## Errata

**Title & Document Type: HP 8719A, 8720B Microwave Network Analyzer Operating Manual**

**Manual Part Number: 08720-90107**

**Revision Date:** 1990-09-01

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### HP References in this Manual

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

### About this Manual

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Agilent Technologies

# HP 8719A
# HP 8720B
# MICROWAVE
# NETWORK ANALYZER
# OPERATING MANUAL

## SERIAL NUMBERS

This manual applies directly to network analyzers with these serial numbers:

8719A: 3029A
8720B: 3029A

For additional information, see "Analyzers covered by this manual" in General Information.



MANUAL PART NO. 08720-90107
Microfiche Part Number (set) 08720-90106

Printed: SEPTEMBER 1990

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 system product is warranted against defects in materials and workmanship for a period corresponding to the individual warranty periods of its component products. Computer and computer peripherals are warranted for a period of 90 days. Instruments are warranted for a period of one year. During the warranty period, Hewlett-Packard Company will, at its option, either repair or replace products which prove to be defective.

Warranty service for products installed by HP and certain other products designated by HP will be performed at Buyer's facility at no charge within HP service travel areas. Outside HP service travel areas, warranty service will be performed at Buyer's facility only upon HP's prior agreement and Buyer shall pay HP's round trip travel expenses. In all other areas, products must be returned to a service facility designated by HP.

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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.

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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.*

BP24.1

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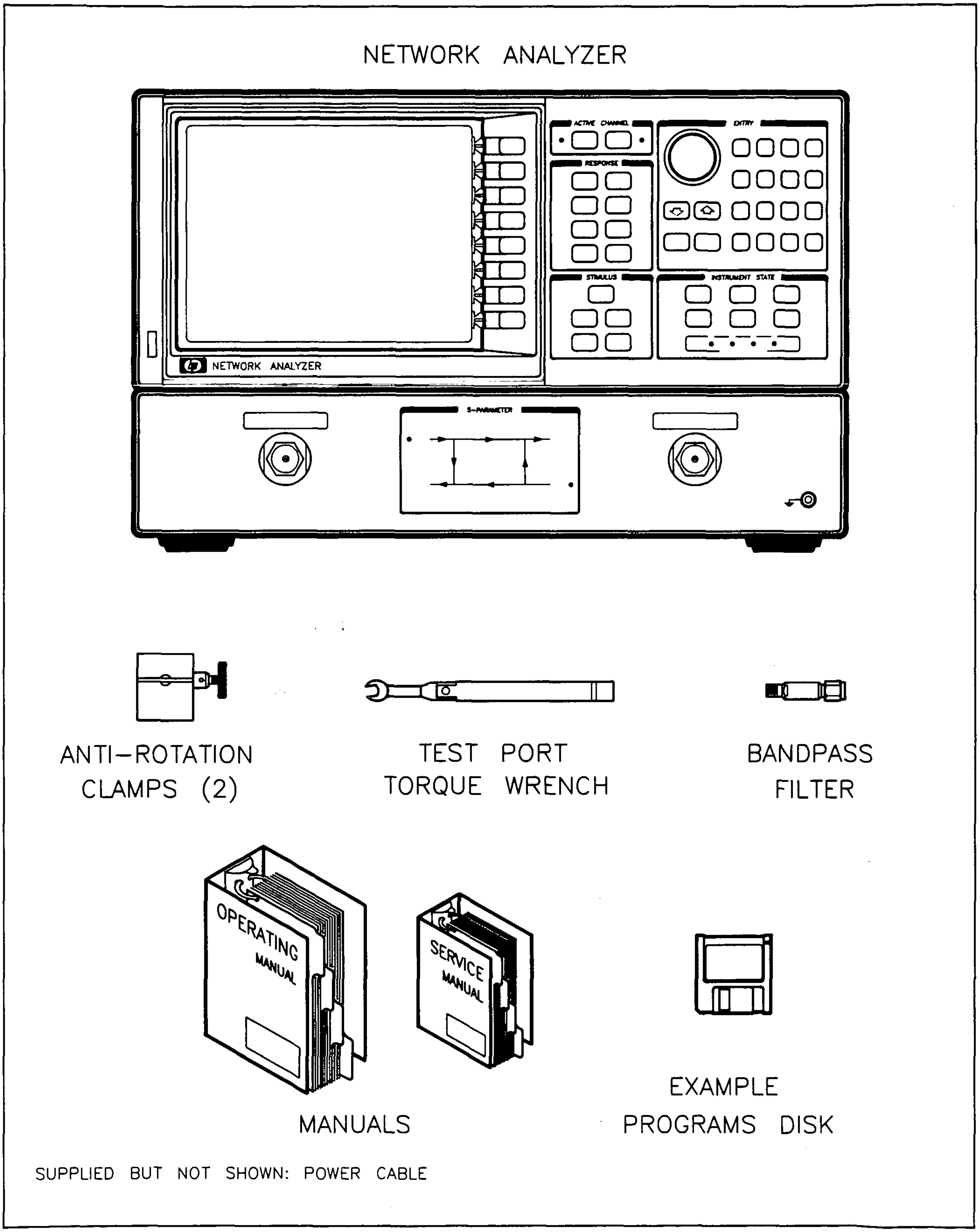


*Figure 1. Network Analyzer and Items Supplied*

# General Information

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## ITEMS SUPPLIED WITH THE ANALYZER

Figure 1 shows the accessories supplied with the instrument.

## BRIEF DESCRIPTION OF THE ANALYZER

The HP 8719A and 8720B are high performance microwave network analyzers for measurements of reflection and transmission parameters. The HP 8719A covers the frequency range of 130 MHz to 13.5 GHz; the HP 8720B goes to 20 GHz. Frequency resolution is 100 kHz (standard) or 1 Hz with option 001. Each integrates a synthesized source, a switching S-parameter test set, and a dual channel receiver to measure and display magnitude, phase, and group delay of transmitted and reflected power. Option 010 provides the capability of transforming measured data from the frequency domain to the time domain.

Digital signal processing and microprocessor controls combine to provide easy operation and measurement improvement. Measurement functions are selected with front panel keys and softkey menus. Two independent display channels and a large screen color CRT display the measurement results of one or both channels, in logarithmic, linear, or Smith chart display formats.

Trace math, data averaging, trace smoothing, electrical delay, and accuracy enhancement provide performance improvement and flexibility. Accuracy enhancement reduces the effects of repeatable measurement variations in the test system.

Displayed measurement results can be printed or plotted directly to a compatible peripheral without the use of an external computer. Instrument states can be saved in internal memory for at least three days without line power to the instrument. In addition, each analyzer can control a compatible disk drive for external storage capability. Built-in service diagnostics are available to simplify troubleshooting procedures.

## Hewlett-Packard Interface BUS (HP-IB)

The analyzer is factory-equipped with a remote programming interface using the Hewlett-Packard Interface Bus (HP-IB). HP-IB is Hewlett-Packard's hardware, software, documentation, and support for IEEE-488.1 and IEC-625, worldwide standards for interfacing instruments. This provides a remote operator with the same control of the instrument available to the local operator, except for control of the line power switch. Remote control is maintained by a controlling computer that sends commands or instructions to and receives data from the analyzer using the HP-IB. A complete general description of the HP-IB is available in *Condensed Description of the Hewlett-Packard Interface Bus* (HP part number 59401-90030), and in *Tutorial Description of the Hewlett-Packard Interface Bus* (HP literature number 5952-0156).

The analyzer itself can use the HP-IB to output measurement results directly to a compatible printer or plotter, or to store instrument states to a compatible disk drive, without the use of an external computer.

# DESCRIPTION OF THE MANUAL SET

This *Operating Manual* is a complete guide to operating the analyzer alone or in a system. It is part of a two manual set; the *Service Manual* completes the set.

To explore the manuals further, inspect their title pages, tabs, and the "Contents" and "Index" sections.

## Analyzers Covered by This Manual

The analyzer you received with this manual is covered by this manual without change. Any other analyzer with one of the serial number prefixes listed on the title page is also described by this manual. (The serial number plate, shown in figure 2, is attached to the rear panel of the analyzer.)

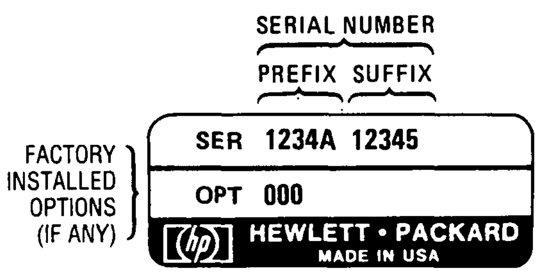



*Figure 2. Typical Serial Number Plate*

Other instruments differ from the instruments covered directly by this manual. Those differences are documented in the "Instrument History" section of this manual. See that section if the serial number prefix of your instrument is not listed on the title page.

## Microfiche Copies of the Manual

Use the microfiche part number on the title page to order a package of 10 x 15 centimeter (4 x 6 inch) microfilm transparencies of this manual and the *Service Manual*.

## OPTIONS AVAILABLE

### Option 001, 1 Hz Frequency Resolution

Devices that have narrow frequency spans (such as crystal or notch filters) require better frequency resolution than the 100 kHz offered by the standard instrument. Option 001 provides 1 Hz frequency resolution for finer control of start, stop, and marker frequencies.

### Option 003, Extended Dynamic Range

Option 003 extends the dynamic range with forward transmission measurements (S21) to about 100 dB. This configuration differs from the standard instrument in that the main arm of the port 2 coupler is connected (through a 6 dB attenuator) to the sampler. This option can be installed after shipment.

### Option 010, Time Domain

Option 010 can display the time domain response of a network by computing the inverse Fourier transform of the frequency domain response. This makes it possible to see the response of a test device as a function of time or distance. Displaying the reflection coefficient of a network versus time determines the magnitude and location of each discontinuity. Displaying the transmission coefficient determines the characteristics of individual transmission paths. Time domain operation retains the calibration that is active in the frequency domain. The time domain capability is useful for designing and characterizing such devices as SAW filters, SAW delay lines, and RF cables. This option can be installed after shipment.

### Option 830, Add Cal Kit and Cables

This option adds the HP 85052D 3.5 mm economy calibration kit and the HP 85131E super-flexible cable. These are described under *Equipment Required.*

### Option 802, Add Disk Drive

This adds the HP 9122 dual 3.5" disk drive and the HP 10833A 1m (3.3 ft) HP-IB cable. The disk drive is covered under one-year return-to-factory warranty agreements.

### Option 913, Rack Mount With Handles

Option 913 is a rack mount kit containing a pair of flanges and the necessary hardware to mount the instrument, with handles attached, in an equipment rack with 482.6 mm (19 inches) spacing.

### Option 910, Extra Manuals

The standard instrument is supplied with an *Operating Manual*, and a *Service Manual*. Option 910 provides an additional one of both of these manuals. To order extra manuals after initial shipment, order by part number, listed on the title page and rear cover of each manual.

### Service and Support Products

A variety of on-site and return-to-HP service and support products are available. These products cover repair, calibration, and verification. Consult your local HP customer engineer for details.

**System On-Site Service.** The analyzer includes a one year on-site service warranty (where available). In the event of failure, an HP customer engineer will provide on-site service for the analyzer, calibration and verification kits, and super flexible cables. Note that system installation (a straightforward operation) is not included.

**Three Year Customer Return Repair Coverage (W30)** adds to product warranty to provide the customer with a total of three years of customer return repair service from the time of hardware delivery.

**Three Year On-Site Repair Coverage (W31)** adds to product warranty to provide the customer with a total of three years of next day on-site coverage from the time of hardware delivery.

**Three Year Customer Return Calibration Coverage (W32)** begins the day of hardware delivery. Includes scheduled calibration at HP's recommended calibration cycle, as well as calibration after a required repair performed by HP.

**Self-Support Tool Kit.** A dedicated tool kit is available for troubleshooting the analyzer. It consists of extender boards and cables, adapters, and fuses. The parts are listed in the "Replaceable Parts" section of the *Service Manual*.

## EQUIPMENT REQUIRED

Compatible calibration kits and cables are required for full error-corrected system performance in accordance with specifications listed in the "Specifications" section. Additionally, a verification kit is required to verify performance.

The following calibration kits contain precision standards (and required adapters) of the indicated connector type. The standards (known devices) facilitate measurement calibration, also called vector error correction. Refer to the data sheet and ordering guide for additional information. Part numbers for the standards are in their manuals.

### Calibration Kits

**HP 85052B 3.5 mm Calibration Kit** contains precision calibration standards used to calibrate the network analyzer for making error-corrected measurements of devices with 3.5 mm connectors, up to 20 GHz. The standards included are:

open circuits (male and female)
short circuits (male and female)
lowband fixed loads (male and female)
sliding loads (male and female)

Also contained in the kit are precision adapters for converting the test ports to a 3.5 mm interface of either sex, as well as a 3.5 mm connector gage kit and other tools for maintaining and verifying the integrity of the test port 3.5 mm connector interface.

**HP 85052D 3.5 mm Economy Calibration Kit** provides the most convenient and economical calibration for measurement of devices with a 3.5 mm connector interface. The kit contains the following standards:

open circuits (male and female)
short circuits (male and female)
precision broadband fixed loads (male and female)

Also included are precision adapters, a torque wrench, and an open-end wrench. (No connector gages are included in this kit.)

**HP 85050B 7 mm Calibration Kit** provides the standards used for calibration up to 18 GHz for error-corrected measurement of devices with 7 mm connectors. The kit contains the following standards:

open circuit
short circuit
lowband fixed load
precision broadband fixed load
sliding load

Also included are a connector gage kit and other tools for maintaining and verifying the integrity of the test port 7 mm connector interface.

**HP 85050D 7 mm Economy Calibration Kit** provides convenient and economical calibration for measurement of devices with 7 mm connectors up to 18 GHz. The following standards are included:

open circuit
short circuit
precision broadband fixed load

A torque wrench is also provided. (No connector gages are included in this kit.)

**HP 85054B Type-N Calibration Kit** contains a set of precision calibration standards used to calibrate for error-corrected measurement of devices with type-N connectors. The standards included are:

open circuits (male and female)
short circuits (male and female)
fixed loads (male and female)
sliding loads (male and female)

Also contained in the kit are precision 7 mm to type-N (male and female) adapters, and tools for maintaining and verifying the integrity of the type-N interface.

**HP 85054D Type-N Economy Calibration Kit** provides economical and convenient calibration for measurement of devices with type-N connectors. It contains:

open circuits (male and female)
short circuits (male and female)
precision broadband fixed loads (male and female)

Also included are precision adapters, a torque wrench, and an open-end wrench.

## Verification Kits

Accuracy-enhanced performance of the system can be verified by measuring known devices other than the standards used in calibration, and comparing the results with recorded data. The following verification kits (with a serial number prefix of 2815A or higher) provide a data disk for specific use with the HP 8719A, HP 8720A and HP 8720B. Kits ordered prior to this serial prefix can be upgraded to include the data disk by recertifying the kit through a local HP Sales and Service office (be sure to request HP 8719A or HP 8720B data). The data disk contains the factory-measured S-parameter data for the devices in the kit, and the uncertainty limits used in the system verification procedure. The data is unique to each kit. (A data tape is also included in the kits, but does not apply to the HP 8720A.)

For the complete procedure to verify the performance of the network analyzer, refer to the *Verification* section of the *Service Manual*.

**HP 85053B 3.5 mm Verification Kit** consists of a set of 3.5 mm measured standards, a data disk, and printouts of device data. The two device data printouts are for calibrations using a broadband fixed load and using a sliding load. The following standards are included:

- 7.5 cm 50Ω airline
- 25Ω to 50Ω stepped impedance airline
- 20 dB attenuator
- 40 dB attenuator

**HP 85051B 7 mm Verification Kit** consists of a set of 7 mm measured standards, a data disk, and printouts of device data. The standards included are:

- 10 cm 50Ω beadless airline
- 25Ω to 50Ω stepped impedance airline
- 20 dB attenuator
- 50 dB attenuator

**HP 85055A Type-N Verification Kit** consists of a set of type-N measured standards, a data disk, and printouts of device data. The standards included are:

- 50Ω airline
- 25Ω to 50Ω stepped impedance airline
- 20 dB attenuator
- 50 dB attenuator

## Test Port Return Cables

These cables are designed to connect the test ports (3.5 mm) to the device under test. Cables are available as single long cables for measurements where one port of the device is connected directly to the test port, or as cable sets that contain two cables, one for each port. Semi-flexible cables offer the best performance and are suitable for applications where the connectors of the device are in-line. Super-flexible cables are more rugged and have a tighter bending radius, and are appropriate for manufacturing environments. Semi-flexible cables are warranted for 90 days, and super-flexible cables for one year.

**For Devices with 3.5 mm Connectors,** use the HP 85131 series test port return cables. These 3.5 mm cables are specified from DC to 26.5 GHz.

| HP Model | Description | Length | Connectors |
|---|---|---|---|
| HP 85131C | Semi-flexible single cable | 81 cm (32 in) | NMD-3.5 mm to 3.5 mm (f) |
| HP 85131D | Semi-flexible cable set | 53 cm (21 in) | NMD-3.5 mm to 3.5 mm (m and f) |
| HP 85131E | Super-flexible single cable | 94 cm (38 in) | NMD-3.5 mm to 3.5 mm (f) |
| HP 85131F | Super-flexible cable set | 58 cm (23 in) | NMD-3.5 mm to 3.5 mm (m and f) |

**For Devices with 7 mm Connectors,** use the HP 85132 series test port return cables. These cables are designed to connect the analyzer's 3.5 mm test ports to a 7 mm device under test. These cables are specified from DC to 18 GHz. For use with the HP 85132C/E single cables, the HP 85130B 7 mm special adapter set is also required.

| HP Model | Description | Length | Connectors |
|---|---|---|---|
| HP 85132C | Semi-flexible single cable | 81 cm (32 in) | NMD-3.5 mm to 7 mm |
| HP 85132D | Semi-flexible cable set | 53 cm (21 in) | NMD-3.5 mm to 7 mm |
| HP 85132E | Super-flexible single cable | 94 cm (38 in) | NMD-3.5 mm to 7 mm |
| HP 85132F | Super-flexible cable set | 58 cm (23 in) | NMD-3.5 mm to 7 mm |

**For Devices with Type-N Connectors,** the HP 85132 series 7 mm cables are recommended. Adapters from 7 mm to type-N (male and female) are included in the HP 85054B and HP 85054D type-N calibration kits. If the type-N device is to be connected directly to the test ports, use the HP 85130C type-N special adapter set and the HP 85132C/E cables.

## EQUIPMENT AVAILABLE

### Adapter Sets

The following compatible adapter sets are recommended for applications where the device under test is connected directly to the test ports.

**HP 85130D 3.5 mm Special Adapter Set** consists of 3.5 mm to 3.5 mm (male and female) adapters, and is recommended for applications which require many direct connections to the test port. The adapters protect the test ports from damage and wear due to heavy use.

**HP 85130B 7 mm Special Adapter Set** converts the test ports to 7 mm.

**HP 85130C Type-N Special Adapter Set** converts the test ports to type-N (male and female).

### System Rack

The recommended system rack for the analyzer is the HP 85043B. This metal cabinet measures 124 cm (49 in) high, 60 cm (24 in) wide, and 80 cm (32 in) deep. The rack is equipped with an extendable work surface, a drawer for calibration kits and other hardware, a bookshelf for system manuals, and a locking rear door for secured access. The total depth of the rack with the work surface installed is 115 cm (45 in). Lightweight steel rails support the instruments along their depth. Heavy-duty casters make the cabinet easily movable even with the instruments in place. Screw-down lock feet permit leveling and semi-permanent installation: the cabinet is extremely stable when the lock feet are down. Power is supplied to the cabinet through a heavy-duty grounded primary power cable, and to the individual instruments through special power cables included with the cabinet. Thermal design is such that no rack fan is needed.

## Plotters and Printers

The analyzer is capable of plotting or printing displayed measurement results directly to a compatible peripheral without the use of an external computer. Plotters tend to be more accurate, but slower and more expensive than printers. These are compatible:

- HP 7470A Option 002 Two-Pen Graphics Plotter plots on ISO A4 or 8.5 x 11 inch charts.
- HP 7440A Option 002 ColorPro Eight-Pen Color Graphics Plotter plots on ISO A4 or 8.5 x 11 inch charts.
- HP 7475A Option 002 Six-Pen Graphics Plotter plots on ISO A4/A3 or 8.5 x 11 inch or 11 x 17 inch charts.

(Option 002 for the plotters listed above is HP-IB interface capability.)

- HP 7550A High-Speed Eight-Pen Graphics Plotter plots on ISO A4/A3 or 8.5 x 11 inch or 11 x 17 inch plots.
- HP 7090A Measurement Plotting System is a high-performance six-pen programmable digital plotter. It plots on ISO A4/A3 or 8.5 x 11 inch or 11 x 17 inch paper or overhead transparency film.

Printers tend to be faster and less expensive, but also less accurate, than plotters. These are compatible:

- HP 2225A ThinkJet printer
- HP 2227B QuietJet printer
- P 3630A PaintJet color graphics printer
- HP 2673A thermal graphics printer (obsolete but compatible)
- HP 82906A option 002 graphics printer (obsolete but compatible)
- HP 9876A thermal graphics printer (obsolete but compatible)

## Disk Drives

The analyzer has the capability of storing instrument states directly to disk drive without the use of a computer. Any disk drive that uses CS80 protocol and HP 200/300 series format (LIF, Logical Interchange Format) is compatible. The recommended disk drives are:

- HP 9122C/D/S dual 3.5 inch disk drive
- HP 9153C option 010/011 10 Mbyte Winchester 3.5 inch hard disk drive
- HP 9153C option 020/021 20 Mbyte Winchester 3.5 inch hard disk drive
- HP 9153C option 040/041 40 Mbyte Winchester 3.5 inch hard disk drive

## Computer

The system can be automated with the addition of an HP 200/300 series computer. (The system verification procedure and automated adjustments do not require an external computer.) For more information about compatible computers, consult your Hewlett-Packard customer engineer.

## System Software

The software below requires an HP 200/300 series computer with BASIC 3.0 or higher.

**HP 85014C Active Device Measurements Pac** can make complete automated S-parameter measurements of active devices in-fixture. Use it with the HP 85041A transistor test fixture to measure transistors in 0.070 and 0.100 packages. The software includes models for this fixture and can de-embed fixture responses from the measurement.

**HP 85162A Measurement Automation Software** complements the analyzer by providing all calibration, measurement, and data output capabilities with a minimum of operator interaction.

**HP 85165A Resonator Measurement Software** performs complete characterization of crystals, SAWs, and other resonant devices. The software guides the user through the measurement process and calculates key parameters of the device under test. The analyzer must have option 001 (1 Hz resolution).

### Anti-Static Mat

Use of an anti-static mat (such as HP part number 85043-80013) is highly recommended to prevent electro-static damage to the analyzer or DUTs.

## REQUIRED TEST EQUIPMENT

The "Service and Equipment Overview" section of the *Service Manual* lists equipment required to test, adjust, and service the system.

## SAFETY CONSIDERATIONS

Do not remove the instrument covers. The analyzer should be serviced only by qualified personnel who are aware of the hazards involved. Safety precautions are detailed in the *Service Manual*.

***This section consists of three parts:***

- System specifications
- Option 003 system specifications
- General characteristics

*Table 1. System Specifications (1 of 5)*

**Specifications** describe the instrument's warranted performance over the temperature range 0° to 55°C (except where noted).

Switch repeatability and overall measurement uncertainty are verified by executing the System Verification procedure, which uses the standards comparison method[1]. Verification is viable for 3.5 mm, 7 mm, and type-N connector types.

Source characteristics can be verified after measurement calibration by executing the Performance Tests[1].

Measurement port characteristics are factory-tested only. They are not field verifiable.

**Supplemental Characteristics** are intended to provide information useful in applying the instrument, by giving typical but non-warranted performance parameters. These are denoted as "typical," "nominal," or "approximate."

**DYNAMIC RANGE** (for transmission measurements)[2]

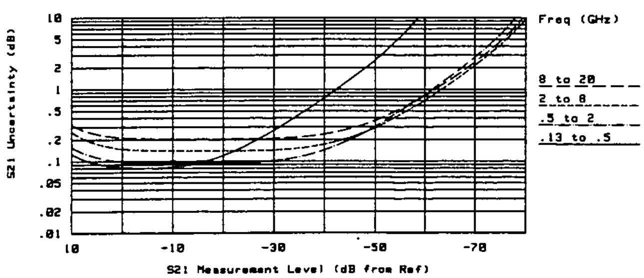
| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 20 GHz**[3] |
| Dynamic Range | 70 dB | 80 dB | 85 dB | 85 dB |

**DEVICES WITH 3.5 MM CONNECTORS**

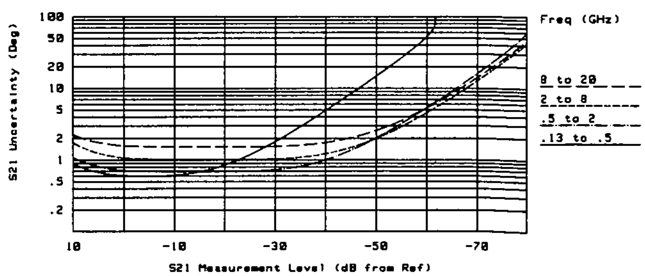
**Measurement Uncertainty**

The following graphs show total worst case uncertainty for the network analyzer after accuracy enhancement using a full 2-port measurement calibration (including isolation) with the HP 85052D 3.5 mm calibration kit, HP 85131D 3.5 mm cable set, and an IF bandwidth of 10 Hz. This includes the residual systematic errors, as well as the system dynamic accuracy, 3.5 mm connector repeatability, noise, and switch repeatability[4]. Specific points on the graphs are verified by measuring the devices in the HP 85053B verification kit.

**Transmission Measurements**[5]




*Magnitude*

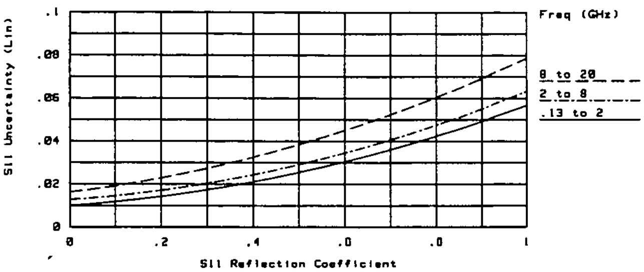



*Phase*

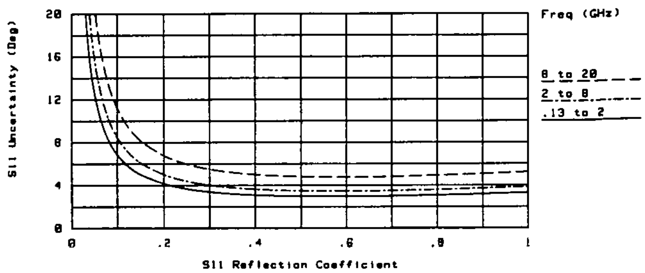
1. Refer to *System Verification and Source Tests* in the *Service Manual*.
2. Limited by maximum output power and system noise floor. Specified for an IF bandwidth of 100 Hz, using a full 2-port calibration (including an isolation calibration performed with an averaging factor of 64).
3. HP 8719A: 8 to 13.5 GHz.
4. Cable stability and system drift are not included.
5. The graphs for transmission measurements assume a well-matched device ($S_{11} = S_{22} = 0$).

**DEVICES WITH 3.5 MM CONNECTORS (cont'd)**
**Measurement Uncertainty**

**Reflection Measurements**[1]




Magnitude




Phase

**Measurement Port Characteristics**[2]

The following specifications show the residual system performance (including switch repeatability) after accuracy enhancement using a full 2-port measurement calibration (including isolation) with an IF bandwidth of 10 Hz and the specified calibration kit. Environmental temperature is 23° ± 3°C.

**Calibration Kit: HP 85052B**
**(male and female lowband and sliding loads)**

| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 20 GHz**[3] |
| Directivity | 40 dB | 40 dB | 40 dB | 40 dB |
| Source Match | 30 dB | 30 dB | 30 dB | 30 dB |
| Load Match | 35 dB | 35 dB | 35 dB | 30 dB |
| Reflection Tracking | ±0.10 dB | ±0.10 dB | ±0.10 dB | ±0.20 dB |
| Transmission Tracking | ±0.10 dB | ±0.10 dB | ±0.12 dB | ±0.15 dB |

**Calibration Kit: HP 85052D**
**(male and female broadband precision fixed load)**

| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 20 GHz**[3] |
| Directivity | 40 dB | 40 dB | 38 dB | 36 dB |
| Source Match | 30 dB | 30 dB | 30 dB | 29 dB |
| Load Match | 35 dB | 35 dB | 30 dB | 30 dB |
| Reflection Tracking | ±0.10 dB | ±0.10 dB | ±0.10 dB | ±0.20 dB |
| Transmission Tracking | ±0.10 dB | ±0.10 dB | ±0.12 dB | ±0.15 dB |

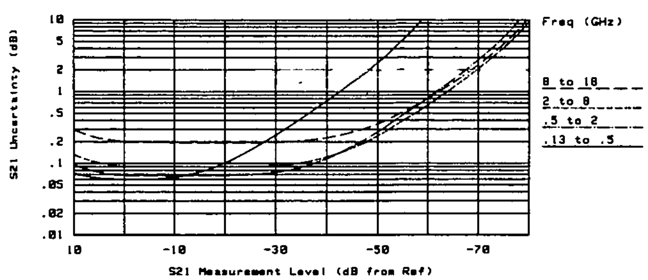
1. The graphs shown for reflection measurement uncertainty apply to a one-port device.
2. Crosstalk, after an isolation calibration, is no higher than the system noise floor and can be ignored.
3. HP 8719A: 8 to 13.5 GHz.

## DEVICES WITH 7 MM CONNECTORS

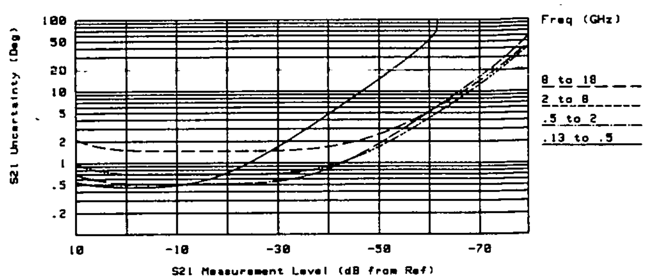
### Measurement Uncertainty

The following graphs show total worst case measurement uncertainty for the network analyzer after accuracy enhancement using a full 2-port measurement calibration (including isolation) with the HP 85050D 7 mm calibration kit, HP 85132D cable set, and an IF bandwidth of 10 Hz. This includes the residual systematic errors, as well as the system dynamic accuracy, 7 mm connector repeatability, noise, and switch repeatability[1]. The HP 85130B special 3.5 mm to 7 mm adapter set is used to adapt the 3.5 mm test ports to 7 mm. Specific points on the graphs are verified by measuring the devices in the HP 85051B verification kit.

### Transmission Measurements[3]

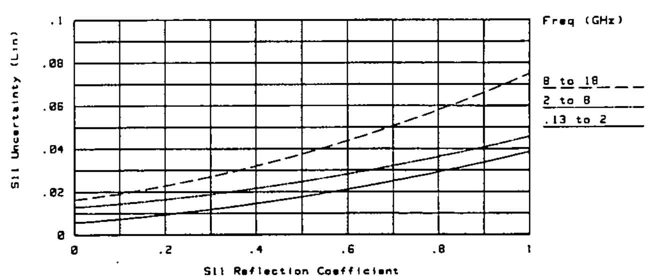



*Magnitude*

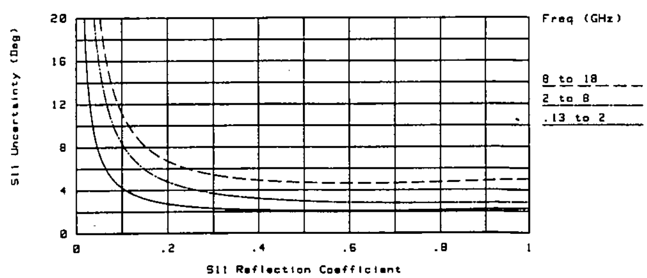



*Phase*

### Reflection Measurements[4]




*Magnitude*




*Phase*

1. Cable stability and system drift are not included.
2. HP 8719A: 8 to 13.5 GHz.
3. The graphs for transmission measurements assume a well-matched device ($S_{11} = S_{22} = 0$).
4. The graphs shown for reflection measurement uncertainty apply to a one-port device.

*Table 1. System Specifications (4 of 5)*

**DEVICES WITH 7 MM CONNECTORS (cont'd)**
**Measurement Port Characteristics**[1]

The following specifications show the residual system performance (including switch repeatability) after accuracy enhancement using a full 2-port measurement calibration (including isolation) with an IF bandwidth of 10 Hz and the specified calibration kit. Environmental temperature is 23° ± 3°C.

**Calibration Kit: HP 85050B**
**(lowband and sliding loads)**

| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 18 GHz**[2] |
| Directivity | 50 dB | 50 dB | 45 dB | 45 dB |
| Source Match | 35 dB | 35 dB | 35 dB | 30 dB |
| Load Match | 40 dB | 40 dB | 35 dB | 30 dB |
| Reflection Tracking | ±0.10 dB | ±0.10 dB | ±0.10 dB | ±0.20 dB |
| Transmission Tracking | ±0.05 dB | ±0.05 dB | ±0.10 dB | ±0.15 dB |

**Calibration Kit: HP 85050D**
**(broadband precision fixed load)**

| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 18 GHz**[2] |
| Directivity | 45 dB | 45 dB | 38 dB | 36 dB |
| Source Match | 35 dB | 35 dB | 35 dB | 30 dB |
| Load Match | 40 dB | 40 dB | 35 dB | 30 dB |
| Reflection Tracking | ±0.10 dB | ±0.10 dB | ±0.10 dB | ±0.20 dB |
| Transmission Tracking | ±0.05 dB | ±0.05 dB | ±0.10 dB | ±0.15 dB |

1. Crosstalk, after an isolation calibration, is no higher than the system noise floor and can be ignored.
2. HP 8719A: 8 to 13.5 GHz.

## DEVICES WITH TYPE-N CONNECTORS

### Measurement Port Characteristics

The following table shows typical residual system performance (including switch repeatability) after accuracy enhancement using a full 2-port measurement calibration (including isolation) with the HP 85054B type-N calibration kit, and an IF bandwidth of 10 Hz. Environmental temperature is 23° ± 3°C.

**Calibration Kit: HP 85054B**
**(male and female lowband and sliding loads)**

| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 18 GHz**[1] |
| Directivity | 45 dB | 45 dB | 42 dB | 40 dB |
| Source Match | 35 dB | 35 dB | 35 dB | 30 dB |
| Load Match | 40 dB | 40 dB | 35 dB | 30 dB |
| Reflection Tracking | ±0.10 dB | ±0.10 dB | ±0.10 dB | ±0.20 dB |
| Transmission Tracking | ±0.05 dB | ±0.05 dB | ±0.10 dB | ±0.15 dB |

**Calibration Kit: HP 85054D**
**(male and female broadband precision fixed load)**

| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 18 GHz**[1] |
| Directivity | 40 dB | 40 dB | 36 dB | 34 dB |
| Source Match | 32 dB | 32 dB | 30 dB | 28 dB |
| Load Match | 40 dB | 38 dB | 34 dB | 32 dB |
| Reflection Tracking | ±0.10 dB | ±0.10 dB | ±0.10 dB | ±0.20 dB |
| Transmission Tracking | ±0.05 dB | ±0.05 dB | ±0.10 dB | ±0.15 dB |

## UNCORRECTED PERFORMANCE

The following table shows typical performance without accuracy enhancement.

| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 20 GHz**[1] |
| Directivity | 32 dB | 32 dB | 26 dB | 18 dB |
| Source Match | 20 dB | 18 dB | 14 dB | 10 dB |
| Load Match (Fwd) | 26 dB | 24 dB | 15 dB | 12 dB |
| Load Match (Rev) | 30 dB | 24 dB | 15 dB | 12 dB |
| Reflection Tracking[2] | ±2 dB | ±2 dB | ±2 dB | ±3 dB |
| Transmission Tracking[3] | ±1 dB | ±1 dB | ±1 dB | ±1 dB |
| Crosstalk | 70 dB | 75 dB | 73 dB | 73 dB |

## SOURCE CHARACTERISTICS

### Frequency Characteristics

**Range:** 130 MHz to 20.0 GHz[1]
**Resolution:** 100 kHz (1 Hz with option 001)
**Stability:** ±7.5 ppm @ 0° to 55°C (typical)
±3 ppm/year (typical)
**Accuracy:** 10 ppm @ 23° ± 3°C

### Output Characteristics: (at test ports, 23° ± 3°C)

**Power Range:** −10 to −65 dBm in 5 dB steps
**Power Level:** −10 dBm ± 3 dB
**Harmonics:** <−15 dBc @ −10 dBm (typical)

1. HP 8719A: to 13.5 GHz.
2 Crosstalk, after an isolation calibration, is no higher than the system noise floor and can be ignored.
3. Excludes −1/+3 dB slope, typical, in magnitude response from 2.0 to 20 GHz and rolloff below 2 GHz, which is typically −4 dB at 1 GHz, −9 dB at 500 MHz, and −20 dB at 130 MHz.

*Table 2. Option 003 System Specifications (1 of 6)*

**DYNAMIC RANGE** (for transmission measurements)[1]

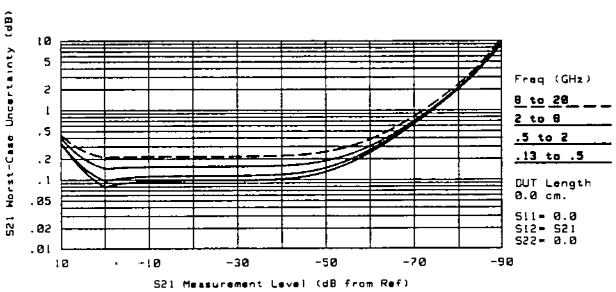
| | Frequency Range | | | |
|---|---|---|---|---|
| **Dynamic Range** | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 20 GHz**[2] |
| forward transmission | 99 dB | 98 dB | 97 dB | 95 dB |
| reverse transmission | 30 dB[3] | 55 dB | 65 dB | 65 dB |

## DEVICES WITH 3.5 MM CONNECTORS

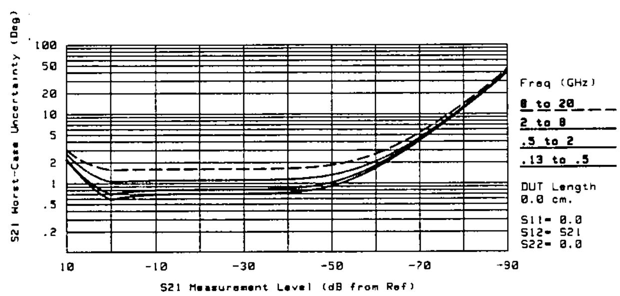
### Measurement Uncertainty

The following graphs show total worst case uncertainty for the network analyzer after accuracy enhancement using a full 2-port measurement calibration (including isolation) with the HP 85052D 3.5 mm calibration kit, HP 85131D 3.5 mm cable set, and an IF bandwidth of 10 Hz. This includes the residual systematic errors, as well as the system dynamic accuracy, 3.5 mm connector repeatability, noise, and switch repeatability[4]. Specific points on the graphs are verified by measuring the devices in the HP 85053B verification kit.

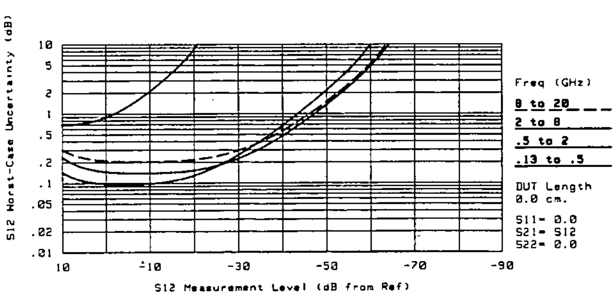
### Transmission Measurements[5]



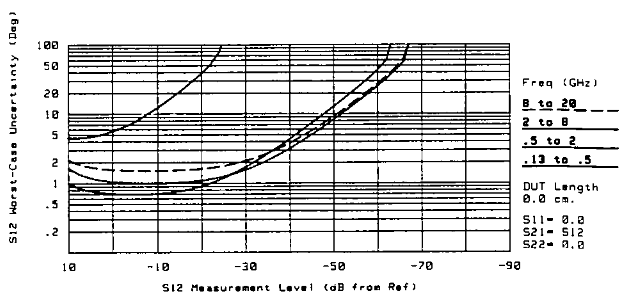

*Magnitude*




*Phase*




*Magnitude*




*Phase*

1 Limited by maximum output power and system noise floor. Specified for an IF bandwidth of 100 Hz, using a full 2-port calibration (including an isolation calibration performed with an averaging factor of 64).

2. HP 8719A: 8 to 13.5 GHz.

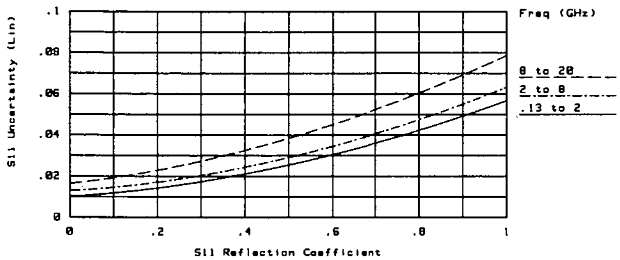
3. Typical.

4. Cable stability and system drift are not included.

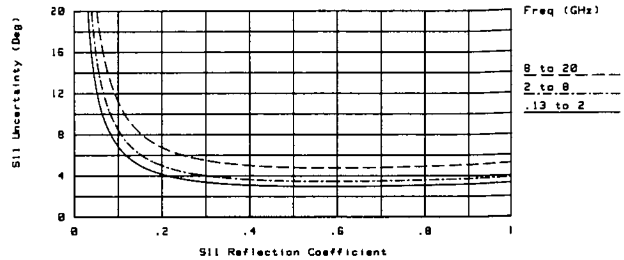
5. The graphs for transmission measurements assume a well-matched device ($S_{11}=S_{22}=0$).

**DEVICES WITH 3.5 MM CONNECTORS (cont'd)**
**Measurement Uncertainty**

**Reflection Measurements**[1]




*Magnitude*




*Phase*

**Measurement Port Characteristics**

The following specifications show the residual system performance (including switch repeatability) after accuracy enhancement using a full 2-port measurement calibration (including isolation) with an IF bandwidth of 10 Hz and the specified calibration kit. Environmental temperature is 23° ± 3°C.

**Calibration Kit: HP 85052B**
**(male and female lowband and sliding loads)**

| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 20 GHz**[2] |
| Directivity | 40 dB | 40 dB | 40 dB | 40 dB |
| Source Match | 30 dB | 30 dB | 30 dB | 30 dB |
| Load Match | 35 dB | 35 dB | 35 dB | 30 dB |
| Reflection Tracking | ±0.10 dB | ±0.10 dB | ±0.10 dB | ±0.20 dB |
| Transmission Tracking (Fwd) | ±0.10 dB | ±0.10 dB | ±0.12 dB | ±0.15 dB |
| Transmission Tracking (Rev) | ±0.25 dB | ±0.15 dB | ±0.12 dB | ±0.15 dB |

**Calibration Kit: HP 85052D**
**(male and female broadband precision fixed load)**

| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 20 GHz**[2] |
| Directivity | 40 dB | 40 dB | 38 dB | 36 dB |
| Source Match | 30 dB | 30 dB | 30 dB | 29 dB |
| Load Match | 35 dB | 35 dB | 30 dB | 30 dB |
| Reflection Tracking | ±0.10 dB | ±0.10 dB | ±0.10 dB | ±0.20 dB |
| Transmission Tracking (Fwd) | ±0.10 dB | ±0.10 dB | ±0.12 dB | ±0.15 dB |
| Transmission Tracking (Rev) | ±0.25 dB | ±0.15 dB | ±0.12 dB | ±0.15 dB |

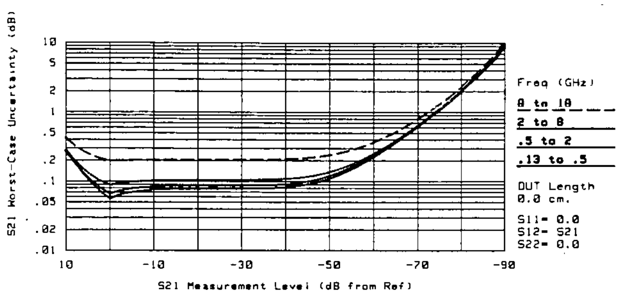
1. The graphs shown for reflection measurement uncertainty apply to a one-port device.
2. HP 8719A: 8 to 13.5 GHz.

## DEVICES WITH 7 MM CONNECTORS

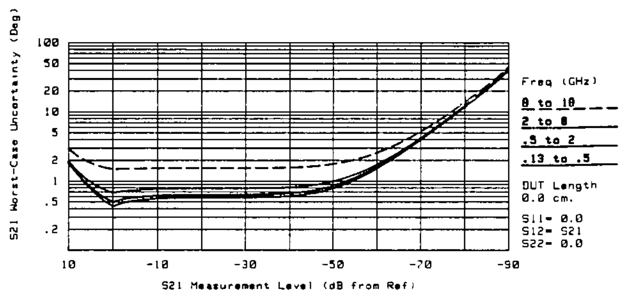
### Measurement Uncertainty

The following graphs show total worst case measurement uncertainty for the network analyzer after accuracy enhancement using a full 2-port measurement calibration (including isolation) with the HP 85050D 7 mm calibration kit, HP 85132D cable set, and an IF bandwidth of 10 Hz. This includes the residual systematic errors, as well as the system dynamic accuracy, 7 mm connector repeatability, noise, and switch repeatability[1]. The HP 85130B special 3.5 mm to 7 mm adapter set is used to adapt the 3.5 mm test ports to 7 mm. Specific points on the graphs are verified by measuring the devices in the HP 85051B verification kit.

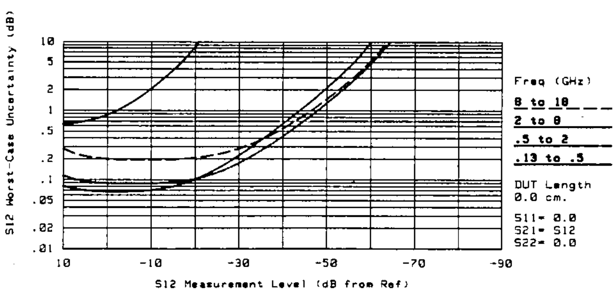
### Transmission Measurements[2]



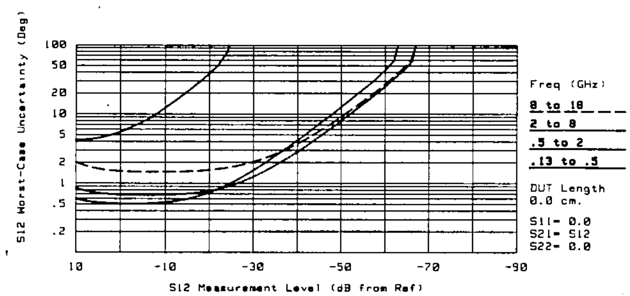

Magnitude




Phase

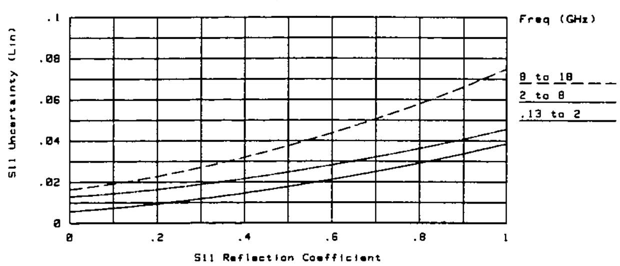



Magnitude

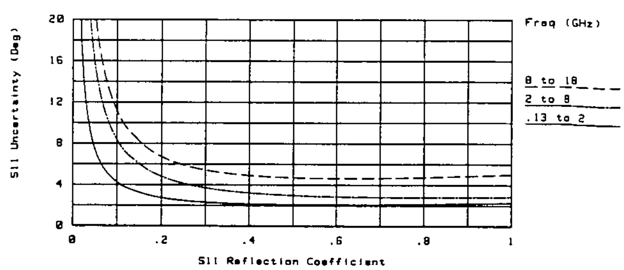



Phase

### Reflection Measurements[4]




Magnitude




Phase

1. Cable stability and system drift are not included.
2. The graphs for transmission measurements assume a well-matched device ($S_{11} = S_{22} = 0$).
3. HP 8719A: 8 to 13.5 GHz.
4. The graphs shown for reflection measurement uncertainty apply to a one-port device.

**DEVICES WITH 7 MM CONNECTORS (cont'd)**
**Measurement Port Characteristics**

The following specifications show the residual system performance (including switch repeatability) after accuracy enhancement using a full 2-port measurement calibration (including isolation) with an IF bandwidth of 10 Hz and the specified calibration kit. Environmental temperature is 23° ± 3°C.

**Calibration Kit: HP 85050B**
**(lowband and sliding loads)**

| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 18 GHz**[1] |
| Directivity | 50 dB | 50 dB | 45 dB | 45 dB |
| Source Match | 35 dB | 35 dB | 35 dB | 30 dB |
| Load Match | 40 dB | 40 dB | 35 dB | 30 dB |
| Reflection Tracking | ±0.10 dB | ±0.10 dB | ±0.10 dB | ±0.20 dB |
| Transmission Tracking (Fwd) | ±0.05 dB | ±0.05 dB | ±0.10 dB | ±0.15 dB |
| Transmission Tracking (Rev) | ±0.25 dB | ±0.15 dB | ±0.10 dB | ±0.15 dB |

**Calibration Kit: HP 85050D**
**(broadband precision fixed load)**

| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 18 GHz**[1] |
| Directivity | 45 dB | 45 dB | 38 dB | 36 dB |
| Source Match | 35 dB | 35 dB | 35 dB | 30 dB |
| Load Match | 40 dB | 40 dB | 35 dB | 30 dB |
| Reflection Tracking | ±0.10 dB | ±0.10 dB | ±0.10 dB | ±0.20 dB |
| Transmission Tracking (Fwd) | ±0.05 dB | ±0.05 dB | ±0.10 dB | ±0.15 dB |
| Transmission Tracking (Rev) | ±0.25 dB | ±0.15 dB | ±0.10 dB | ±0.15 dB |

1. HP 8719A: 8 to 13.5GHz.

**DEVICES WITH TYPE-N CONNECTORS**

**Measurement Port Characteristics**

The following table shows typical residual system performance (including switch repeatability) after accuracy enhancement using a full 2-port measurement calibration (including isolation) with the HP 85054B type-N calibration kit, and an IF bandwidth of 10 Hz. Environmental temperature is 23° ± 3°C.

**Calibration Kit: HP 85054B**
**(male and female lowband and sliding loads)**

| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 18 GHz**[1] |
| Directivity | 45 dB | 45 dB | 42 dB | 40 dB |
| Source Match | 35 dB | 35 dB | 35 dB | 30 dB |
| Load Match | 40 dB | 40 dB | 35 dB | 30 dB |
| Reflection Tracking | ±0.10 dB | ±0.10 dB | ±0.10 dB | ±0.20 dB |
| Transmission Tracking (Fwd) | ±0.05 dB | ±0.05 dB | ±0.10 dB | ±0.15 dB |
| Transmission Tracking (Rev) | ±0.25 dB | ±0.15 dB | ±0.10 dB | ±0.15 dB |

**Calibration Kit: HP 85054D**
**(male and female broadband precision fixed load)**

| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 18 GHz**[1] |
| Directivity | 40 dB | 40 dB | 36 dB | 34 dB |
| Source Match | 32 dB | 32 dB | 30 dB | 28 dB |
| Load Match | 40 dB | 38 dB | 34 dB | 32 dB |
| Reflection Tracking | ±0.10 dB | ±0.10 dB | ±0.10 dB | ±0.20 dB |
| Transmission Tracking (Fwd) | ±0.05 dB | ±0.05 dB | ±0.10 dB | ±0.15 dB |
| Transmission Tracking (Rev) | ±0.25 dB | ±0.15 dB | ±0.10 dB | ±0.15 dB |

**UNCORRECTED PERFORMANCE**

The following table shows typical performance without accuracy enhancement.

| | Frequency Range | | | |
|---|---|---|---|---|
| | **0.13 to 0.5 GHz** | **0.5 to 2 GHz** | **2 to 8 GHz** | **8 to 20 GHz**[1] |
| Directivity | 32 dB | 32 dB | 26 dB | 18 dB |
| Source Match | 20 dB | 18 dB | 14 dB | 10 dB |
| Load Match (Fwd) | 26 dB | 24 dB | 15 dB | 12 dB |
| Load Match (Rev) | 30 dB | 24 dB | 15 dB | 12 dB |
| Reflection Tracking[2] | ±2 dB | ±2 dB | ±2 dB | ±3 dB |
| Transmission Tracking[3] | ±1 dB | ±1 dB | ±1 dB | ±1 dB |
| Crosstalk | 70 dB | 75 dB | 73 dB | 73 dB |

1. HP 8719A: 8 to 13.5 GHz.
2. Excludes −1/+3 dB slope, typical, in magnitude response from 2.0 to 20 GHz (13.5 GHz for HP 8719A) and rolloff below 2 GHz, which is typically −4 dB at 1 GHz, −9 dB at 500 MHz, and −20 dB at 130 MHz.
3. Forward: excludes −5dB slope, typical, in magnitude response from 0.13 to 20 GHz (13.5 GHz for HP 8719A).
   Reverse: excludes −2/+6 dB slope, typical, in magnitude response from 2.0 to 20 GHz (13.5 GHz for HP 8719A) and rolloff below 2 GHz, which is typically −8 dB at 1 GHz, −18dB at 500 MHz, and −40 dB at 130 MHz.

*Table 2. Option 003 System Specifications (6 of 6)*

**SOURCE CHARACTERISTICS**

**Frequency Characteristics**

| | |
|---|---|
| **Range:** | 130 MHz to 20.0 GHz[1] |
| **Resolution:** | 100 kHz (1 Hz with option 001) |
| **Stability:** | ±7.5 ppm @ 0° to 55°C (typical)<br>±3 ppm/year (typical) |
| **Accuracy:** | 10 ppm @ 23°±3°C |

**Output Characteristics:**

at test port 1

| | |
|---|---|
| **Power Range:** | −10 to −65 dBm in 5 dB steps |
| **Power Level:** | −10 dBm ± 3 dB |
| **Harmonics:** | <−15 dBc @ −10 dBm (typical) |

at test port 2 (typical)[2]

| | |
|---|---|
| **Power Range:** | −30 to −85 dBm in 5 dB steps |
| **Power Level:** | −30 dBm |
| **Harmonics:** | <−15 dBc @ −30 dBm |

1. HP 8719A: 130 MHz to 13.5 GHz
2. Excludes −1/+3 dB slope, typical, in magnitude response from 2.0 to 20 GHz (13.5 GHz for HP 8719A) and rolloff below 2 GHz, which is typically −4 dB at 1 GHz, −9 dB at 500 MHz, and −20 dB at 130 MHz.

Values in this table are not specifications, but are intended to provide information useful in applying the instrument by giving typical but non-warranted performance parameters.

**MEASUREMENT THROUGHPUT SUMMARY**

The following table shows typical measurement times for the analyzer.

*Typical time for completion (msec)*

| | Number of Points | | | | | |
|---|---|---|---|---|---|---|
| | **51** | **101** | **201** | **401** | **801** | **1601** |
| **Measurement** | | | | | | |
| 1-port cal[1] | 130 | 130 | 170 | 270 | 470 | 900 |
| 2-port cal[2] | 530 | 610 | 1000 | 1630 | 3000 | 5440 |
| **Time Domain Conversion**[3] | 180 | 300 | 540 | 1150 | 2380 | 2840 |
| **HP-IB Data Transfer**[4] | | | | | | |
| 1: Binary | 30 | 50 | 90 | 170 | 330 | 660 |
| 2: 32-bit* | 60 | 110 | 190 | 380 | 740 | 1500 |
| 3: 64-bit* | 90 | 160 | 310 | 600 | 1200 | 2390 |
| 4: ASCII | 540 | 1060 | 2080 | 4130 | 8240 | 16440 |
| 5: 32-bit (PC) | 70 | 120 | 200 | 400 | 800 | 1600 |

**TEST PORTS**

**Connector Type:** 3.5 mm (male)

**Connector Pin Recession:** 0.0002 to 0.0018 in

**Impedance:** 50 ohms nominal

**Switch Type:** mechanical

**Switch Lifetime:** >3 million cycles (typical)

**Maximum Input Level:** +20 dBm

**DC Bias:** 500 mA, 40 Vdc maximum

**ENVIRONMENTAL CHARACTERISTICS**

**General Conditions**

RFI and EMI suspectibility: defined by VDE 0730, CISPR Publication 11, and FCC Class B Standards.

ESD (electrostatic discharge): must be eliminated by use of static-safe work procedures and an antistatic bench mat (such as HP 92175T).

Dust: the environment should be as dust-free as possible.

**Operating Conditions**

Temperature: 0° to 55°C

**Non-Operating Storage Conditions**

Temperature: −40° to +70°C

**Power:** 48 to 66 Hz: 90 to 132V, 198 to 264V, 280 VA max

**Weight:** Net, 34 kg (75lb); Shipping, 42 kg (92 lb)

**Dimensions:** 267 H x 425 W x 502 mm D (10.5 x 16.75 x 19.75 in)
Add 2 inches to depth to include the front panel instrument handles and connectors.

**REAR PANEL CONNECTORS**

**External Reference Frequency Input**

**Frequency:** 1, 2, 5, and 10 MHz; < ±200 Hz at 10 MHz
**Level:** −10 dBm to +20 dBm, typical
**Impedance:** 50 ohms nominal

**External Trigger**

Triggers start of sweep on a negative TTL transition or contact closure to ground.

**External AM Auxiliary Input**

0 to 10 volts (1 dB/volt) into a 10 kohm resistor, 5 kHz max.

**Auxiliary Voltage Input**

−10V to +10V

**IO Interconnect**

**Type:** DB-25
**Output:** Standard LS TTL output (active high logic) on pin 17 indicative of pass/fail status during limit testing. Output voltage remains at +5 Vdc (nominal) until a fail condition occurs. Remains at 0 Vdc until a pass condition occurs.

**Video Output**

The RGB connectors drive external monitors with these characteristics:
RGB with synch on green.
75 ohm impedance.
1v p-p (0.7V = white; 0V = black; −0.3V = synch).

1. $S_{11}$ measurement using 1-port measurement calibration over a frequency span of 2 GHz using an IF Bandwidth of 3 kHz. Includes system retrace time, but does not include source bandswitch time. Time domain gating is assumed off. If averaging is used, multiply the measurement times by the averaging factor to get the total time.
2. Same as footnote 1, but for an $S_{21}$ measurement using full 2-port measurement calibration. Includes RF switching time (typically 30 ms).
3. Option 010 only, gating off.
4. Measured with an HP 9000 series 300 computer.

*Table 3. General Characteristics (2 of 2)*

**EFFECT OF FREQUENCY RESOLUTION**

The following table shows the differences in operation between the standard analyzer (100 kHz frequency resolution) and the option 001 (1 Hz frequency resolution) analyzer.

| | Standard | Option 001 |
|---|---|---|
| **Source Control:** | | |
| Start/Stop/Center/CW | 100 kHz | 1 Hz |
| Min. span @ 101 points[1] | 10 MHz | 100 Hz |
| Min. span @ 201 points | 20 MHz | 200 Hz |
| **Time domain:** | | |
| Max. time domain range [2] | 10 μs | 1s |
| **Group delay:** | | |
| Max. group delay range | 5 μs | 500 ms |
| Minimum aperture | 100 kHz | 1 Hz |

1. Minimum span = (number of data points −1) × frequency resolution.
2. Using time domain bandpass mode.

REFERENCE

# HP 8719A
# HP 8720B
# MICROWAVE NETWORK ANALYZER

HEWLETT PACKARD

## HP 8719A and HP 8720B Reference
# TABLE OF CONTENTS

## CHAPTER 6. USING MARKERS



## CHAPTER 7. INSTRUMENT STATE AND LIMIT TESTING



## CHAPTER 8. TIME AND FREQUENCY DOMAIN TRANSFORMS



## CHAPTER 9. MAKING A HARD COPY OUTPUT



## CHAPTER 10. SAVING INSTRUMENT STATES



## CHAPTER 11. HP-IB REMOTE PROGRAMMING



## CHAPTER 12. ERROR MESSAGES



## APPENDIX A

# Chapter 1. System Description and Data Processing

## INTRODUCTION

This section of the *Operating Manual* is a complete reference for operation of the microwave network analyzer using either front panel controls or an external controller. The information in this reference is intended to supplement the separately bound tutorial documents in this manual with additional details. It is divided into chapters providing the following information:

- Chapter 1 includes a block diagram and functional description of the analyzer system, with descriptions of the front panel features and CRT labels, and the rear panel features and connectors.
- Chapters 2 through 10 provide detailed information on front panel keys and softkeys, their purpose and use, HP-IB equivalents in parentheses, and expected indications and results. Specific areas of operation described in these chapters include calibration procedures for accuracy enhancement, using markers, limit testing, time domain measurements (option 010), plotting and printing, and saving instrument states.
- Chapter 11 contains information for operating the system remotely with a controller through HP-IB. HP-IB is Hewlett-Packard's hardware, software, documentation, and support for IEEE-488.1 and IEC-625, worldwide standards for interfacing instruments. Chapter 12 lists error messages, with explanations.

An appendix at the end of this *Reference* provides a complete listing of the instrument preset state, a map of the operating softkey menu structure, and an alphabetical index.

Also provided with the network analyzer, in the *Operating Manual* binder, are the following documents that provide operating or programming information:

- The *User's Guide* provides tutorial operating information, showing how the instrument is used for the majority of network analysis measurements. It demonstrates the features and capabilities of the system with actual measurement examples.
- The *Quick Reference* provides a quick review of the softkey menus and manual operation in a small-sized booklet. This guide assumes familiarity with the operation of a network analyzer.
- The *HP-IB Programming Guide* provides tutorial instructions for using the analyzer with a series 300 computer as a controller and HP BASIC language. Familiarity with front panel operation is assumed.
- The HP-IB *Quick Reference* is a programming summary for users familiar with HP-IB programming and the basic functions of the analyzer.

## SYSTEM DESCRIPTION

Network analyzers measure the reflection and transmission characteristics of devices and networks by applying a known swept signal and measuring the responses of the test device. The signal transmitted through the device or reflected from its input is compared with the incident signal generated by a swept RF source. The signals are applied to a receiver for measurement, signal processing, and display. A network analyzer system consists of a source, signal separation devices, a receiver, and a display.

This microwave network analyzer integrates a synthesized source, signal separation devices, and a dual channel receiver to measure and display magnitude, phase, and group delay of transmitted and reflected power. Analyzer Option 010 provides the additional capability of transforming measured data from the frequency domain to the time domain.

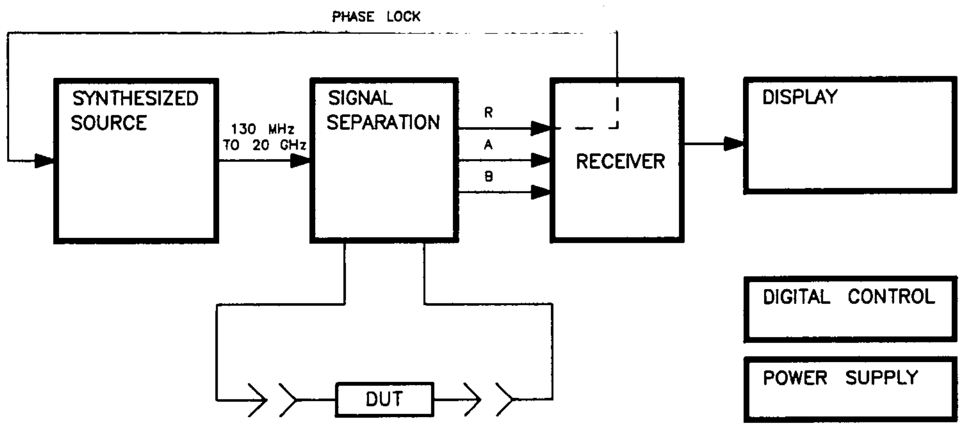



*Figure 1-1. Simplified Block Diagram of the Network Analyzer*

The built-in synthesized source of the analyzer generates a swept or CW (continuous wave) signal in the range of 130 MHz to 13.5 GHz or 20.0 GHz, with a frequency resolution of 100 kHz. Option 001 provides enhanced frequency resolution of 1 Hz. The source output power is leveled by an internal ALC (automatic leveling control) circuit. To achieve frequency accuracy and phase measuring capability, the analyzer is phase locked to a highly stable crystal oscillator. For this purpose, a portion of the transmitted signal is routed to the R sampler in the receiver, and fed back to the source.

The signal separation devices in the analyzer include a power splitter, a transfer switch, and two directional couplers. The power splitter diverts a portion of the incident signal to the R sampler for reference and phase lock. The transfer switch and the couplers provide the capability for simultaneous transmission and reflection measurements in both the forward and reverse directions. A 55 dB step attenuator adjusts the power level to the DUT (device under test) in 5 dB steps, without changing the level of the incident power in the reference path. Two bias tees allow external biasing of active devices connected to the test ports.

The signal transmitted through or reflected from the DUT is applied to the B and/or A samplers and compared with the incident signal at R.

The receiver contains three identical samplers and second converters (R, A, and B), which convert the input signal to a 4 kHz IF (intermediate frequency), retaining both the magnitude and phase characteristics of the source signal. The three signals are multiplexed into the ADC (analog-to-digital converter) and converted to digital signals, to be measured and processed for display on the CRT.

A microprocessor takes the raw data and performs all the required error correction, trace math, formatting, scaling, and marker operations, according to the instructions from the front panel or controller. The formatted data is then displayed on the CRT. The data processing sequence is described below.

In addition to the analyzer itself, a measurement may require calibration standards for vector accuracy enhancement, and cables for interconnections. Model numbers and details of compatible calibration kits, cables, and other accessories are provided in the *General Information* section of the *Operating and Programming Manual*.

A detailed block diagram of the analyzer is provided in the *Service Manual*, together with complete theory of system operation.

## DATA PROCESSING

### Overview

The receiver of the analyzer converts the reflected and transmitted signals from the DUT into useful measurement information. This conversion occurs in two main steps. First, the swept high frequency input signals are translated to fixed low frequency IF signals, using harmonic mixing techniques. (Refer to *Theory of Operation* in the *Service Manual* for details.) Second, the IF signals are converted into digital data by an analog-to-digital-converter (ADC). From this point on, all further signal processing is performed mathematically by microprocessors in the analyzer. The following paragraphs describe the sequence of math operations and the resulting data arrays as the information flows from the ADC to the display. They provide a good foundation for understanding most of the response functions, and the order in which they are performed.

