Errata

Title & Document Type: 85070A Dielectric Probe Kit Operating and Service Guide

Manual Part Number: 85070-90001

Revision Date: April 1991

HP References in this Manual

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

About this Manual

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

Support for Your Product

Agilent no longer sells or supports this product. You will find any other available product information on the Agilent Test & Measurement website: www.tm.agilent.com.

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

Agilent Technologies

MANUAL CHANGES SUPPLEMENT

This supplement contains information to update your manual to match the latest revision of software. Make all changes applicable to your version of software.

To Make Sure You Have the Correct Manual

This supplement should be used with the following manual:

HP 85070A Dielectric Probe Kit
Manual Part Number: 85070-90001
Edition: 2
Date Printed: April 1991

To Update Your Manual

Verify that your software revision is the same as that given on the following page. Then use the information given on the following page to make changes in your manual.

Supplement Part Number: 85070-90011
Supplement Print Date: April 1992

HEWLETT PACKARD

To Verify Your Software Revision Number

The software revision number is printed on the label attached to the disk. If the revision number is A.01.09 *or greater*, make the following changes to your manual. If the revision number is smaller than A.01.09, your manual needs no changes.

Make These Changes

Where On the title page of your manual (the page in front of the "General Information" tab).

What To Do Change the software revision number to match the one printed on your software disk.

Where In the "Software Reference" chapter, under the "CALIBRATE MENU" heading.

What To Do Add a new feature, "Refresh cal ... " in the calibrate menu. A refresh calibration is an incremental calibration performed after a standard calibration procedure in order to adjust for changes in cable position or temperature. These changes would otherwise be reflected as errors in the measurement data. The refresh calibration only requires the measurement of a single standard (either air, short, or water) rather than the three standards normally required. When the refresh calibration is selected, the software prompts you to connect the currently defined refresh calibration standard. The refresh calibration selection only appears if there is a calibration active in the software.

Drawings of the HP BASIC and the MS-DOS versions of the refresh cal selection are provided on the following pages.

Where In the "Software Reference" chapter, under the "CALIBRATE MENU" and "Configure cal ... " headings.

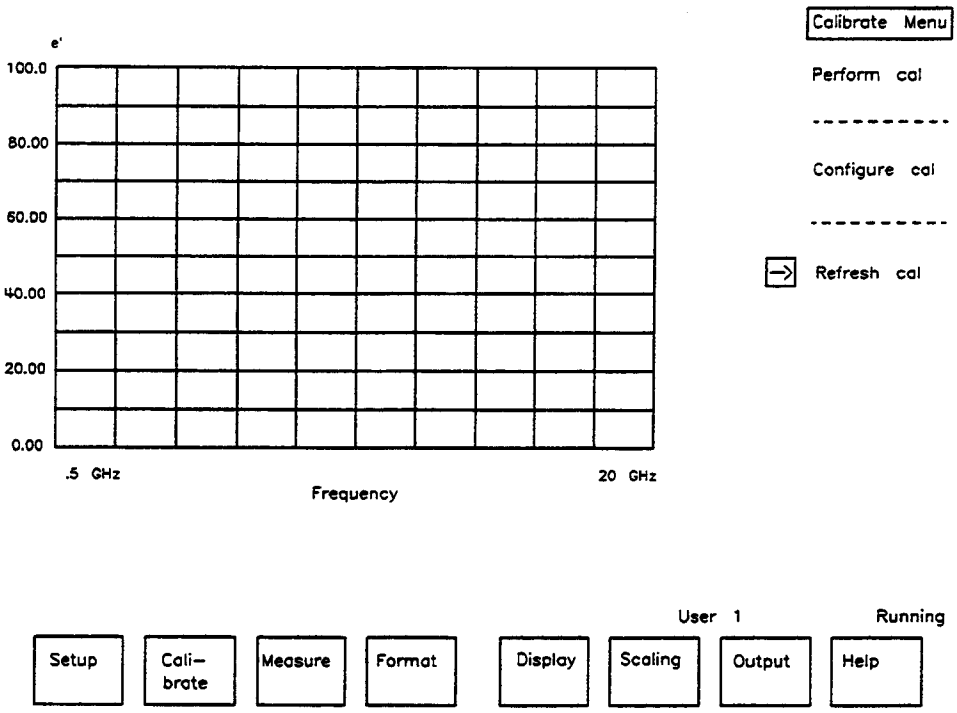
What To Do A new selection has been added to the HP BASIC version of the configure cal menu: "Def refresh std ... ". Use this menu to identify the refresh calibration standard. If you choose water as the standard, you must correctly define the water temperature in this menu.

Replace figure 8-6 (the configure cal menu) with the new figure provided with these instructions. A drawing of the HP BASIC version of the Def refresh std menu is also provided.

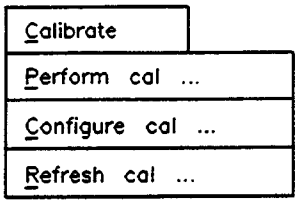
Where In the "Software Reference" chapter, under the "CALIBRATE MENU" and "Configure cal ... " headings.

What To Do The MS-DOS version of the configure cal dialog box has been modified to include the selections to define the refresh standard.

Replace figure 8-5 with the new figure provided with these instructions.



HP BASIC Version of Calibrate Menu With Refresh Cal Selection



MS-DOS Version of Calibrate Menu With Refresh Cal Selection

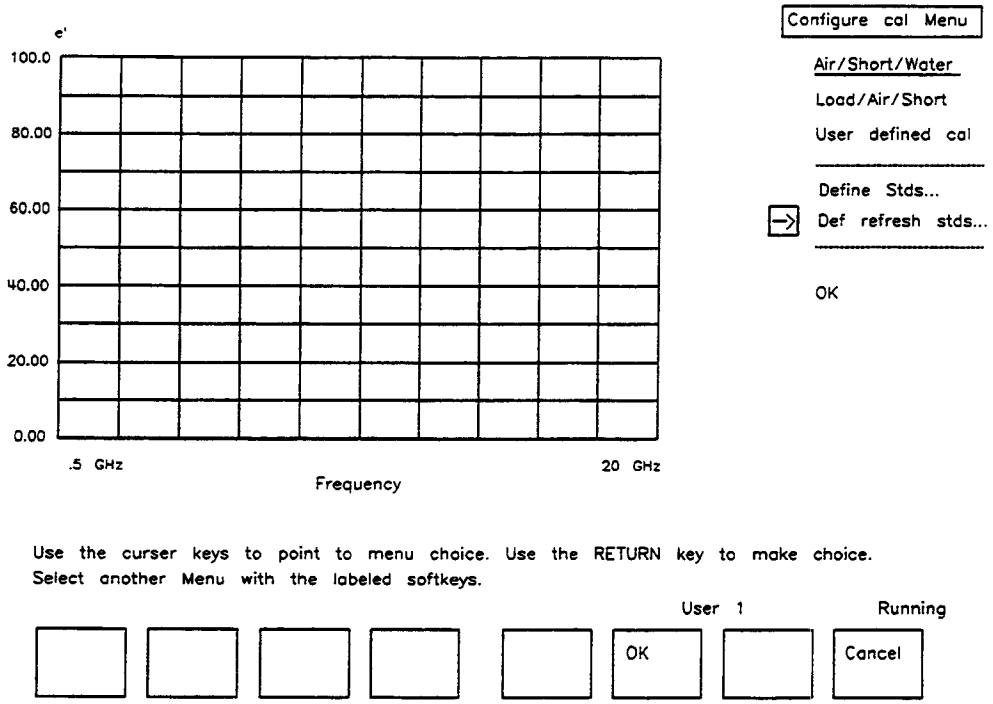
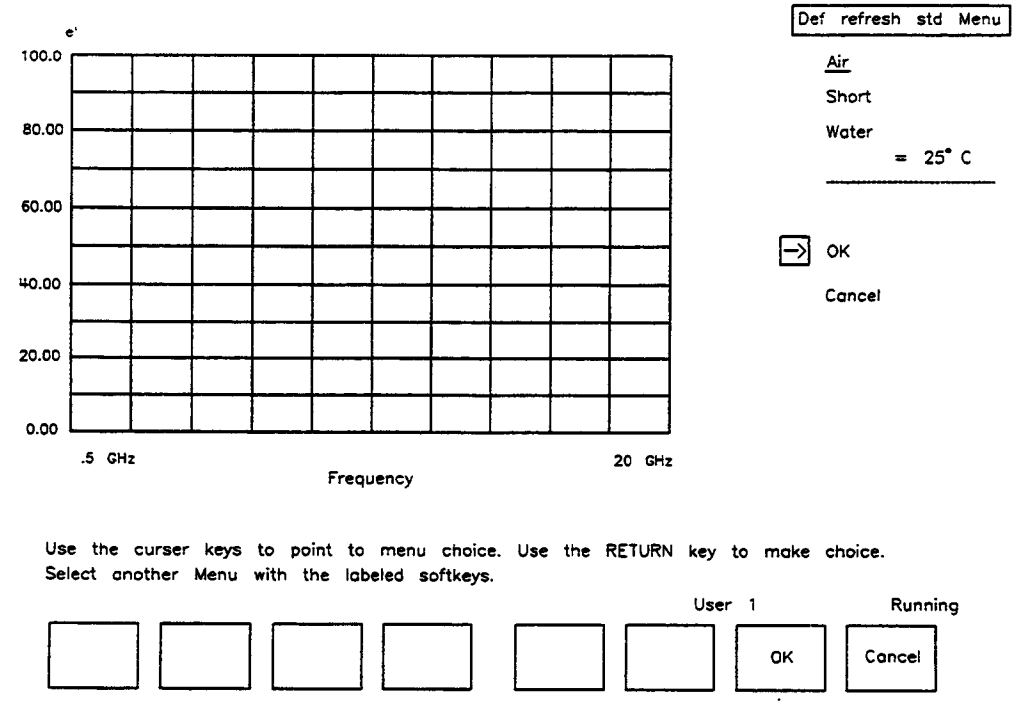


Figure 8-6. HP BASIC Version of Configure Cal Menu



HP BASIC Version of Def Refresh Std Menu

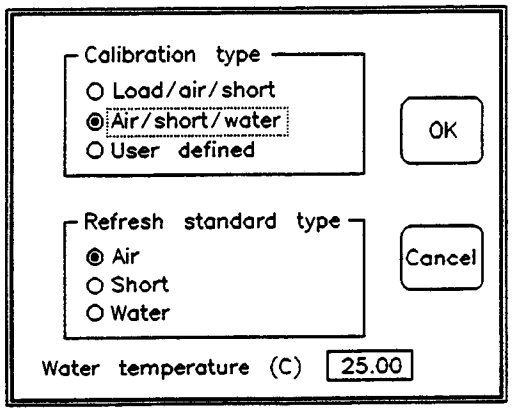


Figure 8-5. MS-DOS Version of Configure cal ... Dialog Box

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HP 85070A
DIELECTRIC PROBE KIT

SOFTWARE REVISION AND SERIAL NUMBERS

This manual applies directly to these HP 85070A dielectric probe kits:

Software revision 1.01

MS-DOS version: Microsoft Windows 3.0
HP BASIC version: all

Kit serial number prefix: 3033A and above

1400 FOUNTAINGROVE PARKWAY, SANTA ROSA, CA 95403 U.S.A.

MANUAL PART NO. 85070-90001
EDITION 2

Printed: APRIL 1991

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.

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

BP21.2

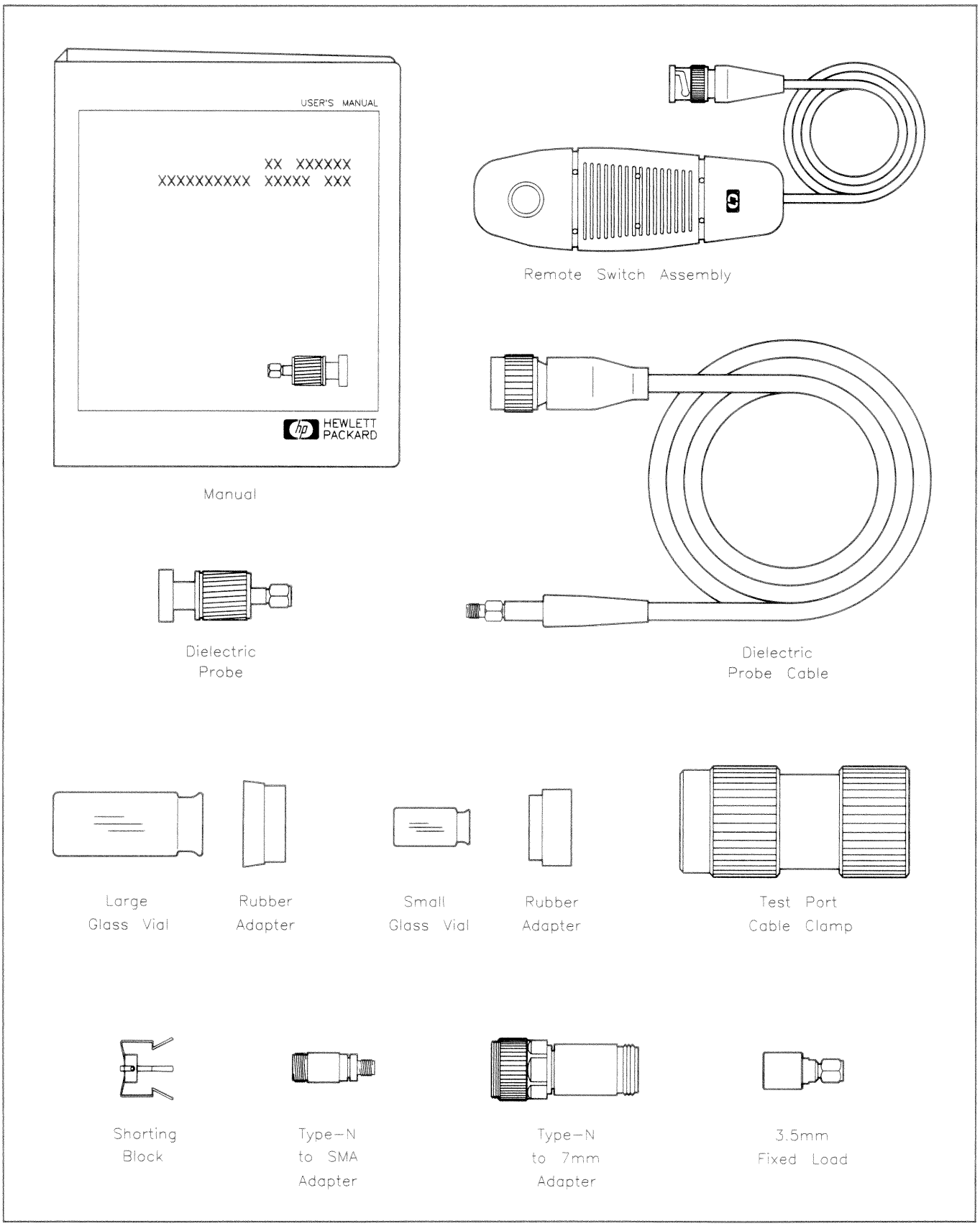

Figure 1-1

Chapter 1. General Information

INTRODUCTION

The HP 85070A dielectric probe kit allows measurements of the complex permittivity for a wide range of solid and liquid materials. It performs all of the necessary network analyzer control, calculation, and data presentation functions. The software controls the network analyzer to measure the complex reflection coefficient of the probe in the MUT (material under test). Then it converts the reflection coefficient into the complex permittivity of the MUT.

Finally it displays the measurement results in a variety of graphical and tabular formats. The software also facilitates printing or plotting the results, saving the results to disk, and saving test setups to disk.

The dielectric probe provides a convenient, repeatable method for measuring various dielectric materials. The convenience is a result of needing only to press the probe against (or immerse it in) the MUT to make a measurement. The probe is used with a vector network analyzer to take advantage of the analyzer's measurement flexibility, speed, and accuracy. Use of the vector network analyzer allows the software to calibrate out (as detailed later) a variety of measurement errors and thus enhance accuracy.

ITEMS SUPPLIED WITH THE KIT

As illustrated in Figure 1-1, these items constitute the HP 85070A dielectric probe kit:

- HP 85070A software disk (one 5.25 in high-density disk)*
- Microsoft® Windows version 3.0 **
- Dielectric probe
- Dielectric probe cable
- Remote switch assembly
- This manual
- 3.5 mm fixed load
- Shorting block and spring clip
- Test port cable clamp
- Small glass vial
- Large glass vial
- Type-N to SMA adapter
- Type-N to 7 mm adapter
- Rubber adapter for small vial
- Rubber adapter for large vial
- Rubber stopper, 2 mm vial

*With option 300, replaced with one 3.5 in double-sided, double-density disk.
** Not included with option 300.
Note: Microsoft® Windows and MS-DOS® are US registered trademarks of Microsoft Corporation

Before using the HP 85070A software, be sure that all of these items have been received and appear to be in good condition. Contact your Hewlett-Packard representative if any item is missing or appears to be damaged.

ABOUT THIS MANUAL

This manual is a complete guide to using the HP 85070A software and probe to make dielectric measurements. As outlined below, it explains how the system works, how to set it up, how to use the software, how to check the system, and where to find reference material.

General Information introduces the concept of material measurements with a network analyzer. It explains the functions of the analyzer, computer, software, and probe in making measurements.

Getting Started lists required system equipment; tells how to configure, load, and install the hardware and software; and presents operator interface techniques. It also discusses display organization (data presentation, entry prompts, instructions). At this point, the user is ready to make a measurement.

Measurement Tutorial provides a step-by-step, guided example of a calibration and measurement with the HP 85070A probe kit. First-time users are urged to perform the sample test procedures outlined in this chapter. This chapter is divided into MS-DOS® and HP BASIC sections.

Advanced Measurement Techniques describes several advanced aspects of using the software including alternative calibrations, permitivitty parameters, measurement uncertainty, how to import data into spreadsheets or word processors, and how to see the source code of the HP BASIC version (option 300 only).

In Case of Difficulty presents common measurement hang-ups and solutions, error messages and what to do about them, and helpful hints.

Operator's Check is a simple procedure to check the operation of the network analyzer and probe.

Ordering Supplies is a compendium of probe part and supply part numbers. It tells how and where to order them. It also contains a bibliography.

Software Reference is designed to serve as a reference for each function and setup parameter in the software. Each menu, menu choice, and entry parameter is explained in this chapter.

Index lists the words, topics, softkeys, hardkeys, and error messages of the software and this manual.

Glossary defines important words and concepts of this manual.

What This Manual Covers

This manual covers dielectric probes and software shipped with the serial number listed on the title page of this manual. The serial number plate is located on the dielectric probe software box and resembles the figure below.

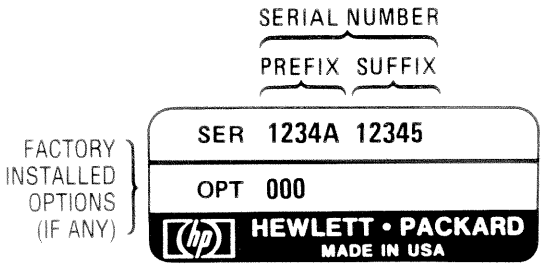

Figure 1-2. Typical Serial Number Plate

DESCRIPTION OF THE DIELECTRIC PROBE KIT

Two versions of the software allow use of either IBM-AT compatible or HP 9000 series 300 computers.

The MS-DOS version of the software (standard) features the clean look of the Windows environment. This version is for IBM-AT compatible machines such as the HP Vectra. It uses a mouse for most commands and entries. It is not user-modifiable.

The HP BASIC version of the software (option 300) features a Windows-like presentation. This is the HP 9000 series 300 (or IBM-AT with Viper Card) version. The user interface portion of the source code may be customized for your individual application. It uses softkey menus for most commands and entries.

Software Features

- Completely controls the network analyzer.
- Guides you through calibration and measurement.
- Automatically computes permittivity (e').
- Offers a variety of data formats and displays.

EQUIPMENT REQUIRED

The equipment required to operate a dielectric measurement system is detailed in chapter 2, "Getting Started."

Recommended Test Equipment

Neither the probe nor the software have any adjustments or repairable parts, so test equipment is required for the other system instruments only. Refer to the appropriate manuals for recommended test equipment.

INSTRUMENT SPECIFICATIONS

Construction materials: stainless steel and polystyrene
Flatness: 100 microinches, typical, over-lapped surface
Temperature, operating and storage: 0°C to 55°C
Pressure: 200 psi, maximum
Shock: 1000 g's
Chemical resistance: The probe is compatible with most materials and liquids and is resistant to strong acids. However, these materials will cause degradation and should be avoided: aromatic hydrocarbons, chlorinated hydrocarbons, and ketones. In particular, avoid materials that might distort or damage polystyrene.

Chapter 2. Getting Started

INTRODUCTION

This chapter details system hardware and software requirements, installation of software and hardware, loading and starting the HP 85070A software program, and basic operator interface techniques. The techniques cover how to use the keyboard, a mouse, softkeys, menus, and dialog boxes. The chapter also illustrates fundamental displays of the software program.

Section 1 of this chapter is for users of the MS-DOS (standard) version of the software. If your system supports Windows with MS-DOS on an HP Vectra, IBM-PC/AT, or equivalent computer, continue with section 1, below.

Section 2 of this chapter is for users of the HP BASIC (option 300) version of the software. If your system uses HP BASIC on an HP 9000 series 300 computer, an HP Vectra with a Viper card, or an IBM-PC/AT with a Viper card, skip to section 2 of this chapter.

By the time you have finished this chapter, your dielectric probe measurement system should be up and running, you should understand how to use the software, and you should know how to manipulate measurement data. You will be ready to make the measurements given as examples in the "Measurement Tutorial" chapter.

SECTION 1: MS-DOS VERSION OF THE SOFTWARE

To run the MS-DOS version of the HP 85070A software program, you must have a windows-compatible computer as defined below. Additionally, you should be familiar with basic Microsoft-DOS (MS-DOS) operations. Refer to the MS-DOS manuals if you are not familiar with operations such as copying files, displaying the directory of a floppy or hard disk, creating directories on a floppy or hard disk, or typing commands at the DOS prompt.

SYSTEM REQUIREMENTS

The system must use the computers, software, interfaces, and printers and plotters mentioned below.

Computer

The system computer must be capable of running Microsoft Windows version 3.0, typically most IBM-PC/AT fully compatible machines with 80286 or 80386 microprocessors, such as the HP Vectra. The computer must be configured with:

- 640 KBytes (minimum) of RAM (Random Access Memory)
- High density 5-1/4'' flexible disk drive
- 20 MByte (minimum) hard disk drive
- EGA or VGA compatible graphics
- Microsoft Windows compatible pointing device (a mouse)
- Coprocessor (recommended)

Software

- MS-DOS disk operating system (version 3.20 or higher)
- Microsoft Windows (version 3.0, supplied)

IEEE-488 (HP-IB) Interface

The system computer must have one of these software-supported IEEE-488 interfaces to control the network analyzer:

- HP 82335A HP-IB Interface
- HP 82990A HP-IB Interface
- National Instruments AT-GPIB Interface
- National Instruments GPIB-II or GPIB-IIA Interface

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

Printers and Plotters

Any printer or plotter that is supported by Microsoft Windows should be supported by the HP 85070A software. Note that Windows supports peripherals connected to serial or parallel interfaces only. Windows does not support printers or plotters connected on the HP-IB IEEE-488 interface. Nonetheless, HP-IB data transfers to printers and plotters have been successful with the HP 82335A HP-IB interface. If you want to try this approach, refer to the interface documentation.

Printers can be used to get tabular listings of measurement results or printer facsimiles of displayed graphical data.

Plotters can also be used to get hardcopy graphical data.

Network Analyzer and Test Set

The HP 85070A software is designed to work with the network analyzer configurations described below. The default HP-IB address is 16.

- HP 8752A: this 300 kHz to 1.3 or 3 GHz network analyzer contains a reflection/transmission test set as part of the analyzer. No other instrumentation is needed to make measurements.
- HP 8753A, HP 8753B, HP 8753C: these 300 kHz to 3 or 6 GHz network analyzers need a companion test set for operation with the software. The following test sets are supported:

  HP 85044A reflection/transmission test set
  HP 85046A S-parameter test set
  HP 85047A S-parameter test set for operation to 6 GHz.
- HP 8719A, HP 8720A or B: these 130 MHz to 13.5 or 20 GHz work analyzers contain S-parameter test sets as part of the analyzer. No other instrumentation is needed to make measurements.
- HP 8510B: this network analyzer requires a companion test set and a source for operation with the software. Frequency range is determined by the test set and source. All test sets supported by the HP 8510B are supported by the software. The source must be synthesizer based. The HP 8340, HP 8341, or HP 8360 family sources are supported by the software. HP 8510B firmware revision 5.0 or higher is recommended.

NOTE: the HP 8510A is not supported by the software but can be upgraded to an HP 8510B with the HP 85103A or B upgrade kit.

INSTALLATION

First Microsoft DOS, then Windows, and finally the HP 85070A software must be installed on the hard disk to run the dielectric measurement program.

Microsoft DOS Installation

Microsoft DOS version 3.20 or higher must be installed on the computer's hard disk. If you are configuring the computer for the first time or installing a new version of DOS, refer to the Microsoft DOS installation documentation.

Microsoft Windows Installation

Microsoft Windows is an extension of the MS-DOS operating environment and features a sophisticated graphical user interface. Version 3.0 must be installed on the computer's hard disk to install and run the HP 85070A dielectric probe software.

To install Windows, run the SETUP program provided with Windows. The SETUP program will ask what type of computer, keyboard, mouse, display, and peripherals are in the system. If the information provided by the SETUP program is insufficient or confusing, refer to the Windows documentation for details.

If your dielectric measurement system includes a printer or plotter and you are not familiar with how to install it, do not install it now. It is more easily installed later when Windows itself is installed and running. When the SETUP program prompts you to install a printer or plotter, select "Continue." You will be directed to install the printer or plotter.

If you want to install your printer or plotter now, keep in mind the following:

- You must specify which printers and plotters are to be used when running the dielectric measurement program.
- You must load drivers for any printers or plotters with the SETUP program.

It is recommened that you let the SETUP program alter the system's AUTOEXEC.BAT file so that Windows can be run from any directory in the system.

HP 85070A Software Installation

The HP 85070A software is provided on one floppy disk. That disk contains four files:

READ.ME describes the files on the disk and the installation procedure (repeated below).
HP85070.HP is the software program designed to operate with the HP 82335A and HP 82990A interfaces.
HPIB.DLL is a second file (a dynamic link library) required for use with either of the above HP interfaces.
HP85070.NAT is the software program designed to operate with the National Instruments AT-GPIB, GPIB-II, and GPIB-IIA interfaces.

You must copy one or two files to the hard disk for program operation.

To copy the file(s) from the floppy disk (assumed to be system disk A) to the hard disk (assumed to be C), follow these instructions:

1. Insert the HP 85070A program disk in the floppy disk drive.
2. On the hard disk, make a directory dedicated for HP 85070A files. At the DOS prompt, type:

   `MKDIR C:\MATERIAL` and press (ENTER)

   If your system uses an HP interface card, continue with step 3a. (Otherwise continue with step 4a.)

For HP 82335A and 82990A Interface Card Systems:

3a. Copy the program from the floppy disk to the hard disk. At the DOS prompt, type:

`COPY A:\HP85070.HP C:\MATERIAL\HP85070.EXE` and press (ENTER)

3b. The HPIB.DLL file must be copied into a directory included in the DOS PATH. (The DOS PATH is typically set up by the AUTOEXEC.BAT file during bootup of the PC.) To see the directories in the DOS PATH, at the DOS prompt, type:

`PATH` and press (ENTER)

Copy the HPIB.DLL file to a directory in PATH. For instance, to copy the file to the WINDOWS directory, at the DOS prompt, type:

`COPY A:\HPIB.DLL C:\WINDOWS\HPIB.DLL` and press (ENTER)

3c. Add an EMMEXCLUDE line to the [386ENH] section of your SYS.INI file to exclude the memory range of the HP-IB card. Add a line like the following whether or not you load an expanded memory manager (EMM) driver (step 3d). For example, with the card at select code 7, include this line:

```
EMMEXCLUDE=0DC00-0E000
```

3d. If your system includes an EMM, modify the CONFIG.SYS file to exclude the memory range used by the interface card. Several examples follow, but each EMM uses its own syntax, so you may need to refer to the EMM documentation. The examples are for the HP-IB card at select code 7.

For HPEMMGR, the modification is: `DEVICE=HPEMMGR.SYS X=DC00-DFFF`

For EMM386, the modification is: `DEVICE=EMM386.SYS X=DC00-DFFF`

For HPEMM386, the modification is: `DEVICE=HPEMM386.SYS EXCLUDE=DC00-E000`

3e. Use the Windows Setup Program to enable the Program Manager to run the HP 85070A application (see the Microsoft Windows User's Guide). Put the original floppy disk away for safe keeping.

For National Instruments AT-GPIB, GPIB-II, or GPIB-IIA Interface Card Systems:

4a. Copy the program from the floppy disk to the hard disk. At the DOS prompt, type:

`COPY A:\HP85070.NAT C:\MATERIAL\HP85070.EXE` and press (ENTER)

4b. Install the interface card by following the directions in "Using Your GP-IB Software with Microsoft Windows" (a manual supplied with the card). Note that both the interface card and the GP-IB software must be versions that operate under Windows 3.0. In case of difficulty, or to arrange for an upgrade, contact National Instruments.

4c. Use the Windows Setup Program to enable the Program Manager to run the HP 85070A application (see the Microsoft Windows User's Guide). Put the original floppy disk away for safe keeping.

