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

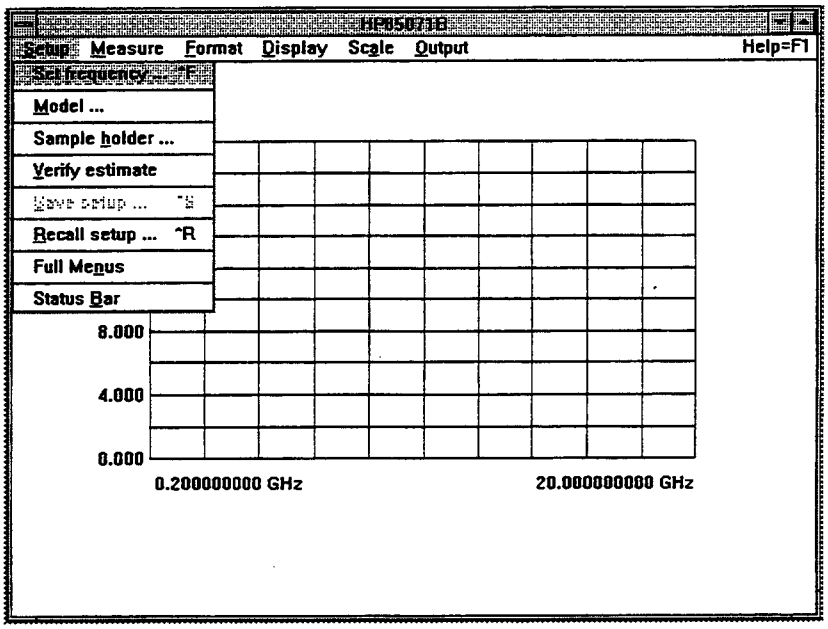


Figure 8-1. Setup Menu (MS-DOS Version)

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

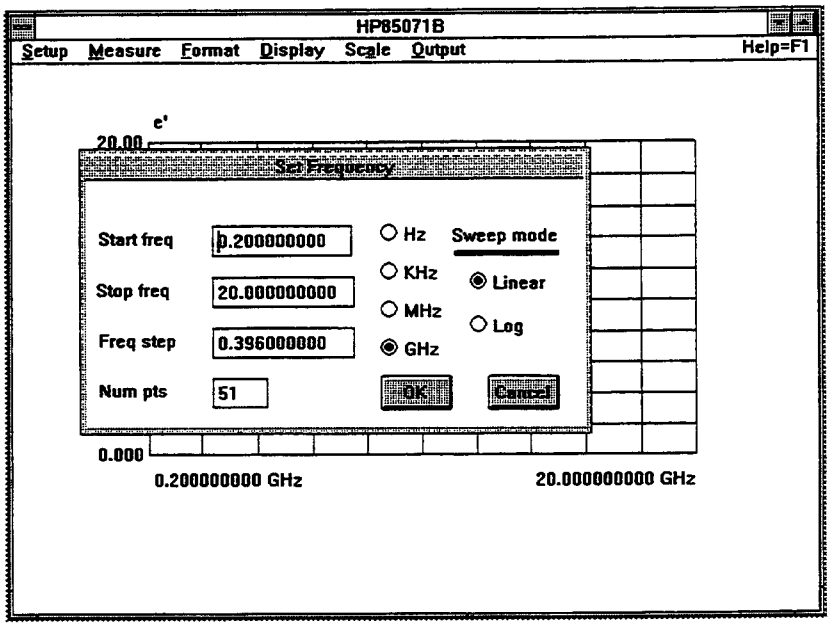


Figure 8-2. Set Frequency ... Dialog Box (MS-DOS Version)

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).

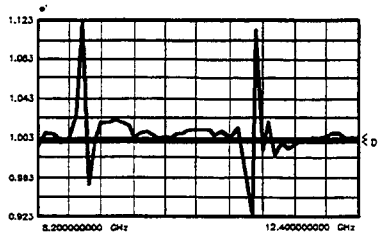


Figure 8-3.
Calculation Anomolies in the Refl/Tran u & e N-R Model

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.

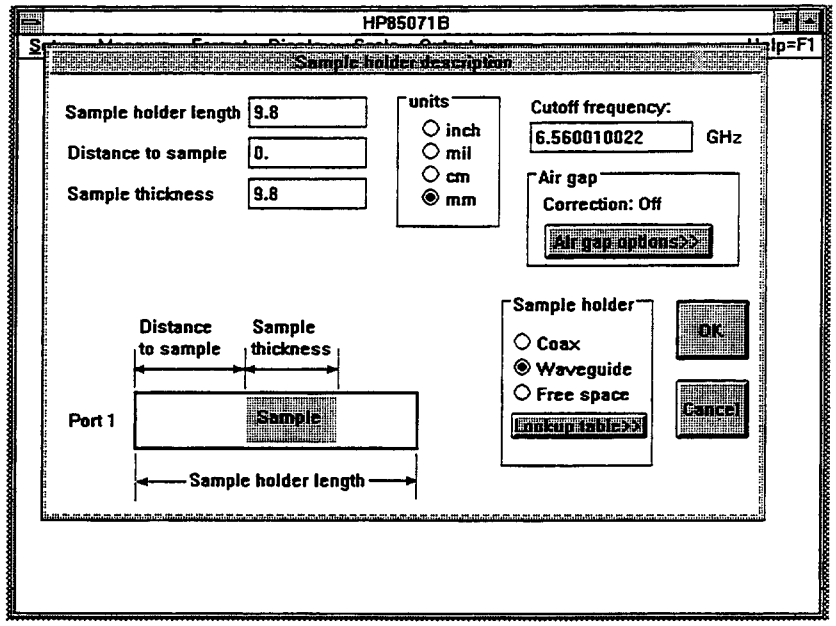


Figure 8-4. Sample Holder ... Screen (MS-DOS Version)

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."