Figure 1-2 is a data processing flow diagram that represents the flow of numerical data from IF detection to display. The data passes through several math operations, denoted in the figure by single-line boxes. Most of these operations can be selected and controlled with the front panel RESPONSE block menus. The data is also stored in arrays along the way, denoted by double-line boxes. These arrays are places in the flow path where data is accessible, usually via HP-IB.

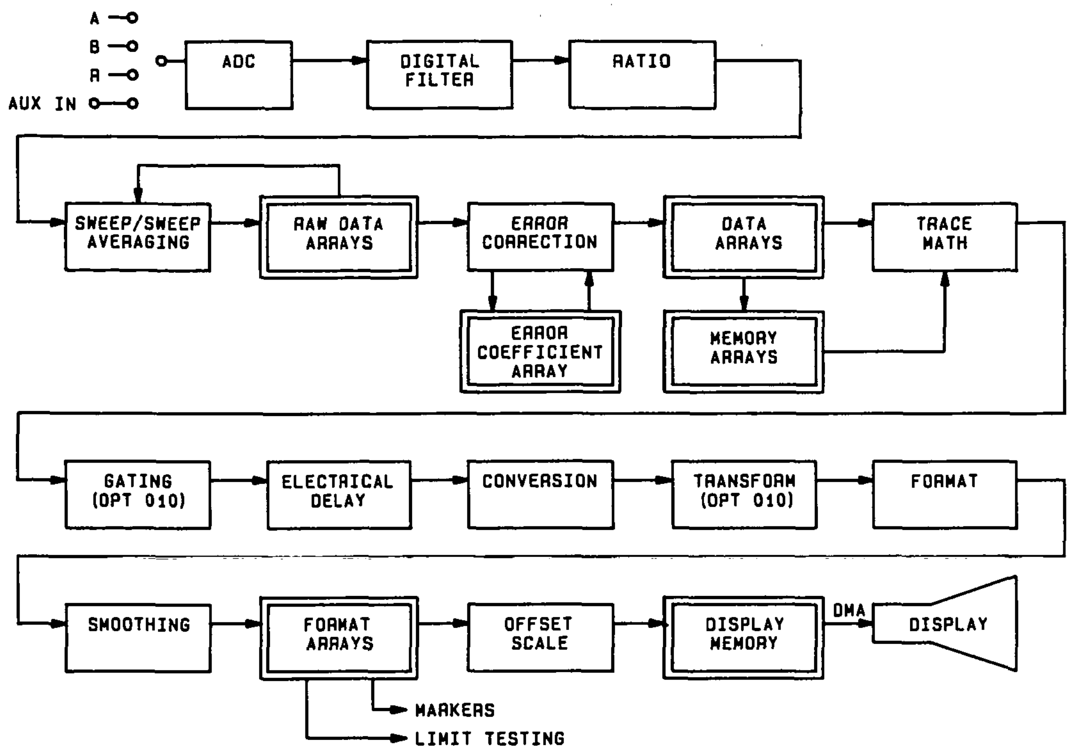



*Figure 1-2. Data Processing Flow Diagram*

While only a single flow path is shown, two identical paths are available, corresponding to channel 1 and channel 2. When the channels are uncoupled, each channel can be independently controlled, so that the data processing operations for one are different from the other.

Two definitions are necessary:

A "data point" or "point" is a single piece of data representing a measurement at a single source stimulus value. Most data processing operations are performed point-by-point; some involve more than one point.

A "sweep" is a series of consecutive data point measurements, taken over a sequence of source stimulus values. A few data processing operations require that a full sweep of data is available. The number of points per sweep can be defined by the user.

## Processing Details

**The ADC** converts the R, A, and B inputs (already down-converted to a fixed 4 kHz IF) into digital words. (The AUX IN connector on the rear panel is a fourth input.) The ADC switches rapidly between these inputs, so they are converted nearly simultaneously.

**The digital filter** detects the IF and performs the discrete Fourier transform (DFT) on the digital words. The samples are converted into complex number pairs (real plus imaginary). The complex numbers represent both the magnitude and phase of the IF signal. If AUX IN is selected as the input, the imaginary part of the pair is set to zero. The DFT filter shape can be altered by changing the IF bandwidth, which is a highly effective technique for noise reduction. (Refer to *[AVG] Key* in Chapter 4 for information on different noise reduction techniques.)

**The ratio calculation** (a complex divide operation) is performed if the selected measurement is a ratio of two inputs (as in all S-parameter measurements). If the selected measurement is absolute (AUX IN or a service measurement), no operation is performed. The R, A, and B values are also split into channel data at this point. (Refer to *[MEAS] Key* in Chapter 4 for more information on S-parameters; information on service measurements is provided in the *Service Manual*.

**Sweep-to-sweep averaging** is another noise reduction technique for ratioed measurements. This calculation involves taking the complex exponential average of several consecutive sweeps. (Refer to *[AVG] Key* in Chapter 4.)

**The raw data arrays** store the results of all the preceding data processing operations. (Up to this point, all processing is performed real-time with the sweep by the IF processor. The remaining operations are not necessarily synchronized with the sweep, and are performed by the main processor.) When full 2-port error correction is on, the raw arrays contain all four S-parameter measurements required for accuracy enhancement. When the channels are uncoupled (coupled channels off), there may be as many as eight raw arrays. These arrays are directly accessible via HP-IB. Note that the numbers here are still complex pairs.

**Vector error correction** (accuracy enhancement) is performed next, if a measurement calibration has been performed and correction is turned on. Error correction effectively removes repeatable systematic errors (stored in the error coefficient arrays) from the raw arrays. This can vary from simple vector normalization to full 12-term error correction. (Refer to Chapter 5, *Measurement Calibration*, for details.)

The error coefficient arrays themselves are created during a measurement calibration using data from the raw arrays. These are subsequently used whenever correction is on, and are accessible via HP-IB. (Refer to Chapter 10, *Saving Instrument States*, for information on memory allocation.)

**The data arrays** store the results or error correction as complex number pairs. These arrays are accessible via HP-IB.

If the data-to-memory operation is performed, the data arrays are copied into the memory arrays. (Refer to *[DISPLAY] Key* in Chapter 4.)

**The trace math** operation selects either the data array, memory array, or both to continue flowing through the data processing path. In addition, the complex ratio of the two (data/memory) or the difference (data—memory) can also be selected. If memory is displayed, the data from the memory arrays goes through exactly the same data processing flow path as the data from the data arrays. (Refer to *[DISPLAY] Key* in Chapter 4 for information on memory math functions.)

**Gating** is a digital filtering operation associated with time domain transformation (option 010 only). Its purpose is to mathematically remove unwanted responses isolated in time. In the time domain, this can be viewed as a time-selective bandpass or band-stop filter. (If both data and memory are displayed, gating is applied to the memory trace only if gating was on when data was stored into memory.) (Refer to Chapter 8.)

**The electrical delay** block involves adding or subtracting phase in proportion to frequency. This is equivalent to "line-stretching" or artificially moving the measurement reference plane. (Refer to *[ELECTRICAL DELAY]* under *[SCALE REF] Key* in Chapter 4.)

**Conversion** transforms the measured S-parameter data to the equivalent complex impedance (Z) or admittance (Y) values, or to inverse S-parameters (1/S). (Refer to *Conversion Menu* under *[MEAS] Key* in Chapter 4.)

**The transform** operation converts frequency domain information into the time domain when transform is on (option 010 only). The results resemble time domain reflectometry (TDR) or impulse-response measurements. The transform employs the chirp-Z inverse fast Fourier transform (FFT) algorithm to accomplish the conversion. The windowing operation is performed on the frequency domain data just before the transform. Windowing is a digital filtering operation that prepares (enhances) the frequency domain data for transformation to time domain. A special tranform mode is available to "demodulate" CW sweep data, with time as the stimulus parameter, and display spectral information with frequency as the stimulus parameter. (Refer to Chapter 8, *Time and Frequency Domain Transforms*.)

**Formatting** converts the complex number pairs into a scalar representation for display, according to the selected format. This includes group delay calculations. These formats are often easier to interpret than the complex number representation. (Polar and Smith chart formats are not affected by the scalar formatting.) Note that after formatting, the complex data can only be retrieved if the trace is in hold, (or it can be read by the controller over the HP-IB). (Refer to *[FORMAT] Key* in Chapter 4 for information on the different formats available and on group delay principles.)

**Smoothing** is another noise reduction technique, which smoothes noise on the trace. When smoothing is on, each point in a sweep is replaced by the moving average value of several adjacent (formatted) points. The number of points included depends on the smoothing aperture, which can be selected by the user. (In spectrum analysis, the effect is often called video filtering.) If data and memory are displayed, smoothing is performed on the memory trace only if smoothing was on when the data was stored into memory. (Refer to *[AVG] Key* in Chapter 4 for information about smoothing.)

**The format arrays** store the current results. It is important to note that marker values and marker functions are all derived from the format arrays. Limit testing is also performed on the formatted data. The format arrays are accessible via HP-IB.

**The offset and scale operations** prepare the formatted data for display on the CRT. This is where the reference line position, reference line value, and scale calculations are performed, as appropriate to the format. (Refer to *[SCALE REF] Key* in Chapter 4.)

**The display memory** stores the display image for presentation on the CRT. The information here includes graticules, annotation, and softkey labels—everything visible on the CRT—in a form similar to plotter commands. If user display graphics are written, these are also stored in display memory. When hardcopy records are made, the information sent to the plotter or printer is taken from display memory. Display memory has limited access—only the user graphics area is available to the user. Further, this is a write-only address block: data cannot be read out of display memory.

Finally, the display memory data is sent to the CRT display. The display is updated frequently, and asynchronously with the data processing operations.

# Chapter 2. Front Panel and Softkey Operation

## INTRODUCTION

This chapter explains how to operate the analyzer using front panel controls and softkey menus. It provides illustrations and descriptions of the front panel features, the CRT display and its labels, and the rear panel features and connectors.

## ACTIVE FUNCTION

The functions of the analyzer are activated from the front panel by the operator using front panel keys or softkeys. (In this manual, all front panel keys are shown in brackets in bold type, e.g. **[MENU]**; softkey labels are shown in brackets in a bold italic type, e.g. ***[POWER]***.) The function currently activated is called the active function, and is displayed in the active entry area at the upper left of the CRT. As long as a function is active it can be modified with the entry block controls (explained later in this chapter). A function remains active until another function is selected or **[ENTRY OFF]** is pressed.

## FRONT PANEL KEYS AND SOFTKEY MENUS

Front panel keys are used to change instrument functions directly or to provide access to additional functions available in softkey "menus." These menus are displayed lists of related functions or choices for a particular function, with each choice corresponding to one of the eight softkeys located to the right of the CRT. Pressing one of the softkeys either executes the labeled function and makes it the active function, or changes the current status of a function, or presents another set of menu labels. Generally whenever a menu changes, the present active function is cleared, unless it is an active marker function.

In cases where several possible menu choices are available for a function, they are joined by vertical lines. When a selection has been made from the listed alternatives, that selection is underlined until another selection is made.

Some softkey functions can be toggled on or off, and this is indicated in the softkey label. When one of these functions is turned on, this is indicated by the word ON in capitals in the softkey label. For example, when averaging is on the label reads ***[AVERAGING ON off]***, and when it is off the label reads ***[AVERAGING on OFF]***.

Some softkey labels show the current selected status of a function. For example, the selected value of the IF bandwidth is shown in brackets in the ***[IF BW]*** softkey label.

## FUNCTION BLOCKS

The front panel keys that provide access to softkey menus are grouped in function blocks.

- The STIMULUS block keys and softkey menus control all the functions of the network analyzer's source.
- The RESPONSE block keys control the receiver section of the network analyzer, providing measurement and display functions specific to the active channel.
- The INSTRUMENT STATE keys control channel-independent system functions including instrument preset, front panel save/recall memory, HP-IB plotter and printer control, time domain transform (option 010), limit testing, and built-in diagnostic tests.

## REMOTE OPERATION

The functions accessible from the front panel can also be accessed remotely by an external computer/controller using HP-IB. Equivalent HP-IB commands are available for most of the front panel keys and softkey menu selections. In this *Reference*, the HP-IB programming command equivalent to each front panel or softkey function is provided in parentheses after the first reference. Additional information about HP-IB programming is provided in Chapter 11.

The following chapters provide information about all instrument functions and softkeys, presented in function block order. The menus available from each front panel key are illustrated in "menu maps" to show the sequence of keys that must be pressed to access each function. Detailed descriptions of each softkey function are provided with illustrations of the individual menus. Additional background information is provided on network analysis topics related to the individual instrument functions. A complete map of the softkey menu structure is provided in *Appendix A* at the end of this *Reference*, together with an alphabetical index.

## Front Panel Features

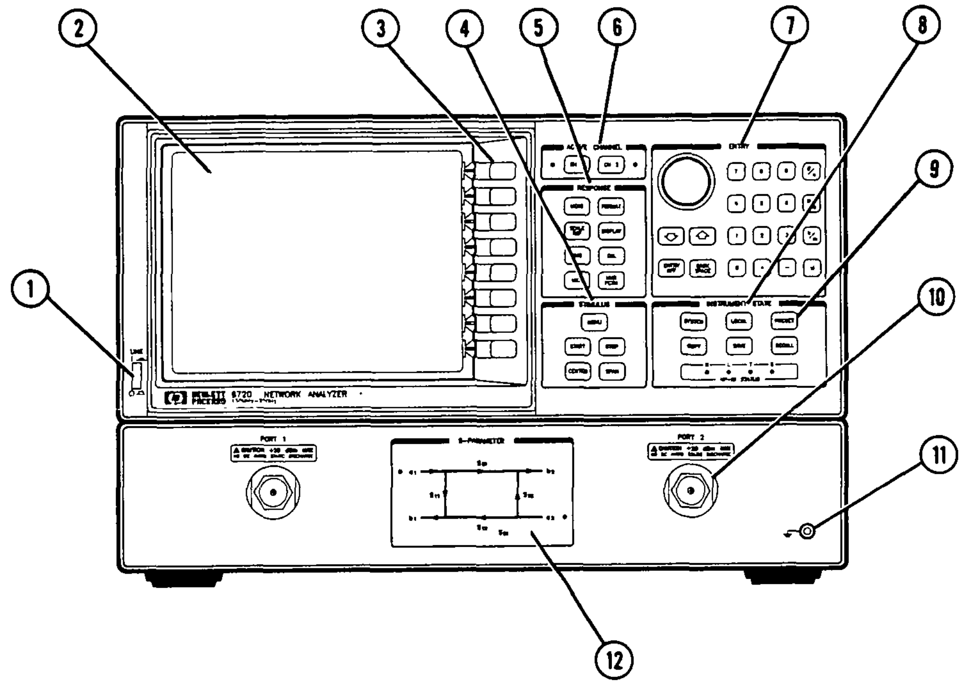



*Figure 2-1. Front Panel*

Figure 2-1 illustrates the following features and function blocks of the front panel. These features are described in more detail in this and subsequent chapters.

1. **LINE Switch** controls AC power. 1 is on, 0 is off.
2. **CRT Display** shows the of data traces, measurement annotation, softkey labels, and other information. The display is divided into specific information areas (see figure 2-4).
3. **Softkeys** expand the capabilities of the analyzer with additional functions beyond those of the front panel keys. They provide access to menu selections displayed on the CRT.
4. **STIMULUS Function Block** keys control the signal from the internal source, and other stimulus functions.
5. **RESPONSE Function Block** keys control the measurement and display functions of the active display channel.
6. **ACTIVE CHANNEL Keys** select the active channel. The analyzer has two independent display channels. Any functions that are then entered apply to this active channel.
7. **The ENTRY Block** includes the knob, the step [▲][▼] keys, and the number pad. These are used for entering numerical data and controlling the markers.
8. **INSTRUMENT STATE Function Block** keys control channel-independent system functions, time domain transform (option 010), and built-in diagnostics. Also included in this block are the HP-IB STATUS indicators.

9. **[PRESET] Key** returns the instrument to a known standard preset state from any step of any manual procedure. A complete listing of the instrument preset condition is provided in *Appendix A* at the end of this *Reference*. Most of the conditions can be observed on the CRT or by pressing **[COPY]** ***[OP PARMS (MKRS etc)]*** on the front panel.

10. **Measurement Ports.** The device under test is connected to one or both of these ports. The network analyzer contains internal signal separation and switching hardware required to make simultaneous transmission and reflection measurements in both the forward and reverse directions.

11. **Chassis Ground Connector** is a convenient place to attach an anti-static wrist strap cord. Work static safe. Many advanced devices, including the analyzer, are susceptible to ESD (electro-static damage).

12. **S-Parameter Flowgraph** shows the four possible S-parameters and the measurement directions for a two-port device. An explanation of S-parameters is provided in Chapter 4 under *[MEAS] Key*.

## ACTIVE CHANNEL KEYS (CHAN1, CHAN2)

The analyzer has two digital channels for independent measurement and display of data. Two different sets of data can be measured simultaneously, for example the reflection and transmission characteristics of a device, or one measurement with two different frequency spans. The data can be displayed separately or simultaneously, as described below.

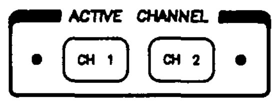



*Figure 2-2. The Active Channel Keys*

The **[CH 1]** and **[CH 2]** keys illustrated in Figure 2-2 are used to select one channel to be the "active channel". This is the channel currently controlled by the front panel keys, and its trace and data annotations are displayed on the CRT. All channel-specific functions selected apply to the active channel. The current active channel is indicated by an amber LED adjacent to the corresponding channel key.

The analyzer has dual trace capability, so that both the active and inactive channel traces can be displayed, either overlaid or on separate graticules one above the other (split display). When both channel traces are displayed, the annotations of the active channel are brighter. The dual channel and split display features are available in the display menus. Refer to Chapter 4 for illustrations and descriptions of the different display capabilities.

Source values can be coupled or uncoupled between the two channels, independent of the dual channel and split display functions. Refer to *Stimulus Menu* in Chapter 3 for a listing of the source values that are coupled in stimulus-coupled mode.

Another coupling capability is coupled markers. Measurement markers can have the same stimulus values for the two channels, or they can be uncoupled for independent control in each channel. Refer to Chapter 6 for more information about markers.

## ENTRY BLOCK

The ENTRY block, illustrated in Figure 2-3, provides the numeric and units keypad, the knob, and the step keys. These are used in combination with other front panel keys and softkeys to modify the active entry, to enter or change numeric data, and to change the value of the active marker. In general the keypad, knob, and step keys can be used interchangeably.

Before a function can be modified, it must be made the active function by pressing a front panel key or softkey. It can then be modified directly with the knob, the step keys, or the digits keys and a terminator, as described below.

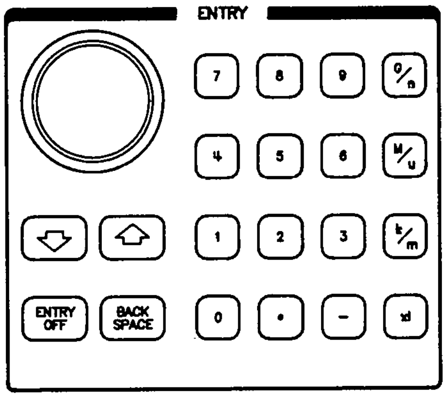



*Figure 2-3. The Entry Block*

**The Numeric Keypad** is used to select digits, decimal point, and minus sign for numerical entries. A units terminator is required, as described below.

**The Units Terminator Keys** are the four keys in the right-hand column of the keypad. These are used to specify the units for numerical entries from the keypad and at the same time terminate the entries. A numerical entry is incomplete until a terminator is supplied, and this is indicated by the data entry arrow ← pointing at the last entered digit in the active entry area. When the units terminator key is pressed, the arrow is replaced by the units selected. The units are abbreviated on the terminator keys as follows:

G/n (HP-IB G, N) = Giga/nano ($10^9$ / $10^{-9}$)
M/μ (M, U) = Mega/micro ($10^6$ / $10^{-6}$)
k/m (K, M) = kilo/milli ($10^3$ / $10^{-3}$)
x1 (HZ, S, DB, V) = basic units: Hz, seconds, dB, dBm, volts, or degrees (also used to terminate unitless entries such as averaging factor)

**The Knob or RPG** (rotary pulse generator) is used to make continuous adjustments to current values for various functions such as frequency, scale, and others. If there is a marker turned on, and no other function is active, the knob can be used to adjust the marker stimulus values. Values changed by the knob are effective immediately, and require no units terminator.

**The Step Keys [▲]** (UP) and **[▼]** (DOWN) are used to step the current value of the active function up or down. The steps, for most functions, are predefined by the analyzer in increments of 1, 2, and 5, and cannot be altered. No units terminator is required.

**[ENTRY OFF]** (ENTO) clears and turns off the active entry area, as well as any displayed prompts, error messages, or warnings. Use this function to clear the display before plotting. Another purpose of this key is to prevent changing of active values by accidental nudging of the knob. The next selected function turns the active entry area back on.

**[BACK SPACE]** deletes the last digit entered from the number pad.

# CRT Display

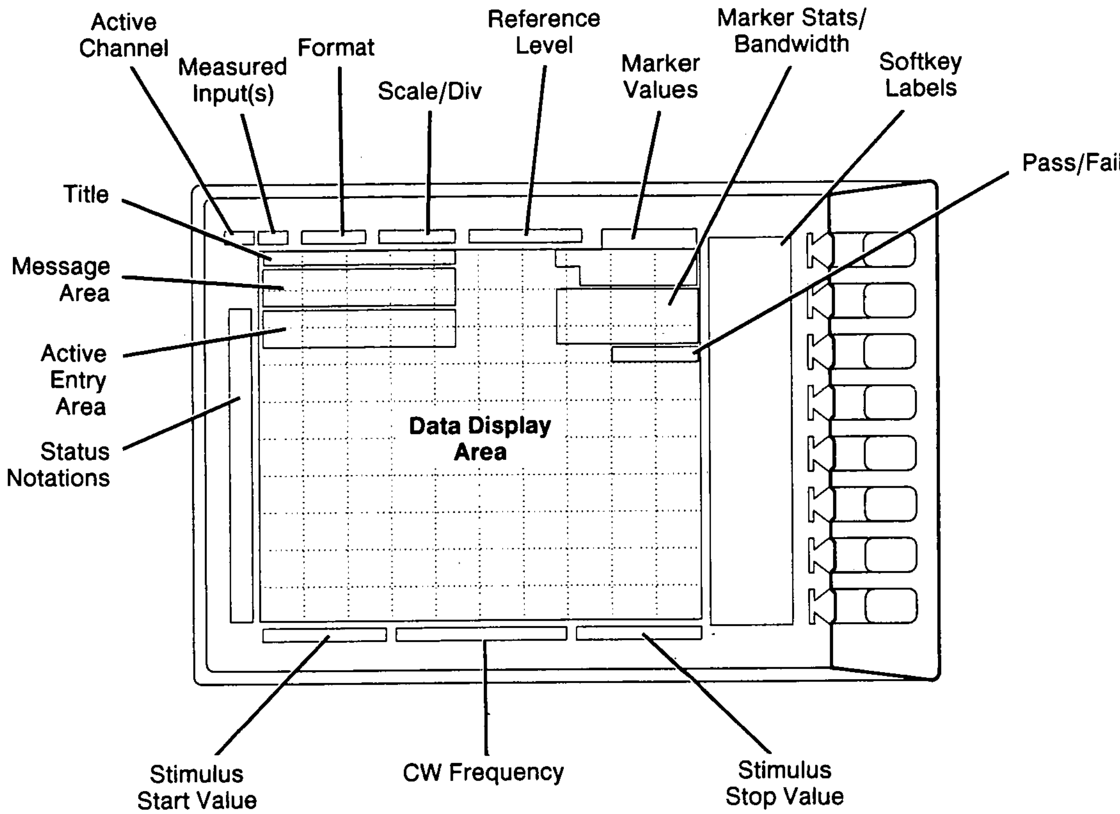



*Figure 2-4. CRT Display (Single Channel, Cartesian Format)*

The CRT displays the grid on which the measurement data is plotted, the currently selected measurement traces, and other information describing the measurement. Figure 2-4 illustrates the locations of the different CRT information labels, described below.

In addition to the full-screen display shown in Figure 2-4, a split display is available, as described under *[DISPLAY] Key, Display More Menu* in Chapter 4. In this case, information labels are provided for each half of the display.

Display formats for different measurements are illustrated and described in Chapter 4, under *[FORMAT] Key*.

**Stimulus Start Value** is the start frequency of the source in frequency domain measurements, or the start time in time domain or CW time mode. When the stimulus is in center/span mode, the center stimulus value is shown in this space.

**Stimulus Stop Value** is the stop frequency of the source in frequency domain measurements, or the stop time in time domain or CW time mode. When the stimulus is in center/span mode, the span is shown in this space. The stimulus values can be blanked, as described under *[DISPLAY] Key, Display More Menu*.

**CW Frequency Value**. For CW time measurements, the CW frequency is displayed centered between the start and stop times.

**Status Notations.** This area is used to show the current status of various functions for the active channel. The following notations are used:

| | | |
|---|---|---|
| * | = | Measurement parameters changed: measured data in doubt until a complete fresh sweep has been taken. |
| Cor | = | Error correction (measurement calibration) is on (see Chapter 5). |
| C? | = | Error correction is on, but may not be valid (see *[CAL] Key* in Chapter 5). |
| C2 | = | Two-port error correction is on (see Chapter 5). |
| C2? | = | Two-port error correction is on, but may not be valid. |
| Hld | = | Hold sweep (see *Trigger Menu* in Chapter 3). |
| ↑ | = | Fast sweep indicator. Displayed here for sweep times $<1.0$ second; moves along the trace for sweep times $>1.0$ second. |
| Ext | = | Waiting for an external trigger at the rear panel. |
| Avg | = | Sweep-to-sweep averaging is on. The averaging count is shown immediately below (see *[AVG] Key* in Chapter 4). |
| Smo | = | Trace smoothing is on (see *[AVG] Key* in Chapter 4). |
| Del | = | Electrical delay has been added or subtracted (see *[SCALE REF] Key* in Chapter 4). |
| Gat | = | Gating is on (time domain option 010 only) (see Chapter 8). |
| tsH | = | Test set hold. Hold mode to protect transfer switch and attenuator against continuous switching. Can be overridden with ***[NUMBER OF GROUPS]***. |

**Active Entry Area** displays the active function and its current value.

**Message Area** displays prompts or error messages.

**Title** is a descriptive alpha-numeric string title defined by the user and entered as described under *[DISPLAY] Key, Title Menu*. (In HP-IB, the title block is replaced by HP-IB commands entered from the external controller, if the special debug mode is on. Refer to Chapter 7.)

**Active Channel** is the number of the current active channel, selected with the **[ACTIVE CHANNEL]** keys. If dual channel is on with an overlaid display, both channel 1 and channel 2 appear in this area.

**Measured Input(s)** shows the S-parameter or other input currently measured, as selected using the **[MEAS]** key or the service menus. Also indicated in this area is the current display memory status.

**Format** is the display format selected using the **[FORMAT]** key.

**Scale/Div** is the scale selected using the **[SCALE REF]** key, in units appropriate to the current measurement.

**Reference Level** is the value of a reference line in Cartesian formats or the outer circle in polar formats, selected using the **[SCALE REF]** key. The reference position is indicated by a small triangle adjacent to the graticule, at the left for channel 1 and at the right for channel 2.

**Marker Values** are the values of the active marker, in units appropriate to the current measurement. Refer to Chapter 6, *Using Markers*.

**Marker Stats, Bandwidth** are statistical marker values determined using the menus accessed with the **[MKR FCTN]** key. Refer to Chapter 6.

**Softkey Labels** are menu labels displayed on the CRT that redefine the function of the softkeys immediately to the right of the CRT.

**Pass/Fail** displays the pass or fail status of a device compared to specified limits (see *Limit Lines and Limit Testing* in Chapter 7).

**NOTE:** The information provided here applies to Cartesian formats. In polar and Smith chart formats the labeling may differ.

## Rear Panel Features and Connectors

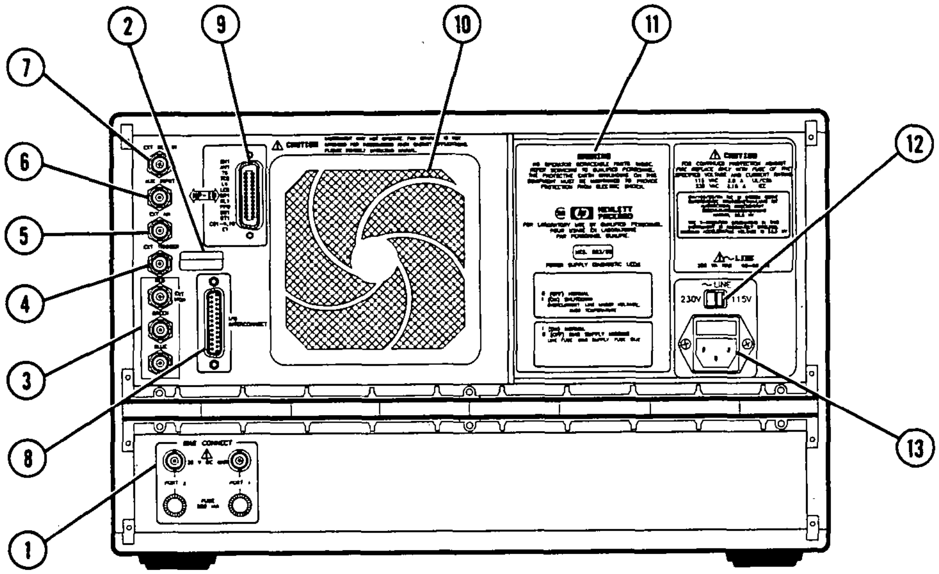



*Figure 2-5. HP 8719A and HP 8720B Rear Panel*

Figure 2-5 illustrates the features and connectors of the rear panel, described below. Requirements for input signals to the rear panel connectors are provided in the *General Characteristics* table of the *System Overview* section.

1. **BIAS CONNECT.** Two ports are provided to connect an external DC voltage, for biasing active devices through the internal bias tees. Maximum input voltage limits and fuse current values are shown on the rear panel.

2. **Serial Number Plate.** For information about serial numbers, refer to *Description of the Manual Set* in the *General Information* section.

3. **EXT MON Connectors.** The red, green, and blue connectors will drive a suitable external monitor (see table 3 in the *Specifications* section).

4. **EXT TRIGGER Connector.** This is used to connect an external negative-going TTL-compatible signal to trigger a measurement sweep. The trigger can be set to external through softkey functions (see Chapter 3, *Trigger Menu*).

5. **EXT AM Connector.** Used to connect an external analog signal to the ALC circuitry of the analyzer to amplitude modulate the source signal.

6. **AUX INPUT Connector.** Used to connect a DC or AC voltage from an external signal source such as a detector or function generator, which can then be displayed and measured using the S-parameter menu (see *[MEAS] Key* in Chapter 4). (It is also used as an analog output in service routines, as described in the *Service Manual*.)

7. **EXT REF INPUT Connector.** This is used to input a frequency reference signal to phase lock the analyzer to an external frequency standard for increased frequency accuracy.

   The external frequency reference feature is automatically enabled when a signal is connected to this input. When the signal is removed, the analyzer automatically switches back to its internal frequency reference.

8. **I/O INTERCONNECT.** Provides a standard LS TTL output (active high logic) on pin 17, indicative of pass/fail status during limit testing. The output remains high until a fail condition occurs, then remains low until a pass condition occurs.

**CAUTION**

**Supply voltages are present on some of the I/O INTERCONNECT pins. Use only pin 17.**

9. **HP-IB Connector.** Connects the analyzer to an external controller and other instruments in an automated system. Also used when the analyzer itself is the controller of compatible peripherals. Refer to *HP-IB and Power Considerations* in the *User's Guide* for information and limitations. Information on different controller modes is provided in chapter 7 of this *Reference* under *HP-IB Menu*.

10. **Fan Filter.** This filter helps to protect the instrument from dust contamination, and should be cleaned regularly. Instructions for cleaning the filter, and other routine maintenance, are provided in the *Service Manual*. A minimum clearance of 15 cm (6 inches) should be maintained behind and on both sides of the instrument or rack to allow for air circulation.

11. **Safety Warnings.** Provides warnings to prevent danger to the operator and cautions to prevent damage to the instrument. Also gives replacement fuse values.

12. **Line Voltage Selector Switch.** For more information refer to *HP-IB and Power Considerations* in the *User's Guide*.

13. **Power Cord Receptacle, with Fuse.** For information on replacing the fuse, refer to the *User's Guide*.

# Chapter 3. Stimulus Function Block

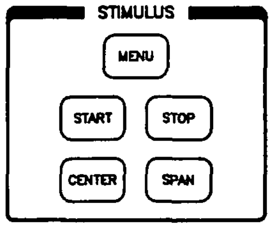



*Figure 3-1*

## INTRODUCTION

The stimulus function block keys and associated menus are used to define and control the source signal to the device under test. They set source characteristics such as range, sweep time and resolution, sweep type, power level, and the number of data points taken during the sweep.

## [START] (STAR) and [STOP] (STOP) KEYS

These keys are used to define the start and stop frequencies of the stimulus (source) or the start and stop times in the time domain (option 010). The source signal can be swept over any portion of the instrument's frequency range. The range can be expressed as either start/stop or center/span (see below). When the **[START]** or **[STOP]** key is pressed, its function becomes the active function. The value is displayed in the active entry area and can be changed with the knob, step keys, or number pad. Current stimulus values for the active channel are also displayed along the bottom of the graticule. Frequency values can be blanked for security purposes, using the display menus (see *Display More Menu* in Chapter 4).

The preset stimulus mode is frequency: the stimulus start value is set to 0.1300 GHz. For the HP 8720, the stop value is 19.9900 GHz (standard) or 20.0000 GHz (with option 001). For the HP 8719 (standard or with option 001), the stop value is 13.5100 GHz. Frequencies are resolved to 100 kHz in the standard instrument, and the frequency span in linear sweep mode is always:

100 kHz x (number of points −1) x n    where n =1, 2, 3. . .

Therefore when **[START]** is the active function, the stop frequency is automatically rounded to the nearest 100 kHz, and when **[STOP]** is the active function, the start frequency is rounded to the nearest 100 kHz (except in instruments with option 001).

For information on setting source values in the time domain, refer to Chapter 8.

Because the display channels are independent, the stimulus signals for the two channels can be uncoupled and their values set independently. The values are then displayed separately on the CRT if the instrument is in dual channel display mode. In the uncoupled mode with dual channel display the instrument takes alternate sweeps to measure the two sets of data. Channel stimulus coupling is explained in this chapter, and dual channel display capabilities are explained in Chapter 4 under *[DISPLAY] Key, Display Menu*.

## [CENTER] (CENT) and [SPAN] (SPAN) KEYS

These keys define the frequency or time range in terms of a center value and a span. When **[SPAN]** is the active function, the center frequency is automatically rounded to the nearest 100 kHz. When **[CENTER]** is the active function, the span is automatically rounded in increments of 200 kHz (100 kHz on either side of the center frequency) (except in instruments with option 001).

When **[SPAN]** is the active function, it can be modified with the numeric keypad, the step **[▲] [▼]** keys, or the knob. Note, however, that while the step keys change the span values in increments of 1, 2, and 5, the knob adds in increments of the span multiple as in **[START]** / **[STOP]** entry (see above).

The minimum span for a standard instrument in a measurement with 201 points is 20 MHz. Refer to *[NUMBER OF POINTS]* under *Stimulus Menu* for a table of minimum frequency spans using different numbers of measurement points. In the option 001 instrument, the frequency span can be defined with 1 Hz resolution.

A span of 0 can be specified, which is equivalent to a CW frequency.

## [MENU] KEY

The **[MENU]** (MENUSTIM) key provides access to the series of menus illustrated in Figure 3-2, which are used to define and control all stimulus functions other than start, stop, center, and span. When the **[MENU]** key is pressed, the stimulus menu is displayed. This in turn provides access to the other illustrated softkey menus. The functions available in these menus are described in the following pages.

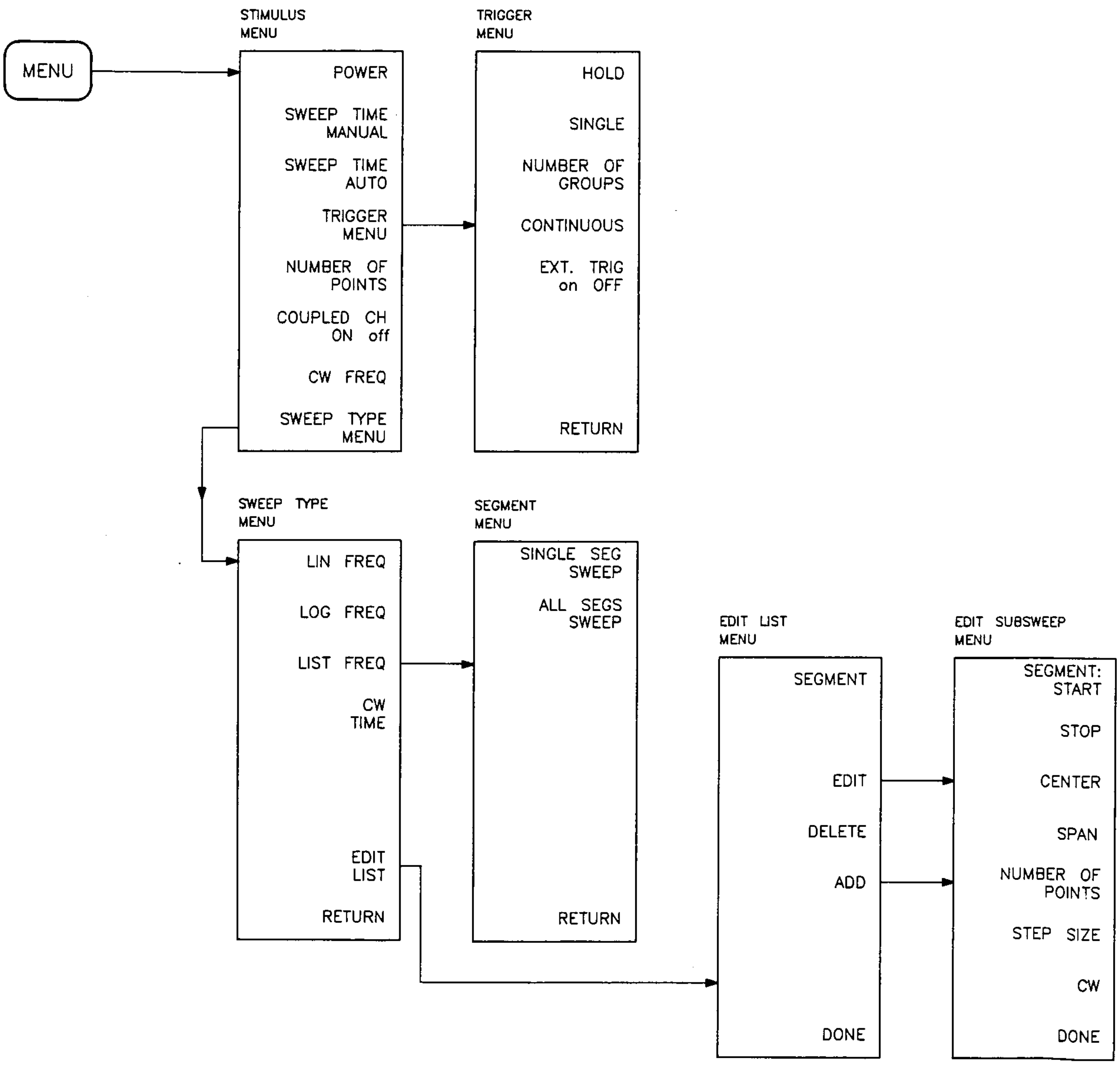



*Figure 3-2. Softkey Menus Accessed from the [MENU] Key*

## Stimulus Menu

The stimulus menu is used to specify the power level, sweep time, number of measurement points per sweep, and the frequency value for a CW (continuous wave) sweep. It includes the capability to couple or uncouple the stimulus functions of the two display channels. In addition, it leads to other softkey menus that define trigger and sweep type. The individual softkey functions of the stimulus menu are described below.

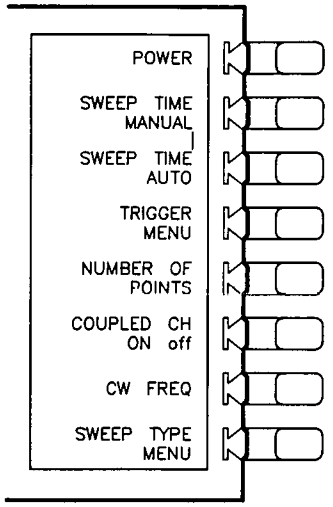



*Figure 3-3. Stimulus Menu*

***[POWER]*** (POWE) makes power level the active function and sets the output power level of the source from −10 to −65 dBm at the measurement port, by switching the internal programmable attenuator in 5 dB steps.

For option 003 instruments, power is set from −30 to −85 dBm at port 2.

If an input power overload is detected at one of the test ports, the analyzer displays the message "TEST PORT OVERLOAD, REDUCE POWER LEVEL." When this occurs, reset the power at a lower level. Overload occurs with about +22 dBm into either port 1 or port 2 of the standard instrument. Option 003 analyzers overload with about +2 dBm into port 2.

When the channels are uncoupled and a different power level is set for each channel, test set hold mode is implemented. In this mode, the attenuator (and transfer switch) are protected against continuous switching, and the status notation "tsH" appears at the left of the screen. This can be overridden with ***[NUMBER OF GROUPS]*** (see *Trigger Menu*).

***[SWEEP TIME MANUAL]*** (SWET) is used to set the sweep time. This refers only to the time that the instrument is sweeping and taking data, and does not include the time required for internal processing of the data. A sweep speed indicator ↑ is displayed on the trace for sweep times slower than 1.0 second (usually). For sweep times typically faster than 1.0 second the ↑ indicator is displayed in the status notations area at the left of the CRT.

The sweep time increases automatically if the number of points is increased or the IF bandwidth is decreased. (However, the reverse is not the case.) Sweep-to-sweep averaging also increases sweep time in dual channel display mode. Post-processing activities such as smoothing, limit lines, error correction, trace math, marker statistics, and time domain will increase the sweep repetition rate.

***[SWEEP TIME AUTO]*** (SWEA) automatically adjusts to the minimum sweep time available for the set frequency span, IF bandwidth, and number of points. For an IF bandwidth of 3000 Hz, the sweep time is 35 GHz per second.

Sweep time also varies according to the sweep type selected, as explained in *Sweep Type Menu*.

*[TRIGGER MENU]* goes to the trigger menu, which is used to select the type and number of the sweep trigger.

*[NUMBER OF POINTS]* (POIN) is used to select the number of data points per sweep to be measured and displayed. Using fewer points allows a faster sweep time but the displayed trace shows less horizontal detail. Using more points gives improved trace resolution, but slows the sweep and requires more memory for error correction or saving instrument states.

The possible values that can be entered for number of points are 3, 11, 21, 51, 101, 201, 401, 801, and 1601. The number of points can be different for the two channels if the stimulus values are uncoupled.

In the standard instrument, the smallest increment between points is 100 kHz, therefore increasing the number of points may increase the measurement span. However, if the number of points is then decreased, the span will not change. The frequency span in linear sweep mode is always:

100 kHz x (number of points −1) x n    where n =1, 2, 3. . .

This table shows the minimum frequency span for different numbers of points in a standard instrument (the option 001 has 1 Hz resolution and therefore allows closer spacing of points).

| | **Number of Points** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **3** | **11** | **21** | **51** | **101** | **201** | **401** | **801** | **1601** |
| **Minimum Span (MHz)** | 0.2 | 1 | 2 | 5 | 10 | 20 | 40 | 80 | 160 |

In list frequency sweep, the number of points displayed is the total number of frequency points for the defined list (see *Sweep Type Menu*).

*[COUPLED CH on OFF]* (COUCON, COUCOFF) toggles the channel coupling of stimulus values. With *[COUPLED CH ON]* (the preset condition), both channels have the same stimulus values (the inactive channel defaults to the stimulus values of the active channel).

In the stimulus coupled mode, the following parameters are coupled:

| | |
|---|---|
| Frequency | Number of points |
| Source power | Number of groups |
| Sweep time | IF bandwidth |
| Trigger type | Time domain transform |
| Sweep type | Gating |

When the channels are uncoupled and a different power level is set for each channel, test set hold mode is implemented. In this mode, the attenuator (and transfer switch) are protected against continuous switching, and the status notation "tsH" appears at the left of the screen. This can be overridden with *[NUMBER OF GROUPS]* (see *Trigger Menu*).

Coupling of stimulus values for the two channels is independent of *[DUAL CHAN on OFF]* in the display menu and *[MARKERS: UNCOUPLED]* in the marker mode menu. *[COUPLED CH OFF]* becomes an alternate sweep function when dual channel display is on: in this mode the analyzer alternates between the two sets of stimulus values for measurement of data, and both are displayed.

*[CW FREQ]* (CWFREQ) is used to set a CW (continuous wave) frequency for CW time measurements. The set frequency defaults to the nearest multiple of 100 kHz in a standard instrument (1 Hz in option 001).

*[SWEEP TYPE MENU]* presents the sweep type menu, where one of the available types of stimulus sweep can be selected.

## Trigger Menu

This menu is used to select the type and number of the sweep trigger.

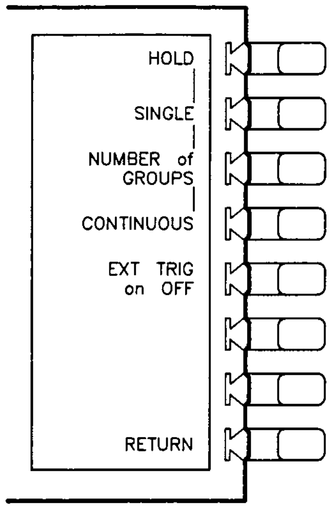



*Figure 3-4. Trigger Menu*

***[HOLD]*** (HOLD) freezes the data trace on the display, and the analyzer stops sweeping and taking data. The notation "Hld" is displayed at the left of the graticule. If the * indicator is on at the left side of the CRT, trigger a new sweep with ***[SINGLE]***.

***[SINGLE]*** (SING) takes one sweep of data and returns to the hold mode.

***[NUMBER OF GROUPS]*** (NUMG) triggers a user-specified number of sweeps, and returns to the hold mode. This function can be used to override the test set hold mode (indicated by the notation "tsH" at the left of the screen). In this mode, the electro-mechanical transfer switch and attenuator are protected against continuous switching. This occurs in a full two-port calibration, or in a measurement of two different parameters, or when the channels are uncoupled and a different power level is set for each channel.

If averaging is on, the number of groups should be at least equal to the averaging factor selected, to allow measurement of a fully averaged trace. Entering a number of groups resets the averaging counter to 1.

***[CONTINUOUS]*** (CONT) is the standard sweep mode. The sweep is triggered automatically and continuously and the trace is updated with each sweep.

***[EXT. TRIG on OFF]*** (EXTT) is used when the sweep is triggered on an externally generated signal connected to the rear panel EXT TRIGGER input. The sweep is started with a high-to-low transition of a TTL signal. If this key is pressed when no external trigger signal is connected, the notation "Ext" is displayed at the left side of the CRT to indicate that the analyzer is waiting for a trigger. When a trigger signal is connected, the "Ext" notation is replaced by the sweep speed indicator ↑ either in the status notations area or on the trace.

***[RETURN]*** goes back to the stimulus menu.

## Sweep Type Menu

Four basic sweep types are available: linear, logarithmic, and list frequency sweeps, and CW time sweep. In the linear frequency sweep mode, in option 010 instruments, data can be transformed to the time domain using the inverse Fourier transform technique. In the CW time sweep mode, data can be transformed for frequency domain measurements. Refer to Chapter 8 for detailed information about time domain transform with option 010.

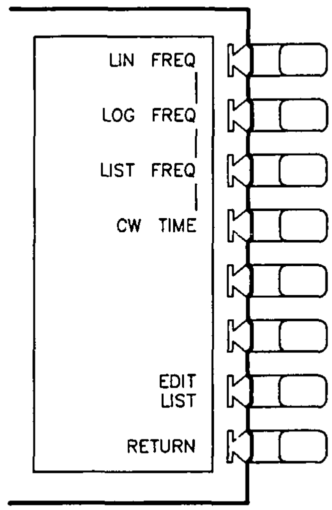



*Figure 3-5. Sweep Type Menu*

***[LIN FREQ]*** (LINFREQ) activates a linear frequency sweep displayed on a standard graticule with ten equal horizontal divisions. This is the default preset sweep type.

For a linear sweep, sweep time is combined with the channel's frequency span to compute a source sweep rate:

sweep rate =(frequency span) / (sweep time)

Since the sweep time may be affected by various factors (see *Stimulus Menu*), the equation provided here is merely an indication of the ideal (minimum) sweep rate. Narrower IF bandwidths require taking more data points, therefore sweep time increases as the IF bandwidth decreases. If the sweep time is greater than 15 ms times the number of points, the sweep changes from a synthesized ramp sweep to a stepped CW sweep.

***[LOG FREQ]*** (LOGFREQ) activates a logarithmic frequency sweep mode. The source is stepped in logarithmic increments and the data is displayed on a logarithmic graticule. This is slower than a continuous sweep with the same number of points, and the entered sweep time may therefore be changed automatically. For frequency spans of less than two octaves, the sweep type automatically reverts to linear sweep.

***[LIST FREQ]*** (LISTFREQ) provides a user-definable arbitrary frequency list mode. Up to 30 frequency subsweeps (or segments) of several different types can be specified, for a maximum total of 1601 points. One list is common to both channels, and different segments cannot be displayed simultaneously on both channels. Once a frequency list has been defined and a measurement calibration performed on the full frequency list, one or all of the frequency segments can be measured and displayed without loss of calibration. Another powerful calibration aid is *frequency subset*, explained in chapter 5 (see **[FRQ SUBSET on OFF]**).

When *[LIST FREQ]* is pressed, the segment menu is presented, for selecting segments of the frequency list. Refer to *Edit List Menu* and *Edit Subsweep Menu* later in this chapter to see how to enter or modify the list frequencies. If no list has been entered, the message "LIST TABLE EMPTY" is displayed.

***[CW TIME]*** (CWTIME) turns on a sweep mode similar to an oscilloscope. The analyzer is set to a single frequency, and the data is displayed versus time. The frequency of the CW time sweep is set with ***[CW FREQ]*** in the stimulus menu. In this sweep mode, the data is continuously sampled at precise, uniform time intervals determined by the sweep time and the number of points minus 1. The entered sweep time may be automatically changed if it is less than the minimum required for the current instrument configuration.

In time domain using option 010, the CW time mode data is translated to frequency domain, and the x-axis becomes frequency. This can be used like a spectrum analyzer to measure signal purity, or for low frequency analysis of amplitude or pulse modulation signals. For details, refer to Chapter 8, *Time and Frequency Domain Transforms*.

***[EDIT LIST]*** presents the edit list menu. This is used in conjunction with the edit subsweep menu to define or modify the frequency sweep list.

***[RETURN]*** goes back to the stimulus menu.

## Segment Menu

When this menu is presented, the frequency list table is displayed in the center of the CRT. A segment can then be selected to be measured, and the choice of a full-trace measurement or a single-segment measurement can be made. Note that the frequency list table is not drawn on a plot.

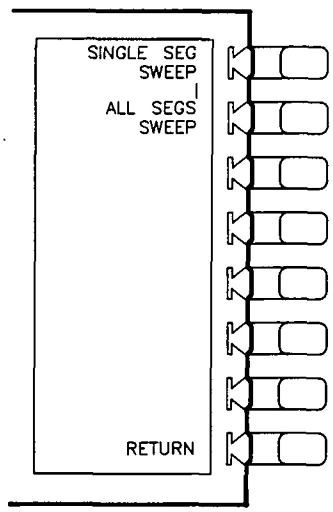



*Figure 3-6. Segment Menu*

***[SINGLE SEG SWEEP]*** (SSEG) enables a measurement of a single segment of the frequency list, without loss of calibration. The segment to be measured is selected using the entry block, after ***[SINGLE SEG SWEEP]*** is pressed.

In single segment mode, selecting a measurement calibration will force the full list sweep before prompting for calibration standards. The calibration will then be valid for any single segment.

If an instrument state is saved in memory with a single-segment sweep, a recall will re-display that segment while also recalling the entire list.

*[ALL SEGS SWEEP]* (ASEG) retrieves the full frequency list sweep.

*[RETURN]* goes back to the sweep type menu.

## Edit List Menu

This menu is used to edit the list of frequency segments (subsweeps) defined with the edit subsweep menu, described next. The segments do not have to be entered in any particular order: the analyzer automatically sorts them and lists them on the CRT in increasing order of start frequency. This menu determines which entry on the list is to be modified, while the edit subsweep menu is used to make changes in the frequency or number of points of the selected entry.

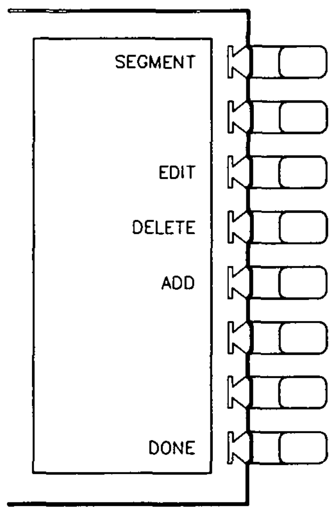



*Figure 3-7. Edit List Menu*

*[SEGMENT]* is used to select which segment on the list is to be modified. Enter the number of a segment in the list, or use the step keys to scroll the pointer >at the left to the required segment number. The indicated segment can then be edited or deleted.

*[EDIT]* goes to the edit subsweep menu, where the selected segment (indicated by the pointer >at the left) can be modified.

*[DELETE]* deletes the segment indicated by the pointer >.

*[ADD]* is used to add a new segment to the frequency list. If the list is empty, a default segment is added, and the edit subsweep menu is displayed so it can be modified. If the list is not empty, the segment indicated by the pointer >is copied and the edit subsweep menu is displayed.

*[DONE]* sorts the segments into CW points in order of ascending frequency and returns to the sweep type menu. (Note that this may change the segment numbers.) If list frequency mode is on, the network analyzer then measures each point and displays a single trace that is a composite of all data taken. If duplicate frequencies exist, the analyzer makes multiple measurements on identical points to maintain the specified number of points for each subsweep. Since the frequency points may not be distributed evenly across the CRT, the display resolution may be uneven, and more compressed in some parts of the trace than in others. However, the stimulus and response readings of the markers are always accurate. Because the list frequency sweep is a stepped CW sweep, the sweep time is slower than for a continuous sweep with the same number of points.

A tabular printout of the frequency list data can be obtained using the *[LIST VALUES]* function in the copy menu.

## Edit Subsweep Menu

This menu lets you select measurement frequencies arbitrarily. Using this menu it is possible to define the exact frequencies to be measured on a point-by-point basis. For example the sweep could include 100 points in a narrow passband, 100 points across a broad stop band, and 50 points across another frequency range. The total sweep is defined with a list of subsweeps. Up to 30 subsweeps can be defined, with a total of up to 1601 data points.

The only limitation is that measurement points cannot be closer than 100 kHz in the standard instrument. Therefore, the span of each segment must be selected such that:

segment span =100 kHz x (number of points −1) x n   where n =1, 2, 3...

For example, for a 5 MHz segment, do not use more than 51 points, otherwise the segment span will be readjusted to meet the segment span criteria.

The option 001 instrument with enhanced frequency resolution does not have this limitation.

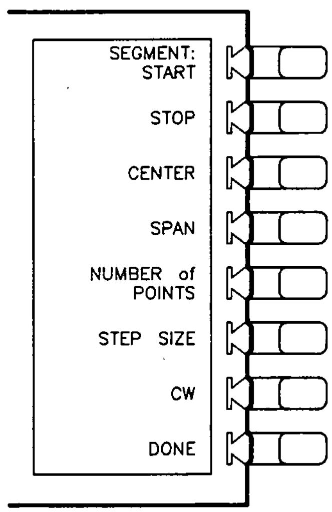



*Figure 3-8. Edit Subsweep Menu*

The frequency subsweeps, or segments, can be defined in any of the following terms:

start / stop / number of points
start / stop / step
center / span / number of points
center / span / step
CW frequency

The subsweeps can overlap, and do not have to be entered in any particular order. The analyzer sorts the segments automatically and lists them on the CRT in order of increasing start frequency, even if they are entered in center/span format. (Note that this may change the segment numbers.) If duplicate frequencies exist, the analyzer makes multiple measurements on identical points to maintain the specified number of points for each subsweep. The data is displayed on the CRT as a single trace that is a composite of all data taken, when ***[ALL SEGS TRACE]*** is selected. The trace may appear uneven because of the distribution of the data points, but the frequency scale is linear across the total range.

The list frequency sweep mode is selected with the ***[LIST FREQ]*** softkey in the sweep type menu.

***[SEGMENT START]*** sets the start frequency of a subsweep.

***[STOP]*** sets the stop frequency of a subsweep.

***[CENTER]*** sets the center frequency of a subsweep.

***[SPAN]*** sets the frequency span of a subsweep about a specified center frequency.

***[NUMBER OF POINTS]*** sets the number of points for the subsweep. The total number of points for all the subsweeps cannot exceed 1601. In a standard instrument, where the measurement points are separated by increments of 100 kHz, take care not to set a high number of points for a narrow subsweep frequency span.

***[STEP SIZE]*** is used to specify the subsweep in frequency steps instead of number of points. Changing the start frequency, stop frequency, span, or number of points may change the step size. Changing the step size may change the number of points and stop frequency in start/stop/step mode; or the frequency span in center/span/step mode. In each case, the frequency span becomes a multiple of the step size. The step size cannot be less than 100 kHz in a standard instrument.

***[CW]*** is used to set a subsweep consisting of a single CW frequency point.

***[DONE]*** returns to the edit list menu.

# Chapter 4. Response Function Block

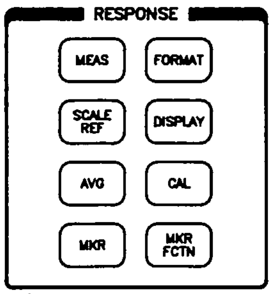



*Figure 4-1*

## INTRODUCTION

The keys in the RESPONSE block are used to control the measurement and display functions of the active channel. They provide access to many different softkey menus that offer selections for the parameters to be measured, the display mode and format of the data, the control of the display markers, and a variety of calibration functions.

The current values for the major response functions of the active channel are displayed in specific locations along the top of the CRT. In addition, certain functions accessed through the keys in this block are annotated in the status notations area at the left-hand side of the CRT. An illustration of the CRT showing the locations of these information labels is provided in Chapter 2, together with an explanation.

The RESPONSE block keys and their associated menus are described briefly below, and in more detail in this chapter and Chapters 5 (calibration) and 6 (markers). Measurement sequences using these menus are described in the *User's Guide*.

The **[MEAS]** (MENUMEAS) key leads to the menus used to select the measurement parameters.

The **[FORMAT]** (MENUFORM) key leads to a menu used to select the display format for the data. Various rectangular and polar formats are available for display of magnitude, phase, impedance, group delay, real data, and SWR.

The **[SCALE REF]** (MENUSCAL) key displays a menu used to modify the vertical axis scale and the reference line value, as well as to add electrical delay.

The **[DISPLAY]** (MENUDISP) key provides access to a series of menus of instrument and active channel display functions. The first menu defines the displayed active channel trace in terms of the mathematical relationship between data and trace memory. Other functions include dual channel display (overlay or split), display focus and intensity, active channel display title, and frequency blanking.

The **[AVG]** (MENUAVG) key is used to access three different noise reduction techniques: sweep-to-sweep averaging, trace smoothing, and variable IF bandwidth.

The **[CAL]** (MENUCAL) key leads to a series of menus to perform measurement calibrations for vector error correction (accuracy enhancement), and for specifying the calibration standards used. Calibration procedures are used to improve measurement accuracy by effectively removing systematic errors prior to making measurements. Several different levels of calibration are available for use in a variety of different measurement applications. Each calibration procedure features CRT prompts to guide you through the calibration sequence.

An explanation of vector error correction techniques to enhance measurement accuracy is included with the description of the calibration menus and procedures. Refer to Chapter 5, *Measurement Calibration*, and to the Appendix to Chapter 5, *Accuracy Enhancement Fundamentals—Characterizing Microwave Systematic Errors*.

The **[MKR]** (MENUMARK) key displays an active marker (▽) on the screen and provides access to a series of menus to control from one to four display markers for each channel. Markers provide numerical readout of measured values at any point on the trace.

The menus accessed from the **[MKR]** key provide several basic marker operations. These include special marker modes for different display formats, and a marker delta mode that displays marker values relative to a specified value or another marker.

The **[MKR FCTN]** (MENUMRKF) key provides access to additional marker functions. These use the markers to search the trace for specified information, to analyze the trace statistically, or to quickly change the stimulus parameters.

Menus accessed from the **[MKR]** and **[MKR FCTN]** keys are explained in Chapter 6, *Using Markers*.

## [MEAS] KEY

The **[MEAS]** (MENUMEAS) key leads to a menu that provides a selection of transmission and reflection measurements, each corresponding to a specific S-parameter. When these measurements are performed, all of the DUT's ports must be properly terminated.

A second menu converts S-parameters to impedance (Z), admittance (Y), or inverse S-parameters through internal math capabilities.

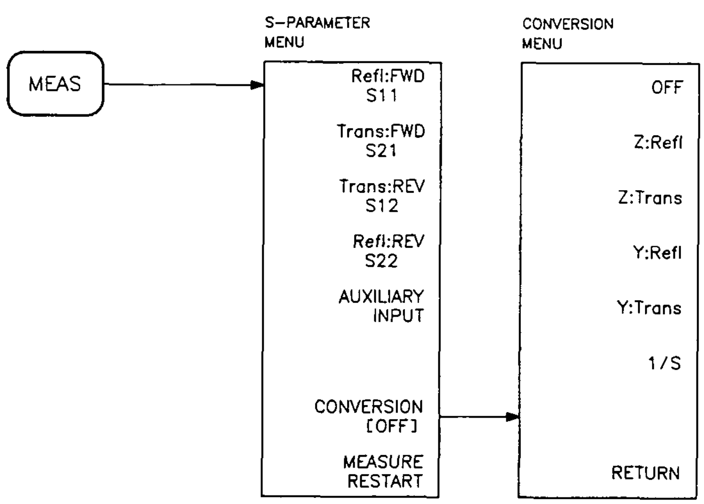



*Figure 4-2. Softkey Menus Accessed from the [MEAS] Key*

## S-Parameters

S-parameters (scattering parameters) are a convention used to characterize the way a device modifies signal flow. A brief explanation is provided here of the S-parameters of a two-port device. For additional details refer to Hewlett-Packard Application Notes AN 95-1 and AN 154.

S-parameters are ratios of two complex (magnitude and phase) quantities. S-parameter notation identifies these quantities using the numbering convention:

S out in

where the first number (out) refers to the port where the signal is emerging from the DUT, and the second number (in) is the port where the signal is incident. For example, the S-parameter S21 identifies the measurement as the complex ratio of the signal emerging at port 2 to the signal incident at port 1.

Figure 4-3 is a representation of the S-parameters of a two-port device, together with an equivalent flowgraph indicating signal flow. In the illustration, "a" represents the signal entering the device and "b" represents the signal emerging.

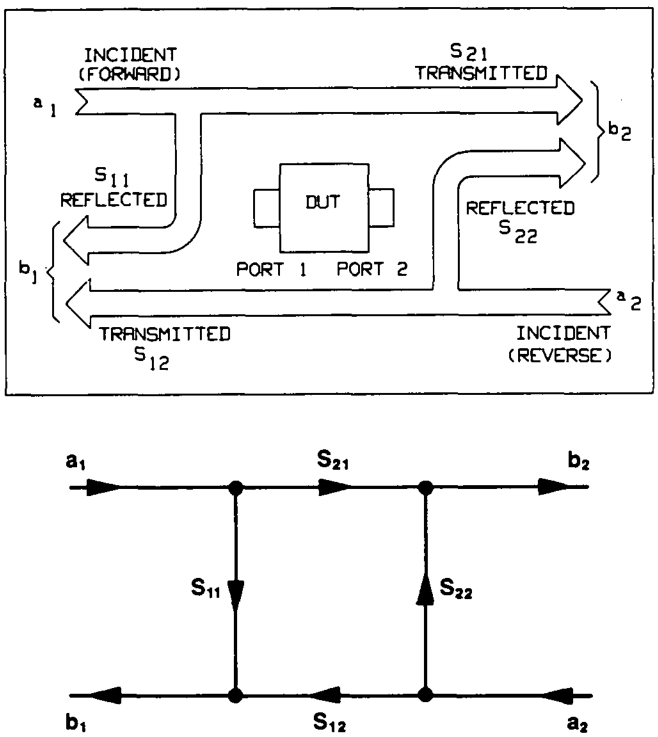



*Figure 4-3. S-Parameters of a Two-Port Device*

The table on the next page shows the reflection and transmission measurement options and their associated S-parameters. The test direction column in the table indicates which measurement port provides the signal output. For forward (FWD) measurements, the source signal is provided at port 1, and for reverse (REV) measurements, at port 2. The signal path column indicates the ratio measurement made. A, B, and R are the internal receiver/detector inputs.

| Measurement | S-Parameter | Test Direction | Signal Path |
|---|---|---|---|
| Input reflection (port 1) | S11 | FWD | A/R |
| Forward gain/loss (transmission) | S21 | FWD | B/R |
| Reverse gain/loss (transmission) | S12 | REV | A/R |
| Output reflection (port 2) | S22 | REV | B/R |

## S-Parameter Menu

The S-parameter menu is presented when the **[MEAS]** key is pressed. This menu provides a selection of transmission and reflection measurements, with each choice corresponding to a specific S-parameter. The analyzer automatically switches the direction of the measurement according to the selections made in this menu. All four S-parameters can be measured with a single connection. The S-parameter being measured is labeled at the top left corner of the CRT.

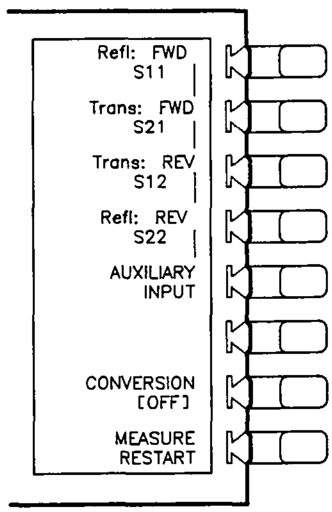



*Figure 4-4. S-Parameter Menu*

***[Refl: FWD S11]*** (S11) configures the instrument for a measurement of S11, the complex reflection coefficient (magnitude and phase) of the test device input.

