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Printed in USA March 2000

User's Manual

HP 85071B Materials Measurement Software

Printed in USA

HP part number: 85071-90004
Printed in USA April 1993

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The following safety notes are used throughout this manual. Familiarize yourself with each of the symbols and its meaning before operating this instrument.

Caution

The *caution* note denotes a hazard. It calls attention to a procedure which, if not correctly performed or adhered to, could result in damage to or destruction of the instrument. Do not proceed beyond a *caution* sign until the indicated conditions are fully understood and met.

Warning

The *warning* note denotes a hazard. It calls attention to a procedure which, if not correctly performed or adhered to, could result in injury or loss of life. Do not proceed beyond a *warning* sign until the indicated conditions are fully understood and met.

Instruction Manual 	The **instruction manual** symbol. The product is marked with this symbol when it is necessary for the user to refer to the instructions in the manual.

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General Information

Introduction

The HP 85071 materials measurement software allows measurements of the complex permittivity (ϵ, epsilon) and permeability (μ, mu) for a wide range of solid materials. It performs all of the necessary network analyzer control, calculation, and data presentation functions.

In brief, the software:

- Controls the network analyzer to measure the complex S-parameters of a material sample,
- Converts these S-parameters of the sample holder/sample material to S-parameters at the sample interface,
- Calculates the complex material parameters, ϵ and μ,
- Displays the measurement results in a variety of graphical and tabular formats,
- Facilitates these functions:
  - Printing or plotting the results,
  - Saving the results to disk,
  - Saving test setups to disk.

Calibration of the measurement system is performed manually on the network analyzer to allow full flexibility in the use of calibration kits and techniques. From this point on the software is used to calculate and analyze the constituent materials parameters.

The Software Incorporates Six Calculation Models

The following paragraphs summarize the calculation models. For details, see chapter 8, "Software Reference."

Reflection/Transmission Mu and Epsilon Nicholson-Ross Model

This is an adaptation of the classical Nicholson-Ross-Weir technique described in the literature and in Hewlett-Packard Product Note 8510-3. This technique characterizes both dielectric and magnetic properties of a material sample from reflection and transmission measurements.

Reflection/Transmission Epsilon Precision Model

This model is based on recently published work by the National Institute of Standards and Technology. It is an accurate technique which is independent of the placement of the sample in the sample holder.

Reflection/Transmission Epsilon Fast Model

This is a faster technique for characterizing the dielectric constant of a material. Both the "fast" and "precision reflection/transmission epsilon" models are immune to the sample half-wavelength calculation problems found with the Nicholson-Ross-Weir technique.

Reflection-Only Epsilon Short-Backed Model

This characterizes the dielectric properties of a material in a coax or waveguide transmission line backed by a short circuit (or bonded to a ground plane). It is simple and best for liquid or powder, or measurements.

Reflection-Only Epsilon Arbitrary-Backed Model

This characterizes dielectric materials backed by an arbitrary but repeatable termination. It is simple and best for thin film measurements.

Reflection-Only Mu and Epsilon Single/Double Model

This is the only reflection model capable of permeability measurements. It is slow and requires two measurements. It is best for liquid or powder measurements.

Items Supplied with the Software

These items constitute the HP 85071 materials measurement software:

- HP 85071 software disk (one 3.5 inch high-density, double-sided disk)
- This manual

First Steps

Before using the HP 85071 software, be sure that both of these items have been received and appear to be in good condition. Contact your Hewlett-Packard representative if either item is missing or appears to be damaged.

About this Manual

This manual is a complete guide to using the HP 85071 software to make materials 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 idea of material measurements with a network analyzer. It explains the functions of the analyzer, computer, software, and sample holder 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 general overview of the software. It also discusses calibration, sample holders and material preparation, and the data reduction models.

A step-by-step, guided example of a calibration and measurement with the HP 85071 software concludes this chapter. First-time users are urged to perform the sample measurement procedures outlined in this chapter.

Advanced Measurement Techniques describes several advanced aspects of using the software.

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 integrity of the software.

Ordering Supplies is a list of 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 this manual.

Glossary defines important words and concepts of this manual.

What This Manual Covers

This manual covers the software it was shipped with:

Serial number prefix: not applicable
Software revision: 1.0 or above
MS-DOS version: 3.2 or higher
Microsoft Windows version: 3.0 or 3.1
HP BASIC version: BASIC 5.0 or higher

Description of the Software

Two versions of the software allow use of either HP Vectra PC compatible or HP 9000 series 300 computers.

MS-DOS® version of the software (standard) features the clean look of the Windows environment. This version is for the HP Vectra PC and compatible machines. It uses a mouse for most commands and entries. It is not user-modifiable. (Note: Microsoft® Windows and MS-DOS® are US registered trademarks of Microsoft Corporation.)

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

The HP BASIC version may also be used with IBM-AT compatible machines (such as the HP Vectra) and an HP 82300C BASIC language processor, release II.

Software Features

- Completely controls the network analyzer.
- Guides you through the measurement sequence.
- Automatically computes ϵ and μ (permittivity and permeability).
- Offers a variety of data formats and displays.

Features New to this Revision

- Improved Nicolson-Ross model provides sample position invariance
- One-port arbitrary backed model measures thin samples accurately
- One-port pemmittivity and permeability reflection only model
- Air gap correction improves accuracy of transmission line methods
- Compatible with free space measurements
- Simpler user-interface

Equipment Required

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

Recommended Test Equipment

Test equipment is required for the other system instruments only. Refer to the appropriate manuals for recommended test equipment.

2

Getting Started

Introduction

This chapter details system hardware and software requirements, installation of software and hardware, loading and starting the HP 85071 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: MS-DOS** 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 computer or equivalent, continue with section 1, below.

Section **2: HP BASIC** 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 or an HP Vectra PC with a BASIC language processor card, skip to section 2 of this chapter.

By the time you have finished this chapter, your materials 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 85071 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 to:

- Copy files
- Display the directory of a floppy or hard disk
- Create directories on a floppy or hard disk
- Type commands at the DOS prompt

System Requirements

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

Computer

The system computer should use a 80386 or 80486 microprocessor. The HP Vectra has been checked and is recommended. It must be configured with:

- 4 MBytes (minimum) of RAM (Random Access Memory)
- High-density, double-sided 3.5 inch flexible disk drive
- 20 MByte hard disk drive (minimum)
- Microsoft Windows compatible pointing device (a mouse)
- Coprocessor (recommended)

Software

- MS-DOS disk operating system (version 3.2 or higher)
- Microsoft Windows (version 3.0 or 3.1, NOT 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 82335B HP-IB Interface (recommended)
- 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 will be supported by the HP 85071 software.

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 85071 software is designed to work with the network analyzer configurations described below. The default HP-IB address is 16.

- HP 8752A: this network analyzer contains a reflection/transmission test set as part of the analyzer. No other instrumentation is needed to make measurements. The network analyzer has these limitations:
  - "Refl/Tran u & e N-R" model: supported in the accurate sample position definition mode
  - "Refl/Tran e Prec'n" model: not supported
  - "Refl/Tran e Fast" model: supported in the accurate sample position definition mode
- HP 8753A, B, or C: these network analyzers need a companion test set for operation with the software. The following test sets are supported:
  - HP 85044A reflection/transmission test set (subject to the same limitations as the HP 8752A)
  - HP 85046A S-parameter test set
  - HP 85047A S-parameter test set

- HP 8719A or C; HP 8720A, B or C; HP 8722A or C: these network analyzers contain S-parameter test sets as part of the analyzer. No other instrumentation is needed to make measurements.
- HP 8510B or C: this network analyzer requires a companion test set and a synthesized 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 HP 8340, HP 8341, or HP 8360 family sources are supported by the software. HP 8510B or C firmware revision 5.0 or higher is required.

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

Installation

First Microsoft DOS, then Windows, and finally the HP 85071 software should be installed on the hard disk to run the materials measurement program.

Microsoft DOS Installation

Microsoft DOS 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 or 3.1 must be installed on the computer's hard disk to install and run the HP 85071 materials measurement 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 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 materials measurement program.
- You must load drivers for any printers or plotters with the SETUP program.

It is recommended 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 85071 Software Installation

The HP 85071 software is provided on a floppy disk with these files:

- READ.ME describes the files on the disk and the installation procedure (repeated below).
- HP85071.HP is the software program designed to operate with the HP 82335B interface.
- HPIB.DLL is a second file (a dynamic link library) required for use with the above HP interface.
- HP85071.NAT is the software program designed to operate with the National Instruments AT-GPIB, GPIB-II, and GPIB-IIA interfaces.
- HPIBSTAT.EXE is a software program designed to check the HP 82335B interface card and recommend the correct memory exclusion address.

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 85071 program disk in the floppy disk drive.
2. On the hard disk, make a directory dedicated for HP 85071 files. At the DOS prompt, type:
   `MKDIR C:\MATERIAL`
   and press ENTER.

HP-IB and GP-IB Interface Card Installation

- HP 82335B Interface Card Users: continue with "For HP 82335B Interface Card Systems," next
- National Interface Card Users: continue with "For National Instruments AT-GPIB, GPIB-II, or GPIB-IIA Interface Card Systems," below

For HP 82335B Interface Card Systems

1. Copy the program from the floppy disk to the hard disk. At the DOS prompt, type:
   `COPY A:\HP85071.HP  C:\MATERIAL\HP85071.EXE`
   and press ENTER

Note

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.)

2. To see the directories in the DOS PATH, at the DOS prompt, type:
   `PATH`
   and press ENTER
3. 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
4. Add an EMMEXCLUDE line in the [386ENH] section of your SYS.INI file to exclude the memory range of the HP-IB card.

   a. Run the HPIBSTAT.EXE program.

b. Add the recommended line. For example, with the card at select code 7, include this line:
`EMMEXCLUDE=DC00-DFFF`

5. 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 cards at select code 7:

   For HPEMMGR: `DEVICE=HPEMMGR.SYS X=DC00-DFFF`
   For EMM386: `DEVICE=EMM386.EXE X=DC00-DFFF`
   For HPEMM386: `DEVICE=HPEMM386.SYS EXCLUDE=DC00-E000`
   For HPMM: `DEVICE=HPMM.SYS EXCLUDE=DC00-E000`

6. Put the original floppy disk away for safe keeping.

7. Use the Windows Setup Program to enable the Program Manager to run the HP 85071 application (see the Microsoft Windows User's Guide).

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

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

   `COPY A:\HP85071.NAT  C:\MATERIAL\HP85071.EXE`
   and press ENTER

2. Install the interface card by following the directions in *Using Your GP-IB Software with Microsoft Windows* (a manual supplied with the card).

Note

Both the interface card and the GP-IB software must be versions that operate under Windows 3.0 (or 3.1). In case of difficulty, or to arrange for an upgrade, contact National Instruments.

3. Put the original floppy disk away for safe keeping.

4. Use the Windows Setup Program to enable the Program Manager to run the HP 85071 application (see the *Microsoft Windows User's Guide*).

Hardware Installation

Connect the computer, network analyzer, cables, 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.

Different systems require various cables and adapters. These items are listed in HP's *RF, Microwave, & Millimeter Wave Measurement Accessories Catalog* and the *Test and Measurement Catalog*.

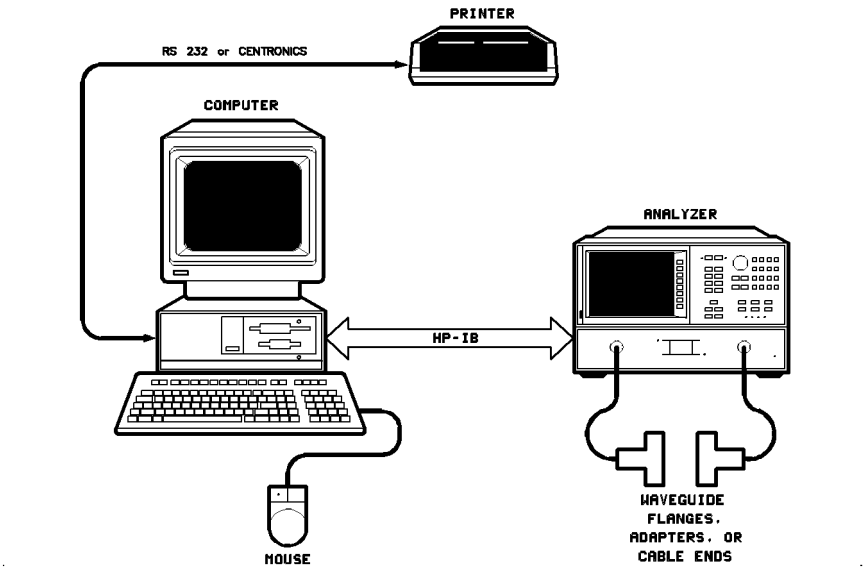


Figure 2-1. Typical MS-DOS System Connection Diagram

The connections for a typical system are shown above. Other systems are similar. Follow these suggestions:

- Computer system: connect keyboard, mouse, etc with instructions provided.
- Printer (or plotter): connect device to Centronics (parallel) connector, RS-232 (serial) connector, or HP-IB connector of computer.
- Network analyzer: connect to HP-IB connector of computer.
- Cables: connect to ports 1 and 2 of the network analyzer (or test set, if they are separate instruments).

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 85071 Software

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

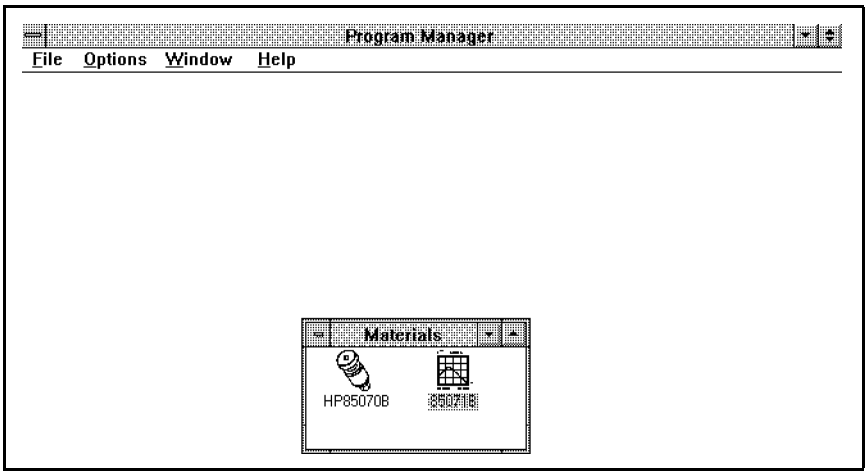


Figure 2-2. Windows Program Manager System

2. Double-click on the HP 85071 icon to start the program. The HP 85071 copyright screen appears with the copyright statement.
3. Click in the OK box. The main menu screen (below) replaces the copyright screen.

Windows Compatible Software Operation

The HP 85071 materials measurement software is ready for operation when the copyright statement is replaced with the main menu screen.

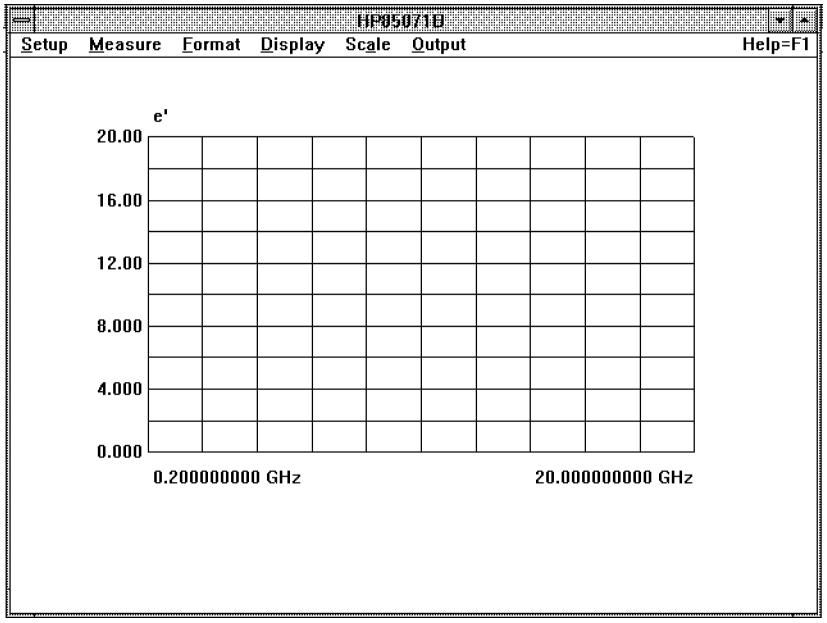


Figure 2-3. HP 85071 Main Menu Screen

Microsoft Windows Basics

Using the HP 85071 materials 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.

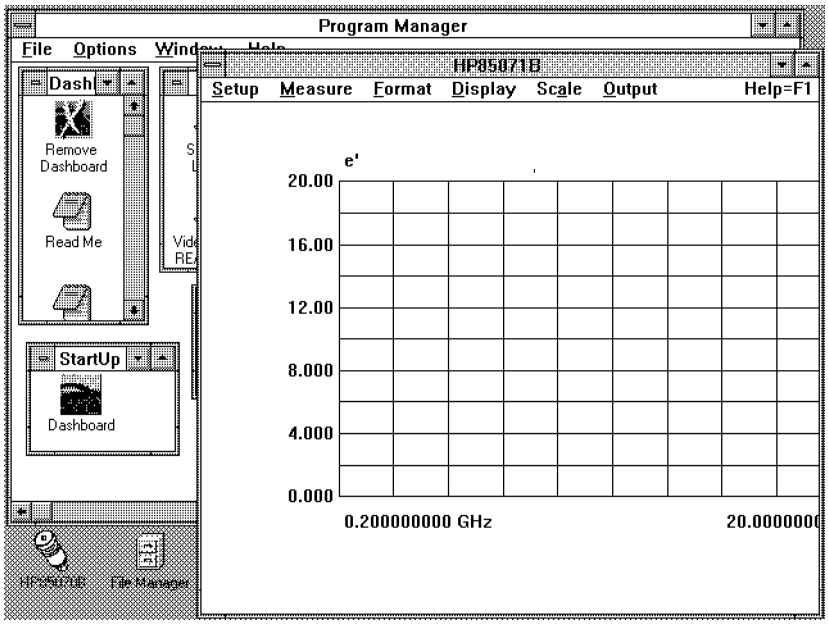


Figure 2-4.
Graphic Showing a Window, Work Area, and Application Icon

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 85071 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.

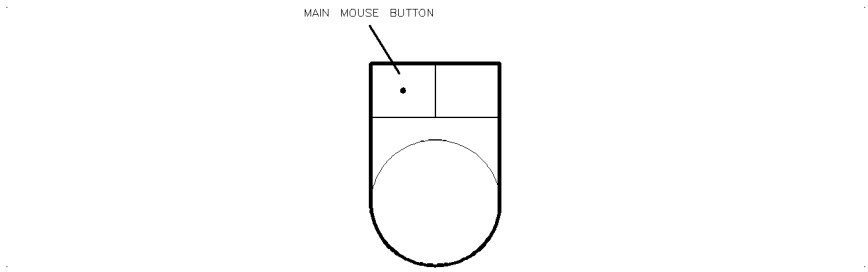


Figure 2-5. Mouse and Location of Main Mouse Button

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 85071 application program.

To select a menu, either

- Point to the name of the menu and click the mouse button, or
- Press Alt (the alternate key) and the underlined letter in the name of the menu. For example, press Alt and "s" for the Setup menu.

To choose a command, do one of the following:

- Point to the name of the command on the menu and click the mouse button
- Use an accelerator key on the keyboard: press Ctrl (the control key) simultaneously with the accelerator key. Accelerator keys are identified with a ^ symbol on menus to the right of some of the commands.
- Point to the desired menu with the mouse, drag the mouse downward to point to the desired command, and then releasing the mouse button.

Note Commands that appear in gray do not currently apply and can not be choosen.

