Model 360
Vector Network Analyzer
Materials Measurement Software

Software User's Guide

This manual applies to the
WILTRON 360 Vector Network Analyzer:

Materials Measurement Software,
Software Version 1.02

and

Materials Measurement Package
WILTRON Model 2300-11A

WILTRON

DISCLAIMER

This software program disk is supplied without representation or warranty of any kind. WILTRON, therefore, assumes no responsibility and will not accept liability (consequential or otherwise) arising from the use of the program material or the program disk.

NEW APPLICATION PROGRAMS

New application programs are continually being developed for the 360 Vector Network Analyzer System. If you would like to receive information about these programs, send us your name and address.

CONTENTS

Chapter 1
General Information

1   **Introduction**

This manual supports the WILTRON Materials Measurement Software. The software operates with the WILTRON 360 Vector Network Analyzer (VNA) System. The manual is organized into six chapters, as follows:

- *General Information* – provides an overview of the materials measurement software and a description of the materials measurement package.

- *Required Equipment* – describes the equipment required to use this materials measurement software.

- *Configuring the System* – describes how the equipment is setup and interconnected.

- *Program Description* – provides an overview of the materials measurement software program.

- *Running the Program* – provides step-by-step instructions for running the materials measurement software program.

- *In Case of Trouble* – contains troubleshooting suggestions and service information.

2   **Capability**

The materials measurement software operates with the 360 VNA system to determine the relative complex permittivity (ε_r) and permeability (μ_r) of a material based on one-port (reflection) S-parameter measurements.

To compute ε_r and μ_r of a material, the software requires data from S_{11} measurements of the following:

- Flush Short – to define the reference plane for the measurement.

- Empty Line (of known length) – to determine the propagation rate and dispersion characteristics of the transmission line.

- Short Sample (length l) – a short-circuited material sample of known length.

- Long Sample (length $2l$) – a short-circuited material sample that is exactly two times the length of the short sample.

The software performs materials measurement over any frequency range supported by the 360 VNA system — coaxial measurements from 40 MHz to 60 GHz, waveguide measurements to 110 GHz. Any type of transmission line may be used — coaxial, waveguide, ridge waveguide, circular waveguide, etc. — without requiring any knowledge of its cut-off frequency, dispersion, loss, or cross-sectional shape or dimensions.

The materials measurement software works together with the 360 VNA system's optional time domain capability to gate out mismatches and discontinuities not related to the samples.

The software makes accurate materials measurements at very high temperatures by compensating for dimensional changes in the measurement fixture and phase dispersion in waveguide fixtures.

The materials measurement software incorporates error bounding. A loose connection, damaged cable, improperly mounted sample, etc. can cause a measurement to be outside of the established error limits. During the calculation of ε_r and μ_r, the software flags the erroneous measurement data and displays an error message to alert the operator.

| 3 | Data Output |

Upon completion of calculations, the materials measurement software sends to the 360 VNA the computed real and imaginary values-vs-frequency of ε_r and μ_r. The data is placed in trace memory and displayed graphically on the 360 VNA's display. In addition, the software outputs to the 360 VNA either the intermediate values of K (impedance ratio; Z/Z_0) and T (transmission factor) or the values of tan δ (loss tangent) and tan δ_m (loss tangent magnetic), depending on operator selection. This data is placed in trace memory and may be displayed to aid in material evaluation. All 360 VNA display and analysis features, such as cursor readout and plot/print, may be applied to these results. Refer to Appendix A for examples of materials measurement data printouts.

| 4 | Materials Measurement Package |

The WILTRON Model 2300-11A Materials Measurement Package consists of a WILTRON 360CC MS-DOS ® Computer/Controller that has the materials measurement software and a GPIB interface card factory-installed and tested, a 2-meter GPIB cable, a 3.5-inch/1.44 Mbyte backup disk containing the materials measurement software, and a set of manuals. Option 1 provides the materials measurement software and manual only.

The 360CC Computer/Controller has a 20 MHz 80386 microprocessor and 80387 numeric coprocessor with 2 Mbytes of RAM, a 3.5-inch/1.44 Mbyte disk drive, and a 40 Mbyte hard disk drive. The 14-inch VGA monitor has 640x480 pixels with 256 colors. The keyboard is a 101-key, enhanced AT-type keyboard. A parallel printer port and an RS-232 serial port provide input/output capability, and a National Instruments GPIB-PCII/IIA (IEEE-488) Interface card provides the interface between the computer/controller and the 360 VNA system.

MS-DOS ® is a registered trademark of Microsoft Corporation.

Chapter 2
Required Equipment

5   Introduction

This chapter describes the equipment required to use the materials measurement software.

NOTE

If you have the WILTRON Model 2300-11A Materials Measurement Package, you only need a 360 VNA system to perform material measurements.

6   Hardware Key

The materials measurement software is linked to a parallel interface hardware key. The hardware key is included with the software. This key must be connected to the 25-pin parallel port (LPT 1) of the computer during software operation. The materials measurement software will *not* operate without the key connected to the computer.

7   Computer/Controller

You need an IBM AT or compatible computer to execute the materials measurement software. WILTRON recommends the use of a computer that has a 20 MHz 80386 microprocessor and 80387 numeric coprocessor, 2 Mbytes of RAM, a 3.5-inch/1.44 Mbyte disk drive, a 40 Mbyte hard disk, and a VGA monitor that has 640x480 pixels with 256 colors. You also need an MS-DOS ® 3.3 (or higher) Operating System.

NOTE

Alternate computer configurations which are not compatible or do not meet or exceed these requirements will either run very slowly or not at all.

A WILTRON 360CC MS-DOS ® Computer/Controller is provided as part of the WILTRON Model 2300-11A Materials Measurement Package.

| **8** | **GPIB Interface Card** |

You need to have a National Instruments GPIB-PCII/IIA (IEEE-488) Interface card installed in the computer/controller. The card provides GPIB interface between the computer/controller and the 360 VNA system. Refer to Appendix C for GPIB Interface card installation and configuration instructions.

The GPIB interface card is provided as part of the WILTRON Model 2300-11A Materials Measurement Package. It has been factory-installed and tested in the computer/controller.

| **9** | **Vector Network Analyzer** |

You need a WILTRON Model 360 Vector Network Analyzer System. The 360 VNA system consists of a 360 Network Analyzer, a 36XX-Series Test Set, and a frequency source. Any 360 VNA system configuration with any suitable frequency range may be used. A calibration kit of the measurement transmission line type is also required.

| **10** | **GPIB Cable** |

You need a GPIB cable to connect the computer/controller to the 360 VNA system. This is in addition to the cables normally required for operation of the 360 VNA system.

A two-meter GPIB cable is provided with the WILTRON Model 2300-11A Materials Measurement Package.

Chapter 3
Configuring the System

11   Introduction

This chapter describes how to connect the system components together and perform the initial system setup necessary for proper operation of the materials measurement software.

12   Hardware Interconnection

Connect the computer/controller to the 360 VNA system using the GPIB cable. The connection is from the computer/controller GPIB port to the GPIB connector on the 360 Network Analyzer's rear panel. The computer/controller GPIB port is part of the National Instruments GPIB-PCII/IIA Interface card.

CAUTION

Ensure that the GPIB cable from the computer/controller to the 360 Network Analyzer's rear panel is connected to the connector labeled 360 GPIB and ***not*** the connector labeled SYSTEM BUS.

If you have a WILTRON 2225C Ink Jet printer, connect it to the connector labeled PRINTER on the 360 Network Analyzer's rear panel.

Any compatible GPIB plotter can be connected to the connector labeled SYSTEM BUS on the 360 Network Analyzer's rear panel.

13   360 VNA GPIB Address

Turn on the 360 VNA system and ensure that the GPIB address for the 360 VNA system is set to 6.

14	Hardware Key

Ensure that the hardware key is installed on the 25-pin parallel port (LPT 1) of the computer/controller. The materials measurement software will *not* operate without the key installed. The message `ERROR – Hardware Key is missing` appears on the computer/controller display whenever you try to run the program without the key installed.

NOTE

If you have the WILTRON Model 2300-11A Materials Measurement Package, no further system configuration is required. You are now ready to run the materials measurement software.

If you are using your computer as computer/controller, continue configuring the system as detailed in paragraphs 15 and 16.

15	GPIB Interface Card Installation and Configuration

Follow the procedures in Appendix C to install and configure the National Instruments GPIB-PCII/IIA interface card and the NI-488 MS-DOS Handler software in your computer.

During the installation of the GPIB handler software, the installation program IBSTART creates the file GPIB.COM and adds the line, DEVICE=GPIB.COM, to the CONFIG.SYS file on your boot disk-drive. This ensures that DOS will load the GPIB handler whenever the computer is booted. Anytime that you use a different disk-drive to boot the computer, you will have to transfer the GPIB.COM file and the CONFIG.SYS file—with the DEVICE=GPIB.COM line—to the new boot disk-drive. Otherwise, the GPIB interface will not function properly.

16	Materials Measurement Software Installation

To install the materials measurement software program on your computer's hard disk, boot the computer and insert the software disk into the disk drive. At the DOS prompt:

Type: `A:`
Press: <ENTER> (The A:\DOS prompt will appear**.)**
Type: `COPY MM.EXE` [hard disk letter]`:\`[directory name]`\MM.EXE`
Press: <ENTER>

When the computer has completed copying the program on to the hard disk, the DOS prompt will appear. Remove the materials measurement software disk from the disk drive and maintain it as a backup for the hard disk resident program.

Chapter 4
Program Description

Contents	Para	Name	Page

17   **Introduction**

The program uses a series of menus to guide the user through the proper sequence of steps necessary to compute ε_r and μ_r of a material. This chapter describes each of the steps involved in running the materials measurement software.

18   **Program Sequence of Operation**

Once you have configured the system and started the materials measurement software, the program displays the main menu and prompts you to select one of the following menu items:

> SETUP
> CALIBRATE
> TIME DOMAIN
> MEASUREMENT
> EXIT PROGRAM

The program automatically positions the selection cursor to SETUP, indicating that this is the first step in the sequence. The program requires that setup and calibration be done before measurements can be performed. Likewise, it requires that calibration be completed before time domain can be selected. Consequently, the program will not permit you to proceed until you have completed each of the required steps in the sequence.