Hardware Installation

Connect the computer, network analyzer, cable, remote trigger, probe, and peripherals, as shown below. For HP 8753 systems, refer to the network analyzer documentation to connect the test set. For HP 8510 systems, refer to the network analyzer documentation to connect the test set and source.

Table 2-1. Adapters Required for Various Network Analyzer/Cable Configurations

Network Analyzer (and Test Set)	Cable	
	8120-5424 or HP 85131E opt C52	HP 85131E
HP 8752	Direct	Not recommended
HP 8753 HP 85044 HP 85046 HP 85047	Type-N to 7mm (supplied)	Not recommended
HP 8719 HP 8720	Type-N to SMA (supplied)	Direct
HP 8510 HP 8514 HP 8515	Type-N to SMA (supplied)	Direct

Cable stability and connection integrity is crucial to accurate, repeatable measurements. The cable clamp is an important part of the measurement system as it prevents the cable from loosening at the test port connector.

When connecting the probe cable to the network analyzer, first slide it through the test port cable clamp. The cable end to be connected to the network analyzer should emerge through the end of the clamp with the rectangular cutout. Connect the cable to port 1 of the network analyzer (or test set, if they are separate instruments). Torque the connector to five inch-pounds. Then slide the cable clamp against the front panel and hand-tighten it firmly to prevent cable rotation.

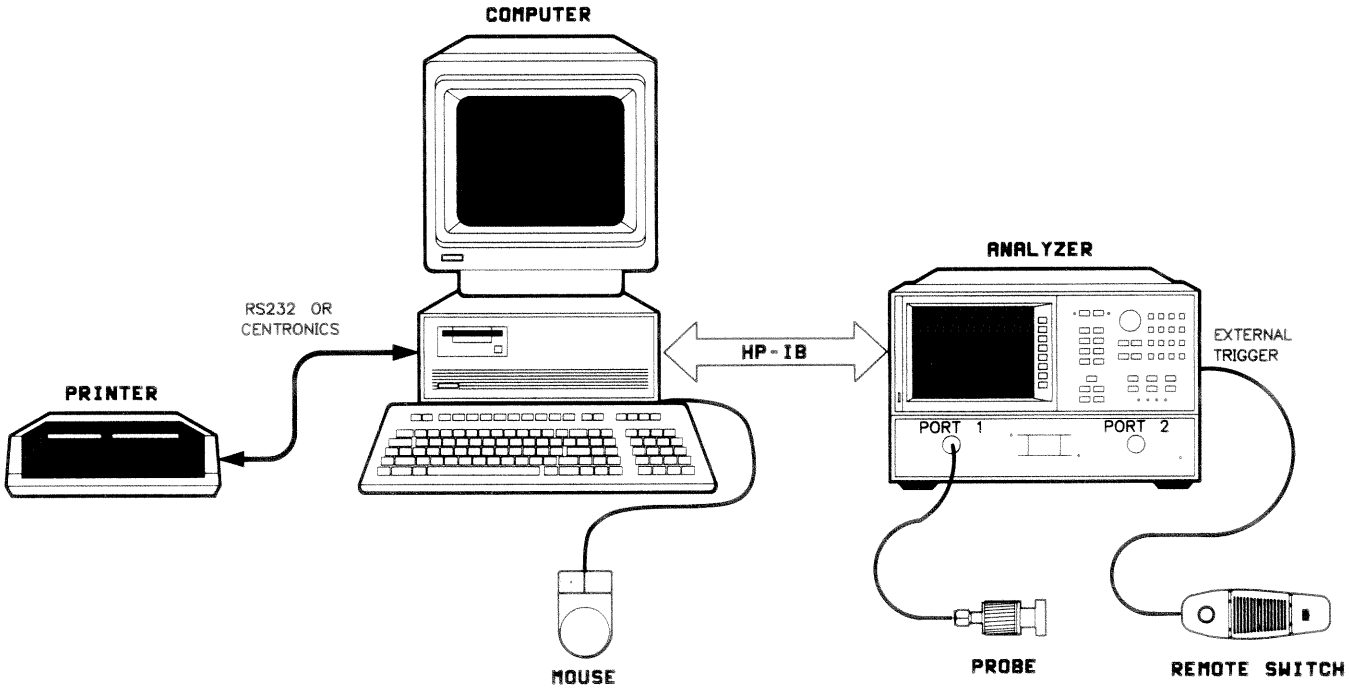

Figure 2-1. Connection Diagram

If your system uses a printer (or plotter, the term is used generically) and you know how to connect it to the computer, do so now. Otherwise connect it later, when directed.

STARTING THE HP 85070A SOFTWARE

1. Start up Windows; at the DOS prompt, type:

```
WIN
```

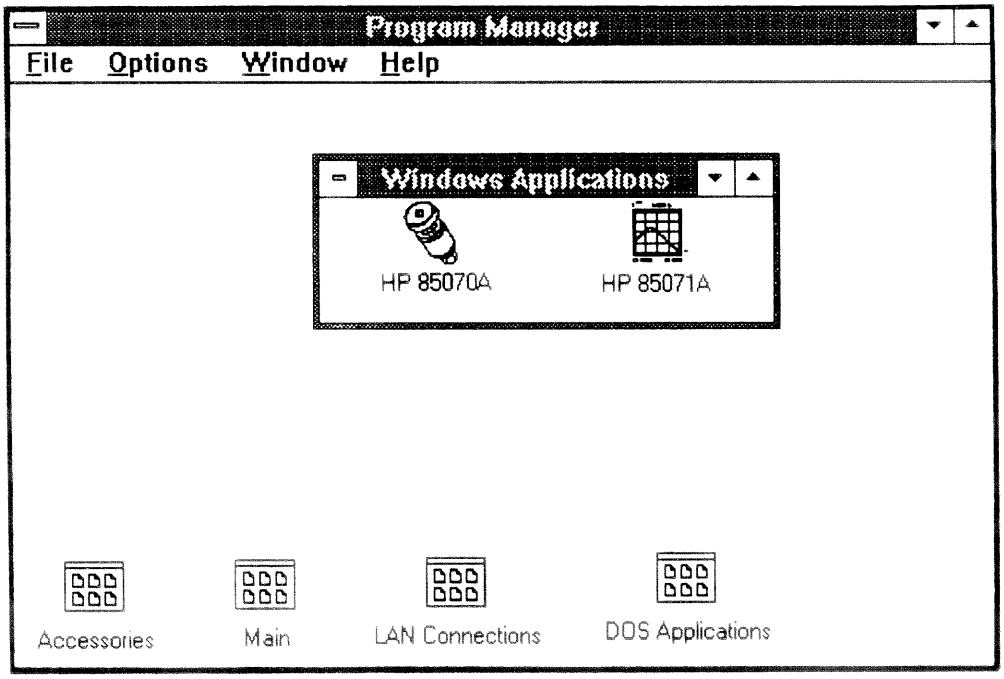

Figure 2-2. Windows Program Manager System

2. Double-click on the HP 85070A icon to start the program.

3. The HP 85070A program's copyright screen will now appear displaying the copyright statement. The statement disappears as soon as the mouse button is clicked with the pointer in the OK box.

WINDOWS COMPATIBLE SOFTWARE OPERATION

The HP 85070A dielectric probe software is ready for operation when the copyright statement is replaced with the main menu screen.

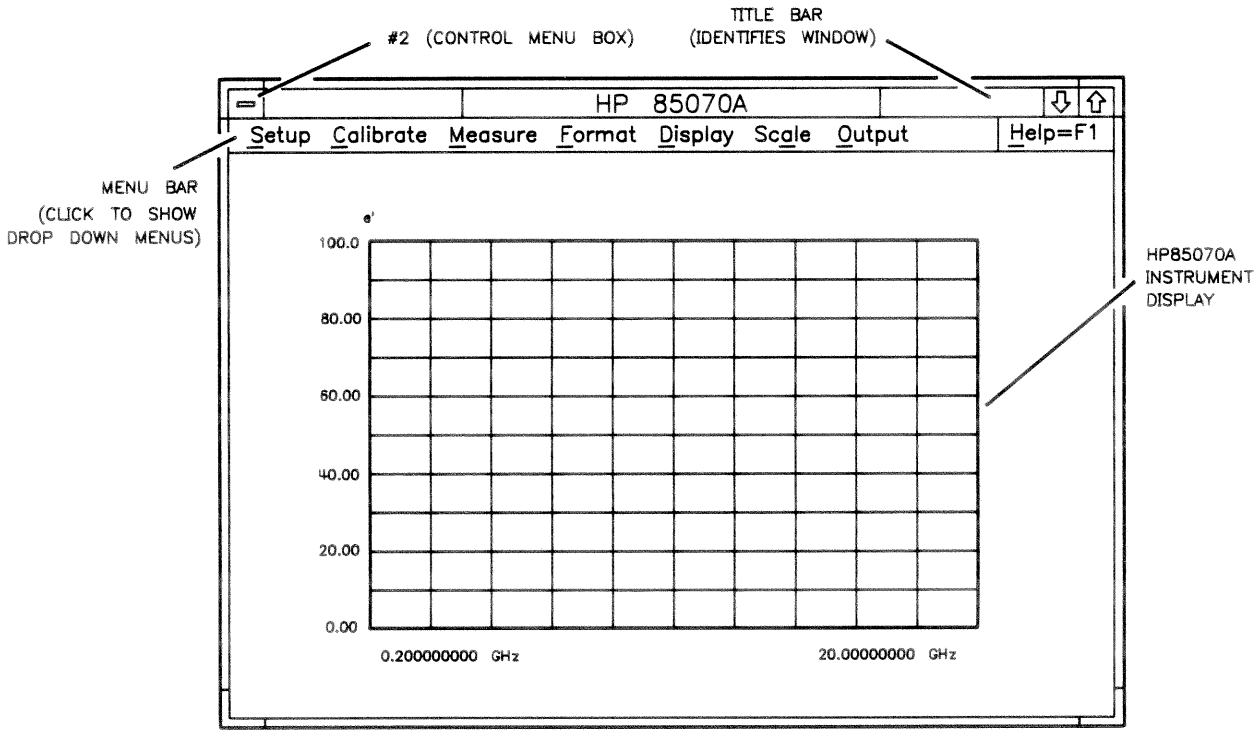

Figure 2-3. Main Menu Screen

Microsoft Windows Basics

Using the HP 85070A dielectric measurement software is very similar to using other Microsoft Windows application programs. Windows techniques for running application programs include using a mouse, choosing commands from menus, working with dialog boxes, and selecting files. Documentation provided with Windows gives a complete description of the techniques for using Windows. In this section a very brief overview of basic Windows techniques is presented.

What Is a Window? A window is an area on the screen that displays a running (open) application program. More than one application can run and be displayed at the same time. Additionally, open windows can be stored as icons at the bottom part of the screen. This way, an application can be kept open without showing it as a window in the work area. Each window is divided into several areas, as shown below.

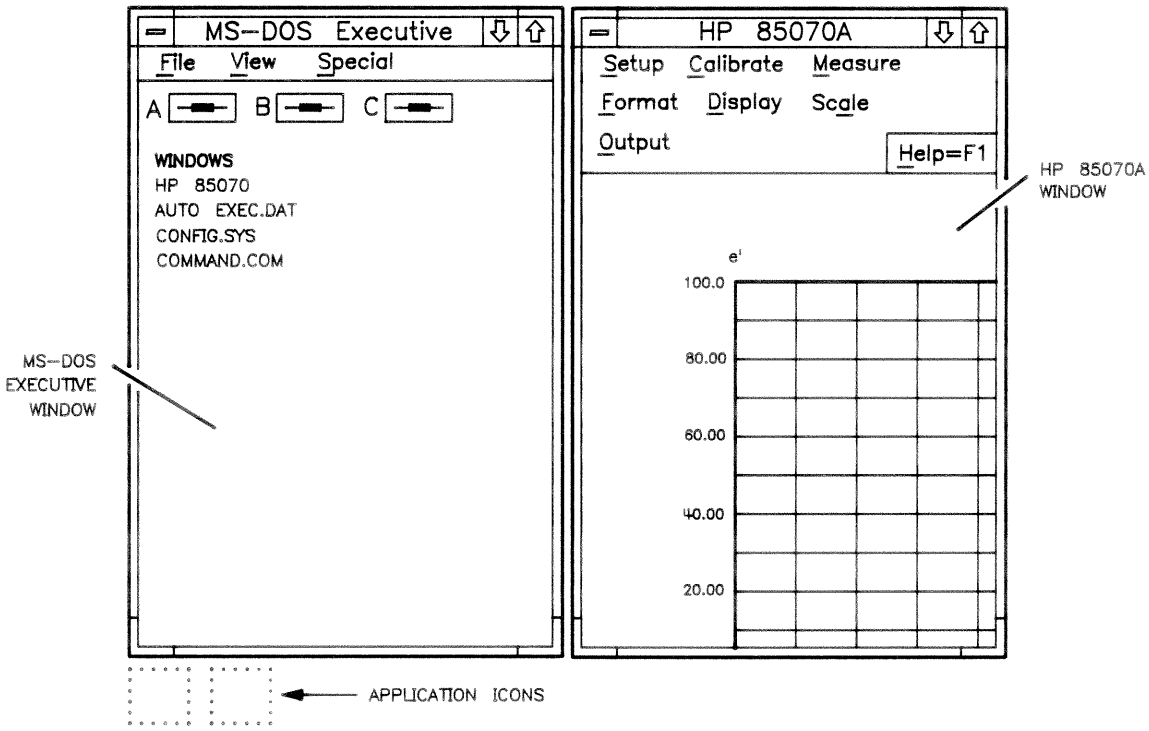

Figure 2-4. Graphic Showing a Window, Work Area, and Application Icon

How to Use a Mouse. A mouse is a hand-held pointing device. As the mouse is moved across the desk, a pointer moves on the screen. Mice have one, two, or three buttons. All HP 85070A software actions require only one button, the main mouse button. This is the left-most button on the mouse. However, on multi-bottoned mice, you can use the right-most button to trigger a measurement.

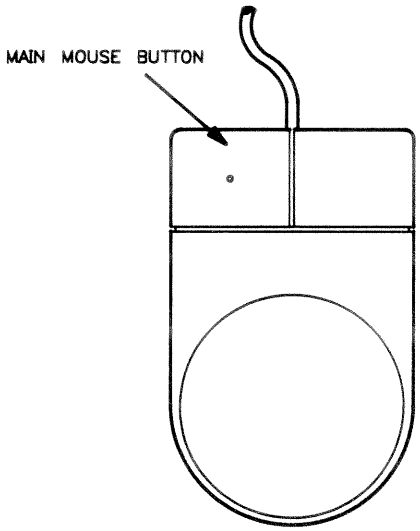

Figure 2-5. Mouse and Location of Main Mouse Button

These terms describe operations with the mouse:

Point to move the tip of the mouse pointer on top of something on the screen.

Click to quickly press and release the mouse button.

Double-click to quickly press and release the mouse button twice in succession.

Drag to hold down the mouse button, move the mouse until the pointer is at the desired location, then release the main button.

Release to quit holding down the mouse button.

Select to point on a menu.

How to Use Drop-Down Menus. Drop-down menus are lists of commands that drop down from the top of the screen when selected. The names of the software menus appear on the menu bar at the top of the window displaying the HP 85070A application program.

To select a menu, point to the name of the menu and click the mouse button. Or press the Alt (alternate) key and the underlined letter in the name of the menu. (For example, press Alt and "s" for the Setup menu.) The menu will drop down on the screen.

To choose a command, point to the name of the command on the menu and click the mouse button. Note that commands that appear in gray do not currently apply and can not be choosen.

Another way to choose a command is to use an accelerator key on the keyboard. Accelerator keys are identified with a "^" symbol on menus to the right of some of the commands. To carry out a command with an accelerator key, press the Ctrl (control) key simultaneously with the accelerator key.

Commands can also be carried out by pointing to the desired menu, dragging the mouse downward to point to the desired command, and then releasing the mouse button.

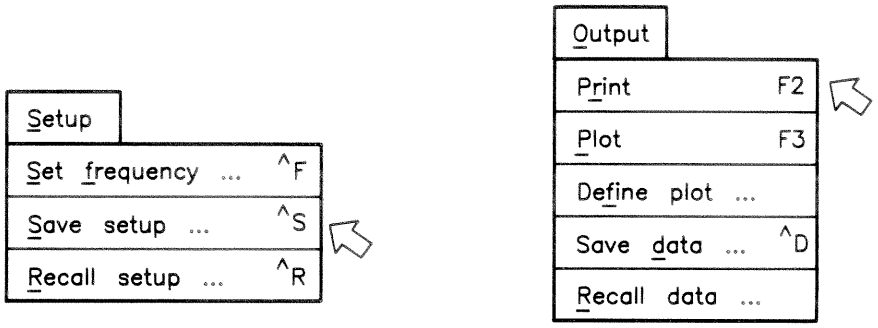

Figure 2-6. A Drop-Down Menu and Highlighted, Selected Command

How to Use Dialog Boxes. A dialog box is a request from the program for information required to carry out a command. Commands that end in an ellipsis (...) indicate that a dialog box is presented when the command is selected. Dialog boxes must be filled in before proceeding with program operation. Some dialog boxes require that you type in text, others allow you to select options within the dialog box.

To exit a dialog box, select ***[OK]*** or ***[Cancel]***. OK keeps all of the changes made in the dialog box. Cancel leaves the dialog box without changing anything.

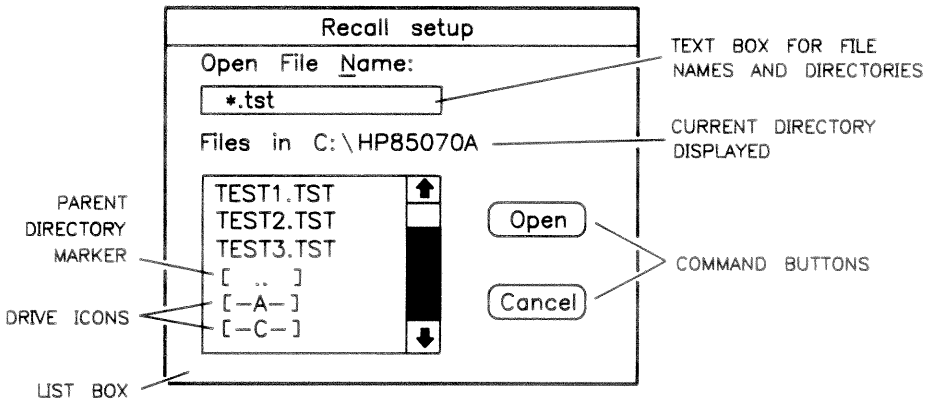

Figure 2-7. Sample Dialog Box and Types of Controls

How to Use Dialog Boxes with File Names. Any time a test setup or data file is to be saved or recalled from disk, the program displays a dialog box. Save and recall dialog boxes contain two other types of boxes.

List boxes display file names and directories on the chosen disk (drive).

To change the disk drive, double-click on the drive name (for example, [-A-]).

To scan the directory, click the arrows on the scroll bars.

To display the files in a directory, double-click on the parent directory marker (the directory is one level higher in the system's disk directory organization).

To save or recall a file, double-click on the desired file name.

Any of these operations can also be performed by clicking once in the list box then pointing the mouse to ***[OK]*** and clicking the mouse button.

Text boxes provide a space to type directories or file names from the keyboard.

To see all of the files in a new directory, type the directory name in the text box. Then click ***[OK]***.

A file name can be typed into the text box. It can begin with a drive letter followed, if needed, by a directory name. The file name itself is usually followed by a three-character file extension. A period separates the file name and extension. For example, C:\WINDOWS\HP85070\TEST1.TST is a valid file name.

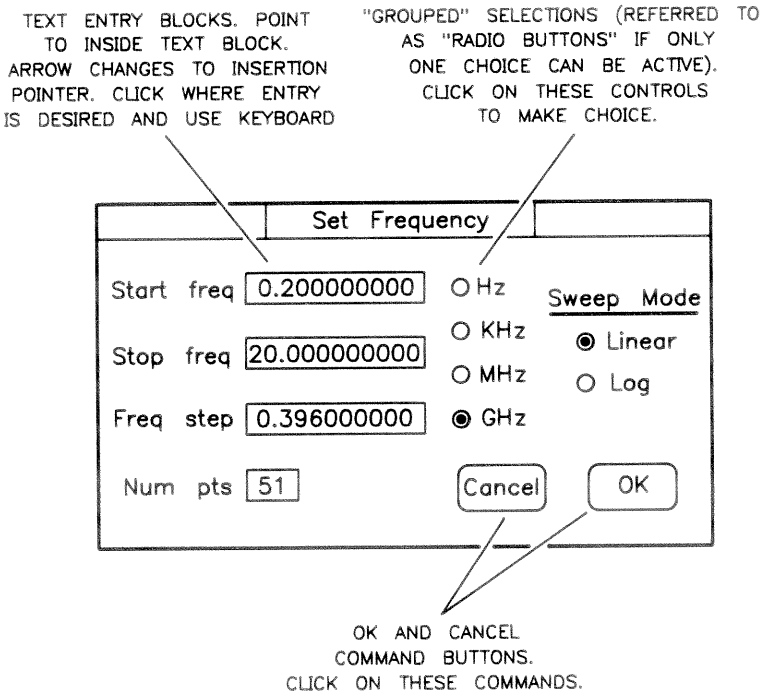

Figure 2-8. The Dialog Box and Types of Controls

HP 85070A Windows Software Fundamentals

The HP 85070A dielectric probe software program is a Windows application program. The techniques for using the HP 85070A software are the same as the techniques used for running other Windows application programs. The HP 85070A display window and its components are shown below.

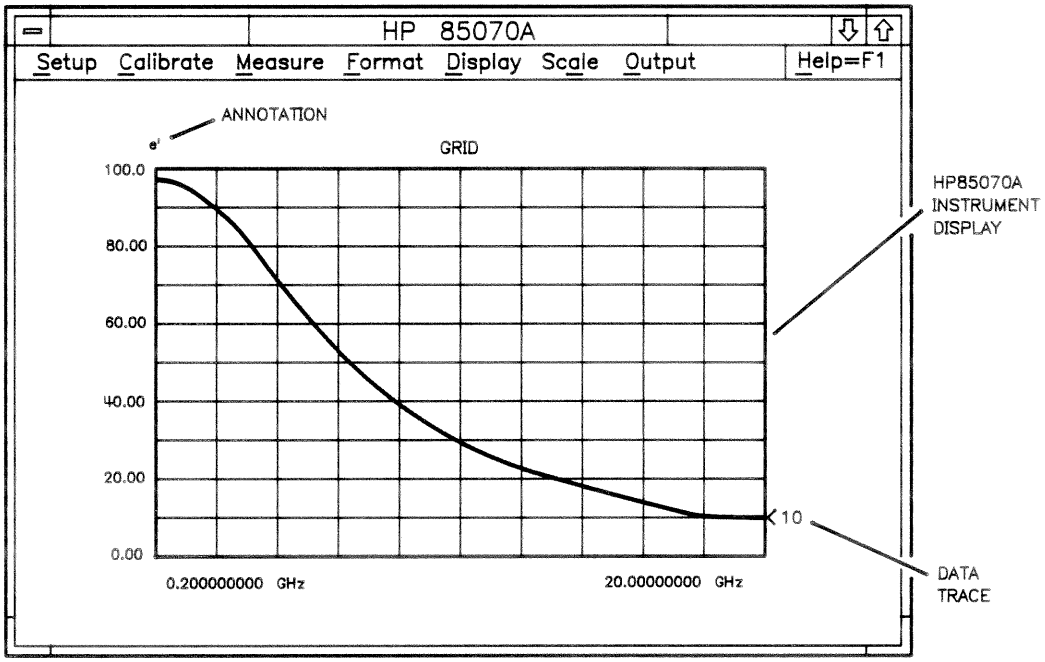

Figure 2-9. Functions of Principal Screen Components of Main Menu

The instrument display is always present in the window. Most of the time the instrument display presents measurement data as a graph. However the data can also be presented as a tabular listing. These terms define components of the instrument display:

Grid is composed of the x-axis and y-axis lines on which the data is plotted.

Traces are graphs of measurement data. They are the measured values of permittivity plotted on the grid.

Annotation is the text on the instrument display which describes the frequency range of the measurement, the permittivity of the MUT, the format of the display, the scaling of the display, and any display titles.

How to Exit the Program. To exit the program, point at the small box in the upper left-hand corner of the display and click the main mouse button.

Conclusion

Now that you have installed the software and hardware, loaded the program, and learned the basic operator interface techniques, you may be ready to make a measurement. If you still need to install a printer or plotter, continue with "Tips for Using Printers and Plotters under Microsoft Windows." Otherwise, continue with section 1 of the next chapter, "Measurement Tutorial."

TIPS FOR USING PRINTERS AND PLOTTERS UNDER MICROSOFT WINDOWS

The following information applies generally to any printer (or plotter, the term is used generically) and any MS-DOS personal computers running Microsoft Windows. Therefore, it does not give exact instructions, but rather lists general issues that must be addressed to print successfully.

At best hooking up a printer to a computer is as simple as connecting the two with a cable. However, computers and printers are each designed for maximum flexibility, so that each can be configured for a particular system or purpose. Unfortunately, this means that both must be configured correctly to communicate with each other. Additionally, in the context of the HP 85070A software probe kit, the software, Windows, MS-DOS, logical and hardware ports, a cable, and the printer itself must all interact properly to acheive the desired results.

Software

Once you have set up your system, you will use only the interface of the HP 85070A software to measure materials and store or print the results. But now you must relate to other, normally invisible, parts of the system to set it up.

Setting Up Windows

At this time, Windows should have been installed on your computer by running a program named SETUP. If you have not already installed Windows, refer to section 1 of chapter 2 to do so. For now, skip the part of the SETUP program that installs printers by selecting continue.

Control Panel Settings

Through the Windows control panel, you can modify a number of printer parameters. Run the control panel application. It will let you install a driver for your printer. Drivers are programs that translate pictorial information (from an application running under Windows) into commands a printer can understand. Each different kind of printer has a separate driver designed for it.

Before actually running the control panel application, consult your printer manual to determine the following:

- Name and model number of printer (exactly)
- Connection type (serial or parallel)
- Baud rate (serial printers only; how fast it will accept information)
- Word length (typically between 4 and 8)
- Parity (odd, even, or none)
- Stop bits (serial printers only; usually between 1 and 2)
- Handshake (usually hardware)

Add New Printer

To install a driver, access the control panel and select the printer icon. Refer to Windows documentation under "Control Panel" for details. Documentation in the form of ASCII text files is often included on the disk containing the drivers. These are READMEx.TXT files.

To list these files, at the DOS prompt type (for example):

```
dir a:*.txt
```

To read a file, at the DOS prompt type (for example, on the HP PCL driver for HP LaserJets):

```
a:readmehp.txt|more
```

The purpose of all this is to install exactly the right driver for your particular printer. Microsoft supplies many driver programs on floppy disks with the Windows package. You must choose the driver for your printer and install it (from floppy disk to hard disk) before you can print. You can install more than one driver, and can have more than one printer connected to the system at one time; however, only one printer can be used at a time.

Drivers are updated from time to time, so it is possible that a newer and better driver is available (to use in place of the one supplied by Microsoft). Drivers may also be available for printers not supported by Microsoft. Contact Microsoft at:

Microsoft Application Assistance Hotline 1-206-454-2030

For HP printers and plotters, contact HP at:

HP Peripheral Support Hotline
1-208-323-2551 or

Boise Printer Division
Printer/Plotter SUPPORT
Building 21 Mailstop 516
11311 Chinden Blvd.
Boise, ID 83714 USA

Connections

After installing the drivers, Windows must be told which computer interface to associate (or connect) with each driver. Access the control panel to do so.

Here, you choose connections such as:

PCL / HP LaserJet on LPT1:
HP Plotter on COM1:
HP QuietJet on None

LPT1 and COM1 refer to the type of hardware interface (or port) through which computers and printers communicate. You must determine which type of interface your printer uses and enter that information. The two main types of interfaces also have associated logical ports. (A logical port is a specific address and interrupt level which the computer associates with a physical port and through which it communicates.)

Interface	Common Name	Logical Ports
Serial	RS-232	COM1, COM2, COM3, COM4
Parallel	Centronics	LPT1, LPT2, LPT3

Logical ports are assigned to physical ports by setting small switches or jumpers on the interface card. These cards are loaded into a "slot" on the rear panel of the computer. Each card typically has two physical ports (serial, parallel, or one of each). Refer to the computer or interface documentation to determine what you have and select the logical port in the control panel accordingly.

A third type of hardware interface exists, called "HP-IB", IEEE-488, or GP-IB. The computer must also have this interface to control the network analyzer.

Communications Port

Control panel settings in Windows can change the **serial** (RS-232) communications protocol by overriding definitions in the AUTOEXEC.BAT file. AUTOEXEC.BAT is an automatically executed (on power up) batch file located on the root directory. It usually contains commands to configure the communications ports.

According to Microsoft, Windows ignores AUTOEXEC.BAT commands when controlling a printer via a serial port. However, if a printer was working successfully before installing Windows, it may help to examine AUTOEXEC.BAT (as explained below) and modify the communications port settings to match it.

Parallel ports are not affected by Windows.

Several parameters define the communications protocol used by serial (RS-232) ports. The protocol must match that of the printer. Some printers are capable of changing their serial protocol, via small switches or other controls. Refer to the printers manual for details. These are the parameters and most common values for HP printers:

BAUD rate: 9600, 4800, 2400, 1200, 19200, 300
Parity: None, Even, Odd
Number of data bits (word length): 8, 7, 6
Number of stop bits: 1, 1.5, 2
Handshake type: Hardware (DTR, Printer Busy), None (XON/XOFF)

To change the communications protocol used by Windows, access the control panel and enter the changes.