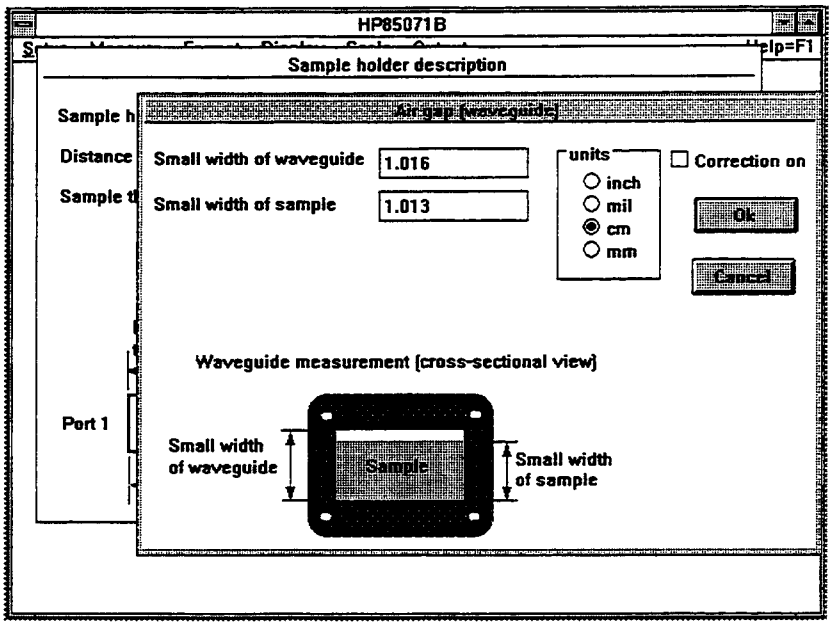


Figure 8-5. Air Gap Waveguide Dialog Box (MS-DOS Version)

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

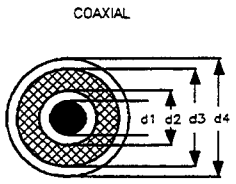


Figure 8-6. Coaxial Air Gap Correction Calculation Dimensions

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

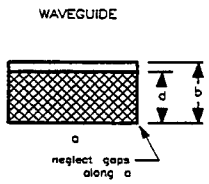


Figure 8-7. Waveguide Air Gap Correction Calculation Dimensions

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

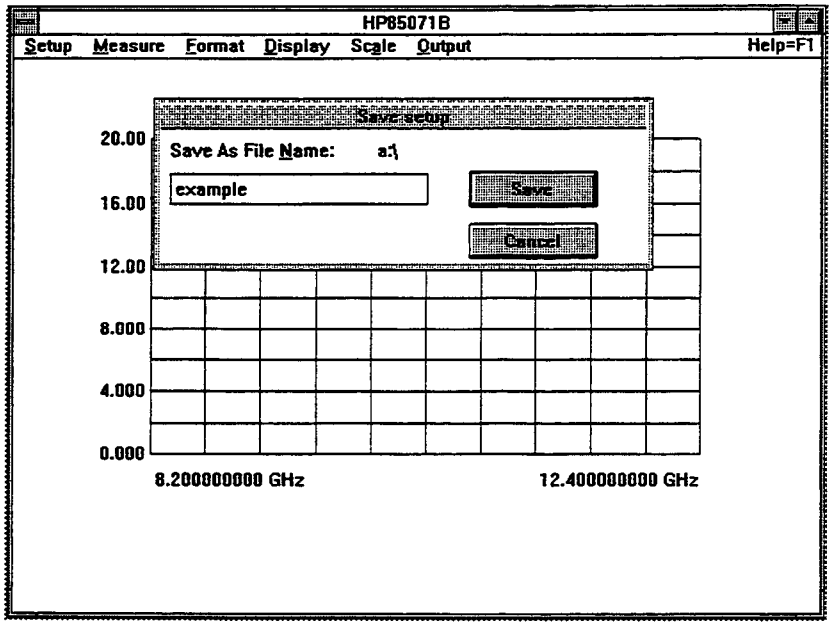


Figure 8-8. Save Setup ... Dialog Box (MS-DOS Version)

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.