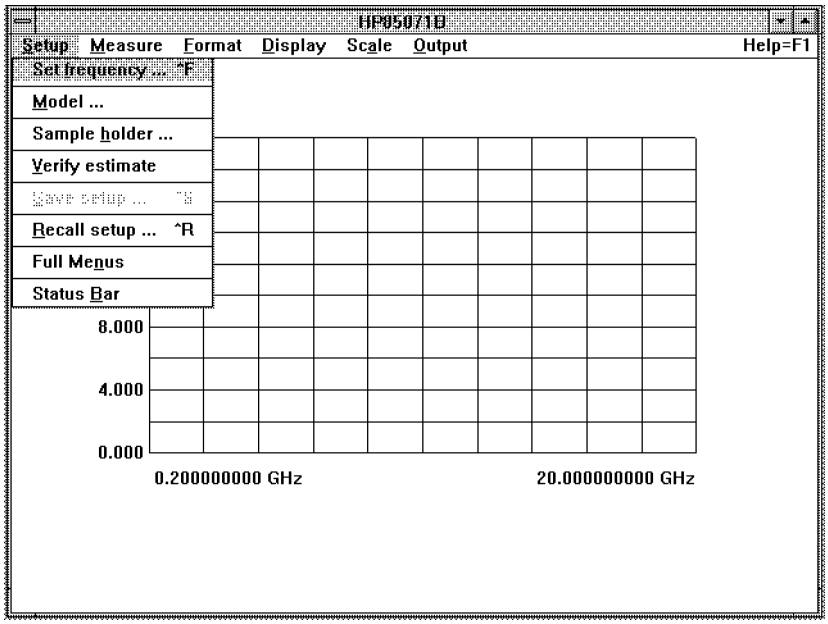


Figure 2-6. Drop-Down Menu and Highlighted, Selected Command

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 one:

- `OK` keeps all of the changes made in the dialog box
- `Cancel` leaves the dialog box without changing anything

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.
- Note: 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.

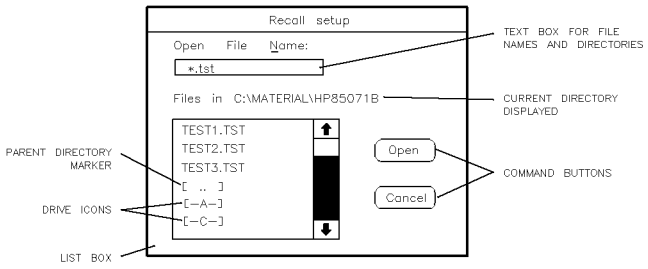


Figure 2-7. Example of Dialog Box

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\HP85071\TEST1.TST is a valid file name.

HP 85071 Windows Software Fundamentals

The HP 85071 materials measurement software program is a Windows application program. The techniques for using the HP 85071 software are the same as the techniques used for running other Windows application programs. The HP 85071 display window and its components are shown below.

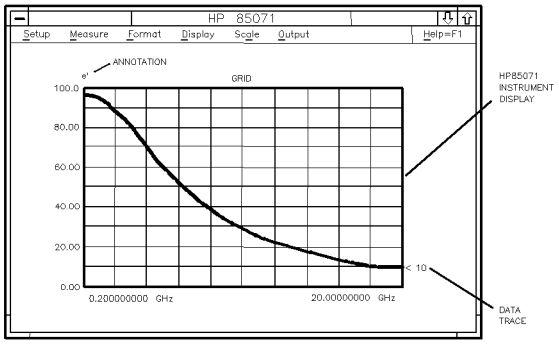


Figure 2-8. Principal Components of the Software Screen

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.

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

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.

Data trace is a graph of measurement data in the chosen format. It may be the current trace or one recalled from memory.

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 chapter 3, "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 85071 software, the software, Windows, MS-DOS, logical and hardware ports, a cable, and the printer itself must all interact properly to achieve the desired results.

Software

Once you have set up your system, you will use only the interface of the HP 85071 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)

- Handshake (usually hardware)
- For serial printers:
  - Baud rate (how fast it will accept information)
  - Word length (typically between 4 and 8)
  - Parity (odd, even, or none)
  - Stop bits (usually between 1 and 2)

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 Product Support Services 1-206-454-2030

For HP printers and plotters, contact HP at:

- HP Customer Support Center 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.)

Table 2-1.

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. 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.

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, restart the computer to read and execute the edited file. Press (CTRL) + (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:

- 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 ORDERING at 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. 408-553-7800 (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 or set 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 the HP 85071 Software

Once you are running the HP 85071 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 that Windows reads when starting up. It is usually in the Windows directory. It stores default settings of the HP 85071 program such as frequency, number of points, type of sweep, etc.

To edit these settings:

1. Use a text editor.
2. Page down to [HP 85071B].
3. Edit as desired.
4. Save and exit.

Conclusion

This information is only a summary. If you are unable to successfully print or plot within the HP 85071 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

To run the HP BASIC version of the HP 85071 software program, you must have a HP BASIC-compatible computer as defined below. Additionally, you should be familiar with basic BASIC operations.

System Requirements

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

Computer

The HP 85071 software supports the HP Vectra PC (with BASIC language processor card) and all HP 9000 series 300 computers *except these*:

- HP 9817
- HP 9826
- HP 9837
- HP 9920

The minimum requirements for the computer are these:

- 2.0 MBytes (minimum) of RAM (Random Access Memory)
- High-density, double-sided 3.5 inch flexible disk drive
- HP 82300C (required for HP Vectra PC)
- HP 82304A high performance measurement co-processor (required for HP Vectra PC)

BASIC and Binaries

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

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

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 85071 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 7440A ColorPro eight-pen plotter with HP-IB interface option
- HP 7470A two-pen graphics plotter with HP-IB interface option
- HP 7475A two-pen graphics plotter with HP-IB interface option
- HP 7550A graphics plotter

Network Analyzer and Test Set

The HP 85071 software is designed to work with the network analyzer configurations described below. The default HP-IB address is 16.

- HP 8752A: this network analyzer contains a reflection/transmission test set as part of the analyzer. No other instrumentation is needed to make measurements. The network analyzer has these limitations:
  - "Refl/Tran u & e N-R" model: supported in the accurate sample position definition mode
  - "Refl/Tran e Prec'n" model: not supported
  - "Refl/Tran e Fast" model: supported in the accurate sample position definition mode
- HP 8753A, B, or C: these network analyzers need a companion test set for operation with the software. The following test sets are supported:
  - HP 85044A reflection/transmission test set (subject to the same limitations as the HP 8752A)
  - HP 85046A S-parameter test set
  - HP 85047A S-parameter test set
- HP 8719A or C; HP 8720A, B or C; HP 8722A or C: these network analyzers contain S-parameter test sets as part of the analyzer. No other instrumentation is needed to make measurements.
- HP 8510B or C: this network analyzer requires a companion test set and a synthesized 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 HP 8340, HP 8341, or HP 8360 family sources are supported by the software. HP 8510B or C firmware revision 5.0 or higher is required.

Note The HP 8510A is not supported by the software but can be upgraded to an HP 8510C with the HP 85103C upgrade kit.

Installation

HP BASIC Installation

The Hewlett-Packard BASIC operating system (version 5.0 or higher) is required for the HP 85071 software. Additionally, the BASIC system must include the previously listed binaries for operation with the HP 85071 software. Refer to the computer's manual set for additional information on installing or configuring the BASIC operating system.

HP 85071 Software Installation

The HP 85071 software program resides in a single file on the HP 85071 program disk. The name of the file is HP85071B.

