HP 8702
LIGHTWAVE COMPONENT ANALYZER

SERIAL NUMBERS

This manual applies directly to instruments beginning with serial number 2749A00101.

If applicable, a Manual Changes Supplement will be supplied with your instrument or made available through the nearest HP office. The supplement will document any changes to this manual or instruments not covered by this manual.

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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 Institute of Standards and Technology (NIST, formerly NBS), to the extent allowed by the Institute's calibration facility, and to the calibration facilities of other International Standards Organization members.

WARRANTY

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

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

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

LIMITATION OF WARRANTY

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

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

EXCLUSIVE REMEDIES

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

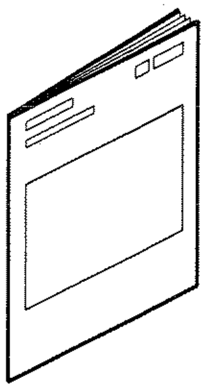
ASSISTANCE

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

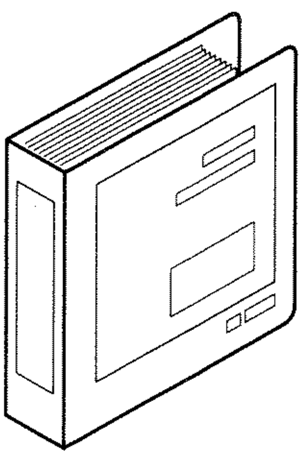
For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

BP21.2

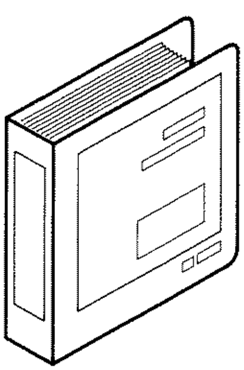
DOCUMENTATION MAP



USER'S GUIDE



OPERATING AND PROGRAMMING
HP Part No. 08702-90002



SERVICE MANUAL
HP Part No. 08753-90156

USER'S GUIDE

Use this to connect your sytem, make sure it works, and begin making measurements. The guided setup is explained and example measurements are given.

OPERATING AND PROGRAMMING

Table of Contents
Complete list of subject headings.

General Information
Read this section to fully understand the system and how to use it.

Specifications and System Performance
This section describes the accuracy of your system and the measurements you make.

User's Guide
(Described above)

Advanced Measurement Techniques
This section has several more measurement examples.

Operating and Programming Reference
This section lists and describes all the key features, mneumonics, menus and details of the analyzer. Use this section as a reference. It also has a menu map.

Programming Guide
These documents show how to use BASIC to control the analyzer over HP-IB.

Appendix-Index
Complete index and appendix containing other varied types of information.

SERVICE MANUAL

Use this section to maintain and repair the analyzer. It also contains performance test information and software.

NOTE: HP Lightwave Sources, Receivers, and Couplers have their own separate manuals.

HP 8702 Operating and Programming Manual
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SECTION 1. GENERAL INFORMATION

SECTION 2. SPECIFICATIONS AND SYSTEM PERFORMANCE

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SECTION 4. ADVANCED MEASUREMENT TECHNIQUES

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SECTION 12. HP-IB PROGRAMMING

HP-IB PROGRAMMING GUIDE

HP-IB QUICK REFERENCE

APPENDIX

SAFETY CONSIDERATIONS

GENERAL

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

SAFETY SYMBOLS

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

Indicates hazardous voltages.

Indicates earth (ground) terminal.

WARNING

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

CAUTION

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

SAFETY EARTH GROUND

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

BEFORE APPLYING POWER

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

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

SERVICING

WARNING

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

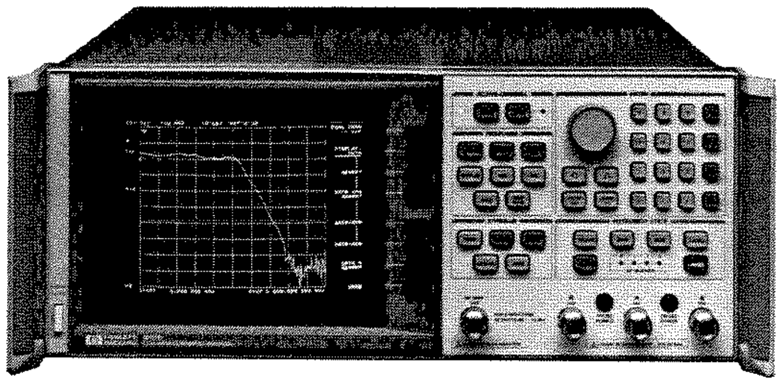
Adjustments described in this manual may be performed with power supplied to the product while protective covers are removed. Energy available at many points may, if contacted, result in personal injury.

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

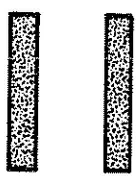
To avoid a fire hazard, only fuses with the required current rating and of the specified type (normal blow, time delay, etc.) are to be used for replacement.

Visual Packing List

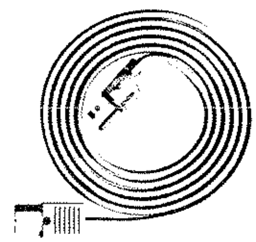
These items are shipped with your HP 8702



HP 8702 Lightwave Component Analyzer



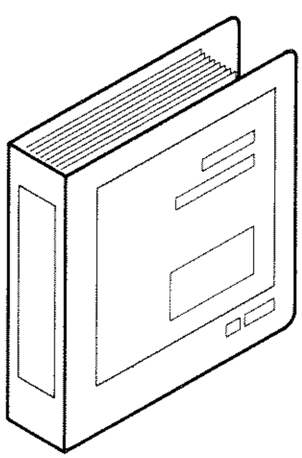
Side Trim: Adhesive-back trim used to cover the area left when handles are removed.



Power Cable
(Power cable and fuse type are dependent upon the country where instrument is first shipped.)

Documentation

Operating and Programming Manual
Complete reference manual and example program disk.



Service Manual
Assembly level repair and two performance test disks.

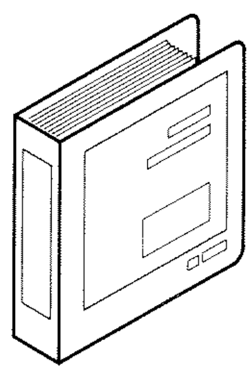


Figure 1-1. Lightwave Component Analyzer as shipped

Section 1. General Information

INTRODUCTION

The Lightwave Component Analyzer is designed to make optical and electrical transmission and reflection measurements of lightwave components and systems, including transducers. In general, the Lightwave Component Analyzer is a system that imposes an electrical modulation signal on a lightwave (laser) carrier and then measures the response of a device under test to this signal. In order to make these measurements, several other system components are required, including a lightwave source, lightwave receiver, and lightwave coupler. However, the analyzer can also make electrical measurements because it has all the capabilities of a RF/microwave network analyzer.

The HP 8702 is shown in Figure 1-1 with the items included in shipment. Figure 1-2 shows the system configured to make a transmission measurement. Here, the modulation bandwidth response of a roll of fiber optic cable is ready to be measured.

The Lightwave Component Analyzer has a menu-driven *Guided Setup* (CRT softkey) as a built-in feature to make it more convenient to learn and use. After initial inspection and installation, you can press the Guided Setup key to begin making measurements. Refer to the User's Guide (in the Getting Started section) for simplified installation instructions and step-by-step measurement examples. Details of the instrument's full capabilities are explained in the Operating and Programming Reference section.

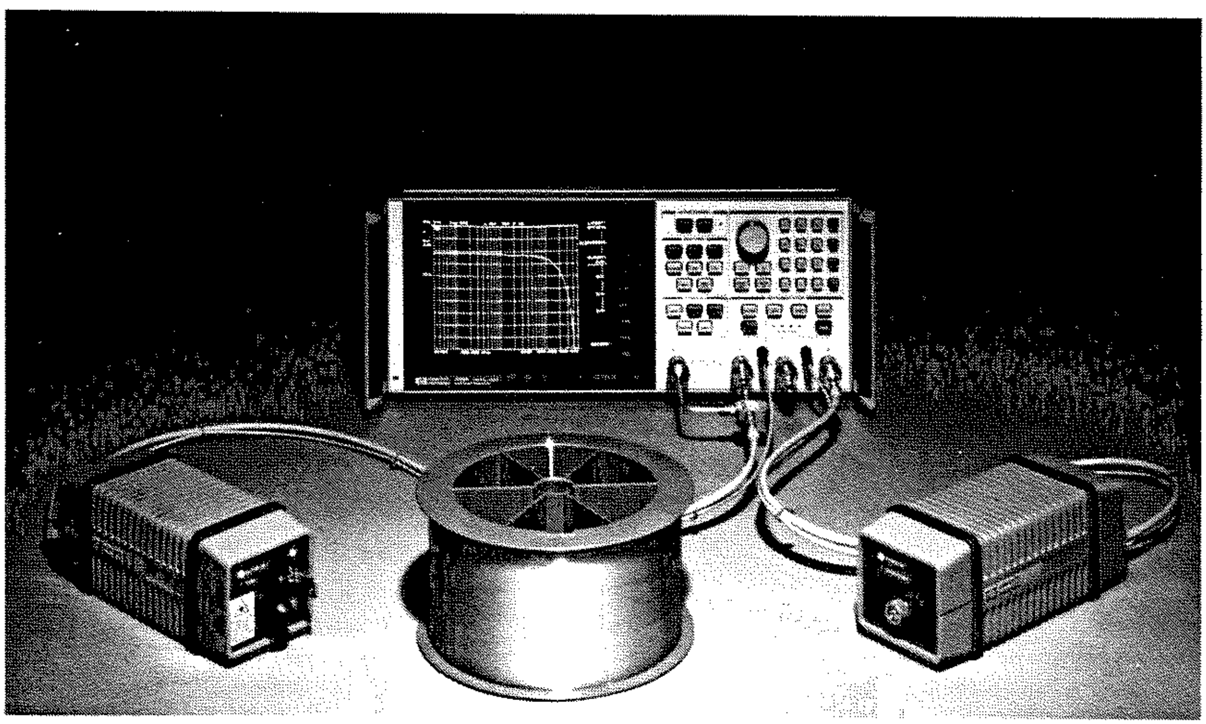


Figure 1-2. Lightwave Component Analyzer System

If you are familiar with RF/microwave network analyzers you will find that the Lightwave Component Analyzer is the same as a RF/microwave network analyzer (measures electrical network responses). However, when combined with the proper accessories, it has the additional feature of measuring lightwave components. Figure 1-3 is a simplified block diagram of the analyzer system.

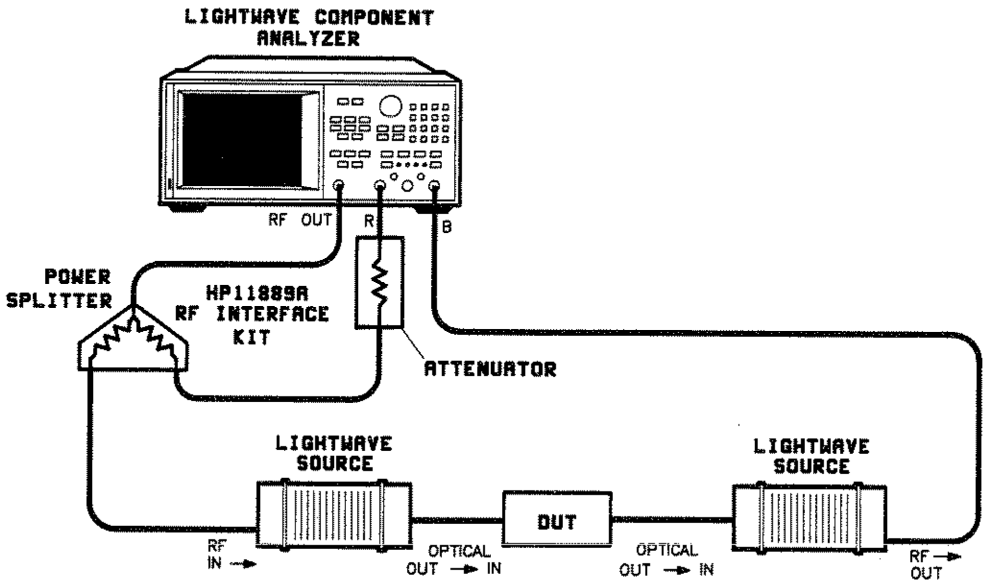


Figure 1-3. Simplified Block Diagram

In addition to its various measurement capabilities, the analyzer can save and recall data and can be calibrated or normalized to provide device measurement reference planes for various measurements. It can make swept power measurements to obtain magnitude and phase (vector) data over a frequency range of 300 kHz to 3 GHz or to 6 GHz (Option 006) using an HP 85047A Test Set. It can also be programmed with an external HP 9000 controller (IEEE-488 standard) to perform any of the same functions that can be performed using its front panel keys. Its color display can also be adjusted by the user.

How to Get Started

Hewlett-Packard recommends that you follow the three steps below after unpacking and inspecting of the product(s):

STEP ONE — Read the rest of this General Information section to get an overview of the Lightwave Component Analyzer system, including details about installation requirements.

STEP TWO — Refer to the tab marked Getting Started and follow the instructions in the User's Guide. It has all the information you need to connect your system and begin making measurements.

STEP THREE — Familiarize yourself with the rest of the manual and any accessory documents.

If you follow the steps above, you will be making measurements within a short time. Afterwards, you can refer to the manuals as needed, using the Operating and Programming Reference section for detailed information.

CAUTION

The analyzer's RF source is static sensitive. Do NOT touch the center conductor of the RF source output port. Do not allow any static charge to come into contact with it.

The rest of this General Information section contains the following topics:

1. Information about this Manual and your Instrument
2. Safety and Service Considerations
3. Types of Devices You Can Measure
4. Making Accurate Measurements
5. Overview: How a Network Analyzer Works
6. Overview: How the Lightwave Component Analyzer Works
7. Detailed System Operation
8. Data Processing
9. Installation Information: Space, Power, Environment
10. List of System Instruments, Options, and Accessories
11. Optical Connector Information

INFORMATION ABOUT THIS MANUAL AND YOUR INSTRUMENT

Two Volume Manual Set

The two volume set is divided by colored tabs and includes:

1) OPERATING AND PROGRAMMING MANUAL — This volume contains fifteen sections, including the User's Guide, Specifications, and an Operating and Programming Reference.

2) SERVICE MANUAL — This volume is designed for use by qualified service personnel. It describes how to troubleshoot several instruments, including system level problems, Performance Tests (HP 8702 stand alone) and electrical System Verification (using the HP Test Set only).

NOTE: This manual can be used for HP 8702A instruments excluding the color display features.

Instrument Serial Numbers

On the rear panel of the instrument is a serial number plate (illustrated in Figure 1-4). The first four digits followed by a letter is called the *prefix*. The last several digits is called the *suffix*. This manual applies directly to instruments with the serial number *prefix* listed on the title page.

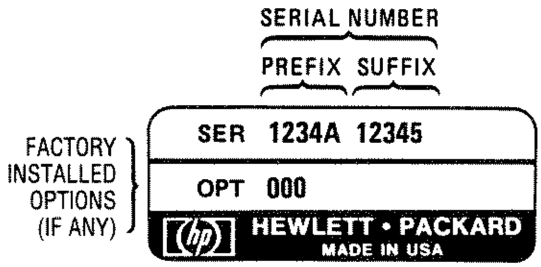


Figure 1-4. Typical Serial Number Plate

An instrument manufactured after the printing of this manual may have a serial number *prefix* that is not listed on the title page. In that case, the manual is accompanied by a Manual Change Supplement that explains how to adapt or change the manual to fit your specific instrument.

SAFETY, SERVICE, AND MAINTENANCE CONSIDERATIONS

Safety: The analyzer stand-alone safety information is in the Service Manual. Detailed safety information, required by the International Electrotechnical Commission (Publication 825, 1984) for the HP Lightwave Source (laser) is described in its accompanying manual.

Service: The analyzer should be serviced only by qualified personnel in accordance with the information in the SERVICE manual. In all other cases, contact your nearest Hewlett-Packard office if you need service.

Maintenance: Keep the area around the analyzer clean and inspect any exposed connectors periodically. Refer to the SERVICE manual for preventive maintenance.

TYPES OF DEVICES YOU CAN MEASURE

In general, the analyzer can measure (analyze) four general types of devices as a function of frequency. These devices are categorized depending upon their input and output signals: electrical or optical. Thus, the Lightwave Component Analyzer can be thought of as both an optical and an electrical measuring instrument. Depending upon the kind of measurement you want to make, and the accessories you have, the types of the devices that the analyzer can characterize are defined as follows:

1. Optical-to-Optical (O/O) device: This is any device with an optical input and optical output signal. This includes fiber cables, fiber cable connectors, couplers, splitters, tees, etc.

2. Electrical-to-Optical (E/O) device: This is any device with an electrical input signal and an optical output signal. This includes E/O modulators or sources, often called E/O converters, directly modulatable laser sources, transmitters, and optical modulators.

3. Optical-to-Electrical (O/E) device: This is any device with an optical input signal and an electrical output signal. This includes O/E demodulators or receivers, often called O/E converters, lightwave receivers, and photo-diodes.

4. Electrical-to-Electrical (E/E) device: This is any device with an electrical input signal and an electrical output signal. This includes any type of device that is typically measured on an RF/microwave network analyzer.

MAKING ACCURATE MEASUREMENTS

When properly combined with a lightwave source, lightwave receiver, and the proper connecting cables and coupler, the analyzer can make reflection and transmission measurements to a high degree of accuracy with specified performance and minimal measurement uncertainty. These specifications and uncertainty values are explained in the Specifications and System Performance section of this manual.

The accuracy of measurement data depends upon several factors, including the ability to make careful and repeatable device connections. However, the analyzer also has the ability to establish a measurement reference plane, either by normalization or by error correction calculation.

Measurement Calibration: The terms *calibration*, *accuracy enhancement*, and *error correction* all refer to the same concept in network or lightwave component analysis. These terms mean that the instrument has the capability of enhancing the accuracy of measurement data by reference plane calibration or error correction. Basically, this means measuring a known standard device and comparing the measured data to the known characteristics. The result of this comparison is an error correction factor that is applied to subsequent measurement data to remove systematic (repeatable) errors.

Optical reference plane calibration can be performed for transmission measurements by normalization, using a *thru* line (patch cord) of cable. Also, for O/O reflection measurements, the reference plane is established by measuring a Fresnel reflection at the output of an optical coupler or connections end of a cable and then calculating (normalizing) the response to establish a zero reference plane at that point.

For E/O and O/E device measurements, HP lightwave sources and lightwave receivers are shipped with data that characterizes the specific individual instrument. By entering this characterization data (called CAL DATA) directly into the analyzer and performing a measurement calibration, the E/O and O/E devices can be accurately measured.

For E/E measurements the analyzer can be calibrated, using a test set, and using specific standard devices (open, short, load) available in an HP calibration kit that is connector-type dependent. Using this kit, you can establish a measurement reference plane where the system's total uncertainty (due to mismatches or systematic errors) can be reduced to enhance the accuracy of your measurement data.

Examples of all these measurements are found in the User's Guide. In addition, further explanations are included in the Operating and Programming Reference section of this manual.

NOTE: The analyzer can only make optical transmission measurements with the lightwave source and receiver. For reflection measurements, one of the following system accessories is required: an optical coupler for optical reflection measurements or, for electrical reflection measurements, an electrical test set.

OVERVIEW: HOW THE LIGHTWAVE COMPONENT ANALYZER WORKS

The Lightwave Component Analyzer, like a RF/microwave network analyzer, can measure the reflection and transmission characteristics of device networks. This is done by applying a known signal, called the incident signal, to the device's input and then measuring the device's output signal or the signal reflected back from the device's input. This measurement results in a ratio value where the transmitted or reflected signal is compared to the incident reference signal. The result is displayed on the analyzer's CRT as a trace value. For example, a typical measurement would be the transmission characteristics of a specified length of fiber cable, where the transmitted signal appeared as a CRT trace showing X dB of loss (optical power) vs. modulation frequency.

In order to make these ratio measurements, an electrical signal source and receiver are required in the analyzer. For this reason, the Lightwave Component Analyzer has its own built-in electrical RF source (300 KHz to 3 GHz) and electrical RF receiver (inputs R, A and B). Of course, the electrical signal (modulation signal) must be superimposed on a carrier frequency (light) to form the lightwave signal for optical measurements —this is the function of the lightwave source. Therefore, to measure a device with an optical input signal, a lightwave source or modulator (E/O) must be connected to the analyzer's output (RF electrical signal source). If the DUT has an optical output signal, a lightwave receiver or demodulator (O/E) must be used to convert (demodulate) the modulated light signal to an RF electrical signal so that it can be input to the analyzer's tuned receiver.

NOTE: If an HP 85047 Test Set is used with the HP 8702 (Option 006), the test set will double the source frequency. This allows you to modulate an appropriate lightwave source to 6 GHz.

Figure 1-5 shows a system configured for making both reflection and transmission measurements (using the RF interface kit). Assume that a DUT with optical inputs and outputs, like an optical attenuator, is being measured for return loss (reflection) and modulation transfer characteristics (transmission). The analyzer's RF signal is split in two: a reference signal and a test signal. The reference RF signal goes directly into the analyzer (reference channel) and the test RF signal goes into the HP lightwave Source to modulate the light. The resulting output signal is modulated light. This intensity modulated light feeds directly into and through the optical coupler and then into the DUT. Any signal traveling in the opposite direction, reflected by the DUT, is captured by the coupling arm inside the coupler and sent to the HP Lightwave Receiver for demodulation (detection of the RF signal). The resulting electrical output signal is then input to receiver sections for down-conversion and processing.

The DUT's optical output signal can be connected to another HP lightwave receiver which converts or demodulates the optical signal that is transmitted through the DUT. However, two receivers are not required because one receiver can remain connected to the receiver's B input while its optical input is connected to the transmitted or reflected signal as required. The resulting electrical RF signal can also be input to the receiver section for down-conversion and processing.

NOTE: The word *coupler* refers to an optical or electrical device that is used to separate an incident signal from a reflected signal in the same path. The word *thru* refers to a jumper cable or patch cord that allows an optical or electrical signal to transmit through it.

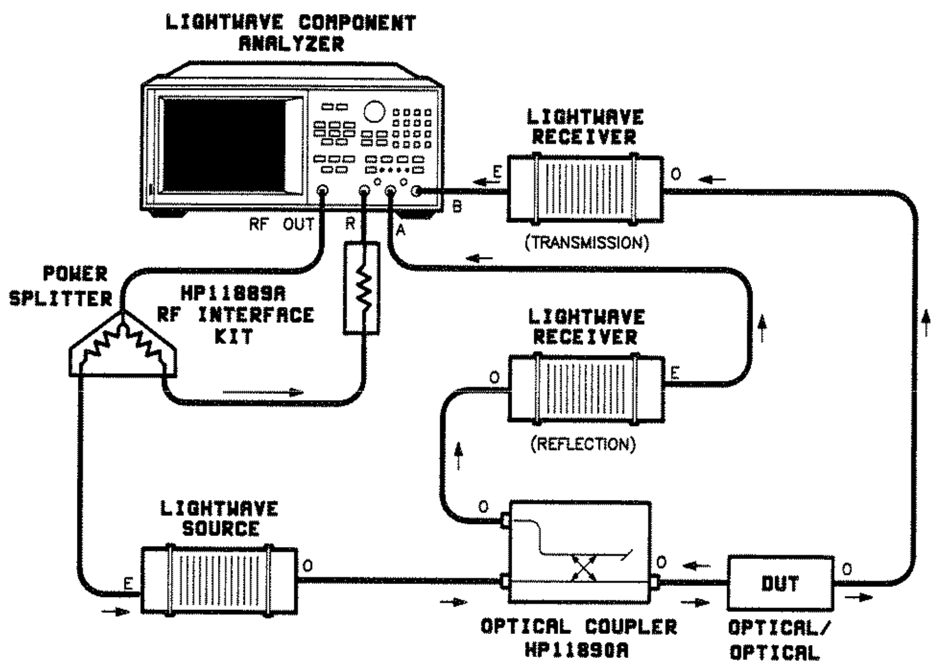


Figure 1-5. HP 8702 Measurement Block Diagram

If you are familiar with microwave network analyzers and S-parameter measurements, you will find that the Lightwave Component Analyzer is essentially a network analyzer. Because of the specially designed CPU board and programmed firmware, it has the the ability to make both RF network and lightwave component measurements. If you are not familiar with microwave network analyzers, the following paragraphs should help you to understand more about how the Lightwave Component Analyzer operates.

OVERVIEW: HOW A NETWORK ANALYZER WORKS

Network analyzers are used by RF engineers and technicians to characterize linear microwave components such as filters, attenuators, amplifiers, cables, adapters, isolators, etc. The network analyzer's main function is to measure the energy that is reflected from or transmitted through a device. This includes reflection measurements like SWR (standing wave ratio), impedance (R+jX), and return loss. It includes transmission measurements like gain/loss, group delay, and insertion phase shift. Furthermore, the most common type of measurement is a ratio where the magnitude or phase of an incident input signal (reference) is compared to a reflected or transmitted signal — this is called an S-parameter measurement.

The physical appearance and the functional block equivalent of an HP 8702 configured as a network analyzer is shown in Figure 1-6. Notice that the network analyzer uses a test set to separate the incident electrical signal from the electrical signal reflected by the DUT. Because there are no optical connections in this example, no lightwave source or reciever is used. Although the Lightwave Component Analyzer does not require a test set, one can be connected to the analyzer to make electrical reflection measurements. In that case, optical transmission measurements could be made by connecting the lightwave source to the test set port 1 (RF out) and the lightwave receiver to port 2 (for RF in) or directly to input B.

Remember that the analyzer does require a test set for electrical reflection measurements. For optical reflection measurements, an optical signal separation device called an optical coupler would be used to separate and route the lightwave energy reflected back from a device's input. It would also separate and route the incident light signal.

The network analyzer, like the Lightwave Component Analyzer, is basically a tuned receiver because its receiver/detector section is tuned to the source RF output frequency by the use of a phase-lock loop. This is what allows the analyzer to make coherent phase and magnitude measurements.

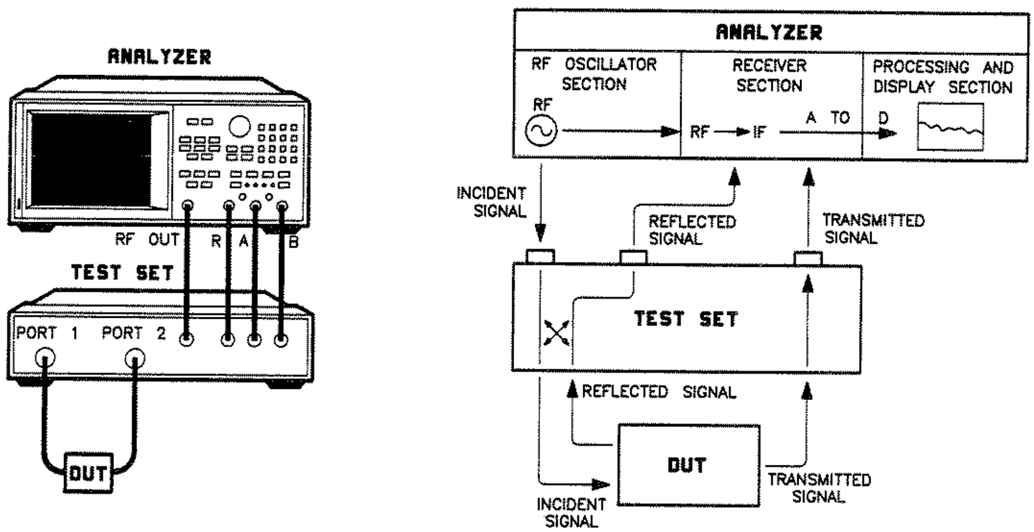


Figure 1-6. Network Analyzer Block Diagram

Notes About Operating an Analyzer: Here are a few things to remember about the Lightwave Component Analyzer:

- A PRESET front panel key puts the analyzer in a default operating/measuring mode. If an HP test set, for electrical reflection measurements, is connected to the analyzer it will default to a reflection measurement format (S_{11}). If you do not have a test set, the PRESET key will set the analyzer to an optical transmission format.
- The analyzer's RF source sweeps across its frequency band and the RF receiver section samples the electrical signal continuously. Like most instruments, it is designed to be kept ON, rather than in a standby or OFF mode. Therefore, the trace on the CRT will be continuously updated as each sweep is completed, even if no DUT is connected. However, you can stop the sweep using the HOLD softkey.

- The front panel keys are grouped in functional blocks that make it easy to set up a measurement. For example, if you wanted to measure the signal reflected from a band-pass filter you would make selections using the STIMULUS, RESPONSE and ENTRY keys like this: set the start and stop frequencies closer to the filter's band, set the number of points (data) to be measured within the band, set the RF input power level, select a display format like *log mag*, select an averaging factor to reduce noise, select the *meas* key function as *reflection A/R*.
- The most common cause of bad or poor measurements is due to poor or improper device connections.

Definition of S-parameter: An S-parameter measurement is commonly used in high frequency measurements made with network analyzers. It is really an abbreviation for the words *scattering parameter* which means the dispersal or scattering of a beam of particles or radiation into a range of directions resulting from physical interactions. However, it is commonly taken to mean the ratio of an incident signal to a transmitted or reflected signal at a single frequency point. The subscripted numbers refer to the device's output/input port ratio. Therefore, using the out/in ratio, S_{21} is a ratio of the power transmitted OUT of port 2 divided by the power that is put IN port 1. The reverse transmission measurement, S_{12}, would be the power coming OUT of port 1 divided by the power going IN port 2. Similarly, for reflection measurements, S_{11} and S_{22} measurements represent the power reflected back from a device divided by the power put into the device depending upon the port (1 or 2) being used. In addition, S-parameters can be either magnitude or phase measurements. The important thing to remember is that S-parameters are ratios. For example, an S_{21} measurement of -20 dB at 60 degrees means that a device has 20 dB of loss and a phase shift of 60 degrees at its output, referenced to its input. This type of data is often displayed on an impedance chart (Smith chart). This chart allows you to see the impedance (inductive or capacitive) of the DUT at the given frequency range.

HP 8702 LIGHTWAVE COMPONENT ANALYZER DETAILED SYSTEM OPERATION

The Lightwave Component Analyzer is a superset of the network analyzer and is designed with special front panel CRT softkey menu selections and CRT display annotations that use both optical and electrical terminology. For this reason, the analyzer can be considered a combination high frequency electrical network analyzer and lightwave component analyzer.

System Operation: Although the *Guided Setup* menu makes most setup, calibration, and device measurements easy to accomplish, you may eventually make some specific selections from the front panel. Below is a brief description of the two main front panel control blocks: STIMULUS and RESPONSE.

In order to compare an incident signal to a transmitted or reflected signal and display the results, you must select the type of measurement you want to make and the parameters that the analyzer can control. For this reason, the front panel keys are divided into functional groups for setting up the measurement as shown in Figure 1-7.

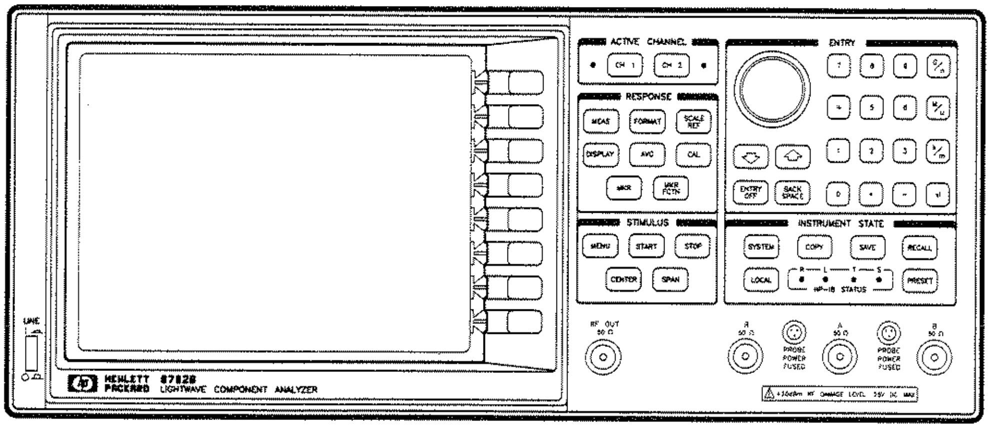


Figure 1-7. Front Panel Controls

STIMULUS refers to the analyzer's stimulus RF signal. This group of keys controls all functions related to the analyzer's internal RF source, including output power levels and power sweep, frequency range (start and stop), sweep time, number of measurement data points measured by the receiver, etc. The stimulus is used to modulate the lightwave source.

RESPONSE refers to the way in which the analyzer responds to the signal at its receiver. It is a group of keys that controls all functions related to the type of measurement made and displayed. This includes the measurement ratios (for example: B/R, A/R, etc.), the display format (log magnitude, phase, delay, polar, etc.), the type of scale, averaging, marker functions, measurement calibration, and several other features.

When the features in these two main function blocks are selected, the analyzer's RF source injects the selected swept signal into the lightwave source (modulator) for example. This modulated lightwave signal passes through or reflects from the DUT, is demodulated (RF detected) by the lightwave receiver, and finally received for processing by the analyzer.

INSTRUMENT STATE refers to those controls that allow you to save, recall or copy data on a disc, including calibrations and previously setup instrument states (operating parameters). In addition, the SYSTEM key gives you access to the internal service diagnostics and the Guided Setup feature.

ENTRY refers to the numerical/unit keys and the rotary pulse generator (RPG), that allows you to enter values for any active function selected.

Using the Front Panel: The use of the front panel commands is made easy by the *Guided Setup* selection. This selection, like many others, is called a *softkey selection* because it is labeled (annotated on the CRT) to correspond to the keys on the side of the CRT. Remember that the labels of these keys change, depending upon the front panel keys that are first selected. Do not be concerned about the front panel keys at this time. The use of the front panel is described in the User's Guide.

300 kHz to 3 GHz RF source: The Lightwave Component Analyzer has its own built-in electrical RF signal source. This source is a high resolution synthesized sweeper with a frequency range of 300 kHz to 3 GHz. For optical measurements, this electrical source functions as a modulating signal that is typically input to a laser. This laser or lightwave source (HP 8340X-series) can be called the modulator because the analyzer's RF output signal modulates the light from the lightwave source (carrier) at any desired RF frequency selected in the STIMULUS block between 300 kHz and 3 GHz or up to 6 GHz if Option 006 is ordered for use with an HP 85047A Test Set.

Three Input Receiver (R, A, B): In order to keep the R (reference) and A (typically reflected) and B (typically transmitted) signals separated, the analyzer has three identical mixer/samplers —one for each input. The sampling circuitry retains each input's magnitude and phase characteristics. Each signal is down-converted in the receiver to a 4 kHz IF (intermediate frequency). It is then multiplexed into the ADC (analog to digital converter) to become a digitized information signal that is processed and formatted for display on the CRT as a measurement trace. This internal multiplexing, processing, and displaying is all under microprocessor control.

Time Domain Measurements: Measured data can be transformed from the frequency domain to the time domain. This is an extremely accurate mathematical manipulation of data using an inverse Fourier (Chirp Z) transform to provide a few of the same reflection measurement capabilities as an OTDR (Optical Time Domain Reflectometer). For example, you can measure fault location on a cable by determining how far out (in time or distance) the fault is located. This is done using an optical coupler to measure the reflection caused by a mismatch or large discontinuity in the cable. Time domain measurement examples are given in the User's Guide.

Simplified Measurement Example: Suppose you wanted to measure a fiber cable's loss over a specific modulation frequency range. After you made the proper connections, as described in the User's Guide, you would use the STIMULUS block to set the START frequency to 1.6 GHz and the STOP frequency to 1.8 GHz. You might also want to use the RESPONSE block keys to display the resulting data on a Log Magnitude graticule with a marker set at 1.7 GHz. By selecting B/R, the analyzer would know that the signal coming into its B input will be processed as a ratio to the signal received at its R input.

The modulated signal coming from the lightwave source would pass into the DUT, and then into the demodulator. The demodulator, or lightwave O/E receiver, outputs an electrical signal that is fed into the analyzer's B input receiver. Note that you could use the A receiver input, but we have chosen the B receiver input for this example. Also, if the DUT was an O/E receiver, instead of a cable (O/O), then its electrical output could be connected directly to the analyzer's receiver. After the signal is received, it is down converted and processed as data for display.

OVERVIEW: HP 8702 DATA PROCESSING

The receiver converts the R, A, and B input signals into useful measurement information in two steps. First, the input signals are converted to fixed low frequency IF signals, using analog sampling and/or mixing techniques. 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.

Figure 1-8 is a data processing flow diagram that represents the flow of numerical data from IF detection to display. Most of the operations (single line boxes) shown in the figure can be selected and controlled with the front panel RESPONSE block menus. The data is also stored in arrays as it is processed (double line boxes). These memory arrays are places in the flow path where data is accessible, usually via HP-IB.

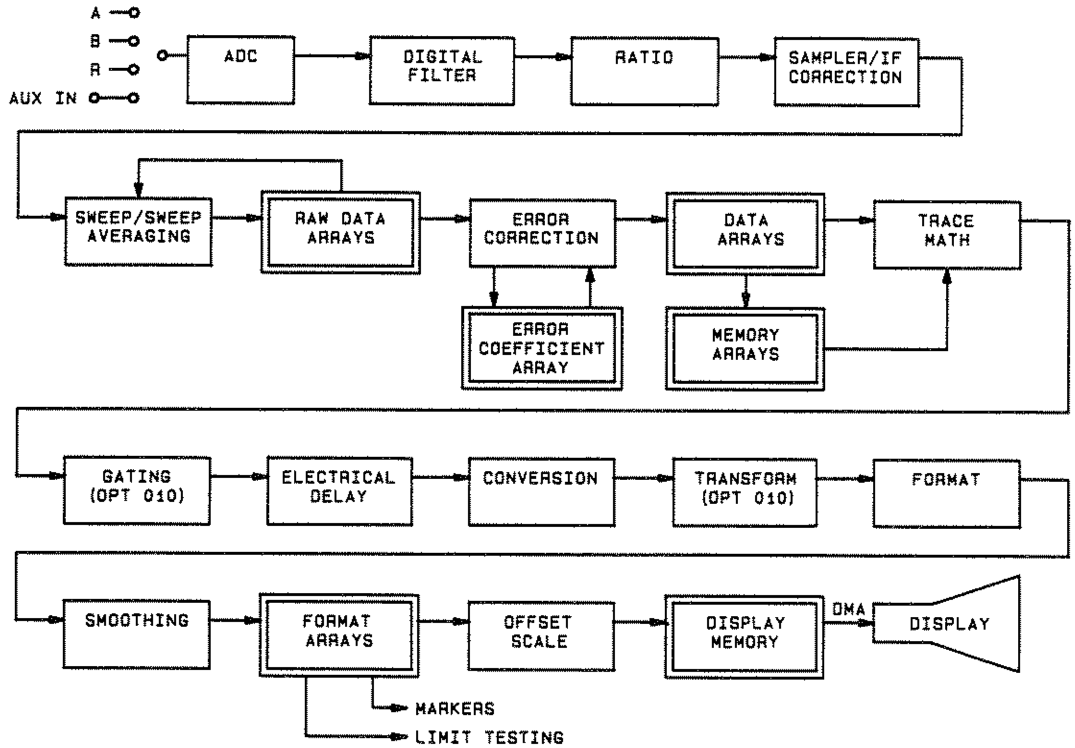


Figure 1-8. Data Processing Flow Diagram

Only a single flow path is shown, but there are two identical paths for channels 1 and 2. When the channels are uncoupled, each channel's data can be independently controlled. Otherwise, when the channels are coupled, their data is processed and formatted in the same manner.

By definition, a *data point* or *point* is a single piece of data representing a measurement at a single stimulus (frequency) value. Most data processing operations are performed point-by-point. Also, note that the term *sweep* is a series of consecutive data point measurements, taken over a range of stimulus (frequency) values. A few data processing operations require a full sweep of data points. The number of points-per-sweep can be selected from the front panel.

OPTICAL CONNECTOR INFORMATION

Lightwave components use several optical connector types. The front panel of the analyzer has electrical connectors (type-N) because its RF output and its receiver input are both electrical. The optical connectors used with the analyzer are the connectors on the lightwave sources and lightwave receivers.

Currently, HP offers the following connector adapters that are used with the HP lightwave sources and receivers:

HP 81000AI HMS-10/HP .... **HP Part Number** 08154-61701
HP 81000FI FC/PC .... **HP Part Number** 08154-61702
HP 81000SI DIN 47256 .... **HP Part Number** 08154-61703
HP 81000VI ST .... **HP Part Number** 08154-61704

Making Optical Connections

The optical connectors on the HP lightwave sources and receivers have conditioned end faces that are HMS-10/HP. These connectors require one of the connector adapters listed above to make the actual fiber connection.

Each adapter has a slot that mates with the corresponding key piece. After mating the connectors, they should be tightened (finger tight) in a consistent and repeatable manner for every measurement. Remember that the spring-loaded side of the connector keeps the fiber from buckling.

Connector Cleaning and Index Matching Compounds:

The threads of the metal portion of all optical connectors should always be clean. Use non-corrosive alcohol that leaves no residue. Or, use a Freon type of product. The fittings should be wiped clean with a lint free swab or cloth. Use canned air to dry the cleaned fitting and to blow away any excess particles.

The fiber ends should always be clean before making the connection. If you are using index matching compound, be sure to apply it as precisely and as evenly as possible. And remove it immediately when you are finished.

Remember that improper optical connections, like electrical connections, can be the cause of bad measurement data.

For cleaning fiber ends, HP offers an optical cleaning kit: HP model number 15475A that includes the following parts:

Part	HP Part Number
Head Cleaner	8500-0270
Hexdriver	8710-1256
Lens Cleaning Paper	9300-0761
Cleaning Kit Box	9300-1130
Blow Brush	9300-1131
Cleaning Tips	9300-1351
Cleaning Tip Box	1540-1100
Adhesive Tape Kit	15475-68701
Cleaning Instructions	15475-90002

NOTE: If you order this kit, contact HP for any changes to part numbers, materials, or methods.

Cleaning Instructions

The following information is taken from the cleaning instructions that come with the kit above (HP part number 15475-90002):

NOTE: Never use abrasive materials to clean optical connectors or lenses.

Fiber Connectors

1. Turn off the laser and remove the connector adapter.
2. Apply a small amount of head cleaner to the cleaning paper and clean the surface and ferrule of the connector.
3. Use another new piece of dry cleaning paper to wipe the connector face clean.
4. Lightly press the adhesive tape against the connector surface several times to remove any remaining dirt or particles left by the cleaning paper. Return the tape to its box.
5. Protect the connector surface by attaching the adapter and cap.

Lenses and Detector Windows

Do not use head cleaner or any cleaning agent for lenses or detector windows.

1. Use the blow brush to clean all surfaces.
2. Wipe all surfaces clean with the cleaning paper and cleaning tips.
3. Remove the brush part of the blow brush and clean all surfaces again.

Connector and Head Adapters

Remove the brush part of the blow brush and press air through the adapter to clean the inside.

Connector Bushings (used on HP 8158B Optical Attenuator)

NEVER insert any cleaning tool into the ferrule, never use cleaning fluid or immersion oil, cleaning paper or cleaning tips to clean the bushing.

Normally, the connector bushings require no cleaning. However, if you want to clean the bushing use only the blow brush with the brush part removed.

RECEIVING AND INSPECTION

Receiving and Unpacking: Before unpacking, verify that all system components ordered have arrived by comparing the shipping forms to the original system purchase order. Inspect all shipping containers. If your shipment is damaged or incomplete, save all packing materials and notify both the shipping carrier and the nearest Hewlett-Packard Sales and Service Office. HP will arrange for repair or replacement of damaged or incomplete shipments without waiting for a settlement from the transportation company. Notify the HP customer engineer of any problems. Also, be sure to verify that the serial numbers listed on the shipping documents are the same as those on the rear panels of the instruments.

INSTALLATION INFORMATION

The *User's Guide* has quick and simple installation instructions for connecting your system.

If you are connecting a test set (HP 85044, 85046, or 85047), you can also use the test set manual to connect the test set to your analyzer. The test set manual was originally written for the HP 8753 Network Analyzer, but it applies directly to the HP 8702 because it is connected in the same exact manner.

Space Requirements

Bench Tops: Use a table that is large enough and strong enough to hold the combination of instruments ordered, preferably with a power distribution strip along the back. The dimensions and weight of the HP 8702 and other instruments in the system are provided in the tables of supplemental characteristics in the individual instrument manuals. Also, allow enough room on the table/bench for connections to the front and rear of the instruments. This includes enough room for the lightwave source, lightwave receiver, devices under test, and any other equipment you will be using.

Racks: For a rack such as the HP 85043B system rack, space must be provided for the rack plus a minimum clearance of 15 cm (6 in) behind and on both sides of the rack to allow proper ventilation. The HP 85043B system rack measures 124 cm (49 in) high by 60 cm (24 in) wide by 80 cm (32 in) deep. The total depth of the rack with the work surface installed is 115 cm (45 in).

Computer: If you are going to use a system controller, the recommended table is HP 92170G, which is 720 mm (28 in) high by 930 mm (36 in) wide by 712 mm (28 in) deep and mounted on casters.

Power Requirements

There are two possible line voltages with a corresponding switch on the rear panel of the analyzer. Also, there is an appropriate fuse, located in the fuse housing on the rear panel.

Voltage Selector Switch: The instrument is shipped with the switch (rear panel) set to the 115 volt position. If you are using the greater line voltage levels (number 2 below), you will have to set the voltage selector switch to the 230 volt position. The switch is located on the rear panel above the ac line power cord connection.

Ratings:

- 90 to 127 Vac, fuse at 3.15 Amps, 47.5 to 66 Hz (single phase).
- 195 to 253 Vac, fuse at 3.15 Amps, 47.5 to 66 Hz (single phase).

If the line voltage is not within one of these ranges, use an autotransformer between the power source and the HP 8702. The fuse is located in a fuse housing immediately above the power receptacle in the AC line module. To remove the fuse housing, insert a small screwdriver into the slot at the base of the housing and pull forward and out. A spare fuse is also supplied in the fuse housing.

If you are using an HP rack, it should be connected to a circuit capable of supplying 2000 VA without interruption, and without interference from other equipment such as air conditioners or large motors.

Environmental Requirements

For best performance, the operating environment for the HP 8702 should meet the following requirements:

- Temperature between 0 degrees C and +55 degrees C
- Relative humidity between 5% and 95% at +40 degrees C (non-condensing)
- Altitude up to 4500 meters (approximately 15,000 feet)
- RFI and EMI susceptibility defined by VDE 0730, CISPR Publication 11, and FCC Class B Standards.

The system can be operated in environments outside this range with a possibility of degradation in performance and a higher risk of failure.

Other: In addition to the above requirements, the environment should be as dust-free as possible and the air filters in the instruments and the rack should be cleaned regularly. Also, electrostatic discharge (ESD) should be controlled by use of static-safe work procedures. For bench installation, the HP 92175T tabletop antistatic mat will decrease the possibility of damage from ESD.

LIST OF SYSTEM INSTRUMENTS, OPTIONS, AND ACCESSORIES

In addition to the Lightwave Component Analyzer, Lightwave Source and Lightwave Receiver, various fiber cables, power splitters, electrical calibration or verification kits, and adapters are required to make the proper measurements. This list is a quick reference for model and part numbers for most of the components. Refer to the HP 8702 Lightwave Component Analyzer Ordering Guide.

NOTE: This list only documents the HP 8702 family of products that may be offered at the time of the printing of this manual. Other products in this family may become available later.

System Instruments

* Asterisks indicate that different connector types are available.

HP 8702 Lightwave Component Analyzer:

Option 006 — 6 GHz operation with an HP 85047A Test Set
Option 802 — External Dual Disc Drive
Option 010 — Time Domain (HP 8702A only)
Option 011 — Delete Time Domain (HP 8702B only)

Lightwave Sources (modulators, O/E):

*HP 83400A Lightwave Source — SMF, 1300 nm, 3 GHz, 9/125 um
*HP 83401A Lightwave Source — MMF, 1300 nm, 3 GHz, 50/125 um
*HP 83402A Lightwave Source — SMF, 1300 nm, 6 GHz, 9/125 um
*HP 83403A Lightwave Source — SMF, 1550 nm, 3 GHz, 9/125 um

Lightwave Receiver (demodulator, E/O):

*HP 83410B Lightwave Receiver — MMF, 1300 nm, 3 GHz
*HP 83410B Lightwave Receiver — MMF, 1300 nm and 1550 nm, 3 GHz, 62.5/125 um
*HP 83411A Lightwave Receiver — SMF, 1300 nm and 1550 nm, 6 GHz, 9/125 um

Cables (required for source/receiver/analyzer/coupler connections):

HP 11886A Interconnect Cable Kit — HMS-10/HP (Diamond) connectors: SMF, 1300 nm, 9/125
HP 11887A Interconnect Cable Kit — HMS-10/HP (Diamond) connectors: MMF, 1300 nm, 50/125

HP 11871A (SMF — PC connectors) Optical Interconnect Cable
HP 1187AB (SMF — ST connectors) Optical Interconnect Cable

HP 11889A Lightwave Component RF Interface Kit (required to separate and route RF output if not using an S-parameter test set) — contains a power splitter, attenuator, and adapter.

Optical Couplers (required for optical reflection measurements):

*HP 11890A Optical Coupler — SMF, 1300 nm and 1550 nm, 9/125 um
*HP 11891A Optical Coupler — MMF, 1300 nm and 1550 nm, 50/125

Test Sets (electrical):

HP 85047A Test Set — used to measure (without DUT disconnection) the transmission and reflection characteristics, up to 6 GHz (using a frequency doubler), of devices with electrical inputs and outputs. The HP test set has built-in signal separation devices (bridges and couplers) that keep the incident, transmitted and reflected signals in separate paths.

HP 85046A/B Test Set — used to measure (without DUT disconnection) the transmission and reflection characteristics, up to 3 GHz, of devices with electrical inputs and outputs. The HP Test Set has built-in signal separation devices (bridges and couplers) that keep the incident, transmitted and reflected signals in separate paths.

HP 85044A/B Transmission/Reflection Test Set — contains the hardware required to make simultaneous transmission and reflection measurements in one direction only.

Options and Service Contracts

Option 006, 6 GHz operation with an HP 85047A Test Set: This extends the maximum receiver frequency of the HP 8702 to 6 GHz, although it does not extend the maximum frequency of the built-in RF Source. When used with the HP 85047A S-parameter test set, the HP 8702 option 006 provides high performance vector measurement capability to 6 GHz.

(HP 8702A only) Option 010, Time Domain: This option has the capability of displaying the time domain response of a network by computing the inverse Fourier transform of the frequency domain response. This option provides the ability to view 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, or displaying the transmission coefficient of a network versus time determines the characteristics of individual transmission paths. Time domain operation retains all accuracy inherent with the calibration that is active in the frequency domain.

(HP 8702B only) Option 011, Delete Time Domain: This option deletes the capability of displaying the time domain response of a network by computing the inverse Fourier transform of the frequency domain response.

Option 802 Dual Disc Drive: This adds a HP 9122-series dual disc drive (3.5 inch) to the HP 8702.

Option 908, Rack Mount Kit without Handles (HP part number 5062-3978).

Option 913, Rack Mount with Handles (HP part number 5062-4072).

Return-to-HP Full Service Agreement (+22A): This is a one year service contract that provides for any repair of the HP 8702 at a Hewlett-Packard repair facility. One complete calibration procedure is included.

Return-to-HP Repair Agreement (+22B): This provides repair of the HP 8702 at a Hewlett-Packard repair facility for a period of one year. Following repair, the instrument is tested functionally but is not fully calibrated.

Return-to-HP Calibration Agreement (+22C): This provides a once-a-year complete calibration procedure at a Hewlett-Packard facility.

Return-to-HP Calibration (+22G): This is a one-time complete calibration procedure performed at a Hewlett-Packard facility. The procedure verifies that the HP 8702 is performing according to its published specifications.

Option W30 Extended Service: This adds two additional years of return-to-HP service, to follow the first year of warranty. Option W30 can be ordered at the time of sale only. Instruments ordered with option W30 are identified on the serial number label.

OTHER ACCESSORIES:

System Rack: The HP 85043B system rack is a 124 cm (49 inch) high metal cabinet designed to rack mount the HP 8702 in a system configuration.

Plotters and Printers: The HP 8702 is capable of plotting or printing displayed measurement results directly to a compatible peripheral without the use of an external computer. Compatible plotters are the HP 7470A Option 002, 7440A Option 002 ColorPro, 7475A Option 002, and 7550A.

Compatible printers for both printing and plotting are the HP 2225A Thinkjet printer, HP 82906A Option 002 graphics printer, HP 2227B QuietJet Plus, HP 2673A thermal graphics printer, and HP 9876A thermal graphics printer. In addition, the HP 3630A PaintJet can be used with the HP 8702B for color hard copy output.

Disc Drive: This is necessary to automatically load the Lightwave Source and Lightwave Receiver calibration disc data into the HP 8702. In addition, the HP 8702 has the capability of storing instrument states directly to an external mass storage device without the use of a computer. Any disc drive that uses CS80 protocol and HP 200/300 series format is compatible. The recommended dual-sided disc drive is the HP 9122-series.

HP-IB Cables: An HP-IB cable is required for interfacing the HP 8702 with a plotter, printer, external disc drive, or computer. The cables available are HP 18033A (1 m), HP 10833B (2 m), and HP 10833D (0.5 m).

Computers (controllers): An external controller is not required for error correction or time domain capability. However, the system can be automated with the addition of an HP 200/300 series computer. In addition, some performance test procedures are semi-automated and require the use of an external controller. The system verification procedure does not require an external controller. For more information about compatible computers, consult your Hewlett-Packard customer engineer.

Tool Kit: This is available for HP 8702 troubleshooting and consists of extender boards, extender cables, and adapters. The contents of the tool kit are listed in the Service Manual.

Power Splitters (for electrical measurements without a test set):

HP 11850C/D Three-Way Power Splitter — These are four-port, three-way power splitters. The ports are used as the reference and test signals to 3 GHz.

HP 11667A/B Power Splitter — These are two-way power splitters with one output arm used for reference and one for test. HP 11667A is DC to 18 GHz (50Ω ohms) and 11667B is DC to 26.5 GHz (50 ohms).

CALIBRATION KITS (for electrical measurement plane calibration):

HP 85033C 3.5 mm Calibration Kit: This kit contains precision standards (load, short, and open) used to calibrate the HP 8702 with an HP Test Set for measurement of devices with precision 3.5 mm connectors, including 7 mm to 3.5 mm adapters that are all of the same electrical length to facilitate calibration of non-insertable devices.

HP 85031B 7 mm Calibration Kit: The precision standards (load, short and open) in this kit are used to calibrate the HP 8702 with an HP Test Set for measurement of devices with precision 7 mm connectors from 300 kHz to 3.0 GHz.

HP 85032B 50 Ohm Type-N Calibration Kit: The precision standards (load, short, and open) in this kit are used to calibrate the HP 8702 with an HP Test Set for measurement of devices with 50 ohm type-N connectors from 300 kHz to 3 GHz. This kit also includes adapters 7mm to type-N that are of the same electrical length to facilitate calibration of non-insertable devices (see Operating and Programming Reference).

HP 85036B 75 Ohm Type-N Calibration Kit: This kit contains precision standards (load, short, and open) used to calibrate the HP 8702 with an HP 75 ohm test set for measurement of devices with 75 ohm type-N connectors, including adapters (m/f) that are all of the same electrical length to facilitate calibration of non-insertable devices.

VERIFICATION KITS (electrical):

Accurate operation and verification of system uncertainty of the HP 8702 can be made by measuring known devices, other than the standards used in calibration, and comparing the results with recorded data for those standards. This is commonly called *performance verification* and requires an HP test set.

HP 85029B (Option 001) 7 mm Verification Kit: This kit contains traceable precision 7 mm devices used to confirm the system's error-corrected electrical measurement uncertainty performance. Also included is verification data on a 3.5 inch disc, together with a hard-copy listing. A system verification procedure (requires an HP 85046A, HP 11857D, HP 9122-series dual sided disc drive) is provided in the Service Manual.

ADAPTER KITS (electrical):

HP 11852B 50 to 75 Ohm Minimum Loss Pad: This device converts impedance from 50 ohms to 75 ohms or from 75 ohms to 50 ohms. It is used to provide a low SWR impedance match between a 75 ohm device under test and the analyzer or a 50 ohm measurement accessory. An HP 11852B pad is included with the HP 85044B 75 ohm transmission/reflection test set. Three HP 11852B pads are included with the HP 11850D 75 ohm power splitter.

HP 11853A 50 Ohm Type-N Adapter Kit: This kit contains the connecting hardware required for making measurements on devices with 50 ohm type-N connectors.

HP 11854A 50 Ohm BNC Adapter Kit: This kit contains the connecting hardware required for making measurements on devices with 50 ohm BNC connectors.

HP 11855A 75 Ohm Type-N Adapter Kit: This kit contains the connecting hardware required for making measurements on devices with 75 ohm type-N connectors.

HP 11856A 75 Ohm BNC Adapter Kit: This kit contains the connecting hardware required for making measurements on devices with 75 ohm BNC connectors.

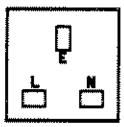
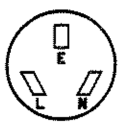
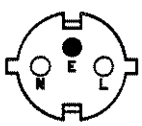
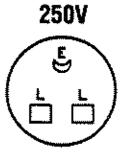
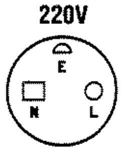
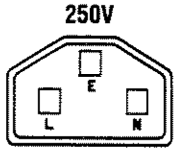
TRANSISTOR TEST FIXTURES (electrical):

HP 11600B and 11602B Transistor Fixtures: These fixtures are used to hold devices for S-parameter measurements in a 50 ohm coaxial circuit. They can be used to measure bipolar or field-effect transistors in several configurations, from DC to 2.0 GHz. The HP 11600B is for transistors with TO-18 to TO-72 package dimensions, and the HP 11602B accepts transistors with TO-5 to TO-12 package dimensions. Both fixtures can also be used to measure other circuit elements such as diodes, resistors, or inductors, which have 0.016 to 0.019 inch diameter leads.

HP 11608A Option 003 Transistor Fixture: This fixture is designed to be user-milled to hold stripline transistors for S-parameter measurements. Option 003 is pre-milled for 0.205 inch diameter disc packages, such as the HP HPAC-200.

HP 11858A Transistor Fixture Adpater: This transistor fixture adapter provides a rigid RF cable interconnection between the HP S-parameter test set and the HP 11600B, 11602B, or 11608A transistor fixture.

Table 1-1. AC Power Plugs Available

Plug Type[1]	Cable HP Part Number[2]	CD[3]	Plug Description[2]	Cable Length (inches)	Cable Color	For Use in Country
250V 	8120-1351 8120-1703	0 6	Straight BS1363A 90°	90 90	Mint Gray Mint Gray	United Kingdom, Cyprus, Nigeria, Zimbabwe, Singapore
250V 	8120-1369 8120-0696	0 4	Straight ZNSS198/ASC112 90°	79 87	Gray Gray	Australia, New Zealand
250V 	8120-1689 8120-1692	7 2	Straight CEE7-VII 90°	79 79	Mint Gray Mint Gray	East and West Europe, Saudi Arabia, Egypt, Republic of So. Africa, India (unpolarized in many nations)
125V 	8120-1348 8120-1398 8120-1754 8120-1378 8120-1521 8120-1676	5 5 7 1 6 2	Straight NEMA5-15P 90° Straight NEMA5-15P Straight NEMA5-15P 90° Straight NEMA5-15P	80 80 36 80 80 36	Black Black Black Jade Gray Jade Gray Jade Gray	United States, Canada, Japan (100V or 200V), Mexico, Philippines, Taiwan
250V 	8120-2104	3	Straight SEV1011.1959 24507,Type 12	79	Gray	Switzerland
250V 	8120-0698	6	Straight NEMA6-15P			United States, Canada
220V 	8120-1957 8120-2956	2 3	Straight DHCK 107 90°	79 79	Gray Gray	Denmark
250V 	8120-1860	6	Straight CEE22-VI (System Cabinet Use)			

1. E = Earth Ground; L = Line; N = Neutral
2. Part number shown for plug is industry identifier for plug only. Number shown for cable is HP Part Number for complete cable including plug.
3. The Check Digit (CD) is a coded digit that represents the specific combination of numbers used in the HP Part Number. It should be supplied with the HP Part Number when ordering any of the power assemblies listed above, to expedite speedy delivery.

Section 2. Specifications and System Performance

This section of the manual describes the following:

TYPICAL SYSTEM PERFORMANCE (measurement uncertainty) — These are a set of typical curves (plots) that describe the measurement accuracy of the Lightwave Component Analyzer system under certain conditions. These curves can be used to assign a value of uncertainty (+/-3 sigma dB value) to your measurements based upon the RF modulation frequency, DUT return loss, or other DUT parameters. In addition, several other plots are shown to further describe measurement repeatability and the HP lightwave source (laser) reflection sensitivity. The APPENDIX contains detailed electrical device measurement uncertainty information (equations, error models, etc.) under the heading *Electrical Device Measurements*.

INSTRUMENT SPECIFICATIONS (stand-alone) — These are a set of values or characteristics that describe the stand-alone performance of the analyzer. *Stand-alone* means the analyzer's performance without an E/O source, O/E receiver, or electrical test set connected. These values describe the accuracy and performance level of the internal RF source, internal RF receiver section, and other general aspects of the analyzer. Refer to the heading marked *Instrument Specifications (stand-alone)* at the end of this section.

CONTENTS OF THIS SECTION

continued next page

TYPICAL SYSTEM PERFORMANCE
(Measurement Uncertainty)

Overview

The following curves and descriptions apply to 3 GHz systems at 1300 nm and 1550 nm, and 6 GHz systems (option 006) at 1300 nm for mostly single mode fiber (SMF) devices. Refer to the measurement type listed in the contents. Then refer to the specific plot configuration, and its assumptions or conditions. The plot can then be used to determine the typical uncertainty of your device measurement.

All curves are based upon typical measurements made at the factory using an HP 8702 system as shown for each configuration below. Minimum and maximum curves were obtained by adjusting a polarization controller at the output of the lightwave source to achieve the greatest differences during the measurement. This method of obtaining minimum and maximum values is shown in the Reflection Sensitivity plot for O/O transmission measurements.

Some plots also show (using a dashed line) the improved uncertainty value that is obtained by inserting a low reflection (high return loss) 10 dB optical attenuator (HP 8157A) between the lightwave source and the DUT. When this is done, all measurement calibrations will correct for this configuration with respect to magnitude and phase data.

The assumptions (conditions) given with each plot describe the type of calibration required, the RF input power level and the DUT insertion or return loss.

System Configuration Information

The system uncertainty plots in this section are given for two different system configurations.

3 GHz system: This system is shown using the HP 11889A RF Interface Kit (no test set) for all optical type measurements. This 3 GHz configuration applies to either 1300 nm (HP 83400A SMF Lightwave Source) or 1550 nm (HP 83403A SMF Lightwave Source). Either wavelength source uses the HP 83410A/B Lightwave Receiver.

6 GHz system: This system is shown using an HP 85047A Test Set, HP 83402A SMF 1300 nm Lightwave Source, HP 83411A Lightwave Receiver, and a polarization controller. In addition, the 6 GHz uncertainty plots assume that the 6 GHz frequency range has been selected on the primary menu of the HP 8702. This selection enables the frequency doubler in the test set for 6 GHz systems (option 006).

Improving Measurement Uncertainty

3 GHz system: By properly connecting and adjusting a *polarization controller*, *optical isolator*, or *low return loss optical attenuator* directly after the lightwave source, the measurement uncertainty and data can be improved. This improvement is a result of reducing the polarization sensitivity of the lightwave source.

6 GHz system: By properly connecting and adjusting a *polarization controller* or an *optical isolator* directly after the lightwave source, the measurement uncertainty and data can be improved. This improvement is a result of reducing the polarization sensitivity of the lightwave source. Note that an optical attenuator is not recommended for use in the 6 GHz system because it could degrade the dynamic range of the system.

Use of the Polarization Controller

Most of the uncertainty plots shown in this section are based upon using a polarization controller to adjust the effects of light reflected back into the laser. This is accomplished by adjusting the elements or loops to change the polarization of the light. This reduces the coherence of the incident light to the reflected light. The result is a decrease in the sensitivity of the laser to the reflected light and less ripple on the displayed trace.

The polarization controller is connected directly after the lightwave source (E/O converter) during the measurement calibration process and the measurement as follows:

> After selecting all the measurement parameters, adjust the polarization controller by moving the elements until the smoothest trace possible (least amount of peak-to-peak ripple) appears on the CRT. Then perform the calibration. After you insert your DUT, readjust the polarization controller again for the smoothest trace possible. This method will provide the best measurement results.
>
> Note that the polarization controller shown in the 6 GHz system configuration has three elements or loops. However, a two element polarization controller can also be used.

The 3 GHz system may show maximum (max) and minimum (min) curves for some plots. The *min* uncertainty curve represents the polarization controller adjusted to minimize the reflection sensitivity. The *max* curve represents the uncertainty where the polarized light results in the greatest effects (most ripple on the trace) as if no polarization controller were used at all. In general, the uncertainty can be read as a window where the measurement uncertainty is between the *min* and *max* curves.

Definitions

INPUT POWER: This is the RF modulation power (dBm) delivered to the lightwave source's electrical input when +20 dBm is selected on the analyzer's RF power menu. After transmission path attenuation, a 3 GHz system, using the RF Interface Kit, will deliver +14 dBm; a 6 GHz system, using the HP 85047A Test Set, will deliver approximately 0 dBm to the lightwave source.

RETURN LOSS: The amount of signal power reflecting off or returning from a device, compared to the incident signal. Return loss is expressed as a linear reflection coefficient (rho) or a dB value. Because the analyzer display is often logarithmic, return loss RL is expressed in dB. The return loss of your DUT can be measured by making an optical reflection measurement, explained in the User's Guide. For example, a 3.5% Fresnel reflection is −14.6 dB where:

RL = −10 log Reflected Power / Incident Power
RL = −10 log 3.5% / 100%
RL = −10 log 0.035
RL = −14.6 dB

INSERTION LOSS: The amount of signal power (dB) dissipated in a device, compared to the incident signal inserted into the device. The loss is usually due to the attenuation of the device as the signal passes through it. For example, if a 10 dBm signal is injected to a DUT and 7 dBm is measured as its output, then insertion loss is 3 dB.

REFLECTION SENSITIVITY: This is a measure of the lightwave source's sensitivity to reflected light entering the laser cavity.

Typical Example: How to Determine Your Measurement Uncertainty

Suppose you were measuring the bandwidth of a roll of fiber and wanted to know the measurement accuracy at 500 MHz modulation. You would perform a *thru* measurement calibration for an O/O device (explained in the *User's Guide*). You would then measure the roll of cable to determine the modulation bandwidth or, in this case, the response (in dB) at a modulation frequency of 500 MHz. You would refer to the O/O transmission measurement plot (figure) titled *3 GHz Typical Uncertainty vs. Frequency*. Using the plot, you would locate the 500 MHz point on the *X* axis. In this case, the solid line curves indicate a minimum and maximum value of about +/-0.85 dB. And the dashed lines show the improvement (about 0.55 dB) in typical measurement performance using a low reflection 10 dB optical attenuator between the lightwave source and the DUT roll of fiber. Assuming that the DUT had −10 dB of insertion loss, −20 dB of return loss on both optical ports, and +14 dBm RF input power input to the lightwave source, the curves show that the 500 MHz point has an uncertainty of +/-0.85 dB (no 10 dB attenuator). Therefore, if the 500 MHz modulation point value showed −10 dB on the CRT of the analyzer, the measurement would have an total uncertainty window of −9.15 dB to −10.85 dB, assuming the insertion loss is ignored.

3 GHz OPTICAL (O/O) TRANSMISSION MEASUREMENTS

Measurements of devices with optical inputs and optical outputs have a value of uncertainty that can be determined by the RF modulation frequency and the insertion loss of the DUT. In addition, the reflection sensitivity of the lightwave source is given as a measure of system performance.

Included in the total uncertainty value (shown by the plots) are the following individual contributing uncertainties:

- Optical connector repeatability
- Drift with temperature (23 +/-3 degrees Centigrade)
- Dynamic accuracy
- Reflection sensitivity
- Optical mismatches or reflections between:
  - —lightwave source/lightwave receiver
  - —lightwave source/DUT
  - —DUT/lightwave receiver

3 GHz System Configuration - O/O

The following plots are based on the system shown configured below, using an HP 83400A or HP 83403A SMF Lightwave Source, HP 83410A or B Lightwave Receiver, HP 11886A Interconnect Cable Kit (HMS-10/HP), and an HP 11889A RF Interface Kit (RF power splitter).

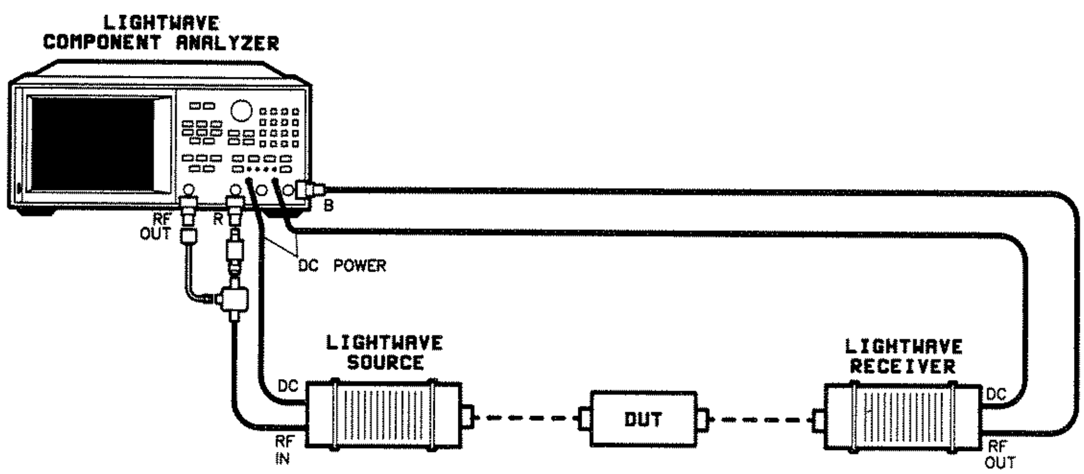


Figure 2-1. 3 GHz Optical Transmission Measurement Configuration

3 GHz Typical Uncertainty vs. Modulation Frequency - O/O

This curve shows the uncertainty (dB) for measurements made over the modulation frequency range of 300 kHz to 3 GHz. The minimum and maximum curves (solid lines) are for the configuration shown in the figure. The dashed line represents the value for the same configuration with a low reflection 10 dB optical attenuator (HP 8157A) connected between the lightwave source and the DUT.

Assumptions or Conditions

- O/O Thru Calibration on HP 8702
- DUT insertion loss = −10 dB
- DUT optical input return loss = −20 dB
- DUT optical output return loss = −20 dB
- RF input power to the lightwave source = +14 dBm

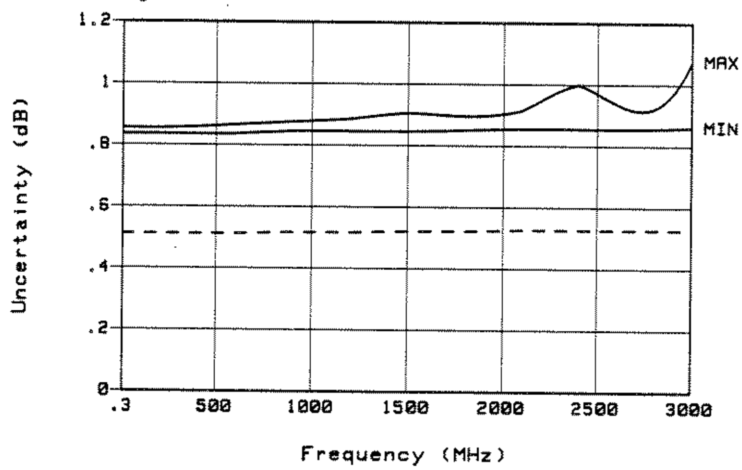


Figure 2-2. 3 GHz Typical Uncertainty vs. Frequency

3 GHz Typical Uncertainty vs. Insertion Loss - O/O

This curve shows the uncertainty (dB) for measurements made with DUT insertion loss between 0 and −40 dB. The solid line represents the uncertainty for measurements made on the configuration shown in the figure. The dashed line represents the value for the same configuration with a low reflection 10 dB optical attenuator (HP 8157A) connected between the lightwave source and the DUT.

Assumptions or Conditions

- O/O Thru calibration on HP 8702
- DUT optical input return loss = −20 dB
- DUT optical output return loss = −20 dB
- RF input power to the lightwave source = +14 dBm

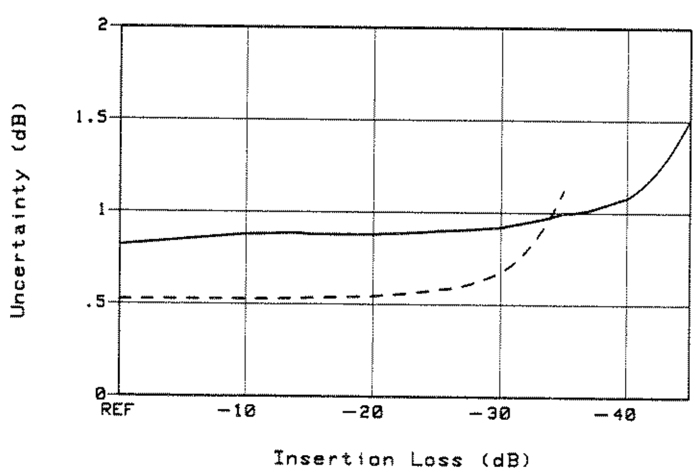


Figure 2-3. 3 GHz Typical Uncertainty vs. Insertion Loss

3 GHz Typical Reflection Sensitivity vs. Modulation Frequency - O/O

This curve shows the uncertainty contribution of reflection sensitivity (dB) to measurements made over the frequency range of 300 kHz to 3 GHz. The solid lines represent the minimum and maximum values for the HP 83400A or HP 83403A Lightwave Source where a polarization controller was adjusted to obtain the maximum and minimum values.

Assumptions or Conditions

O/O Thru calibration on HP 8702
RF input power to the lightwave source = +14 dBm

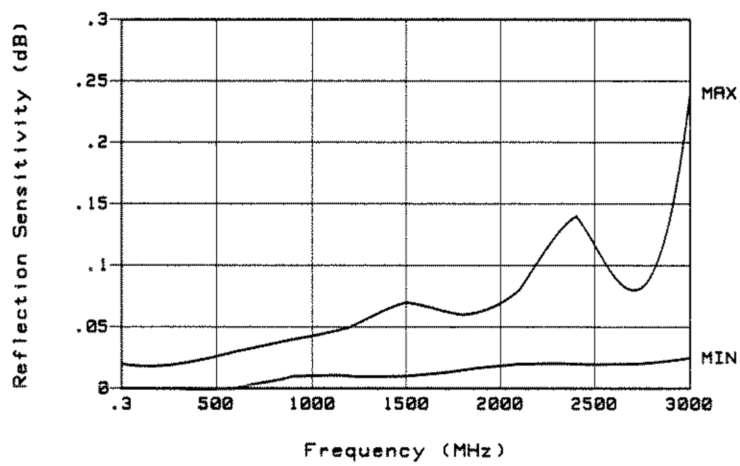


Figure 2-4. 3 GHz Typical Reflection Sensitivity vs. Frequency

3 GHz OPTICAL REFLECTION MEASUREMENTS

Reflection measurements of the optical port of any device have an uncertainty value based upon the amount of return loss (magnitude of reflection).

Included in the total uncertainty value (shown by the plots) are the following individual contributing uncertainties:

- Optical connector repeatability
- Drift with temperature (23 +/-3 degrees Centigrade)
- Dynamic accuracy
- Reflection sensitivity
- Optical mismatches or reflections between:
  - —lightwave source/lightwave coupler
  - —lightwave coupler/DUT
  - —lightwave coupler/lightwave receiver
- Effective system directivity

3 GHz System Configuration - Optical Reflection

The following plots are based on the system shown configured below, using an HP 83400A or HP 83403A SMF Lightwave Source, HP 83410A or B Lightwave Receiver, HP 11890A Lightwave Coupler, HP 11886A Interconnect Cable Kit (HMS-10), and an HP 11889A RF Interface Kit (RF power splitter).

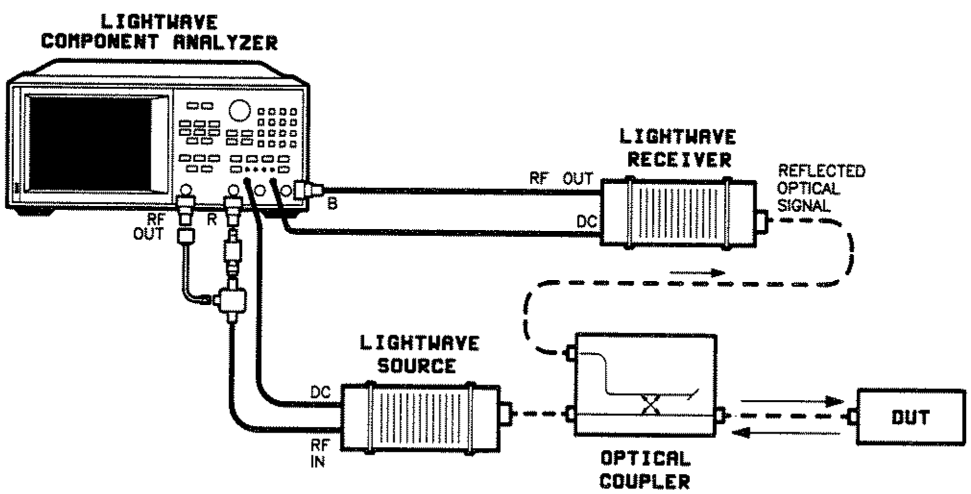


Figure 2-5. 3 GHz Optical Reflection Measurement Configuration

3 GHz Typical Uncertainty vs. Return Loss - Optical Reflection

This curve shows the uncertainty (dB) for reflection measurements made with DUT return loss of 0 to −40 dB. The solid line represents the uncertainty for measurements made on the configuration shown in the figure. The dashed line represents the value for the same configuration with a low loss 10 dB optical attenuator (HP 8157A) connected between the lightwave source and the HP optical coupler.

Reflection calibrations made with a Fresnel reflection (glass to air) on the coupler output port will result in −14.6 dB of return loss which is equal to 3.5% reflected optical power.

NOTE: Return loss $= -10 \log \frac{\text{Reflected Power}}{\text{Incident Power}}$

Assumptions or Conditions

Fresnel reflection calibration on the HP 8702
RF input power to the lightwave source = +14 dBm

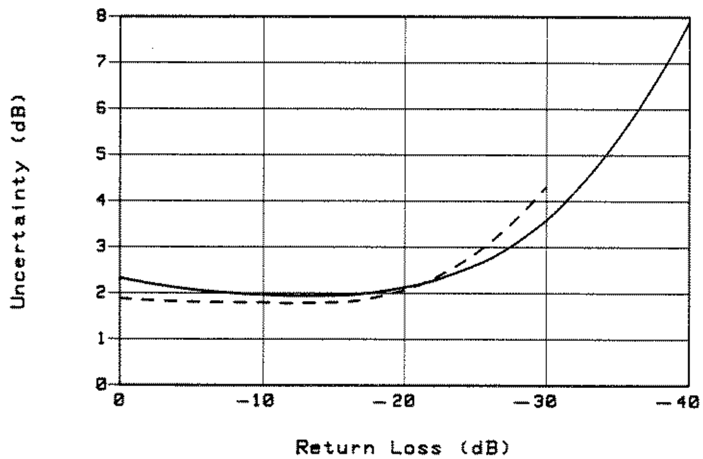


Figure 2-6. 3 GHz Typical Uncertainty vs. Return Loss

3 GHz OPTICAL-ELECTRICAL TRANSMISSION MEASUREMENTS

Measurements of O/E devices with optical inputs and electrical outputs have a total value of uncertainty that includes various individual uncertainties. The total measurement uncertainty (dB) is shown plotted against the DUT responsivity (dB). In addition, there is a plot showing how the RF modulation frequency can also be used to assign an uncertainty value to O/E converter measurements.

Included in the total uncertainty value (shown by the plots) are the following individual contributing uncertainties:

- Optical connector repeatability
- Drift with temperature (23 +/-3 degrees Centigrade)
- Dynamic accuracy
- Reflection sensitivity
- Wavelength accuracy
- Factory test (characterization) system
- Electrical mismatches or reflections between:
  - —RF source/lightwave source RF input
  - —RF receiver/lightwave receiver RF output
- Optical mismatches or reflections between:
  - —lightwave source/lightwave receiver
  - —lightwave source/DUT

3 GHz System Configuration - O/E

The following plots are based on the system shown configured below, using an HP 83400A or HP 84403A SMF Lightwave Source, HP 83410 Lightwave Receiver, HP 11886A Interconnect Cable Kit (HMS-10/HP), and an HP 11889A RF Interface Kit.

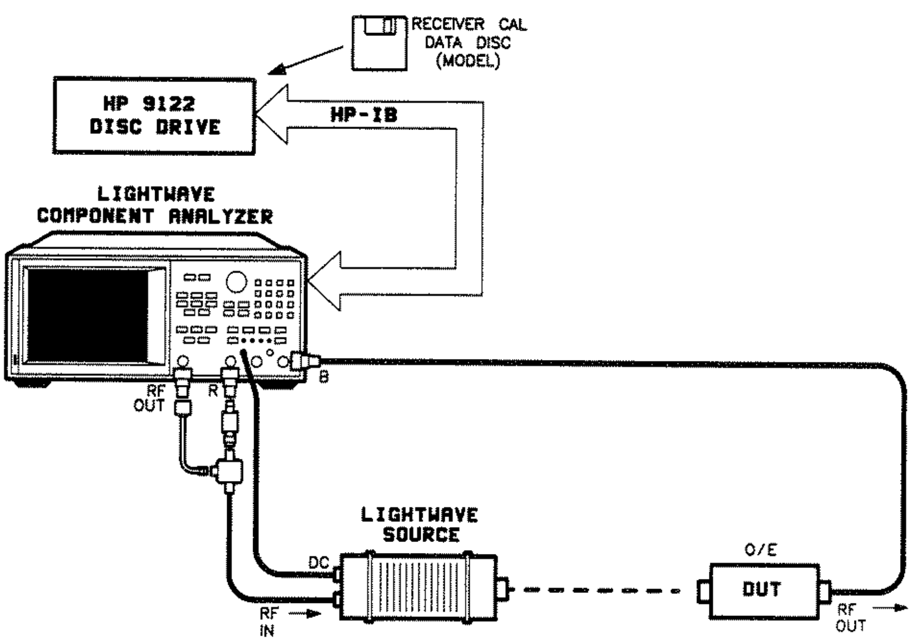


Figure 2-7. 3 GHz O/E Transmission Measurement Configuration

3 GHz Typical Uncertainty vs. Responsivity (dB) - O/E

Two curves are used to show the uncertainty (dB) for measurements made with DUT responsivity from +20 to −70 dB. These curves are plotted for: ABSOLUTE (at 50 MHz modulation only) and RELATIVE (300 kHz to 3 GHz modulation) uncertainty. The solid lines represent values for the configuration shown in the figure. The dashed lines represent values for the same configuration with a low reflection 10 dB optical attenuator (HP 8157A) connected between the lightwave source and the DUT.

The *Absolute* uncertainty plot shows the total measurement uncertainty (dB) calculated for a single modulation frequency (50 MHz) used for factory calibration of HP Lightwave Sources and Lightwave Receivers. This curve includes all optical related uncertainties like wavelength uncertainty, model (disc data) uncertainty, and all lightwave source/receiver mismatch uncertainties for that specific modulation frequency.

The *Relative* uncertainty plot shows the total measurement uncertainty(dB) calculated for DUT transmission characteristics with respect to changes in modulation frequency (also called frequency response) from 300 kHz to 3 GHz. This curve is intended to show the total uncertainty for modulation bandwidth measurements which are not dependent upon uncertainties associated with a calibrated single modulation frequency.

The responsivity of an O/E device can be read off the CRT in dB or linear for any given frequency. The User's Guide describes how to convert the dB value to its corresponding *amps/watt* responsivity value in the example for measuring an O/E converter where,

$$\text{Responsivity R (dB)} = 20 \log_{10}\left[\frac{\text{R (a/w)}}{\text{1 (a/w)}}\right]$$

Assumptions or Conditions

Receiver calibration using disc data on HP 8702
DUT optical input return loss = −14 dB
DUT electrical output return loss = −14 dB
RF input power to the lightwave source = +14 dBm

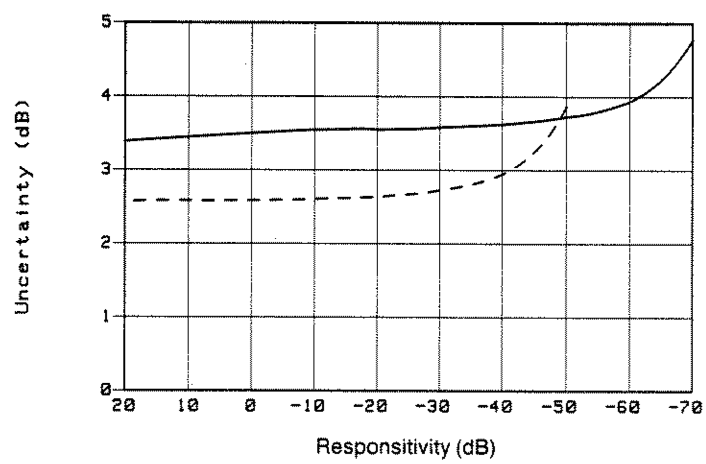


Figure 2-8. Typical Absolute Uncertainty vs. Responsivity at 50 MHz RF Modulation Frequency

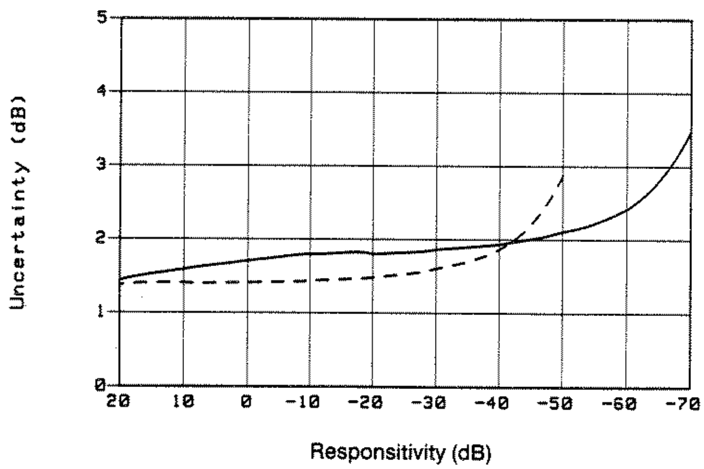


Figure 2-9. Typical Relative Uncertainty vs. Responsivity over 300 kHz to 3 GHz Modulation Frequency

3 GHz Typical Uncertainty vs. Modulation Frequency - O/E

This curve shows the total measurement uncertainty (dB) for a DUT with −10 dB responsivity over the RF modulation frequency range of 300 kHz to 3 GHz. The solid lines represent the maximum and minimum values obtained by adjusting a polarization controller connected directly after the lightwave source. The dashed line represents the value for the same configuration with a low reflection 10 dB optical attenuator (HP 8157A) connected between the lightwave source and the DUT.

Assumptions or Conditions

- Receiver calibration using disc data on HP 8702
- RF input power to the lightwave source = +14 dBm
- DUT optical input return loss = −14 dB
- DUT electrical input return loss = −14 dB
- DUT Responsivity = −10 dB

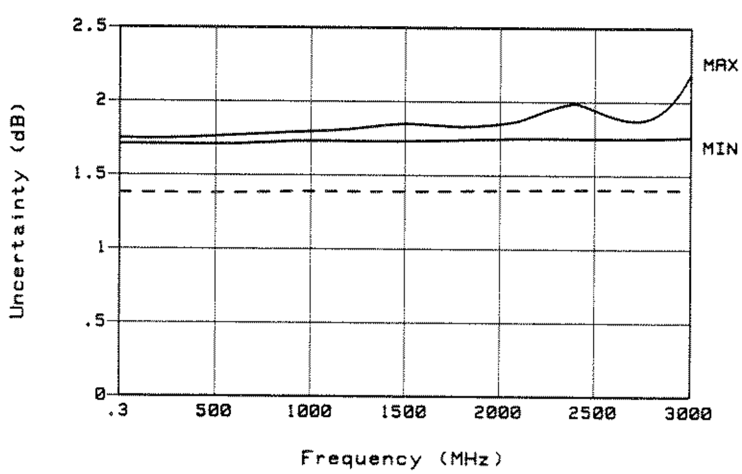


Figure 2-10. 3 GHz Typical Relative Uncertainty vs. Modulation Frequency

3 GHz ELECTRICAL-OPTICAL TRANSMISSION MEASUREMENTS

Measurements of E/O devices with electrical inputs and optical outputs have a total value of uncertainty that includes various individual uncertainties. The total measurement uncertainty (dB) is shown plotted against the DUT responsivity (dB). In addition, there is a plot showing how the RF modulation frequency can also be used to assign an uncertainty value to E/O converter measurements.

Included in the total uncertainty value (shown by the plots) are the following individual contributing uncertainties:

- Optical connector repeatability
- Drift with temperature (23 +/-3 degrees Centigrade)
- Dynamic accuracy
- Reflection sensitivity
- Wavelength accuracy
- Factory test (characterization) system
- Electrical mismatches or reflections between:
    - —RF source/lightwave source RF input
    - —RF receiver/lightwave receiver RF output
- Optical mismatches or reflections between:
    - —lightwave source/lightwave receiver
    - —DUT/lightwave receiver

System Configuration

The following plots are based on the system shown configured below, using an HP 83400A or HP 83403A SMF Lightwave Source, HP 83410A or B Lightwave Receiver, HP 11886A Interconnect Cable Kit (HMS-10/HP —Diamond), and an HP 11889A RF Interface Kit.

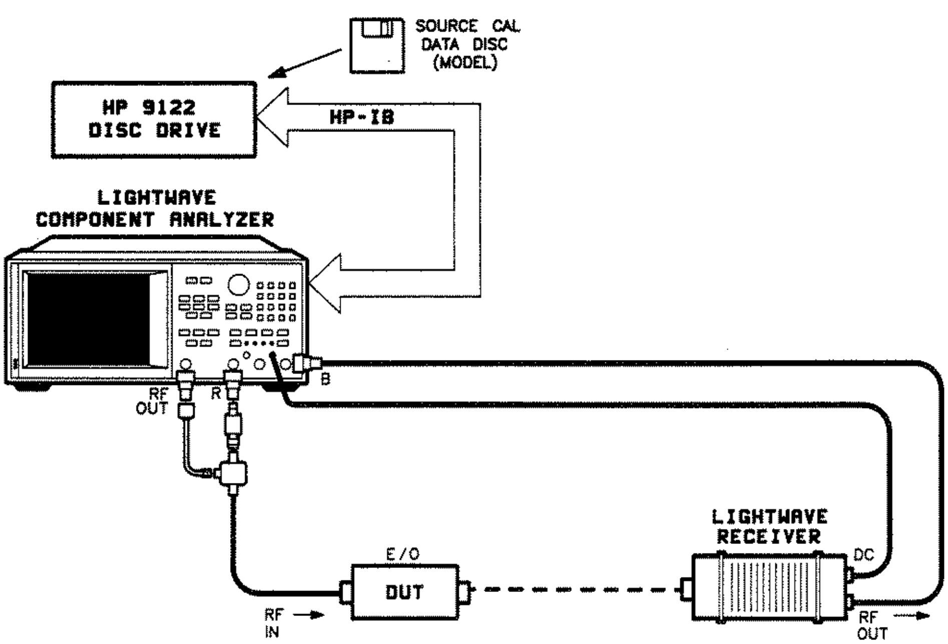


Figure 2-11. 3 GHz E/O Transmission Measurement Configuration

3 GHz Typical Uncertainty vs. Responsivity (dB) - E/O

Two curves show the uncertainty (dB) for measurements made with DUT responsivity from −5 to −45 dB. These curves are plotted for: ABSOLUTE (at 50 MHz modulation only) and RELATIVE (300 kHz to 3 GHz modulation) uncertainty. The solid lines represent values for the configuration shown in the figure. The dashed lines represent values for the same configuration with a low reflection 10 dB optical attenuator (HP 8157A) connected between the DUT and the lightwave receiver.

The *Absolute* uncertainty plot shows the total measurement uncertainty (dB) calculated for a single modulation frequency (50 MHz) used for factory calibration of HP Lightwave Sources and Lightwave Receivers. This curve includes all optical related uncertainties like wavelength uncertainty, model (disc data) uncertainty, and all lightwave source/receiver mismatch uncertainties for that specific modulation frequency.

The *Relative* uncertainty plot shows the total measurement uncertainty(dB) calculated for DUT transmission characteristics with respect to changes in modulation frequency (also called frequency response) from 300 kHz to 3 GHz. This curve is intended to show the total uncertainty for modulation bandwidth measurements which are not dependent upon uncertainties associated with a calibrated single modulation frequency.

The responsivity of an E/O device can be read off the CRT in dB for any given frequency. The HP 8702A User's Guide describes how to convert this dB value to its corresponding *watts/amp* responsivity value where,

$$\text{Responsivity (dB)} = 20 \log_{10}\left[\frac{\text{R (w/a)}}{\text{1 (w/a)}}\right]$$

Assumptions or Conditions

Source calibration using disc data on HP 8702
DUT optical output return loss = −10 dB
DUT electrical input return loss = −14 dB
RF input power (values in parenthesis on plot) = various RF power levels (dBm) input to the lightwave source

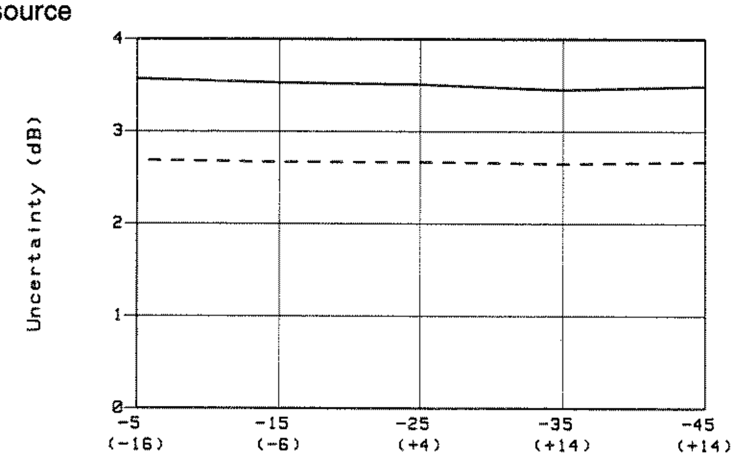


Figure 2-12. Typical Absolute Uncertainty vs. Responsivity at 50 MHz RF Modulation Frequency

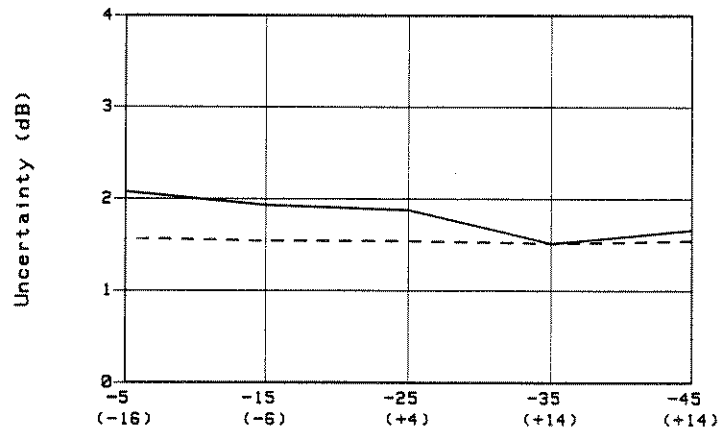


Figure 2-13. Typical Relative Uncertainty vs. Responsivity for 300 kHz to 3 GHz RF Modulation Frequency

3 GHz Typical Uncertainty vs. Modulation Frequency −E/O

This curve shows the measurement uncertainty (dB) for a DUT with −35 dB responsivity over the RF modulation frequency range of 300 kHz to 3 GHz. The solid lines represent the maximum and minimum values obtained by adjusting a polarization controller connected directly after the lightwave source.

Assumptions and Conditions

Source calibration using disc data on HP 8702
RF input power to the lightwave source = +14 dBm
DUT electrical input return loss = −14 dB
DUT optical output return loss = −10 dB
DUT Responsivity = −35 dB

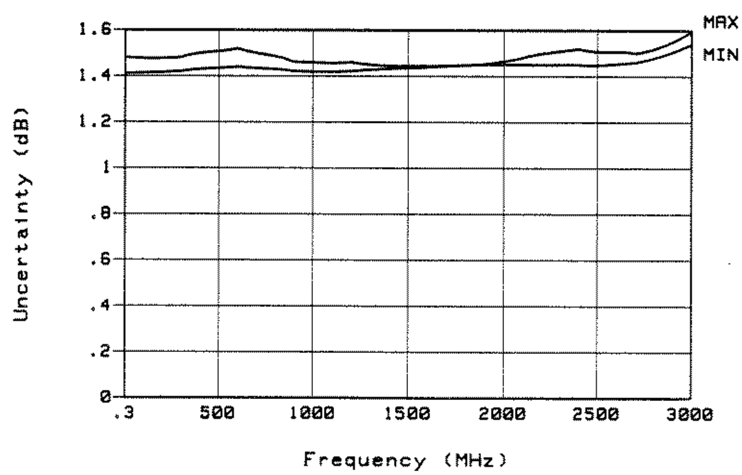


Figure 2-14. Typical Relative Uncertainty vs. Modulation Frequency

3 GHz ELECTRICAL REFLECTION MEASUREMENTS

Reflection measurements of the electrical ports of various devices have a value of uncertainty (magnitude and phase) that can be determined by the reflection coefficient, the type of calibration, and the electrical connector type. The plots below show the uncertainty for one-port and two-port devices using 7 mm connectors.

3 GHz System Configuration - Electrical Reflection

The following plots are based on the system shown configured below, using an HP 85046 or HP 85047 S-Parameter Test Set and 7 mm connectors.

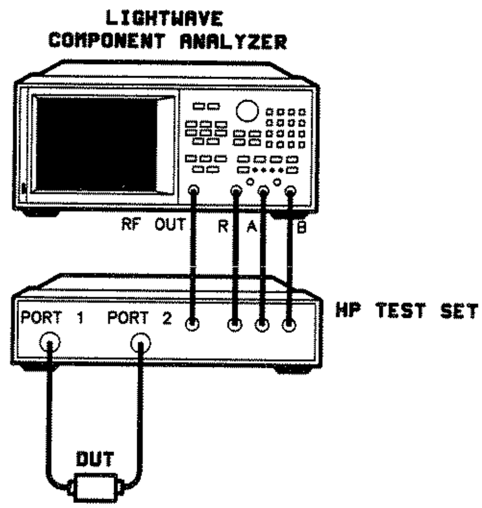


Figure 2-15. 3 GHz Electrical Reflection Measurement Configuration

3 GHz Electrical Reflection Uncertainty of a One-Port Device

Assumptions or Conditions:

Reference = −20 dBm RF power to DUT
S21 = S12 = 0 (one-port device only)

Uncorrected — - — - —
Response · · · · · · · · ·
Response and Isolation — — — — —
Full one or two port ————

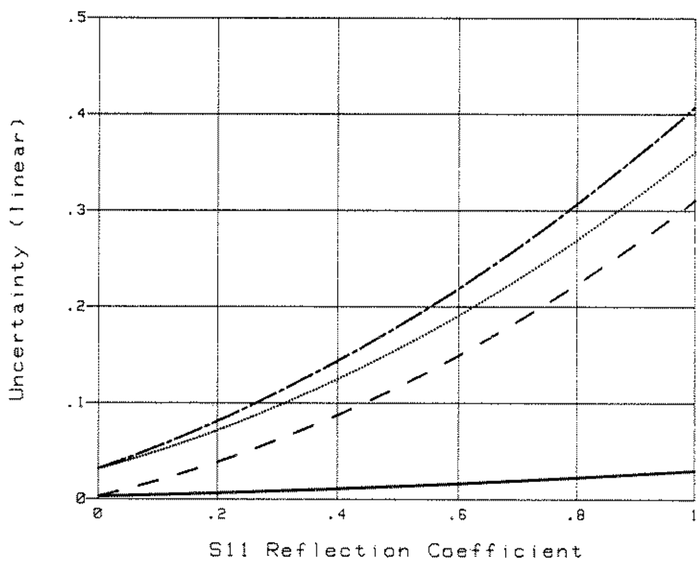


Figure 2-16. Total Reflection Magnitude Uncertainty

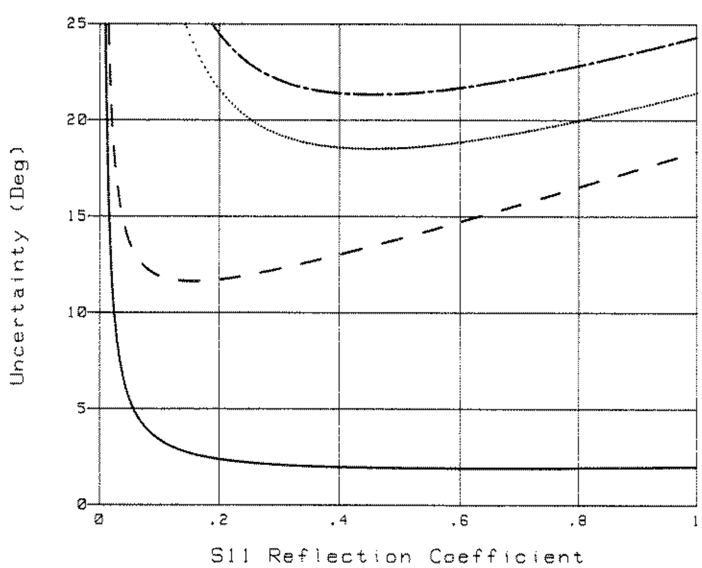


Figure 2-17. Total Reflection Phase Uncertainty

3 GHz Electrical Reflection Uncertainty of a Two-Port Device

Assumptions or Conditions:

Reference = −20 dBm RF power to DUT
S21 = S12 = 0.5 (6 dB insertion loss device)

Uncorrected — - — - —
Response ·········
Response and Isolation — — — — —
Full one or two port ————

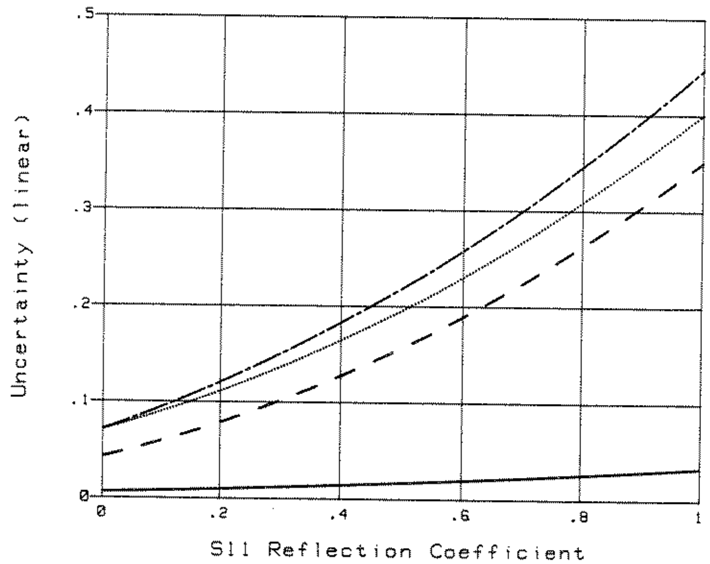


Figure 2-18. Total Reflection Magnitude Uncertainty

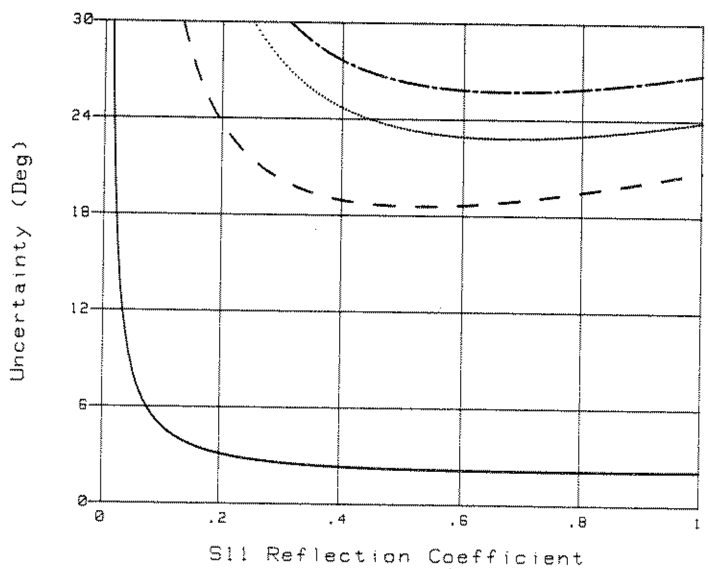


Figure 2-19. Total Reflection Phase Uncertainty

3 GHz ELECTRICAL (E/E) TRANSMISSION MEASUREMENTS

Transmission measurements of devices with electrical input and output ports have a value of uncertainty (magnitude and phase) that can be determined by the insertion loss, the type of calibration, and the electrical connector type. The plots below show the uncertainty for two-port devices using 7 mm connectors.

3 GHz System Configuration - E/E

The following plots are based on the system shown configured below, using an HP 85046 or HP 85047 S-Parameter Test Set and 7 mm connectors.

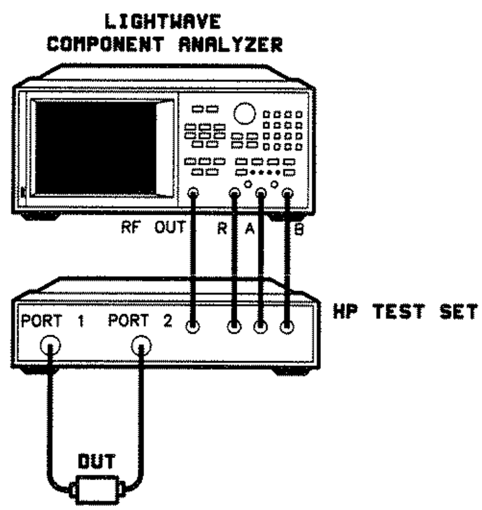


Figure 2-20. 3 GHz Electrical Transmission Measurement Configuration

3 GHz Transmission Uncertainty of a Low-Loss Device

Assumptions or Conditions:

Reference = −10 dBm RF power to DUT
S11 = S22 = 0.1

Uncorrected —·—·—
Response ·········
Response and Isolation — — — — —
Full one or two port ————

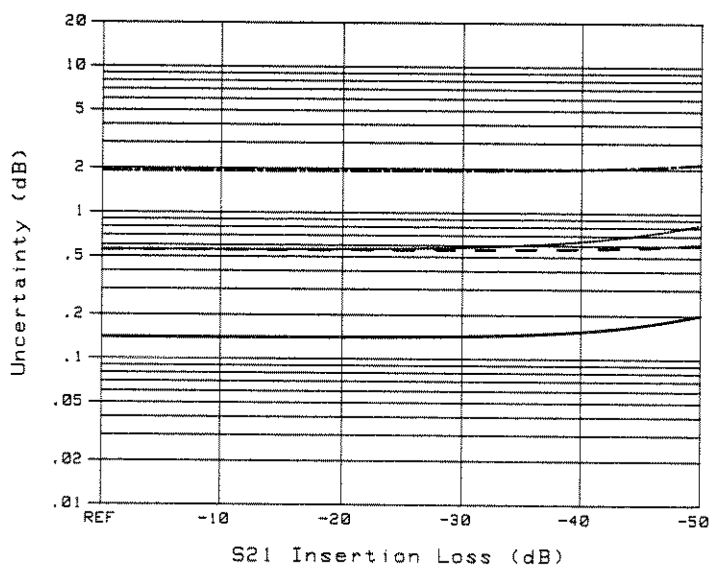


Figure 2-21. Total Transmission Magnitude Uncertainty

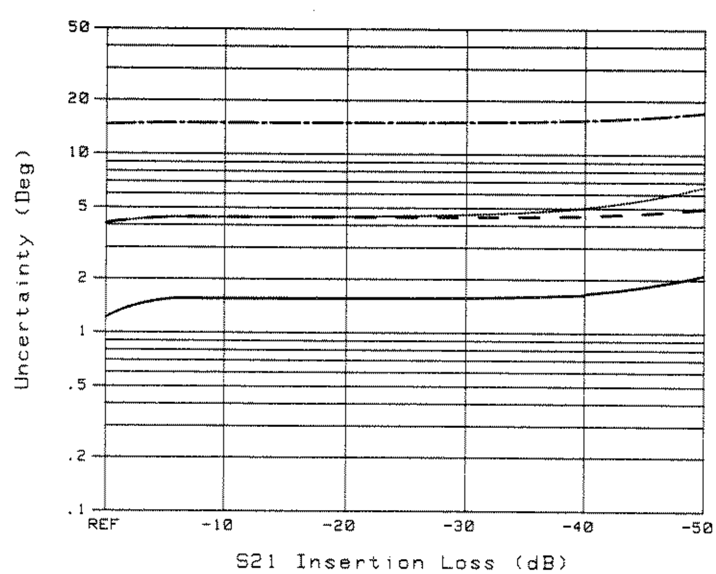


Figure 2-22. Total Transmission Phase Uncertainty

3 GHz Transmission Uncertainty of a Wide Dynamic Range Device

Assumptions or Conditions:

Reference = 0 dBm RF power to DUT
S11 = S22 = 0.1

Uncorrected — · — · —
Response · · · · · · · · ·
Response and Isolation — — — — —
Full one or two port ————

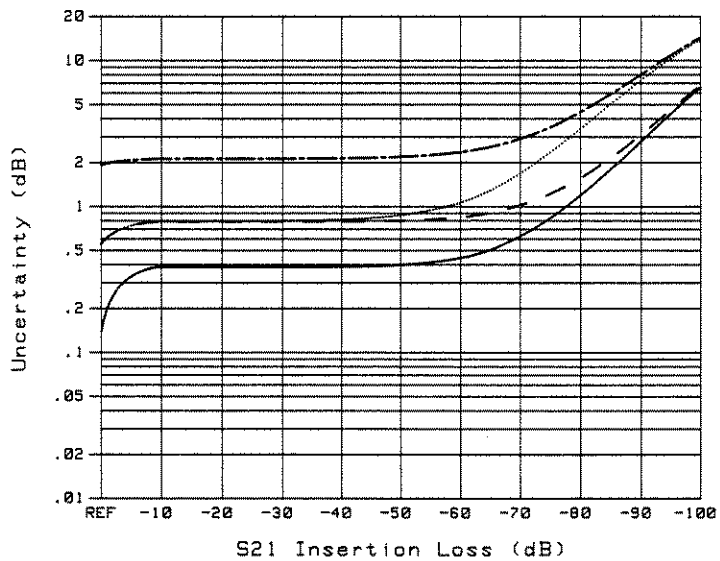


Figure 2-23. Total Transmission Magnitude Uncertainty

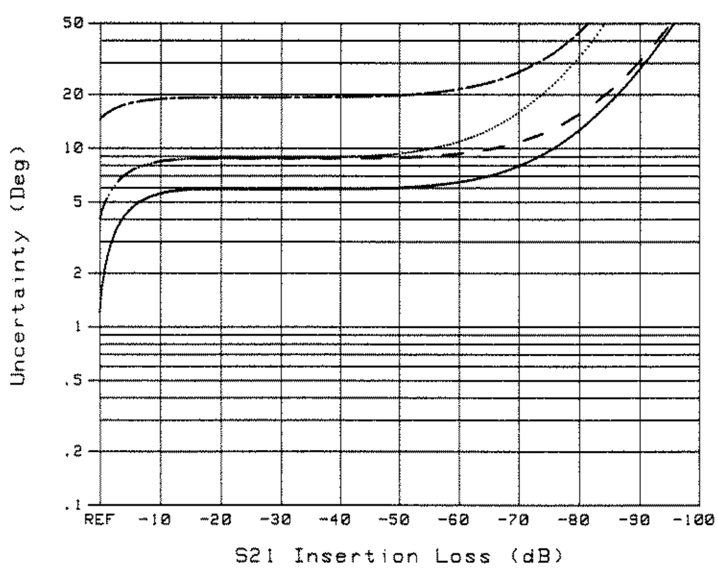


Figure 2-24. Total Transmission Phase Uncertainty

3 GHz TYPICAL SYSTEM REPEATABILITY AND LIGHTWAVE SOURCE REFLECTION SENSITIVITY

The following measurements show the performance of systems using FC/PC connectors in both wet and dry conditions. The curves represent typical test results, using a 3 GHz system, and are intended to show typical system performance.

1. **ELECTRICAL DRIFT**

   This plot shows the system's ability to maintain stable electrical conditions with little change in magnitude response over 15 hours. The measurement is made by performing an electrical thru calibration (300 kHz to 3 GHz) and then selecting a CW time of 15 hours at 1 GHz to make the single sweep 1601 point measurement. To achieve this, the interpolation feature is used to take the single frequency point (1 GHz) from the already acquired calibration data. Note that the drift is only about a few thousands of a dB.

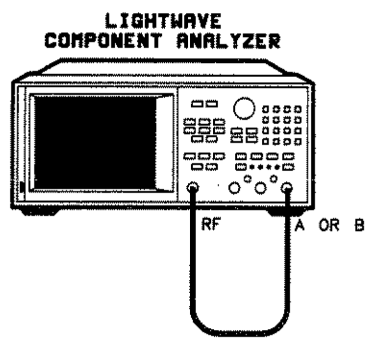


Figure 2-25. E/E Measurement Configuration

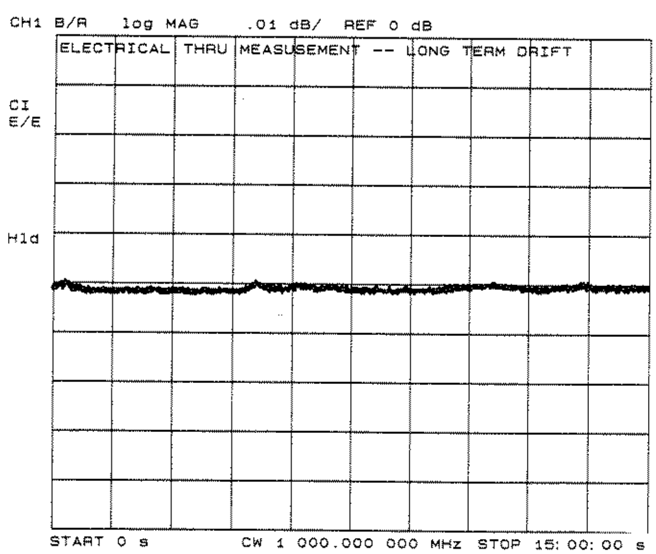


Figure 2-26. 15 Hour E/E Drift

2. OPTICAL DRIFT

This plot shows the system's ability to maintain stable E/O and O/E conditions with little change in the magnitude response over 15 hours. The measurement is made by performing an optical thru calibration (300 kHz to 3 GHz) and then selecting a CW time of 15 hours at 1 GHz to make the measurement. To achieve this, the interpolation feature is used to take the single frequency point (1 GHz) from the already acquired calibration data. Note that the drift is only about a few hundredths of a dB.

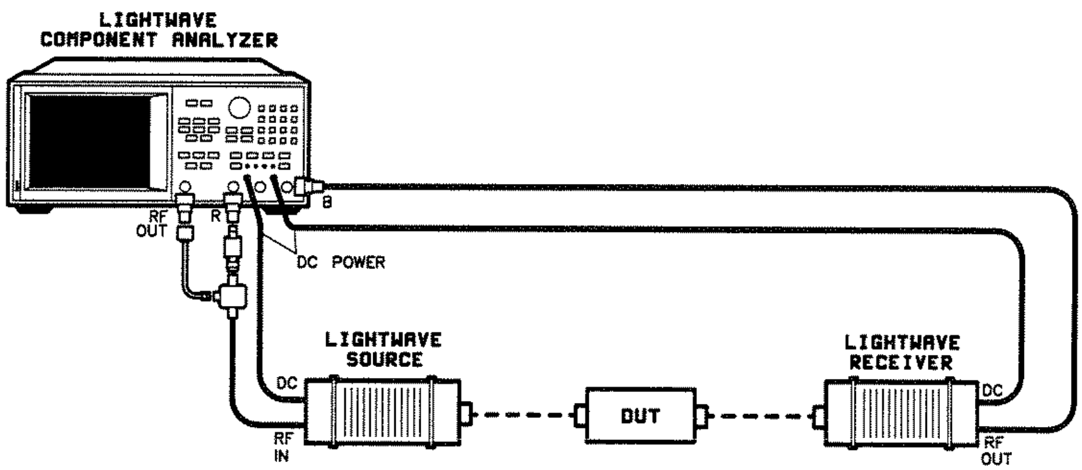


Figure 2-27. O/O Measurement Configuration

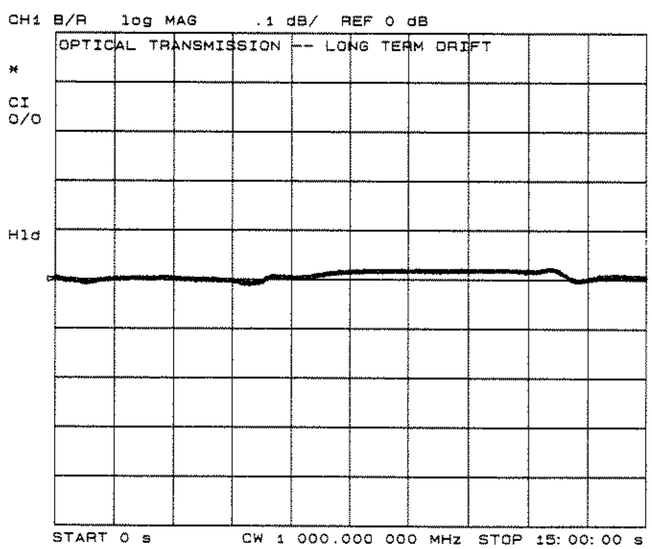


Figure 2-28. 15 Hour O/O Drift

3. LIGHTWAVE RECEIVER MEASUREMENT REPEATABILITY

This plot shows the system's ability to accurately repeat measurements of the same O/E device. The HP lightwave receiver is connected and disconnected 5 times and measured each time. The resultant data shows both the connector (optical and electrical) repeatability and the stability of the calibration. An O/E measurement calibration (using the receiver disc data) is performed for each connection and the data is normalized (data/memory function) to obtain the trace. The plot shows the stability of the system where about 0.6 dB of change (worst case) is noticeable, due to optical connector repeatability contributing the greatest error.

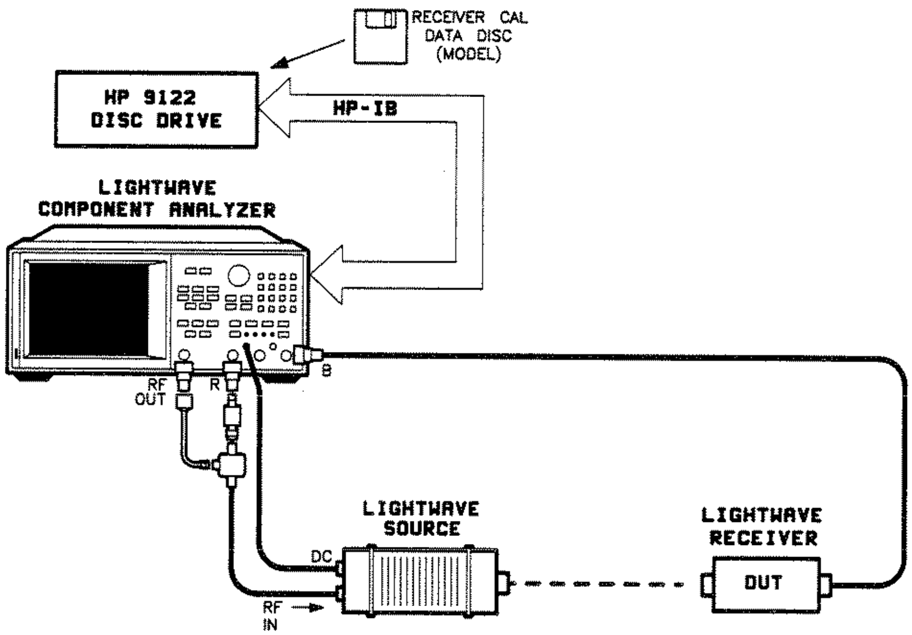


Figure 2-29. Receiver Measurement Configuration

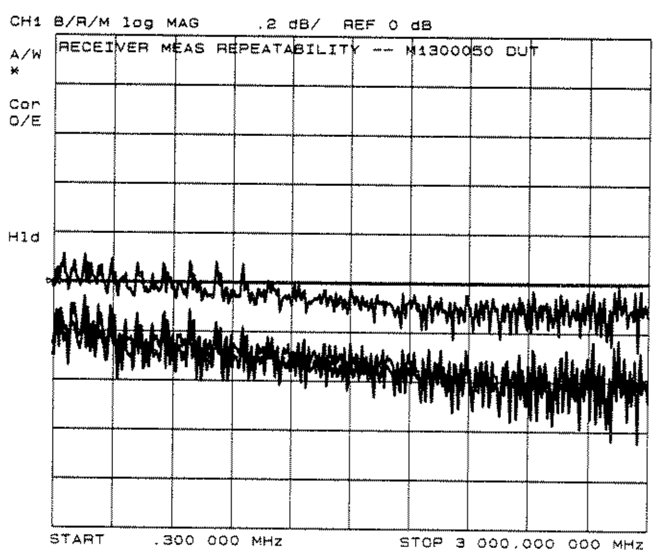


Figure 2-30. Receiver Measurement Repeatability

4. LIGHTWAVE SOURCE REFLECTION SENSITIVITY

Two plots are used to show the sensitivity of the HP lightwave source to measurements where Fresnel reflections are present. The first plot shows a calibrated response to a minimum reflection. The second plot shows the response to a Fresnel reflection (3.5% reflected optical power).

The plotted data is taken using the following procedure:

A measurement calibration is performed. This is a transmission *thru* calibration (not a Fresnel reflection cal) with index matching compound applied to the coupler input/output port as shown in the configuration drawing. Thus, the frequency response to the condition of minimum reflection is used as a reference for the subsequent measurement. This calibrated or normalized response to the minimal source reflection is shown in the figure where a 0 dB reference line is established (Fig. 2-31).

After performing the calibration, the matching compound is removed from the port using proper cleaning techniques. The resulting Fresnel reflection has a nominal effect upon the lightwave source that is seen in the measurement plot. As the curve shows, a 3.5% Fresnel reflection from measured devices (transmission measurement) will have somewhat less than +/-0.1 dB effect upon the source's output. Notice also that the laser's reflection sensitivity to a Fresnel reflection at the coupler's test port is approximately constant over the RF modulation band (3 GHz).

This reflection sensitivity uncertainty term can be minimized further by using a low reflection optical attenuator (HP 8157A) or eliminated by using a low reflection optical isolator (isolation =25 dB).

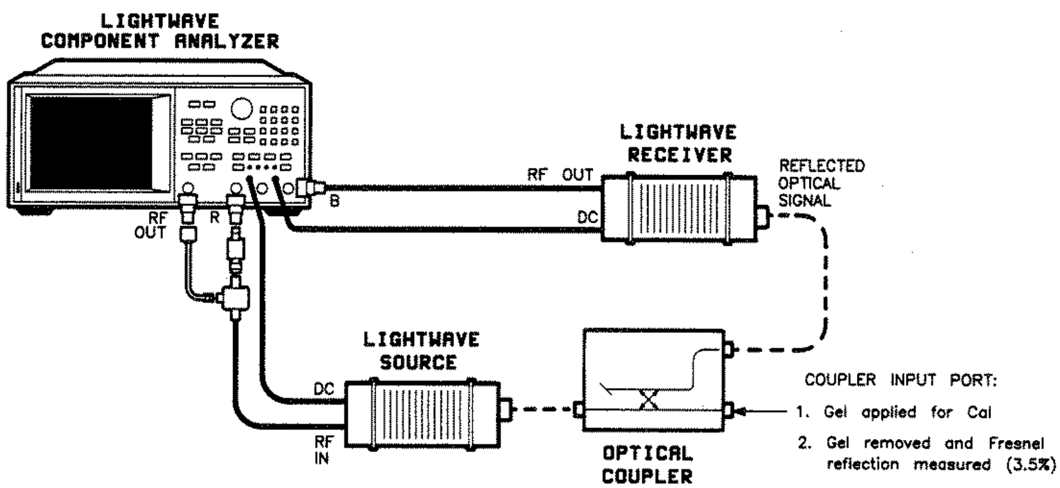


Figure 2-31. Source Sensitivity Measurement Configuration

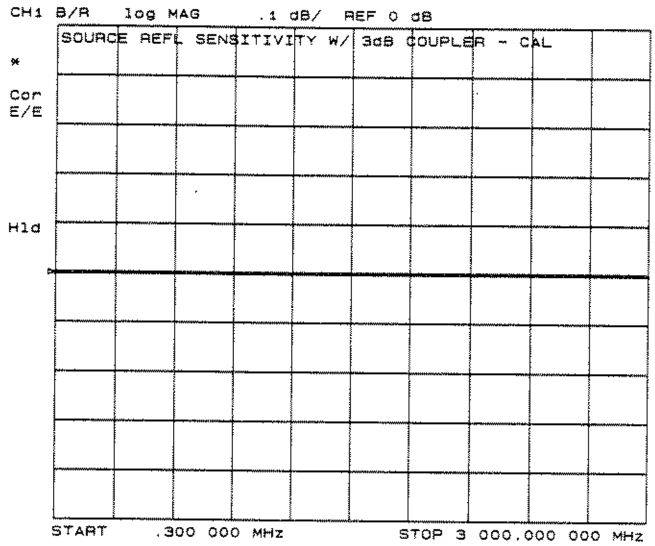


Figure 2-32. Source Sensitivity Thru CAL

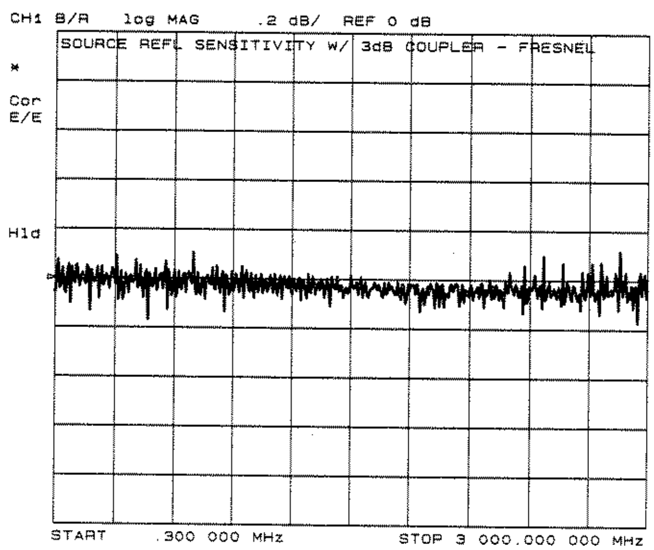


Figure 2-33. Source Sensitivity to Fresnel Reflection

6 GHz OPTICAL (O/O) TRANSMISSION MEASUREMENTS

Measurements of devices with optical inputs and optical outputs have a value of uncertainty that can be determined by the RF modulation frequency and the insertion loss of the DUT. In addition, the reflection sensitivity of the lightwave source is given as a measure of system performance.

Included in the the total uncertainty value (shown by the plots) are the following individual contributing uncertainties:

- Optical connector repeatability
- Drift with temperature (23 +/-3 degrees Centigrade)
- Dynamic accuracy
- Reflection sensitivity
- Optical mismatches or reflections between:
  - lightwave source/lightwave receiver
  - lightwave source/DUT
  - DUT/lightwave receiver

6 GHz System Configuration - O/O

The following plots are based on the system shown configured below, using an HP 83402A SMF Lightwave Source, HP 83411A Lightwave Receiver, HP 11886A Interconnect Cable Kit (HMS-10/HP), and an HP 85047A Test Set.

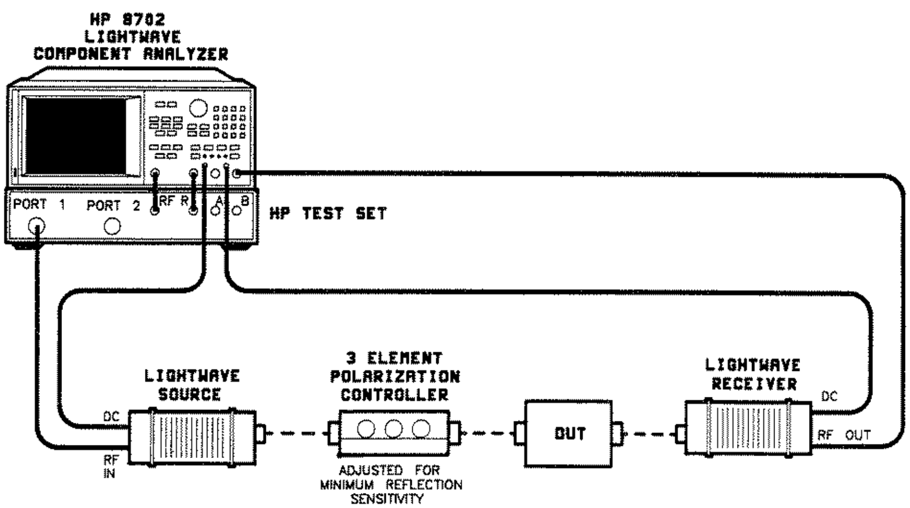


Figure 2-34. 6 GHz Optical Transmission Measurement Configuration

6 GHz Typical Uncertainty vs. Modulation Frequency - O/O

This curve shows the uncertainty (dB) for measurements made over the modulation frequency range of 3 MHz to 6 GHz.

Assumptions or Conditions

O/O Thru Calibration on HP 8702
DUT insertion loss =0 dB
DUT optical input return loss = −20 dB
DUT optical output return loss = −20 dB
RF input power to the lightwave source =0 dBm

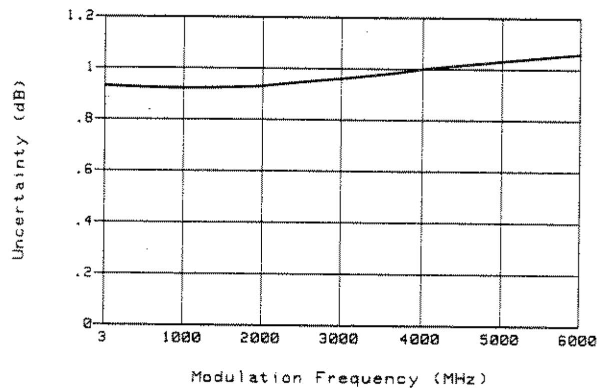


Figure 2-35. 6 GHz Typical Uncertainty vs. Frequency

6 GHz Typical Uncertainty vs. Insertion Loss - O/O

This curve show the uncertainty (dB) for measurements made with DUT insertion loss between 0 and −30 dB.

Assumptions or Conditions

O/O Thru Calibration on HP 8702
DUT optical input return loss = −20 dB
DUT optical output return loss = −20 dB
RF input power to the lightwave source =0 dBm

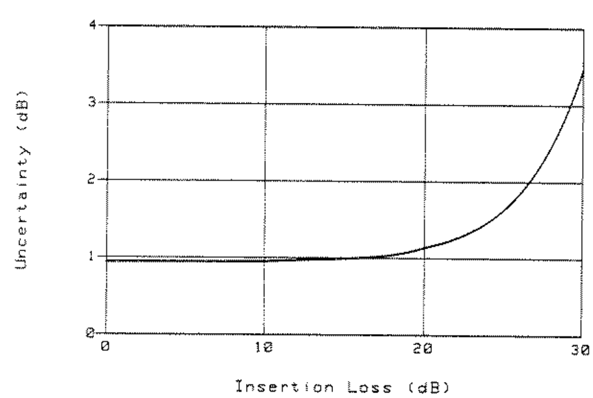


Figure 2-36. 6 GHz Typical Uncertainty vs. Insertion Loss

6 GHz Typical Reflection Sensitivity vs. Frequency - O/O

This curve shows the uncertainty contribution of reflection sensitivity (dB) to measurements made over the frequency range of 3 MHz to 6 GHz. This is the reflection sensitivity of an HP 83402A Lightwave Source with a polarization controller adjusted to obtain the maximum and minimum values.

Assumptions or Conditions

O/O Thru calibration on the HP 8702
RF input power to the lightwave source =0 dBm

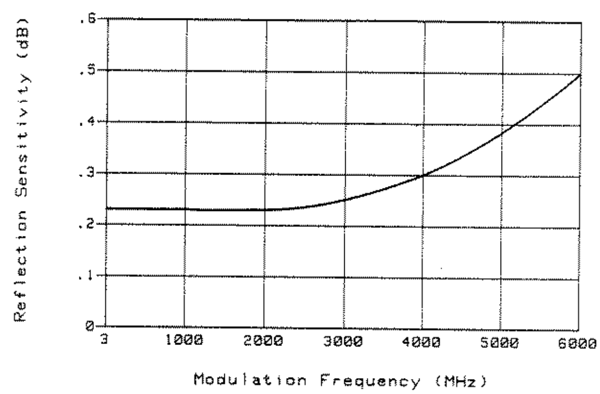


Figure 2-37. 3 GHz Typical Reflection Sensitivity vs. Frequency

6 GHz OPTICAL REFLECTION MEASUREMENTS

Reflection measurements of the optical port of any device have an uncertainty value based upon the amount of return loss (magnitude of reflection).

Included in the total uncertainty value (shown by the plots) are the following individual contributing uncertainties:

- Optical connector repeatability
- Drift with temperature (23 +/-3 degrees Centigrade)
- Dynamic accuracy
- Reflection sensitivity
- Optical mismatches or reflections between:
  - lightwave source/lightwave coupler
  - lightwave coupler/DUT
  - Lightwave coupler/lightwave receiver
- Effective system directivity

6 GHz System Configuration - Optical Reflection

The following plots are based on the system shown configured below, using an HP 83402A SMF Lightwave Source, HP 83411A Lightwave Receiver, HP 11890A Lightwave Coupler, HP 11886A Interconnect Cable Kit (HMS-10/HP), and an HP 85047A Test Set.

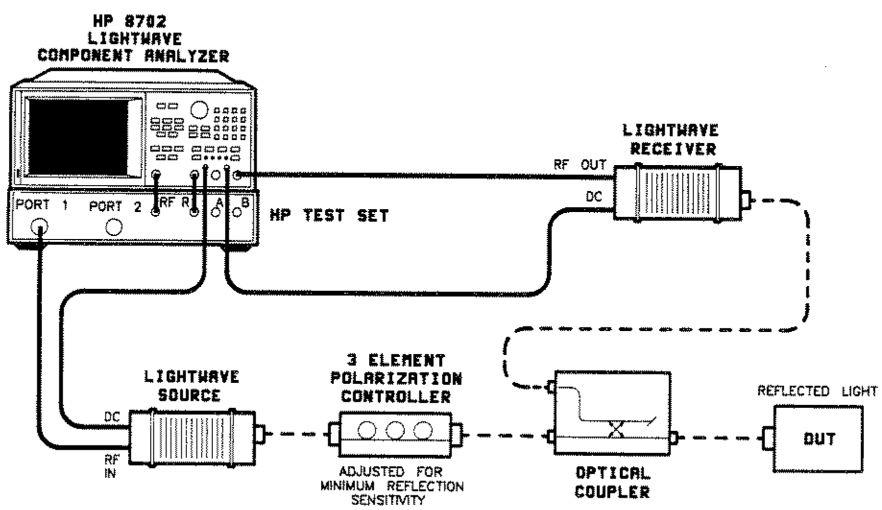


Figure 2-38. 6 GHz Optical Reflection Configuration

6 GHz Typical Uncertainty vs. Return Loss - Optical Reflection

This curve shows the uncertainty (dB) for reflection measurements made with DUT return loss of 0 to −20 dB.

