HEWLETT PACKARD

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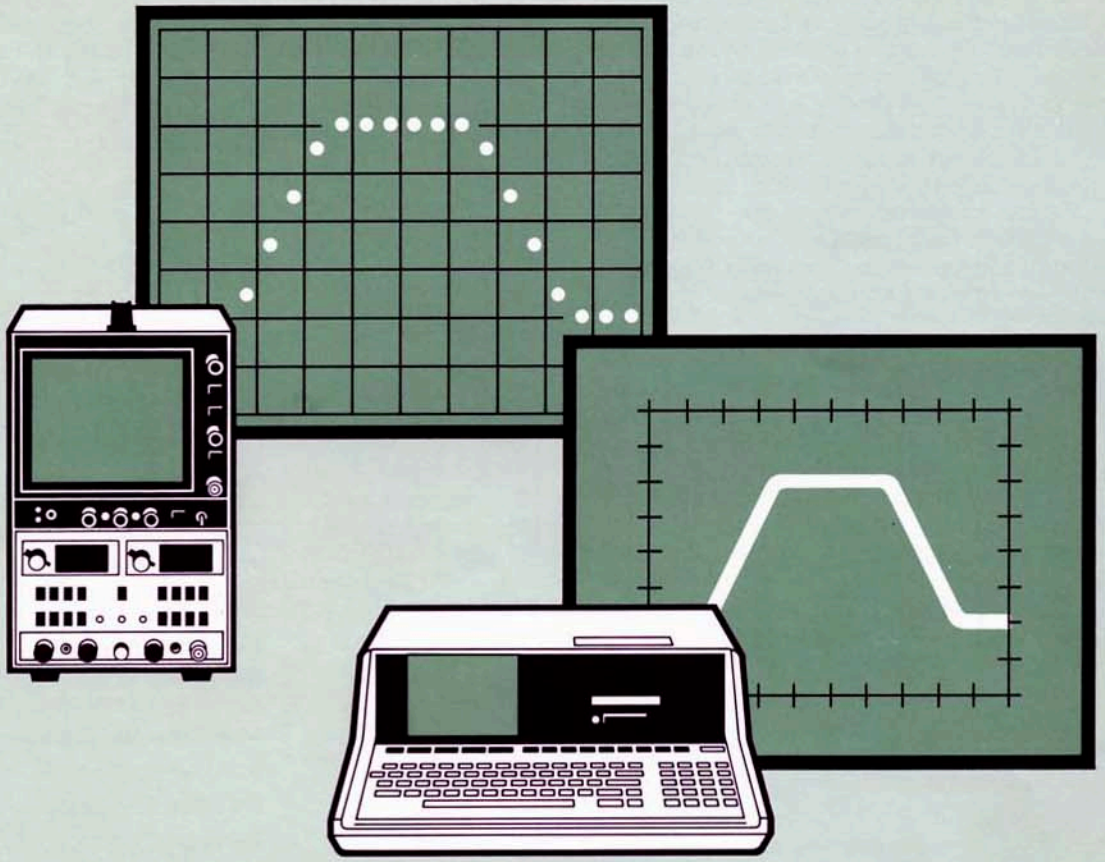

AUTOMATING THE HP 8755 SCALAR NETWORK ANALYZER

PREFACE

This application note describes an economical computer controlled scalar network measurement system using the HP 8755S Frequency Response Test Set, the HP 8350A Sweep Oscillator, the HP 59313A Analog to Digital Converter, and the HP 85A Computing Controller. When the HP 83592A Sweep Oscillator Plug-in is used with the 8350A, the system is capable of making insertion loss measurements over a frequency range of 0.01 to 20 GHz and return loss measurements over a range of 0.04 to 18 GHz. Other plug-ins offer different frequency coverage (up to 22 GHz) and different power levels (up to +17 dBm) for specific applications.

