase lock, numerator, denominator, and conversion definitions for each user parameter. This is done in exactly the same way as the standard S-parameters are redefined.

  Changes are executed immediately when the softkey corresponding to the new definition is pressed. The Redefine Parameter menu also reappears on the CRT, allowing further changes or definitions if desired.

- To redefine the label of the parameter, press the softkey **PARAMETER LABEL.** This will bring the Title Menu and the existing label onto the CRT display.

  To delete the whole title, press the softkey **ERASE TITLE** or use the **BACKSPACE** key in the ENTRY block. To enter a character, position the ↑ symbol below the character by turning the knob, then press **SELECT LETTER**. The character will appear in the title area. Repeat this process to write the rest of the new label.

  When you have finished entering the new label, press the softkey labeled **TITLE DONE**. This will enter the new label and return the Redefine Parameter Menu to the CRT display.

- When you have finished defining and labeling the parameter, press **REDEFINE DONE** to save the instrument state that has now been defined.

Up to four user-defined parameters can be defined in this way. They can be used in frequency response calibrations and can be saved and/or recalled as part of an instrument state.

Pressing **PRESET** restores the standard basic parameter definitions given in Table 6.

MEASURING POWER (dBm)

Signal levels (in dBm) at the first frequency converter in the test set can be measured by using the standard **USER 1** through **USER 4** definitions on the Parameter Menu. In this way it is possible to determine the approximate dynamic range available for measurements in the actual setup being used. The measurement is approximate because no account is taken of variations in losses in the signal path before detection.

Signal flow in the various test sets used with the HP 8510 system is shown in Figures 7, 8, and 9. Table 7 lists the measurements that will be displayed using the standard user parameter definitions given in Table 6.

To measure power:

- Press **PRESET**
  Press PARAMETER **MENU**
  This will bring the Parameter Menu onto the CRT.
- Refer to Table 7 and press the softkey corresponding to the power level you wish to measure: **USER 1** $\mathbf{a_1}$, **USER 2** $\mathbf{b_2}$, **USER 3** $\mathbf{a_2}$, or **USER 4** $\mathbf{b_1}$. Note that since a_2 is defined (Table 6) as phase locking and driving Port 1, with S-parameter test sets it must be redefined before it can be used directly as an indication of the Port 2 drive power.
- Press the front-panel key labeled **MARKER** in the MENUS block.
  The trace now displays the power level in dBm.
  Use the knob to position the marker on the trace to read the power at the first frequency converter.

Table 7. Measuring Power (dBm) at First Frequency Converter

Function	Reflection/Transmission and S-Parameter Test Sets
a_1	Reference (S_{11} and S_{21})
b_2	Transmitted to Port 2. (Connect Thru) or (S-Parameter test sets only) Reflected at Port 2. (Connect Short Circuit)
a_2	Reference (S_{12} and S_{22}) for S-Parameter test set. (Not used for reflection/transmission test set.)
b_1	Reflected at Port 1. (Connect Short Circuit) or (S-Parameter test sets only) Transmitted to Port 2. (Connect Thru)

To approximate the power incident at the device under test, for example, connect a short circuit at PORT 1, and select **b_1** for display. The trace represents the power appearing at the b_1 frequency converter. Since there is loss in the reflection signal path between PORT 1 and the frequency converter, and because of conversion loss, the actual power at the port is greater. Table 8 lists approximate losses in the test sets.

To approximate the power appearing at Port 2, connect the thru and select **b_2** for display. The difference between the power reading with the thru connected and disconnected is the approximate dynamic range available for the transmission measurement.

Table 8. Approximate Insertion Losses in Test Sets (dB)

Test Set	Source to a_1 or a_2 (dB)*	Source to port (dB)*	Port 1 to b_1 or Port 2 to b_2 (S_{11} or S_{22}) (dB)	Port 1 to b_2 or Port 2 to b_2 (S_{21} or S_{12}) (dB)
HP 8512A	-28	-8	-20	-20
HP 8513A	-28	-14	-12	-13
HP 8514A	-28	-8	-20	-20
HP 8515A	-28	-15	-12	-13
	* -0.35 dB/GHz			

In systems with an S-parameter test sets this method can also be used to see the effects of changing the internal attenuator values. Change the attenuator value using the method described earlier under the heading of Attenuator Port: 1 . . . 2. That is, press STIMULUS MENU, **POWER MENU**, **ATTENUATOR PORT: 1** or 2, and then use the **STEP** keys to change the internal attenuator value. Then measure power using the method described here.

DEFINITIONS AND CONVENTIONS

S-parameters are used predominantly at microwave frequencies because they provide a simple notation with exact data on device performance in achievable environments. The fact that the device under test is embedded in a characteristic impedance (usually, Z_0 = 50 ohms) is fundamental to definitions of S-parameter measurements. S-parameters are easy to measure, and there are analytically convenient methods for predicting the response of the device when combined with other devices for which the S-parameters are known.

The test set front panels use S-parameter flowgraph notation in order to identify the measurement capabilities of the test set. Let's examine S-parameter definitions and conventions in order to understand these symbols.

First, S-parameters are always a ratio of two complex quantities. Complex means that both a magnitude and a phase angle must be used to specify the quantity. S-parameter notation identifies these quantities using numbers. The S-parameter numbering convention is:

$$S_{\text{out in}}$$

where the first number (out) refers to the port where energy is emerging and the second number (in) names the port at which energy is incident. Thus, the S-parameter S_{21} identifies the measurement as the complex ratio of the energy emerging at port 2 with respect to the energy incident at port 1.

Figure 33-a shows a two-port device -- a device having an input and an output.

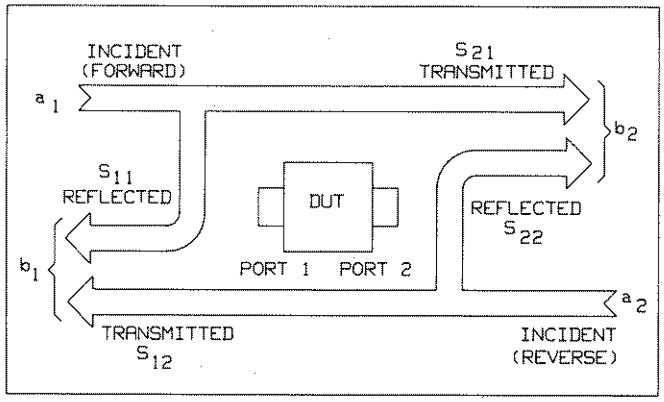


Figure 33-a. Two-Port Device

As a convention, let "a" waves represent the energy wave entering the device at a particular port, and "b" waves represent energy emerging at a particular port. At port 1, the b_1 wave is composed of a portion of the a_1 incident wave that is reflected from port 1, plus the portion of the a_2 wave incident at port 2 that is transmitted through the device. Likewise, at port 2, the emerging b_2 wave is equal to the portion of the incident wave at port 1 that is transmitted through the device plus the reflected portion of the wave incident at port 2.

Thus, we have defined two simple linear algebra equations:

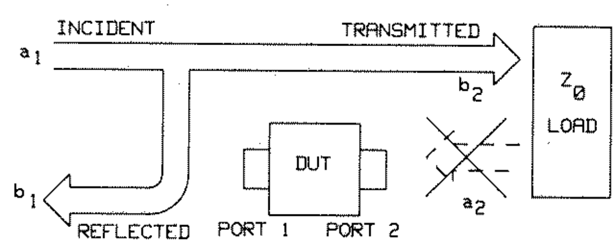
$$b_1 = S_{11}a_1 + S_{12}a_2,$$

and

$$b_2 = S_{21}a_1 + S_{22}a_2.$$

How are S-parameters determined? S_{11} is the complex ratio b_1/a_1 when a_2 is zero. This occurs (a_2 is zero) when the test device is terminated in Z_0: no energy is reflected back into port 2.

S_{11} is the port 1 input reflection coefficient with port 2 terminated in Z_0. In a like manner, S_{21} is the forward transmission coefficient with port 2 terminated in Z_0. These definitions are shown in Figure 33-b.

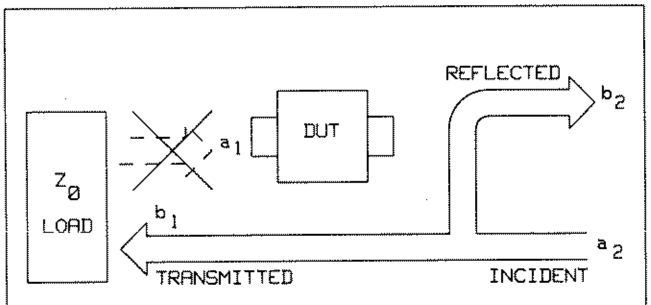


$$S_{11} = \frac{\text{REFLECTED}}{\text{INCIDENT}} = \frac{b_1}{a_1}\bigg|_{a_2 = 0}$$

$$S_{21} = \frac{\text{TRANSMITTED}}{\text{INCIDENT}} = \frac{b_2}{a_1}\bigg|_{a_2 = 0}$$

Figure 33-b. S_{11} and S_{21} Definitions

By placing the Z_0 source at port 2 and terminating port 1 in Z_0, the a_1 term becomes zero. This makes it possible to determine S_{22}, the output reflection coefficient, and S_{12}, the reverse transmission coefficient. These definitions are shown in Figure 33-c.



$$S_{22} = \frac{b_2}{a_2}\bigg|_{a_1 = 0}$$

$$S_{12} = \frac{b_1}{a_2}\bigg|_{a_1 = 0}$$

Figure 33-c. S_{22} and S_{12} Definitions

Figure 33-d, on the next page, is a flowgraph representation of a two-port device. Each port has two nodes: one representing the entering or "a" wave and one for the emerging "b" wave. Lines that connect nodes are called branches. Each branch has an arrow and value corresponding to an S-parameter. Energy will flow only in the direction of an arrow.

This two-port flowgraph is used on the front panel of the S-parameter test set to indicate that the test set can measure any of the four S-parameters by internally switching the incident power to either port 1 or port 2 of the device under test. The indicator near a_1 lights to indicate that power is emerging from Port 1 of the test set (S_{11} or S_{21} selected); the indicator near a_2 lights when power is emerging from Port 2 of the test set (S_{22} or S_{12} selected).