The HP 85071 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 address 700, drive 0 to drive address 700, drive 1, type:

```
COPY "HP85071B:,700,0" TO "HP85071B:,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, cables, 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.

Different systems require various cables and adapters. These items are listed in HP's *RF, Microwave, & Millimeter Wave Measurement Accessories Catalog* and the *Test and Measurement Catalog.*

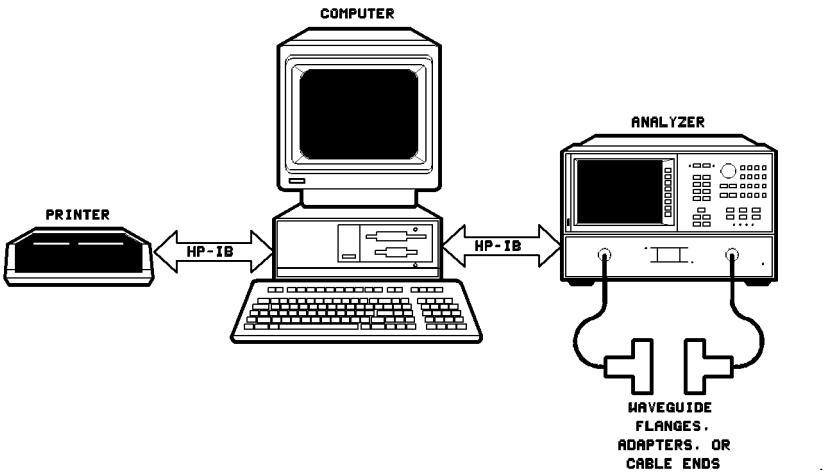


Figure 2-9. Typical HP BASIC System Connection Diagram

The connections for a typical system are shown above. Other systems are similar. Follow these suggestions:

- Computer system: connect keyboard, mouse, etc with instructions provided.
- Printer (or plotter): connect device to HP-IB connector of computer.
- Network analyzer: connect to HP-IB connector of computer.
- Cables: connect to ports 1 and 2 of the network analyzer (or test set, if they are separate instruments). Torque the connectors to five inch-pounds.

Starting the HP 85071 Software

To start the HP 85071 software program, follow these steps:

1. To load the software from the working copy into memory, type `LOAD "HP85071B"` 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 [RUN].

   The HP 85071 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 85071 software is ready for operation when the main menu screen (shown below) replaces the copyright statement.

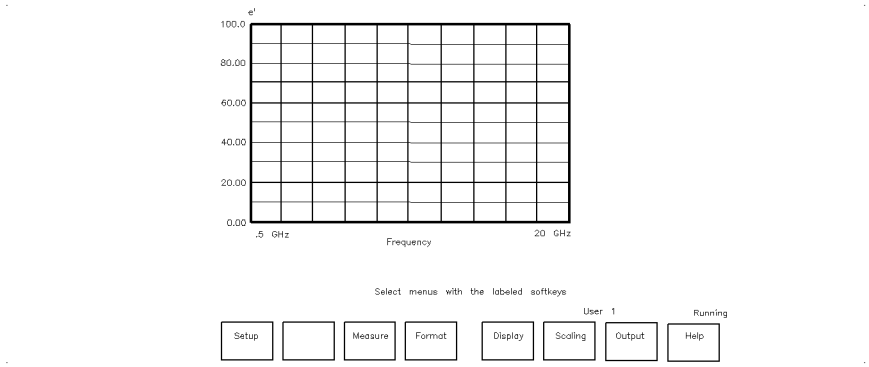


Figure 2-10. HP BASIC Main Menu Screen

HP BASIC Software Operation

As explained below, the HP 85071 software uses softkeys and menus 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 85071, 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 menu of selections.

How to Make Menu Selections

Use the UP/DOWN arrow keys to point to the entry parameter or choice. Then press RETURN or ENTER.

If the choice requires keyboard entry (frequency entry, Y-axis scale entry, etc.), the software displays a prompt for 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 finish the selection, press one:

- `OK` to keep all of the new entries
- `Cancel` to leave the old entries unchanged

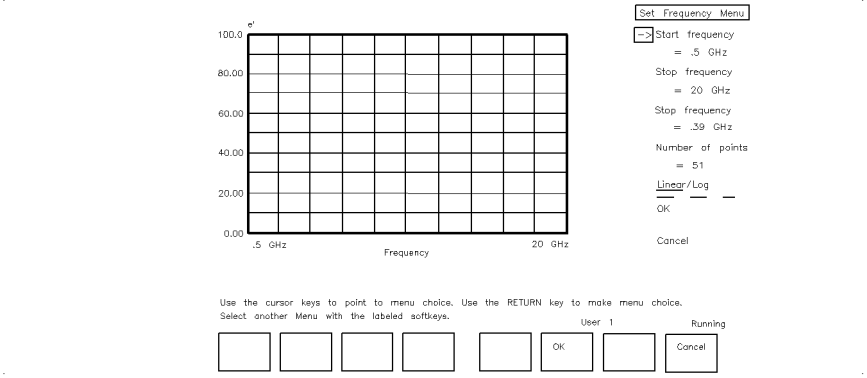


Figure 2-11. HP BASIC Sample Menu Selections

HP 85071 HP BASIC Software Fundamentals

The HP 85071 display window and its components are shown below.

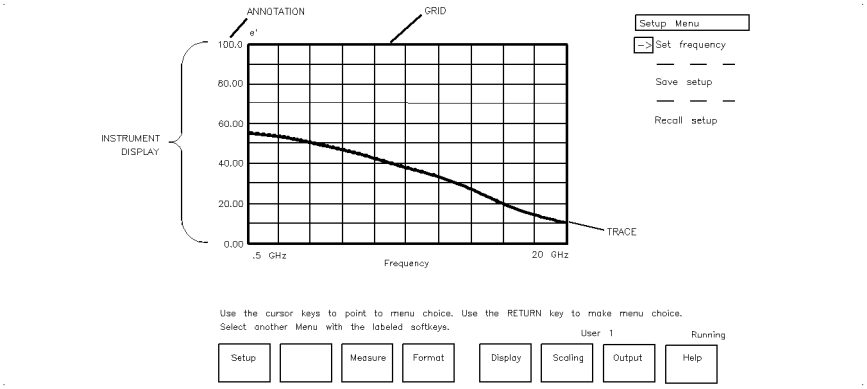


Figure 2-12.
Main Menu Screen with Pull-Outs Describing Principal Functions of Components

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 chapter 3, "Measurement Tutorial."

3

Measurement Tutorial

Introduction

The five sections of this chapter provide a tutorial introduction to the HP 85071 materials measurement software.

1: General Overview summarizes the measurement and data reduction process.
2: Calibration Considerations discusses calibrating various network analyzer for use with the software.
3: Sample and Sample Holder Considerations compares the different types of sample holders and the preparation of materials samples.
4: Measurement Models reviews each of the data reduction models available for use with the software.
5: Waveguide Calibration and Measurement Example is a step-by-step example procedure of a waveguide calibration and measurement.

Section 1: General Overview

The software is designed to calculate materials properties, complex ϵ and μ, from the S-parameter measurements of a sample in waveguide or coaxial transmission line or free space.

Sample Shapes

Each type of "transmission line" requires a different shape sample and sample holder.

- **waveguide:** sample is brick-shaped; sample holder is a section of waveguide transmission line
- **Coax:** sample is donut-shaped; sample holder has a precision connector, such as 7mm, at each port and a precision center conductor
- **Free space:** sample is flat; sample holder varies.

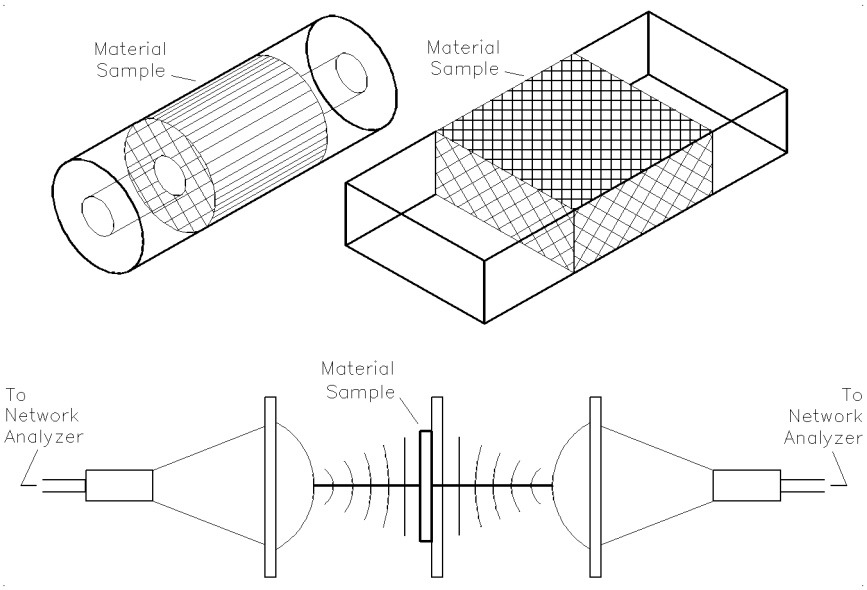


Figure 3-1.
Samples in Coaxial and Waveguide Transmission Lines and Free Space

Calibrating the System

The software requires that you manually calibrate the network analyzer measurement system before making a measurement. Calibration removes measurement uncertainties from the system. If possible, calibrate with the sample holder connected to port 2 (for reasons, see sections 2 and 3, following).

After calibration, minimize changes to the measurement system such as cable movement and temperature variations. More detailed information on the calibration process can be found in the network analyzer's documentation. A calibration example concludes this chapter.

Measuring the MUT's S-Parameters

After calibration, the network analyzer measures the S-parameters of the sample holder and sample material. The measurements may be reflection measurements, transmission measurements, or both. The raw measurements of the sample holder and sample material are then vector error corrected using the system error model obtained during the calibration process. The corrected S-parameters are transferred to the computer.

Converting the S-Parameters to ϵ and μ

The computer mathematically rotates the S-parameters through the appropriate lengths of transmission line. These lengths are input to the software during setup. At this point the S-parameters represent the S11 and S22 input reflection coefficients at the sample interfaces, the S21 and S12 transmission through the sample, or both. The software uses the S-parameters at the sample interface to calculate the complex permittivity and permeability.

Various models are available with the HP 85071 for converting the S-parameters of the material sample to permittivity and permeability. Descriptions of each model are presented later in this chapter

and in chapter 8. Some of the models use iterative calculation routines. As with all iterative routines, it is important to provide an estimate of the solution to start the calculation. The software has built in algorithms for obtaining estimates to start the calculations. Unpredictable results can be overriden with the "verify estimate" command in the setup menu. This presents the estimate that the software is making for the materials parameters at the first frequency. If incorrect, the estimate may be overridden at this point.

Section 2: Calibration Considerations

Take care to store, maintain, and clean the calibration standards properly. Refer to Hewlett-Packard Application Note 326: Coaxial Systems Principles of Microwave Connector Care for reference information.

Calibration Notes

Calibrate the system with the sample holder connected to the cable (or waveguide adapter) at port 2 for best results. If this is not possible, calibrate at the connection interface to the sample holder. For a coaxial holder, this is at the end of the test cables that attatch to the sample holder. For the waveguide holder, this is at the waveguide ends of the coax-to-waveguide adapters.

- Set frequency before calibration
- Calibrate the system manually, from the front panel of the network analyzer
- Calibrate with the sample holder in place if possible (see following section for details)
- Minimize cable movement after calibration
- Use sample holder same length as sample to avoid holder losses

Table 3-1.
Required Calibrations and S-parameter Measurements for Calculation Models

Model Name	Calibration	Measured S-Parameters
Refl/Tran u & e N-R	Full 2-Port	S_{11}, S_{21}, S_{12}, S_{22}
	One Path 2-Port	S_{11}, S_{21}
Refl/Tran e Prec'n	Full 2-Port	S_{11}, S_{21}, S_{12}, S_{22}
Refl/Tran e Fast	Full 2-Port	S_{11}, S_{21}, S_{12}, S_{22}
	One Path 2-Port	S_{11}, S_{21}
Refl e Short-Back	S_{11} 1-Port	S_{11}
Refl e Arbit-Back	S_{11} 1-Port	S_{11}
Refl u & e Sing/Dbl	S_{11} 1-Port	S_{11}

HP 8510 Considerations

Calibrations and measurements should be made with the signal source in a synthesized mode of operation at each measurement frequency. With the HP 8510 this dictates the use of the stepped CW (STEP in the stimulus menu) sweep mode. When the HP 8510 is used in the stepped CW mode, 128 averages can be used without affecting the measurement speed appreciably.

Measurements with the HP 8350 sweeper are not supported with the HP 85071 software.

HP 8719, HP 8720, HP 8722, HP 8753 Considerations

Calibrations and measurements should be made with the signal source in a frequency step mode of operation at each measurement frequency. There is a minimum sweep time which allows the analyzer to operate in the step mode. This minimum sweep time is a function of sweep range, IF bandwidth, and the number of measurement frequencies.

If an "arrow" follows along the trace of the network analyzer CRT as a sweep is taken, the analyzer is in step mode. If not, either reduce the IF bandwidth (the preferred tactic) or increase the sweep time enough for the analyzer to operate in step mode.

Reflection/Transmission Test Set Considerations

Reflection/transmission test sets are subject to some limitations. Examples of such tests sets are the HP 85044 (used with the HP 8743) and the built-in HP 8752 test set. These are the limitations:

- "Refl/Tran u & e N-R" model: supported in the accurate sample position definition mode only
- "Refl/Tran e Prec'n" model: not supported
- "Refl/Tran e Fast" model: supported in the accurate sample position definition mode only

Section 3: Sample and Sample Holder Considerations

Sample Holder

The software assumes that the sample holder is well matched and has negligible loss. Only the phase shift of the known lengths of transmission line is accounted for. Use only a precision, well-matched sample holder. Connect it to port 2 prior to calibration. Any reflections off the input or output of the sample holder will degrade the calculated material parameters.

For best measurement results, the sample should fill the cross-section of the transmission line with no air gaps.

Coaxial versus Waveguide Sample Holders

Coaxial sample holders have the inherent advantage of being broadband. They are however, typically harder to construct for the ease of sample loading. Coaxial samples also require more preparation. Waveguide sample holders are limited to use in the waveguide frequency band. However, they can be easy to fabricate and require less sample preparation.

Free Space

Free space samples should be flat; material preparation may be unnecessary. This type of material measurement is broadband. Rather than the material being contained within a transmission line, antennas radiate energy through the sample. Air gaps are not a problem with this technique.

Dimensions of Holder and Sample

The sample holder length, distance to sample, and sample thickness are entered in the sample holder ... menu. The thickness and distance information needs to be characterized as accurately as possible.

Sample Holder Length

This is the length of transmission line added to the measurement path *after* calibration. For both coaxial and waveguide lines, it is the distance between the outer conductor mating surfaces. In other words, it is the actual length added to the transmission path when the sample holder is tightened in place. It should be calibrated out or precisely measured.

To calibrate out the sample holder length: connect the sample holder to port 2 during calibration as shown below. Then calibrate the system using the sample holder as one of the calibration reference planes. Note that since additional transmission line is not added after calibration, the holder length is 0 (zero).

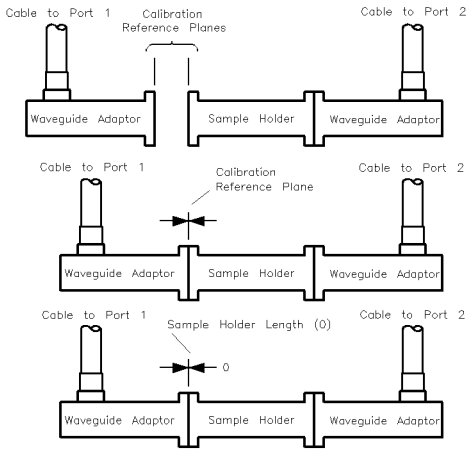


Figure 3-2. Samples in Waveguide, Coaxial and Free Space

To calibrate without the sample holder in place, measure the holder mechanically as precisely as possible. Enter this length in the sample holder menu. As shown below, the calibration reference planes are the ends of the waveguide adapters (or coax cable ends).

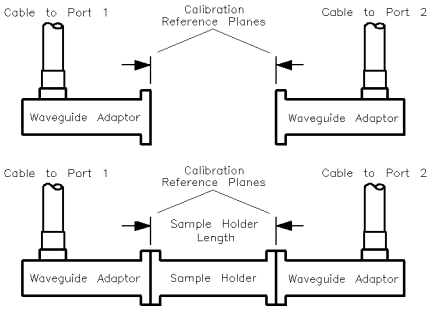


Figure 3-3. Sample Holder Reference Planes

To verify the sample holder length *after calibration*:

- Attach the sample holder to the calibration reference planes.
- Measure the sample holder "empty".
  - If the dielectric constant is calculated as about 1.0006 (air), the length is correctly entered.
  - If the value is not about 1.0006, vary the entered length and use the recalculate feature to close in on the correct number.
  - If the value does not approach 1.0006, recalibrate the system (see section 5 for an example).

Distance to Sample

This dimension is the distance from the port 1 calibration reference plane to the sample. It should be precisely measured when required by the model. Any inaccuracy in this distance causes the "rotated" S-parameters to be in error. This is the most difficult distance measurement to make in that the sample must be loaded in the

sample holder to measure the distance. Some of the models do not depend on precisely knowing the position of the sample in the sample holder.

In many cases, the simplest way to determine the distance to sample, is to place it flush with the port 1 calibration reference plane. Then the distance is simply 0 (zero), and 0 should be entered in the sample holder ... menu.

Sample Thickness

This should be measured by the most accurate mechanical means available (micrometer, vernier caliper, etc.). Uncertainty in the sample thickness will cause inaccuracies in the calculated materials parameters. The inaccuracy due to thickness errors increases with frequency and increases with the magnitude of ϵ and μ.

Table 3-2.
Calculation Models and Optimum Sample Thickness

Calculation Model	Optimum Sample Thickness
Refl/Tran u & e N-R	$\lambda_g/4$
Refl/Tran e Prec'n	$n\lambda_g/2$
Refl/Tran e Fast	$n\lambda_g/2$
Refl e Short-Back	$\lambda_g/2$
Refl e Arbit-Back	$\lambda_g/2$
Refl u & e Sing/Dbl Thk	$\lambda_g/4$ & $\lambda_g/2$

Note:

$$\lambda_g = \frac{\lambda_0}{\sqrt{\epsilon_r * \mu_r - \left(\frac{\lambda_0}{\lambda_c}\right)^2}}$$

where, for TE_{10} mode in rectangular waveguide:

c = speed of light (about $3x10^8$ m/sec)
λ_0 = c/frequency
ϵ_r = relative permittivity
μ_r = relative permeability
a = width of broad wall of waveguide
λ_c = 2a

Other Factors

These include sample composition and fit. It is important that the sample be uniform and completely fill the guide in the transmission line sample holder. Any air gaps between the sample and the center or outer conductor will cause measurement errors. The sample should fit tightly in the holder and be free of nicks.

Air Gap Correction

Gaps between the sample and its transmission line holder may dominate the uncertainties of the measurement, especially for high permittivity materials. The air gap correction function of the software moderates this effect. This function is part of the sample holder command in the setup menu. For details, see "Setup Menu, Air Gap Calculations" in chapter 8, "Software Reference."

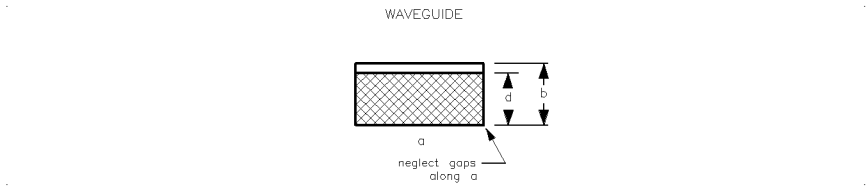


Figure 3-4. Air Gap Correction Figure

Air gap correction applies to coax and waveguide measurements, not free space. It is based on work presented in NIST technical note 1355 (see chapter 7, "Ordering Supplies," for listing).

Section 4: Measurement Models

Six different measurement/calculation models are available in the software. Each model has different advantages and limitations. The use of each model is determined by several factors:

- Optimum sample length (see previous table)
- Measured S-parameters (see table below)
- Desired measurement parameters
- Speed versus accuracy trade-offs

Table 3-3. Measurement Models

Model Name	Measured S-Parameters	Comments
Refl/Tran u & e N-R	all or S_{11}, S_{21}	e_r* & u_r*, fast but has discontinuities, best for magnetic, short, or lossy MUTs
Refl/Tran e Prec'n	all	e_r*, accurate, no discontinuities, best for long, low-loss MUTs
Refl/Tran e Fast	all or S_{11}, S_{21}	e_r*, similar to Precision but faster and better for lossy MUTs, best for long, low-loss MUTs
Refl e Short-Back	S_{11}	e_r*, best for liquids or powders
Refl e Arbit-Back	S_{11}	e_r*, best for thin films
Refl u & e 2 Pos/Thk	S_{11}	e_r* & u_r*, reflection only, requires 2 measurements, slow, best for liquid, powder, magnetic, materials

For details, do one:

- Select the measurement model of interest in the setup menu
- Refer to chapter 8, "Software Reference"

Section 5: Waveguide Calibration and Measurement Example

This is an example of an X-band waveguide calibration and measurement with a MS-DOS driven HP 8720 vector network analyzer system. If you are not familiar with network analyzers, waveguide, or the calibration process, you should read and perform this example sequence before measuring your MUT.

If you are using another network analyzer or a coaxial-based measurement, you may have to adapt this sequence to your setup. The basic sequence for all of the analyzers is quite similar, but if you need additional, specific information, refer to the documentation of the network analyzer.

Before you can make a measurement, you must manually calibrate the network analyzer. In the case of waveguide, you must first load the waveguide cal(ibration) kit information into the network analyzer before the computer takes control of the system. Then you can proceed with the calibration (including setting the frequency range).

Note

If you have not yet configured the hardware or loaded the software for your system, refer to chapter 2, "Getting Started."

How to Begin a Waveguide Calibration

Turn off the system computer. Connect a disk drive to the network analyzer with an HP-IB cable. Turn on the drive and analyzer. Insert the calibration kit disk in the drive. For the HP 8720, press (LOCAL) SYSTEM CONTROLLER (RECALL) LOAD FROM DISK LOAD WR90 to load the waveguide cal kit data into the analyzer.

Note that when the information is correctly loaded, the frequency range of the analyzer changes to match that of the cal kit (in this example, 8.2 to 12.4 GHz). If the analyzer does not seem to load the cal kit data, check that each instrument is set to its default HP-IB address: drive = 0; analyzer = 16.

If your cal kit does not include a cal data disk, refer to the cal kit and network analyzer manuals to see how to enter the cal kit data manually.

Press (LOCAL) TALKER-LISTENER to end network analyzer control of the HP-IB bus.

Start the HP 85071 Software Program

Turn on the computer (it too should be connected to the analyzer with an HP-IB cable). Start the program as explained in the previous chapter. The copyright screen should appear. Continue.

Notice that as the software program begins, it resets the analyzer to the cal kit frequency range in polar chart format.

Set Up the Measurement First

In general, 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 measurement frequency range:

- Must match the calibration frequency range
- Can be as wide as the bandwidth of the cal kit