***[Trans: FWD S21]*** (S21) configures the instrument for a measurement of S21, the complex forward transmission coefficient (magnitude and phase) of the device under test.

***[Trans: REV S12]*** (S12) configures the instrument for a measurement of S12, the complex reverse transmission coefficient (magnitude and phase) of the device under test.

*[Refl: REV S22]* (S22) defines the measurement as S22, the complex reflection coefficient (magnitude and phase) of the output of the device under test.

*[AUXILIARY INPUT]* (ANAI) displays a DC or low frequency AC auxiliary voltage on the vertical axis, using the real format. An external signal source such as a detector or function generator can be connected to the rear panel AUXILIARY INPUT connector. (For service purposes, one of numerous internal voltage nodes on the analog bus can be selected for measurement and display. Applications of this function are described in the *Service Manual*.)

*[CONVERSION]* brings up the conversion menu which converts the measured data to impedance (Z) or admittance (Y). When a conversion parameter has been defined, it is shown in brackets under the softkey label. If no conversion has been defined, the softkey label reads *[CONVERSION OFF]*.

*[MEASURE RESTART]* (REST) aborts the sweep in progress, then restarts the measurement. This can be used to update a measurement following an adjustment of the device under test. When a full two-port calibration is in effect, the *[MEASURE RESTART]* key will initiate another update of both forward and reverse S-parameter data.

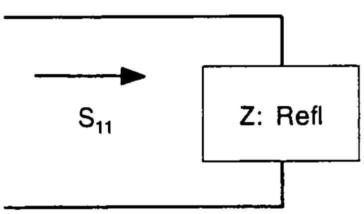
If the instrument is taking a number of groups (see *Trigger Menu* in Chapter 3), the sweep counter is reset at 1. If averaging is on, *[MEASURE RESTART]* resets the sweep-to-sweep averaging and is effectively the same as *[AVERAGING RESTART]*. If the sweep trigger is in *[HOLD]* mode, *[MEASURE RESTART]* executes a single sweep.

## Conversion Menu

This menu converts the measured reflection or transmission data to the equivalent complex impedance (Z) or admittance (Y) values. This is not the same as a two-port Y or Z parameter conversion, as only the measured parameter is used in the equations. Two simple one-port conversions are available, depending on the measurement configuration.

For measurements in an environment that is not 50 ohms, a minimum loss pad or matching transformer should be inserted between the device and the measurement port. In addition, the network analyzer characteristic impedance must be modified using the *[SET Z0]* softkey in the calibrate more menu.

An S11 or S22 trace measured as reflection can be converted to equivalent parallel impedance or admittance using the model and equations shown in Figure 4-5.




Z: Refl

$$Z_R = Z0 \cdot \frac{1 + S_{11}}{1 - S_{11}}$$

Y: Refl

$$Y_R = \frac{1}{Z_R}$$

*Figure 4-5. Reflection Impedance and Admittance Conversions*

In a transmission measurement, the data can be converted to its equivalent series impedance or admittance using the model and equations shown in Figure 4-6.

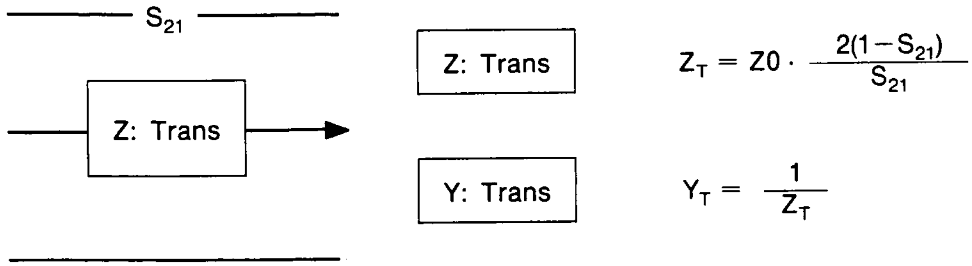



*Figure 4-6. Transmission Impedance and Admittance Conversions*

Avoid the use of Smith chart, SWR, and delay formats for display of Z and Y conversions, as these formats are not easily interpreted.

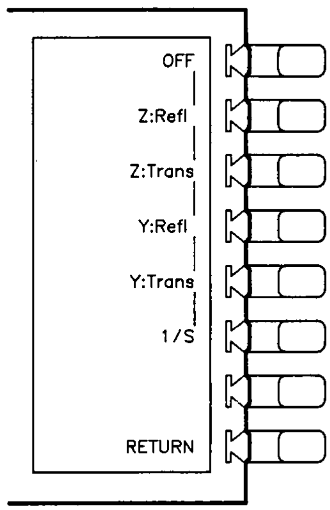



*Figure 4-7. Conversion Menu*

***[OFF]*** (CONVOFF) turns off all parameter conversion operations.

***[Z: Refl]*** (CONVZREF) converts reflection data to its equivalent parallel impedance values.

***[Z: Trans]*** (CONVZTRA) converts transmission data to its equivalent series impedance values.

***[Y: Refl]*** (CONVYREF) converts reflection data to its equivalent parallel admittance values.

***[Y: Trans]*** (CONVYTRA) converts transmission data to its equivalent series admittance values.

***[1/S]*** (CONV1DS) expresses the data in inverse S-parameter values, for use in amplifier and oscillator design. A convenient way to check for transistor stability is to compare S11 and 1/S22 on a Smith chart using a dual channel overlay display (see *Display Menu*).

***[RETURN]*** returns to the S-parameter menu.

## [FORMAT] KEY

### Format Menu

The **[FORMAT]** (MENUFORM) key presents a menu used to select the appropriate display format for the measured data. Various rectangular and polar formats are available for display of magnitude, phase, real data, impedance, group delay, and SWR. The units of measurement are changed automatically to correspond with the displayed format. Special marker menus are available for the polar and Smith formats, each providing several different marker types for readout of values (see Chapter 6).

The format defined for display of a particular S-parameter is remembered with that parameter. Thus if different S-parameters are measured, even if only one channel is used, each parameter is shown in its selected format each time it is displayed.

The illustrations in the following pages show measurements of a bandpass filter displayed in each of the available formats.

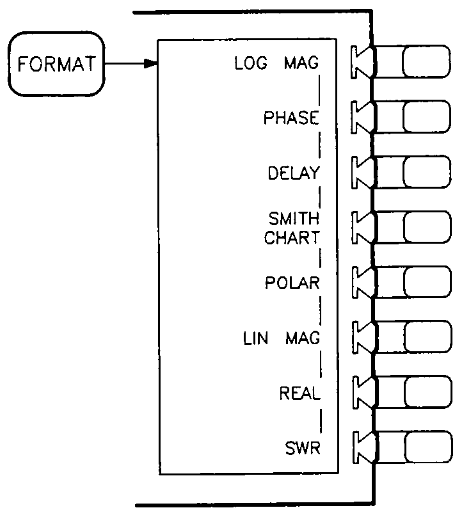



*Figure 4-8. Format Menu*

***[LOG MAG]*** (LOGM) displays the log magnitude format. This is the standard Cartesian format used to display magnitude-only measurements of insertion loss, return loss, or absolute power in dB versus frequency. Figure 4-9 illustrates the bandpass filter reflection data in a log magnitude format.

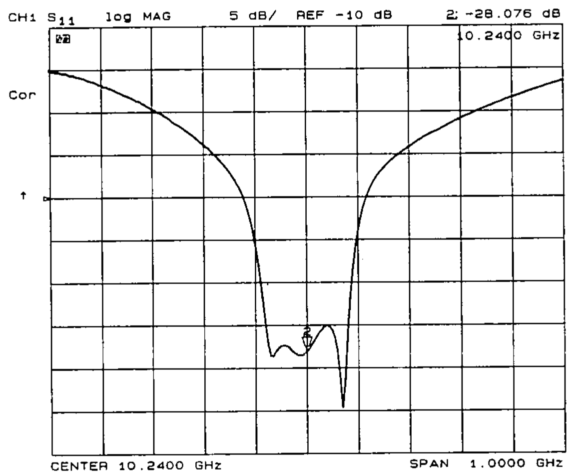



*Figure 4-9. Log Magnitude Format*

***[PHASE]*** (PHAS) displays the phase shift of the data versus frequency in a Cartesian format, as illustrated in Figure 4-10. A measurement of phase response is described in the *User's Guide*.

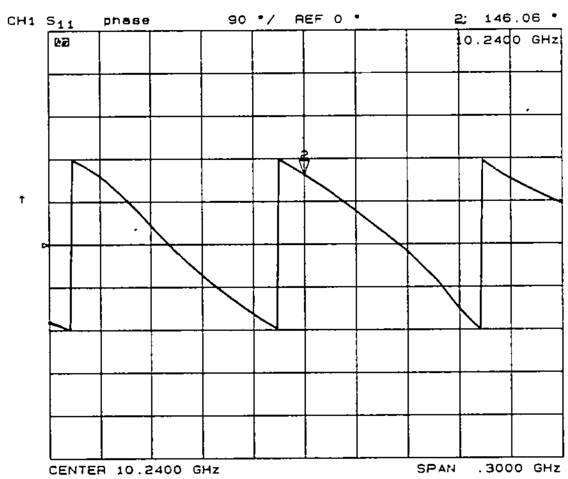



*Figure 4-10. Phase Format*

*[DELAY]* (DELA) selects the group delay format, with marker values given in seconds. Figure 4-11 shows the bandpass filter response formatted as group delay. Group delay principles are described in the next few pages.

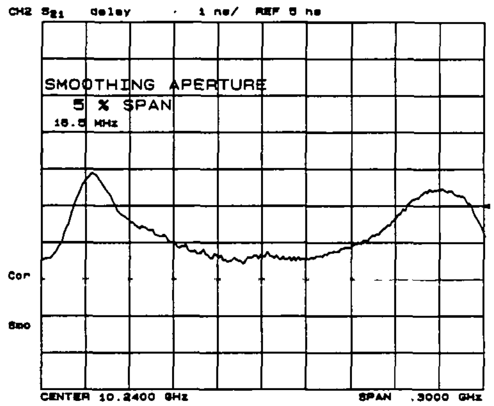



*Figure 4-11. Group Delay Format*

*[SMITH CHART]* (SMIC) displays a Smith chart format (Figure 4-12a). This is used in reflection measurements to provide a readout of the data in terms of impedance. The intersecting dotted lines on the Smith chart represent constant resistance and constant reactance values, normalized to the characteristic impedance, Z0, of the system. Reactance values in the upper half of the Smith chart circle are positive (inductive) reactance, and in the lower half of the circle are negative (capacitive) reactance. The default marker readout is in units of resistance and reactance (R+jX), as well as frequency. Additional marker types are available in the Smith marker menu (refer to Chapter 6, *Using Markers*).

The Smith chart is most easily understood with a full scale value of 1.0. If the scale per division is less than 0.2, the format switches automatically to polar.

For measurements in an environment that is not 50 ohms, modify the impedance value recognized by the analyzer using the *[SET Z0]* softkey in the calibrate more menu, to set the center value of the Smith chart. Refer to Chapter 5, *Measurement Calibration*.

An inverted Smith chart format for admittance measurements (Figure 4-12b) is also available. Access this by selecting *[SMITH CHART]* in this format menu, and pressing *[MKR] [MARKER MODE MENU] [SMITH MKR MENU] [G+jB MKR]*. The Smith chart is then reversed and marker values are read out in units of conductance and susceptance (G+jB).

Procedures for measuring impedance and admittance are provided in the *User's Guide*.

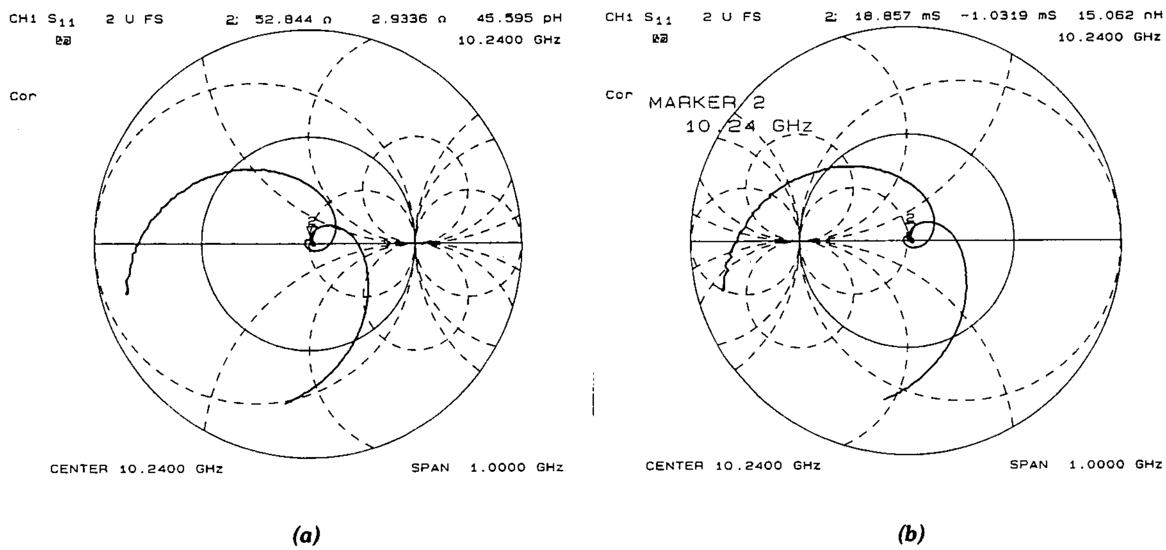



*Figure 4-12. Standard and Inverse Smith Chart Formats*

***[POLAR]*** (POLA) displays a polar format (Figure 4-13). Each point on the polar format corresponds to a particular value of both magnitude and phase. Quantities are read vectorally: the magnitude at any point is determined by its displacement from the center (which has zero value), and the phase by the angle counterclockwise from the positive x-axis. Magnitude is scaled in a linear fashion, with the value of the outer circle usually set to a ratio value of 1. Since there is no frequency axis, frequency information is read from the markers.

The default marker readout for the polar format is in linear magnitude and phase. A log magnitude marker and a real/imaginary marker are available in the polar marker menu (refer to Chapter 6, *Using Markers*).

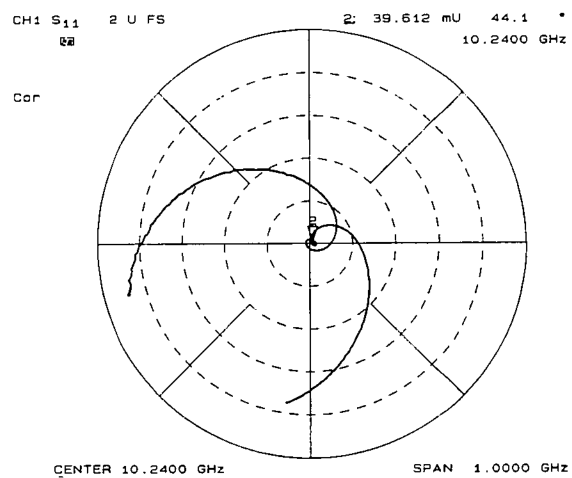



*Figure 4-13. Polar Format*

*[LIN MAG]* (LINM) displays the linear magnitude format (Figure 4-14). This is a Cartesian format used for unitless measurements such as reflection coefficient magnitude ρ or transmission coefficient magnitude τ, and for linear measurement units. It is used for display of conversion parameters and time domain transform data.

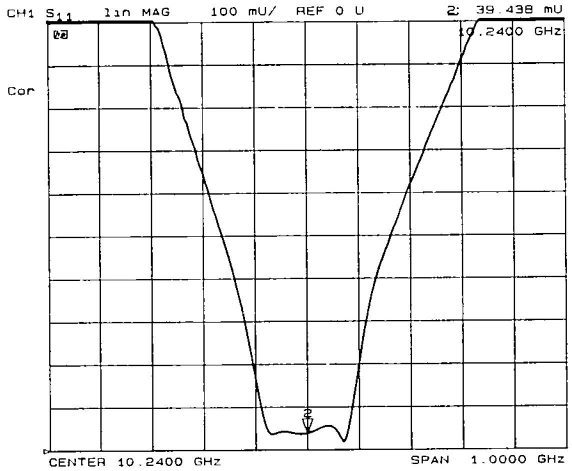



*Figure 4-14. Linear Magnitude Format*

*[REAL]* (REAL) displays only the real part of the measured data on a Cartesian format (Figure 4-15). This is similar to the linear magnitude format, but can show both positive and negative values. It is primarily used for analyzing responses in the time domain, or for display of an auxiliary input voltage signal for service purposes.

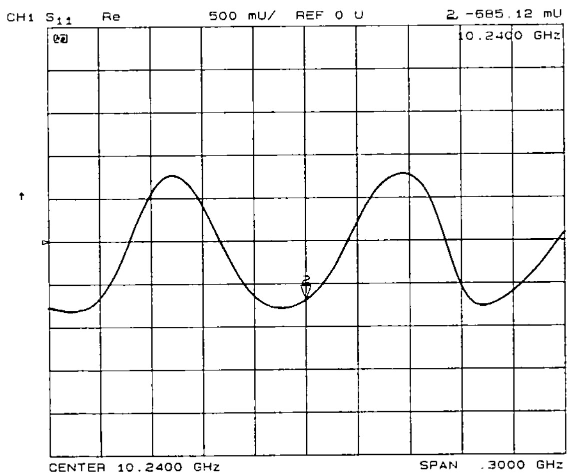



*Figure 4-15. Real Format*

*[SWR]* (SWR) reformats a reflection measurement into its equivalent SWR (standing wave ratio) value (Figure 4-16). SWR is equivalent to $(1+\rho)/(1-\rho)$, where ρ is the reflection coefficient. Note that the results are valid only for reflection measurements. If the SWR format is used for measurements of S21 or S12 the results are not valid.

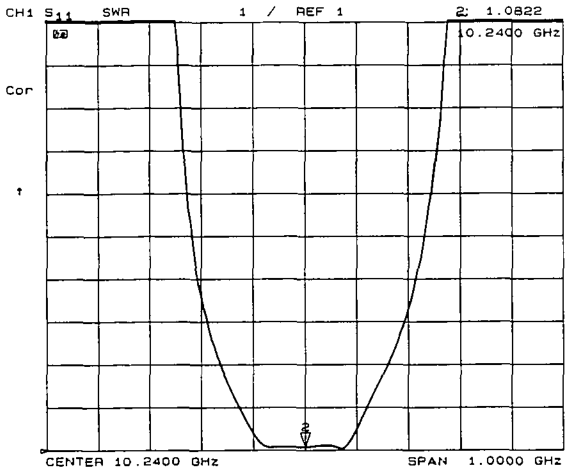



*Figure 4-16. Typical SWR Display*

## GROUP DELAY PRINCIPLES

For many networks, the amount of insertion phase is not as important as the linearity of the phase shift over a range of frequencies. The analyzer can measure this linearity and express it in two different ways: directly, as deviation from linear phase, or as group delay, a derived value. Refer to *[SCALE REF]* in this chapter for information on deviation from linear phase.

Group delay is the measurement of signal transmission time through a test device. It is defined as the derivative of the phase characteristic with respect to frequency. Since the derivative is basically the instantaneous slope (or rate of change of phase with frequency), a perfectly linear phase shift results in a constant slope, and therefore a constant group delay (Figure 4-17).

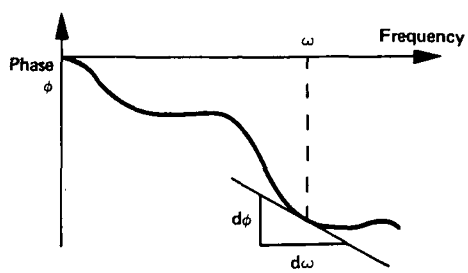
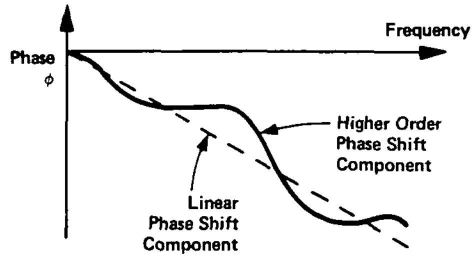



*Figure 4-17*

Note, however, that the phase characteristic typically consists 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 (Figure 4-18).




$$\text{Group Delay} = \tau_g = \frac{-d\phi}{d\omega} \qquad \phi \text{ in Radians}, \ \omega \text{ in Radians}$$

$$= \frac{-1}{360^\circ} \cdot \frac{d\phi}{df} \qquad \phi \text{ in Degrees}, \ f \text{ in Hz } (\omega = 2\pi f)$$

*Figure 4-18*

The network analyzer computes group delay from the phase slope. Phase data is used to find the phase change, $\Delta\varphi$, over a specified frequency aperture, $\Delta f$, to obtain an approximation for the rate of change of phase with frequency (Figure 4-19). This value, $\tau_g$, represents the group delay in seconds assuming linear phase change over $\Delta f$. It is important that $\Delta\varphi$ be $\leq 180°$, or errors will result in the group delay data. These errors can be significant for long delay devices.

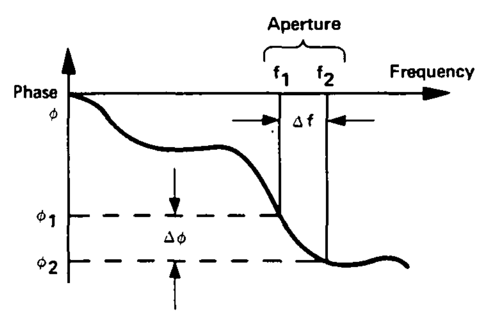



*Figure 4-19*

When deviations from linear phase are present, changing the frequency step can result in different values for group delay. Note that in this case the computed slope varies as the aperture $\Delta f$ is increased (Figure 4-20). 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 it is important to know the aperture used to make the measurement.

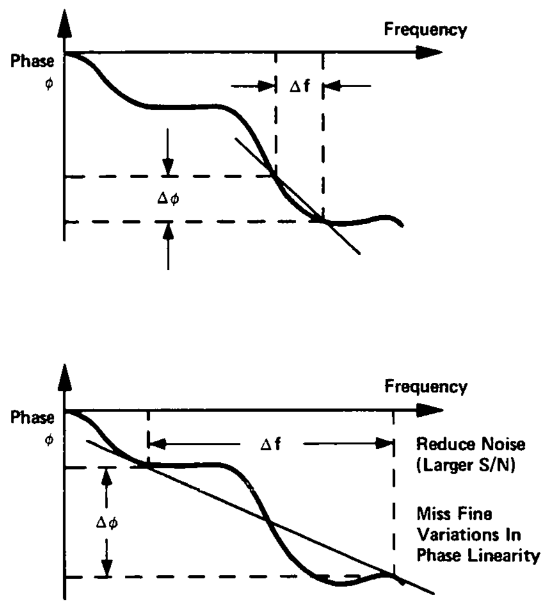



*Figure 4-20*

In determining the group delay aperture, there is a tradeoff between resolution of fine detail and the effects of noise. Noise can be reduced by increasing the aperture, but this will tend to smooth out the fine detail. More detail will become visible as the aperture is decreased, but the noise will also increase, possibly to the point of obscuring the detail. A good practice is to use a smaller aperture to assure that small variations are not missed, then increase the aperture to smooth the trace.

The default (minimum) group delay aperture is the frequency span divided by the number of points across the display. To increase the aperture, turn on smoothing in the average menu, and vary the smoothing aperture (see *[AVG] Key*). The aperture can be varied up to 20% of the span swept.

The maximum delay range is limited to measuring no more than ±180°of phase change within the minimum aperture. For example, with a minimum aperture of 100 kHz, the maximum delay that can be measured is 5 microseconds.

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

$$\pm \frac{0.003 \times \text{Phase Accuracy (deg)}}{\text{Aperture (Hz)}}$$

Group delay measurements can be made on linear frequency, log frequency, or list frequency sweep types (not in CW). Group delay aperture varies depending on the frequency spacing and point density, therefore the aperture is not constant in log and list frequency sweep modes. In list frequency mode, extra frequency points can be defined to ensure the desired aperture.

To obtain a readout of aperture values at different points on the trace, turn on a marker. Then press **[AVG]** ***[SMOOTHING APERTURE]***. Smoothing aperture becomes the active function, and as the aperture is varied its value in MHz is displayed in the active entry area.

A group delay measurement procedure is provided in the *User's Guide*.

# [SCALE REF] KEY

## Scale Reference Menu

The **[SCALE REF]** (MENUSCAL) key makes scale per division the active function. The menu displayed is used to modify the vertical axis scale and the reference line value and position. In addition this menu provides electrical delay offset capabilities for adding or subtracting linear phase to maintain phase linearity.

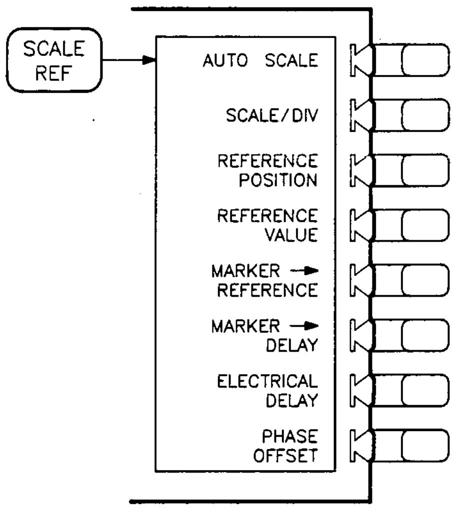



*Figure 4-21. Scale Reference Menu*

***[AUTO SCALE]*** (AUTO) brings the trace data in view on the CRT with one keystroke. Stimulus values are not affected, only scale and reference values. The analyzer determines the smallest possible scale factor that will put all displayed data onto the vertical graticule. The reference value is chosen to put the trace in center screen, then rounded to an integer multiple of the scale factor.

***[SCALE/DIV]*** (SCAL) changes the response value scale per division of the displayed trace. In polar and Smith chart formats, this refers to the full scale value at the outer circumference, and is identical to reference value.

***[REFERENCE POSITION]*** (REFP) sets the position of the reference line on the graticule of a Cartesian display, with 0 the bottom line of the graticule and 10 the top line. It has no effect on a polar or Smith display. The reference position is indicated with a small triangle just outside the graticule, on the left side for channel 1 and the right side for channel 2.

***[REFERENCE VALUE]*** (REFV) changes the value of the reference line, moving the measurement trace correspondingly. In polar and Smith chart formats, the reference value is the same as the scale, and is the value of the outer circle.

***[MARKER →REFERENCE]*** (MARKREF) makes the reference value equal to the active marker's absolute value (regardless of the delta marker value). The marker is effectively moved to the reference line position. This softkey also appears in the marker function menu accessed from the ***[MKR FCTN]*** key. In polar and Smith chart formats this function makes the full scale value at the outer circle equal to the active marker response value.

*[MARKER →DELAY]* (MARKDELA) adjusts the electrical delay to balance the phase of the DUT. This is performed automatically, regardless of the format and the measurement being made. Enough line length is added to or subtracted from the receiver input to compensate for the phase slope at the active marker position. This effectively flattens the phase trace around the active marker, and can be used to measure electrical length or deviation from linear phase. Additional electrical delay adjustments are required on DUTs without constant group delay over the measured frequency span.

*[ELECTRICAL DELAY]* (ELED) adjusts the electrical delay to balance the phase of the DUT. It simulates a variable length lossless transmission line, which can be added to or removed from the analyzer's internal reference port to compensate for interconnecting cables, etc. This function is similar to the mechanical or analog "line stretchers" of other network analyzers. Delay is annotated in units of time with secondary labeling in distance for the current velocity factor. The maximum electrical delay that can be added is 10 microseconds, in standard instrument, 10 seconds with option 001.

With this feature, and with ***[MARKER →DELAY]***, an equivalent length of air is added or subtracted according to the following formula:

$$\text{Length (metres)} = \frac{\varphi}{\text{F(MHz)} * 1.20083}$$

Once the linear portion of the DUT's phase has been removed, the equivalent length of air can be read out in the active marker area. If the average relative permittivity ($\varepsilon_r$) of the DUT is known over the frequency span, the length calculation can be adjusted to indicate the actual length of the DUT more closely. This can be done by entering the relative velocity factor for the DUT using the calibrate more menu. The relative velocity factor for a given dielectric can be calculated by:

$$\text{Velocity factor} = 1/\sqrt{\varepsilon_r}$$

assuming a relative permeability of 1.

A procedure for measuring electrical length or deviation from linear phase using the ***[ELECTRICAL DELAY]*** or ***[MARKER →DELAY]*** features is provided in the *User's Guide*.

***[PHASE OFFSET]*** (PHAO) adds or subtracts a phase offset that is constant with frequency (rather than linear). This is independent of ***[MARKER →DELAY]*** and ***[ELECTRICAL DELAY]***.

## [DISPLAY] KEY

The **[DISPLAY]** (MENUDISP) key provides access to the memory math functions, and other display functions including dual channel display, active channel display title, frequency blanking, and display adjustments.

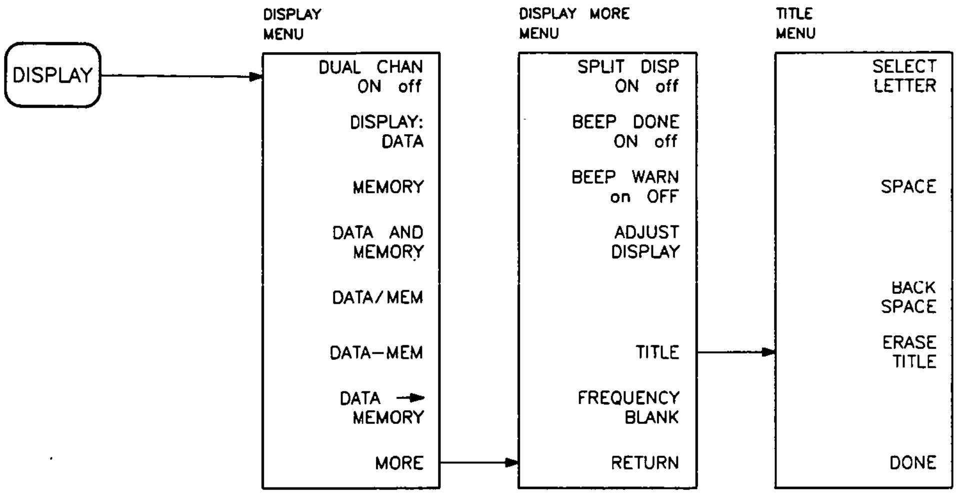



*Figure 4-22. Softkey Menus Accessed from the [DISPLAY] Key*

### Display Menu

This menu provides trace math capabilities for manipulating data, as well as the capability of displaying both channels simultaneously, either overlaid or split.

The analyzer has two available memory traces, one per channel. Memory traces are totally channel dependent: channel 1 cannot access the channel 2 memory trace or vice versa. Memory traces can be saved with instrument states: one memory trace can be saved per channel per saved instrument state. Five save/recall registers are available for each channel. The memory data is stored as full precision, complex data. (Refer to Chapter 10, *Saving Instrument States*.)

Two trace math operations are implemented, data/memory and data−memory. (Note that normalization is data/memory not data−memory.) Memory trace save and recall and trace math are done immediately after error correction. This means that any additional post-processing done after error correction, including S-parameter conversion, time domain transformation (option 010), scaling, etc., can be performed on the memory trace. (Refer to *Data Processing* in Chapter 1.) Trace math can also be used as a simple means of error correction, although that is not its main purpose.

All data processing operations that occur after trace math, except smoothing and gating, are identical for the data trace and the memory trace.

The actual memory for storing a memory trace is allocated only as needed. The memory trace is cleared on instrument preset, power on, or instrument state recall.

Note that if sweep mode or sweep range is different between the data and memory traces, trace math is allowed, and no warning message is given. If the number of points in the two traces is different, the memory trace is not displayed and the message "CAUTION: NO VALID MEMORY TRACE" appears. However, if the number of points for the data trace is changed back to the number of points in the memory, the memory trace can then be displayed.

If trace math or display memory is requested and no memory trace exists, the message "CAUTION: NO VALID MEMORY TRACE" is displayed.

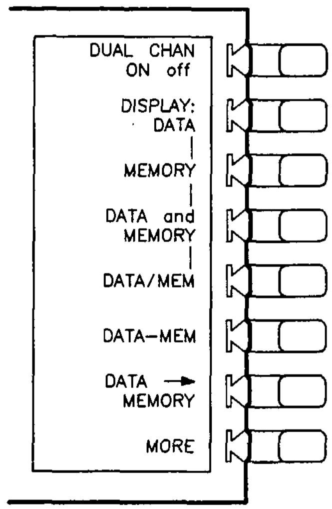
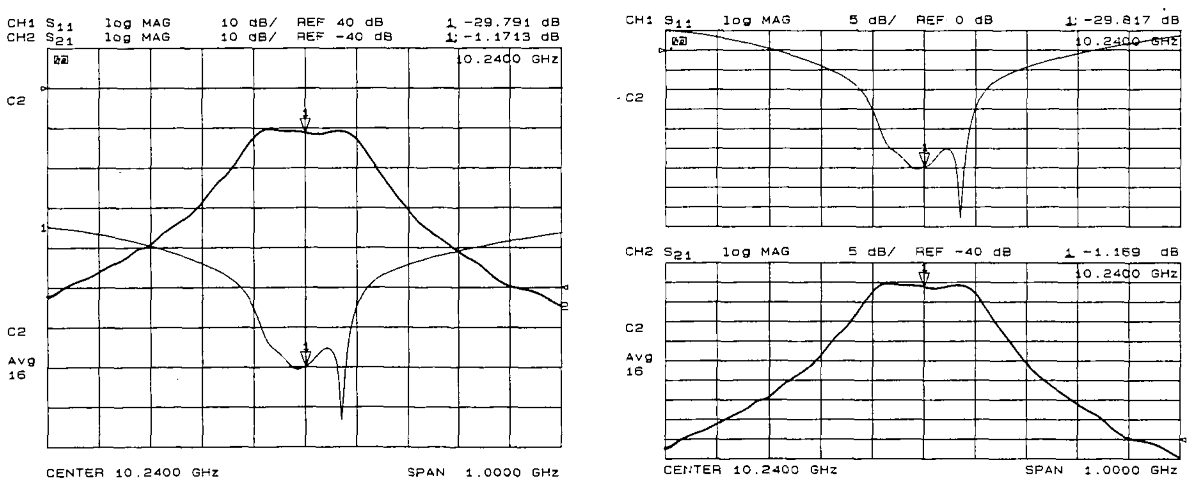



*Figure 4-23. Display Menu*

***[DUAL CHAN on OFF]*** (DUACON, DUACOFF) toggles between display of both measurement channels or the active channel only. This is used in conjunction with ***[SPLIT DISP on OFF]*** in the display more menu to display both channels. With ***[SPLIT DISP OFF]*** the two traces are overlaid on a single graticule (Figure 4-24a); with ***[SPLIT DISP ON]*** the measurement data is displayed on two half-screen graticules one above the other (Figure 4-24b). Current parameters for the two displays are annotated separately.

When two different parameters are measured simultaneously, the test set hold mode is implemented. In this mode, the transfer switch and attenuator are protected against continuous switching, and the status notation "tsH" appears at the left of the screen. This can be overridden with ***[NUMBER OF GROUPS]*** (see *Trigger Menu* in Chapter 3).

The stimulus functions of the two channels can also be controlled independently using ***[COUPLED CH ON]*** in the stimulus menu (see Chapter 3). In addition, the markers can be controlled independently for each channel using ***[MARKERS: UNCOUPLED]*** in the marker mode menu (Chapter 6).




*(a) Overlay Display* *(b) Split Display*

*Figure 4-24. Dual Channel Displays*

*[DISPLAY: DATA]* (DISPDATA) displays the current measurement data for the active channel.

*[MEMORY]* (DISPMEMO) displays the trace memory for the active channel. This is the only memory display mode where the smoothing or gating of the memory trace can be changed. If no data has been stored in memory for this channel, a warning message is displayed.

*[DATA and MEMORY]* (DISPDATM) displays both the current data and memory traces.

*[DATA/MEM]* (DISPDDM) divides the data by the memory, normalizing the data to the memory, and displays the result. This is useful for ratio comparison of two traces, for instance in measurements of gain or attenuation.

*[DATA−MEM]* (DISPDMM) subtracts the memory from the data. The vector subtraction is performed on the complex data. This is appropriate for storing a measured vector error, for example directivity, and later subtracting it from the device measurement.

*[DATA →MEMORY]* (DATI) stores the current active measurement data in the memory of the active channel. It then becomes the memory trace, for use in subsequent math manipulations or display. If a parameter has just been changed and the * status notation is displayed at the left of the CRT, the data is not stored in memory until a clean sweep has been executed.

*[MORE]* leads to the display more menu.

## Display More Menu

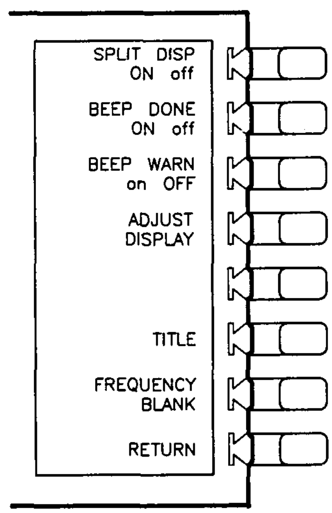



*Figure 4-25. Display More Menu*

*[SPLIT DISP on OFF]* (SPLDON, SPLDOFF) toggles between a full-screen single graticule display of one or both channels, and a split display with two half-screen graticules one above the other. Both displays are illustrated in Figure 4-24. The split display can be used in conjunction with *[DUAL CHAN ON]* in the display menu to show the measured data of each channel simultaneously on separate graticules. In addition, the stimulus functions of the two channels can be controlled independently using *[COUPLED CH ON]* in the stimulus menu. The markers can also be controlled independently for each channel using *[MARKERS: UNCOUPLED]* in the marker mode menu.

*[BEEP DONE ON off]* (BEEPDONEON, BEEPDONEOFF) toggles a low-toned beeper that sounds to indicate completion of certain operations such as calibration or instrument state save.

*[BEEP WARN on OFF]* (BEEPWARNON, BEEPWARNOFF) toggles the warning beeper. When the beeper is on it sounds a warning when a cautionary message is displayed.

**[ADJUST DISPLAY]** presents a menu which allows varying the intensity and color of different parts of the CRT display.

*[TITLE]* (TITL) presents the title menu in the softkey labels area and the character set in the active entry area. These are used to label the active channel display.

*[FREQUENCY BLANK]* (FREO) blanks the displayed frequency notation for security purposes. Frequency labels cannot be restored except by instrument preset or cycling power.

*[RETURN]* goes back to the display menu.

## Adjust Display Menu

Keys in this menu change the overall intensity and background intensity directly, return the CRT to the default colors, and save and recall customized color combinations. **[MODIFY COLORS]** presents a menu explained below.

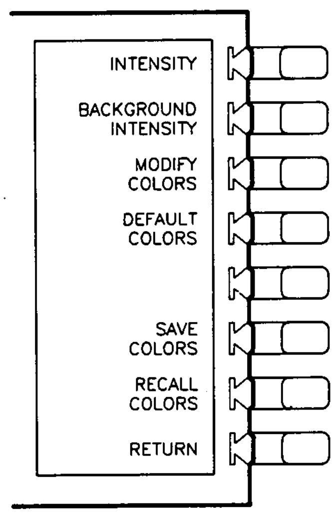



*Figure 4-26. Adjust Display Menu*

*[INTENSITY]*. adjusts the overall intensity of the CRT.

*[BACKGROUND INTENSITY]* adjusts the background intensity from black (default, 0%) to white (100%).

*[MODIFY COLORS]* presents a menu of CRT elements which can be individually modified.

*[DEFAULT COLORS]* returns the CRT to the factory-set color scheme.

*[SAVE COLORS]* saves any modifications made in the modify colors menu. These changes are not affected by preset or cycling power.

*[RECALL COLORS]* recalls any modifications made in the modify colors menu.

*[RETURN]* accesses the previous menu.

## Modify Colors Menu

This menu allows selection of the individual CRT element to be modified by the "tint brightness color" menu. Selecting any softkey but ***[RETURN]*** presents the "tint brightness color" menu.

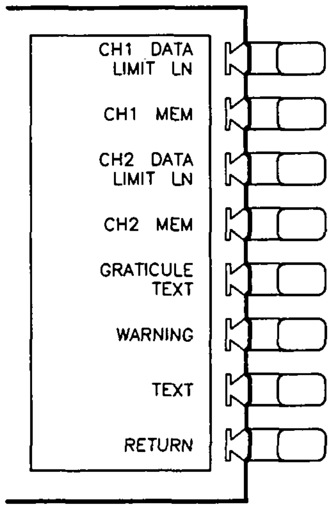



*Figure 4-27. Modify Colors Menu*

***[CH1 DATA LIMIT LN]*** selects the channel 1 data trace and limit line.

***[CH1 MEM]*** selects the channel 1 memory trace.

***[CH2 DATA LIMIT LN]*** selects the channel 2 data trace and limit line.

***[CH2 MEM]*** selects the channel 2 memory trace.

***[GRATICULE TEXT]*** selects the graticule and some softkey text.

***[WARNING]*** selects the warning annotation (like error messages).

***[TEXT]*** selects all non-data text (like softkey labels, operating parameters).

***[RETURN]*** presents the previous menu.

## Tint Brightness Color Menu

This menu makes the changes to the CRT element selected in the previous menu.

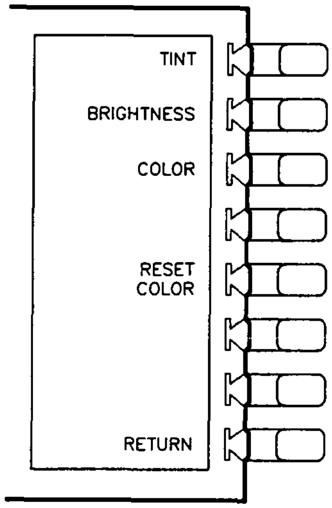



*Figure 4-28. Tint Brightness Color Menu*

***[TINT]*** can be varied from 0% to 100% to change the CRT element from red to orange, yellow, green, blue, violet and back to red. If varying tint has no visible effect, increase the color percentage first.

***[BRIGHTNESS]*** can be varied from 0% (minimum) to 100% (maximum).

***[COLOR]*** can be varied from 0% (no tint, all white) to 100% (all tint, no white). For example when the tint is red, increasing the color will change it from white (no tint) to pale pink, to pink, dark pink, light red, red, and brilliant red.

***[RESET COLOR]*** returns the CRT element selected to its default setting.

***[RETURN]*** recalls the modify colors menu.

## Title Menu

Use this menu to specify a title for the active channel. The title identifies the display regardless of stimulus or response changes, and is printed or plotted with the data. If the display is saved in a register with the instrument state, the title is saved with it.

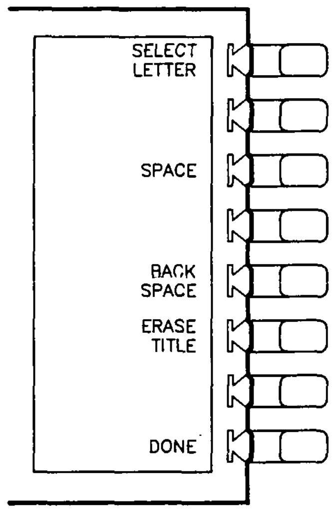



*Figure 4-29. Title Menu*

***[SELECT LETTER]***. The active entry area displays the letters of the alphabet, digits 0 through 9, and mathematical symbols. To define a title, rotate the knob until the arrow ↑ points at the first letter, then press ***[SELECT LETTER]***. Repeat this until the complete title is defined, for a maximum of 50 characters. As each character is selected, it is appended to the title at the top of the graticule.

***[SPACE]*** inserts a space in the title.

***[BACK SPACE]*** deletes the last character entered.

***[ERASE TITLE]*** deletes the entire title.

***[DONE]*** terminates the title entry, and returns to the display more menu.

## [AVG] KEY

The **[AVG]** (MENUAVG) key is used to access three different noise reduction techniques: sweep-to-sweep averaging, display smoothing, and variable IF bandwidth. Any or all of these can be used simultaneously. Averaging and smoothing can be set independently for each channel, and the IF bandwidth can be set independently if the stimulus is uncoupled.

**Averaging** computes each data point based on an exponential average of consecutive sweeps weighted by a user-specified averaging factor. Each new sweep is averaged into the trace until the total number of sweeps is equal to the averaging factor, for a fully averaged trace. Each point on the trace is the vector sum of the current trace data and the data from the previous sweep. A high averaging factor gives the best signal-to-noise ratio, but in order to obtain a valid measurement with a specified averaging factor, it is necessary to wait for the number of sweeps to equal the averaging factor. Doubling the averaging factor reduces the noise by 3 dB. Figure 4-30 illustrates the effect of averaging on a log magnitude format trace.

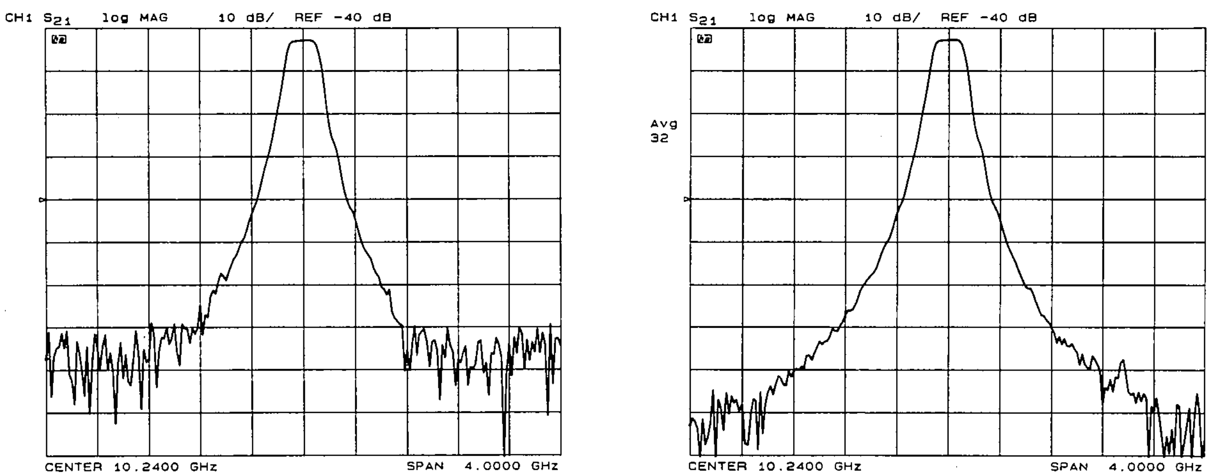



*Figure 4-30. Effect of Averaging on a Trace*

**Smoothing** (similar to video filtering) averages the formatted active channel data over a portion of the displayed trace. Smoothing computes each displayed data point based on one sweep only, using a moving average of several adjacent data points for the current sweep. The smoothing aperture is a percent of the stimulus span swept, up to a maximum of 20%.

Rather than lowering the noise floor, smoothing finds the mid-value of the data. Use it to reduce relatively small peak-to-peak noise values on broadband measured data. Use a sufficiently high number of display points to avoid misleading results. Do not use smoothing for measurements of high resonance devices or other devices with wide variations in trace, as it will introduce errors into the measurement.

Smoothing is used primarily with Cartesian display formats. It is also the primary way to control the group delay aperture, given a fixed frequency span (refer to *Group Delay Principles* earlier in this chapter). CAUTION: in polar display format, large phase shifts over the smoothing aperture will cause shifts in amplitude, since a vector average is being computed. Figure 4-31 illustrates the effect of smoothing on a log magnitude format trace. Smoothing is typically not used with polar and Smith formats.

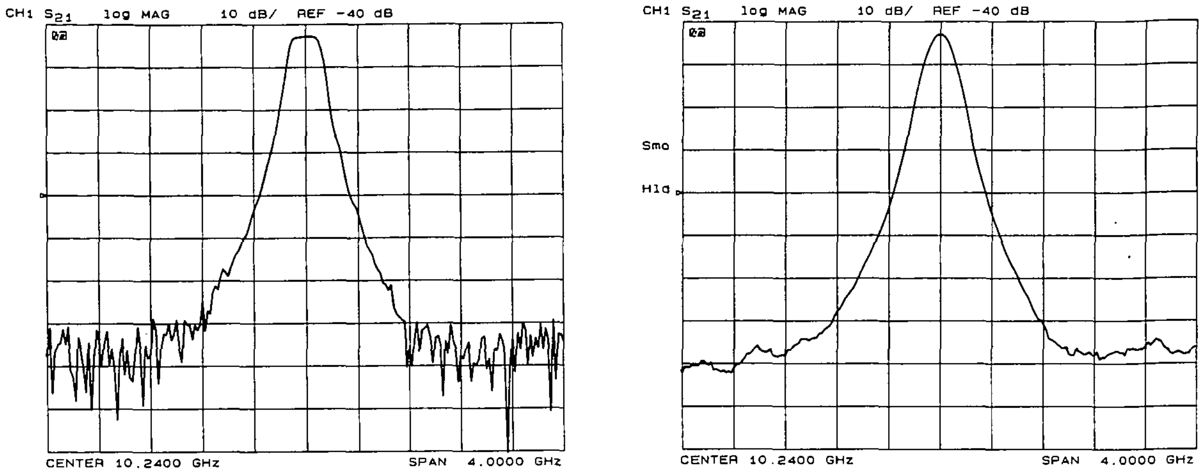



*Figure 4-31. Effect of Smoothing on a Trace*

**IF Bandwidth Reduction** lowers the noise floor by digitally reducing the receiver input bandwidth. It has an advantage over averaging in reliably filtering out unwanted responses such as spurs, odd harmonics, higher frequency spectral noise, and line-related noise. Sweep-to-sweep averaging, however, is better at filtering out very low frequency noise. A tenfold reduction in IF bandwidth lowers the measurement noise floor by about 10 dB. Bandwidths less than 300 Hz provide better harmonic rejection than higher bandwidths.

Another difference between sweep-to-sweep averaging and variable IF bandwidth is the sweep time. Averaging displays the first complete trace faster but takes several sweeps to reach a fully averaged trace. IF bandwidth reduction lowers the noise floor in one sweep, but the sweep time may be slower. Figure 4-32 illustrates the difference in noise floor between a trace measured with a 3000 Hz IF bandwidth and with a 10 Hz IF bandwidth.

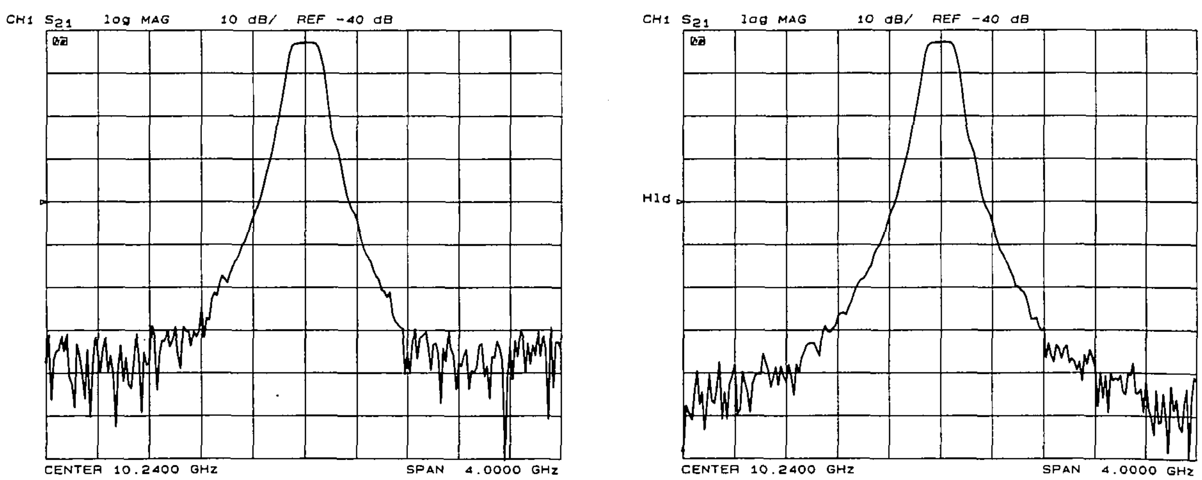



*Figure 4-32. IF Bandwidth Reduction*

Another capability that can be used for effective noise reduction is the marker statistics function, which computes the average value of part or all of the formatted trace. Refer to Chapter 6, *Using Markers*.

Another way of increasing dynamic range is to increase the input power to the device under test. Refer to the *User's Guide* for an example.

## Average Menu

The average menu (Figure 4-33) is used to select the desired noise-reduction technique, and to set the parameters for the technique selected. It is also used to set the aperture for group delay measurements.

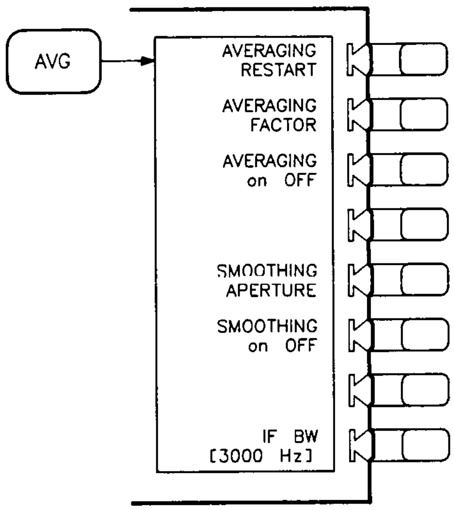



*Figure 4-33. Average Menu*

***[AVERAGING RESTART]*** (AVERREST) resets the sweep-to-sweep averaging and restarts the sweep count at 1 at the beginning of the next sweep. The sweep count for averaging is displayed at the left of the CRT.

***[AVERAGING FACTOR]*** (AVERFACT) makes averaging factor the active function. Any value up to 999 can be used. The algorithm used for averaging is:

$A(n) = S(n)/F + (1-1/F) \times A(n-1)$
where
A(n) = current average
S(n) = current measurement
F = sweep count (1, 2, 3 etc. until averaging factor is reached)
n = measurement number

***[AVERAGING on OFF]*** (AVERON, AVEROFF) turns the averaging function on or off for the active channel. "Avg" is displayed in the status notations area at the left of the CRT, together with the sweep count for the averaging factor, when averaging is on. The sweep count for averaging is reset to 1 whenever an instrument state change affecting the measured data is made.

At the start of averaging or following ***[AVERAGING RESTART]***, averaging starts at 1 and averages each new sweep into the trace until it reaches the specified averaging factor. The sweep count is displayed in the status notations area below "Avg" and updated every sweep as it increments. When the specified averaging factor is reached, the trace data continues to be updated, weighted by that averaging factor.

***[SMOOTHING APERTURE]*** (SMOOAPER) lets you change the value of the smoothing aperture as a percent of the span. When smoothing aperture is the active function, its value in stimulus units is displayed below its percent value in the active entry area.

Smoothing aperture is also used to set the aperture for group delay measurements (refer to *Group Delay Principles* earlier in this chapter). Note that the displayed smoothing aperture is not the group delay aperture unless smoothing is on.

***[SMOOTHING on OFF]*** (SMOOON, SMOOOFF) turns the smoothing function on or off for the active channel. When smoothing is on, the annotation "Smo" is displayed in the status notations area.

***[IF BW]*** (IFBW) is used to select the bandwidth value for IF bandwidth reduction. Settable values (in Hz) are 3000, 1000, 300, 100, 30, and 10. Any other value will default to the next lowest allowable value. A narrow bandwidth slows the sweep speed but provides better signal-to-noise ratio. The selected bandwidth value is shown in brackets in the softkey label.

# Chapter 5. Measurement Calibration

## INTRODUCTION

Measurement calibration is an accuracy enhancement procedure that effectively removes the system errors that cause uncertainty in measuring a device under test. It measures known standard devices, and uses the results of these measurements to characterize the system.

This chapter explains the theoretical fundamentals of accuracy enhancement and the sources of measurement errors. It describes the different measurement calibration procedures available in the analyzer, which errors they correct, and the measurements for which each should be used. An appendix at the end of this chapter provides further information on characterizing systematic errors and using error models to analyze overall measurement performance.

## ACCURACY ENHANCEMENT

If it were possible for a perfect measurement system to exist, it would have infinite dynamic range, isolation, and directivity characteristics, no impedance mismatches in any part of the test setup, and flat frequency response. Vector accuracy enhancement, also known as measurement calibration or error correction, provides the means to simulate a perfect measurement system.

In any high frequency measurement there are certain measurement errors or ambiguities associated with the system that contribute uncertainty to the results. Parts of the measurement setup such as interconnecting cables and signal separation devices (as well as the network analyzer itself) all introduce variations in magnitude and phase that can mask the actual performance of the device under test.

For example, crosstalk due to the channel isolation characteristics of the network analyzer can contribute an error equal to the transmission signal of a high-loss test device. Similarly, for reflection measurements, the primary limitation of dynamic range is the directivity of the test setup. The measurement system cannot distinguish the true value of the signal reflected by the device under test from the signal arriving at the receiver input due to leakage in the system. For both transmission and reflection measurements, impedance mismatches within the test setup cause measurement uncertainties that appear as ripples superimposed on the measured data.

Measurement calibration simulates a perfect network analyzer system. It measures the magnitude and phase responses of known standard devices, and compares the measurement with actual device data. It uses the results to characterize the system and effectively remove the system errors from the measurement data of a test device, using vector math capabilities internal to the network analyzer.

When measurement calibration is used, the dynamic range and accuracy of the measurement are limited only by system noise and stability, connector repeatability, and the accuracy to which the characteristics of the calibration standards are known.

## SOURCES OF MEASUREMENT ERRORS

Network analysis measurement errors can be separated into systematic, random, and drift errors.

Correctable systematic errors are the repeatable errors that the system can measure. These are errors due to mismatch and leakage in the test setup, isolation between the reference and test signal paths, and system frequency response.

Random and drift errors are the non-repeatable errors that the system itself cannot measure, and therefore cannot correct for. These errors affect both reflection and transmission measurements. Random errors are measurement variations due to noise and connector repeatability. Drift errors include frequency drift, temperature drift, and other physical changes in the test setup between calibration and measurement.

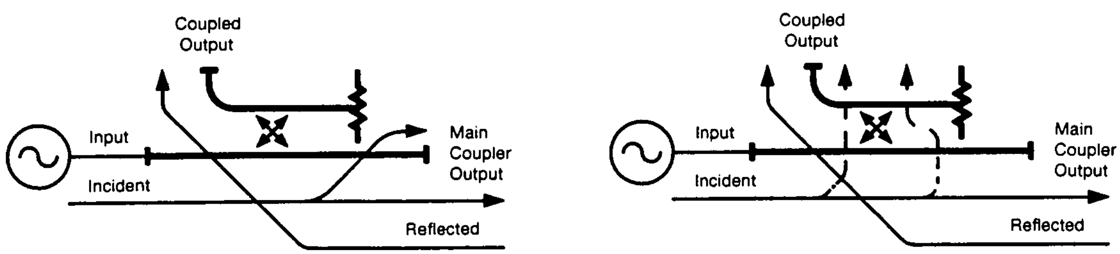
The resulting measurement is the vector sum of the device under test response plus all error terms. The precise effect of each error term depends upon its magnitude and phase relationship to the actual test device response.

In most high frequency measurements the systematic errors are the most significant source of measurement uncertainty. Since each of these errors can be characterized, their effects can be effectively removed to obtain a corrected value for the test device response. For the purpose of vector accuracy enhancement these uncertainties are quantified as directivity, source match, load match, isolation (crosstalk), and frequency response (tracking). Each of these systematic errors is described below.

Random and drift errors cannot be precisely quantified, so they must be treated as producing a cumulative ambiguity in the measured data.

### Directivity

Normally a device that can separate the reverse from the forward traveling waves (a directional bridge or coupler) is used to detect the signal reflected from the device under test. Ideally the coupler would completely separate the incident and reflected signals, and only the reflected signal would appear at the coupled output, as illustrated in Figure 5-1(a).




*(a) Ideal Coupler*    *(b) Real Coupler*

*Figure 5-1. Directivity*

However, a real coupler is not perfect, as illustrated in Figure 5-1(b). A small amount of the incident signal appears at the coupled output due to leakage as well as to reflection from the termination in the coupled arm. Also reflections from the coupler output connector appear at the coupled output, adding uncertainty to the signal reflected from the device. The figure of merit for how well a coupler separates forward and reverse waves is directivity. The larger the directivity, the better the separation of signals. System directivity is the vector sum of all leakage signals appearing at the network analyzer receiver input due to the inability of the signal separation device to absolutely separate incident and reflected waves, and to residual reflection effects of test cables and adapters between the signal separation device and the measurement plane. The error contributed by directivity is independent of the characteristics of the test device and it usually produces the major ambiguity in measurements of low reflection devices.

## Source Match

Source match is defined as the vector sum of signals appearing at the network analyzer receiver input due to the impedance mismatch at the test device looking back into the source, as well as to adapter and cable mismatches and losses. In a reflection measurement, the source match error signal is caused by some of the reflected signal from the DUT being reflected from the source back towards the DUT, and re-reflected from the DUT (Figure 5-2). In a transmission measurement, the source match error signal is caused by reflection from the test device that is re-reflected from the source. Source match is most often given in terms of return loss in dB: thus the larger the number, the smaller the error.

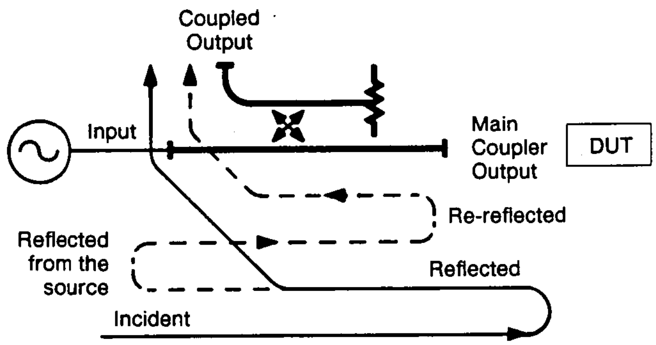



*Figure 5-2. Source Match*

The error contributed by source match is dependent on 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 is particularly a problem in measurements where there is a large impedance mismatch at the measurement plane.

## Load Match

Load match error results from an imperfect match at the output of the test device. It is caused by impedance mismatches between the test device output port and port 2 of the measurement system. As illustrated in Figure 5-3, some of the transmitted signal is reflected from port 2 back to the test device. A portion of this wave may be re-reflected to port 2, or part may be transmitted through the device in the reverse direction to appear at port 1. If the DUT has low insertion loss (for example a transmission line), the signal reflected from port 2 and re-reflected from the source causes a significant error because the DUT does not attenuate the signal significantly on each reflection. Load match is usually given in terms of return loss in dB: thus the larger the number, the smaller the error.

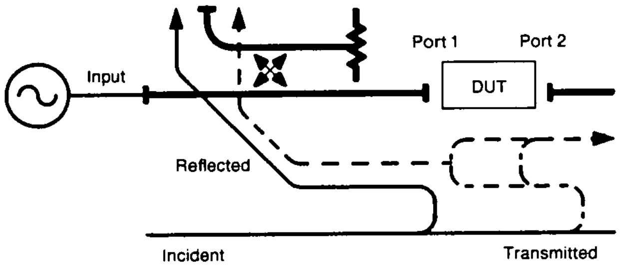



*Figure 5-3. Load Match*

The error contributed by load match is dependent on the relationship between the actual output impedance of the test device and the effective match of the return port (port 2), and is a factor in all transmission measurements and in reflection measurements of two-port devices. Load and source match are usually ignored when the test device insertion loss is greater than about 6 dB, because the error signal is greatly attenuated each time it passes through the DUT. However, load match effects produce major transmission measurement errors for a test device with a highly reflective output port.

## Isolation (Crosstalk)

Leakage of energy between network analyzer signal paths contributes to error in a transmission measurement much like directivity does in a reflection measurement. Isolation is the vector sum of signals appearing at the network analyzer digitizing detectors due to crosstalk between the reference and test signal paths, including signal leakage in both the RF and IF sections of the receiver.

The error contributed by isolation depends on the characteristics of the device under test. Isolation is a factor in high-loss transmission measurements. However, system isolation is more than sufficient for most measurements, and correction for it may be unnecessary. For measuring devices with high dynamic range, accuracy enhancement can provide improvements in isolation that are limited only by the noise floor.

## Frequency Response (Tracking)

This is the vector sum of all test setup variations in which magnitude and phase change as a function of frequency. This includes variations contributed by signal separation devices, test cables, and adapters, and variations between the reference and test signal paths. This error is a factor in both transmission and reflection measurements.

For further explanation of systematic error terms and the way they are combined and represented graphically in error models, refer to the appendix at the end of this chapter, titled *Accuracy Enhancement Fundamentals—Characterizing Microwave Systematic Errors*.

## CORRECTING FOR MEASUREMENT ERRORS

In all, there are twelve different error terms for a two-port measurement that can be corrected by accuracy enhancement in the analyzer. These are:

| | |
|---|---|
| directivity | isolation |
| source match | reflection tracking |
| load match | transmission tracking |

each in both the forward and reverse direction. The analyzer has several different measurement calibration routines to characterize one or more of the systematic error terms and remove their effects from the measured data. The procedures range from a simple frequency response calibration to a full two-port calibration that effectively removes all twelve error terms.

**The Response Calibration** effectively removes the frequency response errors of the test setup for reflection or transmission measurements. This calibration procedure may be adequate for measurement of well matched low-loss devices. This is the simplest error correction to perform, and should be used when extreme measurement accuracy is not a critical factor.

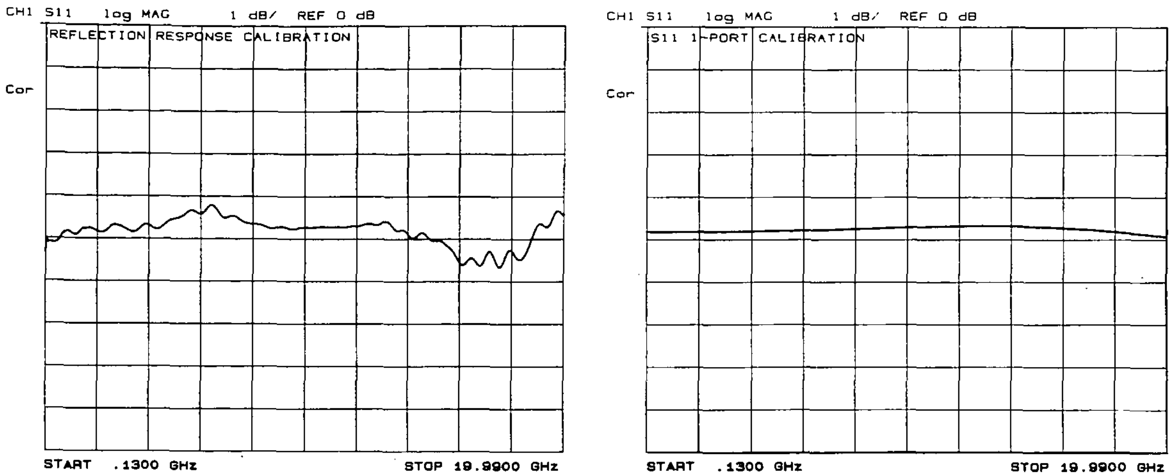
**The Response and Isolation Calibration** effectively removes frequency response and crosstalk errors in transmission measurements, or frequency response and directivity errors in reflection measurements. This procedure may be adequate for measurement of well matched high-loss devices.

