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.

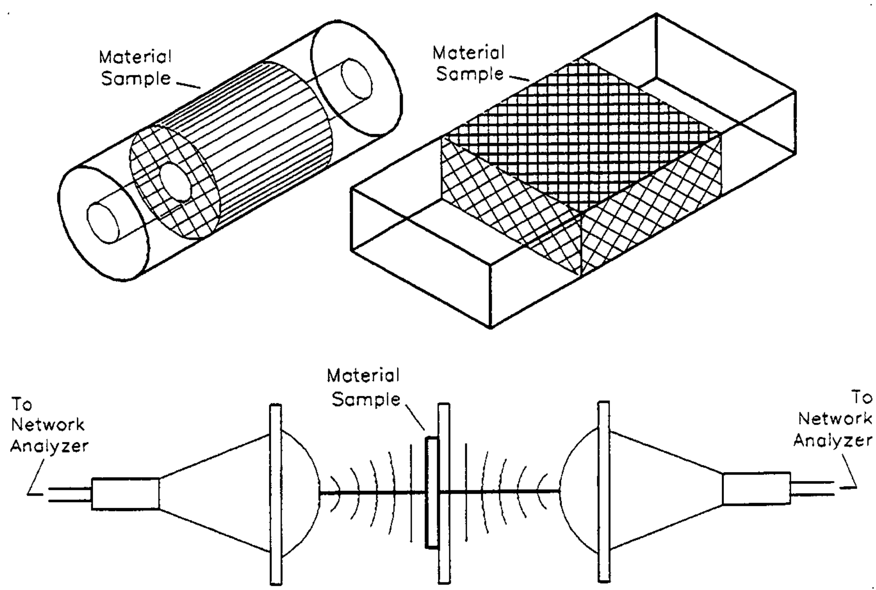

Figure 3-1.
Samples in Coaxial and Waveguide Transmission Lines and Free Space

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).

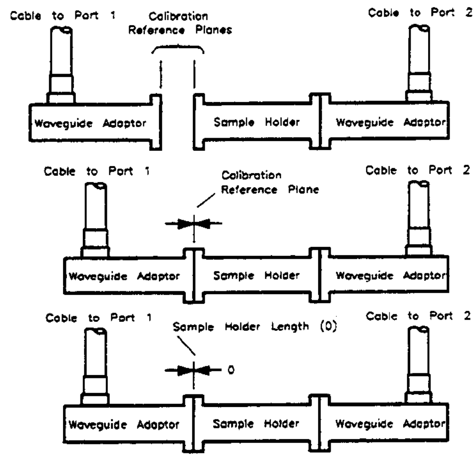

Figure 3-2. Samples in Waveguide, Coaxial and Free Space

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).

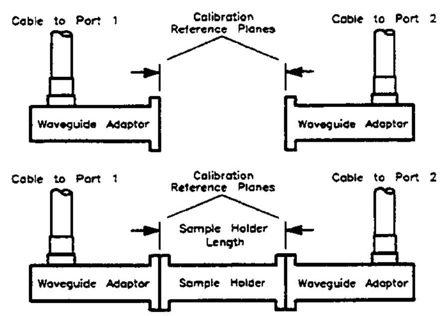

Figure 3-3. Sample Holder Reference Planes

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."

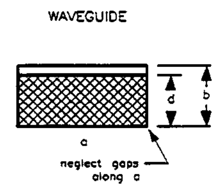

Figure 3-4. Air Gap Correction Figure

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

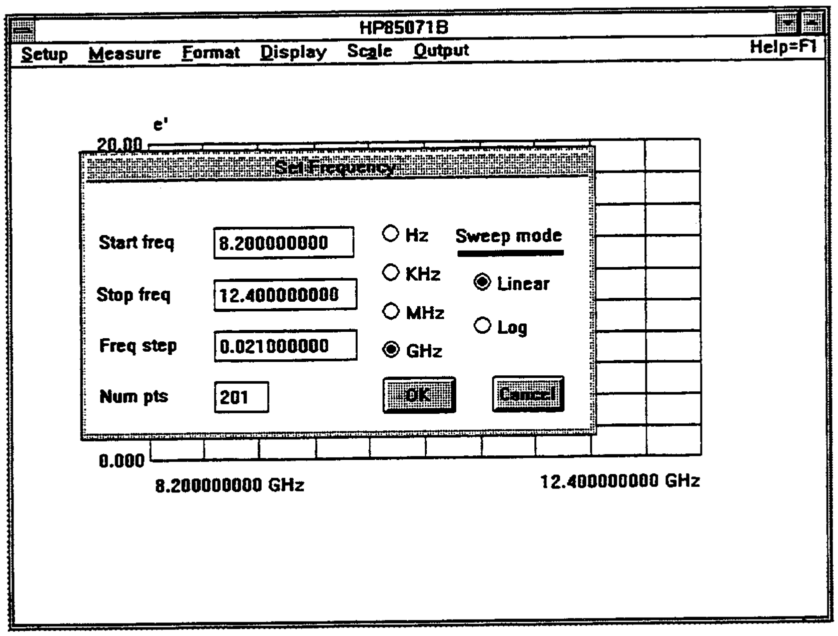

Figure 3-5. Set Frequency ... Dialog Box (MS-DOS Version)

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.