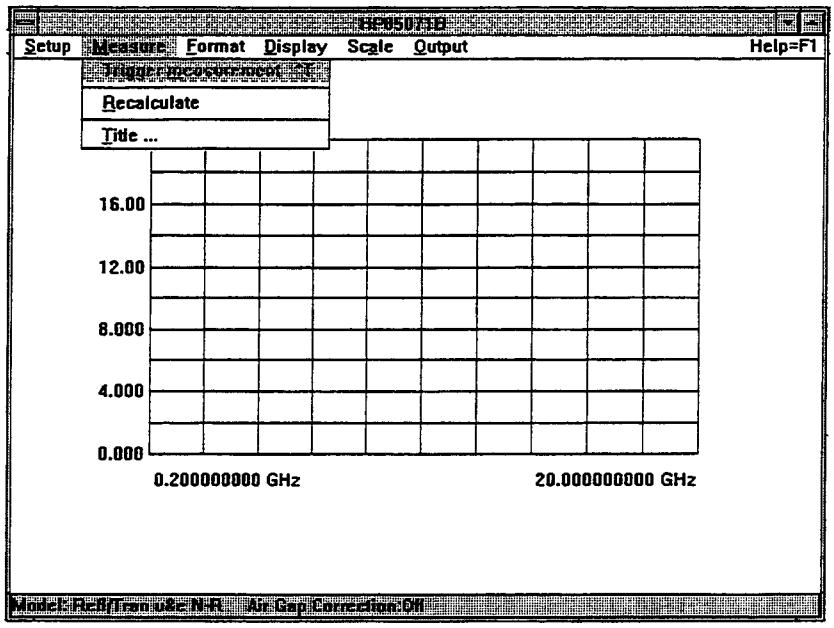


Figure 8-9. Measure Menu (MS-DOS Short Version)

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.

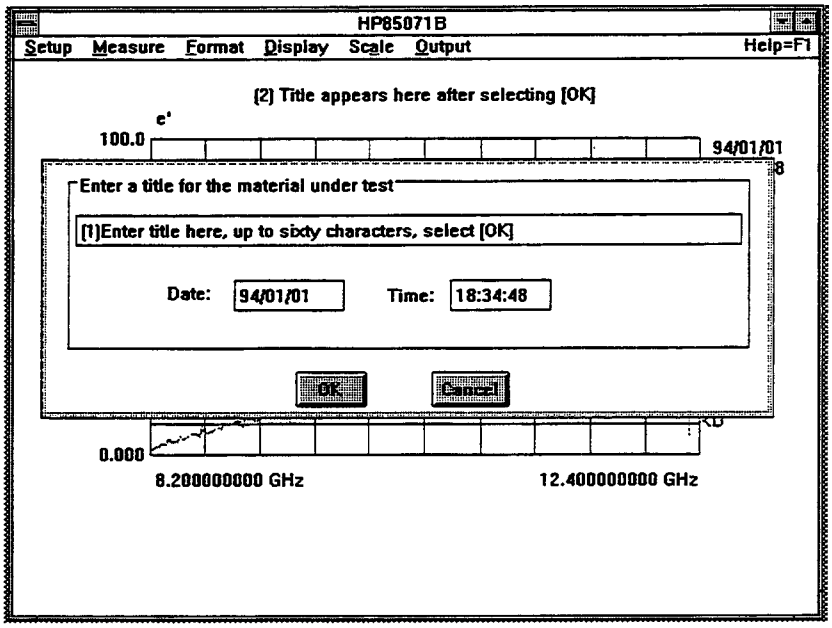


Figure 8-10. Title ... Menu (MS-DOS Version)

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.

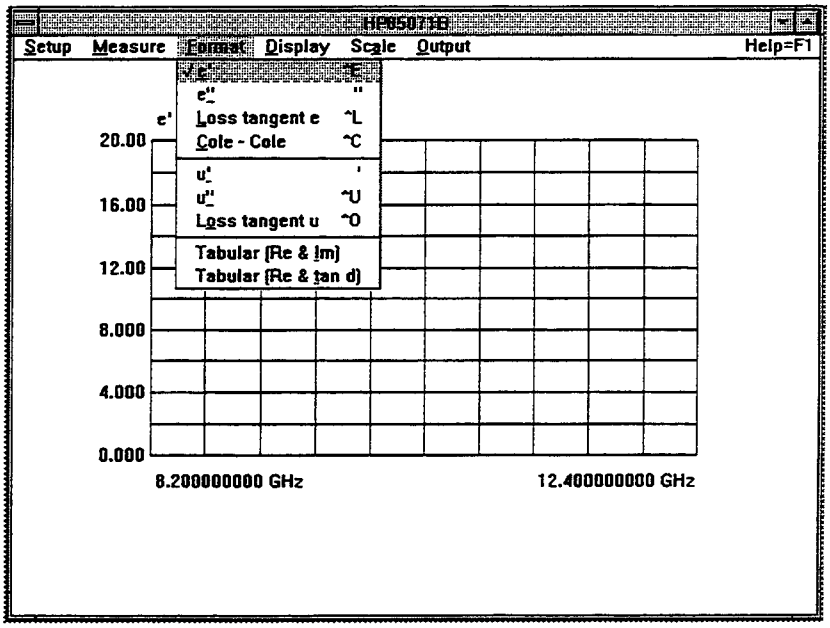


Figure 8-11. Format Menu (MS-DOS Version)

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.