After you have selected SETUP from the main menu, the program displays the setup menu and prompts you to enter sample data and make calculation and display selections. The required data entries and selections are:

> Material Name
> Empty Line Length (in millimeters)
> Short or Long Sample Length (in millimeters)
> Calculation Based On (the short or long sample)
> Z/Zo & T Display (Yes or No)

Because the long sample must always be two times the length of the short sample, you can either enter the length of the short sample or the long sample and the program automatically enters the other value. When you have completed the required data entries and selections, you select exit to the main menu. The program then displays the main menu and positions the selection cursor to CALIBRATE indicating the next step in the sequence.

Once you have selected CALIBRATE from the main menu, the program displays the calibrate menu and instructs you to:

perform a one-port calibration on the 360 VNA system, or
recall a previously stored one-port calibration.

After you have completed the calibration, the program returns to the main menu. The program now advances the selection cursor to TIME DOMAIN, indicating the next logical step in the sequence. This is an optional step. You may bypass it and advance directly to MEASURE-MENT.

Following your selection of TIME DOMAIN, the program displays the time domain menu. The software computes and displays the minimum line length necessary for a practical or beneficial time domain gate. The program then queries you as to whether you have a line of this length. If your response indicates that you do *not* have a line of sufficient length, the program returns to the main menu and advances the selection cursor to MEASUREMENT. If your response indicates that you do have a line of sufficient length, the program advances to the next level time domain menu. It then instructs you to connect the line and set the desired time domain gating parameters on the 360 VNA. When you have set the parameters, the program returns to the main menu and advances the selection cursor to MEASUREMENT.

Once you have selected MEASUREMENT, the program displays the measurement menu containing selections for:

S_{11} measurements of the Flush Short, Short Sample,
Long Sample, and Empty Line,
the calculation of ε_r and μ_r, and
the return to the main menu.

S_{11} measurements are accomplished by connecting the item to the measurement port of the 360 VNA system and selecting the item on the menu. The program allows the four measurements to be performed in any order, but requires that all four be measured before it makes the calculation of ε_r and μ_r a valid selection.

Once you have selected the calculation of ε_r and μ_r, the software calculates the real and imaginary values-vs-frequency of ε_r and μr and graphically displays the results on the 360 VNA display. In addition, the software outputs to the 360 VNA either the intermediate values of K (Z/Zo) and T or the values of tan δ and tan δ_m, depending on the selection made on the setup menu. There they are stored in trace memory and may be displayed to aid in material evaluation. After the calculations are completed, the program advances the cursor to the return to the main menu selection. When you have selected return to the main menu, the program displays the main menu.

At the main menu, you can terminate the program by selecting EXIT PROGRAM, or you can repeat the measurement process for the same samples or another material sample by selecting SETUP and repeating the steps just described. You may also return to the Setup Menu and change the calculation basis to the short or long sample, then advance to the Measurement Menu and recalculate ε_r and μ_r, all without reat-taching or remeasuring the material samples.

Chapter 5
Running the Program

19 **Introduction**

The materials measurement software provides a means of characterizing material by computing its complex permittivity (ε_r) and permeability (μ_r) based on one-port S-parameter measurements of material samples by the 360 VNA system. The software then displays the real and imaginary values-vs-frequency of ε_r and μ_r on the 360 VNA display.

The program provides a series of menus that step you through the proper sequence of setup (input sample data), 360 VNA system calibration, time domain selection (if available), and measurement operations. Before running the program, the following items must be available:

> Flush Short
> Empty Line
> Short Sample (*l*)
> Long Sample (*2l*)
> Calibration kit of the same transmission line type as the samples being measured (same transmission line type is not a requirement if time domain techniques are used)

In addition, the line length (in millimeters) of the Short or Long Sample and the Empty Line must at hand.

NOTE

Proper sample preparation is critical to obtaining accurate measurements. Refer to Appendix B for a discussion of measurement considerations and sample preparation techniques.

With the equipment configured as described in Chapter 3, turn on the computer/controller and the 360 VNA system. At this time, the 360 VNA will be in the Local mode. Ensure that there are no error messages on the 360 VNA display before starting the materials measurement software program.

If you are running the program from the floppy disk, wait until the computer is fully booted and the DOS prompt appears on the computer display before inserting the materials measurement program disk. Then proceed as follows:

Insert the disk into the computer's Drive A
Type: `A:`
Press: <ENTER> (The A:\ DOS prompt will appear.)
Type: `MM`
Press: <ENTER>

If you are running the program from the computer's hard disk (and the program was factory installed on the hard disk), wait until the computer is fully booted and the DOS prompt appears on the computer display. Then proceed as follows:

Type: `MM`
Press: <ENTER>

WILTRON configures the computer/controller, shipped as part of the Materials Measurement Package, with the proper DOS path statement and batch file to invoke the program with the `MM` command only. However, if you have installed the materials measurement software program from the floppy disk onto your computer's hard disk, you must first use the appropriate directory selection commands to properly access the program.

At startup, the program title screen shown below is displayed.

```
360 Materials Measurement                        Wiltron Company
Version 1.02                                   All rights reserved



                COPYRIGHT (C) 1989, MARTIN MARIETTA CORP.
                 COPYRIGHT (C) 1990, WILTRON COMPANY


         Your purchase of this product allows you to use one copy
          of the software program. Use, duplication, or sale of
           the software program, except as described above, is
            strictly prohibited. Violators may be prosecuted.




                          Press ENTER to begin
```

21

Selecting from the Main Menu

On the computer/controller, press <ENTER> to access the Main Menu (shown below). This menu provides selection of the individual steps in the sequence of program operation.

```
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                           MAIN MENU


                      > SETUP

                        CALIBRATE

                        TIME DOMAIN

                        MEASUREMENT

                        EXIT PROGRAM



                    Press ENTER to select


```

The normal sequence of steps for program operation is to progress from the top of the main menu to the bottom, first entering sample data, then calibrating the 360 VNA system, using time domain (if available), and then making the measurements. The program requires that setup and calibration be done before measurements are possible. If you try to select MEASUREMENT before completing SETUP or CALIBRATION, the message Setup (or Calibration) option must be performed first appears at the bottom of the display. The program will not permit you to proceed until you have completed the required selection.

Similarly, the program requires that calibration be completed before time domain can be selected. If you try to select TIME DOMAIN before completing CALIBRATION, the message Calibration option must be performed first appears at the bottom of the display. Again, the program will not permit you to proceed until you have calibrated the 360 VNA system.

Select a menu item by positioning the red arrow cursor adjacent to the item and then pressing <ENTER>. The cursor is moved up and down with the ↑ and ↓ keys on the computer/controller keyboard. This menu-driven interface is similar to the one used on the 360 VNA.

22

Entering Sample Data

On the Main Menu, first select SETUP with the red arrow cursor, then press <ENTER>. The program goes to the Setup Menu (page 12).

Enter the required data for all six entries before selecting Exit to Main Menu. Use the cursor control keys to select the desired item, enter the data, then press <ENTER> or move the cursor to the next field. (Moving the cursor to the next field will cause the data you have input to be automatically entered.)

```
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                           SETUP MENU


         > Material Name:  Teflon

           Short Sample Length (mm):  XXX.XXXXX

           Long Sample Length  (mm):  XXX.XXXXX

           Empty Line Length   (mm):  XXX.XXXXX

           Calculation Based On   :  Short Sample

           Z/Zo & T Display (Y/N)  :  No

           Exit to Main Menu


           Enter Material Name (1 to 12 characters)
```

- `Material Name:` Enter 1 to 12 characters here to identify the sample. This label will be saved in the 360 VNA's internal memory and will appear in the MODEL: field at the top of printouts or plots generated by the 360 VNA.

- `Short Sample Length (mm):` **or** `Long Sample Length (mm):` Enter the length in millimeters of the Short Sample or the Long Sample. The program accepts a field of eight digits displayed in the format XXX.XXXXX. If more than five digits are entered after the decimal point, the program rounds off the display entry. The program automatically computes and displays the sample length of the other sample (Short or Long) since it is half or twice the length you entered.

- `Empty Line Length (mm):` Enter the length in millimeters of the Empty Line. The program accepts a field of eight digits displayed in the format XXX.XXXXX. If more than five digits are entered after the decimal point, the program rounds off the display entry.

- `Calculation Based On:` Type `S` (for Short) or `L` (for Long), then press <ENTER>. This enables you to select either the Short Sample or the Long Sample as the basis of the measurement computations. In most cases, selection of the Short Sample here will provide a measurement with the greatest resolution. Retesting the same set of samples with this selection changed to Long Sample will give you a good indication of whether or not your measurement has problems.

- `Z/Zo & T Display (Y/N):` Type `Y` (for Yes) or `N` (for No), then press <ENTER>. This enables you to select what the software will output to the 360 VNA for display on Channels 2 and 4 when the measurement computations are complete. A response of Yes causes the software to output the intermediate values of K (impedance ratio; Z/Zo) and T (transmission factor) to the 360 VNA — K on Channel 2 and T on Channel 4. A response of No causes the software to output the values of tan δ (loss tangent) and tan δ_m (loss tangent magnetic) to the 360 VNA — tan δ on Channel 2 and tan δ_m on Channel 4.

If you make a mistake or wish to change an entry, you may do so by selecting the item again, reentering the correct data, then pressing <ENTER>. Once you are satisfied with the data entries, select Exit to Main Menu and press <ENTER>.

NOTE

You may return to the Setup Menu and change data entries at any time prior to the start of actual measurements.