**The S11 and S22 One-Port Calibration** procedures provide directivity, source match, and frequency response vector error correction for reflection measurements. These procedures provide high accuracy reflection measurements of one-port devices or properly terminated two-port devices.

**The Full Two-Port Calibration** provides directivity, source match, load match, isolation, and frequency response vector error correction, in both forward and reverse directions, for transmission and reflection measurements of two-port devices. This calibration provides the best magnitude and phase measurement accuracy for both transmission and reflection measurements of two-port devices.

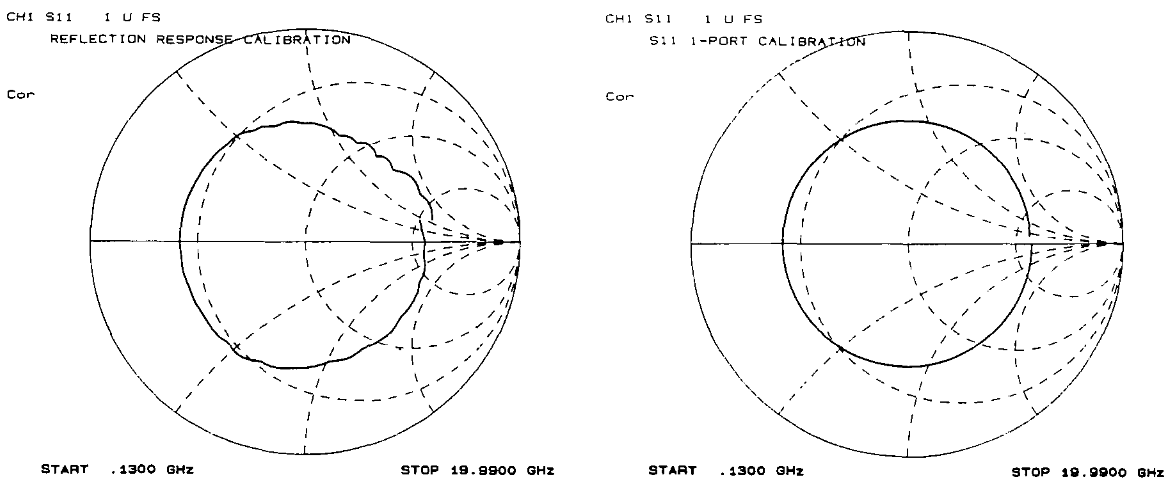
All the calibration procedures described above are accessed from the **[CAL]** key and are described in detail in the following pages.

The uncorrected performance of the network analyzer is sufficient for many measurements. However, the vector accuracy enhancement techniques described in this chapter will provide a much higher level of accuracy. Figures 5-4, 5-5, and 5-6 illustrate the improvements that can be made in measurement accuracy by using a more complete calibration routine. Figure 5-4(a) shows a measurement in log magnitude format with a response calibration only. Figure 5-4(b) shows the improvement in the same measurement using an S11 one-port calibration. Figure 5-5(a) shows the measurement in a Smith chart format with response calibration only, and Figure 5-5(b) shows the same measurement with an S11 one-port calibration.




*(a)* *(b)*

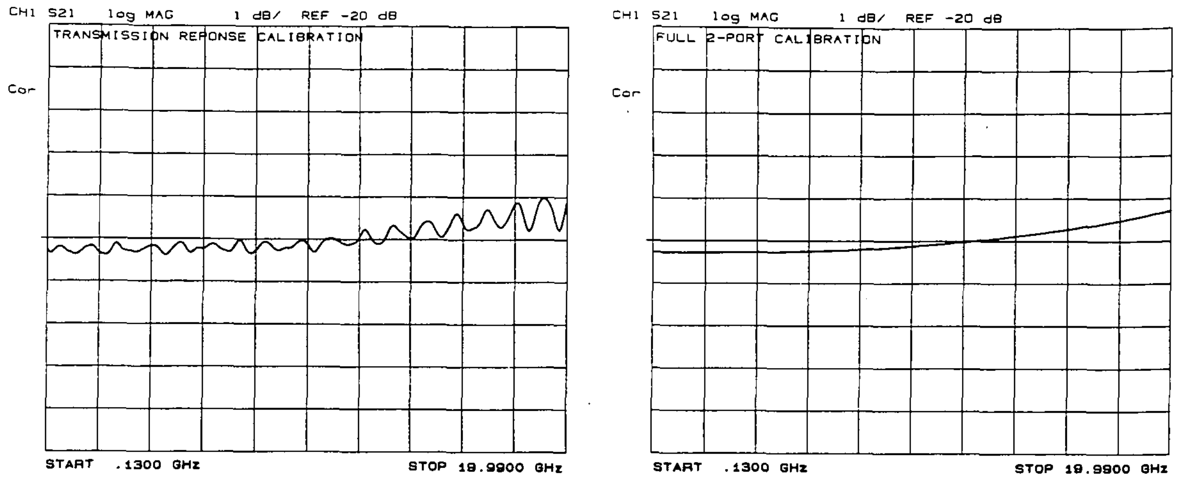
***Figure 5-4. Response vs. S11 1-Port Calibration on Log Magnitude Format***




*(a)* *(b)*

***Figure 5-5. Response vs. S11 1-Port Calibration on Smith Chart***

Figure 5-6 shows the response of a low-loss device in a log magnitude format, using a response calibration in Figure 5-6(a) and a full two-port calibration in Figure 5-6(b).




*(a)* *(b)*

*Figure 5-6. Response vs. Full Two-Port Calibration*

**NOTE:** At microwave frequencies an open circuit exhibits a change in phase with frequency, caused by fringing capacitance. When an open circuit is measured after calibration, this appears as an arc of varying length in the lower right circumference of the Smith chart. This is normal: at microwave frequencies, a capacitance reading of 0°would be inaccurate. Accuracy enhancement in the analyzer models the open circuit capacitance at all frequencies for the compatible calibration kits, and uses it to determine system errors.

A comparable effect may be observed in measuring an offset short. The result appears as an arc in the upper left circumference of the Smith chart. The short circuits in some of the compatible 3.5 mm and type-N calibration kits are offset shorts: refer to the individual calibration kit manuals for details. Accuracy enhancement models the offsets for the default calibration kits and uses the models to determine system errors.

## [CAL] KEY

The **[CAL]** (MENUCAL) key leads to a series of menus that implement the accuracy enhancement procedures described in the preceding pages (see Figure 5-7). Accuracy enhancement (error correction) is performed as a calibration step before measurement of a test device, using measurements of known standard devices to solve for the error terms. The analyzer uses one of several different procedures to characterize the systematic, repeatable errors of the system and remove their effects from the measured data. The calibration menus and procedures are described and illustrated in the following pages. Each procedure compensates for one or more of the systematic errors. They range from a simple frequency response calibration to a full two-port calibration that removes all twelve error terms.

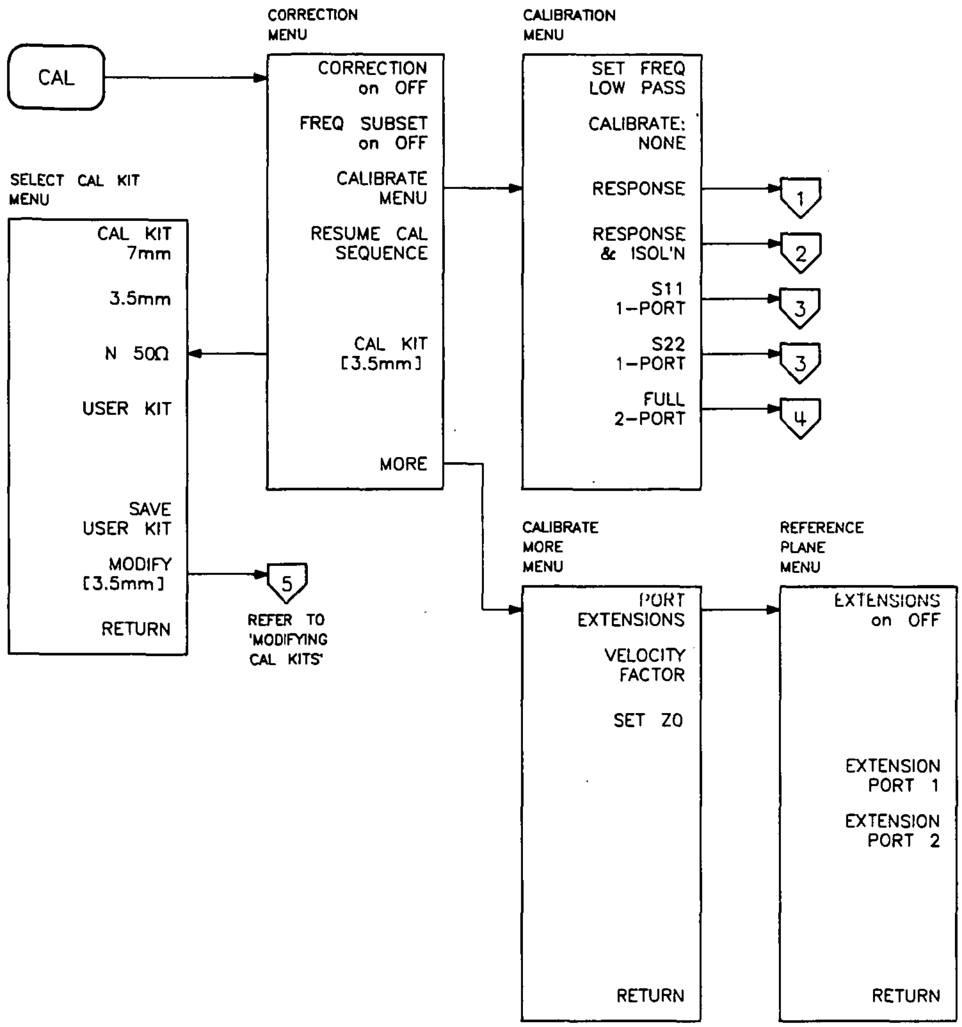



*Figure 5-7. Relationship of the Menus Accessed from the [CAL] Key*

The precision standard devices required for calibration of the system are available in compatible calibration kits with different connector types. The model numbers and contents of these calibration kits are listed in the *General Information* section of this manual. Each kit contains at least one short circuit, one open circuit, and two impedance-matched loads. In kits that require adapters for interface to the test ports, the adapters are phase-matched for calibration prior to measurement of non-insertable and non-reversible devices. The analyzer provides mathematical models of three predefined calibration kits (see *Select Cal Kit Menu*). Other standard devices can be used by specifying their characteristics in a user-defined kit, as described at the end of this chapter under *Modifying Calibration Kits*.

The accuracy improvement of the correction is limited by the quality of the standard devices, and by the connection techniques used. For information about connector care and connection techniques, refer to the *Microwave Connector Care Manual* in the *Connector Care and Applications* section. For maximum accuracy, use a torque wrench for final connections. The techniques for torquing connections and the part numbers for torque wrenches recommended for different connector types are provided in the connector care documents listed above.

Measurement calibrations are valid only for a specific stimulus state, which must be set before calibration is started. The stimulus state consists of the selected frequency range, number of measurement points, sweep time, power level, and sweep type. Changing the frequency range, number of points, or sweep type with correction on invalidates the calibration and turns it off (except as explained in the next paragraph). Changing the sweep time or output power changes the status notation "Cor" at the left of the screen to "C?", to indicate that the calibration is in question. If correction is turned off or in question after the stimulus changes are made, pressing ***[CORRECTION ON]*** recalls the original stimulus state for the current calibration.

In frequency subset mode, any part of a calibrated frequency range may be selected without invalidating the calibration. See ***[FRQ SUBSET]***, below, for details.

In the frequency list stimulus mode, if a measurement calibration has been performed on the full frequency list, one or all of the frequency segments can be measured and displayed without loss of calibration. Refer to *Sweep Type Menu* in Chapter 3 for more information on frequency list mode.

Up to two sets of measurement calibration data can be defined for each instrument state, one for each channel. If the two channels are stimulus coupled and the input ports are the same for both channels, they share the same calibration data. If the two channel inputs are different, they can have different calibration data. If the two channels are stimulus uncoupled, the measurement calibration applies to only one channel. For information on stimulus coupling, refer to *Stimulus Menu* in Chapter 3.

Calibration procedures are parameter-specific, rather than channel-specific. When a parameter is selected, the instrument checks the available calibration data, and uses the data found for that parameter. For example, if a transmission response calibration is performed for S21, and a 1-port calibration for S11, the analyzer retains both calibration sets and corrects whichever parameter is displayed. Once a calibration has been performed for a specific parameter, measurements of that parameter remain calibrated in either channel, as long as stimulus values are coupled. In a frequency response calibration, the parameter must be selected before calibration: other correction procedures select parameters automatically. Changing channels during a calibration procedure invalidates the part of the procedure already performed.

In procedures that require measurement of several different devices, for example a short, an open, and a load, the order in which the devices are measured is not critical. Any standard can be remeasured, until the ***[DONE]*** key is pressed. The change in trace during measurement of a standard is normal.

A frequency response calibration requires measurement of only one standard device. If more than one device is measured, only the data for the last device is retained.

Isolation calibration can be omitted for most measurements, except where wide dynamic range is a consideration. Use the following guidelines. When the measurement requires a dynamic range of:

- $<$70 dB: Omit isolation calibration.
- 70 to 80 dB: Isolation calibration is recommended, using an averaging factor $\geq$16 for the isolation portion of the calibration.
- $>$80 dB: Averaging should be on with an averaging factor $\geq$16, both for isolation calibration and for measurement after calibration.

A calibration that is interrupted to go to another menu can be continued with the ***[RESUME CAL SEQUENCE]*** key in the correction menu.

It is recommended that calibration data be saved, either in internal volatile memory or on an external disc. Refer to Chapter 10, *Saving Instrument States*. If a calibration is not saved, it will be lost if another calibration procedure is selected for the same channel. Instrument preset, power on, and instrument state recall will also clear the calibration data. If the stimulus values are changed, calibration is turned off: turning calibration back on will recall the original values.

**NOTE:** Caution is necessary in storing instrument state files to an external disc from one instrument and later loading them into another. Measurement calibration compensates for system uncertainties, such as those contributed by interconnecting cables and adapters and the condition of the calibration standards. A calibration stored from one instrument and recalled by a different one will be inaccurate. To ensure maximum accuracy, always recalibrate in these circumstances. Listed specifications apply to the instrument on which a measurement calibration has been performed.

Take particular note of the following conditions that may invalidate the calibration data or cause it to be in doubt:

- Frequencies are incompatible between a standard instrument and an option 001. If an instrument state is stored, with correction on, from an option 001 (high resolution) instrument, and later recalled by a standard instrument, the error correction data is not necessarily valid. It can only be valid if the minimum frequency span (or segment span in frequency list mode) conforms to the equation:

  $$\text{span} \doteq 100\ \text{kHz} \times (\text{number of points} - 1) \times n \quad \text{where } n = 1, 2, 3...$$

  Otherwise, correction is turned off and the message "CAUTION: CORR OFF; FREQ INCOMPATIBLE INST STATE" is displayed.

- No record is kept in memory of the temperature when a calibration set was stored. Instrument characteristics change as a function of temperature, and a calibration stored at one temperature may be inaccurate if recalled and used at a different temperature. Refer to *System Specifications* in the *Specifications* section for allowable temperature ranges for individual specifications.

Refer to Chapter 10, *Saving Instrument States*, for more information about direct storage to an external disc.

## Correction Menu

The correction menu is the first menu presented by the **[CAL]** key, and it provides access to numerous menus of additional calibration features.

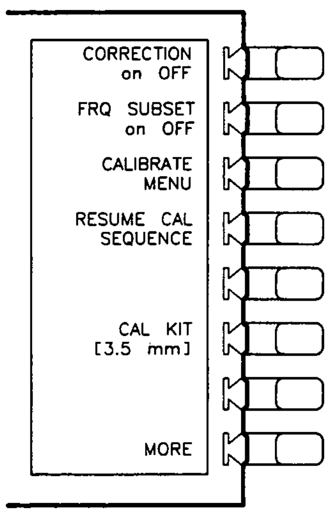



*Figure 5-8. Correction Menu*

*[CORRECTION on OFF]* (CORRON, CORROFF) turns error correction on or off. The analyzer uses the most recent calibration data for the displayed parameter. If the stimulus state has been changed since calibration, the original state is recalled, and the message "SOURCE PARAMETERS CHANGED" is displayed.

A calibration must be performed before correction can be turned on. If no valid calibration exists, the message "CALIBRATION REQUIRED" is displayed on the CRT. At the completion of a calibration procedure correction is automatically turned on, and the notation "Cor" or "C2" is displayed at the left of the screen.

It is recommended that calibration data be saved, either in internal volatile memory or on an external disc, using capabilities described in Chapter 10, *Saving Instrument States*.

*[FRQ SUBSET on OFF]* (FRESON, FRESOFF) lets you select any part of a previously calibrated frequency range while maintaining all of the accuracy of that measurement calibration. For instance assume you have just calibrated a 1 to 9 GHz frequency span with 1601 points. To focus in on the 2 to 3 GHz span, press *[FRQ SUBSET ON]* and chose those frequencies with the start and stop keys. The analyzer will select the points closest to 2 GHz and 3 GHz and display the original data points used in that 1 GHz part of the calibration.

*[CALIBRATE MENU]* leads to the calibration menu, which provides several accuracy enhancement procedures ranging from a simple frequency response calibration to a full two-port calibration for maximum accuracy.

*[RESUME CAL SEQUENCE]* (RESC) eliminates the need to restart a calibration sequence that was interrupted to access some other menu. This softkey goes back to the point where the calibration sequence was interrupted.

*[CAL KIT]* leads to the select cal kit menu, which is used to select one of the default compatible calibration kits available for different connector types. This in turn leads to additional menus used to define calibration standards other than those in the default kits (refer to *Modifying Calibration Kits* later in this chapter). When a calibration kit has been specified, its connector type is displayed in brackets in the softkey label.

*[MORE]* provides access to the calibrate more menu, which is used to extend the test port reference plane, to specify the characteristic impedance of the system, and to specify the relative propagation velocity factor for distance-to-fault measurements using the time domain option.

## Select Cal Kit Menu

The select cal kit menu is used to select the calibration kit to be used for a measurement calibration. Selecting a cal kit chooses the model that mathematically describes the standard devices actually used. (Refer to the beginning of this chapter, and the appendix at the end of this chapter, for more background on measurement calibrations and error correction.)

The analyzer has the capability to calibrate with three predefined cal kit models in different connector types. The cal kit models correspond to the standard calibration kits available as accessories for the HP 8720A:

| | |
|---|---|
| 7mm | HP 85050B/D 7 mm calibration kit |
| 3.5mm | HP 85052B/D 3.5 mm calibration kit |
| N 50Ω | HP 85054B/D 50 ohm type-N calibration kit |

How closely must the model match the actual device? The answer depends on the accuracy required. Certainly *any* calibration provides better accuracy than none at all, yet simple normalization is often quite adequate for many applications. The errors introduced by using the internal 3.5 mm model with a Hewlett-Packard 3.5 mm cal kit other than the HP 85052B/D are vanishingly small. Yet for the highest accuracy, the more closely the model matches the device, the better.

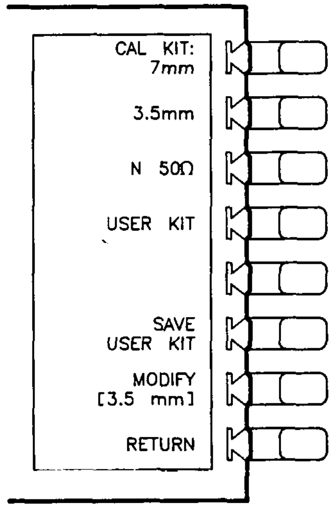



*Figure 5-9. Select Cal Kit Menu*

In addition to the three predefined cal kits, a fourth choice is a "user kit" that is defined or modified by the user. This is described under *Modifying Calibration Kits* at the end of this chapter.

***[CAL KIT: 7mm]*** (CALK7MM) selects the 7 mm calibration kit model.

***[3.5mm]*** (CALK35MM) selects the 3.5 mm calibration kit model.

***[N 50Ω]*** (CALKN50) selects the 50 ohm type-N calibration kit model.

**NOTE:** If ***[N 50Ω]*** is selected, additional menus are provided during calibration procedures to select the connector sex. (This is the connector sex of the instrument test port, not the actual calibration standard.)

***[USER KIT]*** (CALKUSED) selects a cal kit model defined or modified by the user. Refer to *Modifying Calibration Kits* at the end of this chapter for information.

***[SAVE USER KIT]*** (SAVEUSEK) stores the user-modified or user-defined kit into memory, after it has been modified.

***[MODIFY]*** (MODI1) leads to the modify cal kit menu (see the end of this chapter), where a predefined cal kit can be user-modified.

***[RETURN]*** goes back to the correction menu.

## Calibrate More Menu

This menu is used to extend the test port reference plane, to specify the characteristic impedance of the system, and to specify the relative propagation velocity factor for distance-to-fault measurements.

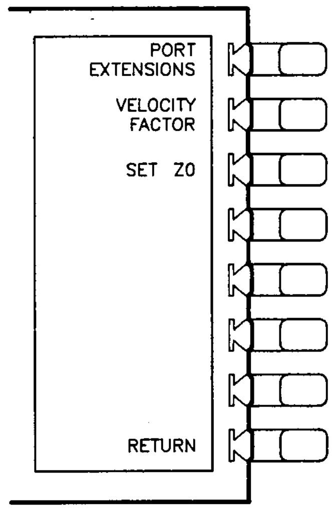



*Figure 5-10. Calibrate More Menu*

***[PORT EXTENSIONS]*** goes to the reference plane menu, which is used to extend the apparent location of the measurement reference plane.

***[VELOCITY FACTOR]*** (VELOFACT) enters the velocity factor used by the analyzer to calculate equivalent electrical length in distance-to-fault measurements using the time domain option. Velocity factor is also used to compute equivalent distance while adjusting electrical delay (explained in chapter 4). Values entered should be less than 1. For example, the velocity factor of teflon is:

$$V_f = \frac{1}{\sqrt{\varepsilon_R}} = 0.666$$

***[SET Z0]*** (SETZ) modifies the characteristic impedance value $Z_0$ recognized by the analyzer (the default value is 50Ω). This characteristic impedance sets the center value of the Smith chart, and is used by the network analyzer in calculating impedance measurements. In addition, it is used in calculating parameter conversions (refer to *Conversion Menu* in Chapter 4 for more information).

If the characteristic impedance of the calibration standards is not 50 ohms, a minimum loss pad or matching transformer should be inserted at the measurement port. The characteristic impedance must be set correctly before calibration procedures are performed.

***[RETURN]*** goes back to the correction menu.

## Reference Plane Menu

This menu adds electrical delay in seconds to the measurement ports to extend the apparent location of the measurement reference plane to the ends of the cables. This is equivalent to adding a length of perfect air line, and makes it possible to measure the delay response of the device only, instead of the device plus the cable.

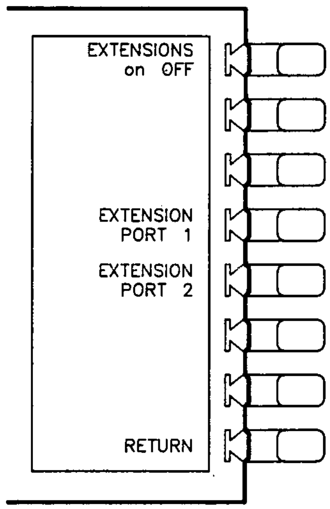



*Figure 5-11. Reference Plane Menu*

***[EXTENSIONS on OFF]*** (POREON, POREOFF) toggles the reference plane extension mode. When this function is on, the port extensions defined below are enabled.

***[EXTENSION PORT 1]*** (PORT1) extends the reference plane at port 1 for measurements of S11, S21, and S12.

***[EXTENSION PORT 2]*** (PORT2) extends the reference plane at port 2 for measurements of S22, S12, and S21.

***[RETURN]*** goes back to the calibrate more menu.

## Calibration Menu

The calibration menu is used to select the appropriate accuracy enhancement procedure for calibration before a measurement is performed. Five different calibration routines are available, each of which effectively removes from one to twelve systematic errors from the measurement data. Each procedure features CRT prompts to guide you through the calibration sequence. The available calibrations are described below, and a comparative summary is provided in Table 5-2. Procedures for performing each of the calibrations are provided in the following pages, with illustrations of the corresponding menus.

Note that all instrument parameters should be established before a calibration procedure is started, including stimulus values, calibration kit, and system characteristic impedance $Z_0$. (To modify $Z_0$, refer to *Calibrate More Menu*, above).

Measurement calibrations requiring load standards provide additional menus to specify the load(s). For broadband calibrations, use either a broadband load or, for the highest level of accuracy, a combination of lowband and sliding loads. For measurements above 3 GHz in 3.5 mm (2 GHz in 7 mm or type-N), the lowband load calibration can be omitted. For measurements below 3 GHz in 3.5 mm (2 GHz in 7 mm or type-N), the lowband load alone is sufficient (see Table 5-1). If you try to use only a sliding load or only a lowband load beyond these frequency cutoff points, the message "CAUTION: ADDITIONAL STANDARDS NEEDED" will be displayed to indicate that both loads are required.

*Table 5-1. Load Cutoff Frequencies*

| **Connector Type** | **Broadband Load** (130 MHz to 20 GHz) | |
|---|---|---|
| | **Lowband Load** | **Sliding Load** |
| 3.5 mm | 130 MHz to 3 GHz | 3 GHz to 20 GHz |
| 7 mm | 130 MHz to 2 GHz | 2 GHz to 20 GHz |
| type-N | 130 MHz to 2 GHz | 2 GHz to 20 GHz |

**NOTE:** By convention, when the connector sex is provided in parentheses for a calibration standard, it refers to the sex of the test port connector, not the actual standard. For example, short (m) indicates that the test port connector, not the short circuit connector, is male.

For measurement of test devices following calibration, refer to the *User's Guide*.

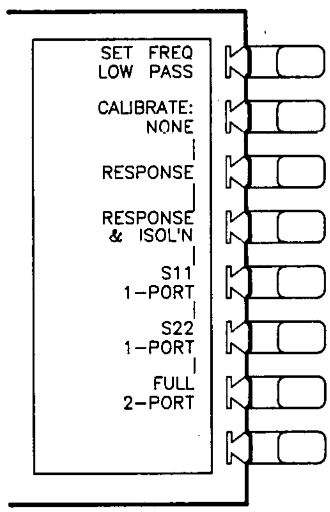



*Figure 5-12. Calibration Menu*

*[SET FREQ LOW PASS]* changes the frequency sweep to harmonic intervals to accommodate time domain low-pass operation in option 010 instruments.

**NOTE:** If time domain low-pass mode is to be used, the frequencies must be set **before calibration.** Refer to Chapter 8, *Time and Frequency Domain Transforms*, for more information.

*[CALIBRATE: NONE]* is underlined if no calibration has been performed or if the calibration data has been cleared. Unless a calibration is saved in memory, the calibration data is lost on instrument preset, power on, or instrument state recall. If stimulus values are changed, calibration is turned off: turning it back on will recall the original values.

***[RESPONSE]*** (CALIRESP) leads to the frequency response calibration. This is the simplest and fastest accuracy enhancement procedure, and should be used when extreme accuracy is not a factor. It effectively removes the frequency response errors of the test setup for reflection or transmission measurements.

For transmission-only measurements or reflection-only measurements, only a single calibration standard is required with this procedure. The standard for transmission measurements is a thru, and for reflection measurements can be either an open or a short. If more than one device is measured, only the data for the last device is retained. The procedures for response calibration for a reflection measurement and a transmission measurement are described in the following pages.

***[RESPONSE & ISOL'N]*** (CALIRAI) leads to the menus used to perform a frequency response and isolation measurement calibration, for measurement of devices with wide dynamic range. This procedure effectively removes the same frequency response errors as the response calibration. In addition, it effectively removes the isolation (crosstalk) error in transmission measurements or the directivity error in reflection measurements. As well as the devices required for a simple response calibration, an isolation standard is required. The standard normally used to correct for isolation in this procedure is a broadband impedance-matched load (usually 50 ohms). Response and isolation calibration procedures for reflection and transmission measurements are provided in the following pages.

***[S11 1-PORT]*** (CALIS111) provides a measurement calibration for reflection-only measurements of one-port devices or properly terminated two-port devices at test port 1. This procedure effectively removes the directivity, source match, and frequency response errors of the test setup, and provides a higher level of measurement accuracy than the frequency response and isolation calibration. It is the most accurate calibration procedure for reflection-only measurements. The standard devices required are a short, an open, and usually either a broadband load or a sliding and a lowband load. The procedure for performing an S11 1-port calibration is described in the following pages.

***[S22 1-PORT]*** (CALIS221) is similar to ***[S11 1-PORT]***. It is used for reflection-only measurements of one-port devices or properly terminated two-port devices in the reverse direction: that is, for devices connected to port 2.

***[FULL 2-PORT]*** (CALIFUL2) leads to the series of menus used to perform a complete calibration for measurement of all four S-parameters of a two-port device. This is the most accurate calibration for measurements of two-port devices. It effectively removes all correctable systematic errors (directivity, source match, load match, isolation, reflection tracking, and transmission tracking) in both the forward and reverse directions. Isolation correction can be omitted for measurements of devices with limited dynamic range.

The standards for this procedure are a short, an open, a thru, and an impedance-matched load (two loads if isolation correction is required). The load(s) used are usually either a broadband load or a sliding and a lowband load, depending on the frequency range and the level of accuracy required. The procedure is described in the following pages.

*Table 5-2. Purpose and Use of Different Calibration Procedures*

| Calibration Procedure | Corresponding Measurement | Errors Removed | Standard Procedure |
|---|---|---|---|
| Response | Transmission or reflection measurement when the highest accuracy is not required. | Freq. response | Thru for trans., open OR short for reflection |
| Response & isolation | Transmission of high insertion loss devices or reflection of high return loss devices. Not as accurate as 1-port or 2-port calibration. | Freq. response PLUS isolation in transmission or directivity in reflection. | Same as response PLUS isolation std (load) |
| S11 1-port | Reflection of any one-port device or well terminated two-port device. | Directivity, source match, freq. response | Short AND open AND load(s) |
| S22 1-port | Reflection of any one-port device or well terminated two-port device. | Directivity, source match, freq. response. | Short AND open AND load(s) |
| Full 2-port | Transmission or reflection of highest accuracy for two-port devices. | Directivity, source match, load match, isolation, freq. response (forward and reverse). | Short AND open AND load(s) AND thru (2 loads for isolation) |

## Response Calibration for Reflection Measurements

The procedure described here uses the menu illustrated in Figure 5-13 to perform a frequency response only calibration for a measurement of S11. It can also be used for S22 by substituting the corresponding softkey in the S-parameters menu.

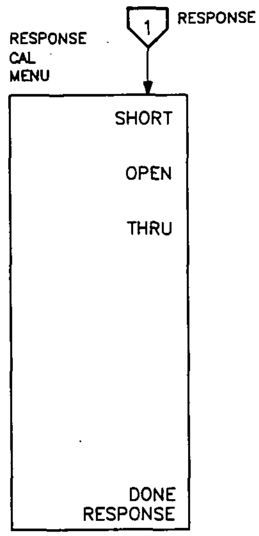



*Figure 5-13*

- Press **[MEAS]** ***[Refl: FWD S11]***.
- Press **[CAL]**.
- Select the proper calibration kit. If the connector type or cal kit name shown in the ***[CAL KIT]*** softkey label is not the same as the calibration kit to be used, refer to *Select Cal Kit Menu*.
- Press ***[CALIBRATE MENU] [RESPONSE]***.
- At port 1, connect either a short OR an open circuit.
- When the trace settles, press ***[SHORT]*** or ***[OPEN]***, depending on the standard used. (If more than one device is measured, only the data for the last device is retained.)
- The message "WAIT—MEASURING CAL STANDARD" is displayed while the data is measured. The softkey label ***[SHORT]*** or ***[OPEN]*** is then underlined.
- Press ***[DONE: RESPONSE]***. The calibration coefficients are computed and stored. A corrected trace is displayed and the notation "Cor" appears at the left side of the screen.
- The save menu is displayed. (It is recommended that calibration data be saved, either in internal volatile memory or on an external disc. Refer to Chapter 10, *Saving Instrument States*, for more information.)
- This completes the frequency response calibration for a reflection measurement. Now the test device can be connected and measured.

## Response Calibration for Transmission Measurements

The procedure described here uses the menu in Figure 5-13 to perform a frequency response only calibration for a measurement of S21. To calibrate for a combined transmission and reflection measurement, perform the transmission calibration on one channel and the reflection calibration described previously on the other channel.

- Press **[MEAS]** ***[Trans: FWD S21]***.
- Press **[CAL]**.
- Select the proper calibration kit. If the connector type or cal kit name shown in the ***[CAL KIT]*** softkey label is not the same as the calibration kit to be used, refer to *Select Cal Kit Menu*.
- Press ***[CALIBRATE MENU] [RESPONSE]***.
- Make a thru connection (connect together the points at which the test device will be connected).
- When the trace settles, press ***[THRU]***.
- The message "WAIT—MEASURING CAL STANDARD" is displayed while the S21 data is measured. The softkey label ***[THRU]*** is then underlined.
- Press ***[DONE: RESPONSE]***. The calibration coefficients are computed and stored. Corrected S21 data is displayed and the notation "Cor" appears at the left side of the screen.
- The save menu is displayed. (It is recommended that calibration data be saved, either in internal volatile memory or on an external disc. Refer to Chapter 10, *Saving Instrument States*, for more information.)

- This completes the frequency response calibration for a transmission measurement. Now the test device can be connected and measured.

## Response and Isolation Calibration for Reflection Measurements

The procedure described here effectively removes the frequency response and directivity errors for reflection measurements. The menus illustrated in Figure 5-14 are used to perform a calibration for a measurement of S11. The same calibration can be used for S22 by substituting the corresponding softkey in the S-parameters menu.

**NOTE:** Corrected directivity is limited to the return loss of the termination. For measurements below 3 GHz in 3.5 mm (2 GHz in 7 mm or type-N), use the lowband load (see Table 5-1). For measurements above 3 GHz in 3.5 mm (2 GHz in 7 mm or type-N), the best directivity correction is provided by a sliding load with the slide fixed.

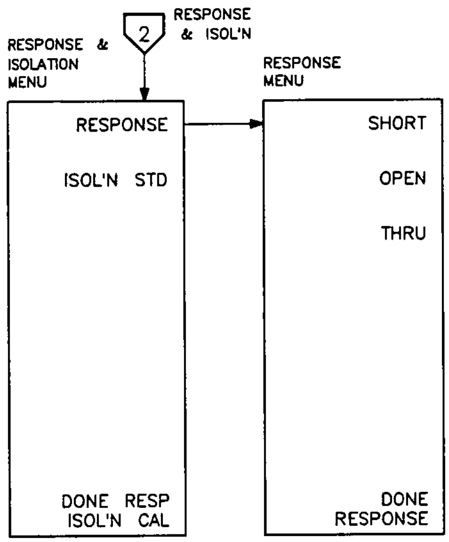



*Figure 5-14*

- Press **[MEAS]** ***[Refl: FWD S11]***.
- Press **[CAL]**.
- Select the proper calibration kit. If the connector type or cal kit name shown in the ***[CAL KIT]*** softkey label is not the same as the calibration kit to be used, refer to *Select Cal Kit Menu*.
- Press ***[CALIBRATE MENU] [RESPONSE & ISOL'N] [RESPONSE]***.
- At port 1, connect either a short OR an open circuit.
- When the trace settles, press ***[SHORT]*** or ***[OPEN]***, depending on the standard used. (If more than one standard is measured, only the data for the last device is retained.)
- The message "WAIT—MEASURING CAL STANDARD" is displayed while the response data is measured. The softkey label ***[SHORT]*** or ***[OPEN]*** is then underlined.
- Press ***[DONE: RESPONSE]***. The calibration coefficients are computed and stored. The response and isolation menu is displayed.
- Connect the isolation standard (impedance-matched termination) to port 1 (see *NOTE* above).
- Press ***[ISOL'N STD]***. The S11 isolation data is measured. The softkey label is underlined.
- Press ***[DONE RESP ISOL'N CAL]***. The directivity error coeffients are computed and stored. A corrected trace is displayed and the notation "Cor" appears at the left side of the screen.
- The save menu is displayed. (It is recommended that calibration data be saved, either in internal volatile memory or on an external disc. Refer to Chapter 10, *Saving Instrument States*, for more information.)
- This completes the response and isolation calibration for correction of frequency response and directivity errors for reflection measurements. Now the test device can be connected and measured.

## Response and Isolation Calibration for Transmission Measurements

The procedure described here effectively removes the frequency response and isolaticn errors for transmission measurements of devices with wide dynamic range, using the menus illustrated in Figure 5-14. To calibrate for a combined transmission and reflection measurement, perform the transmission calibration on one channel and the reflection calibration described above on the other channel.

- Press **[MEAS]** ***[Trans: FWD S21]***.
- Press **[AVG]** ***[IF BW]*** **[1] [0] [0] [x1]** to reduce the IF bandwidth.
- Press **[CAL]**.
- Select the proper calibration kit. If the connector type or cal kit name shown in the ***[CAL KIT]*** softkey label is not the same as the calibration kit to be used, refer to *Select Cal Kit Menu*.
- Press ***[CALIBRATE MENU] [RESPONSE & ISOL'N] [RESPONSE]***.
- Make a thru connection between port 1 and port 2 (connect together the points at which the test device will be connected).
- When the trace has settled, press ***[THRU]***. S21 response data is measured. The softkey label ***[THRU]*** is underlined.
- Press ***[DONE: RESPONSE]***.

- Press **[AVG]** ***[AVERAGING ON]***.*
- Press **[CAL]** ***[RESUME CAL SEQUENCE]***.
- Disconnect the thru and connect impedance-matched terminations to port 1 and port 2. Press ***[ISOL'N STD]***. S21 isolation is measured and averaged over 16 sweeps, and the softkey label is underlined.
- Press **[AVG]** ***[AVERAGING OFF]***.
- Press **[CAL]** ***[RESUME CAL SEQUENCE]***.

- Press ***[DONE RESP ISOL'N CAL]***. The S21 error coefficients are computed and stored. Corrected S21 data is displayed and the notation "Cor" at the left of the screen indicates that correction is on for this channel.
- The save menu is displayed. (It is recommended that calibration data be saved, either in internal volatile memory or on an external disc. Refer to Chapter 10, *Saving Instrument States*, for more information.)

* For maximum dynamic range use an averaging factor of 32.

A similar procedure is used to calibrate for measurement of S12, using the ***[Trans: REV S12]*** softkey in the S-parameters menu.

## S11 1-Port Calibration for Reflection Measurements

This procedure uses the S11 1-port menus illustrated in Figure 5-15 to perform a complete vector error correction for reflection measurements of one-port devices or properly terminated two-port devices. This is a high-accuracy calibration that effectively removes the directivity, source match, and frequency response errors from the measured data.

**NOTE:** For broadband reflection measurements, use either a broadband load or, for the highest level of accuracy, a combination of lowband and sliding loads. For measurements above 3 GHz in 3.5 mm (2 GHz in 7 mm or type-N), the lowband load calibration can be omitted. For measurements below 3 GHz in 3.5 mm (2 GHz in 7 mm or type-N), the lowband load alone is sufficient (see Table 5-1). If you try to use only a sliding load or only a lowband load beyond these frequency cutoff points, the message "CAUTION: ADDITIONAL STANDARDS NEEDED" will be displayed to indicate that both loads are required.

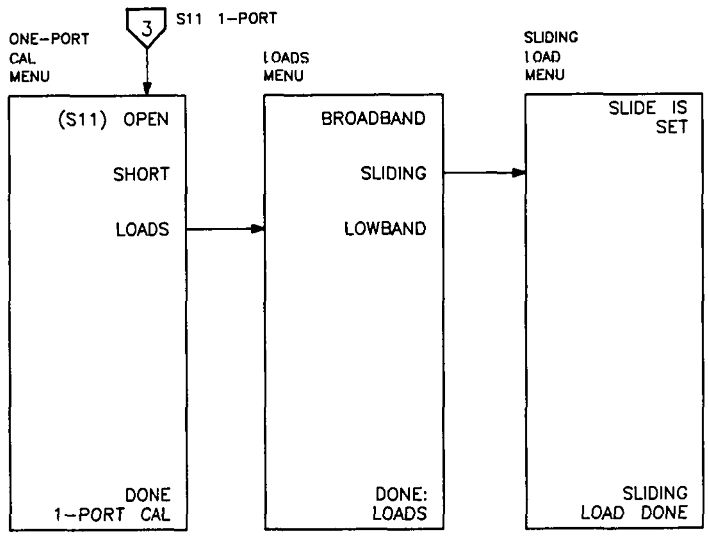



*Figure 5-15. Menus for S11 1-Port Calibration*

- Press **[CAL]**.
- Select the proper calibration kit. If the connector type or cal kit name shown in the ***[CAL KIT]*** softkey label is not the same as the calibration kit to be used, refer to *Select Cal Kit Menu.*
- Press ***[CALIBRATE MENU] [S11 1-PORT]***. (S11 will now be measured regardless of any other S-parameter previously selected.)
- Connect an open circuit to port 1.
- When the trace settles, press (S11) ***[OPEN]***.
- The message "WAIT—MEASURING CAL STANDARD" is displayed while the open circuit data is measured. The softkey label ***[OPEN]*** is then underlined.
- Disconnect the open, and connect a short circuit to port 1.
- When the trace settles, press ***[SHORT]***. The short circuit data is measured and the softkey label is underlined.
- Disconnect the short, and connect an impedance-matched load (see *NOTE* above) at port 1.
- Press ***[LOADS]***. The loads menu is displayed. When the trace settles, press the softkey corresponding to the load used. If a sliding load is used, the sliding load menu is displayed. Position the slide and press ***[SLIDE IS SET]***. The sliding load must be set and measured five times before ***[SLIDING LOAD DONE]*** is pressed. Otherwise, the message "CAUTION: MORE SLIDES NEEDED" is displayed.
- When all the appropriate load measurements are complete, press ***[DONE: LOADS]***. The load data is measured and the ***[LOADS]*** softkey label is underlined.

- Press *[DONE 1-PORT CAL]*. (If you press *[DONE]* without measuring all the required standards, the message "CAUTION: ADDITIONAL STANDARDS NEEDED" will be displayed.) The calibration coefficients are computed and stored. A corrected S11 trace is displayed, and the notation "Cor" appears at the left side of the screen.
- The save menu is displayed. (It is recommended that calibration data be saved, either in internal volatile memory or on an external disc. Refer to Chapter 10, *Saving Instrument States*, for more information.)
- This completes the S11 1-port calibration. The test device can now be connected and measured.

## S22 1-Port Calibration

This procedure performs a complete vector error correction for a reverse reflection measurement of a one-port device or a properly terminated two-port device. It is similar to the S11 1-port calibration except that S22 is selected automatically.

## Full 2-Port Calibration for Reflection and Transmission Measurements

This procedure uses the menu sequence illustrated in Figure 5-16 to perform complete vector error correction for measurement of all four S-parameters. This is the most accurate calibration for measurements of two-port devices, and effectively removes all correctable systematic errors in both the forward and reverse directions.

**NOTE:** For broadband measurements, use either a broadband load or, for the highest level of accuracy, a combination of lowband and sliding loads. For measurements above 3 GHz in 3.5 mm (2 GHz in 7 mm or type-N), the lowband load calibration can be omitted. For measurements below 3 GHz in 3.5 mm (2 GHz in 7 mm or type-N), the lowband load alone is sufficient (see Table 5-1). If you try to use only a sliding load or only a lowband load beyond these frequency cutoff points, the message "CAUTION: ADDITIONAL STANDARDS NEEDED" will be displayed to indicate that both loads are required.

To maximize the lifetime of the electro-mechanical transfer switch in the network analyzer, switching occurs only once in a measurement sequence using full two-port error correction. On the first sweep all four S-parameters are measured. On subsequent sweeps, the assumption is made that the reverse parameters have not changed, and only the forward parameters are measured. It is possible to override this protection feature for applications where the data changes significantly with time, for example with tuning or drift. To perform an override, use ***[MEASURE RESTART]*** in the S-parameter menu (see Chapter 4). Alternatively, for repeated update of all four S-parameters, set an appropriate number of groups using the trigger menu (see Chapter 3).

Isolation calibration can be omitted for most measurements, except where wide dynamic range is a consideration. Refer to the explanation under **[CAL]** *Key*.

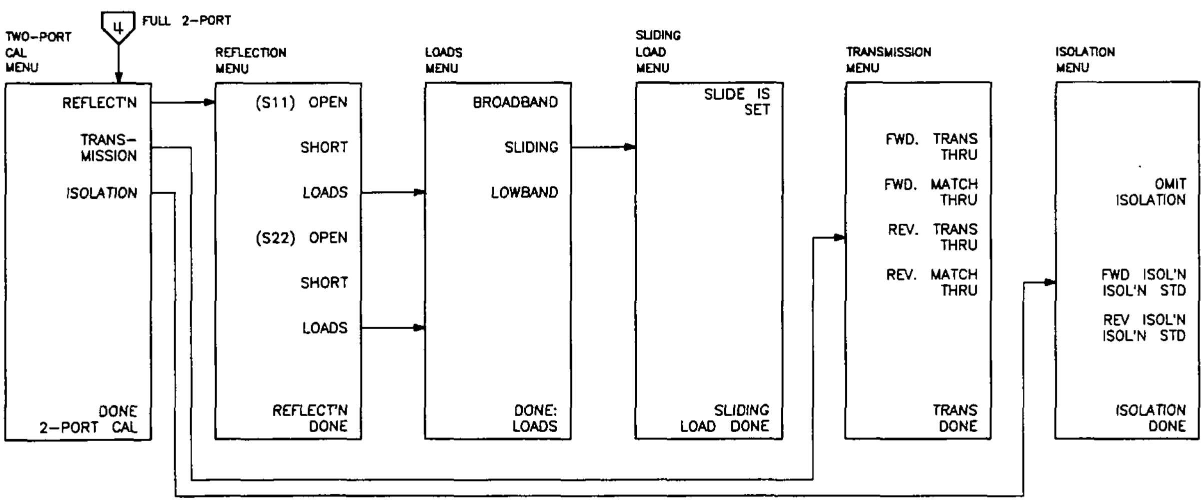



*Figure 5-16. Menus for Full 2-Port Calibration*

- Press **[AVG]** ***[IF BW]*** **[1] [0] [0] [x1]** to reduce the IF bandwidth.
- Press **[CAL]**.
- Select the proper calibration kit. If the connector type or cal kit name shown in the ***[CAL KIT]*** softkey label is not the same as the calibration kit to be used, refer to *Select Cal Kit Menu*.
- Press ***[CALIBRATE MENU] [FULL 2-PORT] [REFLECT'N]***.
- Connect an open circuit to port 1.
- When the trace settles, press (S11) ***[OPEN]***. The open circuit data is measured, and the softkey label ***[OPEN]*** is underlined.

- Disconnect the open, and connect a short circuit to port 1.
- When the trace settles, press (S11) ***[SHORT]***. The short circuit data is measured and the softkey label ***[SHORT]*** is underlined.
- Disconnect the short, and connect an impedance-matched load (see *NOTE* above) at port 1.
- Press (S11) ***[LOADS]***. The loads menu is displayed. When the trace settles, press the softkey corresponding to the load used. If a sliding load is used, the sliding load menu is displayed. Position the slide and press ***[SLIDE IS SET]***. The sliding load must be set and measured five times before ***[SLIDING LOAD DONE]*** is pressed. Otherwise, the message "CAUTION: MORE SLIDES NEEDED" is displayed.
- When all the appropriate load measurements are complete, press ***[DONE: LOADS]***. The load data is measured, and the ***[LOADS]*** softkey label is underlined.

- Repeat the open-short-load measurements described above, connecting the devices in turn to port 2 and using the (S22) softkeys.
- Press ***[REFLECT'N DONE]***. (If you press ***[DONE]*** without measuring all the required standards, the message "CAUTION: ADDITIONAL STANDARDS NEEDED" is displayed.)
- The reflection calibration coefficients are computed and stored. The two-port cal menu is displayed, with the ***[REFLECT'N]*** softkey underlined.

- Press ***[TRANSMISSION]***.
- Make a thru connection between port 1 and port 2 (connect together the points at which the test device will be connected).
- When the trace settles, press ***[FWD. TRANS. THRU]***. S21 frequency response is measured, and the softkey is underlined.
- Press ***[FWD. MATCH THRU]***. S11 load match is measured, and the softkey is underlined.
- Press ***[REV. TRANS. THRU]***. S12 frequency response is measured, and the softkey is underlined.
- Press ***[REV. MATCH THRU]***. S22 load match is measured, and the softkey is underlined.
- Press ***[TRANS. DONE]***. The transmission coefficients are computed and stored. The two-port cal menu is displayed, with the ***[TRANSMISSION]*** softkey underlined.
- Disconnect the thru.

- If correction for isolation is not required, press ***[ISOLATION] [OMIT ISOLATION] [ISOLATION DONE]***.
- If correction for isolation is required, press **[AVG]** ***[AVERAGING ON]***.*
- Press **[CAL]** ***[RESUME CAL SEQUENCE] [ISOLATION]***.
- Connect impedance-matched loads to port 1 and port 2 (broadband or lowband loads are sufficient).
- Press ***[FWD ISOL'N ISOL'N STD]***. S21 isolation is measured and averaged over 16 sweeps. The softkey label is underlined.
- Press ***[REV ISOL'N ISOL'N STD]***. S12 isolation is measured and averaged over 16 sweeps. The softkey label is underlined.
- Press ***[ISOLATION DONE]***. The isolation error coefficients are stored. The two-port cal menu is displayed, with the ***[ISOLATION]*** softkey underlined.
- Press **[AVG]** ***[AVERAGING OFF]***.

- Press **[CAL]** ***[RESUME CAL SEQUENCE]***.
- Press ***[DONE 2-PORT CAL]***. (If you press ***[DONE]*** without measuring all the required standards, the message "CAUTION: ADDITIONAL STANDARDS NEEDED" will be displayed.) The calibration coefficients are computed and stored. A corrected trace is displayed, and the notation "C2" at the left of the screen indicates that two-port error correction is on.
- The save menu is displayed. (It is recommended that calibration data be saved, either in internal volatile memory or on an external disc. Refer to Chapter 10, *Saving Instrument States*, for more information.)

* For maximum dynamic range use an averaging factor of 32.

- This completes the full two-port calibration procedure. Now the test device can be connected and measured.

## MODIFYING CALIBRATION KITS

For most applications, use the default cal kit models provided in the select cal kit menu described earlier in this chapter. Modifying calibration kits is necessary only if unusual standard devices are used, or a calibration kit is used with standards that have different values than the default kit. Unless a cal kit model is provided with the calibration devices used, a solid understanding of error correction and the system error model are absolutely essential to making modifications. Read the introductory part of this chapter for more information, and refer to the *Appendix to Chapter 5*. Additional information on user-modified cal kits is available in *Product Note 8510-5A* (HP part number 5956-4352).

**NOTE:** Numerical data for most Hewlett-Packad calibration kits is provided in the calibration kit manuals.

During measurement calibration, the analyzer measures actual, well-defined standards and mathematically compares the results with ideal "models" of those standards. The differences are separated into error terms which are later removed during error correction. Most of the differences are due to systematic, repeatable errors introduced by the network analyzer and connecting cables, which are correctable. However, differences between the model for a standard and the actual characteristics of the standard reduce the system's ability to remove systematic errors, and thus degrade error-corrected accuracy. Therefore, in addition to the predefined default cal kit models, a "user kit" is provided that can be modified to an alternate calibration standards model.

Several situations exist that may require a user-defined cal kit:

- A calibration may be required for a connector interface different from the three built-in cal kits. (Examples: 2.4 mm, SMA, TNC, or waveguide.)
- A calibration with standards (or combinations of standards) that are different from the predefined cal kits may be required. (Example: Using the HP 85052A 3.5 mm calibration kit instead of the HP 85052B/D.)
- The built-in standard models for predefined kits can be improved or refined. Remember that the more closely the model describes the actual performance of the standard, the better the calibration. (Example: A 7 mm load may be determined to measure 50.4 ohms instead of 50.0 ohms.)
- Unused standards for a given cal type can be eliminated from the predefined set, to eliminate possible confusion during calibration. (Example: A certain application requires calibrating a male test port. The standards used to calibrate a female test port can be eliminated from the set, and will not be displayed during calibration.)

### Definitions

It is necessary to define some of the terms used:

- A "standard" is a specific, well-defined, physical device used to determine systematic errors. Each standard has a precisely known or predictable magnitude and phase response as a function of frequency. The response of each standard is mathematically defined in the error models used by the network analyzer.
- A standard "type" is one of five basic types that define the form or structure of the model to be used with that standard (e.g. short or load).
- Standard "coefficients" are numerical characteristics of the standards used in the model selected.
- A standard "class" is a grouping of one or more standards that determines which standards are used in a particular calibration procedure.

## Procedure

Basically, the following steps are used to modify or define a user kit:

1. **Select Standards.** To modify a cal kit, first select the predefined kit to be modified. This is not necessary for defining a new cal kit.
2. **Define the Standards.** For each standard, define which "type" of standard it is and its electrical characteristics.
3. **Specify the Class** where the standard is to be assigned.
4. **Store** the modified cal kit.

Following the descriptions of the menus for modifying calibration kits, a procedure is provided that enters the HP 85052A 3.5 mm calibration kit values as a "user kit."

## Modify Cal Kit Menu

This menu is accessed from the **[CAL]** key (refer to Figure 5-7), and leads in turn to additional series of menus associated with modifying cal kits. All of these menus and their functions are described in the following pages.

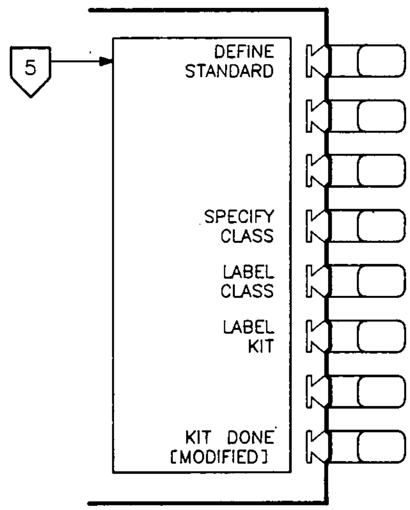



*Figure 5-17. Modify Cal Kit Menu*

***[DEFINE STANDARD]*** (DEFS) makes the standard number the active function, and brings up the define standard menus. The standard number (1 to 8) is an arbitrary reference number used to reference standards while specifying a class. The standard numbers for the predefined calibration kits are as follows:

| | | | |
|---|---|---|---|
| 1 | short | 5 | sliding load |
| 2 | open | 6 | lowband load |
| 3 | broadband load | 7 | short |
| 4 | thru | 8 | open |

***[SPECIFY CLASS]*** leads to the specify class menu. Class assignment groups the standards into classes that correspond to the systematic errors to be corrected by a particular measurement calibration procedure. Define the standards first, then use this key to specify the standards to be grouped in a specific class.

***[LABEL CLASS]*** leads to the label class menu, which is used to give the class a meaningful label for future reference.

***[LABEL KIT]*** (LABEK) leads to a menu to generate a label for the user-modified cal kit. If a label is supplied, it will appear as one of the softkey choices in the select cal kit menu. It will also be used as the file label for a cal kit definition stored to disc. The approach is similar to defining a display title, except that the kit label is limited to eight characters.

***[KIT DONE]*** (KITD) terminates the cal kit modification process, after all standards are defined and all classes are specified. Be sure to save the kit with the ***[SAVE USER KIT]*** softkey in the select cal kit menu, if it is to be used later.

## Define Standard Menus

Standard definition is the process of mathematically modeling the electrical characteristics (delay, attenuation, and impedance) of each calibration standard. These electrical characteristics (coefficients) can be mathematically derived from the physical dimensions and material of each calibration standard or from its actual measured response. The parameters of the standards can be listed in the *Standards Definition Table*, Table 5-3. The menus illustrated in Figure 5-18 are used to specify the type and characteristics for each user-defined standard.

*Table 5-3. Standard Definitions Table*

| STANDARD | | C0 $x10^{-15}$F | C1 $x10^{-27}$F/Hz | C2 $x10^{-36}$F/Hz | C3 $x10^{-45}$F/Hz | FIXED OR SLIDING | OFFSET | | | FREQUENCY (GHz) | | COAX or WAVEGUIDE | STANDARD LABEL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. | TYPE | | | | | | DELAY ps | LOSS MΩ/s | $Z_0$ Ω | MINIMUM | MAXIMUM | | |
| 1 | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | |

Each standard must be identified as one of five "types": open, short, load, delay/thru, or arbitrary impedance.

After a standard number is entered with the ***[DEFINE STANDARD]*** softkey, selection of the standard type will present one of five menus for entering the electrical characteristics corresponding to that standard type. These menus are tailored to the current type, so that only characteristics applicable to that standard type can be modified.

Any standard type can be further defined with offsets in delay, loss, and standard impedance; assigned minimum or maximum frequencies over which the standard applies; and defined as coax or waveguide. Press the ***[SPECIFY OFFSET]*** softkey, and refer to *Specify Offset Menu*.

A distinct label can be defined and assigned to each standard, so that the analyzer can prompt the user with explicit standard labels during calibration (e.g. "SHORT"). Press the ***[LABEL STD]*** key to present a menu similar to the one used in defining a display title.

After each standard is defined, including offsets, press ***[STD DONE (DEFINED)]*** to terminate the standard definition.

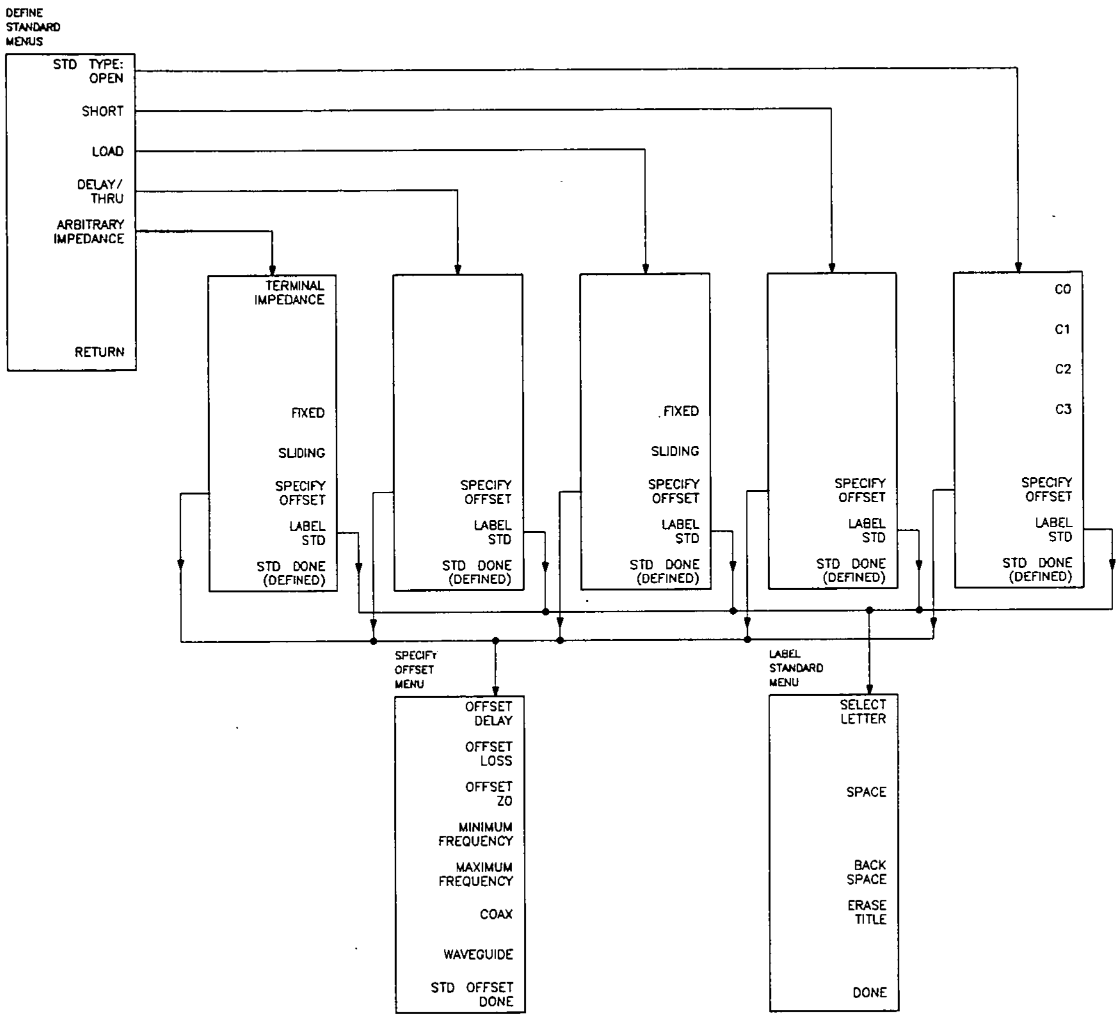



*Figure 5-18. Define Standard Menus*

***[OPEN]*** (STDTOPEN) defines the standard type as an open circuit, used for calibrating reflection measurements. Pressing this key also presents a menu to define the open, including its capacitance. An open circuit is assigned a terminal impedance of infinity ohms, but delay and loss offsets may still be added.

As a reflection standard, an open circuit offers the advantage of broadband frequency coverage. At microwave frequencies, however, an open rarely has perfect reflection characteristics because the fringing capacitance effects cause phase shift that varies with frequency. This can be observed in measuring an open circuit after calibration, when an arc in the lower right circumference of the Smith chart indicates capacitive reactance. These effects are impossible to eliminate, but the calibration kit models include the open circuit capacitance at all frequencies for the analyzer compatible calibration kits. The capacitance model is a cubic polynomial, as a function of frequency, where the polynomial coefficients are user-definable. The capacitance model equation is:

$$C = (C0) + (C1 * F) + (C2 * F^2) + (C3 * F^3)$$

where F is the measurement frequency.

The terms in the equation are defined with the specify open menu as follows:

***[C0]*** (C0) is used to enter the C0 term, which is the constant term of the cubic polynomial and is scaled by $10^{-15}$ Farads.

***[C1]*** (C1) is used to enter the C1 term, expressed in F/Hz (Farads/Hz) and scaled by $10^{-27}$.

***[C2]*** (C2) is used to enter the C2 term, expressed in $F/Hz^2$ and scaled by $10^{-36}$.

***[C3]*** (C3) is used to enter the C3 term, expressed in $F/Hz^3$ and scaled by $10^{-45}$.

***[SHORT]*** (STDTSHOR) defines the standard type as a short, for calibrating reflection measurements. Shorts are assigned a terminal impedance of 0 ohms, but delay and loss offsets may still be added.

***[LOAD]*** (STDTLOAD) defines the standard type as a load (termination). Loads are assigned a terminal impedance equal to the system characteristic impedance $Z_0$ (usually 50Ω), but delay and loss offsets may still be added. If the load impedance is not $Z_0$, use the arbitrary impedance standard definition.

***[FIXED]*** (FIXE) defines the load as a fixed (not sliding) load.

***[SLIDING]*** (SLIL) defines the load as a sliding load. In calibration sequences that use a sliding load, the analyzer will prompt for several load positions, and use the measurement results from all of them to calculate the ideal load value.

***[DELAY/THRU]*** (STDTDELA) defines the standard type as a transmission line of specified length, for transmission calibrations.

***[ARBITRARY IMPEDANCE]*** (STDTARBI) defines the standard type to be a load, but with an arbitrary impedance different from the system $Z_0$.

***[TERMINAL IMPEDANCE]*** (TERI) is used to specify the (arbitrary) impedance of the standard, in ohms.

***[FIXED]*** (FIXE) defines the load as a fixed (not sliding) load.

***[SLIDING]*** (SLIL) defines the load as a sliding load. In calibrations that use a sliding load, the analyzer will prompt for several load positions to calculate the ideal load value.

## Specify Offset Menu

The specify offset menu (Figure 5-19) allows additional specifications for a user-defined standard. Features specified in this menu are common to all five types of standards.

An offset is equivalent to a uniform length of transmission line between the standard being defined and the actual measurement plane. (Example: a waveguide short circuit terminator, offset by a short length of waveguide.) For reflection standards, the offset is assumed to be between the measurement plane and the standard (one-way only). For transmission standards, the offset is assumed to exist between the two reference planes (in effect, the offset is the thru). Three characteristics of the offset can be defined: its delay (length), loss, and impedance. An offset can be specified with any standard type.

The frequency range over which a particular standard is valid can be defined with a minimum and maximum frequency. This is particularly important for a waveguide standard, since its behavior changes rapidly beyond its cutoff frequency. Note that several band-limited standards can together be defined as the same "class" (see specify class menu). Then, if a measurement calibration is performed over a frequency range exceeding a single standard, additional standards can be used for each portion of the range.

Lastly, the standard must be defined as either coaxial or waveguide. If it is rectangular waveguide, dispersion effects are calculated automatically and included in the standard model.

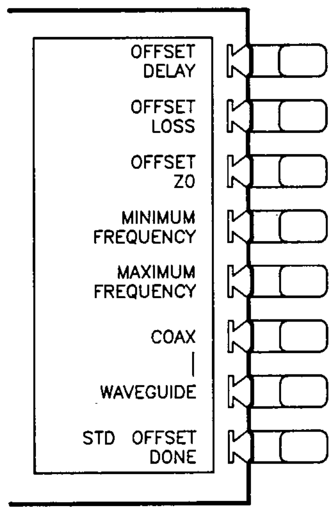



*Figure 5-19. Specify Offset Menu*

***[OFFSET DELAY]*** (OFSD) is used for a standard that has electrical length relative to the calibration plane. Offset delay is entered as the one-way travel time through an offset from the measurement (reference) plane to the standard, in seconds (s). (In a transmission standard, offset delay is the delay from plane to plane.) Delay can be calculated from the precise physical length of the offset, the permittivity constant of the medium, and the speed of light.

In coax, group delay is considered constant. In waveguide, however, group delay is dispersive, that is, it changes significantly as a function of frequency. Hence, for a waveguide standard, offset delay must be defined at an infinitely high frequency.

***[OFFSET LOSS]*** (OFSL) is used to specify energy loss, due to skin effect, along a one-way length of coax offset. The value of loss is entered as ohms/nanosecond (or Gigohms/second) at 1 GHz. (Such losses are negligible in waveguide, so enter 0 as the loss offset.)