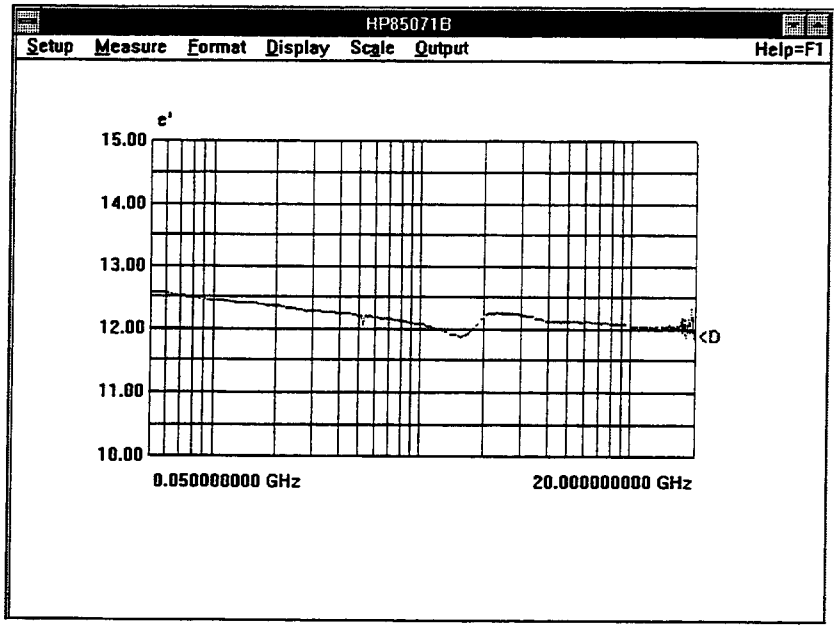


Figure 8-12. Polyiron Measurement in e/ Format

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.

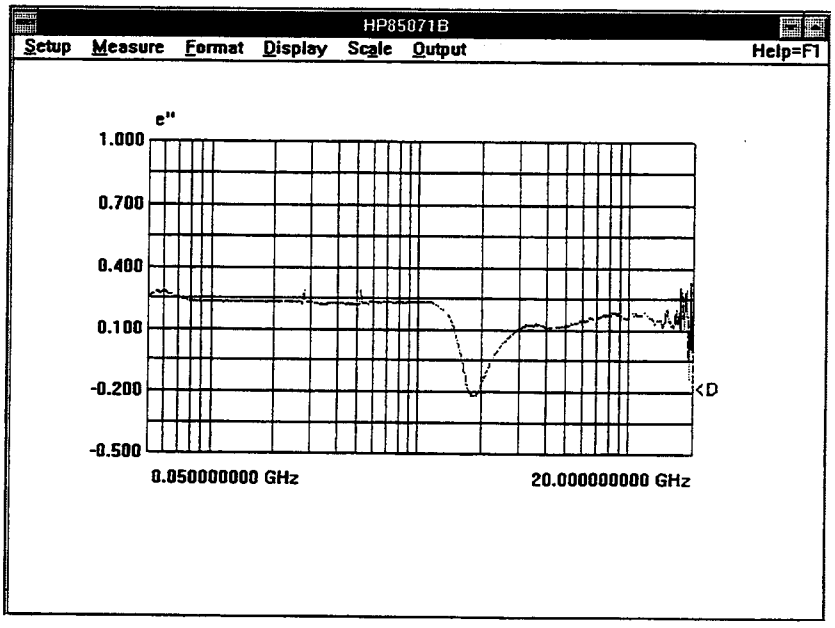


Figure 8-13. Polyiron Measurement in e// Format

Loss tangent e Select (Loss tangent e) to display e//e/ versus frequency.

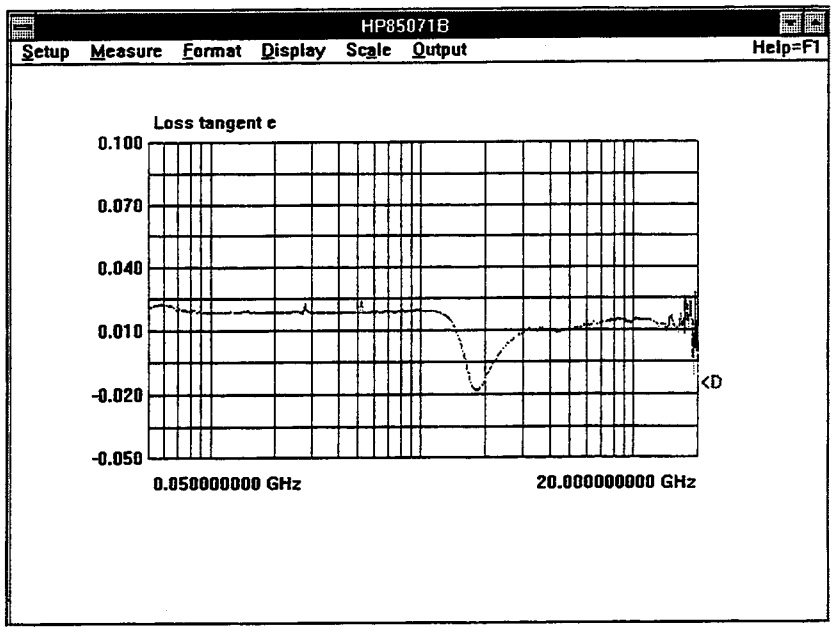


Figure 8-14. Polyiron Measurement in Loss Tangent e Format

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.