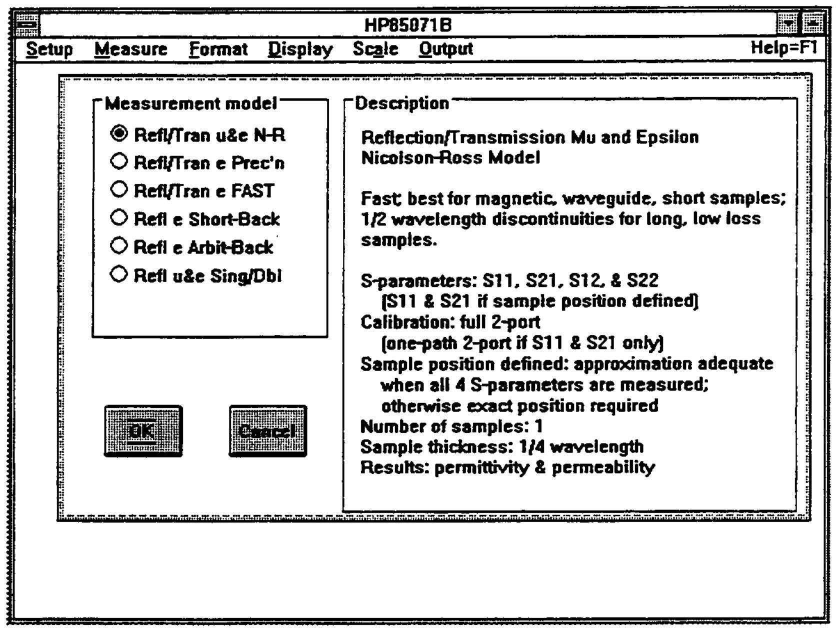

Figure 3-6. Model ... Dialog Box (MS-DOS Version)

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

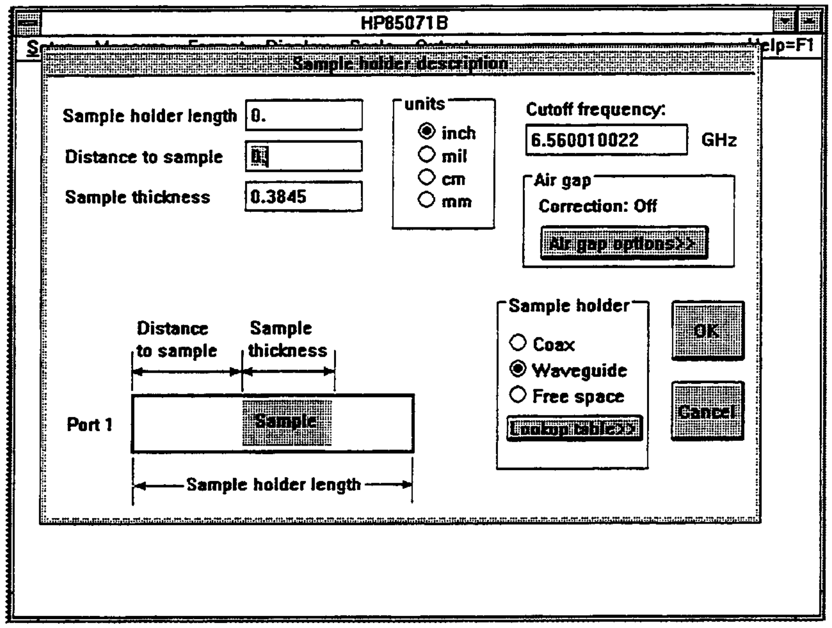

Figure 3-7.
Sample Holder Description Dialog Box (MS-DOS Version)

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.

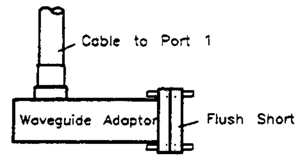

Figure 3-8. Measuring the Flush Short

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)

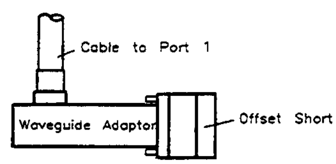

Figure 3-9. Measuring the 1/4 Wavelength Offset Short

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)

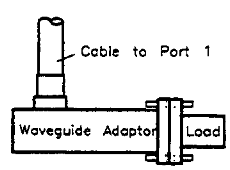

Figure 3-10. Measuring the Fixed Load

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

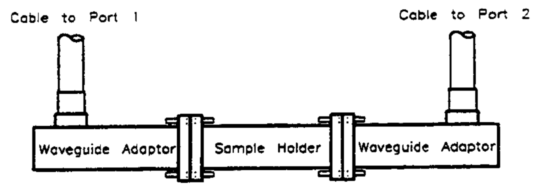

Figure 3-11. Measuring the Thru

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.

