

Errata

Title & Document Type: 8510 Network Analyzer Operating and Service Manual

Manual Part Number: 08510-90001

Revision Date: March 1984

About this Manual

We've added this manual to the Agilent website in an effort to help you support your product. This manual provides the best information we could find. It may be incomplete or contain dated information, and the scan quality may not be ideal. If we find a better copy in the future, we will add it to the Agilent website.

HP References in this Manual

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

Support for Your Product

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www.agilent.com

Search for the model number of this product, and the resulting product page will guide you to any available information. Our service centers may be able to perform calibration if no repair parts are needed, but no other support from Agilent is available.



Agilent Technologies

Table 1-2. Specifications for HP 8510 with HP 8512A Test Set (Cont'd)

Graphics Data of System Dynamic Accuracy Error. Magnitude and phase measurement dynamic accuracy versus signal level is due to the combination of the individual specified factors listed in the previous paragraphs. These measurable factors are combined by vector error analysis using the worst-case method. This combination is shown on the following page in two data graphs, one graph for phase measurement uncertainty and one for magnitude measurement uncertainty.

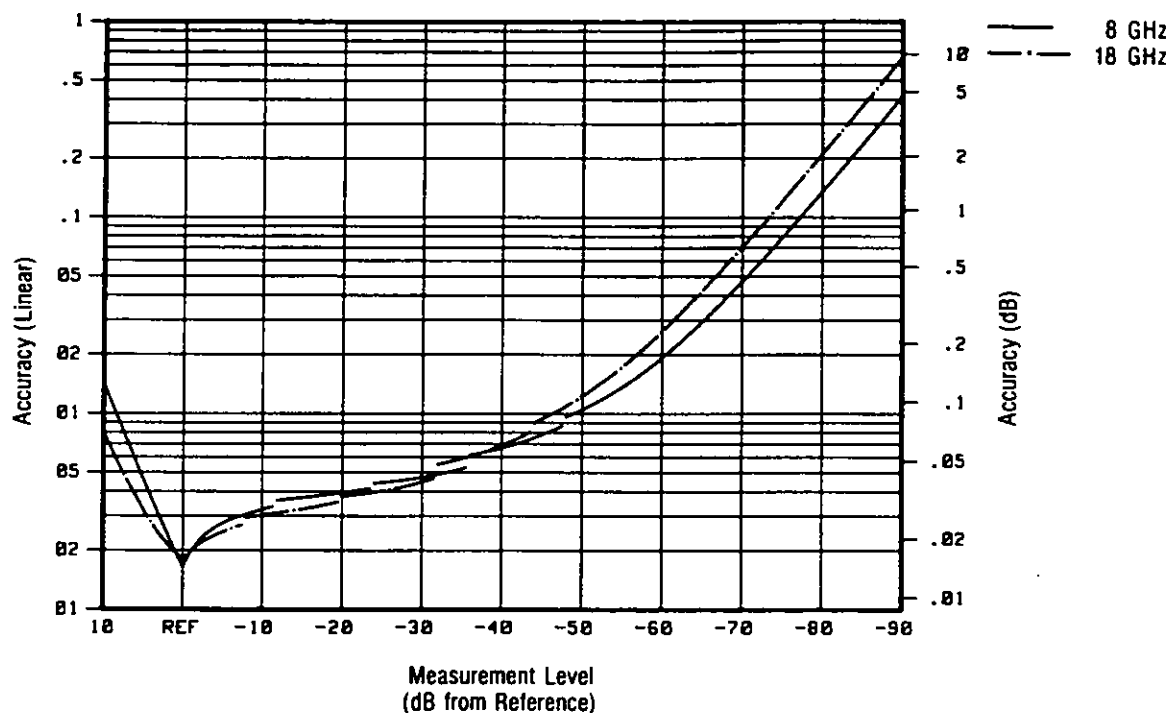
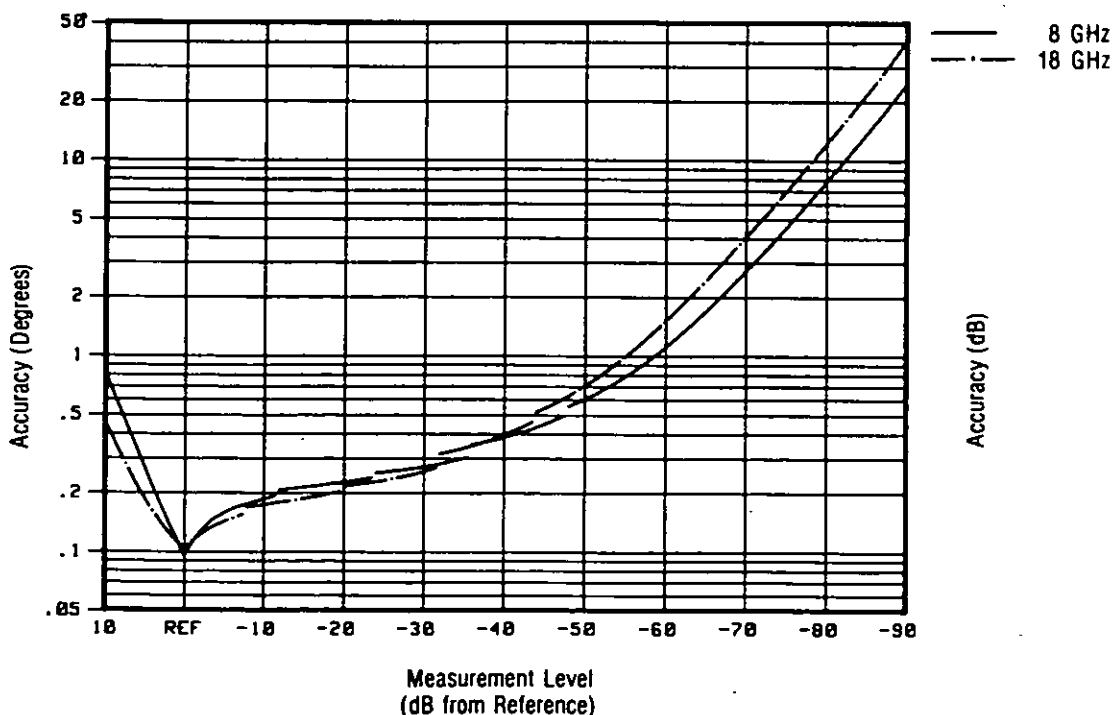
Worst-case Magnitude Dynamic Accuracy Error*Worst-case Phase Dynamic Accuracy Error*

Table 1-2. Specifications for HP 8510 with HP 8512A Test Set (Cont'd)

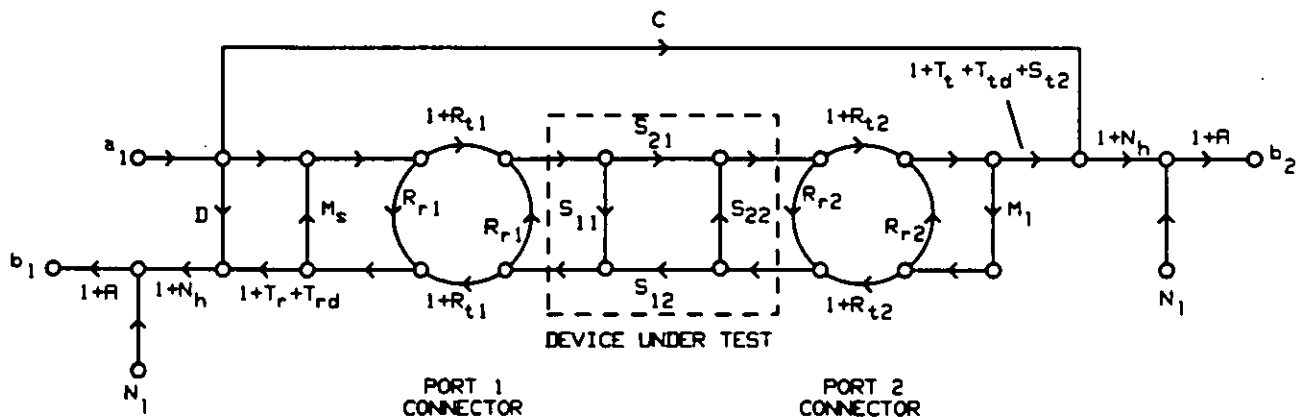
System Flow Graph and Equations

The HP 8510 system error model flow graph and equation are described in the following paragraphs. The flow graph shows the source of errors for the HP 8512A and HP 8510A. The table on page 1-9/1-10 describes each of these error terms and lists the corrected and uncorrected values.

Using the linear error terms in the error-corrected column of the table, and the nominal S-parameter data of the device under test, the following equations calculate the total error-corrected measurement uncertainty with a confidence factor of 99.9%. The procedure for using the equations is as follows:

1. Convert the S-parameters of the device under test to their linear absolute magnitude.
2. Look up the absolute magnitude of the linear error terms from the table on page 1-9.
3. The magnitude dynamic accuracy term "A" must be read from the graph on page 1-13. Be sure to use the linear scale.
4. Combine the above three sets of errors using the equations below.

System Flow Graph



NOTE

The individual terms are as defined in the table on page 1-9.

Table 1-3. Specifications for HP 8510 with HP 8514A Test Set (Cont'd)

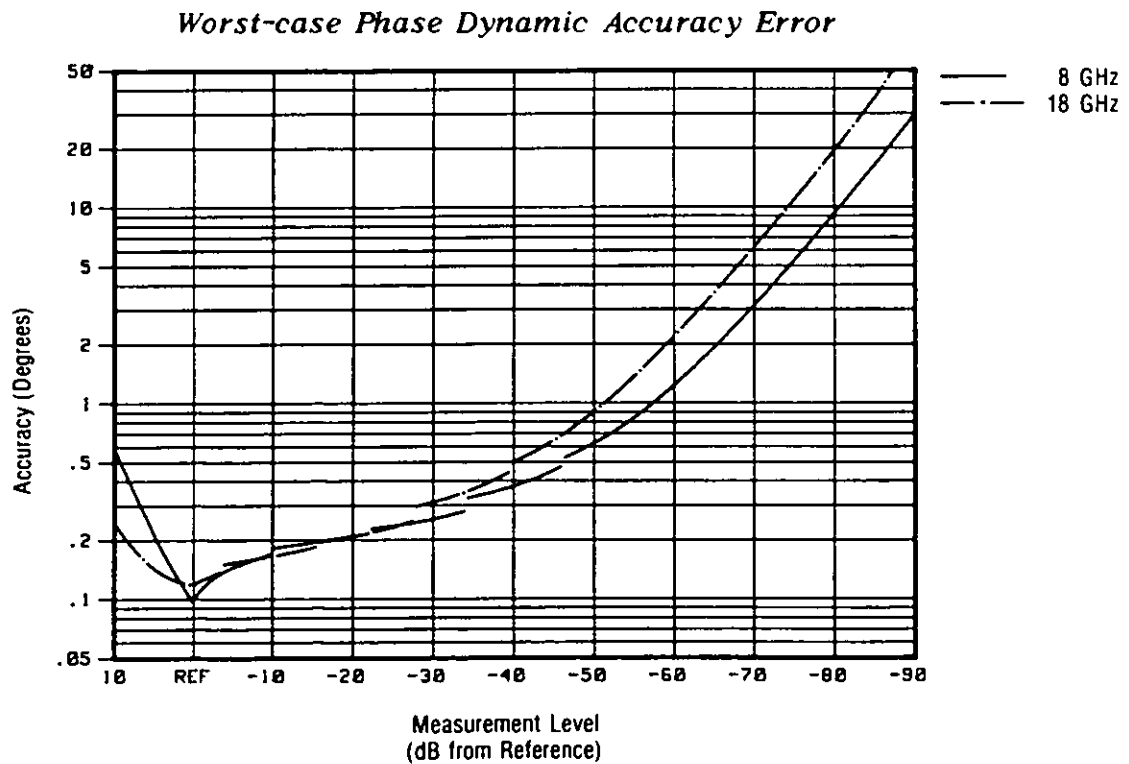
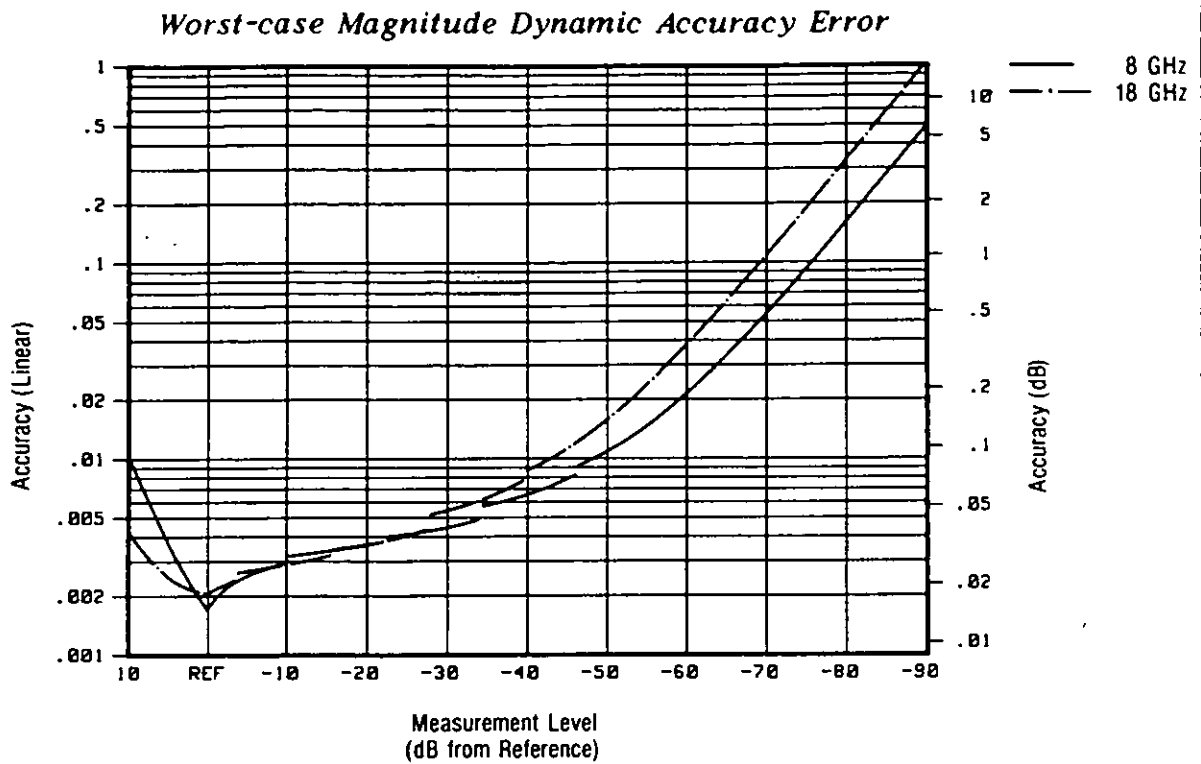


Table 1-2. Specifications for HP 8510 with HP 8514A Test Set (Cont'd)

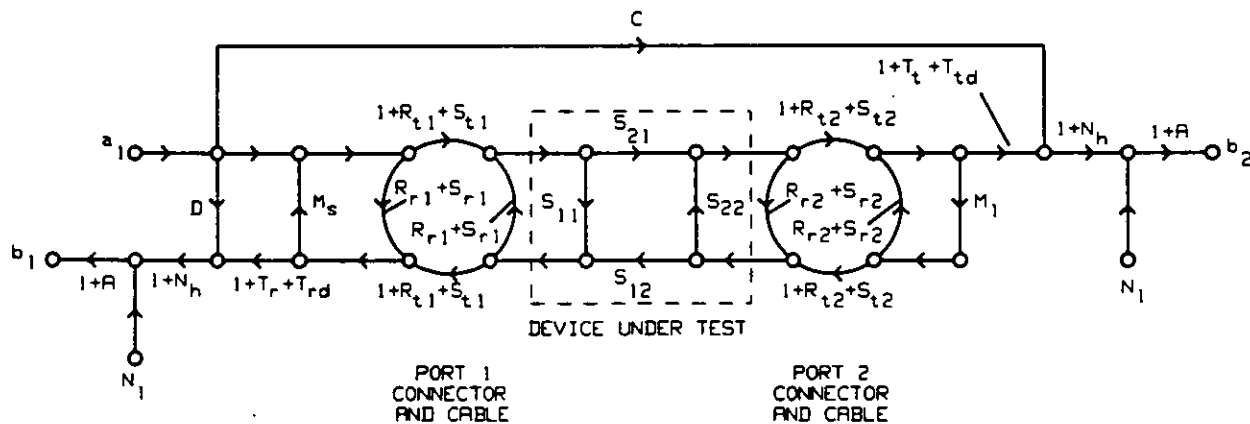
System Flow Graph and Equations

The HP 8510 system error model flow graph and equation are described in the following paragraphs. The flow graph shows the source of errors for the HP 8514A and HP 8510A. The table on page 1-23 describes each of these error terms and lists the corrected and uncorrected values.

Using the linear error terms in the error-corrected column of the table, and the nominal S-parameter data of the device under test, the following equations calculate the total error-corrected measurement uncertainty with a confidence factor of 99.9%. The procedure for using the equations is as follows:

1. Convert the S-parameters of the device under test to their linear absolute magnitude.
2. Look up the absolute magnitude of the linear error terms from the table on page 1-23.
3. The magnitude dynamic accuracy term "A" must be read from the graph on page 1-27. Be sure to use the linear scale.
4. Combine the above three sets of errors using the equations below.

System Flow Graph



NOTE

The individual terms are as defined in the table on page 1-23.

Table 1-6. Accessories Available for the HP 8510 System (Cont'd.)

HP 85131A 3.5mm TEST PORT RETURN CABLE

Used with the HP 8513A reflection/transmission test set.

Frequency Range: dc to 26.5 GHz
 Length: 81.3 cm (32 inches)
 VSWR: ≤ 1.38
 Connectors: 3.5mm NMD female - precision 3.5mm female

HP 85131B 3.5mm TEST PORT RETURN CABLE SET

Used with the HP 8515A S-parameter test set.

Cables Supplied: 2
 Frequency Range: dc to 26.5 GHz
 Length: 53.3 cm (21 inches)
 VSWR: ≤ 1.38 , typical
 Connectors: 3.5mm NMD female - precision 3.5mm male
 3.5mm NMD female - precision 3.5mm female

HP 85131B 7mm TEST PORT RETURN CABLE

Used with the HP 8512A reflection/transmission test set.

Frequency Range: dc to 18.0 GHz
 Length: 81.3 cm (32 inches)
 VSWR: ≤ 1.3
 Connectors: precision 7mm

HP 85132B 7mm TEST PORT RETURN CABLE SET

Used with the HP 8514A S-parameter test set.

Cables Supplied: 2
 Frequency Range: dc to 18.0 GHz
 Length: 53.3 cm (21 inches)
 VSWR: ≤ 1.3
 Connectors: precision 7mm

Table 1-6. Accessories Available for the HP 8510 System (Cont'd.)

HP 8510 A OPTION 010 TIME DOMAIN SOFTWARE PAC

This software pac comprises the system Option 010 and provides time domain measurement capabilities on the HP 8510 system.

HP P/N 85101-10003 HP 85101A SERVICE SOFTWARE

This software is used as an aid in both the electrical adjustments and problem diagnosis in the HP 85101A display/processor.

HP 11591A 7mm SERVICE KIT

This kit contains tools to repair precision 7mm connectors as well as spare collet inserts for the center conductor.

HP 85043A SYSTEM RACK

Size: 124 cm (49 inches) high x 60 cm (24 inches) wide x 80 cm (32 inches) deep. Support rails, ac power distribution (50 to 60 Hz, 100 to 240 Vac), and rack mounting hardware are included. No rack fan is needed.

HP P/N 08510-60001 HP 8510S SYSTEM SERVICE KIT

The HP 8510S Service Kit contains most of the accessories required to adjust and repair the HP Model 8510A network analyzer and its associated test sets (HP Models 8511A, 8512A, 8513A, 8514A, and 8515A).

The kit also contains most of the common fuses that are used in these instruments.

The use of the accessories contained in the kit is described in the adjustment section and the service section of the HP 8510A Operating and Service manual under the individual procedures that use them.

The parts included in this kit are listed on the next page.

Table 1-6. Accessories Available for the HP 8510 System (Cont'd.)

PARTS INCLUDED IN HP 8510S SERVICE KIT HP Part Number 08510-60001		
<u>HP PART NUMBER</u>	<u>QUANTITY</u>	<u>DESCRIPTION</u>
08510-20001	1	CABLE RF I-TEST
08510-20002	1	CABLE RF II-TEST
8510A-1B	1	SERVICE NOTE
08513-60009	1	CA FLEX SCE 26.5
1250-0669	2	ADPT M SMB M SMB
1250-0780	1	CONN ADPT STR
1250-1236	1	ADPT F BNC F SMB
1250-1391	1	ADPT TEE MFM SMB
2110-0001	10	FUSE 1A 250V F
2110-0002	5	FUSE 2A 250V F
2110-0012	5	FUSE .5A 250V F
2110-0043	5	FUSE 1.5A 250V F
2110-0047	5	FUSE 1A 125V N
2110-0063	6	FUSE .75A 250V F
2110-0083	10	FUSE 2.5A 250V F
2110-0218	5	FUSE .1A 125V N
2110-0301	5	FUSE .12A 125V N
2110-0304	5	FUSE 1.5A 250V S
2110-0342	5	FUSE 8A 250V N
2110-0425	5	FUSE 2A 125V N
5061-1022	5	CABLE ASSY
5086-7408	1	POWER SPLITTER
8493C #010	1	APC 3.5 10 DB PAD
85050-20001	4	CONTACT CTR COND
85101-60019	1	X BD AY-LINE GEN
85101-60020	1	X BD AY-SWG REG
85101-60021	1	X BD AY-POST REG
85101-60035	1	BD ASSY-DSPL ADJ
85101-60041	1	X BD AY-XYZ AMP
85102-60030	1	BD AY-SVCE EXTDR
85680-60093	2	CBL AY BNC-SNAP
8710-0055	1	4 SPLINE KEY .048
8710-0630	1	ALIGN TL.08 SCDR
85101-60213	1	SERVICE KIT
consisting of:		
8510A-3A	1	SERVICE NOTE
85101-60209	1	85102 TEST EMULATOR

ADD PAGE - ALL SERIALS

Added 2 December 1985

FOLLOWS PAGE 1-52

Table 1-10. Specifications for HP 8510 with HP 8511A Test Set (Cont'd)

INTRODUCTION AND GENERAL CHARACTERISTICS

The combination of the HP 8511A test set with an HP 8510A network analyzer and an HP 8340A sweeper forms a four channel receiver/signal processor that operates over the frequency range of 45 MHz to 26.5 GHz.

Specification Assumptions

The specifications of this table assume that the following conditions are met:

- The RF source is an HP 8340A synthesized sweeper operating in stepped sweep mode.
- The temperature is in the range of 0° C to 55° C.
- RF source power levels at the input ports are as follows:

Test	Power at Input Port	
	45 MHz-18 GHz	18 GHz-26.5 GHz
Compression	-10 dBm	-15 dBm
Crosstalk	-10 dBm	-15 dBm
Conversion Gain	-15 dBm	-20 dBm
Tracking	-15 dBm	-20 dBm
High Level Noise	-15 dBm	-20 dBm

Frequency Range

45 MHz to 26.5 GHz

Input Ports

Connector Type: Precision 3.5 mm Female

Impedance: 50 ohms nominal

Damage Input Level: > +13 dBm

Minimum Port Input Power (for Phase Lock):

0.045 - 8 GHz > -40 dBm

8 - 18 GHz > -38 dBm

18 - 26.5 GHz > -35 dBm

Maximum Port Input Power (for Phase Lock):

0.45 - 26.5 GHz -5 dBm

Table 1-10. Specifications for HP 8510 with HP 8511A Test Set (Cont'd)

HARDWARE AND SYSTEM PERFORMANCE SPECIFICATIONS**Table of System Errors**

The following table lists the specifications for the various sources of system error. The values listed are the verification limits for uncorrected measurements.

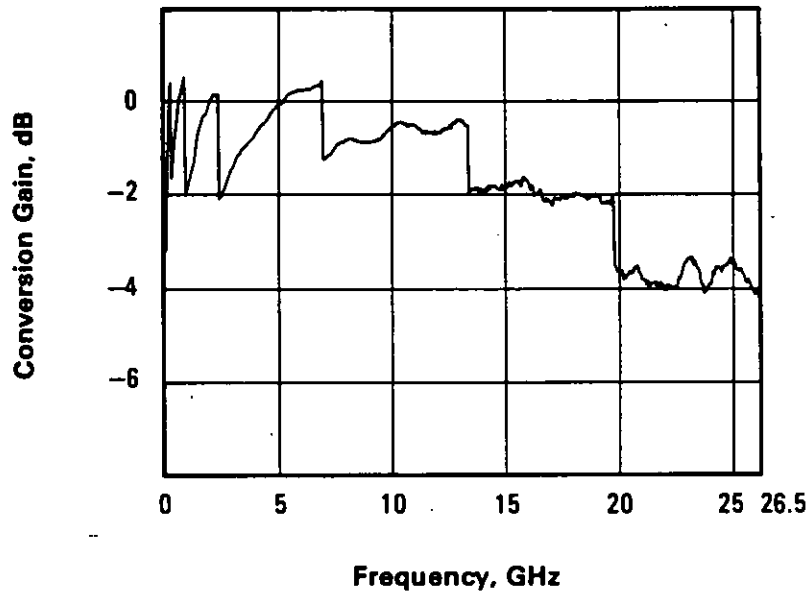
Source of System Errors

Error Source	Verification Limit		
	.045-8GHz	8-18GHz	18-26.5GHz
Conversion Gain ¹	+2 dB to -12 dB		
Tracking	± 0.08 dB/GHz $\pm .5$ dB ± 5 deg		
Magnitude Slope			
Magnitude Ripple ²			
Phase Ripple ²			
Crosstalk ³	≤ -80 dB	≤ -80 dB	≤ -80 dB
Low-Level Noise (Noise Floor) ⁴	≤ -95 dBm	≤ -90 dBm	≤ -85 dBm
High-Level Noise (Trace Noise)			
Ratio - Magnitude	.012 dB rms	.020 dB rms	.040 dB rms
Ratio - Phase	.100 deg rms	.150 deg rms	.250 deg rms
Compression (.1 dB point)	≥ -10 dBm	≥ -10 dBm	≥ -15 dBm
Input Port Return Loss ⁵	≥ 17 dB	≥ 15 dB	≥ 9 dB
Tracking Drift (Typical)	Magnitude $.001 \times \Delta^{\circ} \text{C}$, Linear Phase $(0.1 + .01 \times f(\text{GHz}) \times \Delta^{\circ} \text{C})$, Degrees		

Table 1-10. Specifications for HP 8510 with HP 8511A Test Set (Cont'd)

Footnotes for Table of System Errors

- 1 Typical Conversion Gain Curve:



- 2 Ripple is the deviation from a least-squares-line fit.
- 3 Averaging factor of 1024 is applied.
- 4 Low-Level Noise (Noise Floor) is measured with a 50 Ω load connected to the port.
- 5 Input Port Return Loss is tested with the sampler in a non-conducting state. When the diodes are turned on by the LO pulse, they present a short circuit across the sampler input port. This may affect the measured data.

(REPLACEMENT PAGE - ALL SERIALS)

Revised 31 March 1986

*Table 1-10. Specifications for HP 8510 with HP 8511A Test Set (Cont'd)***Source of System Dynamic Accuracy Errors**

The factors affecting dynamic accuracy listed below are primarily a function of the IF/detector except for the compression. In order to measure these values, some of the system cables must be disconnected to gain access to the individual instruments.

Compression (0.1 dB point):^{6, 8} ≥ -10 dBm up to 18 GHz; ≥ -15 dBm 18-26.5GHz

IF Amplifier Gain Accuracy:

IF Amplifier Power Range (dBm) ⁹	Maximum Gain Error (dB)
-10 to -22	0
-22 to -34	$\pm .005$
-34 to -46	$\pm .01$
-46 to -58	$\pm .02$
< -58	$\pm .03$

Detector Circularity Error: $\pm .003$ dB peak

Detector dc Offset Error: -100 dBm⁹

IF Residuals: -120 dBm⁹

IF Linearity: $\pm .003$ dB

Incremental Phase Accuracy (Phase vs. Phase) at Measurement Reference: ± 0.001 degrees/degree, not to exceed 0.02 degrees peak.

⁸ See Section III, Operation, in this Operating and Service manual for considerations in achieving maximum dynamic range.

⁹ These dBm power level numbers are at the IF input to the HP 8510A, not at the test set test ports.

APPLICATIONS SOFTWARE

Two software application pacs are available to automate the HP 8510 network analyzer system using an external HP controller.

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 I. 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.

VOLUME 1

- I General Information
- II Installation
- III Operating and Programming

VOLUME 2

- IV Performance Tests
- V Adjustments

VOLUME 3

Accessories

VOLUME 4

- VI Replaceable Parts
- VII Backdating
- VIII Service

VOLUME 5

- VIII Service (continued)

Operating and Programming (duplicate)

Keyword Dictionary

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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.

Also shipped with each system is the HP 8510 Operating and Programming Quick Reference. This pocket-sized list of all HP 8510 programming mnemonics is packed in the system accessories box, and copies are also available separately, as HP Part Number 08510-90012. The HP 8510 Keyword Dictionary gives complete programming information for HP 8510 systems. One copy is included in each complete manual set, and extra copies are available separately as HP Part Number 08510-90007.

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.

Copies of the following manuals related to the HP 8510 network analyzer system are also available separately:

<u>MANUAL</u>	<u>DESCRIPTION</u>	<u>HP PART NUMBER</u>
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
85043A	System Rack	85043-90001

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<u>MANUAL</u>	<u>DESCRIPTION</u>	<u>HP PART NUMBER</u>
85050A	7mm Calibration Kit	85050-90001
85051A	7mm Verification Kit	85051-90001
85052A	3.5mm Calibration Kit	85052-90001
85053A	3.5mm Verification Kit	85053-90001
85054A	Type-N Cal Kit	85054-90001
85130A	3.5mm-to-7mm Adapter Kit	85130-90001
85131A	3.5mm Test Port Return Cables	85131-90001
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.

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IMPORTANT NOTE

IF THE SYSTEM SOURCE IS AN HP 8341. . .

SEMI-AUTOMATED PROCEDURES

To verify the HP 8510/8513A/8341 system using the semi-automated procedures, revision 2.00 of the HP 8510/8513A software is required (HP P/N 08510-10003). You will also need HP Service Note 8510A-6, which shows how to modify the software program to accommodate the HP 8341 source.

MANUAL METHOD 2 PROCEDURE

The HP 8510/8513A manual method 2 performance test procedure CANNOT be used if the source is an HP 8341. The HP 8341 frequency range does not allow the data acquisition points to coincide with the data points on the 3.5mm verification data cartridge.

To verify the HP 8510/8513A/8341 system, you must instead do the HP 8510/8512A performance test procedure. This verifies the system in 7mm and requires using an HP 8492A 10 dB attenuator as the system attenuator, HP 85130A special 3.5mm (F)-to-7mm adapters on the HP 8513A test ports, and 7mm cables and calibration and verification standards.

IMPORTANT NOTE

IF THE SYSTEM SOURCE IS AN HP 8341. . .

SEMI-AUTOMATED PROCEDURES

To verify the HP 8510/8515A/8341 system using the semi-automated procedures, revision 2.00 of the HP 8510/8515A software is required (HP P/N 08510-10005). You will also need HP Service Note 8510A-6, which shows how to modify the software program to accommodate the HP 8341 source.

MANUAL METHOD 2 PROCEDURE

The HP 8510/8515A manual method 2 performance test procedure CANNOT be used if the source is an HP 8341. The HP 8341 frequency range does not allow the data acquisition points to coincide with the data points on the 3.5mm verification data cartridge.

To verify the HP 8510/8515A/8341 system, you must instead do the HP 8510/8514A performance test procedure. This verifies the system in 7mm and requires using the HP 85130A special 3.5mm (F)-to-7mm adapters on the HP 8513A test ports and 7mm cables and calibration and verification standards.

HP 8510/8511A PERFORMANCE VERIFICATION

Performance verification procedures for the HP 8510/8511A system are provided as part of the system manual only if an HP 8511A frequency converter has been ordered. If so, the pages containing these procedures are shipped in a separate packet with the HP 8511A frequency converter, not with the system manual. They should be placed into the manual to occupy pages 4-153 through 4-172. Both the original page 4-153/4-154 and this replacement page should then be discarded.

If these procedures are not supplied, put this replacement page into the system manual to replace the original page numbered 4-153/4-154. That original page states (incorrectly) that these procedures "are not available at this time." They are available, as HP Part Number 08510-90065.

Regardless of system configuration, put replacement page 4-155 (31 March 1986) into the manual next. It states that pages 4-173 through 4-250 are not assigned and that pages 4-153 through 4-172 are supplied only with HP 8511A frequency converters although they are available separately. This is now the case.

PAGES 4-153 THROUGH 4-172
CONTAIN HP 8510/8511A PERFORMANCE TESTS
AND ARE SUPPLIED AS PART OF THE SYSTEM MANUAL
WITH HP 8511A FREQUENCY CONVERTERS ONLY

IF DESIRED SEPARATELY,
THESE HP 8510/8511A PAGES ARE AVAILABLE AS
HP PART NUMBER 08510-90065

PAGES 4-173 THROUGH 4-250,
REGARDLESS OF SYSTEM CONFIGURATION,
ARE NOT ASSIGNED

HP 8510/8511A PERFORMANCE VERIFICATION

Performance verification procedures for the HP 8510/8511A system are shipped with HP 8511A frequency converters only. When placed into the HP 8510 system manual, the procedures occupy pages 4-153 through 4-172 and pages 4-173 through 4-250 are not assigned.

These HP 8510/8511A performance verification procedures are also available separately, as HP Part Number 08510-90065.

HP 85102A ADJUSTMENTS

The following procedures for the HP 85102A IF detector adjustments are semi-automated. Each adjustment procedure requires an HP 200 or HP 300 series controller, associated HP-IB cables, and the HP 8510 SERVICE ADJUSTMENTS SOFTWARE (HP Part Number 08510-10001).

Connect the controller to the HP 8510A bus, labeled "HP-IB" on the HP 85101A rear panel. The correct address setting for each instrument on the HP-IB bus is indicated in each adjustment procedure. Additional instruments and equipment required for each adjustment are also listed.

The system source (HP 8340A/41A or HP 8350B) must be connected to the system bus to perform these HP 85102A adjustments. A test set is not required. If a test set is not connected, however, these two cautions will be displayed on the HP 8510 CRT--both of which may safely be ignored: "CAUTION: SYSTEM BUS ADDRESS ERROR" and "CAUTION: VTO FAILURE".

The HP 85102A IF detector adjustments described here are independent of one another. Only the adjustment procedure for whatever module has been repaired or replaced needs to be performed.

If the system appears to be "locked up" at any time while performing any of these adjustments, press [PAUSE], then [CLR I/O], then [RUN].

NOTE - THIS PAGE FOLLOWS
THE WHITE TAB LABELED
HP 85102A Adjustments

LOADING THE CONTROLLER BASIC LANGUAGE SYSTEM

Before loading the HP 85102A adjustment software you must first load one of the controller language systems as follows:

LOADING BASIC 2.0

- a. With the controller OFF, insert the HP 98611A BASIC 2.0 System Disc into either the right or left disc drive. Then turn the controller ON.
- b. When it has finished loading, remove the disc and insert the HP 98612A Extended BASIC 2.1 Disc into the same disc drive.
- c. Type LOAD BIN "AP2_1", then press [RETURN] or [EXECUTE] or [EXEC].

LOADING BASIC 3.0 or 4.0

- a. With the controller OFF, insert the HP 98613A BASIC 3.0 or 4.0 System Disc into either the right or left disc drive. Then turn the controller ON.
- b. Load the Drivers and Extensions files (listed below) after the Basic 3.0 or 4.0 System disc has been loaded. To load the Drivers, first insert the Basic 3.0 or 4.0 Drivers Disc into the same disc drive used to load the BASIC System. Or load the Language Extensions and Drivers Disc if you have the double-sided micro-discs.
- c. Type LOAD BIN "Filename" for each Driver filename (and each Extension filename, if you have the double-sided disc), then press [RETURN] or [EXECUTE] or [EXEC]. If you have the double-sided disc, you are done when all the drivers and extensions listed below are loaded. If you do not have a double-sided disc, go to the next step.
- d. When all Driver files have been loaded, remove the disc.
- e. To load the Extensions, insert the Basic 3.0 or 4.0 Language Extensions Disc into the same disc drive.
- f. Type LOAD BIN "Filename" for each Extension filename, then press [RETURN] or [EXECUTE] or [EXEC].

- g. When all Extension files have been loaded, remove the disc.

<u>Drivers</u>	<u>Extensions</u>
----------------	-------------------

DISC	MATT
HPIB	IO

If you have any of the following system configurations, the following Driver and/or Extension files must also be loaded:

<u>Configuration</u>	<u>Driver File</u>	<u>Extension File</u>
SRM	DCOMM	SRM
HP 9885 Disc Drive	HP9885	
CS80 Disc Drive	CS80	
HP 9122 Disc Drive	CS80	

5-23. SWEEP ADC GAIN ADJUSTMENT (HP 85102A)

Reference:

A20 Sweep ADC

Description:

The SWEEP ADC assembly generates a staircase waveform, that tracks the sweep voltage from the source (VSWP). The following procedure adjusts the SWEEP ADC gain to compensate for component tolerance in the staircase generation circuit.

Equipment:

12" Snap-On Cable Assy (P/O Service Kit).....HP P/N 5061-1022
F-M-M Snap-On Tee (P/O Service Kit)..... HP P/N 1250-1391
HP 8510 SERVICE ADJUSTMENTS SOFTWARE.....HP P/N 08510-10001

Procedure:

1. Insert the disc containing the HP 8510 SERVICE ADJUSTMENTS SOFTWARE into controller as per instructions in the HP 200 series manual.
2. Type LOAD "ADJ_85102". Press [EXECUTE].
3. When the program is loaded, press [RUN].
4. A menu will be displayed on the controller CRT.
5. Press softkey [k5] to select SWEEP ADC Adjustment.
6. Turn the HP 8510A OFF. Configure equipment as shown on the controller display.
7. Turn all instruments ON. Turn the HP 8510A ON last to avoid system "lock up".
8. When a graticule appears on the HP 85101A CRT, the instrument has finished initializing. Press "CONTINUE" softkey on the controller.
9. The prompt will be displayed:

ADJUST GAIN (R26) FOR 300 +/- .3 mUnits.
10. Adjust A20R26 so that the mUnit displayed on the HP 85101A CRT reads 300 +/- .3 (see Figure 5-29). Refer to Figure 5-28 for location of A20R26.

MANUAL CHANGES

**HP 85101A
Display/Processor
Service**

MANUAL IDENTIFICATION

Model Number: HP 8510A
Date Printed: March 1984
Part Number: 08510-90001

HP 85101A DISPLAY/PROCESSOR SERVICE

This Manual Changes supplement will bring you up to date on all new information, changes, and corrections that apply to the service information on the HP 85101A display/processor provided in sections VI, VII, and VIII of the HP 8510 network analyzer system manual. These sections comprise volumes 3 and 4 of the system manual set. When this supplement has been added, the service information in the manual on the HP 85101A display/processor will apply to all HP 85101A instruments that have the serial number prefix given below or any lower serial number prefix.

Other supplements update the system information provided in volumes 1 and 2 of the system manual set, the separate HP 8510 Operating and Programming Manual, the HP 8510 Keyword Dictionary, and the manuals for HP 8510 system accessories such as calibration and verification kits.

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28 APRIL 1986
HP 85101A DISPLAY/PROCESSOR
SERIAL NUMBER PREFIXES 2620A
AND LOWER



HP 8510A SOFTWARE

<u>DESCRIPTION</u>	<u>HP PART NUMBER</u>
Operating System Firmware	85101-10001
Operating System Firmware with Time Domain Option 010	85101-10002
NOTE - Please give the serial number of the HP 85101A display/processor when ordering operating system firmware.	
Service Software	85101-10003
Circuit Modeling Program: BOOT Revision A.02.01 and	85101-60040
Circuit Modeling Program: PROG Revision A.02.01	
NOTE - These discs are available only as a set.	
Cal Kit Cal Constants	08510-10007
7mm Verification Kit Data	None
3.5mm Verification Kit Data	None
Adjustments	08510-10001
Performance Tests: HP 8512A	08510-10002
Performance Tests: HP 8513A	08510-10003
Performance Tests: HP 8514A	08510-10004
Performance Tests: HP 8515A	08510-10005
Performance Tests: HP 8511A	08510-10006
85013A Basic Measurements Application Pac - Option 630 (3.5 in)	85013A, Option 630
85013A Basic Measurements Application Pac - Option 655 (5.25 in)	85013A, Option 655
85014A Active Device Measurement Application Pac - Option 630 (3.5 in)	85014A, Option 630
85014A Active Device Measurement Application Pac - Option 655 (5.25 in)	85014A, Option 655

Replaceable Parts 6-8A/6-8B

HP 85101A DISPLAY/PROCESSOR **CHANGES TO REPLACEABLE PARTS TABLE 6-3**

If you need to replace a part in the HP 85101A display/processor, check this list first. If the part is not listed, use the original parts list. If the part is listed, and if, in the **Serial Prefix(es)** column, it is designated for use in ALL instruments, use the **New HP Part Number** given below. Do not use the original part number in the HP 8510 parts list (*Table 6-3. Replaceable Parts*).

Some parts are used only in certain instruments—beginning with a certain serial number prefix. If the part to be replaced is listed below, and if, in the **Serial Prefix(es)** column, a serial number prefix is given, check the serial number prefix on the instrument being repaired.

If the serial number prefix is the same as or higher than the serial number prefix listed below, use the **New HP Part Number**. If it is lower, use the original HP part number given below and in the HP 8510 parts list (*Table 6-3. Replaceable Parts*).

Reference Designation	Original HP Part Number	Replace with New HP Part Number	New Description	Serial Prefix(es)
A3C8	0160-0543	0160-6420	C MPE 4700P 4000V	ALL
A3C10	0160-0543	0160-6420	C MPE 4700P 4000V	ALL
A3C11	0160-0543	0160-6420	C MPE 4700P 4000V	ALL
A3C13	0160-0543	0160-6420	C MPE 4700P 4000V	ALL
A3T1	01332-61106	85101-60215	TRANSFORMER ASSEMBLY - HV	ALL
THIS ASSEMBLY INCLUDES A3C2, A3C9, A3CR1, and A3MP9.				
A7R33	0698-7267	0698-7266	RESISTOR 17.8 K Ω $\pm$ 1% .05W	ALL
A7U6	1990-0715	1990-1128	OPTO-ISOLATOR LED- PXSTR IF-40MA-MAX	ALL

HP 85101A Display/Processor

Reference Designation	Original HP Part Number	Replace with New HP Part Number	New Description	Serial Prefix(es)
A7U7	1990-0715	1990-1128	OPTO-ISOLATOR LED-PXSTR IF-40MA-MAX	ALL
A9	5180-2636	9100-4392	ASSY. SWITCHING TRANSFORMER	ALL
A11U77	85101-80004	85101-80042	IC UV EPROM 8KX8	ALL
A11U78	85101-80005	85101-80043	IC UV EPROM 8KX8	ALL
A13	85101-60013	85101-60214	BOARD ASSEMBLY, MAGNETIC BUBBLE MEMORY	ALL
A13	85101-60013	85101-60214	BOARD ASSEMBLY,	ALL
A15C23	0180-0291	0180-0374	CAPACITOR-FIXED 1 μ F $\pm$ 10%	ALL
A15C26	0180-0141	0180-2614	CAPACITOR-FIXED 100 μ F $\pm$ 10%	ALL
A15C27	0180-0141	0180-2614	CAPACITOR-FIXED 100 μ F $\pm$ 10%	ALL
A15L1	9140-0131	NONE	NO LONGER REQUIRED	ALL
A15R36	0698-3160	SAME or 0757-0123 or 0698-3161	RESISTOR 34.8K (factory select) 38.3K (factory select)	ALL
A15R59	0757-0280	0698-8827	RESISTOR 1M Ω $\pm$ 1% .125W	ALL
A15R60	0757-0288	0757-0200	RESISTOR 5.62K Ω $\pm$ 1% .125W	ALL

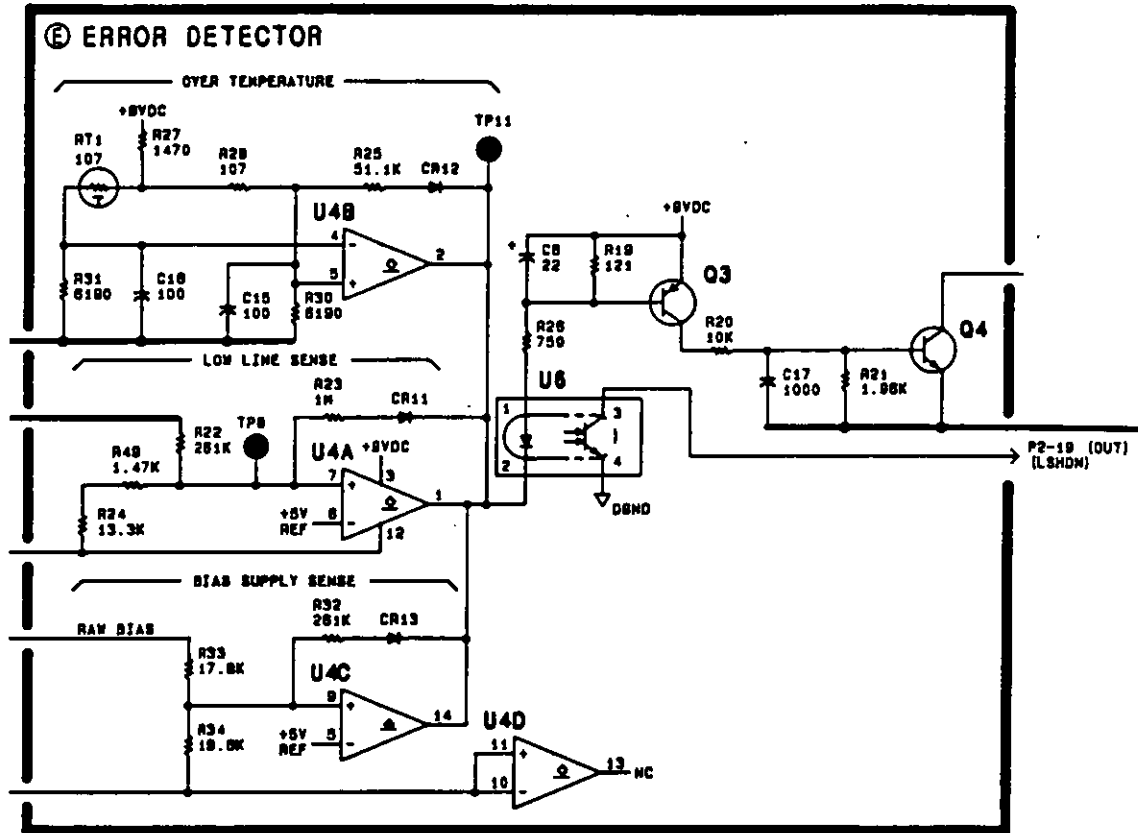
HP 85101A Display/Processor

Reference Designation	Original HP Part Number	Replace with New HP Part Number	New Description	Serial Prefix(es)
A15U10	1826-1058	1826-1349	IC 02C C10PAMP	ALL
A15U15	1820-2483	1850-3513	IC 75161 P8XCVR	ALL
A15U17	1820-1216	1820-1240	IC 74LS138 DCDR TTL	ALL
A15U26	1820-2485	1820-3431	IC 75160 P8XCVR	ALL
A15U35	1820-2802	1820-3093	IC PROGRAMMABLE TIMER	ALL
A15U39	1820-2483	1850-3513	IC 75161 P8XCVR	ALL
A15U40	1820-2485	1820-3431	IC 75160 P8XCVR	ALL
A17K1	0490-1433	0490-1433	RELAY	ALL
NO CHANGE - PART NUMBER MISSING FROM SOME VERSIONS OF <i>Table 6-3. Replaceable Parts.</i>				

HP 8510 - Service
HP 85101A Display/Processor
ALL SERIALS

DESCRIPTION OF CHANGE

To improve the operation of the bias supply sense portion of the error detector circuit, the value of resistor R33 has been reduced to 17.8 K Ω .

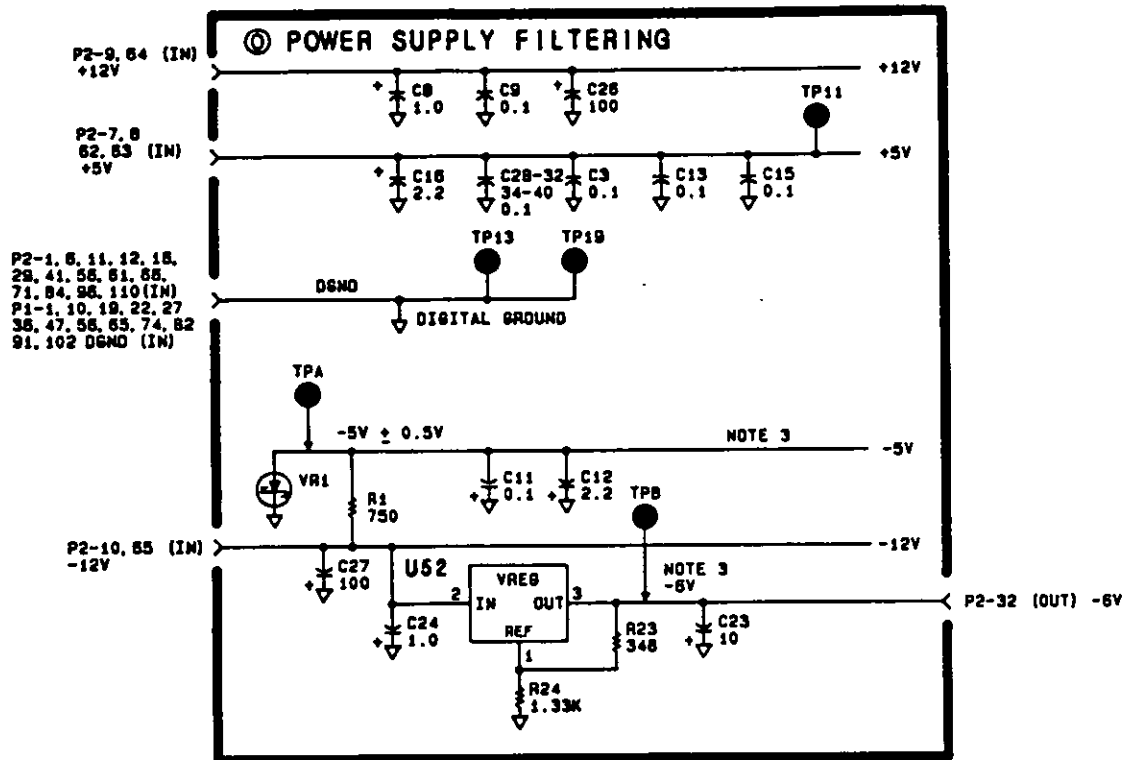


Part of Figure 8-22. A7 Switching Regulator Schematic Diagram

HP 8510 - Service
HP 85101A Display/Processor
ALL SERIALS

DESCRIPTION OF CHANGE

To improve the operation of the power supply filtering circuit during changes in the tape drive motor speed, the values of three capacitors have been changed. Capacitor C23 has been changed from 1 μ F to 10 μ F. Capacitors C26 and C27 have both been changed from 50 μ F to 100 μ F. These changes reduce the possibility of intermittent tape drive despooling due to loss of control.

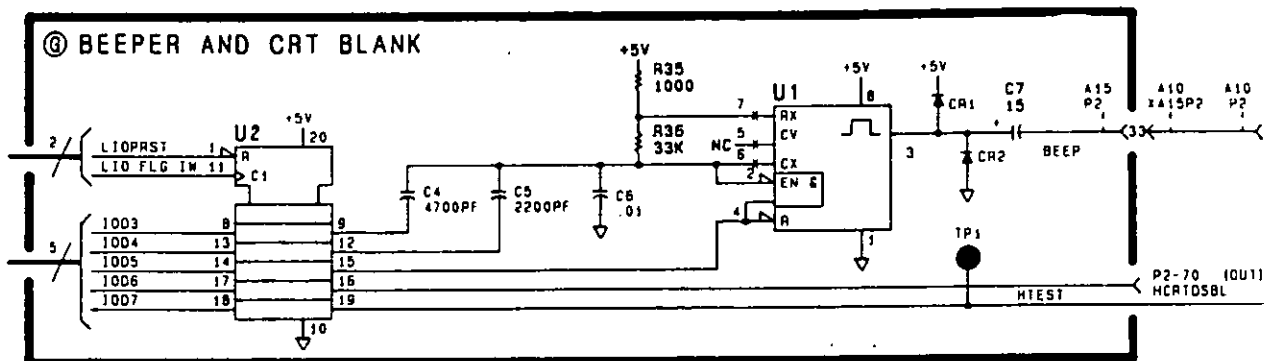


Part of Figure 8-33. A15 I/O Board Schematic Diagram (1 of 3)
Block O. POWER SUPPLY FILTERING

HP 8510 - Service
HP 85101A Display/Processor
ALL SERIALS

DESCRIPTION OF CHANGE

The inductor (A15L1) added to the A15 board to eliminate very high frequencies is no longer used or required.

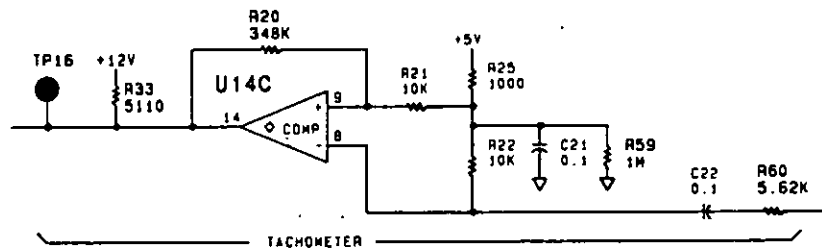


Part of Figure 8-33. A15 I/O Board Schematic Diagram (2 of 3)
Block G. BEEPER AND CRT BLANK

HP 8510 - Service
HP 85101A Display/Processor
ALL SERIALS

DESCRIPTION OF CHANGE

To improve the operation of the tape drive tachometer, the values of two resistors have been changed. These resistors were not numbered originally. They are now numbered R59 (1M Ω) and R60 (5.62k Ω).



Part of Figure 8-33. A15 I/O Board Schematic Diagram (3 of 3)
Block L. TAPE CONTROLLER AND INTERFACE

MANUAL CHANGES

HP 8512A
Reflection/Transmission Test Set

MANUAL IDENTIFICATION

Model Number: HP 8510A
Date Printed: March 1984
Part Number: 08510-90001

HP 8512A REFLECTION/TRANSMISSION TEST SET SERVICE

This Manual Changes supplement will bring you up to date on all new information, changes, and corrections that apply to the service information on the HP 8512A reflection/transmission test set provided in sections VI, VII, and VIII of the HP 8510 network analyzer system manual. These sections comprise volumes 3 and 4 of the system manual set. When this supplement has been added, the service information in the manual on the HP 8512A reflection/transmission test set will apply to all HP 8512A reflection/transmission test sets that have the serial number prefix given below or any lower serial number prefix.

Other supplements update the system information provided in volumes 1 and 2 of the system manual set, the service information on the HP 85101A display/processor, the HP 85102A IF detector, and other HP 851x-series test sets, the separate HP 8510 Operating and Programming Manual, the HP 8510 Keyword Dictionary, and the manuals for HP 8510 system accessories such as calibration and verification kits.

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30 JULY 1986
SERIAL NUMBER PREFIXES 2552A
AND LOWER



**HEWLETT
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HP 8512A REFLECTION/TRANSMISSION TEST SET CHANGES TO REPLACEABLE PARTS TABLE 6-3

If you need to replace a part in the HP 8512A reflection/transmission test set, check this list first. If the part is listed here, use the part and part number given here instead of those in the original HP 8510 parts list, Table 6-3, Replaceable Parts. If the part is not listed, use the original parts list.

Some parts are used only in certain instruments, beginning with the serial number prefix listed here. These parts are used in all instruments with the serial number prefix listed and instruments with all higher serial number prefixes. Parts used in all instruments regardless of serial number prefix are listed here as "All Serials" parts.

Ref. Desig.	Original HP Part Number	Replace with New HP Part Number	New Description	Serial Prefix(es)
A4	08513-60002	08513-67002	BOARD ASSEMBLY, HP-1B	All Serials
A4U12	1820-2485	1820-3431	IC RCVR 75160 TTL	All Serials
A4U13	1820-2483	1820-3513	IC RCVR 75161 TTL	All Serials
B1	3160-0273	08513-20031	FAN-TBAX 34 CFM 115V 50/60-HZ 1.5KV-DIEL	All Serials
5	2360-0123	0515-0915	SCREW-MACH SMM 4.0 6 PNPD	All Serials
57	08512-00001 or 08512-00002	08512-00014	FRONT PANEL	2552A →
65	08514-00002	08514-00010	SUB PANEL	2552A →

72	NONE	0510-1148	RETAINER-PO 0.140 ID	All Serials
60 - 62	NONE	08512-60012	DRESS PANEL REPLACEMENT KIT	See Note 1

Note 1 - Replacement of either the front panel (08512-00001 or 08512-00002) or the interior sub-panel (08514-00002) on an HP 8512A test set with a serial number prefix lower than 2552A requires ordering a complete dress panel replacement kit (08512-60012). These items are replaceable separately only on test sets with serial number prefixes 2552A and higher, using the new part numbers given above. The original parts and part numbers are obsolete.

HP 8512A REFLECTION/TRANSMISSION TEST SET

CHASSIS PARTS IN INSTRUMENTS WITH THE SERIAL NUMBER PREFIX 2515A (AND ALL HIGHER SERIAL NUMBER PREFIXES) ARE MANUFACTURED TO METRIC RATHER THAN ENGLISH DIMENSIONS. PARTS THAT DIFFER ARE LISTED BELOW.

MORE INFORMATION ON ENGLISH AND METRIC CHASSIS PARTS IS AVAILABLE IN HP SERVICE NOTE 8510A-7.

DESCRIPTION	SERIAL NUMBER PREFIXES	
	LESS THAN 2515A INCH P/N	2515A + METRIC P/N
Top Cover	08513-00021	08513-00033
Side Cover-Perforated	08513-00025	08513-00034
Cover FM Bottom	5060-9847	5061-9447
Cover AY Side	5060-9857	5061-9457
Handle AY Front	5060-9899	5061-9499
Kit Rack Mount (Opt. 908)	5061-0077	5061-9677
Kit Rack Flange (Opt. 913)	5061-2071	5061-9771
Frame Front	5020-8803	5021-5803
Frame Rear	5020-8804	5021-5804
Strut Corner	5020-8837	5021-5837
SM 8-32 .250 fIPD M4X0.7X6mm fH 90	2510-0192	0515-1331
SM 8-32 .375 fHPD M4X0.7X10mm fH 90	2510-0195	0515-0896

REPLACEMENT PAGE

Revised 30 July 1986

6-113/6-114

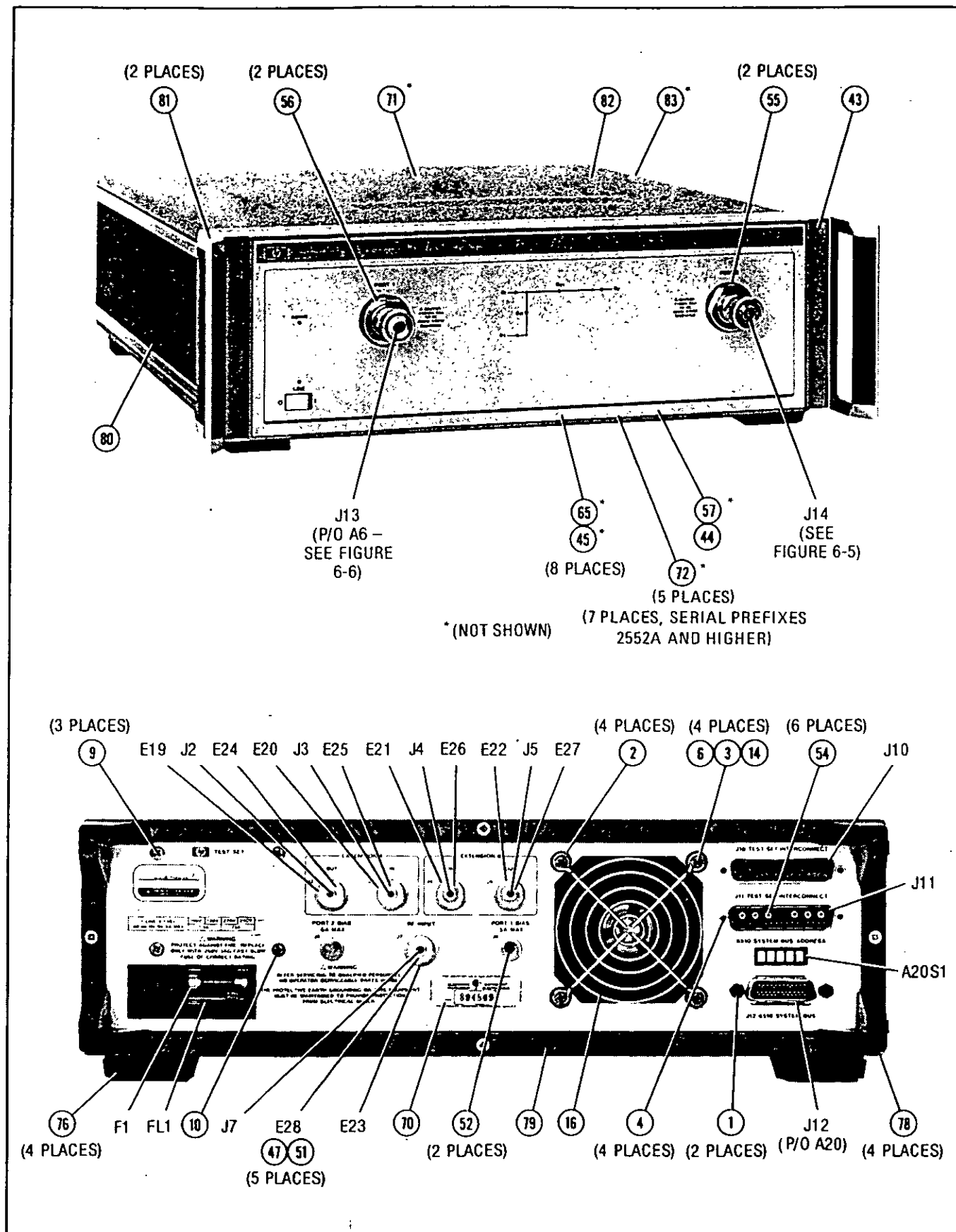


Figure 6-4. HP 8512A Miscellaneous Mechanical, Chassis, and Electrical Parts (1 of 5)

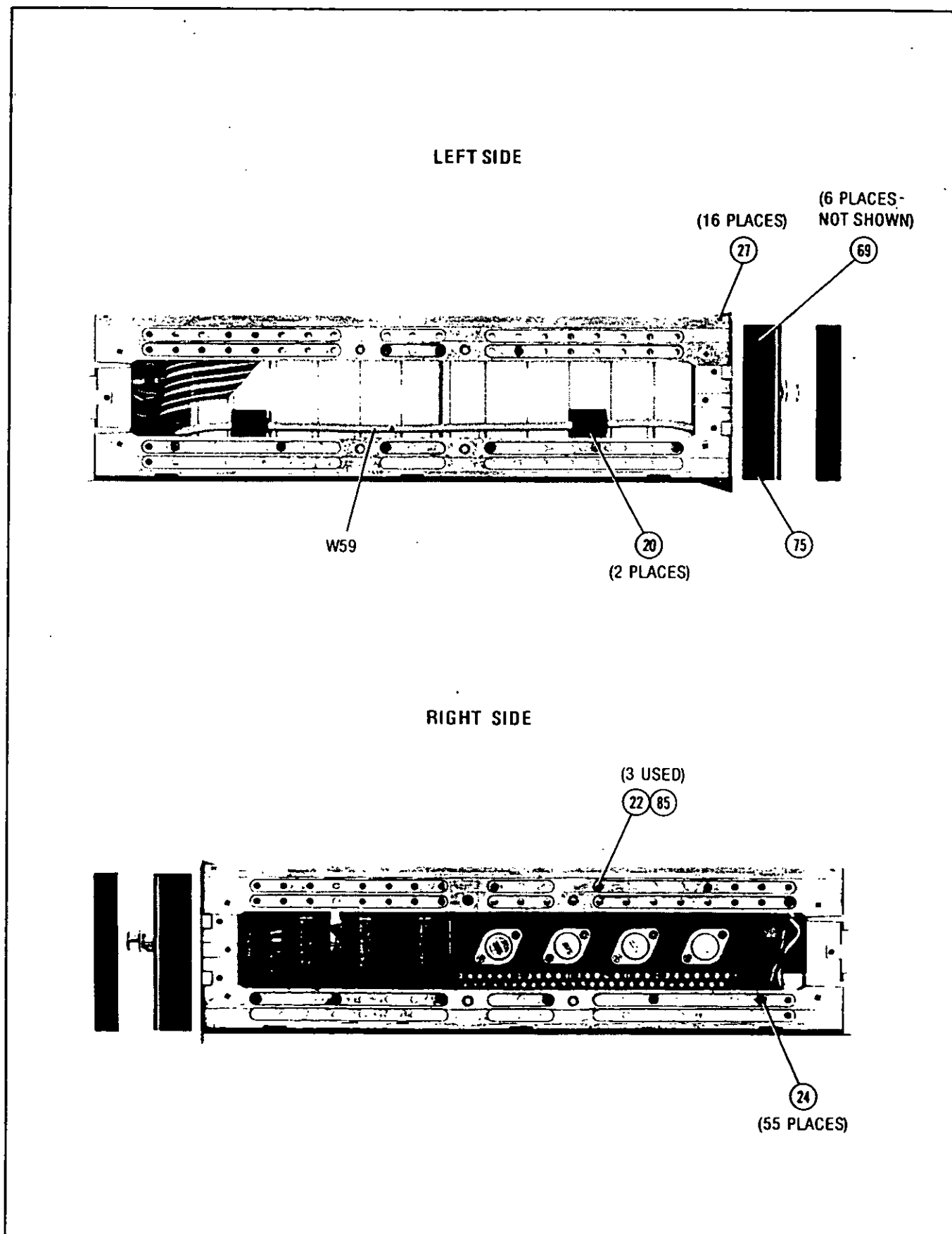


Figure 6-4. HP 8512A Miscellaneous Mechanical, Chassis, and Electrical Parts (2 of 5)

MANUAL CHANGES

HP 8513A
Reflection/Transmission Test Set

MANUAL IDENTIFICATION

Model Number: HP 8510A
Date Printed: March 1984
Part Number: 08510-90001

HP 8513A REFLECTION/TRANSMISSION TEST SET SERVICE

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14 JULY 1986
SERIAL NUMBER PREFIXES 2623A
AND LOWER



HP 8513A REFLECTION/TRANSMISSION TEST SET CHANGES TO REPLACEABLE PARTS TABLE 6-3

If you need to replace a part in the HP 8513A reflection/transmission test set, check this list first. If the part is listed here, use the part and part number given here instead of those in the original HP 8510 parts list, Table 6-3, Replaceable Parts. If the part is not listed, use the original parts list.

Some parts are used only in certain instruments, beginning with the serial number prefix listed here. These parts are used in all instruments with the serial number prefix listed and instruments with all higher serial number prefixes. Parts used in all instruments regardless of serial number prefix are listed here as "All Serials" parts.

Ref. Desig.	Original HP Part Number	Replace with New HP Part Number	New Description	Serial Prefix(es)
A4	08513-60002	08513-67002	BOARD ASSY, HP-IB	All Serials
A4U12	1820-2485	1820-3431	IC RCVR TTL	All Serials
A4U13	1820-2483	1820-3513	IC RCVR TTL	All Serials
AT2	8493C#003	08513-60151	3.5mm 3dB PAD	All Serials
AT3	8493C#006	08513-60152	3.5mm 6dB PAD	All Serials
AT6	8493C#010	08513-60153	3.5mm 10dB PAD	All Serials
B1	3160-0273	08513-20031	FAN-TBAX 34 CFM 115V 50/60-HZ 1.5KV-DIEL	All Serials
7	2360-0123	0515-0915	SCREW-MACH SMM 4.0 6 PNP	All Serials
59	08513-00003 or 08513-00031	08513-00035	FRONT PANEL	2623A →

ADD PAGE - ALL SERIALS

Added 14 July 1986 (1 of 2)

Place over page 6-139/6-140

Ref. Desig.	Original HP Part Number	Replace with New HP Part Number	New Description	Serial Prefix(es)
60	08513-00004	08514-00036	SUB PANEL	2623A →
83	NONE	0510-1148	RETAINER-PO 0.140 ID	All Serials
59 - 60	NONE	08513-60148	DRESS PANEL REPLACEMENT KIT	See Note 1

Note 1 - Replacement of either the front panel (08513-00003 or 08512-00031) or the interior sub-panel (08513-00004) on an HP 8513A test set with a serial number prefix lower than 2623A requires ordering a complete dress panel replacement kit (08513-60148). These items are replaceable separately only on test sets with serial number prefixes 2623A and higher, using the new part numbers given above. The original parts and part numbers are obsolete.

HP 8513A REFLECTION/TRANSMISSION TEST SET

CHASSIS PARTS IN INSTRUMENTS WITH THE SERIAL NUMBER PREFIX 2512A (AND ALL HIGHER SERIAL NUMBER PREFIXES) ARE MANUFACTURED TO METRIC RATHER THAN ENGLISH DIMENSIONS. PARTS THAT DIFFER ARE LISTED BELOW.

MORE INFORMATION ON ENGLISH AND METRIC CHASSIS PARTS IS AVAILABLE IN HP SERVICE NOTE 8510A-7.

DESCRIPTION	SERIAL NUMBER PREFIXES	
	LESS THAN 2512A INCH P/N	2512A → METRIC P/N
Top Cover	08513-00021	08513-00033
Side Cover-Perforated	08513-00025	08513-00034
Cover FM Bottom	5060-9847	5061-9447
Cover AY Side	5060-9857	5061-9457
Handle AY Front	5060-9899	5061-9499
Kit Rack Mount (Opt. 908)	5061-0077	5061-9677
Kit Rack Flange (Opt. 913)	5061-2071	5061-9771
Frame Front	5020-8803	5021-5803
Frame Rear	5020-8804	5021-5804
Strut Corner	5020-8837	5021-5837
SM 8-32 .250fIPD M4X0.7X6mm fH 90	2510-0192	0515-1331
SM 8-32 .375 fHPD M4X0.7X10mm fH 90	2510-0195	0515-0896

REPLACEMENT PAGE

Revised 14 July 1986

6-139/6-140

MANUAL CHANGES

**HP 8515A
S-Parameter Test Set**

MANUAL IDENTIFICATION

Model Number: HP 8510A
Date Printed: March 1984
Part Number: 08510-90001

HP 8515A S-PARAMETER TEST SET SERVICE

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**30 JULY 1986
SERIAL NUMBER PREFIXES 2551A
AND LOWER**



**HEWLETT
PACKARD**

HP 8515A S-PARAMETER TEST SET

CHASSIS PARTS IN INSTRUMENTS WITH THE SERIAL NUMBER PREFIX 2514A (AND ALL HIGHER SERIAL NUMBER PREFIXES) ARE MANUFACTURED TO METRIC RATHER THAN ENGLISH DIMENSIONS. PARTS THAT DIFFER ARE LISTED BELOW.

MORE INFORMATION ON ENGLISH AND METRIC CHASSIS PARTS IS AVAILABLE IN HP SERVICE NOTE 8510A-7.

DESCRIPTION	SERIAL NUMBER PREFIXES	
	LESS THAN 2514A INCH P/N	2514A + METRIC P/N
Top Cover	08513-00021	08513-00033
Side Cover-Perforated	08513-00025	08513-00034
Cover FM Bottom	5060-9847	5061-9447
Cover AY Side	5060-9857	5061-9457
Handle AY Front	5060-9899	5061-9499
Kit Rack Mount (Opt. 908)	5061-0077	5061-9677
Kit Rack Flange (Opt. 913)	5061-2071	5061-9771
Frame Front	5020-8803	5021-5803
Frame Rear	5020-8804	5021-5804
Strut Corner	5020-8837	5021-5837
SM 8-32 .250fIPD M4XO.7X6mm fH 90	2510-0192	0515-1331
SM 8-32 .375 fHPD M4XO.7X10mm fH 90	2510-0195	0515-0896

HP 8515A - Replaceable Parts

HP 8515A S-PARAMETER TEST SET CHANGES TO REPLACEABLE PARTS TABLE 6-3

If you need to replace a part in the HP 8515A S-Parameter Test Set, check this list first. If the part is listed here, use the part and part number given here instead of those in the original HP 8510 parts list, Table 6-3. Replaceable Parts. If the part is not listed, use the original parts list.

Some parts are used only in certain instruments, beginning with the serial number prefix listed here. These parts are used in all instruments with the serial number prefix listed and instruments with all higher serial number prefixes. Parts used in all instruments regardless of serial number prefix are listed here as "All Serials" parts.

Ref. Desig.	Original HP Part Number	Replace with New HP Part Number	New Description	Serial Prefix(es)
A4	08513-60002	08513-67002	BOARD ASSEMBLY, HP-1B	All Serials
A4U12	1820-2485	1820-3431	IC RCVR 75160 TTL	All Serials
A4U13	1820-2483	1820-3513	IC RCVR 75161 TTL	All Serials
AT2	8493C#003	08513-60151	3.5mm 3dB PAD	All Serials
AT3	8493C#006	08513-60152	3.5mm 6dB PAD	All Serials
AT6	8493C#010	08513-60153	3.5mm 10dB PAD	All Serials
60	08515-00004	08515-00008	FRONT PANEL	2551 →

HP 8515A - Replaceable Parts

61	08513-00004	08513-00036	SUB PANEL	2551 →
62	NONE	0510-1148	RETAINER-PO 0.140 ID	All Serials
60 - 62	NONE	08515-60001	DRESS PANEL REPLACEMENT KIT	See Note 1

Note 1 - Replacement of either the front panel (08515-00004) or the interior sub-panel (08513-00004) on an HP 8515A test set with a serial number prefix lower than 2551 requires ordering a complete dress panel replacement kit (08515-60001). These items are not replaceable separately except on test sets with serial number prefixes 2551 and higher, and then only by using the new part numbers given above. The original parts and part numbers are obsolete.

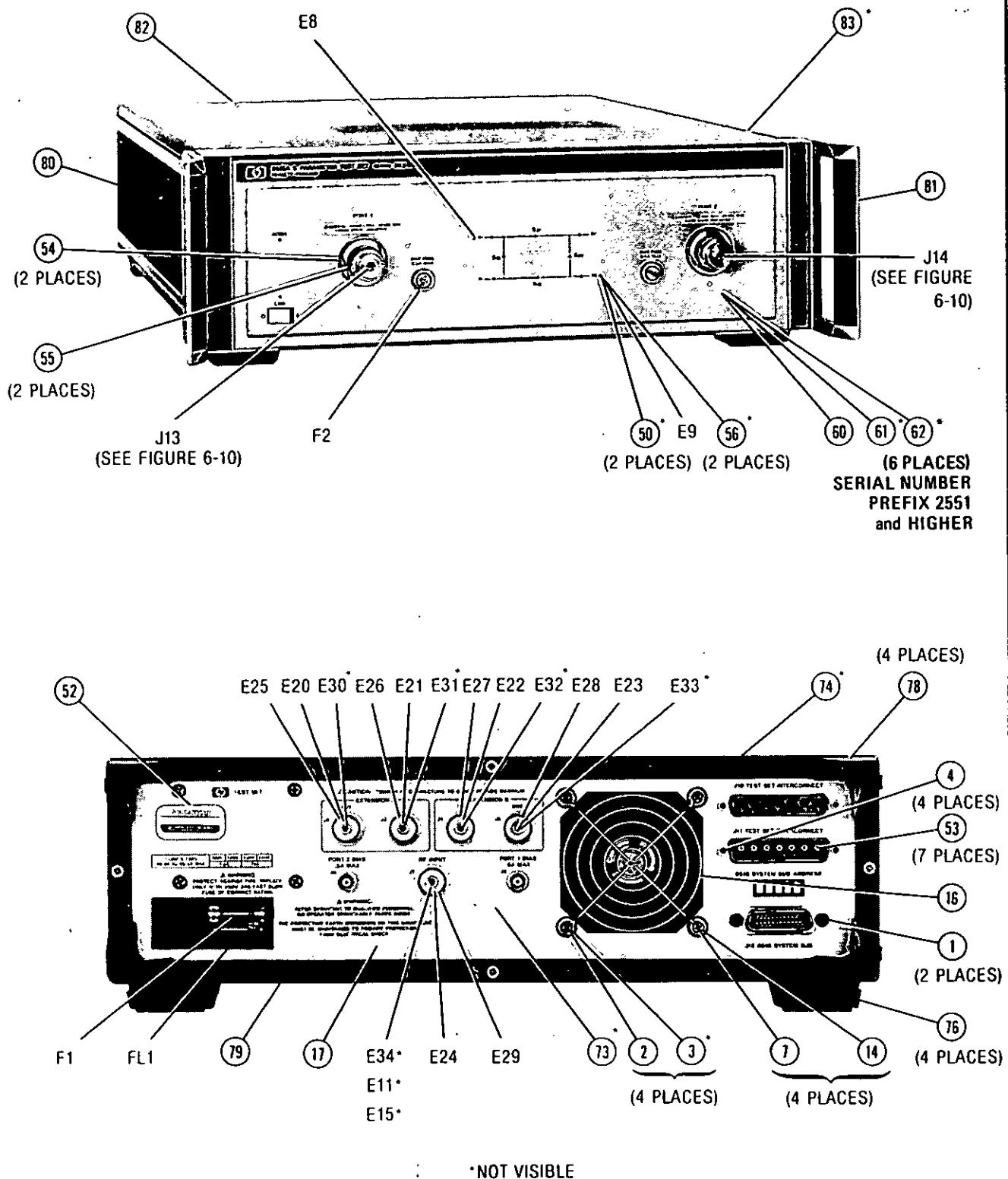


Figure 6-9. HP 8515A Miscellaneous Mechanical, Chassis, and Electrical Parts (1 of 5)

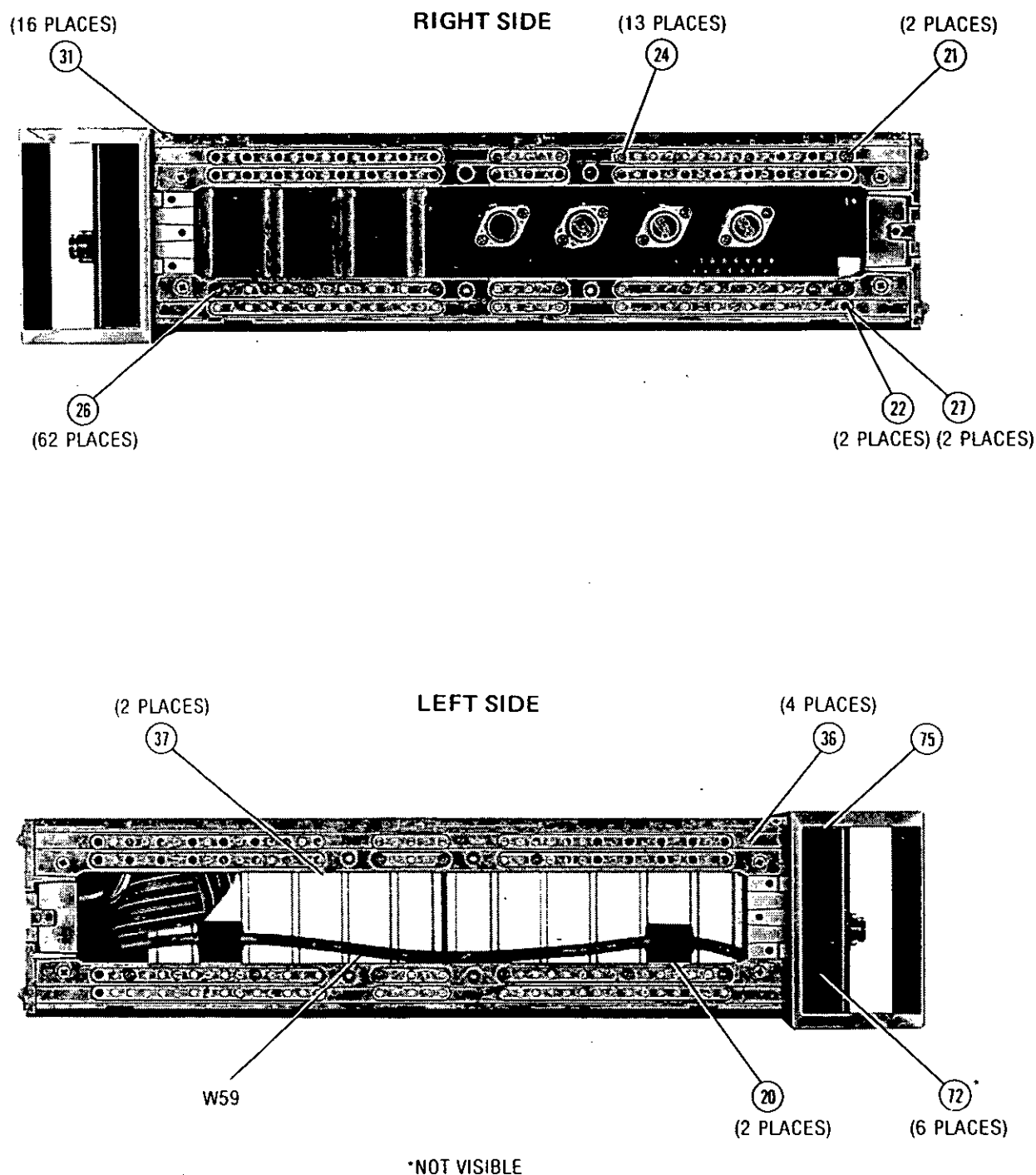


Figure 6-9. HP 8515A Miscellaneous Mechanical, Chassis, and Electrical Parts (2 of 5)

REPLACEMENT PAGE
Revised 9 January 1986

X-RAY RADIATION NOTICE

ACHTUNG

Model 85101 A

WARNING

Während des Betriebs erzeugt dieses Gerät Röntgenstrahlung. Das Gerät ist so abgeschirmt, daß die Dosisleistung weniger als 36 pA/kg (0,5 mR/h) in 5cm Abstand von der Oberfläche der Katodenstrahlröhre beträgt. Somit sind die Sicherheitsbestimmungen verschiedener Länder, u.A. der deutschen Röntgenverordnung eingehalten.

Die Stärke der Röntgenstrahlung hängt im Wesentlichen von der Bauart der Katodenstrahlröhre ab, sowie von den Spannungen, welche an dieser anliegen. Um einen sicheren Betrieb zu gewährleisten, dürfen die Einstellungen der Niederspannungs- und des Hochspannungsnetzteils nur nach der Anleitung in Kapitel V des Handbuches vorgenommen werden.

Die Katodenstrahlröhre darf nur durch die gleiche Type ersetzt werden. (Siehe Kapitel Vi für HP — Ersatzteile).

Das Gerät ist in Deutschland zugelassen unter

der Nummer: BW/179/84/RÖ

When operating, this instrument emits x-rays; however, it is well shielded and meets safety and health requirements of various countries, such as the X-ray Radiation Act of Germany.

Radiation emitted by this instrument is less than 0.5 mR/hr at a distance of five (5) centimeters from the surface of the cathode-ray tube. The x-ray radiation primarily depends on the characteristics of the cathode-ray tube and its associated low-voltage and high-voltage circuitry. To ensure safe operation of the instrument, adjust both the low-voltage and high-voltage power supplies as outlined in Section V of this manual (if applicable).

Replace the cathode-ray tube with an identical CRT only. Refer to Section VI for proper HP part number.

Number of German License: BW/179/84/RÖ



GEWERBEAUFSICHTSAMT STUTTGART

- Zentrale Stelle für Sicherheitstechnik und Vorschriftenwesen in Baden-Württemberg -

□ Gewerbeaufsichtsamt · Breitscheidstr. 48 · Postfach 705 · 7000 Stuttgart 1 □

Hewlett-Packard GmbH
Herrenberger Straße 110

7030 Böblingen

Stuttgart, den 20.06.1984

Fernsprecher

(07 11) 2 05 01 (Behördenzentrum)

Durchwahl 20 50 - 4798

Aktenzeichen: Z 5108/HP/Ws/Vg
(Bitte bei Antwort angeben)

Betr.: Durchführung der Röntgenverordnung (RöV)

Bezug: Ihr Antrag vom 29.05.1984 - PSD/US/ab

Zulassungsschein Nr. BW/179/84/Rö

Hiermit wird Ihnen gemäß § 7 Abs. 2 der Röntgenverordnung vom 1. März 1973 (BGBl. I S. 173) die Zulassung der Bauart der nachstehend beschriebenen Störstrahler erteilt:

Gegenstand	:	Display / Processor	Typ: 85101 A
Bildröhre	:	Hewlett-Packard	Typ: 5083-5791
Betriebsbedingungen	:	Hochspannung: max. 23,5 kV Strahlstrom: max. 7,5 µA	
Hersteller	:	Hewlett-Packard Co. 1400 Fountaingrove Parkway Santa Rosa, CA 95401, USA	
Bauartunterlagen	:	Antrag, Geräte Nr. 85101 A, Blatt 1 bis 4 vom 14.05.84 mit den darin aufgeführten Unterlagen	
Prüfungsschein	:	Physikalisch-Technische Bundesanstalt Braunschweig Nr. 6.62-S 217 vom 08.06.84	

Die Zulassung wird befristet bis 20.06.1994.

Auf § 8 Abs. 2 RöV wird hingewiesen.

Für den Strahlenschutz wesentliche Merkmale

1. Die Art und Qualität der Bildröhre,
2. die der Hochspannungserzeugung und -stabilisierung dienenden Bauelemente.

Auflagen:

Die Zulassung wird gemäß § 8 Abs. 1 der RöV mit folgenden Auflagen verbunden:

1. Die Geräte sind einer Stückprüfung daraufhin zu unterziehen, ob sie bezüglich der für den Strahlenschutz wesentlichen Merkmale der Bauartzulassung entsprechen. Die Prüfung muß umfassen:
 - a) Kontrolle der Hochspannung an jedem einzelnen Gerät,
 - b) Messung der Dosisleistung nach näherer Angabe der Zulassungsbehörde.

Die Ergebnisse der Dosisleistungsmessung sind, den Herstellnummern der Geräte zugeordnet, aufzuzeichnen, drei Jahre aufzubewahren und der Zulassungsbehörde auf Verlangen einzusenden. Die Zulassungsbehörde ist berechtigt, einzelne Geräte nach eigener Auswahl anzufordern, um das Vorliegen der für den Strahlenschutz wesentlichen Merkmale zu überprüfen oder überprüfen zu lassen.

2. Die Herstellung und die Stückprüfung sind durch einen von der Zulassungsbehörde bestimmten Sachverständigen überwachen zu lassen.
3. Die Geräte sind deutlich sichtbar und dauerhaft mit dem Kennzeichen

BW/179/84/Rö

zu versehen sowie mit einem Hinweis folgenden Mindestinhalts:

"Die in diesem Gerät entstehende Röntgenstrahlung ist ausreichend abgeschirmt.
Beschleunigungsspannung maximal 23,5 kV."

4. Jedem Erwerber eines Gerätes ist ein Abdruck des Zulassungsscheins auszuhändigen, auf dem das Ergebnis der Stückprüfung (Auflage 1) bestätigt sein muß.

Jedem Gerät ist ferner eine Betriebsanleitung beizufügen, in der auf den in Auflage 3 genannten Hinweis aufmerksam gemacht wird, und welche die für die Durchführung von Reparaturmaßnahmen und Wartungsarbeiten notwendigen Sicherheitsmaßnahmen bezüglich des Strahlenschutzes enthält.

Hinweis für den Benutzer des Geräts:

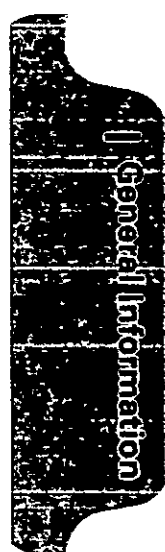
Unsachgemäße Eingriffe, insbesondere Verändern der Hochspannung oder Auswechseln der Bildröhre können dazu führen, daß Röntgenstrahlung in erheblicher Stärke auftritt. Ein so verändertes Gerät entspricht nicht mehr dieser Zulassung und darf infolgedessen nicht mehr betrieben werden.

Reutter
R e u t t e r



Dieses Gerät wurde nach den Auflagen der Zulassungsbehörde einer Stückprüfung unterzogen und entspricht in den für den Strahlenschutz wesentlichen Merkmalen der Bauartzulassung. Die Beschleunigungsspannung beträgt maximal 23,5 kV.

Hewlett - Packard Co.
1400 Fountaingrove Parkway
Santa Rosa, CA 95401, USA



HP 8510 NETWORK ANALYZER

SERIAL NUMBERS

This manual applies directly to HP 8510 network analyzers, and HP 8511A, HP 8512A, HP 8513A, HP 8514A and HP 8515A test sets with serial number prefixes as follows:

HP 85101A	2427	HP 8513A	2345
HP 85102A	2402	HP 8514A	2343
HP 8511A	2345	HP 8515A	2345
HP 8512A	2336		

For additional important information about serial numbers, see INSTRUMENTS COVERED BY MANUAL in Section I of this Operating and Service Manual, or Section VII Backdating.

FIRMWARE AND SOFTWARE REVISIONS

This manual applies directly to the following software and firmware supplied with the HP 8510 system:

Part Number	Revision
85101-10001 (system firmware)	A.01.00
85101-10002 (system firmware w/option 010)	A.01.00
85101-10003 (adjustments and diagnostic)	1.0
08510-10001 (adjustments)	1.0
08510-10006 (performance test HP 8510A/8511A)	1.0
08510-10002 (performance test HP 8510A/8512A)	1.0
08510-10003 (performance test HP 8510A/8513A)	1.0
08510-10004 (performance test HP 8510A/8514A)	1.0
08510-10005 (performance test HP 8510A/8515A)	1.0

For later revisions of these programs, a Manual Changes package will be included with this manual.

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

MANUAL PART NO. 08510-90001
Microfiche Part No. 08510-90002

Printed: MARCH 1984



**HEWLETT
PACKARD**

CERTIFICATION

Hewlett-Packard Company certifies that this product met its published specifications at the time of shipment from the factory. Hewlett-Packard further certifies that its calibration measurements are traceable to the United States National Bureau of Standards, to the extent allowed by the Bureau's calibration facility, and to the calibration facilities of other International Standards Organization members.

WARRANTY

This Hewlett-Packard instrument product is warranted against defects in material and workmanship for a period of one year from date of shipment. During the warranty period, Hewlett-Packard Company will, at its option, either repair or replace products which prove to be defective.

For warranty service or repair, this product must be returned to a service facility designated by HP. Buyer shall prepay shipping charges to HP and HP shall pay shipping charges to return the product to Buyer. However, Buyer shall pay all shipping charges, duties, and taxes for products returned to HP from another country.

HP warrants that its software and firmware designated by HP for use with an instrument will execute its programming instructions when properly installed on that instrument. HP does not warrant that the operation of the instrument, or software, or firmware will be uninterrupted or error free.

LIMITATION OF WARRANTY

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance.

NO OTHER WARRANTY IS EXPRESSED OR IMPLIED. HP SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

EXCLUSIVE REMEDIES

THE REMEDIES PROVIDED HEREIN ARE BUYER'S SOLE AND EXCLUSIVE REMEDIES. HP SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT, OR ANY OTHER LEGAL THEORY.

ASSISTANCE

Product maintenance agreements and other customer assistance agreements are available for Hewlett-Packard products.

For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

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SAFETY CONSIDERATIONS

GENERAL

This product and related documentation must be reviewed for familiarization with safety markings and instructions before operation. This product has been designed and tested in accordance with international standards.

SAFETY SYMBOLS



Instruction manual symbol: the product will be marked with this symbol when it is necessary for the user to refer to the instruction manual (refer to Table of Contents).



Indicates hazardous voltages.



Indicates earth (ground) terminal.

WARNING

The WARNING sign denotes a hazard. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in personal injury. Do not proceed beyond a WARNING sign until the indicated conditions are fully understood and met.

CAUTION

The CAUTION sign denotes a hazard. It calls attention to an operating procedure, practice, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product. Do not proceed beyond a CAUTION sign until the indicated conditions are fully understood and met.

SAFETY EARTH GROUND

This is a Safety Class I product (provided with a protective earthing terminal). An uninterruptible safety earth ground must be provided from the main power source to the product input wiring terminals, power cord, or supplied power cord set. Whenever it is likely that the protection has been impaired, the product must be made inoperative and be secured against any unintended operation.

BEFORE APPLYING POWER

Verify that the product is configured to match the available main power source per the input power configuration instructions provided in this manual.

If this product is to be energized via an autotransformer, make sure the common terminal is connected to the neutral (grounded side of mains supply).

SERVICING

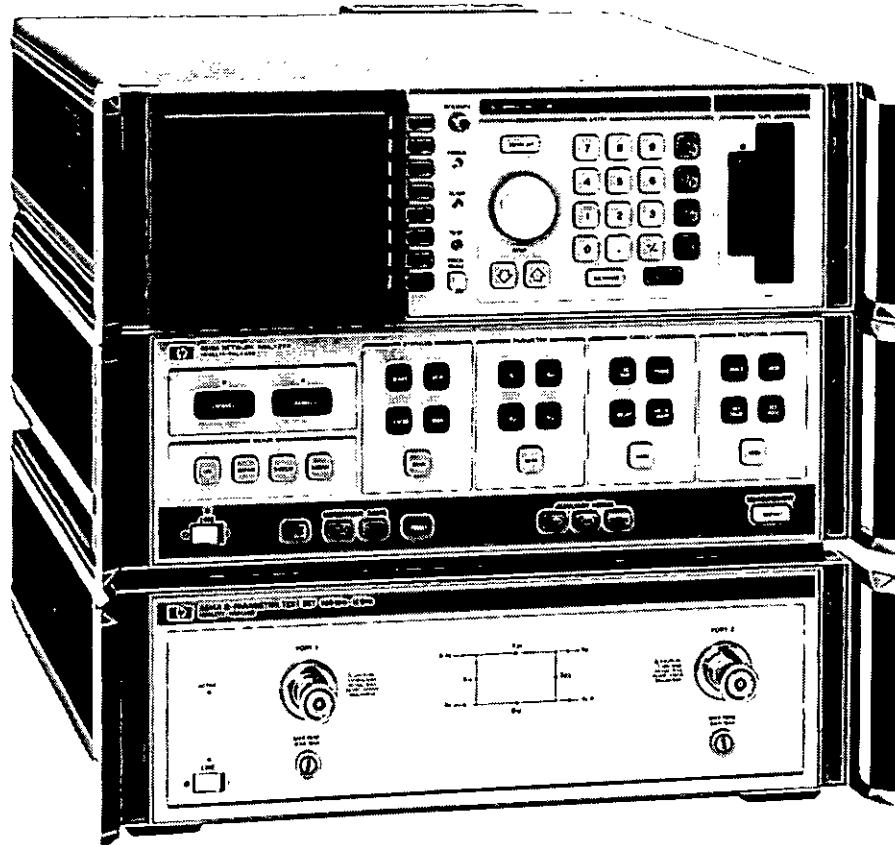
WARNING

Any servicing, adjustment, maintenance, or repair of this product must be performed only by qualified personnel.

Adjustments described in this manual may be performed with power supplied to the product while protective covers are removed. Energy available at many points may, if contacted, result in personal injury.

Capacitors inside this product may still be charged even when disconnected from their power source.

To avoid a fire hazard, only fuses with the required current rating and of the specified type (normal blow, time delay, etc.) are to be used for replacement.



NOTE

Refer to Paragraphs 1-15 and 1-29 for system configurations and accessories available.

Figure 1-1. HP 8510 Network Analyzer System

SECTION I GENERAL INFORMATION

1-1. INTRODUCTION

1-2. The Hewlett-Packard Model 8510 network analyzer system (Figure 1-1) consists of several separate instruments: the display/processor, the IF/detector, single or multiple test sets, and an HP 8340A or HP 8350B sweep oscillator. These instruments are interconnected to make up an HP 8510 system. The HP 8510 system includes all of the connecting cables, as well as various other accessories used with the system in calibration and measurements. Additional system capabilities are obtained by adding an HP desktop computer (controller) and other peripheral equipment.

1-3. This manual covers system and instrument specifications, installation, operation, programming, performance verification, adjustments, replaceable parts, service, and repair of the HP 8510 system.

1-4. SYSTEMS COVERED BY THIS MANUAL

1-5. Attached to each instrument is a serial number label that has the instrument serial number printed on it. These numbers are recorded at the factory upon initial shipment so that service and warranty information can be maintained by the factory for the specific combination shipped.

1-6. A typical serial number label is shown in Figure 1-2. The serial number is in two parts. The first four digits followed by a letter comprise the serial number prefix. The last five digits form the sequential suffix that is unique to each instrument. The contents of this manual apply directly to instruments having the same serial number prefixes as those listed on the Title Page of this manual under SERIAL NUMBERS.

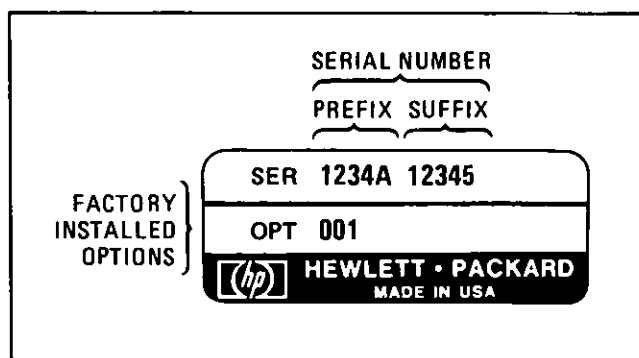


Figure 1-2. Typical Serial Number Label

1-7. An instrument manufactured after the printing of this manual may have a serial prefix that is not listed on the Title Page. An unlisted serial prefix indicates that the instrument is different from those documented in this manual. The manual for the instrument is then supplied with a Manual Changes supplement that contains information that documents the differences.

1-8. In addition to change information, the Manual Changes supplement contains information for correcting errors in the manual. To keep this manual as current as

possible, Hewlett-Packard recommends that you periodically obtain the latest Manual Changes supplement. The supplement for this manual is keyed to both the print date and part number of the manual; both appear on the Title Page. Copies of the Manual Changes supplement are available from Hewlett-Packard or by subscription as part of support option HP 8510T +23U.

1-9. For information concerning a serial number prefix that is not listed on the title page or in the Manual Changes supplement, contact your nearest Hewlett-Packard Sales Support Office.

1-10. SAFETY CONSIDERATIONS

1-11. Refer to the safety sheet at the front of this section for general safety instructions. Other cautions and warnings that appear throughout this manual should also be carefully followed to prevent bodily injury or damage to the equipment.

1-12. SYSTEM SPECIFICATIONS

1-13. Tables 1-2, 1-3, 1-10, 1-11, and 1-12 list measurement specifications for the HP 8510A in combination with an HP 8512A, 8514A, 8511A, 8513A or 8515A test set and an RF source. The specifications describe the warranted performance of the system over the temperature range of 0° C to 55° C, except where noted in the specification table. The specifications shown are those obtained when an HP 8340A synthesized sweeper is used as the system RF source.

1-14. Table 1-4 and some entries in the specification tables denoted as "typical", "nominal", or "approximate" are the typical, but not warranted, operating characteristics of the system. Supplemental characteristics provide information useful in applying the instrument by giving nonwarranted performance parameters.

1-15. SYSTEM DESCRIPTION

1-16. HP 8510A/8511A System

1-17. The combination of the HP 8511A test set with the HP 8510A network analyzer and RF source provides a four channel receiver/signal processor that operates over the frequency range of 45 MHz to 26.5 GHz. This system provides configuration flexibility of a user supplied signal separation network allowing custom measurement capabilities. The test set contains four RF to IF converters all of which can operate over the entire dynamic range of the system.

1-18. HP 8510A/8512A System

1-19. The combination of the HP 8512A test set with the HP 8510A network analyzer and RF source provides a system for making reflection (S_{11}) and transmission (S_{21}) measurements over the frequency range of 500 MHz to 18 GHz. This system provides a broad dynamic range and a simple test set architecture. The design of the test set includes three separate RF-to-IF converters which eliminate the need to mechanically switch between reflection and transmission measurements. This test set uses a directional coupler for signal separation.

1-20. The recommended accessories for the HP 8510A/8512A system are as follows:

HP 85132A 7mm test port return cable
HP 85050A 7mm calibration kit
HP 85051A 7mm verification kit

1-21. HP 8510A/8513A

1-22. The combination of the HP 8513A test set with the HP 8510A network analyzer and source provides a system for making reflection (S_{11}) and transmission (S_{21}) measurement over the frequency range of 45 MHz to 26.5 GHz. This system provides broad frequency coverage with wide dynamic range, and a simple test set architecture. The design of the test set includes three separate RF to IF converters which eliminate the need to mechanically switch between reflection and transmission measurements. This test set uses a bridge for signal separation.

1-23. The recommended accessories for the HP 8510A/8513A system are as follows:

HP 85131A 3.5 mm test port return cable
HP 85052A 3.5 mm calibration kit
HP 85053A 3.5 mm verification kit
HP 85130A 3.5 mm to 7 mm adapter set
HP 85050A 7 mm calibration kit
HP 85051A 7 mm verification kit
HP 85132A 7 mm test port return cable

1-24. HP 8510A/8514A System

1-25. The combination of the HP 8514A test set with the HP 8510A network analyzer and source provides a system for making S-parameter measurements over the frequency range of 500 MHz to 18 GHz. This system is suited for making measurements on two port devices where it is not convenient to physically reverse the test device to measure all four S-parameters. The dual four-port architecture of the test set develops a separate reference channel for each incident port, thus reducing the number of internal switches to one. This test set uses directional couplers for signal splitting. For measurements of active devices, the test set includes two 90 dB step attenuators for changing the incident power level at either port, as well as provisions for applying dc bias from an external power supply to the test port center conductor.

1-26. The recommended accessories for the HP 8510A/8514A system are as follows:

HP 85132B 7mm test port return cable set
HP 85050A 7mm calibration kit
HP 85051A 7mm verification kit

The HP 85132A test port return cable is also suitable for use with the HP 8510A/8514A; however, some increased sensitivity to frequency drift and residual FM may result.

1-27. HP 8510A/8515A System

1-28. The combination of the HP 8515A test set with the HP 8510A network analyzer and source provides a system for making S-parameter measurements over the frequency range of 45 MHz to 26.5 GHz. This system is suited for making measurements on two port devices where it is not convenient to physically reverse the

test device to measure all four S-parameters. The dual four-port architecture of the test set develops a separate reference channel for each incident port, thus requiring only one internal electronic switch. This test set uses bridges for signal splitting. For measurements of active devices, the test set includes two 90 dB step attenuators for changing the incident power level at either port, as well as provisions for applying dc bias from an external power supply to the test port center conductor.

1-29. The recommended accessories for the HP 8510A/8515A system are as follows:

- HP 85131B 3.5 mm test port return cable
- HP 85052A 3.5 mm calibration kit
- HP 85053A 3.5 mm verification kit
- HP 85130A 3.5 mm to 7 mm adapter set
- HP 85050A 7 mm calibration kit
- HP 85051A 7 mm verification kit
- HP 85132B 7 mm test port return cable

1-30. Sweep Oscillators Compatible with an HP 8510 System

1-31. **HP 8340A Synthesized Sweeper Compatibility.** The HP 8510 network analyzer system was specifically designed to work with an HP 8340A synthesized sweeper. Therefore, this sweep oscillator is compatible with the system.

1-32. **HP 8350B Sweep Oscillator Compatibility.** An HP 8350B must have Revision 6 (or above) of the firmware to make it compatible with an HP 8510 system. If it has a lower revision number, retrofit kit HP Part Number 08350-60101 will change it to Revision 6 of the firmware and make it compatible.

1-33. To check the HP 8350B firmware revision number, press the HP 8350 [SHIFT] [4] [9]. The firmware revision number will appear in the right-hand frequency/time display.

1-34. The HP 8350A may be made compatible by installing retrofit kit HP Part Number 08350-60099 or 08350-60100. These kits basically change an HP 8350A to an HP 8350B and update the firmware. If your HP 8350A sweeper had this modification installed prior to the availability of the Revision 6 firmware, you must also install retrofit kit HP Part Number 08350-60101 to obtain the Revision 6 firmware.

1-35. **HP 83500-Series RF Plug-in Compatibility.** The HP 83500-series RF plug-ins used in the HP 8350B sweepers must have Revision 6 (or above) firmware to be compatible with an HP 8510 system. If the plug-in has a lower revision number, the modification kit required for each plug-in model is listed in Table 1-1.

1-36. To check the HP 83500-series RF plug-in firmware revision number, press the HP 8350 [SHIFT] [9] [9]. The firmware revision number will appear in the plug-in POWER window.

Table 1-1. Modification Kits for HP 83500-Series RF Plug-ins

RF Plug-in	Modification Kit	RF Plug-in	Modification Kit
HP 83522A	83525-60074	*HP 83592A	83592-60074
HP 83525A/B	83525-60074	*HP 83592B	83592-60100
HP 83540A/B	83525-60074	*HP 83592C	83592-60102
HP 83545A	83525-60074	HP 83594A	83594-60074
HP 83570A	83525-60074	*HP 83595A	83595-60074
HP 83590A	83590-60074		
*Full performance verification is possible only with these RF plug-ins.			

1-37. OPTIONS

1-38. The HP 8510A network analyzer has one electrical option, Option 010. This option adds time domain measurement capabilities to the measurement system. Other system options provide product support services.

1-39. Option 010 Time Domain

1-40. In time domain operation, data from transmission or reflection measurements in the frequency domain are converted to the time domain using a Fourier transformation technique. The resultant time domain response trace is presented on the CRT display. Table 1-5 lists the supplemental characteristics of the time domain capabilities.

1-41. Product Support Options

1-42. The following product support options may be ordered for an HP 8510 system. The service options listed may be ordered in areas where HP service capability is available. The on-site service and calibration options require that an HP 9816S, 9826S, or 9836S computer is part of the system configuration or can be provided by the customer at the time of service.

1-43. **HP 8510T +24D.** Three-day user training course. This course provides in-depth user knowledge of the HP 8510 system, including both operation and service. Some of the subjects covered are as follows:

1. Block diagram description of the system.
2. Methods of network analysis.
3. System programming using a desktop computer.
4. The sources of errors in a measurement, and calibration for one- and two-port error correction.
5. Save/recall calibration and setups on the external tape.
6. Verification of measurement accuracy.
7. Techniques for making accurate microwave measurements.
8. Time domain measurements.

1-44. **HP 8510T +23N.** On-site installation and verification. This includes up to one full day of an HP customer engineer's time for system installation/operation verification, and for customer orientation. With this option, the warranty clock is restarted at the date of installation rather than continuing from the date of shipment. This option may be selected where HP service capability is available.

1-45. HP 8350A +23L. Update modification to one customer-owned HP 8350A/B sweeper and one HP 83500-series RF plug-in to make them compatible with the HP 8510 system.

1-46. HP 8510T +23G. On-site calibration provides system performance characterization using traceable calibration devices. This service is recommended every six months. This option may be selected where HP service capability is available.

1-47. HP 8510T +23B. One-year, on-site service. This option may be selected where HP service capability is available.

1-48. HP 8510T +23A. Combines HP 8510T +23B one-year, on-site service with two HP 8510T +23G calibrations.

1-49. HP 8510T +25D. Software notification service provides a one-year subscription to status and update bulletins on all system software.

1-50. HP 8510T +23U. Hardware subscription service provides a one-year subscription to service notes and Operating and Service Manual updates.

1-51. System Option 910. This option adds a second complete system Operating and Service Manual.

1-52. System Option 914. This option deletes the service section of the Operating and Service Manual.

1-53. EQUIPMENT REQUIRED

1-54. To have a working HP 8510 system, you must have an HP 8510A (including HP 85101A display/processor and HP 85102A IF/detector), an HP 8512A or 8514A test set, and an HP 8340A or HP 8350B/835XX RF source, together with the interconnect cables for the system. If automatic operation is desired, an HP 9816S, 9826S, 9836S, or 9836CS (with 0.75MB memory) desk-top computer, together with the appropriate software, is recommended.

1-55. ACCESSORIES AVAILABLE

1-56. Table 1-6 lists accessories, calibration and verification kits, and software pacs available for use with the HP 8510 system. Refer to the HP 8510 system ordering guide for additional details.

1-57. RECOMMENDED TEST EQUIPMENT

1-58. Tables 1-7 through 1-9 list all of the test equipment required to test, adjust, and service the HP 8510A and the HP 8512A or 8514A test set. The individual tables list equipment needed for various types or levels of service. Recommended test equipment for the HP 8340A or 8350B/835XX RF source, the HP 200-series controller, or any peripherals may be found in their individual operating and service manuals.

1-59. WARRANTY

1-60. The standard HP warranty is stated in the front of this manual. The terms of the warranty are as stated. If a product support option was selected, the provisions for service are as provided by the support product. The product warranty in all cases remains the same.

Table 1-2. Specifications for HP 8510 with HP 8512A Test Set

INTRODUCTION AND GENERAL CHARACTERISTICS

The combination of an HP 8512A test set with an HP 8510A network analyzer and an HP 8340A sweeper forms a system for making reflection (S_{11}) and transmission (S_{21}) measurements over the frequency range of 500 MHz to 18 GHz.

Specification Assumptions

The specifications of this table assume that the following conditions are met:

- The RF source is an HP 8340A synthesized sweeper operating in stepped sweep mode.
- The temperature is in the range of 0° C to 55° C, except where noted.
- Reflection and transmission calibration and measurement is done at Test Port 1, and the transmission return path is through an HP 8492A 20 dB attenuator and an HP 85132A cable to Test Port 2.
- +10 dBm power level is at the RF source output.
- Calibration is performed with an HP 85050A precision 7mm calibration kit for a full two-port calibration.
- Verification procedures use the HP 85051A precision 7mm verification kit.

Frequency Range

Reflection: 500 MHz to 18.0 GHz (reduced dynamic range below 500 MHz; typically 30 dB of loss in dynamic range at 45 MHz)

Transmission: 45 MHz to 18.0 GHz

Test Ports

Connector Type: Precision 7mm Sexless

Impedance: 50 ohms nominal

Nominal Operating Power Level:

Test Port 1: +4 dBm at 45 MHz -0.25 dB/GHz

RF Input Connector

Connector Type: Precision 3.5mm Female

Damage Input Level: +23 dBm

Minimum and Maximum Reference Channel Power

Minimum input power at rear-panel RF INPUT port (for Reference Channel Phase Lock): -6 dBm

Maximum input power at rear-panel RF INPUT port (level before 0.1 dB compression): +15 dBm

Table 1-2. Specifications for HP 8510 with HP 8512A Test Set (Cont'd)

HARDWARE AND SYSTEM PERFORMANCE SPECIFICATIONS

Table of System Errors⁹

The following table lists specifications for various sources of system error. Values are listed for uncorrected measurements, corrected measurements after accuracy enhancement, and verification limits. Data in the column labeled "Residual After Accuracy Enhancement" is measured accurately at the factory with special standards that are traceable to the National Bureau of Standards. Devices in the calibration and verification kits, HP 85050A and HP 85051A, have the precision and accuracy to calibrate the system and to verify the source of error to the limits shown in the "Verification Limits" column.

Source of System Errors

Symbol	Error Source	Uncorrected		Residual After Accuracy Enhancement ^{1,6}				Verification Limits ^{1,2,6}	
		0.5-8GHz	8-18GHz	0.5-8GHz		8-18GHz		0.5-8GHz	8-18GHz
		dB or Deg.	dB or Deg	Linear	dB	Linear	dB	dB	dB
D	Directivity	-26dB	-22dB	.0032	-50dB	.0032	-50dB	-44dB	-44dB
M _s	Source Match	-18dB	-13dB	.01	-40dB	.01	-40dB	-37dB	-37dB
M _l	Load Match	-23dB	-16dB	.01	-40dB	.01	-40dB	-40dB	-40dB
T _r	Reflection Tracking	±1dB ³	±1dB ³	.006	±.05dB	.006	±.05dB	±.05dB	±.05dB
T _t	Transmission Tracking	±0.75dB	±0.75dB	.0018	±.015dB	.0035	±.03dB	±.015dB	±.03dB
C	Crosstalk ⁴	-80dB	-80dB	.000032	-90dB	.000032	-90dB	-90dB	-90dB
R _{r1}	Port 1 Reflection Connector Repeatability (Typical)	-70dB	-65dB	.00032	-70dB	.0006	-65dB		
R _{t1}	Port 1 Transmission Connector Repeatability (Typical)	-70dB	-65dB	.00032	-70dB	.0006	-65dB		
R _{r2}	Port 2 Reflection Connector Repeatability (Typical)	-70dB	-65dB	.00032	-70dB	.0006	-65dB		
R _{t2}	Port 2 Transmission Connector Repeatability (Typical)	-70dB	-65dB	.00032	-70dB	.0006	-65dB		
N _l	Low-Level Noise (Noise Floor) ⁵	-73dB	-70dB	.000022	-93dB	.000032	-90dB	-93dB	-90dB
N _h	High-Level Noise ⁷ Magnitude	.015dB	.02dB	.00018	.0015dB	.00023	.002dB	.0015dB	.002dB
	Phase	0.1Deg	0.15Deg						
A	8510A Magnitude Dynamic Accuracy Error (Primarily IF and Detector)	Refer to magnitude curve on page 1-13.							
S _{t2}	Port 2 Cable Transmission Phase Stability (Typical) ⁸	0.1 × f(GHz), Degrees							
T _{td}	Transmission Tracking Drift (Typical) Magnitude	.001 × Δ° C, Linear							
	Phase	(0.1 + .01 × f(GHz)) × Δ° C, Degrees							
T _{rd}	Reflection Tracking Drift (Typical) Magnitude	.001 × Δ° C, Linear							
	Phase	(0.1 + .01 × f(GHz)) × Δ° C, Degrees							

Table 1-2. Specifications for HP 8510 with HP 8512A Test Set (Cont'd)

Footnotes for Table of System Errors

- 1 Accuracy enhancement is achieved using the HP 85050A 7mm calibration kit for a full two-port calibration. The environmental temperature is $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$ at calibration; $\pm 1^{\circ}\text{C}$ from the calibration temperature must be maintained for valid calibration and verification.
- 2 Numbers shown are for verification tests using devices in the HP 85050A 7mm calibration kit and the HP 85051A 7mm verification kit. For other standards, use appropriate uncertainty. Parameters of the system are measured at the factory with one set of standards. These same parameters may be tested again in the field with the verification procedures, using a second set of standards, the calibration and verification kits. The measured verification values will always have more uncertainty than the calibration and verification standards. For example, if the parameter value in the system is $>50\text{ dB}$ and the parameter present in the calibration device is $>50\text{ dB}$, then the highest measured value with negligible ambiguity is 6 dB less, or 44 dB.
- 3 Fine-grain ripple that compares the smoothed trace to a normal trace, excluding 3 dB slope in magnitude response from 3.0 GHz to 18 GHz, and rolloff below 3 GHz for magnitude; typically -9 dB at 0.5 GHz.
- 4 Averaging factor of 1024 is applied.
- 5 Valid only above 3 GHz for S_{11} due to coupler rolloff. Low-level noise (noise floor) is measured relative to an S_{21} through measurement in a 10 kHz bandwidth and 20% of span smoothing.
- 6 An averaging factor of 128 is applied.
- 7 High-level noise is an RMS value taken of a continuous measurement of a short circuit or a through connection.
- 8 The cable phase stability term was arrived at by bending it out perpendicular to the front panel and then reconnecting it. The stability will be much better when less flexing is applied.
- 9 Current HP-supplied performance verification tests verify the sum total of these individual specifications by verifying transmission and reflection magnitude and phase uncertainties E_{tm} , E_{rm} , E_{tp} , and E_{rp} , as they are defined in the equation on page 1-15. These detailed performance verification tests are found in Section IV of this Operating and Service Manual.

Table 1-2. Specifications for HP 8510 with HP 8512A Test Set (Cont'd)

Source of System Dynamic Accuracy Errors¹⁰

The factors affecting dynamic accuracy listed below are primarily a function of the IF/detector except for compression. In order to measure these values, some of the system cables must be disconnected to gain access to the individual instruments.

Compression ≤ 0.1 dB:¹¹ -10 dBm into Port 2

IF Amplifier Gain Accuracy:

IF Amplifier Power Range (dBm) ¹²	Maximum Gain Error (dB)
-10 to -34	0
-34 to -46	± 0.005
-46 to -58	± 0.01
-58 to -70	± 0.02
< -70	± 0.03

Detector Circularity Error: ± 0.003 dB peak

Detector dc Offset Error: -100 dBm¹²

IF Residuals: -120 dBm¹²

IF Linearity: ± 0.003 dB

Incremental Phase Accuracy (Phase vs. Phase) at Measurement Reference: ± 0.001 degrees/degree, not to exceed 0.02 degrees peak.

¹⁰ Current HP-supplied performance verification tests verify the sum total of these individual specifications by verifying transmission and reflection magnitude and phase uncertainties E_{tm} , E_{rm} , E_{tp} , and E_{rp} , as they are defined in the equation on page 1-15. These detailed performance verification tests are found in Section IV of this Operating and Service Manual.

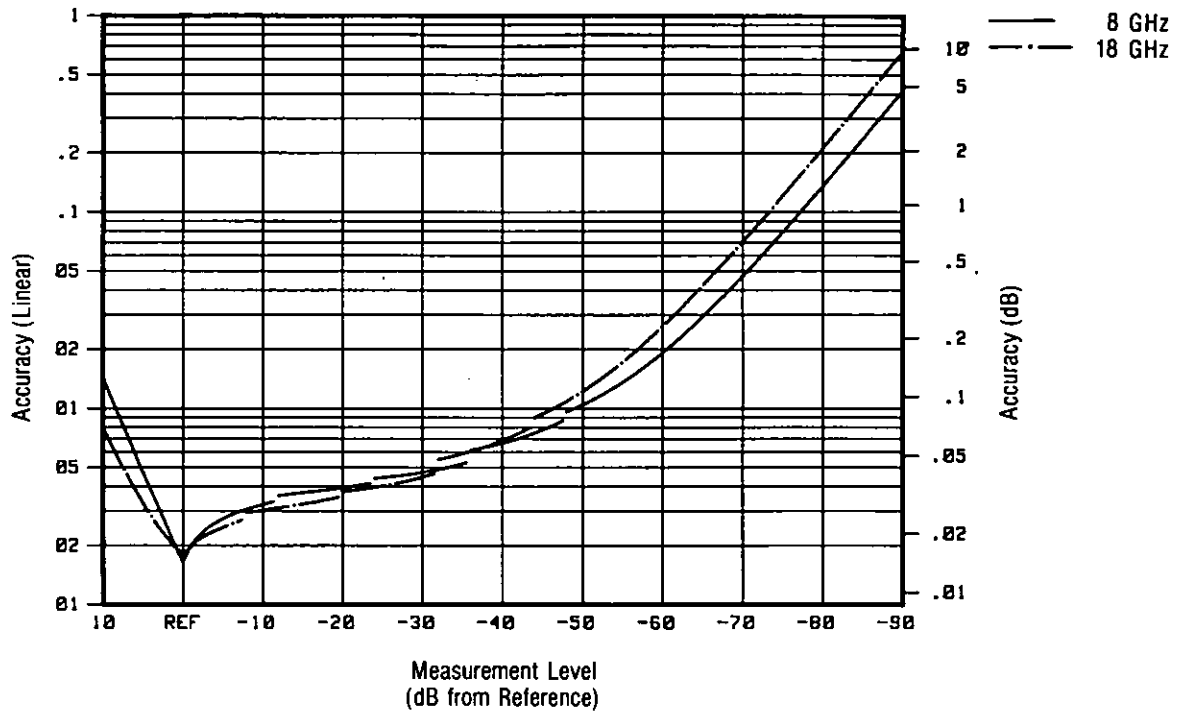
¹¹ See Section III, Operation, in this Operating and Service Manual for considerations in achieving maximum dynamic range.

¹² These dBm power level numbers are at the IF input to the HP 8510A, not at the test set test ports.

Table 1-2. Specifications for HP 8510 with HP 8512A Test Set (Cont'd)

Graphics Data of System Dynamic Accuracy Error. Magnitude and phase measurement dynamic accuracy versus signal level is due to the combination of the individual specified factors listed in the previous paragraphs. These measurable factors are combined by vector error analysis using the worst-case method. This combination is shown on the following page in two data graphs, one graph for phase measurement uncertainty and one for magnitude measurement uncertainty.

Worst-case Magnitude Dynamic Accuracy Error



Worst-case Phase Dynamic Accuracy Error

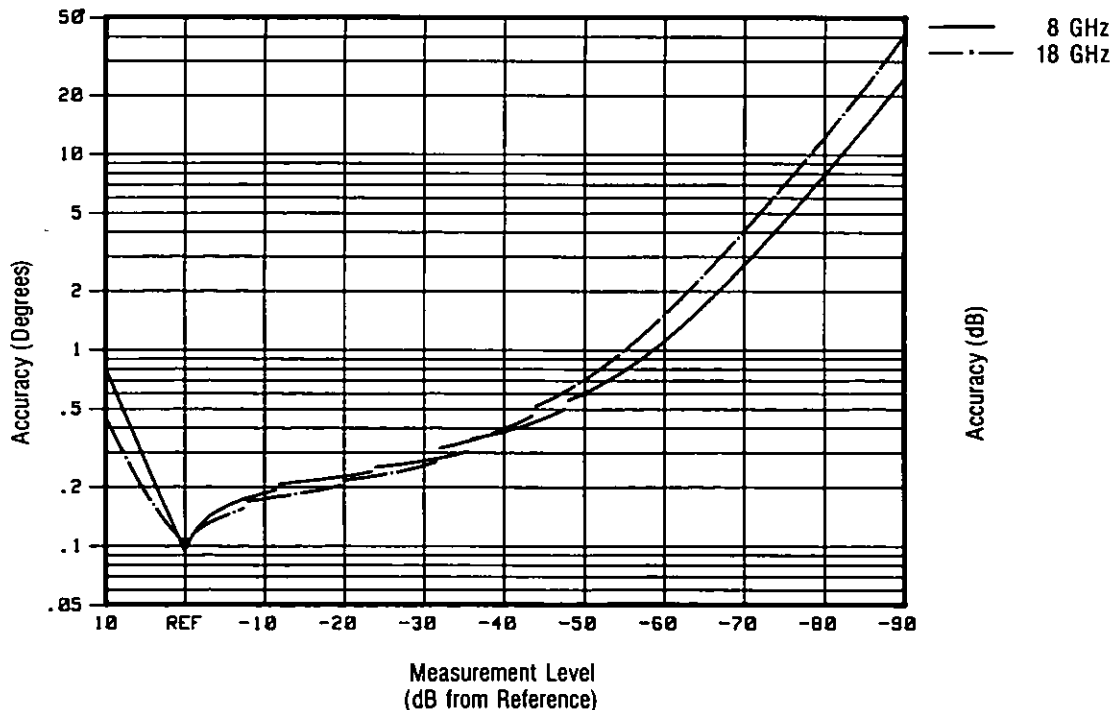


Table 1-2. Specifications for HP 8510 with HP 8512A Test Set (Cont'd)

System Flow Graph and Equations

The HP 8510 system error model flow graph and equation are described in the following paragraphs. The flow graph shows the source of errors for the HP 8512A and HP 8510A. The table on page 1-9/1-10 describes each of these error terms and lists the uncorrected and corrected values.

Using the linear error terms in the error-corrected column of the table, and the nominal S-Parameter data of the device under test, the following equations calculate the total error-corrected measurement uncertainty with a confidence factor of 99.9%. The procedure for using the equations is as follows:

1. Convert the S-Parameters of the device under test to their linear absolute magnitude.
2. Look up the absolute magnitude of the linear error terms from the table on page 1-9.
3. The magnitude dynamic accuracy term "A" must be read from the graph on page 1-13. Be sure to use the linear scale.
4. Combine the above three sets of errors using the equations below.

System Flow Graph

NOTE

The individual terms are as defined in the table on page 1-9.

Table 1-2. Specifications for HP 8510 with HP 8512A Test Set (Cont'd)

Total Transmission Magnitude Uncertainty (E_{tm})

$$E_{tm}(\text{linear}) = V_t + S_{21} \times T_{td}(\text{magnitude}) ; \text{ and}$$

$$E_{tm}(\text{log}) = 20 \log(1 \pm E_{tm}/S_{21})$$

where

$$V_t = S_t + \sqrt{W_t^2 + X_t^2 + Y_t^2 + Z_t^2}$$

$$S_t = \text{Systematic Error} = C + T_t S_{21} + M_s S_{11} S_{21} + M_l S_{22} S_{21} + A S_{21}$$

$$W_t = \text{Random low-level noise} = 3N_l$$

$$X_t = \text{Random high-level noise} = 3N_h S_{21}$$

$$Y_t = \text{Random Port-1 repeatability} = R_{t1} S_{21} + R_{r1} S_{11} S_{21}$$

$$Z_t = \text{Random Port-2 repeatability} = R_{t2} S_{21} + R_{r2} S_{22} S_{21}$$

Total Transmission Phase Uncertainty (E_{tp})

$$E_{tp} = \sin^{-1}(V_t/S_{21}) + S_{t2} + T_{td}(\text{phase})$$

Total Reflection Magnitude Uncertainty (E_{rm})

$$E_{rm}(\text{linear}) = V_r + S_{11} \times T_{rd}(\text{magnitude}) ; \text{ and}$$

$$E_{rm}(\text{log}) = 20 \log(1 \pm E_{rm}/S_{11})$$

where

$$V_r = S_r + \sqrt{W_r^2 + X_r^2 + Y_r^2 + Z_r^2} ; \text{ and}$$

$$S_r = \text{Systematic Error} = D + T_r S_{11} + M_s S_{11}^2 + M_l S_{21} S_{12} + A S_{11}$$

$$W_r = \text{Random low-level noise} = 3N_l$$

$$X_r = \text{Random high-level noise} = 3N_h S_{11}$$

$$Y_r = \text{Random Port-1 repeatability} = R_{r1} + 2R_{t1} S_{11} + R_{r1} S_{11}^2$$

$$Z_r = \text{Random Port-2 repeatability} = R_{r2} S_{21} S_{12}$$

Total Reflection Phase Uncertainty (E_{rp})

$$E_{rp} = \sin^{-1}(V_r/S_{11}) + T_{rd}(\text{phase})$$

Table 1-2. Specifications for HP 8510 with HP 8512A Test Set (Cont'd)

Expected System Performance

The following graphs show measurement uncertainty after accuracy enhancement for both reflection (S_{11}) and transmission (S_{21}) measurement of devices with precision 7mm connectors. The uncertainty is derived by computing the contribution of each source of error by using the equations on page 1-15 and the table on page 1-9. The resultant values are combined in the following graphs. These graphs are for a confidence factor of 99.9%. The following assumptions are made:

Reflection: S_{21} and S_{12} of the device under test is 0.