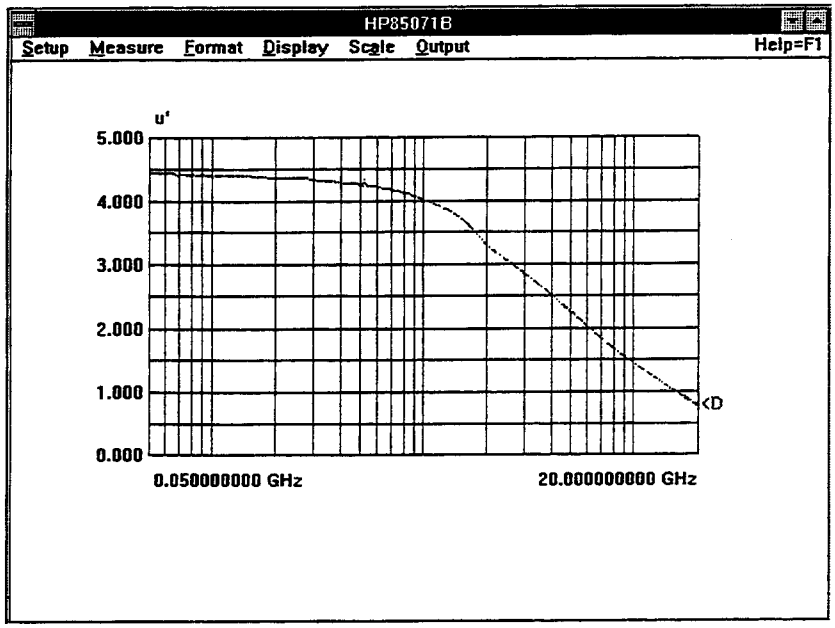


Figure 8-15. Polyiron Measurement in u/ Format

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

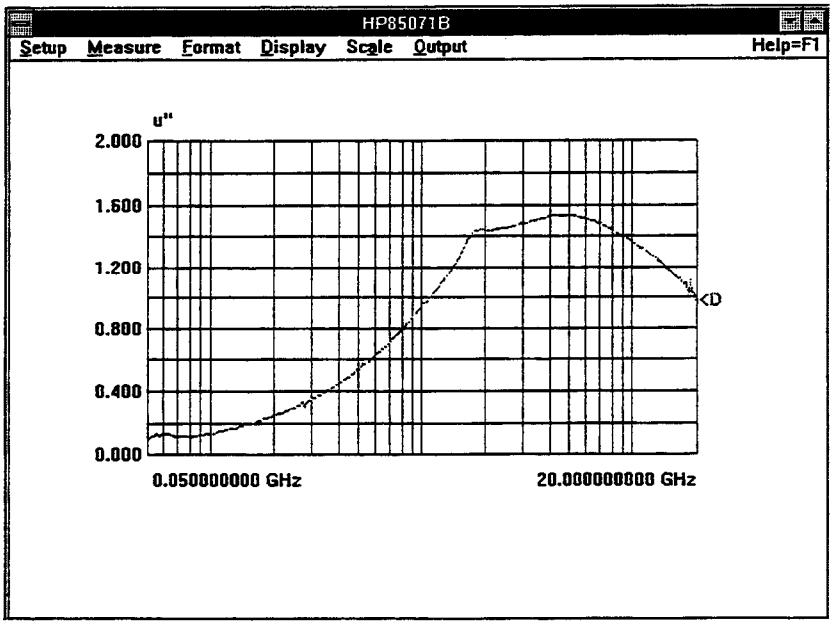


Figure 8-16. Polyiron Measurement in u// Format

Loss tangent u Select (Loss tangent u) to display u''/u' versus frequency.