- Can be just part of the bandwidth of the cal kit

1. Click on (Setup)
2. Select `Set frequency...` to display the dialog box below

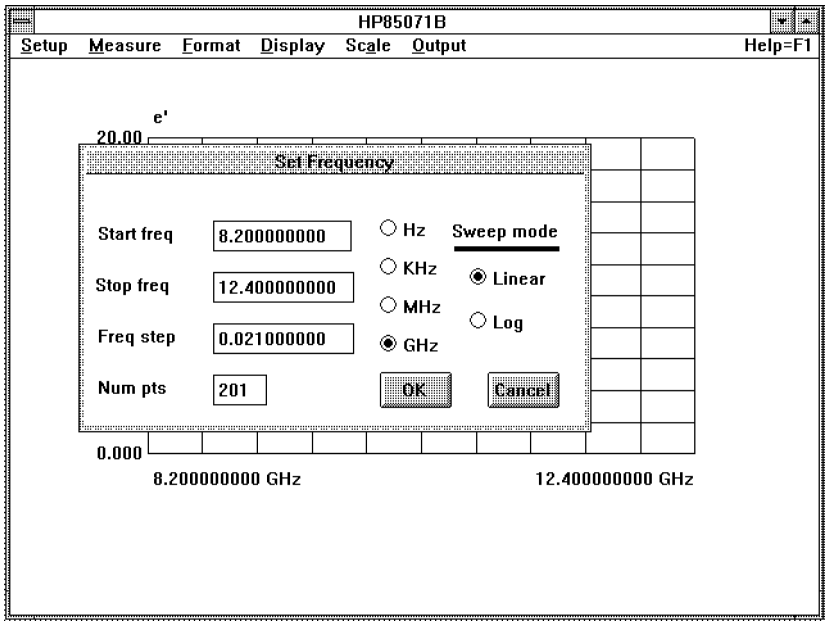


Figure 3-5. Set Frequency ... Dialog Box (MS-DOS Version)

Change Start Frequency to 8.2 (GHz)

If loading the cal kit data made this setting, skip to the next paragraph.

1. Move the pointer to the text box just to the right of Start freq
2. 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.
3. Type in `8.2` (You do not have to enter the units, GHz, as that is the default value.)

   Do NOT select `OK` or press (RETURN) or (ENTER) yet.

Change Stop Frequency to 12.4 (GHz)

If loading the cal kit data made this setting, skip to the next paragraph.

1. Move the pointer to the left end of the Stop freq text box.
2. Click, drag, and release as above.
3. Type in `12.4`

Change Num Pts to 51

- Change the number of points to 51, as above.

OK the Changes and Exit the Dialog Box

In this example, we use the default values for units (GHz) and sweep mode (linear).

- To accept the settings made, do one:
  - Select `OK` command with the mouse
  - Press (ENTER) or (RETURN) on the keyboard

The software displays the hourglass as it updates the network analyzer.

Define the Model

This dialog box lets you select the measurement model.

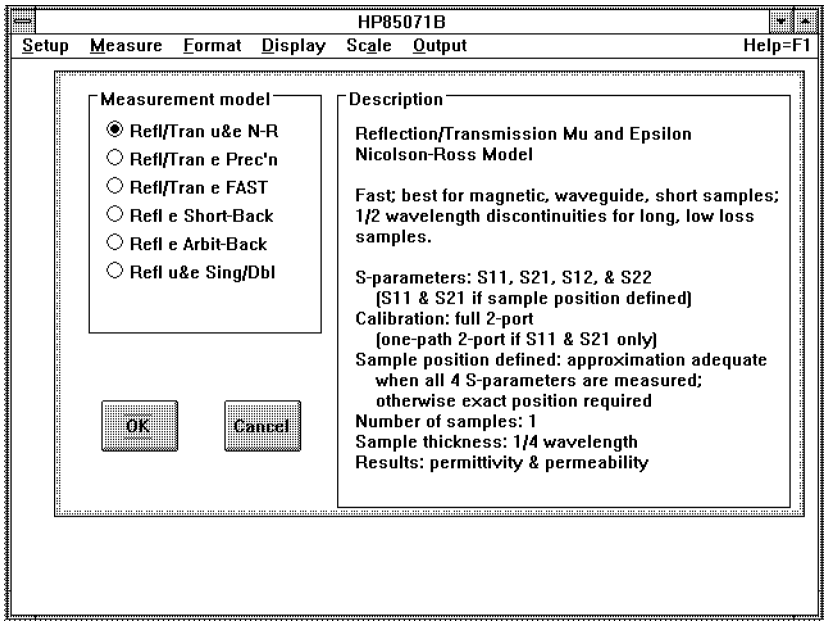


Figure 3-6. Model ... Dialog Box (MS-DOS Version)

1. Select (Setup)
2. Select `Model...` (note that the current measurement model is "Refl/Tran u & e N-R")
3. Select `Cancel` to leave the dialog box without changing it

Define the Sample Holder

If you are using a coaxial system, or a different waveguide cal kit, enter the equivalent data. The software lookup table (explained below) and the "Software Reference" chapter contain tables of common waveguide cutoff frequencies. The cutoff frequency for coaxial systems is 0 GHz.

This example assumes this hardware configuration:

- Cable connected to port 1
- Waveguide adapter connected to port 1 cable
- Cable connected to port 2
- Waveguide adapter connected to port 2 cable
- Sample holder connected to port 2 waveguide adapter

Note

Calibrate the system with the sample holder in place whenever possible. This technique removes uncertainties in sample holder length and to a first order removes sample holder loss. For details, refer to "Sample and Sample Holder Considerations" earlier in this chapter.

To perform this calibration example,

1. Select (Setup)
2. Select `Sample holder...` to enter the sample holder description dialog box.
3. Enter this information for the X-band waveguide cal kit:
   Sample holder length: `0`(default)
   Distance to sample: `0` (default)
   Sample thickness: (enter non-zero value)
   Units: inch (default)
   Sample holder: `Waveguide`
   Click on `Lookup table>>`
   Select "X Band W/G 8.20-12.4 GHz"
   Click on `OK` to leave the lookup table (note that it sets the cutoff frequency)
4. Click on `OK` to exit the dialog box

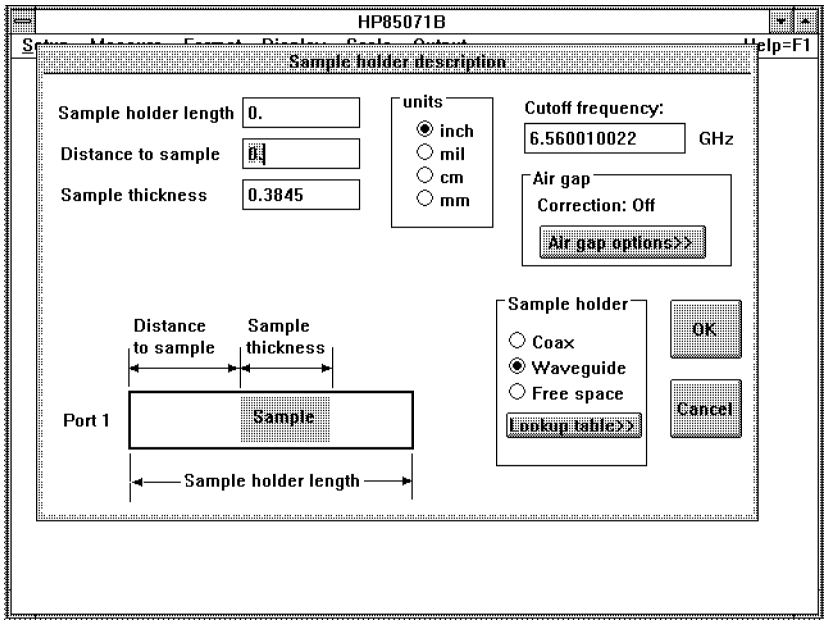


Figure 3-7.
Sample Holder Description Dialog Box (MS-DOS Version)

Perform the Calibration

The calibration consists of measuring known standards and using the results to characterize the three major sources of measurement error. A full 2-port calibration consists of reflection, transmission, and isolation measurements. Isolation should be omitted in most instances. The default calibration standards are a pair of short circuits, a "thru," and a load.

- The shorts are
  - a flush short and a 1/4 wavelength offset short, or
  - a 1/8 and 3/8 wavelength offset short
- The "thru" consists of simply butting the two waveguide flanges together
- Loads may be fixed, sliding, or offset.

NOTE: in the following example, softkey and hardkey names may vary from cal kit to cal kit and from analyzer to analyzer.

To begin the calibration, on the network analyzer,

1. Press (LOCAL) `CAL` `CAL KIT` `USER KIT`. The user kit should be defined as WR-90 (because you previously loaded it from disk).
2. Press (CAL) `CALIBRATE MENU` `FULL 2-PORT` `REFLECT'N` to enter the first part of the calibration sequence.

Stabilize the Cable and Measure the First Standard (Flush Short)

Cable movement degrades measurement accuracy. Before you calibrate, immobilize the cables and adapters: lay the cables flat on a work surface or hold them in place.

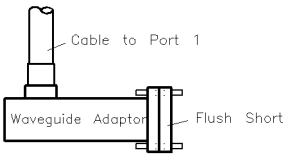


Figure 3-8. Measuring the Flush Short

Note

Measurement degradation can result from changing the position of the cable between calibration and measurements. Keep such changes and flexures to a minimum.

The reflection calibration softkeys should now be visible on the network analyzer display. The top softkey is labelled "S(11): SHORT." S11 means it is a reflection measurement at port 1.

1. Connect a flush short to the port 1 waveguide adapter.
2. Press `S11: SHORT` to measure the short.
3. Remove the short when the analyzer beeps or underlines the softkey label.

Measure the Second Standard (1/4 Wavelength Offset Short)

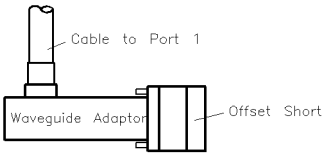


Figure 3-9. Measuring the 1/4 Wavelength Offset Short

1. Connect a 1/4 wavelength offset short to the port 1 waveguide adapter.
2. Press `1/4 OFFS` (immediately below the "(S11): SHORT" softkey) to measure the short.
3. At the beep or underline, remove it.

Measure the Third Standard (Fixed Load)

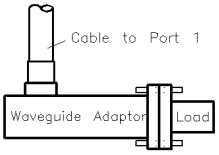


Figure 3-10. Measuring the Fixed Load

1. Connect the fixed load to the port 1 waveguide adapter.
2. Press `FXD LOAD` (immediately below the previous softkey) to measure the fixed load.
3. At the beep and underline, remove it.

Measure the Three Standards at Port 2

Use the same three standards and the next three softkeys (in the S22 group) to calibrate port 2 as above. Whereas the standards were connected directly to the waveguide adapter at port 1 of the analyzer, at port 2 connect the standards to the sample holder attached to the waveguide adapter.

Press `REFLECT'N DONE` after you have measured all of the standards once at each port (waveguide flange).

Measure the Transmission Standards

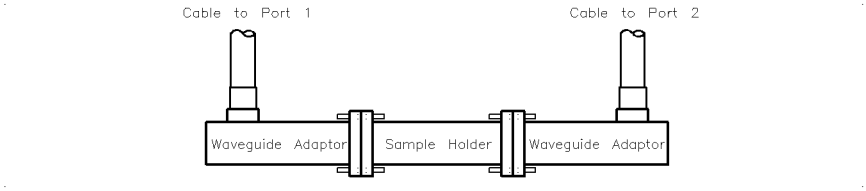


Figure 3-11. Measuring the Thru

1. Connect the two waveguide flanges together (with the sample holder between them).
2. Press `TRANSMISSION`.
3. Make all four transmission measurements, two forward and two reverse.
4. Press `TRANS. DONE` when all four softkeys are underlined.

Conclude the Calibration

Finish the calibration without isolation.

1. Press `ISOLATION` `OMIT ISOLATION` `ISOLATION DONE` and `DONE 2-PORT CAL`.

The network analyzer calculates the error-correction numbers and displays the notation "C2" at the upper left of the display when done.

Measure a Sample Material

With the sample holder between the two waveguide flanges, measure a MUT, air (easily available, no fit problems).

1. Select (Measure) in the main menu.
2. To make the measurement, do one:
   - Select `Trigger meas` in the measure menu
   - Click the right mouse button

The software initiates the measurement, calculates the complex permittivity and permeability, and displays the permittivity results. The initial results are presented on the default scale of 0 to 20 in the e′ versus frequency format as shown below.

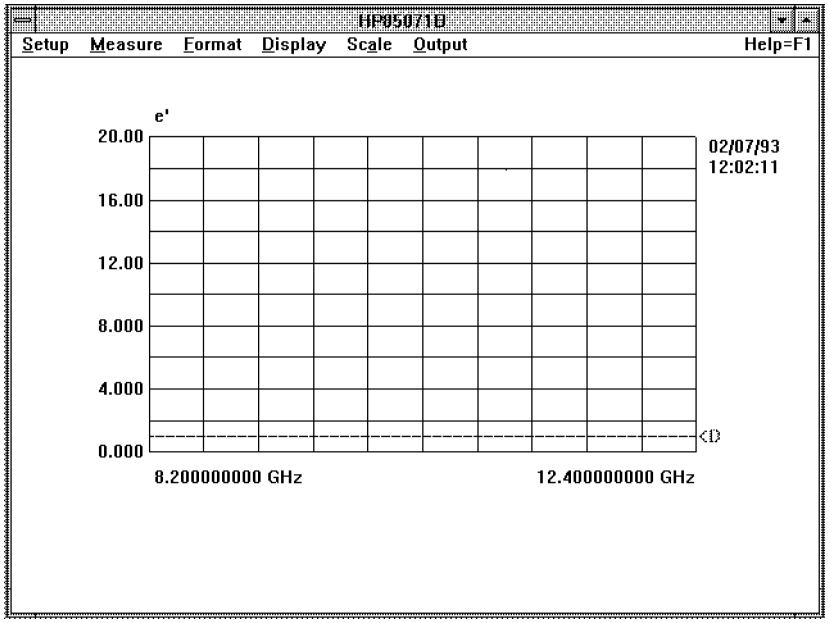


Figure 3-12. Default Display of Air Measurement

Scale the Display

Each format is displayed in the scale last used for that format.

To change the scale of the software display,

- Select (Scale) in the main menu screen.
- Select the three commands in turn to scale the y-axis.

  `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. (To duplicate the figure below, enter `2.0` for the value of Y-Maximum.)

  `Default` scales the y-axis as defined in the software.

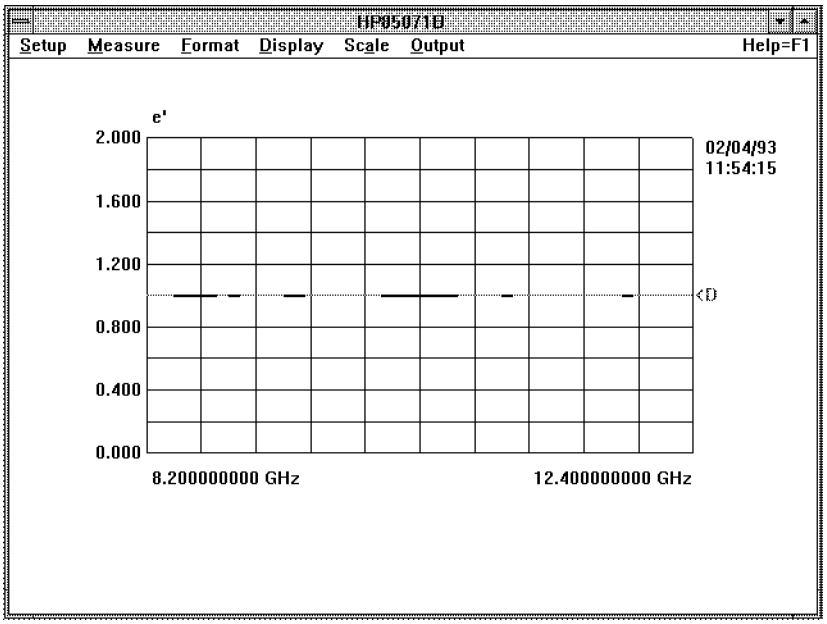


Figure 3-13. Display of Air Measurement with Y-Maximum = 2

Change the Format of the Data

Data can be formatted as one of seven graphs or one of two tables, as indicated on the screen.

To change the format of the data displayed,

1. Select Format in the main menu.
2. Select `Tabular (Re & Im)`.

   The display should resemble the one shown below. Note that not all of the measurement values are visible. Use the scroll bar on the right of the HP 85071 display to scroll through the data.

HP85071B

Setup Measure Format Display Scale Output Help=F1

Reference math : OFF Title:

Pt#	Frequency [GHz]	Ep real	[Data] imag	Mu real	[Data] imag
1	8.200000000	0.9998	-0.0001	1.0004	0.0004
2	8.284000000	0.9999	0.0001	0.9999	-0.0000
3	8.368000000	1.0002	0.0000	0.9997	0.0000
4	8.452000000	1.0001	0.0001	0.9996	-0.0001
5	8.536000000	1.0001	-0.0000	0.9999	0.0001
6	8.620000000	1.0001	-0.0000	0.9998	0.0001
7	8.704000000	1.0002	0.0000	0.9998	-0.0002
8	8.788000000	1.0001	-0.0001	0.9995	-0.0001
9	8.872000000	1.0001	-0.0001	1.0000	0.0001
10	8.956000000	1.0001	-0.0001	0.9997	0.0002
11	9.040000000	1.0001	-0.0000	0.9999	0.0001
12	9.124000000	1.0000	-0.0001	1.0001	0.0001
13	9.208000000	1.0000	-0.0001	1.0000	0.0000
14	9.292000000	1.0000	-0.0001	1.0002	0.0001
15	9.376000000	0.9999	0.0000	1.0001	0.0000
16	9.460000000	0.9999	0.0001	0.9999	0.0001
17	9.544000000	1.0000	-0.0000	1.0002	0.0002
18	9.628000000	1.0000	0.0001	0.9999	-0.0002
19	9.712000000	0.9999	-0.0000	0.9999	-0.0001
20	9.796000000	1.0001	-0.0001	1.0000	-0.0001
21	9.880000000	1.0000	-0.0001	0.9999	-0.0001
22	9.964000000	1.0001	-0.0000	1.0000	0.0000
23	10.048000000	1.0001	0.0000	0.9998	-0.0000
24	10.132000000	1.0001	-0.0000	1.0002	0.0000

Figure 3-14. Example of Tabular (Re & Im) Format

3. Return to the original format of e/ (versus 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 is usually the calculated data of the current measurement (unless a previous measurement has been recalled from memory). Performing another measurement erases the current data unless it is first saved, as explained below.

To save the current measurement data,

1. Select (Display) in the main menu.
2. Select `Data -> memory...` in the display menu.
3. Select `Memory 1`, for example, and `OK`.

   Now the trace of memory 1 is a duplicate of the data trace, although it may not be visible (the two traces are on top of each other since they are the same).

Seeing the Effects of Cable Movement

As explained earlier, moving the cable or fixtures after calibration introduces measurement inaccuracies. To see this effect,

1. Change the position of the cable or fixture. (For example, if it is lying on a work surface, raise it several inches.)
2. Measure the MUT (air) again.

Viewing More Than One Trace

Note that the data trace is erased and replaced by the new measurement (use autoscale if desired). 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.

Note

The difference in the traces is the result of cable movement. It is also an indication of measurement repeatability (purposefully degraded, in this example).

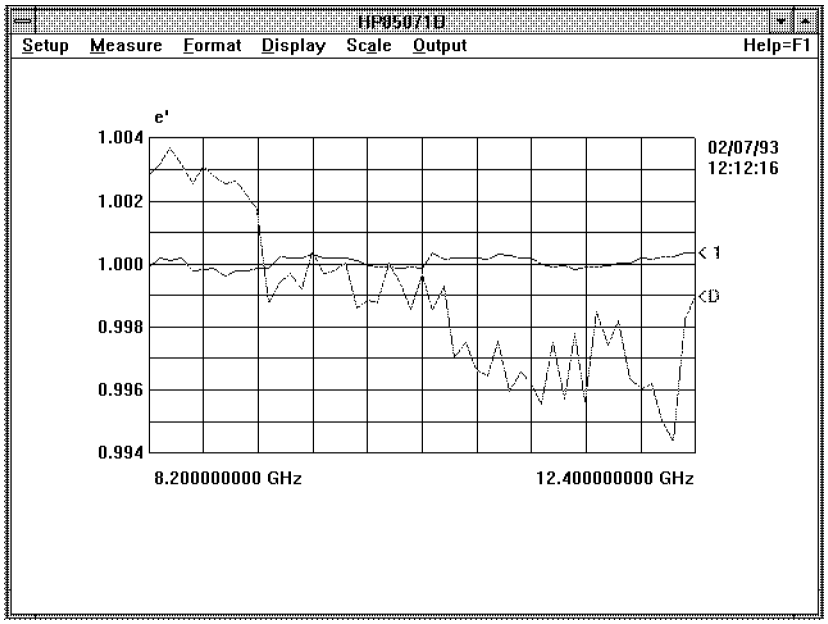


Figure 3-15.
Simultaneous Display of Two Traces Showing Effect of Cable Movement

Compare the Traces with Trace Math

The trace math function lets you compare traces mathematically. It allows you to divide a designated trace by the reference trace or subtract the reference trace from it.

1. Select `Reference trace...` in the display menu.
2. Choose `Memory 1` as the reference trace.
3. Select `Trace math...` in the display menu. Note that trace math is currently off.
4. Select `/ref`. The format indicator changes from e/ to e/[/1] (because memory 1 is the reference trace) as shown below.
   Autoscale if necessary.

Memory trace 1 holds the original air measurement. The data trace holds the second (current) air measurement.

Trace math calculates each of these measurements divided by the reference (original) measurement. The display shows the percent difference above or below the reference. For example, 1.003 means that the trace being compared to the reference is 0.3% greater than the reference trace. Thus, trace 1/trace 1 always has the value of 1.

The data trace should have been fairly close to the original measurement (now in memory 1). Thus data/trace 1 should have values that are close to 1 but not exactly 1.

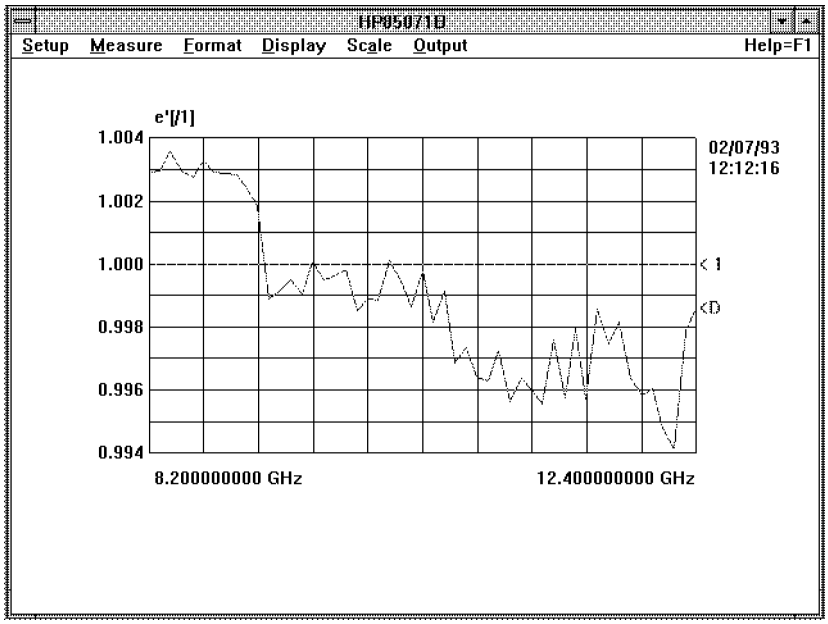


Figure 3-16. Traces Compared With Trace Math

- 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.

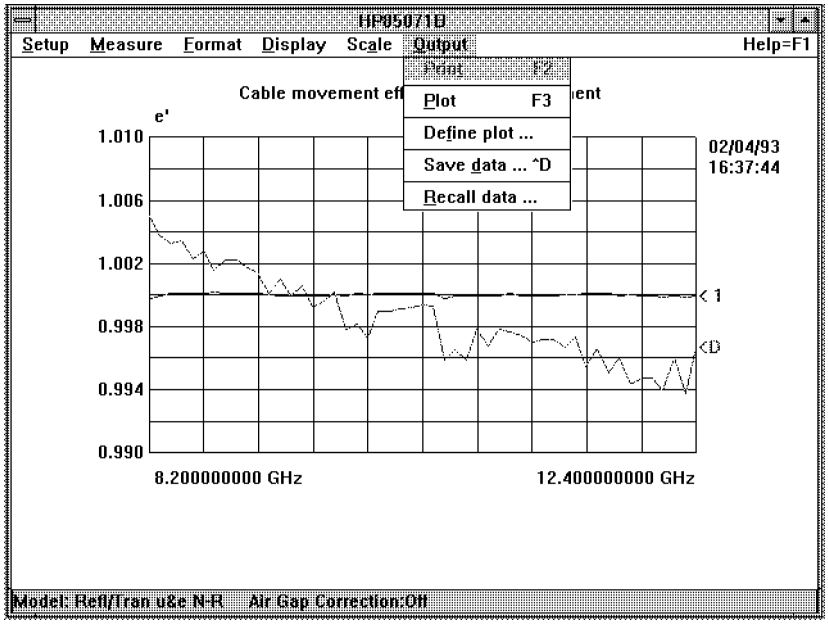


Figure 3-17. Output Menu (MS-DOS Version)

Format Sets Print versus Plot

Type of format determines whether the data can be printed or plotted.

Table 3-4.

Format	Command	Hardcopy Device
Table	`Print`	Printer
Graph	`Plot`	Plotter or Printer

Saving Information

The software lets you save three main types of information:

- Test setup data
- Measurement data
- Data files

The information is saved to disk, in the computer memory, in the network analyzer.

Note

To save calibration data, refer to the network analyzer manual.

Test setup data consists of

- Network analyzer learn string: a full definition of the state or settings of the analyzer
- Software operating state: frequency range, format, traces displayed, measurement data scale
- Measurement data
- Visible memory trace data

Measurement data is of two varieties:

- The most recent measurement or
- Measurement data recalled from memory

Data files consist of

- Measurement data
- Frequency range
- Sweep type

To Save the Test Setup to Disk

This procedure saves the test setup (defined above) to disk.

1. Select (Setup).
2. Select `Save setup...`.
3. Enter the disk drive, directory, and filename of the setup.
   Filenames are limited to eight characters.
   Filenames are given the extension ".TST"
   Other extensions are permissible.
4. Enter file information if desired.
5. Select `Save` to save the test setup file.

Saving Measurement Data

Measurement data can be saved to disk and to memory.

To Save To Disk

To save measurement data to disk as part of a test setup, follow the procedure above, "To Save the Test Setup to Disk."

To Save To Memory

To save measurement data to memory as a memory trace,

1. Select (Display)
2. Select `Data to memory`
3. Select memory 1, 2, or 3.
4. Select `OK`.

To Save Data Files To Disk

Data files include measurement data, frequency range, and sweep type. Data files do not include the data of memory 1, 2, or 3. 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").

To save data files to disk,

1. Select (Output).
2. Select `Save data...`.
3. Enter the disk drive, directory, and file name in the dialog box.
4. Select `Save`.
5. Enter file information if desired.
6. Select `OK`.

Recalling Information

The software lets you recall the same four main types of information that you can save. The types are defined in "Saving Information," above. The types are:

- Test setup data
- Measurement data
- Data files

To Recall a Test Setup from Disk

1. Select (Setup).
2. Select `Recall setup...` to display the recall setup dialog box.
3. To select the desired file, do one:
   - Select file from the list.
   - Change drive, directory, or both and then select.

Recalling Measurement Data

Measurement data can be recalled from disk or memory.

To Recall from Disk

1. Select (Output).
2. Select `Recall data...` to display the recall data dialog box.
3. To select the desired file, do one:
   - Select file from the list.
   - Change drive, or directory, or both and then select.

Note

Recalled measurement data is placed in the data trace for display if the recalled frequency range and sweep type match the current settings. If they do not match, the recalled data is not displayed.

4. To view additional traces,
   a. Place the first in memory 1.
   b. Recall the second and place it in memory 2.
   c. Repeat as desired.

To Recall From Memory

1. Select (Display).
2. Select `Memory -> data...`.
3. Select memory 1, 2, or 3.
4. Select `OK`.

To Recall Data Files from Disk

1. Select (Output).
2. Select `Recall data...`
3. Do one:
   - Select displayed file name
   - Enter disk drive, directory, and file name
4. Do one:
   - Select "View File Info" `Open` `OK`
   - Unselect "View File Info" and select `Open`

Conclusion

After working through this measurement tutorial, you should be familiar with the main operating techniques and features of the HP 85071 materials measurement 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.

Don't overlook the index and glossary for help.

4

Advanced Measurement Techniques

Introduction

This chapter focuses on several topics intended to help you make more accurate measurements and analyze them on different platforms. The topics are these:

- Traceable reference measurements and materials
- Air gap correction
- Sample holder length/loss
- Accessing Data Files

Traceable Reference Measurements and Materials

The accuracy of material measurement procedures and the traceability of such measurements can be established by measuring reference materials with an HP 85071 material measurements system.

Reference materials and a measurement service are currently available through NIST (National Institute of Standards and Technology, formerly National Bureau of Standards). HP is not part of the traceability chain and recommends that, for additional information, you contact NIST . Refer to "NIST Calibration Services User's Guide," NIST Special Publication 250 (1990 or later).

One of the measurement services offered by NIST uses the same algorithm as the HP 85071 software.

Air Gap Correction

This applies to coaxial and waveguide transmission line measurements and is software-driven. For details, see "Setup Menu, Air Gap Calculations" in Chapter 8, "Software Reference".

Sample Holder Length/Loss

To reduce measurement uncertainties due to the sample holder,

- Use a well-matched sample holder with minimum loss.
- Calibrate with the sample holder at port 2.
- If you add the sample holder after calibration, match its length to that of the sample if possible.

For details regarding sample holders, see section 3 of chapter 3.

For an example measurement using a sample holder, see section 5 of chapter 3.

Accessing MS-DOS Data Files

Data files from the MS-DOS and HP BASIC versions of the software can be accessed with the following methods. The HP BASIC method concludes this chapter.

Data files created by the HP 85071 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 issuing 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 pressing 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 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. 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 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.

Accessing HP BASIC Data Files

Use the following BASIC program to access materials measurement data for post-measurement processing. For methods applicable to the MS-DOS version, see "Accessing MS-DOS Data Files," above.