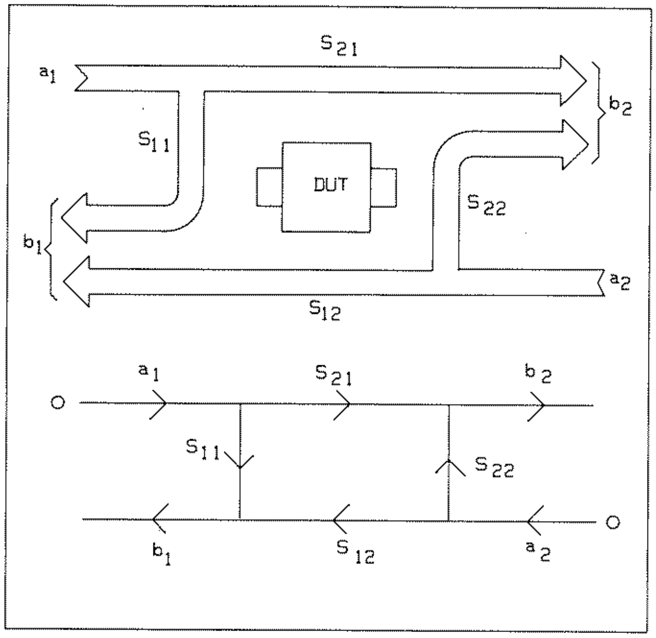


Figure 33-d. Flowgraph: Two-Port Device, S-Parameter Test Sets

The flowgraph shown in Figure 33-e, below, is used on the front panel of reflection/transmission test sets. It shows that energy can only be applied at the a_1 node. To measure the reverse parameters of a two port device using a reflection/transmission test set, the device must be manually reversed.

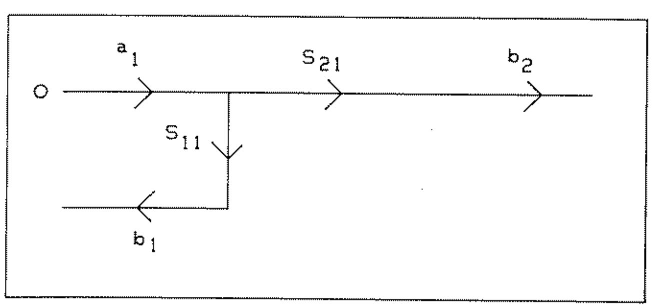
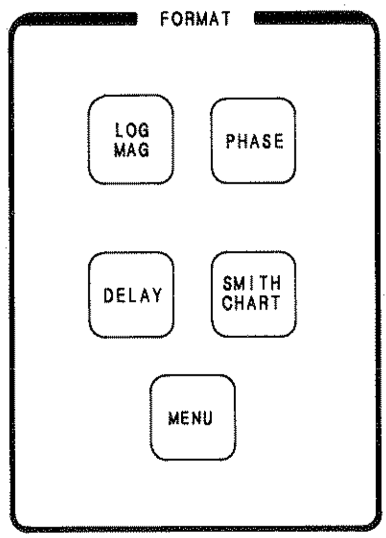


Figure 33-e. Flowgraph, Reflection-Transmission Test Sets

FORMAT



FORMAT block keys and the associated Format Menu (Figure 33) allow choices of the format used in displaying the data for each parameter selected.

Seven cartesian display formats are available: log magnitude, phase, delay, SWR, linear magnitude, imaginary, and real.

Two Smith chart display formats are available: Smith chart and inverted Smith chart.

Three polar displays are available, differing in the nature of the trace marker used: linear magnitude and angle, logarithmic magnitude and angle, and real/imaginary.

Figures 34-a through 34-l show examples of the display formats available.

Four of these display formats are available simply by pressing the labeled front-panel keys: **LOG MAG**, **PHASE**, **DELAY**, and **SMITH CHART**. The others are available by pressing the FORMAT MENU key and the corresponding softkey on the Format Menu.

Explanations of how to use the various display formats in measurement applications appear later in this manual, under the headings Reflection Measurements and Transmission Measurements.

FORMAT MENU

Pressing the FORMAT MENU key brings the Format Menu (Figure 33) onto the CRT display. Choices on this menu allow you to choose any of the display formats listed. Press the corresponding softkey. The display will immediately change to the format you have selected.

Format Menu	Type of Display
SWR	Cartesian: SWR
LINEAR MAGNITUDE	Cartesian: Linear Magnitude
LIN mkr on POLAR	Polar: Linear Magnitude and Angle Marker
LOG mkr on POLAR	Polar: Logarithmic Magnitude and Angle Marker
Re/Im mkr on POLAR	Polar: Real/Imaginary Marker
INVERTED SMITH	Inverted Smith Chart
IMAGINARY	Cartesian: Imaginary
REAL	Cartesian: Real