System control is provided through the Hewlett-Packard Interface Bus, or HP-IB. HP-IB is not just IEEE-488, but the hardware, documentation, and support that delivers the shortest path to a measurement system. Because it's computer controlled, this system can make transmission and reflection measurements quickly and with reduced chance of operator error. The computer improves the accuracy of the system by measuring known standards at each frequency of interest and using this information to correct the measured insertion or return loss of the test device. In addition to increasing the measurement accuracy, the computer can print or display automatically scaled graphical plots or data tables of device response versus frequency. The sample program included in this note demonstrates the capabilities of the system and provides a starting point to those who want to create programs tailored to their specific measurement needs.

INTRODUCTION

All scalar network analyzer systems comprise at least three pieces: a source, a signal separation device, and a receiver/display system. The source provides the "stimulus" or incident RF signal for the device under test. Since measurements are to be made over some frequency span, the stimulus normally is an electronically tuned source. The test device can respond to the stimulus in three ways: it can transmit, reflect, or absorb the incident signal (a typical test device will do all three). The signal separation device is required to separate the reflected from the incident signal. Transmitted and reflected signals are then detected and displayed by the receiver/display (or Frequency Response Test Set). Usually, the Frequency Response Test Set will display a trace of insertion and/or return loss versus frequency on a CRT. This constitutes a manually-operated scalar network analyzer.

With the addition of a computer or "controller" the measurement system becomes largely automatic. In setting up and calibrating the system, the operator interacts with the system by following computer-displayed instructions. The computer tunes the source to each frequency of interest and reads the value of the incident, transmitted, and reflected signals from the Frequency Response Test Set. As the data is collected by the computer, it is corrected with the aid of previously stored calibration data. The corrected insertion and/or return loss data is reformatted and presented in the form of a graph or a table.

In operation, this computer controlled scalar network analyzer makes a measurement in four stages (see Figure 1). First, the measurement must be defined by the parameters to be measured (insertion loss, return loss, or both), the frequency range of interest, and the number of data points to be measured. Next, the response of known standards is measured to calibrate the system at each desired test frequency. The test device is then measured and the data is corrected by the controller (using the stored calibration data). Finally, the controller displays and/or prints the test data as a graphical plot, a table of values, or both. Since the system is still calibrated, subsequent devices can be measured (at the same test frequencies) with no need to remeasure the standards.

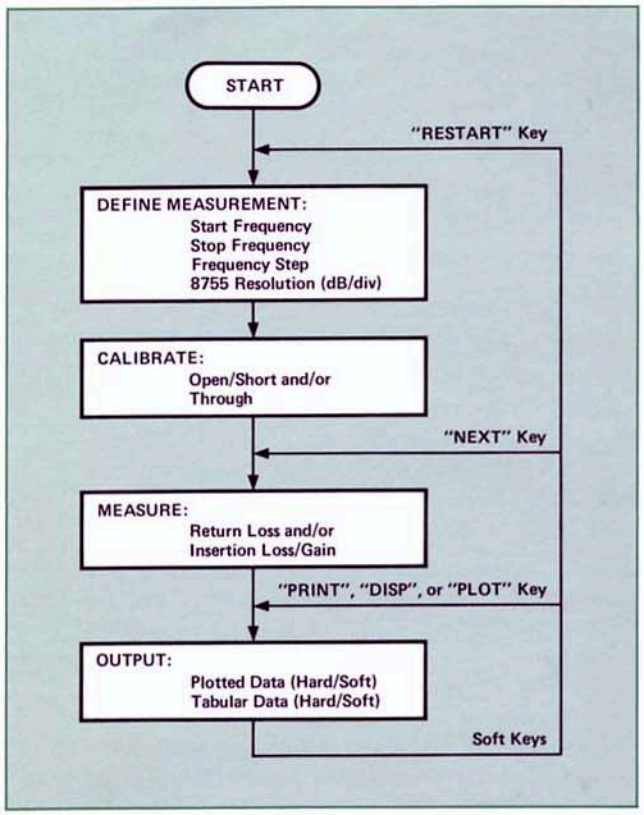

Figure 1. Typical Measurement Sequence.

EQUIPMENT DESCRIPTION

Table 1. Required Equipment.