Transmission: S_{11} and S_{22} of the device under test is 0.

Cable Stability S_{t2} and System Drift T_{td} and $T_{rd} = 0$.

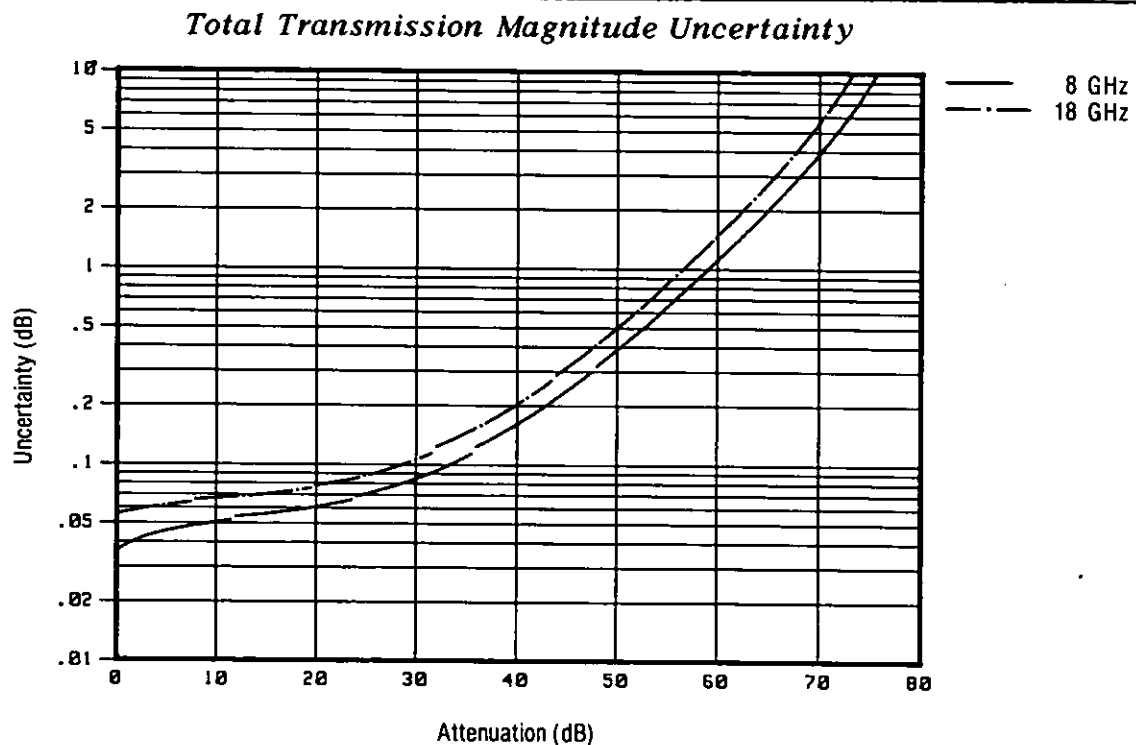


Table 1-2. Specifications for HP 8510 with HP 8512A Test Set (Cont'd)

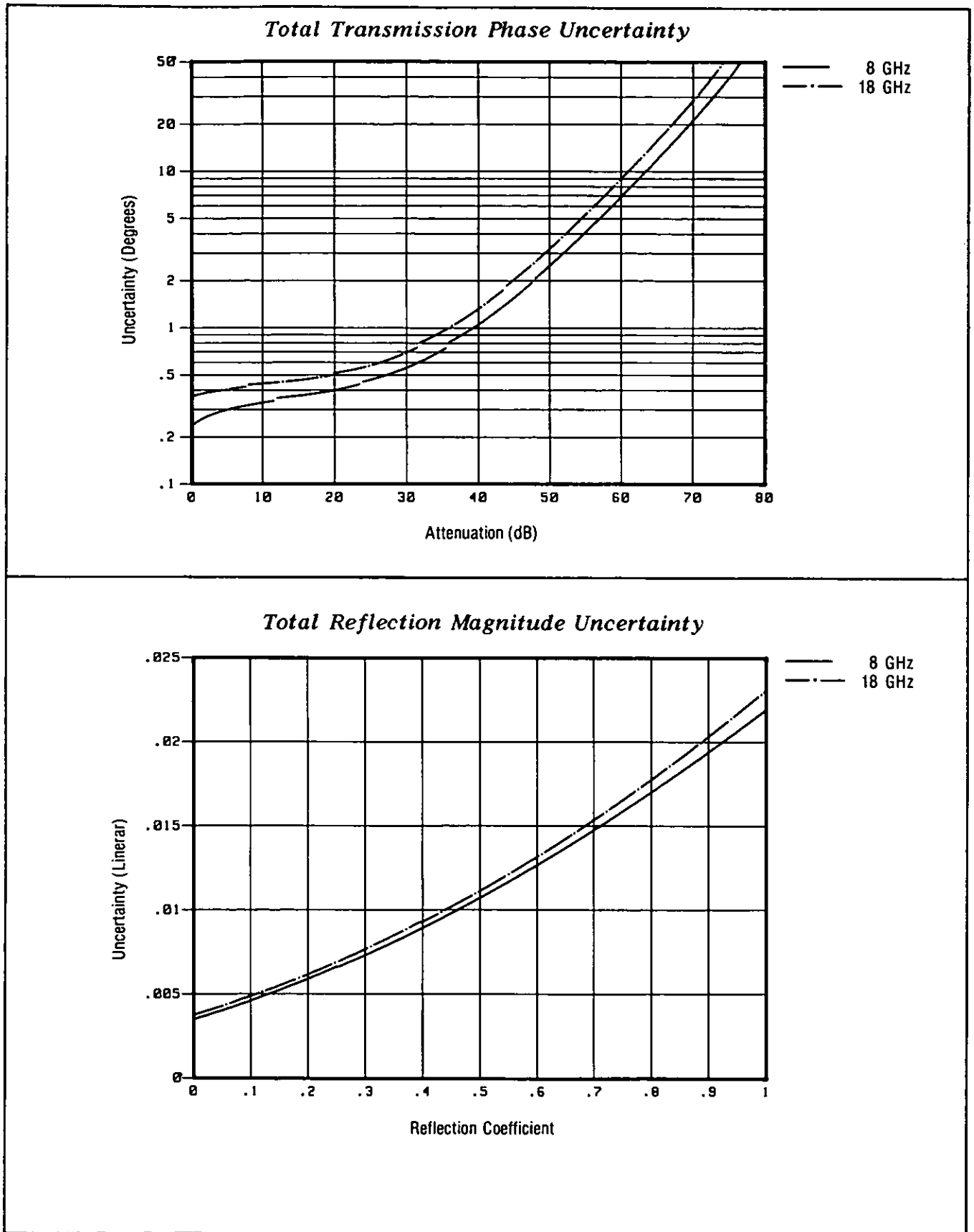
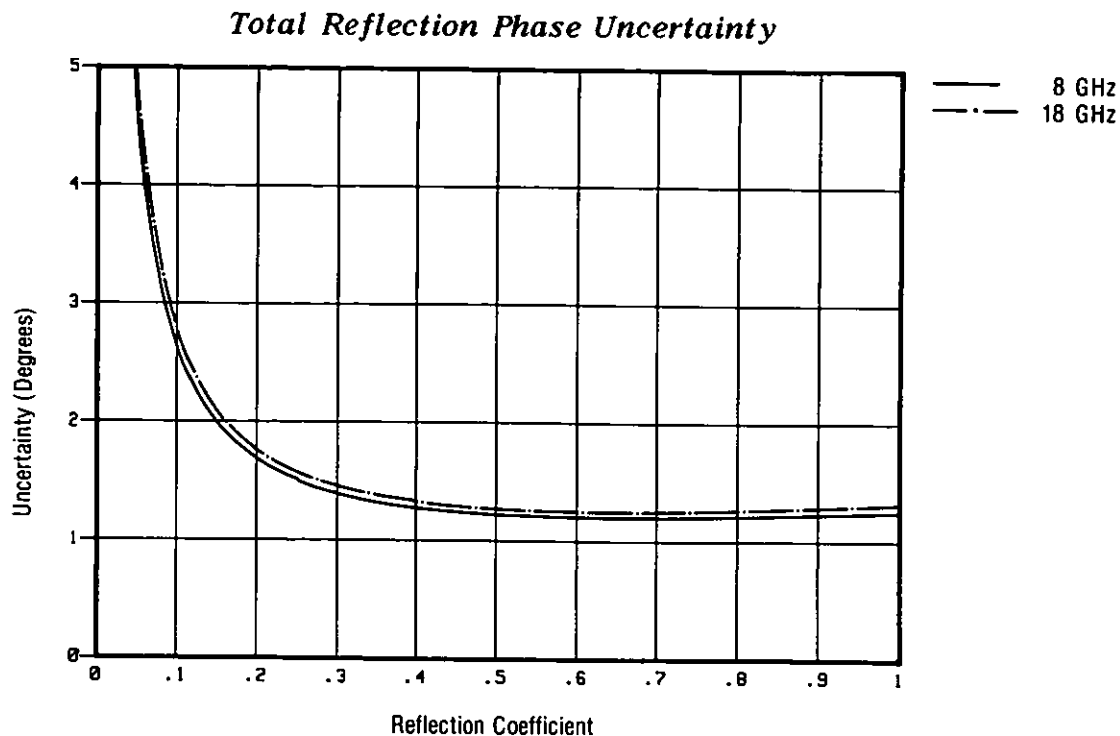


Table 1-2. Specifications for HP 8510 with HP 8512A Test Set (Cont'd)



GROUP DELAY CHARACTERISTICS

Aperture:

Minimum Aperture (Hz) = Frequency Span (Hz)/(no. of points - 1)

Maximum Aperture (Hz) = 20% of Frequency Span (Hz)

Range:

The maximum delay is limited to measuring no more than ± 180 degrees of phase change within the minimum aperture.

$$\text{Range} = \frac{180\text{deg}}{360 (\text{Minimum Aperture})} = \frac{1}{2} \times \frac{\text{Number of Points} - 1}{\text{Frequency Span (Hz)}}$$

EXAMPLE: Frequency Span = 40 MHz
 Number of Points = 201
 Minimum Aperture = 200 kHz
 Range = 2.5 us

Table 1-2. Specifications for HP 8510 with HP 8512A Test Set

Group Delay High-Level Noise:

Continuous measurement of a through connection displays RMS noise as follows:

$$\text{Noise} = \frac{0.004 \times N_h \text{ (the high-level phase noise)}}{\text{Aperture (Hz)}} + \frac{1.41 \times \text{Delay (sec)} \times \text{Residual FM (10 kHz BW, Hz)}}{\text{Aperture (Hz)}}$$

Accuracy:

Delay accuracy is a function of the uncertainty of the phase change and the frequency linearity. The following formula can be used to determine the accuracy, in seconds, of a specific group delay measurement:

$$\text{Accuracy} = \pm \frac{0.003 \times \text{Phase Accuracy (degrees)}^{12}}{\text{Aperture (Hz)}} + \frac{[\text{Delay (sec)}] \times [\text{linearity (Hz)}]}{\text{Aperture (Hz)}}$$

EXAMPLE: Given is a system with an HP 8340A sweeper operating in stepped sweep mode with 101 points per sweep over a 50 MHz span. The device has 50 ns of delay and very little amplitude change over the passband. In this case, the HP 8340A linearity is 4 Hz (resolution).

$$\text{Accuracy} = \pm \frac{0.003 \times [0.02 \text{ deg}] + [50\text{ns}] \times [4\text{Hz}]}{50\text{MHz}/100\text{points}}$$

$$\text{Accuracy} = \pm 0.12 \text{ ns}$$

¹² Phase accuracy can be any of the following types:

- a) **Incremental Phase Accuracy (Phase vs. Phase)** for narrow band applications where very little changes in amplitude occur (page 1-12).
- b) **Worst-Case Phase Dynamic Accuracy** for narrow band applications where significant amplitude changes occur (page 1-13).
- c) **Total Transmission Phase Uncertainty (E_{tp})** for the general case (page 1-15).

Table 1-3. Specifications for HP 8510 with HP 8514A Test Set

INTRODUCTION AND GENERAL CHARACTERISTICS

The combination of an HP 8514A test set with an HP 8510A network analyzer and an HP 8340A sweeper forms a system for making reflection (S_{11} and S_{22}) and transmission (S_{21} and S_{12}) measurements over the frequency range of 500 MHz to 18 GHz.

Specification Assumptions

The specifications of this table assume that the following conditions are met:

- The RF source is an HP 8340A synthesized sweeper operating in stepped sweep mode.
- The temperature is in the range of 0° C to 55° C, except where noted.
- Reflection calibration and measurement is done at the test port (Port 1 or Port 2). The transmission return path for transmission calibration and measurement is through an HP 85132B test port cable set to the opposite port. Load match measurements are taken directly at the test ports.
- +10 dBm power level at the RF source output.
- Calibration is performed with an HP 85050A 7mm calibration kit for a full two-port calibration.
- Verification procedures use the HP 85051A 7mm verification kit.

Frequency Range

Reflection and Transmission: 500 MHz to 18.0 GHz (reduced dynamic range below 500 MHz; typically 30 dB of loss in dynamic range at 45 MHz)

Test Ports

Connector Type: Precision 7mm Sexless

Impedance: 50 ohms nominal

Nominal Operating Power Level:

Test Port 1: +3 dBm at 45 MHz -0.4 dB/GHz

RF Input Connector

Connector Type: Precision 3.5mm Female

Damage Input Level: +20 dBm

Minimum and Maximum Reference Channel Power

Minimum Input Power at rear-panel RF INPUT port (for Reference Channel Phase Lock): -3 dBm

Maximum Input Power at rear-panel RF INPUT port (level before 0.1 dB compression): +16 dBm

Table 1-3. Specifications for HP 8510 with HP 8514A Test Set (Cont'd)

HARDWARE AND SYSTEM PERFORMANCE SPECIFICATIONS

Table of System Errors⁹

The following table lists specifications for various sources of system error. Values are listed for uncorrected measurements, corrected measurements after accuracy enhancement, and verification limits. Data in the column labeled "Residual After Accuracy Enhancement" is measured accurately at the factory with special standards that are traceable to the National Bureau of Standards. Devices in the calibration and verification kits, HP 85050A and HP 85051A, have the precision and accuracy to calibrate the system and to verify the source of error to the limits shown in the "Verification Limits" column.

Table 1-3. Specifications for HP 8510 with HP 8514A Test Set (Cont'd)

Symbol	Error Source	Uncorrected		Residual After Accuracy Enhancement ^{1,6}				Verification Limits ^{1,2,6}	
		0.5-8GHz	8-18GHz	0.5-8GHz		8-18GHz		0.5-8GHz	8-18GHz
		dB or Deg	dB or Deg	Linear	dB	Linear	dB	dB	dB
D	Directivity	-26dB	-22dB	.0032	-50dB	.0032	-50dB	-44dB	-44dB
M _s	Source Match	-15dB	-9dB	.01	-40dB	.01	-40dB	-37dB	-37dB
M _l	Load Match	-15dB	-9dB	.01	-40dB	.01	-40dB	-40dB	-40dB
T _r	Reflection Tracking	±1dB ³	±1dB ³	.006	±.05dB	.006	±.05dB	±.05dB	±.05dB
T _t	Transmission Tracking	±1dB	±1dB	.0036	±.03dB	.007	±.06dB	±.03dB	±.06dB
C	Crosstalk ⁴	-80dB	-80dB	.000032	-90dB	.000032	-90dB	-90dB	-90dB
R _{r1}	Port 1 Reflection Connector Repeatability (Typical)	-70dB	-65dB	.00032	-70dB	.0006	-65dB		
R _{t1}	Port 1 Transmission Connector Repeatability (Typical)	-70dB	-65dB	.00032	-70dB	.0006	-65dB		
R _{r2}	Port 2 Reflection Connector Repeatability (Typical)	-70dB	-65dB	.00032	-70dB	.0006	-65dB		
R _{t2}	Port 2 Transmission Connector Repeatability (Typical)	-70dB	-65dB	.00032	-70dB	.0006	-65dB		
N _l	Low-Level Noise (Noise Floor) ⁵	-71dB	-67dB	.000028	-91dB	.000045	-87dB	-91dB	-87dB
N _h	High-Level Noise ⁷ Magnitude	.015dB	.02dB	.00018	.0015dB	.00023	.002dB	.0015dB	.002dB
	Phase	0.1Deg	0.15Deg						
A	8510A Magnitude Dynamic Accuracy Error (Primarily IF and Detector)	Refer to magnitude curve on page 1-27.							
S _{t1}	Port 1 Cable Transmission Phase Stability ⁸	.05 × f(GHz), Degrees							
S _{r1}	Port 1 Cable Reflection Stability ⁸	-70dB	-60dB	.00032	-70dB	.001	-60dB		
S _{t2}	Port 2 Cable Transmission Phase Stability ⁸	.05 × f(GHz), Degrees							
S _{r2}	Port 2 Cable Reflection Stability ⁸	-70dB	-60dB	.00032	-70dB	.001	-60dB		
T _{td}	Transmission Tracking Drift (Typical) Magnitude	.001 × Δ° C, Linear							
	Phase	(0.1 + .01 × f(GHz)) × Δ° C, Degrees							
T _{rd}	Reflection Tracking Drift (Typical) Magnitude	.001 × Δ° C, Linear							
	Phase	(0.1 + .01 × f(GHz)) × Δ° C, Degrees							

*Table 1-3. Specifications for HP 8510 with HP 8514A Test Set
(Cont'd)*

Footnotes for Table of System Errors

- 1 Accuracy enhancement is achieved using the HP 85050A 7mm calibration kit for a full two-port calibration. The environmental temperature is $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$ at calibration; $\pm 1^{\circ}\text{C}$ from the calibration temperature must be maintained for valid calibration and verification.
- 2 Numbers shown are for verification tests using devices in the HP 85050A precision 7mm calibration kit and the HP 85051A precision 7mm verification kit. For other standards, use appropriate uncertainty. Parameters of the system are measured at the factory with one set of standards. These same parameters may be tested again in the field with the verification procedures, using a second set of standards, the calibration and verification kits. The measured verification values will always have more uncertainty than the calibration and verification standards. For example, if the parameter value in the system is $>50\text{ dB}$ and the parameter present in the calibration device is $>50\text{ dB}$, then the highest measured value with negligible ambiguity is 6 dB less, or 44 dB.
- 3 Fine-grain ripple that compares the smoothed trace to a normal trace, excluding 2 dB slope in magnitude response from 3.0 GHz to 18 GHz, and rolloff below 3 GHz for magnitude; typically -9 dB at 0.5 GHz.
- 4 Averaging factor of 1024 is applied.
- 5 Valid only above 3 GHz due to coupler rolloff. Low-level noise (noise floor) is measured relative to an S_{21} through measurement in a 10 kHz bandwidth and 20% of span smoothing.
- 6 An averaging factor of 128 is applied.
- 7 High-level noise is an RMS measurement taken of a continuous measurement of a short circuit or a through connection.
- 8 The cable phase stability term was arrived at by bending it out perpendicular to the front panel and then reconnecting it. The stability will be much better with less flexing applied.
- 9 Current HP-supplied performance verification tests verify the sum total of these individual specifications by verifying transmission and reflection magnitude and phase uncertainties E_{tm} , E_{rm} , E_{tp} , and E_{rp} , as they are defined in the equation on page 1-29. These detailed performance verification tests are found in Section IV of this Operating and Service Manual.

Table 1-3. Specifications for HP 8510 with HP 8514A Test Set (Cont'd)

Source of System Dynamic Accuracy Errors¹⁰

The factors affecting dynamic accuracy listed below are primarily a function of the IF/detector except for compression. In order to measure these values, some of the system cables must be disconnected to gain access to the individual instruments.

Compression ≤ 0.1 dB:¹¹ +10 dBm into Port 2

IF Amplifier Gain Accuracy:

IF Amplifier Power Range (dBm) ¹²	Maximum Gain Error (db)
-10 to -34	0
-34 to -46	± 0.005
-46 to -58	± 0.01
-58 to -70	± 0.02
< -70	± 0.03

Detector Circularity Error: ± 0.003 dB peak

Detector dc Offset Error: -100 dBm¹²

IF Residuals: -120 dBm¹²

IF Linearity: ± 0.003 dB

Incremental Phase Accuracy (Phase vs. Phase) at Measurement Reference: ± 0.001 degrees/degree, not to exceed 0.02 degrees peak.

Graphics Data of System Dynamic Accuracy Error: Magnitude and phase measurement dynamic accuracy versus signal level is due to the combination of the individual specified factors listed in the previous paragraphs. These measurable factors are combined by vector error analysis using the worst-case method. This combination is shown on the following page in two graphs of data, one graph for phase measurement uncertainty and one for magnitude measurement uncertainty.

¹⁰ Current HP-supplied performance verification tests verify the sum total of these individual specifications by verifying transmission and reflection magnitude and phase uncertainties E_{tm} , E_{rm} , E_{tp} , and E_{rp} , as they are defined in the equation on page 1-29. These detailed performance verification tests are found in Section IV of this Operating and Service Manual.

¹¹ See Section III, Operation, in this Operating and Service Manual for considerations in achieving maximum dynamic range.

¹² These dBm power level numbers are at the IF input to the HP 8510A, not at the test set test ports.

Table 1-3. Specifications for HP 8510 with HP 8514A Test Set (Cont'd)

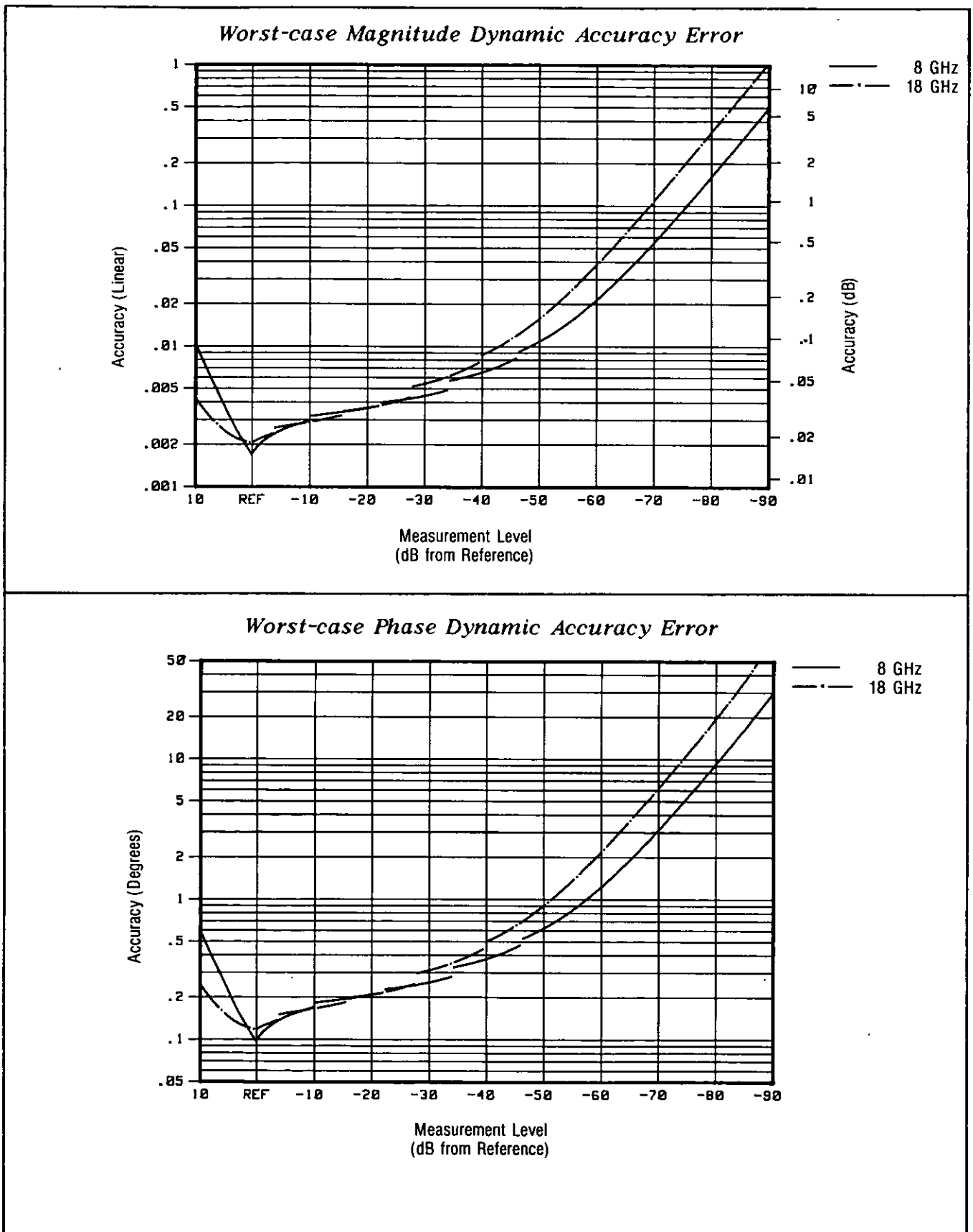


Table 1-3. Specifications for HP 8510 with HP 8514A Test Set (Cont'd)

System Flow Graph and Equations

The HP 8510 system error model flow graph and equation are described in the following paragraphs. The flow graph shows the source of errors for the HP 8514A and HP 8510A. The table on page 1-23 describes each of these error terms and lists the uncorrected and corrected values.

Using the linear error terms in the error-corrected column of the table, combined with the nominal S-Parameter data of the device under test, the following equations calculate the total error-corrected measurement uncertainty with a confidence factor of 99.9%. The procedure for using the equations is as follows:

1. Convert the S-Parameters of the device under test to their linear absolute magnitude.
2. Look up the absolute magnitude of the linear error terms from the table on page 1-23.
3. The magnitude dynamic accuracy term "A" must be read from the graph on page 1-27. Be sure to use the linear scale.
4. Combine the above three sets of errors using the equations below.

System Flow Graph

NOTE

The individual terms are as defined in the table on page 1-23.

Table 1-3. Specifications for HP 8510 with HP 8514A Test Set (Cont'd)

Total Transmission Magnitude Uncertainty (E_{tm})

$$E_{tm} = V_t + S_{21} \times T_{td}(\text{mag}); \text{ and}$$

$$E_{tm}(\log) = 20 \log(1 \pm E_{tm}/S_{21})$$

where

$$V_t = S_t + \sqrt{W_t^2 + X_t^2 + Y_t^2 + Z_t^2}$$

$$S_t = \text{Systematic Error} = C + T_t S_{21} + (M_s + S_{r1}) S_{11} S_{21} + (M_l + S_{r2}) S_{22} S_{21} + A S_{21}$$

$$W_t = \text{Random low-level noise} = 3N_l$$

$$X_t = \text{Random high-level noise} = 3N_h S_{21}$$

$$Y_t = \text{Random Port-1 repeatability} = R_{t1} S_{21} + R_{r1} S_{11} S_{21}$$

$$Z_t = \text{Random Port-2 repeatability} = R_{t2} S_{21} + R_{r2} S_{22} S_{21}$$

Total Transmission Phase Uncertainty (E_{tp})

$$E_{tp} = \sin^{-1}(V_t/S_{21}) + T_{td}(\text{phase}) + S_{t1} + S_{t2}$$

Total Reflection Magnitude Uncertainty (E_{rm})

$$E_{rm} = V_r + S_{11} \times T_{rd}(\text{mag}); \text{ and}$$

$$E_{rm}(\log) = 20 \log(1 \pm E_{rm}/S_{11})$$

where

$$V_r = S_r + \sqrt{W_r^2 + X_r^2 + Y_r^2 + Z_r^2}$$

$$S_r = \text{Systematic Error} = (D + S_{r1}) + T_r S_{11} + (M_s + S_{r1}) S_{11}^2 + (M_l + S_{r2}) S_{21} S_{12} + A S_{11}$$

$$W_r = \text{Random low-level noise} = 3N_l$$

$$X_r = \text{Random high-level noise} = 3N_h S_{11}$$

$$Y_r = \text{Random Port-1 repeatability} = R_{r1} + 2R_{t1} S_{11} + R_{r1} S_{11}^2$$

$$Z_r = \text{Random Port-2 repeatability} = R_{r2} S_{21} S_{12}$$

Total Reflection Phase Uncertainty (E_{rp})

$$E_{rp} = \sin^{-1}(V_r/S_{11}) + T_{rd}(\text{phase}) + 2S_{t1}$$

Table 1-3. Specifications for HP 8510 with HP 8514A Test Set (Cont'd)

Expected System Performance

The following graphs show measurement uncertainty after accuracy enhancement for both reflection (S_{11}) and transmission (S_{21}) measurement of devices with precision 7mm connectors. The uncertainty is derived by computing the contribution of each source of error by using the equations on page 1-29 and the table on page 1-23. The resultant values are combined in the following graphs. These graphs are for a confidence factor of 99.9%. The following assumptions are made:

Reflection: S_{21} and S_{12} of the device under test is 0.

Transmission: S_{11} and S_{22} of the device under test is 0.

Cable Stability S_{t1} , S_{r1} , S_{t2} , and S_{r2} , and System Drift T_{rd} and $T_{td} = 0$.

Total Transmission Magnitude Uncertainty

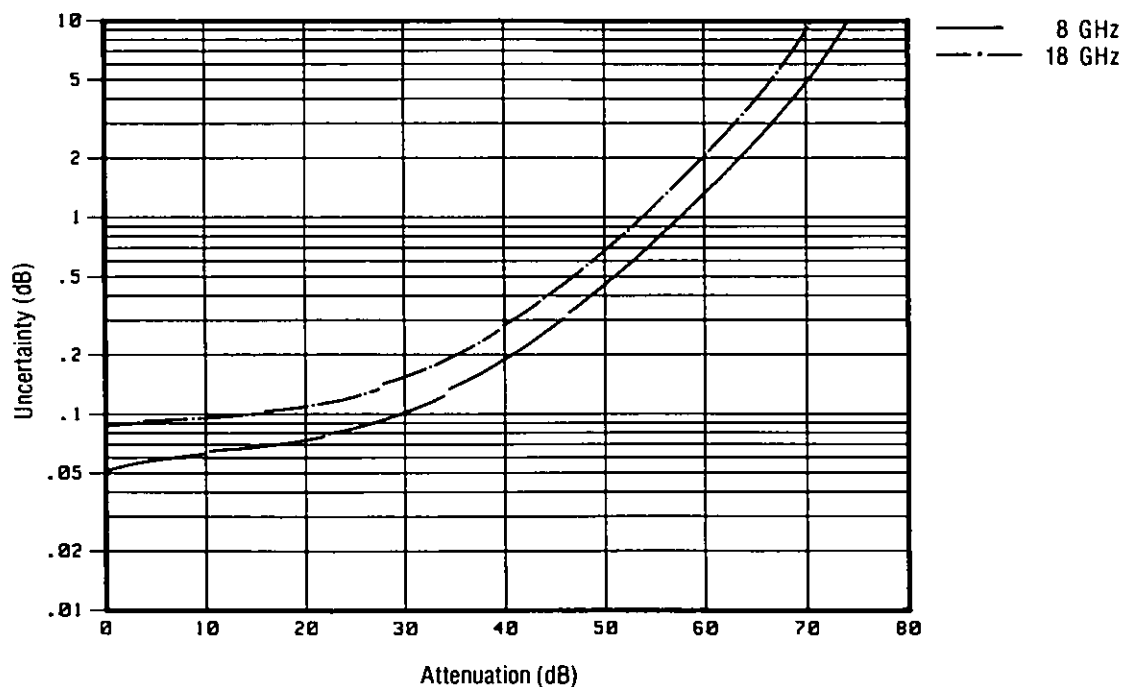


Table 1-3. Specifications for HP 8510 with HP 8514A Test Set (Cont'd)

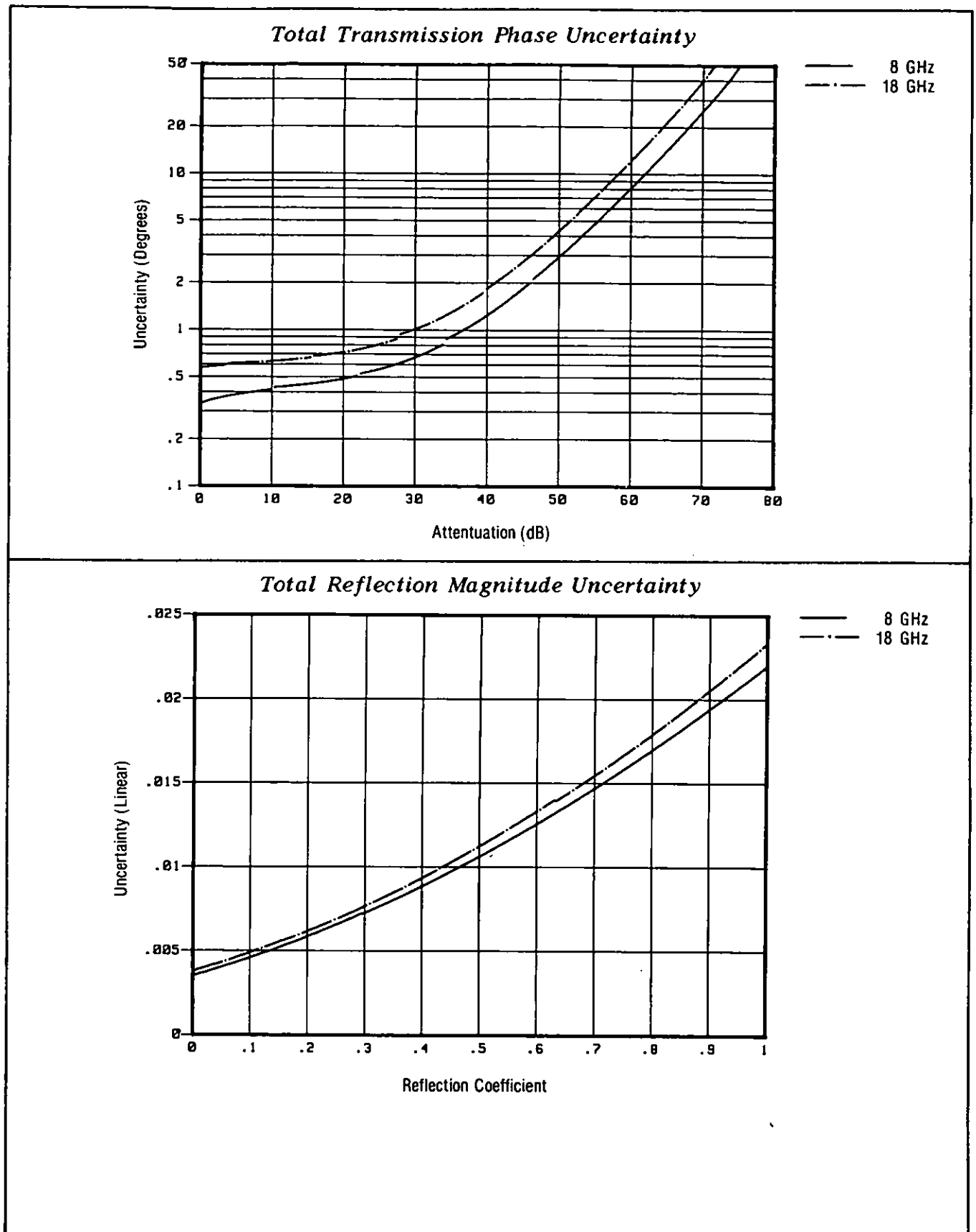
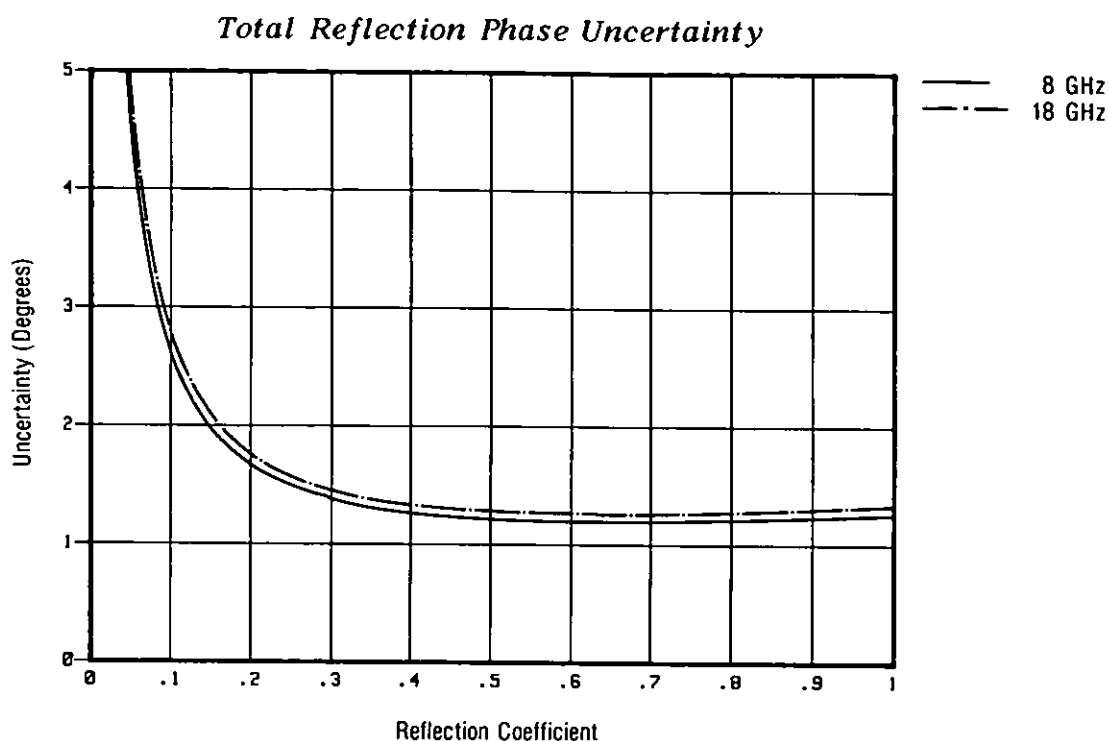


Table 1-3. Specifications for HP 8510 with HP 8514A Test Set (Cont'd)

**GROUP DELAY CHARACTERISTICS****Aperture:**

Minimum Aperture (Hz) = Frequency Span (Hz)/(No. of Points - 1)

Maximum Aperture (Hz) = 20% of Frequency Span (Hz)

Range:

The maximum delay is limited to measuring no more than ± 180 degrees of phase change within the minimum aperture.

$$\text{Range} = \frac{180\text{deg}}{360 \times (\text{Minimum Aperture})} \times \frac{1}{2} = \times \frac{\text{No. of Points} - 1}{\text{Frequency Span (Hz)}}$$

EXAMPLE: Frequency Span = 40 MHz
 Number of Points = 201
 Minimum Aperture = 200 kHz
 Range = 2.5 us

Table 1-3. Specifications for HP 8510 with HP 8514A Test Set (Cont'd)

Group Delay High-Level Noise:

Continuous measurement of a through connection displays RMS noise as follows:

$$\text{Noise} = \frac{0.004 \times N_h \text{ (the high-level phase noise)}}{\text{Aperture (Hz)}} + \frac{1.41 \times \text{Delay (sec)} \times \text{Residual FM (10 kHz BW, Hz)}}{\text{Aperture (Hz)}}$$

Accuracy:

Delay accuracy is a function of the uncertainty of the phase change and the frequency linearity. The following formula can be used to determine the accuracy, in seconds, of a specific group delay measurement:

$$\text{Accuracy} = \pm \frac{0.003 \times \text{Phase Accuracy (degrees)}^{12}}{\text{Aperture (Hz)}} + \frac{[\text{Delay (sec)}] \times [\text{linearity (Hz)}]}{\text{Aperture (Hz)}}$$

EXAMPLE: Given is a system with an HP 8340A sweeper operating in stepped sweep mode with 101 points per sweep over a 50 MHz span. The device has 50 ns of delay and very little amplitude change over the passband. In this case, the HP 8340A linearity is 4 Hz (resolution).

$$\text{Accuracy} = \pm \frac{0.003 \times [0.02 \text{ deg}] + [50\text{ns}] \times [4\text{Hz}]}{50\text{MHz}/100\text{points}}$$

$$\text{Accuracy} = \pm 0.12 \text{ ns}$$

¹² Phase accuracy can be any of the following types:

- a) **Incremental Phase Accuracy (Phase vs. Phase)** for narrow band applications where very little changes in amplitude occur (page 1-26).
- b) **Worst-Case Phase Dynamic Accuracy** for narrow band applications where significant amplitude changes occur (page 1-27).
- c) **Total Transmission Phase Uncertainty (E_{tp})** for the general case (page 1-29).

Table 1-4. Supplemental Characteristics for HP 8510 System

MEASUREMENT

Number of Channels

Two measurement channels are available.

Parameters

S_{11} , S_{21} , S_{12} , S_{22} ; Test and Reference Channels a1, a2, b1, and b2.

Domains (available with Option 010 only)

Frequency, Time, and Auxiliary Voltage (rear panel output acting as device stimulus; range is $\pm 10\text{Vdc}$)

Formats

Cartesian:

- Log magnitude
- Linear magnitude
- Phase
- Group delay (with variable aperture)
- SWR
- Real part of complex parameter
- Imaginary part of complex parameter

Smith Chart:

- Normal ($R+jX$)
- Inverted ($G+jB$)

Polar:

- Log magnitude marker
- Linear magnitude marker
- Real and imaginary marker

Data Points/Sweep

Selectable from 51, 101, 201, or 401

Data Markers

Five independent data markers read out the value of the formatted parameter and stimulus (frequency, time, or auxiliary voltage).

Resolution (Readout)

Magnitude:

- Log: 0.0001dB to 0.1 dB (5 digits)
- Linear: 0.001×10^{-12} to 0.1 units (5 digits)

Phase:

- 0.001×10^{-12} to 0.1 degrees (5 digits)

Group Delay:

- 0.001×10^{-12} to 0.1 seconds (5 digits)

Functions

Marker to maximum/minimum and marker delta

Table 1-4. Supplemental Characteristics for HP 8510 System (Cont'd)

DATA ENHANCEMENT, VECTOR ERROR CORRECTION

Calibrations

Frequency Response. Simultaneous magnitude and phase correction of frequency response errors in either reflection or transmission measurements.

One Port. Correction of Port 1 or Port 2 directivity, source match, and reflection frequency response errors.

Two Port. Full twelve-term error correction of Port 1 and Port 2 directivity, source match, and reflection frequency response, as well as forward and reverse load match, transmission frequency response, and crosstalk. Crosstalk calibration can be omitted.

Calibration Standards

The type of standards used during the calibration procedure can be defined. Also, data can be entered to define the standards (e.g., open circuit capacitance coefficients, offset short length, fixed or sliding load, etc.).

Data for a group of defined standards (called a cal kit) may be stored in memory or on a cassette tape via the built-in tape drive. Data for two cal kits may be stored in memory at any one time, and up to eight sets of calibration data may be stored on a single cassette tape.

The definitions of the standards contained in the HP 85050A 7mm calibration kit and the HP 85052A 3.5mm calibration kit are stored in the cal kit memory in the HP 8510A at time of shipment from the factory.

Other Capabilities

Reference Plane Extension. A reference plane of measurement can be redefined at a plane other than Port 1 or Port 2 of the test set. A new reference plane is defined in seconds of delay from the test set port and can range between ± 1 second.

Set Z_0 . Characteristic impedance of measurement can be redefined to other than 50 ohms.

Data Averaging. Similar in operation to a variable bandwidth IF filter, this function computes the running average of a number of data traces (defined by the averaging factor). Averaging factors range from 1 to 4096 in powers of 2. In ramp sweep mode, each new trace is weighted by a factor of $1/n$ (n = averaging factor). In stepped sweep mode, each data point is averaged n times.

Trace Smoothing. Similar to a variable bandwidth video filter, this function computes the moving average of adjacent data points. The smoothing aperture defines the trace width (number of data points) to be averaged, and ranges from 0.25% to 20% of the trace width. This function also sets the aperture for group delay measurements.

Table 1-4. Supplemental Characteristics for HP 8510 System (Cont'd)

SOURCE CONTROL

Sweep Limit

Sets Start/Stop or Center/Span limits of the stimulus parameter (frequency, time, or auxiliary voltage). Also, stimulus can be set to a single point (CW mode in frequency domain).

Sweep Type

Sets up either Ramp (analog), Stepped (with HP 8340A only), or Single data point type of sweep.

Sweep Mode

Sets either a Continual, Hold, Single, or Group sweep mode. Also, an alternate sweep mode can be set up.

Sweep Time

From the HP 8510A front panel, source sweep time for ramp sweeps only can be set up. Minimum sweep time is dependent on the number of data points per sweep.

Source Power

From the HP 8510A front panel, source output power level and power slope can be set. Range and accuracy depend on the source. With the S-parameter test sets, you can control incident port signal level by setting the internal attenuators.

DISPLAY CONTROL

CRT Formats

Single channel

Two channel overlay (both traces on one graticule)

Two channel split (each trace on separate graticules)

Trace Functions

Display data: Display current measurement data, memory data, or current measurement and memory data simultaneously.

Trace Math: Vector addition, subtraction, multiplication, or division of current measurement data and memory data.

Scale Resolution

Magnitude:

Log format (dB/div): 0.001 to 500

Linear formats (units/div): 10×10^{-12} to 500

Phase:

Cartesian (degrees/div): 10×10^{-12} to 500

Polar (degrees/display graticule): 45

Group delay (seconds/div): 10×10^{-12} to 2

Table 1-4. Supplemental Characteristics for HP 8510 System (Cont'd)

Reference Value

Magnitude:

Log format: $\pm 500\text{dB}$

Linear formats: ± 500 units

Phase: ± 500 degrees

Group Delay: ± 1 second

Reference Position

Ranges from the 0 (bottom) to 10 (top) graticule position can be set.

Auto

The HP 8510A automatically selects Scale Resolution and Reference Value to position the trace on the graticule.

Electrical Delay

The HP 8510A can offset measured phase or group delay data by a defined amount of electrical delay in seconds. The operation is similar to an electronic line stretcher. The amount of electrical delay can range between ± 1 second.

INSTRUMENT CONTROL

Control Knob, Step Keys, Data ENTRY Keyboard, and =Marker Key

Instrument parameters may be set in one or all of four ways. The control knob allows for continuous adjustment of a parameter, while the data entry keyboard is used to enter an exact function value. For incrementing or decrementing parameter values, the step keys can be used. With the =Marker key, you can set the function to the active marker value. (Example: Reference value =Marker sets the reference value to the value of the active marker.)

STORAGE

Instrument State

Up to eight separate instrument states can be stored in eight SAVE registers via the SAVE menu. Each instrument state can then be recalled via the RECALL menu. SAVE register eight is reserved for the power up state, which can be defined by the user.

Trace Storage

Four traces of data can be stored in the trace memories.

Calibration Storage

Up to eight separate calibration sets may be stored.

Table 1-4. Supplemental Characteristics for HP 8510 System (Cont'd)

Tape Unit

The built-in tape unit may be used to store and re-store different types of data on an HP 98200A cassette tape cartridge.¹

Data Types

Instrument State (one or all eight)
Trace Memory (one or all four)
Calibrations (one or all)
Calibration Kit Data
CRT Graphics Data
Internal Data (raw, data, formatted)

Data is stored in a block format (2K bytes/block). For example, trace memory would take one block of storage space on a tape cassette (85 blocks/tape).

DATA PLOTTING

Hard copy plots are automatically produced by the HP 8510 system when used with a digital plotter that is compatible with HPGL (HP graphics language).

Formats

Full- or quarter-page CRT plot.

Functions

Plot All, Trace(s), Graticule(s), Marker(s), or Text. Also, the HP 8510 system can plot operating and system parameters.

REMOTE PROGRAMMING

Interface

HP-IB interface operates according to IEEE 488-1978 and IEC-625 standards.

System Interface

The HP 8510 system interface is an I/O port used exclusively by the HP 8510 to control and extract information from the other instruments in the system (RF source, digital plotter, etc.).

Addressing

The HP-IB address of the HP 8510 system can be verified or set from the front panel via the SYSTEM menu and can range from 0 to 30 decimal (factory set at 16 for HP 8510A and 20 for test set).

¹ For the HP 98200A Tape Cartridge, the environment temperature is 0° C to 45° C (operating) and -40° C to 60° C (storage). The environmental humidity is limited to 20% to 80% relative humidity, noncondensing.

Table 1-4. Supplemental Characteristics for HP 8510 System (Cont'd)

Pass-Through Address

Instruments connected to the HP 8510 system interface bus are talked to via the pass-through address.

Transfer Formats

Binary (48-bit floating point complex format)
ASCII
32/64-bit IEEE 754 floating point format

Speed

Binary (401 point trace): 240 msec, typical
ASCII (401 point trace): 1.40 sec, typical
64-bit IEEE 754 (401 point trace): 440 msec, typical

User-Accessible Graphics

Using a subset of the HPGL, vector or text graphics may be written on the HP 8510A CRT. Approximately 1.5K bytes of data can be stored at one time (4 bytes per vector and 2 bytes per character). It is accessed via the pass-through address.

Interface Function Codes

Using IEEE-488-1978 mnemonics, the HP 8510 system has the following capabilities:

SH1: Source handshake, complete capability.
AH1: Acceptor handshake, complete capability.
T6: Talker, capable of basic talker, serial poll, and unaddress if MLA.
TE0: Talker, extended address; no capability.
L4: Listener, capable of basic listener, and unaddress if MTA.
LE0: Listener, extended address; no capability.
SR1: Service request, complete capability.
RL1: Remote local, complete capability.
PP0: Parallel poll, no capability.
DC1: Device clear, complete capability.
DT1: Device trigger, complete capability.
C0: Control capability, no capability.
E1: Electrical specification indicating open collector outputs.

GENERAL

Rear Panel Outputs

DISPLAY OUTPUTS: X, Y, and Z outputs are for auxiliary CRT displays. X, Y: 1 volt full deflection; Z: 0 to +1 volt intensity modulation, -1V to blank. BLANK output (TTL level >+2.4V for blanking) is compatible with most oscilloscopes.

SWEEP IN: Input for sweep voltage from compatible sweep oscillator.

Table 1-4. Supplemental Characteristics for HP 8510 System (Cont'd)

STOP SWEEP: Input for stop sweep signal from compatible sweep oscillator.

10 MHz IN: Input for external 10 MHz reference. (External reference is not required for normal operation.)

Input Level: -10dBm to +20dBm

Frequency Accuracy: $\pm 0.005\%$ (50ppm)

20 MHz OUT: Output of internal 20 MHz reference oscillator.

Frequency Accuracy: $\pm 0.01\%$, typical

Output Level: ECL, ac coupled

ANALOG +10V: Settable output voltage used for Auxiliary Voltage domain measurements.

Range: -9.995 to +10.000 volts

Linearity: $\pm 0.1\%$, typical

Resolution: 4.88mV

Temperature Range

Manual Operation: 0°C to $+55^{\circ}\text{C}$

Accuracy Enhancement Operation:

Calibration Standards: $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$

Calibration Window: $\pm 1^{\circ}\text{C}$ from calibration temperature

Operating Survival: 0°C to $+65^{\circ}\text{C}$

Magnetic Tape Limits: 0°C to $+45^{\circ}\text{C}$

Storage: -40°C to $+75^{\circ}\text{C}$

Storage of Magnetic Tape: -40°C to $+65^{\circ}\text{C}$

Power Requirements

47.5 to 66 Hz; 100, 120, 200, or 240VAC ($\pm 10\%$)

HP 85101A: 200 VA maximum

HP 85102A: 160 VA maximum

Test Sets: 95 VA maximum

HP 8340A sweeper: 500 VA ON; 40 VA standby

HP 8350A sweeper and RF plug-in: 270 VA

Dimensions

HP 85101A: 133.3mm high $\times$ 460.2mm wide $\times$ 612.6mm deep
(5.25in. $\times$ 18.12in. $\times$ 24.12in.)

HP 85102A: 133.3mm high $\times$ 460.2mm wide $\times$ 571.5mm deep
(5.25in. $\times$ 18.12in. $\times$ 22.5in.)

Test Sets: 133.3mm high $\times$ 460.2mm wide $\times$ 609.6mm deep
(5.25 in. $\times$ 18.12in. $\times$ 24in.)

Table 1-4. Supplemental Characteristics for HP 8510 System (Cont'd)

Weight

HP 85101A: Net, 14 kg (37 lb); Shipping, 20 kg (45 lb)

HP 85102A: Net, 18 kg (40 lb); Shipping, 22 kg (48 lb)

HP 8512A: Net, 15 kg (33 lb); Shipping, 19 kg (41 lb)

HP 8514A: Net, 17 kg (38 lb); Shipping, 21 kg (46 lb)

Table 1-5. Time Domain Supplemental Characteristics

Conversion Speed

The conversion speed, exclusive of the time required to measure data in the Frequency Domain, is typically 600 msec.

Time Stimulus Modes

Two types of time stimulus waveforms can be simulated during the transformation, step and impulse.

Low Pass Step Mode

The low-pass step mode is similar to the traditional Time Domain Reflectometer (TDR) measurement. The Time Domain display shows the step response versus time of the device under test. This mode is typically used for reflection measurements only.

Low Pass Impulse Mode

The low pass impulse mode is similar to the traditional TDR except that it gives the response of the device to an impulse stimulus (mathematically equivalent to the derivative of the step stimulus). This mode is useful for both reflection and transmission measurements.

Band Pass Impulse Mode

The band pass mode comes only with an impulse stimulus. This mode allows the user to measure band-limited devices. It gives the response of the device to a simulated RF pulse with an impulse-shaped envelope. This mode is useful for both reflection and transmission measurements.

Windows

The windowing function can be used to modify (filter) the frequency domain data and reduce ringing and overshoot of the time domain response. Three types of frequency domain windows are available: minimum, normal, and maximum.

Time Domain Stimulus Characteristics

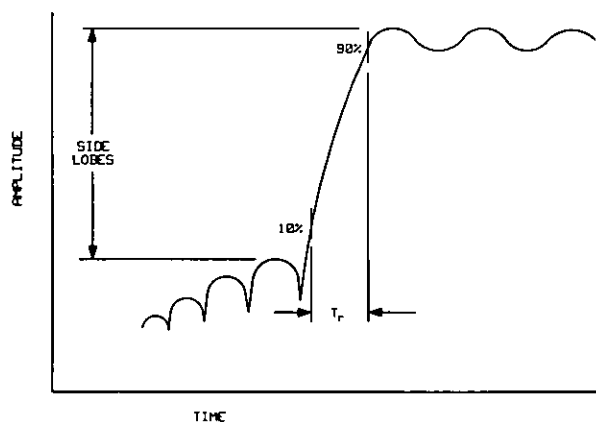
The characteristics of the step and the impulse stimuli depend upon the frequency span and/or the window selected. The sidelobe levels of the stimulus depend only on the window selected. The rise time and impulse width depend on the frequency span and upon the window selected.

Table 1-5. Time Domain Supplemental Characteristics (Cont'd)

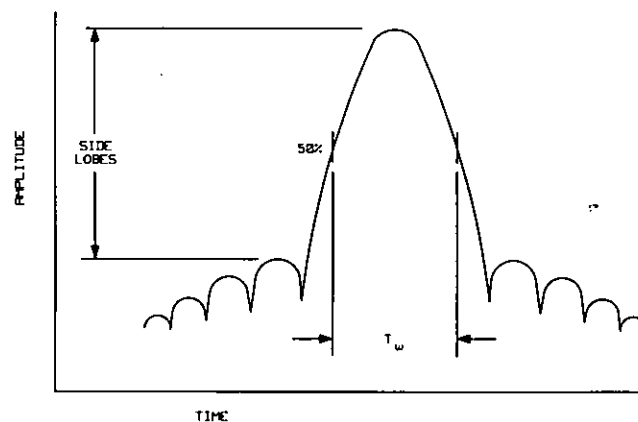
Mode	Window	Rise Time* 10% - 90%	Impulse* Width 50%	Sidelobe
Low Pass Step	Minimum Normal Maximum	25 psec 55 psec 81 psec		-21 dBc -61 dBc <-90 dBc
Low Pass Impulse	Minimum Normal Maximum		34 psec 54 psec 77 psec	-13 dBc -44 dBc <-90 dBc
Band Pass Impulse	Minimum Normal Maximum		66 psec 108 psec 154 psec	-13 dBc -44 dBc <-90 dBc

* 18 GHz Frequency Span

Low Pass Step



Low Pass Impulse and Band Pass Impulse



The step response 10-to-90% rise time and the impulse 50% width can be calculated with the following approximate formulas:

$$\text{Step Rise Time (Low Pass)} = \frac{0.45}{\text{FSPAN}} \times \begin{cases} 1.0 & \text{Minimum} \\ 2.2 & \text{Normal} \\ 3.3 & \text{Maximum} \end{cases}$$

$$\text{Impulse Width} = \begin{cases} 0.6 & \text{(Low Pass)} \\ 1.2 & \text{(Band Pass)} \end{cases} \times \frac{1}{\text{FSPAN}} \times \begin{cases} 1.0 & \text{(Minimum)} \\ 1.6 & \text{(Normal)} \\ 2.3 & \text{(Maximum)} \end{cases}$$

Table 1-5. Time Domain Supplemental Characteristics (Cont'd)

Gating

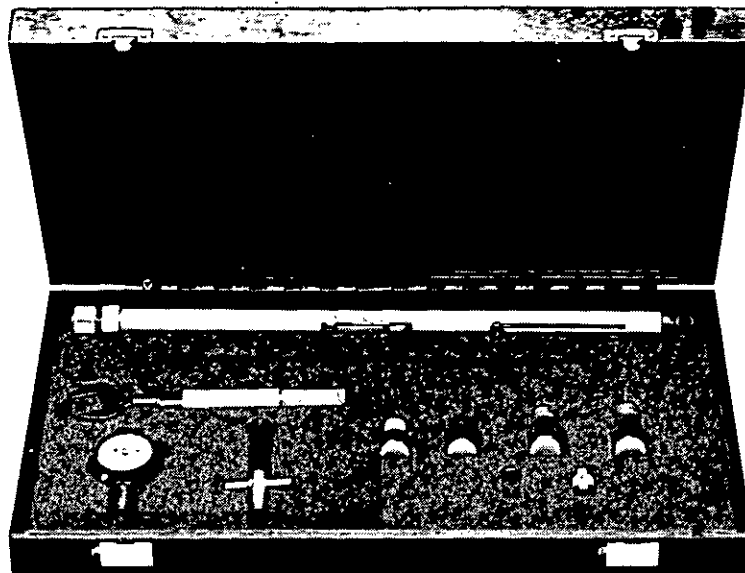
The gating function can be used to selectively remove reflection or transmission responses in time. In converting back to the frequency domain, the effect of the gated response is removed. Location of the gate in time can be controlled by setting the center position and time span of the gate.

Range

The time range, in nanoseconds, over which the display is free of response repetition is given by the following formula:

$$\text{Time Range} = \pm \frac{\text{Number of data points in Frequency Domain} - 1}{\text{Frequency Span (GHz)}}$$

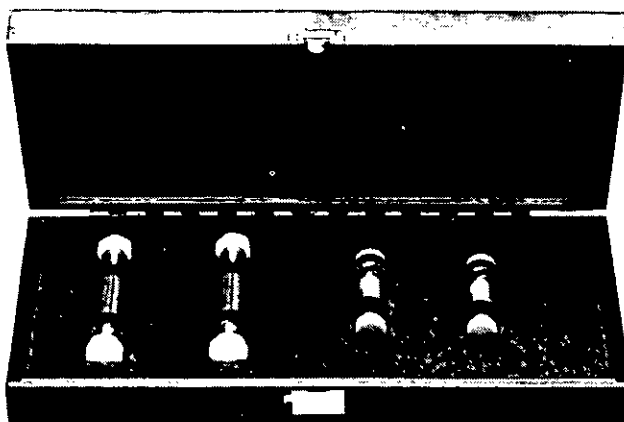
Table 1-6. Accessories Available for the HP 8510 System

HP 85050A 7MM CALIBRATION KIT

The HP 85050A calibration kit contains a set of calibration standards used to calibrate an HP 8510-series network analyzer system when making error-corrected measurements of devices with a 7mm connector interface. Also included are tools for maintaining and verifying the integrity of the test port 7mm connector interface. Option 010 adds a 7mm beadless airline, 30cm long with >50 dB return loss. This is used as an impedance reference in the HP 8510 system for time domain operation. Option 020 deletes torque wrench, gage, and extractor tool.

Qty.	HP Part Number	Description
1	1250-1872	7mm Flush Short with Hole
1	1250-1873	7mm Open with Collet Pusher
1	1250-1875	7mm Connector Gage without Case
1	1250-1874	7mm Torque Wrench (12 lb.-in.)
1	5060-0236	7mm Collet Extracting Tool
2	85050-60001	7mm Fixed Load, >52 dB Return Loss
1	1250-1890	7mm Sliding Load, >52 dB for Airline Section
1	85050-80001	85050A Instrument Case
4	85050-20001	Center Conductor Collet
1		Calibration Data Cartridge
1	1250-1877	30cm Beadless Airline, >54 dB Return Loss (Opt. 010)

Table 1-6. Accessories Available for the HP 8510 System (Cont'd)

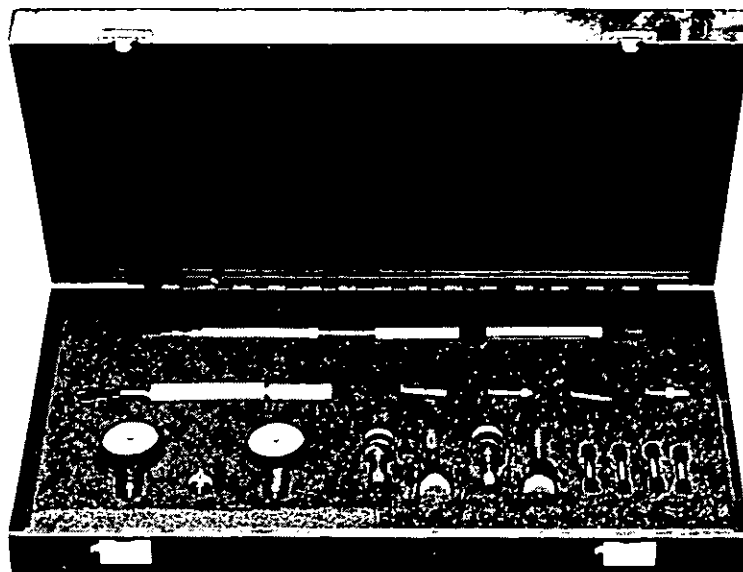
HP 85051A 7MM VERIFICATION KIT

The HP 85051A verification kit includes a set of 7mm measured standards used to verify the performance of an HP 8510-series network analyzer operating with error correction. The devices contained in the kit are supplied with either electrical or mechanical data.

Qty.	HP Part Number	Description
1	1250-1880	7mm Beadless Airline, 50 Ohm, 10cm Long, >52 dB Return Loss
1	1250-1882	7mm Stepped Impedance Airline, Reflection Coefficient = 0.60, 10cm Long
1	85051-60001	7mm 20 dB Attenuator
1	85051-60002	7mm 50 dB Attenuator
1	85050-20001	6-slot Center Collets
1	85051-80001	85051A Instrument Case
1		Printed S-Parameter Data
1		Data Tape Cartridge

Table 1-6. Accessories Available for the HP 8510 System (Cont'd)

HP 85052A 3.5MM CALIBRATION KIT



The HP 85052A calibration kit contains a set of precision calibration standards used to calibrate an HP 8510-series network analyzer system when making error-corrected measurements of devices with a precision 3.5mm connector interface. Also, the kit contains precision adapters to convert a 7mm interface to a precision 3.5mm interface, and to convert the precision 3.5mm connector sex. Tools are included for maintaining and verifying the integrity of the test port precision 3.5mm connector interface.

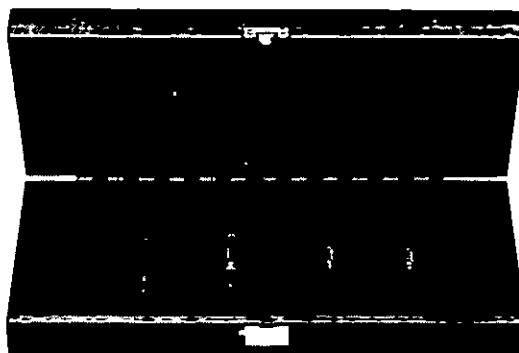
Option 010 adds a precision 3.5mm beadless airline, 15cm long with >44 dB return loss. This is used as an impedance reference in the HP 8510 system for time domain operation.

Option 020 deletes a torque wrench and gages.

HP 8510 - General Information

Table 1-6. Accessories Available for the HP 8510 System (Cont'd)

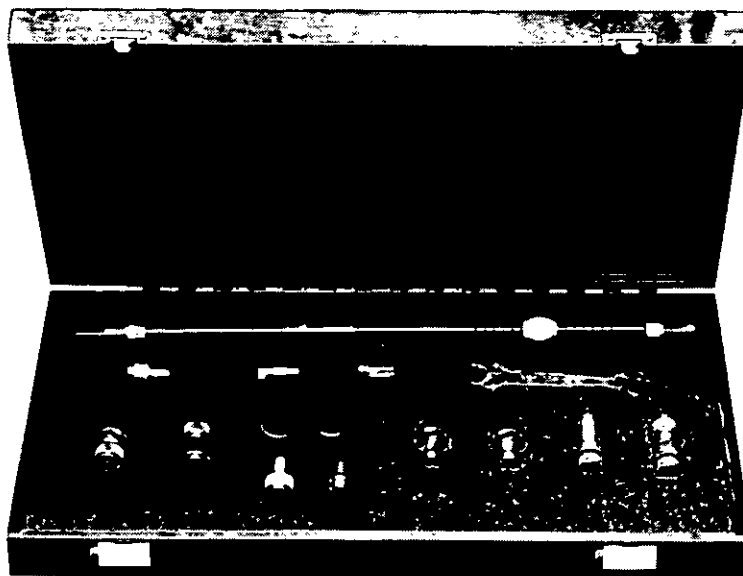
Qty.	HP Part Number	Description
1	1250-1766	Precision 3.5mm Offset Open, male
1	1250-1767	Precision 3.5mm Offset Open, female
1	1250-1768	Precision 3.5mm Offset Short, male, 180 degrees from Open on the average
1	1250-1769	Precision 3.5mm Offset Short, female, 180 degrees from Open on the average
1	1250-1864	Precision 3.5mm Barrel, male-to-male, same electrical length as the following two items
1	1250-1865	Precision 3.5mm Barrel, female-to-female, same electrical length as the previous and the following items
1	1250-1866	Precision 3.5mm Barrel, male-to-female, same electrical length as the two previous items
1	1250-1862	3.5mm Connector Gage, male and female and calibration block
1	1250-1863	3.5mm Torque Wrench (8 lb.-in.)
1	1250-1746	7mm to 3.5mm Male Adapter
1	1250-1747	7mm to 3.5mm Female Adapter
1	85052-60001	Precision 3.5mm Fixed Load, male, return loss >40 dB dc to 4 GHz
1	85052-60002	Precision 3.5mm Fixed Load, female, return loss >40 dB dc to 4 GHz
1	1250-1891	Precision 3.5mm Sliding Load, >46 dB on Airline Section 4 to 26.5 GHz
1	1250-1784	Center Conductor Extender, male
1	1250-1785	Center Conductor Extender, female
1		Calibration Data Cartridge
1	1250-1876	Precision 3.5mm Beadless Airline, 15cm Long, >48dB Return Loss 4 to 26.5 GHz (Opt. 010)
1	85052-80001	85052A Instrument Case

*Table 1-6. Accessories Available for the HP 8510 System (Cont'd)***HP 85053A 3.5MM VERIFICATION KIT**

The HP 85053A verification kit contains a set of precision 3.5mm measured standards used to verify the performance of an HP 8510-series network analyzer operating with error correction. The devices contained in the kit are supplied with either electrical or mechanical data.

Qty.	HP Part Number	Description
1	1250-1869	Precision 3.5mm Beadless Airline, 50 Ohm, 7.5cm Long, >46 dB Return Loss
1	1250-1871	Precision 3.5mm Stepped Impedance Airline, Reflection Coefficient = 0.60, 25 Ohms Nominal, 7.5cm Long
1	85053-60001	Precision 3.5mm 20 dB Attenuator
1	85053-60002	Precision 3.5mm 40 dB Attenuator
1	85053-80001	HP 85053A Instrument Case
1		Calibration Data Cartridge (contains device S-Parameter Data)
1		Printed S-Parameter Data

Table 1-6. Accessories Available for the HP 8510 System (Cont'd)

HP 85054A TYPE N CALIBRATION KIT

The HP 85054A calibration kit contains a set of precision calibration standards used to calibrate an HP 8510-series network analyzer system when making error-corrected measurements of devices with a Type-N connector interface. Also, the kit contains precision 7mm to Type-N adapters for converting the test port interface.

Qty.	HP Part Number	Description
1	85032-20001	Type-N Open Circuit Female
1	85032-20002	Type-N Open Circuit Body, Male
2	85032-20003	Center Conductor Extension, Male
2	85032-20004	Center Conductor Extension Handle
1	11511A	Short Circuit, Type-N, Female
1	11512A	Short Circuit, Type-N, Male
2	11525A	7mm to Type-N Male Adapter
1	905A	Coaxial Sliding Load
1	909C Opt. 012	Fixed Load, 50 Ohms, Male
1	909C Opt. 013	Fixed Load, 50 Ohms, Female
2	85054-60001	7mm to Type-N Female Adapter
1	85054-80001	Instrument Case
1		Calibration Data Cartridge

Table 1-6. Accessories Available for the HP 8510 System (Cont'd)

HP 85131A 3.5MM TEST PORT RETURN CABLE

Used with HP 8513A reflection/transmission test set.

Frequency Range: dc to 26.5 GHz

Length: 92.3 cm (36 inch)

VSWR: <1.22, typical

Connectors: Precision 3.5mm female, both ends

HP 85131B 3.5MM TEST PORT RETURN CABLE SET

Used with HP 8515A S-parameter test set.

Quantity Supplied: 2

Frequency Range: dc to 26.5 GHz

Length: 66.6 cm (26 inch) each

VSWR: <1.22, typical

Connectors: Precision 3.5mm female, one end of each, precision 3.5mm male, and female other end

HP 85132A 7MM TEST PORT RETURN CABLE

Used with HP 8512A reflection/transmission test set.

Frequency Range: dc to 18.0 GHz

Length: 92.3 cm (36 inch)

VSWR: <1.2, typical

Connectors: Precision 7mm

HP 85132B 7MM TEST PORT RETURN CABLE SET

Used with HP 8514A S-parameter test set.

Quantity Supplied: 2

Frequency Range: dc to 18.0 GHz

Length: 66.6 cm (26 inch) each

VSWR: <1.2, typical

Connectors: Precision 7mm

Table 1-6. Accessories Available for the HP 8510 System (Cont'd)

NOTE

The following application pac programs may be ordered on the following recording mediums:

Option 655 for HP 9826S, 9836S, or 9836C computers.

Option 630 for HP 9816S computer with 3-1/2 inch disc.

HP 8510A OPTION 010 TIME DOMAIN SOFTWARE PAC

This software pac comprises the system Option 010 and provides time domain measurement capabilities on the HP 8510 system.

HP P/N 85101-10003 HP 85101A SERVICE SOFTWARE

This software is used as an aid in both the electrical adjustments and problem diagnosis in the HP 85101A display/processor.

HP 11591A 7MM SERVICE KIT

This kit contains tools to repair precision 7mm connectors as well as spare collet inserts for the center conductor.

HP 85043A RACKED SYSTEM KIT

Size: 123.7cm high × 60.0cm wide × 80.0cm deep
(48.7 inches × 23.6 inches × 31.5 inches)

This kit includes support rails, ac power distribution (for 50 to 60 Hz, 100 to 240 Vac), and rack mounting hardware. No rack fan is needed.

HP P/N 08510-60001 8510 SYSTEM SERVICE KIT

Various parts of this kit are used during verification, adjustment, troubleshooting, and repair of the HP 8510 system. This kit contains the following:

HP 8510 - General Information

Table 1-6. Accessories Available for the HP 8510 System (Cont'd)

HP P/N	Description	Reason for Inclusion
HP 85101 DISPLAY PROCESSOR		
85101-60021	Bd., extender	Used to extend A8 board
85101-60020	Bd., extender	Used to extend A7 board
85101-60019	Bd., extender	Used to extend A6 board
85101-60041	Bd., extender	Used to extend A2 & A5
8710-0055	4 spline wrench	Intensity knob removal
2110-0083	Fuse 2.5A 250V (5ea)	Line fuse
2110-0304	Fuse 1.5A 250V (5ea)	Line fuse
2110-0047	Fuse 1A 125V (5ea)	
2110-0218	Fuse .1A 250V (5ea)	
2110-0301	Fuse .12A 125V (5ea)	
2110-0425	Fuse 2A 125V (5ea)	
1490-0025	Claw tip-TP	A3 board adjustments
85101-60035	Board, test	A2/A4/A5 board adjust.
1400-0046	Clip, alligator	
1250-1236	BNC-snap-on F-F adap.	85101A adjustments
HP 85102 IF/DETECTOR		
2110-0012	Fuse .5A 250V (5 ea)	Processor interface
2110-0002	Fuse 2A 250V (5ea)	Line fuse
2110-0001	Fuse 1A 250V (5ea)	Line/-5V supply
2110-0083	Fuse 2.5A 250V (5ea)	+/- 15V supply
2110-0643	Fuse 8A 250V (5ea)	+5V supply
85102-60030	Extender board (2ea)	Also used for Test Sets
85680-60093	BNC-to-snap-on cable assys. (2ea)	85102 adjustments
5061-1022	12" snap-on cable (5ea)	85102 Test Set adjust. assem. and troubleshoot.
1250-1391	Snap-on tee F-M-M (1)	85102 adjustments
1250-0669	Snap-on M-M adap. (2)	85102 adjustments
TEST SETS		
85050-20001	Collets, 7mm (4ea)	Special collets are used
08510-20001	Cable RF 1-Test (1ea)	Test Set adjustment and
08510-20002	Cable RF 2-Test (1ea)	troubleshooting
08512-20006	1.41 cable S-R (1ea)	
1250-1863	Torque wrench 8 in-lb	SMA torque wrench
2110-0001	Fuse 1A 250V (5ea)	Regulator fuse
2110-0043	Fuse 1.5A 250V (5ea)	Line/regulator fuses
2110-0063	Fuse .75A 250V (5ea)	Line fuse
8710-0877	Open-end wrench 9/16	Removal of bulk-head connectors
8710-0630	Alignment tool	Adjustments
HP 8493C	10dB pad 3.5mm	Adjustments
08513-60009	Cable flex 26.5 GHz	Adjustment and troubleshooting

Table 1-7. Required Test Equipment for Board-Level On-site Repair

INSTRUMENT	HP MODEL	CRITICAL SPECIFICATIONS	USE
Digital Multimeter	3466A	General-Purpose Volt-Ohm Meter, 32mV to 300V ac and dc	A, T
Oscilloscope	1740A	100 MHz, Dual Channel	A, T
Computer	9836S or 9826S	Basic 2.0 ROM-based System with BASIC 2.1 and 750K RAM	A, P, T
Counter	5343A	500 MHz to 26.5 GHz	A, P, T
Power Meter	436A	100 kHz to 26.5 GHz	P, T
Power Sensor	8485A	50 MHz to 26.5 GHz 1 μ W to 100 mW	P, T
High Voltage Probe	34111A	1000-to-1 Divider 30 KV	A, T
Calibration Kit	85050A	Precision 7mm	P, T
Calibration Kit	85052A	Precision 3.5mm	P, T
Verification Kit	85051A	Precision 7mm	P, T
Verification Kit	85053A	Precision 3.5mm	P, T
HP 8510 System Service Kit	08510-60001	See Table 1-6 for contents	A, T
Power Splitter	11667B	45 MHz to 26 GHz	A, T
HP-IB Bus Analyzer	59401A	Monitor HP-IB (IEEE-488) Bus Lines	T
Signature Analyzer	5005B	Signature Multimeter	T

A = Adjustments; P = Performance Tests; T = Troubleshooting

Table 1-8. Test Equipment for Display/Processor Component Level Bench Repair

INSTRUMENT	HP MODEL	CRITICAL SPECIFICATIONS	USE
Digital Multimeter	3466A		A, T
Oscilloscope	1980A	100 MHz, Dual Channel, HP-IB	T
Signature Analyzer	5005B	Signature Analyzer Multimeter, HP-IB	T
Pulse Generator	8013B	35 ns to 1 sec., for HP 85101A A2, A4, and A5	A, T
High Voltage Probe	34111A	1000-to-1 Divider 30 KV	A, T
Dual Power Supply	6205C	Dual 0 to 15V supply for HP 85101A A7	A, T
Probe	10004D	10:1 divider probe	A, T

A = Adjustments; P = Performance Tests; T = Troubleshooting

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Table 1-9. Test Equipment for IF/Detector and Test Sets Component Level Bench Repair

INSTRUMENT	HP MODEL	CRITICAL SPECIFICATIONS	USE
Digital Voltmeter	3456A	100 nanovolt resolution, HP-IB	T
Spectrum Analyzer	8566A	100 kHz to 26.5 GHz HP-IB	A, T
Computer	9836S or 9826S	Basic 2.0 ROM, 2.1 extension, and 750K RAM	A, P, T
Counter	5343A Opt. 011	500 MHz to 26.5 GHz	A, T
Function Generator	3335A	1 Hz to 20 MHz 0 to 80dB Attenuator	T, P
Function Generator	3325A	Fast sweep, ≤ 10 msec	A
RF Source	8340A or 8350B/ 83595A	500 MHz to 26.5 GHz, Plug-in Opt. 004 recommended but not required.	A, P, T
Printer (Optional)	2673A or 82905B	Prints using HP 9836S	P, T
HP 8510 System Service Software	85101-10003	Service Software	A, P, T
HP 8510 Operating Software	85101-10002	Opt. 010 Time Domain	P, T
Calibration Kit	85050A	Precision 7mm	P, T
Calibration Kit	85052A	Precision 3.5mm	P, T
Verification Kit	85051A	Precision 7mm	P, T
Verification Kit	85053A	Precision 3.5mm	P, T
HP 8510 System Service Kit	08510-80001	See Table 1-8 for Contents	A, T

A = Adjustments; P = Performance Tests; T = Troubleshooting

*Table 1-10. Specifications for HP 8510 with HP 8511A Test Set (Cont'd)***INTRODUCTION AND GENERAL CHARACTERISTICS**

The combination of the HP 8511A test set with an HP 8510A network analyzer and an HP 8340A sweeper forms a four channel receiver/signal processor that operates over the frequency range of 45 MHz to 26.5 GHz.

Specification Assumptions

The specifications of this table assume that the following conditions are met:

- The RF source is an HP 8340A synthesized sweeper operating in stepped sweep mode.
- The temperature is in the range of 0° C to 55° C.
- RF source power levels at the input ports are as follows:

Test	Power at Input Port	
	45 MHz-18 GHz	18 GHz-26.5 GHz
Compression	-10 dBm	-15 dBm
Crosstalk	-10 dBm	-15 dBm
Conversion Gain	-15 dBm	-20 dBm
Tracking	-15 dBm	-20 dBm
Trace Noise	-15 dBm	-20 dBm

Frequency Range

45 MHz to 26.5 GHz

Input Ports

Connector Type: Precision 3.5 mm Female

Impedance: 50 ohms nominal

Damage Input Level: > +13 dBm

Table 1-10. Specifications for HP 8510 with HP 8511A Test Set (Cont'd)

HARDWARE AND SYSTEM PERFORMANCE SPECIFICATIONS**Table of System Errors**

The following table lists the specifications for the various sources of system error. The values listed are the verification limits for uncorrected measurements.

Source of System Errors

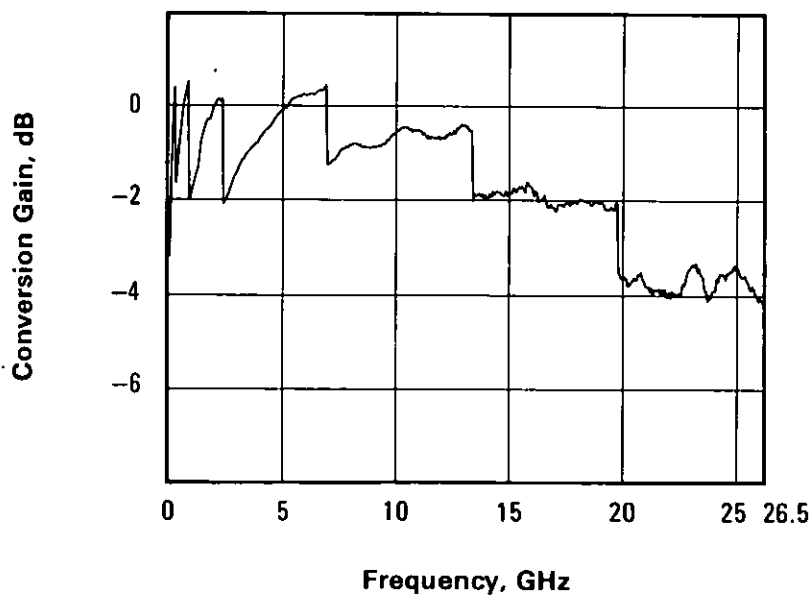
Error Source	Verification Limit		
	.045-8GHz	8-18GHz	18-26.5GHz
Conversion Gain ¹	+ 2 dB to - 14 dB		
Tracking Magnitude Slope Magnitude Ripple ² Phase Ripple ²	± 2.0 dB $\pm .5$ dB ± 5 deg		
Crosstalk ³	≤ -80 dB	≤ -80 dB	≤ -80 dB
Low-Level Noise (Noise Floor) ⁴	≤ -95 dBm	≤ -90 dBm	≤ -85 dBm
High-Level Noise (Trace Noise) ⁵ Ratio - Magnitude Ratio - Phase	.012 dB rms .050 deg rms	.020 dB rms .150 deg rms	.040 dB rms .250 deg rms
Compression (.1 dB point) ⁶	≥ -10 dB,	≥ -10 dBm	≥ -15 dBm
Input Port Return Loss ⁷	≥ 17 dB	≥ 15 dB	≥ 9 dB
Phase Lock Power Level ⁶	≥ -40 dBm	≥ -40 dBm	≥ -35 dBm
	≥ -45 dBm at the 20 MHz IF (measure the absolute level of the reference channel)		
Tracking Drift	.001 $\times \Delta^{\circ}$ C, Linear		
Magnitude Phase	(0.1 + .01 $\times f$ (GHz) $\times \Delta^{\circ}$ C, Degrees		

Table 1-10. Specifications for HP 8510 with HP 8511A Test Set (Cont'd)

Footnotes for Table of System Errors

- 1 A typical Conversion Gain curve is shown below.
- 2 Ripple is the deviation from a least-squares-line-fit.
- 3 Averaging factor of 1024 is applied.
- 4 Low-level noise (Noise Floor) is measured relative to a transmission measurement in a 10 kHz bandwidth and 20% of span smoothing.
- 5 High-level noise is an RMS value taken of a transmission measurement in a 10 kHz bandwidth.
- 6 Do not exceed -5 dBm input to the sampler for proper phase lock operation.
- 7 Input port return loss is tested with the sampler in a non-conducting state. When the diodes are turned on by the L.O. pulse, they present a short circuit across the sampler input port. This may affect the measured data.

Typical Conversion Gain Curve



*Table 1-10. Specifications for HP 8510 with HP 8511A Test Set (Cont'd)***Source of System Dynamic Accuracy Errors**

The factors affecting dynamic accuracy listed below are primarily a function of the IF/detector except for the compression. In order to measure these values, some of the system cables must be disconnected to gain access to the individual instruments.

Compression (0.1 dB point):^{6, 8} ≥ -10 dBm up to 18 GHz; ≥ -15 dBm 18-26.5GHz

IF Amplifier Gain Accuracy:

IF Amplifier Power Range (dBm) ⁹	Maximum Gain Error (dB)
-10 to -22	0
-22 to -34	$\pm .005$
-34 to -46	$\pm .01$
-46 to -58	$\pm .02$
< -58	$\pm .03$

Detector Circularity Error: $\pm .003$ dB peak

Detector dc Offset Error: -100 dBm⁹

IF Residuals: -120 dBm⁹

IF Linearity: $\pm .003$ dB

Incremental Phase Accuracy (Phase vs. Phase) at Measurement Reference: ± 0.001 degrees/degree, not to exceed 0.02 degrees peak.

⁸ See Section III, Operation, in this Operating and Service manual for considerations in achieving maximum dynamic range.

⁹ These dBm power level numbers are at the IF input to the HP 8510A, not at the test set test ports.

Table 1-10. Specifications for HP 8510 with HP 8511A Test Set (Cont'd)

Graphics Data of System Dynamic Accuracy Error. Magnitude and phase measurement dynamic accuracy versus signal level is due to the combination of the individual specified factors listed in the previous paragraph. These measurable factors are combined by vector error analysis using the worst-case method. This combination is shown below in two data graphs, one graph for magnitude measurement uncertainty (worst-case magnitude dynamic accuracy error) and one for phase measurement uncertainty (worst-case phase dynamic accuracy error).

Worst-case Magnitude Dynamic Accuracy Error

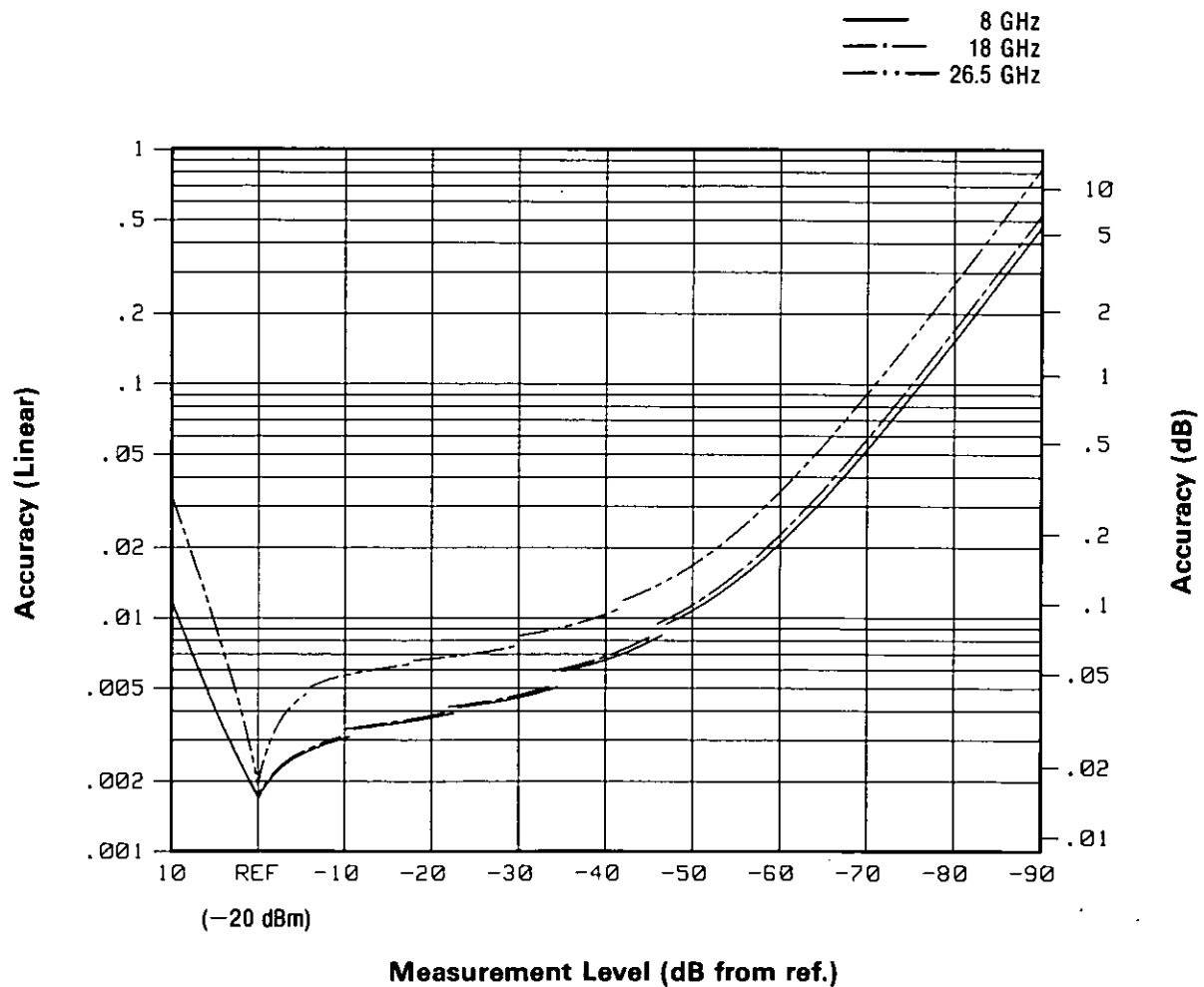


Table 1-10. Specifications for HP 8510 with HP 8511A Test Set (Cont'd)

Worst-case Phase Dynamic Accuracy Error

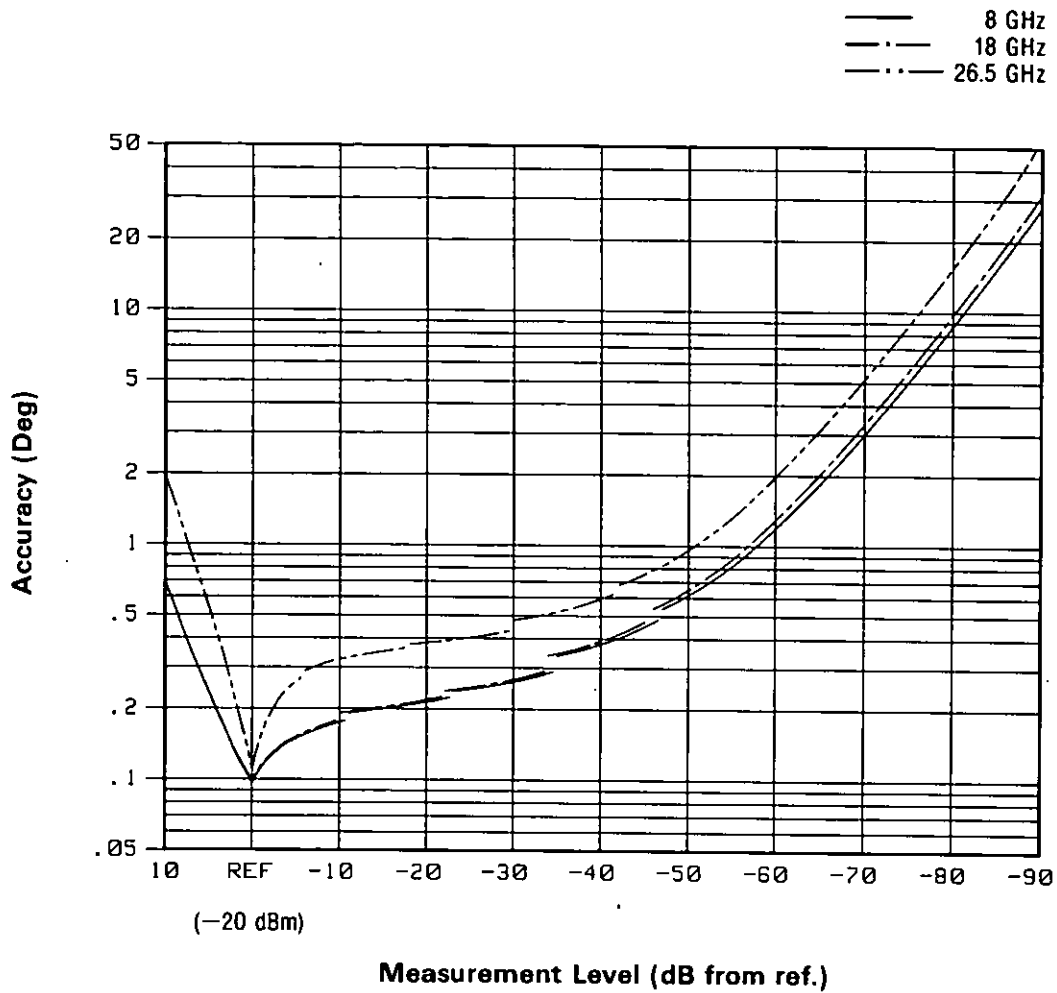


Table 1-10. Specifications for HP 8510 with HP 8511A Test Set (Cont'd)

GROUP DELAY CHARACTERISTICS**Aperture:**

Minimum Aperture (Hz) = Frequency Span (Hz)/(no. of points - 1)

Maximum Aperture (Hz) = 20% of Frequency Span (Hz)

Range:

The maximum delay is limited to measuring no more than ± 180 degrees of phase change within the minimum aperture.

$$\text{Range} = \frac{180 \text{ deg}}{360 (\text{Minimum Aperture})} = \frac{1}{2} \times \frac{\text{Number of Points} - 1}{\text{Frequency Span (Hz)}}$$

EXAMPLE: Frequency Span = 40 MHz
 Number of Points = 201
 Minimum Aperture = 200 kHz
 Range = 2.5 us

Group Delay High-Level Noise:

Continuous measurement of a through connection displays RMS noise as follows:

$$\text{Noise} = \frac{0.004 \times \text{High-Level Phase Noise (Trace Noise)}}{\text{Aperture (Hz)}} + \frac{1.41 \times \text{Delay (sec)} \times \text{Residual FM (10 kHz BW RMS, Hz)}}{\text{Aperture (Hz)}}$$

Accuracy:

Group delay accuracy is a function of the uncertainty in determining the phase change and the frequency linearity. The following formula can be used to determine the accuracy, in seconds, of a specific group delay measurement:

$$\text{Accuracy} = \pm \frac{0.003 \times \text{Phase Accuracy (degrees)}^{10, 11}}{\text{Aperture (Hz)}} + \frac{[\text{Delay (sec)}] \times [\text{linearity (Hz)}]}{\text{Aperture (Hz)}}$$

EXAMPLE: Given is a system with an HP 8340A sweeper operating in stepped sweep mode with 101 points per sweep over a 50 MHz span. The device has 50 nsec of delay and very little amplitude change over the passband. In this case,

$$\text{Accuracy} = \pm \frac{0.003 \times [0.02 \text{ deg}] + [50 \text{ nsec}] \times [4 \text{ Hz}]}{50 \text{ MHz}/101 \text{ points}}$$

$$\text{Accuracy} = \pm 0.12 \text{ nsec}$$

Table 1-10. Specifications for HP 8510 with HP 8511A Test Set (Cont'd)

-
- 10 Phase accuracy is dependent on the test set configuration, the calibration process, and the calibration standards.
- 11 Phase Accuracy can be either of the following types:
- a) **Incremental Phase Accuracy (Phase vs. Phase)** for narrow band applications where very little changes in amplitude occur (page 1-61).
 - b) **Worst-case Phase Dynamic Accuracy** for narrow band applications where significant amplitude changes occur (page 1-62).

*Table 1-11. Specifications for HP 8510 with HP 8513A Test Set***INTRODUCTION AND GENERAL CHARACTERISTICS**

The combination of an HP 8513A test set with an HP 8510A network analyzer and an HP 8340A sweeper forms a system for making reflection (S_{11}) and transmission (S_{21}) measurements over the frequency range of 45 MHz to 26.5 GHz.

Specification Assumptions

The specifications of this table assume that the following conditions are met:

7mm Connector Specification Assumptions:

- The RF source is an HP 8340A synthesized sweeper operating in stepped sweep mode.
- The RF cable from the sweeper power output connector to the test set power input connector is the RF Flex Source Cable, HP Part Number 08513-60009.
- The temperature is in the range of 0° C to 55° C, except where noted.
- HP 85130A 3.5mm to 7mm adapters are connected to port 1 and port 2 of the test set.
- Reflection and transmission calibration and measurement is done at Test Port 1, and the transmission return path is through an HP 8492A 10 dB attenuator and an HP 85132A cable to Test Port 2.
- The power level at the RF source output is +10 dBm.
- Calibration is performed with an HP 85050A precision 7mm calibration kit.
- Verification procedures use the HP 85051A precision 7mm verification kit.

3.5mm Connector Specification Assumptions:

- All corrected error source specifications for 3.5mm connectors are typical.
- The RF source is an HP 8340A synthesized sweeper operating in stepped sweep mode.
- The RF cable from the sweeper power output connector to the test set power input connector is the RF Flex Source Cable, HP Part Number 08513-60009.
- The temperature is in the range of 0° C to 55° C, except where noted.
- From 45 MHz to 18 GHz, the power level at the RF source output is +10 dBm. From 18 GHz to 26.5 GHz, the power level at the RF source output is 0 dBm.
- Reflection and transmission calibration and measurement is done at Test Port 1, and the transmission return path is through an HP 8493C 10 dB attenuator and an HP 85131A cable to Test Port 2.
- Calibration is performed with an HP 85052A precision 3.5mm calibration kit.
- Verification procedures use the HP 85053A precision 3.5mm verification kit.

Table 1-11. Specifications for HP 8510 with HP 8513A Test Set (Cont'd)

Frequency Range

Reflection and Transmission: 45 MHz to 26.5 GHz

Test Ports

Connector Type: Precision 3.5mm Male

Impedance: 50 ohms nominal

Nominal Operating Power Level:

Test Port 1: -6 dBm at 8 GHz
-9 dBm at 18 GHz
-22 dBm at 26.5 GHz

Damage Input Level:

Test Port 1: > +20 dBm

Test Port 2: > +13 dBm

RF Input Connector

Connector Type: Precision 3.5mm Female

Damage Input Level: +23 dBm

Minimum and Maximum Reference Channel Power

Minimum input power at rear-panel RF INPUT port (for Reference Channel Phase Lock): -2 dBm

Maximum input power at rear-panel RF INPUT port (level before 0.1 dB compression): +12 dBm

*Table 1-11. Specifications for HP 8510 with HP 8513A Test Set (Cont'd)***HARDWARE AND SYSTEM PERFORMANCE SPECIFICATIONS****Table of System Errors¹**

The following tables list specifications for various sources of system error. One table lists the 7mm connector specification values for uncorrected measurements, corrected measurements after accuracy enhancement, and verification limits, over the frequency range of 45 MHz to 18 GHz. The other table lists the 3.5mm connector specification values for uncorrected measurements and corrected measurements after accuracy enhancement (typical), over the frequency range of 45 MHz to 26.5 GHz. Devices in the 7mm calibration and verification kits, HP 85050A and 85051A respectively, have the precision and accuracy to calibrate the system and to verify the source of error to the limits shown in the "Verification Limits" column of the 7mm specifications table.

Table 1-11. Specifications for HP 8510 with HP 8513A Test Set with 7mm Connectors

Source of System Errors

Symbol	Error Source	Uncorrected		Residual After Accuracy Enhancement ^{2, 9}				Verification Limits ^{2, 4, 9}	
		.045-8 GHz	8-18 GHz	.045-8 GHz		8-18 GHz		.045-8 GHz	8-18 GHz
		dB or Deg.	dB or Deg.	Linear	dB	Linear	dB	dB	dB
D	Directivity	-22 dB	-24 dB	.0032	-50	.0032	-50	-44	-44
M _S	Source Match	-22 dB	-15 dB	.01	-40	.01	-40	-37	-37
M _L	Load Match	-23 dB	-16 dB	.01	-40	.01	-40	-40	-40
T _r	Reflection Tracking	±1 dB ⁵	±1 dB ⁵	.006	±.05	.006	±.05	±.05	±.05
T _t	Transmission Tracking	±.75 dB	±.75 dB	.0018	±.015	.0035	±.03	±.015	±.03
C	Crosstalk ⁶	-80 dB	-80 dB	.000032	-90	.000032	-90	-90	-90
R _{r1}	Port 1 Reflection Connector Repeatability (Typical)	-70 dB	-65 dB	.00032	-70	.0006	-65		
R _{t1}	Port 1 Transmission Connector Repeatability (Typical)	-70 dB	-65 dB	.00032	-70	.0006	-65		
R _{r2}	Port 2 Reflection Connector Repeatability (Typical)	-70 dB	-65 dB	.00032	-70	.0006	-65		
R _{t2}	Port 2 Transmission Connector Repeatability (Typical)	-70 dB	-65 dB	.00032	-70	.0006	-65		
N _l	Low-Level Noise (Noise Floor) ⁸	-73 dB	-70 dB	.000022	-93	.000032	-90	-93	-90
N _h	High-Level Noise ¹⁰ Magnitude Phase	.015 dB .1 Deg.	.02 dB .15 Deg	.00018	.0015	.00023	.002	.0015	.002
A	8510A Magnitude Dynamic Accuracy Error (Primarily IF and Detector)	Refer to magnitude curve							
S _{t2}	Port 2 Cable Transmission Phase Stability (Typical) ¹¹	0.1 x f (GHz), degrees							
T _{td}	Transmission Magnitude Tracking Drift (Typical) Phase	.001 x Δ°C, linear (0.1 + .01 x f (GHz)) x Δ°C, Degrees							
T _{rd}	Reflection Magnitude Tracking Drift (Typical) Phase	.001 x Δ°C, linear (0.1 + .01 x f (GHz)) x Δ°C, Degrees							

Table 1-11. Specifications for HP 8510 with HP 8513A Test Set with 3.5mm Connectors

Source of System Errors

Symbol	Error Source	Uncorrected			Residual After Accuracy Enhancement (Typical) ^{3, 9}					
		.045-8 GHz	8-18 GHz	18-26.5 GHz	.045-8 GHz		8-18 GHz		18-26.5 GHz	
		dB or Deg.	dB or Deg.	dB or Deg.	Linear	dB	Linear	dB	Linear	dB
D	Directivity	-22 dB	-24 dB	-24 dB	.01	-40	.01	-40	.013	-38
M _S	Source Match	-22 dB	-15 dB	-14 dB	.032	-30	.032	-30	.032	-30
M _L	Load Match	-25 dB	-17 dB	-17 dB	.032	-30	.032	-30	.032	-30
T _r	Reflection Tracking	±1 dB ⁵	±.75 dB ⁵	±1 dB ⁵	.017	±.15	.017	±.15	.017	±.15
T _t	Transmission Tracking	±1 dB	±.75 dB	±1 dB	.0023	±.02	.0046	±.04	.0069	±.06
C	Crosstalk ⁶	-80 dB	-80 dB	-70 dB ⁷	.000032	-90	.000032	-90	.0001	-80 ⁷
R _{r1}	Port 1 Reflection Connector Repeatability (Typical)	-70 dB	-65 dB	-60 dB	.00032	-70	.00056	-65	.001	-60
R _{t1}	Port 1 Transmission Connector Repeatability (Typical)	-70 dB	-65 dB	-60 dB	.00032	-70	.00056	-65	.001	-60
R _{r2}	Port 2 Reflection Connector Repeatability (Typical)	-70 dB	-65 dB	-60 dB	.00032	-70	.00056	-65	.001	-60
R _{t2}	Port 2 Transmission Connector Repeatability (Typical)	-70 dB	-65 dB	-60 dB	.00032	-70	.00056	-65	.001	-60
N _l	Low-Level Noise (Noise Floor) ⁸	-73 dB	-70 dB	-54 dB ⁷	.000022	-93	.000032	-90	.00020	-74 ⁷
N _h	High-Level Noise ¹⁰ Magnitude Phase	.015 dB .1 Deg.	.02 dB .15 Deg	.04 dB .28 Deg	.00017	.0015	.00023	.002	.00046	.004
A	8510A Magnitude Dynamic Accuracy Error (Primarily IF and Detector)	Refer to magnitude curve								
S ₁₂	Port 2 Cable Transmission Phase Stability (Typical) ¹¹	0.1 x f (GHz), degrees								
T _{td}	Transmission Tracking Drift (Typical) Magnitude Phase	.001 x Δ °C, linear (0.1 + .01 x f (GHz)) x Δ °C, Degrees								
T _{rd}	Reflection Tracking Drift (Typical) Magnitude Phase	.001 x Δ °C, linear (0.1 + .01 x f (GHz)) x Δ °C, Degrees								

Table 1-11. Specifications for HP 8510 with HP 8513A Test Set (Cont'd)

Footnotes for Table of System Errors

- 1 Current HP-supplied performance verification tests verify individual error source specifications and/or verify the sum total of these individual specifications by verifying transmission and reflection magnitude and phase uncertainties E_{tm} , E_{rm} , E_{tp} , and E_{rp} , as they are defined in the equation on page 1-74. These detailed performance verification tests are found in Section IV of this Operating and Service Manual.
- 2 7mm connector accuracy enhancement is achieved using the HP 85050A 7mm calibration kit and an HP 85130A adapter set for a full two-port calibration. The environmental temperature is $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$ at calibration; $\pm 1^{\circ}\text{C}$ from the calibration temperature must be maintained for valid calibration and verification.
- 3 Accuracy enhancement is achieved using an HP 85052A 3.5mm calibration kit for a full two-port calibration. The environmental temperature is $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$ at calibration; $\pm 1^{\circ}\text{C}$ from the calibration temperature must be maintained for valid calibration and verification.
- 4 Numbers shown are for verification tests using devices in the HP 85050A 7mm calibration kit and the HP 85051A 7mm verification kit. For other standards, use appropriate uncertainty. Parameters of the system are measured at the factory with one set of standards. These same parameters may be tested again in the field with the verification procedures, using a second set of standards, the calibration and verification kits. The measured verification values will always have more uncertainty than the calibration and verification standards. For example, if the parameter value in the system is $>50\text{ dB}$ and the parameter present in the calibration device is $>50\text{ dB}$, then the highest measured value with negligible ambiguity is 6 dB less, or 44 dB.
- 5 Residual ripple that compares the smoothed trace to a normal trace.
- 6 From 45 MHz to 18 GHz an averaging factor of 1024 is applied. From 18 GHz to 26.5 GHz an averaging factor of 4096 is applied.
- 7 With +10 dBm of source power available, the noise floor specification and the ability to measure crosstalk improves by 10 dB.
- 8 Low-level noise (noise floor) is measured relative to an S_{21} through measurement in a 10 kHz bandwidth and 20% of span smoothing.
- 9 An averaging factor of 128 is applied.
- 10 High-level noise is an RMS value taken of a continuous measurement of a short circuit or a through connection.
- 11 The cable phase stability term was arrived at by bending the cable out perpendicular to the front panel and then reconnecting it. The stability will be much better when less flexing is applied.

Table 1-11. Specifications for HP 8510 with HP 8513A Test Set (Cont'd)

Source of System Dynamic Accuracy Errors¹²

The factors affecting dynamic accuracy listed below are primarily a function of the IF/detector except for compression. In order to measure these values, some of the system cables must be disconnected to gain access to the individual instruments.

Compression 0.1 dB point:¹³ ≥ -7 dBm into Port 2, 45 MHz to 18 GHz
 ≥ -12 dBm into Port 2, 18 GHz to 26.5 GHz

IF Amplifier Gain Accuracy:

IF Amplifier Power Range (dBm) ¹⁴	Maximum Gain Error (dB)
-10 to -22	0
-22 to -34	± 0.005
-34 to -46	± 0.01
-46 to -58	± 0.02
< -58	± 0.03

Detector Circularity Error: ± 0.003 dB peak

Detector dc Offset Error: -100 dBm¹⁴

IF Residuals: -120 dBm¹⁴

IF Linearity: ± 0.003 dB

Incremental Phase Accuracy (Phase vs. Phase) at Measurement Reference: ± 0.001 degrees/degree, not to exceed 0.02 degrees peak.

¹² Current HP-supplied performance verification tests verify the individual error source specifications and/or the sum total of these individual specifications by verifying transmission and reflection magnitude and phase uncertainties E_{tm} , E_{rm} , E_{tp} , and E_{rp} , as they are defined in the equation on page 1-74. These detailed performance verification tests are found in Section IV of this Operating and Service Manual.

¹³ See Section III, Operation, in this Operating and Service Manual for considerations in achieving maximum dynamic range.

¹⁴ These dBm power level numbers are at the IF input to the HP 8510A, not at the test set test ports.

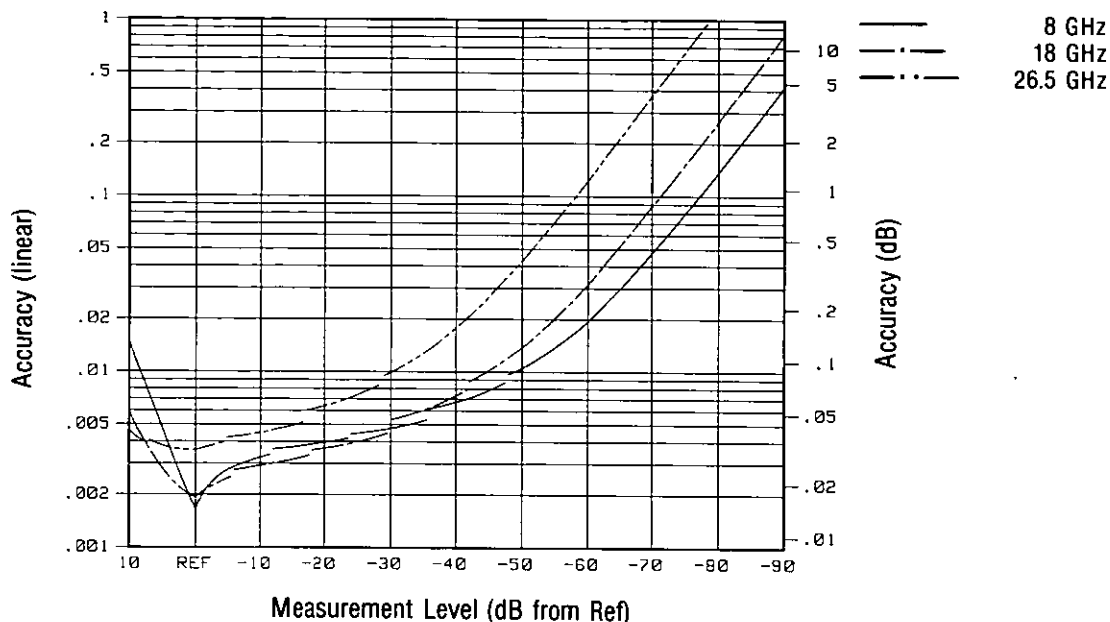
¹⁵ Reference is at the following test port power levels:

- 6 dBm at 8 GHz
- 9 dBm at 18 GHz
- 22 dBm at 26.5 GHz

Table 1-11. Specifications for HP 8510 with HP 8513A Test Set (Cont'd)

Graphics Data of System Dynamic Accuracy Error. Magnitude and phase measurement dynamic accuracy versus signal level is due to the combination of the individual specified factors listed in the previous paragraphs. These measurable factors are combined by vector error analysis using the worst-case method. This combination is shown on the following two data graphs, one graph for phase measurement uncertainty and one for magnitude measurement uncertainty.

Worst-case Magnitude Dynamic Accuracy Error



Worst-case Phase Dynamic Accuracy Error

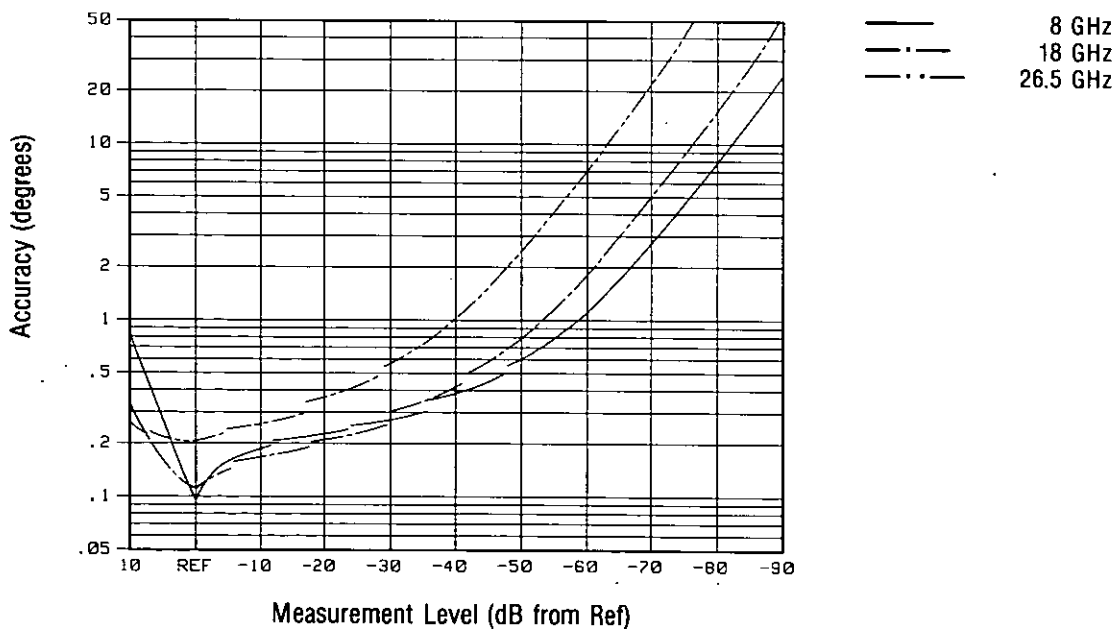


Table 1-11. Specifications for HP 8510 with HP 8513A Test Set (Cont'd)

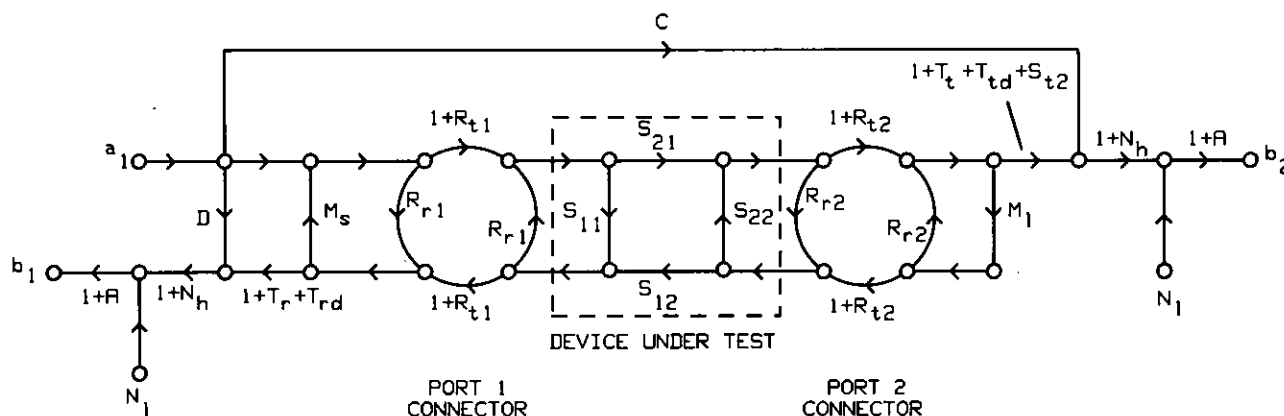
System Flow Graph and Equations

The HP 8510 system error model flow graph and equations are described in the following paragraphs. The flow graph shows the source of errors for the HP 8513A and HP 8510A. The tables on page 1-68/1-69 describe each of these error terms and lists the uncorrected and corrected values.

Using the linear error terms in the error-corrected column of the table, and the nominal S-Parameter data of the device under test, the following equations calculate the total error-corrected measurement uncertainty with a confidence factor of 99.9%. The procedure for using the equations is as follows:

1. Convert the S-Parameters of the device under test to their linear absolute magnitude.
2. Look up the absolute magnitude of the linear error terms from the tables on pages 1-68 and 1-69.
3. The magnitude dynamic accuracy term "A" must be read from the graph on page 1-72. Be sure to use the linear scale.
4. Combine the above three sets of errors using the equations below.

System Flow Graph



NOTE

The individual terms are as defined in the table on page 1-68 and 1-69.

Table 1-11. Specifications for HP 8510 with HP 8513A Test Set (Cont'd)

Total Transmission Magnitude Uncertainty (E_{tm})

$$E_{tm}(\text{linear}) = V_t + S_{21} \times T_{td}(\text{magnitude}) ; \text{ and}$$

$$E_{tm}(\text{log}) = 20 \log(1 \pm E_{tm}/S_{21})$$

where

$$V_t = S_t + \sqrt{W_t^2 + X_t^2 + Y_t^2 + Z_t^2}$$

$$S_t = \text{Systematic Error} = C + T_t S_{21} + M_S S_{11} S_{21} + M_I S_{22} S_{21} + A S_{21}$$

$$W_t = \text{Random low-level noise} = 3N_l$$

$$X_t = \text{Random high-level noise} = 3N_h S_{21}$$

$$Y_t = \text{Random Port-1 repeatability} = R_{t1} S_{21} + R_{r1} S_{11} S_{21}$$

$$Z_t = \text{Random Port-2 repeatability} = R_{t2} S_{21} + R_{r2} S_{22} S_{21}$$

Total Transmission Phase Uncertainty (E_{tp})

$$E_{tp} = \sin^{-1}(V_t/S_{21}) + S_{t2} + T_{td}(\text{phase})$$

Total Reflection Magnitude Uncertainty (E_{rm})

$$E_{rm}(\text{linear}) = V_r + S_{11} \times T_{rd}(\text{magnitude}) ; \text{ and}$$

$$E_{rm}(\text{log}) = 20 \log(1 \pm E_{rm}/S_{11})$$

where

$$V_r = S_r + \sqrt{W_r^2 + X_r^2 + Y_r^2 + Z_r^2} ; \text{ and}$$

$$S_r = \text{Systematic Error} = D + T_r S_{11} + M_S S_{11}^2 + M_I S_{21} S_{12} + A S_{11}$$

$$W_r = \text{Random low-level noise} = 3N_l$$

$$X_r = \text{Random high-level noise} = 3N_h S_{11}$$

$$Y_r = \text{Random Port-1 repeatability} = R_{r1} + 2R_{t1} S_{11} + R_{r1} S_{11}^2$$

$$Z_r = \text{Random Port-2 repeatability} = R_{r2} S_{21} S_{12}$$

Total Reflection Phase Uncertainty (E_{rp})

$$E_{rp} = \sin^{-1}(V_r/S_{11}) + T_{rd}(\text{phase})$$

Table 1-11. Specifications for HP 8510 with HP 8513A Test Set (Cont'd)

Expected System Performance

The following graphs show phase and magnitude measurement uncertainty after accuracy enhancement for both reflection (S_{11}) and transmission (S_{21}) measurement of devices with precision 7mm connectors, and with precision 3.5mm connectors. The uncertainty is derived by computing the contribution of each source of error by using the equations on page 1-74 and the table on page 1-68 and 1-69. The resultant values are combined in the following graphs. These graphs are for a confidence factor of 99.9%. The following assumptions are made:

Reflection: S_{21} and S_{12} of the device under test is 0.

Transmission: S_{11} and S_{22} of the device under test is 0.

Cable Stability S_{t2} and System Drift T_{td} and $T_{rd} = 0$.