Reflection calibrations made with a Fresnel reflection (glass to air) on the coupler output port will result in −14.6 dB of return loss which is equal to 3.5% reflected optical power.

NOTE: Return loss = −10 log (Reflected Power/Incident Power)

Assumptions or Conditions

Fresnel reflection calibration on the HP 8702
RF input power to the lightwave source = 0 dBm

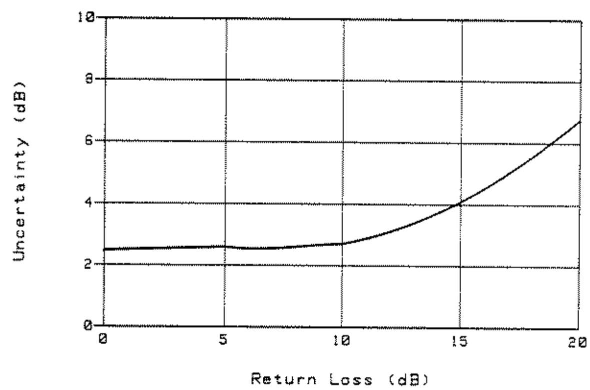


Figure 2-39. 6 GHz Typical Uncertainty vs. Return Loss

6 GHz OPTICAL-ELECTRICAL TRANSMISSION MEASUREMENTS

Measurements of O/E devices with optical inputs and electrical outputs have a total value of uncertainty that includes various individual uncertainties. The total measurement uncertainty (dB) is shown plotted against the DUT responsivity (dB). In addition, there is a plot showing how the RF modulation frequency can also be used to assign an uncertainty value to O/E converter measurements.

Included in the the total uncertainty value (shown by the plots) are the following individual contributing uncertainties:

- Optical connector repeatability
- Drift with temperature (23 +/-3 degrees Centigrade)
- Dynamic accuracy
- Reflection sensitivity
- Wavelength accuracy
- Factory test (characterization) system
- Electrical mismatches or reflections between:
  - RF source/lightwave source RF input
  - RF receiver/lightwave receiver RF output
- Optical mismatches or reflections between:
  - lightwave source/lightwave receiver
  - lightwave source/DUT

6 GHz System Configuration - O/E

The following plots are based on the system shown configured below, using an HP 83402A SMF Lightwave Source, HP 83411A Lightwave Receiver, HP 11890A Lightwave Coupler, HP 11886A Interconnect Cable Kit (HMS-10/HP), and an HP 85047A Test Set.

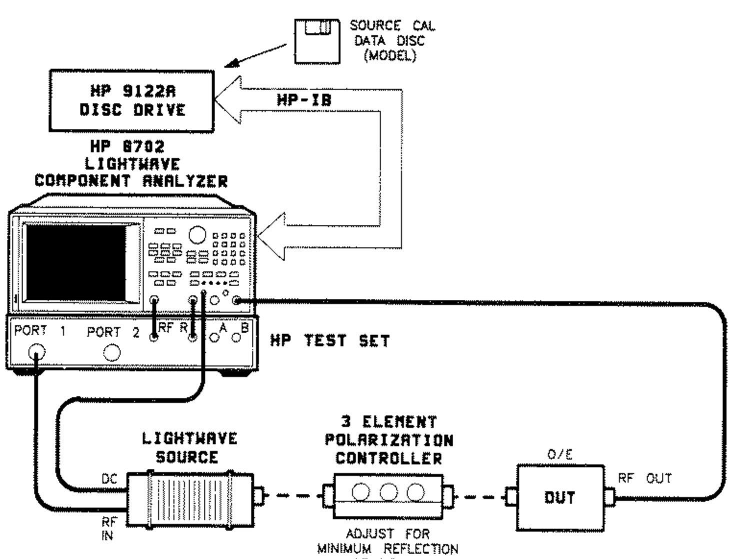


Figure 2-40. 6 GHz O/E Transmission Measurement Configuration

6 GHz Typical Uncertainty vs. Responsivity (dB) - O/E

The following curve shows the uncertainty (dB) for measurements made with DUT responsivity from −35 to −90 dB.

The responsivity of an O/E device can be read off the CRT in dB or linear for any given frequency. The User's Guide describes how to convert the dB value to its corresponding *amps/watt* responsivity value in the example for measuring and O/E converter where,

$$\text{Responsivity R (dB)} = 20 \log_{10} \left[\frac{\text{R (a/w)}}{\text{1 (a/w)}} \right]$$

Assumptions or Conditions

Receiver calibration using data on HP 8702
DUT optical input return loss = −14 dB
DUT electrical return loss = −14 dB
RF input power to the lightwave source = 0 dBm

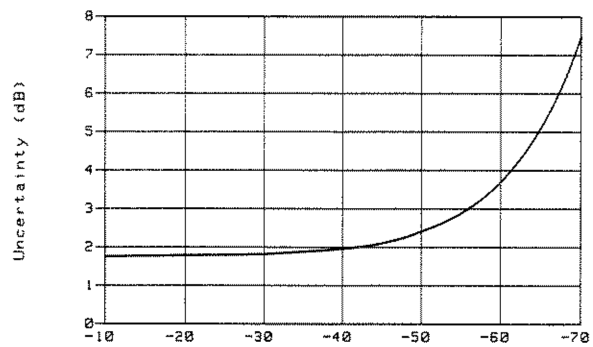


Figure 2-41. Typical Relative Uncertainty vs. Responsivity over 3 MHz to 6 GHz Modulation Frequency

6 GHz Typical Uncertainty vs. Modulation Frequency - O/E

This curve shows the uncertainty (dB) for a DUT with −10 dB responsivity over the RF modulation frequency range of 3 MHz to 6 GHz.

Assumptions or Conditions

Receiver calibration using data on HP 8702
DUT optical input return loss = −14 dB
DUT electrical return loss = −14 dB
RF input power to the lightwave source = 0 dBm

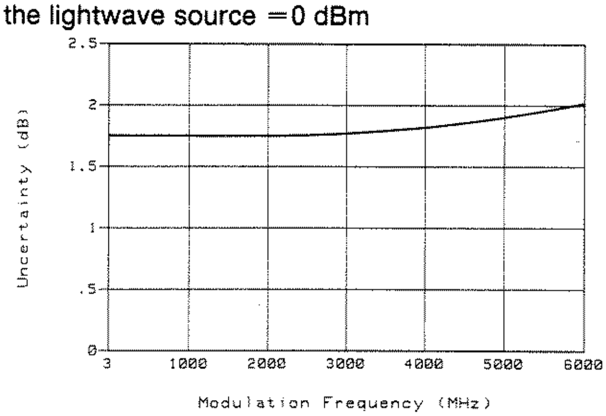


Figure 2-42. 6 GHz Typical Relative Uncertainty vs. Modulation Frequency

6 GHz ELECTRICAL-OPTICAL TRANSMISSION MEASUREMENTS

Measurements of E/O devices with electrical inputs and optical outputs have a total value of uncertainty that includes various individual uncertainties. The total measurement uncertainty (dB) is shown plotted against the DUT responsivity (dB). In addition, there is a plot showing how the RF modulation frequency can also be used to assign an uncertainty value to E/O converter measurements.

Included in the the total uncertainty value (shown by the plots) are the following individual contributing uncertainties:

- Optical connector repeatability
- Drift with temperature (23 +/-3 degrees Centigrade)
- Dynamic accuracy
- Reflection sensitivity
- Wavelength accuracy
- Factory test (characterization) system
- Electrical mismatches or reflections between:
  - RF source/lightwave source RF input
  - RF receiver/lightwave receiver RF output
- Optical mismatches or reflections between:
  - lightwave source/lightwave receiver
  - DUT/lightwave receiver

6 GHz System Configuration E/O

The following plots are based on the system shown configured below, using an HP 83402A SMF Lightwave Source, HP 83411A Lightwave Receiver, HP 11890A Lightwave Coupler, HP 11886A Interconnect Cable Kit (HMS-10/HP), and an HP 85047A Test Set.

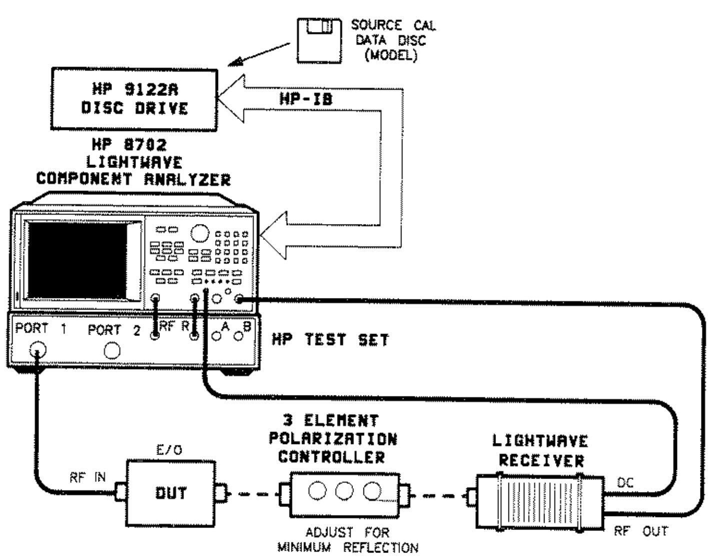


Figure 2-43. 6 GHz E/O Transmission Measurement Configuration

6 GHz Typical Uncertainty vs. Responsivity (dB) - E/O

The following curve shows the uncertainty (dB) for measurements made with DUT responsivity from −35 to −95 dB. The responsivity of an E/O device can be read off the CRT in dB for any given frequency. The User's Guide describes how to convert the dB value to its corresponding *watts/amp* responsivity value where,

$$\text{Responsivity R (dB)} = 20 \log_{10}\left[\frac{\text{R (a/w)}}{\text{1 (a/w)}}\right]$$

Assumptions or Conditions

Source calibration using disc data on HP 8702
DUT optical output return loss = −10 dB
DUT electrical input return loss = −14 dB
RF input power = 0 dBm

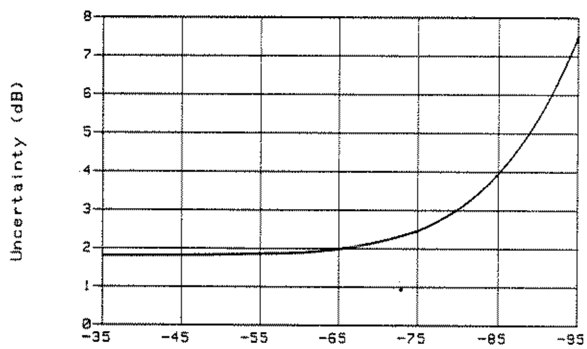


Figure 2-44. 6 GHz Typical Relative Uncertainty vs. Responsivity for 3 MHz to 6 GHz Modulation Frequency

6 GHz Typical Uncertainty vs. Modulation Frequency - E/O

This curve shows the total measurement uncertainty (dB) for a DUT with −10 dB responsivity over the RF modulation frequency range of 3 MHz to 6 GHz.

Assumptions or Conditions

Source calibration using disc data on HP 8702
DUT optical output return loss = −10 dB
DUT electrical input return loss = −14 dB
RF input power = 0 dBm

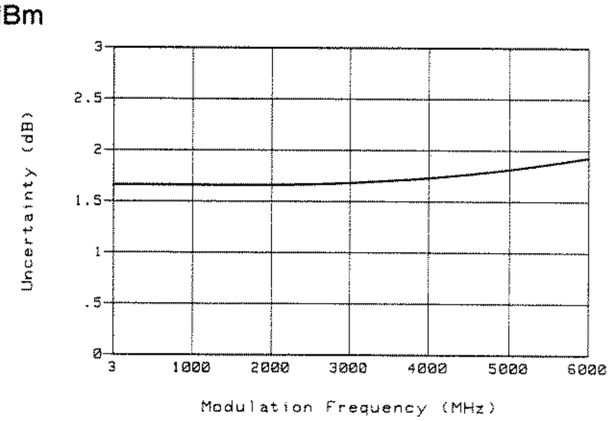


Figure 2-45. 6 GHz Typical Relative Uncertainty vs. Modulation Frequency

6 GHz ELECTRICAL REFLECTION MEASUREMENTS

Reflection measurements of the electrical ports of various devices have a value of uncertainty (magnitude and phase) that can be determined by the reflection coefficient, the type of calibration, and the electrical connector type. The plots below show the uncertainty for one-port and two-port devices using 7 mm connectors.

6 GHz System Configuration

The following plots are based upon the system shown configured below, using an HP 85047 S-Parameter Test Set and 7 mm connectors.

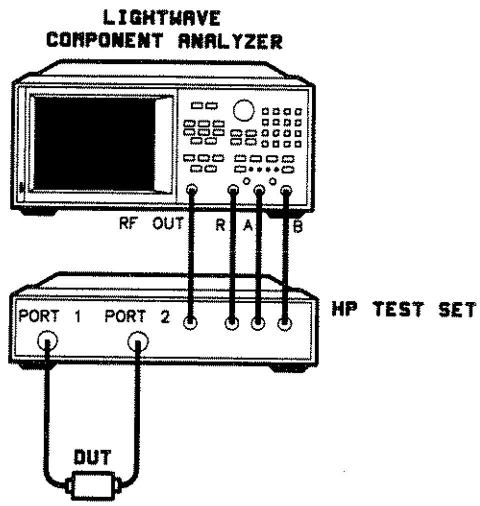


Figure. 2-46. 6 GHz Electrical Reflection Measurement Configuration

6 GHz Electrical Reflection Uncertainty of a One-Port Device

Assumptions or Conditions:

Reference = −20 dBm RF power to DUT
S21 = S12 = 0 (one-port device only)

Uncorrected — - — - —
Response · · · · · · · ·
Response and Isolation — — — — —
Full one or two port ————

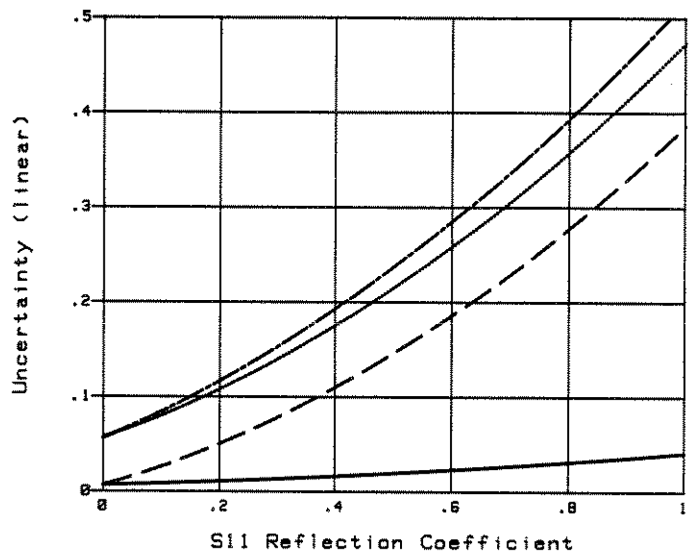


Figure 2-47. Total Reflection Magnitude Uncertainty

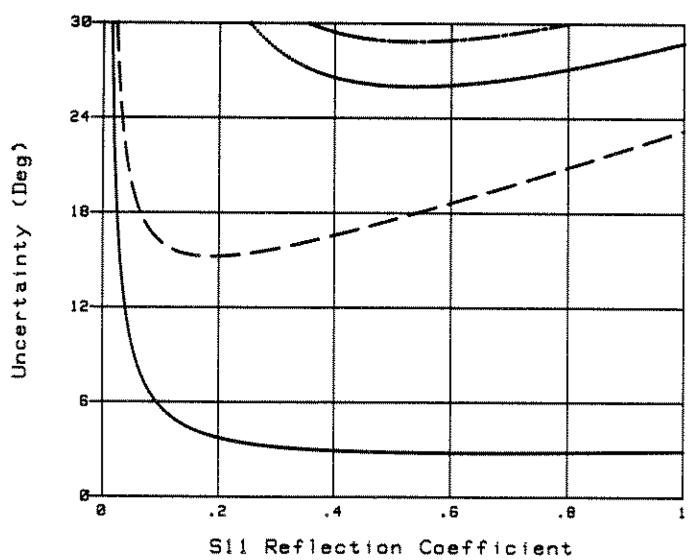


Figure 2-48. Total Reflection Phase Uncertainty

6 GHz Electrical Reflection Uncertainty of a Two-Port Device

Assumptions or Conditions:

Reference = −20 dBm RF power to DUT
S21 = S12 = 0 (one-port device only)

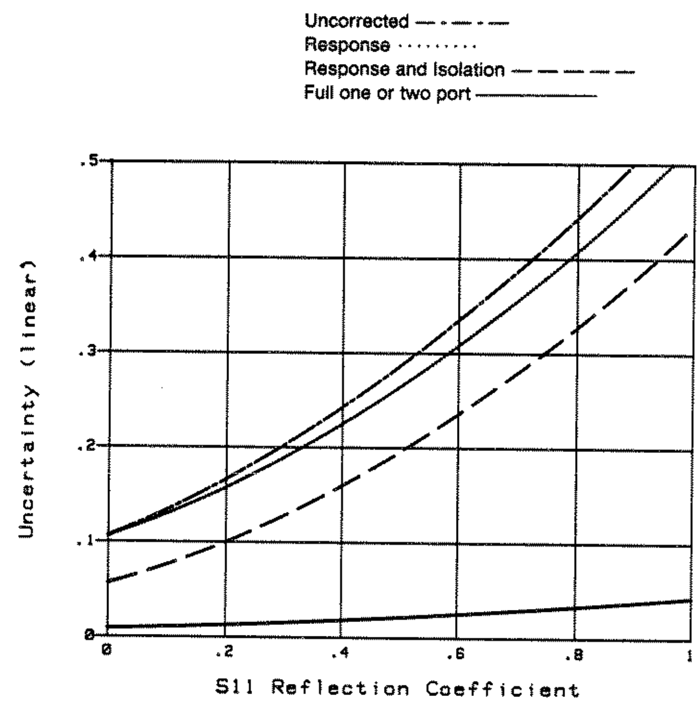


Figure 2-49. Total Reflection Magnitude Uncertainty

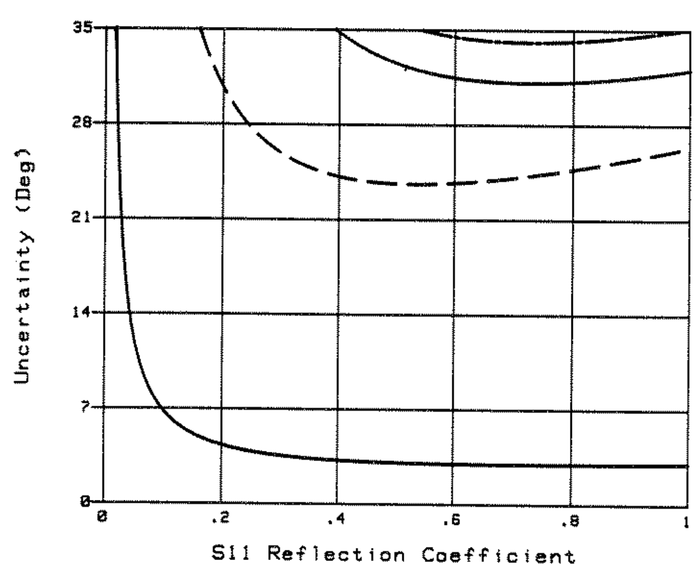


Figure 2-50. Total Reflection Phase Uncertainty

6 GHz ELECTRICAL (E/E) TRANSMISSION MEASUREMENTS

Transmission measurements of devices with electrical input and output ports have a value of uncertainty (magnitude and phase) that can be determined by the insertion loss, the type of calibration, and the electrical connector type. The plots below show the uncertainty for two-port devices using 7 mm connectors.

6 GHz System Configuration - E/E

The following plots are based on the system shown configured below, using an HP 85047 S-Parameter Test Set and 7 mm connectors.

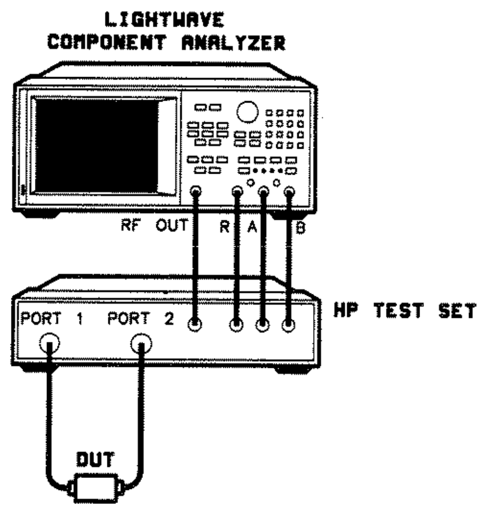


Figure 2-51. 6 GHz Electrical Transmission Measurement Configuration

6 GHz Transmission Uncertainty of a Low-Loss Device

Assumptions or Conditions:

Reference = −10 dBm RF power to DUT
S11 = S22 = 0.1

Uncorrected — - — - —
Response · · · · · · · · ·
Response and Isolation — — — — —
Full one or two port ————

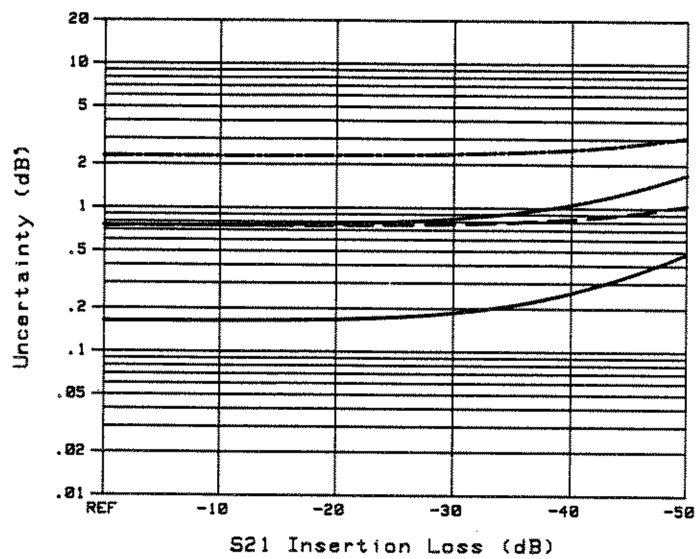


Figure 2-52. Total Transmission Magnitude Uncertainty

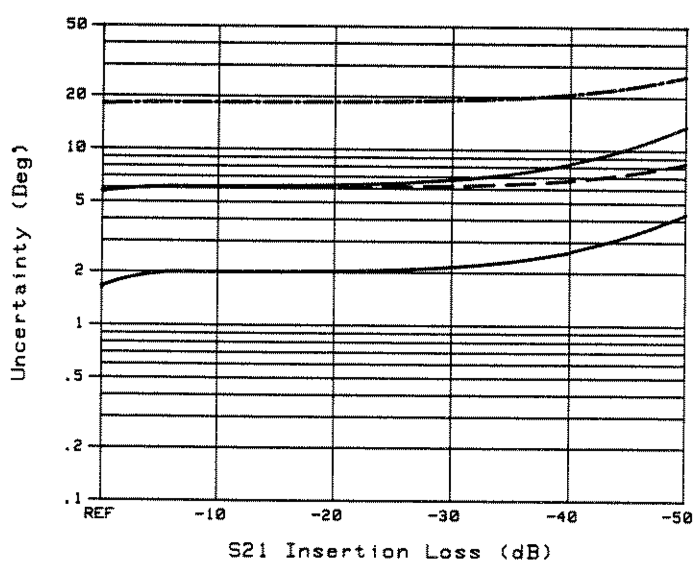


Figure 2-53. Total Transmission Phase Uncertainty

6 GHz Transmission Uncertainty of a Wide Dynamic Range Device

Assumptions or Conditions:

Reference = 0 dBm RF power to DUT
S11 = S22 = 0.1

Uncorrected — - — - —
Response · · · · · · · · ·
Response and Isolation — — — — —
Full one or two port ————

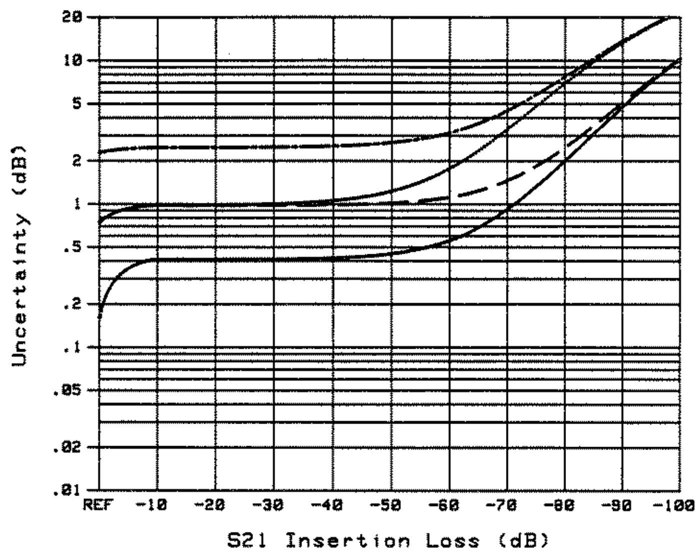


Figure 2-54. Total Transmission Magnitude Uncertainty

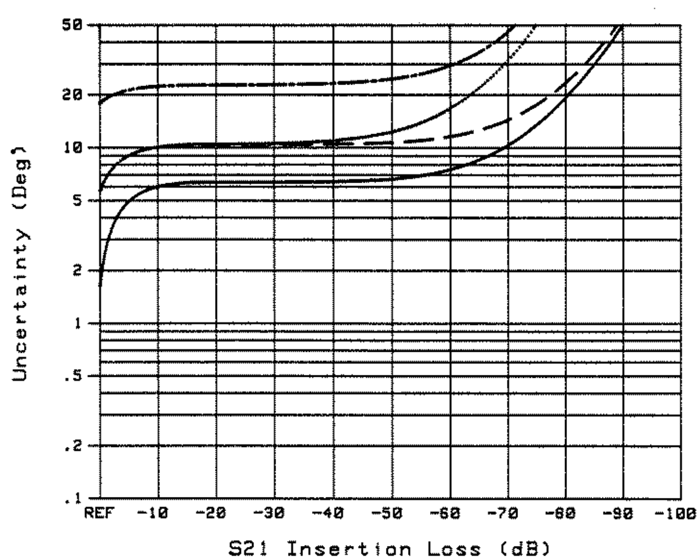


Figure 2-55. Total Transmission Phase Uncertainty

HP 8702
Instrument Specifications (Stand-Alone)

Table 2-1. HP 8702 Instrument Specifications (1 of 10)

The specifications listed in Table 2-1 range from those guaranteed by Hewlett-Packard to those typical of most HP 8702 instruments but not guaranteed. Codes in the far right column of Table 1 reference a specification definition listed below. These definitions are intended to clarify the extent to which Hewlett-Packard supports the specified performance of the HP 8702.

S-1: This performance parameter is verifiable using performance tests documented in the service manual.

* Explicitly tested as part of an on-site verification performed by Hewlett-Packard.

S-2: Due to limitations on available industry standards, the guaranteed performance of the instrument cannot be verified outside the factory. Field procedures can verify performance with a confidence prescribed by available standards.

S-3: These specifications are generally digital functions or are mathematically derived from tested specifications, and can therefore be verified by functional pass/fail testing.

T: Typical but non-warranted performance characteristics intended to provide information useful in applying the instrument. Typical characteristics are representative of most instruments, though not necessarily tested in each unit. Not field tested.

RF SOURCE

FREQUENCY CHARACTERISTICS

		Code
Range	300 kHz to 3 GHz	S-1 *
Accuracy (*at 25°C ±5°C*)	±10 ppm	S-1 *
Stability		
0° to 55°C	±7.5 ppm	T
per year	±3 ppm	T
Resolution	1 Hz	S-3

OUTPUT POWER CHARACTERISTICS

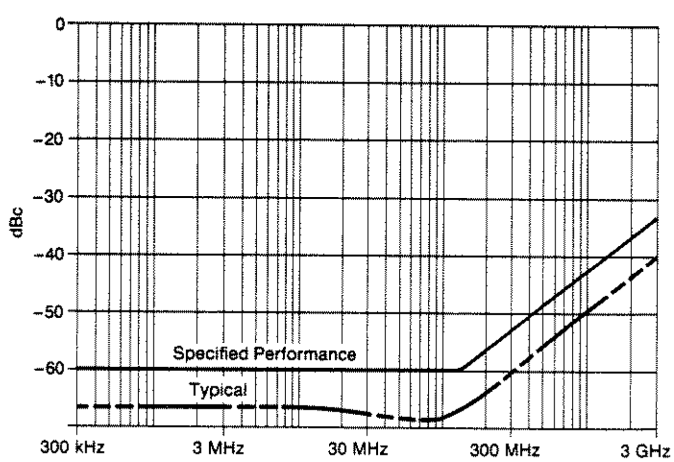
Range	−5 to +20 dBm	S-1 *
Resolution	0.1 dB	S-3
Level Acuracy (*at +10 dBm output level, 50 MHz*) (*at 25°C ± 5°C*)	±0.5 dB	S-1 *
Flatness (*at 25°C ± 5°C*)	±1 dB	S-1 *
Linearity (*at 25°C ±5°C*)		
−5 to +15 dBm	±0.2 dB (*relative to +10 dBm output level*)	S-1
+15 to +20 dBm	±0.5 dB (*relative to +10 dBm output level*)	S-1
Impedance	50 ohms; >16 dB return loss (<1.38 SWR)	T

Table 2-1. HP 8702 Instrument Specifications (2 of 10)

RF SOURCE (Cont'd)

SPECTRAL PURITY CHARACTERISTICS
(*with 0 to −10 dBm into R input*)

		Code
2nd Harmonic		
at +20 dBm output level	<−25 dBc	S-1 *
at +10 dBm	<−40 dBc	T
at 0 dBm	<−50 dBc	T
3rd Harmonic		
at +20 dBm output level	<−25 dBc	S-1 *
at +10 dBm	<−40 dBc	T
at 0 dBm	<−50 dBc	T
Non-Harmonic Spurious Signals		
Mixer Related		
at +20 dBm output level	<−32 dBc	S-1
at 0 dBm output level	<−55 dBc	T
Other Spurious Signals (see graph) (25°C ±5°C) (*within 20 kHz*)		
f <135 MHz	−60 dBc	S-1
f ≥135 MHz	[−60 +20 log (f/135 MHz)] dBc	S-1



Other Spurious Signals

Phase Noise (*10 kHz offset from fundamental in 1 Hz bandwidths*)		
f <135 MHz	−90 dBc	S-1
f ≥135 MHz	[−90 +20 log (f/135 MHz)] dBc	S-1

Table 2-1. HP 8702 Instrument Specifications (3 of 10)

RF RECEIVER (R, A, B inputs)

INPUT CHARACTERISTICS

Parameter	Specification	Code
Frequency Range		
Standard	300 kHz to 3 GHz	S-1 *
Option 006[1]	300 kHz to 6 GHz	S-1 *
Impedance	50 ohms nominal	
300 kHz to 2 MHz	>20 dB return loss	S-1
2 MHz to 2 GHz	>23 dB return loss	S-1
2 GHz to 3 GHz	>20 dB return loss	S-1
3 GHz to 6 GHz[1]	>8 dB return loss	T
Dynamic Range (*10 Hz IF bandwidth*)		
A, B		
300 kHz to 3 GHz	100 dB	S-1
3 GHz to 6 GHz[1]	95 dB	S-1
R		
300 kHz to 3 GHz	35 dB	S-1
3 GHz to 6 GHz[1]	30 dB	S-1
Maximum Input Level	0 dBm	S-1
Damage Level	+20 dBm or >25 volts DC	T
Noise Level (*A, B*)		
300 kHz to 3 GHz		
3 kHz IF bandwidth	−90 dBm	S-1
10 Hz IF bandwidth	−100 dBm	S-1
	−110 dBm	T
3 GHz to 6 GHz[1]		
3 kHz IF bandwidth	−85 dBm	S-1
10 Hz IF bandwidth	−95 dBm	S-1
	−105	T
Minimum R Level (*required for source operation*)		
300 kHz to 3 GHz	−35 dBm	S-1
3 GHz to 6 GHz[1]	−30 dBm	S-1

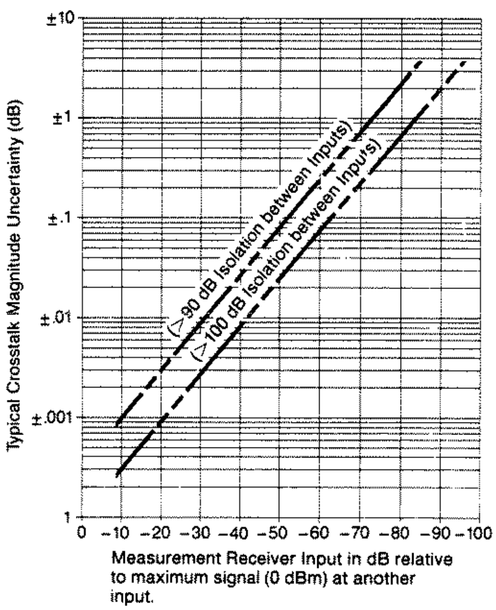
1. Operation from 3 GHz to 6 GHz requires option 006. Operation from 3 GHz to 6 GHz in the normal analyzer mode requires option 006 and an HP 85047A S-parameter test set.

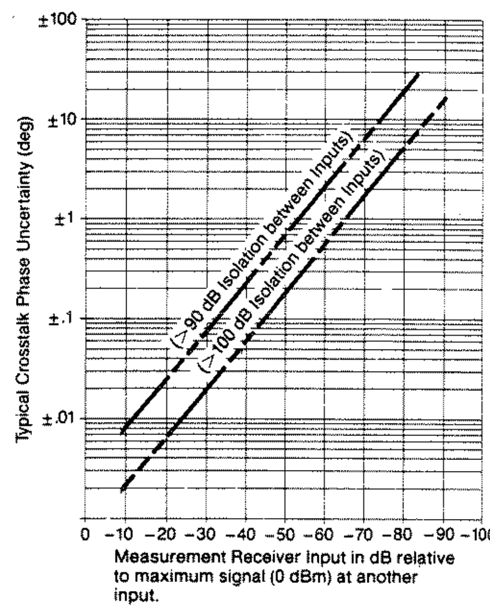
Table 2-1. HP 8702 Instrument Specifications (4 of 10)

RF RECEIVER (Cont'd)

INPUT CHARACTERISTICS (Cont'd)

		Code
Input Crosstalk (*10 Hz IF bandwidth*) (see graphs)		
300 kHz to 1 GHz	−100 dB	S-1
1 GHz to 3 GHz	−90 dB	S-1
3 GHz to 4.5 GHz[1]	−85 dB	S-1
4.5 GHz to 6 GHz[1]	−75 dB	S-1





Input Crosstalk

Source Crosstalk (*10 Hz IF bandwidth*)	<−135 dB	T
Receiver Harmonics (*option 002*)		
2nd Harmonic		
at 0 dBm input level	−15 dBc	S-1 *
at −10 dBm	−35 dBc	T
at −30 dBm	−45 dBc	T
3rd Harmonic		
at 0 dBm input level	−30 dBc	S-1 *
at −10 dBm	−50 dBc	T
at −30 dBm	−50 dBc	T
Harmonic Measurement Accuracy		
300 kHz to 3 GHz	±1 dB	S-1
3 GHz to 6 GHz[1]	±3 dB	S-1
Harmonic Measurement Dynamic Range (*with source at 0 dBm and receiver at <−30 dBm*)	−40 dBc	T

1. Operation from 3 GHz to 6 GHz requires option 006. Operation from 3 GHz to 6 GHz in the normal network analyzer mode requires option 006 and an HP 85047A S-parameter test set.

Table 2-1. HP 8702 Instrument Specifications (5 of 10)

RF RECEIVER (Cont'd)

INPUT CHARACTERISTICS (Cont'd)

Parameter	Specification	Code
Frequency Offset Operation[1,2]		
Frequency Range	16 MHz to 3 GHz	S-1
R Channel Input Requirements (*required for phase-locked operation*)		
Power Level	0 to −35 dBm	S-1
LO Spectral Purity and Accuracy		
Maximum Spurious Input	<−25 dBc	T
Residual FM	<20 kHz	T
Frequency Accuracy	−1 to +5 MHz of nominal frequency	T
Accuracy (see *Magnitude Characteristics* and *Phase Characteristics*)		
External Source Mode[2,3] (*CW Time sweep only*)		
Frequency Range[4]	300 kHz to 6 GHz	S-1
R Input Requirements		
Power Level	0 to −25 dBm	S-1
Spectral Purity		
Maximum Spurious Input	<−30 dBc	T
Residual FM	<20 kHz	T
Settling Time		
Auto	500 ms	T
Manual	50 ms	T
Frequency Readout Accuracy (auto)	0.1%	T
Input Frequency Margin		
Manual	−0.5 to 5 MHz	T
Auto		
≤50 MHz	±5 MHz of nominal CW frequency	T
>50 MHz	±10% of nominal CW frequency	T
Accuracy (see *Magnitude Characteristics* and *Phase Characteristics*)[3]		

1. The HP 8702 RF source characteristics in this mode are dependent on the stability of the external LO source. The RF source tracks the LO to maintain a stable IF signal at the R channel receiver input. Degradation in accuracy is negligible with an HP 8642A/B or HP 8656B RF signal generator as the LO source.
2. Refer to *Operating and Programming Reference* for a functional description.
3. Measurement accuracy is dependent on the stability of the input signal.
4. Operation from 3 GHz to 6 GHz requires option 006.

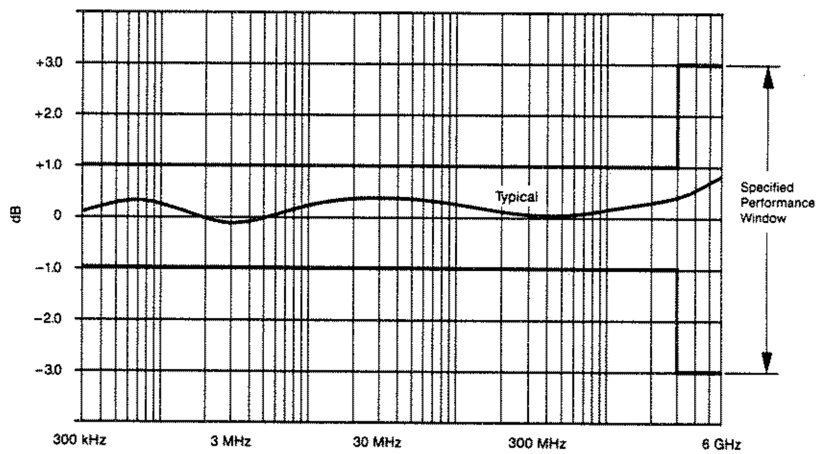
Table 2-1. HP 8702 Instrument Specifications (6 of 10)

RF RECEIVER (Cont'd)

MAGNITUDE CHARACTERISTICS

Absolute Amplitude Accuracy (*A, B, R*) (see graph)
(*with −10 dBm into input, 25°C ±5°C*)

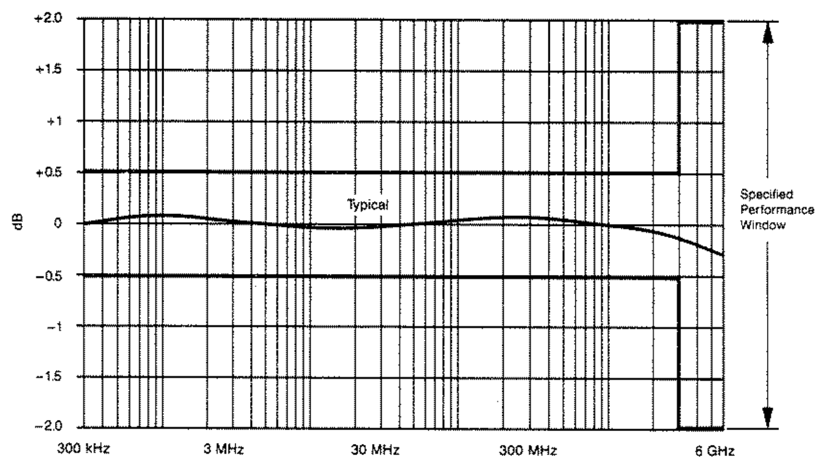
		Code
300 kHz to 3 GHz	±1.0 dB	S-1
3 GHz to 6 GHz[1]	±3.0 dB	S-1



Absolute Amplitude Accuracy

Ratio Accuracy (*A/R, B/R, A/B*)[2]
(*25°C ±5°C, with −10 dBm on all inputs*)

300 kHz to 3 GHz	±0.5 dB	S-1
3 GHz to 6 GHz[1]	±2.0 dB	S-1



Ratio Accuracy

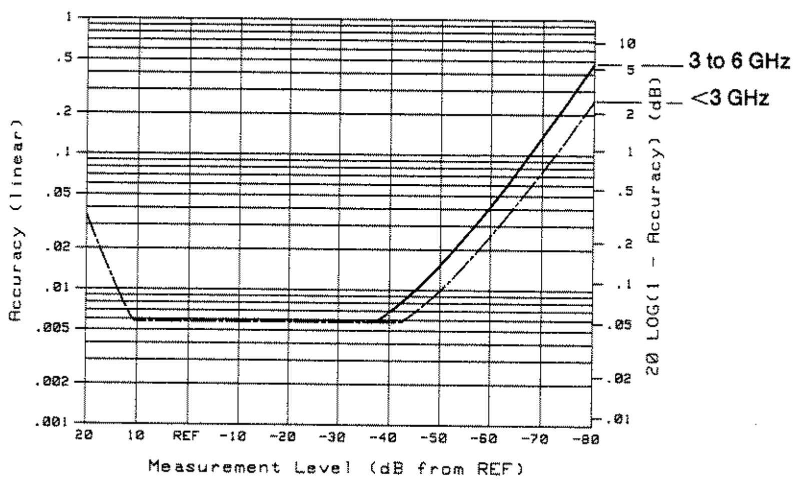
1. Operation from 3 GHz to 6 GHz requires option 006. Operation from 3 GHz to 6 GHz in the normal analyzer mode requires option 006 and an HP 85047A S-parameter test set.
2. Unnormalized

Table 2-1. HP 8702 Instrument Specifications (7 of 10)

RF RECEIVER (Cont'd)

MAGNITUDE CHARACTERISTICS (Cont'd)

		Code
Display Resolution	0.01 dB/division	S-3
Marker Resolution[1]	0.001 dB	S-3
Dynamic Accuracy (see graph) *(10 Hz bandwidth, inputs A and B; R to −35 dBm)*		S-1



Dynamic Accuracy (Magnitude)

Trace Noise (*CW sweep*) *(A/R, B/R, A/B, at −10 dBm, 3 kHz bandwidth)*	<0.006 dB rms	S-1
Reference Level		
Range	±500 dB	S-3
Resolution	0.001 dB	S-3
Stability (300 kHz to 3 GHz)	0.01 dB/degree C	T
(3 to 6 GHz)	0.02 dB/degree C	T

PHASE CHARACTERISTICS

(A/R, B/R, A/B)

Range	±180°	S-3
Display Resolution	0.01°/division	S-3
Marker Resolution	0.01°	S-3

1. Marker resolution for magnitude, phase, and delay is dependent upon the value measured; resolution is limited to 5 digits.

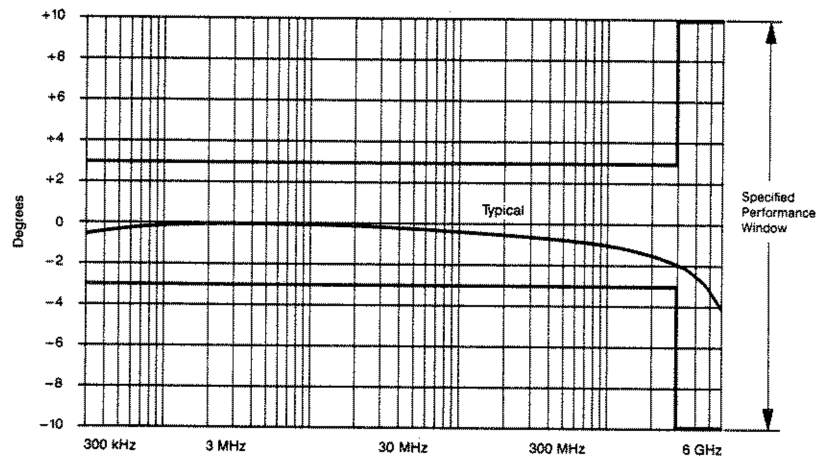
Table 2-1. HP 8702 Instrument Specifications (8 of 10)

RF RECEIVER (Cont'd)

PHASE CHARACTERISTICS (Cont'd)

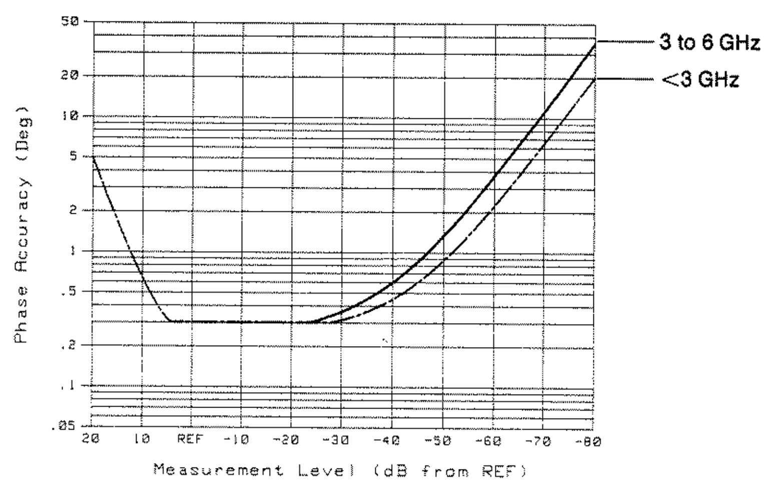
Frequency Response (deviation from linear) (see graph)
(*with −10 dBm into inputs, 25°C ±5°C*)

		Code
300 kHz to 3 GHz	±3°	S-1
3 GHz to 6 GHz[1]	±10°	S-1



Frequency Response

Dynamic Accuracy (see graph) S-1
(*10 Hz bandwidth A/R, B/R, and A/B; R to −35 dBm*)



Dynamic Accuracy (Phase)

Trace Noise (*A/R, B/R, A/B*)

300 kHz to 3 GHz	<0.035° rms	S-1
3 GHz to 6 GHz[1]	<0.06° rms	S-1

1. Operation from 3 GHz to 6 GHz requires option 006. Operation from 3 GHz to 6 GHz in the normal analyzer mode requires option 006 and an HP 85047A S-parameter test set.

Table 2-1. HP 8702 Instrument Specifications (9 of 10)

RF RECEIVER (Cont'd)

PHASE CHARACTERISTICS (Cont'd)

		Code
Reference Level		
Range	±500°	S-3
Resolution	0.01°	S-3
Stability		
300 kHz to 3 GHz	0.05°/degree C	T
3 GHz to 6 GHz[1]	0.10°/degree C	T

POLAR CHARACTERISTICS

(A/R, B/R, A/B)

Range	10 x 10^{-12} up to 1000 units full scale	S-3
Reference	range of ±500 units	S-3

GROUP DELAY CHARACTERISTICS

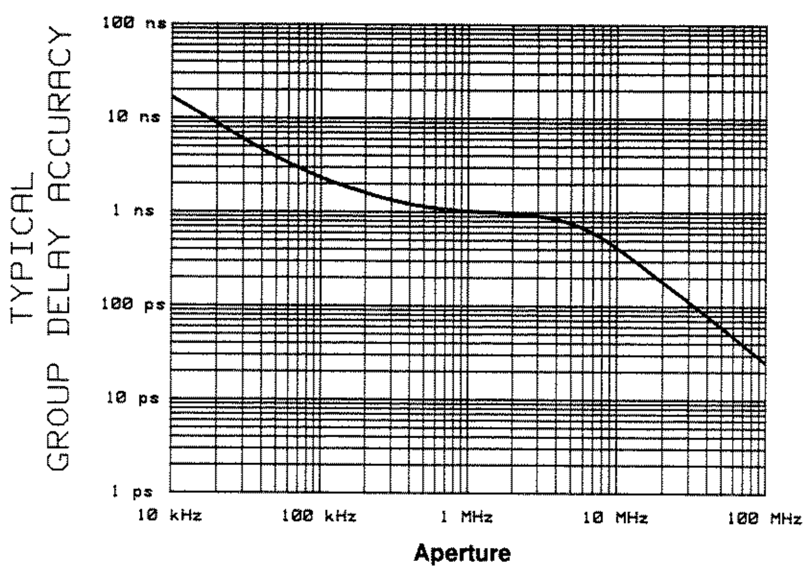
Group delay is computed by measuring the phase change within a specified frequency step (determined by the frequency span and the number of points per sweep).

Aperture (selectable)	(frequency span)(number of points −1)	S-3
Maximum aperture	20% of frequency span	S-3
Range	1/2 x (1/minimum aperture)	S-3

(The maximum delay is limited to measuring no more than 180°of phase change within the minimum aperture.)

Accuracy S-3

The following graph shows group delay accuracy at 3 GHz with an HP 85046A S-parameter test set with 7 mm full 2-port calibration and a 10 Hz IF bandwidth. Insertion loss is assumed to be <1 dB and electrical length to be 1 meter.



1. Operation from 3 GHz to 6 GHz requires option 006. Operation from 3 GHz to 6 GHz in the normal analyzer mode requires option 006 and an HP 85047A S-parameter test set.

Table 2-1. HP 8702 Instrument Specifications (10 of 10)

RF RECEIVER (Cont'd)

GROUP DELAY CHARACTERISTICS (Cont'd)

In general, the following formula can be used to determine the accuracy, in seconds, of a specific group delay measurement:

$\pm$(0.003 x Phase Accuracy (deg))/ Aperture (Hz)

Depending on the aperture and device length, the phase accuracy used is either incremental phase accuracy or worst case phase accuracy. The graph on the previous page shows this transition.

Table 2-2. HP 8702 General Characteristics (1 of 3)

MEASUREMENT COMPLETION TIME SUMMARY

The following table shows typical measurement time in milliseconds.

Typical Time for Completion (ms)

	Number of Points			
	51	**201**	**401**	**1601**
Measurement				
Uncorrected	75	150	255	900
1-port cal[1]	75	150	255	900
2-port cal[2]	350	980	1640	5500
Time Domain Conversion [3]	110	500	1000	2500
HP-IB Data Transfer [4]				
Internal	20	20	20	20
ASCII	360	1350	2700	10,800
IEEE 754 floating point format				
32 bit	40	100	190	700
64 bit	80	290	560	2200

REMOTE PROGRAMMING

Interface

HP-IB interface operates according to IEEE 488-1978 and IEC 625 standards and IEEE 728-1982 recommended practices.

Transfer Formats

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

Interface Function Codes

SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C1, C2, C3, C10, E2

1. S11 1-port calibration, with a 3 kHz IF bandwidth. Includes system retrace time, but does not include bandswitch time. Time domain gating is assumed off.
2. S21 measurement with full 2-port calibration, using a 3 kHz IF bandwidth. Includes system retrace time and RF switching time, but does not include bandswitch time. Time domain gating is assumed off.
3. Option 010 only, gating off.
4. Measured with an HP 9000 series 300 computer.

Table 2-2. HP 8702 General Characteristics (2 of 3)

FRONT PANEL CONNECTORS

Connector Type .... type-N (female)
Impedance .... 50 ohms (nominal)
Connector Pin Recession .... 0.201 to 0.207 in

REAR PANEL CONNECTORS

External Reference Frequency Input (EXT REF INPUT)

Frequency .... 1, 2, 5, and 10 MHz (±200 Hz @ 10 MHz)
Level .... −10 dBm to +20 dBm, typical
Impedance .... 50 ohms

External Auxiliary Input (AUX INPUT)

Input Voltage Limits .... −10V to +10V

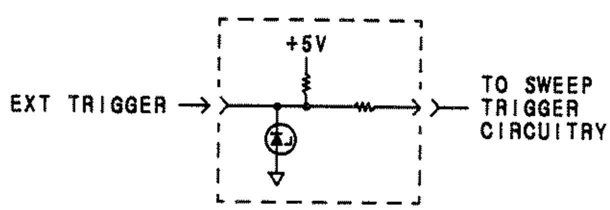
External AM Input (EXT AM)

±1 volt into a 5k ohm resistor, 1 kHz maximum, resulting in 8 dB/volt amplitude modulation.

External Trigger (EXT TRIGGER)

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

External Trigger Circuit



Red, Green, and Blue Video Outputs

Impedance .... 75 ohms
Voltage Limit .... 1v p−p (0.7v = white; 0v = black; −0.3v = sync

LINE POWER

47 to 63 Hz
115V nominal (90V to 132V) or 230V nominal (198 to 264V). 280 VA max.

PROBE POWER

+15V ±2% .... 400 mA (combined load for both probe connections)
−12.6V ±5.5% .... 300 mA (combined load for both probe connections)

Table 2-2. HP 8702 General Characteristics (3 of 3)

ENVIRONMENTAL CHARACTERISTICS

Operating Conditions

Temperature (*unless otherwise noted*) . . . . . 0° to 55°C
Humidity . . . . . 5% to 95% at 40°C (non-condensing)
Altitude . . . . . 0 to 4500 meters (15,000 feet)

Non-Operating Storage Conditions

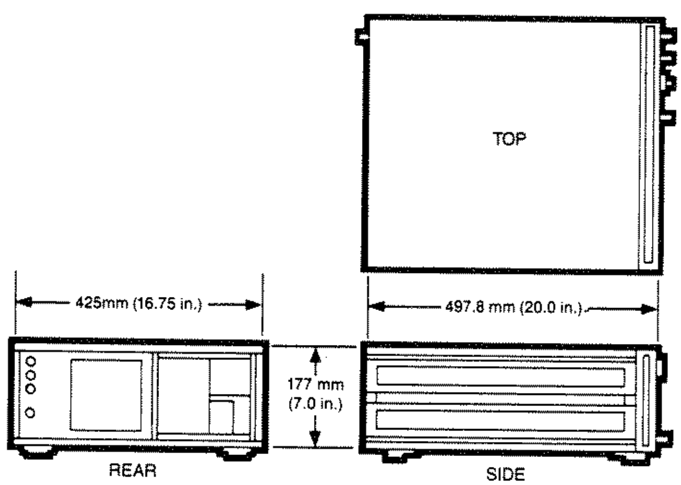
Temperature . . . . . −40°C to +70°C
Humidity . . . . . 0 to 90% relative at +65°C (non-condensing)
Altitude . . . . . 0 to 15,240 metres (50,000 feet)

WEIGHT

Net . . . . . 22 kg (48 lb)
Shipping . . . . . 25 kg (55 lb)

CABINET DIMENSIONS

177 mm H x 425 mm W x 497.8 mm D
(7.0 x 16.75 x 20.0 in)
(These dimensions exclude front and rear panel protrusions.)



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HP 8702
Lightwave Component Analyzer

User's Guide

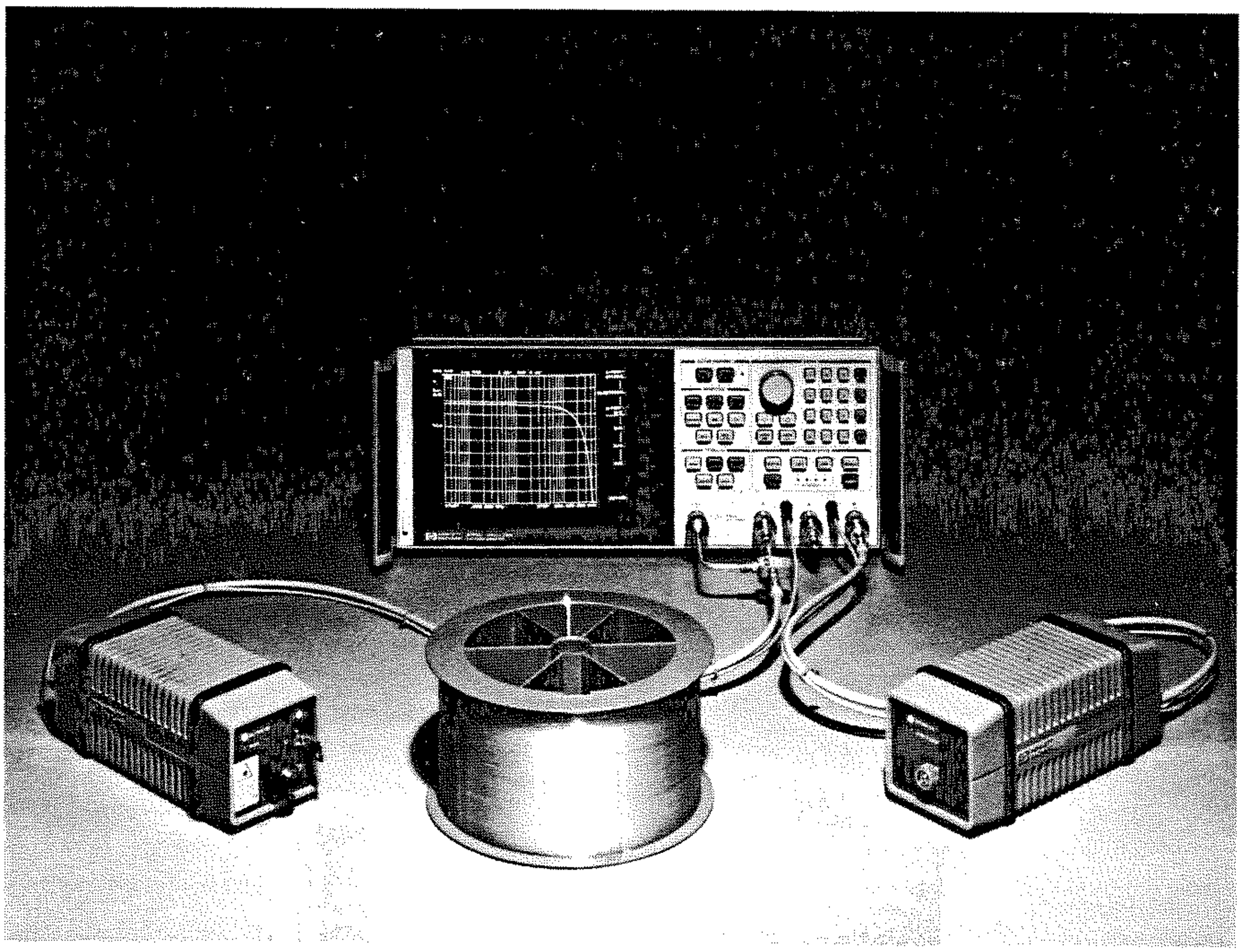


TABLE OF CONTENTS

Introduction

This *User's Guide* will give you an operator's introduction to the HP 8702 Lightwave Component Analyzer. It will show you how to make common optical and electrical measurements. The Guided Setup feature will demonstrate how easy it is to use the HP 8702. In addition, many of the features and capabilities of the HP 8702 will be demonstrated by making actual measurements.

If you are unfamiliar with the operation of a lightwave component analyzer, then you will find Chapter 1 helpful. It has tutorial information about the two kinds of analyzers (network analyzer and lightwave component analyzer) and the measurements they can make. Because the HP 8702 is capable of making both optical and electrical measurements, this information will help you understand the instrument's capabilities. In addition, this chapter discusses some of the HP 8702's special features, including an overview of the Guided Setup and a short tutorial to get you acquainted with the analyzer's front panel selections.

The purpose of Chapter 2 is to get you started making measurements as soon as possible. It has connection (installation) instructions, a power-up sequence, and a short tour of the Guided Setup menus. After reading this chapter, you should be ready to make measurements following the examples in Chapters 3 and 4.

Chapters 3 and 4 illustrate the HP 8702 at work, making a variety of transmission and reflection measurements on both optical and electrical devices. The examples have been chosen to demonstrate the full range of capabilities. The example devices under test (DUTs) are common optical and electrical components found in fiber optic systems.

Finally, Chapter 5 is presented as a summary of the HP 8702 Lightwave Component Analyzer, including further discussion of measurement calibration, connection techniques, and tips for finding information in the rest of this manual.

After reading this *User's Guide* and performing the example measurements, you will have a good understanding of the instrument. For further information, refer to the complete HP 8702 *Operating and Programming* manual.

CHAPTER ONE

Understanding the HP 8702

Overview

For most applications, the HP 8702 Lightwave Component Analyzer is a measurement system that injects a modulated signal into a test device and compares this modulated input signal to the signal which is transmitted or reflected by the test device. This comparison of the reflected or transmitted signal to the incident signal results in a ratio measurement (magnitude or phase) that characterizes the test device's response.

The concept of making ratio measurements to test the response of electrical devices and systems has traditionally been used in the RF (radio frequency) and microwave industries. The instrument used to make these transmission and reflection measurements of high frequency electrical networks is called a network analyzer.

A lightwave component analyzer is similar to a network analyzer. It provides an electrical signal to modulate a lightwave source. It also provides an electrical receiver section that compares the transmitted and reflected (demodulated) electrical signals to the RF modulation signal. Thus, three basic items are required to allow the analyzer to make optical measurements: 1) a lightwave source that can be modulated with the analyzer's electrical signal, 2) a lightwave receiver that can detect (demodulate) the RF modulation imposed on the optical carrier signal, and 3) an analyzer (signal processor) that is specifically designed to make transmission and reflection measurements of lightwave systems and components.

In fact, the HP 8702 Lightwave Component Analyzer combines the capabilities of a network analyzer for measuring electrical devices and the capabilities of a lightwave component analyzer for measuring optical devices. In addition, the HP 8702 provides new calibration routines and measurement features for characterizing opto-electrical and electro-optical devices directly and conveniently. A comparison of the two analyzers may help you understand the HP 8702 better.

The Network Analyzer and Lightwave Component Analyzer

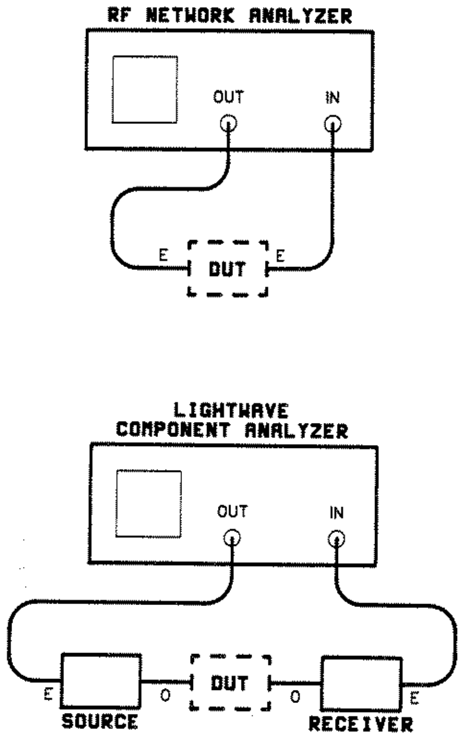


Figure 1. Network Analyzer and Lightwave Component Analyzer

Network analyzers use a swept RF frequency source as a stimulus signal to the device under test (DUT). This incident sinewave signal is also used as a known reference signal. The signal that is transmitted through the DUT is routed to the analyzer's receiver and compared to the reference signal. If a reflection measurement is made, an electrical test set is used to separate the incident from the reflected signal. The result of this process is a ratio measurement comparing an incident signal to a transmitted or reflected signal.

In the microwave world, this type of measurement is called an S-parameter (scattering parameter) measurement. It is an OUT/IN ratio. For example, S_{21} means that the scattering parameter is a ratio of the signal OUT of port 2 (device output) compared to the signal IN to port 1 (device input). S_{11} would be a reflection measurement, where 11 represents the signal coming OUT of (reflected from) port 1 of a device compared to the signal (incident) going IN to port 1 (same port) of the device.

For optical measurements, the HP 8702 uses the specially designed HP lightwave source (modulator) and lightwave receiver (demodulator) to modulate and demodulate the lightwave signal with an electrical RF signal. In this manner, the HP 8702 measures the test device's response to modulated light and processes the signals in the same way as a network analyzer.

Figure 1 shows that the lightwave component analyzer is the same as the network analyzer except that the incident RF signal (for example, 300 kHz to 3 GHz or to 6 GHz depending upon the system) is used to modulate the lightwave source (given wavelength laser) carrier; and the lightwave receiver (photo detector) is used to demodulate or remove the electrical signal from the lightwave carrier. In this manner, the optical device under test (DUT) is being characterized for its transmission modulation response. The ratio measurement can then be analyzed using the data which is typically displayed as magnitude vs. modulation frequency.

In summary, most optical measurements on the HP 8702 measure a DUT's response to a modulated lightwave signal, not the DUT's response to the lightwave carrier. However, other devices that have electrical ports, like E/E or E/O devices, respond to the RF signal and not the modulated lightwave signal. In any case, the HP 8702 can measure four types of devices which are easily categorized by their input and output ports:

- O/O devices: optical input / optical output
- O/E devices: optical input / electrical output
- E/O devices: electrical input / optical output
- E/E devices: electrical input / electrical output

Comparison to an OTDR (Optical Time Domain Reflectometer)

The HP 8702 can convert frequency domain measurements into time domain measurements. However, the HP 8702 should not be confused with an OTDR. An OTDR is excellent for measuring fiber discontinuities and backscatter in fiber optic systems. The HP 8702 is excellent for characterizing components and measuring relative reflections.

The following list summarizes most of the reflection measurement differences and similarities between the two instruments.

Measurement Capabilities	HP 8702	OTDR
Rayleigh backscatter and slope (atten. vs. length)	no	yes
Connector insertion or splice loss (see Note 1)	no	yes
Distance	yes	yes
2-point resolution (see Note 2)	2 or 6 cm	>25 m
Fresnel reflections	yes	yes
Return loss magnitude	yes	no
Transducer characterization of return loss	yes	no
Dead zone	no	yes

NOTE 1: For transmission measurements, the HP 8702 can make accurate measurements of splices and connectors.

NOTE 2: If an HP 84047A Test Set (Option 006) is used, the modulation frequency range is increased to 6 GHz. This allows the resolution of a Time Domain response to be approximately 2 cm, using an HP 83411A Lightwave Receiver and an HP 83402A Lightwave Source.

HP 8702 System Description

The HP 8702 Lightwave Component Analyzer is a measurement system that allows you to analyze the modulation frequency response of lightwave components, including E/O and O/E devices. With a complete system, you can measure the reflection and transmission characteristics of lightwave system devices including cables, connectors, attenuators, sources (E/O modulators), receivers (O/E demodulators), isolators, and more. All of these measurements are possible because of the HP 8702's measurement calibration ability (accuracy enhancement) that allows you to make accurate measurements.

Basically, accuracy enhancement is achieved by measuring a known standard device and comparing the measured data to the standard's mathematical model. The results of this process are then used to adjust or correct subsequent measurement data. This accuracy enhancement capability also makes it possible to measure the modulation transfer characteristics of your E/O and O/E devices. By using the HP lightwave source or lightwave receiver as a standard, and by performing a measurement calibration, you can accurately characterize your E/O and O/E devices.

In order to make a complete system, several key system components are required. These include an HP lightwave source, HP lightwave receiver, HP RF interface kit or HP 85044A/46A or 850447A Test Set, optical and electrical cables, and an HP lightwave coupler (not shown in Figure 2) for making optical reflection measurements.

Refer to Figures 2A and 2B. In Figure 2A, an HP 11889A RF Interface Kit is used to route the RF modulation signal to the lightwave (laser) source and the reference R input with the proper attenuation and balance. In Figure 2B, an HP test set is used to perform the same routing of the RF signal. In general, the test set is required only for making electrical reflection measurements, similar to a lightwave (optical) coupler being required for making optical reflection measurements. However, an HP 85047A Test Set is part of an Option 006 system and includes a frequency doubler, activated by the HP 8702, to increase the modulation frequency to 6 GHz when used (currently) with an HP 83402A Lightwave Source and an HP 83411A Lightwave Receiver.

The HP 8702 has a large annotated CRT display and a completely digitized front panel keyboard. It is also fully programmable (HP-IB) using an IEEE 488 controller like the HP 200- or 300-series computers and HP BASIC. It has a built-in RF electrical signal source that provides the stimulus signal. This RF signal is used to amplitude modulate the lightwave source over the frequency range of 300 kHz to 3 GHz or to 6 GHz (Option 006) depending upon the system configuration. The receiver portion of the HP 8702 has three 50 ohm inputs (R, A, and B) that receive the electrical signals. The R input is the reference signal or the denominator of the ratio measurement. The other inputs A or B represent the numerator and receive the reflected or transmitted signal. For example, a transmission measurement is a B/R ratio.

When an HP test set is used, instead of the RF interface kit, the connections to the R, A, and B inputs are made with short RF cables (type-N) supplied with the test set as shown in Figure 2B.

The optical portion of the HP 8702 measurement system consists of an HP lightwave source (HP 8340x family) and an HP lightwave receiver (HP 8341x family). These two system components allow you to make optical transmission measurements. The lightwave source is a laser that receives the RF signal input and outputs a modulated optical signal. The lightwave source's RF input is where the HP 8702's RF source is connected to modulate the laser, producing a modulated optical output signal. The lightwave receiver is a PIN photodiode detector with an optical input connector. The receiver removes the modulation signal from the lightwave carrier resulting in an electrical output signal that is fed directly into the HP 8702 receiver A or B input ports. When used with an HP lightwave coupler, the HP 8702 system (lightwave source and receiver included) is capable of making reflection and transmission measurements of lightwave components and displaying the data in both the frequency and time domains.

In order to make electrical reflection measurements or two-port transmission measurements without DUT disconnection, an HP test set (HP 85044A, 85046A, or 85047A) is required.

NOTE: The recommended optical connectors used with the HP 8702 are HMS-10/HP (Diamond). The HP lightwave source and lightwave receiver can be ordered with different connector/adapters, including FC/PC, DIN 46256, and ST. However, any connector type can be used with the proper adapter.

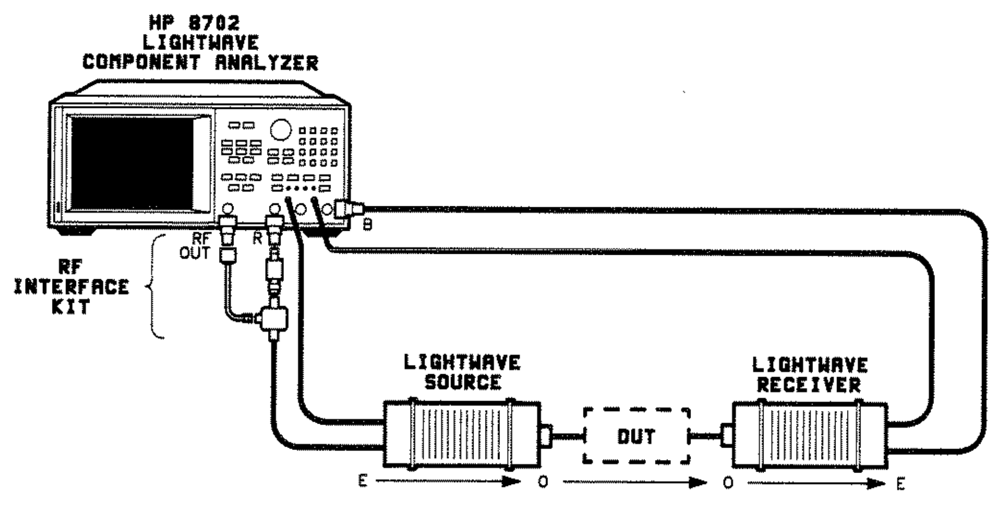


Figure 2A. Typical System Configuration using an RF Interface Kit

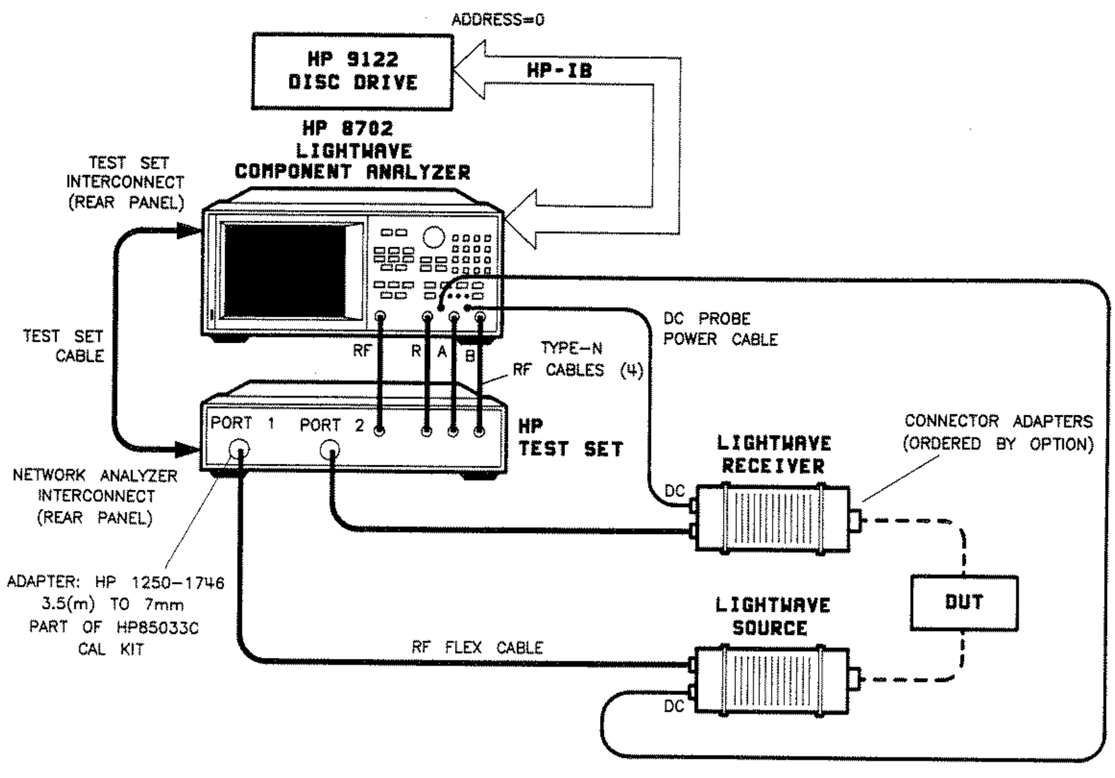


Figure 2B. Typical System Configuration using an HP Test Set

List of Typical System Instruments

A complete current system, capable of making most all of the measurements described in this *User's Guide*, would consist of the following:

- HP 8702 Lightwave Component Analyzer
- HP 83400A or 83401A Lightwave Source (1300 nm)
- HP 83410A or 83410B Lightwave Receiver
- HP 11890A or 11891A Lightwave Coupler
- HP 11889A RF Interface Kit (20 dB attenuator, power splitter, adapters) or HP Test Set.
- HP 11886A or 11887A Interconnect Cable Kit (optical thru or jumper cable)
- HP 9122-series Dual-sided Disc Drive (HP 9122C or D is currently recommended)
- HP 85046A or 85047A S-parameter Test Set and accessories for electrical reflection measurements only
- HP 85033C or other compatible calibration kit (for electrical measurements)
- 6 GHz systems (Option 006), used with an HP 85047A Test Set, requires two types of connector adapters: 3.5mm (male) to 7mm adapter and 3.5mm (male) to type-N (female) adapter. In addition, these systems currently use an HP 83402A SMF Lightwave Source and HP 83411A Lightwave Receiver (non-amplified) that operate up to 6 GHz.

Features and Capabilities

Guided Setup

A key feature of the HP 8702 is the *Guided Setup*. It is a series of graphic menus with easy-to-read choices that guide you through setting up a basic measurement. When the instrument is first turned on, the Guided Setup menu can be accessed by the press of one button. For example, if you were measuring the bandwidth response of a receiver (O/E converter), the Guided Setup would help you select the type of measurement you want, the type of device you are going to test, and the connections you need to make. Figure 3 shows how three of these menus would look (using an RF interface kit) after making the selections. If you have an HP test set connected to your HP 8702, the analyzer will display a graphic menu showing it connected.

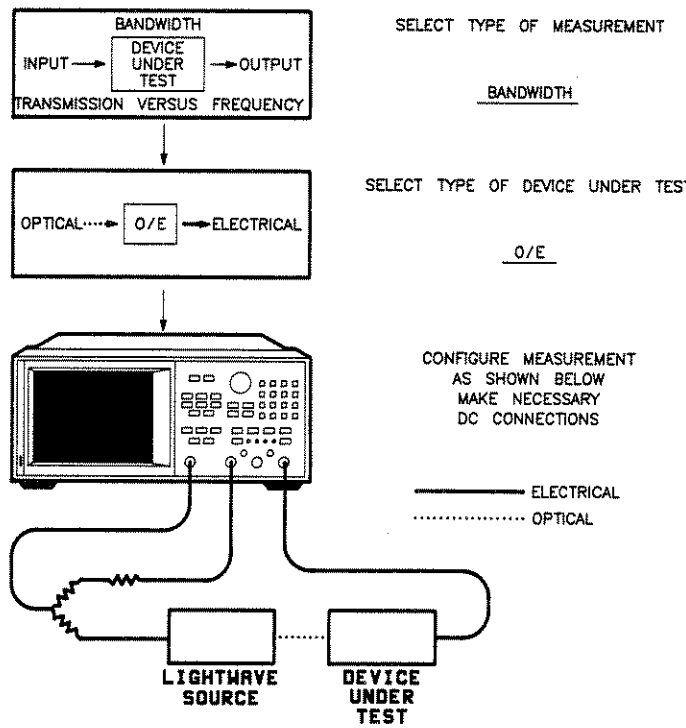


Figure 3. Example of Guided Setup Menus

The Guided Setup is not the only way to make measurements. You can also use the front panel menu keys directly. This is called *normal operation*.

The *General Information* section of the HP 8702 *Operating and Programming* manual has a description of the HP 8702 front panel features.

Measurement Calibration

This type of calibration is performed by the operator of the HP 8702. It is a process that removes the systematic instrument errors and enhances the accuracy of your measurement. The Guided Setup guides you through making the calibration. In simple terms, an optical measurement calibration is performed by measuring a standard device such as a thru connection (short length of cable) for a transmission measurement or a Fresnel reflection (3.5% reflected power) for a reflection measurement. For electrical measurement calibrations the typical devices are a short circuit, open circuit, termination (for example: 50 ohm load), and thru connection. These standards have been previously characterized and their mathematical descriptions are already loaded into the memory of the HP 8702. These mathematical definitions are called a *cal kit* (or standard definition) as they reside in memory. Using the definitions, the analyzer measures the standard and compares the measured data to the mathematical definition. Any differences caused by repeatable systematic errors in the measurement system are removed from DUT measurements by error correction terms. In this manner, the HP 8702 can mathematically remove systematic errors and enhance the accuracy of a measurement.

Getting Acquainted

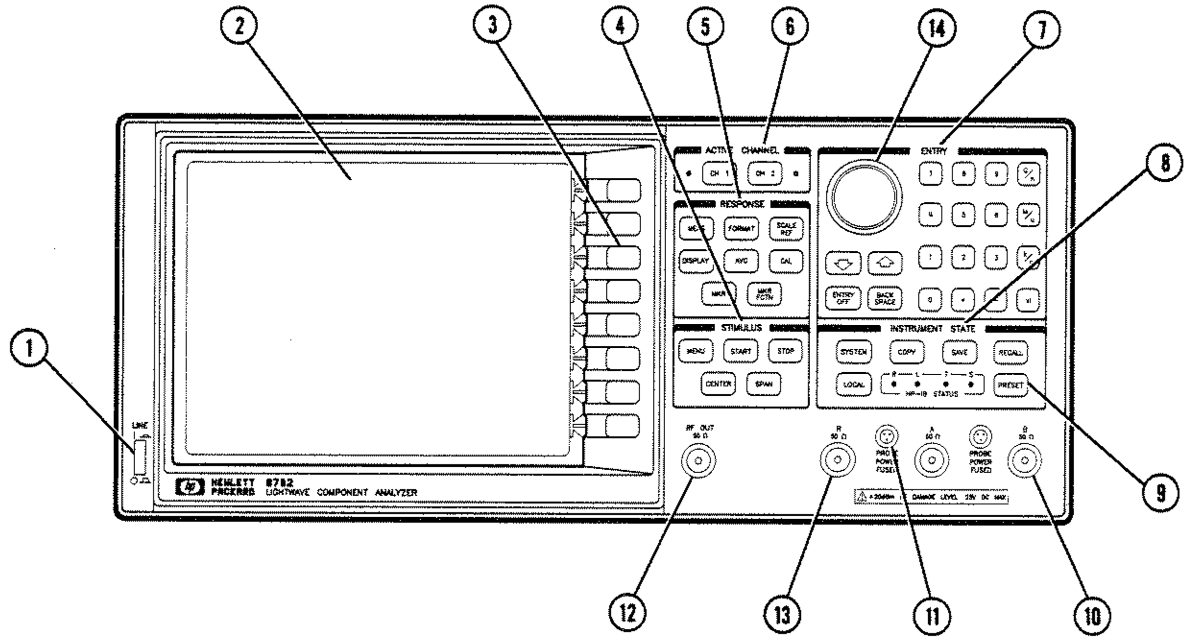
Before you connect the system and begin using the analyzer, there are some basic facts about the front panel keys that you should know.

Rather than individual keys for each of its many functions, the HP 8702 uses CRT-displayed *menus* for operator input. These menus list the possible choices for a particular function, with each choice corresponding to one of the eight *softkeys* located to the right of the CRT. The *hardkeys* on the right front panel provide access to the various menus, and are grouped by function.

Although the *Operating and Programming Reference* lists and describes all the menus and features, following is a short description of some of the major functions:

Color Display

The color version (HP 8702B) of the analyzer alows you to adjust the tint, brightness, and color using the DISPLAY feature. You can refer to the STIMULUS and RESPONSE section of the Operating and Programming Reference for details. You can also print in color using the COPY feature.



1. line on/off switch
2. CRT display
3. softkeys
4. stimulus keys
5. response keys
6. active channel keys
7. entry keys
8. instrument state keys
9. preset key
10. receiver input B
11. DC probe power
12. RF out
13. receiver reference input R
14. knob (rotary pulse generator or RPG)

Figure 4. Front Panel

Active Channel

The HP 8702 has dual trace capability where many of the measurement and display functions can be selected independently for each trace. To modify the parameters of a particular trace, you would select either channel 1 or 2 and then make the modifications. For example, you could measure the transmission characteristics of a device and display the results in linear magnitude on one channel and in logarithmic scale on the other channel.

Response

The analyzer's receiver section is controlled using these keys. The top three keys allow you to choose the type of measurement configuration (B/R, A/R, A only, etc.), the presentation format, and the scale or reference values for a full screen display. Presentation formats include amplitude/phase vs. frequency, polar coordinates, Smith chart, etc.

The lower five keys are used to enhance the measurement data for your own needs. The displayed traces may be overlaid, manipulated using the math function keys, averaged, normalized, or read out at specific frequency points along the trace with up to four independent markers for each channel.

Stimulus

These keys allow you to define the RF output signal that will either modulate your lightwave source or stimulate an electrical device (network). The RF source frequency may be swept over any portion of the available modulation frequency range using the start, stop, center, and span keys. The menu key gives you access to softkeys that allow you to change the RF source power level (+20 to −5 dBm), the number of data points measured, the number of averages, etc. The stimulus keys can also control the stimulus in the time domain mode, where *start* and *stop* become values of time instead of frequency. Note that Option 006 systems using an HP 85047A Test Set can increase the modulation frequency to 6 GHz because that test set contains a frequency doubler. This option is activated by pressing the appropriate softkey (labeled 6 GHz) on the HP 8702.

Data Entry

Sometimes a number must be supplied for a chosen parameter, such as frequency or amplitude. The ten digit keypad is used to supply these values. The keys to the right of the digits terminate the data entry with the appropriate units. For example, to enter a start frequency of 700 megahertz, you would enter **[700] [M/u]**, where the M represents *mega* or one million; the u represents micro or 1×10^{-6} (the HP 8702 will always know to use M or u, depending upon the selection). In addition, the x1 key is used to identify basic units such as dB, dBm, degree, second, Hz. In addition, the RPG (rotary pulse generator) knob on the front panel can be used to make continuous numerical adjustments by turning it to the left or the right, while the arrow keys can be used to change values in steps.

Instrument State

Several utility functions are implemented with these keys, including resetting the HP 8702 to its preset state , saving and recalling from memory, copying to disc, local operation as opposed to computer control, and many other functions. In addition, the system key can be used to access the built-in diagnostic tests and the Guided Setup.

C H A P T E R   T W O

Getting Started with Guided Setup

This chapter will get you started using the HP 8702. Follow the three steps below to connect your system, power-up and preset it, and learn front panel operation by touring the Guided Setup.

Step 1: Connect the System

The first step that you need to take is to connect the system. If you want information about environmental, power or space requirements, refer to the *General Information* section of the manual. If not, go ahead and connect the HP 8702 system as shown in Figure 5A or 5B.

TEST SET NOTE: If you are using an HP test set (HP 85044A, 85046A, or 85047A) you can refer to Figure 5B or Figure 2B which shows two different methods of connection. The test set attenuates the RF signal by approximately 10 dB more than using the RF interface kit because the RF signal passes through the separation/routing (bridge or coupler) in the test set. By connecting the lightwave receiver's output directly to the B input of the analyzer, rather than through the test set port 2, your system will gain more dynamic range proportional to the extra attenuation in the test set. If necessary, refer to the test set manual for further information.

Although the measurements in this *User's Guide* are best suited to systems using the RF interface kit within the 300 kHz to 3 GHz range, systems using test sets will have similar results as long as the HP lightwave source and receiver are also 3 GHz instruments.

After connecting the test set, continue with the steps below to connect the lightwave source and receiver.

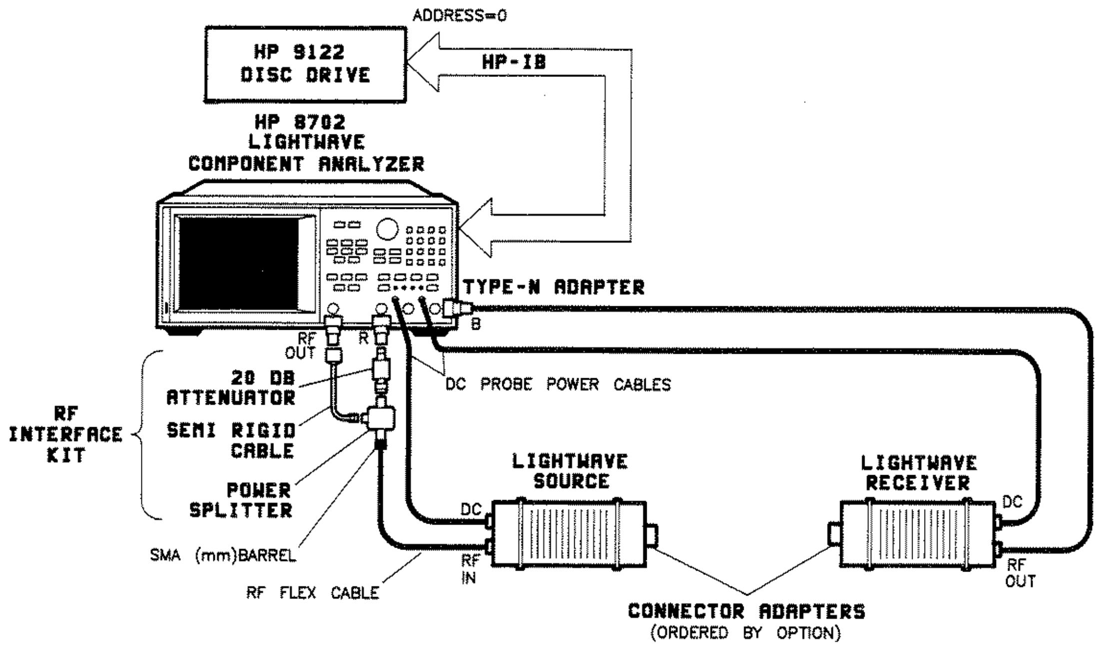


Figure 5A. System Connection using the RF Interface Kit

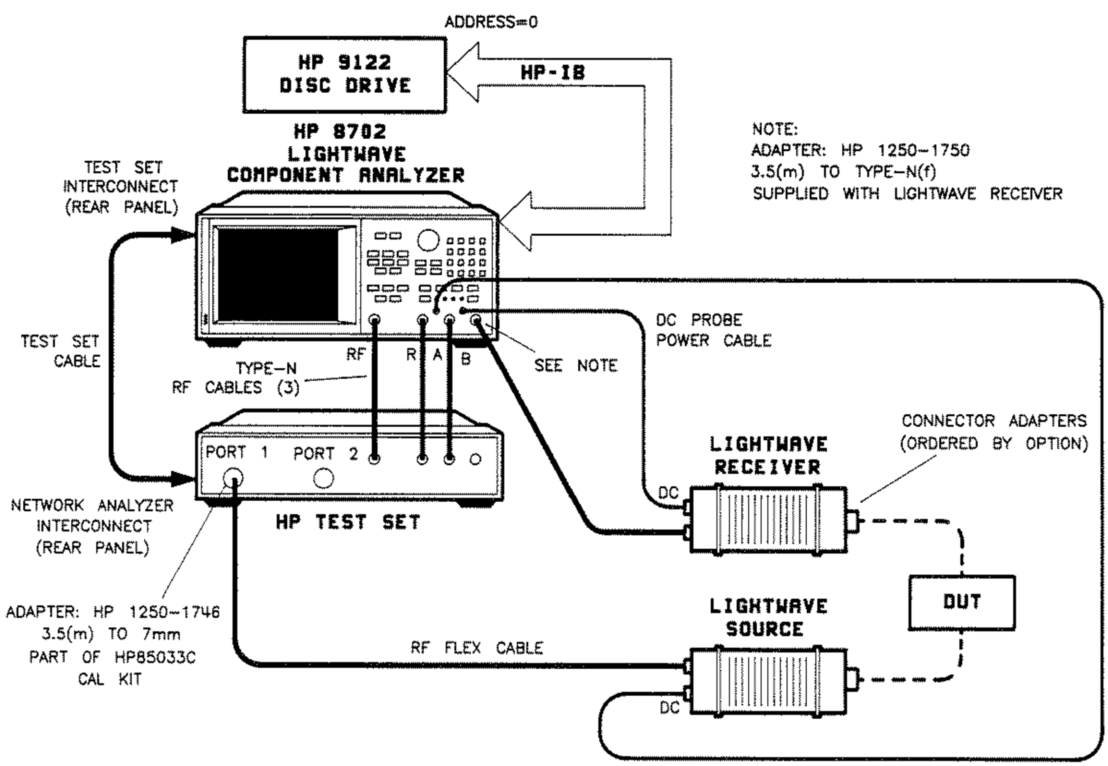


Figure 5B. System Connection using a Test Set

Connection Procedure

Refer to Figures 5A and 5B.

1. Place all the instruments on the bench or table. Leave enough room in front or on the side of the analyzer to set the lightwave source, lightwave receiver, accessories and test devices.

   NOTE: The lightwave source and lightwave receiver connector adapters should already be connected to their optical ports (refer to those manuals). In addition, note that the connector adapters are keyed to a slot. Be sure that the connector is properly attached before tightening the connector adapter.

2. With the line switch off, plug in the HP 8702 to the appropriate power outlet and check the rear panel AC switch for the proper voltage. Do not turn it on yet. If you have one, connect the disc drive to the HP-IB on the HP 8702. Later in this *User's Guide*, you can use the disc drive to load the source or receiver calibration data into the HP 8702.

3. Connect the RF interface kit to the HP 8702. If necessary, refer to its operating note for connection details.

CAUTION

Do not touch the center pin of the HP 8702 RF OUT connector. Static discharge can damage the internal RF source.

4. Connect the lightwave source and lightwave receiver DC inputs to the HP 8702 probe power using the cables supplied.

   NOTE: Plastic cable clips are supplied with the source and receiver to keep the RF and DC cables clipped together.

5. Connect the RF cable (supplied with source) from the power splitter (use the SMA m-m barrel in the RF interface kit) to the lightwave source RF input. Connect the lightwave receiver RF output to the B input on the HP 8702 (use the type-N to SMA adapter).

Step 2: Power-up the System and Use the Preset Key

WARNING

For safe operation, turn the source laser ON when you are making a measurement. Turn it OFF when not in use. Remember not to look directly into the laser output or any fiber connected to it because damage to the eye can result. Read the laser safety information in the HP lightwave source manual.

1. Turn on the HP 8702 LINE switch on the front panel and turn on the disc drive.
2. If connected to the HP 8702 probe power, the lightwave source and lightwave receiver are automatically turned on when the HP 8702 is turned on.

   The CRT on the HP 8702 will display a message, giving you a choice between Guided Setup and normal operation. Press *[NORMAL OPERATION]* and note the change in the CRT display.

OPTION 006 NOTE: If your HP 8702 is equipped with Option 006 for modulation frequency up to 6 GHz using an HP 85047A Test Set, DO NOT activate the 6 GHz operation. An example of 6 GHz operation is given in the chapter on reflection measurements to demonstrate its capabilities.

Press the green **[PRESET]** front panel key and notice the difference between the instrument now and when you first turned on the LINE switch. Pressing the **[PRESET]** key returns the instrument to a pre-defined state. In addition, the HP 8702 performs a self test that, if passed, sets the the instrument to the following default conditions:

Major Default Conditions at [PRESET]	
DISPLAY	
Measurement	O/O on Channel 1
Format	Log Magnitude
Display Mode	Dual Channel Off
Scale	10 dB/division
Reference	0 dB, center of CRT
STIMULUS	
Start Frequency	300 kHz
* Stop Frequency	3 GHz
Number of Data Points	201
Power	0 dBm
Sweep Time	800 ms
* Option 006 (using an HP 85047A Test Set) allows you to set the frequency range to 6 GHz).	
RECEIVER	
IF Bandwidth	3 kHz
Averaging	Off
Smoothing	Off
Cal Correction	Off

Step 3: A Tour of Guided Setup

If you are already familiar with the operation of a network analyzer, you may want to go directly to the examples in the next chapter. If not, continue below.

The following procedure will show you how to use Guided Setup. It will take you right up to the point of making an optical measurement. When you are finished, you will be prepared to make the measurements in Chapters 3 and 4.

Instructions: Read through the text on the right for an explanation of the procedure. Then press the keys listed on the left side of each paragraph.

[GUIDED SETUP] — Press the *[GUIDED SETUP]* softkey and notice the three measurement choices for bandwidth, reflection and gain/compression.

When you press the softkey the name of the selection is underlined and a graphics box appears around the selected measurement.

[BANDWIDTH]
[CONTINUE] — Press the *[BANDWIDTH]* softkey and then *[CONTINUE]*. The next menu allows you to select the device type. Press each one and notice how the user interface reacts. Then press the *[O/O]* device type and *[CONTINUE]*.

[O/O]
[CONTINUE] — The next menu shows the configuration or connections. Because you selected bandwidth and O/O in prior menus, the configuration shows an optical test device connected between the source and receiver. In order to see the other configurations, return to the previous menus.

[PRIOR MENU]
[PRIOR MENU] — For example, return to the measurement selection menu by pressing the *[PRIOR MENU]* key twice. Then select a reflection measurement.

[REFLECTION]
[CONTINUE] — In this menu, you can select either an optical or an electrical device where 1-PORT refers to the a device with only one measurement port. Also, notice that a coupler (symbol: four arrows diagonally opposed) is shown connected with the reflected signal going into the receiver.

If you were making an electrical reflection measurement, you would need an HP test set.

[PRIOR MENU]
[BANDWIDTH]
[CONTINUE]
[O/O]
[CONTINUE] — Go back and select a bandwidth — O/O measurement. Connect a short line of cable between the source and receiver to take the place of a DUT, as shown in the diagram on the CRT. Then press *[CONTINUE]*. Notice that you have to press the *[CONTINUE]* key again after the connection diagram appears on the CRT.

[CONTINUE] — The CRT display should now have a trace on a graticule, showing the measurement system response. Also, notice that the top, side, and bottom borders of the graticule show the following: O/O measurement, channel 1 is active making a B/R ratio measurement (receiver input B divided by the reference R input), a logarithmic magnitude scale where, typically, each division is 10 dB and the reference is the middle line at 0 dB.

[START] **[450] [k/m]** **[STOP]** **[1] [M/u]** *[CONTINUE]* **[MENU]**	The main purpose of this menu is to set the start and stop RF modulation frequencies. Notice that a start frequency of 300 kHz is the default. Use the RPG knob, the step (arrow) keys, or the key pad to change the start frequency to 450 kHz and the stop frequency to 1 MHz, then press *[CONTINUE]*. Notice the new frequencies displayed on the bottom of the CRT.
[SWEEP TIME] **[2] [x1]** *[SOURCE POWER]* **[4] [x1]**	The next menu allows you to set the sweep time, source power, and type of sweep: linear or logarithmic. Set the sweep time to 2.0 seconds for this example. Then set the source RF power to +4 dBm by pressing the up arrow step key, or the entry keys. Leave the instrument in linear frequency sweep since log sweep requires a 2 octave minimum and appropriate sweep time to work. If you choose log sweep here, an error message would be displayed on the CRT directing you to correct the operational error.
[CONTINUE] *[RESPONSE]*	Continue and notice that a set of measurement calibration selections are displayed. In this example, you will be making a response calibration with a standard cal kit definition. Notice that the display shows a *[STD]* standard cal kit. However, you can use your own calibration kit *[USER]* if you load the definitions into the HP 8702. In this case, the term kit refers to a set of numerical definitions that are loaded into the HP 8702 to describe a particular calibration device such as a load or a Fresnel reflection.
	NOTE: A user kit would be a set of definitions that you have entered into the HP 8702 to describe your own calibration device.
[CONTINUE]	For now, keep the standard kit and continue. This means that the response calibration will use a previously defined standard — a *thru*. This thru is the short piece of optical cable that is connected between your source and receiver.
[THRU] *[DONE: RESPONSE]*	With the thru (optical jumper or patch cord) already connected between the source and receiver, perform the calibration by selecting the thru. The HP 8702 will make a measurement and underline the word THRU when it is finished. The *[DONE: RESPONSE]* key is used to complete the calibration procedure. When complete, notice that the trace is now a flat line across the CRT. This normalizes or corrects the displayed trace. Therefore, when you insert your O/O device between the end of the thru line and the receiver, only the response of your DUT will be displayed on the HP 8702 CRT.

At this point, you would normally save your calibration in a register (memory) in the HP 8702. This is easily done using the **[SAVE]** key and then selecting a register. Also, notice that the annotation *Cor* is displayed on the side of the CRT whenever the measurement calibration (error correction coefficient) is turned ON.

The Guided Setup is now complete: the system is properly configured, the measurement parameters have been defined, and a measurement calibration (similar to normalization) has been performed. Remember that the Guided Setup makes it easy to measure devices within the parameters it allows you to set. The *Normal Operation* mode requires that you select the HP 8702 features by pressing the individual response, stimulus and instrument state keys and the softkey selections in those blocks. However, your choices are much greater because you can use all of the features available. In general, *Normal Operation* has more versatility than the Guided Setup sequence.

Tips on using Guided Setup

- If you leave the Guided Setup sequence, you can always press the **[SYSTEM]** key to access the Guided Setup menu selection again. If you press the **[PRESET]** key, any of the modifications you made in Guided Setup will return to the default preset state.
- Guided Setup has certain default conditions, including: 0 averages, no active markers, 201 measurement data points, channel 1 and 2 coupled together (one active channel), and no auto scale.
- You can modify the conditions (parameters) using normal operation but you will have to re-enter the Guided Setup sequence from the beginning (use **[SYSTEM]** key) when you do.
- You can make different types of measurements, including pulse dispersion, phase, etc. Some of these other measurements are described in the *Operating and Programming* manual in the *Advanced Measurement Techniques* section.

Transmission Measurements

Transmission measurements show you the insertion loss, flatness, responsivity, and modulation bandwidth of the test device. Transmission phase measurements show you device delay and device length information. Also, by using the frequency response calibration (response cal) feature of the HP 8702, you can enhance the accuracy of the measurement so that only the response of your DUT remains.

The examples in this section show you how to make three types of transmission measurements: 1) the modulation frequency response (bandwidth) of a roll of fiber, 2) the modulation frequency response of an E/O device and, 3) the modulation frequency response of an O/E device.

Although all the measurement configurations in this chapter use the RF interface kit, systems with HP test sets connected can also be used with similar results. The difference in configuration is that the RF signal comes out of test set port 1 and goes into the lightwave source; and the lightwave receiver RF output goes into port 2 of the test set or the analyzer's B input.

Example 1 — O/O: Modulation Bandwidth of of 1 km of Multimode Fiber Using Guided Setup

In this example, the DUT is a roll of multimode fiber optic cable about 1 kilometer long. The result of this measurement will be a plot of insertion loss vs. modulation frequency, indicating the exact frequency at which the 3 dB roll-off point occurs.

NOTE: You can use a different length of multimode cable, but it should be as close to 1 km as possible. However, you may have to set the sweep time slightly greater for longer cable lengths. As you will see in this example, the sweep time is set to 3.5 seconds is more than adequate for one kilometer of cable. One way to determine if sweep time is long enough is to set it and then increase or decrease the sweep time (with the DUT connected) until a change in the displayed results indicates that the setting is incorrect.

Procedure:

1. Connect the system with the thru optical cable as shown in Figure 6. Do not connect the DUT yet. Press the following keys to begin setting up the measurement.

   [PRESET] *[GUIDED SETUP] [BANDWIDTH] [CONTINUE] [O/O] [CONTINUE]* and *[CONTINUE]* again.

   NOTE: O/O and start 300 kHz are default conditions set by pressing the **[PRESET]** key. You do not have to press these keys. They are included only to describe the parameters you are setting.

2. Set the modulation start and stop frequencies.

   [START] [300] [k/m] [STOP] [700] [M/u] *[CONTINUE].*

   NOTE: This modulation bandwidth was selected for this type of cable. If desired, you can use the full band.

3. Set the sweep time. This is the time it takes the RF source to sweep from the start to the stop frequency (HP recommends about 15 ms per frequency point). This time must be long enough to allow each modulation frequency to propagate down the fiber and be properly sampled by the HP 8702 receiver. Approximate the amount of sweep time you need. In this case, with 201 data points (preset default) and 15 ms per point, about 3.5 seconds is enough for the measurement of the low loss 1 kilometer cable (15ms x 201 points = 3.1s, use 3.5). If the DUT had delay or extreme length, extra sweep time would be required.

   [SWEEP TIME] **[3.5] [x1]**

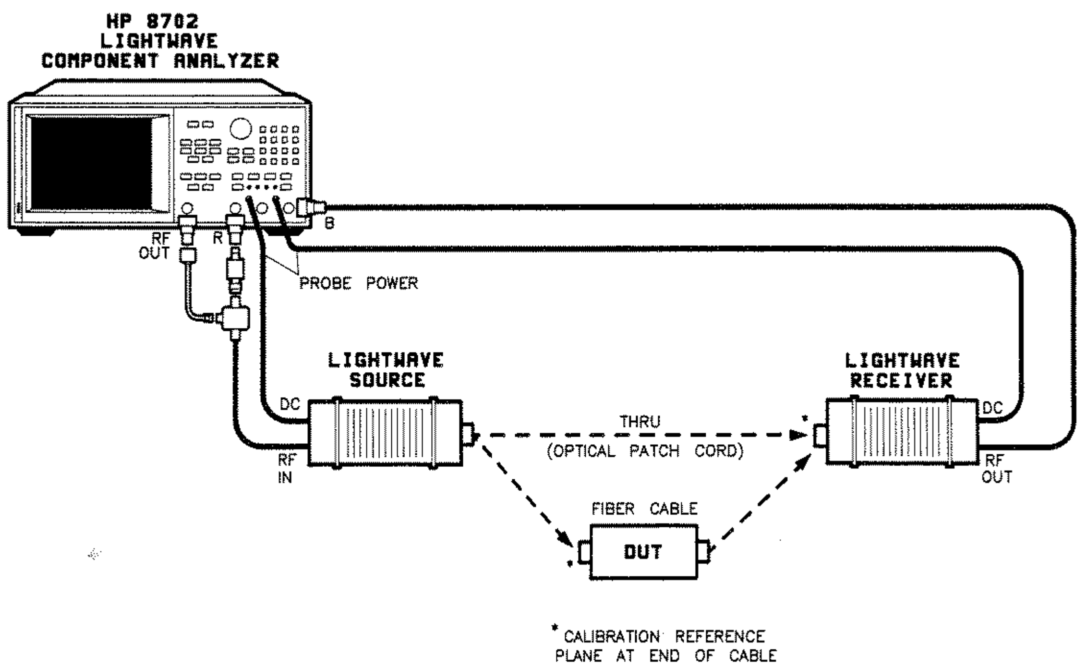


Figure 6. Optical Cable Transmission Measurement Configuration

4. Set the source power. In this example, use 10 dBm, which should give you enough dynamic range for measuring this low loss line. Note that the RF input to the lightwave source will actually be +4 dBm because the power splitter has a 6 dB loss.

   [SOURCE POWER] [10] [x1]

   Also, select the log sweep type to get a better view of the bandwidth response on the display.

   [SWEEP TYPE LIN FREQ] [LOG FREQ] and *[CONTINUE]*

5. Perform a response calibration.

   Connect a thru cable, from the interconnect cable kit or your own short cable with the appropriate connector/adapters, between the source and receiver. Notice that the HP 8702 shows the response of the entire measurement system. You could imagine that if you inserted your device at this point, the measurement would include your DUT's response added to the response now being displayed on the CRT. However, the following calibration procedure will remove the system's response from your measurement.

   [RESPONSE] [CONTINUE] [THRU].

   The thru cable acts as the optical thru standard which is already defined in the HP 8702 cal kit.

6. When the analyzer has finished the measurement, it will beep and underline the word THRU. Complete the calibration by pressing:

   [DONE: RESPONSE]

   The measured data is now normalized, setting the magnitude values to unity or 0 dB. Notice the abbreviation *Cor* on the side of the CRT. This means that the calibration (error correction coefficient) is active.

7. You are now ready to measure the roll of cable. Notice that the CRT trace is a flat line across the graticule. The end of the thru cable, connected to the receiver, is now the measurement reference plane.

   Connect the roll of fiber between this cable and the receiver, using the appropriate connectors. All connectors should be clean and undamaged.

   After one complete measurement sweep, the transmission response of the multimode fiber roll will be displayed on the CRT.

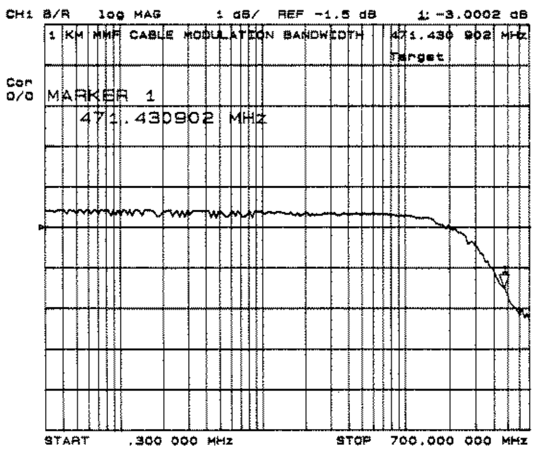


Figure 7. Bandwidth Response of Example DUT

8. Get a better view of the results by using the display features.

   [SCALE REF] *[AUTO SCALE]*.

   The bandwidth response of your fiber cable depends upon the cable you use. Bandwidth is defined as the −3 dB point. Figure 7 shows the bandwidth of a typical roll of fiber cable. The marker is placed on the 3 dB point by using the **[MKR FCTN]** key and the *[SEARCH]* and *[TARGET]* softkey features.

   The results of this example show that the bandwidth of the roll of fiber cable is approximately 470 MHz. In other words, any modulation frequency above that point would be attenuated past the half-power point.

NOTE: You can use the HP 8702 marker function to read the trace value at any modulation frequency. Press the **[MKR]** key and select *[MARKER]* **[1]**. Then use the knob or the arrow keys to go to a particular frequency or to set the marker to the 3 dB point. The marker amplitude (dB) is noted at the top right of CRT display. The *Using Markers* section of the *Operating and Programming* manual describes all of the marker features.

Example 2 — E/O: Source Measurement Using Guided Setup

In this example, you will use the Guided Setup menus to measure the modulation transfer characteristics of a source or E/O converter. This example is very similar to an O/E measurement.

Bandwidth, responsivity, and flatness of an E/O device can be measured by performing a measurement calibration that uses the HP lightwave source cal data (model).

In general, transducers (E/O and O/E devices) are difficult to measure and often have to be measured in pairs, where the known response of one is used as a reference to measure the unknown response of another. Also, because the measurement system includes the lightwave receiver and lightwave source, optical and electrical cables, and the HP 8702 itself, a way must be found to separate the source response from the response of the system. This is where the HP 8702 differs from other measurement systems. It provides a way to make a measurement on a single transducer by the use of the HP 8702 error correction feature.

When you insert your source (E/O) and have the calibration turned on (symbol on CRT: *Cor*), the HP 8702 does two things:

(1) It removes the entire system response (electrical and optical) using the measurement calibration data. This is similar to what you observed by performing a measurement calibration during the tour of the Guided Setup.

(2) It corrects the source (E/O) DUT response using the HP source cal data (model) loaded into the HP 8702. This is similar to comparing a known standard response to its measured response and correcting for any differences when DUT measurements are made.

Thus, when you replace the HP lightwave source with your own, the HP 8702 will measure the system response and apply the correction to the data. the result is an accuracy enhanced measurement that describes the modulation transfer characteristics of your E/O device alone.

The HP 8702 can read the disc supplied with the lightwave source or receiver using an HP 9122 series dual-sided disc drive. Remember that the disc contains 101 data points that characterize or model the lightwave source or lightwave receiver. The characterization can also be entered through the front panel by using the 9 numbers (coefficients) supplied on the label on the instrument. The following measurement example shows you how to do this.

NOTE: The HP lightwave source RF input is a 50 ohm input that uses an SMA connector. Other connector types require electrical adapters.

Procedure:

1. Connect the system as shown in Figure 8. The thru cable (preferably the HP 11886A or 11887) is connected between the source and receiver. Press the following keys to begin setting up the measurement.

   [PRESET] *[GUIDED SETUP] [BANDWIDTH] [CONTINUE] [E/O] [CONTINUE]* and press *[CONTINUE]* again.

2. Set the modulation start and stop frequencies. In this case, leave the default frequency range of 300 kHz to 3 GHz. Then press:

   [CONTINUE].

3. The sweep time can be left at the default of 800 ms. But the source power should be increased to 20 dBM to get more dynamic range:

   [SOURCE POWER] **[20] [x1]** and *[CONTINUE].*

   Note that the RF signal power input to the lightwave source will be +14 dBm because the splitter has a 6 dB loss. Also, leave the sweep type in linear unless you want to view the results with a logarithmic scale.

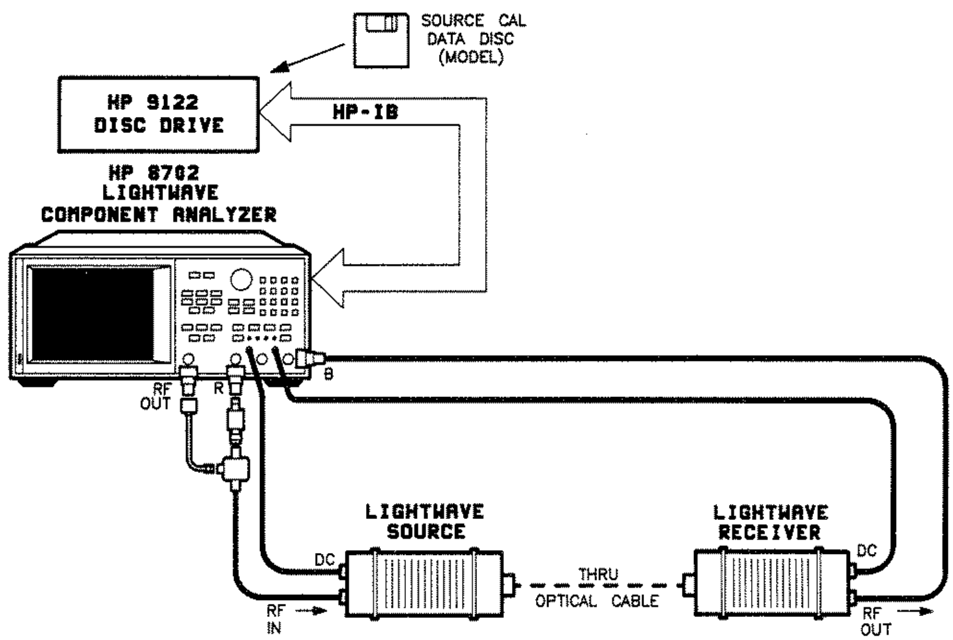


Figure 8. Source Measurement Configuration

4. Perform a source response calibration. You are going to use the HP 8702's accuracy enhancement capabilities to get an accurate measurement of your DUT. You will be loading the cal data (model) that is supplied with your lightwave source into the HP 8702.

   Notice that the preset state sets the *[CAL STD]* selection to *[COEFF]*. This means that the HP 8702 expects you to enter the lightwave source's nine calibration data coefficients that are on the label. There are two ways to enter the source's characterization data: automatically using the disc, or manually entering nine coefficients that approximate the disc data. However, HP recommends that you use the disc calibration data for the most accurate data.

   If you have a disc drive, change the setting from *[COEFF]* to *[SRC DISC]*. Press:

   [CAL STD (COEFF)][CAL STD: SRC DISC] and then press *[LOAD SRC DISC]*.

   If you do not have a disc drive, see the note in step 5 below.

5. Be sure the disc drive is connected to the HP-IB bus on the back of the HP 8702. Insert the 3.5 inch Source Cal Data disc in drive 0 and press:

   [SYSTEM CONTROLLER] and *[READ FILE TITLES]*.

   The system controller key is used to tell the HP 8702 that it, and not an external computer, can access the disc drive. Be sure the disc drive is set to the proper HP-IB address. For example, set the disc drive HP-IB address = 0: press, **[LOCAL]** *[SET ADDRESSES][ADDRESS: DISC]* **[0] [x1]** ; and be sure the switches on the disc drive are also set = 0. However, you will have to re-enter the Guided Setup sequence again.

   NOTE: The system controller command is also accessed by pressing the **[LOCAL]** key. However, you would usually only access it that way in normal operation, not in Guided Setup.

   Information about computer control of the HP 8702 is described in the HP-IB programming portion of the *Operating and Programming* manual.

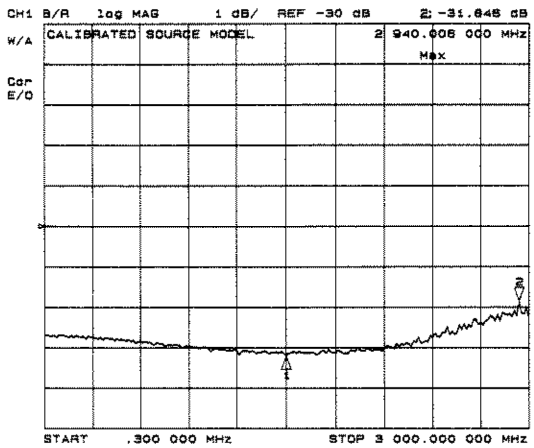


Figure 9. HP Source CAL DATA Model Response

The HP 8702 will read the files on the disc and create a label next to a CRT softkey for the file. Select the file that corresponds to the number on your source. For example, you would press the softkey that is labeled the same as the filename on your disc. For example, press:

[LOAD xxxxxx].

The HP 8702 will read the data and store it into its cal kit memory. Notice that the CRT label will be underlined when complete. You must now return to a prior menu to make the actual calibration measurement. Press:

[PRIOR MENU] and *[CONTINUE].*

NOTE (entering 9 coefficients): If you do not have a disc drive, you can use the coefficients on the label by pressing the following keys: *[SRC COEFF] [ENTER SRC COEFF].* Then press each softkey corresponding to the 9 coefficients (A through I, using the *[MORE]* softkey) and enter the coefficient from the label on the HP lightwave source using the HP 8702 keypad and the **[x1]** key. When all have been entered, press *[PRIOR MENU] [SAVE SRC COEFF] [PRIOR MENU]* and *[CONTINUE].*

6. Complete the calibration process and press:

   [SOURCE].

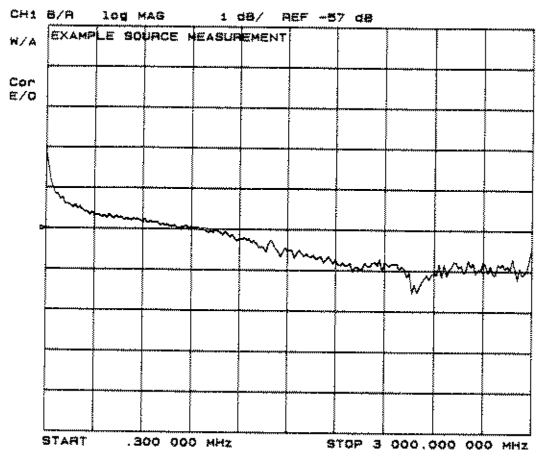
   After the measurement is complete, the HP 8702 will beep and underline the word SOURCE. Press:

   [DONE: RESPONSE].

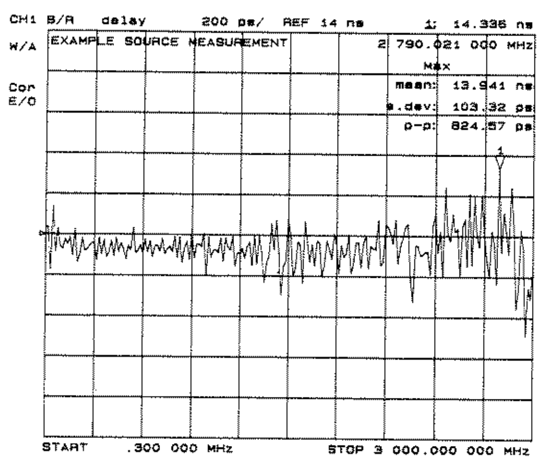
7. The Guided Setup is now complete and you are ready to insert your E/O Device.

   Before you do, notice that the HP 8702 is now displaying the response of the source used for calibration. The display units are log responsivity: the ratio of RF power out to modulation power in. The HP 8702 has normalized out the electrical response of the measurement system and the response of the lightwave receiver.

   Insert your DUT and, after one complete sweep, the HP 8702 will display the response. Figures 9 and 10 show typical results of the calibration and the DUT measurement.



A



B

Figures 10A and 10B. *Typical E/O Source DUT Measurement*

Notice that the annotation shows the following items:

CH1:	Measurement is on channel 1.
B/R:	The measurement ratio is the modulation signal at input B divided by the modulation signal received at reference input R.
log mag:	The display is a logarithmic display of power versus frequency.
1 dB/:	The graticule scale is 1 dB per division.
REF:	The graticule reference value is marked by a small triangle (left edge of graticule) and has a value of −30 dB.
W/A:	This indicates that a source (E/O) is being measured where the dB values are watts per amp.
2:	This is marker 2 (active) and its value is about −31 dB, 2.94 GHz. The marker function has searched for the MAX (maximum) trace value.

NOTE: Referring to Figure 9, marker 2 shows the responsivity R_s as a dB value of −31.846. This can be calculated as:

$$R_s(\text{dB}) = 20\log_{10}\frac{Rs\,(W/A)}{1\,(W/A)}$$

In addition, note that the briefly displayed HP 8702 message about W/A and responsivity correspond to this calculation. Refer to page 36 for details.

Other: Notice that the start and stop frequencies are displayed on the bottom of the graticule. Also, the plot is titled EXAMPLE SOURCE MEASUREMENT. This was done using the **[DISPLAY]** key Title menu.

The measurement example in Figure 10A shows the modulation bandwidth response of a typical source. Notice that marker 1 is placed on the reference line at −57 dB (975 MHz).

The measurement example in Figure 10B shows the same measurement data as Figure 10A, but is now showing group delay, where the **[FORMAT]** *[DELAY]* selection has been chosen to show the source's time delay response. This delay is referenced from the source's electrical input to its optical output. These reference planes are established by the calibration procedure. Notice that the marker can be set to read the delay at any particular frequency. In addition, the statistics feature has been selected to show the mean, standard deviation, and peak-peak value in delay time. This selection is made by pressing: **[MKR FCTN]** *[MORE]* *[STATS]*.

Example 3 — O/E: Receiver Measurement

This example is similar to the previous source measurement where the modulation transfer characteristics were measured. However, in this example, you will use the HP 8702 in normal operation, without the Guided Setup. First, you will perform an electrical (E/E) response calibration to see how the HP 8702 removes the electrical system response. Then you will perfrom a receiver response calibration to see how the HP 8702 uses the receiver as a calibration standard before measuring your own receiver response to determine its responsivity.

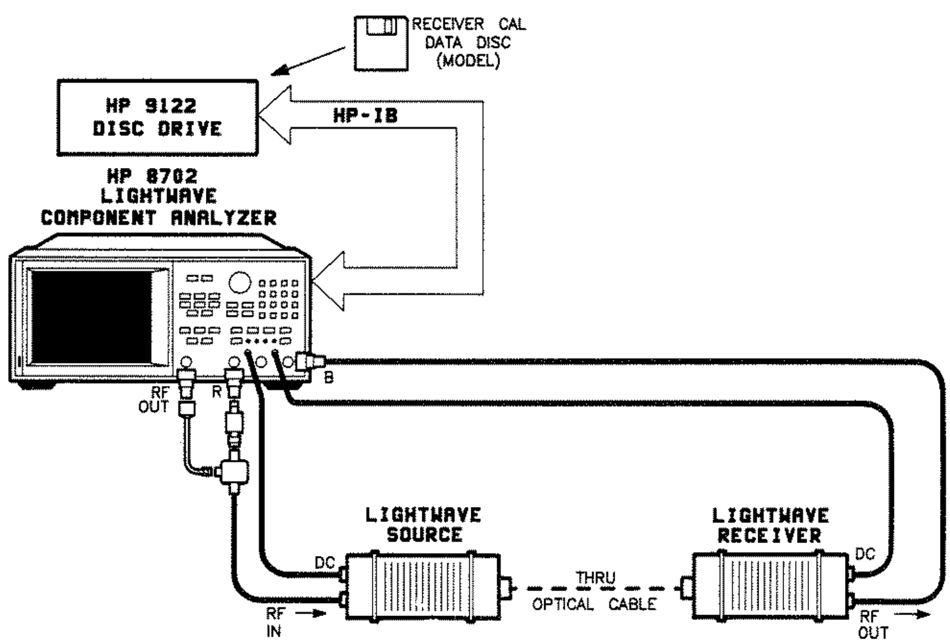


Figure 11. O/E Transducer Measurement Configuration

Procedure:

1. Select the HP 8702 parameters. As usual, you will preset the HP 8702 and then set the start frequency to 300 kHz and the stop frequency to 600 MHz. Now, instead of the Guided Setup prompts, select the measurement parameters by using the response, stimulus, and instrument state keys. Make the following selections:

   [PRESET]
   [START] [300] [k/m]
   [STOP] [600] [M/u].

2. In order to reduce the effects of noise, you can decrease the IF bandwidth of the HP 8702. In the response block, press:

   [AVG] then the softkey *[IF BW]* and enter **[300] [x1]**.

3. Set the sweep time to 0.7 seconds and RF output power to 20 dBm. The Guided Setup prompted you to set these items in a previous example. Here, from the stimulus block you set them yourself by pressing:

   [MENU] *[SWEEP TIME]* and enter **[.] [7] [x1]**.

   Note that HP 8702 will display 702 ms. This is normal.

   Press *[POWER]* and enter **[5] [x1]**.

   The power is set to 5 dBm in this example to avoid overdriving the HP 8702's receiver B input. Because you will be making an electrical thru response calibration, all the RF power leaving the splitter will go directly into input B. The inputs (R, A, B) will only allow a maximum of 0 dBm. Thus, if 20 dBm were selected, the HP 8702 would automatically reduce the power, indicated by a display message.

4. Set the measurement ratio. In Guided Setup, this was automatically defaulted to be receiver input B over reference input R: B/R. In normal operation, after you press the preset key, the HP 8702 defaults to A/R. Of course, you can connect your receiver RF output to the A input. However, set the ratio to B/R by pressing in the response block:

   [MEAS] and *[B/R]*.

Up to this point, you may have noticed that the O/O notation is on the CRT display. Before you change this to the O/E device type and measure the receiver, you should look at the combined response of the lightwave source, receiver, and HP 8702 system components that is currently displayed on the CRT. Notice that the trace is about 10 dB (± 4 dB depending upon your system) above the 0 dB reference line and has some frequency response.

You are now going to perform a simple measurement calibration using the **[CAL]** selection.

5. Disconnect the source and receiver from the system. Begin by removing only the electrical response of the measurement system. Remove the source, receiver, and optical cables from the system by making a thru connection between the RF cables (use the SMA adapter barrel supplied in the RF Interface Kit). Make the following selections. In the response block, press:

   [CAL] and then *[DEVICE TYPE] [E/E]*.

   This tells the HP 8702 to employ the proper scaling and calibrations for an electrical measurement. To complete the calibration, select:

   [RETURN] [CALIBRATE MENU]
   [RESPONSE] [THRU].

   Wait for the beep, and press *[DONE: RESPONSE]* and *[SAVE REG 2]* to save the calibration in register 2.

   You should now see a flat line across the CRT at 0 dB.

   You may have noticed that there were several registers where you could store the calibration and the complete instrument state settings. You can use the instrument state front panel recall key to recall a calibration stored in any one of these registers. Remember that calibrations remain in these registers if the preset key is pressed but NOT if the instrument is turned off.

6. Disconnect the barrel and reconnect the lightwave source and lightwave receiver. Then connect a thru optical cable between them and press in the response block:

   [SCALE REF] and then *[AUTO SCALE]*.

   The HP 8702 now shows the insertion loss of the source/receiver pair. To 600 MHz, the response of the system is fairly flat, within 1 or 2 dB. However, you can not tell whether it is the source or the receiver that is creating the response. You only know that the response of electrical portions of the system have been removed. In fact, the source has insertion loss and the receiver has gain.

7. In order to show the response of only the receiver, you have to perform an O/E measurement calibration using the cal data that describes the receiver.

   There are two ways to enter the receiver characterization data: automatically using the disc, or manually entering the nine coefficients of a polynomial curve fit supplied on a label. Using the disc is recommended. If you do not have a disc drive, see the note in step 8.

   Be sure the disc drive is connected to the HP-IB bus on the back of the HP 8702. Insert the 3.5-inch receiver cal data disc in drive 0, and from the HP 8702 instrument state block press:

   [LOCAL] and then *[SYSTEM CONTROLLER]*.

   This sets the HP 8702 to a controller state so that it can access the disc drive (HP-IB address = 0). Be sure the switches on the disc drive are set to zero (default address set at HP 8702 preset).

8. In the response block, press: **[CAL]** and then the softkey *[CAL KITS & STDS]*.

   The preset condition for a receiver or source calibration is set for entering the nine coefficients on the label. However, you will change this setting to inform the HP 8702 that you are going to load the disc data by pressing:

   [RECEIVER (COEFF)] [RCVR DISC] [LOAD RCVR DISC] [READ FILE TITLES].

   The HP 8702 will read the files on the disc and create a label next to a CRT softkey for each file. Select the file that corresponds to the cal data number on the label on your receiver.

   Press *[LOAD xxxxxx]* and the HP 8702 will read the data and store it into its cal kit memory.

NOTE: If you do not have a disc drive, you can use the coefficients on the label by pressing the following keys: *[RCVR (COEFF)], [ENTER RCVR COEFF]*. Then press each softkey corresponding to the 9 coefficients (A through I, using the *[MORE]* softkey) and enter the coefficient from the label on the HP receiver, using the HP 8702 keypad and the **[x1]** key. When all have been entered, press *[RETURN]* and *[STD DONE (DEFINED)]*. You can also label this kit by pressing *[LABEL STD]* key to access the easy-to-use HP 8702 labeling feature.

9. To perform the calibration process, in the response block, press:

   [CAL] and then the softkeys *[DEVICE TYPE] [O/E]*.

   This informs the HP 8702 that you are calibrating for a receiver measurement. Press *[RETURN] [CALIBRATE MENU] [RESPONSE] [RECEIVER]*. Wait for the beep, and press *[DONE: RESPONSE]* and *[RE-SAVE REG 2]*.

   Note that you have just written over the last register where you saved the E/E thru response calibration. To complete this example, you don't need that previous calibration.

The HP 8702 is now displaying the response of the receiver used for calibration. The display units are log responsivity: the ratio of RF current out to modulation power in. The HP 8702 has normalized out the electrical response of the measurement system and the response of the lightwave source. It now displays only the response of the HP receiver. Figure 12 shows a typical plot.

10. Measure the DUT receiver. Turn off and disconnect the lightwave receiver. Then insert your DUT (O/E) receiver. When properly connected, turn on the power of your DUT and wait for one complete sweep of the HP 8702. Then use the auto scale feature to view the trace by pressing the response block keys:

    [SCALE REF] and *[AUTO SCALE]*.

You should now be looking at the accuracy enhanced, also called *calibrated*, response of your O/E receiver. The plot below shows the modulation transfer characteristics of a typical receiver measurement.

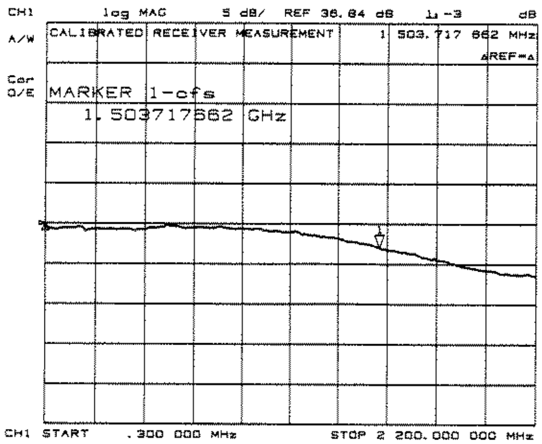


Figure 12. Typical Receiver Response

Refer to Figure 12. The marker has been offset (MARKER 1-ofs) to locate the −3 dB point to read the modulation bandwidth of the receiver. This was done by using the *[MKR ZERO]* delta feature of the **[MKR]** key. Notice the triangle on the middle graticule line, marker one is referenced to it. The HP 8702 *Operating and Programming Reference* describes how to use markers.

Responsivity Calculation

Without the marker offset feature, the marker will read out the actual value in dB. Suppose marker one has a value of 36 dB, indicating the gain of the receiver at a specific frequency. This is the responsivity (R) of the receiver, at the given frequency, and can be calculated as follows:

Responsivity Calculation:

Responsivity = R (dB) at a given frequency =

$$R(dB) = 20\log_{10}\frac{R(A/W)}{1(A/W)}$$

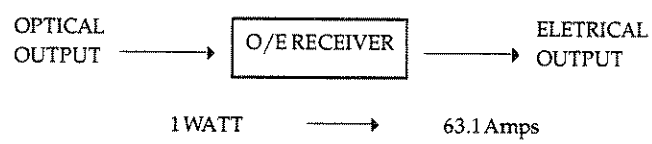
$$\frac{R(dB)}{20} = \log_{10}\frac{R(A/W)}{1(A/W)}$$

$$1(A/W) \times 10^{R(dB)/20} = \frac{R(A/W)}{1(A/W)} \times 1(A/W)$$

$$R(dB) = 10^{R(dB)/20} = 10^{R(dB)/20}$$ A/W for O/E DUTS or, W/A for E/O DUTs

For example: If R(dB) = +36 dB, then

$$R(dB) = 10^{(36/20)} = 10^{(1.8)} = 63.1\ A/W$$



NOTE: Electrical transmission measurements are easily made by removing the source and receiver and inserting an E/E DUT between the RF output from the power splitter and the B receiver input of the HP 8702. The RF cables must have connectors or adapters that are compatible with the DUT. Measurement calibration for electrical transmission measurements requires an HP calibration kit.

Reflection Measurements

The examples in this chapter show how to make reflection measurements to determine cable length, find faults or bad connections, and determine the electrical input impedance of an E/O source. The first example uses the Guided Setup menus and the remaining examples use normal operation. Although the examples in this section use single-mode fibers, similar measurements can be made with multimode.

The HP 8702, when equipped with a lightwave coupler, can measure the optical return loss of optical components such as connectors, splices, and photo-diodes. Then, by transforming the data from the frequency domain to the time domain, you can locate the position (in time/distance) of the fault that is causing the reflection.

Although all the measurement configurations (except example 7) in this chapter use the RF interface kit, systems with HP test sets connected can also be used with similar results. The difference in configuration is that the RF signal comes out of test set port 1 and goes into the HP lightwave source; and the HP lightwave receiver RF output goes into port 2 of the test set or the analyzer's B input.

Example 4: Optical Reflection Measurement of a 3 meter Optical Cable using Guided Setup

This measurement configuration is similar to a transmission measurement because modulated light is input to the device under test. The difference is that the lightwave source drives the input of the optical coupler and the lightwave receiver measures the light captured by the coupled arm: light reflected from the test device. An optical coupler separates the forward going light from the reverse traveling light, including the modulation signal imposed on the lightwave carrier signal. By measuring the amount of reflected modulation signal in the coupled arm, the HP 8702 shows how much light is being reflected back. And the Time Domain feature can be used to view the responses as a function of time.

This example will demonstrate how Guided Setup can help you make a simple optical reflection measurement of a short length of cable (3 meters). The example will also help you verify that you have the system properly connected and properly calibrated.

Procedure:

1. Connect the system as shown in Figure 13, but do not connect the DUT. Turn on the power.
2. Begin the measurement sequence by selecting the Guided Setup and choosing a reflection measurement of a one-port device (the short cable). Press:

   [PRESET]
   [GUIDED SETUP]
   [REFLECTION]
   [CONTINUE]
   [1-PORT OPTICAL]
   [CONTINUE]

3. The connection diagram shown on the screen has the DUT connected to the coupler. However, do not connect the DUT yet because you are going to calibrate the system with a Fresnel reflection on the coupler test port as shown in Figure 13. Press:

   [CONTINUE]

   Leave the start and stop frequencies in their preset state: 300 kHz to 3 GHz. This wide frequency span provides the necessary resolution when converting to the time domain.