```
10 !
20 !
30 ! This SUB will read an HP 85071 datafile when incorporated
40 ! as part of an HP BASIC program. It is assumed that the
50 ! complex arrays 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(*),Mu(*),REAL Freq (*))
90 !
100 !
110 ! INPUT : Data_file$ - The filename and mass storage
120 ! specifier of the HP 85071 datafile to recall
130 !
140 ! OUTPUT : Start_freq - The start frequency for the stored
150 ! measurement 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 INTEGER
220 ! type
230 !
240 ! Sweep_type$ - The type of frequency distribution for the
250 ! stored measurement data. The string read back from the
260 ! file will either be "LINEAR" for a linear frequency
270 ! sweep or "LOG" for a logarithmic frequency sweep.
280 !
290 !
300 ! Freq(*) - An array containing each measurement frequency
310 ! for the stored measurement data. For example, Epsilon(5)
320 ! holds the epsilon measurement data from the 5th frequency.
330 ! The 5th frequency is held in the array element Freq(5).
340 !
350 !
360 ! Epsilon(*) - The stored epsilon measurement data
370 !
380 ! Mu(*) - The stored mu measurement data
390 !
400 !
410 OPTION BASE 1
420 ASSIGN @File TO Data_file$
430 ENTER @File;File_type$
440 IF File_type$ "HP85071DATAFILE" THEN
450 ! not a proper HP 85071 file, take appropriate action
460 ELSE
470 ENTER @File;Num_freq,Start_freq,Stop_freq,Sweep_type$
480 ALLOCATE COMPLEX Temp_epsilon (Num_freq),Temp_mu
```