Figure 33. Format Menu

CARTESIAN DISPLAYS

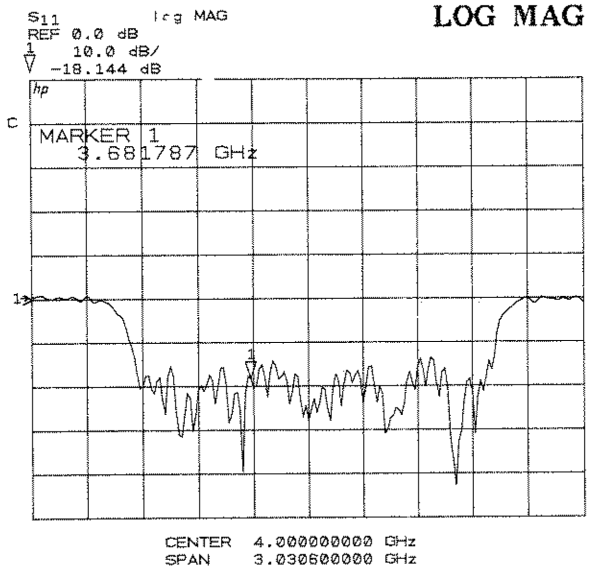


Figure 34-a. LOG MAG *Format*

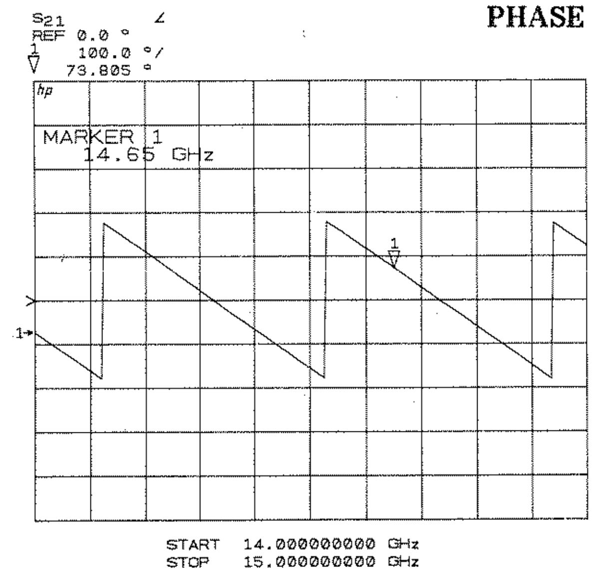


Figure 34-b. PHASE *Format*

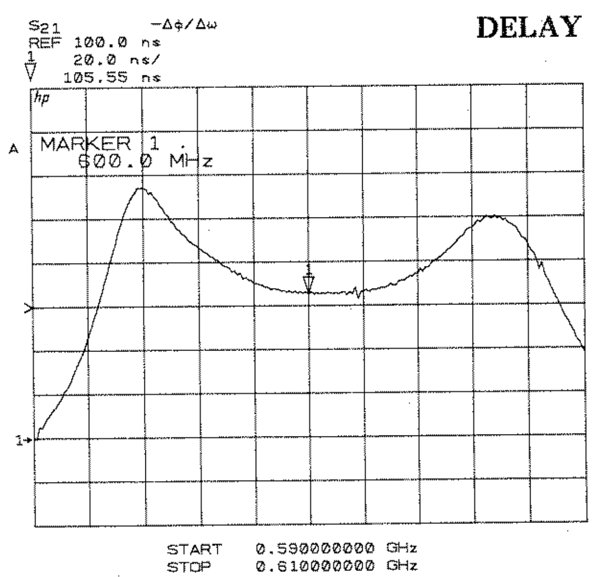


Figure 34-c. DELAY *Format*

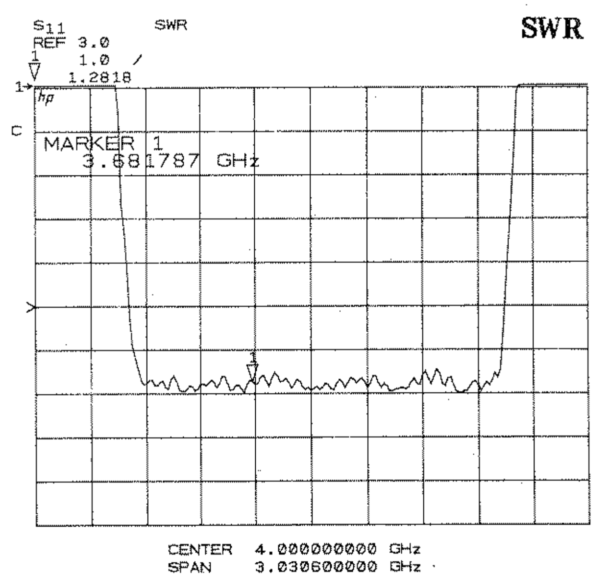


Figure 34-d. SWR *Format*

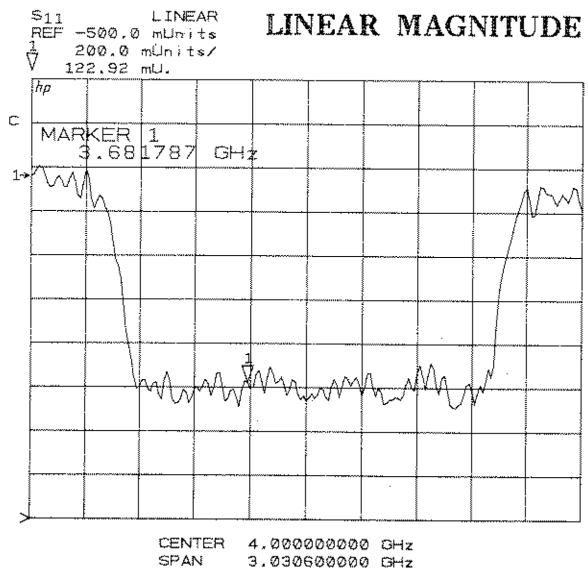


Figure 34-e. LIN MAG *Format*

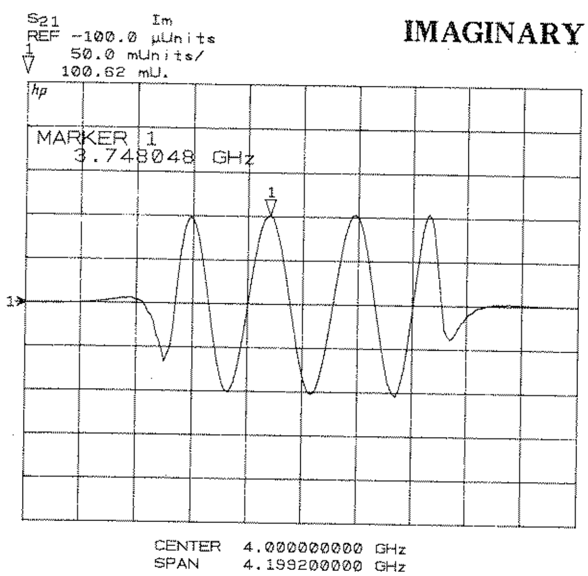


Figure 34-f. IMAGINARY *Format*

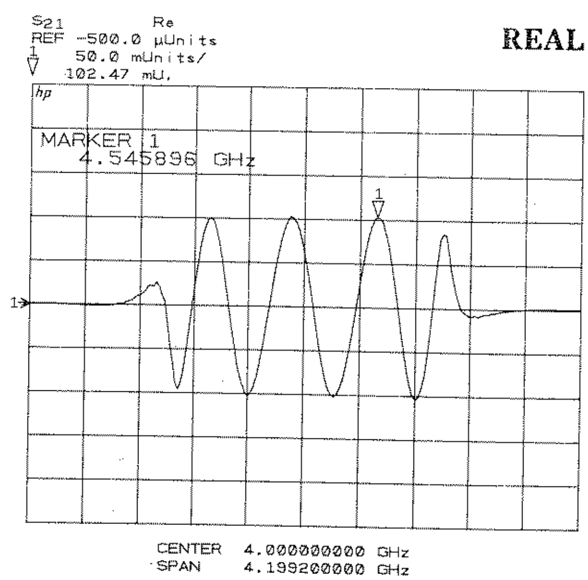


Figure 34-g. REAL *Format*

SMITH CHART DISPLAYS

SMITH CHART

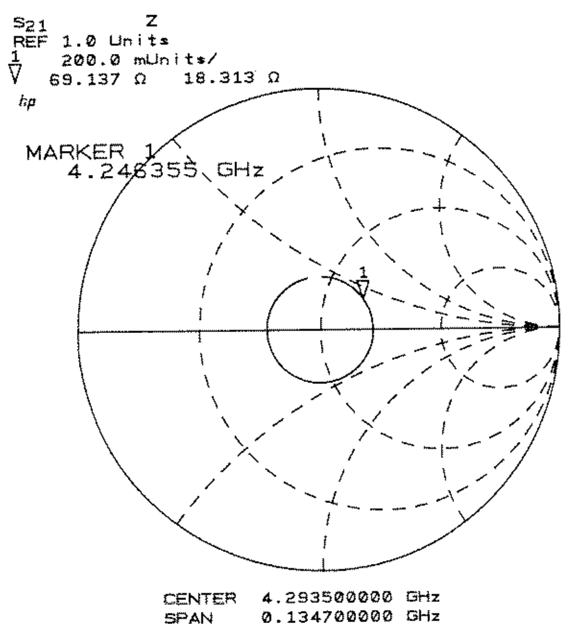


Figure 34-h. Smith Chart Format

INVERTED SMITH CHART

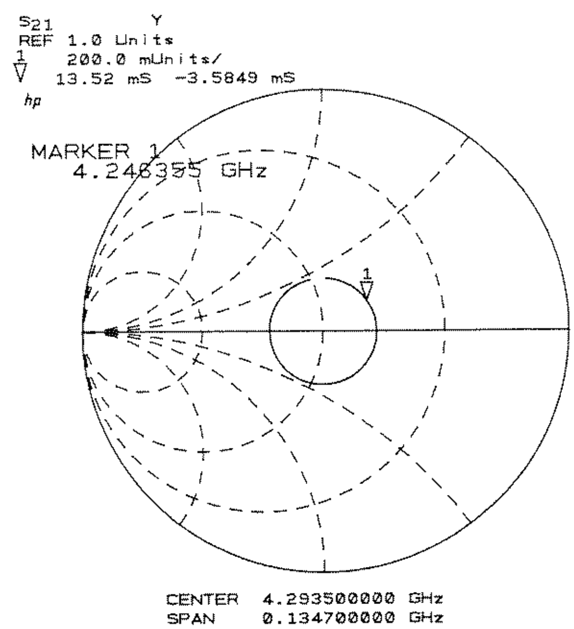


Figure 34-i. Inverted Smith Chart

POLAR DISPLAYS

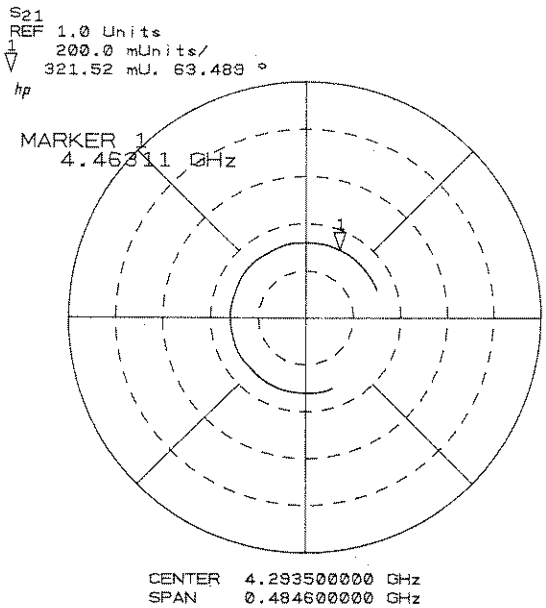


Figure 34-j. LIN mkr on POLAR *Format*

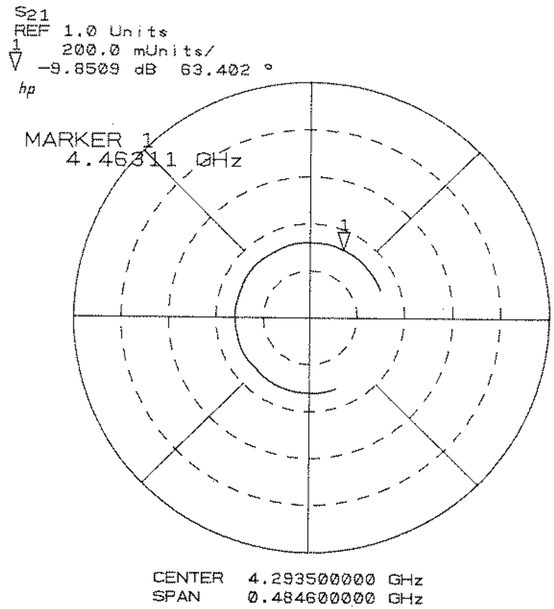


Figure 34-k. LOG mkr on POLAR *Format*

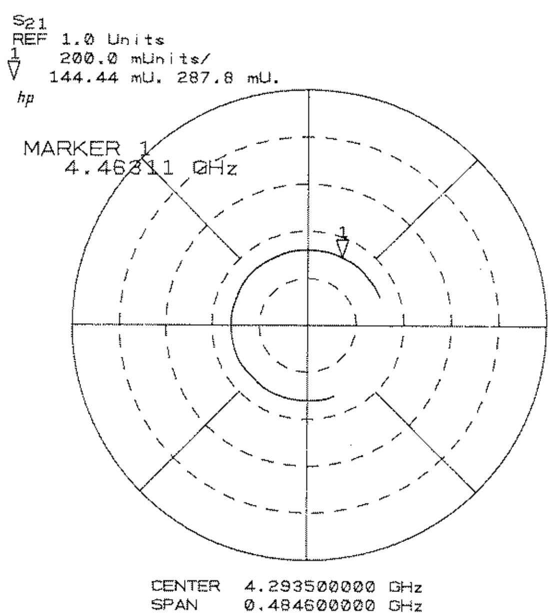
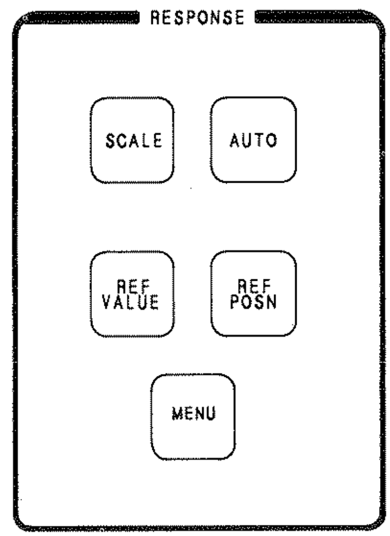


Figure 34-l. Re/Im mkr on POLAR *Format*

RESPONSE



RESPONSE block keys offer various options in positioning the trace and the reference line on the CRT display. The associated Response Menu (Figure 35) offers options used to add linear phase compensation and phase offset to the trace, and to apply averaging and smoothing to the trace to enhance its usefulness in making the measurement.

Pressing **AUTO** automatically selects a scale/division value that results in the display of the entire trace and the reference line on the CRT.

Pressing **SCALE**, and then using the knob, **STEP**, or numeric **x1** keys in the ENTRY block allows you to change the scale/division value. The trace expands or contracts around the reference position line.

Pressing **REF POSN** makes it possible to move the reference position line on cartesian displays. The reference position line for Channel 1 is identified by the > indicator on the left of the graticule; for Channel 2 it is the < indicator on the right side of the graticule for Channel 2. In Smith chart and polar displays, **REF POSN** is not used.

To move the reference position line, press **REF POSN**, and then use the knob, **STEP**, or numeric **x1** keys to change its position. Using the numeric **x1** keys, 0 is bottom; 10 is top. To return to an integer position, press **STEP** to move the line to the top or bottom.

The trace is positioned relative to the reference position line, so changing the reference value moves the trace, but does not change the marker value. For Smith and Polar displays, changing **REF VALUE** also changes scale/division. Also, use **REF VALUE, =MARKER** to position the trace.

RESPONSE MENU

Pressing the RESPONSE MENU key brings the Response Menu (Figure 35) onto the CRT display. Choices on this menu allow you to add electrical delay or phase offset to the trace or to apply averaging or smoothing to it.