   NOTE: Time domain responses and their relationship to the frequency domain are covered more thoroughly in Example 5. Press:

   [CONTINUE]

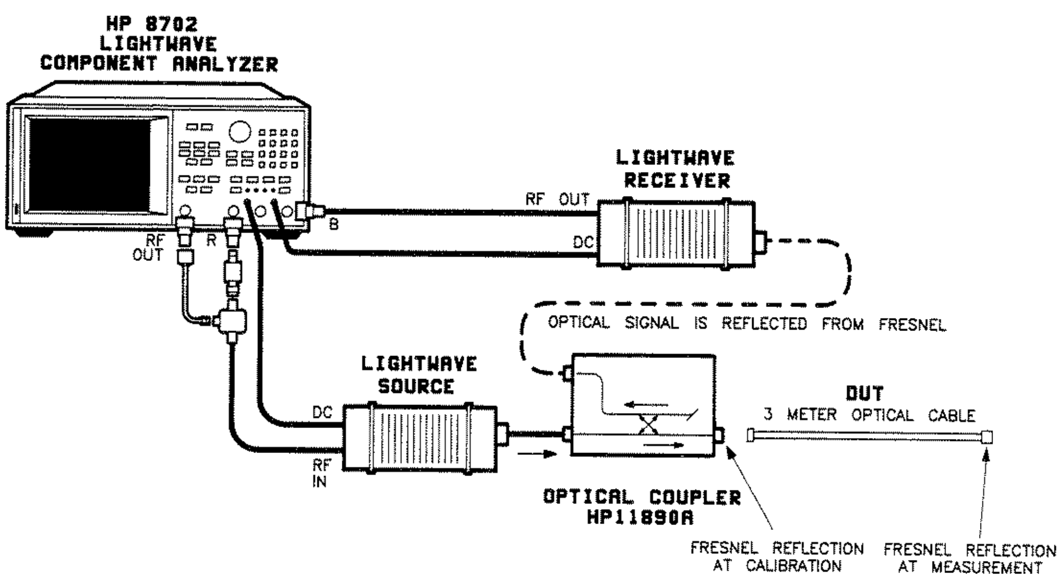


Figure 13. Optical Reflection Measurement Configuration

4. Set the sweep time and the source power. Again, 201 points will require about 3.5 seconds. Also, reflection measurements should always be made with the maximum amount of power, here 20 dBm. Press:

   [SWEEP TIME] **[3.5] [x1]**
   [SOURCE POWER] **[20] [x1]**
   [CONTINUE]

5. Perform a response calibration.

   The measurement calibration will set the measurement reference plane at the optical coupler's output connector (transmitted signal). The reflection off an open fiber, called a Fresnel reflection, has a known response that can be used to calibrate the system. For reflection measurements, the calibration standard is a Fresnel reflection:the clean output connector of the optical coupler resulting in 3.5% reflected optical power or about −14.6 dB. After performing the measurement calibration, a measurement reference plane will be established where zero seconds (zero meters) is located at the output connector of the coupler.

   Be sure that the coupler's output test port connector interface is clean and dry so that a Fresnel reflection (3.5% reflected power) will result during the calibration process. Do not apply any index matching compounds. Matching compounds are used to reduce reflections, but are difficult to work with because they often spread or get onto other parts of the connector. Also, the matching compound should be removed from the fiber end immediately after use.

   Be sure that the coupler's reflected (coupled) output is connected to the lightwave receiver. In this configuration, the coupler is going to receive the light coming from the Fresnel reflection to establish the measurement reference plane. The Fresnel reflection is a general purpose standard definition assuming a clean connector interface at the test port. This mathematical definition has already been loaded into the HP 8702 cal kit at the factory.

   NOTE: On metal connectors, you can use non-corrosive alcohol or a similar liquid freon product to clean the connectors. This can be applied with a lint-free swab or cloth. Then use clean compressed air to dry them and blow away any loose particles. The fiber ends should be cleaned with a recommended cleaning kit such as the HP 15475A. This kit and its use is described in the *Summary* in Chapter 5 of this *User's Guide*. Alcohol or freon is often used to clean fiber ends and then they are dried with clean compressed air.

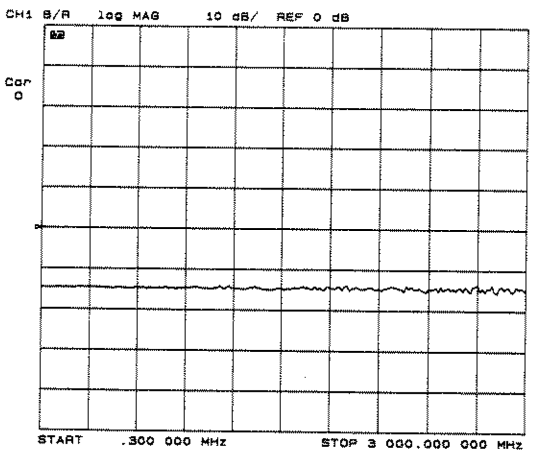


Figure 14. Response Calibration with a Fresnel Reflection

(continued)

Be sure the test port connector on the output path of the coupler is clean and dry to obtain a reliable and repeatable Fresnel reflection. Then press:

[RESPONSE]
[CONTINUE]
[FRESNEL]

When the measurement is complete, the HP 8702 will beep and underline the word FRESNEL. After this happens, press:

[DONE: RESPONSE]

Examine the response on the display and compare it to Figure 14. It should be a flat line (approximately) around −14.6 dB (optical return loss). Again, −14.6 dB is the return loss of the Fresnel reflection, which is related to the fiber's index of refraction and air at the coupler port.

NOTE: The percentage of reflected optical power is calculated as:

$$\left[\frac{n1-n2}{n1+n2}\right]^2 \times 100 = \%\ \text{Reflected Optical Power}$$

or, to obtain the dB value, multiply the result by 10 log. In this example, n1=1.46 and n2=1. Therefore, 3.5% reflected power corresponds to a return loss of −14.6 dB.

NOTE: A smoother trace can be obtained by using the smoothing or averaging features of the HP 8702. You can press the **[AVG]** key to access these features. Then enter a number of averages or a percentage of smoothing span and turn on the respective feature.

If the response is not similar to the one in the figure above, check your connections, re-clean the connectors, and repeat the procedure.

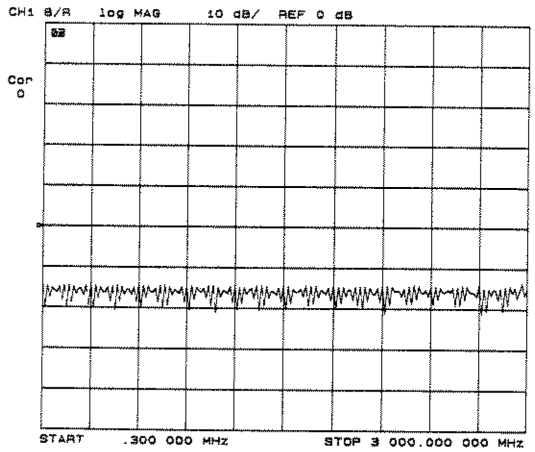


Figure 15. Response in the Frequency Domain (beating)

Transform Menu

TRANSFORM PARAMETER	Channel 1
RANGE	6.8452 m
RESPONSE RESOLUTION	66.894 mm
TRANSFORM SPAN	60 ns
RANGE RESOLUTION	30.801 mm
TRANSFORM MODE	BANDPASS
START FREQUENCY	300 kHz
STOP FREQUENCY	3 GHz
FREQUENCY SPAN	2.9997 GHz
NUMBER OF POINTS	201
INDEX OF REFRACTION	2.92
PULSE WIDTH	
SOURCE POWER	20 dBm
SWEEP TIME	3.5 s
IF BANDWIDTH	3000 Hz

6. Clean the ends of the short cable DUT (3 meters) and connect it to the coupler's output/input port. Refer to Figure 15 and notice the response in the frequency domain. The trace is still at about −14 dB but shows a ripple pattern caused by the reflected modulated light bouncing back and forth along the path. The effect is sometimes called *beating*, where re-reflected light is adding and subtracting (as a vector) to the signal as the modulation frequency is varied. The re-reflections occur because of the light bouncing off the end of the short cable (Fresnel), returning back to the coupler, and bouncing back again. This entire re-reflecting process results in the reflections beating against each other.

7. Use the time domain feature and transform the frequency domain data to the time domain. The first thing that you need to do is: enter the index of refraction of the fiber. Although the value in this example is 1.46 (fiber), it must be doubled for a reflection measurement. This is because the light travels forward and backward (two directions) between the measurement reference plane and the reflection point. Because of the way the HP 8702 calculates and displays distance measurements, you must double the index of refraction in order to obtain a one-way length measurement of the DUT response. To accomplish this, use 2 x 1.46 = 2.92.

   [CAL] ***[MORE] [INDEX OF REFRACTION]***
   [2.92] [x1]

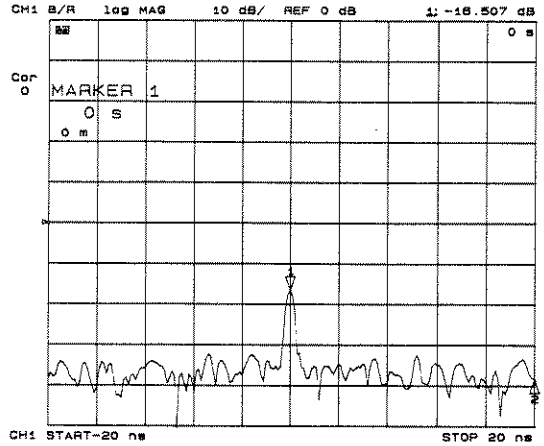
   Then turn on the time domain transform. Press:

   [SYSTEM] ***[TRANSFORM MENU]***
   [TRANSFORM ON]

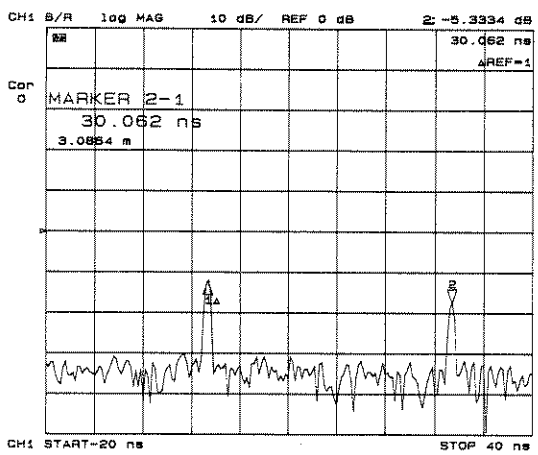
   See Transform menu.

   Use the marker to locate the calibration reference plane at 0 seconds and 0 meters. This is the connector on the coupler where the Fresnel reflection was measured. Press:

   [MKR] ***[MARKER 1]*** **[0] [x1]**



A



B

Figure 16A and 16B. Time Domain Response of 3 meter Fiber Cable.

8. The results should be similar to the plot in Figure 16A.

   The marker shows the initial reflection that occurs at time zero. The location is 0 meters at the coupler connector. Notice also that the reflection from the end of the short cable is not shown. This is because the stop time is too short (20 ns). Even though the start and stop frequencies have already been set in the frequency domain, you can change the start and stop times in the time domain without losing the calibration. Therefore, increase the stop time to 40 ns. Press:

   [STOP] [40] [G/n]

   A second peak should now appear on the trace as shown in Figure 16B. Use the marker function to locate this second peak. It should be the end of the cable, three meters from the 0 reference plane. Press:

   [MKR] and *[MARKER 2]*

   Then use the front panel's RPG knob to move marker 2 to the peak. The HP 8702 will read out the location of the marker. In this case, about 3 meters as shown in the plot below.

Example 5: Simulated Lightwave System Fault Location

This example demonstrates how the HP 8702 can locate faults in distance and time. The simulated lightwave system is comprised of a roll of fiber cable (about 2 km long) with two short cables (1 meter and 6 meters) connected to it, terminated with a Fresnel reflection.

This example also demonstrates how to use the HP 8702 Transform Parameter menu to obtain the resolution necessary to locate reflections that are close together, like the 1 meter resolution in this example.

Procedure:

1. Connect the system as shown in Figure 17. Also, be sure that all connectors are clean.
2. Set the HP 8702 to its preset state and then set the instrument parameters using the Transform Parameter menu. This menu will help you determine how to setup your calibration parameters for the proper results. Press:

   [PRESET]

   [SYSTEM] *[TRANSFORM MENU]*
   [TRANSFORM PARAMETERS]

   Notice that this menu allows you to set many of the parameters that you previously set using the front panel keys. This menu is designed to help you with time domain measurements that require the proper settings for resolution and length.

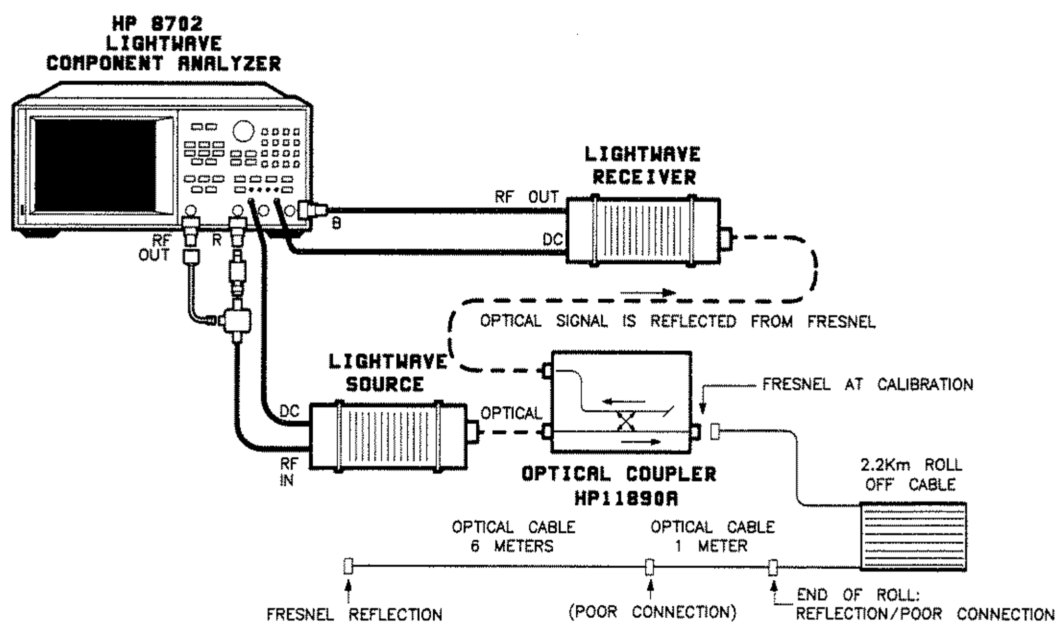


Figure 17. Simulated Lightwave System Fault Location Configuration

3. Begin by setting the index of refraction to 2.92. As in the previous example, the index of refraction is set to twice 1.46 = 2.92. Although the index of refraction of the cable is 1.46, it must be doubled because you are measuring reflected light: light that is traveling down the cable, and then traveling back again. Additionally, by setting the index of refraction, the velocity factor is automatically calculated and set by the HP 8702 because one is the inverse of the other.

   Then set the span (start and stop frequencies), in the frequency domain, to get the proper resolution. The easiest way to remember the relationship between time and frequency domains is: they are the inverse of each other. Therefore, a small or narrow frequency span allows you to view responses that are further out in time (distance); a large or wider frequency span allows you to look at responses which are close together, requiring the greatest amount of resolution.

   Here, a span of about 500 MHz will not give you enough range, but it will give the proper resolution as you will see in the Transform Parameter menu. You are setting these parameters so that you can calibrate for the resolution required to see the reflections of the short lengths of cable (1 and 6 meters).

   In addition, the number of points selection also has an effect on range: the greater the number of points, the greater the range.

   NOTE: In the time domain, range = 1/step size (in seconds), where step size = frequency span/number of points).

   For this measurement, we can leave the 201 points defaulted at Preset. Press:

   [START FREQUENCY] **[300] [k/M]**
   [STOP FREQUENCY] **[500] [M/u]**
   [INDEX OF REFRACTION] **[2.92] [x1]**

4. Set the remaining parameters as follows:

   [AVG] *[IF BW]* **[30] [x1]**
   From the stimulus block, press:
   [MENU] *[POWER]* **[20] [x1]**
   [RETURN] [SWEEP TIME] **[3.5] [x1]**
   From the response block, press:
   [MEAS] *[B/R]*

   Because the signal is a reflected optical signal, and is therefore quite low compared to the incident signal, reducing the IF bandwidth (Averaging menu selection) will help filter out or reduce any noise.

5. Calibrate the system. Remember that this calibration will give you the resolution you need rather than the range. After you turn on the transform (time domain) you can adjust the frequency span using the HP 8702 interpolation feature as you will see.

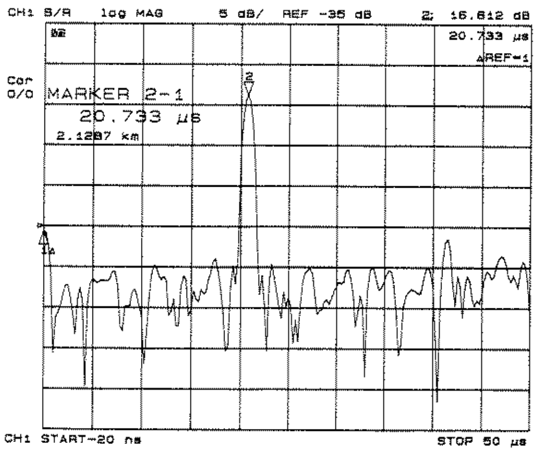


Figure 18. Cable Length Measurement of 2.2 km Roll SMF

Start by cleaning and drying the reflected signal port of the coupler to obtain a good Fresnel reflection. Then perform the response calibration by pressing:

[CAL] ***[DEVICE TYPE] [1-PORT: OPTICAL]*** ***[RETURN] [CALIBRATE MENU] [RESPONSE]*** and ***[FRESNEL]***.

After the measurement sweep, the HP 8702 will beep and underline FRESNEL. Then press: ***[RESPONSE: DONE]***.

The result of the calibration should be a flat line at about −14.6 dB with very little noise due to the 30 Hz IF bandwidth setting. If you do not have this response, re-clean the connectors and re-calibrate.

6. Connect the roll of cable to the coupler's reflection port. Do not connect the short cable lengths (1 and 6 meters) yet. You will now turn on the interpolation feature and the time domain transform. Then, using the Transform Parameter menu, you can reset the span to about 8 megahertz (about 2.6 km range) to locate the end of the cable. The Transform Parameter menu is designed to help you transform frequency domain data into the time domain. Press:

   [CAL] ***[INTERPOL ON]***
   [SYSTEM] [TRANSFORM MENU]
   [TRANSFORM PARAMETERS]
   [STOP FREQUENCY] **[8] [M/u]**
   [RETURN]
   [TRANSFORM ON]. From stimulus block, press:
   [START] [−20] [G/n]
   [STOP] [50] [M/u].

   Use the autoscale feature if necessary, and put marker one on the highest peak (approximately 2.2 km) or the end of the roll of cable. It should look similar to the plot in Figure 18.

7. Connect the two short lengths of cable (1 meter and 6 meters) to the end of the 2.2 km roll.

   In order to get the proper resolution to view the 1 and 6 meter cable reflections, you must return to the Transform Menu and reset the frequency domain settings. In addition, you will need to turn on the alias span feature (see explanation below).

   Aliasing

   In time domain (transform), *aliasing* is a term that refers to a repetition of data due to the finite number of data samples taken by the analyzer as it makes a measurement. These repeating or alias responses occur because the equivalent time domain stimulus used by the analyzer is a simulated periodic function. The period of repetition is determined by the frequency step size, which is calculated from the number of points and the frequency span.

   If the response to one impulse is recorded after the next impulse is sent out, then it will overlap or alias. For example, with a 3 GHz span and 201 points, the HP 8702 can only measure up to about 67 nanoseconds or about 20 meters before the data is repeated. This is called the *alias free range*. Normally, the alias span feature is off (preset state) to limit the measurement to the alias free range. However, in this measurement, to locate connections at 2 km you need to go beyond the alias free range of 20 meters. Therefore, the alias span feature is turned on.

   Press:

   [SYSTEM] *[TRANSFORM MENU]*
   [MORE] [ALIAS SPAN ON] [RETURN]
   [TRANSFORM PARAMETERS]
   [STOP FREQUENCY] **[500] [M/u]**

   Notice the resolution is now about one-half meter.

   Press: *[RETURN]*

8. Set the start and stop times to a span that allows you to view about 10 meters of length, at the approximate end of the cable. Here, (see Figure 19) you should see the two peaks on the cable ends: at one and six meters. From the stimulas block, press:

   [CENTER] **[20.7] [M/u]**
   [SPAN] [200] [G/n]

   Use the markers to locate the reflections from the short cables as shown in the plot below. Marker 1 is set to the end of the roll of cable and markers 2 and 3 are set to the 1 and 6 meter cable ends, respectively.

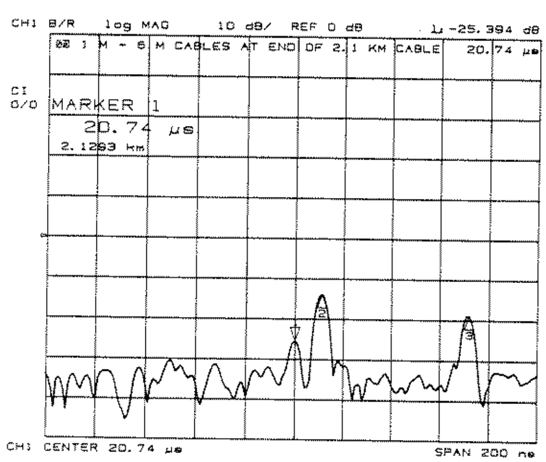


Figure 19. Fault Location of 1 and 6 meters

Example 6: Optical Reflection of a Receiver Input

This example demonstrates how the HP 8702 can measure the optical input port of a lightwave receiver. The measurement results will be a plot of the receiver's input response to a 300 kHz to 3 GHz modulated signal. The reflected optical power from the receiver DUT input is captured by the coupler. The coupled output signal is then input to the HP lightwave receiver (demodulated) and then routed to the HP 8702.

This measurement can be of great value when designing lightwave systems (especially receivers) or when troubleshooting lightwave systems where optical match values are desired.

Procedure:

1. Connect the system as shown in Figure 20, but do not connect the DUT yet.

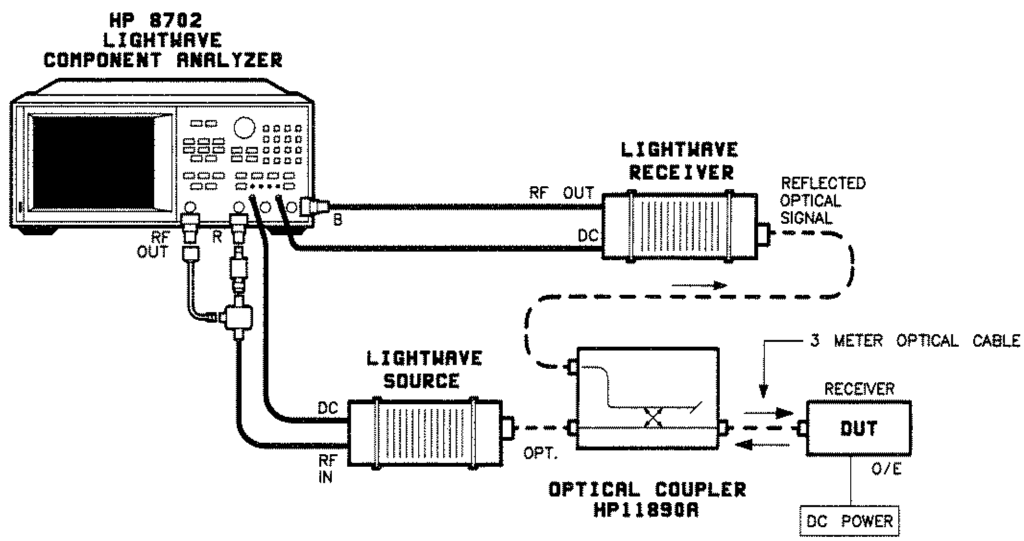


Figure 20. Receiver Optical Reflection Measurement Configuration

2. Set the HP 8702 measurement parameters by pressing the following keys:

   [PRESET]
   [AVG] ***[IF BANDWIDTH]*** **[100] [x1].**

   From the stimulus block, press:
   [MENU] ***[SWEEP TIME]*** **[3.5] [x1]**
   [POWER] [10] [x1]

   From the response block, press:
   [MEAS] [B/R]

   Note that the start and stop modulation frequency is 300 kHz to 3 GHz because the preset key was pressed, resulting in the default frequency range settings.

3. Calibrate the system. In this example, the coupler's output/input port is the measurement calibration plane. However, you can connect a short length of cable to the coupler's port and make the cable end the reference plane. This measurement example uses a three meter patch cord to show how the HP 8702 can measure a short length of cable.

   Clean the test port so that a Fresnel reflection (3.5% reflected power) results. This Fresnel reflection is the standard that is used to calibrate the system. From the response block, press:

   [CAL] ***[CALIBRATE MENU] [RESPONSE] [FRESNEL]***

   When the HP 8702 has finished measuring the Fresnel reflection, it will beep and underline the Fresnel selection. Press:

   [DONE: RESPONSE]

   Save the measurement calibration in one of the registers if desired. The softkeys and CRT display make this easy to do.

   Be sure the measurement calibration was successful by verifying that a flat line trace, at about −14.6 dB, is displayed on the CRT. As with the previous examples, this optical return loss is dependent upon the index of refraction of the fiber.

   If the trace is not flat or if it is not about −14.6 dB, then re-clean the connector end (Fresnel) and recalibrate.

4. Measure the receiver. Connect the receiver DUT to the lightwave coupler using the appropriate cable/connectors. In this example, a 3 meter cable with is used and it becomes part of the measurement.

   NOTE: The receiver can have its electrical output terminated in its characteristic impedance (for example: 50 ohms) and its DC power supplied. However, the optical reflection of photodiodes is typically the same if the electrical output is not terminated and if there is no DC bias power supplied.

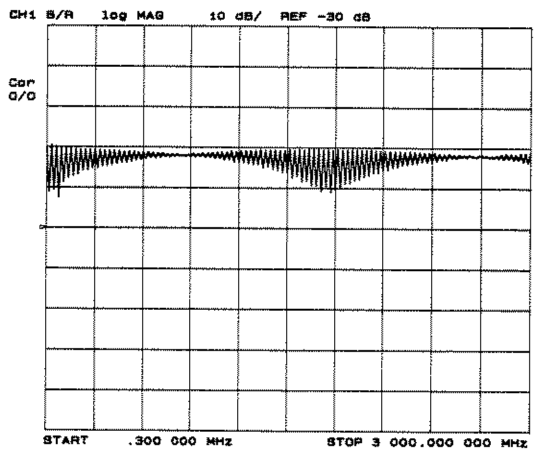


Figure 21. Optical Return Loss of a Typical Receiver

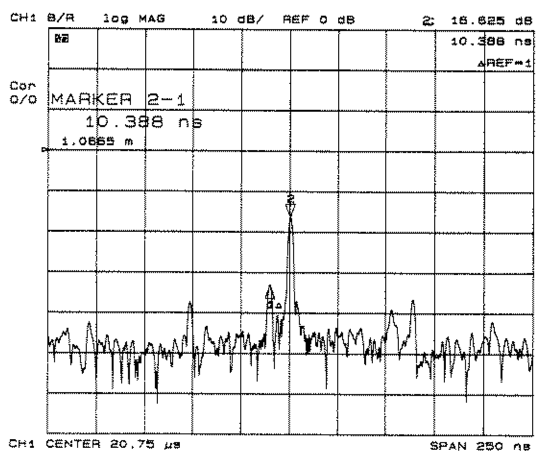


Figure 22. Time Domain Response of Example Receiver

The frequency domain response shows the return loss of the input signal as a ripple pattern trace (spikes), where *beating* occurs because of the three reflections in the example system: 1) the coupler input, 2) the receiver input, and 3) the receiver itself. The signal enters the receiver connector with some attenuation and then reaches the actual receiver (for example: photodiode) where it is reflected back. It goes through the receiver input and then back to the coupler. Each of these reflections beats against the other, resulting in a beat pattern similar to the one shown in Figure 21.

5. In general, frequency domain reflection measurements show only the overall magnitude of the reflected signal and not the magnitude of the individual reflections. In fact, a single reflection can disguise the pattern so that you cannot distinguish which reflection is greatest. However, by using the time domain option, each of the reflections can be measured separately to determine their individual magnitude and location as follows. Press:

   [SYSTEM] *[TRANSFORM MENU]*
   [TRANSFORM ON]

6. Then set the start and stop times. In this case, the start time (time zero) will be the coupler calibrated reference plane where the first reflection occurs. The stop time setting will correspond to a length of about 5 meters to include the patch cord (3 meters) and the receiver. Press the following stimulus menu keys:

   [START] [0] [G/n]
   [STOP] [50] [G/n]

7. Set the velocity factor to accurately view the response. This is similar to setting the index of refraction. Enter the actual velocity of light in the fiber relative to that in free space or a vacuum. In this case, the light in the fiber travels at about two-thirds the speed of light in free space. It also travels in two directions for a reflection measurement and therefore becomes about one-third. To enter this velocity factor, press:

   [CAL] *[MORE] [VELOCITY FACTOR]* **[0.33] [x1]**.

   Figure 22 shows the time domain response of the example DUT receiver. The marker is used to locate the reflection of the receiver interface at the end of the 3-meter cord. Notice that this connection causes the greatest reflection. About one-third meter beyond that is the receiver diode itself, with some small re-reflections beyond it.

Example 7: Using the 6 GHz System (Option 006) to Measure 2.5 cm between a Splice and a Cleave

This experiment requires an HP 8702 with Option 006 and an HP 85047A S-parameter Test Set. This test set has a frequency multiplier that allows you to make measurements with modulation frequencies up to 6 GHz.

This 6 GHz system uses the HP 83402A Lightwave Source and HP 83411A Lightwave Receiver (non-amplified). This 1300 nm SMF source and receiver combination can modulate and demodulate the lightwave carrier up to 6 GHz.

This increase in modulation frequency allows you to make measurements with greater resolution and bandwidth response, especially useful for characterizing E/O and O/E devices. This measurement example demonstrates the system's resolution capabilities.

The 6 GHz option provides greater two-point resolution (less than 2 cm) when using time domain (Option 010). With the HP 85047A Test Set and Option 006 firmware, the system will have a default frequency range of 3 MHz to 6 GHz; this is the specified frequency range of the test set. However, you can still make measurements down to 300 kHz by decreasing the start frequency.

An HP optical coupler (such as an HP 11890A) is also used here to measure the Fresnel reflection from the end of the short DUT used in this example.

The DUT used in this example demonstrates the time domain resolution capabilities of the 6 GHz system. The DUT is a one-port SMF cable (index of refraction = 1.46), approximately 12.5 cm total length. It has an FC/PC connector on the connecting end and a cleave resulting in a Fresnel reflection (3.5%) on the other end. In addition, there is an AT&T mechanical splice 2.5 cm back from the Fresnel end.

The 6 GHz capability is used in conjunction with the calibration procedure to establish a measurement plane at 0 cm and 0 seconds. Then the DUT is loosely connected (FC/PC) to the coupler port (reference plane). After the measurement sweep, the display shows the FC/PC connection at 0 cm, the mechanical splice at 10 cm, and the Fresnel reflection from the cleave at the end of the fiber.

Procedure:

1. Connect the system as shown in Figure 23. Be sure all the connections are clean. Index matching gel can be used on the connections, if properly applied and properly cleaned afterwards.

   The optical coupler's output/input port should be cleaned so that its fiber end will have a Fresnel reflection of 3.5% optical power.

2. Begin by selecting the measurement type, number of points, and IF bandwidth required. Press:

   [PRESET] and the
   [FREQ RANGE 6 GHz] softkey.

   When the HP 8702 Option 006 (with HP 85047A) is first powered-up, you press the *[NORMAL OPERATION]* key to access the *[FREQ RANGE 6 GHz]* key. Continue by pressing in the response block:

   [MEAS] *[TRANSMIS'N PORT 1 −> 2]*
   Then, from the stimulus block, press: **[MENU]**
   [NUMBER OF POINTS] *[401]* **[x1]**
   [AVG] *[IF BW]* *[10]* **[x1]**

   Note that the sweep time will be automatically set to about 41 seconds because the smaller IF bandwidth setting (used to lower the noise floor) and the 401 points require this much time to make a measurement sweep. In addition, the 6 GHz system has a default power setting of 20 dBm which is used in this example.

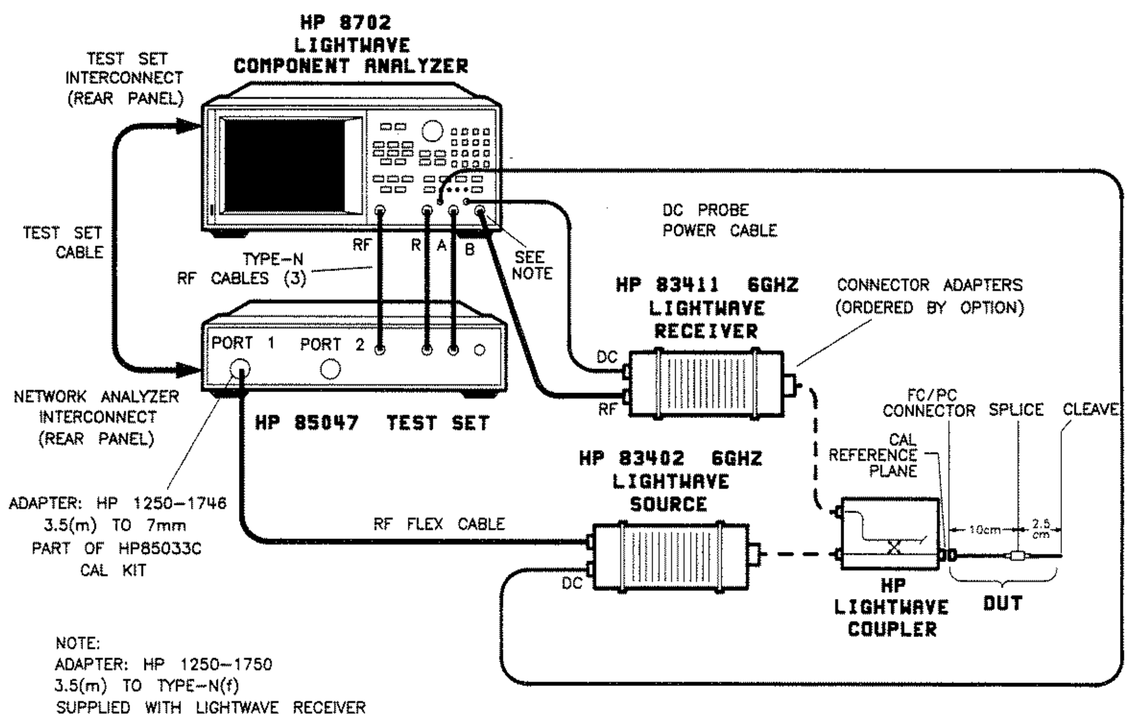


Figure 23. Reflection Test Setup

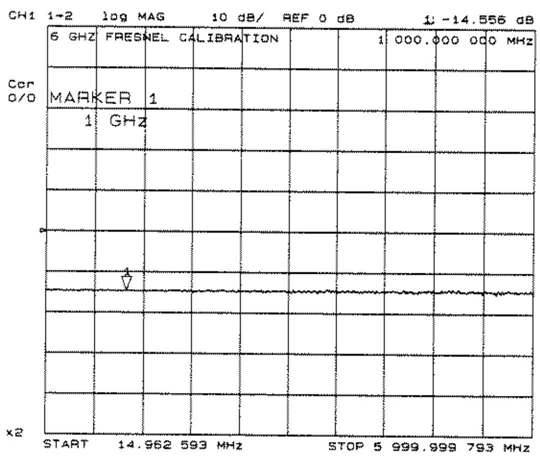


Figure 24. 6 GHz Fresnel Reflection Calibration

3. Select the low pass mode for time domain and perform a response calibration by pressing:

   [CAL] *[CALIBRATE MENU] [SET FREQ LOW PASS]*

   The low pass selection will change the RF modulation frequency range. Note that the start frequency is re-adjusted to about 14 MHz.

   Before continuing the calibration process, be sure the fiber end of the coupler's output/input port is clean and dry so that a good reflection will result (3.5% reflected optical power). Then press:

   [RESPONSE] [FRESNEL]

   After the sweep, the HP 8702 will beep and underline the word FRESNEL on the CRT. To complete the calibration, press:

   [DONE: RESPONSE]

   The CRT display should now show a trace at about −14.6 dB, similar to the plot as shown in Figure 24. This is the corrected frequency domain response of the Fresnel reflection. Note that the trace may have a slight amount of fine-grain ripple. The output/input port of the coupler is now the reference plane for the DUT to measured.

4. Select the time domain transform feature, and press:

   [SYSTEM] *[TRANSFORM MENU]*
   [TRANSFORM PARAMETERS]
   [LOW PASS IMPULSE]

   The low pass impulse selection is used to mathematically simulate an impulse. The narrow width of the impulse response is used because it gives better resolution than the bandpass mode (refer to the *Time Domain* section of the manual for more information). Continue by pressing:

   [TRANSFORM PARAMETERS]
   [INDEX OF REFRACTION] **[2.92] [x1]**

   Notice that the response resolution is about 16 mm or 1.6 cm, using the 6 GHz frequency range. Also, note that the index of refraction is doubled (1.46 x 2) for two-way travel: down the fiber and return. Continue by pressing:

   [TRANSFORM ON] and *[RETURN]*

   The CRT will now display the impulse response out to the Fresnel reflection.

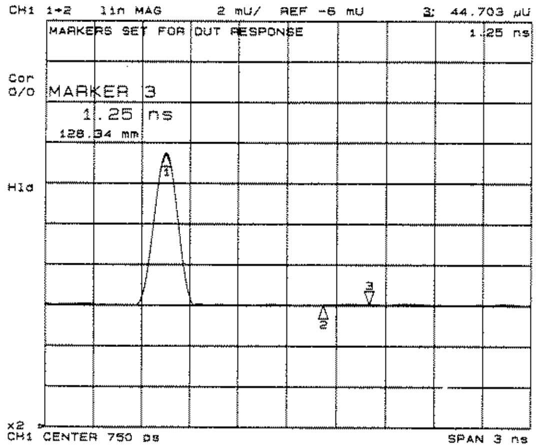


Figure 25. Markers Set for DUT Measurement

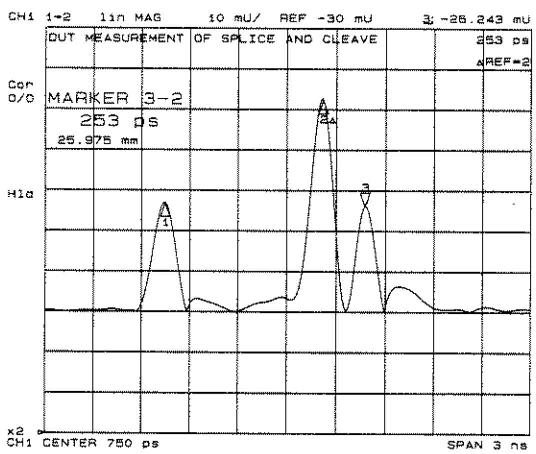


Figure 26. DUT Measurement of Splice and Cleave: about 2.5 cm

5. Adjust the display. Change the span to 3 nanoseconds, the center to 750 picoseconds, and the format to linear magnitude to better view the trace. Then, from the response block press:

   [FORMAT] *[LIN MAG]*
   From the stimulus block, press:*[SPAN]* **[3] [G/n]** and **[CENTER] [.750] [x1]**

   Then set the marker to 0 seconds (0 meters) to locate the Fresnel reflection at the coupler output/input port. This is the time domain measurement reference plane (0 seconds and 0 meters), where you will connect the DUT. From the response block, press:

   RESPONSE **[MKR]** *[MARKER 1]* **[0] [x1]**

   Because the approximate 12.5 cm DUT has an AT&T mechanical splice about 10 cm from the FC/PC connector, and about 2.5 cm of fiber beyond that (with a cleave for 3.5% reflected power), you can also set markers 2 and 3 to those positions before attaching the DUT. Of course, if you did not know the DUT faults, you would not be doing this. However, this example is specifically designed to demonstrate the analyzer's capabilities. Press:

   [MARKER 2] **[1] [G/n]** and
   [MARKER 3] **[1.25] [G/n]**

   At this point the display should look similar to the plot as shown in Figure 25.

6. Connect the DUT as follows:

   Carefully attach the FC/PC end of the DUT to the coupler output/input port so that it is loosely connected. The quality of this connection will determine the magnitude of the DUT response at the reference plane (0 meters/0 seconds) and at the other peaks.

   After the DUT is connected and after the measurement sweep is completed, the results should be similar to the plot below. If three distinct peaks are not seen, readjust the FC/PC connection, by loosening or tightening it, and view the response after the next measurement sweep. Repeat this process if necessary.

   The distance between the splice (marker 2) and the cleave (marker 3) can be determined by moving the markers to the respective peaks and reading the response from the display, using the delta marker mode. The markers can be moved to the peak tops by selecting each marker **[MRK]** and adjusting the RPG knob to position the marker. The distance between the peaks can be read using the delta mode menu:

   [MKR] *[DELTA MODE MENU] [DELTA REF=2]*, or referenced to the last marker selected.

Example 8: Electrical Reflection (Impedance) of a Source Input

In the same way that you measured optical reflection in previous examples, you can measure electrical reflections. This type of measurement is important for matching the impedance of electrical inputs to electrical outputs. However, in order to separate the forward going electrical signal from the reverse traveling signal, an electrical signal separation device must be used: the HP 85044 Reflection/Transmission or the HP 85046 S-parameter Test Sets are recommended.

A typical application in a fiber optic system would be to measure the electrical match of a source (E/O device). In many cases, this would be checking for a 50 ohm impedance. For this example, you can measure the impedance of the HP lightwave source's RF input if you do not have another DUT.

The amount of power reflected from a device is directly related to the impedances of both the device and the measuring system. In fact, each value of the reflection coefficient uniquely defines a device impedance. A reflection coefficient of zero only occurs when the DUT and the measuring system test set impedance are exactly the same value. In other words, there is no power reflected. A short circuit has a reflection coefficient of 1 at ± 180 degrees. This is because all of the incident power is reflected back 180 degrees out of phase. Every other value of reflection coefficient also corresponds uniquely to a complex device impedance according to the equation:

$$Zn = \frac{Z\,DUT}{Z_0}$$

or,

$$Zn = \frac{1 + \text{Reflection Coefficient}}{1 - \text{Reflection Coefficient}}$$

where Zn is the DUT impedance normalized to (divided by) the measuring system's characteristic impedance.

In electrical RF measurements, a special display called a Smith chart is used to read the impedance data in the R + jX format, where R is the resistive component and jX is the reactive (capacitive or inductive) component. The HP 8702 generates this display as a Smith chart overlayed on a polar coordinate chart.

The following example will show you how to make an electrical calibration and measure the reflection coefficient of a simulated source (E/O converter) electrical input. Remember that you will now be measuring an E/E device and the HP 8702 will respond by displaying the data as a ratio of the reflected signal compared to the incident signal (using the A receiver input, this is A/R).

NOTE: An HP test set is required and can be connected to the HP 8702 (described in the test set manual) in the same manner as it would be connected to a network analyzer. Also, an HP calibration kit with electrical standards (short, open, load) in the connector type of your DUT is required. In order to measure the electrical input of the SMA RF input to the HP lightwave source, a 3.5mm calibration kit and a 7mm to 3.5mm adapter is required. Note that 3.5mm is compatible with and will adapt easily to SMA.

Procedure:

1. Connect the system as shown in Figure 27. Do NOT connect the DUT yet.
2. Setup the instrument parameters using the knowledge you have already gained about the front panel. Set it for an A/R (or S_{11}) measurement on channel 1 with a Smith chart display, and full band RF stimulus. Press the following keys:

   [PRESET] *[MEASURE] [INPUT PORTS] [A/R]* **[FORMAT]** *[SMITH CHART]*
3. Perform an electrical measurement calibration. This is an S_{11} 1-port calibration. Begin by selecting the 3.5mm cal kit definitions that describe the devices in the kit. These definitions are installed at the factory and nominally characterize the devices in the kit. Press:

   [CAL] *[CAL KITS & STDS] [ELECTRICAL (7mm)]* and then press the **[3.5mm]** softkey and **[RETURN]**.

   Notice the changed 3.5mm annotation next to the electrical selection.

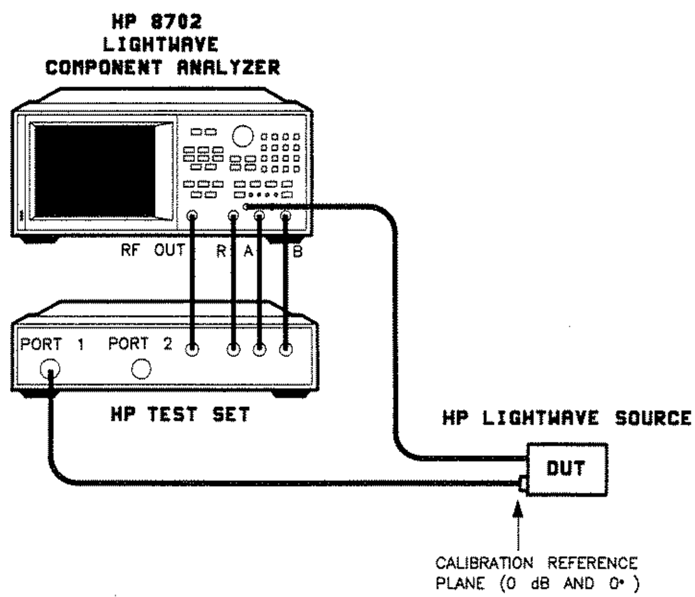


Figure 27. Electrical Reflection Configuration using an HP Test Set

4. Then perform the actual calibration. At this point, you may want to review the HP *Connector Care* manual to be sure you know how to properly clean devices and make the connections. To start the calibration process, press:

   [CAL] *[DEVICE TYPE][E/E]*
   [CAL] *[CALIBRATE MENU][S_{11} 1-PORT]*.

   Connect and measure the open, short, and load (in any order) to the test set port 1 connector or cable. Each time you will press the corresponding softkey. After one sweep, the HP 8702 will beep and underline the device label.

   When all of the electrical standards have been measured, press:

   [DONE].

   Notice that the *Cor* notation is now displayed. This means that the test set port 1 (or end of cable) is a measurement reference plane of 0 dB and 0 degrees phase.

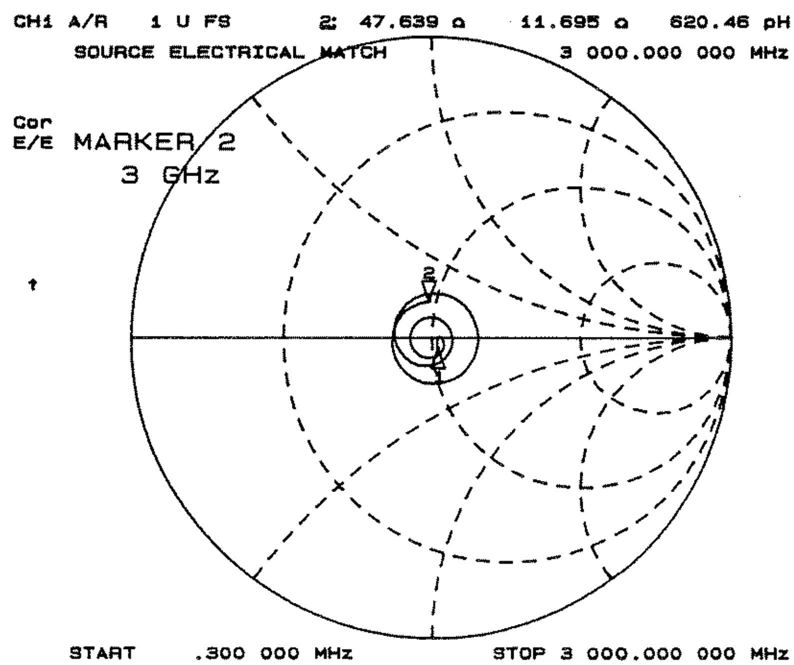


Figure 28. Typical Reflection Measurement of Source Electrical Input

CHAPTER FIVE

Summary

If you have read the first four chapters and performed all of the example measurements, you should have a very good fundamental understanding of the HP 8702 and the kinds of measurements it can make.

However, there are many features and measurement capabilities that have not been covered by this *User's Guide*. These include such measurements as phase response, distortion, group delay, reflection coefficient, standing wave ratio, connector repeatability, and others.

Refer to the *Operating and Programming* manual for more information. The *Advanced Measurement Techniques* section and the *Operating and Programming Reference* contains more information and details about the HP 8702 and its use.

In addition, for more detailed information on fiber optic principles and measurements, Hewlett-Packard publishes the *Fiber Optics Handbook* (HP part number 5952-9654). Contact your nearest HP office to order this book.

Summary of Calibration

The term *calibration* is used to refer to the measurement process that allows the HP 8702 to calculate error correction coefficients that will enhance the accuracy of your measurements. This process requires you to measure standard (characterized) devices before measuring your DUT. These standard devices have corresponding mathematical models that must be loaded into the HP 8702 memory.

Some standard device models have been loaded into the HP 8702 at the factory (for example: Fresnel reflection). However, other devices must be defined by the user and the mathematical characterization (model) must be loaded into the HP 8702. This is done using the Cal menu and selecting the cal, cal kits and standards, user kit, and modify features.

Optical transmission calibrations (O/O) use a thru (jumper), which can be the HP interconnect cable kit. For optical reflection calibrations, a Fresnel reflection is used; this is the clean connector on the output of the HP lightwave coupler.

Lightwave sources (E/O) and lightwave receivers (O/E) have calibration data (characterization model) that must be loaded into the HP 8702 cal kit and used with a response calibration.

Electrical calibrations use an HP calibration kit (open, short, and load) that are connected to the test set port or the cable(s) attached to the port. Refer to the measurement calibration section and/or the appropriate calibration kit and verification manuals for details.

Things to Remember

Local Key Operation

This instrument state key allows you to change the control of the HP 8702 from an HP-IB controller (computer) to front panel manual operation. Sometimes, when you try to use the disc drive, the HP 8702 will give you a message that that tells you to change to *System Controller*. Use the local key to access the menu that allows you to do this.

Isolating the Lightwave Source Laser

Avoid measuring devices that will reflect greater than about −14 dB back into the laser, because the laser is sensitive to reflections. If necessary, use a well-matched optical attenuator between the laser source and the test device. Or, use an optical isolator to minimize and/or eliminate the laser sources reflection sensitivity response.

Sweep Time

This is the amount of time it takes the RF source to sweep from its start to its stop frequency. When measuring test devices with long lengths (rolls of cable), the sweep time must be long enough to allow the HP 8702 to sample the modulation properly. In general, the sweep time should be set to a value equal to the number of points times 15 ms.

Power Sweep and Gain/Compression

The power sweep selection, in the Sweep Type menu in the stimulus block, allows you to set the RF source to a CW (single frequency or continuous wave) and sweep the power level from low to high (dB value) to measure the response (gain/compression) of a DUT.

Length and Distance Measurements

The time domain feature is used to calculate the distance between any two measurement reference planes. Electrical length and optical length are displayed in the same manner; however, the correct value in optical length measurements require that you enter the proper index of refraction or velocity factor into the analyzer. In addition, these measurements can be made in two different manners: reflection or transmission. If the DUT has only one port or one end for connection, then an optical coupler is required and a reflection measurement made. If the DUT has two ports or two ends for connection, then a transmission measurement can be made without the use of an optical coupler.

Connector Information

The HP 8702 has electrical connectors (type-N) because its RF output and its receiver input are both electrical. The lightwave sources and lightwave receivers have optical connectors.

Currently, HP offers the following connector adapters that are used with the HP lightwave sources and receivers:

HP 81000AI HMS-10/HP (HP part number 08154-61701)
HP 81000FI FC/PC (HP part number 08154-61702)
HP 81000SI DIN 47256 (HP part number 08154-61703)
HP 81000VI ST (HP part number 08154-61704)

Making Optical Connections

The optical connectors on the HP lightwave sources and receivers have conditioned end-faces that are HMS-10/HP. These connectors require one of the connector adapters listed above to make the actual fiber connection.

Each adapter has a slot that mates with the corresponding key piece. After mating the connectors, they should be tightened (finger tight) in a consistent and repeatable manner for every measurement.

Cleaning Optical Connectors

All optical connectors, like electrical connectors, should always be cleaned properly before a connection is made. This is especially important because a small particle of lint or dust can result in poor measurement data. Use non-corrosive alcohol or a liquid freon product and clean the mechanical connectors with a lint-free swab or cloth. Then blow them dry with clean compressed air. Make all connections in a consistent and repeatable manner; do not over-tighten or under-tighten. Whenever possible, keep protective caps on all connectors. In addition, optical cables should be kept as still as possible when making measurements.

Cleaning Fiber Ends and Using Index Matching Compounds

The fiber ends should always be clean before making the connection. If you are using index matching compound, be sure to apply it as precisely and as evenly as possible. Remove it completely when you are finished.

Remember that improper optical connections, like electrical connections, can be the cause of bad measurement data. Optical connections must be properly made, especially where fiber ends meet or where a Fresnel reflection occurs. Alcohol or freon and a lint free swab or cloth is often used to clean fiber ends. The ends are then blown dry with clean compressed air.

However, HP currently offers the HP 15475A, a complete optical cleaning kit that uses an adhesive tape to clean the fiber ends. This kit includes the following parts:

HP 15475A Optical Connector Cleaning Kit

Part	HP Part Number
Head Cleaner	8500-0270
Hexdriver	8710-1256
Lens Cleaning Paper	9300-0761
Cleaning Kit Box	9300-1130
Blow Brush	9300-1131
Cleaning Tips	9300-1351
Cleaning Tip Box	1540-1100
Adhesive Tape Kit	15475-68701
Cleaning Instructions	15475-90002

Cleaning Instructions

The following information is taken from the cleaning instructions that come with the kit above:

NOTE: Never use abrasive materials to clean optical connectors or lenses.

Fiber Connectors

1. Turn off the laser and remove the connector adapter.
2. Apply a small amount of head cleaner to the cleaning paper and clean the surface and ferrule of the connector.
3. Use another new piece of dry cleaning paper to wipe the connector face clean.
4. Lightly press the adhesive tape against the connector surface several times to remove any remaining dirt or particles left by the cleaning paper. Return the tape to its box.
5. Protect the connector surface by attaching the adapter and cap.

Index Matching Compounds

The proper use of index matching compounds can be used for best return loss characteristics when making measurements with the HP 8702.

System Performance and Specifications

The HP 8702 has a level of performance that is described in the *System Performance and Specifications* section of the manual. General *System Specifications* describes the overall performance of an HP 8702 system where typical uncertainty values determine the accuracy of a measurement. These uncertainty values are assigned to each type of measurement: O/O, E/O, O/E, E/E. Each type of measurement is shown with a configuration drawing, a list of contributing measurement uncertainties that correspond to the configuration, and plotted uncertainty curves.

The HP 8702 is further specified by the *Instrument Specifications* that refer to the stand-alone characteristics of each system instrument. The HP 8702 instrument specifications are given in the manual. The lightwave source and receiver have their own manuals and specifications.

The HP 8702 Complete Manual Set

A two-volume manual set is supplied with the HP 8702 and described in the *General Information* section of the *Operating and Programming* manual.

Error Messages

The HP 8702 has a set of error messages that appear on the CRT whenever the CPU detects an operational malfunction. These messages are designed to help you identify the problem. For example, the message "No IF found: Check R input level" means that the reference R input is not receiving a signal. In this case, it could mean that you haven't made a connection to this input.

Operator's System Check

The most practical way to determine if the system is working properly is to measure a device with known characteristics. However, the following simple and quick procedure can be used to check the general operation of the system. Follow the procedure below to verify that the system is working and can be calibrated. If the results are different from those in this check, inspect and/or replace all cables and connectors. Repeat the procedure and compare results again. If a large difference still exists, you can suspect the HP 8702, the lightwave source, or the lightwave receiver. Refer to their respective service/performance test documents to verify the problem.

Procedure: General O/O System Check (Source and Receiver)

1. Connect the lightwave source and lightwave receiver to the HP 8702. Make a thru optical connection and turn the laser on.
2. Press: **[PRESET] [MEAS] [B/R]**.

   The result should show that the trace is about 0 dB (± 5 dB over the full-band) as shown in Figure 29.
3. Perform a response (thru) calibration. Press:

   [CAL] *[CALIBRATE MENU] [RESPONSE] [THRU]* and *[DONE: RESPONSE]*.

   The trace should become very flat across the band, indicating that the HP 8702 is performing a proper measurement calibration.

Results

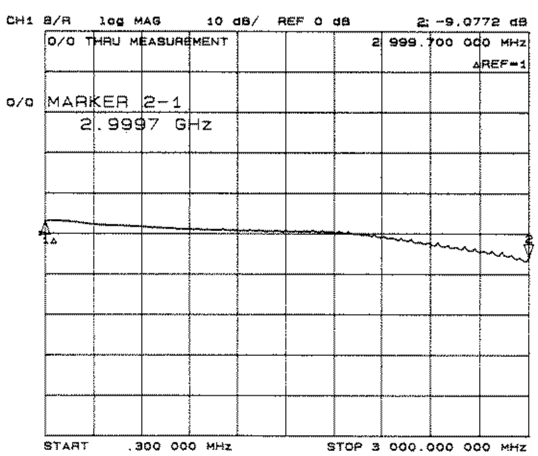


Figure 29. O/O Thru Measurement

If the trace is similar to the plot shown above and if it becomes extremely flat (± <1 dB) after calibration, it indicates that the HP 8702 system components are all working properly.

NOTE: The power splitter has 6 dB of loss in each path and has no effect on the ratio measurement. The typical source has about 30 dB of loss and the typical receiver has about 20 dB of gain. Also, there is a 20 dB difference between R and B inputs (due to the 20 dB attenuator). This may appear to have a net effect of +10 dB for a B/R measurement. However, because of the O/O configuration, the trace is offset 10 dB due to the detection of optical power by the HP lightwave receiver and the resulting measurement by the HP 8702: optical power $= 10 \log P_1/P_2$, not voltage $20 \log V_1/V_2$ as measured by HP 8702. Therefore, the trace should be near 0 dB across the band.

For more information, call your local HP sales office listed in your telephone directory or an HP regional office listed below for the location of your nearest sales office.

United States:
Hewlett-Packard Company
4 Choke Cherry Road
Rockville, MD 20850
(301) 670-4300

Hewlett-Packard Company
5201 Tollview Drive
Rolling Meadows, IL 60008
(312) 255-9800

Hewlett-Packard Company
5161 Lankershim Blvd.
No. Hollywood, CA 91601
(818) 505-5600

Hewlett-Packard Company
2015 South Park Place
Atlanta, GA 30339
(404) 955-1500

Canada:
Hewlett-Packard Ltd.
6877 Goreway Drive
Mississauga, Ontario L4V1M8
(416) 678-9430

Australia/New Zealand:
Hewlett-Packard Australia Ltd.
31-41 Joseph Street,
Blackburn, Victoria 3130
Melbourne, Australia
(03) 895-2895

Europe/Africa/Middle East:
Hewlett-Packard S.A.
Central Mailing Department,
P.O. Box 529
1180 AM Amstelveen,
The Netherlands
(31) 20/547 9999

Far East:
Hewlett-Packard Asia Ltd.
22/F Bond Centre
West Tower
89 Queensway
Central, Hong Kong
(5) 8487777

Japan:
Yokogawa-Hewlett-Packard Ltd.
29-21, Takaido-Higashi 3-chome
Suginami-ku, Tokyo 168
(03) 331-6111

Latin America:
Latin American Region Headquarters
Monte Pelvoux Nbr. 111
Lomas de Chapultepec
11000 Mexico, D.F. Mexico
(905) 596-79-33

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OPERATING NOTE

Techniques For Making High Performance Lightwave Connections

Includes information on the use of index matching compounds

HEWLETT PACKARD

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Techniques for Making High Performance Lightwave Connections

INTRODUCTION

The purpose of this note is to describe and suggest practices for making lightwave (optical) connections, cleaning and caring for lightwave connectors, and using index matching compounds. Specifically, this note can help you make repeatable and low loss lightwave (optical) connections when making measurements on a Hewlett-Packard Lightwave Component Analyzer.

Overview

Lightwave connectors are used to connect two fiber ends together. These connections may be used to join cables between optical ports on devices, laser sources, receivers, patch panels, terminals and many other types of systems or components.

Fiber optic cables may be of different sizes, different modes (SMF or MMF), different core/cladding combinations, and different indexes of refraction. However, regardless of the fiber type, the connectors have only one function: to provide a direct and lossless optical signal transition from one fiber end to another. When these connectors are used in a measurement system like the Lightwave Component Analyzer, repeatability becomes an important factor.

Optical connectors differ from electrical or microwave system connectors. In a fiber optic system, light from a laser source is transmitted or guided through the fiber core. Therefore, the fiber path and especially the connector interface (where two cores meet) must be precisely aligned with no air gap and no foreign particles between them. Because SMF cores are often 9 microns (.009 mm) or less in diameter, and dust particles range from tenths of a micron to several microns in diameter, dust and particulant contamination on the fiber core may degrade the insertion loss and return loss of the connector interface.

Insertion loss is also an important characteristic of a lightwave connection. Typical values are less than 1 dB of loss, and sometimes as little as 0.1 dB of loss when using high performance connectors. In addition, the best physical contact connectors can have as good as −40 dB of return loss, although −20 to −30 dB is more common.

Causes of connector loss and reflections include core misalignment, differences in the numerical aperture of two fibers, spacing and air gaps, reflections caused by damaged, worn, or loose fiber ends, and the improper use and removal of index matching compounds.

Achieving the best possible connection, where the fiber end faces are flush (no air gap) and properly aligned, is dependent upon two things: 1) the type of connector and 2) the way the connector is used. If the least amount of loss or reflection is not achieved or if the connection is not repeatable, light will not make a smooth transition and measurement data taken on a Lightwave Component Analyzer system will be less accurate. For this reason, lightwave connections can make the critical difference in optical measurement systems.

In theory, the ideal connector is one where the index of refraction remains unchanged at the connecting interface. Although some connectors (physical contact) are designed to provide an ideal connection that is dry (no index matching compounds) and flush, their performance may degrade because of wear, misalignment, or damage. If this occurs, their performance can sometimes be improved by making a wet connection (using gel or oil).

The wet connector (oil or gel) may have a slight change in the refractive index where light encounters the transition from fiber to gel and back to fiber again. However, this change in the refractive index has minimal loss (less than 1 dB) and is usually very repeatable.

In practice, many connectors work best with the wet technique because the compound fills any possible air gap between the interfacing cores. This allows the refractive index (n) of the transition to be well matched between the cores, allowing the light to pass from one fiber to another with minimal reflection.

The figure below shows the mating of two fiber ends (cores), designed to make physical contact. However, the radius area is exaggerated to show how an index matching oil or gel is used to displace any possible air gap and keep the medium of the transmission path as consistent as possible.

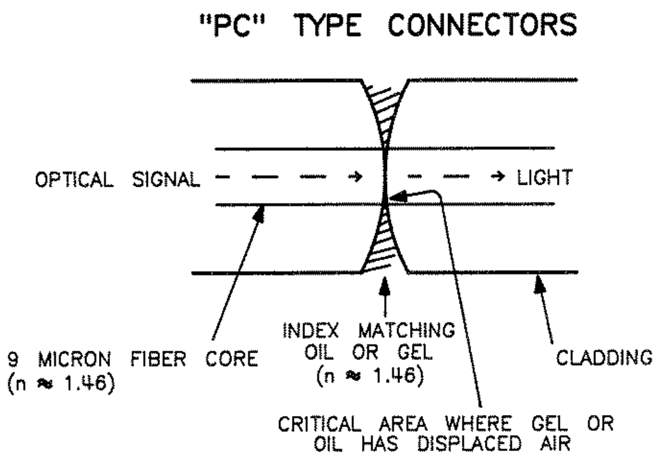

Figure 1. Typical Lightwave Connection Using Oil or Gel

Notice also that the figure shows how the index matching oil or gel allows the signal to pass from one fiber core to another without a drastic change in the refractive index. Without the matching compound, reflections would occur at the rounded edges of the interface. Although this figure shows two good cores, a matching compound can often be used to improve the performance of connectors where other factors (recessed or damaged cores) have caused an increase in the reflection off the connector.

Besides improper alignment, one of the most common problems in making connections is due to dust particles on the fiber ends and in index matching compounds. In fact, environmental dust is an almost inescapable problem that affects all optical connections, whether they are wet or dry.

The rest of this note will discuss techniques for the care, cleaning, and mating of lightwave connectors, including the use of index matching compounds.

TECHNIQUES AND GENERAL PRACTICES

The following information can help improve the performance of measurements made on the Lightwave Component Analyzer.

Caring for Connectors

In general, optical connector manufacturers will provide some recommendations when connectors are purchased. Most agree that an optical fiber end (core) must be clean and undamaged for the best results and this can only be verified under a high power microscope. Therefore, you should always keep the cleaned connectors covered with a protective cap when not in use.

Using Index Matching Compounds

Many types of index matching compounds are available, including gels, oils, and grease. In general, wet connections are most often made with a clear non-curing gel or oil.

Measurements made on the Lightwave Component Analyzer, using index matching compounds, resulted in improved performance of certain connector interfaces. These compounds were used on various types of connectors to obtain the best possible return loss when compared to the return loss of the same connector in a dry condition. However, gel is most often used on optical connectors where physical contact of the cores is *not* made at the connecting interface (like 2 FC connectors).

If a connecting interface does not result in the lowest possible reflection performance, oil or gel may be used to improve the performance. Depending upon the connector type used (PC, ST, DIN, Biconic, or HMS-10/HP, etc.), dry connector interfaces can typically achieve return loss performance between 30 and 40 dB. In general, if a physically contacting connector interface has a return loss of 30 dB or worse in a dry condition, it may be improved by the use of oil or gel. If a physically contacting connector has 40 dB return loss or better, then the use of gel or oil will most likely show little or no improvement. Also, oil or gel can be used on any connector where the cores have recessed or the end faces have been damaged or worn.

For most measurement applications, the HMS-10/HP connector with a dry connector interface (no index matching compound) should yield adequate low insertion loss and high return loss. However, if it should become necessary to use the HMS-10/HP connector with a wet interface, HP currently recommends using an index matching oil (available as HP Part Number 8500-4922).

Index matching oils are designed to achieve the same results as the gels. Oils are often used on connecting interfaces where little or no air gap is expected. However, oils have a tendency to flow or drip onto unwanted areas and may not adhere as well to the fiber ends as gel. Gels, on the other hand, may be more difficult to remove after repeated use.

For practical purposes, index matching compounds are often applied to fiber ends with a clean wooden toothpick, the opposite end of a swab, or by a syringe type of applicator. The goal is to apply only that amount necessary to lightly cover the fiber core: the less the better. Avoid spreading the gel around excessively, ensuring that the end face, and not the sleeve, becomes coated. Also, if using an applicator, be sure to use a clean or a new one every time.

Cleaning Wet Connectors

Many measurements made on the Lightwave Component Analyzer (described in the User's Guide) were done with connectors using a matching oil or gel. In order to remove the oil or gel, clean lens paper is used to wipe off the end face initially. Then a solvent like liquid *Freon TF* is used to remove the remaining compound. This is done by applying the solvent directly to the end face or to a lint free swab and wiping it across the end face. After the gel or oil is removed, and the solvent has dried (after about one minute), the connector is considered dry but not clean. At this point, the dry connector should be cleaned (described below).

Because there are many types of solvents, be sure to contact the gel or oil manufacturer for specific information about recommended solvents and cleaning procedures. Also, obtain all of the information necessary to ensure safety when using the solvent or when disposing of it. It is important to note that many solvents are toxic and may even leave residues on connectors or possibly damage certain types of components.

Cleaning Dry Connectors

After the connector is dry, a product like *Freon TF* or isopropyl alcohol can be used to clean the fiber end. Regardless of the type of connector, the TF can be applied in several ways: spraying, wiping, or dipping. In addition, some amount of wiping or mild scrubbing of the fiber end can help remove particles when application of TF alone will not remove them. This can be done by generously applying the TF or alcohol to a lint-free swab and moving the swab *back-and-forth* across the fiber end face several times. If performed correctly, this technique can help remove or displace particles smaller than one or two microns.

After cleaning the end face, spray a little TF or alcohol on the fiber end and allow it to dry. Although alcohol and TF dry in about one minute, *clean* compressed air can also be used to dry the surface immediately. After this, the connector should be ready for use.

Also, a special adhesive tape can be used to remove particles from a dry end face. However, if the tape is not perfectly clean, it can actually increase the number of particles on the fiber. This type of tape is currently included in a connector cleaning kit available from Hewlett-Packard; its contents are described in the Lightwave Component Analyzer's User's Guide and it can be ordered from any HP sales office, currently as model number HP 15475A.

In addition, always clean ferrules and other mating surfaces as well as the fiber end face. Use TF or alcohol, clean lint-free swabs and clean compressed air. These parts of the connector should be cleaned before the fiber end face is cleaned.

Using Swabs and Compressed Air to Remove Particles

Clean compressed air is often used to dry a connector or to displace unwanted particles (dust) from the fiber end. Do not shake the compressed air can because it may cause particles in the can to be released with the air.

The only way to insure that as little dust as possible attaches to the fiber ends is to keep gel and oil containers/applicators covered, keep swabs covered, and make connections as soon after cleaning and applying gel as possible. In addition, keep the work area as clean as possible.

Lint free rubber type swabs are recommended for cleaning the connectors because they leave no particles. Cotton swabs can also be used as long as you check that no cotton fibers remain on the end face after cleaning. In addition, use a clean swab each time you clean a connector and use a clean applicator when applying index matching oil or gel.

When using a Lightwave Component Analyzer to make reflection measurements, dust can cause a Fresnel calibration to degrade both during and after the calibration process. In fact, dust can attach itself so quickly to a connector (wet or dry) that it is difficult to determine if the connection is good or not. To avoid this problem, clean the connector again, using the mild scrubbing technique detailed above, and attach the DUT or cable to the coupler as quickly as possible, before any dust can settle on the connector end face.

Making the Connection

Most connectors using springs to push cores against one another are designed to exert about one to two pounds of force at the interface. Over-tightening or under-tightening these connectors can result in non-repeatable connections and misalignment of the cores. Always finger tighten the connector in a consistent and repeatable manner. Refer to the manufacturer's data sheet for any information on the amount of torque suggested.

When you insert the ferrule into a connector, keep it aligned so that it does not rub against the inside of the mating connector. In this way, you will not rub the fiber end against any undesirable surface —this is especially important if the end has oil or gel on it. After the ferrule is properly seated inside the other connector, use one hand to keep it straight and tighten it with the other hand. Many connectors have a key slot that should help you better align and seat the two connectors.

After a connection is made, be sure not to move the cable around. In this way, the light traveling through the connection and the cables will have a stable and repeatable path.

Determining Connector Return Loss under Wet and Dry Conditions

The Lightwave Component Analyzer can be used to measure the return loss of two connecting interfaces. Refer to the User's Guide to perform a reflection (Fresnel) calibration at the output port of the coupler. As the conceptual diagram in Figure 2 shows, the return loss of any two connecting interfaces can be measured to a high degree of certainty assuming a good connection at the output port of the coupler. Measure the return loss with a dry connection; then measure the return loss with a wet connection. The results of the data will allow you to determine the level of performance you require from the connectors: wet or dry.

To obtain the most accurate results after performing the Fresnel reflection calibration on the Lightwave Component Analyzer, the cable connection made at the coupler's output port (see Figure 2) must be an extremely low loss connection. The reason for this is to minimize any possible contributing error from this connection to the measurement of the DUT connectors; if necessary, use an index matching compound at that connection point.

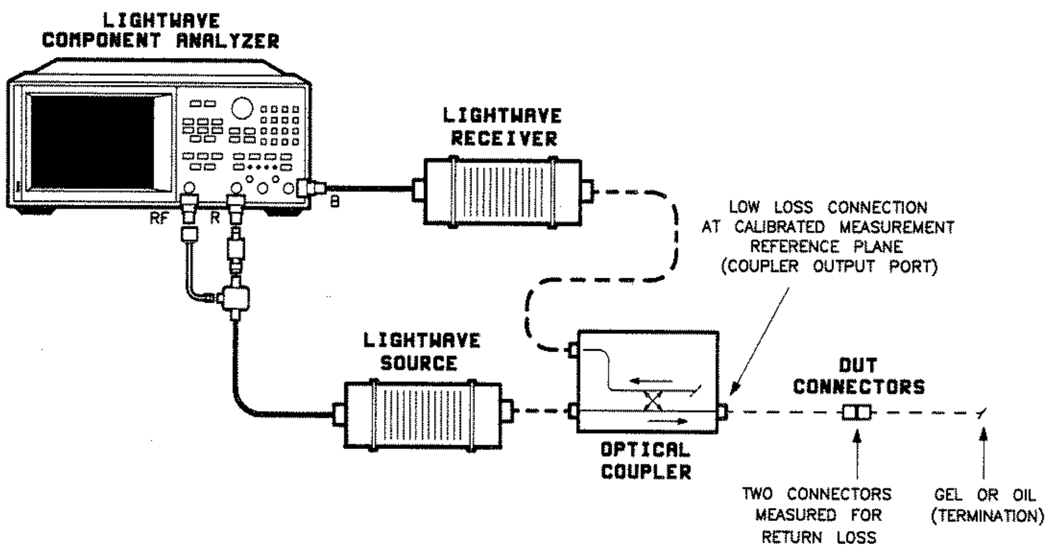

Figure 2. Connector Return Loss Measurement Configuration

SUMMARY

Lightwave connector types, especially those used with the Lightwave Component Analyzer or any of its accessory products, will vary depending upon your needs. HMS-10/HP, ST, DIN, FC/PC, D4, Biconic, and many other connector types will be used with different techniques.

In general, Hewlett-Packard suggests that you use the following approach to achieve the best possible performance when making measurements on a system like the Lightwave Component Analyzer:

1. Use care in handling all lightwave (optical) connectors.
2. Characterize the connector interfaces under both dry and wet conditions to determine the level of return loss that is acceptable for your specific use.
3. Use the cleaning methods described in this note for wet connectors (where gel or oil is used) and for dry connectors.
4. Use a reliable or recommended index matching compound at optical connector interfaces to achieve the lowest possible return loss and the lowest optical reflection when proper flush physical contact is not made at the fiber interface.

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Section 4. Advanced Measurement Techniques

The purpose of this section is to provide measurement examples that demonstrate advanced techniques, including many features of the HP Lightwave Component Analyzer. This section is not intended to cover all applications of the analyzer. It is intended to help you make measurements that are beyond the level of examples in the User's Guide. In addition, these measurements demonstrate certain features not used in the User's Guide. Therefore, be sure you know how to make the measurements described in the User's Guide before attempting to use the examples in this section.

This section contains the four measurement examples listed below.

1. Length Measurement of a 44 km Cable SMF
2. Pulse Dispersion of a 1.5 km MMF Cable
3. Swept Power Measurement of an O/E DUT (Photo Diode)
4. Phase Distortion Measurement of an O/E DUT (Photo Diode)

EXAMPLE 1: 0/0 Transmission Measurement of a 44 km Cable

A practical application of the analyzer is its ability to measure the exact length of a long roll of cable: 44 kilometers (about 24 miles) long.

This measurement configuration is very similar to a transmission measurement, except that the Lightwave Source drives the input of the coupler, and the Lightwave Receiver measures the light captured by the coupled arm...this is light reflected from the test device. Remember that the coupler separates the forward going light from the reverse traveling light. By measuring the amount of reflected modulation in the coupled arm, the analyzer shows how much light is being reflected back. The time domain option is then used to convert the frequency response into a time and distance response.

Procedure:

1. Connect the system as shown in the figure below. You will have to clean the connectors on the Lightwave Coupler and also clean the connectors on the cables for the most accurate results.

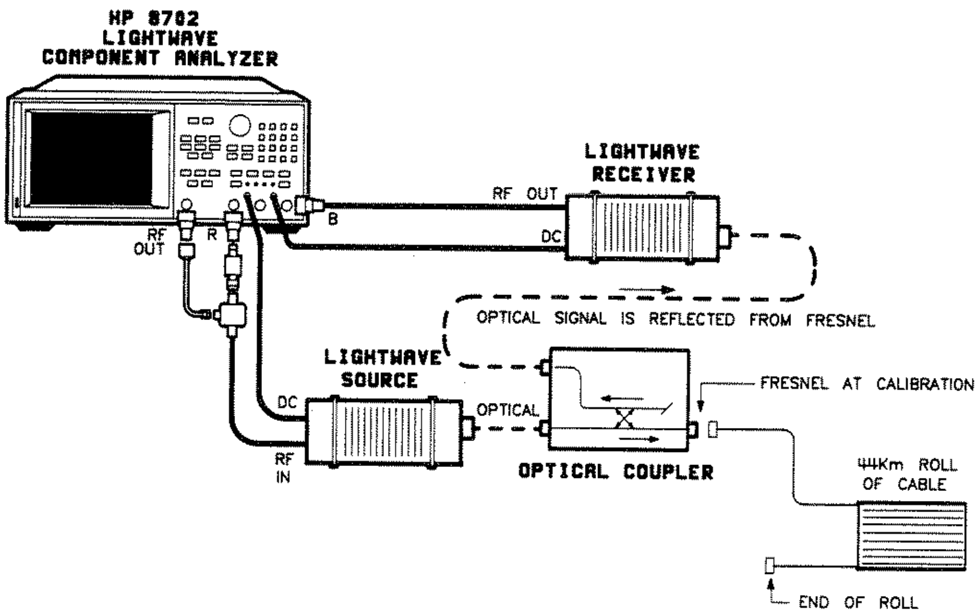


Figure 4-1. Optical Reflection Measurement Configuration

2. Begin by setting up the instrument parameters in the frequency domain. Press:

   [PRESET]

   RESPONSE **[MEAS]** *[B/R]*
   RESPONSE **[AVG]** *[IF BW] [10]* **[x1]**
   [CAL] *[MORE] [Index of Refraction] [2.92]* **[x1]**

   The IF Bandwidth is decreased as low as possible because the reflected signal will be quite low compared to the incident signal. The lower IF BW will filter out noise and lower the noise floor. The Index of Refraction is set to 2 x 1.46 =2.92 because the light is traveling down the cable and back again. By setting the Index of Refraction, the Velocity Factor is automatically calculated and set by the analyzer as they are the inverse of each other.

3. Set the STIMULUS block functions by pressing:

   [MENU] ***[POWER] [20]*** **[x1]**
   [RETURN]
   [SWEEP TIME] [3.5] **[x1]**
   [NUMBER OF POINTS] [801] **[x1]**

   Note that the Sweep Time setting has not taken account of the length of the cable. However, when you select 801 data points, the analyzer will automatically reset the sweep time to about 83 seconds because it knows how much time it takes to measure that many data points. This number of data points will also give you better resolution when you convert from the frequency domain to the Time Domain.

   [CENTER] [1] [M/u]
   [SPAN] ***[1.4]*** **[M/u]**

4. Calibrate the system. You are going to make a measurement calibration that will set the measurement reference plane at the optical coupler's output connector (transmitted signal). The reflection off the open fiber, called a Fresnel reflection, has a flat response that can be used to calibrate the system. For reflection measurements, the Fresnel is actually the clean OUTPUT/INPUT connector of the HP optical coupler: about 3.5% reflected optical power or about 14.6 dB. After calibration, the roll of cable that you connect will have a measurement reference plane at that connection.

   Be sure that all connectors are clean and dry, without any matching gel or oil on them. Matching compound can reduce reflections. Be sure that the coupler's reflected (coupled) output is connected to the Lightwave Receiver. In this configuration, the coupler is going to receive the light coming from the Fresnel reflection to establish the measurement reference plane.

   Press the following RESPONSE block keys:

   [CAL] ***[DEVICE TYPE] [1-PORT OPTICAL]***
   [RETURN]
   [CALIBRATE MENU] [RESPONSE]
   [FRESNEL]

   When the calibration measurement is complete, the analyzer will underline the Fresnel and beep. After this happens, press:

   [DONE: RESPONSE]
   [SAVE REG 1] or any register you want

   Remember that the Fresnel reflection is a general purpose standard definition assuming a clean Fresnel reflection at the test port. This mathematical definition has already been loaded into the analyzer.

   Examine the response on the display. It should be a flat line around −14.6 dB, the optical return loss of the Fresnel reflection (3.5% reflected optical power). This value always depends upon the index of refraction of the fiber (in this case it is 1.46).

   Noise on top of the trace may be observed. That noise is caused by reflected light re-entering the laser cavity and changing its modulation characteristics. This is called *reflection sensitivity*.

5. You are now ready to measure the roll of cable to determine its exact length. Be sure the cable is terminated with a Fresnel reflection so that enough light can return down the fiber and enter the coupler. Remember that you must have the proper connectors on the cable to connect it to the coupler's transmitted output. The Lightwave Source and Receiver will remain connected in their present positions.

Connect the roll of cable. After one complete sweep, look at the response in the frequency domain. Use the RESPONSE **[SCALE REF]** keys to AUTOSCALE the trace, if necessary. Then convert the measurement to the Time Domain, press:

INSTRUMENT STATE **[SYSTEM]**
[TRANSFORM MENU]
[TRANSFORM ON]

6. The response should now show two distinct peaks on the trace. One peak is the signal at zero seconds (calibrated reference plane), where it leaves the coupler's transmitted output connector at time zero or zero meters. The next peak is where the lightwave signal has hit the Fresnel reflection, at the end of the cable.

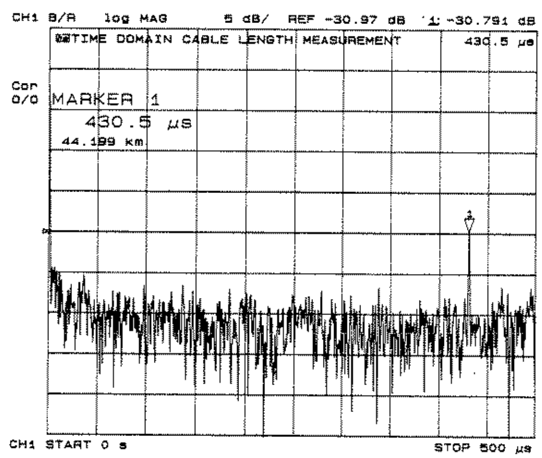


Figure 4-2. Cable (44 km) Measurement Results

The signal has loss in each direction due to the long length of the cable, and another 14.6 dB of loss due to the Fresnel reflection. Therefore, most of the measurement signal received by the analyzer is greater than −40 dB, except where the reflected signal occurs.

The marker can be used to locate the end of the fiber if the distance you read is adjusted for the actual velocity of light in the fiber. Light travels down the fiber at about 2/3 the speed of light in free space. However, because it is reflected light, traveling in two directions, use only 1/3. Although the velocity factor is automatically set when the Index of Refraction is set, this can also be done by selecting **[CAL]** ***[MORE] [VELOCITY FACTOR] [0.33]*** **[x1]**.

EXAMPLE 2: Pulse Dispersion Measurement of MMF Cable

Pulse dispersion is a measure of the amount of change in the width of a modulation frequency pulse. The change is due to the cumulative dispersive effects in the transmission path, especially in MMF. Although pulse dispersion can be derived from the bandwidth of a DUT, this measurement also demonstrates the split screen display, data storage into memory, and many other features of the analyzer.

In this example, the time domain option of the analyzer is used to convert the frequency domain data into the impulse response of the DUT. Here, pulse dispersion is calculated as:

$$\text{Pulse Dispersion (s/km)} = \sqrt{\text{transmitted signal}^2 - \text{incident signal}^2}$$

In addition, pulse dispersion measurements must be made using a frequency span that is equal to the bandwidth of the fiber.

Although this measurement is conceptually simple, the following procedure includes all of the techniques and necessary keystrokes used to produce the accurate results shown in the plots that follow.

Procedure:

1. Measure the bandwidth of the fiber cable (refer to the User's Guide). In this example, the bandwidth was measured at about 1 GHz.

2. Connect the system as shown in the figure below. Although the figure shows the RF Interface Kit used to separate the RF signals, a system using an HP Test Set can also be used in its transmission configuration.

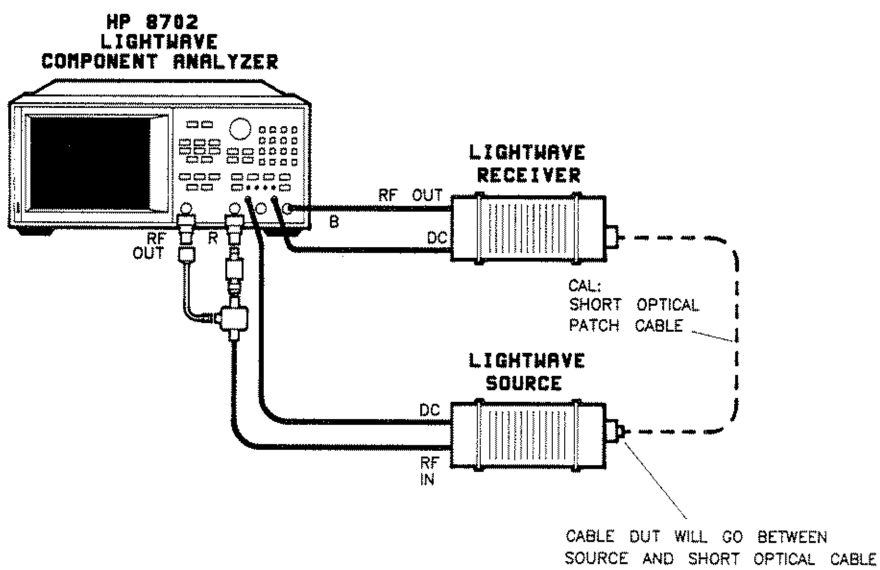


Figure 4-3. Pulse Dispersion Test Setup

3. Perform a RESPONSE calibration. Note that the number of points is increased to 401 to give better resolution. The power is set to 10 dBm to compensate for any loss through the cable and the IF Bandwidth is set to 300 Hz to reduce the noise. Because of the increased number of points and the IF Bandwidth reduction, the sweep time must be increased to 8 seconds in this example.

   Press the following keys on the analyzer:

   [PRESET]
   [MEAS] ***[B/R]***
   STIMULUS **[STOP] [1] [G/n]**
   STIMULUS **[MENU]**
   [POWER] [10] **[x1]**
   [RETURN]
   [SWEEP TIME] [8] **[x1]**
   [NUMBER OF POINTS] [401] **[x1]**
   RESPONSE **[AVG]** ***[IF BW] [300]*** **[x1]**

   RESPONSE **[CAL]**
   [MORE] [INDEX of REFRACTION] [1.46] **[x1]**
   [RETURN]
   [CALIBRATE MENU] [RESPONSE]
   [THRU] and after the beep, ***[DONE: RESPONSE]***

   The trace should now be a flat line in the frequency domain at 0 dB. You can also save this calibration in a register.

   NOTE: Because the sweep time is 8 seconds, the response of the system to front panel commands will not be extremely rapid. Therefore, execute the following procedures somewhat slowly to obtain the best results.

4. In order to view the time domain response of the incident signal, press the following keys:

   [SYSTEM] ***[TRANSFORM MENU] [TRANSFORM ON]***
   RESPONSE **[FORMAT]** ***[LIN MAG]***
   [SCALE REF] [AUTO SCALE]
   STIMULUS **[SPAN] [8] [G/n]**
   RESPONSE ***[MKR FCTN] [MORE] [PULSE WIDTH]***

   The response should be similar to the plot shown in the figure below:

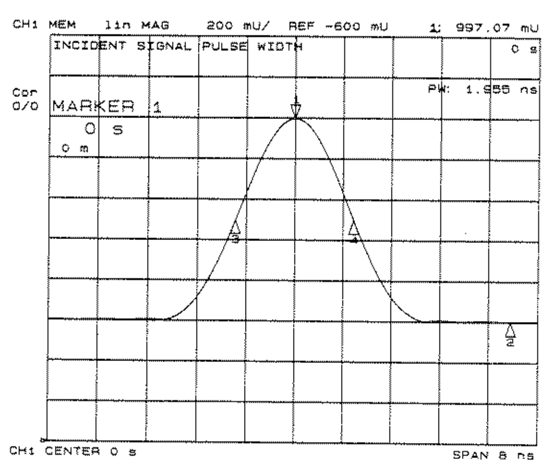


Figure 4-4. Incident Signal Pulse Width

5. Store the data into memory and split the display for comparison of the incident and transmitted signal pulse widths. Press the following keys:

   RESPONSE **[DISPLAY]** ***[DATA→MEMORY]***
   [DISPLAY: MEMORY]
   STIMULUS **[MENU]** ***[COUPLED CH OFF]***
   RESPONSE **[DISPLAY]** ***[DUAL CHANNEL ON]***
   RESPONSE **[MKR]** ***[MARKER MODE MENU]*** ***[MARKERS: UNCOUPLED]***
   and, if desired, the channel 1 data in a register.

   Connect the DUT (roll of MMF cable). Be sure to connect the cable interface directly to the HP Lightwave Source. Connect the other end of the DUT to the short cable that is connected to the HP Lightwave Receiver.

6. Locate the end of the cable in time domain. Use the marker function, in the time domain, and note the uncorrected length.

   ACTIVE CHANNEL **[CH 2]**
   [SYSTEM] ***[TRANSFORM MENU]*** ***[TRANSFORM ON]***

   Decrease the stop frequency, using the Transform Parameter menu's range window, until the range is slightly beyond the length of the cable. In this example, press:

   [TRANSFORM PARAMETERS] ***[STOP FREQUENCY]*** ***[50 MHz]***

   Notice that the range is now about 1.6 km. Then press:

   [RETURN]
   STIMULUS **[STOP]**, and press the up arrow key until the stop time/range is slightly greater than the length of the roll of cable. In this example, the stop time is about 8 μs and the length is about 1.6 km. Press:

   [MKR FCTN] ***[MKR SEARCH]*** ***[MAX]***

   The marker now shows the location of the transmitted pulse in the time domain (LOG MAG) at the end of the cable, similar to the plot below.

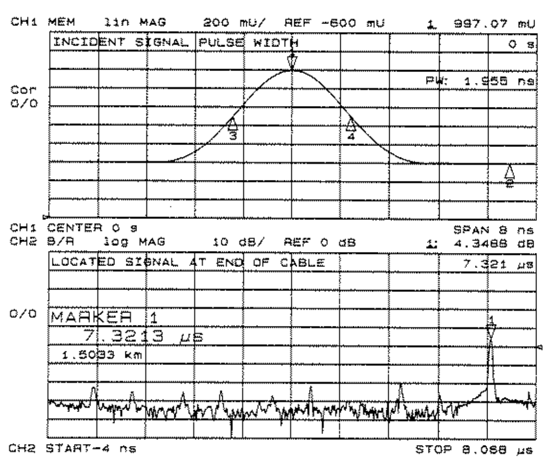


Figure 4-5. Location of Transmitted Signal at End of Cable.

7. Center the peak and use the marker features in combination with the display scaling features to focus on the transmitted signal pulse width. Press:

   [RETURN] [MARKER→CENTER]
   and ***[MKR SEARCH] [MAX]*** again.

   The marker will move off of the center (max) of the peak because of the spacing of the data points (number of points). This is expected. Then, after converting to a linear format, use the scaling feature and the span feature to focus on the signal. Press:

   [FORMAT] ***[LIN MAG]*** and ***[SCALE REF] [AUTO SCALE]***

   If necessary, decrease the span by pressing the down arrow key one time and then readjust the scaling again. Press:

   [SPAN] and **[↓]** down arrow key
   [SCALE REF] ***[AUTO SCALE]***
   [MKR FCTN] [MARKER SEARCH] [MAX]
   [RETURN] [MARKER→CENTER]

   NOTE: Do not decrease the span too much. If you do, the true response may not be displayed because it is off the CRT. If you know the cable length, you can look at the marker value to be sure it is on the proper response peak.

8. Turn correction ON, turn the alias span ON, and adjust the display trace. Press:

   [CAL] ***[CORRECTION ON]*** and **[SCALE REF]** ***[AUTO SCALE]***
   [SYSTEM] ***[TRANSFORM MENU] [MORE] [ALIAS SPAN ON]***

   The alias span is used so that electrical delay (mathematically adding electrical length) is not required. The frequency bandwidth limitation does not allow you to look out to the end of the cable. However, by turning the alias span on, you can go look out far enough and view the correct response.

   In addition, the correction coefficients will almost certainly change the displayed data. When you turn on the calibration, the start and stop frequencies set in the Transform Parameters menu will return to their previous settings; in this case, 300 kHz to 1 GHz. And the peak (max) signal at the end of the cable will no longer be in the center of the display where the marker has been set. Therefore, readjust the marker, the scaling, and the span so that the transmitted signal is centered.

Display adjustment technique

The following key press sequence is a suggested method for adjusting the trace display. Although each DUT will have a different response, the following method can be used. Press the marker and scaling keys as needed.

A. The following key presses will center the trace and put the marker on the peak value:

   [MKR FCTN] ***[MKR SEARCH] [MAX]***
   [RETURN] and ***[MARKER→CENTER]*** and ***[MKR SEARCH] [MAX].***

B. Then use the scaling feature to properly adjust the graticule values and the span. Be careful not to decrease the span below the value used on channel 1.

[SCALE REF] ***[AUTO SCALE]***
[SPAN] [↓]

C. Be sure you have the marker on the correct response and repeat A and B above until the pulse width is displayed similar to the trace on channel 1. Then, set the pulse width markers and reduce span so that it matches or is close to the span used on channel 1. If necessary, change the span on channel 1 to match:

[SPAN] and enter the value. In this example, **[10] [G/n]** was entered. Then the markers were set by pressing:

[MKR FCTN] ***[MORE] [PULSE WIDTH]***

As shown in the plot below, the span of channel 1 was set to 10 ns to match channel 2 and allow easy analysis of the data at 1 ns per division.

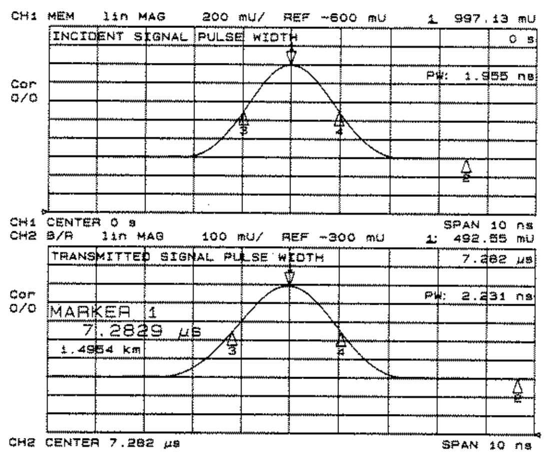


Figure 4-6. Pulse Width Signal Comparison

9. To calculate the actual dispersion, in seconds/km, the following equation can be used:

$$\text{Dispersion} = \sqrt{\text{transmitted}^2 - \text{incident}^2}$$

where the transmitted and incident signal values are the measured pulse widths in seconds.

In this example, the pulse dispersion PD is calculated as:

$PD = \sqrt{2.231\text{ns}^2 - 1.955\text{ns}^2}$

$PD = \sqrt{4.9774 - 3.822}$

$PD = \sqrt{1.1554 = 1.0749}$

$PD = \sqrt{1.0749 \text{ nsec per } 1.4954 \text{ km}}$, or

Pulse Dispersion =0.7188 nano-seconds per kilometer MMF

EXAMPLE 3: Swept Power Measurement of an O/E DUT (photo diode)

Accuracy enhanced (calibrated) measurements of absolute and ratioed power at the input and/or output of a DUT can be made on the analyzer. This example demonstrates how an O/E DUT (photo diode with MMF interface) can be stimulated by a wide-range input power sweep using a single frequency (CW) modulation signal.

In order to calibrate the system, the HP Lightwave Receiver and its corresponding CAL DATA (101 points) are used in conjunction with measurements of the RF cable losses (normalization). The result of this RESPONSE calibration is a correction coefficient that removes all of the systematic errors and RF cable losses so that the DUT response is accurate.

NOTE: HP recommends that power sweep measurements be made without a test set and below 3 GHz, due to attenuation in the test set. Therefore, use the RF Interface Kit as shown in Figure 4-7.

Procedure:

Do not connect the system yet.

1. Preset the system and set it to system controller to load the receiver disc, press:

   [PRESET] [LOCAL] ***[SYSTEM CONTROLLER]***

   Load the HP Lightwave Receiver CAL DATA from the disc into the analyzer. Be sure the HP 9122C or 9122D dual-sided disc drive's address corresponds to the address set in the analyzer, accessed by the **[LOCAL]** and ***[SET ADDRESSES]*** keys. Although the procedure for loading the CAL DATA is described in the User's Guide and the HP Lightwave Receiver manual, here are the basic key presses:

   [CAL] ***[CAL KITS & STDS] [RECEIVER]*** and CAL STD: ***[RCVR DISC]***
   [LOAD RCVR DISC] [READ FILE TITLES]

   Be sure the file title matches the serial number of your HP Lightwave Receiver and then press the corresponding softkey:

   [LOAD xxxxxx] and wait until the files have been loaded.

2. Select the start and stop power sweep levels, press:

   STIMULUS **[MENU]** ***[SWEEP TYPE MENU] [POWER SWEEP] [RETURN]***

   Set the power sweep to the widest possible range without damaging the test equipment or the DUT. Note that the power level should not be so great that it trips (triggers) the power sensor on the R, A, or B inputs (must be less than 0 dBm at the inputs). Keep in mind that there is some attenuation in the RF paths (6 dB splitter, 20 dB attenuator on R input, etc.). For this example select 0 dBm to +20 dBm as the RF output power sweep. Note that the power delivered to the DUT input will be less than this, due to losses in the electrical and optical path.

   STIMULUS [START] [0] [x1]
   STIMULUS [STOP] [20] [x1]

3. Select a CW frequency (single frequency or continuous wave).

   In this example, the CW frequency is chosen so that it is within the bandwidth of the DUT. Note that this CW frequency can be changed later to measure the DUT's swept power response at a different modulation frequency. Enter the desired CW frequency. In this example, it is 300 MHz:

   ***[CW FREQ] [300]* [M/u]**

   Also, decrease the IF Bandwidth to reduce the effects of noise on the measurement:

   RESPONSE **[AVG]** ***[IF BW] [300]*** **[X1]**

4. Select the calibration device type. Here, it is the HP Lightwave Receiver:

   [CAL] ***[DEVICE TYPE] [O/E]***

5. Select the type of power sweep measurement: ratio or absolute measurement.

   This selection depends upon the type of swept power measurement you want. B/R and A/R use the respective analyzer inputs for ratio measurements (gain vs. power) where the X axis shows the swept power and the Y axis shows the responsivity (gain/compression) in dB. A or B measurements use the respective inputs for measurements showing the power IN (X axis) vs. power OUT (Y axis). For this example, press:

   [CAL] ***[POWER CAL MENU] [B/R POWER]***

6. Perform the calibration in several steps.

   A. RESPONSE and RECEIVER —Connect the system as shown in the figure below.

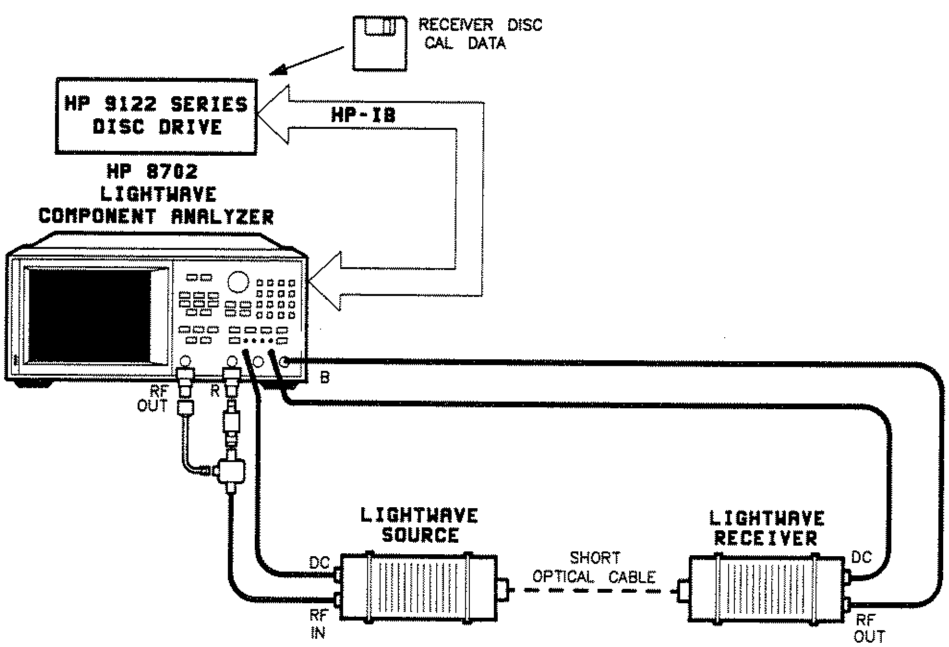


Figure 4-7. Measurement Calibration Setup: RESPONSE and RECEIVER

The lightwave source and receiver should be connected together using a short optical patch cord (thru).

NOTE: It may be necessary to add optical attenuation between the lightwave source and receiver during the calibration and the measurement if the power out of the laser source could send the HP Lightwave Receiver into compression or damage the O/E DUT. In this example, the maximum input (average optical power) to the HP Lightwave Receiver is 5 mW.

If that is the case, enter the value of optical attenuation with the softkey selection on the CRT. After the calibration procedure, you would put that attenuator in the optical path (between source and receiver) to protect the DUT from too much power. For the DUT used in this example, no attenuation was required.

[RESPONSE] and wait until the beep. Then press:

[RECEIVER] and wait for the beep.

The next two calibration measurement steps (B and C below) are necessary to remove the effects of RF cable loss.

B. RF SRC CBL —Connect the system as shown in the figure below. The RF source cable is connected from the power splitter output to the B input which is attenuated by 20 dB.

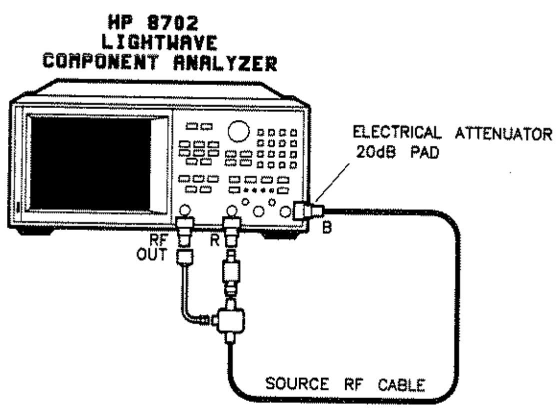


Figure 4-8. Measurement Calibration Setup: SRC CBL

The RF source cable must be attenuated by an amount sufficient to keep the analyzer B input from being overdriven (*power trip*) beyond its 0 dBm input limit. With the stop power set to +20 dBm, and attenuated by 6 dB through the power splitter, a 20 dB pad is sufficient for this example: 20dBm −6dB −20 dB = −6 dBm. However, any pad that results in 0 dBm or less at the R input is acceptable.

In addition, at the time of DUT measurement, a pad is required at the B input if the receiver DUT will put more than 0 dBm into the B input of the analyzer.

To make the calibration measurement, press:

[RF SRC CBL] and wait for the beep.

C. RF TOT CBL — Connect the system as shown in the figure below. The RF source and receiver cables are connected together from the power splitter output to the B input which is attenuated with a 20 dB pad.

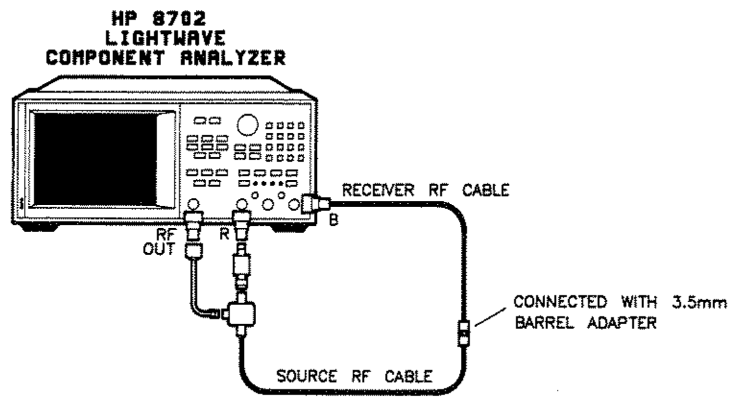


Figure 4-9. Measurement Calibration Setup: TOT CBL

The two RF cables (source and receiver) must be connected together using the same attenuator as in step C above. To make the calibration measurement, press:

[RF TOT CBL] and wait for the beep.

D. Press ***[DONE B/R]*** when all four of the calibration measurements have been made. Save the B/R calibration in a register if desired.

To verify that a good calibration was made, reconnect the HP Lightwave Source and Receiver (using the same patch cord between them) and leave the 20 dB pad connected to the B input.

If the calibration process is successful, the display will look similar to the responsivity plot below. The marker has been set to show the calibrated reference plane at 0 dB on the Y axis. If the 20 dB pad were removed from the B input, the reference would be at 20 dB.

The annotation below the CRT graticule will now display the adjusted power sweep range: about 9.75 dBm total range between the start and stop power. This is the start/stop power level that will appear at the input to the DUT. The original start/stop power (0/+20) is the level out of the RF source. The display annotation *CP*, on the left side of the graticule, stands for *Corrected Power*.

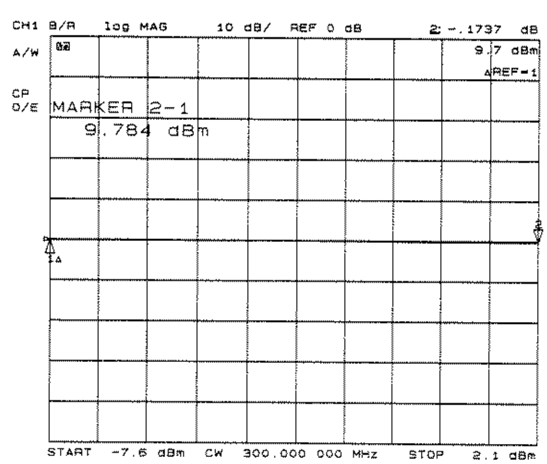


Figure 4-10. Swept Power Calibration Plot

NOTE: If the optical attenuator was used during the calibration, it should remain connected in the optical path. For this example, no optical attenuator is necessary.

7. Remove the 20 dB pad from the B input and measure the DUT. The 20 dB pad was only required to avoid over-powering the B input while measuring the cable losses during calibration. The DUT is inserted in place of the HP Lightwave Receiver as shown below. However, if the DUT has gain, a pad is required and the measurement data will be offset by the amount of that attenuation.

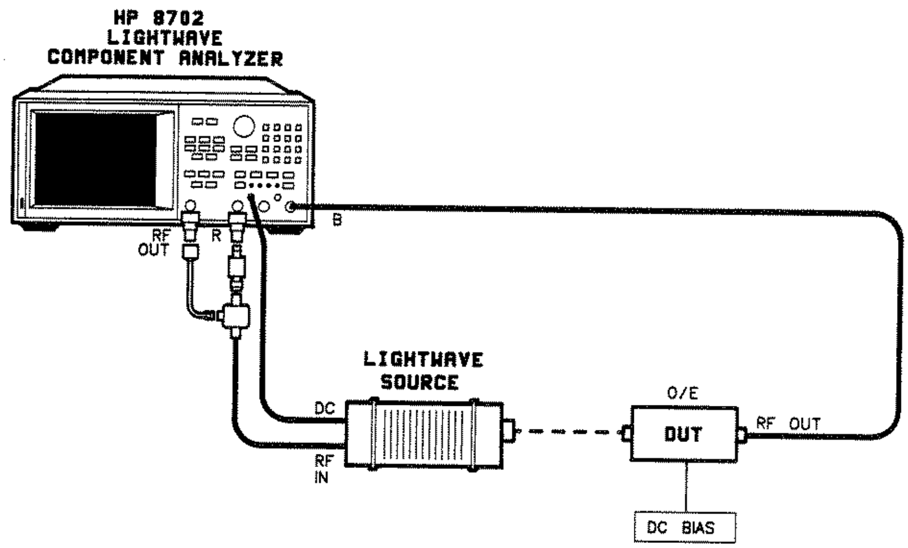


Figure 4-11. DUT Measurement Configuration

8. Adjust the DUT's DC bias level for comparison purposes.

   In this example, the DUT is adjusted with minimal bias and this trace data is stored in memory by pressing:

   RESPONSE **[DISPLAY]** ***[DATA→MEMORY]***

   Then the bias is readjusted for maximum output and the trace data is compared to the data in memory by pressing:

   DISPLAY ***[DATA and MEMORY]***

   The example plot below shows two data traces. The lower trace shows the non-amplified photodiode's response to the power sweep before maximizing its DC bias. The upper trace shows the DUT response after DC bias adjustment. In both cases, the DUT response is rather linear and shows no signs of compression.

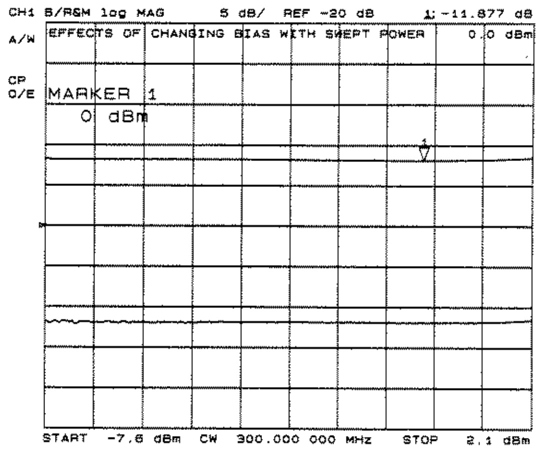


Figure 4-12. O/E DUT Response to Bias Changes and Swept Power

To test this DUT further, the power sweep could be increased to determine the compression point.

NOTE: To measure a laser source, the same basic procedure is used. The HP Lightwave Receiver CAL DATA is used (NOT the source CAL DATA). There are some slight differences in the calibration process, but they are easily understood by following the softkey menu selections during calibration.

EXAMPLE 4: Phase Distortion Measurement of an O/E DUT (photo diode)

A digital communication system is often limited by the amount of distortion that occurs. This distortion increases the bit error rate and can also distort the transmitted data. Although distortion can be caused by the fiber, it is usually associated with the system components such as O/E receivers, amplifiers, and other devices in the transmission path.

The analyzer can display phase distortion as either deviation from linear phase or group delay. The measurement is essentially a transmission measurement displayed in the phase format. With electrical delay mathematically added to the DUT response, the transit time through the DUT and its deviation from linear phase can be determined.

In this example, an O/E (non-amplified photo diode) DUT is used to demonstrate how the analyzer can measure deviation from linear phase and delay (transit time) through the device. To do this, the HP Lightwave Receiver CAL DATA disc is used to perform the transmission calibration.

Procedure:

1. Connect the system as shown in the figure below.

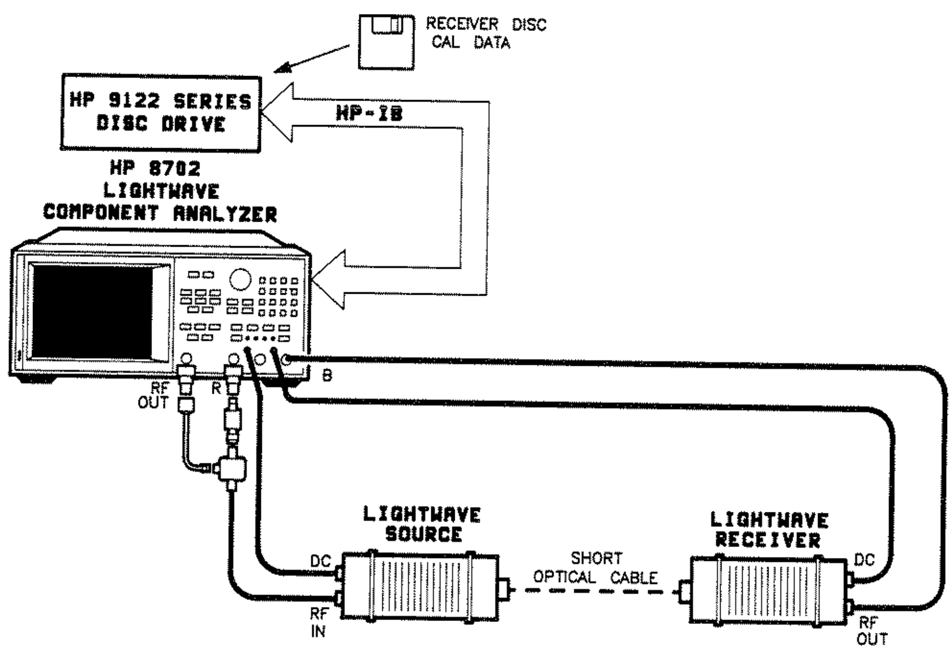


Figure 4-13. Phase Distortion CAL Test Setup

2. Select the measurement parameters and perform a RESPONSE calibration.

   The IF Bandwidth is decreased to reduce the effects of noise, the power is increased to 15 dBm to get better dynamic range, and the modulation STOP frequency is set just about the DUT's bandwidth.

   [PRESET] [MEAS] ***[B/R]***
   [CAL] ***[DEVICE TYPE] [O/E]***
   RESPONSE **[AVG]** ***[IF BW] [100]*** **[x1]**
   STIMULUS **[MENU]**
   [POWER] [15] **[x1]** ***[RETURN]***
   STIMULUS **[STOP] [2] [G/n]**

3. Load the HP Lightwave Receiver CAL DATA from the disc into the analyzer.

   The HP 9122-series dual-sided disc drive's address must be the same as the address set in the analyzer, accessed by the **[LOCAL]** and ***[SET ADDRESSES]*** keys.

   Although the procedure for loading the CAL DATA is described in the User's Guide and the HP Lightwave Receiver manual, here are the basic key presses:

   [CAL] ***[CAL KITS & STDS] [RECEIVER]*** and CAL STD: ***[RCVR DISC]***
   [LOAD RCVR DISC] [READ FILE TITLES]

   Be sure the file title matches the serial number of your HP Lightwave Receiver and then press the corresponding softkey:

   [LOAD xxxxxx] and wait until the files have been loaded.

4. Perform the calibration, press:

   [CAL] ***[CALIBRATE MENU] [RESPONSE] [RECEIVER]***, and after the beep, ***[DONE: RESPONSE]***

5. Select the phase format to view the calibrated phase response of the HP Lightwave Receiver, press:

   RESPONSE **[FORMAT]** ***[PHASE]***

   The display should look similar to the plot below, except for the markers. The markers on the example plot help to explain how phase is displayed on the analyzer. Note that the X axis is the modulation frequency range and the Y axis is phase, set to 90 degrees per division:

   Marker 1 is at 0 degrees, marker 2 is at −180 degrees, marker 3 is near +180 degrees, and marker 4 is near 0 degrees (−3.1778 degrees). Note that better resolution can be obtained by increasing the number of points.

   You can set the marker to any frequency and read the phase shift for that frequency on the display.

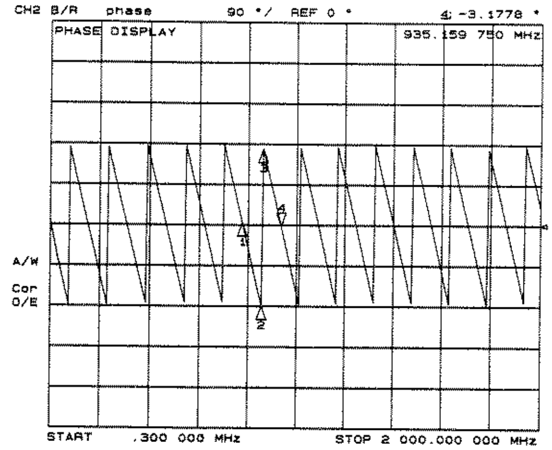


Figure 4-14. Calibrated HP Receiver System Phase Response

6. Insert the O/E DUT into the system in place of the HP Lightwave Receiver. The plot below shows the phase response of the diode receiver.

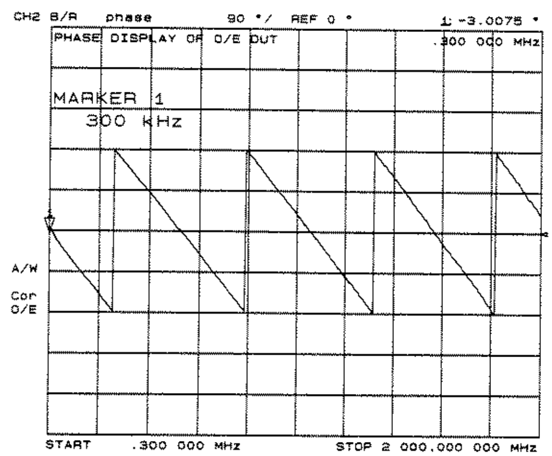


Figure 4-15. Phase Response of O/E (photo diode) DUT

7. To measure the electrical delay or transit time trough the DUT, you must add enough electrical length or delay to the device to flatten out the phase response as close to zero degrees as possible. Adding electrical delay is a mathematical function that attempts to remove the length of the device by adding the delay to the measurement data. Press the following keys:

   [SCALE REF] ***[ELECTRICAL DELAY]***

   Then rotate (clockwise) the RPG knob until the trace is as flat as possible, similar to the plot below.

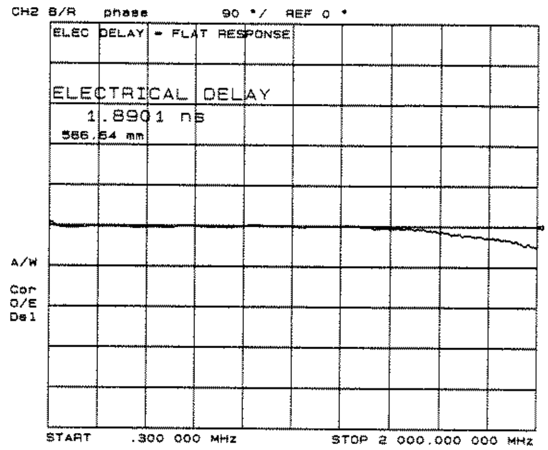


Figure 4-16. ***Electrical Delay Used to Flatten Phase Response***

8. Obtain greater resolution by pressing:

   [SCALE REF] ***[SCALE/DIV] [10]*** **[x1]**

   If necessary, readjust the ***[ELECTRICAL DELAY]*** so that the trace is as flat as possible across most of the band. The plot below shows an electrical transit time of 1.886 ns through the DUT. In this example, about 6 degrees of deviation from linear phase are shown across the band within the markers: approximately 1.56 MHz. To view the deviation at any particular modulation frequency, simply put the marker on that value and read the display.

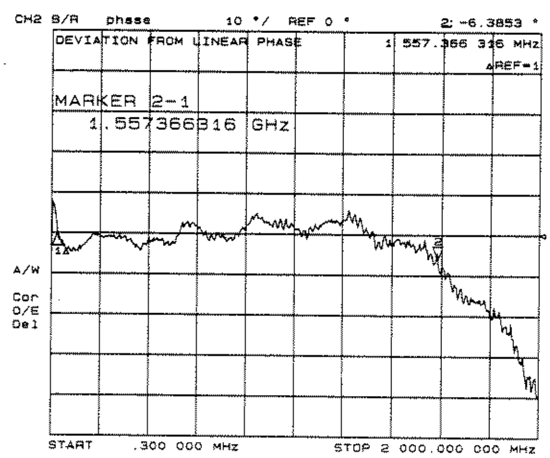


Figure 4-17. ***Deviation from Linear Phase of O/E DUT (diode)***

Section 5. Operating and Programming Reference

OPERATING AND PROGRAMMING REFERENCE

Including a Complete HP 8702 Menu Map

The remaining portion of this manual is a reference document that describes all of the menus and the key selections in those menus. Each section (divided by its functional tab) describes the features in that functional group. The purpose of this section is to describe what a particular key does and to list its HP-IB mneumonic in parenthesis; this section is not intended as a tutorial on making measurements, it is intended as a reference document only.

The menus and key selections are in functional order as they appear (sequentially) in the menus.

In addition, a complete system menu map is given on the following page for reference purposes.

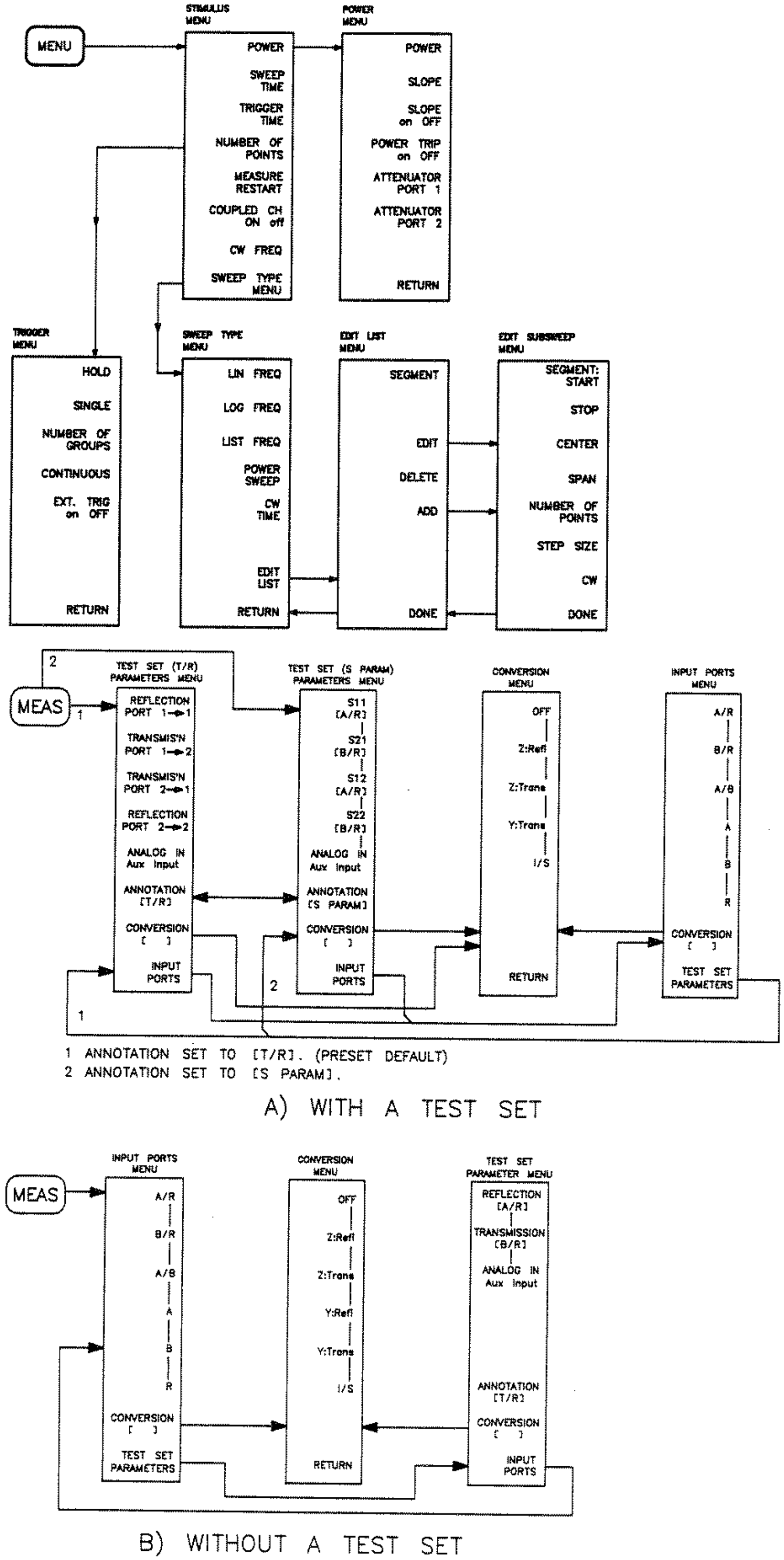
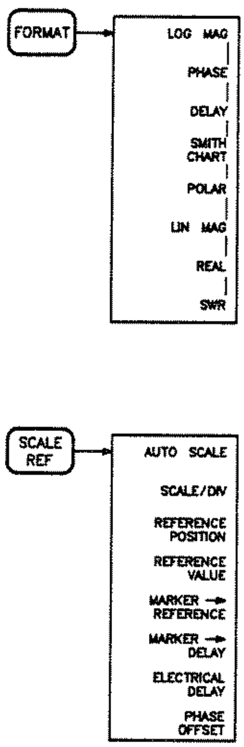
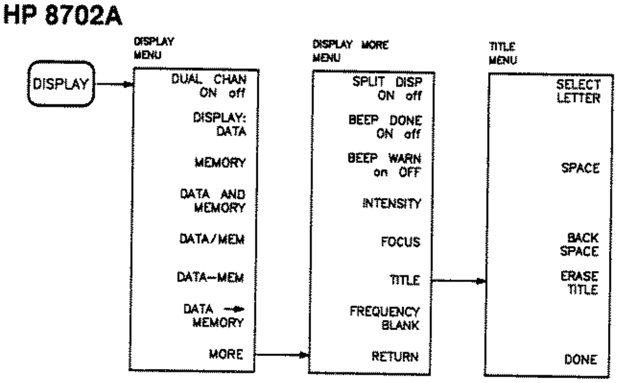


Figure 5-1. Operating Softkey Menu Map (1 of 6)



HP 8702A



HP 8702B

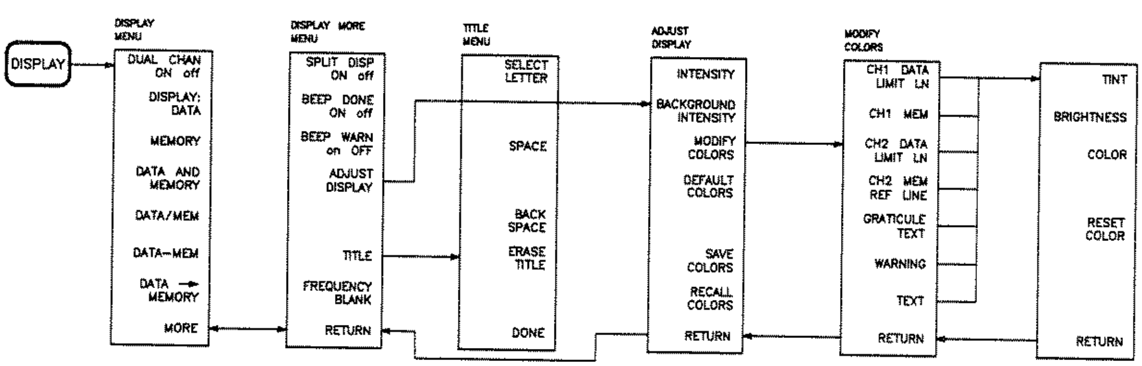


Figure 5-1. Operating Softkey Menu Map (2 of 6)

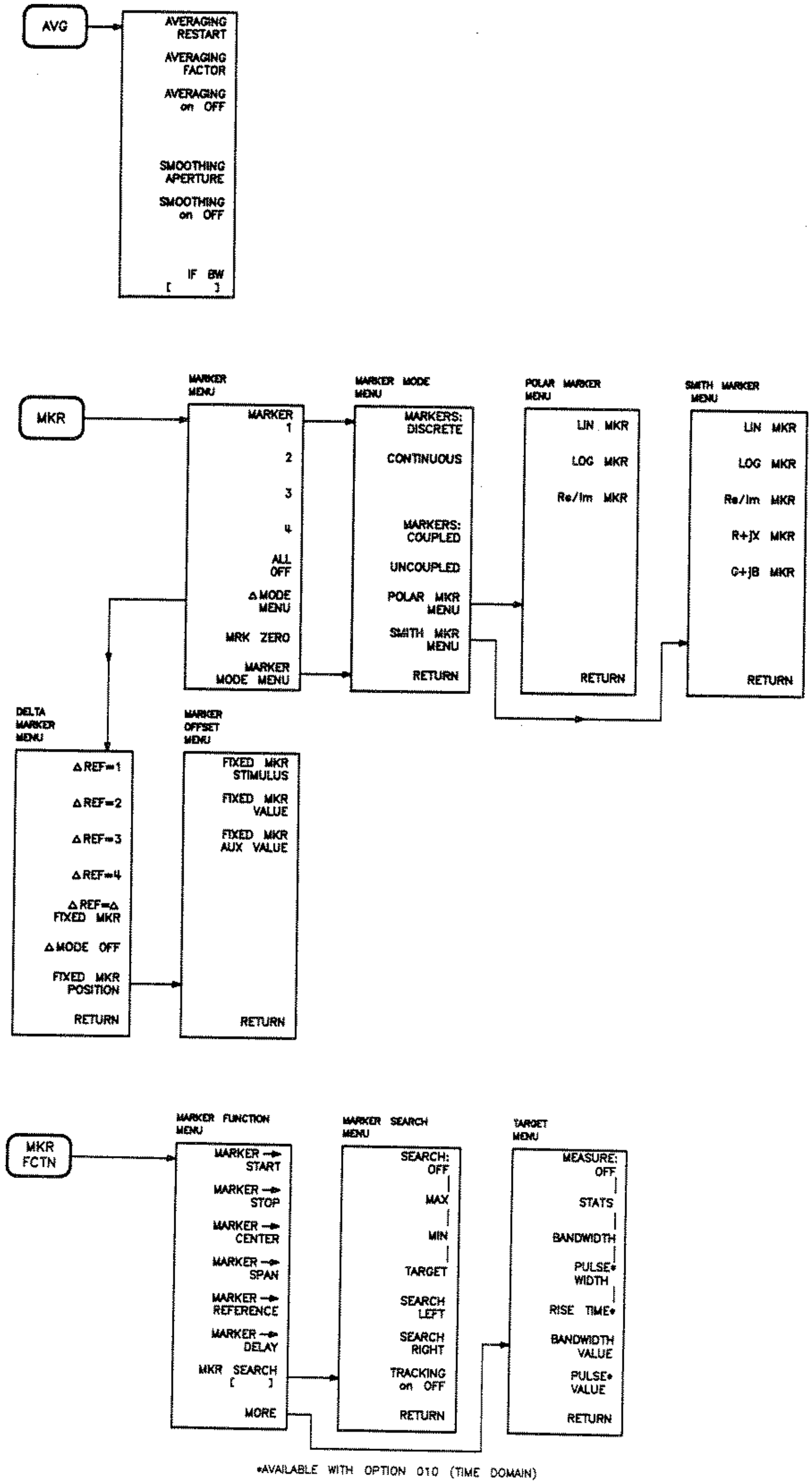


Figure 5-1. Operating Softkey Menu Map (3 of 6)

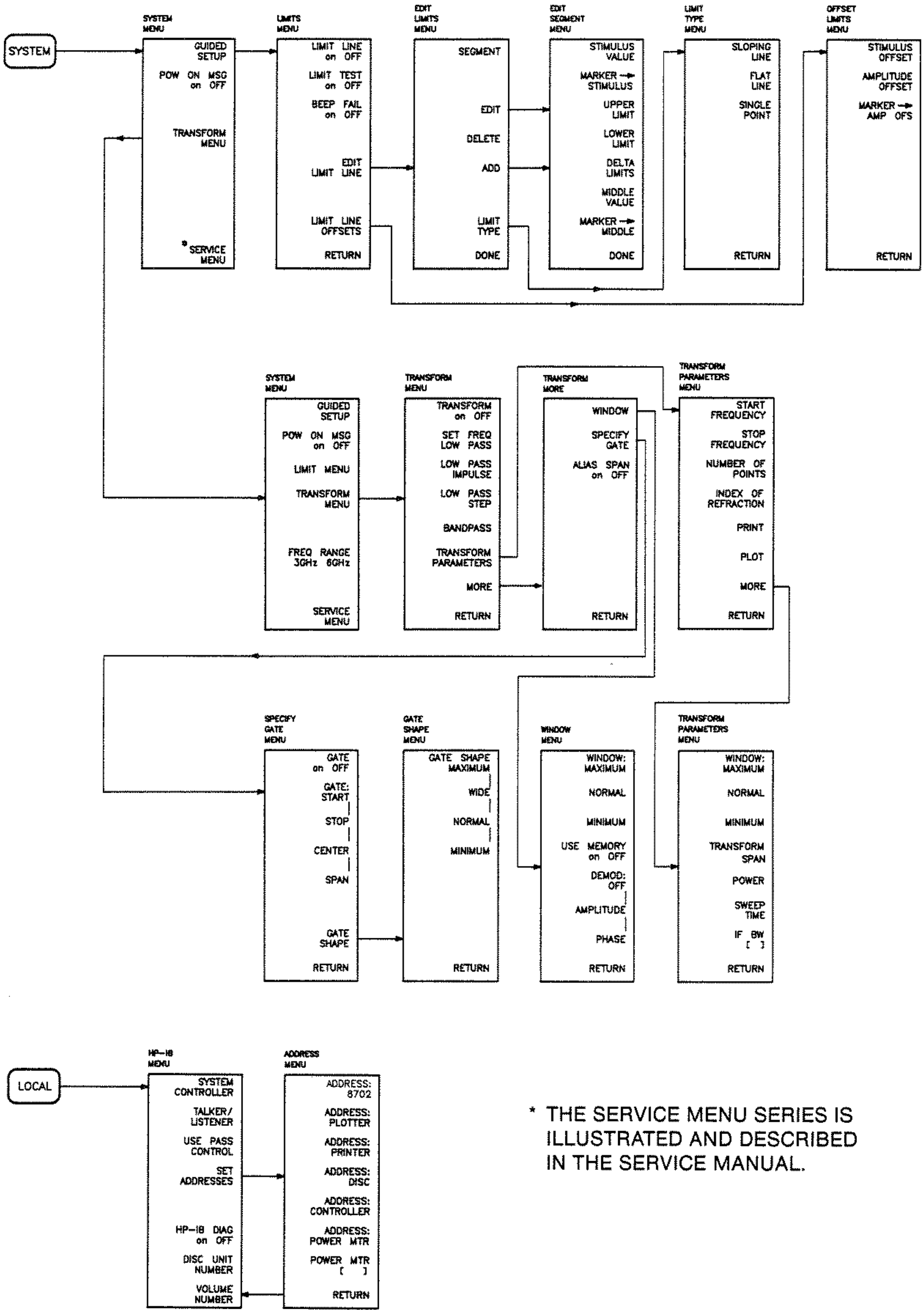


Figure 5-1. Operating Softkey Menu Map (4 of 6)

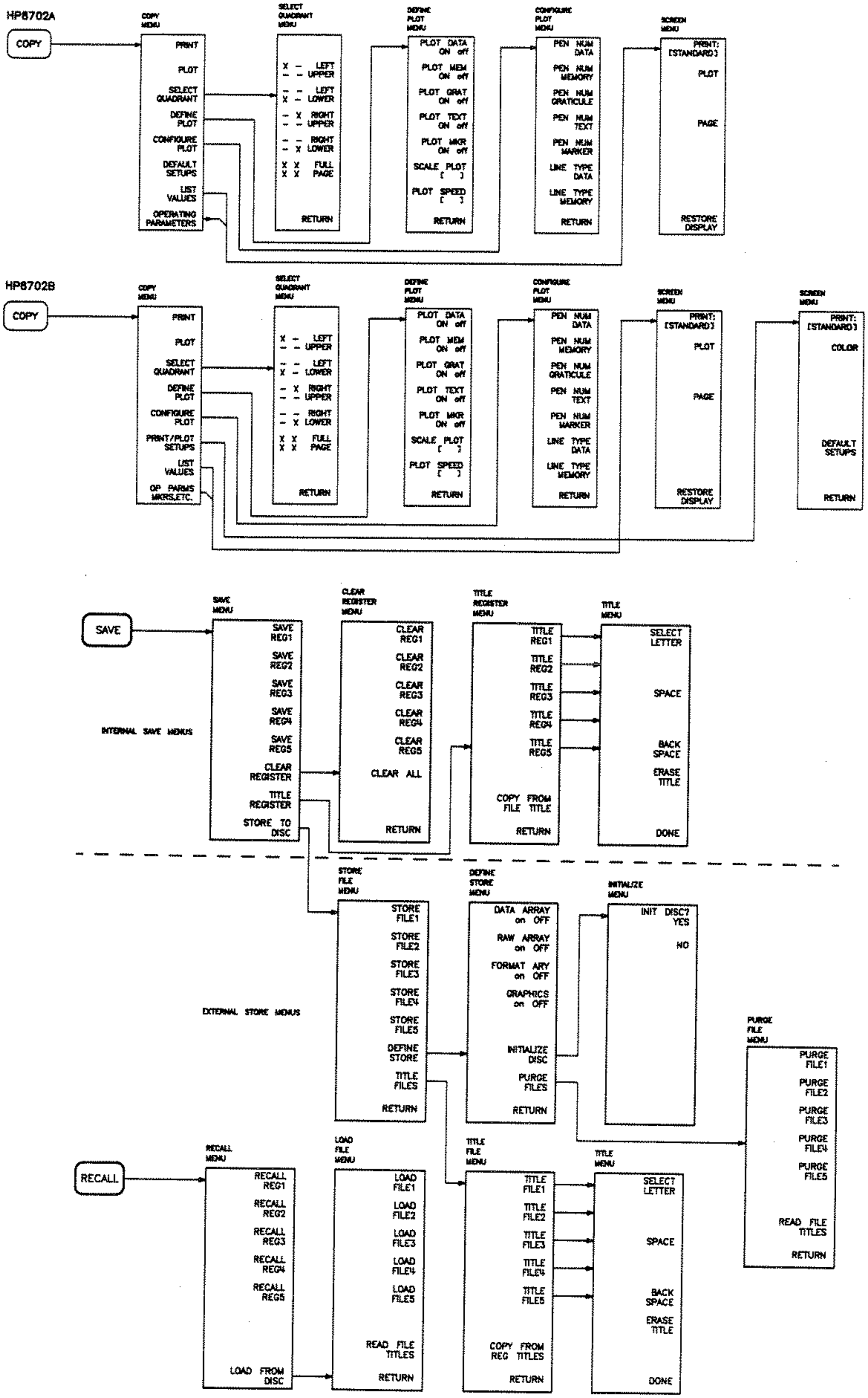


Figure 5-1. Operating Softkey Menu Map (5 of 6)

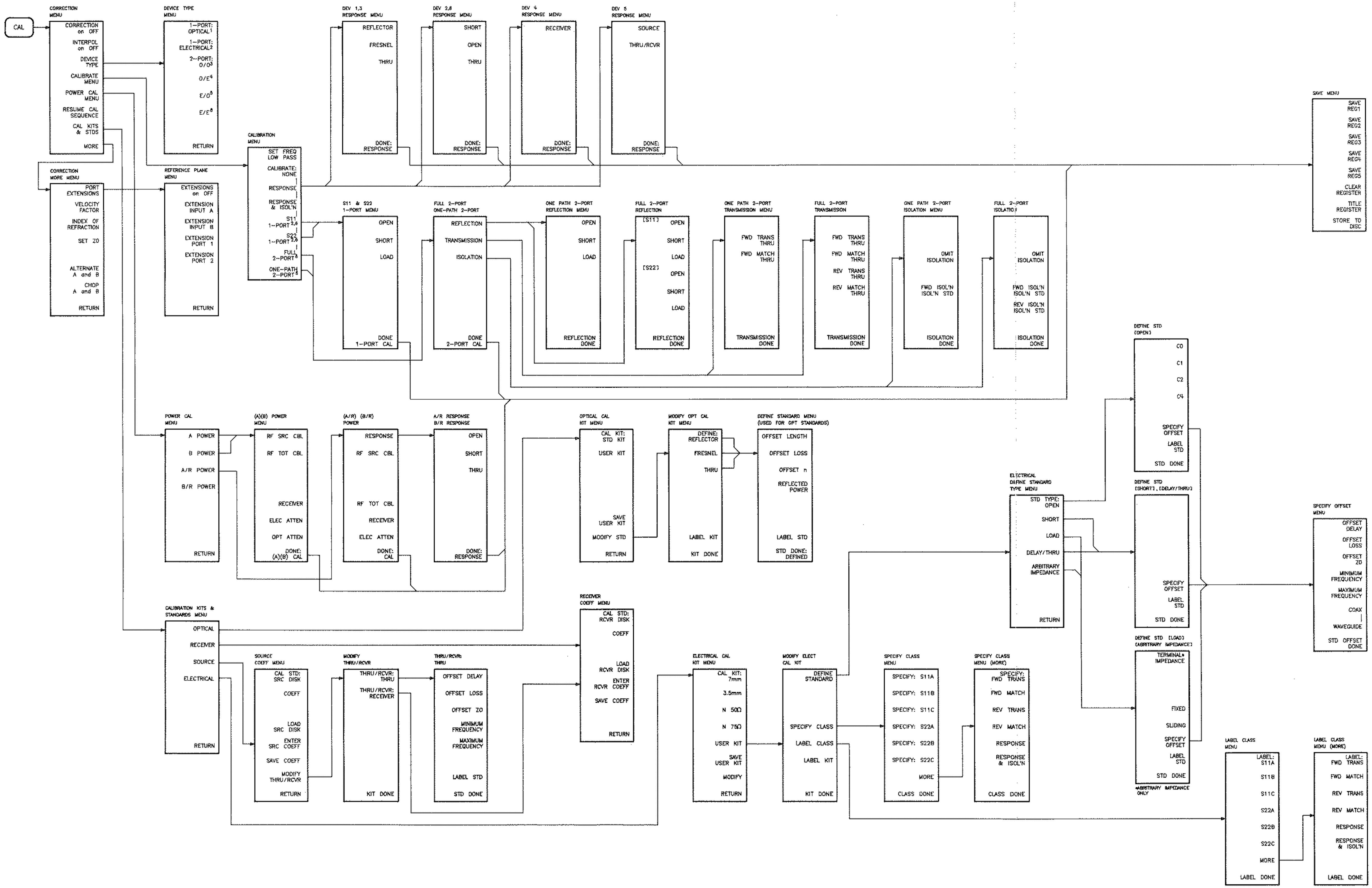


Figure 5-1. Operating Softkey Menu Map (6 of 6)

Section 6. Stimulus and Response Function Blocks

—CONTENTS OF THIS SECTION—

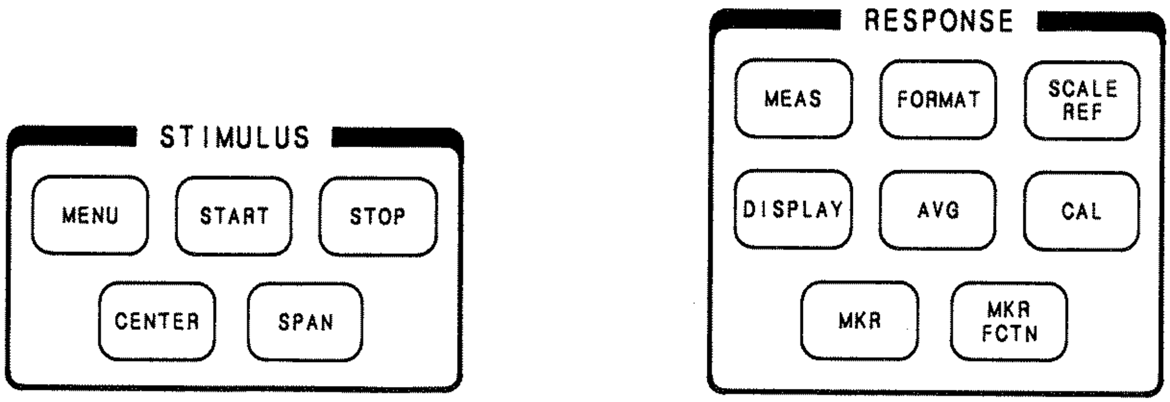


Figure 6-1.