The AUTOEXEC.BAT File

Commands that configure a serial port typically look like this:

```
MODE COM1:9600,N,8,1
```

If the printer is connected to a parallel port, the mode command may look like this:

```
MODE LPT1:,,P
```

Note that the MODE command can also redirect the printer from one logical port to another. The default printer is usually assumed to be at LPT1. If the printer is a serial type, the printer data may be redirected via LPT1 to COM1 with this command:

```
MODE LPT1:=COM1:
```

If needed, the AUTOEXEC.BAT file can be modified with EDLIN or other ASCII text editors. Refer to DOS documentation for details on the "MODE" command.

After editing AUTOEXEC.BAT, the computer must be restarted (to read and execute the edited file). Press ***[CONTROL] [ALT] [DEL]*** to do so.

Other files can have an effect on printer performance, though not as often as AUTOEXEC.BAT. Those files are described below in "Other Files Worth Knowing About."

Cables

A cable is needed to connect printer to computer. There are many cables to choose from. Do not assume that a cable with connectors that merely "mate" correctly at each end will work correctly; this is rarely the case.

The choice of cable is based on:

- the printer model
- type of interface (serial RS-232, or parallel Centronics)
- connector type at each end (e.g. 9-pin, 25-pin, or 36-pin)
- sex at each end (male or female)

For HP printers, the "Computer Users Catalog" provides an excellent look-up table to help choose the correct cable. To request a catalog, or to order cables and adapters with a credit card, call HP DIRECT at this number:

1-800-538-8787 (toll-free from US)

Outside the US, similar services are usually available locally. Refer to your local phone directory under "HP", or call these numbers (international toll call to the US):

U.S.A. 408-730-6129 (for information on local services)
U.S.A. 415-857-5027 (to place an order from a non-US country)

Printer Settings

Most printers can be configured by the user with small switches, jumpers, or buttons. Settings fall into two categories: serial and mode.

Serial settings select the protocol used by the serial port. The protocol includes BAUD rate, parity, word length, and handshake. See printer's manual for recommendations, and see "Communications Port" to make sure the computer's serial port protocol matches the printer.

Mode settings control how the printer responds to certain commands (after being received correctly via the communications port). Settings may affect: response to CR, response to LF, page size, font selection, font size, etc.

Some HP printers have a mode switch that selects between "Alternate" and "HP" mode. Use the "HP" setting, unless using a non-HP driver.

"Define plot..." in HP 85070A

Once you are running the HP 85070A software, select ***[Output]*** then ***[Define plot...]*** to specify the printer driver you want to record measurement results. This selection points to a driver in Microsoft Windows, described above.

If that driver supports more than one printer, the printer must already have been chosen in the control panel. The control panel also selects the hardware port to which the output will be sent, and the protocol (used by a serial port). The port and protocol selected must match the actual port and protocol used (often user settable) on the printer.

Other Files Worth Knowing About

CONFIG.SYS is another file (on the root directory) containing commands which are executed when the computer is started. It may contain references to device drivers such as keyboard, mouse, display, hard disk, etc. CONFIG.SYS may act in the same way as AUTOEXEC.BAT, but it is more common to edit AUTOEXEC.BAT as explained above.

WIN.INI is a file (usually in the \Windows directory) that Windows reads when starting up. It establishes many conditions and settings used by Windows and applications under Windows. Most settings can be changed by the control panel or by various applications. However, the following change (which has been known to solve printer problems) can only be changed by editing the WIN.INI file with EDLIN or other ASCII text editor.
To disable the automatic spooler, find the line beginning with "spooler" (near the top of the file) and change it to

```
spooler=no
```

Refer to Windows documentation for details.

CONCLUSION

This information is only a summary. If you are unable to successfully print or plot within the HP 85070A software program, do not hesitate to review the documentation of Windows, the printer, the cable, and the interface.

SECTION 2: HP BASIC VERSION OF THE SOFTWARE

SYSTEM REQUIREMENTS

The system requires the computers, software, interfaces, printers and plotters, and network analyzers described below.

Computer

All HP 9000 series 300 computers are supported by the HP 85070A software except these:

HP 9817	HP 9920
HP 9826	HP 9837

The minimum requirements for the computer are these:

2.0 MBytes (minimum) of RAM (Random Access Memory)
Double-sided, double-density 3-1/2" flexible disk drive

Software

The computer must have BASIC operating system version 5.0 (or higher) and these binaries:

IO	MAT	COMPLEX	ERR	HPIB
CS80	MS	GRAPH (GRAPHX if color CRT)		

Other binaries may be present in the BASIC operating system but, when additional binaries are present, the computer may require more than 2.0 MBytes RAM.

The HFS (hierarchical file system) binary can also be used to specify volumes and directories for saving program information.

The HP 85070A software will also run under the HP-UX system with HP-RMB-UX BASIC language support.

IEEE-488 (HP-IB) Interface

The computer must have an HP-IB interface to control the network.

Printers and Plotters

An HP-IB printer can be used to produce tabular listings of measurement results or printer facsimiles of graphed data. A number of HP-IB printers may operate properly with the software but have not been tested. The following printer has been tested to insure compatibility with the program and is therefore recommended for use with the software:

- HP 2225A, ThinkJet printer with HP-IB interface option

HP-IB plotters can also be used to produce hardcopy graphs of the data. A number of HP-IB plotters may operate properly with the software but have not been tested. The following plotters have been tested to insure compatibility with the program and are therefore recommended for use with the software:

- HP 7470A two-pen graphics plotter with HP-IB interface option
- HP 7475A two-pen graphics plotter with HP-IB interface option
- HP 7440A ColorPro eight-pen plotter with HP-IB interface option
- HP 7550A graphics plotter

Network Analyzer and Test Set

The HP 85070A software is designed to work with the network analyzer configurations described below. The default HP-IB address is 16.

- HP 8752A: this 300 kHz to 1.3 or 3 GHz network analyzer contains a reflection/transmission test set as part of the analyzer. No other instrumentation is needed to make measurements.
- HP 8753A, HP 8753B, HP 8753C: these 300 kHz to 3 or 6 GHz network analyzers need a companion test set for operation with the software. The following test sets are supported:

  HP 85044A reflection/transmission test set
  HP 85046A S-parameter test set
  HP 85047A S-parameter test set for operation to 6 GHz.

- HP 8719A, HP 8720A or B: these 130 MHz to 13.5 or 20 GHz work analyzers contain S-parameter test sets as part of the analyzer. No other instrumentation is needed to make measurements.
- HP 8510B: this network analyzer requires a companion test set and a source for operation with the software. Frequency range is determined by the test set and source. All test sets supported by the HP 8510B are supported by the software. The source must be synthesizer based. The HP 8340, HP 8341, or HP 8360 family sources are supported by the software. HP 8510B firmware revision 5.0 or higher is recommended.

NOTE: the HP 8510A is not supported by the software but can be upgraded to an HP 8510B with the HP 85103A or B upgrade kit.

INSTALLATION

HP BASIC Installation

The Hewlett-Packard BASIC operating system (version 5.0 or higher) is required for the HP 85070A software. Additionally, the BASIC system must include the previously listed binaries for operation with the HP 85070A software. Refer to the computer's manual set for additional information on installing or configuring the BASIC operating system.

HP 85070A Software Installation

The HP 85070A software program resides in a single file on the HP 85070A program disk, a 3-1/2" floppy disk. The name of the file is *HP85070A*.

The HP 85070A program should be copied to a working disk so that the original disk can be stored as a back-up. Thus, if the (new) working copy is damaged or lost, the back-up is still available.

Use the COPY command in HP BASIC to copy the program to another disk drive. The syntax of the COPY command is:

```
COPY ``FILENAME:MSUS'' to ``FILENAME:MSUS''
```

where MSUS is short for mass storage unit specifier. MSUSs are typically of the form ",700,1" where ",700" is the drive address and "1" is the drive number. For example, to copy the program from drive 0 at drive address 700 to drive 1 at drive address 700, you would type the following:

```
COPY ``HP85070A:,700,0'' TO ``HP85070A:,700,1''
```

Refer to the BASIC operating system manuals for more information of mass storage specifiers and the COPY command.

Hardware Installation

Connect the computer, network analyzer, cable and clamp, remote trigger, probe, and peripherals, as shown below. For HP 8753 systems, refer to the network analyzer documentation to connect the test set. For HP 8510 systems, refer to the network analyzer documentation to connect the test set and source.

Table 2-1. Adapters Required for Various Network Analyzer/Cable Configurations

Network Analyzer (and Test Set)	Cable	
	8120-5424 or HP 85131E opt C52	HP 85131E
HP 8752	Direct	Not recommended
HP 8753 HP 85044 HP 85046 HP 85047	Type-N to 7mm (supplied)	Not recommended
HP 8719 HP 8720	Type-N to SMA (supplied)	Direct
HP 8510 HP 8514 HP 8515	Type-N to SMA (supplied)	Direct

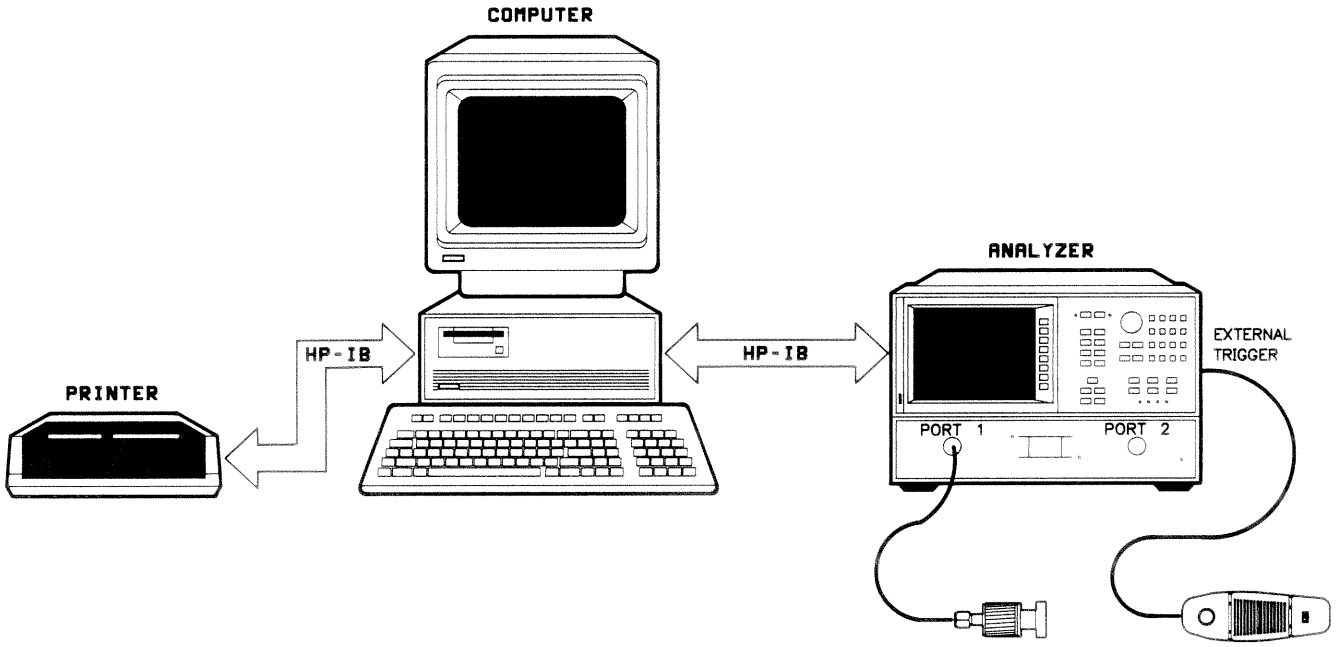

Figure 2-10. Connection Diagram

Starting the HP 85070A Software

To start the HP 85070A software program, follow these steps:

1. To load the software from the working copy into memory, type

   LOAD ''HP85070A'' and press (ENTER) or (RETURN).

When the disk access annunciator in the bottom right of the computer CRT goes out, the program is loaded. If the system does not respond as expected, change the mass storage unit with the MSUS command.

2. To run the program, type

   RUN or press the ***[RUN]*** softkey.

The HP 85070A program's copyright screen will now appear displaying the copyright statement.

3. To erase the statement and view the main menu screen, press (ENTER) or (RETURN).

The HP 85070A software is ready for operation when the Main menu screen (shown below) replaces the copyright statement.

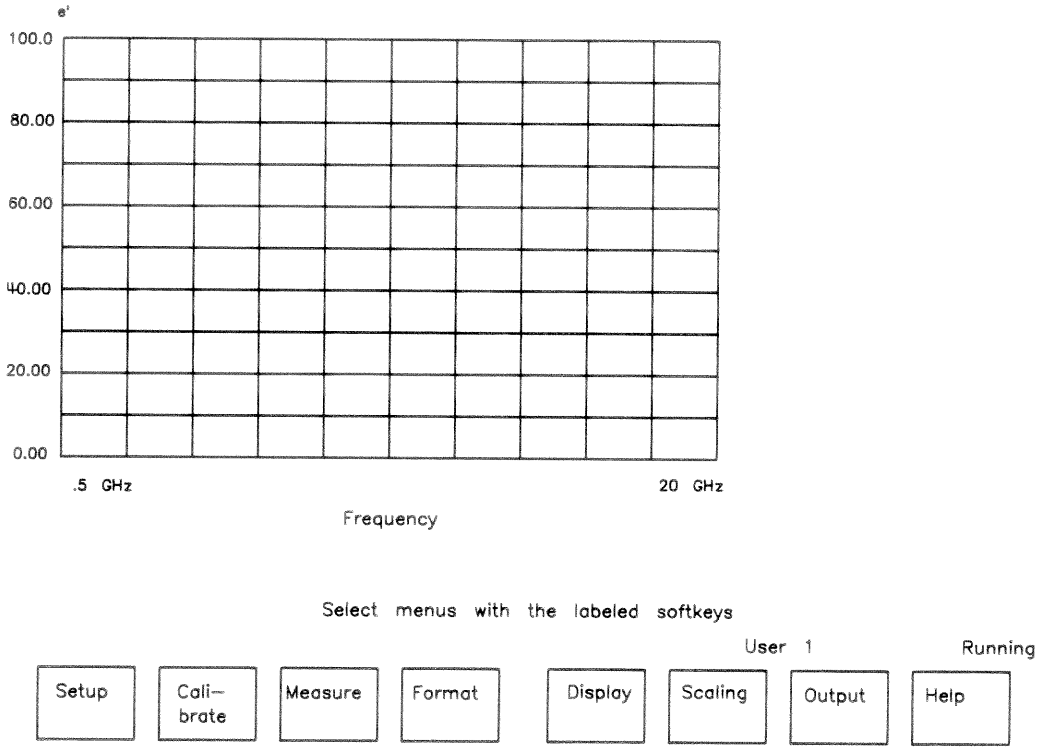

Figure 2-11. Main Menu Screen

HP BASIC SOFTWARE OPERATION

As explained below, the HP 85070A software uses softkeys, menus, and dialog boxes to interact with the operator.

What are Softkeys?

Softkeys are keys which are relabeled to perform different functions as the program runs. The labels for the softkeys are located on the bottom of the computer display. The softkey labels correspond to the function keys (F1 through F8) on the computer keyboard.

The softkeys are labeled with the names of the menus in the program. Pressing a menu softkey brings up that menu of choices for working with the program. Any time the softkeys are labeled, they are active and can be used to select a menu.

Sometimes during the program the softkeys are relabeled. When input from the keyboard is required, the softkeys are labeled with terminators for the entry. For example, if start frequency is being entered, the softkeys are re-labeled GHz, MHz, KHz, and Hz.

How to Use Menus

Menus are lists of commands or other menus or both. When a menu is selected in the HP 85070A, menu choices, or commands are presented in the upper right portion of the computer's display. The various menus in the software are found on the softkeys at the bottom of the computer display.

To select a menu, press the function key on the keyboard that corresponds to the menu softkey on the computer display. The menu choices will appear on the upper right portion of the display with a cursor arrow pointing to one of the commands in the menu.

To choose a command, use the UP/DOWN cursor (arrow) keys to point the cursor arrow to the desired command. Then press (RETURN) or (ENTER) to select that command.

Some commands take immediate action, for example the autoscale command. Other commands require additional keyboard input. Those commands present a dialog box when selected.

How to Use Dialog Boxes

A dialog box is a request from the program for information required to carry out a command. Commands that end in an ellipsis (...) indicate that a dialog box is presented when the command is selected. Dialog boxes must be filled in before proceeding with program operation. Some dialog boxes require that you type in text, others allow you to select options within the dialog box. If a field in the dialog box requires keyboard input, the current value of the setup parameter is displayed below the field. If a field is a toggle option (on or off; one of three possible choices) then the current state is underlined.

Working with the dialog box is similar to working with commands in a menu. Use the UP/DOWN arrow keys to point to the entry parameter or choice in the dialog box. Then press (RETURN) or (ENTER).

If the choice requires keyboard entry (frequency entry, Y-axis scale entry, etc.) then a prompt will be displayed for operator input. The softkeys are labeled with terminator units for the input (GHz, MHz for frequency entry; etc.) Type the desired response to the prompt on the keyboard and use the appropriate softkey to terminate the entry.

To exit a dialog box, select the ***[OK]*** or ***[Cancel]*** command and press (RETURN) or (ENTER) or press the corresponding softkey. OK will keep all setup parameter changes made in the dialog box. Cancel will leave the dialog box without changing any setup parameters.

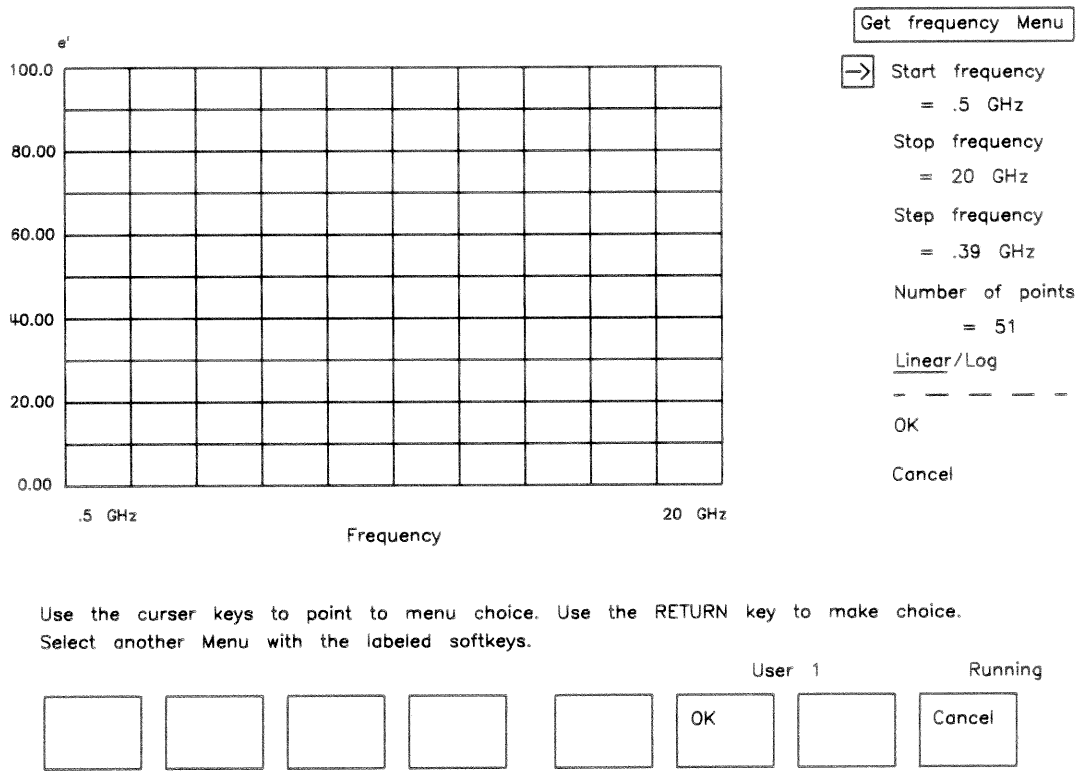

Figure 2-12. Sample Dialog Box

HP 85070A HP BASIC Software Fundamentals

The HP 85070A display window and its components are shown below.

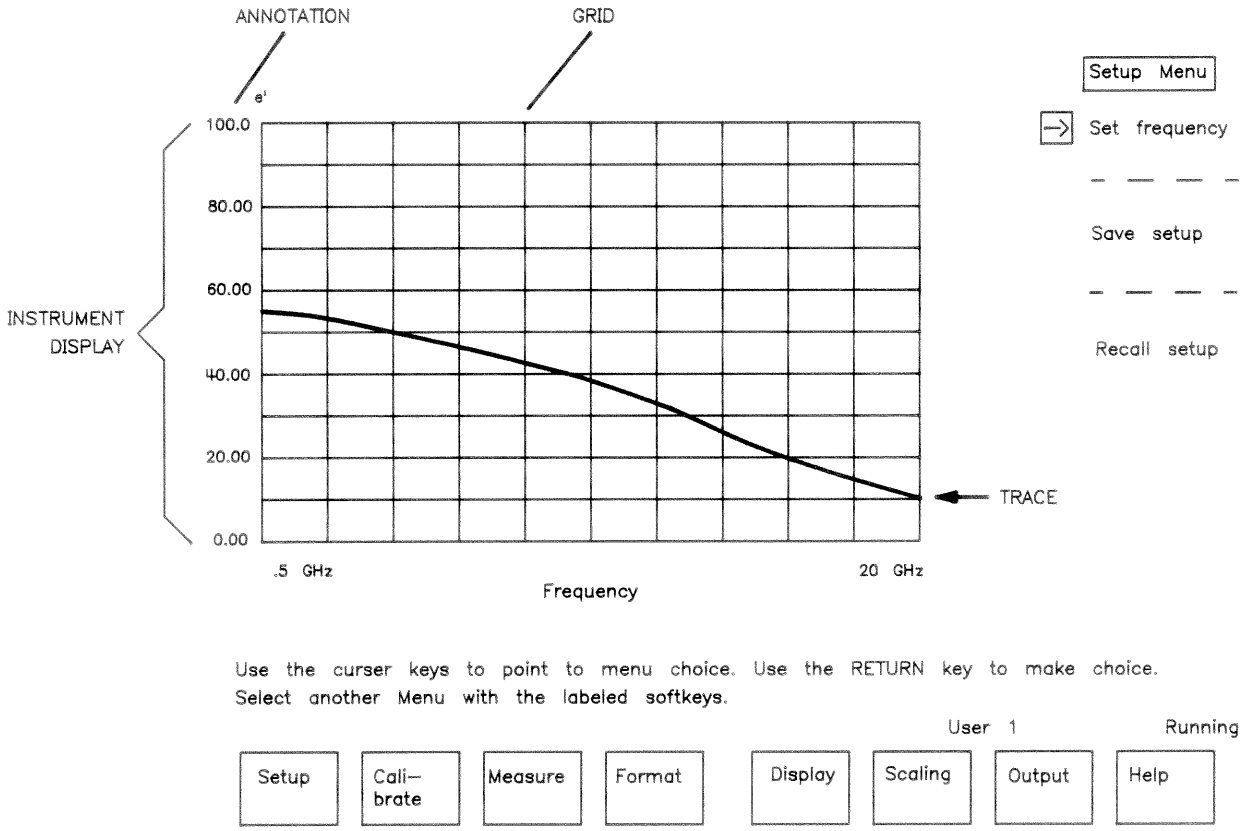

Figure 2-13. Main Menu Screen with Pull-Outs Describing Principal Functions of Components

The instrument display is always present. Most of the time the instrument display presents measurement data as a graph. But it can also present the data as a tabular listing.

These terms refer to parts of the instrument display:

Grid is composed of the x-axis and y-axis graticules on which the data is plotted.

Traces are graphs of measurement data. They are the measured values of permittivity plotted on the grid. When the software first starts up, no measurement traces are presented.

Annotation is the text on the instrument display which describes the frequency range of the measurement, the format of the display, the scaling of the display, and any display titles.

CONCLUSION

Now that you have installed the software and hardware, loaded the program, and learned the basic operator interface techniques, you are ready to make a measurement. Please continue with section 2 of the next chapter, "Measurement Tutorial."

Measurement Tutorial

INTRODUCTION

This chapter provides a step-by-step, guided example of a calibration and measurement sequence with the HP 85070A software. Use the instructions in the previous chapter to load the software and advance to the main menu screen. This tutorial uses a 95% ethanol (grain alcohol) and 5% water mixture as the MUT.

Section 1 of this chapter (below) is for users of the MS-DOS version of the software.

Section 2 of this chapter (the second half) is for users of the HP BASIC version of the software.

SECTION 1: MS-DOS VERSION OF THE SOFTWARE

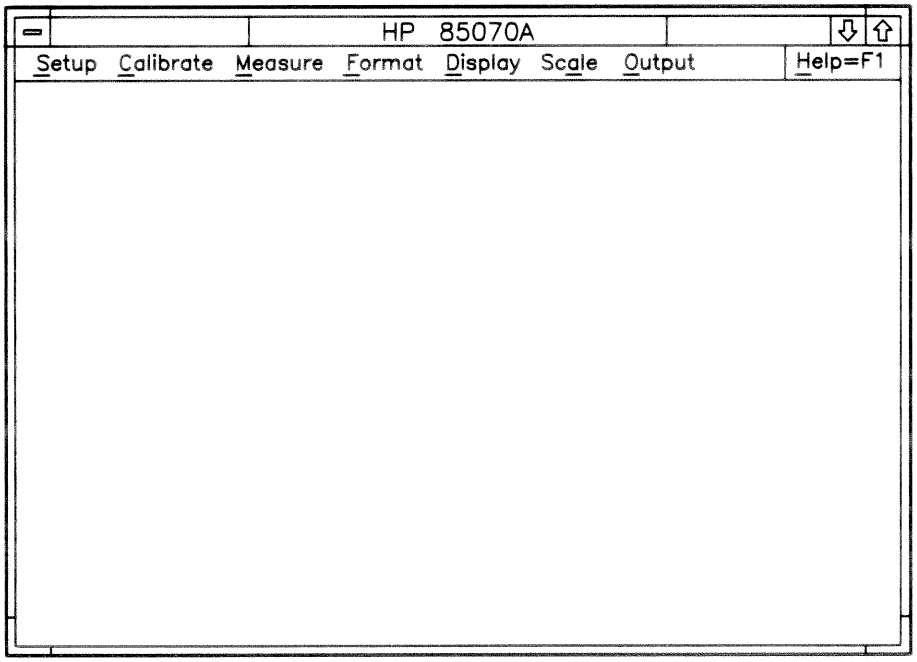

Figure 3-1. The HP 85070A Main Menu

The figure above shows the instrument display and the menu bar. The menu bar displays , from left to right, the menus in the order in which they are typically used. The menus are these:

Setup
Calibrate
Measure
Format
Display
Scale
Output (also for inputing data)
Help (strictly speaking, not really a menu)

HOW TO MAKE A MEASUREMENT

Set Up the Measurement First

Point to the setup menu and select the ***[Set frequency...]*** command. The first step in setting up the system for calibration and measurement is to select the frequency range (a start and stop frequency, and either the number of frequency points or a step frequency). The set frequency... command presents the dialog box shown below.

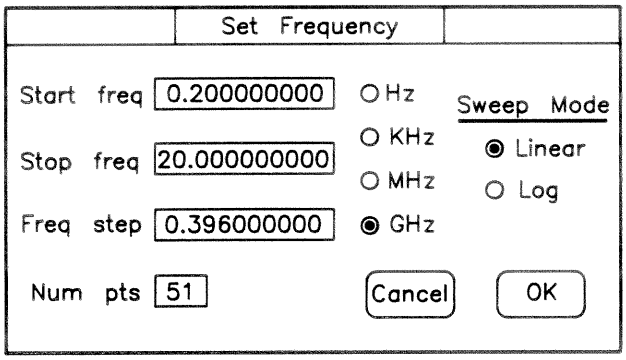

Figure 3-2. Set Frequency Dialog Box

Change the Start Frequency to 0.6 GHz

Move the pointer to the text box just to the right of Start Freq. Click at the far left end of the text box, drag across to the far right end of the text box, and then release the mouse button. This highlights the entire current entry. Type in 0.6.

Do NOT press (RETURN) or (ENTER) yet.

Change the Stop Frequency to 3 GHz

Move the pointer to the right of Stop Freq, click, drag, and release as above. Type in 3.0.

OK the Changes and Exit the Dialog Box

In this example, we use the default number of points (51) and sweep mode (linear). To accept the settings made, select the ***[OK]*** command with the mouse or press (ENTER) or (RETURN) on the keyboard. The software will display the hourglass as it updates the network analyzer. The network analyzer display will look as shown below.