Response Menu	Effect on Trace
ELECTRICAL DELAY	provides calibrated linear phase compensation
PHASE OFFSET	adds fixed phase shift to each frequency point
AVERAGING ON/restart ... OFF	removes random noise variations
SMOOTHING ON ... OFF	changes effective measurement aperture by averaging adjacent points

Figure 35. Response Menu

ELECTRICAL DELAY

The electrical delay function acts as an Electronic Line Stretcher providing a calibrated linear phase compensation with femtosecond resolution. The active function shows delay in terms of seconds and centimeters relative to the speed of light in a vacuum.

On the Response Menu select **PHASE**, and then use the knob, **STEP** keys, or numeric and units keys to enter the amount of electrical delay desired. Electrical delay can be set independently for each parameter on each channel.

PHASE OFFSET

The phase offset function makes it possible to enter phase offset to the current active trace by adding a fixed phase shift to each frequency point. It also changes the marker value. Phase offset can be set independently for each channel.

AVERAGING

Averaging is used to remove random noise variations from measurements, improving both accuracy and resolution. Smoothing changes the effective measurement aperture by averaging adjacent points. Both averaging and smoothing can be used simultaneously. Both can be set independently for each channel.

Averaging is used to enhance meaningful resolution and to increase dynamic range by effectively decreasing the input noise bandwidth. Press **AVERAGE ON/restart** then use the knob, **STEP** keys, or numeric **x1** to select the averaging factor applied to the displayed data. Averaging restarts when the averaging factor is changed, an important measurement or display characteristic is changed, when a measurement calibration device is selected for measurement, and when **AVERAGE ON/restart** or the front-panel key MEASUREMENT **RESTART** is pressed.

In the **RAMP** sweep mode, the new trace, weighted by 1/n, is summed with the current trace, weighted by (n - 1)/n, where n is the averaging factor. This is an exponential running average. Also, the averaging factor selection controls the number of sweeps taken for measurement of a standard during measurement calibration. When a selection key for the standard is pressed, n+1 groups are taken, where n is the selected averaging factor.

(A group consists of a certain number of sweeps that must be taken in order to make one complete measurement; how many sweeps make up a group thus depends on the calibration model being used and other details of the measurement.)

Note that in the **RAMP** sweep mode each time averaging is restarted, the averaging algorithm starts with a small averaging factor, then increases the averaging factor group-by-group, up to the selected factor, thus allowing fast convergence to the final value.

In the **STEP** sweep and Single Point modes, each data point is averaged n times as it is read, so only one group is required. This is a linear block average.

Select an averaging factor appropriate to the operation being performed. When adjustments to the test device or test setup are being made, select a lower averaging factor (128 or below) to see changes quickly. If a very noisy trace is being analyzed, use a higher value (up to 4096) and allow more time for the trace to settle.

Averaging operates in powers of 2 only. Averaging factors which are not powers of two are rounded down to the next power of 2. For example, if a factor of 150 is entered, it is rounded down to 128.

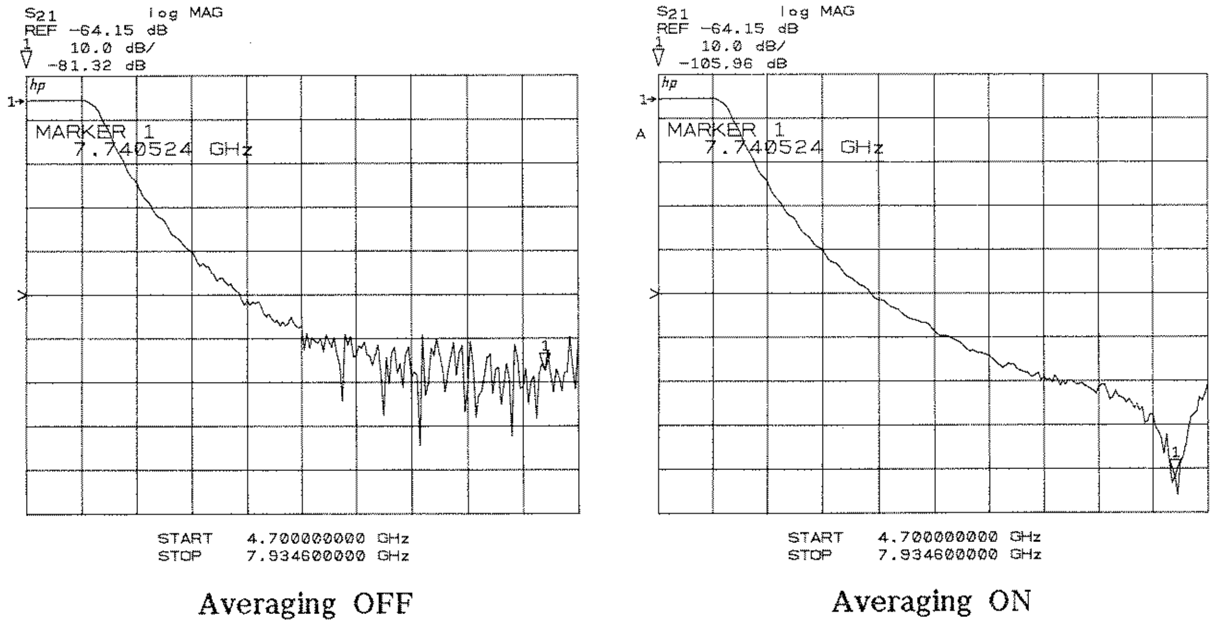


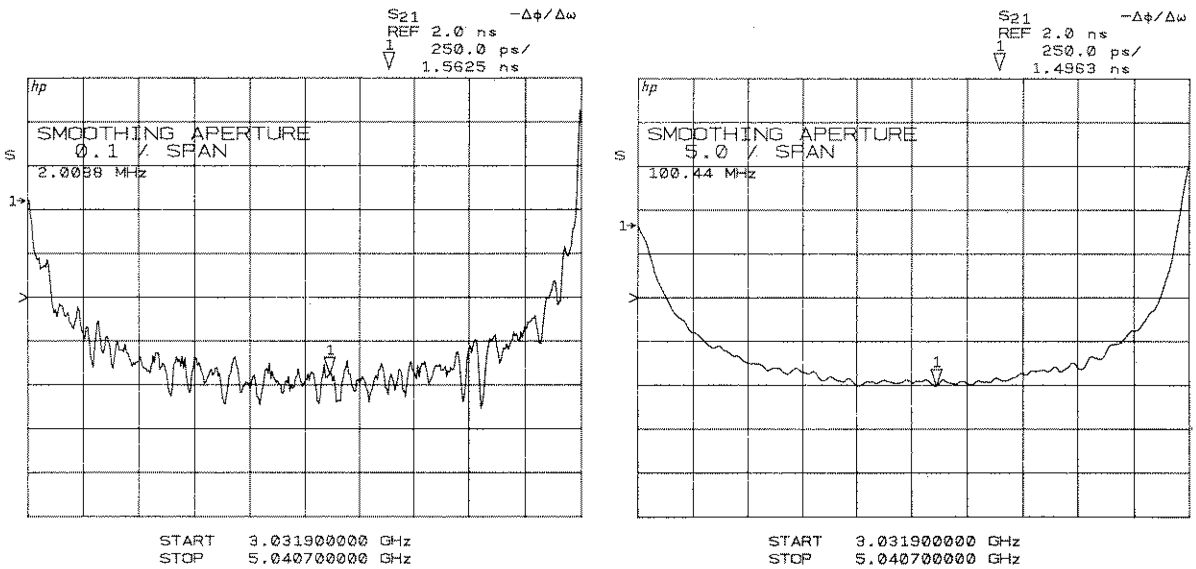
Figure 36. Results of Averaging

SMOOTHING

Smoothing operates on cartesian data formats in much the same way as a video filter operates, producing a linear moving average of adjacent points. The presently selected smoothing aperture is displayed in percent of sweep width (SPAN), as shown in Table 9. Stimulus Aperture (the width of the linear moving average) is displayed in Hz, seconds, or volts, depending upon the domain selected. When Smith Chart or polar display formats are selected, the smoothing aperture can be adjusted but the trace data is not smoothed.

Table 9. Smoothing Aperture

% SPAN	Number of Points			
	401	201	101	51
0.1	1	1	1	1
0.2	1	1	1	1
0.5	3	1	1	1
1.0	5	3	1	1
2.0	9	5	3	1
5.0	21	11	5	3
10.0	41	21	11	5
20.0	81	41	21	11



Smoothing Aperture	0.1% SPAN	Smoothing Aperture	5% SPAN
Stimulus Aperture	~ 2 MHz	Stimulus Aperture	~ 100 MHz

Figure 37. Results of Smoothing

MEASUREMENT MARKERS

Measurement Markers (Figure 38) are used to read the trace value at the marker position. This value is displayed in the channel identification block(s) on the CRT. Marker units depend on the display format and are as given in Table 10. The value of the independent (stimulus) variable at the marker position is displayed in the Active Function area of the CRT.

Since trace values are always read at actual data points, as the marker is moved along the trace, the value displayed moves in steps rather than continuously.

Markers are made active by pressing the **MARKER** key in the MENUS block and choosing a marker from the Marker Menu:

- Press **MARKER**
  This will bring the Marker Menu onto the CRT.
- Use the corresponding softkey to select **MARKER 1, 2, 3, 4,** or **5** as the Active Marker.
- Use the knob, step, or numeric keys to position the Marker.

The Active Marker is indicated by a downward-pointing triangle, inactive markers by an upward-pointing triangle. Thus in Figure 38, marker 1 is active, markers 2, 3, 4, and 5 are inactive. To change the position of a marker, it must be made the Active Marker.

To move the Active Marker to the position of a given stimulus value, enter the numeric value and its units. The Active Marker will move to the data point nearest to that value and display the trace value as the Active Entry.

To move the Active Marker left (down) or right (up) one x division press the corresponding **STEP** key. To move the Marker to the minimum or maximum measured value on the displayed trace press the softkey **MORE** to bring the continuation of the Marker Menu onto the CRT display. Then press the corresponding softkey: **MARKER to MINIMUM** or **MARKER to MAXIMUM.**

To re-position the trace so that the marker position is on the Reference Line, press the STIMULUS block key labeled **REF VALUE**, then press **=MARKER.** This will re-position the trace with the point originally marked now positioned on the reference line.