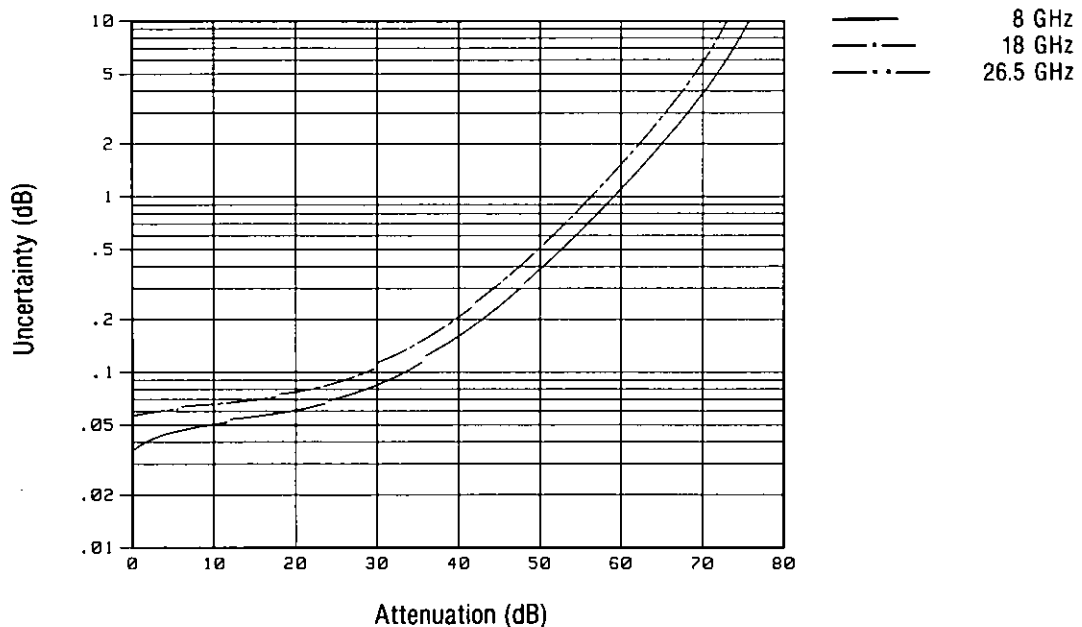
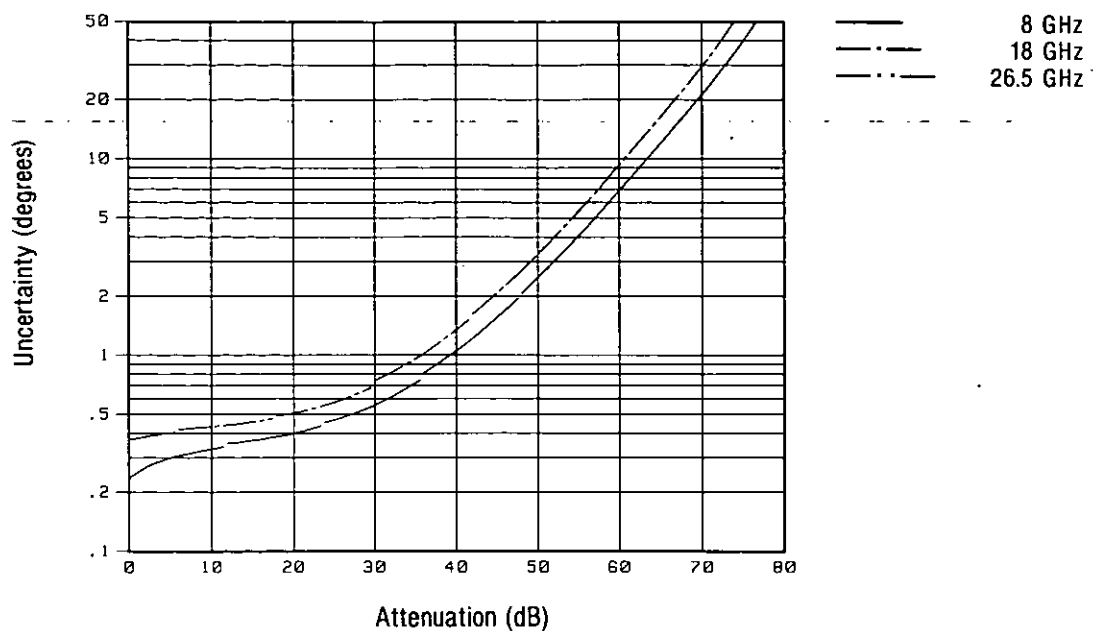
Total Transmission Magnitude Uncertainty with 7mm Connectors

Table 1-11. Specifications for HP 8510 with HP 8513A Test Set (Cont'd)

Total Transmission Phase Uncertainty with 7mm Connectors



Total Reflection Magnitude Uncertainty with 7mm Connectors

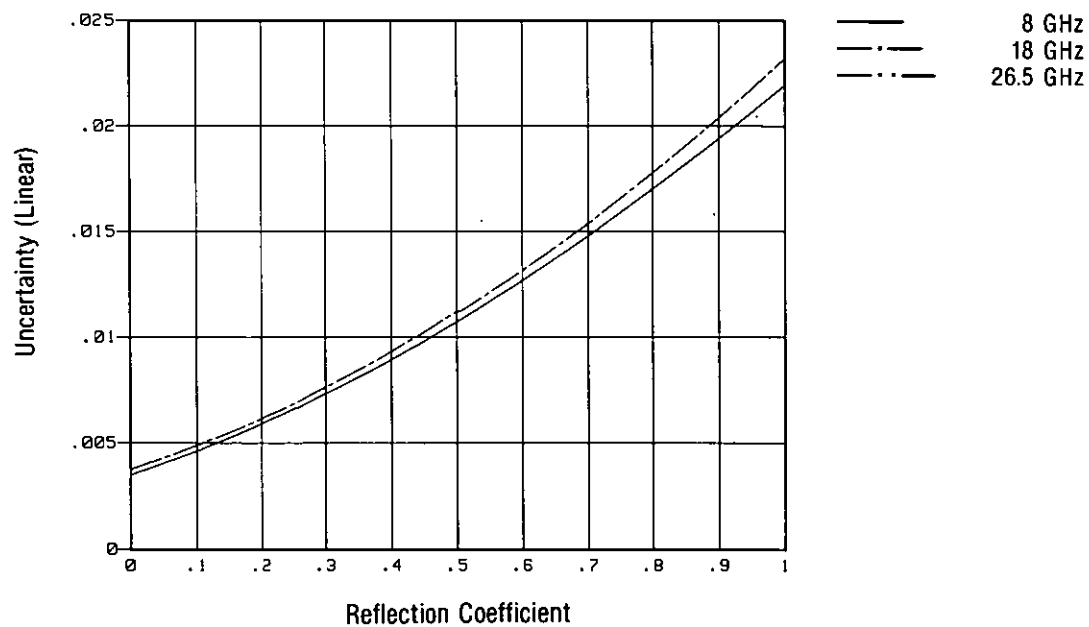
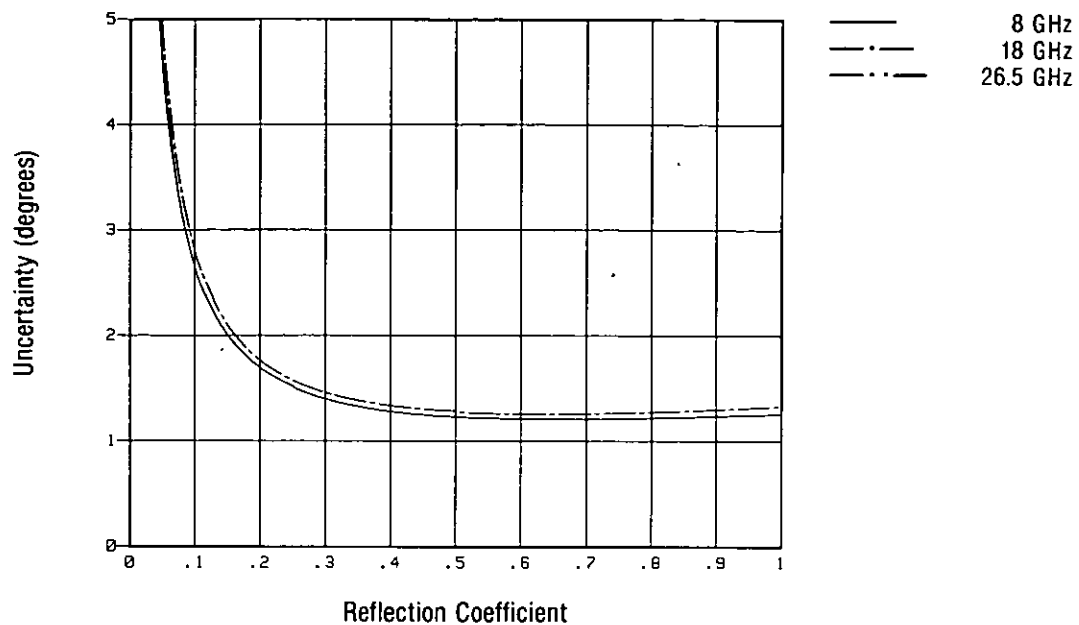


Table 1-11. Specifications for HP 8510 with HP 8513A Test Set (Cont'd)

Total Reflection Phase Uncertainty with 7mm Connectors



Total Transmission Magnitude Uncertainty with 3.5mm Connectors

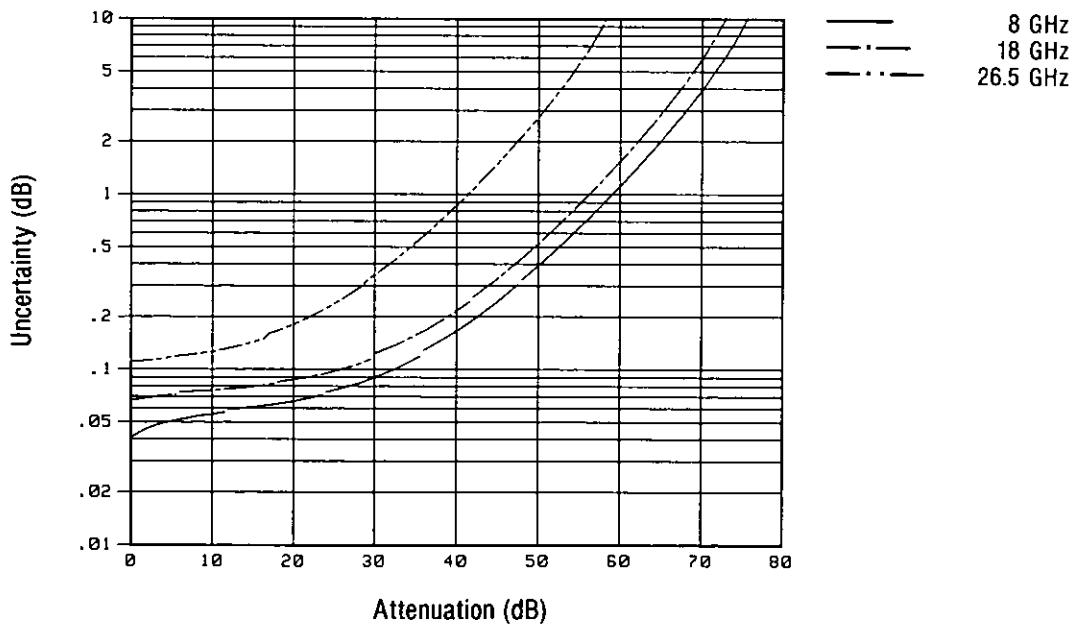
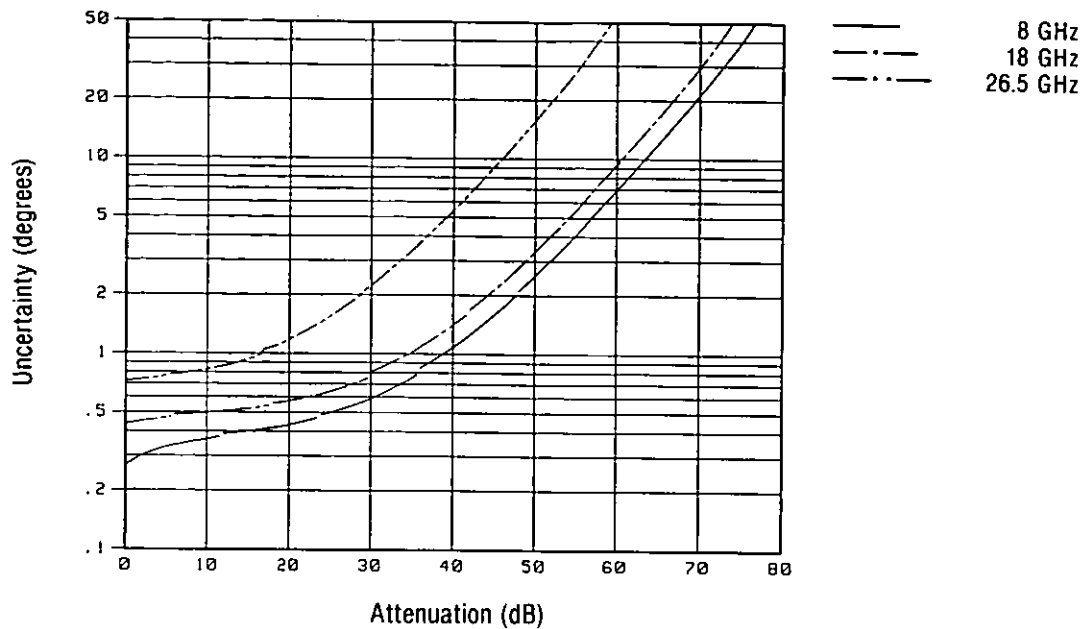


Table 1-11. Specifications for HP 8510 with HP 8513A Test Set (Cont'd)

Total Transmission Phase Uncertainty with 3.5mm Connectors



Total Reflection Magnitude Uncertainty with 3.5mm Connectors

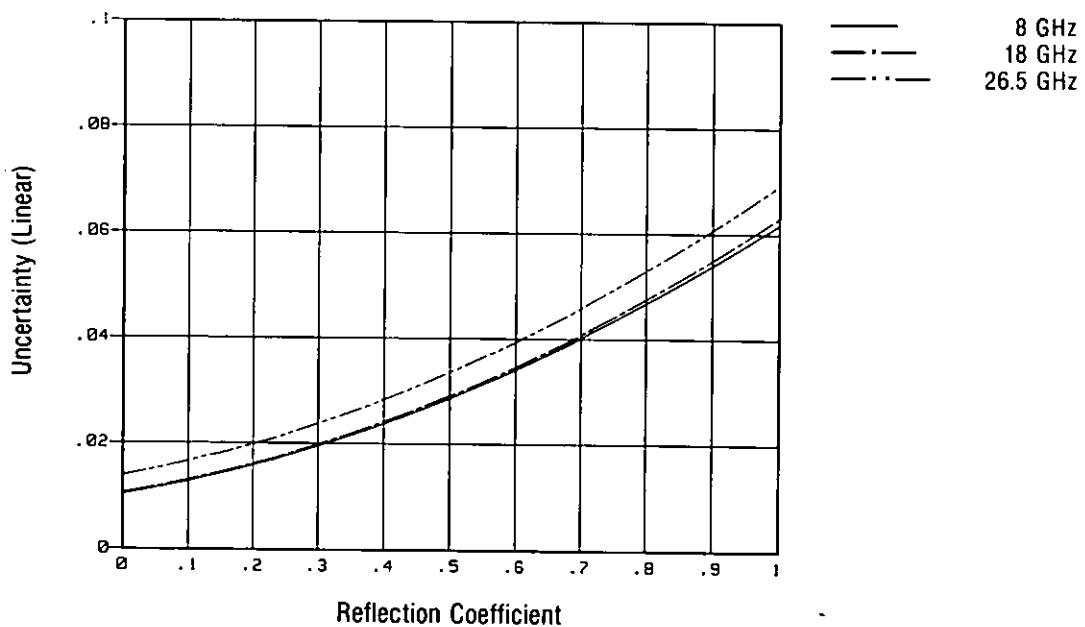
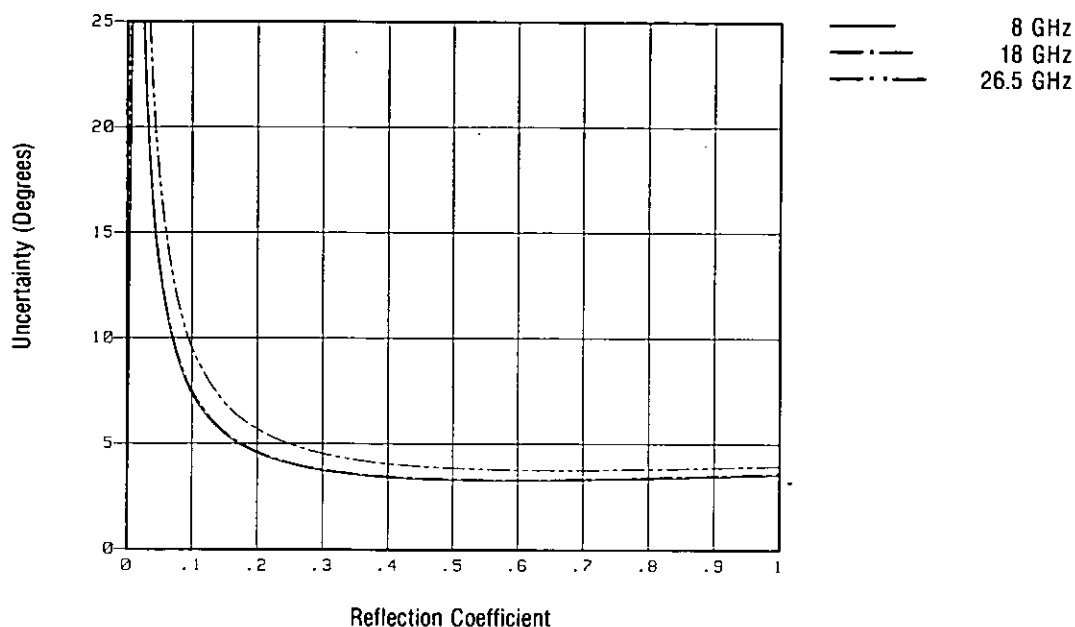


Table 1-11. Specifications for HP 8510 with HP 8513A Test Set (Cont'd)

Total Reflection Phase Uncertainty with 3.5mm Connectors



GROUP DELAY CHARACTERISTICS

Aperture:

Minimum Aperture (Hz) = Frequency Span (Hz)/(no. of points - 1)

Maximum Aperture (Hz) = 20% of Frequency Span (Hz)

Range:

The maximum delay is limited to measuring no more than ± 180 degrees of phase change within the minimum aperture.

$$\text{Range} = \frac{180\text{deg}}{360 (\text{Minimum Aperture})} = \frac{1}{2} \times \frac{\text{Number of Points} - 1}{\text{Frequency Span (Hz)}}$$

EXAMPLE: Frequency Span = 40 MHz
 Number of Points = 201
 Minimum Aperture = 200 kHz
 Range = 2.5 μ s

Group Delay High-Level Noise:

Continuous measurement of a through connection displays RMS noise as follows:

$$\text{Noise} = \frac{0.004 \times N_h \text{ (the high-level phase noise)}}{\text{Aperture (Hz)}} + \frac{1.41 \times \text{Delay (sec)} \times \text{Residual FM (10 kHz BW, Hz)}}{\text{Aperture (Hz)}}$$

Table 1-11. Specifications for HP 8510 with HP 8513A Test Set (Cont'd)

Accuracy:

Delay accuracy is a function of the uncertainty of the phase change and the frequency linearity. The following formula can be used to determine the accuracy, in seconds, of a specific group delay measurement:

$$\text{Accuracy} = \pm \frac{0.003 \times \text{Phase Accuracy (degrees)}^{16}}{\text{Aperture (Hz)}} + \frac{[\text{Delay (sec)}] \times [\text{linearity (Hz)}]}{\text{Aperture (Hz)}}$$

EXAMPLE: Given is a system with an HP 8340A sweeper operating in stepped sweep mode with 101 points per sweep over a 50 MHz span. The device has 50 ns of delay and very little amplitude change over the passband. In this case, the HP 8340A linearity is 4 Hz (resolution).

$$\text{Accuracy} = \pm \frac{0.003 \times [0.02 \text{ deg}] + [50\text{ns}] \times [4\text{Hz}]}{50\text{MHz}/(101\text{points} - 1)}$$

$$\text{Accuracy} = \pm 0.12 \text{ ns}$$

¹⁶ Phase accuracy can be any of the following types:

- a) **Incremental Phase Accuracy (Phase vs. Phase)** for narrow band applications where very small changes in amplitude occur (page 1-71).
- b) **Worst-Case Phase Dynamic Accuracy** for narrow band applications where significant amplitude changes occur (page 1-72).
- c) **Total Transmission Phase Uncertainty (E_{tp})** for the general case (page 1-76 for 7mm E_{tp} and page 1-78 for 3.5mm E_{tp}).

Table 1-12. Specifications for HP 8510 with HP 8515A Test Set

INTRODUCTION AND GENERAL CHARACTERISTICS

The combination of an HP 8515A test set with an HP 8510A network analyzer and an HP 8340A sweeper forms a system for making reflection (S_{11} and S_{22}) and transmission (S_{21} and S_{12}) measurements over the frequency range of 45 MHz to 26.5 GHz.

Specification Assumptions

The specifications of this table assume that the following conditions are met:

7mm Connector Specification Assumptions:

- The RF source is an HP 8340A synthesized sweeper operating in stepped sweep mode.
- The RF cable from the sweeper power output connector to the test set power input connector is the RF Flex Source Cable, HP Part Number 08513-60009.
- The temperature is in the range of 0° C to 55° C, except where noted.
- Calibration and verification measurements are performed with HP 85130A 3.5mm to 7mm adapters connected to port 1 and port 2 of the test set. The reference plane is at the 7mm end of the adapter when calibration and measurement is performed.
- Reflection calibration and measurement is done at the test port (Port 1 or Port 2) reference plane. The transmission return path for transmission calibration and measurement is through an HP 85132B test port cable set to the opposite port. Load match measurements are taken directly at the test ports.
- The power level at the RF source output is +10 dBm.
- Calibration is performed with an HP 85050A precision 7mm calibration kit.
- Verification procedures use the HP 85051A precision 7mm verification kit.

3.5mm Connector Specification Assumptions:

- All corrected error source specifications for 3.5mm connectors are typical.
- The RF source is an HP 8340A synthesized sweeper operating in stepped sweep mode.
- The RF cable from the sweeper power output connector to the test set power input connector is the RF Flex Source Cable, HP Part Number 08513- 60009.
- The temperature is in the range of 0° C to 55° C, except where noted.
- Reflection calibration and measurement is done at the test port (Port 1 or Port 2). The transmission return path for calibration and measurement is through an HP 85131B cable set to the opposite port. Load match measurements are taken directly at the test ports.
- From 45 MHz to 18 GHz, the power level at the RF source output is +10 dBm. From 18 GHz to 26.5 GHz, the power level at the RF source output is 0 dBm.
- Calibration is performed with an HP 85052A precision 3.5mm calibration kit.
- Verification procedures use the HP 85053A precision 3.5mm verification kit.

Table 1-12. Specifications for HP 8510 with HP 8515A Test Set (Cont'd)

Frequency Range

Reflection and Transmission: 45 MHz to 26.5 GHz

Test Ports

Connector Type: Precision 3.5mm Male

Impedance: 50 ohms nominal

DC Bias: 500 mA, 40Vdc maximum

Incident Signal Attenuation Range: 0 to 90 dB, in 10 dB steps

Nominal Operating Power Level:

Test Port 1 and Test Port 2: -8 dBm at 8 GHz
 -12 dBm at 18 GHz
 -28 dBm at 26.5 GHz

Damage Input Level:

Test Port 1 and Test Port 2: > +20 dBm, > 40Vdc

RF Input Connector

Connector Type: Precision 3.5mm Female

Damage Input Level: > +20 dBm

Minimum and Maximum Reference Channel Power

Minimum Input Power at rear-panel RF INPUT port (for Reference Channel Phase Lock): 0 dBm

Maximum Input Power at rear-panel RF INPUT port (level before 0.1 dB compression): +14 dBm

*Table 1-12. Specifications for HP 8510 with HP 8515A Test Set (Cont'd)***HARDWARE AND SYSTEM PERFORMANCE SPECIFICATIONS****Table of System Errors¹**

The following tables lists specifications for various sources of system error. One table lists the 7mm connector specification values for uncorrected measurements, corrected measurements after accuracy enhancement, and verification limits, over the frequency range of 45 MHz to 18 GHz. The other table lists the 3.5mm connector typical specification values for uncorrected measurements, and corrected measurements after accuracy enhancement (typical), over the frequency range of 45 MHz to 26.5 GHz. Devices in the calibration and verification kits (HP 85050A and HP 85051A) have the precision and accuracy to calibrate the system and to verify the source of error to the limits shown in the "Verification Limits" column of the 7mm specifications table.

Table 1-11. Specifications for HP 8510 with HP 8515A Test Set with 7mm Connectors

Source of System Errors

Symbol	Error Source	Uncorrected		Residual After Accuracy Enhancement ^{2, 9}				Verification Limits ^{2, 4, 9}	
		.045-8 GHz	8-18 GHz	.045-8 GHz		8-18 GHz		.045-8 GHz	8-18 GHz
		dB or Deg.	dB or Deg.	Linear	dB	Linear	dB	dB	dB
D	Directivity	-22	-24	.0032	-50	.0032	-50	-44	-44
M _S	Source Match	-22	-15	.01	-40	.01	-40	-37	-37
M _L	Load Match	-22	-15	.01	-40	.01	-40	-40	-40
T _r	Reflection Tracking	±1 ⁵	±.75 ⁵	.0058	±.05	.0058	±.05	±.05	±.05
T _t	Transmission Tracking	±1	±.75	.0035	±.03	.0070	±.06	±.03	±.06
C	Crosstalk ⁶	-80	-80	.000032	-90	.000032	-90	-90	-90
R _{r1}	Port 1 Reflection Connector Repeatability (Typical)	-70 dB	-65 dB	.00032	-70	.00032	-65		
R _{t1}	Port 1 Transmission Connector Repeatability (Typical)	-70 dB	-65 dB	.00032	-70	.00032	-65		
R _{r2}	Port 2 Reflection Connector Repeatability (Typical)	-70 dB	-65 dB	.00032	-70	.00032	-65		
R _{t2}	Port 2 Transmission Connector Repeatability (Typical)	-70 dB	-65 dB	.00032	-70	.00032	-65		
N _L	Low-Level Noise (Noise Floor) ⁸	-71	-66	.000028	-91	.000050	-86	-91	-86
N _h	High-Level Noise ¹⁰ Magnitude Phase	.015 .1 Deg.	.02 .15 Deg.	.00017	.0015	.00023	.002		
A	8510A Magnitude Dynamic Accuracy Error (Primarily IF and Detector)	Refer to magnitude curve on Page 1-85							
S _{t1}	Port 1 Cable Transmission Phase Stability (Typical) ¹¹	.05 x f (GHz), degrees							
S _{r1}	Port 1 Cable Reflection Stability (Typical)	-70 dB	-60 dB	.00032	-70	.001	-60		
S _{t2}	Port 2 Cable Transmission Phase Stability (Typical) ¹¹	.05 x f (GHz), degrees							
S _{r2}	Port 2 Cable Reflection Stability (Typical)	-70 dB	-60 dB	.00032	-70	.001	-60		
T _{td}	Transmission Magnitude Tracking Drift (Typical) Phase	.001 x Δ°C, linear (0.1 + .01 x f (GHz)) x Δ°C, Degrees							
T _{rd}	Reflection Magnitude Tracking Drift (Typical) Phase	.001 x Δ°C, linear (0.1 + .01 x f (GHz)) x Δ°C, Degrees							

Table 1-11. Specifications for HP 8510 with HP 8515A Test Set with 3.5mm Connectors

Source of System Errors

Symbol	Error Source	Uncorrected			Residual After Accuracy Enhancement (Typical) ^{3, 9}					
		.045-8 GHz	8-18 GHz	18-26.5 GHz	.045-8 GHz		8-18 GHz		18-26.5 GHz	
		dB or Deg.	dB or Deg.	dB or Deg.	Linear	dB	Linear	dB	Linear	dB
D	Directivity	-22 dB	-24 dB	-24 dB	.01	-40	.01	-40	.013	-38
M _S	Source Match	-22 dB	-15 dB	-13 dB	.032	-30	.032	-30	.032	-30
M _L	Load Match	-22 dB	-15 dB	-13 dB	.032	-30	.032	-30	.032	-30
T _r	Reflection Tracking	±1 dB ⁵	±1 dB ⁵	±1.5 dB ⁵	.017	±.15	.017	±.15	.017	±.15
T _t	Transmission Tracking	±1 dB	±1 dB	±1.7 dB	.0023	±.02	.0058	±.05	.0093	±.08
C	Crosstalk ⁶	-80 dB	-80 dB	-70 dB ⁷	.000032	-90	.000032	-90	.0001	-80 ⁷
R _{r1}	Port 1 Reflection Connector Repeatability (Typical)	-70 dB	-65 dB	-60 dB	.00032	-70	.00056	-65	.001	-60
R _{t1}	Port 1 Transmission Connector Repeatability (Typical)	-70 dB	-65 dB	-60 dB	.00032	-70	.00056	-65	.001	-60
R _{r2}	Port 2 Reflection Connector Repeatability (Typical)	-70 dB	-65 dB	-60 dB	.00032	-70	.00056	-65	.001	-60
R _{t2}	Port 2 Transmission Connector Repeatability (Typical)	-70 dB	-65 dB	-60 dB	.00032	-70	.00056	-65	.001	-60
N _l	Low-Level Noise (Noise Floor) ⁸	-71 dB	-66 dB	-50 dB ⁷	.000028	-91	.000050	-86	.00032	-70 ⁷
N _h	High-Level Noise ¹⁰ Magnitude Phase	.015 dB .1 Deg.	.02 dB .15 Deg	.04 dB .28 Deg	.00017	.0015	.00023	.002	.00046	.004
A	8510A Magnitude Dynamic Accuracy Error (Primarily IF and Detector)	Refer to magnitude curve on page 1-85								
S _{t1}	Port 1 Cable Transmission Phase Stability (Typical) ¹¹	.05 x f (GHz), degrees								
S _{r1}	Port 1 Cable Reflection Stability (Typical)	-70 dB	-60 dB	-55	.00032	-70	.001	-60	.0018	-55
S _{t2}	Port 2 Cable Transmission Phase Stability (Typical) ¹¹	.05 x f (GHz), degrees								
S _{r2}	Port 2 Cable Transmission Stability (Typical)	-70 dB	-60 dB	-55	.00032	-70	.001	-60	.0018	-55
T _{td}	Transmission Tracking Drift (Typical) Magnitude Phase	.001 x Δ°C, linear (0.1 + .01 x f (GHz)) x Δ°C, Degrees								
T _{rd}	Reflection Tracking Drift (Typical) Magnitude Phase	.001 x Δ°C, linear (0.1 + .01 x f (GHz)) x Δ°C, Degrees								

Table 1-12. Specifications for HP 8510 with HP 8515A Test Set (Cont'd)

Footnotes for Table of System Errors

- 1 Current HP-supplied performance verification tests verify the individual error source specifications and/or verify the sum total of these individual specifications by verifying transmission and reflection magnitude and phase uncertainties E_{tm} , E_{rm} , E_{tp} , and E_{rp} , as they are defined in the equation on page 1-90. These detailed performance verification tests are found in Section IV of this Operating and Service Manual.
- 2 Accuracy enhancement is achieved using the HP 85050A 7mm calibration kit and an HP 85130A adapter set for a full two-port calibration. The environmental temperature is $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$ at calibration; $\pm 1^{\circ}\text{C}$ from the calibration temperature must be maintained for valid calibration and verification.
- 3 Accuracy enhancement is achieved using an HP 85052A 3.5mm calibration kit for a full two-port calibration. The environmental temperature is $23^{\circ}\text{C} \pm 3^{\circ}\text{C}$ at calibration; $\pm 1^{\circ}\text{C}$ from the calibration temperature must be maintained for valid calibration and verification.
- 4 Numbers shown are for verification tests using devices in the HP 85050A 7mm calibration kit and the HP 85051A 7mm verification kit. For other standards, use appropriate uncertainty. Parameters of the system are measured at the factory with one set of standards. These same parameters may be tested again in the field with the verification procedures, using a second set of standards, the calibration and verification kits. The measured verification values will always have more uncertainty than the calibration and verification standards. For example, if the parameter value in the system is $>50\text{ dB}$ and the parameter present in the calibration device is $>50\text{ dB}$, then the highest measured value with negligible ambiguity is 6 dB less, or 44 dB.
- 5 Residual ripple that compares the smoothed trace to a normal trace.
- 6 From 45 MHz to 18 GHz an averaging factor of 1024 is applied. From 18 GHz to 26.5 GHz an averaging factor of 4096 is applied.
- 7 With +10 dBm of source power available, the noise floor specification and the ability to measure crosstalk improves by 10 dB.
- 8 Low-level noise (noise floor) is measured relative to an S_{21} through measurement.
- 9 An averaging factor of 128 is applied.
- 10 High-level noise is an RMS value taken of a continuous measurement of a short circuit or a through connection.
- 11 The cable phase stability term was arrived at by bending the cable out perpendicular to the front panel and then reconnecting it. The stability will be much better when less flexing is applied.

Table 1-12. Specifications for HP 8510 with HP 8515A Test Set (Cont'd)

Source of System Dynamic Accuracy Errors¹²

The factors affecting dynamic accuracy listed below are primarily a function of the IF/detector except for compression. In order to measure these values, some of the system cables must be disconnected to gain access to the individual instruments.

Compression 0.1 dB Point:¹³ $\geq +2$ dBm into Test Port, 45 MHz to 18 GHz
 ≥ -3 dBm into Test Port, 18 GHz to 26.5 GHz

IF Amplifier Gain Accuracy (Typical):

IF Amplifier Power Range (dBm) ¹⁴	Maximum Gain Error (db)
-10 to -22	0
-22 to -34	± 0.005
-34 to -46	± 0.01
-46 to -58	± 0.02
< -58	± 0.03

Detector Circularity Error: ± 0.003 dB peak

Detector dc Offset Error: -100 dBm¹⁴

IF Residuals: -120 dBm¹⁴

IF Linearity: ± 0.003 dB

Incremental Phase Accuracy (Phase vs. Phase) at Measurement Reference: ± 0.001 degrees/degree, not to exceed 0.02 degrees peak.

¹² Current HP-supplied performance verification tests verify the individual error source specifications and/or verify the sum total of these individual specifications by verifying transmission and reflection magnitude and phase uncertainties E_{tm} , E_{rm} , E_{tp} , and E_{rp} , as they are defined in the equation on page 1-90. These detailed performance verification tests are found in Section IV of this Operating and Service Manual.

¹³ See Section III, Operation, in this Operating and Service Manual for considerations in achieving maximum dynamic range.

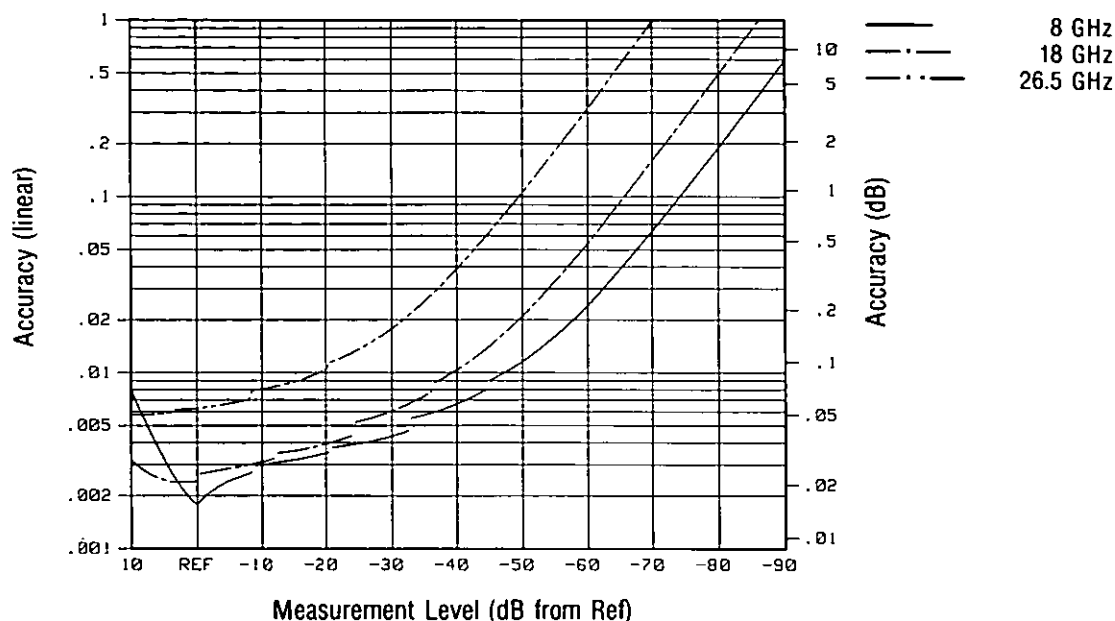
¹⁴ These dBm power level numbers are at the IF input to the HP 8510A, not at the test set test ports.

¹⁵ Reference is at the following test port power levels:
 -8 dBm at 8 GHz
 -12 dBm at 18 GHz
 -28 dBm at 26.5 GHz

Table 1-12. Specifications for HP 8510 with HP 8515A Test Set (Cont'd)

Graphics Data of System Dynamic Accuracy Error: Magnitude and phase measurement dynamic accuracy versus signal level is due to the combination of the individual specified factors listed in the previous paragraphs. These measurable factors are combined by vector error analysis using the worst-case method. This combination is shown on the following page in two graphs of data, one graph for magnitude measurement uncertainty and one for magnitude phase uncertainty.

Worst-case Magnitude Dynamic Accuracy Error



Worst-case Phase Dynamic Accuracy Error

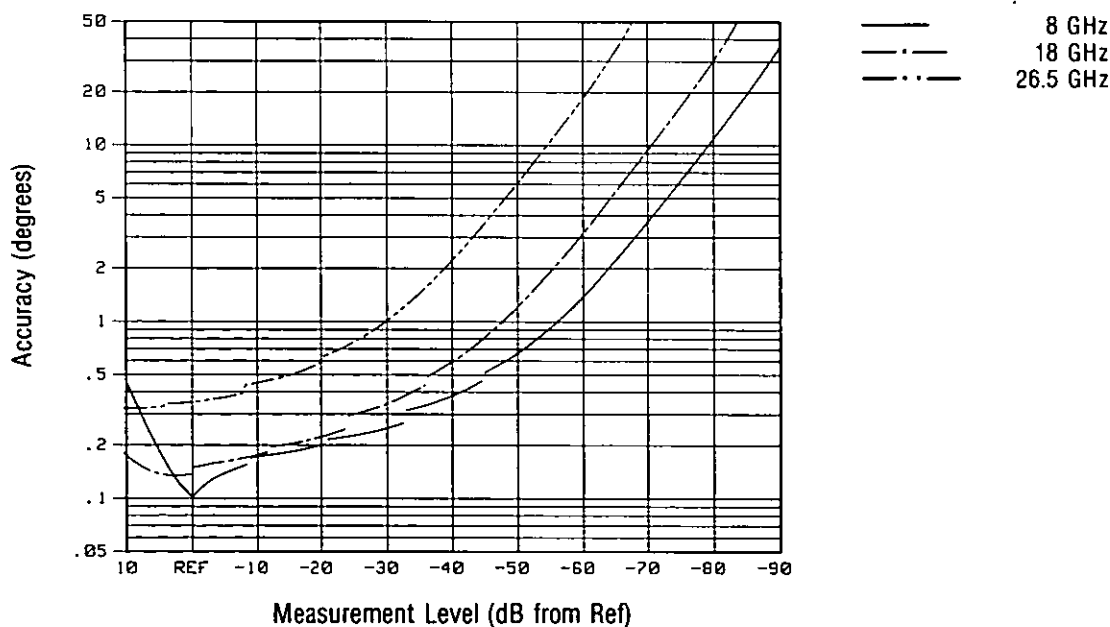


Table 1-12. Specifications for HP 8510 with HP 8515A Test Set (Cont'd)

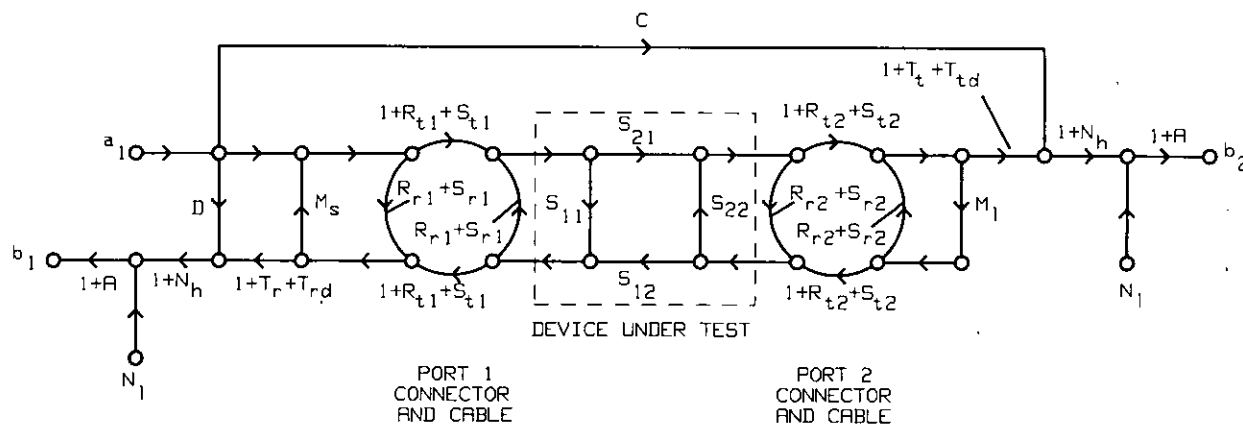
System Flow Graph and Equations

The HP 8510 system error model flow graph and equation are described in the following paragraphs. The flow graph shows the source of errors for the HP 8515A and HP 8510A. The tables on pages 1-84 and 1-85 describe each of these error terms and list the uncorrected and corrected values.

Using the linear error terms in the error-corrected column of the table, combined with the nominal S-Parameter data of the device under test, the following equations calculate the total error-corrected measurement uncertainty with a confidence factor of 99.9%. The procedure for using the equations is as follows:

1. Convert the S-Parameters of the device under test to their linear absolute magnitude.
2. Look up the absolute magnitude of the linear error terms from the tables on pages 1-84 and 1-85.
3. The magnitude dynamic accuracy term "A" must be read from the graph on page 1-88. Be sure to use the linear scale.
4. Combine the above three sets of errors using the equations below.

System Flow Graph



NOTE

The individual terms are as defined in the table on page 1-84 and 1-85.

Table 1-12. Specifications for HP 8510 with HP 8515A Test Set (Cont'd)

Total Transmission Magnitude Uncertainty (E_{tm})

$$E_{tm} = V_t + S_{21} \times T_{td}(\text{mag}); \text{ and}$$

$$E_{tm}(\log) = 20 \log(1 \pm E_{tm}/S_{21})$$

where

$$V_t = S_t + \sqrt{W_t^2 + X_t^2 + Y_t^2 + Z_t^2}$$

$$S_t = \text{Systematic Error} = C + T_t S_{21} + (M_s + S_{r1}) S_{11} S_{21} + (M_1 + S_{r2}) S_{22} S_{21} + A S_{21}$$

$$W_t = \text{Random low-level noise} = 3N_l$$

$$X_t = \text{Random high-level noise} = 3N_h S_{21}$$

$$Y_t = \text{Random Port-1 repeatability} = R_{t1} S_{21} + R_{r1} S_{11} S_{21}$$

$$Z_t = \text{Random Port-2 repeatability} = R_{t2} S_{21} + R_{r2} S_{22} S_{21}$$

Total Transmission Phase Uncertainty (E_{tp})

$$E_{tp} = \sin^{-1}(V_t/S_{21}) + T_{td}(\text{phase}) + S_{t1} + S_{t2}$$

Total Reflection Magnitude Uncertainty (E_{rm})

$$E_{rm} = V_r + S_{11} \times T_{rd}(\text{mag}); \text{ and}$$

$$E_{rm}(\log) = 20 \log(1 \pm E_{rm}/S_{11})$$

where

$$V_r = S_r + \sqrt{W_r^2 + X_r^2 + Y_r^2 + Z_r^2}$$

$$S_r = \text{Systematic Error} = (D + S_{r1}) + T_r S_{11} + (M_s + S_{r1}) S_{11}^2 + (M_1 + S_{r2}) S_{21} S_{12} + A S_{11}$$

$$W_r = \text{Random low-level noise} = 3N_l$$

$$X_r = \text{Random high-level noise} = 3N_h S_{11}$$

$$Y_r = \text{Random Port-1 repeatability} = R_{r1} + 2R_{t1} S_{11} + R_{r1} S_{11}^2$$

$$Z_r = \text{Random Port-2 repeatability} = R_{r2} S_{21} S_{12}$$

Total Reflection Phase Uncertainty (E_{rp})

$$E_{rp} = \sin^{-1}(V_r/S_{11}) + T_{rd}(\text{phase}) + 2S_{t1}$$

Table 1-12. Specifications for HP 8510 with HP 8515A Test Set (Cont'd)

Expected System Performance

The following graphs show measurement uncertainty after accuracy enhancement for both reflection (S_{11}) and transmission (S_{21}) measurement of devices with precision 7mm connectors, and with precision 3.5mm connectors. The uncertainty is derived by computing the contribution of each source of error by using the equations on page 1-90 and the table on page 1-84 and 1-85. The resultant values are combined in the following graphs. These graphs are for a confidence factor of 99.9%. The following assumptions are made:

Reflection: S_{21} and S_{12} of the device under test is 0.

Transmission: S_{11} and S_{22} of the device under test is 0.

Cable Stability S_{t1} , S_{r1} , S_{t2} , and S_{r2} , and System Drift T_{rd} and $T_{td} = 0$.

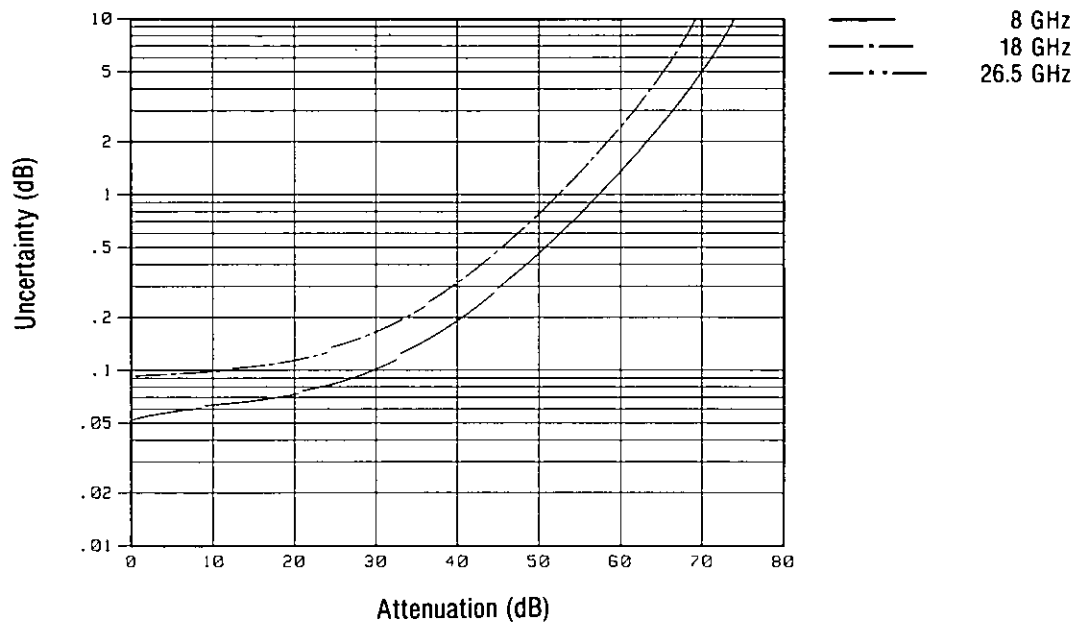
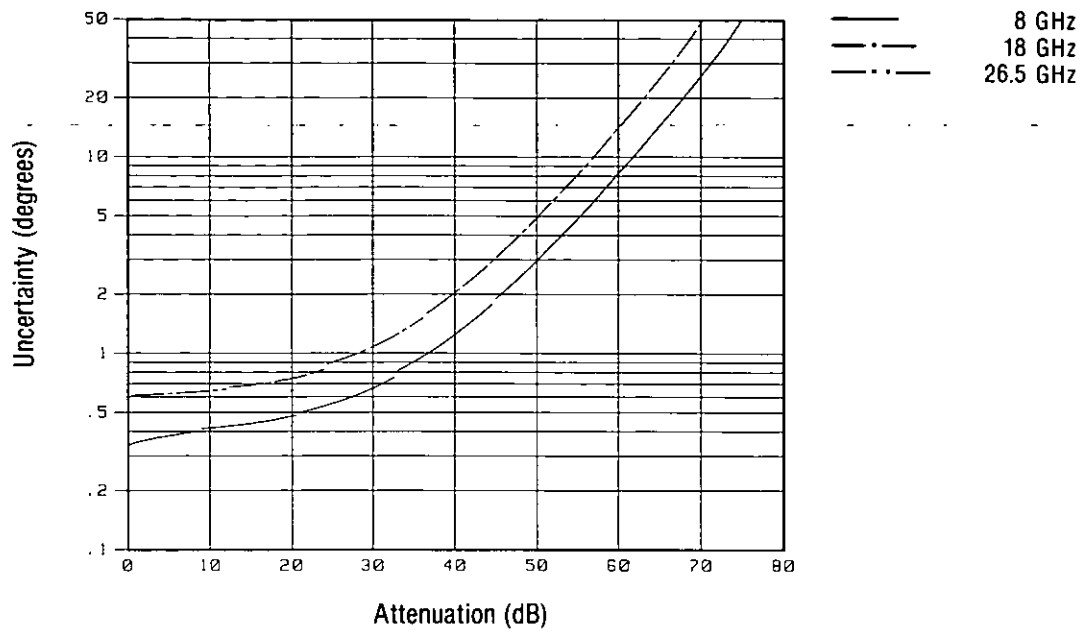
Total Transmission Magnitude Uncertainty with 7mm Connectors

Table 1-12. Specifications for HP 8510 with HP 8515A Test Set (Cont'd)

Total Transmission Phase Uncertainty with 7mm Connectors



Total Reflection Magnitude Uncertainty with 7mm Connectors

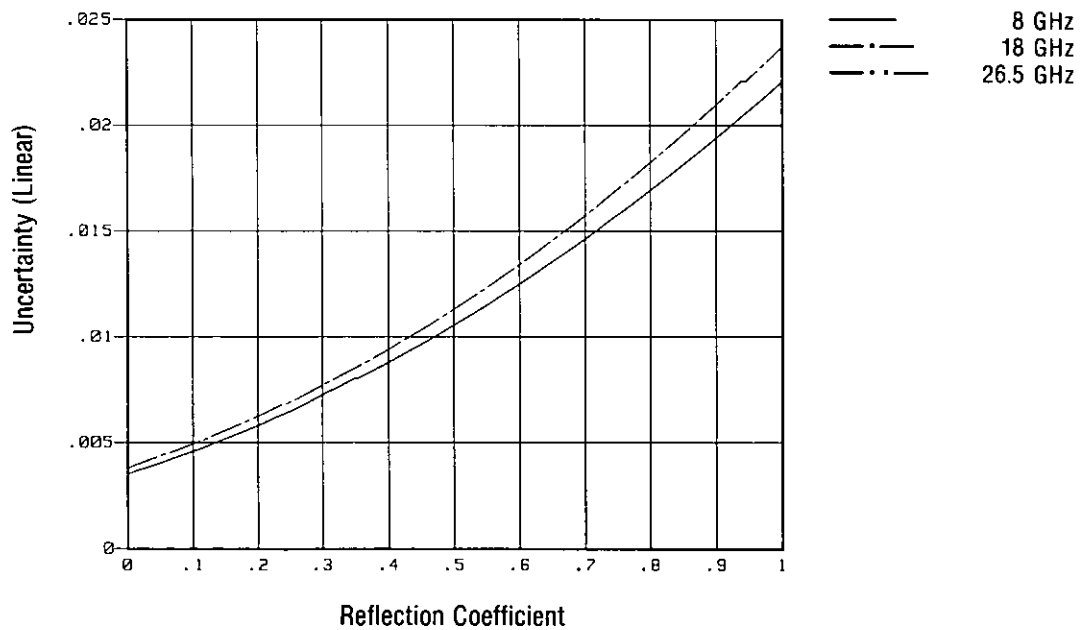
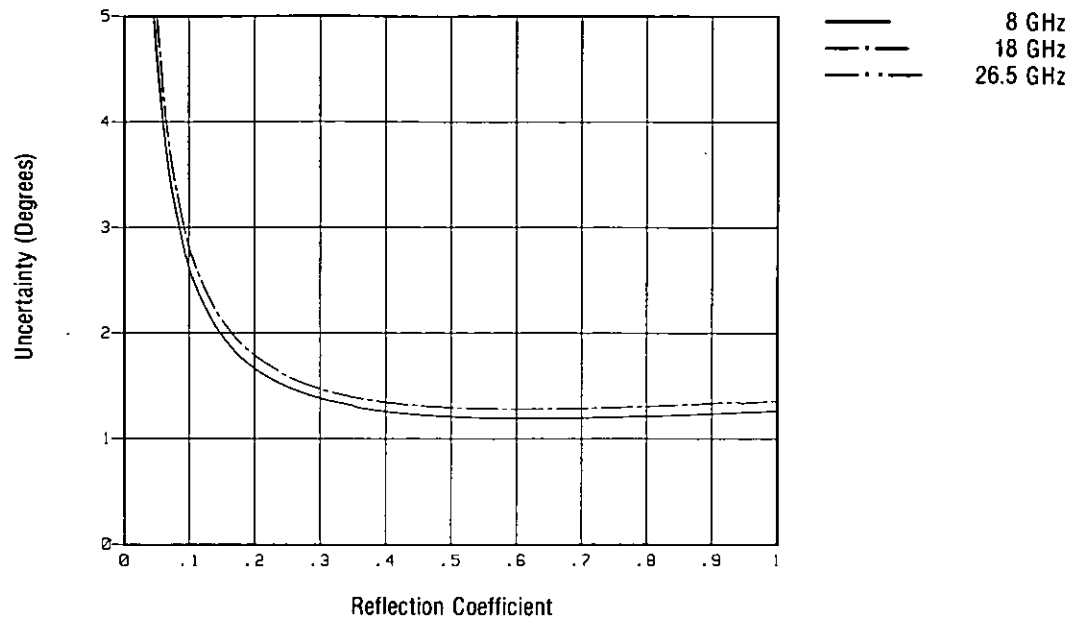


Table 1-12. Specifications for HP 8510 with HP 8515A Test Set (Cont'd)

Total Reflection Phase Uncertainty with 7mm Connectors



Total Transmission Magnitude Uncertainty with 3.5mm Connectors

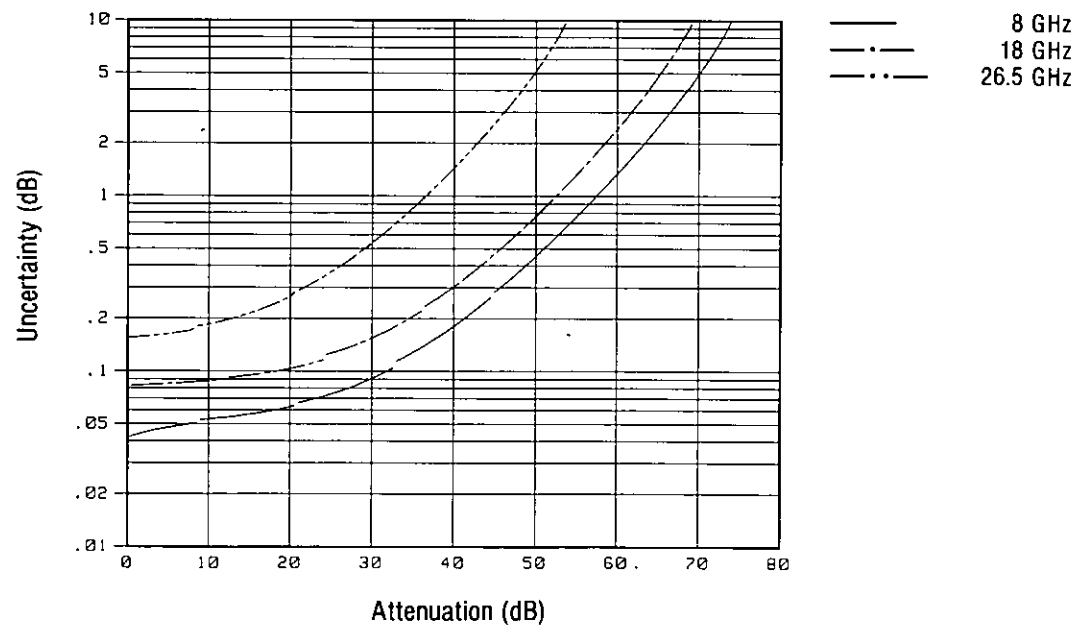
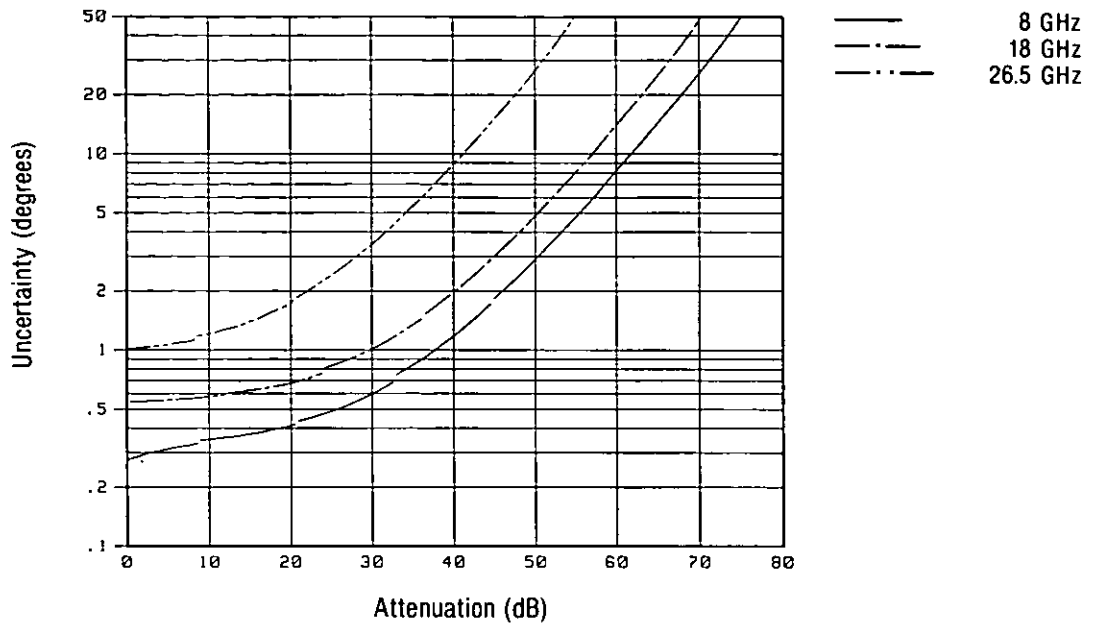


Table 1-12. Specifications for HP 8510 with HP 8515A Test Set (Cont'd)

Total Transmission Phase Uncertainty with 3.5mm Connectors



Total Reflection Magnitude Uncertainty with 3.5mm Connectors

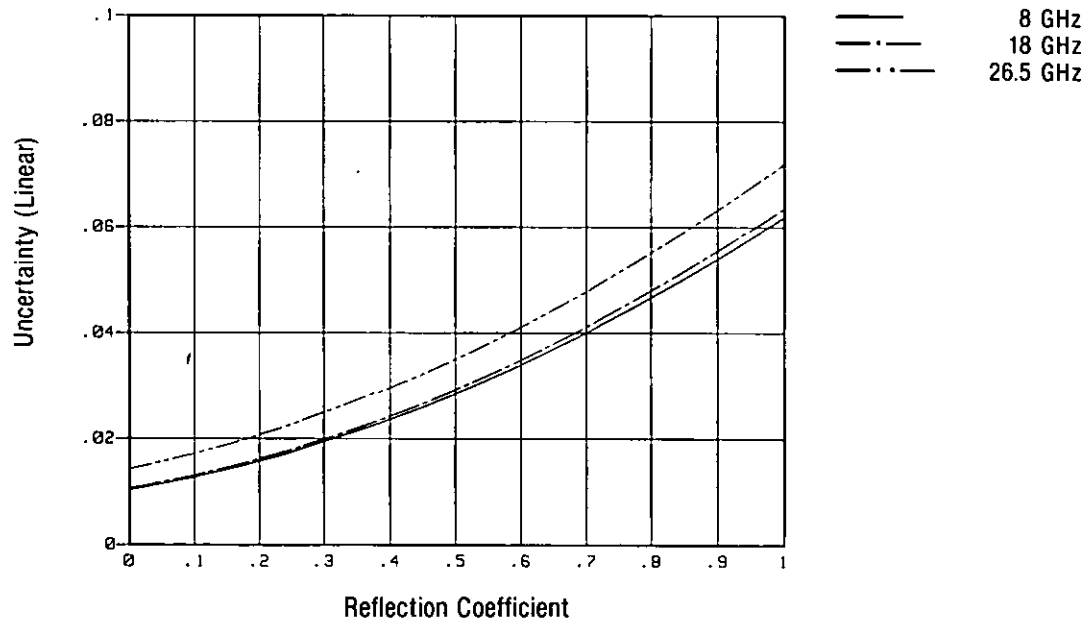
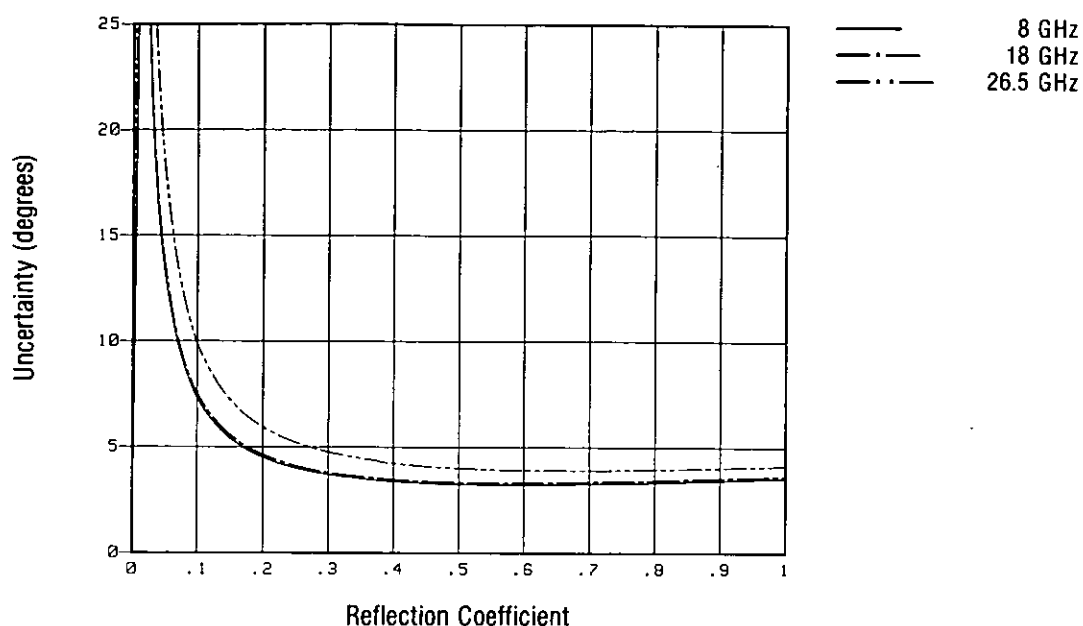


Table 1-12. Specifications for HP 8510 with HP 8515A Test Set (Cont'd)

Total Reflection Phase Uncertainty with 3.5mm Connectors**GROUP DELAY CHARACTERISTICS****Aperture:**

Minimum Aperture (Hz) = Frequency Span (Hz)/(No. of Points - 1)

Maximum Aperture (Hz) = 20% of Frequency Span (Hz)

Range:

The maximum delay is limited to measuring no more than ± 180 degrees of phase change within the minimum aperture.

$$\text{Range} = \frac{180\text{deg}}{360 \times (\text{Minimum Aperture})} = \frac{1}{2} \times \frac{\text{No. of Points} - 1}{\text{Frequency Span (Hz)}}$$

EXAMPLE: Frequency Span = 40 MHz
 Number of Points = 201
 Minimum Aperture = 200 kHz
 Range = 2.5 us

Table 1-12. Specifications for HP 8510 with HP 8515A Test Set (Cont'd)

Group Delay High-Level Noise:

Continuous measurement of a through connection displays RMS noise as follows:

$$\text{Noise} = \frac{0.004 \times N_h \text{ (the high-level phase noise)}}{\text{Aperture (Hz)}} + \frac{1.41 \times \text{Delay (sec)} \times \text{Residual FM (10 kHz BW, Hz)}}{\text{Aperture (Hz)}}$$

Accuracy:

Delay accuracy is a function of the uncertainty of the phase change and the frequency linearity. The following formula can be used to determine the accuracy, in seconds, of a specific group delay measurement:

$$\text{Accuracy} = \pm \frac{0.003 \times \text{Phase Accuracy (degrees)}^{16}}{\text{Aperture (Hz)}} + \frac{[\text{Delay (sec)}] \times [\text{linearity (Hz)}]}{\text{Aperture (Hz)}}$$

EXAMPLE: Given is a system with an HP 8340A sweeper operating in stepped sweep mode with 101 points per sweep over a 50 MHz span. The device has 50 ns of delay and very little amplitude change over the passband. In this case, the HP 8340A linearity is 4 Hz (resolution).

$$\text{Accuracy} = \pm \frac{0.003 \times [0.02 \text{ deg}] + [50\text{ns}] \times [4\text{Hz}]}{50\text{MHz}/100\text{points}}$$

$$\text{Accuracy} = \pm 0.12 \text{ ns}$$

¹⁶ Phase accuracy can be any of the following types:

- a) **Incremental Phase Accuracy (Phase vs. Phase)** for narrow band applications where very small changes in amplitude occur (page 1-87).
- b) **Worst-Case Phase Dynamic Accuracy** for narrow band applications where significant amplitude changes occur (page 1-88).
- c) **Total Transmission Phase Uncertainty (E_{tp})** for the general case (page 1-92 for 7mm E_{tp} and 1-94 for 3.5mm E_{tp}).

Table 1-13. Specifications for the HP 8510/8350B with the HP 8512A, 8513A, 8514A, or 8515A test set.

The S-parameter verification limits are specified for the HP 8510/8530B system when the following HP 85051A (7mm) or HP 85053A (3.5mm) verification devices are used:

VERIFICATION DEVICE	S11/S22 magnitude	S11/S22 phase	S21/S12 magnitude	S21/S12 phase
20 dB attenuator			x	x
40/50 dB attenuator			x	x
Beadless Airline			x	x
Beadless Airline/ Short	x	x		

NOTE: The beadless airline/short referred to in the chart above is the beadless airline verification device terminated with the short circuit calibration device. It is used to verify reflection measurements (S11/S22).

The uncertainty limits listed in the verification kit printout (supplied with each verification kit) are for HP 8510/8340A systems in step mode. The HP 8510/8350B system uncertainty limits (specifications) are calculated from the uncertainty limits listed in each printout as follows:

Magnitude Specifications:

1. **The 20 dB Attenuator, the 40/50 dB Attenuator, and the Beadless Airline:** The transmission magnitude uncertainty specifications are same as the transmission (S21 and S12) uncertainty limits listed in the verification kit printout.
2. **The Beadless Airline/Short Combination:** For each frequency, add the *magnitude addition number* from the table below to the *airline transmission (S21 or S12) magnitude uncertainty data* listed in the verification kit printout. Then, multiply the result by the *magnitude multiplication number* from the table below. Do this for all frequencies within the frequency range of your HP 8350B plug-in and your test set.

Table 1-13. Specifications for the HP 8510/8350B with the HP 8512A, 8513A, 8514A, or 8515A test set. (Cont'd.)

Phase Specifications:

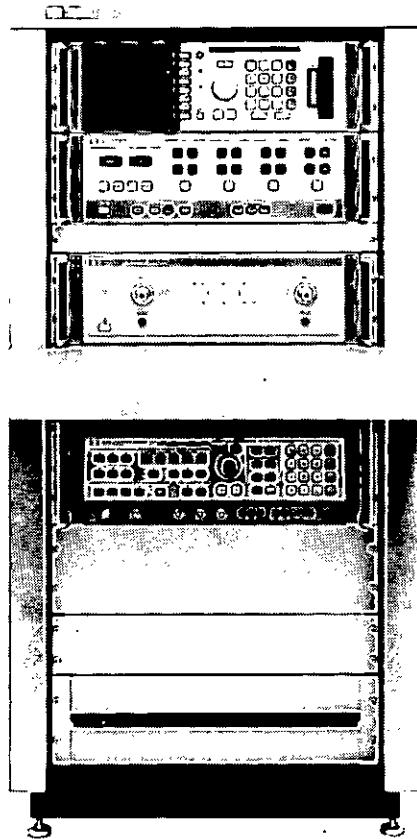
1. **The 20 dB Attenuator, the 40/50 dB Attenuator, and the Beadless Airline:** Add the phase value from the table below to the *phase uncertainty* data listed in the verification kit printout. Do this for all frequencies within the frequency range of your HP 8350B plug-in and your test set.
2. **The Beadless Airline/Short Combination:** Add the phase value from the table below to the *airline phase uncertainty* data listed in the verification kit printout. Do this for all frequencies within the frequency range of your HP 8350B plug-in and your test set.

TEST SET	ATTENUATORS		AIRLINE (deg)	AIRLINE/SHORT		
	20 dB (deg)	40/50 dB (deg)		PHASE (deg)	MAGNITUDE Add Multiply	
HP 8512A	5	5	6	12	.2	1.3
HP 8513A 7 mm 3.5 mm	5	5	6	12	.2	1.3
	2	5	5	10	.65	1.0
HP 8514A	5	6	6	14	.2	1.3
HP 8515A 7 mm 3.5 mm	5	7	6	14	.2	1.3
	3	15	5	14	.65	1.0



INSTALLATION MANUAL

HP 8510 NETWORK ANALYZER



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CERTIFICATION

Hewlett-Packard Company certifies that this product met its published specifications at the time of shipment from the factory. Hewlett-Packard further certifies that its calibration measurements are traceable to the United States National Bureau of Standards, to the extent allowed by the Bureau's calibration facility, and to the calibration facilities of other International Standards Organization members.

WARRANTY

This Hewlett-Packard instrument product is warranted against defects in material and workmanship for a period of one year from date of shipment. During the warranty period, Hewlett-Packard Company will, at its option, either repair or replace products which prove to be defective.

For warranty service or repair, this product must be returned to a service facility designated by HP. Buyer shall prepay shipping charges to HP and HP shall pay shipping charges to return the product to Buyer. However, Buyer shall pay all shipping charges, duties, and taxes for products returned to HP from another country.

HP warrants that its software and firmware designated by HP for use with an instrument will execute its programming instructions when properly installed on that instrument. HP does not warrant that the operation of the instrument, or software, or firmware will be uninterrupted or error free.

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The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance.

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Product maintenance agreements and other customer assistance agreements are available for Hewlett-Packard products.

For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

HP 8510 NETWORK ANALYZER INSTALLATION MANUAL

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		2336
HP 85102A	2402	2420	HP 8513A	2345
			HP 8514A	2343
			HP 8515A	2345

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INTRODUCTION

This HP 8510 network analyzer system Installation Manual explains how to install an HP 8510 system in either a rack-mounted or a bench configuration. The system consists of the HP 8510 network analyzer (HP 85101A and HP 85102A), one of five system test sets (HP 8511A - HP 8515A), and a microwave source (HP 8340A/41A or HP 8350B with RF plug-in). Information on installing controllers and/or peripherals appears in the manuals supplied with those instruments.

In addition to installation, this manual discusses site preparation, unpacking, incoming inspection, operating environment, power requirements, cable interconnections, and packing instruments for re-shipment.

An overview of the whole installation process, from assembling the system manual through performance verification, appears in the HP 8510 Installation Checklist, HP Part Number 08510-90050. A copy is shipped with each system order.

Performance verification after system installation is explained in Section IV (Performance Tests) of the HP 8510 Operating and Service manual.

If option HP 8510T +23N on-site installation and verification has been ordered, contact your Hewlett-Packard Customer Engineer to assist in answering site-preparation questions and, after all of the instruments have arrived, to install the system and conduct its performance verification.

This manual is designed to be useful, and it is based on the experience gained by Hewlett-Packard factory and field personnel actually installing HP 8510 systems. Please let us have your comments, too. A reader comment sheet is enclosed with this manual, postage paid in the United States.

OPERATING ENVIRONMENT/PRE-INSTALLATION

Tables 2-1 through 2-5 give instrument dimensions, weights, power requirements, environmental characteristics and other operating information useful for preparing an installation site. Environments that contain excessive airborne contaminants, oils, salts, corrosives, extremes in temperature or humidity, vibration, or electromagnetic interference can impair system operation and reduce the useful life of the system. Avoid such areas when choosing an installation site, and consult your Hewlett-Packard Customer Engineer if you have any doubts about the suitability of a given area.

As noted in Table 2-4, ambient temperature of the device under test as compared to the temperature of the calibration device during calibration is critical. The temperature differential between the two devices must be within the calibration window given in Table 2-4 for continued adherence to all HP 8510 accuracy enhanced published specifications. These specifications may be found in Section I (General Information) of the HP 8510 Operating and Service manual. The temperature calibration window is necessarily small. Although certain HP 8510 applications will require a specially conditioned, temperature controlled room, the decision to provide such an environment is discretionary and should be based upon customer need.

Table 2-1. Instrument Dimensions

INSTRUMENT	HEIGHT	WIDTH	DEPTH
NETWORK ANALYZER			
HP 85101A	133.4 mm 5.25 inches	460.2 mm 18.125 inches	609.6 mm 24.00 inches
HP 85102A	133.4 mm 5.25 inches	460.2 mm 18.125 inches	612.6 mm 24.125 inches
TEST SETS			
HP 8511A - HP 8515A	133.4 mm 5.25 inches	460.2 mm 18.125 inches	609.6 mm 24.00 inches
SOURCES			
HP 8340A/41A	188.0 mm 7.40 inches	460.2 mm 18.125 inches	609.6 mm 24.00 inches
HP 8350B	133.4 mm 5.25 inches	460.2 mm 18.125 inches	612.6 mm 24.125 inches

Table 2-2. Instrument Weights

INSTRUMENT	NET WEIGHT	SHIPPING WEIGHT
NETWORK ANALYZER		
HP 85101A	14 kg (31 lb)	20 kg (44 lb)
HP 85102A	18 kg (40 lb)	22 kg (48 lb)
TEST SETS		
HP 8511A	13 kg (29 lb)	17 kg (38 lb)
HP 8512A	15 kg (33 lb)	19 kg (41 lb)
HP 8513A	16 kg (35 lb)	20 kg (44 lb)
HP 8514A	17 kg (38 lb)	21 kg (46 lb)
HP 8515A	19 kg (41 lb)	22 kg (48 lb)
SOURCES		
HP 8340A/41A	34 kg (75 lb)	52 kg (112 lb)
HP 8350B	16.5 kg (36 lb)	22.7 kg (50 lb)
HP 8359x-series	6.0 kg (13.2 lb)	9.2 kg (20 lb)
HP 8352x-series	4.5 kg (10 lb)	7.7 kg (17 lb)
HP 8354x-series		
HP 8357x-series		

Table 2-3. Instrument Power Requirements

FREQUENCY	
47.5 to 66 Hertz	
VOLTAGE	
100, 120, 200, 240 volts ac, $\pm 10\%$	
POWER CONSUMPTION	
HP 85101A	200 VA maximum
HP 85102A	160 VA maximum
TEST SETS	95 VA maximum
HP 8340A/41A	500 VA maximum (ON)
	40 VA maximum (STANDBY)
HP 8350B	270 VA maximum including RF plug-in

Table 2-4. System Environmental Requirements

TEMPERATURE, PRESSURE, HUMIDITY			
GENERAL			
	Operating	Non-Operating/ Storage	HP 98200A Tape Cartridge
Temperature	0 to +55°C (+32 to +131°F)	- 40 to +75°C (- 40 to +167°F)	0 to +45°C (+32 to +113°F)
Humidity	40°C maximum wet-bulb temperature, 5% to 95% RH, non-condensing	65°C maximum wet-bulb temperature, 5% to 95% RH, non-condensing	30°C maximum wet-bulb temperature, 20% to 80% RH, non-condensing
Pressure Altitude	less than 4,600 metres (15,000 feet)	less than 15,300 metres (50,000 feet)	less than 15,300 metres (50,000 feet)
ACCURACY-ENHANCED PERFORMANCE Measurement calibration must be performed within the window of 20°C to 26°C (68°F to 79°F). Performance verification and actual device measurements must be made within $\pm 1^\circ\text{C}$ ($\pm 1.8^\circ\text{F}$) of the measurement calibration temperature. This is true even if the measurement temperature, found in this way, falls outside the 20°C to 26°C (68°F to 79°F) window for measurement calibration. Examples. If measurement calibration is performed at 23°C (73.4°F), verification and measurements must be made between 22°C (71.6°F) and 24°C (75.2°F). If measurement calibration is performed at 20°C (68°F), verification and measurements must be made between 19°C (66.2°F) and 21°C (69.8°F).			
ELECTROMAGNETIC INTERFERENCE HP 8510 conducted and radiated interference is in compliance with CISPR Publication 11 (1975), and Messemppfaenger-Postverfuegung 526/527/79 (Kennzeichnung Mit F-Nummer/Funkschutzzeichen).			

Table 2-5. Instrument Warmup Times

NON-ERROR-CORRECTED SPECIFICATIONS VALID	
Instrument	Warmup Time
HP 8510A Test Set HP 8340A/41A HP 8350B	30 minutes
ACCURACY ENHANCEMENT SPECIFICATIONS VALID	
Instrument	Warmup Time
HP 8510A Test Set HP 8340A/41A HP 8350B	1 hour

Table 2-6. Other System Information

MAXIMUM CABLE LENGTHS	
HP 8510 Interface Bus	10 metres (32 feet, 9 inches)
Controller HP-IB Bus	10 metres (32 feet, 9 inches)
HP 8510 Test Set/IF Detector	6 metres (19 feet, 7 inches)
MAXIMUM BIAS RATINGS	
HP 8514A and HP 8515A S-Parameter Test Sets	- 40 V to +40 V at 0.5 A

HARDWARE AND FIRMWARE REQUIREMENTS: SYSTEMS USING HP 835x-SERIES SOURCES

If an HP 8350B sweep oscillator will be used as the system source, make sure that the necessary hardware and firmware revisions for both the HP 8350 and HP 83500-series RF plug-in have been installed. These are explained in the next several paragraphs. HP 8340A/41A synthesized sweepers equipped with rear panel output Option 004 or 005 can be used as the system source without modification.

HP 8350B SWEEP OSCILLATORS

When an HP 8350B sweep oscillator is used as the source in an HP 8510 system, the HP 8350B must have system firmware Revision 6. To check the firmware revision number, press the HP 8350 [SHIFT] [4] [9]. The firmware revision number will appear in the right-hand FREQUENCY/TIME display. HP 8350B sweep oscillators shipped after March 30, 1984 are equipped with the correct firmware revision for use in an HP 8510 system. If updating to Revision 6 is required, use the firmware retrofit kit, HP Part Number 08350-60101.

HP 83500-SERIES RF PLUG-INS

HP 83500-series RF plug-ins (except the HP 83590-series) must have Revision 6 firmware to be compatible with an HP 8510 system. HP 83590-series RF plug-ins require Revision 7 firmware.

To check the plug-in firmware revision number, press the HP 8350 [SHIFT] [9] [9]. The firmware revision number will appear in the plug-in POWER window. HP 83500-series RF plug-ins shipped after March 30, 1984 are equipped with the correct firmware revision for use in an HP 8510 system. If modification is required, the modification kit required for each plug-in model is listed in Table 2-7.

Table 2-7. Modification Kits for HP 83500-Series RF Plug-ins

RF PLUG-IN	MODIFICATION KIT
HP 83522A	83525-60074
HP 83525A/B	83525-60074
HP 83540A/B	83525-60074
HP 83545A	83525-60074
HP 83570A	83525-60074
HP 83590A	83590-60074
HP 83592A	83592-60074
HP 83592B	83592-60100
HP 83592C	83592-60102
HP 83594A	83594-60074
HP 83595A	83595-60074

HP 86200-SERIES RF PLUG-INS

HP 86200-series RF plug-ins are incompatible with the HP 8510, and cannot be used.

HP 8350A SWEEP OSCILLATORS

To be used in an HP 8510 system, an HP 8350A sweep oscillator must have an HP 8350A-to-HP 8350B retrofit kit installed. This updates both the firmware and the HP-IB capability. The recommended modification kit is HP Part Number 08350-60100, which replaces the A3, A5, and A8 board assemblies.

SYSTEM UNPACKING/SHIPMENT VERIFICATION

Regardless of the configuration chosen, all components of the HP 8510 system are shipped to arrive within two weeks of each other. If they do not, contact your Hewlett-Packard Customer Engineer.

Before unpacking any system components, inspect all shipping containers. If any carton or packaging material is damaged, keep it until the entire shipment has been verified for completeness and the instrument has been checked mechanically and electrically.

If the shipment is damaged or incomplete, notify the nearest Hewlett-Packard office. If the shipping container itself is damaged or the packaging material shows signs of stress, also notify the carrier and keep all shipping materials for the carrier's inspection. Hewlett-Packard will arrange for repair or replacement of damaged equipment without waiting for a claim settlement from the carrier.

UNPACKING

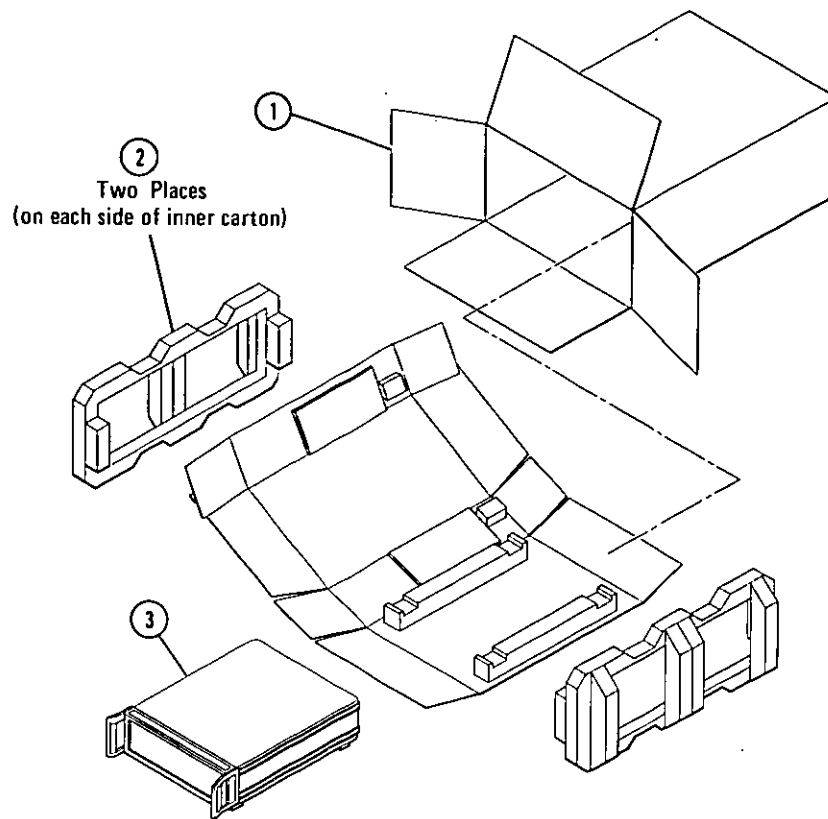
Unpack the HP 8510 system manual set first. The HP 8510 Installation Checklist is packed with the manual set and provides a time-saving overview of the installation process, reference to the particular parts of the manual needed during system installation, and detailed checklists for shipment verification. It is recommended that this Checklist be kept on file for use if the system is ever moved or re-installed.

Figure 2-1 shows how to unpack the two instruments that make up the HP 8510 network analyzer (the HP 85101A display/processor and the HP 85102A IF detector). The same procedure is used to unpack the HP 8510 system test set(s). These instructions are also given with the packing slips on the outside of the instrument boxes.

Figure 2-2 shows how to unpack the HP 85043A system rack. These instructions are also given on the ramp that is part of the shipping crate for the rack.

DETAILED SHIPMENT VERIFICATION

Verify the completeness of your shipment as it is unpacked by using the packing slips included with each instrument, the checklists provided in the HP 8510 Installation Checklist, and the parts lists in the manuals shipped with such system accessories as calibration and verification kits. It is desirable to keep shipping containers in one area to aid in verifying the receipt of all components ordered.

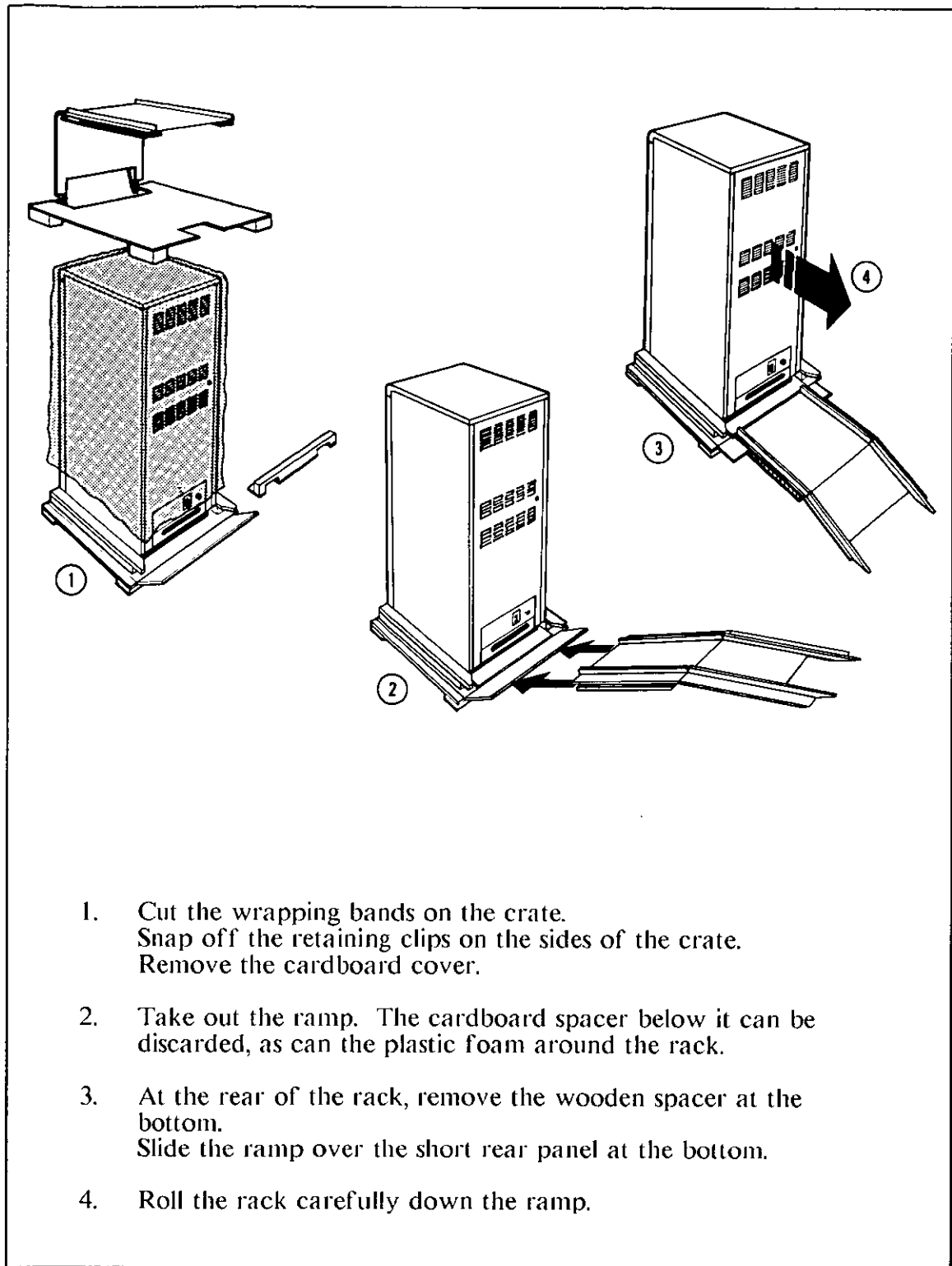


1. Open the marked end of the outer carton and fold all four flaps outward.

Carefully place the open end of the carton face downward on the floor. Pull the outer carton upward so that only the inner carton remains, surrounded by the two foam rails. It will be helpful to have another person hold the inner carton (and the instrument) as you do this.

2. Remove the foam rails from the sides of the inner carton and lay the inner carton flat. Then open the inner carton and remove the instrument.
3. Remove the polyethylene wrapper (not shown) from the instrument.

Figure 2-1. Unpacking HP 8510 System Instruments



1. Cut the wrapping bands on the crate.
Snap off the retaining clips on the sides of the crate.
Remove the cardboard cover.
2. Take out the ramp. The cardboard spacer below it can be discarded, as can the plastic foam around the rack.
3. At the rear of the rack, remove the wooden spacer at the bottom.
Slide the ramp over the short rear panel at the bottom.
4. Roll the rack carefully down the ramp.

Figure 2-2. Uncrating the HP 85043A System Rack

INSTRUMENT INSTALLATION: RACK-MOUNTED CONFIGURATIONS

Instructions for assembling the HP 85043A system rack appear in the system rack manual shipped in the accessories box inside the rack. In addition to the rack itself, Hewlett-Packard offers the HP 92170G work station table and the HP 92209C ergonomic chair as recommended work-station accessories. These should be unpacked and assembled at the same time as the rack.

INSTRUMENT LOCK FEET REMOVAL

Before the instruments can be put into the rack, the four plastic lock feet on the bottom panel of each instrument must be removed. Follow the instructions shown in Figure 2-3. If an HP 8350B sweep oscillator is used as the source, remove the instruction card assembly attached to the bottom of the instrument at the same time.

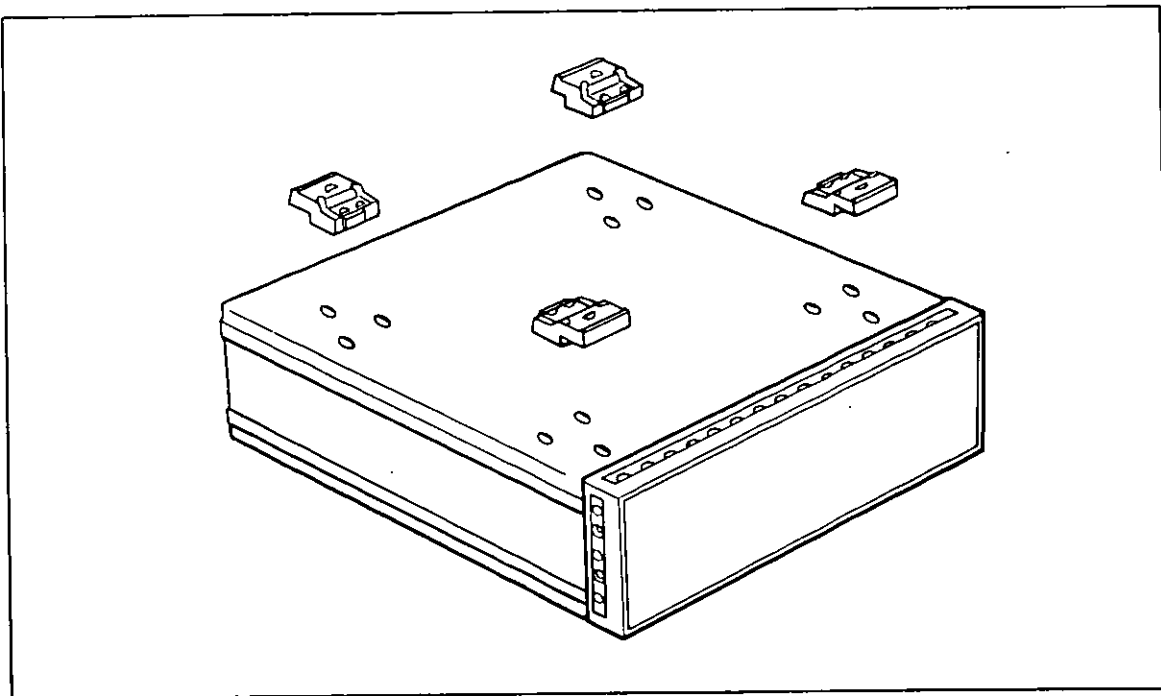


Figure 2-3. Lock Feet Removal

RACK MOUNT FLANGE INSTALLATION

When the lock feet have been removed, install on each instrument the correct rack mount flanges. Follow the instructions shown in Figure 2-4. Hardware and an instruction sheet is packed with each rack mount flange kit. If space is limited, the rack mount flanges can be installed after the instrument has been placed partly into the rack on its support shelves.

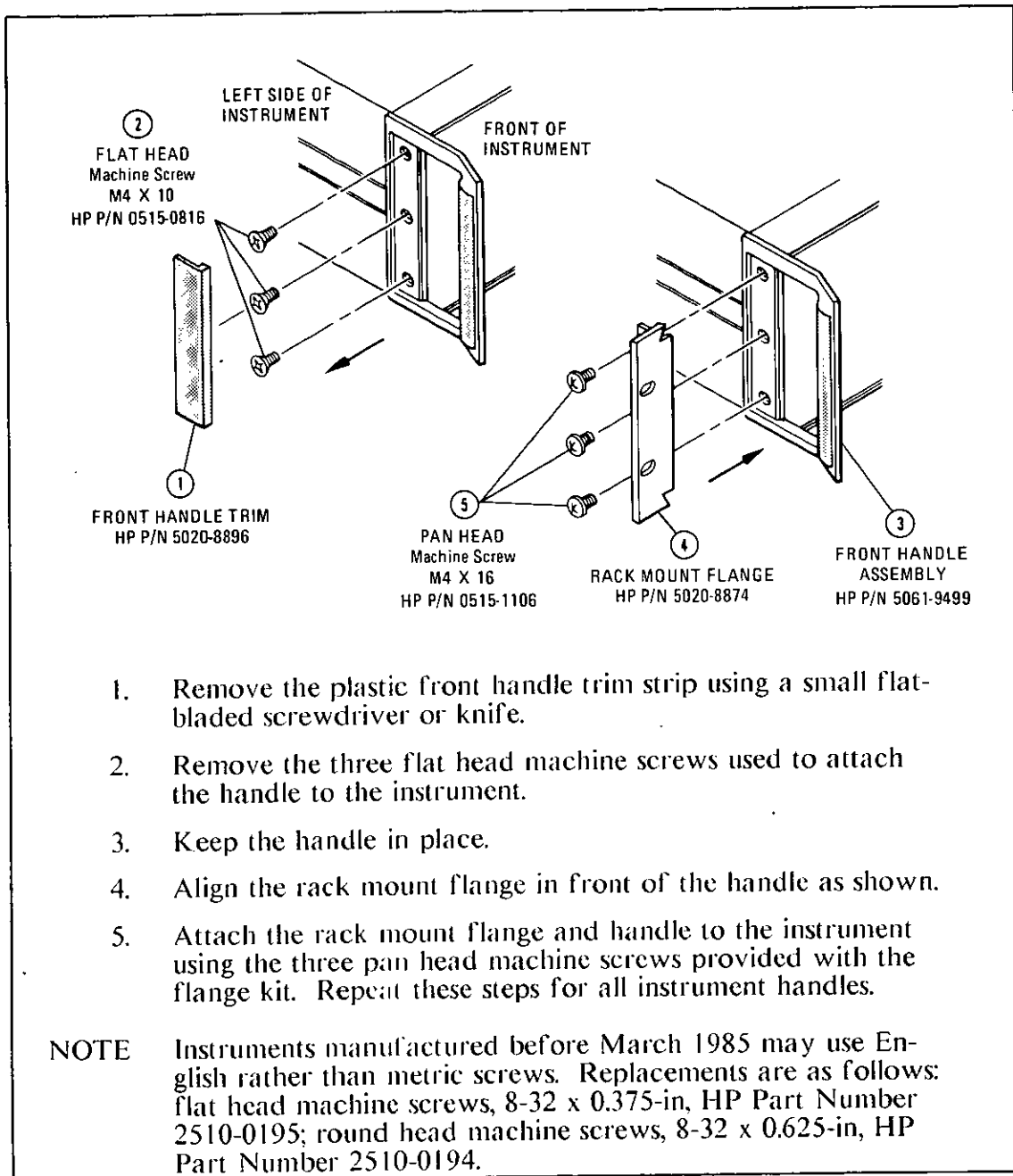


Figure 2-4. Rack Mount Flange Installation

ALTERNATIVE CONFIGURATIONS USING THE HP 85043A RACK

The HP 85043A system rack has been designed specifically for one configuration of the instruments which are used together in the HP 8510 network analyzer system. Other configurations of HP 8510 system instruments in this rack may result in overheating which will adversely affect electrical and mechanical specifications and system reliability.

Using the HP 85043A system rack to hold instruments other than those in the HP 8510 network analyzer system is possible. But this should be done only after careful temperature and air-flow tests have been made of the proposed configuration. These tests are especially necessary because the HP 85043A system rack does not include a cabinet fan.

Consult your Hewlett-Packard Customer Engineer for advice before using a non-standard rack configuration.

RACK-MOUNTED CONFIGURATIONS NOT USING THE HP 85043A SYSTEM RACK

Hewlett-Packard is not obligated to support user-configured rack systems other than the HP 85043A with instruments arranged in the recommended configuration. If a specially-configured rack system is being considered, please consult your Hewlett-Packard Customer Engineer for advice and for warranty and support details. Tables 2-3 through 2-6 in this Installation Manual give information on environmental requirements, power requirements, and maximum cable lengths.

INSTRUMENT INSTALLATION: BENCH CONFIGURATIONS

Five different bench configurations of HP 8510 network analyzer systems are recommended. These are shown in Figure 2-5. Other bench configurations are not recommended, as they present problems with cooling, cable length limitations, and ease of use. If the system source is the HP 8350B, only configurations C and D can be used. The HP 8350B must not be placed underneath any other instrument.

Configurations A and B are best suited for relatively short benches. Configurations C and D are best suited for relatively tall benches, and one or the other is required if the source is an HP 8350B sweep oscillator. Configuration E is suited for either short or tall benches and uses bench space most efficiently.

In choosing a configuration, pay special attention to the height of the HP 8510A display relative to the user's vision. The center line of the display should be at or slightly above eye level.

INSTRUMENT COOLING

Take particular note of the horizontal clearances required between instruments shown in the configuration diagrams in Figure 2-5. A minimum clearance of 3 inches (7.6 cm) on both sides is required for instrument cooling.

Several other points about cooling are also essential.

The lock feet on the bottom panel of the HP 85102A IF detector must not be removed in bench configurations. This instrument is cooled by exhausting warm air through the bottom panel. If the lock feet are removed and the bottom cover rests against another flat surface, overheating may result and damage the instrument.

Never place anything on top of a test set that might impede the air flow. Test sets are cooled by exhausting warm air through the top cover as well as through the right rear ventilator panel.

If an HP 8350B sweep oscillator is used as the source, remove the instruction card assembly attached to the bottom of the instrument by removing the lock feet on the bottom panel as shown in Figure 2-3. Then re-install the lock feet.

Do not operate any HP 8510 instrument for extended periods with any cover removed. Adequate cooling is impaired in instruments without all covers on, and overheating and subsequent damage to the instruments could result.

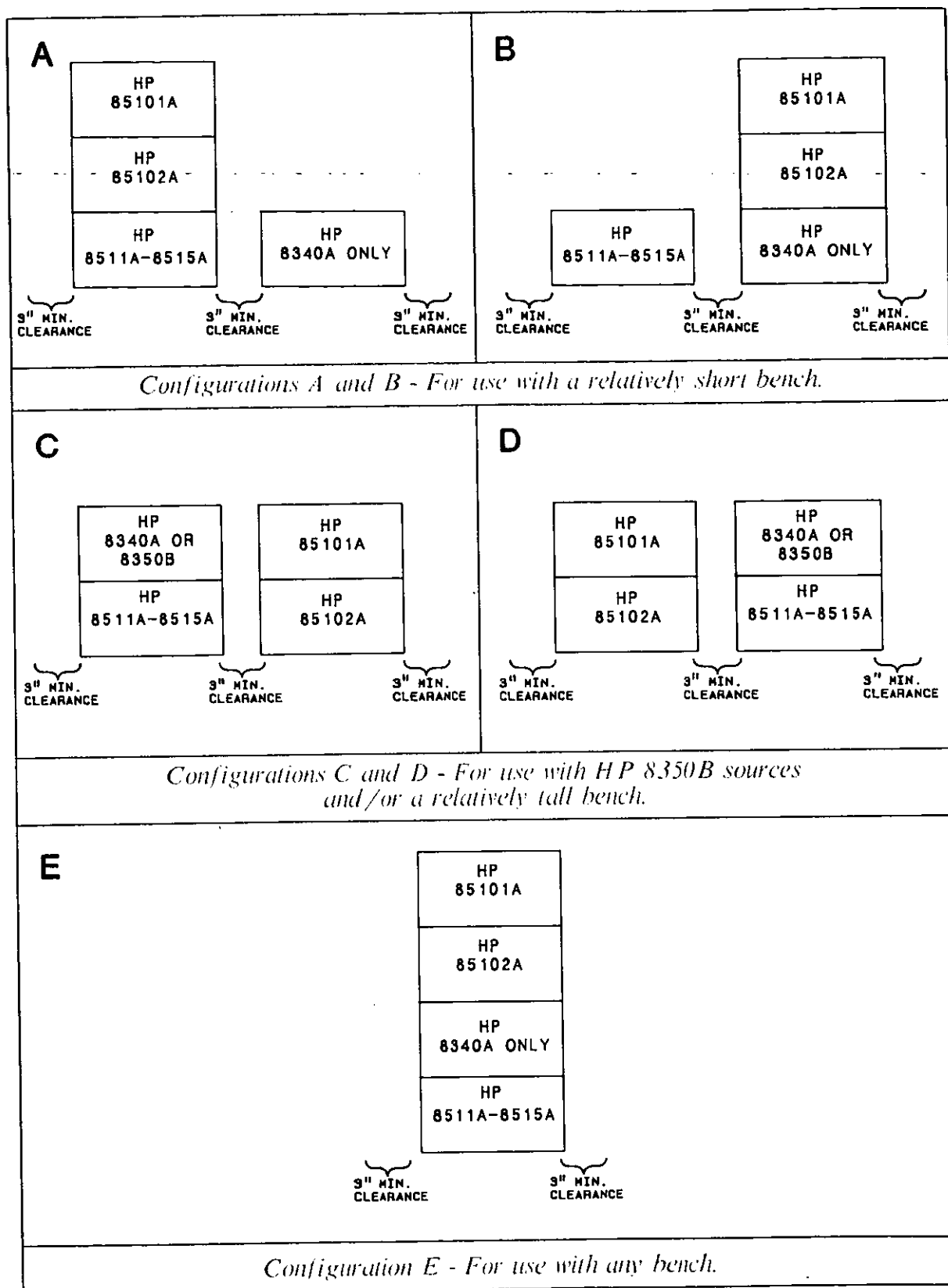


Figure 2-5. Recommended Bench Configurations

BENCH INSTALLATION

WARNING

All of the instruments you will be installing are large and heavy. To prevent accidental damage to the instruments or injury to yourself, have someone help you put the instruments in position.

Also be sure to put the HP 85102A IF detector in position *before* putting the HP 85101A display/processor on top of it, and do not attempt to lift these instruments after they have been locked together. Their combined weight is 32 kg (more than 70 lb), and serious personal injury could result.

When a suitable configuration has been chosen from Figure 2-5, place the bottom instrument in each column into its intended final position. Leave at least 3 inches (7.6 cm) clearance on both sides of each instrument for cooling.

If Configuration A or B has been chosen, next place the HP 85102A IF detector on top of the HP 8511A - HP 8515A test set.

If Configuration C, D, or E has been chosen, next place the source (HP 8340A/41A or HP 8350B) on top of the HP 8511A - HP 8515A test set.

Now the HP 85101A display/processor can be put in place and locked to the HP 85102A IF detector. This is done as follows.

First, put the HP 85101A display/processor on top of the HP 85102A IF detector so that the front edge of the HP 85101A is about 0.6 cm (0.25 inch) in front of the HP 85102A.

Second, slide the HP 85101A back until its front edge is even with the front edge of the HP 85102A. Hooks on the top of the HP 85102A will slide into slots on the HP 85101A and lock the fronts of the two instruments together. Check that the two instruments are locked together by lifting up on the front of the HP 85101A.

Finally, at the rear of the two instruments, tighten the thumbscrews on the rear lock feet on the bottom of the HP 85101A into the rear lock feet on the top of the HP 85102A as shown in Figure 2-6.

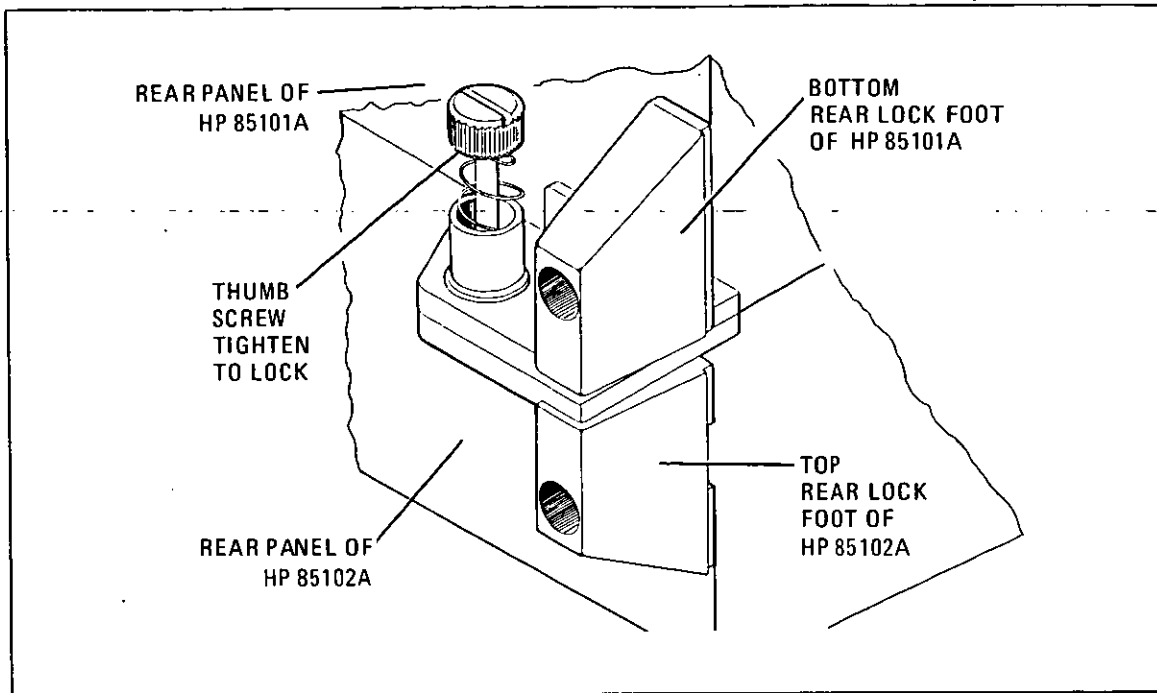


Figure 2-6. HP 85101A/HP 85102A Rear Lock Feet

LINE VOLTAGE AND FUSE SELECTION

CAUTION

Line voltage and fuse selections must be made before power is applied to any instrument. This is true of both rack-mounted and bench installations.

Failure to set these instrument ac power inputs correctly could cause severe damage to the instruments when power is turned on.

In both rack-mounted and bench installations, the line voltage and fuses for each instrument must be set according to the voltage of the ac power source. Details appear in Table 2-8.

Line voltage is set for the HP 85101A display/processor by means of a line voltage selector switch on the rear panel of the instrument. For the HP 85102A IF detector and the HP 8511A - HP 8515A test sets, line voltage is set by aligning the voltage selector cards in the rear panel power line module. To set the line voltage for the sources and any peripherals used in the HP 8510 system, consult the Operating and Service manuals supplied with those instruments.

HP 85101A DISPLAY/PROCESSOR

Set the line voltage and select the correct fuse for the HP 85101A display/processor as follows:

Remove the HP 85101A fuse from the fuse holder located on the rear panel of the HP 85101A display/processor, in the upper right-hand corner above the power cord receptacle. A medium-sized flat-bladed screwdriver is required.

Consult Table 2-8 to determine which fuse is correct for the ac line voltage that will be used. (This information also appears on the rear panel, above the fuse.) If the fuse is not correct, replace it with the correct fuse.

Set the line voltage selector switch located on the rear panel of the HP 85101A display/processor, below the serial number tag. The 115V position is correct for ac line voltages from 90 V to 143 V. The 230V position is correct for ac line voltages from 196 V to 246 V.

Table 2-8. Line Voltage/Fuse Selection

INSTRUMENT	ACTUAL LINE VOLTAGE (VOLTS AC)	VOLTAGE SELECTOR SWITCH POSITION	FUSE HP Part Number
HP 85101A	90 V to 143 V	115 V	2.5 A 2110-0083 (fast blow)
	196 V to 264 V	230 V	1.5 A 2110-0043 (fast blow)
INSTRUMENT	ACTUAL LINE VOLTAGE (VOLTS AC)	PC SELECTOR BOARD POSITION	FUSE HP Part Number
HP 85102A	90 V to 110 V	100	2.0 A 2110-0002 (fast blow)
	108 V to 132 V	115/120	
	198 V to 242 V	220	1.0 A 2110-0001 (fast blow)
	216 V to 264 V	230/240	
TEST SETS	90 V to 110 V	100	1.5 A 2110-0043 (fast blow)
HP 8511A	108 V to 132 V	115/120	
HP 8512A	198 V to 242 V	220	0.75 A 2110-0063 (fast blow)
HP 8513A	216 V to 264 V	230/240	
HP 8514A			
HP 8515A			
SOURCES and PERIPHERALS	Refer to individual Operating and Service manuals.		

HP 85102A IF DETECTOR, HP 851x TEST SETS

Follow the steps given in Figure 2-7 to set the line voltage and select the correct fuse for the HP 85102A IF detector and for all HP 8511A - HP 8515A test sets. The power line modules for these instruments are located in the lower left-hand corner of the rear panel, adjacent to the power cord receptacle.

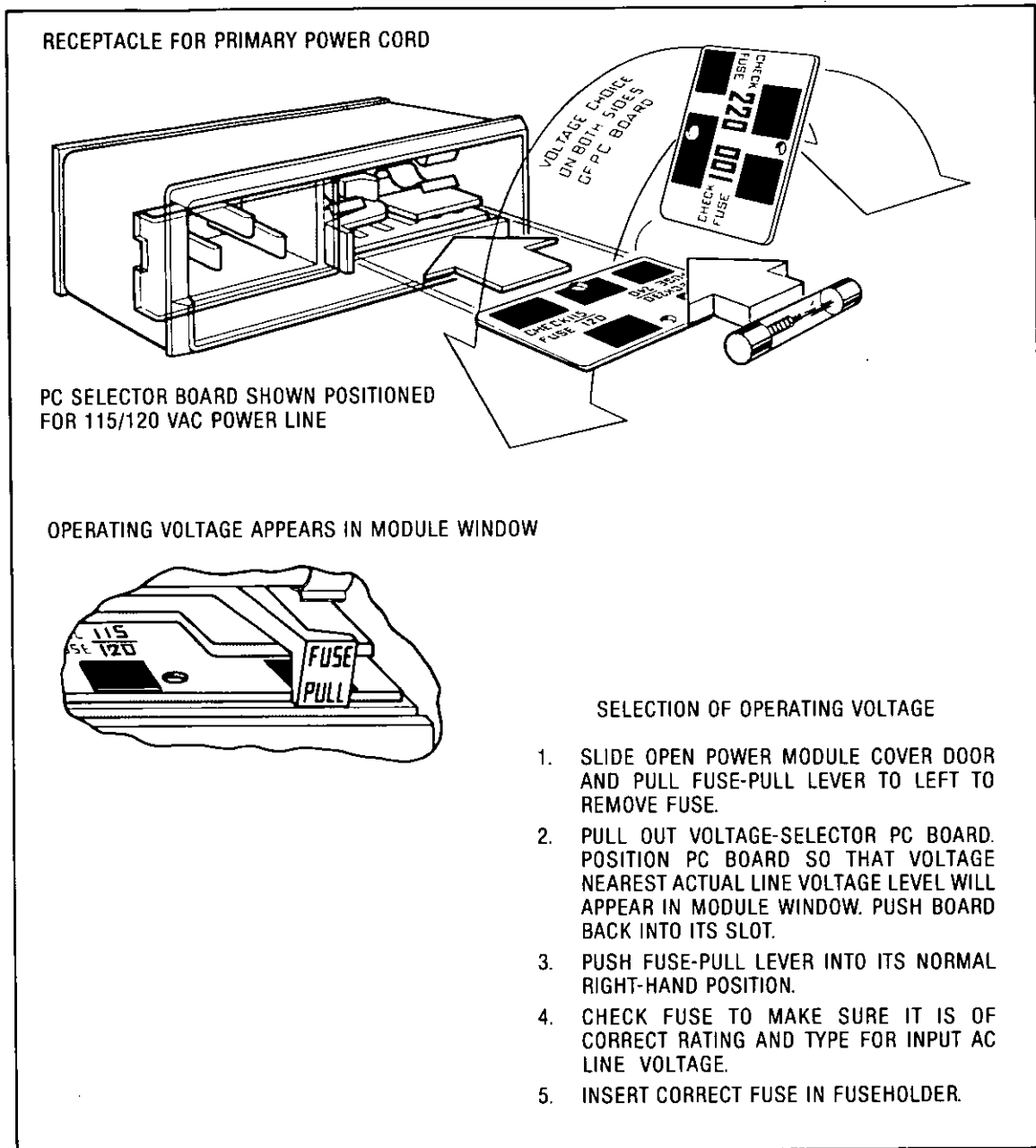


Figure 2-7. Power Line Module

OTHER LINE VOLTAGES

The line voltages marked on the HP 85101A voltage selector switch (115 V, 230 V) and PC selector boards (100, 115/120, 220, 230/240) are nominal voltages. But each of these nominal settings will accept a range of actual voltages, given in Table 2-8. If the actual voltage is within the necessary range, it is not necessary for nominal voltage marked on the switch or PC selector board to match it exactly.

If, however, the actual voltage used is not within any of the ranges shown in Table 2-8, an autotransformer is required between the source of ac power and all HP 8510 system instruments. Consult your Hewlett-Packard Customer Engineer for help in making such an installation.

WARNING

The common terminal of any autotransformer used with an HP 8510 system instrument must be connected to earth ground. The protective earth terminals of the HP 8510 system instruments must also be connected to earth ground.

This protection must not be negated through the use of an extension cord (power cable) without a protective ground conductor. Any interruption of the protective ground, inside or outside the instruments, can result in personal injury, or even death.

AC POWER CONNECTIONS AND CABLES

In compliance with international safety standards, the HP 8510 system instruments are equipped with three-wire power cables. When connected to properly installed power line outlets, these cables ground the individual chassis of these instruments. Table 2-9 shows the different kinds of mains plugs available for the power cables supplied with HP 8510 instruments. The number shown under each plug is the HP part number for the HP 8510 power cable with that kind of mains plug.

The power cable supplied with HP 8510 instruments is selected to be compatible with power line outlet sockets in the country of destination. If the cable you receive does not fit your power line outlet socket, refer to Table 2-9 to determine which cable is correct. Order the required cable by the HP part number shown from the nearest Hewlett-Packard office.

Power cable connections to the HP 85043A system rack are discussed in the system rack manual.

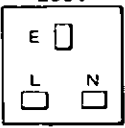
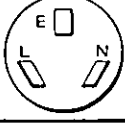
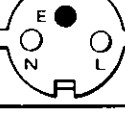
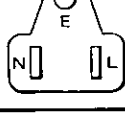
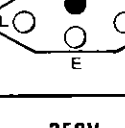
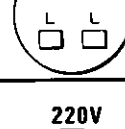
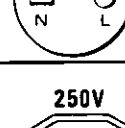
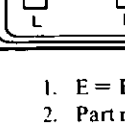
WARNING

Before applying ac power to any instruments or to the system rack, be sure that the ac power inputs of all instruments are set to the correct ac line voltage and that correct fuses have been installed.

Also make sure that the ac power outlet to be used is properly grounded and able to supply the maximum power required for the installation.

Failure to observe these precautions could result in serious personal injury or major damage to the instruments or both.

Table 2-9. Mains Plugs and AC Power Cords

Plug Type ¹	Cable HP Part Number ²	CD ³	Plug Description ²	Cable Length (inches)	Cable Color	For Use in Country
250V 	8120-1351 8120-1703	0 6	Straight BS1363A 90°	90 90	Mint Gray Mint Gray	United Kingdom, Cyprus, Nigeria, Zimbabwe, Singapore
250V 	8120-1369 8120-0696	0 4	Straight NZSS198/ASC112 90°	79 87	Gray Gray	Australia, New Zealand
250V 	8120-1689 8120-1692	7 2	Straight CEE7-VII 90°	79 79	Mint Gray Mint Gray	East and West Europe, Saudi Arabia, Egypt, Republic of So. Africa, India (unpolarized in many nations)
125V 	8120-1348 8120-1398 8120-1754 8120-1378 8120-1521 8120-1676	5 5 7 1 6 2	Straight NEMA5-15P 90° Straight NEMA5-15P 90° Straight NEMA5-15P 90°	80 80 36 80 80 36	Black Black Black Jade Gray Jade Gray Jade Gray	United States, Canada, Japan (100V or 200V), Mexico, Philippines, Taiwan
250V 	8120-2104	3	Straight SEV1011.1959 24507, Type 12	79	Gray	Switzerland
250V 	8120-0698	6	Straight NEMA6-15P			United States, Canada
220V 	8120-1957 8120-2956	2 3	Straight DHCK 107 90°	79 79	Gray Gray	Denmark
250V 	8120-1860	6	Straight CEE22-VI (System Cabinet Use)			

1. E = Earth Ground; L = Line; N = Neutral
2. Part number shown for plug is industry identifier for plug only. Number shown for cable is HP Part Number for complete cable including plug.
3. The Check Digit (CD) is a coded digit that represents the specific combination of numbers used in the HP Part Number. It should be supplied with the HP Part Number when ordering any of the power assemblies listed above, to expedite speedy delivery.

HP-IB ADDRESSES

Before interconnecting the HP 8510 system, verify that the HP-IB address setting for each instrument (and peripheral, if used) is as given in Table 2-10. The HP 8510 system bus expects the HP-IB addresses of the source, test set, printer, and plotter to be as given in Table 2-10. These are the standard addresses.

Table 2-10. Standard HP 8510 System Bus Addresses

Source Address	19
Test Set Address	20
Printer Address	01
Plotter Address	05
8510 HP-IB Address	16
System Bus Address	17
Pass Thru Address	31

CHECKING HP-IB ADDRESS SETTINGS

When the HP 8510 system is running, it is possible to check the address of any instrument, the 8510 HP-IB address, the system bus address, or the pass thru address by pressing the front-panel key labeled **LOCAL** or the **SYSTEM MENU** key. Then press the softkey labeled **HP-IB ADDRESSES** to bring the Address Menu onto the CRT. Then press the softkey corresponding to the instrument or bus desired. Its address will appear in the active function area of the CRT.

To change this address, enter the new address desired using the **ENTRY** block keys, following it by **x1**. For the source, test set, plotter, or printer the address becomes effective the next time the HP 8510 addresses the instrument.

SETTING HP-IB ADDRESSES

Consult the individual Operating and Service manuals for information on checking and setting the HP-IB addresses of the source, printer, and plotter that will be used.

Figure 2-8 shows how to check and set the address of HP 8511A - HP 8515A test sets. In the example shown, the test set address is set correctly to 20. The address is read in binary, with the most significant digit on the right. Thus the address shown, in binary, is 10100, which corresponds to a decimal address of 20. To change the address, set the five switches either on (1) or off (0) to produce the desired address in binary.

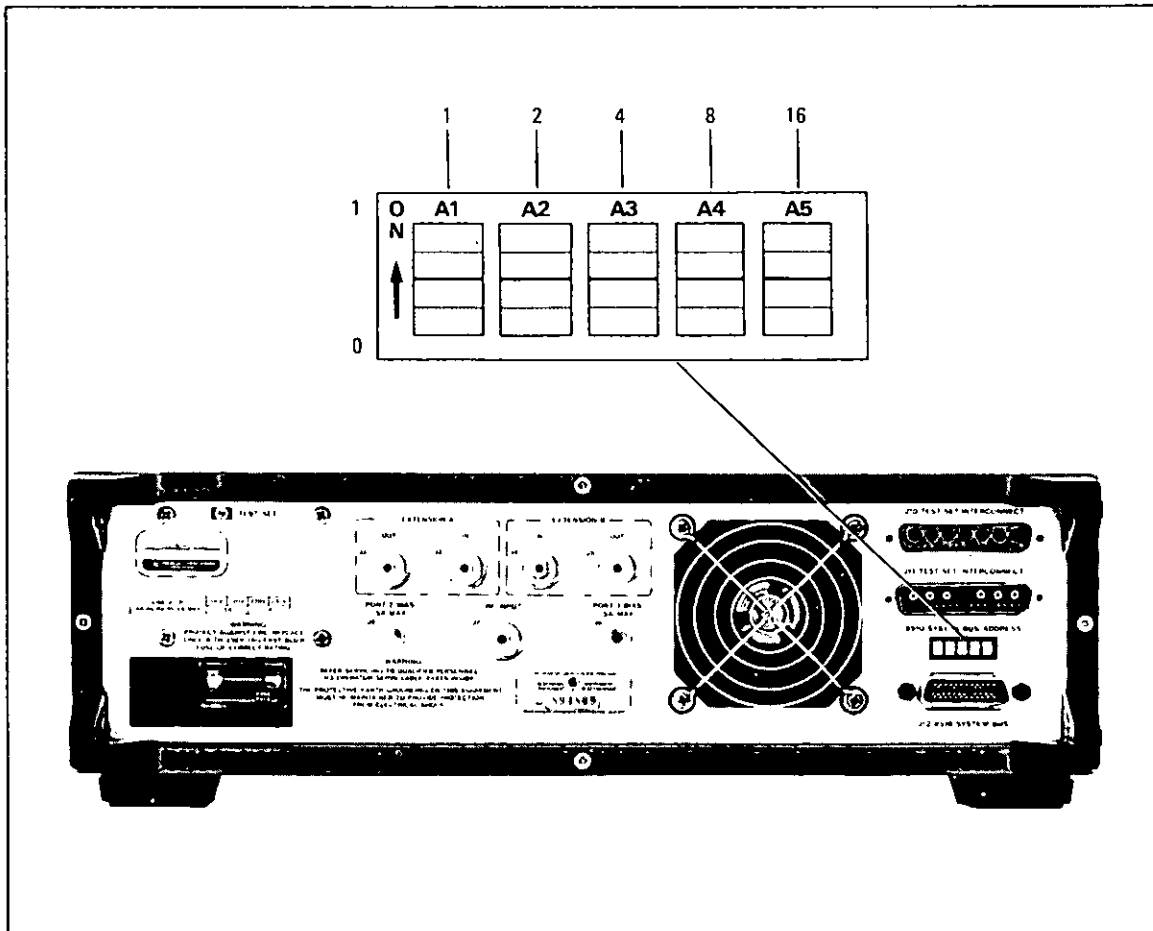


Figure 2-8. Setting the Test Set HP-IB Address

ELECTRICAL INTERCONNECTIONS

The cables listed in Table 2-11 are required for electrical interconnection of the instruments in the HP 8510 system. They are shipped in the accessories box for the HP 85101A display/processor and in the accessories box shipped with each test set.

In bench installations, the ac power cord listed, HP Part Number 8120-1348, is standard for the United States and Canada. Two such cords are supplied in the HP 8510 accessories box and one in each test set accessories box. Different ac power cords may be required in other locations and are listed in Table 2-9.

In rack-mounted installations, instrument ac power connections are made inside the HP 85043A system rack cabinet. The instruments are connected directly to the power strip inside the cabinet, using the 3-conductor grounded power cords supplied with the system rack. These power cords can and should be used without modification--for all ac line voltages and no matter what type of 3-conductor grounded power plug is used for the external ac power connection. Use these cables instead of the power cords supplied with the instruments.

The Type N (male)-to-SMA (male) adapter, HP Part Number 1250-1894, is shipped with each test set but is needed only if the source used is the HP 8341A synthesized sweeper or the HP 8350B sweep oscillator.

Table 2-11. Required Cables

DESCRIPTION	QUANTITY	HP PART NUMBER
AC Power Cord	3	8120-1348
BNC Cables, 0.9 metre (3 feet)	2	8120-2582
HP-IB Cables, 1 metre (3.3 feet)	2	8120-3445
Model 10833A		
IF/Display Interconnect Cable Assembly	1	08510-60101
Test Set/IF Display Interconnect Cable Assembly	1	08510-60102
Hardline Port Extension Cables (short)	2	08512-20019
Hardline Port Extension Cables (long)	2	08512-20013
Type N (Male)-to- SMA (Male) Adapter	1	1250-1894
Flexible Source Cable	1	08513-60009

HARDLINE PORT EXTENSION CABLES

Hardline port extension cables are used to balance the reference and test signal path lengths. They are connected on the test set rear panel, at J2 and J3 for Extension A, at J4 and J5 for Extension B.

A 3.5mm torque wrench (5/16-inch, open end) set to 8 in-lb is required. This wrench is available as HP Part Number 1250-1863 and is included in the HP 85052A 3.5mm calibration kit unless deleted by calibration kit Option 020.

Which hardline cable to use (short or long) depends on the test set and on the test port return cables that will be used in actual measurements. These requirements are discussed in the next three paragraphs.

Reflection/Transmission Test Sets: HP 8512A, HP 8513A. The standard test setup for these test sets uses either an HP 85132A or an HP 85131A cable and a 20 dB or 10 dB attenuator. The device-under-test is connected directly to Port 1 of the test set. In this situation, use the short hardline port extension cables, HP Part Number 08512-20019.

S-Parameter Test Sets: HP 8514A, HP 8515A. The standard test setup for these test sets uses either the HP 85132B or the HP 85131B cable set. The device-under-test is connected between the two cables. In this situation, use the long hardline port extension cables, HP Part Number 08512-20013.

If the device-under-test is connected directly to Port 1 of an S-parameter test set and a single cable (HP 85132A or HP 85131A) is used, use the short hardline port extension cables, HP Part Number 08512-20019.

**ELECTRICAL INTERCONNECTIONS:
SYSTEMS USING AN HP 8340A/41A SYNTHESIZED SWEEPER**

Figures 2-9 through 2-11 show the electrical interconnections to be made if the source used in the system is an HP 8340A/41A synthesized sweeper. Instructions for making instrument interconnections if the source is an HP 8350B sweep oscillator are given in the next section of this manual.

The instruments in Figures 2-9 through 2-11 are arranged in Configuration B using the HP 8340A/41A synthesized sweeper as the source (Figure 2-5). The same connections should be made in the same order if another HP 8340A/41A bench configuration is used and in all rack-mounted HP 8340A/41A installations.

	INTERCONNECTION SEQUENCE (HP 8340A/41A SOURCE)
1.	Connect HP 8340A/41A power line module to ac power source (lower left, rear panel) Cable - AC Power Cord, HP 8120-1348 (USA and Canada). Rack-mounted installations use special cord. See Table 2-9 for other applications. Set HP 8340A/41A switch to STANDBY
2.	Connect HP 8340A/41A: STOP SWP to HP 85102A: SOURCE IN/OUT STOP SWEEP (above 8410B/C interface connection) (below and right of fan) Cable - BNC, HP 8120-2582
3.	Connect HP 8340A/41A: SWEEP to HP 85102A: SOURCE OUTPUT SWEEP IN 0-10V (above power line module) (right of fan) Cable - BNC, HP 8120-2582
4.	Connect Test Set: J12 8510 SYSTEM to HP 85101A: 8510 BUS connector INTERCONNECT (below 8510 SYSTEM BUS ADDRESS switch) (near and left of fan) Cable - HP-IB, HP 8120-3445 (Model 10833A)
5.	Connect HP 8340A/41A: HP-IB to Test Set: J12 8510 connector SYSTEM BUS connector (right of fan) (below SYSTEM BUS ADDRESS switch) Cable - HP-IB, HP 8120-3445 (Model 10833A)
	<i>continued →</i>

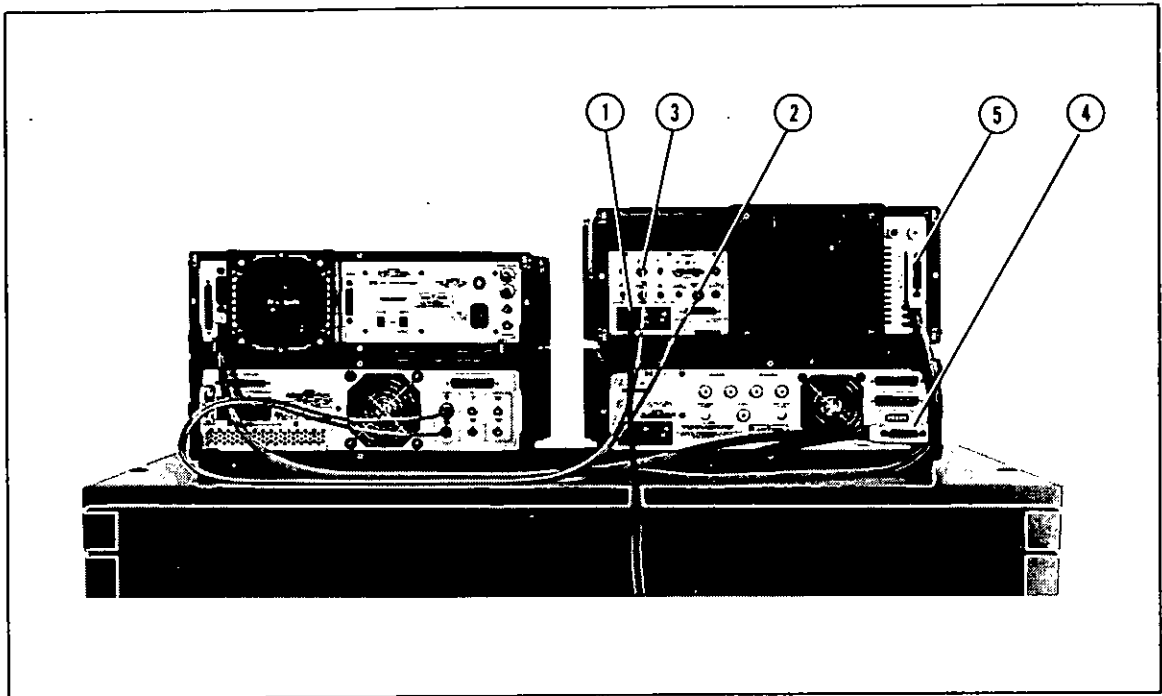


Figure 2-9. System Interconnections, HP 8340A/41A Source (1)

	INTERCONNECTION SEQUENCE (HP 8340A/41A SOURCE) - 2	
6.	Connect HP 85102A: J2 IF-DISPLAY INTERCONNECT to HP 85101A IF-DISPLAY INTERCONNECT (above power line module) (away and left of fan) Cable - IF-Display Interconnect Cable, HP 08510-60101	
7.	Connect Plotter or Printer (if used) to HP 85101A: 8510 SYSTEM BUS connector (near and left of fan) Cable - HP-IB. Route cable through brush seal on side of rack cabinet in rack-mounted installations.	
8.	Connect HP 85102A: J1 TEST SET INTERCONNECT to Test Set: J11 TEST SET INTERCONNECT (right of fan) (above SYSTEM BUS ADDRESS switch) Cable - Test Set-IF Interconnect Cable, HP 08510-60102	
9.	Connect Controller: HP-IB (if used) to HP 85101A: HP-IB Connector (right of fan) Cable - HP-IB. Route cable through brush seal on side of rack cabinet in rack-mounted installations.	
	<i>continued →</i>	

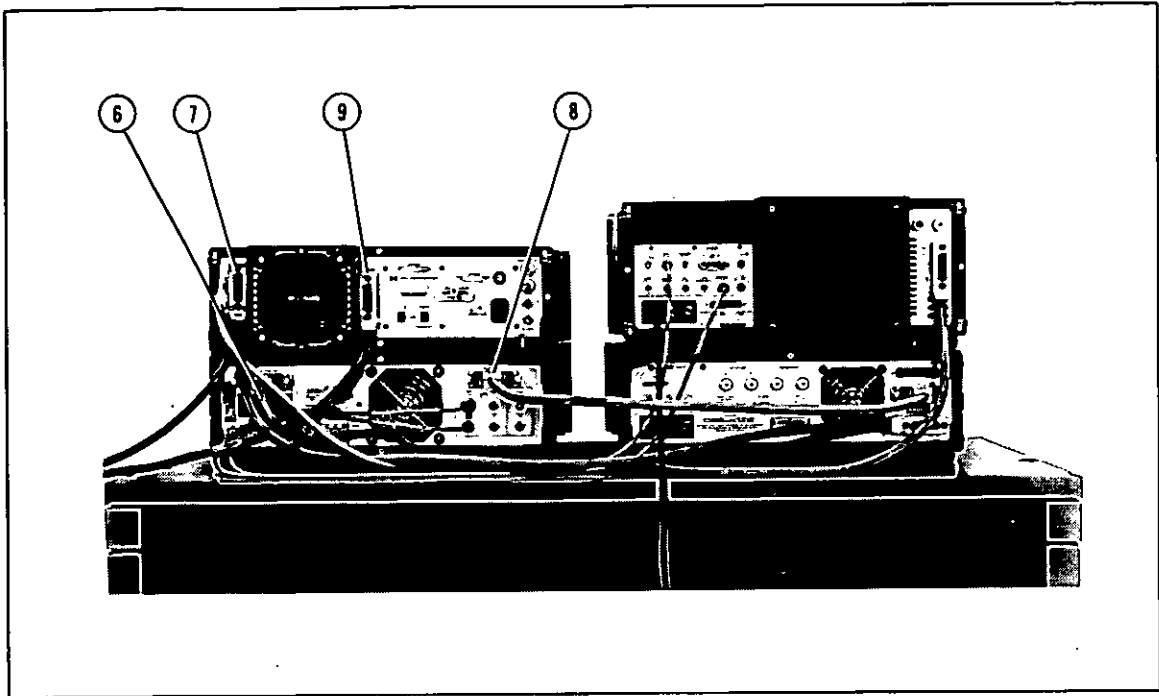


Figure 2-10. System Interconnections, HP 8340A/41A Source (2)

	INTERCONNECTION SEQUENCE (HP 8340A/41A SOURCE) - 3
10.	Connect Test Set: Extension A, Extension B (J2 to J3 and J4 to J5: connect both cables) Cables - Hardline Port Extension Cables, HP 08512-20019 (short) <i>or</i> HP 08514-20013 (long). See page 2-26. Wrench - 3.5mm torque wrench, 5/16-inch open-end, set to 8 in-lb, HP 1250-1863
11.	Connect HP 8340A/41A: RF OUTPUT to Test Set: RF INPUT (above HP-IB connector) (below reference port extension cable connections) Cable - Flexible Source Cable (female end) HP 08513-60009 Adapter (HP 8341A only) - Type N (Male)-to-SMA (Male) HP 1250-1894 Wrench - 3.5mm torque wrench, 5/16-inch open-end, set to 8 in-lb, HP 1250-1863
12.	Connect HP 85102A: power line module to ac power source (below J2 IF Display Interconnect)
13.	Connect HP 85101A: ac receptacle to ac power source (far right, lower rear panel)
14.	Connect Test Set: power line module to ac power source (far left, lower rear panel) Cables - AC Power Cord, HP 8120-1348 (USA and Canada). Rack-mounted installations use special cord. See Table 2-9 for other applications.