INTRODUCTION

The stimulus and response function block keys are used to define and control the analyzer RF output signal, and to control the measurement and display functions of the analyzer's active channel. This section explains the keys and associated menus for each of these function blocks.

STIMULUS FUNCTIONS

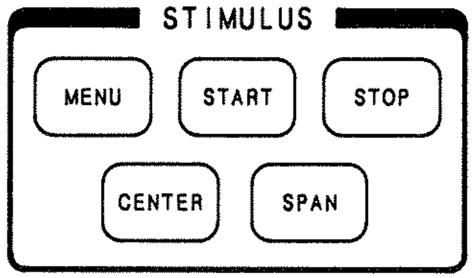


Figure 6-2.

The RF source signal can be swept over any portion of the instrument's frequency and power range. The menus are used to set source characteristics such as sweep time and resolution, RF power level, and the number of data points taken during the sweep.

[START] (STAR) **[STOP]** (STOP) **[CENTER]** (CENT) **[SPAN]** (SPAN)

These stimulus keys are used to define the frequency range or other horizontal axis parameters of the RF stimulus. The range can be expressed as either start/stop or center/span. When one of these keys is pressed, its function becomes the active function. The value is displayed in the active entry area (CRT) and can be changed with the RPG (rotary pulse generator), step keys, or number pad. Current stimulus values for the active channel are also displayed along the bottom of the graticule.

In the time domain (option 010) or in CW time mode, the stimulus keys refer to time (with certain exceptions that are explained in the Time Domain section).

[MENU] Key

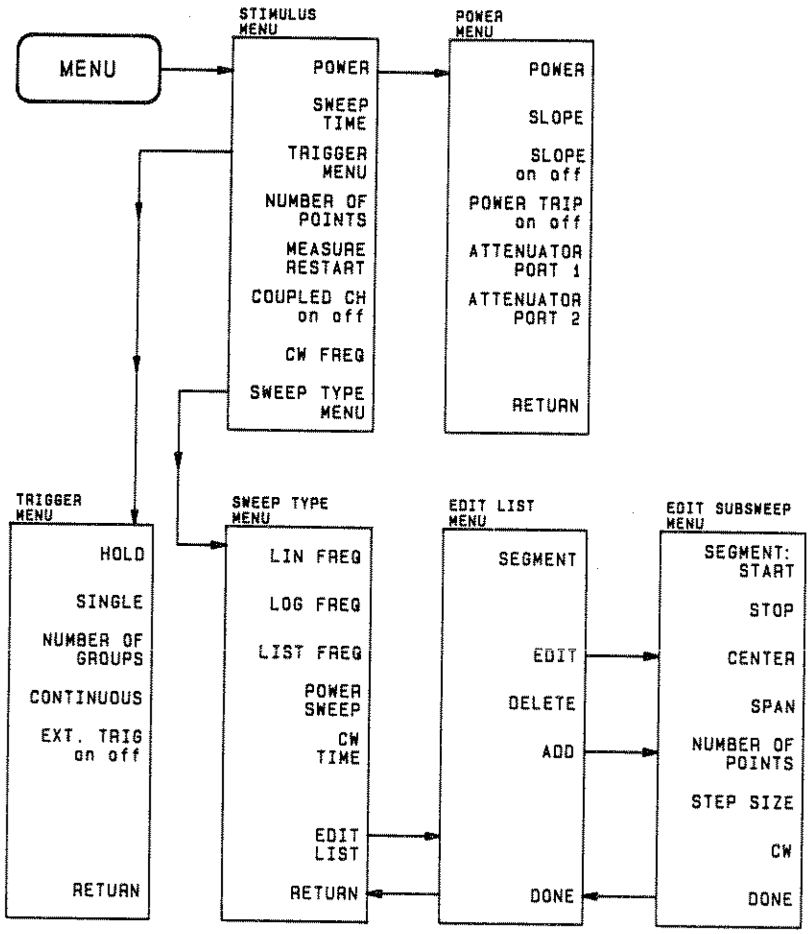


Figure 6-3. Softkey Menus Accessed from the [MENU] Key

The **[MENU]** (MENUSTIM) key provides access to the series of menus illustrated in Figure 6-2, which are used to define and control all stimulus functions other than start, stop, center, and span.

Stimulus Menu

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

[POWER] (POWE) makes power level the active function and presents the power menu, which is used to set the output power level and slope compensation of the source, and control the attenuator in a programmable S-parameter test set.

[SWEEP TIME] (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. For sweep times faster than 1.0 second the indicator is displayed in the status notations area at the left of the CRT.

The sweep time will increase automatically if the number of points is increased or the IF bandwidth is decreased. Sweep-to-sweep averaging also increases sweep time in dual channel display mode. Other processes such as smoothing, limit lines, error correction, trace math, marker statistics, and time domain affect the sweep repetition rate.

Sweep time also varies according to the sweep type selected, in the sweep type menu.

The following table is a partial guide for determining the minimum sweep time for the listed IF bandwidths and number of measurement points. The values listed represent the minimum time required for a CW time measurement with averaging off. Values are given in seconds.

Number of Points	**IF Bandwidth**			
	3000 Hz	**1000 Hz**	**300 Hz**	**10 Hz**
11	0.0055	0.012	0.036	1.14
51	0.0255	0.06	0.166	5.3
101	0.0505	0.12	0.328	10.5
201	0.1005	0.239	0.653	20.9
401	0.2005	0.476	1.303	41.7
801	0.4005	0.951	2.603	83.3
1601	0.8005	1.901	5.203	166.5

[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 and requires less memory for error correction or saving instrument states but the displayed trace shows less horizontal detail.

The possible values that can be entered for number of points are 3, 11, 26, 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 list frequency sweep, the number of points displayed is the total number of frequency points for the defined list (see sweep type menu).

[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 use, the ***[MEASURE RESTART]*** key will initiate another update of both forward and reverse S-parameter data.

If the analyzer is taking a number of groups (see trigger menu), 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.

[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.

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 section, as well as dual channel display capabilities.

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

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

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 the frequency for power sweep and CW time sweep modes. If the instrument is not in either of these two modes, it is automatically switched into CW time mode.

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

Power Menu

The power menu is used to set the output power level of the analyzer, to set power slope to compensate for measured power loss with frequency, and to control the programmable attenuator in an HP 85046A/B or 85047A S-parameter test set.

[POWER] (POWE) makes power level the active function and sets the RF output power level of the analyzer internal source. The analyzer will detect an input power overload at any of the three receiver inputs of over +4 dBm and automatically reduce the output power of the analyzer to −5 dBm. This is indicated with the message "OVERLOAD ON INPUT (R, A, B)." In addition, the ***[POWER TRIP ON]*** flag (see below) is set, and the annotation "P⬇" appears at the left side of the CRT. When this occurs, toggle the power trip off and reset the power at a lower level.

If the source power is unleveled at the start or stop of a sweep, the notation "P?" is displayed at the left of the CRT. This indicates that the automatic leveling control circuit of the source is unable to keep the source power leveled to instrument specifications, and the power is therefore potentially uncalibrated. Refer to the service manual for troubleshooting information.

[SLOPE] (SLOPE) compensates for power loss versus frequency sweep, by sloping the output power upwards proportionally to frequency. Enter the power slope in dB per GHz of sweep.

[SLOPE on off] (SLOPon, SLOPoff) toggles the power slope function on or off. With slope on, the output power increases with frequency, starting at the selected power level.

[POWER TRIP on off] (POWTon, POWToff) toggles the power trip function on or off. Power trip is a reduced power state triggered by a power overload. It forces the analyzer output power to −5 dBm when a power overload of approximately +4 dBm, or above, is detected at an input channel regardless of the user-specified power level.

To reset the power level following a power trip, toggle the power trip **OFF**, and reset the power level using the ***[POWER]*** softkey described above.

[ATTENUATOR PORT 1] (ATTP1) controls the attenuation at port 1 of an HP 85046A/B or 85047A S-parameter test set connected to the analyzer. The attenuator range is 0 to 70 dB, controllable in 10 dB steps. Attenuation is used to reduce the signal level at the test port without reducing the reference signal.

[ATTENUATOR PORT 2] (ATTP2) serves the same function for the attenuation at port 2 of the HP 85046A/B or 85047A S-parameter test set.

[RETURN] goes back to the stimulus menu.

Trigger Menu

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

[HOLD] (HOLD) freezes the data trace on the display, and the analyzer stops sweeping and taking data. 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 is useful for keeping the test set transfer switch switching in a full two-port calibration. Normally the test set transfer switch is switched only once during the calibration procedure, for protection of the mechanical switch assembly. If a particular application requires that the switch be switched repeatedly, this can be accomplished by setting an appropriate number of groups.

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 of the analyzer. 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.

[RETURN] goes back to the stimulus menu.

Sweep Type Menu

Five basic sweep types are available: linear and logarithmic frequency sweeps in Hz, power sweep in dBm, CW time sweep in seconds, and list frequency sweep in Hz. The data from a linear frequency sweep mode can be transformed for time domain measurements. (Refer to the Time Domain section). In the CW time sweep mode, the data can be transformed for frequency domain measurements.

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

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 (maximum) sweep rate. If the user-specified sweep time is greater than 15 ms times the number of points, the sweep changes from a continuous ramp sweep to a stepped CW sweep. Also for narrow IF bandwidths the sweep is automatically converted 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, therefore, the entered sweep time may be changed automatically. For frequency spans of less than two octaves, the sweep type automatically reverts to linear sweep.

[LIST FREQ] (LISTFREQ) activates a measurement sweep of a list of frequencies specified by the user. This list is defined and modified using the edit list menu and the edit subsweep menu. Up to 30 frequency subsweeps of several different types can be specified, for a maximum total of 1632 points. One list is common to both channels. Refer to the edit subsweep menu later in this section.

When the ***[LIST FREQ]*** key is pressed, the analyzer sorts all the defined frequency segments into CW points in order of increasing frequency. It 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. 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.

[POWER SWEEP] (POWS) turns on a power sweep mode that is used to characterize power-sensitive circuits. In this mode, power is swept at a single frequency, from a start power value to a stop power value, selected by the **[START]** and **[STOP]** keys. To set the frequency of the power sweep, use ***[CW FREQ]*** in the stimulus menu.

The entered sweep time may be automatically changed if it is less than the minimum required for the current configuration (number of points, IF bandwidth, averaging, etc.).

Note that the attenuator switch in the S-parameter test set is not switched in power sweep mode.

[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.

Using option 010, time domain, 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 (>1 kHz) analysis of amplitude or pulse modulation signals. For details, refer to the Time Domain section.

[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. The list frequency sweep mode is selected with the ***[LIST FREQ]*** softkey described above.

[RETURN] goes back to the stimulus menu.

Edit List Menu

This menu is used to edit the list of frequency segments (subsweeps) defined with the edit subsweep menu, described next.

[SEGMENT] determines 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 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 be defined with the edit subsweep menu. 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 frequency points and returns to the sweep type menu.

Edit Subsweep Menu

This menu presents measurement frequencies selection. 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 the third harmonic response. The total sweep is defined with a list of subsweeps. Up to 30 subsweeps can be defined, with a total of up to 1632 data points.

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

start / stop / number of points
start / stop / step
center / span / step
CW frequency
CF / delta F / number of points
CF / delta F / step

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. 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. The trace may appear uneven because of the distribution of the data points, but the frequency scale is linear across the total range.

The frequency list parameters can be saved with an instrument state.

[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 1632.

[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.

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

[DONE] returns to the edit list menu.

RESPONSE FUNCTION BLOCK

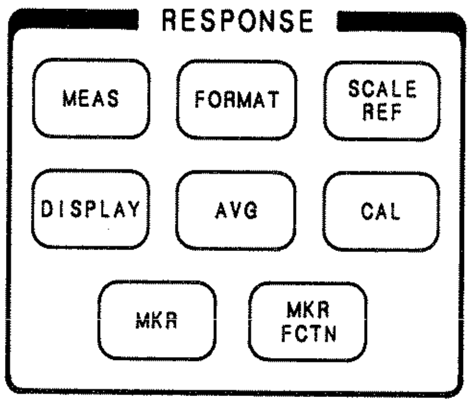


Figure 6-4.

The keys in the RESPONSE block are used to control the measurement and display functions of the active channel. They provide access to 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.

The **[MEAS]** (MENUMEAS) key provides access to a series of menus for selecting the parameters or inputs to be measured.

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]** (MENUDISP) 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 leads to a series of menus for 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 (overlaid or split), display color 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.

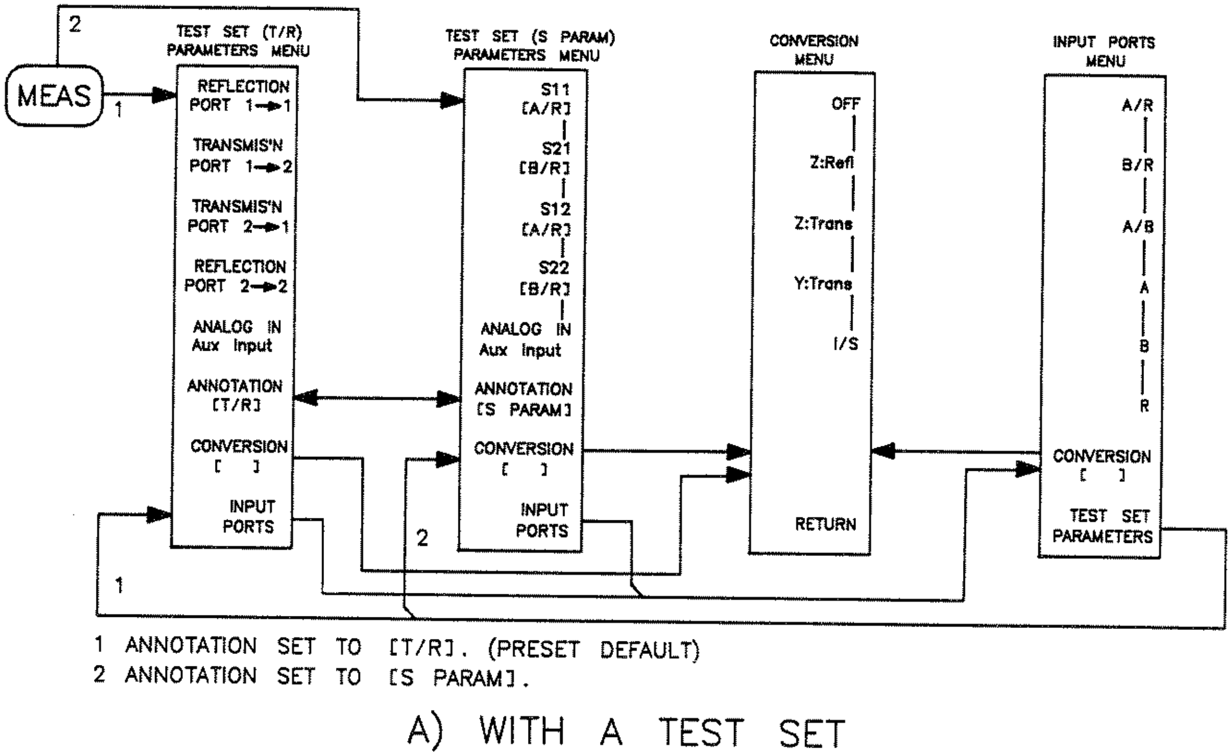
The **[CAL]** (MENUCAL) key leads to a series of menus to perform measurement calibrations for both electrical and optical measurements. Several different levels of calibration are available for use in a variety of different measurement applications. Refer to the Measurement Calibration section.

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 of the trace.

The menus accessed from the **[MKR]** key provide several marker operations. Refer to the Using Markers section.

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. Refer to the Using Markers section.

[MEAS] Key



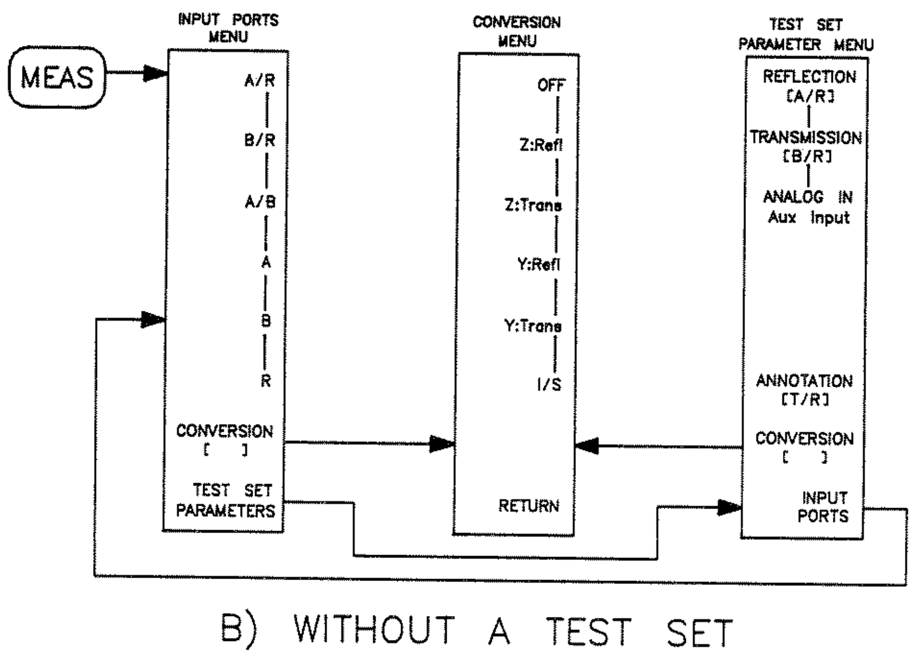


Figure 6-5. Softkey Menus Accessed from the [MEAS] Key

The **[MEAS]** (MENUMEAS) key leads to a series of softkey menus used to determine the parameters or inputs to be measured. If an HP 85046A/B or 85047A S-parameter test set is connected, all four S-parameters can be measured with a single connection. Or S-parameters can be measured using a transmission/reflection test set by reversing the device under test between measurements.

Alternatively, the power ratio of any two inputs or the absolute power at a single input can be measured and displayed, using either test set.

S-parameters can be converted to impedance (Z), admittance (Y), or inverse S-parameters through internal math capabilities of the analyzer.

Test Set Parameter Menu

If an HP 85046A/B or 85047A S-parameter test set is connected to the analyzer or if two-port error correction is on, the test set parameter menu is presented when the **[MEAS]** key is pressed. This menu is used to define the input ports and test signal direction for S-parameter measurements. The analyzer controls the S-parameter test set and automatically switches the direction of the measurement according to the selections made in this menu.

S-parameter measurements can also be made using an HP 85044A transmission/reflection test set, by reversing the device under test after making the forward reflection and transmission measurements.

[REFLECTION (A/R)] (S11) configures the S-parameter test set for a measurement of S11, the complex reflection coefficient (magnitude and phase) of the test device input.

[TRANSMISN (B/R)] (S21) configures the S-parameter test set for a measurement of S21, the complex forward transmission coefficient (magnitude and phase) of the device under test.

[ANALOG IN Aux 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.

[ANNOTATION] toggles between the softkeys to select different S-parameter measurements and the softkeys to select transmission/reflection measurement choices.

[CONVERSION] brings up the conversion menu which converts the measured data to impedance (Z) or admittance (Y).

[INPUT PORTS] goes to the input ports menu, which is used to define a ratio or single-input measurement rather than an S-parameter measurement.

Input Ports Menu

The input ports menu is presented when the **[MEAS]** key is pressed if there is no S-parameter test set connected and two-port error correction is not on. This menu is used to define the input ports for power ratio measurements, or a single input for magnitude only measurements of absolute power. Single inputs cannot be used for phase or group delay measurements, or any measurements with averaging turned on.

[A/R] (AR) calculates and displays the complex ratio of the signal at input A to the reference signal at input R.

[B/R] (BR) calculates and displays the complex ratio of input B to input R.

[A/B] (AB) calculates and displays the complex ratio of input A to input B.

[A] (MEASA) measures the absolute power amplitude at input A.

[B] (MEASB) measures the absolute power amplitude at input B.

[R] (MEASR) measures the absolute power amplitude at input R. The R input is part of the source phase locking scheme, therefore, has a limited dynamic range.

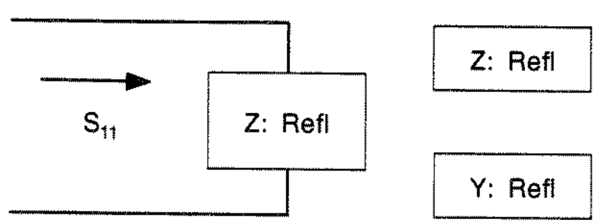
[CONVERSION] brings up the conversion menu, which converts the measured data to impedance (Z) or admittance (Y).

[TEST SET PARAMETERS] presents the test set parameter menu, which is used to define the input ports and test signal direction for S-parameter measurements.

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.

An S11 or S22 trace measured as reflection can be converted to equivalent parallel impedance or admittance using the model and equations shown below.



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

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

Figure 6-6. 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 below.

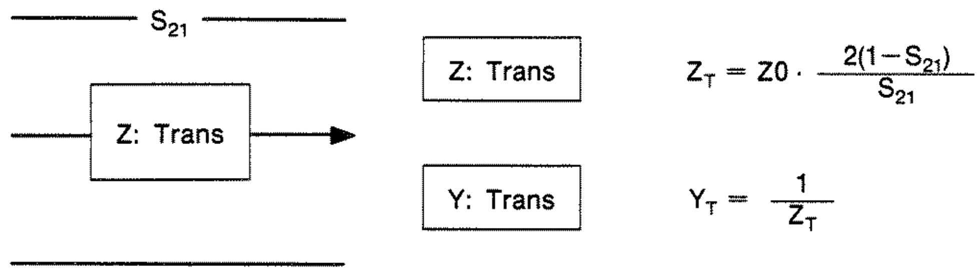


Figure 6-7. Transmission Impedance and Admittance Conversions

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

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

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

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

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

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

[1/S] (CONV1DS) expresses the data in inverse S-parameter values.

[RETURN] returns to the last menu, either the test set parameter or the input ports 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 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 the Using Markers section).

The format defined for the display of a particular S-parameter or input is remembered with that parameter. Therefore, if different parameters are measured, each parameter is shown in its selected format each time it is displayed.

The illustrations below show a reflection measurement of a bandpass filter displayed in each of the available formats.

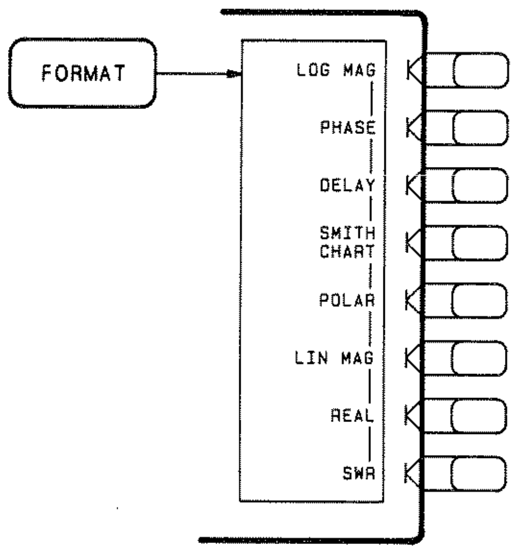


Figure 6-8. Format Menu

[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. The figure below illustrates the bandpass filter reflection data in a log magnitude format.

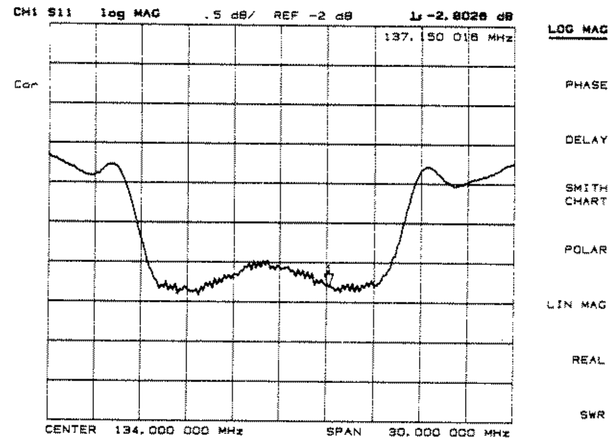


Figure 6-9. Log Magnitude Format

[PHASE] (PHAS) displays a Cartesian format of the phase portion of the data, measured in degrees. This format displays the phase shift versus frequency. The figure below illustrates the phase response of the same filter in a phase-only format.

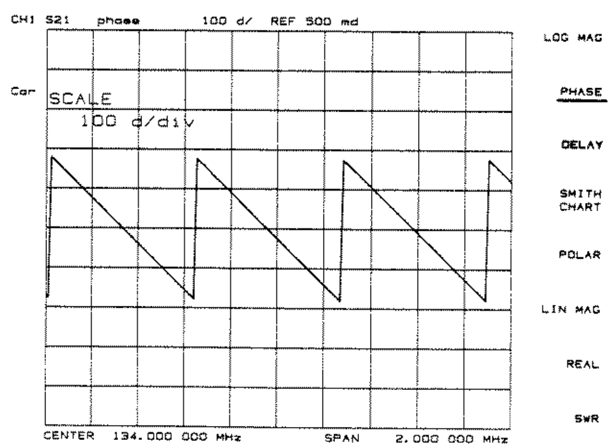


Figure 6-10. Phase Format

[DELAY] (DELA) selects the group delay format with marker values given in seconds. The figure below shows the bandpass filter response formatted as group delay. Group delay principles are described in the next few pages.

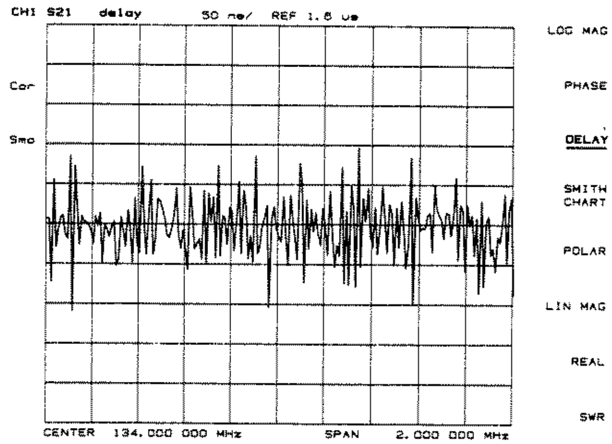


Figure 6-11. Group Delay Format

[SMITH CHART] (SMIC) displays a Smith chart format. This is used in electrical 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 where R is the resistive component and +/−jx is the reactive component (capative or inductive). Additional marker types are available in the Smith marker menu (refer to the Using Markers section).

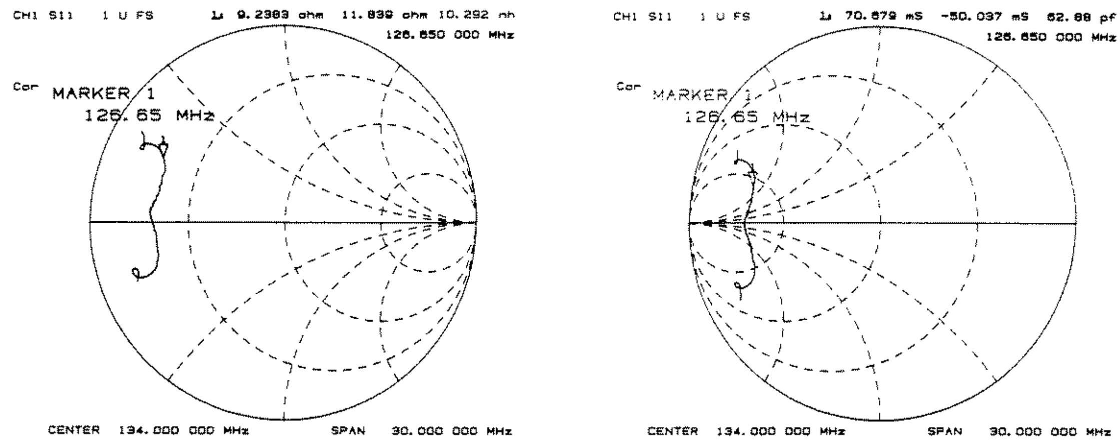
The Smith chart is most easily understood with a full scale value of 1.0. If the scale per division is less than 0.2, the format switches automatically to polar.

If the characteristic impedance of the system is not 50 ohms, modify the impedance value recognized by the analyzer using the ***[SET Z0]*** softkey in the calibrate more menu. Refer to the Measurement Calibration section.

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

NOTE: Either HP 85044A, 85046A or 85047A test set is required to make electrical reflection measurements. An HP calibration kit of the same connector type as the device to be measured is also required.

A procedure for measuring the impedance is provided in the User's Guide.



(a) *(b)*

Figure 6-12. Standard and Inverse Smith Chart Formats

[POLAR] (POLA) displays a polar format (Figure 6-13). 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 the Using Markers section).

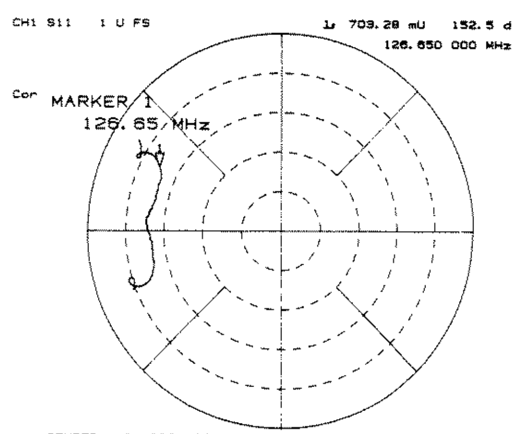


Figure 6-13. Polar Format

[LIN MAG] (LINM) displays the linear magnitude format. 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.

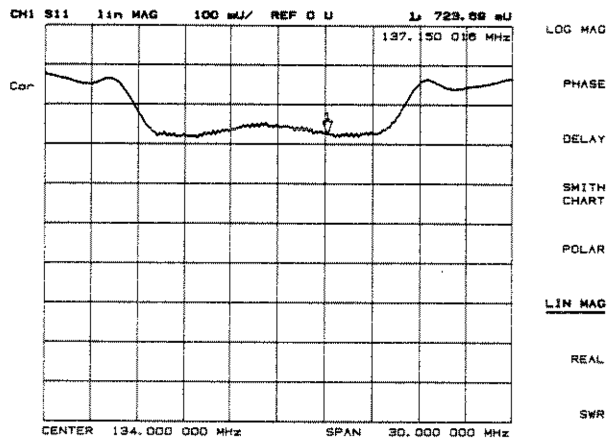


Figure 6-14. Linear Magnitude Format

[REAL] (REAL) displays only the real part of the measured data on a Cartesian format. 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, and also for display of an auxiliary input voltage signal for service purposes.

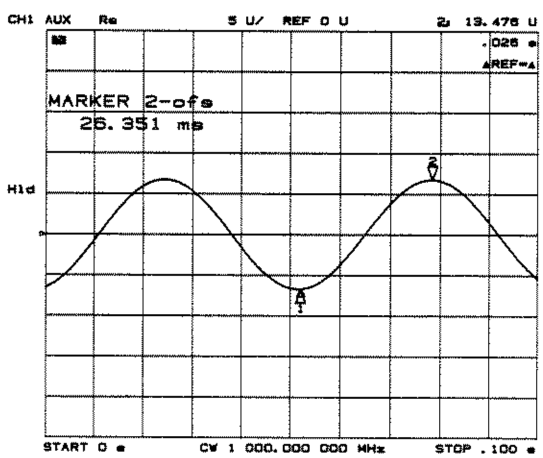


Figure 6-15. Real Format

[SWR] (SWR) reformats a reflection measurement into its equivalent SWR (standing wave ratio) value. 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.

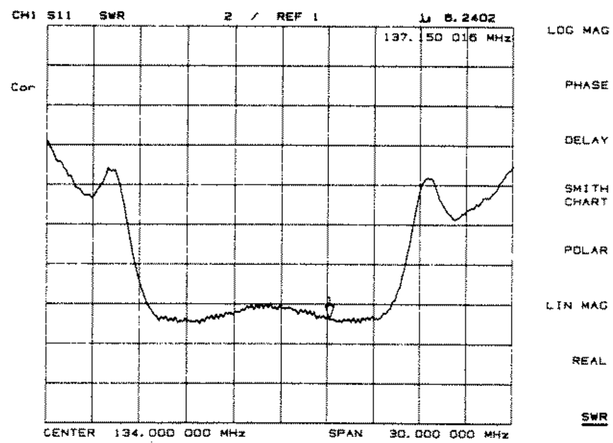


Figure 6-16. Typical SWR Display

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 section 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 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 as shown below.

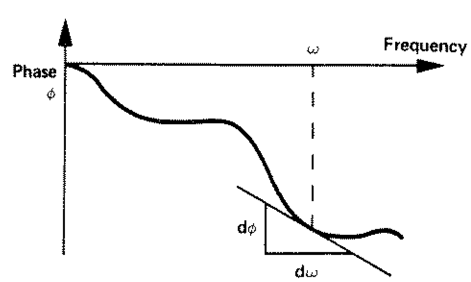
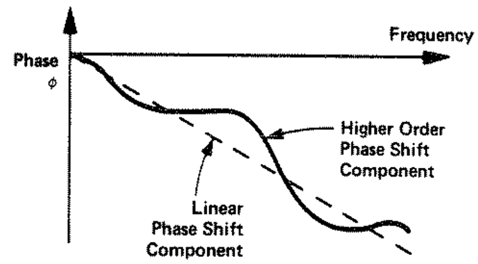


Figure 6-17.

The phase characteristic typically consists of both linear and higher order (deviations from linear) components. The linear component that represents the average signal transit time can be attributed to the electrical length of the test device. The higher order components are interpreted as variations in transit time for different frequencies, and represent a source of signal distortion.



$$\text{Group Delay} = \tau_g = \frac{-d\phi}{d\omega} \quad \begin{array}{l}\phi \text{ in Radians} \\ \omega \text{ in Radians}\end{array}$$

$$= \frac{-1}{360^\circ} \cdot \frac{d\phi}{df} \quad \begin{array}{l}\phi \text{ in Degrees} \\ f \text{ in Hz } (\omega = 2\pi f)\end{array}$$

Figure 6-18.

The analyzer computes group delay from the phase slope. Phase data is used to find the phase change, $\Delta\varphi$, over a specified frequency aperture, Δf, to obtain an approximation for the rate of change of phase with frequency. This value, τg, represents the group delay in seconds assuming linear phase change over Δf. 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. You can verify that $\Delta\varphi$ is $\leq 180°$ by increasing the number of points or narrowing the frequency span (or both) until the group delay data no longer changes.

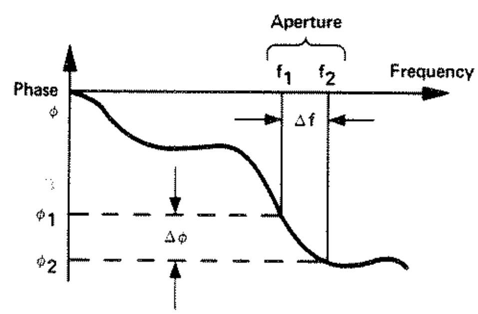


Figure 6-19.

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 Δf is increased. A wider aperture results in loss of the fine grain variations in group delay. This loss of detail is the reason that in any comparison of group delay data it is important to know the aperture used to make the measurement.

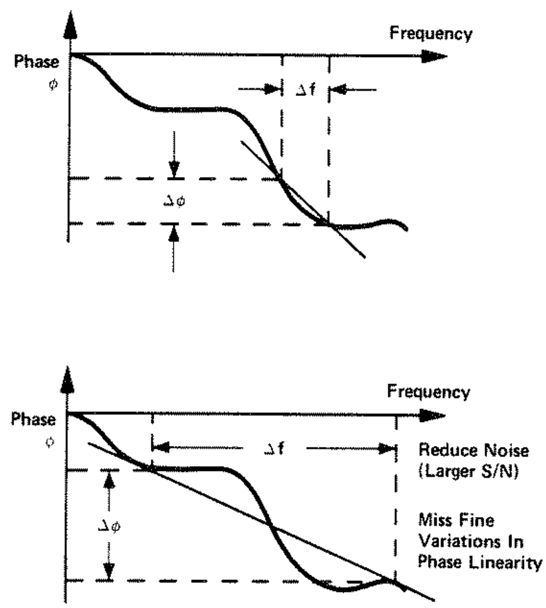


Figure 6-20.

In determining the group delay aperture, there is a tradeoff between resolution of fine detail and the effects of noise. 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 group delay aperture is the frequency span divided by the number of points across the display. To set the aperture to a different value, 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.

Group delay measurements can be made on linear frequency, log frequency, or list frequency sweep types (not in CW or power sweep). 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 Hz is displayed below the active entry area.

[SCALE REF] Key

Scale Reference Menu

The **[SCALE REF]** (MENUSCAL) key makes scale per division the active function. A menu is displayed that 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.

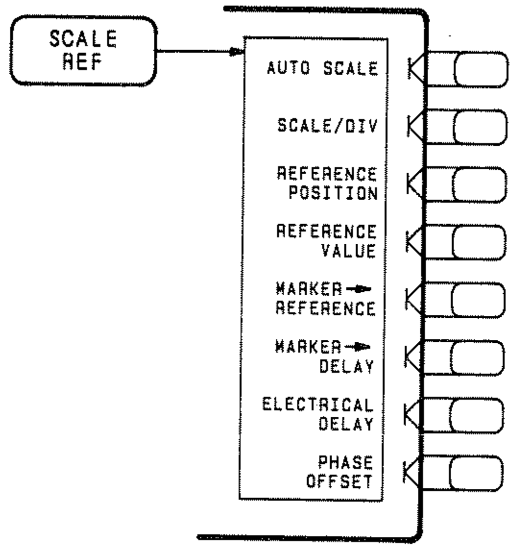


Figure 6-21.

[AUTO SCALE] (AUTO) brings the trace data in view on the CRT. Only scale and reference values are affected. The analyzer determines the smallest possible scale factor that will put all displayed data onto 80% of the vertical graticule. The reference value that puts the trace in center screen is chosen, then rounded to an integer multiple of the scale factor.

[SCALE/DIV] (SCAL) changes the response value of scale per division of the CRT. 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. The bottom line of the graticule is 0 and 10 is 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 value of the active marker equal to the reference value. 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) automatically adjusts the electrical delay to balance the phase of the DUT. Enough line length is added to or subtracted from the receiver input to compensate for the phase slope at the active marker position. This 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. Since this feature adds phase to a variation in phase versus frequency, it is applicable only for ratioed inputs.

[ELECTRICAL DELAY] (ELED) adjusts the electrical delay to balance the phase of the DUT. A variable length lossless transmission line is simulated, which can be added to or removed from a receiver input to compensate for interconnecting cables, etc.

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

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

Once the linear portion of the DUT's phase has been removed, the equivalent length of air can be read on the CRT. If the average relative permittivity (εr) 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.

[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 presents the menus in Figure 6-22. These menus provide access to the memory math functions, and other trace functions.

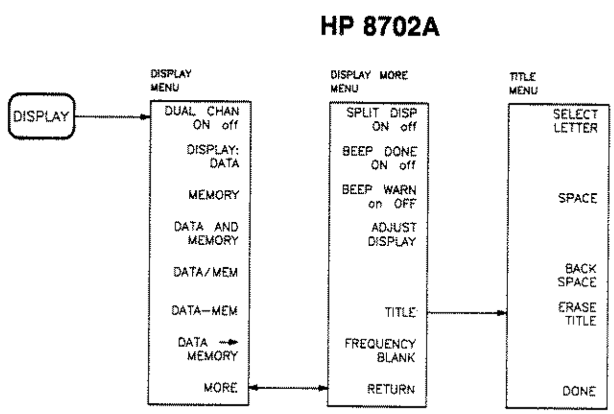


Figure 6-22. Softkey Menus Accessed from the [DISPLAY] Key (1 of 2)

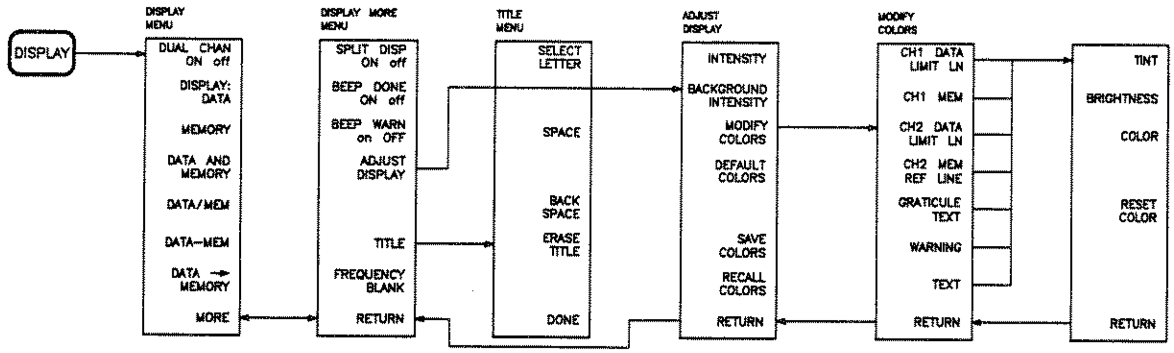


Figure 6-22. Softkey Menus Accessed from the [DISPLAY] Key (2 of 2)

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 also be saved with instrument states. (Refer to the Instrument State Function section).

Two trace math operations can be implemented, data/memory and data--memory. (Note that normalization is data/memory.) Memory traces are saved and recalled and then trace math is done after error correction. This means that any additional processing done after error correction, may be performed on the memory trace. Trace math can also be used as a simple means of error correction.

All data processing operations that occur after trace math, except smoothing and gating, are identical for the data trace and the memory trace. If smoothing or gating is on when a trace is saved, this state is maintained in memory regardless of the data trace smoothing or gating status. However, these features can be turned on or off with the CRT displaying the memory only.

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

If the number of points in the memory trace and data trace are different, the memory trace is not displayed nor rescaled. However, the memory trace can be displayed if the number of points for the data trace is changed to match the memory trace.

[DUAL CHAN on off] (DUACon, DUACoff) displays 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; with ***[SPLIT DISP ON]*** the measurement data is displayed on two half-screen graticules one above the other. Parameters for the two displays are annotated separately.

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

[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 and gating of the memory trace can be changed.

[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.

[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.

[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. The gating and smoothing status of the trace are stored with the measurement data.

[MORE] leads to the display more menu.

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. 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.

HP 8702A only **[INTENSITY]** (INTE) sets the CRT intensity as a percent of the brightest setting. The factory-set default value is stored in non-volatile memory.

[FOCUS] (FOCU) sets the CRT focus as a percent of the maximum focus voltage. The factory-set default value is stored in non-volatile memory.

HP 8702B only **[ADJUST DISPLAY]** presents a menu for adjusting display intensity, colors, and accessing save and recall functions for modified CRT display color sets.

[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 turning the power off and then on.

Adjust Display Menu (HP 8702B only)

[INTENSITY] (INTE) sets the CRT intensity as a percent of the brightest setting. The factory-set default value is stored in non-volatile memory.

[BACKGROUND INTENSITY] (BACI) sets the background intensity of the CRT as a percent of white. The factory-set default value is stored in non-volatile memory.

[MODIFY COLORS] presents a menu for color modification of CRT display elements. Refer to "Adjusting Color" for a complete explaination on how to modify CRT display elements.

[DEFAULT COLORS] (DEFC) returns all the color settings back to the factory-set default value that is stored in non-volatile memory.

[SAVE COLORS] (SVCO) saves the modified version of the color set.

[RECALL COLORS] (RECO) recalls the previously saved modified version of the color set. This key appears only when a color set has been saved.

Modify colors Menu (HP 8702B only)

[CH1 DATA / LIMIT LN] (COLOCH1D) selects channel 1 data trace and limit line for color modification.

[CH1 MEM] (COLOCH1M) selects channel 1 memory trace for color modification.

[CH2 DATA / LIMIT LN] (COLOCH2D) selects channel 2 data trace and limit line for color modification.

[CH2 MEM / REF LINE] (COLOCH2M) selects channel 2 memory and the reference line for color modification.

[GRATICULE / TEXT] (COLOGRAT) selects the graticule and a portion of softkey text (where there is a choice of a feature being on or off) for color modification. For example: FREQUENCY BLANK [on off].

[WARNING] (COLOWARN) selects the warning annotation for color modification.

[TEXT] (COLOTEXT) selects all the non-data text for color modification. For example: operating parameters.

Color Adjust Menu (HP 8702B only)

[COLOR] (COLOR) adjusts the degree of whiteness of the color being modified. A scale from white to pure color.

[BRIGHTNESS] (CBRI) adjusts the brightness of the color being modified.

[TINT] (TINT) adjusts the continuum of hues on the color wheel, ranging from red, through green and blue, and back to red.

[RESET COLOR] (RSCO) resets the color being modified to the default color.

ADJUSTING COLOR (HP 8702B only)

This procedure explains how to adjust the colors on your analyzer CRT display. The default colors in this instrument have been scientifically chosen to maximize your ability to discern the difference between the colors, and to comfortably and effectively view the colors. These colors are recommended for normal use because they will provide a suitable contrast that is easy to view for long periods of time.

You may choose to change the default colors to suit environmental needs, individual preferences, or to accommodate color deficient vision. You can use any of the available colors for any of the seven CRT display elements listed by the softkey names below:

[CH 1 DATA / LIMIT LN]
[CH 1 MEM]
[CH 2 DATA / LIMIT LN]
[CH 2 MEM / REF LINE]
[GRATICULE / TEXT]
[WARNING]
[TEXT]

To change the color of a CRT display element, press the softkey for that element (such as [CH 1 DATA]). Then press [TINT] and turn the analyzer front panel knob until the desired color appears.

Color is comprised of three parameters:

Tint —The continuum of hues on the color wheel, ranging from red, through green and blue, and back to red.

Brightness —A measure of the brightness of the color.

Color —The degree of whiteness of the color. A scale from white to pure color.

The most frequently occuring color deficiency is the inability to distinguish red, yellow, and green from one another. Confusion between these colors can usually be eliminated by increasing the brightness between the colors. To accomplish this, press the [BRIGHTNESS] softkey and turn the analyzer front panel knob. If additional adjustment is needed, vary the degree of whiteness of the color. To accomplish this, press the [COLOR] softkey and turn the analyzer front panel knob.

Color changes and adjustments remain in effect until changed again in these menus or the analyzer is powered off and then on again. Cycling the power changes all color adjustments to default values. Preset does not affect color selection.

Setting Default Colors (HP 8702B only)

To set all the CRT display elements to the factory-defined default colors, press:

[DISPLAY] [MORE] [ADJUST DISPLAY] [DEFAULT COLORS].

NOTE: [PRESET] does not reset or change colors to the default color values.

Saving Modified Colors (HP 8702B only)

To save the modified color set, press:

[DISPLAY] [MORE] [ADJUST DISPLAY] [SAVE COLORS].

Recall Modified Colors (HP 8702B only)

To recall the previously saved color set, press:

[DISPLAY] [MORE] [ADJUST DISPLAY] [RECALL COLORS].

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.

[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 included in 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. For a fully averaged trace, each new sweep is averaged into the trace until the total number of sweeps is equal to the averaging factor. 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 slows down the trace update time. Doubling the averaging factor reduces the noise by 3 dB. Averaging is used for ratioed measurements only. The figure below illustrates the effect of averaging on a log magnitude format trace.

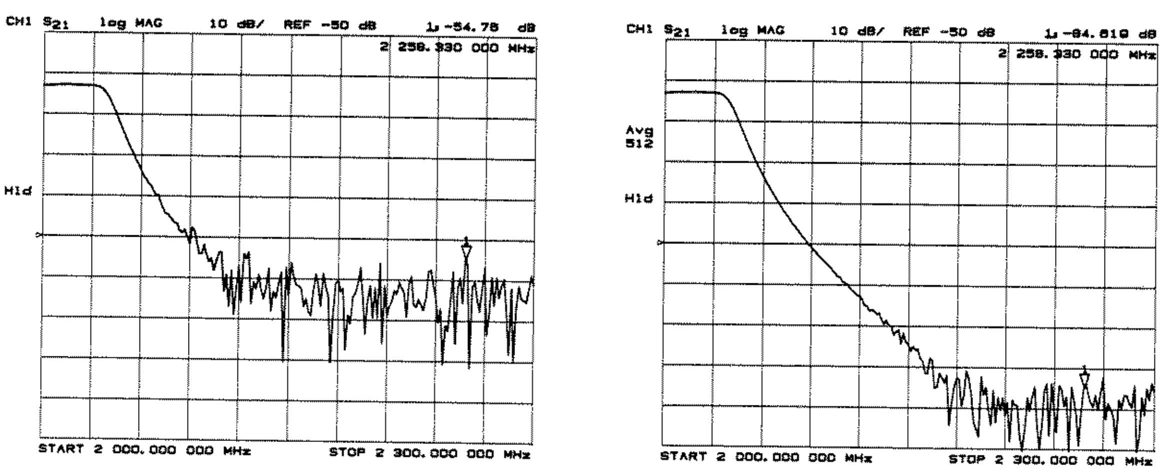


Figure 6-23. Effect of Averaging on a Trace

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. This reduces 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, it will introduce errors into the measurement.

Smoothing is used with Cartesian and polar display formats. It is also the primary way to control the group delay aperture, given a fixed frequency span. In polar display format, large phase shifts over the smoothing aperture will cause shifts in amplitude, since a vector average is being computed. The figure below illustrates the effect of smoothing on a log magnitude format trace.

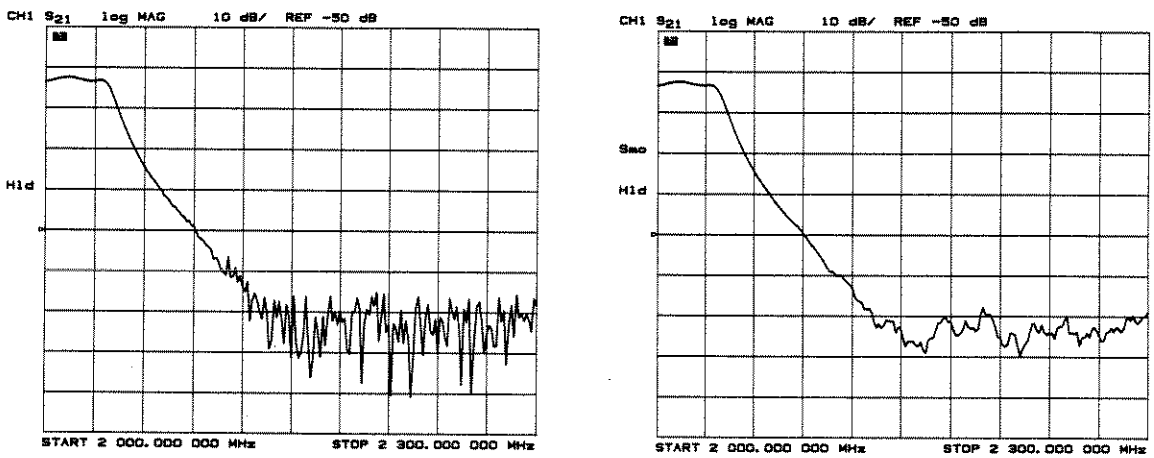


Figure 6-24. Effect of Smoothing on a Trace

IF Bandwidth Reduction lowers the noise floor by digitally reducing the receiver input bandwidth, and works in all ratio and non-ratio modes. 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 kHz 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.

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 the Using Markers section.

Increasing the input power to the device under test is another way of increasing dynamic range.

Average Menu

The average menu is used to select a noise-reduction technique, and to set the parameters for the technique selected. It is also used to set the aperture for group delay measurements.

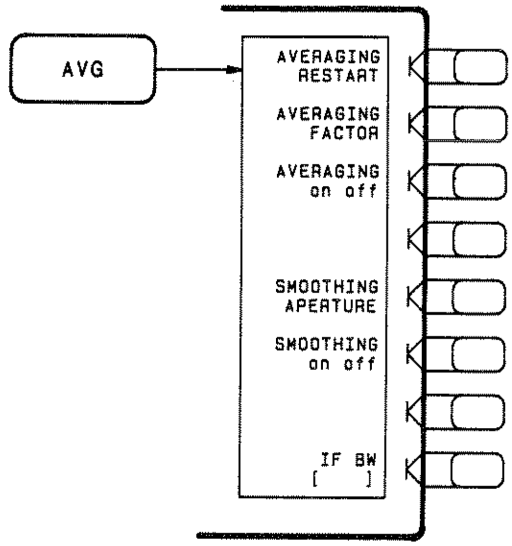


Figure 6-25. Average Menu

[AVERAGING RESTART] (AVERREST) resets the sweep-to-sweep averaging and restarts the sweep count to 1, at the beginning of the next sweep.

[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 = average factor

[AVERAGING on off] (AVERon, AVERoff) turns the averaging function on or off for the active channel. 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. 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.

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.

[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 allowable value. A narrow bandwidth slows the sweep speed but provides better signal-to-noise ratio.

Section 7. Measurement Calibration

—CONTENTS OF THIS SECTION—

INTRODUCTION

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 analyzer itself) all introduce variations in magnitude and phase that can mask the actual performance of the device under test.

Measurement calibration is a procedure where you measure standard (characterized) devices where the corresponding mathematical models (calibration data) have already been loaded into the analyzer memory. The analyzer then calculates error correction coefficients. This creates a reference plane to enhance the accuracy of your measurements.

This section explains the correlation between stimulus state and measurement calibration and describes the different ways calibration data can be loaded into the analyzer memory. It also describes the different types of calibration procedures available in the analyzer and the measurements for which each should be used.

STIMULUS STATE

A measurement calibration is valid only for a specific stimulus state (instrument state), which must be set before calibration is begun. The stimulus state consists of the selected frequency range, number of points, sweep time, output power, and sweep type. Changing the frequency range, number of points, or sweep type with correction on invalidates the calibration and turns it off. Changing the sweep time or output power changes the status notation "Cor" at the left of the analyzer display 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 (except when interpolated error correction is on).

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 channels are stimulus uncoupled, the measurement calibration applies to only one channel. For information on stimulus coupling, refer to section 6, Stimulus and Response Functions.

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 analyzer memory or on an external disc. Refer to section 9, under saving instrument states. If a calibration is not saved, it will be lost if another calibration procedure is selected for the same channel, or if stimulus values are changed. Instrument preset, power on, and instrument state recall will also clear the calibration.

CALIBRATION DATA

Some standard device mathematical characterizations (calibration data) have been loaded into the analyzer memory at the factory under what is called a Cal Kit (or standard definition): Fresnel reflection, thru response, isolation standard, and several default calibration kits of electrical connector types. All other devices must be defined by the user and the calibration data must be loaded into the analyzer memory. This is done by either selecting the **[CAL]** ***[CAL KITS & STDS] [USER KIT]*** and ***[MODIFY]*** features or following the Guided Setup and selecting ***[CAL STD]*** in the calibration type menu.

Each HP lightwave source and receiver is accompainied with a disc that contains calibration data of that particular device. This data includes 101 digitized data points that describe the magnitude and phase modulation response of that device. The calibration data is also located on a label adhered to the lightwave source and receiver for loading manually into the analyzer. This data consists of nine coefficients that are used in a polynomial curve to describe the response of that device. Although the calibration data is available on the label, the disc contains the most accurate data and is the recommended method for loading the data into the analyzer memory.

Verify Performance

Once a measurement calibration has been generated with a user-defined calibration kit, this performance should be checked before making device measurements. 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 a measure of repeatability.

For a 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 for verifiable measurement accuracy.

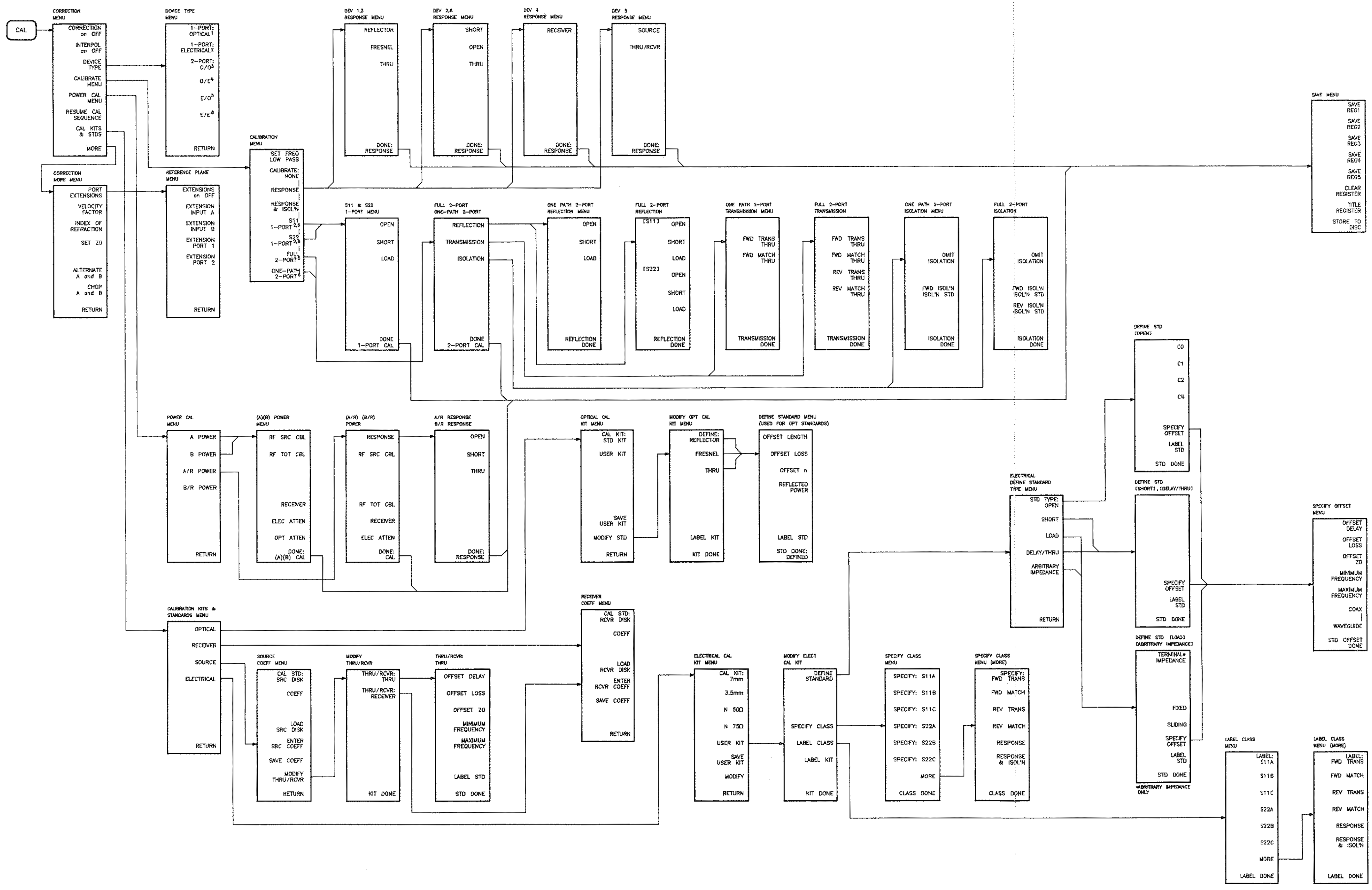


Figure 7-1. Measurement Calibration Menu Map

[CAL] KEY

(Refer to the main menu map in Figure 7-1 for the relationship of the menus accessed from the **[CAL]** key.)

[CAL] (MENUCAL) leads to a series of menus for performance of measurement calibration.

Correction Menu

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

[CORRECTION on off] (CORR<ON|OFF>) 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.

[INTERPOL on off] (CORI<ON|OFF>) enables or disables interpolated error correction. The interpolated error correction feature allows the operator to calibrate the system, then select a subset of the frequency range or a different number of points. Interpolated error correction functions in linear frequency, power sweep and CW time modes. It is recommended that the original calibration be performed with at least 101 points for linear frequency sweep type.

[DEVICE TYPE] presents the menu where the device type to be measured is selected: 1-port optical or electrical, 2-port; O/O, O/E, E/O, E/E.

[CALIBRATE MENU] presents the calibration menu, which provides several measurement calibration procedures. At the completion of a calibration procedure, correction is automatically turned on, and the notation "Cor" is displayed at the left of the screen.

[POWER CAL MENU] leads to the menu for making a power calibration for single or ratioed port measurements.

[RESUME CAL SEQUENCE] (RESC) eliminates the need to restart a calibration sequence that was interrupted to access some other menu and returns to the point where the calibration sequence was interrupted.

[CAL KIT & STDS] presents a sequence of menus used to modify and enter standard definitions into the analyzer.

[MORE] provides access to the correction more menu.

Correction More Menu

[PORT EXTENSIONS] presents the reference plane menu which is used to extend the apparent location of the measurement reference plane or input.

[VELOCITY FACTOR] (VELOFACT[D]) enters the velocity factor used by the analyzer to calculate equivalent electrical length in distance-to-fault measurements using the time domain option. Values entered should be less than 1. A change to the velocity factor has an inverse effect to the index of refraction.

[INDEX OF REFRACTION] (INDEREFR[D]) enters the refractive index used by the analyzer to calculate equivalent electrical length in distance-to-fault measurements using the time domain option. The default value is 1 which is the value for air. A change to the index of refraction has an inverse effect to the velocity factor.

[SET Z0] (SETZ[D]) sets the characteristic impedance used by the analyzer in calculating measured impedance with Smith chart markers and conversion parameters. With the HP 85047A or 85044A test set used, set Z0 to 50 ohms. Characteristic impedance must be set correctly before electrical calibration procedures are performed.

[ALTERNATE A and B] (ALTAB) measures only one input per frequency sweep, in order to reduce spurious signals. This mode optimizes the dynamic range for all four S-parameter measurements. This is the default measurement mode.

The disadvantages of this mode are associated with simultaneous transmission/reflection measurements or full two-port calibrations: this mode takes twice as long as the chop mode to make these measurements. In addition, the port match changes due to either input A or B being inactive during each sweep, which are in the order of $<$-55 dB, may affect transmission measurements.

[CHOP A and B] (CHOPAB) measures both inputs A and B during each sweep. If each channel is measuring a different parameter and both channels are displayed, the chop mode offers the fastest measurement time. This is the recommended measurement mode for full two-port calibrations because both inputs remain active.

The disadvantage of this mode is that in measurements of high rejection devices, such as filters with a low-loss passband ($>$400 MHz wide), maximum dynamic range may not be achieved.

NOTE: If more dynamic range is desired for a measurement of S21 in either the chop or the alternate mode, a 10 dB attenuator can be connected to input A and another to input R. This improves the crosstalk into input B. The dynamic range of input B is increased, but the usable dynamic range of input A is reduced.

[RETURN] goes back to the correction menu.

Device Type Menu

[1-PORT: OPTICAL] (DEVT1PO)

[1-PORT: ELECTRICAL] (DEVT1PE)

[2-PORT: O/O] (DEVTOO)

[2-PORT: O/E] (DEVTOE)

[2-PORT: E/O] (DEVTEO)

[2-PORT: E/E] (DEVTEE)

[RETURN] takes you back to the correction menu.

Calibrate Menu

[SET FREQ LOW PASS] changes the frequency sweep to harmonic intervals to accommodate time domain low-pass operation (option 010). If this mode is to be used, the frequencies must be set before calibration. Refer to section 10, Time Domain, 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, instrument state recall, or if stimulus values are changed.

[RESPONSE] (CALIRESP) leads to the menu used to perform a response measurement calibration. This is the simplest and fastest measurement calibration, but the least accurate. It effectively removes the frequency response errors of the test setup for reflection or transmission measurements. The following keys are presented:

> ***[REFLECTOR]*** is selected to perform a response measurement calibration for an optical reflection measurement when using a standard other than a Fresnel. This standard must first be defined to the analyzer with the ***[CAL KITS & STDS]*** menus.
>
> ***[FRESNEL]*** is selected to perform a response measurement calibration for an optical reflection measurement when using a Fresnel reflection for a standard.
>
> ***[THRU]*** is selected to perform a response measurement calibration for optical and electrical transmission measurements.
>
> ***[SOURCE]*** is selected to perform a response measurement calibration when measuring a 2-port E/O type device and using a calibrated lightwave source as a standard.
>
> ***[THRU/RCVR]*** is selected to perform a response measurement calibration when measuring a 2-port E/O type device and using a calibrated lightwave receiver as a standard. First an electrical thru is measured for calibration then the system is connected with the calibrated receiver.
>
> ***[RECEIVER]*** is selected to perform a response measurement calibration when measuring a 2-port O/E type device and using a calibrated lightwave receiver as a standard.
>
> ***[SHORT]***
>
> ***[OPEN]***

[DONE: RESPONSE] (RESPDONE) takes you to the save menu, where you can save the response calibration in a register or store on a disc.

[RESPONSE & ISOL'N] (CALIRAI) leads to the menus used to perform a response and isolation measurement calibration, for measurement of all device types with a wide dynamic range. This procedure effectively removes the same frequency response errors as the response calibration and when selecting the added key, ***[ISOL'N STD]***, also removes the isolation error in transmission measurements or the directivity error in reflection measurements.

[DONE RESP ISOL CAL] (RAID) takes you to the save menu, where you can save the response and isolation calibration in a register or store on a disc.

[S11 1-PORT] (CALIS111) presents a measurement calibration for reflection-only measurements of one-port electrical devices or properly terminated two-port electrical devices, at port 1 of an S-parameter test set or the test port of a transmission/reflection test set. Three standard devices are required: a short, an open, and an impedance-matched load. This procedure provides a higher level of measurement accuracy than the response and isolation calibration. The following keys are presented:

[OPEN] (CLASS11A)

[SHORT] (CLASS11B)

[LOAD] (CLASS11C)

[DONE 1-PORT CAL] (SAV1) takes you to the save menu where you can save the 1-port calibration in a register or store on a disc.

[S22 1-PORT] (CALIS221) is similar to ***[S11 1-PORT]***. This procedure is used for reflection-only measurements of one-port or properly terminated two-port electrical devices in the reverse direction: that is, for devices connected to port 2 of the S-parameter test set. The following keys are presented:

[OPEN] (CLASS22A)

[SHORT] (CLASS22B)

[LOAD] (CLASS22C)

[DONE 1-PORT CAL] (SAV1) takes you to the save menu where you can save the 1-port calibration in a register or store on a disc.

[FULL 2-PORT] (CALIFUL2) leads to the following series of menus used to perform a complete calibration for measurement of all four S-parameters of a two-port electrical device. This procedure is the most accurate calibration for measurements of two-port electrical devices. Isolation correction can be omitted for measurements of devices with limited dynamic range.

[REFLECTION] (REFL) presents the following keys:

[S11:OPEN] (CLASS11A)

If the connector type selected for the calibration kit is a type-N, this softkey appears as ***[S11:OPENS]***. When the key is pressed, a menu is presented with a choice of male and female default opens and any previously user-defined open standards. The following mnemonics correspond to the softkeys where the standard names appear, STANA being the top key: (STANA, STANB, STANC, STAND, STANE, STANF, STANG).

[S11:SHORT] (CLASS11B)

If the connector type selected for the calibration kit is a type-N, this softkey appears as ***[S11:SHORTS]***. When the key is pressed, a menu is presented with a choice of male and female default shorts, and any previously user-defined short standards. The following mnemonics correspond to the softkeys where the standard names appear, STANA being the top key: (STANA, STANB, STANC, STAND, STANE, STANF, STANG).

[S11:LOAD] (CLASS11C)

[S22:OPEN] (CLASS22A)

If the connector type selected for the calibration kit is a type-N, this softkey appears as ***[S22:OPENS]***. When the key is pressed, a menu is presented with a choice of male and female default opens, and any previously user-defined open standards. The following mnemonics correspond to the softkeys where the standard names appear, where STANA is the top key: (STANA, STANB, STANC, STAND, STANE, STANF, STANG).

[S22:SHORT] (CLASS22B)

If the connector type selected for the calibration kit is a type-N, this softkey appears as ***[S22:SHORTS]***. When the key is pressed, a menu is presented with a choice of male and female default shorts, and any previously user-defined short standards. The following mnemonics correspond to the softkeys where the standard names appear, where STANA is the top key: (STANA, STANB, STANC, STAND, STANE, STANF, STANG).

[S22:LOAD] (CLASS22C)

[REFLECTION DONE] (REFD)

[TRANSMISSION] (TRAN) presents the following keys:

[FWD. TRANS. THRU] (FWDT) measures the S21 frequency response.

[FWD. MATCH THRU] (FWDM) measures the S11 load match.

[REV. TRANS. THRU] (REVT) measures the S12 frequency response.

[REV. MATCH THRU] (REVM) measures the S22 load match.

[TRANS. DONE] (TRAD) computes and stores the transmission coefficients.

[ISOLATION] (ISOL) presents the following keys:

[OMIT ISOLATION] (OMII) is selected when correction for isolation is not required.

[FWD ISOL'N ISOL'N STD] (FWDI) averages the trace and the S21 isolation is measured.

[REV ISOL'N ISOL'N STD] (REVI) averages the trace and the S12 isolation is measured.

[ISOLATION DONE] (ISOD) computes and stores the isolation error coefficients.

[DONE 2-PORT CAL] (SAV2) computes and stores the error coefficients.

[ONE-PATH 2-PORT] (CALIONE2) leads to the following series of menus used to perform a high-accuracy two-port calibration of an electrical device without an S-parameter test set. (The device under test must be manually reversed between sweeps to accomplish measurement of both input and output responses.)

[REFLECT'N] (REFL) presents the following keys:

[OPEN] (CLASS11A)

[SHORT] (CLASS11B)

[LOAD] (CLASS11C)

[REFLECTION DONE] (REFD)

[TRANSMISSION] (TRAN) presents the following keys:

[FWD. TRANS. THRU] (FWDT) measures the S21 frequency response.

[FWD. MATCH THRU] (FWDM) measures the S11 load match.

[TRANS. DONE] (TRAD) computes and stores the transmission coefficients.

[ISOLATION] (ISOL) presents the following keys:

[OMIT ISOLATION] (OMII) is selected when correction for isolation is not required.

[FWD ISOL'N ISOL'N STD] (FWDI) averages the trace and the S21 isolation is measured.

[ISOLATION DONE] (ISOD) computes and stores the isolation error coefficients.

[DONE 2-PORT CAL] (SAV2) computes and stores the error coefficients.

Power Calibration Menu

Two forms of power calibration are available and two choices for each input are available: A, B, A/R, B/R. A and B calibration types correct the measurement to display absoulute power at the output of the DUT vs. absolute power at the input of the DUT. A/R and B/R calibration types include response correction as well as displaying absolute input power at the DUT.

An example of a power calibration is located in section 4 in the swept power measurement.

[A POWER] (CALIAPOW) presents the following keys:

[RF SRC CBL] (CALPRFSC) measures the RF source cable that is connected to the DUT for E/E devices, or to the lightwave source for O/E, E/O, and O/O devices.

[RF TOT CBL] (CALPRFTC) measures all the RF cables connected together in the test setup.

[RECEIVER] (CALPRECE) measures a calibrated lightwave receiver.

[ELEC ATTEN] (ELEA[D]) presents the option to add electrical attenuation to avoid power trip.

[OPT ATTEN] (OPTA[D]) presents the option to add optical attenuation to prevent the calibrated receiver from going into compression.

[DONE: A CAL] (DONACAL) takes you to the save menu.

[B POWER] (CALIBPOW) presents the following keys:

[RF SRC CBL] (CALPRFSC) measures the RF source cable that is connected to the DUT for E/E devices, or to the lightwave source for O/E, E/O, and O/O devices.

[RF TOT CBL] (CALPRFTC) measures all the RF cables connected together in the test setup.

[RECEIVER] (CALPRECE) measures a calibrated lightwave receiver.

[ELEC ATTEN] (ELEAD[D]) presents the option to add electrical attenuation to prevent power trip.

[OPT ATTEN] (OPTA[D]) presents the option to add optical attenuation to prevent the calibrated receiver from going into compression.

[DONE: B CAL] (DONBCAL) takes you to the save menu.

[A/R POWER] (CALIARPO) presents the following keys:

[RESPONSE] (CALPRESP) performs response correction.

[RF SRC CBL] (CALPRFSC) measures the RF source cable that is connected to the DUT for E/E devices or the the lightwave source for O/E, E/O, and O/O devices.

[RF TOT CBL] (CALPRFTC) measures all of the RF cables connected together in the test setup.

[RECEIVER] (CALPRECE) measures a calibrated lightwave receiver.

[ELEC ATTEN] (ELEA[D]) presents the option to add electrical attenuation to prevent power trip.

[DONE A/R CAL] (DONARCAL) takes you to the save menu.

[B/R POWER] (CALIBRPO) presents the following keys:

[RESPONSE] (CALPRESP) performs response correction.

[RF SRC CBL] (CALPRFSC) measures the RF source cable that is connected to the DUT for E/E devices or the lightwave source for O/E, E/O, and O/O devices.

[RF TOT CBL] (CALPRFTC) measures all of the RF cables connected together in the test setup.

[RECEIVER] (CALPRECE) measures a calibrated receiver.

[ELEC ATTEN] (ELEA[D]) presents the option to add electrical attenuation to prevent power trip.

[DONE B/R CAL] (DONBRCAL) takes you to the save menu.

Calibration Kits and Standards Menu

[OPTICAL (STD)] is selected to define or modify an optical standard. The following keys are presented:

[CAL KIT: STD KIT] (CALKOPTS) is selected when using the default definitions for calibration standards already loaded in the analyzer memory: Fresnel reflection, and thru.

[USER KIT] (CALKOPTU) is selected when the user defines the calibration standard.

[SAVE USER KIT] (SAVEOPTK) saves the user-defined calibration standards data in analyzer memory.

[MODIFY STD] (MODIO) presents the modify cal kit menu where the type of standard to be modified or defined is choosen. The following keys are presented.

[DEFINE: REFLECTOR] (STDTREFL) is selected to define the standard device for an optical reflection measurement when the standard is other than a Fresnel reflection. Refer to the define standard menu.

[DEFINE: FRESNEL] (STDTFRES) is selected to define the Fresnel reflection used for the optical reflection measurement standard. Refer to the define standard menu.

[DEFINE: THRU] (STDTOTHR) is selected to define the thru standard used for a transmission measurement. Refer to the define standard menu.

[LABEL KIT] (LABO[$]) is used to define labels for the modified kit. Labels are created in exactly the same way as dislay titles. Refer to **[DISPLAY]** key in section 6.

[KIT DONE] (KITD) returns you to the optical calibration kit menu.

[RECEIVER (COEFF)] (STDTRECE) presents the following menus to define the lightwave receiver to be used as a calibration standard.

[CAL STD: RCVR DISC] (CALSRECD) is selected when using a disc for entering the lightwave receiver calibration data into the analyzer.

[CAL STD: RCVR COEFF] (CALSRECC) selects the manual method for loading the lightwave receiver coeffecients into the analyzer.

[LOAD RCVR DISC] presents the menu for loading receiver calibration data files into the analyzer, and for storing the receiver model in display memory. The following keys are presented:

[LOAD (filename)] for softkey 1 (LOADREC1)
[LOAD (filename)] for softkey 2 (LOADREC2)
[LOAD (filename)] for softkey 3 (LOADREC3)
[LOAD (filename)] for softkey 4 (LOADREC4)
[LOAD (filename)] for softkey 5 (LOADREC5)

[DISC STD→MEMORY] (RECDSTDI) stores the receiver model in display memory.

[READ FILE TITLES] (READRECT) reads the data file titles contained on the receiver calibration data disc.

[RETURN] takes you back to the receiver coefficient menu.

[ENTER RCVR COEFF] presents the menus to manually enter the calibration data (coefficients), for a lightwave receiver measurement standard. The following keys are presented:

[A] (COEFA[D])
[B] (COEFB[D])
[C] (COEFC[D])
[D] (COEFD[D])
[E] (COEFE[D])
[F] (COEFF[D])
[G] (COEFG[D])
[H] (COEFH[D])
[I] (COEFI[D])

[LABEL STD] (LABS [$]) takes you to the label standard menu. Labels are created in exactly the same way as display titles. Refer to the **[DISPLAY]** key in Section 6.

[STD DONE (DEFINED)] (STDODEFI) returns you to the receiver coefficients menu.

[SAVE RCVR COEFF] (SAVERECC) saves the receiver coeffecients that have just been entered into the analyzer memory.

[RETURN] takes you back to the calibration kits and standards menu.

[SOURCE (COEFF)] (STDTSOUR) presents the following menus to define the lightwave source to be used as a measurement standard.

[CAL STD: SRC DISC] (CALSSOUD) is selected when using a disc for entering the calibration data into the analyzer.

[CAL STD: SRC COEFF] (CALSSOUC) is selected when the calibration data for the measurement standard is to be manually entered into the analyzer.

[LOAD SRC DISC] is used to enter the lightwave source calibration data (coeffecients), from a disc to the analyzer, and to store the source model in display memory. The following keys are presented:

[LOAD (filename)] for softkey 1 (LOADSOU1)
[LOAD (filename)] for softkey 2 (LOADSOU2)
[LOAD (filename)] for softkey 3 (LOADSOU3)
[LOAD (filename)] for softkey 4 (LOADSOU4)
[LOAD (filename)] for softkey 5 (LOADSOU5)

[DISC STD→MEMORY] (SOUDSTDI) stores the lightwave source model in display memory.

[READ FILE TITLES] (READSOUT) reads and displays the data file titles contained on the lightwave source calibration data disc.

[RETURN] takes you back to the source coefficient menu.

[ENTER SRC COEFF] presents the following menus to manually enter the calibration data (coefficients), for a lightwave source.

[A] (COEFA[D])
[B] (COEFB[D])
[C] (COEFC[D])
[D] (COEFD[D])
[E] (COEFE[D])
[F] (COEFF[D])
[G] (COEFG[D])
[H] (COEFH[D])
[I] (COEFI[D])

[LABEL STD] (LABS [$]) takes you to the label standard menu. Labels are created in exactly the same way as display titles. Refer to the **[DISPLAY]** key in Section 6.

[STD DONE (DEFINED)] (STDODEFI) takes you back to the source coefficient menu.

[SAVE SRC COEFF] (SAVESOUC) saves the lightwave source coefficients that have just been entered into the analyzer memory.

[MODIFY THRU/RCVR] (STDTTHRR) presents the specify offset menu for modification of the thru/rcvr measurement standard.

[RETURN] takes you back to the source coefficient menu.

[ELECTRICAL ( )] presents the following menu for selecting a user-defined cal kit or one of the predefined cal kits.

[CAL KIT: 7 mm] (CALK7MM)

[CAL KIT: 3.5 mm] (CALK35MM)

[CAL KIT: N 50Ω] (CALKN50)

[CAL KIT: N 75Ω] (CALKN75)

[USER KIT] (CALKUSED) is selected when the user defines the measurement standards.

[SAVE USER KIT] (SAVEUSEK) saves the user-defined measurement standard data in analyzer memory.

[MODIFY ( )] (MODI1) presents the following keys that lead to further menus.

[DEFINE STD] (DEFS[D]) takes you to the standard type menu.

[SPECIFY CLASS] takes you to the specify class menu.

[LABEL CLASS] takes you to the label class menu.

[LABEL KIT] (LABK[$]) is used to label the modified kit. Labels are created in exactly the same way as display titles. Refer to **[DISPLAY]** key in section 6.

[KIT DONE] (KITD) returns you to the electrical calibration kit menu.

[RETURN] takes you back to the calibration kits and standards menu.

Define Standard Menu

This menu is used to define the following user-modified optical standards: reflector, Fresnel reflection, and a thru.

[OFFSET LENGTH] (OFSOLENG[D]) sets the length of an optical cable that is connected to the reference plane.

[OFFSET LOSS] (OFSOLOSS[D]) sets the loss in dB/m of the optical cable that is connected to the reference plane.

[OFFSET n] (OFSOINDR[D]) sets the refractive index (n), of the optical cable or the reflector device connected to the reference plane.

[REFLECTED POWER] (OFSORPOW[D]) sets the percent of reflectance for a reflector device or Fresnel reflection.

[LABEL STD] (LABS[$]) is used to labels for the modified standard. Labels are created in exactly the same way as display titles. Refer to **[DISPLAY]** key in section 6.

[STD DONE:DEFINED] (STDODEFI) returns you to the modify optical calibration kit menu.

Standard Type Menu

This menu is used to define the model type and model coefficients (characteristics) for each user-modified electrical standard.

These standard types 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]*** key, and refer to the specify offset menu.

[STD TYPE: OPEN] (STDTOPEN) defines the electrical standard type as an open, used for calibrating reflection measurements. Opens are assigned a terminal impedance of infinity ohms, but delay and loss offsets may still be added. Pressing this key also brings up a menu for defining the open, including its capacitance.

Opens rarely have perfect reflection characteristics because the fringing (capacitance) effects cause phase shift that varies with frequency. These effects are impossible to eliminate, but can be included in the model for the open. The capacitance model is a cubic polynomial, as a function of frequency, where the polynomial coefficients are user-definable. The capacitance model equation is:

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

where F is the measurement frequency.

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

[C0] (C0[D]) 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[D]) is used to enter the C1 term, expressed in F/Hz (Farads/Hz) and scaled by 10^{-27}.

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

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

[STD TYPE: SHORT] (STDTSHOR) defines the electrical 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.

[STD TYPE: LOAD] (STDTLOAD) defines the electrical standard type as a load (termination). Loads are assigned a terminal impedance equal to the system characteristic impedance Z0, but delay and loss offsets may still be added. If the load impedance is not Z0, use the arbitrary impedance standard definition.

[FIXED] (FIXE) defines the electrical standard type as a load (termination). Loads are assigned a terminal impedance equal to the system characteristic impedance Z0, but delay and loss offsets may still be added. If the load impedance is not Z0, use the arbitrary impedance standard definition.

[SLIDING] (SLIL) defines the load as a sliding load. When such a load is measured during calibration, the analyzer will prompt for several load positions, and calculate the ideal load value from it.

[STD TYPE: DELAY/THRU] (STDTDELA) defines the electrical standard type as a transmission line of specified length, for calibrating transmission measurements.

[STD TYPE: ARBITRARY IMPEDANCE] (STDTARBI) defines the standard type to be a load, but with an arbitrary impedance (different from system Z0). The following keys are presented:

[TERMINAL IMPEDANCE] (TERI[D]) 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. When such a load is measured during calibration, the analyzer will prompt for several load positions, and calculate the ideal load value from it.

[SPECIFY OFFSET] presents a menu where a 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.

Specify Offset Menu

Offsets may be specified with any electrical standard type.

[OFFSET DELAY] (OFSD[D]) is used to specify the one-way electrical delay from the measurement (reference) plane to the standard, in seconds. (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. Offset delay must be defined at an infinitely high frequency for a waveguide standard.

[OFFSET LOSS] (OFSL[D]) 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[D]) is used to specify the characteristic impedance of the coax offset. For waveguide, the offset impedance is always assigned a value equal to the system Z0.

[MINIMUM FREQUENCY] (MINF[D]) is used to define the lowest frequency at which the standard can be used during measurement calibration.

[MAXIMUM FREQUENCY] (MAXF[D]) is used to define the highest frequency at which the standard can be used during measurement calibration.

[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.

[STD OFFSET DONE] (STDD) returns to the standard type menu.

Specify Class Menu

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

[SPECIFY: 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.)

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

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

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

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

[MORE] leads to the class more menu. The following keys are presented.

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

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

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

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

[RESPONSE] (SPECRESP[I,I...]) is used to enter the electrical 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 cal 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.

[CLASS DONE] (CLAD) takes you back to the modify kit menu.

Label Class Menu

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 ten characters long.

Labels are created in the exact same way as display titles. Refer to **[DISPLAY]** key in Section 6.

[RESPONSE] (LABERESP[$]) is used to label the electrical standard used for a response calibration.

[RESP&ISOL] (LABERESP[$]) is used to label the electrical standard used for a response and isolation calibration.

[S11A] (LABES11A[$]) is used to label the electrical standard used for the first class required for an S11 1-port calibration.

[S11B] (LABES11B[$]) is used to label the electrical standard used for the second class required for an S11 1-port calibration.

[S11C] (LABESS11C[$]) is used to label the electrical standard used for the third class required for an S11 1-port calibration.

[S22A] (LABES22A[$]) is used to label the electrical standard used for the first class required for an S22 1-port calibration.

[S22B] (LABES22B[$]) is used to label the electrical standard used for the second class required for an S22 1-port calibration.

[S22C] (LABES22C[$] is used to label the electrical standard used for the third class required for an S22 1-port calibration.

[FOWARD TRANS.] (LABEFWDT[$]) is used to label the electrical standard used for the forward transmisssion (thru) calibration.

[FORWARD MATCH] (LABEFWDM[$]) is used to label the electrical standard used for the forward match (thru) calibration.

[REVERSE TRAN.] (LABEREVT[$]) is used to label the electrical standard used for the reverse transmission (thru) calibration.

[REVERSE MATCH] (LABEREVM[$]) is used to label the electrical standard used for the reverse match (thru) calibration.

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.

[EXTENSIONS on off] (PORE<ON|OFF>) toggles the reference plane extension mode. When this function is on, all extensions defined below are enabled; when off, none of the extensions are enabled.

[EXTENSION INPUT A] (PORTA[D]). Use this feature to add electrical delay in seconds to extend the reference plane at input A to the end of the cable. This is used for any input measurements including S-parameters.

[EXTENSION INPUT B] (PORTB[D]) adds electrical delay to the input B reference plane for any B input measurements including S-parameters.

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

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

[RETURN] goes back to the calibrate more menu.

OPTICAL/OPTICAL (O/O)

The calibrate menu for an O/O type device gives access for two main measurement calibrations: response and isolation std/response.

The response calibration removes frequency response of the system. The response menu has three calibration choices: reflector, Fresnel, and thru. The reflector and Fresnel methods are used for reflection measurements and the thru method is used for transmission measurements.

The isolation std/response calibration adds an isolation step to the response calibration. This reduces the effect of crosstalk between the input and output ports. In general, the isolation step is only useful in measuring optical losses greater than 35 dB. If this calibration is performed, a narrow IF bandwidth and a large amount of averaging is needed.

RESPONSE CALIBRATION FOR REFLECTION MEASUREMENTS

Reflector Calibration

A reflection calibration can be performed with any reflective device that the percent of reflected power or the refractive index is known.

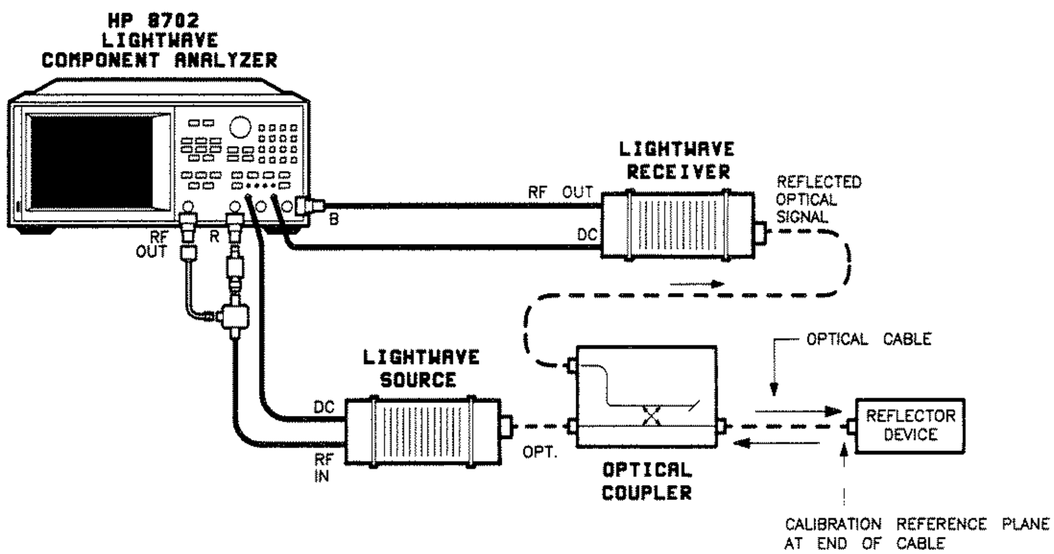


Figure 7-2. Setup for Response Calibration of Optical Reflection Measurements

Procedure

- Connect the system as shown in Figure 7-2 with the reflector device. Setup the stimulus parameters for the measurement.
- Press **[CAL]** ***[DEVICE TYPE] [O/O] [RETURN]***.
- Press ***[CAL KITS & STDS] [OPTICAL (STD)] [MODIFY (STD)] [DEFINE:REFLECTOR]***.
- Select the various offset softkeys to describe the optical cable connected to the coupler output and the reflector device.

  Press ***[OFFSET LENGTH]***, enter the cable length in meters, and then press the **[x1]** key.

  Press ***[OFFSET LOSS]***, enter the loss of the cable in dB/meter, and then press the **[x1]** key.

  Press ***[OFFSET n]***, enter the refractive index and then press the **[x1]** key.

  Press ***[REFLECTED POWER]***, enter the reflected power in percent, and then press the **[x1]** key.

The reflector device can be defined with either the ***[OFFSET n]*** or ***[REFLECTED POWER]*** key. If the percent of reflected power is unknown press ***[REFLECTED POWER] [0]*** **[x1]**. Then press ***[OFFSET n]*** and enter the index of refraction. The analyzer will calculate the percent of reflected power with that information.

- You can label this kit by pressing ***[LABEL STD]***. Select the letters for the label with the knob and the ***[SELECT LETTER]*** key. When the label is complete, press ***[DONE] [STD DONE (DEFINED)]***.
- Press **[CAL]** ***[CALIBRATE MENU] [RESPONSE] [REFLECTOR]***.
- The message "WAIT—MEASURING CAL STANDARD" is displayed while the response data is measured.
- When the measurement is complete, the analyzer will beep and underline REFLECTOR.
- Press ***[DONE:RESPONSE]***.

NOTE: The calibration should be saved either in analyzer memory or on external disc. Refer to section 9 under Saving Instrument States.

- Now the test device can be connected and measured.

Fresnel Reflection Calibration

The reflection of an open fiber, (Fresnel reflection), has a known response and therefore can be used as a standard for reflection measurements. You can use the factory loaded calibration data for a Fresnel reflection (3.5% reflected power) if you do not connect an optical cable to the coupler output, otherwise, you must define your own.

Procedure

- Connect the system as shown in Figure 7-2 without the reflector device. Setup the stimulus parameters for the measurement.
- Clean and dry the end of the cable on the output path of the coupler.

NOTE: The cable interface must be clean and dry for a Fresnel reflection. On metal connectors, you can use non-corrosive alcohol or a similar liquid freon product to clean the connectors. This can be applied with a lint-free swab or cloth. Then use clean compressed air to dry them and blow away any loose particles. The fiber ends should be cleaned with a cleaning kit. HP 15475A is recommended. This kit, and its use, is described in chapter 5 summary of the User's Guide. Alcohol or freon is often used to clean fiber ends and then they are dried with clean compressed air. However, the HP kit recommends the use of an adhesive cleaning tape.

- Press **[CAL]** ***[DEVICE TYPE] [O/O] [RETURN]***.
- Press ***[CALIBRATE MENU] [CAL KITS & STDS] [OPTICAL (STD)] [MODIFY (STD)] [DEFINE: FRESNEL].***
- Select the various offset softkeys to describe the optical cable connected to the coupler output.

  Press ***[OFFSET LENGTH]***, enter the cable length in meters, and then press the **[x1]** key.

  Press ***[OFFSET LOSS]***, enter the loss of the cable in dB/meter, and then press the **[x1]** key.

  Press ***[OFFSET n]***, enter the refractive index and then press the **[x1]** key.

  Press ***[REFLECTED POWER]***, enter the reflected power in percent, and then press the **[x1]** key.

The Fresnel reflection can be defined with either the ***[OFFSET n]*** or ***[REFLECTED POWER]*** key. If the percent of reflected power is unknown press ***[REFLECTED POWER] [0]*** **[x1]**. Then press ***[OFFSET n]*** and enter the index of refraction. The analyzer will calculate the percent of reflected power with that information.

- You can label this kit by pressing ***[LABEL STD].*** Select the letters for the label with the knob and the ***[SELECT LETTER]*** key. When the label is complete, press ***[DONE] [STD DONE (DEFINED)].***
- Press **[CAL]** ***[CALIBRATE MENU] [RESPONSE] [FRESNEL]***.
- The message "WAIT—MEASURING CAL STANDARD" is displayed while the response data is measured.
- When the measurement is complete, the analyzer will beep and underline FRESNEL.
- Press ***[DONE:RESPONSE]***.

NOTE: The calibration should be saved either in analyzer memory or on external disc. Refer to section 9 under Saving Instrument States.

- Now the test device can be connected and measured.

RESPONSE CALIBRATION FOR TRANSMISSION MEASUREMENTS

The data measured in this procedure is normalized, setting the magnitude values to unity or 0 dB. The end of the thru cable, connected to the receiver, is the measurement reference plane.

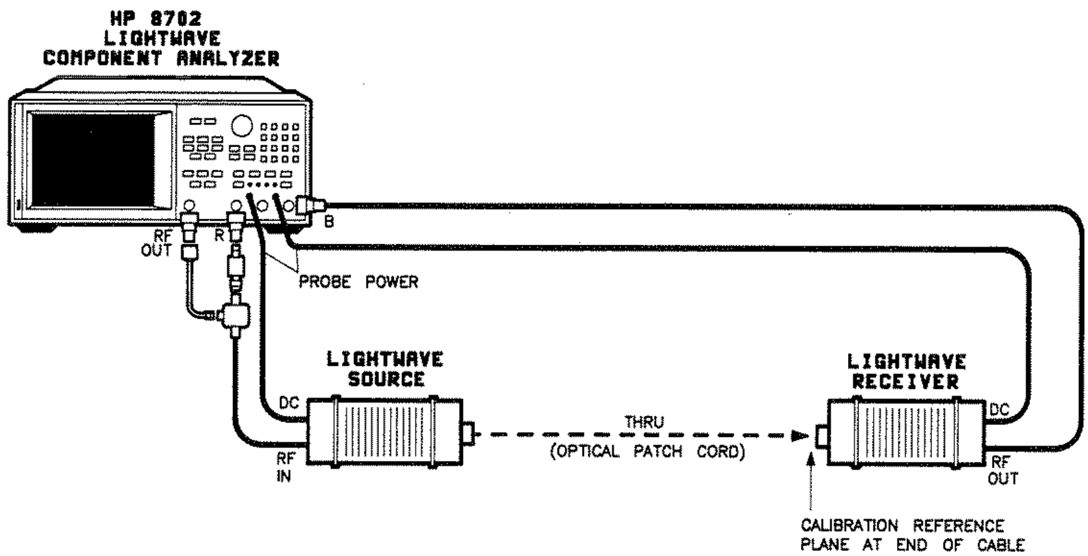


Figure 7-3. Setup for Response Calibration for Transmission Measurement

Procedure

- Connect the system as shown in Figure 7-3 with a thru optical cable from the Interconnect Cable Kit or your own short cable with the appropriate connector/adapters. Setup the stimulus parameters for the measurement.
- Press **[CAL]** ***[DEVICE TYPE] [O/O]***
- If you are going to leave the thru cable in the system during the measurement, continue the procedure sequence with the next step. If the thru is removed from the system, you must define it so it will be removed from the measurement calculation also.

  Press ***[CALIBRATE MENU] [CAL KITS & STDS] [OPTICAL (STD)] [MODIFY (STD)] [DEFINE:THRU]***.

  Select the various offset softkeys to describe the thru cable.

  Press ***[OFFSET LENGTH]***, enter the cable length in meters, and then press the **[x1]** key.

  Press ***[OFFSET LOSS]***, enter the loss of the cable in dB/meter, and then press the **[x1]** key.

  Press ***[OFFSET n]***, enter the refractive index and then press the **[x1]** key.

  You can label this kit by pressing ***[LABEL STD]***. Select the letters for the label with the knob and the ***[SELECT LETTER]*** key. When the label is complete, press ***[DONE] [STD DONE (DEFINED)]***.

- Press **[CAL]** *[CALIBRATION MENU] [RESPONSE] [THRU]*.
- The message "WAIT—MEASURING CAL STANDARD" is displayed while the data is measured. When the measurement is complete the analyzer will beep and underline THRU.
- Press *[DONE:RESPONSE]*.

NOTE: The calibration data should be saved in the analyzer memory or on external disc. Refer to Section 9 under Saving Instrument States.

- Now the test device can be inserted and measured.

RESPONSE AND ISOLATION CALIBRATION FOR REFLECTION MEASUREMENTS

The procedure described here effectively removes the frequency response and directivity errors for reflection measurements. A reflector device used for this calibration must be defined in the define standard menu. You can use the factory loaded calibration data (3.5% reflected power), for a Fresnel reflection if you do not connect an optical cable to the coupler output, otherwise, you must define your own.

Procedure

- Connect the system as shown in Figure 7-2 with the selected reflection measurement standard. Setup the stimulus parameters for the measurement.
- Clean and dry the end of the cable connected to the output path of the coupler for a Fresnel reflection.

NOTE: The end of the cable connected to the coupler's output test port must be clean and dry for a Fresnel reflection. On metal connectors, you can use non-corrosive alcohol or a similar liquid freon product to clean the connectors. This can be applied with a lint-free swab or cloth. Then use clean compressed air to dry them and blow away any loose particles. The fiber ends should be cleaned with a recommended cleaning kit. HP 15475A is recommended. This kit and its use is described in chapter 5 summary in the User's Guide. Alcohol or freon is often used to clean fiber ends and then they are dried with clean compressed air. However, the HP kit recommends the use of an adhesive cleaning tape.

- Press **[CAL]** *[DEVICE TYPE] [O/O] [RETURN]*.
- If the standard is a reflector or you want to define a Fresnel reflection, the calibration data for must be loaded into the analyzer.

  Press *[CAL KITS & STDS] [OPTICAL (STD)] [MODIFY (STD)] [DEFINE:REFLECTOR]* or *[DEFINE:FRESNEL]*.

  Select the various offset softkeys to define your optical cable that is connected to the coupler output and the reflector device.

  Press *[OFFSET LENGTH]*, enter the cable length in meters, and then press the **[x1]** key.

  Press *[OFFSET LOSS]*, enter the loss of the cable in dB/meter, and then press the **[x1]** key.

  Press *[OFFSET n]*, enter the refractive index and then press the **[x1]** key.

Press ***[REFLECTED POWER]***, enter the reflected power in percent, and then press the **[x1]** key.

The reflector device can be defined with either the ***[OFFSET n]*** or ***[REFLECTED POWER]*** key. If the percent of reflected power is unknown press ***[REFLECTED POWER] [0]*** **[x1]**. Then press ***[OFFSET n]*** and enter the index of refraction. The analyzer will calculate the percent of reflected power with that information.

You can label this kit by pressing ***[LABEL STD]***. Select the letters for the label with the knob and the ***[SELECT LETTER]*** key. When the label is complete, press ***[DONE] [STD DONE (DEFINED)]***.

- Press **[CAL]** ***[CALIBRATE MENU] [RESPONSE & ISOL'N] [RESPONSE] [FRESNEL]*** or ***[REFLECTOR]***.
- The message "WAIT—MEASURING CAL STANDARD" is displayed while the response data is measured.
- When the measurement is complete, the analyzer will beep and underline the selected reflection standard. Press ***[DONE:RESPONSE]***.
- Terminate the cable connected to the optical coupler output with index matching compound or device. Apply the compound as precisely and as evenly as possible. Remove it completely when you are finished with the calibration.
- Press ***[ISOLATION STD]***.
- The message "WAIT—MEASURING CAL STANDARD" is displayed while the response data is measured.
- When the measurement is complete, the analyzer will beep and underline ISOL'N STD.
- Press ***[DONE RESPONSE & ISOL'N CAL]***.

NOTE: The calibration should be saved either in analyzer memory or on external disc. Refer to Section 9 under Saving Instrument States.

- 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 isolation errors for transmission measurements of devices with wide dynamic range.

Procedure

- Connect the system as shown in the previous figure with a thru optical cable from the Interconnect Cable Kit or your own short cable with the appropriate connector/adapters. Setup the stimulus parameters for the measurement.
- Press **[CAL]** *[DEVICE TYPE] [O/O]*
- If you are going to leave the thru cable in the system during the measurement, continue the procedure sequence with the next step. If the thru is removed from the system, you must define it so it will be removed from the measurement calculation also.

  Press ***[CALIBRATE MENU] [CAL KITS & STDS] [OPTICAL (STD)] [MODIFY (STD)] [DEFINE:THRU]***.

  Select the various offset softkeys to describe the thru cable.

  Press ***[OFFSET LENGTH]***, enter the cable length in meters, and then press the **[x1]** key.

  Press ***[OFFSET LOSS]***, enter the loss of the cable in dB/meter, and then press the **[x1]** key.

  Press ***[OFFSET n]***, enter the refractive index and then press the **[x1]** key.

  You can label this kit by pressing ***[LABEL STD]***. Select the letters for the label with the knob and the ***[SELECT LETTER]*** key. When the label is complete, press ***[DONE] [STD DONE (DEFINED)]***.
- Press **[CAL]** ***[CALIBRATION MENU] [RESPONSE] [THRU]***.
- The message "WAIT—MEASURING CAL STANDARD" is displayed while the data is measured. When the measurement is complete the analyzer will beep and underline THRU. Press ***[DONE:RESPONSE]***.
- Disconnect the thru from the receiver. Do not aim the end of the cable toward the receiver input.
- Press ***[ISOL'N STD]***.
- The message "WAIT—MEASURING CAL STANDARD" is displayed while the data is measured. When the measurement is complete the analyzer will beep and underline ISOL'N STD.
- Press ***[DONE RESP ISOL'N CAL]***.

NOTE: The calibration data should be saved in the analyzer memory or on external disc. Refer to Section 9 under Saving Instrument States.

- Now the test device can be inserted and measured.

ELECTRICAL/OPTICAL (E/O)

The calibrate menu for an E/O type device gives access for two main measurement calibrations: response and isolation std/response.

The response calibration menu has two calibration choices: source, and thru/receiver. The source method is used when you have a calibrated lightwave source to use as a standard device; i.e. a source with calibration data. The thru/receiver method is used when you don't have a calibrated source but you do have a calibrated lightwave receiver to use as a standard.

The isolation std/response calibration adds an isolation step to the response calibration. This reduces the effect of crosstalk between the input and output ports. In general, the isolation step is only useful in measuring optical losses greater than 35 dB. If this calibration is performed, a narrow IF bandwidth and a large amount of averaging is needed.

SOURCE RESPONSE CALIBRATION

In this procedure the response of the lightwave source is measured and then normalized.

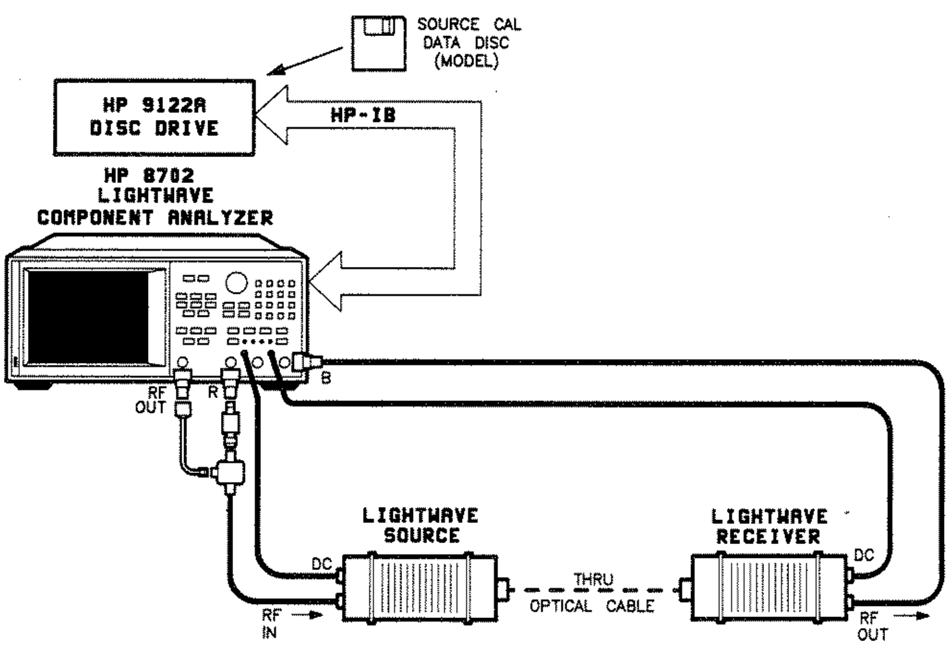


Figure 7-4. Setup for Calibration Data Loading

Procedure

- Connect the system as shown in the figure above with the thru cable from the Interconnect Cable Kit or you own short cable with the appropriate connector/adapters. Setup the stimulus parameters for the measurement.

- Press **[LOCAL]** ***[SYSTEM CONTROLLER]*** **[CAL]** ***[DEVICE TYPE] [E/O] [RETURN] [CAL KITS & STDS] [SOURCE (COEFF)]***.

- The preset state sets the CAL STD selection to ***[COEFF]***. The analyzer expects the nine calibration data coefficients (adhered to the lightwave source), to be loaded into the analyzer. The calibration data can also be entered using an HP 9122 series disc drive and the disc that was supplied with the source. The most accurate data is contained on the disc, therefore, the recommended method for loading the data into analyzer.

NOTE: If you do not have a disc drive, you can enter the coefficients on the source label by pressing the following keys: ***[SRC COEFF] [ENTER SRC COEFF]***. Then press each softkey corresponding to the nine coefficients (A through I, using the ***[MORE]*** softkey) enter the coefficient, and then press the **[x1]** key. When all coefficients have been entered, press ***[RETURN]***. You can label the standard by pressing ***[LABEL STD]***. Select the letters for the label with the knob and the ***[SELECT LETTER]*** key. When the label is complete, press ***[DONE] [STD DONE (DEFINED)] [SAVE SRC COEFF]***. Continue with the procedure sequence after the next step.

- If you have a disc drive:

  Press ***[CAL STD:SRC DISC] [LOAD SRC DISC]***.

  Insert the source calibration data disc in drive 0 and press ***[READ FILE TITLES]***.

  The analyzer will read the files on the disc and create a label next to a CRT softkey for the file. Select the file that corresponds to the number on your source.

  The analyzer will read the data and store it into it's Cal Kit memory. The softkey label will be underlined when complete. Press ***[DISC STD→MEMORY]***.

  Be sure the disc drive is set to the correct HP-IB address. For example, set the disc drive HP-IB address = 0: press **[LOCAL]** ***[SET ADDRESSES] [ADDRESS:DISC] [0]*** **[x1]**; and be sure the switches on the disc drive are also set =0. (Information on computer control of the analyzer is described in the HP-IB Programming section.)

- Press **[CAL]** ***[CALIBRATE MENU] [RESPONSE] [SOURCE]***.

- After the measurement is complete, the analyzer will beep and underline SOURCE. Press ***[DONE:RESPONSE]***.

NOTE: The calibration should be saved in the analyzer memory or on external disc. Refer to Section 9 under Saving Instrument States.

- Now the test device can be connected and measured.

THRU/RECEIVER RESPONSE CALIBRATION

The procedure described here measures the response of a lightwave receiver for an E/O measurement calibration.

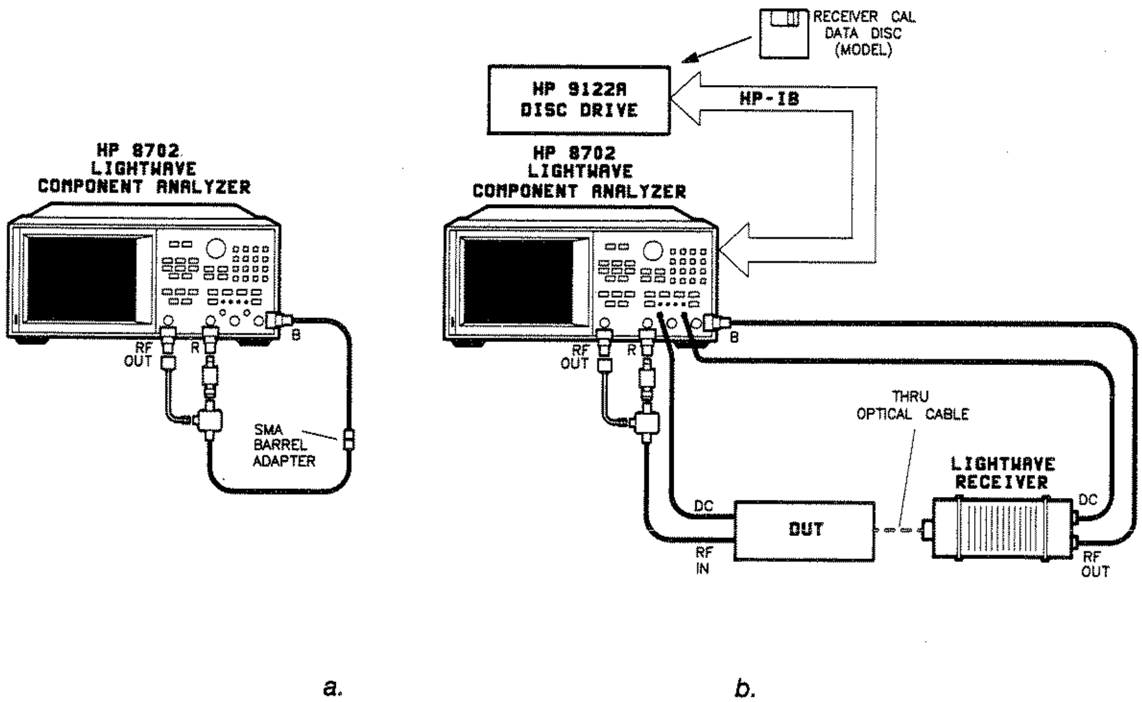


Figure 7-5. Thru/Receiver Calibration for an E/O Device

Procedure

- Connect the system as shown in Figure 7-5a with the thru connection between the RF cables (use the SMA adapter barrel supplied in the RF Interface Kit). Setup the stimulus parameters for the measurement.
- Press **[LOCAL] [SYSTEM CONTROLLER] [CAL]** ***[DEVICE TYPE] [E/O] [RETURN] [CAL KITS & STDS] [RECEIVER (COEFF)]***.

- The preset state sets the CAL STD selection to ***[COEFF]***. The analyzer expects the nine calibration data coefficients (adhered to the lightwave receiver), to be loaded into the analyzer. The calibration data can also be entered using an HP 9122 series disc drive and the disc that was supplied with the receiver. The most accurate data is contained on the disc, therefore, the recommended method for loading the data into the analyzer.

NOTE: If you do not have a disc drive, you can use the coefficients on the receiver label by pressing the following keys: ***[RCVR COEFF] [ENTER RCVR COEFF]***. Then press each softkey corresponding to the nine coefficients (A through I, using the ***[MORE]*** softkey), enter the coefficient and press the **[x1]** key. When all coefficients have been entered, press ***[RETURN]***. You can label this standard by pressing ***[LABEL STD]***. Select the letters for the label with the knob and the ***[SELECT LETTER]*** key. Press ***[STD DONE (DEFINED)] [SAVE RCVR COEFF]***. Continue with the procedure sequence after the next step.

- If you have a disc drive, press ***[CAL STD:RCVR DISC] [LOAD RCVR DISC]***.

  Insert the receiver calibration data disc in drive 0 and press ***[READ FILE TITLES]***.

  The analyzer will read the files on the disc and create a label next to a CRT softkey for the file. Select the file that corresponds to the number on your lightwave receiver.

  The analyzer will read the data and store it into it's Cal Kit memory. The CRT label will be underlined when complete. Press ***[DISC STD→MEMORY]***.

  Be sure the disc drive is set to the correct HP-IB address. For example, set the disc drive HP-IB address = 0: press **[LOCAL]** ***[SET ADDRESSES] [ADDRESS:DISC] [0]*** **[x1]**; and be sure the switches on the disc drive are also set = 0. (Information on computer control of the analyzer is described in the HP-IB Programming section.)

- Press **[CAL]** ***[CALIBRATE MENU] [RESPONSE] [THRU/RCVR]***.
- Wait for the beep, and press ***[DONE:RESPONSE]***.

NOTE: The calibration should be saved in the same analyzer register or on external disc. Refer to Section 9 under Saving Instrument States.

- Now the test device can be inserted, followed by the calibrated receiver, and measured. Refer to Figure 7-5b.

SOURCE RESPONSE AND ISOLATION CALIBRATION

The procedure described here reads the calibration data for a lightwave source and then measures it. Differences caused by repeatable systematic errors in the measurement system are removed from test device measurements by error correction terms.

Procedure

- Connect the system as shown above in Figure 7-4 with the thru cable from the Interconnect Cable Kit or you own short cable with the appropriate connector/adapters. Setup the stimulus parameters for the measurement.
- Press **[LOCAL]** ***[SYSTEM CONTROLLER]*** **[CAL]** ***[DEVICE TYPE] [E/O] [RETURN] [CAL KITS & STDS] [SOURCE (COEFF)]***.

- The preset state sets the CAL STD selection to ***[COEFF]***. The analyzer expects the nine calibration data coefficients (adhered to the lightwave source), to be loaded into the analyzer. The calibration data can also be entered using an HP 9122 series disc drive and the disc that was supplied with the source. The most accurate data is contained on the disc, therefore, the recommended method for loading the data into the analyzer.

NOTE: If you do not have a disc drive, you can use the coefficients on the source label by pressing the following keys: ***[SRC COEFF] [ENTER SRC COEFF]***. Then press each softkey corresponding to the nine coefficients (A through I, using the ***[MORE]*** softkey) and enter the coefficient from the label on the HP lightwave source using the analyzer keypad and the **[x1]** key. When all coefficients have been entered, press ***[RETURN]***. You can label this standard by pressing ***[LABEL STD]***. Select the letters for the label with the knob and the ***[SELECT LETTER]*** key. Press ***[STD DONE (DEFINED)] [SAVE SRC COEFF]***. Continue with the procedure sequence after the next step.

- If you have a disc drive, press ***[CAL STD:SRC DISC] [LOAD SRC DISC]***.

  Insert the source calibration data disc in drive 0 and press ***[READ FILE TITLES]***.

  The analyzer will read the files on the disc and create a label next to a CRT softkey for the file. Select the file that corresponds to the number on your source.

  The analyzer will read the data and store it into it's Cal Kit memory. The CRT label will be underlined when complete. Press ***[DISC STD→MEMORY]***.

  Be sure the disc drive is set to the correct HP-IB address. For example, set the disc drive HP-IB address = 0: press **[LOCAL]** ***[SET ADDRESSES] [ADDRESS:DISC] [0]*** **[x1]**; and be sure the switches on the disc drive are also set = 0. (Information on computer control of the analyzer is described in the HP-IB Programming section.)

- Press **[CAL]** ***[CALIBRATE MENU] [RESPONSE] [SOURCE]***.
- After the measurement is complete, the analyzer will beep and underline SOURCE. Press ***[DONE:RESPONSE]***.
- Disconnect the optical cable at the output of the source.
- Press ***[ISOL'N STD]***.
- After the measurement is complete, the analyzer will beep and underline ISOL'N STD.
- Press ***[DONE RESP & ISOL'N CAL]***.

NOTE: The calibration should be saved in the analyzer memory or on external disc. Refer to Section 9 under Saving Instrument States.

- Now the test device can be inserted and measured.

THRU/RECEIVER RESPONSE AND ISOLATION CALIBRATION

The procedure described here effectively removes the response of the lightwave receiver and analyzer, leaving the analyzer to display the DUT response only.

Procedure

- Connect the system as shown in Figure 7-5a with the thru connection between the RF cables (use the SMA adapter barrel supplied in the RF Interface Kit). Setup the stimulus parameters for the measurement.
- Press **[LOCAL]** ***[SYSTEM CONTROLLER]*** **[CAL]** ***[DEVICE TYPE] [E/O] [RETURN] [CAL KITS & STDS] [RECEIVER (COEFF)].***
- The preset state sets the CAL STD selection to ***[COEFF]***. The analyzer expects the nine calibration data coefficients (adhered to the lightwave receiver), to be loaded into the analyzer. The calibration data can also be entered using an HP 9122 series disc drive and the disc that was supplied with the receiver. The most accurate data is contained on the disc, therefore, the recommended method for loading the data into the analyzer.

NOTE: If you do not have a disc drive, you can use the coefficients on the receiver label by pressing the following keys: ***[RCVR COEFF] [ENTER RCVR COEFF]***. Then press each softkey corresponding to the nine coefficients (A through I, using the ***[MORE]*** softkey), enter the coefficient and press the **[x1]** key. When all coefficients have been entered, press ***[RETURN]***. You can label this standard by pressing ***[LABEL STD]***. Select the letters for the label with the knob and the ***[SELECT LETTER]*** key. Press ***[STD DONE (DEFINED)] [SAVE RCVR COEFF]***. Continue with the procedure sequence after the next step.

- If you have a disc drive, press ***[CAL STD:RCVR DISC] [LOAD RCVR DISC]***.

  Insert the receiver calibration data disc in drive 0 and press ***[READ FILE TITLES]***.

  The analyzer will read the files on the disc and create a label next to a CRT softkey for the file. Select the file that corresponds to the number on your receiver.

  The analyzer will read the data and store it into it's Cal Kit memory. The CRT label will be underlined when complete. Press ***[DISC STD→MEMORY]***.

Be sure the disc drive is set to the correct HP-IB address. For example, set the disc drive HP-IB address =0: press **[LOCAL]** ***[SET ADDRESSES] [ADDRESS:DISC] [0]*** **[x1]**; and be sure the switches on the disc drive are also set = 0. (Information on computer control of the analyzer is described in the HP-IB Programming section.)

- Press **[CAL]** ***[CALIBRATE MENU] [RESPONSE] [THRU/RCVR]***.
- After the measurement is complete, the analyzer will beep and underline THRU/RCVR. Press ***[DONE:RESPONSE]***.
- Disconnect the optical cable at the lightwave receiver input.
- Press ***[ISOL'N STD]***.
- After the measurement is complete, the analyzer will beep and underline ISOL'N STD. Press ***[DONE RESP & ISOL'N CAL]***.

NOTE: The calibration should be saved in the same analyzer register or on external disc. Refer to Section 9 under Saving Instrument States.

- Now the test device can be inserted, followed by the calibrated receiver, and measured. Refer to Figure 7-5b.

OPTICAL/ELECTRICAL (O/E)

The calibration menu for an O/E type device gives access for two main types of calibration: response and isolation.

The response calibration measures and normalizes the phase and magnitude response of a lightwave receiver with a thru calibration.

The isolation calibration measures and normalizes the response of the rest of the system. In general, the isolation step is only useful in measuring optical losses greater than 35 dB. If this calibration is performed, a narrow IF bandwidth and a large amount of averaging is needed.

RECEIVER RESPONSE CALIBRATION

In this procedure, the response of the lightwave receiver is measured and then normalized.

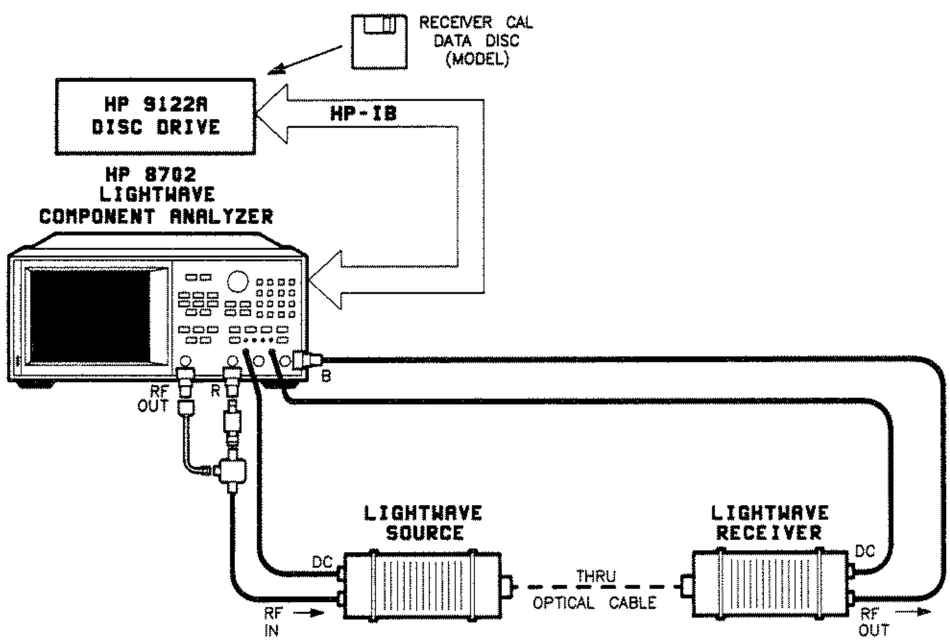


Figure 7-6. O/E Transducer Measurement Configuration

Procedure

- Connect the system as shown in the figure above with the thru cable from the Interconnect Cable Kit or you own short cable with the appropriate connector/adapters. Setup the stimulus parameters for the measurement.

- Press **[LOCAL]** ***[SYSTEM CONTROLLER]*** **[CAL]** ***[DEVICE TYPE] [O/E] [RETURN] [CAL KITS & STDS] [RECEIVER (COEFF)]***.

- The preset state sets the CAL STD selection to ***[COEFF]***. The analyzer expects the nine calibration data coefficients (adhered to the lightwave receiver), to be loaded into the analyzer. The calibration data can also be entered using an HP 9122 series disc drive and the disc that was supplied with the receiver. The most accurate data is contained on the disc, therefore, the recommended method for loading the data into analyzer.

NOTE: If you do not have a disc drive, you can enter the coefficients on the receiver label by pressing the following keys: ***[RCVR COEFF] [ENTER RCVR COEFF]***. Then press each softkey corresponding to the nine coefficients (A through I, using the ***[MORE]*** softkey) enter the coefficient, and then press the **[x1]** key. When all coefficients have been entered, press ***[RETURN]***. You can label the standard by pressing ***[LABEL STD]***. Select the letters for the label with the knob and the ***[SELECT LETTER]*** key. When the label is complete, press ***[DONE] [STD DONE (DEFINED)] [SAVE RCVR COEFF]***. Continue with the procedure sequence after the next step.

- If you have a disc drive:

  Press ***[CAL STD:RCVR DISC] [LOAD RCVR DISC]***.

  Insert the receiver calibration data disc in drive 0 and press ***[READ FILE TITLES]***.

  The analyzer will read the files on the disc and create a label next to a CRT softkey for the file. Select the file that corresponds to the number on your lightwave receiver.

  The analyzer will read the data and store it into it's Cal Kit memory. The softkey label will be underlined when complete. Press ***[DISC STD→MEMORY]***.

  Be sure the disc drive is set to the correct HP-IB address. For example, set the disc drive HP-IB address = 0: press **[LOCAL]** ***[SET ADDRESSES] [ADDRESS:DISC] [0]*** **[x1]**; and be sure the switches on the disc drive are also set = 0. (Information on computer control of the analyzer is described in the HP-IB Programming section.)

- Press **[CAL]** ***[CALIBRATE MENU] [RESPONSE] [RECEIVER]***.

- After the measurement is complete, the analyzer will beep and underline RECEIVER. Press ***[DONE:RESPONSE]***.

NOTE: The calibration should be saved in the analyzer memory or on external disc. Refer to Section 9 under Saving Instrument States.

- Now the test device can be connected and measured.

RECEIVER RESPONSE AND ISOLATION CALIBRATION

The procedure described here reads the calibration data for a lightwave receiver and then measures it. Differences caused by repeatable systematic errors in the measurement system are removed from test device measurements by error correction terms.

Procedure

- Connect the system as shown above in Figure 7-6 with the thru cable from the Interconnect Cable Kit or you own short cable with the appropriate connector/adapters. Setup the stimulus parameters for the measurement.
- Press **[LOCAL]** ***[SYSTEM CONTROLLER]*** **[CAL]** ***[DEVICE TYPE] [O/E] [RETURN] [CAL KITS & STDS] [SOURCE (COEFF)]***.
- The preset state sets the CAL STD selection to ***[COEFF]***. The analyzer expects the nine calibration data coefficients (adhered to the lightwave receiver), to be loaded into the analyzer. The calibration data can also be entered using an HP 9122 series disc drive and the disc that was supplied with the receiver. The most accurate data is contained on the disc, therefore, the recommended method for loading the data into the analyzer.

NOTE: If you do not have a disc drive, you can use the coefficients on the receiver label by pressing the following keys: ***[RCVR COEFF] [ENTER RCVR COEFF]***. Then press each softkey corresponding to the nine coefficients (A through I, using the ***[MORE]*** softkey) and enter the coefficient from the label on the HP lightwave receiver using the analyzer keypad and the **[x1]** key. When all coefficients have been entered, press ***[RETURN]***. You can label this standard by pressing ***[LABEL STD]***. Select the letters for the label with the knob and the ***[SELECT LETTER]*** key. Press ***[STD DONE (DEFINED)] [SAVE RCVR COEFF]***. Continue with the procedure sequence after the next step.

- If you have a disc drive, press ***[CAL STD:RCVR DISC] [LOAD RCVR DISC]***.

  Insert the source calibration data disc in drive 0 and press ***[READ FILE TITLES]***.

  The analyzer will read the files on the disc and create a label next to a CRT softkey for the file. Select the file that corresponds to the number on your source.

  The analyzer will read the data and store it into it's Cal Kit memory. The CRT label will be underlined when complete. Press ***[DISC STD→MEMORY]***.

  Be sure the disc drive is set to the correct HP-IB address. For example, set the disc drive HP-IB address = 0: press **[LOCAL]** ***[SET ADDRESSES] [ADDRESS:DISC] [0]*** **[x1]**; and be sure the switches on the disc drive are also set = 0. (Information on computer control of the analyzer is described in the HP-IB Programming section.)

- Press [CAL] ***[CALIBRATE MENU] [RESPONSE] [RECEIVER]***.
- After the measurement is complete, the analyzer will beep and underline RECEIVER. Press ***[DONE:RESPONSE]***.
- Disconnect the optical cable at the output of the receiver.
- Press ***[ISOL'N STD]***.
- After the measurement is complete, the analyzer will beep and underline ISOL'N STD.
- Press ***[DONE RESP & ISOL'N CAL]***.

NOTE: The calibration should be saved in the analyzer memory or on external disc. Refer to Section 9 under Saving Instrument States.

- Now the test device can be inserted and measured.

ELECTRICAL/ELECTRICAL (E/E)

There are six choices of calibration procedures for E/E devices: response, response and isolation, S11 1-port, S22 1-port, full 2-port, and one-path 2-port.

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, but also the least accurate.

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. Isolation calibration can be omitted for most measurements, except where wide dynamic range is a consideration.

The S11 and S22 one-port calibration procedures are best applied to high accuracy reflection measurements of one-port devices or properly terminated two-port devices.

The full two-port calibration provides the best magnitude and phase measurement accuracy for both transmission and reflection measurements of two-port devices, and requires an S-parameter test set.

The one-path two-port calibration is used for high accuracy transmission and reflection measurements using a transmission/reflection test set. (The device under test must be manually reversed between sweeps to accomplish measurements in both the forward and reverse directions.)

Standard devices required for an electrical measurement calibration of the analyzer system (which includes HP 85044A, 85046A, or 85047A test set), are available in calibration kits with different connector types. The analyzer select cal kit menu is used to choose the cal kit definitions that describe the devices in the type of kit to be used. Other standard devices can be used by specifying their characteristics in a user-defined kit, as described earlier in this section in the Calibration Data paragraph.

For information about connector care and connection techniques, refer to the Microwave Connector Care Manual or the application note, Principles of Microwave Connector Care. Both of these documents are provided in the analyzer Accessories Manual.

INTERPOLATED ERROR CORRECTION

The interpolated error correction feature allows the operator to select a subset of the frequency range or a different number of points without recalibration. The system errors for the newly selected frequencies are calculated from the system errors of the original calibration.

System performance is unspecified when using interpolated error correction. The quality of this calibration is dependent on the amount of phase shift between measurement points. If phase shift is no greater than 180° per approximately 5 measurement points, interpolated calibration offers a great improvement over uncorrected measurements. The accuracy of this calibration improves as phase shift decreases. When using an HP 85046A/B or 85047A test set, it is recommended that the original calibration be performed with at least 67 points per 1 GHz frequency span while in linear frequency sweep type.

Interpolated error correction functions in three sweep modes, linear frequency, power, and CW time.

Example Procedure for Specifying a User-Defined Electrical Calibration Kit

The following procedure enters the HP 85033C 3.5 mm calibration kit values as an example user kit 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 KITS & STDS] [ELECTRICAL] [7MM] [MODIFY]*
> *[DEFINE STANDARD] [SHORT]*
> *[SPECIFY OFFSET] [OFFSET DELAY] [.016695]* [G/n]
> *[STD OFFSET DONE] [STD DONE (DEFINED)]*

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

> *[DEFINE STANDARD] [2]* [x1] *[OPEN]*
> *[CO] [53]* [x1]
> *[C1] [150]* [x1]
> *[C2] [0]* [x1]
> *[C3] [0]* [x1]
> *[SPECIFY OFFSET] [OFFSET DELAY] [.014491]* [G/n]
> *[STD OFFSET DONE] [STD DONE (DEFINED)]*

The next sequence specifies standard #3, the low band load.