***[OFFSET Z0]*** (OFSZ) is used to specify the characteristic impedance of the coax offset. (Note: This is *not* the impedance of the standard itself.) (For waveguide, the offset impedance is always assigned a value equal to the system $Z_0$.)

*[MINIMUM FREQUENCY]* (MINF) is used to define the lowest frequency at which the standard can be used during measurement calibration. In waveguide, this *must* be the lower cutoff frequency of the standard, so that the analyzer can calculate dispersive effects correctly (see *[OFFSET DELAY]* above).

*[MAXIMUM FREQUENCY]* (MAXF) is used to define the highest frequency at which the standard can be used during measurement calibration. In waveguide, this is normally the upper cutoff frequency of the standard.

*[COAX]* (COAX) defines the standard (and the offset) as coaxial. This causes the analyzer to assume linear phase response in any offsets.

*[WAVEGUIDE]* (WAVE) defines the standard (and the offset) as rectangular waveguide. This causes the analyzer to assume a dispersive delay (see *[OFFSET DELAY]* above).

## **Label Standard Menu** (LABS)

This menu (Figure 5-20) is used to label individual standards for reference during the menu-driven measurement calibration sequence. The labels are user-definable using a character set displayed on the CRT that includes letters, numbers, and some symbols, and they may be up to eight characters long. The analyzer will prompt you to connect standards using these labels, so they should be meaningful to you, and distinct for each standard.

It is recommended that the label include information carried on the standard, such as the serial number, to avoid confusing multiple standards that are similar in appearance.

By convention, 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.

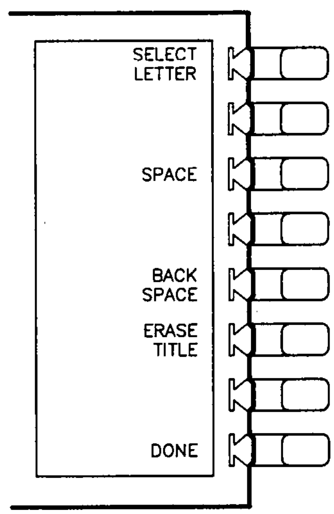



*Figure 5-20. Label Standard Menu*

Standard labels are created in exactly the same way as titles. Refer to *[DISPLAY] Key, Title Menu* in Chapter 4.

## Specify Class Menus

Once a standard is defined, it must be assigned to a standard "class." This is a group of from one to seven 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 *Standard Class Assignments Table*, Table 5-4. A class often consists of a single standard, but may be composed of more than one standard if band-limited standards are used. (Example: The predefined 3.5 mm cal kit model for the analyzer has a single short circuit standard and a single open circuit standard. However, the load standard class includes three standards: a broadband load, a sliding load for high frequencies, and a lowband load.)

*Table 5-4. Standard Class Assignments Table*

| | 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 | | | | | | | | |
| Response | | | | | | | | |
| Response & Isolation | | | | | | | | |

The number of standard classes required depends on the type of calibration being performed, and is equal to the number of error terms corrected. (Examples: A response calibration requires only one class, and the standards for that class may include an open and/or short and/or thru. A 1-port calibration requires three classes. A full 2-port calibration requires ten classes, not including two for isolation.)

The number of standards that can be assigned to a given class may vary from none (class not used) to one (simplest class) to seven. When a certain class of standards is required during calibration, the analyzer will display the labels for all the standards in that class (except when the class consists of a single standard). This does not, however, mean that all standards in a class must be measured during calibration. Unless band-limited standards are used (such as a lowband load and a sliding load), only a single standard per class is required. Note that it is often simpler to keep the number of standards per class to the bare minimum needed (often one) to avoid confusion during calibration.

Standards are assigned to a class simply by entering the standard's reference number (established while defining a standard) under a particular class. Each class can be given a user-definable label as described under *Label Class Menus*, below.

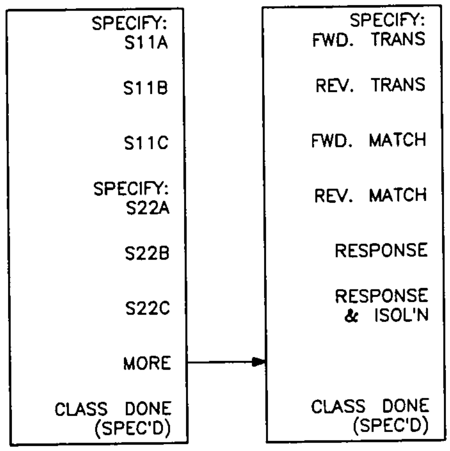



*Figure 5-21. Specify Class Menus*

***[SPECIFY: S11A]*** (SPECS11A) is used to enter the standard number(s) for the first class required for an S11 1-port calibration. (For predefined cal kits, this is the open.)

***[S11B]*** (SPECS11B) is used to enter the standard number(s) for the second class required for an S11 1-port calibration. (For predefined cal kits, this is the short.)

***[S11C]*** (SPECS11C) is used to enter the standard number(s) for the third class required for an S11 1-port calibration. (For predefined kits, this is the load.)

***[SPECIFY: S22A]*** (SPECS22A) is used to enter the standard number(s) for the first class required for an S22 1-port calibration. (For predefined cal kits, this is the open.)

***[S22B]*** (SPECS22B) is used to enter the standard number(s) for the second class required for an S22 1-port calibration. (For predefined cal kits, this is the short.)

***[S22C]*** (SPECS22C) is used to enter the standard number(s) for the third class required for an S22 1-port calibration. (For predefined kits, this is the load.)

***[MORE]*** leads to the following softkeys.

***[FWD.TRANS.]*** (SPECFWDT) is used to enter the standard number(s) for the forward (port 1 to port 2) transmission thru calibration. (For predefined kits, this is the thru.)

***[REV.TRANS.]*** (SPECREVT) is used to enter the standard number(s) for the reverse (port 2 to port 1) transmission (thru) calibration. (For predefined kits, this is the thru.)

***[FWD.MATCH]*** (SPECFWDM) is used to enter the standard number(s) for the forward match (thru) calibration. (For predefined kits, this is the thru.)

***[REV.MATCH]*** (SPECREVM) is used to enter the standard number(s) for the reverse match (thru) calibration. (For predefined kits, this is the thru.)

***[RESPONSE]*** (SPECRESP) is used to enter the standard number(s) for a response calibration. This calibration corrects for frequency response in either reflection or transmission measurements, depending on the parameter being measured when a calibration is performed. (For predefined kits, the standard is either the open or short for reflection measurements, or the thru for transmission measurements.)

***[RESPONSE & ISOL'N]*** (SPECRESI) is used to enter the standard number(s) for a response & isolation calibration. This calibration corrects for frequency response and directivity in reflection measurements, or frequency response and isolation in transmission measurements.

## Label Class Menus

The label class menus are used to define meaningful labels for the calibration classes. These then become softkey labels during a measurement calibration. Labels can be up to eight characters long.

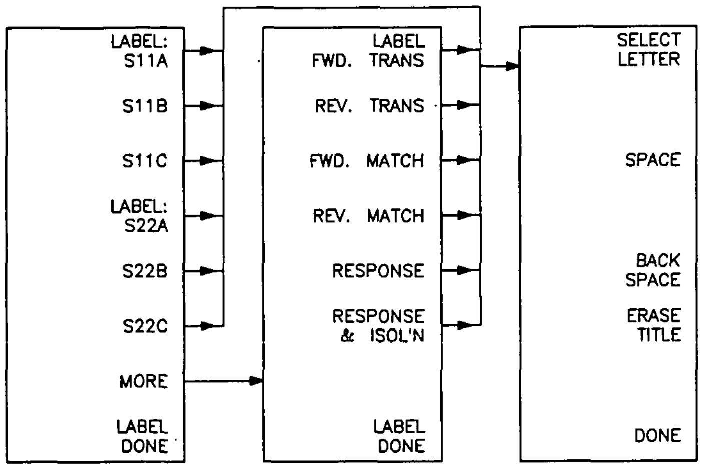



*Figure 5-22. Label Class Menus*

Labels are created in exactly the same way as display titles. Refer to *[DISPLAY] Key, Title Menu* in Chapter 4.

## Label Kit Menu

After a new calibration kit has been defined, be sure to specify a label for it. Choose a label that describes the connector type of the calibration devices. This label will then appear in the ***[CAL KIT]*** softkey label in the correction menu and the ***[MODIFY]*** label in the select cal kit menu. It will be saved with calibration sets.

This menu is accessed with the ***[LABEL KIT]*** softkey in the modify cal kit menu, and is identical to the label class menu and the label standard menu described above. It allows definition of a label up to eight characters long.

## Verify Performance

Once a measurement calibration has been generated with a user-defined calibration kit, 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. The verification device must not be one of the calibration standards: measurement of one of these standards is merely a measure of repeatability.

To achieve more complete verification of a particular measurement calibration, 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.

**NOTE:** The published specifications for the network analyzer system include accuracy enhancement with compatible calibration kits. Measurement calibrations made with user-defined or modified calibration kits are not subject to those analyzer specifications, although a procedure similar to the system verification procedure may be used.

## Example Procedure for Specifying a User-Defined Calibration Kit

The following procedure enters the HP 85052A 3.5 mm calibration kit values as a "user kit." This is provided as an example to illustrate the steps required in defining a calibration kit model.

The first keystroke sequence enters the values for standard #1, the short circuit.

- [CAL] *[CAL KIT] [MODIFY]*
- *[DEFINE STANDARD] [SHORT]*
- *[SPECIFY OFFSET] [OFFSET DELAY]* [.] [0] [1] [6] [6] [8] [4] [G/n]
- *[STD OFFSET DONE] [STD DONE (DEFINED)]*

The next sequence specifies standard #2, the open circuit.

- *[DEFINE STANDARD]* [2] [x1] *[OPEN]*
- *[C0]* [5] [6] [x1]
- *[C1]* [2] [0] [0] [x1]
- *[C2]* [0] [x1]
- *[C3]* [0] [x1]
- *[SPECIFY OFFSET] [OFFSET DELAY]* [.] [0] [1] [4] [4] [4] [8] [G/n]
- *[STD OFFSET DONE] [STD DONE (DEFINED)]*

The next sequence specifies standard #5, the sliding load.

- *[DEFINE STANDARD]* [5] [x1] *[LOAD]*
- *[SPECIFY OFFSET] [MINIMUM FREQUENCY]* [1] [.] [9] [9] [9] [G/n]
- *[STD OFFSET DONE] [STD DONE (DEFINED)]*

The next sequence specifies standard #6, the lowband load.

- *[DEFINE STANDARD]* [6] [x1] *[LOAD]*
- *[SPECIFY OFFSET] [MAXIMUM FREQUENCY]* [2] [.] [0] [0] [1] [G/n]
- *[STD OFFSET DONE] [STD DONE (DEFINED)]*

The final sequence labels the kit and saves it in memory.

- *[LABEL KIT]*
- Use the knob and softkeys to modify the label to read "3.5mmA"
- *[DONE] [KIT DONE (MODIFIED)]*

- [CAL]
- *[CAL KIT [3.5mmA]]*
- *[SAVE USER KIT] [USER KIT]*

The *[USER KIT]* softkey is now underlined, and the user-specified kit definition is saved in non-volatile memory.

# Appendix to Chapter 5

## ACCURACY ENHANCEMENT FUNDAMENTALS—CHARACTERIZING MICROWAVE SYSTEMATIC ERRORS

This appendix explains how the systematic errors in a measurement can be characterized in a flowgraph model and used to reduce measurement uncertainty. These errors are directivity, source match, load match, isolation (crosstalk), and frequency response (tracking). Refer to *Sources of Measurement Errors* at the beginning of Chapter 5 for more information on each of the sytematic errors.

### One-Port Error Model

First consider a measurement of the complex reflection coefficient of an unknown one-port device. The complex reflection coefficient, $S_{11}$, is measured by first separating the incident signal (I) from the reflected signal (R), then taking the ratio of the two values (Figure 5-23). No matter how carefully the device is measured, the measured value $S_{11M}$ will differ from the actual value $S_{11A}$, because of the presence of systematic errors.

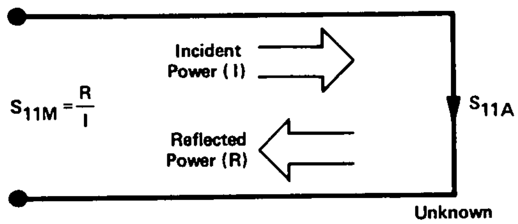



*Figure 5-23*

In such a measurement, all of the incident signal does not always reach the unknown (see Figure 5-24). Some of (I) may appear at the measurement system input due to leakage through the signal separation devices. 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, $E_{DF}$. The measurement is distorted when the directivity signal combines vectorally with the actual reflected signal from the unknown, $S_{11A}$.

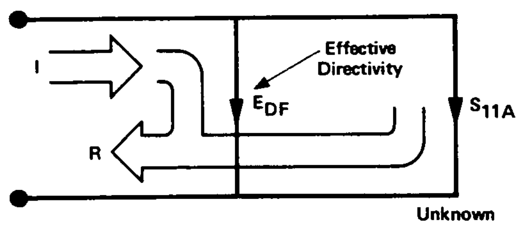



*Figure 5-24*

Since the measurement system test port is never exactly the characteristic impedance (50 ohms), some of the reflected signal bounces off the test port, or other impedance transitions 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 $S_{11A}$ and frequency. Leveling the source to produce constant (I) reduces this error, but since the source cannot be exactly leveled at the test device input, leveling cannot eliminate all power variations. This re-reflection effect and the resultant incident power variation are caused by the source match error, $E_{SF}$ (Figure 5-25).

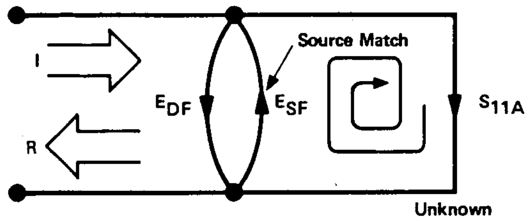



*Figure 5-25*

Frequency response (tracking) 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 in length and loss between incident and test signal paths. The vector sum of these variations is the reflection signal path tracking error, $E_{RF}$ (Figure 5-26).

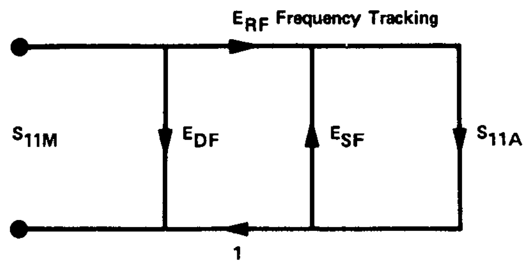



*Figure 5-26*

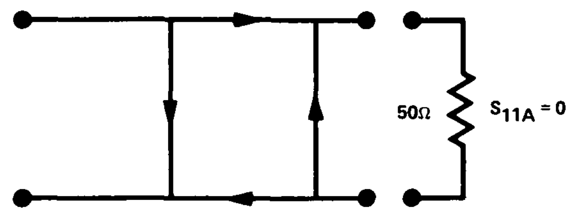
These three errors are mathematically related to the actual data, $S_{11A}$, and measured data, $S_{11M}$, by the following equation:

$$S_{11M} = E_{DF} + \frac{S_{11A}(E_{RF})}{1 - E_{SF}S_{11A}}$$

If the value of these three "E" errors and the measured test device response is known, the above equation can be solved for $S_{11A}$ to obtain the actual test device response. Measurement calibration is the process of characterizing these terms. The errors are vector quantities that can be measured by the system and used in accuracy enhancement equations to reduce or eliminate their effects.

However, each of these errors changes with frequency, and their values must be determined at each test frequency over the range of interest. These values are found by measuring the response of at least three independent standards whose characteristics are known at all frequencies.

The first standard applied is a "perfect load", which makes $S_{11A} = 0$ and essentially measures directivity (Figure 5-27). "Perfect load" implies 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 term. In practice, of course, the "perfect load" is difficult to achieve, although the terminations in the analyzer compatible calibration kits are of a very high quality.




$$S_{11M} = E_{DF} + \frac{(0)(E_{RF})}{1 - E_{SF}(0)}$$

*Figure 5-27*

In measurement calibrations with the network analyzer system, different loads are used depending on the frequency range of the measurements. At frequencies below 3 GHz in 3.5 mm (2 GHz in 7 mm or type-N) a fixed $Z_0$ lowband load is used. For measurements of frequencies both below and above 3 GHz (2 GHz), a high quality fixed $Z_0$ broadband load is available in the HP 85052D and 85050D calibration kits. For the highest level of accuracy (the best directivity) in calibration for measurements above 3 GHz (2 GHz), a sliding load is used. This is available in the HP 85052B (3.5 mm), 85050B (7 mm), and 85054B (type-N) calibration kits.

At any single frequency, the measured value for directivity is the vector sum of the actual directivity and the reflection coefficient Γ of the load (Figure 5-28).

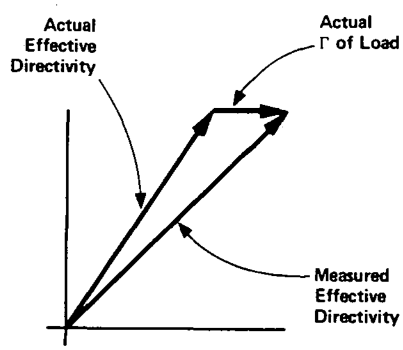



*Figure 5-28*

At higher frequencies, the sliding load is used at each test frequency to separate the reflection of the termination from the actual effective directivity. Moving the load element with respect to the reference plane produces a change in the measured phase angle. Moving the load element one-half wavelength of the test frequency produces a complete 360°change in the phase of $S_{11M}$. The center of the resulting circle is the tip of the directivity vector, and its radius is the reflection coefficient of the sliding load (Figure 5-29). The sliding load calibration sequence used in the accuracy enhancement program measures the sliding load at five or more positions, computes the center of the circle, then stores that value as system effective directivity $E_{DF}$. It is recommended that the sliding load element positions be unequally spaced to reduce the possibility of overlapping data points.

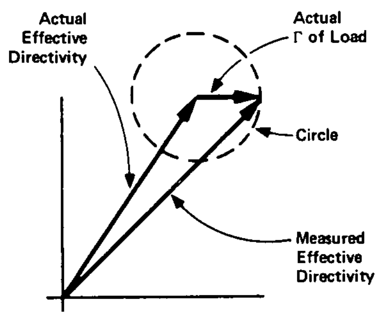
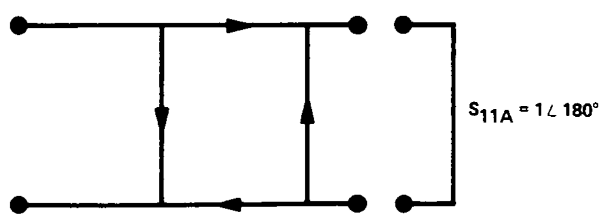



*Figure 5-29*

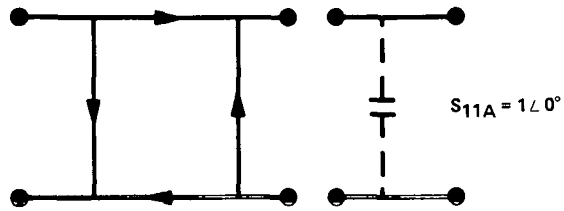
After the response of the load has been measured and the directivity error term $E_{DF}$ is known, the remaining errors can be determined by measuring two additional standards. The second standard to be measured is a short circuit with a reflection coefficient of $1\angle 180°$at all frequencies (Figure 5-30). This establishes the first condition ($S_{11A} = -1$) of a two-equation, two-unknown solution to find $E_{SF}$ (source match) and $E_{RF}$ (reflection tracking).




$$S_{11M} = E_{DF} + \frac{(-1)(E_{RF})}{1-E_{SF}(-1)}$$

*Figure 5-30*

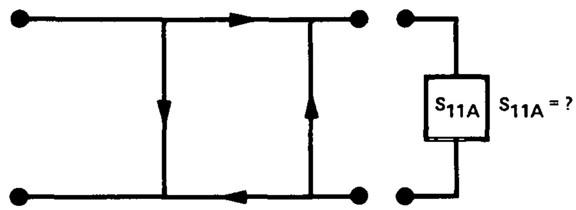
The open circuit is the third independent measurement standard. It provides the second condition ($S_{11A} = 1$) needed to solve the equations. An ideal open circuit would have a reflection coefficient of $1\angle 0°$ at all frequencies. In practice, however, the reflection from a real open circuit has a magnitude near 1 and a phase response that varies with frequency, causing the apparent reference plane to shift with frequency. The open circuits in the analyzer compatible calibration kits are shielded to reduce the magnitude and phase variations with frequency (the open circuit capacitance is different with each connector type). Now the values for $E_{DF}$, directivity, $E_{SF}$, source match, and $E_{RF}$, reflection frequency response, are computed and stored (Figure 5-31).




$$S_{11M} = E_{DF} + \frac{(1)(E_{RF})}{1 - E_{SF}(1)}$$

*Figure 5-31*

Now the unknown is measured to obtain a value for the measured response, $S_{11M}$, at each frequency (Figure 5-32).




$$S_{11M} = E_{DF} + \frac{S_{11A}(E_{RF})}{1 - E_{SF}S_{11A}}$$

*Figure 5-32*

This is the one-port error model equation solved for $S_{11A}$. Since the three errors and $S_{11M}$ are now known for each test frequency, $S_{11A}$ can be computed as follows:

$$S_{11A} = \frac{S_{11M} - E_{DF}}{E_{SF}(S_{11M} - E_{DF}) + E_{RF}}$$

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 (have as low a 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 one-port error model.

## Two-Port Error Model

The error model for measurement of the transmission coefficients (magnitude and phase) of a two-port device is derived in a similar manner. The major sources of error are frequency response (tracking), source match, load match, and isolation. These errors are effectively removed using the full two-port error model.

The transmission coefficient is measured by taking the ratio of the incident signal (I) and the transmitted signal (T) (Figure 5-33). Ideally, (I) consists only of power delivered by the source, and (T) consists only of power emerging at the test device output.

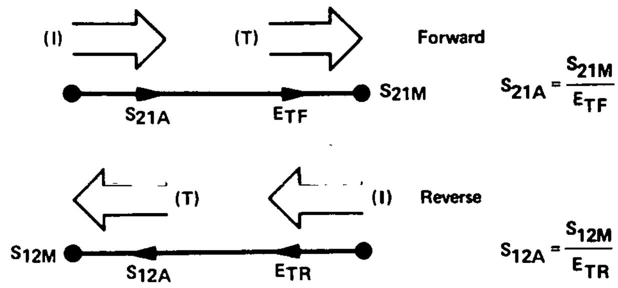



*Figure 5-33*

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 test port 2, and from other mismatches between the test device output and the receiver input, to return to the test device. A portion of this signal 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, $E_{LF}$ (Figure 5-34).

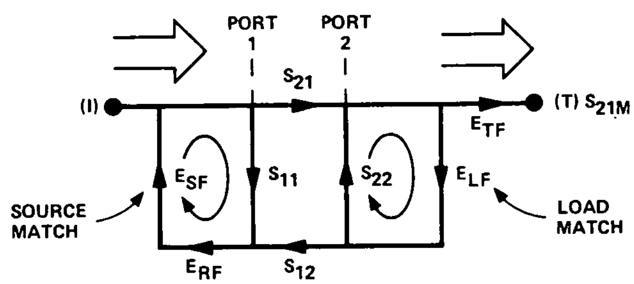



*Figure 5-34*

The measured value, $S_{21M}$, consists of signal components that 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 the directivity, $E_{DF}$, source match, $E_{SF}$, and reflection frequency response, $E_{RF}$, terms for the reflection measurements.

Now that a calibrated port is available for reflection measurements, the thru is connected and load match, $E_{LF}$, is determined by measuring the reflection coefficient of the thru connection.

Transmission signal path frequency response is then measured with the thru connected. The data is corrected for source and load match effects, then stored as transmission frequency response, $E_{TF}$.

Isolation, $E_{XF}$, represents the part of the incident signal that appears at the receiver without actually passing through the test device (Figure 5-35). Isolation is measured with the network analyzer in the transmission configuration and with terminations installed at the points where the test device will be connected.

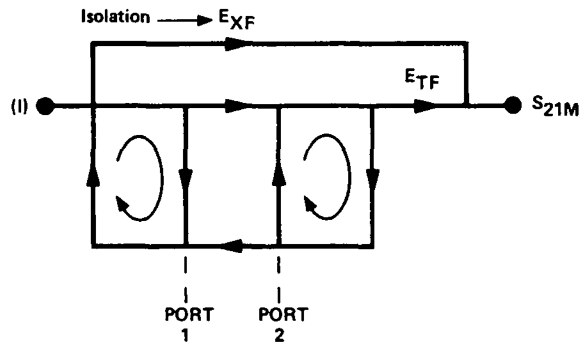



*Figure 5-35*

Thus there are two sets of error terms, forward and reverse, with each set consisting of six error terms, as follows:

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 $E_{TR}$
Reflection tracking, $E_{RF}$ and $E_{RR}$.

The network analyzer can measure both the forward and reverse characteristics of the test device without the need to manually remove and physically reverse it. The full two-port error model illustrated in Figure 5-36 effectively removes both the forward and reverse error terms for transmission and reflection measurements.

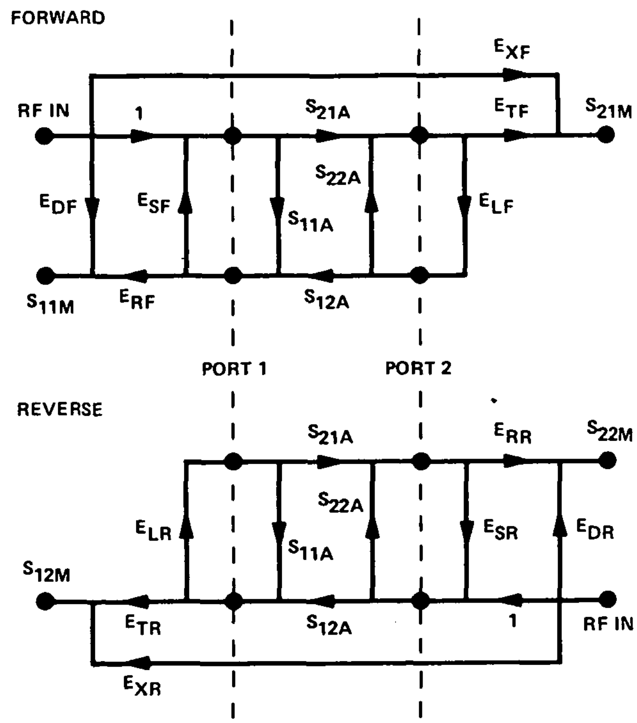



*Figure 5-36*

Figure 5-37 shows the full two-port error model equations for all four S-parameters of a two-port device. Note that the mathematics for this comprehensive model use all forward and reverse error terms and measured values. Thus, to perform full error correction for any one parameter, all four S-parameters must be measured.

Applications of these error models are provided in the calibration procedures described in Chapter 5.

$$S_{11A} = \frac{\left[\left(\frac{S_{11M}-E_{DF}}{E_{RF}}\right)\left[1+\left(\frac{S_{22M}-E_{DR}}{E_{RR}}\right)E_{SR}\right]\right]-\left[\left(\frac{S_{21M}-E_{XF}}{E_{TF}}\right)\left(\frac{S_{12M}-E_{XR}}{E_{TR}}\right)E_{LF}\right]}{\left[1+\left(\frac{S_{11M}-E_{DF}}{E_{RF}}\right)E_{SF}\right]\left[1+\left(\frac{S_{22M}-E_{DR}}{E_{RR}}\right)E_{SR}\right]-\left[\left(\frac{S_{21M}-E_{XF}}{E_{TF}}\right)\left(\frac{S_{12M}-E_{XR}}{E_{TR}}\right)E_{LF}E_{LR}\right]}$$

$$S_{21A} = \frac{\left[1+\left(\frac{S_{22M}-E_{DR}}{E_{RR}}\right)\left(E_{SR}-E_{LF}\right)\right]\left(\frac{S_{21M}-E_{XF}}{E_{TF}}\right)}{\left[1+\left(\frac{S_{11M}-E_{DF}}{E_{RF}}\right)E_{SF}\right]\left[1+\left(\frac{S_{22M}-E_{DR}}{E_{RR}}\right)E_{SR}\right]-\left[\left(\frac{S_{21M}-E_{XF}}{E_{TF}}\right)\left(\frac{S_{12M}-E_{XR}}{E_{TR}}\right)E_{LF}E_{LR}\right]}$$

$$S_{12A} = \frac{\left[1+\left(\frac{S_{11M}-E_{DF}}{E_{RF}}\right)\left(E_{SF}-E_{LR}\right)\right]\left(\frac{S_{12M}-E_{XR}}{E_{TR}}\right)}{\left[1+\left(\frac{S_{11M}-E_{DF}}{E_{RF}}\right)E_{SF}\right]\left[1+\left(\frac{S_{22M}-E_{DR}}{E_{RR}}\right)E_{SR}\right]-\left[\left(\frac{S_{21M}-E_{XF}}{E_{TF}}\right)\left(\frac{S_{12M}-E_{XR}}{E_{TR}}\right)E_{LF}E_{LR}\right]}$$

$$S_{22A} = \frac{\left[\left(\frac{S_{22M}-E_{DR}}{E_{RR}}\right)\left[1+\left(\frac{S_{11M}-E_{DF}}{E_{RF}}\right)E_{SF}\right]\right]-\left[\left(\frac{S_{21M}-E_{XF}}{E_{TF}}\right)\left(\frac{S_{12M}-E_{XR}}{E_{TR}}\right)E_{LR}\right]}{\left[1+\left(\frac{S_{11M}-E_{DF}}{E_{RF}}\right)E_{SF}\right]\left[1+\left(\frac{S_{22M}-E_{DR}}{E_{RR}}\right)E_{SR}\right]-\left[\left(\frac{S_{21M}-E_{XF}}{E_{TF}}\right)\left(\frac{S_{12M}-E_{XR}}{E_{TR}}\right)E_{LF}E_{LR}\right]}$$

*Figure 5-37*

## INTRODUCTION

The **[MKR]** (MENUMARK) key displays a movable active marker (∇) on the screen and provides access to a series of menus to control from one to four display markers for each channel (a total of eight). Markers are used to obtain numerical readings of measured values. They also provide capabilities for reducing measurement time by changing stimulus parameters, searching the trace for specific values, or statistically analyzing part or all of the trace. Figure 6-1 illustrates the displayed trace with all markers on and marker 3 the active marker.

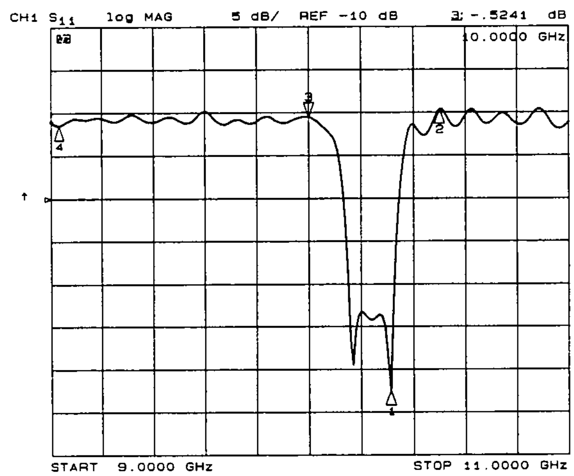



*Figure 6-1. Markers on Trace*

Markers have a stimulus value (the x-axis value in a Cartesian format) and a response value (the y-axis value in a Cartesian format). In a polar or Smith chart format, the second part of a complex data pair is also provided as an auxiliary response value. When a marker is turned on and no other function is active, its stimulus value is displayed in the active entry area and can be controlled with the knob, the step keys, or the numerical keypad. The active marker can be moved to any point on the trace, and its response and stimulus values are displayed at the top right corner of the graticule for each displayed channel, in units appropriate to the display format. The displayed marker response values are valid even when the measured data is above or below the range displayed on the graticule.

To see or copy (to plotter or printer) the response and stimulus values of all eight markers, press **[COPY]** ***[OP PARM MKRS etc]***.

Marker values are normally continuous: that is, they are interpolated between measured points, with 100 kHz resolution in the standard instrument and 1 Hz in the option 001. Alternatively, they can be set to read only discrete measured points. The markers for the two channels normally have the same stimulus values, or they can be uncoupled so that each channel has independent markers, regardless of whether stimulus values are coupled or dual channel display is on.

If both data and memory are displayed, the marker values apply to the data trace. If memory only is displayed, the marker values apply to the memory trace. In a memory math display (data/memory or data−memory), the marker values apply to the trace resulting from the memory math function.

With the use of a reference marker, a delta marker mode is available that displays both the stimulus and response values of the active marker relative to the reference. Any of the four markers or a fixed point can be designated as the delta reference marker. If the delta reference is one of the four markers, its stimulus value can be controlled by the user and its response value is the value of the trace at that stimulus value. If the delta reference is a fixed marker, both its stimulus value and its response value can be set arbitrarily by the user anywhere in the display area (not necessarily on the trace).

Markers can be used to search for the trace maximum or minimum point or any other point on the trace. The four markers can be used together to search for specified bandwidth cutoff points and calculate the bandwidth and Q values (see *Marker Search Menu*). Statistical analysis uses markers to provide a readout of the mean, standard deviation, and peak-to-peak values of all or part of the trace (see *Marker Function Menu*).

## [MKR] KEY

Basic marker operations are available in the menus accessed from the **[MKR]** key. The marker search and statistical functions, together with the capability for quickly changing stimulus parameters with markers, are provided in the menus accessed from the **[MKR FCTN]** key.

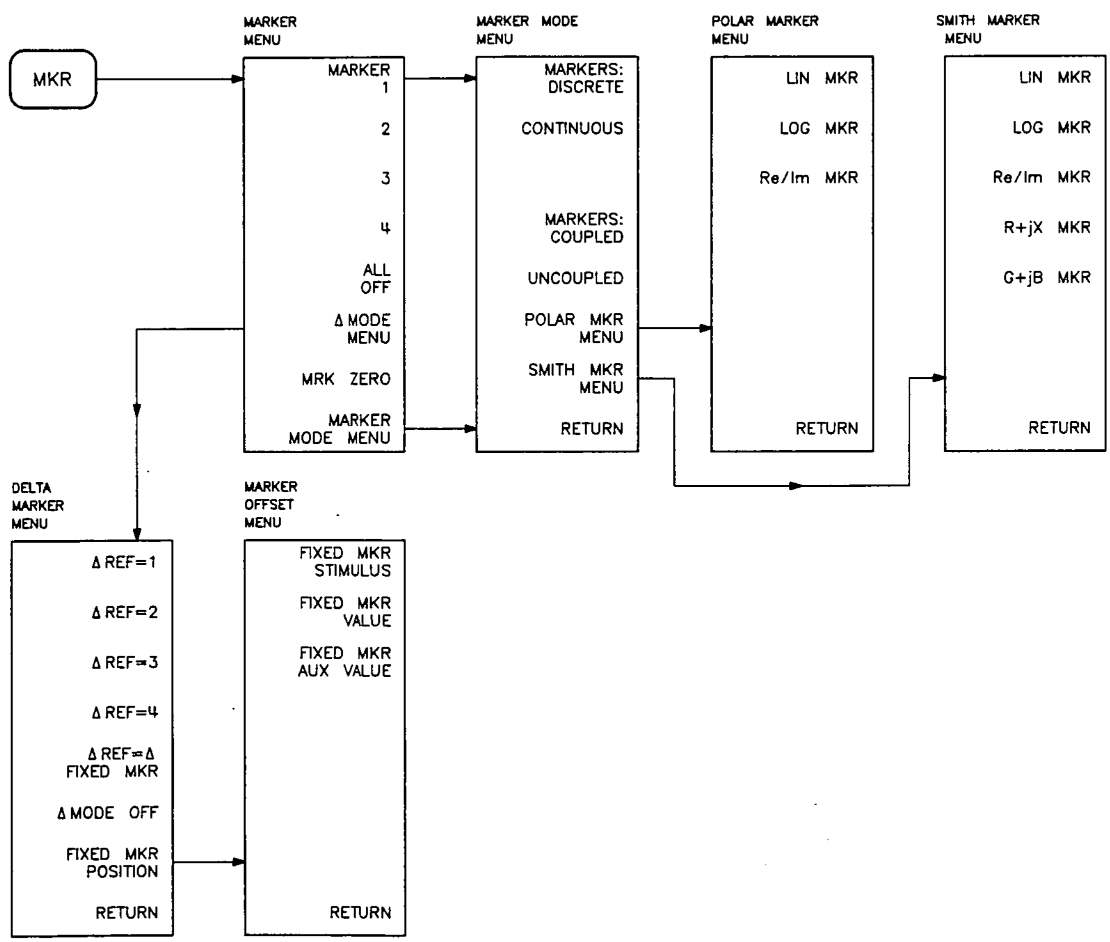



*Figure 6-2. Menus Accessed from the [MKR] Key*

The menus accessed from the **[MKR]** key (Figure 6-2) provide several basic marker operations. These include different marker modes for different display formats, and the delta marker mode that displays marker values relative to a specified value.

## Marker Menu

The marker menu (Figure 6-3) is used to turn the display markers on or off, to designate the active marker, and to gain access to the marker delta mode and other marker modes and formats.

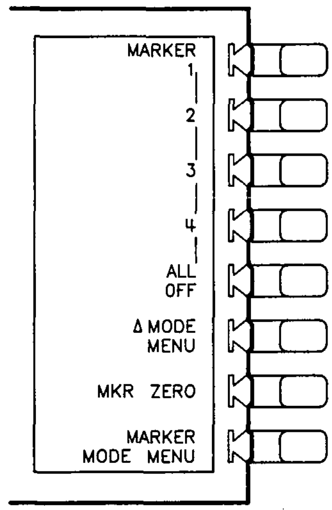



*Figure 6-3. Marker Menu*

***[MARKER 1]*** (MARK1) turns on marker 1 and makes it the active marker. The active marker appears on the CRT as ∇. The active marker stimulus value is displayed in the active entry area, together with the marker number. If there is a marker turned on, and no other function is active, the stimulus value of the active marker can be controlled with the knob, the step keys, or the number pad. The marker response and stimulus values are displayed in the upper right corner of the screen.

***[MARKER 2]*** (MARK2) turns on marker 2 and makes it the active marker. If another marker is present, that marker becomes inactive and is represented on the CRT as Δ.

***[MARKER 3]*** (MARK3) turns on marker 3 and makes it the active marker.

***[MARKER 4]*** (MARK4) turns on marker 4 and makes it the active marker.

***[ALL OFF]*** (MARKOFF) turns off all the markers and the delta reference marker, as well as the tracking and bandwidth functions that are accessed with the **[MKR FCTN]** key.

***[Δ MODE MENU]*** goes to the delta marker menu, which is used to read the difference in values between the active marker and a reference marker.

***[MKR ZERO]*** (MARKZERO) puts a fixed reference marker at the present active marker position, and makes the fixed marker stimulus and response values at that position equal to zero. All subsequent stimulus and response values of the active marker are then read out relative to the fixed marker. The fixed marker is shown on the CRT as a small triangle Δ (delta), smaller than the inactive marker triangles. The softkey label changes from ***[MKR ZERO]*** to ***[MKR ZERO Δ REF = Δ]*** and the notation "ΔREF=Δ" is displayed at the top right corner of the graticule. Marker zero is canceled by turning delta mode off in the delta marker menu or turning all the markers off with the ***[ALL OFF]*** softkey.

*[MARKER MODE MENU]* provides access to the marker mode menu, where several marker modes can be selected including special markers for polar and Smith formats.

## Delta Marker Mode Menu

The delta marker mode is used to read the difference in stimulus and response values between the active marker and a designated delta reference marker. Any of the four markers or a fixed point can be designated as the reference marker. If the reference is one of the four markers, its stimulus value can be controlled by the user and its response value is the value of the trace at that stimulus value. If the reference is a fixed marker, both its stimulus value and its response value can be set arbitrarily by the user anywhere in the display area. The delta reference is shown on the CRT as a small triangle Δ (delta), smaller than the inactive marker triangles. If one of the markers is the reference, the triangle appears next to the marker number on the trace.

The marker values displayed in this mode are the stimulus and response values of the active marker minus the reference marker. If the active marker is also designated as the reference marker, the marker values are zero.

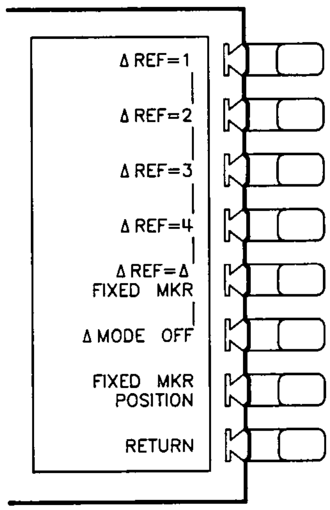



*Figure 6-4. Delta Marker Mode Menu*

*[Δ REF =1]* (DELR1) establishes marker 1 as a reference. The active marker stimulus and response values are then shown relative to this delta reference. Once marker 1 has been selected as the delta reference, the softkey label *[Δ REF =1]* is underlined in this menu, and the marker menu is returned to the screen. In the marker menu, the first key is now labeled *[MARKER Δ REF =1]*. The notation "ΔREF=1" appears at the top right corner of the graticule.

*[Δ REF =2]* (DELR2) makes marker 2 the delta reference. Active marker stimulus and response values are then shown relative to this reference.

*[Δ REF =3]* (DELR3) makes marker 3 the delta reference.

*[Δ REF =4]* (DELR4) makes marker 4 the delta reference.

*[Δ REF = Δ FIXED MKR]* (DELRFIXM) sets a user-specified fixed reference marker. The stimulus and response values of the reference can be set arbitrarily, and can be anywhere in the display area consistent with the 100 kHz frequency resolution of the standard instrument (1 Hz in the option 001). Unlike markers 1 to 4, the fixed marker need not be on the trace. The fixed marker is indicated by a small triangle Δ, and the active marker stimulus and response values are shown relative to this point. The notation "ΔREF=Δ" is displayed at the top right corner of the graticule.

Pressing this softkey turns on the fixed marker. Its stimulus and response values can then be changed using the fixed marker menu, which is accessed with the *[FIXED MKR POSITION]* softkey described below. Alternatively, the fixed marker can be set to the current active marker position, using the *[MKR ZERO]* softkey in the marker menu.

*[Δ MODE OFF]* (DELO) turns off the delta marker mode, so that the values displayed for the active marker are absolute values.

*[FIXED MKR POSITION]* leads to the fixed marker menu, where the stimulus and response values for a fixed reference marker can be set arbitrarily.

Alternatively, the current position of the active marker can be entered as the fixed reference by using *[MARKER ZERO]* in the marker menu.

*[RETURN]* goes back to the marker menu.

## Fixed Marker Menu

This menu (Figure 6-5) is used to set the position of a fixed reference marker, indicated on the display by a small triangle Δ. Both the stimulus value and the response value of the fixed marker can be set arbitrarily anywhere in the display area, and need not be on the trace. The units are determined by the display format, the sweep type, and the marker type.

There are two ways to turn on the fixed marker. One way is with the *[Δ REF = Δ FIXED MKR]* softkey in the delta marker menu. The other is with the *[MKR ZERO]* function in the marker menu, which puts a fixed reference marker at the present active marker position and makes the marker stimulus and response values at that position equal to zero.

The softkeys in this menu make the values of the fixed marker the active function. The marker readings in the top right corner of the graticule are the stimulus and response values of the active marker minus the fixed reference marker. Also displayed in the top right corner is the notation "ΔREF=Δ."

The stimulus value, response value, and auxiliary response value (the second part of a complex data pair) can be individually examined and changed. This allows active marker readings that are relative in amplitude yet absolute in frequency, or any combination of relative/absolute readouts. Following a *[MKR ZERO]* operation, this menu can be used to reset any of the fixed marker values to absolute zero for absolute readings of the subsequent active marker values.

If the format is changed while a fixed marker is on, the fixed marker values become invalid. For example, if the value offset is set to 10 dB with a log magnitude format, and the format is then changed to phase, the value offset becomes 10 degrees. However, in polar and Smith chart formats, the specified values remain consistent between different marker types for those formats. Thus an R+jX marker set on a Smith chart format will retain the equivalent values if it is changed to any of the other Smith chart markers.

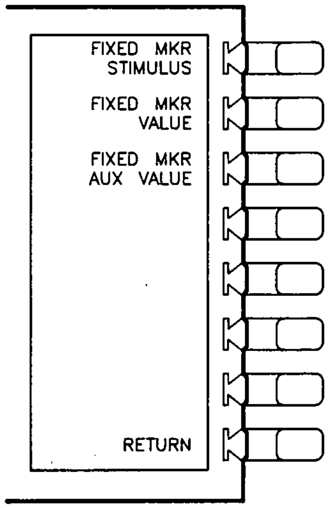



*Figure 6-5. The Fixed Marker Menu*

***[FIXED MKR STIMULUS]*** (MARKFSTI) changes the stimulus value of the fixed marker. In the standard instrument, this value must be divisible by 100 kHz. Fixed marker stimulus values can be different for the two channels if the channel markers are uncoupled using the marker mode menu.

To read absolute active marker stimulus values following a ***[MKR ZERO]*** operation, the stimulus value can be reset to zero.

***[FIXED MKR VALUE]*** (MARKFVAL) changes the response value of the fixed marker. In a Cartesian format this is the y-axis value. In a polar or Smith chart format with a magnitude/phase marker, a real/imaginary marker, an R+jX marker, or a G+jB marker, this applies to the first part of the complex data pair. Fixed marker response values are always uncoupled in the two channels.

To read absolute active marker response values following a ***[MKR ZERO]*** operation, the response value can be reset to zero.

***[FIXED MKR AUX VALUE]*** (MARKFAUV) is used only with a polar or Smith format. It changes the auxiliary response value of the fixed marker. This is the second part of a complex data pair, and applies to a magnitude/phase marker, a real/imaginary marker, an R+jX marker, or a G+jB marker. Fixed marker auxiliary response values are always uncoupled in the two channels.

To read absolute active marker auxiliary response values following a ***[MKR ZERO]*** operation, the auxiliary value can be reset to zero.

***[RETURN]*** goes back to the delta marker menu.

## Marker Mode Menu

This menu provides different marker modes and makes available two additional menus of special markers for use with Smith chart or polar formats.

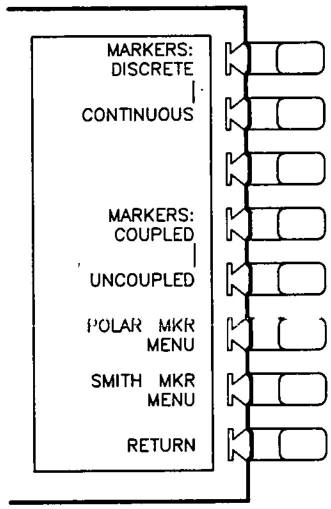



*Figure 6-6. Marker Mode Menu*

***[MARKERS: DISCRETE]*** (MARKDISC) places markers only on measured trace points determined by the stimulus settings.

***[CONTINUOUS]*** (MARKCONT) interpolates between measured points to allow the markers to be placed at any point on the trace. The marker readout values are also interpolated, with 100 kHz resolution in a standard instrument and 1 Hz in an option 001. This is the default marker mode.

***[MARKERS: COUPLED]*** (MARKCOUP) couples the marker stimulus values for the two display channels. Even if the stimulus is uncoupled and two sets of stimulus values are shown, the markers track the same stimulus values on each channel as long as they are within the displayed stimulus range. Markers are normally coupled.

***[UNCOUPLED]*** (MARKUNCO) allows the marker stimulus values to be controlled independently on each channel.

***[POLAR MKR MENU]*** leads to a menu of special markers for use with a polar format.

***[SMITH MKR MENU]*** leads to a menu of special markers for use with a Smith chart format.

***[RETURN]*** goes back to the marker menu.

## Polar Marker Menu

This menu is used only with a polar display format, selectable using the **[FORMAT]** key. In the polar format, the magnitude at the center of the circle is zero and the outer circle is the full-scale value set in the scale reference menu. Phase is measured as the angle counterclockwise from 0°at the positive x-axis. The analyzer automatically calculates different mathematical forms of the marker magnitude and phase values, selected using the softkeys in this menu. Marker frequency is displayed in addition to other values regardless of the selection of marker type.

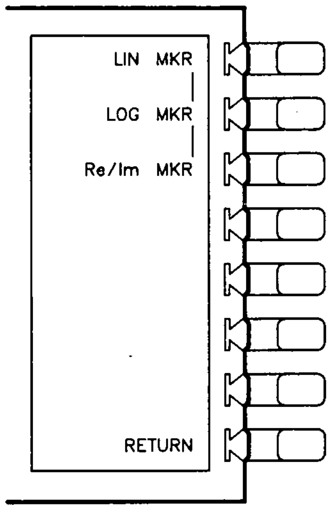



*Figure 6-7. Polar Marker Menu*

***[LIN MKR]*** (POLMLIN) displays a readout of the linear magnitude and the phase of the active marker. This is the preset marker type for a polar display. Magnitude values are read in units and phase in degrees.

***[LOG MKR]*** (POLMLOG) displays the logarithmic magnitude and the phase of the active marker. Magnitude values are expressed in dB and phase in degrees. This is useful as a fast method of obtaining a reading of the log magnitude value without changing to log magnitude format.

***[Re/Im MKR]*** (POLMRI) displays the values of the active marker as a real and imaginary pair. The complex data is separated into its real part and imaginary part. The first marker value given is the real part $M \cos \theta$, and the second value is the imaginary part $M \sin \theta$, where $M$ = magnitude and $\theta$ = phase angle.

***[RETURN]*** goes back to the marker mode menu.

## Smith Marker Menu

This menu is used only with the Smith chart format, selected from the format menu. The analyzer automatically calculates different mathematical forms of the marker magnitude and phase values, selected using the softkeys in this menu. Marker frequency is displayed in addition to other values for all marker types.

For additional information about the Smith chart display format, refer to *[FORMAT] Key* in Chapter 4.

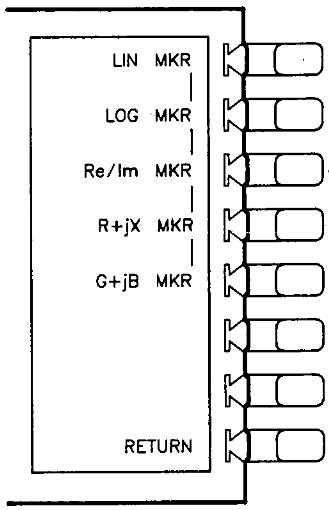



*Figure 6-8. Smith Marker Menu*

***[LIN MKR]*** (SMIMLIN) displays a readout of the linear magnitude and the phase of the active marker. Marker magnitude values are expressed in units and phase in degrees.

***[LOG MKR]*** (SMIMLOG) displays the logarithmic magnitude value and the phase of the active marker. Magnitude values are expressed in dB and phase in degrees. This is useful as a fast method of obtaining a reading of the log magnitude value without changing to log magnitude format.

***[Re/Im MKR]*** (SMIMRI) displays the values of the active marker on a Smith chart as a real and imaginary pair. The complex data is separated into its real part and imaginary part. The first marker value given is the real part M cos θ, and the second value is the imaginary part M sin θ, where M =magnitude and θ=phase angle.

***[R+jX MKR]*** (SMIMRX) converts the active marker values into rectangular form. The complex impedance values of the active marker are displayed in terms of resistance, reactance, and equivalent capacitance or inductance. This is the default Smith chart marker.

For measurements in an environment that is not 50 ohms, the network analyzer characteristic impedance must be modified using the ***[SET Z0]*** softkey in the calibrate more menu (Chapter 5). $Z_0$ sets the center value of the Smith chart, and is used in calculating impedance measurements. In addition, a minimum loss pad or matching transformer must be inserted between the device and the measurement port.

***[G+jB MKR]*** (SMIMGB) displays the complex admittance values of the active marker in rectangular form. The active marker values are displayed in terms of conductance (in Siemens), susceptance, and equivalent capacitance or inductance. Siemens are the international units of admittance, and are equivalent to mhos (the inverse of ohms).

***[RETURN]*** goes back to the marker mode menu.

## [MKR FCTN] KEY

The **[MKR FCTN]** (MENUMRKF) key activates a marker if one is not already active, and provides access to additional marker functions. These can be used to quickly change the measurement parameters, to search the trace for specified information, and to analyze the trace statistically.

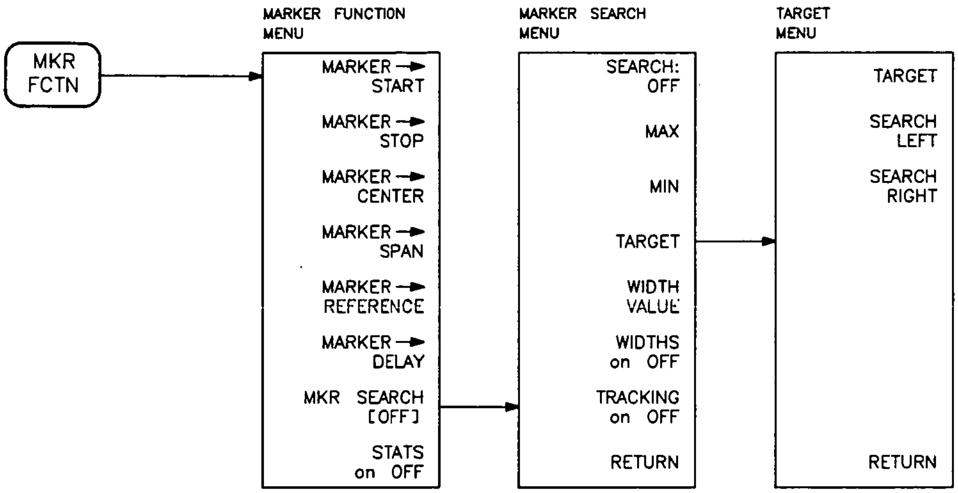



*Figure 6-9. Menus Accessed from the [MKR FCTN] Key*

### Marker Function Menu

This menu provides softkeys that use markers to quickly modify certain measurement parameters without going through the usual key sequence. In addition, it provides access to two additional menus used for searching the trace and for statistical analysis.

The ***[MARKER →]*** functions change certain stimulus and response parameters to make them equal to the current active marker value. Use the knob or the keypad to move the marker to the desired position on the trace, and press the appropriate softkey to set the specified parameter to that trace value. When the values have been changed, the marker can again be moved within the range of the new parameters.

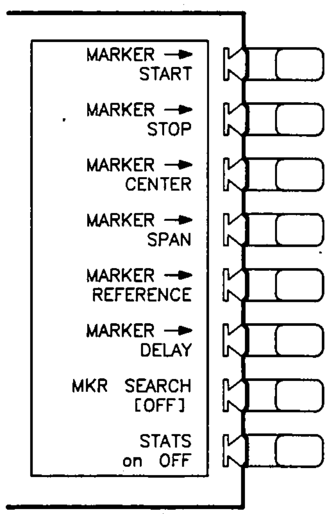



*Figure 6-10. Marker Function Menu*

*[MARKER →START]* (MARKSTAR) changes the stimulus start value to the stimulus value of the active marker.

*[MARKER →STOP]* (MARKSTOP) changes the stimulus stop value to the stimulus value of the active marker.

*[MARKER →CENTER]* (MARKCENT) changes the stimulus center value to the stimulus value of the active marker, and centers the new span about that value.

*[MARKER →SPAN]* (MARKSPAN) changes the start and stop values of the stimulus span to the values of the active marker and the delta reference marker. If there is no reference marker, the message "NO MARKER DELTA−SPAN NOT SET" is displayed.

*[MARKER →REFERENCE]* (MARKREF) makes the reference value equal to the active marker's response value, without changing the reference position. In a polar or Smith chart format, the full scale value at the outer circle is changed to the active marker response value. This softkey also appears in the scale reference menu.

*[MARKER →DELAY]* (MARKDELA) adds electrical delay, up to a maximum of 10 µsec, to balance the phase of the DUT. This is performed automatically, regardless of the format and the measurement being made. Enough line length is added to or subtracted from the receiver input to compensate for the phase slope at the active marker position. This effectively flattens the phase trace around the active marker, and can be used to measure electrical length or deviation from linear phase. Additional electrical delay adjustments are required on DUTs without constant group delay over the measured frequency span. Refer to *Scale Reference Menu* in Chapter 4 for more information on electrical delay.

*[MARKER SEARCH]* leads to the marker search menu, which is used to search the trace for a particular value or bandwidth.

*[STATS on OFF]* (MEASTAT) calculates and displays the mean, standard deviation, and peak-to-peak values of the section of the displayed trace between the active marker and the delta reference marker. If there is no delta reference, the statistics are calculated for the entire trace. A convenient use of this feature is to find the peak-to-peak value of passband ripple without searching separately for the maximum and minimum values. The *User's Guide* provides an example of such a measurement, illustrated here in Figure 6-11.

The statistics are absolute values: the delta marker here serves to define the span. For polar and Smith formats the statistics are calculated using the first value of the complex pair (magnitude, real part, resistance, or conductance).

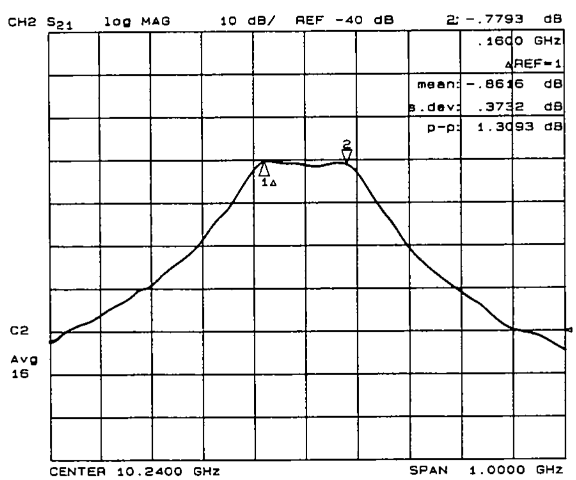



*Figure 6-11. Measurement Using Marker Statistics*

## Marker Search Menu

This menu is used to search the trace for a specific magnitude-related point, and place the marker on that point. The capability of searching for a specified bandwidth is also provided. Tracking is available for a continuous sweep-to-sweep search. If there is no occurrence of a specified value or bandwidth, the message "TARGET VALUE NOT FOUND" is displayed.

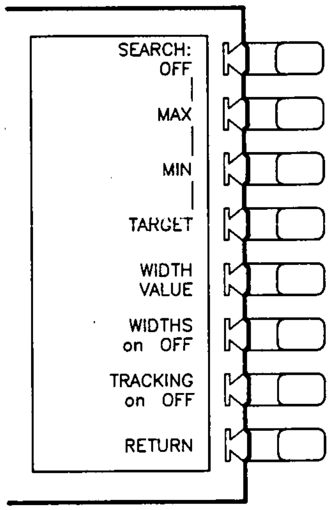



*Figure 6-12. Marker Search Menu*

***[SEARCH: OFF]*** (SEAOFF) turns off the marker search function.

***[MAX]*** (SEAMAX) moves the active marker to the maximum point on the trace.

***[MIN]*** (SEAMIN) moves the active marker to the minimum point on the trace.

***[TARGET]*** (SEATARG) makes target value the active function, and places the active marker at a specified target point on the trace. The default target value is −3 dB. The target menu is presented, providing search right and search left options to resolve multiple solutions.

For relative measurements, a search reference must be defined with a delta marker or a fixed marker before the search is activated.

***[WIDTH VALUE]*** (WIDV) is used to set the magnitude parameter (for example 3 dB) that defines the start and stop points for a bandwidth search. The bandwidth search feature analyzes a bandpass or band reject trace and calculates the center point, bandwidth, and Q (quality factor) for the specified bandwidth.

***[WIDTHS on OFF]*** (WIDTON, WIDTOFF) turns on the bandwidth search feature and calculates the center stimulus value, bandwidth, and Q of a bandpass or band reject shape on the trace. Bandwidth units are the units of the current format. Bandwidth frequencies are resolved to 100 kHz in the standard instrument (1 Hz in the option 001). The magnitude value that defines the passband or rejectband is set using the ***[WIDTH VALUE]*** softkey.

All four markers are turned on, and each has a dedicated use. Marker 1 is a starting point from which the search is begun. Marker 2 goes to the bandwidth center point. Marker 3 goes to the bandwidth cutoff point on the left, and marker 4 to the cutoff point on the right.

If a delta marker or fixed marker is on, it is used as the reference point from which the bandwidth magnitude is measured. For example, if marker 1 is the delta marker and is set at the passband maximum, and the width value is set to −3 dB, the bandwidth search finds the bandwidth cutoff points 3 dB below the maximum and calculates the 3 dB bandwidth and Q.

If marker 2 (the dedicated bandwidth center point marker) is the delta reference marker, the search finds the points 3 dB down from the center.

If no delta reference marker is set, the bandwidth values are absolute values.

***[TRACKING on OFF]*** (TRACKON, TRACKOFF) is used in conjunction with other search features to track the search with each new sweep. Turning tracking on makes the HP 8720A search every new trace for the specified target value and put the active marker on that point. If bandwidth search is on, tracking searches every new trace for the specified bandwidth, and repositions the dedicated bandwidth markers.

When tracking is off, the target is found on the current sweep and remains at the same stimulus value regardless of changes in trace response value with subsequent sweeps.

A maximum and a minimum point can be tracked simultaneously using two channels and uncoupled markers.

***[RETURN]*** goes back to the marker function menu.

## Target Menu

The target menu places the marker at a specified target response value on the trace, and provides search right and search left options. If there is no occurrence of the specified value, the message "TARGET VALUE NOT FOUND" is displayed.

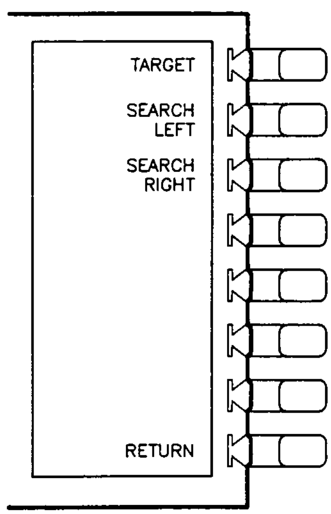



*Figure 6-13. Target Menu*

***[TARGET]*** (SEATARG) places the marker at the specified target response value. If tracking is on (see previous menu) the target is automatically tracked with each new trace. If tracking is off, the target is found each time this key is pressed. The target value is in units appropriate to the current format. The default target value is −3 dB.

In delta marker mode, the target value is the value relative to the reference marker. If no delta reference marker is on, the target value is an absolute value.

*[SEARCH LEFT]* (SEAL) searches the trace for the next occurrence of the target value to the left.

*[SEARCH RIGHT]* (SEAR) searches the trace for the next occurrence of the target value to the right.

*[RETURN]* goes back to the marker search menu.

# Chapter 7. Instrument State and Limit Testing

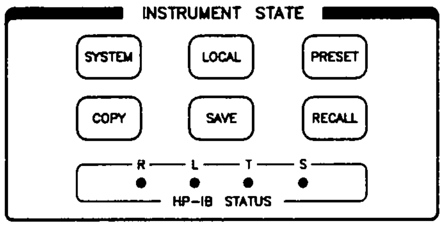



*Figure 7-1*

## INTRODUCTION

The **[LOCAL]** key and the **[SYSTEM]** key are part of the instrument state function block. The keys in this block, and their associated menus, provide control of channel-independent system functions.

The **[LOCAL]** key leads to the menus used to define controller modes, instrument addresses, and HP-IB status information. (Additional HP-IB information is provided in Chapter 11.)

The **[SYSTEM]** key provides access to the limit testing feature, which compares measured data with user-defined limits. It also leads to the option 010 time domain transform function and the service menus. Limit testing is described in this chapter, and time domain is explained in Chapter 8. The *Service Manual* provides complete information on the service menus.

Other functions provided by the instrument state block and its associated menus are plotting and printing, and saving instrument states either in internal memory or on an external disc. The printing and plotting capabilities available using the **[COPY]** key are described in Chapter 9. Chapter 10 explains the use of instrument state save registers and external storage files, and the **[SAVE]** and **[RECALL]** keys.

## [LOCAL KEY]

This key is used to return the analyzer to local (front panel) operation from remote (computer controlled) operation. In this local mode, with a controller still connected on HP-IB, the analyzer can be operated manually (locally) from the front panel. This is the only front panel key that is not disabled when the analyzer is remotely controlled over HP-IB by a computer. The exception to this is when local lockout is in effect: this is a remote command that disables the **[LOCAL]** key, making it difficult to interfere with the network analyzer while it is under remote control.

In addition, this key gives access to the HP-IB menu, which sets the controller mode, and to the address menu, where the HP-IB addresses of peripheral devices are entered.

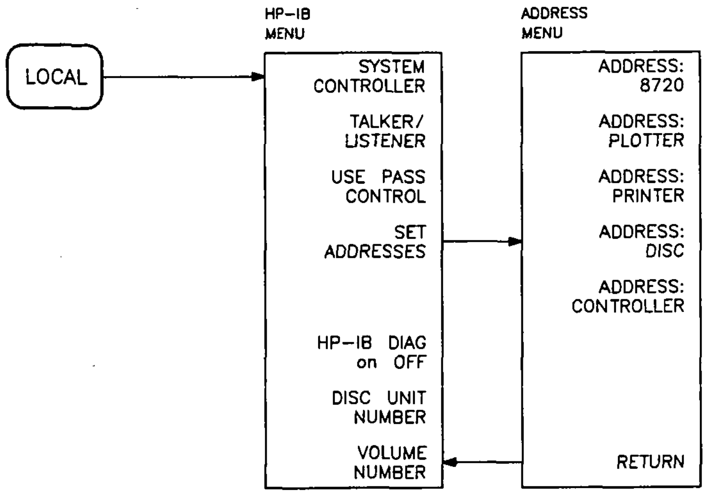



*Figure 7-2. Softkey Menus Accessed from the [LOCAL] Key*

## HP-IB Menu

The analyzer is factory-equipped with a remote programming interface using the Hewlett-Packard Interface Bus (HP-IB). This enables communication between the network analyzer and a controlling computer and other peripheral devices. This menu indicates the present HP-IB controller mode of the analyzer. Three HP-IB modes are possible: system controller, talker/listener, and pass control.

Talker/listener is the normal mode of operation. In this mode, a computer controller communicates with the network analyzer and other compatible peripherals over the bus. The computer sends commands or instructions to and receives data from the analyzer. All of the capabilities available from the analyzer front panel can be used in this remote operation mode, except for control of the power line switch and some internal tests.

In the system controller mode, the analyzer itself can use HP-IB to control compatible peripherals, without the use of an external computer. It can output measurement results directly to a compatible printer or plotter, and store instrument states using a compatible disc drive.