23   **Calibrating the 360 VNA System**

The Main Menu is now displayed and the selection cursor advances to CALIBRATE. Press <ENTER> and the program advances to the Calibrate Menu shown below.

```
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                          CALIBRATE MENU


          A One-Port Calibration is needed for this measurement.

              Perform a One-Port Calibration on the 360.

                                OR

          Recall a previously stored One-Port Calibration.




                          Pres ENTER when done
```
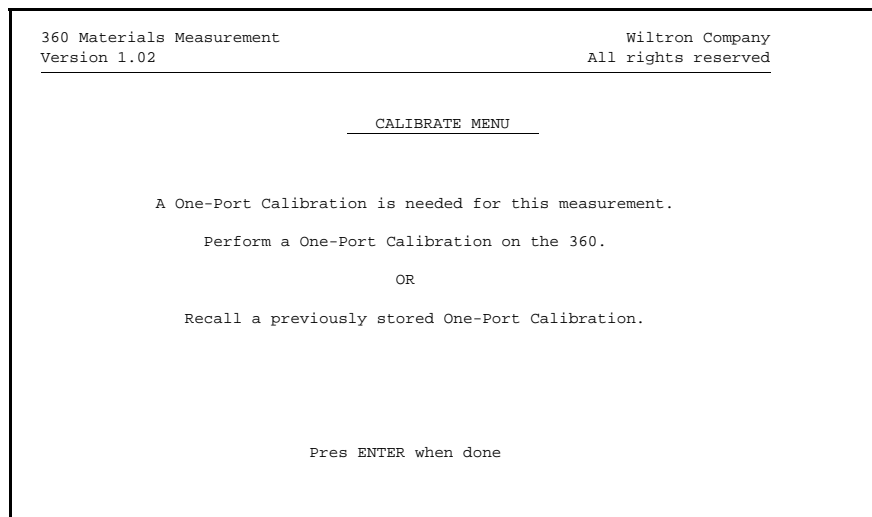
The Calibrate Menu prompts you to perform a one-port (reflection only) calibration or to recall a previously stored calibration. The 360 VNA system will be in Local mode to allow you to perform the calibration procedure of your choice.

NOTE

A good calibration is crucial for accurate results. Do not hesitate to recalibrate often, particularly if there are thermal variations in the sample environment. Although a two-port calibration can be used by the program, a one-port calibration is recommended.

The calibration must be performed with a calibration kit having the same transmission line type as the samples being tested (the same transmission line type is not a requirement if time domain techniques are used). Any calibration method can be used; OSL, Offset Short, LRL, and LRM.

NOTE

> As you perform the calibration, you must also choose the frequency of interest. Later, if you desire a narrower or wider frequency range, you can return to this menu. Whenever the Calibrate Menu is selected, the 360 VNA system is placed in Local mode and its front panel keys are enabled. You can then use the 360 VNA system's setup menu to modify the frequency range.

When the calibration is complete and while the 360 VNA is still in Local mode, it is a good idea to connect the Flush Short to the measurement port and examine the displayed trace on a linear polar display. As shown in the figure below, the trace should track cleanly in a semi-circle with no loops or other discontinuities along the unity circle. If the trace is not smooth, check the connection of the Flush Short to the measurement port. If it still does not smooth out to a clean arc, you must recalibrate the 360 VNA system. Otherwise, the accuracy of your sample measurements will be severely compromised.

FLUSH SHORT   90   SHORT SAMPLE

135   45

>10 degrees   >10 degrees

180   0

FLUSH SHORT AFTER "AUTO" REFERENCE PLANE ROTATION

-135   -45

-90
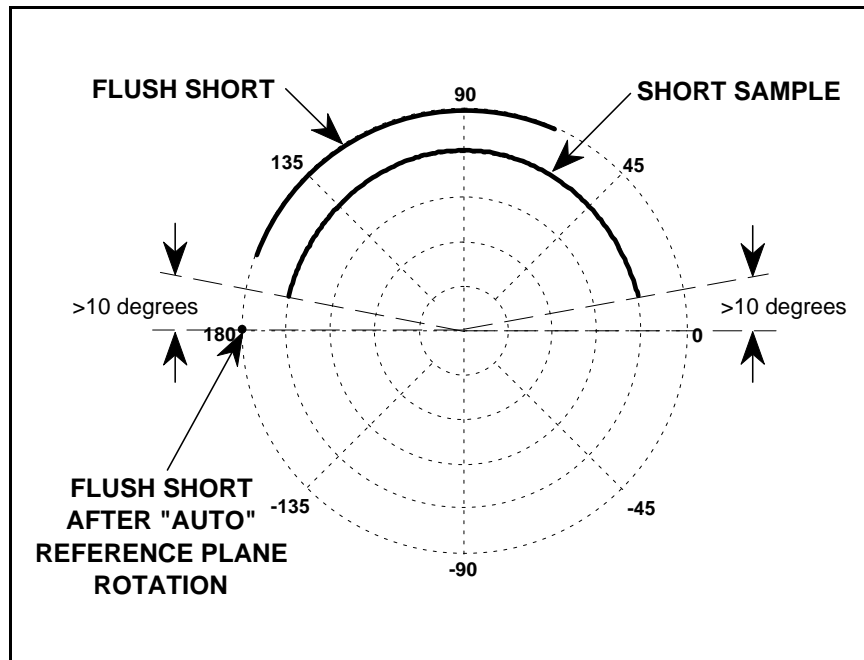
With the Flush Short connected, adjust the reference position so that the trace is a dot at 180°. (This is accomplished by selecting "AUTO" on the SET REFERENCE PLANE menu.) Disconnect the Flush Short from the measurement port and connect the Short Sample to the port. Note the start and stop points of the displayed trace now.

At the optimum measurement frequency range, the Short Sample trace should be between 170° and 10° greater than the 0° phase reference line. If the Short Sample trace exceeds these limits, reduce the start and stop points of the frequency range to bring the displayed trace within these limits.

Once 360 VNA system calibration is completed, exit the Calibrate Menu by pressing <ENTER>. The program goes to the Main Menu.

Upon returning to the Main Menu from the Calibrate Menu, the selection cursor advances to TIME DOMAIN. This is an optional selection. You may chose to bypass it and advance to MEASUREMENT. Selecting TIME DOMAIN and pressing <ENTER> allows you to do a time domain analysis of the sample. (This is only possible if your 360 VNA system has option 2A – High Speed Time Domain installed.) Time Domain is used to gate out fixture, connector, or other system discontinuities not related to the sample that would detract from the accuracy of the reflection measurements of the sample.

When selected, the Time Domain Menu shown below is displayed.

```
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                         TIME DOMAIN MENU



            You must have a line length greater than 17.52034 mm

              Do you have a line of such length? ( Y / N ) :



```

The program computes the minimum line length necessary for a practical or beneficial time domain gate based upon the measurement frequency range and the number of measurement data points available. This value is displayed as shown in the Time Domain Menu above.

Respond to the query Do you have a line of such length? as follows:

- If you do *not* have sufficient line length, type N and press <ENTER>. The program will return you to the Main Menu and the selection cursor will advance to MEASUREMENT.
- If you do have sufficient line length, type Y and press <ENTER>. The program will present the next level Time Domain Menu (shown on the following page). The 360 VNA system will be in Local mode. Connect the line, then set the desired time domain gating parameters on the 360 VNA front panel.

```
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                         TIME DOMAIN MENU



            Connect line and then set Time Domain Gate parameters.







                        Press ENTER when done
```

When you have completed setting the time domain gating parameters, exit the Time Domain Menu by pressing <ENTER>. If you have not already done so, the program will automatically turn on the time domain gating and change the 360 VNA's display to the frequency domain gated by time. The program then goes to the Main Menu.

25 **Measuring the Samples**

Upon returning to the Main Menu from the Time Domain Menu, the selection cursor advances to `MEASUREMENT`. Press <ENTER> and the program shifts to the Measurement Menu shown below.

```
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                         MEASUREMENT MENU

                  > Measure  FLUSH  SHORT

                    Measure  SHORT  SAMPLE

                    Measure  LONG  SAMPLE

                    Measure  EMPTY  LINE

                    Calculate  μr and εr

                    RETURN  TO  MAIN  MENU


                 Connect FLUSH SHORT and Press ENTER
```

Note that the menu items on the Measurement Display are in different colors — valid selections are green, invalid selections are blue and red. Selecting a blue and red menu item, in this case `Calculate` μ_r and ε_r, results in the appearance of the message `Calculation can not be made` at the bottom of the display.

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You are now ready to perform the S_{11} measurements of the Flush Short, the Short Sample, the Long Sample, and the Empty Line. These four items can be measured in any order, but all four must be measured before the software can calculate ε_r and μ_r of the material.

To perform an S_{11} measurement, proceed as follows:

- select the item on the menu with the cursor control keys,
- connect it to the measurement port of the 360 VNA system, and
- press <ENTER>.

Each measurement takes several seconds. Upon completion of the measurement, the menu item's color changes from green to red.

After all four items have been measured, the menu item, `Calculate` μ_r `and` ε_r, becomes a valid selection changing color from blue and red to green. Select `Calculate` μ_r `and` ε_r, then press <ENTER>. The software now calculates the real and imaginary values-vs-frequency of ε_r and μ_r based on the S_{11} measurements. During this process, the message `Calculation in progress` appears at the bottom of the computer/controller display.

NOTE

Occasionally, during the calculation of ε_r and μ_r, you may see a data manipulation error message appear momentarily at the bottom of the computer/controller display. These identify areas where the software has detected an out-of-bounds parameter. Data manipulation errors are only warnings; they do *not* halt the program. Refer to Chapter 6 for a listing of the error messages and the recommended actions you should take.

Upon completion of the calculations, the next level Measurement Menu shown below is displayed.

```
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                          MEASUREMENT MENU




              The calculation of the μr and εr is complete.

            The graphics are displayed on the 360 VNA system.






                    Press ENTER to return to Main Menu

```

The software sends the results to the 360 VNA where the data is placed in trace memory — ε_r in Channel 1 and μ_r in Channel 3 — and displayed graphically on the 360 VNA's display. In addition, the software outputs to the 360 VNA either the intermediate values of K (impedance ratio; Z/Z_0) and T (transmission factor) or the values of tan δ (loss tangent) and tan δ_m (loss tangent magnetic), depending on the selection made on the Setup Menu. Here the data is stored in trace memory — K in Channel 2 and T in Channel 4 or tan δ in Channel 2 and tan δ_m in Channel 4 — for use as an aid in material evaluation. You may apply all 360 VNA display and analysis features, such as cursor readout and plot/print, to these results. However, you can not change the frequency range of the display because the trace data is in static trace memory as opposed to the normal dynamic data display mode. Appendix A provides some examples of materials measurement data printouts.

Upon completion of the calculation of ε_r and μ_r for the material under test, select RETURN TO MAIN MENU, then press <ENTER>. The program returns to the Main Menu (shown on page 10).