```
(Num_freq), Temp_freq (Num_freq)
490 ENTER @File;Temp_epsilon(*)
500 ENTER @File;Temp_mu(*)
510 ENTER @File;Temp_freq(*)
520 FOR I=1 TO Num_freq
530 Epsilon(I)=Temp_epsilon(I)
540 Mu(I)=Temp_mu(I)
550 Freq(I)=Temp_freq(I)
560 NEXT I
570 END IF
580 ASSIGN@File TO *
590 SUBEND
```

5

In Case of Difficulty

Introduction

Although the HP 85071 materials measurement software has been designed for convenience and ease of use, problems can arise. This chapter contains three sections to deal with possible problems:

- Common problems and solutions
- MS-DOS error messages
- HP BASIC error messages

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.

Common Problems and Solutions

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. They should be given time to stabilize prior to calibration. Excessive flexing can result in measurement inaccuracies. With waveguide systems, allow the test port (usually port 2) to waveguide flange cable to maintain the same position (don't flex or bend it) long enough to minimize phase changes.

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 surfaces of the waveguide or coaxial sample holder, non-perpendicular sample faces, or changing location of the sample within the sample holder.

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, details appear in "System Requirements" in section 1 of chapter 2. Considerations include the following:

- Minimum amount of RAM
- Type of flexible disk drive
- Size of hard disk drive
- Graphics requirements
- Required MS-DOS and Windows versions

For the HP BASIC version, details appear in "System Requirements" in section 2 of chapter 2. Considerations include the following:

- The computer is not one of the unsupported exceptions
- Minimum amount of RAM
- Type of flexible disk drive
- BASIC version and required binaries
- HP-IB interface card

Before You Contact HP ...

If problems persist and you want to contact HP, *first*

- Save a copy of the setup file

Then log this information:

- Product: HP 85071B
- Software revision:
- Computer:
  - □ If DOS, type of HP-IB card:
- Network analyzer (and test set):
  - □ network analyzer revision:
  - □ network analyzer options:
- Problem description:
- Is the problem intermittent?
- How can one duplicate the problem?

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 85071 is already running. You can run only one copy of the HP 85071 application at a time.

A full two port calibration is not on. Recall or perform a calibration. You must recall or perform a two-port calibration for any of the "Refl/Tran" models before making a measurement.

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 85071. 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.

A one port calibration is not on. Recall a setup file that includes a calibration or perform a new calibration. Before making a measurement, you must recall or perform a one port calibration for any of these models:

- Reflection-only ϵ short-backed
- Reflection-only ϵ arbitrary-backed
- Reflection-only μ and ϵ single/double thickness

A one port calibration is not on. Recall or perform a calibration. You must recall or perform a two-port calibration for any of the "Refl/Tran" models before making a measurement.

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.

Calibration does not match the current setup. The setup will be modified. 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 change its frequency range to match the calibration.

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.

Instrument log sweep is not supported by this program. An attempt to recall a calibration performed using the network analyzer's internal log sweep mode failed. This mode of operation is not supported.

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.

Sample thickness must be greater than zero. Sample thickness must be define in the setup menu as a positive value greater than zero.

Selected model requires a one port measurement. The attempt to recalculate materials parameters for the Refl e model failed because a full 2-port calibration had been performed, not the required one port cal.

Selected model requires a two port measurement. The attempt to recalculate materials parameters for the one of the Refl/Trans modela failed because a one port cal had been performed, not the required full two port calibration.

The cutoff frequency must be less than the start frequency. Change one of the frequencies as indicated.

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. Run the HPIBSTAT.EXE program to troubleshoot the problem.

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 or press (PRESET) on the network analyzer and select the RETRY software function.

There is not enough memory to run HP 85071. Close all other applications and try again.

There is no valid measurement.

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

The sample holder must be defined before a measurement can be taken. Select "Holder . . . " in the setup menu, define sample thickness, sample holder length, and cutoff frequency. Then measure again.

The selected frequency list mode not supported by the program. The software cannot recall calibrations performed using frequency list mode.

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

The single point mode is not supported by this program. The software cannot recall calibrations performed using single point mode.

This software does not support the HP 8510A. Only the HP 8510B and HP 8510C are supported by the software. Upgrade the HP 8510A to a C with the upgrade kit (see "Network Analyzer and Test Set" in chapter 2).

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. Enter a filename with these limitations:

- Eight characters maximum
- Only letters, numbers, and underline (_)
- Software adds prefix (D_ or S_)

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.

Cutoff frequency >= start frequency not allowed. Select the Holder ... choice in the Setup menu to define the cutoff frequency as less than the start frequency.

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 press `Try Again` or press `Exit` to abort.

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 `Try Again` or press `Exit` 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 85071 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.

Sample holder is not yet defined. The attempt to trigger a measurement failed. First return to the Holder . . . choice in the Setup Menu to define the sample holder.

Sample thickness <= 0 not allowed. Redefine the sample as thicker than 0 using the Holder . . . choice in the Setup menu.

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 85071 data file. An attempt was made to recall a data file that was not created using the HP 85071 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.

The 'Refl e' model requires a one port calibration. Perform a one port cal and remeasure.

The 'Refl/Tran' measurement models require a two port calibration. Perform a two port cal and remeasure.

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.

6

Operator's Check

The HP 85071 materials measurement software consists of just the software and the manual. Thus the operator's check consists of successfully loading the software onto the system hard disk. Depending on your type of computer system, follow either the MS-DOS or HP BASIC procedure below.

Note

Loading the software is a powerful, quick check. It is not a substitute for installing it to run. To install and run the software, refer to chapter 2.

Procedure for MS-DOS Software Version

Before loading the software, you must:

- Install Microsoft DOS (not supplied).
- Install Microsoft Windows (not supplied).

Computer system requirements, required DOS and Windows versions, are listed in "System Requirements," chapter 2, section 1.

If you are configuring the computer for the first time or installing a new version of DOS, refer to the Microsoft DOS installation documentation.

If you are installing Windows for the first time, refer to "Microsoft Windows Installation", chapter 2, section 1.

HP 85071 Software Check

Check the integrity of the HP 85071 software by copying it to the hard disk. The following procedure assumes:

- Floppy disk is **A**
- Hard disk is **C**

To copy the program from the floppy disk to the hard disk:

1. Insert the HP 85071 program disk in the floppy disk drive.
2. On the hard disk, make a directory dedicated for HP 85071 files. At the DOS prompt type:

   `MKDIR C:\HP85071B` and press ENTER
3. Copy the software from the floppy disk to the hard disk. At the DOS prompt type:

   `COPY A:*.* C:\HP85071B` and press ENTER
4. Put the original floppy disk away for safe keeping.

If the software loads successfully (without error messages or warnings), its integrity is good. If you experience any problems, make sure MS-DOS and Windows are properly installed and repeat the

software loading steps above. If problems persist, refer to chapter 5, "In Case of Difficulty."

Procedure for HP BASIC Software Version

Before loading the software, you must:

- Install Hewlett-Packard BASIC operating system (not supplied).
- Install the required binaries (not supplied).

If you have not installed BASIC or the binaries previously, or if you are unsure of the hardware or software requirements, refer to "HP BASIC Installation" in section 2 of chapter 2.

HP 85071 Software Check

Check the integrity of the HP 85071 software by copying it to another disk. The HP 85071 software program resides in a single file on the HP 85071 program disk, a floppy disk. The name of the file is HP85071B.

1. Insert the HP 85071 program disk in the disk drive.
2. 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. MSUS's 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 address 700, drive 0 to drive address 700, drive 1, type:

   ```
   COPY "HP85071B:,700,0" TO "HP85071B:,700,1"
   ```
3. Put the original away for safe keeping.

If the software loads successfully (without error messages or warnings), its integrity is good. If you experience any problems, make sure that BASIC and the binaries are properly installed, then repeat the steps above. If problems persist, refer to chapter 5, "In Case of Difficulty."

7

Ordering Supplies

Introduction

This chapter lists the part number of the materials measurement manual and other materials measurement literature.

Table 7-1. Orderable Material Measurements Items

HP Part Number	Qty	Description
85071-90004	1	user's manual

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. It is divided in two sections: Hewlett-Packard literature and public technical papers.

Hewlett-Packard Literature

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

- "Basics of Measuring the Dielectric Properties of Materials," application note 1217-1, part number 5091-3300E, March 1992.
- "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 Microwave Instruments 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 1986. This is an excellent short survey of many methods. Taken together, the methods span a 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 a 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.
- Richard G. Geyer; "Dielectric Characterization and Reference Materials," NIST Technical Note 1338.
- Baker-Jarvis; "Transmission/Reflection and Short-Circuit Line Methods," NIST Technical Note 1341.
- Baker-Jarvis; "Transmission/Reflection and Short-Circuit Line Methods for Measuring Permittivity and Permeability," NIST Technical Note 1355.
- 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 slmost 40 years old, but still the bible on dielectrics and measurements; a good introduction to basics.

8

Software Reference

This chapter details the operation of each menu, command, and entry parameter in the HP 85071 materials measurement software. To learn how to perform basic software operations, refer to chapter 2, "Getting Started." To see how to perform a typical calibration and measurement sequence, see chapter 3, "Measurement Tutorial".

There are seven menus in the software. The menus are indexed in the order in which they are used and appear on the screen. The MS-DOS version of the menus are illustrated; the BASIC version is similar. These are the general functions of the menus:

Setup describes the sample holder and sample thickness as well as selects which measurement model is to be used for obtaining materials parameters. It also selects the frequency range and linear or logarithmic frequency distribution. It also allows you to save and recall test setups to disk.

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 for displaying calculated permittivity and permeability data.

Display offers data manipulation choices: transfer the current measurement Data trace to any of three memory traces, select which traces are displayed, transfer any of the three memory traces to the Data trace, 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 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 measurements
- Select the measurement model for obtaining complex material parameters
- Describe the material sample and sample holder
- Save and recall complete test setups to disk

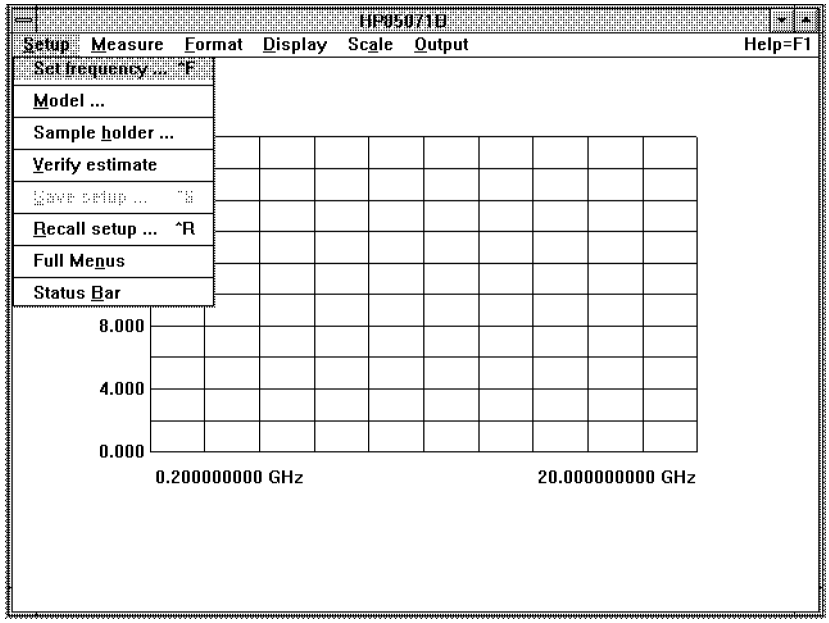


Figure 8-1. Setup Menu (MS-DOS Version)

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.

Start freq & Stop freq

Start and stop frequencies define the frequency range. They can be set manually or by selecting a type of waveguide sample holder in the sample holder menu.

Freq step

Frequency step is the frequency difference between successive frequency points. It is a valid choice in linear or log sweep mode (see below). For example, 1.0 GHz frequency steps in the range of 10.0 to 18.0 GHz results in nine measurements being taken at 1.0 GHz intervals (10.0, 11.0, 12.0 ... 18.0 GHz).

Num pts

Number of frequency points is the number of frequencies measured within the defined range. It takes precedence over frequency step when both are entered. It is a valid choice in linear sweep mode only

(see below). For example, 51 points in the range of 2.0 to 7.0 GHz, results in 51 measurements being taken between 2.0 and 7.0 GHz at every 0.1 GHz inteval.

Hz, KHz, MHz, GHz

These are the four choices for frequency unit. The same choice applies to start frequency, stop frequency, and frequency step (also cutoff frequency in the sample holder menu). For example, if you specify a start frequency in GHz, the stop frequency and frequency step are also defined in GHz.

Sweep mode

The software can make measurements over the specified frequency range by distributing the frequencies in either a linear or logarithmic fashion.

In linear sweep mode the start, stop, and step or number of frequencies is specified.

In a logarithmic sweep the start, stop, and number of frequencies is defined. The number of frequencies 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.

MS-DOS version:

- Presents the dialog box shown below

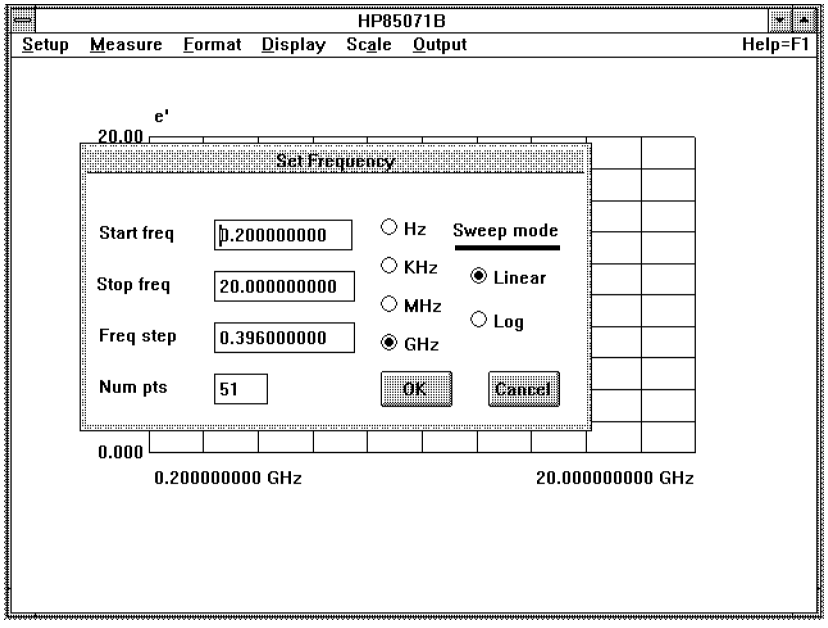


Figure 8-2. Set Frequency ... Dialog Box (MS-DOS Version)

HP BASIC version:

- Sweep mode toggles when [Linear/Log] command is chosen
- The current sweep mode is underlined

Model ... This command presents a dialog box to choose one of the measurement models. It also briefly describes each model. The models calculate materials parameters from the measured S-parameters.

Select the [Model...] command. Then select the desired measurement model by filling in the buttons or underlining the choices. Acknowledge your selection with [OK]. (Selecting [Cancel] does not change the measurement model selected.)

Refl/Tran u & e N-R

Model requirements:

- Measurement of S11, S21, S12, and S22
- Full 2-port calibration
- Approximate sample position

or

- Measurement of S11 and S21
- One path 2-port calibration
- Exact sample position

and

- One sample
- $\lambda_g/4$ wavelength sample thickness is optimum

This model measures all four, or a pair of, S-parameters of the material under test. Both μ and ϵ for the material are computed. The materials parameters are obtained by a direct solution calculation (for example μ and ϵ can be obtained directly from the S-parameter data). For low loss materials, sample thicknesses near $n\lambda_g/2$ cause discontinuities in the measurement results (as shown below).

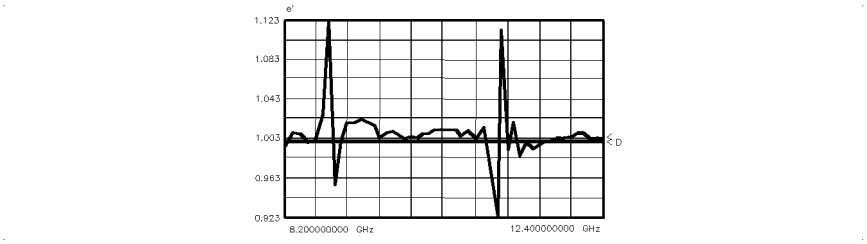


Figure 8-3.
Calculation Anomolies in the Refl/Tran u & e N-R Model

At the first frequency of measurement, the calculation routine must determine the number of 360 degree phase shifts through the sample to correctly solve for materials parameters. This is determined by the sample thickness and an initial estimate for μ and ϵ of the sample. Mu and ϵ of air are used to determine the number of phase rotations at the first frequency unless other materials parameters are entered using the [Verify estimate] command.

Refl/Tran e Prec'n

Model requirements:

- Measurement of S11, S21, S12, and S22
- Full 2-port calibration
- Approximate sample position
- One sample
- $n\lambda_g/2$ wavelength sample thickness is optimum

This model measures all four S-parameters of the material under test, but calculates only ϵ. The dielectric properties of the material parameters are obtained by a iterative calculation. This technique is an implementation of work published by the National Institute of Standards and Technology (NIST). The ϵ value at the first frequency is obtained by a direct calculation and is used to "seed" the iterative calculation. Since all four S-parameters are used in the calculation, this technique has a desirable feature of being independent of the entered position of the sample in the sample holder.