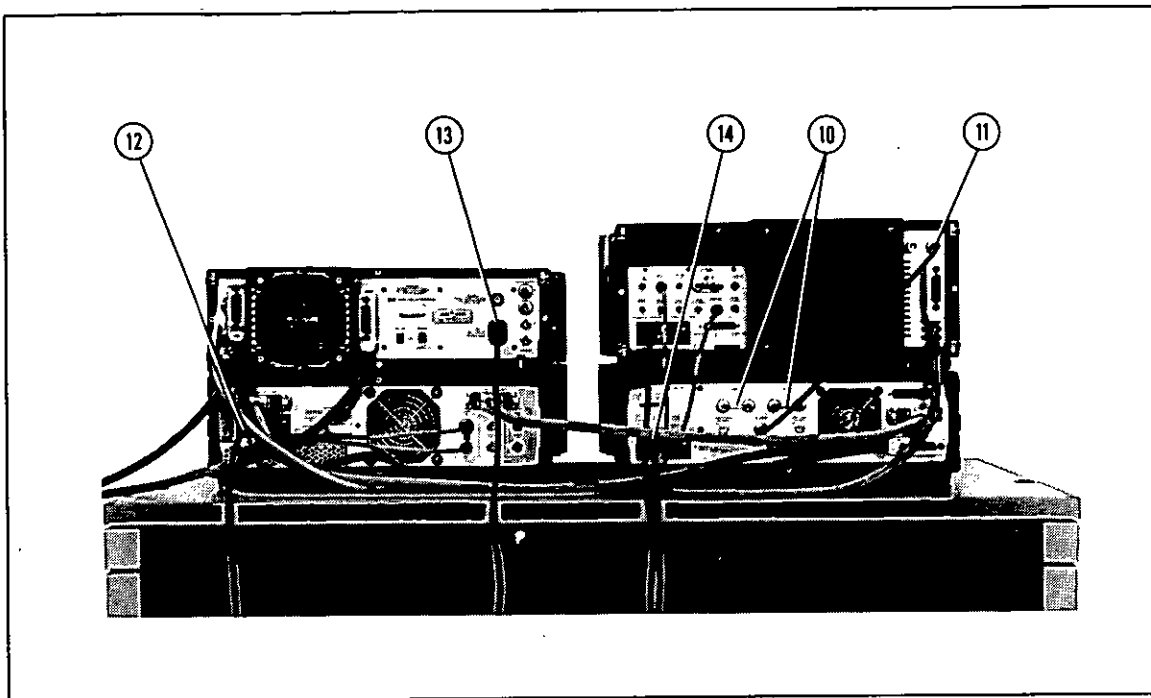


Figure 2-11. System Interconnections, HP 8340A/41A Source (3)

	INTERCONNECTION SEQUENCE (HP 8350B SOURCE) - 1
1.	Connect HP 8350B power line module to ac power source (far right, rear panel) Cable - AC Power Cord, HP 8120-1348 (USA and Canada). Rack-mounted installations use special cord. See Table 2-9 for other applications. Set HP 8350B switch to ON
2.	Connect HP 8350B: STOP SWEEP to HP 85102A: SOURCE STOP SWEEP (left of PROGRAMMING CONNECTOR) (below and right of fan) Cable - BNC, HP 8120-2582
3.	Connect HP 8350B: SWEEP OUT/IN to HP 85102A: SOURCE SWEEP IN 0-10V (below and right of fan) (right of fan) Cable - BNC, HP 8120-2582
4.	Connect Test Set: J12 8510 SYSTEM BUS connector to HP 85101A: 8510 INTERCONNECT (below SYSTEM BUS ADDRESS switch) (near and left of fan) Cable - HP-IB, HP 8120-3445 (Model 10833A)
5.	Connect HP 8350B: HP INTERFACE BUS connector to Test Set: J12 8510 SYSTEM BUS connector (left of fan) (below SYSTEM BUS ADDRESS switch) Cable - HP-IB, HP 8120-3445 (Model 10833A)
	<i>continued →</i>

ELECTRICAL INTERCONNECTIONS: SYSTEMS USING AN HP 8350B SWEEP OSCILLATOR

Figures 2-12 through 2-14 show the electrical interconnections to be made if the source used in the system is an HP 8350B sweep oscillator. Instructions for making instrument interconnections if the source is an HP 8340A/41A synthesized sweeper are given in the preceding section of this manual.

The instruments in Figures 2-9 through 2-11 are arranged in Configuration B using the HP 8350B sweep oscillator as the source (Figure 2-5). The same connections should be made in the same order if another HP 8350B bench configuration is used and in all rack-mounted HP 8350B installations.

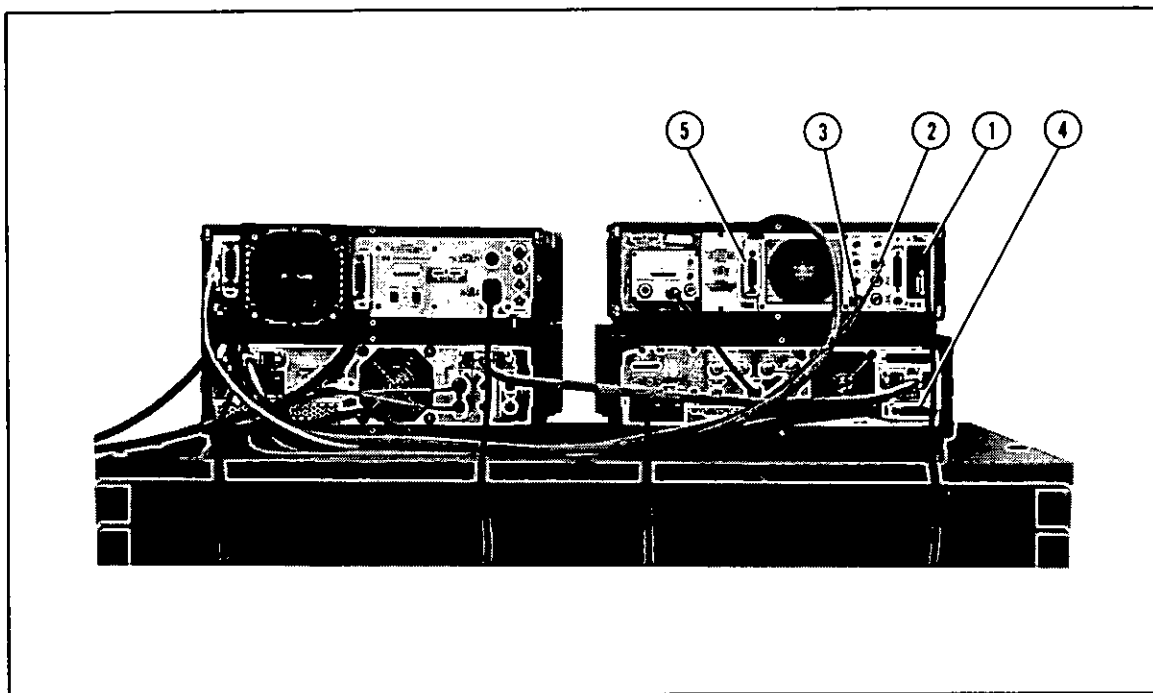


Figure 2-12. System Interconnections, HP 8350B Source (1)

	INTERCONNECTION SEQUENCE (HP 8350B SOURCE) - 2	
6.	Connect HP 85102A: J2 IF-DISPLAY to HP 85101A IF-DISPLAY INTERCONNECT (above power line module) (away and left of fan) Cable - IF/Display Interconnect Cable, HP 08510-60101	
7.	Connect Plotter or Printer (if used) to HP 85101A: 8510 SYSTEM BUS connector (near and left of fan) Cable - HP-IB. Route cable through brush seal on side of rack cabinet in rack-mounted installations.	
8.	Connect HP 85102A: J1 TEST SET to Test Set: J11 TEST SET INTERCONNECT (right of fan) (above SYSTEM BUS ADDRESS switch) Cable - Test Set-IF Interconnect Cable, HP 08510-60102	
9.	Connect Controller: HP-IB (if used) to HP 85101A: HP-IB connector (bright of fan) Cable - HP-IB. Route cable through brush seal on side of rack cabinet in rack-mounted installations.	
10.	Connect Test Set: Extension A, Extension B (J2 to J3 and J4 to J5: connect both cables) Cables - Hardline Port Extension Cables, HP 08512-20019 (short) or HP 08514-20013 (long). See page 2-26. Wrench - 3.5mm torque wrench, 5/16-inch open-end, set to 8 in-lb, HP 1250-1863	
	<i>continued →</i>	

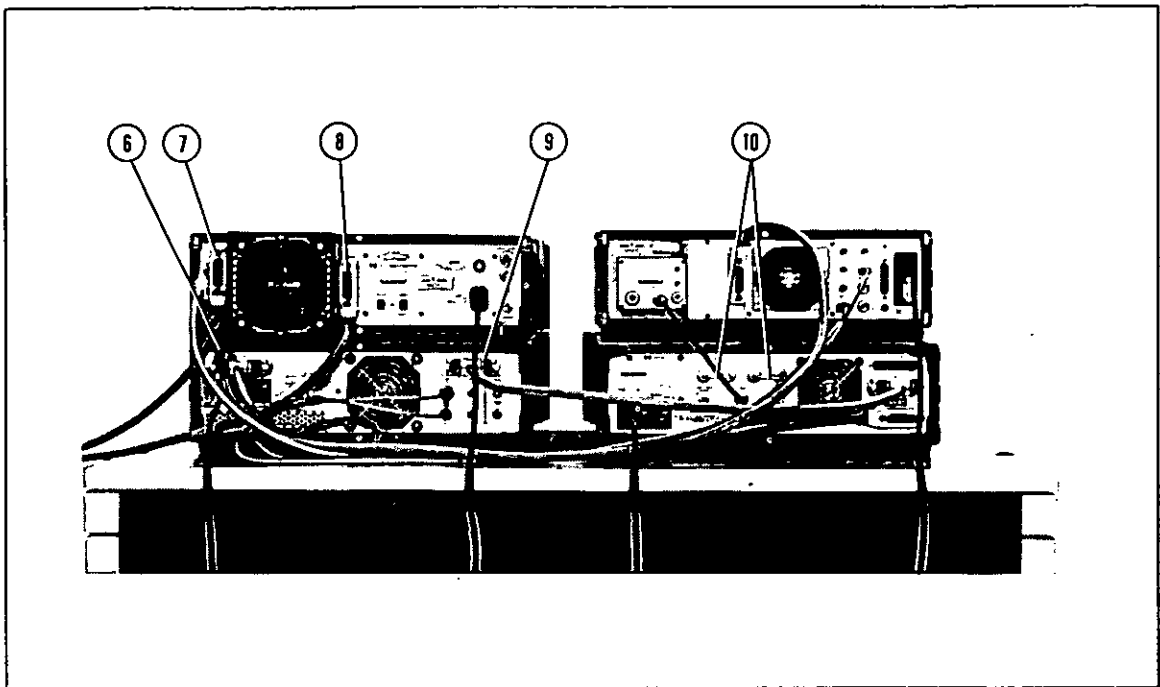


Figure 2-13. System Interconnections, HP 8350B Source (2)

	INTERCONNECTION SEQUENCE (HP 8350B SOURCE) - 3
11.	Connect at RF OUTPUT connector, HP 835xx-series RF plug-in (HP 8350B plug-in, rear panel) Adapter - Type N (Male)-to-SMA (Male), HP 1250-1894 Required only if plug-in is equipped with Option 004 Type N female RF Output Connector rear panel power output.
12.	Connect HP 835xx-series RF plug-in to Test Set: RF INPUT RF OUTPUT (HP 8350B plug-in, rear panel) (below reference port extension cable connections) Cable - Flexible source cable (female end) HP 08513-60009 Wrench - 3.5mm torque wrench, 5/16-inch open-end, set to 8 in-lb, HP 1250-1863
13.	Connect HP 85102A: power line module to ac power source (below J2 IF Display Interconnect)
14.	Connect HP 85101A: ac receptacle to ac power source (far right, lower rear panel)
15.	Connect Test Set: power line module to ac power source (far left, lower rear panel) Cables - AC Power Cord, HP 8120-1348 (USA and Canada). Rack-mounted installations use special cord. See Table 2-9 for other applications.

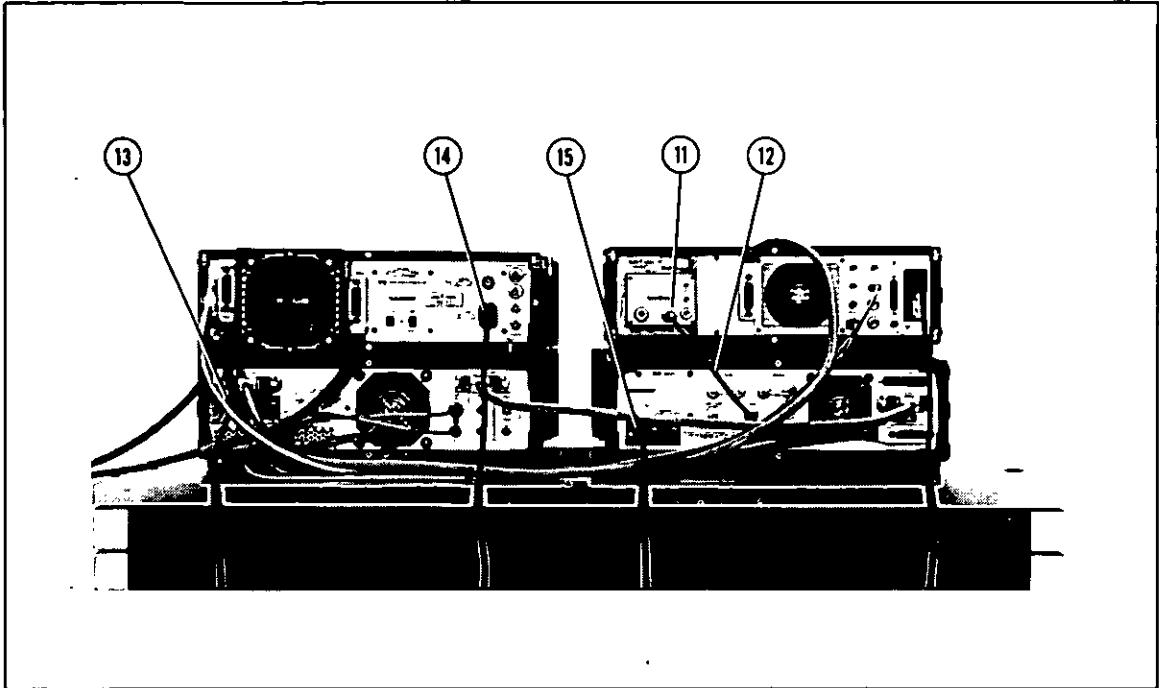


Figure 2-14. System Interconnections, HP 8350B Source (3)

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.

WARNING

Before applying ac power to any instruments or to the system rack, be sure that the ac power inputs of all instruments are set to the correct ac line voltage and that correct fuses have been installed.

Also make sure that the ac power outlet to be used is properly grounded and able to supply the maximum power required for the installation.

Failure to observe these precautions could result in serious personal injury or major damage to the instruments or both.

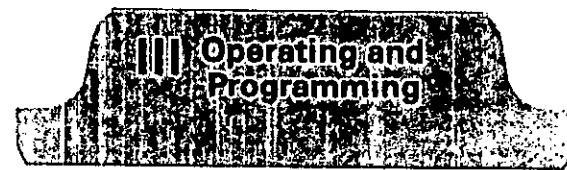
Apply power to the instruments in the following order:

- SOURCE : HP 8340A/41A or HP 8350B
- TEST SET : HP 8511A - HP 8515A
- SYSTEM PERIPHERALS : PLOTTER (if used)
PRINTER (if used)
- NETWORK ANALYZER : LINE switch, front panel of
HP 85102A IF detector

Power to both the HP 85101A display/processor and the HP 85102A 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 come on, check the position of this rear-panel switch first.

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

- CONTROLLER PERIPHERALS
- CONTROLLER



STORAGE AND SHIPMENT

Table 2-4 gives the environmental requirements for storage of the HP 85101A display/processor, HP 85102A IF detector, and the HP 8511A - HP 8515A test sets. For similar information on sources and peripherals used in HP 8510 systems consult the Operating and Service manuals for those instruments.

SHIPMENT

If it is necessary to ship any of the instruments in the HP 8510 system, pack each instrument separately and use the original packaging materials if possible. Figure 2-1 will be helpful in repacking some instruments. Containers and materials used for factory shipments are also available, through any Hewlett-Packard office.

If an instrument is being returned to Hewlett-Packard for service, please complete and attach a blue service tag indicating the nature of the problem and who to contact for more information about the service required. Identify the instrument by model number and full serial number and list the other HP 8510 system instruments it is being used with. A supply of service tags is included with this Installation manual.

These general instructions should be followed whenever instruments are packed for shipping:

- Wrap the instrument in heavy paper or plastic. If the instrument is being returned to Hewlett-Packard for service, complete a blue service tag and attach it to the instrument.

- Place the wrapped instrument in a strong shipping container. A double-wall carton made of 350-pound test material is adequate.

- Place enough shock-absorbing material around all sides of the instrument to provide a firm cushion and prevent any movement of the instrument inside the container. A three-inch to four-inch layer is generally sufficient.

- Seal each shipping container carefully and mark it FRAGILE to ensure careful handling.

Instruments installed in the HP 85043A system rack must be removed from the rack before shipping. Unlike some rack systems, the HP 85043A system rack cannot be used for shipment, and in storage the rack must be kept in its normal upright position. *Do not store or install instruments in the rack when it is on its side or its back. Major damage to the instruments and to the rack can occur.*

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Microfiche Part Number 08510-90011

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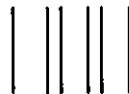
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Should one of your HP Instruments need repair, the HP service organization is ready to serve you. However, you can help us serve you more effectively. When sending an Instrument to HP for repair, please fill out this card and attach it to the product. Increased repair efficiency and reduced turn-around time should result.

COMPANY

ADDRESS

TECHNICAL CONTACT PERSON

PHONE NO. EXT.

MODEL NO. SERIAL NO.

MODEL NO. SERIAL NO.

P.O. NO. DATE

Accessories returned with unit

☐ NONE ☐ CABLE(S)

☐ POWER CABLE ☐ ADAPTER(S)

OTHER over



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COMPANY

ADDRESS

TECHNICAL CONTACT PERSON

PHONE NO. EXT.

MODEL NO. SERIAL NO.

MODEL NO. SERIAL NO.

P.O. NO. DATE

Accessories returned with unit

☐ NONE ☐ CABLE(S)

☐ POWER CABLE ☐ ADAPTER(S)

OTHER over



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MODEL NO. SERIAL NO.

MODEL NO. SERIAL NO.

P.O. NO. DATE

Accessories returned with unit

☐ NONE ☐ CABLE(S)

☐ POWER CABLE ☐ ADAPTER(S)

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MODEL NO. SERIAL NO.

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Accessories returned with unit

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OTHER over



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COMPANY

ADDRESS

TECHNICAL CONTACT PERSON

PHONE NO. EXT.

MODEL NO. SERIAL NO.

MODEL NO. SERIAL NO.

P.O. NO. DATE

Accessories returned with unit

☐ NONE ☐ CABLE(S)

☐ POWER CABLE ☐ ADAPTER(S)

OTHER over

Service needed

☐ CALIBRATION ONLY
☐ REPAIR ☐ REPAIR & CAL

OTHER _____

Observed symptoms/problems

FAILURE MODE IS:

☐ CONSTANT ☐ INTERMITTENT

SENSITIVE TO:

☐ COLD ☐ HEAT ☐ VIBRATION

FAILURE SYMPTOMS/SPECIAL
CONTROL SETTINGS _____

If unit is part of system list model
number(s) of other interconnected in-
struments. _____

9320-3896

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Service needed

☐ CALIBRATION ONLY
☐ REPAIR ☐ REPAIR & CAL

OTHER _____

Observed symptoms/problems

FAILURE MODE IS:

☐ CONSTANT ☐ INTERMITTENT

SENSITIVE TO:

☐ COLD ☐ HEAT ☐ VIBRATION

FAILURE SYMPTOMS/SPECIAL
CONTROL SETTINGS _____

If unit is part of system list model
number(s) of other interconnected in-
struments. _____

9320-3896

Printed in U.S.A.

Service needed

☐ CALIBRATION ONLY
☐ REPAIR ☐ REPAIR & CAL

OTHER _____

Observed symptoms/problems

FAILURE MODE IS:

☐ CONSTANT ☐ INTERMITTENT

SENSITIVE TO:

☐ COLD ☐ HEAT ☐ VIBRATION

FAILURE SYMPTOMS/SPECIAL
CONTROL SETTINGS _____

If unit is part of system list model
number(s) of other interconnected in-
struments. _____

9320-3896

Printed in U.S.A.

Service needed

☐ CALIBRATION ONLY
☐ REPAIR ☐ REPAIR & CAL

OTHER _____

Observed symptoms/problems

FAILURE MODE IS:

☐ CONSTANT ☐ INTERMITTENT

SENSITIVE TO:

☐ COLD ☐ HEAT ☐ VIBRATION

FAILURE SYMPTOMS/SPECIAL
CONTROL SETTINGS _____

If unit is part of system list model
number(s) of other interconnected in-
struments. _____

9320-3896

Printed in U.S.A.

Service needed

☐ CALIBRATION ONLY
☐ REPAIR ☐ REPAIR & CAL

OTHER _____

Observed symptoms/problems

FAILURE MODE IS:

☐ CONSTANT ☐ INTERMITTENT

SENSITIVE TO:

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struments. _____

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HP 8510
NETWORK ANALYZER SYSTEM
OPERATING AND PROGRAMMING MANUAL

System Firmware
Revision A.02.00

Copyright HEWLETT-PACKARD COMPANY 1985
1400 FOUNTAINGROVE PARKWAY SANTA ROSA, CA 95401 U.S.A.

Manual Part Number 08510-90005
Microfiche Part Number 08510-90006

Printed January 1985



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

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.

APPLICATIONS SOFTWARE

Two software application pacs are available to automate the HP 8510 network analyzer system using an external HP controller.

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 all the capabilities of the HP 85013A application pac including the following 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.

VOLUME 1

- I General Information
- II Installation
- III Operating and Programming

VOLUME 2

- IV Performance Tests
- V Adjustments

VOLUME 3

Accessories

VOLUME 4

- VI Replaceable Parts
- VII Backdating
- VIII Service

VOLUME 5

- VIII Service (continued)

Operating and Programming (duplicate)

Keyword Dictionary

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.

Also shipped with each system is the HP 8510 Operating and Programming Quick Reference. This pocket-sized list of all HP 8510 programming mnemonics is packed in the system accessories box, and copies are also available separately, as HP Part Number 08510-90012. The HP 8510 Keyword Dictionary gives complete programming information for HP 8510 systems. One copy is included in each complete manual set, and extra copies are available separately as HP Part Number 08510-90007.

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.

Copies of the following manuals related to the HP 8510 network analyzer system are also available separately:

<u>MANUAL</u>	<u>DESCRIPTION</u>	<u>HP PART NUMBER</u>
8340A	Synthesized Sweeper	08340-90020
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
85043A	System Rack	85043-90001

<u>MANUAL</u>	<u>DESCRIPTION</u>	<u>HP PART NUMBER</u>
85050A	7mm Calibration Kit	85050-90001
85051A	7mm Verification Kit	85051-90001
85052A	3.5mm Calibration Kit	85052-90001
85053A	3.5mm Verification Kit	85053-90001
85054A	Type-N Cal Kit	85054-90001
85130A	3.5mm-to-7mm Adapter Kit	85130-90001
85131A	3.5mm Test Port Return Cables	85131-90001
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.

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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.

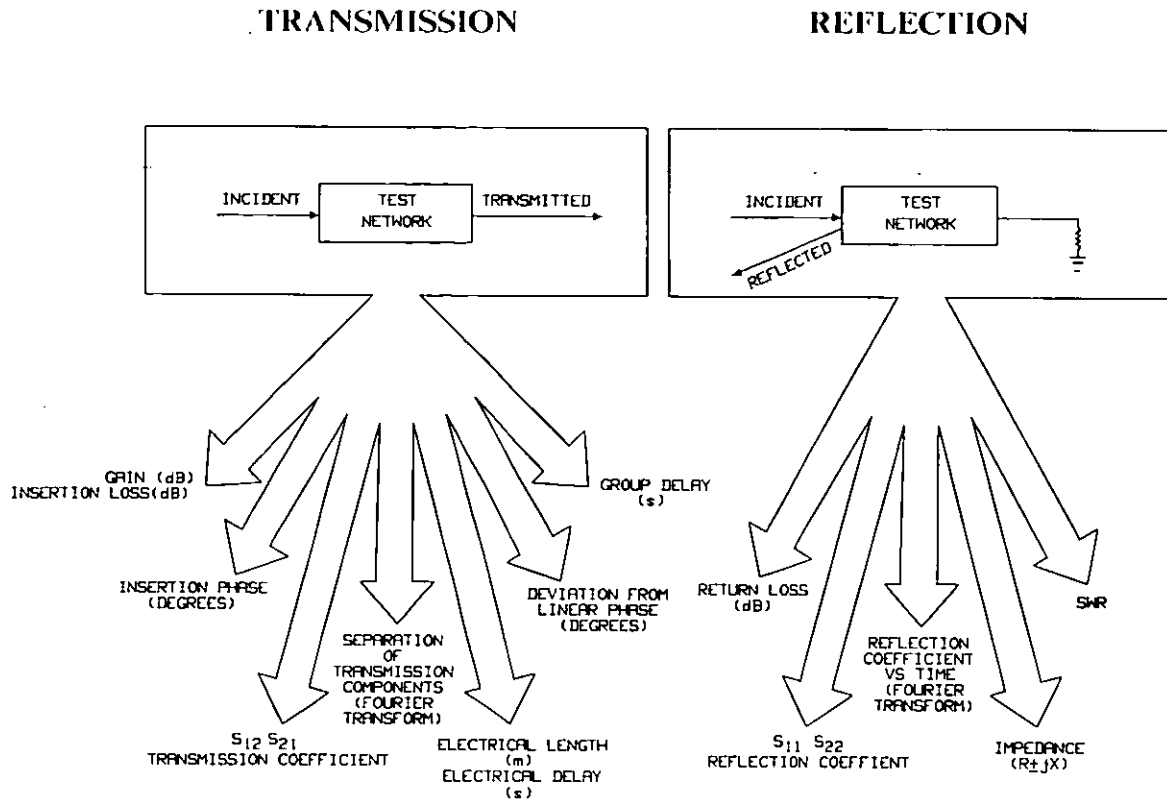
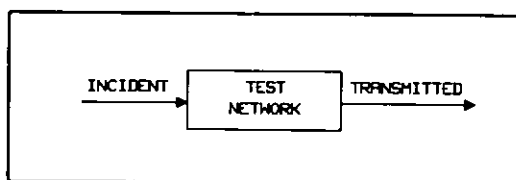


Figure 1. Transmission and Reflection Measurements

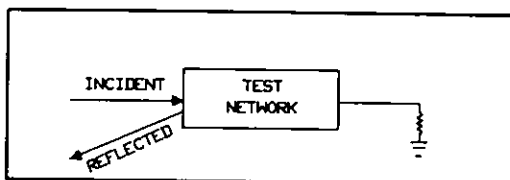
BASIC PRINCIPLES

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.

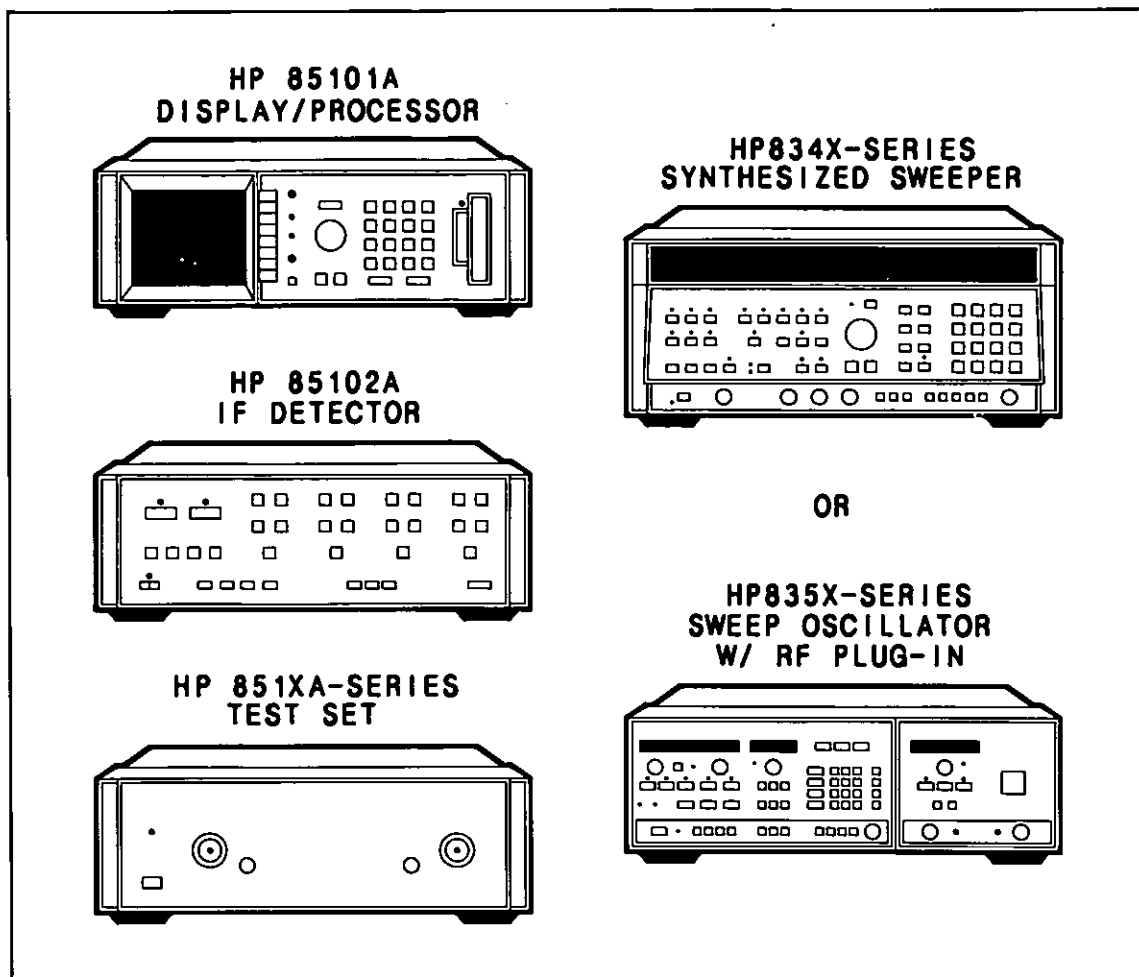


Figure 2. HP 8510 Network Analyzer System

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.

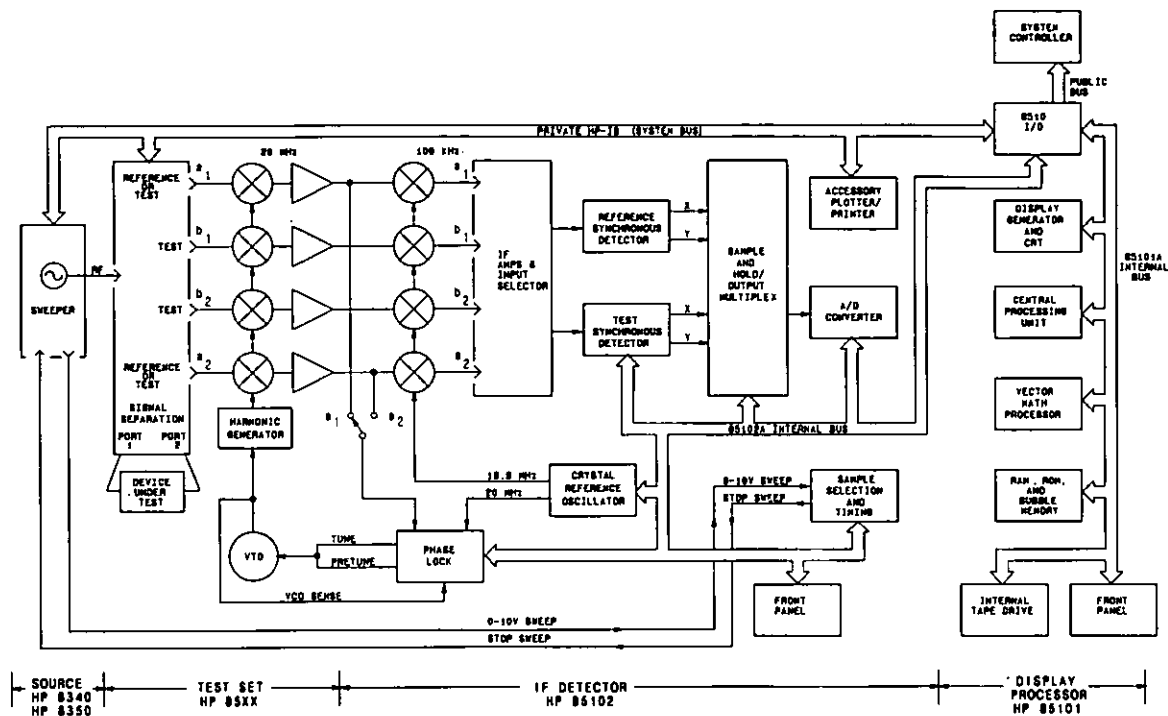


Figure 3. Simplified Block Diagram

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 circularity 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 many sweeps are taken thus depends on the measurement); PRESET initializes the system to a pre-defined state.

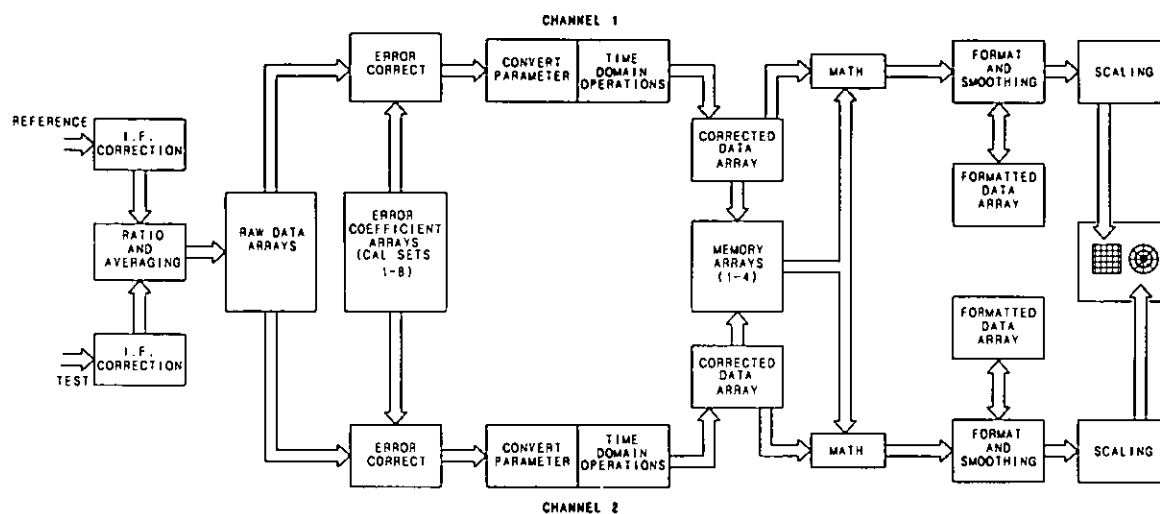


Figure 4. Post-Detection Digital Signal Processing

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.

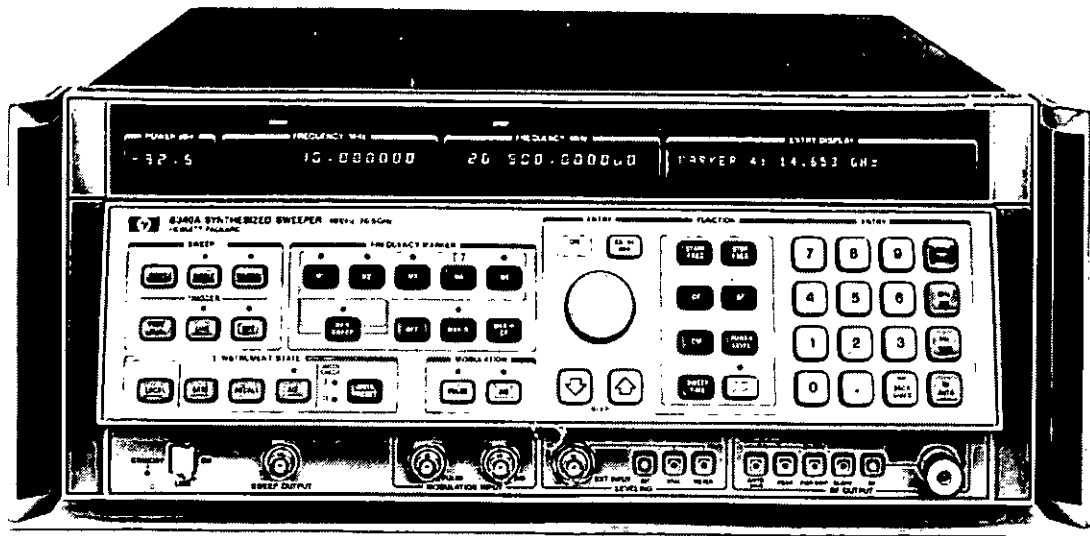


Figure 5. HP 834x-Series Synthesized Sweeper

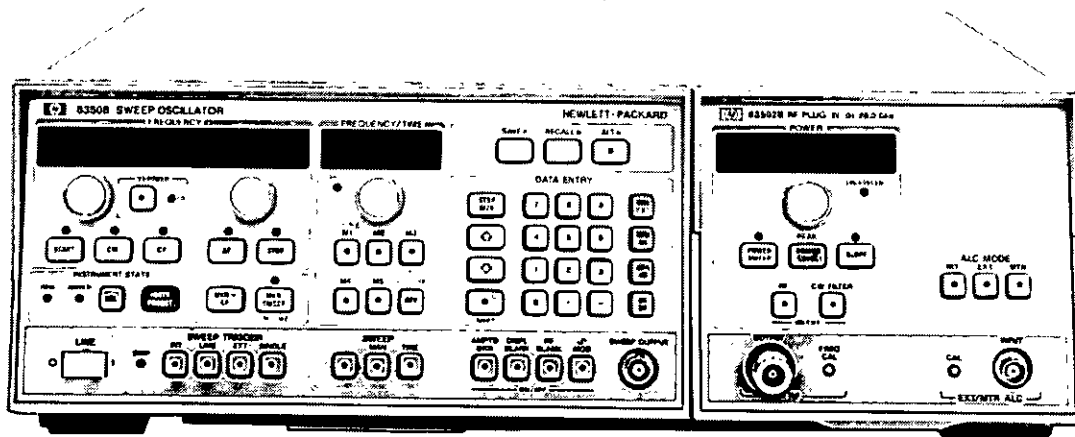


Figure 6. HP 835x-Series Sweep Oscillator with HP 835xx Plug-In

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.

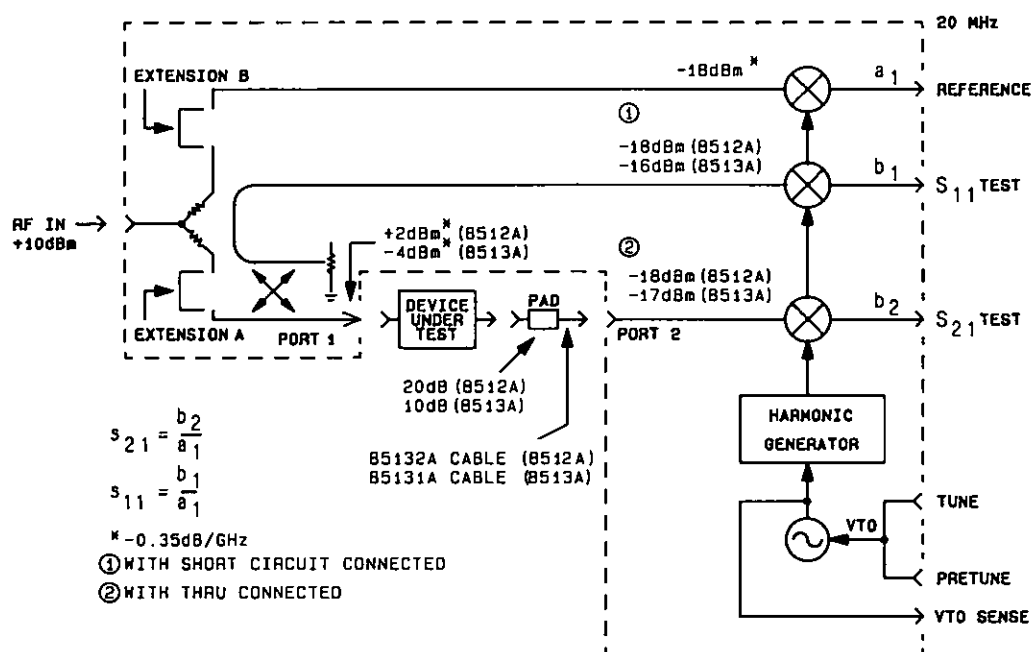


Figure 7. Reflection/Transmission Test Sets Signal Flow

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.

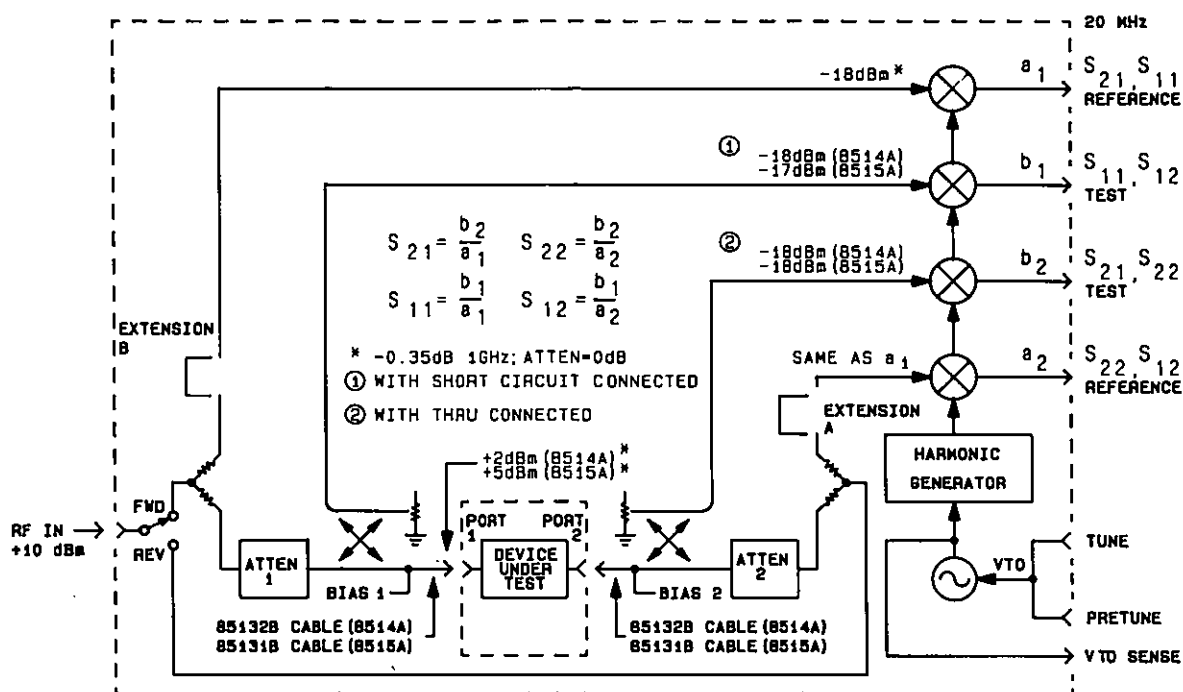


Figure 8. S-Parameter Test Sets Signal Flow

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.

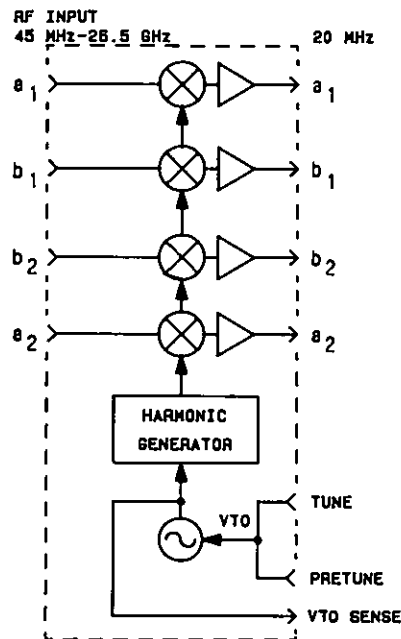


Figure 9. HP 8511A Frequency Converter

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 HP 8513A HP 8514A HP 8515A	7 mm 3.5 mm (m) 7 mm 3.5 mm (m)	HP 85132A, 8492A-020 HP 85131A, 8493C-010 HP 85132B (2 in set) 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.

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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.

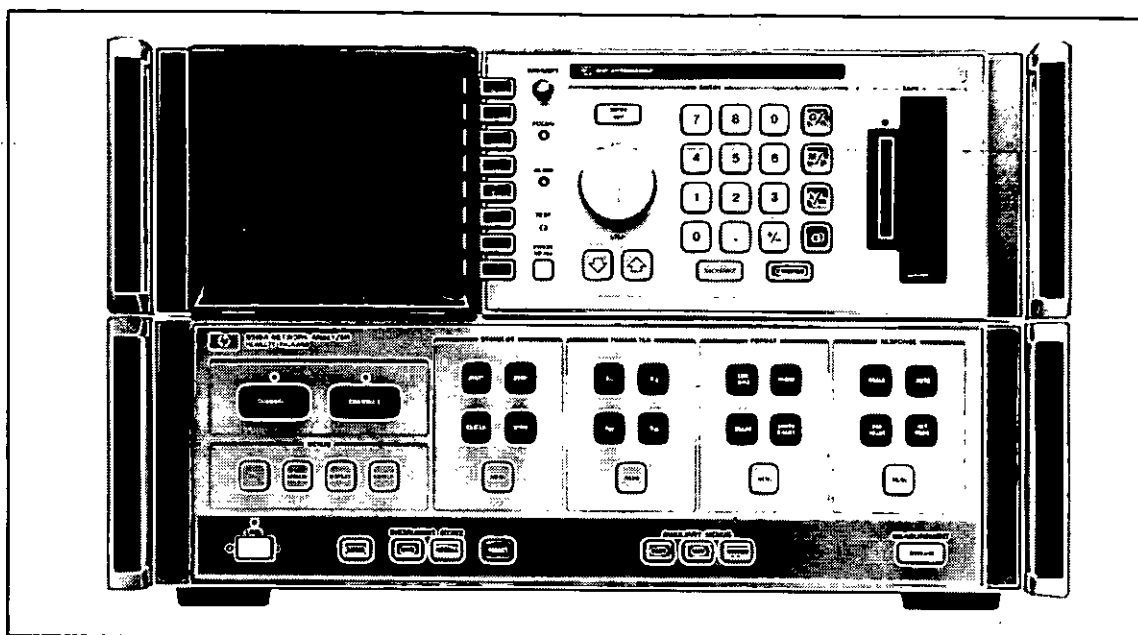


Figure 10. HP 8510 Network Analyzer Front Panel

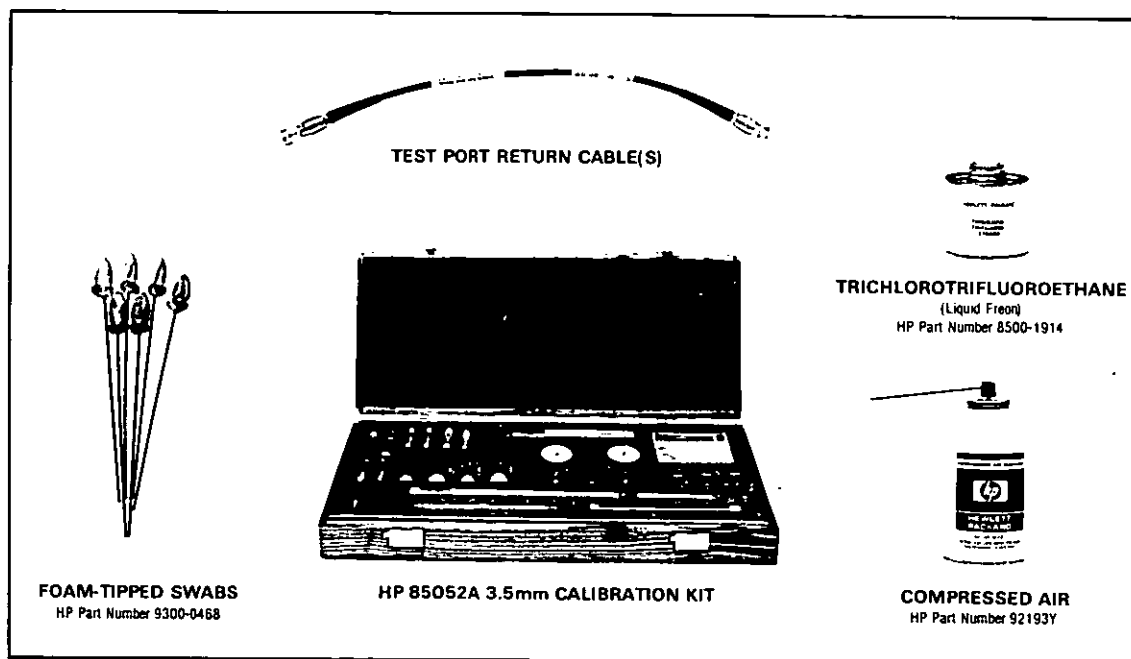


Figure 11. Equipment Required

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.

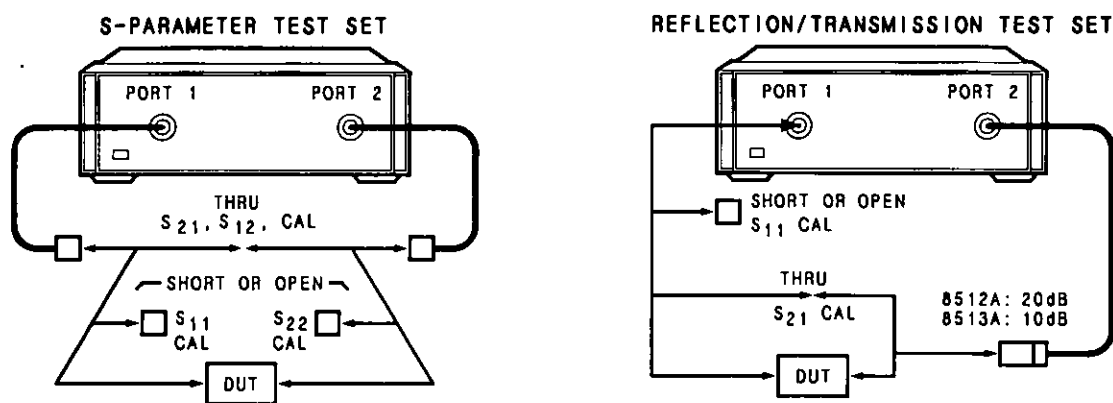


Figure 12. Measurement Setup

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

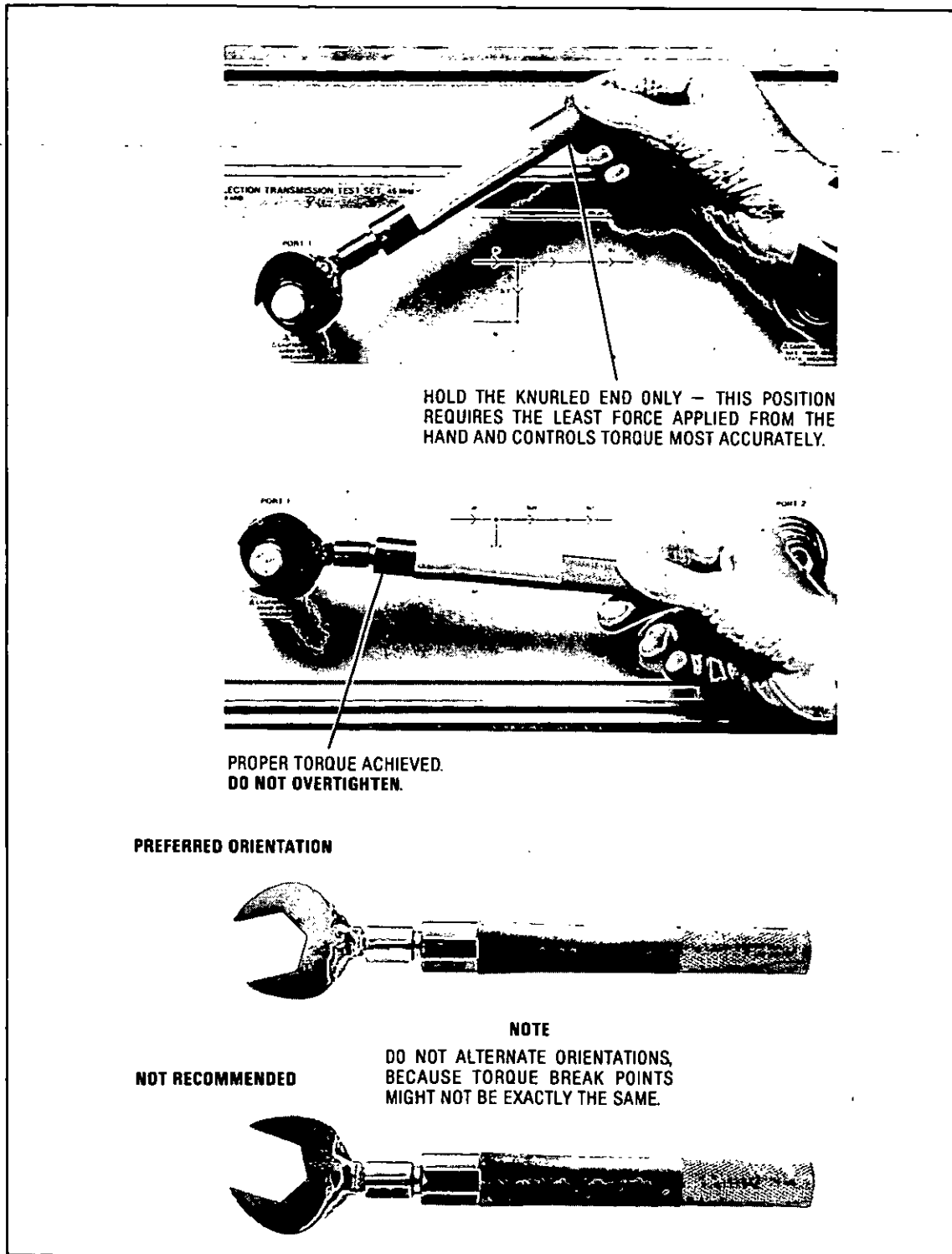


Figure 14. Using a Torque Wrench

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 connectors. 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 initialization 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.

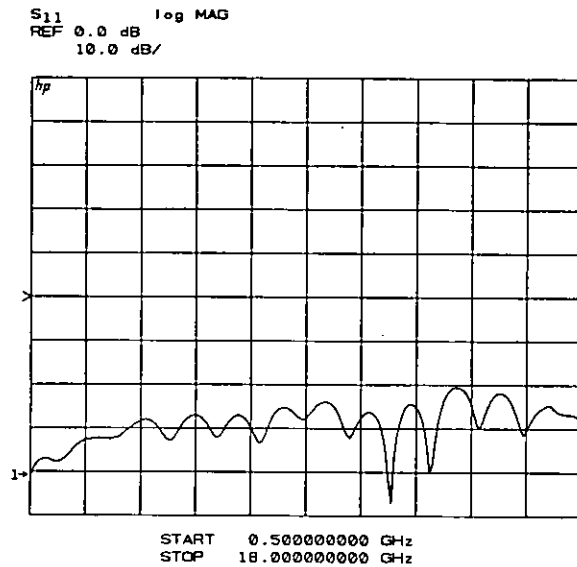


Figure 15-a. Thru Connection:
PRESET, ENTRY OFF

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

S₁₁ 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.

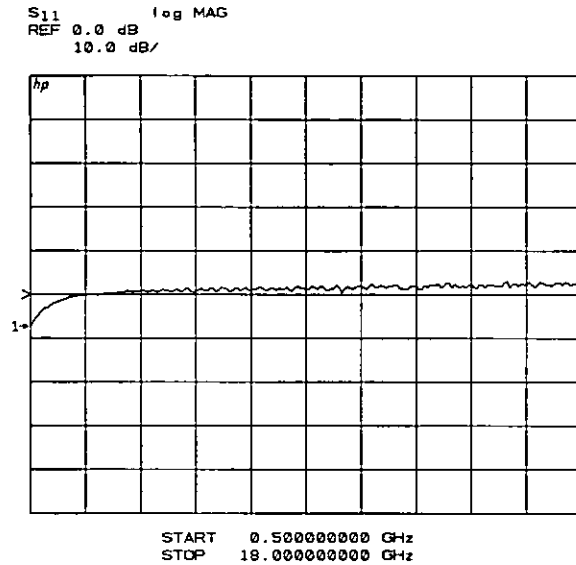
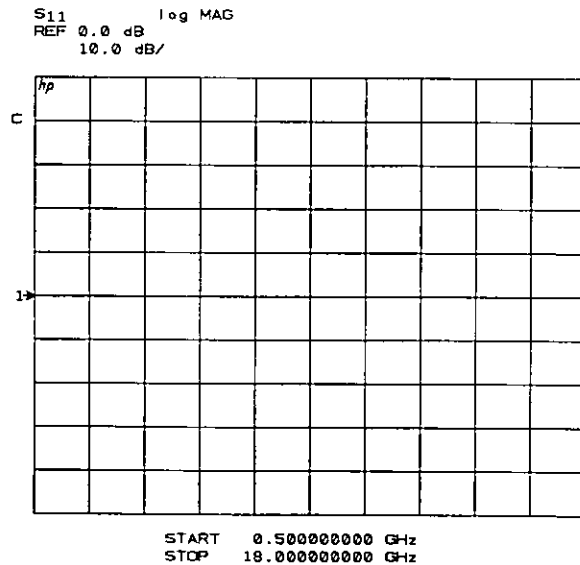


Figure 15-b. Open Circuit Connected

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, S₁₁, 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.

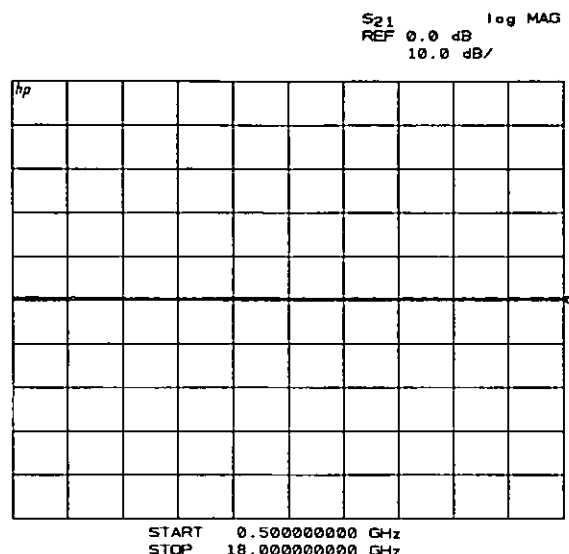
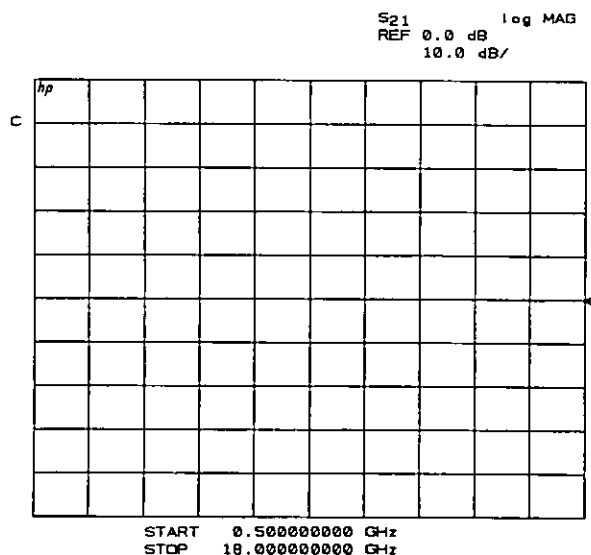


Figure 15-d. Thru Connection

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**, **S₁₁**, 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**, **S₂₁**, 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.

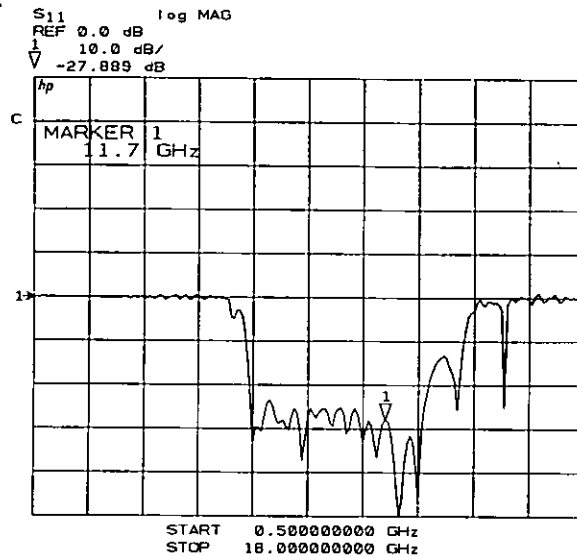


Figure 15-f. Device-Under Test
Return Loss: S_{11} , LOG MAG.

- 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.

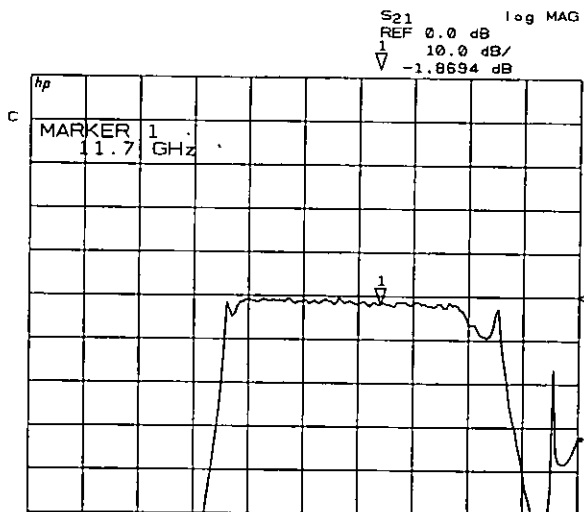


Figure 15-g. Device-Under Test
Insertion Loss: S_{21} , LOG MAG.

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 **S₁₁**. 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.

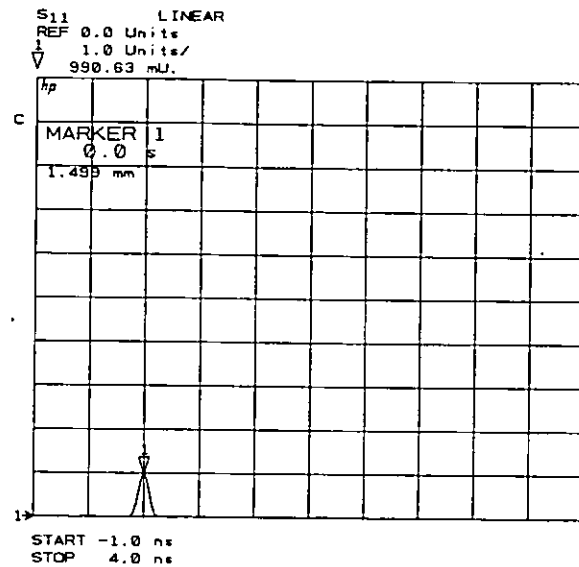


Figure 15-h. Time Domain Short:
S₁₁, TIME BAND PASS.

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

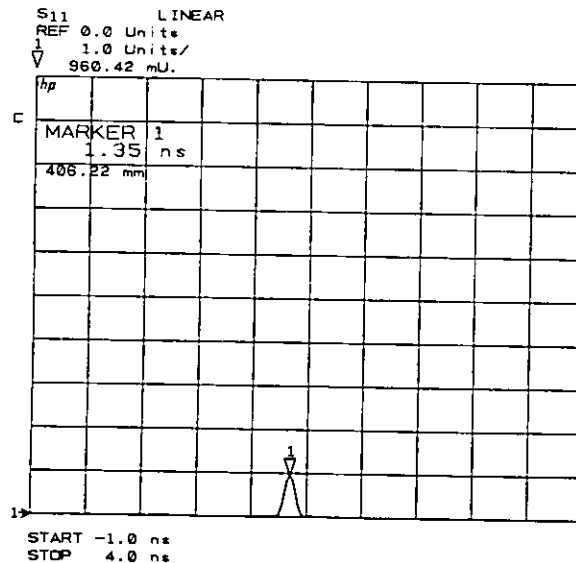


Figure 15-i. Time Domain Airline
and Short Circuit

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.

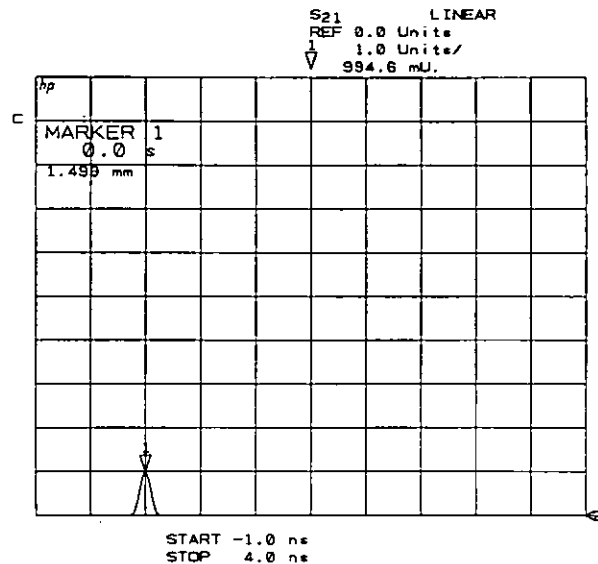


Figure 15-j. Time Domain Thru:
S₂₁, TIME BAND PASS.

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

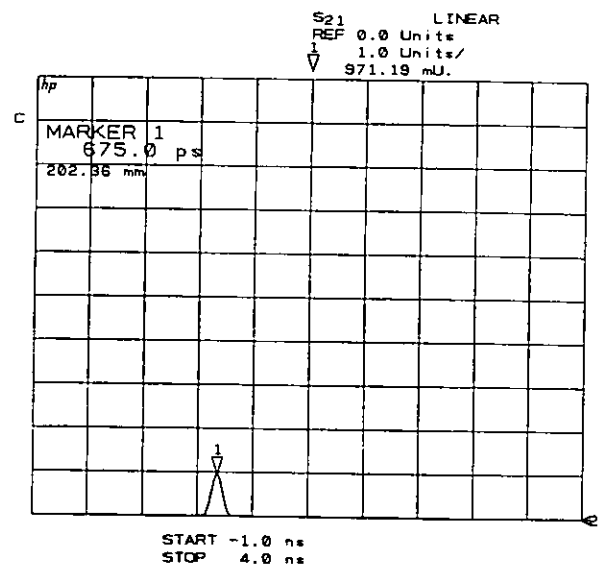


Figure 15-k. Time Domain Airline
and Thru Connection

NOTES

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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 initialization 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.

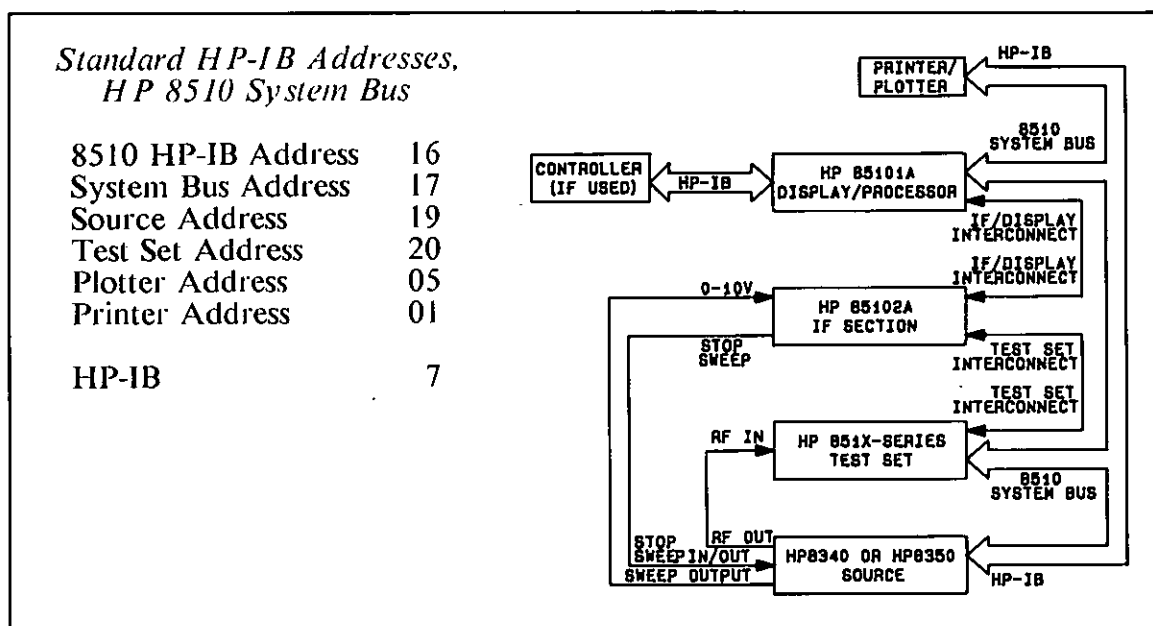


Figure 16. System Interconnections and HP-IB Addresses

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.

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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.

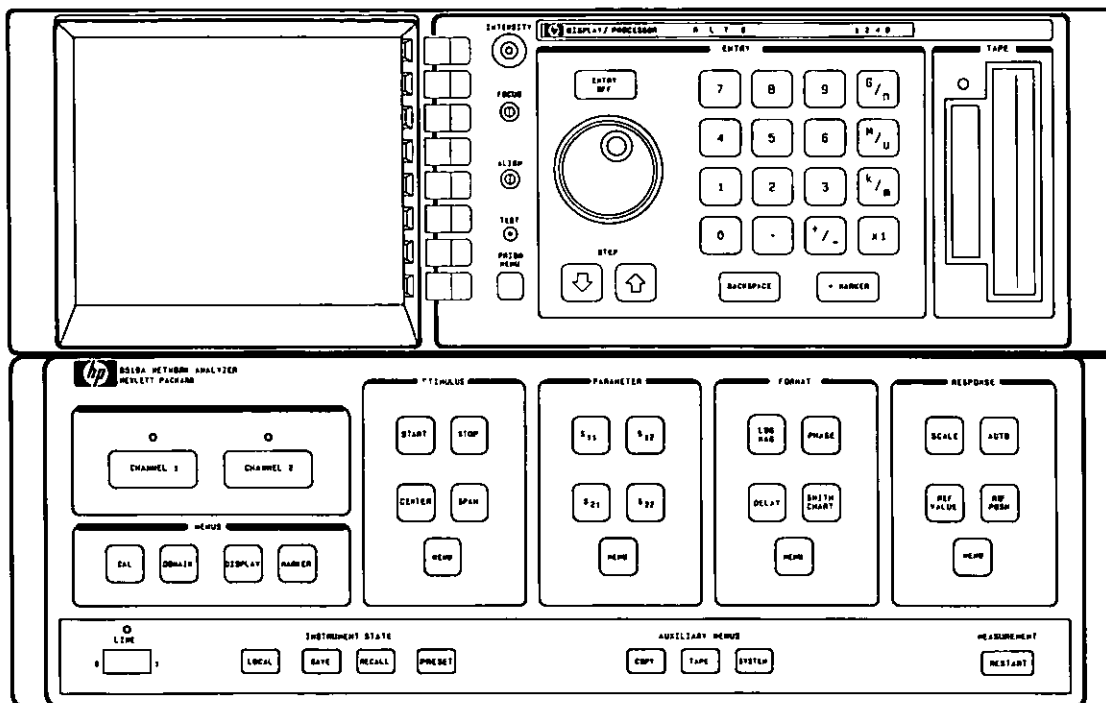


Figure 17. Front Panel Controls

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.

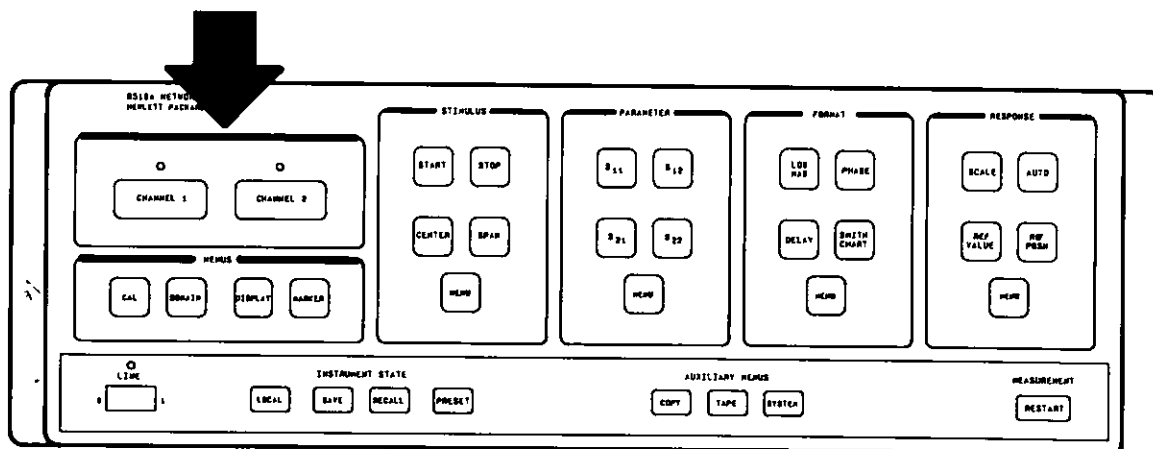


Figure 18. Channel Selection Keys

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
S = smoothing on
D = electrical delay on
H = hold

A = averaging on
G = time domain gating on
O = IF overload
* = 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 **SYS-TEM** 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 $\uparrow$ 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.

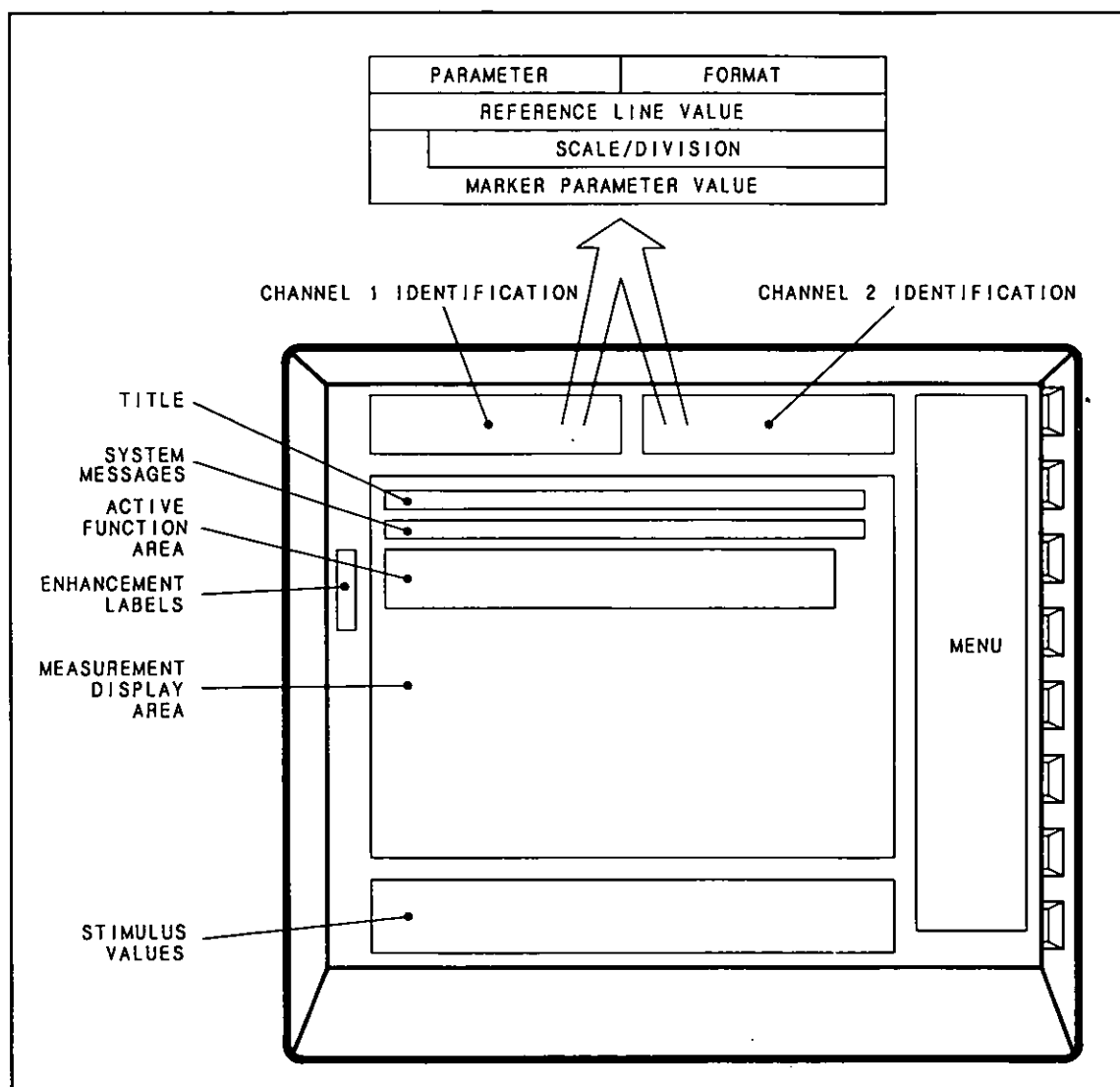


Figure 19. CRT Display

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.

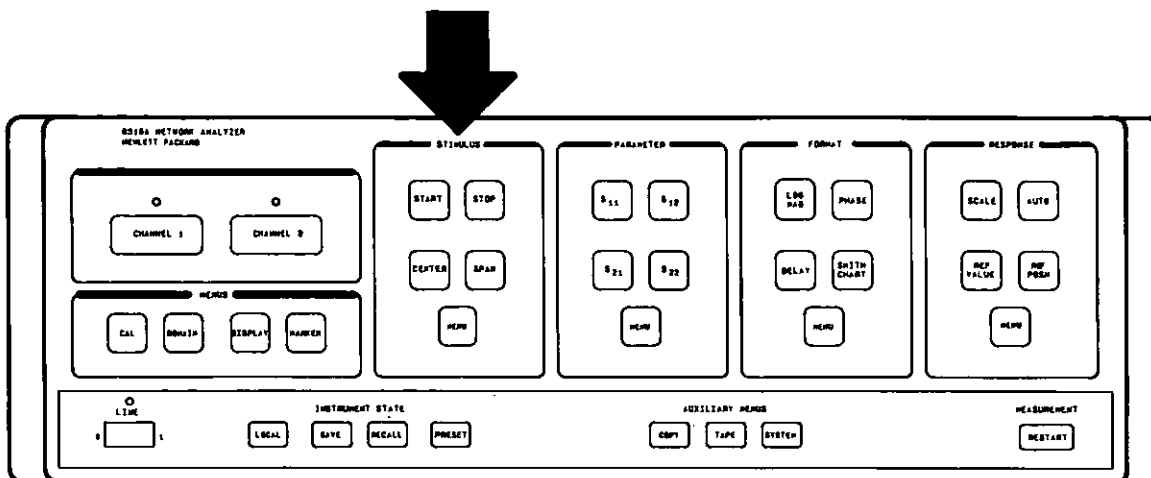


Figure 20. Main Function Blocks

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.

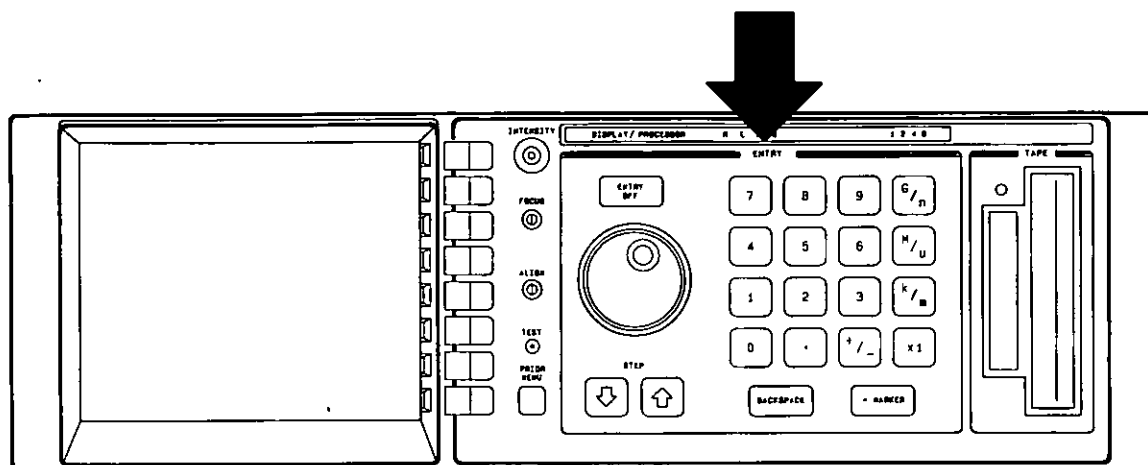


Figure 21. ENTRY Block

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.

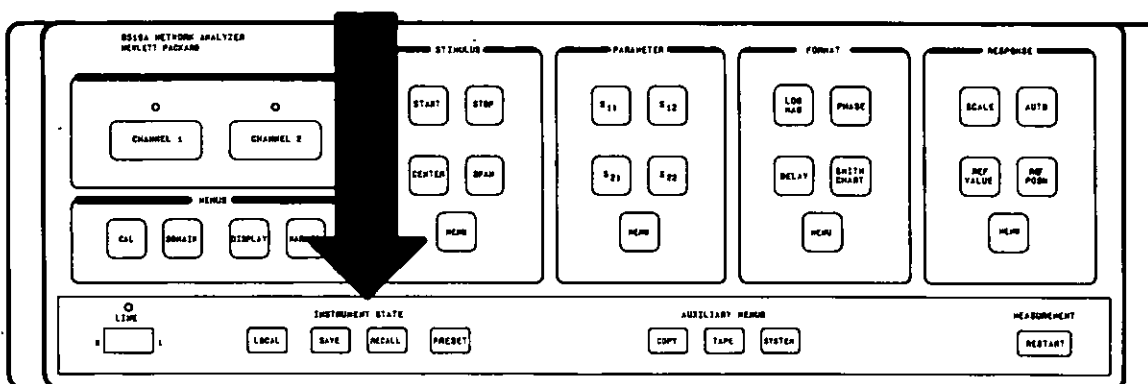


Figure 22. INSTRUMENT STATE Block

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.

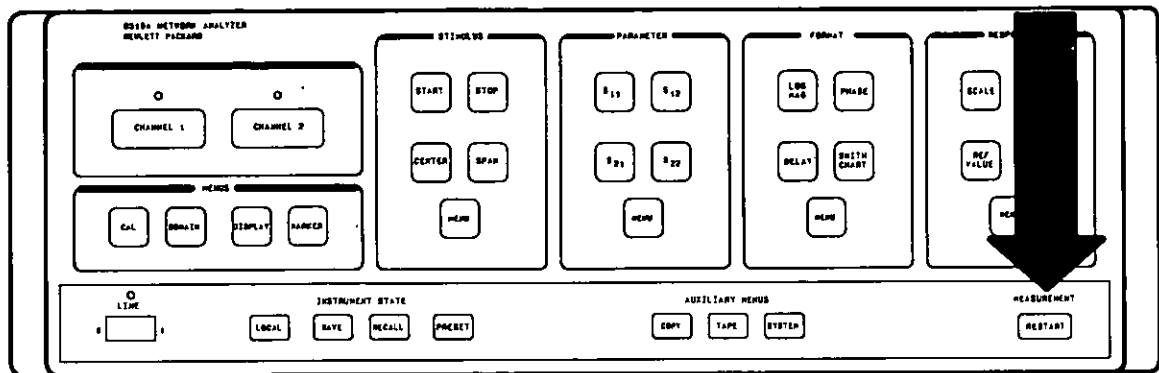


Figure 23. Measurement RESTART Key

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 **PRE-SET** 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.

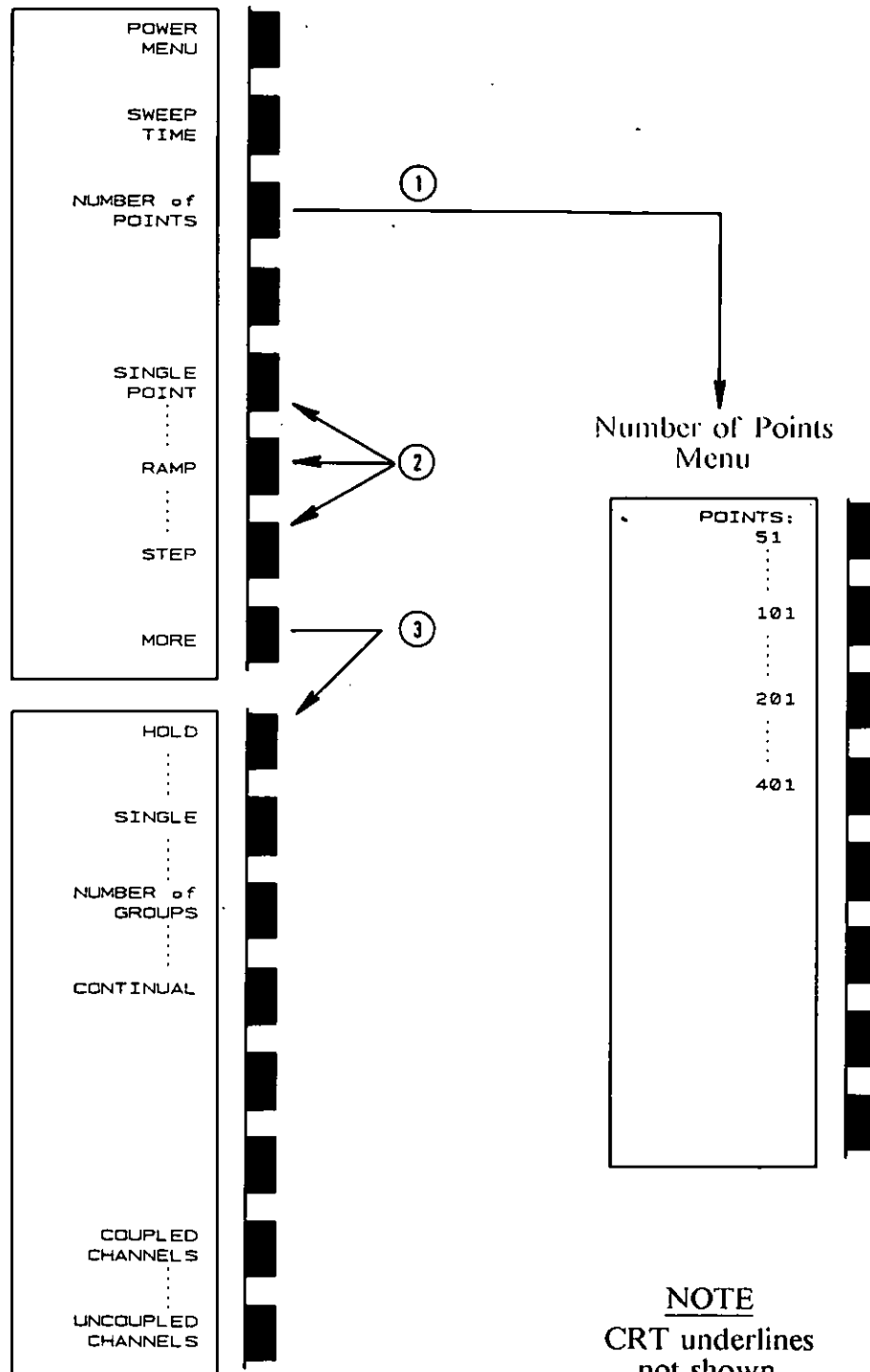
Press the softkey beside **RAMP**. This will cause the source to operate in the **RAMP** mode. This mode label will be underlined on the CRT display, indicating that it is now the current choice.

(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.

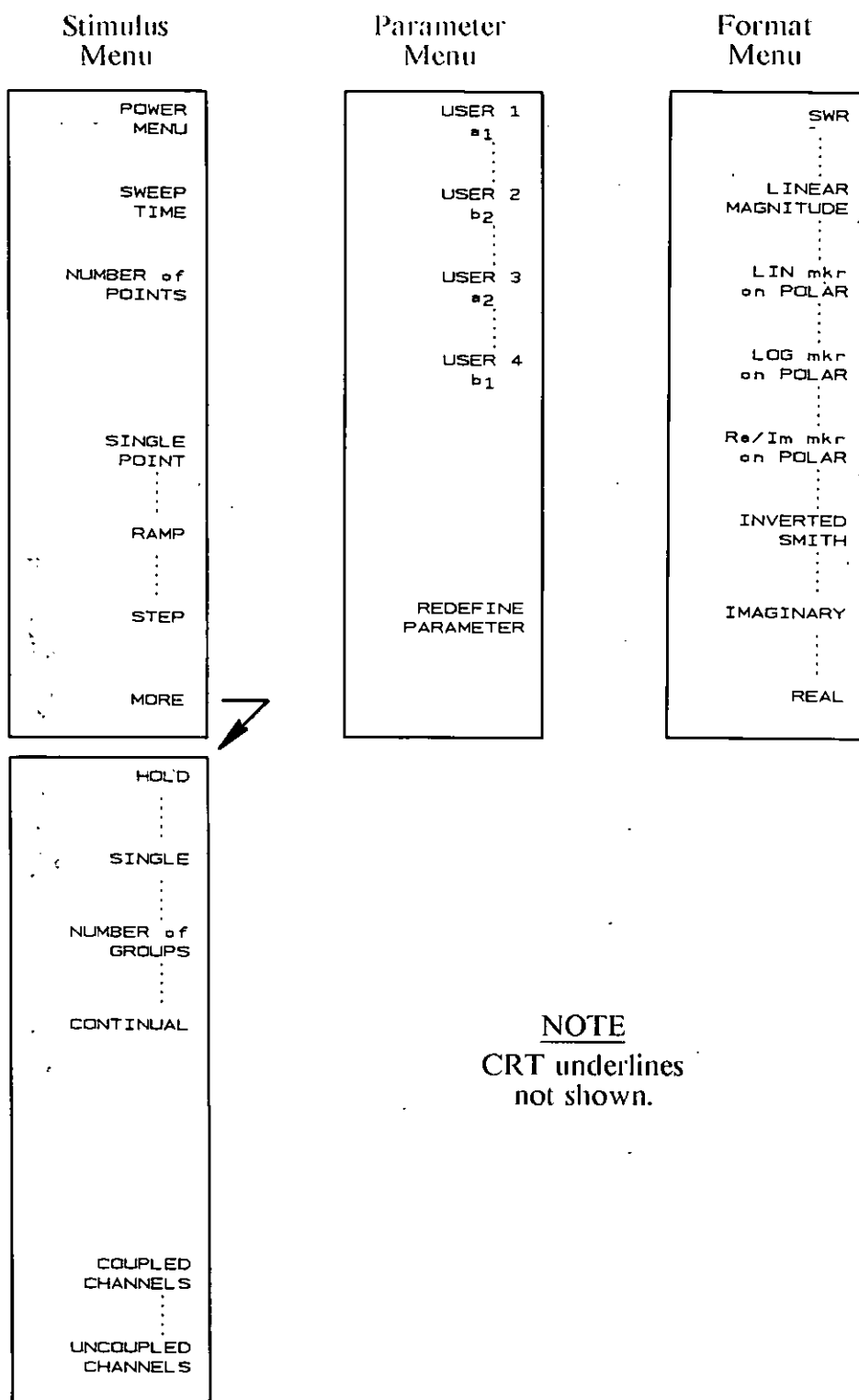
This choice does not appear on the Stimulus Menu as it is first displayed. Therefore press the softkey beside **MORE** to display the continuation of the Stimulus Menu.

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.

Stimulus Menu



NOTE
CRT underlines
not shown.



NOTE
CRT underlines
not shown.

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

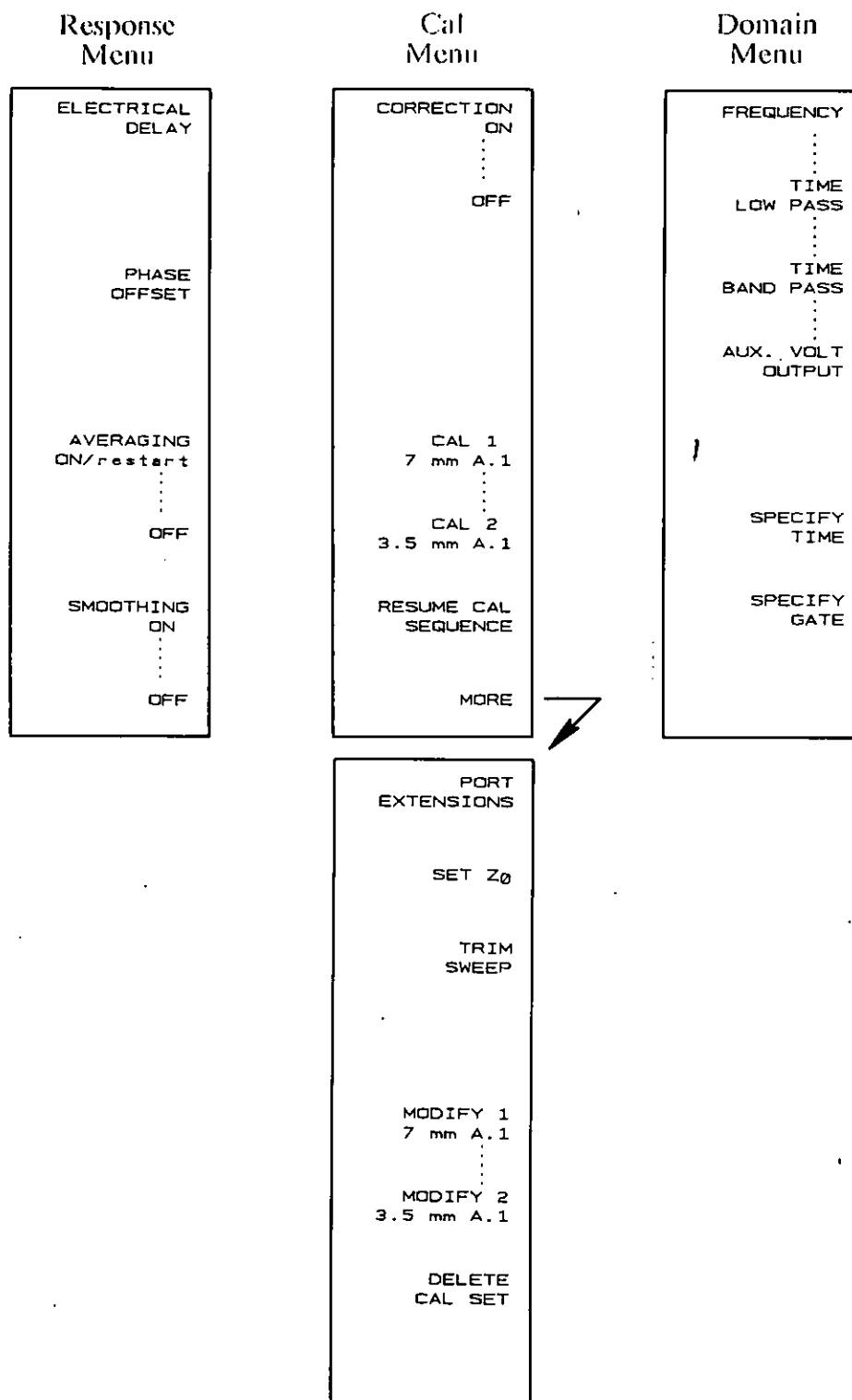


Figure 24. First-Level Menus (2 of 4)

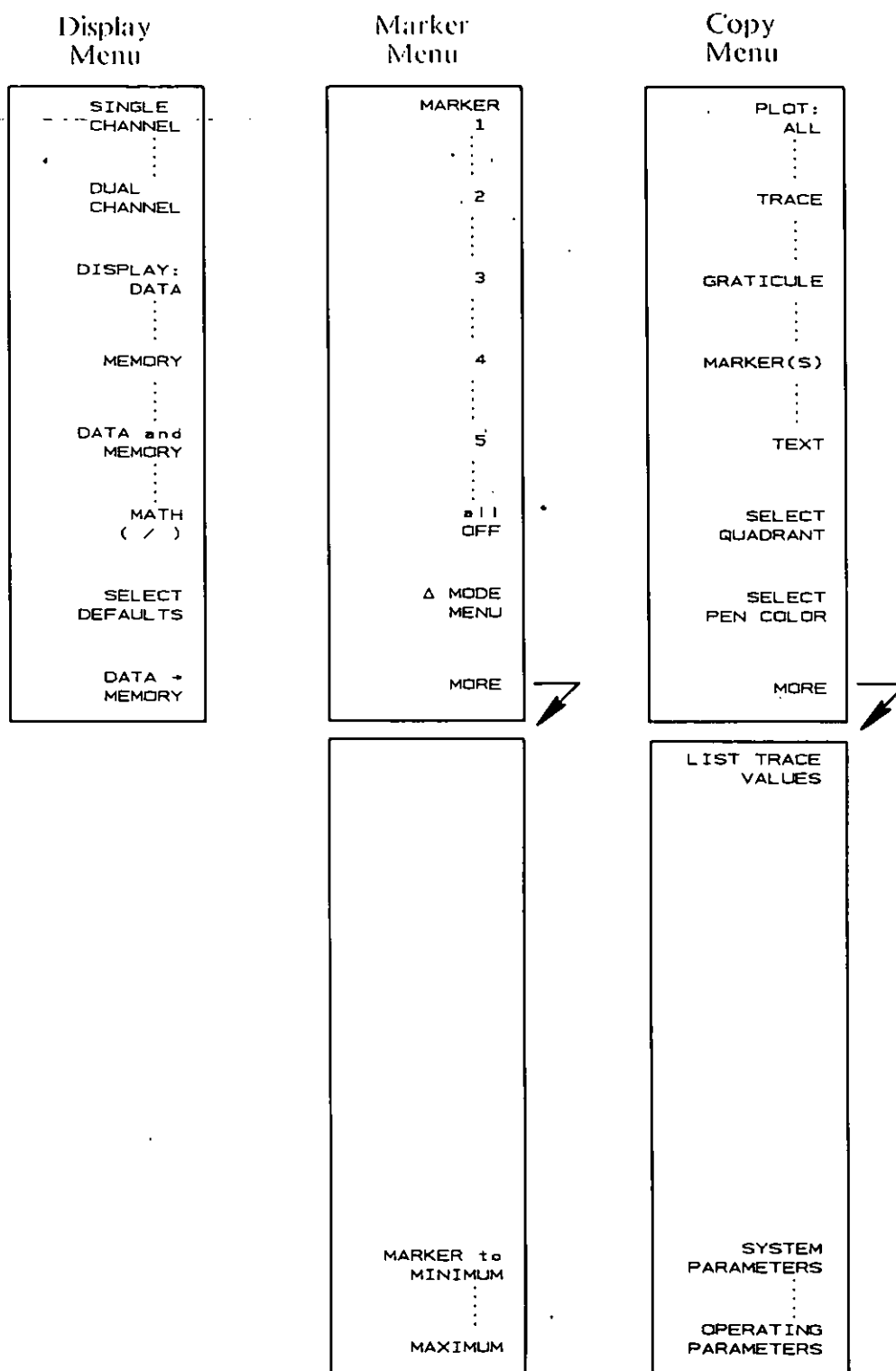
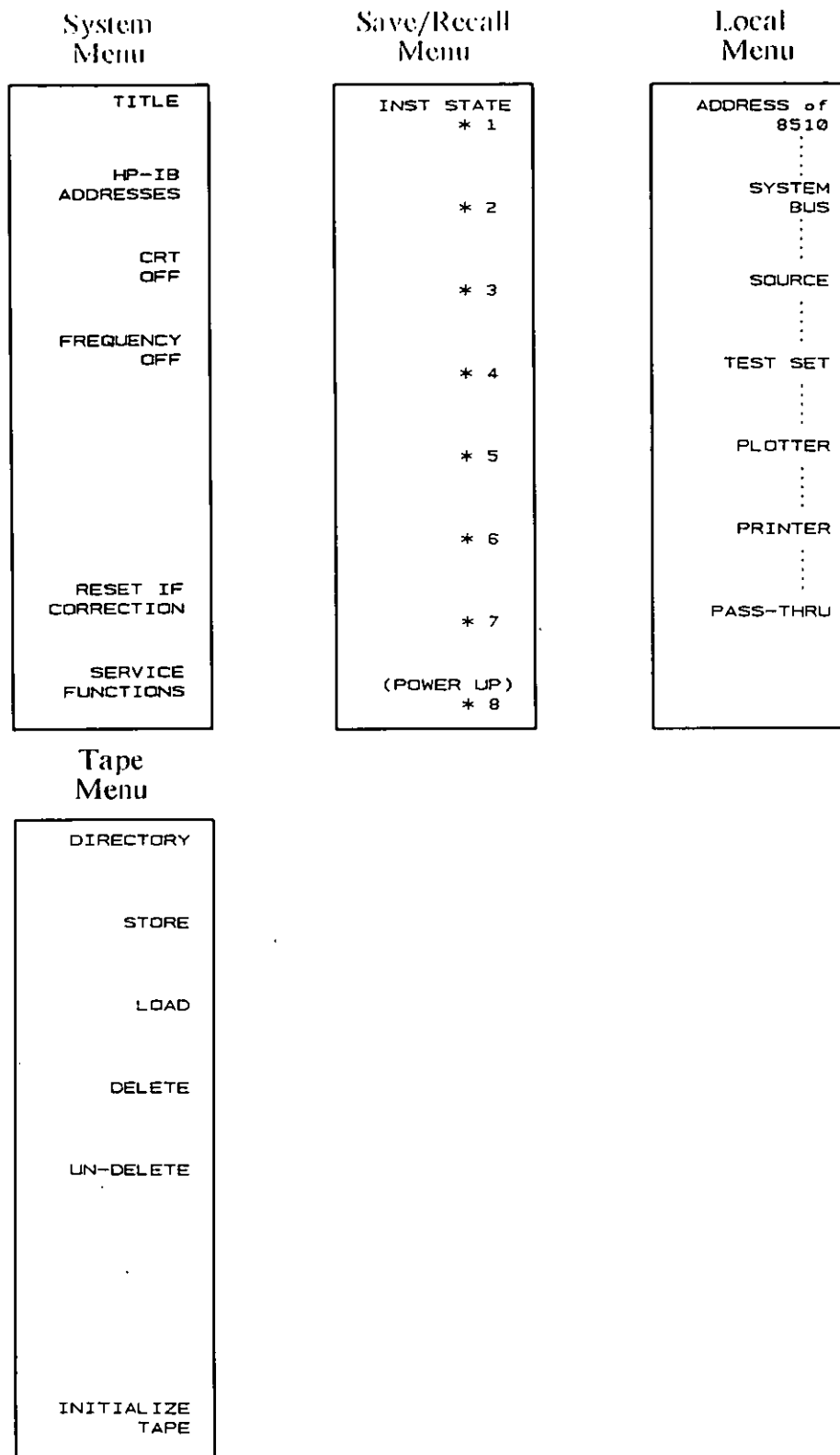


Figure 24. First-Level Menus (3 of 4)

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

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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.

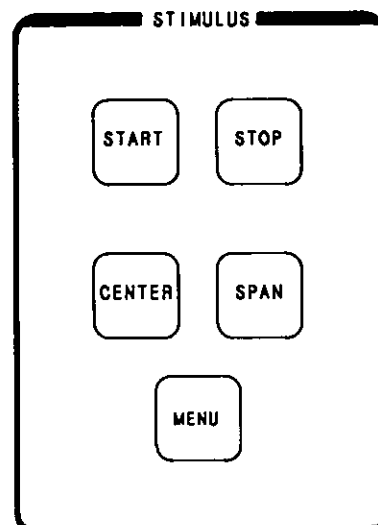
RESPONSE block keys control such details of the display as the trace position, the scale units per division, and the value of the reference line. Response menus give access to other features in displays of the data such as electrical delay, phase offset, averaging, and smoothing.

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.

Stimulus Menu

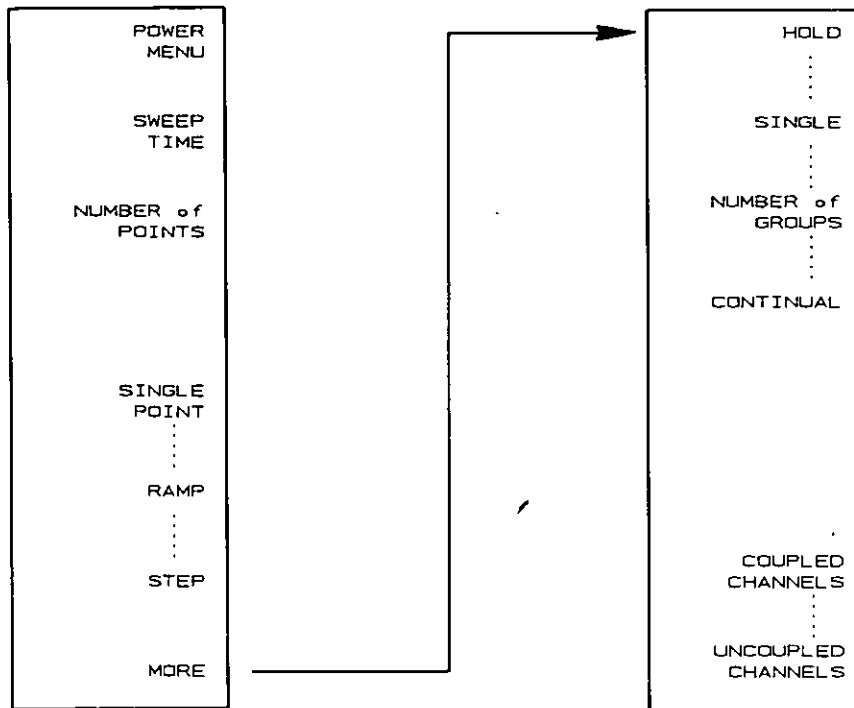


Figure 25. Stimulus Menu

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**.

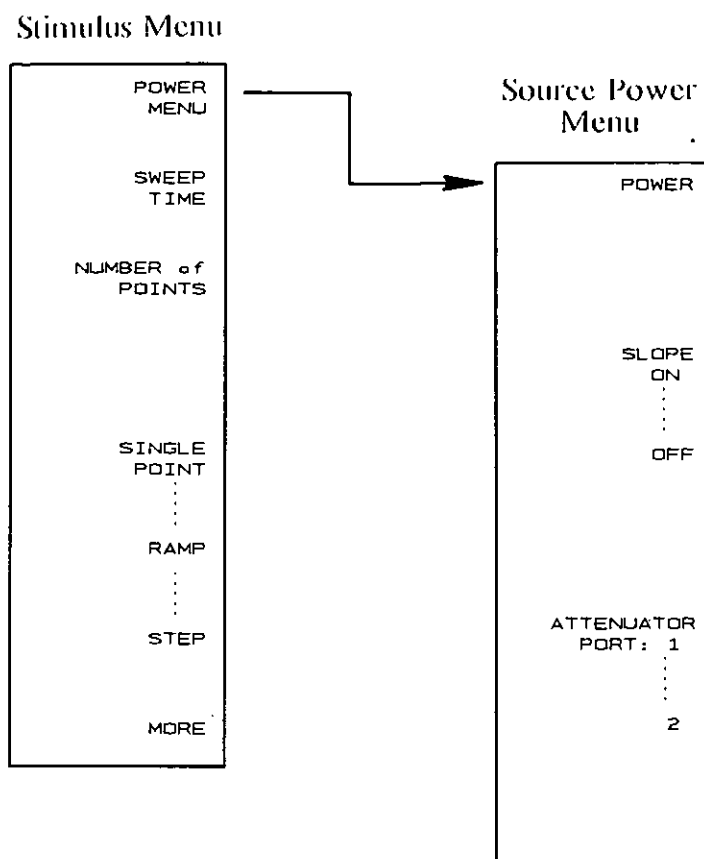


Figure 26. Source Power Menu

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 reflection/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.

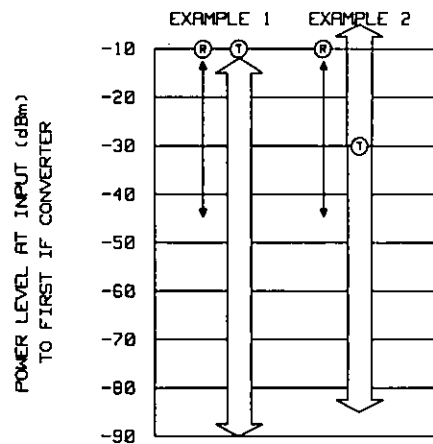


Figure 27. Dynamic Range Considerations

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.

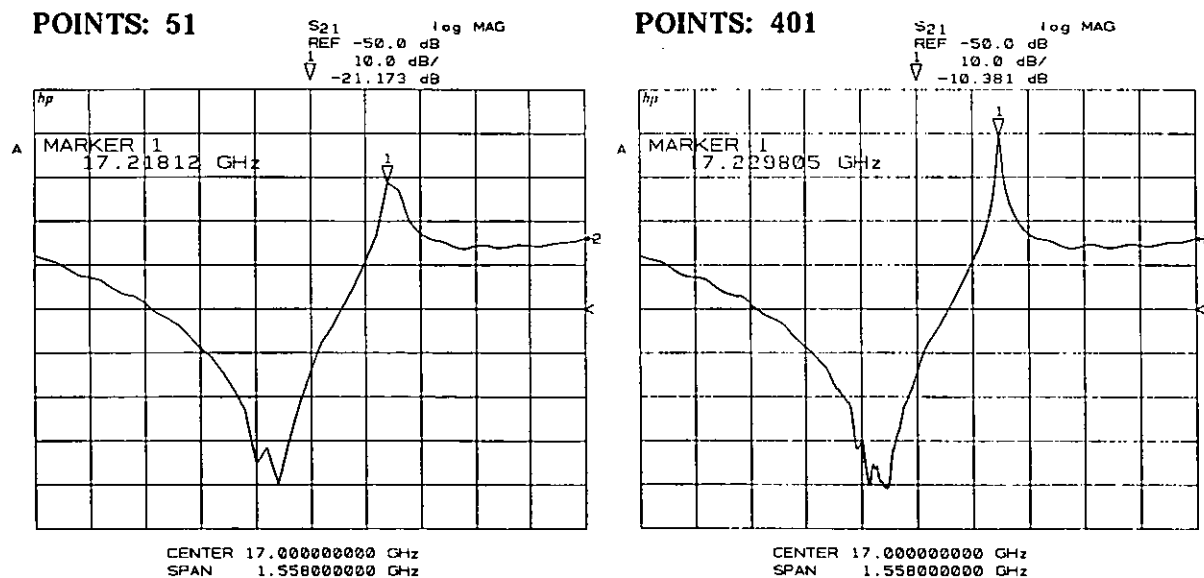


Figure 28. Narrowband Responses

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.

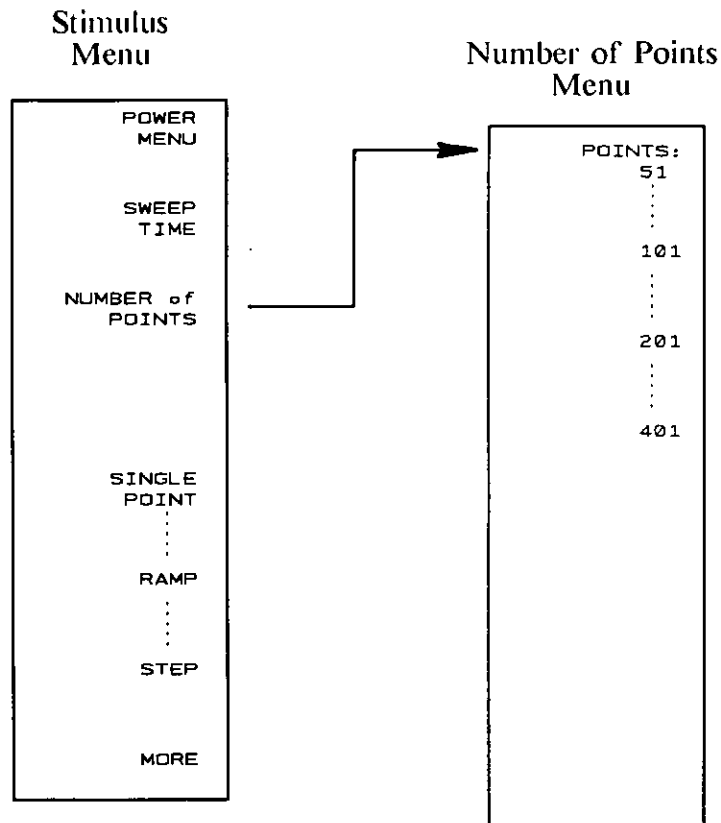


Figure 29. Number of Points Menu

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:

$$\text{Dwell Time (ms)} = \text{Sweep Time (ms)} / \text{Number of Points}$$

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.

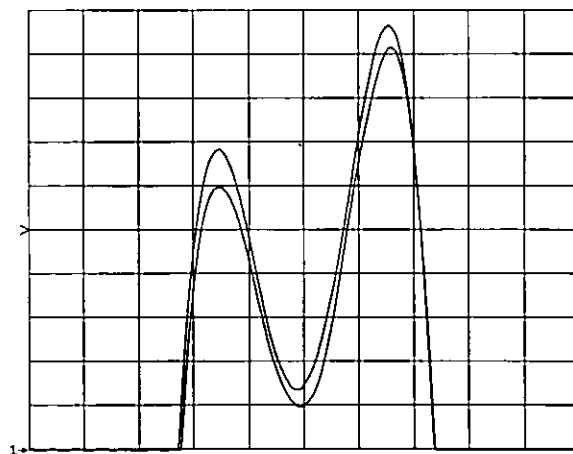


Figure 30. Effects of Sweep Time

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 **UNCOUPLLED 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**

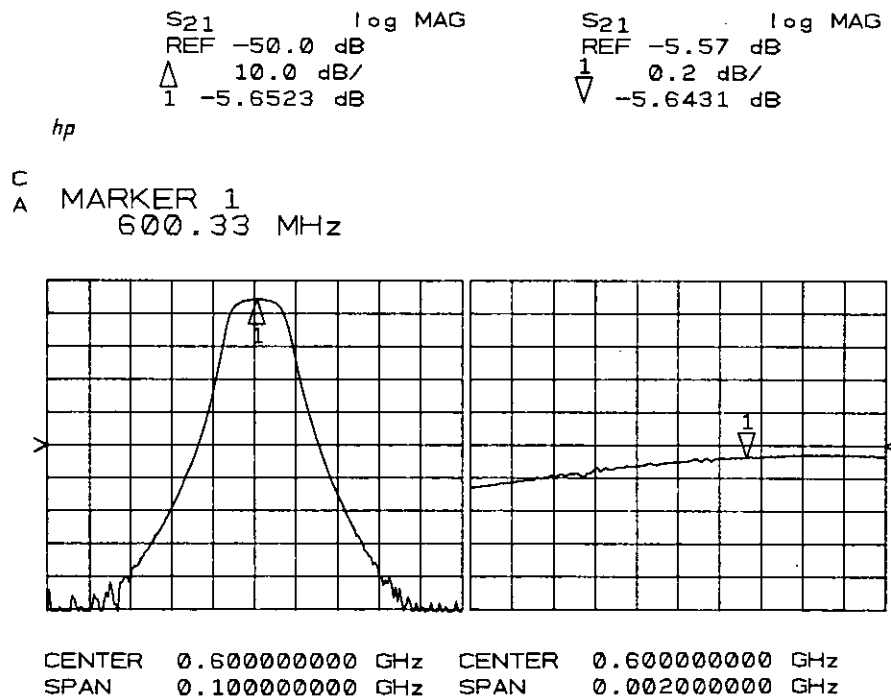


Figure 31. Alternate Sweep: DUAL CHANNEL, SPLIT

PARAMETER

PARAMETER block keys are used to select the parameter to be measured. The Parameter and Re-define 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.

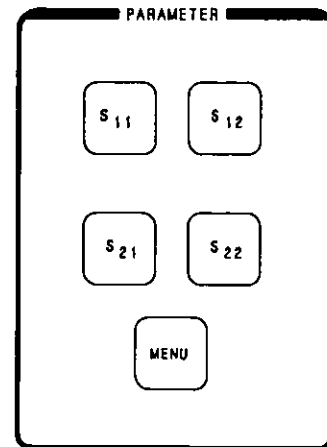
The S_{11} , S_{21} , S_{12} , and S_{22} keys are used to select the parameter to be measured. These selections correspond to the signal flow diagram on the front panel of the test set. When a parameter is selected, test set switching is done automatically to choose the correct reference and test signal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

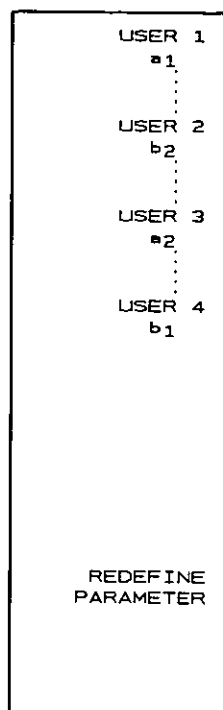
In addition to explaining the controls and features in the PARAMETER block, this section also offers a basic discussion defining S-parameters and explaining the important conventions used to identify them.



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.

Parameter Menu



Redefine Parameter Menu

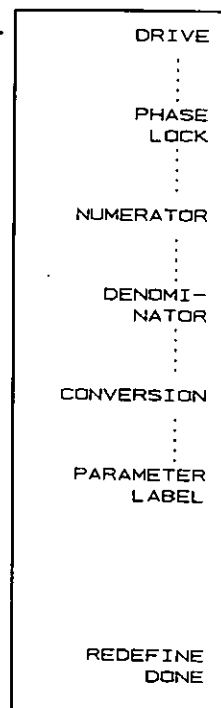


Figure 33. Parameter and Redefine Parameter Menus

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 a₁**, **USER 2 b₂**, **USER 3 a₂**, or **USER 4 b₁**. Note that since **a₂** 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
a₁	Reference (S_{11} and S_{21})
b₂	Transmitted to Port 2. (Connect Thru) or (S-Parameter test sets only) Reflected at Port 2. (Connect Short Circuit)
a₂	Reference (S_{12} and S_{22}) for S-Parameter test set. (Not used for reflection/transmission test set.)
b₁	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:

$$S_{out\ in}$$

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.

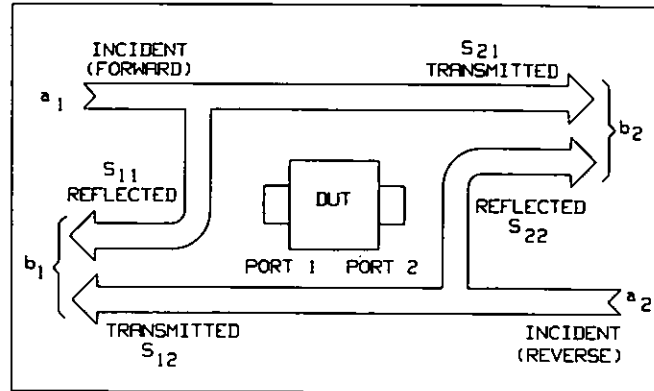


Figure 33-a. Two-Port Device

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.

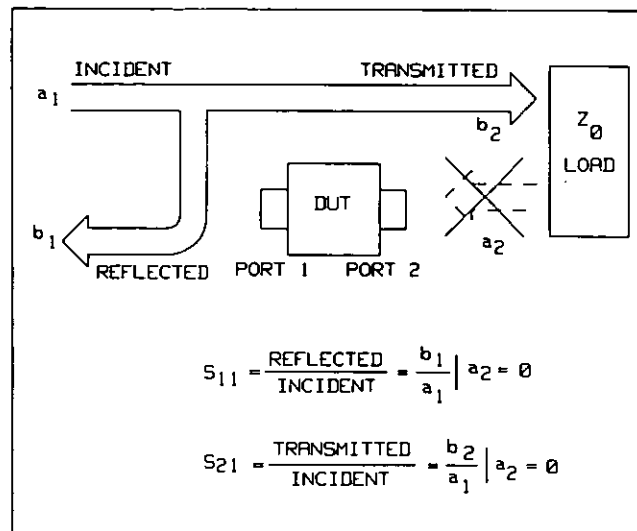


Figure 33-b. S_{11} and S_{21} Definitions

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.

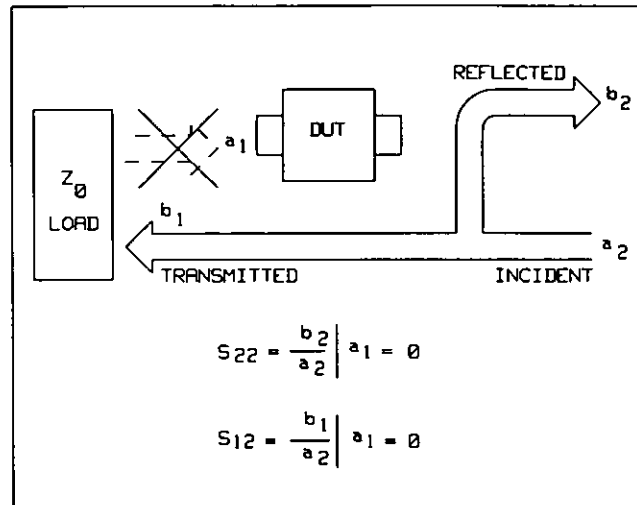


Figure 33-c. S_{22} and S_{12} Definitions

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).

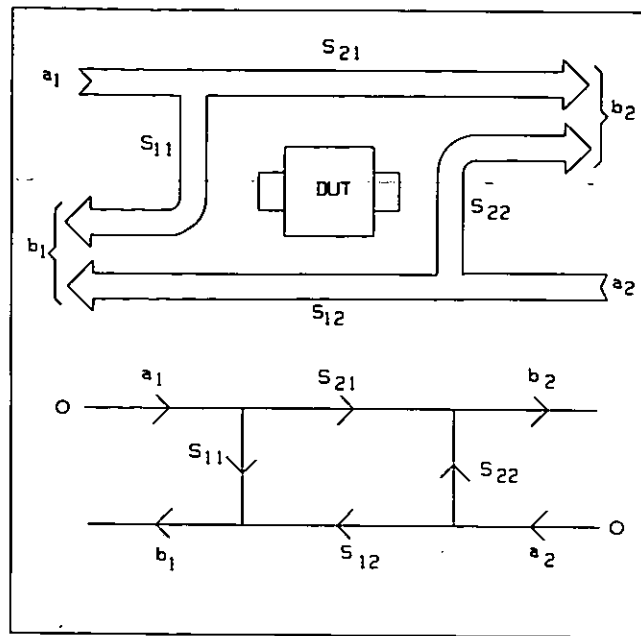


Figure 33-d. Flowgraph: Two-Port Device, S-Parameter Test Sets

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.

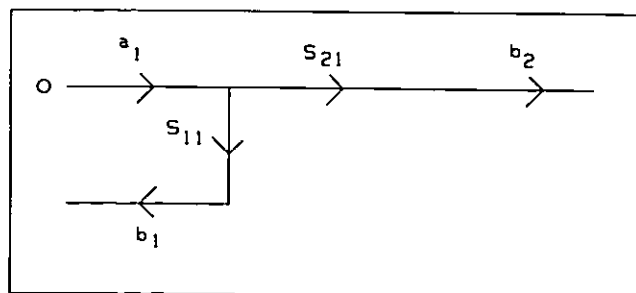


Figure 33-e. Flowgraph, Reflection-Transmission Test Sets

FORMAT

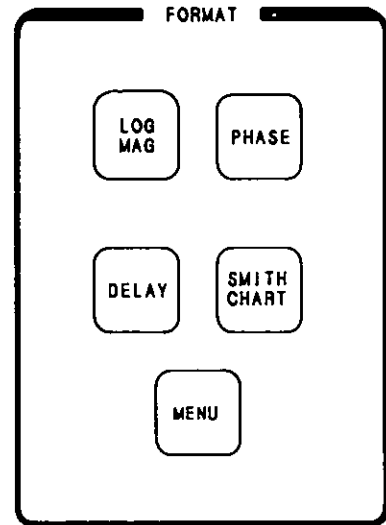
FORMAT block keys and the associated Format Menu (Figure 33) allow choices of the format used in displaying the data for each parameter selected.

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.