Marker values remain displayed even when you select another function (such as **SCALE**) that uses the knob. The knob no longer controls the marker position, but the marker values remain displayed.

To remove all marker values from the CRT display press the softkey **all OFF.**

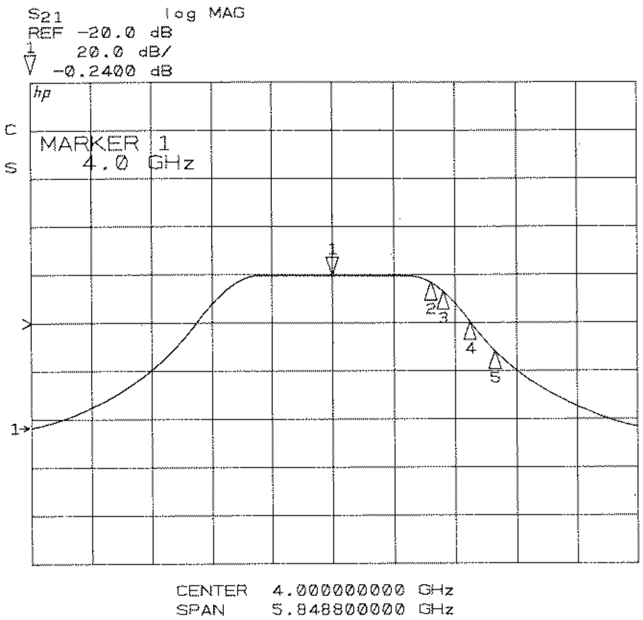


Figure 38. Markers on Trace

Table 10. Marker Units

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

For unitless quantities such as Linear Magnitude and Real, the marker value is displayed in units (u=units; mu=milliunits). A reflection coefficient measurement of 0.94 is displayed as 940.00 milliunits.

Δ MARKERS

The Δ Marker Mode (Figure 39) is used to read the difference in trace value between any currently selected Active Marker and another marker designated as the Reference Marker. Any marker can be designated as the Reference Marker, causing the currently selected Active Marker to read relative to it.

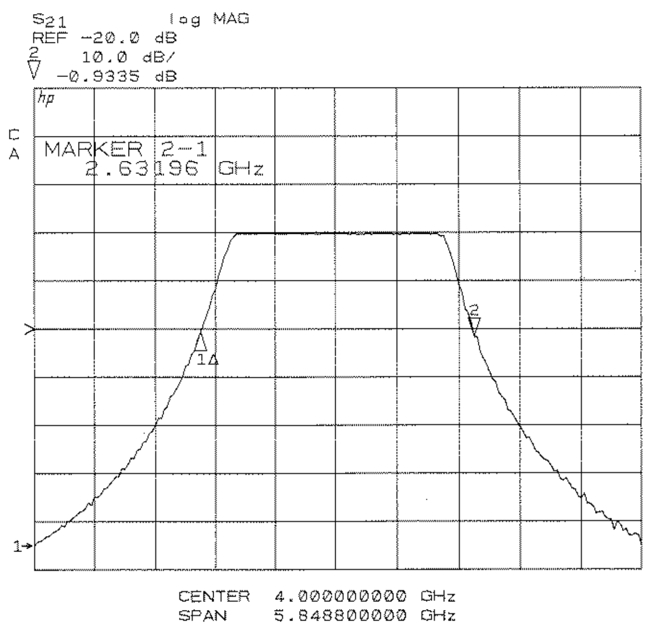


Figure 39. Δ Mode Markers on Trace

The Δ Mode sequence uses both the Marker and the Δ Mode Menus (Figure 40), as follows:

- Press **MARKER**
  This will bring the Marker Menu onto the CRT.

- From the Marker Menu, select **MARKER 1**, **2**, **3**, **4**, or **5**.
  Use the knob to position this marker to any desired point on the trace. Then select another marker and position it on the trace. Up to five different markers can be selected and positioned in this manner.

- Press the softkey Δ **MODE MENU**.
  This will bring the Δ Mode Menu onto the CRT.

- Press the softkey Δ **REF = 1**, **2**, **3**, **4**, or **5** corresponding to the marker desired as the reference marker.
  The Marker Menu will now reappear on the CRT with the designated marker labeled Δ REF=.

- From this Marker Menu, select any other Marker.
  The marker selected is now the Active Marker.
  If the current Active Marker is also selected as the Reference Marker, the displayed value will be zero because the marker is reading relative to itself.

- Use the knob to position the Active Marker anywhere on the trace.
  The difference between this Active Marker and the Reference Marker is displayed as the Active Entry.

To exit the Δ Marker Mode press Δ **MODE MENU**, Δ **OFF**.

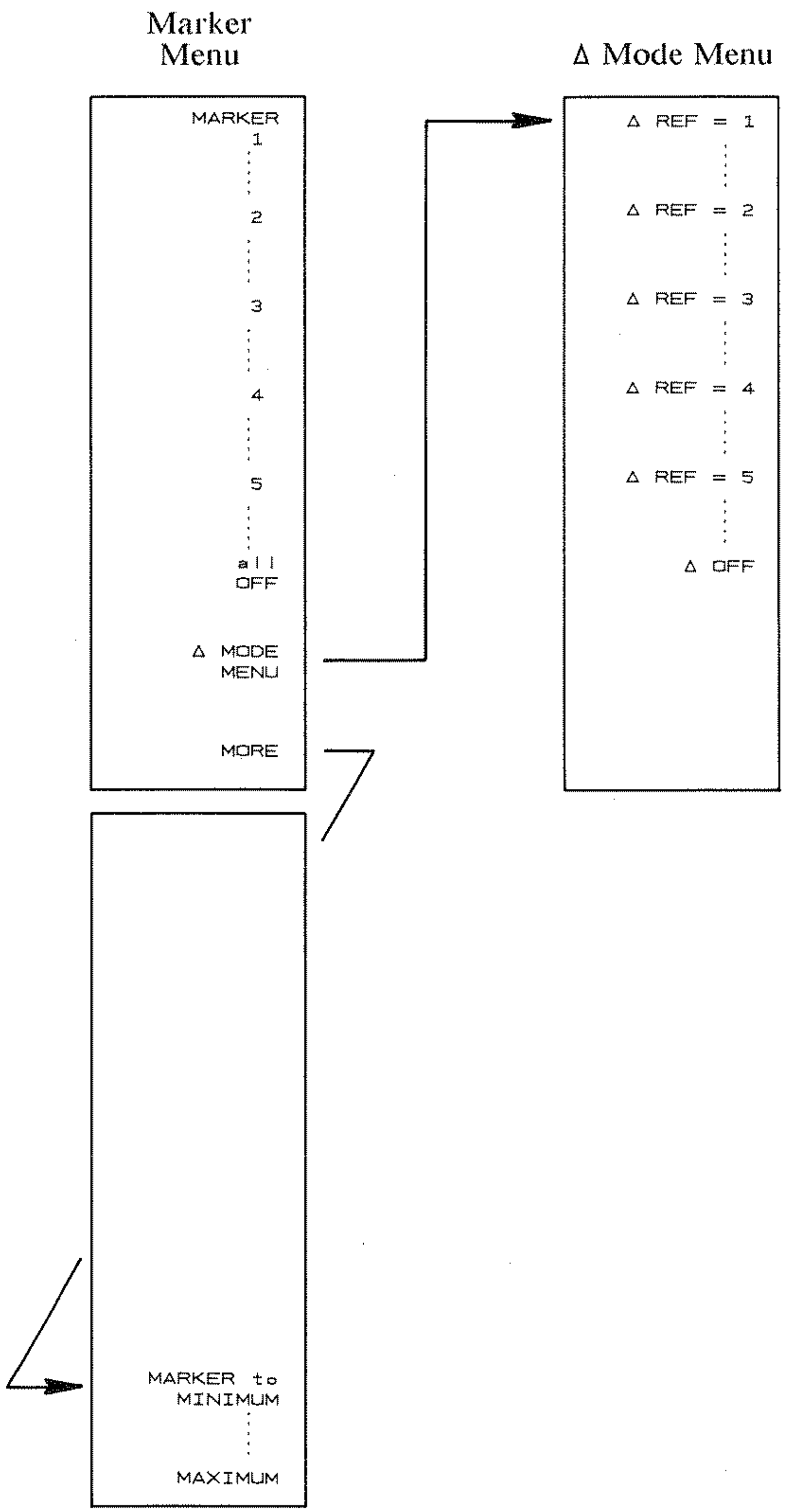


Figure 40. Marker and Δ Mode Menus

COMPARISON MEASUREMENTS

The display capabilities of the HP 8510 network analyzer make it possible to store a response (MEMORY) and then compare it with the current response (DATA) in any format. Using softkeys on the Display Menu, either the DATA trace or the MEMORY trace can be displayed alone, or the two traces can be displayed together (DATA and MEMORY). Complex mathematical operations (vector addition, subtraction, multiplication, and division) can also be performed on the DATA trace, for example to display the ratio between the DATA trace and the MEMORY trace directly.

The choices on the Dual Channel Menu make it possible to display two traces at the same time, on the same grid (OVERLAY) or side by side (SPLIT). Figure 41 illustrates this capability, showing an overlay display of S_{11} and S_{21} and beside it a split display of the same S_{21} measurement with different frequency spans.

Examples of other comparison measurement displays possible with the HP 8510 system are shown in Figures 43 and 44. Ways to make these various comparison measurements are explained in the next several pages.