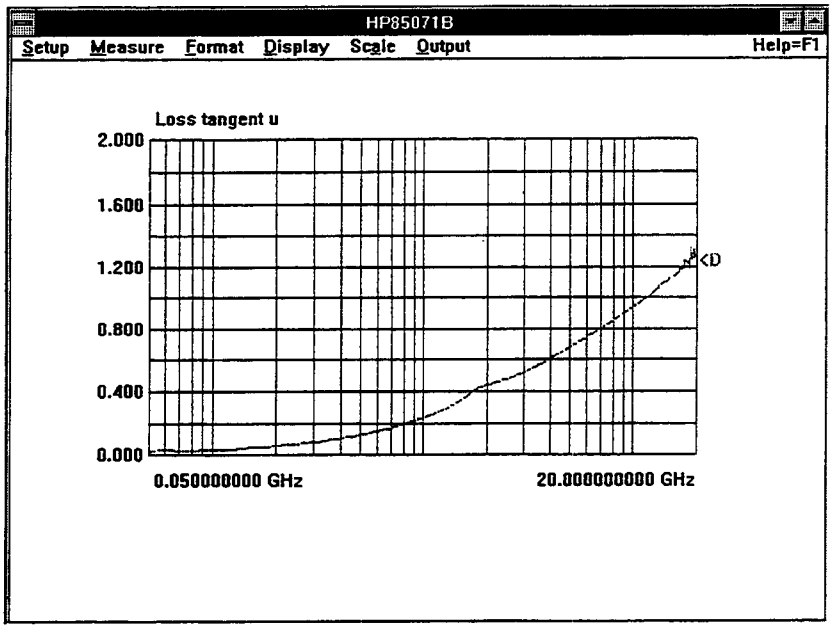


Figure 8-17. Polyiron Measurement in Loss Tangent u Format

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

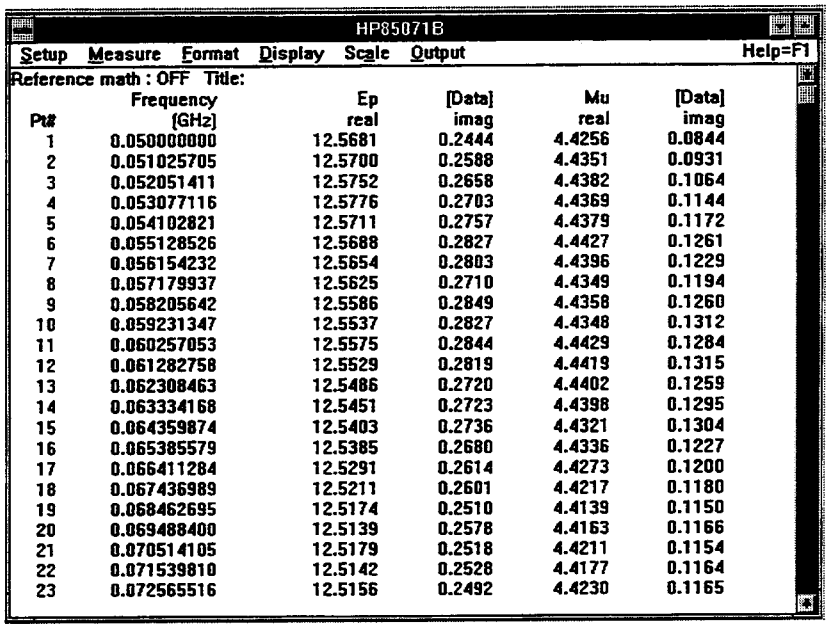
Reference math : OFF Title:

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	[Data] imag	Mu real	[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.

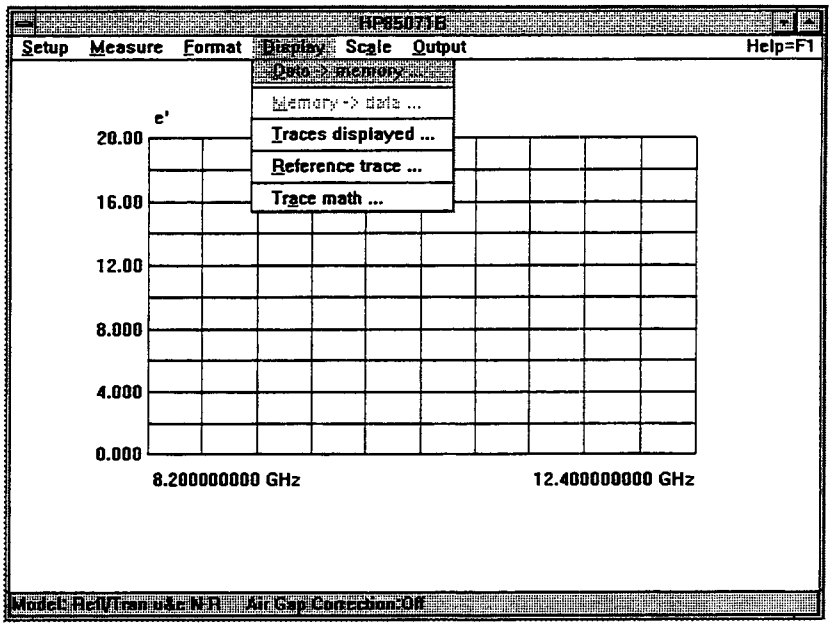


Figure 8-20. Display Menu (MS-DOS Version)

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.