<u>Format Menu</u>	<u>Type of Display</u>
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

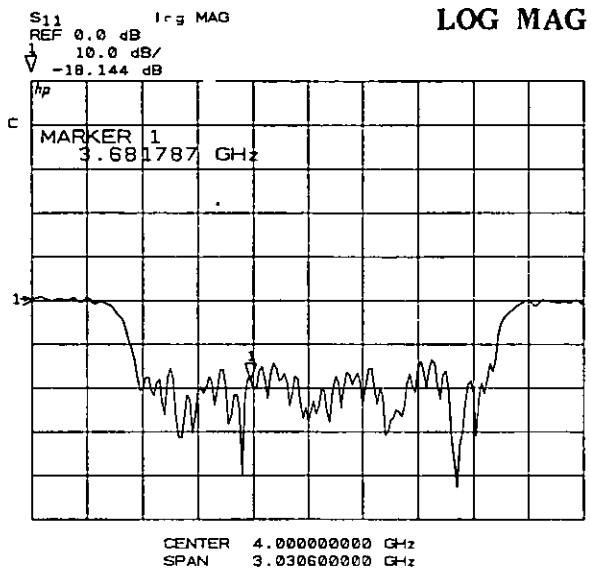


Figure 34-a. LOG MAG Format

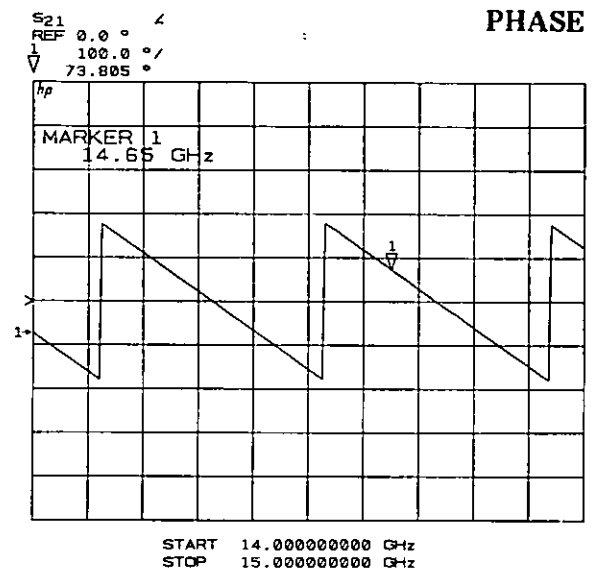


Figure 34-b. PHASE Format

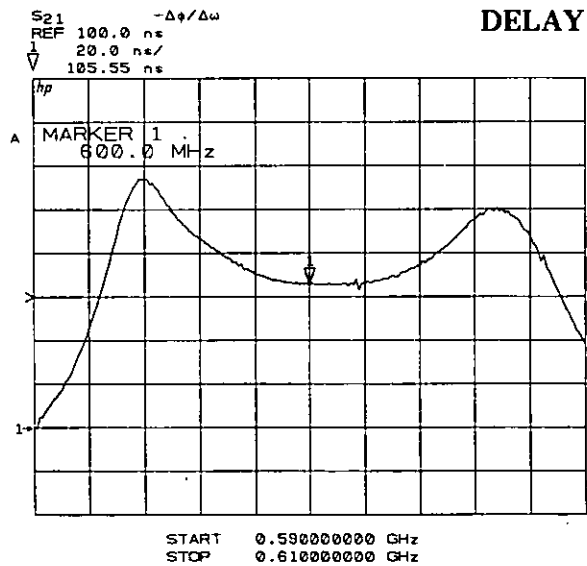


Figure 34-c. DELAY Format

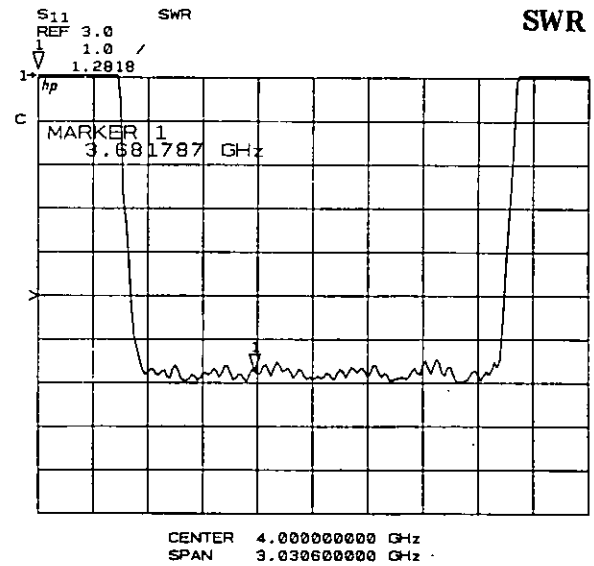


Figure 34-d. SWR Format

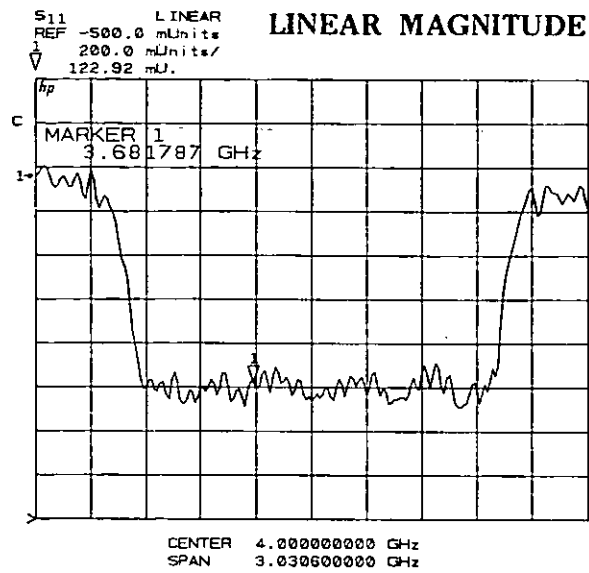


Figure 34-e. LIN MAG Format

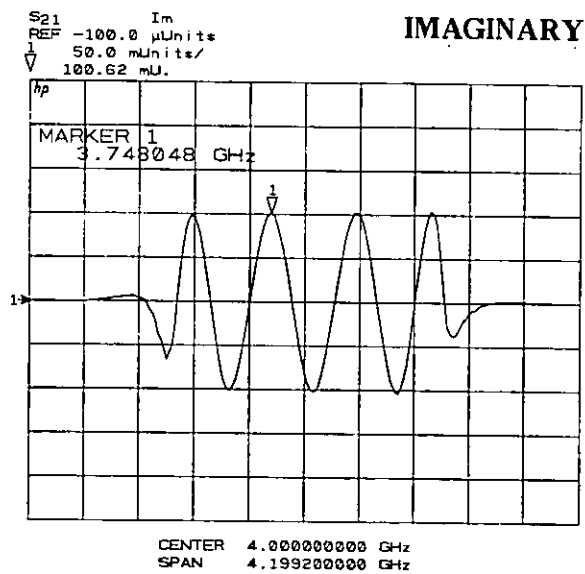


Figure 34-f. IMAGINARY Format

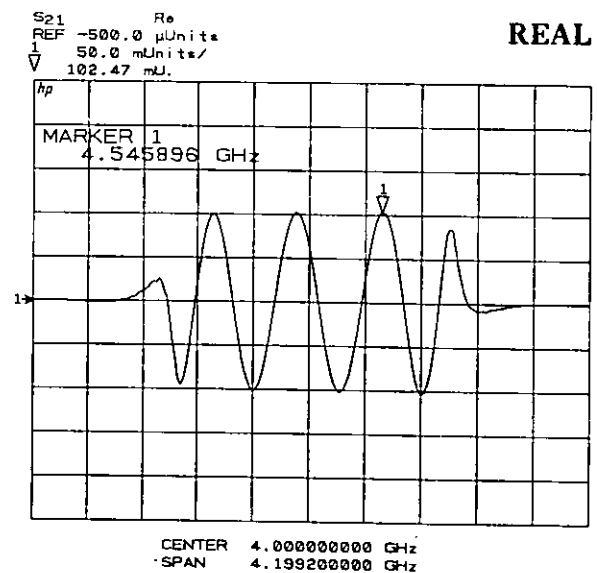
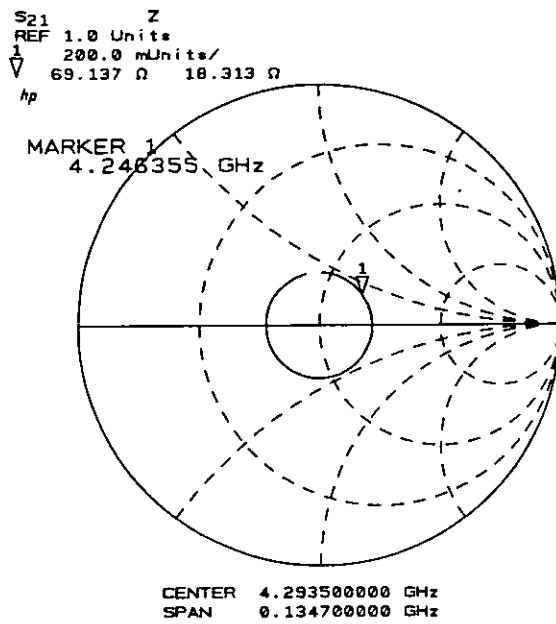


Figure 34-g. REAL Format

SMITH CHART DISPLAYS

SMITH CHART

Figure 34-h. Smith Chart
Format

INVERTED SMITH CHART

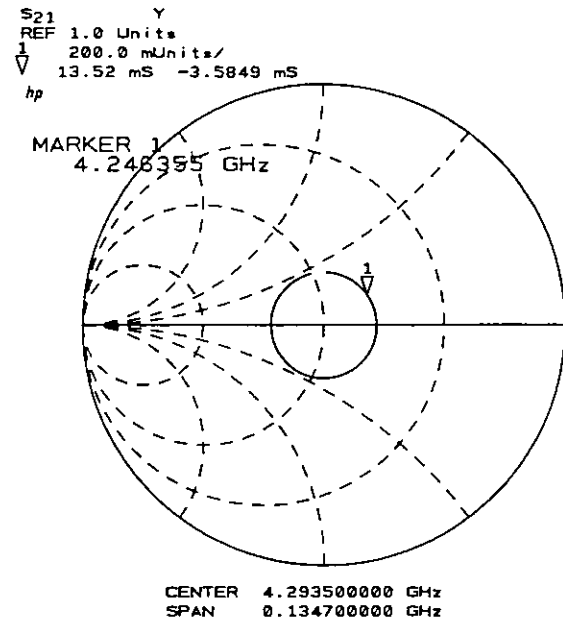


Figure 34-i. Inverted Smith Chart

POLAR DISPLAYS

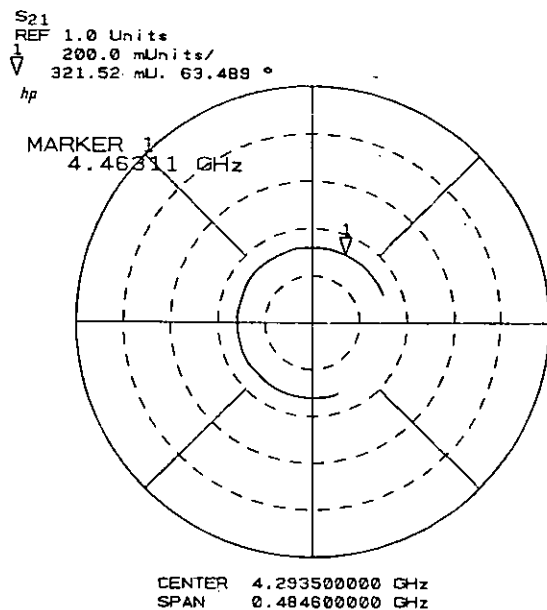


Figure 34-j. LIN mkr on POLAR Format

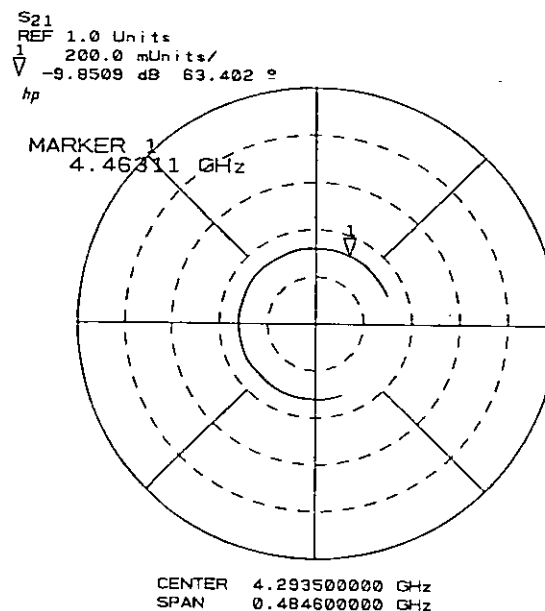


Figure 34-k. LOG mkr on POLAR Format

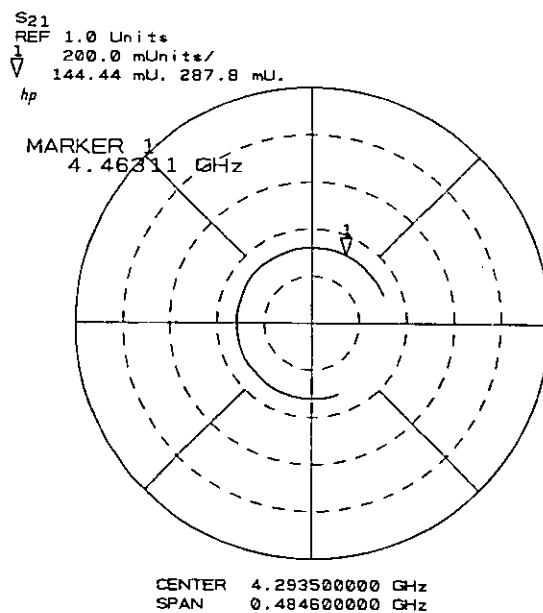


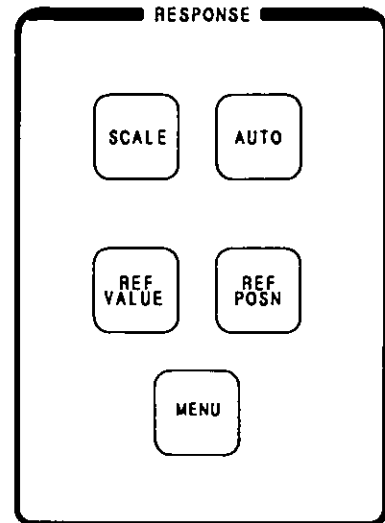
Figure 34-l. Re/Im mkr on POLAR Format

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.

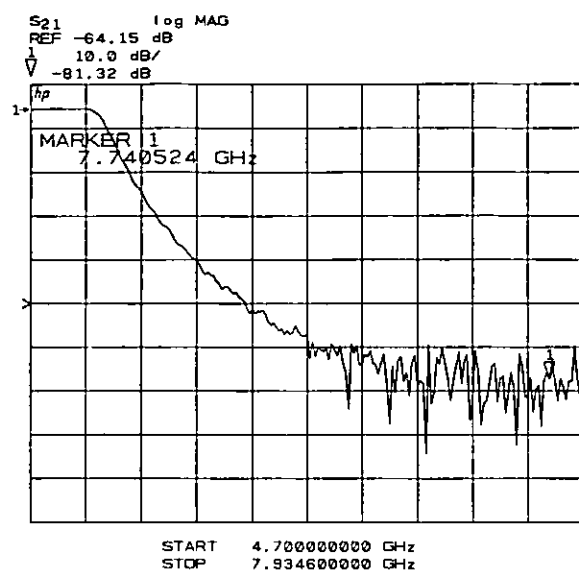
(A group consists of a certain number of sweeps that must be taken in order to make one complete measurement; how many sweeps make up a group thus depends on the calibration model being used and other details of the measurement.)

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.

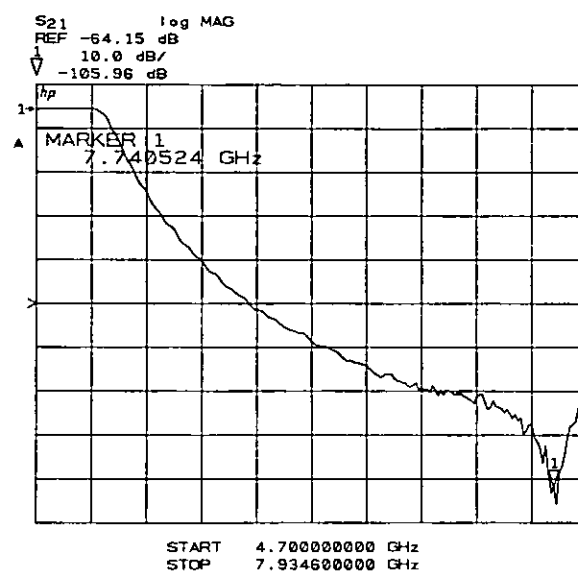
In the **STEP** sweep and Single Point modes, each data point is averaged n times as it is read, so only one group is required. This is a linear block average.

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.



Averaging OFF



Averaging ON

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

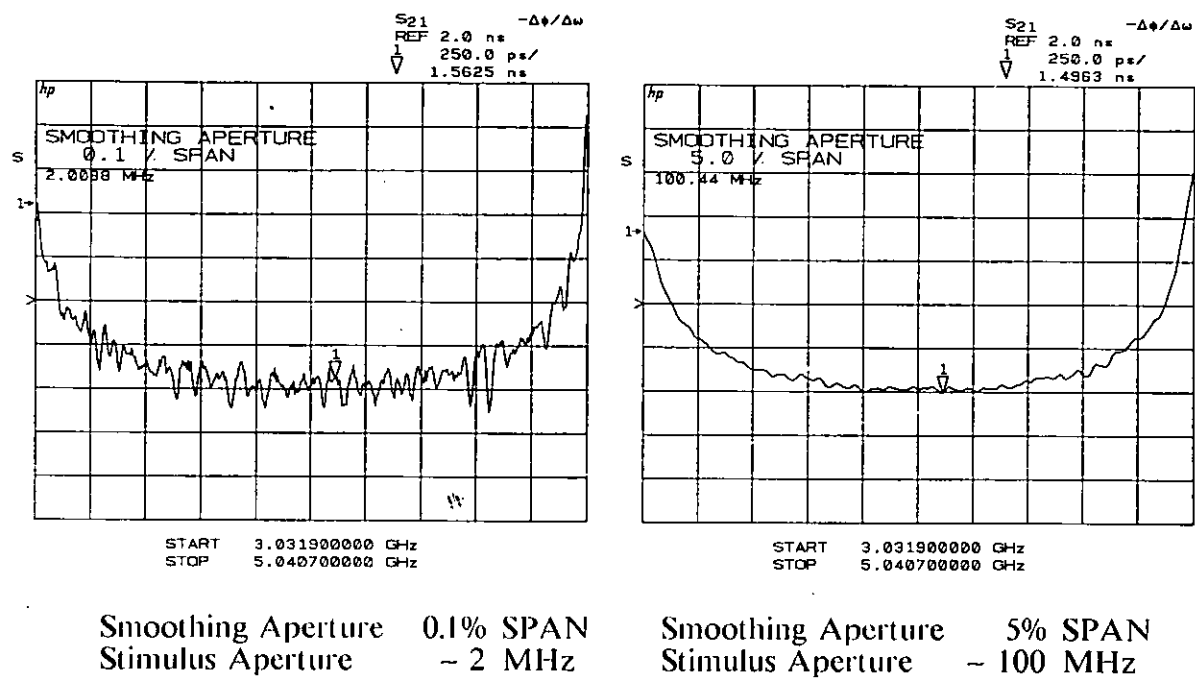


Figure 37. Results of Smoothing

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**.

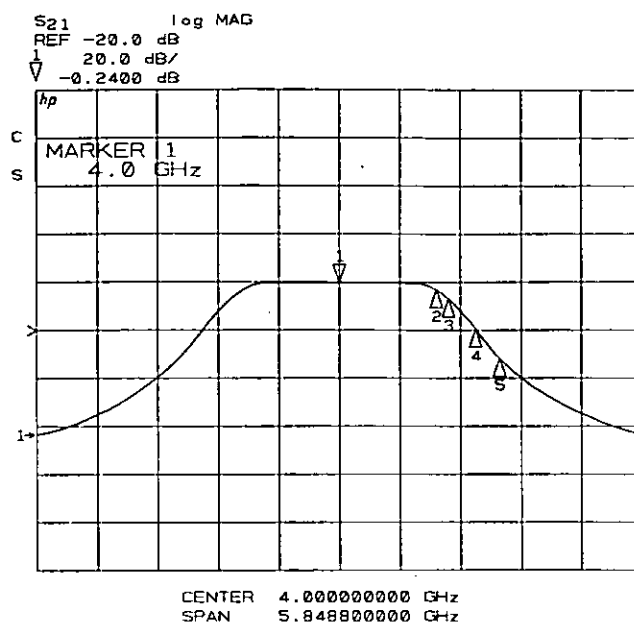


Figure 38. Markers on Trace

Table 10. Marker Units

FORMAT	MARKER Basic Units
LOG MAG	dB
PHASE	degrees ($^{\circ}$)
DELAY	seconds (s)
SMITH CHART	$R \pm jX$ (Ω)
SWR	(unitless)
LINEAR MAGNITUDE	ρ (unitless) (reflection)
	τ (unitless) (transmission)
LIN mkr on POLAR	$\rho \angle \phi^{\circ}$ (reflection)
	$\tau \angle \theta^{\circ}$ (transmission)
LOG mkr on POLAR	dB $\angle \phi^{\circ}$
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.

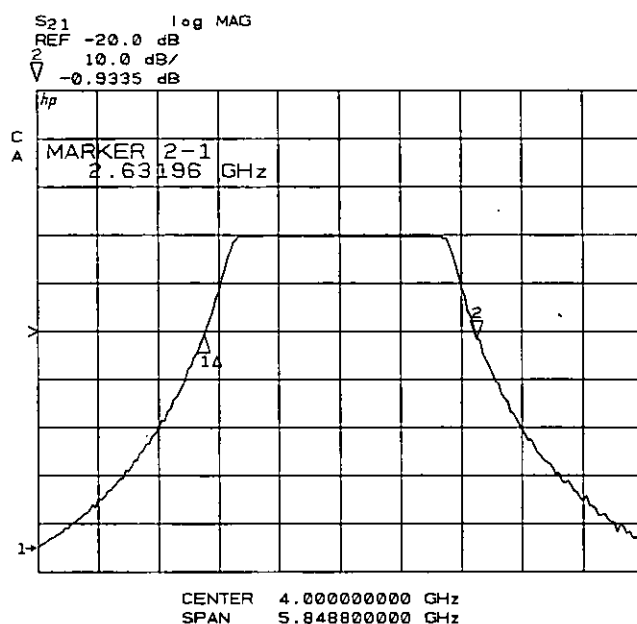


Figure 39. Δ Mode Markers on Trace

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**.

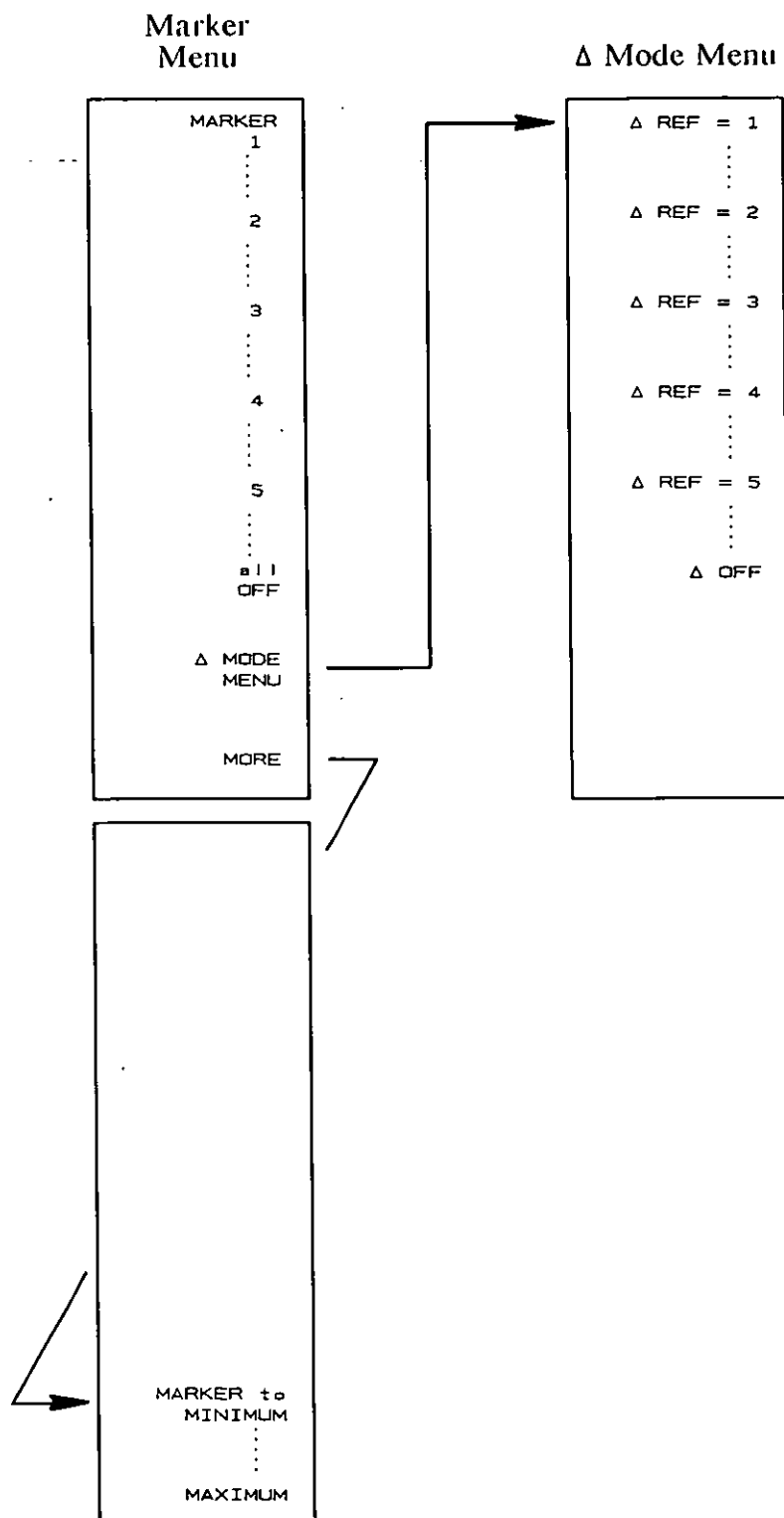


Figure 40. Marker and Δ Mode Menus

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.

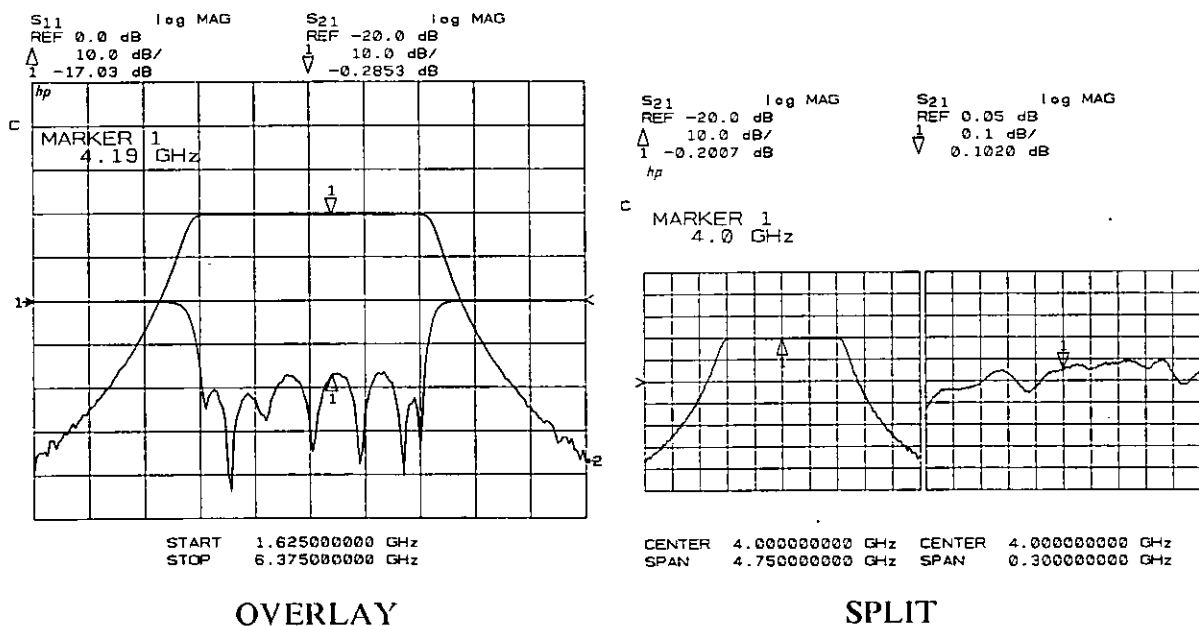


Figure 41. Dual Channel Measurement Displays

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.

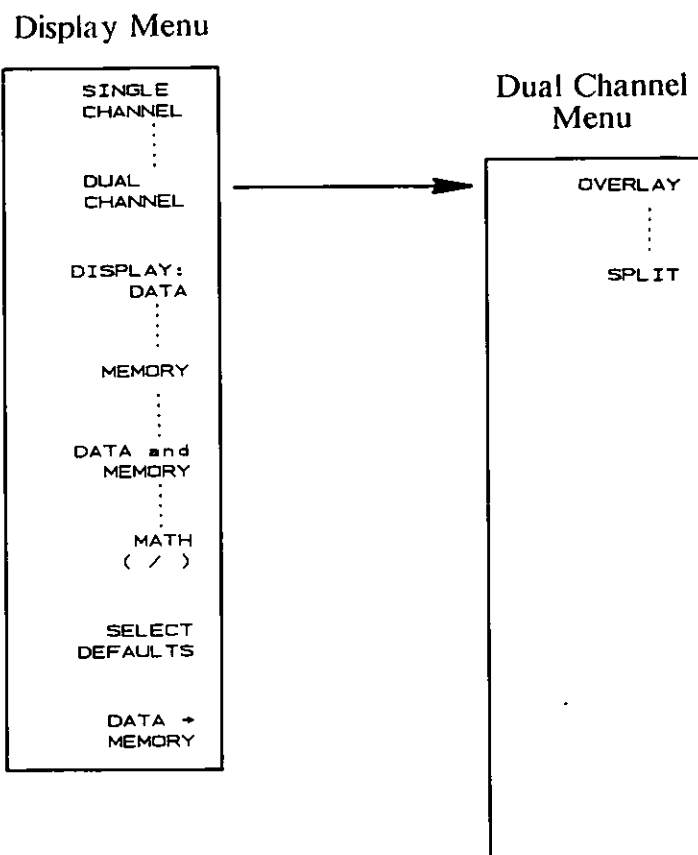


Figure 42. Display and Dual Channel Menus

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 $1 \angle 0^\circ$.

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.

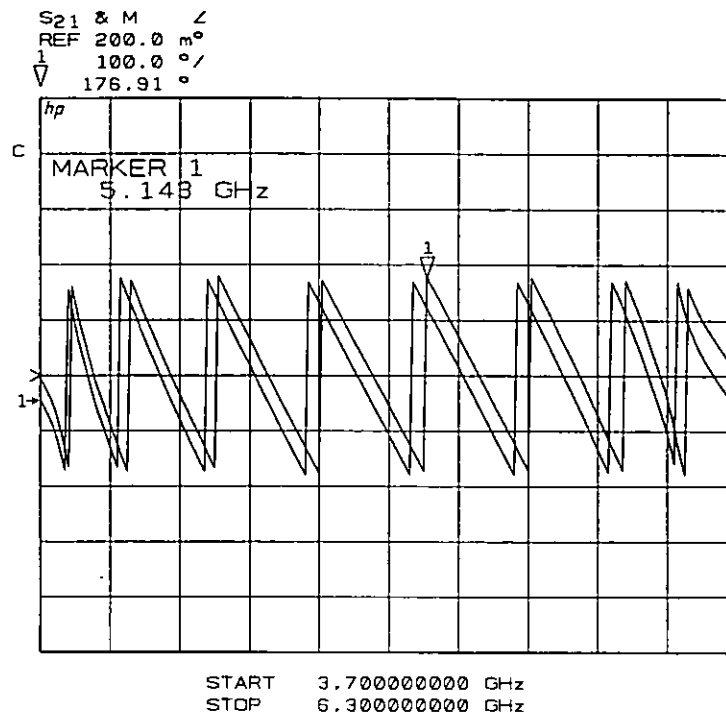


Figure 43. Current Trace Compared with Stored Memory

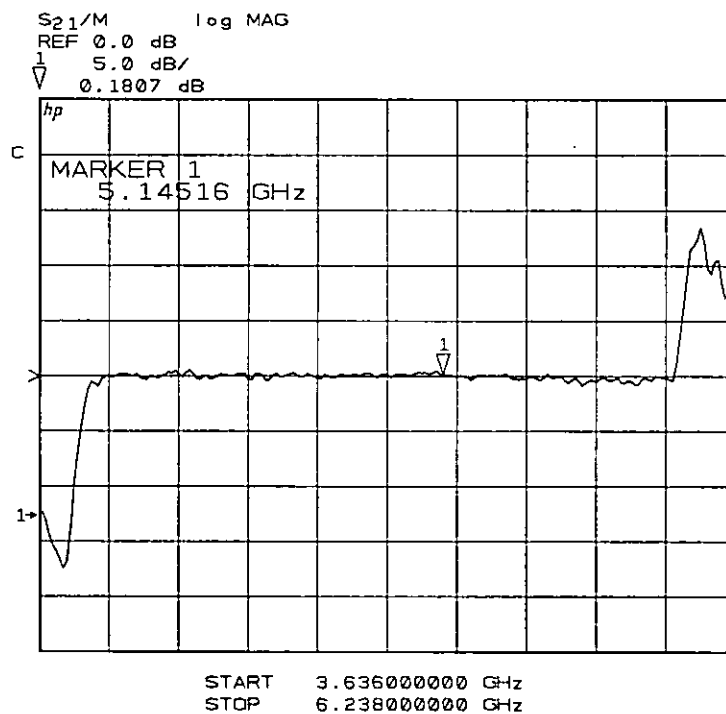


Figure 44. Math Operations: Division (/)

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.

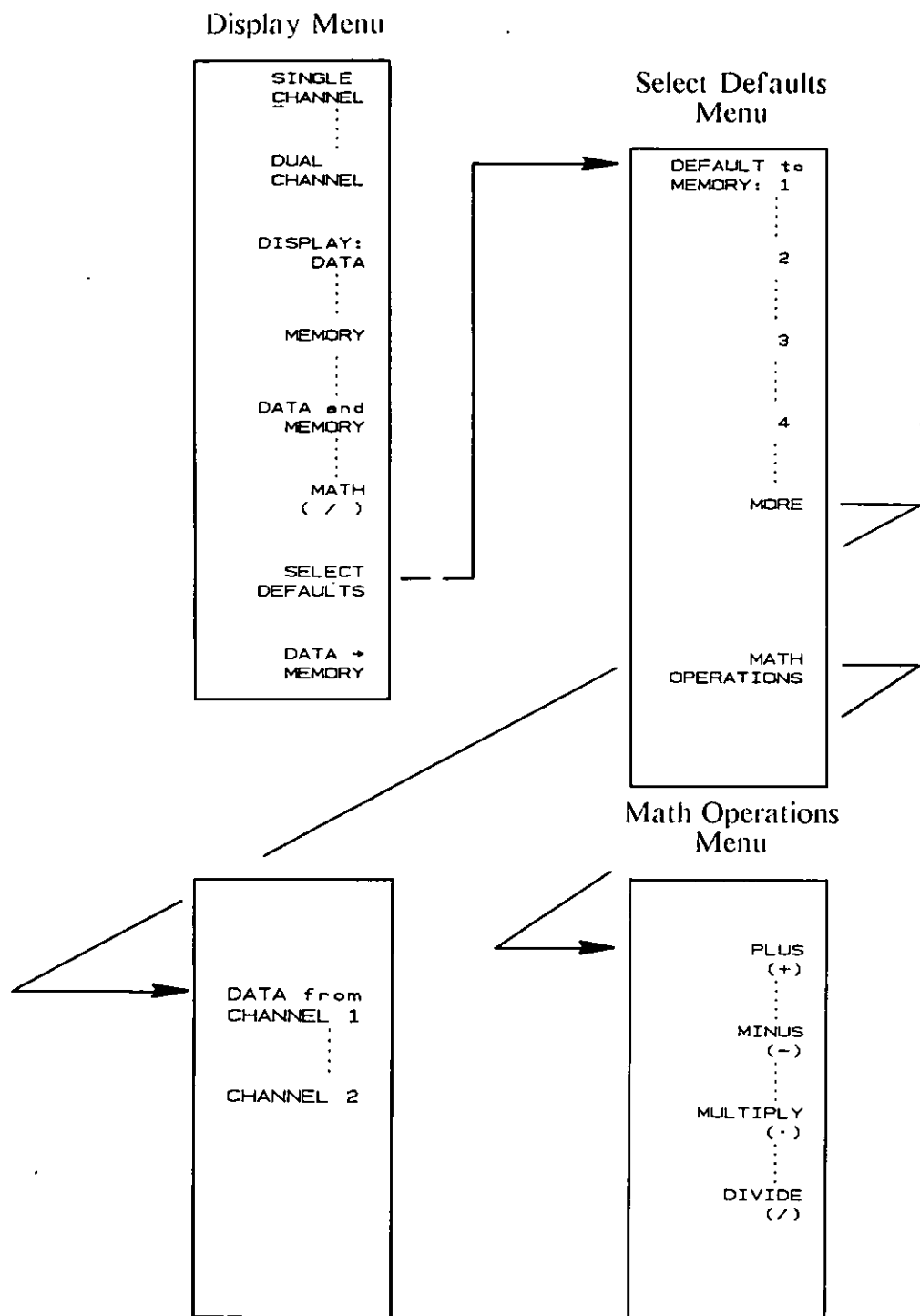


Figure 45. Select Defaults and Math Operations Menus

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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

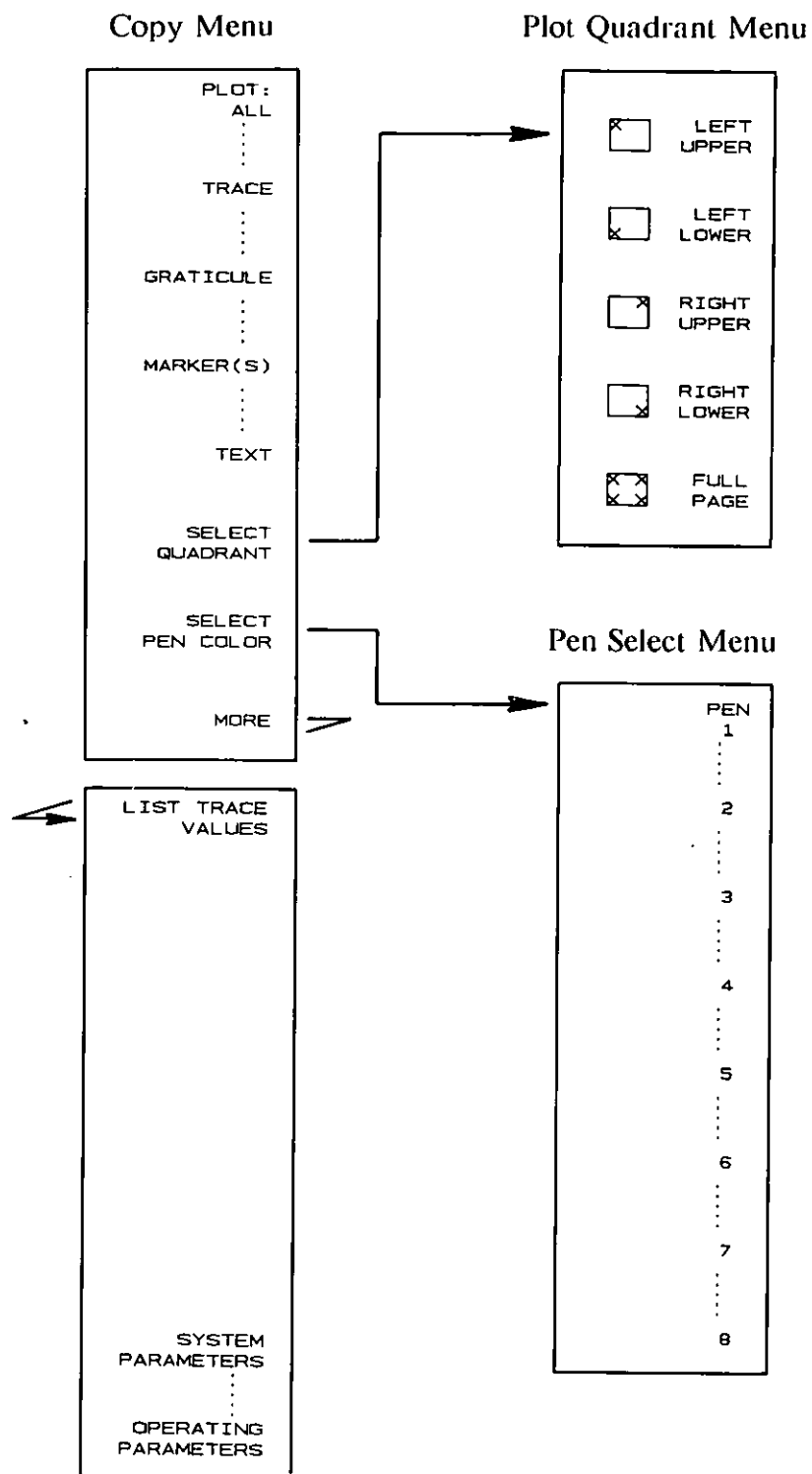
To output all or part(s) of the current CRT measurement display (trace, graticule, marker or markers, and text) to a plotter, first press the **COPY** key in the **AUXILIARY MENUS** block. This brings the Copy Menu (Figure 46) onto the CRT display.

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*

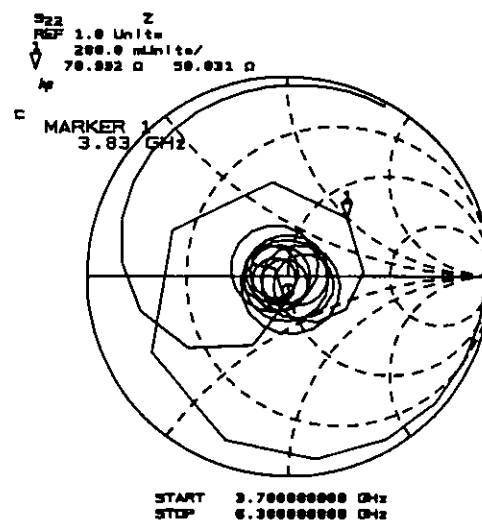
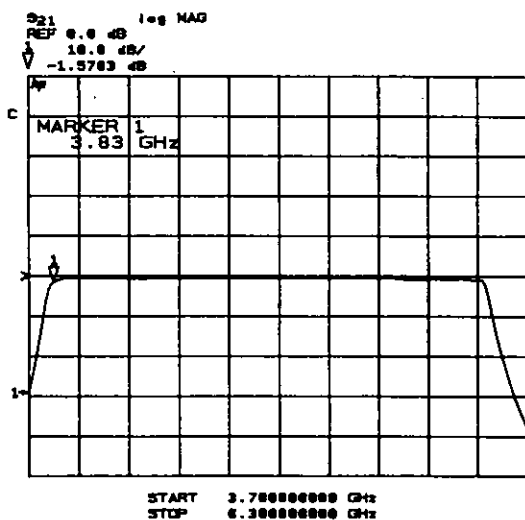
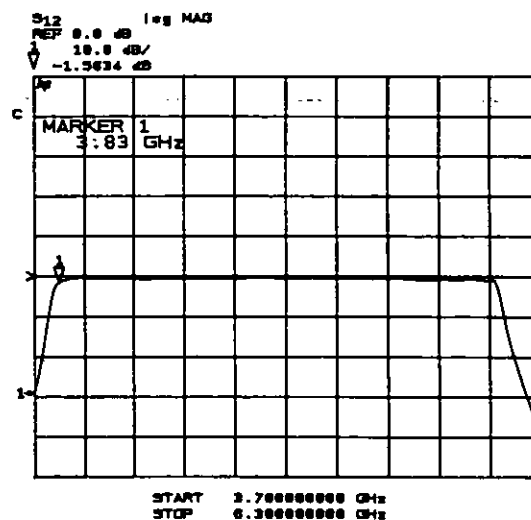
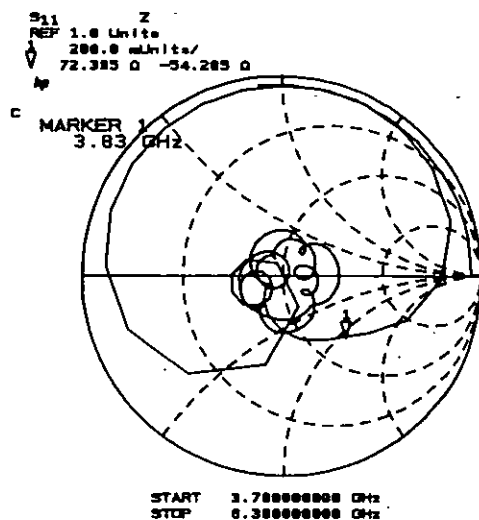


Figure 47. Four Quadrant Plot

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 **S₁₁**, **SELECT QUADRANT**, **LEFT UPPER**, **PLOT ALL**.
- Press **S₂₁**, **SELECT QUADRANT**, **LEFT LOWER**, **PLOT ALL**.
- Press **S₁₂**, **SELECT QUADRANT**, **RIGHT UPPER**, **PLOT ALL**.
- Press **S₂₂**, **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.

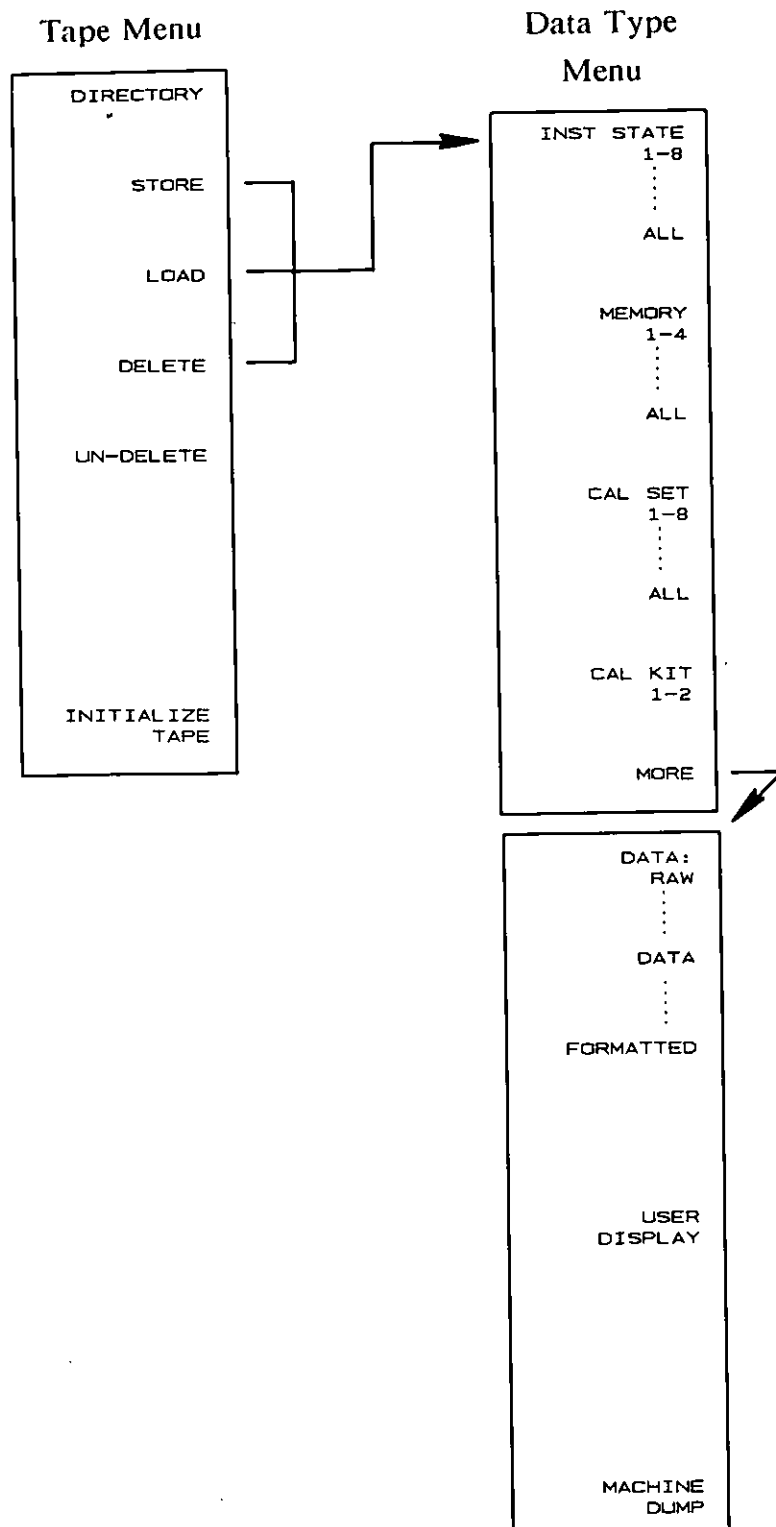


Figure 49. Tape and Data Type Menus

TAPE MENU

Figure 49 shows the Tape Menu and the associated Data Type Menu. Pressing the softkey **DIRECTORY** displays a list of currently recorded files. Each cartridge holds up to 85 blocks.

STORE, **LOAD**, **DELETE**, and **UN-DELETE** describe operations performed on specified files:

- **STORE** moves the selected data type to the cartridge;
- **LOAD** transfers the data file into network analyzer memory;
- **DELETE** eliminates the specified file from the directory;
- **UN-DELETE** restores the most recently deleted file to the directory listing unless the space has been reallocated to a file recorded after it was deleted or the tape has been removed from the tape drive.

To record a file, press **STORE** to present the Data Type Menu (Figure 49). This menu lists all possible data types which can be recorded. Up to eight files of each data type may be stored, tape space permitting. Details on each of the choices on the Data Type Menu appear on the next page.

Remove the tape cartridge by pressing the eject bar and then pulling the cartridge straight out. *Do not remove the tape cartridge when the tape drive light is on. Serious damage to the tape drive mechanism and to the tape can result.*

PREVIOUS INSTRUMENT STATES

To bring the Data Type Menu (Figure 49) onto the CRT display, first press the **TAPE** key in the **AUXILIARY MENUS** block. This brings the Tape Menu onto the CRT display. Next press the softkey corresponding to the operation you wish to perform: **STORE**, **LOAD**, or **DELETE**. This brings the Data Type Menu onto the CRT. Pressing **UNDELETE** before any other tape operations occur restores the last file deleted.

Press **INSTRUMENT STATE 1-8** to store a single instrument state previously saved in HP 8510 internal memory using the sequence: **STORE**, **INSTRUMENT STATE 1-8**, then 1, 2, 3, 4, 5, 6, 7, or 8.

Press **INSTRUMENT STATES ALL** to save all instrument states 1 through 8 on a single tape file.

In the same way you can select a single memory trace previously stored in HP 8510 internal memory using the **DISPLAY, DATA → MEMORY** sequence, or you can record all four memory traces.

Press **CAL SET 1-8** to select a single calibration error coefficient set for recording, or **CAL SETS ALL** to select recording of all cal sets. Press **CAL KIT 1-2** presents a menu to allow selection of either Cal Kit 1 or Cal Kit 2.

The softkeys **DATA: RAW**, **DATA**, and **FORMATTED** refer to measurement data for the currently selected channel at various stages in the digital signal processing steps. **RAW** refers to ratioed and averaged data, **DATA** refers to the data in the corrected data array, and **FORMATTED** refers to data in the formatted array. See Figure 4, Post-Detection Digital Signal Processing.

USER DISPLAY allows recording of any graphics or text written into the user CRT memory via the HP-IB by an external controller. Details for this operation are contained in the HP 8510 Introduction to Programming manual.

MACHINE DUMP records a large file consisting of the complete instrument state, including contents of the various memories for both channels.

After selection of the data type, the File Menu appears. Select any file 1 through 8 and the recording process begins.

EXAMPLE: SAVING DATA

As an example of use of the tape, the following sequence saves important data which could be overwritten by another user. This procedure assumes that calibration has been performed using Cal Kit 1, that the measurement calibration is saved in Cal Set 1, and that the instrument state has been saved in Instrument State memory 1.

- Insert tape.
- Press **TAPE, INITIALIZE TAPE, INITIALIZE TAPE? YES.**
- Press **STORE, INSTRUMENT STATE 1-8, INSTRUMENT STATE 1, FILE 1.**
- Press **CHANNEL 1, STORE, MORE, FORMATTED, FILE 1,**
- Press **CHANNEL 2, STORE, MORE, FORMATTED, FILE 2.**
- Press **STORE, MEMORY 1-4, MEMORY 1, FILE 1.**
- Press **STORE, MEMORY 1-4, MEMORY 2, FILE 2.**
- Press **STORE, CAL SET 1-8, CAL SET 1, FILE 1.**
- Press **STORE, CAL SET 1-8, CAL SET 2, FILE 2.**
- Press **STORE, CAL KIT 1-2, CAL KIT 1, FILE 1.**
- Press **DIRECTORY** and verify that the selected files have been recorded.

Do not press any keys during the tape operation unless it is your intent to stop the process.

LOADING FROM TAPE

To retrieve the data files, press the **LOAD** key, then specify the data type and file number. You can load files in any sequence. Before loading **RAW, DATA,** or **FORMATTED** traces, select **STIMULUS MENU, MORE,** then **HOLD** or else the current measurement data will overlay the trace just loaded. Even in the **HOLD** mode, loading Raw, Data, or Formatted traces from tape initiates a cycle in which the displayed trace is updated to reflect the data just loaded from tape.

TAPE CARTRIDGE CATALOG FORM

Although the tape directory lists the data type, file number, and block size, it does not list any other attributes of the file such as frequency range or conditions under which the data was taken. For this reason you may wish to photocopy the tape cartridge catalog form (Figure 50), fill it out with descriptive information about the file, and keep it with the tape cartridge.

[illegible]

Figure 50. Tape Cartridge Catalog Form

MAKING A BACKUP PROGRAM TAPE

It is strongly recommended that you make a duplicate, backup tape of the HP 8510 operating system software installed in your system. Then put the original away for safekeeping in case the duplicate, working copy is ever lost or damaged.

Use a new, blank tape for the backup, or use a tape that has on it files you no longer want. When the backup is made, all existing files are removed from the tape. The original is not needed in order to make the duplicate: the duplicate is copied from information already stored in the HP 8510 system itself.

First disable the write-protect feature on the tape cartridge that is to be used for the backup, 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 at the bottom of the CRT: **ENTER SELECTION THEN PRESS =MARKER**. Using the entry keys on the front panel of the HP 8510, first enter **21**, then press **=MARKER**. Selection **21** is the **INITIALIZE TAPE** command, and when it is followed by **=MARKER** it prepares the tape to receive the data.

Initialization takes about 1.5 minutes, and you will find that during loading the tape drive starts and stops often. This is normal. Initialization is complete when the number **21** disappears from the CRT display and the tape drive goes out.

When the tape has been initialized, enter **20**, then press **=MARKER**. Selection **20** is the **RECORD PROGRAM TAPE** command, and recording takes about 3 minutes.

Recording is complete when the number **20** disappears from the CRT display and the tape drive light goes out. The system then automatically begins running the main program, and after about 1 minute the graticule will appear.

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

The tape can be removed at any time after the graticule (grid) appears, and it now contains a copy of the operating system software. Move the RECORD tab back to its original position to write-protect the copy. Use this copy and put the original tape away for safekeeping.

Note that as it is installed for the first time the program keys itself uniquely to one HP 8510 system and cannot be used in any other system. You may want to mark the backup tape with the serial number that appears on the original tape to prevent confusion.

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INTRODUCTION

Measurement calibration transfers the accuracy of your standards to the measurement of your device. Since the response of the standards is known to a high degree of accuracy, the system can measure one or more standards, then use the results of these measurements to provide data to the error-correction algorithms which process the measured data for display.

This part of the HP 8510 network analyzer system manual explains the theoretical fundamentals of accuracy enhancement, the sources of measurement errors, and the error-correction models used in the HP 8510 system. Then it describes in detail typical measurement calibration sequences using the HP 8510 system. These sequences are then discussed and summarized according to type. Finally, storing calibrations, calibration standards, evaluating calibration data, and adjusting trim sweep are discussed.

ACCURACY ENHANCEMENT FUNDAMENTALS

Vector accuracy enhancement techniques provide the means of reducing network measurement ambiguities. For example, crosstalk due to the channel isolation characteristics of the network analyzer can contribute an error equal to the transmission characteristic of a high loss test device.

Similarly, for reflection measurements the primary limitation of dynamic range is directivity of the test setup. When the magnitude of the test signal equals the leakage signal, the measurement system cannot distinguish the true value of the signal reflected or transmitted by the device from the signal arriving at the receiver input due to leakage in the system. For all measurements, any impedance mismatches within the test setup can cause severe errors.

A perfect measurement system would have infinite dynamic range, isolation, and directivity characteristics, no impedance mismatches in any part of the test setup, and flat frequency response. In practice, this "perfect" network analyzer is achieved by measuring the magnitude and phase response of known standard devices, using this data in conjunction with a model of the measurement system to determine error contributions, then measuring a test device and using vector mathematics to compute the actual test device response by removing the error terms.

The dynamic range and accuracy of the measurement is then limited by system noise and the accuracy to which the characteristics of the calibration standards are known. This is the basic concept of vector accuracy enhancement. The following paragraphs describe the error model, the calibration standards, and the vector mathematics.

SOURCES OF MEASUREMENT ERRORS

Network analysis measurement errors can be separated into two categories:

- (1) Random Errors are non-repeatable measurement variations that occur due to noise, environmental changes and other physical changes in the test setup between calibration and measurement. These are any errors that the system itself cannot measure or cannot model with an acceptable degree of certainty.
- (2) Systematic Errors are repeatable errors. They include mismatch and leakage terms in the test setup, isolation characteristics between the reference and test signal paths, and system frequency response.

Thus, any measurement result is the vector sum of the actual test device response plus all error terms. The precise effect of each error term depends upon its magnitude and phase relationship to the actual test device response. Random errors cannot be precisely quantified, so they must be treated as producing a cumulative ambiguity in the measured data.

Fortunately, in most microwave measurements systematic errors are the ones which produce the most significant measurement uncertainty. Since each of these errors produces a predictable effect upon the measured data, their effects can be removed to obtain a corrected value for test device response. For the purpose of vector accuracy enhancement, these uncertainties are quantified as directivity, source match, load match, isolation, and tracking (frequency response). When accuracy enhancement techniques are used, the resultant values after correction are termed Effective Directivity, Effective Source and Load Match, Effective Isolation, and Effective Tracking.

Directivity. The vector sum of all leakage signals appearing at the network analyzer test input due to the inability of the signal separation device to absolutely separate incident and reflected waves, as well as residual reflection effects of test cables and adapters between the signal separation device and the measurement plane. The uncertainty contributed by directivity is independent of the characteristics of the test device and it usually produces the major ambiguity in reflection measurements.

The standard test sets typically provide uncorrected directivity of greater than 26 dB. However, the vector accuracy enhancement technique described here will typically produce much greater Effective Directivity.

Source Match. The vector sum of signals appearing at the network analyzer test input due to the inability of the source to maintain absolute constant power at the test device input as well as cable and adapter mismatches and losses outside the source leveling loop. The uncertainty contributed by source match is dependent upon the relationship between the actual input impedance of the test device and the equivalent match of the source, and it is a factor in both transmission and reflection measurements.

Source match error is particularly a problem when measuring very high or very low impedances (large mismatch at the measurement plane). The Effective Source Match can be improved considerably by using vector error correction techniques.

Load Match. The vector sum of signals appearing at the network analyzer test input due to effects of impedance mismatches between the test device output port and the network analyzer test input. The uncertainty contributed by Load Match is dependent upon the relationship between the actual output impedance of the test device and the effective match of the return port, and is a factor in all transmission measurements and in reflection measurements of two-port devices.

Load match effects are analyzed similarly to source match effects and will produce major transmission measurement errors for a test device whose output port is highly reflective. Effective Load match can typically be improved by a factor of 15 to 20 dB using vector accuracy enhancement techniques.

Isolation. The vector sum of signals appearing at the network analyzer detectors due to crosstalk between the reference and test signal paths, including signal leakage within both the RF and IF sections of the receiver. The uncertainty contributed by isolation is a factor in high loss transmission measurements.

The system typically maintains greater than 80 dB of isolation between the reference and test signal paths. Characterization and removal of repeatable crosstalk and leakage, along with extensive averaging, improves the Effective Isolation to extend the measurement system dynamic range by up to 20 dB.

Tracking. The vector sum of all test setup variations in magnitude and phase frequency response, including signal separation device, test cables and adapters, and variations in frequency response between the reference and test signal paths. This error is a factor in both transmission and reflection measurements.

The magnitude and phase frequency response variations and the resultant measurement errors are reduced using vector accuracy enhancement, making the Effective Tracking typically under 0.02 dB and 0.1 degree.

CORRECTING MEASUREMENT ERRORS

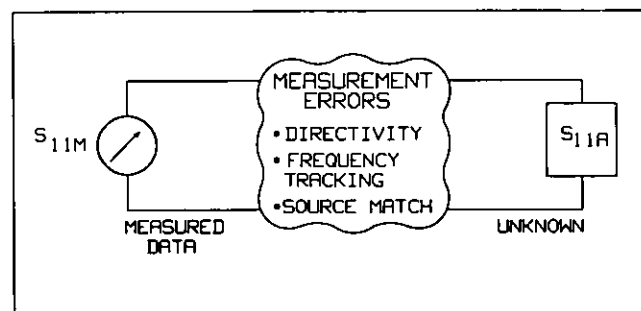
The HP 8510 network analyzer system offers a choice between Frequency-Response-Only, 1-Port, and 2-Port error models. The frequency-response-only error model provides signal path frequency response error correction for the selected parameter. This model may be adequate for measurement of well matched low loss devices where vector normalization of magnitude and phase frequency response errors provides sufficient measurement accuracy.

The 1-Port error model provides directivity, source match, and reflection signal path frequency response vector error correction for reflection measurements. This model is best applied to high accuracy reflection measurements of one-port devices.

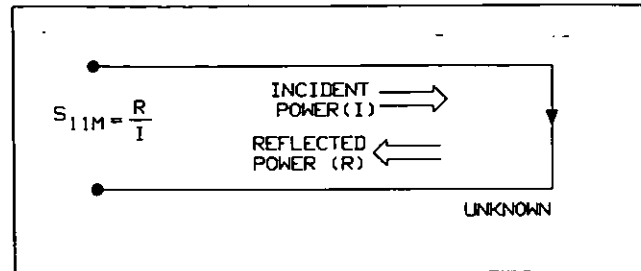
The 2-Port error model provides full directivity, isolation, source match, load match, and frequency response vector error correction for transmission and reflection measurements of two-port devices. This model provides best magnitude and phase measurement accuracy for two-port devices but requires measurement of all four S-parameters of the two-port device.

The following discussion describes these error models in greater detail and, more importantly, explains how they can be characterized and used to reduce measurement uncertainty. In actual system operation, error correction is not always done exactly as this discussion suggests, but the results are in all cases mathematically equivalent.

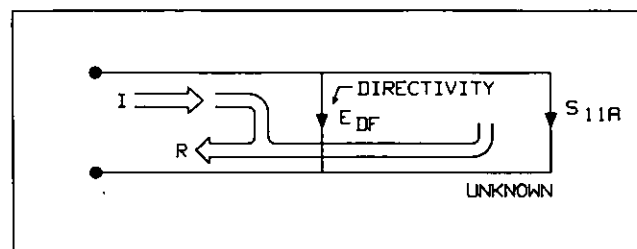
Let's consider measurement of reflection coefficients (magnitude and phase) of some unknown one-port device. No matter how careful we are, the measured data will differ from the actual. Directivity, Source Match, and Tracking are the major sources of error.



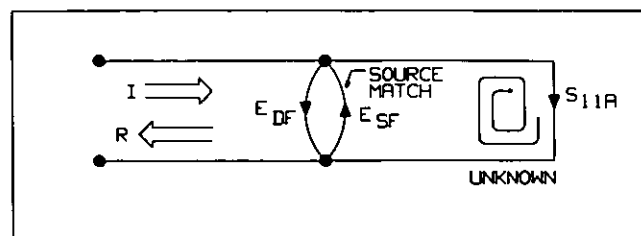
Reflection coefficient is measured by first separating the incident voltage wave (I) from the reflected voltage wave (R) then taking the ratio of the two values. Ideally, (R) consists only of the wave actually reflected by the test device (S_{11A}).



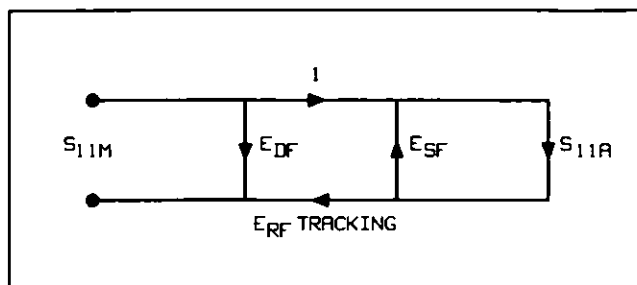
Unfortunately, all of the incident wave doesn't always reach the unknown. Some of (I) may appear at the measurement system input due to leakage through the signal separation device (coupler/bridge). Also, some of (I) may be reflected by imperfect adapters between signal separation and the measurement plane. The vector sum of the leakage and miscellaneous reflections is directivity, E_{DF} . Understandably, our measurement is distorted when the directivity signal combines vectorally with the actual reflected signal from the unknown, S_{11A} .



Since the measurement system test port is never exactly the characteristic impedance (normally 50 ohms), some of the reflected signal bounces off the test port (or other impedance changes further down the line) and back to the unknown, adding to the original incident signal (I). This effect causes the magnitude and phase of the incident signal to vary as a function of S_{11A} . Leveling the source to produce constant (I) reduces this error, but since the source cannot be leveled exactly at the test device input, leveling cannot eliminate all power variations. This re-reflection effect and the resultant incident power variation is caused by the source match error, E_{SF} .



Tracking (frequency response) error is caused by variations in magnitude and phase flatness versus frequency between the test and reference signal paths. These are due mainly to imperfectly matched samplers and differences between reference and test signal paths. The vector sum of these variations is the reflection signal path tracking error, E_{RF} .

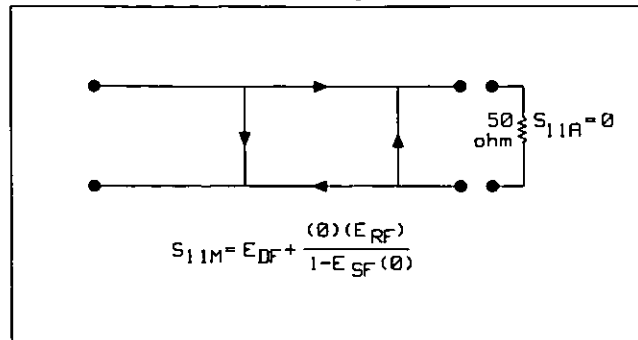


It can be shown that these three errors are mathematically related to the actual, S_{11A} , and measured, S_{11M} , data by the following equation.

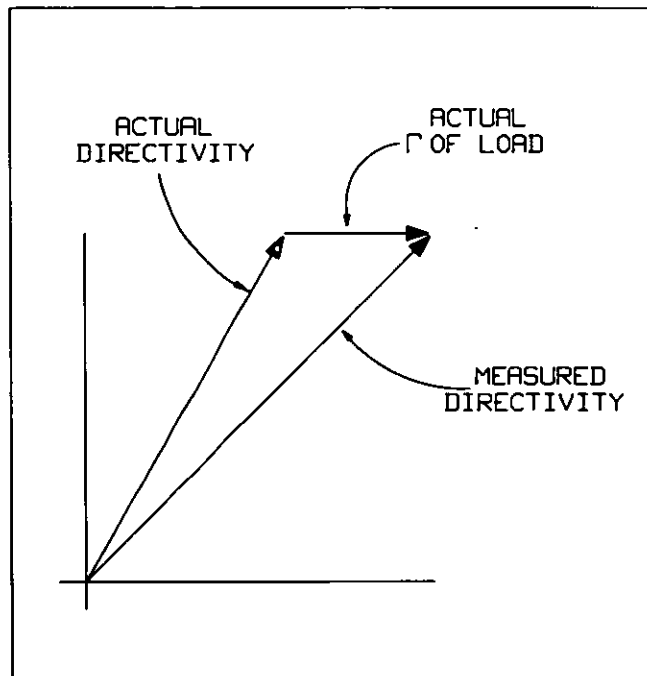
$$S_{11M} = E_{DF} + \frac{S_{11A}(E_{RF})}{1 - E_{SF}S_{11A}}$$

If we knew the value of these three "E" errors and the measured test device response at each frequency, we could simply solve the above equation for S_{11A} to obtain the actual device response. Because each of these errors changes with frequency, it is necessary that their values be known at each test frequency. They are found by measuring (calibrating) the system at the measurement plane using three independent standards whose S_{11A} is known at all frequencies.

The first standard we apply is a "perfect" load which makes $S_{11A} = 0$ and essentially measures directivity. By "perfect" load we mean a reflectionless termination at the measurement plane. All incident energy is absorbed. With $S_{11A} = 0$ the equation can be solved for E_{DF} , the directivity error term. Of course, in practice the "perfect load" cannot be achieved.

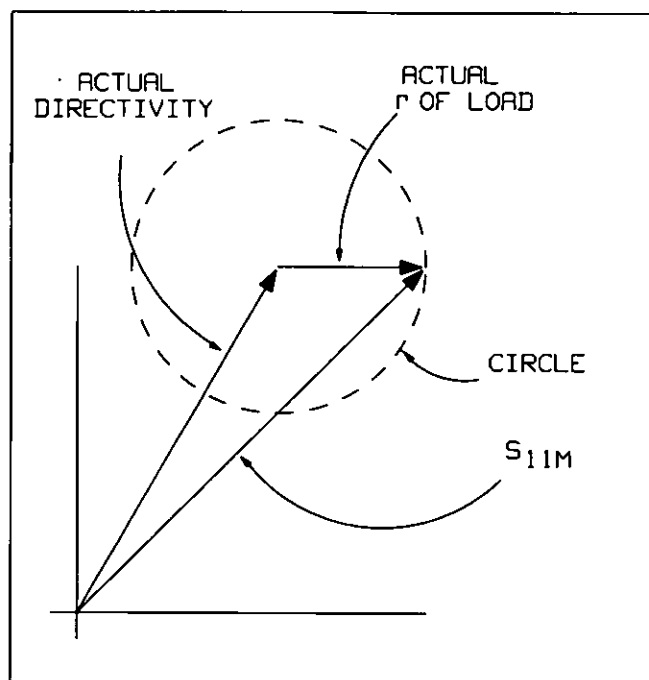


Since the measured value for directivity is the vector sum of the actual directivity plus the actual reflection coefficient of the "perfect" load, any reflection from the termination represents an error. System Effective Directivity becomes the actual reflection coefficient of the "perfect" load. In general, any termination having a return loss greater than the uncorrected system directivity reduces reflection measurement uncertainty.



Due to the difficulty of producing a high quality fixed coaxial termination at microwave frequencies, a sliding load can be used at each test frequency to separate the reflection of a somewhat imperfect termination from the actual directivity.

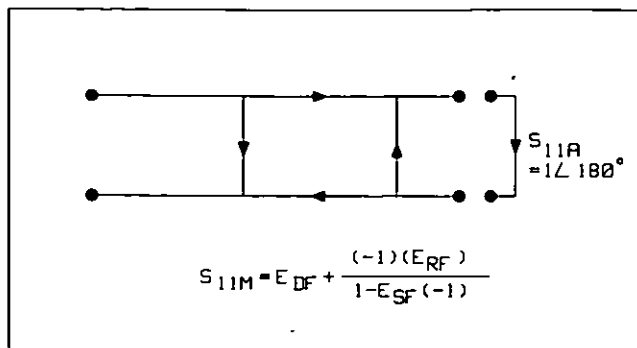
At any single frequency, moving the sliding termination with respect to the measurement plane produces a complete circle when the sliding element is displaced one-half wavelength of the test frequency. Its reflection coefficient magnitude remains constant but the phase of the coefficient changes. The radius of that circle is the actual reflection coefficient of the sliding termination, and the center of the circle is determined by the actual directivity of the test setup and the geometry of the air line within the sliding load.



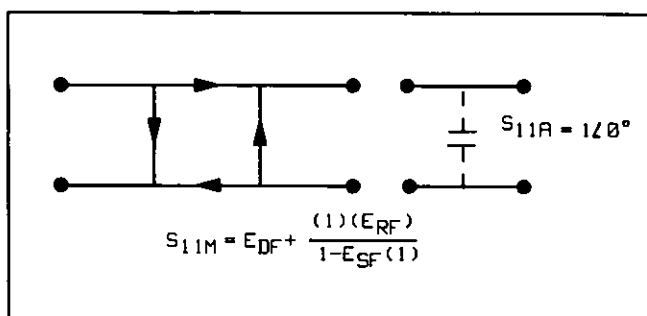
Thus, the critical specifications for the sliding load assembly are the mechanical dimensions (impedance) of the connector, of the transmission line between the measurement plane and the termination, and that the termination maintains a constant reflection coefficient magnitude at all positions.

The sliding load calibration sequence used here measures the sliding load at eight or more positions. The firmware can compute the center of the circle with five positions, but more slides (6 to 8 are recommended) increase precision.

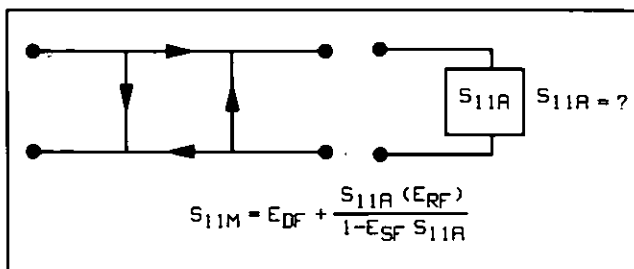
Next, a short circuit termination is used to establish another condition.



The open circuit gives us the third independent condition. Now the values for E_{DF} , directivity, E_{SF} , source match, and E_{RF} , reflection tracking, are computed and stored.



Now we measure the unknown to obtain a value for the measured response, S_{11M} , at each frequency.

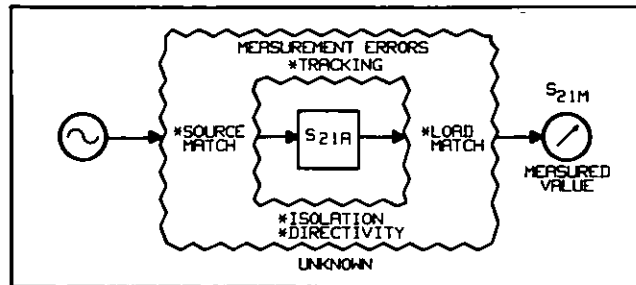


This is the 1-Port error model equation solved for S_{11A} . Since we have the three errors and S_{11M} for each test frequency we can compute S_{11A} .

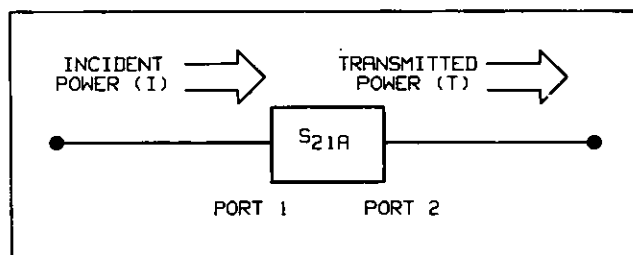
$$S_{11A} = \frac{S_{11M} - E_{DF}}{E_{SF} (S_{11M} - E_{DF}) + E_{RF}}$$

For reflection measurements on two-port devices, the same technique can be applied, but the test device output port must be terminated in the system characteristic impedance. This termination should be at least as good (low reflection coefficient) as the load used to determine directivity. The additional reflection error caused by an improper termination at the test device output port is not incorporated into the 1-Port error model.

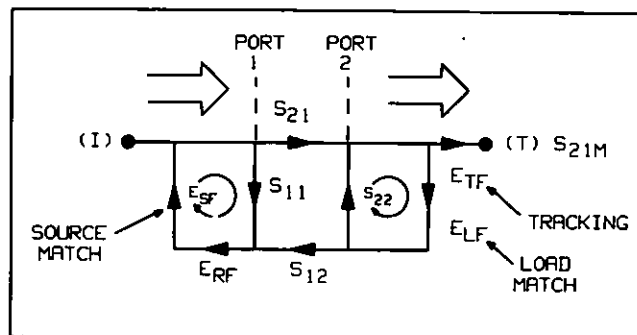
Now consider measurement of transmission coefficients (magnitude and phase) of an unknown two-port device. The major sources of error are Tracking, Source Match, Load Match, and Isolation. These errors are reduced or eliminated using the 2-Port error model.



Transmission coefficient is measured by taking the ratio of the incident voltage wave (I) and the transmitted wave (T). Ideally, (I) consists only of power delivered by the source and (T) consists only of power emerging at the test device output.



As in the reflection model, source match can cause the incident signal to vary as a function of test device S_{11A} . Also, since the test setup transmission return port is never exactly the characteristic impedance, some of the transmitted signal is reflected from the test set port 2, and other mismatches between the test device output and the detector, to return to the test device. A portion of this wave may be re-reflected at port 2, thus affecting S_{21M} , or part may be transmitted through the device in the reverse direction to appear at port 1, thus affecting S_{11M} . This error term, which causes the magnitude and phase of the transmitted signal to vary as a function of S_{22A} , is called load match, E_{LF} .

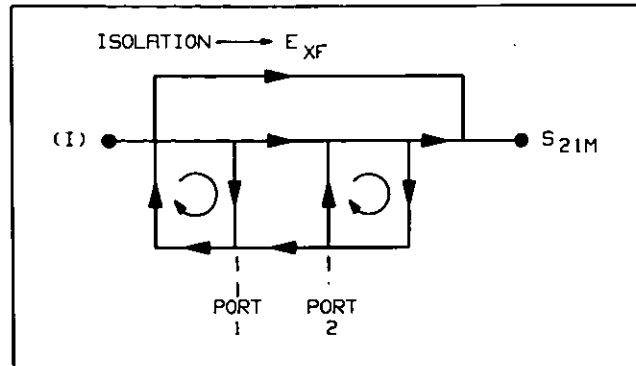


The measured value S_{21M} , consists of wave components which vary as a function of the relationship between E_{SF} and S_{11A} as well as E_{LF} and S_{22A} , so the input and output reflection coefficients of the test device must be measured and stored for use in the S_{21A} error correction computation. Thus, the test setup is calibrated as described above for reflection to establish directivity, E_{DF} , source match, E_{SF} , and reflection tracking, E_{RF} , terms for the reflection measurements.

Since we now have a calibrated port for reflection measurements, we connect the thru and determine load match, E_{LF} by measuring the reflection coefficient of the thru connection.

Transmission tracking is then measured with the thru connection. The data is corrected for source and load match effects, then stored as transmission tracking, E_{TF} .

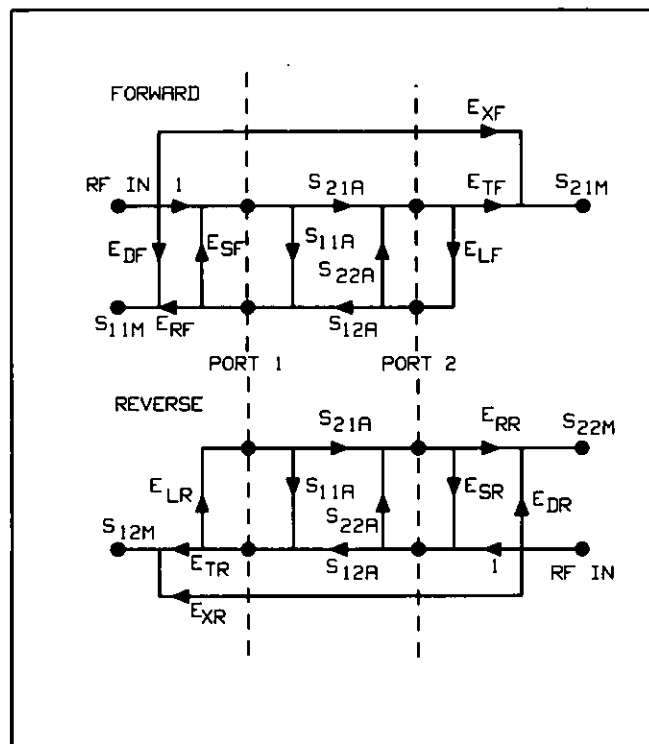
Isolation, E_{XF} , represents the part of the incident wave that appears at the receiver detectors without actually passing through the test device. Isolation is measured with the test set in the transmission configuration and terminations installed at the points at which the test device will be connected.



Some microwave test sets (HP 8514A and HP 8515A) can measure both the forward and reverse characteristics of the test device without the need to manually remove and physically reverse it. For these test sets, the Full 2-Port transmission and reflection error model shown above includes terms for:

Directivity, E_{DF} (forward) and E_{DR} (reverse),
 Isolation, E_{XF} and E_{XR} ,
 Source Match, E_{SF} and E_{SR} ,
 Load Match, E_{LF} and E_{LR} ,
 Transmission Tracking, E_{TF} and E_{TR} , and
 Reflection Tracking, E_{RF} and E_{RR} .

Thus, there are two sets of error terms, forward and reverse, with each set consisting of six error terms.



If the test set cannot switch between forward and reverse (HP 8512A and HP 8513A reflection/transmission test sets), then the reverse terms cannot be measured and the forward error terms are used in their place when the test device is manually reversed. The One-Path 2-Port error model makes this assumption.

These are the 2-Port error model equations for all S-parameters of a two-port device. Note the mathematics for this comprehensive model uses all forward and reverse error terms and measured values. Thus, to perform full error correction, for any one parameter of a two-port device, all four S-parameters must be measured.

$$S_{11A} = \frac{\left[\left(\frac{S_{11M} - E_{DF}}{E_{RF}} \right) \left[1 + \left(\frac{S_{22M} - E_{DR}}{E_{RR}} \right) E_{SR} \right] \right] - \left[\left(\frac{S_{21M} - E_{XF}}{E_{TF}} \right) \left(\frac{S_{12M} - E_{XR}}{E_{TR}} \right) E_{LF} \right]}{\left[1 + \left(\frac{S_{11M} - E_{DF}}{E_{RF}} \right) E_{SF} \right] \left[1 + \left(\frac{S_{22M} - E_{DR}}{E_{RR}} \right) E_{SR} \right] - \left[\left(\frac{S_{21M} - E_{XF}}{E_{TF}} \right) \left(\frac{S_{12M} - E_{XR}}{E_{TR}} \right) E_{LF} E_{LR} \right]}$$

$$S_{21A} = \frac{\left[1 + \left(\frac{S_{22M} - E_{DR}}{E_{RR}} \right) (E_{SR} - E_{LF}) \right] \left(\frac{S_{21M} - E_{XF}}{E_{TF}} \right)}{\left[1 + \left(\frac{S_{11M} - E_{DF}}{E_{RF}} \right) E_{SF} \right] \left[1 + \left(\frac{S_{22M} - E_{DR}}{E_{RR}} \right) E_{SR} \right] - \left[\left(\frac{S_{21M} - E_{XF}}{E_{TF}} \right) \left(\frac{S_{12M} - E_{XR}}{E_{TR}} \right) E_{LF} E_{LR} \right]}$$

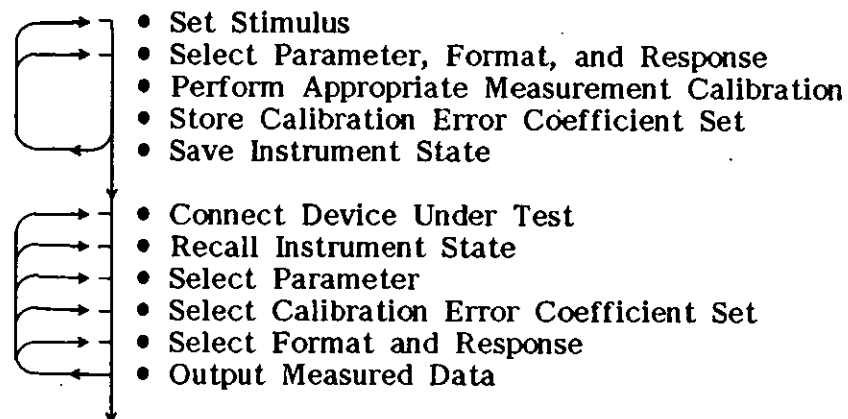
$$S_{12A} = \frac{\left[1 + \left(\frac{S_{11M} - E_{DF}}{E_{RF}} \right) (E_{SF} - E_{LR}) \right] \left(\frac{S_{12M} - E_{XR}}{E_{TR}} \right)}{\left[1 + \left(\frac{S_{11M} - E_{DF}}{E_{RF}} \right) E_{SF} \right] \left[1 + \left(\frac{S_{22M} - E_{DR}}{E_{RR}} \right) E_{SR} \right] - \left[\left(\frac{S_{21M} - E_{XF}}{E_{TF}} \right) \left(\frac{S_{12M} - E_{XR}}{E_{TR}} \right) E_{LF} E_{LR} \right]}$$

$$S_{22A} = \frac{\left[\left(\frac{S_{22M} - E_{DR}}{E_{RR}} \right) \left[1 + \left(\frac{S_{11M} - E_{DF}}{E_{RF}} \right) E_{SF} \right] \right] - \left[\left(\frac{S_{21M} - E_{XF}}{E_{TF}} \right) \left(\frac{S_{12M} - E_{XR}}{E_{TR}} \right) E_{LR} \right]}{\left[1 + \left(\frac{S_{11M} - E_{DF}}{E_{RF}} \right) E_{SF} \right] \left[1 + \left(\frac{S_{22M} - E_{DR}}{E_{RR}} \right) E_{SR} \right] - \left[\left(\frac{S_{21M} - E_{XF}}{E_{TF}} \right) \left(\frac{S_{12M} - E_{XR}}{E_{TR}} \right) E_{LF} E_{LR} \right]}$$

Applications of these error models, frequency response, 1-port, and 2-port depending on the capabilities of the test sets, are described in the rest of this part of the HP 8510 network analyzer system manual.

MEASUREMENT CALIBRATION

In a typical application, the system is set up for a particular measurement, appropriate measurement calibration is performed for each parameter to be measured, the calibration is saved in a cal set memory, the test device is connected, its response is measured, and then the data is corrected and output. When the device-under-test is to be measured over several different frequency ranges, the appropriate measurement calibration is repeated for each frequency range. After connecting the device, the calibration set for each measurement is recalled in sequence. The eight cal sets and the eight instrument states are used together to choose the appropriate instrument state for the measurement.



When you recall the instrument state, you select the complete stimulus, parameter, format, and response settings used during calibration. Select the parameter to be measured, turn correction On, then make the measurement. If you select an instrument state to which the current cal set does not apply, then correction is turned Off. Since recalling the calibration set recalls a limited instrument state consisting of important stimulus settings, if the appropriate parameter is already selected it is only necessary to recall the calibration set in order to achieve the correct instrument state for measurement.

Always calibrate using the same adapters and cables that will be used for the measurement. If the adapters or cables are changed between calibration and measurement, unpredictable errors will result due to the fact that the error coefficients determined during calibration do not apply to the altered setup. If you change the setup, you must perform the measurement calibration procedure again to find appropriate error terms for the new setup.

When the test setup must be changed between calibration and measurement (as in measuring non-insertable devices), you can minimize errors by switching between components which have equal loss and length. But since no two components exhibit exactly equal magnitude and phase response, the measurement uncertainty is greater.

CAL MENU

Pressing the CAL MENU key brings the Cal Menu (Figure 51) onto the CRT display. Choices on this menu offer you a wide range of calibration options.

CORRECTION ON and **OFF** provides selection of vector error-corrected or measured data for display.

Pressing **CORRECTION ON** brings the Cal Set Selection menu onto the CRT display and the message **SELECT CALIBRATION SET** onto the CRT display. An asterisk (*) next to the cal set number indicates that calibration error coefficients are already stored in that cal set. Selecting a cal set recalls a limited instrument state of important stimulus values. If the selected cal set applies to the presently selected parameter, the stimulus values are set to the defined values and the Cal menu is displayed with **CORRECTION ON**.

In the general sequence for performing a measurement calibration, first select the parameter, then press **CORRECTION OFF**.

Pressing **CAL 1 (<kit name>)** or **CAL 2 (<kit name>)** allows you to select the appropriate cal kit depending upon the category of calibration standards to be used. Pressing either of these softkeys brings the accuracy enhancement error model selection menu, known as the Cal Type menu (Figure 51), onto the CRT display.

Now select the calibration model, frequency **RESPONSE**, **S₁₁ 1-PORT**, **S₂₂ 1-PORT**, **ONE-PATH 2-PORT**, or **FULL 2-PORT**. Selections from this menu branch to procedures involving connection and measurement of calibration standards.

The **RESUME CAL SEQUENCE** key allows you to interrupt the calibration procedure currently in progress, for example to change the averaging factor, then return to the same point in the sequence.

If the **TIME DOMAIN LOW PASS** mode will be used for measurements, set the **STOP** frequency and number of points, then press **SET FREQ. (LOW PASS)** before proceeding with measurement calibration.

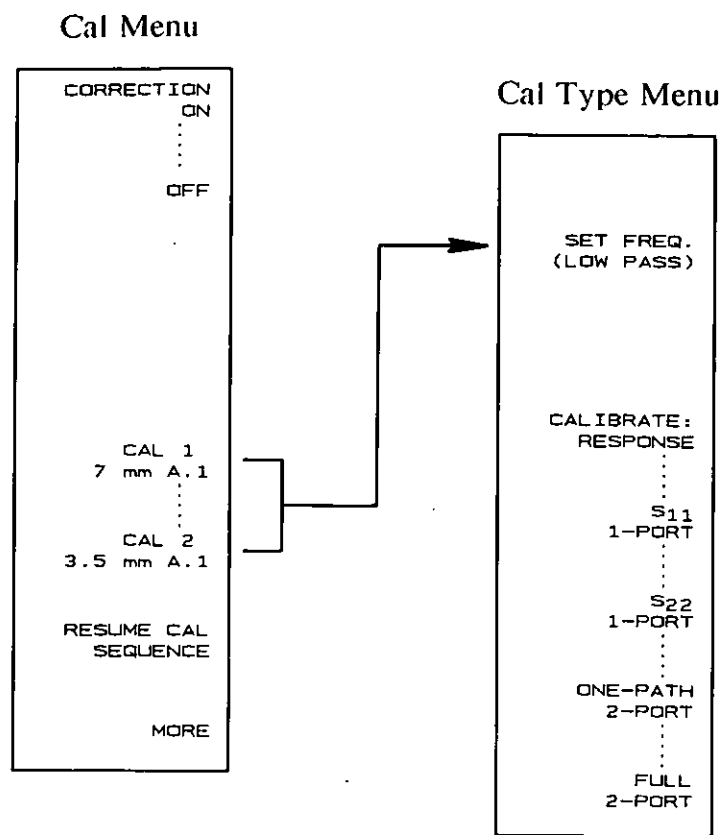
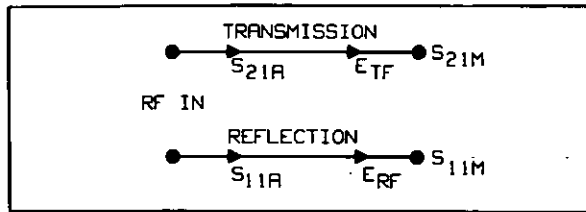


Figure 51. Cal and Cal Type Menus

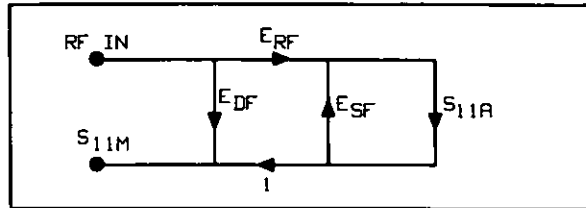
RESPONSE

Selected signal path
frequency response.



S_{11} 1-PORT

S_{11} Directivity,
Source Match,
Frequency Response.



S_{22} 1-PORT

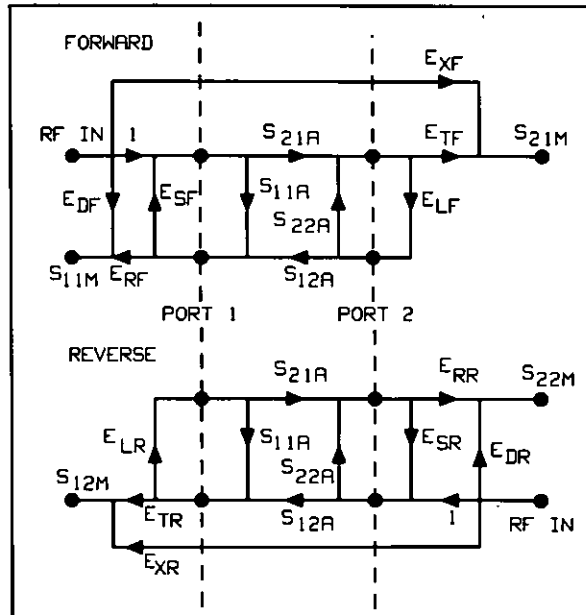
S_{22} Directivity,
Source Match,
Frequency Response.

All error terms with
respect to PORT 2.

**FULL
2-PORT**

(S-Parameter
Test Sets)

S_{11} , S_{21} , S_{12} , S_{22}
Directivity,
Source Match,
Frequency Response,
Load Match,
Isolation.



All error terms with
respect to PORT 1,
FORWARD model only.

**ONE-PATH
2-PORT**

(Reflection/
Transmission
Test Sets)

S_{11} , S_{21}
Directivity,
Source Match,
Frequency Response,
Load Match,
Isolation.

Figure 52. Cal Type Selections

STANDARDS AND CALIBRATION TYPES

Select an appropriate standard from the list, connect the standard, and press the key. The message WAIT-MEASURING CAL STANDARD appears while the standard is being measured. Do not press any front panel key while this message is displayed unless it is your intent to stop the measurement process. When the standard has been measured, the standard name will be underlined to indicate measurement is complete.

If the standard label includes an (M), for male, or an (F) for female, the reference is to the test port connector sex. For example, in the Type-N calibration kit, the standard labeled SHORT (F) would be selected when the appropriate short circuit is connected to the Type-N female test port.

The **RESPONSE** measurement calibration sequence requires a single standard: the **SHORT** or **OPEN** for reflection, or the **THRU** for transmission. If more than one standard is measured, the last standard pressed is used to compute the frequency response correction term.

The **S₁₁ 1-PORT** and **S₂₂ 1-PORT** measurement calibration sequences require a minimum of three standards, an **OPEN**, a **SHORT**, and at least one standard from the **LOADS** menu. For some calibration kits, the standards on the **LOADS** menu are specified as to the frequency range covered:

The **LOWBAND** selection is specified from the lowest frequency up to 2.001 GHz.

The **SLIDING** load is specified from 1.999 GHz up to the highest frequency.

The **BROADBAND** load is specified over the full frequency range.

Thus, for sweeps that cross 2 GHz, calibration using such a kit requires that you use both the **LOWBAND** and **SLIDING** loads, or the **BROADBAND** load.

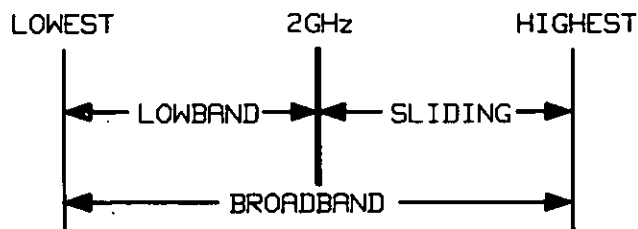


Figure 53. *LOADS Frequency Ranges*

If the standards thus far measured are not specified over the full frequency range being swept, then pressing **SAVE** causes the message **ADDITIONAL STANDARDS NEEDED** to appear.

Selecting **FULL 2-PORT** brings the Full 2-Port measurement calibration menu onto the CRT display. Select **REFLECTION**, **TRANSMISSION**, then **ISOLATION** in any sequence to bring these menus (Figure 54) onto the display. Parameter selection is automatic during these sequences.

Select **REFLECTION** then measure at least three standards, just as in the 1-Port sequence. Connect the appropriate S_{11} standards at Port 1 and the appropriate S_{22} standards at Port 2, then press **REFLECT'N DONE**.

For **TRANSMISSION**, connect the thru, then press the four standard selection softkeys to measure transmission frequency response and the terminating impedance.

The standard for the **ISOLATION** calibration step is to disconnect the Thru connection, then install appropriate Z_0 terminations (fixed loads) at Port 1 and Port 2. For best isolation cal, select an averaging factor of at least 128 by pressing **RESPONSE MENU**, **AVERAGING ON**, **256 x1**, **CAL**, **RESUME CAL SEQUENCE**. If a large averaging factor is not used, the error may be greater than if the isolation cal were not performed. To skip isolation cal, press **OMIT ISOLATION**, then **ISOLATION DONE**.

When all necessary standards on the list have been measured, press the bottom softkey labeled **DONE** or **SAVE**. You may measure the standards in any order. Until you press **DONE** or **SAVE** you may remeasure any standard on the currently displayed list and the last measurement on any particular standard will be used.

Reflection Cal Menu

(S₁₁):
OPEN

SHORT

LOADS

(S₂₂):
OPEN

SHORT

LOADS

REFLECT'N
DONE

Transmission Cal Menu

FWD. TRANS.
THRU

FWD. MATCH
THRU

REV. TRANS.
THRU

REV. MATCH
THRU

TRANS.
DONE

Isolation Cal Menu

OMIT
ISOLATION

FWD ISOL'N
ISOL'N STD

REV ISOL'N
ISOL'N STD

ISOLATION
DONE

Figure 54. Reflection, Transmission, and Isolation Cal Menus (Full 2-Port Cal)

STORING CALIBRATIONS

At this point the Cal Set Selection menu and the message **SELECT CALIBRATION SET** are displayed. A * next to the cal set number indicates that calibration error coefficients are already stored in that cal set. If you select a cal set which is already marked by an *, that cal set will be deleted and replaced by the new calibration coefficients.

When you press a key, the error coefficients are stored in the selected cal set, an underline appears under the cal set number to indicate that the cal set is currently selected, then the Cal Menu is displayed with **CORRECTION ON**.

The cal set includes a limited instrument state (Table 11) describing the parameter to which the cal set applies and important stimulus settings in effect when the calibration was saved. If a parameter is selected to which the cal set does not apply, the message **THIS PARAMETER NOT IN COEFFICIENT SET** will appear, indicating that correction cannot be turned on for this parameter using this calibration set. If the Frequency Range or Number of Points is changed, the message **CORRECTION RESET** is displayed and correction is automatically turned off. (If this is done when time domain low pass mode is selected, the message **CORRECTION AND DOMAIN RESET** appears, correction is turned off, and the domain is changed back to the frequency domain.) Other changes that may affect error correction result in the display of the message **CAUTION: CORRECTION MAY BE INVALID**.

Table 11. Cal Set Limited Instrument State

Parameter(s) Corrected
turns Correction Off if changed and new parameter is not included; will not turn Correction On if parameter is not included;
Frequency Range
Number of Points
both turn Correction Off if changed; will not turn Correction On if changed;
Source Power
Sweep Time
Power Slope
Ramp/Step/Single Point
Trim Sweep
Sweep Mode
CAUTION: CORRECTION MAY BE INVALID displayed if any of these is changed.

Note that the current ATTENUATOR PORT: 1 .. 2 settings (under STIMULUS MENU, SOURCE POWER) are not saved with the cal set. If you change these functions during measurement calibration, or during measurement, error correction is not turned off even though the displayed data may be in error.

With COUPLED CHANNELS selected, when you turn correction on for a parameter on one channel, it is also turned on for that parameter on the other channel. Selecting UNCOUPLED CHANNELS allows you to apply a different cal set to the same parameter on the other channel.

For example, to display real time responses of corrected and uncorrected data:

- Press **DISPLAY, DUAL CHANNEL, OVERLAY**
- Select the same parameter for display on both channels.
- Press **CAL, CORRECTION OFF**
 - Correction is turned off for both channels.
- Press **STIMULUS MENU, MORE, UNCOUPLED CHANNELS**
- Press **CHANNEL 1, CAL, CORRECTION ON, CAL SET n**
 - Correction is turned ON only for Channel 1.

When UNCOUPLED CHANNELS is selected, correction off/on and cal set must be selected independently for each channel.

MESSAGES DURING MEASUREMENT CALIBRATION SEQUENCE

Various messages appear on the CRT during the measurement calibration sequence.

CONNECT STD THEN PRESS KEY TO MEASURE. Connect the calibration standard to be measured, then press the softkey corresponding to the name of the standard. Pressing a standard selection key causes Measurement Restart. In Ramp sweep, $n+1$ sweeps are taken where n is the averaging factor. In Step sweep, 1 sweep is taken.

WAIT--MEASURING CAL STANDARD. This message appears after the calibration standard is selected; a beep sounds when the measurement is complete. Pressing any key stops the sequence. In Ramp sweep, $n+1$ sweeps are taken where n is the averaging factor. In Step sweep, one sweep is taken.

PRESS 'DONE' IF FINISHED WITH STD(s). This message appears when enough standards have been measured to satisfy the error model and to cover the required frequency range. If the calibration for the listed standards is complete, press the bottom 'DONE' key (label may vary depending upon the class of standards used) to proceed to the next step in the calibration sequence.

PRESS 'SAVE' IF FINISHED WITH CAL. This message appears when measurement of the last standard in the calibration sequence has been accomplished. When all the standards required for the calibration type have been measured, press 'SAVE' (the label varies depending upon the calibration type) to compute the error coefficients to be stored.

SELECT CALIBRATION SET. Press a CAL SET 1 through 8 key to select storage of the calibration error coefficients.

ADDITIONAL STANDARDS NEEDED. This message appears if you press 'DONE' or 'SAVE' when all standards required for the calibration have not been measured. Look at the standard selection menu presently displayed. The underlined standards have been measured. You will need to measure one or more of the remaining non-underlined standards to complete the sequence.

This message will also appear if the standards thus far measured are not specified over the full frequency range being swept. For example, the 7mm cal kit includes three loads, the LOWBAND (up to 2 GHz), the BROADBAND (0 to 18 GHz), and the SLIDING (2 to 18 GHz). If the sweep crosses 2 GHz and only the LOWBAND load was measured, then this message would appear.

MORE SLIDES NEEDED. For best accuracy, measure the sliding load at up to eight (or more) randomly spaced positions covering the entire range of the sliding load. If fewer than five slides are used, this message will appear.

NO SPACE FOR NEW CAL; DELETE A CAL SET. Even though all cal sets 1 through 8 are not marked by an asterisk (*), when this message appears it indicates

that there is not enough memory to store a new cal set. Press **MORE**, then **DELETE A CAL SET**, then press one of the cal set keys which is marked with the (*). This cal set will be deleted and measurement calibration can proceed. If you want to save a cal set, first save the set to tape, then delete it from memory. The cal set can then be loaded later from tape.

THIS PARAMETER NOT IN COEFFICIENT SET. The selected cal set does not contain error coefficients for the presently selected parameter. Thus, correction cannot be turned on for this parameter using this calibration set.

CORRECTION RESET. The instrument state has been changed so that the current cal set applied to the measurement does not apply. Correction is automatically turned OFF.

CORRECTION AND DOMAIN RESET. Same as **CORRECTION RESET** except that this message appears when time domain low pass mode is currently selected. Correction is automatically turned OFF and the domain is changed back to the frequency domain.

S-PARAMETER TEST SET (TWO-PATH) CALIBRATION ERROR MODELS

Three calibration error models exist for S-Parameter test sets:

Frequency Response: S_{11} , S_{21} , S_{12} , or S_{22}

1-Port: S_{11} or S_{22}

Full 2-Port

These measurement calibration sequences are described in the next several pages.

FREQUENCY RESPONSE

This calibration error model provides vector error correction for the selected parameter signal path frequency response using a single standard (usually a thru for transmission, a short or an open for reflection). The nominal calibration kit designations are CAL 1 for 7mm and CAL 2 for 3.5mm; thus if a 3.5mm calibration kit is used, instead of CAL 1 and CAL SET 1 in the following procedures substitute CAL 2. Calibration kit designations may be changed by the user, for example to define CAL 1 as 3.5mm and CAL 2 as Type-N.

ONE-PORT DEVICE: REFLECTION FREQUENCY RESPONSE CALIBRATION

- Press S_{11} , CAL, CAL 1, CALIBRATE: RESPONSE.
- At Port 1, connect either a short or a shielded open circuit.
- When the trace is correct, press SHORT or OPEN.
Data is measured.
- Press DONE: RESPONSE, then select a CAL SET 1 through 8.
Error coefficients are computed and stored;
Cal Menu is displayed with CORRECTION ON.
A Corrected trace is displayed.
- Connect the test device, and measure S_{11} .

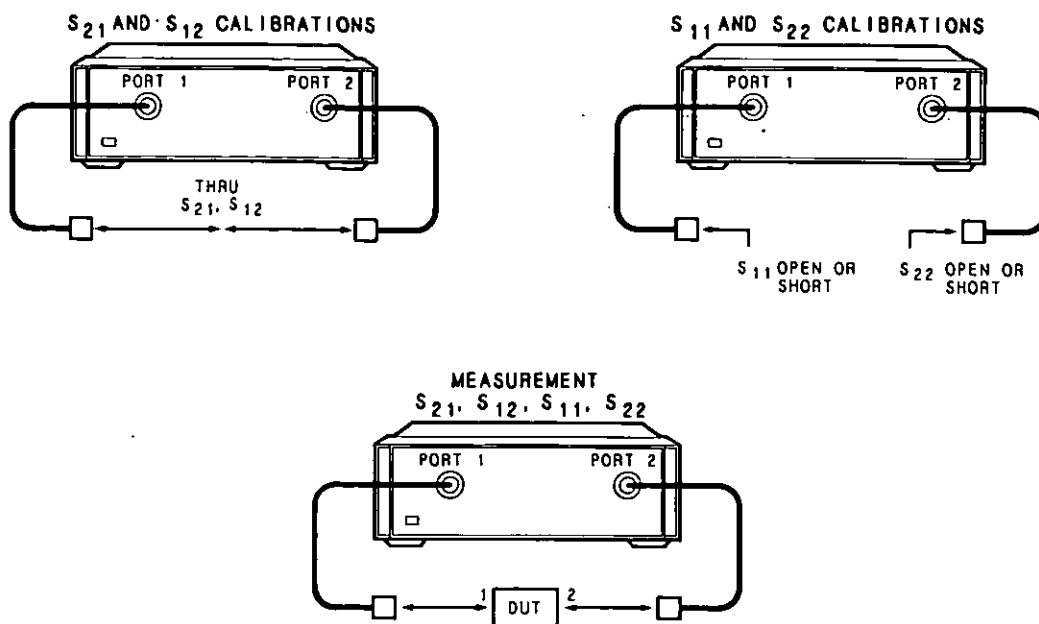


Figure 55. S-Parameter Test Set Frequency Response Calibrations

*TWO-PORT DEVICE: TRANSMISSION AND REFLECTION
FREQUENCY RESPONSE CALIBRATION*

This procedure performs frequency response calibrations for all four S-parameters. If the test set being used has 3.5mm test port connectors, instead of CAL 1 use CAL 2.

- At Port 1, connect either a short circuit or a shielded open circuit.
- Press S_{11} , CAL, CAL 1, CALIBRATE: RESPONSE.
- When the trace is correct, press SHORT or OPEN.
(S_{11} data is measured.)
- Press DONE: RESPONSE, then select CAL SET 1.
(Error coefficients are computed and stored;
Cal Menu is displayed with CORRECTION ON.)
- Corrected S_{11} data is displayed.
- Connect Port 1 to Port 2 Thru.
- Press S_{21} , CAL 1, CALIBRATE: RESPONSE.
- When the trace is correct, press THRU.
(S_{21} thru data is measured.)
- Press DONE: RESPONSE then select CAL SET 2.
(Error coefficients are computed and stored;
Cal Menu is displayed with CORRECTION ON.)
- Corrected S_{21} data is displayed.
- Press S_{12} , CAL 1, CALIBRATE: RESPONSE.
- When the trace is correct, press THRU.
(S_{12} thru data is measured.)
- Press DONE: RESPONSE, then select CAL SET 3.
(Error coefficients are computed and stored;
Cal Menu is displayed with CORRECTION ON.)
- Corrected S_{12} data is displayed.
- At Port 2, connect either a short circuit or a shielded open circuit.
- Press S_{22} , CAL 1, CALIBRATE: RESPONSE.
- When the trace is correct, press OPEN or SHORT.
(S_{22} data is measured.)
- Press DONE: RESPONSE, then select CAL SET 4.
(Error coefficients are computed and stored;
Cal Menu is displayed with CORRECTION ON.)
- Corrected S_{22} data is displayed.
- Connect the test device.
- Measure any parameter.

1-PORT

This calibration error model provides the best accuracy for measurement of a one-port device, providing full vector error correction for directivity, source match, and reflection signal path frequency response. The procedure uses three standards, usually a shielded open circuit, a short circuit, and a load.

During the S_{11} 1-Port calibration, all standards are connected at Port 1 (the point at which the test device input port will be connected). During the S_{22} 1-Port calibration, all standards are connected at Port 2 (the alternate point at which the test device output port will be connected). This model also can be used to measure S_{11} and S_{22} of a two-port device.

To obtain greater accuracy in measurement of a one-port device, perform the S_{11} 1-Port and S_{22} 1-Port calibration sequences described on the next page instead of the S_{11} and S_{22} frequency response calibrations described above.

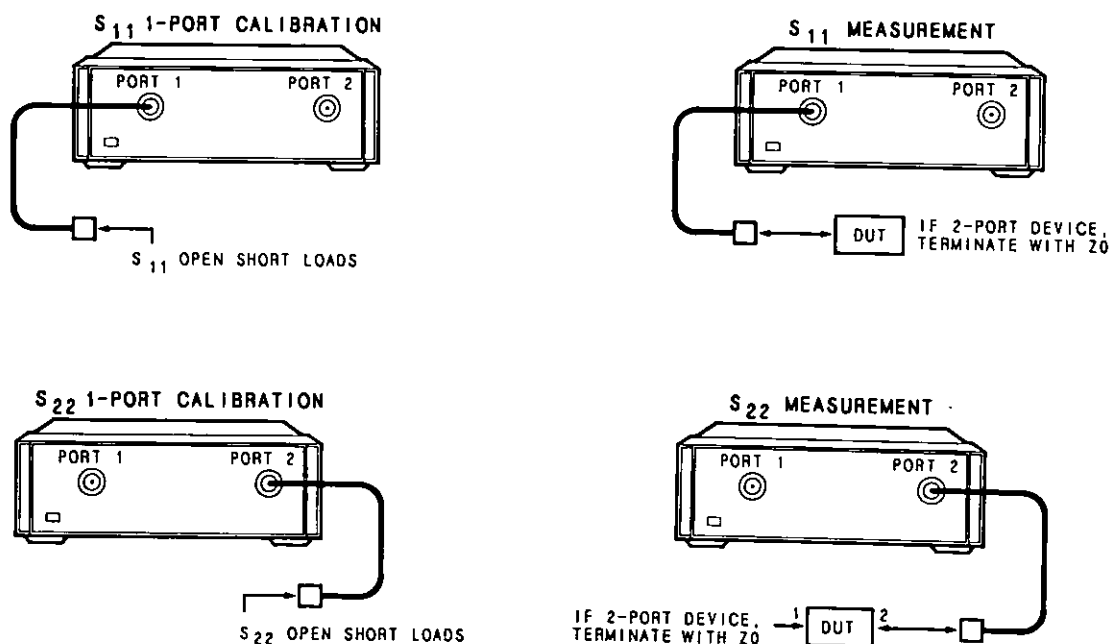


Figure 56. S-Parameter Test Set 1-Port Calibrations

1-PORT CALIBRATION SEQUENCE (7 mm)
S-PARAMETER TEST SETS

- Press **S₁₁**, **CAL**, **CAL 1**, **S₁₁ 1-PORT**.
- At Port 1, connect a shielded open circuit.
- When the trace is correct, press **S₁₁ OPEN**.
Open circuit data is measured.
- At Port 1, connect a short circuit.
- When the trace is correct, press **SHORT**.
Short circuit data is measured.
- Press **LOADS** to present the Standard Selection Menu.
If the frequency sweep crosses 2 GHz, then both the **LOWBAND** and **SLIDING** loads, or the **BROADBAND** load must be used.)
- At Port 1 connect a fixed load.
- When the trace is correct, press **LOWBAND**.
Load data is measured.
- At Port 1, connect a sliding load.
- Move sliding element to the first index mark; then, when the trace is correct, press **SLIDE IS SET**.
Load data is measured.
- Repeat 5 to 8 times, each time moving the sliding element to the next index mark, then pressing **SLIDE IS SET** each time.
- Press **SLIDING LOAD DONE**.
If the message **MORE SLIDES NEEDED** appears, measure at more slide positions.
- Press **DONE: LOADS**.
If the message **ADDITIONAL STANDARDS NEEDED** appears, then the loads were not specified for the current frequency range (for example, only the **LOWBAND** load was used for a sweep that crossed 2 GHz).
- Press **SAVE 1-PORT CAL**, then select a **CAL SET 1** through **8**.
(Error coefficients are computed and stored;
old cal set 1 is replaced with the new error coefficients,
Cal Menu is displayed with **CORRECTION ON**.)
- Corrected **S₁₁** trace is displayed.
- Press **S₂₂**, **CAL 1**, **S₂₂ 1-PORT**.
- Perform the **S₂₂ 1-Port** calibration procedure,
use **S₂₂ OPEN**, **SHORT**, and **LOADS**,
connect all standards at Port 2,
press **SAVE 1-PORT CAL**, then
store the error coefficients using another
CAL SET 1 through **8**.
- Connect the test device.
- Measure **S₁₁** or **S₂₂**.

FULL 2-PORT

The Full 2-Port measurement calibration procedure can be used only with the S-parameter test sets. This calibration error model provides the best accuracy when measuring two-port devices. Four standards are used, usually a shielded open circuit, a short circuit, a load or loads, and a thru. This model provides full error correction of directivity, source match, reflection and transmission signal path frequency response, load match, and isolation for S_{11} , S_{21} , S_{12} , and S_{22} .

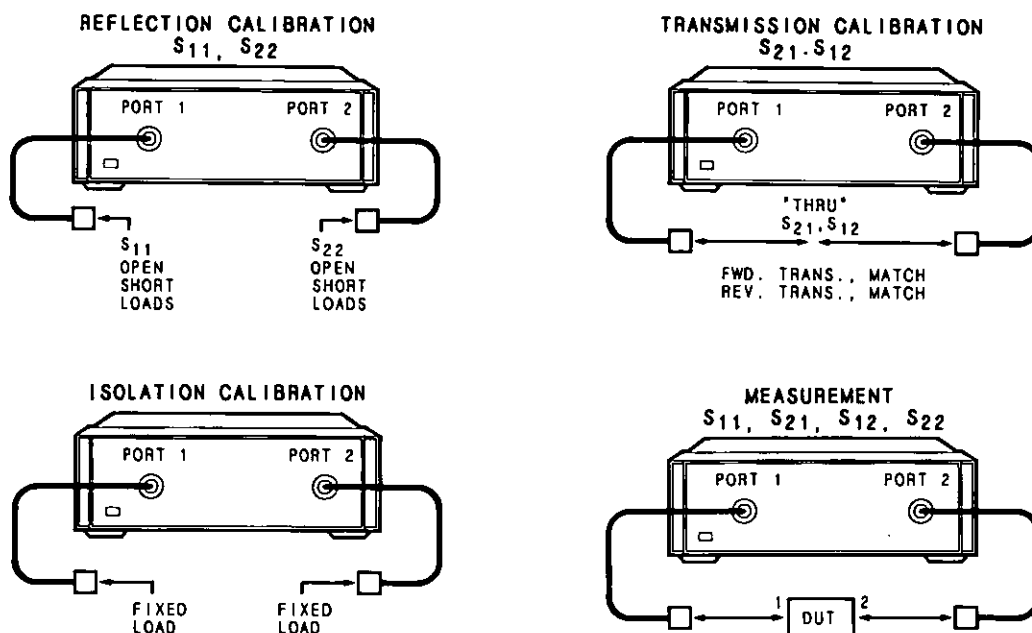


Figure 57. S-Parameter Test Set Full 2-Port Calibration

*FULL 2-PORT CALIBRATION SEQUENCE (7 mm)
S-PARAMETER TEST SETS*

NOTE - If the test set being used has 3.5mm test port connectors, instead of CAL 1 use CAL 2.

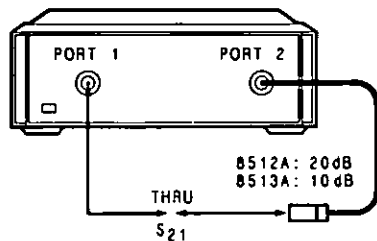
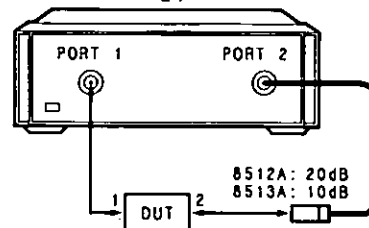
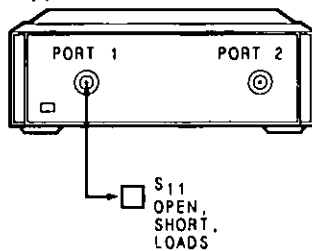
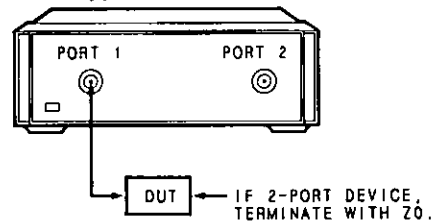
- Press CAL, CAL 1, FULL 2-PORT, REFLECT'N.
- Proceed as for the S_{11} 1-PORT calibration sequence, already described; connect standards at Port 1, use S_{11} OPEN, SHORT, and LOADS, do not press REFLECT'N DONE.
- Proceed as for the S_{22} 1-PORT calibration sequence, already described; connect standards at Port 2, use S_{22} OPEN, SHORT, and LOADS.
- Press REFLECT'N DONE.
Reflection error coefficients are stored.
- Press TRANSMISSION.
- Connect Port 1 to Port 2 Thru.
- When the trace is correct, press FWD. TRANS. THRU.
 S_{21} frequency response is measured.
- Press FWD. MATCH THRU.
 S_{21} load match is measured.
- Press REV. TRANS. THRU.
 S_{12} frequency response is measured.
- Press REV. MATCH THRU.
 S_{12} load match is measured.
- Press TRANS. DONE.
Transmission error coefficients are stored.
- Press ISOLATION.
- Connect a load at Port 1 and a load at Port 2.
- When the trace is correct, press FWD. ISOL'N ISOL'N STD.
 S_{21} noise floor is measured.
- Press REV. ISOL'N ISOL'N STD.
 S_{12} noise floor is measured.
- Press ISOLATION DONE.
Forward and reverse isolation error coefficients are stored.
- Press SAVE 2-PORT CAL, then select a CAL SET 1 through 8 to save the error coefficients.
Error coefficients are computed and stored; Cal Menu is displayed with CORRECTION ON.
- Corrected trace is displayed.
- Connect test device.
- Press any PARAMETER key, S_{11} , S_{21} , S_{12} , or S_{22} , to display corrected data for that parameter.

REFLECTION/TRANSMISSION TEST SET (ONE-PATH) CALIBRATION ERROR MODELS

You may choose S_{11} Frequency Response, S_{21} Frequency Response, S_{11} 1-Port, or One-Path 2-Port calibration error models. Reverse calibration may also be performed (S_{12} and S_{22} frequency response and S_{22} 1-Port), but in this case, the standards (open, short, and load) are still connected to port 1 and during measurement you must use care to physically reverse the test device and select the appropriate parameter (S_{11} or S_{22}).

FREQUENCY RESPONSE. This model provides vector error correction for selected parameter signal path frequency response using a single standard (usually a thru for transmission; a short circuit or a shielded open circuit for reflection). The S_{11} and S_{21} frequency response calibrations are performed using the same basic procedures as described previously for the S-parameter test set.

S_{11} 1-PORT. This model provides the best accuracy for measurement of a one-port device, providing full vector error correction for directivity, source match, and reflection signal path frequency response. The procedure uses three standards, usually a shielded open circuit, a short circuit, and load, in the same sequence as described for the 1-Port calibration on the S-parameter test set described previously. If the S_{22} 1-PORT procedure is used with the reflection/transmission test set, the test device must be manually reversed.

S₂₁ FREQUENCY RESPONSE CALIBRATION**MEASUREMENT
S₂₁****S₁₁ 1-PORT CALIBRATION****S₁₁ MEASUREMENT**

*Figure 58. Reflection/Transmission Test Set
Frequency Response and 1-Port Calibrations*

TWO-PORT DEVICE: TRANSMISSION AND REFLECTION FREQUENCY RESPONSE CALIBRATION

This procedure presents a calibration sequence for measurement of a two-port device using a combination of S_{21} and S_{12} frequency response and S_{11} and S_{22} 1-Port error models. Since the reflection/transmission test set cannot produce real-time error corrected measurements using the One-Path 2-Port error model (the device under test must be manually reversed), this sequence is usually the quickest way to measure a two-port device on a reflection/transmission test set where source and load match effects are not an important factor in the accuracy of the measurement.

NOTE - If the test set being used has 3.5mm test port connectors, instead of CAL 1 use CAL 2.

- Press S_{11} , CAL, CAL 1, S_{11} 1-PORT.
- Perform the S_{11} 1-PORT calibration sequence, already described; use S_{11} OPEN, SHORT, and LOADS, connect standards at Port 1.
- Press SAVE 1-PORT CAL, then select CAL SET 1.
- Corrected S_{11} data is displayed.

- Connect Port 1 to Port 2 Thru.
- Press S_{21} , CAL 1, FREQUENCY RESPONSE.
- When the trace is correct, press THRU.
 S_{21} thru data is measured.
- Press DONE: RESPONSE, then select CAL SET 2.
- Corrected S_{21} data is displayed.

- Press S_{12} , CAL 1, FREQUENCY RESPONSE.
- When the trace is correct, press THRU.
 S_{12} thru data is measured.
- Press DONE: RESPONSE, then select CAL SET 3.
- Corrected S_{12} data is displayed.

- Press S_{22} , CAL 1, S_{22} 1-PORT.
- Perform the S_{22} 1-PORT calibration sequence, already described; use S_{22} OPEN, SHORT, and LOADS, connect standards at Port 1.
- Press SAVE 1-PORT CAL, then select CAL SET 4.
- Corrected S_{22} data is displayed.

- Connect the test device for forward measurement.
- Measure S_{11} and S_{21} .
- Reverse the device and adapters.
- Measure S_{22} and S_{12} .

ONE-PATH 2-PORT

The One-Path 2-Port calibration error model is designed specially for the reflection/transmission test set. It provides vector error correction of directivity, source match, reflection and transmission signal path frequency response, load match, and isolation errors for S_{11} , S_{21} , S_{12} , and S_{22} . This procedure is similar to the Full 2-Port calibration procedure described previously for S-parameter test sets, except that all calibration takes place with respect to Port 1, and the device under test (and possibly the adapters if used) must be manually reversed in the process of measuring any S-parameter.

This manual reversal makes it impossible to obtain fully error-corrected data in real time. Instead, pressing the softkey labeled **PRESS TO CONTINUE** controls a measurement process that includes operator prompts to connect the test device for forward and reverse measurements, finishing with the corrected data for the selected parameter displayed and ready for data output. Pressing another parameter key either displays the corrected data for the new parameter choice immediately, or restarts the measurement process.

When load and source match effects are not major error contributors in the measurement, or when you wish to view the real time response of the device under test and are not concerned with absolute measurement accuracy, use a combination of S_{11} 1-Port and S_{22} 1-Port reflection calibrations with S_{21} and S_{12} frequency response transmission calibrations, instead of this One-Path 2-Port sequence.

Averaging may be used during measurement calibration, but in the ramp mode due to the fact that the One-Path 2-Port model takes only one sweep for each S-parameter, averaging cannot be used with correct results during measurement, unless the test device is repeatedly reversed.

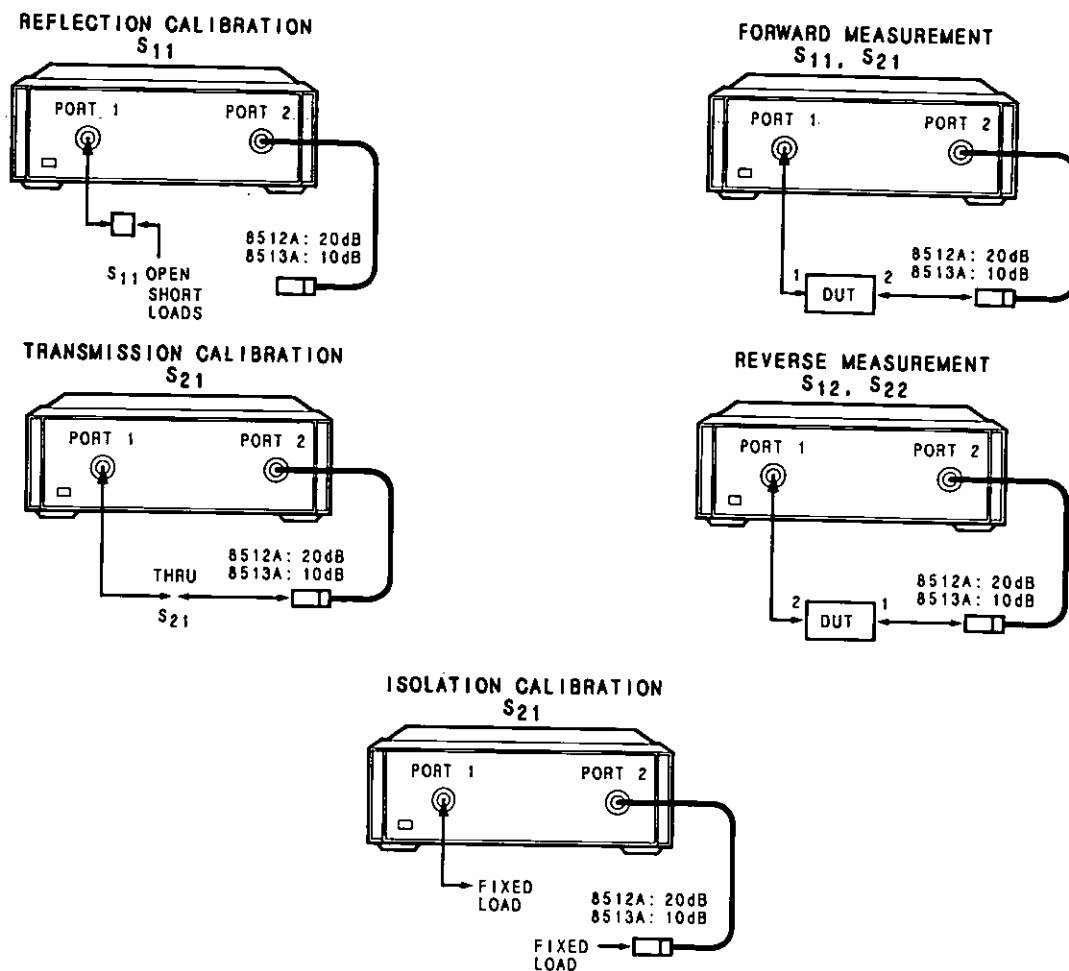


Figure 59. Reflection/Transmission Test Set
One-Path 2-Port Calibration

*ONE-PATH 2-PORT CALIBRATION SEQUENCE (7 mm)
REFLECTION/TRANSMISSION TEST SET*

NOTE - If the test set being used has 3.5mm test port connectors, instead of CAL 1 use CAL 2.