Quantity	HP Part No.	Description
1	8755S Opt 002	Frequency Response Test Set. Includes 8755C, 182T CRT display, 11666A Reflectometer Bridge, 11664A Detector, and 8750A Normalizer.
1	8350A	Sweep Oscillator mainframe. Includes one HP 10631B two meter HP-IB cable.
1	83592A	Sweep Oscillator Plug-in. Frequency range of 10 MHz to 20 GHz.
1	HP 85F	Computing Controller. Includes 82937A HP-IB Interface, 00085-15003 I/O ROM, and 82936A ROM Drawer.
1	82903A	16K Memory Module. Strongly recommended, but not required by the system.
1	00085-15002	Printer/Plotter ROM. Required.
1	59313A[1]	Analog to Digital Converter.
2	11170A	BNC cables, 1 foot length.
4	11170C	BNC cables, 2 foot length.
2	1250-0781	BNC "T" adapters, female-male-female.
1	Calibration kit consisting of:	
1	85032-60001	Type-N shielded open circuit.
1	11512A	Type-N short circuit.
1	909A	Type-N 50Ω termination.
1	1250-1472	Type-N female-female adapter.
2	1250-1475	Type N male-male adapter.

[1]The HP 47310A Analog to Digital Converter may be substituted.

The Receiver/Display

The HP 8755S Frequency Response Test Set is designed specifically for making microwave scalar measurements. Employing Schottky diode detection, it has three detector inputs (A, B, and R), each with 60 dB of calibrated dynamic range (+10 dBm to −50 dBm). For improved performance, the 8755S uses an amplitude modulated RF test signal, which is demodulated by the diode detector and then processed in the 8755S. In testing amplifiers and mixers that add noise and unwanted signals, modulation can improve the effective dynamic range of the measurement. The absolute signal level or the ratio of two detector inputs is displayed on the CRT and is available on the rear panel as a calibrated (dB) analog voltage. Although the 8755S is not directly programmable, data can be read from the 8755S by monitoring the rear panel voltages with an HP-IB Analog to Digital Converter (A/D).

The Signal Separation Device

The HP 11666A Reflectometer Bridge functions as a signal separation device, separating the reflected from the incident signal and permitting simultaneous transmission and reflection measurements. It has an extremely broad, flat frequency response (0.04 to 18 GHz) and it is very compact and rugged. Two Schottky diode detectors are built into the 11666A, for the R and A detector inputs of the 8755S. The 11666A may be used alone for reflection-only measurements, or with one detector (HP 11664A) for simultaneous reflection and transmission measurements. For transmission-only measurements, a power splitter (HP 11667A) and two detectors (HP 11664A) may be substituted for the Bridge yielding a cost savings and greater dynamic range.

The Source

The source for this system is the HP 8350A Sweep Oscillator mainframe and the HP 83592A Plug-in. Together they form a completely programmable sweeper that can produce a +10 dBm signal over a frequency range of 0.01 to 20 GHz. All controls and settings are accessible through HP-IB commands: sweep mode, frequency span, frequency markers, sweep time, and even power level on the 83500 series Plug-ins. It also has a 27.8 kHz modulator built in, to provide the properly modulated RF test signal for the 8755S. The 8350A mainframe may be used with any of the 83500 series Plug-ins, or any of the 86200 series Plug-ins with an HP 11869A Adapter. Some plug-ins produce enough power (+17 dBm) to take advantage of the full dynamic range of the 8755S even when system losses due to power splitters and bridges are included.

The A/D

Analog to digital conversion is performed by the HP 59313A A/D Converter. Four separate input channels and an HP-IB interface make this A/D especially useful. Each channel is independent and can be set for ±1, ±2.5, ±5, or ±10 volts full scale. Within each range, the 59313A has 0.1% resolution.

The Controller

Instrument control, data computation, and output for the system is provided by the economical HP 85A Computing Controller. The HP 85A is a complete computer with a CRT screen, a full-size typewriter-style keyboard, a 32-column thermal printer, and a 200K byte tape cartridge drive built into a compact and attractive desktop enclosure. The HP 85A programs in easy-to-learn HP Enhanced BASIC with special commands for graphics and HP-IB operations. The HP 85F, listed in Table 1, provides system control with the HP 85A, the HP-IB Interface, and the I/O ROM (these accessories are required for the system).