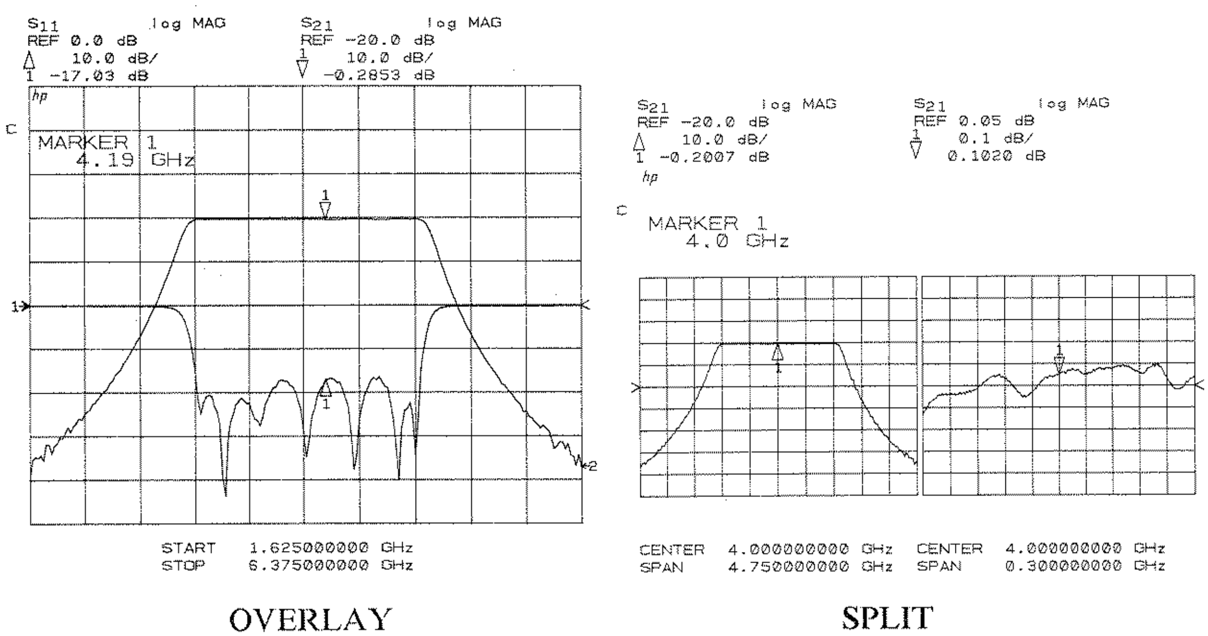


Figure 41. Dual Channel Measurement Displays

COMPARISON WITH STORED MEMORY

Pressing the **DISPLAY** key in the **MENUS** block brings the first level Display Menu (Figure 42) onto the CRT. Press the softkey **DISPLAY: DATA** to display the current data trace. To store this data, press the softkey **DATA → MEMORY**. When the softkey **MEMORY** is pressed, this data will be recalled and displayed.

To display the stored trace data at the same time as a current data trace, press the softkey **DATA and MEMORY.** The two traces will then be displayed on the same grid, using the same scale/division, reference line value, and reference line position used for the current data trace. An example of such a display appears in Figure 43.

The stored trace should be viewed in the same domain (frequency, time, or voltage) as when it was stored: changing domains does not change the domain of the **MEMORY** trace. And it must be viewed using the same number of frequency sample points as when it was stored. Most other display details, however, can be those chosen for the current trace. This is made possible by the fact that the transfer of data to memory is done before any math operations which may be in use on the displayed trace have been performed. Figure 4, showing post-detection signal processing, will be helpful in knowing which operations are and are not part of the stored trace data.

Display selections (**DATA**, **MEMORY**, **DATA and MEMORY**) are independent for Channel 1 and Channel 2.

DUAL CHANNEL OPERATION

Pressing the **DUAL CHANNEL** softkey on the Display Menu brings the Dual Channel Menu (Figure 42) onto the CRT display. In dual channel operation, the current Channel 1 and Channel 2 measurements are both displayed at the same time. Most functions, including the start and stop frequencies, the parameter, and the format, can be selected independently for each channel, although some may require that the channels be uncoupled first.

In addition, the display for each channel can include stored measurements, either instead of or in addition to the current measurement. These selections can be made for either channel directly from the Display Menu, which appears on the CRT along with the dual channel measurement display.

Examples of the two display choices made available by the Dual Channel Menu appear in Figure 41:

- **OVERLAY** displays both measurements full size on the same graticule (grid). Trace labels identify the traces from the two channels: the label **1** (identifying the trace from channel 1) appears on the left of the graticule, the label **2** (channel 2) appears on the right of the graticule.

- **SPLIT** displays the measurements on two half-size graticules side by side. Channel 1 measurements are on the left, channel 2 measurements on the right.

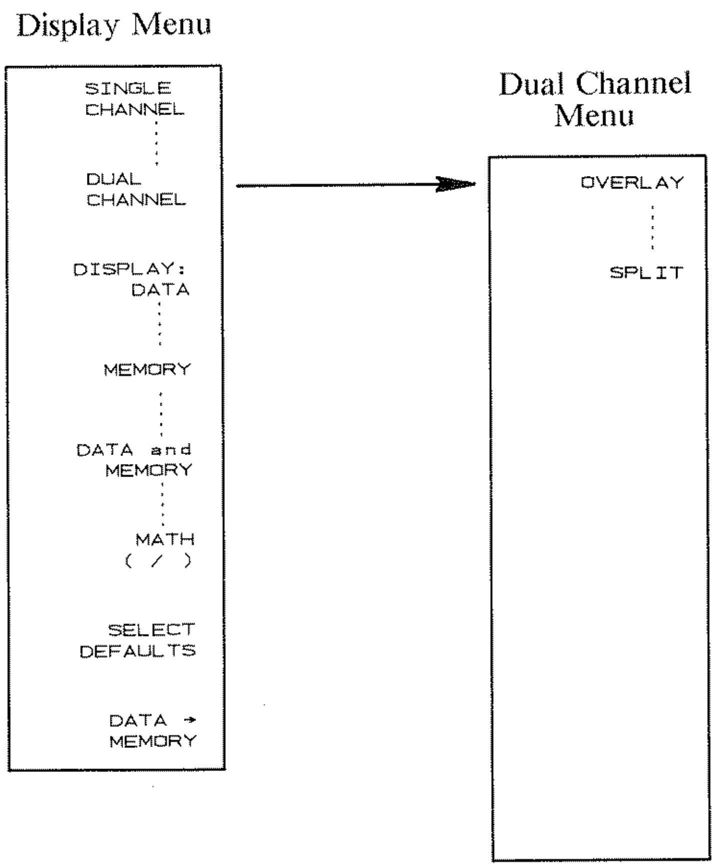


Figure 42. Display and Dual Channel Menus

MEMORY MATH OPERATIONS

Complex math operations (vector addition, subtraction, multiplication, and division) can be performed on the current trace, using data from another trace stored in memory. Regardless of the operation, the display which results will represent the mathematical result of taking the current trace (**DATA**) and then performing on it the mathematical operation selected, using the stored trace data (**MEMORY**) in the mathematical operation. Math operations are performed before the data is formatted for display.

For example, selecting the default math operation, division (/), causes the display to show the ratio between the current trace and the stored trace:

$$\frac{\text{current trace (DATA)}}{\text{stored trace (MEMORY)}}$$

If the current trace and the stored trace are identical, the ratio between them is 1 and a cartesian display of the result will a flat line at 0 dB, degrees, or seconds. Figure 44 shows a typical result of such a comparison. A polar display of the result will be a small cluster of points at $1 \angle 0°$.

To use a complex math operation, first store the trace in memory using **DATA → MEMORY** softkey on the Display Menu. Then, also on the Display Menu, press the softkey **MATH** (/) if the operation desired is division: the display will then show the ratio between the current trace and the stored trace. An example of such a display appears in Figure 44.

If another mathematical operation is desired:

- On the Display Menu, press **SELECT DEFAULTS.**
  This will bring the Select Defaults Menu (Figure 45) onto the CRT display.

- Press **MATH OPERATIONS.**
  This will bring the Math Operations Menu (Figure 45) onto the CRT display. The current selection will be underlined.

- Press **PLUS** (+), **MINUS** (-), **MULTIPLY** (•), or (if the default selection has been changed) **DIVIDE** (/).
  Press **PRIOR MENU** to leave the math operation unchanged.

The CRT display will now show the result of this math operation and the selected operation will appear in parentheses ( ) under **MATH** on the Display Menu.

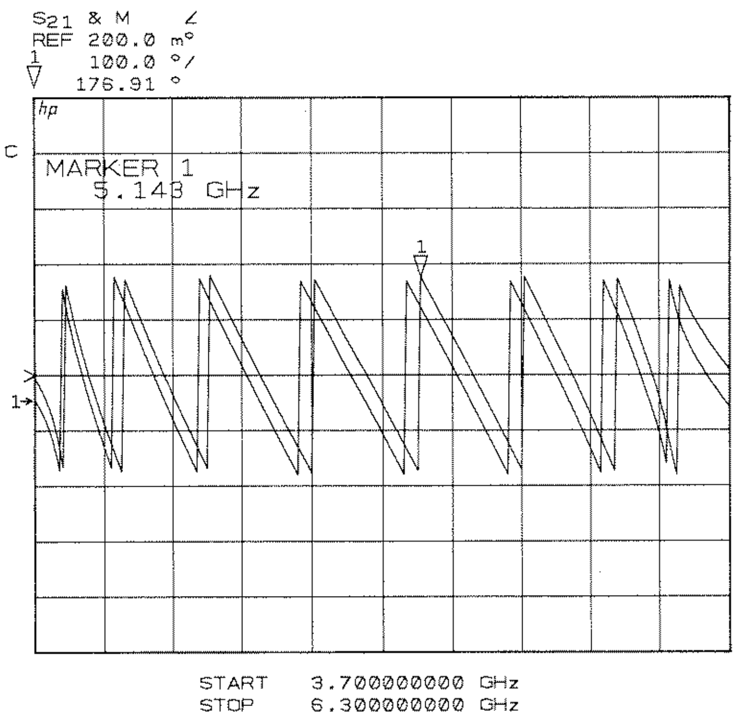


Figure 43. Current Trace Compared with Stored Memory

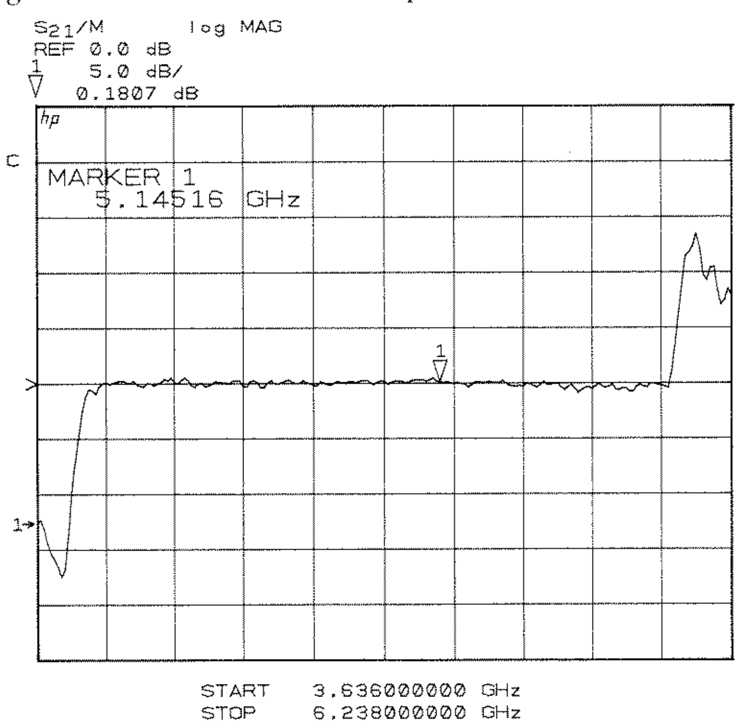


Figure 44. Math Operations: Division (/)

SELECT DEFAULTS MENU

Pressing the **SELECT DEFAULTS** softkey on the Display Menu brings the Select Defaults Menu (Figure 45) onto the CRT. Choices on this menu make it possible to store trace data in any of four memory locations. Memory locations can be selected independently for Channel 1 and Channel 2.