- Press **CAL, CAL 1, ONE-PATH 2-PORT.**
- Press **REFLECT'N**, then proceed as for the S_{11} 1-PORT calibration sequence, already described; use S_{11} **OPEN, SHORT, and LOADS**, connect standards at Port 1.
- Press **REFLECT'N DONE.**
Reflection error coefficients are stored.
- Press **TRANSMISSION.**
- Connect Port 1 to Port 2 using a Thru.
- When the trace is correct, press **FWD. TRANS. THRU.**
 S_{21} frequency response is measured.
- Press **FWD. MATCH THRU.**
 S_{21} load match is measured.
- Press **TRANS. DONE.**
Transmission error coefficients are stored.
- Press **ISOLATION.**
- Connect a load at Port 1 and a load at Port 2.
- When the trace is correct, press **FWD. ISOL'N ISOL'N STD'.**
 S_{21} noise floor is measured.
- Press **ISOLATION DONE.**
Forward isolation error coefficients are stored.
- Press **SAVE 2-PORT CAL**, then select a **CAL SET 1** through **8.**
Error coefficients are computed and stored; Cal Menu is displayed with **CORRECTION ON.**)
- Connect test device.
- Select parameter for display by pressing S_{11} , S_{21} , S_{12} , or S_{22} .
- Follow instructions to connect the test device for forward measurement, then **PRESS TO CONTINUE.**
- Follow instructions to connect the test device for reverse measurement, then **PRESS TO CONTINUE.**
- Observe the corrected trace.
- To measure another parameter, press the key for the desired **PARAMETER.**
- To measure the next test device, connect the test device, then **PRESS TO CONTINUE.**

STORING CALIBRATION DATA

Internal Storage. Error terms are computed and stored in the internal calibration set storage area you specify at the end of the measurement calibration sequence. Up to eight calibration sets can be stored, depending upon the type of calibration performed and the number of points selected for the sweep. That is, if you perform two 401 point Full 2-Port calibrations and store the results in Cal Sets 1 and 2, the internal storage will be full even though cal set numbers 3 through 8 are not designated with the * symbol.

If internal storage is already full, a cal set must be deleted using **DELETE CAL SET** before calibration can proceed. Selecting a cal set to receive error coefficient data automatically replaces the old data with the new data.

Table 12. Calibration Error Coefficient Storage

Cal Type	Number of Points			
	51	101	201	401
Frequency Response	8	8	8	8
1-Port	8	8	8	8
2-Port	8	8	4	2

Tape Storage. Cal data can be stored on tape, recalled, checked for validity, then used if acceptable results are obtained. To store a cal set on tape:

- **TAPE, STORE,**
CAL SET 1-8,
CAL SET n,
CAL SET FILE n.

To transfer the cal set from tape to internal memory:

- **TAPE, LOAD,**
CAL SET 1-8,
CAL SET n,
CAL SET FILE n.

Since up to eight tape files of all the cal sets, and up to eight files of a single cal set can be stored on tape, it is convenient to save a cal set and use it at another time rather than recalibrate the system. If an appropriate instrument state is also saved, or the system can be restored to the state during calibration, then the cal set may be used. However, if the test setup has changed, the cal set may no longer apply.

CALIBRATION STANDARDS

For best accuracy and repeatability, use great care in handling and storing the calibration devices. Their performance and accuracy depends on very precise mechanical tolerances, sometimes on the order of a few ten thousandths of an inch. Therefore, the standards must be handled and stored more carefully than ordinary devices. Inspect and clean the connectors as required using the methods recommended in the calibration kit manuals. Use gages on the test port connectors, standards, cables, and the test device to verify that the mating plane dimensions of all connectors are within the allowable tolerances. Always use an appropriate torque wrench when tightening or loosening connections. Detailed information on calibration standards, and on recommended techniques of using them and for making connections, appears in the HP 85050A 7mm and HP 85052A 3.5mm calibration kit manuals.

In simple terms, accuracy enhancement is accomplished by measuring the known standards, comparing the measured response with the predicted response, then computing error terms that are derived from the magnitude and phase difference between the measured response and the predicted response. The predicted response is determined by using a complex mathematical model which predicts its magnitude and phase response of the calibration standard over its entire frequency range. Thus, the accuracy improvement which can be expected is directly related to how well the models predict the response of the standard. The model for each standard is specified in a data file on the tape supplied with the calibration kits.

Examples of "perfect" standards are shown in the assumptions made for the fixed and sliding loads used in reflection calibration. The characteristic impedance, Z_0 , is assumed to be exactly 50 ohms.

The standards under the **LOADS** key on the standards selection menu are also specified as to frequency range. For example, if the loads specification is that the sliding load is usable down to 2 GHz, for sweeps that cross this frequency it is necessary to use both the **LOWBAND** and **SLIDING** loads, or the **BROADBAND** load.

The quality of the load used for calibration determines the effective directivity for reflection measurements. A high quality fixed load exhibits the lowest repeatable return loss under 2 GHz. The quality of the sliding load is determined by the return loss of the connector and the transmission line between the connector and the sliding element.

Standard models differ according to connector type. For example, the short circuit in the HP 85050A 7mm calibration kit is modeled as a perfect zero ohm termination, having a reflection coefficient of $1\angle\pm 180^\circ$ positioned at the reference plane. The short circuit in the HP 85052A 3.5mm calibration kit is modeled as a perfect short displaced 16.684 ps (mechanically, 0.5 cm) from the reference plane.

Specifications for the shielded open circuits add a reactive phase shift to the modeled response characteristic. In order to model the typical non-linear phase shift, the shielded open circuit is assumed to exhibit a phase shift with frequency that can be approximated using the equation

$$C_{\text{total}} = C_0 + C_1 * F + C_2 * F^2 + C_3 * F^3$$

where C_0 is the dc capacitance, $C_1 * F$ is the capacitance times frequency, $C_2 * F^2$ is the capacitance times frequency squared, and $C_3 * F^3$ is the capacitance times frequency cubed. The shielded open circuits in the HP 85052A calibration kit use a center pin extender, so the models for these devices also include a linear phase shift component to account for the offset from the reference plane.

The specifications contained on the calibration kit data cartridge are nominal values based on typical expected responses of the standards. If you wish to substitute your own standards, or change the models for the standards supplied in the calibration kit, you may use the **MODIFY CAL KIT** sequence discussed later in this section of the manual.

Common calibration problems which can be traced to standards are:

- Non-repeatable contact due to wear, dirt, grease, or other contaminants on the contacting surfaces or other accessible parts of the standard. Assure that the standard is properly cleaned and dried.
- Connector damage due to connecting the standard to a connector with mechanical defects or out-of-spec tolerances. Use the connector gage on both the test port and the standard prior to measurement calibration.
- Poor contact due to improper alignment or torquing practice. Use the counter-rotation technique and the proper torque wrench for each connection.
- Using cal standards whose response does not match the constants used in the HP 8510 internal cal kit definitions. Refer to the calibration kit manuals for electrical and mechanical specifications.

EVALUATING CALIBRATION DATA

Immediately following calibration, and at intervals during the measurement process, it is recommended that you measure a standard device with known responses. This is to verify that the system characteristics have not changed thus making the current calibration error coefficients invalid. Measuring a device from the calibration kit used for measurement calibration will allow you to determine that the system is making repeatable measurements. The measured response of a calibration standard will be exactly the modeled response if the connection is repeatable.

To determine measurement accuracy, however, it is necessary to measure an independent standard with known responses, such as the coaxial attenuators or air lines in the HP 8510 verification kit, or a standard you produce that is representative of the devices you are testing. If standards-quality data for the device is available, it can be compared with your measurement results to determine accuracy. If the data is outside acceptable limits and good technique was used during the calibration, then the system characteristics have changed, thus making the current calibration error coefficients invalid.

In any measurement calibration or measurement procedure it is important that the connections be properly tightened. The correct torque wrench settings for various connector types are listed below.

7 mm	12 lb-in	136 N-cm
Type-N	12 lb-in	136 N-cm
3.5 mm	8 lb-in	90 N-cm
SMA to 3.5 mm	5 lb-in	60 N-cm

For details of connection procedures, refer to the calibration kit manuals. Standards class information is supplied with the verification devices.

MODIFY CAL KIT

Begin the process by making certain you have a copy of the cal kit definition you are about to modify. Standard cal kit definitions are on the tape supplied with the calibration kit, and listed in the calibration kit manual. You may copy either the cal kit presently using the **TAPE, RECORD, CAL KIT 1-2** sequence.

Now fill out a copy of the tables found in the cal kit manuals. Use them as worksheets to specify the characteristics and a label for each standard, to assign each standard to a class, and to specify a label for the class. Refer to the performance specifications tables in the manuals for the HP 85050A (7mm) and HP 85052A (3.5mm) calibration kits for guidance.

To modify a cal kit, first press **CAL, MORE**, then either **MODIFY 1** <cal kit 1 label> or **MODIFY 2** <cal kit 2 label>.

Press **SELECT STANDARD**, then select the device to be modified by entering a Standard Number between 1 and 21 by pressing numeric keys, then **x1**. Assign this standard a type designation by pressing the appropriate *Standard Type Menu* key, then enter the appropriate characteristics using the *Standard Definition Menu* and the *Specify Offset Menu*.

Label the standard using eight or less characters or numbers using **LABEL STD**. This label will appear on the *Standard Selection Menu* during the calibration procedure. When all characteristics of the standard are specified, press **STANDARD DONE (DEFINED)** to return to the *Modify Cal Kit Menu*.

Repeat this sequence for each new or modified standard in the modified cal kit. Standard definitions not changed during this process are included in the modified cal kit with their pre-existing values.

Press **SPECIFY CLASS**. Use the *Specify Class Menu* to assign appropriate standards to each of the classes required for the calibration. Select a class then enter one, or a sequence of, Standard Number followed by **x1** for each standard to be used in the class, then press **CLASS DONE (SPEC'D)**.

Now press **LABEL CLASS** and name each appropriate standard class using 10 or less characters. This label will appear on the *Frequency Response, 1-Port, 2-Port Reflection, 2-Port Transmission, and Isolation Calibration Menus*.

Repeat this sequence for each of the standard classes required for the calibration procedure.

Next press **LABEL KIT** and name the modified cal kit using 10 or less characters. This name will appear on the *Cal Menu*. Finally, press **KIT DONE (MODIFIED)** to store the new cal kit in place of the selected kit.

ADJUSTING TRIM SWEEP

The **TRIM SWEEP** function performs a different purpose for HP 834x and HP 835x sources. For HP 8340 sources used in the Ramp Sweep mode, it is used to adjust the end frequency at the band switch points to minimize the frequency difference between the end frequency of one band and the start frequency of the next higher band. **TRIM SWEEP** is not used in the Step Sweep mode.

For HP 835x sources, **TRIM SWEEP** is adjusted to provide the best frequency accuracy. The **TRIM SWEEP** setting is saved as part of the instrument state when you press **SAVE, INSTRUMENT STATE n**, and as part of the limited instrument state saved when you save a cal set. It is set to zero by **PRESET**.

With either HP 834x or HP 835x sources, the **TRIM SWEEP** adjustment is not identical for all frequency ranges. It will have a slightly different value for different sweep widths. As you narrow the sweep, internal HP 8510 logic changes the band switch points in order to, when possible, eliminate band switch points from the frequency range being swept. For best measurement accuracy, perform this sweep trim adjustment for each different frequency range immediately prior to measurement calibration.

HP 834x Sources

If you are using the **RAMP** sweep mode, set **TRIM SWEEP** to provide minimum frequency difference between the **STEP** and **RAMP** modes as follows:

- a. Press **PRESET**. Select **S₂₁** for display.
- b. Connect measurement Port 1 to measurement Port 2 (thru connection).
- c. Set the **START/STOP** or **CENTER/SPAN** controls to sweep the frequency range of interest.
- d. Select **STIMULUS MENU, STEP**. When the sweep is complete, press **DISPLAY DATA → MEMORY, MATH (1)**. When the next sweep is complete, the trace should be a flat line at zero degrees.
- e. Press **STIMULUS MENU, RAMP**. The displayed trace may exhibit a sharp phase transition at the band switch points. Sharp transitions indicate the need to adjust **TRIM SWEEP**.
- f. Press **CAL, MORE, TRIM SWEEP**. Then use the knob to adjust the phase trace for minimum phase change at the band switch points. When the best (flattest) phase trace is achieved, press **SAVE, INSTRUMENT STATE n** to save this setting. Now proceed with the appropriate measurement calibration.

HP 835x Sources

Set **TRIM SWEEP** to provide best frequency accuracy as follows:

- a. Press **PRESET**. Select **S₂₁, PHASE** for display.
- b. Connect measurement Port 1 to measurement Port 2 (thru connection).
- c. Set the **START/STOP** or **CENTER/SPAN** controls to sweep the frequency range of interest.
- d. Press **DISPLAY, DATA → MEMORY, MATH (/)**. The trace should be a flat line at zero degrees.
- e. Connect an electrical delay of known length between measurement Port 1 and measurement Port 2. The device should have a low loss and exhibit a precisely known electrical delay, as do the airlines in the 3.5mm and 7mm verification kits.
- f. Enter the electrical delay of the airline by pressing **RESPONSE MENU, ELECTRICAL DELAY**, and then entering the specified electrical delay of the device. The phase transitions should disappear, leaving a phase trace with some slope. Any residual slope indicates a need to adjust **TRIM SWEEP**.
- g. Press **CAL, MORE, TRIM SWEEP**. Then use the knob to adjust the phase trace for minimum phase change at the band switch points. When the best (flattest) phase trace is achieved, press **SAVE, INSTRUMENT STATE n** to save this setting. Now proceed with the appropriate measurement calibration.

Basic Measurement

1. Length

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INTRODUCTION

This part of the HP 8510 network analyzer system manual explains how to make transmission measurements on a typical two-port device: insertion loss and gain, insertion phase, S-parameters, group delay, electrical delay, and deviation from linear phase. These measurements are described individually, each with separate setup, measurement calibration, and measurement sequences. A brief theoretical review of group delay principles is also included.

TRANSMISSION MEASUREMENTS

When planning a test sequence for a two-port device, there are two important factors to consider: the type of two-port device you are going to measure and the type of test set you are using to measure the device.

DEVICE TYPES

Electrical characteristics notwithstanding, there are basically three types of two-port devices (Figure 60): insertable, reversible, and transitional.

For Insertable devices, port 1 connector type will mate with the port 2 connector type (port 2 is of the same family but is of opposite sex to that of port 1). Reversible devices use the same connector type on both port 1 and port 2 (port 2 is the same family and same sex as port 1). Transitional devices use connectors from different families on port 1 and port 2. Only hermaphroditic (sexless) connectors, like the standard 7 mm, are both insertable and reversible.

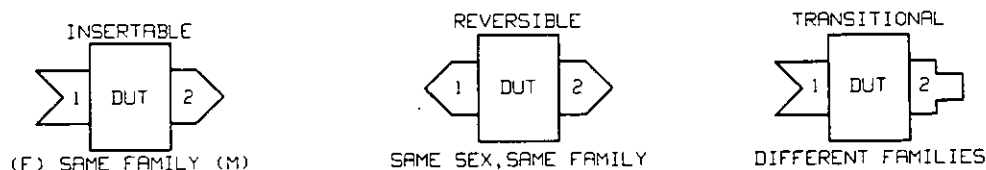


Figure 60. Two-Port Device Types

TEST SETS

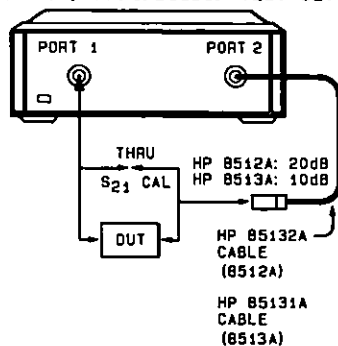
There are basically two types of test sets. The S-parameter test sets are called two-path test sets because the stimulus can be switched to either port 1 or port 2, thus allowing both forward and reverse characteristics of the test device to be measured without manually reversing the test device. The reflection/transmission test sets are called one-path test sets because the stimulus can only be applied to port 1 and the test device must be physically reversed to measure its reverse parameters.

Each combination of device type and test set type calls for a slightly different measurement calibration and measurement sequence. For example, measurement of an insertable device using a two-path test set is the ideal case. Because the test device has connector types which can be mated on its port 1 and port 2, measurement calibration can be performed with the correct adapters in place, and since the test set can switch the stimulus between port 1 and port 2, all parameters can be measured without manually reversing the test device.

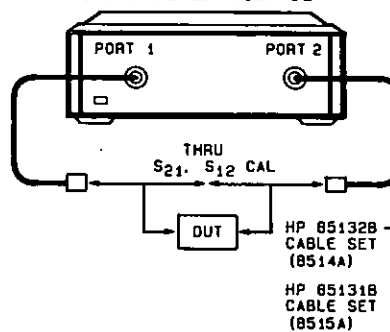
TRANSMISSION TEST SETUPS

Figure 61 shows typical transmission test setups for reflection/transmission test sets and S-parameter test sets.

REFLECTION/TRANSMISSION TEST SET



S-PARAMETER TEST SET

*Figure 61. Transmission Test Setups*

TRANSMISSION MEASUREMENT CALIBRATION CHOICES

Frequency Response Only Calibrations. The RESPONSE calibration model uses a thru (connect Port 1 and Port 2 together at the point at which the test device will be connected) as the standard device. The RESPONSE model can be used for S_{21} forward transmission calibration and for S_{12} reverse transmission calibration. It can also be used for calibration with all user parameters.

Full 2-Port Calibration. This model provides fully corrected transmission and reflection measurements with an S-parameter test set. It uses a thru, a shielded open circuit, a short circuit, and loads to calibrate at Port 1 and Port 2.

One-Path 2-Port Calibration. This model provides fully corrected transmission and reflection measurements (although not in real time) for a reflection/transmission test set. It uses a thru, a shielded open circuit, a short circuit, and loads to calibrate at Port 1. The operator follows instructions displayed on the CRT to manually reverse the test device for measurement of the reverse parameters.

INSERTION LOSS/GAIN MEASUREMENT

This sequence lists the steps for a typical insertion loss or gain measurement.

- Perform appropriate S_{21} or S_{12} measurement calibration.
- Select LOG MAG.
- Press MARKER, and read insertion loss (dB).

Measurement calibration sets the magnitude and phase ratio between the reference and test signal paths to zero with a thru connection. After connecting the test device, a negative measured value indicates insertion loss; a positive measured value indicates gain. Take care to choose signal levels to achieve maximum dynamic range.

Figure 62 shows a display of the magnitude response of a bandpass filter using the LOG MAG format. The measurement marker is positioned to the minimum insertion loss point using the sequence MARKER, MORE, MARKER TO MAXIMUM.

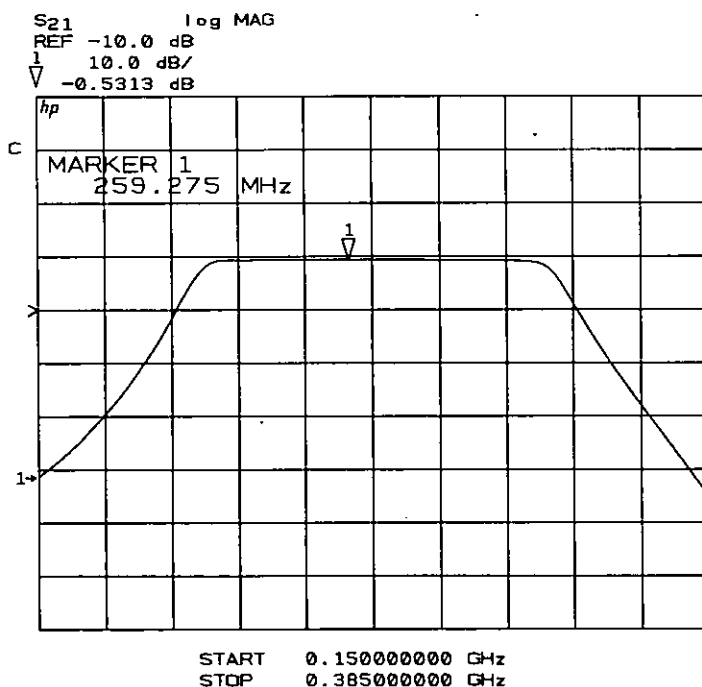


Figure 62. Typical Insertion Loss Display

3 dB FREQUENCIES. The insertion loss and gain measurement procedure can be extended to measure the 3 dB insertion loss points of the filter.

- Press **MARKER, MARKER 1, MORE, MARKER TO MAXIMUM.**
- Press **PRIOR MENU, Δ MODE MENU, Δ REF = 1, MARKER 2.**
- Use the knob to position Marker 2 to read upper frequency -3 dB point.
- Press **MARKER 3.**
- Use the knob to position marker 3 to read lower frequency -3 dB point.

Markers 2 and 3 are now set to the 3 dB points of the filter. To read the entire 3 dB bandwidth frequency span:

- Press **Δ MODE MENU, Δ REF = 3, MARKER 2.**

The frequency span between the 3 dB points will be shown in the Active Entry area.

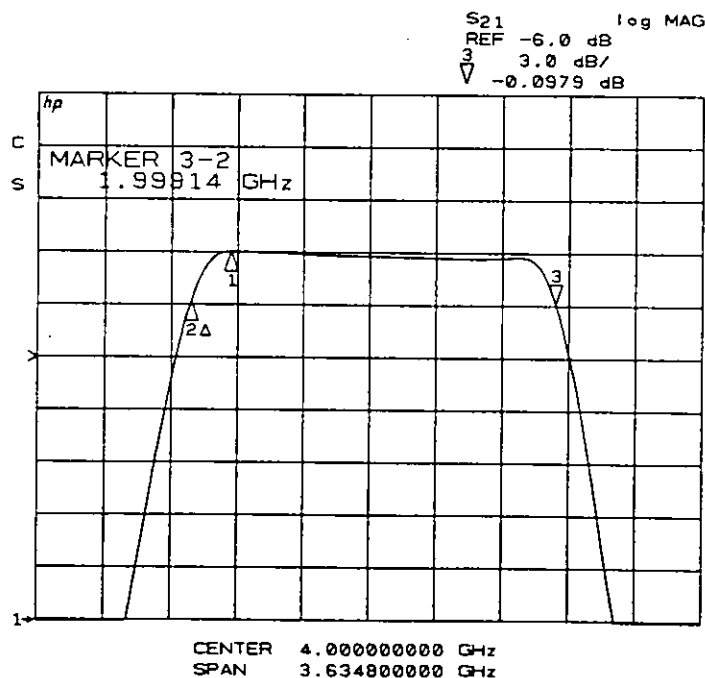


Figure 63. Measuring 3 dB Points

MAXIMUM AND MINIMUM VALUES. Measure the maximum and minimum values of the response using this sequence.

First, find the appropriate start/stop or center/span frequencies over which the maximum and minimum values are to be measured. Then perform appropriate measurement calibration over this frequency range.

- Press **MARKER, MARKER 1, MORE, MARKER TO MINIMUM.**
- Press **PRIOR MENU.**
- Press **MARKER 2, Δ MODE MENU, Δ REF = 1, MORE, MARKER TO MAXIMUM.**

Marker 2 is active, and the Active Entry shows the difference between Marker 1 (at the trace minimum) and Marker 2 (at the trace maximum).

In the example shown below (Figure 64), the test frequencies are chosen so that passband flatness can be measured. Marker 1 is set to the minimum value and marker 2 is set to the maximum value. The sequence provides direct readout of the peak-to-peak difference in the trace.

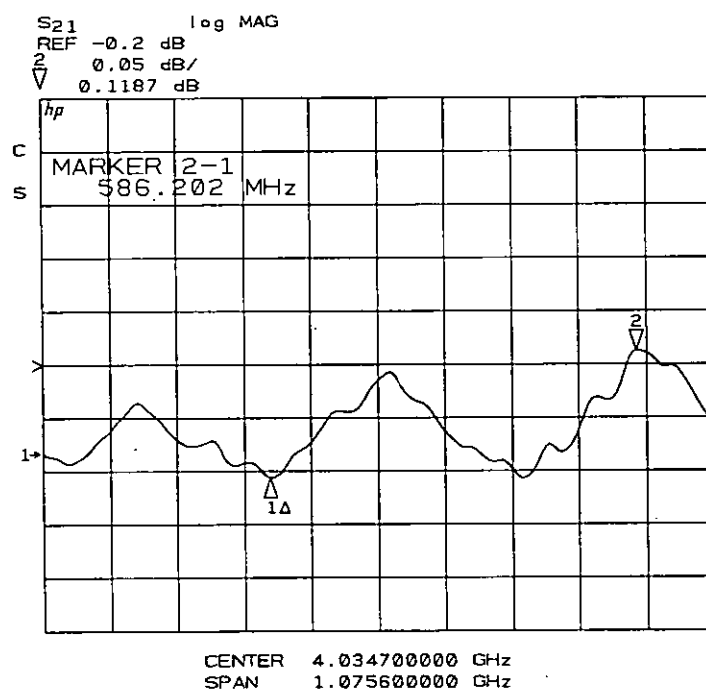


Figure 64. Measuring Minimum and Maximum Insertion Loss

INSERTION PHASE MEASUREMENT

This sequence lists the steps for a typical insertion phase measurement.

- Perform appropriate S_{21} or S_{12} measurement calibration.
- Select **PHASE**.
- Press **MARKER**, and read insertion phase (degrees).

Figure 65 shows a bandpass filter insertion phase display using the **PHASE** format. The measurement range is +180 degrees to -180 degrees, and the vertical line represents the transition between these two values. Thus, the trace between any two of these transitions represents 360 degrees of phase shift.

To illustrate the display format, determine the total phase shift for the selected sweep width as follows: Position the marker as far to the left as possible and note the phase reading. Determine the number of degrees before the first transition. Next, count the second and following transition traces and multiply by 360. Now determine the number of degrees from the last transition trace to the right edge of the screen. The sum of these numbers is the total phase shift over the frequency sweep.

For example, in Figure 65:

$$\text{TOTAL PHASE SHIFT} = 49.313^\circ + 3(360^\circ) + 40^\circ = 1169.3^\circ$$

When the transmitted signal is below the noise floor for insertion phase measurements, the CRT trace usually becomes random.

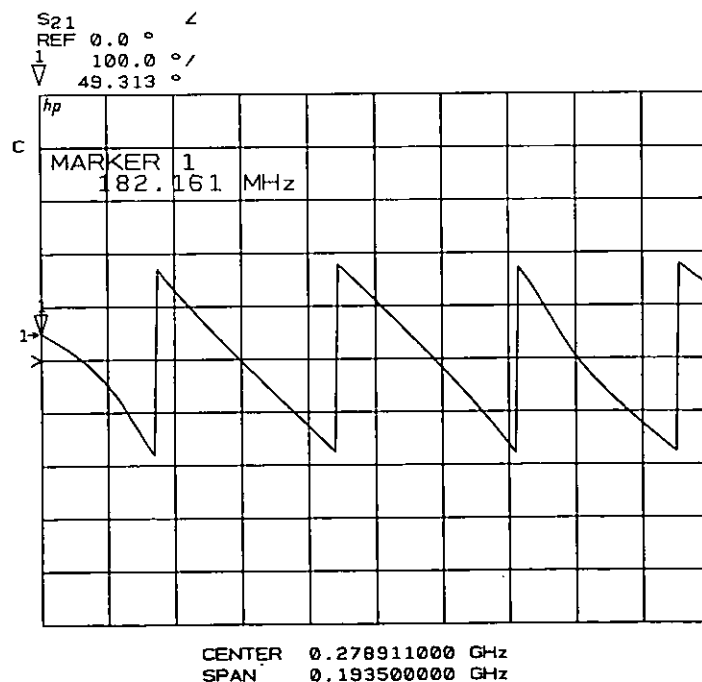


Figure 65. Typical Insertion Phase Display

S-PARAMETERS

The procedure for measurement of transmission S-parameters is identical to measurement of insertion loss and insertion phase described earlier except that the response is viewed using the **LIN mkr** on **POLAR** display on the **FORMAT** menu.

The magnitude is given in linear terms (τ) and an angle $\angle\theta$, in degrees. A magnitude value greater than one indicates gain; less than one indicates loss. The conversion from dB to linear units is given by the equation

$$\text{dB} = 20 (\log \tau).$$

Note that the **LOG mkr** on **POLAR** format presents the same data with magnitude given in dB.

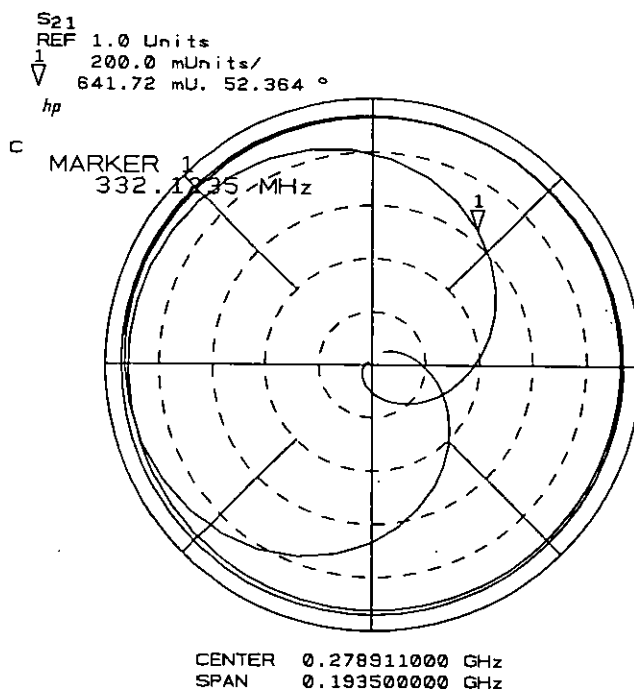


Figure 66. Typical S-Parameter Display

GROUP DELAY MEASUREMENT

This sequence lists the steps for a typical group delay measurement.

- Perform appropriate S_{21} or S_{12} measurement calibration.
- Select DELAY.
- Press MARKER, and read group delay (seconds).

Measurement calibration sets the group delay to zero seconds with a zero-length thru connection. After connecting the test device, a positive measured value indicates transit time through the test device.

- Press RESPONSE MENU, SMOOTHING ON.

With smoothing selected, the displayed smoothing aperture represents the percent of span (and the actual frequency range) over which the point-to-point group delay values are averaged. Discontinuities in the group delay trace may appear if there are more than 180 degrees of phase shift that occur from one frequency point to the next. With smoothing off, the minimum aperture for a given sweep width depends on the number of points selected.

$$\text{Measurement Aperture} = \frac{(\text{stop frequency} - \text{start frequency})}{(\text{number of points} - 1)}$$

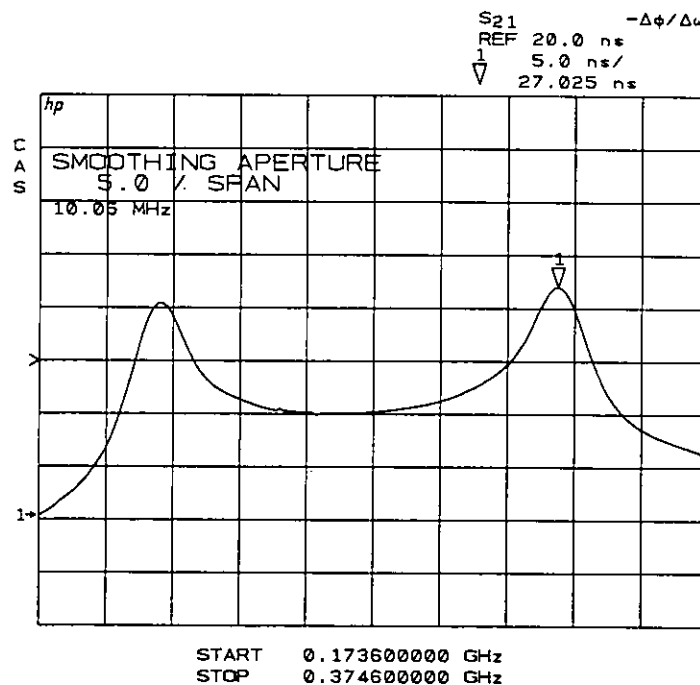
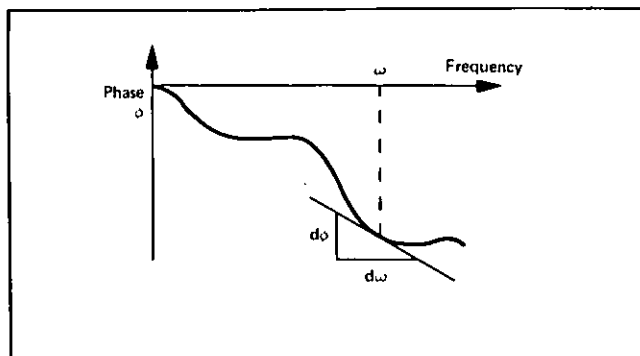


Figure 67. Typical Group Delay Display

GROUP DELAY PRINCIPLES

Reduced phase measurement uncertainty due to error correction provides very meaningful and flexible group delay measurements. This implementation makes it quite simple to make accurate, very high resolution group delay measurements at microwave frequencies.

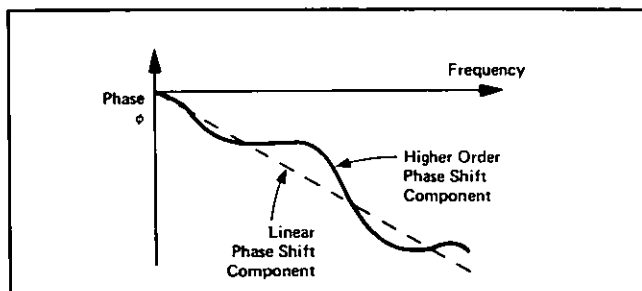
Group delay is the measurement of signal transit time through a test device. It is defined as the derivative of the phase characteristic with respect to frequency:



$$\begin{aligned} \text{GROUP DELAY} &= \tau_g = \frac{-d\phi}{d\omega} && \begin{array}{l} \phi \text{ in Radians} \\ \omega \text{ in Radians} \end{array} \\ &= \frac{-1}{360^\circ} \cdot \frac{d\phi}{df} && \begin{array}{l} \phi \text{ in Degrees} \\ f \text{ in Hz } (\omega = 2\pi f) \end{array} \end{aligned}$$

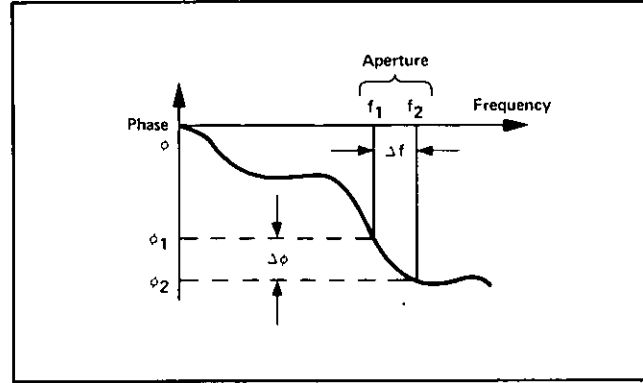
Since the derivative is basically the instantaneous slope (or rate of change of phase with frequency), a perfectly linear phase shift will result in a constant slope and, therefore, a constant group delay.

Note, however, that the phase characteristic will typically consist of both linear and higher order (deviations from linear) components:



The linear component can be attributed to the electrical length of the test device and represents the average signal transit time. The higher order components are interpreted as variations in transit time for different frequencies, and represent a source of signal distortion.

The HP 8510 network analyzer computes group delay from the phase slope. Phase data for the selected parameter is used to find the phase change, $\Delta\phi$, over a specified frequency aperture, Δf , to obtain a linear approximation for the rate of change of phase with frequency:

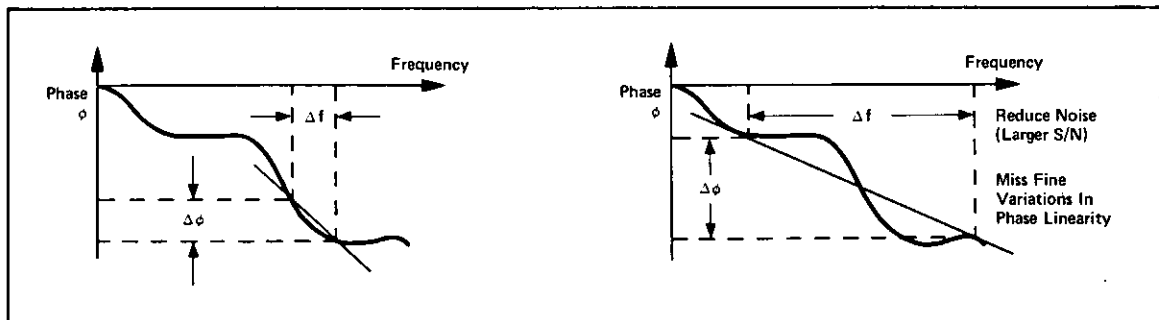


$$\text{GROUP DELAY} = \tau_g = \frac{-d\phi}{d\omega} \quad \begin{array}{l} \phi \text{ in Radians} \\ \omega \text{ in Radians} \end{array}$$

$$= \frac{-1}{360^\circ} \cdot \frac{d\phi}{df} \quad \begin{array}{l} \phi \text{ in Degrees} \\ f \text{ in Hz } (\omega = 2\pi f) \end{array}$$

This value, τ_g , represents the group delay in seconds assuming linear phase change over the frequency aperture Δf .

When deviations from linear phase are present, changing the frequency aperture can result in different values for group delay:



Note that in this case the computed slope varies as the aperture is increased. A wider aperture results in loss of the fine grain variations in group delay. This loss of detail is the reason that in any comparison of group delay data you must know the aperture used to make the measurement.

In using aperture, there is a tradeoff between resolution of fine detail and the effects of noise. The effects of noise can be reduced by increasing the aperture; however, this will tend to smooth out the fine detail. In decreasing the aperture, more fine detail will become visible but the noise will also increase, possibly to the point of obscuring the detail.

For a specific measurement, the average electrical length, or phase slope characteristic of the test device must be considered. To maintain phase resolution uncertainty below 1 percent, use an aperture which results in a phase change of at least 1 degree.

Smoothing is used to change the aperture during the measurement. For example, with smoothing off, group delay is computed using the phase change between each frequency step. With smoothing on, the phase change over the selected percent of sweep is used to compute group delay. Errors in the computation will result if more than 180 degrees of phase shift occurs from one frequency point to the next.

The two CRT display plots in Figure 68 show the effect of increasing the aperture. You may find it to be good practice to use a smaller aperture to assure that fine grain variations are not missed, then increase the aperture to smooth the trace.

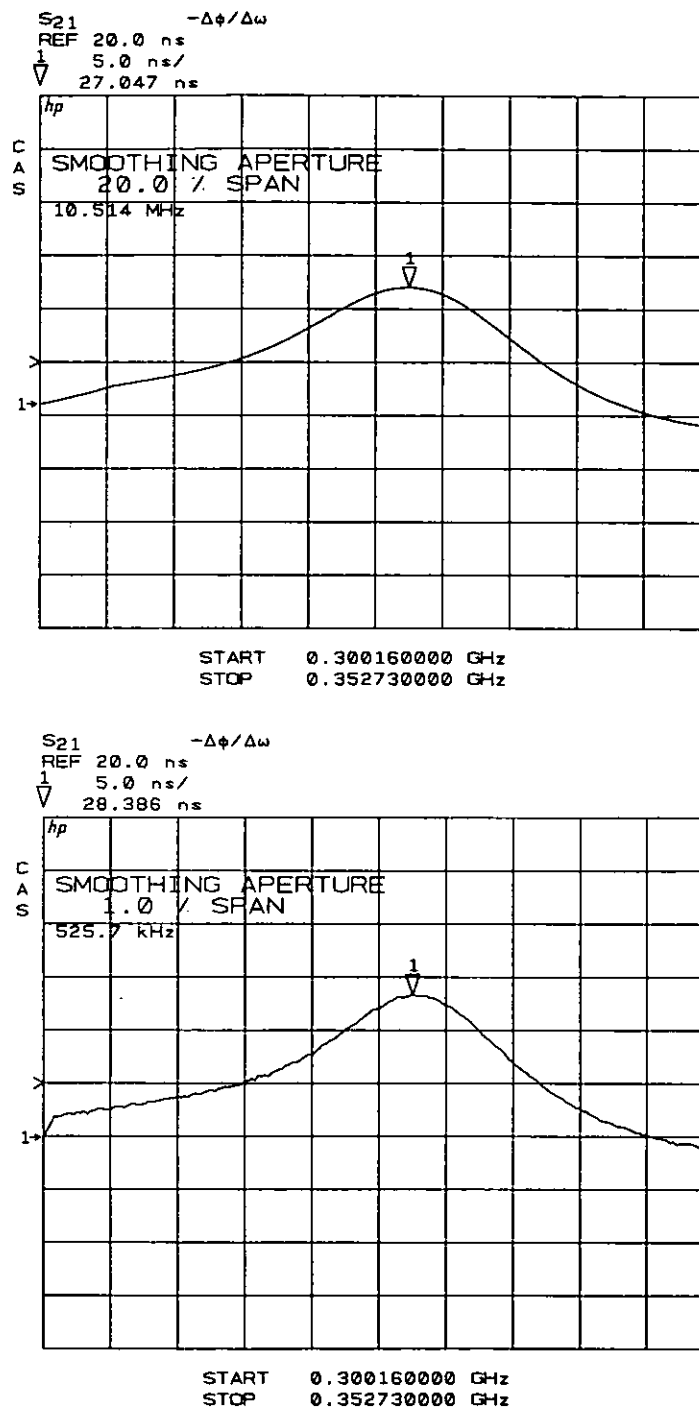


Figure 68. Group Delay Plots with Different Aperture Selections

DEVIATION FROM LINEAR PHASE MEASUREMENT

Measuring deviation from linear phase is an alternative to measuring group delay made possible by the range of the Electrical Delay capability. Insertion phase consists of two components, linear and non-linear. Deviation from linear phase is a measure of the non-linear component of the insertion phase. By compensating the linear insertion phase component using the Electrical Delay controls, the deviation from linear phase over the frequency sweep can be measured directly.

Measuring deviation from linear phase typically produces greater detail than measuring group delay when the phase response of the device under test changes rapidly over a small frequency range. This is because group delay is a derived measurement (the derivative of the phase change with frequency) and is averaged over the specified aperture.

- Perform appropriate measurement calibration.
- Select **PHASE**.
- Press **RESPONSE MENU, ELECTRICAL DELAY**.
- Use the knob (femtosecond resolution), **STEP** keys (1, 2, 5 sequence), or numeric and units (x1=seconds) to enter Electrical Delay.

This measurement determines the linear insertion phase required to equalize the electrical length of the reference and test signal paths, and thus achieve a flat phase trace, with the test device installed. Adding positive Electrical Delay tends to flatten the trace. When the phase response in the area of interest is flat, read the Electrical Delay value in seconds (and the corresponding free space distance in metres).

As an alternate way to enter the Electrical Delay value necessary to flatten the trace, use the Group Delay measurement results as follows:

- Press **RESPONSE MENU, ELECTRICAL DELAY, 0, x1** to zero the Electrical Delay value.
- Press **DELAY**.
- Position the Marker to the center of the area of interest.
- Press **ELECTRICAL DELAY, =MARKER**.
- Press **PHASE**.
- Use the knob for fine adjustment of the Electrical Delay required to flatten the trace in the area of interest.

Note that adding Electrical Delay changes the phase slope and thus changes the group delay measurement. Since Electrical Delay is independent for Channel 1 and Channel 2, you can measure Deviation from Linear Phase and Group Delay simultaneously, as shown in in Figure 69. In Figure 69, Group Delay is the top trace, Deviation From Linear Phase the bottom trace. Press **DISPLAY, DUAL CHANNEL**, then **OVERLAY**. Present the deviation from linear phase display on Channel 1, then select Channel 2, **DELAY**, and zero seconds.

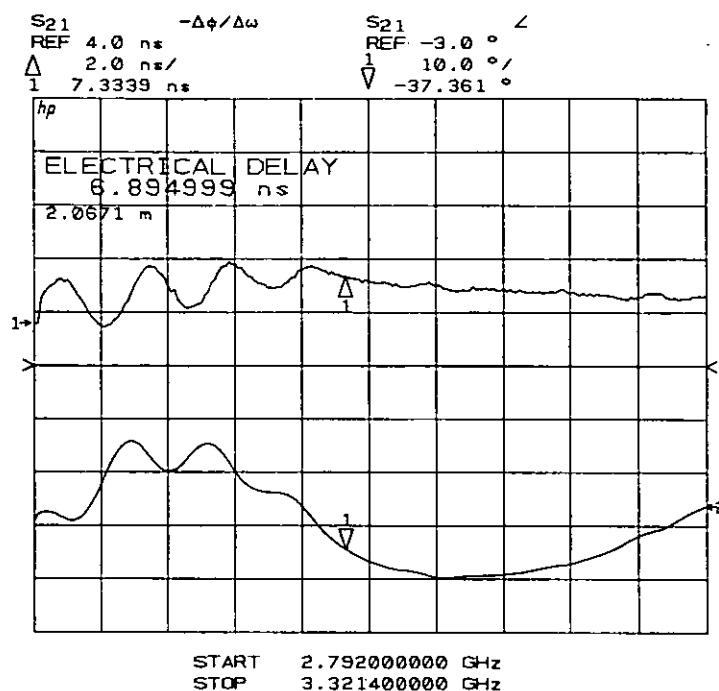


Figure 69. Typical Group Delay and Deviation From Linear Phase Displays

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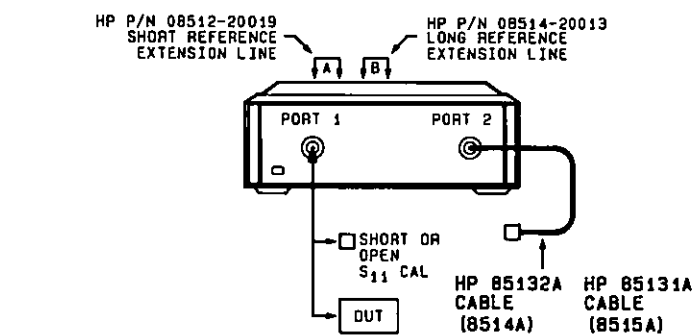
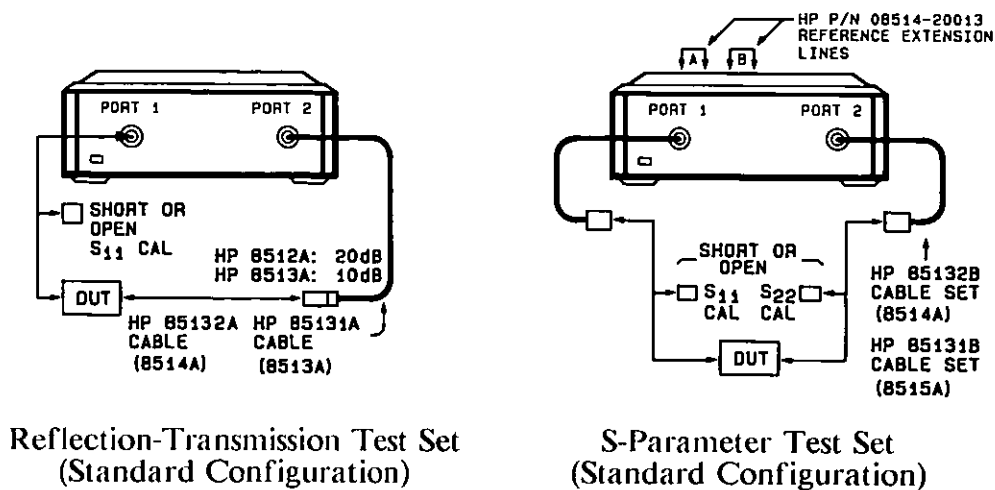
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INTRODUCTION

This part of the HP 8510 network analyzer system manual explains how to make reflection return loss, SWR, S-parameter, impedance, and admittance measurements on a typical one-port or two-port device.

To make reflection measurements on multiport devices all ports except the test port are assumed to be terminated with Z_0 .



S-Parameter Test Set
(Device Under Test Connected Directly to Port 1)

Figure 70. Test Setup for Measuring One-Port Device

REFLECTION MEASUREMENTS

REFLECTION TEST SETUPS

One Port Devices. To measure 1-Port devices, connect the appropriate adapter (if necessary) at Port 1, perform the appropriate measurement calibration, then connect the device under test.

Two-Port Devices. When measuring reflection of a two-port device the device output port must be terminated in Z_0 . This is accomplished either by actually terminating the device output with Z_0 or by using 2-Port error correction to compensate the measurement for the actual terminating impedance.

REFLECTION MEASUREMENT CALIBRATION CHOICES

Frequency Response Only Calibration. A Short Circuit or a Shielded Open Circuit is used as the standard.

1-Port Calibration. Use this for fully error-corrected Reflection Measurements for one-port devices. A Load, a Short Circuit, and a Shielded Open Circuit are used as the standards.

Full 2-Port Calibration. This model provides fully corrected transmission and reflection measurements with an S-parameter test set. It uses a thru, a shielded open circuit, a short circuit, and loads to calibrate at Port 1 and Port 2.

One-Path 2-Port Calibration. This model provides fully corrected transmission and reflection measurements (although not in real time) for a reflection/transmission test set. It uses a thru, a shielded open circuit, a short circuit, and loads to calibrate at Port 1. The operator follows instructions displayed on the CRT to manually reverse the test device for measurement of the reverse parameters.

RETURN LOSS MEASUREMENT

This sequence lists the steps for a typical Return Loss measurement.

- Perform appropriate S_{11} or S_{22} measurement calibration.
- Select LOG MAG.
- Press MARKER, read return loss (dB).

Measurement calibration sets the magnitude and phase ratio between the reference and test signal paths to zero dB at ± 180 degrees with a short circuit at the reference plane. Figure 71 shows the return loss of a bandpass filter. The measurement marker is positioned to the minimum return loss in the passband.

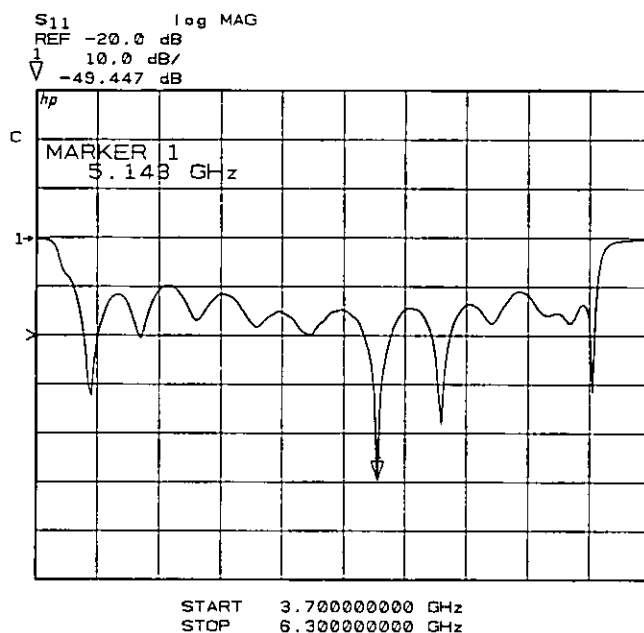


Figure 71. Typical Return Loss Display

SWR MEASUREMENT

The measurement sequence for Standing Wave Ratio, SWR, is the same as that for return loss.

Select the SWR display by pressing FORMAT MENU, then SWR.

SWR is calculated from the return loss value using these equations:

$$\rho = 10^{D/20} \quad \text{where } D = \text{measured value (dB)}$$

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

For example, if the measured magnitude ratio is -30 dB, then ρ is 0.032 and the SWR is 1.07.

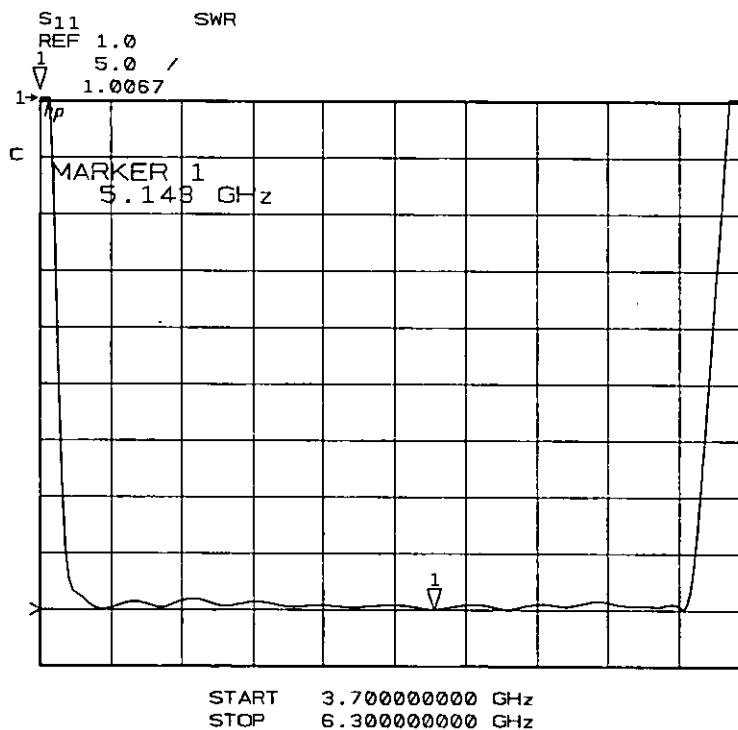


Figure 72. Typical SWR Display

S-PARAMETER MEASUREMENT

The procedure for measurement of reflection S-parameters is identical to measurement of return loss and reflection phase discussed earlier except that the response is viewed using the **LIN mkr** on **POLAR** display on the **FORMAT** menu.

The magnitude is given in linear terms (ρ) and an angle $\angle\theta$, in degrees. A magnitude value greater than one indicates greater than unity reflection; less than one indicates lower than unity reflection. The conversion from dB to linear units is given by the equation

$$\text{dB} = 20 (\log \rho).$$

Note that the **LOG mkr** on **POLAR** format (Figure 73) presents the same data with magnitude given in dB.

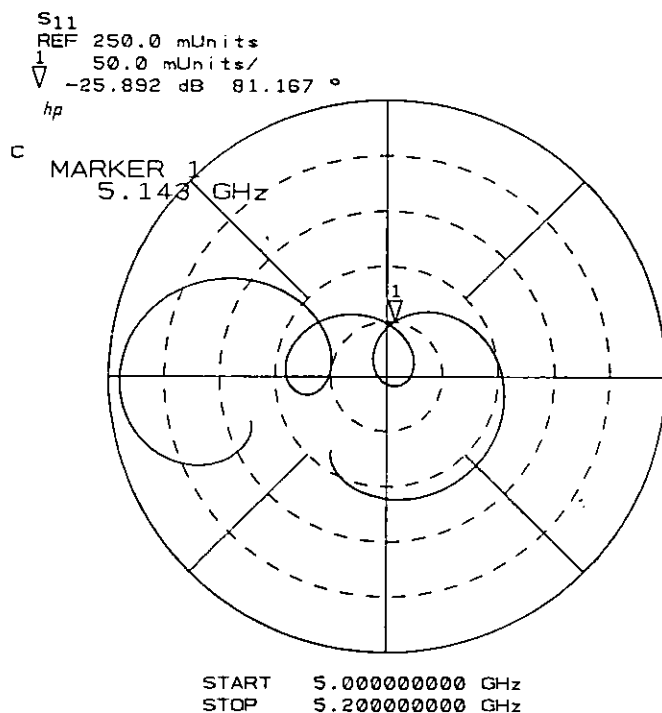


Figure 73. Typical S-Parameter Display

IMPEDANCE MEASUREMENT

Pressing the softkey labeled **SMITH CHART** on the Format Menu presents the reflection measurement using the Smith Chart, providing readout in units of resistance and reactance ($R \pm jx$). The measurement calibration and measurement procedure are the same as for Return Loss described above. The impedance base for the marker readout is set by the system Z_0 .

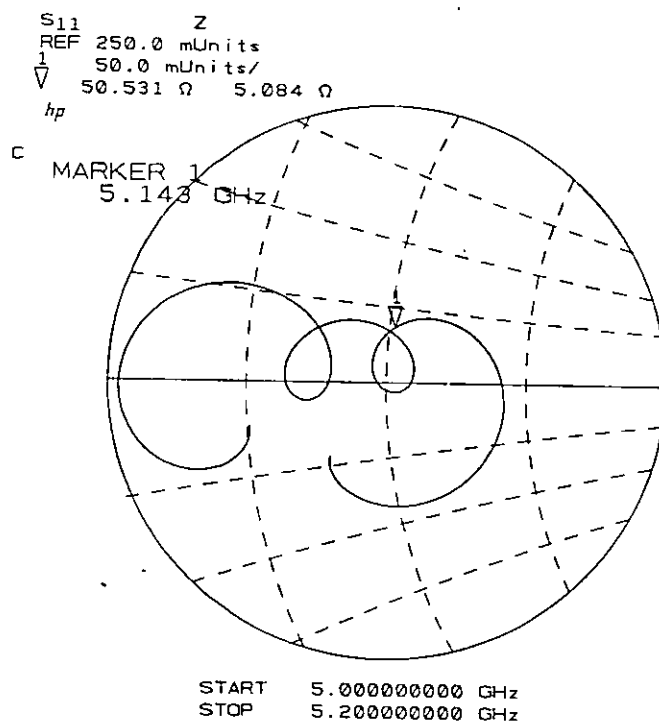


Figure 74. Typical Impedance Display

ADMITTANCE MEASUREMENT

Pressing the softkey labeled **INVERTED SMITH** on the Format Menu presents the reflection measurement using an inverted Smith, or Admittance, chart. The readout is in terms of susceptance and conductance ($G \pm jB$). The measurement calibration and measurement procedure are the same as for the Return Loss measurement described above.

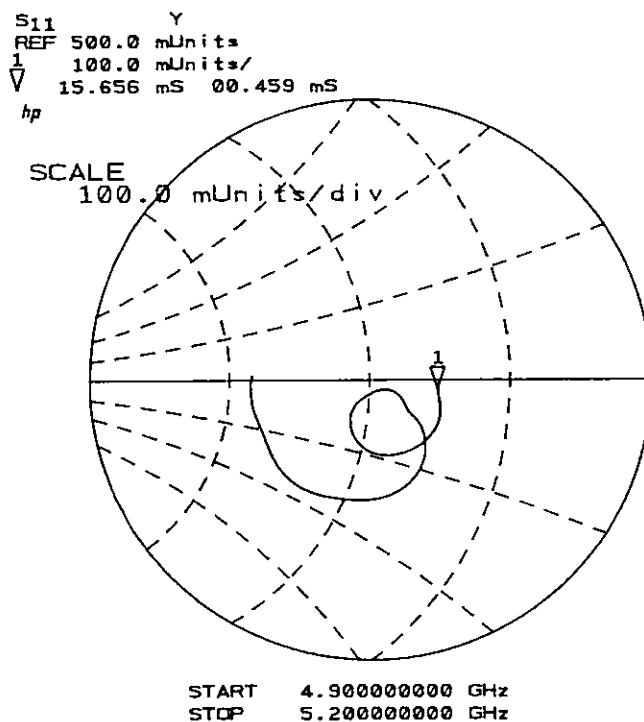


Figure 75. Typical Admittance Display

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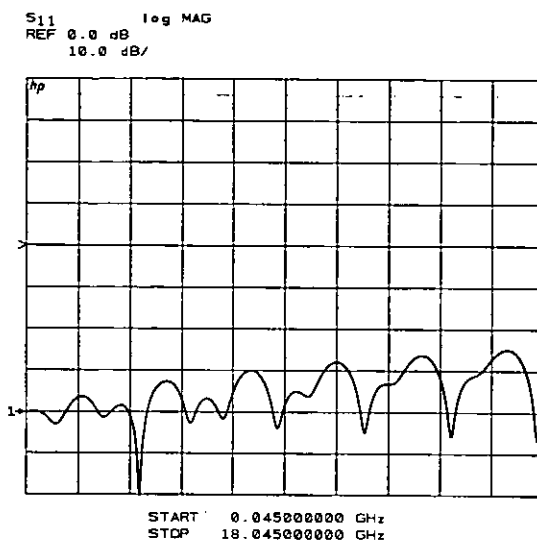
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INTRODUCTION

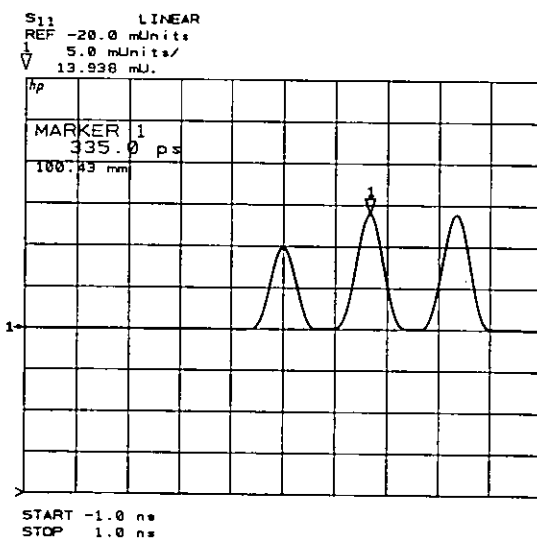
This part of the HP 8510 network analyzer system manual explains how to make reflection and transmission measurements in the time domain. Measurements actually made in the frequency domain are transformed mathematically into the time domain using the internal high-speed computer in the HP 8510, and this requires that the system be equipped with Time Domain Option 010, either at the time of original shipment or by means of the HP 85012A Time Domain Software Package.

The time domain band pass mode is especially useful for measuring band-limited devices and in making fault location measurements. The time domain low pass mode simulates the traditional TDR measurement and makes it possible to determine the type of discontinuity present in a device. Both modes are explained here, as are special time domain features such as masking, windowing, and gating.

FREQUENCY DOMAIN



TIME DOMAIN

*Figure 76. Frequency Domain and Time Domain Measurements*

GENERAL THEORY

The relationship between the Frequency Domain response and the Time Domain response of a network is described by the Fourier Transform:

FREQUENCY DOMAIN

TIME DOMAIN

$H(f)$ -----> $h(t)$

It is therefore possible to measure the response of a device under test (DUT) in the Frequency Domain and then mathematically calculate the inverse Fourier Transform of the data to give the Time Domain response. The internal high-speed computer in the HP 8510 does this calculation using Chirp-Z Fast Fourier Transform computation techniques. The resulting measurement is the fully error-corrected Time Domain reflection or transmission response of the device displayed in near real time.

In Figure 76, the Frequency and Time Domain responses of the same device are displayed. The Frequency Domain reflection measurement is a composite response of all of the discontinuities present in the device under test.

The Time Domain measurement shows the effect of each individual discontinuity as a function of time (or distance). The time domain response shows that the device response consists of three separate impedance changes, with the second discontinuity having a reflection coefficient magnitude of 0.013. This discontinuity is located 167.5 picoseconds from the reference plane relative to the speed of light in a vacuum. (In the time domain trace shown in Figure 76, the display and the marker show the round-trip time to the reflection and back: 335 ps.)

TIME DOMAIN MODES

The HP 8510 network analyzer system has two different modes of operation for Time Domain measurements, Band Pass and Low Pass.

The Band Pass mode, the most general purpose mode of operation, gives the Impulse response of the device. Band Pass will work with any device and over any frequency range and is the least complicated mode to use.

The Low Pass mode is used to simulate the traditional Time Domain Reflectometer (TDR) measurement. The response gives the user information to determine the type of discontinuity present (R, L, or C). The Low Pass mode will also provide either the impulse or step response of the device.

TIME DOMAIN BAND PASS

The Band Pass mode is so named because it will work with band-limited devices. This is a distinct advantage over traditional TDR, which requires that the DUT be able to operate down to dc. With Band Pass there are no restrictions on the frequency range of the measurement.

Reflection Measurements Using Band Pass

Before making Time Domain reflection measurements, it is necessary to perform the appropriate measurement calibration.

- Press **PRESET**.
- Perform an **S₁₁ 1-PORT** calibration.
Leave the sliding load connected and observe the Frequency Domain response as the sliding element is moved.
- Press **DOMAIN, TIME BAND PASS**.
- Press **AUTO** to display the trace and observe the Time Domain response as the sliding element is moved.

The typical Frequency Domain and Time Domain responses of a sliding load are shown in Figure 77.

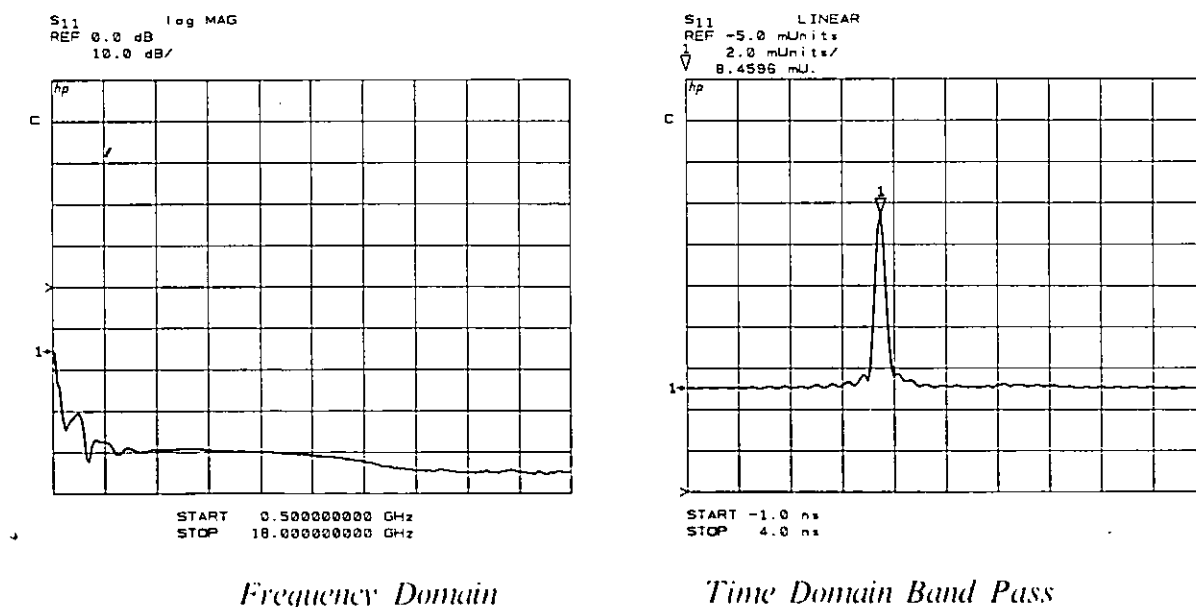


Figure 77. Measurement of a Sliding Load

Move the sliding element and observe the response in both the Frequency Domain and the Band Pass Time Domain. The Frequency Domain measurement of the sliding load should change very little when the slide is moved (unless the calibration is bad). However, the Time Domain measurement shows the individual response of the load element, and it moves along the horizontal axis as the slide is moved.

Interpreting the Band Pass Response Horizontal Axis. In Band Pass reflection measurements, the horizontal axis represents the amount of time that it takes for an impulse, launched at the test port, to reach the discontinuity and return. Thus, this is the two-way travel time to the discontinuity, which in Figure 77 is the load element of the sliding load.

The Marker reads out both the time (x2) and the electrical length (x2) to the discontinuity. The electrical length is obtained by multiplying the time by the velocity of light in a vacuum (2.997925E8 m/sec). To get the physical length, multiply the electrical length by the relative velocity of light in the transmission medium.

In the Time Domain, the **STIMULUS** keys (**START**, **STOP**, **CENTER**, and **SPAN**) refer to time, and they can be used to change the horizontal (time) axis of the display independent of the frequency range chosen. This can be done using the knob, step keys, or the keypad. The keypad terminators also refer to time in seconds (with the lowercase prefixes).

Interpreting the Band Pass Response Vertical Axis. The quantity displayed on the vertical axis depends on the format selected. Band Pass is **PRESET** to the Linear Magnitude format which displays the response in reflection coefficient (ρ) units. This can be thought of as an average reflection coefficient of the discontinuity over the frequency range of the measurement.

Other useful formats are listed in Table 13. The Band Pass response gives the magnitude of the reflection only and has no impedance information (R, L, or C). This information is available, however, in the Low Pass response.

Table 13. Useful Time Domain Band Pass Formats

FORMAT	PARAMETER
LINEAR MAG LOG MAG SWR	REFLECTION COEFFICIENT UNITS RETURN LOSS (dB) SWR UNITS

Fault Location Measurements Using Band Pass

The Band Pass mode is very useful in making fault location measurements. Figure 78 shows the Band Pass Time Domain measurement of a length of coaxial cable having multiple discontinuities and terminated in 50 ohms. Note the responses of each discontinuity and of the terminating element.

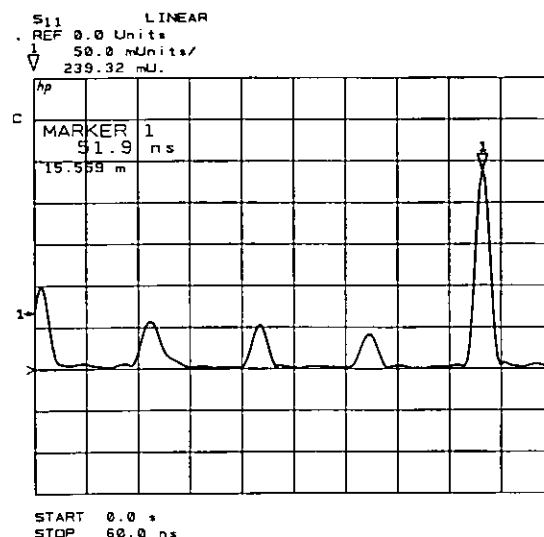


Figure 78. Cable Fault Location Measurement Using Band Pass

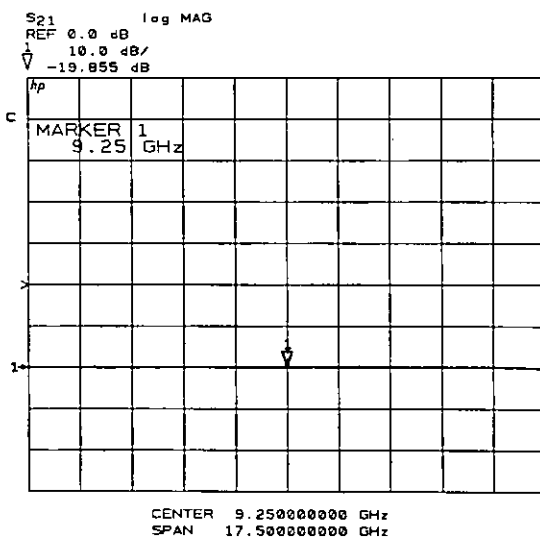
Also, because the Band Pass mode will work over any frequency range, it can be used to do fault location in band-limited transmission media, such as waveguide.

Transmission Measurements in Band Pass

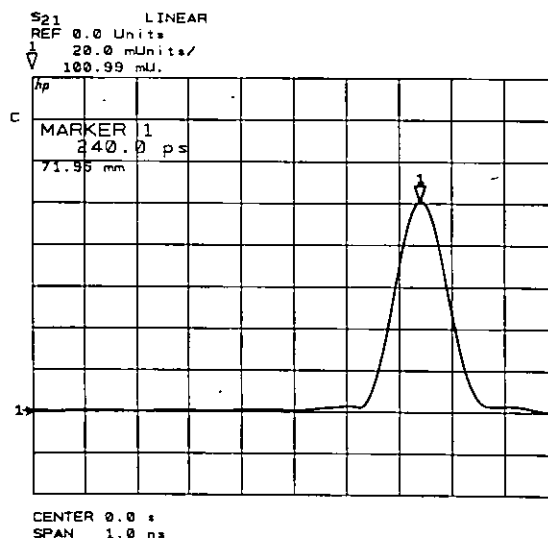
The Band Pass mode is also useful in making transmission measurements. Before making Time Domain transmission measurements, it is necessary to perform the appropriate measurement calibration.

- Press **PRESET**.
- Perform an **S₂₁ RESPONSE, FULL 2-PORT, or ONE PATH 2-PORT** calibration.
- Connect a 20 dB coaxial attenuator and observe the Frequency Domain response.
- Press **DOMAIN, TIME BAND PASS**.
- Press **AUTO** to display the trace.

The Frequency Domain and Time Domain responses of a 20 dB attenuator are shown in Figure 79.



Frequency Domain Response



Time Domain Response

Figure 79. Transmission Measurement in Time Domain Band Pass

Interpreting the Band Pass Transmission Response Horizontal Axis. In Time Domain transmission measurements, the horizontal axis is displayed in units of time. The response of the thru connection used in the calibration is an impulse at $t = 0$ and with unit height, indicating that the impulse made it through in zero time and with no loss. When a device is inserted, the time axis indicates the propagation delay or electrical length of the device. Note that in Time Domain transmission measurements, the value displayed is the actual electrical length (not $\times 2$). The Marker reads out the electrical length in both time and distance. You must multiply the distance number by the relative velocity of the transmission medium to get the actual physical length.

Interpreting the Band Pass Transmission Response Vertical Axis. The vertical axis displays the transmission response in transmission coefficient units (τ) in the Linear Magnitude format and the transmission loss or gain in dB in the Log Magnitude format. This can be thought of as an average of the transmission response over the frequency range of the measurement. For the 20 dB attenuator example, the Band Pass response has a magnitude of 0.10 transmission coefficient units (-20 dB insertion loss).

TIME DOMAIN LOW PASS

The Low Pass mode of Time Domain is used to simulate the traditional TDR measurement. This mode gives the user information to determine the type of discontinuity (R, L, or C) that is present. Low Pass provides the best resolution (fastest rise time), and it may be used to give either the Step or Impulse response of a device.

The Low Pass mode is less general purpose than Band Pass in that it places strict limitations on the frequency range of the measurement. It requires that the Frequency Domain data points be harmonically related from dc to STOP frequency ($STOP = N \times START$, where $N = \text{NUMBER of POINTS}$). The dc frequency response is extrapolated from the low frequency data. The requirement to pass dc is the same limitation that exists for traditional TDR measurements.

Setting Frequency Range for Time Domain Low Pass

Before making measurements in the Low Pass mode, the frequency range of the measurement must be set so that $STOP = n \times START$, where n is the number of points. This can be done directly by the user, or else it will be done automatically when the **SET FREQ. (LOW PASS)** softkey is pressed. This key is included in the CAL Menu and also after the **TIME LOW PASS** softkey. Because the HP 8510 will not convert to the Low Pass mode until the **SET FREQ. (LOW PASS)** key is pressed at least once, it is very important that this be done before calibrating. Otherwise, going to Low Pass will change the measurement frequencies which will turn off error correction.

Pressing **SET FREQ. (LOW PASS)** will set the STOP frequency as close as possible to the value entered by the user, and it will set the START frequency equal to $STOP / N$. As an example, if the user selects 101 points, with $START = 100$ MHz, and $STOP = 5.05$ GHz, then pressing **SET FREQ. (LOW PASS)** will change START to 50.0 MHz ($= STOP / 101$).

Because the lowest measurement frequency for the HP 8510 is 45 MHz, for each value of N there is a minimum allowable STOP frequency that can be used, and this is given by $N \times 45$ MHz. Table 14 describes the minimum frequency range that can be used for each value of N when making Low Pass Time Domain measurements.

Table 14. Minimum Frequency Ranges For Time Domain Low Pass

NUMBER of POINTS (N)	MINIMUM FREQUENCY RANGE
51	45 MHz to 2.295 GHz
101	45 MHz to 4.545 GHz
201	45 MHz to 9.045 GHz
401	45 MHz to 18.045 GHz
NOTE: If the source cannot operate over the required frequency range, the HP 8510 will nevertheless attempt the operation.	

If the STOP frequency entered is lower than the minimum that is available for the value of N selected, then pressing the **SET FREQ. (LOW PASS)** softkey will change the STOP frequency to that minimum value. For example, if Number of Points = 201, START = 100 MHz, and STOP = 6.00 GHz, then pressing **SET FREQ. (LOW PASS)** will change START to 45 MHz and STOP to 9.045 GHz (= START x 201). Because of these restrictions on the frequency range of the measurement, the Low Pass mode is most useful for measuring lowpass broad band devices.

Analyzing Low Pass Reflections

As mentioned, the Low Pass mode gives the TDR response of the device under test. This response contains information that is useful in determining the type of discontinuity present. Before making actual measurements in the Low Pass mode, it is helpful to review the Low Pass responses of known discontinuities. Each circuit element of Figure 80 was simulated to show the corresponding Low Pass Time Domain S_{11} response waveform. The Low Pass mode will give the response of the device to either a Step or an Impulse stimulus. (Mathematically, the Low Pass Impulse stimulus is the derivative of the Step stimulus.)

These Time Domain responses were generated using the Circuit Modeling Program which is supplied with the Time Domain option (described at the end of the Time Domain section).

LOW PASS REFLECTIONS (REAL FORMAT)

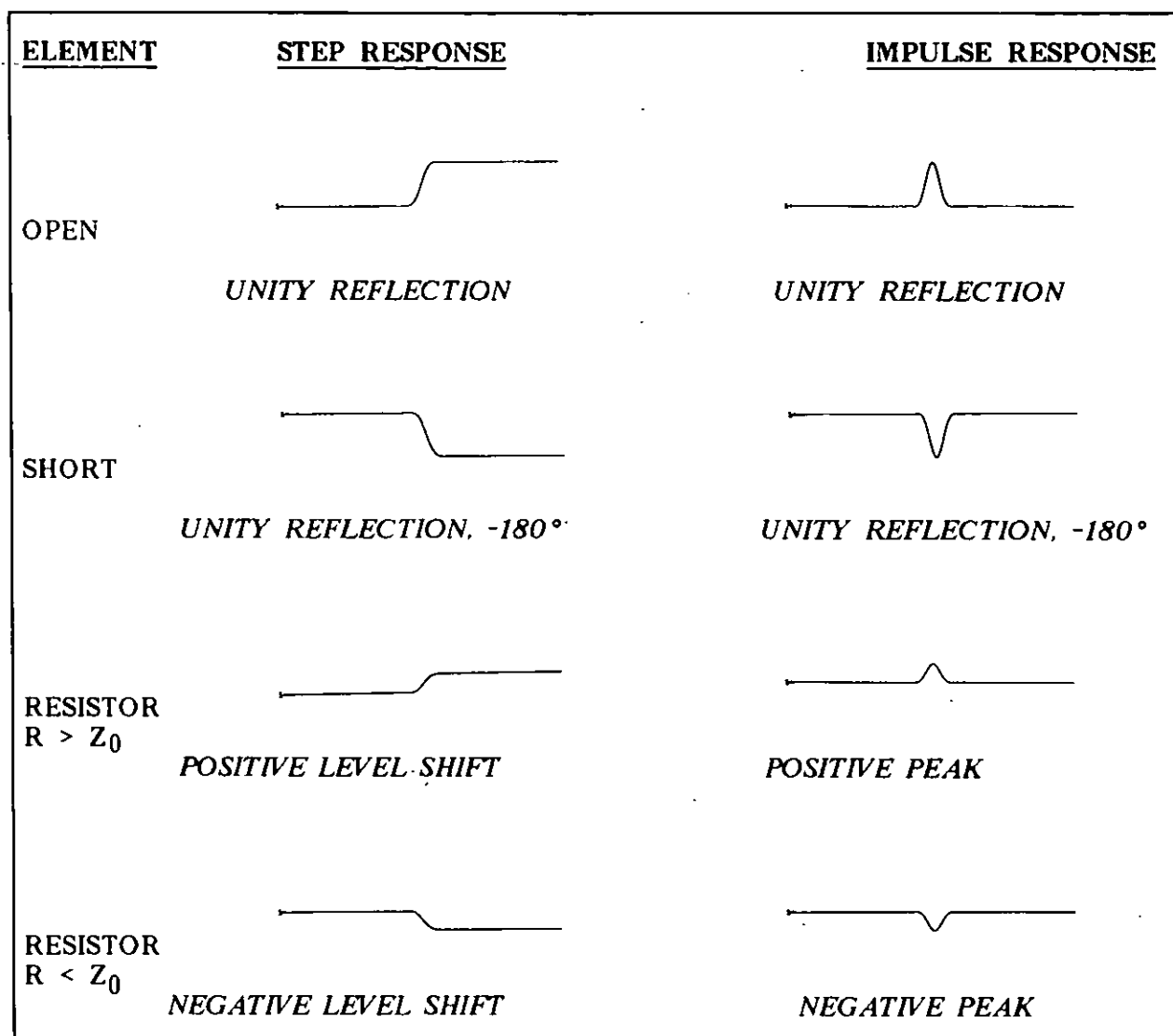


Figure 80. Low Pass Step and Impulse Response Waveforms (1 of 2)

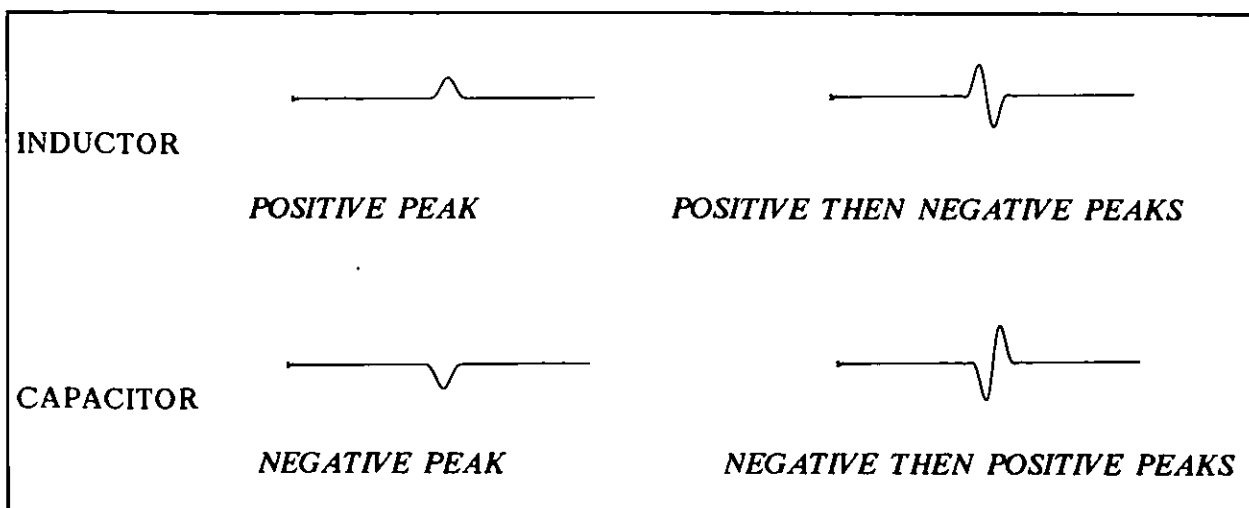


Figure 80. Low Pass Step and Impulse Response Waveforms (2 of 2)

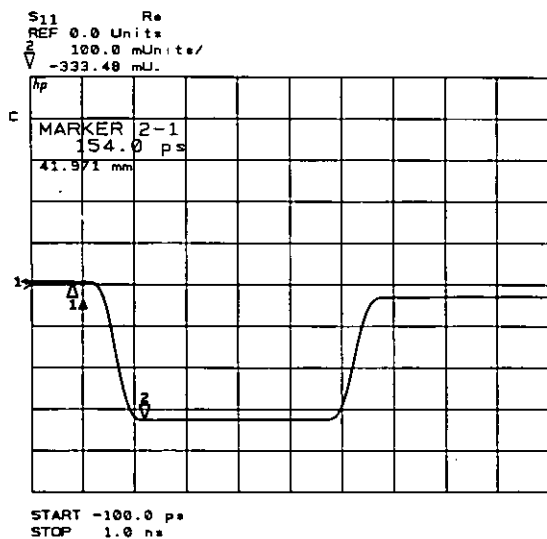
Reflection Measurements in Time Domain Low Pass

To make measurements in the Low Pass mode, use the following procedure:

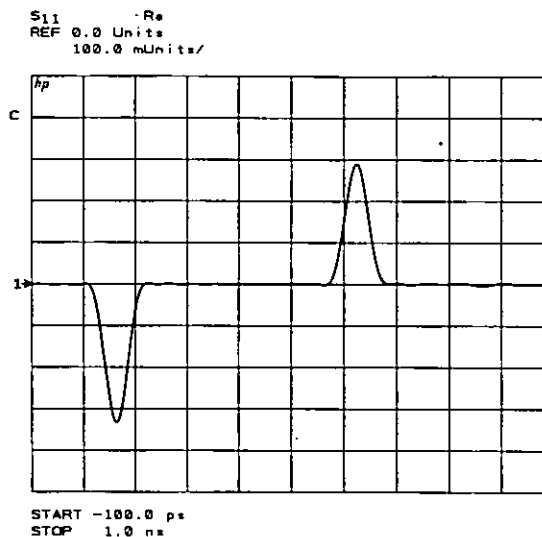
- Press **PRESET**.
- **CAL**, **CAL 1** (7 mm) or **CAL 2** (3.5 mm).

The Cal Type menu (Figure 51, p. 183) will be displayed.

- Press **SET FREQ. (LOW PASS)**.
- Perform an **S₁₁ 1-PORT** calibration.
- Connect a 25 Ω airline and broadband load.
- Press **DOMAIN, TIME LOW PASS, SET FREQ. (LOW PASS)**.
- Press **AUTO** to view the STEP response, Figure 81.
- To view the Low Pass Impulse response of the device, press **DOMAIN, SPECIFY TIME, IMPULSE (LOW PASS)**.



STEP Response



IMPULSE Response

Figure 81. Low Pass Step Response of a 25 Ω Airline and Fixed Load

Interpreting the Low Pass Response Horizontal Axis. The horizontal axis for the Low Pass measurement is the 2-way travel time to the discontinuity, the same as for the Band Pass mode. Also, the Marker function displays both the time (x2) and electrical length (x2), obtained by multiplying the time by the velocity of light in a vacuum (2.997925E8 m/sec). To get the actual physical length, multiply by the relative velocity of light in the propagation medium.

Interpreting the Low Pass Response Vertical Axis. The vertical axis depends upon the format chosen. In the Low Pass mode, the most useful format is **REAL**, which displays the TDR response in reflection coefficient units.

This points out a key difference between the Band Pass and Low Pass modes. The Band Pass measurement is actually the response of the device to an RF pulse with an impulse shaped envelope. For Band Pass, the Inverse Fourier Transform of the (complex) Frequency Domain data gives a complex (real and imaginary parts) Time Domain response, and it is the magnitude of this response that is displayed.

In the Low Pass mode, because the Frequency Domain data is taken at harmonically related frequencies down to dc, the Inverse Fourier Transform has only a real part (the imaginary part is zero). Therefore, the most useful format for the Low Pass mode is the **REAL** format, which displays the response in reflection coefficient units. Other useful formats are listed in Table 15.

Table 15. Useful Time Domain Low Pass Formats

FORMAT	PARAMETER
REAL LOG MAG SWR	REFLECTION COEFFICIENT UNITS RETURN LOSS (dB) SWR UNITS

Trace Bounce. Depending on the magnitude of the response and on the test set used, the Low Pass Step response of the device may exhibit a phenomenon called display trace bounce. This is normal, and it can be improved by turning on **AVERAGING** (under the Response MENU). This trace bounce is caused by a loss of measurement dynamic range at low frequencies because of the roll off of the coupler-based test sets (HP 8512A and HP 8514A) below 500 MHz (down -30 dB at 45 MHz). The trace bounce is a factor of 30 times less in the bridge-based test sets (HP 8513A and HP 8515A), which have flat magnitude frequency responses down to 45 MHz.

As a second example of Low Pass reflection measurements, consider the Low Pass Step response of a 30 cm airline and fixed load, shown in Figure 82.

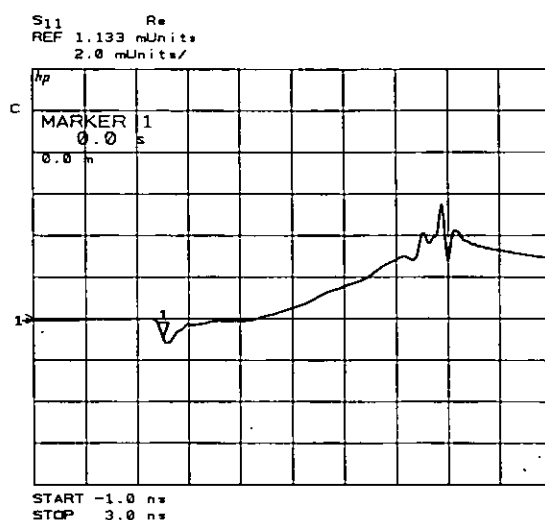


Figure 82. Step Response of a 30 cm Airline and Fixed Load

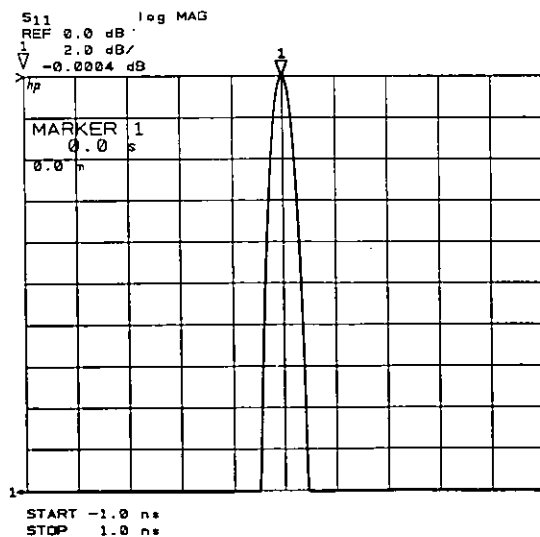
The Low Pass response at $t = 0$ is that of the airline connection. By comparing this response with the theoretical Low Pass responses, one can determine whether the mismatch present is capacitive or inductive. The discontinuity at the first connection of the airline is capacitive. The upward slope of the center section of the response is caused by the loss in the airline. The second major response is that of the fixed load.

TIME DOMAIN CONCEPTS

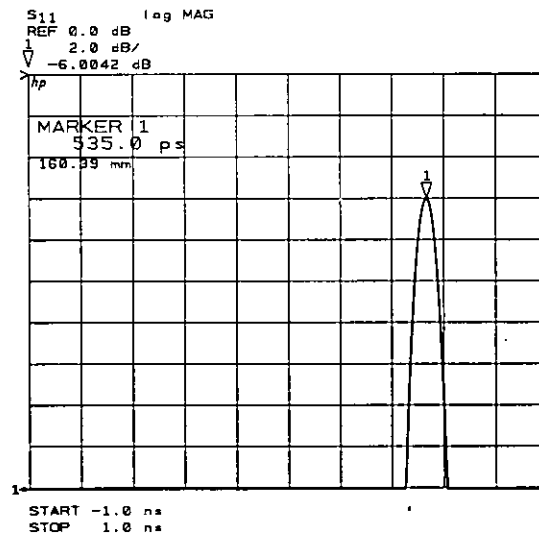
MASKING

Masking is a physical phenomenon in which the Impulse or Step response of one discontinuity affects the response of each subsequent discontinuity in the circuit. This occurs because the energy reflected from or absorbed in the first discontinuity never reaches the second. In the 25 Ω airline example (Figure 81), the Low Pass step response shows the reflection coefficient at the first discontinuity of -0.33, which is correct for an impedance of 25 Ω . However, at the end of the 25 Ω section the response does not return to zero reflection coefficient, which it should at a 50 Ω impedance. The reason is that the step incident on the second response is of less than unity amplitude because of the energy reflected in the first mismatch.

As a second example of masking, consider the Time Domain response of a 3 dB attenuator and a short circuit. The Impulse response of the short circuit alone, Figure 83, shows a return loss of 0 dB. However, the response of the short circuit placed at the end of the 3 dB attenuator displays a return loss of -6 dB. This value actually represents the forward and return path loss through the attenuator, and it illustrates how a lossy network can affect the responses that follow it.



Short Circuit



Short at End of 3dB Pad

Figure 83. Masking Example: 3 dB Pad and Short Circuit

WINDOWING

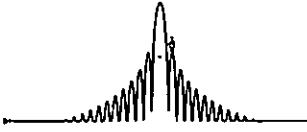
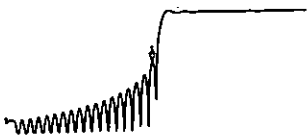
The HP 8510 has a feature called WINDOWING that is designed to enhance Time Domain measurements. The need for Windowing is due to the abrupt transitions in the Frequency Domain measurement at the START and STOP frequencies. This band-limiting of the Frequency Domain response causes overshoot and ringing in the Time Domain response. It causes the (un-Windowed) Impulse stimulus to have a $\sin(kt)/kt$ shape ($k = \pi/\text{frequency span}$), which has two effects that limit the usefulness of the Time Domain measurement:

- (1) Finite Impulse Width. This limits the ability to resolve between two closely spaced responses. The effects of the finite impulse width cannot be improved without increasing the frequency span of the measurement. See Table 16.
- (2) Sidelobes. The Impulse sidelobes limit the dynamic range of the Time Domain measurement by hiding low level responses within the sidelobes of the higher level responses. The effects of sidelobes can be improved by Windowing. See Table 17.

Windowing improves the dynamic range of the Time Domain measurement by modifying (filtering) the Frequency Domain data prior to conversion to the Time Domain to produce an impulse stimulus with lower sidelobes. This greatly enhances the effectiveness in viewing Time Domain responses that are very different in magnitude. The sidelobe reduction is achieved, however, as the tradeoff with increased impulse width. The effect of Windowing on the STEP stimulus (integral of the impulse stimulus, Low Pass mode only) is a reduction of overshoot and ringing at the tradeoff with increased rise time.

Three Windows are available: **MINIMUM**, **NORMAL**, and **MAXIMUM**. The Window may be selected by pressing **DOMAIN**, **SPECIFY TIME**. The sidelobe levels of the Time Domain stimulus depend only on the Window that is selected (see Table 17). **MINIMUM** is essentially no window and therefore gives the highest sidelobes; **NORMAL** (selected by **PRESET**) gives reduced sidelobes and is normally the most useful; **MAXIMUM** gives the minimum sidelobes and thus provides the greatest dynamic range.

Table 16. Time Domain Window Characteristics

	WINDOW TYPE	IMPULSE SIDELOBE LEVEL	STEP SIDELOBE LEVEL
	MINIMUM	-13 dB	-21 dB
	NORMAL	-44 dB	-60 dB
	MAXIMUM	< -90 dB	< -90 dB

The sidelobe reduction due to Windowing is achieved at a tradeoff with an increase in the Step (10% - 90%) Rise Time and the Impulse (50%) width. These parameters also depend upon the frequency span of the measurement, and they can be calculated using the approximate formulas given in Table 17.

Table 17. Approximate Formulas For Step Rise Time and Impulse Width

<u>LOW PASS</u>			
STEP RISE TIME (10% - 90%)	$= \frac{0.45}{\text{FREQ SPAN}}$	x	{ 1.0 MINIMUM WINDOW 2.2 NORMAL WINDOW 3.3 MAXIMUM WINDOW
IMPULSE WIDTH (50%)	$= \frac{0.60}{\text{FREQ SPAN}}$	x	{ 1.0 MINIMUM WINDOW 1.6 NORMAL WINDOW 2.4 MAXIMUM WINDOW
<u>BAND PASS</u>			
IMPULSE WIDTH (50%)	$= \frac{1.20}{\text{FREQ SPAN}}$	x	{ 1.0 MINIMUM WINDOW 1.6 NORMAL WINDOW 2.4 MAXIMUM WINDOW

Multiply by the velocity of light in a vacuum (2.997925E8 m/sec) to get electrical length, and then by the relative velocity of light in the the propagation medium to get physical length.

The purpose of windowing is to make the Time Domain response more useful in isolating and identifying individual responses. The window does not affect the displayed Frequency Domain response. It is turned on only when the Time Domain response is viewed. Figure 84 shows typical effects of windowing on the Time Domain response of the reflection measurement of a short circuit.

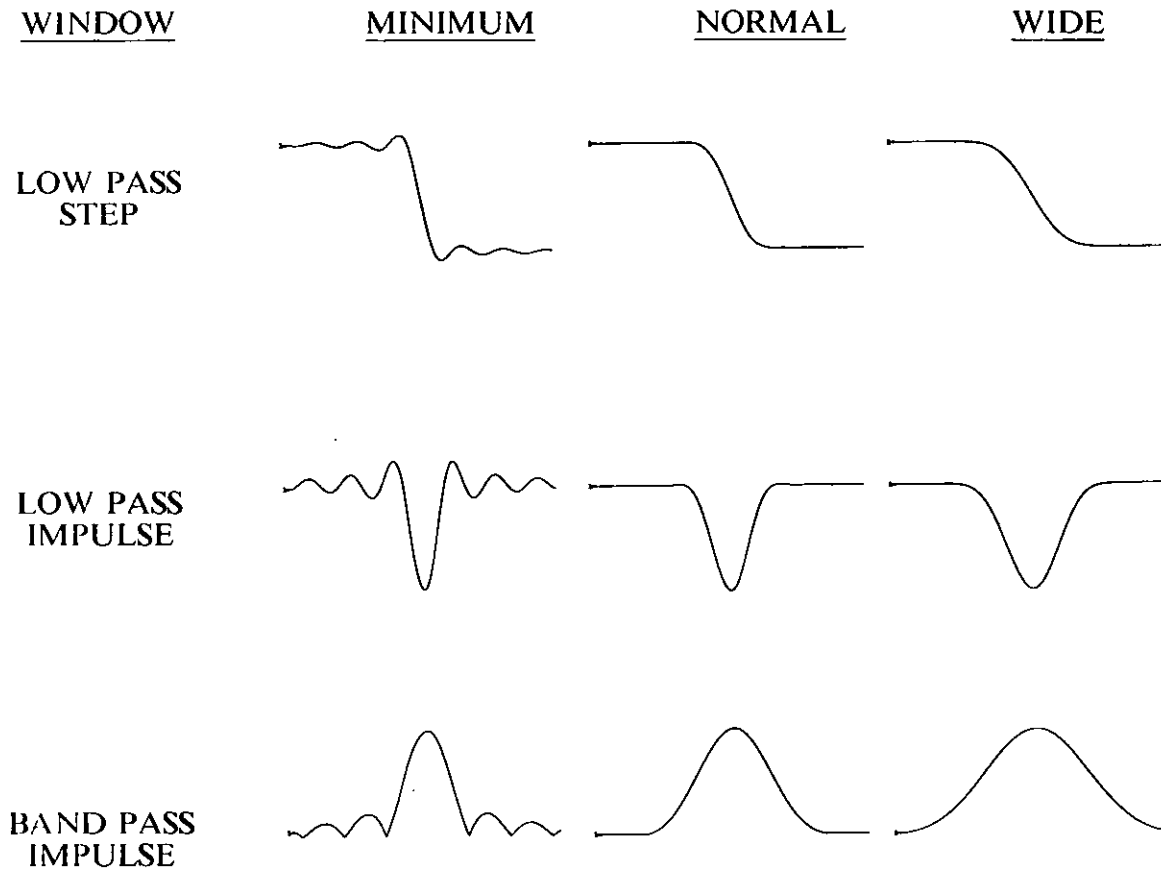


Figure 84. Effect of Windowing on Time Domain Responses of a Short Circuit

RANGE

In the Time Domain, the RANGE is defined as the length in time that a measurement can be made without encountering a repetition of the response (see Figure 85). The repetition of the Time Domain response occurs at regular intervals of time and is a consequence of the Frequency Domain data being taken at discrete frequency points rather than being continuous.

The Range of a measurement is equal to $1/\Delta F$, the spacing between frequency data points. It is therefore directly proportional to the number of points and inversely proportional to the Frequency Span (STOP - START frequency) and can be calculated using the following formula.

$$\text{RANGE} = 1/\Delta F = (\text{Number of Points} - 1)/\text{Frequency Span}$$

As a sample calculation, for a 201 point measurement from 50 MHz to 18 GHz (SPAN = 17.95 GHz), the Range is $(201 - 1) / 17.95 \text{ GHz} = 11.1 \text{ nsec}$ (3.34 m). Thus the device under test has to be 3.34 m or less in electrical length for a transmission measurement (1.67 m for a reflection measurement) or else an overlapping of the Time Domain responses (aliasing) will occur. (Remember to multiply by the relative velocity of light in the medium to get actual physical length.)

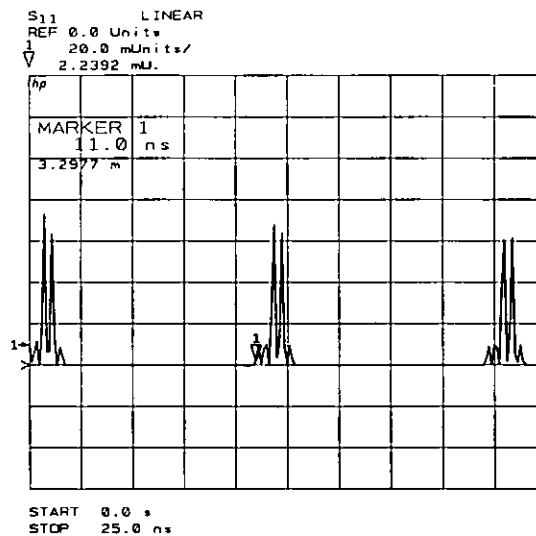


Figure 85. Time Domain Measurement Showing Response Repetitions

To increase the Time Domain measurement Range, it is usually better to first increase the number of points, because decreasing the frequency span will reduce the resolution.

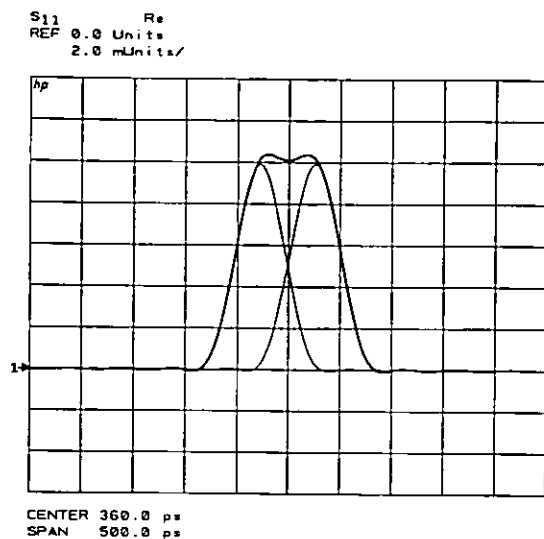
RESOLUTION

There are two different terms involving resolution in Time Domain: RESPONSE-RESOLUTION and RANGE-RESOLUTION. The Time Domain Response-Resolution is defined as the ability to resolve two closely spaced responses. In other words, if two responses are present, this is how closely they can be spaced and still be distinguished from one another. For responses of equal amplitude, the Response-Resolution is equal to the 50% (-6 dB) impulse width. It therefore is inversely proportional to the frequency span of the measurement and is also a function of the window that is used. Approximate formulas for calculating the 50% Impulse width are given in Table 17. For responses that are of different amplitudes, the Response-Resolution will be wider.

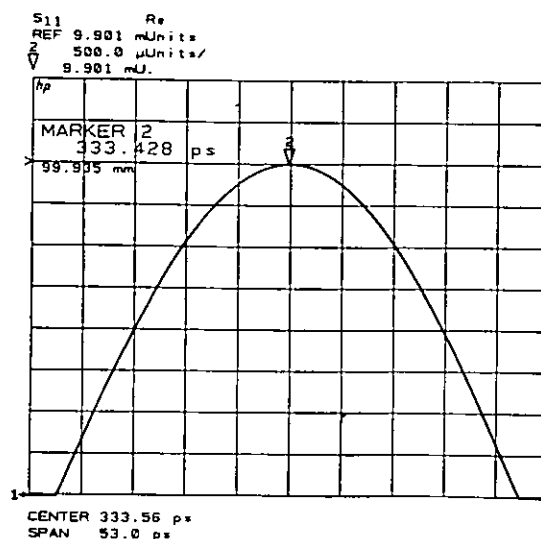
Range-Resolution is defined as the ability to locate a single response in time. In other words, if only one response is there, this is how closely you can pinpoint the peak of that response. The Range-Resolution is equal to the digital resolution of the CRT display which is the time span displayed divided by the number of points. Maximum Range-Resolution is achieved by centering the response on the display and then reducing the time span. Therefore, the Range-Resolution is always much finer than the Response-Resolution.

To illustrate the difference between these two resolution terms, consider a measurement with a frequency span of 18 GHz. For Low Pass, with a Normal Window, the Response-Resolution (Impulse width) is 53 psec ($0.6 \times (1/18 \text{ GHz}) \times 1.6$) or 16 mm in electrical length (53 psec $\times 2.997925 \text{E}8 \text{ m/sec}$). As illustrated in Figure 86, two Time Domain responses of equal amplitude separated by 16 mm could be resolved in this Time Domain measurement. (This indicates an actual discontinuity separation of 8 mm for reflection measurements.)

Now consider the case where only one response is present. By centering that response on the display and adjusting the time SPAN to equal the 50% Impulse width (53 psec, 16 mm), Figure 86, the Range-Resolution is reduced to 40 μm (16 mm/401 points). The Range-Resolution can be further reduced by narrowing the time span.



Response-Resolution



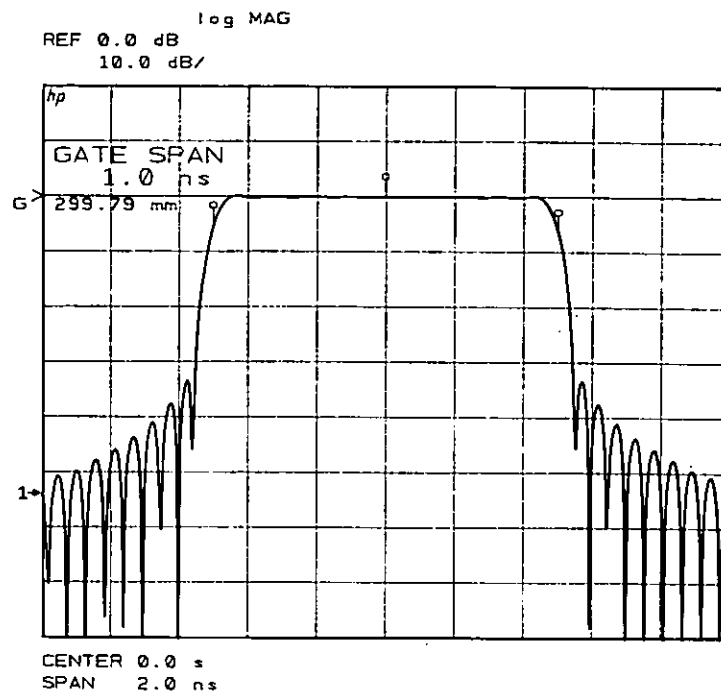
Range-Resolution

Figure 86. Resolution in Time Domain

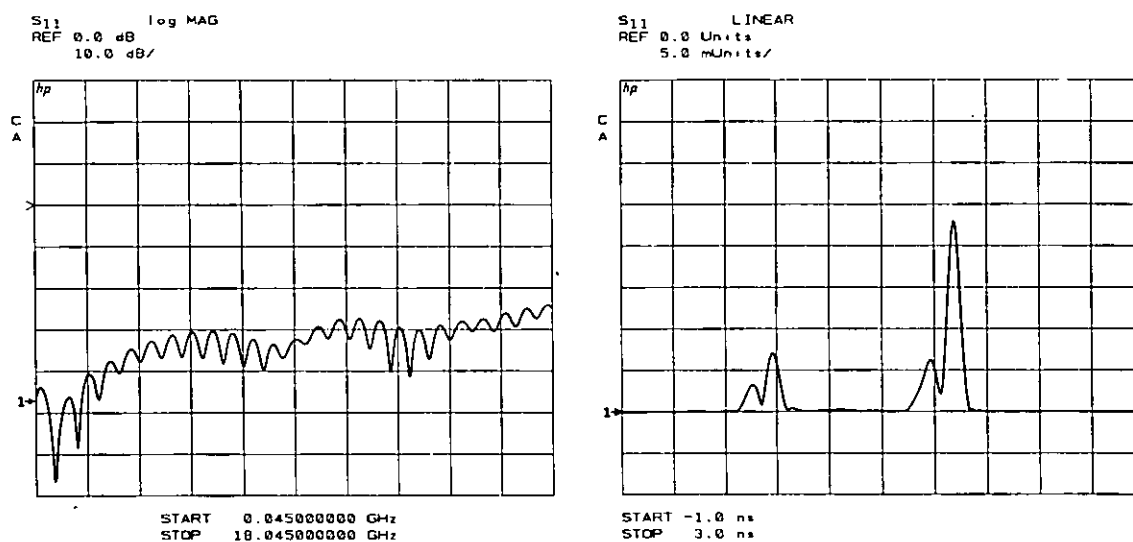
GATING

The HP 8510 gating feature gives the user the flexibility to selectively remove reflection or transmission Time Domain responses. In converting back to the Frequency Domain, the effects of the responses outside the Gate are removed. In a reflection measurement, you can remove the effects of unwanted mismatches or else isolate and view the response of an individual mismatch. In a transmission measurement you can remove the responses of multiple transmission paths.

Setting the Gate. A Gate is a temporal band pass filter used to filter out unwanted Time Domain responses. Responses outside the selected gate are not included in the trace. There are three Gate indicators: START, CENTER, and STOP. The Gate has a bandpass filter shape, as shown in Figure 87. The GATE CENTER indicates the center time (not frequency) of this filter, and the Gate START and STOP indicate the -6 dB cutoff times. Gate SPAN = STOP - START.

*Figure 87. Gate Shape*

Consider using gating to analyze the response of a 7mm-to-3.5mm adapter connected to a 3.5mm airline and a fixed load. The Frequency Domain and the Band Pass Time Domain responses of such a setup are shown in Figure 88.



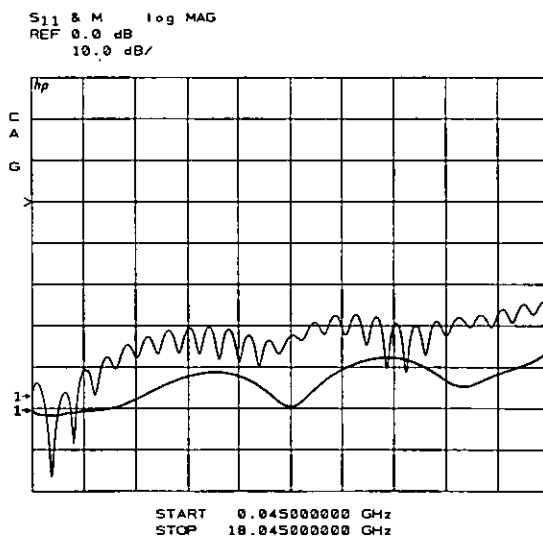
Frequency Domain Response

Time Domain Response

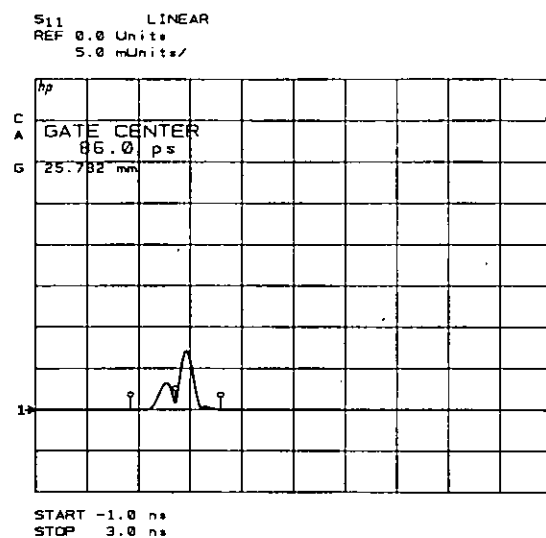
Figure 88. Reflection Measurement of 7mm-to-3.5mm Adapter, Airline, and Load

We will now use gating to analyze the response of the adapter only.

- Press **DOMAIN, TIME BAND PASS, SPECIFY GATE**.
- The three Gate indicators will now appear on the screen. Press **GATE CENTER**, and use the knob or keypad to move the center indicator to $t = 0$.
In Figure 89, the time domain display shows the gate center, 86 ps, as the Active Function.
- Press **GATE SPAN** and use the knob or keypad to adjust the Gate Span to 0.70 ns.
- Press **GATE ON** to turn on the Gate.
The responses outside the Gate will be removed. See Figure 89.
- Press **DOMAIN, FREQUENCY**.
View the gated Frequency Domain response of the adapter. See Figure 89.



Frequency Domain Response



Time Domain Response

Figure 89. Gated Responses of the 7mm-to-3.5mm Adapter

The darker shaded trace in the Frequency Domain plot of Figure 89 shows the Gated Frequency Domain response, which is that of the adapter only. The effects of the fixed load on the measurement are removed.

Select Gate Shape. Four different Gate shapes are available: **MINIMUM**, **NORMAL**, **WIDE**, and **MAXIMUM**. Each of the Gates have different passband flatness, cutoff rate, and sidelobe levels. T1 indicates the Gate span which is the time between the Gate start and stop indicators. T2 is the time between the edge of the Gate passband and the -6 dB Gate stop time. T3, equal to T2, is the time between the Gate stop time and the point where the filter first reaches the level of the highest Gate sidelobe. The Gate characteristics for each Gate shape are listed in Table 18.

Table 18. Gate Characteristics

GATE SHAPE	PASSBAND RIPPLE	SIDELOBE LEVELS	CUTOFF TIME T2 = T3	MINIMUM GATE SPAN
MINIMUM	± 0.40 dB	-24 dB	0.6/ FSPAN	1.2/ FSPAN
NORMAL	± 0.04 dB	-45 dB	1.4/ FSPAN	2.8/ FSPAN
WIDE	± 0.02 dB	-52 dB	4.0/ FSPAN	8.0/ FSPAN
MAXIMUM	± 0.01 dB	-80 dB	11.2/ FSPAN	22.4/ FSPAN

The Passband Ripple and Sidelobe Levels are descriptive of the gate (filter) shape. The Cutoff Time, T2 = T3 (see Table 18), indicates how fast the gate filter rolls off. For each gate shape, there is also a Minimum Gate Span ($T1_{min} = 2 \times T2$) which gives a filter passband of zero. To enter a Gate span smaller than minimum will produce a distorted filter shape that will have no passband, will not have a narrower shape, may have higher sidelobe levels, and will give an incorrect indication of gate START and STOP times. Therefore, it is important to always select a Gate span that is higher than the minimum value. The Cutoff time and the Minimum Gate Span are inversely proportional to the frequency span of the measurement as indicated in Table 18.

For best results using Gating, it is important to always center the Gate around the response(s) that you want to retain in the measurement and to make the Gate span wide enough to include all of those responses. It is also recommended to use the widest Gate shape possible.

MEASUREMENT RECOMMENDATIONS

When making Time Domain measurements, it is generally a good practice to measure the device within the frequency range that it is designed to operate. There are two reasons for this. First, the noise floor of the Time Domain response is directly related to the noise in the Frequency Domain data. Therefore, if many of the Frequency Domain data points are taken at or below the noise floor of the measurement, then the noise floor of the Time Domain measurement will be increased. A second reason to measure the device within its operating frequency range is because the in band response is normally of interest. The Time Domain measurement is an average of the response over the frequency range of the measurement, and if the Frequency Domain data is measured out of band, then the Time Domain measurement will also be the out of band response. However, since the Time Domain Response-Resolution is inversely proportional to the frequency span, it may at times be desirable (with these limitations in mind) to use a frequency span that is slightly wider than the device bandwidth to give better resolution.

Source Considerations

Although either source will work well in making Time Domain measurements, the HP 8340A synthesized sweeper has the advantage that it provides greater dynamic range than the HP 8350B sweeper. The main reason for this is the frequency stability of a synthesized source. The small nonlinearities and phase discontinuities that occur in the ramp sweep mode cause low level noise sidebands on the Time Domain Impulse or Step stimulus. These interfere in measurements requiring large dynamic range. Perform a TRIM SWEEP adjustment before calibrating to help minimize these noise sidebands. Adjusting trim sweep is explained at the end of the section of this manual titled Measurement Calibration.

In the HP 8340A (synthesized) step sweep mode, the improvement in source stability eliminates these noise sidebands and improves the Time Domain measurement dynamic range by as much as 30 dB. A second improvement is that the HP 8340A stepped sweep mode allows the use of many averages per point without greatly affecting the sweep time, and this lowers the noise floor of the Time Domain measurement. It is recommended to perform a Trim Sweep adjustment prior to calibrating when making measurements in the ramp sweep mode to minimize phase discontinuities.

Test Set Considerations

The bridge-based test sets (HP 8513A and HP 8515A) have two advantages over the coupler-based test sets (HP 8512A and HP 8514A) when making Time Domain measurements. First, the bridge-based test sets extend in frequency to 26.5 GHz, versus 18 GHz for the coupler-based test sets. When measuring broadband devices, this extra bandwidth provides better Time Domain Response-Resolution.

The second advantage is that the bridge-based test sets have a flat response down to 45 MHz, whereas the coupler-based test sets begin to roll off (but are still usable) below 500 MHz. This coupler roll off reduces the dynamic range available at the low frequencies (-30 dB at 45 MHz) and therefore increases the Time Domain noise floor when measurements are made at those frequencies (this causes the trace bounce in the Low Pass Step response).

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INTRODUCTION

This part of the HP 8510 network analyzer system manual, Introduction to Programming, explains how to automate network measurement and data processing operations using the HP 8510 system with an external controller via the Hewlett-Packard Interface Bus (HP-IB). Only programming is covered: familiarity with manual operation of the HP 8510 system is assumed, and details of how each function works are not given unless these are unique to programmed operation or are different for manual and programmed operation.

The first part of this Introduction to Programming is general, and it introduces the basic programmable capabilities of the HP 8510 network analyzer system. Sample program segments are discussed to show typical solutions to measurement and data processing problems. These can be adapted and developed to suit specific requirements.

The programming examples given are controller-independent. They are written in a simplified Meta Language in order to focus on the HP 8510 instrument control and data processing protocol rather than on language and controller requirements.

The BASIC program listing at the end presents all of the programming examples in a form that can be used with an HP 200 series computer as the external controller.

Programming mnemonics for all HP 8510 front panel controls and menu softkeys are given in the Reference Data part of this manual.

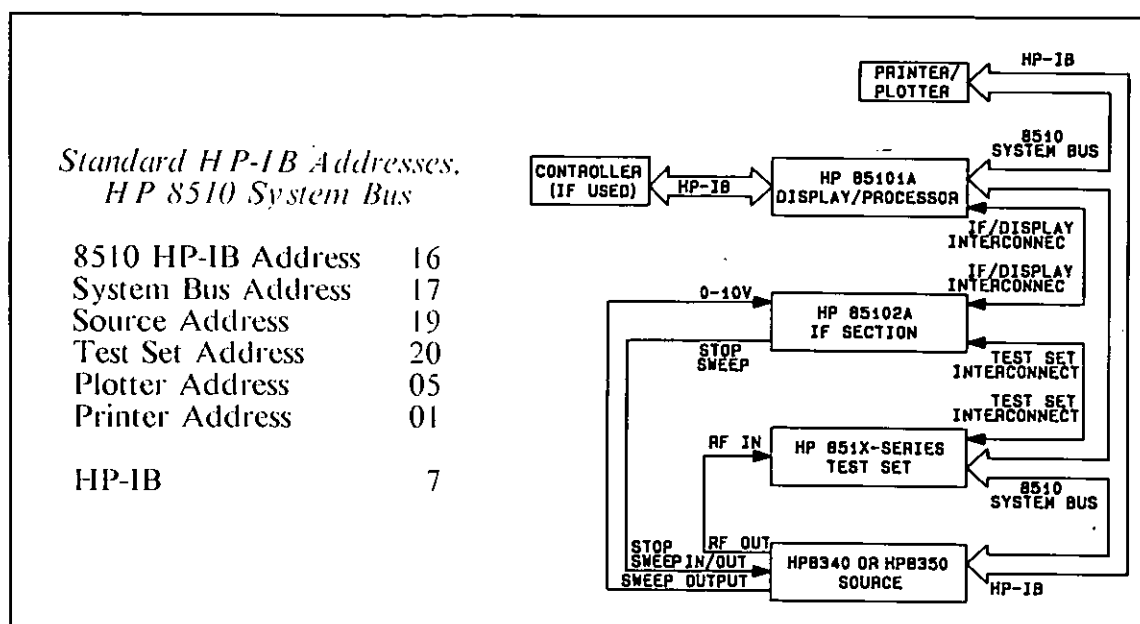


Figure 1. System Interconnections and HP-IB Addresses

INTERFACING THE HP 8510 SYSTEM TO A CONTROLLER

INTER-UNIT CABLE CONNECTIONS

All signal, control, and HP 8510 System Bus connections that are used for manual operation are used without change in programmed operation. Simply connect the HP-IB cable from the controller to the HP 85101A display/processor rear panel connector labeled HP-IB. Figure 1 shows the system interconnections required.

ADDRESS ASSIGNMENTS

Figure 1 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 1. These are the standard addresses.

To check address assignments, press **COPY, MORE, SYSTEM PARAMETERS**. A list of current assigned addresses will appear on the CRT. This list shows the address used by the HP 85101A to program each system element.

To change an address, press the HP 8510 front-panel key **LOCAL** or **SYSTEM** and then the softkey **HP-IB ADDRESSES**. This will bring the Address menu onto the HP 8510 CRT. Next press the softkey beside the name of the device whose address you wish to change. Use the **ENTRY** block keys to enter the number of the new HP-IB address you wish this device to have and follow the number with **x1**. Address settings are not changed by pressing **PRESET**, by pressing **TEST**, or by turning system power on and off.

An address must match the address set on the corresponding system instrument using the HP-IB address controls of the individual instrument. If the HP 8510 does not find the instrument at the expected address on the HP 8510 System Bus, a warning message is displayed in the entry area of the CRT when an operation is attempted.

If you need more information about instrument power requirements, other connections, or address assignments, see the Installation section of the HP 8510 network analyzer system manual.

PROGRAMMING OVERVIEW

The HP 8510A network analyzer system, consisting of the HP 834x-series synthesized sweeper or HP 8350B/835xx-series source, the HP 851x-series test set, an HP-IB compatible printer and/or plotter, and the HP 8510 network analyzer, is a stand-alone system and does not require an external computer to perform a fully error-corrected measurement in the frequency or time domain. Its internal microprocessor controls the system instruments via the 8510 System Bus and computes all data internally.

However, an external controller can be connected to the 8510 HP-IB interface to provide complete external control of the system state, to transfer data to and from HP 8510 memory, to control instruments connected to the HP 8510 System Bus, and to use the HP 8510 CRT as a graphics display. These capabilities can extend the HP 8510 system features to provide detailed guidance of the measurement process, including interpretation of results, and saving of important data in external mass storage for computer-aided design and manufacturing applications.

Remote operation of the HP 8510 system is accomplished using the Hewlett-Packard Interface Bus, HP-IB, which is the Hewlett-Packard implementation of IEEE standard 488, dated 1978, and IEC 625-1. For technical information on the HP-IB, refer to the "Tutorial Description of the Hewlett-Packard Interface Bus," Part Number 5952-0156. Also see IEEE standard 728-1982, "IEEE Recommended Practice for Code and Format Conventions."

Use standard HP-IB protocol to program the system state using generally the same sequence as you press HP 8510 front panel hardkeys and softkeys. The controller is connected to the HP 8510 by a single interface bus. The system components are connected to the HP 8510 via the 8510 System Bus and are not linked directly to the controller. From the controller, the network analyzer system is treated as a single instrument, just as the various instruments that make up the system are controlled using the HP 8510 front panel.

For applications that require programming the system instruments directly, a Pass-Thru mode exists, in which the controller can communicate directly with an instrument on the HP 8510 System Bus without interpretation by the HP 8510 CPU. The next several pages present a general overview of programming features.

MNEMONICS

The program code for each function is a four- to eight-character mnemonic version of its label followed by a numeric, if required, in the basic measurement units. For example, the STIMULUS START key is programmed using STAR. Strings of commands are written in logical sequences, separated by the semicolon, such as

```
"PRES;STAR2E9;STOP18E9;S21;LINP;MARK19E9;"
```

to Preset the system, select a 2 GHz to 18 GHz sweep, display S_{21} using the polar format, and then position measurement Marker 1 to 9 GHz. The semicolon (;) is used to terminate each individual command.

NUMERIC ENTRIES AND UNITS

Numeric entries with no units terminator are equivalent to pressing the x1 key in the entry area. If desired, statement readability may be improved by including the actual units for frequency and time values following the numeric as in

```
"PRES; STAR 2 GHz; STOP 18 GHz; S21; LINP; MARK 1 9 GHz;"
```

using GHz, MHz, kHz, and Hz units for Frequency entries; for Time entries use fs, ps, ns, us (microseconds), ms, and s. Either uppercase or lowercase characters may be used. The HP 8510 will generally accept syntax with extraneous blanks; however note that spaces are not allowed within the function name -- the entry MARK 1 would cause a syntax error.

Sequences involving multiple menu levels are programmed in the same way. Certain functions must be programmed in strict order, but it is not necessary to program a key whose only function is to present a new menu. For example, the sequence

```
"MARK2; MARKMINI;"
```

is sufficient and it is not necessary to program the MARKER hard key or the MORE softkey.

MEASUREMENT DATA

Read measurement data over the HP-IB by outputting the current active marker value or by outputting a complete data trace. Required timing considerations are handled internally and, typically, measurement data is not presented until it is complete. The sequence

```
! RAMP Mode
"AVERON 16; NUMG 17; MARK1; OUTPMARK;"
```

for operation in the Ramp sweep mode, or

```
! STEP Mode
"AVERON 16; NUMG 1; MARK1; OUTPMARK;"
```

for operation in the Step sweep mode, turns averaging on, and commands that the necessary number of groups be taken. A group is the number of sweeps needed to make the measurement completely; thus the number of sweeps that make up a group depends on the calibration model being used and other details of the measurement. In the Ramp sweep mode, the number of groups needed to present a fully averaged trace is $n + 1$, where n is the averaging factor selected. In the Step sweep mode, the number of groups needed to present a fully averaged trace is 1. OUTPMARK readies the HP 8510 to output the trace value at the marker position.

The marker value is output as two ASCII numbers in the basic units for the selected display format. Use two real variables, for example,

```
Mag,Phase
```

to accept the data. If the marker value consists of a single value, as when LOG MAG (LOGM) or PHASE (PHAS) is selected, then the second value is set equal to zero.

The current value of the Active Function is read as a single ASCII number in the basic units for the quantity. The sequence

```
"MARK2; MARKMAX1; OUTPACT1;"
```

turns on Marker 2, moves the marker to the maximum value on the trace, then OUTPACT1 readies the HP 8510 to output the current active function, which is the stimulus value at the marker position in this sequence. Use a single real variable, for example,

```
Freq
```

to accept the data.

A complete trace (block) of data can be read from network analyzer memory using

```
"FORM3; OUTPDATA;"
```

which prepares the HP 8510 to transfer trace data from the Corrected Data array for the currently selected channel. To read data, use a real array variable such as

```
Data(*)
```

where Data is the two-dimensional array (n elements by 2 elements where n is the current number of points selected) which receives the real/imaginary data pairs that make up the trace.

Trace data can be loaded into HP 8510 memory using

```
"FORM3; INPUDATA;"
```

which prepares the network analyzer to receive a data block and store the real/imaginary pairs into the selected channel corrected data array.

Raw, Corrected, Formatted, error coefficients, and trace math memory arrays can be selected for input/output. All transfers use IEEE 728 block transfer formats with EOI asserted with the last data byte.

COMMUNICATION WITH THE OPERATOR

Messages to the operator of up to 50 characters may be displayed using

```
"TITL"MEASUREMENT NUMBER 1";
```

that causes the message MEASUREMENT NUMBER 1 to appear in the Title area of the HP 8510 CRT.

Text and graphics information may also be written to the CRT using a special area of HP 8510 memory, using an internal HP-GL subset or the standard plotting language implemented by the controller.