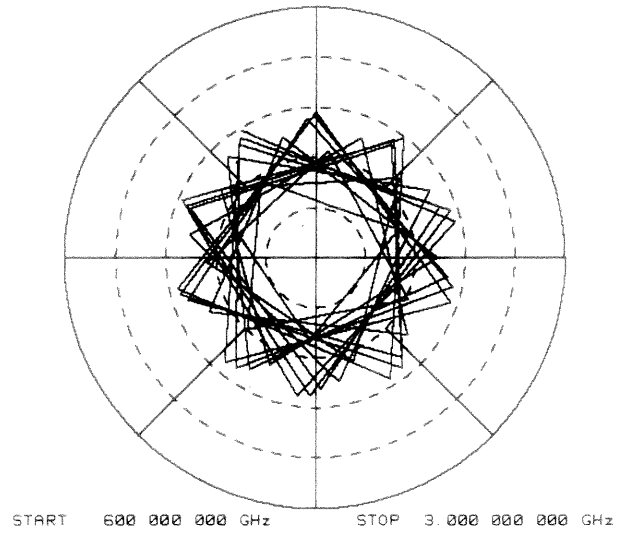

Figure 3-3. Network Analyzer Display Showing Changed Start and Stop Frequencies

Perform a Calibration

The calibration consists of measuring three known dielectrics (standards) and using the results to characterize the three major sources of measurement error. The default calibration standards are air, a short circuit, and water.

To begin the calibration, click on the calibrate menu and select the ***[Perform cal]*** command.

Stablize the Cable and Measure the First (Air) Standard

Changing the position of the cable (especially the standard gray cable) between calibration and measurements can cause inaccurate measurements. Keep such changes and flexures to a minimum.

Position the cable in a configuration similar to the measurement configuration. Connect the probe to the cable end so that the probe does not contact anything. Select the ***[OK]*** command with the (ENTER) or (RETURN) key or with the mouse.

Measure the Second (Short) Standard

Connect the short (circuit) to the probe with the spring clip as shown below. Make sure all three clips snap firmly behind the probe face.

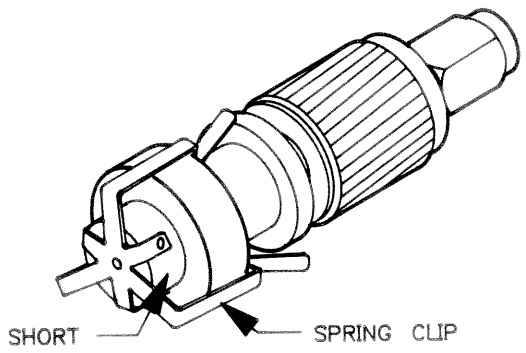

Figure 3-4. Probe with Short Circuit Attached

Now the network analyzer display should appear as shown below. If not, check the short to make sure it is making good contact with the inner and outer conductors of the probe. Note that if you wiggle it, the trace changes. But left alone, the trace should be steady.

The trace of high frequency measurements (up to 20 GHz, for example) will not be as tightly clustered as shown below. This is normal. However good traces will always be on the left side of the polar chart.

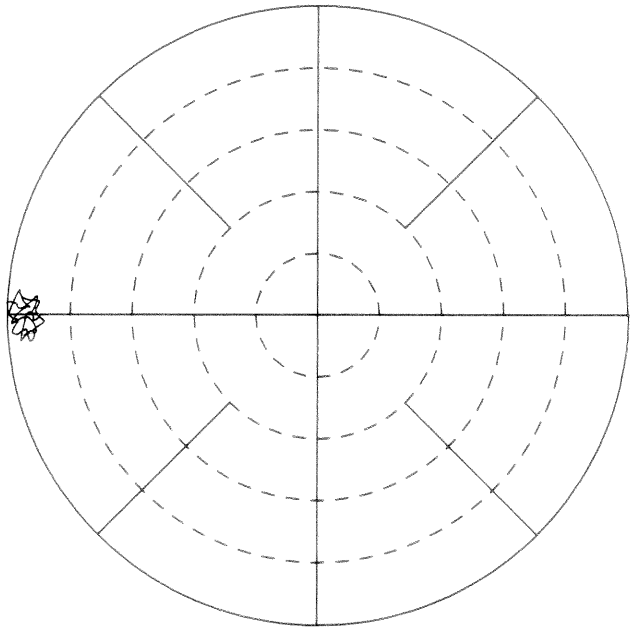

Figure 3-5. Network Analyzer Display of Short Circuit

Trigger the measurement with the ***[OK]*** command. Remove the short circuit.

Measure the Third (Water) Standard

Place the probe in deionized water (tap water and distilled water can be used, but impurities will reduce the low frequency accuracy of the measurements). The network analyzer display should appear as shown below.

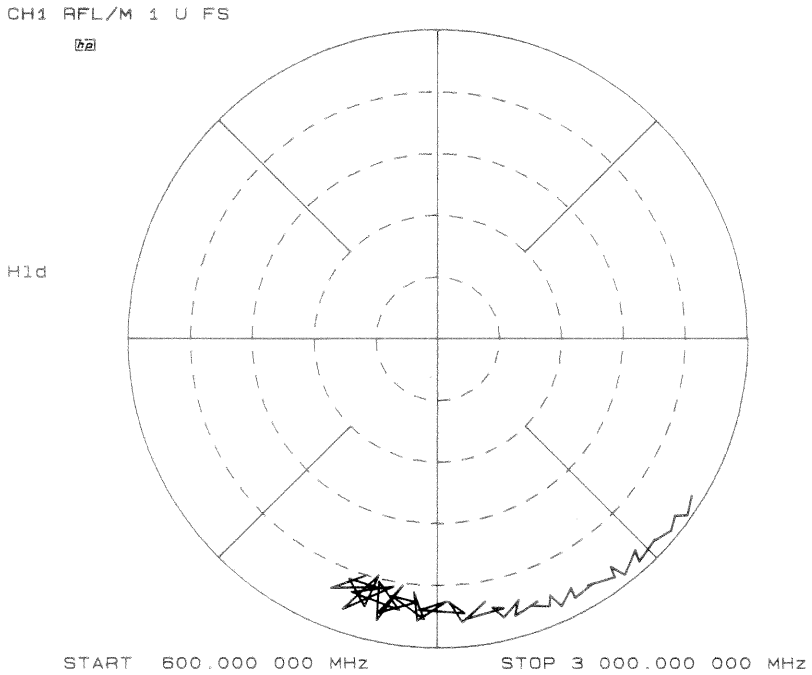

Figure 3-6. Network Analyzer Display of Deionized Water During Calibration

Trigger the measurement with the ***[OK]*** command. Remove the probe from the water and dry it.

Observe the Results

As soon as the software calculates the error (correction) terms for each of the frequencies, it will display the main menu window on the CRT. The system is now calibrated and ready to characterize the permittivity of unknown materials.

MEASURE A SAMPLE MATERIAL

Fill a container with a solution of 95%, by volume, ethanol (grain alcohol) and 5% water. This will be the sample MUT. Immerse the probe in the MUT. The network analyzer should look like the one shown below.

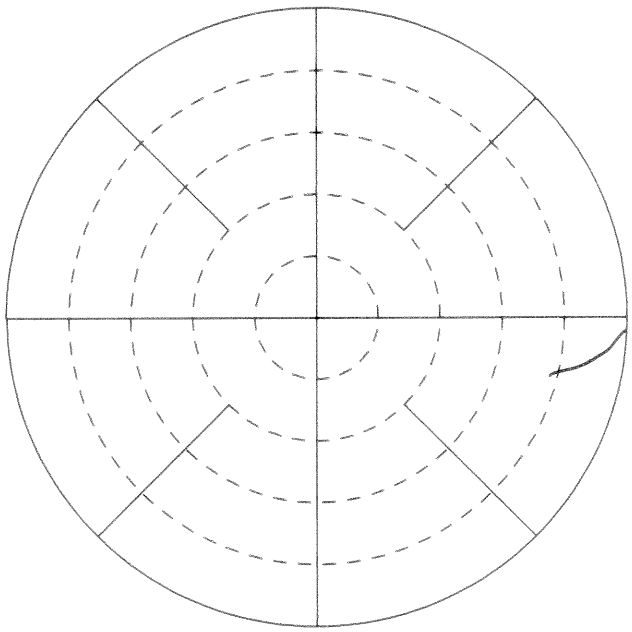

Figure 3-7. Calibrated Measurement of 95% Ethanol Solution

To measure the ethanol, select the ***[Trigger meas]*** command in the measure menu. The software will initiate the measurement, calculate the complex permittivity (e' and e''), and display the results.

The initial results will be presented on the default scale of 0 to 100 in the e' versus frequency format.

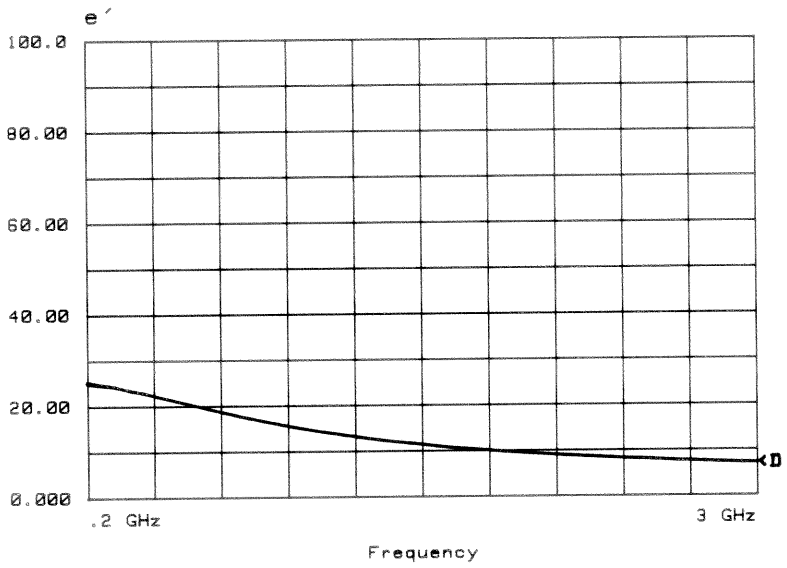

Figure 3-8. Default Display of Ethanol Measurement

Scale the Display

To change the scale of the software display, select the scale menu in the main menu screen. All three of the commands visible scale the Y-axis as explained below.

Autoscale enables the software to automatically set the minimum and maximum values on the Y-axis, based on the range of the measurement data.

Set scale presents a dialog box to allow you to enter minimum and maximum values for the Y-axis.

Default scales the Y-axis as defined in the software.

Each display format will be seen in the scale last used for that format.

Change the Format of the Data

To change the format of the data displayed, select the format menu in the main menu screen. The data can be formatted as one of four graphs or one of two tables, as indicated on the screen.

Select the ***[Tabular (e' & e")]*** command. The display should resemble the one shown below.

	Data	
Freq (GHz)	e'	e''
0.200000000	25.48	2.98
0.256000000	24.91	4.20
0.312000000	24.59	5.21
0.368000000	23.92	6.21
0.424000000	23.25	7.05
0.480000000	22.51	7.76
0.536000000	21.82	8.35
0.592000000	21.12	8.90
0.648000000	20.39	9.34
0.704000000	19.64	9.75
0.760000000	18.94	10.04
0.816000000	18.25	10.31
0.872000000	17.54	10.45
0.928000000	16.91	10.59
0.984000000	16.31	10.68
1.040000000	15.71	10.72

Figure 3-9. Example of Tabular (e' & e'') Format

Notice that the last measurement (3.0 GHz) is not visible. Use the scroll bar on the right of the HP 85070A display to scroll through the data. Return to the original format of e' vs. frequency as a graph.

Save the Measurement Data to Memory

Often it is important to compare two (or more) different materials or measurements. To ease such comparisions, the software can display up to four separate traces: the data trace, memory 1, memory 2, and memory 3. The data trace always consists of the calculated permittivity data of the current measurement. Performing another measurement erases the current data unless it is first saved, as explained below.

Save the Data to a Memory Trace

To save the current measurement data, select the ***[Data → memory...]*** command in the display menu. Select one of the three traces, say memory 1, with the pointer and the ***[OK]*** command. Now the trace of memory 1 is a duplicate of the data trace.

Viewing More Than One Trace

Measure the ethanol solution again. Note that the data trace is erased and replaced by the new measurement. Note too that both the data trace and trace 1 are visible, as illustrated by the figure below. They are identified to the right of the display as <D and <1. Data stored in memory is displayed automatically unless you turn it off with the display menu.

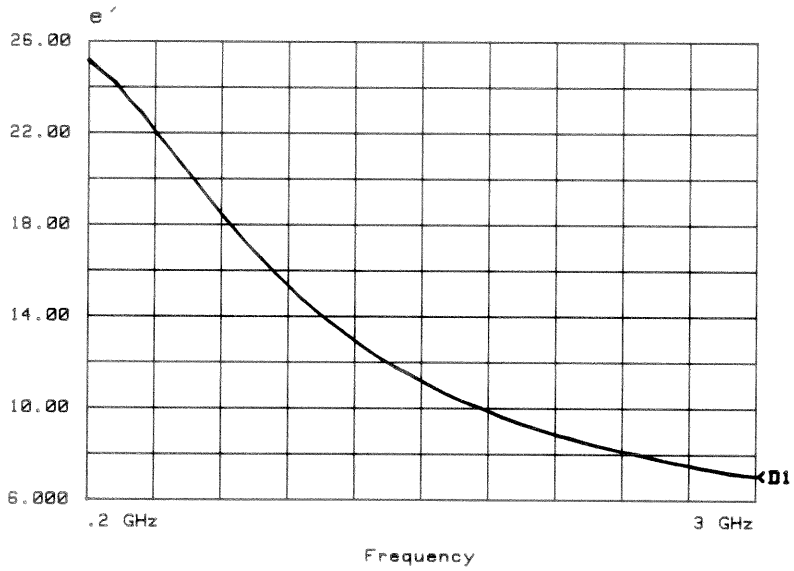

Figure 3-10. Simultaneous Display of Two Traces

Compare the Traces with Trace Math

To compare the traces mathematically, use the trace math feature. This function allows you to divide a designated trace by the reference trace or subtract the reference trace from it.

Select the ***[Reference trace...]*** command in the display menu and choose memory 1 as the reference trace. Then select the ***[Trace math...]*** command in the display menu. Note that trace math is currently off. The other two choices are "/ref" (for divide by the reference) and "-ref" (subtract the reference).

Select the ***[/ref]*** command. The format indicator changes from e' to e'/1 (because memory 1 is the reference trace) as shown below.

Memory trace 1 holds the original ethanol mixture measurement. Memory trace 2 holds the second ethanol measurement. The data trace holds the measurement of the diluted ethanol mixture.

Trace math calculates each of these measurements divided by the reference (original) measurement. The display shows the per cent difference above or below the reference (for example, 1.24 means that the trace being compared to the reference is 24% greater than the reference trace). Thus, trace 1/trace 1 always has the value of 1.

Memory trace 2 should have been very close to the original measurement of the ethanol mixture. Thus, trace 2/trace 1 should have values that are close to 1 but not exactly 1.

The data trace is different from the original ethanol mixture depending on the amount of water added. For e' vs. frequency, the ratio of data/trace 1 will be values greater than 1. For e'' vs. frequency, the ratio of data/trace 1 will be values sometimes less than 1 and sometimes greater than 1.

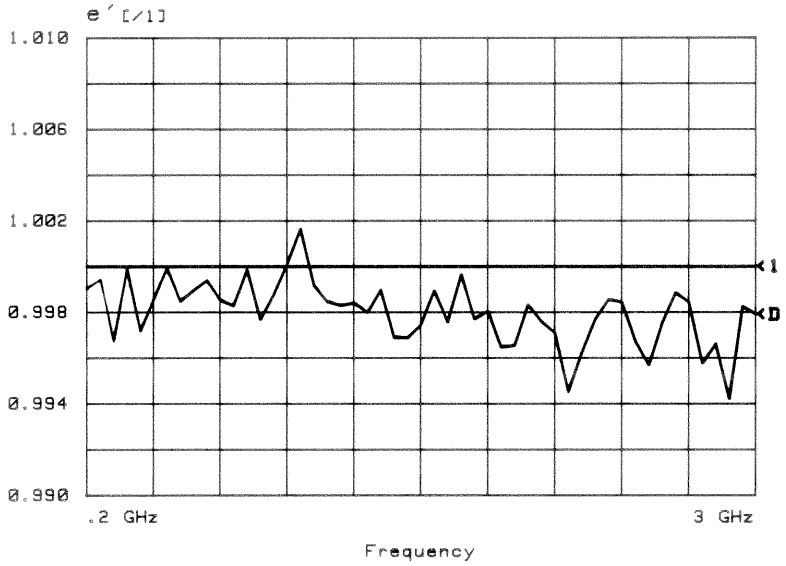

Figure 3-11. Traces Compared With Trace Math

Now turn off the trace math feature (in the display menu).

Print or Plot the Data

Printing or plotting measurement data is as easy as selecting the appropriate command in the output menu. However before a printer or plotter can be used with the software, it must be installed and configured. If you have not already done so, or if you have any problems getting a print or plot, refer to the previous chapter.

When the data is a table, the software allows you to print it. When the data is a graph, the software allows you to plot it. (In such instances, the "plotter" can, in fact, be a printer.) Recall that the choice of graph or table is in the format menu.

Save the Test Setup, Calibration, and Displayed Traces to Disk

To save the test setup, calibration, and all valid measurement traces to disk, select the ***[Save setup...]*** command in the setup menu. Enter the disk drive, directory, and filename of the setup. Filenames are limited to eight characters and will be given the extension ".TST" (unless you specify otherwise). Press ***[OK]*** to save the test setup file.

The test setup file contains this information:

Learn string of the network analyzer, a full definition of the state (settings) of the analyzer.

Calibration (if any) error terms used by the software to make more accurate measurements.

Software operating state, the frequency range, format, traces displayed, and scale of the current measurement.

Visible data and memory traces are also saved and can be recalled.

Save the Measurement Data to Disk

To save the measurement data to disk, select the ***[Save data...]*** command in the output menu. Enter the disk drive, directory, and file name in the dialog box.

Data files contain the frequency range and the measurement data. The data file does not include the data of memory 1, 2, or 3. (To save memory traces, use the ***[Memory to data...]*** command in the display menu.)

Data files are stored in an ASCII format compatible with Lotus 1-2-3. The Lotus program can import the data file directly in spreadsheet form for further analysis (details in chapter 4, "Advanced Measurement Techniques"). Data files can also be recalled by the HP 85070A software.

Recall the Files from Disk

To recall a test setup file from disk, select the ***[Recall setup...]*** command in the setup menu. This presents the recall setup dialog box. Select the desired file from the list or, if need be, change the drive or directory or both and then select the desired file. The setup file includes any data traces that were displayed when the file was saved.

To recall measurement data from disk, select the ***[Recall data...]*** command in the output menu. This presents the recall data dialog box. Select the desired file from the list or, if need be, change the drive or directory or both and then select the desired file. When measurement data is recalled, the software first compares frequency range of the recalled data to the current frequency range. If the frequency ranges (and type of sweep) match, the recalled data is placed in the data trace for display. If they do not match, the recalled data is not displayed.

To view up to four recalled traces at once, place the first in memory 1 and then recall the second. Place the second in memory 2 and recall the third and so forth.

CONCLUSION

After working through this measurement tutorial, you should be familiar with the main operating techniques and features of the HP 85070A dielectric probe software. Using the program is the best way to master it. But other aids are available. The Help menu provides an on-line definition of each command in the program. Additionally the "Software Reference" chapter details each command and operation of the program (useful for infrequent users and infrequently used features).

Don't overlook the index and glossary for help.

SECTION 2: HP BASIC VERSION OF THE SOFTWARE

This section provides a step-by-step, guided example of a calibration and measurement sequence with the HP 85070A software. Use the instructions in the previous chapter to load BASIC, load and run the software program, and advance to the main menu screen.

This tutorial uses a 95% ethanol (grain alcohol) and 5% water mixture, by volume, as the MUT (material under test).

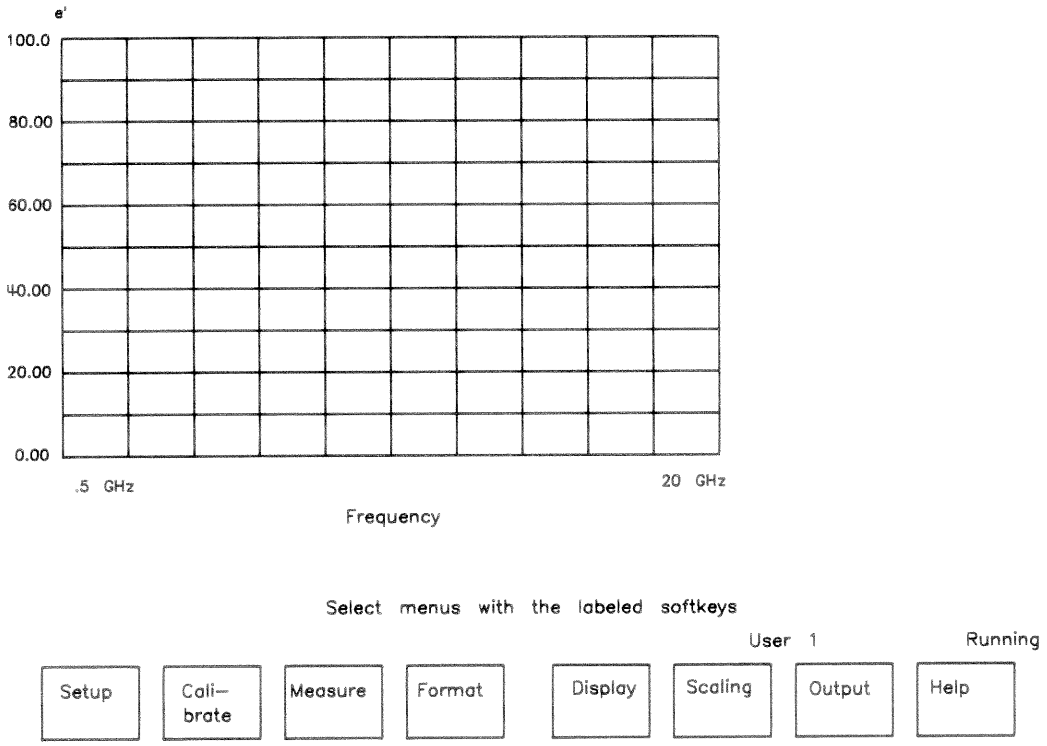

Figure 3-12. HP BASIC Version of Main Menu

The figure above shows the instrument display and the softkeys. Each softkey corresponds to one of the eight menus in the software. They are ordered, from left to right, in the order in which they are typically used. The menus are these:

Setup
Calibrate
Measure
Format
Display
Scale
Output (also for inputing data)
Help (strictly speaking, not really a menu)

HOW TO MAKE A MEASUREMENT

Follow the instructions below to make a measurement. Note that when the software is first run, no measurement data is visible.

Set Up the Measurement First

The first step in setting up the system for a measurement is selecting the frequency range because calibrations are frequency dependent (if you change the frequency range you must re-calibrate). And a calibration must precede measurements.

Press the ***[Setup]*** softkey and then use the cursor (up and down arrow) keys to position the pointer next to the ***[Set frequency...]*** command. Press (RETURN) or (ENTER) to select that function. The set frequency selections should now appear on the right side of the computer display.

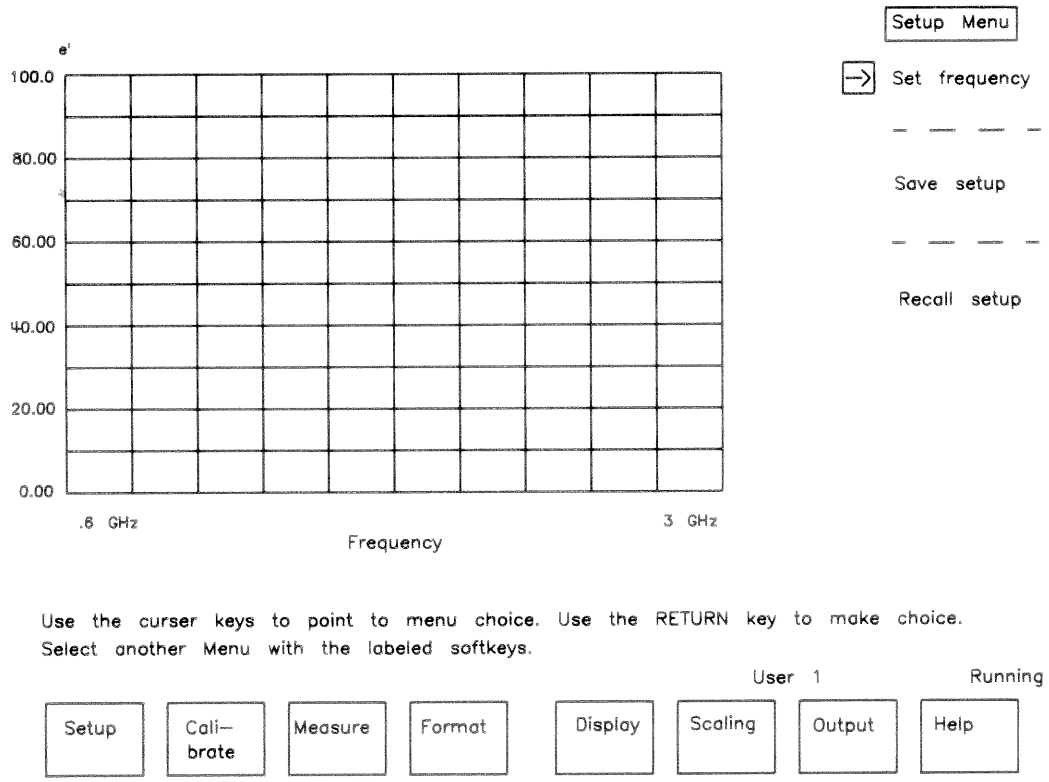

Figure 3-13. HP BASIC Version of Setup Menu

Change the Start Frequency to 0.6 GHz

Use the cursor (up and down arrow) keys to position the pointer next to the start frequency choice, then press the (RETURN) or (ENTER) key. The software will prompt for entry of the new start frequency. Notice that the softkeys are labeled with the entry terminators (GHz, MHz, KHz, and Hz).

Type in 0.6 and press the ***[GHz]*** softkey. The new value of 0.6 GHz is now displayed below start frequency in the dialog box but the frequency annotation on the graph will not be updated until you leave the dialog box by selecting the OK command.

Change the Stop Frequency to 3 GHz

Position the pointer at the stop frequency choice and press (RETURN) or (ENTER). The software will prompt for entry of the new stop frequency.

Type in 3 and press the ***[GHz]*** softkey. The new value of 3 GHz is now displayed below stop frequency in the dialog box.

OK the Changes and Exit the Dialog Box

Press the OK softkey and (RETURN) or (ENTER). The software will update the network analyzer to the new frequency range. (In this example we will not change the default number of frequency points: 51.)

Perform a Calibration

The calibration consists of measuring three known dielectrics (standards) and using the results to characterize the three major sources of measurement error. (The three major sources of measurement error are explained in the network analyzer manual). The default calibration standards are air, a short circuit, and deionized water. To begin the calibration, press the ***[Calibrate menu]*** softkey and select the perform cal command. This will initiate the calibration process.

Stablize the Cable and Measure the First (Air) Standard

Changing the position of the cable (especially the standard gray cable) between calibration and measurements can cause inaccurate measurements. Keep such changes and flexures to a minimum.

Position the cable in a configuration similar to the measurement configuration. Connect the probe to the cable end so that the probe does not contact anything. Select the ***[OK]*** command with the (ENTER) or (RETURN) key or with the mouse.

Measure the Second (Short) Standard

Connect the short (circuit) to the probe with the spring clip as shown below. Make sure all three clips snap firmly behind the probe face.

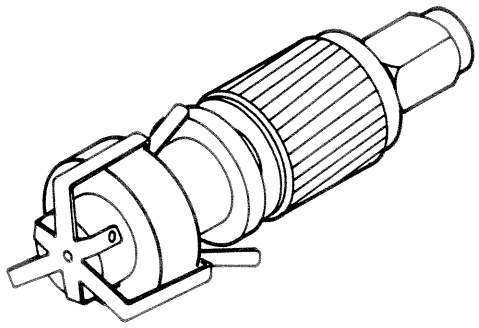

Figure 3-14. Probe with Short Circuit Attached

Now the network analyzer display should appear as shown below. If not, check the short to make sure it is making good contact with the inner and outer conductors of the probe. Note that if you wiggle it, the trace changes. But left alone, the trace should be steady.

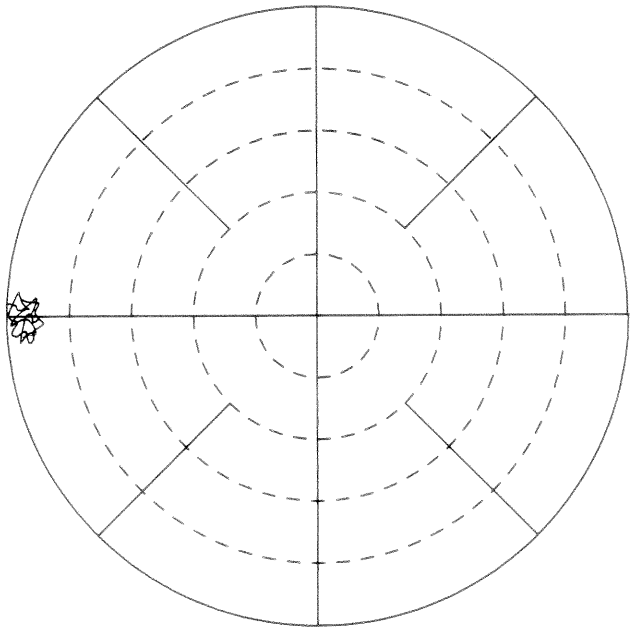

Figure 3-15. Network Analyzer Display of Good Short Circuit Connection (Normalized to Open, 0.6 to 3 GHz)

At this point the network analyzer display should look something like the figure above. The measurement data from the air standard is now used as a reference. The measurement data for the short circuit is normalized to the air data (open circuit) by dividing the two measurements. The network analyzer is left in a continuous sweep mode so that the quality of the connection can be monitored.