The distance to the sample is used only to obtain the estimate of ϵ at the first frequency and thus "seed" the calculation routine. This technique has no calculation anomolies at frequencies where the sample thickness is an integer multiple of one half-wavelength ($n\lambda_g/2$). This technique is very useful for long samples and for characterizing very low loss materials. If the (Verify estimate) command is turned on, then the software presents its estimate of ϵ at the first frequency. You can enter a new estimate of ϵ or acknowledge the estimate presented by the software.

Refl/Tran e Fast

Model requirements:

- Measurement of S11, S21, S12, and S22
- Full 2-port calibration
- Approximate sample position

or

- Measurement of S11 and S21
- One path 2-port calibration
- Exact sample position

and

- One sample
- $n\lambda_g/2$ wavelength sample thickness is optimum

This model measures all four or a pair of S-parameters of the material under test. Only ϵ for the material is computed.

The dielectric properties of the material parameters are obtained by a iterative calculation. The ϵ value at the first frequency is obtained by a direct calculation and is used to "seed" the iterative calculation.

This technique computes the uncertainty of the transmission and reflection measurement at each frequency. (Uncertainty is based on the systematic error terms of the network measurement system: directivity, source match, load match, and isolation.) The model then

uses the measurement less effected by systematic uncertainties to determine ϵ.

This calculation is faster than the "refl/tran e prec'n" technique. This technique has no calculation anomolies at frequencies where the sample thickness is an integer multiple of one half-wavelength ($\lambda_g/2$). This technique is very useful for long samples and for quick characterization of dielectric materials. If the (Verify estimate) command is turned on, then the software presents its estimate of ϵ at the first frequency. You can enter a new estimate of ϵ or acknowledge the estimate presented by the software.

Refl e Short-Back

Model requirements:

- Measurement of S11
- S11 1-port calibration
- Defined sample position
- One sample
- $\lambda_g/2$ wavelength sample thickness is optimum

This model measures the reflection coefficient, S11, of a sample in a transmission line backed by a short circuit. The sample can either be "butted" against a short circuit at the end of the transmission line, or bonded to a ground plane which serves as a short at the end of the transmission line. Only ϵ for the material is computed. The dielectric properties of the material parameters are obtained by a iterative calculation. This technique is an extension of several published approaches.

You must enter an ϵ value for the first frequency because the software is unable to directly calculate that initial value. The value you enter should be as accurate as possible to avoid measurement anomalies. If the subsequent results are unexpected, recalculate the measurement parameters by entering another value.

This technique is convenient for materials that must be bonded to a ground plane. It has also proven to be a convenient technique for measuring liquids with vertical cells (the metal "floor" at the bottom of the cell acts as a dam).

Refl e Arbit-Back

Model requirements:

- Measurement of S11
- S11 1-port calibration
- Defined sample position
- One sample
- $\lambda_g/2$ wavelength sample thickness is optimum

This model requires a sample that is backed by an arbitrary but repeatable termination. Two measurements are required: one with backing alone and the other with the sample and backing together. It is simple and best for thin film measurements. It is not applicable to magnetic materials.

Use the verify estimate feature to ensure that the correct seed value is selected.

Refl u & e Sing/Dbl

Model requirements:

- Measurement of S11
- S11 1-port calibration
- Defined sample position
- Two samples backed by a short
- Optimum sample thickness:
  - Selected for transmission loss of 5 dB or less (shorter sample, lossy materials)
  - About $\lambda_g/4$ and $\lambda_g/2$ wavelength (lower loss materials)

This is the only reflection-only model that measures permeability of magnetic materials. The model requires two measurements: two measurements of one sample in different positions backed by a short circuit or two samples backed by a short circuit each measured once. It is best for liquid or powder measurements. Use the verify estimate feature to ensure a correct seed value is selected.

Where possible, a transmission/reflection measurement gives much better results:

- T/R measurements are possible with thicker samples
- T/R measurements are not compromised by errors of relative length of the samples

Sample holder ...

This command presents a dialog box to define:

- Sample holder dimensions
- Sample thickness
- Units of measurement
- Cutoff frequency
- Air gap
- Sample holder type

Sample holder length (shown below) is the electrical length of the sample holder added *after* calibration. If you calibrate the system with the sample holder in place as recommended, the length is zero (0), you add nothing more after calibration. If you calibrate without the sample holder in place and then add it for measurements, determine its length with a physical measurement of the sample holder or from phase, group delay, or time domain measurements made on the empty sample holder with the network analyzer.

Distance to sample (shown below) is the distance from the calibration plane for port 1 to the sample interface. For a short-backed line measurement, this distance does not need to be specified and is not available for entry.

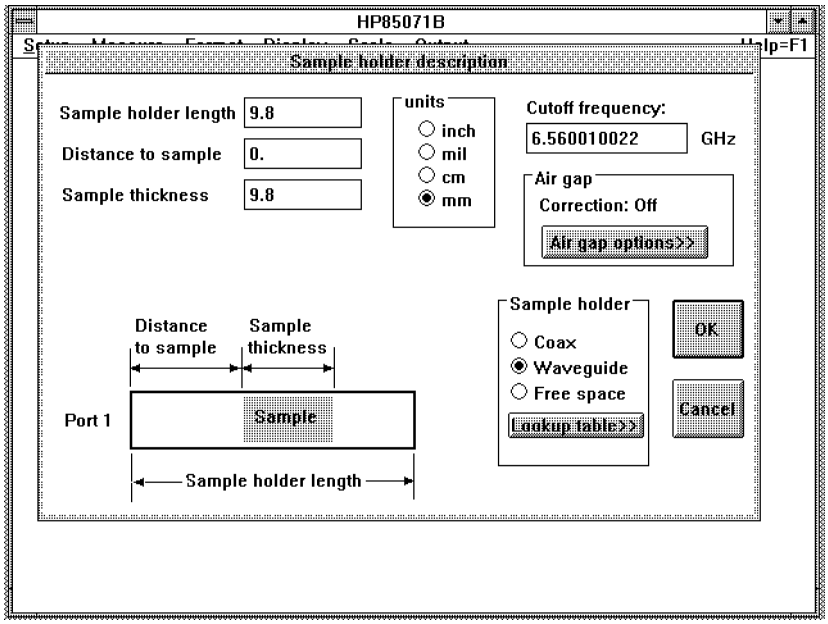


Figure 8-4. Sample Holder ... Screen (MS-DOS Version)

Sample thickness (shown above) is the physical thickness of the sample. This is typically obtained by a micrometer measurement.

Units is the measurement unit: inch, mil, cm, or mm. It applies to the sample holder length, distance, and thickness.

Cutoff frequency is 0 units for coaxial sample holders. (Units [Hz, kHz, MHz, and GHz] are selected in the set frequency menu.) For waveguide sample holders, the low cutoff frequency depends on the dimensions of the guide. You can enter the frequency manually or let the software enter it by selecting one of the waveguides in the lookup table. Common waveguide designations, operating and cutoff frequencies, and dimensions are tabled below.

Measurements are less practical at higher frequencies:

- Samples are smaller (and more difficult to handle and mount)
- Tolerances are tighter (air gaps cause larger errors)
- Samples must be thinner (for ϵ/μ measurements)

Common Waveguide Bands

EIA WR-	Band	Frequency Range (GHz)	Cutoff Frequency (GHz)	Width a (inch)
340	-	2.20-3.30	1.736	3.400
284	S	2.60-3.95	2.078	2.840
187	G	3.95-5.85	3.152	1.872
137	J	5.85-8.20	4.301	1.372
90	X	8.20-12.4	6.557	0.900
62	P	12.4-18.0	9.486	0.622
42	K	18.0-26.5	14.047	0.420
28	R	26.5-40.0	21.080	0.280
22	Q	33.0-50.0	26.340	0.224
19	U	40.0-60.0	31.360	0.188

Air gap allows definition of gaps between the sample and its coaxial or waveguide holder for increased measurement accuracy. Remember: the best gap is no gap; next best is a small, precisely measured gap. To use this feature, select "Correction on."

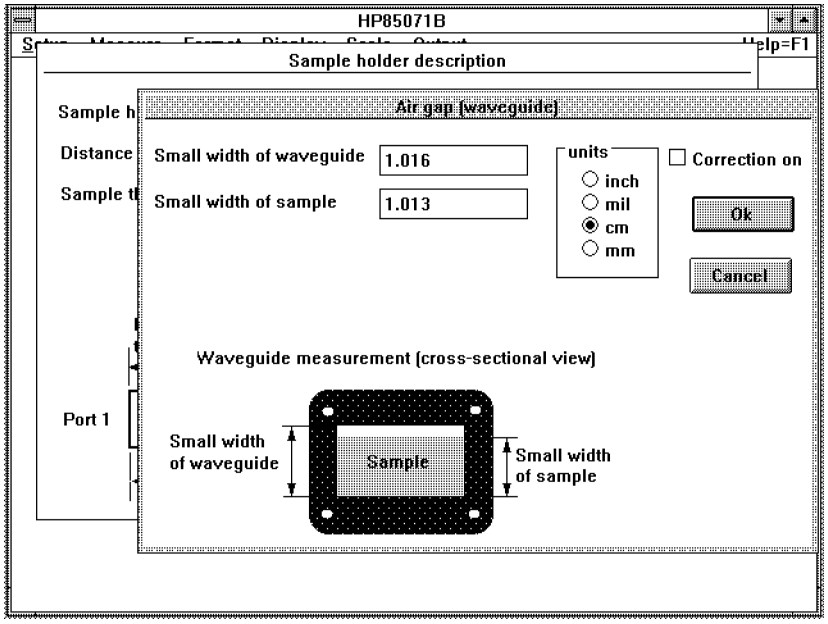


Figure 8-5. Air Gap Waveguide Dialog Box (MS-DOS Version)

Air Gap Calculations

The software calculates air gap corrections based on the following figure and equations.

X_c = corrected value of X
X_m = measured value of X

Coaxial Equations

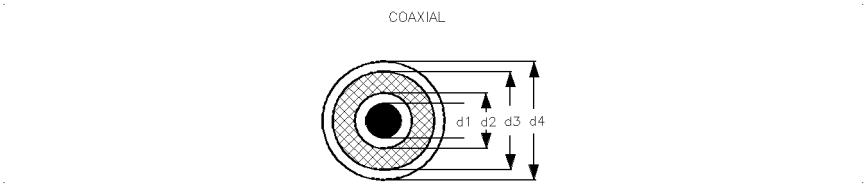


Figure 8-6. Coaxial Air Gap Correction Calculation Dimensions

Coaxial Dimension Equivalents

$$L_1 = ln\frac{d_2}{d_1} + ln\frac{d_4}{d_3}$$

$$L_2 = ln\frac{d_4}{d_1}$$

$$L_3 = ln\frac{d_3}{d_2}$$

Coaxial Permittivity Equations

$$\epsilon'_c = \epsilon'_m \frac{L_2}{L_3 - \epsilon'_m L_1}$$

$$\epsilon''_c = (\epsilon'_c * \frac{\epsilon''_m}{\epsilon'_m})\frac{L_3}{L_3 - L_1\epsilon'_m(1 + (\frac{\epsilon''_m}{\epsilon'_m})^2)}$$

Coaxial Permeability Equations

$$u'_c = \frac{u'_m(L_3 - L_1)}{L_2}$$

$$u''_c = u''_m\frac{L_3}{L_2}$$

Waveguide Equations

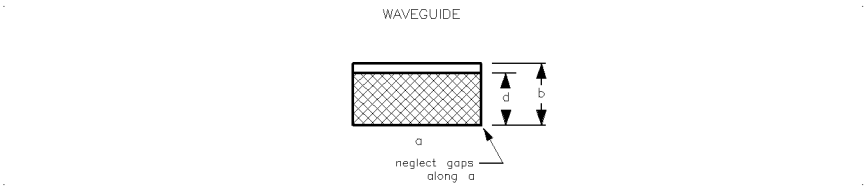


Figure 8-7. Waveguide Air Gap Correction Calculation Dimensions

Waveguide Dimension Equivalents

a = large width of waveguide, not relevant
b = small width of waveguide
d = small width of sample

Waveguide Permittivity Equations

$$\epsilon'_c = \epsilon'_m \frac{d}{b-(b-d)\epsilon'_m}$$

$$\epsilon''_c = \epsilon'_c \left(\frac{\epsilon''_m}{\epsilon'_m}\right) \frac{b}{b-(b-d)\epsilon'_m}$$

Waveguide Permeability Equations

$$\mu'_{cR} = \mu'_{mR}\left(\frac{b}{d}\right) - \left(\frac{b-d}{d}\right)$$

$$\mu''_{cR} = \mu''_{mR}\left(\frac{b}{d}\right)$$

Sample holder offers a choice of coax, waveguide, or freespace. It can also display a lookup table to select one of two types of coax or a dozen types of waveguide.

The Lookup table also allows setting these to nominal:

- Start/stop frequency
- Cutoff frequency
- Air gap parameters

Enter the distances and dimensions in the desired physical units. Acknowledge your entries with (OK). (Selecting (Cancel) does not change the current values.)

Verify estimate

This command presents the software's estimate of the calculated materials parameter at the first measurement frequency. The estimate is displayed in a dialog box after the measurement and before the calculations. For the "refl/tran u & e" model this can insure that the proper number of phase rotations through the sample at the first frequency is choosen. For the "refl/tran e prec'n" and "refl/tran e fast" models this can insure that the proper first estimate of ϵ is used in the iterative calculation.

For the "refl e" model the software may require an estimate of ϵ at the first frequency. For this model the default espilon is 1 + j 0. This value allows convergence for many but not all measurements. Unfortunately there is no direct calculation for this short-backed line technique to get a rough estimate of ϵ.

The software gives very good estimates of materials parameters to be used to seed the calculation routines and that verifying these estimates is unnecessary. However if unexpected results occur, use (Verify estimate) to see the calculation routine starting points and override them if desired.

Save setup ...

Selecting [Save setup...] allows you to specify a file and file location for saving away complete test setup information. The setup file must include a calibration. The HP 85071 setup file contains:

- S-parameter measurement data for the sample material in the sample holder. The S-parameters before they are "rotated" to the sample interface are stored so that other sample holder descriptions can be used to analyze the same measurement data at a later time.
- All valid 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 display scaling, trace math information, trace display information, title information, and pen color information.

The test setup file can be saved to any disk drive and directory in the computer. Press [OK] to save the test setup.

MS-DOS version:

- [Save setup...] presents a dialog box to name the test setup file
- Dialog box lists current disk drive and directory
- To change disk drive or directory, type in new information
- Filenames have a maximum of eight characters
- The default test setup file extension is `.TST`
- As an option, you can save additional file information: title, operator, time, date, and comments

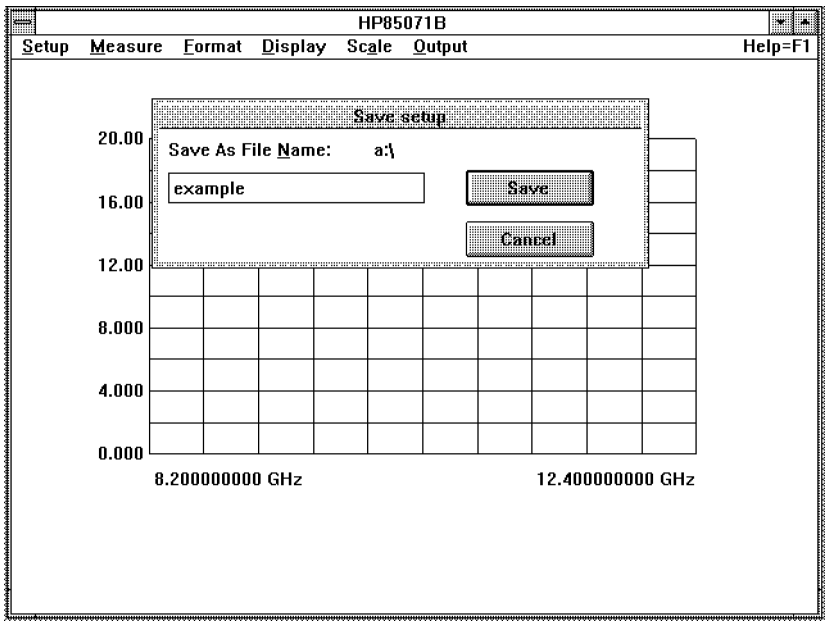


Figure 8-8. Save Setup ... Dialog Box (MS-DOS Version)

HP BASIC version:

- To change the disk drive, type in a new mass storage specifier (for example, `:,700,1`)
- To save a file, enter the file name at the prompt and press [RETURN] or [ENTER]

- Filenames have a maximum of ten characters
- Default file preface is `S_`
- The full directory structure of the HFS (Hierarchical File System) is supported

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.

MS-DOS version:

- Displays drive icons (i.e. [-A-], [-B-])
- Displays directory icons (directory names presented in bold)
- Single click on icon presents files on indicated drive or directory
- Allows choice of displaying file information: Title, Operator, Time, Date, Comments

HP BASIC version:

- To change the disk directory, type in a new mass storage specifier (for example ":,700,1" or "/HP85071/Data")

Short menus
Full menus

This command offers a choice of the short or full version of the softkey menu. The short menu has less choices. Interestingly, the alternate (*not current*) choice is displayed. Thus, when `Short Menus` is visible, you are looking at the full menus with the option to select the short menus.

Status bar

This command toggles on and off the status bar at the bottom of the computer screen. When on, the status bar shows the calculation model in use and whether air gap correction is on. It is shown below.

Measure Menu

The measure menu presents commands to trigger a measurement of the material and sample holder. (Then the software converts the S-parameter measurements of the sample holder/sample material to the permittivity and permeability of the unknown material and presents them in the current display format.) This menu also allows entry of display titles.

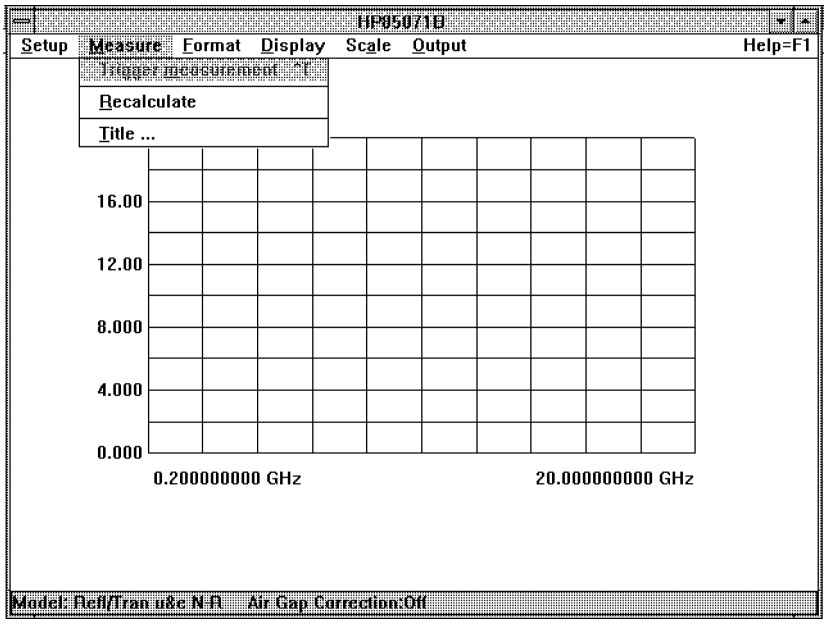


Figure 8-9. Measure Menu (MS-DOS Short Version)

Trigger measurement

Selecting (Trigger measurement) triggers a measurement of the sample holder/sample material. The measurement is triggered immediately after the command is selected, thus the sample should be loaded in the holder and the holder connected to the test cables. Once the measurement is complete, the program beeps.

Note

Pressing the right mouse button also triggers the measurement.

A message is displayed to indicate the current status of the calculation (for example, "Calculating permittivity, 50% complete"). When the calculation is complete, the material 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 S-parameter measurements of the sample holder/sample material before triggering a measurement.

If a valid calibration does not exist on the analyzer, the software indicates that a calibration is required and then return to the main menu. If the frequency range of the current calibration does not match the frequency range currently defined in the software, the program warns you before taking measurements. Once started, the measurement can always be aborted by selecting (Cancel).

Recalculate

Selecting (Recalculate) allows the software to recompute the materials parameters without remeasuring the material under test. This is useful for seeing the results one measurement while changing

- Measurement model
- Sample holder definition

It is also useful for examining the sensitivity of the calculation to different sample position entries.

Title ...

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

In the MS-DOS version you can also enter the date and time. It is displayed and printed to the right of the measurement graticule.

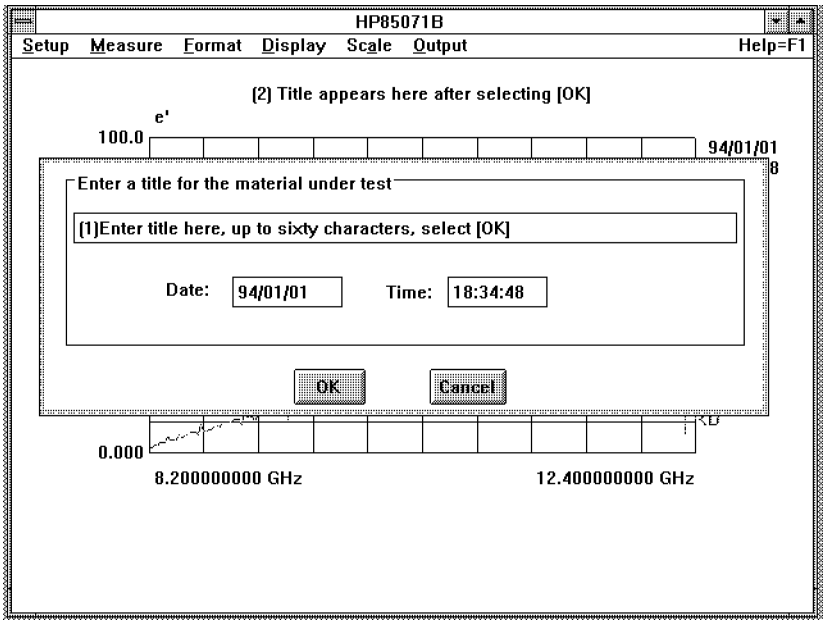


Figure 8-10. Title ... Menu (MS-DOS Version)

Forward measurement ONLY

This feature applies to two models:

- Refl/Tran u & e N-R
- Refl/Tran e Fast

When selected, this command limits measurements to forward measurements only: S_{11} and S_{21}. As a result,

- All four S-parameters need not be measured
- Reflection/transmission test sets are sufficient
- Position invariance of the sample is lost

This feature appears in the full menu mode only (see "Short menus, Full menus," part of the setup menu).

Retrieve measurement

Retrieve measurement is displayed in the full menu mode. It is a valid choice only when the sample holder and sample thickness have been defined. When selected, it displays one of three dialog boxes:

- Retrieving measurement . . .
- Measure/Retrieve (backing)
- Measure/Retrieve (sample)

Retrieving measurement . . .

This dialog box appears as the software recalculates the measurement with one of these models:

- Refl/Tran u & e N-R
- Refl/Tran e Prec'n
- Refl/Tran e Fast
- Refl e Short-Back

To stop the recalculation, select `Cancel`. Cancellation may not be immediate.

Measure/Retrieve (Backing)

The dialog box choices below appear with the "Refl e Arbit-Back" model.

Sample & backing measures the sample and its backing, may be repeated if the first measurement is invalid
Backing only measures only the backing, may be repeated if the first measurement is invalid
Calculate calculates e with the current measurement data, use after (1) sample and backing and (2) backing only have been measured
Cancel exits this box

Measure/Retrieve (Sample)

The dialog box choices below appear with the "Refl u & e Sing/Dbl" model.

Sample one measures (1) the sample in its first position or (2) the first of two samples, may be repeated if the first measurement is invalid
Sample two measures (1) the sample in its second position or (2) the second of two samples, may be repeated if the first measurement is invalid
Calculate calculates u & e with the current measurement data, use after both measurements have been taken