LOCAL OPERATION

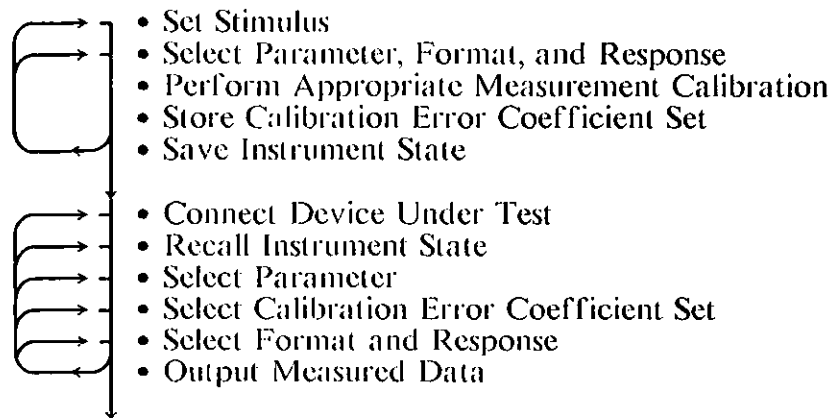
Return the HP 8510 to local control by pressing the front panel **LOCAL** key or by issuing the HP-IB command GTL 716 (HP Series 200 BASIC language LOCAL 716). After programming GTL 716, you must issue REN 7 (HP Series 200 BASIC language REMOTE 7) in order for the HP 8510 to accept data.

SYSTEM STATUS

Important system status information is available by reading a two-byte status word, and by using other statements to interrogate specific functions. To further assist in program development, statements DEBUON (Debug On) and DEBUOFF (Debug Off) are used to control a network analyzer debug mode in which the instruction currently being executed is displayed in the Title area of the HP 8510 CRT.

PROGRAMMING EXAMPLES

In a typical application, the system is set up for a particular measurement, appropriate measurement calibration is performed for each parameter to be measured, the test device is connected, its response is measured, and the data is output. When the test device is to be measured over several different frequency ranges, a separate calibration for each frequency range is performed. After connecting the device under test, recall the calibration set for each measurement sequence. Use the eight cal sets and the eight instrument state sets together to choose the appropriate instrument state for the measurement.



When you recall the instrument state, you select the complete stimulus, parameter, format, and response settings used during calibration. Select the parameter to be measured, turn correction On, then make the measurement. If you select an instrument state to which the current cal set does not apply, then correction is turned Off. Since recalling the calibration set recalls a limited instrument state consisting of important stimulus settings, if the appropriate parameter is already selected it is only necessary to recall the calibration set in order to achieve the correct instrument state for measurement.

META LANGUAGE DEFINITION

Programming examples given in this discussion use generalized statement structures in order to be controller independent.

HP-IB INSTRUMENT CONTROL. Communication with the HP 8510 over the HP-IB is shown using the following statement structures:

Listen Nwa; "mnemonic [value]: ... "

Talk Nwa__data; variable; ...

Listen Nwa__systbus; "instrument syntax ... "

Talk Nwa__systbusdata; variable; ...

The term Listen represents the controller language program statement that commands the addressed instrument to listen for and accept data transmission from the controller. The term Talk represents the controller language program statement that commands the addressed instrument to transmit data to the controller. For example, Listen and Talk correspond to BASIC Language statements OUT-PUT and ENTER, respectively.

The symbols Nwa, Nwa__data, Nwa__systbus, and Nwa__systbusdata specify input/output path assignments. These correspond to I/O paths created using BASIC language ASSIGN @Nwa TO statements. Nwa and Nwa__data designate the standard HP 8510 HP-IB programming address, typically 716 if the controller addresses the HP-IB as address 7, and the standard 8510 HP-IB address of 16 is selected. Nwa__systbus and Nwa__systbusdata represent the HP 8510 System Bus programming address used for the pass-thru mode, typically 717.

The term mnemonic represents the HP 8510 program code to command the function. Spaces are not allowed in the mnemonic construction. If alpha or numeric input is allowed for the function, then it follows the mnemonic, shown here by the term [value] in which the brackets indicate an optional entry, which may be a pre-assigned variable or a literal. Mnemonics that command an active function are followed by a value if you intend to change the value of the function.

The term variable represents a simple or complex numeric or string variable which accepts data from the HP 8510. The term instrument syntax represents program codes used in the Pass-Thru mode that have the form required by the specific system instrument on the HP 8510 system bus being programmed.

OPERATOR INTERFACE. During the execution of the example program the following statement structure is used to request an input from the operator:

Input "message";variable

The term message is displayed to instruct the operator that some action is required (make a connection or enter a value) before program execution can continue. The term variable represents a program variable; it will accept a value that the operator enters using the controller keyboard. If you are using an HP Series 200 controller, the LINPUT statement is used for this purpose.

OTHER PROGRAM CONTROL. Other statements used in the example programs include:

Goto label

which represents a simple program branch to the specified label;

If expression Then label

which represents a conditional branch based on the true or false evaluation of the expression:

For variable = constant1 To constant2 By constant3

.
.
.

Next variable

which represents a controlled loop in which the statements between the For and the Next statements are repeated (constant2-constant1)/constant3 times; and

! remark

where remark is explanatory information for the programmer.

SYNTAX REQUIREMENTS

Mnemonics may be written using all uppercase characters (as in STAR, preferred), or using initial uppercase followed by lowercase (as in Star, allowed).

No spaces may be embedded in a mnemonic. Spaces are allowed between a mnemonic and a value, and between a value and its units.

Use the semicolon (;) to separate instructions. Use the comma (,) to separate each value in a series.

If no units terminator follows the value for frequency and time units, the system defaults to HP 8510 Basic Units (Hz, seconds). Other quantities (power, length) do not use a units terminator. The following units terminators may be used:

FREQUENCY		TIME	
Giga	GHz	basic units	s
Mega	MHz	milli	ms
kilo	kHz	nano	ns
basic units	Hz	micro	us
		femto	fs

These units terminators may be uppercase or lowercase characters.

GENERAL HP-IB PROGRAMMING

After the HP-IB REMOTE command is issued, addressing the HP 8510 using an appropriate Listen statement causes the HP 8510 to enter the Remote mode in which the front panel hardkeys and softkeys, except for the LOCAL key, are locked out. After the initial Listen statement, either Talk or Listen statements will be accepted.

Pressing the LOCAL key restores front panel control functions until the next Listen command is received. Programming the Local Lockout command, LLO, locks out the front panel completely, even the LOCAL key. Issue the HP-IB LOCAL command to cancel Local Lockout.

If the HP 8510 is already addressed as a listener, a GTL 716 (LOCAL 716) sets the HP 8510 system to the normal manual mode without changing the current instrument state.

All HP-IB Universal and Addressed Commands and the HP 8510 system response to the commands are listed below. Controller-specific considerations are discussed in the Example Program Listings later in this Introduction to Programming, where specific controllers and languages are considered.

INTERFACE FUNCTIONS. The following identification codes for the interface functions indicate the HP 8510 HP-IB interface capability. For more information, refer to the "Tutorial Description of the HP-IB," HP Part No 5952-0156.

SH1	Source Handshake: Full Capability.
AH1	Acceptor Handshake: Full Capability.
T6	Talker: Basic Talker, Serial Poll.
TE0	No Extended Talker.
L4	Listener: Basic Listener.
LE0	No Extended Listener.
SR1	Service Request: Full Capability.
RL1	Remote/Local: Complete Capability.
PP0	No Parallel Poll Capability.
DC1	Device Clear: Full Capability.
DT1	No Device Trigger Capability.
C0	No Controller Capability.
E1	Driver Electronic: Open Collector.

RESPONSE TO HP-IB UNIVERSAL COMMANDS. The HP 8510 HP-IB responds to the following universal commands from an external controller at any time regardless of whether or not it is addressed. Refer to the language reference manual of the controller being used to find the corresponding commands allowed by the controller.

- DCL** Device Clear: Clears HP 8510 status, no change in instrument state, system is ready to accept HP-IB commands and data.
- LLO** Local Lockout: Disables the HP-IB front panel **LOCAL** button. GTL to clear.
- SPD** Serial Poll Disable: Disables the Serial Poll mode over the HP 8510 HP-IB.
- SPE** Serial Poll Enable: Enables the Serial Poll mode over the HP 8510 HP-IB.
- PPU** Parallel Poll Unconfigure: The HP 8510 system does not respond.

RESPONSE TO HP-IB ADDRESSED COMMANDS. The HP 8510 HP-IB responds to the following addressed commands when it is addressed as a listener. Refer to the language reference manual of the controller being used to find the corresponding commands allowed by the controller.

GET Group Execute Trigger: The HP 8510 system, already in the triggered data acquisition mode, initiates the pre-programmed action of continuing the data acquisition process.

GTL Go To Local: Returns the HP 8510 system to local control.

Following GTL, the HP 8510 HP-IB will respond only to HP-IB Universal and Addressed Commands, not to HP-IB data. Issue REN to enable data transfer using controller Listen and Talk commands.

REN Remote Enable. Enable all HP-IB command and data functions.

SDC Selected Device Clear: Clears HP 8510 status, no change to instrument state, system is ready to accept instructions and data.

The HP 8510 system does not respond to the following Addressed Commands.

PPC Parallel Poll Configure.

TCT Take Control.

GENERAL INPUT SYNTAX

This example can help you become familiar with the HP 8510 HP-IB instructions. It allows you to type an HP 8510 instruction and have it sent to the HP 8510 for execution. Refer to the Example Program Listings at the end of this Introduction to Programming section for the Example 1 program that is executable on your controller.

```
! Example 1   Input Syntax Familiarization
Start: !
Input "Type 8510 command"; String$
Listen Nwa; String$
Goto Start
```

The Input statement displays a message, then waits for an input (type the string and then press controller CONTINUE). Using a simple program like this one, you can input commands one at a time and observe the network analyzer response. At first, try instructions such as

```
STAR 10 GHz;
```

because the change in instrument state can easily be observed. Refer to the menu structures in the Reference Data section to see the syntax required for operation of each programmable function.

You may enter a sequence of instructions by separating each instruction with the semicolon (;), as follows.

```
STAR 2 GHz; STOP 10 GHz; CHAN2; LINP;
```

The HP 8510 instruction DEBUON causes all HP 8510 instructions to be displayed in the Title area of the HP 8510 CRT. The last 30 characters in the instruction queue are displayed, with the most recently received instruction at the left of the area, pushing instructions higher on the queue off of the area to the right. This means that the currently executing command may not be visible if the queue is over 30 characters in length. Use the HP 8510 instruction DEBUOFF to disable display of the command queue.

If the network analyzer does not recognize the mnemonic, or cannot execute it in the correct sequence, then HP-IB activity stops and the instruction in error is displayed in the Title area of the HP 8510 CRT. Press HP 8510 LOCAL, then continue operation, or issue an HP-IB DCL or SDC (run the example program from the beginning).

Commands are executed in the sequence in which they are received by the HP 8510. When a command is received, it is syntax checked, stored on the command queue, then executed. Some commands, such as SING, free the processor for other tasks during the time that they are executing. If time becomes available while such a command is executing, the process of reading a command, syntax checking, storage in the command queue, and sometimes overlapping execution continues until up to eight commands are stored for pending execution.

MARKER DATA OUTPUT

If the system is currently operating in either the HOLD or the CONTINUAL mode (see STIMULUS menu), then the data is output immediately; if SINGLE, or NUMBER OF GROUPS has been selected, then the data output operation waits until the specified number of sweeps is complete. For example, the sequence

```
! Example 2 Marker Data Output (Ramp Mode)
Listen Nwa; "LINP: AVERON 16;"
Listen Nwa; "NUMG 17; MARK1; MARKMAX1; OUTPMARK;"
Talk Nwa_data; Mag, Phase
```

selects the linear magnitude polar display, turns on averaging, and commands 17 groups of sweeps. When complete, marker 1 is turned on, moved to the maximum trace value, then the marker value is assigned to the variables Mag and Phase.

The OUTPMARK statement always transfers two values in standard ASCII format. As shown in Table 1, the values depend upon the currently selected display format. Two values are output in every display format, but for cartesian displays the second value is zero.

Data taken in the Step mode requires only one group of sweeps (NUMG 1) because each data point is averaged before the next point is measured.

To move the marker to a specific stimulus value, include a numeric value in the instruction. The sequence

```
Listen Nwa; "MARK1 9.123456789 GHz; OUTPMARK;"
Talk Nwa_data; Mag, Phase
```

moves marker 1 to the data point closest to 9.123456789 GHz, then transfers the marker value.

Table 1. Marker Units for all Display Formats

FORMAT	MARKER Basic Units	OUTPMARK A, B VALUE
LOG MAG	dB	dB, 0
PHASE	degrees (°)	degrees, 0
DELAY	seconds (s)	seconds, 0
SMITH CHART	$R \pm jX (\Omega)$	ohms, ohms
SWR	(unitless)	SWR, 0
LINEAR MAGNITUDE	ρ (unitless) (reflection)	lin mag, 0
	τ (unitless) (transmission)	lin mag, 0
LIN mkr on POLAR	$\rho \angle \phi^\circ$ (reflection)	lin mag, degrees
	$\tau \angle \theta^\circ$ (transmission)	lin mag, degrees
LOG mkr on POLAR	dB $\angle \phi^\circ$	log mag, degrees
Re/Im mkr on POLAR	$x \pm jy$ (unitless)	real, imag
INVERTED SMITH	$G \pm jB$	Siemens, Siemens
REAL	x (unitless)	real, 0
IMAGINARY	jy (unitless)	real, 0

ACTIVE FUNCTION OUTPUT

The value of the current Active Function is output as a single ASCII value in the basic units of the function. For example,

```
! Example 3 Active Function Output
Listen Nwa:"OUTPACTI;"
Talk Nwa:Freq
```

when executed with a marker as the active function, such as following Example 2, returns the frequency in Hertz at the marker position.

The sequence AVERON then OUTPACTI outputs the currently selected averaging factor. The sequence ELED then OUTPACTI returns the currently selected Electrical Delay value in seconds.

The title and various other user-defined labels can also be read over the HP-IB by making it the active function, then reading the characters into a string variable. For example,

```
Listen Nwa:"TITL; OUTPTITL;"
Talk Nwa:String$
```

returns the current title as the active function. Note that the title, cal kit, standard class, standard, or user parameter label instructions do not include any quotation marks for this application.

DELTA MARKER MODES

The delta marker functions are programmed in the same way as the buttons are pressed in a manual procedure. For example, the sequence

```
- ! Example 4 Peak-to-Peak Measurement -  
Listen Nwa;"MARK2; MARKMAXI; DELR2; MARK1;  
  MARKMINI; OUTPMARK;"  
Talk Nwa_data;Mag.Phase  
Listen Nwa;"OUTPACTI"  
Talk Nwa_data;Freq  
Listen Nwa;"DELO; MARKOFF"
```

moves Marker 2 to the maximum trace value, selects the delta marker mode with Marker 2 as the reference marker, moves Marker 1 to the maximum trace value, then outputs the difference between Marker 2 and Marker 1. Then the delta mode is turned off, and the markers are turned off.

ALTERNATE SWEEP

This example of dual-channel operation sets up an alternate sweep.

! Example 5 Alternate Sweep

Listen Nwa:"UNCC;"

Listen Nwa:"CHAN1: STAR 2 GHz; STOP 5 GHz;"

Listen Nwa:"CHAN2: STAR 3 GHz; STOP 4 GHz;"

Listen Nwa:"SPLI;"

Uncoupled channels is selected, the Channel 1 and Channel 2 frequency sweeps are set, then the dual-channel split display mode is selected.

READ MARKER VALUES IN DUAL CHANNEL MODES

To read marker values in dual-channel display modes, first select the Channel, as in

```
! Example 6 Dual Channel Read Marker
Listen Nwa:"MARK1 3.5 GHz"
Listen Nwa:"CHAN1; SING; AUTO; OUTPMARK;"
Talk Nwa _data:Mag.Phase
Listen Nwa:"CHAN2; SING; AUTO; OUTPMARK;"
Talk Nwa _data:Mag.Phase
```

The SING instruction (take single group of sweeps) or the NUMG instruction following channel selection, parameter change, or domain change, ensures that the trace has been updated and the data is ready to be read. After SING or NUMG the network analyzer is placed in the HOLD mode. It is generally best to select the hold mode for data output. Use the CONT (CONTINUAL) instruction to restart the sweep.

When 2-port error correction is On and the network analyzer is in HOLD, it is not necessary to take a sweep to update the display when the parameter selection is changed. This is because raw data for all parameters is available. In all other situations, when the parameter selection is changed, it is necessary to take at least one group of sweeps to assure current data.

Note that if the system is in Hold, the parameter is changed, and raw data is not available, then the raw data array is initialized to the equivalent of measured data equal to 0.0 at every data point. If LOG MAG is selected, the marker magnitude value will be approximately -700 dB. The raw data array and trace will be updated at the completion of the next group of sweeps.

In general, timing considerations are handled automatically and data is not presented until it is valid. The SING and NUMG instructions hold off execution of the instruction which follows until the specified number of groups is complete. The output instructions (OUTPMARK, OUTPRAW n , OUTPDATA, OUTPFORM, OUTPMEMO, and OUTPCALC n), and AUTO, MARKMAXI, MARKMINI, and EQUA (=MARKER), are held off until all preceding instructions are complete. For example, in the sequence

"TIMB; OUTPDATA;"

the instruction TIMB performs a time domain conversion, which requires about 1 second. Execution of OUTPDATA is delayed until the conversion is complete. Thus, the data which is output is the actual converted data.

However, if multiple instrument state changes are input sequentially and the programmer wishes to assure that a particular instruction has completed its execution before the next instruction is executed, the programmer can control the holdoff using the HP 8510 WAIT instruction. WAIT is used at any time you wish to make certain that all preceding instructions have completed before the instruction which follows WAIT begins execution.

USING =MARKER

Use of the =MARKER function to measure deviation from linear phase is shown in the following example.

```
! Example7 Using =MARKER  
Listen Nwa:"CHAN2; PHAS; ELED 0;"  
Listen Nwa:"DELA; SING; CONT; ELED; EQUA; PHAS;"
```

The sequence selects Channel 2, sets Electrical Delay to 0 seconds, selects DELAY, commands a group of sweeps to ensure that the data is current, returns to continuous sweep mode, sets Electrical Delay equal to the marker value, and then selects the PHASE display. Upon completion, the phase trace should will be flat if the marker value is representative of the phase slope over the sweep.

In all =MARKER applications, the current marker value becomes the value of the current active function. Valid functions for use with =MARKER are START, STOP, CENTER, SPAN, REF VALUE, ELECTRICAL DELAY, PHASE OFFSET, and PORT EXTENSIONS.

TRACE DATA OUTPUT

Complete traces may be read from various HP 8510 memory locations using the following instructions.

OUTPFORM;	read from selected channel Formatted data array,
OUTPDATA;	read from selected channel Corrected data array,
OUTPRAW1;	read from selected channel S_{11} Raw data array,
OUTPRAW2;	read from selected channel S_{21} Raw data array,
OUTPRAW3;	read from selected channel S_{12} Raw data array, and
OUTPRAW4;	read from selected channel S_{22} Raw data array.

These statements prepare the network analyzer to output trace data for the currently selected channel at the HP 8510 HP-IB.

Data in the Formatted array is the same as data in the Corrected data array except that the Formatted data has trace math and smoothing applied.

OUTPDATA and OUTPRAW n output data in real/imaginary pairs regardless of the currently selected display format.

For cartesian displays, OUTPFORM selects data output in the basic units of the current FORMAT with the imaginary part zero, as for OUTPMARK (refer to Table 1 LOG MAG, PHASE, DELAY, SWR, LINEAR MAGNITUDE, REAL, and IMAGINARY). If a polar, Smith, or Inverted Smith FORMAT is selected, data is output in real/imaginary pairs.

The assignments listed above for the raw data arrays are valid only when 2-port error correction is turned on. If uncorrected, response-only, or 1-port error-corrected is displayed, then only RAW1 for the currently selected channel holds valid data.

A trace currently stored in one of the four trace math memories may be output by selecting the memory, using

DEFM1;	to select Memory 1.
DEFM2;	to select Memory 2.
DEFM3;	to select Memory 3. or
DEFM4;	to select Memory 4.

Turn on memory by issuing a DISPMEMO instruction, then use

OUTPMEMO; to read currently selected memory.

This transfers the memory data in real/imaginary pairs.

The IEEE 728 data block transfer format transfers is selected by the following mnemonics:

FORM4	ASCII floating point format (ASCII strings separated by comma),
FORM1	HP 8510 internal Binary format (6 bytes/point),
FORM2	IEEE 32 bit floating point format (8 bytes/point),
FORM3	IEEE 64 bit floating point format (16 bytes/point).

After PRESET the FORM1 format, HP 8510 internal binary, is selected.

FORM1, FORM2, and FORM3 select output formats in which the data is transferred in a sequence consisting of a preamble, #A; an ASCII integer, Size (two bytes), which gives the total number of bytes to be transferred; and pairs of real/imaginary numbers. The total number of pairs that are output corresponds to the number of points currently selected.

FORM3 is the standard internal format for HP 9000 Series 200 controllers and is the typical method used in the examples here. FORM1 is useful for fast transfer of traces between the HP 8510 and the controller, but it should not be used where further processing of the trace data by the controller is required.

FORM4 provides standard ASCII transfers like those used for OUTPMARK and does not use the Preamble or Size variables. The total number of pairs that are output corresponds to the number of points currently selected.

This example shows the data transfer to the controller when FORM3 is selected.

```
! Example 8 Trace Data Output
Listen Nwa; "FORM3; NUMG 1; OUTPDATA"
Talk Nwa_Data; Preamble, Size, Data(*)
```

Use NUMG or SING to synchronize data output with completion of data acquisition. The variable Preamble accepts the #A block header, the variable Size accepts the value representing the total number of data bytes in the block, and Data(*) accepts the real/imaginary data pairs.

If Data(*) is dimensioned to less than the number of points currently selected, then the controller will probably terminate the talk operation when the receiving array is full. If Data(*) is dimensioned to less than the number of points currently selected, then the talk operation will not terminate and you may issue another talk statement to read the remaining data, or send another HP 8510 command (such as ENTO;) to terminate the HP 8510 data output mode. Since the Size variable can be used to determine the length of the block transfer, Preamble and Size may be read and then used to dynamically allocate the required data array storage.

Note that all transfers use standard IEE 728 block transfer formats with EOI asserted with the last byte of data.

TRANSFER TRACE DATA TO NWA MEMORY

Trace data may be loaded into network analyzer memory while in HOLD or CONTINUOUS modes. When HOLD is selected, completion of a data input operation initiates a data processing cycle in which the displayed trace is updated to reflect the new data. The following mnemonics

INPUFORM:	load into selected channel Formatted data array,
INPUdata:	load into selected channel Corrected data array,
INPURAW1:	load into selected channel S_{11} Raw data array,
INPURAW2:	load into selected channel S_{21} Raw data array,
INPURAW3:	load into selected channel S_{12} Raw data array, and
INPURAW4:	load into selected channel S_{22} Raw data array,

prepare the network analyzer to transfer data pairs at the HP 8510 HP-IB to the specified array for the currently selected channel.

INPUdata and INPURAW n expect data in real/imaginary pairs regardless of the currently selected display format.

For cartesian displays, INPUFORM expects data in the basic units of the current FORMAT with the imaginary part zero, as for OUTPFORM (refer to Table 1 LOG MAG, PHASE, DELAY, SWR, LINEAR MAGNITUDE, REAL, and IMAGINARY). If a polar, Smith, or Inverted Smith FORMAT is selected, data is expected in real/imaginary pairs.

The assignments listed above for the raw data arrays are valid only when 2-port error correction is turned on. If uncorrected, response-only, or 1-port error-corrected is displayed, then only RAW1 for the currently selected channel should be loaded.

Select the trace memory to be loaded using

DEFM1:	select Memory 1.
DEFM2:	select Memory 2.
DEFM3:	select Memory 3, or
DEFM4:	select Memory 4.

then

INPUdata; DATA

to load data into the Corrected data array and store the data into the selected memory.

The data format for these transfers is selected by the FORM1, FORM2, FORM3, and FORM4 mnemonics as for the OUTP instructions. One of the FORM n instructions should precede each transfer.

This example shows the data transfer from the controller to HP 8510 Corrected data array for the currently selected channel using FORM3.

```
! Example 9 Trace Data Input
Listen Nwa; "HOLD; FORM3; INPUDATA;"
Listen Nwa; Preamble, Size, Data(*)
```

HOLD prevents overwriting the data just input with data from the next group of sweeps. The variable Preamble holds the #A block header, the variable Size holds the value representing the total number of data bytes in the block, and Data(*) holds the real/imaginary data pairs.

The HP 8510 will accept data until the specified number of bytes is received, or EOI is detected, then terminate the listen mode. If the number of data bytes is not equal to the value of the variable Size, the message "BLOCK INPUT ERROR" is displayed. If the value of the variable size does not correspond to the current number of points selected, then the message "BLOCK INPUT LENGTH ERROR" is displayed. If more than the internally allocated number of bytes are input, then these bytes are treated like regular commands, which will most likely cause a syntax error. If less than the specified number of bytes are input without an EOI, you may continue with another Listen statement.

When using FORM 4, always suppress the CR/LF which would normally terminate the Listen statement that sends the INPU instruction as follows.

```
Listen Nwa; "HOLD; FORM4; INPUDATA;";
Listen Nwa; Data(*)
```

The semicolon following the last quote mark is used in BASIC to suppress the normal CR/LF sent at the end of the statement. Failure to suppress this character results in the HP 8510 accepting the CR/LF as the first data byte.

MEASUREMENT CALIBRATION

This example shows a sequence for accomplishing an S_{11} 1-Port calibration and an S_{21} frequency response calibration under program control. Refer to the Cal menu structure in Reference Data.

```
! Example 10 S11 1-Port and S21 Response Cals
Listen Nwa; "S11; CAL1; CALIS11;"
Input "Port 1, connect open, then press CONTINUE."
Listen Nwa; "CLASS1A;" ! (Open circuit data measured.)
Input "Port 1, connect short, then press CONTINUE."
Listen Nwa; "CLASS1B;" ! (Short circuit data measured.)
Listen Nwa; "CLASS1C;" ! (Uses both LOWBAND and SLIDING.
Input "Port 1 connect fixed load, then press CONTINUE."
Listen Nwa; "STANC;" ! (Lowband Fixed load data measured.)
Input "Port 1, connect sliding load, then press CONTINUE."
Listen Nwa; "STANB;" ! (Select Sliding Load)
Input "Move element to first index mark, then press CONTINUE."
Listen Nwa; "SLIS;" ! (Sliding Load Data Measured)
For Slide= 2 to 6
Input "Move element to next index mark, then press CONTINUE."
Listen Nwa; "SLIS;" ! (Sliding Load Data Measured)
Next Slide
Listen Nwa; "SLID; DONE; SAV1; CALS1;"
! (Error coefficients computed and stored;
! Cal Menu displayed with CORRECTION ON.)
! Corrected S11 trace displayed.
Listen Nwa; "S21;"
Input "Connect Thru, then press CONTINUE."
Listen Nwa; "CAL1; CALIRESP; STANC; DONE; CALS2;"
! (Error coefficients computed and stored;
! Cal Menu displayed with CORRECTION ON.)
! Corrected S21 trace displayed.
Input "Connect Device Under Test, then press CONTINUE."
Listen Nwa; "S11; SING;"
! (S11 data displayed)
Listen Nwa; "S21; SING;"
! (S21 data displayed)
```

During measurement, when the parameter is changed, the cal set which was last turned On for that parameter is recalled and applied to the measurement.

The measurement calibration sequence is performed under program control using the same procedure as manually. First select the calibration kit using CAL1 or CAL2, then select the type of calibration to be performed using:

Select Calibration Type

<u>Mnemonic</u>	<u>Cal Type</u>
CALIRESP;	RESPONSE
CALIS11;	S_{11} 1-PORT
CALIS22;	S_{22} 1-PORT
CALIFUL2;	FULL 2-PORT
CALIONE2;	ONE-PATH 2-PORT

The RESPONSE measurement calibration always consists of a single standard class. If a single standard is assigned to the class, then CALIRESP causes a Measurement Restart and the standard is measured. The message WAIT--MEASURING CAL STANDARD appears while the measurement is being made. The speed of the measurement depends on the mode (Ramp or Step) selected and the number of averages. If multiple standards are assigned to the class, then the standard to be measured must be selected using STANA through STANG. All other calibration types consist of multiple standard classes.

Since the Standard Class labels are user-definable, a special mnemonic is used to select measurement of each standard class.

Select Standard Class

<u>Mnemonic</u>	<u>Example Standard Class Labels</u>
CLASS11A;	S ₁₁ OPEN (1 st S ₁₁ standard class)
CLASS11B;	S ₁₁ SHORT (2 nd S ₁₁ standard class)
CLASS11C;	S ₁₁ LOADS (3 rd S ₁₁ standard class)
CLASS22A;	S ₂₂ OPEN (1 st S ₂₂ standard class)
CLASS22B;	S ₂₂ SHORT (2 nd S ₂₂ standard class)
CLASS22C;	S ₂₂ LOADS (3 rd S ₂₂ standard class)
FWDT;	FORWARD TRANSMISSION THRU
FWDM;	FORWARD MATCH THRU
REVT;	REVERSE TRANSMISSION THRU
REVM;	REVERSE MATCH THRU
FWDI;	FORWARD ISOLATION
REVI;	REVERSE ISOLATION

If a single standard is assigned to the class, then any of these causes a Measurement Restart and the standard is measured. The message WAIT-MEASURING CAL STANDARD appears while the measurement is being made. The speed of the measurement depends on the mode (Ramp or Step) selected and the number of averages.

If two or more standards are assigned to the class (up to seven standards may be assigned to a class), then the standard to be measured is selected using the STANA through STANG instructions.

Select Calibration Standards in Class

<u>Mnemonic</u>	<u>Example Standard Labels</u>	
	(S ₁₁ and S ₂₂ LOADS)	(RESPONSE)
STANA;	BROADBAND	OPEN
STANB;	SLIDING	SHORT
STANC;	LOWBAND	THRU
STAND;	(not used)	(not used)
STANE;	(not used)	(not used)
STANF;	(not used)	(not used)
STANG;	(not used)	(not used)

Any of these causes a Measurement Restart and the standard is measured. The message WAIT--MEASURING CAL STANDARD appears while the measurement is being made. The speed of the measurement depends on the mode (Ramp or Step) selected and the number of averages.

Issue DONE; when the necessary standards in the class are measured. The CAUTION 25 message "ADDITIONAL STANDARDS NEEDED" is displayed if the standards thus far measured do not cover the current frequency range.

The SAV_{xx} instruction initiates final error coefficient computation. Finally, issue CALS_{xx} to specify the cal set to receive the error coefficients. Correction is turned on for the parameters covered by the cal set; for both channels if Coupled Channels is selected, or for the current channel if Uncoupled Channels is selected.

USING THE TAPE CARTRIDGE

The HP 8510 tape cartridge mass storage can be use to great advantage in large tests by providing capacity to store instrument states (INSS*n*), cal sets (CAL*S**n*), calibration kits (CALK*n*), and trace data (DATAFORM*i*). Refer to the Tape Menu in Reference Data for a more complete list of mnemonics.

```
! Example 11 Tape Cartridge Store and Load
Input "Insert Tape Cartridge".Input$
Input "Initialize Tape Cartridge? (Enter Y or N)".Input$
If Input$="Y" Then Listen Nwa:"INIT"
!
Listen Nwa:"STOR; INSS1; FILE1"
Listen Nwa:"CHAN1; STOR; DATAFORM; FILE1"
Listen Nwa:"CHAN2; STOR; DATAFORM; FILE2"
Listen Nwa:"STOR; MEMO1; FILE1"
Listen Nwa:"STOR; CALS1; FILE1"
Listen Nwa:"STOR; CALK1; FILE1"
Listen Nwa:"DIRE"
! View directory on HP 8510 CRT display
```

Load the network analyzer memory from the tape cartridge as follows:

```
Listen Nwa:"HOLD"
Listen Nwa:"LOAD; INSS1; FILE1"
Listen Nwa:"CHAN1; LOAD; DATAFORM; FILE1"
Listen Nwa:"CHAN2; LOAD; DATAFORM; FILE2"
Listen Nwa:"DISPDATA; LOAD; MEMO1; FILE1"
Listen Nwa:"CORROFF; LOAD; CALS1; FILE1"
Listen Nwa:"LOAD; CALK1; FILE1"
```

If HOLD is not programmed, the formatted data traces would be overwritten by new data during the next sweep.

Note that in order to use DATAFORM, DATARAW, or DATADATA, the channel to which the data applies must be selected. When loaded, the trace is automatically updated. DATARAW stores information on the tape from the Raw data array for the currently displayed parameter on the currently selected channel, or, if 2-Port correction is turned on, all four raw data arrays for the selected channel.

To load a memory trace, the memory display must be off (DISPDATA). Correction must be off (CORROFF) before cal sets can be loaded into HP 8510 memory from tape.

HARDCOPY OUTPUT TO PLOTTER

Measurement results are output to a plotter connected to the HP 8510 System Bus using a sequence of commands to specify the quadrant on the paper, the pen color, and the data to be plotted. The following sequence plots the four S-parameters.

```
! Example 12 Plots Using COPY Menu
Input "Load Paper, then CONTINUE"
Listen Nwa:"S11; SING: LEFU; PLOTALL"
Listen Nwa:"S21; SING: LEFL; PLOTALL"
Listen Nwa:"S12; SING: RIGU; PLOTALL"
Listen Nwa:"S22; SING: RIGL; PLOTALL"
```

PLOTALL causes the entire screen, except the Menu, to be plotted. Other commands to specify the part of the screen to be plotted and the pen color may be used.

HARDCOPY OUTPUT TO PRINTER

The printer connected to the 8510 System Bus may be used in the same way as in manual operation. The instruction

```
! Example 13 List Trace Values
Listen Nwa:"LIST"
```

uses the LIST TRACE VALUES function to output the list of trace values to the printer.

**PASS-THRU TO SYSTEM BUS INSTRUMENTS:
GENERAL INPUT/OUTPUT**

The HP 8510 uses a pass-thru technique to allow the external controller to communicate directly with instruments on the HP 8510 System Bus. All pass-thru exchanges are handled in the same way. First designate the device on the 8510 System Bus to receive/send the data using the ADDRPASS instruction and the two digit HP 8510 System Bus address of the instrument, then Talk/Listen to the 8510 System Bus address. To send data, use

```
Listen Nwa:"ADDRPASS nn;"  
Listen Nwa_systbus;"instrument specific syntax"
```

where *nn* is the address of the device on the HP 8510 system bus which is to receive the data, and "instrument specific syntax" is the instructions and data sent to the instrument.

If the instrument is instructed to output data, then use

```
Talk Nwa_systbusdata: String$
```

to receive the data, where String\$ is dimensioned to accept the ASCII string sent from the device. Note that if the device on the system bus does not terminate its output with the CR/LF, then it is the responsibility of the programmer to terminate the Talk operation.

The specified pass-thru address remains in effect until changed by the programmer. Instructions and data may be sent to the HP 8510 HP-IB address or to the HP 8510 System Bus address in any sequence. When the HP 8510 System Bus is addressed, an automatic System Bus 'Local' is issued which halts all system bus activity and places the HP 8510 in Hold. When the HP 8510 HP-IB is addressed following a pass thru, an automatic System Bus 'Remote' is issued which returns control of the system bus to the HP 8510.

The addressed device cannot handshake to the controller or respond to HP-IB Universal or Addressed commands via the system bus.

OUTPUT TO PRINTER

You may print directly to the printer using the Pass-Thru mode as follows.

```
! Example 14 Print to Printer on 8510 System Bus
Listen Nwa:"ADDRPASS 01;" ! Printer's System Bus address is 01
PRINTER IS 717           ! (Nwa_systbus)
PRINT "MEASUREMENT NUMBER 1"
```

This example begins with the HP 8510 instruction ADDRPASS 01 that sets the state in which data addressed to 717 (the 8510 System Bus address) is passed-thru to the device at address 01 on the 8510 System Bus. Next, a controller-specific command, HP 9000 Series 200 in this example, specifies the hardcopy device as the printer at address 717. Finally, the controller-specific hardcopy output statement outputs the message. The string is accepted at the HP 8510 System Bus address 717 and passed-thru to the printer.

OUTPUT TO PLOTTER

Likewise, you may plot directly to an HP-IB digital plotter on the system bus as follows.

```
! Example 15 Plot to Plotter on HP 8510 System Bus
Listen Nwa:"ADDRPASS 05;"
PLOTTER IS 717, HPGL
.
. Controller HPGL Plotting statements
.
```

The HP 8510 instruction ADDRPASS 05 routes data received at HP 8510 System Bus address 717 to the plotter at address 05 on the HP 8510 System Bus. Next, the controller-specific command PLOTTER IS specifies the plotter is be the device at address 717. Controller-specific plotting statements generate the HPGL data to be plotted.

USING THE HP 8510 STATUS BYTES

Table 2 shows bit assignments of the HP 8510 Primary and Secondary status bytes. These bits are set according to the current instrument state of the HP 8510 system.

Important HP 8510 instructions relating to the status word are:

- OUTPSTAT: Prepare the HP 8510 to output the status word as two ASCII numbers, 0 to 255. Completion clears the status word to 0,0.
- CLES: Clear status bytes to 0,0; clear SRQ.
- SRQM a,b: Send two integer ASCII values, 0 to 255 to set the Service Request Mask. Power On, TEST, and PRESET clear the Service Request Mask to 0,0.

READ STATUS BYTES

Both status bytes are read using a sequence such as

```
! Example 16 Read HP 8510 Status Bytes
Listen Nwa;"OUTPSTAT;"
Talk Nwa__data; Primary;Secondary
```

where Primary and Secondary are variables to receive the value of each byte. You may read the status bytes in separate Talk operations.

After the Power Up sequence is complete, bit 2 of the Extended status byte is set, making the value of OUTPSTAT 0,4.

Table 2. HP 8510 Status Bytes

PRIMARY STATUS BYTE (#1)				
Bit #	7	6	5	4
Decimal Value	128	64	32	16
Function	Reason in Extended Byte	RQS (SRQ issued)	Syntax Error	SING, NUMG, complete
Bit #	3	2	1	0
Decimal Value	8	4	2	1
Function	One-Path 2-Port Measurement. Wait for GET after REVERSE DEVICE.	TRIG Mode, Waiting for GET (next point or sweep)	Data Entry Complete	CAUTION Message Displayed

EXTENDED STATUS BYTE (#2)				
Bit #	7	6	5	4
Decimal Value	128	64	32	16
Function				
Bit #	3	2	1	0
Decimal Value	8	4	2	1
Function		Power ON Sequence Complete	Key Pressed	

SETTING THE SERVICE REQUEST MASK

After Power ON, TEST, and PRESET, the HP 8510 SRQ mask is set to 0,0 and no changes in the Primary or Secondary status byte will generate an SRQ. To enable generation of an SRQ when one or more of the status bits changes from 0 to 1 (changes from cleared to set), specify the SRQ mask to sense the change in status. Using the HP 8510 SRQM instruction, send two bytes, each having a value from 0 to 255, as follows.

```
! Example 17 Setting HP 8510 SRQ Mask  
Listen Nwa:"SRQM 16,0;"
```

This will cause the HP 8510 to generate an SRQ when bit 4 of the Primary Status byte changes from 0 to 1.

Detect and service the SRQ according to the controller protocol. Normal completion of a service cycle clears the HP 8510 status bytes to 0,0 and does not change the SRQ mask.

Examples in the Example Program Listings show various interrupt service routines.

USING THE HP 8510 LEARN STRING

The HP 8510 Learn String is a binary coded string which describes the current instrument state. This string may be read from the HP 8510 to controller memory via the HP-IB, then it may be loaded back into HP 8510 memory in order to reset the system to the state represented by the string. This learn string is transferred using internal HP 8510 binary format (FORM 1), and it is not intended that the user attempt to decode or modify the string.

The commands

OUTPLEAS; Output Learn String to HP-IB,

INPULEAS; Input Learn String from HP-IB;
 Set the HP 8510 controls to that state,

control transfer of the string. The contents of the learn string is identical to the information processed by the SAVE and RECALL features for HP 8510 internal storage, and the TAPE STORE and LOAD Instrument State functions for the HP 8510 tape cartridge.

The following example shows a sequence to transfer the learn string. The learn string is 3400 bytes in length and can be read into an integer type array of length 1700.

```
! Example 17 Transfer HP 8510 Learn String
dim Integer Learn_string (1700)
Listen Nwa:"OUTPLEAS;"
Talk Nwa_data:Preamble, Size, Learn_string (*)
! Preamble = #A
! Size = 3400
.
.
.
Listen Nwa:"INPULEAS;"
Listen Nwa:Preamble, Size, Learn_string (*)
```

OUTPLEAS and INPULEAS select FORM 1 data format transfers. The data is transferred in a sequence beginning with the Preamble, #A; an integer size, having the value 3400 for the Learn String; followed by 3400 bytes of HP 8510 internal binary format data which represents the control state of the HP 8510, with EOI asserted on the last byte.

USER DISPLAY GRAPHICS

Vector diagrams and Text can be written to a reserved area of the HP 8510 CRT display memory via the HP 8510 system bus using either an HP-GL subset internal to the HP 8510, or the standard controller language graphics commands. This reserved graphics area is output using PLOTALL; and may be recorded using tape USED;

VECTOR DIAGRAMS

A vector diagram consists of a PA, Plot Absolute, display instruction followed by any number of x,y integer pairs.

```
! Example 18 Plot Absolute Using HP 8510 HP-GL Subset
Listen Nwa:"ADDRPASS 31"
Listen Nwa_systbus:"CS; PU"
Listen Nwa_systbus:"PA 128,384; PD; PA 3328,384, 3328,3584,
128,3584 128,384"
```

ADDRPASS 31 sets up the Pass-Thru mode in which data sent to the 8510 System Bus address, 717, is routed to the User Display area of the HP 8510 CRT display memory. The CS instruction clears the screen. The PU instruction lifts the pen, causing the following PA instruction to draw a blank vector. The PD, Pen Down, causes the following PA instruction to draw a visible line. The PA, Plot Absolute, instruction is followed by the coordinates for the other three corners of the box.

The plotting area of the HP 8510 CRT is:

x = 0 to 4095
y = 0 to 4095

Figure 2 shows internal scaling for PA vector diagrams.

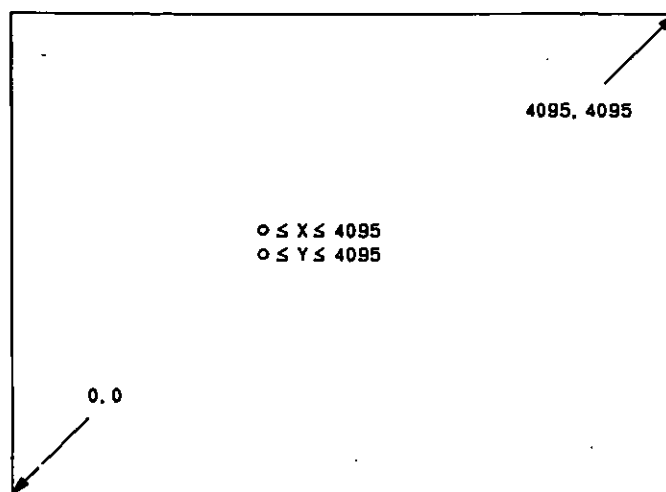


Figure 2. PA Vector Scaling

To increase the intensity of the vector, draw it multiple times as shown in controller-specific examples at the end of this section.

The PR, Plot Relative, instruction moves the pen from its present position to the new position x,y units away.

```
! Example 18A Plot Relative
Listen Nwa:"ADDRPASS 31"
Listen Nwa_systbus:"CS; PU"
Listen Nwa_systbus:"PA 128,384; PD; PR 3200,0, 0,3200, -3200,0,
0,-3200"
```

This outlines the Menu labels area.

TEXT

Position standard ASCII text on the screen by addressing the text location with a PA or PR vector. Text between the LB mnemonic and the end of text character, CTRL C, is displayed beginning at the character cell position of the current vector. Figure 3 shows the 64 by 128 element character cell which encloses the 48 by 64 element character image area. Part of Example 18 in the Example Program Listings demonstrates the use of the LB instruction.

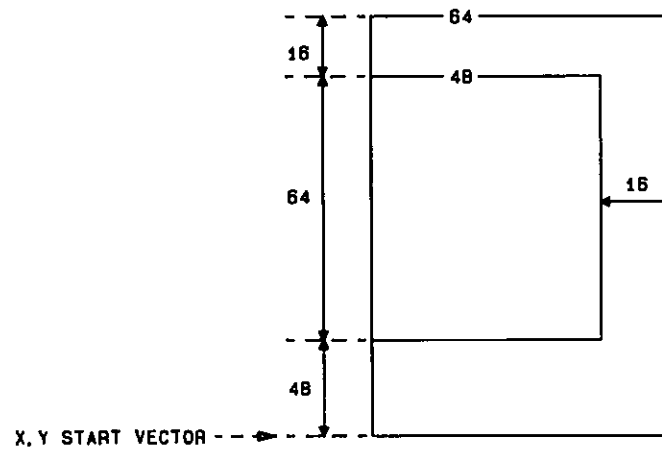


Figure 3. Text Character Cell

USING THE TAPE TO STORE THE USER DISPLAY

By storing the User Display on the HP 8510 internal tape cartridge, the vector diagrams and text can be recalled for display even if the controller is disconnected from the HP 8510. For example:

```
Listen Nwa;"STOR; USED; FILE1"
```

stores the vector and text data presently in user display memory in User Display File 1.

The User Display graphics may be loaded from tape using

```
Listen Nwa;"LOAD; USED; FILE1"
```

which erases the current User Display, then loads and displays the previously stored graphics and text.

SUMMARY OF USER GRAPHICS STATEMENTS

The following statements are used to control plotting of vectors and text into the HP 8510 User Display area of internal memory.

PA $\overline{\downarrow x1,y1}$	Plot Absolute vector. Move the pen from the current location to the location specified by the following x,y pair. Any number of x,y pairs may follow the PA instruction; each number must be separated from the previous number by a comma. $0 \leq x \leq 4095; 0 \leq y \leq 4095.$
PR $\overline{\downarrow x1,y1}$	Plot Relative vector. Move the pen from the current location to the relative position specified by the following x,y pair. Any number of x,y pairs may follow the PR instruction; each number must be separated from the previous number by a comma. $0 \leq x \leq 4095; 0 \leq y \leq 4095.$
PD	Pen Down. When followed by a PA or PR instruction, this instruction will cause a visible vector to be drawn to the new location.
PU	Pen Up. When followed by a PA or PR instruction, this instruction will cause a blank vector to be drawn to the new location.
LB $\overline{\downarrow \text{ASCII char}} \text{ etc}$	Label Text. The ASCII characters following the LB command are drawn on the CRT beginning in the character cell at the current vector position. The string must be terminated with the end-of-text character, CNTRL C.
DF	Set to Default state (PU, PA).

SUMMARY OF USER DISPLAY INSTRUCTIONS

The following instructions control whether the standard CRT measurement display (graticule, labels, etc.) and the User Display are on or off.

- | | |
|----|--|
| KP | Turn off User Display. Memory contents are not changed. |
| RP | Turn on User Display. Memory contents are not changed. |
| PG | Clear (Erase) User Display Memory. |
| CS | Turn off measurement display (standard graticule, trace, and labels).
User display is not affected. |
| RS | Turn on measurement display. User display is not changed. |

EXAMPLE PROGRAM LISTINGS

HP 9000 Series 200 BASIC Language Examples

Series 200: 9816, 9826, 9836

Language : HP BASIC

Executable examples:

EXAMPLE	FUNCTION
1	Input Syntax Familiarization
2	Marker Data Output
3	Active Function Output
4	Peak-to-Peak Measurement
5	Alternate Sweep
6	Dual Channel Read Markers
7	Using =MARKER
8	Trace Data Output
9	Trace Data Input
10	S ₁₁ 1-Port and S ₂₁ Response Cals
11	Using Tape Cartridge
12	Plots Using COPY
13	List Trace Values
14	Print to Printer on 8510 System Bus
15	Plot User Graphics
16	Plot using BASIC HP-GL
17	Process Error Coefficient Data
18	Modify Cal Kit
19	Redefine Parameter
20	Read and Output Caution/Tell Message
21	Read and Output Status Bytes
22	Output Key Code
23	Triggered Data Acquisition
24	Triggered Sweep for One-Path 2-Port
25	WAIT Required
26	WAIT Not Required


```

10  ! EXAMPLES FOR INTRODUCTION TO PROGRAMMING- 12/27/84 *
20  ! HP8510A.02.00: DEC 11, 1984
30  !
40  ! Copyright © HEWLETT-PACKARD COMPANY 1984
50  ! NETWORK MEASUREMENTS DIVISION
60  !
70  ! Used with 201 Point Trace I/O
80  OPTION BASE 0
90  DIM Data(200,1)
100 DIM Formatted_data(200,1)
110 !
120 DIM Input$(80)
130 INTEGER Length,Error_number,Bytea,Byteb
140 !
150 REAL Freq,Real,Imag,Mag,Phase
160 !
170 DIM Freq_list(400),Mag_list(400),Phase_list(400)
180 !
190 ! Write to 8510 HP-IB
200 ASSIGN @Nwa TO 716
210 !
220 ! Read ASCII Data to/from HP 8510 HP-IB (OUTPMARK, OUTPACT1, FORM4 I/O)
230 ASSIGN @Nwa_data1 TO 716;FORMAT ON
240 !
250 ! Read non-ASCII Data to/from HP 8510 HP-IB (FORM1, FORM2, and FORM3 I/O)
260 ASSIGN @Nwa_data2 TO 716;FORMAT OFF
270 INTEGER Size,Preamble
280 !
290 ! Write to 8510 System Bus
300 ASSIGN @Nwa_systbus TO 717
310 !
320 ! Read from HP 8510 System Bus
330 ASSIGN @Nwa_systbusdata TO 717;FORMAT ON
340 !
350 Begin: !
360 REMOTE 7
370 PRINTER IS 1
380 OUTPUT @Nwa;"DEBUON;"
390 !
400 OUTPUT @Nwa;"ENTO;"
410 GOSUB Example1 ! Input Syntax Familiarization
420 !
430 OUTPUT @Nwa;"PRES;"
440 LINPUT "Example 2: Press CONTINUE",Input$
450 GOSUB Example2 ! Marker Data Output
460 !
470 OUTPUT @Nwa;"AVEROFF;"
480 LINPUT "Example 3: Press CONTINUE",Input$
490 GOSUB Example3 ! Active Function Output
500 !
510 OUTPUT @Nwa;"CONT;"
520 LINPUT "Example 4: Press CONTINUE",Input$
530 OUTPUT @Nwa;"AUTO;"
540 GOSUB Example4 ! Peak-to-Peak Measurement
550 !
560 LINPUT "Example 5: Press CONTINUE",Input$
570 GOSUB Example5 ! Alternate Sweep
580 !
590 LINPUT "Example 6: Press CONTINUE",Input$
600 GOSUB Example6 ! Dual Channel Read Markers

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610 !
620 LINPUT "Example 7: Press CONTINUE",Input$
630 GOSUB Example7 ! Using =MARKER
640 !
650 LINPUT "Example 8: Press CONTINUE",Input$
660 OUTPUT @Nwa;"PRES;"
670 GOSUB Example8 ! Trace Data Output
680 !
690 LINPUT "Example 9: Press CONTINUE",Input$
700 OUTPUT @Nwa;"CONT; ENTO;"
710 GOSUB Example9 ! Trace Data Input
720 !
730 LINPUT "Example 10: Press CONTINUE",Input$
740 OUTPUT @Nwa;"PRES;"
750 GOSUB Example10 ! S11 1-Port and S21 Response Cals
760 !
770 OUTPUT @Nwa;"ENTO;"
780 LINPUT "Example 11: Press CONTINUE",Input$!
790 OUTPUT @Nwa;"PRES; SING; DATI;"
800 GOSUB Example11 ! Using Tape Cartridge
810 !
820 LINPUT "Example 12: Press CONTINUE",Input$
830 OUTPUT @Nwa;"DISPDATA;"
840 GOSUB Example12 ! Plots Using Copy
850 !
860 OUTPUT @Nwa;"S21;"
870 LINPUT "Example 13: Press CONTINUE",Input$
880 GOSUB Example13 ! List Trace Values
890 !
900 LINPUT "Example 14: Press CONTINUE",Input$
910 GOSUB Example14 ! Print to Printer on HP 8510 System Bus
920 !
930 PRINTER IS 1
940 LINPUT "Example 15: Press CONTINUE",Input$
950 GOSUB Example15 ! Plot User Graphics
960 !
970 OUTPUT @Nwa;"SINC; FULP;"
980 LINPUT "Example 16: Press CONTINUE",Input$
990 GOSUB Example16 ! Plot Using BASIC HPGL
1000 !
1010 OUTPUT @Nwa;"PRES;"
1020 LINPUT "Example 17: Press CONTINUE",Input$
1030 GOSUB Example17 ! Process Error Coefficient Data
1040 !
1050 LINPUT "Example 18: Press CONTINUE",Input$
1060 OUTPUT @Nwa;"PRES;"
1070 GOSUB Example18 ! Modify Cal Kit
1080 !
1090 LINPUT "Example 19: Press CONTINUE",Input$
1100 GOSUB Example19 ! Redefine Parameter
1110 !
1120 GOSUB Example20 ! Read and Output Caution/Tell Message
1130 !
1140 GOSUB Example21 ! Read and Output Status Bytes
1150 !
1160 GOSUB Example22 ! Output Key Code
1170 !
1180 OUTPUT @Nwa;"PRES;"
1190 GOSUB Example23 ! Triggered Data Acquisition.
1200 !
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1210 !GOSUB Example24                      ! Triggered Sweep for One-Path 2-Port
1220 ! Example 24 executes only if ONE-PATH 2-PORT correction is turned on
1230 ! using a Reflection/Transmission test set.
1240 !
1250 LINPUT "Example 25: Press CONTINUE",Input$
1260 GOSUB Example25                      ! WAIT Required
1270 !
1280 LINPUT "Example 26: Press CONTINUE",Input$
1290 OUTPUT @Nwa;"PRES;"
1300 GOSUB Example26                      ! WAIT Not Required
1310 !
1320 OUTPUT @Nwa;"PRES;"
1330 DISP "END OF EXAMPLES"
1340 !
1350 STOP
1360 !
1370! *****
1380 !
1390 Example1: ! INPUT SYNTAX FAMILIARIZATION *****
1400 !
1410 REMOTE @Nwa
1420 LINPUT "TYPE STRING, THEN CONTINUE; ENTER 0 TO EXIT",Input$
1430 IF Input$[1,1]="0" THEN RETURN
1440 Length=LEN(Input$)
1450 OUTPUT @Nwa;Input$[1,Length];";"
1460 GOTO Example1
1470 !
1480 Example2: ! MARKER DATA OUTPUT *****
1490 !
1500 PRINT "Averaging On."
1510 OUTPUT @Nwa;"AVERON 16;"
1520 LINPUT "Press CONTINUE",Input$
1530 OUTPUT @Nwa;"NUMG 17; MARK1; MARKMAX1; OUTPMARK;"
1540 ENTER @Nwa_data1;Mag,Phase
1550 !
1560 PRINT "Marker Value."
1570 PRINT Mag,Phase
1580 !
1590 RETURN
1600 !
1610 Example3: ! ACTIVE FUNCTION OUTPUT *****
1620 !
1630 OUTPUT @Nwa;"OUTPACTI;"
1640 ENTER @Nwa_data1;Freq
1650 !
1660 PRINT "Active Function Value."
1670 PRINT Freq
1680 !
1690 RETURN
1700 !
1710 Example4: ! PEAK-TO-PEAK MEASUREMENT *****
1720 !
1730 PRINT "Peak-to-Peak Measurement."
1740 OUTPUT @Nwa;"NUMG 2; MARK2; MARKMAX1; DELR2; MARK1; MARKMINI; OUTPMARK;"
1750 ENTER @Nwa_data1;Mag,Phase
1760 !
1770 OUTPUT @Nwa;"OUTPACTI;"
1780 ENTER @Nwa_data1;Freq
1790 !
1800 PRINT Mag,Phase,Freq

```

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1810 !
1820 INPUT "Press CONTINUE",Input$
1830 !
1840 OUTPUT @Nwa;"DELO; MARKOFF; CONT;"
1850 !
1860 RETURN
1870 !
1880 Example5: ! ALTERNATE SWEEP *****
1890 !
1900 PRINT "Alternate Sweep."
1910 OUTPUT @Nwa;"UNCC;"
1920 OUTPUT @Nwa;"CHAN1; STAR 2 GHz; STOP 5 GHz;"
1930 OUTPUT @Nwa;"CHAN2; STAR 3 GHz; STOP 4 GHz;"
1940 OUTPUT @Nwa;"SPLI;"
1950 !
1960 RETURN
1970 !
1980 Example6: ! DUAL CHANNEL READ MARKERS *****
1990 !
2000 OUTPUT @Nwa;"MARK1 3.5 GHz;"
2010 PRINT "Channel 1 Marker."
2020 OUTPUT @Nwa;"CHAN1; SING; AUTO; OUTPMARK;"
2030 ENTER @Nwa_data1;Mag,Phase
2040 PRINT Mag,Phase
2050 !
2060 INPUT "Press CONTINUE for Channel 2 Data",Input$
2070 !
2080 PRINT "Channel 2 Marker."
2090 OUTPUT @Nwa;"CHAN2; SING; AUTO; OUTPMARK; CONT;"
2100 ENTER @Nwa_data1;Mag,Phase
2110 PRINT Mag,Phase
2120 !
2130 RETURN
2140 !
2150 Example7: ! USING =MARKER TO MEASURE DEV. FROM LIN. PHASE *****
2160 !
2170 PRINT "Measure Deviation from Linear Phase Using =MARKER."
2180 OUTPUT @Nwa;"CHAN2; PHAS; ELED 0;"
2190 !
2200 INPUT "Press CONTINUE",Input$
2210 !
2220 OUTPUT @Nwa;"DELA; NUMG 1; CONT; ELED; EQUA; PHAS; AUTO;"
2230 !
2240 RETURN
2250 !
2260 Example8: ! TRACE DATA OUTPUT *****
2270 !
2280 DEG
2290 !
2300 OUTPUT @Nwa;"REIP; NUMG 2; AUTO; FORM3; OUTPDATA;"
2310 ENTER @Nwa_data2;Preamble,Size,Data(*)
2320 !
2330 FOR N=0 TO 200
2340   Real=Data(N,0)
2350   Imag=Data(N,1)
2360   !
2370   ! Convert to Polar
2380   !
2390   Mag=SQR(Real^2+Imag^2)
2400   Phase=2*ATN(Imag/(Real+Mag))

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2410 !
2420 PRINT N;Real;Imag;
2430 PRINT N;Mag;Phase
2440 !
2450 NEXT N
2460 !
2470 PRINT "Compare Re/Im and LIN mkr values."
2480 !
2490 RETURN
2500 !
2510 Example9: ! Trace Data Input *****
2520 !
2530 PRINT "Input Trace Data."
2540 OUTPUT @Nwa;"HOLD; FORM3; INPUDATA;"
2550 OUTPUT @Nwa_data2;Preamble,Size,Data(*)
2560 !
2570 RETURN
2580 !
2590 Example10: ! S11 1-PORT AND S21 RESPONSE CALIBRATIONS *****
2600 !
2610 PRINT "S11 1-Port Measurement Calibration."
2620 !
2630 OUTPUT @Nwa;"CHAN1; S11; CORROFF; CAL1; CALIS11;"
2640 INPUT "Port 1, Connect Shielded Open, then press CONTINUE",Input$
2650 OUTPUT @Nwa;"CLASS11A;" ! (Shielded Open Circuit Data Measured)
2660 INPUT "Port 1, Connect Short, then press CONTINUE",Input$
2670 OUTPUT @Nwa;"CLASS11B;" ! (Short Circuit Data Measured)
2680 OUTPUT @Nwa;"CLASS11C;" ! (Uses Both LOWBAND and SLIDING)
2690 INPUT "Port 1, Connect Fixed Load, then press CONTINUE",Input$
2700 OUTPUT @Nwa;"STANC;" ! (LOWBAND Load Data Measured)
2710 INPUT "Port 1, Connect Sliding Load, then press CONTINUE",Input$
2720 OUTPUT @Nwa;"STANB;" ! (Select Sliding Load)
2730 INPUT "Move Element to First Index Mark, then press CONTINUE",Input$
2740 OUTPUT @Nwa;"SLIS;" ! (Sliding Load Data Measured)
2750 FOR Slide=2 TO 6
2760 INPUT "Move Element to Next Index Mark, then press CONTINUE",Input$
2770 OUTPUT @Nwa;"SLIS;" ! (Sliding Load Data Measured)
2780 NEXT Slide
2790 DISP "Remove Sliding Load."
2800 OUTPUT @Nwa;"SLID; DONE; SAV1; CALS1;"
2810 ! (Error coefficients computed and stored;
2820 ! Cal Menu displayed with CORRECTION ON;
2830 ! Corrected S11 trace displayed.)
2840 !
2850 INPUT "Press CONTINUE",Input$
2860 !
2870 PRINT "S21 Response Measurement Calibration."
2880 !
2890 OUTPUT @Nwa;"CHAN2; S21; CORROFF; CAL1; CALIRESP;"
2900 INPUT "Connect Thru, then press CONTINUE",Input$
2910 OUTPUT @Nwa;"STANC;" ! (Thru Data Measured)
2920 OUTPUT @Nwa;"DONE; CALS2;"
2930 ! (Vector frequency response computed and stored;
2940 ! Cal Menu displayed with CORRECTION ON;
2950 ! Corrected S21 trace displayed.)
2960 !
2970 INPUT "Press CONTINUE",Input$
2980 !
2990 PRINT "Measure S11 and S21."
3000 !

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3010 FOR N=1 TO 3 ! Repeat Measurement Sequence 3 Times
3020 LINPUT "Connect Device Under Test, then press CONTINUE",Input$
3030 OUTPUT @Nwa;"CHAN1; S11; SING; AUTO;"
3040 !
3050 ! Read S11 Data
3060 !
3070 OUTPUT @Nwa;"MARKMINI; CONT;"
3080 WAIT 3 ! Observe Trace
3090 OUTPUT @Nwa;"CHAN2; S21; SING; AUTO;"
3100 !
3110 ! Read S21 Data
3120 !
3130 OUTPUT @Nwa;"MARKMAXI; CONT;"
3140 WAIT 3 ! Observe Trace
3150 NEXT N
3160 !
3170 RETURN
3180 !
3190 Example11: ! USING TAPE CARTRIDGE *****
3200 !
3210 LINPUT "Insert Data Tape Cartridge, then CONTINUE",Input$
3220 LINPUT "Initialize Data Tape Cartridge? (ENTER Y or N)",Input$
3230 IF Input$="Y" THEN OUTPUT @Nwa;"INIT;"
3240 !
3250 Store: !
3260 PRINT "Store Data"
3270 OUTPUT @Nwa;"STOR; INSS1; FILE1;"
3280 OUTPUT @Nwa;"CHAN1; STOR; DATAFORM; FILE1;"
3290 OUTPUT @Nwa;"CHAN2; STOR; DATAFORM; FILE2;"
3300 OUTPUT @Nwa;"STOR; MEMO1; FILE1;"
3310 OUTPUT @Nwa;"STOR; CALS1; FILE1;"
3320 OUTPUT @Nwa;"STOR; CALK1; FILE1;"
3330 OUTPUT @Nwa;"DIRE;"
3340 !
3350 LINPUT "Press CONTINUE to Load Data",Input$
3360 !
3370 Load: !
3380 PRINT "Load Data"
3390 OUTPUT @Nwa;"LOAD; INSS1; FILE1;"
3400 OUTPUT @Nwa;"HOLD;"
3410 OUTPUT @Nwa;"CHAN1; LOAD; DATAFORM; FILE1;"
3420 OUTPUT @Nwa;"CHAN2; LOAD; DATAFORM; FILE2;"
3430 OUTPUT @Nwa;"CHAN1; DISPDATM;"
3440 ! Must Turn Both Channel's Memories Off Before Loading any Memory
3450 OUTPUT @Nwa;"LOAD; MEMO1; FILE1;"
3460 OUTPUT @Nwa;"S11; CORROFF;"
3470 ! Must Turn All Cals Off Before Loading Any Cal Set
3480 OUTPUT @Nwa;"LOAD; CALS1; FILE1;"
3490 !
3500 OUTPUT @Nwa;"CHAN1; S11; CORRON; CALS1; DISPDATM; CONT;"
3510 !
3520 RETURN
3530 !
3540 Example12: ! PLOTS USING COPY *****
3550 !
3560 PRINT "Press HP 8510 ENTRY OFF to abort Plot."
3570 LINPUT "Load Paper, then CONTINUE",Input$
3580 OUTPUT @Nwa;"S11; SING; PEN1; LEFU; PLOTALL;"
3590 OUTPUT @Nwa;"S21; SING; PEN2; LEFL; PLOTALL;"
3600 OUTPUT @Nwa;"S12; SING; PEN3; RIGU; PLOTALL;"

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3610 OUTPUT @Nwa;"S22; SING; PEN4; RIGL; PLOTALL;"
3620 !
3630 RETURN
3640 !
3650 Example13: ! TRACE LIST TO PRINTER *****
3660 !
3670 PRINT "List Trace Values."
3680 OUTPUT @Nwa;"LINP; POIN51; SING; LIST;"
3690 !
3700 RETURN
3710 !
3720 Example14: ! PRINT TO PRINTER ON 8510 SYSTEM BUS *****
3730 !
3740 PRINT "Print Title via Pass-Thru."
3750 OUTPUT @Nwa;"ADDRPASS 01;"
3760 PRINTER IS 717 ! (Nwa_systbus)
3770 PRINT
3780 PRINT "MEASUREMENT NUMBER 1"
3790 PRINT
3800 !
3810 RETURN
3820 !
3830 Example15: ! PLOT USER GRAPHICS USING HP-GL SUBSET *****
3840 !
3850 Plot absolute: !
3860 PRINT "Plot User Graphics."
3870 OUTPUT @Nwa;"ADDRPASS 31;"
3880 OUTPUT @Nwa_systbus;"CS; PU;"
3890 FOR N=1 TO 5
3900 OUTPUT @Nwa_systbus;"PA 128,384; PD; PA 3328,384, 3328,3584, 128,3584"
3910 NEXT N
3920 OUTPUT @Nwa_systbus;"PU; PA 2000,2000; PD; LBSINGLE CHANNEL;"
3930 LINPUT "Press CONTINUE",Input$
3940 OUTPUT @Nwa_systbus;"PU;"
3950 FOR N=1 TO 5
3960 OUTPUT @Nwa_systbus;"PA 128,1184; PD; PA 1728,1184, 1728,2784, 128,2784"
3970 NEXT N
3980 OUTPUT @Nwa_systbus;"PU; PA 2000,1872; PD; LBDUAL, CHANNEL 1;"
3990 LINPUT "Press CONTINUE",Input$
4000 OUTPUT @Nwa_systbus;"PU;"
4010 FOR N=1 TO 5
4020 OUTPUT @Nwa_systbus;"PA 1760,1184; PD; PA 3360,1184, 3360,2784, 1760,2784"
4030 NEXT N
4040 OUTPUT @Nwa_systbus;"PU; PA 2000,1744; PD; LBDUAL, CHANNEL 2;"
4050 LINPUT "Press CONTINUE",Input$
4060 OUTPUT @Nwa_systbus;"PU;"
4070 FOR N=1 TO 5
4080 OUTPUT @Nwa_systbus;"PA 3424,2; PD; PA 4092,2, 4092,4092, 3424,4092"
4090 NEXT N
4100 OUTPUT @Nwa_systbus;"PU; PA 2000,1616; PD; LBMENU AREA;"
4110 OUTPUT @Nwa_systbus;"PU;"
4120 !
4130 LINPUT "Turn On Measurement Display: Press CONTINUE",Input$
4140 !
4150 OUTPUT @Nwa_systbus;"RS;"
4160 !
4170 LINPUT "Show Split Display: Press CONTINUE",Input$
4180 !
4190 OUTPUT @Nwa;"SPLI;"

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4200 !
4210 LINPUT "Store User Display on Tape: Press CONTINUE",Input$
4220 PRINT "Store User Display."
4230 OUTPUT @Nwa;"STOR; USED; FILE1;"
4240 !
4250 LINPUT "Turn Off Measurement Display: Press CONTINUE",Input$
4260 OUTPUT @Nwa_systbus;"CS;"
4270 !
4280 LINPUT "Erase User Display: Press CONTINUE",Input$
4290 OUTPUT @Nwa_systbus;"PG;"
4300 !
4310 LINPUT "Turn On Measurement Display: Press CONTINUE",Input$
4320 OUTPUT @Nwa_systbus;"RS;"
4330 !
4340 LINPUT "Load User Display from Tape: Press CONTINUE",Input$
4350 PRINT "Load User Display."
4360 OUTPUT @Nwa;"LOAD; USED; FILE1;"
4370 !
4380 LINPUT "Next Example: Press CONTINUE",Input$
4390 !
4400 OUTPUT @Nwa_systbus;"PG; RS;"
4410 !
4420 RETURN
4430 !
4440 Example16: ! PLOT USING BASIC HP-GL *****
4450 !
4460 OUTPUT @Nwa;"ADDRPASS 31;"
4470 PLOTTER IS 717,"HPGL"
4480 WINDOW 0,4095,0,4095
4490 !
4500 ! HP-GL PLOTTING STATEMENTS
4510 !
4520 FRAME
4530 MOVE 100,100
4540 DRAW 3995,3995
4550 MOVE 3995,100
4560 DRAW 100,3995
4570 !
4580 OUTPUT @Nwa;"PLOTALL;"
4590 !
4600 PRINT "Press HP 8510 ENTRY OFF to abort Plot."
4610 LINPUT "Press CONTINUE",Input$
4620 !
4630 OUTPUT @Nwa;"ADDRPASS 31;"
4640 OUTPUT @Nwa_systbus;"PG; RS;"
4650 RETURN
4660 !
4670 Example17: ! STORE ERROR COEFFICIENT DATA, PROCESS DATA, LOAD DATA
4680 !
4690 Read_response: !
4700 PRINT "Read Cal Coefficients."
4710 OUTPUT @Nwa;"S21; CORR0N; CALS2; FORM3; OUTPCALC01;"
4720 ENTER @Nwa_data2;Preamble,Size,Data(*)
4730 !
4740 FOR N=0 TO 200
4750   Formatted_data(N,0)=Data(N,0)
4760   Formatted_data(N,1)=Data(N,1)
4770 NEXT N
4780 !
4790 PRINT "Store Processed Cal Coefficients."

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4800 OUTPUT @Nwa;"CORROFF; CAL1; CALIRESP; FORM3; INPUCALC01;"
4810 OUTPUT @Nwa_data2;Preamble,Size,Formatted_data(*)
4820 OUTPUT @Nwa;"SAVC; CALS2; CONT; CORRON; CALS2;"
4830 !
4840 PRINT "Correction On."
4850 LINPUT "Press CONTINUE",Input$
4860 !
4870 Read_1_port: !
4880 !
4890 PRINT "Reading and Plotting Directivity Coefficient."
4900 OUTPUT @Nwa;"HOLD; S11; CORRON; CALS1; FORM3; OUTPCALC01;"
4910 ENTER @Nwa_data2;Preamble,Size,Data(*)
4920 !
4930 OUTPUT @Nwa;"CORROFF; FORM3; INPUDATA;"
4940 OUTPUT @Nwa_data2;Preamble,Size,Data(*)
4950 OUTPUT @Nwa;"AUTO; DEBUOFF; TITL"DIRECTIVITY PLOT"";"
4960 LINPUT "Press CONTINUE",Input$
4970 !
4980 PRINT "Reading and Plotting Source Mismatch Coefficient."
4990 OUTPUT @Nwa;"DEBUON; S11; CAL1; CORRON; CALS1; FORM3; OUTPCALC02;"
5000 ENTER @Nwa_data2;Preamble,Size,Data(*)
5010 !
5020 OUTPUT @Nwa;"CORROFF; FORM3; INPUDATA;"
5030 OUTPUT @Nwa_data2;Preamble,Size,Data(*)
5040 OUTPUT @Nwa;"AUTO; DEBUOFF; TITL"SOURCE MISMATCH PLOT"";"
5050 LINPUT "Press CONTINUE",Input$
5060 !
5070 PRINT "Reading and Plotting Relection Tracking Coefficient."
5080 OUTPUT @Nwa;"DEBUON; S11; CAL1; CORRON; CALS1; FORM3; OUTPCALC03;"
5090 ENTER @Nwa_data2;Preamble,Size,Data(*)
5100 !
5110 OUTPUT @Nwa;"CORROFF; FORM3; INPUDATA;"
5120 OUTPUT @Nwa_data2;Preamble,Size,Data(*)
5130 OUTPUT @Nwa;"AUTO; DEBUOFF; TITL"REFLECTION TRACKING PLOT"";"
5140 !
5150 RETURN
5160 !
5170 Example18: ! MODIFY CAL KIT (TYPICAL X-BAND WAVEGUIDE) *****
5180 !
5190 PRINT "Define New Cal Kit."
5200 LINPUT "Insert Initialized Data Tape Cartridge, then CONTINUE",Input$
5210 OUTPUT @Nwa;"STOR; CALK2; FILE2;"
5220 PRINT "Old Cal Kit 2 now on File 2."
5230 !
5240 PRINT "Defining New Cal Kit."
5250 OUTPUT @Nwa;"MODI2; DEFS 1; STDTSHOR;"
5260 OUTPUT @Nwa;"OFFD 0.018652 ns; OFFL 0; OFFZ 50;"
5270 OUTPUT @Nwa;"MINF 6.557 GHz; MAXF 999 GHz;"
5280 OUTPUT @Nwa;"WAVE; LABS"XSHORT 1""; STDD;"
5290 !
5300 OUTPUT @Nwa;"DEFS 2; STDTSHOR;"
5310 OUTPUT @Nwa;"OFFD 0.055957 ns; OFFL 0; OFFZ 50;"
5320 OUTPUT @Nwa;"MINF 6.557 GHz; MAXF 999 GHz;"
5330 OUTPUT @Nwa;"WAVE; LABS"XSHORT 2""; STDD;"
5340 !
5350 OUTPUT @Nwa;"DEFS 3; STDTLOAD;"
5360 OUTPUT @Nwa;"OFFD 0; OFFL 0; OFFZ 50; MINF 6.557 GHz; MAXF 999 GHz;"
5370 OUTPUT @Nwa;"FIXE; WAVE; LABS"XLOAD""; STDD;"
5380 !
5390 OUTPUT @Nwa;"DEFS 11; STDTDELA;"

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5400 OUTPUT @Nwa;"OFFD 0; OFFL 0; OFFZ 50; MINF 6.557 GHz; MAXF 999 GHz;"
5410 OUTPUT @Nwa;"WAVE; LABS""XTHRU""; STDD;"
5420 !
5430 OUTPUT @Nwa;"SPECS11A 1; CLAD; SPECS11B 2; CLAD; SPECS11C 3; CLAD;"
5440 !
5450 OUTPUT @Nwa;"LABES11A""1/8 SHORT"";"
5460 OUTPUT @Nwa;"LABES11B""3/8 SHORT"";"
5470 OUTPUT @Nwa;"LABES11C""STDXLD"";"
5480 !
5490 OUTPUT @Nwa;"SPECS22A 1; CLAD; SPECS22B 2; CLAD; SPECS22C 3; CLAD;"
5500 !
5510 OUTPUT @Nwa;"LABES22A""1/8 SHORT"";"
5520 OUTPUT @Nwa;"LABES22B""3/8 SHORT"";"
5530 OUTPUT @Nwa;"LABES22C""STDXLD"";"
5540 !
5550 OUTPUT @Nwa;"SPECFWD 11; CLAD; SPECREVT 11; CLAD;"
5560 OUTPUT @Nwa;"SPECFWD 11; CLAD; SPECREVM 11; CLAD;"
5570 OUTPUT @Nwa;"SPECRESP 1, 2, 11; CLAD;"
5580 !
5590 OUTPUT @Nwa;"LABEFWD"" THRU ""; LABEREVT"" THRU "";"
5600 OUTPUT @Nwa;"LABEFWD"" THRU ""; LABEREVM"" THRU "";"
5610 OUTPUT @Nwa;"LABERESP""RESPONSE"";"
5620 !
5630 OUTPUT @Nwa;"LABK"" X BAND "";"
5640 OUTPUT @Nwa;"KITD;"
5650 !
5660 OUTPUT @Nwa;"STOR; CALK2; FILE3;"
5670 PRINT "New Cal Kit now on File 3."
5680 !
5690 LINPUT "Reload Old cal kit? (Y/N)",Input$
5700 IF Input$="N" THEN RETURN
5710 OUTPUT @Nwa;"LOAD; CALK2; FILE2;"
5720 PRINT "Old Cal Kit 2 Reloaded."
5730 !
5740 RETURN
5750 !
5760 Example19: ! REDEFINE PARAMETER *****
5770 !
5780 OUTPUT @Nwa;"USER3; DRIVPORT2; LOCKA2; REDD;"
5790 LINPUT "USER 3 Redefine Done - Press CONTINUE",Input$
5800 OUTPUT @Nwa;"SAVE1;"
5810 PRINT "Redefined USER 3 now Saved in INST STATE 1."
5820 !
5830 ! PRESET selects standard User parameter definition.
5840 ! RECALL selects previously saved user parameter definitions.
5850 !
5860 RETURN
5870 !
5880 Example20: ! READ AND OUTPUT CAUTION/TELL MESSAGE *****
5890 !
5900 LINPUT "Press CONTINUE to Read HP 8510 Caution/Tell",Input$
5910 !
5920 OUTPUT @Nwa;"OUTPERRO;"
5930 ENTER @Nwa_datal;Error_number,Input$
5940 PRINT Error_number,Input$
5950 !
5960 LINPUT "ANOTHER? (Y/N)",Input$
5970 IF Input$="Y" OR Input$="y" THEN GOTO Example20
5980 RETURN
5990 !

```

```

6000 Example21: ! READ AND OUTPUT STATUS BYTES *****
6010 !
6020 LINPUT "Press CONTINUE to Read HP 8510 Status",Input$
6030 !
6040 OUTPUT @Nwa;"OUTPSTAT;"
6050 ENTER @Nwa_data1;Bytea,Byteb
6060 PRINT Bytea,Byteb
6070 !
6080 LINPUT "ANOTHER? (Y/N)",Input$
6090 IF Input$="Y" OR Input$="y" THEN GOTO Example21
6100 RETURN
6110 !
6120 !
6130 Wait_loop: GOTO Wait_loop
6140 !
6150 Example22: ! OUTPUT KEY CODE *****
6160 !
6170 DISP "PRESS HP 8510 Front Panel Key. (f5 to EXIT.)"
6180 !
6190 OUTPUT @Nwa;"DEBUON; CLES; SRQM 128,2"
6200 ON INTR 7 GOSUB Key_code
6210 ENABLE INTR 7;2
6220 ON KEY 5 LABEL "NEXT EXAMPLE" GOTO Exit_example22
6230 GOTO Wait_loop
6240 !
6250 Exit_example22: !
6260     DISABLE INTR 7
6270     OFF KEY 5
6280     PRINT ""
6290     RETURN
6300 !
6310 Key_code: !
6320     Ser_poll=SPOLL(@Nwa)
6330     OUTPUT @Nwa;"OUTPKEY"
6340     ENTER @Nwa_data1;A
6350     PRINT A;
6360     ENABLE INTR 7
6370     RETURN
6380 !
6390 Example23: ! TRIG Mode, TRIGGERED DATA ACQUISITION *****
6400 !
6410 LINPUT "CONTINUE to start Triggered sweep. (f5 to exit.)",Input$
6420 !
6430 OUTPUT @Nwa;"CLES; SRQM 4,0"
6440 ON INTR 7 GOTO Next_point
6450 ENABLE INTR 7;2
6460 Points=0
6470 OUTPUT @Nwa;"STEP; TRIG;"
6480 GOTO Wait_loop
6490 !
6500 Exit_example23: !
6510     DISABLE INTR 7
6520     RETURN
6530 !
6540 Next_point: !
6550     Ser_poll=SPOLL(716)
6560     IF Points=201 THEN GOTO End_of_sweep
6570     TRIGGER 716
6580     Points=Points+1
6590     PRINT Points;

```

```

6600          ENABLE INTR 7
6610          GOTO Wait_loop
6620      !
6630 End_of_sweep: !
6640          OFF INTR 7
6650          PRINT "END OF SWEEP"
6660          OUTPUT @Nwa;"RAMP; FRER;"
6670          OUTPUT @Nwa;"CLES; SRQM 0,0"
6680          LINPUT "ANOTHER? (Y/N)",Input$
6690          IF Input$="Y" OR Input$="y" THEN GOTO Example23
6700          GOTO Exit_example23
6710      !
6720 Example24: ! GET Triggered Sweep, Reverse Device During ONE-PATH 2-PORT ***
6730      !
6740      ! This example only operates when ONE-PATH 2-PORT correction
6750      ! is turned on using a Reflection/Transmission test set.
6760      RETURN ! Eliminate this line to run example
6770      LINPUT "Connect Device Under Test, then CONTINUE. (f5 to exit).",Input$
6780      Forward=1
6790      !
6800      ON KEY 5 LABEL "NEXT EXAMPLE" GOTO Exit_example24
6810      OUTPUT @Nwa;"CLES; SRQM 8,0"
6820      ON INTR 7 GOTO Next_sweep
6830      ENABLE INTR 7;2
6840      GOTO Wait_loop
6850      !
6860 Next_sweep: !
6870          IF Forward=1 THEN GOTO Trig
6880          LINPUT "Reverse Device then CONTINUE.",Input$
6890 Trig:      Ser_poll=SPOLL(716)
6900          TRIGGER 716
6910          IF Forward=0 THEN GOTO Example24
6920          Forward=0
6930          ENABLE INTR 7
6940          GOTO Wait_loop
6950      !
6960 Exit_example24: !
6970          DISABLE INTR 7
6980          OFF KEY 5
6990          DISP
7000          RETURN
7010      !
7020 Example25: ! WAIT Required *****
7030      !
7040      ON KEY 5 LABEL "NEXT EXAMPLE" GOTO Exit_example25
7050      !
7060      M=.0000000001
7070      OUTPUT 716;"PRES; REIP; SING; DATI; DISPMATH;"
7080      OUTPUT 716;"ELED 0 s;"
7090      FOR N=0 TO 1 STEP M
7100          OUTPUT 716;N;" s;"
7110          OUTPUT 716;"WAIT;"
7120      NEXT N
7130      !
7140 Exit_example25: !
7150          OFF KEY 5
7160          RETURN
7170      !
7180 Example26: ! WAIT Not Required (holdoff included in OUTPxxxx) *****
7190      !

```

```
7200  ON KEY 5 LABEL "NEXT EXAMPLE" GOTO Exit_example26
7210  !
7220  OUTPUT @Nwa;"STAR 1 GHz; STOP 15 GHz; S11; LINP; S21; LOGM;"
7230  !
7240  Restart26:  !
7250  Param=1
7260  Read_marker:  !
7270  IF Param=1 THEN OUTPUT 716;"S11; SING; AUTO;"
7280  IF Param=2 THEN OUTPUT 716;"S21; SING; AUTO;"
7290  OUTPUT 716;"MARK1"
7300  FOR N=1 TO 15 STEP (14/201)*10
7310  OUTPUT 716;N;" GHz;"
7320  OUTPUT 716;"OUTPACT1;"
7330  ENTER 716;Freq
7340  OUTPUT 716;"OUTPMARK;"
7350  ENTER 716;Mag,Phase
7360  PRINT Freq,Mag,Phase
7370  NEXT N
7380  IF Param=2 THEN GOTO Restart26
7390  Param=2
7400  GOTO Read_marker
7410  !
7420  Exit_example26:  !
7430  OFF KEY 5
7440  RETURN
7450  !
7460  END
```

CIRCUIT MODELING PROGRAM

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INTRODUCTION

This part of the HP 8510 network analyzer system manual explains how to use the Circuit Modeling Program (CMP) that runs on an HP Series 200 computer controlling an HP 8510 network analyzer system with the time domain Option 010. The Circuit Modeling Program is designed to show you what simple circuits look like in the frequency and time domains.

Hardware requirements, program loading, statements, and commands are discussed first. Then three example circuits are discussed, showing CRT displays that you can expect to see: an RCL circuit, a lossy transmission line, and a two-port stepped impedance standard. Lists of CMP program statements and commands are given at the end.

CIRCUIT MODELING PROGRAM

The HP 8510 network analyzer system Circuit Modeling Program (CMP) is designed to show you what simple circuits look like in the frequency and time domains. You may enter a nodal description (up to 200 nodes) of a circuit containing resistors, capacitors, inductors, and lossy transmission lines. The circuit is then analyzed by the Circuit Modeling Program and the S-parameters are loaded into the HP 8510 trace memories via the HP-IB interface bus.

Using the HP 8510 front panel controls, the computed data can then be viewed in the frequency domain or the time domain. Circuit descriptions may also be stored on an HP series 200/300 computer disc device library and loaded again later.

HARDWARE REQUIREMENTS

The Circuit Modeling Program runs on HP series 200/300 computers: HP model numbers 9816, 9826, 9836, 9836C, 9920, 310, and 320. It requires that your HP 8510 network analyzer system have the time domain Option 010 installed.

The Circuit Modeling Program is compiled in Pascal 3.1. The HP 8510 is not required for program operation; computed frequency domain (only) data may be printed or plotted under control of the HP series 200/300 computer.

LOAD AND EXECUTE CMP

Load the Circuit Modeling Program as follows:

1. Connect the HP series 200/300 computer to the HP 8510 rear panel using an HP-IB cable. Turn on the test set, source, printer, plotter, and other instruments which may be connected to the HP 8510 system bus. Then turn on the power to the HP 8510.
2. Turn on any external mass storage devices and wait a few seconds for any possible self-test to complete.
3. Remove the write protect tab from the disc labeled BOOT: (HP Part Number 85101-10006) and place the disc in the right-hand internal disc drive of the HP series 200/300 computer or in drive 0 of the external disc drive.
4. Turn on the computer. It will take about 1 minute for the BOOT: disc to load.
5. When the message "Put in the PROG: disc and press ENTER" appears, remove the BOOT: disc and insert the PROG: disc (HP Part Number 85101-10007). Press the ENTER key. The CMP program should display a title message and then a > prompt. Leave the PROG: disc in the drive. The program is now loaded and ready to use.

To copy the program use the HP series 200/300 BASIC or Pascal operating system.

COMMANDS

Commands are instructions to the CMP for some immediate action to take place. Commands are entered by typing them on the keyboard. When ENTER is pressed, the requested action is begun. When the action is completed a > prompt is displayed.

STATEMENTS

Statements are different from commands in that they are stored for future execution rather than immediate action. All statements must begin with a line number from 1 to 9999. Statement numbers are used to determine the order of execution of the various statements.

EDITING COMMANDS AND STATEMENTS

The HP series 200 computer editing keys (INS LN, DEL LN, INS CHR, DEL CHR, RECALL, CLR>END) on the computer keyboard are not used with this program. The BACKSPACE key is used to correct typing errors as they are entered.

To enter a line, type a line number followed by the keyword and parameters, and then press ENTER.

To replace a line, type the same line number as the number of the line you want to replace, then type the keyword.

To insert a line in a program, type the line with a unique line number that is between the two line numbers between which you wish to insert the line.

To delete a line, type the line number with no text following it. To delete the entire program, type the DEL command.

HELP

For a list of commands and statements, type the command HELP, then press ENTER.

To get more information about any command or statement, type the command HELP <keyword>, using as the <keyword> any command or statement.

RCL EXAMPLE

The following circuit is stored as an example on the PROG: disc, and it can be analyzed and the data sent to the HP 8510 using the program below. Figure 1 shows a schematic diagram of this circuit.

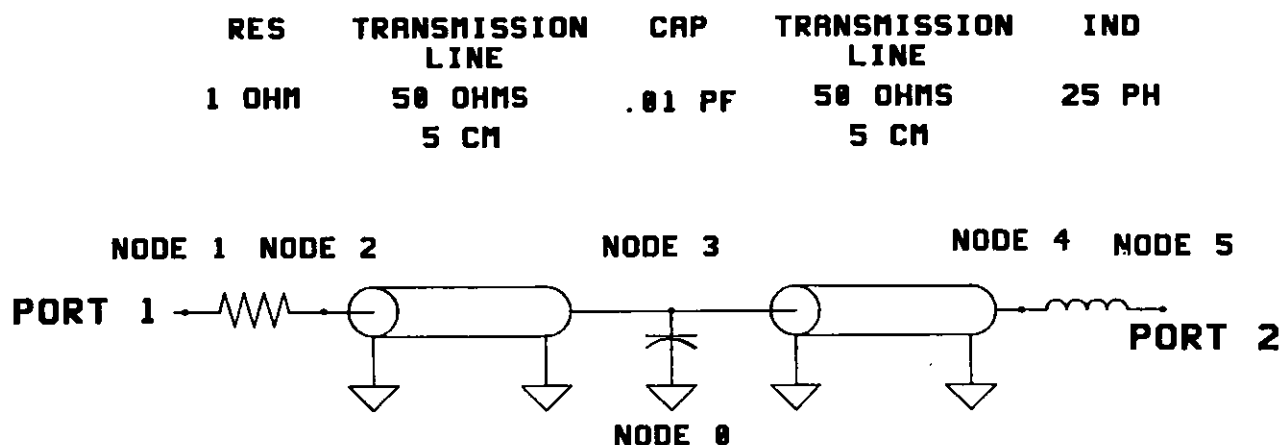


Figure 1. RCL Example Schematic Diagram

Load this example by typing the following command:

GET RCL

Next type:

LIST

You should see the following:

```

10  PORT 1 0
20  R      1 2      1 OHMS
30  TL     2 3      50 OHMS  5 CM
40  C      3 0      .01 PF
50  TL     3 4      50 OHMS  5 CM
60  L      4 5      25 PH
70  PORT 5 0
80  FREQ 90 MHZ 18090 MHZ 201 POINTS
90  PLOT S11, S12, S21, S22
100 OUTPUT S11

```

Next type: RUN

For approximately the next 20 seconds the computer will generate data, output the data to the HP series 200 controller display (PLOT statements), then output data to the HP 8510 (OUTPUT statement). Data sent the HP 8510 via the HP-IB includes commands to set the network analyzer to display the selected parameter in the frequency domain, and data representing the response of the modeled circuit. When data transfer is completed, the HP 8510 CRT is updated with new trace data and set to HOLD.

The S-parameters of this circuit are displayed on the HP series 200 computer and S_{11} is displayed on the HP 8510 CRT. The trace on the HP 8510 CRT display should resemble the plot shown in Figure 2. You may have to press AUTO on the HP 8510 in order to bring the response fully onto the screen.

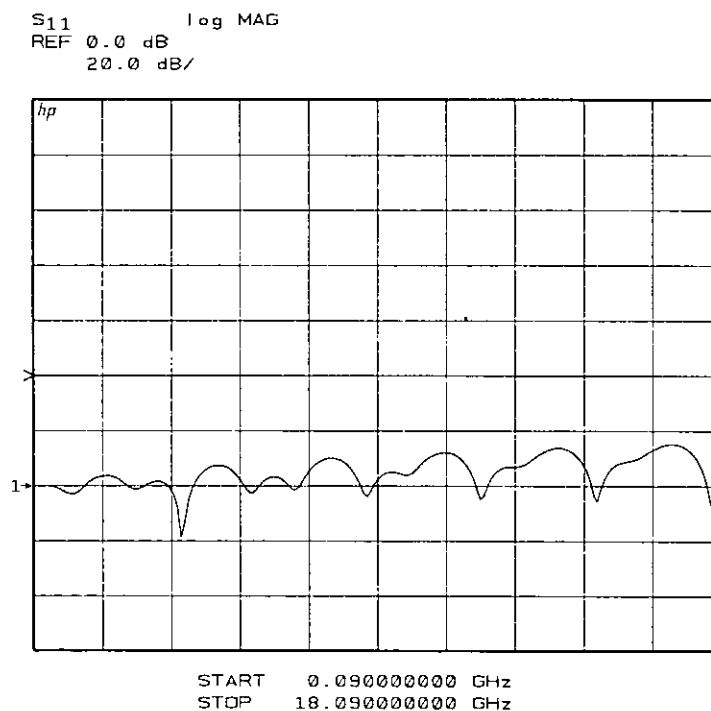


Figure 2. RCL Example S_{11} Frequency Domain Response

Any of the four S-parameters (S_{11} , S_{12} , S_{21} , S_{22}) can be displayed on the HP 8510 using the OUTPUT command. Issue a command by typing the statement, then pressing ENTER. Issue this command to display S_{21} on the HP 8510 CRT display:

OUTPUT S21

The trace should resemble the plot shown in Figure 3.

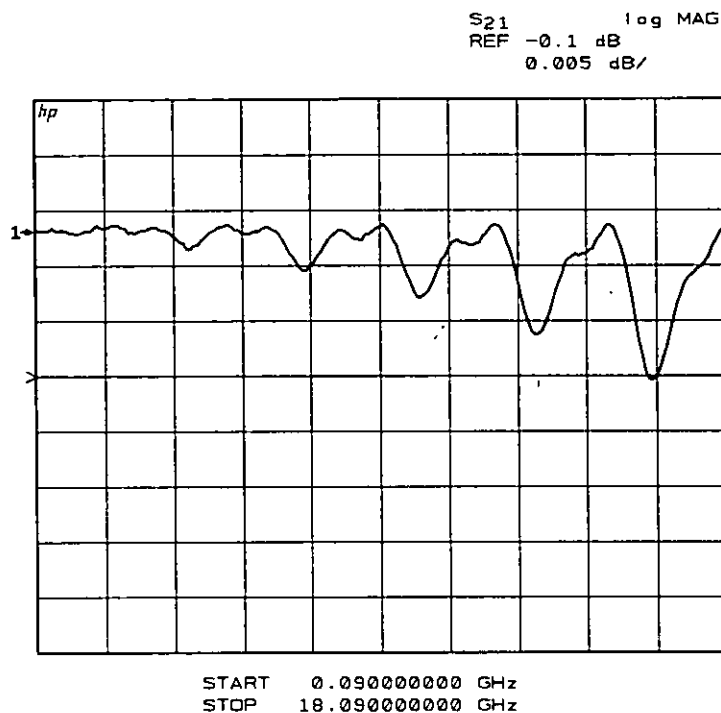


Figure 3. RCL Example S_{21} Frequency Domain Response

The time domain response of the circuit model can be displayed on the HP 8510 CRT in the following way. First issue the following command:

OUTPUT S11

The HP 8510 CRT should now display the frequency domain S_{11} response of the circuit.

To display the time domain response, press the following on the HP 8510:

- Press **DOMAIN**
TIME LOW PASS
SET FREQ. (LOW PASS)
- Press **START**
Enter -0.5 G/n
Press **STOP**
Enter 1.5 G/n
- Press **AUTO**

The trace on the HP 8510 CRT should resemble the plot shown in Figure 4.

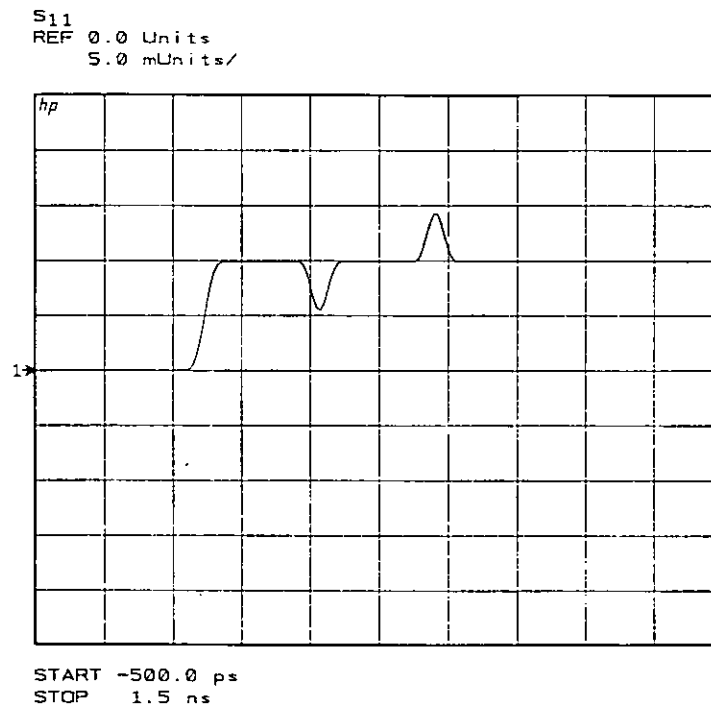


Figure 4. RCL Example S_{11} Time Domain Response

LOSSY TRANSMISSION LINE EXAMPLE

A transmission line can have two different types of loss: series and shunt. Series loss is a resistance that is distributed in series with the length of the transmission line, and it is usually expressed as resistance per unit length.

Shunt loss is a resistance shown between the center and outer conductors. It is distributed along the length of the transmission line, and it is usually expressed as conductance per unit length.

Figure 5 shows a schematic diagram of this simple lossy transmission line.

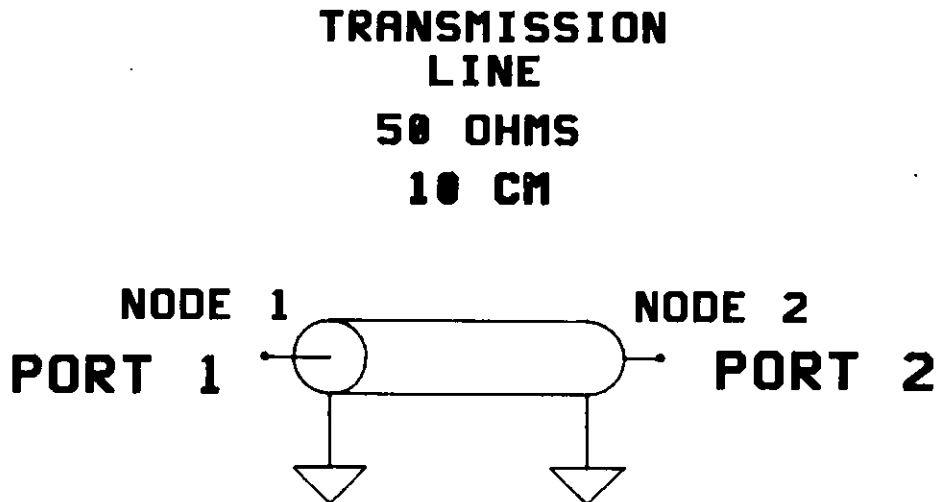


Figure 5. Lossy Transmission Line Schematic Diagram

To analyze this example, first type DELETE to delete the previous circuit model from memory. Then type the following command:

GET TL SERIES

Now type LIST to view the circuit description:

```
10  PORT    1 0
20  TL      1 2 50 OHMS 10 CM 1 .1
30  PORT    2 0
40  FREQ    90 MHZ 18090 MHZ 201 POINTS
50  PLOT     S11
60  OUTPUTS11
```

This transmission line has 50 ohms impedance, 10 cm length, velocity factor of 1, and a series loss of 0.1 ohm/cm (unit of length was set by the length parameter).

Now type: RUN

S_{11} of the transmission line is displayed on the screen of the HP 8510. The trace on the HP 8510 CRT should resemble the plot shown in Figure 6.

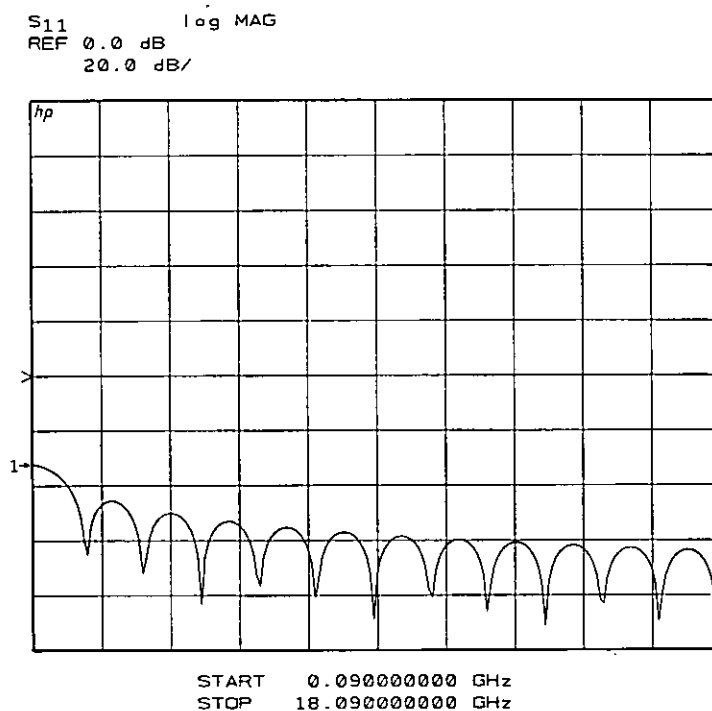


Figure 6. Lossy Transmission Line S_{11} Frequency Domain Response

The time domain response of the circuit can be displayed on the HP 8510 CRT using the same control sequence as described in the RCL example:

- Type OUTPUT S11

The HP 8510 CRT should now display the frequency domain S_{11} response of the circuit.

To display the time domain response, press the following on the HP 8510:

- Press DOMAIN
TIME LOW PASS
SET FREQ. (LOW PASS)
- Press START
Enter -0.5 G/n
Press STOP
Enter 1.5 G/n
- Press AUTO

The trace which now appears on the HP 8510 CRT should resemble the plot shown in Figure 7.

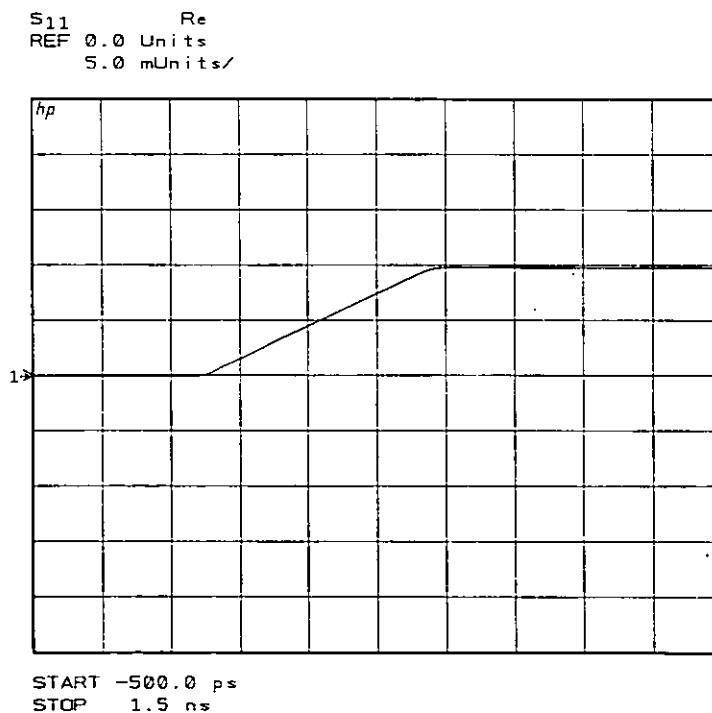


Figure 7. Lossy Transmission Line S_{11} Time Domain Response

Now, to see an example of a transmission line with shunt loss, change the program by typing:

```
20 TL 1 2 50 OHMS 10 CM 1 0 0 .0001
```

This will give a shunt conductance of 0.0001 mhos per cm (10000 ohm-cm). Since the transmission line is 10 cm long, it will have 1000 ohms in shunt with it. Enter RUN. The frequency response trace on the HP 8510 CRT should resemble the plot shown in Figure 8.

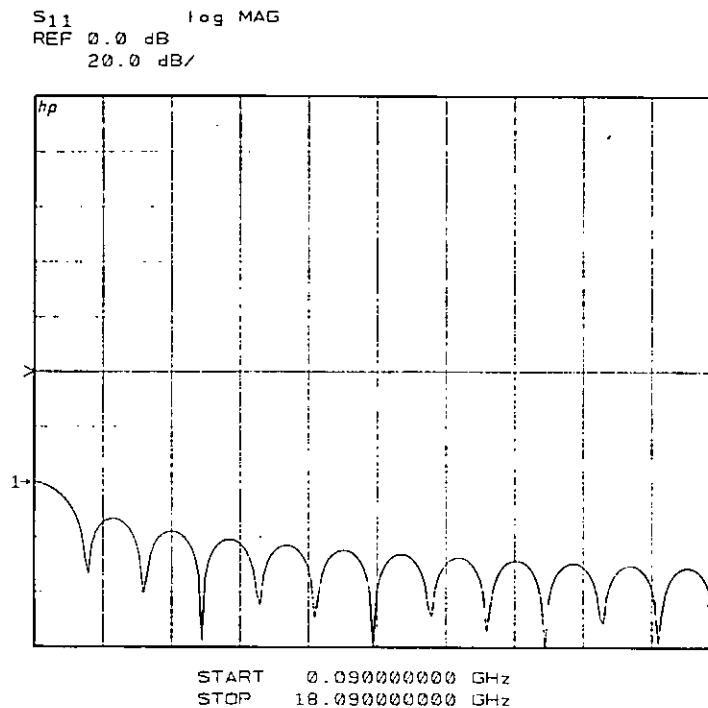


Figure 8. Lossy Transmission Line Example S_{11} Frequency Domain Response with Shunt Loss Added

The appearance of the series and shunt loss is hard to distinguish in the frequency domain. But in time domain it is easy to see the difference.

To display shunt loss in the time domain, convert to the TIME LOW PASS mode using the same time domain sequence with the HP 8510 used before. The trace on the HP 8510 CRT should resemble the plot shown in Figure 9.

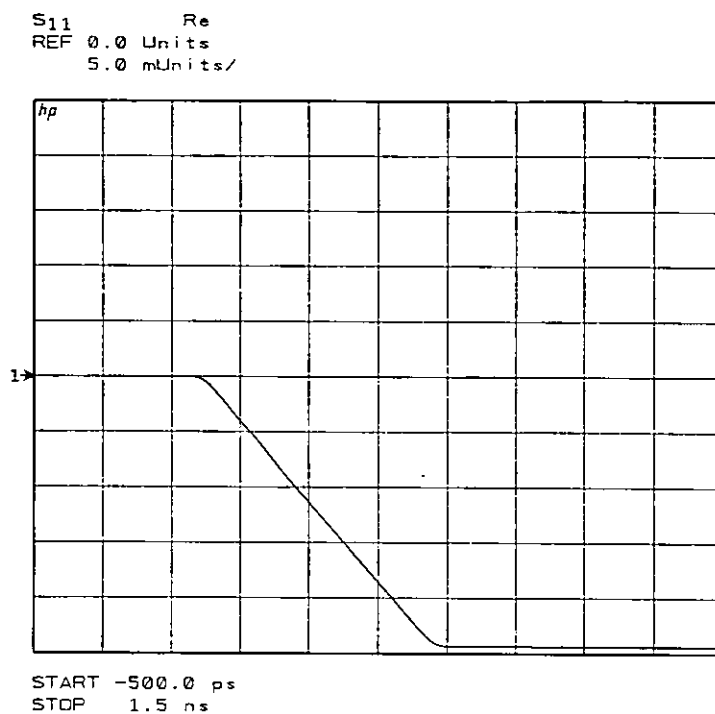
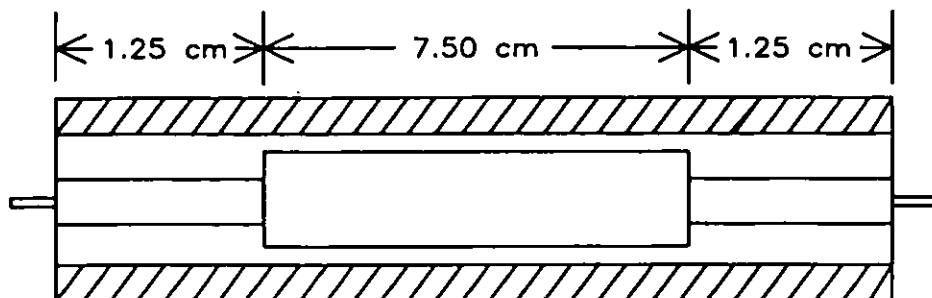


Figure 9. Lossy Transmission Line Example S_{11} Time Domain Response with Shunt Loss Added

TWO-PORT STEPPED IMPEDANCE STANDARD EXAMPLE

This example shows the use of time domain to observe the effects of mismatched transmission lines. The following example is based on the two-port stepped impedance standard in the HP 85051A 7mm verification kit. Details on this device appear in Figure 10.

Physical Example



Circuit Schematic Model

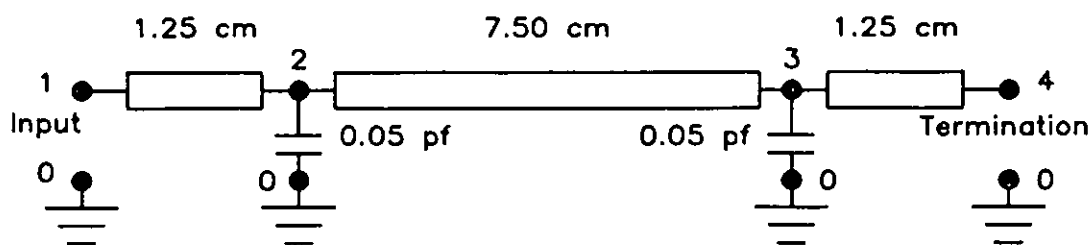


Figure 10. Two-Port Stepped Impedance Standard

To load this example, first type DELETE to delete the previous circuit model from memory. Then type the following command:

GET IMPSTD

LIST

Now enter the following statements:

```
10  PORT      1 0
20  TL        1 2    50 OHMS  1.25 CM
30  C         2 0    50 fF
40  TL        2 3    25 OHMS  7.50 CM
50  C         3 0    50 fF
60  TL        3 4    50 OHMS  1.25 CM
70  PORT      4 0
80  FREQ      45 MHZ 18045 MHZ 401 POINTS
90  PLOT      S11
100 OUTPUTS11
```

To analyze the circuit, now type:

RUN

The program takes about 45 seconds to run. The trace on the HP 8510 CRT should resemble the S_{11} frequency domain plot shown in Figure 11.

If converted to the TIME DOMAIN LOW PASS mode, the trace on the HP 8510 CRT should resemble the S_{11} time domain plot shown in Figure 12.

F.

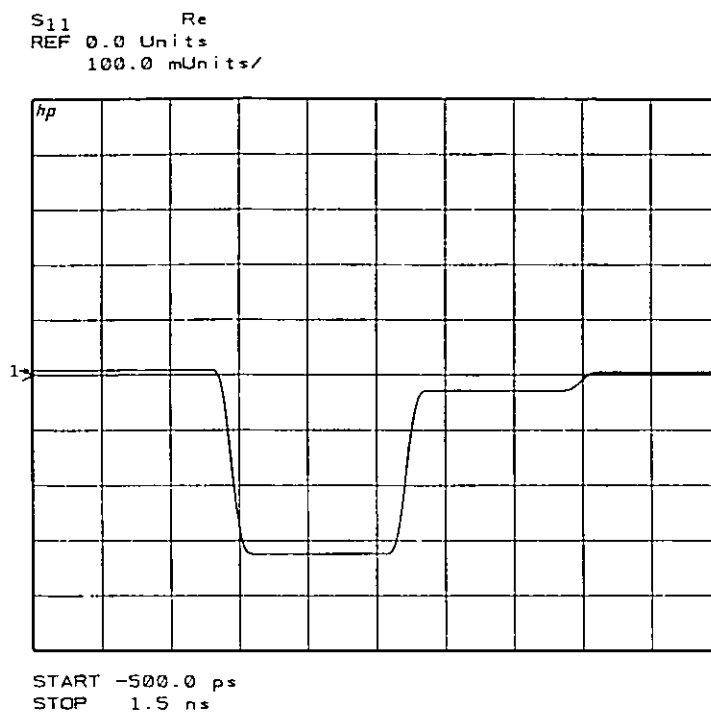


Figure 11. Two-Port Stepped Impedance Standard
 S_{11} Frequency Domain Response

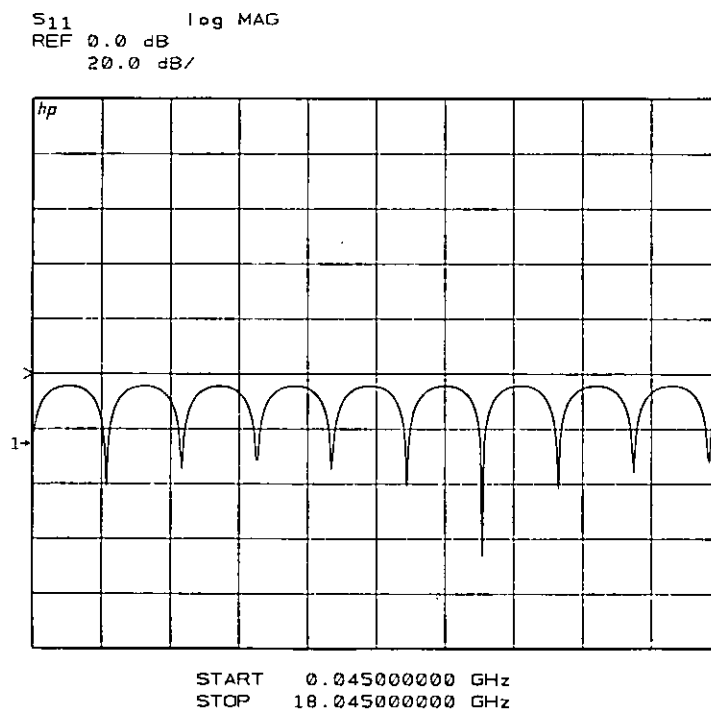


Figure 12. Two-Port Stepped Impedance Standard
 S_{11} Time Domain Response

COMMAND AND STATEMENT REFERENCE

CMP PROGRAM STATEMENTS

nnn PORT	Node	(50 ohm termination)
nnn R	Node1 Node2	Resistance
nnn L	Node1 Node2	Inductance
nnn C	Node1 Node2	Capacitance
nnn TL	Node1 Node2	Z Len Velocity Series Reffreq Shunt
nnn	FREQ parameters	
nnn	OUTPUT parameter	(Send S parameter data to HP 8510)
nnn	PLOT parameters	(Plot S parameter data on CRT)

NOTES: nnn represents a line number.
 OUTPUT and PLOT can also be used as commands after
 the program has been RUN once.
 The key [CLR I/O] interrupts an executing command
 and returns the program to user control.

CMP COMMANDS

CAT	END
DEL	BYE
GET	EXIT
HELP	QUIT
LIST	
RUN	
SAVE	
PURGE	
OUTPUT	
PLOT	

CMP STATEMENT SYNTAX

PORT

This circuit element mimics a network analyzer port. It appears from the circuit to be a simple 50 ohm resistor but it is capable of both supplying and measuring power.