> *[DEFINE STANDARD] [3]* [x1] *[LOAD]*
> *[SPECIFY OFFSET] [MAXIMUM FREQUENCY] [6.001]* [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 KITS & STDS] [ELECTRICAL (7M*3.5MM)]*
> *[SAVE USER KIT] [USER KIT]*

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

RESPONSE CALIBRATION FOR REFLECTION MEASUREMENTS

The procedure described here is a frequency response only calibration that uses an S-parameter test set for a measurement of S11. It can also be used for S22 by substituting the corresponding softkey in the test set parameters menu.

A similar procedure can be performed with a transmission/reflection test set, using the input ports menu instead of the test set parameters menu (described in the Stimulus and Response Functions section.

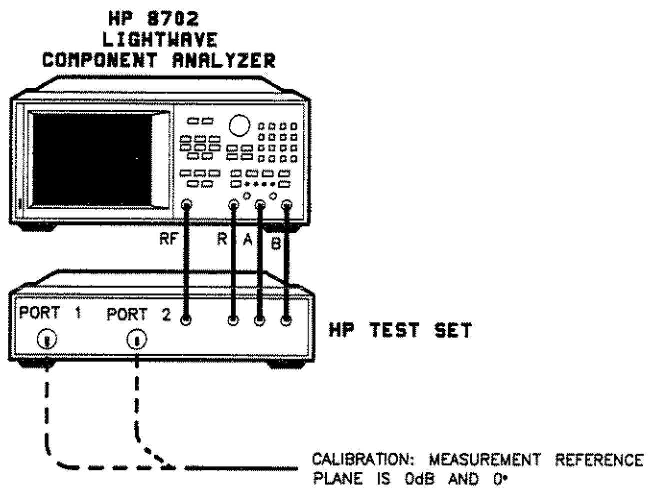


Figure 7-7. Setup for Electrical Measurement Calibration

Procedure

- Connect the system as shown in Figure 7-7. Setup the stimulus parameters for the measurement.
- Press **[CAL]** ***[DEVICE TYPE] [E/E]*** **[MEAS]** ***[ANNOTATION] [S11 (A/R)]***.
- Press **[CAL]** ***[CAL KITS & STDS] [ELECTRICAL]***.
- Select the connector type to be used. If the type to be used does not appear in the ***[CAL KIT]*** softkey label, select the ***[USER KIT]*** and ***[MODIFY]*** keys to define your standards.
- Press ***[RETURN] [RETURN] [CALIBRATE MENU] [RESPONSE]***.
- At port 1, connect either a short or a shielded 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]***. A corrected trace is displayed.

NOTE: It is recommended that calibration data be saved, either in analyzer memory or on an external disc. Refer to section 9 under Saving Instrument States.

- Now the test device can be connected and measured.

RESPONSE CALIBRATION FOR TRANSMISSION MEASUREMENTS

The procedure described here is a frequency response only calibration that uses an S-parameter test set 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 above on the other channel.

A similiar procedure can be performed with a transmission/reflection test set, using the input ports menu instead of the test set parameters menu (refer to the Stimulus and Response Functions section).

Procedure

- Press [CAL] *[DEVICE TYPE] [E/E]* [MEAS] *[ANNOTATION] [S21(B/R)]*.
- Press [CAL] *[CAL KITS & STDS] [ELECTRICAL]*.
- Select the connector type of the calibration kit to be used. If the connector type or cal kit name does not appear in the *[CAL KIT]* softkey label, select the *[USER KIT]* and *[MODIFY]* keys to define your standards.
- Press *[RETURN] [RETURN] [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]*. Corrected S21 data is displayed.

NOTE: It is recommended that calibration data be saved, either in analyzer memory or on an external disc. Refer to section 9 under Saving Instrument States.

- This completes the 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. Performance of this calibration requires an S-parameter test set for a measurement of S11. The same calibration can be used for S22 by substituting the corresponding softkey in the test set parameters menu.

A similar procedure can be performed with a transmission/reflection test set, using the input ports menu instead of the test set parameters menu (refer to the Stimulus and Response Functions section).

- Press [CAL] *[DEVICE TYPE] [E/E]* [MEAS] *[ANNOTATION] [S11(A/R)]*.

- Press [CAL] *[CAL KITS & STDS] [ELECTRICAL]*.
- Select the connector type of the calibration kit to be used. If the connector type or cal kit name does not appear in the *[CAL KIT]* softkey label, select *[USER KIT]* and *[MODIFY]* keys to define your standards.
- Press *[RETURN] [RETURN] [CALIBRATE MENU] [RESPONSE & ISOL'N] [RESPONSE]*.
- At port 1, connect either a short or a shielded 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 error coefficients are computed and stored. The response and isolation menu is displayed.
- Connect the isolation standard to port 1. This is an impedance-matched load (usually 50 or 75 ohms).
- Press *[ISOL'N STD]*. The S11 isolation data is measured. The softkey label is underlined.
- Press *[DONE RESP ISOL'N CAL]*. Corrected S21 cata is displayed.

NOTE: It is recommended that calibration data be saved, either in analyzer memory or on an external disc. Refer to section 9 under Saving Instrument States.

- This completes the response and isolation calibration for correction of frequency response and directivity errors for reflection measruements. 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 isolation errors for transmission measurements of devices with wide dynamic range. 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.

This procedure uses an S-parameter test set. A similar procedure can be performed with a transmission/reflection test set, using the input ports menu instead of the test set parameters menu. Refer to the Stimulus and Response Functions section.

- Press [MEAS] *[DEVICE TYPE] [E/E]* [MEAS] *[ANNOTATION] [S21 B/R]*.
- Press [CAL] *[CAL KITS & STDS] [ELECTRICAL]*.
- Select the connector type for the calibration kit to be used. If the connector type or cal kit name does not appear in the *[CAL KIT]* softkey label, select the *[USER KIT]* and *[MODIFY]* keys to define your standards.

- Press *[RETURN] [RETURN] [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]*.
- Connect impedance-matched loads to port 1 and port 2. Press *[ISOL'N STD]*. The trace is averaged and the S21 isolation is measured. The softkey label is underlined.
- Press *[DONE RESP ISOL'N CAL]*. Corrected S21 data is displayed and the notation "Cor" at the left of the screen indicates that correction is on for this channel.

NOTE: It is recommended that calibration data be saved, either in analyzer memory or on an external disc. Refer to section 9 under Saving Instrument States.

A similar procedure is used to calibrate for measurement of S12, using the *[S12 A/R]* softkey in the test set parameters menu.

RESPONSE CALIBRATION FOR A REFLECTION MEASUREMENT

The procedure described here is a frequency response only calibration with an S-parameter test set for a measurement of S11. It can also be used for S22 by substituting the corresponding softkey in the test set parameters menu.

A similar procedure can be performed with a transmission/reflection test set, using the input ports menu instead of the test set parameters menu (described in Stimulus and Response Functions section).

- Press **[CAL]** *[DEVICE TYPE] [E/E]* **[MEAS]** *[ANNOTATION] [S11 A/R]*.
- Press **[CAL]** *[CAL KIT & STDS] [ELECTRICAL]*.
- Select the connector type for the calibration kit to be used. If the connector type or cal kit name does not appear in the *[CAL KIT]* softkey label, select the *[USER KIT]* and *[MODIFY]* keys to define your standards.
- Press *[RETURN] [RETURN] [CALIBRATE MENU] [RESPONSE]*.
- At port 1, connect either a short OR a shielded 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]*. A corrected trace is displayed.

NOTE: It is recommended that calibration data be saved, either in analyzer memory or on an external disc. Refer to section 9 under Saving Instrument States.

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

S11 1-PORT CALIBRATION FOR REFLECTION MEASUREMENTS

This procedure uses the S11 1-port menu 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. The calibration described here uses an S-parameter test set: a similar procedure can be performed with a transmission/reflection test set, using the input ports menu instead of the test set parameters menu (described in Stimulus and Response Functions section).

Procedure

- Press [CAL] ***[DEVICE TYPE] [E/E] [RETURN] [CAL KITS & STDS] [ELECTRICAL]***.
- Select the connector type for the calibration kit to be used. If the connector type or cal kit name does not appear in the ***[CAL KIT]*** softkey label, select the ***[USER KIT]*** and ***[MODIFY]*** keys to define your standards.
- Press ***[RETURN] [RETURN] [CALIBRATE MENU] [S11 1-PORT]***.
- Connect a shielded 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 (usually 50 or 75 ohms) at port 1.
- When the trace settles, press ***[LOAD]***. The load data is measured and the softkey label is underlined.
- Press ***[DONE 1-PORT CAL]***. A corrected S11 trace is displayed with the notation "Cor" at the left side of the screen.

NOTE: It is recommended that calibration data be saved, either in analyzer memory or on an external disc. Refer to section 9 under Saving Instrument States.

- 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.

This calibration is used only with an S-parameter test set. For S-parameter measurements in the reverse direction with a transmission/reflection test set use the S11 1-port or one-path 2-port calibration and reverse the device under test between measurement sweeps.

FULL 2-PORT CALIBRATION FOR REFLECTION AND TRANSMISSION MEASUREMENTS

This procedure is a 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.

An S-parameter test set is required for this calibration. The procedure automatically switches the test set to select the appropriate S-parameter at each step. A similar two-port procedure can be performed with a transmission/reflection test set using the one-path 2-port calibration.

For protection of the mechanical transfer switch in the HP 85046A/B S-parameter test set, 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 extreme accuracy is required or in cases where the data changes significantly. To perform an override, use ***[MEASURE RESTART]*** in the stimulus menu, or for repeated update of all four S-parameters set an appropriate number of groups using the trigger menu. These menus are described in the Stimulus and Response Functions section.

Procedure

- Press [CAL] ***[DEVICE TYPE] [E/E] [RETURN] [CAL KITS & STDS] [ELECTRICAL]***.
- .Select the connector type for the calibration kit to be used. If the connector type or cal kit name does not appear in the ***[CAL KIT]*** softkey label, select the ***[USER KIT]*** and ***[MODIFY]*** keys to define your standards.
- Press ***[RETURN] [RETURN] [CALIBRATE MENU] [FULL 2-PORT] [REFLECTION]***.
- Connect a shielded 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 (usually 50 or 75 ohms) at port 1.
- When the trace settles, press (S11) ***[LOAD]***. The load data is measured, and the softkey label ***[LOAD]*** is underlined.
- Repeat the open-short-load measurements described above, connecting the devices in turn to port 2 and using the (S22) softkeys.
- Press ***[REFLECTION DONE]***.
- The two-port cal menu is displayed, with the ***[REFLECTION]*** 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 two-port cal menu is displayed, with the *[TRANSMISSION]* softkey underlined.
- If correction for isolation is not required, press *[ISOLATION] [OMIT ISOLATION] [ISOLATION DONE]*.
- If correction for isolation is required, connect impedance-matched loads to port 1 and port 2.
- Press *[FWD ISOL'N ISOL'N STD]*. The trace is averaged and the S21 isolation is measured. The softkey label is underlined.
- Press *[REV ISOL'N ISOL'N STD]*. The trace is averaged and the S12 isolation is measured. 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 *[DONE 2-PORT CAL]*. A corrected trace is displayed, with the notation "C2" at the left of the screen that indicates two-port error correction is on.

NOTE: It is recommended that calibration data be saved, either in analyzer memory or on an external disc. Refer to section 9 under Saving Instrument States.

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

ONE-PATH 2-PORT CALIBRATION FOR REFLECTION AND TRANSMISSION MEASUREMENTS

This procedure performs a two-port calibration without an S-parameter test set. This is a highly accurate calibration for measurements of two-port devices, and effectively removes all correctable systematic errors in one direction only.

For measurements of all four S-parameters, the device under test must be reversed between sweeps. The analyzer compatible calibration kits contain sets of phase-matched adapters that can be interchanged for measurements of non-insertable, non-reversible devices.

Procedure

- Press [CAL] *[DEVICE TYPE] [E/E] [RETURN] [CAL KITS & STDS]*.

- Select the connector type of the calibration kit to be used. If the connector type or cal kit name does not appear in the ***[CAL KIT]*** softkey label, select the ***[USER KIT]*** and ***[MODIFY]*** keys to define your standards.
- Press ***[RETURN] [RETURN] [CALIBRATE MENU] [ONE-PATH 2-PORT] [REFLECT'N]***.
- Connect a shielded open circuit to the test port.
- 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 the test port.
- When the trace settles, press ***[SHORT]***. The short circuit data is measured and the softkey label ***[SHORT]*** is underlined.
- Disconnect the short, and connect an impedance-matched load (50 or 75 ohms) to the test port.
- When the trace settles, press ***[LOAD]***. The load data is measured, and the softkey label ***[LOAD]*** is underlined.
- Press ***[REFLECTION DONE]***.
- The two-port cal menu is displayed, with the ***[REFLECTION]*** softkey underlined.
- Make a thru connection between the test port and the return cable to the network analyzer (connect together the points at which the test device will be connected). Press ***[TRANSMISSION]***.
- 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 ***[TRANS. DONE]***. The transmission coefficients are computed and stored. The two-port cal menu is displayed, with the ***[TRANSMISSION]*** softkey underlined.
- If correction for isolation is not required, press ***[ISOLATION] [OMIT ISOLATION] [ISOLATION DONE]***.
- If correction for isolation is required, connect impedance-matched loads to the test port and the return port.
- Press ***[FWD ISOL'N ISOL'N STD]***. The trace is averaged and the S21 isolation is measured. The softkey label is underlined.
- Press ***[ISOLATION DONE]***. The two-port cal menu is displayed, with the ***[ISOLATION]*** softkey underlined.
- Press ***[DONE 2-PORT CAL]***. A corrected trace is displayed, and the notation "C2" at the left of the screen indicates that 2-port error correction is on.

NOTE: It is recommended that calibration data be saved, either in analyzer memory or on an external disc. Refer to section 9 under Saving Instrument States.

- This completes the one-path 2-port calibration procedure. Now the test device can be connected and measured in the forward direction. When forward measurement is complete, disconnect the test device and manually reverse it, then press the softkey ***[PRESS to CONTINUE]***, or trigger another sweep using the trigger menu (Stimulus and Response Functions section).

Section 8. Using Markers

—CONTENTS OF THIS SECTION—

[MKR] KEY

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 8-1 illustrates the displayed trace with all markers on and marker 1 the active marker.

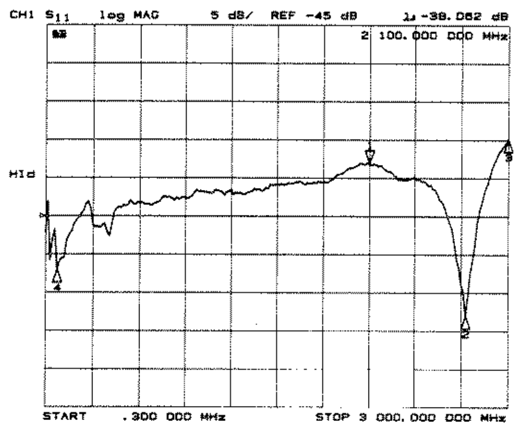


Figure 8-1. Markers on Trace

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.

Marker values are normally continuous: that is, they are interpolated between measured points. 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. 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.

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.

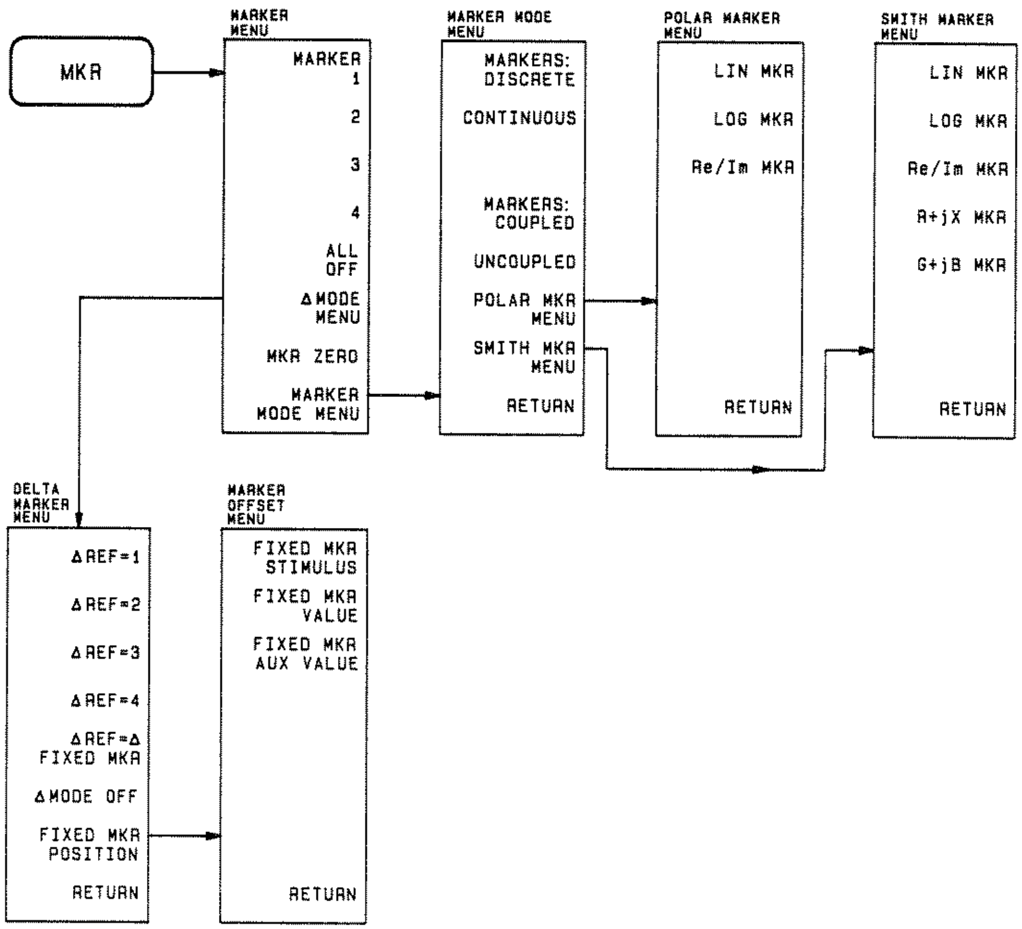


Figure 8-2. Menus Accessed from the [MKR] Key

The menus accessed from the **[MKR]** key (Figure 8-2) 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 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.

[MARKER 1] (MARK1) turns on marker 1 and makes it the active marker. The active marker appears on the CRT as ∇. The active marker response value is displayed in the active entry area, with the marker number. If there is a marker turned on, and no other function is active, the response value of the active marker can be controlled with the knob, the step keys, or the number pad.

[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 designated delta reference marker or a fixed point.

[MKR ZERO] (MARKZERO) puts a fixed zero reference marker at the present active marker position. 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. 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 reference. Any of the four markers or a fixed point can be designated as the reference. If the reference is one of the four markers, its stimulus can be controlled by the user and its response value is equal to the trace value 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.

[Δ REF = 1] (DELR1) establishes marker 1 as a reference.

[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 unlike markers 1 to 4, can be anywhere in the display area.

[FIXED MKR POSITION] leads to the fixed marker menu, where the stimulus and response values for a fixed reference marker can be set.

Alternatively, the current position of the active marker can be entered as the fixed reference by using ***[MARKER ZERO]*** in the marker menu.

[Δ MODE OFF] (DELO) turns off the delta marker mode. Now the values displayed for the active marker are absolute values.

[RETURN] goes back to the marker menu.

Fixed Marker Menu

This menu 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. 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. This 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.

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.

If the format is changed while a fixed marker is on, the fixed marker values become invalid.

[FIXED MKR STIMULUS] (MARKFSTI) changes the stimulus value of the fixed marker. 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, reset the stimulus value 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, reset the response value 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, reset the auxiliary value to zero.

[RETURN] goes back to the delta marker menu.

Marker Mode Menu

This menu provides different marker modes and two additional menus of special markers for use with Smith chart or polar formats.

[MARKERS: DISCRETE] (MARKDISC) places markers only on measured trace points determined by the stimulus settings.

[CONTINUOUS] (MARKCONT) interpolates between measured points so the markers can be placed at any point on the trace. Displayed marker values are also interpolated. 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.

[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, selected in the **[FORMAT]** menu. In a 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.

[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.

[RETURN] goes back to the marker mode menu.

Smith Marker Menu

This menu is intended for measurements of electrical devices and is used only with a 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."

[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] (SIMIMLOG) 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 $M \cos \theta$, and the second value is the imaginary part $M \sin \theta$, where $M =$ magnitude.

[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.

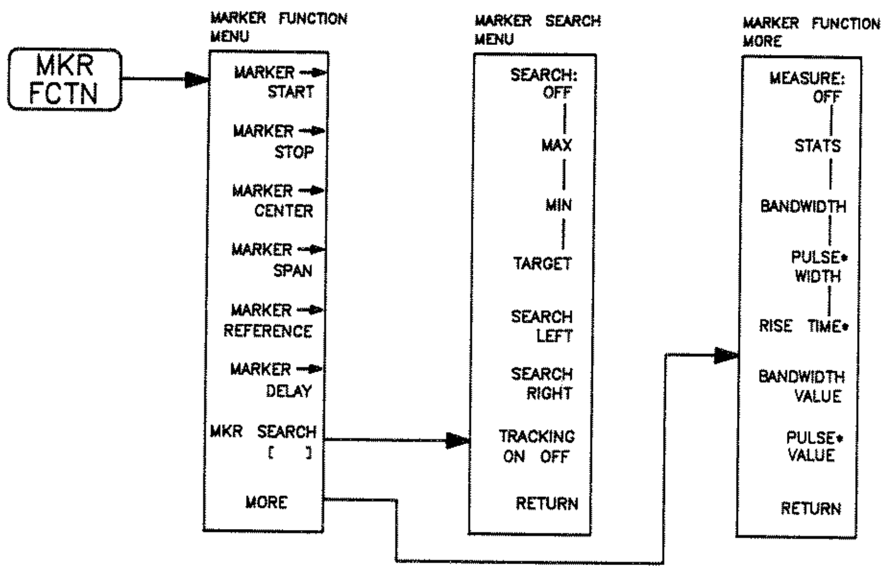
The normalized impedance Z0 for characteristic impedances other than 50 ohms can be selected in the calibrate more menu (section 7).

[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.



* Available with option 010 (time domain)

Figure 8-3. Menus Accessed from the [MKR FCTN] Key

Marker Function Menu

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.

[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 to 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.

[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) adjusts the electrical delay to balance the phase of the DUT. This is performed automatically, regardless of the format and the measurement being made. 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. Since this feature adds phase to a variation in phase versus frequency, it is applicable only for ratioed inputs. This softkey also appears in the scale reference menu.

[MARKER SEARCH] leads to the marker search menu, which is used to search the trace for a particular value or bandwidth.

[MORE] leads to the marker function more menu that accesses marker measurement functions.

Marker Search Menu

This menu is used to search the trace for a specific amplitude-related point, or specified bandwidth, and place the marker on that point. Tracking is also available for a continuous sweep-to-sweep search.

[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 −3dB. The target menu is also 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.

[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.

[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 analyzer 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.

Marker Function More Menu

[MEASURE off] (MEASOFF) clears the CRT of measurement annotation.

[STATS 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.

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).

[BANDWIDTH] (WIDT) turns on bandwidth search and calculates the bandwidth, the center point of the bandwidth, and Q (quality factor) of a bandpass or band reject shape on the trace.

All four markers are turned on, and each has a dedicated use. Marker 1 is at a starting point from which the search is begun, initially placed at the maxium point on the trace. Marker 2 is at the bandwidth center point. Marker 3 is at the bandwidth cutoff point on the left, and marker 4 is at the cutoff point on the right.

*~~~~***[PULSE WIDTH]*** (PULW) turns on pulse width search and calculates the pulse width.

All four markers are turned on, and each has a dedicated use. Marker 1 is at a starting point from which the search is begun, initially placed at the maximum point on the trace. Marker 2 is at the minimum point on the trace. (This point can be used as a reference when selecting the pulse value.) Marker 3 is at the pulse width cutoff point on the left, and marker 4 is at the cutoff point on the right.

****[RISE TIME]*** (RIST) turns on rise time search and calculates the rise time.

All four markers are turned on, and each has a dedicated use. Marker 1 is at a starting point from which the search is begun, initially placed at the maximum point on the trace. Marker 2 is at the minimum point on the trace. Marker 3 is at a default value of 10% of the trace maximum and marker 4 is at a default value of 90% of the trace maximum.

[BANDWIDTH VALUE] (WIDV) is used to set the amplitude parameter (for example 3 dB) that defines the start and stop points for a bandwidth search. Bandwidth units are the same as the current format.

****[PULSE VALUE]*** (PULV) is used to set the amplitude parameter that defines the start and stop points for a pulse width search. (The default value is 50%).

[RETURN] goes back to the marker search menu.

* Available with option 010 (time domain).

Section 9. Instrument State Functions

—CONTENTS OF THIS SECTION—

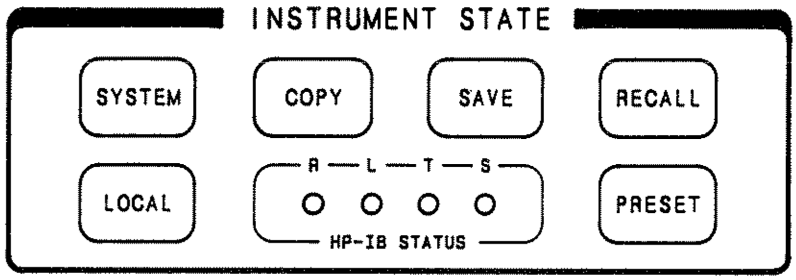


Figure 9-1.

INSTRUMENT STATE FUNCTION BLOCK

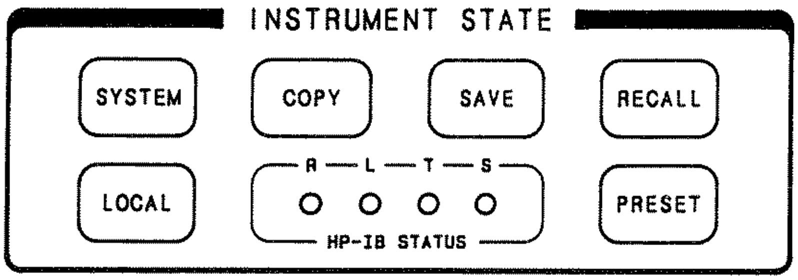


Figure 9-2

This chapter discusses the instrument state function block keys and associated menus that provide control of channel-independent system functions. These include controller modes, instrument addresses, HP-IB status information, and saving instrument states either in internal memory or on an external disc.

Limit testing, which compares measured data with user-defined limits, is also available in this function block, as well as options 010 (time domain transform function) and 006 (6 GHz operation). In addition, the service menus are accessed from these keys.

[LOCAL KEY]

This key is used to return the analyzer to local (front panel) operation from remote (computer controlled) operation. 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.

In addition, this key gives access to the HP-IB menu that sets the controller mode, and to the address menu where the HP-IB addresses of peripheral devices are entered.

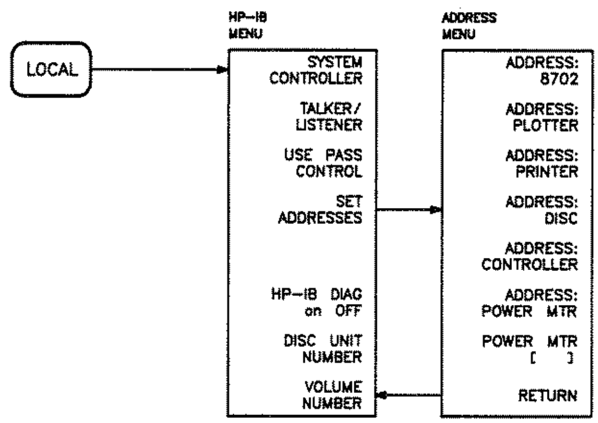


Figure 9-3. Softkey Menus Accessed from the [LOCAL] Key

HP-IB Menu

The analyzer has a remote programming interface called HP-IB, (Hewlett-Packard Interface Bus). This enables communication between the analyzer, 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.

Preset does not affect the selected controller mode, but cycling the power returns the analyzer to talker/listener mode.

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 the current status of the analyzer.

R = Remote operation.
L = Listen mode.
T = Talk mode.
S = Service request (SRQ) asserted by the analyzer.

Complete detailed information on all aspects of HP-IB operation of the analyzer is provided in the HP-IB Programming section.

[SYSTEM CONTROLLER] is the mode used when the analyzer controls peripheral devices.

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 analyzer front panel, and can be used only if no active computer controller is connected to the system through HP-IB. 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 analyzer and all peripheral devices are controlled from an external controller. Therefore, the analyzer can be either a talker or a listener, as required by the controlling computer for the particular operation in progress.

[USE PASS CONTROL] (USEPASC) lets you control the analyzer with the computer controller over HP-IB as with the talker/listener mode, and also allows the analyzer to become a 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 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.

[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 to debug a program the first time. When you use this command, the analyzer scrolls a history of incoming HP-IB commands across the display in the title line. Nonprintable characters are represented as π. If a syntax error is received, the commands halt and a pointer indicates the misunderstood character.

[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.

[VOLUME NUMBER] (DISCVOLU) specifies the number of the disc volume to be accessed. In general, all 3 1/2'' 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 HP-IB, each instrument on the bus is identified by an HP-IB address. 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 do not need to 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)
Analyzer	16
Plotter	05
Printer	01
External Disc Dive	00
Controller	21
Power Meter (service)	13

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 in the analyzer softkey label 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 switch: its address is set only from the front panel.

These addresses are stored in short-term non-volatile memory and are not affected by preset or by cycling the power.

[ADDRESS: 8702] sets the HP-IB address of the analyzer, using the entry controls. There is no physical address switch to set in the analyzer.

[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.

[ADDRESS: POWER MTR] (ADDRPOWM) sets the HP-IB address the analyzer will use to communicate with the power meter used in service routines.

[POWER MTR] (POWM) toggles between ***[438A]*** and ***[436A]***. The HP 438A and 436A are the two power meters compatible with the analyzer. The model number in the softkey label must match the power meter to be used.

[RETURN] goes back to the HP-IB menu.

[SYSTEM] KEY (MENUSYST)

This key presents the system menu, which provides access to four additional series of menus (five with option 006).

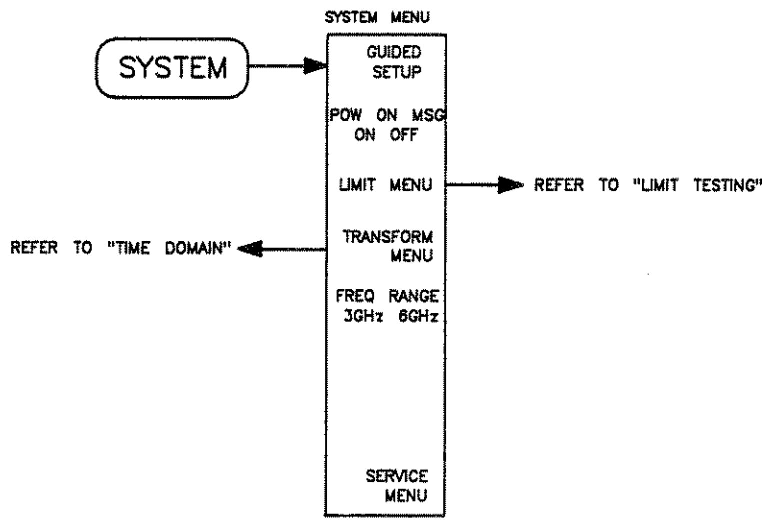


Figure 9-4. The System Menu

[GUIDED SETUP] leads to a series of graphic menus used as a guide to setting up a basic measurement.

[POW ON MSG on off] (POWOM) is used to turn on or off the message that appears on the display at instrument power on. The message includes instructions on GUIDED SETUP and NORMAL OPERATION. The default is on, but the state is not changed by PRESET or instrument power on.

[LIMIT MENU] leads to a series of menus used to define limits or specifications to compare with a test device. Refer to the following paragraphs titled "Limit Lines and Limit Testing."

[TRANSFORM MENU] 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 the Time Domain section.

[FREQ RANGE 3 GHz 6 GHz] (FREQRANG 3 GHz, FREQRANGE 6 GHz) toggels between two frequency ranges when equipped with option 006:

- 300 kHz to 3 GHz
- 3 MHz to 6 GHz

This softkey appears under the system menu, after power-on when in normal operation (or with Pow on MSG on) and at preset.

[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 of device specifications to compare to 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.

Limits can be defined independently for the two channels, up to 15 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 five ways: a FAIL message on the screen, a beep, portion of trace out of limit turns RED, an asterisk in tabular listings of data, and a bit in the HP-IB event status register B.

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. The limit testing PASS/FAIL is displayed as green for PASS; red for FAIL.

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.

It is possible for a device to be out of specification without a limit test failure indication if the point density is insufficient. Limits are checked only at the measured data points. 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 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. For more information on list value features, refer to the Copy Functions: Printing and Ploting section.

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.

The series of menus for defining limits is accessed from the **[SYSTEM]** key. These menus are illustrated in Figure 9-5.

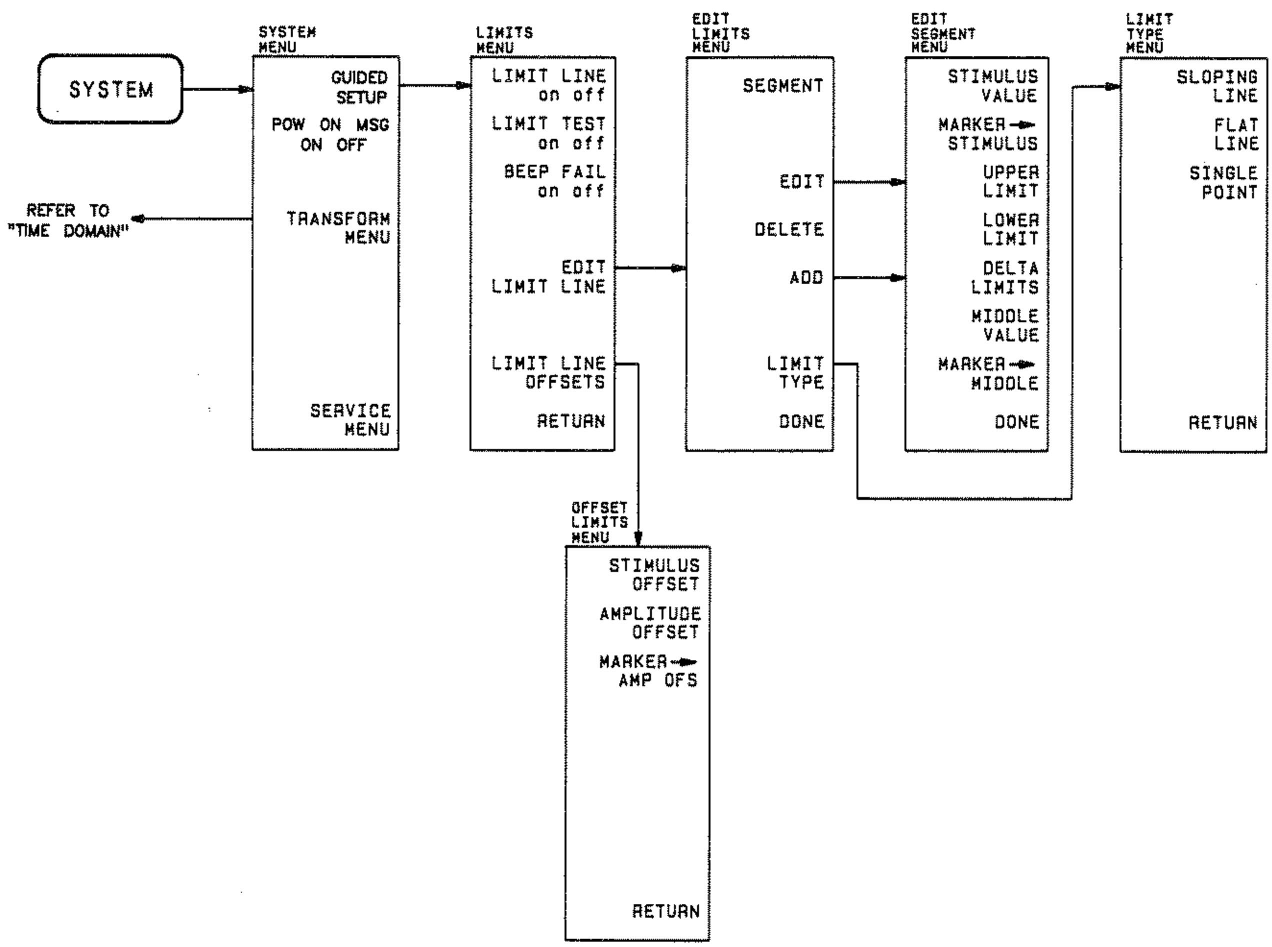


Figure 9-5. The Limit Softkey Menu Series

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.

[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.

[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.

[BEEP FAIL on off] (BEEPFAILON, BEEPFAILOFF) turns the limit fail beeper on or off. The limit fail beeper is independent of the warning beeper and the operation complete beeper.

[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.

[LIMIT LINE OFFSETS] leads to the offset limits menu, which is used to offset the complete limit set in either stimulus or amplitude value.

[RETURN] goes back to the system menu.

Edit Limits Menu

This menu 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. Each segment is a portion of the stimulus span. Up to 15 limit segments can be specified for each channel. The limit segments do not have to be entered in any particular order.

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 plotted on the CRT.

[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.

[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, power, 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.

[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 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 limit values can be defined as upper and lower limits, or delta limits and middle value.

Segments do not have to be listed in any particular order. 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.

[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 line segment. No more than one segment can be defined over the same stimulus range.

[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 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 +500 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.

[LOWER LIMIT] (LIML) sets the lower limit 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 −500 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.

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 amplitude value vertically centered between the limits.

[MARKER →MIDDLE] (MARKMIDD) sets the midpoint for ***[DELTA LIMITS]*** using the active marker to set the middle amplitude 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.

[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.

[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 stop stimulus. 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 stop stimulus. 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 γ, and the lower limit is displayed as λ. A limit test at a single point not terminating a flat or sloped line tests the nearest actual measured data point.

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 γ and λ. The indication for a single point 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.

[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.

[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.

SAVING INSTRUMENT STATES

The analyzer has five internal registers for saving complete instrument states, and can use direct disc access as an extension to internal memory.

NOTE: 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.

Refer to the HP-IB Programming section for a detailed explanation of 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 the line power to the instrument.
- External memory. This utilizes disc media for unlimited storage of instrument states, calibration and measurement data.

Table 9-1. Analyzer Memory Usage

Non-Volatile Memory
Five learn string registers
CRT intensity defaults
HP-IB configuration
User calibration kit definition
Volatile Memory (see Table 9-2)
User graphics (5K bytes)
Calibration data
Current instrument state
Data processing and display
Save colors (HP 8702B only)
External Memory
Instrument states
Calibration sets
Measurement data

INSTRUMENT STATES

An instrument state consists of all the stimulus and response parameters that set up the analyzer to make a specific measurement. This part of the instrument state is called the learn string and, when saved, is saved to non-volatile memory.

An instrument state also includes calibration data and memory traces. This data is stored in volatile memory and will be lost when line power to the instrument is turned off.

Calibration sets compete with other instrument processes for volatile memory space. Table 9-2 contains the memory requirements of calibration arrays and other functions. Use table 9-2 to approximate available space.

Table 9-2. Analyzer User Allocatable Memory (1 of 2)

Variable	Data Length (bytes)
Calibration Arrays	N x 6 +52
Response	
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	N x 6 +52
· Raw Data*	
Correction Data	
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[1]	N x 6 +52
Display Memory*	N x 2
Trace (Data or Memory)	
(If polar, log frequency, or frequency list mode)	N x 4
Graticule	196
Rectangular	
Semilog	420
Polar	1956
Smith or Inverted Smith	4000
Limit Lines*	32 x number of segments

Notes:

N = number of points

* This variable is allocated once per active channel.

1. Insufficent memory for allocation of this array is not fatal. The array is used to recalculate the data for display anytime formatting factors are changed. If not allocated, trace data will not be redisplayed after a scaling change until a new sweep occurs.

2. Not used when error correction is on.

Table 9-2. Analyzer User Allocatable Memory (2 of 2)

Variable	Data Length (bytes)
Operating Modes	
Sampler Correction Arrays[2]	≤N x 4
Smoothing ON* (20% aperture, 1601 points)	<2000
Frequency List mode*	N x 12
Log Frequency mode*	N x 12
Time Domain	
FFT Array	
≤51 points	128 x 6
101 points	256 x 6
201 points	512 x 6
401 points	1024 x 6
801 points	5000 x 6
1601 points	5000 x 6
Window & Chirp Array	N x 4 +FFT array size
Gating Array	≅5/3 x FFT array size

Notes:

N =number of points

* This variable is allocated once per active channel.

1. Insufficent memory for allocation of this array is not fatal. The array is used to recalculate the data for display anytime formatting factors are changed. If not allocated, trace data will not be redisplayed after a scaling change until a new sweep occurs.

2. Not used when error correction is on.

INTERNAL SAVE

A maximum of six instrument states can reside in internal memory at any one time: five saved states and the active instrument 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 number may be limited by available memory). When an instrument state is deleted from memory (see "***[CLEAR REGISTER]***"), the associated calibration set is also deleted.

EXTERNAL STORE

With the analyzer in system controller mode or pass control mode, it can access an external CS80 disc drive. Storing to external disc records not only the instrument state, but calibration sets and measurement data (see "***[DEFINE STORE]***").

The analyzer uses one file name per stored instrument state when communicating with the user via the front panel display. Several files are actually stored to the disc when an instrument state is stored. Thus, when the disc catalog is accessed from a remote system controller, the directory will show several files associated with a particular saved state. See the HP-IB Programming section for further information.

If correction is on at the time of an external store, and not currently marked "externally stored", the calibration set is stored to disc. The "externally stored" tag is then applied to the active calibration. In this way, if the same calibration set is active for multiple instrument state saves, duplicate calibration files are not recorded on the disc.

If correction is on for the restored state, the analyzer first searches internal memory for a valid calibration set. (This requires a match between the critical stimulus parameters plus calibration title in the learn string and those of the calibration set).

If the user chooses to recalibrate the instrument, the calibration title remains the same. Therefore any of the old instrument states will use the new calibration. If any state is restored to disc, the new calibration set will be written over the old calibration set because it is not marked "externally stored".

[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.

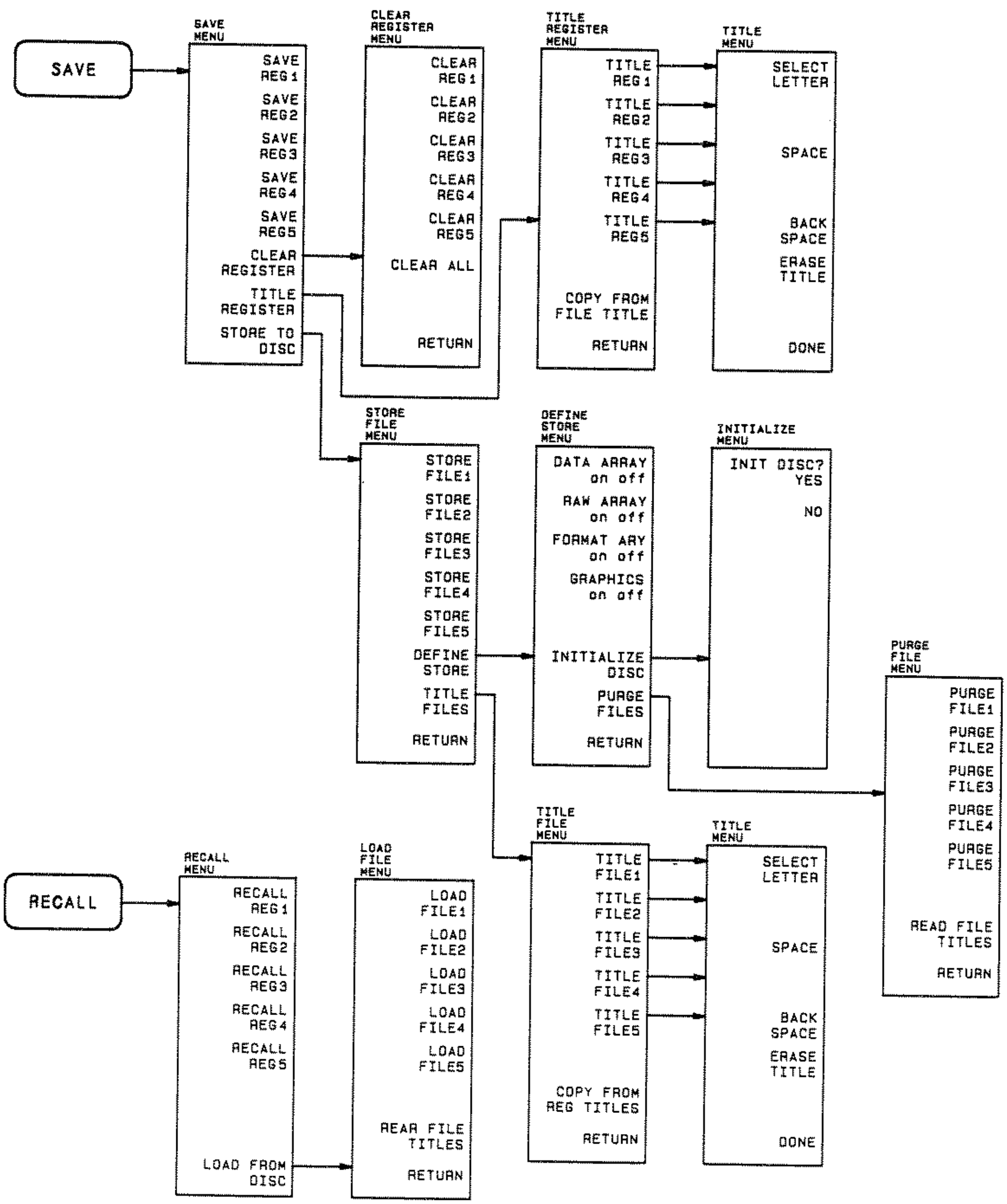


Figure 9-6. Softkey Menus Accessed from the [SAVE] and [RECALL] Keys

Save Menu

This menu 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 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.

[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 allows unused instrument states to be cleared from save registers. When an instrument state is deleted from memory, the associated calibration set is also deleted if it is no longer needed by any other state. You can choose to selectively clear individual registers, or clear all registers with one keystroke.

Only registers that have instrument states previously stored in them are listed in this 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.

[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.

[RETURN] goes back to the save menu.

Title Menu

Use this menu 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.

The register title is limited to eight characters. The title must be all alpha-numeric, and must start with an alpha character. No special characters or spaces are allowed.

The save register title is independent of the display title, which is also saved and recalled as part of the display.

[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.

[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 is used to store instrument states to an external disc rather than to internal memory registers. The HP analyzer can use HP-IB to store directly to an external disc drive. Refer to the General Information section of this manual for information about compatible disc drives.

To store information on an external disc from the front panel when there is no other controller on the bus, the HP analyzer must be in system controller HP-IB mode. If there is another controller on the bus, the HP analyzer must be in pass control mode. Refer to "**[LOCAL]** Key" in this chapter and to the HP-IB Programming section for information on HP-IB controller modes and setting addresses.

Note that if an instrument state has previously been stored with calibration on, the calibration is remembered and is not stored again, to maximize the storage space available. Refer to "External Store" earlier in this chapter for details.

[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. You can use this menu to specify what data is to be stored on disc 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 disc 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" in the General Information section for more information about data arrays and the sequence of data processing events.

[DATA ARRAY on off] (EXTMDATAON, EXTMDATAOFF) specifies whether or not to store the error-corrected data on disc with the instrument state.

[RAW ARRAY on off] (EXTMRAWON, EXTMRAWOFF) specifies whether or not to store the raw data (ratioed and averaged) on disc with the instrument state.

[FORMAT ARY on off] (EXTMFORMON, EXTMFORMOFF) specifies whether or not to store the formatted data on disc with the instrument state.

[GRAPHICS on off] (EXTMGRAPON, EXTMGRAPOFF) specifies whether or not to store display graphics on disc with the instrument state.

[INITIALIZE DISC] (INID) leads to the initialize menu.

[PURGE FILES] leads to the purge files menu, which is used to purge the information stored on an external disc.

[RETURN] goes back to the store file menu.

Initialize Disc Menu

Initializing a disc prepares it to store data. A disc must be initialized for compatible format before it can be used for storage. This menu initializes discs using LIF (logical interchange format) to provide compatibility with HP 9000 series 200/300 computers. A disc initialized on one of these computers will work with the analyzer. Only the gray double-sided discs are recommended with the disc drives used for storage.

[INIT DISC? YES] initializes the disc unit number and volume number selected in the HP-IB menu. If more than one volume is to be initialized, each volume must be selected and initialized individually.

If the disc is damaged, the message "INITIALIZATION FAILED" is displayed.

NOTE: The wrong files could be purged with incorrect addresses.

[NO] leaves this menu without initializing the disc.

Purge File Menu

This menu is used to remove (purge) instrument states from a disc. When the purge file menu is entered, the file titles currently in analyzer memory are displayed. (File titles are stored in non-volatile memory.) These titles may or may not reside on the disc currently being used. The file titles can be updated by reading the disc's directory with the ***[READ FILE TITLES]*** key.

The purge file menu is the disc equivalent of the clear register menu.

[PURGE FILE1] (PURG1) purges FILE1 from disc.

[PURGE FILE2] (PURG2) purges FILE2 from disc.

[PURGE FILE3] (PURG3) purges FILE3 from disc.

[PURGE FILE4] (PURG4) purges FILE4 from disc.

[PURGE FILE5] (PURG5) purges FILE5 from disc.

[READ FILE TITLES] (REFT) searches the directory of the disc 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.

[RETURN] goes back to the define store menu.

Title File Menu

This menu is used to select a disc 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.

[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 disc). 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.

When the recall menu is displayed, only the names of those registers containing instrument states are displayed in the top five softkey labels.

[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 DISC] accesses the load file menu. Use this menu to restore instrument states previously stored to disc.

Load File Menu

This menu is used to search the directory of a floppy disc and to restore instrument states previously stored to that disc.

There are three ways to locate a file on disc.

1. The analyzer remembers the names of the last five files it previously found on any disc. (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 disc currently in the drive.

2. The ***[READ FILE TITLES]*** key causes the analyzer to search the directory of the current disc 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. This method is useful only if you know the exact name of the instrument state to be restored.

[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 disc 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.

[RETURN] goes back to the recall menu.

Section 10. Time Domain

INTRODUCTION

The analyzer measures in the frequency domain, yielding such parameters as: bandwidth, insertion loss, return loss and impedance. The time domain feature can then convert the frequency domain data into the time domain, where the impulse or step response of the device can be used to better understand the operation of the device.

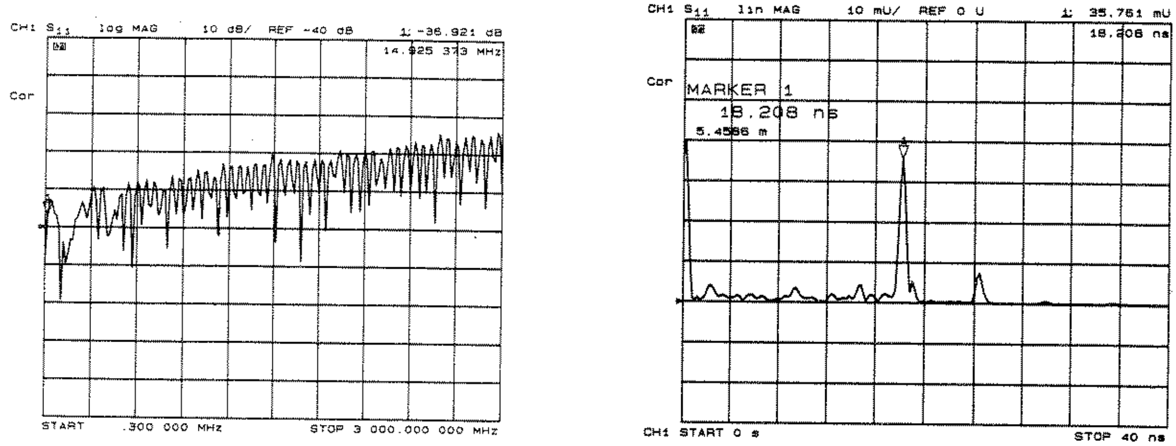
In normal operation, the analyzer measures a device under test's (DUT) characteristics as a function of frequency (the horizontal display axis is scaled in frequency units). In time domain the horizontal display axis is scaled in time units. Responses now appear separated in time or distance.

This section explains the time domain: general theory, modes of operation available, measurement applications, outline for making measurements, associated concepts, and transformation of CW measurements into the frequency domain.

GENERAL THEORY

The analyzer makes time domain measurements by translating frequency domain information to the time domain. The concept of equivalent domains was developed in waveform analysis by J.B.J. Fourier. He asserted that any repetitive waveform can be represented by a series of harmonically related sine waves. Given a series of coefficients in the frequency domain, there must be an equivalent repetitive time domain waveform. The superposition property of linear devices tells us that the Fourier transform of the output frequencies is equivalent to the response of the device to the Fourier transform of the input frequencies. 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 resulting measurement is the fully error-corrected time domain reflection or transmission response of the DUT, displayed in near real time.

Figure 10-1 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. The time domain reflection measurement illustrates the effect of each discontinuity as a function of time (or distance), and shows that the device response consists of three separate impedance changes.



a. Frequency Domain *b. Time Domain*

Figure 10-1. Frequency Domain and Time Domain Reflection Response of a Device

Marker 1 on the time domain trace shows the round-trip time to the discontinuity and back to the reference plane (established with a Fresnel measurement calibration): 18.2 nanoseconds. The distance shown (5.45 metres) assumes that the signal travels at the speed of light. If the signal travels slower than the speed of light, the slower velocity can be compensated for by adjusting the analyzer relative velocity factor for electrical devices or the index of refraction for optical devices.

In the case of a non-terminated optical cable, the discontinuity at marker 1 could be two FC connectors without an index matching compound. The reflection coefficient magnitude is therefore displayed as 35.781 mU (milli units) which is a Fresnel reflection equal to 3.5% reflected optical power. The third small discontinuity could be a splice which has degraded, thus the Fresnel reflection appears considerably less than the FC-FC connection shown at the marker.

Table 10-1. Time Domain Reflection Display Formats

Format	Parameter
LIN MAG	I Reflection Coefficient I (unitless) $(0 < \rho < 1)$
REAL	Reflection Coefficient (unitless) $(-1 < \rho < 1)$
LOG MAG	Return Loss (dB)
SWR	Standing Wave Ratio (unitless)
SMITH CHART	Impedance (ohms)

Table 10-1 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 section.

Transform Menus

The time domain transform menus are accessed using the **[SYSTEM]** key and are illustrated in Figure 10-2 below.

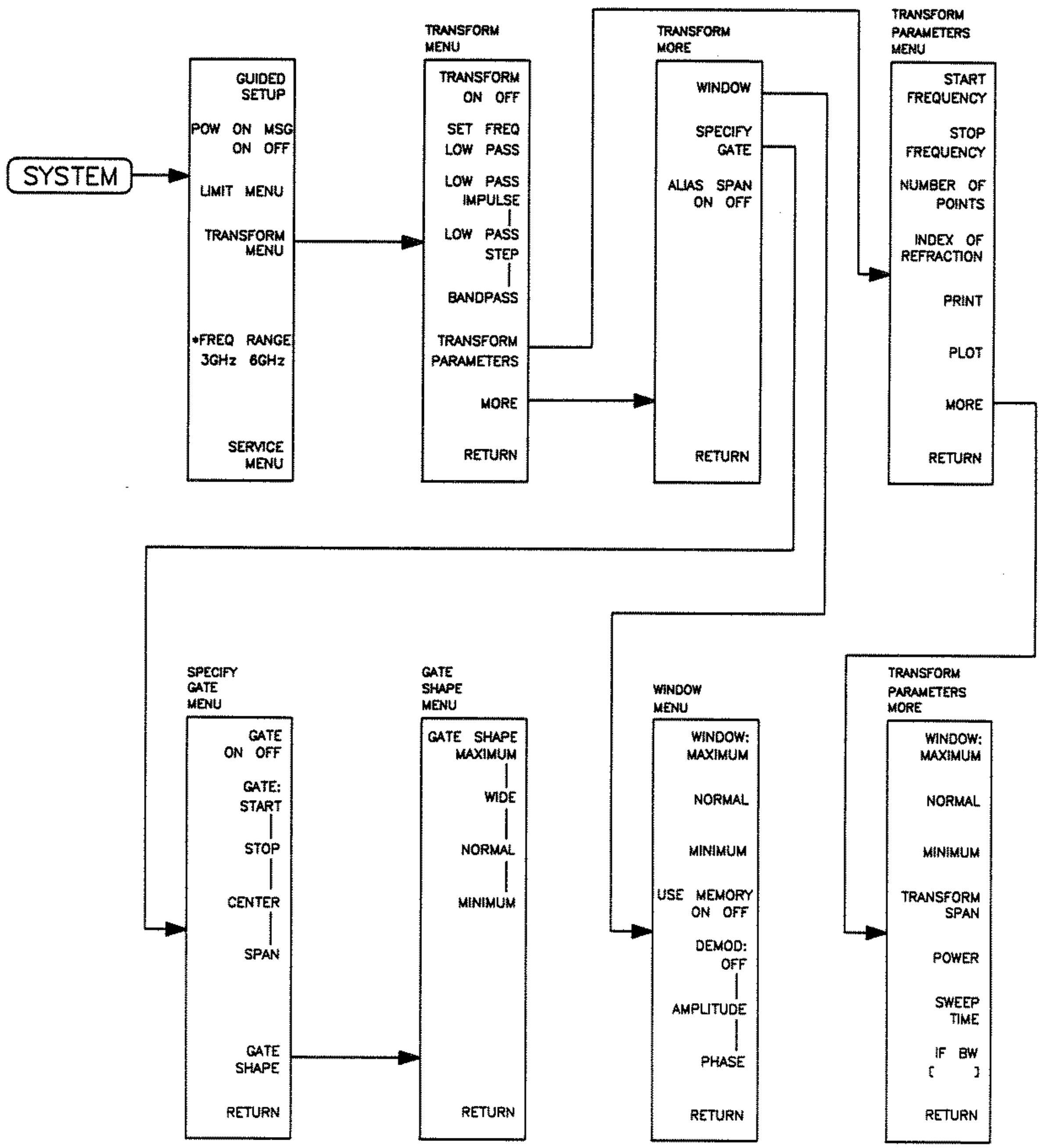


Figure 10-2. The Time Domain Transform Menus

Operation Modes

The analyzer has two different modes of operation for time domain measurements: bandpass and low pass.

The time bandpass mode gives the impulse response of the device. It is also used for measuring band-limited devices and making fault location measurements. This mode will work with any device, over any frequency range, and is the simplest mode to use. It is also the default mode for optical measurements.

The time low pass mode is used to simulate the Time Domain Reflectometer (TDR) measurement for electrical devices. This mode calculates the step or impulse response. The step response is most commonly used in reflection measurements to identify the location and complex impedance of elements inside the electrical device under test. The impulse response is for identifying multi path responses in transmission measurements on broad band devices.

The analyzer has one time-to-frequency transform mode:

- The forward transform mode transforms CW signals measured over time into the frequency domain, to measure the spectral content of a signal.

TIME DOMAIN BANDPASS

In this mode, the analyzer calculates the response of the device stimulated by an RF modulation burst. It places no restrictions on the measured frequencies as in the low pass mode. The RF burst has twice the effective pulse width as the low pass impulse. The magnitude of the bandpass response looks like the magnitude of the low pass impulse response, with twice the pulse width. Only the log and linear magnitude of the bandpass response is generally useful. The real display format is not used.

Reflection Measurements Using Bandpass Mode

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 to return.

With a marker, both the time (×2) and the electrical length (×2) to the discontinuity are displayed on the analyzer screen. The electrical length is obtained by multiplying the time by the velocity of light in free space. To get the physical length, multiply the displayed electrical length by the relative velocity of light in the transmission medium, or use the analyzer velocity factor function:

1. Press **[CAL]** ***[MORE] [VELOCITY FACTOR]*** or ***[INDEX OF REFRACTION]***.
2. Enter a velocity factor between 0 and 1.0 (1.0 corresponds to the speed of light in a vacuum) or an index of refraction greater than 1.0.

NOTE: To cause the markers to read the one-way distance to a discontinuity, enter one-half the actual velocity factor or twice the index of refraction.

In the time domain, the stimulus keys (START, STOP, CENTER, and SPAN) refer to time. They can be used to change the horizontal (time) axis of the display independent of the frequency range chosen. This can be done by using the knob, step keys, or the keypad. The keypad terminators also refer to time in seconds (e.g. to enter 10 picoseconds, press **[0.01] [G/n]**).

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.

The time bandpass response gives the magnitude of the reflection only and has no impedance information (R, L, or C) for electrical devices. This information is available in the time low pass response.

Transmission Measurements Using Bandpass Mode

The time bandpass mode is useful in making transmission measurements. It provides the means to analyze the length and loss of multiple signal propagation paths of the device. The bandpass mode can also transform transmission measurements to the time domain for dispersion measurements.

Interpreting the Bandpass Transmission Response Horizontal Axis. In time domain transmission measurements, the horizontal axis is displayed in units of time. The response of the thru connection used in the measurement calibration is an impulse at $t = 0$ seconds and with unit height, indicating that the impulse made it through in zero time and with no loss. When a device is inserted, the time axis indicates the propagation delay or electrical length of the device. Note that in time domain transmission measurements, the value displayed is the actual delay (not $\times 2$). The marker provides the propagation delay in both time and distance. You must multiply the distance number by the relative velocity of the transmission medium to get the actual physical length, or use the analyzer velocity factor or index of refraction function.

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 (τ). This can be thought of as an average of the transmission response over the measurement frequency range.

TIME DOMAIN LOW PASS

The time low pass mode has two types of transform modes:

1. The time low pass step mode simulates the time domain response to a step input. As in an electrical TDR measurement, the distance to the discontinuity in the DUT and the type of discontinuity (resistive, capacitive, inductive) can be determined.

2. The time domain impulse mode simulates the time domain response to an impulse input. It is possible to accurately locate responses as a function of time and estimate the magnitude of the responses. Both low pass modes yield better time domain resolution for a given frequency span than does the bandpass mode.

The time low pass requires that the frequency domain data points be harmonically related from dc to the stop frequency (STOP $= n \times$ START, where n = number of points). The dc frequency response is extrapolated from the low frequency data. The requirement to pass dc is the same limitation that exists for traditional TDR measurements. The measured frequencies become the spectral lines of an impulse or step train. Therefore, the spacing of the spectral lines becomes the impulse or step repetition rate.

Setting Frequency Range for Time Domain Low Pass

Before making a low pass mode measurement, ensure that the measurement frequency range meets the stop = $n \times$ start requirement mentioned above.

NOTE: If the start and stop frequencies do not conform to the low pass requirement before either low pass mode is selected, the analyzer sets the start and stop frequencies to meet this requirement when the ***[SET FREQ LOW PASS]*** key is pressed. However, the calibration frequency range is changed and error correction is turned off.

The lowest analyzer modulation frequency is 300 kHz or 3 MHz for the 6 GHz system. Because of this, for each value of *n* there is a minimum allowable stop frequency that can be used. Table 10-2 lists the minimum frequency range that can be used for each value of *n* when making low pass time domain measurements where the stop frequency = start F $\times$ number of points.

Table 10-2. Minimum Frequency Ranges for Time Domain Low Pass

Number of Points	Minimum Frequency Range
3	300 kHz to 0.9 MHz
10	300 kHz to 3.0 MHz
26	300 kHz to 7.8 MHz
51	300 kHz to 15.3 MHz
101	300 kHz to 30.3 MHz
201	300 kHz to 60.3 MHz
401	300 kHz to 120.3 MHz
801	300 kHz to 240.3 MHz
1601	300 kHz to 480.3 MHz

Analyzing Time Low Pass Reflections of Electrical Devices

As mentioned earlier, time low pass gives the electrical TDR response of the device under test. This response contains information that is useful in determining the type of discontinuity present. Before making measurements using time low pass mode, it is helpful to review the time low pass response of a known discontinuities as shown in Figure 10-3. Each circuit element was simulated to show the corresponding low pass time domain S_{11} response waveform.

Reflection Measurements Using Time Low Pass

Interpreting the Low Pass Reflection 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 time ($\times$2) and the electrical length ($\times$2) along the trace. To determine the actual physical length, multiply by the relative velocity of light in the propagation medium, or use the velocity factor or index of refraction function.

Interpreting the Low Pass Reflection Vertical Axis. 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.

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.

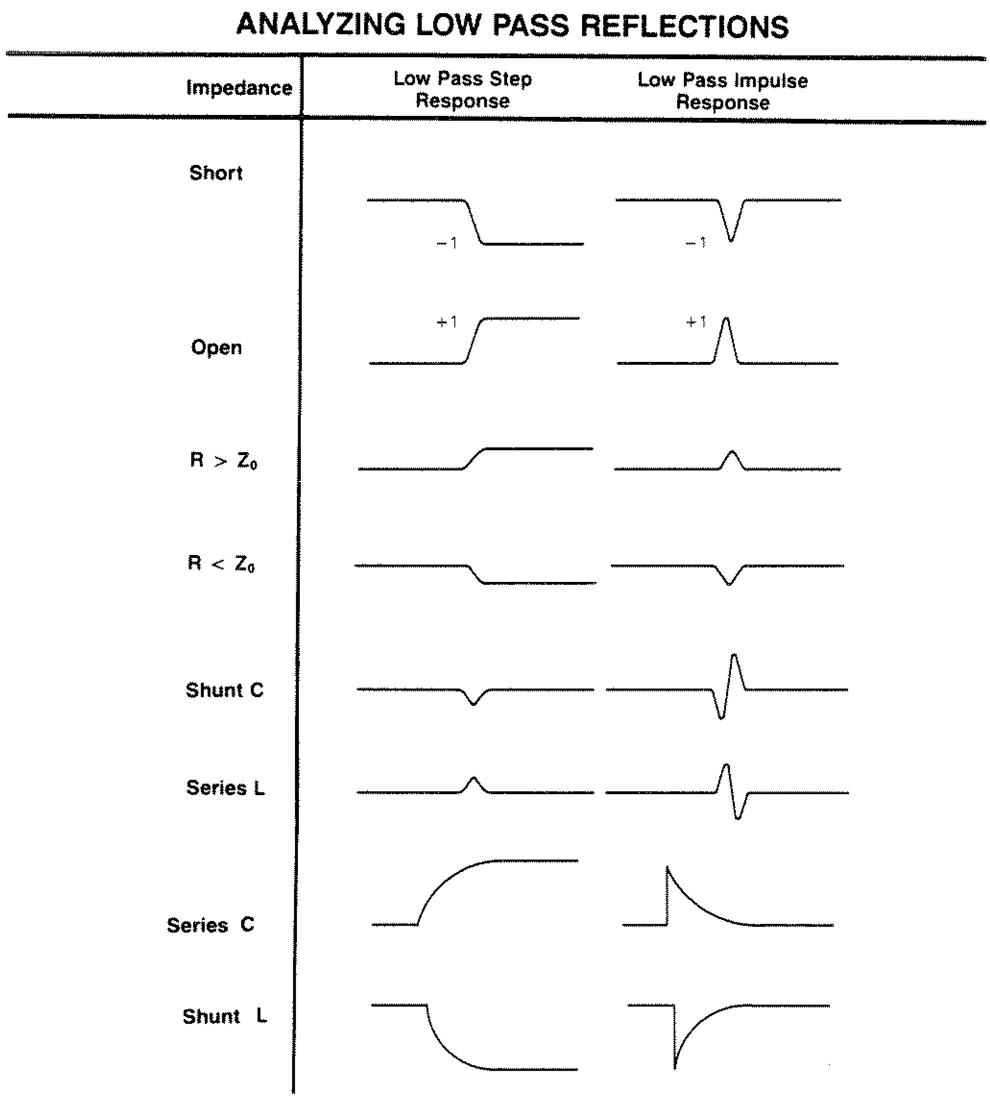


Figure 10-3. Time Low Pass Step and Impulse Responses

The time low pass response of a short circuit is a total reflection of the stimulus, 180 degrees out of phase. This represents a reflection coefficient fo −1.00. The response of an open circuit is a total in-phase reflection, or a reflection coefficient of +1.00.

The time low pass step response for a resistive impedance is a positive level shift for $R > Z°$ and a negative level shift for $R < Z°$. The impulse response is a positive-going peak for $R > Z°$ and a negative-going peak for $R < Z°$. In each case the height of the response is equal to the reflection coefficient:

$$R = (R - Z°) / (R + Z°)$$

where $Z°$ represents the characteristic impedance that precedes the discontinuity.

Reactive impedance discontinuities are identified as shown. The shunt C and series L circuit elements are low pass type devices. The series C and shunt L circuit elements are high pass type devices which exhibit very long transients.

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, with a function generator and sampling oscilloscope. The low pass step mode extends the frequency range of this type of measurement to 3 GHz.

The step input shown in Figure 10-4 is 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 10-4 is from 10 MHz to 1 GHz.

Figure 10-4 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.

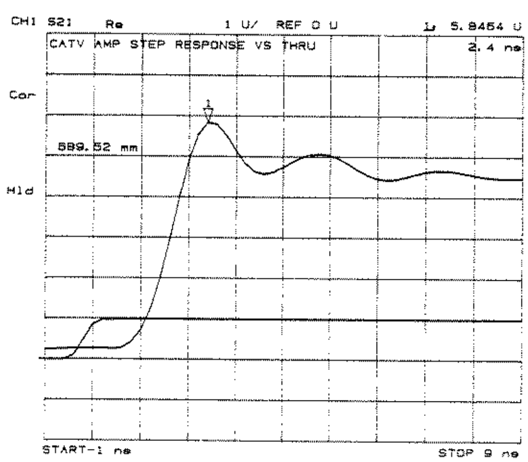


Figure 10-4. Time Domain Low Pass Measurement of an Amplifier Small Signal Transient Response

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 section.

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 10-4, 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.

Measuring Separate Transmission Paths through the DUT Using Low Pass Impulse mode.

The low pass impulse mode can be used to identify the different transmission paths through DUTs that have a response at frequencies down to dc (or at least have a predictable response, above the noise floor, below 300 kHz). For example, use the low pass impulse mode to measure the relative transmission times through a multipath device. Another example is to measure the pulse dispersion through a fiber optic cable. The last example is illustrated in Figure 10-5. The horizontal and vertical axes can be interpreted as already described in the transmission measurements using bandpass portion of this section.

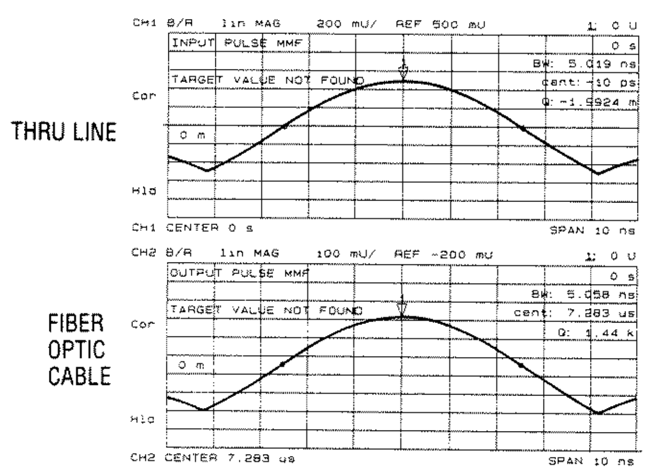


Figure 10-5. Measuring Pulse Dispersion on a 1.5 km Fiber Optic Cable Using Low Pass Impulse Transmission Measurements

MEASUREMENT APPLICATIONS

The analyzer time domain feature can be used to show how a circuit is constructed and give an idea of the behavior of each element inside the circuit. Below, these, and other applications are grouped under four broad headings:

- Analyzing the reflection response of the DUT

  Converting a reflection measurement to the time domain is like aiming a radar into the device under test: the response shows reflections off of the elements in the DUT as well as re-reflections within the DUT. This can be used to identify components, look for faults, and to check the match of elements mounted in the circuit.

- Analyzing the transmission response of the DUT

  Converting a transmission measurement to the time domain shows all the different transmission paths through a device under test. This can be used to evaluate such paths as triple travel and isolation, showing the delay and transmission coefficient of each path.

- Characterizing a specific element or sub-circuit

  The time domain feature can be used to extract the complex impedance of a single element in a larger network. A function called gating can be used to isolate the time response of the specific element, and the complex impedance of the element can then be analyzed in the frequency domain.

- Gating unwanted reflection and transmission paths

  If spurious time domain signals have been identified, removing them with gating improves the frequency domain measurement. For example, if reflections off of connectors or launches can be identified in a reflection measurement of a substrate, gating those reflecions will give a more true representation of the behavior of the substrate in the frequency domain.

MAKING A TIME DOMAIN MEASUREMENT

This portion of this section outlines the process of making a time domain measurement. Before making the measurement, certain choices must be made: the transform mode (low pass or bandpass) and whether the measurement is transmission or reflection. Then survey the device and set the measurement parameters consistently with the properties of the device.

The time domain measurement process can be divided into the following steps:

1. Survey device
2. Set stimulus
3. Calibrate
4. Measure
5. Transform
6. Gate (if needed)

1. Survey Device

Before the final measurement is made, determine the major measurement needs. This can be done by making a quick survey of the device and answering the following questions:

- Is the device broad band?

  The low pass mode requires that a device be broad band. The specific requirement is that the frequency range of operation of the device be broad enough so that the stop frequency can be set to *n* times the start frequency, where *n* is the number of points. If the device will allow the low pass mode, low pass mode is generally chosen over the band pass mode. If the device is too narrow band for low pass mode, bandpass mode is used.

- What is the longest delay to be measured in the time domain?

  When the time domain response is calculated, the result is a repetitive waveform. The period of that repetition should be longer that the longest measured delay to avoid an effect called aliasing. The longest delay, determines the minimum alias free range.

- How close are unique responses going to be?

  In reflection measurements, this corresponds to how close the elements are. In transmission, this corresponds to the minimum time delay between responses. This minimum delay determines the desired response resolution. Response resolution is the minimum spacing between two responses before they overlap so much that they are not uniquely identifiable.

- Are any important responses close to the noise floor?

  Time domain can show a small response in the presence of a large response as long as the skirts of the larger response or the noise floor do not obscure the small response. The smallest signal determines the needed sensitivity in the frequency domain.

2. Set Stimulus

Prior to a measurement, stimulus parameters such as start/stop frequencies, power, IF bandwidth, and sweep time have to be set. As outlined below, these parameters interact with certain time domain parameters. Once a measurement calibration is done, they should not be modified.

Start and Stop Frequencies

Low pass requires that the frequency samples are placed at harmonic intervals, starting with the fundamental. The [SET FREQ LOW PASS] key arranges the frequencies into a harmonic spacing. Therefore, a device must be relatively broad band in order for the low pass mode to be useful. If the device is not broad band, then use the bandpass mode.

The frequency span and step determine response resolution and alias free range. These values should be determined earlier under survey device.

Response resolution is the minimum time spacing between two equal responses which can be uniquely identified. In a specific measurement, the 10 to 90% step rise time or the 50% impulse width is the response resolution. For example, with a wide impulse, two close responses may overlap so much that they are indistinguishable. Using a narrower impulse to reduce the response overlap allows unique identification of each response. Response resolution is inversely proportional to frequency span, so broad spans give good response resolution:

$$\text{response resolution (s)} = W/\text{Fspan (Hz)}$$

where W is the windowing multiplier, normally equal to 0.96 for low pass reflection and 1.92 for bandpass reflection.

Alias free range is the maximum time delay the network analyzer can measure without a form of distortion called aliasing. When the delay of a response exceeds the alias free range, it folds back on itself and its magnitude and delay become ambiguous. The alias free range is inversely proportion to the frequency step:

$$\begin{aligned}\text{Alias free range(s)} &= 1/\text{Fstep (Hz)}\\ &= (\text{points}-1)/\text{Fspan (Hz)}\end{aligned}$$

By selecting the start and stop frequencies, and the number of points, the response resolution and the alias free range are determined.

Power and IF Bandwidth

As determined by surveying the device, there may be a minimum required sensitivity. The sensitivity can be estimated by looking at the noise floor measured at an open port, and it can be improved by reducing the IF bandwidth, increasing the incident power, and using averaging.

3. Calibrate

Once the stimulus parameters are set, a measurement calibration should be performed. Performing a measurement calibration reduces systematic errors in both frequency and time domains, and it defines the calibration plane as the zero time point.

In many cases, a response calibration is sufficient. A response calibration removes the magnitude and phase frequency response errors of the measurement system. In cases where very small or very large reflections are being measured, a 1-port calibration will improve the measurement because it corrects for source match and directivity as well as flatness. Also, when measuring very low loss electrical devices, a full 2-port calibration will improve accuracy because it corrects for load match. For transmissiom measurements on high loss devices, a calibration including an isolation step will improve measurement of low level signals.

Refer to measurement calibration, section 7 for details on calibration menus and procedures.

4. Measure

Connect the device under test and make the frequency domain measurement.

5. Transform

Once frequency domain data is obtained, transform the data to the time domain. There are three modes available in the network analyzer:

- **Low pass step** calculates the step response of the device under test. The most useful display format is the real portion of the data. In this format, the data displayed is similar to the data displayed by an electrical TDR. The REAL display format is the most useful, becoming ρ in reflection and τ for transmission.

- **Low pass impulse** calculates the impulse response of the device under test. The real portion of the data shows response shapes well, and the LOG MAG format magnifies small responses.

- **Bandpass** calculates the response of the device to an RF modulation burst, and processes the data so that the magnitude of the response looks like the magnitude of the low pass impulse response, except with twice the pulse width for the same frequency span. Only the LOG MAG and LIN MAG display formats are used with the bandpass mode.

There is a choice of pulse shape within each of the three modes through the window function. While in most cases the normal window shape is the shape of choice, there are certain situations where it is desirable to modify the pulse shape. For example, if two responses are only slightly overlapping, switching from the normal to minimum window may narrow the impulses enough to separate the two responses. The minimum window offers narrower impulses, but higher side lobes around the impulse. Alternatively, if the skirts of a larger response partially obscure a smaller response, going from normal to maximum window gives much lower side lobes and ringing around the responses, but wider impulses.

6. Gate (if needed)

Any isolated response in the time domain can be removed with the gating function. That means that signals can be removed and the corresponding frequency domain trace can be viewed. Alternatively, a single response can be isolated from the surrounding network, and be analyzed independently in the frequency domain.

Gating can be used to separate responses to the point where the responses are so close together that removing one entails removing part of the other. The needed separation is determine by the gate cutoff rate, which is a function of frequency span and gate shape, and is normally calculated with:

$$\text{Cutoff time} = 1.4/\text{Fspan (Hz)}$$

TIME DOMAIN CONCEPTS

Masking

Masking is a physical phenomenon in which the impulse or step response of one discontinuity affects the response of each subsequent discontinuity in the circuit. In reflection measurements, an element deep inside a circuit receives a smaller incident signal than earlier elements because of energy reflected off of and absorbed by earlier elements. Therefore, the returned response will be smaller than would be measured off of that element alone. The earlier elements are said to have masked the later elements. Masking cannot be removed with gating.

For example, if an electrical transmission line has two discontinuities that each reflect 50% of the incident voltage ($\rho = 0.50$), the time domain response (real format) shows the correct reflection coefficient for the first discontinuity ($\rho = 0.50$), but the second discontinuity appears as a 25% reflection ($\rho = 0.25$) because only half the incident voltage reached the second discontinuity.

NOTE: This example assumes a lossless electrical transmission line. Real transmission lines, with non-zero loss, attenuate signals as a function of the distance from the reference plane.

Windowing

The purpose of windowing is to make the time domain response more useful in isolating and identifying individual responses. The window does not affect the displayed frequency domain response. It is turned on only when the time domain response is viewed. Windowing is needed because of the abrupt transitions in a frequency domain measurement at the start and stop frequencies. This 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 $k = \pi$/frequency span. This has two effects that limit the usefulness of the time domain measurement:

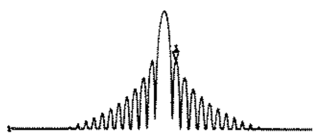
1. Finite impulse width (or rise time). This limits the ability to resolve between two closely spaced responses. The effects of the finite impulse width cannot be improved without increasing the frequency span of the measurement (see Table 10-3).

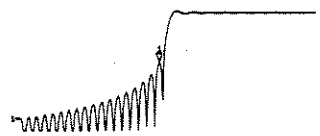
2. Sidelobes. The impulse sidelobes limit the dynamic range of the time domain measurement by hiding low-level responses within the sidelobes of higher level responses. The effects of sidelobes can be improved by windowing (see Table 10-4).

Windowing improves the dynamic range of a time domain measurement by filtering the frequency domain data prior to converting it to the time domain, which produces 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.

Three windows are available: MINIMUM, NORMAL, and MAXIMUM. The window may be selected by pressing **[SYSTEM]** ***[TRANSFORM MENU] [WINDOW]***. The sidelobe levels of the time domain stimulus depend only on the window that is selected (see Table 10-4). MINIMUM is essentially no window and therefore gives the highest sidelobes; NORMAL (selected by PRESET) gives reduced sidelobes and is normally the most useful; MAXIMUM gives the minimum sidelobes which provides the greatest dynamic range.

Table 10-3. Time Domain Window Characteristics





Window Type	Impulse Sidelobe Level	Step Sidelobe Level
Minimum	−13 dB	−21 dB
Normal	−44 dB	−60 dB
Maximum	<−90 dB	<−90 dB

The sideslobe reduction due to windowing is achieved at a tradeoff with an increase in the step (10% −90%) rise time and the impulse (50%) width. These parameters also depend upon the frequency span of the measurement, and they can be calculated using the approximate formulas given in Table 10-4.

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.

Table 10-4. Approximate Formulas for Step Rise Time and Impulse Width

LOW PASS

Step Rise Time (10% to 90%) $= \frac{0.45}{\text{Frequency Span}} \times$ { 1.0 Minimum Window; { 2.2 Normal Window; { 3.3 Maximum Window

Impulse Width (50%) $= \frac{0.60}{\text{Frequency Span}} \times$ { 1.0 Minimum Window; { 1.6 Normal Window; { 2.4 Maximum Window

BAND PASS

Impulse Width (50%) $= \frac{1.20}{\text{Frequency Span}} \times$ { 1.0 Minimum Window; { 1.6 Normal Window; { 2.4 Maximum Window

Multiply by the velocity of light in a vacuum (2.997925E8 m/sec) to get electrical length, and then by the index of refraction or relative velocity of light in the propagation medium to get physical length.

Figure 10-6 shows typical effects of windowing on th time domain response of the reflection measurement of a short circuit.

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.

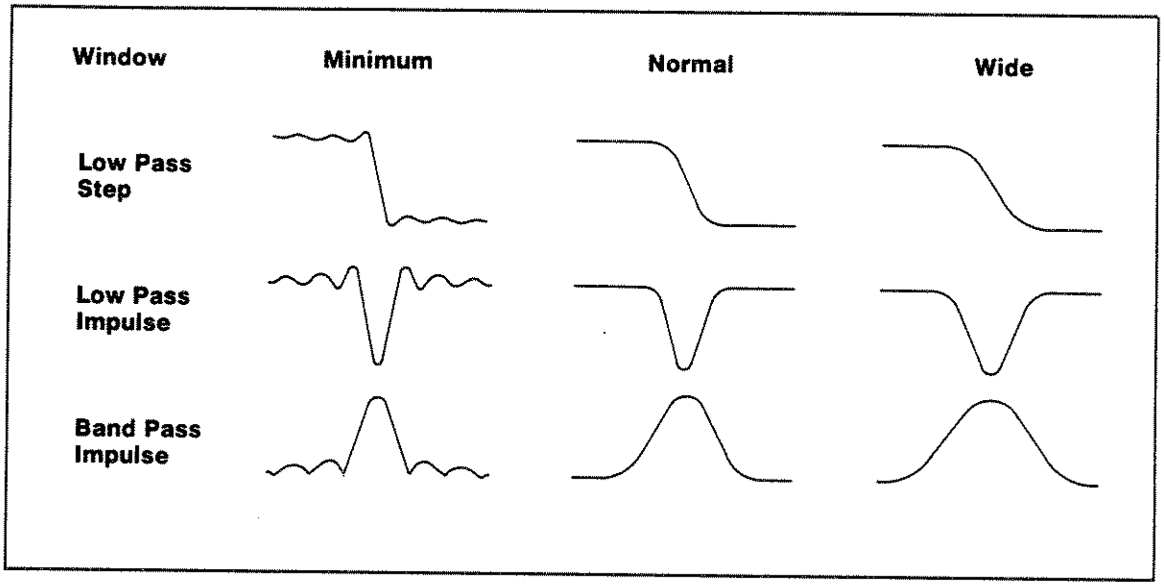


Figure 10-6. Effect of Windowing on Time Domain Responses of a Short Circuit

Range

In the time domain, the range is defined as the maximum time or distance the analyzer can measure without distortion due to response overlap (aliasing). Responses overlap because the equivalent time domain stimulus used by the analzyer is an impulse or step train. For example, if the response to one impulse is recorded after the next impulse is sent out, then it will overlap with the response from the next impulse. The alias range is simply the pulse repetition rate.

The range of a measurement is equal to $1/\Delta F$, the spacing between frequency data points. It is directly proportional to the number of points and inversely proportional to the frequency span (stop − start frequency) and can be calculated using the following formula.

$$\text{RANGE} = 1/\Delta F = (\text{number of points} - 1)/\text{frequency span}$$

Example:

Measurement = 201 points
1 MHz to 2.001 GHz

Range = $1/\Delta F$ or (number of points − 1)/frequency span
= $1/(10 \times 10^6)$ or $(201 - 1)/(2 \times 10^9)$
= 100×10^{-9} seconds

or

= range × the speed of light (3×10^8 m/s)
= $(100 \times 10^{-9}$ s) x (3×10^8 m/s)
= 30 metres

In this example, the range is 100 ns, or 30 metres. To prevent the time domain responses from overlapping, the DUT must be 30 metres or less in 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, it is usually better to first increase the number of points, because decreasing the frequency span will reduce the time domain resolution.

Resolution

In the time domain, there are two different resolution terms: response and range. Both of these are shown in Figure 10-7.

Response Resolution. Time domain response resolution is defined as the ability to resolve two closely-spaced responses, or 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% impulse width. It is inversely proportional to the measurement frequency span, and is also a function of the window used. Approximate formulas for calculating the 50% impulse width are given in Table 10-4.

For example, using the formula for the bandpass mode with a normal windowing function for a 1 MHz to 3.001 GHz measurement (3 GHz span):

The 50% calculated impulse width: $= 1.2 \times (1/3\ \text{GHz}) \times 1.6$
$= 0.64$ nanoseconds

The length (in air): $= (0.64 \times 10^{-9}\ \text{s}) \times (30 \times 10^{9}\ \text{cm/s})$
$= 19.2$ centimetres

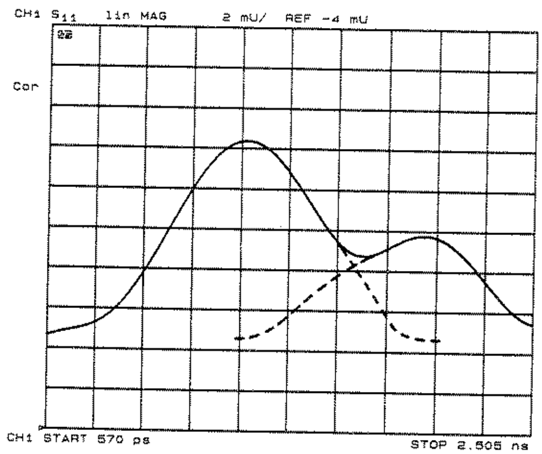
With this measurement, two equal responses can be distinguished when they are separated by at least 19.2 centimetres.

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.

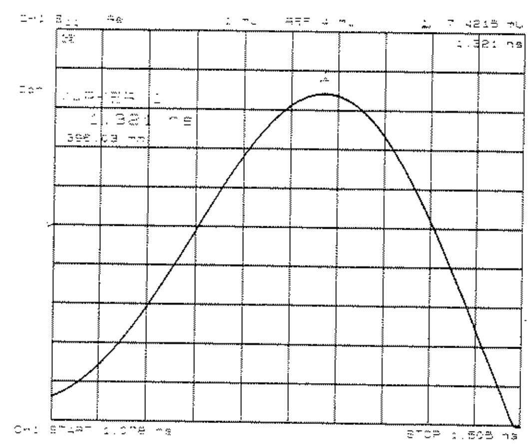
For reflection measurements, which measure the round trip time to the response, divide the response resolution by two. Using the example above, you can distinguish two faults of equal magnitude provided they are 3 centimetres or more apart.

NOTE: Remember, to determine the physical length, enter the index of refraction of the transmission medium under test. 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 10-7 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.



a. Response Resolution



b. Range Resolution

Figure 10-7. Resolution in Time Domain

Since increasing the frequency span increases the response resolution, keep the following points in mind:

- The time domain response noise floor is directly related to the frequency domain data noise floor. If the frequency domain data points are taken at or below the measurement noise floor, the time domain measurement noise floor is degraded.
- 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 an out-of-band response.

You can (with these points 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 how closely you can discern 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.

Gating

Gating allows you to selectively remove the reflection or transmission time domain responses. In converting back to the frequency domain, the effects of the responses outside the gate are removed. In a reflection measurement, this feature is used to remove the effects of unwanted mismatches or to isolate and view the response of an individual mismatch In a transmission measurement, you can remove the effects of multiple transmission paths.

Setting the Gate

A gate is a time bandpass filter used to filter out unwanted time domain responses. Responses outside the selected gate are not included in the trace. There are three gate indicators: START, CENTER, and STOP. The gate has a bandpass filter shape, as shown in Figure 10-8. The gate center indicates the center time (not frequency) of this filter, and the gate START and STOP indicate the −6 dB cutoff times. Gates have a negative span where the responses inside the gate are mathematically removed. Gate SPAN = STOP − START.

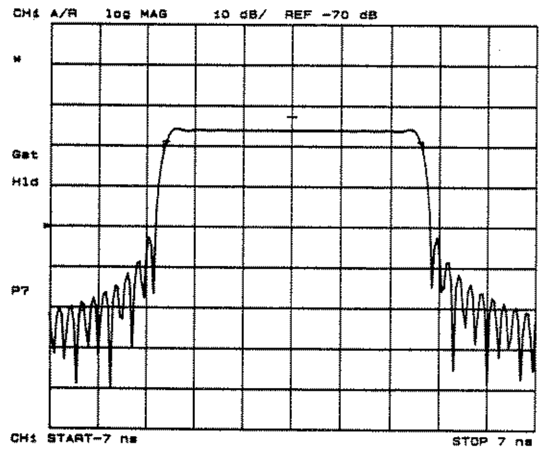
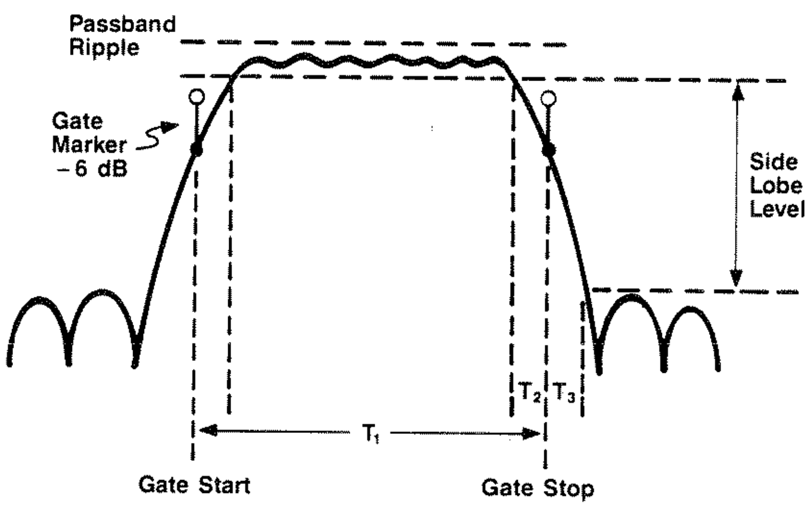


Figure 10-8. Typical Gate Shape

Selecting the Gate Shape

Four different gate shapes are available: MINIMUM, NORMAL, WIDE, and MAXIMUM. Each of the gates has a different pass band flatness, cutoff rate, and sidelobe level. T_1 indicates the gate span which is the time between the gate start and stop indicators. T_2 is the time between the edge of the gate pass band and the −6 dB gate stop time. T_3, equal to T_2, is the time between the gate stop time and the point where the filter first reaches the level of the highest gate sidelobe. The gate characteristics for each gate shape are listed in Table 10-5.

Table 10-5. Gate Characteristics



Gate Shape	Passband Ripple	Sidelobe Levels	Cutoff Time $T_2 = T_3$	Minimum Gate Span T_1
Minimum	±0.40 dB	−24 dB	$0.6/f_{SPAN}$	$1.2/f_{SPAN}$
Normal	±0.04 dB	−45 dB	$1.4/f_{SPAN}$	$2.8/f_{SPAN}$
Wide	±0.02 dB	−52 dB	$4.0/f_{SPAN}$	$8.0/f_{SPAN}$
Maximum	±0.01 dB	−80 dB	$11.2/f_{SPAN}$	$22.4/f_{SPAN}$

NOTE: With 1601 frequency points, gating is available only in the bandpass mode.

The passband ripple and sidelobe levels are descriptive of the gate (filter) shape. The cutoff time, $T_2 = T_3$ (see Table 10-5), indicates how fast the gate filter rolls off. For each gate shape, there is also a minimum gate span ($T_1 min = 2 \times T_2$) which gives a filter pass band of zero. If a gate span smaller than minimum is entered, the gate start and stop cutoff begin to overlap. This will produce a distorted filter shape that will have no pass band, and will give an incorrect indication of gate start and stop times. Therefore, it is important to always select a gate span that is higher than the minimum value. The cutoff time and the minimum gate span are inversely proportional to the frequency span of the measurement as indicated in Table 10-5.

For best results using gating, it is important to always center the gate around the response(s) that you want to retain in the measurement and to make the gate span wide enough to include all of those responses. It is also recommended to use the widest gate shape possible.

TRANSFORMING CW TIME MEASUREMENTS INTO THE FREQUENCY DOMAIN

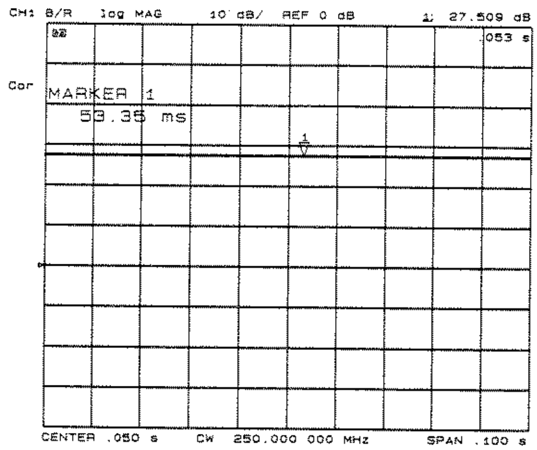
The analyzer can display the amplitude and phase of continuous wave (CW) signals versus time. For example, this mode can be used for measurements such as amplifier gain as a function of warm-up time (drift). In the past, drift measurements were often made using strip chart recorders. The analyzer can display the measured parameter (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 measurements as a function of time, where 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 10-9). The transform into the frequency domain yields a display that looks similar to a spectrum analyzer display of signal amplitude versus frequency.

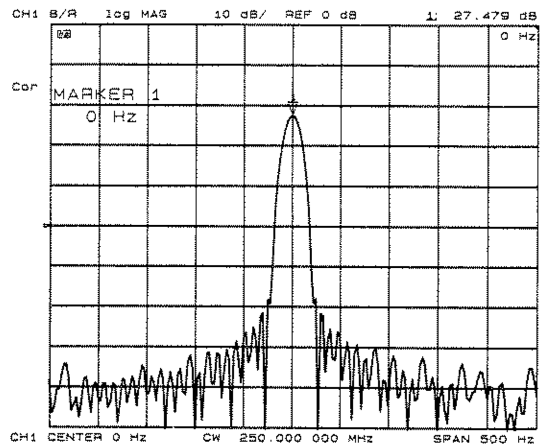
Forward Transform Measurements

To make measurements using the Fourier transform in the forward direction (from time domain to frequency domain):

1. Press **[PRESET]** and select the device type.
2. Press **[MEAS]** and select the desired measurement (A, B, or B/R, ratioed measurement).
3. Press **[MENU]** ***[CW FREQ]***.
4. Set the frequency to the desired value (e.g. center 250 MHz).
5. Press ***[SWEEP TYPE MENU]***. The ***[CW TIME]*** sweep mode is active.
6. Using the **[STOP]** key, enter the time over which you wish to take data (up to 24 hours), and take the sweep.
7. Press ***[SYSTEM] [TRANSFORM MENU] [TRANSFORM ON]***.
8. Using **[SPAN]**, set the desired frequency span. The maximum span is 4000 Hz for the default sweep time (100 ms) and number of points (201). The center frequency is the CW frequency entered earlier.



a. CW Time



b. Transform to Frequency Domain

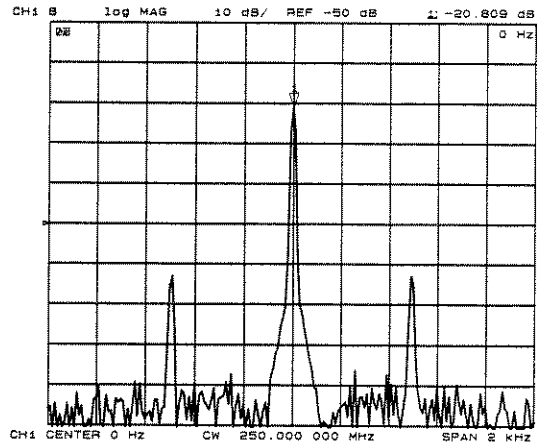
Figure 10-9. Amplifier Gain Measurement

Interpreting the Forward Transform Horizontal Axis. In a frequency domain transform of a CW time measurement, the horizontal axis is measured in units of frequency. This axis has a maximum span of 4 kHz (2 kHz on either side of the CW frequency). The center frequency (with zero offset) is the frequency of the CW time measurement. 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. 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.

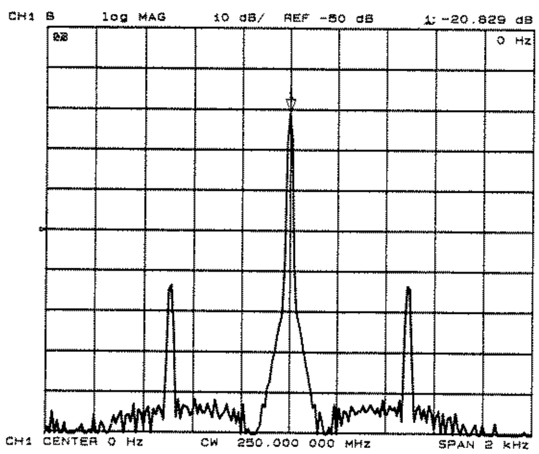
Interpreting the Forward Transform Vertical Axis. With the log magnitude format selected, the vertical axis displays dB. When making a single channel measurement, the analyzer displays the absolute power versus frequency.

Demodulating the Results of the Forward Transform

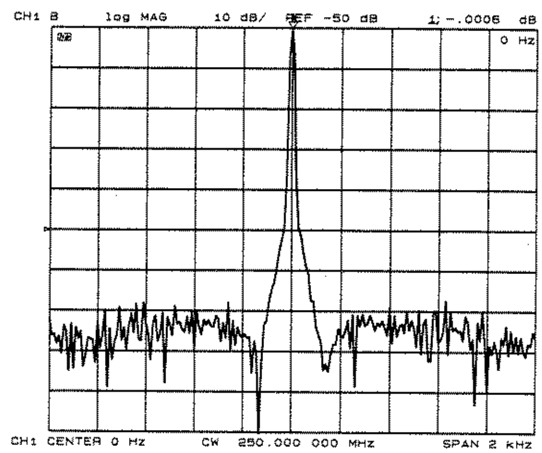
The forward transform can separate the effects of the CW frequency modulation amplitude and phase components. For example, if the DUT modulates the transmission response (S_{21}) with a 500 Hz AM signal, you can see the effects of that modulation (Figure 10-10). To simulate this effect, connect a 500 Hz sine wave to the analyzer rear panel EXT AM input.



a. Combined Effects of Amplitude and Phase Modulation



b. Amplitude Modulation Component



c. Phase Modulation Component

Figure 10-10. Measuring 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:

$$\begin{aligned} \text{Range} &= (\text{number of points } -1)/\text{time span} \\ &= (201 - 1)/(200 \times 10^{-3}) \\ &= 1000 \text{ Hz} \end{aligned}$$

For the example given above, a 201 point CW time measurement made over a 200 ms time span, choose a total span of 2 kHz or less (Figure 10-11).

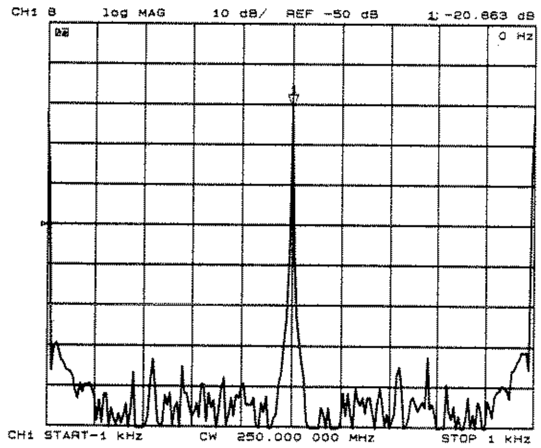


Figure 10-11. Range of a Forward Transform Measurement

To increase the frequency domain measurement range, increase the number of points or decrease the sweep time. Because increasing the number of points increases the sweep time, the maximum range is 4 kHz total span. To display a total frequency span of 4 kHz, enter the span as 4000 Hz. The k/m, M/μ, and G/n keys terminate a selection as millihertz, microhertz, and nanohertz.

Section 11. Copy Functions: Printing and Plotting

—CONTENTS OF THIS SECTION—

MAKING A HARD COPY OUTPUT

The analyzer can use the HP-IB (Hewlett-Packard Interface Bus) to output displayed information directly to a compatible plotter, and measurement results, tables, and plots directly to a compatible printer or plotter. Tables or plots can also be copied to a compatible graphics printer. The HP 8702B can also use a compatible color printer to generate a color hard copy output. Refer to the General Information section of this manual for information about compatible plotters and printers.

The analyzer must be in system controller HP-IB mode or pass control mode to generate a plot or printout from the front panel. Refer to Instrument State Functions and HP-IB Programming sections for information on HP-IB controller modes and setting addresses.

[COPY] KEY

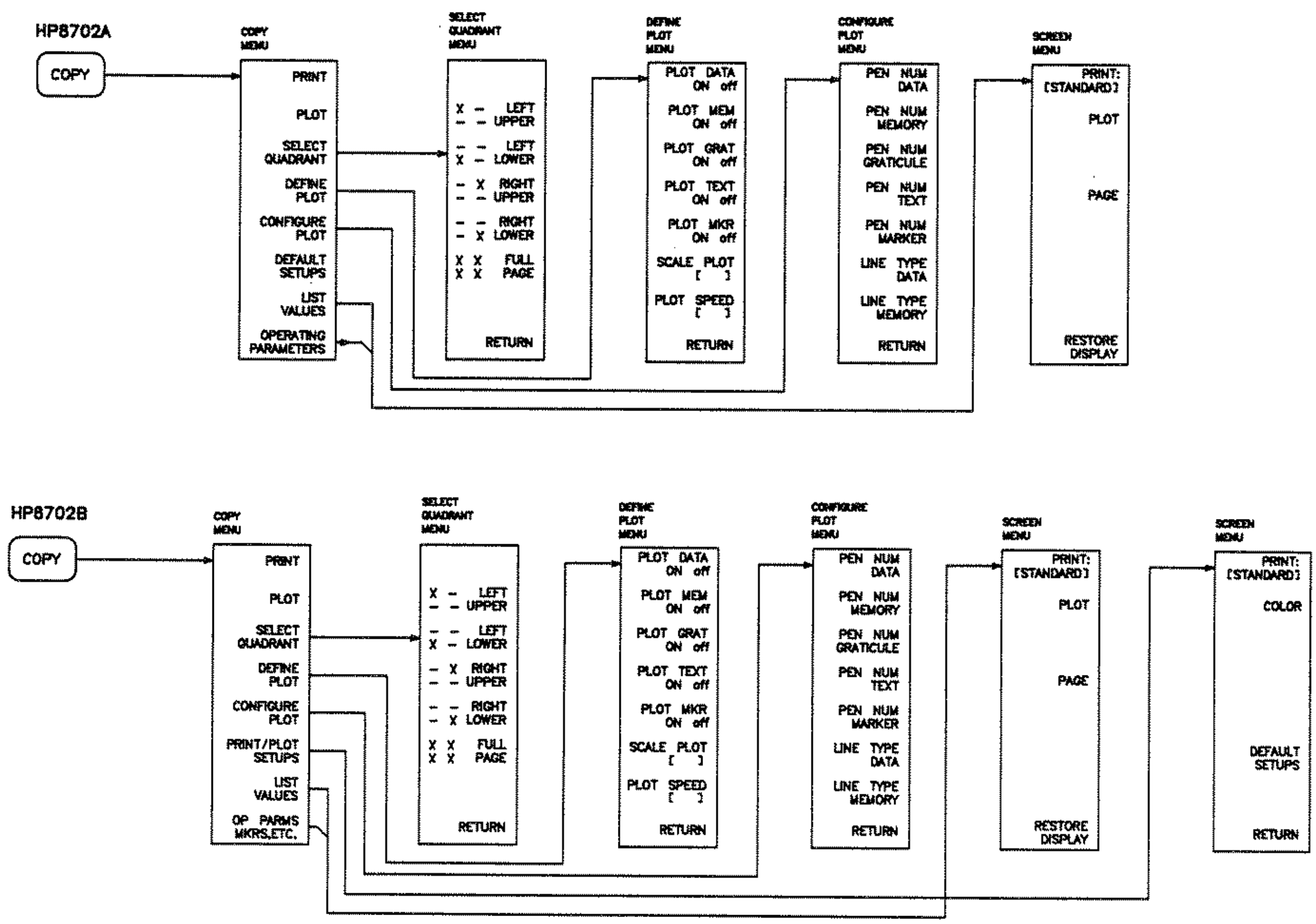


Figure 11-1. Softkey Menus Accessed from the [COPY] Key

The **[COPY]** key provides access to the menus used to control external plotters and printers, and to define the plot parameters.

Copy Menu

To copy to a printer, or to plot using default plot parameters, the copy menu can be used without the need to access other menus. For user-defined plot parameters, a series of additional menus is available.

The copy 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 process, press the **[LOCAL]** key. An aborted plot or printout cannot be continued: if a copy is still required, the process should be initiated again.

HP 8702A only **[PRINT]** (PRINALL) copies the CRT display to a compatible graphics printer. Tabular listings or data displays can also be printed. All information from the display is printed except the softkey labels.

HP 8702B only **[PRINT]** (PRINALL) allows you to copy the CRT display to a printer capable of a graphics plot or tabular listings. The analyzer is designed to be compatible with the HP 2225A ThinkJet, the HP 3630A PaintJet, and the HP 2227B QuietJet Plus. Other Hewlett-Packard printers may also be compatible with the analyzer.

When one of the print softkeys is pressed, the analyzer freezes the data to be printed on the CRT and sends it to the printer through a buffer. Once the data is transferred to the buffer, the analyzer is free to continue measurements while the data is printing.

[PRINT: STANDARD] (PRIS) sets up the print command when you are using a standard printer that prints in black only.

[PRINT: COLOR] (PRIC) sets up the print command when you are using a color printer. The printer output is always in HP 8702B default color values.

[PLOT] (PLOT) plots the CRT display to a compatible graphics plotter, using the currently defined plot parameters (or default parameters). Any or all displayed information can be plotted, except the softkey labels.

[SELECT QUADRANT] leads to the the select quadrant menu, which provides the capability of quarter-page plots.

[DEFINE PLOT] leads to the define plot menu, which is used to specify the elements of the display to be plotted.

[CONFIGURE PLOT] leads to the configure plot menu, which defines the pen number and line type for each of the plot elements.

HP 8702A only ***[DEFAULT SETUPS]*** (DFLT) resets the plotting parameters to their default values. These defaults are as follows:

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 setups do not apply to printing.

HP 8702B only ***[PRINT/PLOT SETUPS]*** presents the following keys to select hardcopy setups.

[PRINT: STANDARD] (PRIS) sets up the print command when you are using a standard printer that prints in one color only.

[PRINT: COLOR] (PRIC) sets up the print command when you are using a color printer. The printer output is always in HP 8702B default color values.

[DEFAULT PLOT SETUPS] (DFLT) resets the plotting parameters to the default values. The defaults are as follows:

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 setups do not apply to printing.

[LIST VALUES] (LISV) is a tabular listing of all the measured data points and their current values. A menu is presented for hard copy listings and access of new pages of the table. 30 lines of data are listed on each page depending upon the number of points, with up to five columns of data. If limit testing is turned on, an asterisk appears next to any measured value that is out of limits.

HP 8702A only ***[OPERATING PARAMETERS]*** (OPEP) provides a tabular CRT listing of the key parameters for both channels, including the screen menu. Four pages of information are supplied: the first two pages list operating parameters, the third page lists marker parameters, the fourth page lists system parameters that relate to control of peripheral devices.

HP 8702B only **[OP PARMS/MKRS etc]** (OPEP) provides a tabular CRT listing of the key parameters for both channels, including the screen menu. Four pages of information are supplied: the first two pages list operating parameters, the third page lists marker parameters, the fourth page lists system parameters that 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.

[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.

[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. To plot on transparencies and preprinted forms, different selections are available for plot speed and plot scale.

[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.

[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.

[PLOT TEXT on off] (PTEXTON, PTEXTOFF) selects plotting of all displayed text except softkeys and marker values. (Softkey labels can be plotted from an external controller — refer to HP-IB Programming).

[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.

[GRAT], the horizontal and vertical scale are expanded or reduced. This is convenient for plotting on preprinted rectangular or polar forms.

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. If P1 and P2 are set to within 10% of 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 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.

[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.

Line types 0 through 10 can be selected. The line types depend on the model of plotter used. In general, 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.

[PEN NUM DATA] 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] 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] 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] selects the pen number for plotting the text. The default pen for channel 1 is pen #1, and for channel 2 is pen #2.

[PEN NUM MARKER] selects the pen number for plotting both the markers and the marker values. The default pen for channel 1 is pen #5, and for channel 2 is pen #6.

[LINE TYPE DATA] selects the line type for the data trace plot. The default line type is 7, which is a solid unbroken line.

[LINE TYPE MEMORY] 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 ***[OPERATING PARAMETERS]*** features, to make hard copy listings of the tables displayed on the screen.

HP 8702A only ***[PRINT]*** (PRINALL) copies one page of the tabular listings to a compatible HP graphics printer connected to the HP 8702A over HP-IB.

HP 8702B only **[STANDARD PRINT]** (PRINALL) copies one page of the tabular listings to a compatible HP graphics printer connected to the HP 8702B 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.

[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.

Section 12. HP-IB 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. HP-IB allows the analyzer to be controlled by an external computer that sends commands or instructions to and receives data from the HP 8702 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 HP 8702 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.

More complete information on programming the HP 8702 remotely over HP-IB is provided in the following documents:

- *Introductory Programming Guide for the HP 8702 Using Series 200/300 Computers*. This is a tutorial introduction to remote operation of the 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 example programs disc provided with the analyzer. The *Introductory Programming Guide* assumes familiarity with front panel operation of the instrument.
- *HP 8702 Quick Reference Guide*. This is a complete reference summary. It includes both functional and alphabetical lists of all HP 8702 HP-IB commands. This guide is intended for use by those familiar with HP-IB programming and the basic functions of the HP 8702.

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.

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 to the analyzer. 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 low, all devices 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 low, the bus is in the command mode and the data lines carry bus commands. When this line is 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 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 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 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 12-1 illustrates the structure of the HP-IB bus lines.

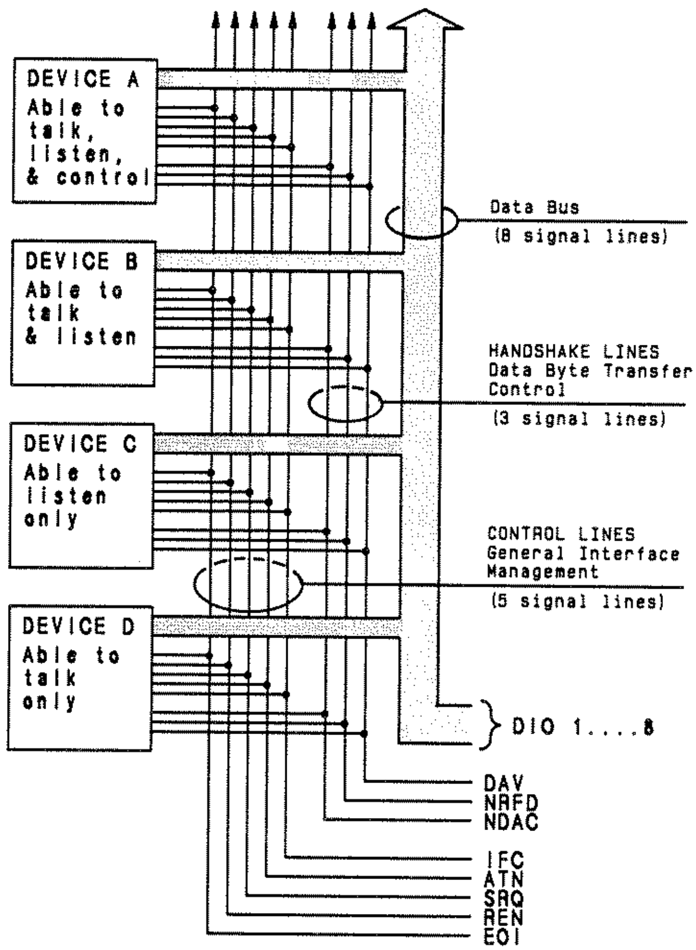


Figure 12-1. HP-IB Structure

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 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 8702 HP-IB CAPABILITIES

As defined by the IEEE 488.1 standard, the analyzer has the following capabilities:

SH1 Full source handshake.

AH1 Full acceptor handshake.

T6 Basic 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.

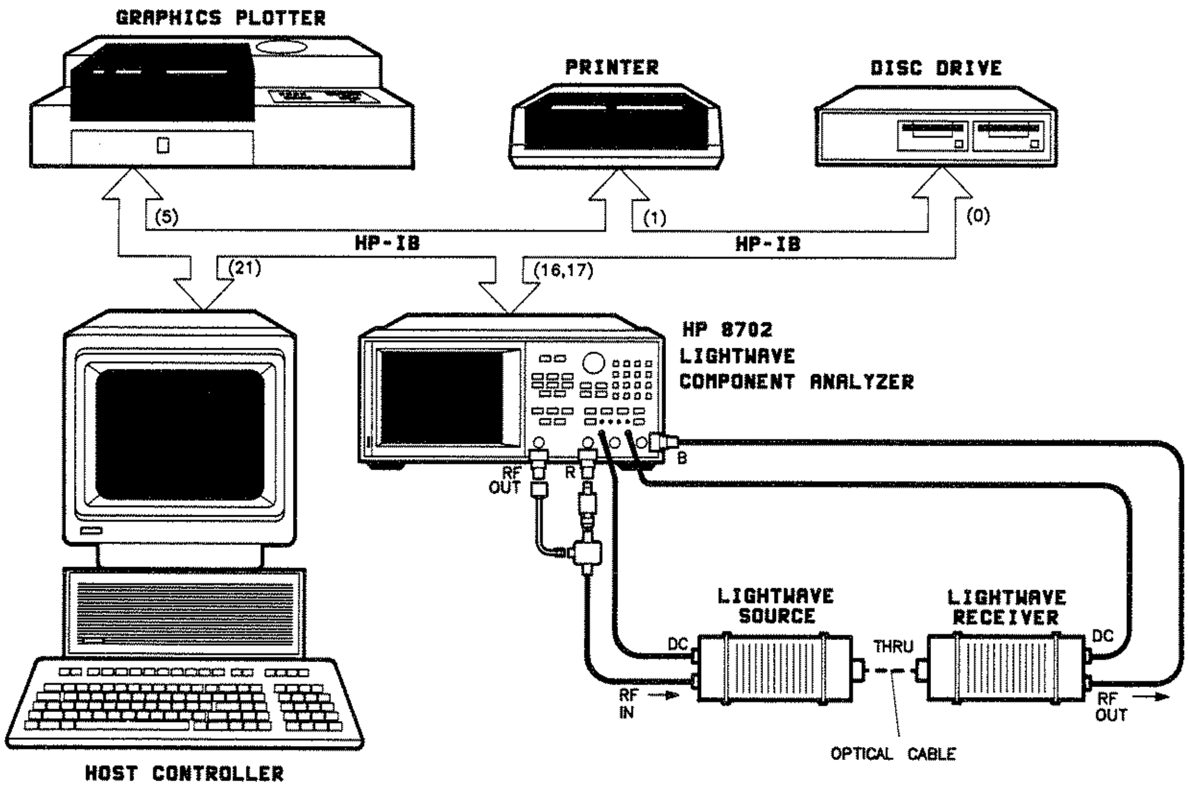


Figure 12-2. HP 8702 Single Bus Concept

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, unless you desire direct peripheral access. Preset does not affect the selected bus mode, but the bus mode returns talker/listener if power is cycled.

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. 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 *Introductory Programming Guide*.

HP 8702 CODE NAMING CONVENTION

The analyzer 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 Start	First Four Letters	POWE STAR
Two Words	Electrical Delay Search Right	First Three Letters of First Word First Letter of Second Word	ELED SEAR
Two Words in a Group	Marker →Center Gate →Span	First Four Letters of Both	MARKCENT GATESPAN
Three Words	Cal Kit N 50Ω Pen Num Data	First Three Letters of First Word First Letter of Second Word First Four Letters of Third Word	CALKN50 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.

Front panel equivalent codes and HP-IB only codes are summarized in the *HP-IB Quick Reference Guide*.

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 π. Any time the analyzer receives a syntax error, the commands halt, and a pointer $\wedge$ indicates the misunderstood character. The *Introductory Programming Guide* explains how to clear a syntax error.

CRT GRAPHICS

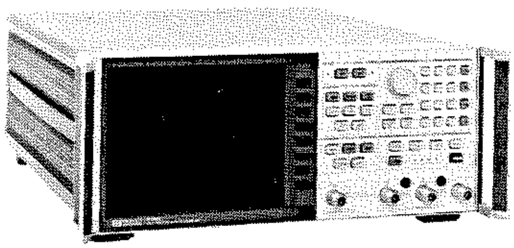
The analyzer CRT can be used as a graphics display for displaying connection diagrams or custom instructions to an operator. The CRT accepts a subset of Hewlett-Packard Graphics Language (HP-GL) commands.

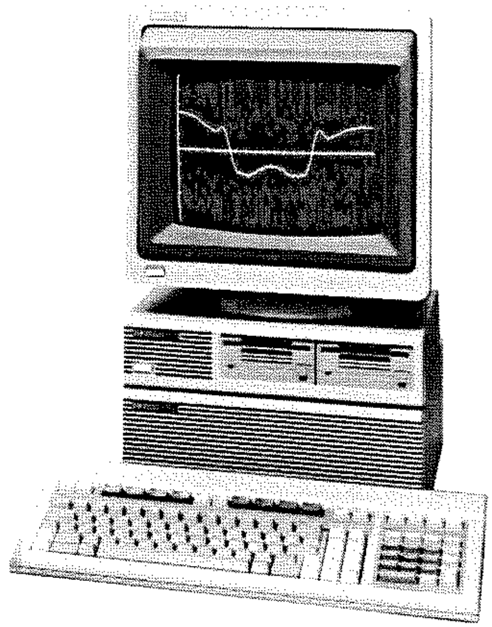
NOTE: The analyzer display occupies an additional address on the HP-IB. Determine the CRT bus address by adding 1 to the analyzer address if the analyzer address is an even number, or subtracting 1 if it is an odd number. Thus the factory default CRT address for graphics is 17.

HP-IB Programming Guide

HEWLETT PACKARD

For the HP 8702 Lightwave Component Analyzer with the HP 9000 series 200/300 desktop computer (BASIC)





Introduction

This programming note is an introduction to remote operation of the HP 8702 lightwave component analyzer using an HP 9000 series 200 or 300 computer. It is a tutorial introduction, using BASIC programming examples to demonstrate the remote operation of the HP 8702. The examples are on the Example Programs disk (part number 08702-10001), included with the HP 8702 operating manual. This document is closely associated with the HP 8702 *HP-IB Quick Reference Guide*. The *HP-IB Quick Reference Guide* provides complete programming information in a concise format. Included in the *HP-IB Quick Reference Guide* are both functional and alphabetical lists of HP-IB commands.

The Hewlett-Packard computers specifically addressed are the HP 9000 series 200 and 300 computers, operating with BASIC 2.0 with AP2—1, or BASIC 3.0 or higher. This includes the 216 (9816), 217 (9817), 220 (9920), 226 (9826), 236 (9836), 310 and 320 computers.

The reader should become familiar with the operation of the HP 8702 before controlling it over HP-IB. This document is not intended to teach BASIC programming or to discuss HP-IB theory except at an introductory level: see below for documents better suited to these tasks.

For more information

For more information concerning the operation of the HP 8702, refer to the following:

User's Guide	P/O 08702-90002
Operating and Programming Manual	08702-90002

For more information concerning BASIC, see the manual set for the BASIC revision being used. For example:

BASIC 5.0 Programming Techniques	98613-90012
BASIC 5.0 Language Reference	98613-90052

For more information concerning HP-IB, see:

BASIC 5.0 Interfacing Techniques	98613-90022
Tutorial Description of the Hewlett-Packard Interface Bus	5952-0156
Condensed Description of the Hewlett-Packard Interface Bus	59401-90030

Table of Contents

Required equipment

To run the examples, the following equipment is required.

1. HP 8702 Lightwave Component Analyzer.
2. A test set. For optical measurements use an HP 11889A RF Interface Kit or an HP 85047A to go to 6 GHz. For electrical measurements use an HP 85046A/B or 85047A S-parameter test set, an HP 85044A/B Transmission/Reflection test set, or a power splitter.
3. A cable set such as an HP 11886A for single-mode applications, and an HP 11887A for multimode applications. Use an HP 11851B for a transmission/reflection test set or power splitter, HP 11857D for an S-parameter test set, or equivalent.
4. HP 83400 Family Lightwave Source for single-mode fiber or for multimode fiber.
5. HP 83410 Family Lightwave Receiver.
6. HP 9000 series 200 or 300 computer with enough memory to hold BASIC, needed binaries, and at least 64 kBytes of program space. In addition, 512 kBytes are needed for BASIC 3.0 or higher operating systems, with the binaries suggested in step 2 in the section *Powering up the system*. A disk drive (e.g. HP 9122 is required to load BASIC if no internal disk drive is available.
7. HP BASIC 2.0 with AP2—1, or BASIC 3.0 or higher operating system.
8. HP 10833A/B/C/D HP-IB cables to interconnect the computer, the HP 8702, and any peripherals.

Optional Equipment

1. HP 85031B 7 mm calibration kit, or equivalent.
2. HP 11890A single-mode or HP 11891A multi-mode lightwave coupler for optical reflection measurements.
3. A test device such as a roll of fiber to use in the example measurement programs.
4. HP 7440A ColorPro plotter, an HP 2227B QuietJet printer, an HP 2225A ThinkJet printer, or an HP 9122 or HP 9154 CS80 disk drive. See the General Information section of the manual for a more complete list of compatible peripherals.

Powering up the system

1. **Set up the HP 8702 as shown in Figure 1.** Connect the HP 8702 to the computer with an HP-IB cable. The HP 8702 has only one HP-IB interface, but it occupies two addresses: one for the instrument, one for the display. The display address is the instrument address with the least significant bit complemented. The default addresses are 16 for the instrument, 17 for the display. Devices on the HP-IB cannot occupy the same address as the HP 8702.
2. **Turn the computer on and load the BASIC operating system.** For BASIC 2.0, load AP2—1, if available. If BASIC 3.0 or higher is used, load the following BASIC binary extensions: HPIB, GRAPH, IO, KBD, and ERR. Depending on the disk drive, a binary such as CS80 may be also be required.
3. **Turn the HP 8702 on.** To verify the HP 8702's address, press **[LOCAL]** *[SET ADDRESSES]* and *[ADDRESS: 8702]*. If the address has been changed from the default value, return it to 16 while performing the examples in this document by pressing **[1] [6] [x1]** and then presetting the instrument. Make sure the instrument is in either *[USE PASS CONTROL]* or *[TALKER/LISTENER]* mode, as indicated under the **[LOCAL]** key. These are the only modes that the HP 8702 will accept HP-IB commands over.
4. **Type the following on the computer:** `OUTPUT 716;"PRES;"` **[EXECUTE]** (or **[RETURN]**) This will preset the HP 8702. If Preset does not occur, check all HP-IB addresses and connections. Most HP-IB problems are caused by an incorrect address and bad or loose HP-IB cables.

NOTE: Only the 9826 and 9836 computers have an **[EXECUTE]** key. An HP 216 has an **[EXEC]** key with the same function. All the other computers use the **[RETURN]** key as both execute and enter. The notation **[EXECUTE]** is used throughout this document.

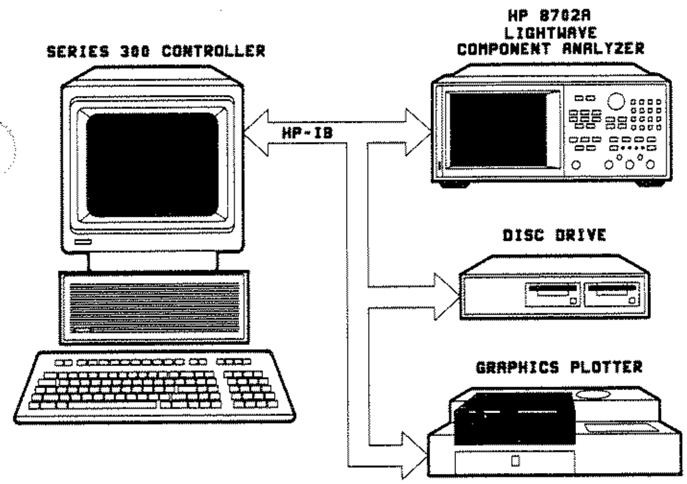


Figure 1. HP-IB connections in a typical setup.

Basic Instrument Control

A computer controls the HP 8702 by sending it commands over HP-IB. The commands sent are specific to the HP 8702. Each command is executed automatically upon receipt, taking precedence over manual control of the HP 8702. A command applies only to the active channel except where functions are coupled between channels, just as with front panel operation. Most commands are equivalent to front panel functions. For example, type:

```
OUTPUT 716;"STAR 10 MHZ;"
```

and press **[EXECUTE]**.

The HP 8702 now has a start frequency of 10 MHz. The construction of the command is:

```
OUTPUT 716;"STAR 10 MHZ;"
```

The BASIC data output statement. The data is directed to interface 7 (HP-IB), and on out to the device at address 16 (the HP 8702).

The HP 8702 mnemonic for setting the start frequency. The mnemonic, less the quotation marks, is sent literally by the **OUTPUT** statement, followed by a carriage return, line feed.

The `STAR 10 MHZ;` command performs the same function as pressing **[START]** and keying in **10 [M/u]**. `STAR` is the root mnemonic for the start key, `10` is the data, and `MHZ` are the units. The HP 8702's root mnemonics are derived from the equivalent key label where possible, otherwise from the common name for the function. The *HP-IB Quick Reference Guide* lists all the root mnemonics, and all the different units accepted.

The semicolon following `MHZ` terminates the command inside the HP 8702. It removes start frequency from the active entry area, and prepares the HP 8702 for the next command. If there is a syntax error in a command, the HP 8702 will ignore the command and look for the next terminator. When it finds the next terminator, it starts processing incoming commands normally. Characters between the syntax error and the next terminator are lost. A line feed also acts as terminator. The BASIC `OUTPUT` statement transmits a carriage return, line feed following the data. This can be suppressed by putting a semicolon at the end of the statement.

The `OUTPUT 716;` statement will transmit all items listed, as long as they are separated by commas or semicolons. It will transmit literal information enclosed in quotes, numeric variables, string variables, and arrays. A carriage return, line feed is transmitted after each item. This can be suppressed by separating items with semicolons rather than commas.

Note that the front panel remote (R) and listen (L) HP-IB status indicators are on: the HP 8702 automatically goes into remote mode when sent a command with the `OUTPUT` statement. In remote mode, the HP 8702 ignores all front panel keys except the local key. Pressing the **[LOCAL]** key returns the HP 8702 to manual operation, unless the universal HP-IB command `LOCAL LOCKOUT 7` has been issued. The only way to get out of local lockout is to either issue the `LOCAL 7` command, or to cycle power on the HP 8702.

Setting a parameter is just one form of command the HP 8702 will accept. It will also accept simple commands that require no operand at all. For example, execute:

```
OUTPUT 716;"AUTO;"
```

In response, the HP 8702 autoscales the active channel. Autoscale only applies to the active channel, unlike start frequency, which applies to both channels as long as the channels are stimulus coupled.

The HP 8702 will also accept commands that turn various functions on and off. Execute:

```
OUTPUT 716;"DUACON;"
```

This causes the HP 8702 to display both channels. To go back to single channel display mode, execute:

```
OUTPUT 716;"DUACOFF;"
```

The construction of the command starts with the root mnemonic `DUAC` (dual channel display,) and `ON` or `OFF` is appended to the root to form the entire command.

The HP 8702 does not distinguish between upper and lower case letters. For example, execute:

```
OUTPUT 716;"auto;"
```

The HP 8702 also has a debug mode to aid in trouble-shooting systems. When debug mode is on, the HP 8702 scrolls incoming HP-IB commands across the display. To turn the mode on manually, press **[LOCAL]** *[HP-IB DIAG ON]*. To turn it on over HP-IB, execute:

```
OUTPUT 716;"DEBUON;"
```

Command interrogate

Suppose the operator has changed the power level from the front panel. The computer can find out the new power level using the HP 8702's command interrogate function. If a question mark is appended to the root of a command, the HP 8702 will output the value of that function. For instance, `POWE 7 DB;` sets the output power to 7 dB, and `POWE?;` outputs the current RF output power at the test port. For example, type **SCRATCH** and press **[EXECUTE]** to clear old programs. Type **EDIT** and press **[EXECUTE]** to get into the edit mode. Then type in:

```
10   OUTPUT 716;"POWE?;"
20   ENTER 716;Reply
30   DISP Reply
40   END
```

Run the program. The computer will display the source power level in dBm. The preset source power level is 0 dBm. Change the power level by pressing **[LOCAL] [MENU]** *[POWER]* and then entering **[1] [5] [x1]**. Now run the program again.

When the HP 8702 receives `POWE?`, it prepares to transmit the current RF source power level. The BASIC statement `ENTER 716` allows the HP 8702 to transmit information to the computer by addressing it to talk. This turns the HP 8702 front panel talk light (T) on. The computer places the data transmitted by the HP 8702 into the variables listed in the enter statement. In this case, the HP 8702 transmits the output power, which gets placed in the variable `Reply`.

The `ENTER` statement takes the stream of binary data output by the HP 8702 and reformats it back into numbers and ASCII strings. With the formatting in its default state, the enter statement will format the data into real variables, integers, or ASCII strings, depending on the variable being filled. The variable list must match the data the HP 8702 has to transmit: if there are too few variables, data is lost, and if there are too many variables for the data available, a BASIC error is generated.

The formatting done by the enter statement can be changed. As discussed in *Data transfer from analyzer to computer*, the formatting can be turned off to allow binary transfers of data. Also, the `ENTER USING` statement can be used to selectively control the formatting.

On/off commands can also be interrogated. The reply is a one if the function is on, a zero if it is off. Similarly, if a command controls a function that is underlined on the HP 8702 display when active, interrogating that command yields a one if the command is underlined, a zero if it is not. For example, there are nine options on the format menu: only one is underlined at a time. The underlined option will return a one when interrogated.

For instance, rewrite line 10 as:

```
10   OUTPUT 716;"DUAC?;"
```

Run the program once, note the result, the press **[LOCAL] [DISPLAY]** *[DUAL CHAN]* to toggle the display mode, and run the program again.

Another example is to rewrite line 10 as:

```
10   OUTPUT 716;"PHAS?;"
```

In this case, the program will display a one if phase is currently being displayed. Since the command only applies to the active channel, the response to the `PHAS?` inquiry depends on which channel is active.

Held commands

When the HP 8702 is executing a command that cannot be interrupted, it will hold off processing new HP-IB commands. It will fill the 16 character input buffer, and then halt HP-IB until the held command has completed execution. This action will be transparent to a program unless HP-IB timeouts have been set with the `ON TIMEOUT` statement.

While a held command is executing, the HP 8702 will still service the HP-IB interface commands, such as `SPOLL(716)`, `CLEAR 716`, and `ABORT 7`. Executing `CLEAR 716` or `CLEAR 7` will abort a command hold off, leaving the held command to complete execution as if it had been begun from the front panel. These commands also clear the input buffer, destroying any commands received after the held command. If the HP 8702 has halted the bus because its input buffer was full, `ABORT 7` will release the bus.

Operation complete

Occasionally, there is a need to find out when certain operations have completed inside the HP 8702. For instance, a program should not have the operator connect the next calibration standard while the HP 8702 is still measuring the current one.

To provide such information, the HP 8702 has an Operation Complete reporting mechanism that will indicate when certain key commands have completed operation. The mechanism is activated by sending either `OPC` or `OPC?` immediately before an OPC'able command. When the command completes execution, bit 0 of the event status register will be set. If OPC was interrogated with `OPC?`, the HP 8702 will also output a 1 when the command completes execution.

As an example, type **SCRATCH**, press **[EXECUTE]**, type **EDIT**, press **[EXECUTE]**, and type in the following program:

`10 OUTPUT 716;"SWET 3 S;OPC?;SING;"`	Set the sweep time to 3 seconds, and OPC a single sweep.
`20 DISP "SWEEPING"`	
`30 ENTER 716;Reply`	The program will halt at this point until the HP 8702 completes the sweep and issues a one.
`40 DISP "DONE"`	
`50 END`	

This program causes the computer to display the sweeping message for about 3 seconds, as the instrument executes the sweep. The computer will display `DONE` just as the instrument goes into hold. When the `DONE` message appears, the program could then continue on, being assured that there is a valid data trace in the instrument. Without single sweep, we would have had to wait at least two sweep times to ensure good data.

Preparing for HP-IB control

At the beginning of a program, the HP 8702 has to be taken from an unknown state and brought under computer control. One way to do this is with an abort/clear sequence. `ABORT 7` is used to halt bus activity and return control to the computer. `CLEAR 716` will then prepare the HP 8702 to receive commands by clearing syntax errors, the input command buffer, and any messages waiting to be output.

The abort/clear sequence makes the HP 8702 ready to receive HP-IB commands. The next step is to put the HP 8702 into a known state. The easiest way to do this is to send `PRES;` which returns the instrument to the preset state. If preset cannot be used and the status reporting mechanism is going to be used, `CLES` can be sent to clear all of the status reporting registers and their enables.

Type **SCRATCH**, press **[EXECUTE]**, type **EDIT**, press **[EXECUTE]**, and type in the following program:

`10 ABORT 7`	This halts all bus action and gives active control to the computer.
`20 CLEAR 716`	This clears all HP-IB errors, resets the HP-IB interface, clears syntax errors. It does not affect the status reporting system.
`30 OUTPUT 716;"PRES;"`	Preset the instrument. This clears the status reporting system, as well as resetting all of the front panel settings, except the HP-IB mode and the HP-IB addresses.
`40 END`	

Running this program brings the HP 8702 to a known state, ready to respond to HP-IB control.