A third mode of HP-IB operation is the pass control mode. In an automated system with a computer controller, the controller can pass control of the bus to the analyzer on request from the network analyzer. The analyzer is then the controller of the peripherals, and can direct them to plot, print, or store without going through the computer. When the peripheral operation is complete, control is passed back to the computer. Only one controller can be active at a time. The computer remains the system controller, and can regain control at any time.

Preset does not affect the selected controller mode, but cycling the power returns the network analyzer to talker/listener mode.

Information on compatible peripherals is provided in the *General Information* section of this manual.

**HP-IB Status Indicators.** When the analyzer is connected to other instruments over HP-IB, the HP-IB STATUS indicators in the instrument state function block light up to display its current status.

R = Remote operation.
L = Listen mode.
T = Talk mode.
S = Service request (SRQ) asserted by the analyzer.

Refer to Chapter 11 for additional information on HP-IB operation of the analyzer.

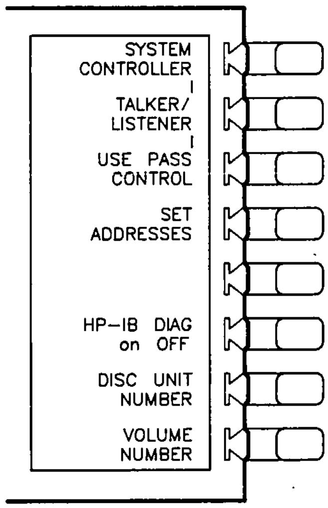



*Figure 7-3. HP-IB Menu*

*[SYSTEM CONTROLLER]* is the mode used when peripheral devices are to be used and there is no external controller. In this mode, the analyzer can directly control peripherals (plotter, printer, or disc drive). System controller mode must be set in order for the network analzyer to access peripherals from the front panel to plot, print, or store on disc, if there is no other controller on the bus.

The system controller mode can be used without knowledge of HP-IB programming. However, the HP-IB addresses displayed in the address menu must match the addresses set in the peripheral instruments.

This mode can only be selected manually from the network analyzer front panel, and can be used only if no active computer controller is connected to the system through HP-IB. If you try to set system controller mode when another controller is present, the message "CAUTION: CAN'T CHANGE—ANOTHER CONTROLLER ON BUS" is displayed. Do not attempt to use this mode for programming.

*[TALKER/LISTENER]* (TALKLIST) is the mode normally used for remote programming of the analyzer. In this mode, the network analyzer and all peripheral devices are controlled by the external controller. The controller can command the analyzer to talk, and the plotter or other device to listen. The analyzer and peripheral devices cannot talk directly to each other unless the computer sets up a data path between them.

This mode allows the analyzer to be either a talker or a listener, as required by the controlling computer for the particular operation in progress.

A talker is a device capable of sending out data when it is addressed to talk. There can be only one talker at any given time. The analyzer is a talker when it sends information over the bus.

A listener is a device capable of receiving data when it is addressed to listen. There can be any number of listeners at any given time. The analyzer is a listener when it is controlled over the bus by a computer.

*[USE PASS CONTROL]* (USEPASC) lets you control the analyzer with the computer over HP-IB as with the talker/listener mode, and also allows the network analyzer to become the active controller in order to plot, print, or directly access an external disc. During this peripheral operation, the host computer is free to perform other internal tasks that do not require use of the bus (the bus is tied up by the network analyzer during this time).

The pass control mode requires that the external controller is programmed to respond to a request for control and to issue a take control command. When the peripheral operation is complete, the analyzer passes control back to the computer. Refer to Chapter 11 for more information.

In general, use the talker/listener mode for programming the analyzer unless direct peripheral access is required.

*[SET ADDRESSES]* goes to the address menu, which is used to set the HP-IB address of the analyzer, and to display and modify the addresses of peripheral devices in the system.

*[HP-IB DIAG on OFF]* (DEBUON, DEBUOFF) toggles the HP-IB diagnostic feature (debug mode). This mode should only be used the first time a program is written: if a program has already been debugged, it is unnecessary.

When diagnostics is on, the network analyzer scrolls a history of incoming HP-IB commands across the display in the title line. Nonprintable characters are represented as $\pi$. Any time a syntax error is received, the commands halt and a pointer $\wedge$ indicates the misunderstood character. To clear a syntax error, refer to the *HP-IB Programming Guide*.

*[DISC UNIT NUMBER]* (DISCUNIT) specifies the number of the disc unit in the disc drive that is to be accessed in an external disc store or load routine. This is used in conjunction with the HP-IB address of the disc drive, and the volume number, to gain access to a specific area on a disc. The access hierarchy is:

HP-IB address
disc unit number
disc volume number.

More information on storing information to an external disc is provided in Chapter 10, *Saving Instrument States*.

*[VOLUME NUMBER]* (DISCVOLU) specifies the number of the disc volume to be accessed. In general, all 3.5" floppy discs are considered one volume (volume 0). For hard disc drives, such as the HP 9153A (Winchester), a switch in the disc drive must be set to define the number of volumes on the disc. For more information, refer to the manual for the individual disc drive.

## Address Menu

In communications through the Hewlett-Packard Interface Bus (HP-IB), each instrument on the bus is identified by an HP-IB address. This decimal-based address code must be different for each instrument on the bus.

This menu is used to set the HP-IB address of the analyzer, and to enter the addresses of peripheral devices so that the analyzer can communicate with them.

Most of the HP-IB addresses are set at the factory and need not be modified for normal system operation. The standard factory-set addresses for instruments that may be part of the system are as follows:

| Instrument | HP-IB Address (decimal) |
|---|---|
| HP 8719/20 | 16 |
| Plotter | 05 |
| Printer | 01 |
| External Disc Dive | 00 |
| Controller | 21 |

The address displayed in this menu for each peripheral device must match the address set on the device itself. If the addresses do not match, they can be matched in one of two ways. Either the address displayed on the CRT for the device can be modified using the entry controls; or the address of the device can be changed using instructions provided in the device manual. The analyzer does not have an HP-IB address switch: its address is set only from the front panel. An address change becomes effective after the next preset.

These addresses are stored in short-term non-volatile memory and are not affected by preset or by cycling the power.

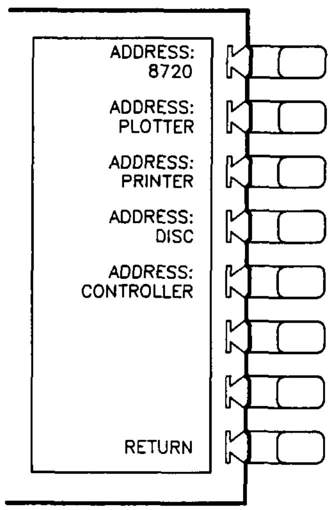



*Figure 7-4. Address Menu*

***[ADDRESS: 87XX]*** sets the HP-IB address of the analyzer, using the entry controls. There is no physical address switch.

***[ADDRESS: PLOTTER]*** (ADDRPLOT) sets the HP-IB address the analyzer will use to communicate with the plotter.

***[ADDRESS: PRINTER]*** (ADDRPRIN) sets the HP-IB address the analyzer will use to communicate with the printer.

***[ADDRESS: DISC]*** (ADDRDISC) sets the HP-IB address the analyzer will use to communicate with the disc drive.

***[ADDRESS: CONTROLLER]*** (ADDRCONT) sets the HP-IB address the analyzer will use to communicate with the external controller.

***[RETURN]*** goes back to the HP-IB menu.

## [SYSTEM] KEY (MENUSYST)

This key presents the system menu, which provides access to two additional series of menus (three in the option 010).

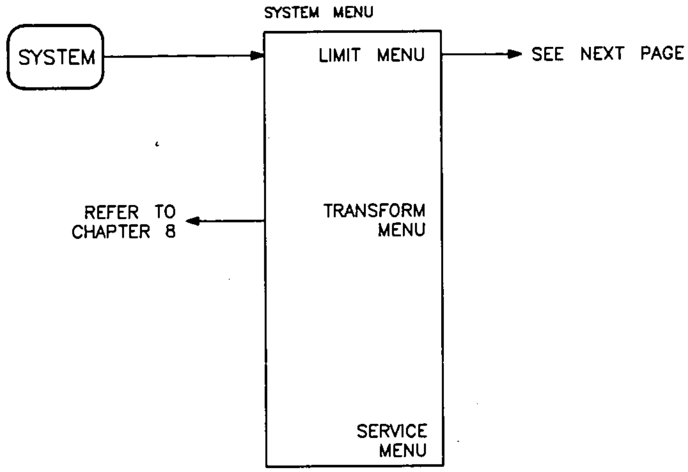



*Figure 7-5. System Menu*

*[LIMIT MENU]* leads to a series of menus used to define limits or specifications with which to compare a device under test. Refer to *Limit Lines and Limit Testing* on the next page.

*[TRANSFORM MENU]* (option 010) leads to a series of menus that transform the measured data from the frequency domain to the time domain. Time domain modes and features are explained in Chapter 8, *Time and Frequency Domain Transforms*. This softkey is present only in instruments with option 010.

*[SERVICE MENU]* leads to a series of service menus described in detail in the *Service Manual*.

## LIMIT LINES AND LIMIT TESTING

Limit lines are lines drawn on the CRT to represent upper and lower limits or device specifications with which to compare the device under test. Limits are defined in segments, where each segment is a portion of the stimulus span. Each limit segment has an upper and a lower starting limit value. Three types of segments are available: flat line, sloping line, and single point. Figure 7-6 illustrates limit lines defined for a bandpass filter.

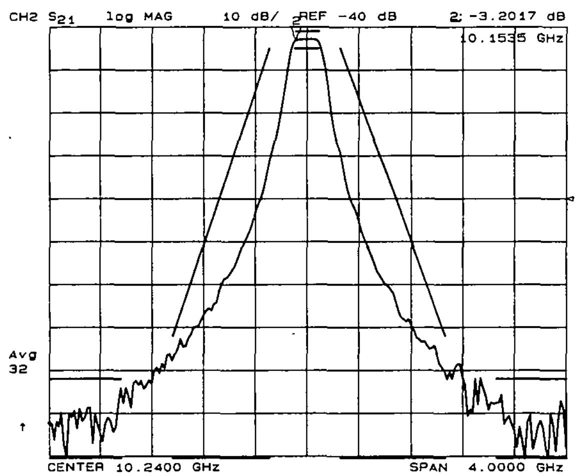



*Figure 7-6. Limit Lines for Bandpass Filter Testing*

Limits can be defined independently for the two channels, up to 22 segments for each channel. These can be in any combination of the three limit types.

Limit testing compares the measured data with the defined limits, and provides pass or fail information for each measured data point. An out-of-limit test condition is indicated in several different ways: with a FAIL message on the screen, with a beep, by blanking of portions of the trace, with an asterisk in tabular listings of data, with a bit in the HP-IB event status register B, and with a TTL low on pin 17 of the IO interconnect.

Limit lines and limit testing can be used simultaneously or independently. If limit lines are on and limit testing is off, the limit lines are displayed on the CRT for visual comparison and adjustment of the measurement trace. However, no pass/fail information is provided. If limit testing is on and limit lines are off, the specified limits are still valid and the pass/fail status is indicated even though the limit lines are not displayed on the CRT.

Limits are entered in tabular form. Limit lines and limit testing can be either on or off while limits are defined. As new limits are entered, the tabular columns on the CRT are updated, and the limit lines (if on) are modified to the new definitions. The complete limit set can be offset in either stimulus or amplitude value.

Limits are checked only at the actual measured data points. It is possible for a device to be out of specification without a limit test failure indication if the point density is insufficient. Be sure to specify a high enough number of measurement points in the stimulus menu.

Limit lines are displayed only on Cartesian formats. In polar and Smith chart formats, limit testing of one value is available: the value tested depends on the marker mode and is the magnitude or the first value in a complex pair. The message "NO LIMIT LINES DISPLAYED" is shown on the CRT in polar and Smith formats.

The list values feature in the copy menu provides tabular listings to the CRT or a printer for every measured stimulus value. These include limit line and/or limit test information if these functions are turned on. If limit testing is on, an asterisk * is listed next to any measured value that is out of limits. If limit lines are on, and other listed data allows sufficient space, the upper limit and lower limit are listed, together with the margin by which the device data passes or fails the nearest limit. For more information about the list values feature, refer to Chapter 9, *Making a Hard Copy Output*.

If limit lines are on, they are plotted with the data on a plot. If limit testing is on, the PASS or FAIL message is plotted, and the failing portions of the trace that are blanked on the CRT are also blanked on the plot. If limits are specified, they are saved in memory with an instrument state.

An example of a measurement using limit lines and limit testing is provided in the *User's Guide*.

The menus for defining limits, illustrated in Figure 7-7, are accessed from the **[SYSTEM]** key.

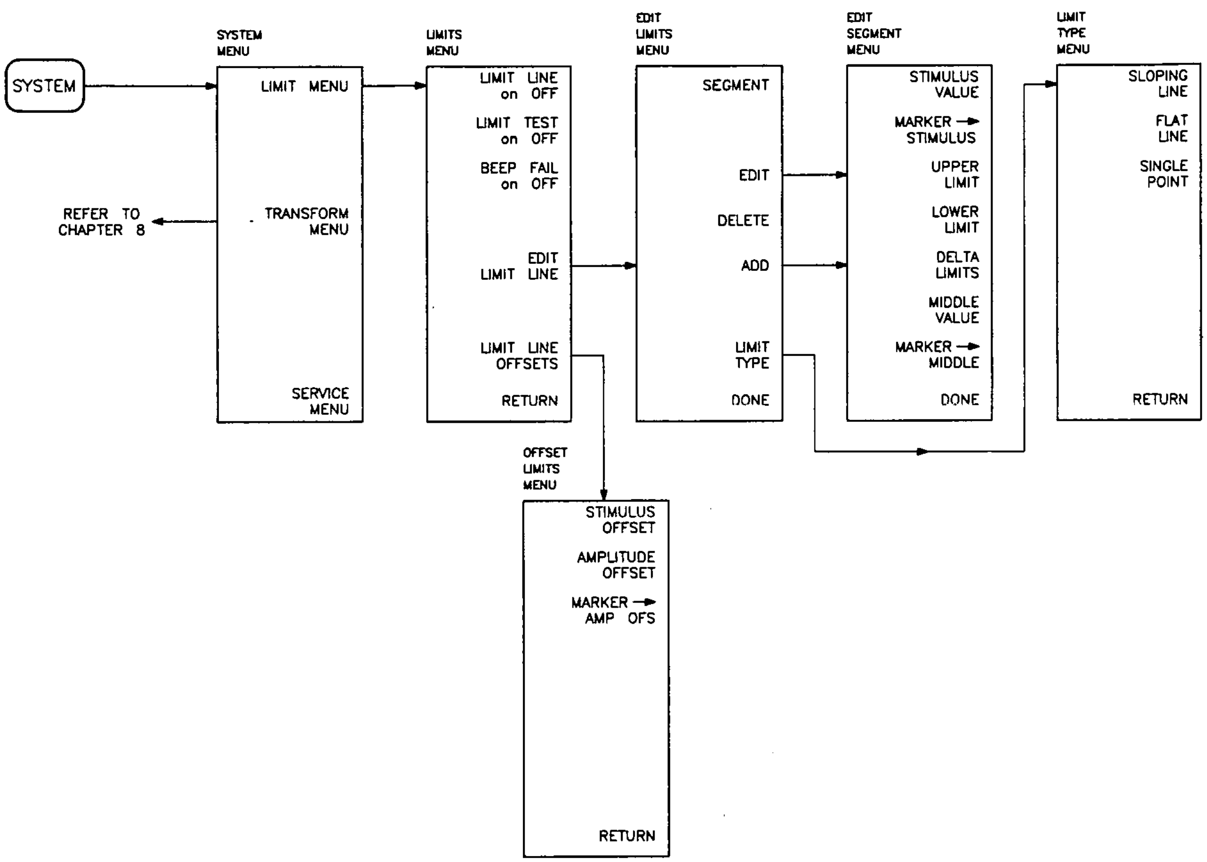



*Figure 7-7. The Limit Softkey Menu Series*

## Limits Menu

This menu independently toggles the limit lines, limit testing, and limit fail beeper. In addition, it leads to the menus used to define and modify the limits.

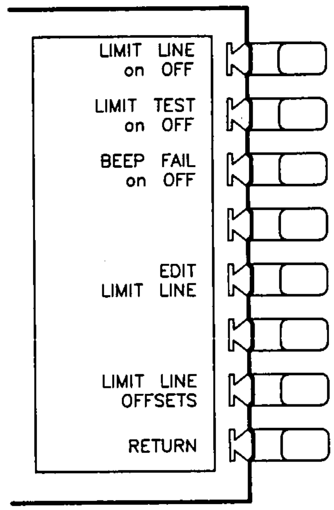



*Figure 7-8. Limits Menu*

***[LIMIT LINE on OFF]*** (LIMILINEON, LIMILINEOFF) turns limit lines on or off. To define limits, use the ***[EDIT LIMIT LINE]*** softkey described below. If limits have been defined and limit lines are turned on, the limit lines are displayed on the CRT for visual comparison of the measured data in all Cartesian formats.

If limit lines are on, they are plotted with the data on a plot, and saved in memory with an instrument state. In a listing of values from the copy menu with limit lines on, the upper limit and lower limit are listed together with the pass or fail margin, as long as other listed data allows sufficient space.

***[LIMIT TEST on OFF]*** (LIMITESTON, LIMITESTOFF) turns limit testing on or off. When limit testing is on, the data is compared with the defined limits at each measured point. Limit tests occur at the end of each sweep, whenever the data is updated, when formatted data is changed, and when limit testing is first turned on.

Limit testing is available for both magnitude and phase values in Cartesian formats. In polar and Smith chart formats, the value tested depends on the marker mode and is the magnitude or the first value in a complex pair. The message "NO LIMIT LINES DISPLAYED" is displayed in polar and Smith formats if limit lines are turned on.

Several indications of pass or fail status are provided when limit testing is on. A PASS or FAIL message is displayed at the right of the CRT. The trace vector leading to any measured point that is out of limits is blanked at the end of every limit test, both on a CRT plot and a hard copy plot. The limit fail beeper sounds if it is turned on. In a listing of values using the copy menu, an asterisk * is shown next to any measured point that is out of limits. A bit is set in the HP-IB status byte. Pin 17 of the IO interconnect is set at TTL low for a fail condition and TTL high for a pass condition.

***[BEEP FAIL on OFF]*** (BEEPFAILON, BEEPFAILOFF) turns the limit fail beeper on or off. When limit testing is on and the fail beeper is on, a beep is sounded each time a limit test is performed and a failure detected. The limit fail beeper is independent of the warning beeper and the operation complete beeper, both of which are set in the display more menu (Chapter 4).

*[EDIT LIMIT LINE]* (EDITLIML) displays a table of limit segments on the CRT, superimposed on the trace. The edit limits menu is presented so that limits can be defined or changed. It is not necessary for limit lines or limit testing to be on while limits are defined, although it is helpful to turn on limit lines as a visual aid. Note that the table of limit segments is not plotted with the display.

*[LIMIT LINE OFFSETS]* leads to the offset limits menu, which is used to offset the complete limit set by a user-defined amount in either stimulus or amplitude value.

*[RETURN]* goes back to the system menu.

## Edit Limits Menu

This menu (Figure 7-9) is used to specify limits for limit lines and/or limit testing, and presents a table of limit values on the CRT. Limits are defined in segments, where each segment is a portion of the stimulus span. Up to 22 limit segments can be specified for each channel (a total of 44 for both channels). The limit segments do not have to be entered in any particular order: the analyzer automatically sorts them and lists them on the CRT in increasing order of start stimulus value.

For each segment, the table lists the segment number, the starting stimulus value, upper limit, lower limit, and limit type. The ending stimulus value is the start value of the next segment, or a segment can be terminated with a single point segment. Limit values are entered as upper and lower limits or delta limits and middle value. As new limit segments are defined the tabular listing is updated, and if limit lines are switched on they are drawn on the CRT.

If no limits have been defined, the table of limit values shows the notation "EMPTY." Limit segments are added to the table using the *[ADD]* key or edited with the *[EDIT]* key, as described below. The last segment on the list is followed by the notation "END."

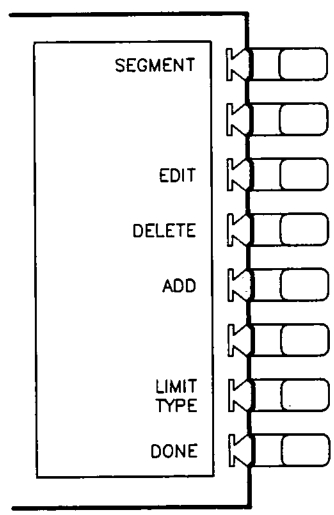



*Figure 7-9. Edit Limits Menu*

*[SEGMENT]* specifies which limit segment in the table is to be modified. A maximum of three sets of segment values are displayed at one time, and the list can be scrolled up or down to show other segment entries. Use the entry block controls to move the pointer >to the required segment number. The indicated segment can then be edited or deleted. If the table of limits is designated "EMPTY," new segments can be added using the *[ADD]* or *[EDIT]* softkey.

*[EDIT]* (SEDI) displays the edit segment menu, which is used to define or modify the stimulus value and limit values of a specified segment. If the table was empty, a default segment is displayed. The default segment is a sloping line with zero limits and stimulus values that vary according to the current stimulus mode (frequency or time).

*[DELETE]* (SDEL) deletes the limit segment indicated by the pointer >.

*[ADD]* (SADD) displays the edit segment menu and adds a new segment to the end of the list. The new segment is initially a duplicate of the segment indicated by the pointer > and selected with the *[SEGMENT]* softkey. If the table was empty, a default segment is displayed, as described under *[EDIT]* above.

*[LIMIT TYPE]* leads to the limit type menu, where one of three segment types can be selected.

*[DONE]* (EDITDONE) sorts the limit segments and displays them on the CRT in increasing order of stimulus value. The limits menu is returned to the screen.

## Edit Segment Menu

This menu (Figure 7-10) sets the values of the individual limit segments. The segment to be modified, or a default segment, is selected in the edit limits menu. The stimulus value can be set with the controls in the entry block or with a marker (the marker is turned on automatically when this menu is presented). The limit values can be defined as upper and lower limits, or delta limits and middle value. Both an upper limit and a lower limit (or delta limits) must be defined: if only one limit is required for a particular measurement, force the other out of range (for example +200 dB or −200 dB).

As new values are entered, the tabular listing of limit values is updated.

Segments do not have to be listed in any particular order: the analyzer sorts them automatically in increasing order of start stimulus value when the *[DONE]* key in the edit limits menu is pressed. However, the easiest way to enter a set of limits is to start with the lowest stimulus value and define the segments from left to right of the display, with limit lines turned on as a visual check.

Phase limit values can be specified between +500° and −500°. Limit values above +180° and below −180° are mapped into the range of −180° to +180° to correspond with the range of phase data values.

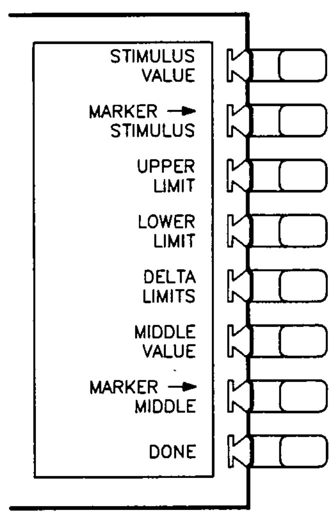



*Figure 7-10. Edit Segment Menu*

***[STIMULUS VALUE]*** (LIMS) sets the starting stimulus value of a segment, using entry block controls. The ending stimulus value of the segment is defined by the start of the next segment. No more than one segment can be defined over the same stimulus range. In a standard instrument, the starting stimulus value must be a multiple of 100 kHz (this limitation does not apply to option 001 instruments).

***[MARKER →STIMULUS]*** (MARKSTIM) sets the starting stimulus value of a segment using the active marker. Move the marker to the desired starting stimulus value before pressing this key, and the marker stimulus value is entered as the segment start value.

***[UPPER LIMIT]*** (LIMU) sets the upper limit response value for the start of the segment. If a lower limit is specified, an upper limit must also be defined. If no upper limit is required for a particular measurement, force the upper limit value out of range (for example +200 dB).

When ***[UPPER LIMIT]*** or ***[LOWER LIMIT]*** is pressed, all the segments in the table are displayed in terms of upper and lower limits, even if they were defined as delta limits and middle value.

If you attempt to set an upper limit that is lower than the lower limit, or vice versa, both limits will be automatically set to the same value.

***[LOWER LIMIT]*** (LIML) sets the lower limit response value for the start of the segment. If an upper limit is specified, a lower limit must also be defined. If no lower limit is required for a particular measurement, force the lower limit value out of range (for example −200 dB).

***[DELTA LIMITS]*** (LIMD) sets the limits an equal amount above and below a specified middle value, instead of setting upper and lower limits separately. This is used in conjunction with ***[MIDDLE VALUE]*** or ***[MARKER →MIDDLE]***, to set limits for testing a device that is specified at a particular value plus or minus an equal tolerance.

For example, a device may be specified at 0 dB ±3 dB. Enter the middle value as 0 dB and the delta limits as 3 dB.

When ***[DELTA LIMITS]*** or ***[MIDDLE VALUE]*** is pressed, all the segments in the table are displayed in these terms, even if they were defined as upper and lower limits.

***[MIDDLE VALUE]*** (LIMM) sets the midpoint for ***[DELTA LIMITS]***. It uses the entry controls to set a specified magnitude value vertically centered between the limits.

***[MARKER →MIDDLE]*** (MARKMIDD) sets the midpoint for ***[DELTA LIMITS]*** using the active marker to set the middle magnitude value of a limit segment. Move the marker to the desired value or device specification, and press this key to make that value the midpoint of the delta limits. The limits are automatically set an equal amount above and below the marker.

***[DONE]*** (SDON) terminates a limit segment definition, and returns to the edit limits menu.

## Limit Type Menu

This menu defines the selected limit segment as a sloping line, a flat line, or a single point.

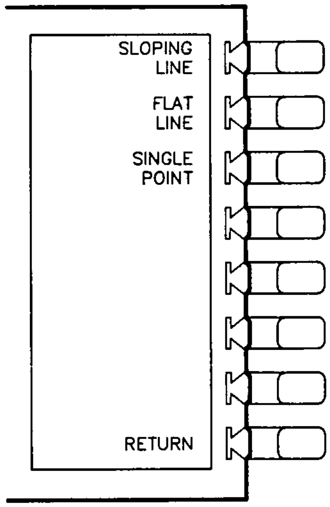



*Figure 7-11. Limit Type Menu*

*[SLOPING LINE]* (LIMTSL) defines a sloping limit line segment that is linear with frequency or other stimulus value, and is continuous to the next stimulus value and limit. If a sloping line is the final segment it becomes a flat line terminated at the stimulus stop value. A sloping line segment is indicated as SL on the displayed table of limits.

*[FLAT LINE]* (LIMTFL) defines a flat limit line segment whose value is constant with frequency or other stimulus value. This line is continuous to the next stimulus value, but is not joined to a segment with a different limit value. If a flat line segment is the final segment it terminates at the stimulus stop value. A flat line segment is indicated as FL on the table of limits.

*[SINGLE POINT]* (LIMTSP) sets the limits at a single stimulus point. If limit lines are on, the upper limit value of a single point limit is displayed as ∨, and the lower limit is displayed as ∧. A limit test at a single point not terminating a flat or sloped line tests the nearest actual measured data point. In a standard instrument, single point limits can only be defined at frequencies that are multiples of 100 kHz (this limitation does not apply to option 001 instruments).

A single point limit can be used as a termination for a flat line or sloping line limit segment. When a single point terminates a sloping line or when it terminates a flat line and has the same limit values as the flat line, the single point is not displayed as ∨ and ∧. The indication for a sloping line segment in the displayed table of limits is SP.

*[RETURN]* goes back to the edit limits menu.

## Offset Limits Menu

This menu allows the complete limit set to be offset in either stimulus value or amplitude value. This is useful for changing the limits to correspond with a change in the test setup, or for device specifications that differ in stimulus or amplitude. It can also be used to move the limit lines away from the data trace temporarily for visual examination of trace detail.

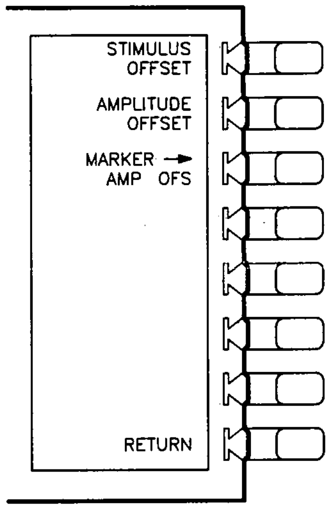



*Figure 7-12. Offset Limits Menu*

***[STIMULUS OFFSET]*** (LIMISTIO) adds or subtracts an offset in stimulus value. This allows limits already defined to be used for testing in a different stimulus range. Use the entry block controls to specify the offset required. In a standard instrument, the stimulus offset must be a multiple of 100 kHz (this limitation does not apply to an option 001 instrument).

***[AMPLITUDE OFFSET]*** (LIMIAMPO) adds or subtracts an offset in amplitude value. This allows limits already defined to be used for testing at a different response level. For example, if attenuation is added to or removed from a test setup, the limits can be offset an equal amount. Use the entry block controls to specify the offset.

***[MARKER →AMP. OFS.]*** (LIMIMAOF) uses the active marker to set the amplitude offset. Move the marker to the desired middle value of the limits and press this key. The limits are then moved so that they are centered an equal amount above and below the marker at that stimulus value.

***[RETURN]*** goes back to the limits menu.

# Chapter 8. Time and Frequency Domain Transforms

## INTRODUCTION

With option 010, the analyzer can transform frequency domain data to the time domain or time domain data to the frequency domain. In normal operation, the analyzer measures the characteristics of a device under test (DUT) as a function of frequency. Using a mathematical technique (the inverse Fourier transform), it transforms frequency domain information into the time domain, with time as the horizontal display axis. Response values (measured on the vertical axis) now appear separated in time or distance, providing valuable insight into the behavior of the DUT beyond simple frequency characteristics.

**NOTE:** The analyzer can be ordered with option 010, or the option can be added at a later date using the HP 86380A time domain retrofit kit.

The transform used by the analyzer resembles time domain reflectometry (TDR) measurements. TDR measurements, however, are made by launching an impulse or step into the DUT and observing the response in time with a receiver similar to an oscilloscope. In contrast, the network analyzer makes swept frequency response measurements, and mathematically transforms the data into a TDR-like display.

The analyzer has three frequency-to-time transform modes:

**Time Domain Bandpass Mode** is designed to measure band-limited devices and is the easiest mode to use. This mode simulates the time domain response to an impulse input.

**Time Domain Low Pass Step Mode** simulates the time domain response to a step input. As in a traditional TDR measurement, the distance to the discontinuity in the DUT, and the type of discontinuity (resistive, capacitive, inductive) can be determined.

**Time Domain Low Pass Impulse Mode** simulates the time domain response to an impulse input (like the bandpass mode). Both low pass modes yield better time domain resolution for a given frequency span than does the bandpass mode. In addition, using the low pass modes you can determine the type of discontinuity. However, these modes have certain limitations that are defined in the low pass section of this chapter.

The analyzer has one time-to-frequency transform mode:

**Forward Transform Mode** transforms CW signals measured over time into the frequency domain, to measure the spectral content of a signal. This mode is known as the CW time mode.

In addition to these transform modes, this chapter discusses special transform concepts such as masking, windowing, and gating.

## GENERAL THEORY

The relationship between the frequency domain response and the time domain response of a network analyzer is defined by the Fourier transform. Because of this transform, it is possible to measure, in the frequency domain, the response of a linear DUT and mathematically calculate the inverse Fourier transform of the data to find the time domain response. The analyzer's internal computer makes this calculation using the chirp-Z Fourier transform technique. The resulting measurement is the fully error-corrected time domain reflection or transmission response of the DUT, displayed in near real time.

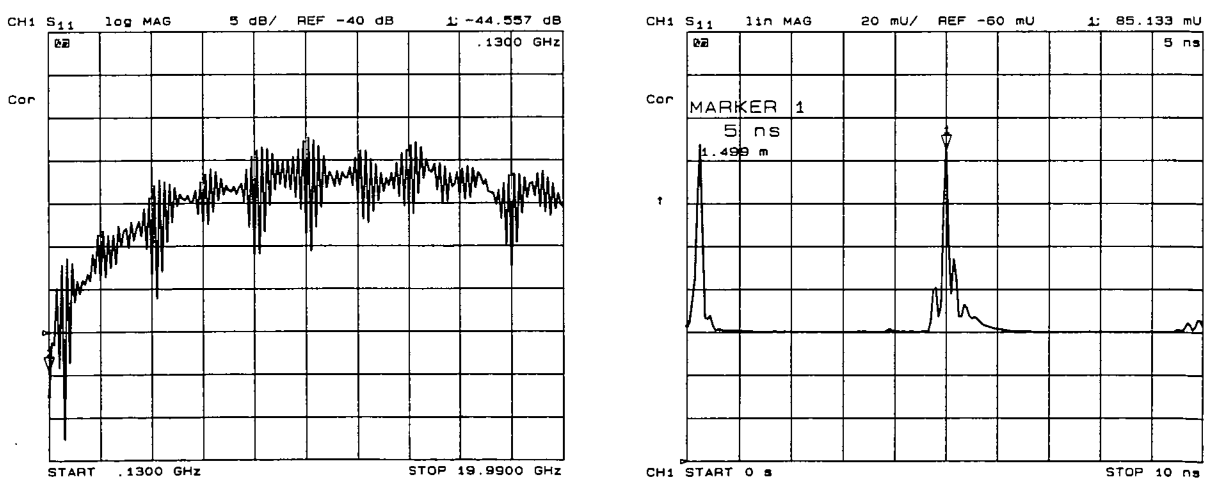
Table 8-1 lists the useful formats for time domain reflection measurements. Time domain transmission measurements are displayed using the linear magnitude or log magnitude formats, as described later in this chapter.

*Table. 8-1. Time Domain Reflection Formats*

| Format | Parameter |
|---|---|
| LIN MAG | Reflection Coefficient (unitless) $(0 < \rho < 1)$ |
| REAL | Reflection Coefficient (unitless) $(-1 < \rho < 1)$ |
| LOG MAG | Return Loss (dB) |
| SWR | Standing Wave Ratio (unitless) |

Figure 8-1 illustrates the frequency and time domain reflection responses of a device. The frequency domain reflection measurement is the composite of all the signals reflected by the discontinuities present in the DUT over the measured frequency range.

**NOTE:** In this chapter, all points of reflection are referred to as discontinuities.




*(a) Frequency Domain* *(b) Time Domain Bandpass*

*Figure 8-1. Device Frequency Domain and Time Domain Reflection Responses*

The time domain measurement shows the effect of each discontinuity as a function of time (or distance), and shows that the device response consists of three separate impedance changes. The second discontinuity has a reflection coefficient magnitude of 0.085 (i.e. 8.5% of the incident signal is reflected). Marker 1 on the time domain trace shows the round-trip time to the discontinuity and back to the reference plane (where the calibration standards are connected): 5 nanoseconds. The distance shown (1.499 metres) assumes that the signal travels at the speed of light. The signal travels slower than the speed of light in most media (e.g. coax cables). This slower velocity (relative to light) can be compensated for by adjusting the relative velocity factor. This procedure is described later in this chapter.

Figure 8-2 illustrates the transform menus, which are accessed from the **[SYSTEM]** key.

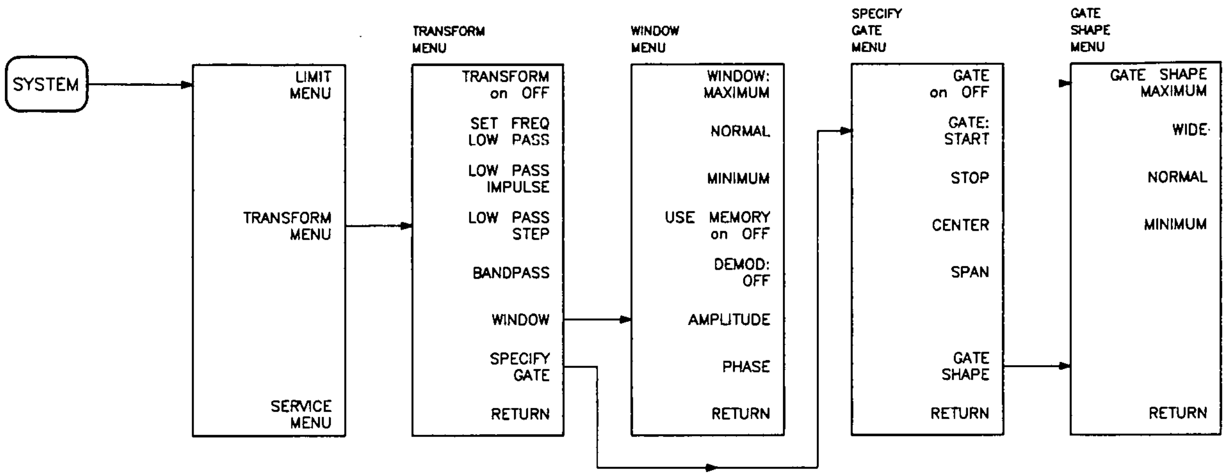



*Figure 8-2. The Time Domain Transform Menus*

## TIME DOMAIN BANDPASS

This mode is called bandpass because it works with band-limited devices. Traditional TDR requires that the DUT be able to operate down to DC. Using bandpass mode, there are no restrictions on the measurement frequency range. Bandpass mode characterizes the DUT impulse response.

### Reflection Measurements Using Bandpass Mode

**NOTE:** Before making time domain reflection measurements, perform the appropriate calibration.

Example:

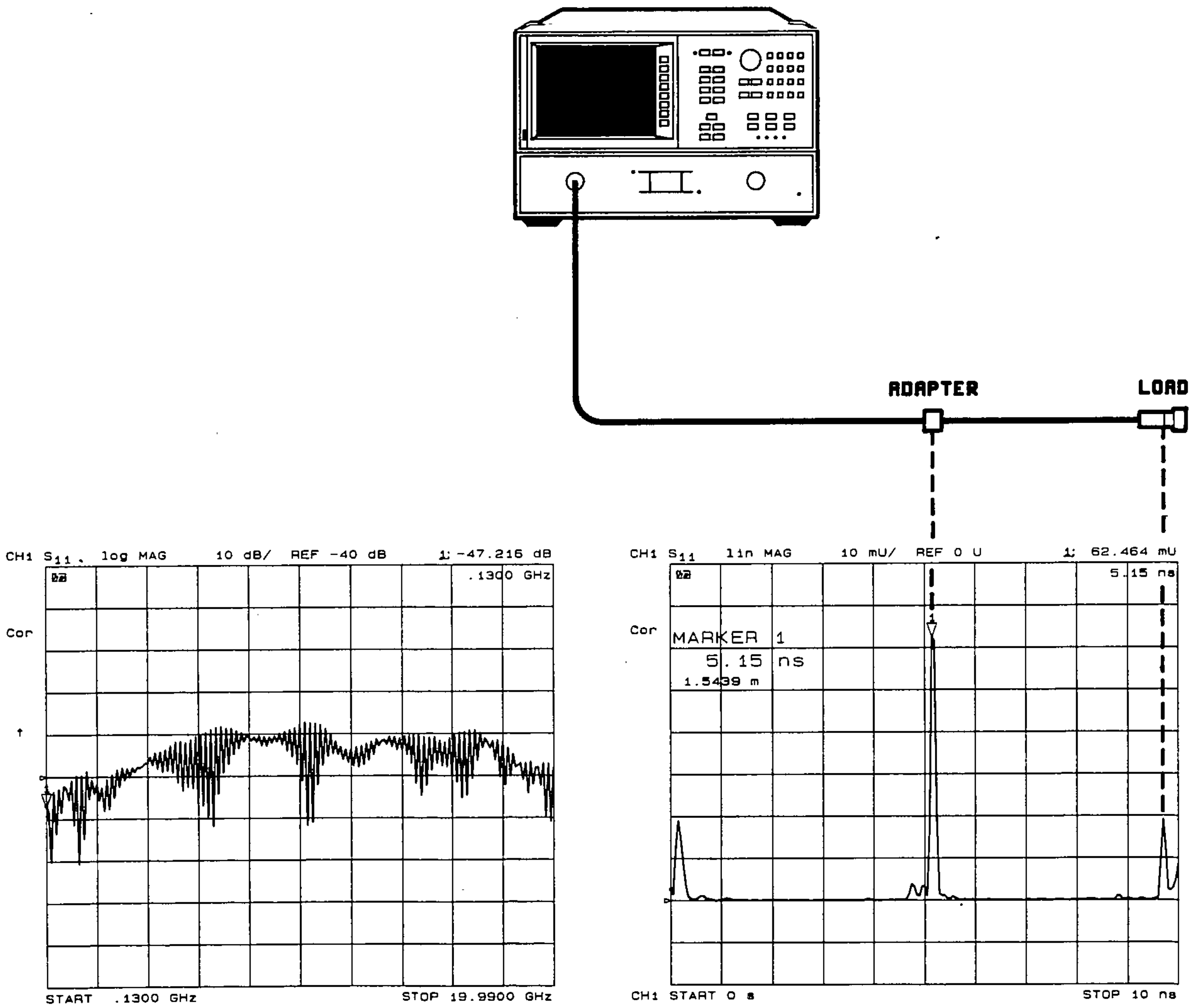
1. Press **[PRESET]**. The default measurement at preset is S11 on channel 1.
2. Press **[CAL]** ***[CALIBRATE MENU] [S11 1-PORT]*** and perform an S11 1-port calibration using an open, a short, and a load connected to port 1. Press ***[DONE 1-PORT CAL]***, then save the configuration in one of the save registers.
3. Connect one or more lengths of cable, with adapters between cable sections, as shown at the top of Figure 8-3.
4. Press **[SYSTEM]** ***[TRANSFORM MENU] [BANDPASS] [TRANSFORM ON]***.

5. Press **[START]** **[0]** **[x1]** to select a start time of zero seconds.
6. Press **[STOP]** **[1]** **[0]** **[G/n]** to select a stop time of 10 nanoseconds.

**NOTE:** In the time domain, the STIMULUS keys (**[START]**, **[STOP]**, **[CENTER]** and **[SPAN]**) refer to time, and can be used to change the horizontal (time) axis of the display, independent of the chosen frequency range. To set the STOP time long enough to let you "see" the end of the cable under test, enter a STOP time of 10 nanoseconds per metre of cable under test. This is a good rule-of-thumb number that accounts for the approximate round-trip time for most cables.

7. Press **[FORMAT]** ***[LIN MAG]*** for a display of reflection coefficient versus time (or distance).
8. Press **[SCALE REF]** ***[AUTO SCALE]***.

Figure 8-3 shows typical frequency and time domain responses of a reflection measurement of two sections of cable.




*(a) Frequency Domain* *(b) Time Domain Bandpass*

*Figure 8-3. A Reflection Measurement of Two Cables*

The ripples in reflection coefficient versus frequency in the frequency domain measurement are caused by the reflections at each connector "beating" against each other.

One at a time, loosen the connectors at each end of the cable and observe the response in both the frequency domain and the time domain. The frequency domain ripples grow as each connector is loosened, corresponding to a larger reflection adding in and out of phase with the other reflections. The time domain responses grow as you loosen the connector that corresponds to each response.

**Interpreting the Bandpass Reflection Response Horizontal Axis.** In bandpass reflection measurements, the horizontal axis represents the time it takes for an impulse launched at the test port to reach a discontinuity and return to the test port (the two-way travel time). In Figure 8-3, each connector is a discontinuity.

**Interpreting the Bandpass Reflection Response Vertical Axis.** The quantity displayed on the vertical axis depends on the selected format. The default format is LOG MAG (logarithmic magnitude), which displays the return loss in decibels (dB). LIN MAG (linear magnitude) is a format that displays the response as reflection coefficient (ρ). This can be thought of as an average reflection coefficient of the discontinuity over the frequency range of the measurement. Use the REAL format only in low pass mode. The common formats are listed in Table 8-1.

## Adjusting the Relative Velocity Factor

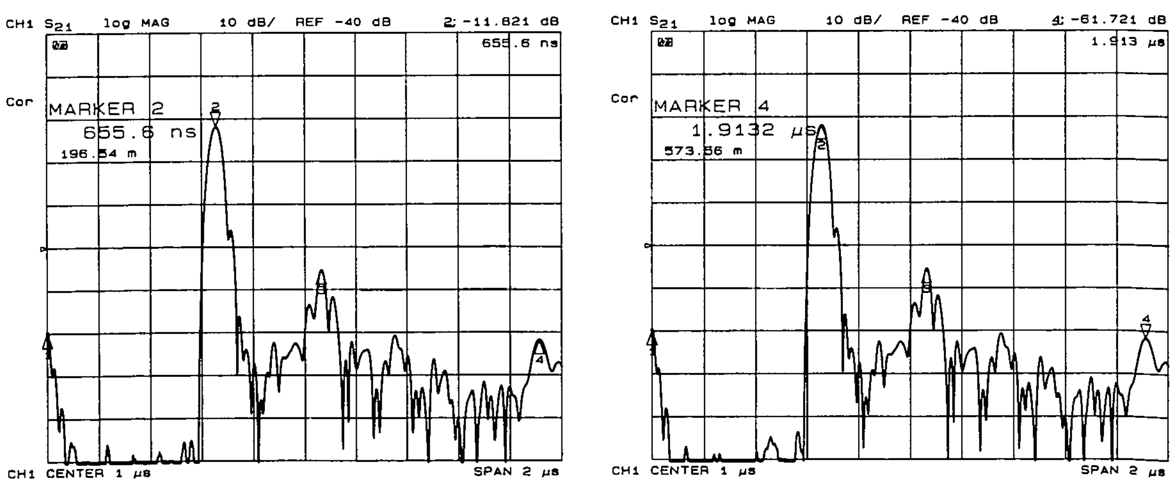
A marker provides both the time (x2) and the electrical length (x2) to a discontinuity. To determine the physical length, rather than the electrical length, change the velocity factor to that of the medium under test:

1. Press **[CAL]** ***[MORE] [VELOCITY FACTOR]***.
2. Enter a velocity factor between 0 and 1.0 (1.0 corresponds to the speed of light in a vacuum). Most cables have a velocity factor of 0.66 (polyethylene dielectrics) or 0.70 (teflon dielectrics).

**NOTE:** To cause the markers to read the actual one-way distance to a discontinuity, rather than the round trip distance, enter one-half the actual velocity factor.

## Transmission Measurements Using Bandpass Mode

The bandpass mode can also transform transmission measurements to the time domain. For example, this mode can provide information about a surface accoustic wave (SAW) filter that is not apparent in the frequency domain. Figure 8-4 illustrates a time domain bandpass measurement of a 321 MHz SAW filter.




*(a)* *(b)*

*Figure 8-4. Transmission Measurement in Time Domain Bandpass Mode*

**Interpreting the Bandpass Transmission Response Horizontal Axis.** In time domain transmission measurements, the horizontal axis is displayed in units of time. The time axis indicates the propagation delay through the device. Note that in time domain transmission measurements, the value displayed is the actual delay (not x2). The marker provides the propagation delay in both time and distance.

Marker 2 in Figure 8-4 (a) indicates the main path response through the device, which has a propagation delay of 655.6 ns, or about 196.5 meters in electrical length. Marker 4 in Figure 8-4 (b) indicates the triple-travel path response at 1.91 μs, or about 573.5 meters. The response at marker 1 (at 0 seconds) is an RF feedthrough leakage path. In addition to the triple travel path response, there are several other multi-path responses through the device, which are inherent in the design of a SAW filter.

**Interpreting the Bandpass Transmission Response Vertical Axis.** In the log magnitude format, the vertical axis displays the transmission loss or gain in dB; in the linear magnitude format it displays the transmission coefficient ($\tau$). Think of this as an average of the transmission response over the measurement frequency range.

## TIME DOMAIN LOW PASS

This mode is used to simulate a traditional time domain reflectometry (TDR) measurement. It provides information to determine the type of discontinuity (resistive, capacitive, or inductive) that is present. Low pass provides the best resolution for a given bandwidth in the frequency domain. It may be used to give either the step or impulse response of the DUT.

The low pass mode is less general-purpose than the bandpass mode because it places strict limitations on the measurement frequency range. The low pass mode requires that the frequency domain data points are harmonically related from DC to the stop frequency. That is, stop = n x start, where n = number of points. For example, with a start frequency of 130 MHz and 101 points, the stop frequency would be 13.13 GHz. Since the frequency range of the analyzer starts at 130 MHz, the DC frequency response is extrapolated from the lower frequency data. The requirement to pass DC is the same limitation that exists for traditional TDR.

### Setting Frequency Range for Time Domain Low Pass

Before a low pass measurement is made, the measurement frequency range must meet the (stop = n x start) requirement described above. The following steps must be taken, in this order:

- Set the start and stop frequencies close to the intended values.
- Press ***[SET FREQ LOW PASS]***.
- Perform a calibration.

The start and stop frequencies should be set as close as possible to the intended values, especially at the low end, to avoid distortion of the measurement results. When ***[SET FREQ LOW PASS]*** is pressed, the network analyzer automatically sets the start and stop frequencies so that the stop frequency is a harmonic multiple of the start. The stop frequency is set close to the entered stop frequency, and the start frequency is set equal to stop/n. For example, if you select 101 points across the display and a stop frequency of 19.9900 GHz in a standard instrument, when you press ***[SET FREQ LOW PASS]*** the start frequency changes to 0.1979 GHz and the stop frequency changes to 19.9879 GHz. (The procedure below instead sets the start frequency to 130 MHz and the stop frequency to 13.13 GHz with 101 points.) For convenience in setting the sweep frequency before beginning a calibration, the ***[SET FREQ LOW PASS]*** softkey is in both the transform menu and the calibration menu.

If the start and stop frequencies do not conform to the low pass requirement before one of the low pass modes (step or impulse) is selected and transform is turned on, the analyzer resets the start and stop frequencies. If error correction is on when the frequency range is changed, this turns it off.

The analyzer's lowest measurement frequency is 130 MHz, therefore for each value of n there is a minimum allowable stop frequency that can be used. That is, the minimum stop frequency = n x 130 MHz. Because of this limitation, the largest number of points that can be used in time domain low pass is 201 (with 201 points, an additional point is extrapolated at 65 MHz). If the number of points exceeds 201, the network analyzer automatically reverts to bandpass mode. Table 8-2 lists the minimum frequency range that can be used for each value of n when making low pass time domain measurements.

*Table 8-2. Minimum Frequency Ranges for Time Domain Low Pass*

| Number of Points | Minimum Frequency Range |
|---|---|
| 3 | 130 MHz to 390 MHz |
| 11 | 130 MHz to 1.43 GHz |
| 21 | 130 MHz to 2.73 GHz |
| 51 | 130 MHz to 6.63 GHz |
| 101 | 130 MHz to 13.13 GHz |
| 201 | 130 MHz to 13.13 GHz |

## Reflection Measurements in Time Domain Low Pass

**NOTE:** Before making time domain measurements in the low pass mode, perform the appropriate calibration.

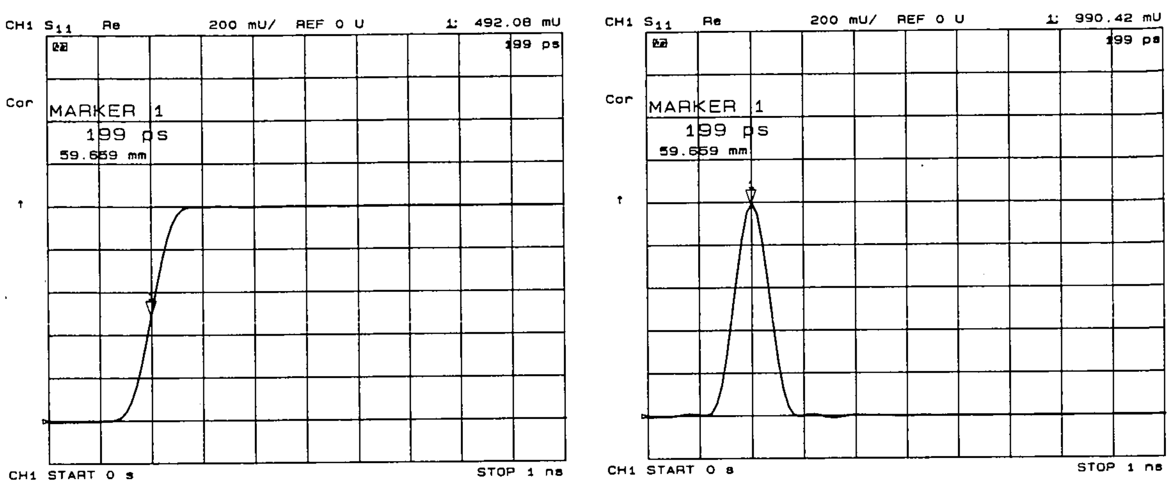
Example:

1. Press **[PRESET]**. The default measurement at preset is S11 on channel 1, with a start frequency of 130 MHz.
2. Press **[STOP] [1] [3] [.] [1] [3] [G/n]** to set a stop frequency of 13.13 GHz.
3. Press **[MENU]** ***[NUMBER OF POINTS]*** **[1] [0] [1] [x1]**.
4. Press **[CAL]** ***[CALIBRATE MENU] [SET FREQ LOW PASS]*** and perform an S11 1-port calibration.
5. Connect an airline or cable to port 1 and leave the other end unterminated.
6. Press **[SYSTEM]** ***[TRANSFORM MENU] [LOW PASS STEP] [TRANSFORM ON]***.
7. Press **[START] [0] [x1]** to select a start time of 0 seconds.
8. Press **[STOP] [1] [G/n]** to select a stop time of 1 nanosecond.

**NOTE:** In the time domain, the STIMULUS keys (**[START]**, **[STOP]**, **[CENTER]** and **[SPAN]**) refer to time, and can be used to change the horizontal (time) axis of the display, independent of the chosen frequency range.

9. Press **[FORMAT]** ***[REAL]*** **[SCALE REF]** ***[AUTOSCALE]*** to view the step response, as shown in Figure 8-5 (a). (The step response is reflected back from the unterminated cable.)

10. Press **[SYSTEM]** ***[TRANSFORM MENU] [LOW PASS IMPULSE]*** to view the impulse response, shown in Figure 8-5 (b).




*(a) Low Pass Step* *(b) Low Pass Impulse*

*Figure 8-5. Time Domain Low Pass Measurements of an Unterminated Cable*

11. Now connect a short circuit to the end of the airline or cable and press **[SCALE REF]** ***[AUTO SCALE]***. The polarity of the impulse response is now reversed.

12. Press **[SYSTEM]** ***[TRANSFORM MENU] [LOW PASS STEP]*** to view the low pass step response with the polarity reversed.

**Interpreting the Low Pass Response Horizontal Axis.** The low pass measurement horizontal axis is the two-way travel time to the discontinuity (as in the bandpass mode). Also, the marker displays both the two-way time and the electrical length along the trace. To determine the actual physical length, enter the appropriate velocity factor as described earlier in this chapter under *Adjusting the Relative Velocity Factor*.

**Interpreting the Low Pass Response Vertical Axis.** The vertical axis depends on the chosen format. In the low pass mode, the frequency domain data is taken at harmonically related frequencies and extrapolated to DC. Because this results in the inverse Fourier transform having only a real part (the imaginary part is zero), the most useful low pass step mode format in this application is the real format. It displays the response in reflection coefficient units. This mode is similar to the traditional TDR response, which displays the reflected signal in a real format (volts) versus time (or distance) on the horizontal axis.

The real format can also be used in the low pass impulse mode, but for the best dynamic range for simultaneously viewing large and small discontinuities, use the log magnitude format.

## Fault Location Measurements Using Low Pass

As described, the low pass mode can simulate the TDR response of the device under test. This response contains information useful in determining the type of discontinuity present. Review the low pass responses of known discontinuities as shown in Figure 8-6. Each circuit element was simulated to show the corresponding low pass time domain S11 response waveform. The low pass mode gives the device response either to a step or to an impulse stimulus. Mathematically, the low pass impulse stimulus is the derivative of the step stimulus.

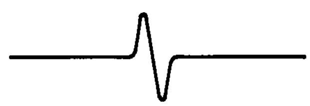
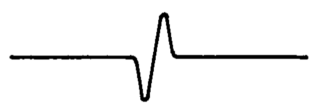
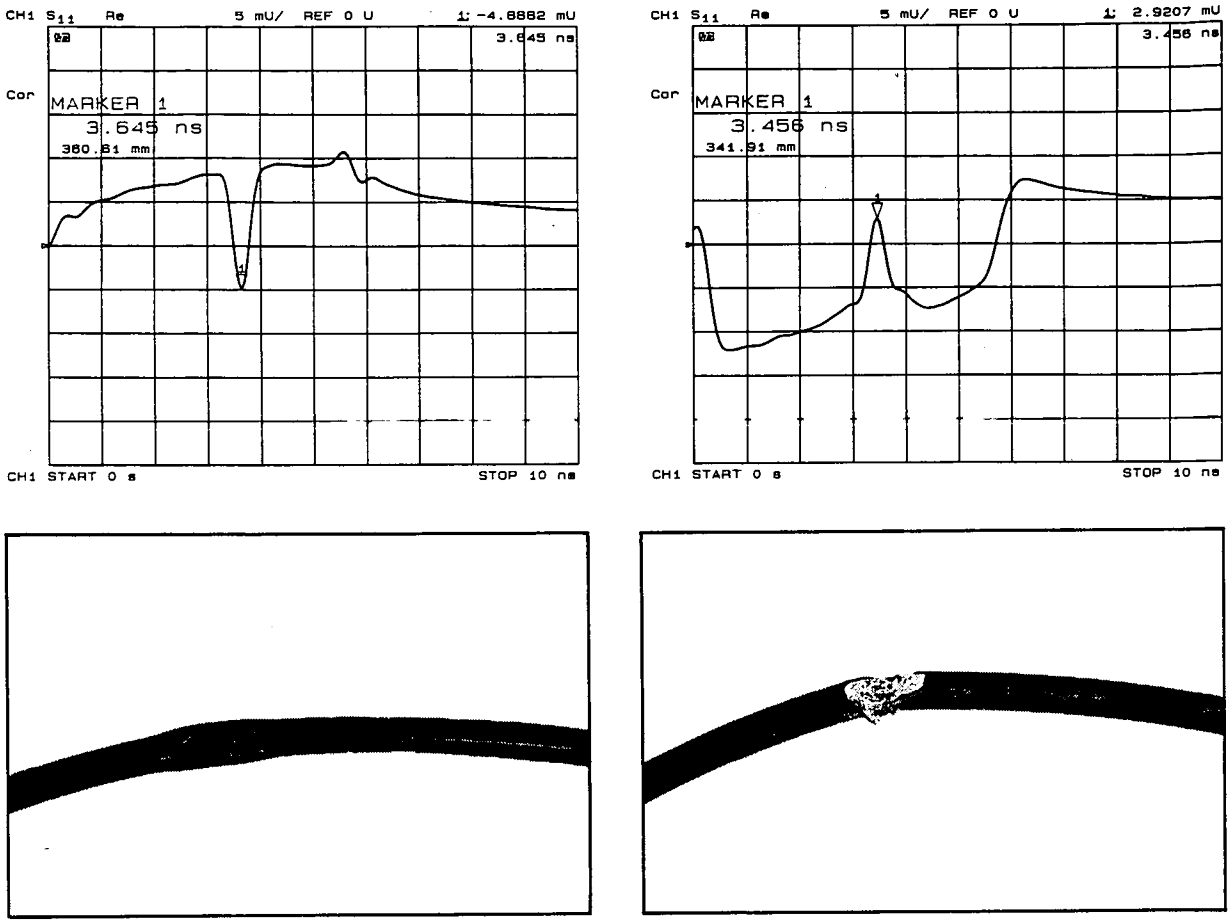
| **Element** | **Step Response** | **Impulse Response** |
|---|---|---|
| Open |  Unity Reflection |  Unity Reflection |
| Short |  Unity Reflection, −180° |  Unity Reflection, −180° |
| Resistor $R > Z_0$ |  Positive Level Shift |  Positive Peak |
| Resistor $R < Z_0$ |  Negative Level Shift |  Negative Peak |
| Inductor |  Positive Peak |  Positive Then Negative Peaks |
| Capacitor |  Negative Peak |  Negative Then Positive Peaks |

*Figure 8-6. Simulated Low Pass Step and Impulse Response Waveforms (Real Format)*

Figure 8-7 shows example cables with discontinuities (faults) using the low pass step mode with the real format.




*(a) Crimped Cable (Capacitive)* *(b) Frayed Cable (Inductive)*

*Figure 8-7. Low Pass Step Measurements of Common Cable Faults (Real Format)*

## Transmission Measurements in Time Domain Low Pass

**Measuring Small Signal Transient Response Using Low Pass Step.** Use the low pass mode to analyze the DUT small signal transient response. The transmission response of a device to a step input is often measured at lower frequencies, using a function generator (to provide the step to the DUT) and sampling oscilloscope (to analyze the DUT output response). The low pass step mode extends the frequency range of this type of measurement to 20 GHz.

The step input shown in Figure 8-8 is actually the inverse Fourier transform of the frequency domain response of a thru measured at calibration. The step rise time is proportional to the highest frequency in the frequency domain sweep; the higher the frequency, the faster the rise time. The frequency sweep in Figure 8-8 is from 130 MHz to 1 GHz.

Figure 8-8 also illustrates the time domain low pass response of an amplifier under test. The average group delay over the measurement frequency range is the difference in time between the step and the amplifier response. This time domain response simulates an oscilloscope measurement of the amplifier's small signal transient response. Note the ringing in the amplifier response that indicates an underdamped design.

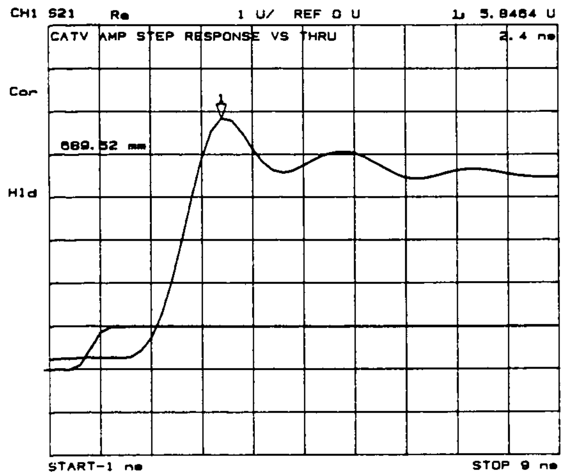



*Figure 8-8. Time Domain Low Pass Measurement of an Amplifier Small Signal Transient Response*

**Interpreting the Low Pass Step Transmission Response Horizontal Axis.** The low pass transmission measurement horizontal axis displays the average transit time through the device over the frequency range used in the measurement. The response of the thru connection used in the calibration is a step that reaches 50% unit height at time = 0. The rise time is determined by the highest frequency used in the frequency domain measurement. The step is a unit high step, which indicates no loss for the thru calibration. When a device is inserted, the time axis indicates the propagation delay or electrical length of the device. The markers read the electrical delay in both time and distance. The distance can be scaled by an appropriate velocity factor as described earlier in this chapter under *Adjusting the Relative Velocity Factor*.

**Interpreting the Low Pass Step Transmission Response Vertical Axis.** In the real format, the vertical axis displays the transmission response in real units (e.g. volts). For the amplifier example in Figure 8-8, if the amplifier input is a step of 1 volt, the output, 2.4 nanoseconds after the step (indicated by marker 1), is 5.84 volts.

In the log magnitude format, the amplifier gain is the steady state value displayed after the initial transients die out.

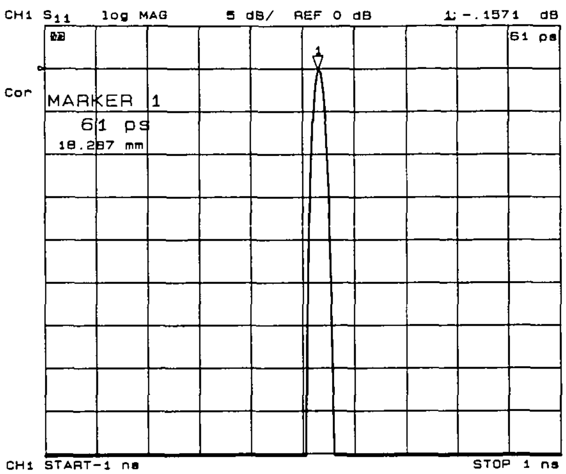
## TIME DOMAIN CONCEPTS

### Masking

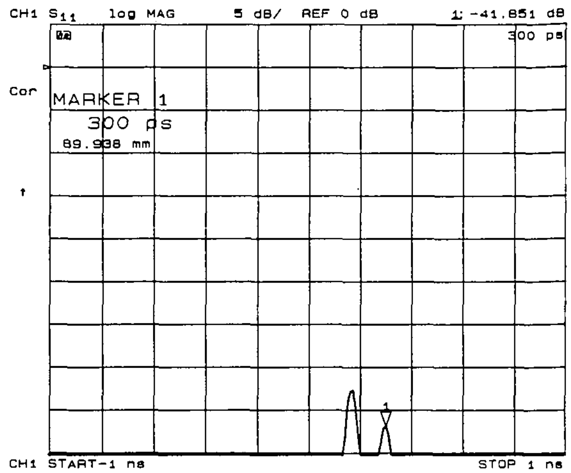
Masking occurs when a discontinuity (fault) closest to the reference plane affects the response of each subsequent discontinuity. This happens because the energy reflected from the first discontinuity never reaches subsequent discontinuities. For example, if a transmission line has two discontinuities each with a ρ of 0.5, the time domain response (real format) shows the correct reflection coefficient for the first discontinuity (ρ=.50). However, the second discontinuity appears as a 25% reflection (ρ=.25) because only half the incident voltage reached the second discontinuity.

**NOTE:** This example assumes a lossless transmission line. Real transmission lines, with non-zero loss, attenuate signals as a function of the distance from the reference plane.

As an example of masking due to line loss, consider the time domain response of a 20 dB attenuator and a short circuit. The impulse response (log magnitude format) of the short circuit alone is a return loss close to 0 dB, as shown in Figure 8-9 (a). When the short circuit is placed at the end of the 20 dB attenuator, the return loss is −41 dB, as shown in Figure 8-9 (b). This value actually represents the forward and return path loss through the attenuator, and illustrates how a lossy network can affect the responses that follow it. In Figure 8-9 (b), the response of the short circuit is in fact slightly masked by the response of the connector, causing a return loss greater than the expected 40 dB.




*(a). Short Circuit*




*(b). Short Circuit at the End of a 20 dB Pad*

*Figure 8-9. Masking Example*

## Windowing

Windowing makes time domain measurements more useful for isolating and identifying individual responses. Windowing is needed because of the abrupt transitions in a frequency domain measurement at the start and stop frequencies. The band limiting of a frequency domain response causes overshoot and ringing in a time domain response, and causes a non-windowed impulse stimulus to have a sin(kt)/kt shape, where $k = \pi/\text{frequency span}$ (see Figure 8-10). This has two effects that limit the usefulness of the time domain measurement:

1. Finite impulse width (or rise time). 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 8-3).

2. Sidelobes. The impulse sidelobes limit the dynamic range of the time domain measurement by hiding low-level responses within the sidelobes of higher level responses. The effects of sidelobes can be improved by windowing (see Table 8-3).