The short circuit tace should be in the area around the edge of the circle on the negative real axis: the coordinate of −1,0. (By definition, an open circuit trace on the display is at the edge of the circle lying on the positive real axis: the coordinate of 1,0). Verify that the short circuit standard measurement is roughly as shown above.

Note that the trace of high frequency measurements (up to 20 GHz, for example) will not be as tightly clustered as shown above. Normally, high frequency measurements will ressemble the figure below. However good traces will always be on the left side of the polar chart.

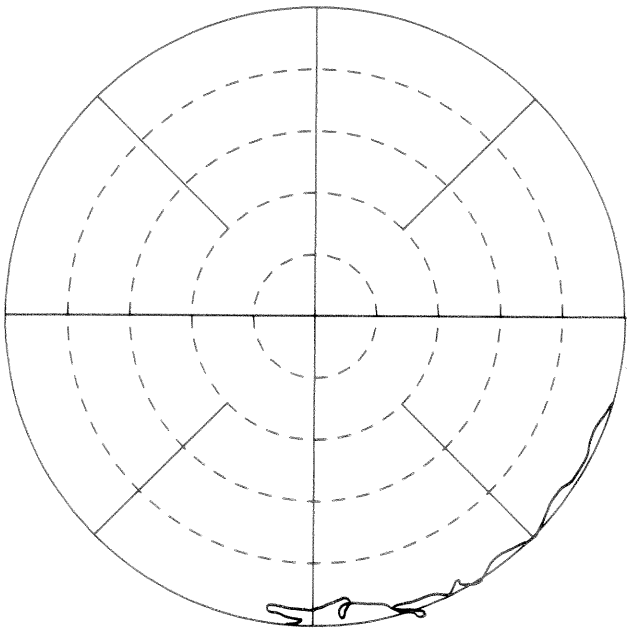

Figure 3-16. Network Analyzer Display of Short Circuit with Poor Contact (Normalized to Open, .6 to 3 GHz)

When the short circuit is properly connected, select the ***[OK]*** command from the computer or network analyzer. The software will trigger a measurement of the short circuit standard and transfer the data to the computer.

Measure the Third (Water) Standard

When the program prompts you to place the probe in water, use deionized water. (Tap water and distilled water can be used but the impurities will reduce the accuracy of the measurement.) Use one of the vials provided with the probe kit and the rubber coupling ring, as shown below, or dip the probe into a beaker.

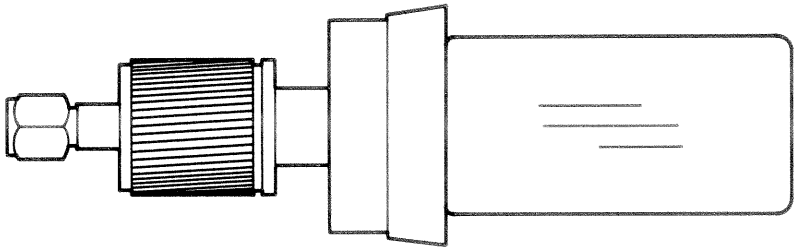

Figure 3-17. The Probe, Rubber Adapter, and Vial

The network analyzer should now display the measurement of the water relative to the measurement of air, as shown below. This is helpful in making sure that the probe is immersed properly.

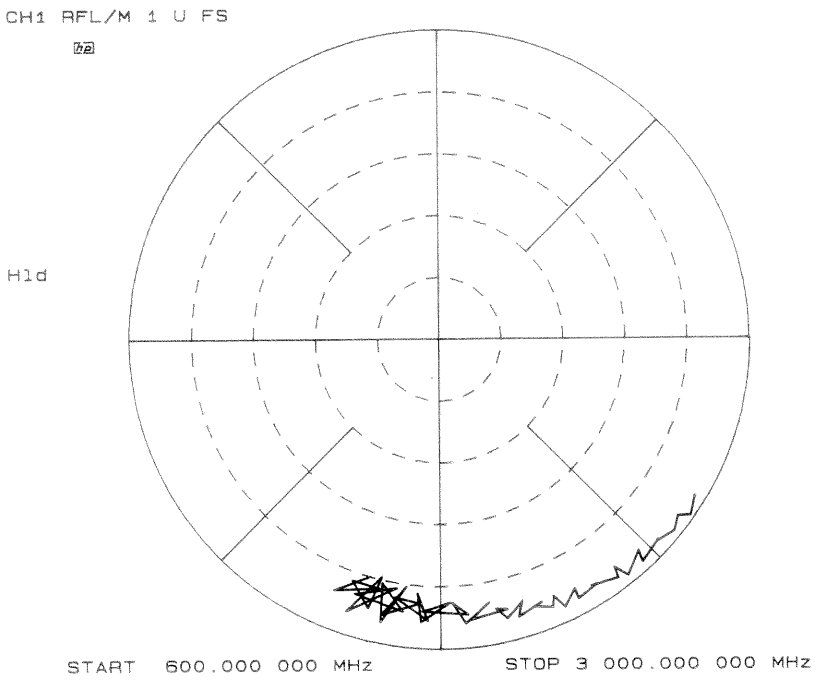

Figure 3-18. Network Analyzer Display of Deionized Water During Calibration (200 MHz to 20 GHz)

When the probe is properly immersed, select the ***[OK]*** command.

Observe the Results

Remove the probe from the water and dry it. As soon as the software calculates the error (correction) terms for each of the frequencies, it will display the main menu window on the CRT. The response on the network analyzer should look like the figure below.

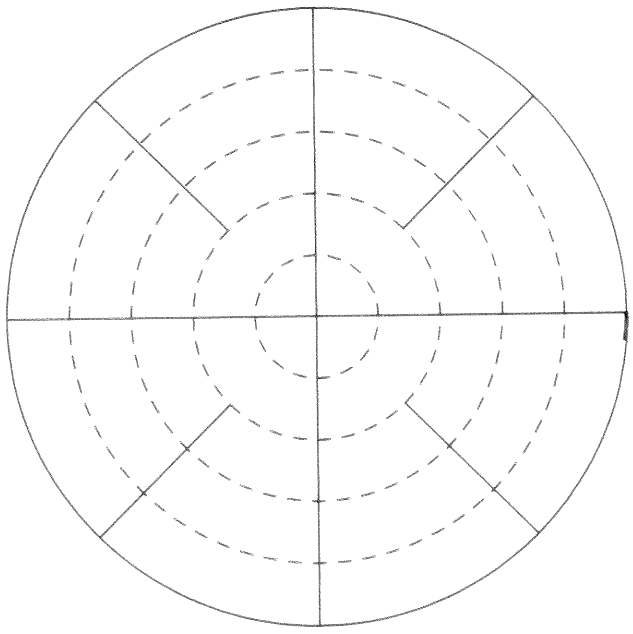

Figure 3-19. Calibrated Display of Air

The system is now calibrated and ready to characterize the permittivity of unknown materials.

Measure a Sample Material

In this example, a 95% ethanol (grain alcohol)/ 5% water,by volume, mixture is the material under test. Fill one of the vials in the probe kit with this liquid and use the rubber coupling ring to immerse the probe. The network analyzer display should look something like the display below.

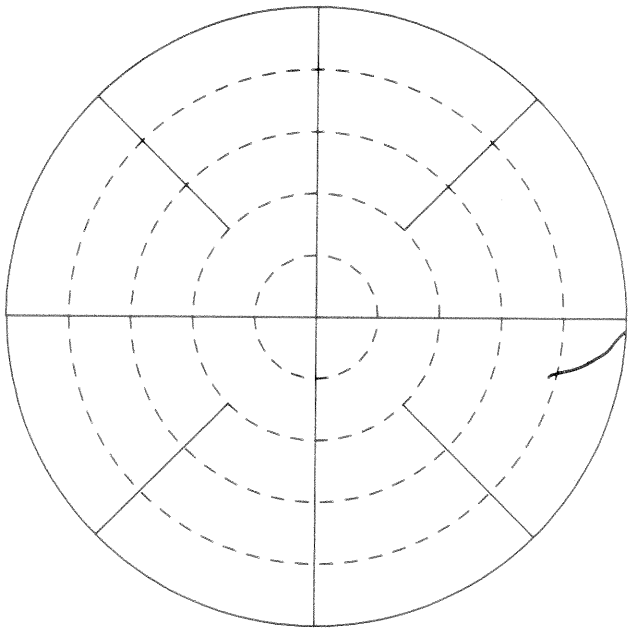

Figure 3-20. Network Analyzer Display of Ethanol Solution

To trigger the measurement, press ***[Measure]*** and select the ***[Trigger Meas]*** command. This will initiate the measurement sequence and allow the computer to calculate the complex permittivity (e' and e'') from the measured data. Note that the computer displays the progress of the calculation during this time.

When the calculation of the dielectric properties is complete, the results are displayed on the computer CRT. The default display format is e' vs. frequency. The default scaling for e' is from 0 to 100. There are ten divisions in the instrument display grid, thus each division represents 10 units. The measurement on the computer CRT should resemble the figure below.

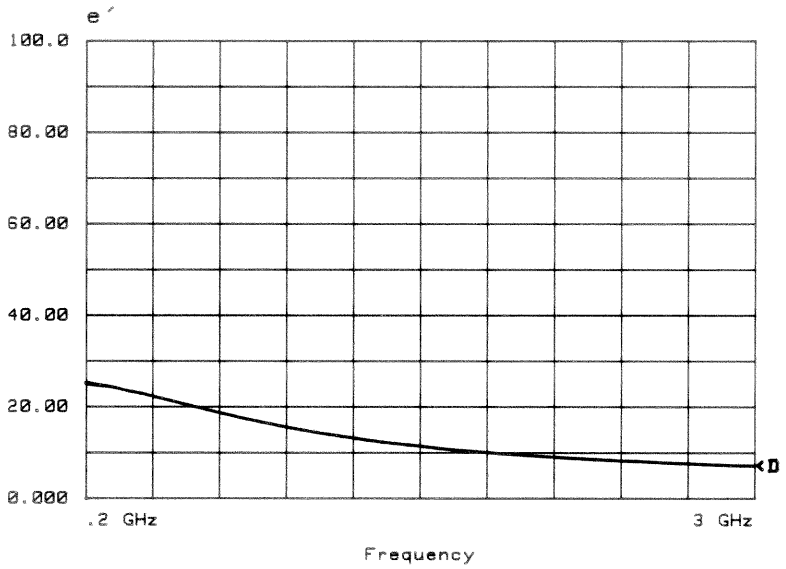

Figure 3-21. Default Computer Display of Ethanol Measurement

Scale the Display

You can change the Y-axis scale in the scale menu. Press ***[Scale]*** in the main menu. As described below, there are three ways to change the scale.

Select the ***[Autoscale]*** command. As you can see, the program automatically scales the graph based on the range of measurement data.

Now select the ***[Set Scale...]*** command. This presents a dialog box with Y-min and Y-max entry choices. Move the pointer next to the Y-max choice and press (RETURN) or (ENTER). Change the Y-maximum value to 50 by typing the number from the keyboard and then pressing the ***[Units]*** softkey. Select the ***[OK]*** command and the program rescales the graph.

Select the ***[Default]*** command (remember to select the ***[OK]*** command to enact the choice). Now the graph is redrawn with the default Y-maximum and Y-minimum scales.

To minimize repetitive selections, the program always uses the last scaling values for each graphical display format.

Change the Format of the Data

Graphical display formats are good for showing the overall picture of the dielectric behavior of a material. But sometimes it is helpful to see the actual numbers calculated for the dielectric properties of the material. The two tabular display formats can be used for this.

To change the display format, press the ***[Format]*** softkey in the main menu. Commands for e′, e″, Loss tangent e, Cole-Cole, Tabular (e′ & e″), and Tabular (e′ & tan d) are shown.

Now select the ***[Tabular e′ & e″]*** command to change the graphical display format to tabular format. The software will present the data as shown below.

	Data	
Freq (GHz)	e'	e''
0.200000000	25.48	2.98
0.256000000	24.91	4.20
0.312000000	24.59	5.21
0.368000000	23.92	6.21
0.424000000	23.25	7.05
0.480000000	22.51	7.76
0.536000000	21.82	8.35
0.592000000	21.12	8.90
0.648000000	20.39	9.34
0.704000000	19.64	9.75
0.760000000	18.94	10.04
0.816000000	18.25	10.31
0.872000000	17.54	10.45
0.928000000	16.91	10.59
0.984000000	16.31	10.68
1.040000000	15.71	10.72

Figure 3-22. Example of Tabular e' & e'' Format

You can now see the values of e' and e'' at each measurement frequency. Notice that the displayed values stop before the last measurement frequency of 3.0 GHz. This is because all of the tabular data will not fit on the screen at one time. But you can use the UP and DOWN arrows to "scroll" the displayed data one frequency at a time. Similarly, the PREV and NEXT keys scroll the data one page at a time.

Return the display to the graphical e' versus frequency format by pressing the format menu softkey and selecting the ***[e']*** command.

Save the Measurement Data to Memory

Often it is important to see how two (or more) different materials or measurements compare. The HP 85070A has four separate traces that can be shown on the instrument display. The traces are referred to as the data trace, memory 1, memory 2, and memory 3. After a measurement sequence, the calculated permittivity data is placed in the data trace. Performing another measurement will cause the new data to be stored in the data trace. The previous measurement would be lost at this point.

The measurement data trace can be stored into any of the three other traces so subsequent measurements can be compared. Any or all of the traces can be displayed. One of the traces can be defined as a reference trace. Math operations (divide by the reference trace, or subtract the reference trace) can be performed to make it easy to analyze differences in the traces.

All of these analysis features are accessed from the display menu.

Save the Data to a Memory Trace

The current measurement of the ethanol mixture is in the data trace. To save the measured data into memory 1, press the ***[Display]*** softkey in the main menu and select the ***[Data → Memory...]*** command. The software will present choices for saving the data in memory 1, memory 2 and memory 3.

Move the pointer to the ***[Data → Memory 1]*** command and press (RETURN) or (ENTER) to underline the choice. Press the ***[OK]*** command to enact the choice. Memory 1 now has the same permittivity data as the data trace.

Viewing More Than One Trace

Measure the ethanol solution again. Note that the data trace is erased and replaced by the new measurement. Note too that both the data trace and trace 1 are visible, as illustrated by the figure below. They are identified to the right of the display as <D and <1. Data stored in memory is displayed automatically unless you turn it off with the display menu.

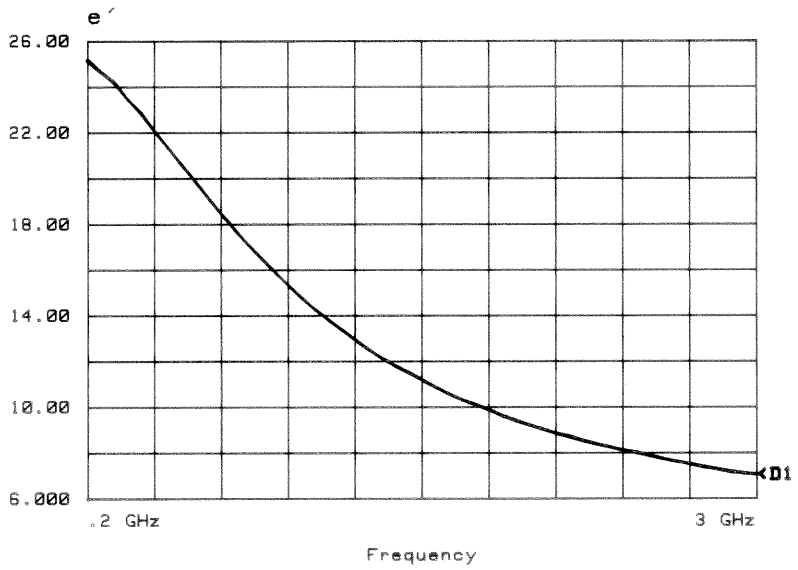

Figure 3-23. HP 85070A Display with Two Ethanol Traces

Compare the Traces with Trace Math

The software is capable of performing math operations between the different traces. One memory trace must be specified as the reference trace. The other traces displayed can either be divided by the reference trace or have the reference trace subtracted from them. These two math features operate on the complex data for each displayed trace and the reference trace.

First, save the data trace into memory 2 as you saved the previous measurement (above). Then put several drops of water into the ethanol solution, mix the solution, and trigger another measurement.

Specify the reference trace by selecting the ***[Reference Trace...]*** command in the display menu. Move the pointer next to memory 1 and press (RETURN) or (ENTER). Memory 1 is now underlined to indicate it is the intended choice for reference trace. Now position the pointer next to the ***[OK]*** command and press (RETURN) or (ENTER) to enact the choice and leave the dialog box.

The only remaining step in applying trace math is to select a math operator. To specify the math operation, select the ***[Trace Math...]*** command in the display menu. A dialog box presents choices for math off, /ref, and -ref. The math off choice is underlined to indicate that trace math is currently turned off. (In this menu, only one choice can be selected at a time.)

Position the pointer next to ***[/ref]*** and press (RETURN) or (ENTER). /ref is underlined to indicate the selected math operation. Use the ***[OK]*** command to enact the choice and leave the dialog box. The traces selected for display will now be divided by the reference trace (memory 1) before being displayed. Notice that the format indicator on the instrument display has changed from e' to e'/1. Autoscale the display (in the scale menu). Depending on the amount of water added to the mixture, the display should resemble the figure below.

When using the trace math function /ref, the operation is performed on the active format, not on the complex permittivity.

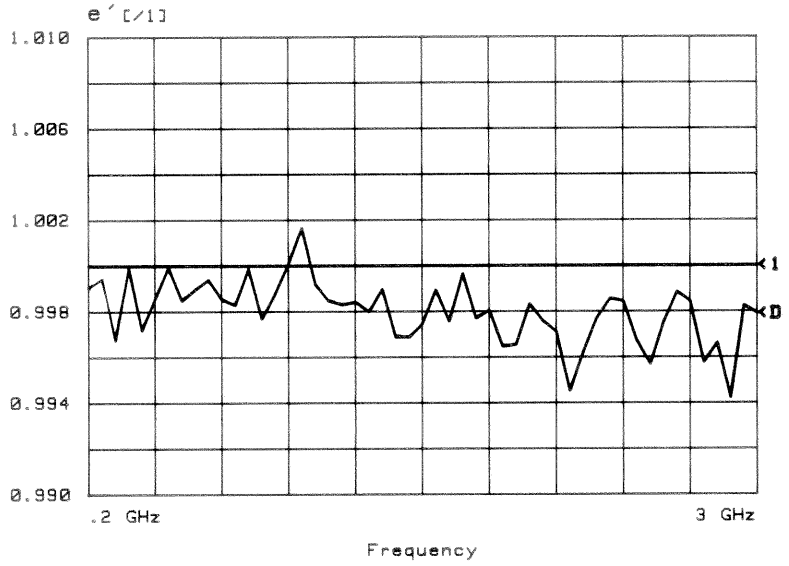

Figure 3-24. HP 85070A Display with Three Traces and Trace Math

* Memory trace 1 holds the original ethanol mixture measurement. Memory trace 2 holds the second ethanol measurement. The data trace holds the measurement of the diluted ethanol mixture.

Trace math calculates each of these measurements divided by the reference (original) measurement. The display shows the per cent difference above or below the reference (for example, 1.24 means that the trace being compared to the reference is 24% greater than the reference trace). Thus, trace 1/trace 1 always has the value of 1.

Memory trace 2 should have been very close to the original measurement of the ethanol mixture. Thus, trace 2/trace 1 should have values that are close to 1 but not exactly 1.

The data trace is different from the original ethanol mixture depending on the amount of water added. For e' vs. frequency, the ratio of data/trace 1 will be values greater than 1. For e'' vs. frequency, the ratio of data/trace 1 will be values sometimes less than 1 and sometimes greater than 1.*

Turn off trace math by using the ***[Trace Math...]*** command in the display menu and selecting ***[Math Off]***.

Print or Plot the Data

Hardcopy of measurement results is very easy to obtain. Graphical display formats can be directed to printers which support graphics and to Hewlett-Packard HPGL plotters. Tabular display formats can be directed to printers.

The output menu is used to generate hardcopy of measurement data. If the current display format is graphical, then a plot command is present in the menu. If the current display format is tabular, then a print command is present in the menu.

The software can work with a printer capable of supporting a BASIC language DUMP GRAPHICS. Change the plot type to DUMP in the define plot... dialog box to dump graphics to a printer. The default plotter type is HPGL.

For systems with plotters: Press the ***[Output]*** menu softkey and choose the ***[Plot]*** command to plot the current e' vs frequency graph.

For systems with printers: press the ***[Format]*** menu softkey and choose the ***[Tabular (e' & e")]*** command. Then return to the output menu and choose the ***[Print]*** command to print the current table.

Save the Test Setup, Calibration, and Displayed Traces to Disk

To save a test file (consisting of test setup, calibration data and all valid measurement traces) to disk, press the ***[Setup]*** menu softkey and select the ***[Save Setup...]*** command. This will display a list of the test setups saved on the current drive and directory. At the software prompt, type the name of the new file name and press (RETURN) or (ENTER). The components of the save setup... screen are shown below.

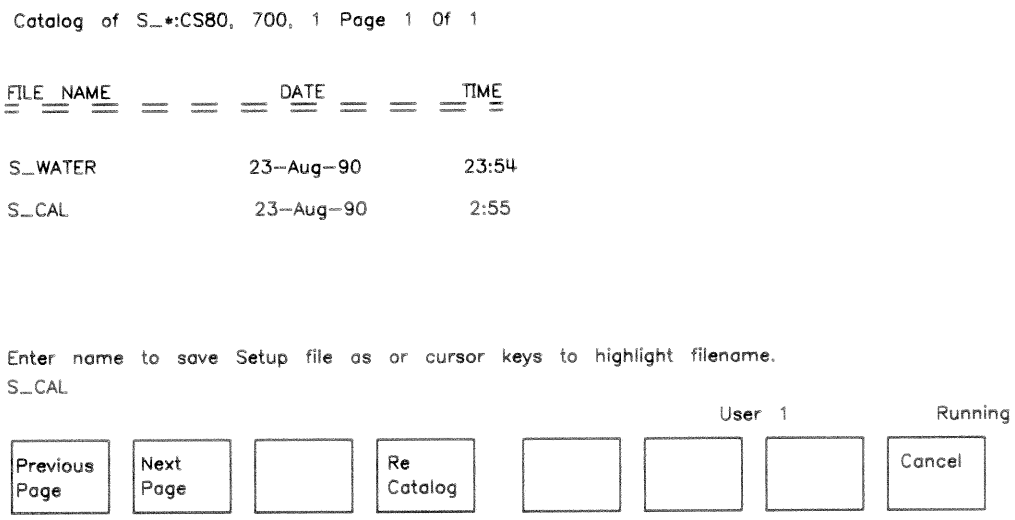

Figure 3-25. HP BASIC Save Setup... Dialog Box

As you save test files to disk, keep these facts in mind:

- The full directory structure of the HFS (hierarchical file system) is supported by the software.
- Floppy disk file names in HP BASIC have a maximum of ten characters (SRM and HFS file names can exceed this).
- The default file preface for test setup files is S_ (but you can specify other prefaces).
- The drive and directory can be changed by typing in new mass storage unit specifier, volume, and directory information at the display prompt.

Save the Measurement Data to Disk

You can also save measurement data to disk. This data file contains the following:

- The frequency range
- The measurement data trace, all of the current measurement data. (Note: memory 1, memory 2, and memory 3 are not saved with a data file.)

To save a data file to disk, press the ***[Output]*** softkey in the main menu and select the ***[Save data...]*** command. This presents a screen for entering the disk drive, directory, and filename for the data file.

The data file is stored in a binary HP 9000 series 200/300 format.

Recall the Files from Disk

To recall a test setup file from disk, select the ***[Recall setup...]*** command in the Setup menu. This presents a file dialog box. Enter the drive, directory, and file name of the desired file.

To recall a data file from disk, select the ***[Recall data...]*** command in the output menu. This initiates a search for all files with the S_ preface on the current disk drive and directory. It also presents a file dialog box. Select one of the listed files or enter the disk drive, directory, and file name of the desired file.

When measurement data is recalled, the software first compares the frequency range of the recalled data to the current frequency range displayed. If the ranges (and type of sweep) match, the recalled data is placed in the data trace for display. If they do not match, the recalled data is not displayed.

The recalled data is placed in the data trace for display. To view more than one saved data file, place the first recalled data trace in memory 1 and recall another. In this manner, you can view up to four saved data files.

CONCLUSION

After working through this measurement tutorial, you should be familiar with the main operating techniques and features of the HP 85070A dielectric probe software. Using the program is the best way to master it. But other aids are available. The help menu provides an on-line definition of each command in the program. Additionally the "Software Reference" chapter details each command and operation of the program (useful for infrequent users and infrequently used features).

Don't overlook the index and glossary for help.

Chapter 4. Advanced Measurement Techniques

INTRODUCTION

This chapter discusses a variety of topics intended to help you make more accurate measurements and analyze them on different platforms. The topics are these:

- When to use different calibrations
- Permittivity parameters
- Measurement uncertainty
- Importing data into other programs

WHEN TO USE DIFFERENT CALIBRATIONS

The software allows a choice of three major types of calibration:
(1) air/short/water (the default choice), (2) load/air/short, and (3) user defined. Note that the difference between the first two choices is water versus a load. Thus the question of when to use either calibration in essence becomes "what are the relative merits of water and a load as calibration standards?"

In brief, water is better at frequencies above 500 MHz. The software model of water does not account for ionic effects which are greatest at low frequencies. Additionally, loads are less predictable at high frequencies.

If you favor the user defined calibration, keep these suggestions in mind:

- Two of the standards should appear on (or as nearly as possible) opposite sides of the polar or Smith chart. In the two software defined calibrations these standards are air (an open) and the short.
- The third standard should be about midway between the other two standards on the polar or Smith chart. For instance, if air is one of the standards, Teflon should not be used as another standard because they are too close on the chart.

PERMITTIVITY PARAMETERS FOR VARIOUS MATERIALS

Four material parameters must be entered at the software prompts to use non-software defined materials as calibration standards. The parameters are used in the following Cole-Cole dielectric model equation to compute E* for any frequency (f).

Eq. 1: $$E^*(f) = E_\infty + \frac{E_0 - E_\infty}{1 + (j2\pi f\tau)^{1-\alpha}}$$

The table below lists those parameters for water at various temperatures. You can use other materials as standards as long as you enter their appropriate parameters.

Table 4-1. Material Parameters for Water at Various Temperatures

T, °C	α_S	α_∞	τ, $\times 10^{-11}$ sec	$\propto$
0	88.3	4.46	1.79	0.014
10	84.1	4.10	1.26	0.014
20	80.4	4.23	0.93	0.013
30	76.8	4.20	0.72	0.012
40	73.2	4.16	0.58	0.009
50	70.0	4.13	0.48	0.013
60	66.6	4.21	0.39	0.011
75	62.1	4.49	0.32	—

The information contained in this table is from *Water, A Comprehensive Treatise*, edited by Felix Franks, Plenum Publishing Corporation, NYC.

To define a material that is flat with frequency, assume the following:

E0 = Einf = E (the desired value) and
Tau = Alpha = 0 (zero)

MEASUREMENT UNCERTAINTY

Uncertainty is an integral part of measurements in this imperfect world, but not an undefineable part. The uncertainty of probe measurement results can be estimated with sensitivity numbers (or data) and the equation below. Sensitivity numbers represent the slope of the model which relates permittivity to reflection coefficient. Recall that the network analyzer measures the reflection coefficient of the MUT. The software, through a model, converts reflection coefficient to permittivity.

Since the actual measurement is a reflection coefficient measurement, the question of measurement uncertainty is this: what effect does a reflection coefficient measurement error have on permittivity?

Sensitivity numbers can show a relative, qualitative indication of uncertainty. For example, if in one instance the sensitivity number is 50 and in a second instance it is 25, the measurement uncertainties of the first instance are twice (50/25 = 2) those of the second.

More precisely, error sources can be divided into two categories: network analyzer error sources and dielectric error sources. Examples of network analyzer error sources are noise (about 0.0006) and the fixed load/probe directivity contribution (.03 to .06, for a LOAD/AIR/SHORT calibration, depending on frequency). Examples of dielectric error sources are probe model accuracy (3% to 5%) and uncertainty due to the accuracy of the permittivity characterization of calibration or reference standards.

The sensitivity numbers are useful in determining the measurement error contributions from both categories.

Network Analyzer Error Sources

The effect of network analyzer error sources can be calculated as follows:

Eq. 2: E = N x S where

E is the error (or delta epsilon)
N is network analyzer uncertainty (in linear terms)
S is the sensitivity number (absolute value)

For example, assume Teflon (Er=2.1) is measured at 10 GHz with a LOAD/AIR/SHORT calibration. At 10 GHz the fixed load/probe directivity contribution would be about 0.05. At 10 GHz for Er=2.1 the sensitivity is 8.1.

The measurement error due to the fixed load/probe directivity would be computed as:

Eq. 3: E= .05 x 8.1 = .4 (delta epsilon)

The delta epsilon error will split between the orthogonal e' and e'' terms such that SQRT(delta e'^2 + delta e''^2)<=.4. (Note this is not total measurement error, only the portion due to the fixed load/probe directivity.)

Dielectric Error Sources

The effect of dielectric error sources can be calculated as follows:

Eq. 4: E = Sm/Ss x Ds where

E is the measurement error (delta permittivity)
Sm is the sensitivity of the measured material
Ss is the sensitivity of the calibration standard
Ds is the delta uncertainty of the material used in calibration

Overall Measurement Accuracy

To determine the overall accuracy, combine the various measurement error terms as illustrated by the following example.