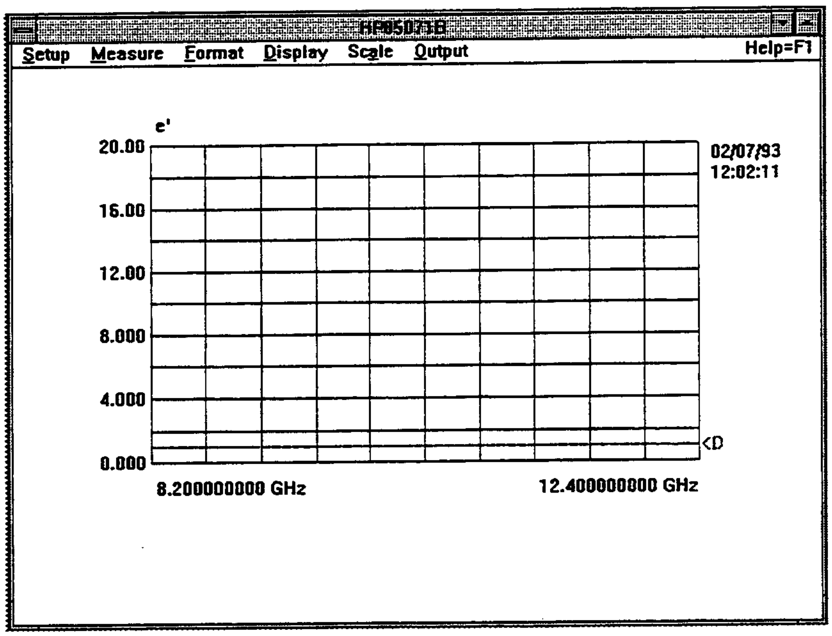

Figure 3-12. Default Display of Air Measurement

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.

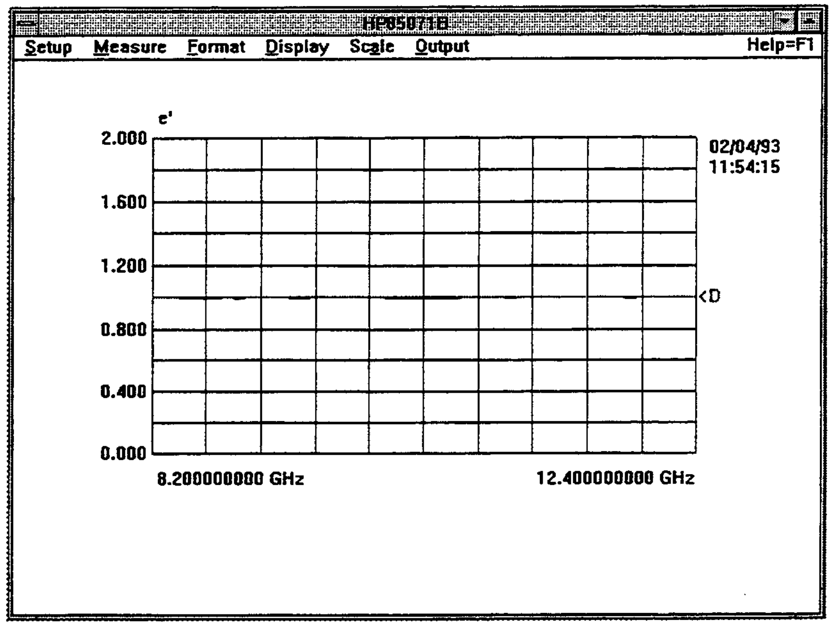

Figure 3-13. Display of Air Measurement with Y-Maximum = 2

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 ϵ' (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).