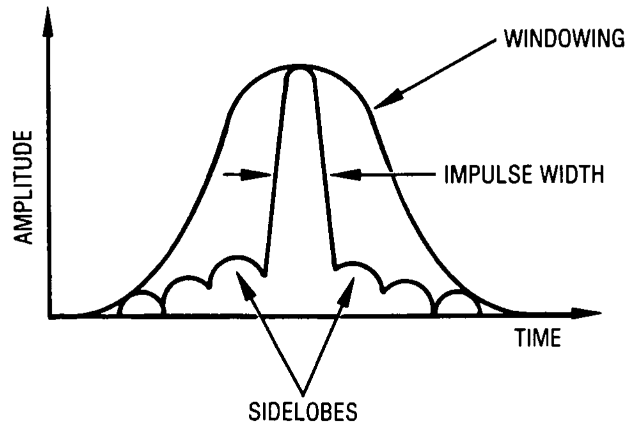



*Figure 8-10. Impulse Width, Sidelobes, and Windowing*

Windowing improves the dynamic range of a time domain measurement by filtering the frequency domain data prior to converting it to the time domain, producing an impulse stimulus that has lower sidelobes. This makes it much easier to see time domain responses that are very different in magnitude. The sidelobe reduction is achieved, however, at the expense of increased impulse width. The effect of windowing on the step stimulus (low pass mode only) is a reduction of overshoot and ringing at the expense of increased rise time.

To select a window, press **[SYSTEM]** ***[TRANSFORM MENU] [WINDOW]***. A menu is presented that allows the selection of three window types (see Table 8-3).

*Table 8-3. Impulse Width, Sidelobe Level, and Windowing Values*

| Window Type | Impulse Sidelobe Level | Low Pass Impulse Width (50%) | Step Sidelobe Level | Step Rise Time (10 − 90%) |
|---|---|---|---|---|
| Minimum | −13 dB | 1.20/Freq Span | −21 dB | 0.45/Freq Span |
| Normal | −44 dB | 1.92/Freq Span | −60 dB | 0.99/Freq Span |
| Maximum | −90 dB | 2.88/Freq Span | −90 dB | 1.48/Freq Span |
| **NOTE:** The bandpass mode simulates an impulse stimulus. Bandpass impulse width is twice that of lowpass impulse width. The bandpass impulse sidelobe levels are the same as lowpass impulse sidelobe levels. | | | | |

Choose one of the three window shapes listed in Table 8-3. Or you can use the knob to select any windowing pulse width (or rise time for a step stimulus) between the softkey values. The time domain stimulus sidelobe levels depend only on the window selected.

***[MINIMUM]*** is essentially no window. Consequently, it gives the highest sidelobes.

***[NORMAL]*** (the preset mode) gives reduced sidelobes and is the mode most often used.

***[MAXIMUM]*** window gives the minimum sidelobes, providing the greatest dynamic range.

***[USE MEMORY on OFF]*** remembers a user-specified window pulse width (or step rise time) different from the standard window values.

A window is turned on only for viewing a time domain response, and does not affect a displayed frequency domain response. Figure 8-11 shows the typical effects of windowing on the time domain response of a short circuit reflection measurement.

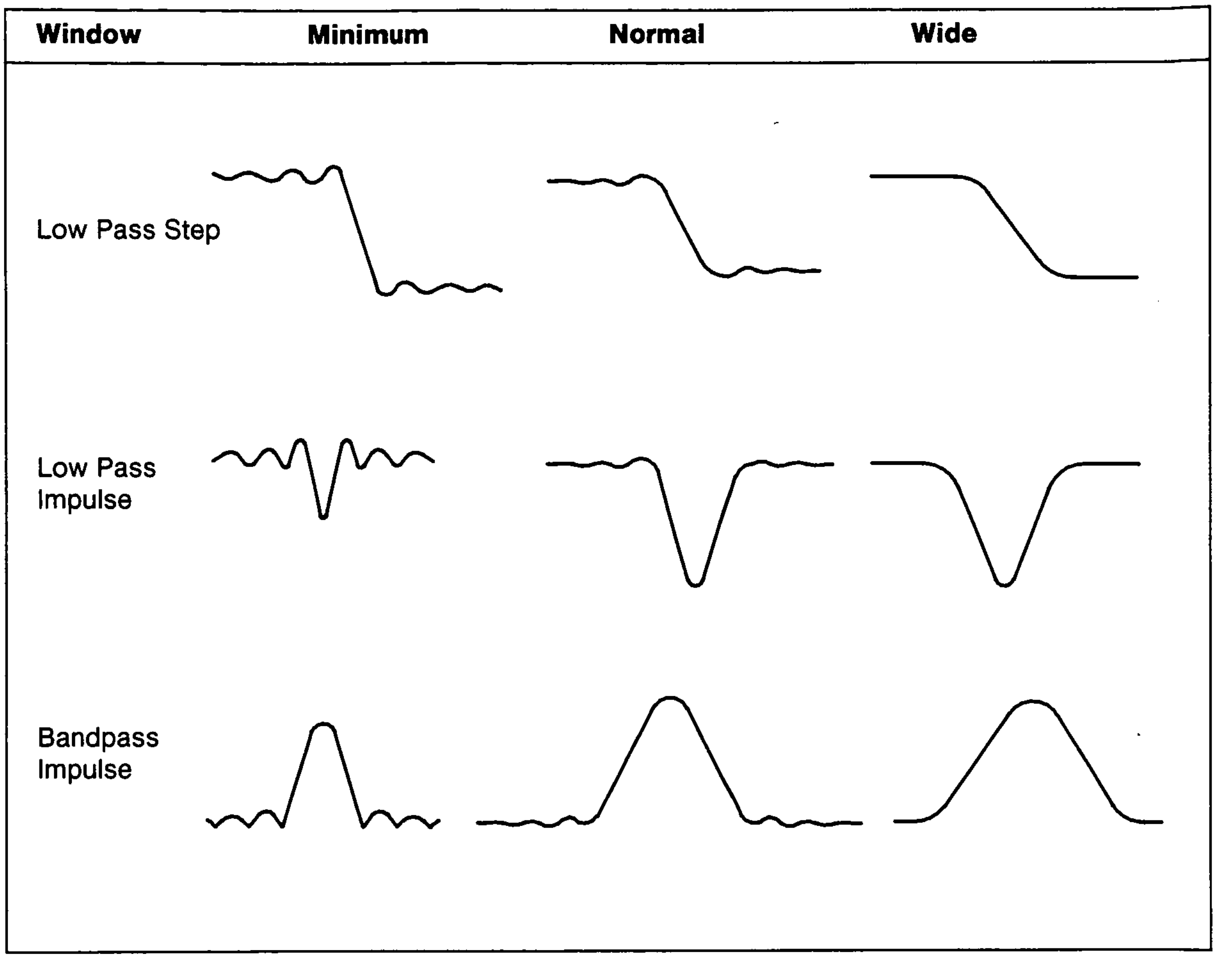



*Figure 8-11. The Effects of Windowing on the Time Domain Responses of a Short Circuit*

## Range

In the time domain, range is defined as the length in time that a measurement can be made without encountering a repetition of the response, called aliasing. A time domain response repeats at regular intervals because the frequency domain data is taken at discrete frequency points, rather than continuously over the frequency band.

Measurement range is equal to $1/\Delta F$ ($\Delta F$ is the spacing between frequency data points). Measurement range = (Number of Points $-1$)/Frequency Span (Hz).

Example:

| | |
|---|---|
| Measurement | = 201 points<br>1.00 GHz to 3.00 GHz |
| Range | = $1/\Delta F$ or (Number of Points −1)/Frequency Span<br>= $1/(10 \times 10^6)$ or $(201 - 1)/(2 \times 10^9)$<br>= $100 \times 10^{-9}$ seconds |
| Electrical length | = range x the speed of light ($3 \times 10^8$ m/s)<br>= $(100 \times 10^{-9}$ s$) \times (3 \times 10^8$ m/s$)$<br>= 30 metres |

In this example, the range is 100 ns, or 30 metres electrical length. To prevent the time domain responses from overlapping, the DUT must be 30 metres or less in electrical length for a transmission measurement (15 metres for a reflection measurement). The analyzer limits the stop time to prevent the display of aliased responses.

To increase the time domain measurement range, first increase the number of points, but remember that as the number of points increases, the sweep speed decreases. Decreasing the frequency span also increases range, but reduces resolution.

## Resolution

In the time domain, there are two different resolution terms:

1. Response Resolution
2. Range Resolution

**Response Resolution.** Time domain response resolution is defined as the ability to resolve two closely-spaced responses, or a measure of how close two responses can be to each other and still be distinguished from each other. For responses of equal amplitude, the response resolution is equal to the 50% (−6 dB) impulse width. It is inversely proportional to the measurement frequency span, and is also a function of the window used in the transform. The approximate formulas for calculating the 50% impulse width are given in Table 8-3.

For example, using the formula for the bandpass mode with a normal windowing function for a 1 GHz to 4 GHz measurement (3 GHz span):

| | |
|---|---|
| 50% calculated impulse width | = $1.2 \times (1/3\ \text{GHz}) \times 1.6$<br>= 0.64 nanoseconds |
| Electrical length (in air) | = $(0.64 \times 10^{-9}$ s$) \times (30 \times 10^9$ cm/s$)$<br>= 19.2 centimetres |

With this measurement, two equal responses can be distinguished when they are separated by at least 19.2 centimetres.

Using the low pass mode (the low pass frequencies are slightly different) with a minimum windowing function, you can distinguish two equal responses that are about 6 centimetres or more apart.

For reflection measurements, which measure the round trip time to the response, divide the response resolution by 2. Using the example above, you can distinguish two faults of equal magnitude provided they are 3 centimetres (electrical length) or more apart.

**NOTE:** Remember, to determine the physical length, enter the relative velocity factor of the transmission medium under test.

For example, a cable with a teflon dielectric (0.7 relative velocity factor), measured under the conditions stated above, has a fault location measurement response resolution of 2.1 centimetres. This is the maximum fault location response resolution. Factors such as reduced frequency span, greater frequency domain data windowing, and a large discontinuity shadowing the response of a smaller discontinuity, all act to degrade the effective response resolution.

Figure 8-12 illustrates the effects of response resolution. The solid line shows the actual reflection measurement of two approximately equal discontinuities (the input and output of an SMA barrel). The dashed line shows the approximate effect of each discontinuity, if they could be measured separately.

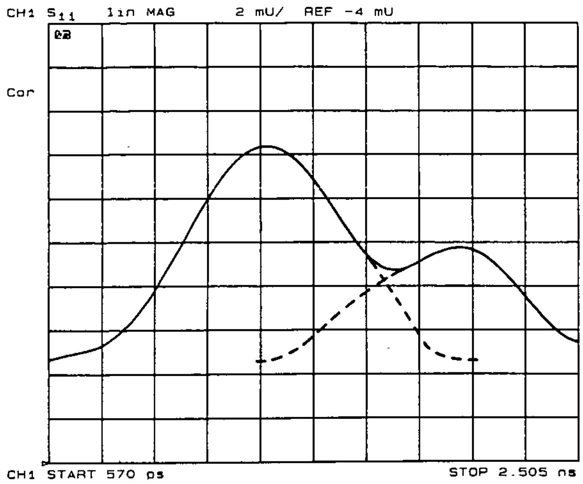



*Figure 8-12. Response Resolution*

While increasing the frequency span increases the response resolution, keep the following points in mind:

1. The time domain response noise floor is directly related to the frequency domain data noise floor. Because of this, if the frequency domain data points are taken at or below the measurement noise floor, the time domain measurement noise floor is degraded.
2. The time domain measurement is an average of the response over the frequency range of the measurement; if the frequency domain data is measured out-of-band, the time domain measurement is also the out-of-band response.

You may (with these limitations in mind) choose to use a frequency span that is wider than the DUT bandwidth to achieve better resolution.

**Range Resolution.** Time domain range resolution is defined as the ability to locate a single response in time. If only one response is present, range resolution is a measure of how closely you can pinpoint the peak of that response. The range resolution is equal to the digital resolution of the display, which is the time domain span divided by the number of points on the display. To get the maximum range resolution, center the response on the display and reduce the time domain span. The range resolution is always much finer than the response resolution.

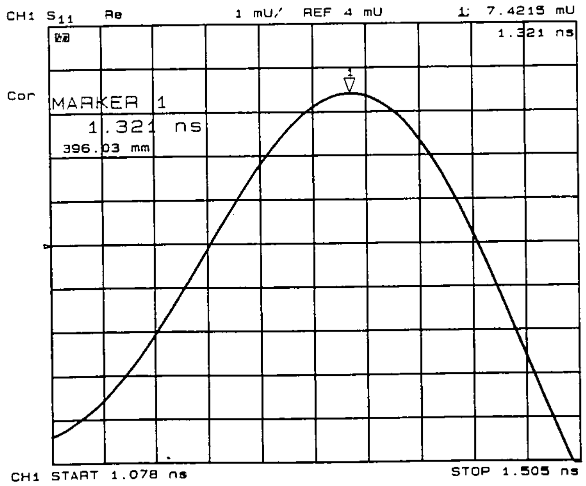
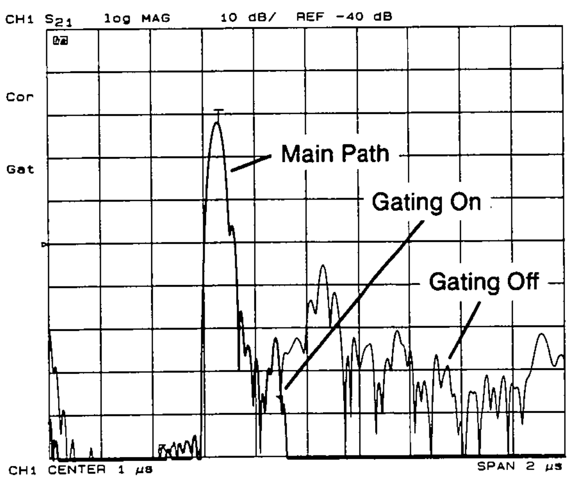



*Figure 8-13. Range Resolution of a Single Discontinuity*

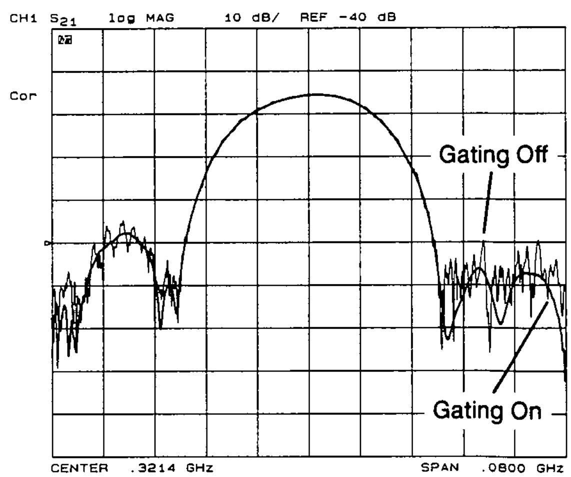
## Gating

Gating provides the flexibility of selectively removing time domain responses. The gated time domain responses can then be transformed back to the frequency domain. For reflection (or fault location) measurements, use this feature to remove the effects of unwanted discontinuities in the time domain. You can then view the frequency response of the remaining discontinuities. In a transmission measurement, you can remove the effects of multiple transmission paths.

Figure 8-14 illustrates the time domain response of a SAW filter. Gating has been applied in the time domain to remove the effects of all but the main signal path response. When the gated response is transformed back to the frequency domain, the display shows only the direct path response.




*(a) Time Domain*




*(b) Frequency Domain*

*Figure 8-14. SAW Filter Transmission Measurement with Gating*

**Setting the Gate.** Think of a gate as a bandpass filter in the time domain (Figure 8-15). When the gate is on, responses outside the gate are mathematically removed from the time domain trace. Enter the gate position as a start and stop time (not frequency) or as a center and span time. The start and stop times are the bandpass filter −6 dB cutoff times. Gates can have a negative span, in which case the responses **inside** the gate are mathematically removed.

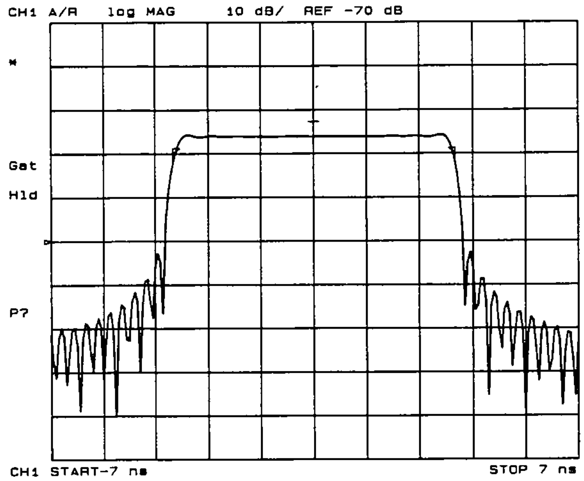



*Figure 8-15. Gate Shape*

**Selecting Gate Shape.** The four gate shapes available are listed in Table 8-4. Each gate has a different passband flatness, cutoff rate, and sidelobe levels.

*Table 8-4. Gate Characteristics*

| Gate Shape | Passband Ripple | Sidelobe Levels | Cutoff Time | Minimum Gate Span |
|---|---|---|---|---|
| Minimum | ±0.40 dB | −24 dB | 0.6/Freq Span | 1.2/Freq Span |
| Normal | ±0.04 dB | −45 dB | 1.4/Freq Span | 2.8/Freq Span |
| Wide | ±0.02 dB | −52 dB | 4.0/Freq Span | 8.0/Freq Span |
| Maximum | ±0.01 dB | −80 dB | 11.2/Freq Span | 22.4/Freq Span |

The passband ripple and sidelobe levels are descriptive of the gate shape. The cutoff time is the time between the stop time (−6 dB on the filter skirt) and the peak of the first sidelobe, and is equal on the left and right side skirts of the filter. Because the minimum gate span has no passband, it is just twice the cutoff time. Always choose a gate span wider than the minimum. For most applications, do not be concerned about the minimum gate span, simply use the knob to position the gate markers around the desired portion of the time domain trace.

## TRANSFORMING CW TIME MEASUREMENTS INTO THE FREQUENCY DOMAIN

The analyzer can display the amplitude and phase of continuous wave (CW) signals versus time. For example, use this mode for measurements such as amplifier gain as a function of warm-up time (i.e. drift). In the past, drift measurements were often made using strip chart recorders. The analyzer can display the measured parameter (e.g. amplifier gain) for periods of up to 24 hours and then output the data to a digital plotter for hardcopy results.

These "strip chart" plots are actually measurements as a function of time (time is the independent variable), and the horizontal display axis is scaled in time units. Transforms of these measurements result in frequency domain data. Such transforms are called forward transforms because the transform from time to frequency is a forward Fourier transform, and can be used to measure the spectral content of a CW signal. For example, when transformed into the frequency domain, a pure CW signal measured over time appears as a single frequency spike (Figure 8-16). The transform into the frequency domain yields a display that looks similar to a spectrum analyzer display of signal amplitude versus frequency.

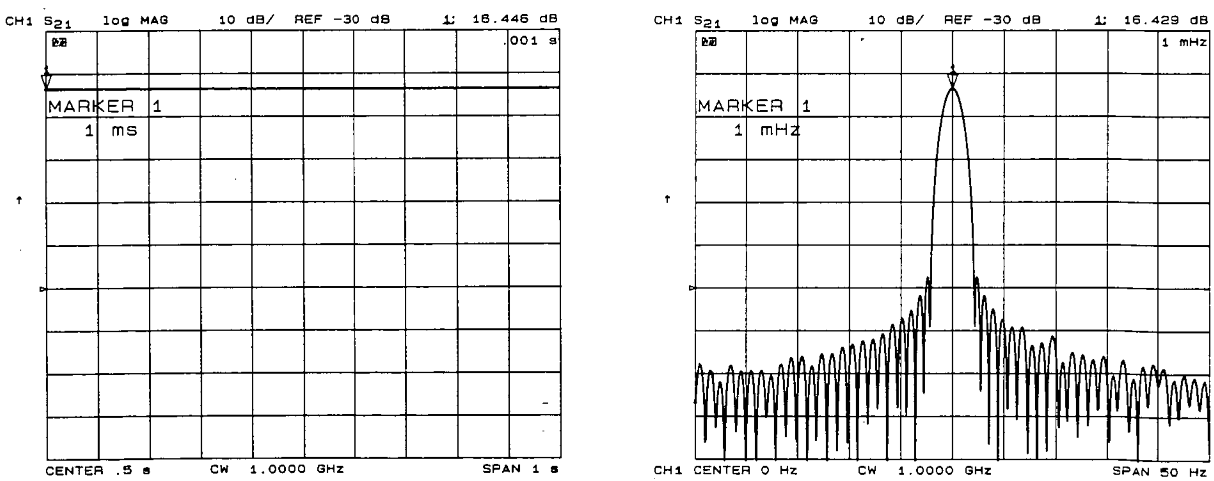
## Forward Transform Measurements

This is an example of a measurement using the Fourier transform in the forward direction from time domain to frequency domain (see Figure 8-16):

1. Press **[PRESET]**.
2. Press **[MEAS]** *[Trans: FWD S21]*.
3. Press **[MENU]** *[CW FREQ]* and set the CW frequency to the desired value (in this case, the default CW frequency of 1 GHz). The CW time mode is now active.
4. Press *[SWEEP TIME MANUAL]* **[2] [0] [0] [k/m]** to increase the sweep time to 200 milliseconds.
5. Press **[SYSTEM]** *[TRANSFORM MENU]* *[TRANSFORM ON]* to transform the data into the frequency domain.
6. Press **[SPAN] [1] [0] [0] [0] [x1]** to increase the frequency span to 1 kHz. The center frequency of ≅ 0 Hz represents the CW frequency of 1 GHz entered earlier.

**NOTE:** In the forward transform mode, the k/m, M/μ, and G/n keys terminate a selection as millihertz, microhertz, and nanohertz.

7. Press **[SCALE REF] [1] [0] [x1]** to view the trace centered on the screen.
8. Press **[MKR FCTN]** *[MKR SEARCH]* *[MAX]* to see the peak value.




*(a) CW Time* *(b) Transform to Frequency Domain*

*Figure 8-16. Amplifier Gain Measurement*

**Interpreting the Forward Transform Measurement.** With the log magnitude format selected, the vertical axis displays dB. This format simulates a spectrum analyzer display of power versus frequency. In a frequency domain transform of a CW time measurement, the horizontal axis is measured in units of frequency. The center frequency is the offset of the CW frequency. For example, if you enter a center frequency value of 0 Hz with the transform on, the center of the display shows the CW frequency (1 GHz in the example on the previous page). A positive center frequency value entered with the transform on shifts the CW frequency to the left half of the display; a negative value shifts it to the right half of the display. The span value entered with the transform on is the total frequency span shown on the display. Alternatively, the frequency display values can be entered as start and stop.

## Demodulating the Results of the Forward Transform

The forward transform can separate the effects of the CW frequency modulation amplitude and phase components. For example, if a DUT modulates the transmission response (S21) with a 300 Hz AM signal, you can see the effects of that modulation as shown in Figure 8-17. To simulate this effect, connect a 300 Hz sine wave to the modulation input of a PIN modulator connected between port 1 and port 2.

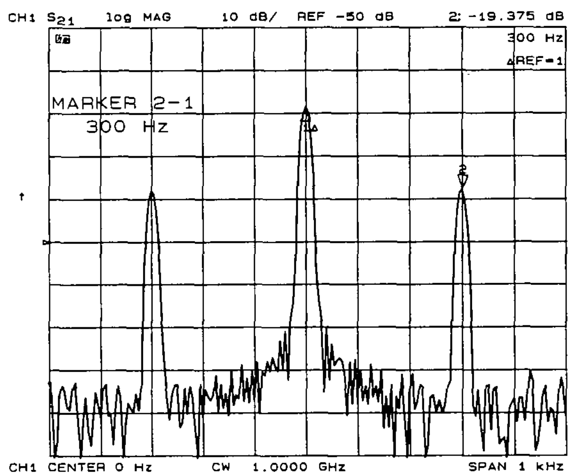


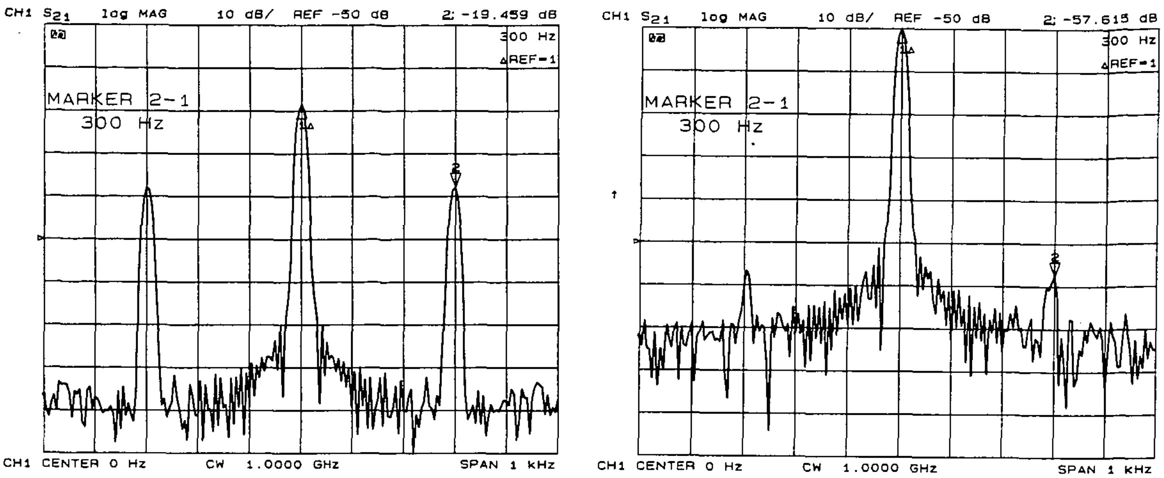

*Figure 8-17. Combined Effects of Amplitude and Phase Modulation*

Using the demodulation capabilities of the analyzer, it is possible to view the amplitude or the phase component of the modulation separately. The window menu (see Figure 8-2) includes the following softkeys to control the demodulation feature:

***[DEMOD: OFF]*** This is the normal preset state, in which both the amplitude and phase components of any DUT modulation appear on the display.

***[AMPLITUDE]*** displays only the amplitude modulation (AM), as illustrated in Figure 8-18 (a).

***[PHASE]*** displays only the phase modulation (PM), as shown in Figure 8-18 (b).




*(a) Amplitude Modulation Component* *(b) Phase Modulation Component*

*Figure 8-18. Separating the Amplitude and Phase Components of DUT-Induced Modulation*

## Forward Transform Range

In the forward transform (from CW time to the frequency domain), range is defined as the frequency span that can be displayed before aliasing occurs, and is similar to range as defined for time domain measurements. In the range formula, substitute time span for frequency span.

Example:

Range = (Number of points −1)/Time Span
= (201 −1)/(200 x $10^{-3}$)
= 1000 Hertz

For the example given above, a 201 point CW time measurement made over a 200 ms time span, choose a span of 1 kHz or less on either side of the center frequency (Figure 8-19). That is, choose a total span of 2 kHz or less.

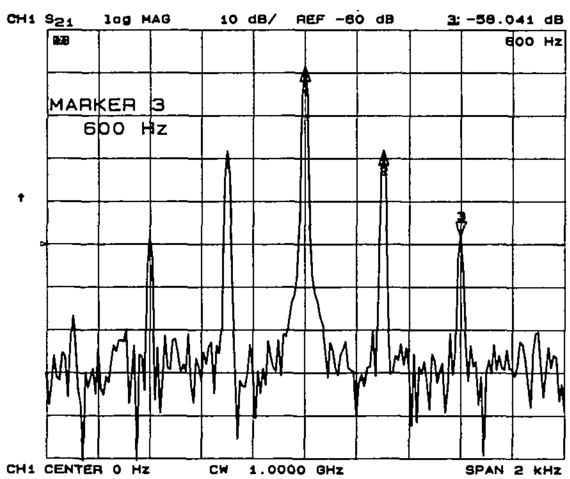



*Figure 8-19. Range of a Forward Transform Measurement*

To increase the frequency domain measurement range, increase the span. The maximum range is inversely proportional to the sweep time, therefore it may be necessary to increase the number of points or decrease the sweep time. Because increasing the number of points increases the auto sweep time, the maximum range is 2 kHz on either side of the selected CW time measurement center frequency (4 kHz total span). To display a total frequency span of 4 kHz, enter the span as 4000 Hz.

# Chapter 9. Making a Hard Copy Output

## INTRODUCTION

The analyzer can use HP-IB to output measurement results directly to a compatible printer or plotter, without the use of an external controller. The information displayed on the CRT can be copied to a compatible Hewlett-Packard plotter or graphics printer. Refer to the *General Information* section of this manual for information about compatible plotters and printers.

To generate a plot or printout from the front panel when there is no other controller on the bus, the analyzer must be in system controller HP-IB mode. To take control from the computer and initiate a plot or printout, the analyzer must be in pass control mode. If it is not in one of these modes, the message "CHANGE HP-IB to SYS CTRL or PASS CTRL" is displayed. Refer to *[LOCAL] Key* in Chapter 7 for information on HP-IB controller modes and setting addresses.

## [COPY] KEY

The **[COPY]** key provides access to the menus used for controlling external plotters and printers and defining the plot parameters.

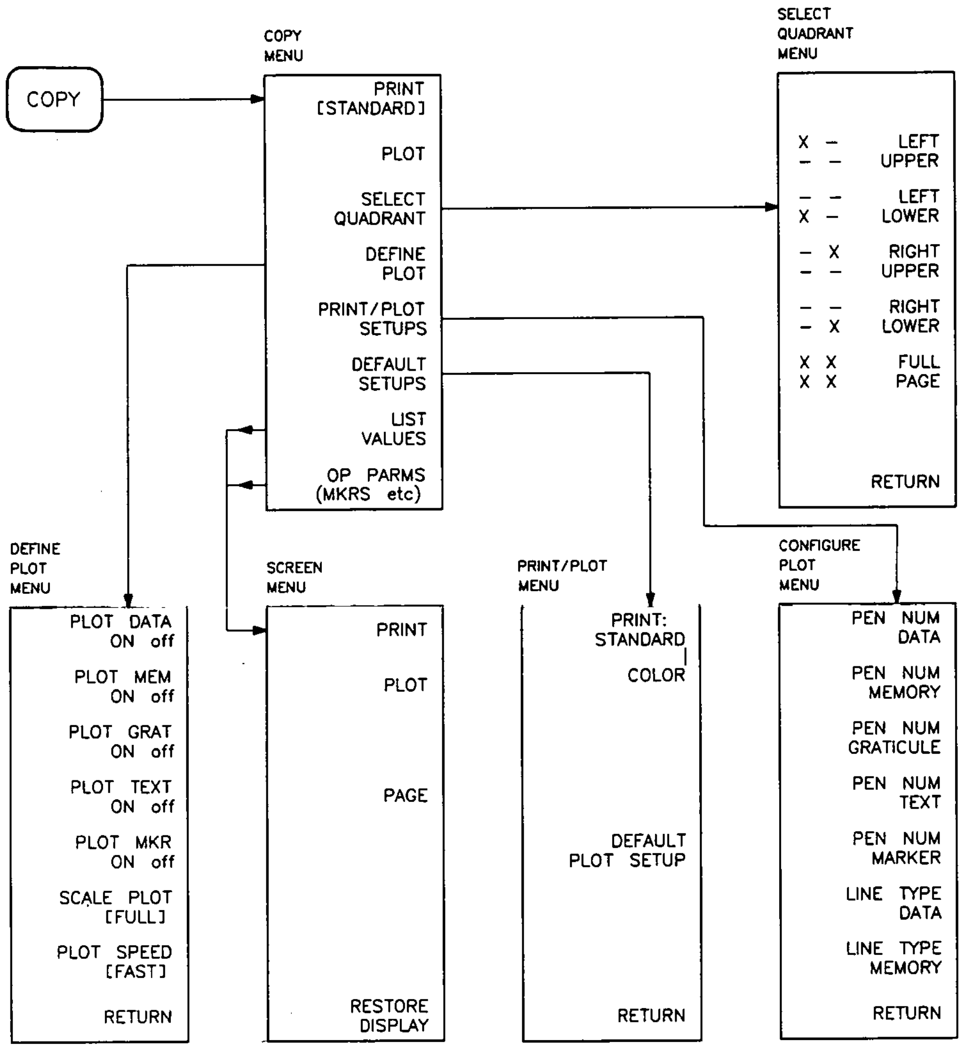



*Figure 9-1. Softkey Menus Accessed from the [COPY] Key*

## Copy Menu

The copy menu can be used to copy to a printer or to plot using default plot parameters, without the need to access other menus. For user-defined plot parameters, a series of additional menus is available.

This menu also provides tables of operating parameters and measured data values, which can be copied from the screen to a printer or plotter.

To abort a plot or print, press any front panel key except **[PRESET]**. The analyzer will stop the copying process, and the message "CAUTION: PRINT (PLOT) ABORTED" will be displayed. An aborted plot or printout cannot be continued: if a copy is still required, the process should be initiated again.

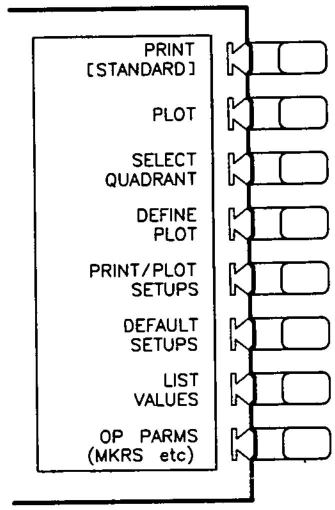



*Figure 9-2. Copy Menu*

***[PRINT]*** (PRINALL) copies the CRT display to a compatible HP graphics printer. Tabular listings or data displays can be printed, although a plotter provides better resolution for data displays. All information from the CRT display is printed except the softkey labels.

***[PLOT]*** (PLOT) plots the CRT display to a compatible HP graphics plotter, using the currently defined plot parameters (or default parameters). Any or all displayed information can be plotted, except a frequency list table or limit table, or the softkey labels. If a printer is not available, tabular listings can be plotted, although plotting is considerably slower than printing.

***[SELECT QUADRANT]*** leads to the the select quadrant menu, which provides the capability of drawing quarter-page plots. This is not used for printing.

***[DEFINE PLOT]*** leads to the define plot menu, which is used to specify which elements of the display are to be plotted. This is not used for printing.

***[CONFIGURE PLOT]*** leads to the configure plot menu, which defines the pen number and line type for each of the plot elements. This is not used for printing.

**[PRINT/PLOT SETUPS]** presents a menu to select a standard (non-color) or color printer as the default, and lets you reset the print and plot definitions.

***[LIST VALUES]*** (LISV) provides a tabular listing of all the measured data points and their current values, together with limit information if it is turned on. At the same time, the screen menu is presented, to enable hard copy listings and access new pages of the table. 30 lines of data are listed on each page, and the number of pages is determined by the number of measurement points specified in the stimulus menu.

Up to five columns of data are provided. The specific information listed for each measured data point varies depending on the display format, the limit testing status, and whether or not dual channel display or stimulus coupling is selected. If limit testing is on, an asterisk * is listed next to any measured value that is out of limits. If limit lines are on, and other listed data allows sufficient space, the limits are listed together with the margin by which the device data passes or fails the nearest limit.

***[OP PARMS (MKRS etc)]*** (OPEP) provides a tabular listing of key parameters for both channels. The screen menu allows printing or plotting of the parameters visible or paging through the 4 pages of information. The information consists of marker parameters, operating parameters, and system parameters. System parameters relate to control of peripheral devices.

## Select Quadrant Menu

This menu offers the selection of a full-page plot, or a quarter-page plot in any quadrant of the page.

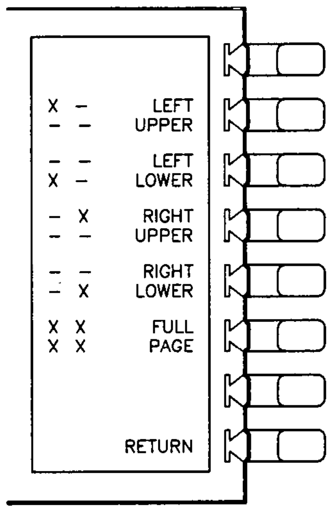



*Figure 9-3. Select Quadrant Menu*

***[LEFT UPPER]*** (LEFU) draws a quarter-page plot in the upper left quadrant of the page.

***[LEFT LOWER]*** (LEFL) draws a quarter-page plot in the lower left quadrant of the page.

***[RIGHT UPPER]*** (RIGU) draws a quarter-page plot in the upper right quadrant of the page.

***[RIGHT LOWER]*** (RIGL) draws a quarter-page plot in the lower right quadrant of the page.

***[FULL PAGE]*** (FULP) draws a full-size plot according to the scale defined with ***[SCALE PLOT]*** in the define plot menu (described next).

***[RETURN]*** goes back to the copy menu.

## Define Plot Menu

This menu allows selective plotting of portions of the measurement display. Different plot elements can be turned on or off as required. In addition, different selections are available for plot speed and plot scale, to allow plotting on transparencies and preprinted forms.

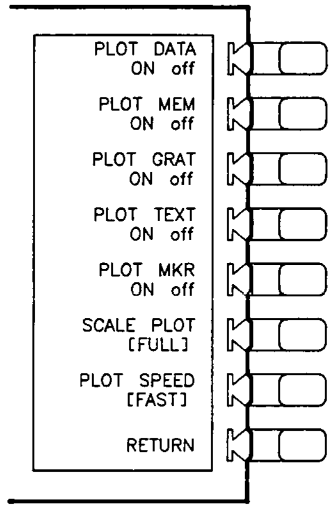



*Figure 9-4. Define Plot Menu*

***[PLOT DATA ON off]*** (PDATAON, PDATAOFF) specifies whether the data trace is to be drawn (on) or not drawn (off) on the plot.

***[PLOT MEM ON off]*** (PMEMON, PMEMOFF) specifies whether the memory trace is to be drawn (on) or not drawn (off) on the plot. Memory can only be plotted if it is displayed (refer to *Display Menu* in Chapter 4).

***[PLOT GRAT ON off]*** (PGRATON, PGRATOFF) specifies whether the graticule and the reference line are to be drawn (on) or not drawn (off) on the plot. Turning ***[PLOT GRAT ON]*** and all other elements off is a convenient way to make preplotted grid forms. However, when data is to be plotted on a preplotted form, ***[PLOT GRAT OFF]*** should be selected.

***[PLOT TEXT ON off]*** (PTEXTON, PTEXTOFF) selects plotting of all displayed text except frequency list table, limits table, softkeys, and marker values. (Softkey labels can be plotted under the control of an external controller. The frequency list table and limits table can be printed from an external controller. Refer to the *HP-IB Programming Guide*.

***[PLOT MKR ON off]*** (PMKRON, PMKROFF) specifies whether the markers and marker values are to be drawn (on) or not drawn (off) on the plot.

***[SCALE PLOT]*** (SCAPFULL, SCAPGRAT) provides two selections for plot scale, ***[FULL]*** and ***[GRAT]***. ***[FULL]*** is the normal scale selection for plotting on blank paper, and includes space for all display annotations such as marker values, stimulus values, etc. The entire CRT display fits within the user-defined boundaries of P1 and P2 on the plotter, while maintaining the exact same aspect ratio as the CRT display.

With the selection of ***[GRAT]***, the horizontal and vertical scale are expanded or reduced so that the graticule lower left and upper right corners exactly correspond to the user-defined P1 and P2 scaling points on the plotter. This is convenient for plotting on preprinted rectangular or polar forms (for example, on a Smith chart).

To plot on a rectangular preprinted graticule, set P1 of the plotter at the lower left corner of the preprinted graticule, and set P2 at the upper right corner.

To plot on a polar format, set P1 to either the left (or bottom) end point of a diameter and P2 to the right (or top) end point. The analyzer will then compute and set new P1 and P2 values to obtain the current circularity. If P1 and P2 are set to within 10% of already being a perfect square, the analyzer will not change the boundaries but will distort the circles to fit the user-defined boundaries.

The procedure for plotting on a Smith chart format depends on the plotter capabilities. Some HP plotters have a 90° rotate feature that enables plotting on a portrait (vertical) format rather than a landscape (horizontal) format. Since most Smith charts are printed in portrait format, this rotate feature should be used prior to setting the P1 and P2 points, as described above for a polar format.

***[PLOT SPEED]*** (PLOSFAST, PLOSSLOW) provides two plot speeds, ***[FAST]*** and ***[SLOW]***. Fast is the proper plot speed for normal plotting. Slow plot speed is used for plotting directly on transparencies: the slower speed provides a more consistent line width. A color plot can be prepared directly on a transparency so that the color is not lost in converting a paper plot to a transparency.

***[RETURN]*** goes back to the copy menu.

## Configure Plot Menu

This menu is used to select the pens to be used for plotting different elements of a plot, and the line types for the data and memory traces.

Pen numbers 0 through 10 can be selected (0 indicates no pen). It is possible to select a pen number higher than the number of pens in the plotter used. The convention in most Hewlett-Packard plotters is that when the pen number count reaches its maximum number it starts again at 1. Thus in a four-pen plotter, pen #5 actually calls pen #1.

The default pen numbers for the different plot elements vary between channels 1 and 2, so that when a color plotter is used the plots for the two channels can be identified quickly by their colors.

Line types 0 through 10 can be selected. The line types depend on the model of plotter used. In general, however, line type 0 specifies dots only at the points that are plotted; line types 1 through 6 specify broken lines with different spacing; and lines 7 through 10 are solid lines. Refer to the plotter manual for specific line type information.

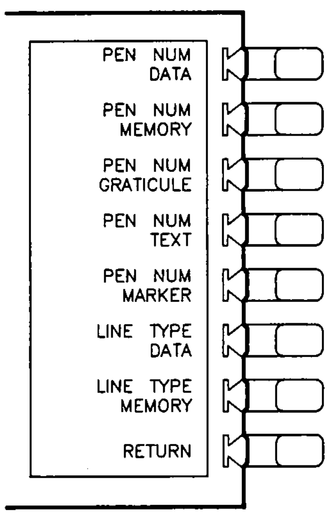



*Figure 9-5. Configure Plot Menu*

***[PEN NUM DATA]*** (PENNDATA) selects the number of the pen to plot the data trace. The default pen for channel 1 is pen #1, and for channel 2 is pen #2.

***[PEN NUM MEMORY]*** (PENNMEMO) selects the number of the pen to plot the memory trace. The default pen for channel 1 is pen #1, and for channel 2 is pen #2.

***[PEN NUM GRATICULE]*** (PENNGRAT) selects the pen number for plotting the graticule. The default pen for channel 1 is pen #3, and for channel 2 is pen #4.

***[PEN NUM TEXT]*** (PENNTEXT) selects the pen number for plotting the text. The default pen for channel 1 is pen #5, and for channel 2 is pen #6.

***[PEN NUM MARKER]*** (PENNMARK) selects the pen number for plotting both the markers and the marker values. The default pen for channel 1 is pen #7, and for channel 2 is pen #8.

***[LINE TYPE DATA]*** (LINTDATA) selects the line type for the data trace plot. The default line type is 7, which is a solid unbroken line.

***[LINE TYPE MEMORY]*** (LINTMEMO) selects the line type for the memory trace plot. The default line type is 7.

***[RETURN]*** goes back to the copy menu.

## Screen Menu

This menu is used in conjunction with the ***[LIST VALUES]*** and ***[OP PARMS (MKRS etc)]*** features, to make hard copy listings of the tables displayed on the screen. To make copies from the front panel, make sure that the analyzer is in system controller or pass control mode (see Chapter 7).

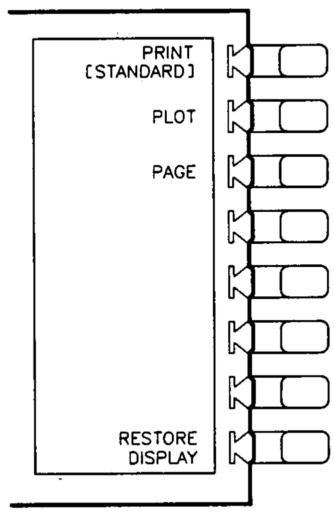



*Figure 9-6. Screen Menu*

***[PRINT]*** (PRINALL) copies one page of the tabular listings to a compatible HP graphics printer connected to the analyzer over HP-IB.

***[PLOT]*** (PLOT) makes a hard copy plot of one page of the tabular listing on the CRT, using a compatible HP plotter connected to the analyzer through HP-IB. This is much slower than printing.

***[PAGE]*** (NEXP) displays the next page of information in a tabular listing onto the CRT.

***[RESTORE DISPLAY]*** (RESD) turns off the tabular listing and returns the measurement display to the screen.

## Print/Plot Setups Menu

This menu allows selection of printer type and plot setup.

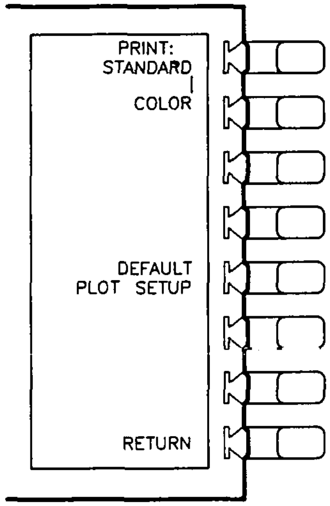



*Figure 9-7. Print/Plots Setups Menu*

**[PRINT: STANDARD]** (PRIS) is used with non-color printers.

**[COLOR]** (PRIC) is used with color printers.

**[DEFAULT PLOT SETUP]** (DFLT) resets the plotting parameters to their default values.

| | |
|---|---|
| Select quadrant: | Full page |
| Define plot: | All plot elements on |
| Plot scale: | Full |
| Plot speed: | Fast |
| Line type: | 7 (solid line) |
| Pen numbers: | Default values |

Default plot setups do not apply to prints.

# Chapter 10. Saving Instrument States

## INTRODUCTION

The analyzer has the capability of saving complete instrument states for later retrieval. It has five internal registers for this purpose, and can use direct disc access as an extension to internal memory. Because instrument states can be of varying complexities, it is possible to fill the available internal memory with less than five states. Also, it is possible to fill memory with instrument states and prevent such memory-intensive functions as two-port error correction, time domain (option 010), or 1601 measurement points.

This chapter discusses instrument state definition, memory allocation, and the treatment of saved calibration data. Refer to the *HB-IB Programming Guide* for information on external disc storage using an external controller.

The analyzer can utilize three types of memory for the storage of instrument states:

- Volatile memory. This is dynamic read/write memory, containing the current instrument state, calibration sets, and the variables listed in Table 2. It is cleared upon power cycle to the instrument and, except as noted, upon instrument preset.
- Non-volatile memory. This is CMOS read/write memory, providing short term (minimum 72 hour) storage of data without line power to the instrument.
- External memory. This utilizes disc media for unlimited storage of instrument states, as well as calibration and measurement data.

*Table 1. Memory Usage*

| |
|---|
| **Volatile Memory** (see Table 2) |
| Current instrument state |
| Calibration sets |
| Variables |
| **Non-Volatile Memory** |
| Five learn string registers |
| CRT intensity default |
| HP-IB configuration |
| User calibration kit definition |
| **External Memory** |
| Instrument states |
| Calibration sets |
| Measurement data |

## INSTRUMENT STATE

An instrument state consists of two types of data: (1) the learn string and, (2) variables.

### Instrument State Learn String

The learn string is an encoded array. It contains only the data needed to set up the analyzer to make a specific measurement. That data consists of stimulus and response parameters and operating modes status. Each measurement point is not recorded. For example, to re-create a frequency list the analyzer needs to save only the start frequency, frequency span, and number of points in each segment. Thus the size of the learn string is constant, not proportional to the number of points in the sweep.

Learn strings are saved in non-volatile, short-term (72 hour minimum) memory. Learn strings will survive instrument preset and cycling power.

### Instrument State Variables

The instrument state variables are calibration sets, measurement data, and operating modes data. They vary in size with the number of points and compete with other instrument functions and modes for volatile memory space. This size may be approximated with the information in table 2.

The variables are stored in volatile memory. Calibration sets will survive instrument preset but will be lost when the analyzer is turned off. Measurement data and operating modes data will not survive preset or cycling power.

*Table 2. Instrument State Variables Stored in Volatile Memory*

| Variable | Data Length (bytes) | | |
|---|---|---|---|
| **Calibration Sets** | | | |
| Response | N x 6 +52 | | |
| Response and isolation | N x 6 x 2 +52 | | |
| 1 port | N x 6 x 3 +52 | | |
| 2 port | N x 6 x 12 +52 | | |
| **Measurement Data** | | | |
| Raw data* | | | |
| Correction data | N x 6 +52 | | |
| 2 port cal | 4(N x 6 +52) | | |
| Data array* | N x 6 +52 | | |
| Formatted array* | N x 6 +52 | | |
| Memory array* | N x 6 +52 | | |
| Scratchpad array** | N x 6 +52 | | |
| **Operating Modes Data** | | | |
| Smoothing ON* (20% aperture, 1601 points) | <2000 | | |
| Frequency list mode* | N x 12 | | |
| Log frequency mode* | N x 12 | | |
| Time domain | | **With Additional Features** | |
| | | **Window and Chirp Array** | **Gating Array** |
| FFT array | | | |
| ≤51 points | 768 | 972 | 1612 |
| 101 points | 1536 | 1940 | 3233 |
| 201 points | 3072 | 3876 | 6456 |
| 401 points | 6144 | 7748 | 12913 |
| 801 points | 12288 | 15492 | 25820 |
| 1601 points | 24576 | 26177 | 43628 |

**Notes:**

User allocatable memory: ≈ 960 Kbytes

N = number of points

*This variable is allocated once per active channel.

**Insufficent memory for allocation of this array is not fatal. The array is used to recalculate the data for display any time formatting factors are changed. If sufficient memory is not allocated, trace data will not be redisplayed after a scaling change until a new sweep occurs.

## SAVING AND STORING INSTRUMENT STATES

Instrument states can be saved internally or stored to external disks. Each method has advantages and disadvantages.

### Saving Instrument States Internally

Data saved internally requires no external equipment. But cycling power erases calibration sets, measurement data, and operating modes data saved in volatile memory. Thus storing instrument states to disk (see *Instrument States* below) is more appropriate at times. That aside, up to six instrument states can reside in internal memory at any one time: five saved states and the active state. Calibration sets are linked to the instrument state and measurement parameter for which the calibration was done. Up to 12 calibrations can exist (the actual may be limited by available memory). When an instrument state is cleared (deleted) from memory (see *[CLEAR REGISTER]*), the associated calibration set is also deleted.

### Storing Instrument States to Disk

With the analyzer in system controller or pass control mode, data can be stored to an external disk drive. The entire stored instrument state (learn string and variables) will survive both preset and cycling power.

Note that instrument states stored to disk by one instrument may be recalled by another. This can be a convenient method for transfering limit line data and frequency lists. This method can ease the transition of upgrading from an HP 8720A to HP 8719A or 8720B, for instance. However frequencies stored by an option 001 (high resolution) instrument and recalled by a standard instrument may be incompatible. And storing calibration sets requires caution (see below).

In local mode (no controller), the analyzer displays on the CRT one file name for each stored instrument state. In reality, when an instrument state is stored to disk, several associated files are stored. When the disk catalogue is accessed from a remote system controller, the directory will show all of the files associated with a particular instrument state. All of the files stored on a disk may not exceed 255 (see *HP-IB Programming Guide*).

### Calibration Set Cautions

Calibration sets stored by one instrument and recalled by another instrument are not valid. Watch out for situations like this:

- Correction is ON when analyzer A stores instrument state A to disk,
- Analyzer B recalls instrument state A from disk; as a result,
- Analyzer B recalls calibration set A, and
- Analyzer B turns correction ON (but it is not valid; recalibrate).

Calibration sets should not be recalled at one temperature if stored (by the same or different instrument) at another temperature. Refer to the "Specifications" section for allowable temperature ranges for individual specifications.

## [SAVE] AND [RECALL] KEYS

The **[SAVE]** key provides access to all the menus used for saving instrument states in internal memory and for storing to exernal disc. This includes the menus used to define titles for internal registers and external files, to define the content of external files, to initialize discs for storage, and to clear data from the registers or purge files from an external disc.

The **[RECALL]** key leads to the menus that recall the contents of internal registers, or load files from external disc back into the analyzer.

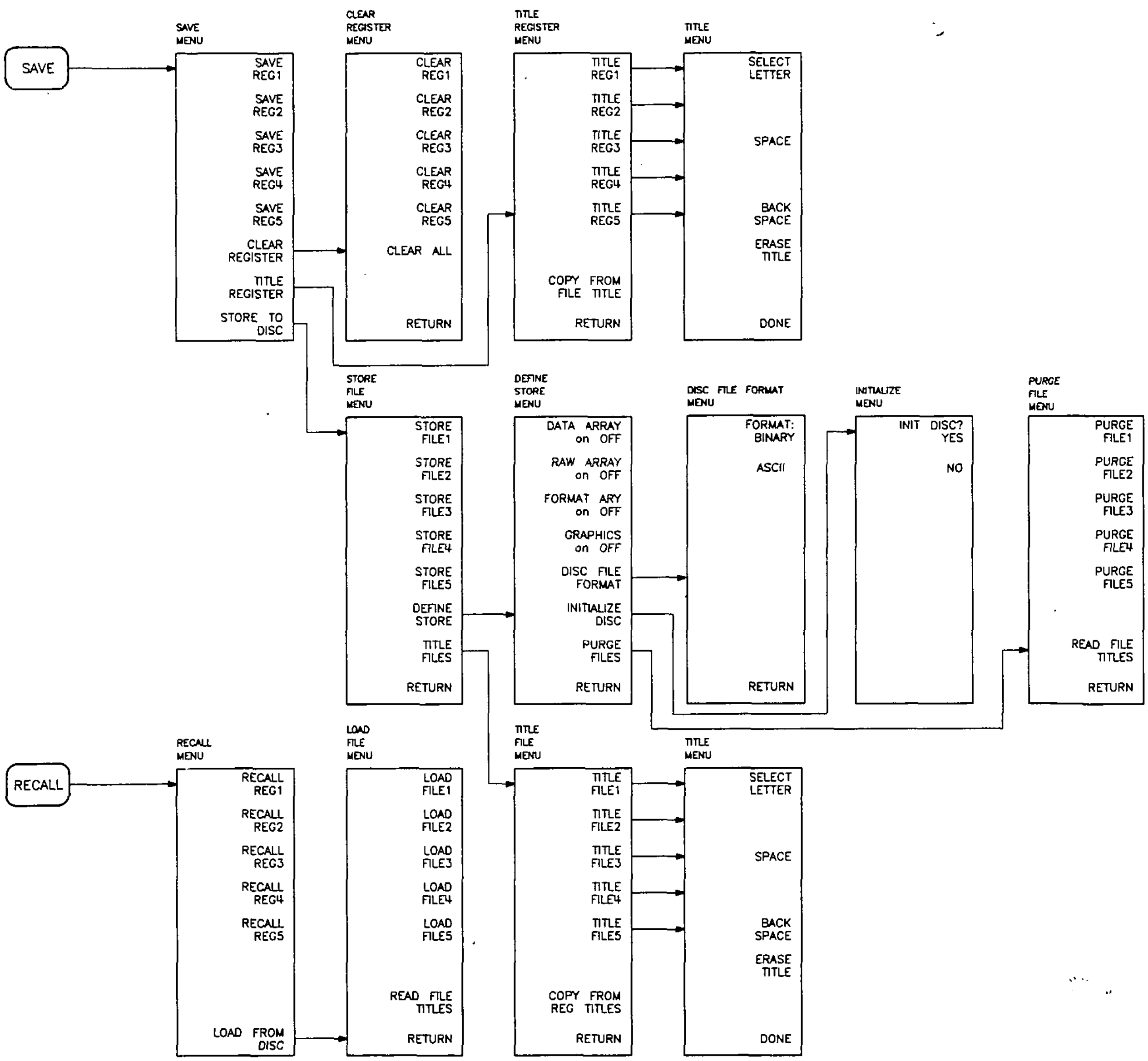



*Figure 10-1. Softkey Menus Accessed from the [SAVE] and [RECALL] Keys*

## Save Menu

This menu (Figure 10-2) selects an internal memory register to store the current instrument state. If a register contains a previously saved instrument state, the softkey label changes to ***[RESAVE]***. This is intended to prevent inadvertent destruction of saved states.

This also leads to the series of menus for external disc storage.

The default titles for the save registers are REG1 through REG5, but these titles can be modified using the title register menu and the title menu.

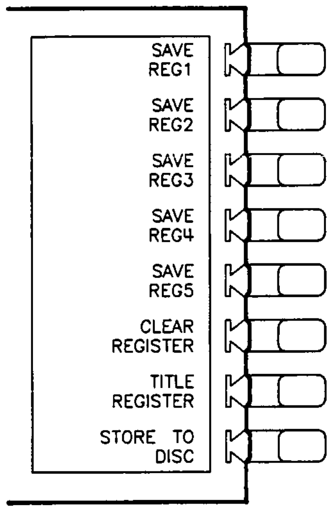



*Figure 10-2. Save Menu*

***[SAVE REG1]*** (SAVE1) saves the present instrument state in an internal register titled REG1.

***[SAVE REG2]*** (SAVE2) saves the present instrument state in internal register REG2.

***[SAVE REG3]*** (SAVE3) saves the present instrument state in internal register REG3.

***[SAVE REG4]*** (SAVE4) saves the present instrument state in internal register REG4.

***[SAVE REG5]*** (SAVE5) saves the present instrument state in internal register REG5.

***[CLEAR REGISTER]*** leads to the clear register menu, described on the next page.

***[TITLE REGISTER]*** leads to the title register menu, where the default register titles can be modified.

***[STORE TO DISC]*** leads to the store file menu, which introduces a series of menus for external disc storage.

## Clear Register Menu

This menu (Figure 10-3) allows unused instrument states to be cleared from save registers, making the assigned memory available for other uses. When an instrument state is deleted from memory, the associated calibration set is also deleted. You can choose to selectively clear individual registers, or clear all registers with one keystroke.

Clearing of registers is performed internally with 100 alternating 0 and 1 rewrite operations over the entire non-volatile portion of the specified register memory.

Only registers that have instrument states previously stored in them are listed in this menu.

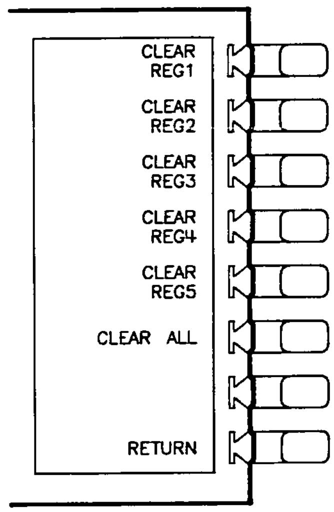



*Figure 10-3. Clear Register Menu*

***[CLEAR REG1]*** (CLEA1) clears a previously saved instrument state from register 1.

***[CLEAR REG2]*** (CLEA2) clears a saved instrument state from register 2.

***[CLEAR REG3]*** (CLEA3) clears a saved instrument state from register 3.

***[CLEAR REG4]*** (CLEA4) clears a saved instrument state from register 4.

***[CLEAR REG5]*** (CLEA5) clears a saved instrument state from register 5.

***[CLEAR ALL]*** (CLEARALL) clears all instrument states.

***[RETURN]*** goes back to the save menu.

## Title Register Menu

This menu can be used to select a register to be retitled. All registers are listed, regardless of whether or not they contain saved instrument states. When any of the title register softkeys is pressed, the title menu is presented and the character set is displayed in the active entry area.

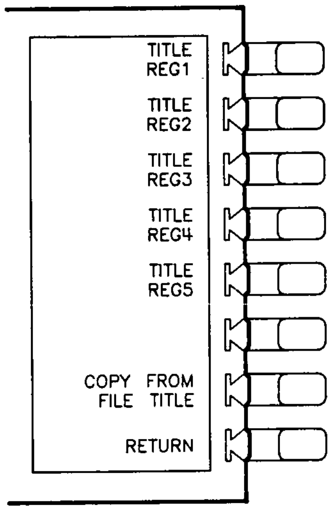



*Figure 10-4. Title Register Menu*

*[TITLE REG1]* (TITR1) selects register 1 to be retitled and presents the title menu and the character set.

*[TITLE REG2]* (TITR2) selects register 2 to be retitled.

*[TITLE REG3]* (TITR3) selects register 3 to be retitled.

*[TITLE REG4]* (TITR4) selects register 4 to be retitled.

*[TITLE REG5]* (TITR5) selects register 5 to be retitled.

*[COPY FROM FILE TITLE]* (COPYFRFT) renames the internal registers to match the current names of the store files. For example, the default names of the internal registers are REG1 through REG5. The default names of the store files are FILE1 through FILE5. Pressing this key would rename the internal registers FILE1 through FILE5. If you have modified the names of the store files, the modified names would be copied to the internal save register names.

*[RETURN]* goes back to the save menu.

## Title Menu

Use this menu (Figure 10-5) to define a title for the register selected in the title register menu. The title replaces the default register title in the softkey label, and is recalled with the saved instrument state.

This is similar to the menu used to set the display title (described in Chapter 4), except that certain restrictions apply. The register title is limited to eight characters. If more than eight characters are selected, the last character is repeatedly written over. The title must be all alpha-numeric, and must start with an alpha character. If the first character selected is not an alpha character, the message "CAUTION: FIRST CHARACTER MUST BE A LETTER" is displayed when the ***[DONE]*** key is pressed. No special characters or spaces are allowed. If a disallowed character is selected, the message "CAUTION: ONLY LETTERS & NUMBERS ARE ALLOWED" is displayed. (The special characters are used only for the display title.)

The save register title is independent of the display title, which is also saved and recalled as part of the display.

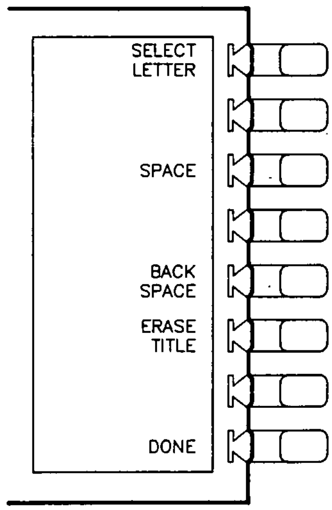



*Figure 10-5. Title Menu*

***[SELECT LETTER]***. The active entry area displays the letters of the alphabet, digits 0 through 9, and mathematical symbols. The mathematical symbols are not used in register titles. To define a title, rotate the knob until the arrow ↑ points at the first letter, then press ***[SELECT LETTER]***. Repeat this until the complete title is defined, for a maximum of eight characters. As each character is selected, it is appended to the title at the top left corner of the graticule.

***[SPACE]***. Do not use this softkey in defining a register title.

***[BACK SPACE]*** deletes the last character entered.

***[ERASE TITLE]*** deletes the entire register title.

***[DONE]*** terminates the title entry, and returns to the title register menu. The new title appears in the softkey label in all applicable menus.

## Store File Menu

This menu (Figure 10-6) is used to store instrument states to an external disk rather than to internal memory registers. The analyzer can use HP-IB to store directly to a compatible external disk drive, without the use of an external controller. Refer to the *General Information* section of this manual for information about compatible disk drives. Refer to the first part of this chapter for information about disk storage.

To store information on an external disk from the front panel when there is no other controller on the bus, the analyzer must be in system controller HP-IB mode. To take control from the computer and initiate a store operation, the analyzer must be in pass control mode. If it is not in one of these modes, the message "CHANGE HP-IB to SYS CTRL or PASS CTRL" is displayed. Refer to *[LOCAL] Key* in Chapter 7 for information on HP-IB controller modes and setting addresses.

If you attempt to store a file and the message "CAUTION: DISK: not on, not connected, wrong addrs" is displayed, check the disk drive line power and HP-IB cable connection. Also make sure that the HP-IB address of the disk drive matches the address set in the address menu (see Chapter 7).

The analyzer uses one file name per instrument state for communicating with the user via the front panel display. In reality, several files can actually be stored to the disk when an instrument state is saved, depending on the functions being saved. This does not affect operation from the front panel. The default names for the stored files are FILE1 through FILE5. These file names can be modified using the title file menu.

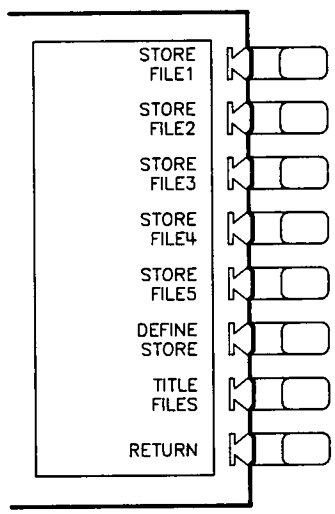



*Figure 10-6. Store File Menu*

***[STORE FILE1]*** (STOR1) stores the current instrument state in external file 1, together with any data specified in the define store menu (see next page).

***[STORE FILE2]*** (STOR2) stores the current instrument state and specified data in file 2.

***[STORE FILE3]*** (STOR3) stores the current instrument state and specified data in file 3.

***[STORE FILE4]*** (STOR4) stores the current instrument state and specified data in file 4.

***[STORE FILE5]*** (STOR5) stores the current instrument state and specified data in file 5.

*[DEFINE STORE]* leads to the define store menu. Use this menu to specify what data is to be stored on disk in addition to the instrument state.

*[TITLE FILES]* leads to the title file menu, where the default file titles can be modified.

*[RETURN]* goes back to the save menu.

## Define Store Menu

Data and user graphics can be stored on disk along with the basic instrument state. The data can be stored from different points in the data processing flow. It is possible to store raw, error-corrected, or formatted data, or any combination of the three. This menu allows the option of specifying what data is to be stored. Refer to *Data Processing Flow* in Chapter 1 for more information about data arrays and the sequence of data processing events.

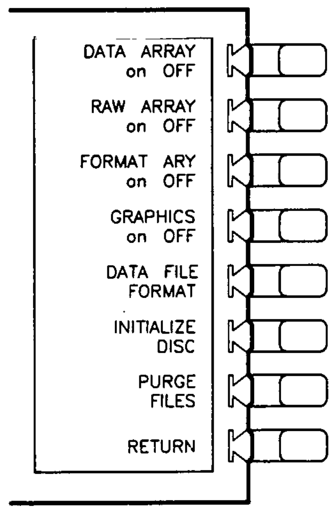



*Figure 10-7. Define Store Menu*

*[DATA ARRAY on OFF]* (EXTMDATAON, EXTMDATAOFF) specifies whether or not to store the error-corrected data on disk with the instrument state.