CAUTION

> Once you return to the Main Menu, the 360 VNA system will be restored to its pre-calculation state. Both ε_r and μ_r data traces will be overwritten and replaced by a standard S-parameter display. Therefore, do *not* return to the Main Menu until you have finished displaying, evaluating, plotting, printing, and/or storing the calculated data traces.

At the Main Menu, you can choose to repeat the measurement process or terminate the program.

- To change the calculation basis and repeat the calculation for the same samples, select SETUP, then press <ENTER>. At the Setup Menu, select Calculation Based On, type S (for Short Sample) or L (for Long Sample), then select Exit To Main Menu and press <ENTER>. At the Main Menu, select MEASUREMENT, then press <ENTER>. When the Measurement Menu is dislayed, select Calculate μ_r and ε_r, then press <ENTER>.

- To repeat the measurement process for the same samples over a smaller segment of the calibrated frequency range, select CALIBRATE, then press <ENTER>. Set the desired frequency range using the 360 VNA system's setup menu, then press <ENTER> to return to the Main Menu. At the Main Menu, select MEASUREMENT, then press <ENTER>. Repeat the steps just described beginning at paragraph 25.

- To repeat the measurement process for another material sample, select SETUP, then press <ENTER>. Repeat the steps just described beginning at paragraph 22.

- To terminate the program, select EXIT PROGRAM, then press <ENTER>.

Chapter 6
In Case of Trouble

Contents	Para	Name	Page

26　Introduction

This chapter is intended to help you if you have difficulty running the materials measurement software. Troubles can usually be traced to an improper system configuration or a hardware failure. Many of the problems result in an error message that provides you with a clue as to its source. The following paragraphs present the error messages you are most likely to encounter and provide some recommended actions you can take to overcome difficulties in operating the program.

During actual calculations, the materials measurement software outputs error messages whenever it detects an out-of-bounds parameter. Paragraph 30 lists these error messages and describes the recommended actions you can take.

27　Difficulty Running the Program

If you have difficulty running the program:

a. Ensure that the system is configured as described in Chapter 3 — Configuring the System.

b. If you are going to be running the program from a floppy disk, ensure that the disk contains the program MM.EXE. Also be sure that your computer is fully booted before inserting the program disk into the computer's disk drive.

c. If your are going to be running the program from your computer's hard disk, ensure that the program MM.EXE is resident on the disk.

d. If a system or GPIB error message appears on the computer/controller display, ensure that the discrepancy is corrected before attempting to run the program (see paragraphs 28 and 29).

If, after checking the above, you still have problems running the program, contact WILTRON at (408) 778-2000 for further assistance.

System Errors

System error messages can appear on the computer/controller display at any time during program operation. These are "fatal" errors and cause the system to halt until the condition causing the failure is corrected. The possible system error messages are:

```
ERROR – Illegal Function Call
ERROR – Overflow
ERROR – Out of Memory
ERROR – Division by Zero
ERROR – Out of String Space
ERROR – Code = (Error Code Number)
```

These system errors normally indicate a computer problem. In some cases, rebooting the computer may correct the problem. Normally, we recommend that you thoroughly test the computer and repair any discrepancies before attempting to run the materials measurement software. You may wish to refer to the operation and maintenance manuals that were received with your computer. If you need further assistance, contact WILTRON at (408) 778-2000.

GPIB Errors

GPIB error messages normally appear on the computer/controller display during startup and indicate a problem either in configuration, addressing, or cabling. These are "fatal" errors and cause the system to halt until the condition causing the failure is corrected. The possible GPIB error messages are:

```
ERROR – DOS Error
ERROR – Function requires GPIB-PC to be CIC
ERROR – No listener on write function
ERROR – GPIB-PC not addressed correctly
ERROR – Non-existent GPIB-PC board
ERROR – IBERR = (Error code number)
```

Most GPIB problems can be resolved as follows:

a. Ensure that the GPIB cable is properly connected between the computer/controller and the connector labeled 360 GPIB on the rear panel of the 360 VNA.

b. Ensure that the GPIB address for the 360 VNA system is set to 6.

c. Ensure that the GPIB-PCII/IIA interface card is configured and installed in the computer/controller per Appendix C.

d. Following the procedures in Appendix C, reinstall the NI-488 MS-DOS Handler software and change the software configuration. Be sure to reboot your computer to install the new software configuration.

For further definition of the error messages, you may wish to refer to the GPIB-PC Users Manual that accompanied your GPIB board. If you need assistance, contact WILTRON at (408) 778-2000.

Occasionally, during the calculation of ε_r and μ_r by the software, data manipulation error messages appear momentarily at the bottom of the computer/controller display. They identify areas where the software has detected an out-of-bounds parameter. Data manipulation errors are only warnings; they do not halt the program.

The appearance of the error message `SHORTER or LONGER length improperly selected` indicates that you may have inadvertently selected `Measure LONG SAMPLE` on the Measurement Menu when you had the Short Sample connected to the 360 VNA system's measurement port, or vice versa. Since this will cause the results of the calculations to be inaccurate, you should return to the Main Menu, select `MEASUREMENT`, then perform the measurements and the calculation of ε_r and μ_r again.

The appearance of any of the following error messages normally indicates a poor calibration of the 360 VNA system. This causes the sample measurements to be inaccurate.

```
Negative sample line delay fit! Set to zero
Divide by zero! Quotient set to zero
Data too corrupt! Invalid solution at F = (Frequency)
```

We recommend that you return to the Main Menu, select `CALIBRA-TION`, and then calibrate the 360 VNA system. Upon completion, you should check the calibration by the method described on page 14 before continuing the materials measurement process.

If you require further assistance, contact WILTRON at (408) 778-2000.

Appendix A
Examples of Materials
Measurement Data Output

```
 (WILTRON)
360 NETWORK ANALYZER


MODEL:   Polystyrene  DATE:
DEVICE:               OPERATOR:

START:  26.5000 GHz   GATE START:  404.7059 ps ERROR CORR: NONE
STOP:   40.0000 GHz   GATE STOP:     1.4047 ns AVERAGING:  1 PTS
STEP:    0.0810 GHz   GATE:      MIN SIDELOBE   IF BNDWDTH: REDUCED
                      WINDOW:      NOMINAL
```

```
 Er
 REAL              ▷REF=0.000pU        10.000U/DIV      CH 1 - Er
                                                        REF. PLANE
                  ┌─┐                                       0.0000 mm
                  │4│
                  └─┘
                                                       ▷MARKER 1
                                                        29.4160 GHz
                                                           2.540 U
 26.5000               GHz                 40.0000       -99.435 jmU

                  ┌─┐                                   MARKER TO MAX
                  │1│                                   MARKER TO MIN
                  └─┘



 IMAGINARY        ▷REF=0.000pU         5.000U/DIV
 Ur                                    FGT
 REAL             ▷REF=0.000pU        10.000U/DIV

                  ┌─┐
                  │1│
                  └─┘



 26.5000               GHz                 40.0000

                  ┌─┐
                  │1│
                  └─┘


 IMAGINARY        ▷REF=0.000pU         5.000U/DIV
```

Figure A1.   Graphic Display of ε_r and μ_r for Polystyrene

Figure A2.   Graphic Display of K (Z/Z$_0$) and T for Polystyrene

CWILTRON

360 NETWORK ANALYZER

MODEL: Polystyrene   DATE: Page 1
DEVICE ID: OPERATOR:

SWEEP DATA
START: 26.5000 GHz   GATE START: 404.7059 ps   ERROR CORR: NONE
STOP: 40.0000 GHz   GATE STOP: 1.4047 ns   AVERAGING: 1 PTS
STEP: 0.0810 GHz   GATE: MIN SIDELOBE   IF BNDWDTH: REDUCED
                                         WINDOW: NOMINAL

	------------CH1------------		------------CH2------------		------------CH3------------		------------CH4------------	
PARAMETER:	Er		Z/Zo		Ur		T	
NORMALIZATION:	MEMORY		MEMORY		MEMORY		MEMORY	
REFERENCE PLANE:	0.0000 mm		0.0000 mm		0.0000 mm		0.0000 mm	
SMOOTHING:	0.0 PERCENT		0.0 PERCENT		0.0 PERCENT		0.0 PERCENT	
DELAY APERTURE:	-		-		-		-	
PROCESSING:	FREQ		FREQ		FREQ W/GATE		FREQ	
GATING:	-		-		ON		-	

MARKERS:

MKR #	FREQ GHz	REAL UNITS	IMAG UNITS	REAL UNITS	IMAG UNITS	REAL UNITS	IMAG UNITS	MAGNITUDE UNITS	PHASE Deg
1	29.4160	2.540E+00	-99.435E-03	494.388E-03	-24.083E-03	987.742E-03	-60.888E-03	972.343E-03	-112.195

FREQUENCY POINTS:

PNT #	FREQ GHz	REAL UNITS	IMAG UNITS	REAL UNITS	IMAG UNITS	REAL UNITS	IMAG UNITS	MAGNITUDE UNITS	PHASE Deg
1	26.5000	2.599E+00	-23.659E-03	449.268E-03	-3.251E-03	1.010E+00	-17.916E-03	966.860E-03	-101.228
2	26.5810	2.620E+00	-12.765E-03	447.747E-03	-14.987E-03	997.600E-03	-21.167E-03	958.059E-03	-101.381
3	26.6620	2.639E+00	-12.970E-03	451.165E-03	-26.751E-03	984.709E-03	-31.173E-03	949.682E-03	-101.767
4	26.7430	2.644E+00	-54.460E-03	460.296E-03	-35.925E-03	976.720E-03	-49.082E-03	944.266E-03	-102.427
5	26.8240	2.621E+00	-98.644E-03	473.517E-03	-38.028E-03	980.226E-03	-71.117E-03	946.042E-03	-103.231
6	26.9050	2.575E+00	-123.485E-03	483.994E-03	-30.513E-03	997.080E-03	-87.285E-03	956.281E-03	-103.716
7	26.9860	2.526E+00	-53.275E-03	484.459E-03	-19.166E-03	1.023E+00	-47.579E-03	966.783E-03	-103.526
8	27.0670	2.489E+00	-24.371E-03	476.705E-03	-13.316E-03	1.039E+00	-34.983E-03	968.309E-03	-102.980
9	27.1480	2.478E+00	-52.967E-03	468.248E-03	-15.726E-03	1.041E+00	-57.780E-03	960.909E-03	-102.594
10	27.2290	2.494E+00	-20.804E-03	464.375E-03	-23.315E-03	1.031E+00	-42.187E-03	949.406E-03	-102.621
11	27.3100	2.525E+00	-11.713E-03	466.583E-03	-31.422E-03	1.014E+00	-38.200E-03	938.871E-03	-103.107
12	27.3910	2.550E+00	-27.880E-03	473.185E-03	-35.937E-03	1.000E+00	-46.397E-03	934.011E-03	-103.925
13	27.4720	2.555E+00	-55.684E-03	480.204E-03	-35.162E-03	996.277E-03	-60.043E-03	937.166E-03	-104.740
14	27.5530	2.542E+00	-78.682E-03	483.922E-03	-30.906E-03	1.002E+00	-70.989E-03	945.372E-03	-105.198
15	27.6340	2.520E+00	-87.683E-03	483.503E-03	-26.806E-03	1.011E+00	-74.643E-03	952.414E-03	-105.246
16	27.7150	2.500E+00	-81.780E-03	480.906E-03	-25.395E-03	1.019E+00	-70.891E-03	954.417E-03	-105.123
17	27.7960	2.492E+00	-67.483E-03	478.806E-03	-26.812E-03	1.021E+00	-63.257E-03	951.746E-03	-105.095
18	27.8770	2.498E+00	-55.377E-03	478.796E-03	-29.458E-03	1.016E+00	-57.061E-03	947.260E-03	-105.307
19	27.9580	2.510E+00	-53.328E-03	480.751E-03	-31.394E-03	1.009E+00	-56.015E-03	944.205E-03	-105.744
20	28.0390	2.519E+00	-61.480E-03	483.310E-03	-31.624E-03	1.003E+00	-59.825E-03	944.487E-03	-106.267
21	28.1200	2.521E+00	-73.934E-03	485.071E-03	-30.536E-03	1.002E+00	-65.276E-03	947.662E-03	-106.710
22	28.2010	2.516E+00	-83.969E-03	485.561E-03	-29.268E-03	1.004E+00	-69.039E-03	951.567E-03	-106.999
23	28.2820	2.508E+00	-87.797E-03	485.292E-03	-28.735E-03	1.007E+00	-69.493E-03	954.183E-03	-107.182
24	28.3630	2.503E+00	-85.925E-03	485.149E-03	-29.085E-03	1.008E+00	-67.172E-03	954.912E-03	-107.363
25	28.4440	2.503E+00	-82.192E-03	485.716E-03	-29.797E-03	1.007E+00	-64.155E-03	954.534E-03	-107.625
26	28.5250	2.508E+00	-80.812E-03	486.949E-03	-30.175E-03	1.003E+00	-62.584E-03	954.356E-03	-107.982

Figure A3.   Partial Tabular Printout of ε_r, K, μ_r, and T for Polystyrene

```
(WILTRON)

460 NETWORK ANALYZER

MODEL:      Teflon        DATE:                        Page   1
DEVICE ID:                OPERATOR:

SWEEP DATA
START:        2.0000 GHz   GATE START:      -    ERROR CORR:   NONE
STOP:        18.0000 GHz   GATE STOP:       -    AVERAGING:      1 PTS
STEP:         0.1920 GHz   GATE:            -    IF BNDWDTH:   REDUCED
                           WINDOW:          -

               ------------CH1------------   ------------CH3------------
PARAMETER:                  Er                          Ur
NORMALIZATION:            MEMORY                       MEMORY
REFERENCE PLANE:        0.0000    mm           4.7145    mm
SMOOTHING:              0.0 PERCENT           0.0 PERCENT
DELAY APERTURE:             -                          -
```
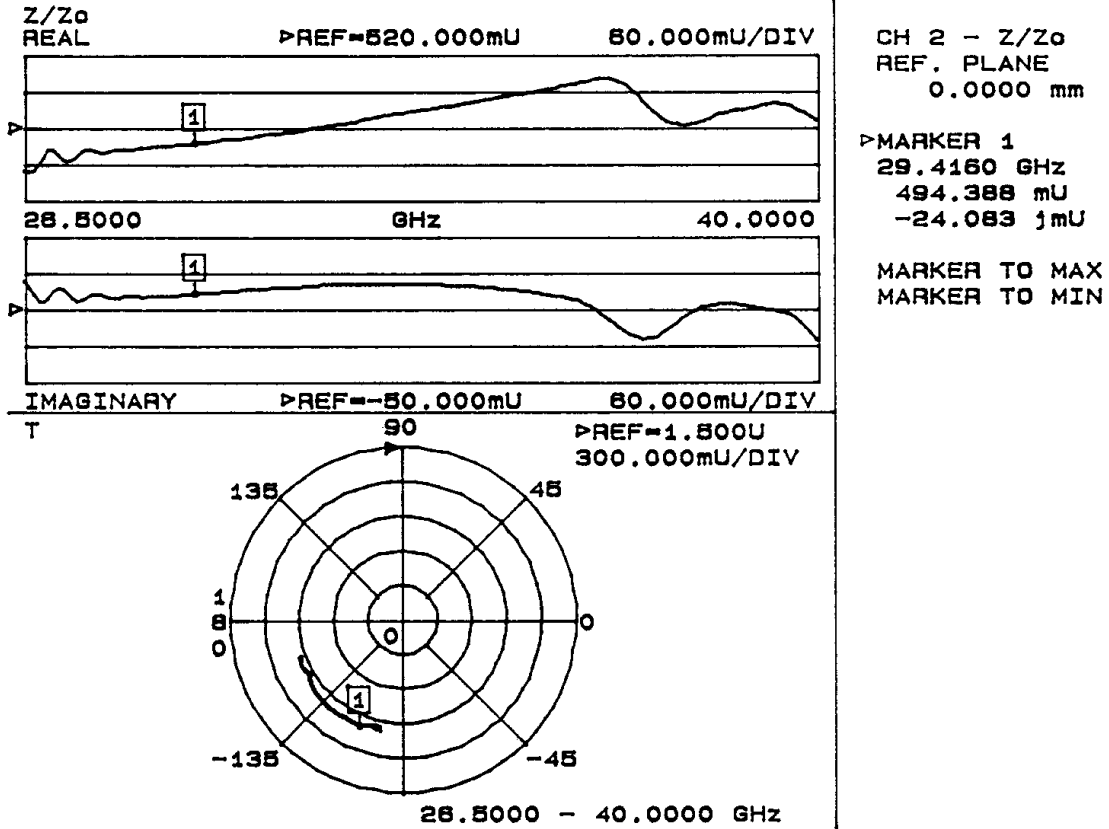

Figure A4.   Graphic Display of ε_r and μ_r for Teflon

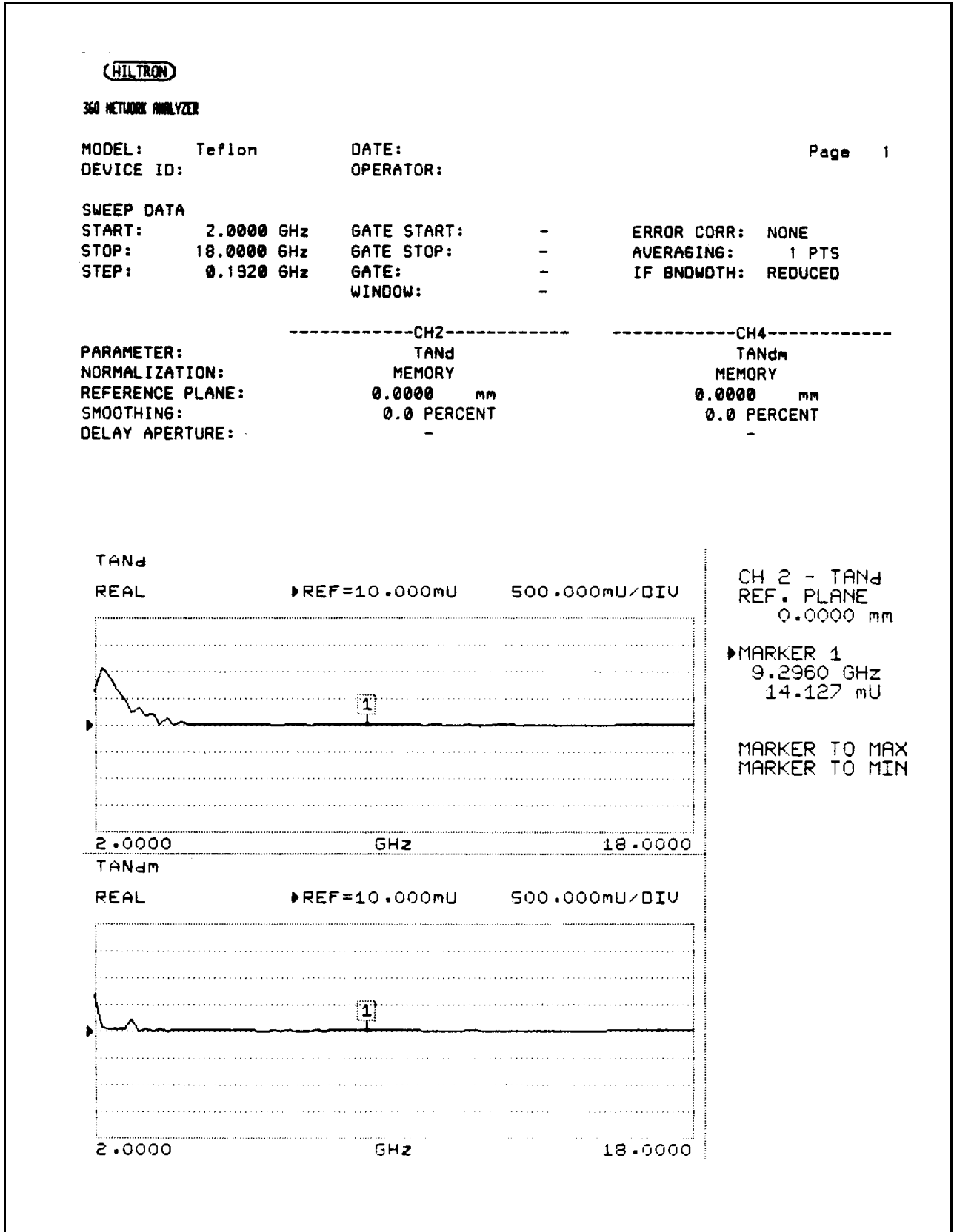**Figure A5.** Graphic Display of tan δ and tan δ_m for Teflon

Appendix B
Measurement Considerations,
including
Sample Preparation Techniques [1]

There are a number of practical considerations for successfully implementing this materials measurement method. These relate to sample length, time-domain gating, mode suppression, and sample fabrication.