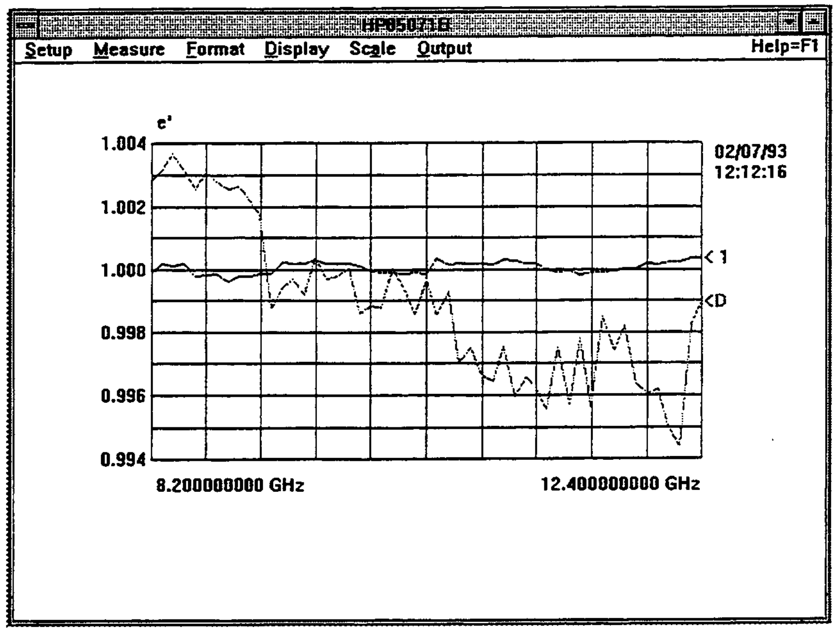

Figure 3-15.
Simultaneous Display of Two Traces Showing Effect of Cable Movement

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.

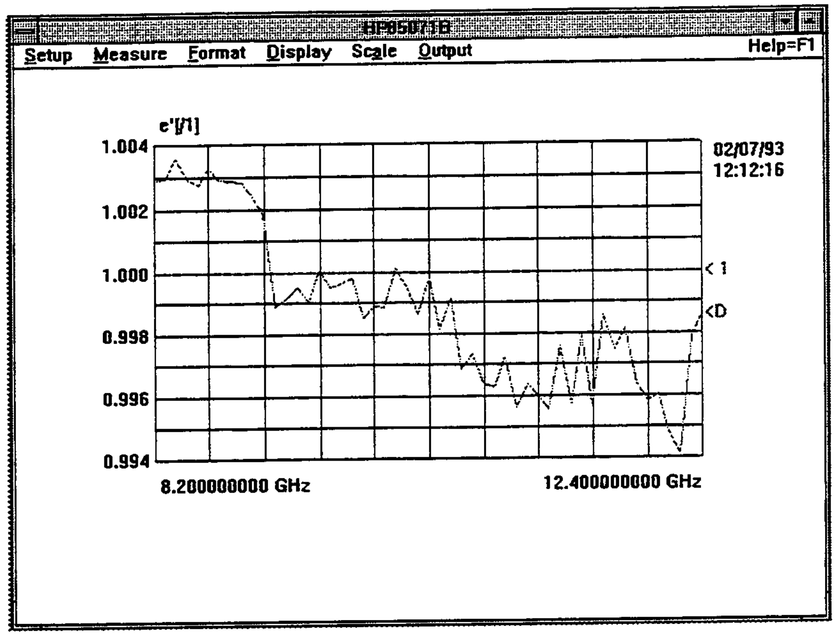

Figure 3-16. Traces Compared With Trace Math

- 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.

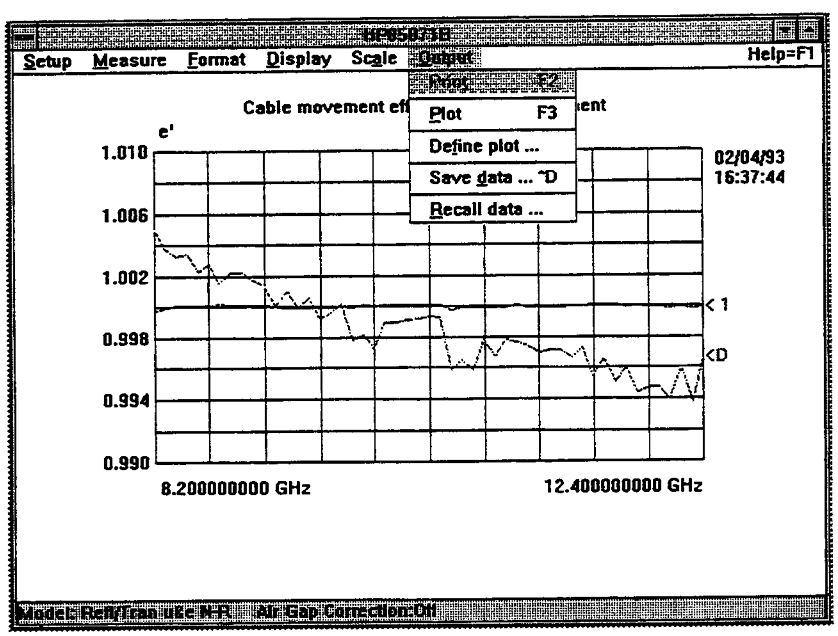

Figure 3-17. Output Menu (MS-DOS Version)

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.