*[RAW ARRAY on OFF]* (EXTMRAWON, EXTMRAWOFF) specifies whether or not to store the raw data (ratioed and averaged) on disk with the instrument state.

*[FORMAT ARY on OFF]* (EXTMFORMON, EXTMFORMOFF) specifies whether or not to store the formatted data on disk with the instrument state.

*[GRAPHICS on OFF]* (EXTMGRAPON, EXTMGRAPOFF) specifies whether or not to store display graphics on disk with the instrument state.

*[DATA FILE FORMAT]* leads to the data file format menu.

*[INITIALIZE DISK]* (INID) leads to the initialize menu. Before data can be stored on a disk, the disk must be initialized for format compatibility. If you attempt to store without initializing the disk, the message "CAUTION: DISK MEDIUM NOT INITIALIZED" is displayed.

*[PURGE FILES]* leads to the purge files menu, which is used to purge the information stored on an external disk.

*[RETURN]* goes back to the store file menu.

## Data File Format Menu

Use this menu to select one of two *data* file formats for disk storage. The data file format refers to how the data is encoded (formatted). The advantages of each is explained below. Remember that data may be stored selectively as previously explained in "Define Store Menu".

The learn string, calibration kit, and user graphics display data are always stored in binary format because it is useful only to the network analyzer. They should not be modified with an external computer.

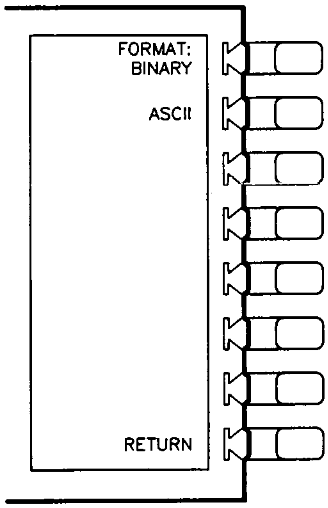



*Figure 10-8. Data File Format Menu*

**[FORMAT:BINARY]** (SAVUBINA) selects binary data format, the faster, more compact data storage format. When selected, this data is formated in binary:

- Data arrays (corrected)
- Raw data arrays
- Formatted array
- Display memory array
- Calibration sets

**[ASCII]** (SAVUASCI) selects an ASCII data format known as CITIFile (common instrumentation transfer and interchange file). This ASCII data format is useful when data will be exchanged with a compatible computer (see next page) to run, for instance, the HP 85150A/B Microwave Design System. See "Equipment Available" in the "General Information" section for additional software information.

When selected, the following data is formated in CITIFile ASCII. Each array is stored separately.

- Data arrays (corrected)
- Raw data arrays
- Formatted array
- Display memory array
- Calibration sets

**[RETURN]** goes back to the define store menu.

## Initialize Menu

Initializing a disk erases all existing data and prepares it to store data. The preparation places a specific arrangement (format) of tracks and sectors on the disk. The disk format used by the analyzer is LIF (logical interchange format).

- LIF is compatible with HP series 9000 model 200/300 computers.
- LIF is compatible with the HP Vectra Personal computer with HP82300 HP BASIC language processor.
- LIF is not compatible with most PCs. The analyzer will not read from or write to disks formated by PCs.

For information on transferring the contents of a disk from a LIF disk to a PC-compatible disk, contact your local HP Sales and Service Office.

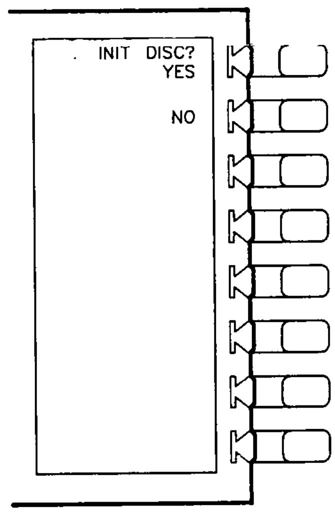



*Figure 10-9. Initialize Menu*

***[INIT DISK? YES]*** initializes the disk unit number and volume number selected in the HP-IB menu (see Chapter 7), then returns to the define store menu. If more than one volume is to be initialized, each volume must be selected and initialized individually.

If the disk is damaged, the message "INITIALIZATION FAILED" is displayed. During the initialization process, the message "WAITING FOR DISK" is displayed. This is normal.

***[NO]*** leaves this menu without initializing the disk, and returns to the define store menu.

## Purge File Menu

This menu is used to remove (purge) instrument states from a disk. When the purge file menu is entered, the file titles currently in memory are displayed. (File titles are stored in non-volatile memory.) These titles may or may not reside on the disk currently being used. The file titles can be updated to match the files on disk by reading the disk's directory with the ***[READ FILE TITLES]*** key.

The purge file menu is the disk equivalent of the clear register menu.

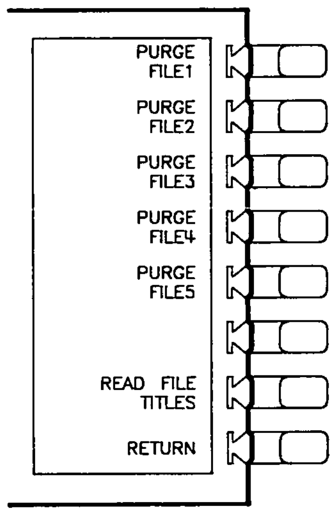



*Figure 10-10. Purge File Menu*

***[PURGE FILE1]*** (PURG1) purges FILE1 from disk. If no file of that name exists on the disk, the message "CAUTION: NO FILE(S) FOUND ON DISK" will appear.

***[PURGE FILE2]*** (PURG2) purges FILE2 from disk.

***[PURGE FILE3]*** (PURG3) purges FILE3 from disk.

***[PURGE FILE4]*** (PURG4) purges FILE4 from disk.

***[PURGE FILE5]*** (PURG5) purges FILE5 from disk.

***[READ FILE TITLES]*** (REFT) searches the directory of the disk for file names recognized as belonging to an instrument state. No more than five titles are displayed at one time. If there are more than five, repeatedly pressing this key causes the next five to be displayed. If there are fewer than five, the remaining softkey labels are blanked.

***[RETURN]*** goes back to the define store menu.

## Title File Menu

This menu is used to select a disk file to be retitled. When the softkey for the selected file is pressed, the title menu is presented and the character set is displayed in the active entry area. The title menu is described earlier in this chapter. The same restrictions apply to file titles as to internal register titles: that is, a file title is limited to eight characters, must be all alpha-numeric, and must begin with an alpha character.

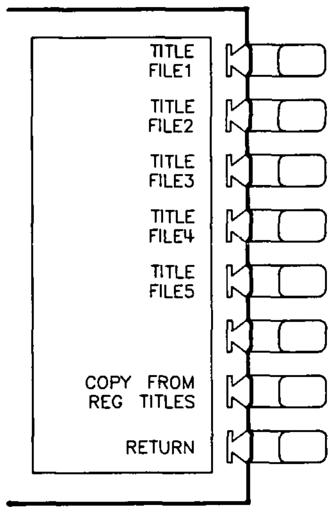



*Figure 10-11. Title File Menu*

***[TITLE FILE1]*** (TITF1) selects file 1 to be retitled, and leads to the title menu.

***[TITLE FILE2]*** (TITF2) selects file 2 to be retitled.

***[TITLE FILE3]*** (TITF3) selects file 3 to be retitled.

***[TITLE FILE4]*** (TITF4) selects file 4 to be retitled.

***[TITLE FILE5]*** (TITF5) selects file 5 to be retitled.

***[COPY FROM REG TITLES]*** renames the store files to match the current names of the internal registers. (It does not alter the names of any files already stored to disk). For example, the default names of the internal registers are REG1 through REG5. The default file names of the store files are FILE1 through FILE5. Pressing this key would rename the store files REG1 through REG5. If you have modified the names of the internal save registers, the modified names would be copied to the store file names.

***[RETURN]*** goes back to the store file menu.

## Recall Menu

This menu is used to recall instrument states from internal memory. It is also used to access the load file menu, which loads files from external disk.

When the recall menu is displayed, only the names of registers containing instrument states are displayed in the top five softkey labels. Any register that does not currently contain a saved instrument state has its softkey label blanked.

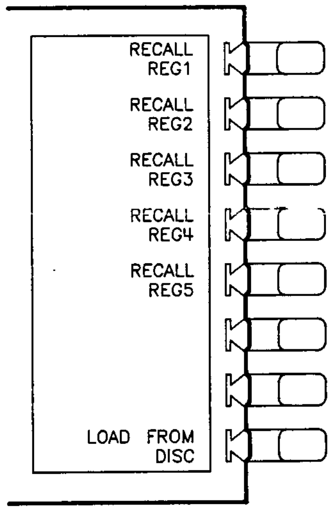



*Figure 10-12. Recall Menu*

***[RECALL REG1]*** (RECA1) recalls the instrument state saved in register 1. The current instrument state is overwritten.

***[RECALL REG2]*** (RECA2) recalls the instrument state saved in register 2.

***[RECALL REG3]*** (RECA3) recalls the instrument state saved in register 3.

***[RECALL REG4]*** (RECA4) recalls the instrument state saved in register 4.

***[RECALL REG5]*** (RECA5) recalls the instrument state saved in register 5.

***[LOAD FROM DISK]*** accesses the load file menu. Use this menu to restore instrument states previously stored to disk.

## Load File Menu

This menu (Figure 10-13) is used to search the directory of a floppy disk and to restore instrument states previously stored to that disk.

There are three ways to locate a file on disk.

1. The analyzer remembers the names of the last five files it previously found on any disk. (File titles are stored in non-volatile memory.) Therefore, when you enter this menu, the file titles in memory will appear in the top five softkeys, whether or not they reside on the disk currently in the drive.

2. The ***[READ FILE TITLES]*** key causes the analyzer to search the directory of the current disk and display any recognized file titles.

3. From the store file menu, use the ***[TITLE FILES]*** key to title a store file softkey with the name of the file you want to restore. Return to the load file menu. The title you just created will appear in one of the load file softkey labels. Press that softkey. If the file does not exist, the message "CAUTION: NO FILE(S) FOUND ON DISK" will be displayed. This method is useful only if you know the exact name of the instrument state to be restored. Using ***[READ FILE TITLES]*** is a more efficient method of finding file names, unless a large number of instrument states have been stored to the disk.

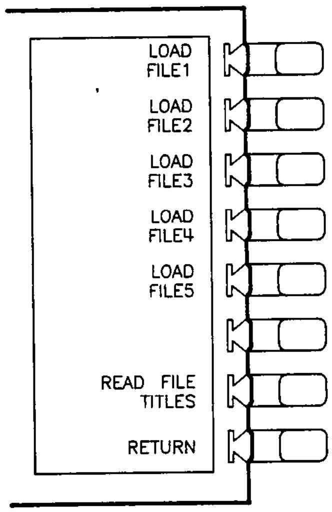



*Figure 10-13. Load File Menu*

***[LOAD FILE1]*** (LOAD1) restores the instrument state contained in FILE1. The current instrument state is overwritten.

***[LOAD FILE2]*** (LOAD2) restores the instrument state contained in FILE2.

***[LOAD FILE3]*** (LOAD3) restores the instrument state contained in FILE3.

***[LOAD FILE4]*** (LOAD4) restores the instrument state contained in FILE4.

***[LOAD FILE5]*** (LOAD5) restores the instrument state contained in FILE5.

***[READ FILE TITLES]*** (REFT) searches the directory of the disk for file names recognized as belonging to an instrument state. No more than five titles are displayed at one time. If there are more than five, repeatedly pressing this key causes the next five to be displayed. If there are fewer than five, the remaining softkey labels are blanked.

***[RETURN]*** goes back to the recall menu.

# Chapter 11. HP-IB Remote Programming

## INTRODUCTION

The analyzer is factory-equipped with a remote programming digital interface using the Hewlett-Packard Interface Bus (HP-IB). (HP-IB is Hewlett-Packard's hardware, software, documentation, and support for IEEE 488.1 and IEC-625, worldwide standards for interfacing instruments.) This allows the analyzer to be controlled by an external computer that sends commands or instructions to and receives data from the analyzer using the HP-IB. In this way, a remote operator has the same control of the instrument available to a local operator from the front panel, except for control of the line power switch.

In addition, the analyzer itself can use HP-IB to directly control compatible peripherals, without the use of an external controller. It can output measurement results directly to a compatible printer or plotter, or store instrument states to a compatible disc drive.

This chapter provides an overview of HP-IB operation. Chapter 7 provides information on different controller modes, and on setting up the analyzer as a controller of peripherals. Chapters 9 and 10 explain how to use the analyzer as a controller to print, plot, and store to an external disc. In addition, HP-IB equivalent mnemonics for front panel functions are provided in parentheses throughout this *Reference*.

More complete information on programming the analyzer remotely over HP-IB is provided in the following documents:

- *HB-IB Programming Guide for the HP 8719A HP 8720B Using Series 200/300 Computers*. This is a tutorial introduction to remote operation of the network analyzer using an HP 9000 series 200 or 300 computer. It includes examples of remote measurements using BASIC programming. These examples are also stored on the supplied example programs disc. The *HB-IB Programming Guide* assumes familiarity with front panel operation of the instrument.
- *HP 8719A HP 8720B Quick Reference*. This is a complete reference summary for remote operation of the analyzer with a controller. It includes both functional and alphabetical lists of all HP-IB commands. This guide is intended for use by those familiar with HP-IB programming and the basic functions of the analyzer.

A complete general description of the HP-IB is available in *Tutorial Description of the Hewlett-Packard Interface Bus*, HP publication 5952-0156. For more information on the IEEE-488.1 standard refer to *IEEE Standard Digital Interface for Programmable Instrumentation*, published by the Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, New York 10017.

## HOW HP-IB WORKS

The HP-IB uses a party-line bus structure in which up to 15 devices can be connected on one contiguous bus. The interface consists of 16 signal lines and 8 ground lines in a shielded cable. With this cabling system, many different types of devices including instruments, computers, plotters, printers, and disc drives can be connected in parallel.

Every HP-IB device must be capable of performing one or more of the following interface functions:

### Talker

A talker is a device capable of sending device-dependent data when addressed to talk. There can be only one talker at any given time. Examples of this type of device are voltmeters, counters, and tape readers. The analyzer is a talker when it sends trace data or marker information over the bus.

### Listener

A listener is a device capable of receiving device-dependent data when addressed to listen. There can be any number of listeners at any given time. Examples of this type of device are printers, power supplies, and signal generators. The analyzer is a listener when it is controlled over the bus by a computer.

### Controller

A controller is a device capable of managing the operation of the bus and addressing talkers and listeners. There can be only one active controller at any time. Examples of controllers include desktop computers and minicomputers. In a multiple-controller system, active control can be passed between controllers, but there can only be one *system controller*, which acts as the master, and can regain active control at any time. The analyzer is an active controller when it plots, prints, or stores to an external disc drive in the pass control mode. The analyzer is a system controller when it is in the system controller mode. These modes are discussed in more detail in Chapter 7 under *HP-IB Menu*.

## HP-IB BUS STRUCTURE

### Data Bus

The data bus consists of eight bidirectional lines that are used to transfer data from one device to another. Programming commands and data are typically encoded on these lines in ASCII, although binary encoding is often used to speed up the transfer of large arrays. Both ASCII and binary data formats are available. In addition, every byte transferred over HP-IB undergoes a *handshake* to ensure valid data.

### Handshake Lines

A three-line handshake scheme coordinates the transfer of data between talkers and listeners. This technique forces data transfers to occur at the speed of the slowest device, and ensures data integrity in multiple listener transfers. With most computing controllers and instruments, the handshake is performed automatically, which makes it transparent to the programmer.

## Control Lines

The data bus also has five control lines that the controller uses both to send bus commands and to address devices.

**IFC.** Interface Clear. Only the system controller uses this line. When this line is true (low), all devices (addressed or not) unaddress and go to an idle state.

**ATN.** Attention. The active controller uses this line to define whether the information on the data bus is a *command* or is *data*. When this line is true (low), the bus is in the command mode and the data lines carry bus commands. When this line is false (high), the bus is in the data mode and the data lines carry device-dependent instructions or data.

**SRQ.** Service Request. This line is set true (low) when a device requests service: the active controller services the requesting device. The analyzer can be enabled to pull the SRQ line for a variety of reasons.

**REN.** Remote Enable. Only the system controller uses this line. When this line is set true (low), the bus is in the remote mode, and devices are addressed either to listen or to talk. When the bus is in remote and a device is addressed, it receives instructions from HP-IB rather than from its front panel (the **[LOCAL]** key returns the device to front panel operation). When this line is set false (high), the bus and all devices return to local operation.

**EOI.** End or Identify. This line is used by a talker to indicate the last data byte in a multiple byte transmission, or by an active controller to initiate a parallel poll sequence. The analyzer recognizes the EOI line as a terminator, and it pulls the EOI line with the last byte of a message output (data, markers, plots, prints, error messages). The analyzer does not respond to parallel poll.

Figure 11-1 illustrates the structure of the HP-IB bus lines.

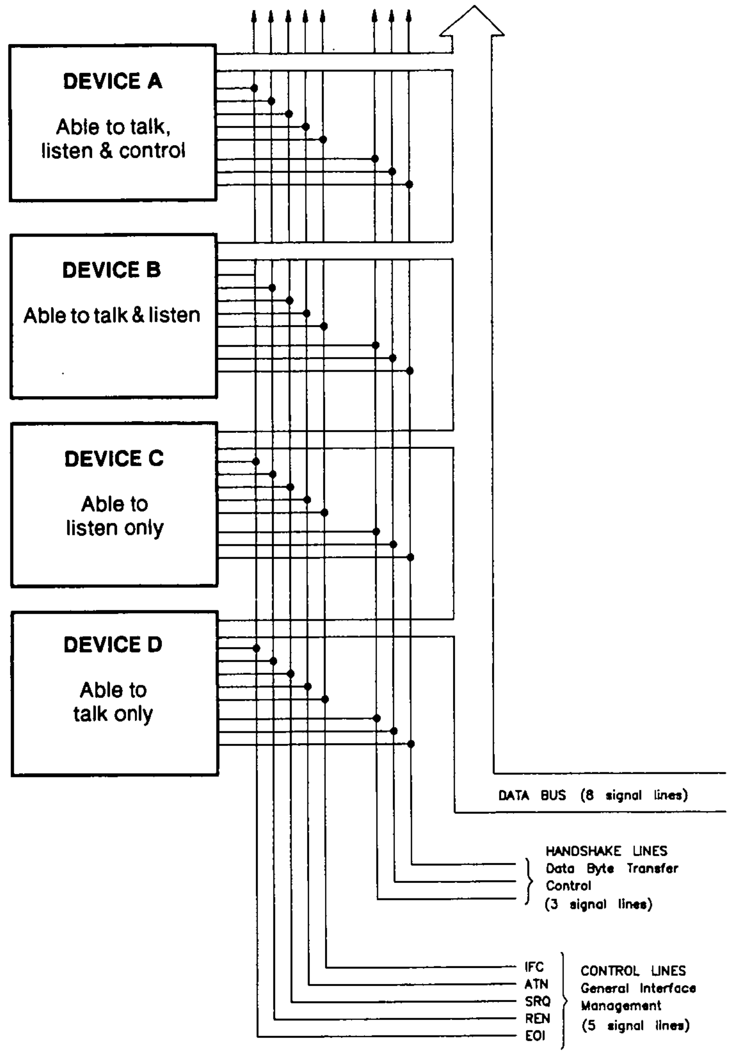



*Figure 11-1. HP-IB Structure*

## HP-IB REQUIREMENTS

**Number of Interconnected Devices:** 15 maximum.

**Interconnection Path/ Maximum Cable Length:** 20 metres maximum or 2 metres per device, whichever is less.

**Message Transfer Scheme:** Byte serial/ bit parallel asynchronous data transfer using a 3-line handshake system.

**Data Rate:** Maximum of 1 megabyte per second over limited distances with tri-state drivers. Actual data rate depends on the transfer rate of the slowest device involved.

**Address Capability:** Primary addresses: 31 talk, 31 listen. A maximum of 1 talker and 14 listeners at one time.

**Multiple Controller Capability:** In systems with more than one controller (like the network analyzer system), only one can be active at a time. The active controller can pass control to another controller, but only the system controller can assume unconditional control. Only one system controller is allowed. The system controller is hard-wired to assume bus control after a power failure.

## HP-IB CAPABILITIES OF THE ANALYZER

As defined by the IEEE 488.1 standard, the analyzer has the following capabilities:

| | |
|---|---|
| **SH1** | Full source handshake. |
| **AH1** | Full acceptor handshake. |
| **T6** | Basiç talker, answers serial poll, unaddresses if MLA is issued. No talk-only mode. |
| **L4** | Basic listener, unaddresses if MTA is issued. No listen-only mode. |
| **SR1** | Complete service request (SRQ) capabilities. |
| **RL1** | Complete remote/local capability including local lockout. |
| **PP0** | Does not respond to parallel poll. |
| **DC1** | Complete device clear. |
| **DT1** | Responds to a group execute trigger in the hold trigger mode. |
| **C1,C2,C3** | System controller capabilities in system controller mode. |
| **C10** | Pass control capabilities in pass control mode. |
| **E2** | Tri-state drivers. |

## BUS MODE

The analyzer uses a single-bus architecture. The single bus allows both the analyzer and the host controller to have complete access to the peripherals in the system.

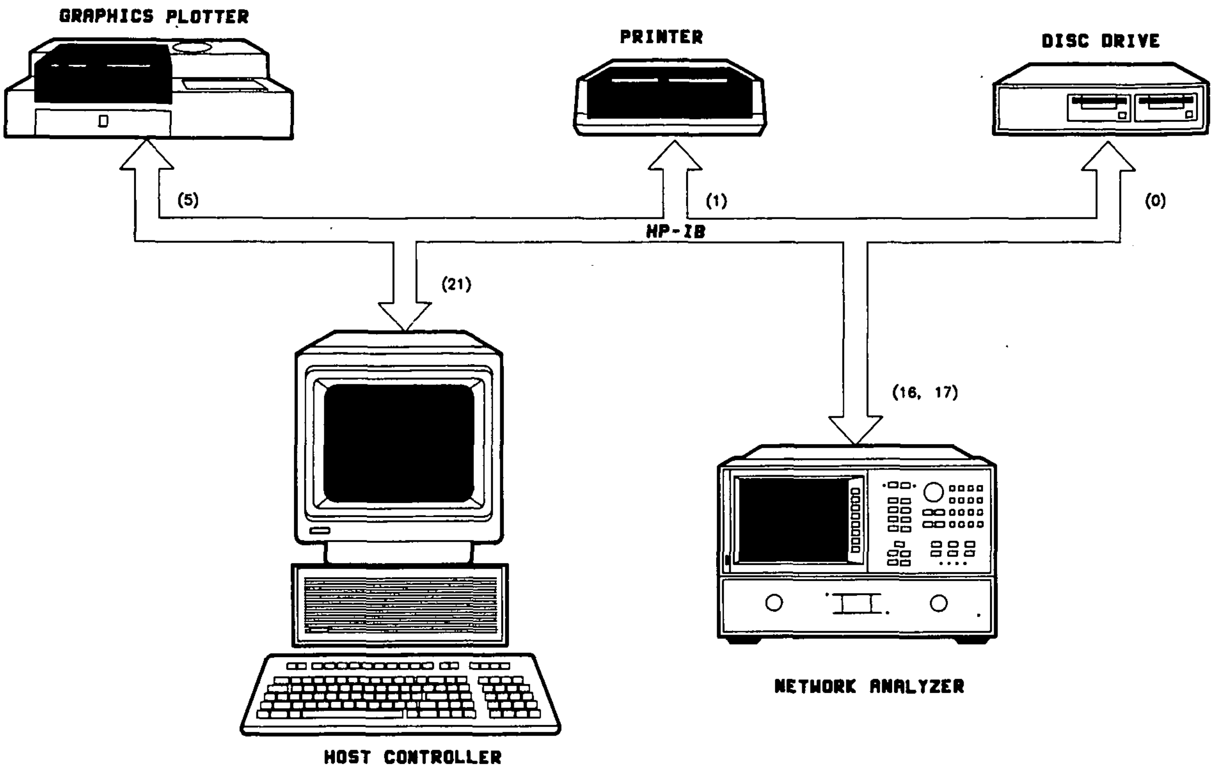



*Figure 11-2. analyzer Single Bus Concept*

Three different controller modes are possible, system controller, talker/listener, and pass control.

**System Controller.** This mode allows the analyzer to control peripherals directly in a stand-alone environment (without an external controller). This mode can only be selected manually from the network analyzer front panel. Use this mode for operation when no computer is connected to the analyzer. Do not use this mode for programming.

**Talker/Listener.** This is the traditional programming mode, in which the computer is involved in all peripheral access operations. Peripheral access (plotting and printing only) is also possible by addressing the analyzer to talk, addressing the peripheral to listen, and placing the HP-IB in the data mode.

**Pass Control.** This mode allows you to control the analyzer over HP-IB as with the talker/listener mode, and also allows the analyzer to take or pass control in order to plot, print, and access a disc. During the peripheral operation, the host computer is free to perform other internal tasks such as data or display manipulation (the bus is tied up by the analyzer during this time). After a task is completed, the host controller accepts control again when the analyzer returns it.

In general, use the talker/listener mode for programming the analyzer unless you desire direct peripheral access. Preset does not affect the selected bus mode, but the bus mode returns to talker/listener if power is cycled.

Chapter 7 explains the three different bus modes in detail, and provides information on setting the correct bus mode. Programming information for talker/listener mode and pass control mode is provided in the *HP-IB Programming Guide*.

## SETTING ADDRESSES

In communications through HP-IB, each instrument on the bus is identified by an HP-IB address. This address code must be different for each instrument on the bus. Refer to *Address Menu* in Chapter 7 for information on default addresses, and on setting and changing addresses. These addresses are stored in short-term non-volatile memory and are not affected when you press **[PRESET]** or cycle the power (although the **[PRESET]** key must be pressed to implement a change to the analyzer address).

## VALID CHARACTERS

The analyzer accepts ASCII letters, numbers, decimal points, +/−, semicolons, quotation marks ("), carriage returns (CR), and linefeeds (LF). Both upper and lower case are acceptable. Leading zeros, spaces, carriage returns, and unnecessary terminators are ignored, except those within a command or appendage. Carriage returns are ignored. An invalid character causes a syntax error. Syntax errors are described in more detail under in the *HP-IB Programming Guide*.

## HP-IB CODE NAMING CONVENTION

The HP-IB commands are derived from their front panel key titles (where possible), according to the naming convention below.

| Convention | Key Title | For HP-IB Code Use | Example |
|---|---|---|---|
| One Word | Power<br>Start | First Four Letters | POWE<br>STAR |
| Two Words | Electrical Delay<br>Search Right | First Three Letters of First Word<br>First Letter of Second Word | ELED<br>SEAR |
| Two Words in a Group | Marker →Center<br>Gate →Span | First Four Letters of Both | MARKCENT<br>GATESPAN |
| Three Words | Cal Kit N 50Ω<br>Pen Num Data | First Three Letters of First Word<br>First Letter of Second Word<br>First Four Letters of Third Word | CALKN50<br>PENNDATA |

Some codes require appendages (on, off, 1, 2, etc.). Codes that have no front panel equivalent are HP-IB only commands, and use a similar convention based on the common name of the function. Where possible, these codes are compatible with HP 8510 codes.

Front panel equivalent codes and HP-IB only codes are summarized in the *HP-IB Quick Reference*.

## UNITS AND TERMINATORS

The analyzer outputs data in basic units and assumes these basic units when it receives an input, unless the input is otherwise qualified. The basic units and allowable expressions follow; either upper or lower case is acceptable.

| Basic Units | Allowable Expressions |
|---|---|
| Seconds | S |
| Milliseconds | MS |
| Microseconds | US |
| Nanoseconds | NS |
| Picoseconds | PS |
| Femtoseconds | FS |
| Hertz | HZ |
| Kilohertz | KHZ |
| Megahertz | MHZ |
| Gigahertz | GHZ |
| dB or dBm | DB |
| Volts | V |

Terminators are used to indicate the end of a command to allow the analyzer to recover to the next command in the event of a syntax error. The semicolon is the recommended command terminator. The line feed (LF) character and the HP-IB EOI line can also be used as terminators. The analyzer ignores the carriage return (CR) character.

## HP-IB DEBUG MODE

An HP-IB diagnostic feature (debug mode) is available in the HP-IB menu. Activating the debug mode causes the analyzer to scroll incoming HP-IB commands across the display. Nonprintable characters are represented with a $\pi$. Any time the analyzer receives a syntax error, the commands halt, and a pointer $\wedge$ indicates the misunderstood character. The *HP-IB Programming Guide* explains how to clear a syntax error.

## CRT GRAPHICS

The CRT can be used as a graphics display for displaying connection diagrams or custom instructions to an operator. The CRT accepts a subset of Hewlett-Packard Graphics Language (HP-GL) commands.

**NOTE:** The CRT occupies an additional address on the HP-IB. Determine the CRT bus address by adding 1 to the analyzer address if it is an even number, or subtracting 1 if it is an odd number. Thus the factory default CRT address for graphics is 17.

## INTRODUCTION

This chapter lists the error messages that may be displayed on the CRT or transmitted by the instrument over HP-IB. Each error message is accompanied by an explanation, and suggestions are provided to help in solving the problem. Where applicable, references are given to related sections of the operating and service manuals.

When displayed, all error messages are preceded with the word CAUTION:. That part of the error message has been omitted here for the sake of brevity. Two listings are provided: the first is in alphabetical order, and the second in numerical order.

## ERROR MESSAGES IN ALPHABETICAL ORDER

(Error numbers are provided in parentheses.)

**ADDITIONAL STANDARDS NEEDED** (error #68). Error correction for the selected calibration class cannot be computed without measuring the necessary standards.

**ADDRESSED TO TALK WITH NOTHING TO SAY** (error #31). An enter command was sent to the analyzer without first requesting data with an appropriate output command (such as OUTPDATA). The analyzer has no data in the output queue to satisfy the request.

**AIR FLOW RESTRICTED: CHECK FAN FILTER** (error #20). An inadequate air flow condition has been detected. Clean the fan filter. For most efficient cooling, the instrument covers should be in place. If the problem persists, troubleshoot the power supply.

**ANALOG INPUT OVERLOAD** (error #60). The maximum input voltage level to the rear panel AUX INPUT has been exceeded.

**AVERAGING INVALID ON NON-RATIO MEASURE** (error #13). This error occurs only in single-input measurements using an auxiliary input signal or a service input. Sweep-to-sweep averaging is valid only for ratioed (S-parameter) measurements. Other noise reduction techniques are available for single input measurements. Refer to *[AVG] Key* in Chapter 4 for a discussion of trace smoothing and variable IF bandwidths.

**BLOCK INPUT ERROR** (error #34). The analyzer did not receive a complete data transmission. This is usually caused by an interruption of the bus transaction. Clear by pressing the **[LOCAL]** key or aborting the IO process at the controller.

**BLOCK INPUT LENGTH ERROR** (error #35). The length of the header received by the analyzer did not agree with the size of the internal array block. Refer to the *HP-IB Programming Guide* for instructions on using input commands.

**CALIBRATION ABORTED** (error #74). The calibration in progress was terminated due to change of the active channel.

**CALIBRATION REQUIRED** (error #63). A calibration set could not be found that matched the current stimulus state or measurement parameter. Refer to Chapter 5, *Measurement Calibration.* Calibration sets can be saved in internal or external memory. Refer to *[SAVE] Key* in Chapter 10.

**CAN'T CHANGE-ANOTHER CONTROLLER ON BUS** (error #37). The analyzer cannot assume the mode of system controller until the active controller is removed from the bus or relinquishes the bus.

**CHANGE HP-IB to SYST CTRL or PASS CTRL** (error #36). The analyzer cannot control a peripheral device on the bus while it is in talker/listener mode. Refer to *[LOCAL] Key* in Chapter 7.

**CONTINUOUS SWITCHING NOT ALLOWED** (error #10). The current measurement requires switching between forward and reverse measurements (driving test port 1, then test port 2). To guard against undue mechanical wear in the RF switch, continuous switching is not allowed. The "tsH" indicator in the left margin of the display indicates that the inactive channel has been put in the sweep hold mode.

**CORRECTION TURNED OFF** (error #66). Critical parameters in the current instrument state do not match the parameters for the calibration set, therefore correction has been turned off. The critical instrument state parameters are sweep type, start frequency, frequency span, and number of points.

**CORR OFF; FREQ INCOMPATIBLE INST STATE** (error #76). An instrument state, with correction on, has been loaded into a standard instrument from a disk that had been stored previously by an option 001 instrument. The option 001 frequencies used when the correction was stored are not compatible nor settable on the standard instrument, therefore correction has been turned off.

**CURRENT PARAMETER NOT IN CAL SET** (error #64). Correction is not valid for the selected measurement parameter. Refer to Chapter 5, *Measurement Calibration*.

**DEMODULATION NOT VALID** (error #17). Demodulation is only valid for the CW time mode. Refer to Chapter 8, *Time and Frequency Domain Transforms*.

**DISK HARDWARE PROBLEM** (error #39). The disk drive is not responding correctly. Refer to the disk drive operating manual.

**DISK IS WRITE PROTECTED** (error #48). The store operation cannot write to a write-protected disk. Slide the write-protect tab over the write-protect opening in order to write data on the disk.

**DISK MEDIUM NOT INITIALIZED** (error #40). The disk must be initialized before it can be used. Refer to *Initialize Menu* in Chapter 10.

**DISK: not on, not connected, wrong addrs** (error #38). The disk cannot be accessed by the analyzer. Verify power to the disk drive, and check the HP-IB connection between the analyzer and the disk drive. Ensure that the disk drive address recognized by the network analyzer matches the HP-IB address set on the disk drive itself. Refer to *[LOCAL] Key* in Chapter 7 for instructions on setting peripheral addresses.

**DISK WEAR—REPLACE DISK SOON** (error #49). Cumulative use of the disk is approaching the maximum. Copy files as necessary using an external controller. If no controller is available, load instrument states from the old disk and store them to a newly initialized disk using the save/recall features of the analyzer. Refer to Chapter 10, *Saving Instrument States*, for information. Discard the old disk.

**EXCEEDED 7 STANDARDS PER CLASS** (error #72). A maximum of seven standards can be defined for any class. Refer to *Modifying Calibration Kits* in Chapter 5.

**FIRST CHARACTER MUST BE A LETTER** (error #42). The first character of a disk file title or an internal save register title must be an alpha character.

**FORMAT NOT VALID FOR MEASUREMENT** (error #75). A conversion to Y or Z parameters has been selected, and the format selected is Smith chart or SWR. In these formats, the conversion trace value is not consistent with the graphical display.

**FUNCTION NOT VALID** (error #14). The requested function is incompatible with the current instrument state.

**ILLEGAL UNIT OR VOLUME NUMBER** (error #46). The disk unit or volume number set in the analyzer is not valid. Refer to *HP-IB Menu* in Chapter 7 and to the disk drive operating manual.

**INIT DISK removes all data from disk** (not a CAUTION message). Continuing with the initialize operation will DESTROY any data currently on the disk.

**INITIALIZATION FAILED** (error #47). Disk initialization failed, usually due to a damaged disk.

**INSTRUMENT STATE MEMORY CLEARED** (error #56). The five instrument state registers have been cleared from memory along with any calibration data or calibration kit definitions.

**INSUFFICIENT MEMORY** (error #51). The last front panel or HP-IB request could not be implemented due to insufficient memory space. In some cases, this is a fatal error which can only be escaped by presetting the instrument. See Chapter 10 for information on memory allocation.

**INVALID KEY** (error #2). An undefined softkey was pressed.

**LIST TABLE EMPTY** (error #9). The frequency list is empty. To implement list frequency mode, add segments to the list table. Refer to *Edit List Menu* in Chapter 3.

**LOW PASS: FREQ LIMITS CHANGED** (not a CAUTION message). The frequency domain data points must be harmonically related from DC to the stop frequency. If this condition is not true when ***[SET FREQ LOW PASS]*** is selected, the end points of the frequency range are modified as necessary.

**LOW PASS MODE NOT ALLOWED** (error #18). Low pass time domain mode is allowed only with 201 points or less.

**MORE SLIDES NEEDED** (error #71). At least five positions of the sliding load are required to complete the calibration.

**NO CALIBRATION CURRENTLY IN PROGRESS** (error #69). The ***[RESUME CAL SEQUENCE]*** softkey is not valid unless a calibration was previously in progress. Start a new calibration. Refer to *Correction Menu* in Chapter 5.

**NO DISK MEDIUM IN DRIVE** (error #41). No disk was found in the current disk unit. Insert a disk, or check the disk unit number stored in the analyzer. Refer to *HP-IB Menu* in Chapter 7.

**NO FAIL FOUND** (service error). The self-diagnose function of the instrument operates on an internal test failure. At this time, no failure has been detected. Refer to *Internal Tests* in the *Service Key Menus* section of the *Service Manual*.

**NO FILE(S) FOUND ON DISK** (error #45). No files of the type created by an analyzer store operation were found on the disk.

**NO LIMIT LINES DISPLAYED** (not a CAUTION message). Limit lines are turned on but cannot be displayed on polar or Smith chart display formats.

**NO MARKER DELTA —SPAN NOT SET** (error #15). The ***[MARKER →SPAN]*** softkey function requires that delta marker mode be turned on, with at least two markers displayed. Refer to Chapter 6, *Using Markers*.

**NO SPACE FOR NEW CAL. CLEAR REGISTERS** (error #70). Insufficient memory is available to store a calibration set. Memory can be freed by clearing a saved instrument state, which will result in the deletion of a saved calibration set. The saved instrument state and calibration set can be stored to an external disk before being cleared from the internal register. Refer to Chapter 10 for information on the allocation of memory.

**NO VALID MEMORY TRACE** (error #54). In order to display or otherwise use the memory trace, a data trace must first be stored to memory. Refer to *Display Menu* in Chapter 4.

**NO VALID STATE IN REGISTER** (error #55). A request to load an instrument state from an internal register was received over HP-IB, and that register is empty.

**NOT ENOUGH SPACE ON DISK FOR STORE** (error #44). The store operation will overflow the available disk space. Insert a new disk or purge files appearing last in the directory to create free disk space.

**ONLY LETTERS AND NUMBERS ARE ALLOWED** (error #43). Only alpha-numeric characters are allowed in disk file titles or internal save register titles. Other symbols are not allowed.

**OPTIONAL FUNCTION; NOT INSTALLED** (error #1). The function you requested requires a capability provided by an option to the standard analyzer. That option is not currently installed. (Options are 001, enhanced frequency resolution, and 010, time domain transform.)

**PHASE LOCK CAL FAILED** (error #4). An internal phase lock calibration routine is automatically executed at power-on and preset any time loss of phase lock is detected. This message indicates that phase lock calibration was initiated and the first IF detected, but a problem prevented the calibration from completing successfully. Refer to the *Troubleshooting* section of the *Service Manual*.

**PHASE LOCK FAILURE**. Source phase lock failed. Refer to the *Troubleshooting* section in the *Service Manual*.

**PLOT ABORTED** (error #27). Depressing any front panel key causes the analyzer to abort the plot in progress.

**PLOTTER: not on, not connected, wrong addrs** (error #26). The plotter does not respond to control. Verify power to the plotter, and check the HP-IB connection between the analyzer and the plotter. Ensure that the plotter address recognized by the network analyzer matches the HP-IB address set on the plotter itself. Refer to *[LOCAL] Key* in Chapter 7 for instructions on setting peripheral addresses.

**PLOTTER NOT READY-PINCH WHEELS UP** (error #28). The plotter pinch wheels are responsible for clamping the paper in place. When the pinch wheels are raised, the plotter indicates a "not ready" status on the bus.

**POWER SUPPLY HOT!** (error #21). The temperature sensors on the A8 post-regulator assembly have detected an overtemperature condition. Note that the power supplies regulated on the post-regulator have been shut down.

**POWER SUPPLY SHUT DOWN!** (error #22). One or more supplies on the A8 post-regulator assembly have been shut down due to an overcurrent, overvoltage, or undervoltage condition.

**PRINT ABORTED** (error #25). Depressing any front panel key causes the analyzer to abort output to the printer.

**PRINTER: not on, not connected, wrong addrs** (error #24). The printer does not respond to control. Verify power to the printer, and check the HP-IB connection between the analyzer and the printer. Ensure that the printer address recognized by the network analyzer matches the HP-IB address set on the printer itself. Refer to *[LOCAL] Key* in Chapter 7 for instructions on setting peripheral addresses.

**REQUESTED DATA NOT CURRENTLY AVAILABLE** (error #30). The analyzer does not currently contain the data being requested. For example, this condition occurs when error term arrays are requested and no calibration is active.

**SELF TEST #n FAILED** (service error). Internal test #n has failed. Several internal test routines are executed at instrument preset. The analyzer reports the first failure detected. Refer to the *Troubleshooting* section of the *Service Manual* for more information on internal tests and the self-diagnose feature.

**SLIDES ABORTED (MEMORY REALLOCATION)** (error #73). Insufficient memory is available for sliding load measurements. Reduce memory usage if possible (see Chapter 10, *Saving Instrument States*), then repeat the sliding load measurements.

**SOURCE PARAMETERS CHANGED** (error #61). Some of the stimulus parameters of the instrument state have been changed, due to a request to turn correction on. A calibration set for the current measurement parameter was found and activated. The instrument state was updated to match the stimulus parameters of the calibration state.

**SWEEP TIME INCREASED** (error #11). Sweep time is automatically increased to compensate for other instrument state changes. Some parameter changes that cause an increase in sweep time are narrower IF bandwidth, an increase in the number of points, and a change in sweep type.

**SYNTAX ERROR** (error #33). An improperly formatted command was received over HP-IB. Refer to the *HP-IB Quick Reference* for proper command syntax.

**SYSTEM IS NOT IN REMOTE** (error #52). The analyzer is in local mode. In this mode, it will not respond to HP-IB commands with front panel key equivalents. It will, however, respond to commands that have no such equivalents, such as status requests.

**TARGET VALUE NOT FOUND** (not a CAUTION message). The target value requested for the marker search function does not exist on the current data trace.

**TEST PORT OVERLOAD, REDUCE POWER** (error #57, 58, 59). Whenever the power level at one of the test ports exceeds approximately +20 dBm, the source power level must be reduced.

**TOO MANY SEGMENTS OR POINTS** (error #50). Frequency list mode is limited to 30 segments or 1601 points. This error also occurs when ***[SET FREQ LOW PASS]*** is selected and the number of points is greater than 201. Refer to *Edit List Menu* in Chapter 3 for more information.

**TRANSFORM, GATE NOT ALLOWED** (error #16). Transformation to the time domain is not allowed for sweep types other than linear and CW.

**TROUBLE! CHECK SET-UP AND START OVER** (service error). The equipment setup for the adjustment procedure in progress is not correct. Check the setup diagram and instructions in the *Adjustments* section of the *Service Manual*. Start the procedure again.

**WAITING FOR CLEAN SWEEP** (no error #). In single sweep mode, the instrument ensures that all changes to the instrument state, if any, have been implemented before taking the sweep. The command that the instrument is currently processing will not complete until the new sweep completes.

**WAITING FOR DISK** (no error #). This message is displayed between the start and finish of a read or write operation to a disk.

**WAITING FOR HP-IB CONTROL** (no error #). The analyzer has been instructed to use pass control (USEPASC). When the instrument next receives an instruction requiring active controller mode, it requests control of the bus and simultaneously displays this message. If the message remains, the system controller is not relinquishing the bus.

**WRITE ATTEMPTED WITHOUT SELECTING INPUT TYPE** (error #32). The data header "#A" for the HP 8720A was received with no preceding input command (such as INPUDATA). The instrument recognized the header but did not know what type of data to receive. Refer to the *HP-IB Quick Reference Guide* for command syntax information.

**WRONG DISK FORMAT, INITIALIZE DISK** (error #77). A command to store, load, or read file titles has been received, but the disk format does not conform to the Logical Interchange Format (LIF). Refer to *Initialize Menu* in Chapter 10.

## ERROR MESSAGES IN NUMERICAL ORDER

Explanation of these error messages are given in the previous section *(Error Messages in Alphabetical Order)*.

1 OPTIONAL FUNCTION; NOT INSTALLED
2 INVALID KEY
4 PHASE LOCK CAL FAILED
7 PHASE LOCK FAILURE
9 LIST TABLE EMPTY

13 AVERAGING INVALID ON NON-RATIO MEASURE
14 FUNCTION NOT VALID
15 NO MARKER DELTA —SPAN NOT SET
16 TRANSFORM, GATE NOT ALLOWED
17 DEMODULATION NOT VALID
18 LOW PASS MODE NOT ALLOWED

20 AIR FLOW RESTRICTED: CHECK FAN FILTER
21 POWER SUPPLY HOT!
22 POWER SUPPLY SHUT DOWN!
24 PRINTER: not on, not connected, wrong addrs
25 PRINT ABORTED
26 PLOTTER: not on, not connected, wrong addrs
27 PLOT ABORTED.
28 PLOTTER NOT READY-PINCH WHEELS UP

30 REQUESTED DATA NOT CURRENTLY AVAILABLE
31 ADDRESSED TO TALK WITH NOTHING TO SAY
32 WRITE ATTEMPTED WITHOUT SELECTING INPUT TYPE
33 SYNTAX ERROR
34 BLOCK INPUT ERROR
35 BLOCK INPUT LENGTH ERROR
36 CHANGE HP-IB to SYS CTRL or PASS CTRL
37 CAN'T CHANGE-ANOTHER CONTROLLER ON BUS
38 DISK: not on, not connected, wrong addrs
39 DISK HARDWARE PROBLEM

40 DISK MEDIUM NOT INITIALIZED
41 NO DISK MEDIUM IN DRIVE
42 FIRST CHARACTER MUST BE A LETTER
43 ONLY LETTERS AND NUMBERS ARE ALLOWED
44 NOT ENOUGH SPACE ON DISK FOR STORE
45 NO FILE(S) FOUND ON DISK
46 ILLEGAL UNIT OR VOLUME NUMBER
47 INITIALIZATION FAILED
48 DISK IS WRITE PROTECTED
49 DISK WEAR-REPLACE DISK SOON

50 TOO MANY SEGMENTS OR POINTS
51 INSUFFICIENT MEMORY
52 SYSTEM IS NOT IN REMOTE
54 NO VALID MEMORY TRACE
55 NO VALID STATE IN REGISTER
56 INSTRUMENT STATE MEMORY CLEARED
57 TEST PORT OVERLOAD, REDUCE POWER (R sampler)
58 TEST PORT OVERLOAD, REDUCE POWER (A sampler)
59 TEST PORT OVERLOAD, REDUCE POWER (B sampler)

60 ANALOG INPUT OVERLOAD
61 SOURCE PARAMETERS CHANGED
63 CALIBRATION REQUIRED
64 CURRENT PARAMETER NOT IN CAL SET
66 CORRECTION TURNED OFF
68 ADDITIONAL STANDARDS NEEDED
69 NO CALIBRATION CURRENTLY IN PROGRESS

70 NO SPACE FOR NEW CAL. CLEAR REGISTERS
71 MORE SLIDES NEEDED
72 EXCEEDED 7 STANDARDS PER CLASS
73 SLIDES ABORTED (MEMORY REALLOCATION)
74 CALIBRATION ABORTED
75 FORMAT NOT VALID FOR MEASUREMENT
76 CORR OFF; FREQ INCOMPATIBLE INST STATE
77 WRONG DISK FORMAT, INITIALIZE DISK

## PRESET STATE

When the **[PRESET]** key is pressed, the analyzer reverts to a known state. This state is defined in Table A-1, below. There are subtle differences between the preset state and the power-up state. These differences are documented in Table A-2.

When line power is cycled, or the **[PRESET]** key pressed, the analyzer performs a self-test routine. Upon successful completion of that routine, the instrument state is set to the following preset conditions. The same conditions are true following a "PRES;" or "RST;" command over HP-IB, although the self-test routines are not executed.

*Table A-1. Preset Conditions (1 of 2)*

| Operating Parameter | Preset Value |
|---|---|
| **Stimulus Conditions** | |
| SWEEP TYPE | linear frequency |
| DISPLAY MODE | start/stop |
| TRIGGER TYPE | continuous |
| EXTERNAL TRIGGER | off |
| SWEEP TIME auto/manual | auto |
| SWEEP TIME auto (HP 8719A) | 387.5 milliseconds |
| (auto (HP 8720B) | 575 milliseconds |
| START FREQUENCY (standard) | .1300 GHz |
| (option 001) | .130 000 000 GHZ |
| STOP FREQUENCY (standard HP 8719A) | 13.5100 GHz |
| (option 001 HP 8719A) | 13. 510 000 000 GHz |
| STOP FREQUENCY (standard HP 8720B) | 19.9900 GHz |
| (option 001 HP 8720B) | 20. 000 000 000 GHz |
| CW FREQUENCY | 1 GHz |
| START TIME | 0 |
| TIME SPAN | 100 milliseconds |
| SOURCE POWER | −10 dBm |
| COUPLED CHANNELS | on |
| **Response Conditions** | |
| PARAMETER | Channel 1: S11<br>Channel 2: S21 |
| CONVERSION | off |
| FORMAT | log magnitude |
| DISPLAY | data |
| DUAL CHANNEL | off |
| ACTIVE CHANNEL | channel 1 |
| FREQUENCY BLANK | disabled |
| SPLIT DISPLAY | on |
| BEEPER: DONE | on |
| BEEPER: WARNING | off |
| NUMBER OF POINTS | 201 |
| IF BANDWIDTH | 3000 Hz |
| IF AVERAGING FACTOR | 16; off |
| SMOOTHING APERTURE | 1% span; off |
| PHASE OFFSET | 0 degrees |
| ELECTRICAL DELAY | 0 seconds (all parameters) |

| Format Table | Scale | Reference Position | Reference Value | Marker Offset |
|---|---|---|---|---|
| LOG MAGNITUDE (dB) | 10.0 | 5.0 | 0.0 | 0.0 |
| PHASE (degree) | 90.0 | 5.0 | 0.0 | 0.0 |
| GROUP DELAY (nsec) | 10.0 | 5.0 | 0.0 | 0.0 |
| SMITH CHART | 1.00 | – | 1.0 | 0.0 |
| POLAR | 1.00 | – | 1.0 | 0.0 |
| LINEAR MAGNITUDE | 0.1 | 0.0 | 0.0 | 0.0 |
| REAL | 2.0 | 5.0 | 0.0 | 0.0 |
| SWR | 1.00 | 0.0 | 1.0 | 0.0 |

| Operating Parameter | Preset Value |
|---|---|
| **Calibration** | |
| CORRECTION | off |
| CALIBRATION TYPE | none |
| CALIBRATION KIT | 3.5 millimeter |
| SYSTEM Z0 | 50 ohms |
| VELOCITY FACTOR | 1 |
| EXTENSIONS | off |
| PORT 1 | 0 |
| PORT 2 | 0 |
| **Markers** (coupled) | |
| MARKERS 1,2,3,4 | 1 GHz; all markers off |
| LAST ACTIVE MARKER | 1 |
| REFERENCE MARKER | none |
| MARKER MODE | continuous |
| DELTA MARKER MODE | off |
| MARKER SEARCH | off |
| MARKER TARGET VALUE | −3 dB |
| MARKER WIDTH VALUE | −3 dB; off |
| MARKER TRACKING | off |
| MARKER STIMULUS OFFSET | 0 |
| MARKER VALUE OFFSET | 0 |
| MARKER AUX OFFSET (PHASE) | 0 degrees |
| MARKER STATISTICS | off |
| POLAR MARKER | lin mkr |
| SMITH MARKER | R+jX |

*Table A-1. Preset Conditions (2 of 2)*

| Operating Parameter | Preset Value | Operating Parameter | Preset Value |
|---|---|---|---|
| **Limit Lines** | | PLOT DATA | on |
| LIMIT LINES | off | PLOT MEMORY | on |
| LIMIT TESTING | off | PLOT GRATICULE | on |
| LIMIT LIST | empty | PLOT TEXT | on |
| EDIT MODE | upper/lower limits | PLOT MARKER | on |
| STIMULUS OFFSET | 0 Hz | PLOT QUADRANT | full page |
| AMPLITUDE OFFSET | 0 | SCALE PLOT | full |
| LIMIT TYPE | sloping line | PLOT SPEED | fast |
| BEEP FAIL | off | **System Parameters** | |
| **Frequency List** | | HP-IB ADDRESSES | last active state |
| FREQUENCY LIST | empty | HP-IB MODE | last active state |
| EDIT MODE | start/stop, number of points | INTENSITY and FOCUS | last active state |
| **Time Domain** | | **External Memory Array (Define Store)** | |
| TRANSFORM | off | DATA | off |
| TRANSFORM TYPE | bandpass | RAW DATA | off |
| START TRANSFORM | −1 nanosecond | FORMATTED DATA | off |
| STOP TRANSFORM | 4 nanoseconds | GRAPHICS | off |
| GATING | off | **Service Modes** | |
| GATE SHAPE | normal | HP-IB DIAGNOSTICS | off |
| GATE START | −500 picoseconds | SOURCE PHASE-LOCKED LOOP | on |
| GATE STOP | +500 picoseconds | SAMPLER CORRECTION | on |
| DEMODULATION | off | SPUR AVOIDANCE | on |
| WINDOW | normal | AUX INPUT RESOLUTION | high |
| USE MEMORY | off | ANALOG BUS NODE | 11 (auxiliary input) |

| **Plot** | **Channel 1** | **Channel 2** |
|---|---|---|
| PEN NUMBER: | | |
| Data | 1 | 2 |
| Memory | 1 | 2 |
| Graticule | 3 | 4 |
| Text | 1 | 2 |
| Marker | 5 | 6 |
| LINE TYPE | | |
| Data, Memory | 7 | 7 |

*Table A-2. Power-On Conditions (versus Preset)*

HP-IB MODE is talker/listener.

MEMORY and CALIBRATION data of saved registers are cleared.

INTENSITY value is set to factory encoded value. The factory value can be changed by running the appropriate service routine. Refer to *Adjustments* in the *Service Manual.*

If short term memory is lost prior to power-up of the instrument, the following is true:

HP-IB ADDRESSES are set to the following defaults:

- NETWORK ANALYZER .......... 16
- USER DISPLAY .......... 17
- PLOTTER .......... 5
- PRINTER .......... 1
- DISK .......... 0
- DISK UNIT NUMBER .......... 0
- DISK VOLUME NUMBER .......... 0

INTERNAL REGISTER TITLES are set to defaults: REG1 through REG5.

EXTERNAL FILE TITLES (store files) are set to defaults: FILE1 through FILE 5.

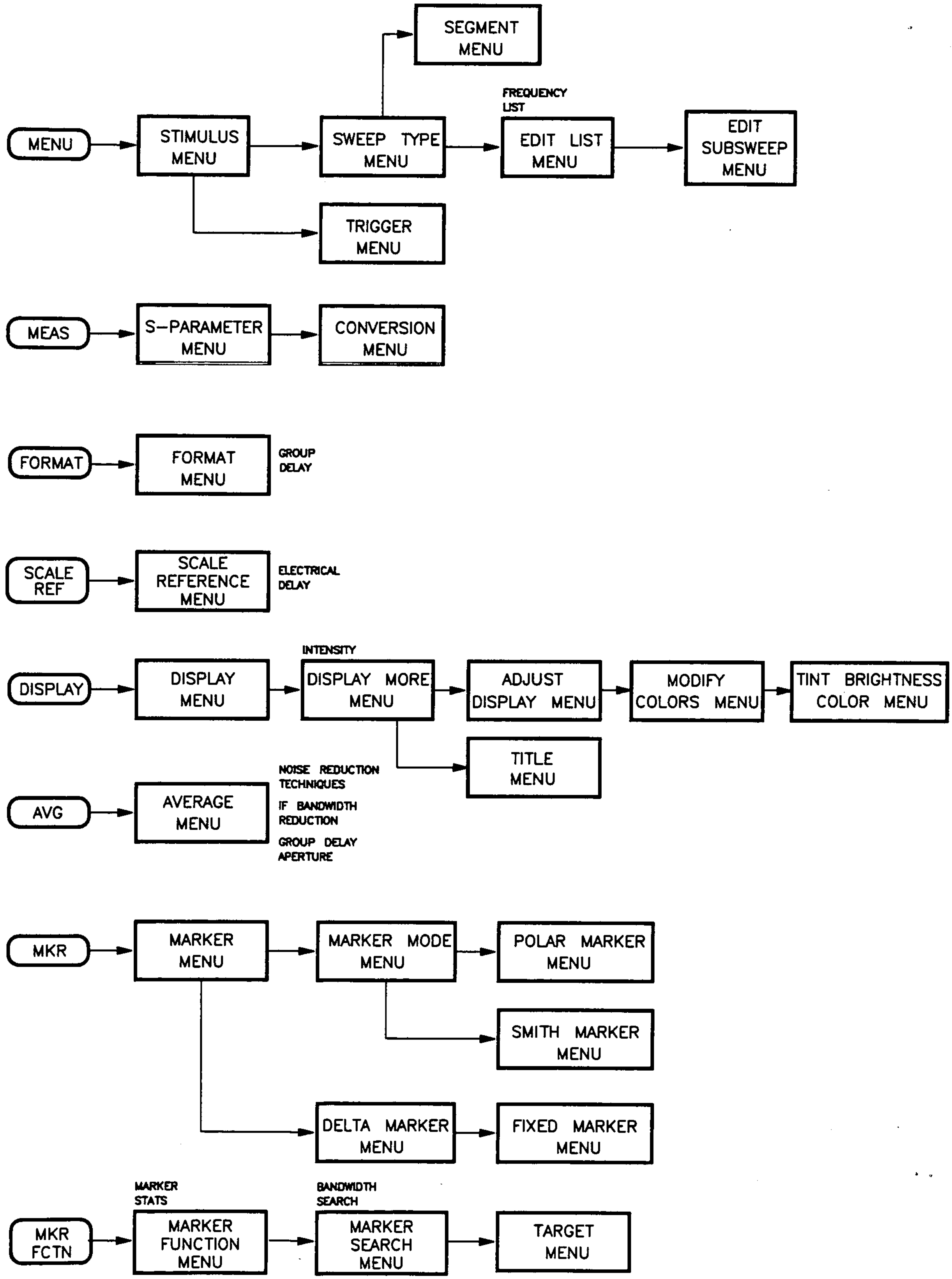



*Figure A-1. Operating Softkey Menu Map (1 of 3)*

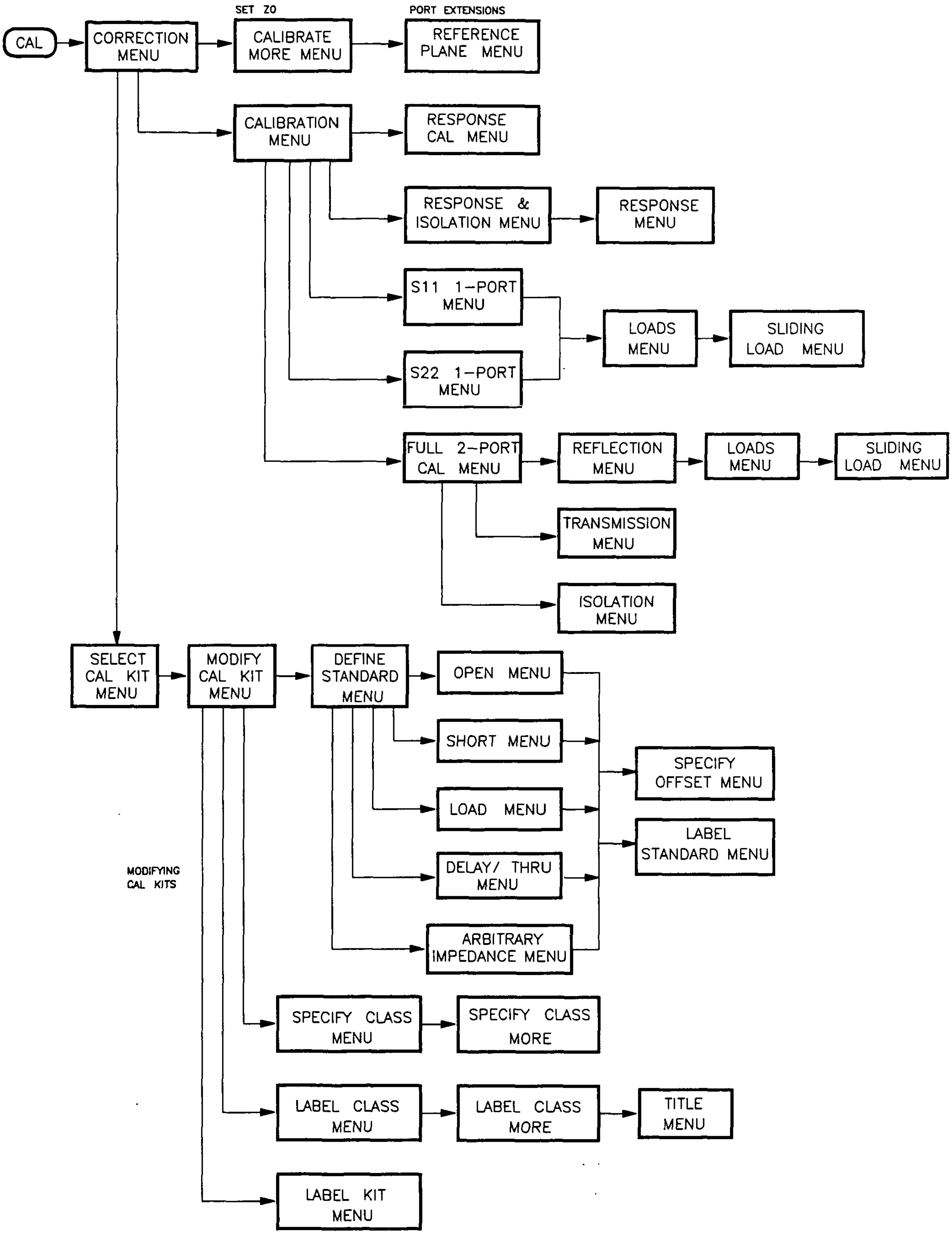



*Figure A-1. Operating Softkey Menu Map (2 of 3)*

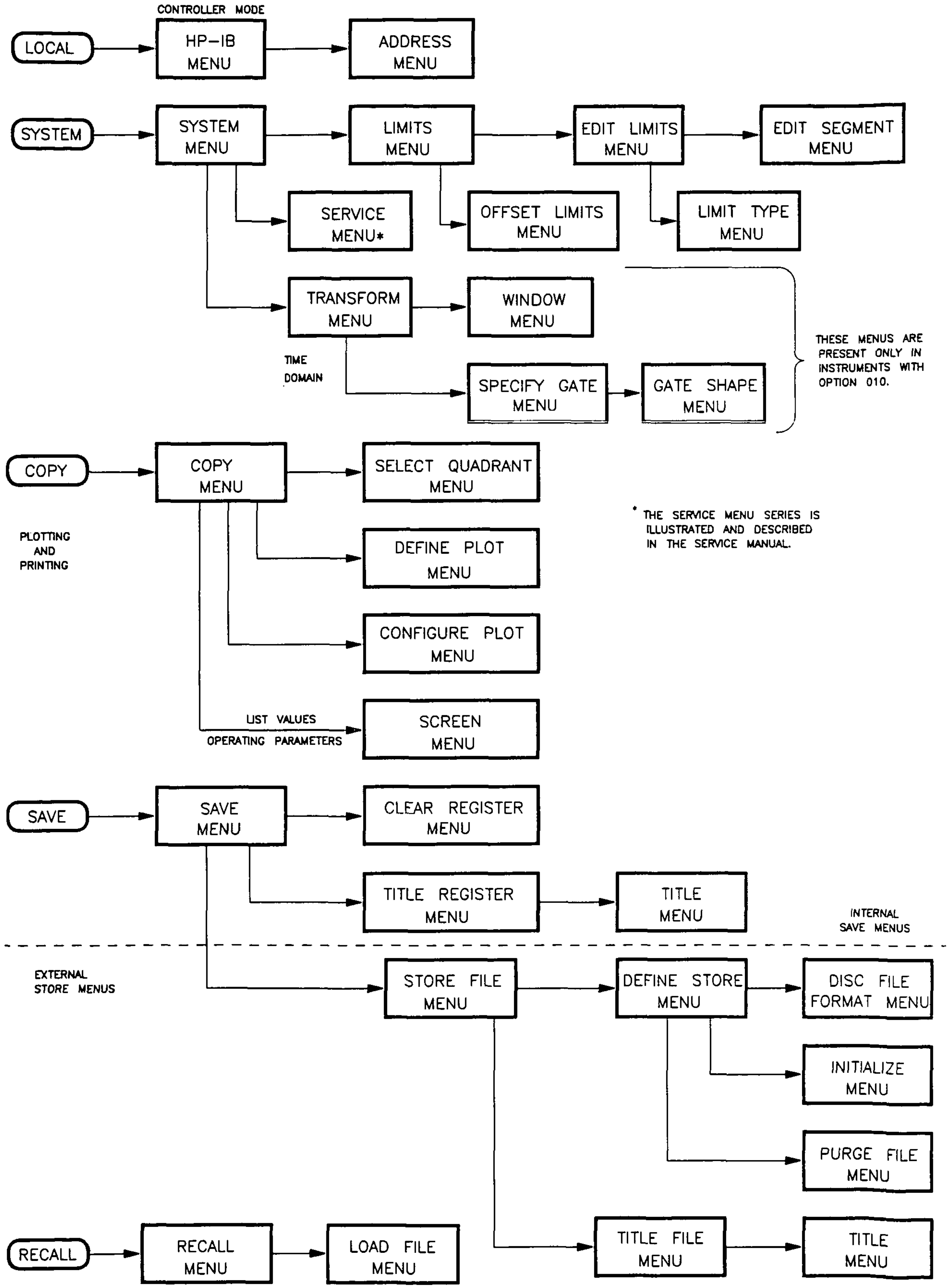



*Figure A-1. Operating Softkey Menu Map (3 of 3)*

# Instrument History

## INTRODUCTION

This manual applies directly to the instrument it came with, specifically to network analyzers with the serial number prefixes on the title page.

If your instrument were to have a lower serial number prefix and need additional documentation, it would be located in this section. For additional information see *Analyzers Covered by this Manual* in the *General Information* section.

# Accessories

Use this section to store the manuals of the system accessories (calibration and verification kits, cable sets, test sets).

# HP 8719A and HP 8720B Operating Manual

# INDEX

**(The HP-IB Programming Guide and HP-IB Programming Reference have their own tables of contents and are not indexed here.)**



**KEY:** GI = General Information section; QR = Quick Reference manual; R = Reference section; S = Specifications section; UG = User's Guide manual.

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