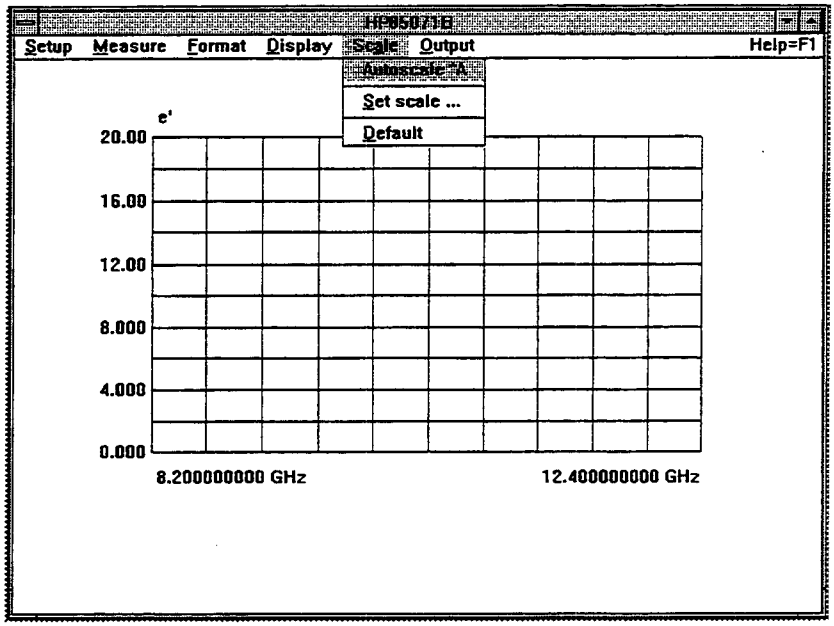


Figure 8-21. Scale Menu (MS-DOS Version)

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.

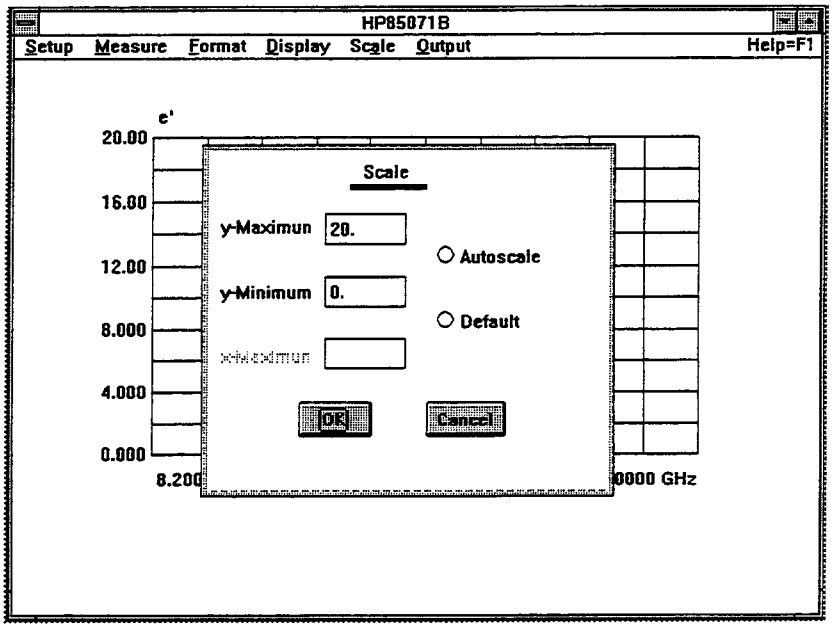


Figure 8-22. Set Scale ... Screen (MS-DOS Version)

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.

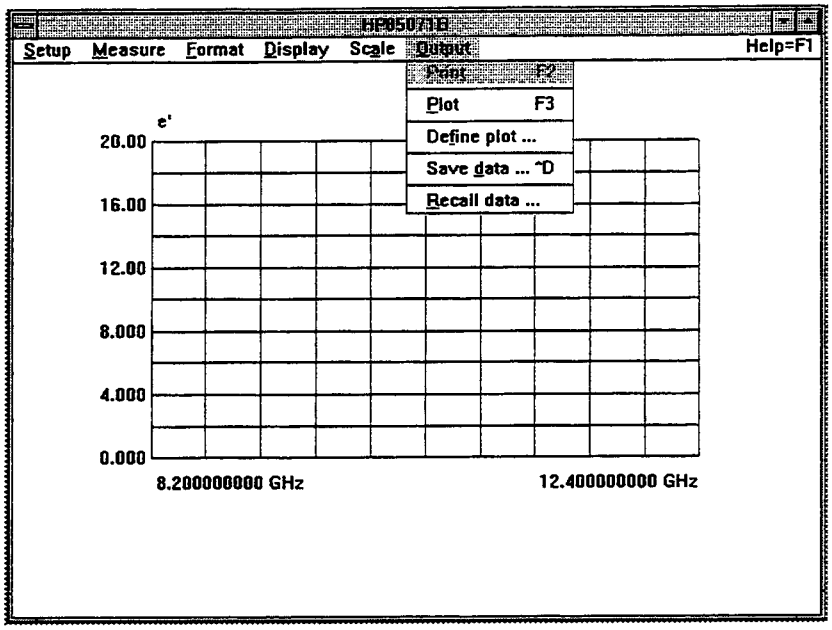


Figure 8-23. Output Menu (MS-DOS Version)

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.