The HP 8702 will not respond to HP-IB commands unless the remote line is asserted. When the remote line is asserted and the HP 8702 is addressed to listen, it automatically goes into remote mode. Remote mode means that all the front panel keys are disabled except **[LOCAL]** and the line power switch. `ABORT 7` asserts the remote line, which remains asserted until a `LOCAL 7` statement is executed. Another way to assert the remote line is to execute:

```
REMOTE 716
```

This statement asserts remote and addresses the HP 8702 to listen so that it goes into remote mode. Press any front panel key except local. None will respond until after you press **[LOCAL]**.

The local key can also be disabled with the sequence:

```
REMOTE 716
LOCAL LOCKOUT 7
```

Now no front panel keys will respond at all. The HP 8702 can be returned to local mode temporarily with:

```
LOCAL 716
```

But as soon as the HP 8702 is next addressed to listen, it goes back into local lockout. The only way to clear local lockout, aside from cycling power, is to execute:

```
LOCAL 7
```

Which un-asserts the remote line on the interface. This puts the instrument into local mode and clears local lockout. Be sure to put the instrument back into remote mode.

Measurement Programming

The previous section of this document outlined how to get commands into the HP 8702. The next step is to organize the commands into a measurement sequence. A typical measurement sequence consists of the following steps:

1. Set up the instrument.
2. Calibrate.
3. Connect the device.
4. Take data.
5. Post process data.
6. Transfer data.

Set up the instrument

Define the measurement by setting all of the basic measurement parameters. First, determine the type of measurement: E/E, O/E, E/O, or O/O. Set all the stimulus parameters: sweep type, span, sweep time, number of points, and RF/modulation power level. They also include both IF averaging and IF bandwidth. These parameters define the way data is gathered and processed within the instrument, and to change one requires that a new sweep be taken.

There are other parameters that can be set within the instrument that do not affect data gathering directly, such as smoothing, trace scaling or trace math. These functions are classed as post processing functions: they can be changed with the instrument in hold mode, and the data will correctly reflect the current state.

The save/recall registers and the learn string are two rapid ways of setting up an entire instrument state. The learn string is a summary of the instrument state compacted into a string that can be read into the computer and retransmitted to the HP 8702. See Example 6A, *Using the learn string*, for a discussion of how to do this.

Calibrate

Measurement calibration is normally performed once the instrument state has been defined. Because the HP 8702 has the capability to measure optical, electro-optical, optical-electrical, and electrical devices, the calibration used is particular to the measurement medium. Measurement calibration is not required to make a measurement, but it does improve the accuracy of the data.

There are several ways to calibrate the instrument. The simplest is to stop the program and have the operator perform the calibration from the front panel. Alternatively, the computer can be used to guide the operator through the calibration, as discussed in Example 2A and 2B, S_{11} *1-port calibration* and *electro-optical calibration*. The last option is to transfer calibration data from a previous calibration back into the instrument, as discussed in Example 6C, *Reading calibration data*.

Connect device

Have the operator connect and adjust the device. The computer can be used to speed the adjustment process by setting up such functions as limit testing, bandwidth searches, and trace statistics. All adjustments take place at this stage so that there is no danger of taking data from the device while it is being adjusted.

Take data

With the device connected and adjusted, measure its frequency response, and hold the data within the instrument so that there is a valid trace to analyze.

The single sweep command `SING` is designed to ensure a valid sweep. All stimulus changes are completed before the sweep is started, and the HP-IB hold state is not released until the formatted trace is displayed. When the sweep is complete, the instrument is put into hold, freezing the data inside the instrument. Because single sweep is OPC'able, it is easy to determine when the sweep has been completed.

The number of groups command `NUMGn` is designed to work the same as single sweep, except that it triggers n sweeps. This is useful, for example, in making a measurement with an averaging factor n. (n can be 1 to 999). Both single sweep and number of groups restart averaging.

Post process

With valid data to operate on, the post-processing functions can be used. Referring ahead to Figure 2, any function that affects the data after the error correction stage can be used. The most useful functions are trace statistics, marker searches, electrical delay offset, time domain, and gating. If a 2-port calibration is active, then any of the four S-parameters can be viewed without taking a new sweep.

Transfer data

Lastly, read the results out of the instrument. All the data output commands are designed to ensure that the data transmitted reflects the current state of the instrument:

- `OUTPDATA`, `OUTPRAWn`, and `OUTPFORM` will not transmit data until all formatting functions have completed.
- `OUTPLIML`, `OUTPLIMM`, and `OUTPLIMF` will not transmit data until limit test has occurred, if on.
- `OUTPMARK` will activate a marker if one is not already selected, and it will make sure that any current marker searches have completed before transmitting data.
- `OUTPMSTA` makes sure that statistics have been calculated for the current trace before transmitting data. If statistics is not on, it will turn statistics on to update the current values, and then turn it off.
- `OUTPMWID` makes sure that a bandwidth search has been executed for the current trace before transmitting data. If bandwidth search is not on, it will turn the search on to update the current values, and then turn it off.

Data transfer is discussed further in Examples 3A through 3C, *Data transfer using ASCII transfer format*, etc.

Basic Programming Examples

Example 1: Setting up a basic measurement

In general, the procedure for setting up measurements on the HP 8702 via HP-IB follows the same sequence as if the setup was performed manually. There is no required order, as long as the device type, desired frequency range, number of points and power level is set prior to performing the calibration.

This example illustrates how a basic measurement can be set up on the HP 8702. The sequence will be to first select the device type, the desired ratio to be measured, the measurement format, and then the frequency range. Performing calibrations is described later.

By interrogating the analyzer to determine the actual values of the start and stop frequencies, the computer can keep track of the actual frequencies.

This example program is stored on the Example Programs disk as **IPG1.**

`10 ABORT 7`	
`20 CLEAR 716`	Prepare for HP-IB control.
`30 OUTPUT 716;"PRES;DEVTOO"`	Preset the HP 8702 and prepare for optical measurement.
`40 OUTPUT 716;"CHAN1; BR; LOGM;"`	Make channel 1 the active channel, and measure B/R, displaying its magnitude in dB.
`50 INPUT "ENTER START FREQUENCY (MHz):",F_start`	Input a start frequency.
`60 INPUT "ENTER STOP FREQUENCY (MHz):",F_stop`	Input a stop frequency.
`70 OUTPUT 716;"STAR"; F_start;"MHZ;"`	Set the start frequency to `F_start`.
`80 OUTPUT 716;"STOP"; F_stop;"MHZ;"`	Set the stop frequency to `F_stop`.
`90 DISP F_start, F_Stop`	Show the current start and stop frequencies.
`100 END`	

Running the program

The program will set up a measurement of S_{11}, log magnitude on channel 1. When prompted for start and stop frequencies, enter any value in MHz from 0.3 (300 kHz) to 3 GHz. These will be entered into the HP 8702, and the frequencies are then displayed.

Performing a measurement calibration

This section will demonstrate how to coordinate a measurement calibration over HP-IB. The HP-IB command sequence follows the key sequence required to calibrate from the front panel: there is a command for every step.

The general key sequence is to select the calibration, measure the calibration standards, and then declare the calibration done. The actual sequence depends on the calibration kit and changes slightly for 2-port calibrations, which are divided into three calibration sub-sequences.

Electro-optical calibrations require source or receiver calibration data. This information can either be read from a disk or loaded via coefficients for a polynomial fit.

Calibration kits (Electrical)

The calibration kit tells the HP 8702 what standards to expect at each step of the calibration. The set of standards associated with a given calibration is termed a class. For example, measuring the short during an S_{11} 1-port calibration is one calibration step. All of the shorts that can be used for this calibration step make up the class, which is called class S_{11}B. For the 7 mm and the 3.5 mm cal kits, class S_{11}B has only one standard in it. For type-N cal kits, class S_{11}B has two standards in it: male and female shorts.

Calibration disks (Electro-optical)

Each HP Lightwave Source and Receiver is shipped with a disk containing 101 points of calibration data. If this disk is unavailable, one could alternately load the calibration coefficients available located directly on the source or receiver.

When doing an S_{11} 1-port calibration in 7 or 3.5 mm, selecting *[SHORT]* automatically measures the short because there is only one standard in the class. When doing the same calibration in type-N, selecting *[SHORTS]* brings up a second menu, allowing the user to select which standard in the class is to be measured. The sex listed refers to the test port: if the test port is female, then the user selects the female short option.

Doing an S_{11} 1-port calibration over HP-IB is very similar. In 7 or 3.5 mm, sending `CLASS11B` will automatically measure the short. In type-N, sending `CLASS11B` brings up the menu with the male and female short options. To select a standard, use `STANA` or `STANB`. The `STAN` command is appended with the letters A through G, corresponding to the standards listed under softkeys 1 through 7, softkey 1 being the topmost softkey.

The `STAN` command is OPC'able. A command that calls a class is only OPC'able if that class has only one standard in it. If there is more than one standard in a class, the command that calls the class only brings up another menu, and there is no need to OPC it.

Therefore, both the manual and HP-IB calibration sequences depend heavily on which calibration kit is active.

Full 2-port calibrations

Each full 2-port measurement calibration is divided into three sub-sequences: transmission, reflection, and isolation. Each subsequence is treated like a calibration in its own right: each must be opened, have all the standards measured, and then be declared done.

The opening and closing statements for the transmission sub-sequence are `TRAN` and `TRAD`. The opening and closing statements for the reflection sub-sequence are `REFL` and `REFD`. The opening and closing statements for isolation are `ISOL` and `ISOD`.

Example 2A: S_{11} 1-port electrical calibration

To demonstrate coordinating a calibration over HP-IB, the following program does an S_{11} 1-port calibration, using the HP 85032B 50 ohm type-N calibration kit. This program simplifies the calibration for the operator by giving explicit directions on the HP 8702 display, and allowing the user to continue the program from the HP 8702 front panel.

This example program is stored on the Example Programs disk as **IPG2A**.

`10 ABORT 7`	
`20 CLEAR 716`	Prepare for HP-IB control.
`30 OUTPUT 716;"DEVTEE; CALKN50;MENUOFF;CLES; ESE 64;"`	This is the minimum instrument set up: an electrical measurement is being made, the 50 ohm type-N cal kit is selected, the softkey menu is turned off, and the status reporting system is set up so that bit 6, User Request, of the event status register, is summarized by bit 5 of the status byte. This allows us to detect a key press with a serial poll. Refer to Appendix A.
`40 OUTPUT 716;"CALIS111;"`	Open the calibration by calling the S_{11} 1-port calibration.
`50 CALL Waitforkey("CONNECT LOAD AT PORT 1")`	Now ask for the load, and wait for the operator. The Waitforkey subroutine will not return until the operator presses a key on the front panel of the HP 8702.
`60 OUTPUT 716;"OPC?; CLASS11C;"`	There is only one choice in this class, so the CLASS command is OPC'able. Using the OPC? command causes the program to wait until the standard has been measured before continuing. This is very important, because the prompt to connect the next standard should only appear after the first standard is measured.
`70 ENTER 716;Reply`	Wait until the HP 8702 is done with the standard.
`80 CALL Waitforkey("CONNECT OPEN AT PORT 1")`	Ask for an open, and wait for the operator to connect it.
`90 OUTPUT 716; "CLASS11AOPC?;STANB;"`	Measure the open. There is more than one standard in this loads class, so we must identify the specific standard within that class. The female open is the second softkey selection from the top in the menu, so select a lowband load as the standard using the command `STANB`.
`100 ENTER 716;Reply`	Wait for the standard to be measured.
`110 CALL Waitforkey("CONNECT SHORT LOAD AT PORT 1")`	Have the operator connect the short and wait for his reply.
`120 OUTPUT 716; "CLASS11B:OPC?;STANB;"`	There is more than one standard in the short class, too. The specific standard is the female short, or STAN B. Measure the short.
`130 ENTER 716;Reply`	Wait for the standard to be measured.
`140 OUTPUT 717;"PG;"`	The `PG` command sent to the display clears the user graphics, removing the last prompt.
`150 DISP "COMPUTING CALIBRATION COEFFICIENTS"`	
`160 OUTPUT 716;"DONE;OPC?; SAV1;"`	Affirm the completion of the calibration, and save the calibration.

`170 ENTER 716;Reply`	Wait until the HP 8702 is done calculating the calibration coefficients before allowing the program to go on.
`180 DISP "S11 1-PORT CAL COMPLETED. CONNECT TEST DEVICE."`	
`190 OUTPUT 716;"MENUON;"`	The calibration is completed, so turn the softkey menu back on.
`200 END`	
`210 SUB Waitforkey(Lab$)`	This subroutine displays the passed message on the HP 8702, and waits for the operator to press a key. It assumes that bit 6, User Request, of the event status register has been enabled.
`220 DISP Lab$`	First, display a message on the computer in case the operator has returned to the computer keyboard.
`230 OUTPUT 717;"PG;PU;PA390, 3600;PD;LB";Lab$;", PRESS ANY KEY WHEN READY;"`	This statement writes on the HP 8702's display. `PG` (page) clears old user graphics. `PU` (pen up) prevents anything from being drawn. `PA390,3600;` moves the logical pen to just above the message area on the display. `PD` (pen down) enables drawing. `LB` (label) writes the message on the display. The label command is terminated with an ETX symbol, which is **[CTRL] [C]** (pressed simultaneously) on the keyboard.
`240 CLEAR 716`	Clear the message line on the HP 8702.
`250 OUTPUT 716;"ESR?;"`	Clear the latched User Request bit so that old key presses will not trigger a measurement.
`260 ENTER 716;Estat`	
`270 Stat=SPOLL(716)`	Now wait for a key press to be reported.
`280 IF NOT BIT(Stat,5) THEN GOTO 340`	
`290 SUBEND`	

Running the program

The program assumes that the port being calibrated is an electrical 50 ohm, type-N female test port. The prompts appear just above the message line on the HP 8702 display. Pressing any key on the front panel of the HP 8702 continues the program and measures the standard. The program will display a message when the measurement calibration is complete.

Before running the program, set up the desired instrument state. This program does not modify the instrument state in any way. Run the program, and connect the standards as prompted. When the standard is connected, press any key on the HP 8702's front panel to measure it.

Example 2B: E/O source calibration using disk data

The following example shows how to perform an electro-optical source calibration. This example assumes source calibration data is available from disk. Alternately, if calibration coefficients are used for calibration, the program can be easily modified to do so.

This example is stored on the Example Programs disk as **IPG2B**.

`10 ABORT 7`	
`20 CLEAR 716`	Prepare for HP-IB control.
`30 OUTPUT 716;"DEVTEO;BR;MENUOFF;CLES;ESE 64;"`	This is the minimum instrument set up: the device type E/O is chosen, the B/R measurement is selected, the softkey menu is turned off, and the status reporting system is set up so that bit 6, User Request, of the event status register, is summarized by bit 5 of the status byte. This allows us to detect a key press with a serial poll.
`40 OUTPUT 716;"CALSSOUD;"`	This tells the instrument to obtain source calibration data from disk.
`50 OUTPUT 716;"USEPASC;"`	Put the HP 8702 in pass control mode.
`60 OUTPUT 716;"READSOUT;LOADSOU1;"`	Read the calibrated source data file and load it into the HP 8702 for calibration.
`70 SEND 7;TALK 16 CMD 9`	This is the bus command to pass active control to device 16. With BASIC 3.0, 4.0, 5.0, or 2.0 with extensions 2.1, the command `PASS CONTROL 716` can be used instead.
`80 DISP "LOADING CAL SOURCE DATA FROM DISC"`	
`90 STATUS 7,6;Hpib`	To determine when the transfer is finished, watch for return of active control.
`100 IF NOT BIT (Hpib,6) THEN GOTO 90`	If control has not returned, loop and wait.
`110 OUTPUT 716;"CALIRESP;"`	
`120 DISP "CONNECT CALIBRATED SOURCE"`	
`130 OUTPUT 717;"PG;PU;PA390,3600;PD;LB";"CONNECT SOURCE, PRESS ANY KEY WHEN READY*;"`	This statement writes on the HP 8702's display `PG` (page) clears old user graphics. `PU` (pen up) prevents anything from being drawn. `PA390,3600` moves the logical pen to just above the message on the display. `PD` (pen down) enables drawing. `LB` (label) writes the message on the display. The label command is terminated with an ETX symbol, which is **[CTRL] [C]** (pressed simultaneously) on the keyboard.
`140 CLEAR 716`	Clear the message line on the HP 8702.
`150 OUTPUT 716;"ESR?;"`	Clear the latched User Request bit so that old key presses will not trigger a measurement.
`160 ENTER 716;Estat`	
`170 Stat=SPOLL(716)`	Now wait for a key press to be reported.
`180 IF NOT BIT(Stat,5) THEN GOTO 170`	Loop until key is pressed.
`190 OUTPUT 716;"OPC?STANA;"`	Using the `OPC?` command causes the program to wait until the standard has been measured before continuing. The thru is the first softkey selection from the top of the menu, so select it using the `STANA` command.

`200 ENTER 716;Reply`	Wait until the HP 8702 is done with the standard.
`210 OUTPUT 717;"PG;"`	Clear the user graphics from the HP 8702 display.
`220 OUTPUT 716;"OPC?; RESPDONE;"`	Affirm the completion of the calibration and save it.
`230 ENTER 716;Reply`	Wait until the calibration is saved before proceeding.
`240 DISP "CAL COMPLETED. INSERT TEST SOURCE."`	
`250 END`	

Running the program

The program assumes that a calibration data disk is available for the HP Lightwave Source used. The data must be the only source file on the disk to ensure a valid calibration. Connect the source when the prompt appears just above the message line on the HP 8702 display. Pressing any key on the front panel of the HP 8702 continues the program and measures the standard. A message will be displayed when the calibration is complete.

Before running the program, set up the desired instrument state. This program does not modify the instrument state in any way. Run the program, and connect the standard as prompted.

Data transfer from analyzer to computer

Using markers to obtain trace data at specific points

Trace information can be read out of the HP 8702 in several ways. Data can be read off the trace selectively using the markers, or the entire trace can be read out. If only specific information such as a single point off the trace or the result of a marker search is needed, the marker output command can be used to read the information. If all the trace data is needed, see Examples 3A thru 3C.

To get data off the trace using the marker, the marker first has to be put at the frequency desired. This is done with the marker commands. For example, execute:

```
OUTPUT 716;"MARK1  1.56 GHZ;"
```

This places marker one at 1.56 GHz. If the markers are in continuous mode, the marker value will be linearly interpolated from the two nearest points if 1.5600 GHz was not sampled. This interpolation can be prevented by putting the markers into discrete mode. The key sequence for this is **[LOCAL] [MKR]** *[MARKER MODE MENU] [MARKERS:DISCRETE].* To do it over HP-IB, execute:

```
OUTPUT 716;"MARKDISC;"
```

After executing this, note that the marker is may no longer be precisely on 1.56 GHz. (This depends on the start and stop frequencies).

Another way of using the markers is to let the HP 8702 pick the stimulus value on the basis of one of the marker searches: max, min, target value, or bandwidths search. For example, execute:

```
OUTPUT 716;"SEAMAX;"
```

This executes a one-time trace search for the trace maximum, and puts the marker at that maximum. In order to continually update the search, turn tracking on. The key sequence is **[MKR FCTN]** *[MKR SEARCH] [TRACKING] [SEARCH: MAX].* To do it over HP-IB, execute:

```
OUTPUT 716;"TRACKON;SEAMAX;"
```

The trace maximum search will stay on this time, until search is turned off, tracking is turned off, or all markers are turned off. For example, execute:

```
OUTPUT 716;"MARKOFF;"
```

Marker data is read out with the command `OUTPMARK`. This command causes the HP 8702 to transmit three numbers: marker value 1, marker value 2, and marker stimulus value. In this case we get the log magnitude at marker 1, zero, and the marker frequency. See Table 1 for all the different possibilities for values one and two. The third value is frequency in this case, but it could have been time as in time domain (option 010 only) or CW time.

Run the program. The values displayed by the computer should agree with the marker values displayed on the HP 8702, except that the second value displayed by the computer will be meaningless in phase and log mag formats. To see the possibilities for different values, run the program three times: once in log magnitude format, once in phase format, and once in Smith chart format. To change display format, press **[LOCAL] [FORMAT]** and then select the desired format.

Type **SCRATCH**, press **[EXECUTE]**, type **EDIT**, press **[EXECUTE]**, and then type in the following program:

`10 OUTPUT 716;"SEAMIN;OUTPMARK;"`	Have the HP 8702 search out the trace minimum, and then output the marker values at that point.
`20 ENTER 716;Val1,Val2,Stim`	Read marker value 1, marker value 2, and the stimulus value.
`30 DISP Val1,Val2,Stim`	Display the values.
`40 END`	

Table 1. Units as a Function of Display Format

DISPLAY FORMAT	MARKER MODE	OUTPMARK value 1, value 2	OUTPFORM value 1, value 2	MARKET READOUT** value, aux value
LOG MAG		dB,*	dB,*	dB,*
PHASE		degrees,*	degrees,	degrees,*
DELAY		seconds,*	seconds,*	seconds,*
SMITH	LIN MKR	lin mag, degrees	real, imag	lin mag, degrees
CHART				
	LOG MKR	dB, degrees	"	dB, degrees
	Re/Im	real, imag	"	real, imag
	R + jX	real, imag ohms	"	real, imag ohms
	G + jB	real, imag Siemens	"	real, imag Siemens
POLAR	LIN MKR	lin mag, degrees	real, imag	lin mag, degrees
	LOG MKR	dB, degrees	"	dB, degrees
	Re/Im	real, imag	"	real, imag
LIN MAG		lin mag,*	lin mag,*	lin mag,*
REAL		real,*	real,*	real,*
SWR		SWR,*	SWR,*	SWR,*

* Value not significant in this format, but is included in data transfers.

** The marker readout values are the marker values displayed in the upper left hand corner of the display. They also correspond to the value and aux value associated with the fixed marker.

Trace transfer

Getting trace data out of the HP 8702 with a 200/300 series computer can be broken down into three steps:

1. Setting up the receive array.
2. Telling the HP 8702 to transmit the data.
3. Accepting the transferred data.

Data inside the HP 8702 is always stored in pairs, to accommodate real/imaginary pairs, for each data point. Hence, the receiving array has to be two elements wide, and as deep as the number of points. This memory space for this array must be declared before any data is to be transfered from the HP 8702 to the computer.

The HP 8702 can transmit data over HP-IB in four different formats. The type of format affects what kind of data array is declared (real or integer), since the format determines what type of data is transferred. Examples for data transfers using different formats are given below. The first, Example 3A, illustrates the basic transfer using form 4, an ASCII transfer. For more information on the various data formats, see the section entitled *Data Formats.* For information on the various types of data that can be obtained (raw data, corrected data and so on), see the section entitled *Data Levels.*

Note that Example 9, *Reading disk files into a computer,* allows the operator to access disk files from a computer.

Example 3A: Data transfer using form 4 (ASCII transfer)

As detailed in the *HP-IB Quick Reference Guide,* when form 4 is used, each number is sent as a 24 character string, each character being a digit, sign, or decimal point. Since there are two numbers per point, a 201 point transfer in form 4 takes 9,648 bytes. An example simple data transfer using form 4, an ASCII data transfer is shown in this program.

This example program is stored on the Example Programs disk as **IPG3A.**

`10 ABORT 7`	
`20 CLEAR 716`	Prepare for HP-IB control.
`30 OUTPUT 716;"PRES;"`	Preset the analyzer.
`40 DIM Dat(1:11,1:2)`	This line sets up an array to receive the data. The `ENTER 716;Dat(*)` statement in line 60 fills the array `Dat` automatically, changing the second subscript fastest. Since the HP 8702 transmits the data as ordered pairs, we make the second dimension two so that the pairs will be properly grouped. The number of points will be set to 11, so we know to make the first dimension 11.
`50 OUTPUT 716;"POIN 11; SING; FORM4; OUTPFORM;"`	Set the number of points, tell the HP 8702 to use ASCII transfer format, and request the formatted trace data. Frequency information is not included in the transfer.
`60 ENTER 716;Dat(*)`	The computer takes the data from the instrument and puts it in the receiving array. By specifying `Dat(*)`, we have told the enter statement to fill every location in the array.
`70 DISP DAT(1,1),DAT(1,2)`	This line checks the first data point received. The data is in the current HP 8702 display format: see Table 1 for the contents of the array as a function of display format.
`80 END`	

Running the program

The first number of the result is a trace value in dB, and the second is zero. Put a marker at 300 kHz, which was the first point transmitted, to see that the values displayed by the computer agree with the HP 8702. Keep in mind that no matter how many digits are displayed, the HP 8702 is specified to measure magnitude to a resolution of .001 dB, phase to a resolution of 0.01 degrees, and group delay to a resolution of 0.01 psec.

Changing the display format will change the data sent with the `OUTPFORM` transfer. See Table 1 for a list of what data is provided with what formats. The data from `OUTPFORM` reflects all the post processing such as time domain, gating, electrical delay, trace math, and smoothing. Note that if time domain (option 010 only) is on, operation is limited to 201 points in the lowpass mode.

Relating the data from a linear frequency sweep to frequency can be done by interrogating the start frequency, the frequency span, and the number of points. Given that information, the frequency of point N in a linear frequency sweep is just:

$$F = \text{Start\_frequency} + (N-1) \times \text{Span}/(\text{Points}-1)$$

Alternatively, it is possible to read the frequencies directly out of the instrument with the `OUTPLIML` command. `OUTPLIML` reports the limit test results by transmitting the stimulus point tested, a number indicating the limit test results, and then the upper and lower limits at that stimulus point, if available. The number indicating the limit results is a −1 for no test, 0 for fail, and 1 for pass. If there are no limits available, the HP 8702 transmits zeros.

Running the following program will print out all the trace data and the stimulus values. Put the instrument into a log frequency sweep by pressing **[LOCAL] [MENU]** *[SWEEP TYPE MENU] [LOG FREQ]*, and run the program again. If you define a list frequency table with 11 points, this program will still show the sampled frequencies. If you define a limit test table, `Reslt` will hold the limit test results.

For this example, we throw away the limit test information and keep the stimulus information. Edit line 40 to read:

```
40  DIM Dat(1:11,1:2),
    Stim(1:11)
```

And type in:

`70  OUTPUT 716;"OUTPLIML;"`	Request the limit test results.
`80  FOR I=1 TO 11`	Loop 11 times to read in all 11 data points.
`90  ENTER 716;Stim(I),Reslt, Upr,Lwr`	Read the stimulus values in, throw the rest away. Because we are not loading the data into a single array, it is necessary to loop and read every point.
`100 PRINT Stim(I),Dat(I,1), Dat(I,2)`	Print the data value and stimulus value.
`110 NEXT I`	
`120 DISP Reslt,Upr,Lwr`	Show what the last limit test result was, just to see what came out.
`130 END`	

Data levels

Different levels of data can be read out of the instrument. Referring to the data processing chain in Figure 2, there is available:

- Raw data. The basic measurement data, reflecting the stimulus parameters, IF averaging, and IF bandwidth. If a full 2-port measurement calibration is on, there are four raw arrays kept: one for each raw S-parameter. The data is read out with the commands `OUTPRAW1, OUTPRAW2, OUTPRAW3, OUTPRAW4`. Normally, only raw 1 is available, and it holds the current parameter. If a 2-port calibration is on, the four arrays refer to S_{11}, S_{21}, S_{12}, and S_{22} respectively. This data is in real/imaginary pairs.

- Error Corrected data. This is the raw data with error correction applied. The array is for the currently measured parameter, and is in real/imaginary pairs. The error corrected data is read out with `OUTPDATA`. `OUTPMEMO` reads the trace memory if available, which is also error corrected data. Neither raw nor error corrected data reflect such post-processing functions as electrical delay offset, trace math, or time domain gating.

- Formatted data. This is the array of data being displayed. It reflects all post-processing functions such as electrical delay or time domain, and the units of the array read out depends on the current display format. See Table 1 for the various units as a function of display format.

- Calibration coefficients. The results of a calibration are arrays of calibration coefficients which are used in the error correction routines. Each array corresponds to a specific error term in the error model. The *HP-IB Quick Reference Guide* details which error coefficients are used for specific calibration types, and which arrays those coefficients are to be found in. Not all calibration types use all 12 arrays. The data is stored as real/imaginary pairs.

Formatted data is generally the most useful data, being the same information an operator sees on the display. However, if the post processing is unneeded or unwanted, as may be the case with smoothing, error corrected data is preferred. Error corrected data also gives you the opportunity to put the data into the instrument and apply post-processing at a later time.

As an example of error corrected data, change line 50 to:

```
50   OUTPUT 716;"POIN 11; SING; FORM4; OUTPDATA;"
```

Running the program now displays real and imaginary trace data, regardless of what display format is currently being used. Select the real display format to verify that the data is the real portion.

Data formats

As stated earlier, the HP 8702 can transmit data over HP-IB in four different formats. We have been using form 4, an ASCII data transfer. Another option is to use form 3, which is the IEEE 64 bit floating point format. In this mode, each number takes 8 bytes instead of 24. This means that a 201 point transfer takes only 3,216 bytes. Data is stored internally in the 200/300 series computer with the IEEE 64 bit floating point format, removing the need for any reformatting by the computer.

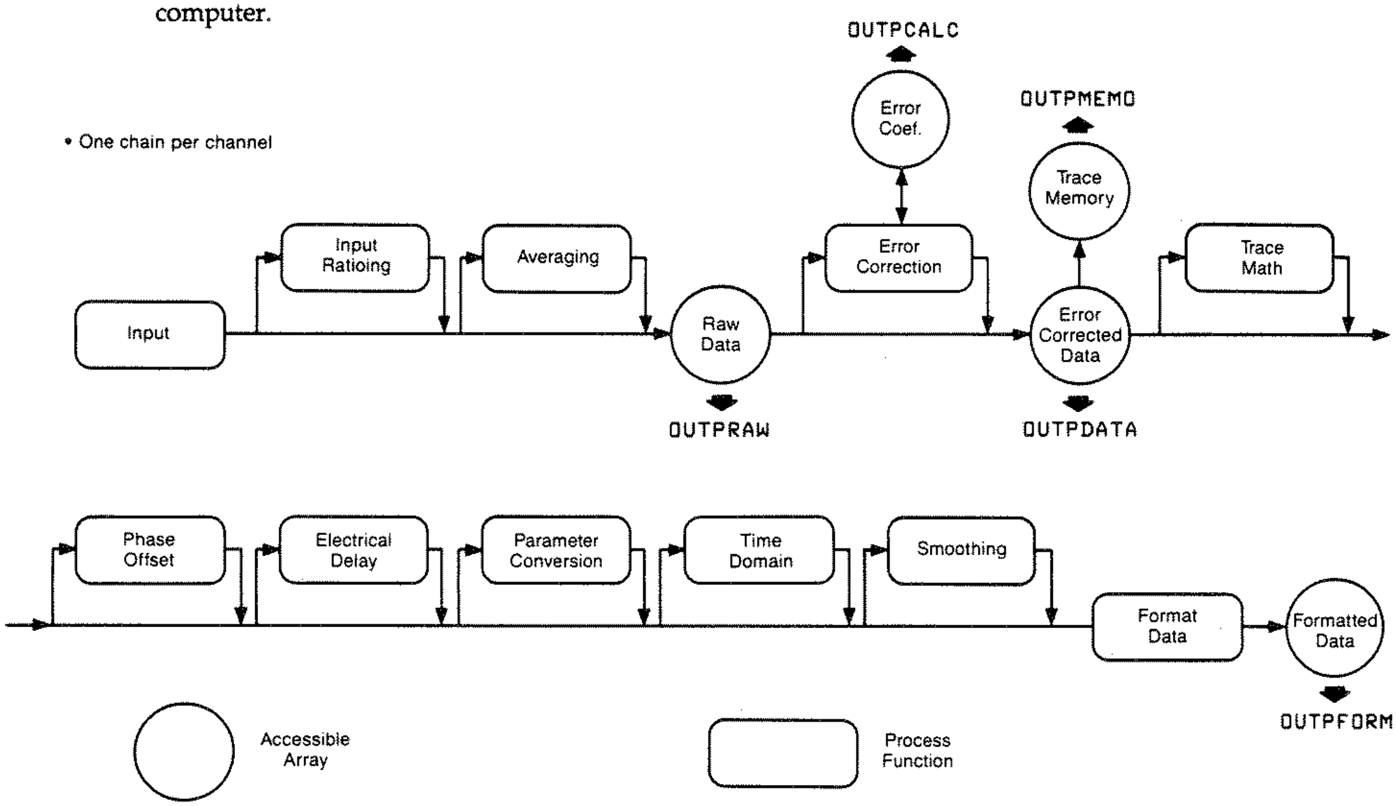


Figure 2. Data processing chain

Example 3B: Data transfer using form 3 (IEEE 64 bit floating point format)

Example program 3B illustrates data transfer using form 3, in which data is transmitted in the IEEE 64 bit floating point format.

To use form 3, the computer is told to stop formatting the incoming data with the `ENTER` statement. This is done by defining an I/O path with formatting off. Form 3 also has a four byte header to deal with. The first two bytes are the ASCII characters "#A" that indicate that a fixed length block transfer follows, and the next two bytes form an integer containing number of bytes in the block to follow. The header must read in so that data order is maintained.

This example program is stored on the Example Programs disk as **IPG3B.**

`10 ABORT 7`	
`20 CLEAR 716`	Prepare for HP-IB control.
`30 DIM Dat(1:201,1:2)`	As before, prepare the receiving array.
`40 INTEGER Hdr,Lgth`	Since an integer takes two bytes, `Hdr` and `Lgth` will take care of the four byte header. `Lgth` will hold the number of bytes in the data block.
`50 ASSIGN @Dt TO 716;FORMAT OFF`	This statement defines a data I/O path with ASCII formatting off. The I/O path points to the HP 8702, and can be used to read or write data to the instrument, as long as that data is in binary rather than ASCII format.
`60 OUTPUT 716;"SING;FORM3; OUTPFORM;"`	The analyzer is told to output formatted data using form 3.
`70 ENTER @Dt;Hdr,Lgth,Dat(*)`	The data is read in much as before, but the I/O path has format off to accept the binary data from form 3. The HP 8702 and the computer must be in agreement as to the format of the data being transmitted.
`80 DISP Lgth,Dat(1,1),Dat (1,2)`	
`90 END`	

Running the program

Preset the instrument and run the program. The computer displays 3,216 and the trace values at 300 kHz. The number 3,216 comes from 201 points, 2 values per point, 8 bytes per value. Note that this transfer is much faster than a form 4 transfer: more than twice as fast.

To illustrate a point, go to the instrument and press **[LOCAL] [MENU]** *[NUMBER of POINTS]*, and key in **101 [x1]**. Now run the program again: a BASIC error will be generated because the HP 8702 ran out of data to transmit before the variable list was full.

Go to the instrument again, and this time change the number of points to 401. Running the program again does not generate an error, but not all of the data was read in. The HP 8702 is still waiting to transmit data, but the program has not been designed to detect the situation.

As illustrated above, it is imperative that the receiving array be correctly dimensioned. There are two things that assure correct dimensions. First, the number of points is readily available through `POIN?` or through the header that precedes forms 1, 2 and 3. Second, BASIC allows dimensioning, redimensioning, allocating, and deallocating statements anywhere in a program. We can take advantage of this in simple programs to wait until we know how many points to expect before we dimension.

BASIC offers two options to those who want to dimension an array with a variable expression, such as the number of points in the sweep. One is the `REDIM` statement, available with AP2—1 or the MAT binary, which redimensions a given array to any size less than or equal to its originally dimensioned size. The other option is to `ALLOCATE` the array just before using it, and `DEALLOCATE` when it's no longer needed. `ALLOCATE` works exactly like `DIM`, except that when you deallocate, the memory space is returned to general use and you can re-use the variable name. All of the following examples use `ALLOCATE`.

For example, delete line 30 and type in the following lines over the last program:

`70 ENTER @Dt;Hdr,Lgth`	
`80 ALLOCATE Dat(1:Lgth/16,1:2)`	This guarantees that the receiving array is the correct size. In form 3, each number is 8 bytes, and there are two numbers per point, so we divide `Lgth` by 16 to get number of points.
`90 ENTER @Dt;Dat(*)`	
`100 DISP Dat(Lgth/16,1)`	Display the last number read in.
`110 END`	

Set the number of points to 51 and run the program: this time no errors are generated. Set the number of points to 401, and run the program again. Move a marker to the last point on the trace, and check to see that the last point read in was the last point on the trace, as expected.

There are two other formats available. Form 2 is not used with 200/300 computers, and form 1 is a special high speed transfer. Form 1 is a condensed transfer format that is useful if data is being transferred out of the HP 8702 for direct storage and later re-transmission to the HP 8702. Example 3C gives an example of a data transfer using form 1.

Example 3C: Data transfer using form 1 (HP 8702 internal format)

In form 1, each data point is sent out as it is stored inside the HP 8702, in a six byte binary string. It is a very fast transfer, using only 1206 bytes to transfer 201 points, but it is difficult to decode. (Real/imaginary data uses the first two bytes for the imaginary fraction mantissa, the middle two bytes for the real fraction mantissa, the fifth byte is used for additional resolution when transferring raw data, and the last byte as the common power of two). The data could be recombined and displayed in the computer, but this requires significant reformatting time.

In this example, we use form 1 to get data to store on disc. Before running this program, be sure that the mass storage device is a disc drive with a formatted disc in it. We also introduce a method of loading data back into the HP 8702. For most `OUTPxxxx` commands, there is a corresponding `INPUxxxx` command, and here we take advantage of that to load error corrected data back into the instrument.

This example program is stored on the Example Programs disc as **IPG3C**.

`10 ABORT 7`	
`20 CLEAR 716`	Prepare for HP-IB control.
`30 INTEGER Hdr,Lgth`	Set up to integers to take the header, the same as with form 3.
`40 ASSIGN @Dt TO 716;FORMAT OFF`	
`50 OUTPUT 716;"SING;FORM1; OUTPDATA;"`	Have the HP 8702 take a sweep, and prepare to transmit the trace data to the computer.
`60 ENTER @Dt;Hdr,Lgth`	
`70 CREATE BDAT "TESTDATA",1,Lgth+4`	This statement creates a disk file to store the form 1 data in. It creates a binary data file name `TESTDATA`. The file is 1 record long, using a record length of Lgth+4 bytes. The extra 4 bytes are for the header. This example will not run unless `MASS STORAGE IS` points to a disk drive with a formatted disk in it, and that disk cannot have a file named `TESTDATA` on it.
`80 ASSIGN @Disc TO "TESTDATA"`	This statement creates a data I/O path pointing to the file `TESTDATA`.
`90 ALLOCATE INTEGER Dat(1:Lgth/6,1:3)`	We create an integer receiving array. There are six bytes per point in form 1, so allocating 3 integers per point will hold the data correctly, since an integer is two bytes.
`100 ENTER @Dt;Dat(*)`	The data is received much as before.
`110 OUTPUT @Disc;Hdr,Lgth,Dat(*)`	Write the data to the disk drive.
`120 INPUT "CHANGE TRACE AND HIT RETURN",Dum$`	At this point, disconnect the test device, and take a sweep. We will then go on to read the data off the disk, and put it back in the instrument.
`130 OUTPUT 716;"SING;"`	Take one sweep and hold.
`140 ASSIGN @Disc TO "TESTDATA"`	Re-establish the data path. This is necessary in order to begin reading data from the start of the file, rather than the end of the file where the file pointer was left by line 110.
`150 ENTER @Disc;Hdr,Lgth, Dat(*)`	Get the information.
`160 OUTPUT 716;"INPUDATA"`	
`170 OUTPUT @Dt;Hdr,Lgth,Dat(*)`	Copy it out to the HP 8702.

`180 ASSIGN @Disc TO *`	Close the file.
`190 DEALLOCATE Dat(*)`	Release the memory for the data array.
`200 PURGE "TESTDATA"`	And purge the data file.
`210 END`	

Running the program

Preset the HP 8702, and run the program. When the program pauses, press **[LOCAL]**, change the trace (for example, START frequency) and press **[RETURN]**. When the data is reloaded into the HP 8702, it will be formatted and displayed as the current trace. This form of data transfer is even faster than the transfer using form 3.

Advanced Programming Examples

Using list frequency mode

The HP 8702 normally takes data points spaced at regular intervals across the overall frequency range of the measurement. For example, for a 2 GHz frequency span, using 201 points, data will be taken at intervals of 10 MHz. The list frequency mode allows the operator to select the specific points or frequency spacing between points at which measurements are to be made. This mode of operation allows flexibility in setting up tests to ensure device performance in an efficient manner. By only sampling specific points, measurement time is reduced, since additional time is not spent measuring device performance at frequencies which are of no concern.

The following example illustrates the use of the HP 8702's list frequency mode to perform arbitrary frequency testing. Example 4 lets the operator construct a table of list frequency segments which is then loaded into the HP 8702's list frequency table. Each segment stipulates a start and stop frequency, and the number of data points to be taken over that frequency range. Note that list frequency segments can be overlapped, but the total number of points in all the segments must not exceed 1632 points.

Example 4: Setting up a list frequency sweep

The purpose of this example is to show how to create a list frequency table and transmit it to the HP 8702.

The command sequence for entering a list frequency table imitates the key sequence followed when entering a table from the front panel: there is a command for every key press. Editing a segment is also the same as the key sequence, but remember the HP 8702 automatically reorders each edited segment in order of increasing start frequency.

The list frequency table is also carried as part of the learn string. While it cannot be modified as part of the learn string, it can be stored and recalled with very little effort.

This example takes advantage of the computer's capabilities to simplify creating, adding to, and editing the table. The table is entered and completely edited before being transmitted to the HP 8702. To simplify the programming task, options such as entering center/span or step size are not included. For information on reading list frequency data out of the HP 8702, see the section *Data transfer from analyzer to computer.*

This program is stored on the Example Programs disk as **IPG4**.

`10 ABORT 7`	
`20 CLEAR 716`	Prepare the HP 8702 for HP-IB control
`30 OUTPUT 716;"EDITLIST;"`	Activate the frequency list edit mode.
`40 FOR I=1 to 30`	Setup a `FOR NEXT` loop.
`50 OUTPUT 716;"SDEL;"`	Delete any existing segments.
`60 NEXT I`	
`70 INPUT "Number of segments?",Numb`	Find out how many segments to expect.
`80 ALLOCATE Table(1:Numb,1:3)`	Create a table to hold the segments. We only keep start frequency, stop frequency, and number of points.
`90 PRINTER IS 1`	Make sure we print on the screen.
`100 OUTPUT 2;CHR$(255)&"K";`	Clear the screen.
`110 PRINT USING "10A,10A,10A,20A";"SEGMENT", "START(MHZ)","STOP(MHZ)","NUMBER OF POINTS"`	Print the table header.
`120 FOR I=1 TO Numb`	Read in each segment.

`130 GOSUB Loadpoin`	`Loadpoin` (line 300) reads in the start frequency, stop frequency, and number of points for segment I. Since `Loadpoin` is a subroutine, I is used as a global variable.
`140 NEXT I`	
`150 LOOP`	Use the LOOP, EXIT IF, END LOOP structure to loop and edit the table until the operator indicates that editing is no longer desired. This structure sets up a loop with the exit point in the middle of the loop rather than at the beginning (as with `WHILE`, `END WHILE`), or at the end (as with `REPEAT`, `UNTIL`).
`160 INPUT "DO YOU WANT TO EDIT? Y OR N",An$`	Let the operator edit the table. Editing is actually re-entering the entire segment. The old segment values are left in place if the operator presses return without typing anything.
`170 EXIT IF An$="N"`	Exit the edit loop if editing is finished. Execution is continued at line 210.
`180 INPUT "ENTRY NUMBER?",I`	For editing, get the entry number.
`190 GOSUB Loadpoin`	And have `Loadpoin` re-enter the values.
`200 END LOOP`	
`210 OUTPUT 716;"EDITLIST"`	Begin the table entry by opening the list frequency table for editing. The table must be empty, or these segments will write over the old ones.
`220 FOR I=1 TO Numb`	Loop for each segment.
`230 OUTPUT 716;"SADD;STAR";Table(I,1);"MHZ;"`	
`240 OUTPUT 716;"STOP";Table(I,2);"MHZ;"`	
`250 OUTPUT 716;"POIN",Table(I,3),";"`	Enter the segment values.
`260 OUTPUT 716;"SDON;"`	Declare the segment done.
`270 NEXT I`	
`280 OUTPUT 716;"EDITDONE;LISFREQ;"`	Close the table, and turn on the list frequency mode.
`290 STOP`	
`300 Loadpoin: !`	Enter in a segment.
`310 INPUT "START FREQUENCY?(MHZ)",Table(I,1)`	
`320 INPUT "STOP FREQUENCY?(MHZ)",Table(I,2)`	
`330 INPUT "NUMBER OF POINTS?",Table(I,3)`	Enter the segment values.
`340 IF Table(I,3)=1 THEN Table(I,2)=Table(I,1)`	If only one point in the segment, make the stop frequency equal to the start frequency to avoid ambiguity.
`350 PRINT TABXY(0,I+1);I;TAB(10);Table(I,1);TAB(20);Table(I,2);TAB(30),Table`	Print the segment out. Because of the `TABXY`, this will print over old segments if a segment is being edited.
`360 RETURN`	
`370 END`	

Running the program

The program displays the frequency list table as it is entered. During editing, the displayed table is updated as each line is edited. The table is not re-ordered. At the completion of editing, the table is entered into the HP 8702, and list frequency mode turned on. During editing, simply pressing **[RETURN]** leaves an entry at the old value.

Any segments already in the list frequency table in the HP 8702 will be deleted by the program. If this is not desired, delete lines 40 thru 60. New segments will then simply be entered on top of the old list frequency segments.

Using limit lines to perform PASS/FAIL tests

There are two steps to performing limit testing on the HP 8702 under HP-IB control. First, limit specifications must be specified and loaded into the analyzer. Second, the limits are activated, the device is measured, and its performance to the specified limits is signaled by a pass or fail message on the HP 8702's display.

Example 5A illustrates the first step, setting up limits, and Example 5B performs the actual limit testing.

Example 5A: Setting up limit lines

The purpose of this example is to show how to create a limit table and transmit it to the HP 8702.

The command sequence for entering a limit table imitates the key sequence followed when entering a table from the front panel: there is a command for every key press. Editing a limit is also the same as the key sequence, but remember that the HP 8702 automatically re-orders the table in order of increasing start frequency.

The limit table is also carried as part of the learn string. While it cannot be modified as part of the learn string, it can be stored and recalled with very little effort.

This example takes advantage of the computer's capabilities to simplify creating and editing the table. The table is entered and completely edited before being transmitted to the HP 8702. To simplify the programming task, options such as entering offsets are not included.

This program is stored as **IPG5A** on the Example Programs disk.

`10 ABORT 7`	
`20 CLEAR 716`	Prepare the HP 8702 for HP-IB control.
`30 OUTPUT 716;"EDITLIML; CDEL;"`	Delete any existing limits.
`40 INPUT "Number of limits?",Numb`	Find out how many limits to expect.
`50 ALLOCATE Table(1:Numb,1:3)`	Create a table to hold the limits. It will contain stimulus value (frequency), upper limit value, and the lower limit value.
`60 ALLOCATE Limtype$(Numb)[2]`	Create a string array to indicate the limit types.
`70 PRINTER IS 1`	Make sure we print on the screen.
`80 OUTPUT 2;CHR$(255)&"K";`	Clear the screen.
`90 PRINT USING "10A,20A,15A, 20A";"SEG", "STIMULUS(MHZ)", "UPPER (dB)","LOWER (dB)","TYPE"`	Print the table header.
`100 FOR I=1 TO Numb.`	Read in each segment.
`110 GOSUB Loadlimit`	`Loadlimit` (line 310) reads in the stimulus value (frequency), upper value, lower value, and the limit type for limit `I`. Since `Loadlimit` is a subroutine, I is used as a global variable.

`120 NEXT I`	
`130 LOOP`	Use the `LOOP`, `EXIT IF`, `END LOOP` structure to loop and edit the table until the operator indicates that editing is no longer desired. This structure sets up a loop with the exit point in the middle of the loop rather than at the beginning (as with `WHILE`, `END WHILE`), or at the end (as with `REPEAT`, `UNTIL`).
`140 INPUT "DO YOU WANT TO EDIT? Y OR N",An$.`	Let the operator edit the table. Editing is actually re-entering the entire limit. The old limit values are left in place if the operator presses return without typing anything.
`150 EXIT IF An$="N"`	Exit the edit loop if editing is finished. Execution is continued at line 190.
`160 INPUT "ENTRY NUMBER?",I`	For editing, get the entry number.
`170 GOSUB Loadlimit`	And have `Loadlimit` re-enter the values.
`180 END LOOP`	
`190 OUTPUT 716;"EDITLIML;"`	Begin the table entry by opening the limit table for editing. The limit table must be empty, or these limits will just be added on top of the old ones.
`200 FOR I=1 TO Numb`	Loop for each limit.
`210 OUTPUT 716;"SADD;LIMS"; Table(I,1);"MHZ;"`	Enter the stimulus value.
`220 OUTPUT 716;"LIMU"; Table(I,2);"DB;"`	Enter the upper limit value.
`230 OUTPUT 716;"LIML", Table(I,3),"DB;"`	Enter the lower limit value.
`240 IF Limtype$(I)="FL" THEN OUTPUT 716;"LIMTFL;"`	Set flat limit type.
`250 IF Limtype$(I)="SL" THEN OUTPUT 716;"LIMTSL;"`	Set sloped limit type.
`260 IF Limtype$(I)="SP" THEN OUTPUT 716;"LIMTSP;"`	Set point limit type.
`270 OUTPUT 716;"SDON;"`	Declare the limit done.
`280 NEXT I`	
`290 OUTPUT 716;"EDITDONE; LIMILINEON; LIMITESTON;"`	Close the table, display the limits, and activate limit testing.
`300 STOP`	
`310 Loadlimit: !`	Enter in a segment.
`320 INPUT "STIMULUS VALUE? (MHZ)",Table(I,1)`	
`330 INPUT "UPPER LIMIT VALUE (DB)?",Table(I,2)`	
`340 INPUT "LOWER LIMIT VALUE (DB)?",Table(I,3)`	Enter the limit values.
`350 INPUT "LIMIT TYPE" (FL=FLAT, SL=SLOPED, SP=SINGLE POINT)",Limtype$(I)`	Enter the limit type.

```
360 PRINT TABXY(0,I+1);I;
    TAB(10);
    Table(I,1);TAB(30);
    Table(I,2); TAB(45),
    Table(I,3),TAB(67);
    Limtype$(I)
```

Print the limit values out. Because of the TABXY, this will print over old limits if a limit is being edited.

```
370 RETURN

380 END
```

Running the program

The program displays the limit table as it is entered. Be certain that the limit table is empty before running the program. During editing, the displayed table is updated as each line is edited. The table is not reordered. At the completion of editing, the table is entered into the HP 8702, and limit testing mode turned on. During editing, simply pressing **[RETURN]** leaves an entry at the old value.

Example 5B: Performing PASS/FAIL tests while tuning

The purpose of this example is to demonstrate the use of the limit/search fail bits in event status register B, to determine whether a device passes the specified limits. Limits can be entered manually, or using the Example 5A.

The limit/search fail bits are set and latched when limit testing or a marker search fails. There are four bits, one for each channel for both limit testing and marker search. Their purpose is to allow the computer to determine whether the test/search just executed was successful. The sequence of their use is to clear event status register B, trigger the limit test or marker search, and then check the appropriate fail bit.

In the case of limit testing, the best way to trigger the limit test is to trigger a single sweep. By the time the `SING` command finishes, limit testing will have occurred. A second consideration when dealing with limit testing is that if the device is tuned during the sweep, it may be tuned into and then out of limit, causing a limit test pass when the device is not in fact within limits.

In the case of the marker searches (max, min, target, and widths), outputting marker or bandwidth values automatically triggers any related searches. Hence, all that is needed is to check the fail bit after reading the data.

In this example, the requirement that several sweeps in a row must pass is used in order to give confidence that the limit test pass was not extraneous due to the device settling or the operator tuning during the sweep. Upon running the program, the number of passed sweeps for qualification is entered. For very slow sweeps, a small number of sweeps such as two is appropriate. For very fast sweeps, where the device needs time to settle after tuning and the operator needs time to get away from the device, as many sweeps as six or more sweeps might be appropriate.

A limit test table can be entered over HP-IB: the sequence is very similar to that used in entering a list frequency table and is shown in Example 5A. The manual sequence is closely followed.

This program is stored under **IPG5B** on the Example Programs disk.

`10 ABORT 7`	
`20 CLEAR 716`	Prepare the HP 8702 for remote control.
`30 OUTPUT 716;"LIMILINEON; LIMITESTON;"`	Turns on limit lines and limit test.
`40 INPUT "Number of consecutive passed sweeps for qualification?",Qual`	Find out how many sweeps must pass before the device is considered to have passed the limit test.
`50 DISP "TUNE DEVICE"`	Tell operator to begin tuning.
`60 Reap=0`	`Reap` is a counter holding how many sweeps have passed the limit test.
`70 OUTPUT 716;"OPC?;SING;"`	Take a sweep. When it is done, limit test will have occurred.
`80 ENTER 716;Reply`	Wait for the end of the sweep.
`90 OUTPUT 716;"ESB?;"`	Check to see if the fail bit is set.
`100 ENTER 716;Estat`	
`110 IF BIT(Estat,4) THEN`	If the fail bit for channel one is set, reset the number of sweeps passed counter.
`120 IF Reap<>0 THEN BEEP 1200,.05`	If sweeps had been passing, warn the operator that the device is now failing.
`130 Reap=0`	
`140 GOTO 50`	
`150 END IF`	If the fail bit was not set, tell the operator.

`160 BEEP 2500,.01`	
`170 Reap=Reap+1`	Increment the sweeps passed counter.
`180 DISP "STOP TUNING"`	Encourage the operator to stop tuning the device.
`190 IF Reap<Qual THEN GOTO 70`	If not enough sweeps have passed, loop.
`200 DISP "DEVICE PASSED!"`	The device has passed.
`210 FOR I=1 TO 10`	Warble, telling the operator the device has passed, using an audible signal.
`220 BEEP 1000,.05`	
`230 BEEP 2000,.01`	
`240 NEXT I`	
`250 INPUT "HIT RETURN FOR NEXT DEVICE",Dum$`	Wait for the next device.
`260 GOTO 50`	
`270 END`	

Running the program

Set up a limit table on channel 1 for a specific device either manually, or use the program in Example 5A. Run the program, and enter the number of passed sweeps desired for qualification. After entering the qualification number, connect the filter. When a sweep passes, the computer beeps. When enough sweeps in a row pass to qualify the device, the computer warbles, and then asks for a new device.

The program assumes the desired instrument state has been set up. Try causing the DUT to fail by loosening the cables connecting the DUT to the HP 8702, and then retightening them.

Storing and recalling instrument states

This example demonstrates ways of storing and recalling entire instrument states over HP-IB. The two methods discussed are to use the learn string, and to use the computer to coordinate direct store/load of instrument states to disk.

Using the learn string is a rapid way of saving the instrument state, but using direct disk access has the advantage of automatically storing calibrations, cal kits, and data along with the instrument state.

Example 6A: Using the learn string

The learn string is a fast and easy way to read an instrument state. The learn string includes all front panel settings, the limit table for each channel, and the list frequency table. The learn string is read out with `OUTPLEAS`, and put back into the instrument with `INPULEAS`. The string itself is in form 1, and is no longer than 3000 bytes.

This example program is stored on the Example Programs disk as **IPG6A**.

10 DIM State$[3000]	Set up the receive string.
20 OUTPUT 716;"OUTPLEAS;"	Request the learn string.
30 ENTER 716 USING "-K";State$	Read in the learn string. Normally, the enter statement will terminate if a line feed is received, so `USING "-K"` is used, which allows termination only on End Or Identify.
40 LOCAL 716	Put the analyzer in LOCAL mode.
50 INPUT "CHANGE STATE AND HIT RETURN",Dum$	Give the operator a chance to modify the state.
60 OUTPUT 716;"INPULEAS"; STATE$	Transmit the state back to the HP 8702.
70 DISP "INITIAL INSTRUMENT STATE RESTORED"	
80 END	

Running the program

Run the program. When the program stops, change the instrument state and press **[RETURN]**. The HP 8702 will return to its original state.

Example 6B: Coordinating disk storage

To have the HP 8702 store an instrument state on disk, specify the state name by titling a file using `TITFn`, then specify a `STORn` of that file, where `n` is the file number, 1 to 5. On receipt of the store command, the HP 8702 will request active control. When control is received, the HP 8702 will store the instrument state on disk as defined under the *[DEFINE STORE]* menu.

Similarly, to have the HP 8702 load a file from disk, specify the state name as before, and then request a `LOADn` of that
file. The best way of learning what the register titles on the disk are is to use the *[READ FILE TITLES]* under the **[RECALL]** key.

This example program is stored on the Example Programs disk as **IPG6B**.

`10 ABORT 7`	
`20 CLEAR 716`	Prepare the HP 8702 for remote control.
`30 INPUT "STATE TITLE? PRESS RETURN",Nam$`	Get the name of the file to create.
`40 OUTPUT 716;"USEPASC;"`	Tell the HP 8702 to use pass control mode.
`50 OUTPUT 716;"TITF1""";Nam$;""";STOR1;"`	Title register 1, and store it. The title must be preceded and followed by double quotation marks. The only way to do that with an output statement is to use two sets of quotation marks: "".
`60 DISP "SAVING ON DISC"`	
`70 SEND 7;TALK 16 CMD 9`	Pass control to the HP 8702, assuming it has interpreted the `STOR1` command and set the request control bit.
`80 STATUS 7,6;Stat`	
`90 IF NOT BIT(Stat,6) THEN GOTO 80`	Wait for active control to return.
`100 INPUT "STATE STORED. HIT RETURN TO RECALL",Dum$`	
`110 INPUT "STATE TITLE?",Nam$`	Get the name of the file to read.
`120 OUTPUT 716;"TITF1""";Nam$;""";LOAD1;"`	Title register one, and request a load.
`130 DISP "READING DISC"`	
`140 SEND 7;TALK 16 CMD 9`	Pass control.
`150 STATUS 7,6;Stat`	
`160 IF NOT BIT(Stat,6) THEN GOTO 150`	Wait for control to return.
`170 DISP "DONE"`	The program is done, and the state has been loaded back into the instrument.
`180 END`	

Running the program

Put a formatted disk in the disk drive, and point the HP 8702's disk address, unit number, and volume number towards that drive. Run the example, and when the program pauses, change the instrument state so that a change will be noticeable. Pressing return will recall the state just stored, or a completely different state can be recalled.

Example 6C: Reading calibration data

This example demonstrates how to read measurement calibration data out of the HP 8702, how to put it back into the instrument, and how to determine which calibration is active.

The data used to perform measurement error correction is stored inside the HP 8702 in up to twelve calibration coefficient arrays. Each array is a specific error coefficient, and is stored and transmitted as an error corrected data array: each point is a real/imaginary pair, and the number of points in the array is the same as the number of points in the sweep. The four data formats also apply to the transfer of calibration coefficient arrays. Appendix C, *Calibration*, of the *HP-IB Quick Reference Guide* specifies where the calibration coefficients are stored for different calibration types.

A computer can read out the error coefficients using the commands `OUTPCALC01, OUTPCALC02, ... OUTPCALC12`. Each calibration type uses only as many arrays as needed, starting with array 1. Hence, it is necessary to know the type of calibration about to be read out: attempting to read an array not being used in the current calibration causes the "REQUESTED DATA NOT CURRENTLY AVAILABLE" warning.

A computer can also store calibration coefficients in the HP 8702. To do this, declare the type of calibration data about to be stored in the HP 8702 just as if you were about to perform that calibration. Then, instead of calling up different classes, transfer the calibration coefficients using the `INPUCALCnn` commands. When all the coefficients are in the HP 8702, activate the calibration by issuing the mnemonic `SAVC`, and have the HP 8702 take a sweep.

This example reads the calibration coefficients into a very large array from which they can be examined, modified, stored, or put back into the instrument. If the data is to be directly stored onto disk, it is usually more efficient to use form 1 (HP 8702 internal binary format), and to store each coefficient array as it is read in.

This program is stored on the Example Programs disk as **IPG6C**.

`10 ABORT 7`	
`20 CLEAR 716`	Prepare the HP 8702 for HP-IB control.
`30 DATA "CALIRESP",1, "CALIRAI",2, "CALIS111",3`	
`40 DATA "CALIS221",3, "CALIONE2",6, "CALIFUL2",12`	
`50 DATA "NOOP",0`	Set up the data base of possible calibrations and the number of arrays associated with each calibration.
`60 INTEGER Hdr,Lgth,I,J`	Define integers to hold the header and to act as counters.
`70 ASSIGN @Dt TO 716;FORMAT OFF`	
`80 READ Calt$,Numb`	Get a calibration type and the number of associated arrays.
`90 IF Numb=0 THEN GOTO 360`	If correction was not on, stop the program.
`100 OUTPUT 716;Calt$;"?;"`	Interrogate the HP 8702 to see if this calibration is active.
`110 ENTER 716;Active`	
`120 IF NOT Active THEN GOTO 80`	If the calibration was not active, loop.
`130 DISP Calt$,Numb`	Show the operator that we have found the calibration and number of arrays.
`140 OUTPUT 716;"FORM3;POIN?;"`	Find out how many points to expect.
`150 ENTER 716;Poin`	
`160 ALLOCATE Cal(1:Numb,1:Poin,1:2)`	Create a very large array to hold all the coefficients.

`170 FOR I=1 TO Numb`	Loop once for each calibration coefficient.
`180 OUTPUT 716 USING "K,ZZ";"OUTPCALC",I`	Request the calibration coefficient. The K transmits OUTPCALC literally, and ZZ transmits I as two digits, using a leading zero if needed.
`190 ENTER @Dt;Hdr,Lgth`	Read the header.
`200 FOR J=1 TO Poin`	
`210 ENTER @Dt;Cal(I,J,1), Cal(I,J,2)`	Since we are not filling the entire array, we have to read each point individually.
`220 NEXT J`	
`230 NEXT I`	
`240 INPUT "HIT RETURN TO RE-TRANSMIT CALIBRATION",Dum$`	The calibration data is now all in the computer.
`250 OUTPUT 716;Calt$,";"`	Begin the calibration retransmission by declaring what calibration type is about to be loaded.
`260 FOR I=1 TO Numb`	Now load each calibration coefficient.
`270 DISP "TRANSMITTING ARRAY: ",I`	
`280 OUTPUT 716 USING"K,ZZ";"FORM3;INPUCALC",I`	
`290 OUTPUT @Dt;Hdr,Lgth`	
`300 FOR J=1 TO Poin`	
`310 OUTPUT @Dt;Cal(I,J,1), Cal(I,J,2)`	
`320 NEXT J`	
`330 NEXT I`	All of the calibration data has been loaded.
`340 OUTPUT 716;"SAVC;"`	End the sequence by activating the calibration.
`350 OUTPUT 716;"CONT;"`	Trigger a sweep so the calibration becomes active.
`360 DISP "DONE"`	
`370 END`	

Running the program

Before executing the program, perform a calibration.

The program is able to detect what calibration is active, and with that information it predicts how many arrays to read out. When all the arrays are inside the computer, the program prompts the user. At this point, turn calibration off, or perform a completely different calibration on the HP 8702. Then press continue on the computer, and the computer will reload the old calibration.

Note that the retransmitted calibration is associated with the current instrument state: the instrument has no way of knowing the original state associated with the calibration data. For this reason, it is recommended that the learn string be used to store the instrument state whenever calibration data is stored. See Example 6A, *Using the learn string.*

Miscellaneous Programming Examples

Controlling peripherals

The purpose of this section is to demonstrate how to coordinate printers, plotters, power meters, and disk drives with the HP 8702.

The HP 8702 has three operating modes with respect to HP-IB, as set under the **[LOCAL]** menu. System controller mode is used when no computer is present. The other two modes allow the computer to coordinate certain actions: in talker/listener mode the computer can control the HP 8702, as well as coordinate plotting and printing, and in pass control mode the computer can pass active control to the HP 8702 so that the HP 8702 can plot, print, control a power meter, or load/store to disk. Peripheral control is the major difference between the two modes.

Note that the HP 8702 assumes that the address of the computer is correctly stored in its HP-IB addresses menu under the *[ADDRESS: CONTROLLER]* entry. If this address is incorrect, control will not return to the computer. Similarly, if control is passed to the HP 8702 while it is in talker/listener mode, control will not return to the computer.

Example 7A: Operation using Talker/Listener mode

The commands `OUTPPLOT` and `OUTPPRIN` allow talker/listener mode plotting and printing via a one way data path from the HP 8702 to the plotter or printer. The computer sets up the path by addressing the HP 8702 to talk and the plotter to listen and then placing the bus into data mode. The HP 8702 will then make the plot or print. When it is finished, it asserts the End or Identify (EOI) control line on HP-IB.

This program makes a plot using the talker/listener mode. It is stored on the Example Programs disk as **IPG7A**.

```
10  OUTPUT 716;"OUTPPLOT;".
```

Command the HP 8702 to plot using the talker/listener mode plot command. For a printer, use `OUTPPRIN;`.

```
20  SEND 7;UNL LISTEN 5 TALK 16
    DATA
```

Use the HP-IB control commands to establish a data path from the HP 8702 to the plotter. `SEND 7` sends bus control commands. `UNL` clears out the last data path. `LISTEN 5` tells the device at address 5, the default address for a plotter, to accept the data. For printing, substitute the address 1, the default for a printer, and change `"OUTPPLOT;"` in line 10 to `"OUTPPRIN;"`. `TALK 16` tells the HP 8702 to talk; that is, transmit the contents of its output queue. When `DATA` is executed, the bus changes from command to data mode, and the HP 8702 makes the plot.

```
30  DISP "PLOTTING"
```

This statement serves the dual purpose of informing the user of the state of the program and preventing interrogation of status register 7 immediately after the `SEND` statement, when the register state is unstable.

```
40  STATUS 7,7;Stat
```

Now wait for the HP 8702 to assert the EOI line, indicating the end of transmission. The `STATUS` command accesses the status registers for the interfaces installed on the computer. In this case, we access interface 7 (HP-IB), register 7, HP-IB status. The value of the register is placed in the variable `Stat`. We are specifically interested in bit 11, which is assigned to the EOI line.

`50 IF NOT BIT(Stat,11) THEN GOTO 40`	If bit 11 is not set, then the EOI line is not being asserted by the HP 8702, so loop and check again.
`60 DISP "DONE"`	The HP 8702 has asserted EOI to indicate that it has finished with the plot.
`70 END`	

Running the program

The HP 8702 will go into remote, and make the plot. During the plot, the computer will display the message `PLOTTING`. One of the attributes of the `OUTPPLOT` command is that the plot can include the current softkey menu. The plotting of the softkeys is enabled with the command `PSOFTON` and disabled with `PSOFTOFF`.

When the plot is completed, the HP 8702 asserts the EOI line on HP-IB. The computer detects this and displays the DONE message. The HP 8702 will go on asserting EOI until some other activity on the bus causes it to clear the line.

If a problem occurs with the plotter, such as no pen or paper, the HP 8702 cannot detect the situation because it only has a one-way path of communication. Therefore, the HP 8702 will try to continue plotting until the operator intervenes and aborts the plot by pressing the **[LOCAL]** key. This key aborts the plot, causes the warning message "CAUTION: PLOT ABORTED," asserts EOI, and frees the computer. Because of possible malfunctions, it is advisable to use pass control mode, which allows two way communication between the plotter and the HP 8702.

Example 7B: Operation using pass control mode

If the HP 8702 is in pass control mode and receives a command telling it to plot, print, control a power meter, or store/load to disk, it sets bit 1 in the event status register to indicate that it needs control of the bus. If the computer then uses the HP-IB control command to pass control to the HP 8702, the HP 8702 will take control of the bus, and access the peripheral. When the HP 8702 no longer requires control, it will pass control back to the computer. When performing a power meter cal over HP-IB, the HP 8702 requests control at each measurement point in a sweep which is typically ≅3* the number of readings.

Control should not be passed to the HP 8702 before it has set event status register bit 1, Request Active Control. If the HP 8702 receives control before the bit is set, control is immediately passed back.

While the HP 8702 has control, it is free to address devices to talk and listen. The only functions denied it are the ability to assert the interface clear line (IFC), and the remote line (REN). These are reserved for the system controller. As active controller, the HP 8702 can send messages to and read replies back from printers, plotters, and disk drives.

This example prints the display. It is stored on the Example Programs disk as **IPG7B**. The program may request a plot with `PLOT`, or a disk access `REFT` (read file titles.)

`10 OUTPUT 716;"CLES;ESE2;"`	Clear the status reporting system, and enable the Request Active Control bit in the event status register.
`20 OUTPUT 716;"USEPASC; PRINALL;"`	Put the HP 8702 in pass control mode, and request a print) if using a color printer, COLOR).
`30 Stat=SPOLL(716)`	Get the status byte of the HP 8702.
`40 IF NOT BIT(Stat,5) THEN GOTO 30`	If the HP 8702 is not requesting control, loop and wait.
`50 SEND 7;TALK 16 CMD 9`	This is the bus command to pass active control to device 16. With BASIC 3.0 or higher, or 2.0 with extensions 2.1, the command `PASS CONTROL 716` can be used instead.
`60 DISP "PRINTING"`	
`70 STATUS 7,6;Hpib`	To determine when the print is finished, watch for return of active control. The `STATUS` command loads the interface 7 (HP-IB) register 6, the computer's status with respect to HP-IB, into the variable `Hpib`. Bit 6 tells if the computer is the active controller: it will be set when the HP 8702 returns control.
`80 IF NOT BIT(Hpib,6) THEN GOTO 70`	If control has not returned, loop and wait.
`90 DISP "DONE"`	Control has returned.
`100 END`	

Running the program

The HP 8702 will briefly flash the message WAITING FOR CONTROL, before receiving control and making the print. The computer will display the PRINTING message.

When the print is complete, the HP 8702 passes control back to the address stored as the controller address under the **[LOCAL]** *[SET ADDRESSES]* menu. The computer will detect the return of active control and exit the wait loop.

Because the program waits for the HP 8702's request for control, it can be used to respond to front panel requests as well. Delete `PRINALL;` from line 20, and run the program. Nothing will happen until you go to the front panel of the HP 8702 and request a print, plot, or disk access. For example, press **[LOCAL]** **[COPY]** and *[PRINT]*.

Example 8: Creating a user interface

This example shows how to create a custom user interface using only the front panel keys and display of the HP 8702.

User graphics

The HP 8702's display can be treated as an HP-GL plotter. The BASIC graphics commands can be used to create a custom display. Some of the more useful commands are as follows. `VIEWPORT` defines what area of the display is to be plotted on. `WINDOW` allows you to specify the plotting units (i.e. how many units per axis) in the `VIEWPORT` defined area. `DRAW` draws lines from point to point. `MOVE` moves the logical pen without drawing anything. `GCLEAR` clears the graphics display area. `PEN` selects the line intensity, and `LINE TYPE` selects various line types.

All of the BASIC graphics statements are accepted. The LABEL statement is not recommended because it fills the display memory up very rapidly as opposed to when the HP-GL `LB` command is used. See the Waitforkey subroutine of Example 2A for an example of the `LB` command.

HP-GL (Hewlett-Packard Graphics Language) commands, such as the `LB` command mentioned above, can be directly sent to the HP 8702 display with the `OUTPUT` statement. See Appendix D, *Display Graphics,* of the *HP-IB Quick Reference Guide* for a list of the HP-GL commands accepted, and their functions.

Front panel control

It is possible to take over the front panel keys. The user request bit in the event status register is set whenever a front panel key is pressed or the knob is turned, whether the instrument is in remote or local mode. Each key has a number associated with it, as shown in Figure E.4, *Front Panel Keycodes* of the *HP-IB Quick Reference Guide*. The number of the key last pressed can be read with the `KOR?` and the `OUTPKEY?` commands. With `KOR?`, a knob turn is reported as a negative number encoded with the number of counts turned. With `OUTPKEY?`, a knob turn is always reported as a negative one.

The keycode encoding with `KOR?` is as follows. Clockwise rotations are reported as numbers from −1 to −64, −1 being a very small rotation. Counter-clockwise rotations are reported as the numbers −32,767 to −32,703, −32,767 being a very small rotation. Hence, clockwise rotations don't need any decoding at all, and counter-clockwise rotations can be decoded by adding 32,768.

There are approximately 120 counts per knob rotation, and sign of the count depends on the direction the knob was turned.

This example uses the knob and the up and down keys on the HP 8702 to position a grid on the display. Pressing **[ENTRY OFF]** on the HP 8702 causes the computer to put a trace on the grid.

This example program is stored on the Example Programs disk as **IPG8**.

`10 INTEGER Hdr,Lgth,Keyc`	Declare variables to hold the header and the key code.
`20 ASSIGN @Dt TO 716;FORMAT OFF`	Define an IO path with formatting off, to receive the form 3 trace data for plotting.
`30 OUTPUT 716;"HOLD;AUTO; CLES;ESE 64;POIN?;"`	Prepare the instrument. `HOLD;AUTO;` freezes and scales the trace for plotting. `CLES;ESE 64;` clears the status reporting system and enables the User Request bit in the event status register. Lastly, `POIN?;` requests the number of points.
`40 ENTER 716;Poin`	Read in the number of points.
`50 GINIT`	Initialize the graphics functions in the computer.
`60 PLOTTER IS 717,"HPGL"`	Specify the HP 8702 display as the plotting device.
`70 OUTPUT 717;SP3;"CS;"`	Turn off the measurement display and the color of the trace.
`80 Cx=55`	Initialize the x position of the center of the rectangle.
`90 Cy=60`	Initialize the y position of the center of the rectangle.
`100 S=20`	Set the size of the rectangle.
`110 REPEAT`	The `REPEAT, UNTIL` structure sets up a loop that keeps repeating until the condition specified in the `UNTIL` statement is found to be true. The condition is checked at the end of the loop. In this case, loop and redraw the rectangle until **[ENTRY OFF]** has been pressed.
`120 GCLEAR`	Clear the graphics area on the HP 8702.
`130 IF Cx>160 THEN Cx=160`	Prevent box from going off the screen.
`140 IF Cx<-17 THEN Cx=-17`	Note that these values are linked to the increments set in lines 270/310 and 320.
`150 IF Cy>115 THEN Cy=115`	
`160 IF Cy<-15 THEN Cy=-15`	
`170 VIEWPORT Cx-S,Cx+S,Cy-S,Cy+S`	Define the area of the rectangle, which will become the plotting area for the grid and trace.
`180 WINDOW 0,Poin-1,0,1`	Define the units along the edges of the rectangle. In this case, the horizontal edge has as many units as points in the sweep, and the vertical edge is simply unity.
`190 FRAME`	Draw the rectangle around the plotting area.
`200 Stat=SPOLL(716)`	Read the status byte.
`210 IF NOT BIT(Stat,5) THEN GOTO 170`	If bit 5 is not set, a key has not been pressed, so loop and wait.
`220 OUTPUT 716;"ESR?;"`	A key press has occurred, so read the event status register in order to clear the latched bit.
`230 ENTER 716;Estat`	Read in the register value, but do nothing with it.
`240 OUTPUT 716;"KOR?;"`	Now read in the key or knob count.
`250 ENTER 716;Keyc`	
`260 IF Keyc=26 THEN Cy=Cy+5`	Key 26 is the up key, so shift the rectangle up.
`270 IF Keyc=18 THEN Cy=Cy-5`	Key 18 is the down key. Shift the rectangle down.
`280 IF Keyc<0 THEN`	If the keycode was negative, then it is a knob count.
`290 Knb=Keyc`	Decode the knob count into the variable `Knb`.

`300 IF Knb<-64 THEN Knb=Knb+32768`	If the count is less then −64, add 32768 (2^{15}) to recover the knob count. If the count is more than −64, then no decoding is needed.
`310 Cx=Cx-Knb*3`	Shift the rectangle according the knob count, multiplying the knob count to make the rectangle move farther.
`320 END IF`	
`330 UNTIL Keyc=34`	This is the end of the `REPEAT, UNTIL` structure. Leave the loop only when key 34, **[ENTRY OFF]** has been pressed.
`340 GRID (Poin-1)/10,.1`	**[ENTRY OFF]** has been pressed, so draw the grid and the trace. This statement draws a grid with 10 divisions on each axis.
`350 OUTPUT 717;"SPI;"`	Select a different color for the trace data.
`360 OUTPUT 716;"FORM3; OUTPFORM;"`	Now get the trace data.
`370 ENTER @Dt;Hdr,Lgth`	Get the header information.
`380 ALLOCATE Dat(1:Poin,1:2)`	Define the receiving array.
`390 ENTER @Dt;Dat(*)`	And read in the data.
`400 OUTPUT 716;"SCAL?;"`	Instead of scaling the data in this program, interrogate the scale factor the HP 8702 was using.
`410 ENTER 716;Scal`	
`420 OUTPUT 716;"REFV?;"`	Similarly, use the value at the reference position to decide where to draw the trace.
`430 ENTER 716;Ref`	
`440 OUTPUT 716;"REFP?;"`	Interrogate the current reference position being used.
`450 ENTER 716;Refp`	
`460 Bot=Rev-Refp*Scal`	Calculate the value of the bottom grid line.
`470 Full=10*Scal`	And define the full scale span across the grid.
`480 MOVE 0,(Dat(1,1)-Bot)/Full`	Go to the first point on the trace without drawing anything.
`490 FOR I=1 TO Poin-1`	And draw all the rest of the points in the trace.
`500 DRAW I,(Dat(I,1)-Bot)/Full`	
`510 NEXT I`	The trace is drawn, so end the program.
`520 END`	

Running the program

Before running the program, set the instrument up to make a measurement. The HP 8702 will not accept a graphics dump of a trace of greater than 1601 points.

Run the program, and go to the front panel of the HP 8702. measurement display has been turned off, and there is a box on the screen. The knob moves the box left and right, and the up/down keys move the box up and down. When you are satisfied with the position of the box, press **[ENTRY OFF]**. The computer will fill the box with a grid, and plot the current measurement data on the grid.

Transferring disk data files

An external disk drive is often used to store data files in addition to instrument states (see Example 6B). Instrument states, graphics files, data trace files, calibration data files, and memory trace files can be stored on disk. The file name is then appended with up to two characters to indicate what is in the file. For example, if channel 2 error-corrected data is saved to disk as DEVICE, the actual error-corrected data would be stored in DEVICED2. As with all data files stored on disk, they are stored in form 3. See Appendix E.3: *Disk file names* in the *HP-IB Quick Reference Guide* for a complete list of the types of files saved to disk as well as the corresponding appendages to file names.

Example 9: Reading data files into a computer

This example demonstrates how to recall a specific disk file into a computer. First, EXTMADTAON defines the storage of the current trace as error-corrected data. After the file is stored to disk, the computer reads the error-corrected data into an array. The program can easily be modified to read and transfer raw data, memory traces, and formatted data.

`10 ABORT 7`	
`20 CLEAR 716`	Prepare the HP 8702 for remote control.
`30 INPUT "STATE TITLE?",Nam$`	Get the name of the file to create.
`40 OUTPUT 716;"USEPASC;"`	Tell the HP 8702 to use pass control mode.
`50 OUTPUT 716;"TITF1""";Nam$;""";EXTMDATAON;STOR1;"`	Title register 1, and store the instrument state and error-corrected data. The title must be preceded and followed by double quotation marks. The only way to do this within an output statement is to use two sets of quotation marks: `" "`.
`60 DISP "SAVING ON DISC"`	
`70 SEND 7;TALK 16 CMD 9`	Pass control to the HP 8702, assuming it has interpreted the STOR 1 command and set the request control bit.
`80 STATUS 7,6;Stat`	
`90 IF NOT BIT(Stat,6) THEN GOTO 80`	Wait for active control to return.
`100 DISP "READING DATA INTO Disc_dat ARRAY"`	
`110 ASSIGN @Dt TO Nam$&"D1";FORMAT OFF`	This statement defines an I/O path with ASCII formatting off. The I/O path points to the chosen error-corrected data file, and can be used to read or write data from the file, since it is in binary rather than ASCII format.
`120 ALLOCATE Disc=dat(1:201,1:2)`	Allocate an array for a 201 point data trace. Real and imaginary pairs will be transferred for each data point.
`130 ENTER @Dt;Disc_dat(*)`	The computer takes the data from disk and transfers it into the receiving array. By specifying `Disc_dat(*)`, the ENTER statement will fill every location in the array.
`140 ASSIGN @Dt TO *`	Close the I/O path.
`150 DISP Disc_dat(1,1),Disc_dat(1,2)`	Show the first real imaginary pair.
`160 END`	

Running the program

Perform a measurement calibration with 201 points. Connect a test device and run the program. The first/real imaginary pair will be displayed. Place a marker at the beginning of the trace and look at both real and imaginary formats to verify this point.

Appendix A: Status Reporting

The HP 8702 has a status reporting mechanism that gives information about specific functions and events inside the HP 8702. The status byte is an 8 bit register with each bit summarizing the state of one aspect of the instrument. For example, the error queue summary bit will always be set if there are any errors in the queue. The value of the status byte can be read with the `SPOLL(716)` statement. This command does not automatically put the instrument in remote mode, thus giving the operator access to the HP 8702 front panel functions. The status byte can also be read by sending the command `OUTPSTAT`. Reading the status byte does not affect its value. The sequencing bit can be set by the operator during execution of a test sequence.

The status byte summarizes the error queue, as mentioned before. It also summarizes two event status registers that monitor specific conditions inside the instrument. The status byte also has a bit that is set when the instrument is issuing a service request over HP-IB, and a bit that is set when the HP 8702 has data to send out over HP-IB. See Figure A.1 for a definition of the status registers.

Example A1: Using the error queue

The error queue holds up to 20 instrument errors and warnings in the order that they occurred. Each time the HP 8702 detects an error condition and displays a message on the CRT, it also puts the error in the error queue. If there are any errors in the queue, bit 3 of the status byte will be set. The errors can be read from the queue with the `OUTPERRO` command, which causes the HP 8702 to transmit the error number followed by the error message of the oldest error in the queue.
This example program is stored on the Example Programs disk as **IPGA1**.

`10 DIM Err$[50]`	Prepare a string to hold the error message.
`20 Stat=SPOLL(716)`	Use the serial poll statement to read the status byte into the variable `Stat`. Serial poll is an HP-IB function dedicated specifically to getting the status byte of an instrument quickly, and does not cause the HP 8702 to go into remote.
`30 IF NOT BIT(Stat,3) THEN GOTO 20`	If the error queue summary bit is not set, we loop until it gets set.
`40 OUTPUT 716;"OUTPERRO;"`	If the error queue has something in it, instruct the HP 8702 to output the error number and the error message. This will put it in remote mode.
`50 ENTER 716;Err,Err$`	`Err` holds the error number, `Err$` the error message.
`60 PRINT Err,Err$`	
`70 LOCAL 716`	Return the HP 8702 to local mode so that the front panel is available to the operator.
`80 BEEP 600,.01`	Give an audible signal that there is a problem.
`90 GOTO 20`	
`100 END`	

Running the program

Preset the HP 8702 and run the program. Nothing should happen at first. To get something to happen, press a blank softkey. The message "CAUTION: INVALID KEY" will appear on the HP 8702, the computer will beep and print two lines. The first line will be the invalid key error, and the second message will be the "NO ERRORS" message. Therefore, to clean the error queue, you can either loop until the no errors message is received, or until the bit in the status register is cleared. In this case, we wait until the status bit is clear. Note that all through this, the front panel of the HP 8702 is in local mode.

Because the error queue will keep up to 20 errors until either all the errors are read out or the instrument is preset, it is important to clear out the error queue whenever errors are detected so that old errors are not associated with the current instrument state.

Not all messages displayed by the HP 8702 are put in the error queue: operator prompts and cautions are not included.

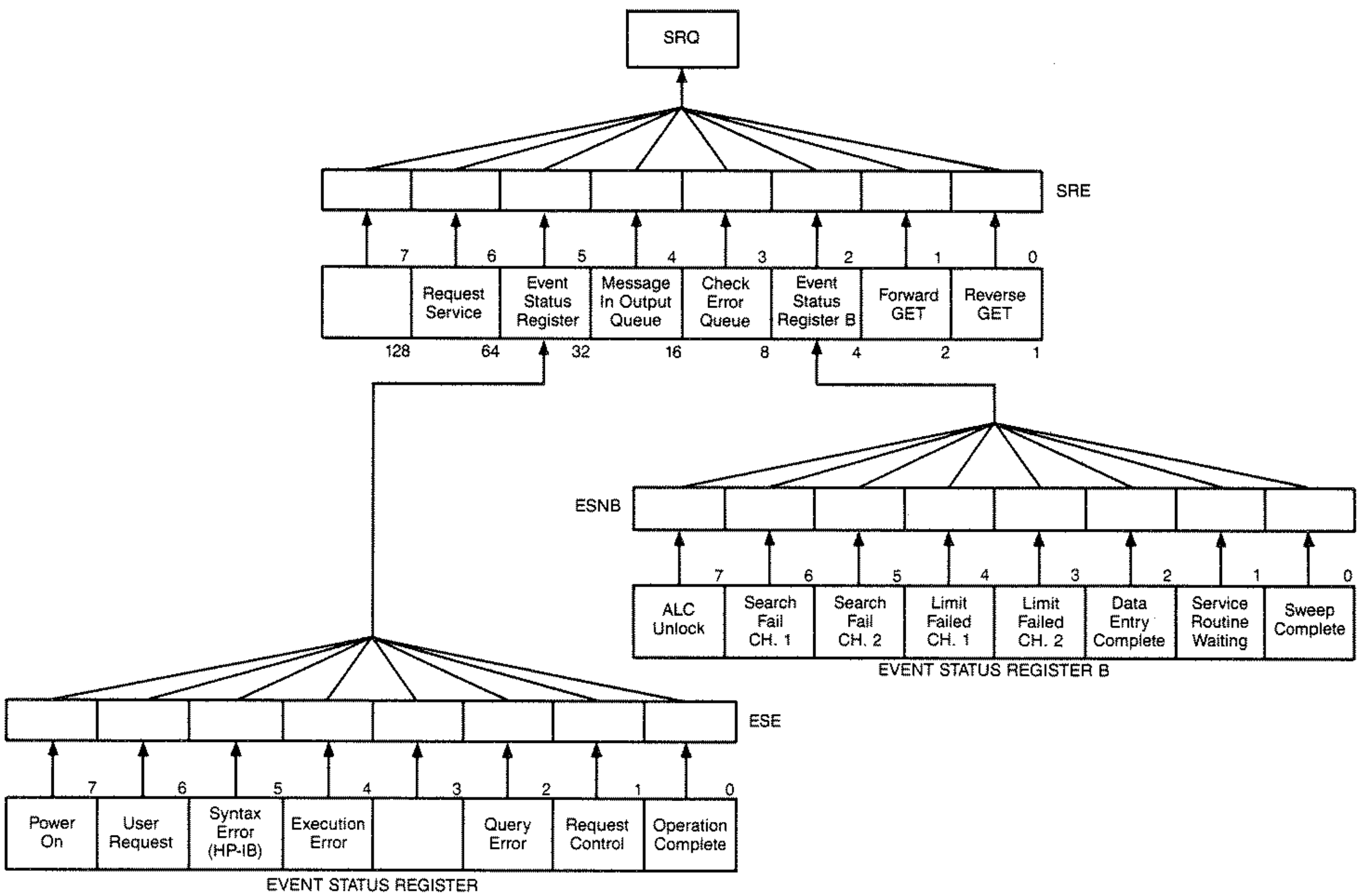


Figure A.1. Status reporting system.

Example A2: Using the status registers

The other key components of the status reporting system are the event status register, and event status register B. These 8-bit registers consist of latched event bits. A latched bit is set at the onset of the monitored condition, and is cleared by a read of the register or by clearing the status registers with CLES.

This example program is stored on the Example Programs disk as **IPGA2**.

`10 CLEAR 716`	Clear out any old conditions.
`20 OUTPUT 716;"ESR?;"`	Read out the event status register.
`30 ENTER 716;Estat`	
`40 IF NOT BIT(Estat,6) THEN GOTO 20`	If the user request bit of the event status register is not set, loop back.
`50 OUTPUT 716;"KOR?;"`	If the user request bit has been set, there has been some front panel activity, and we read out the key code. The HP 8702's reply to KOR?; includes the knob count if the knob was turned. The information comes as a negative number, and has to be decoded.
`60 ENTER 716;Keyc`	
`70 IF Keyc≥0 then PRINT "KEY ";`	If the code was positive, it was a key press rather than a knob turn, and print the leader KEY. Placing a semicolon after the statement suppresses the carriage return, line feed, allowing the code to be printed on the same line.
`80 IF Keyc<-400 THEN Keyc=Keyc+32768`	If the keycode is negative, it is a knob count. If it isn't less than −400, then the count is a clockwise rotation and needs no modification. If the count is less than −400, add 32,768 (2^{15}) to get the counter-clockwise count.
`90 PRINT "CODE =",Keyc`	Print the decoded key code.
`100 GOTO 20`	Wait for the next key press.
`110 END`	

Running the program

Run the program. Pressing a key on the HP 8702 causes the computer to display the keycode associated with that key. Note that since the HP 8702 is in remote mode, the normal function of the key is not executed. In effect, we have taken over the front panel and can now redefine the keys.

Example A3: Generating interrupts

It is also possible to generate interrupts using the status reporting mechanism. The status byte bits can be enabled to generate a service request (SRQ) when set. The 200/300 series computers can in turn be set up to generate an interrupt on the SRQ.

To be able to generate an SRQ, a bit in the status byte has to be enabled using `SREn`. A one in a bit position enables that bit in the status byte. Hence, `SRE 8` enables an SRQ on bit 3, check error queue, since 8 equals 00001000 in binary representation. That means that whenever an error is put into the error queue and bit 3 gets set, the SRQ line is asserted, and the (S) indicator on the front panel of the HP 8702 comes on. The only way to clear the SRQ is to disable bit 3, re-enable bit 3, or read out all the errors from the queue.

A bit in the event status register can be enabled so that it is summarized by bit 5 of the status byte. If any enabled bit in the event status register is set, bit 5 of the status byte will also be set. For example `ESE 66` enables bits 1 and 6 of the event status register, since in binary, 66 equals 01000010. Hence, whenever active control is requested or a front panel key is pressed, bit five of the status byte will be set. Similarly, `ESNBn` enables bits in event status register B so that they will be summarized by bit 2 in the status byte.

To generate an SRQ from an event status register, enable the desired event status register bit. Then enable the status byte to generate an SRQ. For instance, `ESE 32;SRE 32;` enables the syntax error bit, so that when the syntax error bit is set, the summary bit in the status byte will be set, and it enables an SRQ on bit 5 of the status byte, the summary bit for the event status register.

The following example program is stored on the Example Programs disk as **IPGA3**.

`10 OUTPUT 716;"CLES; ESE 32; SRE 32;"`	Clear the status reporting system, and then enable bit 5 of the event status register, and bit 5 of the status byte so that an SRQ will be generated on a syntax error.
`20 ON INTR 7 GOTO Err`	Tell the computer where to branch it gets the interrupt.
`30 ENABLE INTR 7;2`	Tell the 200/300 series to enable an interrupt from interface 7 (HP-IB) when bit 1 (value 2, the SRQ bit) of the interrupt register is set. If there is more than one instrument on the bus capable of generating an SRQ, it is necessary to use serial poll to determine which device has issued the SRQ. In this case, we assume the HP 8702A did it. A branch to `Err` will disable the interrupt, so the return from `Err` re-enables it.
`40 GOTO 40`	Do nothing loop.
`50 Err:!`	
`70 OUTPUT 716;"ESR;?"`	The interrupt has come in! Read the register to clear the bit.
`80 ENTER 716;Estat`	
`90 PRINT "SYNTAX ERROR DETECTED"`	
`100 ENABLE INTR 7`	
`110 GOTO 30`	
`120 END`	

Running the program

Preset the instrument, and run the program. The computer will do nothing. With the program still running, execute:

```
OUTPUT 716;"STAP 2 GHZ;"
```

The computer will display `SYNTAX ERROR DETECTED`, and the HP 8702 will display CAUTION: SYNTAX ERROR, and display the incorrect command, pointing at the first character it did not understand.

The SRQ can be cleared by reading the event status register and hence clearing the latched bit, or by clearing the enable registers with `CLES`. The syntax error message on the HP 8702 display can only be cleared by `CLEAR 7` or `CLEAR 716`. `CLEAR 7` is not commonly used because it clears every device on the bus.

Note that an impossible data condition does not generate a syntax error. For example, execute:

```
CLEAR 716
OUTPUT 716;"STAR 10 HZ;"
```

The HP 8702 simply sets the start frequency to 300 kHz, without generating a syntax error.

For more information, call your local HP sales office listed in your telephone directory or an HP regional office listed below for the location of your nearest sales office.

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HEWLETT PACKARD

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HP-IB Quick Reference

HEWLETT PACKARD

For the HP 8700-series analyzers

This document provides a quick reference for the HP-IB operation of the HP 8700-series analyzers, including the HP 8702, 8703, 8719, 8720, 8752, and 8753. Use this information as a reference to the syntax requirements and general function of the individual commands. You should already be familiar with making measurements with the analyzer using the front panel keys and with general programming of the instrument using the HP-IB.

Not all commands listed apply to all instruments. The general response of an instrument that does not support a specific operation is to report a syntax error when the command is input. Refer to the tutorial and reference information in other portions of the Operating and Programming manual, particularly the menu structures, for the specific instrument you are working with to determine its capabilities.

Contents

Notation

Symbols used in this document are:

BOLD — Upper case bold characters represent the program keywords which must appear exactly as shown with no embedded spaces.

[ ] — Square brackets indicate that the enclosed information is optional.

[suffix] — Optional programmer entry Units Terminator for stimulus values:

Frequency Suffix	Time Suffix	Voltage Suffix	Power Suffix
	fs		
	ps		
GHz	ns		
MHz	us (micro)		
kHz	ms	mV	
Hz	s	V	dB

If no suffix is used, the instrument assumes the basic units (Hz or seconds) for the instruction. Upper and lower case characters are equivalent.

<appendage> — Characters enclosed in the <> brackets are qualifiers attached to the root mnemonic. An example is <**ON | OFF**> which shows that either **ON** or **OFF** can be attached to the code. Another is <**1-6**> which shows that the numeral **1**, **2**, **3**, **4**, **5**, or **6** can be attached to the code. There can be no spaces or symbols between the code and the appendage.

; — Semicolon is the required terminator character for each program instruction.

, — The comma is used in program instructions to separate a series of values.

(range of values) — Lower case characters enclosed in parentheses describe the range of values which may be input for the selected function.

value — A constant or a pre-assigned simple or complex numeric or string variable transferred to the instrument.

Display Graphics

HP-GL subset

AF; Erases the user graphics display.

CS; Turns off the measurement display.

DF; Sets the default values.

DIX,Y; Sets absolute character direction.

x	y	Character direction
1	0	0°
0	0	90°
−1	0	180°
0	−1	270°

LB[text][etx]; Labels the display, placing the symbols starting at the current pen position. All incoming characters are printed until the etx symbol is received. The default etx symbol is the ASCII value 3 (not the character 3).

LTa; Specifies line type:

a	line
0	solid
1	solid
2	short dashes
3	long dashes

OP; Outputs P1 and P2, the scaling limits: 0,0,5850,4095.

PAx,y; Draws from the current pen position to x,y. There can be several pairs of x,y coordinates within one command. They are separated by commas, and the entire sequence is terminated with a semicolon.

PD; Pen down. A line is drawn only if the pen is down.

PG; Erases the user graphics display.

PRx,y; Plot relative: draws a line from the current pen position to a position y up and x over.

PU; Pen up. Stops anything from being drawn.

RS; Turns on the measurement display.

SIh,w; Sets the character size, for height h and width w in centimeters:

h	w	size
.16	.20	smallest
.25	.30	
.33	.39	
.41	.49	largest

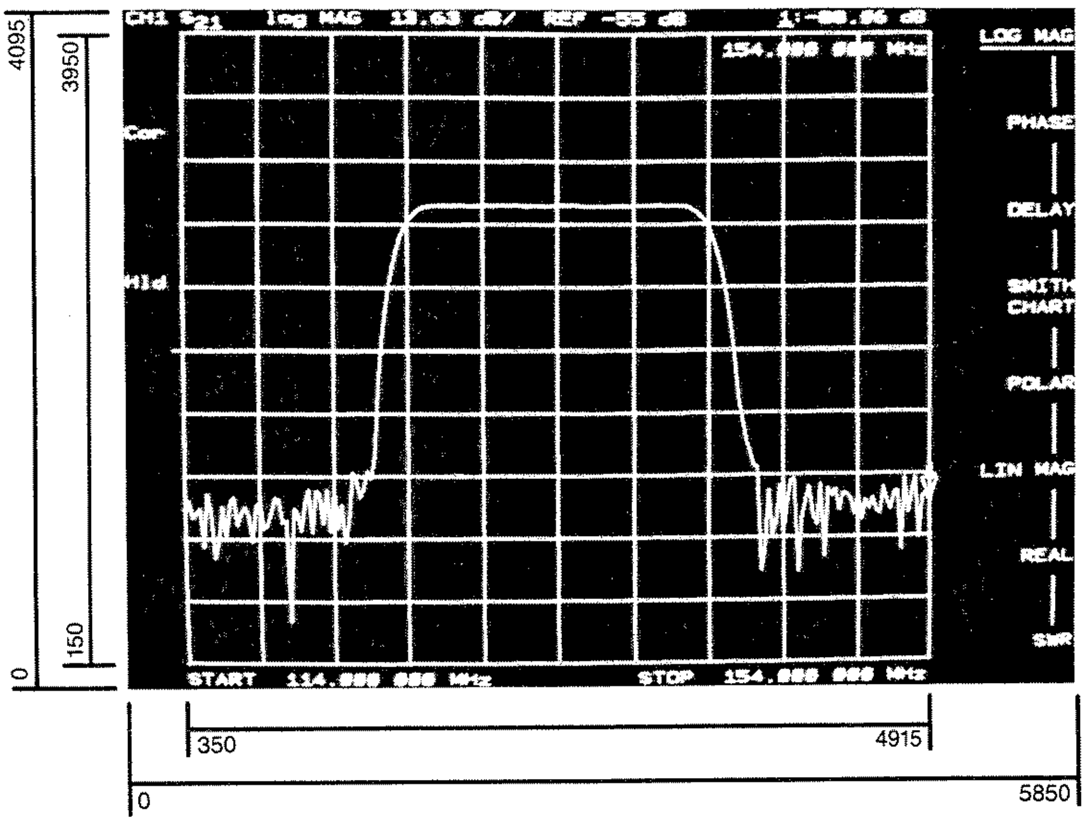
SPn; Selects color: n = 1-7

COLORm; m = 1-7

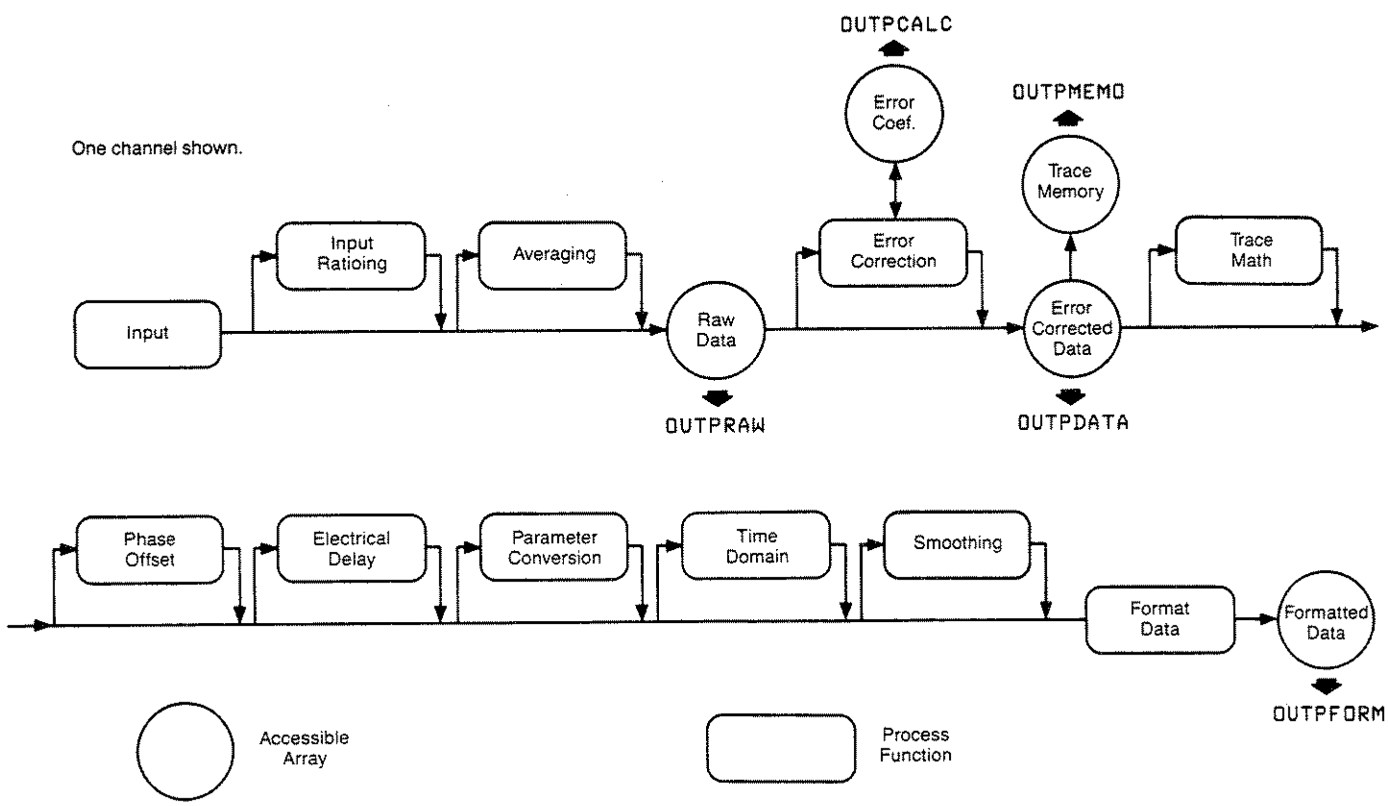
Accepted but ignored HP-GL commands

IM	Input service request mask
IP	Input P1, P2 scaling points
IW	Input window
OC	Output current pen position
OE	Output error
OI	Output identity
OS	Output status
SL	Character slant
SR	Relative character size

User Graphics Units



Processing Chain



Marker and Data Array Units

DISPLAY FORMAT	MARKER MODE	OUTPMARK value 1, value 2	OUTPFORM value 1, value 2	MARKET READOUT** value, aux value
LOG MAG		dB,*	dB,*	dB,*
PHASE		degrees,*	degrees,	degrees,*
DELAY		seconds,*	seconds,*	seconds,*
SMITH CHART	LIN MKR	lin mag, degrees	real, imag	lin mag, degrees
	LOG MKR	dB, degrees	"	dB, degrees
	Re/Im	real, imag	"	real, imag
	R + jX	real, imag ohms	"	real, imag ohms
	G + jB	real, imag Siemens	"	real, imag Siemens
POLAR	LIN MKR	lin mag, degrees	real, imag	lin mag, degrees
	LOG MKR	dB, degrees	"	dB, degrees
	Re/Im	real, imag	"	real, imag
LIN MAG		lin mag,*	lin mag,*	lin mag,*
REAL		real,*	real,*	real,*
SWR		SWR,*	SWR,*	SWR,*

* Value not significant in this format, but is included in data transfers.

** The marker readout values are the marker values displayed in the upper left hand corner of the display. They also correspond to the value and aux value associated with the fixed marker.

Disk file names

Disk file names consist of a user-defined state name of up to 8 characters, such as FILTER, appended with up to two characters, defined by the instrument, which indicate what is in the file. ASCII files use the CITIFile format. Binary files are not meant to be decoded.

FILTERXX

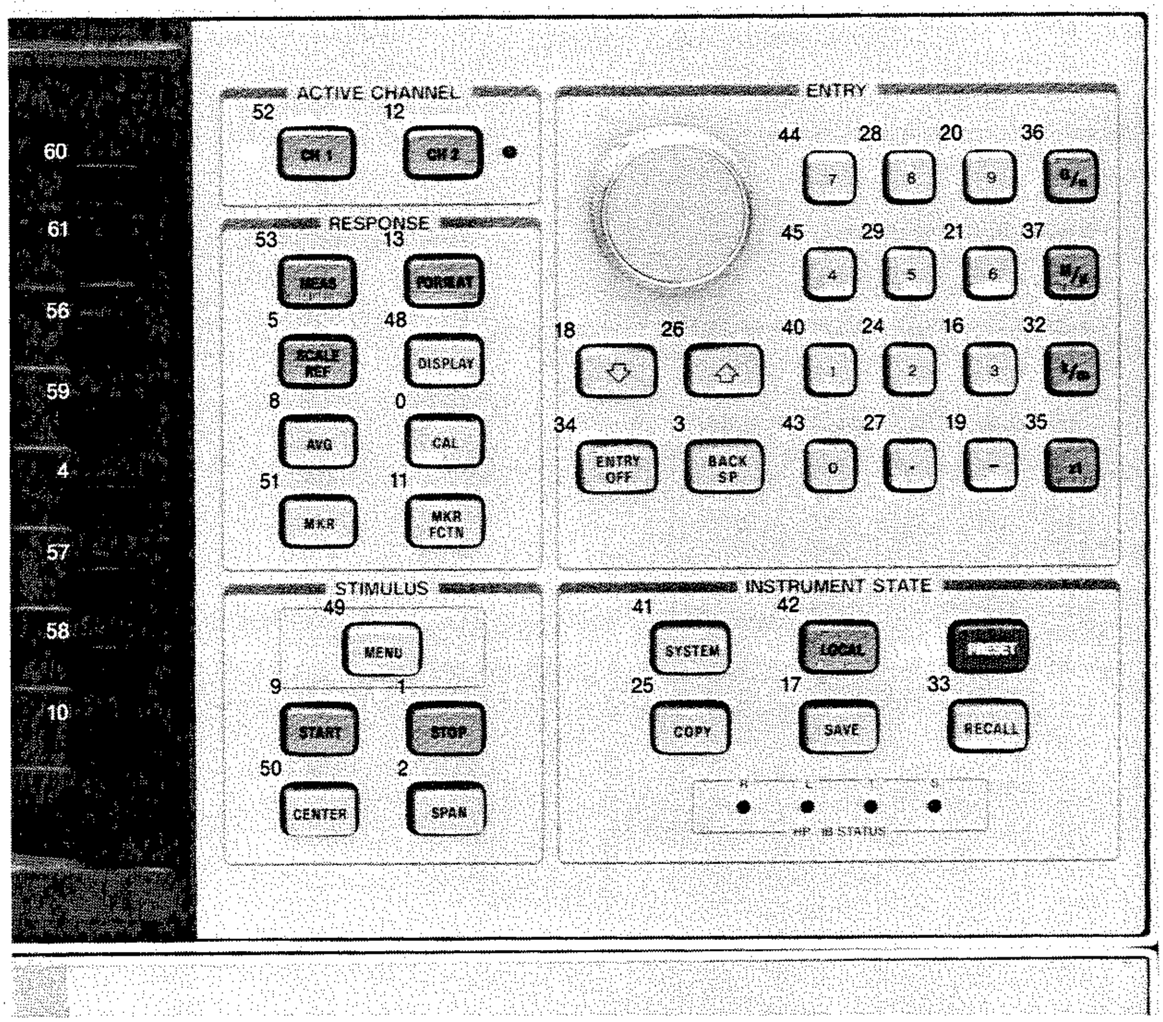
The first character is the file type, telling the kind of information in that file.	The second character is a data index, used to distinguish files of the same type.

Char 1	Meaning	Char 2	Meaning
I	Instrument state	**(blank)**	
G	Graphics	1	Display graphics
		0	Graphics index
D	Error corrected data	1	Channel 1
		2	Channel 2
R	Raw data	**Binary**	
		1 to 4	Channel 1, raw arrays 1 to 4
		5 to 8	Channel 2, raw arrays 1 to 4
		CITIFILE: single file	
			Last digit 1 (ch 1) or 5 (ch 2)
F	Formatted data	1	Channel 1
		2	Channel 2
M	Memory trace	1	Channel 1
		2	Channe 2
1	Cal data, channel 1	**Binary:**	
		K	Cal kit (Multiple files)
		0	Stimulus state (Multiple files)
		1 to 9	Coefficients 1 to 9 (Multiple files)
		A	Coefficient 10
		B	Coefficient 11
		C	Coefficient 12
		CITIFILE: single file	
			last digit shows number of coefficients
2	Cal data, channel 2	**0 to C,K**	Same as channel 1

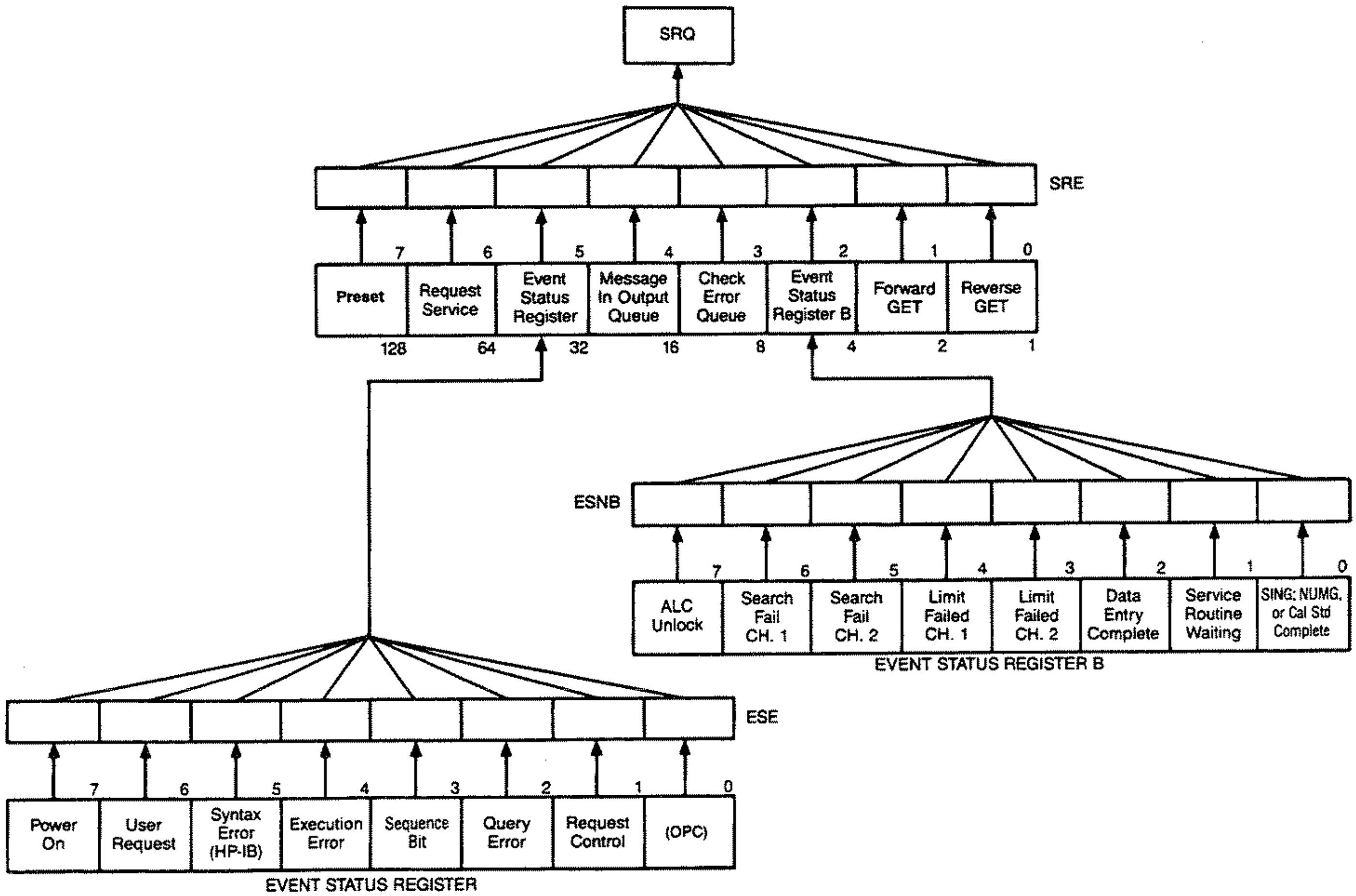
Key Codes

Notes:

1. Key code 63 is invalid key.
2. **OUTPKEY;** reports a knob turn as a −1.
3. If the two byte integer sent back from **KOR?** is negative, it is a knob count. If the knob count was negative, no modification is needed. If the knob count was positive, however, bit 14 will not be set. In this case, the number must be decoded by clearing the most significant byte, as by AND'ing the integer with 255.



Status Reporting Structure



Status Bit Definitions

Status Byte

Bit	Name	Description
0	Waiting for reverse GET	A one path, 2–port calibration is active, and the instrument has stopped, waiting for the operator to connect the device for reverse measurement.
1	Waiting for forward GET	A one path, 2–port calibration is active, and the instrument has stopped, waiting for the operator to connect the device for forward measurement.
2	Check event status register B	One of the enabled bits in event status register B has been set.
3	Check error queue	An error has occurred and the message has been placed in the error queue, but has not been read yet.
4	Message in output queue	A command has prepared information to be output, but it has not been read yet.
5	Check event status register	One of the enabled bits in the event status register has been set.
6	Request service,	One of the enabled status byte bits is causing an SRQ.
7	Request service on Preset	The front panel preset key has been pressed.

Event Status Register

Bit	Name	Description
0	Operation complete	A command for which OPC has been enabled completed operation.
1	Request control	The analyzer has been commanded to perform an operation that requires control of a peripheral, and needs control of HP–IB. Requires pass control mode.
2	Query error	The analyzer has been addressed to talk, but there is nothing in the output queue to transmit.
4	Execution error	A command was received that could not be executed. Commonly due to invalid operands.
5	Syntax error	The incoming HP–IB commands contained a syntax error. The syntax error is cleared only by a device clear or an instrument preset.
6	User request	The operator has pressed a front panel key or turned the knob.
7	Power on	A power on sequence has occurred since the last read of the register.

Event Status Register

Bit	Name	Description
0	Sweep or group complete	A single sweep or group has been completed since the last read of the register. Operates in conjunction with SING or NUMG.
1	Service routine waiting or done	An internal service routine has completed operation, or is waiting for an operator response.
2	Data entry complete	A terminator key has been pressed, or a value entered over HP–IB since last read of the register.
3	Limit failed, Ch 2	Limit test failed on channel 2.
4	Limit failed, Ch 1	Limit test failed on channel 1.
5	Search failed, Ch 2	A marker search was executed, but the target value was not found.
6	Search failed, Ch 1	Same as on channel 2.
7	ALC unlock	Unleveled output power at the beginning or end of a sweep. Data may be invalid.

Calibration Types and Standard Classes

Class	Response	Response and Isolation	S11 1-port	S22 1-port	One path 2-port	Full 2-port	E/O Response and Match	O/E Response and Match
Reflection:[1]					●	●	●	●
S11A (opens)			●		●	●	●	●
S11B (shorts)			●		●	●	●	●
S11C (loads)			●		●	●		
S22A (opens)				●		●		
S22B (shorts)				●		●		
S22C (loads)				●		●		
Transmission:[1]					●	●		
Forward match					●	●		●
Forward thru					●	●	●	●
Reverse match						●		
Reverse thru						●		
Isolation:[1]					●	●		
Forward					●	●	●	●
Reverse						●		
Response	●							
Response and isolation:								
Response		●						
Isolation		●						

1. These subheadings must be called when doing 2-port calibrations.

Calibration Arrays

Array	Response	Response and Isolation	1-port	2-port[1]	E/O Response and Match	O/E Response and Match
1	E_R or E_T	E_X $(E_D)^2$	E_D	E_{DF}	E_{DF}	E_{DF}
2		E_T (E_R)	E_S	E_{SF}	E_{SF}	E_{SF}
3			E_R	E_{RF}	E_{RF}	E_{RF}
4				E_{XF}	E_{XF}	E_{XF}
5				E_{LF}	E_{TF}	E_{LF}
6				E_{TF}		E_{TF}
7				E_{DR}		
8				E_{SR}		
9				E_{RR}		
10				E_{XR}		
11				E_{LR}		
12				E_{TR}		

Meaning of first subscript: D=directivity; S=source match; R=reflection tracking; X=crosstalk; L=load match, T=transmission tracking.

Meaning of second subscript: F=forward; R=reverse.

1. One path, 2-port cal duplicates arrays 1 to 6 in arrays 7 to 12.
2. Response and isolation corrects for crosstalk and transmission tracking in transmission measurements, and for directivity and reflection tracking in reflection measurements.

Alphabetical List of Codes

AB;
Measure and display A/B on the active channel.

ADDRCONT [value];
Controller HP-IB address.
Control is returned to this address after a pass control.

ADDRDISC [value];
Disk HP-IB address. (0-30)

ADDRLSCR [value];
External source address.

ADDRPLOT [value];
Plotter HP-IB address.

ADDRPOWM [value];
Power Meter HP-IB address. (0-30)

ADDRPRIN [value];
Printer HP-IB address. (0-30)

ADJB;
Executes autobiasing of optical modulator.

ALC;
ALC control.

ALIS<ON | OFF>;
Select time domain span limit.
On to display past time domain alias-free range.
Preset selects ALISOFF;.

ALTAB;
Select alternate sweeps for Channel 1 and Channel 2.

ANAB;
Analog bus Enable.

ANAI;
Measure and display data at the Analog Input (ANALOG IN).

ANNO<ON | OFF>;
Select measurement annotation.
S-parameter test set = On;
Reflection/transmission test set = Off.

AR;
Measure and display A/R on the active channel.

ASAMP <ON | OFF>;
Switch A, sampler to: ON = LW, OFF = RF.

ASEG;
Measure all frequency list segments.

ASSS;
Assert the sequence status bit.

ATTP<1 | 2>[value];
Set port 1 or port 2 attenuator (0-90 dB, 10 dB steps).

AUTO;
Automatic selection of REF VALUE and SCALE for the active
channel.

AUTB <ON | OFF>;
Enable or disable autobiasing of optical modulator.

AVERFACT [value];
Set averaging factor for active channel.

AVER<ON | OFF>;
Select averaging for active channel.

AVERON [value]; can also be used.

AVERREST;
Restart averaging on the active channel.

BACI [0-100];
Background intensity percent.

BANDPASS;
Select time domain bandpass mode.

BEEPDONE<ON | OFF>;
Beep when done:
Save instrument state, Calibration standard, Data trace saved.

BEEPFAIL<ON | OFF>;
Beep when limit test failure.

BEEPWARN<ON | OFF>;
Beep when warning message displayed.

BR;
Measure and display B/R on the active channel.

BSAMP <ON | OFF>;
Switch B, sampler to: ON = LW, OFF = RF.

C0 [value]; x10^{-15}F
C1 [value]; x10^{-27}F
C2 [value]; x10^{-36}F
C3 [value]; x10^{-45}F
Open circuit capacitance model values:
$C = C0 + (C1*F) + (C2*F^2) + (C3*F^3)$

CAL1;
Begin measurement calibration.

CALFCALC [value];
Set current frequency power meter calibration factor.

CALFFREQ [value[freq suffix]];
Select power meter calibration factor frequency.

CALFSEN<A | B>;
Edit the sensor A or B calibration factor table.

CALIAPOW; A input.
CALIARPO; A/B ratio
CALIBPOW; B input.
CALIBRPO; B/R ratio.
Begin power calibration sequence for selected measurement.

CALIEORM;
Select E/O response and match calibration.

CALIFUL2;
Select Full 2–Port measurement calibration.

CALIOERM; CALIOERM;
Select O/E response and match calibration.

CALIONE2;
Select One–Path 2–Port measurement calibration.

CALIRAI;
Select Response and Isolation measurement calibration for current parameter.

CALIRESP;
Select Response measurement calibration for current parameter.

CALIS111;
Select 1-Port measurement calibration for current parameter at port 1.

CALIS221;
Select 1–Port measurement calibration for current parameter at port 2.

CALK35MM; 3.5 mm
CALK7MM; 7 mm
CALKN50; type–N, 50Ω
CALKN75; type–N, 75Ω
CALKOPTS; Standard optical
CALKOPTU; User–defined optical
CALKUSED; Use–defined electrical
Begin measurement calibration using selected cal kit.

CALN;
Select Cal none.

CALPRECE; O/E DUT
CALPRESP; Response cable
CALPRFSC; Source RF cable
CALPRFTC; Total RF cable
Select calibration standard class. Measure if single standard in class, or, if multiple standards in class, use **STAN**<char>; and **DONE**; to measure standards in class.

CALSRECC; Receiver coefficients
CALSRECD; Receiver from disc
CALSSOUC; Source coefficients
CALSSOUD; Source from disc
Select standard location for source/receiver model.

CBRI [0–100];
Color brightness percent.

CENT [value[suffix]];
Set CENTER stimulus value.

CHAN1; Channel 1
CHAN2; Channel 2
Select Active measurement Channel.

CHOPAB;
Alternate measurements between Channel 1 and Channel 2 at each frequency point.

CLAD;
Class done, modify cal kit, specify class.
Current standard class is complete.

CLASS11A; S11A; S11 1-port
CLASS11B; S11B; S11 1-port
CLASS11C; S11C: S11 1-port
CLASS22A; S22A: S22 1-port
CLASS22B; S22B: S22 1-port
CLASS22C; S22B: S22 1-port
Select port 1 (S11) and port 2 (S22) calibration standard class. Measure if single standard in class, or, if multiple standards in class, use **STAN**<char>; and **DONE**; to measure standards in class.

CLEA<1-5>;

CLEARALL;
Clear specified Save/Recall register or all.

CLEAL;
CLEL;
Clear current list:
Frequency list, Power Loss list, or Limit Test list.

CLEASE<1-6>;
Clear specified test sequence.

CLES;
CLS;
Clear Status. Clears (0) status byte, event status registers, and event status enable registers.

COAX;
Define current cal standard as Coaxial (linear phase).

COEF<A-I>;
Set optical cal **STDTSOUR**; and **STDTRECE**; coefficients.

COEFA <1-4> [value];
Set numerator coefficients of response model.

COEFB <1-4> [value];
Set denominator coefficents of response model.

COEFDELA [value];
Set delay coefficient of response model.

COEFK;
Set scaling coefficent of the response model.

COLOCH1D; Ch 1 data, limit line
COLOCH1M; Ch 1 memory
COLOCH2D; Ch 2 data, limit line
COLOCH2M; Ch 2 memory
COLOGRAT; Graticule
COLOMEM1; Memory 1
COLOMEM2; Memory 2 and Ref. line
COLOTEXT; Text
COLOWARN; Warning message
Specify display element to change color.

COLOR [0–100];
Specify saturation percent.

CONS;
Continue test sequence.

CONT;
Continuous sweep trigger mode.

CONV1DS; Reciprocal (1/S)
CONVOFF; Conversion Off
CONVYREF; Y: reflection
CONVYTRA; Y: transmission
CONVZREF; Z: reflection
CONVZTRA; Z: transmission
Convert current measurement.

COPYFRFT;
Copy file titles to register titles.

COPYFRRT;
Copy save/recall register titles to disc.

CORI<ON | OFF>;
Select Interpolative error correction for active channel.

CORR<ON | OFF>;
Select error correction for active channel current parameter set.

COUC<ON | OFF>;
Couple/Uncouple channel stimulus values.

COUP<ON | OFF>;
Couple power when uncoupled channels.

COUS <ON | OFF>;
Switch coupling to measurement parameter on or off.

CWEXT;
CW mode using external input.

CWFREQ [value[freq suffix]];
Select CW frequency in single frequency measurement modes. During frequency list edit, set center frequency of current segment.

CWTIME;
Select CW time sweep type.

D1DIVID2<ON | OFF>;
Perform complex divide of current Channel 1 data by current Channel 2 data and display in Channel 2. Dual channel only.

DATI;
Active channel data stored to trace memory.

DEBU<ON | OFF>;
Select HP–IB program debug mode to display instrument commands.

DECONV;
Select down conversion.

DECRLOOC;
Decrement test sequence loop counter by one.

DEFC; Set default colors.

DEFOKIT;
Default optical kit.

DEFS [std no.];
Define number of cal standard to be modified.

DELA;
Select DELAY format for current measurement.

DELO;
Delta Marker mode Off.

DELR<1–4>;
Select delta reference marker.

DELRFIXM;
Select fixed marker as delta reference marker.

DEMOAMPL;	Amplitude Demodulation
DEMOOFF;	Demodulation Off
DEMOPHAS;	Phase Demodulation

Select CW Time transform demodulation.

DEVT1PE;	1–port electrical
DEVT1PO;	1–port optical
DEVTEE;	E/E
DEVTEO;	E/O
DEVTOE;	O/E
DEVTOO;	O/O

Specify current device type.

DFLT;
Select default plotter setup.

DIRS [value];
Set the number of files in directory at disc initialization.

DISCUNIT [value];
Specify disc unit number.
Usually 0 (left drive); 1 (right drive).

DISCVOLU [value];
Specify disc volume number.

DISM<ON | OFF>;
Select display of all four marker values.

DISPDATA;	Display data
DISPDATM;	Display both data and memory
DISPDDM;	Display data divided by memory
DISPDMM;	Display data minus memory
DISPMATH;	Display current math function
DISPDPM;	Display data plus memory
DISPDTM;	Display data times memory
DISPM1DM;	Display memory 1 divided by memory 2
DISPM1MM;	Display memory 1 minus memory 2
DISPM1PM;	Display memory 1 plus memory 2
DISPM1TM;	Display memory 1 times memory 2
DISPM2DM;	Display memory 2 divided by memory 1
DISPM2MM;	Display memory 2 minus memory 1
DISPM2PM;	Display memory 2 plus memory 1
DISPMEMO;	Display memory only

Select display for active channel.

DIVI;
Select complex divide default trace math.

DONACAL;

DONARCAL;

DONBCAL;

DONBRCAL;
Done with power meter calibration sequence.

DONE;
Done with standard class during cal.

DONM;
Done with modify test sequence.

DOSE<1-6>;
Do specified test sequence.

DOWN;
Decrement current active function value.

DRIVPORT <ON | OFF>;
Drive port; ON=LW, OFF=RF.

DUAC<ON | OFF>;
Select dual (On) or single channel (Off) display.

DUPLSE<1-6>SEQ<1-6>;
Duplicate test sequence (from–to).

EOCAL;
Internal E/O service calibration parameter.

EDITDONE;
Done with edit frequency list or edit limit line table.

EDITLIML;
Begin edit limit line table.

EDITLIST;
Begin edit frequency list.

ELEA [value];
Electrical attenuation for power cal.

ELED [value[time suffix]]; Set electrical delay for active channel.

EMIB;
Beep during test sequence.

ENTO;
Entry Off.
Turn off active function and clear entry area.

ESB?;
Output event status register B value.

ESE [value];
Specify bits of event status register to be summarized by bit 5 of the status byte.

ESNB [value];
Specify bits of event status register B to be summarized by bit 2 of the status byte.

ESR?;
Output event status register value.

EXET;
Execute a service test.

EXTAOPTI;
Extension auxiliary optical port.

EXTMDATA<ON | OFF>; Error–corrected data
EXTMFORM<ON | OFF>; Formatted data
EXTMGRAP<ON | OFF>; User graphics
EXTMRAW<ON | OFF>; Raw data arrays
Specify data types included in register storage to disc.

EXTOINPU;
Extension optical input.

EXTOSOUR;
Extension optical source.

EXTT<ON | OFF>; External/Internal trigger

EXTTHIGH;
(HP–IB only) Selects external trigger on low to high signal transition.

EXTTLOW;
(HP–IB only) Selects external trigger on high to low signal transition.

EXTTPOIN; External trigger
Select internal or external measurement trigger mode.

EXTTOFF;
Selects external trigger off.

EXTTON;
Selects external trigger on.

FAST;
Select fast plot speed.

FIXE;
Define load standard type as fixed.

FOCU [0–100];
Set CRT focus value percent.

FORM1; Instrument internal binary
FORM2; IEEE 32–bit fp (8 bytes/point)
FORM3; IEEE 64–bit fp (16 bytes/point)
FORM4; ASCII
FORM5; PC–DOS 32–bit fp (8 bytes/point)
Select HP–IB trace data input/output formats.

FREO;
Select frequency annotation Off.
(Preset to turn On).

FREQOFFS<ON | OFF>;
Select frequency offset mode.

FREQRANG<3GHZ | 6GHZ>;
Select frequency doubler in HP 85047 test set.

FRER;
Select internal trigger free–run sweep (same as CONT;).

FRES<ON | OFF>;
Select frequency subset cal On/Off.

FULP;
Select full page plot.

FWDI; Isolation
FWDM; Load match
FWDT; Tracking
Select forward transmission (S21) calibration standard class. Measure if single standard in class, or, if multiple standards in class, use **STAN**<char>; and **DONE;** to measure standards in class.

GATECENT [value[time suffix]];
Set gate center.

GATE<ON | OFF>;
Select gate off/on.

GATESTAR [value[time suffix]];
GATESPAN [value[time suffix]];
GATESTOP [value[time suffix]];
Set gate span, start, stop values.

GATSMAXI; Maximum
GATSMINI; Minimum
GATSNORM; Normal
GATSWIDE; Wide
Select gate shape.

GRAT;
Selects graticule parameter.

GUIS;
Begin guided setup instructions.
HARMOFF; Second harmonic
HARMSEC; Third harmonic
HARMTHIR; Select harmonic measurement.

HOLD;
Hold present measurement.
Restart using **CONT;**.

IDN?;
Output ASCII instrument identification string. "HEWLETT PACKARD,<model>,<op sys rev>"

IFBW [value];
Select IF bandwidth.

IFLCEQZE<1-6>; Loop counter equals zero
IFLCNEZE<1-6>; Loop counter does not equal zero
IFLTFAIL<1-6>; Limit test fail
IFLTPASS<1-6>; Limit test pass
Branch from executing test sequence to specified test sequence if condition is satisfied.

IFPRTSWR;
Selects IF port match measurement parameter.

IMAG;
Select display of Imaginary data using cartesian format for active channel.

INCRLOOC;
Increment test sequence loop counter by one.

INDEREFR;
Index of refraction.

INID;
Initialize disc for instrument data storage.

INPUCALC<01-12>;
Store measurement calibration error coefficient set real/imaginary pairs input via HP-IB into instrument memory. Select appropriate cal type then input necessary coefficient sets (see **OUTPCALCn;**) then issue **SAVC;**. Issue **SING;** or **CONT;** to measure.

INPUCALK; Input cal kit, use **SAVEUSEK;**
INPUCALR; Receiver cal data
INPUCALS; Source cal data
INPUDATA; Active channel corrected data
INPUFORM; Active channel formatted data
INPULEAS; Learn string
INPUPMCAL<1-2>; Power meter calibration array
INPURAW<1-4>; Active channel raw data array
Input specified data via HP-IB.

INSMEXSA; External source, auto
INSMEXSM; External source, manual
INSMNETA; Standard analyzer
INSMTUNR; Tuned receiver
Select instrument mode.

INTE [0-100];
Set display intensity percent.

ISOD;
Done with isolation part of 2-port cal.

ISOL;
Begin isolation part of 2-port cal.

KEY [keycode];
Send keycode. See Keycode table.
Equivalent to actually pressing a key.

KITD;
Done with modify cal kit.
Modified cal kit replaces existing kit.

KOR?;
Output two byte key code or knob count.
See Keycode table.
Positive value = key code.
Negative value can be converted to knob count.

LABEFWDM ["string"]; Forward match
LABEFWDT ["string"]; Forward transmission
LABERESI ["string"]; Response, Response & Isolation
LABERESP ["string"]; Response
LABEREVM ["string"]; Reverse match
LABEREVT ["string"]; Reverse transmission
LABES11A ["string"]; S11A (opens)
LABES11B ["string"]; S11B (shorts)
LABES11C ["string"]; S11C (loads)
LABES22A ["string"]; S22A (opens)
LABES22B ["string"]; S22B (shorts)
LABES22C ["string"]; S22C (loads)

LABK ["string"]; Electrical cal kit

LABO ["string"]; Optical cal kit
Define cal kit label during modify cal kit.

LABS ["string"];
Define standard label during modify cal kit.

LASEXT;
Select external laser.

LASEINT;
Select internal laser.

LASEOFF;
Laser off.

LASEON;
Laser on.

LEFL; Left lower
LEFU; Left upper
Set plot quadrant option.

LIMD [value];
Set limit line delta value.

LIMIAMPO [value];
Set limit line amplitude offset.

LIMILINE<ON | OFF>;
Select limit line display.

LIMIMAOF [value[suffix]];
Marker to limit line stimulus offset.
Center limit lines using active marker position and limit line amplitude offset.

LIMISTIO [value[suffix]];
Set limit line stimulus offset.

LIMITEST<ON | OFF>;
Select limit test.

LIML [value]; Lower limit
LIMM [value]; Middle limit
LIMS [value]; Stimulus break point limit
LIMTFL; Flat line
LIMTSL; Sloping line
LIMTSP; Single point
LIMU [value]; Upper limit
Define characteristics of limit test segment.

LINFREQ;
Select linear frequency sweep.

LINM;
Select cartesian Linear Magnitude format for active channel.

LINTDATA [value]; Data

LINTMEMO [value]; Memory
Set line type plot options.

LISFREQ;
Select frequency list sweep mode.

LISV;
List data values to display.

LOAD<1-5>;
Recall specified disc file.
Must pass control.

LOADREC<1-5>;
Load specified receiver cal data disc file.

LOADSEQ<1-6>;
Load specified test sequence disc data file.

LOADSOU<1-5>;
Load specified source cal data disc file.

LOCONT;
Selects external LO control

LOFREQ;
Selects frequency offset CW.

LOFSTAR;
Selects start frequency for frequency offset.

LOFSTOP;
Selects stop frequency for frequency offset.

LOFSWE;
Selects sweep frequency mode for frequency offset.

LOGFREQ;
Select log frequency sweep.

LOGM;
Select log magnitude display format for active channel.

LOIFISOL;
Selects LO to IF isolation measurement parameter.

LOOC [value];
Set value of test sequence loop counter.

LOPOWER;
Selects LO power level in frequency offset mode.

LOPSTAR;
Selects LO start power level in frequency offset mode.

LOPSTOP;
Selects LO stop power level in frequency offset mode.

LOPSWE;
Selects sweep power in frequency offset mode.

LORFISOL;
Selects LO to RF isolation measurement parameter.

LOWPIMPU; Impulse

LOWPSTEP; Step
Select time domain stimulus model.

LRN?;
Output learn string.

LWALCI <ON | OFF>;
LW ALC IN : ON=EXT, OFF=INT.;

LWALCO <ON | OFF>;
LW ALC on or off.

LWALCV [value];
Save value of LW ALC.

MANTRIG;
Select manual trigger.

MARK<1-4>[value[suffix]];
Select active marker.
Move it to specified stimulus value.

MARKBUCK [0-# of pts-1];
Move active marker to specified data point number.

MARKCENT [value[suffix]];
Move active marker to Center stimulus value.

MARK<COUP | UNCO>;
Select Markers always coupled/uncoupled.
Preset selects Coupled.

MARKCW;
Change Center stimulus value to active marker stimulus value.

MARKDELA;
Set electrical delay to balance phase at marker frequency.
Delay = zero seconds; flat phase at marker.

MARK<DISC | CONT>;
Select Discrete (measured data points only), or Continuous (linear interpolation between actual data points), Preset selects Discrete.

MARKFAUV [value[suffix]];
Set fixed marker auxiliary value offset.

MARKFSTI [value[suffix]];
Set fixed marker stimulus offset value.

MARKFVAL [value];
Set fixed marker position value offset.

MARKMAXI;
Select Marker Search mode; execute search for maximum data value.

MARKMIDD;
In limit table segment edit, change the segment middle value to the current marker amplitude.

MARKMINI;
Select Marker Search mode; execute search for minimum data value.