```
nnn PORT Node
```

Example: 10 PORT 1

RESISTOR

```
nnn R Node1 Node2 Resistance in ohms
```

Example: 10 R 1 0 50 Ohms

(The keyword Ohms is optional.)

INDUCTOR

```
nnn L Node1 Node2 Inductance
```

The following inductance suffixes are allowed:

H mH uH nH pH fH

Example: 10 L 1 0 10 nH

CAPACITOR

```
nnn C Node1 Node2 Capacitance
```

The following capacitance suffixes are allowed:

F mF uF nF pF fF

Example: 10 C 1 0 100pF

TRANSMISSION LINE

nnn TL Node1 Node2 Z0 Length Velocity Series CorFreq Shunt

Node1	Center conductor of port 1.						
Node2	Center conductor of port 2.						
Z	Characteristic impedance of lossless line.						
Length	Length of line. The default units are meters but the following units are also accepted: cm, mm, in.						
Velocity	Propagation velocity relative to the speed of light in a vacuum. Default value is 1.0.						
Series	DC series resistance per unit length. Default value is 0.0.						
CorFreq	Corner frequency for skin effect. This is the frequency at which the depth of penetration equals the metal thickness. This occurs when the series resistance is 1.086 times larger than the DC value. A parallel line structure is assumed. Default value is 0.0, which removes skin effect.						
Shunt	Shunt conductance per unit length. Default value is 0.0.						

Examples:

```
10 TL 1 2 50 10 mm
10 TL 1 2 50 10 mm 1.0 0.01 1 GHZ 0.0
```

FREQUENCY

Used to set the start frequency, stop frequency, and number of points used for the circuit simulation. Frequencies used must be within the limits of the HP 8510 and its source.

Format: nnn FREQ Fstart Fstop NumOfSteps

or

nnn FREQ LOWPASS Fstop NumOfSteps

Fstart Start frequency.

Fstop Stop frequency.

The following frequency suffixes are allowed:

Hz kHz MHz GHz.

NumOfSteps Number of frequency points to calculate. Default is 51. NumOfSteps must be 51, 101, 201 or 401 to send data to the HP 8510.

LOWPASS Keyword causes the Fstart to be calculated by the HP 8510. This is used by the low pass time domain mode of the HP 8510.

Examples: 100 FREQ 1 GHz 10 GHz
 100 FREQ LOWPASS 10 GHz 201

OUTPUT

This command transfers data to the HP 8510. To use this command an HP 8510 must be present on the HP-IB at address 16.

Format: nnn OUTPUT Snn

Where Snn is one of the following: S11, S12, S21 or S22.

When the OUTPUT command is executed, the HP 8510 state will be modified as follows:

- Domain set to frequency,
- Frequency range and number of points set,
- Error correction turned off,
- Averaging turned off,
- Smoothing turned off,
- Sweep time set to 301 ms,
- Placed in HOLD mode,
- Placed in LOCAL mode.

Example: 100 OUTPUT S11

PLOT

Format: nnn PLOT parameters

Available parameters are S11, S12, S21, and S22. S11 and S22 will always be plotted on a Smith chart. S12 and S21 will always be plotted in log-magnitude format. One PLOT statement can plot all four S-parameters.

Separating parameters by a space causes them to be plotted on the same grid. Separating parameters by a comma causes them to be plotted on separate grids. It is not possible to plot S11 or S22 on the same grid as S12 or S21.

Examples:

100	PLOT S11	(Plots S11 on a Smith chart.)
100	PLOT S11 S22	(Plots both on a Smith chart.)
100	PLOT S11,S12,S21,S22	(Plots each on a separate grid.)
100	PLOT S11 S22,S12 S21	(Plots S11 and S22 together on the same Smith chart, and S12 and S21 together on a separate Cartesian grid.)

COMMANDS

CATALOG

This command lists the files available on prefix volume.

Format: CAT <optional volume specifier - Pascal syntax>

Examples: CAT
CAT #4:

CRT

This command directs plots to the controller screen.

Format: CRT

DELETE

This command deletes the current circuit.

Format: DEL

GET

This command loads a circuit description from a file.

Format: GET FileName

LIST

This command lists the circuit description.

Format: LIST

PLOTTER

This command directs plots to a plotter. The plotter must be connected to the controller HP-IB bus at address 705.

Format: **PLOTTER**

PURGE

This command purges a file from the disc.

Format: **PURGE FileName**

RUN

This command performs a circuit analysis.

Format: **RUN**

SAVE

This command saves a circuit description to a file.

Format: **SAVE FileName**

EXIT

This command exits the CMP program.

Format: **BYE
EXIT
QUIT**

REPLACEMENT PARTS

HP PART NUMBERDESCRIPTION

85101-60040

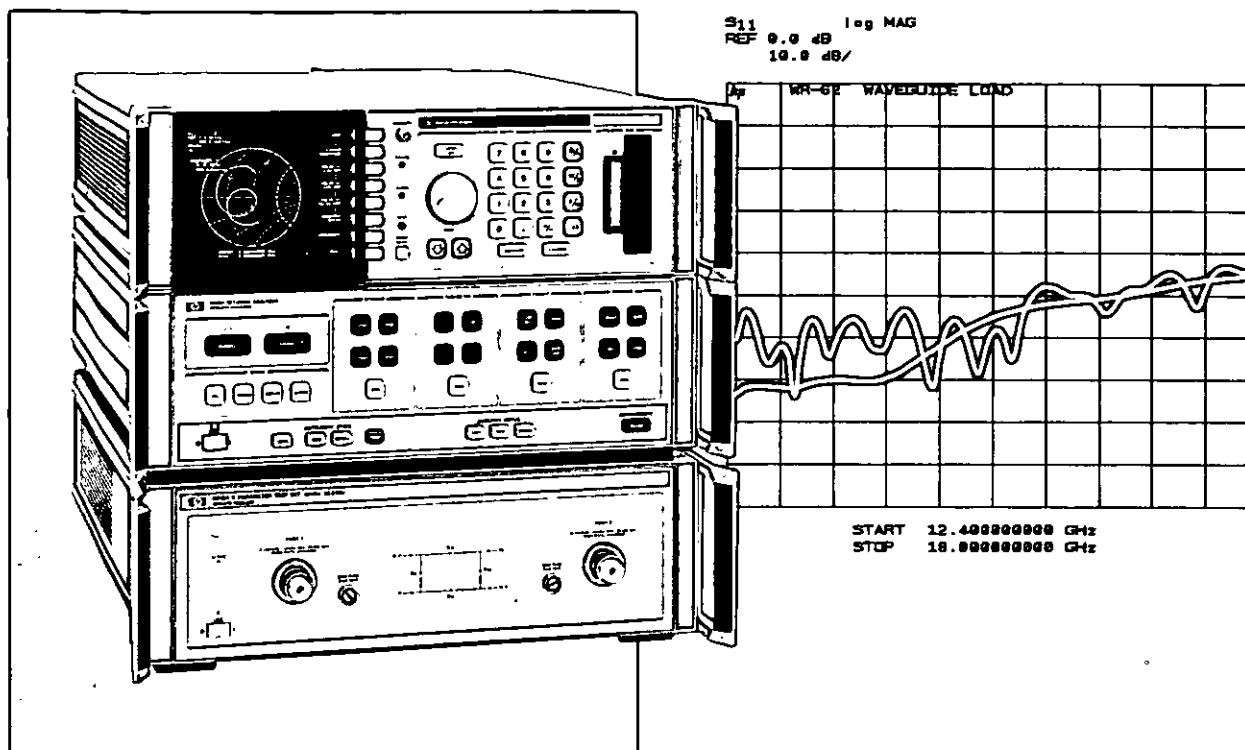
COMPLETE SET OF DISCS
(3.5 AND 5.25 INCH)

Application Pacs

Product Note 8510-5



Specifying calibration standards for the HP 8510 network analyzer



Known devices called calibration standards provide the measurement reference for network analyzer error correction. This note covers methods for specifying these standards and describes the procedures for their use with the HP 8510 network analyzer.

The HP 8510 network analyzer system has the capability to make real-time error-corrected measurements of components and devices in a variety of transmission media. Fundamentally, all that is required is a set of known devices (standards) that can be defined physically or electrically and used to provide a reference for the physical interface of the test devices.

Hewlett-Packard supplies full calibration kits in 7mm, 3.5mm and Type N coaxial interfaces. The HP 8510 system can be calibrated in other interfaces such as other coaxial types, waveguide and microstrip, given good quality standards that can be defined.

The HP 8510's built-in flexibility for calibration kit definition allows the user to derive a precise set of definitions for a particular set of calibration standards from precise physical measurements. For example, the characteristic impedance of a matched impedance airline can be defined from its actual physical dimensions (diameter of outer and inner conductors) and electrical characteristics (skin depth). Although the airline is designed to provide perfect signal

transmission at the connection interface, the dimensions of individual airlines will vary somewhat — resulting in some reflection due to the change in impedance between the test port and the airline. By defining the actual impedance of the airline, the resultant reflection is characterized and can be removed through measurement calibration.

The scope of this product note includes a general description of the capabilities of the HP 8510 to accept new cal kit descriptions via the MODIFY CAL KIT function found in the HP 8510 CAL menu. It does not, however, describe how to design a set of physical standards. The selection and fabrication of appropriate calibration standards is as varied as the transmission media of the particular application and is beyond the scope of this note.

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Introduction

Measurement Errors

Measurement errors in network analysis can be separated into two categories: random and systematic errors. Both random and systematic errors are vector quantities. Random errors are non-repeatable measurement variations and are usually unpredictable. Systematic errors are repeatable measurement variations in the test setup.

Systematic errors include mismatch and leakage signals in the test setup, isolation characteristics between the reference and test signal paths, and system frequency response. In most microwave measurements, systematic errors are the most significant source of measurement uncertainty. The source of these errors can be attributed to the signal separation scheme used.

The systematic errors present in an S-parameter measurement can be modeled with a signal flowgraph. The flowgraph model, which is used for error correction in the HP 8510A for the errors associated with measuring the S-parameters of a two port device, is shown in the figure.

The six systematic errors in the forward direction are directivity, source match, reflection tracking, load match, transmission tracking and isolation. The reverse error model is a mirror image, giving a total of 12 errors for two-port measurements. The process of removing these systematic errors from the network analyzer S-parameter measurement is called measurement calibration.

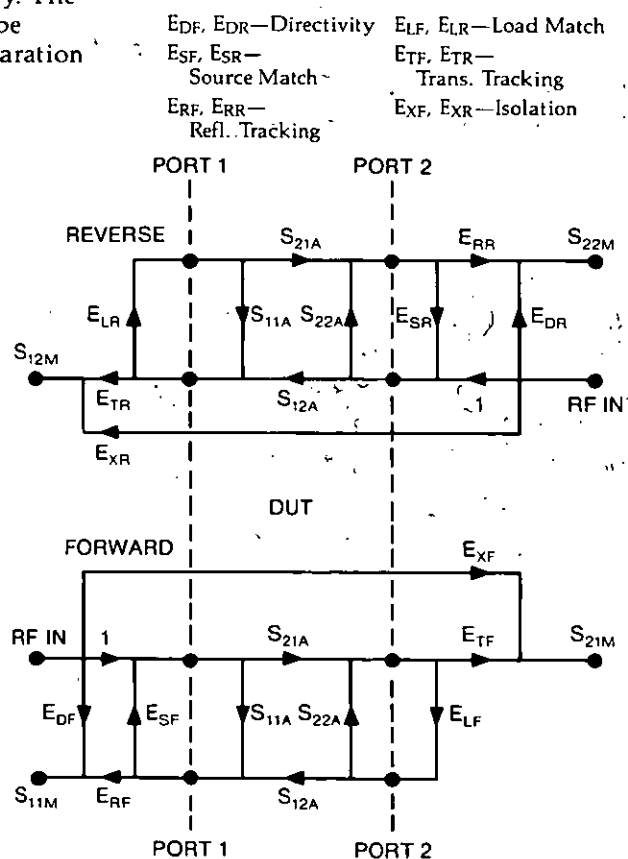


Figure 1. HP 8510A Full 2-Port Error Model

Measurement Calibration

A more complete definition of measurement calibration using the HP 8510A, and a description of the error models is included in Section III of the HP 8510A Operating and Service manual. The basic ideas are summarized here.

A measurement calibration is a process which mathematically derives the error model for the HP 8510A. This error model is an array of vector coefficients used to establish a fixed reference plane of zero phase shift, zero magnitude and known impedance. The array coefficients are computed by measuring a set of "known" devices connected at a fixed point and solving as the vector difference between the modeled and measured response.

The full 2-port error model shown in figure 1 is an example of only one of the measurement calibrations available with the HP 8510A. The measurement calibration process for the HP 8510A must be one of five types; RESPONSE, S_{11} 1-PORT, S_{22} 1-PORT, ONE PATH 2-PORT, and FULL 2-PORT. Each of these calibration types solves for a different set of the systematic measurement errors. A RESPONSE calibration solves for the systematic error term for reflection or transmission tracking depending on the S-parameter which is activated on the HP 8510A at the time. An S_{11} 1-PORT calibration solves for the forward error terms, directivity, source match and reflection tracking. Likewise, the S_{22} 1-PORT calibration solves for the same error terms in the reverse direction. A ONE PATH 2-PORT calibration solves for all the forward error terms. FULL 2-PORT calibration includes both forward and reverse error terms.

The type of measurement calibration selected by the user depends on the device to be measured (ie. 1-port or 2-port device) and the extent of accuracy enhancement desired. Further, a combination of calibrations can be used in the measurement of a particular device.

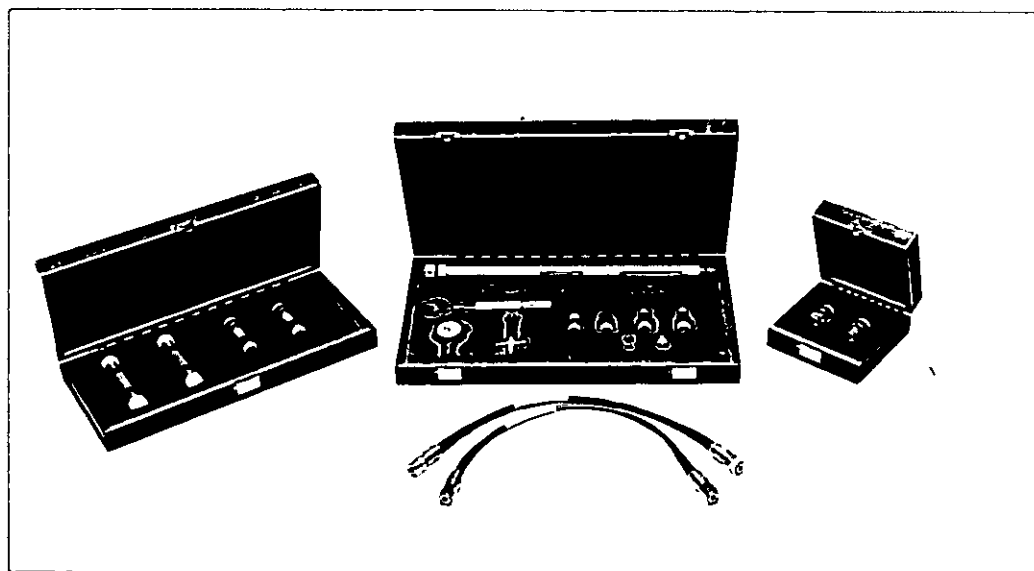
The accuracy of subsequent test device measurements is dependent on the accuracy of the test equipment, how well the "known" devices are modeled and the exactness of the error correction model.

Calibration Kit

A calibration kit is a set of physical devices called standards. Each standard has a precisely known or predictable magnitude and phase response as a function of frequency. In order for the HP 8510A to use the standards of a calibration kit, the response of each standard must be mathematically defined and then organized into standard classes which correspond to the error models used by the HP 8510A.

HP currently supplies calibration kits with 7mm (HP 85050A), 3.5mm (HP 585052A) and N type (HP 85054A) coaxial connectors. To be able to use a particular calibration kit, the known characteristics from each standard in the kit must be entered into the HP 8510A nonvolatile memory. The Operating and Service manuals for the 7mm and 3.5mm HP calibration kits contain the physical characteristics for each standard in the kit and mathematical definitions in the format required by the HP 8510A.

Waveguide calibration using the HP 8510A is possible although HP does not presently supply the waveguide standards for all frequency bands.



Standard Definition

Standard Definition is the process of mathematically modeling the electrical characteristics (delay, attenuation and impedance) of each calibration standard. These electrical characteristics can be mathematically derived from the physical dimensions and material of each calibration standards or from its actual measured response. A Standard Definition Table (see Table 1) lists the parameters that are used by the HP 8510A to specify the mathematical model.

Class Assignment

Class Assignment is the process of organizing calibration standards into a format which is compatible with the error models used in measurement calibration. A class or group of classes correspond to the systematic errors which are to be removed from the measured network analyzer response. The particular systematic errors which correspond to each of the 12 available classes are identified later in this note (see Assign Classes).

Modification Procedure

Calibration kit modification provides the capability to adapt to measurement calibrations in other connector types or to generate more precise error models from existing kits. Provided the appropriate standards are available, cal kit modification can be used to establish a reference plane in the same transmission media as the test devices and at a specified point, generally the point of device connection/insertion. After calibration, the resultant measurement system, including any adapters which would reduce system directivity, is fully corrected and the systematic measurement errors are mathematically removed. Additionally, the modification function allows the user to input more precise physical definitions for the standards in a given cal kit.

The process to modify or create a cal kit consists of the following steps.

1. Select Standards
2. Define Standards
3. Assign Classes
4. Enter Standards/Classes
5. Verify Performance

To further illustrate, an example waveguide calibration kit is developed as the general descriptions in MODIFY CAL KIT process are presented.

Select Standards

Determine what standards are necessary for calibration and are available in the transmission media of the test devices.

Calibration standards are chosen based on the following criteria.

- A well defined response which is mechanically repeatable and stable over typical ambient temperatures and conditions. The most common

Table 1. Standard Definitions Table

		CALIBRATION KIT				P BAND				TAPE FILE NUMBER			
STANDARD		C0	C1	C2	C3	FIXED OR SLIDING	OFFSET			FREQUENCY (MHz)		COAX WAVEGUIDE	STANDARD LABEL
NO	TYPE	$\pm 10^{-10}$	$\pm 10^{-10}$	$\pm 10^{-10}$	$\pm 10^{-10}$		DELAY IN	LOSS IN DB	Z ₀ IN	MINIMUM	MAXIMUM		
1	SHORT						0.6309	0	50	9.487	18.974	W/G	P SHORT 1
2	SHORT						31.4925	0	50	9.487	18.974	W/G	P SHORT 2
3	LOAD					FIXED	0	0	50	9.487	18.974	W/G	P LOAD
4	THRU						0	0	50	9.487	18.974	W/G	P THRU
5													
6													
7													
8													

Table 2. Standard Class Assignments

Standard Class Assignments

		CALIBRATION KIT LABEL				P BAND				TAPE FILE NUMBER			
		A	B	C	D	E	F	G	STANDARD CLASS LABEL				
S ₁₁ A		1							P SHORT 1				
S ₁₁ B		2							P SHORT 2				
S ₁₁ C		3							P LOAD				
S ₂₂ A		1							P SHORT 1				
S ₂₂ B		2							P SHORT 2				
S ₂₂ C		3							P LOAD				
Forward Transmission		4							THRU				
Reverse Transmission		4							THRU				
Forward Match		4							THRU				
Reverse Match		4							THRU				
Frequency Response		1	2	4					RESPONSE				

coaxial standards are zero-electrical-length short, shielded open and matched load terminations which ideally have fixed magnitude and broadband phase response. Since waveguide open circuits are generally not modelable, the types of standards typically used for waveguide calibration are a pair of offset shorts and a fixed or sliding load.

- An independent frequency response. To fully calibrate each test port (that is to provide the standards necessary for S_{11} or S_{22} 1-PORT calibration), three standards are required that exhibit distinct phase and/or magnitude at each particular frequency within the calibration band. For example: in coax, a zero-length short and a perfect shielded open exhibit 180 degree phase separation while a matched load will provide 40 to 50 dB magnitude separation from both the short and the open. In waveguide, a pair of offset shorts of correct length provide phase separation.

- Broadband frequency coverage. In broadband applications, it is often difficult to find standards that exhibit a known, suitable response over the entire band. A set of frequency-banded standards of the same type can be selected in order to characterize the full measurement band.

Define Standards

A glossary of standard definition parameters used with the HP 8510A is included in this section. Each parameter is described and appropriate conversions are listed for implementation with the HP 8510A. To illustrate, a calibration kit for WR-62 rectangular waveguide (operating frequency range 12.4 to 18.0 GHz) will be defined as shown in Table 1. Subsequent sections will continue to develop this waveguide example.

The mathematical models are developed for each standard in accordance with the standard definition parameters provided by the HP 8510A. These standard definition parameters are shown below in Figure 2.

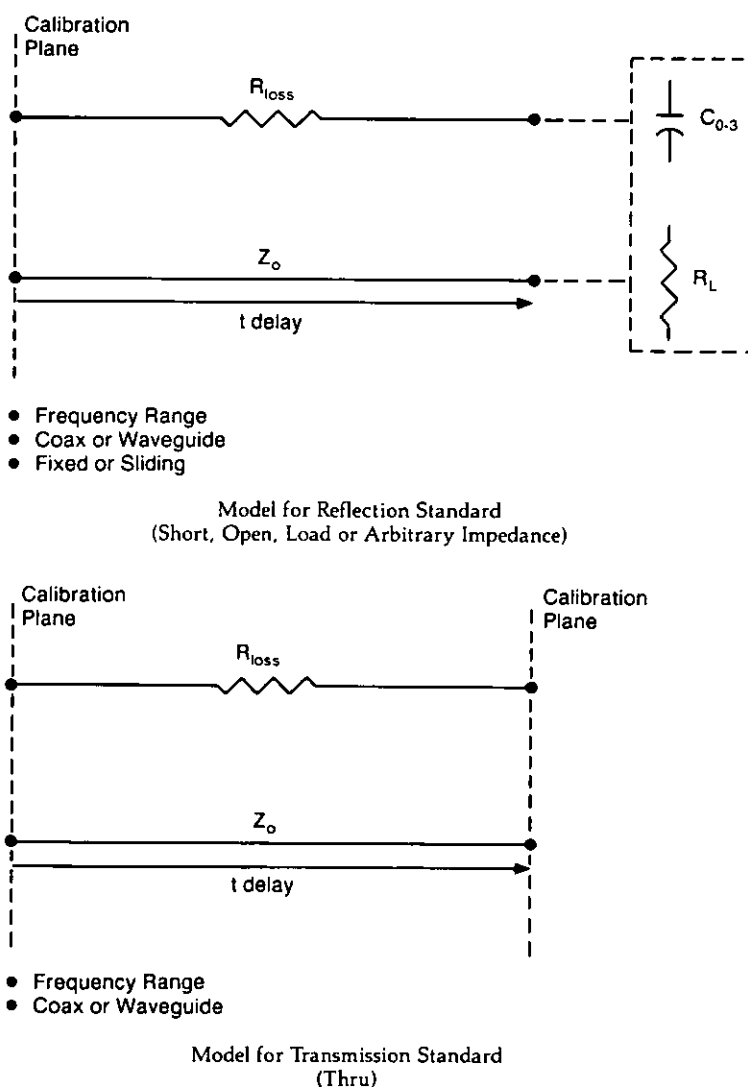


Figure 2. Standard Definition Models

Each standard is described using the Standard Definition Table in accordance with the 1 or 2 port model. The Standard Definition Table for a waveguide calibration kit is shown in Table 1. Each standard type (short, open, load, thru and arbitrary impedance) may be defined by the parameters as specified below.

- Standard number and standard type
- Fringing capacitance of an open, which is specified by a third order polynomial
- Load/arbitrary impedance, which is specified as fixed or sliding
- Terminal Resistance of an arbitrary impedance
- Offsets which are specified by delay, Z_0 , R_{loss}
- Frequency range
- Connector type: coaxial or waveguide
- Label (up to 10 alphanumeric characters)

Standard Number

A calibration kit may contain up to 22 standards (See Table 1). The required number of standards will depend on frequency coverage and whether thru adapters are needed for sexed connectors.

For the WR-62 waveguide example four standards will be sufficient to perform all of the calibration types available with the HP 8510A. Three reflection standards are required, and one transmission standard (a thru) will be sufficient to complete this calibration kit.

Standard Type

A standard type must be classified as a "short", "open", "load", "thru" or "arbitrary impedance". The associated models for reflection standards (short, open, load and arbitrary impedance) and transmission standards (thru) are shown in Figure 1.

For the WR-62 waveguide calibration kit, the 4 standards are a $1/8\lambda$ & $3/8\lambda$ offset short, a fixed matched load and a thru. Standard types are entered into the Standard Definition Table under STANDARD NUMBERS 1 through 4 as short, short, load and thru respectively.

Open Circuit Capacitance:

C_0 , C_1 , C_2 and C_3

If the standard type selected is an 'open', the C_0 through C_3 coefficients are specified and then used to mathematically model the phase shift caused by fringing capacitance as a function of frequency.

As a reflection standard, an 'open' offers the advantage of broadband frequency coverage, while offset shorts cannot be used over more than an octave. The reflection coefficient ($\Gamma = \rho e^{-j\phi}$) of a perfect zero-length-open is 1 at 0° for all frequencies. At microwave frequencies however, the magnitude and phase of an 'open' are affected by the radiation loss and capacitive "fringing" fields, respectively. In coaxial transmission media, shielding techniques are effective in reducing the radiation loss. The magnitude (ρ) of an 'open' is assigned to be 1 (zero radiation loss) for all frequencies when using the HP 8510A Standard Type 'open'.

It is not possible to remove fringing capacitance, but the resultant phase shift can be modeled as a function of frequency using C_0 through C_3 ($C_0 + C_1 \times F + C_2 \times F^2 + C_3 \times F^3$, where F is frequency), which are the coefficients for a cubic polynomial that best fits the actual capacitance of the 'open'.

A number of methods can be used to determine the fringing capacitance of an 'open'. These methods range from mathematically derived physical models to iterative "trial and error" procedures.

1. Physical Models — Mathematically derive the capacitance values for an 'open' by solving for the electric field from the geometry of the transmission media. For complex geometries however, it is difficult to get a useful answer.

2. Empirical Models — Perform a full one-port cal including the 'open' as a "perfect" standard (1 at zero degrees). That is, set C_0 through C_3 equal to zero. Turn on the calibration and measure another known standard (i.e. an offset short). By comparing the measured response of the known standard with its expected response and modifying the C_0 through C_3 coefficients in an iterative manner to approach the expected response, approximate values for the C_0 through C_3 coefficients can be found.

Two further techniques involve a calibrated reflection coefficient measurement of an open standard and subsequent calculation of the effective capacitance. The value of fringing capacitance can be calculated from the measured phase or reactance as a function of frequency as follows.

$$C_{eff} = \frac{\tan(\frac{\Delta\phi}{2})}{2\pi f Z_0} = \frac{1}{2\pi f X}$$

C_{eff} — effective capacitance

$\Delta\phi$ — measured phase shift

f — measurement frequency

Z_0 — characteristic impedance

X — measured reactance

This capacitance can then be modeled by choosing coefficients to best fit the measured response when measured by either method 3 or 4 below.

3. Fully calibrated 1 Port — Establish a calibrated reference plane using three independent standards (i.e. 2 sets of banded offset shorts and load). Measure the phase response of the open and solve for the capacitance function.

4. Gating — Use time domain gating to correct the measured response of the open by isolating the reflection due to the open from the source match reflection and signal path leakage (directivity). Figure 3 shows the time domain response of the open at the end of an airline. Measure the gated phase response of the open at the end of an air-line and again solve for the capacitance function.

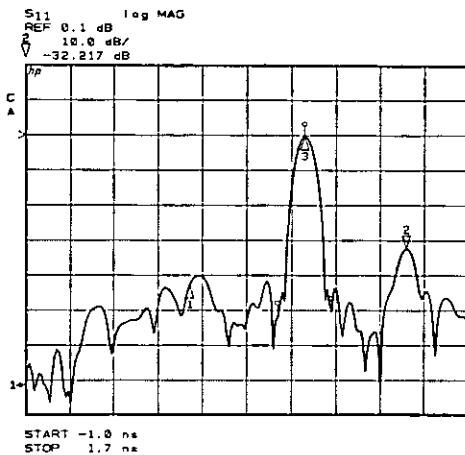


Figure 3. Time Domain Response of Open at the End of an Airline

Note

In some cases (when the phase response is linear with respect to frequency) the response of an open can be modeled as an equivalent 'incremental' length.

$$\Delta\phi(\text{radians}) = \frac{2\pi f(\Delta\text{length})}{c}$$

This method will serve as a first order approximation only, but can be useful when data or standards for the above modeling techniques are not available.

For the waveguide example, this parameter is not addressed since opens cannot be made valid standards in waveguide, due to the excessive radiation loss and indeterminant phase.

Fixed or Sliding

If the standard type is specified to be a load or an arbitrary impedance, then it must be specified as fixed or sliding. Selection of "sliding" provides a sub-menu in the calibration sequence for multiple slide positions and measurement. This enables calculation of the directivity vector by mathematically eliminating the response due to a non-ideal terminal impedance. A further explanation of this technique is found in the Measurement Calibration section in the HP 8510A Operating and Programming manual.

The load standard #4 in the WR-62 waveguide calibration kit is defined as a fixed load. Enter FIXED in the table.

Terminal Impedance

Terminal impedance is only specified for "arbitrary impedance" standards. This allows definition of only the real part of the terminating impedance in ohms. Selection as the Standard Type 'short', 'open' or 'load' automatically assigns the terminal impedance to be 0, ∞ or 50 ohms respectively.

The WR-62 waveguide calibration kit example does not contain an arbitrary impedance standard.

Offset Delay

If the standard has electrical length (relative to the calibration plane), a standard is specified to have an offset delay. Offset delay is entered as the one-way travel time through an offset that can be obtained from the physical length using propagation velocity of light in free space and the appropriate permittivity constant. The effective propagation velocity equals $c\sqrt{\epsilon_r}$. See Appendix B for a further description of physical offset lengths for sexed connector types.

$$\text{Delay (seconds)} = \frac{l\sqrt{\epsilon_r}}{c}$$

l = precise measurement of offset length in meters

ϵ_r = relative permittivity
(= 1.000649 for coaxial airline or air-filled waveguide in standard lab conditions)

$c = 2.997925 \times 10^8$ m/s

In coaxial transmission line, group delay is constant over frequency. In waveguide however, group velocity does vary with frequency due to dispersion as a function of the cut-off frequency.

The convention for definition of offset delay (in waveguide) used in the HP 8510A requires entry of the delay at infinite frequency (where the dispersion is negligible). For waveguide transmission line, the HP 8510A calculates the actual delay as a function of frequency as follows:

$$\text{Actual Delay} = \frac{\text{Delay (at } f = \infty)}{\sqrt{1 - (f_{co}/f)^2}}$$

Delay (at $f = \infty$) or TEM mode delay
 f_{co} = lower cutoff frequency
 f = measurement frequency

Note

To assure accurate definition of offset delay, a physical measurement of offset length is recommended. The actual length of specified fractional λ_g ref offsets will vary by manufacturer. For example, the physical length of an $1/8 \lambda$ offset depends on the center frequency chosen. In waveguide this may correspond to the arithmetic or geometric mean frequency or be selected for a phase balanced response. The arithmetic mean frequency is simply $(F_1 + F_2)/2$, where F_1 and F_2 are minimum and maximum operating frequencies of the waveguide type. The geometric mean frequency is calculated as the square root of $F_1 \times F_2$. The corresponding (λ_g) is then calculated from the mean frequency and the cut-off frequency of the waveguide type. Fractional wavelength offsets are then specified with respect to this wavelength. The (λ_g) for an offset with phase balanced response can be found from the following equation.

$$\lambda_g(\text{ref}) = \frac{2(\lambda_g(\text{lower}) \times \lambda_g(\text{upper}))}{\lambda_g(\text{lower}) + \lambda_g(\text{upper})}$$

For the WR-62 calibration kit, offset delay is zero for the "thru" (std #4) and the "load" (std #3). To find the offset delay of the $1/8\lambda$ and $3/8\lambda$ offset shorts, precise offset length measurements are necessary. For the $1/8\lambda$ offset short, $l = 3.24605$ mm, $\epsilon_r = 1.000649$, $c = 2.997925 \times 10^8$ m/s.

$$\text{Delay} = \frac{(3.24605 \times 10^3 \text{ m}) (\sqrt{1.000649})}{2.997925 \times 10^8 \text{ m/s}} \\ = 10.8309 \text{ pS}$$

For the $3/8\lambda$ offset short, $l = 9.7377$ mm, $\epsilon_r = 1.000649$, $c = 2.997925 \times 10^8$ m/s.

$$\text{Delay} = \frac{(9.7381 \times 10^3 \text{ m}) (\sqrt{1.000649})}{2.997925 \times 10^8 \text{ m/s}} \\ = 32.4925 \text{ pS}$$

Offset Z_0

Offset Z_0 is the characteristic impedance within the offset length. For coaxial type offset standards, specify the real (resistive) part of the characteristic impedance in the transmission media. The characteristic impedance in lossless coaxial transmission media can be calculated from its physical geometry as follows.

$$Z_0 = \frac{1}{2\pi} \sqrt{\frac{\mu}{\epsilon}} \ln \left(\frac{D}{d} \right) \\ = 59.9585 \sqrt{\frac{\mu_r}{\epsilon_r}} \ln \left(\frac{D}{d} \right)$$

μ_r = relative permeability constant of the medium (equal to 1.0 in air)

ϵ_r = relative permittivity constant of the medium (equal to 1.000649 in air)

D = inside diameter of outer conductor

d = outside diameter of inner conductor

The HP 8510A requires that the characteristic impedance of waveguide transmission line is assigned to be equal to the system Z_0 .

The characteristic impedance of any transmission media is not easily determined, but through "normalization" this problem is eliminated. (Normalization, as it is applied here, is a technique which establishes the characteristic impedance of the standards being defined as "perfectly" matched to the incident test port).

Provided that the geometry of the transmission media remains constant at the point of calibration standard connection (or insertion), the characteristic impedance remains uniform. Uniform characteristic impedance between the standard and the test port will allow all of the incident signal to be transmitted into the standard. When calibrating in waveguide, the characteristic impedance in the incident and transmitted sides of the reference plane are equal and therefore, "normalized" (provided both are the same waveguide type). The HP 8510A system Z_0 (SET Z_0), which assigns the characteristic impedance at the calibration plane, must be the same as the Offset Z_0 for waveguide offset standards.

System Z_0 (SET Z_0) is the assigned convention in the HP 8510A for matched waveguide impedance.

Offset Loss

Offset loss is used to model the magnitude loss due to skin effect of offset coaxial type standards only. The value of loss is entered into the standard definition table as Gigohms/second or ohms/nanosecond at 1 GHz. The following equation converts to equivalent resistance in ohms from loss in dB per unit length (at 1 GHz) for low loss lines.

$$R_{\text{loss}} (\Omega) \Big|_{1 \text{ GHz}} = 10 \left[\frac{40 - \text{loss dB/lo}}{20} \right] - 100$$

where:

R_{loss} = equivalent resistance in ohms at 1 GHz

loss dB/lo = insertion loss of offset transmission line in dB/unit length at 1 GHz.

l = length of offset (in units of loss dB/lo).

The offset loss in Gigohms/second can then be calculated from the equivalent resistance at 1 GHz and the offset delay of the particular standard by the following equation.

$$\text{Offset Loss} \left(\frac{\text{G}\Omega}{\text{s}} \right) \Big|_{1 \text{ GHz}} = \frac{R_{\text{loss}} (\Omega) \Big|_{1 \text{ GHz}}}{\text{Offset Delay (ns)}}$$

The HP 8510A calculates the skin loss as a function of frequency as follows:

$$\text{Offset Loss} \left(\frac{\text{G}\Omega}{\text{s}} \right) = \text{Offset Loss} \left(\frac{\text{G}\Omega}{\text{s}} \right) \Big|_{1 \text{ GHz}} \times \sqrt{f(\text{GHz})}$$

For all offset standards, including shorts or opens, enter the one way skin loss. The offset loss in waveguide should always be assigned zero ohms by the HP 8510A.

Therefore, for the WR-62 waveguide standard definition table, offset loss of zero ohm/sec is entered for all four standards.

Lower/Minimum Frequency

Lower frequency defines the minimum frequency at which the standard is to be used for the purposes of calibration.

Note

When defining coaxial offset standards, it may be necessary to use banded offset shorts to specify a single standard class. The lower and upper frequency parameters should be used to indicate the frequency range of desired response. It should be noted that lower and upper frequency serve a dual purpose of separating banded standards which comprise a single class as well as defining the overall applicable frequency range over which a calibration kit may be used.

In waveguide, this must be its lower cut-off frequency of the principal mode of propagation. Waveguide cut-off frequencies can be found in most waveguide textbooks. The cutoff frequency of the fundamental mode of propagation (TE_{10}) in rectangular waveguide is defined as follows.

$$f = \frac{c}{2a}$$

$c = 2.997925 \times 10^{10}$ cm/sec.

a = inside width of waveguide, larger dimension in cm

As referenced in offset delay, the minimum frequency is used to compute the dispersion effects in waveguide.

For the WR-62 waveguide example, the lower cutoff frequency is calculated as follows.

$$f = \frac{c}{2a} = \frac{2.997925 \times 10^{10} \text{ cm/s}}{2 \times 1.58 \text{ cm}} = 9.487 \text{ GHz}$$

$$c = 2.997925 \times 10^{10} \text{ cm/s}$$

$$a = 1.58 \text{ cm}$$

The lower cut-off frequency of 9.487 GHz is entered into the table for all four WR-62 waveguide standards.

Upper/Maximum Frequency

This specifies the maximum frequency at which the standard is valid. In broadband applications, a set of banded standards may be necessary to provide constant response. For example, coaxial offset standards (ie. $1/4 \lambda$ offset short) are generally specified over bandwidths of an octave or less. Bandwidth specification of standards, using minimum frequency and maximum frequency, enables the HP 8510A to characterize only the specified band during calibration. Further, a submenu for banded standards is enabled which requires the user to completely characterize the current measurement frequency range. In waveguide, this is the upper cutoff frequency for the waveguide class and mode of propagation. For the fundamental mode of propagation in rectangular waveguide the maximum upper cutoff frequency is twice the lower cutoff frequency and can be calculated as follows.

$$F(\text{upper}) = 2 \times F(\text{lower})$$

The upper frequency of a waveguide standard may also be specified as the maximum operating frequency as listed in a textbook.

The MAXIMUM FREQUENCY of the WR-62 waveguide cal kit is 18.974 GHz and is entered into the standard definition table for all four standards.

Coax or Waveguide

It is necessary to specify whether the standard selected is coaxial or waveguide. Coaxial transmission line has a linear phase response as follows.

$$\phi(\text{radians}) = \frac{2\pi f}{\lambda} = 2\pi f(\text{delay})$$

Waveguide transmission line exhibits dispersive phase response as follows.

$$\phi(\text{radians}) = \frac{2\pi f}{\lambda_g}$$

where

$$\lambda_g = \frac{\lambda}{\sqrt{1 - (\lambda/\lambda_{co})^2}}$$

Selection of WAVEGUIDE computes offset delay using the dispersive response, of rectangular waveguide only, as a function of frequency as

$$\text{Delay (seconds)} = \frac{\text{Delay (at } f = \infty)}{\sqrt{1 - (f_{co}/f)^2}}$$

This emphasizes the importance of entering 'f_{co}' as the LOWER FREQUENCY.

Selection of COAXIAL assumes linear response of offset delay.

Note

Mathematical operations on measurements (and displayed data) after calibration are not corrected for dispersion.

Enter WAVEGUIDE into the standard definition table for all four standards.

Standard Labels

Labels are entered through the title menu and may contain up to 10 characters. Standard Labels are entered to facilitate menu driven calibration. Labels that describe and differentiate each standard should be used. This is especially true for multiple standards of the same type.

When sexed connector standards are labeled, male (M) or female (F), the designation refers to the test port connector sex — not the connector sex of the standard. Further, it is recommended that the label include information carried on the standard such as the serial number of the particular standard to avoid confusing multiple standards which are similar in appearance.

The labels for the four standards in the waveguide example are; #1-PSHORT1, #2-PSHORT2, #3-PLOAD, and #4-THRU.

Assign Classes

In the previous section, Define Standards, the characteristics of calibration standards were derived. Class assignment organizes these standards for computation of the various error models used in calibration. The HP 8510A requires a fixed number of standard classes to solve for the n terms used in the error models (n = 1, 3 or 12). That is, the number of calibration error terms required by the HP 8510A to characterize the measurement system (1 Port, 2-Port, etc.) equals the number of classes utilized.

Standard Classes

A single Standard Class is a standard or group of (up to 7) standards that is required to calibrate for a single error term. The standards within a single class are assigned to locations A through G as listed on the Class Assignments Table. It is important to note that a class must be defined over the entire frequency range that a calibration is made, even though several separate standards may be required to cover the full measurement frequency range. In the measurement calibration process, the order of standard measurement within a given class is not important unless significant frequency overlap exists among the standards used. When two standards have

overlapping frequency bands, the last standard to be measured will be used by the HP 8510A. The order of standard measurement between different classes is not restricted, although the HP 8510A requires that all standards that will be used within a given class are measured before proceeding to the next class. Standards are organized into specified classes which are defined by a Standards Class Assignment table. See Table 2 for the class assignments table for the waveguide calibration kit.

S_{11} A,B,C and S_{22} A,B,C:

S_{11} A,B,C and S_{22} A,B,C correspond to the S_{11} and S_{22} reflection calibrations for port 1 and port 2 respectively. These 3 classes are used by the HP 8510A to solve for the systematic errors; directivity, source match, and reflection tracking. The three classes used by the 7mm cal kit are labeled 'short,' 'open,' and 'loads.' 'Loads' refers to a group of standards which is required to complete this standard class. A class may include a set of standards of which there is more than one acceptable selection or more than one standard required to calibrate the desired frequency range.

Table 2 contains the class assignment for the WR-62 waveguide cal kit. The $1/8\lambda$ offset short (Standard #1) is assigned to $S_{11}A$. The $3/8\lambda$ offset short (Standard #2) is assigned to $S_{11}B$. The matched load (Standard #3) is assigned to $S_{11}C$.

Forward Transmission Match and Thru

Forward Transmission (Match and Thru) classes correspond to the forward (port 1 to port 2) transmission calibration of the "thru" standard.

During measurement calibration the response of the match standard is used to find the systematic Load Match error term. Similarly the response of the thru standard is used to characterize transmission tracking.

The class assignments for the WR-62 waveguide cal kit are as follows. The thru (Standard #4) is assigned to both FORWARD TRANSMISSION and FORWARD MATCH.

Reverse Transmission Match and Thru

Reverse Transmission (Match and Thru) classes correspond to the reverse transmission calibration of the "thru" standard. For S-parameter test sets, this is the port 2 to port 1 transmission path. For the reflection/transmission test sets, the device is reversed and is measured in the same manner using the forward transmission calibration.

The class assignments for the WR-62 waveguide cal kit are as follows. The thru (Standard #4) is assigned to both REVERSE TRANSMISSION and REVERSE MATCH.

Isolation

Isolation (not listed on the Standard Class Assignments table) is simply the leakage from port 1 to port 2 internal to the test set. The isolation standard, which assumes perfect isolation, cannot be changed by the user. As a result, no physical standard is required to characterize, although the HP 8510 assumes that matched loads are connected to both test ports during isolation measurements to minimize radiation between the test ports.

Frequency Response

Frequency Response is a single class which corresponds to a one-term error correction that characterizes only the vector frequency response of the test set. Transmission calibration typically uses a 'thru' and reflection calibration typically uses either an 'open' or a 'short'.

Note

The Frequency Response calibration is not a simple frequency normalization. A normalized response is a mathematical comparison between measured data and stored data. The important difference is, that when a standard with non-zero phase, such as an offset short, is remeasured after calibration using Frequency Response, the actual phase offset will be displayed, but its normalized response would display zero phase offset (measured response minus stored response).

Therefore, the WR-62 waveguide calibration kit class assignment includes standard #1, standard #2 and Standard #4.

Standard Class Labels

Standard Class labels are entered to facilitate menu-driven calibration. A label can be any user-selected term which best describes the device or class of devices that the operator should connect. Predefined labels exist for each class. These labels are $S_{11}A$, $S_{11}B$, $S_{11}C$, $S_{22}A$, $S_{22}B$, $S_{22}C$, FWD TRANS, FWD MATCH, REV TRANS, REV MATCH and RESPONSE. ISOLATION labels are not modifiable.

The class labels for the WR-62 waveguide calibration kit are as follows; $S_{11}A$ and $S_{22}A$ — PSHORT1; $S_{11}B$ and $S_{22}B$ — PSHORT2; $S_{11}C$ and $S_{22}C$ — PLOAD; FWD TRANS, FWD MATCH, REV TRANS and REV MATCH — PTHRU; and RESPONSE — RESPONSE.

Calibration Kit Label

A calibration kit label is selected to describe the connector type of the devices to be measured. If a new label is not generated, the calibration kit label for the kit previously contained in that calibration kit register (CAL 1 or CAL 2) will remain. The predefined labels for the two calibration kit registers are:

Calibration Kit 1	Cal 1	HP 85050A
	7mm A.1	
Calibration Kit 2	Cal 2	HP 85052A
	3.5mm A.1	

Again, cal kit labels should be chosen to best describe the calibration devices. The "A.1" default suffix corresponds to the kit's mechanical revision (A) and mathematical revision (1).

Note

To prevent confusion, if any standard definitions in a calibration kit are modified but a new kit label is not entered, the default label will appear with the last character replaced by a "***". This is not the case if only a class is redefined without changing a standard definition.

The WR-62 waveguide calibration kit can be labeled simply — P BAND.

Enter Standards/Classes

The specifications for the Standard Definition Table and Standard Class Assignments Table can be entered into the HP 8510 through front panel menu-driven entry or under program control by an external controller. The procedure for entry of standard definitions, standard labels, class assignments, class labels and calibration kit label is described in Appendix A.

Note

DO NOT exit the calibration kit modification process without saving the calibration kit definitions in the appropriate register in the HP 8510. Failure to save the redefined calibration kit will result in not saving the new definitions and the original definitions for that register will remain. Once this process is completed, it is recommended that the new calibration kit should be saved on tape.

Verify Performance

Once a measurement calibration using a particular calibration kit has been generated, its performance should be checked before making device measurements. To check the accuracy that can be obtained using

the new calibration kit, a device with a well defined frequency response (preferably unlike any of the standards used) should be measured. It is important to note that the verification device must not be one of the calibration standards. Calibrated measurement of one of the calibration standards is merely a measure of repeatability.

A performance check of waveguide calibration kits is often accomplished by measuring a zero length short or a short at the end of a straight section of waveguide. The measured response of this device on a polar display should be a dot at $1 \angle 180^\circ$. The deviation from the known is an indication of the accuracy.

To achieve a more complete verification of a particular measurement calibration, (including dynamic accuracy) accurately known verification standards with a diverse magnitude and phase response should be used. NBS traceable or HP standards are recommended to achieve verifiable measurement accuracy. Further, it is recommended that verification standards with known but different phase and magnitude response than any of the calibration standards be used to verify performance of the HP 8510A.

User Modified Cal Kits and HP 8510A Specifications

As noted previously, the resultant accuracy of the HP 8510A when used with any calibration kit is dependent on how well its standards are defined and is verified through measurement of a device with traceable frequency response.

The published Measurement Specifications for the HP 8510A Network Analyzer system include calibration with HP Calibration Kits such as the HP 85050A. Measurement calibrations made with user defined or modified calibration kits are not subject to the HP 8510A performance specifications although a procedure similar to the standard verification procedure may be used.

Modification Examples

Modeling A 'Thru' Adapter

The MODIFY CAL KIT function allows more precise definition of existing standards, such as the 'thru'. For example, when measuring devices with the same sex coaxial connectors, a set of 'thru' standards to adapt non-insertable devices on each end is needed. Various techniques are used to cancel the effects of the 'thru' adapters. However, using the modify cal kit function to make a precise definition of the 'thru' enables the HP 8510A to mathematically "remove" the attenuation and phase shift due to the 'thru' adapter. To model correctly a 'thru' of fixed length, accurate gauging (see OFFSET DELAY) and a precise measurement of skin-loss attenuation (see OFFSET LOSS) are required. The characteristic impedance of the 'thru' can be found from the inner and outer conductor diameters and the permittivity of the dielectric (see OFFSET Z_0).

Modeling An 'Arbitrary Impedance' Standard

The 'arbitrary impedance' standard allows the user to model the actual response of any one port passive device for use as a calibration standard. As previously stated, the calibration is mathematically derived by comparing the measured response to the known response which is modeled through the standard definition table.

However, when the known response of a one-port standard is not purely reflective (short/open) or perfectly matched (load) but the response has a fixed real impedance, then it can be modeled as an arbitrary impedance.

A 'load' type standard has an assigned terminal impedance equal to the system Z_0 . If a given load has an impedance which is other than the system Z_0 , the load itself will produce a systematic error in solving for the directivity of the measurement system during calibration. A portion of the incident signal will be reflected from the mismatched load and sum together with the actual leakage between the reference and test channels within the measurement system. However, since this reflection is systematic and predicatable (provided the terminating impedance is known) it may be mathematically removed. The calibration can be improved if the standard's terminal impedance is entered into the definition table as an 'arbitrary impedance' rather than as a 'load'.

A procedure similar to that used for measurement of open circuit capacitance (see method #3) could be used to make a calibrated measurement of the terminal impedance.

Appendix A Calibration Kit Entry Procedure

Calibration Kit specifications can be entered into the HP 8510 using the HP 8510 tape drive, by front panel entry or through program control by an external controller.

Tape Procedure

The tape drive is an important feature since the HP 8510A can internally store only two calibration kits at one time while eight calibration kits can be stored on a single tape.

Below is the generic procedure to load or store calibration kits from and to the tape drive.

To Load Calibration Kits from a Tape into the HP 8510A

1. Insert the calibration data tape into the HP 8510A network analyzer.
2. Press the TAPE key; then press the following CRT-displayed softkeys:

LOAD

CAL KIT 1-2

CAL KIT 1 or CAL KIT 2 (This selection determines which of the HP 8510A non-volatile registers that the calibration kit will be loaded.)

FILE #__ (The file, 1 through 8, is selected which contains the appropriate calibration kit definitions.)

3. To verify that the correct calibration kit was loaded into the instrument, press the CAL key. If properly loaded, the calibration kit label will be shown under "CAL 1" or "CAL 2" on the CRT display.

To Store Calibration Kits from the HP 8510A onto a Tape

1. Insert the calibration data tape into the HP 8510A network analyzer.
2. Press the TAPE key; then press the following CRT displayed softkeys:

STORE

CAL KIT 1-2

CAL KIT 1 or CAL KIT 2 (This selection determines which of the HP 8510A non-volatile calibration kit registers that is to be stored on the data tape.)

FILE #__ (The selection, 1 through 8, determines the data tape location of the stored calibration kit.)

3. Examine Directory to verify that file has been stored. This completes the sequence to store a calibration kit onto a tape.

To generate a new cal kit or modify an existing one, either front panel or program controlled entry can be used.

In this guide, procedures have been given to define standards and assign classes. This section will list the steps required for front panel entry of the standards and appropriate labels.

Front Panel Procedure:

(P-Band Waveguide Example)

1. Prior to modifying or generating a cal kit, store one or both of the cal kits in the HP 8510A's non-volatile memory to a tape file.
2. Select CAL menu, MORE.
3. Prepare to modify cal kit 2: press MODIFY 2.
4. To define a standard: press DEFINE STANDARD.
5. Enable standard no. 1 to be modified: press 1, X1.
6. Select standard type: SHORT.
7. Specify an offset: SPECIFY OFFSETS.
8. Enter the delay from Table 1: OFFSET DELAY, 0.0108309, ns.
9. Enter the loss from Table 1: OFFSET LOSS, 0, X1.
10. Enter the Z_0 from Table 1: OFFSET Z_0 , 50, X1.
11. Enter the lower cutoff frequency: MINIMUM FREQUENCY, 9.487 GHz.
12. Enter the upper frequency: MAXIMUM FREQUENCY, 18.97 GHz.
13. Select WAVEGUIDE.
14. Prepare to label the new standard: PRIOR MENU, LABEL STANDARD, ERASE TITLE.
15. Enter PSHORT 1 by using the knob, SELECT LETTER soft key and SPACE soft key.
16. Complete the title entry by pressing TITLE DONE.
17. Complete the standard modification by pressing STANDARD DONE (DEFINED).

Standard #1 has now been defined for a $1/8\lambda$ P-band waveguide offset short. To define the remaining standards, refer to Table 1 and repeat steps 4 - 17. To define standard #3, a matched load, specify 'fixed'.

The front panel procedure to implement the class assignments of Table 2 for the P-band waveguide cal kit are as follows:

1. Prepare to specify a class: SPECIFY CLASS.
2. Select standard class $S_{11}A$.
3. Inform the HP 8510A to use standard no. 1 for the $S_{11}A$ class of calibration: 1, X1, CLASS DONE (SPECIFIED).
4. Change the class label for $S_{11}A$: LABEL CLASS, $S_{11}A$, ERASE TITLE.
5. Enter the label of PSHORT 1 by using the knob, the SELECT soft key and the SPACE soft key.
6. Complete the label entry procedure: TITLE DONE, LABEL DONE.

Follow a similar procedure to enter the remaining standard classes and labels shown below:

Standard Class	Standard No(s).	Class Label
$S_{11}B$	2	PSHORT 2
$S_{11}C$	3	PLOAD
$S_{22}A$	1	PSHORT 1
$S_{22}B$	2	PSHORT 2
$S_{22}C$	3	PLOAD
FWD TRANS	4	THRU
FWD MATCH	4	THRU
REV TRANS	4	THRU
REV MATCH	4	THRU
RESPONSE	1,2,4	RESPONSE

Finally, change the cal kit label as follows:

1. Press LABEL KIT.
2. Enter the title "P BAND".
3. Press TITLE DONE, KIT DONE (MODIFIED). The message 'CAL KIT SAVED' should appear.

This completes the entire cal kit modification for front panel entry. An example of programmed modification over the HP-IB bus through an external controller is shown in the Introduction To Programming section of the Operating and Service manual (Section III).

Appendix B Dimensional Considerations In Coaxial Connectors

This appendix describes dimensional considerations and required conventions used in determining the physical offset length of calibration standards in sexed coaxial connector families.

Precise measurement of the physical offset length is required to determine the OFFSET DELAY of a given calibration standard. The physical offset length of one and two port standards is as follows.

One port standard — Distance between 'calibration plane' and terminating impedance.

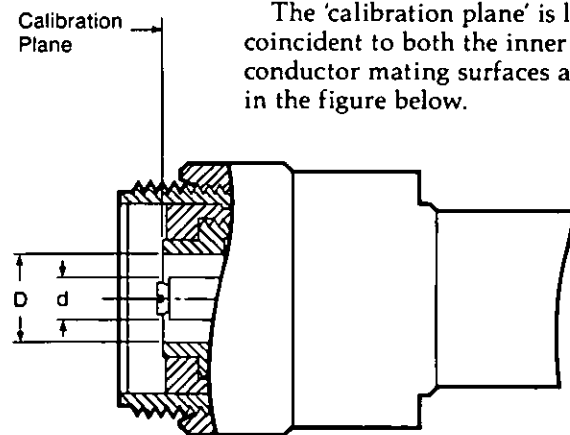
Two port standard — Distance between the Port 1 and Port 2 'calibration planes'.

The definition (location) of the 'calibration plane' in a calibration standard is dependent on the geometry and sex of the connector type. The 'calibration plane' is defined as a plane which is perpendicular to the axis of the conductor and either coincident with, or at a fixed distance from, the outer conductor mating surface. This mating surface is located at the contact points of the outer conductors of the test port and the calibration standard.

To illustrate this, consider the following connector type interfaces.

7mm Coaxial Connector Interface

The 'calibration plane' is located coincident to both the inner and outer conductor mating surfaces as shown in the figure below.



7 mm Coaxial Connector

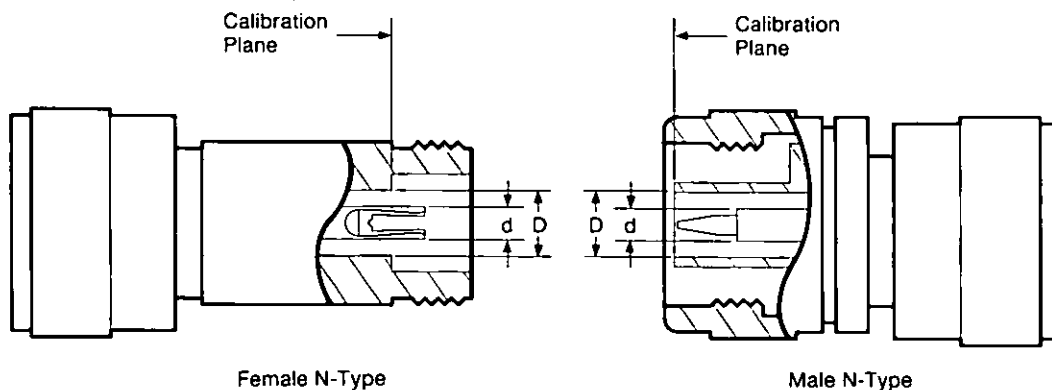
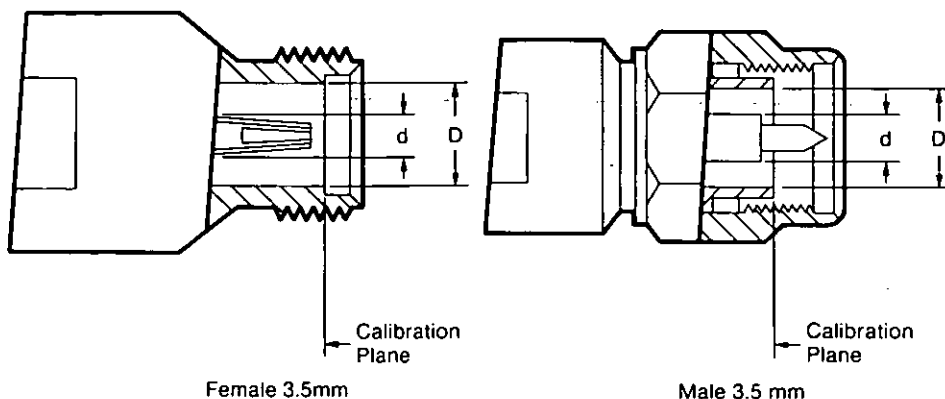
Unique to this connector type is the fact that the inner and outer conductor mating surfaces are located coincident as well as having hermaphroditic (sexless) connectors. In all other coaxial connector families this is not the case.

3.5mm Coaxial Connector Interface

The location of the 'calibration plane' in 3.5mm standards, both sexes, is located at the outer conductor mating surface as shown.

N-Type Coaxial Connector Interface

The location of the 'calibration plane' in N-type standards is the outer conductor mating surfaces as shown below.



Note

During measurement calibration using the HP 85054A N-type Calibration Kit, standard labels for the 'opens' and 'shorts' indicate both the standard type and the sex of the calibration test port. The sex (M or F) indicates the sex of the Test Port, NOT the sex of the standard.

The calibration plane in other coaxial types should be defined at one of the conductor interfaces to provide an easily verified reference for physical length measurements.

CALIBRATION KIT _____

TAPE FILE NUMBER _____

STANDARD		C0 $\times 10^{-15}F$	C1 $\times 10^{-27}F/Hz$	C2 $\times 10^{-28}F/Hz$	C3 $\times 10^{-45}F/Hz$	FIXED OR SLIDING	OFFSET			FREQUENCY (GHz)		COAX or WAVEGUIDE	STANDARD LABEL
NO.	TYPE						DELAY ps	LOSS dB/2/s	Z_0 Ω	MINIMUM	MAXIMUM		
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													

Standard Class Assignments

CALIBRATION KIT LABEL _____

TAPE FILE NUMBER _____

	A	B	C	D	E	F	G	STANDARD CLASS LABEL
S ₁₁ A								
S ₁₁ B								
S ₁₁ C								
S ₂₂ A								
S ₂₂ B								
S ₂₂ C								
Forward Transmission								
Reverse Transmission								
Forward Match								
Reverse Match								
Frequency Response								

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**General Application
Information**

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INTRODUCTION

This part of the HP 8510 network analyzer system manual provides detailed, application-independent descriptions of the controls, indicators, connections, operating characteristics, and HP-IB programming codes of the HP 8510 system. It is designed for quick reference rather than to duplicate the detailed operating information provide elsewhere.

FRONT PANEL CONTROLS AND MNEMONICS gives the names and, when applicable, also the HP-IB programming mnemonics of all HP 8510 network analyzer system front panel controls.

OVERALL MENU STRUCTURE presents in outline form the overall structure and relationship of the first-level, second-level, and other menus displayed on the HP 8510 system CRT display.

MENUS follow this overall outline, showing each menu structure and menu pictorially and, when applicable, also giving the HP-IB programming mnemonics for each menu choice. Notes on using the individual menus are also supplied when needed. Menus identified only by name on a menu structure diagram will be found on pages immediately after the structure diagram, except for the Title Menu and the Service Selections Menu. These two menus are given separately after all of the other menus.

HP-IB ONLY PROGRAMMING CODES lists and briefly explains the function of each of the HP-IB programming codes used with the HP 8510 network analyzer system.

ERROR MESSAGES lists each of the error messages displayed by the HP 8510 system by error number.

USER DISPLAY GRAPHICS explains the programming statements used to plot vectors and text onto the User Display area of the HP 8510 network analyzer system CRT.

CIRCUIT MODELING PROGRAM MNEMONICS explains programming syntax and commands used in the Circuit Modeling Program.

FRONT PANEL CONTROLS AND MNEMONICS

Listed here are the names and, when applicable, also the HP-IB programming mnemonics of all HP 8510 network analyzer system front panel controls.

FRONT PANEL CONTROL	Mnemonic
LINE	
CRT	
INTENSITY	
FOCUS	
ALIGN	
TEST	
PRIOR MENU	MENUPRIO
ENTRY	
knob	
STEP ↑	DOWN
STEP ↓	UP
ENTRY OFF	ENTO
Numeric Pad	0 1 2 3 4 5 7 8 9 . + -
Units Pad	
G/n (Giga/nano)	GHZ, NS, PS, FS
M/μ (mega/micro)	MHZ, US
k/m (kilo/milli)	KHZ, MS
x1 (basic units)	HZ, S
BACKSPACE	
= MARKER	EQUA
CHANNEL 1	CHAN1
CHANNEL 2	CHAN2

NOTE: The Units Pad mnemonics PS and FS (picoseconds, femtoseconds) have no front-panel key equivalents but can be used in programming.

<u>STIMULUS</u> START STAR STOP STOP CENTER CENT SPAN SPAN MENU MENUSTIM	<u>MENUS</u> CAL MENCAL DOMAIN MENDOMA DISPLAY MENUDISP MARKER MENUMARK
<u>PARAMETER</u> S ₁₁ S11 S ₂₁ S21 S ₁₂ S12 S ₂₂ S22 MENU MENUPARA	<u>INSTRUMENT STATE</u> LOCAL SAVE MENUSAVE RECALL MENURECA PRESET PRES
<u>FORMAT</u> LOG MAG LOGM DELAY DELA PHASE PHAS SMITH CHART SMIC MENU MENUFORM	<u>AUXILIARY MENUS</u> COPY MENCOPY TAPE MENUTAPE SYSTEM MENUSYST
<u>RESPONSE</u> SCALE SCAL REF VALUE REFV AUTO AUTO REF POSN REFP MENU MENURESP	<u>MEASUREMENT</u> <u>RESTART</u> REST

OVERALL MENU STRUCTURE

Thirteen first-level (or main) menus exist in the HP 8510 network analyzer system, and each is shown here with the second-level and other menus to which it gives access.

First-level menus are brought onto the CRT display by pressing the front-panel keys labeled **MENU** in the four HP 8510 function blocks, **STIMULUS**, **PARAMETER**, **FORMAT**, and **DISPLAY**, or by pressing front-panel keys, labeled with the menu name, in other blocks. Second-level and other menus are brought onto the display by pressing softkeys beside the CRT display after the first-level menu or another previous menu has appeared. Press the front-panel key labeled **PRIOR MENU** to return to the menu previously displayed.

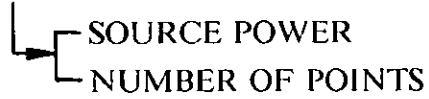
On the menu display, the value or choice currently being used in system operation is underlined. Mutually exclusive choices are connected by dots. Pressing the softkey beside a label displayed on the CRT either executes the function or presents another menu. If the choice selected requires an input, a prompt will appear on the CRT display when the softkey is pressed. Use the knob, step, and numeric keys in the **ENTRY** block to change the current value of the active function.

The overall menu structure of the HP 8510 system is shown first, in outline. Then each individual menu structure or first-level menu is shown pictorially. HP-IB programming mnemonics are given with the individual menus when a programming mnemonic exists for that function or choice.

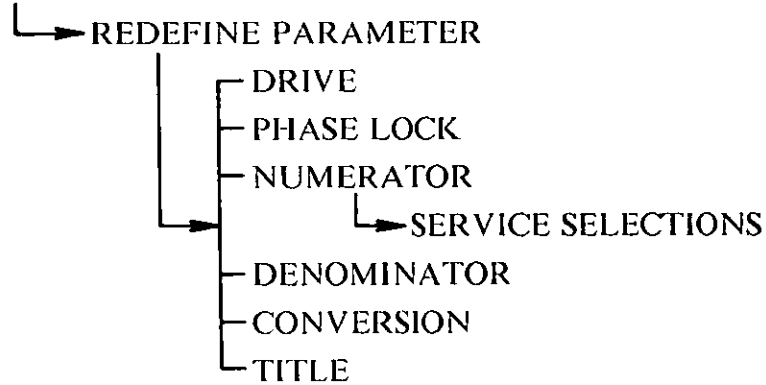
Menus identified only by name on a menu structure diagram will be found on pages immediately after the structure diagram, except for the Title Menu and the Service Selections Menu. These two menus are given separately after all of the other menus. Consult the Table of Contents in this section if you have trouble finding a particular menu.

OVERALL MENU STRUCTURE

STIMULUS

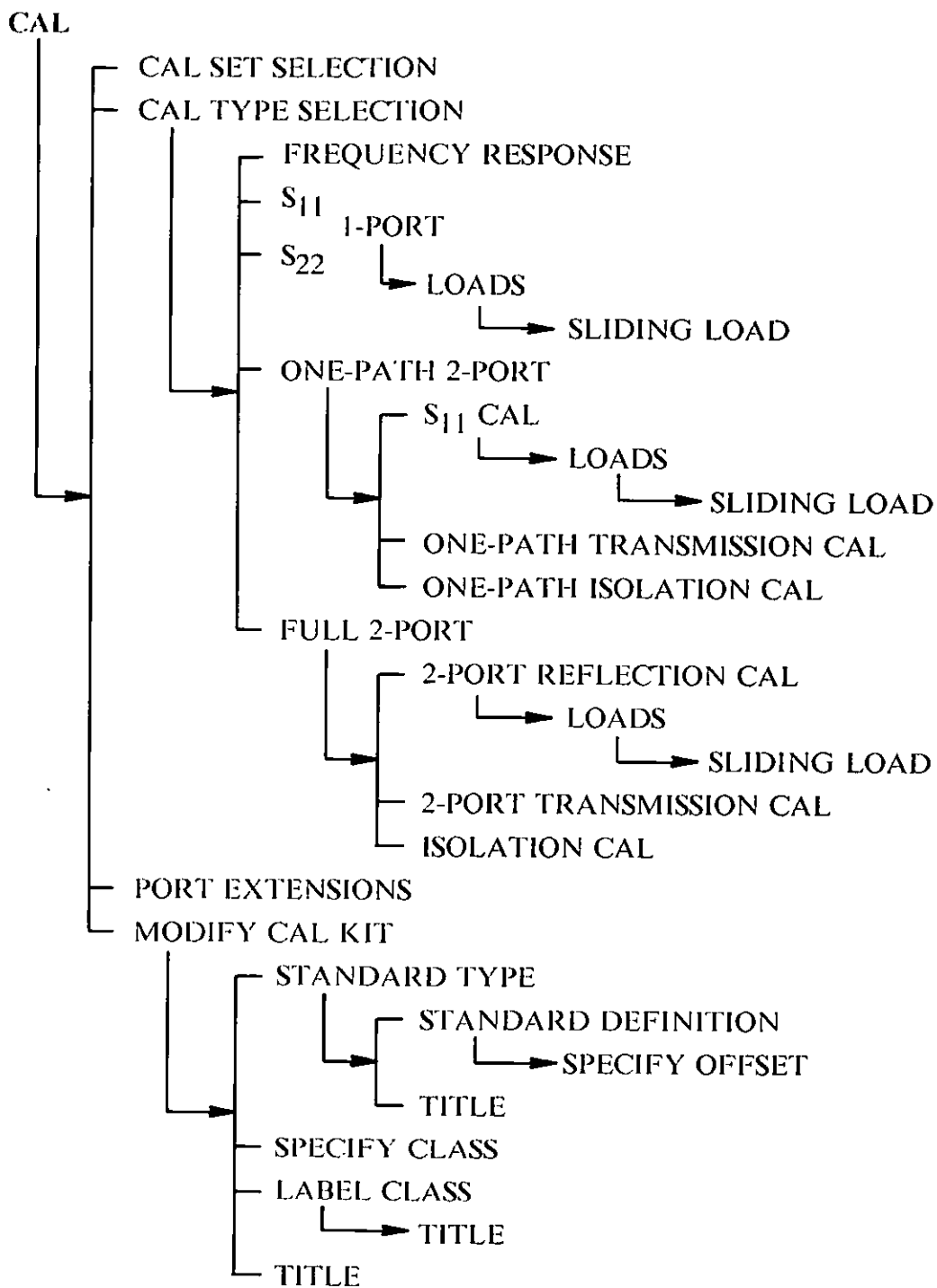


PARAMETER

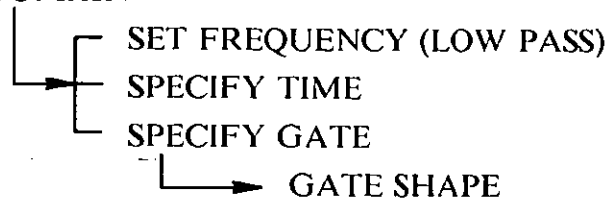


FORMAT

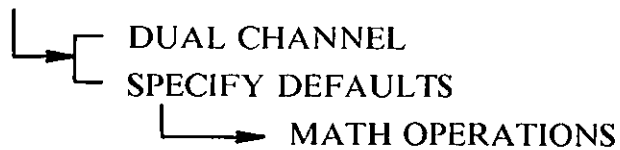
RESPONSE



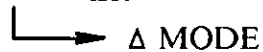
DOMAIN



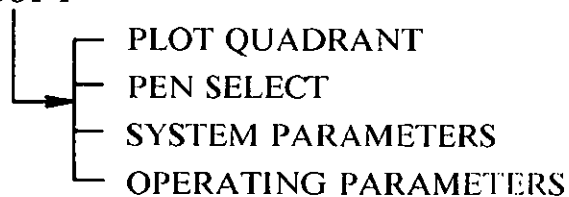
DISPLAY



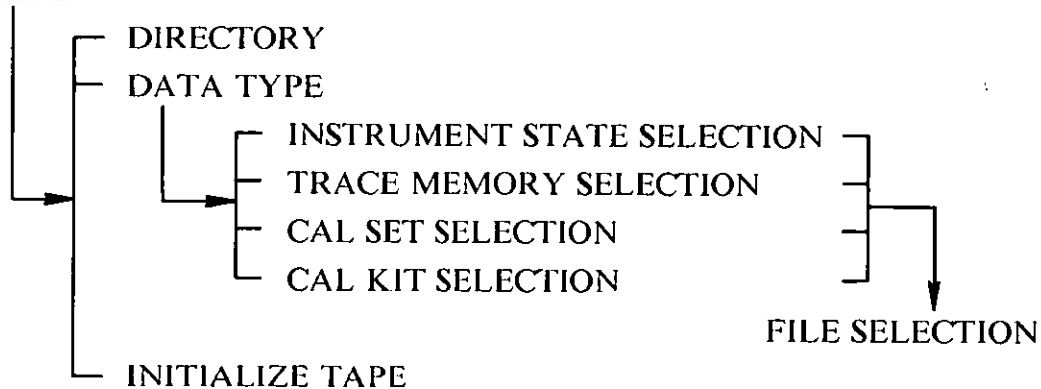
MARKER

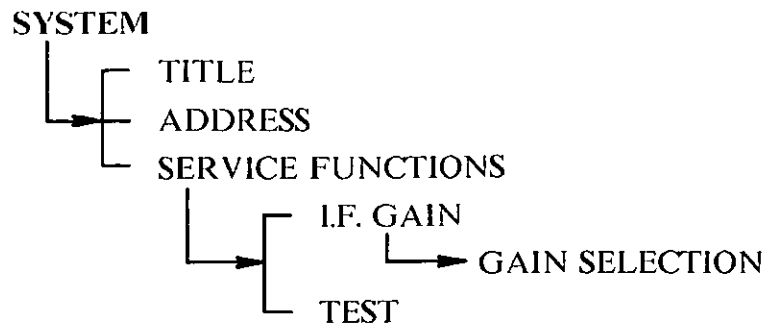


COPY



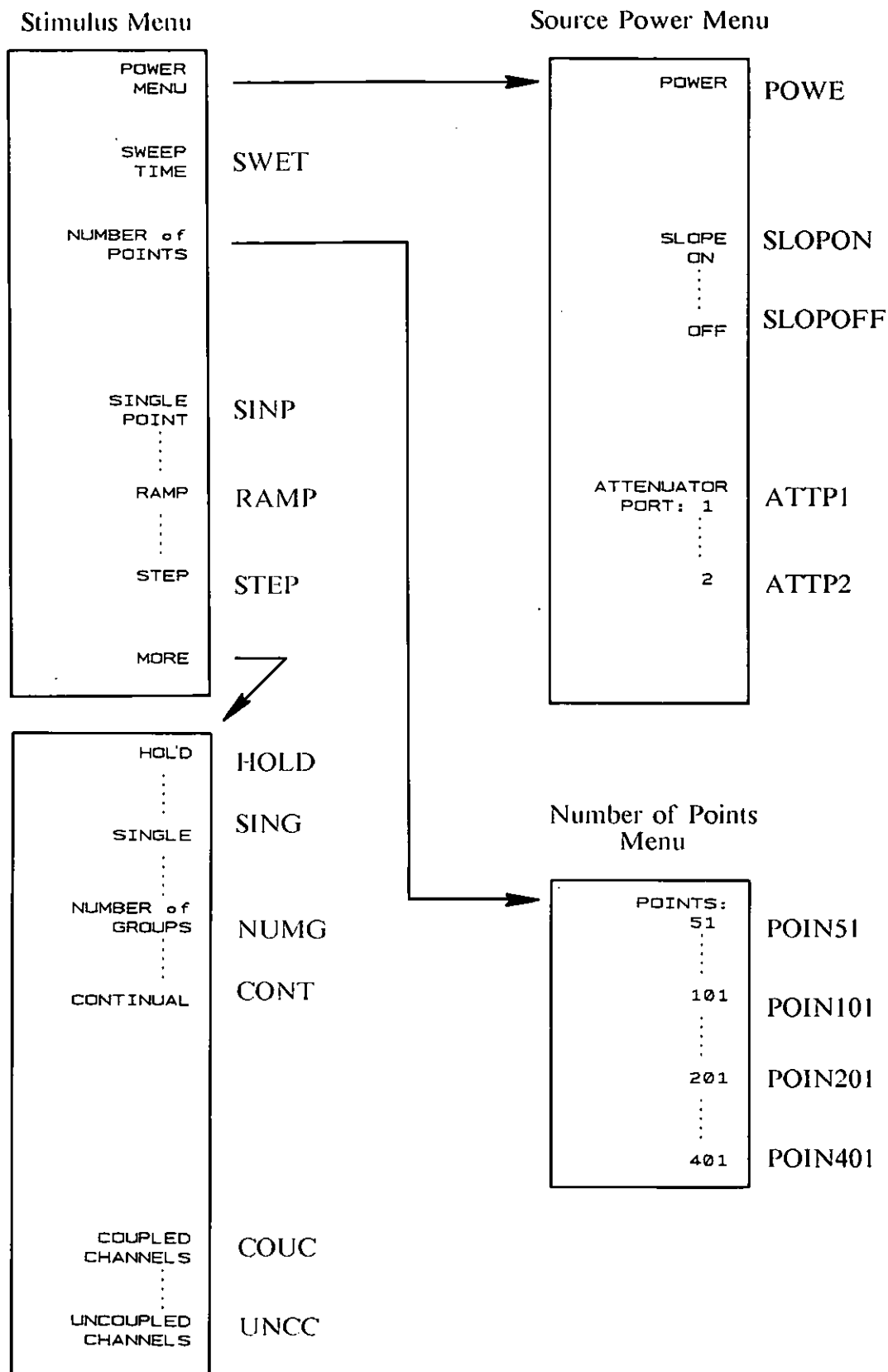
TAPE



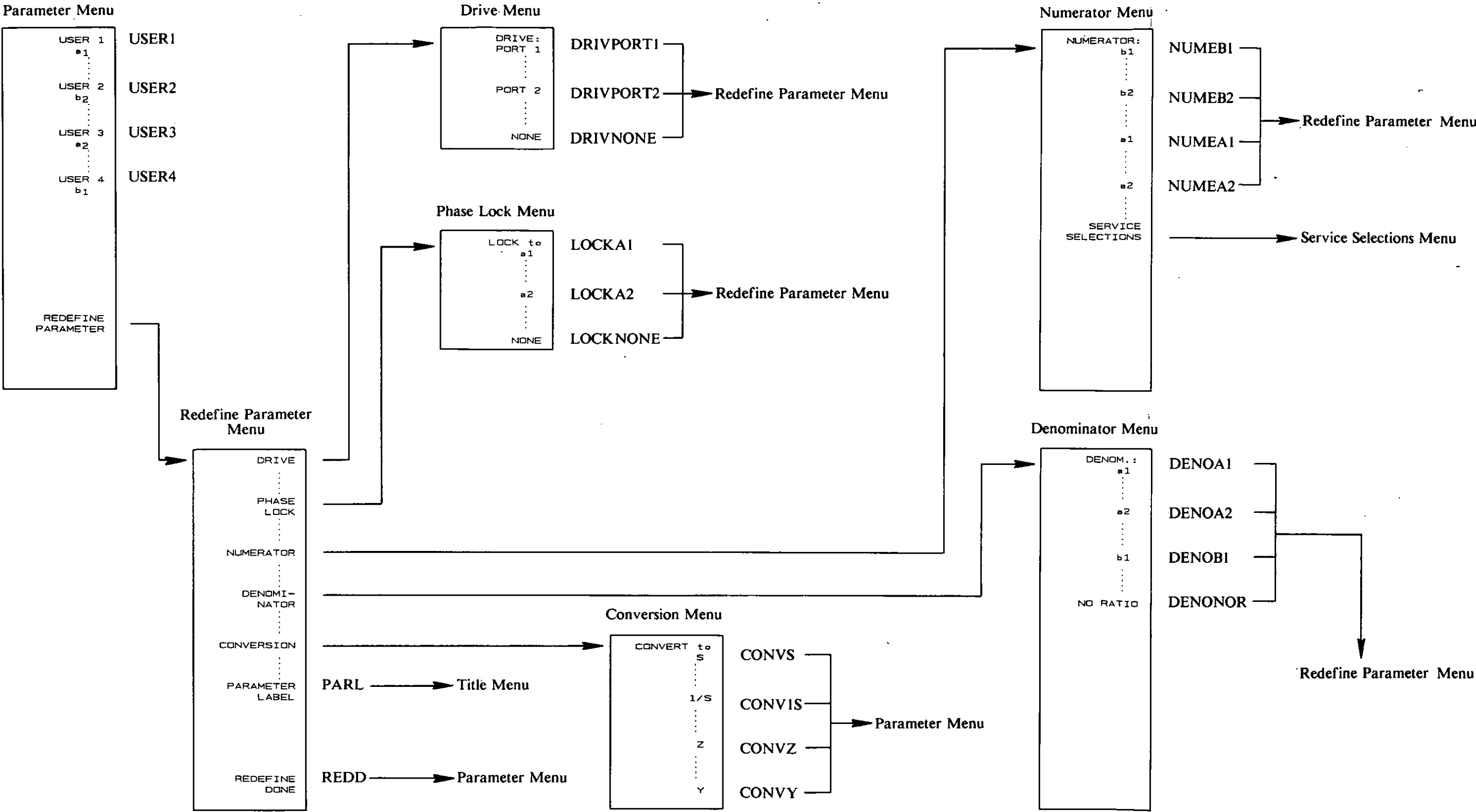


SAVE/RECALL

LOCAL

STIMULUS MENU STRUCTURE

PARAMETER MENU STRUCTURE



PARAMETER MENU

FORMAT MENU

Format Menu

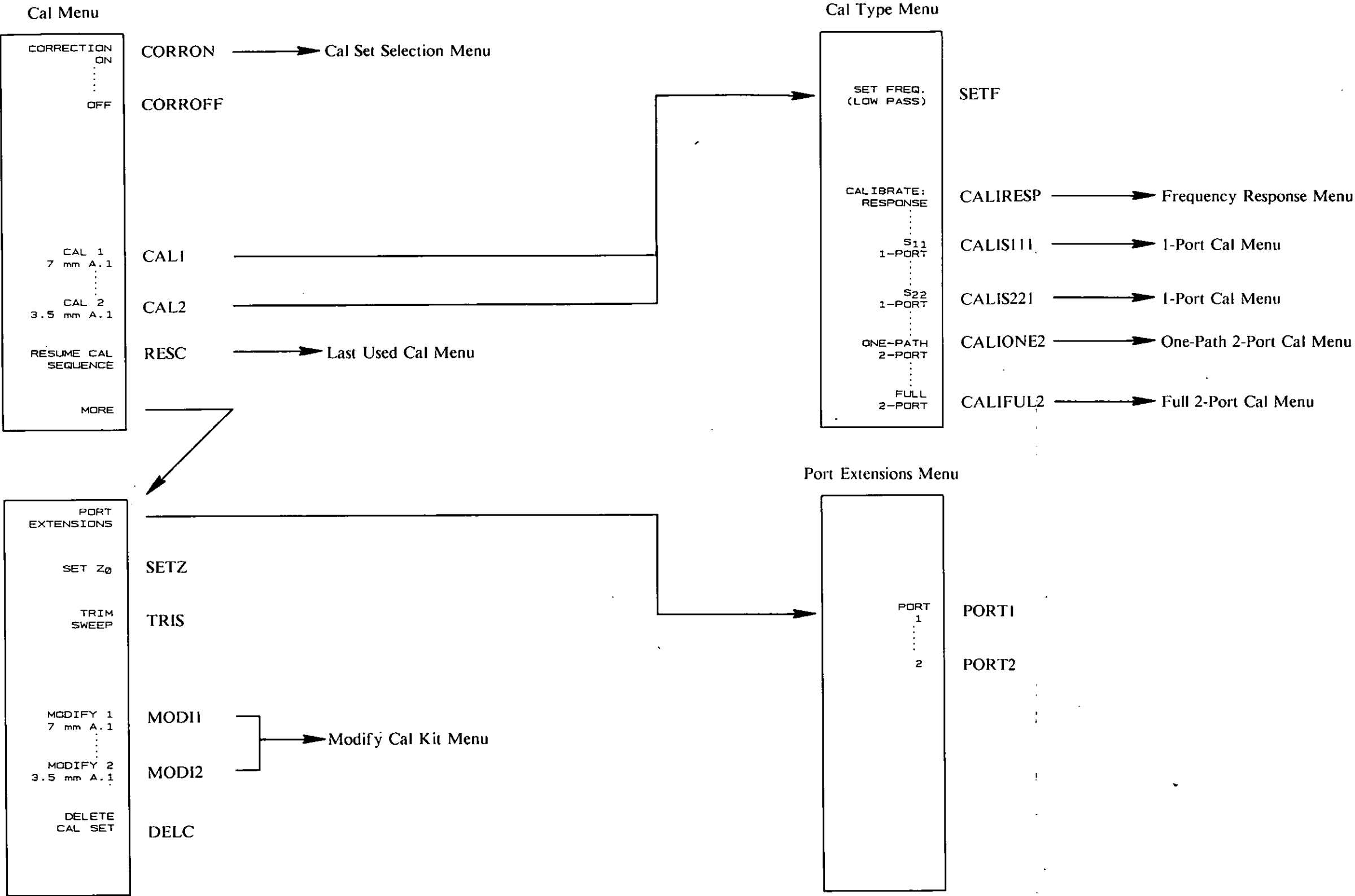
SWR	SWR
.....	
LINEAR MAGNITUDE	LINM
.....	
LIN mkr on POLAR	LINP
.....	
LOG mkr on POLAR	LOGP
.....	
Re/Im mkr on POLAR	REIP
.....	
INVERTED SMITH	INVS
.....	
IMAGINARY	IMAG
.....	
REAL	REAL

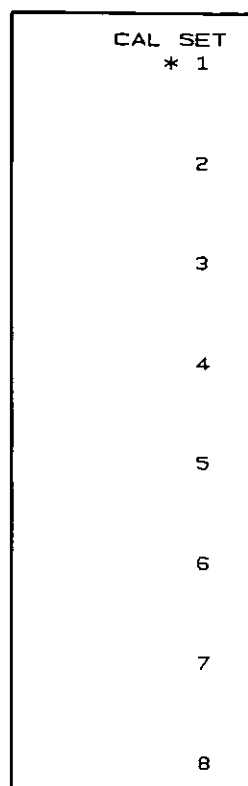
RESPONSE MENU

Response Menu

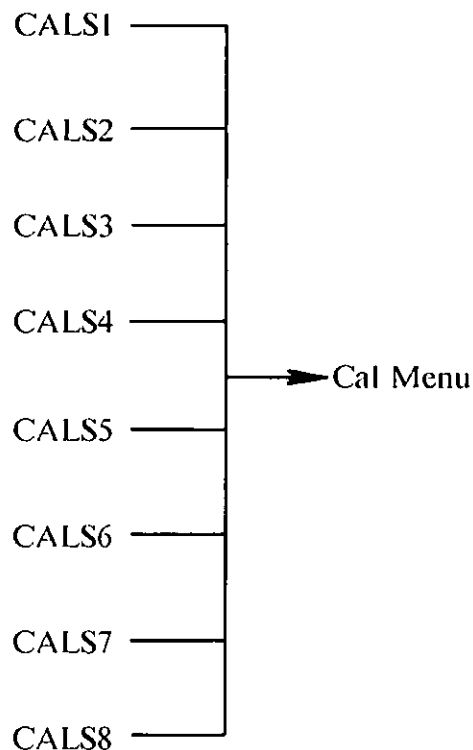
ELECTRICAL DELAY	ELED
PHASE OFFSET	PHAO
AVERAGING ON/restart ...	AVERON
OFF	AVEROFF
SMOOTHING ON ...	SMOON
OFF	SMOOFF

CAL MENU STRUCTURE



Cal Set Selection
Menu

Next Menu

**SELECTING CAL SETS**

In addition to the Cal Set Selection Menu, the prompt **SELECT CALIBRATION SET** will appear, and there will be an asterisk (*) beside all cal set numbers in which calibration coefficients have already been stored.

STORING CAL SETS

After measurement calibration, selecting a cal set using the Cal Set Select Menu stores the error coefficients and the Cal Set Limited Instrument State given on the next page in the Cal Set. If the selected cal set applies to the presently selected parameter, the stimulus values are set to the defined values and the CAL menu is displayed with **CORRECTION ON**. Selecting a cal set already used deletes the existing cal coefficients and stores the new cal coefficients in the Cal Set. An asterisk (*) will appear beside the cal set number.

REGISTERS AND CALIBRATION COEFFICIENT STORAGE

The system keeps track of assignments and available storage. Maximum storage for calibration coefficients depends on the type of calibration and the number of points. Maximum storage available for calibrations of each single type is as follows; storage for calibrations of several types can be approximated from the table knowing the relative space requirements.

Cal Type	Number of Points			
	51	101	201	401
Frequency Response	8	8	8	8
1-Port	8	8	8	8
2-Port	8	8	4	2

The Cal Set also includes critical calibration information relating to the stimulus settings.

RECALLING CAL SETS

The Cal Set Limited Instrument State listed below contains important network analyzer control settings at the time the cal set was stored. Recalling a cal set restores all of the stimulus settings (listed below) to their state at the time the cal set was saved.

Cal Set Limited Instrument State

Parameter(s) Corrected will not turn Correction On if parameter is not included
Frequency Range Number of Points both turn Correction Off if changed and new parameter is not included
Source Power Sweep Time Power Slope Ramp/Step/Single Point Trim Sweep Sweep Mode

CALIBRATION ERROR COEFFICIENT STORAGE

To load error coefficients into the HP 8510 network analyzer memory from an external controller, first load all appropriate calibration coefficient arrays. Then issue the HP-IB SAVC;CALSn instruction. This will save the coefficients in their proper location.

INPUT/OUTPUT MNEMONIC	CALIBRATION TYPE		
	RESPONSE	1-PORT	2-PORT
CALC01	E_R or E_T	E_D	E_{DF}
CALC02		E_S	E_{SF}
CALC03		E_R	E_{RF}
CALC04			E_{XF}
CALC05			E_{LF}
CALC06			E_{TF}
CALC07			E_{DR}
CALC08			E_{SR}
CALC09			E_{RR}
CALC10			E_{XR}
CALC11			E_{LR}
CALC12			E_{TR}

" E_{xx} " terms in these models are error terms, and the subscripts indicate the source of the error:

E_{xx}

First subscript

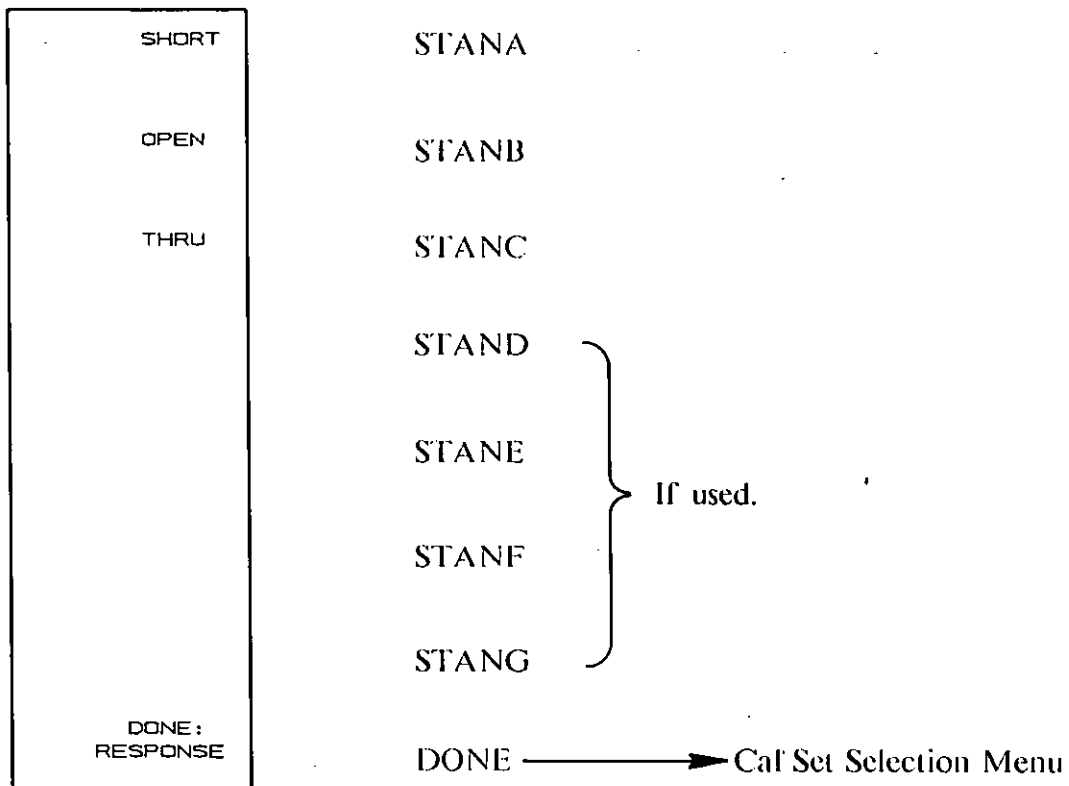
Second Subscript

D = Directivity
 S = Source match
 L = Load match
 X = Isolation (crosstalk)
 R = Reflection signal-path tracking
 T = Transmission signal-path tracking

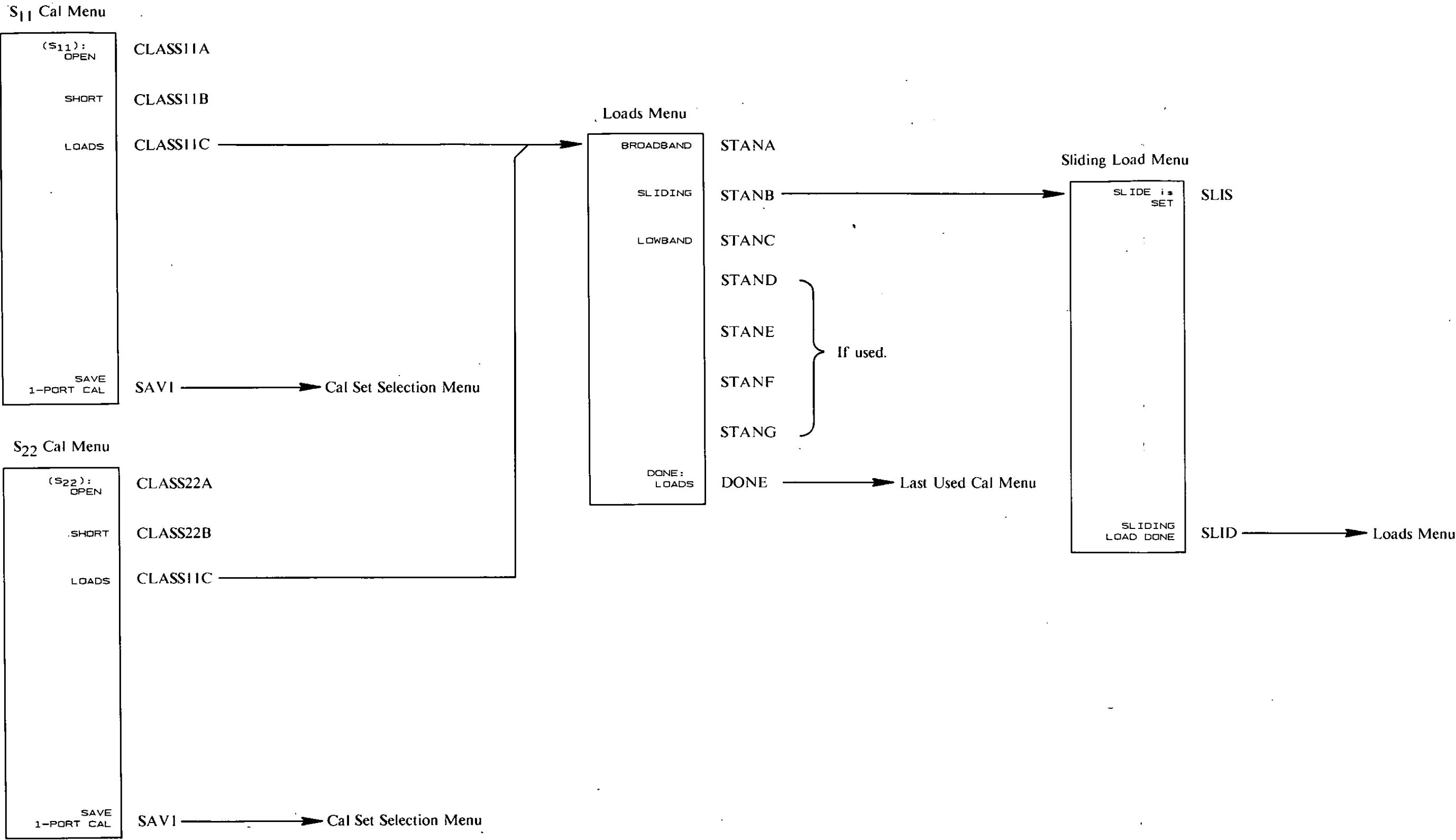
F = Forward
 R = Reverse

Frequency Response Menu

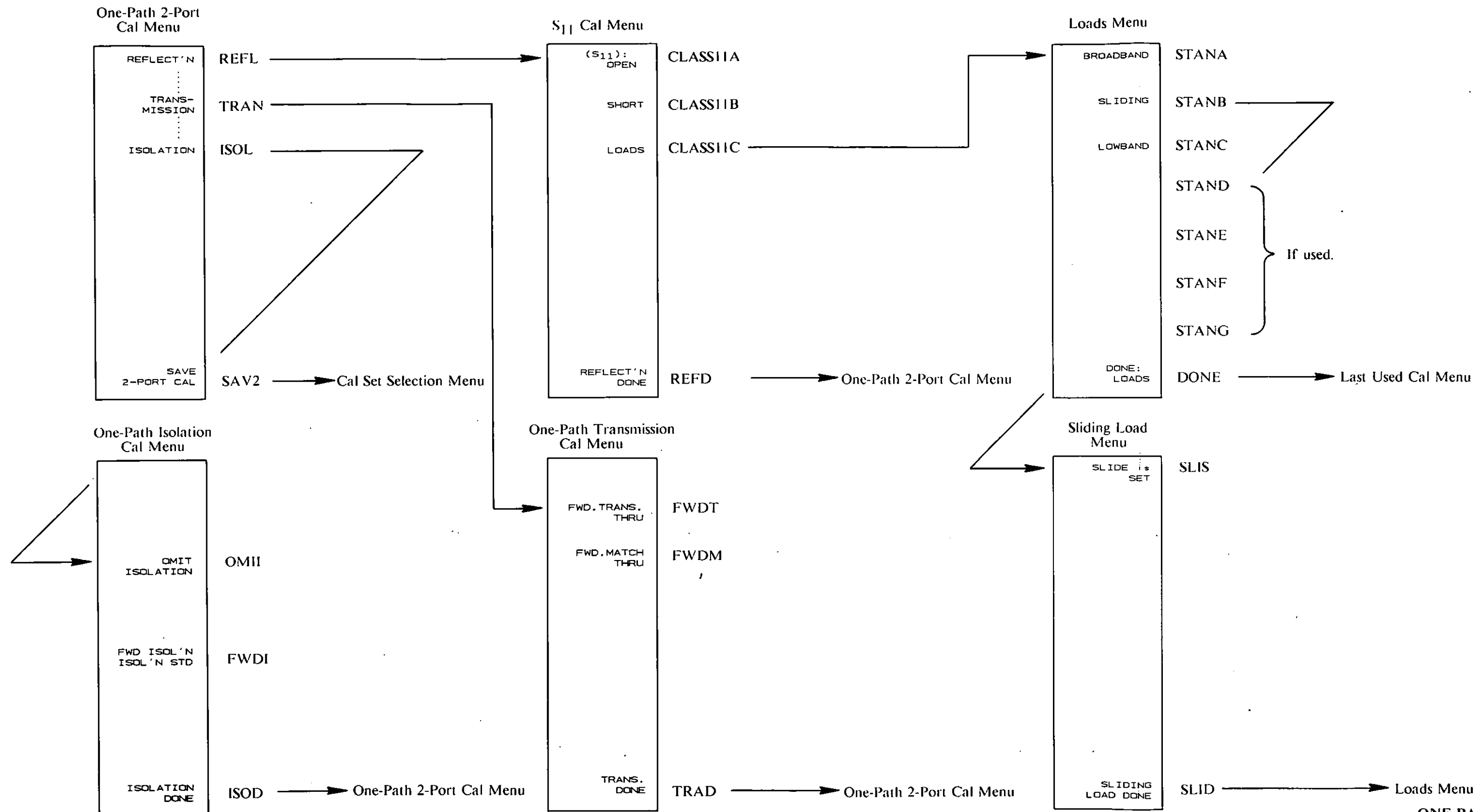
Next Menu



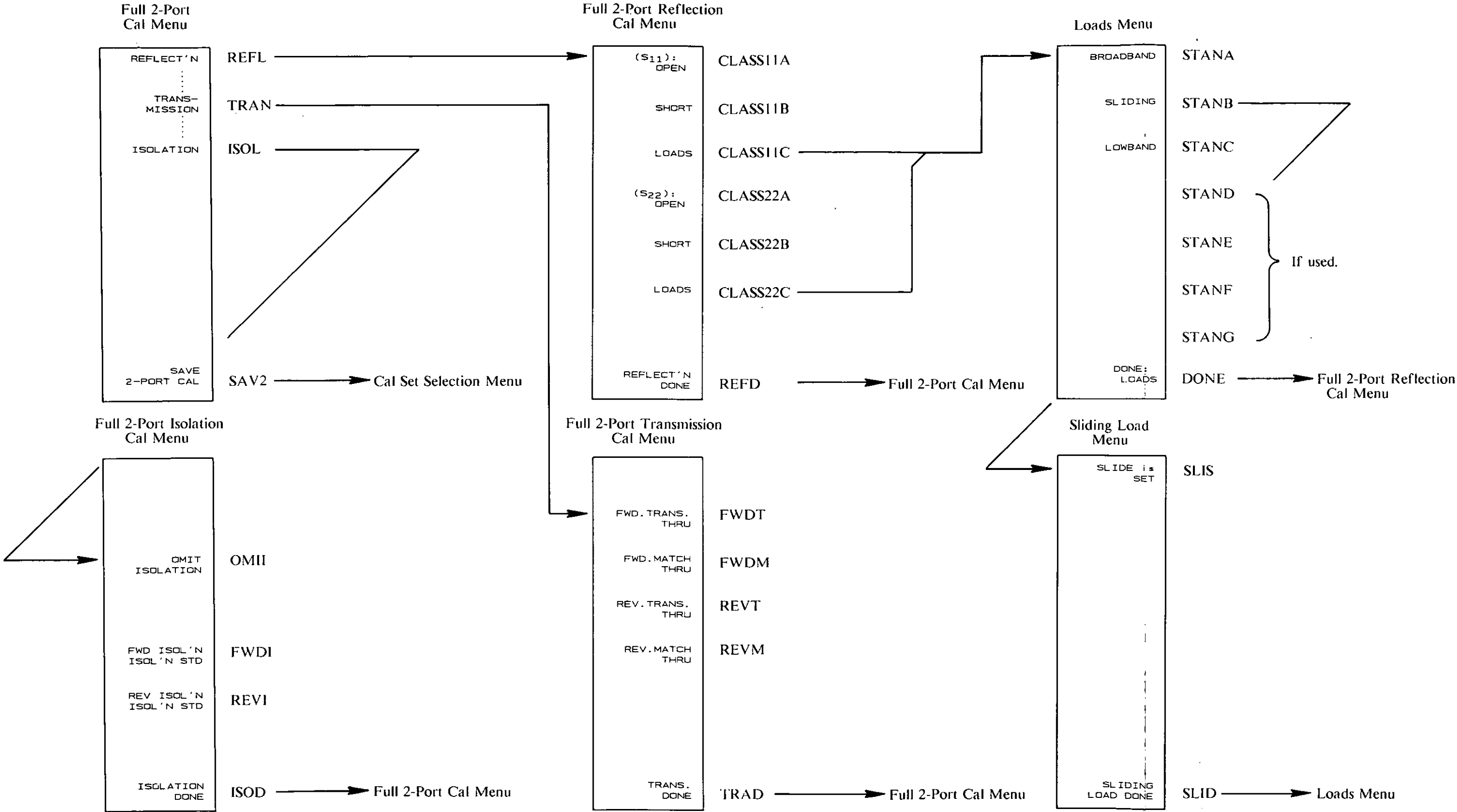
1-PORT CAL MENU STRUCTURE



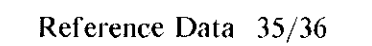
ONE-PATH 2-PORT CAL MENU STRUCTURE



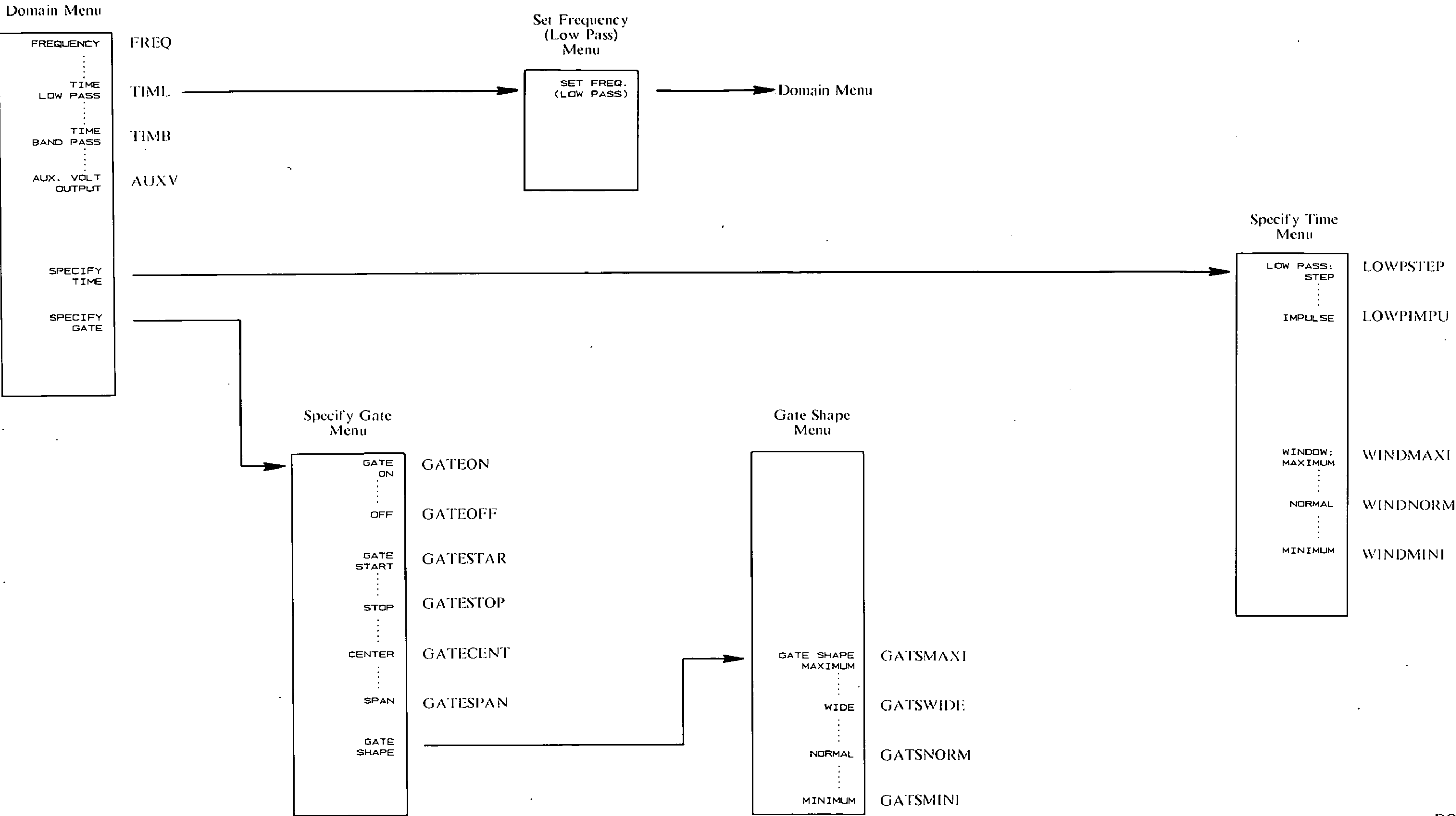
FULL 2-PORT CAL MENU STRUCTURE



MODIFY CAL KIT MENU

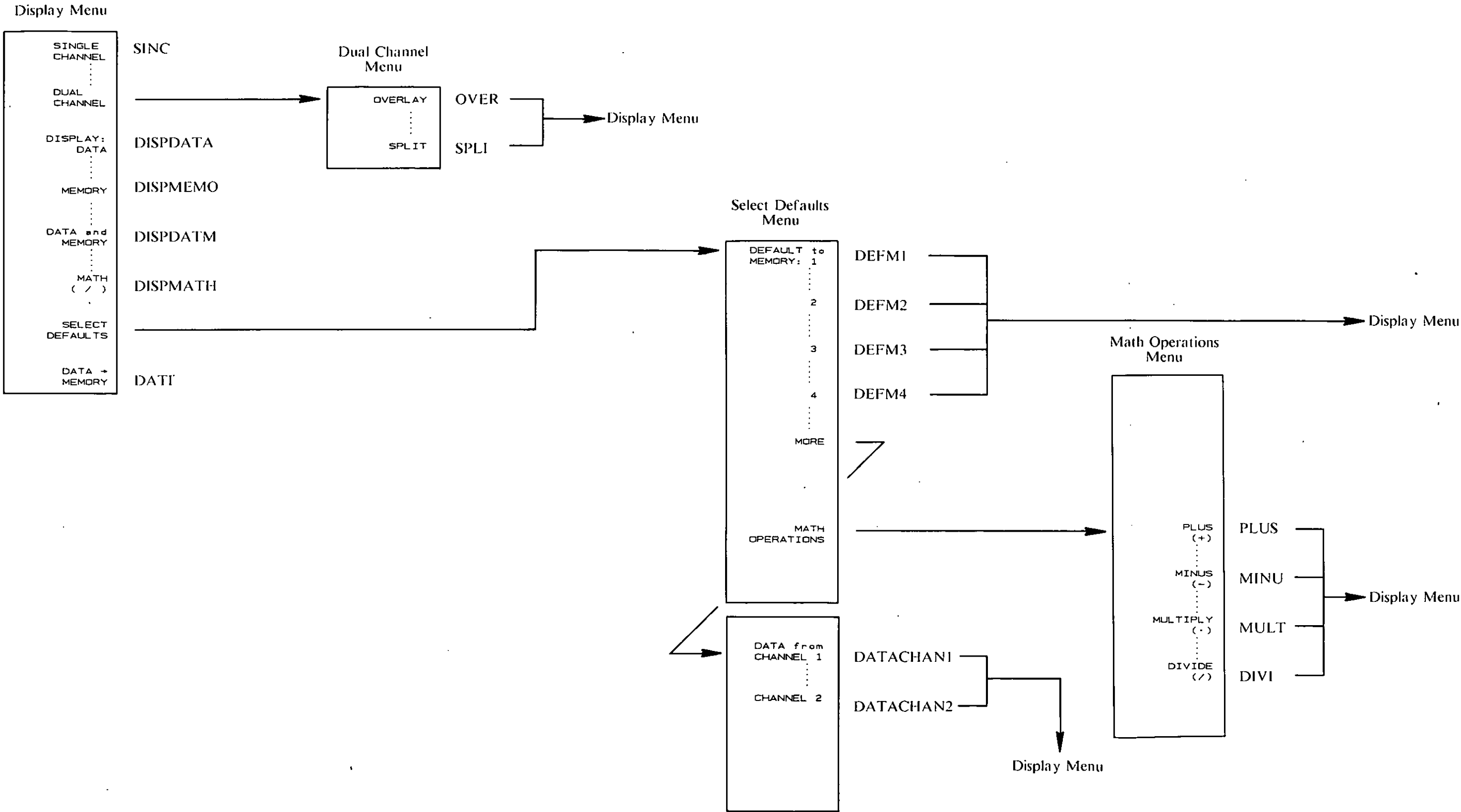


DOMAIN MENU STRUCTURE



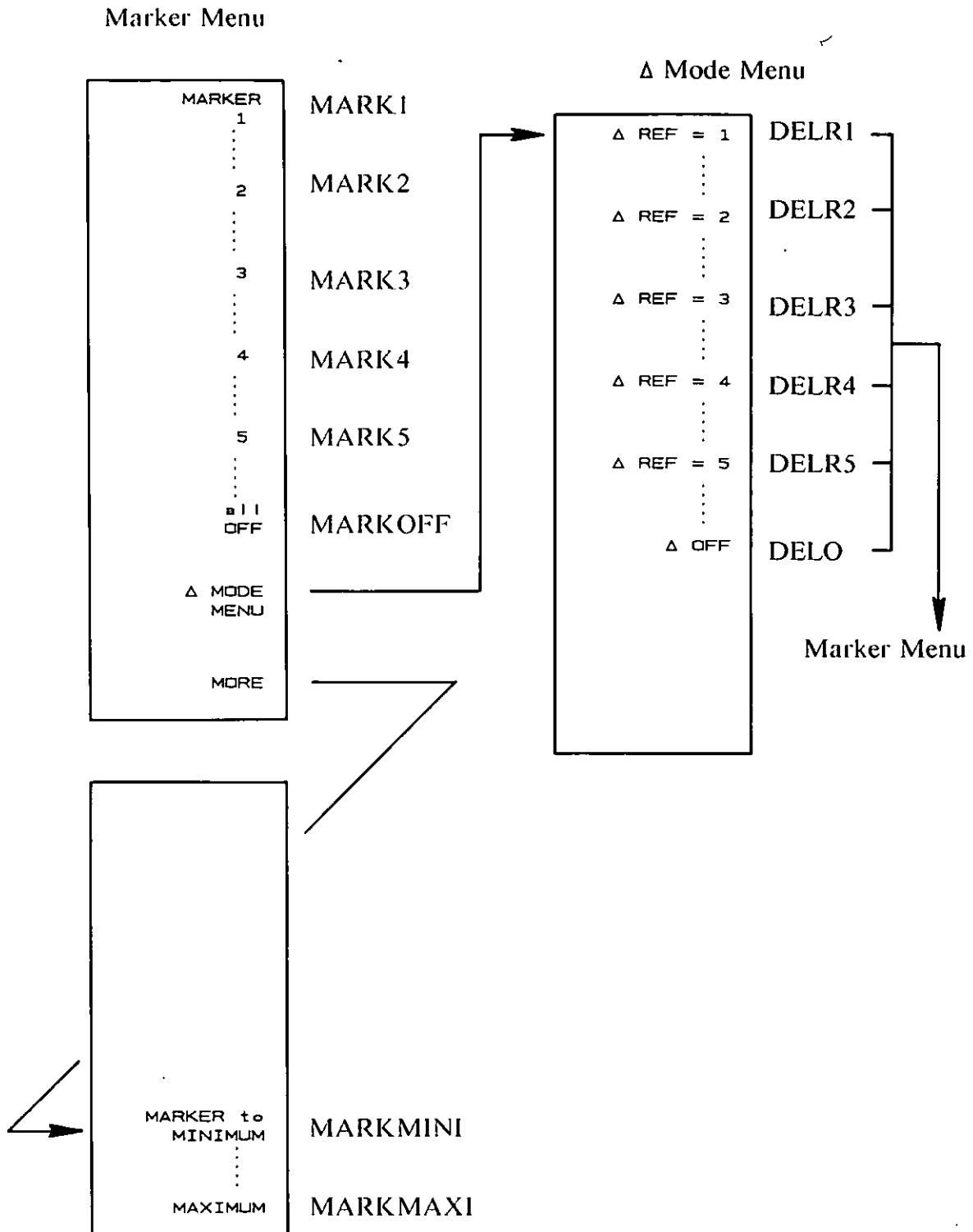
DOMAIN
MENU

DISPLAY MENU STRUCTURE

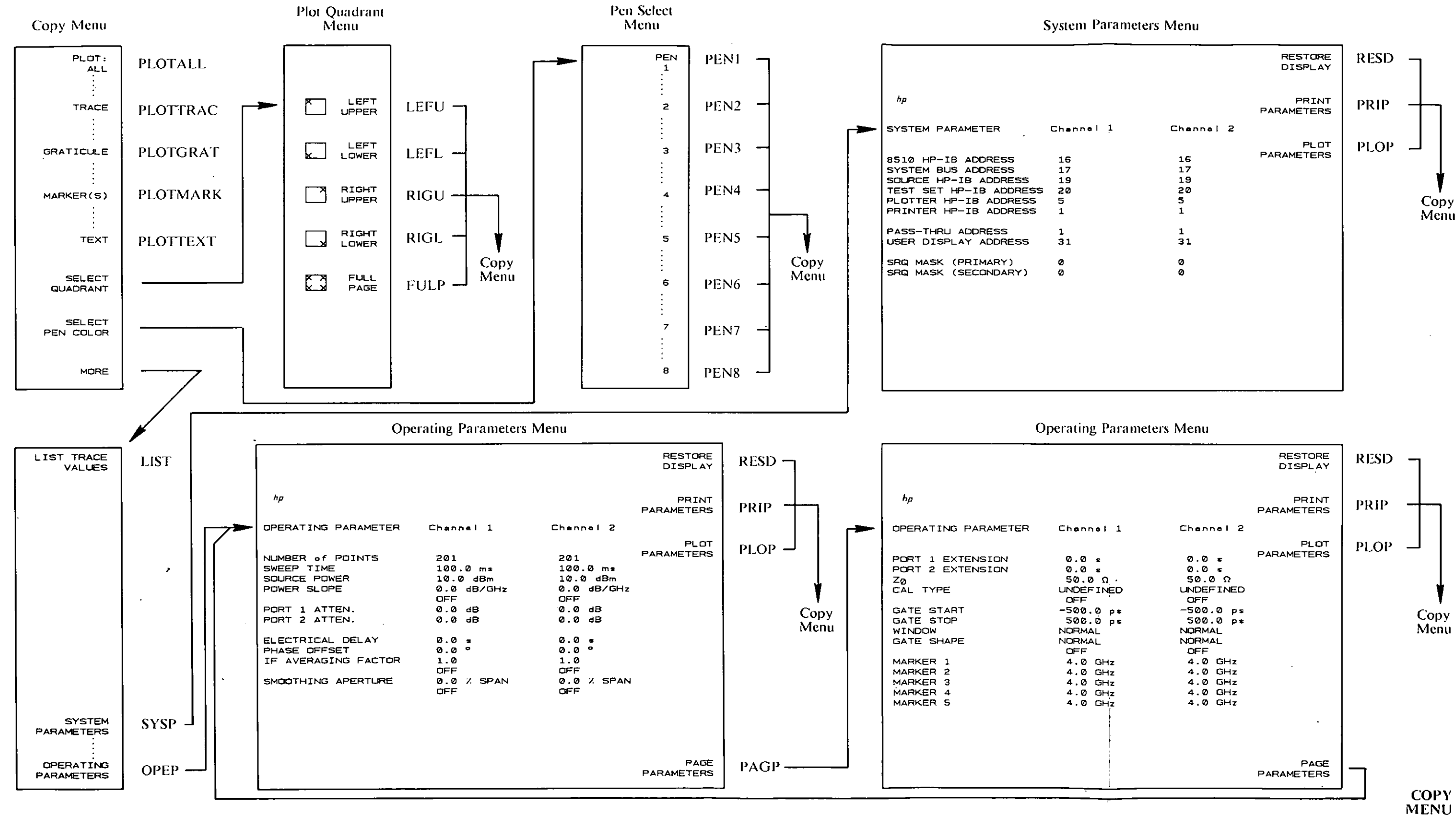


DISPLAY
MENU

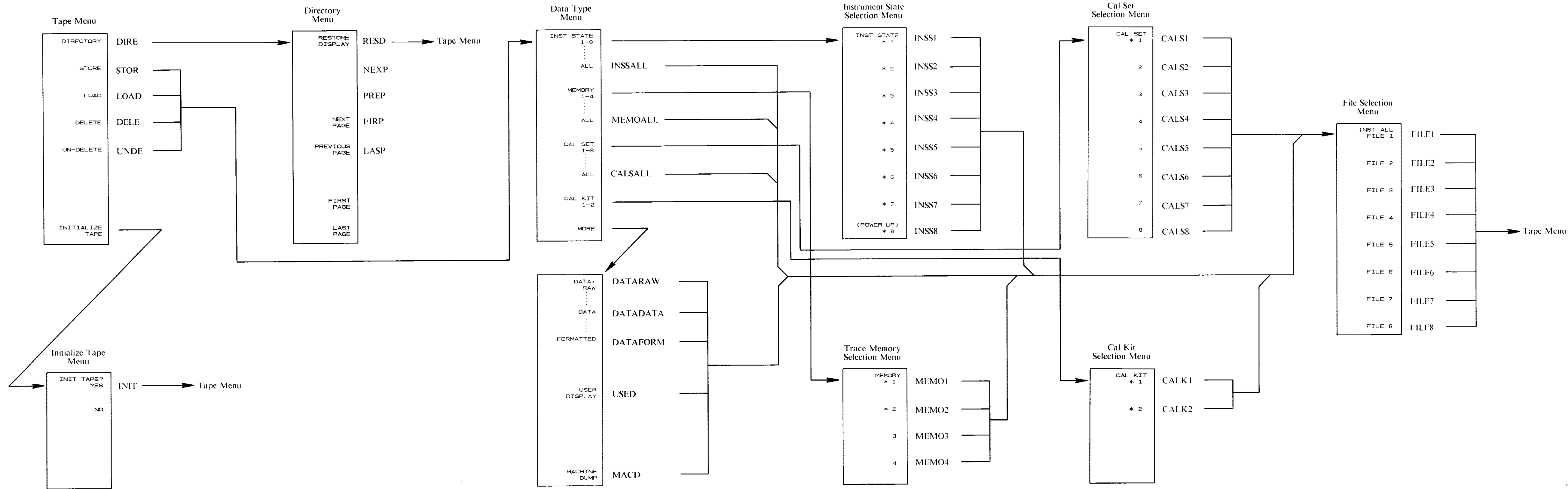
MARKER MENU STRUCTURE



COPY MENU STRUCTURE



TAPE MENU STRUCTURE



TAPE
MENU

FILE TYPES AND SIZE

8 files for each data type, 85 blocks each tape.

FILE TYPE	BLOCK SIZE
INSTRUMENT STATE 1-8	2
INSTRUMENT STATES ALL	13
MEMORY TRACE 1-4	1 2, if 401 points
MEMORY TRACES ALL	8
CAL SET 1-8	depends on cal type and number of points
CAL SET ALL	23
CAL KIT 1-2	1
RAW DATA	2 3, if 401 points
DATA	1 2, if 401 points
FORMATTED DATA	1 2, if 401 points
USER DISPLAY	2
MACHINE DUMP	58

STORING INSTRUMENT STATES: SAMPLE SEQUENCE

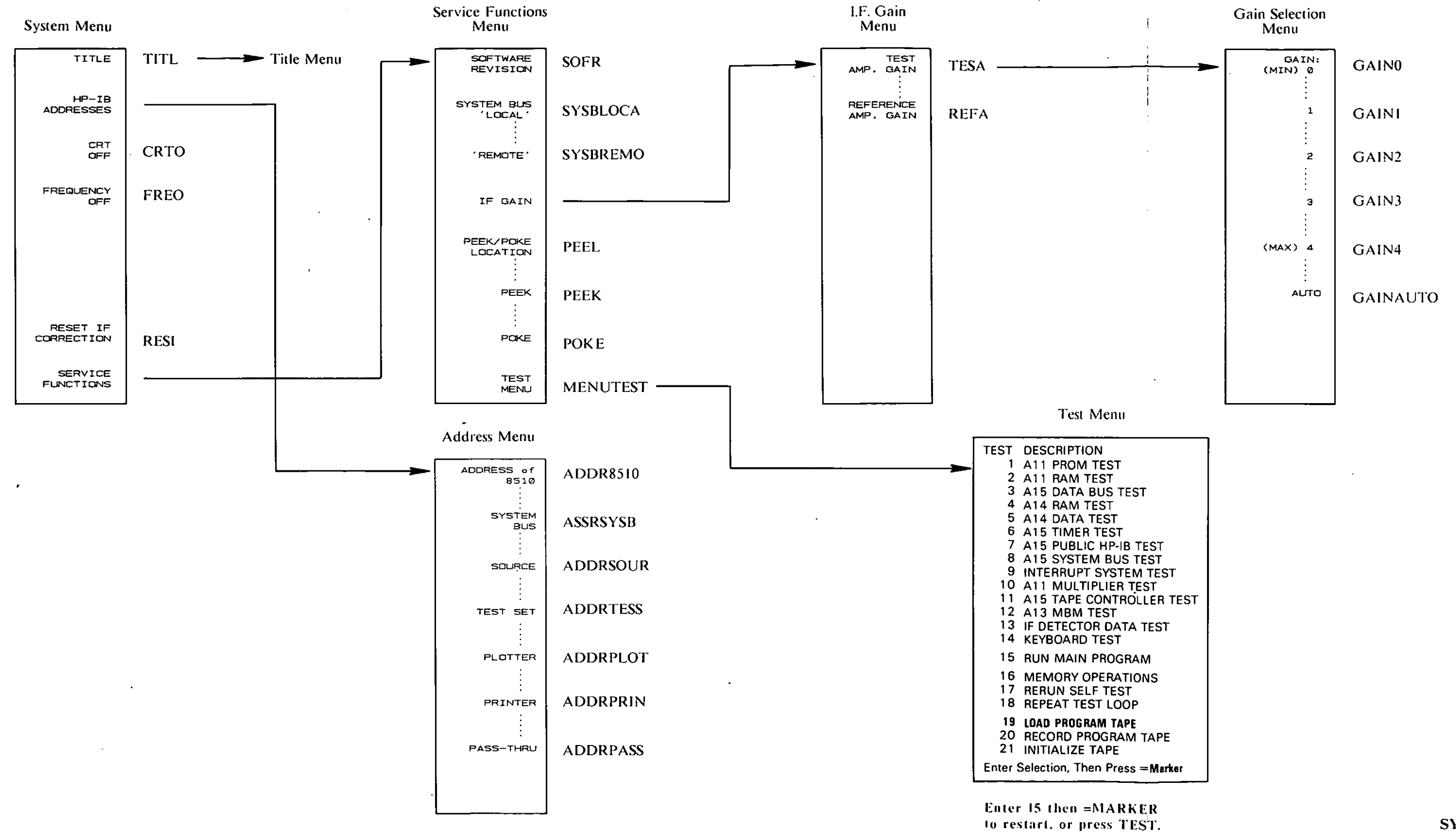
The following sequence illustrates how to save instrument states using the TAPE menu and the SAVE/RECALL menu.

Turn On Power (RECALL register 5 recalled)
Press **PRESET** (Standard PRESET state recalled)
Setup for measurement 1, **SAVE 1**.
Setup for measurement 2, **SAVE 2**.
Setup for measurement 3, **SAVE 3**.
Setup for measurement 4, **SAVE 4**.
Setup state you want after Power On, **SAVE 8**.

Check states:
RECALL 1, 2, 3, 4, 8.
Turn Off Power, Turn On Power.
(System recalls Instrument State stored in 8.)

To record, insert blank cartridge, then press:
INITIALIZE TAPE,
INITIALIZE TAPE YES.
RECORD,
INST STATE ALL,
INST ALL FILE (select 1 - 8).
DIRECTORY.
(The tape now contains states 1, 2, 3, 4, 5, 6, 7 and 8.)

SYSTEM MENU STRUCTURE



SAVE/RECALL MENU

Save Menu

INST STATE	
* 1	SAVE1
* 2	SAVE2
* 3	SAVE3
* 4	SAVE4
* 5	SAVE5
* 6	SAVE6
* 7	SAVE7
(POWER UP)	
* 8	SAVE8

Recall Menu

INST STATE	
* 1	RECA1
* 2	RECA2
* 3	RECA3
* 4	RECA4
* 5	RECA5
* 6	RECA6
* 7	RECA7
(POWER UP)	
* 8	RECA8

LOCAL MENU

Local Menu

ADDRESS of 8510 SYSTEM BUS SOURCE TEST SET PLOTTER PRINTER PASS-THRU	ADDR8510 ADDRSYSB ADDRSOUR ADDRTESS ADDRPLOT ADDRPRIN ADDRPASS
--	--

The Local Menu is identical with the Address Menu. To check or change an address, press the softkey and observe the address displayed in the Active Function area of the CRT. Use the knob, STEP keys, or numeric x1 to change the address. For the source, test set, plotter, or printer the address becomes effective the next time the HP 8510 addresses the instrument.

TITLE MENU

		SELECT LETTER
<i>hp</i> POINT WITH KNOB; THEN PRESS 'SELECT LETTER'		
TITLE		
ABCDEFGHIJKLMNOPQRSTUVWXYZ.0123456789()+-*/=abmΓ12		SPACE
↑		
		BACK SPACE
		ERASE TITLE
		TITLE DONE

SERVICE SELECTIONS MENU

Service Selections Menu

SERVICE: TEST CAL REF CAL DETECTOR GROUND ADC GROUND VCAL VREF TEMP. 1 TEMP. 2	SERVTESC SERVREFC SERVDETG SERVADCG SERVVCAL SERVVREF SERVTEMP1 SERVTEMP2
---	--

SERVICE SELECTIONS

These selections are used in servicing the HP 8510 network analyzer system, and their use is explained in the Service section of the HP 8510 manual. Selections change the instrument state immediately. If you do not want to make a selection, press the front-panel key labeled **PRIOR MENU**. To clear any selection made from this menu, press the front-panel key labeled **PRESET**.

HP-IB ONLY PROGRAMMING CODES

CLES	MONI	OUTPDATA
DEBUON	MENUOFF	OUTPERRO
DEBUOFF	MENUON	OUTPFORM
		OUTPIDEN
		OUTPKEY
INPUALC01	OUTPACTI	OUTPMARK
INPUALC02		OUTPMEMO
INPUALC03	OUTPCALC01	OUTPPLOT
INPUALC04	OUTPCALC02	OUTPRAW1
INPUALC04	OUTPCALC03	OUTPRAW2
INPUALC05	OUTPCALC04	OUTPRAW3
INPUALC06	OUTPCALC05	OUTPRAW4
INPUALC08	OUTPCALC06	OUTPSTAT
INPUALC09	OUTPCALC07	OUTPTITL
INPUALC10	OUTPCALC08	
INPUALC11	OUTPCALC09	SAVC
INPUALC12	OUTPCALC10	
	OUTPCALC11	SOFT1
INPUALC12	OUTPCALC12	SOFT2
INPUALC12		SOFT3
INPUALC12		SOFT4
INPUALC12		SOFT5
INPUALC12		SOFT6
INPUALC12		SOFT7
INPUALC12		SOFT8
KEYC		
		SQRM

ERROR MESSAGES

When an error message appears, press ENTRY OFF or program OUTPERRO and read error number to clear message from CRT. All "Tell" messages are error number 0 (zero).

NUMBER	ERROR MESSAGE STRING
1	OPTIONAL FUNCTION, NOT INSTALLED Attempt to use option not available with current system. Time Domain Option not installed.
2	SYNTAX ERROR
3	INVALID KEY Pressed unlabeled softkey.
4	SOURCE SYNTAX ERROR
5	TEST SET SYNTAX ERROR
6	SYSTEM BUS ADDRESS ERROR Source or test set not connected to HP 8510 System Bus. Check address selection at instrument and check HP 8510 address assignments.
7	SYSTEM BUS SRQ ERROR
8	VTO FAILURE Pretune cycle not successfully completed. Possible causes are: Failure in VTO or summing amplifier. Bad IF Detector/Test Set interconnect cable.
9	NO IF FOUND Possible causes of no IF are: IF counter failure. Defective sampler. Weak VTO. Bad cable in IF path.
10	PHASE LOCK FAILURE Pretune has been accomplished but phase lock not achieved. Refer to Service procedures.

- 11 PHASE LOCK LOST
Phase lock established then lost.
Refer to Service procedures.
- 12 VTO OVERRANGE
VTO swept beyond its normal range.
Refer to Service procedures.
- 13 SOURCE SWEEP SYNC ERROR
- 14 IF OVERLOAD
IF level is too high. Possible causes are:
 Source Power too high.
 Test Device Output level too high.
- In the normal ramp mode, the algorithm for autoranging the IF gain allows the gain to change 1 step at each point. If the response changes more than one IF gain step (about 15 dB) then the IF gain cannot follow the response and the message is issued to indicate a possible, but not definite, error. The error indication is displayed as an O symbol in the Enhancement Labels area of the CRT display.
- 15 ADC CAL FAILED
The automatic calibration sequence for the Analog-to-Digital Converter has failed.
Refer to Service procedures.
- 16 IF CAL FAILED
The IF calibration is out of limits.
Refer to Service procedures.
- 17 ADC NOT RESPONDING
Power up message.
Analog-to-Digital Converter not responding.
Refer to Service procedures.
- 18 AUTORANGE CAL FAILED
One or more of the IF gain steps out of limits.
Refer to Service procedures.
- 19 SWEEP TIME TOO FAST
Slow down the source Sweep Time.
- 20 UNABLE TO LOCK TO EXT 10 MHZ
REFERENCE

- 21 NOT IMPLEMENTED IN SOURCE
Requested function cannot be executed by source.
- 22 ERROR IN SAVING/STORING <INST.
STATE/CAL SET/MEMORY>
A write error has been detected while saving data into HP 8510 internal memory. If repeated attempts fail, service is required.
- 23 'NEW' CAL OR 'STORED' CAL REQUIRED
- 24 CURRENT PARAMETER NOT IN CAL SET
The recalled cal set does not include the currently selected parameter.
Correction is not turned on.
- 25 ADDITIONAL STANDARDS NEEDED
- 26 CORRECTION MAY BE INVALID.
Cal Set Inst. State changed.
Correction not turned off.
- 27 NO CALIBRATION CURRENTLY IN
PROGRESS
Attempted RESUME CAL with no cal in progress.
- 28 NO SPACE FOR NEW CAL
Must DELETE CAL SET.
- 29 MORE SLIDES NEEDED
- 30 EXCEEDED 7 STANDARDS PER CLASS

31	NO <MEMORY/CAL SET/INST STATE> FOUND
32	ERROR IN RECALLING <MEMORY/CAL SET> Possible HP 8510 memory malfunction. If repeated attempts fail, service is required.
33	DATA OVERFLOW
34	ERROR IN DELETING CAL Same as 32.
35	NO PRINTER CONNECTED
36	PRINT ABORTED
37	NO PLOTTER CONNECTED
38	PLOT ABORTED
39	NO TAPE IN DRIVE
40	TEST SET IS TOO HOT
41	ATTEMPTED ILLEGAL TEST SET OPERATION
42	READ ATTEMPTED WITHOUT SELECTING OUTPUT TYPE
43	WRITE ATTEMPTED WITHOUT SELECTING INPUT TYPE
44	NOT USED
45	BLOCK ERROR INPUT
46	BLOCK INPUT LENGTH ERROR
47	FILE NOT FOUND
48	TAPE INIT ABORTED
49	COMMAND OUT OF SEQUENCE
50	FILE <STORE/LOAD/DELETE/ UN-DELETE> ERROR

- 51 FILE <STORE/LOAD/DELETE/
UN-DELETE> ABORTED
- 52 LOAD ABORTED <data type> DATA
MAY BE BAD
- 53 NO ROOM ON TAPE
Current data type to be stored exceeds avail-
able remaining tape blocks.
- 54 UNABLE TO LOAD <stored data number of
points> POINTS
Attempting to load DATA: <data type> stored
with different number of points than current
selection.
- 55 <tape format/tape drive/parity/write protect/
checksum/unknown> ERROR
- 56 USING BACKUP DIRECTORY
Transfer important data files to new tape.
Primary tape directory error.
- 57 DIRECTORY NOT DISPLAYED
- 58 PARAMETERS NOT DISPLAYED
Display System or Operating parameters before
attempting page, plot, or print operations.
- 59 TURN <MEMORY/CORRECTION> OFF
BEFORE LOADING FILE
- 60 LOAD ERROR. <data type> DATA MAY BE
BAD
- 61 CAN ONLY LABEL USER PARAMETERS
- 62 CORRECTION AND DOMAIN RESET
- 63 ILLEGAL '101 KEY
Keyboard error.
- 64 ILLEGAL '102 KEY
Keyboard error.
- 65 REQUESTED DATA NOT AVAILABLE
- 66 INSUFFICIENT MEMORY

- 67 SYSTEM IS NOT IN REMOTE
 Controller issued LOCAL. Non-remote-only
 functions cannot be processed until controller
 issued REMOTE.
- 68 COMMAND NOT IMPLEMENTED
- 69 CAL ABORTED (MEMORY
 REALLOCATION)
- 70 TURN OFF CORRECTION AND/OR TIME
 DOMAIN
- 71 CORRECTION RESET.
 Correction turned off due to change in instru-
 ment state.
 See Cal Set Instrument State.
- 72 DOMAIN RESET
 Domain changed from time to frequency due
 to instrument state change. (Cal Set instrument
 state, or turning correction on.)
- 73 INCONSISTENT WITH CURRENT
 FORMAT
 Attempt to use function which does not work
 with current format.

USER DISPLAY GRAPHICS

Instructions and data are sent to the HP 8510 User Display area of CRT display memory by setting the Pass Thru address to 31 (see ADDRESS of PASS THRU), then writing to the HP 8510 System Bus address (see ADDRESS of SYSTEM BUS).

mnemonic CS

Turn off Measurement Display.

mnemonic DF

Plotter Default Conditions.

Plotting mode	Absolute (PA)
* Relative character direction	Horizontal (DR1,0)
* Line type	Solid line
* Relative character size	HP 8510 Character Set
* Scale	Off
* Standard character set	HP 8510 Character Set
* Label terminator	ETX (ASCII decimal equivalent 3)
* Character slant	0 degrees

P1 and P2 are not affected by device clear and the default command (DF).

* Cannot be changed by User.

mnemonic KP

Turn off User Display.

mnemonic LB

Label Instruction.

ASCII String Terminated with CONTROL C.

LB<string>t

Purpose: Draws the character string using the currently selected character set.

Parameters: <string> ASCII characters from HP 8510 character set (which may include control characters).

Terminator: t - label terminator defined by DF.
Default is ETX, decimal 3.

mnemonic PA

Plot Absolute Instruction

PA x_1, y_1 [$x_2, y_2 \dots x_n, y_n$]

or

PA;

Purpose: Plots to the X,Y coordinates in the order listed using the current pen up/down status. PA; sets absolute plotting.

Parameters: Pairs of integers representing plotter units if scaling not in effect, otherwise user units, integers or decimals.

$0 \leq x \leq 4095$,
 $0 \leq y \leq 4095$.

mnemonic PD

Pen Down Instruction

PD;

or

PD x_1, y_1 [$x_2, y_2, \dots, x_n, y_n$]

Purpose: Programmatically lowers the pen, then plots to the X,Y coordinates in the order listed. Parameters may be included as in PA or PR.

Parameters: Pairs of integers representing plotter units if scaling not in effect, otherwise user units, integers or decimals.

mnemonic PG

Clear (erase) User Display.

mnemonic PR

Plot Relative Instruction

PR x_1, y_1 [$x_2, y_2, \dots, x_n, y_n$]

or

PR;

Purpose: Plots, in order, to the points indicated by the X,Y increments, relative to the previous pen position. PR; sets relative plotting for PU or PD with parameters.

Parameters: Pairs of integers representing plotter units if scaling is not in effect; otherwise user units, integers or decimals.

mnemonic PU

Pen Up Instruction

PU;

or

PU x_1, y_1 [$x_2, y_2 \dots x_n, y_n$]

Purpose: Programmatically raises the pen.
Parameters may be included as in PD.

mnemonic RP

Turn on user display.

mnemonic RS

Turn on measurement display.

CIRCUIT MODELING PROGRAM MNEMONICS**STATEMENTS**

mnemonic PORT
(50 ohm termination)

mnemonic R
Resistance.

mnemonic L
Inductance

mnemonic C
Capacitance

mnemonic TL
Transmission Line.

node1 node2 Z len Er series corfreq shunt

mnemonic **FREQ**

Frequency range.

fstart fstop numsteps

mnemonic **FREQ LOWPASS**

Set Time Domain Lowpass frequency range.

fstop numsteps

mnemonic **OUTPUT**

Send S-parameter data to HP 8510.

mnemonic **PLOT**

Plot data on Controller CRT.

NOTES

nnn represents a line number.

OUTPUT and PLOT can also be used as commands after the program has been RUN once.

The key [CLR I/O] interrupts an executing command and returns the program to user control.

COMMANDS

mnemonic **CAT**

mnemonic **DEL**

mnemonic **GET**

filename

mnemonic **HELP**

[statement or command]

mnemonic **LIST**

mnemonic **RUN**

mnemonic **SAVE**

mnemonic **PURGE**

filename

mnemonic **OUTPUT**

Snn

mnemonic **PLOT**

Snn [, Snn] ...

mnemonic END

mnemonic BYE

mnemonic EXIT

mnemonic QUIT





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