Unless the memory location is changed using the Select Defaults Menu, pressing **DATA → MEMORY** with Channel 1 selected stores the trace in Memory 1, and pressing **DATA → MEMORY** with Channel 2 selected stores the trace in Memory 2. These are the default memory locations.

To change the default memory location:

- Select **CHANNEL 1** or **CHANNEL 2.**
- On the Display Menu, press **SELECT DEFAULTS.**
  This will bring the Select Defaults Menu (Figure 45) onto the CRT display. The current selection will be underlined.
- Press **DEFAULT to MEMORY: 1, 2, 3,** or **4.**
  Or press **PRIOR MENU** to leave default storage unchanged.

The Display Menu will now reappear, and when the channel whose defaults have been changed is selected, pressing **DATA → MEMORY** will cause the current trace data to be stored in the memory you have selected.

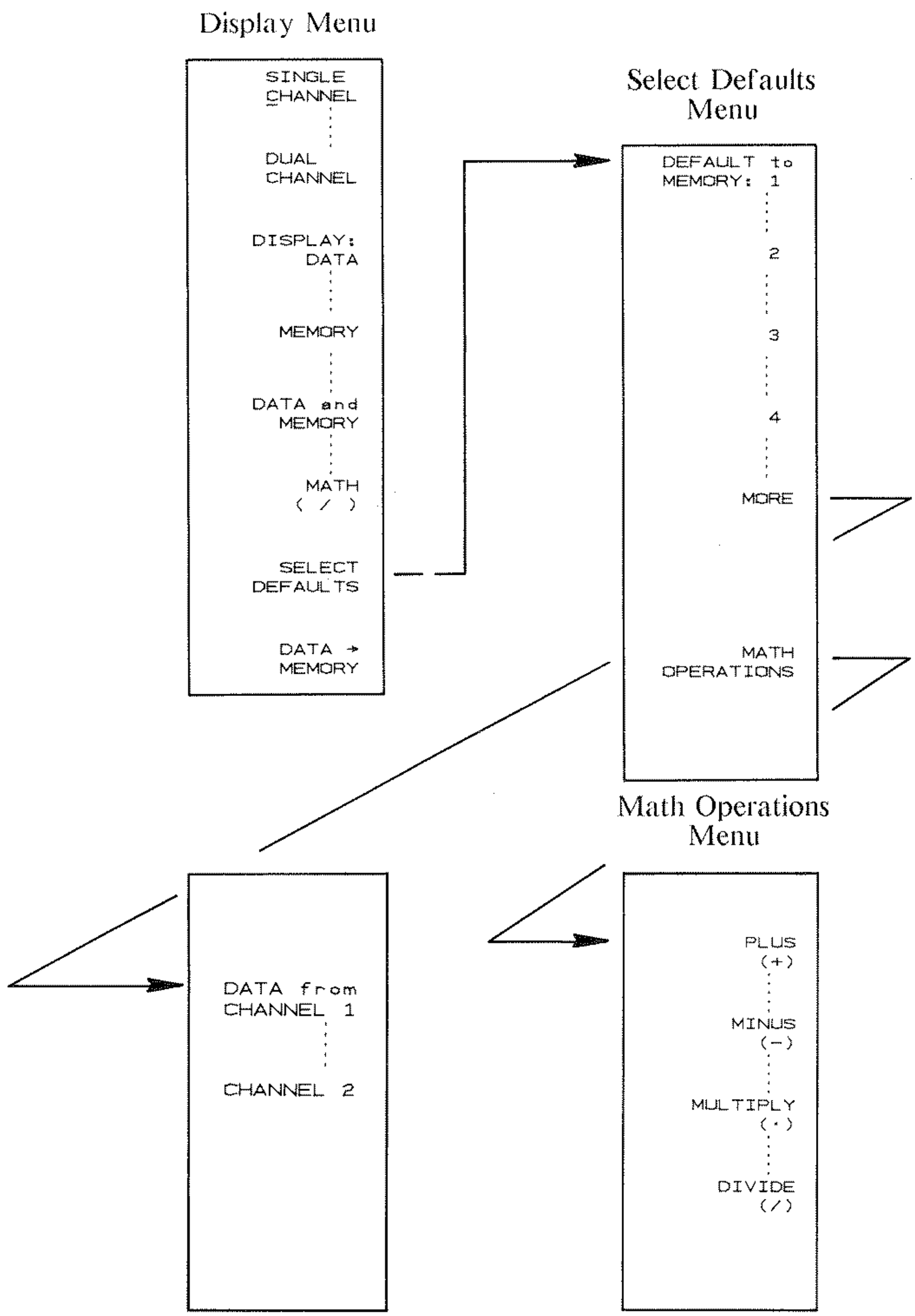


Figure 45. Select Defaults and Math Operations Menus

PRINTER/PLOTTER/TAPE

ILLUSTRATIONS

INTRODUCTION

This part of the HP 8510 network analyzer system manual explains how to use the Copy Menu and its associated menus to plot or print measurement data and to document the instrument state and system configuration. It also explains how to use the Tape Menu and its associated menus to store measurement data and other information and to make a backup copy of the operating system tape.

COPY MENU

The Copy Menu and its associated menus provide a means to output CTR data to an HP-IB type digital plotter or to output a tabular listing of trace data to an HP-IB type printer.

PLOTTER OUTPUT

To output all or part(s) of the current CRT measurement display (trace, graticule, marker or markers, and text) to a plotter, first press the **COPY** key in the AUXILIARY MENUS block. This brings the Copy Menu (Figure 46) onto the CRT display.

To plot the entire display on the full size of the plotter paper, press the softkey labeled **PLOT: ALL**. Plotting will begin immediately. Wait for the plot to be completed before pressing another key. Pressing any front-panel key or any softkey while a plot is in progress aborts the plot.

To plot only part of the display, instead of **PLOT: ALL** press the softkey corresponding to the material you wish plotted: **TRACE**, **GRATICULE**, **MARKER(S)**, or **TEXT**. To plot more than one of these, for example to plot the trace and then the graticule, wait for the first plot to be completed. Then, without changing the plotter paper, press the softkey corresponding to the further material you wish plotted. Plotting of this material will begin immediately.

To plot all or part of the display at approximately quarter size, press the **SELECT QUADRANT** softkey on the Copy Menu. This brings the Plot Quadrant Menu (Figure 46) onto the CRT display and allows you to select the location of this reduced-size plot; a full-page plot can also be selected.

Choose the location of the plot by pressing one of the four softkeys on the Plot Quadrant Menu. Then press **PLOT: ALL** or one of the softkeys for plotting only part of the display. The material selected will now be plotted at approximately one-quarter size in the location you have specified. Wait for the plot to be completed before pressing any other key.