In the case where Teflon is measured at 10 GHz using an AIR/SHORT/WATER calibration, the total measurement error would be the sum of the errors due to probe model accuracy (typically about 2% to 5%), air, and water.

First compute Ds for air. The only effect to consider is the probe model accuracy of about 3%. Thus

$Ds_{air} = .03$

Next compute Ds for water. The model is accurate to within about 1 percent and the probe model contributes another 3%. The permittivity of water at 10 GHz and 25 deg C is 62.3-j*30. | Erwater | is then SQRT(62.3^2+30^2) or 69.

$Ds_{water} = (.03+.01)*69 = 2.8$

Next find the sensitivities for the various permittivities at 10 GHz. The values for Ss_{air}, Ss_{water}, and Sm_{teflon} can be generated by first performing an air/short/water calibration. After the calibration, remeasure air and store the measurement data into a data file. Remeasure water and store it into a data file. Then measure teflon and store it into a data file.

Finally, refer to "Obtaining Sensitivity Numbers," below, and use a spreadsheet or the program listed to read the sensitivity numbers. Insert those sensitivity numbers in equation 5 or 6 to calculate the uncertainty of the measured permittivity of the MUT.

Assume that the data files yield these sensitivity numbers:

$Ss_{air} = 8.2$
$Ss_{water} = 223$
$Sm_{teflon} = 8.1$

The worst case combination yields:

Eq. 5: E = 8.1/8.2 *.03 + 8.1/223 * 2.8 + .03*2.1 = .2 (delta epsilon)

The RSS combination yields:

Eq. 6: E = SQRT[(8.1/8.2 * .03)^2 + (8.1/233 * 2.8)^2 + (0.03 * 2.1)^2] = .1 (delta epsilon)

The delta epsilon error will split between the orthogonal e' and e'' terms such that SQRT(delta e'^2 + delta e''^2) <= delta epsilon.

Other Measurement Uncertainties

Temperature drift also introduces an error. The predominant source of this error is the cables that connect the probe to the network analyzer. Temperature drift usually exhibits itself as a linear phase change with frequency and arises when the temperature changes between the time the system is calibrated and subsequent measurements are made. To determine the effect on measurement error take the arcsin of the phase drift and treat the resulting linear term as a network analyzer error source.

Since the phase drift is repeatable, a first order correction is possible. By characterizing the amount of phase drift that occurs, the port extension feature of the vector network analyzers can be used to compensate. This may be useful when making a measurement in a temperature chamber. First calibrate the probe at a fixed temperature, then connect the short. A small dot should appear at the left edge of the polar display. Change the temperature and at each desired temperature adjust the port extension to bring the measurement back to a dot. Record the value of port extension required to correct the system for each temperature. Later prior to making a measurement enter the corresponding port extension for that temperature into the network analyzer.

Obtaining Sensitivity Numbers

Sensitivity numbers are available only when measurement data is stored to a file. The file is written in ASCII for the MS-DOS version of the program and in BDAT LIF format for the HP-BASIC version. It may be accessed with the following program.

```
10   !
20   !
30   !  This SUB will read an HP 85070 datafile when incorporated as part of an HP
40   !  BASIC program. It is assumed that the complex arrays for Epsilon and
50   !  Sensitivity are dimensioned in the main program.
60   !
70   !
80   SUB Read_file (Data_file$,Start_freq,Stop_freq,INTEGER
     Num_freq,Sweep_type$,COMPLEX Epsilon(*),REAL Sensitivity(*),Freq(*))
90  Read_file:!
100       !
110       !   INPUT  : Data_file$   - The filename and mass storage specifier of the
120       !                           HP 85070 datafile to recall
130       !
140       !   OUTPUT : Start_freq   - The start frequency for the stored measurement
150       !                           data that is read from the data file
160       !
170       !            Stop_freq    - The stop frequency for the stored measurement
180       !                           data that is read from the data file
190       !
200       !            Num_freq     - The number of frequencies for the stored
210       !                           measurement data. This variable must be an
220       !                           INTEGER type
230       !
240       !            Sweep_type$  - The type of frequency distribution for the
250       !                           stored measurement data. The string read back
260       !                           from the file will either be "LINEAR" for a
270       !                           linear frequency sweep or "LOG" for a
280       !                           logarithmic frequency sweep.
290       !
300       !            Freq(*)      - An array containing each measurement
310       !                           frequency for the stored measurement data. For
320       !                           example, Epsilon(5) holds the epsilon
330       !                           measurement data from the 5th frequency. The
340       !                           5th frequency is held in the array element
                                    Freq(5).
350       !
360       !            Epsilon(*)   - The stored epsilon measurement data
370       !
380       !            Sens(*)      - The stored sensitivity of the measured epsilon
390       !                           data to uncertainty in the S11 measurement
400       !
410       OPTION BASE 1 DIM File_type$[20]
420       ASSIGN @File TO Data_file$
430       ENTER @File;File_type$
440       IF File_type$<>"HP85070DATAFILE" THEN
450          !  not a proper HP 85070 file, take appropriate action
460       ELSE
470         ENTER @File;Num_freq,Start_freq,Stop_freq,Sweep_type$
480         ALLOCATE COMPLEX Temp_epsilon(Num_freq),REAL
            Temp_sens(Num_freq),Temp_freq(Num_freq)
490         ENTER @File;Temp_epsilon(*)
500         ENTER @File;Temp_sens(*)
510         ENTER @File;Temp_freq(*)
520         FOR I=1 TO Num_freq
530           Epsilon(I)=Temp_epsilon(I)
540           Data_sens(I)=Temp_sens(I)
550           Freq(I)=Temp_freq(I)
560         NEXT I
570       END IF
580       ASSIGN@File TO *
590  SUBEND
```

The Merits of Relative Measurements

Typically relative measurements are more accurate than absolute measurements. Relative measurement comparisons are facilated by the trace math feature "Trace-Ref." Comparing measured results to a known reference of nearly the same permittivity is recommended in general. But the recommendation is stronger when measuring samples in the small vial.

Small vial measurements can violate the semi-infinite model used by the software and thus lead to less accurate results. However, relative measurements tend to factor out this influence. In the case of biological liquids, saline solutions are an effective reference standard.

IMPORTING DATA INTO LOTUS 1-2-3, MICROSOFT EXCEL OR WORD PROCESSORS

The data files created by the HP 85070 materials measurement software can be imported into Lotus 1-2-3 or Excel for further calculations. There is no difference between the file formats for bringing the data into Lotus 1-2-3, Excel, or anything else - the one file will import into almost any other program since it is in ASCII format.

The detailed instructions below are specific to Lotus 1-2-3 and Excel. For instructions on importing into a particular word processor, see the hints in the paragraph titled "Importing Data into Word Processors." If that information is insufficient, consult the documentation for the word processor under "Importing ASCII Files."

Importing Data into Lotus 1-2-3

The three methods described here are different ways of dealing with the limitation that Lotus 1-2-3 can import both text and numbers but cannot import both simultaneously. The header information at the top of the data file needs to be imported in text mode and the data needs to be imported in number mode for it to be useful.

If you do not require the header information for your calculations, use method I. Otherwise the method you choose is mostly a matter of preference.

All three methods assume that you have Lotus 1-2-3 running, it is in the 'READY' mode, and the data file you are importing is in the current directory with a '.PRN' extension.

Lotus 1-2-3 Method I: Importing Numbers without the Header

This quick method is useful when the textual header information is of no value to your spreadsheet.

Move to the upper left corner of the range where you wish to import the data and execute the /FIN (file import number) command. This will take a little while as it reads in the file.

The data is ready to be used.

Lotus 1-2-3 Method II: Two Imports and a Copy

1. Import the Text

Move to the upper left corner of the range where you want your data to be imported. Issue the /FIT (file import text) command. You can then select your data file from the list presented by moving to the file name and pressing (RETURN).

This will take a short while to read in the data. It will appear to spread out over several columns, but it is actually long text labels all in the first column.

2. Import the Numbers

Move the highlight cursor one column to the right. This is where you will bring in the file again; this time as numbers instead of text.

Issue the /FIN (file import numbers) command and select the same filename as before.

This will again take a short while. You will notice that some of the data will be turned into scientific notation. This indicates that we have numbers which can be added, subtracted, etc.

3. Erase the Excess Numbers

There will be a few numbers that were pulled out of the header (for example, the date and the number of points). These can be discarded by following these steps:

Issue the /RE (range erase) command. To select all of the numbers pulled out of the header, move the highlight cursor down eight rows and over two columns. This should select a range which is 9x3 cells. Press (ENTER) to clear the cells.

Of course, if you would like to make use of any of these numbers (the number of points is certainly useful), you do not have to clear them.

4. Parse the Column Headings

This step is necessary only if you wish to keep the column headings with the columns of data. In normal use and especially when there are many columns of data, this is almost essential for keeping track of the data is each column.

The column heading is the row which starts with the word "frequency". Move down to this row and column (the entire row will show up in the status bar at the top of the screen). Issue the /DPFC (data parse format-Line create) command. This will insert a row just above the heading row that is Lotus 1-2-3's best guess at how to parse the heading. It will work for the current parse.

Next issue the input-column command. Select both the current row and the one below by typing a "." and then pressing the down arrow. This will select two cells. Then press (ENTER) to execute.

Set the output-range (type "O") and press (ENTER) (because the currently selected cell is the destination of the parsed result).

Finally, type "G" to execute the go command.

If the spreadsheet is to be printed, it may be desirable to change the alignment of the headings. This can be done by editing each heading and replacing the leading single quote (') with a caret (^) for centering or a double quote (") for right justified.

5. Move the Data Under the Headings

The data was automatically parsed by issueing the /FIN command, but it is one column and one row away from the desired location. The move command will fix this.

Move the highlight cursor to the first parsed number. This should be the first frequency value in the second column. Issue the /M command and select the data to be moved by presing the END key, the right arrow, the END key again, and the down arrow. This should select all the data in the file that was imported using the /FIN command. Press (ENTER) to confirm the "From" part of the move.

Move the highlight cursor to the row just below the parsed column headings. To wipe out the single column of text, move over this first column. Press (ENTER) to complete the move.

6. Discard the Last Line of Text

There will be one last text label at the end of the data. This can be removed by pressing the END key, the down arrow to get to the last cell, and then using the /RE (range erase) command to clear.

Lotus 1-2-3 Method III: One Import and a Parse

1. Import the Text

Move to the upper left corner of the range where you want your data to be imported.

Then issue the /FIT (file import text) command. You can then select your data file from the list presented by moving to the file name and hitting return.

This will take a short while to read in the data. It will appear to spread out over several columns, but it is actually long text labels all in the first column.

2. Parse the Column Headings

This step is necessary only if you wish to keep the column headings with the columns of data. In normal use and especially when there are many columns of data, this is almost essential for keeping track of the data is each column.

The column heading is the row which starts with the word "frequency". Move down to this row and column (the entire row will show up in the status bar at the top of the screen).

Issue the /DPFC (data parse format-line create) command. This will insert a row just above the heading row that is Lotus 1-2-3's best guess at how to parse the heading. The guess is correct for the upcoming the parse.

Next issue the input-column command. Select both the current row and the one below by typing a "." and then pressing the down arrow. This will select two cells. Press (ENTER) to execute.

Set the output-range (type "O") and press (ENTER) (because the currently selected cell is the destination of the parsed result). Press "G" to execute the go command.

If the spreadsheet is to be printed, it may be desirable to change the alignment of the headings. This can be done by editing each heading and replacing the leading single quote (') with a caret (^) for centering or a double quote (") for right justified.

3. Parse the Data

Move the highlight cursor to the first row of data. Issue the /DPFC (data parse format-line create) command. This will insert a row just above the heading row that is Lotus 1-2-3's best guess at how to parse the heading. The guess is correct for the next parse.

Issue the input-column command. Select both the current row and all the data below by typing a "." and then pressing the END and down arrow. This will select the entire column of text labels. Press (ENTER) to execute.

Type "O" and press (ENTER) to set the output-range (the currently selected cell is the destination of the parsed result).

Type "G" to execute the go command.

4. Discard the Last Line of Text

There will be one last text label at the end of the data. This can be removed by pressing the (END) key and then the down arrow to get to the last cell and then using the /RE (range erase) command to clear.

Importing Data into Microsoft Excel

This assumes that Excel is running and the data file to be imported is in the current directory.

There is only one step to importing the data into Excel. Choose the file open command and change the file box to read "*.PRN" instead of "*.XL*". Once Excel has read the directory, it will display all the files with a ".PRN" extension. Choose the desired data file. This will take a little while as the file is read - the percent completion will indicate how this is proceeding.

Once this command is completed, the data is ready to be used.

Importing Data into Word Processors

There are a large number of word processors that this file can be read into. Your documentation for the word processor will probably have a section for importing ASCII files. If it does not, try loading the file the same way you would any other file and see if it works.

It may be helpful to know that the columns of data are separated by tab characters. Each row ends with a carriage return and a line feed.

Chapter 5. In Case of Difficulty

INTRODUCTION

Although the HP 85070A dielectric prove kit has been designed for convenience and ease of use, problems can arise. Listed below, in alphabetical order, are some common problems and their solutions. To deal with problems associated with a specific instrument (like the computer, printer, or network analyzer) refer to its manual.

Bad filename entered, press any key to continue results from trying to enter an improper title for a file. File names must be eight (8) letters or less without digits or special characters.

Cables should be held in the same position during measurement as during calibration. Excessive flexing can result in measurement inaccuracies. Allow the standard probe cable to maintain the same position (don't flex or bend it) for one-half hour prior to measurements.

Deionized water should be used instead of tap water as a calibration standard for best measurement results.

Flatness of the probe is crucial for accurate measurements. Visually inspect the measurement surface of the probe, especially the center portion. Look for nicks, dents, discoloration, and other signs of stress. Solid materials must also be flat.

Hand-lapping the probe can restore its surface and facilitate reliable calibrations and measurements. If it becomes difficult to obtain a reliable short circuit when using the shorting block on the probe, inspect the surfaces of each. If the surface of the shorting block shows deep scratches, refer to "Show circuit measurements," below.

If the surface of the probe shows deep scratches (or neither the probe nor the shorting block are scratched), hand-lap the probe's contact surface. Use fine-grit (800 to 100 grit, 35 to 25 micron grit size,) paper or cloth. One example is 3M 48Q wet or dry, 30 micron, polishing paper.

Place the paper on a hard, flat surface. Hold the probe's contact surface on the paper with light pressure and move the probe in a figure-eight pattern three to eight times. Do not rock the probe. Check the probe and shorting block to see if they make a reliable short circuit. If not, hand-lap the probe again and recheck.

Hardware problems should be resolved by referring to the manual of the instrument (network analyzer, printer, computer) at fault.

Non-repeatable measurements may be the result of excess cable flexing, poor or inconsistent contact of the MUT with the probe, temperature variation between measurements.

Plotter won't plot. See "Printer won't print," below.

Printer won't print. Make sure the printer is plugged in and turned on. With the HP BASIC version, make sure the printer is connected to the computer and set to address 01 (plotter address is 05).

Program won't run usually results from improper installation.

For the MS-DOS version, make sure the computer has the minimum 640 Kbytes of RAM, a high density flexible disk drive, at least a 20 Mbyte hard disk drive, EGA or VGA compatible graphics, and a mouse. The computer must also have MS-DOS version 3.20 or higher. See chapter 2, "Getting Started," for details.

For HP BASIC versions of the program, confirm that the computer is not one of the unsupported exceptions, make sure that the computer has at least 2.0 Mbytes of RAM, a double-sided, double-density disk drive, BASIC 5.0, the required binaries, and an HP-IB interface card. See section 2 of chapter 2, "Getting Started," for details.

Short circuit measurements are unreliable if either the shorting block or the probe face are scratched. Inspect each. If the shorting block shows deep scratches, carefully remove it from the clip, turn it over, and reinstall it. If both sides of the shorting block show deep scratches, replace the assembly.

If the surface of the probe shows deep scratches (or neither the probe nor the shorting block are scratched), refer to "Hand-lapping the probe," above.

Temperature should be constant for best measurement results. Avoid thermal shock. Allow one-half hour for the probe to achieve temperature equalization if it has been subject to temperature variations. When deionized water is used as a calibration standard, it is important to enter the correct temperature and maintain that temperature during calibration and measurements.

To deal with error messages specific to the MS-DOS or HP BASIC versions of the program, refer to section 1 or 2 (following).

SECTION 1: MS-DOS ERROR MESSAGES

This section alphabetically lists the error messages of the MS-DOS version of the program. The error messages are in **bold**; explanations (if any) in normal type.

A calibration has not been performed. The attempt to make a measurment failed. You must perform a calibration or recall a Setup file containing a calibration first.

A copy of HP 85070 is already running. You can run only one copy of the HP 85070A application at a time.

An error occured allocating memory during the measurement. Reduce the number of points and close any other application programs immediately. There is not enough system memory to perform calculations with the specified number of frequency points. This is usually due to having several other Windows applications running at the same time as the HP 85070A. Either reduce the number of points and recalibrate the system, or close the other applications.

An HP-IB error has occured. No space for new cal; delete a cal set. This error will occur with the HP 8510 network analyzer if there is no space to store a calibration. Use the CAL menu on the HP 8510 to delete a previous calibration to make room for the calibration just performed.

Calibration does not match the current setup. A measurement was triggered but the frequency range of the calibration in the network analyzer does not match the setup in the software. The software will not allow measurment.

Cannot find plotter or Problem with plotter. The program is unable to communicate with the hardcopy device when performing a plot operation. Recheck the cabling to the hardcopy device or make sure that it is properly installed in the Windows Control Panel. Try to communicate with this device with another Windows application.

Cannot find printer or Problem with printer. The program is unable to communicate with the hardcopy device when performing a print operation. Recheck the cabling to the hardcopy device or make sure that it is properly installed in the Windows Control Panel. Try to communicate with this device with another Windows application.

Can not write to 'filename'. This error typically occurs when the disk is removed from the drive.

Data does not exist. The attempt to save data to memory failed because no data trace exists.

Error number xxx opening 'filename'. These errors are generated by the DOS system. Refer to DOS documentation for the nature of this particular error.

Illegal FILENAME. Illegal characters were specified in the filename. Only alphanumeric characters are allowed in the filename.

Illegal number of points. Must be at least 11 and a multiple of 10 +1. For the LOG sweep mode, the number of points must be 11, 21, 31, ..., 101, etc.

Illegal number of points. Must be 3 or more. A minimum of 3 points must be specified.

Illegal start frequency. Start frequency is either (1) less than minimum allowed by network analyzer, (2) more than maximum allowed by network analyzer, or (3) greater than stop frequency.

Illegal step frequency. Step frequency is smaller than the minimum resolution of the network analyzer source.

Illegal stop frequency. Stop frequency is either (1) less than minimum allowed by network analyzer, (2) more than maximum allowed by network analyzer, or (3) less than start frequency.

No filename specified. An attempt was made to load or store a file without specifying a filename. This would occur if no entry was made in the dialog box.

The IEEE-488 card is not responding as configured. Please check and correct configuration. The HP or National Instruments IEEE-488 card is not operating properly. Try repowering the computer to see if this cures the problem. If not, refer to the card's operation manual to run diagnostic routines to insure that the card is properly installed.

There is not enough memory to run HP 85070A. Close all other applications and try again.

The selected filename is too long. Only eight characters are allowed. DOS filenames can only be eight characters long.

The metallic shorting block may not be properly connected. The software has detected possible poor contact of the metallic shorting standard. Refer to the Measurement Tutorial for screen responses of good and poor contact with short circuit standards.

The Network Analyzer is not responding as configured. Please check and correct configuration. The software is unable to communicate with the network analyzer. Check HP-IB connections. You may also try pressing the green PRESET button on the network analyzer then pressing the RETRY choice in the software.

This revision does not support more than xxx pts. The entered number of points is greater than the software and network analyzer allow.

This software does not support the HP 8510A. Only the HP 8510B and HP 8510C are supported by the software.

SECTION 2: HP BASIC ERROR MESSAGES

This section alphabetically lists the error messages of the HP BASIC version of the program. The error messages are in **bold**; explanations (if any) in normal type.

Bad filename entered. A filename that is not accepted by the BASIC operating system was entered. Filenames have a maximum of 10 characters, including the "D_" or "S_" prefix that the software includes. Only alphanumeric characters and the underline (_) character are allowed in the filename.

Drive not found or bad address. The software cannot find the disk at the currently defined mass storage specifier. A new mass storage unit specifier can be entered by executing another Save (data or setup) command and entering the new MSUS, ex. :,700,1 (see the HP BASIC documentation for more details on the syntax of mass storage specifiers), when promted for the filename.

Entered frequency above network analyzer source range. The frequency entry is outside the range of the network analyzer source. Enter the value again and make sure that you are terminating the entry with the desired terminator (GHz or MHz).

Entered frequency below network analyzer source range. The frequency entry is outside the range of the network analyzer source. Enter the value again and make sure that you are terminating the entry with the desired terminator (GHz or MHz).

File 'Filename' already exists! Do you wish to overwrite it?. An attempt was made to save a file on disk when a file with the same name already exists. Press the OK softkey to replace the old file, press the Cancel softkey to abort the save process, then use a different filename.

Mass storage medium overflow (no space left on disk). There is not enough space on disk to save the file. Insert another initialized disk and hit the Try Again softkey, or abort the process by pressing the Exit softkey.

Maximum string length of entry is xx characters. The string entry (filename, display title) has exceeded the maximum length allowed. The software will present this message. After any key is pressed, the string will be presented again. Use the back space key or left arrow key to delete characters.

Media is not in drive. The software can find the disk drive but a disk is not in the drive. Put the disk in and press the Try Again softkey, or press the Exit softkey to abort the process.

Media is not initialized. An attempt was made to save or recall a file from an uninitialized disk. Only disks which have been initialized with the BASIC operating system can be used. This initialization must be done outside the HP 85070A software with the BASIC INITIALIZE command. See the BASIC manuals for more information.

Media is write protected. An attempt was made to save a Setup or Data file to a write-protected disk. Use another disk or move the write protect tab on the current disk to enable the storage and press the Try Again softkey. Press the Exit softkey to abort the storage process.

No active traces. An attempt was made to autoscale the data with no active data or memory traces.

No current data trace. An attempt was made to save data to a memory trace without having a valid data trace.

No current memory trace. An attempt was made to save a memory to data without having a valid memory trace.

No room for calibration in HP 8510. Delete a calibration set manually. There is no more room inside the HP 8510 for the calibration just performed. Use the CAL menu in the HP 8510 to delete a cal set to make room for the new calibration.

No valid calibration. An attempt was made to take a measurement without performing a calibration. Calibrate the system.

No valid data trace to save. An attempt was made to save a data file without a valid measurement data trace. Turn data on in the Traces Displayed choice of the Display menu if a Data trace exists or perform the desired measurement.

No valid reference trace. An attempt was made to perform trace mathematics without a valid reference trace. Save a trace to the reference trace and try again.

Number of frequencies in log mode must be 11 or greater. A minimum of 11 frequencies must be specified for the LOG sweep setup.

Number of frequencies must be greater than 1. A minimum of 2 frequencies must be specified for the setup.

Number of points must be (multiple of 10) + 1 for log mode. The number of frequencies must be 11, 21, 31, ..., 101, etc. for the LOG sweep mode.

Setup file is incompatible with current network analyzer. An attempt was made to recall a setup file that was created with the software using a different model network analyzer.

Specified file 'Filename' is not a valid HP 85070A data file. An attempt was made to recall a data file that was not created using the HP 85070A software. This error will also occur if an attempt is made to recall a Setup file and the specified file was not created by the software.

Step frequency is too small for current span. The entered value of step frequency would result in a number of frequencies greater than that supported by the network analyzer.

Step frequency of 0 Hz not allowed. The step frequency must be greater than 0 Hz. This entry would cause a calculation error.

Stop frequency must be greater start frequency. The specified start frequency is greater than the specified stop frequency . Change the frequencies to correct this situation.

Stored data (1 to 2 GHz, 51 pts., log) does not match setup. The frequency setup in the software must exactly match the frequency range of any stored data to bring the data trace back into the software. The frequency range of the data is presented in the error message so that you can go back to the Set frequency ... choice in the Setup menu to change the frequency setup.

Y-max and Y-min can not be the same value. The maximum and minimum values for the graphical display were specified to be the same value. Enter new, different values.

Chapter 6. Operator's Check

INTRODUCTION

The following procedure is a simple, effective means of checking the functionality of the cable, probe, and shorting block. Use it for incoming inspection or routine system check. Note that all of the items shipped with the product are listed in chapter 1, "General Information."

PROCEDURE

1. Visually inspect the measurement surface of the probe with a magnifying glass or low powered microscope. Look for nicks, dents, discoloration and other signs of stress especially in the center portion.
2. Connect the probe to the dielectric probe cable and the cable to port 1 of the network analyzer. (For HP 8510-based systems, refer to chapter 2 to see how to connect the network analyzer, source, and test set.)
3. Secure the cable to prevent its movement during the next steps. Cable movement may produce erroneous test results.
4. Turn on the network analyzer and press (PRESET). This should set the analyzer to sweep from its lowest to highest frequency.
5. Set the analyzer to polar format and turn on a marker. Set the marker to the lowest frequency.
6. Store the active trace in memory (on most analyzers press (DISPLAY) ***[DATA → MEMORY]***).

7. Divide the data by memory to normalize the data (on most analyzers press ***[DATA/MEMORY]***). If all of the connections are tight and the probe is OK, the network analyzer display should resemble the figure below.

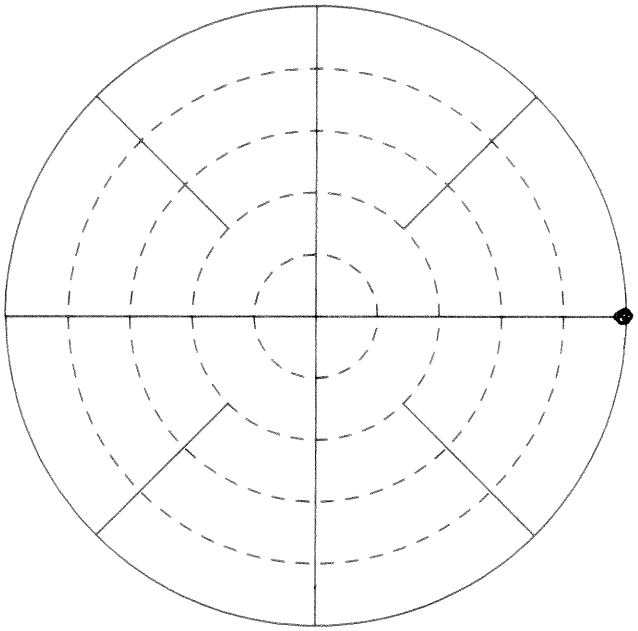

Figure 6-1. Normalized Measurement of Air

There should be a small dot (the trace) on the right edge of the polar chart. A blurry or elongated "dot" indicates that the connections or the probe are not stable. In this case, remedy the situation before proceeding.

8. Attach the short circuit to the probe. Make sure that all three tabs of the spring clip are fully engaged on the flange of the probe as shown below. It should feel very secure.

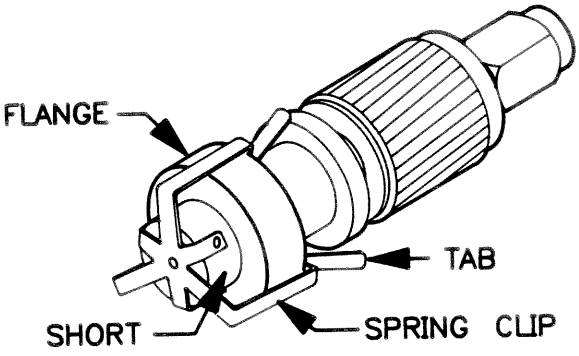

Figure 6-2. Short Circuit Held on Probe by Spring Clip

9. Observe the trace on the network analyzer display. It should look like the figure below, concentrated at the far left side of the Smith chart. It will not be as small a dot as the one you just observed on the right edge. Nonetheless, such a trace indicates that the probe, short circuit and network analyzer are operating as designed.

10. The marker readout is in Units (or milli-Units) and degrees (or milli-degrees). It should read within 0.1 Units of 1 Unit and within 10 degrees of ±180 degrees.

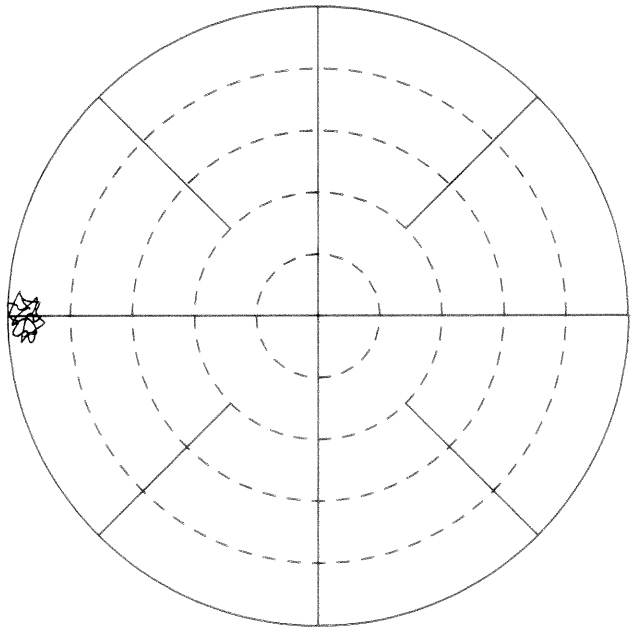

Figure 6-3. Measurement Trace of Good Short Circuit to 20 GHz

IN CASE OF DIFFICULTY

If the short measurement does not ressemble the trace shown above, reposition the short on the probe end. Make sure the short is in firm, even contact with the probe. If trouble persists, refer to chapter 5, "In Case of Difficulty."