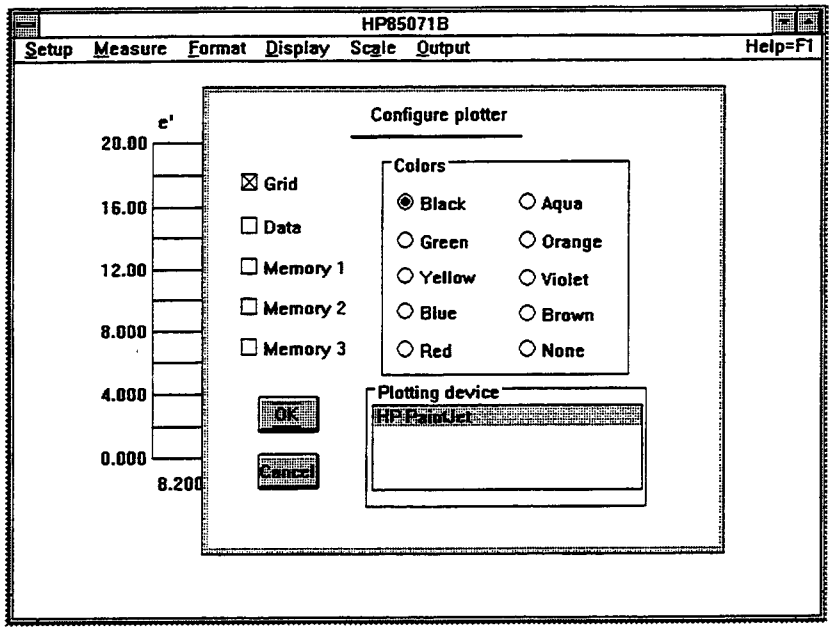


Figure 8-24. Define plot ... Dialog Box (MS-DOS Version)

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

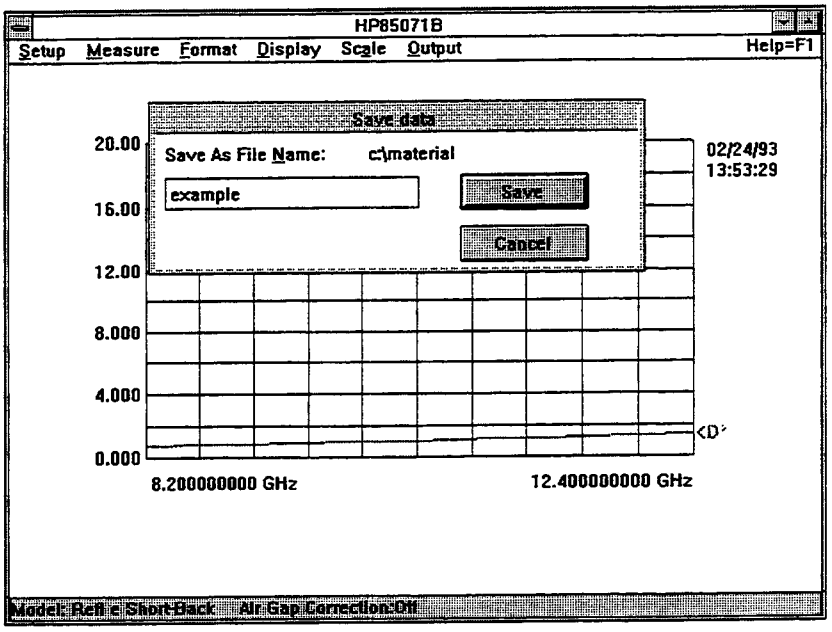


Figure 8-25. Save Data ... Dialog Box (MS-DOS Version)

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.

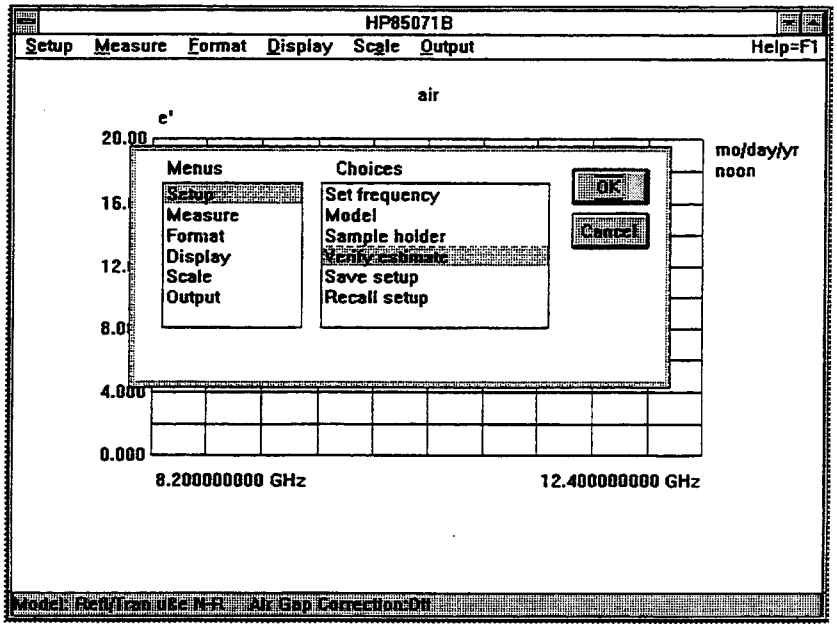


Figure 8-26. Help Menu (MS-DOS Version)

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.