B1 SAMPLE LENGTH

If the sample has low loss and is an odd integral multiple of a quarter wavelength at some frequency, $K = Z/Z_0$ becomes ill-defined at that frequency. In practice, ε_r and μ_r will show uncontrolled fluctuation at and in the neighborhood of the frequency. Obviously, the shorter length, l, must be chosen to avoid this condition in the frequency range of interest. However, doing so requires some prior knowledge of ε_r and μ_r, the very quantities we seek to determine.

If the sample has high loss, another restriction arises out of the need for independent measurements from the two sample lengths. For these measurements, the instrument must detect reflected waves from the sample's front surface and those from the roundtrip path through the sample to its rear (short-circuited) face. If the latter component of the reflection is too highly attenuated, as in a lossy sample, the instrument will not detect it, and the measurements from the two sample lengths will be electrically indistinguishable. Thus, l must be chosen thin enough to avoid this condition, and the experimental designer must have sufficient *a priori* knowledge to anticipate this occurrence.

The spacing between adjacent frequency points places an upper bound on the choice for l. If $2l$ (nl in the general case) is so large that the phase change between adjacent frequencies of measurement exceeds 2π, the data will be severely aliased to the total detriment of the algorithm. The larger the product $\varepsilon_r\mu_r$, the smaller the value of l. Here also, some prior knowledge of the material properties is needed for successful experimental design.

B2 TIME-DOMAIN GATING

Application of time-domain gating places restrictions not only on the sample lengths but also on the separation between the calibration and measurement planes, α. The nature of these interactions can best be illustrated by an example. Suppose that measurements are desired between 26.5 and 40 GHz, or a bandwidth of BW = 40 − 26.5 = 13.5 GHz. The equivalent time impulse width is approximately 1.5/BW = 1.5/13.5 = 111 ps, or an equivalent spatial resolution of 1.3 inches. This is the minimum roundtrip separation distance, $2\alpha_{min}$, between the calibration and measurement planes that will adequately separate (resolve) the desired response from the instrument's spurious responses. For successful gating, $\alpha \approx 3\alpha_{min} \approx 2$ inches. Different lengths are required for other frequency ranges.

The spacing between adjacent frequency points imposes an upper limit on α. In the example above, suppose that the 13.5 GHz frequency interval is divided into 85 equal intervals spaced 159 MHz apart. In the time domain, the desired impulse response will be repeated every $1/159$ μs= 6.3 ns, which places an upper limit of 37 inches on α. This upper bound presents no problems for most practical waveguide lengths in this frequency range. However, it should be considered in any plan to reduce the number of frequency points, extend the bandwidth, or otherwise increase the spacing between adjacent frequencies.

---

[1] Martin Marietta Laboratories, MML TR 89-83 Extracting μ_r and ε_r of Solids From One-Port Phasor Network Analyzer Measurements (Baltimore, MD, 1989), pp.24-29

Time-domain gating also imposes constraints on the choice of *l* for a given α or vice versa. If the $\sqrt{\mu_r \epsilon_r}\ l$ is small compared with both α and the spatial resolution of the instrument (1.3 inches in the above example), the application of time-domain gating is relatively straightforward. However, if either of those conditions is not satisfied, time-domain gating must be applied with care. For example, if $\sqrt{\mu_r \epsilon_r}\ l << \alpha$ but larger than the instrument's spatial resolution, the separate responses from the front and rear faces of the sample will be resolved, and the gate must be adjusted to encompass both peaks adequately. However, if $\sqrt{\mu_r \epsilon_r}\ l >> \alpha$, the response from the rear face of the sample may not be separable from the instrument's spurious response, and gating should not be applied at all! Again, we emphasize that some knowledge of the ϵ_r and μ_r of the material under test is necessary to anticipate the above conditions.

B3   MODE SUPPRESSION

We highly recommended that the user perform the calculation of ϵ_r and μ_r twice — once using the short sample, *l*, as the basis for measurement computations and again using the long sample, 2*l*, as the basis. The values of ϵ_r and μ_r obtained from the two calculations are different if higher order modes are present. Better agreement among values is obtained when higher order modes are suppressed.

Once the initial measurement detects the presence of undesired modes, several remedies are available to suppress them. One convenient method is to modify the waveguide cross section so that the spurious modes are suppressed without perturbation of the propagation characteristics of the desired mode. For example, at the National Institute for Standards and Technology (NIST), circular waveguide is formed by winding insulated wire in a tight helix, which allows propagation of the desirable TE_{01} mode and suppresses all other modes, notably the (dominant) TE_{11} mode. A second example is the rectangular waveguide shown in Figure B1, where reducing the waveguide height and introducing slots at the mid-section of both its broad walls suppresses spurious modes with minimal effect on the desired mode.
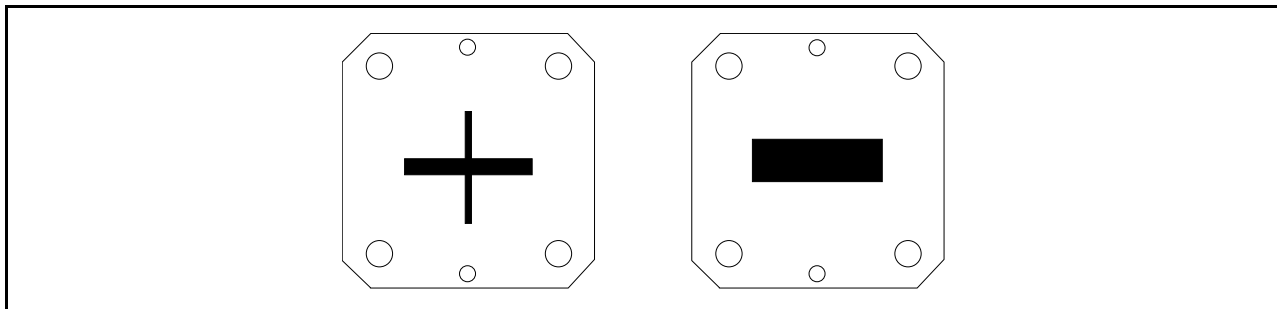

Figure B1.   Mode suppression in a rectangular waveguide, accomplished by reducing waveguide height and cutting a slot in the upper and lower walls. A standard waveguide that operates in the same band is shown alongside for comparison.

B4   SAMPLE FABRICATION

This materials measurement method is fabrication intensive. Therefore, the measurement outcome is critically dependent on the extent to which sample length and waveguide fit can be controlled. For example, in rectangular waveguide, poor sample contact with the waveguide's broad wall will produce large errors in ϵ_r, while poor contact with the waveguide's narrow wall or back short will produce large errors in μ_r. Because intimate contact between the metal and sample is of primary importance, we have developed a number of vacuum- and electrodeposition-based methods for depositing metals directly on the sample surfaces. The subsequent insertion and soldering of the metallized sample into a waveguide holder is a less critical operation because the desired contact between metal wall and dielectric or magnetic sample has already been achieved.

One sample preparation method is illustrated in Figure B2. A sample substrate is bonded to a metal block, and its free surface is polished to the desired finish. Next, the substrate is cut to a waffle pattern such that each element conforms to the dimensions of the waveguide holder of interest, and metal is

deposited by vacuum evaporation and electroplating. The researcher should allow sufficient width for the cutting lanes to ensure that metal adequately deposits on the vertical walls of the structure. The individual pieces are then separated from the metal block for soldering into the waveguide holder. An obvious variation of this technique entailing a core drill and ultrasonic drilling techniques can produce circular washers for thin coaxial samples that are suitable for high-dielectric-constant/high-frequency sample measurements.
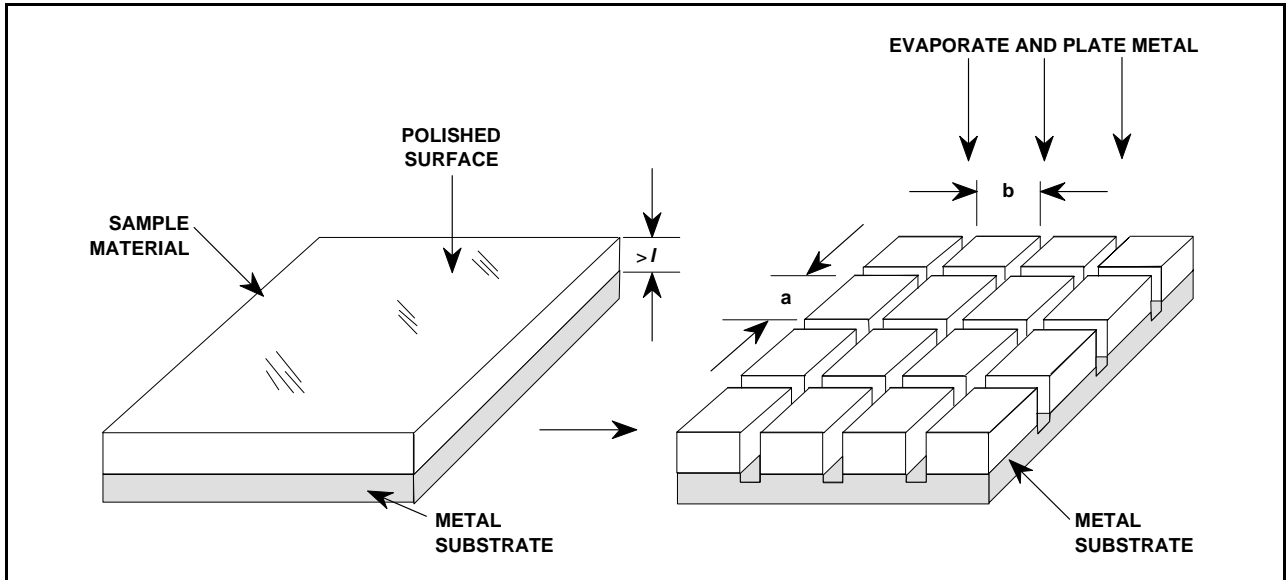
Figure B2. A sample fabrication sequence suitable for sheet dielectrics that are difficult to machine.