MARKOFF;
Select all markers and marker functions Off.

MARKREF;
Change reference position value to current marker amplitude value.

MARKSPAN;
Change stimulus span to current delta marker stimulus value.

MARKSTAR;
Change stimulus start to current marker stimulus value.

MARKSTIM;
In limit table segment edit, change the limit stimulus break point to the current marker stimulus value.

MARKSTOP;
Change stimulus stop to current marker stimulus value.

MARKZERO;
Fixed marker moves to current active marker position and becomes delta ref marker.

MATI;
MATI to current memory.

MAXF [value[freq suffix]];
Maximum frequency for current cal standard.

MEASA;	Input A
MEASB;	Input B
MEASE01;	Transmission measurement E/O
MEASE02;	Transmission measurement E/O (aux)
MEASOE1;	Transmission measurement O/E (port 1)
MEASOE2;	Transmission measurement O/E (port 2)
MEASOFF;	Marker function measure off
MEASR;	Input R

Select measurement for active channel.

MEASTAT<ON | OFF>;
Select trace statistics.

MEASOO1;
Transmission measurement O/O.

MEAS 002;
Transmission measurement O/O (aux).

MEAS01;
Optical reflection measurement.

MEAS02;
Optical reflection measurement (aux).

MEMO1;
Display memory 1.

MEMO2;
Display memory 2.

MEM1I;
Memory 1 to memory 2.

MEM2I;
Memory 2 to memory 1.

MENUAVG;
MENUCAL;
MENUCOPY;
MENUDISP;
MENUFORM;
MENUMARK;
MENUMEAS;
MENUMRKF;
MENU<ON | OFF>;
MENURECA;
MENUSAVE;
MENUSCAL;
MENUSTIM;
MENUSYST;
Display specified softkey menu.

MINF [value[freq suffix]];
Minimum frequency for current cal standard.

MINU;
Select display of complex data minus memory.

MODB [value];
Optical modulator bias.

MODEI;
Model to memory.

MODI1;
Modify current electrical cal kit.

MODIO;
Modify current optical cal kit.

MOD RF <ON | OFF>;
Optical modulator RF input: ON = ext, OFF = int.

NEWSE<1-6>;
Modify specified test sequence.

NEXP;
Display next page of operating parameters list.

NOOP;
No Operation.
Sets Operation Complete status bit.

NUMG [value];
Restart averaging, execute the specified number of groups of sweeps, then hold.

NUMR [value];
Set number of power meter readings per point during cal.

OFSD [value[time suffix]];	Electrical delay
OFSL [value];	Electrical loss
OFSOINDR [value];	Optical refractive index
OFSOLENG [value];	Physical length
OFSOLOSS [value];	Optical loss
OFSORPOW [value];	Percent reflectance
OFSZ [value];	Electrical offset line Z0.

Specify offset characteristics of current cal standard.

OMII;
Omit isolation part of cal.

OPC[?];
Operation complete.
If ?, send "1" when following command is complete.

OPEP;
Display operating parameters list.

OPTA [value];
Set optical attenuator.

OUTPACTI; Active function value.
OUTPAFR; Signal Processor RF frequency
OUTPAPER; Smoothing aperture, stimulus unirs.

OUTPCALC
<01-12>; Active cal set array

OUTPICAL
<01-12>; Active interpolated cal set array

OUTPCALK; Current cal kit (Form1)
OUTPCALR; Receiver cal data
OUTPCALS; Source cal data
OUTPCNTR; Service, abus counter.
OUTPDATA; Active channel corrected data
OUTPERRO; Error message (ASCII #,"string")
OUTPFORM; Active channel formatted data
OUTPIDEN; Instrument id string (see IDN?;)

OUTPIPMCL <1 | 2>;
Active interpolated power meter cal array.
OUTPKEY; Last key pressed (Keycode table)
OUTPLEAS; Instrument learn string (Form1)
OUTPLIMF; Limit test, failed point
OUTPLIML; Limit test, each point
OUTPLIMM; Limit test, marker position
OUTPMARK; Active marker (x,y,stimulus)
OUTPMPUL; Current memory data
OUTPMEMO; Pulse width (x,y,duty cycle)
OUTPMRIS; Rise time (x,y,z)
OUTPMSTA; Marker stats (mean, std dev, p–p)
OUTPMUPL; Output pulsewidth
OUTPMWID; Bandwidth search (bw, center, Q)
OUTPMWIL; Band search (bw,center,Q,loss)
OUTPOPTS; Service, option sum
OUTPPLOT; HP–GL plot string

OUTPPMCAL
<1 | 2>; Power meter cal, Channel

OUTPPRIN; Raster dump to printer

OUTPRAF <1 - 4>;
Current raw data.

OUTPRAW
<1-4>; Current raw data

OUTPRFFR; External source frequency

OUTPSEQ
<1-6>; Specified test sequence

OUTPSTAT; Status byte (FORM4)
OUTPTESS; Test status
OUTPTITL; Display title (FORM4)
OUTPTPLL; True pll sequence
Output specified data via HP–IB.

PAUS;
Pause in test sequence.

PCB [value];
Pass Control Back address.
See **ADDRCONT;**.

PDATA<ON | OFF>;
Select data trace plot option.

PEEK;
PEEL<memory address>;
Peek/Poke location.
Service use only.
PENNDATA [value]; Data trace, limit lines
PENNGRAT [value]; Graticule
PENNMARK [value]; Markers and marker text
PENNMEMO [value]; Memory trace
PENNTEXT [value]; Text and User graphics
Define plotter pen color for portion of plot.

PGRAT<ON | OFF>;
Select graticule plot option.

PHAO [value];
Set phase offset.

PHAS;
Select cartesian phase format for active channel.

PLOS<FAST | SLOW>;
Select plotter pen speed.
Preset selects fast.

PLOT;
Request a plot.
Requires pass control mode.

PMEM<ON | OFF>;
Select memory trace plot option.

PMKR<ON | OFF>;
Select marker and marker text plot option.

PMTRTTIT;
In test sequence, read power meter/HP-IB value into title string.

POIN [value];
Define number of points in current frequency list segment.

POKE value;
Change contents of memory location.
Service use only.

POLA;
Select Polar display format for active channel.

POLMLIN; lin mag, phase
POLMLOG; log mag, phase
POLMRI; real, imaginary
Select polar format marker units.

PORE<ON | OFF>; Select Port Extensions On/Off.
NUMR [value]PORE<ON | OFF> **PORT1** [value[time suffix]];

PORT1 [value[time suffix]];
PORT2 [value[time suffix]];
PORTA [value[time suffix]];
PORTB [value[time suffix]];
Set port extensions electrical delay.

PORTR [value[time suffix]]; Reflection

PORTT [value[time suffix]]; Transmission
Set port extensions electrical delay

POWE [value];
Set source output level (dBm).

POWLFREQ [value[freq suffix]];
Define current frequency in the power loss list.

POWLLIST;
Begin power loss list edit for power meter cal.

POWLLOSS [value];
Set the power loss value for the current frequency in the power loss list.

POWM<ON | OFF>;
Selects that HP 436 (On) or HP 438 (Off) is used in service
procedures.

POWOM<ON | OFF>;
Select guided setup instructions at instrument power up.

POWS<ON | OFF>;
Select Power sweep mode.

POWT<ON | OFF>;
Set Power Trip Off, then On to clear port input power overload condition.

PRES;
Instrument Preset.

PRIC;
Select color print.

PRINALL;
Copy measurement display to printer according to plot options.

PRINSEQ<1-6>;
Print specified test sequence.

PRIS;
Select standard print.

PSOFT<ON | OFF>;
Select plot softkey labels option.

PTEXT<ON | OFF>;
Select plot text option.

PTOS;
Pauses for selection of available sequences.

PULV [value];
Set pulse width search value.

PULW<ON | OFF>;
Select pulse width search Off/On.

PURG<1-5>;
Purge specified file from disc.
Requires pass control.

PWMCEACS; Cal each sweep; no cal sweep
PWMCOFF; Correction Off
PWMCONES; One sweep cal; use cal sweep
Select power meter cal.
Preset selects Off.

PWRLOSS<ON | OFF>;
Select power loss table.
Preset selects Off.

RAID;
Done with Response and Isolation cal. If all necessary standard classes have been measured, a cal set is created.

RAIISOL;
Measure Isolation standard in Response & Isolation cal.

RAIRESP;
Measure Response standard in Response & Isolation cal.

RAMD;
Response and match cal done.

READRECT; Receiver
READSOUT; Source
Read disc electro–optical cal data file titles.

REAL;
Select Real cartesian format for active channel.

RECA<1-5>;
Recall the specified instrument state.

RECCSTDI; Current coefficients
RECDSTDI; Load from disk.
Select receiver model.

RECEOUT <ON | OFF>;
Select path to receiver output; ON = CAL, OFF = OPT.

RECO;
Recall colors.

REFD;
Done with Reflection part of Full 2–port cal.

REFL;
Begin Reflection part of Full 2–port cal.

REFP [value];
Set Reference Position Line graticule.
0 = bottom; 10 = top.

REFT;
Recall register titles from disk.
Requires pass control mode.

REFV [value];
Set current format reference position line value.

RESC;
Resume last measurement calibration sequence.

RESD;
Restore measurement display.

RESM;
Reset mode 1.

RESPDONE;
Finished with Response cal. If all necessary standards are measured, a cal set will be created.

REST;
Measurement restart.

REVI; Isolation
REVM; Load match
REVT; Tracking
Select reverse transmission (S12) calibration standard class. Measure if single standard in class, or, if multiple standards in class, use **STAN**<char>; and **DONE**; to measure standards in class.

RFIFISOL;
Selects RF to IF isolation measurement parameter.

RFLP;
Select reflection port.

RFLTLO;
Selects RF less than LO.

RFGTLO;
Selects RF greater than LO.

RFPRTSWR;
Selects RF port match measurement parameter.

RIGL; Right Lower
RIGU; Right Upper
Select plot quadrant.

RIST<ON | OFF>;
Select rise time search Off/On.

RSCO;
Reset color.

RST;
Instrument Preset.

S11;
S12;
S21;
S22;
Select parameter displayed on current active channel.

SADD;
Add a segment to current frequency list or limit table.

SAMC<ON | OFF>;
Select internal sampler correction Off/On.
Preset selects On.

SAV1;
Finished with 1-port cal. If all necessary standards are measured, a 1-port cal set is created.

SAV2;
Finished with 2=Port cal. If all necessary standards are measured, a 2-port cal set is created.

SAVC;
Create a cal set using current error coefficient arrays.

SAVE<1-5>;
Save the current instrument state in specified register.

SAVEOPTK;
Save active optical cal kit as optical user cal kit.

SAVERECC;	Receiver
SAVESOUC;	Source

Store current electro-optical coefficients.

SAVEUSEK;
Store the active calibration kit as the User kit.

SAVUASCI;	Save using CITIFile ASCII
SAVUBINA;	Save using binary

Select disc file format.
See Disc File Name table.

SCAL [value];
Set graticule x-axis or polar scale/division for current format.

SCAPFULL;	Full plot.
SCAPGRAT;	Expand to P1 and P2.

Select plot option.

SDEL;
Delete current frequency list segment or limit table segment.

SDON;
Done with current frequency list segment or limit table segment, include segment in list.

SEAL;	Search Left
SEAR;	Search Right

Initiate marker search left or right from current position for selected Min, Max, or Target. Message if not found.

SEAMAX;	Search for Maximum
SEAMIN;	Search for Minimum
SEAOFF;	Search Mode Off
SEATARG [value];	Search for target.

Select Marker Search mode; execute search.

SEDI [value];
Edit current or specified frequency list segment.

SEQ <1 - 6>;
Selects specified sequence for test.

SEQWAIT [value];
In test sequence, wait integer seconds.

SETF;
Set harmonic frequency steps for time domain low pass transform.

SETZ;
Define Z0 of Smith Chart, Inverted Smith,
Load cal standard type, **CONVZ;** and **CONV;**.
Preset selects Z0=50 ohms.

SHOM;
In test sequence, show menu.

SING;
Single sweep or set of sweeps, then hold.

SLID;
Sliding load done.

SLIL;
Define load standard type as sliding.

SLIS;
Slide is set; measure sliding load.
RESMSLIS **SLOPE** [value];
Enter power slope value (dB/GHz)

SLOPE [value];
Enter power slope value (dB/GHz).

SLOP<ON | OFF>;
Select power slope Off/On.

SLOW;
Selects slow plot speed.

SM<1-8>

SM2<D,E,H,L, or M>;
Service, source control.

SMIC;
Select Smith chart display format for current channel.

SMIMGB;	G±jB
SMIMLIN;	linear magnitude, phase angle
SMIMLOG;	20log10(linear mag), phase angle
SMIMRI;	real/imaginary pair
SMIMRX;	R±jX

Select Smith chart marker readout format.

SMOOAPER [0.1–20];	Smoothing aperture
SMOOOFF;	Smoothing Off
SMOOON [0.1–20];	Smoothing On

Control smoothing for selected channel.
value = percent of span: 0.1, 0.2, 0.5,...20 sequence.

SOFR;
Display instrument operating system revision.

SOFT<1-8>;
Select the softkey function for the current displayed menu.

SOUCSTDI;	Current coefficients
SOUDSTDI;	Load from disc.

Select source model.

SPAN [value[suffix]];
Set stimulus span.

SPAR<ON | OFF>;
S-parameter notation On/Off.

SPECFWDM	stanAno[,stanBno...[stanGno]];
SPECFWDT	stanAno[,stanBno...[stanGno]];
SPECRESI	stanAno[,stanBno...[stanGno]];
SPECRESP	stanAno[,stanBno...[stanGno]];
SPECREVM	stanAno[,stanBno...[stanGno]];
SPECREVT	stanAno[,stanBno...[stanGno]];
SPECS11A	stanAno[,stanBno...[stanGno]];
SPECS11B	stanAno[,stanBno...[stanGno]];
SPECS11C	stanAno[,stanBno...[stanGno]];
SPECS22A	stanAno[,stanBno...[stanGno]];
SPECS22B	stanAno[,stanBno...[stanGno]];
SPECS22C	stanAno[,stanBno...[stanGno]];

Specify from 1 to 7 standards in each calibration standard class.
StanAno = first standard in class,
StanGno = last standard in class.

SPEG<ON | OFF>;
Select gate markers.

SPLD<ON | OFF>;
Select split display On/Off.

SRE [value];
Service request enable. (0–256)
Value defines bits enabled to generate SRQ.

SSEG [value];
Measure specified single segment of frequency list.

STAF [value[freq suffix]];
Set start frequency with transform On.

STAN<A-G>;
Measure cal standard in current standard class.

STAR [value[suffix]];
Set Start stimulus value.

STB?;
Output status byte.

STDD:
Done with current standard definition.

STDODEFI;
Done with optical cal standards.

STDTARBI;	1-port arbitrary impedance
STDTDELA;	Delay/Thru 2-port
STDTFRES;	Fresnel
STDTLOAD;	1-port Z0 load
STDTOPEN;	Open circuit
STDTOTHR;	Thru
STDTRECE;	Receiver
STDTREFL;	Reflector
STDTSHOR;	Short circuit
STDTSOUR;	Source
STDTTHRR;	Thru/receiver

Define current standard type.

STOP [value[suffix]];
Set Stop stimulus value.

STOR<1–5>;
Store file to disc.

STORSEQ<1–6>;
Store specified test sequence.

STPSIZE [value[freq suffix];
Define current frequency list segment step size.

SVCO;
Save colors.

SWEA;
Select sweep time, auto.

SWET [value[time suffix]];
Set sweep time.

SWR;
Select SWR display for active channel.

TAKCS;
Begin power meter calibration sweep.

TALKLIST;
Set instrument to talker/listener mode.

TERI [value];
Define real terminal impedance of arbitrary impedance standard.

TESR<1,2,4,6,or 8>;
Service, send test response.

TESS?;
Return "1" if S-parameter test set.
Return "2" if doubler test set.

TEST [value];
Service, select test.

TIMDTRAN<ON | OFF>;
Select time domain transform On/Off.

TINT [0–100];
Set color hue
(0 = red, 100 = violet).

TITF<1–5>["string"];	Disk file.
TITL ["string"];	CRT title.
TITR<1–5>["string"];	Save/recall register.
TITSEQ<1–6>["string"];	Test sequence.
TITSQ ["string"];	Current test sequence.
TITTMEM ["string"];	Trace memory.
TITTPMTR ["string"];	Power meter address
TITTPRIN ["string"];	printer address

Send title string to specifed function.

TO<1–2><ON | OFF>;
Service, test record option.

TRACK<ON | OFF>;
Select marker search tracking Off/On.

TRAD;
Done with transmission part of Full 2–port cal.

TRAN;
Begin transmission part of Full 2–port cal.

TRAP;
Display transform parameters.

TRAS [value[freq suffix]];
Enter new frequency span with transform On.

TRIG;
Select HP–IB triggered data acquisition.
Instrument does Hold, sets status bit, then wait for HP–IB Group Execute Trigger for next measurement step, executes trigger, then sets status bit.
Exit using **FRER;, CONT;, or PRES;**.

TST?;
Initiate self–test sequence;
Return zero if pass.

TTLOH; High
TTLOL; Low
Defines active level of test set TTL output.

UCONV;
Selects upconverter.

UP;
Increment current active function value.

USEPASC;
Instrument enters pass control mode.

USESENSA;

USESENSB;
Sensor A
Sensor B
Select power sensor.

VELOFACT [value];
Define velocity factor of transmission medium.

VIEM;
Selects view measure, which displays frequency offset configuration.

VOFF [value];
Define frequency offset value.

WAIT;
Wait for a clean sweep.

WAVE;
Define cal standard as Waveguide (dispersive) phase).
Standard rectangular waveguide,

MAXF; sets cutoff frequency.

WAVL 1300;
Optical wavelength is 1300 nm..

WAVL 1550;
Optical wavelength is 1550 nm.

WIDT<ON | OFF>;
Select bandwidth search On/Off.

WIDV [value];
Define bandwidth search value in current format.

WINDMAXI;	Maximum window
WINDMINI;	Minimum window
WINDNORM;	Normal window
WINDOW [value];	Arbitrary window
WINDUSEMOFF;	Above commands define window
WINDUSEMON;	Trace memory defines window

Select time domain window shape.

WRSK<1-8>["string"];
Enter new softkey label.

List of OPC'able Codes

The Operation Complete (OPC) function allows syncronization of the program by causing a specific action when the current command has completed executing, before the next command begins executing. There are two forms for this process. The function is enabled by issuing **OPC**; or **OPC?**; prior to an OPC'able command. An example of this usage is **OPC**; **PRES**;. In this instance, the Operation Complete bit is automatically set when the Preset command has completed execution. Issuing **OPC?**; prior to the command causes the instrument to set the Operation Complete status bit then output a "1" when the command has completed execution.

Following is an alphabetical list of OPC'able commands.

ADJB;	**MATI;**
CHAN1;	**MEM1I;**
CHAN2;	**MEM2I;**
CLEARALL;	**MODEI;**
DATI;	**NOOP;**
DONE;	**NUMG;**
DON<A,B,AR,BR>CAL;	**PRES;**
EDITDONE;	**RAID;**
EXTTOFF;	**RECA<1-5>;**
EXTTPOIN;	**REFD;**
FREQOFFS<ON | OFF>;	**RESPDONE;**
FREQRANG<3GHZ | 6GHZ>;	**RST;**
HARMOFF;	**SAV1;**
HARMSEC;	**SAV2;**
HARMTHIR;	**SAVC;**
INSMEXSA;	**SAVE<1-5>;**
INSMEXSM;	**SING;**
INSMNETA;	**STAN<A-G>;**
INSMTUNR;	**TRAD;**
ISOD;	**WAIT;**
MANTRIG;	

Interrgate Instrument State (Query) Commands

All instrument functions can be interrogated to find the current On/Off state or value.

For instrument state commands, append the question mark (**?**) character instead of **<ON | OFF>** to interrogate the state of the functions. An example is **AVER?**;. The analyzer responds to the next controller Enter operation with a "1" or a "0" to indicate On or Off, respectively.

For settable functions such as **SCAL** [value];, using **SCAL?**; causes the analyzer to respond to the next controller enter operation by outputting the current function value then clearing the instrument entry area.

If a command that does not have a defined response is interrogated, the instrument outputs a zero.

For more information, call your local HP sales office listed in your telephone directory or an HP regional office listed below for the location of your nearest sales office.

United States:
Hewlett–Packard Company
4 Choke Cherry Road
Rockville, MD 20850
(301) 670–4300

Hewlett–Packard Company
5201 Tollview Drive
Rolling Meadows, IL 60008
(312) 255–9800

Hewlett–Packard Company
5161 Lankershim Blvd.
No. Hollywood, CA 91601
(818) 505–5600

Hewlett–Packard Company
2015 South Park Place
Atlanta, GA 30339
(404) 955–1500

Canada:

Hewlett–Packard Ltd.
6877 Goreway Drive
Mississauga, Ontario L4V1M8
(416) 678–9430

Australia/New Zealand:
Hewlett–Packard Australia Ltd.
31–41 Joseph Street,
Blackburn, Victoria 3130
Melbourne, Australia
(03) 895–2895

Europe/Africa/Middle East:
Hewlett–Packard S.A.
Central Mailing Department,
P.O. Box 529
1180 AM Amstelveen,
The Netherlands
(31) 20/547 9999

Far East:
Hewlett–Packard Asia Ltd.
22/F Bond Centre
West Tower
89 Queensway
Central, Hong Kong
(5) 8487777

Japan:
Yokogawa–Hewlett–Packard Ltd.
29–21, Takaido–Higashi 3–chome
Suginami–ku, Tokyo 168
(03) 331–6111

Latin America:
Latin American Region Headquarters
Monte Pelvoux Nbr. 111
Lomas de Chapultepec
11000 Mexico, D.F. Mexico
(905) 596–79–33

HEWLETT PACKARD

January 15, 1992

Appendix

This section of the manual contains miscellaneous information and includes the following:

PRESET STATE CONDITIONS

When the **[PRESET]** key is pressed, the analyzer reverts to a known predefined 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 4)

Operating Parameter	Preset Value
Stimulus Conditions	
SWEEP TYPE	linear frequency
DISPLAY MODE	start/stop
TRIGGER TYPE	continuous
EXTERNAL TRIGGER	OFF
SWEEP TIME	800 milliseconds
START FREQUENCY	.300 MHz
FREQUENCY SPAN	2999.7 MHz
START TIME	0s
TIME SPAN	800.5 milliseconds
CW FREQUENCY	1000 MHz
SOURCE POWER	0 dBm
POWER SLOPE	0 dB/GHz; OFF
START POWER	−5.0 dBm
POWER SPAN	5 dB
COUPLED CHANNELS	ON
Response Conditions	
PARAMETER	Channel 1: S11; Channel 2: S21
(without test set)	A/R B/R
CONVERSION	OFF
FORMAT	log magnitude (all inputs)
DISPLAY	data
COLOR DISPLAY	same as before PRESET
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)

Table A-1. Preset Conditions (2 of 4)

Format Table	Reference 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	0.2	5.0	0.0	0.0
SWR	1.00	0.0	1.0	0.0

Operating Parameter	Preset Value
Calibration	
CORRECTION	OFF
DEVICE TYPE	O/O
CALIBRATION TYPE	none
CALIBRATION KIT	7 millimeter
SYSTEM Z0	50 ohms
VELOCITY FACTOR	1
EXTENSIONS	OFF
PORT 1	0
PORT 2	0
INPUT A	0
INPUT B	0
ALTERNATE A and B	ON
Markers (coupled)	
MARKERS 1,2,3,4	1 GHz; all OFF
LAST ACTIVE MARKER	1
REFERENCE MARKER	none
MARKER MODE	continuous
DELTA MARKER MODE	OFF
MARKER MEASURE	OFF
MARKER SEARCH	OFF
MARKER TARGET VALUE	−3 dB
MARKER WIDTH VALUE	−3 dB; OFF
MARKER PULSE WIDTH	50%
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 (3 of 4)

Operating Parameter	Preset Value	
Limit Lines		
LIMIT LINES	OFF	
LIMIT TESTING	OFF	
LIMIT LIST	empty	
EDIT MODE	upper/lower limits	
STIMULUS OFFSET	0 Hz	
AMPLITUDE OFFSET	0	
LIMIT TYPE	sloping line	
BEEP FAIL	OFF	
Frequency List		
FREQUENCY LIST	empty	
EDIT MODE	start/stop, number of points	
Time Domain		
TRANSFORM	OFF	
TRANSFORM TYPE	bandpass	
START TRANSFORM	−20 nanoseconds	
TRANSFORM SPAN	40 nanoseconds	
GATING	OFF	
GATE SHAPE	normal	
GATE START	−10 nanoseconds	
GATE SPAN	20 nanoseconds	
DEMODULATION	OFF	
WINDOW	normal	
USE MEMORY	OFF	
Plot		
PEN NUMBER:	Channel 1	Channel 2
Data	1	2
Memory	1	2
Graticule	3	4
Text	1	2
Marker	5	6
LINE TYPE		
Data, Memory	7	7
PLOT DATA	ON	
PLOT MEMORY	ON	
PLOT GRATICULE	ON	
PLOT TEXT	ON	
PLOT MARKER	ON	
PLOT QUADRANT	FULL PAGE	
SCALE PLOT	FULL	
PLOT SPEED	FAST	
System Parameters		
HP-IB ADDRESSES	last active state	
HP-IB MODE	last active state	
INTENSITY and FOCUS	last active state	

Table A-1. Preset Conditions (4 of 4)

Operating Parameter	Preset Value
Test Set Attenuation	
PORT 1	0
PORT 2	0
External Memory Array (Define Store)	
DATA	OFF
RAW DATA	OFF
FORMATTED DATA	OFF
GRAPHICS	OFF
Service Modes	
HP-IB DIAGNOSTIC	OFF
SOURCE PHASE LOCK LOOP	ON
SAMPLER CORRECTION	ON
SPUR AVOIDANCE	ON
AUX INPUT RESOLUTION	HIGH
ANALOG BUS NODE	11 (aux input)

Table A-2. Power-on Conditions (versus Preset)

HP-IB MODE is talker/listener.

MEMORY and CALIBRATION data of saved registers are cleared.

TEST SET: The analyzer checks for presence of Test Set.

COLOR DISPLAY: Default color values. (HP 8702B)

INTENSITY and FOCUS values are set to factory encoded values. The factory values can be changed by running the appropriate service routine. Refer to the Troubleshooting section of 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:

HP 8702	16
USER DISPLAY	17
PLOTTER	5
PRINTER	1
DISC	0
DISC UNIT NUMBER	0
DISC VOLUME NUMBER	0

INTERNAL REGISTER TITLES are set to defaults: REG1 through REG5.

EXTERNAL REGISTER TITLES (store files) are set to defaults: FILE1 through FILE 5.

ERROR MESSAGES

Below is a list of the analyzer error (CAUTION) messages that are displayed on the CRT or transmitted by the instrument over HP-IB. The list is in alphabetical order and includes an explanation of the message.

ADDITIONAL STANDARDS NEEDED
Error correction for the selected calibration class cannot be computed without measuring the necessary standards. This message means that you have not measured all the required devices.

ADDRESSED TO TALK WITH NOTHING TO SAY
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
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 is not corrected after cleaning the fan, troubleshoot power supplies for overheated components.

AVERAGING INVALID ON NON-RATIO MEASURE
Sweep-to-sweep averaging is only valid for ratio measurements: A/R, B/R, A/B. Other noise reduction techniques are available for single input measurements. Refer to the **[AVG]** key in the Stimulus and Response Blocks section for a discussion of variable IF bandwidths and trace smoothing.

BLOCK INPUT ERROR
The analyzer did not receive a complete data transmission, usually caused by an interruption of the bus transaction such aspressing the **[LOCAL]** key or aborting the IO process at the controller.

BLOCK INPUT LENGTH ERROR
The length header received by the analyzer did not agree with the size of the internal array block. Refer to the HP-IB Programming section for instructions on using analyzer input commands.

CALIBRATION REQUIRED
A valid calibration set could not be found that matched the current stimulus state or measurement parameter. Refer to the Measurement Calibration section. Calibration sets can be saved to internal or external memory. Refer to the **[SAVE]** key in the Instrument State Function Block section.

CAN'T CHANGE-ANOTHER CONTROLLER ON BUS
The analyzer cannot assume the mode of system controller until the active controller is removed from the bus or releases control of the bus.

CHANGE HP-IB to SYST CTRL or PASS CTRL
The analyzer cannot communicate with another peripheral while in TALKER/LISTENER mode on the bus. Refer to the **[LOCAL]** key in the Instrument State Function Block section.

CONTINUOUS SWITCHING NOT ALLOWED
The current measurement states require the HP S-parameter test set to switch between a forward and reverse measurement, driving test port 1, then test port 2. To prevent excessive mechanical wear in the RF switch, continuous switching is not allowed. The **tsH** indicator in the left margin of the display indicates that the instrument has been put in the sweep HOLD mode due to the test set operation. Turn dual channel OFF and make one measurement at a time.

CORRECTION TURNED OFF
Critical parameters in the current measurement state do not match the parameters for the calibration set. Therefore, correction has been turned off. Critical state parameters are: sweep type, start frequency, frequency span, and number of points.

CURRENT PARAMETER NOT IN CAL SET
The calibration is not valid for the selected measurement parameter. Refer to the Measurement Calibration section.

DEADLOCK
A fatal firmware error has occurred. Press the **[PRESET]** key or cycle the line power to reset the instrument.

DEMODULATION NOT VALID
Demodulation is only valid for the CW time mode. Refer to the Time Domain section.

DISC ERROR: not on, no disc #0, HP-IB mode
Check that the disc drive power is turned on. If the disc drive is a single drive, change the disc unit number to 1. Refer to the **[LOCAL]** key in the Instrument State Function Section.

DISC: not on, not connected, wrong addrs
The disc cannot be accessed by the analyzer. Verify that power is applied to the disc drive and that the HP-IB connection is good. Check the disc HP-IB address in the analyzer and the HP-IB address switch on the disc drive. Refer to the **[LOCAL]** key in the Instrument State Function section for instructions on setting peripheral addresses for the analyzer.

DISC HARDWARE PROBLEM
The disc drive is not responding correctly. Refer to the disc drive operating manual.

DISC MEDIUM NOT INITIALIZED
The disc must be initialized before it is used. Refer to the ***[INITIALIZE DISC]*** key in the Instrument State Function section.

DISC MEDIUM FULL
The STORE operation will overflow available disc space. If this occurs, insert a new disc or purge files from the full disc to create disc space.

DISC IS WRITE PROTECTED
The STORE operation cannot write to a write-protected disc. Slide the write-protect tab over the write-protect opening in order to write onto the disc.

DISC WEAR —REPLACE DISC SOON
The disc has been used too much and is wearing out. Copy files onto a new disc using an external controller. If no controller is available, load instrument states from the old disc and store them to a newly initialized disc using the SAVE/RECALL features of the analyzer. Refer to **[SAVE/RECALL]** in the Instrument State Function section.

EXCEEDED 7 STANDARDS PER CLASS
A maximum of seven calibration standard devices can be defined for any class. Refer to Modifying Calibration Kits in the Measurement Calibration section.

FIRST CHARACTER MUST BE A LETTER
The first character of a disc file title or an internal register title must be an alpha character.

FUNCTION NOT VALID
The requested function is incompatible with the current instrument state.

ILLEGAL UNIT OR VOLUME NUMBER
The disc unit or volume number set in the analyzer is not valid. Refer to **[LOCAL]** key in the Instrument State Function section and the disc drive operating manual for information.

INIT DISC removes all data from disc
Warning! Continuing the initialize operation will destroy any data currently on the disc.

INPUT OVERLOAD, attenuator set to max
This message applies to Option 006 (6 GHz operation with an HP 85047A Test Set) and is displayed when too much input power from the test set doubler is received into the R input. Decrease the output power.

INITIALIZATION FAILED
Disc initialization failed, usually due to a damaged disc.

INSTRUMENT STATE MEMORY CLEARED
The five instrument state registers have been cleared from memory along with any calibration data, calibration kit definitions, or user graphics.

INSUFFICIENT MEMORY
The last front panel or HP-IB command could not be implemented due to insufficient memory space. In some cases, this error can only be corrected by pressing the **[PRESET]** key. Refer to the Instrument State Function section for information on memory allocation.

INVALID KEY
An undefined key (usually an unlabeled softkey) was pressed.

KEY DISABLED IN GUIDED SETUP
This message occurs because **[CH 1]** or **[CH 2]** was pressed in Guided Setup mode.

LIST TABLE EMPTY
The frequency list is empty. To implement LIST FREQ mode, add segments to the list table. Refer to the ***[EDIT LIST]*** key in the Sweep Type menu in the Stimulus and Response Blocks section.

LOAD RECEIVER CAL DATA FROM DISC FILE
RCVR DISC standard was selected but NO cal data has been loaded from disc. This message usually appears when an O/E calibration is started. Be sure to load the proper files.

LOAD SOURCE CAL DATA FROM DISC FILE
SOURCE DISC standard is selected and no cal data has been loaded from disc. This message usually appears whenan E/O calibration is started. Be sure to load the proper files.

LOW-PASS: FREQ LIMITS CHANGED
The frequency domain data points must be harmonically related from DC to the stop frequency. If this condition is not true when a low-pass mode is selected, the end points of the frequency range are modified by the analyzer as necessary, resulting in this message.

MORE SLIDES NEEDED
At least three slides are required to complete this E/E calibrations.

NO CALIBRATION CURRENTLY IN PROGRESS
The ***[RESUME CAL SEQUENCE]*** key is not valid unless a calibration was previously in progress. Refer to the Measurement Calibration section.

NO DISC MEDIUM IN DRIVE
No disc was found in the current disc unit (drive). Insert the disc or check the disc unit number stored in the analyzer. Refer to the **[LOCAL]** key in the Instrument State Function section.

NO FILE(S) FOUND ON DISC
No files of the type created by an analyzer were found on the disc. Check the disc.

NO FAIL FOUND
The self-diagnostic function of the instrument operates on an internal test failure. If this message is displayed, no failure has been detected. Refer to the troubleshooting information in the Service Manual for information on internal tests.

NO IF FOUND: CHECK R INPUT LEVEL
The first IF was not detected during the pretune stage of the analyzer internal phase-lock sequence. Check that the R input is connected and has at least −35 dBm input power. Refer to the Service Manual if this message does not go away.

NO INTERPOLATION FOR POWER CALIBRATION
An attempt is made to turn on INTERP while the POWER CAL is on. and INTERP is on. INTERP is set to OFF when this message appears.

NO LIMIT LINES DISPLAYED
Limit lines are turned on, but cannot be displayed on polar or
Smith chart display formats.

NO MARKER DELTA −SPAN NOT SET
The ***[MARKER→SPAN]*** key function requires *delta marker* mode be turned on, with at least two markers displayed. Refer to the Using Markers section.

NO PHASE LOCK: CHECK R INPUT LEVEL
The first IF was detected at the pretune stage of the analyzer internal phase-lock sequence, but the instrument could not acquire phaselock. Refer to the system level troubleshooting in the service manual.

NO SPACE FOR NEW CAL: CLEAR REGISTERS
No memory is available to store a calibration set. Memory can be added by clearing a previously saved instrument state (calibration). Refer to the Instrument State Functionsection for information on the memory allocation.

NO VALID STATE IN REGISTER
A request to load an instrument state, from an empty register, was received over HP-IB.

NO VALID MEMORY TRACE
In order to display or use the memory trace, a data trace must first be stored to memory. Refer to the ***[DISPLAY→MEMORY]*** key in the Stimulus and Response Blocks section.

NOT VALID FOR PRESENT TEST SET
The calibration requested is inconsistent with the test set type. This message occurs when a *full two port* calibration is requested without an S-Parameter test set or a *1 port 2 path* calibration is requested with an S-Parameter test set.

ONLY LETTERS AND NUMBERS ARE ALLOWED
Non-alphanumeric characters are not allowed in disc file titles or internal save register titles.

OPTIONAL FUNCTION; NOT INSTALLED
This message will appear if you select a function that requires an option not installed in your analyzer.

OVERLOAD ON INPUT R, POWER REDUCED
OVERLOAD ON INPUT A, POWER REDUCED
OVERLOAD ON INPUT B, POWER REDUCED
Whenever the power level at one of the three receiver (R, A, B) inputs exceeds approximately +2 dBm, the RF OUT power level is reduced to the minimum possible level. A **P↓** appears in the left margin of the display to indicate that the power trip function has been activated. To change this condition, decrease the power level at the input below 0 dBm. Then turn the power trip off using the ***[POWER TRIP on/off]*** key in the Stimulus and Response section.

PHASE LOCK LOST
Internal phase-lock was acquired but then lost. Refer to the Troubleshooting section of the Service Manual and execute the phase-lock diagnostic routine (Service Modes).

PHASE LOCK CAL FAILED
An internal phase-lock routine is automatically executed at power-on, when a drift in pretune values has been detected, or anytime a phase-lock problem is detected. This message indicates that phase-lock was initiated and the first IF detected, but a problem caused the internal phase-lock calibration to fail. Refer to the Troubleshooting section of the Service Manual (Pretune Correction test).

PLOT ABORTED
The plot is stopped on the plotter. This occurs when the **[LOCAL]** key is pressed on the analyzer.

PLOTTER: not on, not connect, wrong addrs
Plotter doesn't respond. Check line power and the HP-IB connections. Verify that the plotter address set in the analyzer matches the actual address switches of the plotter. For more information, refer to the **[LOCAL]** key in the Instrument State Function section.

PLOTTER NOT READY-PINCH WHEELS UP
The plotter pinch wheels are not holding down the paper. Check them to clear the *not ready* status on the bus.

POSSIBLE FALSE LOCK
The instrument is phase locked, but it may not be using the correct harmonic frequency. Refer to the Adjustments and Correction Constants information in the Service Manual.

POW MET INVALID
The power meter indicates an out-of-range condition. Check the test setup.

POW MET NOT SETTLED
Sequential power meter readings are not consistent. Verify that equipment is set up correctly. If so, **[PRESET]** the instrument and restart the routine.

POW MET NOT FOUND
Power meter does not respond over HP-IB. Check line power and HP-IB connections to the power meter. Verify that the power meter address and model number set in the analyzer matches the address and model number of the actual power meter.

POWER SUPPLY HOT!
The temperature sensors on the A8 Post Regulator assembly have detected too much heat and have shut down the power supply.

POWER SUPPLY SHUT DOWN!
One or more supplies on the A8 Post Regulator assembly have been shut down due to one of the following conditions: over-current, over-voltage, or under-voltage.

PRINT ABORTED
Pressing the **[LOCAL]** key causes the analyzer to abort output to the printer.

PRINTER: not on, not connect, wrong addrs
Printer doesn't respond. Check line power and HP-IB connections. Verify that the printer address set in the analyzer matches the actual address switches of the printer. For more information, refer to the **[LOCAL]** key in the Instrument State Function section.

PRINT/PLOT IN PROGRESS, abort with LOCAL
This message is displayed when you attempt to stop a print or plot function. You must use the **[LOCAL]** key to stop the print or plot.

PROBE POWER SHUT DOWN!
The biasing supplies (Probe Power) are shut down due to exessive current draw. Check the instruments using this supply.

REQUESTED DATA NOT CURRENTLY AVAILABLE
The analyzer does not have the data being requested. For example, this condition occurs when requesting error term arrays without an active calibration in the instrument.

SELF TEST #n FAILED
Internal test #n has failed. The analyzer reports the first failure detected during the test routines. Refer to the Troubleshooting section of the Service Manual for more information on internal tests and the self-diagnostic feature.

SOURCE PARAMETERS CHANGED
This message usually occurs when you turn on a calibration that does not match the current STIMULUS (RF source) parameters. When this happens, a calibration set (instrument state) is updated to match the stimulus parameters.

S-PARAMETERS NOT VALID FOR DEVICE TYPE
This message is displayed if you change ANNOTATION to S-parameter when the device type is anything other than a 1-port electrical or E/E. Also, it appears if S-parameters annotation is selected and the device type is changed from electrical. ANNOTATION is set to T/R when this appears.

SWEEP TIME INCREASED
Sweep time is automatically increased to compensate for other instrument state changes. Some parameters that cause an increase in sweep time are an increase in the number of points, narrower IF bandwidths, and sweep type.

SWEEP TIME TOO FAST
The fractional-N and the digital IF circuits have lost synchronization. Refer to the System Troubleshooting section in the Service Manual for more information.

SWEEP TRIGGER SET TO HOLD
The instrument is in a *hold* state and is no longer sweeping.

SYNTAX ERROR
An improperly formatted command was received over HP-IB. Refer to the HP-IB Programming section, or the QRG for proper command syntax.

SYSTEM IS NOT IN REMOTE
The analyzer is in *local* (front panel operation) mode. In this mode, the analyzer will not respond to most HP-IB commands.

TARGET VALUE NOT FOUND
The target value for the marker search function does not exist on the current data trace.

TOO MANY SEGMENTS OR POINTS
Frequency list mode is limited to 30 segments or 1632 points. Change the number to clear this message.

TRANSFORM, GATE NOT ALLOWED
Transformation to the time domain is not allowed for sweep types other than linear and CW.

TROUBLE! CHECK SET-UP AND START OVER
Refer to the Adjustments and Correction Constants section of the Service Manual for the appropriate equipment set up for this routine.

WAITING FOR CLEAN SWEEP
In single sweep mode, the instrument ensures that all changes to the instrument state, if any, have been implemented before taking the sweep. The HP-IB command that the instrument is currently processing will not complete until the sweep completes.

WAITING FOR HP-IB CONTROL
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.

WAITING FOR DISC
This message is displayed between the start and finish of a read or write operation to a disc.

WRITE ATTEMPTED WITHOUT SELECTING INPUT TYPE
The data header for the analyzer, "#A", 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 Programming section, or the Quick Programming Guide for command syntax.

CRT DISPLAY INFORMATION

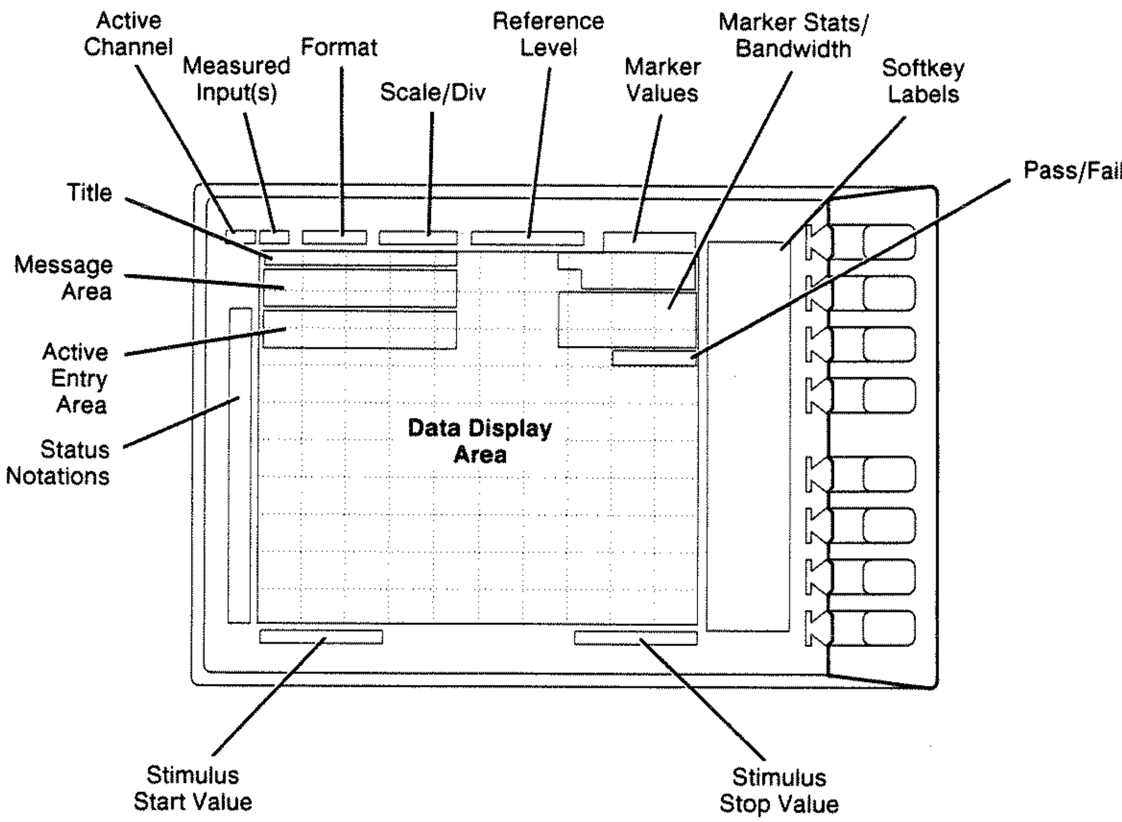


Figure A-1. CRT Display (Single Channel, Cartesian Format)

The CRT displays the grid on which measurement trace data is plotted, including other annotation describing the measurement as shown in the figure.

In addition to the full-screen display, a split or dual display is available using the **[DISPLAY]** key. In this case, information labels are provided for each half of the display.

Several different display formats (Smith chart, polar, etc.)are availible using the **[FORMAT]** key.

Stimulus Start Value is the start frequency of the source in frequency domain measurements, the start time in CW mode (0 seconds) or time domain measurements, or the lower power value in power sweep. 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, the stop time in time domain measurements or CW sweeps, or the upper limit of a power sweep. When the stimulus is in center/span mode, the span is shown in this space. The stimulus values can be blanked, as described in the Stimulus and Response section (see: DISPLAY).

For CW time and power sweep measurements, the CW frequency is displayed centered between the start and stop times or power values.

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

- * = Source parameters changed: measured data in doubt until a complete fresh sweep has been taken.
- Cor = Error correction is on.
- C? = Error correction is on, but may not be valid (stimulus parameters changed).
- C2 = Two-port error correction is on.
- C2? = Two-port error correction is on, but stimulus parameters have changed.
- CP = Power Calibration.
- CI = Calibration with interpolation on.
- Hld = Hold sweep.
- ▲ = Fast sweep indicator.
- Ext = Waiting for an external trigger.
- Avg = Sweep-to-sweep averaging is on. The averaging count is shown immediately below.
- Smo = Trace smoothing is on.
- Del = Electrical delay has been added or subtracted.
- Gat = Gating is on (time domain option 010 only).
- P? = Source power is unleveled at start or stop of sweep. Refer to Service Manual for troubleshooting.
- P▼ = Source power has been automatically set to minimum due to overload.
- A/W = Amps/Watt (responsivity)
- W/A = Watts/Amp (responsivity)
- O/O = Optical input / Optical output device type.
- E/O = Electrical input / Optical output device type.
- O/E = Optical input / Electrical output device type.
- E/E = Electrical input / Electrical output device type.

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 accessed using the **[DISPLAY]** key, ***[MORE] [TITLE]***.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 HP-IB section).

Active Channel is the number of the current active channel (1 or 2). 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 input or ratio of inputs currently measured, as selected using the **[MEAS]** key. Also indicated in this area is the current display memory status.

Format is the display format selected: LOG MAG, LIN MAG, SMITH CHART, etc.

Scale/Div is the graticule vertical scale 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. The reference level is also 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.

Marker Stats, Bandwidth are statistical marker values determined using the menus accessed with the **[MKR FCTN]** key (refer to Using Markers).

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

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

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.

The **[CH 1]** and **[CH 2]** keys 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 also 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.

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

A third 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, as described in the Using Markers section.

Entry Block

The ENTRY block, 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.

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 units of 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: dB, dBm, degrees, seconds, Hz, or dB/GHz (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 scale, reference level, 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 are defined by the analyzer for different functions 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 softkey 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 entry, or the last digit entered from the number pad.

REAR PANEL FEATURES AND CONNECTORS

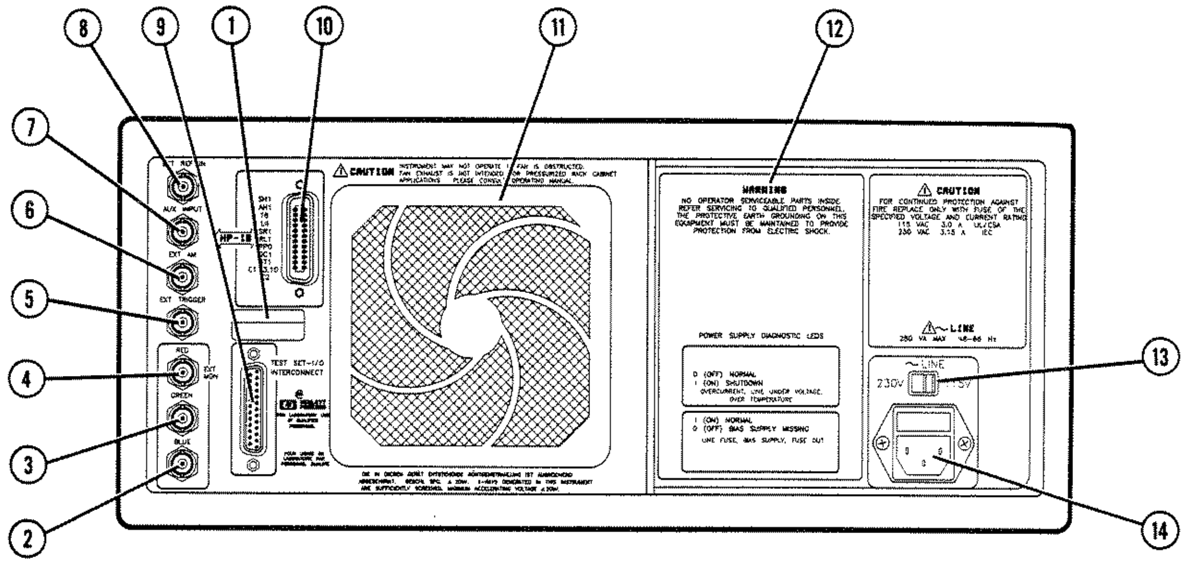


Figure A-2. Rear Panel

The figure above illustrates the features and connectors on the rear panel, described below. Requirements for input signals to the rear panel connectors are provided in the Supplemental Characteristics table in the *Specifications* section.

1. Serial number plate. For information about serial numbers, refer to the General Information section.

2. BLUE connector.
3. GREEN connector.
4. RED connector.
   Red, green, and blue video output connectors provide analog red, green, and blue video signals which can be used to drive an external monitor such as the HP 3571A/B or monochrome monitor such as the HP 35731A/B. Other analog multi-sync monitors can be used if they are compatible with the analyzer's 25.5 KHz scan rate and video levels: 1vp−p, 0.7v=white, 0v=black, −0.3v sync, sync on green.

5. 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.

6. EXT AM connector. This is used to connect an external analog signal to the ALC circuitry of the analyzer source to amplitude modulate the RF output signal.

7. AUX INPUT connector. This is 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. It is also used as an analog output in service routines, described in the Service manual.

8. 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.

9. TEST SET INTERCONNECT connects the analyzer to an HP S-parameter test set only using the test set interconnect cable supplied with the test set. The test set is then fully controlled by the analyzer. The HP 85044A/B transmission/reflection test set does not use this interconnection.

10. HP-IB connector. This is used to connect the analyzer to an external controller and other instruments in an automated system. This connector is also used when the analyzer itself is the controller of compatible peripherals. Refer to the Instrument State section and the HP-IB section.

11. Fan filter. This filter helps to protect the instrument from dust contamination, and should be cleaned regularly. 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.

12. Safety warnings.

13. Line voltage selector. Switch for 115V or 230V line voltage.

14. Power cord receptacle with fuse (fuse value and rating marked under CAUTION label).

ELECTRICAL DEVICE MEASUREMENTS

The analyzer system performance depends not only on the performance of the individual instruments, but also on the system configuration, the user-selected operating conditions, and the measurement calibration.

This section explains the residual errors remaining in a measurement system after accuracy enhancement. It provides information to calculate the total measurement uncertainty.

The sources of measurement errors are explained, with an error model flowgraph and uncertainty equations. Information is provided for conversion of the dynamic accuracy error (in dB) to a linear value for use in the uncertainty equations. The effects of temperature drift on measurement uncertainty are illlustrated with graphs.

System specification tables are provided for an analyzer 7 mm system using an HP 85046A, 85044A, or 85047A test set. Typical system performance tables are given for 50 ohm type-N and 3.5 mm systems, and for 75 ohm type-N systems using the HP 85046B and 85044B test sets.

Procedures and blank worksheets are supplied to compute the total error-corrected measurement uncertainty of a system. These procedures combine the terms in the tables, the uncertainty equations, and the nominal S-parameter data of the device under test.

COMPARISON OF TYPICAL ERROR-CORRECTED MEASUREMENT UNCERTAINTY

Figures on the following pages are examples of the measurement uncertainty data that can be calculated using the information provided in this section. These figures compare the reflection and transmission measurement uncertainty of a 7 mm system using different levels of error correction. Each figure shows uncorrected values and residual uncertainty values after response calibration, response and isolation calibration, and full one or two port calibration. The data applies to a frequency range of 300 kHz to 3 GHz with a stable temperature (no temperature drift), and using compatible 7 mm calibration devices from the HP 85031B calibration kit.

The results shown in the graphs can be obtained using the HP 85046A, 85044A, or 85047A test sets up to 3 GHz. Different measurement calibration procedures provide comparable measurement improvement for the following compatible connector types and test sets (using the compatible calibration kits):

50 ohm type-N connectors
3.5 mm connectors
HP 85047A test set from 3 GHz to 6 GHz (with analyzer option 006)
HP 85046B and 85044B with 75 ohm type-N connectors

SOURCES OF MEASUREMENT ERRORS

Network analysis measurement errors can be separated into systematic, random, and drift errors. In addition to the errors removed by calibration (accuracy enhancement), other systematic errors exist that, combined with random and drift errors, also contribute to total system measurement uncertainty. Therefore, after accuracy enhancement procedures are performed, residual measurement uncertainties remain.

Systematic Error Sources

Residual (post-calibration) systematic errors result from imperfections in the calibration standards, the connector standards, the connector interface, the interconnecting cables, and the instrumentation. All measurements are affected by dynamic accuracy, effective switch port match, switch tracking, and frequency error effects. For reflection measurements, the associated residual errors are effective directivity, effective source match, and effective reflection tracking. For transmission measurements, the additional residual errors are effective crosstalk, effective load match, effective transmission tracking, and cable stability.

Random Error Sources

Non-repeatable measurement variations occur due to trace noise, noise floor, and connector repeatability. These errors affect both reflection and transmission measurements.

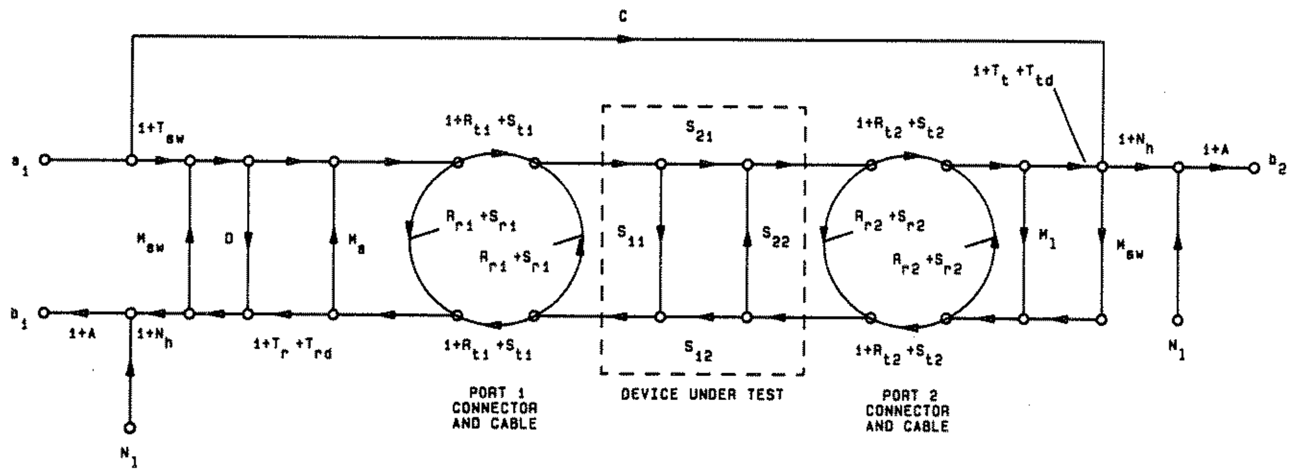
Drift Error Sources

Drift error sources fall into two basic categories: frequency drift and instrumentation drift. Primary causes for instrumentation drift are the thermal expansion characteristics of the interconnecting cables within the test set, and the conversion stability of the frequency converter within the receiver. These errors affect both reflection and transmission measurements.

SYSTEM ERROR MODEL

Any measurement result is the vector sum of the actual test device response plus all error terms. The precise effect of each error term depends upon its magnitude and phase relationship to the actual test device response. When the phase of an error response is not known, phase is assumed to be worst case (0 or 180 degrees). Random errors such as noise and connector repeatability are generally combined in a root-sum-of-the-squares (RSS) manner. The error term related to thermal drift is combined on a worst-case basis as shown in each uncertainty equation given in the following paragraphs.

Figure A-3 illustrates the error model for the HP 8753B with the HP 85046A or 85047A S-parameter test set. This error model shows the relationship of the various error sources in the forward direction, and may be used to analyze overall measurement performance. The model for signal flow in the reverse direction is similar. Note the appearance of the dynamic accuracy, noise errors, switch errors, and connector repeatability terms in both the reflection and transmission portions of the model.



A	=	Dynamic Accuracy (A_m = Magnitude Dynamic Accuracy) (A_p = Phase Dynamic Accuracy)	D	=	Residual Directivity
N_l	=	Noise Floor	M_s	=	Residual Source Match
N_h	=	High Level Noise	M_l	=	Residual Load Match
T_{sw}*	=	Switch Repeatability (Transmission)	C	=	Residual Crosstalk
M_{sw}*	=	Switch Repeatability (Reflection)	T_r	=	Residual Reflection Tracking
R_r	=	Reflection Repeatability	T_t	=	Residual Transmission Tracking
R_t	=	Transmission Repeatability	S_r	=	Cable Reflection Stability
T_{rd}	=	Reflection Tracking Drift	S_t	=	Cable Transmission Stability
T_{td}	=	Transmission Tracking Drift			

Figure A-3. HP 8702/85046A/85047A System Error Model

For measurement of one-port devices, set the crosstalk (C), load match (M_l), transmission tracking (T_t), port 2 connector repeatability (R_{r2}, R_{t2}), and port 2 cable stability (S_{r2}, S_{t2}) error terms to zero.

* In the tables of specifications and typical system performance, the effects of switch repeatability are included in the terms for source match, load match, reflection tracking, and transmission tracking.

REFLECTION UNCERTAINTY EQUATIONS

Total Reflection Magnitude Uncertainty (E_{rm})

An analysis of the error model yields an equation for the reflection magnitude uncertainty. The equation contains all of the first order terms and the significant second order terms. The error term related to thermal drift is combined on a worst case basis with the total of systematic and random errors. The four terms under the radical are random in character and are combined on an RSS basis. The terms in the systematic error group are combined on a worst case basis. In all cases, the error terms and the S-parameters are treated as linear absolute magnitudes.

$$E_{rm} \text{ (linear)} = V_r + S11 \times T_{rd} \text{ (magnitude); and}$$

$$E_{rm} \text{ (log)} = 20 \log (1 \pm E_{rm}/S11)$$

where

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

$$S_r = \text{systematic error} = D + S_{r1} + T_r \times S11 + (M_s + S_{r1}) \times S11^2 + M_l \times S21 \times S12 + A_m \times S11$$

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

$$X_r = \text{random high-level noise} = 3 \times N_h \times S11$$

$$Y_r = \text{random port 1 repeatability} = R_{r1} + 2 \times R_{t1} \times S11 + R_{r1} \times S11^2$$

$$Z_r = \text{random port 2 repeatability} = R_{r2} \times S21 \times S12$$

Total Reflection Phase Uncertainty (E_{rp})

Reflection phase uncertainty is determined from a comparison of the magnitude uncertainty with the test signal magnitude. The worst case phase angle is computed. This result is combined with the error terms related to thermal drift of the total system, port 1 cable stability, and phase dynamic accuracy.

$$E_{rp} = \arcsin ((V_r - A_m \times S11) / S11) + T_{rd} \text{ (phase)} + 2S_{t1} + A_p$$

TRANSMISSION UNCERTAINTY EQUATIONS

Total Transmission Magnitude Uncertainty (E_{tm})

An analysis of the error model yields an equation for the transmission magnitude uncertainty. The equation contains all of the first order terms and some of the significant second order terms. The error term related to thermal drift is combined on a worst case basis with the total of systematic and random errors. The four terms under the radical are random in character and are combined on an RSS basis. The terms in the systematic error group are combined on a worst case basis. In all cases, the error terms are treated as linear absolute magnitudes.

E_{tm} (linear) $= V_t + S21 \times T_{td}$ (magnitude); and

E_{tm} (log) $= 20 \log (1 \pm E_{tm} / S21)$

where

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

S_t = systematic error $= C + T_t \times S21 + (M_s + S_{r1}) \times S11 \times S21 + (M_l + S_{r2}) \times S21 \times S22 + A_m \times S21$

W_t = random low-level noise $= 3 \times N_l$

X_t = random high-level noise $= 3 \times N_h \times S21$

Y_t = random port 1 repeatability $= R_{t1} \times S21 + R_{r1} \times S11 \times S21$

Z_t = random port 2 repeatability $= R_{t2} \times S21 + R_{r2} \times S22 \times S21$

Total Transmission Phase Uncertainty (E_{tp})

Transmission phase uncertainty is calculated from a comparison of the magnitude uncertainty with the test signal magnitude. The worst case phase angle is computed. This result is combined with the error terms related to phase dynamic accuracy, cable phase stability, and thermal drift of the total system.

$E_{tp} = \arcsin ((V_t - A_m \times S21) / S21) + T_{td}$ (phase) $+ S_{t1} + S_{t2} + A_p$

DYNAMIC ACCURACY

The dynamic accuracy value used in the system uncertainty equations is obtained from the dynamic accuracy specifications. The specification for magnitude dynamic accuracy is in dB, and it must be converted to a linear value to be used in the uncertainty equations. In addition, the dynamic accuracy specifications are given for an absolute input signal in dBm, and must be converted to a relative error (relative to the power at which the accuracy enhancement calibration occurs) to be used in the system uncertainty equations.

$$\text{Dynamic Accuracy (linear)} = \frac{10^{(+\text{DynAcc(dB)}/20)} - 1}{10^{(-\text{DynAcc(dB)}/20)} + 1}$$

$$\text{Dynamic Accuracy (dB)} = 20^{*}\log(1 \pm \text{Dynamic Accuracy (linear)})$$

Definitions

Pcal = the calibration (thus the reference) power level at the instrument input port (A or B) when the short is measured in a reflection calibration OR when the thru is measured in a transmission calibration

Pmeas = the measured input signal (dBm) when the DUT is measured

Residual dynamic accuracy = the residual error remaining when Pmeas = Pcal

Linacc = relative dynamic accuracy (linear magnitude or phase) for the ratioed measurement used in the linear system performance calculation

Lincal = dynamic accuracy (linear magnitude or phase) term for single input at Pcal

Linmeas = dynamic accuracy (linear magnitude or phase) term for single input at Pmeas

Determining Relative Dynamic Accuracy Error Contribution

The example given here shows how to determine the relative dynamic accuracy error contribution to a measurement in a ratio mode. Six example graphs (on the following pages) are provided.

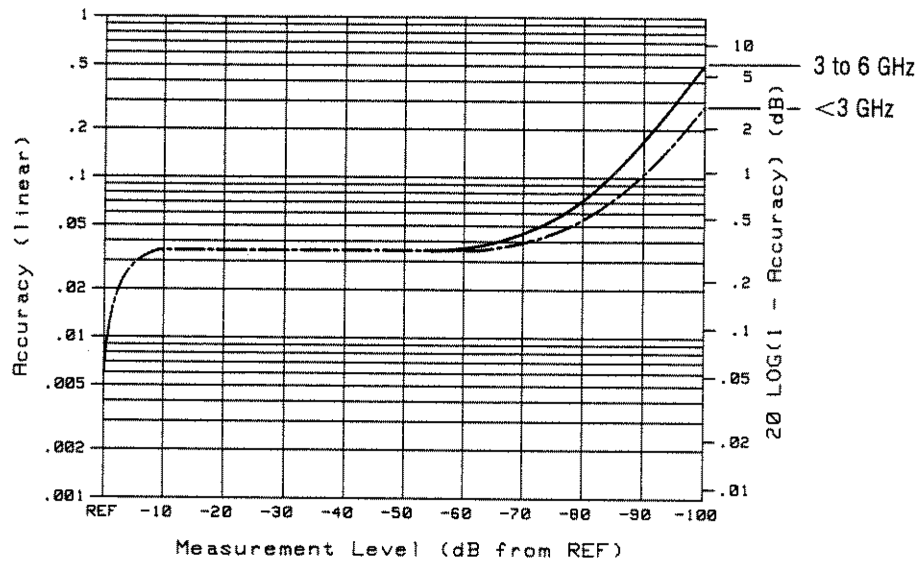
Assume R channel power level to be constant (Pcal = Pmeas)

Example: 0 dBm ≥ Pcal ≥ −60 dBm (magnitude)
0 dBm ≥ Pcal ≥ −50 dBm (phase)

0 dBm ≥ Pmeas ≥ −60 dBm (magnitude)	−60 dBm ≥ Pmeas ≥ −100 dBm (magnitude)
0 dBm ≥ Pmeas ≥ −50 dBm (phase)	−50 dBm ≥ Pmeas ≥ −100 dBm (phase)
Linacc = ABS (Lincal − Linmeas) + Residual	Linacc = Lincal + Linmeas − Residual

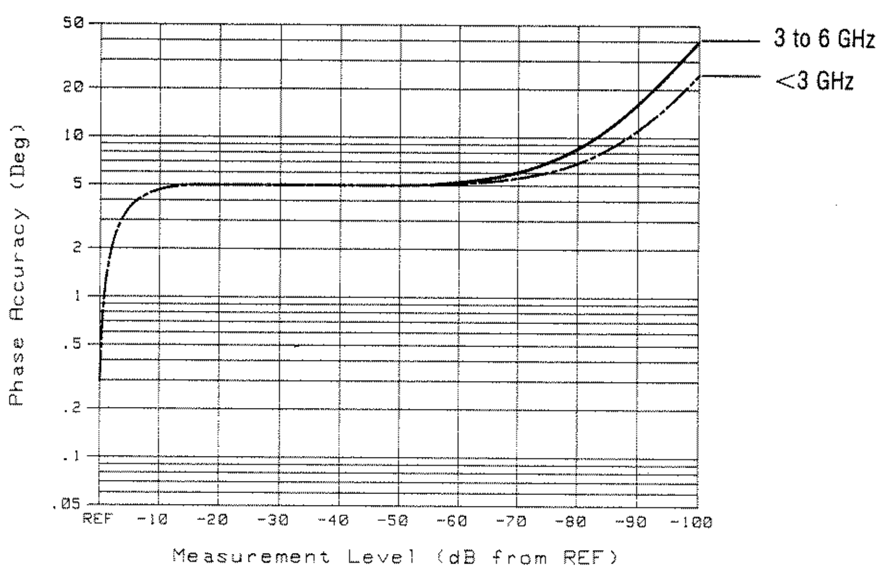
Residual Magnitude Dynamic Accuracy (linear) = 0.00577
Residual Phase Dynamic Accuracy = 0.331 degrees

Dynamic Accuracy Error Contribution



Assumption: Reference Power Level = 0 dBm

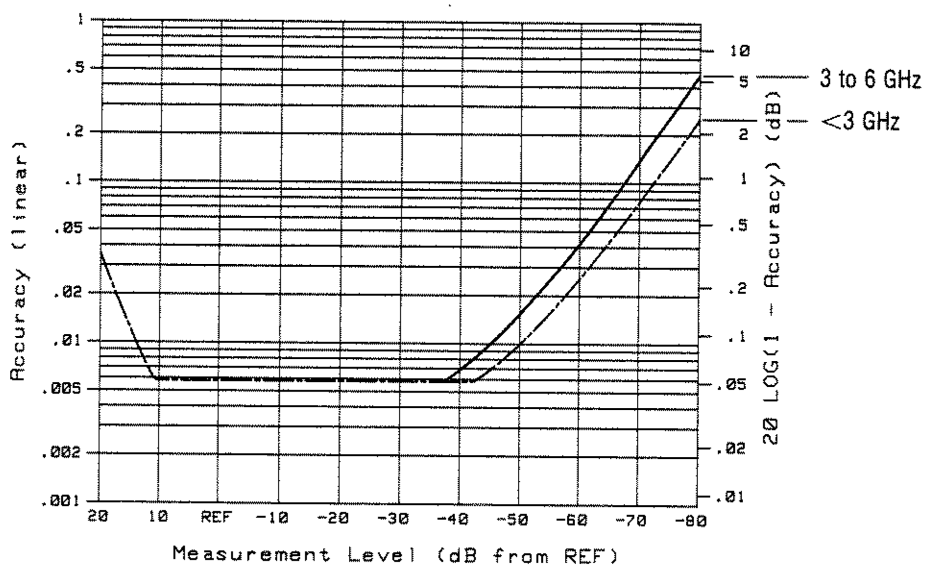
Figure A-4. Worst-Case Magnitude Dynamic Accuracy Error



Assumption: Reference Power Level = 0 dBm

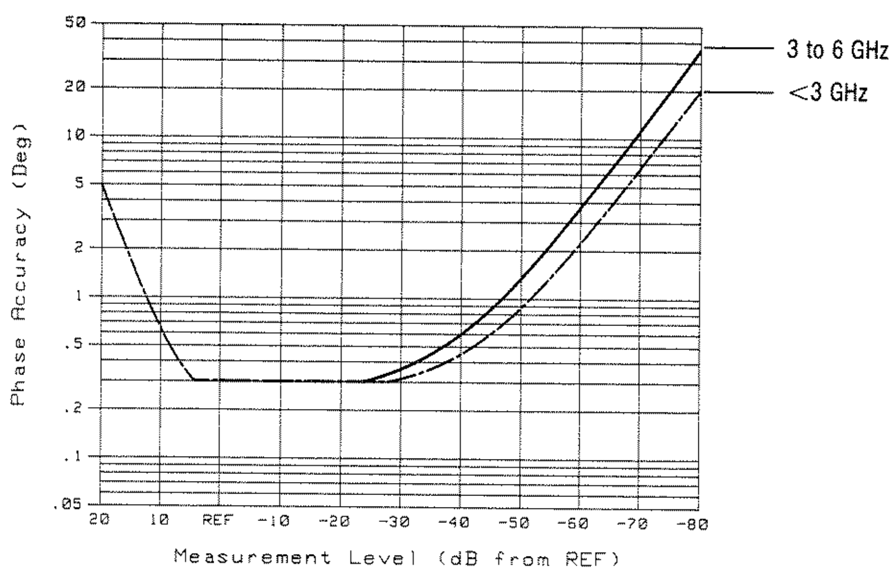
Figure A-5. Worst-Case Phase Dynamic Accuracy Error

Dynamic Accuracy Error Contribution



Assumption: Reference Power Level = −20 dBm

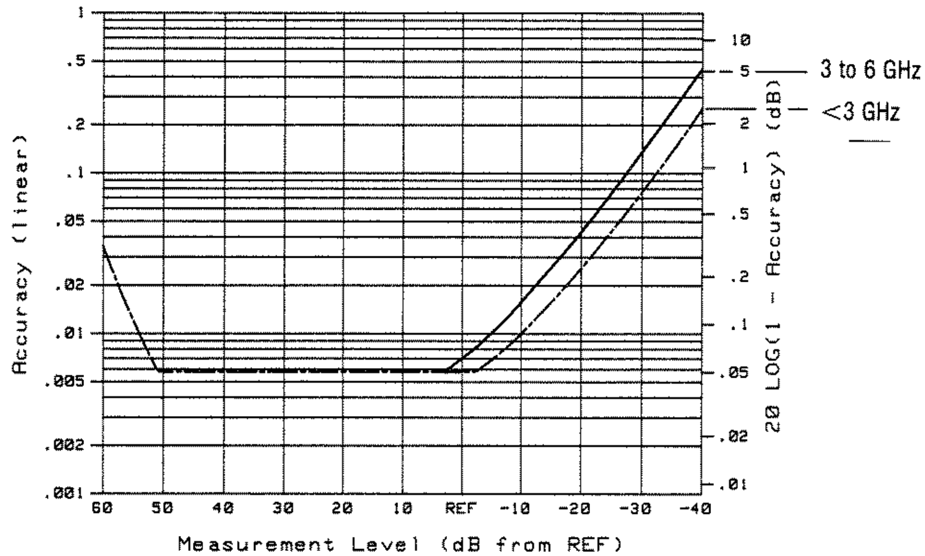
Figure A-6. Worst-Case Magnitude Dynamic Accuracy Error



Assumption: Reference Power Level = −20 dBm

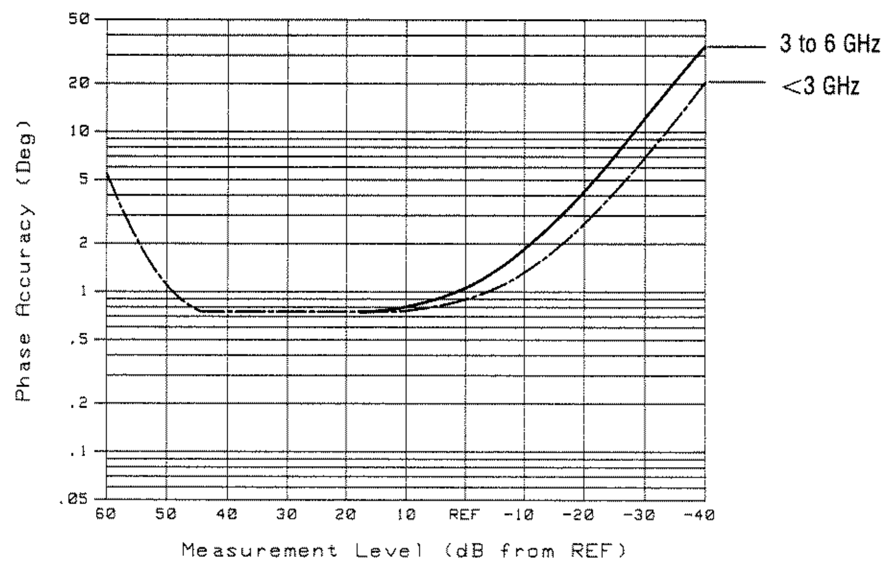
Figure A-7. Worst-Case Phase Dynamic Accuracy Error

Dynamic Accuracy Error Contribution



Assumption: Reference Power Level = −60 dBm

Figure A-8. Worst-Case Magnitude Dynamic Accuracy Error



Assumption: Reference Power Level = −60 dBm

Figure A-9. Worst-Case Phase Dynamic Accuracy Error

Temperature Drift with S11 One-Port Calibration (up to 3 GHz)

Assumptions: Reference Power Level = −20 dBm
S21 = S12 = 0

ΔT = 0°C ————
ΔT = ±3°C ·········
ΔT = ±5°C — — — — —

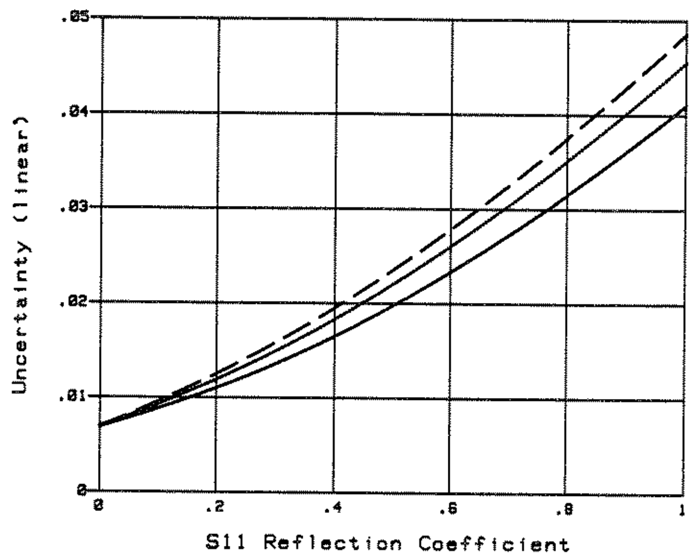


Figure A-10. Total Reflection Magnitude Uncertainty

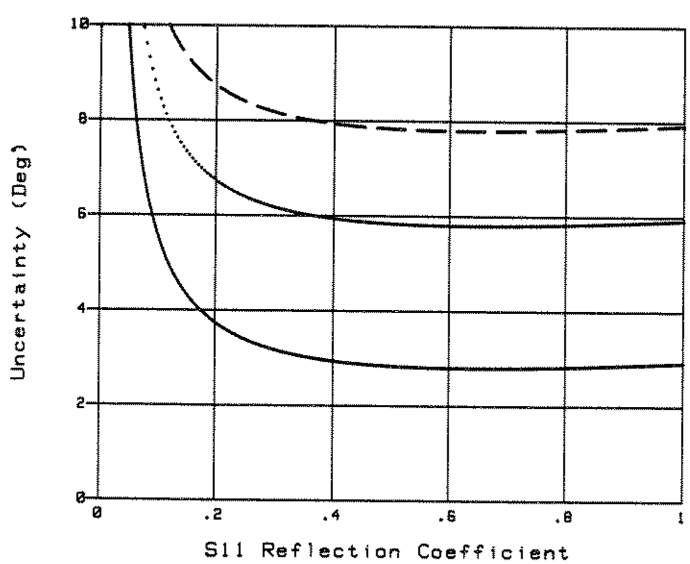


Figure A-11. Total Reflection Phase Uncertainty

Temperature Drift with Full Two-Port Calibration (up to 3 GHz)

Assumptions: Reference Power Level = −10 dBm
S11 − S22 = 0

ΔT = 0°C ————
ΔT = ±3°C ·········
ΔT = ±5°C — — — — —

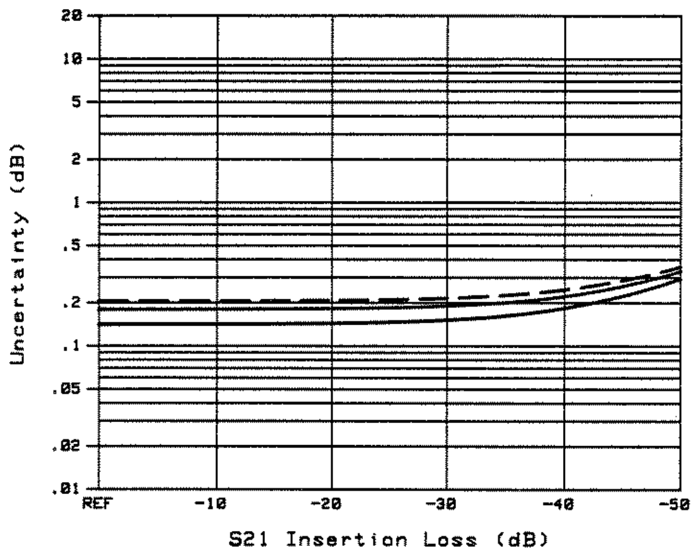


Figure A-12. Total Transmission Magnitude Uncertainty

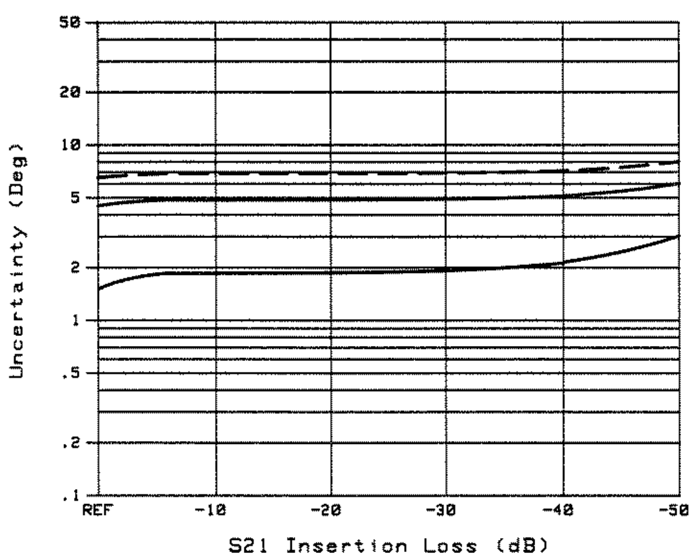


Figure A-13. Total Transmission Phase Uncertainty

SYSTEM PERFORMANCE WITH DIFFERENT TEST SETS AND CONNECTOR TYPES

The tables in the following pages provide system specifications or typical system performance for analyzer systems using different test sets and different connector types. The values listed are for uncorrected measurements and for corrected measurements after accuracy enhancement.

Table	Connector	Test Set	Frequency Range
A-2	7 mm	HP 85046A, 85044A, 85047A	300 kHz to 3 GHz
A-3	7 mm	HP 85047A	3 GHz to 6 GHz
A-4	50 ohm type-N	HP 85046A, 85044A, 85047A	300 kHz to 3 GHz
A-5	50 ohm type-N	HP 85047A	3 GHz to 6 GHz
A-6	3.5 mm	HP 85046A, 85044A, 85047A	300 kHz to 3 GHz
A-7	3.5 mm	HP 85047A	3 GHz to 6 GHz
A-8	75 ohm type-N	HP 85046B, 85044B	300 kHz to 2 GHz

These tables provide specifications for analyzer 7 mm systems. Error correction was performed using precision devices from the HP 85031B 7 mm calibration kit. Data listed in the columns headed *Residuals After Accuracy Enhancement* was measured accurately at the factory with standards traceable to the National Bureau of Standards. These residuals can be verified only at the factory (USA). Aggregate system performance after accuracy enhancement can be verified using the HP 85029B 7 mm verification kit and the *System Verification* procedure in the *Service Manual*.

Tables A-4 through A-8 provide typical performance figures for other analyzer systems. These are not specifications, but are intended to provide information useful in applying the instrument by giving typical but non-warranted performance parameters. Error correction for these systems is performed using the compatible calibration kits.

NOTE: Tables A-2 through A-8 are generated with the analyzer in chop A and B sweep mode.

Table A-2. System Specifications for Devices with 7mm Connectors

HP 8702 with HP 85046A, 85044A, or 85047A Test Set, up to 3 GHz

Symbol	Error Terms	Uncorrected		Residual after Accuracy Enhancement [1, 2]							
				Response Only		Response and Isolation		One-Port		Full Two-Port [3]	
		dB	Linear	dB	Linear	dB	Linear	dB	Linear	dB	Linear
D	Directivity	−30	0.032	−30	0.032	−50 [4]	0.0032	−50	0.0032	−50	0.0032
M_s	Source Match [5]	−16 [6]	0.16	−16 [6]	0.16	−16	0.16	−40	0.01	−40	0.01
M_l	Load Match [5]	−16 [6, 7]	0.16 [7]	−16 [6, 7]	0.16 [7]	−16 [7]	0.16 [7]	—	—	−42	0.005
T_r	Reflection Tracking [5]	±1.5 [7]	+0.19 [7] −0.16 [7]	+1.5 [7] −1.8 [7]	0.19 [7]	+1.3 [7] −1.5 [7]	0.16 [7]	±0.05	0.006	±0.05	0.006
T_t	Transmission Tracking [5]	±1.5 [7, 8]	+0.19 [7] −0.16 [7]	±0.20 [7]	0.026 [7]	±0.20 [7]	0.026 [7]	—	—	±0.03	0.0035
C	Crosstalk	−90 [7]	0.000032 [7]	−90 [7]	0.000032	−100 [9]	0.00001	—	—	−100 [9]	0.00001
R_{r1}	Port 1 Reflection Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
R_{t1}	Port 1 Transmission Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
R_{r2}	Port 2 Reflection Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
R_{t2}	Port 2 Transmission Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
N_l	Low-Level Noise (Noise Floor)	−100 dBm									
N_h	High-Level Noise [10]	Magnitude: 0.004 dB or 0.00046 linear									
A_m, A_p	HP 8753B Magnitude and Phase Dynamic Accuracy Error	Refer to "Dynamic Accuracy" in this section									
S_{t1}	Port 1 Cable Transmission Phase Stability [11]	0.05 x f(GHz), degrees									
S_{r1}	Port 1 Cable Reflection Stability [11]	−70 dB or 0.00032 linear									
S_{t2}	Port 2 Cable Transmission Phase Stability [11]	0.05 x f(GHz), degrees									
S_{r2}	Port 2 Cable Reflection Stability [11]	−70 dB or 0.00032 linear									
T_{td}	Transmission Tracking Drift (Typical)	Magnitude: 0.0015 x Δ°C, linear Phase: [0.1 + 0.15 x f(GHz)] x Δ°C, degrees									
T_{rd}	Reflection Tracking Drift (Typical)	Magnitude: 0.0015 x Δ°C, linear Phase: [12] [0.1 + 0.15 x f(GHz)] x Δ°C, degrees									

1. Accuracy enhancement procedures are performed using HP 85031B 7 mm calibration kit. Environmental temperature is 25°C ±5°C at calibration: ±1°C from calibration temperature must be maintained for valid measurement calibration.
2. With IF bandwidth of 10 Hz.
3. One-path 2-port calibration with HP 85044A.
4. With impedance-matched load.
5. Includes effects of switch repeatability.
6. Applies over most of the frequency range. Refer to test set manual for detailed specifications.
7. Typical.
8. HP 85044A typically has a +6 dB offset.
9. Typically, crosstalk after accuracy enhancement is −110 dB.
10. High-level noise is the RMS of a continuous measurement of a short circuit or thru. Refer to the trace noise performance test.
11. Arrived at by bending HP 11857D cables out perpendicular to front panel and reconnecting. Stability is much better with less flexing.
12. Arrived at using HP 11857D cables and full 2-port calibration. Drift is much better without cables and with 1-port calibration. For this case, drift typically is [0.1 + 0.05 x f(GHz)] x Δ°C, degrees.

Table A-3. System Specifications for Devices with 7mm Connectors

HP 8702 with HP 85047A Test Set, 3 GHz to 6 GHz

Symbol	Error Terms	Uncorrected		Residual after Accuracy Enhancement [1, 2]							
				Response Only		Response and Isolation		One-Port		Full Two-Port	
		dB	Linear	dB	Linear	dB	Linear	dB	Linear	dB	Linear
D	Directivity	−25	0.06	−25	0.06	−44 [3]	0.006	−44	0.0032	−44	0.006
M_s	Source Match [4]	−14	0.20	−14	0.20	−14	0.20	−36	0.01	−36	0.016
M_l	Load Match [4]	−14 [5]	0.20 [5]	−14 [5]	0.20 [5]	−14 [5]	0.20 [5]	—	—	−42	0.008
T_r	Reflection Tracking [4]	+0.5 [5] −2.5 [5]	+0.06 [5] −0.25 [5]	+2.0 −2.6	0.26 [5]	+1.6 −1.9	0.20 [5]	±0.06	0.007	±0.06	0.007
T_t	Transmission Tracking [4]	+0.5 [5] −2.5 [5]	+0.06 [5] −0.25 [5]	±0.35 [5]	0.04 [5]	±0.35 [5]	0.04 [5]	—	—	±0.05	0.006
C	Crosstalk	−80 [5]	0.0001 [5]	−80 [5]	0.0001	−90 [6]	0.000032	—	—	−90 [6]	0.000032
R_{r1}	Port 1 Reflection Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
R_{t1}	Port 1 Transmission Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
R_{r2}	Port 2 Reflection Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
R_{t2}	Port 2 Transmission Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
N_l	Low-Level Noise (Noise Floor)	−95 dBm									
N_h	High-Level Noise [7]	Magnitude: 0.004 dB or 0.00046 linear									
A_m, A_p	HP 8753B Magnitude and Phase Dynamic Accuracy Error	Refer to "Dynamic Accuracy" in this section									
S_{t1}	Port 1 Cable Transmission Phase Stability [8]	0.05 x f(GHz), degrees									
S_{r1}	Port 1 Cable Reflection Stability [8]	−70 dB or 0.00032 linear									
S_{t2}	Port 2 Cable Transmission Phase Stability [8]	0.05 x f(GHz), degrees									
S_{r2}	Port 2 Cable Reflection Stability [8]	−70 dB or 0.00032 linear									
T_{td}	Transmission Tracking Drift (Typical)	Magnitude: 0.0015 x Δ°C, linear Phase: [0.1 + 0.15 x f(GHz)] x Δ°C, degrees									
T_{rd}	Reflection Tracking Drift (Typical)	Magnitude: 0.0015 x Δ°C, linear Phase: [9] [0.1 + 0.15 x f(GHz)] x Δ°C, degrees									

1. Accuracy enhancement procedures are performed using HP 85031B 7 mm calibration kit. Environmental temperature is 25°C ±5°C at calibration: ±1°C from calibration temperature must be maintained for valid measurement calibration.
2. With IF bandwidth of 10 Hz.
3. With impedance-matched load.
4. Includes effects of switch repeatability.
5. Typical.
6. Typically, crosstalk after accuracy enhancement is −100 dB.
7. High-level noise is the RMS of a continuous measurement of a short circuit or thru. Refer to trace noise performance test.
8. Arrived at by bending HP 11857D cables out perpendicular to front panel and reconnecting. Stability is much better with less flexing.
9. Arrived at using HP 11857D cables and full 2-port calibration. Drift is much better without cables and with 1-port calibration. For this case, drift typically is [0.1 + 0.05 x f(GHz)] x Δ°C, degrees.

Table A-4. Typical System Performance for Devices with 50 Ohm Type-N Connectors

HP 8702 with HP 85046A, 85044A, or 85047A Test Set up to 3 GHz

Symbol	Error Terms	Uncorrected		Typical Residual after Accuracy Enhancement [1, 2]							
				Response Only		Response and Isolation		One-Port		Full Two-Port [3]	
		dB	Linear	dB	Linear	dB	Linear	dB	Linear	dB	Linear
D	Directivity	−30	0.032	−30	0.032	−44 [4]	0.0063	−44	0.0063	−44	0.0063
M_s	Source Match [5]	−16 [6]	0.16	−16	0.16	−16	0.16	−35	0.018	−35	0.018
M_l	Load Match [5]	−16 [6]	0.16	−16 [6]	0.16	−16	0.16	—	—	−42	0.008
T_r	Reflection Tracking [5]	±1.5	+0.19 −0.16	+1.5 −1.8	0.19	+1.4 −1.6	0.17	±0.06	0.007	±0.06	0.007
T_t	Transmission Tracking [5]	±1.5 [7]	+0.19 −0.16	±0.20	0.026	±0.20	0.026	—	—	±0.05	0.006
C	Crosstalk	−90	0.000032	−90	0.000032	−100 [8]	0.00001	—	—	−100 [8]	0.00001
R_{r1}	Port 1 Reflection Connector Repeatability (Typical)	−65 dB or 0.00056 linear									
R_{t1}	Port 1 Transmission Connector Repeatability (Typical)	−65 dB or 0.00056 linear									
R_{r2}	Port 2 Reflection Connector Repeatability (Typical)	−65 dB or 0.00056 linear									
R_{t2}	Port 2 Transmission Connector Repeatability (Typical)	−65 dB or 0.00056 linear									
N_l	Low-Level Noise (Noise Floor)	−100 dBm									
N_h	High-Level Noise [9]	Magnitude: 0.004 dB or 0.00046 linear									
A_m, A_p	HP 8753B Magnitude and Phase Dynamic Accuracy Error	Refer to "Dynamic Accuracy" in this section									
S_{t1}	Port 1 Cable Transmission Phase Stability [10]	0.05 x f(GHz), degrees									
S_{r1}	Port 1 Cable Reflection Stability [10]	−70 dB or 0.00032 linear									
S_{t2}	Port 2 Cable Transmission Phase Stability [10]	0.05 x f(GHz), degrees									
S_{r2}	Port 2 Cable Reflection Stability [10]	−70 dB or 0.00032 linear									
T_{td}	Transmission Tracking Drift (Typical)	Magnitude: 0.0015 x Δ°C, linear Phase: [0.1 + 0.15 x f(GHz)] x Δ°C, degrees									
T_{rd}	Reflection Tracking Drift (Typical)	Magnitude: 0.0015 x Δ°C, linear Phase: [11] [0.1 + 0.15 x f(GHz)] x Δ°C, degrees									

1. Accuracy enhancement procedures are performed using HP 85032B 50Ω type-N calibration kit. Environmental temperature is 25°C ±5°C at calibration: ±1°C from calibration temperature must be maintained for valid measurement calibration.
2. With IF bandwidth of 10 Hz.
3. One-path 2-port calibration with HP 85044A.
4. With impedance-matched load.
5. Includes effects of switch repeatability.
6. Applies over most of the frequency range. Refer to test set manual for detailed specifications.
7. HP 85044A typically has a +6 dB offset.
8. Typically, crosstalk after accuracy enhancement is −110 dB.
9. High-level noise is the RMS of a continuous measurement of a short circuit or thru. Refer to the trace noise performance test.
10. Arrived at by bending HP 11857D cables out perpendicular to front panel and reconnecting. Stability is much better with less flexing.
11. Arrived at using HP 11857D cables and full 2-port calibration. Drift is much better without cables and with 1-port calibration. For this case, drift typically is [0.1 + 0.05 x f(GHz)] x Δ°C, degrees.

Table A-5. Typical System Performance for Devices with 50 Ohm Type-N Connectors

HP 8702 with HP 85047A Test Set, 3 GHz to 6 GHz

Symbol	Error Terms	Uncorrected		Typical Residual after Accuracy Enhancement [1, 2]							
				Response Only		Response and Isolation		One-Port		Full Two-Port	
		dB	Linear	dB	Linear	dB	Linear	dB	Linear	dB	Linear
D	Directivity	−25	0.06	−25	0.06	−40 [3]	0.01	−40	0.01	−40	0.01
M_s	Source Match [4]	−14	0.20	−14	0.20	−14	0.20	−32	0.025	−32	0.025
M_l	Load Match [4]	−14	0.20	−14	0.20	−14	0.20	—	—	−38	0.013
T_r	Reflection Tracking [4]	+0.5 −2.5	+0.06 −0.25	+2.0 −2.6	0.26	+1.7 −2.0	0.21	±0.12	0.014	±0.12	0.014
T_t	Transmission Tracking [4]	+0.5 −2.5	+0.06 −0.25	±0.35	0.04	±0.35	0.04	—	—	±0.06	0.007
C	Crosstalk	−80	0.0001	−80	0.0001	−90 [5]	0.000032	—	—	−90 [5]	0.000032
R_{r1}	Port 1 Reflection Connector Repeatability (Typical)	−65 dB or 0.00056 linear									
R_{t1}	Port 1 Transmission Connector Repeatability (Typical)	−65 dB or 0.00056 linear									
R_{r2}	Port 2 Reflection Connector Repeatability (Typical)	−65 dB or 0.00056 linear									
R_{t2}	Port 2 Transmission Connector Repeatability (Typical)	−65 dB or 0.00056 linear									
N_l	Low-Level Noise (Noise Floor)	−95 dBm									
N_h	High-Level Noise [6]	Magnitude: 0.004 dB or 0.00046 linear									
A_m, A_p	HP 8753B Magnitude and Phase Dynamic Accuracy Error	Refer to "Dynamic Accuracy" in this section									
S_{t1}	Port 1 Cable Transmission Phase Stability [7]	0.05 x f(GHz), degrees									
S_{r1}	Port 1 Cable Reflection Stability [7]	−70 dB or 0.00032 linear									
S_{t2}	Port 2 Cable Transmission Phase Stability [7]	0.05 x f(GHz), degrees									
S_{r2}	Port 2 Cable Reflection Stability [7]	−70 dB or 0.00032 linear									
T_{td}	Transmission Tracking Drift (Typical)	Magnitude: 0.0015 x Δ°C, linear Phase: [0.1 + 0.15 x f(GHz)] x Δ°C, degrees									
T_{rd}	Reflection Tracking Drift (Typical)	Magnitude: 0.0015 x Δ°C, linear Phase: [8] [0.1 + 0.15 x f(GHz)] x Δ°C, degrees									

1. Accuracy enhancement procedures are performed using HP 85032B 50Ω type-N calibration kit. Environmental temperature is 25°C ±5°C at calibration: ±1°C from calibration temperature must be maintained for valid measurement calibration.
2. With IF bandwidth of 10 Hz.
3. With impedance-matched load.
4. Includes effects of switch repeatability.
5. Typically, crosstalk after accuracy enhancement is −100 dB.
6. High-level noise is the RMS of a continuous measurement of a short circuit or thru. Refer to trace noise performance test.
7. Arrived at by bending HP 11857D cables out perpendicular to front panel and reconnecting. Stability is much better with less flexing.
8. Arrived at using HP 11857D cables and full 2-port calibration. Drift is much better without cables and with 1-port calibration. For this case, drift typically is [0.1 + 0.05 x f(GHz)] x Δ°C, degrees.

Table A-6. Typical System Performance for Devices with 3.5 mm Connectors

HP 8702 with HP 85046A, 85044A, or 85047A Test Set up to 3 GHz

Symbol	Error Terms	Uncorrected		Typical Residual after Accuracy Enhancement [1, 2]							
				Response Only		Response and Isolation		One-Port		Full Two-Port [3]	
		dB	Linear	dB	Linear	dB	Linear	dB	Linear	dB	Linear
D	Directivity	−30	0.032	−30	0.032	−40 [4]	0.01	−40	0.01	−40	0.01
M_s	Source Match [5]	−16 [6]	0.16	−16 [6]	0.16	−16	0.16	−36	0.015	−36	0.015
M_l	Load Match [5]	−16 [6]	0.16	−16 [6]	0.16	−16	0.16	—	—	−38	0.012
T_r	Reflection Tracking [5]	±1.5	+0.19 −0.16	+1.51 −1.83	0.19	+1.3 −1.6	0.17	±0.14	0.016	±0.14	0.016
T_t	Transmission Tracking [5]	±1.5 [7]	+0.19 −0.16	±0.2	0.026	±0.20	0.026	—	—	±0.05	0.006
C	Crosstalk	−90	0.000032	−90	0.000032	−100 [8]	0.00001	—	—	−100 [8]	0.00001
R_{r1}	Port 1 Reflection Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
R_{t1}	Port 1 Transmission Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
R_{r2}	Port 2 Reflection Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
R_{t2}	Port 2 Transmission Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
N_l	Low-Level Noise (Noise Floor)	−100 dBm									
N_h	High-Level Noise [9]	Magnitude: 0.004 dB or 0.00046 linear									
A_m, A_p	HP 8753B Magnitude and Phase Dynamic Accuracy Error	Refer to "Dynamic Accuracy" in this section									
S_{t1}	Port 1 Cable Transmission Phase Stability [10]	0.05 x f(GHz), degrees									
S_{r1}	Port 1 Cable Reflection Stability [10]	−70 dB or 0.00032 linear									
S_{t2}	Port 2 Cable Transmission Phase Stability [10]	0.05 x f(GHz), degrees									
S_{r2}	Port 2 Cable Reflection Stability [10]	−70 dB or 0.00032 linear									
T_{td}	Transmission Tracking Drift (Typical)	Magnitude: 0.0015 x Δ°C linear Phase: [0.1 + 0.15 x f(GHz)] x Δ°C, degrees									
T_{rd}	Reflection Tracking Drift (Typical)	Magnitude: 0.0015 x Δ°C linear Phase: [11] [0.1 + 0.15 x f(GHz)] x Δ°C, degrees									

1. Accuracy enhancement procedures are performed using HP 85033C 3.5 mm calibration kit. Environmental temperature is 25°C ±5°C at calibration: ±1°C from calibration temperature must be maintained for valid measurement calibration.
2. With IF bandwidth of 10 Hz.
3. One-path 2-port calibration with HP 85044A.
4. With impedance-matched load.
5. Includes effects of switch repeatability.
6. Applies over most of the frequency range. Refer to test set manual for detailed specifications.
7. HP 85044A typically has a +6 dB offset.
8. Typically, crosstalk after accuracy enhancement is −110 dB.
9. High-level noise is the RMS of a continuous measurement of a short circuit or thru. Refer to the trace noise performance test.
10. Arrived at by bending HP 11857D cables out perpendicular to front panel and reconnecting. Stability is much better with less flexing.
11. Arrived at using HP 11857D cables and full 2-port calibration. Drift is much better without cables and with 1-port calibration. For this case, drift typically is [0.1 + 0.05 x f(GHz)] x Δ°C, degrees.

Table A-7. Typical System Performance for Devices with 3.5 mm Connectors

HP 8702 with HP 85047A Test Set, 3 GHz to 6 GHz

Symbol	Error Terms	Uncorrected		Typical Residual after Accuracy Enhancement [1, 2]							
				Response Only		Response and Isolation		One-Port		Full Two-Port	
		dB	Linear	dB	Linear	dB	Linear	dB	Linear	dB	Linear
D	Directivity	−25	0.06	−25	0.06	−35	0.018	−35	0.018	−35	0.018
M_s	Source Match [4]	−14	0.20	−14	0.20	−14	0.20	−30	0.032	−30	0.032
M_l	Load Match [4]	−14	0.20	−14	0.20	−14	0.20	—	—	−32	0.025
T_r	Reflection Tracking [4]	+0.5 −2.5	+0.06 −0.25	+2.0 −2.6	0.26	+1.7 −2.0	0.21	±0.12	0.016	±0.12	0.014
T_t	Transmission Tracking [4]	+0.5 −2.5	+0.06 −0.25	±0.35	0.04	±0.35	0.04	—	—	±0.1	0.012
C	Crosstalk	−80	0.0001	−80	0.0001	−90 [5]	0.000032	—	—	−90 [5]	0.000032
R_{r1}	Port 1 Reflection Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
R_{t1}	Port 1 Transmission Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
R_{r2}	Port 2 Reflection Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
R_{t2}	Port 2 Transmission Connector Repeatability (Typical)	−70 dB or 0.00032 linear									
N_l	Low-Level Noise (Noise Floor)	−95 dBm									
N_h	High-Level Noise [6]	Magnitude: 0.004 dB or 0.00046 linear									
A_m, A_p	HP 8753B Magnitude and Phase Dynamic Accuracy Error	Refer to "Dynamic Accuracy" in this section									
S_{t1}	Port 1 Cable Transmission Phase Stability [7]	0.05 x f(GHz), degrees									
S_{r1}	Port 1 Cable Reflection Stability [7]	−70 dB or 0.00032 linear									
S_{t2}	Port 2 Cable Transmission Phase Stability [7]	0.05 x f(GHz), degrees									
S_{r2}	Port 2 Cable Reflection Stability [7]	−70 dB or 0.00032 linear									
T_{td}	Transmission Tracking Drift (Typical)	Magnitude: 0.0015 x Δ°C linear Phase: [0.1 + 0.15 x f(GHz)] x Δ°C, degrees									
T_{rd}	Reflection Tracking Drift (Typical)	Magnitude: 0.0015 x Δ°C linear Phase: [8] [0.1 + 0.15 x f(GHz)] x Δ°C, degrees									

1. Accuracy enhancement procedures are performed using HP 85033C 3.5 mm calibration kit. Environmental temperature is 25°C ±5°C at calibration: ±1°C from calibration temperature must be maintained for valid measurement calibration.
2. With IF bandwidth of 10 Hz.
3. With impedance-matched load.
4. Includes effects of switch repeatability.
5. Typically, crosstalk after accuracy enhancement is −100 dB.
6. High-level noise is the RMS of a continuous measurement of a short circuit or thru. Refer to trace noise performance test.
7. Arrived at by bending HP 11857D cables out perpendicular to front panel and reconnecting. Stability is much better with less flexing.
8. Arrived at using HP 11857D cables and full 2-port calibration. Drift is much better without cables and with 1-port calibration. For this case, drift typically is [0.1 + 0.05 x f(GHz)] x Δ°C, degrees.

Table A-8. Typical System Performance for Devices with 75 Ohm Type-N Connectors

HP 8702 with HP 85046B or 85044B Test Set

Symbol	Error Terms	Uncorrected		Typical Residual after Accuracy Enhancement [1, 2]							
				Response Only		Response and Isolation		One-Port		Full Two-Port [3]	
		dB	Linear	dB	Linear	dB	Linear	dB	Linear	dB	Linear
D	Directivity	−30	0.032	−30	0.032	−44 [4]	0.0063	−44	0.0063	−44	0.0063
M_s	Source Match [5]	−16 [6]	0.16	−16 [6]	0.16	−16	0.16	−35	0.018	−35	0.018
M_l	Load Match [5]	−16 [6]	0.16	−16 [6]	0.16	−16	0.16	—	—	−42	0.008
T_r	Reflection Tracking [5]	±1.5	+0.19 −0.16	+1.5 −1.8	0.19	+1.3 −1.6	0.17	±0.06	0.007	±0.06	0.007
T_t	Transmission Tracking [5]	±1.5 [7]	+0.019 −0.16	±0.21	0.025	±0.20	0.026	—	—	±0.05	0.006
C	Crosstalk	−85	0.000063	−85	0.000063	−94 [8]	0.00002	—	—	−94 [8]	0.00002
R_{r1}	Port 1 Reflection Connector Repeatability (Typical)	−65 dB or 0.00056 linear									
R_{t1}	Port 1 Transmission Connector Repeatability (Typical)	−65 dB or 0.00056 linear									
R_{r2}	Port 2 Reflection Connector Repeatability (Typical)	−65 dB or 0.00056 linear									
R_{t2}	Port 2 Transmission Connector Repeatability (Typical)	−65 dB or 0.00056 linear									
N_l	Low-Level Noise (Noise Floor)	−94 dBm									
N_h	High-Level Noise [9]	Magnitude: 0.004 dB or 0.00046 linear									
A_m, A_p	HP 8753B Magnitude and Phase Dynamic Accuracy Error	Refer to "Dynamic Accuracy" in this section									
S_{t1}	Port 1 Cable Transmission Phase Stability [10]	0.05 x f(GHz), degrees									
S_{r1}	Port 1 Cable Reflection Stability [10]	−70 dB or 0.00032 linear									
S_{t2}	Port 2 Cable Transmission Phase Stability [10]	0.05 x f(GHz), degrees									
S_{r2}	Port 2 Cable Reflection Stability [10]	−70 dB or 0.00032 linear									
T_{td}	Transmission Tracking Drift (Typical)	Magnitude: 0.0015 x Δ°C linear Phase: [0.1 + 0.15 x f(GHz)] x Δ°C, degrees									
T_{rd}	Reflection Tracking Drift (Typical)	Magnitude: 0.0015 x Δ°C linear Phase: [11] [0.1 + 0.15 x f(GHz)] x Δ°C, degrees									

1. Accuracy enhancement procedures are performed using HP 85036B 75Ω type-N calibration kit. Environmental temperature is 25°C ±5°C at calibration: ±1°C from calibration temperature must be maintained for valid measurement calibration.
2. With IF bandwidth of 10 Hz.
3. One-path 2-port calibration with HP 85044B.
4. With impedance-matched load.
5. Includes effects of switch repeatability.
6. Applies over most of the frequency range. Refer to test set manual for detailed specifications.
7. HP 85044B typically has a +6 dB offset.
8. Typically, crosstalk after accuracy enhancement is −104 dB.
9. High-level noise is the RMS of a continuous measurement of a short circuit or thru. Refer to the trace noise performance test.
10. Arrived at by bending HP 11857B cables out perpendicular to front panel and reconnecting. Stability is much better with less flexing.
11. Arrived at using HP 11857B cables and full 2-port calibration. Drift is much better without cables and with 1-port calibration. For this case, drift typically is [0.1 + 0.05 x f(GHz)] x Δ°C, degrees.

DETERMINING EXPECTED SYSTEM PERFORMANCE

The uncertainty equations, dynamic accuracy calculations, and tables of system performance values provided in the preceding pages can be used to calculate the expected system performance. The following pages explain how to determine the residual errors of a particular system and combine them to obtain total error-corrected residual uncertainty values, using worksheets provided. The uncertainty graphs at the beginning of this section are examples of the results that can be calculated using this information.

Procedures

Table A-9 is a worksheet used to calculate the residual uncertainty in reflection measurements. Table A-10 is a worksheet for residual uncertainty in transmission measurements. Determine the linear values of the residual error terms and the nominal linear S-parameter data of the device under test as described below and enter these values in the worksheets. Then use the instructions and equations in the worksheets to combine the residual errors for total system uncertainty performance. The resulting total measurement uncertainty values have a confidence factor of 99.9%.

S-Parameter Values. Convert the S-parameters of the test device to their absolute linear terms.

Noise Floor. Refer to the *Receiver Noise Level Performance Test* in the *Service Manual* to determine the actual noise floor performance of your measurement setup.

Crosstalk. Refer to the *Input Crosstalk Performance Test.* Connect an impedance-matched load to each of the test ports and measure S21 or S12 after calibration. Turn on the marker statistics function and measure the mean value of the trace. Use the mean value plus one standard deviation as the residual crosstalk value of your system.

Dynamic Accuracy. Determine the absolute linear magnitude dynamic accuracy as described under *Dynamic Accuracy* in this chapter.

Other Error Terms. Refer to Tables A-2 through A-8, depending on the test set and connector type in your system. Find the absolute linear magnitude of the remaining error terms.

Combining Error Terms. Combine the above terms using the reflection or transmission uncertainty equations in the worksheets.

Table A-9. Reflection Measurement Uncertainty Worksheet

In the columns below, enter the appropriate values for each term. Frequency: ________

Error Term	Symbol	dB Value	Linear Value
Directivity	D	________	________
Reflection tracking	T_r	________	________
Source match	M_s	________	________
Load match	M_l	________	________
Dynamic accuracy			
Magnitude	A_m	________	________
Phase	A_p	________	________
S11	S11	________	________
S21	S21	________	________
S12	S12	________	________
Noise floor	N_l	________	________
High level noise	N_h	________	________
Connector reflection repeatability	R_r	________	________
Connector transmission repeatability	R_t	________	________
Magnitude drift due to temperature	T_{rd} (mag)	________	________
Phase drift due to temperature	T_{rd} (phase)	________	________
Cable reflection stability	S_r	________	________
Cable transmission stability	S_t	________	________

Magnitude

Combine Systematic Errors. In the space provided, enter the appropriate linear values from the list of errors. Then combine these errors to obtain the total sum of systematic errors.

$(D+S_{r1})$	(___ + ___) = ______ [k]
$(T_r)\times(S11)$	(___)×(___) = ______ [l]
$(S_{r1}+M_{sw}+M_s)\times(S11)\times(S11)$	(___ + ___ + ___)×(___)×(___) = ______ [m]
$M_l\times S21\times S12$	(___ × ___ × ___) = ______ [n]
$(A_m)\times(S11)$	(___)×(___) = ______ [o]
Total: k + l + m + n + o	___ + ___ + ___ + ___ = ______ [S]

Combine Random Errors. In the space provided, enter the appropriate linear values from the list of errors. Then combine these errors in an RSS fashion to obtain a total sum of the random errors.

$3\times(N_l)$	3 ×(___) = ______ [w]
$3\times(N_h)\times(S11)$	3×(___)×(___) = ______ [x]
$R_{r1}+2\times(R_{t1})\times(S11)+(R_{r1})\times(S11)\times(S11)$	___ +2×(___)×(___)+(___)×(___)×(___) = ______ [y]
$(R_{r2})\times(S21)\times(S12)$	(___)×(___)×(___) = ______ [z]
$\sqrt{w^2+x^2+y^2+z^2}$	$\sqrt{\_\_\times\_\_+\_\_\times\_\_+\_\_\times\_\_+\_\_\times\_\_}$ = ______ [R]
$V_r=S+R$	___ + ___ = ______
$E_{rm}(\text{linear})=V_r+T_{rd}(\text{mag})\times S11$	___ +(___ × ___) = ______
$E_{rm}(\log)=20\ \text{Log}\ (1\pm E_{rm}/S11)$	20 Log (1 ± ___ / ___) = ______ dB

Phase

$E_{rp}=\text{Arcsin}[(V_r-A_m\times S11)/S11]+T_{rd}(\text{phase})+2\times S_{t1}+A_p$	Arcsin[(___ − ___ × ___)/ ___]+ ___ +2× ___ + ___ = ± ______ degrees

Table A-10. Transmission Measurement Uncertainity Worksheet

In the columns below, enter the appropriate values for each term. Frequency: ______

Error Term	Symbol	dB Value	Linear Value
Crosstalk	C	____	____
Transmission tracking	T_t	____	____
Source match	M_s	____	____
Load match	M_l	____	____
Dynamic accuracy		____	____
Magnitude	A_m	____	____
Phase	A_p	____	____
S11	S11	____	____
S21	S21	____	____
S12	S12	____	____
S22	S22	____	____
Noise floor	N_l	____	____
High level noise	N_h	____	____
Connector reflection repeatability	R_r	____	____
Connector transmission repeatability	R_t	____	____
Magnitude drift due to temperature	T_{rd} (mag)	____	____
Phase drift due to temperature	T_{rd} (phase)	____	____
Cable reflection stability	S_r	____	____
Cable transmission stability	S_t	____	____

Magnitude

Combine Systematic Errors. In the space provided, enter the appropriate linear values from the list of errors. Then combine these errors to obtain the total sum of systematic errors.

C	= ____ [k]
$(T_t)\times(S21)$	(__)×(__) = ____ [l]
$(S_{r1}+M_{sw}+M_s)\times(S11)\times(S21)$	(__+__+__)×(__)×(__) = ____ [m]
$(S_{r2}+M_{sw}+M_l)\times(S21)\times(S22)$	(__+__+__)×(__)×(__) = ____ [n]
$(A_m)\times(S21)$	(__)×(__) = ____ [o]
k + l + m + n + o	__+__+__+__+__ = ____ [S]

Combine Random Errors. In the space provided, enter the appropriate linear values from the list of errors. Then combine these errors in an RSS fashion to obtain a total sum of the random errors.

$3\times(N_l)$	3 ×(__) = ____ [w]
$3\times(N_h)\times(S21)$	3×(__)×(__) = ____ [x]
$(R_{t1})\times(S21)+(R_{r1})\times(S11)\times(S21)$	(__)×(__)+(__)×(__)×(__) = ____ [y]
$(R_{t2})\times(S21)+(R_{r2}\times S22\times S21)$	(__)×(__)+(__)×(__)×(__) = ____ [z]
$\sqrt{w^2+x^2+y^2+z^2}$	$\sqrt{\_\_\times\_\_+\_\_\times\_\_+\_\_\times\_\_+\_\_\times\_\_}$ = ____ [R]
$V_t=S+R$	__+__ = ____
$E_{tm}(\text{linear})=V_t+T_{td}(\text{mag})\times S21$	__+(__×__) = ____
$E_{tm}(\log)=20\ \text{Log}\ (1\pm E_{tm}/S21)$	20 Log (1 ± __/__) = ____ dB

Phase

$E_{tp}=\text{Arcsin}[(V_t-A_m\times S21)/S21]+T_{td}(\text{phase})+S_{t1}+S_{t2}+A_p$ Arcsin[(__ − __ × __)/__]+__+__+__+__ = ± ____ degrees

NOTE

Before You Start:

Proper connector care and connection techniques are critical for accurate, repeatable measurements.

Refer to the calibration kit documentation for connector care infromation. Prior to making connections to the network analyzer, carefully review the information about inspecting, cleaning, and gaging connectors.

Having good connector care and connection techniques extends the life of these devices. In addition, you obtain the most accurate measurements.

This type of information is typically located in Chapter 3 of the calibration kit manuals.

For additional connector care instruction, contact your local Hewlett–Packard Sales and Service Office about course numbers HP 85050A+24A and HP 85050A+24D.

See the reverse side of this notice for quick reference tips about connector care.

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Principles of Microwave Connector Care—Quick Reference Card

Handling and Storage

Do	Do Not
• Keep connectors clean • Extend sleeve or connector nut • Use plastic end caps during storage	• Touch mating–plane surfaces • Set connectors contact–end down

Visual Inspection

Do	Do Not
• Inspect all connectors carefully before every connection • Look for metal particles, scratches, and dents	• Use a damaged connector—–ever

Connector Cleaning

Do	Do Not
• Try compressed air first • Use isopropyl alcohol • Clean connector threads	• Use any abrasives • Get liquid into plastic support beads

Gaging Connectors

Do	Do Not
• Clean and zero the gage before use • Use the correct gage type • Use correct end of calibration block • Gage all connectors before first use	• Use an out–of–spec connector

Making Connections

Do	Do Not
• Align connectors carefully • Make preliminary connection lightly • Turn only the connector nut • Use a torque wrench for final connect	• Apply bending force to connection • Overighten preliminary connection • Twist or screw any connection • Tighten past torque wrench "break" point

Connector Care

For

RF & Microwave Coaxial Connectors

HEWLETT PACKARD

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Introduction

Note

For a summary of general recommendations for coaxial connectors, see the Hewlett-Packard application note number 326, *Principles of Microwave Connector Care*, available from your local Hewlett-Packard representative.

Connectors

Table 1-1. Connectors

Connector	Usable Frequency Range (GHz)
Precision 7 mm	DC to 20
Type-N	DC to 18
PSC-N	DC to 18
SMA	DC to 23
Precision 3.5 mm	DC to 34
PSC-3.5 mm	DC to 34
Precision 2.4 mm	DC to 50
PSC-2.4 mm	DC to 50

Precision 7 mm Connectors

Precision 7 mm connectors are air dielectric devices. A plastic bead inside the connector body supports the center conductor. These connectors provide the lowest SWR and the most repeatable connections of any 7 mm connector type. Durable, they are used in test and measurement applications that require a high degree of accuracy and repeatability.

Generally made of beryllium copper alloy plated with gold, these sexless connectors have replaceable inserts (collets). The collets provide contact between the center conductors, making spring-loaded butt contact when you tighten the connection.

Occasionally small mechanical differences that exist between precision 7 mm connectors made by different manufacturers can cause connection problems. Always mechanically inspect connectors to ensure they meet specifications.

Type-N Connectors

Relatively inexpensive, general-purpose, sexed connectors, these rugged 7 mm connectors perform well in severe operating environments and in applications that require repeated connections.

Standard Type-N

These connectors, made of brass, have slotted female connectors.

PSC-N

As with other precision slotless female connectors, a PSC-N connector has no slots. This stainless steel connector provides better electrical performance, repeatability of connection, and durability than a standard type-N connector.

75Ω Type-N

A 75Ω type-N connector has a smaller center conductor, male contact pin, and female contact hole than a 50Ω connector. Because of this, if you mate a male 50Ω connector with a female 75Ω connector you either break the female contact fingers apart or permanently spread them.

3.5 mm Connectors

SMA

Sexed connectors, SMA (subminiature, type A) connectors have a solid plastic dielectric that separates the center and outer conductors. These are non-precision, low-cost 3.5 mm connectors.

These connectors do not work well in applications that require repeated connections; they wear out quickly. They work best as one-time-only connectors, or in applications that require very few reconnections.

Precision 3.5 mm

Precision 3.5 mm connectors are sexed, air-dielectric connectors; air provides the insulating dielectric between the center and outer conductors. A plastic bead inside the connector body supports the center conductor.

Precision 3.5 mm connectors will mate with SMA connectors, and (unlike SMA connectors) are durable enough for repeated connections.

PSC-3.5 mm

As with other precision slotless female connectors, a PSC-3.5 mm connector has no slots. This connector provides better electrical performance, repeatability of connection, and durability than a standard precision 3.5 mm connector.

NMD-3.5 mm

Hewlett-Packard uses these rugged 3.5 mm connectors on cables, test port connectors, and on special adapters. These connectors have larger-than-standard coupling threads, providing an exceptionally strong coupling mechanism for measurement applications.

Female NMD connectors (used on the test set end of adapters and cables) *cannot* be connected to standard male 3.5 mm connectors.

Male NMD connectors (used on test sets (as test ports), and on the DUT end of adapters and cables) have *both* larger threads (to connect to female NMD connectors) *and* standard threads (to directly couple to a device under test).

2.4 mm Connectors

The Three Grades

Production Grade

Also defined as "economy," this grade applies to connectors used in components, cabling and microstrip applications. This grade, usually used internal to instruments, has a slotted female center conductor.

Instrument Grade

These connectors, principally intended for use in precision test and measurement equipment, maintain high performance during many connect-disconnect cycles. This grade, usually used external to instruments, has a slotted female center conductor.

Metrology Grade

These connectors, used on measurement standards that require a high degree of dimensional precision, have direct traceability to national measurement standards through well-defined mechanical dimensions. This grade of connector has a slottless female center conductor.

Precision 2.4 mm

These sexed connectors have air as the dielectric; air provides the insulating dielectric between the center and outer conductors. A plastic bead inside the connector body supports the center conductor.

PSC-2.4 mm

As with other precision slotless female connectors, a PSC-2.4 mm connector has no slots. This connector provides better electrical performance, repeatability of connection, and durability than a standard precision 2.4 mm connector.

NMD-2.4 mm

Hewlett-Packard uses these rugged 2.4 mm connectors on cables, test port connectors, and on special adapters. These connectors have larger-than-standard coupling threads, providing an exceptionally strong coupling mechanism for measurement applications.

Female NMD connectors (used on the test set end of adapters and cables) *cannot* be connected to standard male 2.4 mm connectors.

Male NMD connectors (used on test sets (as test ports), and on the DUT end of adapters and cables) have *both* larger threads (to connect to female NMD connectors), *and* standard threads (to directly couple to a device under test).

Electrostatic Discharge

Protect against electrostatic discharge before cleaning or inspecting a connector attached to a static-sensitive circuit. Static electricity builds up on the body, on calibration components, and on devices under test, and can easily damage sensitive circuits when discharged by contact with a center conductor. A static discharge too small to feel can cause permanent damage.

Static-Safe Work Station

Figure 1-1 illustrates a static-safe station using two types of ESD protection that you can use either together or separately (see Appendix B for ordering information):

- A conductive table mat and wrist-strap combination.
- A conductive floor mat and heel-strap combination.

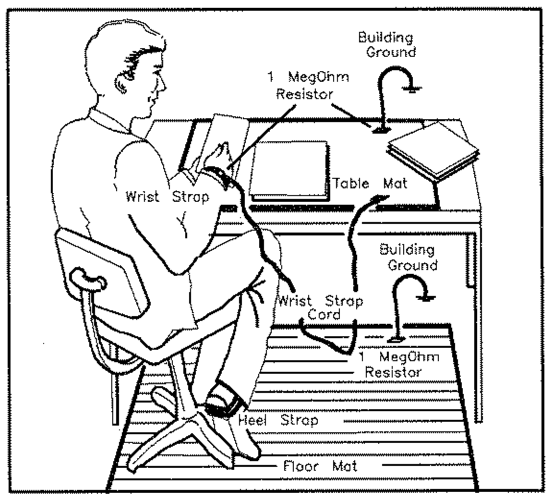


Figure 1-1. Example of a Static-Safe Work Station

Static-Safe Practices

- Before cleaning, inspecting, or making a connection to a static-sensitive device or test port, ground yourself at a grounded device as far as possible from the test port.
- Discharge static electricity from a device before connecting it:

  Touch the device briefly (through a resistor of at least 2 MΩ) to either the outer shell of the test port, or another exposed ground. This discharges static electricity and protects test equipment circuitry.

Handling

Handle connectors carefully, and inspect them before use:

1. Keep connectors clean.
2. Do not touch mating plane surfaces. Natural skin oils and microscopic particles of dirt (easily transferred to a connector interface) are difficult to remove.
3. Do not set connectors contact-end down on a hard surface. You can damage the plating and the mating plane surfaces if the interface comes in contact with a hard surface.

Storing

When not using a device, store it in a way that gives it maximum protection:

1. Before storing a connector, extend the sleeve or connector nut. This protects the mating surfaces.
2. When you are not using a connector, use plastic end caps over the mating plane surfaces to keep them clean and protected.
3. Never store connectors loosely in a box, or drawer (the most common cause of connector damage during storage).

   Store calibration devices, verification devices, and test fixtures in a foam-lined storage case.
4. Store cables in the same shape they have when you use them; do not either straighten a cable or flex it more tightly. Even flexible cables last longer if you flex them as little as possible.

2

Visually Inspecting & Cleaning Connectors

Because of the small size of some coaxial connectors, and because of very precise mechanical tolerances (on the order of a few hundreds of microinches in some cases), minor defects, damage, and dirt can significantly degrade repeatability and accuracy. In addition, a precision connector mating surface may have gold plating, making it susceptible to mechanical damage because of the softness of the metal. A dirty or damaged connector can destroy any connector mated to it.

Caution Never use a damaged connector.

Note You do not need to magnify a connector when you inspect it. In fact, inspecting a connector under magnification can mislead you. Defects and damage that you cannot see without magnification generally have no effect on the electrical or mechanical performance of a coaxial connector.

Visual Inspection Procedure

1. Check for Obvious Defects

Before each connection, visually inspect all connectors. If necessary, clean the connectors each time you make a connection.

Look for obvious defects or damage (badly worn plating, deformed threads, or bent, broken, or misaligned center conductors). Connector nuts should move smoothly and have no burrs, loose metal particles, or rough spots.

Discard or send for repair any connector with an obvious defect.

2. Check for Particles, Scratches, and Dents

Metal particles from the connectors threads can adhere to the mating plane surfaces when you disconnect a connector.

Check for:

- Flat contact between the connectors at all points on their mating plane surfaces.
- Deep scratches (see "Scratches").
- Dents (see "Dents").
- Dirt, or metal particles (see "Metal and Metal By-Product Particles").
- Bent or rounded edges on the center and outer conductor mating plane surfaces.
- Any sign of damage due to excessive or uneven wear or misalignment.

If a connector shows deep scratches or dents, particles clinging to the mating plane surfaces, or uneven wear, clean it and inspect it again.

Determine the cause and extent of the damage before using a connector that has dents or scratches deep enough to displace metal on the connector mating plane surface.

Scratches

On a gold plated connector, a scratch that goes through the gold plating to the metal underneath can cause trouble. The exposed bimetal surface accelerates corrosion and needs cleaning more often than an all-gold surface. Inspect the scratch carefully under magnification to see if it left a high spot of pushed-up metal on the mating plane surface. If so, do not use the connector; it will damage any connector you mate to it.

If you remove all metal displaced by a scratch, or it wears away (so that no high spots remain), the connector may work. Full, flat circular contact between the mating plane surfaces may not happen, but the connection may prove satisfactory for most purposes.

Light Burnishing

Light burnishing (light scratches or shallow circular marks distributed uniformly over the mating plane surface) does not affect electrical or mechanical performance. Burnishing (caused by the normal, slight rotation of the mating planes against one another as you make a connection) and other small defects and cosmetic imperfections are normal.

Deep Scratches

Individual, hard particles (metal particles or burrs left from machining) cause deep scratches. These particles slide across the mating plane surface and displace metal.

Concentric Scratches

Deep scratches running concentrically (like the groove in a phonograph record) generally indicate that one or both of the connector mating plane surfaces were not perfectly clean, or that one of the connectors has a burr or high spot on its surface.

Long scratches running concentrically generally indicate too much rotation on a connector, or a connector nut that seizes during connection.

Scratches Across the Mating Plane

Most often, deep scratches that run across the mating plane surface result from rough handling during connection, disconnection, or storage.

Dents

You usually find dents on the outside edge of a mating plane surface. Under magnification a dent looks like a small crater or valley, with metal pushed outward and upward from the point of impact.

Careless handling or assembly of a connector during manufacture can cause dents, but more often a dent results from dirt or metallic particles pressing into the mating plane surface. This can happen during connection or during storage. Even a work surface that looks clean can have particles on it large enough and hard enough to, with pressure, dent or scratch a connector. Sudden, sharp, metal-to-metal impact, (such as when a connector drops or has another metal part bumped against it) can also cause dents.

A connectors that has a dent anywhere on the mating plane surfaces will not make perfect contact, and the raised edges will dent any connector mated to it. Except for very slight damage, replace a dented connector.

Particles

Metal and Metal By-product Particles

Metal and metal by-product particles on connector mating plane surfaces often come from the connector nut threads. These very hard particles can scratch or dent a connector's gold plating. If you find these particles, completely clean the connector (see "Cleaning Connectors") then reinspect it.

Other Types of Particles

You can also contaminate a connector with particle by setting the connector contact-end down on a work surface (even though the surface looks clean) or by touching the mating plane surfaces. You can usually remove particles left behind after cleaning by blowing the connector dry with clean, compressed air.

Cleaning Connectors

For a long, reliable connector life, carefully clean all connectors. Appendix B lists part numbers for recommended cleaning supplies.

Periodically Check for Alcohol Contamination

1. Let a few drops of alcohol evaporate on a clean glass plate or microscope slide.
2. Examine the glass in reflected light. It should be perfectly clean and free of residue. If not, do not use the alcohol from that container.

To keep your main supply of alcohol free from contamination, pour a small amount into a clean container and use that as your cleaning supply. Safely discard any remaining alcohol in the small container and clean the container.

Cautions

If you must use a solvent, use *only* isopropyl alcohol.

Use the least amount of alcohol possible, and avoid wetting any plastic parts in the connectors.

On 3.5 mm (and smaller) connectors, openings are very small, interior surfaces difficult to reach, and generally a plastic dielectric bead supports the center conductor only at the inner end. You can easily bend or break the center conductor.

General Cleaning Procedure

Warnings

Always use protective eyewear when using compressed air or nitrogen.

This procedure assumes you have taken the necessary ESD precautions.

1. Use Compressed Air or Nitrogen

1. Use compressed air (or nitrogen) to loosen particles on the connector mating plane surfaces. Clean air cannot damage a connector, or leave particles or residues behind.

   You can use any source of clean, dry, low-pressure compressed air or nitrogen that has an effective oil-vapor filter and liquid condensation trap placed just before the outlet hose. Ground the hose nozzle to prevent electrostatic discharge, and set the air pressure to a very low velocity (<60 psi). High-velocity air can cause electrostatic effects when directed into a connector.

2. Clean the Connector Threads

For dirt or stubborn contaminants on a connector that you cannot remove with compressed air or nitrogen, try a foam swab or lint-free cleaning cloth moistened with isopropyl alcohol:

a. Apply a small amount of isopropyl alcohol to a foam swab or a lint-free cleaning cloth.

b. Clean the connector threads.

c. Let the alcohol evaporate, then blow the threads dry with a gentle stream of clean, low-pressure compressed air or nitrogen.

3. Clean the Mating Plane Surfaces

a. Apply a small amount of isopropyl alcohol to a new swab and clean the mating plane surfaces.

   If the connector has a center conductor, use very short horizontal or vertical strokes (across the connector), and the least pressure possible, especially when cleaning a female connector (to avoid snagging the cleaning swab on the center conductor contact fingers). An illuminated magnifying glass helps.

4. Clean the Interior Surfaces

In the following steps, use the proper size toothpick. The wooden handle of a foam swab, for example, is too large even if it fits into the connector.

- For 3.5 mm connectors, use a toothpick with a diameter no greater than 1.7 mm (0.070 in).
- For precision 2.4 mm connectors, use a toothpick with a diameter no greater than 1.2 mm (0.047 in).

Caution

Never use metal in place of a toothpick, it will scratch the plated surfaces.

a. Cut off the sharp tip off a round, wooden toothpick.

b. Wrap the trimmed toothpick with a single layer of lint-free cleaning cloth (see Figure 2-1).

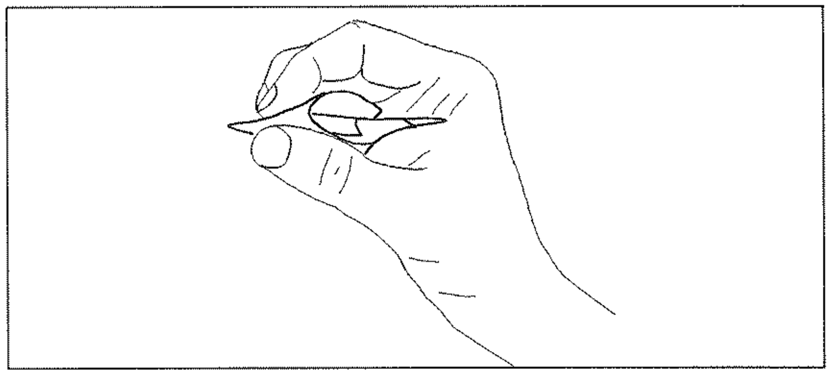


Figure 2-1.
Trimmed Toothpick Wrapped in a Single Layer of Lint-Free Cleaning Cloth

c. Moisten the cloth with a small amount of isopropyl alcohol and carefully insert it into the connector. To clearly see the areas you wish to clean, use an illuminated magnifying glass or microscope.

5. Dry the Connector

After cleaning, blow the connector dry with a gentle stream of clean compressed air or nitrogen. Always completely dry a connector before you reassemble or use it.

6. Reinspect

Inspect the connector again under a magnifying glass to be sure that no particles or residues remain.

Precision 7 mm

Center Collet in Place

You do not have to remove the center conductor collet to clean a precision 7 mm connector. With the center collet in place:

1. Put a lint-free cleaning cloth flat on a table.
2. Put a drop or two of isopropyl alcohol in the center of the cloth.
3. Retract the connector sleeve threads to expose the connector interface.
4. Gently press the contact end of the connector into the moistened cloth and turn the connector (Figure 2-2). The cloth scrubs away dirt on the connector interface without damaging the connector.
5. Blow the connector dry with a gentle stream of compressed air or nitrogen.
6. When not in use, keep the cloth in a plastic bag or box so that it does not collect dust or dirt.

Fixed Connectors

Use the following procedure to clean a fixed connector:

1. Fold a lint-free cleaning cloth several times.
2. Moisten the cloth with isopropyl alcohol.
3. Press the moistened cloth against the connector interface and turn the cloth to clean the connector.
4. Blow the connector dry with a gentle stream of compressed air or nitrogen.

Center Collet Removed

Clean and inspect the interior surfaces any time you remove the center conductor collet. Use a wooden toothpick and list-free cleaning cloth, as described in the general cleaning procedure.

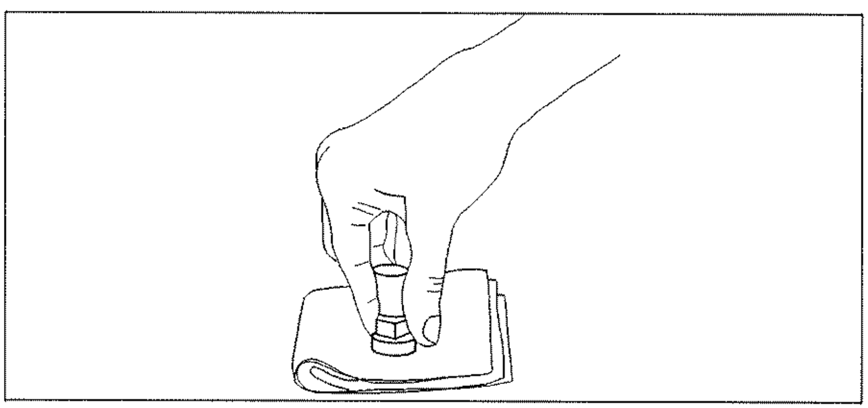


Figure 2-2.
Cleaning a 7 mm Connector with the Connector Collet in Place

SMA, Precision 3.5 mm, & Precision 2.4 mm

Because of their delicacy, small size, and intricate geometry, clean these connectors carefully. The center conductor contact pins, and especially the contact fingers on female connectors, can easily bend or break. In the precision connectors, a plastic dielectric bead supports the center conductor only at the inner end.

Use the general cleaning procedure.

3

Mechanically Inspecting & Connecting Connectors

Because coaxial connector mechanical tolerances can be very precise (on the order of a few hundreds of microinches), even a perfectly clean, unused connector can cause trouble if out of mechanical specification. Use a connector gage to mechanically inspect coaxial connectors.

When to Gage Coaxial Connectors

Gage a connector:

- Before you use it for the first time.
- If either visual inspection or electrical performance suggests that the connector interface may be out of specification (due to wear or damage, for example).
- If someone else uses the device.
- If you use the device on another system or piece of equipment.
- As a matter of routine: initially after every 100 connections, and after that as often as experience suggests.

Note

Gage 2.4 mm, 3.5 mm, and SMA connectors relatively more often than other connectors, because the center pins can pull out of specification during disconnection.