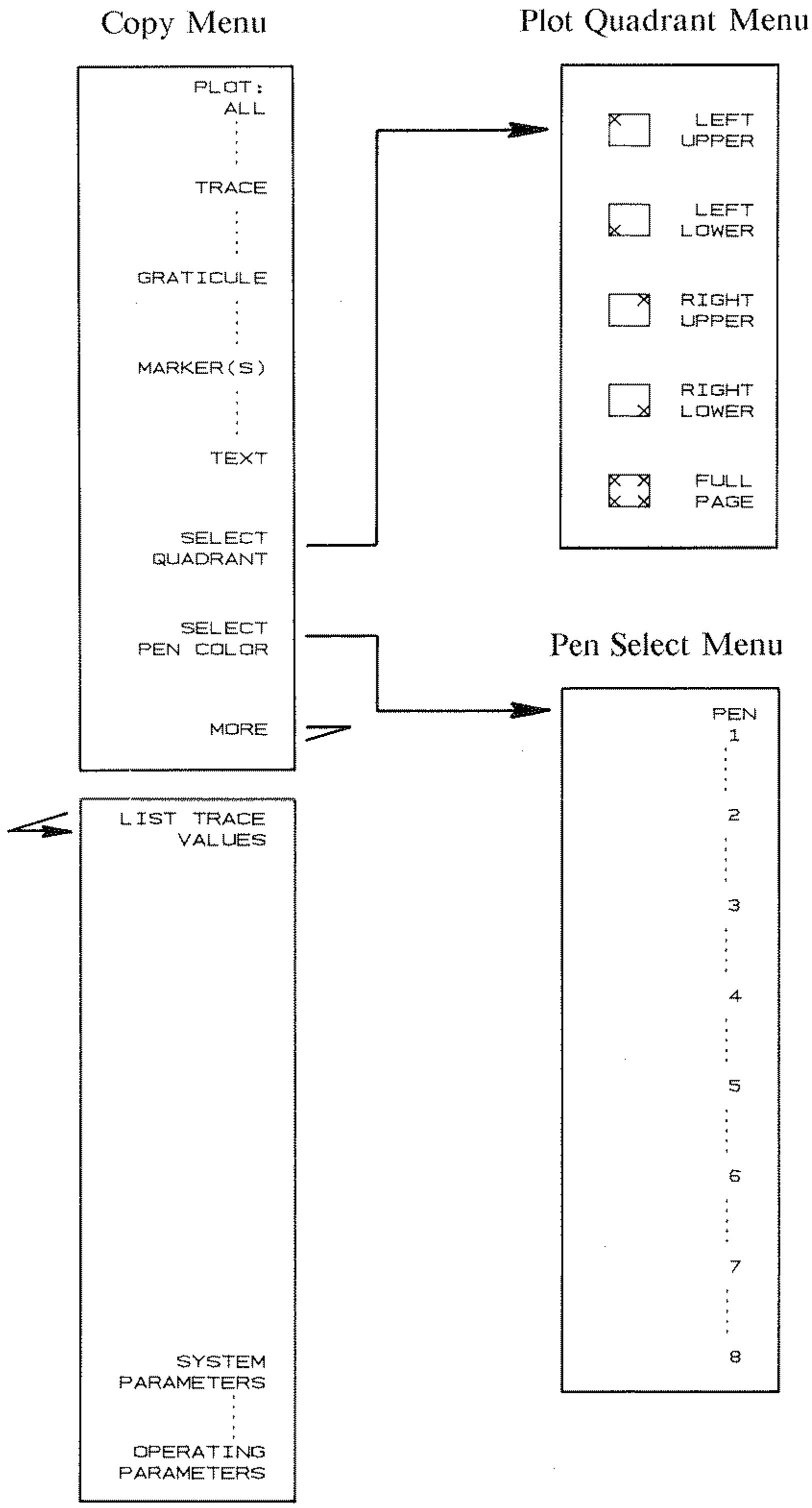


Figure 46. Copy, Select Quadrant, and Pen Select Menus

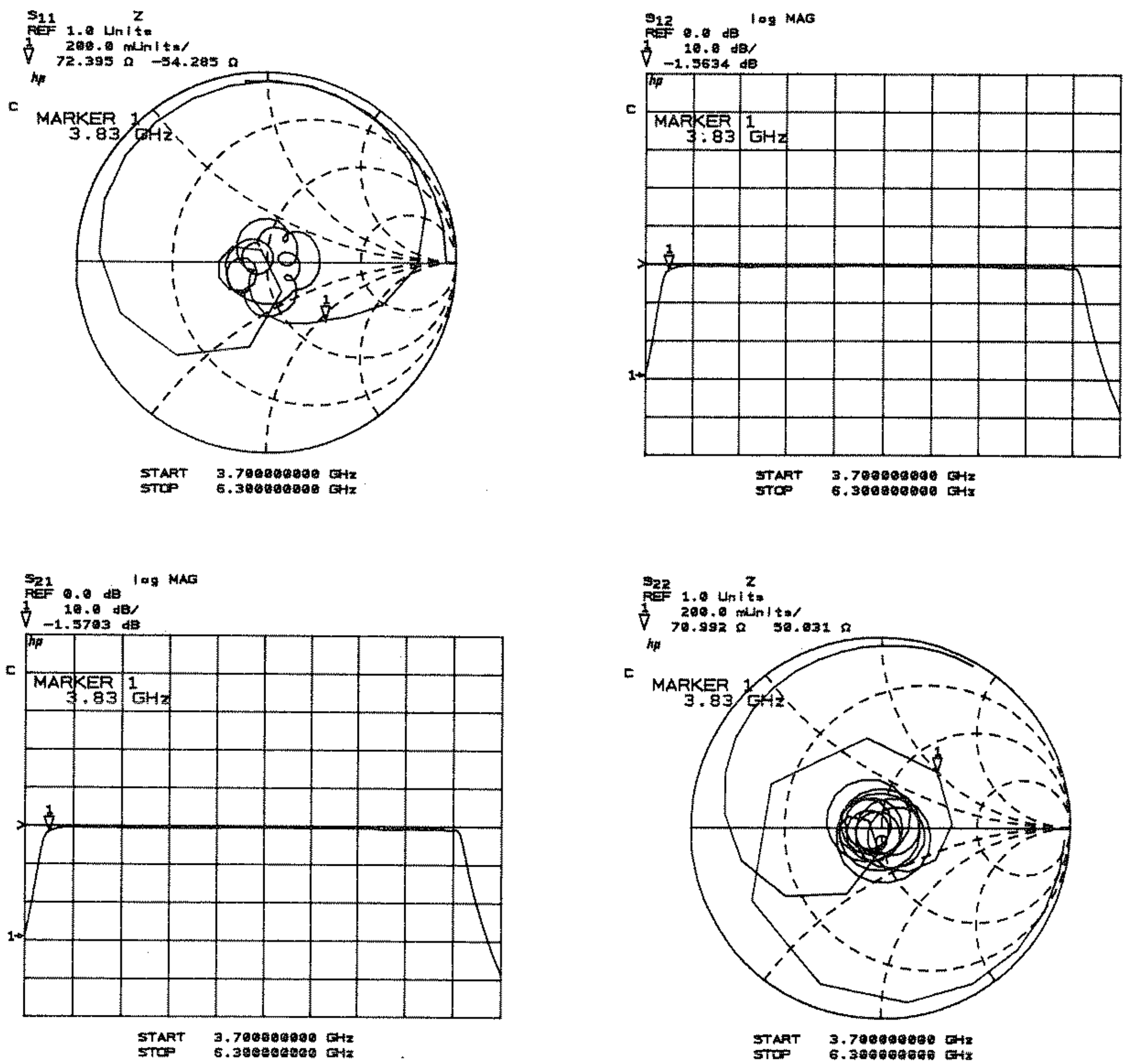


Figure 47. Four Quadrant Plot

The same procedure can be used to plot more than one measurement, for example to produce a single-page plot consisting of four independent plots as in Figure 47.

Before pressing **SELECT QUADRANT** on the Copy Menu, use the front-panel keys to select the measurement to be plotted. Then press **SELECT QUADRANT** and choose the location desired for that measurement by pressing one of the four softkeys on the Plot Quadrant Menu. Finally, press **PLOT: ALL** or, if only a partial plot is desired, one of the softkeys for plotting only part of the display.

Wait for the first plot to be completed. Then, without changing the plotter paper, repeat the process for the other three measurements.

The four quadrant plot in Figure 47 was produced using the following sequence:

- Press **COPY**
- Press S_{11}, **SELECT QUADRANT, LEFT UPPER, PLOT ALL.**
- Press S_{21}, **SELECT QUADRANT, LEFT LOWER, PLOT ALL.**
- Press S_{12}, **SELECT QUADRANT, RIGHT UPPER, PLOT ALL.**
- Press S_{22}, **SELECT QUADRANT, RIGHT LOWER, PLOT ALL.**

Pen and quadrant selections can be saved as part of an instrument state. The Standard Preset State selects a full page plot for both channels, pen 1 for channel 1 and pen 2 for channel 2.

MULTIPLE PEN PLOTTERS

For multiple-pen plotters, each part of the plot can be plotted using a different color by pressing the softkey **SELECT PEN COLOR** on the Copy Menu. This brings the Pen Select Menu (Figure 46) onto the CRT.

Press the softkey corresponding to the pen number you wish used. This will bring the Copy Menu onto the CRT again. Now press the softkey corresponding to the material you wish plotted using the pen number just chosen: **PLOT: ALL, TRACE, GRATICULE, MARKER(S), TEXT**. Wait for the plot to be completed, then repeat the process as often as needed to complete the multi-pen plot. Pen colors for each item can be selected independently for Channel 1 and Channel 2.

For example, the following sequence will cause the entire plot of a single-channel display to be drawn using pen 4; then the trace alone will be plotted again, using pen 5:

- SELECT PEN COLOR, PEN 4, PLOT ALL.
- SELECT PEN COLOR, PEN 5, PLOT TRACE.

PRINTER OUTPUT

Tabular listings of the trace data for the parameter displayed on the currently selected channel can be made by pressing the softkey **LIST TRACE VALUES** on the continuation of the Copy Menu (Figure 46). Figure 48 shows an example of the output.

The number of lines of data printed depends upon the number of points selected for the trace. For example, if 401 points has been selected, 401 lines of data will be printed. The first column is the frequency, followed by two columns of trace values in the basic units selected by the current FORMAT selection. If the marker value consists of a single value, for example LOG MAG or PHASE, the second column is zero.

NO.	FREQUENCY (Hz)	dB	deg.
0	7.3800000000E+09	-9.3339370000E+00,	5.7908930000E+01
1	7.3974250000E+09	-9.9088440000E+00,	5.4139240000E+01
2	7.4148500000E+09	-1.0114810000E+01,	4.7937460000E+01
3	7.4322750000E+09	-1.0655270000E+01,	4.0494220000E+01
4	7.4497000000E+09	-1.1087050000E+01,	3.6256250000E+01
5	7.4671250000E+09	-1.1078590000E+01,	3.0547480000E+01
6	7.4845500000E+09	-1.1792220000E+01,	2.2111350000E+01
7	7.5019750000E+09	-1.2012800000E+01,	1.8951410000E+01
8	7.5194000000E+09	-1.2000030000E+01,	1.1980590000E+01
9	7.5368250000E+09	-1.2588070000E+01,	6.6316220000E+00
10	7.5542500000E+09	-1.2339750000E+01,	2.9649350000E+00
11	7.5716750000E+09	-1.2379260000E+01,	-5.9504700000E+00
12	7.5891000000E+09	-1.2705200000E+01,	-9.6556090000E+00

Figure 48. Typical Printer Output

INSTRUMENT AND SYSTEM PARAMETERS

The Copy Menu also makes it possible to document the HP 8510 system configuration (System Parameters) and instrument state (Operating Parameters). To display the current System Parameters or Operating Parameters, press the corresponding softkey on the continuation of the Copy Menu (Figure 46). Examples of both System Parameters and Operating Parameters lists are shown in the description of the Copy Menu in the Reference Data section of this manual.

Hardcopy listings of System Parameters or Operating Parameters can be obtained by pressing the softkey **PRINT PARAMETERS**, which lists the parameters to a printer, or **PLOT PARAMETERS**, which lists the parameters to a plotter. Current page position and pen number are used for the plot. To restore the measurement display press the softkey **RESTORE DISPLAY** or any front-panel key other than a softkey.

TAPE CARTRIDGE STORAGE AND PREPARATION

The tape cartridge is designed as a convenient personal data storage for instrument setups, raw data, formatted data, memory data, calibration error coefficient sets, and calibration kit definitions. The tape drive uses the standard HP Series 9800 data cartridge (HP part number 98200A). When it is not in use, store the tape cartridge in its protective case in a cool, dry location safe for magnetic media.

To prepare the tape cartridge for use, move its RECORD tab in the direction of the arrow to the RECORD position, then insert the cartridge with the labeled side of the cartridge toward the right of the network analyzer.

For a new (uninitialized) tape, press **TAPE** to bring the Tape Menu (Figure 49) onto the CRT, then press the softkey **INITIALIZE TAPE**, and then press **INITIALIZE TAPE? YES**. The initialization process takes about 1.5 minutes. Pressing any key on the front panel stops the tape operation currently in progress, unless that operation is **INITIALIZE**. This step can be omitted if the tape has already been initialized.