Figure B3 shows another technique, whereby the sample is cut accurately to the transverse waveguide dimensions but is otherwise longer than the final dimension, *l*. Metal can be deposited by a simple screening method on all but a small region around the midpoint of the broad dimension parallel to its length. The sample is then soldered into a holder, such as that shown in Figure B1, and the resulting structure is sliced and polished to the dimension *l*.
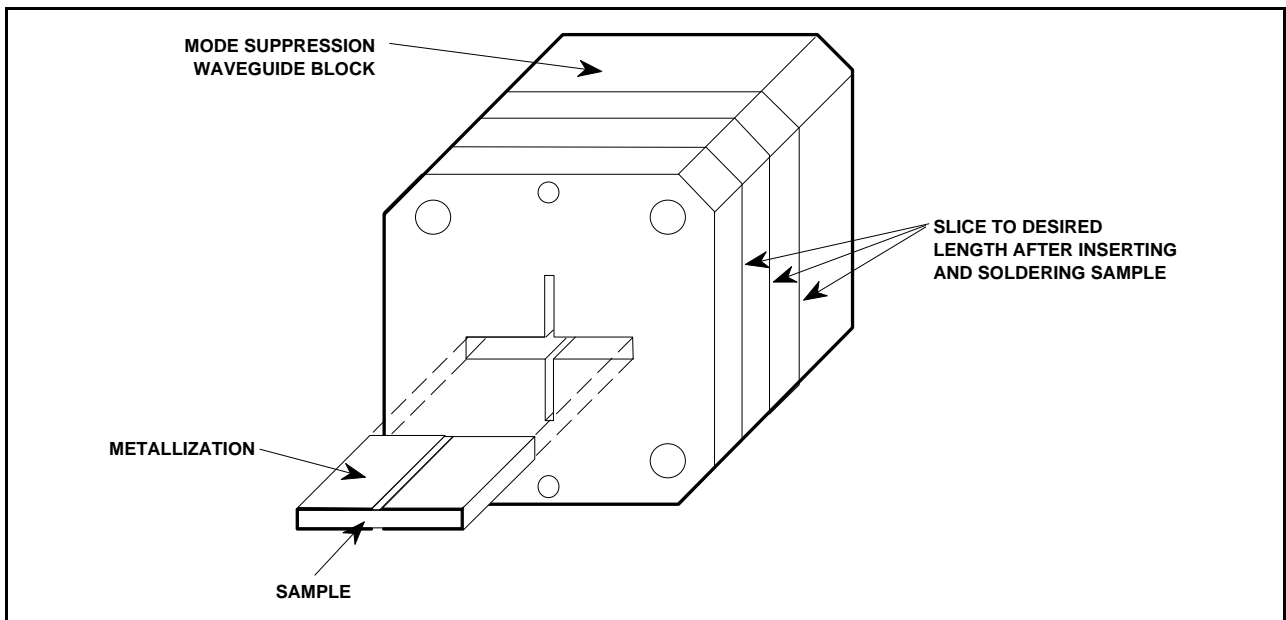
Figure B3. An alternative fabrication method for samples that can be machined and processed readily.

The inadequacy of solders at 800^0C necessitates a different approach in the fabrication of samples for measurements at these temperatures. Our approach is to mill blind wells, somewhat deeper than necessary, into a stainless steel or other refractory metal slab, plasma spray the material to be tested into these wells, and then grind and polish the surface to the correct dimensions, as illustrated in Figure B4.
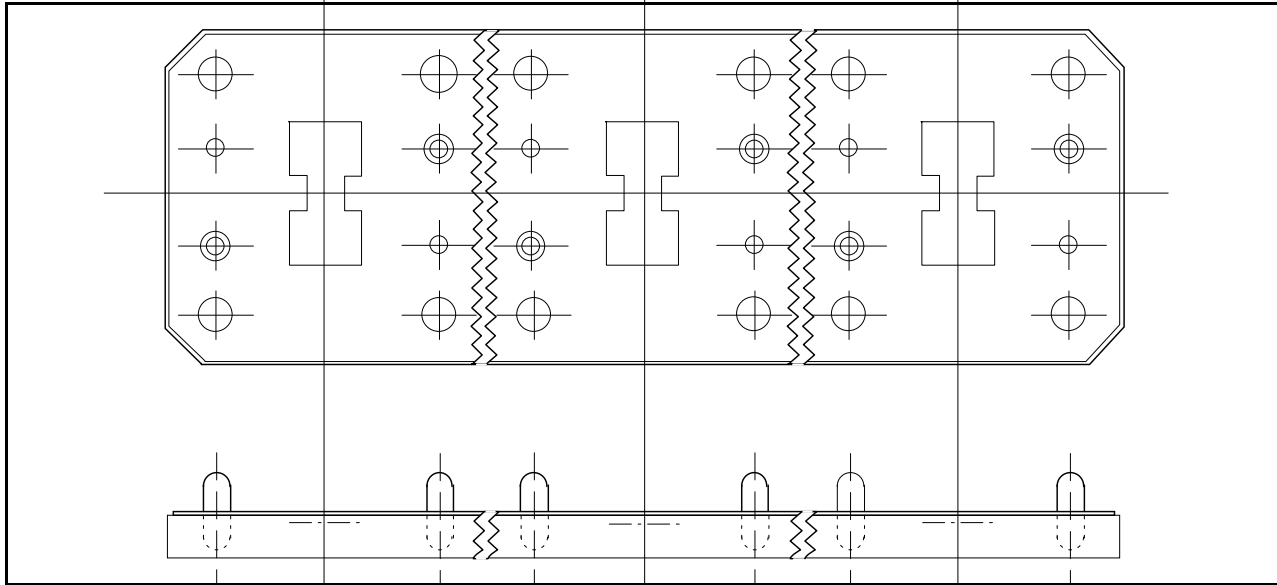
Figure B4.   Plasma-spray the material under test into a blind well of the required shape to prepare test samples for high-temperature measurement.

Appendix C
Installation and Configuration Instructions
for the National Instruments GPIB-PCII/IIA Card
and NI-488 MS-DOS Handler Software
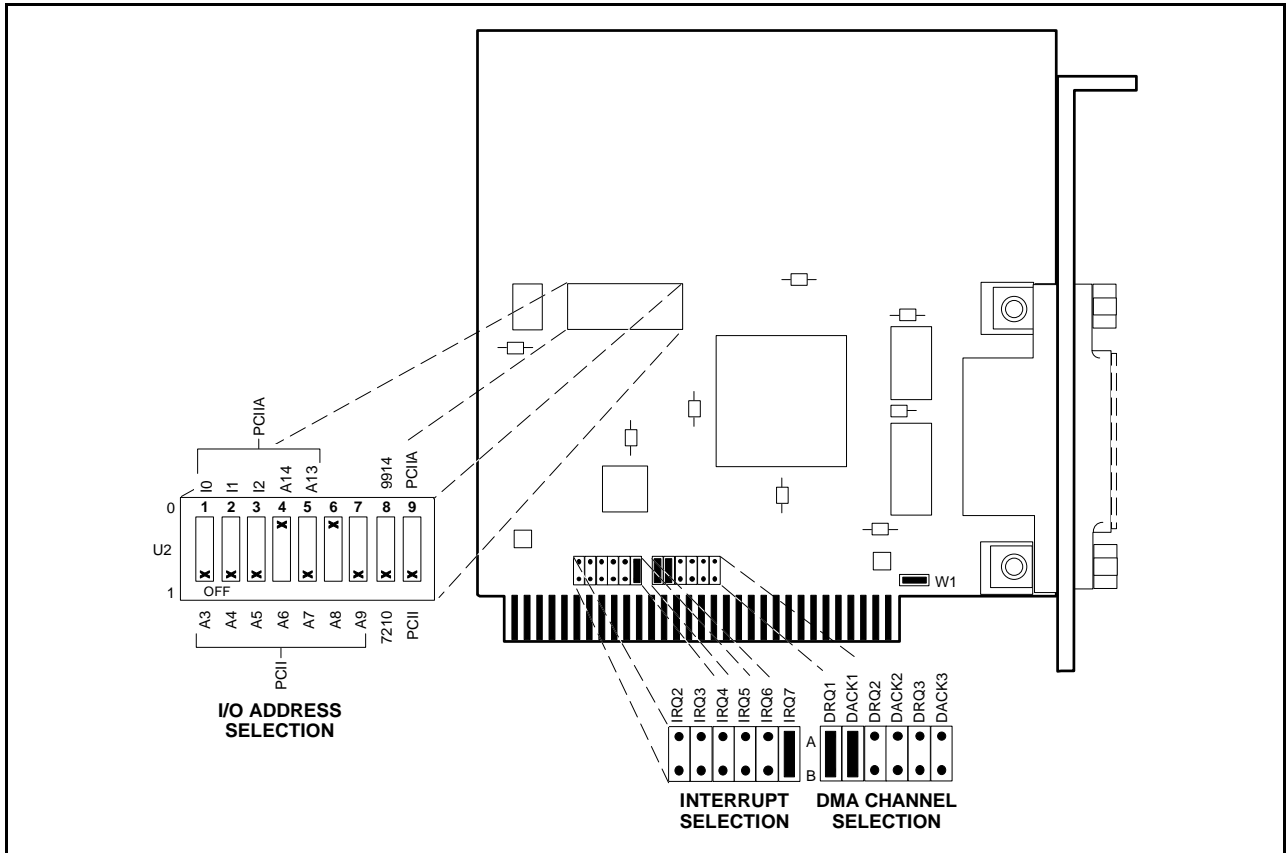
Figure C-1. GPIB-PCII/IIA Hardware Configuration

C1 INSTALLING THE GPIB-PCII/IIA CARD

The following steps provide detailed instructions for installing the National Instruments GPIB-PCII/IIA Interface Card (P/N 181065-02) into a personal computer.