Chapter 7. Ordering Supplies

INTRODUCTION

This chapter details the parts of the probe kit, explains how to order those and other parts, and lists materials measurement literature.

HP Part Number	Qty	Description
85070-10001	1	dielectric probe kit software (MS-DOS version, standard)
9010-0007	1	MS Windows, version 3.0 (not included with option 300)
85070-10002	*	dielectric probe kit software (HP BASIC version, option 300)
85070-60001**	1	probe assembly
00902-60003**	1	50 ohm 3.5 mm fixed load
85070-20004**	1	shorting block
85070-20006**	1	spring clip (for shorting block)
85070-60002**	1	test port cable clamp
8120-5424**	1	cable, type-N (m) to 3.5 mm (f)
85070-80003**	1	remote switch assembly
85070-40003**	1	rubber adapter for small vial
85070-40002**	1	rubber adapter for large vial
9301-1212	2	rubber vial stopper, 7x13 mm
9301-1213**	2	small glass vial
9301-1214**	2	large glass vial
1250-2301**	1	adapter, type-N (f) to SMA (f)
1250-1464**	1	adapter, type-N (f) to 7 mm
85070-90001**	1	this manual

* When option 300 is ordered, this software substitutes for the MS-DOS version software.

** Illustrated in figure 1-1.

Ordering Information

To order a part listed in the replaceable parts list, quote the part number, indicate the quantity required, and address the order to the nearest Hewlett-Packard office.

Literature

A variety of materials measurement literature exists. This list is by no means complete but should prove helpful in providing directions for further reading. The list is organized in three sections: Hewlett-Packard literature, public techinical papers, and authors in the field of materials measurements.

Hewlett-Packard Literature. To order HP literature, contact your nearest Hewlett-Packard office.

- "HP 16451B Dielectric Test Fixture," data sheet, part number 5950-2368, May 1989.
- "LCR Meters, Impedance Analyzers, and Test Fixtures," selection guide, part number 5952-1430, January 1990.
- "Using the HP 16451B Dielectric Test Fixture," application note 380-1, part number 5950-2390, October 1989.
- "Characteristic Impedance Measurement of PC Board Circuit Patterns," application note 339-2, part number 5950-2908, June 1986.
- "Measuring the Dielectric Constant of Solid Materials," application note 339-13, part number 5950-2935, December 1987.
- "Measuring the Dielectric Constant of Solids with the HP 8510 Network Analyzer," product note 8510-3, part number 5954-1535, August 1985.
- "Measuring Complex Permittivity and Permeability at RF and Microwave Frequencies," RF & Microwave Symposium paper, September 1989, available from Network Measurements Division, Santa Rosa, CA.

Public Technical Papers

To obtain copies of these papers, contact the organization or publisher listed.

- M. Afsar et al; "Measurement of the Properties of Materials"; proceedings of the IEEE, volume 74, number 1, January 19 86. This is an excellent short survey of many methods across wide frequency range. With its 187 references, it is a good starting point for beginners.
- H. M. Altschuler; "Dielectric Constant"; chapter 9 of "Handbook of Microwave Measurements" by M. Sucher and J. Fox; Wiley, 1963. This is a good technical reference covering high frequency techniques. It contains detailed procedures and equations (but using slotted line instead of a network analyzer).
- ASTM; "Standard Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials"; Standard D-150-87; American Society for Testing and Materials, Philadelphia, PA 19103. The US authority on testing methods features great technical depth on parallel-plate capacitor methods for low frequencies.
- Richard G. Geyer; "Electrodynamics of Materials for Dielectric Measurement Standardization"; proceedings of the IEEE, IM-TC, January 1990. A review of measurement concerns, standards, and traceability with examples of state-of-the-art measurements including NIST X-band cavity and the first public reference to Baker-Jarvis enhancement to S-parameter technique.

- Deepak K. Ghodgaonkar et al; "Free Space Method for Measurement of Dielectric Constants and Loss Tangents at Microwave Frequencies"; IEEE Transactions on IM volume 37 number 3, June 1989. This describes the work at Penn State's Center for Engineering of Electronic/Acoustic Materials. The topic is the free-space method using spot-focusing antennas with an HP 8510B and TRL calibration.

- Arthur R. von Hippel, ed; "Dielectric Materials and Applications"; MIT Press, 1954. This book is over 35 years old, but still the bible on dielectrics and measurements; a good introduction to basics.

Other Authors

- Stuart O. Nelson, US Department of Agriculture. He has written many articles on microwave measurement of moisture in raw grains.

- Stan Stuchley, U of Ottowa, Canada. He is an authority on dielectric measurements using coax open-ended probe.

- Gordon Kent, Dielectric Lab Inc. He invented novel cavity methods and simplified equations to measure dielectric properties of ceramic substrates.

Chapter 8. Software Reference

INTRODUCTION

This chapter details the operation of each menu, command, and entry parameter in the HP 85070A dielectric probe software. There are eight menus in the software. The menus are indexed in the order in which they appear (left to right) on the screen. These are the general functions of each of the menus:

Setup selects the frequency range and linear or logarithmic frequency distribution. It also allows you to save and recall test setups to disk.

Calibrate allows calibration of the measurement system. In this menu you can enter the temperature of the water calibration standard and select the types of calibration standards desired.

Measure triggers a measurement and converts the measurement to complex permittivity for display. In this menu, you can also title the graphs and tabular listings of measurement data.

Format allows selection of graphical formats or tabular formats.

Display offers data manipulation choices: transfer the current measurement data trace to any of three memory traces, select which traces are displayed and specify a reference trace and complex math operations between the traces.

Scale lets you scale the data automatically or manually.

Output permits hardcopy plots of graphs and prints of data tables. This menu also lets you save and recall measurement data to and from disk.

Help is an indexed summary of the function of all commands.

SETUP MENU

The setup menu is used to select the range of frequencies for complex permittivity measurements. The frequencies can be distributed in a linear or logarithmic fashion. The setup menu is also used to save and recall complete test setups (and measurement traces, if any) to disk.

The commands in the setup menu are these:

Set Frequency...

The ***[Set frequency...]*** command is used to select the frequency parameters of the system for calibration and measurement.

Frequency range can be defined in two ways:

1. Start frequency to stop frequency with a number of frequencies. For example, a range from 2.0 to 7.0 GHz with 51 points would result in measurements being taken between 2.0 and 7.0 GHz at every 0.1 GHz inteval.

2. Start frequency to stop frequency with a step frequency. For example, a range from 10.0 to 18.0 GHz with 1.0 GHz steps would result in measurements being taken between 10.0 and 18.0 GHz at 9 equally spaced points.

The software will allow either step frequency or number of frequencies to be entered for linear frequency sweep mode measurements. If both the number of frequencies and the step frequency are entered, the number of frequencies will take precedence.

Sweep Mode

The software can make measurements over the specified frequency range by distibuting the frequencies in either a linear or logarithmic fashion. In a linear sweep mode the start, stop, and step/number of frequencies is specified. In a logarithmic sweep the start, stop, and number of frequencies is defined.

The number of frequencies in the log mode must be a multiple of ten plus one (for example, 11, 21,....101, etc.). This restriction enables the software to evenly distribute the frequencies into ten different frequency list segments and operate the network analyzer in the frequency list mode. The start of each frequency segment is distributed logarithmically.

The dialog box for the MS-DOS set frequency... command is shown below.

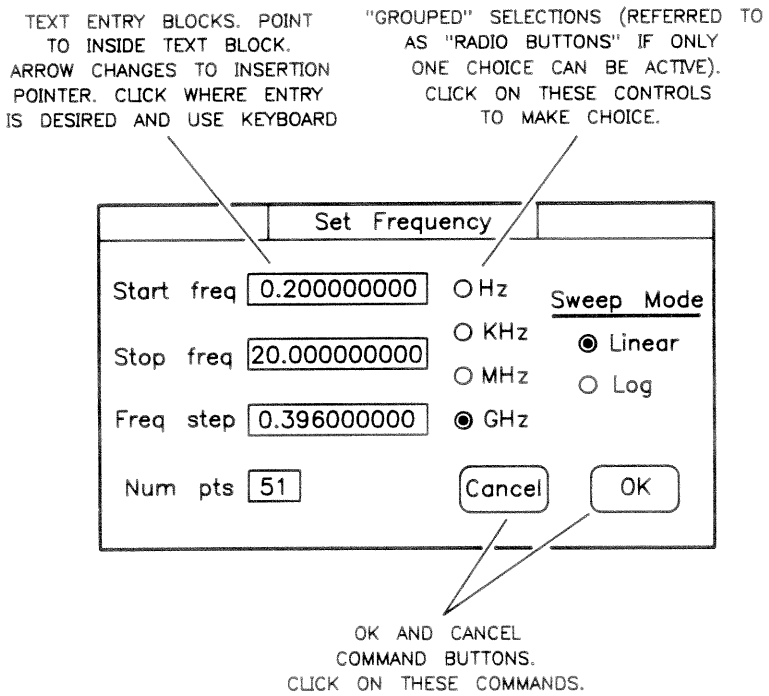

Figure 8-1. MS-DOS Version of Set Frequency... Dialog Box

The HP BASIC dialog box for the set frequency... command is shown below. When the linear/log command is chosen, the sweep mode toggles and the chosen sweep mode is underlined. A choice for step frequency is not be presented in the log mode.

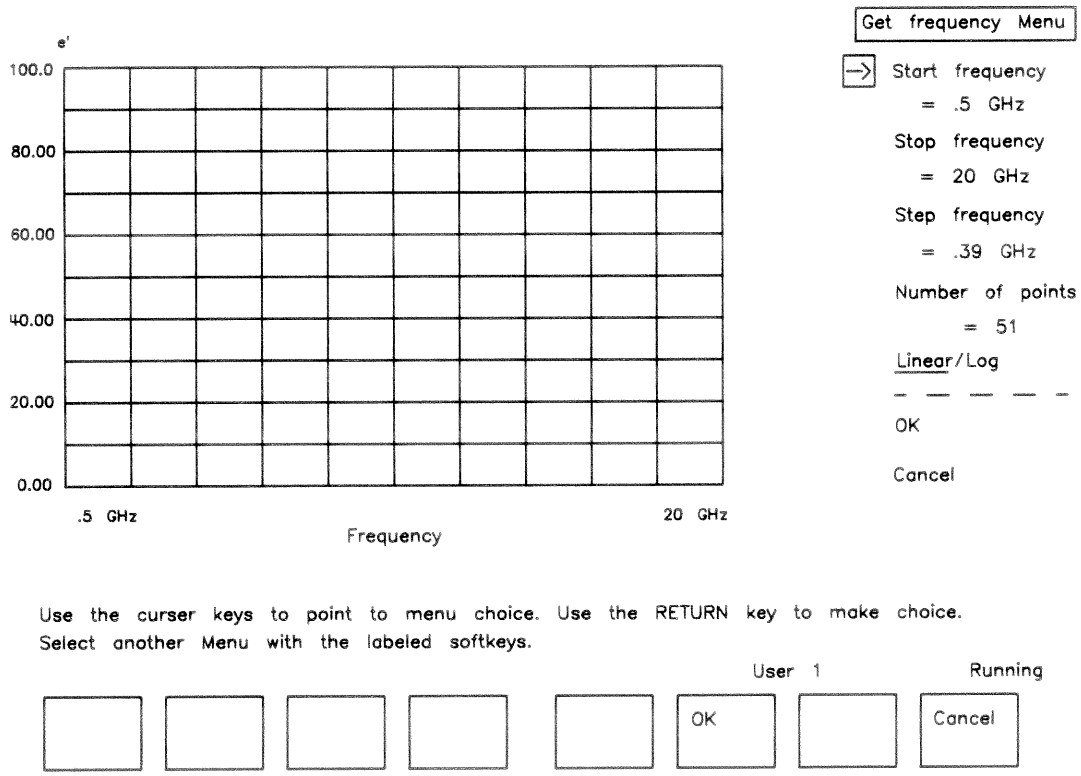

Figure 8-2. HP BASIC Version of Set Frequency... and Set Sweep Mode... Dialog Box

Save Setup...

Selecting ***[Save setup...]*** allows you to specify a file and file location for saving complete test setup information. The HP 85070A setup file contains these items:

- Calibration error terms (if a calibration is active).
- Learn string of the network analyzer at the time of calibration (if a calibration is not active, the learn string of the network analyzer at the time the setup file is saved is included). The learn string completely defines the operating state of the network analyzer.
- All displayed measurement traces.
- Software operating state at the time the setup file is saved. The state of the software includes; the calibration type and calibration standard models, the current display format and scale, trace math information, trace display information, title information, and pen color information.

Saved calibrations can be reused IF there have been no changes in the cabling of the probe and network analyzer. But it is important to have a verification standard (air, teflon or methanol, for example) to evaluate whether the saved calibration is still valid. Before re-using a saved calibration, measure the verification standard. If the measurement is good, you can re-use the saved calibration. Otherwise, recalibrate the system before making additonal measurements.

In the MS-DOS version of the program, selecting ***[Save setup...]*** presents a dialog box to specify the file to save the test setup. The components of that dialog box are shown below.

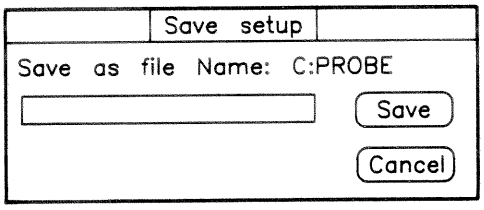

Figure 8-3. MS-DOS Version of Save Setup... Dialog Box

The test setup file can be saved to any disk drive and directory in the computer. Use the drive icons and directory icons in the list box to select where the data file is to be saved. Use the file name list box to select the name for the data file. File names in DOS have a maximum of eight characters. The default file extension for data files is .TST. (The Recall setup... dialog box first searches for all files with the .TST extension on the current disk drive and directory.) Press the ***[OK]*** command to save the test setup.

The HP BASIC version components of the Save setup... screen are shown below.

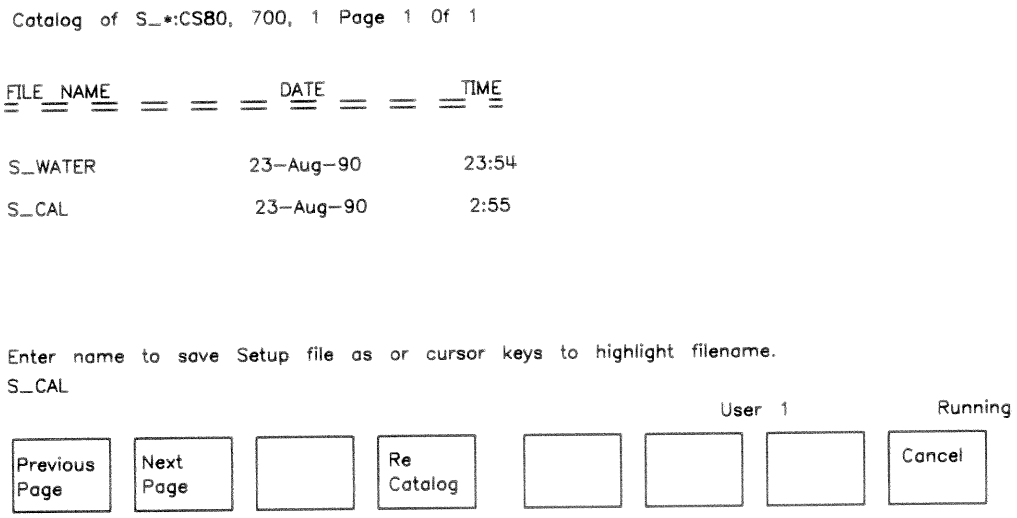

Figure 8-4. HP BASIC Version of Save Setup... Screen

The screen lists all of the test setup files saved on the current drive and directory. At the software prompt, type the file name to be used for saving the file and press (RETURN) or (ENTER). Filenames in HP BASIC have a maximum of ten characters. The default file preface for datafiles is S_. (You can specify other prefaces, but keep in mind that the recall setup... function first searches for files with the S_ preface on the current disk drive and directory.)

The drive and directory can be changed by typing in new volume, directory, and mass storage unit specifier information at the display prompt. The full directory structure of the HFS (hierarchical file system) is supported by the software.

Recall setup...

Test setups can be recalled from disk by choosing the ***[Recall setup...]*** command. A file dialog box is presented to enter the drive, directory, and file name of the test setup to recall from disk.

In the MS-DOS version, drive icons (for example, [-A-], [-B-]) and directory icons (directory names presented in bold) are presented in a list box. Single click on these icons to get a list of the files on a different drive or directory.

In the HP BASIC version, to change the disk drive, type in a new mass storage specifier (for example, ":,700,1", "/HP85070/Data").

CALIBRATE MENU

The calibrate menu is used to calibrate the measurement system. The calibration process consists of measuring the probe in three well-known dielectric environments. These well-known dielectric environments are referred to as calibration standards. The default calibration standards are air, a short circuit, and deionized water. Alternate standards can be defined by selecting the ***[Configure cal...]*** command.

At the end of the calibration process, the software will provide the opportunity to save the current setup file to disk. This setup file includes the calibration just performed. The setup file, containing the current calibration, can also be saved to disk at a later time in the setup menu.

Perform cal

Selecting ***[Perform cal]*** begins the calibration process. You will be instructed to connect calibration standards to the probe. There will be an OK key accessible from both the computer and the network analyzer to indicate that each standard is connected and ready for measurement. The prompts will give the name of each calibration standard. If alternate calibration standards are defined, the software will present the labels you have specified for these standards in the configure cal.. menu.

When the calibration process is complete, the software will provide the opportunity to save the current setup file to disk, then return to the main menu.

Configure cal...

Selecting ***[Configure cal...]*** allows the definition of alternative calibration standards.

For the MS-DOS version of the program, selecting this command brings up the dialog box shown below.

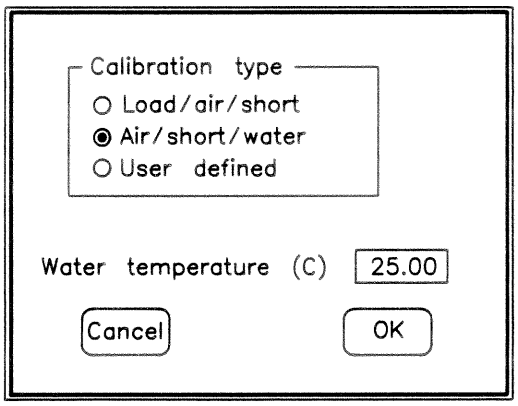

Figure 8-5. MS-DOS Version of Configure cal... Dialog Box

There are three circles in the configure cal... dialog box. They are labelled Air/Short/Water (the default

User defined selects three user-defined calibration standards for the calibration process. This choice lets you define and descrive any three calibration standards in terms of a Cole-Cole relaxation model. That model (equation 1, page 4-1) describes the complex permittivity of the standard as a function of frequency and uses these constants:

E0, the DC value of dielectric constant,
Einf, the infinite frequency dielectric constant,
Alpha the relaxation width, and
Tau, the relaxation time constant.

The values of E0, Einf, Alpha, and Tau are entered for each user-defined standard. The label for each standard is also entered. This label is presented when the software prompts you to connect each calibration standard. The calibration standards are requested in this order: Std1, Std2, Std3. Measurements of each standard are presented without any trace math applied in the network analyzer.

For the HP BASIC version of the software, selecting the ***[Configure cal...]*** command brings up a series of dialog boxes. The first dialog box is shown below.

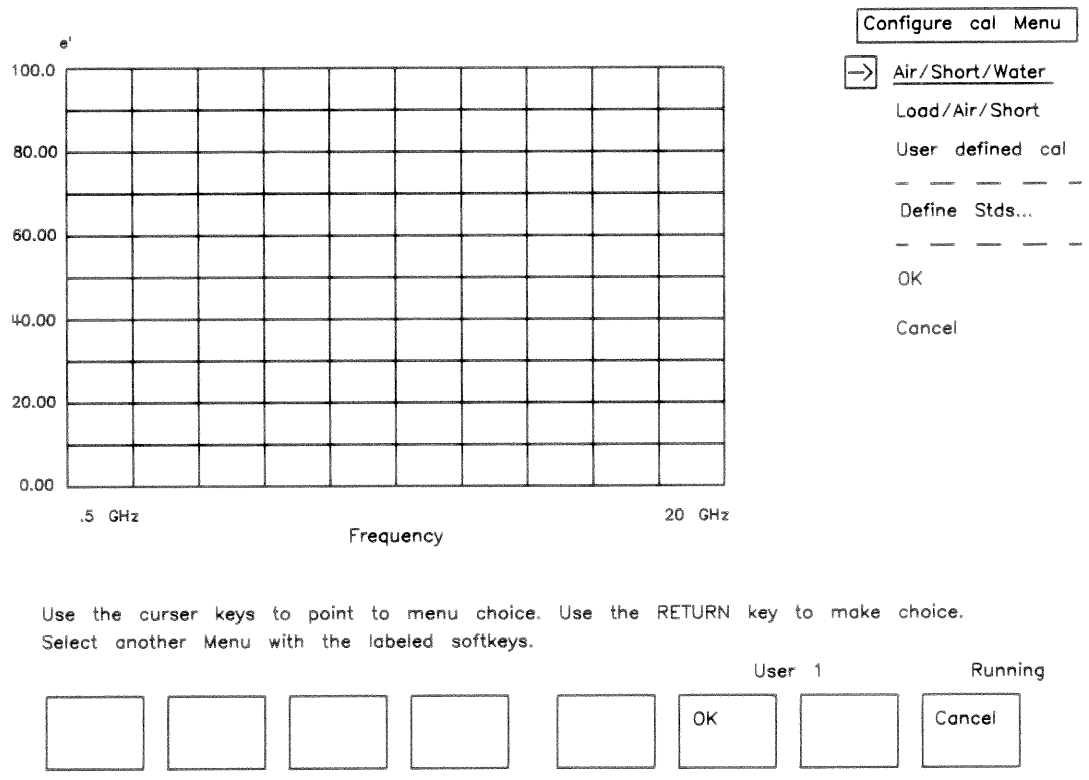

Figure 8-6. HP BASIC Version of Configure Cal... Dialog Box

The first three choices are used to select the standards used during calibration. The ***[Define stds...]*** command presents another dialog box for entering the temperature of the water standard, and defining the Cole-Cole relaxation model for each of the user defined calibration standards.

MEASURE MENU

The measure menu presents commands to trigger a measurement of the probe in the unknown dielectric environment. The probe measurement is then converted to the permittivity of the unknown dielectric and presented in the current display format. Titles to place at the top of the display are also entered from the measure menu.

The commands in the measure menu are these:

Trigger Meas

Selecting the ***[Trigger meas]*** command triggers a measurement of the probe in the unknown dielectric environment. The measurement is triggered immediately after the command is selected, thus the probe should be stable in the desired dielectric environment. Once the measurement is complete, the program will give an audible beep. Then it is all right to move the probe.

In the MS-DOS version, a message is displayed to indicate the current status of the calculation (for example, "Calculating permittivity, 55% complete). When the calculation is complete, the permittivity data is presented in the current display format, and the program returns to the main menu.

The software usually leaves the network analyzer in a continuous sweep mode so that you can evaluate the probe's contact with the MUT before triggering a measurement.

Arm External Trig

Selecting the ***[Arm external trig]*** command places the software in an "armed" state, ready to recognize a trigger from the external trigger switch. The switch is connected to the external trigger port on the back of the network analyzer. After the command is selected, the switch is used to trigger the network analyzer measurement. When the measurement is complete, data is transferred to the computer and converted to permittivity for display.

When the external trigger mode is selected, the network analyzer is not in a continuous sweep mode. Thus, it is important to make sure that the probe is stable in the unknown dielectric environment before selecting the command and pressing the external switch. The command must be selected each time before using the external switch to trigger a measurement.

This command does not operate with the HP 8510 network analyzer.

Title

Selecting the ***[Title]*** command allows you to enter information (description of material, name of operator, etc.) you wish to place at the top of the graphical and tabular displays. Selecting this command and entering no information clears the current title.

FORMAT MENU

The format menu presents commands to select the display format for the measured data. There are four different graphical formats and two different tabular listing formats available for presenting the permittivity data.

The complex permittivity, epsilon can be expressed as:

$e^* = e' - j\,e''$ where $e' = \text{Re[Permittivity]}$
$e'' = \text{Im[Permittivity]}$

e' is often referred to as dielectric constant. e'' is often referred to as loss factor and is used to determine how "lossy" the material is. e'' is proportional to the amount of microwave energy absorbed in the material By definition e'' is a positive quantity. An e'' <0 can however occur if e'' is near 0. It is often convenient to look at the ratio, e''/e'. This ratio is called the loss tangent.

The commands for changing the display formats in the format menu are these:

e'

Select the ***[e']*** command to display the real part of permittivity versus frequency. The real part of permittivity, e'(or k', kappa), is often referred to as dielectric constant.

Figure 8-7. Water Measurement in e' Format

e''

Select the ***[e'']*** command to display the imaginary part of permittivity versus frequency. This is also called the dielectric loss factor and is the imaginary part of the dielectric constant (represented by k'').

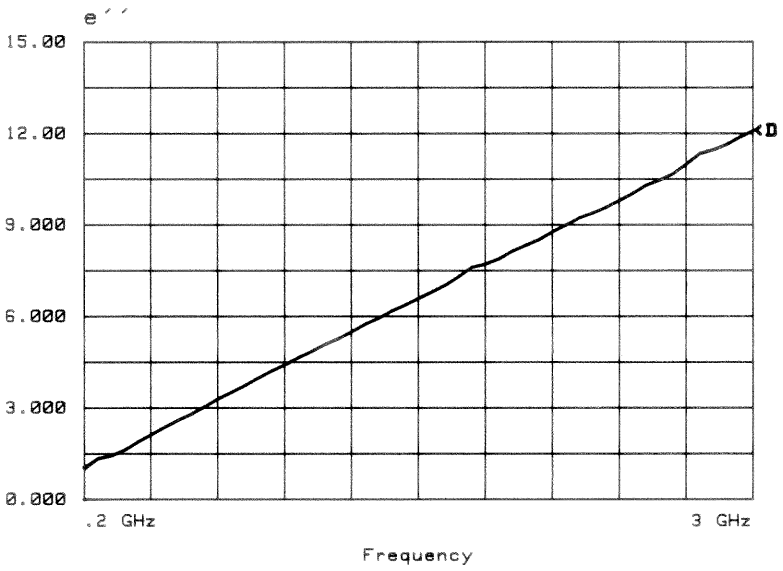

Figure 8-8. Water Measurement in e'' Format

Loss Tangent

Select the ***[Loss tangent]*** command to display e''/e' versus frequency. Loss tangent is also know as tan d.

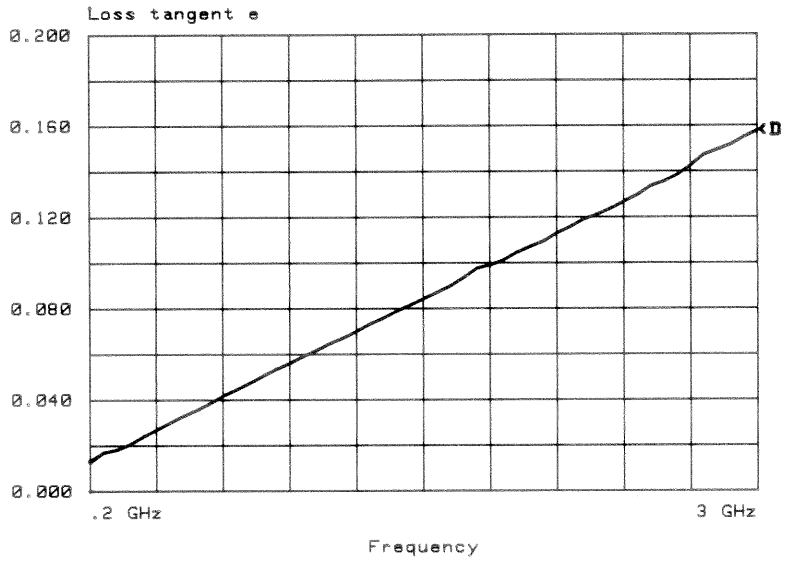

Figure 8-9. Water Measurement in Loss Tangent Format

Cole-Cole

Select the ***[Cole-Cole]*** command to display e'' versus e' at each frequency. The Cole-Cole format refers to the Cole-Cole relaxation model for e' and e'' versus frequency. Materials which exhibit a well defined peak in the loss factor at some frequency yield a semicircle when displayed in the Cole-Cole format.