Connector Gages

Types

Each type of connector uses a different connector gage (Figure 3-1 shows a typical connector gage):

- There are push-on type gages and screw-on type gages.
- Sexed connectors use either two gages (one male and one female), or (in the case of type-N connectors) a single gage with male and female adapter bushings.
- Every connector gage requires a gage calibration block (to zero the gage).
- Connector gages for precision 7 mm connectors also require an aligning pin and pin wrench to measure the center conductor depth of beadless airlines with the centering pin removed.

Appendix B lists connector gage kits containing the gages recommended for coaxial connectors. Also, many calibration kits include connector gages.

Caution

Use the proper gage for your connector (see Appendix B). Some gages have a very strong gage plunger spring that, if used on the wrong connector, can push the center conductor back through the connector, damaging the device itself. Other gages, if used improperly, can compress the center conductor collet in precision 7 mm connectors during a measurement, giving an inaccurate reading when you measure the collet protrusion.

Accuracy

Because of connector gage measurement uncertainties (typically one small division on the dial) and variations in measurement technique from user to user, connector setback dimensions are difficult to measure.

For example, if you use a gage with 0.0001-inch small divisions on the dial to measure a connector that has an actual setback of 0.0005 inches, you can get a gage reading from 0.0004 to 0.0006 inches, depending on the gage (due strictly to gage measurement uncertainty). Note that other variables (such as cleaning and gage technique) can increase this range of readings. Before you decide a connector fails specification, do the following:

1. Carefully clean the connector, the connector gage, and the gage block again.
2. Zero the gage again.
3. Repeat the measurement.

   Dirt and contamination can be affected measurements in which differences of 0.0001 inch are significant.

4. After you measure the connector several times yourself, have another person measure the connector several times. This helps reduce uncertainties due to differences of technique and random variations in gage accuracy.
5. Keep records of the setback measurements for each device over time. Noticeable differences from one set of measurements to the next can indicate errors in measurement technique, or that a damaged connector needs replacing.

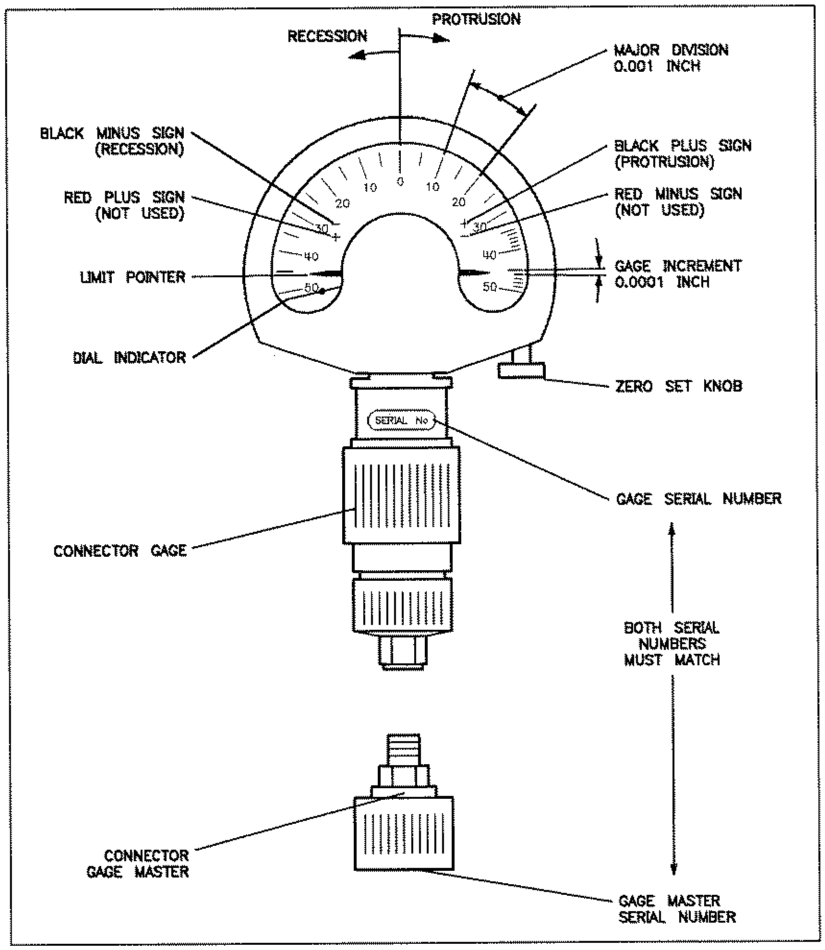


Figure 3-1. Typical Connector Gage

Using a Centering Bead

Use a centering bead to keep a sliding load or airline beadless center conductor centered as you connect it to a *gage*. Always remove the centering bead before you connect the device to anything other than a gage. If you leave the bead on, the device will fail its electrical specifications.

General Gaging Procedure

Caution

Before you gage a connector, consult the mechanical specifications provided with that connector or device.

Notes

Hold a connector gage by the gage barrel, below the dial indicator. This gives the best stability, and improves measurement accuracy (cradling the gage in your hand or holding it by the dial applies stresses to the gage plunger mechanism through the dial indicator housing).

When you measure a connector several times, use different orientations of the gage within the connector. Averaging several readings, each taken after a quarter-turn rotation of the gage, reduces measurement variations that result from the gage or the connector face not being exactly perpendicular to the center axis.

Because of the differences in the outer conductor of measured devices and the amount of pressure applied, screw on and press on type gages give slightly different readings.

1. Select the proper gage for your connector.
2. Inspect and clean the gage:
   a. Inspect the connector gage and the gage calibration block carefully, exactly as you inspected the connector itself.
   b. Clean or replace the gage and the gage calibration block if necessary.

      Dirt on either the gage or the gage calibration block makes gage measurements inaccurate, and can damage a connector.
3. Zero the gage:

   Push-on Type (see Figure 3-2):

   a. Hold the gage by the plunger barrel (not the dial housing or cap). This prevents gage reading errors caused by stresses to the gage plunger mechanism through the dial indicator housing.
      i. For male connectors, slip the protruding end of the calibration block into the circular bushing on the connector gage.
      ii. For precision 7 mm connectors, and female precision 3.5 mm connectors, use the flat end of the gage calibration block.
      iii. For female type-N connectors, use the recessed end of the gage calibration block.

b. Carefully bring the gage and gage block together. Apply only enough pressure to the gage and gage block to settle the dial indicator pointer at a reading.

c. Gently rock the two surfaces together, to make sure that they have come together flatly.

The gage pointer should line up exactly with the zero mark on the gage. If not, inspect and clean the gage and gage calibration block again and repeat this process. If the gage pointer still does not line up with the zero mark on the gage, loosen the dial lock screw and turn the graduated dial until the gage pointer exactly lines up with zero. Then re-tighten the lock screw.

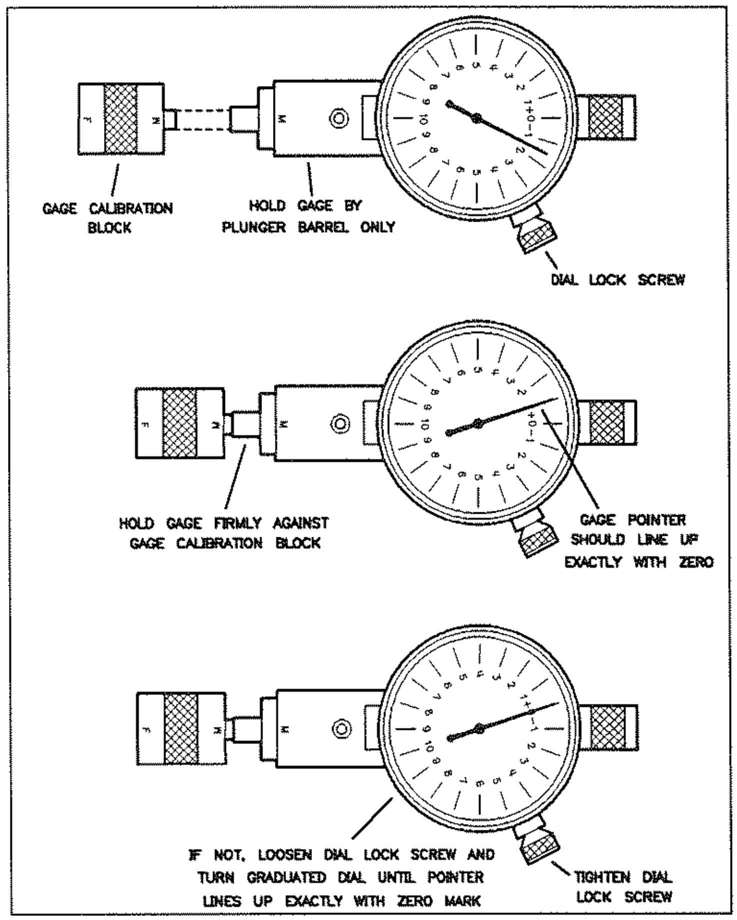


Figure 3-2. Zeroing a Push-on Connector Gage

Screw-on Type (see Figure 3-3):

a. Holding the gage by the plunger barrel, screw on the calibration device just until you meet resistance.

b. Use a torque wrench to tighten the connection.

c. As you watch the gage pointer, gently tap the calibration device .

   The gage pointer should line up exactly with the zero mark on the gage. If not, adjust the zero set knob until the gage pointer exactly lines up with zero.

Note

Check gages often to make sure that the zero setting has not changed. Generally, when the pointer on a recently zeroed gage does not line up exactly with the zero mark, the gage or calibration block needs cleaning. Clean both of these carefully and check the zero setting again.

4. Measure the connector.

   Measure the recession of the center conductor behind the outer conductor mating plane exactly the same way you zeroed the gage, but *do not* reset the graduated dial.

5. For the best accuracy, measure the connector several times (rotating the gage relative to the connector between each measurement), and take an average of the readings.

6. To monitor connector wear, record the readings for each connector over time.

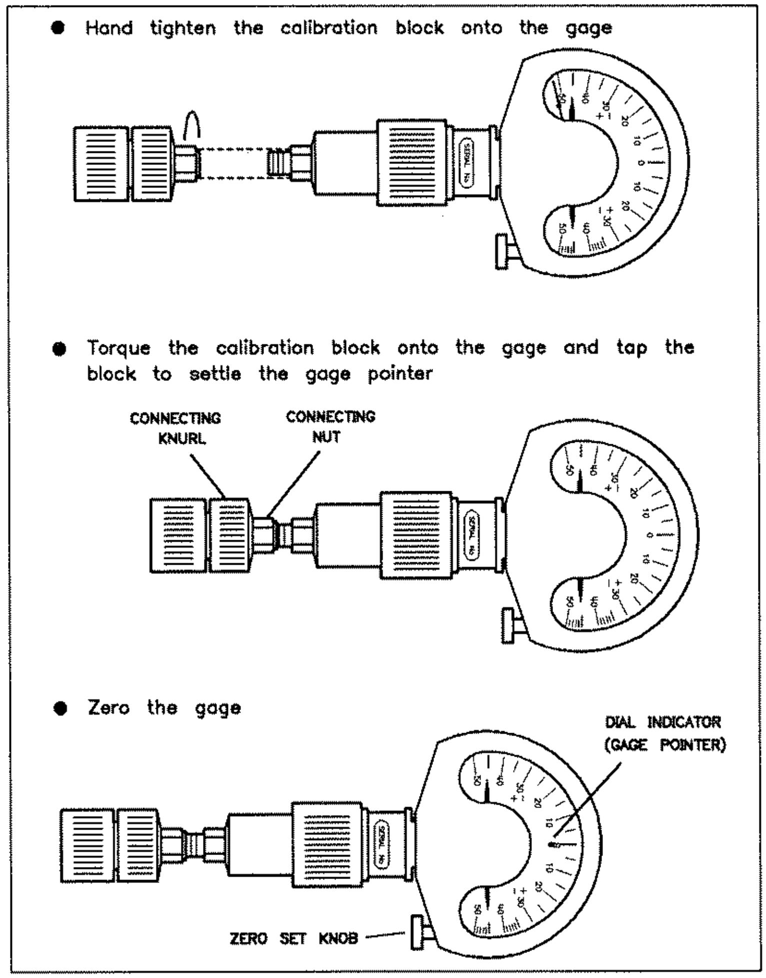


Figure 3-3. Zeroing a Screw-on Connector Gage

Precision 7 mm

In precision 7 mm connectors (Figure 3-4), replaceable inserts (collets) that make spring-loaded butt contact when you tighten the connection provide contact between the center conductors. The collets protrude slightly in front of the outer conductor mating plane when the connectors are apart. When the connection tightens, the collets compress into the same plane as the outer conductors.

Specifications

Two mechanical specifications are generally given for precision 7 mm connectors:

1. A minimum and maximum allowable protrusion of the center conductor collet in front of the outer conductor mating plane with the collet in place.
   a. Measure the collet protrusion.
   b. If attached, remove the aligning pin from the connector gage.
   c. Use the flat end of the gage calibration block.
2. The maximum recession of the center conductor behind the outer conductor mating plane with the center conductor collet removed.
   a. Measure the center conductor recession.
   b. The center conductor must not protrude beyond the outer conductor mating plane.
   c. For an airline, attach the aligning pin to the connector gage and use the recessed end of the gage calibration block.

   Also, the center conductor collet should immediately spring back if you compress it fully with a blunt plastic rod or with the rounded plastic handle of the collet removing tool.

Caution

With the center conductor collet removed, the center conductor may not protrude in front of the outer conductor mating plane, and sometimes must recede minimally. Consult the mechanical specifications provided with your connector or device.

Note

Before you gage a precision 7 mm connector, fully extend the sleeve. This creates a cylinder into which the gage fits, minimizing the danger of the gage slipping sideways and damaging the connector.

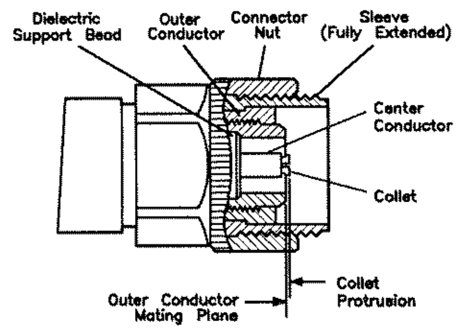


Figure 3-4. Precision 7 mm Connector Mechanical Specifications

Type-N

A type-N connector differs from other connector types in that its outer conductor mating plane is offset from the mating plane of the center conductor (Figure 3-5). The outer conductor sleeve in the male connector extends in front of the shoulder of the male contact pin. When you make a connection, this outer conductor sleeve fits into a recess in the female outer conductor behind the plane defined by the tip of the female contact fingers.

In a male type-N connector, the position of the shoulder of the male contact pin (not the position of the tip) defines the position of the center conductor. The male contact pin slides into the female contact fingers; the inside surfaces of the tip of the female contact fingers on the sides of the male contact pin provide electrical contact.

Specifications

Type-N connector critical mechanical specifications:

- A maximum protrusion of the female center conductor in front of the outer conductor mating plane.
- A minimum recession of the shoulder of the male contact pin behind the outer conductor mating plane (0.207 inches).
- A maximum recession of the shoulder of the male contact pin behind the outer conductor mating plane (0.210 inches).

In the Hewlett-Packard precision specification for type-N connectors, the male contact pin shoulder minimum allowable recession is 0.001 inches *less* than in the MIL-C-39012, Class II specification.

As type-N connectors wear, the protrusion of the female contact fingers generally increases, due to wear of the outer conductor mating plane inside the female connector. Check this periodically, because it decreases the total center conductor contact separation.

Cautions

Never use a type-N connector if the possibility of interference between the shoulder of the male contact pin and the tip of the female contact fingers exists; *do not* mate type-N connectors if, when you make the connection, the separation between the tip of the female contact fingers and the shoulder of the male contact pin could measure less than zero.

If you use both 75 and 50Ω type-N connectors, mark the 75Ω connectors so that you never accidentally mate them with 50Ω connectors. The center conductor, male contact pin, and female contact hole are smaller on 75Ω connectors.

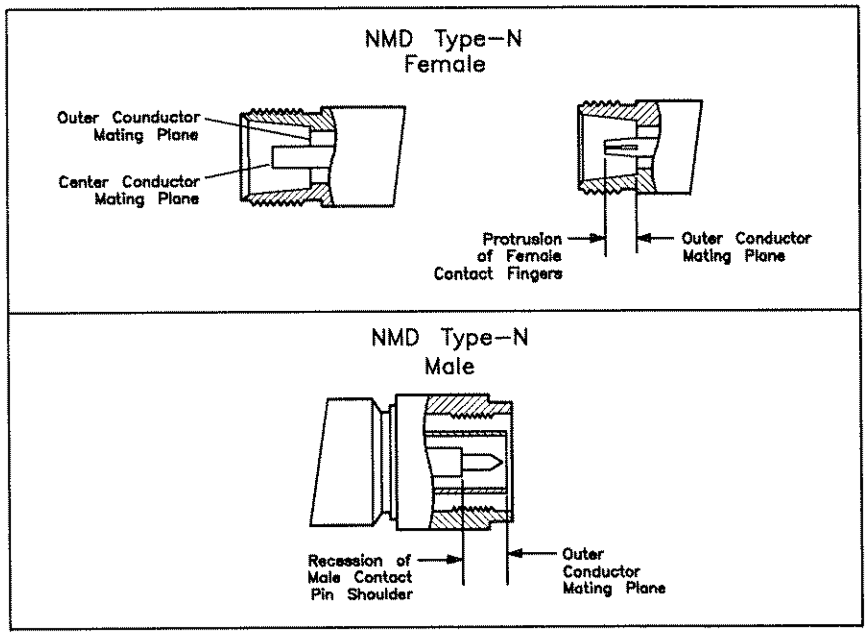


Figure 3-5. Type-N Connector Mechanical Specifications

Electrical Effects of Contact Separation

You may be able to use a type-N connector in an application where the total separation between the shoulder of the male contact pin and the tip of the female contact fingers exceeds the maximum implied by the mechanical specifications. Figure 3-6 shows the approximate effects of total contact separation on the reflection coefficient of standard (*not* PSC) type-N connections. At lower frequencies, the effects (even of fairly wide total contact separation) are small; at higher frequencies, contact separation becomes important.

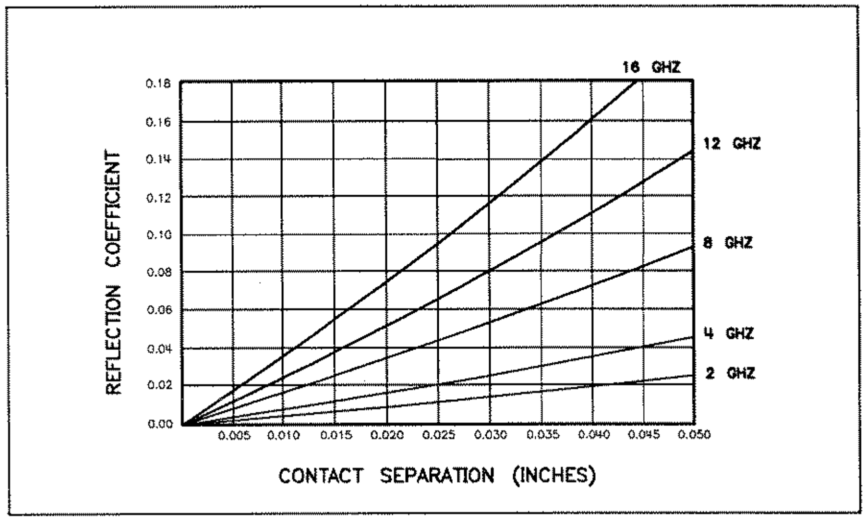


Figure 3-6.
The Approximate Effects of Contact Separation on the Reflection Coefficient of Type-N Connectors

Gaging Techniques

Male Type-N

1. Refer to Figure 3-7.
2. Attach the bushing for male connectors to the dial indicator assembly.
3. Slip the bushing over the gage plunger assembly and fasten it with the two Allen screws in the bushing.

   The male bushing has a flat outer end with a hole in it. Insert the gage plunger through the bushing so that with the bushing attached, the plunger protrudes from the bushing.
4. Using the recessed end of the gage calibration block, zero the gage as described in the general procedure at the beginning of this chapter.
5. Measure the connector:
   a. Carefully center and insert the gage into the male connector; the flat outer part of the gage bushing rests on the outer conductor (the male contact pin slips into the hole in the gage plunger for this purpose).
   b. Gently rock the connector gage within the connector to make sure the gage and the outer conductor mate flatly.
   c. When the gage pointer settles consistently at a reading, read the gage indicator dial.

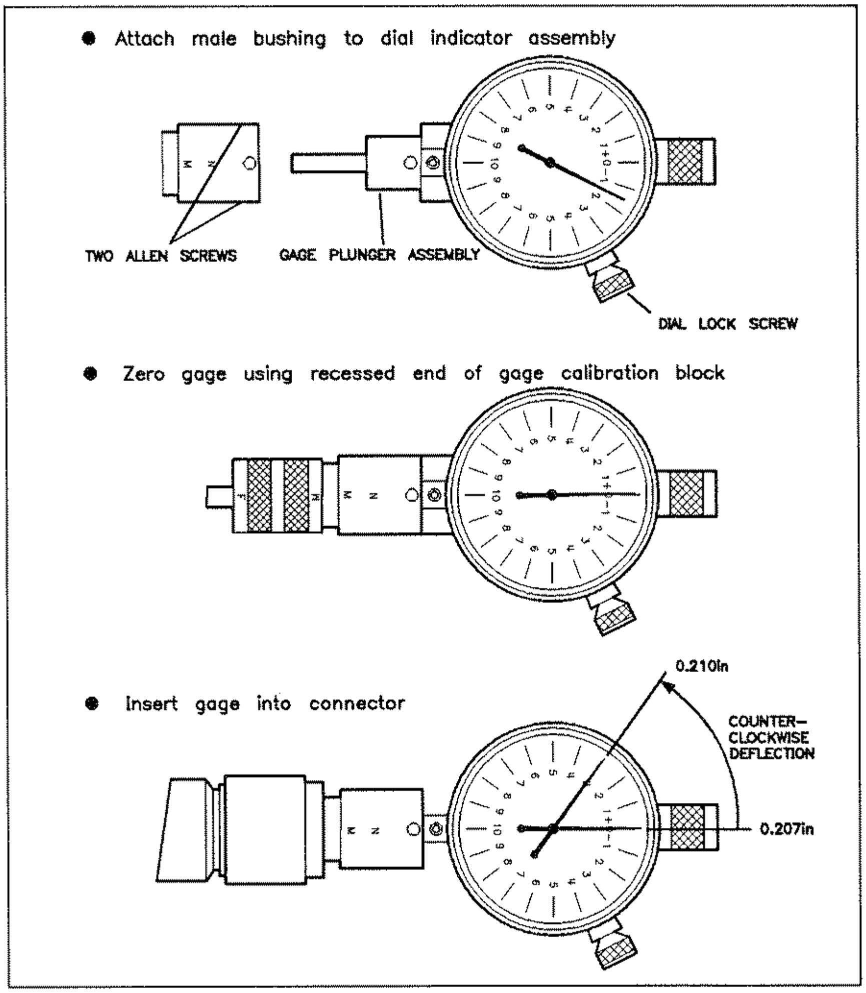


Figure 3-7. Gaging a Type-N Male Connector

Female Type-N

1. Refer to Figure 3-8.
2. Attach the bushing for female connectors to the dial indicator assembly. This bushing has a protruding circular sleeve.
3. Slip the bushing over the gage plunger assembly and fasten it with the two Allen screws in the bushing.
4. Insert the protruding end of the gage calibration block into the circular sleeve so it comes to rest on the gage plunger inside the female bushing.
5. Zero the gage as described in the general procedure at the beginning of this chapter.
6. Measure the connector:
   a. Carefully center and insert the gage into the female connector; the female contact fingers in the connector slip inside the protruding circular sleeve on the gage.

      The circular sleeve on the bushing should come to rest on the outer conductor mating plane inside the connector, behind the female contact fingers.

   b. Gently rock the connector gage within the connector to make sure the gage and the outer conductor are together flatly.
   c. When the gage pointer settles consistently at a reading, read the gage indicator dial.

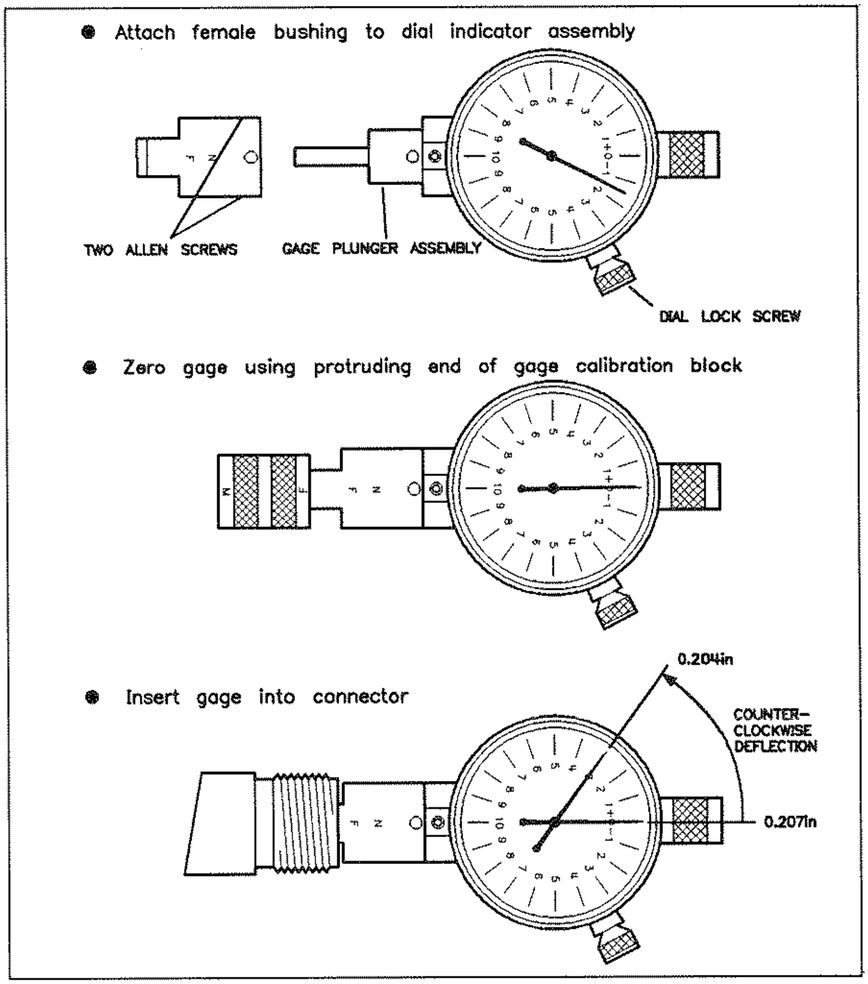


Figure 3-8.
Gaging a Type-N Female Connector Using a Push-on Type Gage

SMA

SMA connectors are sexed connectors. The male contact pin slides into the female contact fingers; the inside surfaces of the tip of the female contact fingers on the sides of the male contact pin provide electrical contact.

Specifications

- A maximum and minimum recession of the shoulder of the male contact pin.
- A maximum and minimum recession of the tip of the female center conductor behind the outer conductor mating plane.

Dielectric Protrusion

Some SMA connector specifications allow protrusion of the solid plastic dielectric in front of the outer conductor mating plane (as much as 0.003 inches). This does not harm an SMA connector mated to another SMA connector, because some compression of the dielectric can occur, but protruding dielectric can force the rigid center conductor of a precision 3.5 mm connector back through the connector itself, damaging both the connector and the device to which you attach it.

Out-of-Specification Male Pins

Some SMA connectors have insecurely held male contact pins, making them easy to pull out of specification (especially with tight female connector contact fingers). Also, some SMA male pins are not true pins, but the cut-off ends of the center conductor in semi-rigid coaxial cable. In this case, misalignment and burrs are not unusual.

Cautions

Neither the shoulder of the male contact pin nor of the tip of the female contact fingers may protrude in front of the outer conductor mating plane, and sometimes must *recede* minimally. Consult the mechanical specifications provided with your connector or device.

Never mate a precision 3.5 mm connector to an SMA connector in which the solid plastic dielectric protrudes in front of the outer conductor mating plane.

Inspect all male SMA connectors for misalignment or burrs on the male contact pin. Discard any that are damaged.

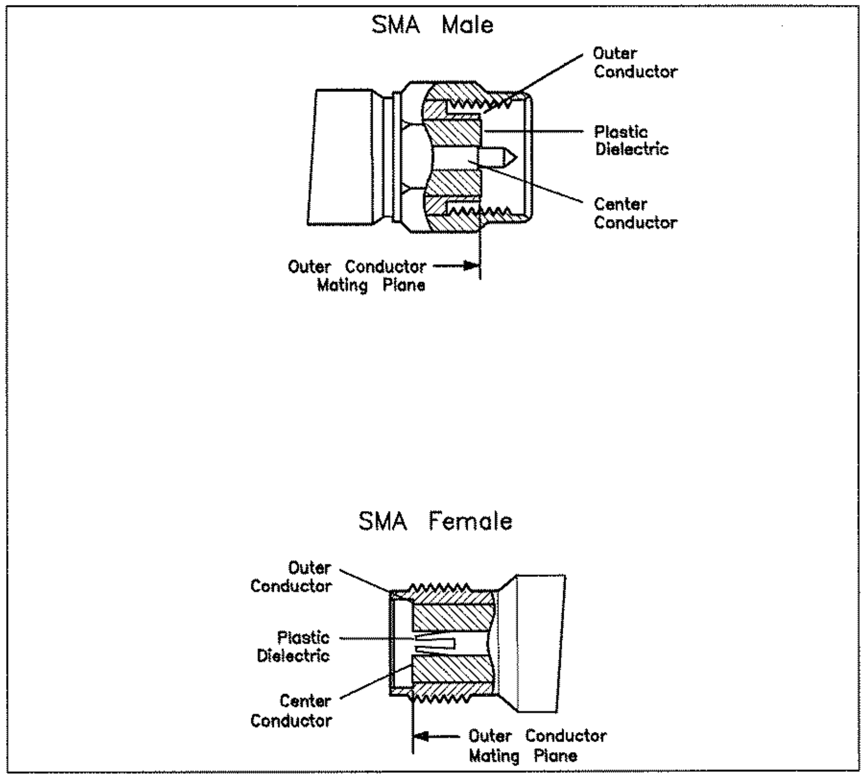


Figure 3-9. SMA Connector Mechanical Specifications

Gaging Techniques

Male SMA (Push-on Type Gage)

1. Refer to Figure 3-10. The male SMA connector gage (usually marked M) has a circular metal bushing surrounding the gage plunger.
2. Use the protruding end of the gage calibration block (also usually marked M).
3. Slip the calibration block into the outer bushing so that the bushing comes to rest on the outer, flat area of the calibration block. When you measure a connector, the gage outer bushing rests on the outer conductor mating plane inside the connector.
4. Zero the gage as described in the general procedure at the beginning of this chapter.
5. Measure the connector:
   a. Carefully center and insert the gage into the male connector; the flat outer part of the gage bushing rests on the outer conductor (the male contact pin slips into the hole in the gage plunger for this purpose).
   b. Gently rock the connector gage within the connector to make sure the gage and the outer conductor mate flatly.
   c. When the gage pointer settles consistently at a reading, read the gage indicator dial.

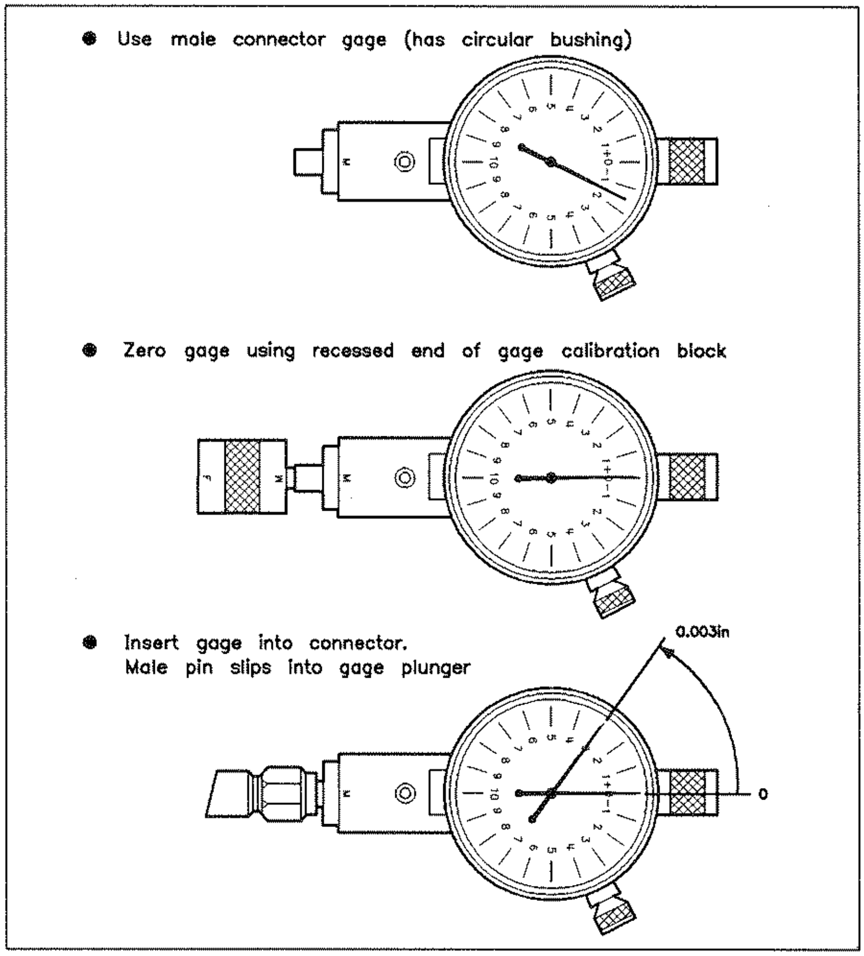


Figure 3-10.
Gaging an SMA Male Connector Using a Push-on Type Gage

Male SMA (Screw-on Type Gage)

1. Refer to Figure 3-11.
2. Use the steps in the general procedure at the beginning of this chapter to zero the gage.
3. Hold the gage by the barrel only and screw it on the connector, connecting the knurl (do not turn the gage or the device) finger-tight.
4. Torque the connector onto the gage to 56 N-cm (5 in-lb).
5. Tap the connector with your finger to settle the gage.
6. Read the gage indicator dial.
7. For maximum accuracy, measure the connector several times and take an average of the readings.

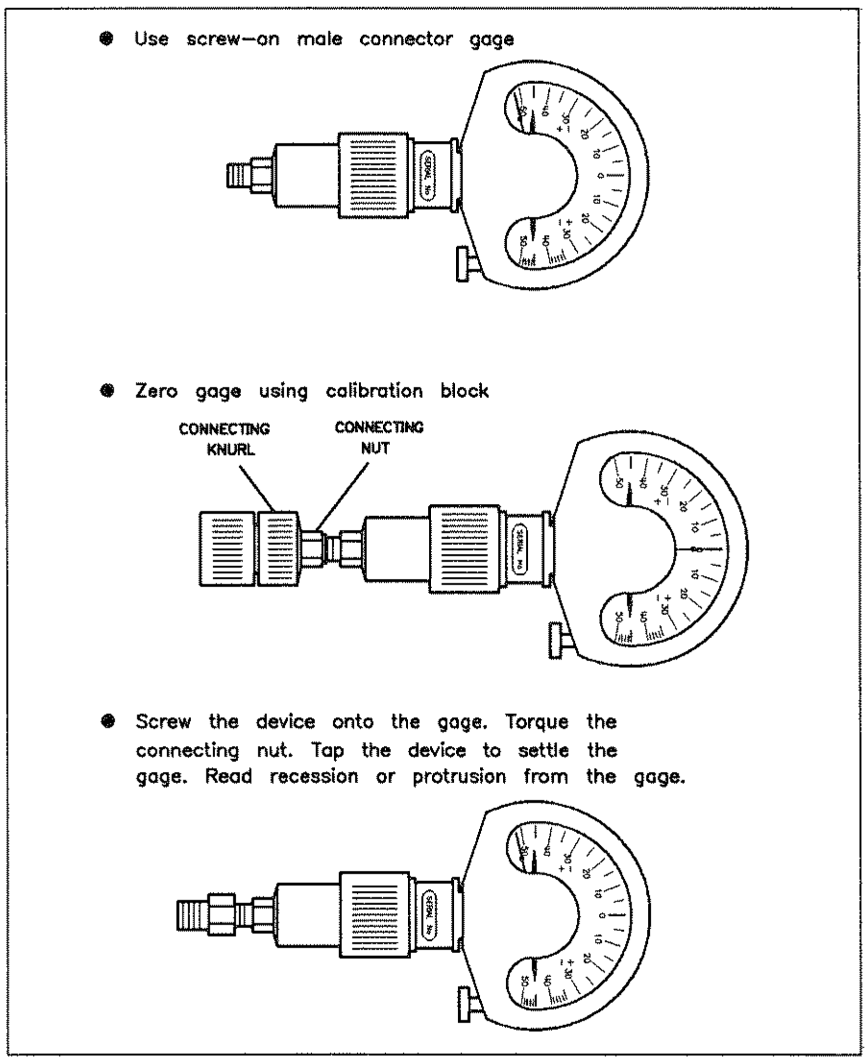


Figure 3-11. Gaging an SMA Male Connector Using a Screw-on Type Gage

Female SMA
(Push-on Type Gage)

1. Refer to Figure 3-12. Locate the female SMA connector gage (usually marked F.
2. Using the flat end of the gage calibration block (also usually marked F), zero the gage as described in the general procedure at the beginning of this chapter.
3. Measure the connector:
   a. Carefully center and insert the gage into the connector; the gage plunger rests on the outer end of the female contact fingers.
   b. Gently rock the connector gage within the connector to make sure the gage and the outer conductor mate flatly.
   c. When the gage pointer settles consistently at a reading, read the gage indicator dial.

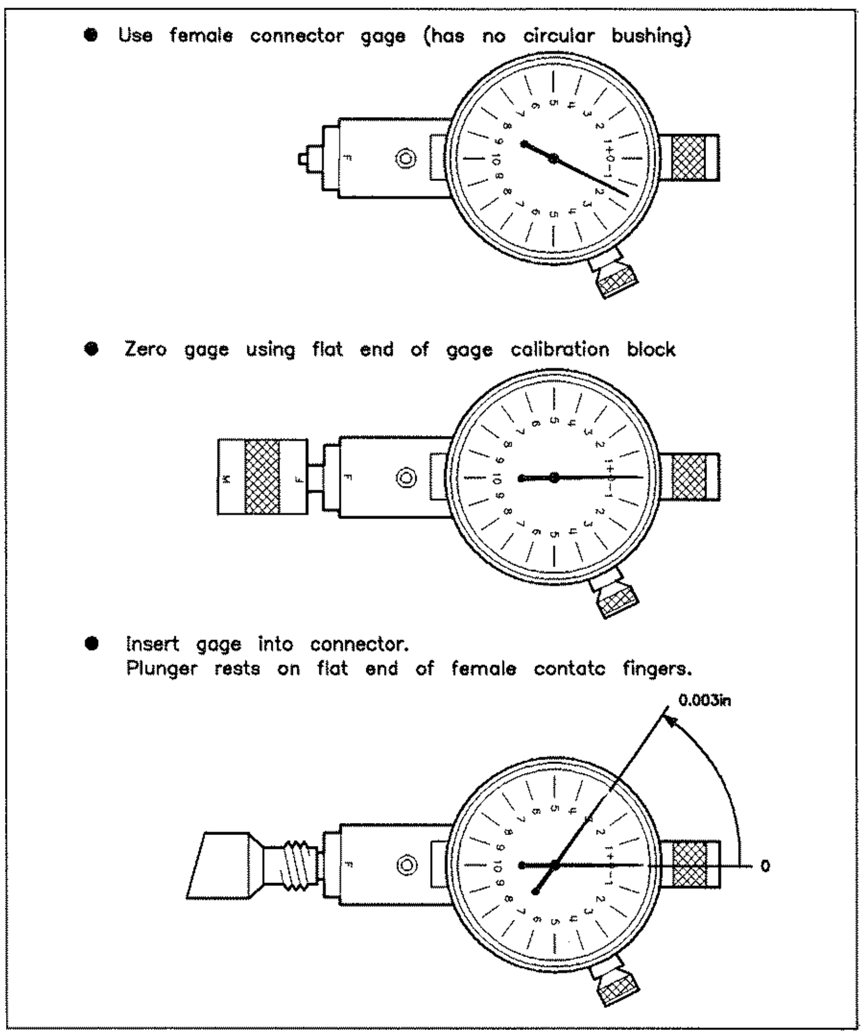


Figure 3-12.
Gaging an SMA Female Connector Using a Push-on Type Gage

Female SMA (Screw-on Type Gage)

1. Refer to Figure 3-13.
2. Use the steps in the general procedure at the beginning of this chapter to zero the gage.
3. Hold the gage by the barrel only and screw it on the connector, connecting the knurl (do not turn the gage or the device) finger-tight.
4. Torque the connector onto the gage to 56 N-cm (5 in-lb).
5. Tap the connector with your finger to settle the gage.
6. Read the gage indicator dial.
7. For maximum accuracy, measure the connector several times and take an average of the readings.

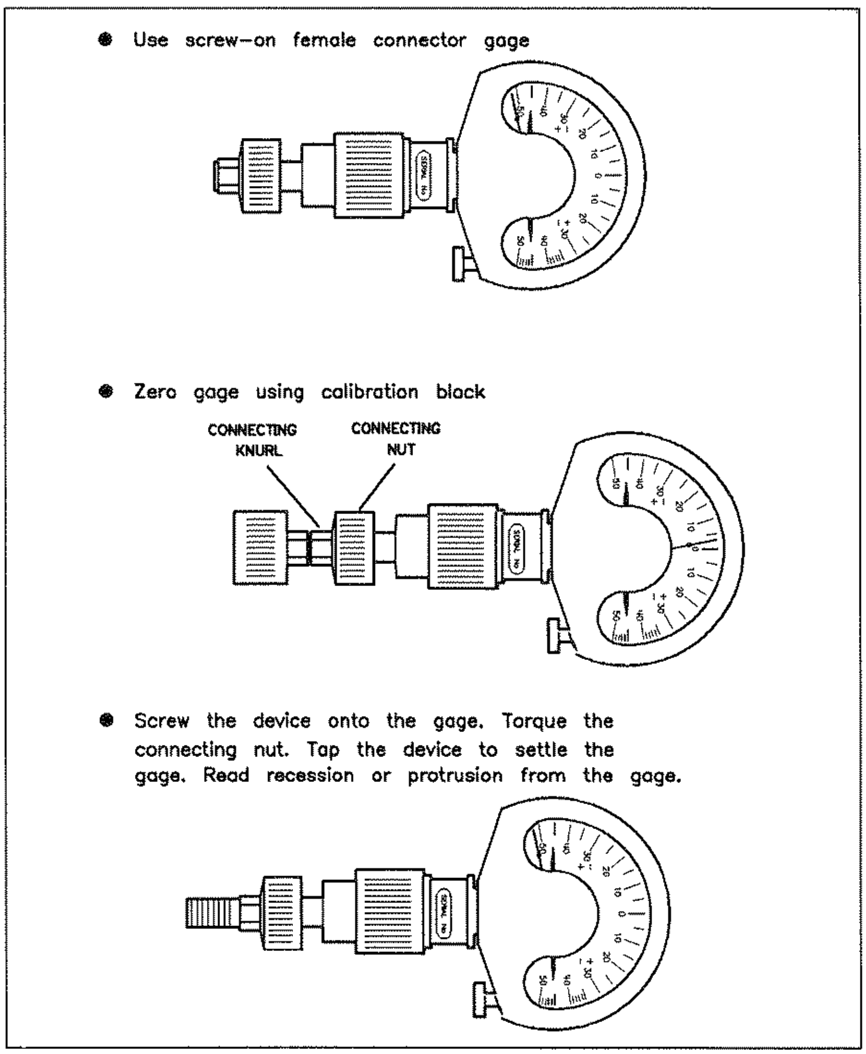


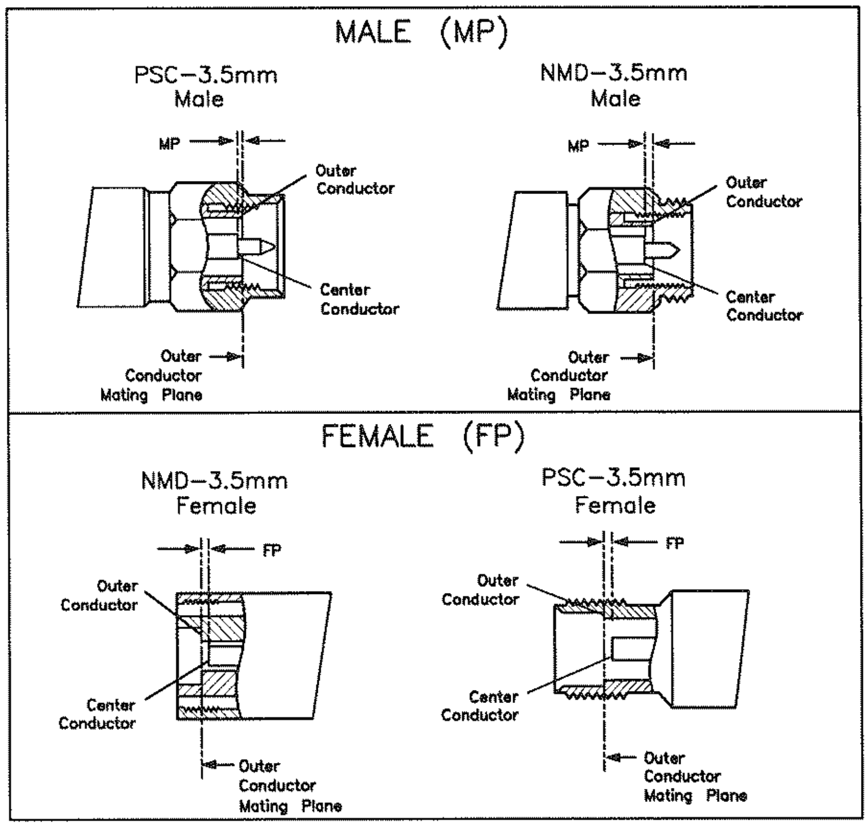
Figure 3-13.
Gaging an SMA Female Connector Using a Screw-on Type Gage

Precision 3.5 mm

Precision 3.5 mm connectors are sexed connectors. The male contact pin slides into the female contact fingers; the inside surfaces of the tip of the female contact fingers on the sides of the male contact pin provide electrical contact.

Specifications

- A maximum and minimum recession of the shoulder of the male contact pin.
- A maximum and minimum recession of the tip of the female center conductor behind the outer conductor mating plane.



MP = male contact pin shoulder recession behind the outer conductor mating plane.
FP = recession of the end of female center pin behind the outer conductor mating plane.

Figure 3-14. 3.5 mm Connector Mechanical Specifications

Gaging Techniques

Male 3.5 mm (Push-on Type Gage)

1. Refer to Figure 3-15. The male 3.5 mm connector gage (usually marked M) has a circular metal bushing surrounding the gage plunger.
2. Use the protruding end of the gage calibration block (also usually marked M).
3. Slip the calibration block into the outer bushing so that the bushing comes to rest on the outer, flat area of the calibration block. When you measure a connector, the gage outer bushing rests on the outer conductor mating plane inside the connector.
4. Zero the gage as described in the general procedure at the beginning of this chapter.
5. Measure the connector:
   a. Carefully center and insert the gage into the male connector; the flat outer part of the gage bushing rests on the outer conductor (the male contact pin slips into the hole in the gage plunger for this purpose).
   b. Gently rock the connector gage within the connector to make sure the gage and the outer conductor mate flatly.
   c. When the gage pointer settles consistently at a reading, read the gage indicator dial.

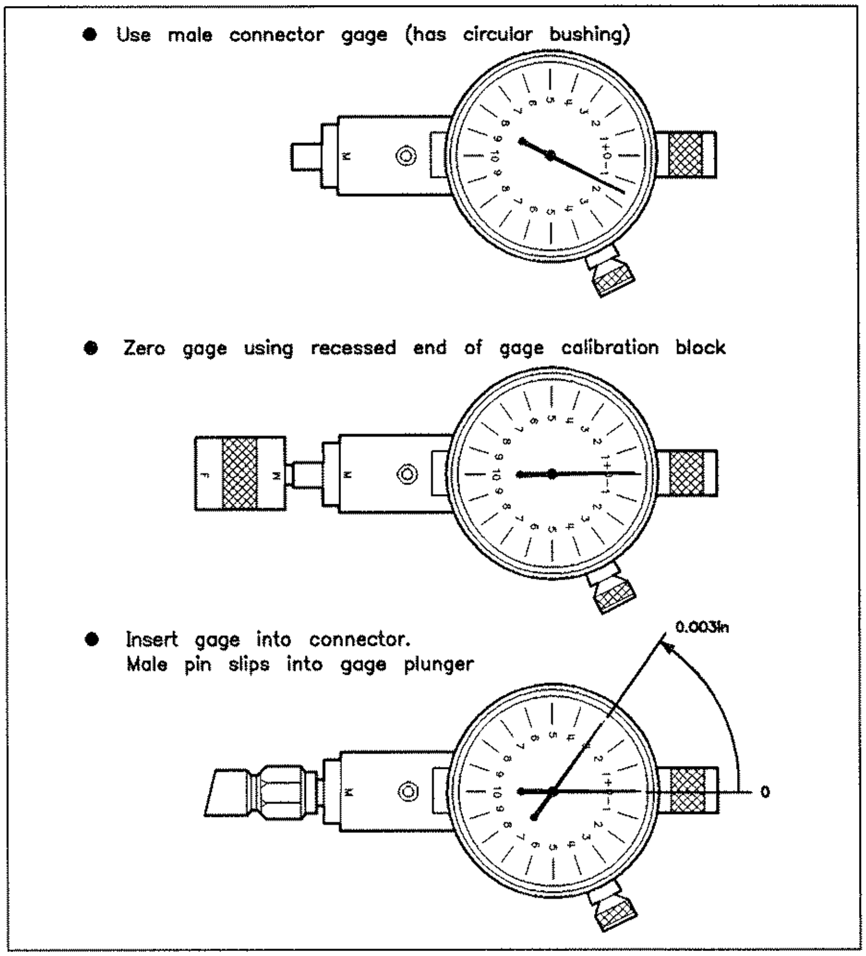


Figure 3-15.
Gaging a 3.5 mm Male Connector Using a Push-on Type Gage

Male 3.5 mm (Screw-on Type Gage)

1. Refer to Figure 3-16.
2. Use the steps in the general procedure at the beginning of this chapter to zero the gage.
3. Hold the gage by the barrel only and screw it on the connector, connecting the knurl (do not turn the gage or the device) finger-tight.
4. Torque the connector onto the gage to 90 N-cm (8 in-lb).
5. Tap the connector with your finger to settle the gage.
6. Read the gage indicator dial.
7. For maximum accuracy, measure the connector several times and take an average of the readings.

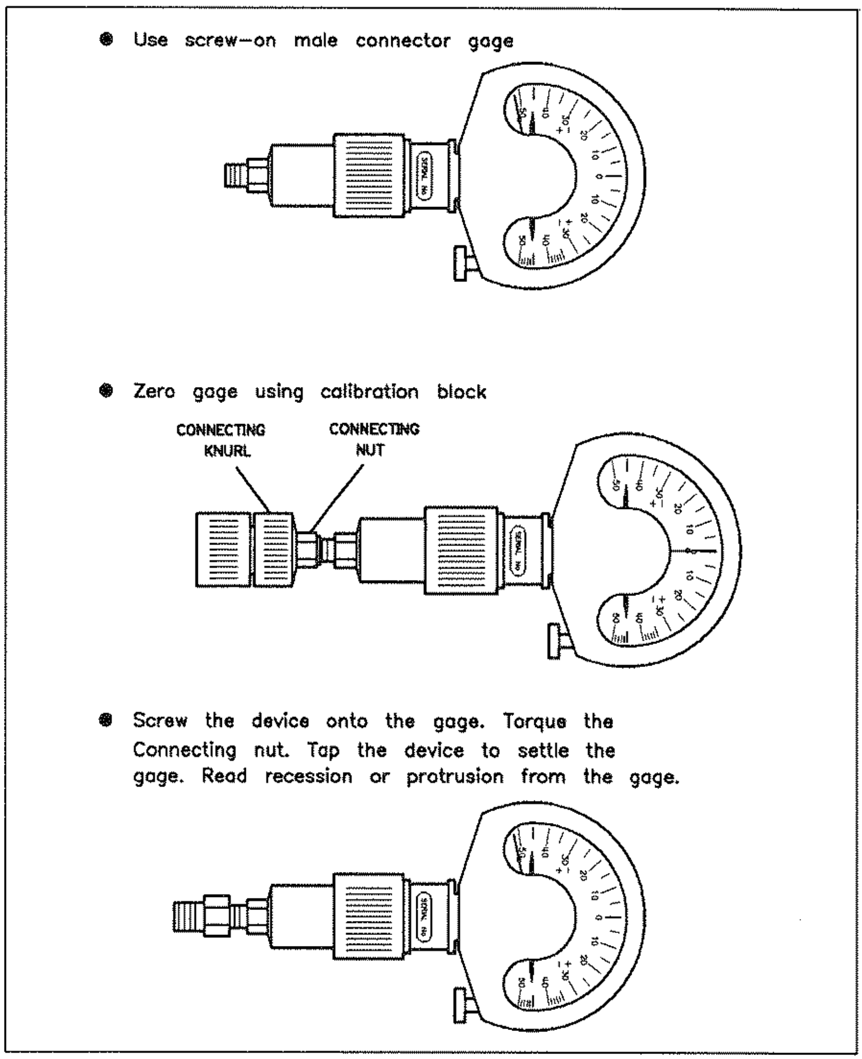


Figure 3-16.
Gaging a 3.5 mm Male Connector Using a Screw-on Type Gage

Female 3.5 mm (Push-on Type Gage)

1. Refer to Figure 3-17. Find the female 3.5 mm connector gage (usually marked F).
2. Using the flat end of the gage calibration block (also usually marked F), zero the gage as described in the general procedure at the beginning of this chapter.
3. Measure the connector:
   a. Carefully center and insert the gage into the connector; the gage plunger rests on the outer end of the female contact fingers.
   b. Gently rock the connector gage within the connector to make sure the gage and the outer conductor mate flatly.
   c. When the gage pointer settles consistently at a reading, read the gage indicator dial.

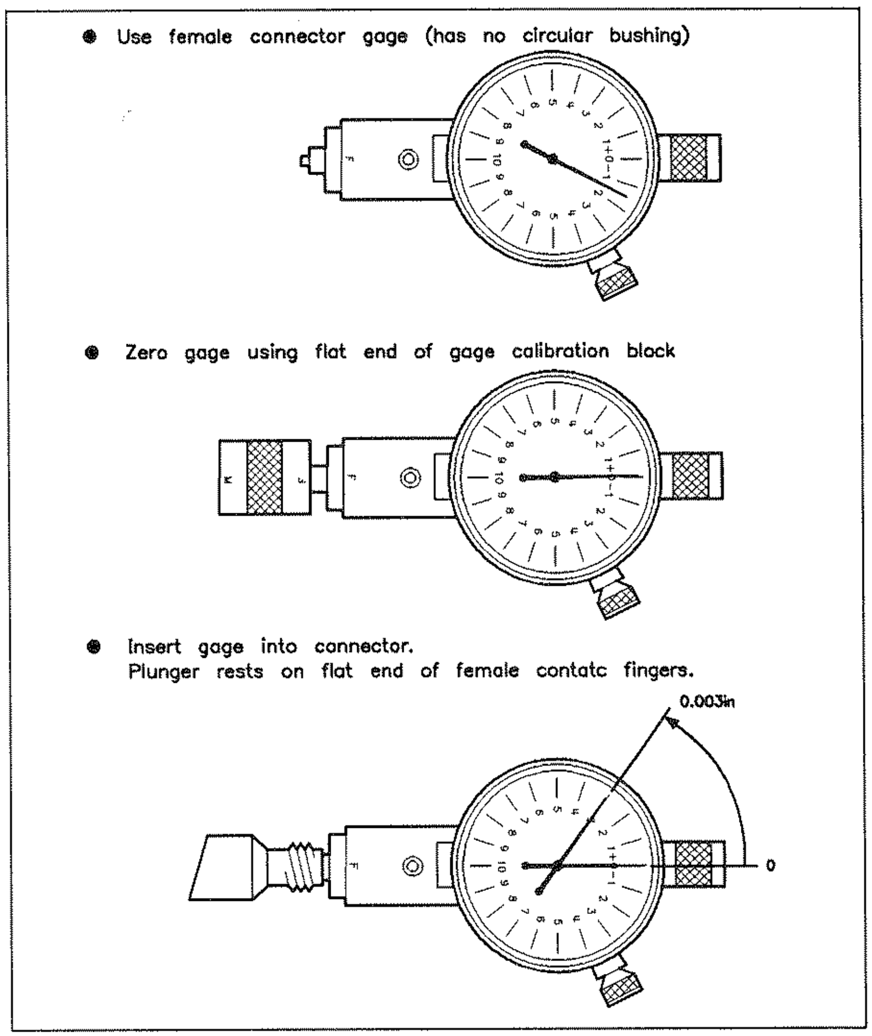


Figure 3-17.
Gaging a 3.5 mm Female Connector Using a Push-on Type Gage

Female 3.5 mm (Screw-on Type Gage)

1. Refer to Figure 3-18.
2. Use the steps in the general procedure at the beginning of this chapter to zero the gage.
3. Hold the gage by the barrel only and screw it on the connector, connecting the knurl (do not turn the gage or the device) finger-tight.
4. Torque the connector onto the gage to 90 N-cm (8 in-lb).
5. Tap the connector with your finger to settle the gage.
6. Read the gage indicator dial.
7. For maximum accuracy, measure the connector several times and take an average of the readings.

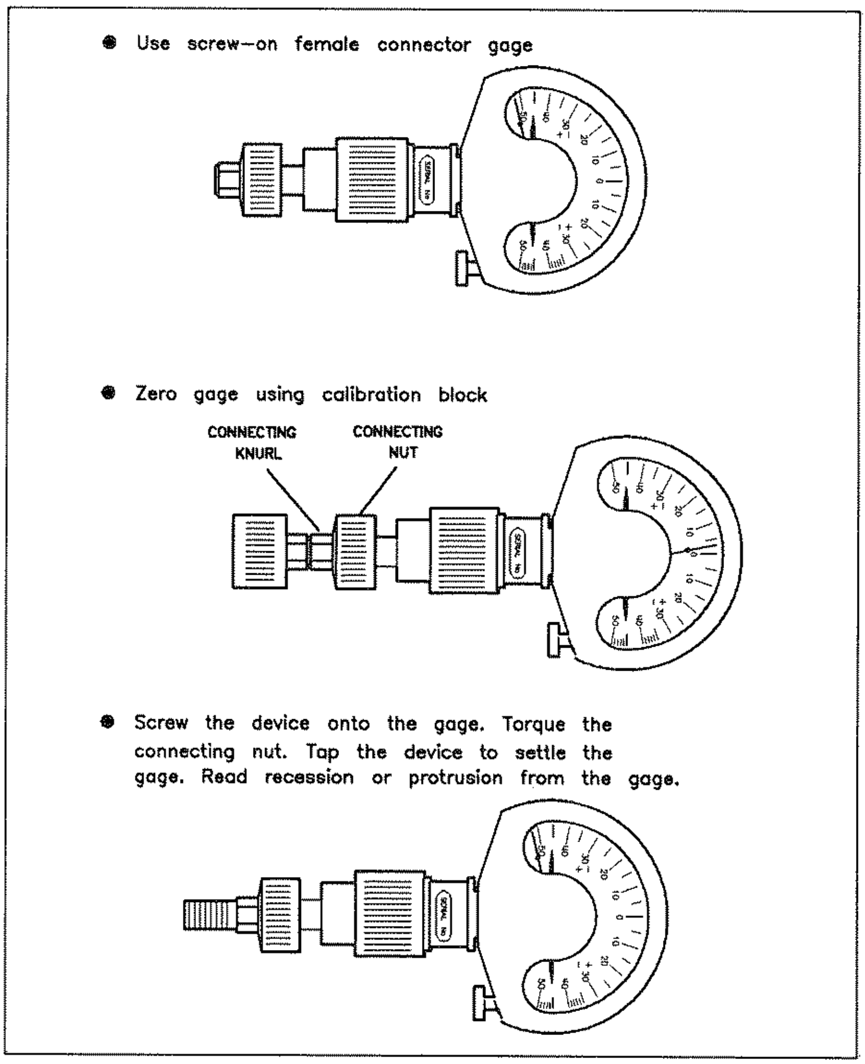
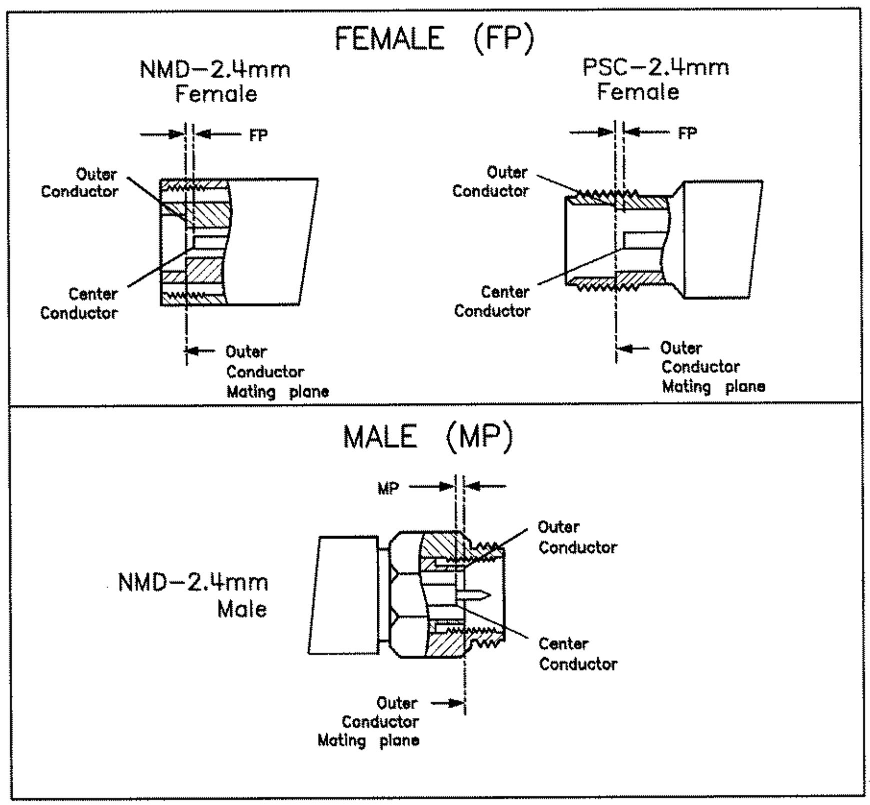


Figure 3-18.
Gaging a 3.5 mm Female Connector Using a Screw-on Type Gage

2.4 mm

Specifications

- A maximum and a minimum recession of the shoulder of the male contact pin.
- A maximum and a minimum recession of the end of the female center conductor behind the outer conductor mating plane.
- Neither the shoulder of the male contact pin nor of the tip of the female contact fingers may protrude in front of the outer conductor mating plane, and sometimes must *recede* minimally. Consult the mechanical specifications provided with your connector or device.
- The maximum allowable recession depends on the connector and the device. Consult the mechanical specifications provided with the connector or the device itself.



MP = male contact pin shoulder recession behind the outer conductor mating plane.
FP = recession of the end of female center pin behind the outer conductor mating plane.

Figure 3-19. 2.4 mm Connector Mechanical Specifications

Gaging Techniques

Male 2.4 mm Connectors

1. Refer to Figure 3-20 Using the male calibration block, zero the gage as described in the general procedure at the beginning of this chapter.
2. Hold the gage by the barrel only and screw it on the connector, connecting the knurl (do not turn the gage or the device) finger-tight.
3. Torque the connector onto the gage to 90 N-cm (8 in-lb).
4. Tap the connector with your finger to settle the gage.
5. Read the gage indicator dial.
6. For maximum accuracy, measure the connector several times and take an average of the readings.

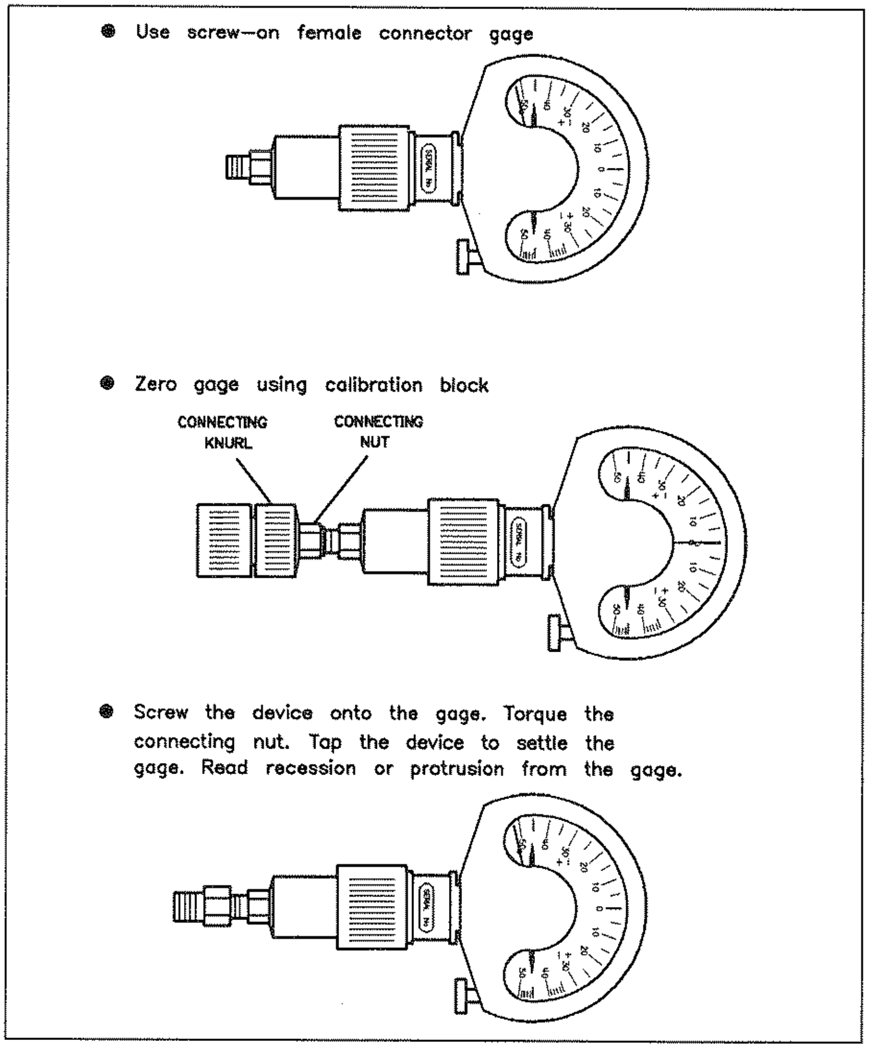


Figure 3-20. Gaging a 2.4 mm Male Connector

Female 2.4 mm Connectors

1. Refer to Figure 3-21 Using the female calibration block, zero the gage as described in the general procedure at the beginning of this chapter.
2. Hold the gage by the barrel only and screw it on the connector, connecting the knurl (do not turn the gage or the device) finger-tight.
3. Torque the connector onto the gage to 90 N-cm (8 in-lb).
4. Tap the connector with your finger to settle the gage.
5. Read the gage indicator dial.
6. For maximum accuracy, measure the connector several times and take an average of the readings.

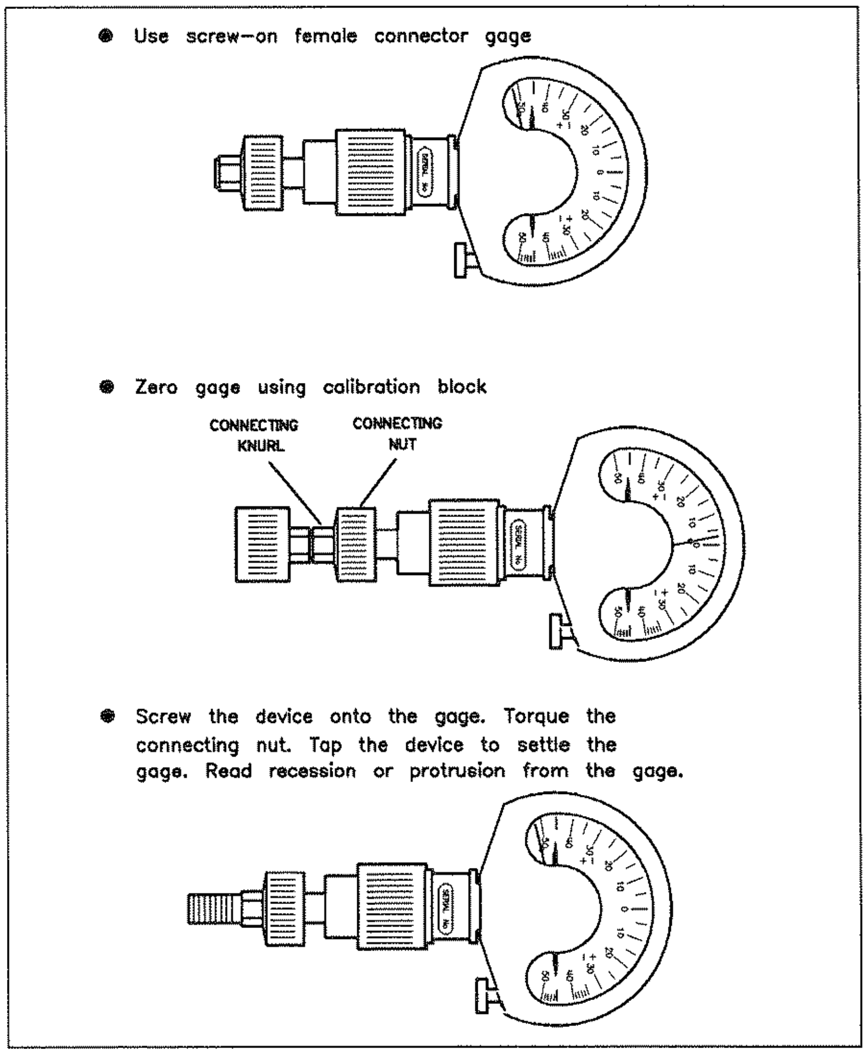


Figure 3-21. Gaging a 2.4 mm Female Connector

Making Connections

Good connections require a skilled operator. Because of instrument sensitivity and coaxial connector mechanical tolerances, slight errors in operator technique can significantly effect measurements and measurement uncertainties.

Note

Before you make *any* connections, clean and inspect (visually and mechanically) all connectors.

General Connecting Procedure

Connecting

The following procedure uses a 7 mm fixed load and a 7 mm test port connector, but the steps and principles are the same for all coaxial connector types. Read this general procedure, then read any information that applies specifically to your connector type.

Caution

This procedure assumes that you have taken the necessary ESD precautions, and have *already* inspected (visually and mechanically) and cleaned the connectors.

1. Carefully align the connectors (see Figure 3-22).
   a. Fully extended the connector sleeve on one of the connectors and fully retract the sleeve on the other. The extended sleeve creates a cylinder into which the second connector fits. If one of the connectors is fixed (as on a test port) fully extend *that* connector sleeve (spin its knurled connector nut to make sure the threads are fully extended). Fully retract the connector sleeve on the other connector.
   b. As you bring one connector up to the other, and as you make the actual connection, be sure the connectors align perfectly. If not, stop and begin again.

      On sexed connectors, the male connector center pin must slip concentrically into the contact fingers of the female connector.

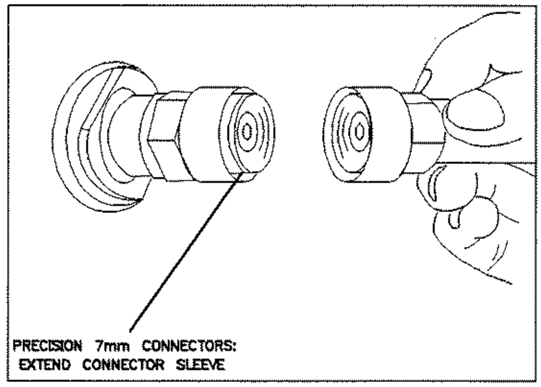


Figure 3-22. Align the Connectors

2. Push the connectors straight together. *Do not* twist or screw them together. As the center conductors mate, you may feel a slight resistance.

3. Engage the connector nut over the threads on the second connector. Turn *only* the connector nut. Let the connector nut pull the two connectors straight together (see Figure 3-23).

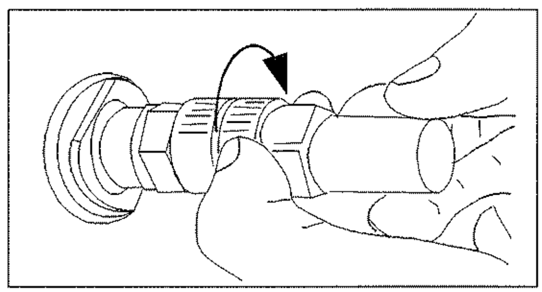


Figure 3-23. Make the Preliminary Connection Gently

Caution Do *not* twist one connector into the other (like changing a light bulb). This happens if you turn the device body rather than the connector nut.

In a preliminary connection, the mating plane surfaces make uniform, light contact. Do not overtighten this connection.

At this point you want a connection in which the outer conductors make gentle contact at all points on both mating surfaces. This requires very light finger pressure (no more than 2 inch-pounds of torque).

4. Relieve any side pressure on the connection from long or heavy devices or cables. This assures consistent torque in the following steps.

5. Use a torque wrench to make the final connection (Figure 3-24).

   Using a torque wrench prevents overtightening (and possible connector damage). It also guarantees that all connections are equally tight each time.

   a. Prevent the rotation of anything other than the connector nut you wish to tighten. Do this by hand for a fixed connector (as on a test port). Otherwise, use an open-end wrench to keep the body of the connector from turning.
   b. Hold the torque wrench lightly.

      Hold the torque wrench at the same point near the end of the handle each time you use it. Always use the wrench in the proper orientation (see Figure 3-25), and when possible, hold the wrench horizontally as you begin tightening the connection.
   c. Apply force at the *end* of the torque wrench, perpendicular to the wrench, in a plane parallel to the outer conductor mating planes. This applies torque to the connection *through* the wrench.

      Do not hold the wrench so tightly that you push the handle straight down along its length rather than pivoting it (Figure 3-26). If you do, you apply an unlimited amount of torque.

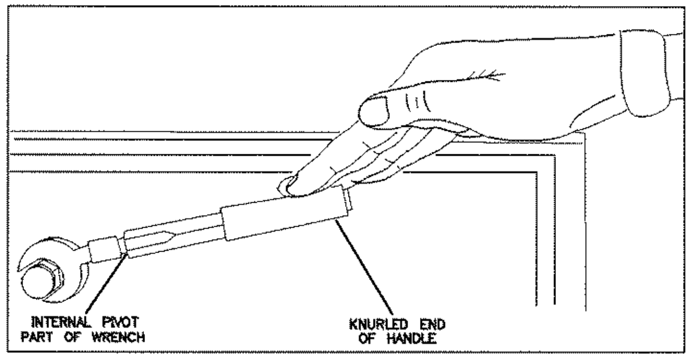


Figure 3-24. Make the Final Connection With a Torque Wrench

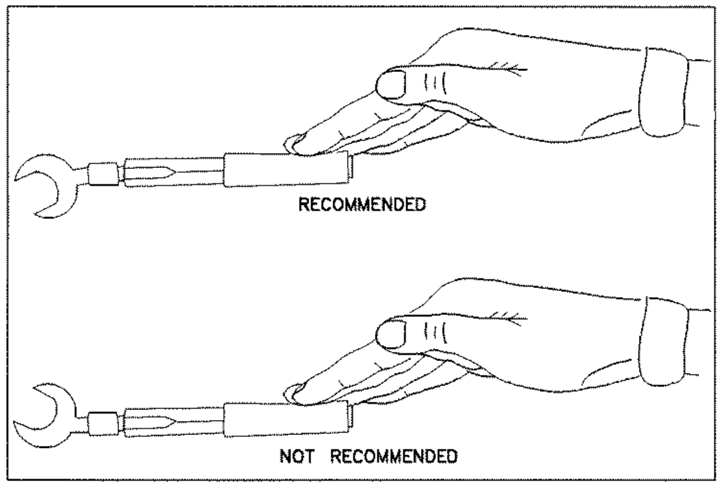


Figure 3-25. Proper Torque Wrench Orientation

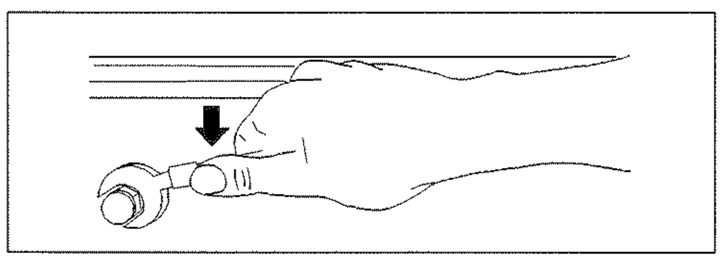


Figure 3-26. Do not Push the Torque Wrench Straight Down

d. Tighten the connection just to the torque wrench "break" point (the wrench handle gives way at its internal pivot point. See Figure 3-27). *Do not* tighten the connection further.

cautions

You don't have to "fully break" the handle of the torque wrench to reach the specified torque, and doing so can cause the handle to kick back and loosen the connection.

Do not pivot the wrench handle on your thumb or other fingers (Figure 3-28). If you do, you apply an unknown amount of torque to the connection when the wrench reaches its "break" point.

Do not twist the head of the wrench relative to the outer conductor mating plane. If you do, you apply more than the recommended torque.

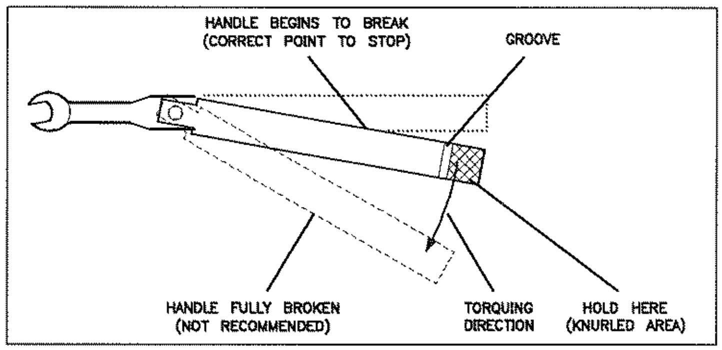


Figure 3-27. Tighten Only to the Torque Wrench Break Point

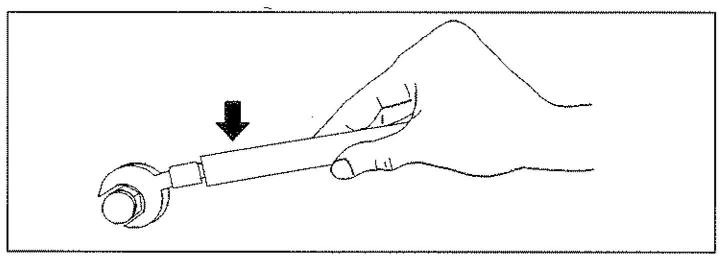


Figure 3-28. Do Not Pivot the Torque Wrench on Your Thumb

Disconnecting

Note

To avoid lateral (bending) force on the connector mating plane surfaces, always support the devices and connections.

1. Firmly grasp the device body (to prevent it from turning).
2. Loosen the connector nut that you tightened to make the connection.

   If necessary, use the torque wrench or an open-end wrench to start the disconnection, but leave the connection finger tight.
3. Complete the disconnection by hand, turning only the connector nut.
4. For sexed connectors, pull the connectors straight apart.

Caution

Do not twist the connection or you may damage the center conductors or the interior component parts to which the connectors attach. You can also scrape the plating off the male contact pin, or (rarely) slightly unscrew the male or female contact pin from its interior mounting, taking it out of specification.

Precision 7 mm

Seating

The general procedure in this chapter describes how to connect a precision 7 mm connector. In certain applications, however, an additional step may prove helpful. Use the following procedure only for the most demanding measurement applications, and only with gold-plated precision 7 mm connectors.

1. After making the preliminary connection (using light finger pressure), hold the connector nut stationary with one hand. With the other hand, gently turn *the body of the connecting device* 5 to 15 degrees opposite the direction of tightening (Figure 3-29). You should feel smooth, uniform movement, without resistance.

   You may feel a sudden, slight "breaking loose" of the connection when you rotate the connected device. This happens as the mating plane surfaces or the connector nut threads move into correct alignment, and it slightly loosens the connector nut.

2. If the connector nut loosens, tighten it slightly and repeat the rotation. You should feel smooth, uniform motion, without resistance.
3. Use a torque wrench to make the final connection (136 N-cm (12 in-lb)).

Caution

Because this technique does wear the gold plating on the mating plane surfaces, use seating only in the most demanding measurement applications. Never use this seating technique as a substitute for careful cleaning and complete mechanical inspection.

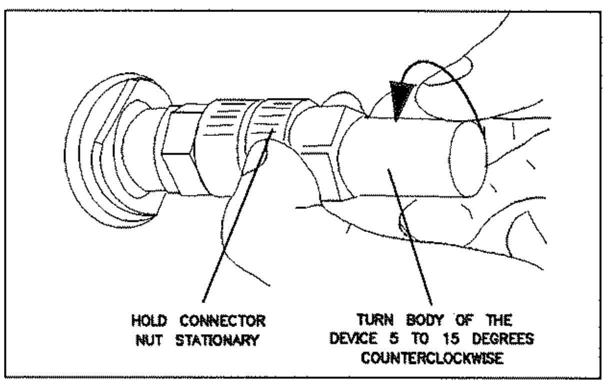


Figure 3-29. Seating a Precision 7 mm Connector

Type-N

For proper torque, finger-tighten a type-N connector (these connectors do not have wrench flats).

If you wish, you can use a torque wrench with a special non-slip end (136 N-cm (12 in-lb)).

Never rotate the mating plane surfaces against each other.

3.5 mm

For proper torque, finger-tighten this type of connector.

Mating a Precision 3.5 mm Connector to an SMA Connector

Using the following procedure *very carefully*, you can mate a precision 3.5 mm connector to an SMA connector (Figure 3-30). The two connectors have slightly different dimensions and mechanical characteristics. Mating a precision 3.5 mm connector to an SMA connector also affects electrical performance (see "Electrical Performance").

1. Gage both connectors. The SMA connector must meet the precision 3.5 mm connector setback specifications. If not, it will damage the 3.5 mm connector.
2. Carefully align the connectors.
3. Push the two connectors straight together, with the male contact pin precisely concentric with the female.
4. Do not twist either connector or device.
5. Turn only the outer male connector nut.
6. Use a torque wrench for the final connection (56 N-cm (5 lb-in)).

   If you must make more than a few connections, use a 3.5 mm-to-3.5 mm adapter to protect the 3.5 mm connector (see Appendix B).

Electrical Performance

The junction of two precision 3.5 mm connectors provides superior electrical performance compared to either the junction of two SMA connectors, or an SMA connector mated to a precision 3.5 mm connector (see Figure 3-31).

When you mate an SMA connector with a precision 3.5 mm connector, the connection has a typical mismatch (SWR) of 1.10 at 2 GHz (less than that of two SMA connectors, but much greater than that of two precision 3.5 mm connectors).

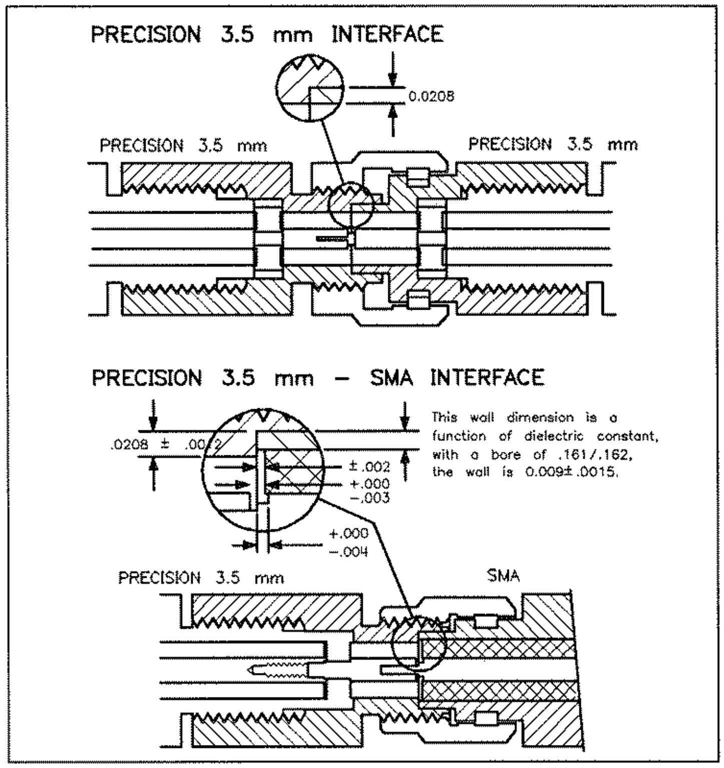


Figure 3-30.
A Precision 3.5 mm Connector Interface Compared to A Precision 3.5 mm-to-SMA Connector Interface

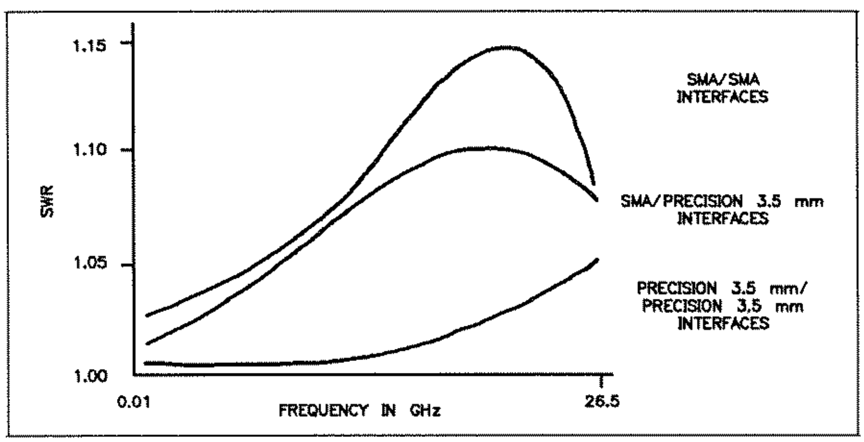


Figure 3-31.
Typical SWR of SMA and Precision 3.5 mm Coupled Junctions

2.4 mm

For proper torque, finger-tighten this type of connector.

A

Removing, Inspecting, & Replacing Center Conductor Collets

Collet Types

Slotted (page A-2)

This appendix covers two types of slotted 7 mm collets:

- 4-slot collets.
- 6-slot collets.

The more durable 6-slot collets provide more repeatable connections. Never replace a 6-slot collet with a 4-slot collet. You can reuse either type, but inspect them carefully before you do.

Slotless (page A-4)

This appendix covers two types of slotless collets:

- 3.5 mm slotless collets.
- 7 mm slotless collets.

Slotted Collets

Removing a Center Slotted Collet

Use this procedure to remove a slotted center conductor collet for any of the following reasons:

- You wish to gage the connector with the collet removed.
- You find a damaged collet.
- The collet protrusion measures out of specification.

1. Wear a grounded wrist strap, and ground yourself as far as possible from the test port.
2. To open the interior collet removal jaws fully, pull back the handle of the collet removing tool.
3. With the handle pulled back, carefully insert the tool completely into the connector, inside the outer conductor, until it comes to rest lightly on the interior support bead (Figure A-1).
4. Release the handle and remove the tool (and collet) from the connector.

Note

Removing the collet should not damage it. If it does, replace the collet and the collet removing tool.

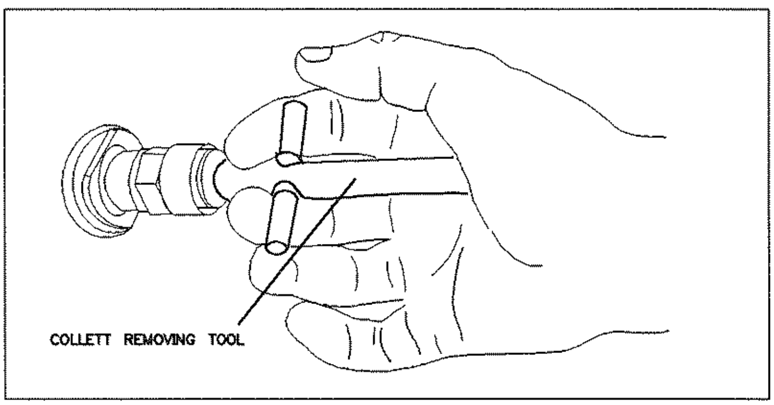


Figure A-1. Using the Collet Removal Tool

Inspecting a Slotted Collet

- Look for edge or surface damage.
- Look for any signs of bent or twisted spring contacts. If necessary, replace both the collet and the collet removing tool.

Replacing a Slotted Collet

1. Wear a grounded wrist strap, and ground yourself as far as possible from the test port. .
2. With tweezers, pick up the collet by the slotted end.
3. Carefully insert the collet (narrow end first) into the connector center conductor (Figure A-2).

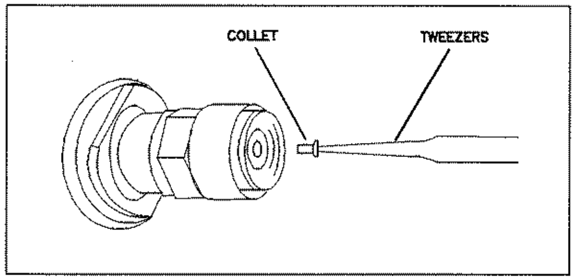


Figure A-2. Inserting a Collet

4. Using a blunt plastic rod (or the rounded plastic handle of the collet removing tool) press the collet gently until it snaps into place (Figure A-3).

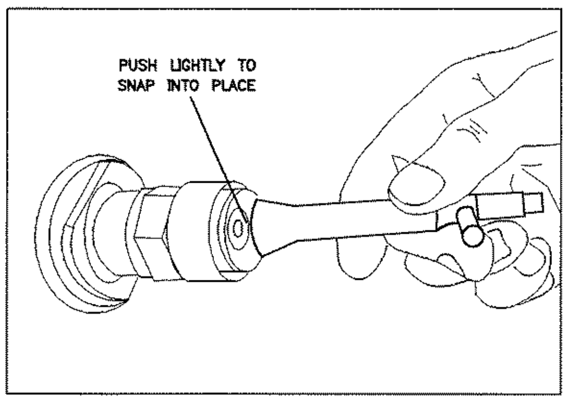


Figure A-3. Gently Press the Collet into Place

Slotless Collets

When properly used, a precision slotless connector should have the same lifespan as a standard slotted connector. Hewlett-Packard designed the precision slotless contacts to mate with all connectors within a connector series *when those connectors meet published interface dimensions.* Mating a connector that *does not* meet published specifications can damage a precision slotless connector. For this reason, ensure that any device you connect measures within its specifications.

The following procedure calls for items contained in HP 85052B option K11 and 85054B option K11 slotless contact repair kits:

- Alcohol.
- Foam swabs.
- Tweezers.
- Inner contact removal tool.
- Inner contact insertion tool.
- Inner contact testing tool.
- Testing weight.
- Replacement inner contacts.

HP 85052B Option K11

Use the 3.5 mm slotless contact repair kit to repair the female contacts on all HP PSC-3.5 mm connectors except for the precision slotless contacts on the air lines in the HP 85052C 3.5 mm precision calibration kit. If damaged, these contacts must be repaired at the factory.

HP 85054B Option K11

Use the type-N slotless contact repair kit to repair the female contacts on all HP type-N precision slotless connectors.

Repairing A Slotless Contact

If you suspect a problem with the slotless contact, make a visual inspection to check for damage. As you use a connector, dirt and metal particles can accumulate in and around the slotless contact. In extreme cases this accumulation can render the contact non-functional. Often, simply cleaning the contact fixes the problem.

This section provides procedures on how to clean both the inner contact and the center conductor, how to reinstall the inner contact, how to test for functionality, and, if necessary, how to replace the inner contact.

Repairing a damaged slotless contact comprises six-steps:

1. Gage the connector.
2. Under $\geq$x10 magnification, inspect the connector to determine the damage.
3. Remove the damaged inner contact.
4. Inspect the center conductor. If undamaged, clean it.
5. Install the replacement inner contact.
6. Test the slotless contact.

Inspecting A Damaged Slotless Contact

Inspect the contact under $\geq$x10 magnification to define the problem. Usually you can make the repair without disassembling the device to which the precision slotless contact is attached.

Inspect the slotless contact to see if any of the following conditions exist:

- The inner contact has one or more fingers bent inward or crushed, preventing proper contact to the male pin (see Figure A-4).

  If so, go to step 1 of "Removing A Slotless Contact".

- The inner contact has one or more fingers broken (see Figure A-5).

  If so, go to step 2 of "Removing A Slotless Contact".

- The inner contact is pushed inside the center conductor and does not make contact with the mating connector's male pin (see Figure A-6).

  If so, go to step 3 of "Removing A Slotless Contact".

- The end of the center conductor appears dented or scraped near where it touches the inner contact (see Figure A-7).

  If so, the slotless contact may be damaged beyond the capabilities of this repair kit, and the device must be repaired or replaced by Hewlett-Packard.

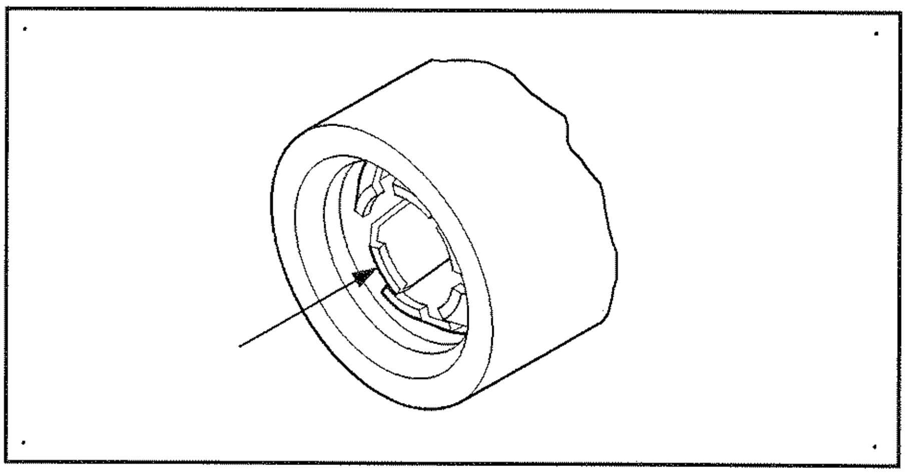


Figure A-4. Finger Bent In or Crushed

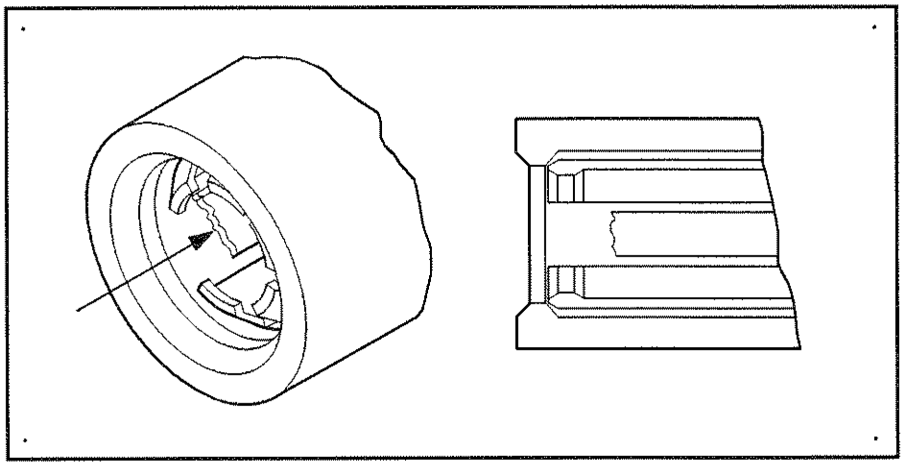


Figure A-5. Broken Inner Contact

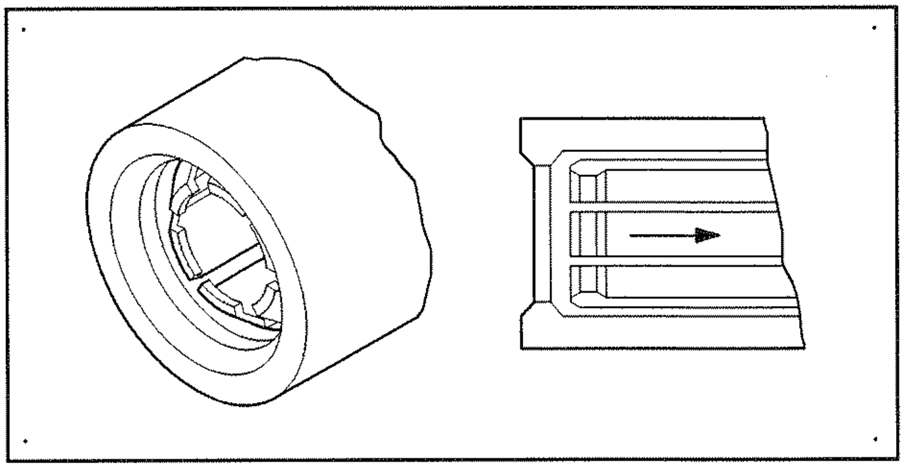


Figure A-6. Inner Contact Pushed Inside

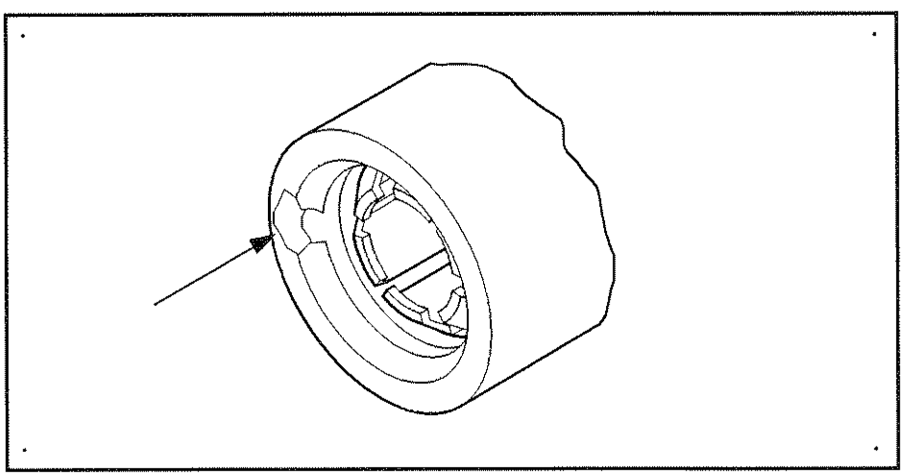


Figure A-7. Damaged Center Conductor

Removing A Slotless Contact

Step 1

If one or more of the inner contact's fingers are bent inward or crushed, you must straighten or remove those fingers before you remove the entire inner contact. Figure A-8 shows both the inner contact and the center conductor.

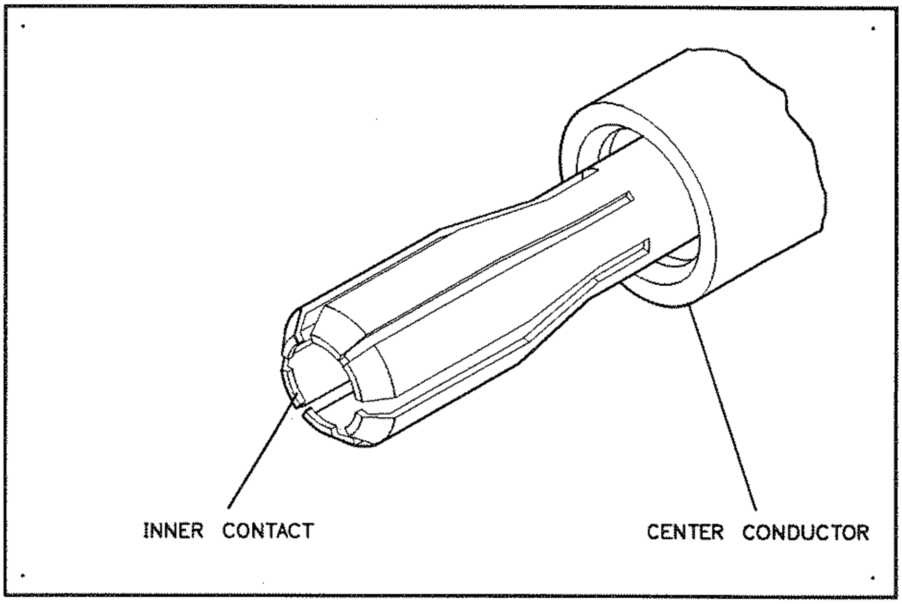


Figure A-8. The Inner Contact and Center Conductor

a. Under magnification, *carefully* try to insert the removal tool (see Figure A-9).

b. If the damaged fingers prevent you from inserting the tool, use tweezers to either move aside or remove the damaged fingers (see Figure A-10).

   Be *extremely cautious* to avoid damaging the center conductor, which houses the inner contact. Do not touch the tweezers to anything but the damaged inner contact. Do not, under any circumstances, use anything to squeeze or clamp on to the center conductor that might cause damage.

c. After you move or remove the damaged inner contact fingers and can insert the inner contact removal tool, go to step 3.

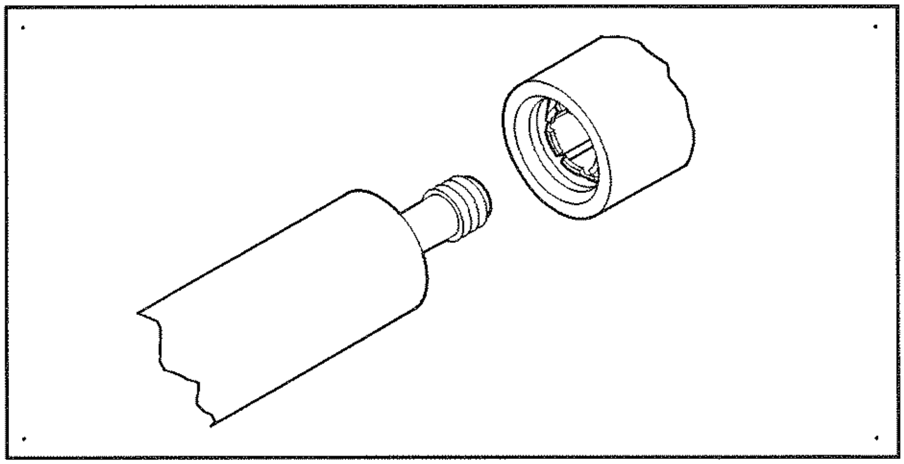


Figure A-9. Inserting the Removal Tool

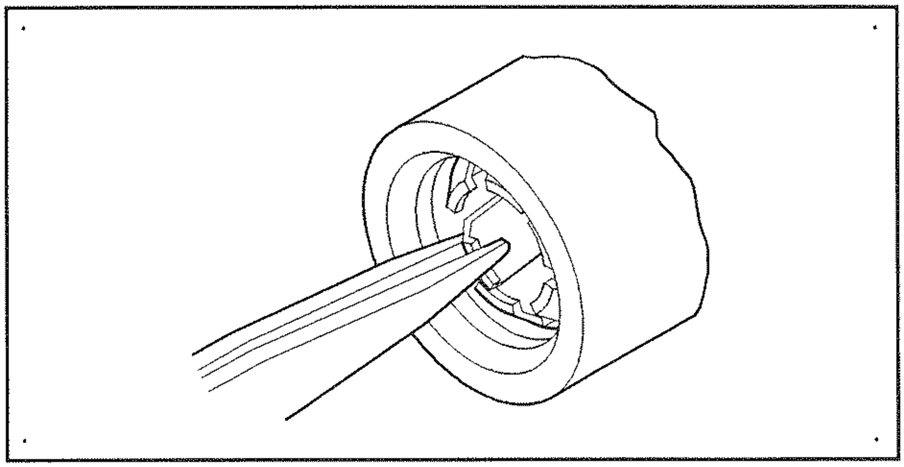


Figure A-10. Moving a Damaged Finger

Step 2

If one or more of the inner contact's fingers are broken, you must remove that finger before you remove the entire inner contact:

a. Under magnification, look down inside the inner contact and locate the broken finger or fingers.

   The fingers may have already fallen out. If so, continue with step 3.

b. If you can see the broken fingers inside the inner contact, turn the device upside down and gently tap on it (see Figure A-11).

   Using this gentle tapping, try to force the broken fingers to drop out or at least move forward far enough so that you can remove them with the tweezers (see Figure A-12). Do not, under any circumstances, use anything other then gentle tapping.

c. After you remove the broken inner contact fingers and can carefully insert the inner contact removal tool, go to step 3.

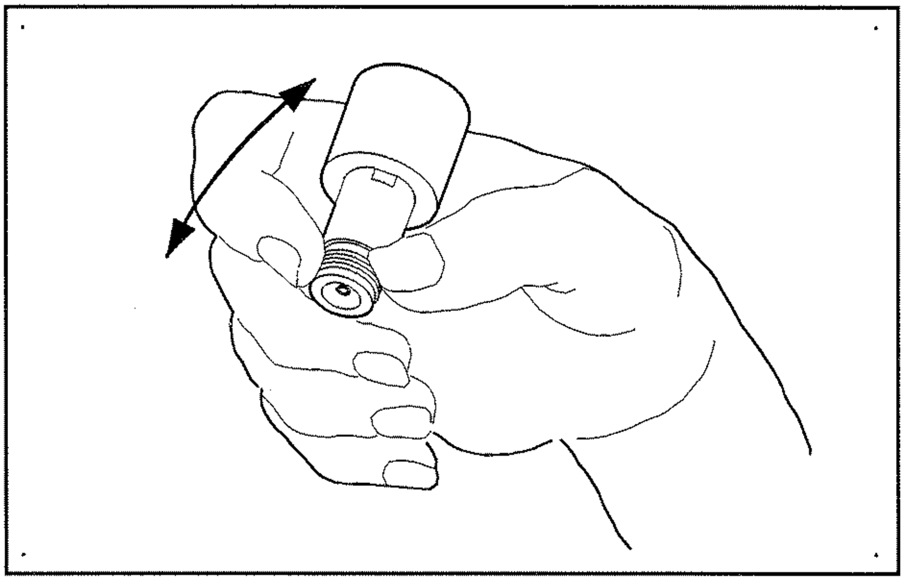


Figure A-11. Freeing a Broken Contact Finger

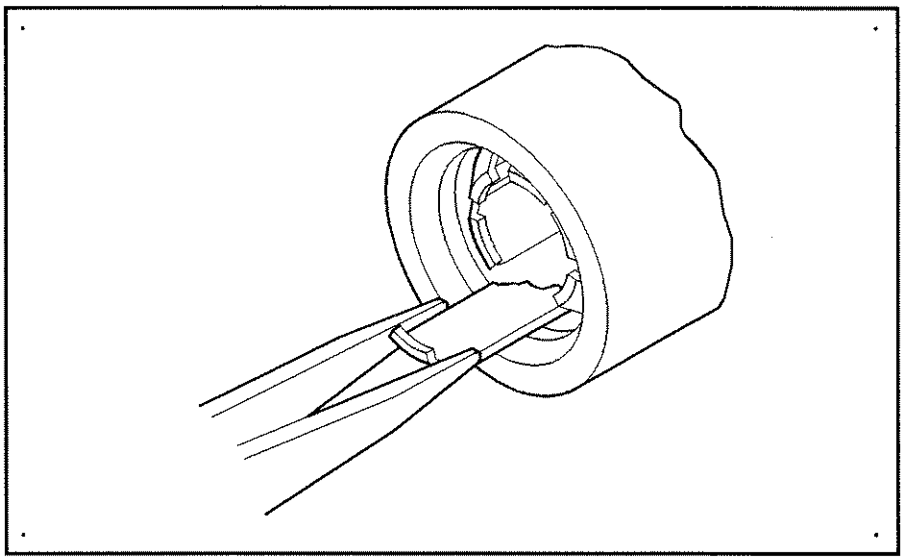


Figure A-12. Removing a Broken Contact Finger

Step 3

If the inner contact is pushed inward and no longer makes contact with the mating connector's male pin, you must remove and replace the inner contact:

a. Under magnification, insert the removal tool into the damaged contact far enough so that it touches the bottom of the inside of the inner contact.

b. Turn the tool clockwise to engage the tool coupling thread with the thread on the inside of the contact (see Figure A-13).

c. Occassionally the inner contact spins with the tool, preventing the tool from engaging. If this happens, apply a small amount axial pressure to the tool and continue to turn it clockwise.

d. Once you engage the tool by 2 turns, you can remove the inner contact. Pull the tool and inner contact straight out away from the center conductor (see Figure A-14).

Caution

Do not damage the center conductor as you remove the inner contact.

e. Unthread the broken inner contact from the removal tool and discard the contact; it cannot be repaired or reused.

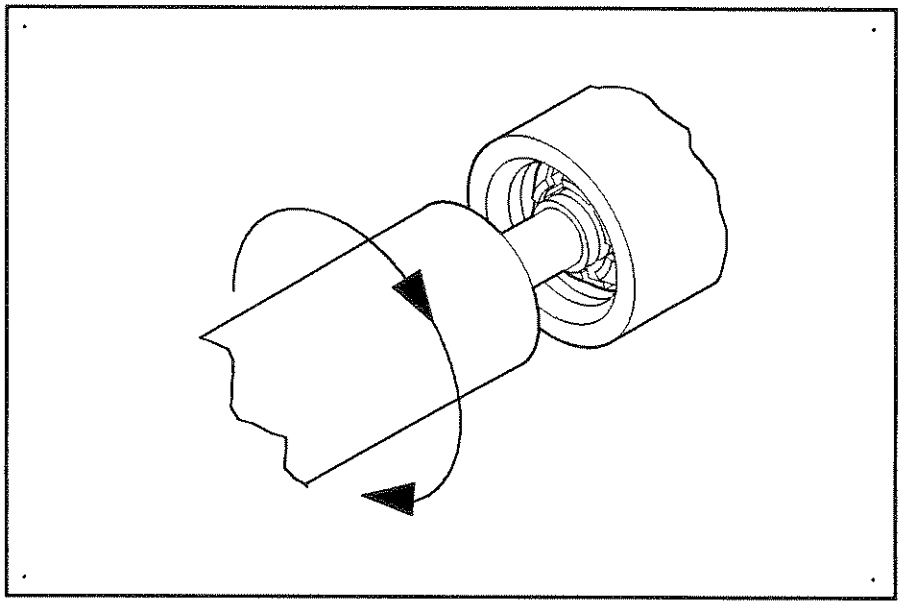


Figure A-13.
Threading the Removal Tool into
the Inner Contact

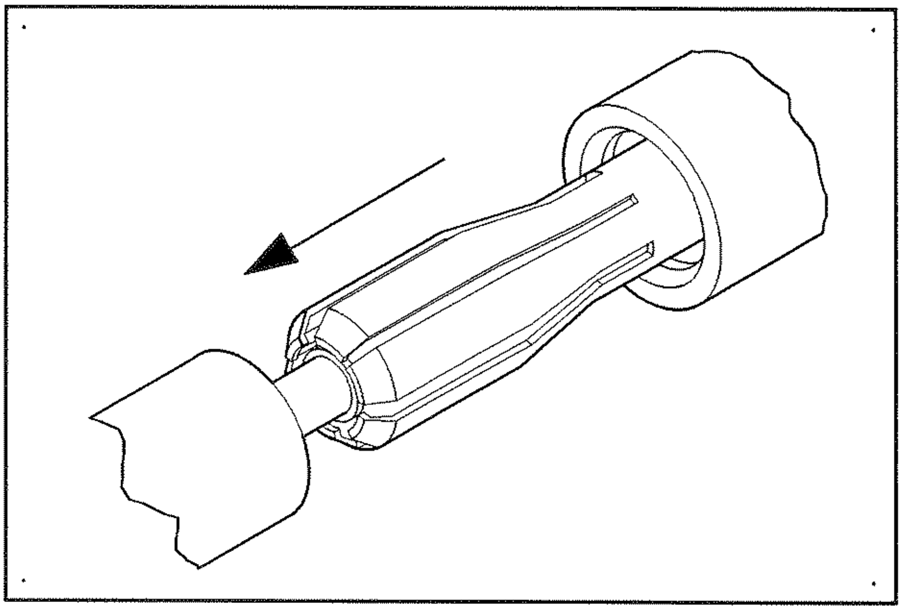


Figure A-14. Removing the Inner Contact

Slotless

Inspecting & Cleaning A Center Conductor

Inspecting

1. Under magnification, inspect the center conductor for damage.
2. Refer to Figure A-15. Is the center conductor gouged? Does it have any imperfection that would interfere with the insertion of a new inner contact? If so, you must return the device to Hewlett-Packard for repair; you cannot repair a center conductor with either kit.
3. If the center conductor is undamaged, or if the damage is too light to affect device performance, clean the center conductor.

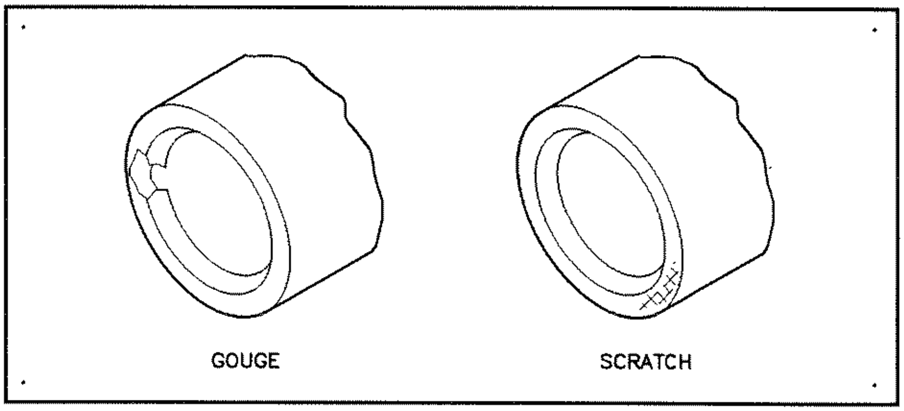


Figure A-15. Damaged Center Conductor

Cleaning

1. Under magnification, look for loose dirt or metal particles.
2. Using foam swabs and isopropyl alcohol, clean the center conductor.
3. Using a source of dry air or nitrogen, blow out the hole in the center conductor; be sure that all the alcohol evaporates.
4. Now you can insert a new inner contact into the clean center conductor.

Inserting an Inner Contact

When you install a replacement inner contact, be careful handling the replacement parts. These parts are fragile until they are inside the center conductor; do not squeeze or misuse them in any way.

1. Using tweezers, carefully pick up a new inner contact by its small-diameter end (away from the fingers, see Figure A-16). Do not use excessive pressure. Holding the contact by the fingers will damage it.

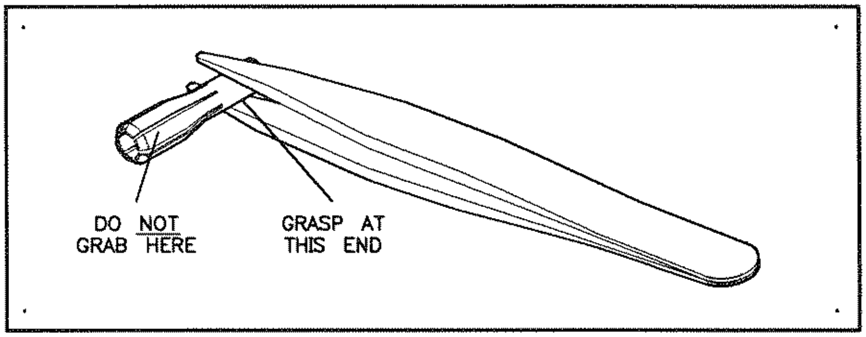


Figure A-16. Holding the Inner Contact Properly

2. Under magnification, carefully insert the insertion tool into the new inner contact until it hits bottom. Do not use the removal tool (with the threaded end) to insert the inner contact, or you may damage the new inner contact.
3. Let go of the contact with tweezers and slowly insert the contact into the center conductor (see Figure A-17). As you install the contact, its fingers compress and the force required to insert it first increases and then decreases. When the insertion force begins to decrease, do not push too hard or you may damage the new inner contact or center conductor.
4. At the point that the contact snaps into place, stop pushing.
5. Carefully withdraw the insertion tool from the inner contact.
6. Under magnification, visually inspect the assembly and make sure the inner contact is properly installed (see Figure A-18).

Caution

Never apply either lubricant or adhesive to an inner contact.

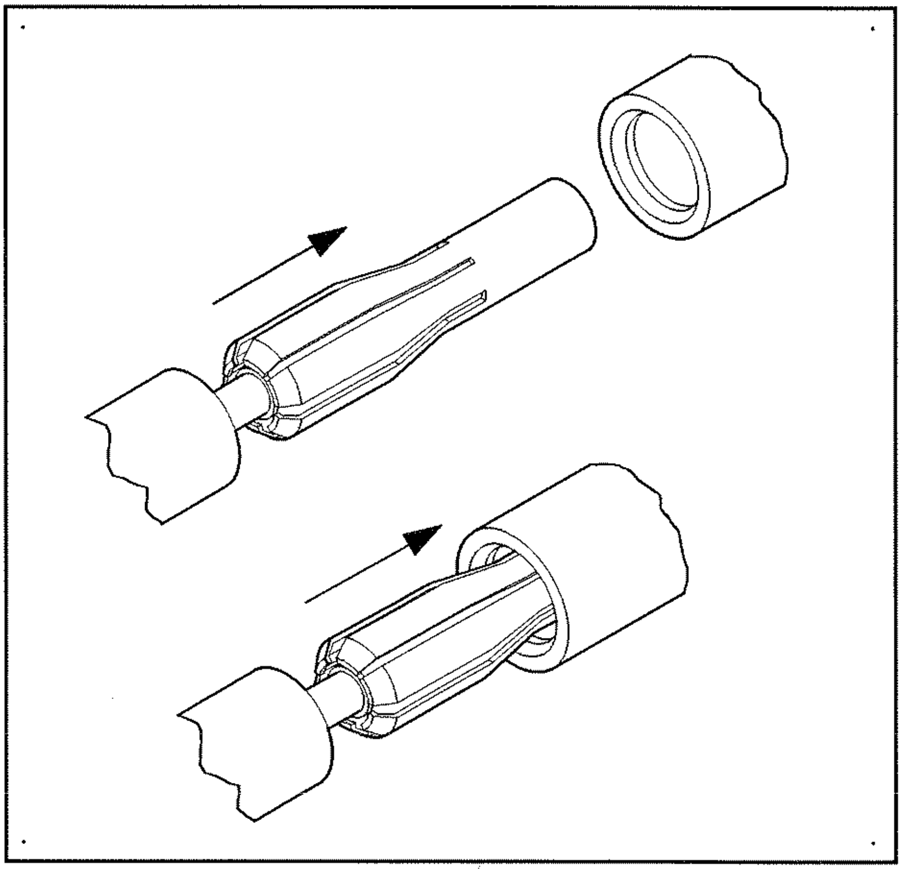


Figure A-17. Installing a New Inner Contact

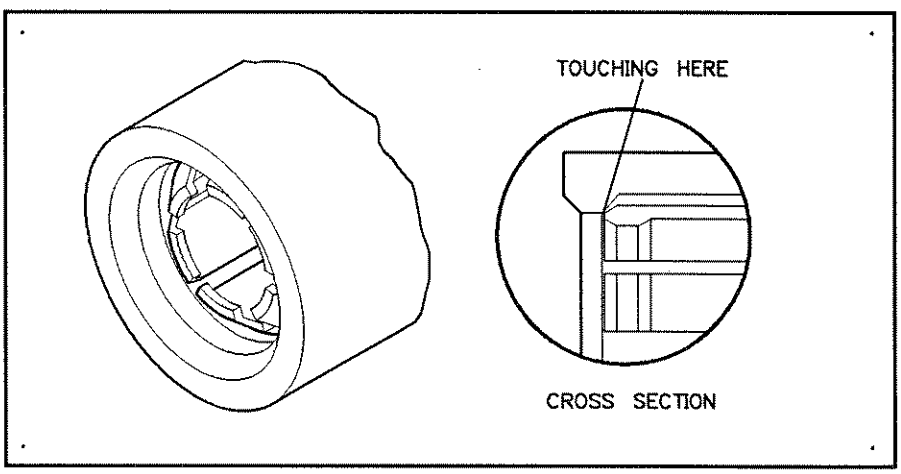


Figure A-18. Inspecting the Installation

Testing a Slotless Contact

After you install a new inner contact, you must test it using the tools provided in the repair kit.

1. Using a foam swab and alcohol, clean the testing tool.
2. Under magnification, carefully install the testing tool in the slotless contact assembly (see Figure A-19).
3. Repeat step 2 two more times.
4. Inspect the inner contact. If the fingers are damaged, remove and replace the inner contact.
5. Insert the testing tool.
6. With the testing tool inserted, turn the device upside down so that the testing tool hangs by the grip of the slotless contact.
7. Hook the testing weight to the testing tool.

   If the contact has the proper minimum retention force, it does not lose its grip.
8. Remove the testing weight.
9. Remove the testing tool.
10. Visually inspect the slotless contact.
11. If you see any dirt or metal particles, clean the contact using alcohol and foam swabs.
12. The clean, precision slotless connector is ready for use.

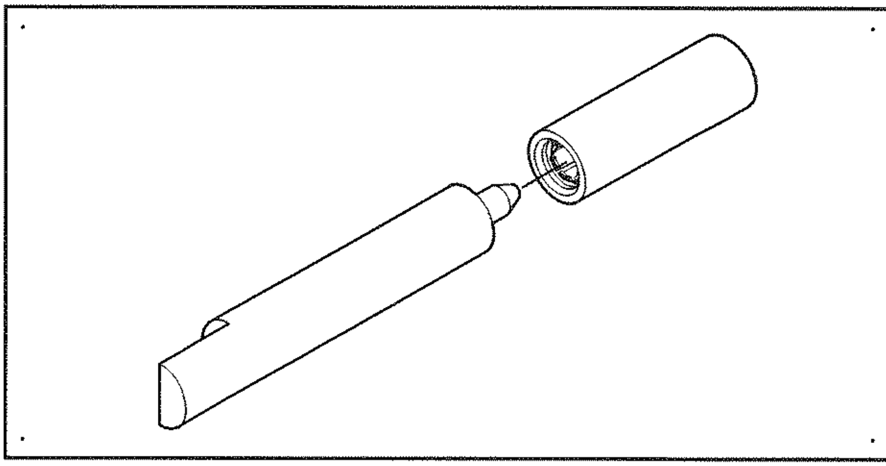


Figure A-19. Inserting the Testing Tool

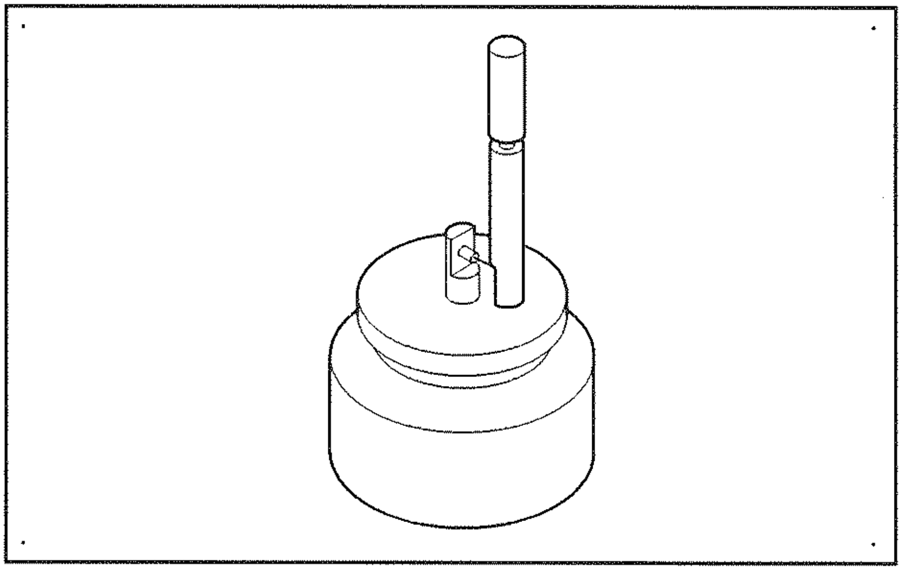


Figure A-20. Testing the Retention Force of the Contact

B

Accessories & Cleaning Supplies

Adapters

Table B-1 lists many of the adapters available from Hewlett-Packard. Use adapters for the following reasons:

- To reduce wear on an expensive or difficult to replace connector.
- To change the connector interface.
- When you measure a coaxial device that has an SMA connector.

  SMA connectors are:

  - Not precision mechanical devices.
  - Not designed for repeated connections.
  - Quickly worn out.
  - Easily out of specification.
  - Potentially destructive (because of the previous characteristics).

Precision 7 mm

The HP 85130B Adapter Kit

This adapter kit interfaces NMD-3.5 mm tests ports to 7 mm devices.

Directional Bridges

If you measure devices with SMA connectors at frequencies from 0.01 to 18 GHz, and can tolerate a slight loss in directivity, use a 7 mm directional bridge and 7 mm-to-3.5 mm adapters. The larger 7 mm connector is more durable than a 3.5 mm connector, and the adapters protect the bridge connectors.

Figure B-1 shows the typical directivity of HP 85021/27 directional bridges with and without connector-saver adapters.

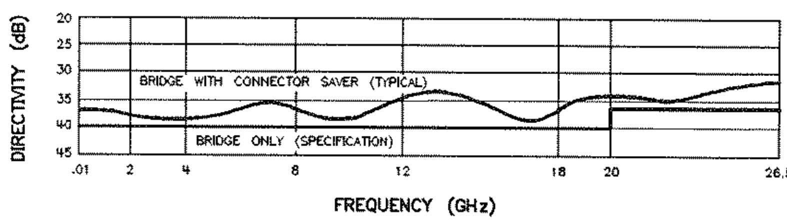


Figure B-1. Typical Directivity Using Connector-Saver Adapters

Precision 3.5 mm

Directional Bridges

If you measure devices with SMA connectors at frequencies from 0.01 to 26.5 GHz, and can tolerate a slight loss in directivity, use a 3.5 mm directional bridge and 3.5 mm-to-3.5 mm adapters. The adapters protect the bridge connectors.

Figure B-1 shows the typical directivity of HP 85021/27 directional bridges with and without connector-saver adapters.

Precision 2.4 mm

PSC 2.4 mm

2.4 mm-to-2.4 mm Adapters

Use high-quality precision adapters, sometimes called "connector savers," when you make more than a few connections. This protects the port connector from wear and accidental damage, and you need replace only a worn adapter.

Table B-1 lists 2.4 mm-to-2.4 mm adapters.

3.5 mm-to-2.4 mm Adapters

Using 3.5 mm-to-2.4 mm adapters (listed in Table B-1), you can connect a device or cable that has a precision slotless 2.4 mm connectors to a device or cable that has a precision 3.5 mm connector.

You can order other PSC-2.4 mm adapters, this section describes only the most frequently used.

Table B-1. Cleaning Supplies and Accessories

Item	HP Part or Model Number
Cleaning Supplies	
Compressed Air	8500-5262
99.5% Isopropyl Alcohol (8 oz)	8500-0559
99.5% Isopropyl Alcohol (30 ml)	8500-05344
Foam Swabs (500)	9300-1270
Alcohol Wipes	92193N
Lint-free Cleaning Cloth	9310-4242
Adapters	
7 mm to 7 mm	85050-60005
7 mm to type-$N_{(m)}$	11525A
7 mm to type-$N_{(f)}$	11524A
7 mm to PSC-N	85054-60031
7 mm to $SMA_{(m)}$	11533A
7 mm to $SMA_{(f)}$	11534A
7 mm to 3.5 $mm_{(m)}$	1250-1746
7 mm to 3.5 $mm_{(f)}$	1250-1747
7 mm to NMD-3.5 mm	85130-60003
7 mm to 2.4 $mm_{(m)}$	11902A
7 mm to 2.4 $mm_{(f)}$	11902B
7 mm to NMD-2.4 $mm_{(f)}$	85130-60014
Type-$N_{(m)}$ to Type-$N_{(m)}$	1250-0778
Type-$N_{(f)}$ to Type-$N_{(f)}$	1250-0777
Type-$N_{(m)}$ to $SMA_{(m)}$	1250-1636
Type-$N_{(f)}$ to $SMA_{(m)}$	1250-1562
Type-$N_{(f)}$ to $SMA_{(f)}$	1250-1772
Type-$N_{(m)}$ to 3.5 $mm_{(m)}$	1250-1743
Type-$N_{(m)}$ to 3.5 $mm_{(f)}$	1250-1744
Type-$N_{(f)}$ to 3.5 $mm_{(f)}$	1250-1745
Type-$N_{(m)}$ to 2.4 $mm_{(m)}$	11903A
Type-$N_{(m)}$ to 2.4 $mm_{(f)}$	11903D
Type-$N_{(f)}$ to 2.4 $mm_{(f)}$	11903B
Type-$N_{(f)}$ to 2.4 $mm_{(m)}$	11903C
PSC-$N_{(f)}$ to PSC-$N_{(f)}$	85054-60037
PSC-$N_{(m)}$ to NMD-3.5 mm	85054-60030
PSC-$N_{(f)}$ to NMD-3.5 mm	85054-60029
$SMA_{(m)}$ to $SMA_{(m)}$	1250-1159
$SMA_{(f)}$ to $SMA_{(f)}$	1250-1158
3.5 $mm_{(m)}$ to 3.5 $mm_{(m)}$	1250-1748
3.5 $mm_{(m)}$ to 3.5 $mm_{(f)}$	1250-1750
3.5 $mm_{(f)}$ to 3.5 $mm_{(f)}$	1250-1749
3.5 $mm_{(m)}$ to 2.4 $mm_{(m)}$	11901A
3.5 $mm_{(m)}$ to 2.4 $mm_{(f)}$	11901C
3.5 $mm_{(f)}$ to 2.4 $mm_{(f)}$	11901B
3.5 $mm_{(f)}$ to 2.4 $mm_{(m)}$	11901D
3.5 $mm_{(m)}$ to NMD-3.5 $mm_{(f)}$	85130-60006
NMD-3.5 $mm_{(f)}$ to PSC-3.5 $mm_{(f)}$	85130-60005
NMD-3.5 $mm_{(m)}$ to NMD-2.4 $mm_{(f)}$	85130-60010
PSC-3.5 $mm_{(f)}$ to NMD-2.4 $mm_{(f)}$	85130-60011
2.4 $mm_{(m)}$ to 2.4 $mm_{(m)}$	11900A
2.4 $mm_{(m)}$ to 2.4 $mm_{(f)}$	11900C
2.4 $mm_{(f)}$ to 2.4 $mm_{(f)}$	11900B
NMD-2.4 $mm_{(f)}$ to NMD-2.4 $mm_{(m)}$	85130-60015
NMD-2.4 $mm_{(f)}$ to PSC-2.4 $mm_{(f)}$	85130-60016
Bridge Connector-Savers	
3.5 $mm_{(m)}$ to 3.5 $mm_{(m)}$	85027-60002
3.5 $mm_{(m)}$ to 3.5 $mm_{(f)}$	85027-60003

Table B-1. Cleaning Supplies and Accessories (continued)

Item	HP Part or Model Number
Connector Gage Kits	
7 mm	85050-80012
Type-N	85054-60049
$SMA_{(m)}$	11752C Opt 001
$SMA_{(f)}$	11752C Opt 002
3.5 mm	11752D
3.5 $mm_{(m)}$	11752DZ
3.5 $mm_{(f)}$	11752DY
2.4 mm	11752E
2.4 $mm_{(m)}$	11752EZ
2.4 $mm_{(f)}$	11752EY
Connector Centering Beads	
Type-N	85054-80028
3.5 mm	85052-20057
2.4 mm	85056-20001
Protective End Caps	
7 mm	1401-0123
Type-$N_{(m)}$	1401-0124
Type-$N_{(f)}$	1401-0225
$SMA_{(m)}$, 3.5 $mm_{(m)}$, and 2.4 $mm_{(m)}$	1401-0208
$SMA_{(f)}$, 3.5 $mm_{(f)}$, and 2.4 $mm_{(f)}$	1401-00202
NMD-3.5 mm and NMD-2.4 mm	1401-0214
Torque Wrenches	
3/4-in 136 N-cm (12 in-lb)	8710-1766
5/16-in 56 N-cm (5 in-lb)	8710-1582
5/16-in 90 N-cm (8 in-lb)	8710-1765
20 mm 90 N-cm (8 in-lb)	8710-1764

Item	HP Part or Model Number
Open-End Wrenches	
7 mm	8710-1761
1/4-in	8720-0014
3/4-in	8720-0011
5/16-in	8720-0015
11/32-in	8720-0018
Spanner Wrench	
NMD-2.4 mm or NMD-3.5 mm	08513-20014
Miscellaneous Items	
Collet Extractor Tool	5060-80012
3.5 mm Slotless Contact Repair Kit	85052B Opt K11
7 mm Slotless Contact Repair Kit	85054B Opt K11
6-Slot Collet	85050-20001
Coaxial & Waveguide Measurement Accessories Catalog	5954-6401
Support Materials Organization Materials Handling and Packaging Guide	5181-1930
2.4 mm Adapters and Calibration Accessories Operating Note	11900-9003
Grounding Wrist Strap	9300-1367
5 ft Wrist-Strap to Table-Mat Grounding Cord	9300-1980
2 x 4 ft Conductive Table Mat & 15 ft Ground Wire	9300-0797
EDS Heel Strap	9300-1169
Hard-Surface Conductive Floor Mat	
4 x 5 ft	92175A
3 x 4 ft	92175C
Soft-Surface Conductive Floor Mat	
4 x 8 ft	92175B

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Hewlett-Packard Sales and Service Offices

IN THE UNITED STATES

California
Hewlett-Packard Co.
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Fullerton, CA 92631
(714) 999-6700

Hewlett-Packard Co.
301 E. Evelyn
Mountain View, CA 94039
(415) 694-2000

Colorado
Hewlett-Packard Co.
24 Inverness Place, East
Englewood, CO 80112
(303) 649-5000

Georgia
Hewlett-Packard Co.
2000 South Park Place
P.O. Box 105005
Atlanta, GA 30339
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Illinois
Hewlett-Packard Co.
5201 Tollview Drive
Rolling Meadows, IL 60008
(312) 255-9800

New Jersey
Hewlett-Packard Co.
120 W. Century Road
Paramus, NJ 07653
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Texas
Hewlett-Packard Co.
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Hewlett-Packard Inter-Americas
3495 Deer Creek Rd.
Palo Alto, California 94304

HP 8702 Operating and Programming Manual

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NOTE: UG = User's Guide
A = Appendix

REGIONAL SALES AND SUPPORT OFFICES

For information relating to Sales or Support of Hewlett-Packard products first contact your local Hewlett-Packard office listed in the white pages of your telephone directory. If none is listed locally, contact one of the addresses listed below to obtain the address or phone number of the Hewlett-Packard Sales or Support office nearest you.

ASIA
Hewlett-Packard Asia Ltd.
47/F, 26 Harbour Road,
Wanchai, **HONG KONG**
G.P.O. Box 863, Hong Kong
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Telex: 76793 HPA HX
Cable: HPASIAL TD

AUSTRALASIA
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31-41 Joseph Street
BLACKBURN, Victoria 3130
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Hewlett-Packard (Canada) Ltd.
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Hewlett-Packard France
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Telex: 6923 15F

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