1. Before installation, set the switches and jumpers on the GPIB-PCII/IIA card as shown in the Figure C-1.

2. Turn off the computer and unplug the power cord from the power source.

3. Remove the top cover from the computer and install the GPIB-PCII/IIA card into any unused slot. Install the card with the IEEE-488 connector protruding out of the back panel.

4. Secure the card by fastening the GPIB-PCII/IIA mounting bracket to the back panel rail with a screw, then replace the computer cover.

5. Plug the power cord into the power source and power up (boot) the computer.

C2   INSTALLING AND CONFIGURING THE NI-488 MS-DOS HANDLER SOFTWARE

The following steps provide detailed instructions for installing the NI-488 MS-DOS Handler software in support of the GPIB-PCII/IIA card and for changing the default software configuration options of the handler.

NOTE

When installing the MS-DOS Handler software, use *only* the National Instruments NI-488 Distribution Disk for GPIB-PCII/PCIIA MS-DOS Handler, P/N 420039-09, Revision C.11. Use of any other versions of the GPIB handler software can cause interfacing problems between the handler and the devices on the bus.

1. Insert the NI-488 Distribution Disk for the GPIB-PCII/IIA MS-DOS Handler into the disk drive. At the DOS prompt:
    Type: `A:`
    Press: <ENTER> (The A:\DOS prompt will appear.)

2. Run the installation program IBSTART and specify the start up (boot) drive. For example, if C: is the boot drive, at the DOS prompt:
    Type: `IBSTART C:`
    Press: < ENTER>

3. Follow the instructions on the display. The installation program first copies the files, GPIB.COM and IBCONF.EXE, from the distribution disk to the root directory of the boot drive, then creates the directory GPIB-PC on the boot drive and copies all the files on the distribution disk into this directory. Next the program adds the line, DEVICE = GPIB.COM, to the computer's CONFIG.SYS file so that DOS will load the handler whenever the computer is booted. The program then prompts you to run the hardware diagnostic program (IBDIAG) to insure the GPIB-PCII/IIA card is installed and working properly.

4. Run the software program (IBCONF) to change the default software configuration options of the GPIB handler. At the DOS prompt:
    Type: `IBCONF`
    Press: <ENTER>

5. Follow the instructions on the display. The program firsts displays a device map for the GPIB card (Figure C-2). Select the GPIB-PCII/IIA Card or device whose parameters you wish to display, then press the function key, F8. Change the configuration of the GPIB-PC-II/IIA card to that shown in Figure C-3 and verify the configuration of the device DEV6 matches Figure C-4.

6. Reboot your computer to install the GPIB handler software and the software configuration changes.

7. Run the software diagnostic program (IBTEST) to verify that the GPIB handler software is installed correctly. To do this, at the DOS prompt:
    Type: `CD\GPIB-PC`
    Press: <ENTER>
    Type: `IBTEST`
    Press: <ENTER>
    If errors are encountered, refer to Appendix B of the GPIB-PC Users Manual, that accompanied your GPIB board, for an explanation of the errors and their solutions.

```
╔══════════════════════════════════════════════════════════════════╗
║  National Instruments ║   Device Map for Board GPIB0   ║   IBM PC-AT  ║
╠══════════════════════════════════════════════════════════════════╣

        ┌─────────────┐    * Use cursor control keys to select a device or board.
        │   GPIB0     │    * Use function keys below to select desired action.
        └─────────────┘    * Use PgUp/PgDn to display maps for other boards.

        ┌─▌ DEV1      ┌─▌ DEV5       ┌─▌ DEV9       ┌─▌ DEV13
        │             │              │              │
        ├─▌ DEV2      ├─▌ DEV6       ├─▌ DEV10      ├─▌ DEV14
        │             │              │              │
        ├─▌ DEV3      ├─▌ DEV7       ├─▌ DEV11      ├─▌ DEV15
        │             │              │              │
        └─▌ DEV4      └─▌ DEV8       └─▌ DEV12      └─▌ DEV16



  F1: Help      F4: Rename      F5: (Dis)connect      F8: Edit      F9: Exit
╚══════════════════════════════════════════════════════════════════╝
```
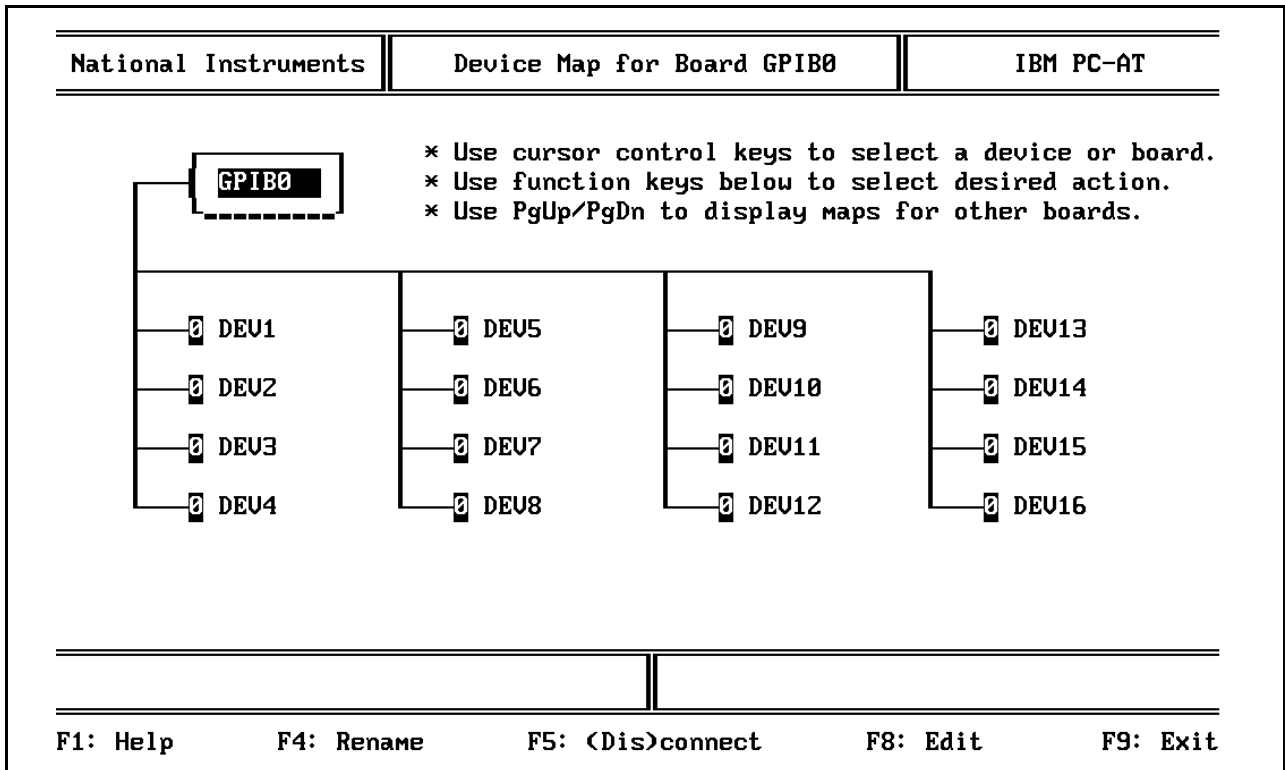
Figure C-2. Device Map for the GPIB-PCII/IIA Card

```
╔══════════════════════════════════════════════════════════════════╗
║  National Instruments ║      Board Characteristics     ║   IBM PC-AT  ║
╠══════════════════════════════════════════════════════════════════╣
  Board: GPIB0                            SELECT (use right/left arrow keys):

  ▐ Primary GPIB Address        ↔ 0 ▌     0 to 30
  Secondary GPIB Address ........ NONE
  Timeout setting ............... T10s
  EOS byte ...................... 00H
  Terminate Read on EOS ......... no
  Set EOI with EOS on Write ..... no
  Type of compare on EOS ........ 7-bit
  Set EOI w/last byte of Write .. yes
  GPIB-PC Model ................. PC2
  Board is System Controller .... yes
  Local Lockout on all devices .. yes
  Disable Auto Serial Polling ... yes
  Disable Device Unaddressing ... no
  High-speed timing ............. no
  Interrupt jumper setting ...... NONE
  Base I/O Address .............. 2B8H
  DMA channel ................... NONE
  Internal Clock Freq (in MHz) .. 8

  F1: Help    F2: Explain Field     F6: Reset Value     F9: Return to Map
╚══════════════════════════════════════════════════════════════════╝
```

Figure C-3. GPIB-PCII/IIA Card Configuration Parameters

```
┌──────────────────────────────────────────────────────────────────────────┐
│ ╔════════════════════════╦═══════════════════════════╦══════════════════╗ │
│ ║ National Instruments   ║   Device Characteristics  ║     IBM PC-AT    ║ │
│ ╚════════════════════════╩═══════════════════════════╩══════════════════╝ │
│ Device: DEV6           Access: GPIB0      │ SELECT (use right/left arrow keys): │
│ ──────────────────────────────────────────┼──────────────────────────────│
│ ▐Primary GPIB Address        ↔ 6▌          │ 0 to 30                        │
│ Secondary GPIB Address ........ NONE       │                                │
│ Timeout setting ............... T10s       │                                │
│ EOS byte ...................... 0AH        │                                │
│ Terminate Read on EOS ......... no         │                                │
│ Set EOI with EOS on Write ..... no         │                                │
│ Type of compare on EOS ........ 7-bit      │                                │
│ Set EOI w/last byte of Write .. yes        │                                │
│                                            │                                │
│                                            │                                │
│                                            │                                │
│                                            │                                │
│                                            │                                │
│                                            │                                │
│                                            │                                │
│ ──────────────────────────────────────────────────────────────────────── │
│ F1: Help      F2: Explain Field      F6: Reset Value      F9: Return to Map │
└──────────────────────────────────────────────────────────────────────────┘
```

Figure C-4.   GPIB Device 6 (360 VNA) Configuration Parameters