Cancel exits this box

Format Menu

The format menu presents commands to select the graphical or tabular display format for the measured data.

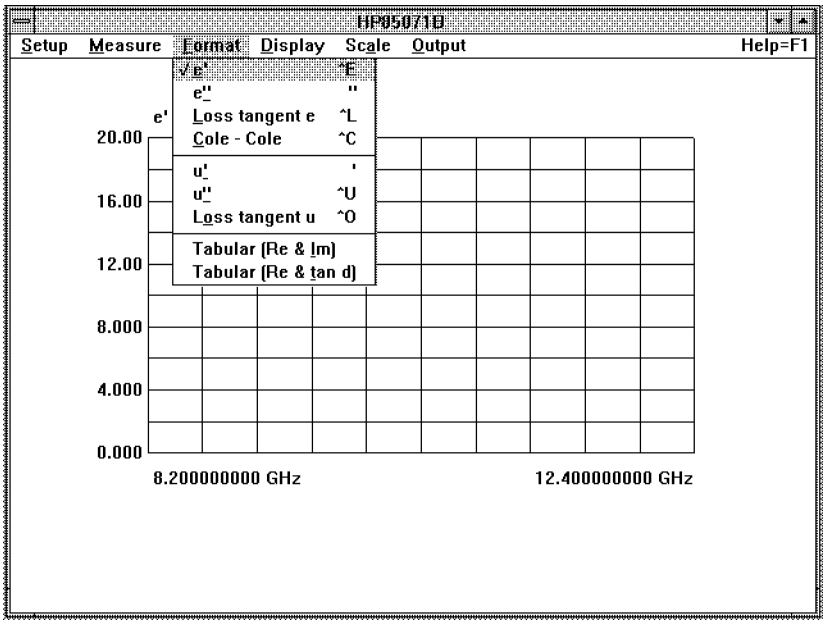


Figure 8-11. Format Menu (MS-DOS Version)

The complex permittivity, ϵ 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. However, $e'' < 0$ can be measured due to noise if e'' is near 0. This is not unusual.

It is often convenient to look at the ratio, e''/e'. This ratio is called the loss tangent.

The complex permeability, μ (or u^*) can be expressed as:

$u^* = u' - j\ u''$ where

$u' = \text{Re[Permittivity]}$

$u'' = -\text{Im[Permittivity]}$

For measurement models that are dielectric only (Refl/Tran e Prec'n, Refl/Tran e Fast, Refl e Short-Back, and Refl e Arbit-Back), the software assigns $u = 1 + j\ 0$ at each measurement frequency. Selecting a μ display format simply presents the $1 + j\ 0$ values.

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

e/ Select (e/) to display the real part of permittivity versus frequency. The real part of permittivity, e/, is often referred to as the dielectric constant.

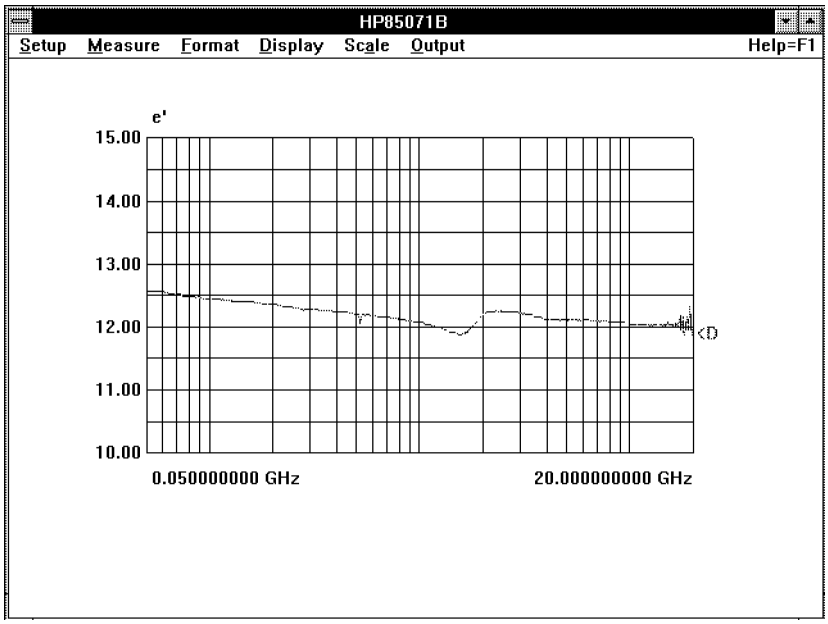


Figure 8-12. Polyiron Measurement in e/ Format

e// Select (e//) to display the imaginary part of permittivity versus frequency. In the figure below, the measurement anomoly that occurs around 2 GHz is non-physical. There is a corresponding artifically high loss in $\mu//$ at the same frequency.

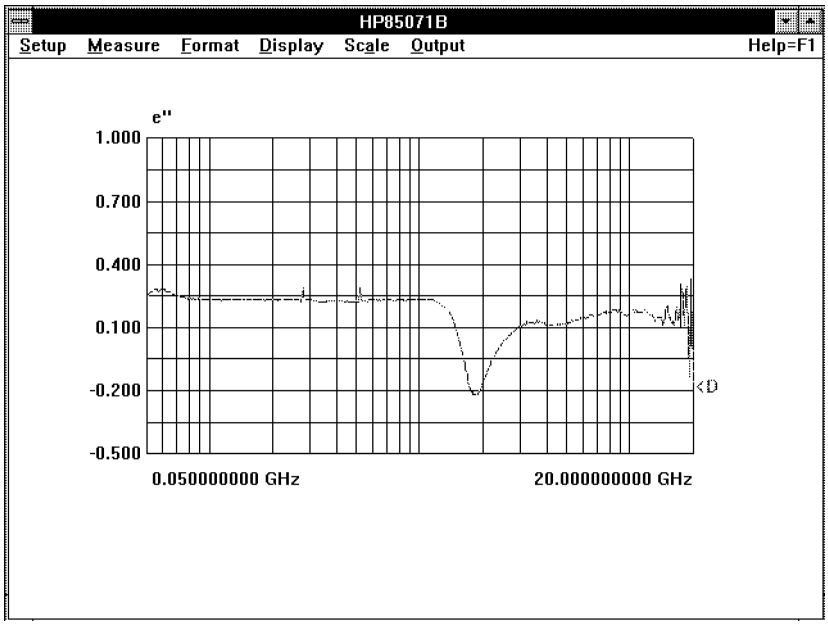


Figure 8-13. Polyiron Measurement in e// Format

Loss tangent e Select [Loss tangent e] to display e″/e′ versus frequency.

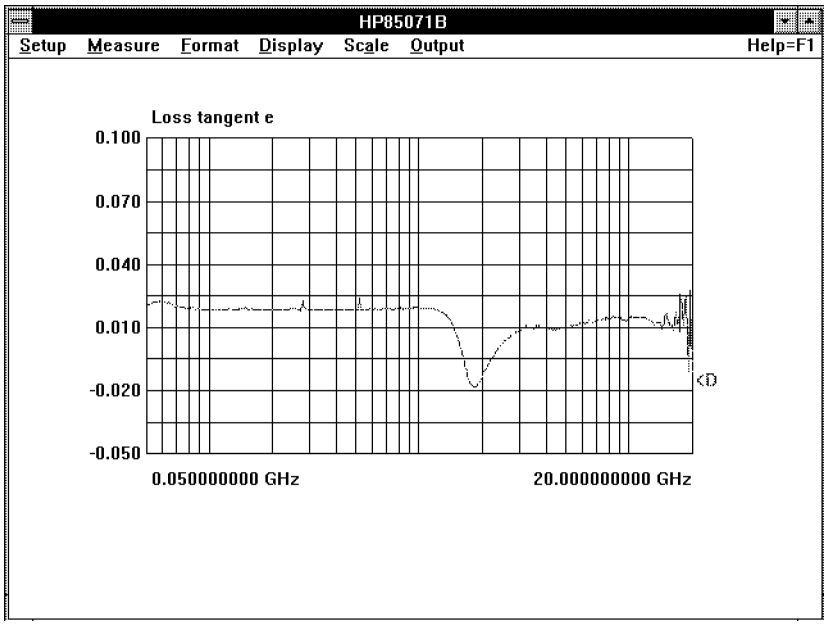


Figure 8-14. Polyiron Measurement in Loss Tangent e Format

Cole-Cole Select [Cole-Cole] to display the data formated with e″ on the vertical axis and e′ on the horizontal axis. In this format, frequency is an independent parameter and not displayed. This measurement is most useful for materials, such as water, with polar responses.

u/ Select (u/) to display the real part of permeability versus frequency.

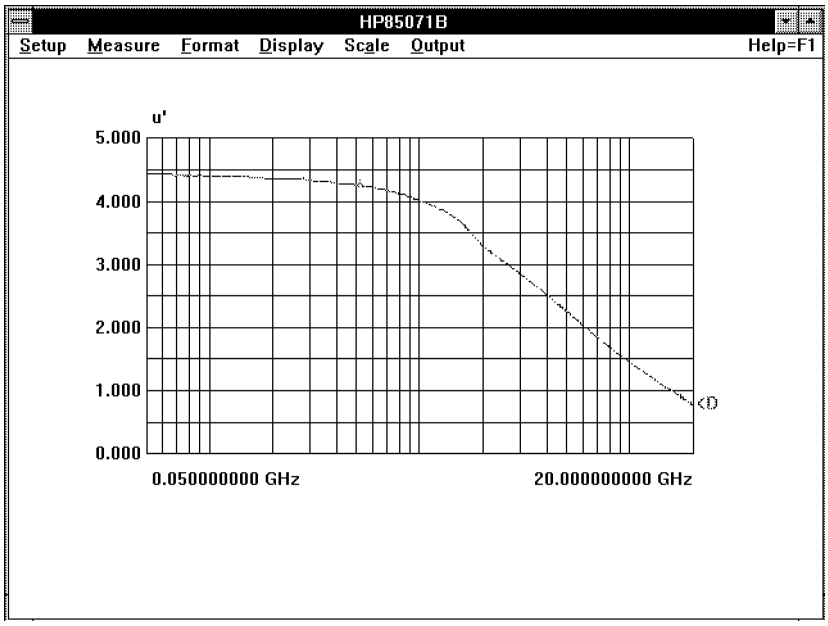


Figure 8-15. Polyiron Measurement in u/ Format

u// Select (u//) to display the imaginary part of permeability versus frequency.

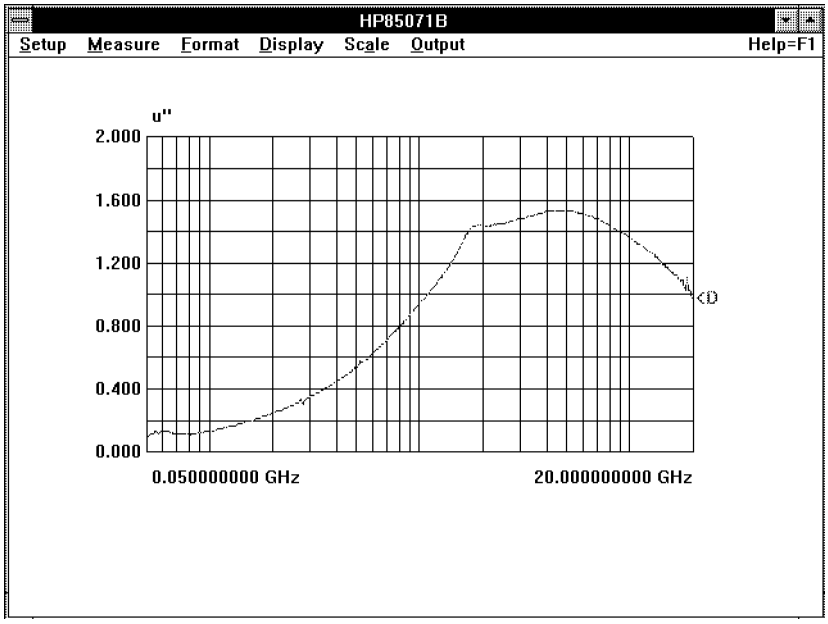


Figure 8-16. Polyiron Measurement in u// Format

Loss tangent u Select [Loss tangent u] to display u//u/ versus frequency.

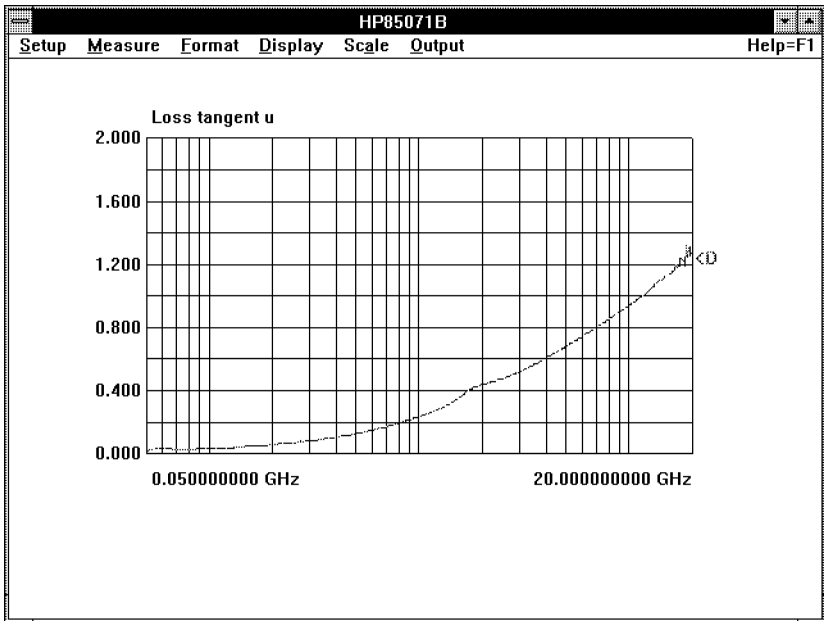


Figure 8-17. Polyiron Measurement in Loss Tangent u Format

Tabular (Re & Im) Select [Tabular (Re & Im)] to display a listing of the calculated materials parameters at each measurement frequency. If the measurement model gives magnetic and dielectric parameters, then the real and imaginary parts of both μ and ϵ are listed.

HP85071B

Setup Measure Format Display Scale Output Help=F1

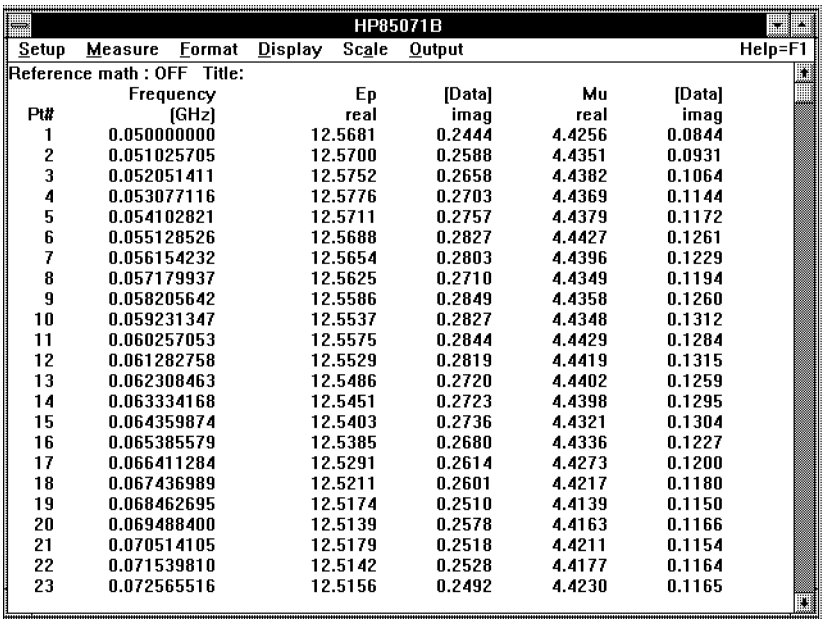
Reference math : OFF Title:

Pt#	Frequency [GHz]	Ep real	[Data] tan d	Mu real	[Data] tan d
1	0.050000000	12.5681	0.01945	4.4256	0.01908
2	0.051025705	12.5700	0.02058	4.4351	0.02098
3	0.052051411	12.5752	0.02114	4.4382	0.02397
4	0.053077116	12.5776	0.02149	4.4369	0.02579
5	0.054102821	12.5711	0.02193	4.4379	0.02641
6	0.055128526	12.5688	0.02250	4.4427	0.02838
7	0.056154232	12.5654	0.02231	4.4396	0.02768
8	0.057179937	12.5625	0.02157	4.4349	0.02693
9	0.058205642	12.5586	0.02268	4.4358	0.02841
10	0.059231347	12.5537	0.02252	4.4348	0.02958
11	0.060257053	12.5575	0.02265	4.4429	0.02890
12	0.061282758	12.5529	0.02245	4.4419	0.02962
13	0.062308463	12.5486	0.02167	4.4402	0.02835
14	0.063334168	12.5451	0.02171	4.4398	0.02916
15	0.064359874	12.5403	0.02182	4.4321	0.02942
16	0.065385579	12.5385	0.02138	4.4336	0.02767
17	0.066411284	12.5291	0.02086	4.4273	0.02711
18	0.067436989	12.5211	0.02077	4.4217	0.02669
19	0.068462695	12.5174	0.02005	4.4139	0.02607
20	0.069488400	12.5139	0.02060	4.4163	0.02641
21	0.070514105	12.5179	0.02012	4.4211	0.02611
22	0.071539810	12.5142	0.02020	4.4177	0.02634
23	0.072565516	12.5156	0.01991	4.4230	0.02634

Figure 8-18. Polyiron Measurement in Tabular (Re & Im) Format

Tabular (Re & Tan d)

Select (Tabular (Re & tan d)) to display a listing of the dielectric constant and loss tangent at each measurement frequency. If the measurement model gives magnetic and dielectric parameters, then the real part and loss tangent of both μ and ϵ are listed.



Pt#	Frequency [GHz]	Ep real	Ep [Data] imag	Mu real	Mu [Data] imag
1	0.050000000	12.5681	0.2444	4.4256	0.0844
2	0.051025705	12.5700	0.2588	4.4351	0.0931
3	0.052051411	12.5752	0.2658	4.4382	0.1064
4	0.053077116	12.5776	0.2703	4.4369	0.1144
5	0.054102821	12.5711	0.2757	4.4379	0.1172
6	0.055128526	12.5688	0.2827	4.4427	0.1261
7	0.056154232	12.5654	0.2803	4.4396	0.1229
8	0.057179937	12.5625	0.2710	4.4349	0.1194
9	0.058205642	12.5586	0.2849	4.4358	0.1260
10	0.059231347	12.5537	0.2827	4.4348	0.1312
11	0.060257053	12.5575	0.2844	4.4429	0.1284
12	0.061282758	12.5529	0.2819	4.4419	0.1315
13	0.062308463	12.5486	0.2720	4.4402	0.1259
14	0.063334168	12.5451	0.2723	4.4398	0.1295
15	0.064359874	12.5403	0.2736	4.4321	0.1304
16	0.065385579	12.5385	0.2680	4.4336	0.1227
17	0.066411284	12.5291	0.2614	4.4273	0.1200
18	0.067436989	12.5211	0.2601	4.4217	0.1180
19	0.068462695	12.5174	0.2510	4.4139	0.1150
20	0.069488400	12.5139	0.2578	4.4163	0.1166
21	0.070514105	12.5179	0.2518	4.4211	0.1154
22	0.071539810	12.5142	0.2528	4.4177	0.1164
23	0.072565516	12.5156	0.2492	4.4230	0.1165

Figure 8-19.
Polyiron Measurement in Tabular (Re & Tan d) Format

Display Menu

There are four traces for presenting permittivity or permeability data with the HP 85071 software. The traces are called Data, Memory 1, Memory 2, and Memory 3. Each time a measurement is taken, the calculated materials measurement is placed in the Data trace. The active data trace can be saved into any of the other 3 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 help 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:

/ref: each trace divided by the reference trace. This format is useful for the ratio comparison of measurements. Two like traces yield a ratio near 1.

-ref: the reference trace subtracted from each trace. This format shows the difference between measurements. Two like traces yield a difference near 0.

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

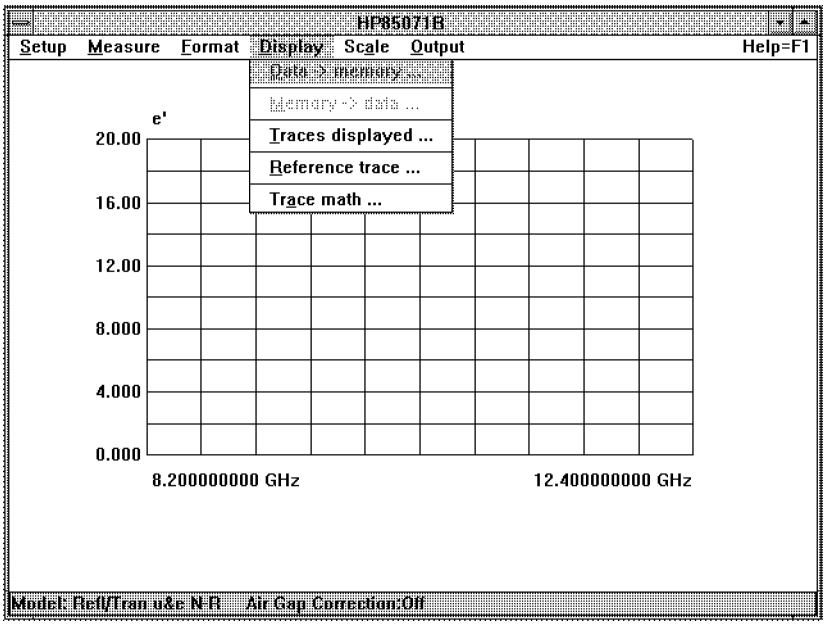


Figure 8-20. Display Menu (MS-DOS Version)

Data-> memory ...

Selecting (Data-> memory...) presents a dialog box to select a memory trace in which to save the current measurement data. The choices are Data -> memory 1, Data -> memory 2, and Data -> memory 3. This operation is a valid choice only when there is current measurement data. All measurement data can be saved into and recalled from any of the memory traces. Selecting any of the data-> memory commands also selects the choosen memory trace for display.

Data can be saved in one format and recalled in any other format. Keep in mind though, that only the "Refl/Tran u & e N-R" and "Refl u & e Sing/Dbl" measurement models actually measure u (μ). The other models assign u = 1 + j0 at each measurement frequency. Initially measuring a material with an e (ϵ) only format, saving the data, and then displaying it in a u format presents the 1 + j0 values (a straight line).

MS-DOS version:

- Fill in the button to indicate selection
- Click on OK to make selection

HP BASIC version:

- Underline the choice
- Acknowledge your selection with (OK). (Selecting (Cancel) does not save the measurement data trace to any of the memory traces.)

Memory-> data ... Selecting [Memory-> data...] presents a dialog box to select the memory trace to save into the active data trace. Choices for Memory 1-> data, Memory 2-> data, and Memory 3-> data are presented. This operation is a valid choice only when data is in memory. **MS-DOS version:**

- Fill in the button to indicate selection
- Click on OK to make selection

HP BASIC version:

- Underline the choice
- Acknowledge your selection with [OK]. (Selecting [Cancel] does not perform any memory-> data operation.)

Traces displayed ... Selecting [Traces displayed...] presents a dialog box to select the trace to be displayed. Choices for Data, Memory 1, Memory 2, and Memory 3 are presented. To select the desired traces for display, fill in the buttons or underline the choices. Then acknowledge your selection with [OK]. (Selecting [Cancel] does not change the traces displayed.)

Reference trace ... Selecting [Reference trace...] presents a dialog box to choose which trace is defined as the reference trace for trace mathematics. Choices for Data, Memory 1, Memory 2, and Memory 3 are presented. Select the desired trace to define as the reference trace by filling in the buttons or underlining the choices. Then acknowledge your selection with [OK]. (Selecting [Cancel] does not change which trace is defined as the reference trace.)

Trace math ... Selecting [Trace math...] presents a dialog box to select the type of trace math to be performed. Choices for Math off, /ref, and -ref are presented. Select the desired math operation with the button or the underline. Acknowledge your selection with [OK]. (Selecting [Cancel] does not change the current math operation.) 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 are either divided by or subtracted from each other.

If trace math is requested and no reference trace exists, the software displays the data trace divided by or subtracted from itself (a straight line in graphic form).

Scale Menu

The scale menu presents commands to select the maximum and minimum values for graphical display formats. The scaling for each graphical display format (e′, e″, loss tangent e, Cole-Cole) is retained with that format. Thus, when the graphical format is changed, the scale will return to the same settings as the last time that format was selected. All graphical formats have a Y-axis maximum and minimum value which can be changed in the scale menu.

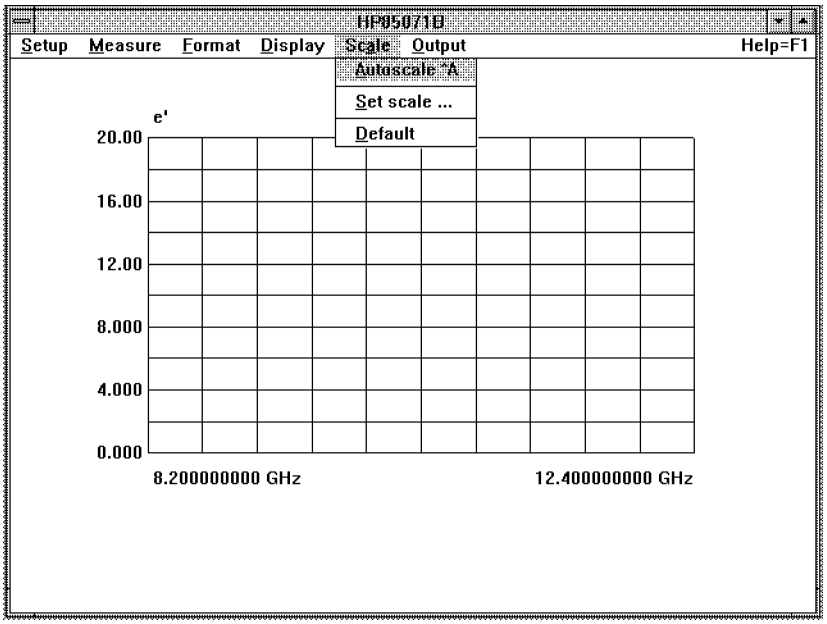


Figure 8-21. Scale Menu (MS-DOS Version)

Autoscale

Select [Autoscale] to bring the permittivity data in view with one command. The software selects Y-maximum and Y-minimum 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 [Set scale...] to bring up a dialog box to enter new Y-maximum and Y-minimum values for scaling the graph.

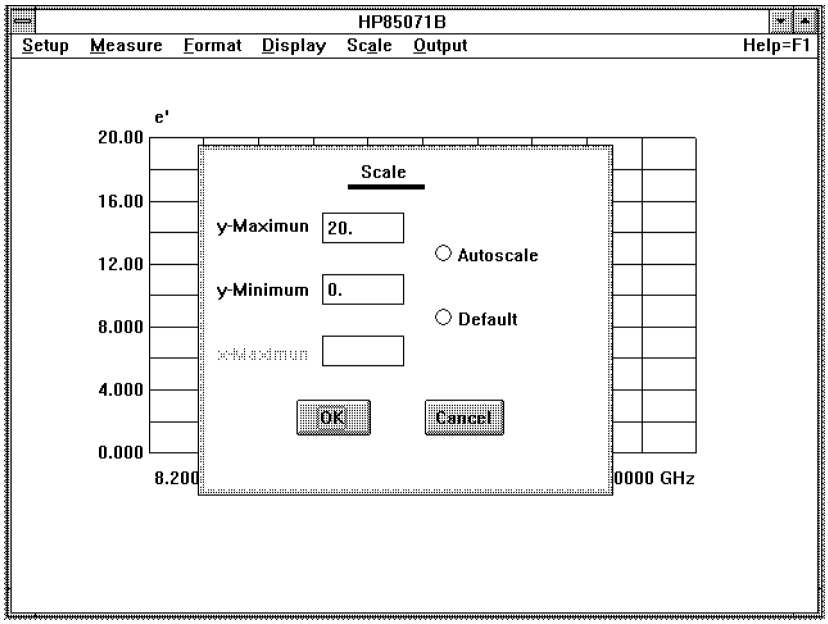


Figure 8-22. Set Scale ... Screen (MS-DOS Version)

Use the text boxes to enter new scaling parameters. Select (OK) 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. Select (OK) to keep these values or change them as appropriate.

Default

Select (Default) 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. For details on analyzing data files with other programs, refer to "Accessing Data Files" in chapter 4.

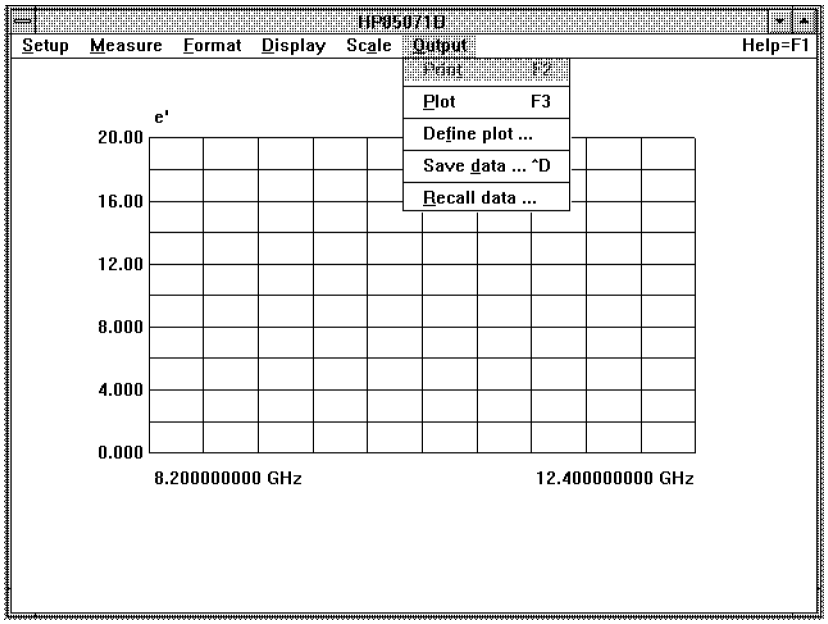


Figure 8-23. Output Menu (MS-DOS Version)

In the MS-DOS version of the program, the peripherals are selected when installing the Microsoft Windows system. See the Windows documentation for installing the Windows system and using the Windows Control Panel for adding or configuring peripherals with the Windows system. These are the commands in the output menu:

Print Selecting this command produces a hardcopy printout of the materials data in the current tabular display format. Print is presented as a choice only when the current display format is tabular.

Plot Selecting (Plot) produces a hardcopy plot of the materials data in the current display format. The hardcopy display is the same as the current HP 85071 program display. Plot is presented as a choice only when the current display format is graphical. Hardcopy plots can be directed to printers which support graphics printing modes.

Define plot ... Selecting (Define plot...) allows the settings of the hardcopy plotter to be altered or customized. In the MS-DOS version of the program, selecting define plot ... brings up the dialog box shown below.

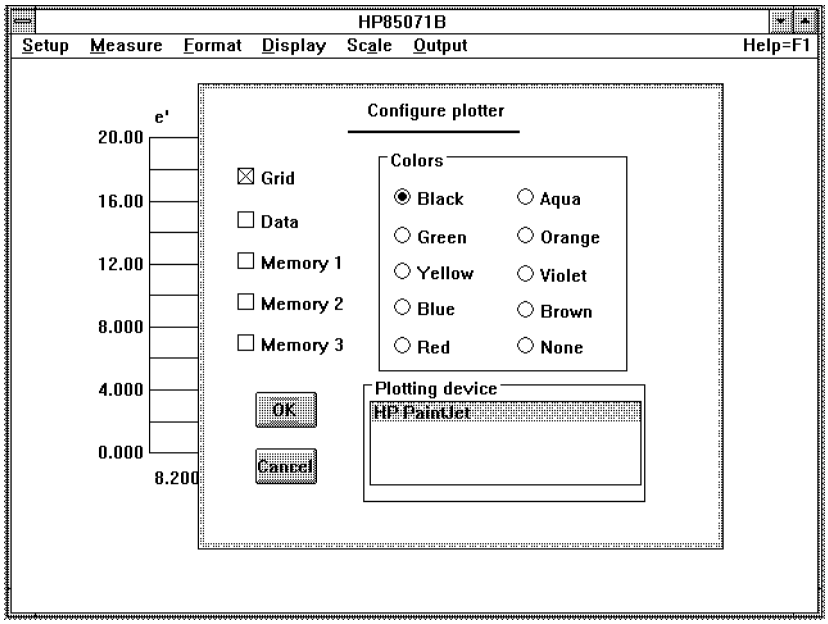


Figure 8-24. Define plot . . . Dialog Box (MS-DOS Version)

Save data . . .

Selecting [Save data...] presents a dialog box to specify the file to save measurement data for future analysis. For details on transferring data files into other application programs, see chapter 4, "Advanced Measurement Techniques."

- The data file includes:
  - The current measurement data trace (both μ and ϵ)
  - The number of frequencies for the current data trace measurement

MS-DOS version:

- File names have a maximum of eight characters
- Default file extension is .PRN (recognized by Lotus 1-2-3, others are possible)
- Save data dialog box lists current disk drive and directory
- Allows choice of saving file information: Title, Operator, Time, Date, Comments
- Data files can be saved to any disk drive and directory in the computer
- Data files are in ASCII, compatible with Lotus 1-2-3, Microsoft Excel, and most word processing programs
- To save data:
  1. Use the filename list box to select the name for the data file (include drive and directory information to save to another location)
  2. Press [OK] to save the data file

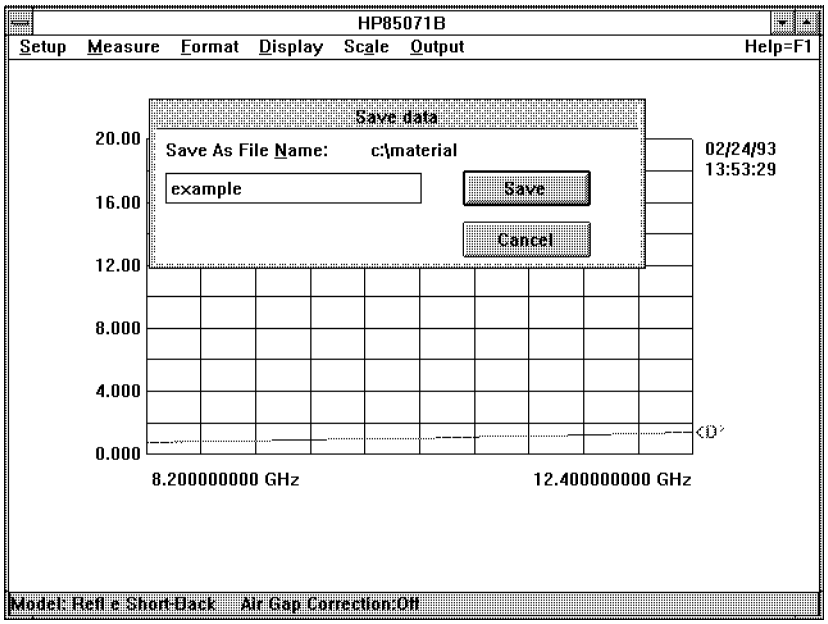


Figure 8-25. Save Data ... Dialog Box (MS-DOS Version)

HP BASIC version:

- File names have a maximum of ten characters
- Default data file preface is `D_` (for example, "D_51ptlog")
- Screen lists all of the datafiles saved on the current drive and directory
- Other file names are permissible.
- Data files are stored in an internal binary format
- Data files can easily be read by other HP Series 200/300 programs
- Full directory structure of the HFS (hierarchical file system) is supported
- To save data:
  1. Type in the file name at the prompt.
  2. To change drive or directory, type in new volume, directory, and mass storage unit specifier information at the display prompt.
  3. Press ENTER or RETURN.

Recall data ...

Recall data... recalls data files from disk.

MS-DOS version:

- File dialog box presents drive icons ([-A-], [-B-], etc.) and directory icons (directory names presented in bold)
- Single click on icons to list their files
- Single click on filename to recall data file from disk

HP BASIC version:

- Type in new mass storage specifier (for example, `:,700,1"`, `"/HP85071/Data`) to change the disk drive used with the program

Help Menu

The help menu is an on-line, indexed description of the different commands in the software.

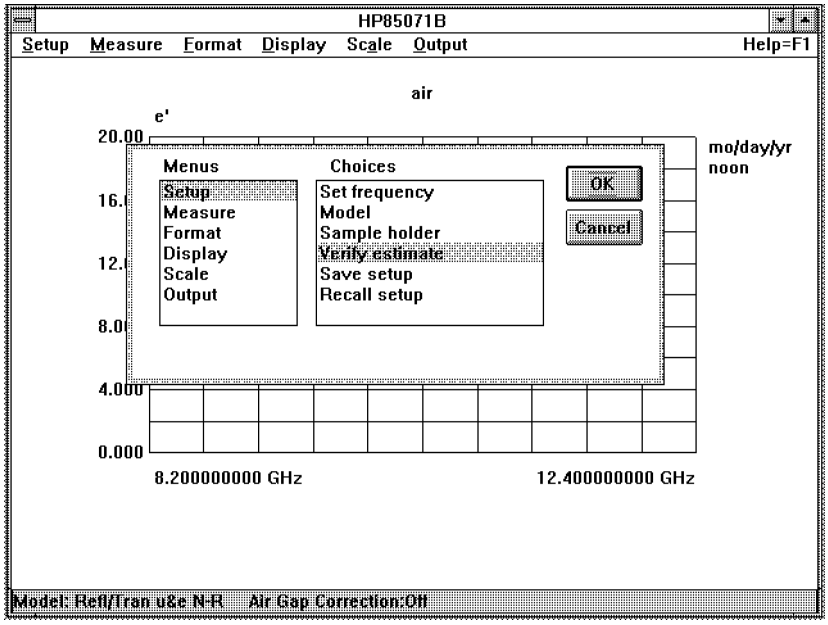


Figure 8-26. Help Menu (MS-DOS Version)

MS-DOS version:

- Selecting help in the main menu brings up two list boxes with scroll bars
- List box on left shows the menus in the software (setup, display, measure, etc.)
  - Double click on menu to see its help message
  - Single click on menu to list its constituent commands in the choice list box on the right
- Double click on command to see its help message
- Single click `Cancel` to exit help menu

HP BASIC version:

- Selecting (Help) in the main menu displays list of menus and commands
- Select the menu that help is required for. The software lists and summarizes each command
- Select `Morehelp` to return to the beginning of the help screen with choices for each menu displayed
- Select `Leave help` to leave the help screen
- Select `Exit` to return to the main menu and restore the instrument display

Conclusion

In terms of learning how the software works, reading this chapter is a poor substitute for actually using the software. Nonetheless, if you need additional information, you should not overlook two other information sources: the index and the glossary.

Glossary

The following entries are defined in terms of material measurements with the HP 85071 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")

Baker-Jarvis method
a 2-port S-parameter transmission line method, using new algorithms that promise to eliminate the "multiple half wavelength" drop-outs of the Nicolson-Ross method; does not yield μ^*

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

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

dipolar
dielectric mechanism; see "rotational"

dipole
a 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

ϵ
symbol for absolute permittivity; ϵ_r is used more often

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

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

induced dipoles
temporary dipoles, created by electric fields

ionic
a 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
see κ'' or ϵ_r''

loss index
κ'' or ϵ_r''

loss tangent
see tan δ

MUT
Material Under Test

Nicolson-Ross method
S-parameter method using 2-port transmission lines (see Product Note 8510-3)

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

RAM
Radiation-Absorbing-Materials, Radar-Absorbing-Materials

relative permeability
μ_r, see μ

relative permittivity
see ϵ_r

relaxation constant
see τ

relaxation time
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

Roberts/von-Hipple
1-port short-backed reflection-only transmission line method to determine both ϵ and μ by moving the short by $\lambda/4$

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 ϵ''/ϵ'; 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; $\theta = 90° - \delta$

μ
symbol for permeability; use μ_r if relative to free space; if complex, $\mu^* = \mu' - j\mu''$ (imaginary part represents loss)

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