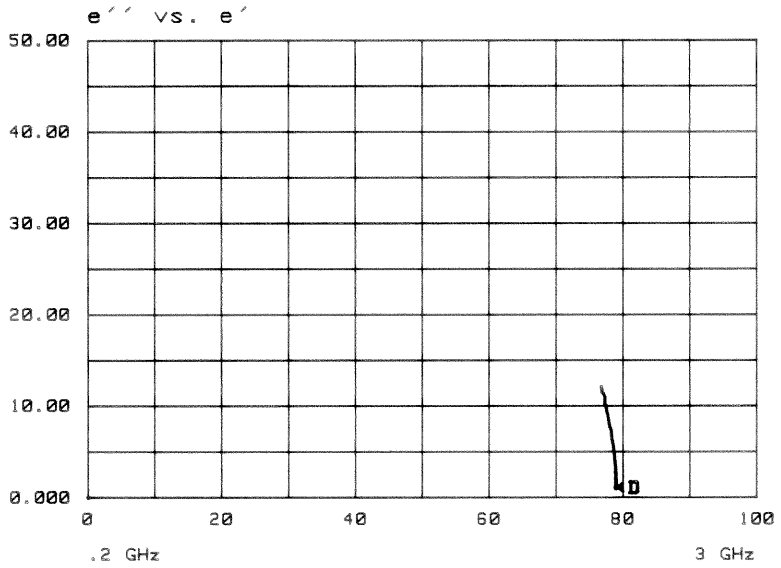

Figure 8-10. Water Measurement in Cole-Cole Format

Tabular (Re&Im)

Select the ***[Tabular (Re&Im)]*** command to display a listing of the dielectric constant and loss factor at each measurement frequency.

	Data	
Freq (GHz)	e'	e''
0.200000000	78.83	1.04
0.256000000	78.84	1.34
0.312000000	78.87	1.43
0.368000000	78.83	1.62
0.424000000	78.83	1.89
0.480000000	78.79	2.12
0.536000000	78.80	2.37
0.592000000	78.80	2.60
0.648000000	78.75	2.80
0.704000000	78.78	3.03
0.760000000	78.78	3.30
0.816000000	78.73	3.51
0.872000000	78.69	3.74
0.928000000	78.68	3.98
0.984000000	78.62	4.21
1.040000000	78.64	4.41

Figure 8-11. Water Measurement in Tabular (Re&Im) Format

Tabular (Re&tan d)

Select the ***[Tabular (Re&tan d)]*** command to display a listing of the dielectric constant and loss tangent at each measurement frequency.

	Data	
Freq (GHz)	e'	tan d
0.200000000	78.83	0.013
0.256000000	78.84	0.017
0.312000000	78.87	0.018
0.368000000	78.83	0.021
0.424000000	78.83	0.024
0.480000000	78.79	0.027
0.536000000	78.80	0.030
0.592000000	78.80	0.033
0.648000000	78.75	0.036
0.704000000	78.78	0.039
0.760000000	78.78	0.042
0.816000000	78.73	0.045
0.872000000	78.69	0.047
0.928000000	78.68	0.051
0.984000000	78.62	0.054
1.040000000	78.64	0.056

Figure 8-12. Water Measurement in Tabular (Re&Tan d) Format

DISPLAY MENU

There are four traces for presenting permittivity data with the HP 85070A software. The traces are called data, memory 1, memory 2, and memory 3.

Each time a measurement is taken, the calculated permittivity is placed in the data trace. All four traces hold complex permittivity data. The active data trace can be saved into any of the other three traces for comparison to other measurements. Any combination of the four traces can be displayed at a time. The traces are presented in different colors if your computer has a color display. Trace indicators (<D, <1, <2, and <3) are placed on the display to identify each trace.

Trace mathematics can be performed on each trace with any one of the traces defined as the reference trace. Trace math can be defined as each trace divided by the reference trace (/ ref), or the reference trace subtracted from each trace (- ref). The / ref math format is useful for the ratio comparison of measurements. Two like traces would yield a ratio near one (1). The - ref math format shows the difference between measurements. Two like trace traces would yield a difference near zero (0).

There are four commands in the display menu. Each command presents a dialog box for selecting the parameters particular to implementing the command.

Data → Memory...

Selecting ***[Data → memory...]*** presents a dialog box to select the memory trace in which to save the current measurement data. Choices for data → memory 1, data → memory 2, and data → memory 3 are presented.

With the MS-DOS version, fill in the circles to select the memory.

With the HP BASIC version, underline the choices. Then acknowledge your selection with the ***[OK]*** command. (Selecting ***[Cancel]*** does not save the measurement data trace to any of the memory traces.)

Selecting any of the data → memory commands also selects the choosen memory trace for display.

Memory → Data...

Selecting ***[Memory → data...]*** presents a dialog box to designate the memory trace to be saved into the active data trace. Choices are memory 1 → data, memory 2 → data, and memory 3 → data.

With the MS-DOS version, to designate the memory trace fill in a circle.

With the HP BASIC version, underline the choices.

Then enact your selection with the ***[OK]*** command. (Selecting ***[Cancel]*** will not perform any memory → data operation.)

Traces Displayed...

Selecting ***[Traces displayed...]*** presents a dialog box to select which of the four traces will be displayed: data, memory 1, memory 2, and memory 3. To select the desired traces for display, fill in the circles or underline the choices. Then enact your selection with the ***[OK]*** command. (Selecting ***[Cancel]*** will not change the displayed traces.)

Reference Trace...

Selecting ***[Traces displayed...]*** presents a dialog box to choose which of the four traces will be defined as the reference trace for trace mathematics. The choices are data, memory 1, memory 2, and memory 3. Select and enact the desired trace as above.

Trace Math...

Selecting ***[Trace math...]*** presents a dialog box to select the type of trace math to be performed. Choices are math off, /ref, and -ref. Select and enact the desired math operation as above.

/ref is the ratio of the two traces and shows the percentage change from the reference trace. For example, if the data value were 4 and the reference value 3, the /ref value would be 1.333. /ref should not be used when the reference value is at or near zero (0).

-ref is the simple difference between the two values; data less reference. For example, if the data value were 4 and the reference value 3, the -ref value would be 1.00. -ref retains the sign: 3 (data value) minus 4 (reference) would be −1.00.

Trace math is performed on the data based on the current display format. If the e' format (real part of permittivity) is selected, then the real parts of the two traces will be either divided by or subtracted from each other.

If trace math is requested and no reference trace exists, an error message is displayed.

SCALE MENU

The scale menu presents commands to select the maximum and minimum values for graphical display formats. The scale for each graphical display format (e', e'', Loss tangent, Cole-Cole) is recalled with that format. Thus, when the graphical format is changed, the scale returns to the settings last used in that format. All graphical formats have Y-axis maximum and minimum values which can be changed in the scale menu. The Cole-Cole format has a X-axis minimum which is always 0. The X-axis maximum for the Cole-Cole format can be changed in the scale menu. The X-axis for the other display formats are set by the frequency range of measurement. The commands in the scale menu follow.

Autoscale

Select the ***[Autoscale]*** command to bring the permittivity data in view with one command. The software selects Y-maximum and Y-minimum (and X-maximum for Cole-Cole) values for the data such that all data appears on screen, and the scale factor ((Ymax-Ymin)/10) is a multiple of 1, 2, or 5. After the display is autoscaled, the program returns to the main menu.

Set Scale...

Select the ***[Set scale...]*** command to bring up a dialog box to enter new Y-maximum and Y-minimum (and X-maximum if Cole-Cole) values to scale the graph. The set scale... dialog box for the HP BASIC version of the program is shown below.

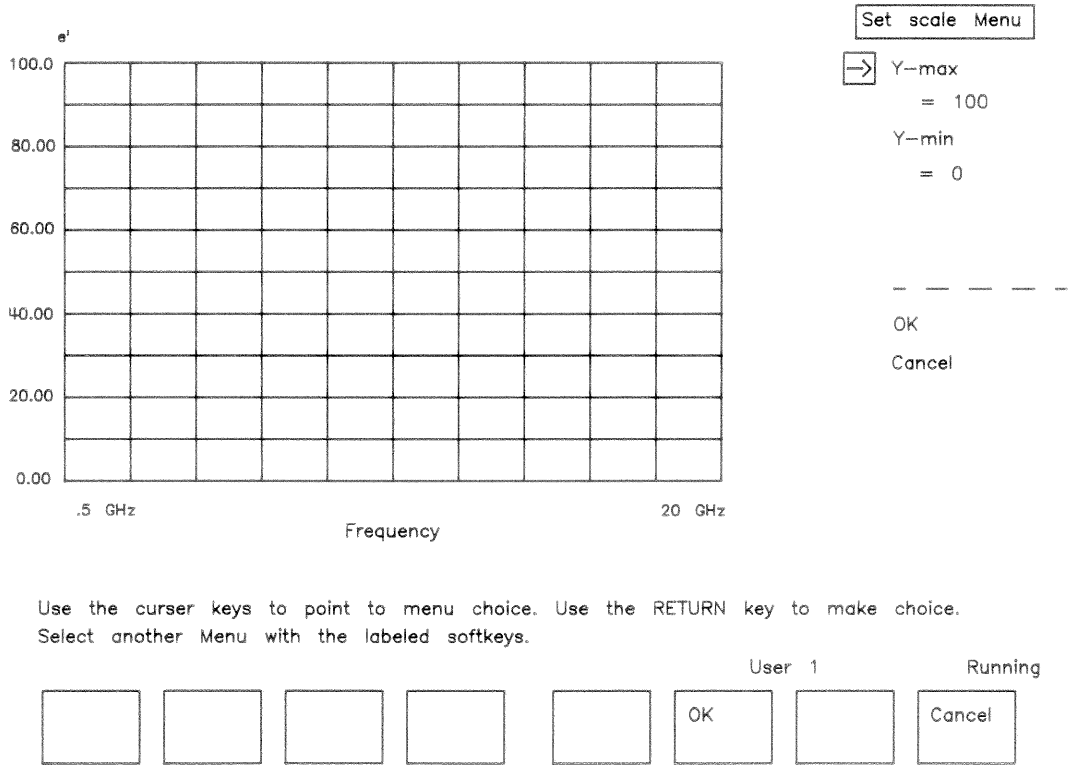

Figure 8-13. HP BASIC Version of Set scale... Dialog Box

Use the text boxes to enter new scaling parameters. Select the ***[OK]*** command to redraw the graph with the new scale parameters or select ***[Cancel]*** to leave the graph unchanged.

To autoscale the graph from the set scale... dialog box, select ***[Autoscale]***. The values that the software has calculated for the new scaling parameters are displayed in the dialog box. Press ***[OK]*** to keep these values or change them as appropriate. Default values can also be selected from the set scale... dialog box in the same way. After the display is rescaled, the program returns to the main menu.

Default

Select the ***[Default]*** command to return the graph to the default scale defined in the software. After the display is rescaled, the program returns to the main menu.

OUTPUT MENU

The ***[Output]*** menu presents commands to plot graphs, print tables, and save and recall measurement data to disk for future analysis or for analysis by other application programs.

In the MS-DOS version of the program, the peripherals are selected after installing the Microsoft Windows system. To add or configure peripherals, see appendix A at the end of chapter 2, "Getting Started."

These are the commands in the output menu:

Plot

Selecting the ***[Plot]*** command will produce a hardcopy plot of the permittivity data in the current display format. The hardcopy display will be the same as the current HP 85070A program display. Plot is presented as a choice only when the current display format is graphical. Hardcopy plots can be directed to printers that support graphics printing modes.

Define Plot...

Selecting the ***[Define plot...]*** command allows the settings of the hardcopy plotter to be altered or customized. In the MS-DOS version of the program, selecting this command brings up the dialog box shown below.

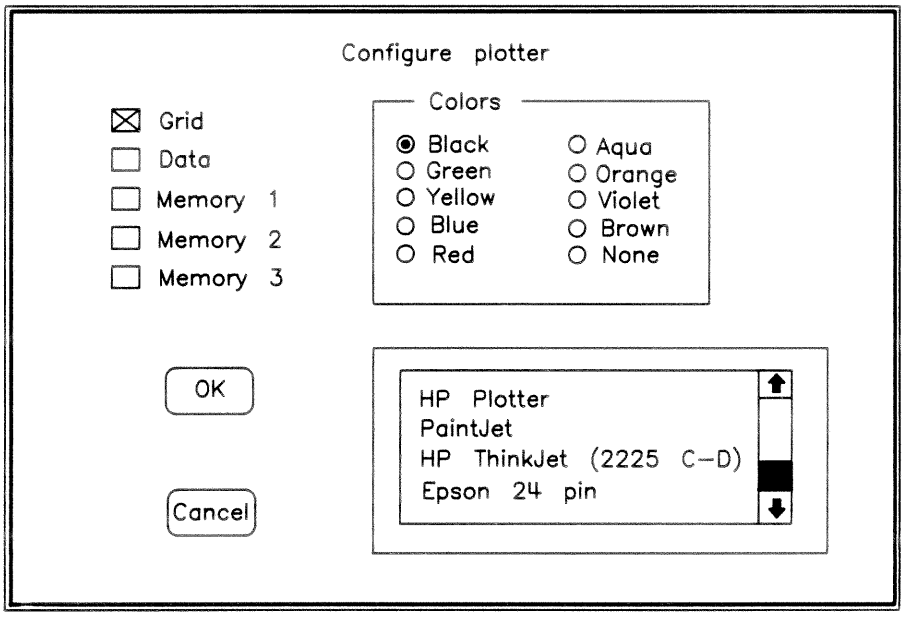

Figure 8-14. MS-DOS Version of Define Plot... Dialog Box

In the HP BASIC version of the program, selecting ***[Define plot...]*** brings up the dialog box shown below.

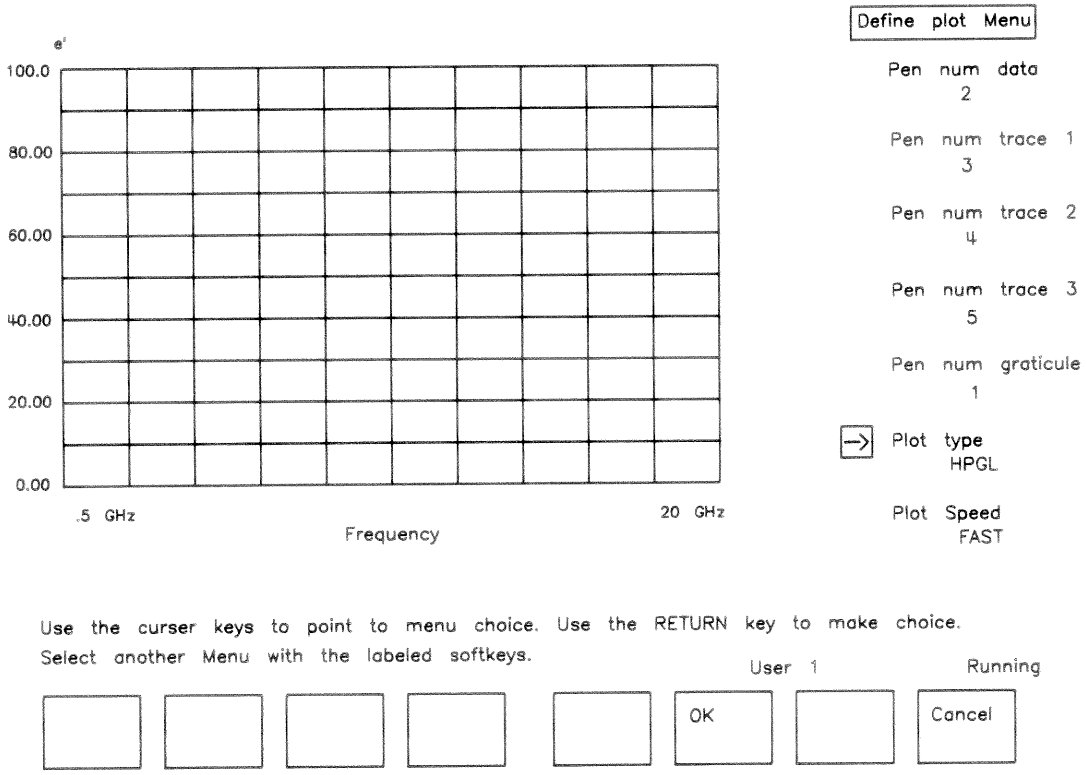

Figure 8-15. HP BASIC Version of Define Plot... Dialog Box

Print

Selecting the ***[Print]*** command will produce a hardcopy printout of the permittivity data in the current tabular display format. This choice is presented as a choice only when the current display format is tabular.

Save data...

Selecting ***[Save data...]*** presents a dialog box to specify the file to save measurement data for future analysis. The HP 85070A datafile includes these items:

- The current measurement data trace,
- The sensitivity of the current measurement data trace to the reflection coefficient measurement, and
- The number of frequencies for the current measurement data trace.

For the MS-DOS version of the program, the ASCII data files are compatible with Lotus 123 and Microsoft Excel. These ASCII data files are also easily entered by most word processing programs. See chapter 4, "Advanced Measurement Techniques," for details on importing data into Lotus 123, Excel, or word processors.

The components of the save data... dialog box for the MS-DOS version of the program are shown below.

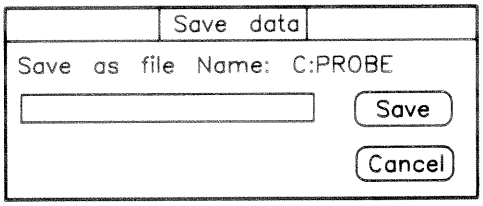

Figure 8-16. MS-DOS Version of Save Data... Dialog Box

The data file can be saved to any disk drive and directory in the computer. Use the drive icons and directory icons in the list box to select where to save the data file. Use the file name list box to select the name for the data file. File names in DOS have a maximum of eight characters. The default file extension for datafiles is .PRN (this file extension is recognized by Lotus 123, you can specify other extensions if so desired). When the recall data... dialog box first comes up it will look for all files with the .PRN extension on the current disk drive and directory. Press the ***[OK]*** command to save the data file.

For the HP BASIC version, the data files are stored in an internal binary format. These files can be read by other HP 9000 series 200/300 programs as explained in chapter 4, "Advanced Measurement Techniques."

The components of the save data... screen for the HP BASIC version of the program are shown below.

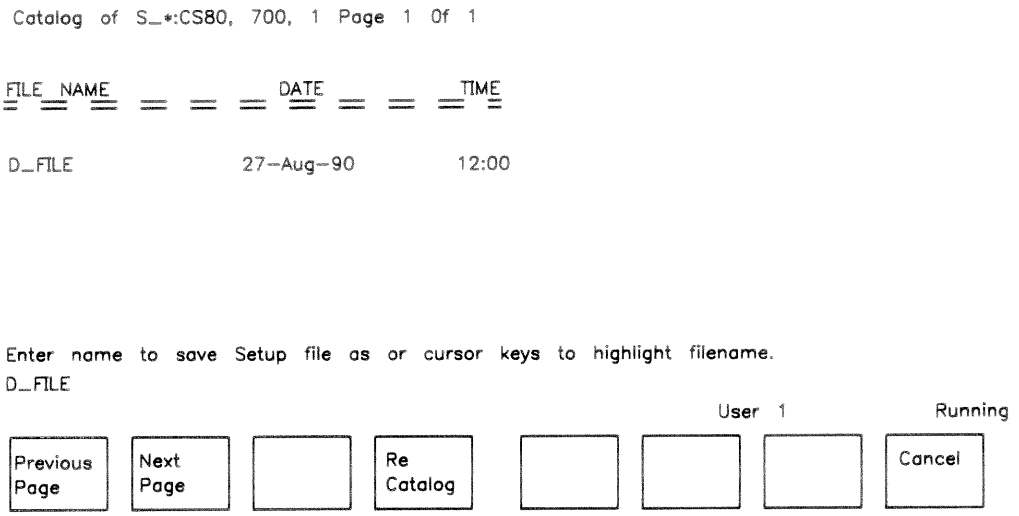

Figure 8-17. HP BASIC Version of Save Data... Screen

The screen lists all of the data files saved on the current drive and directory. The full directory structure of the HFS (hierarchical file system) is supported by the software. The software will prompt for the file name to use for saving the data. Type in the file name at the prompt line. Then press (ENTER) or (RETURN). The drive and directory can be changed by typing in new volume, directory, and mass storage unit specifier information at the display prompt.

Filenames in HP BASIC have a maximum of ten characters. The software includes a "D_" preface for data files (a file named "D_51ptlog" is a data file. The "D_" is the default file preface, but you can specify other prefaces. However, when the recall data... dialog box first comes up it initially looks for all files with the D_ preface on the current disk drive and directory.

Recall data...

Data files can be recalled from disk by choosing the ***[Recall data...]*** command.

In the MS-DOS version, drive icons (such as [-A-] or [-B-]) and directory icons (directory names presented in bold) are presented in a list box. To see the files on a different drive or directory, single click on these icons.

In the HP BASIC version, a file dialog box is presented to enter the drive, directory, and file name of the data file to recall from disk. To change the disk drive, type in a new mass storage specifier (like ":,700,1", "/HP85070/Data").

HELP MENU

The help menu is used as an on-line, indexed description of the different commands in the HP 85070A dielectric probe software.

For the MS-DOS version of the program, selecting ***[Help]*** in the main menu brings up two list boxes with scroll bars. The list box on the left shows the menus in the software (Setup, Calibrate, Measure, etc.). One menu at a time can be highlighted in the menu list box. The right list box shows the choice of commands in the highlighted menu. To see the description of a particular command, first point and click on the menu that contains it. Then point and click on the command itself. Finally select the ***[OK]*** command to read the description. Exit with the ***[Cancel]*** command.

To see the general menu (normally hidden), use the scroll bar.

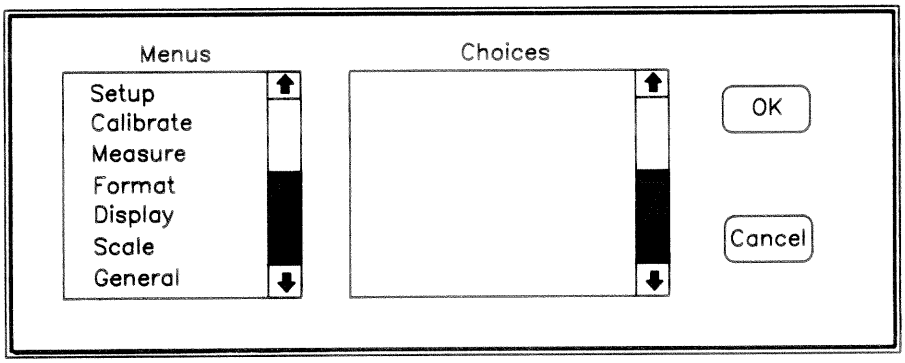

Figure 8-18. MS-DOS Version of Help Screen

For the HP BASIC version of the program, selecting ***[Help]*** in the main menu brings up a list of the menus on the upper right of the computer display. Selecting a menu presents a list of all of the commands (and a summary of the function of each) within the menu. The help command also presents three other commands:

- ***[More Help]*** returns to the beginning of the help screen.
- ***[Leave Help]*** exits the help screen.
- ***[Exit]*** returns to the main menu and returns the instrument display to the same status as before help was selected.

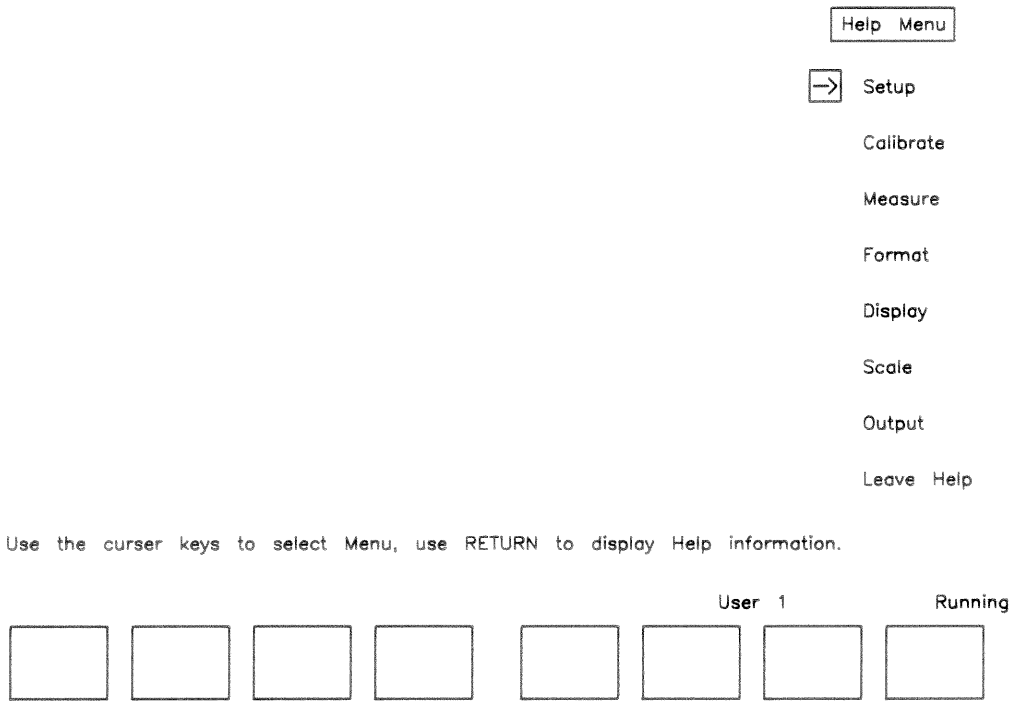

Figure 8-19. HP BASIC Version of Help Screen

HP 85070A DIELECTRIC PROBE KIT
INDEX

This index lists all of the major topics, important terms, softkeys, menus, and commands of the HP 85070A dielectric probe kit manual and software.

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Glossary

INTRODUCTION

The following entries are defined in terms of material measurements with the HP 85070A software.

absorption: to take in electro-magnetic energy, usually as heat

absorption bands: distinct frequency bands at which electro-magnetic energy is strongly coupled into a material and absorbed

AC loss: dielectric loss (as D for capacitors, but excluding DC "leakage")

bound water: water that is ionically attached to a host material, and so is restricted in its freedom to align with an electric field

Cole-Cole plot: data format, with ε'' on vertical axis and ε' on horizontal axis, with frequency as the independent parameter not displayed; lossy materials with relaxation mechanisms follow a semi-circle on these plots

conductivity: usually ionic dielectric loss; in dielectric measurements, does not mean true conduction (movement of electrons)

D: dissipation factor; usually measured for capacitors; $D = \tan \delta$

Debye functions: simplified model to explain dielectric properties versus frequency, assuming that a single rotational relaxation phenomenon is acting

δ: angle formed between the j-axis and vector representing the sum of storage and loss vectors; δ is small (nearly 0°) for low-loss materials, and large (up to about 45°) for lossy materials; see tan δ (used more often)

dielectric constant: κ; ratio of electric field storage capacity in a material to that of free space; usually means real (lossless) case only

dielectric loss: energy "lost" (absorbed) in material when applying an AC electric field; may be due to ionic, polar, atomic, or electronic mechanisms

dielectric after-effect: polarization in a material lags behind the applied field in time; modeled by relaxation process; related to losses

dipolar: dielectric mechanism; see "rotation"

dipole: structure where the net charge distribution can be represented by two equal and opposite charges separated by distance.

dispersion: propogation characteristics change with frequency

dissipation factor: D; ratio of energy lost to energy stored (per cycle) in a system; same as tan δ, inverse of Q

electronic: dielectric mechanism (resonant, very weak, at very high frequencies), where the "orbits" of electrons around a nucleus are "stretched"

ε: symbol for absolute permittivity; ε_r is used more often

ε_r: symbol for relative permittivity (to free space); if complex, $\varepsilon_r^* = \varepsilon_r' - j\varepsilon_r''$

free water: water molecules which are not "bound" and are free to orient themselves in an electric field

homogeneous: having uniform properties throughout; non-homogeneous materials are usually mixtures of two materials

induced dipoles: temporary dipoles, created by electric fields

ionic: dielectric mechanism (fairly strong, lossy, operating at all frequencies), where mobile ionic charges migrate in a material

isotropic: properties do not vary with orientation; non-isotropic materials are usually fibrous or crystaline

κ: symbol for dielectric constant, and always relative to free space; if complex, $\kappa^* = \kappa' - j\kappa''$; equivalent to ε_r

loss angle: see δ

loss factor: κ'' or ε_r''

loss index: κ'' or ε_r''

loss tangent: see tan δ

MUT: Material Under Test

NDE: Non-Destructive Evaluation

non-destructive: attribute of test method, when material can be used for its end-purpose after testing

penetration depth: distance through a lossy dielectric over which the field strength falls by 1/e, due to energy absorption

permanent dipoles: molecular structures that inherently have a non-symmetrical charge distribution

permeability: measure of effect a material has on magnetic fields; ratio of flux over field

permittivity: measure of effect a material has on electric fields; ratio of flux over field

phase angle: see θ

phase defect angle: see δ

polar: having permanent electric dipoles

polarize: to align dipoles in electric field

power factor: sin δ (or cos θ)

Q: see quality factor

quality factor: ratio of energy stored to energy lost (per cycle) in a system; inverse of tan δ and D

relative permittivity: see ε_r

relaxation time: see τ

relaxation constant: see τ

relaxation wavelength: free-space wavelength corresponding to the frequency $1/\tau$

restricted mobility dipoles: dipoles (such as H_2O molecules) which are "bound" to a host material, and so are restricted in their ability to become oriented in an electric field

rotational: a dielectric mechanism (relaxation, fairly strong, often lossy, at moderate frequencies), where permanent dipoles (often entire molecules) "rotate" to align with an electric field

susceptor: material that can "respond" to electro-magnetic fields

tan δ: ratio of $\varepsilon''/\varepsilon'$; indicates "lossiness" of material; typically varies from about 1.5 (high loss) to 10^{-5} (very low loss)

τ: relaxation time constant; for a simple substance, the time it takes for 1/e of the constituent molecules to become aligned in response to an electric field

θ: angle between real-axis and vector representing sum of storage and loss vectors; $\theta = 90° - \delta$

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