SYSTEM CONNECTION

Connect the system as shown in Figure 2 and set the controls as follows:

CHANNEL 1 ..... A/R
CHANNEL 2 ..... B/R
VERTICAL RESOLUTION (dB/div) ....0.25, 1, 5, or 10
REFERENCE OFFSET VERNIERS ..... OFF
REFERENCE POSITION LINE .....see Operation section of this note

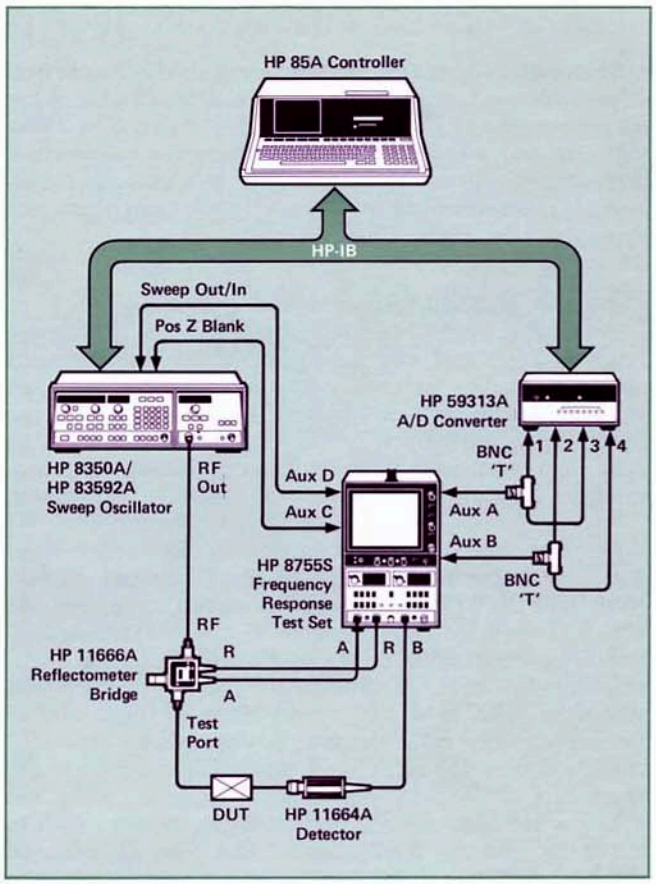

Figure 2. Connection Diagram.

In this application, Channel 1 of the 8755S is used for reflection measurements and Channel 2 is used for transmission measurements. The vertical resolution (dB/DIV) of the 8755S can be set to any value as long as both channels are set the same. To prevent accidentally uncalibrating the system during measurement, it is recommended that the Reference Level Offset verniers be turned off before running the system. See the Operation section of this note for instructions on setting the Reference Position line.

Make certain the HP-IB address of the 8350A sweeper is set to 19 (decimal) by pressing SHIFT, LCL and observing the HP-IB address that appears in the FREQUENCY/TIME display on the 8350A. If the HP-IB address is not 19, refer to the 8350A Operating and Service Manual for instructions on changing it.

Set the sensitivity of the 59313A A/D so that channels 1 and 2 respond to ±1 volt full scale and channels 3 and 4 respond to ±5 volts full scale, and set the HP-IB address to 10 (decimal) according to the instructions in the 59313A Operating and Service Manual. The A/D must be calibrated before making any measurements, and should be recalibrated periodically. Refer to Appendix II of this note for a calibration program and instructions for using it.

The Select Code of the HP-IB Interface for the HP 85A (HP 82937A) must be set to 7 (decimal). Refer to the operating information supplied with the interface for instructions.

SYSTEM OPERATION

The operation of this system is relatively simple and straightforward, because much of the detail of making measurements is handled by the controller. The tasks that remain for the operator to perform are broken into three types; those done when the system is first connected, those done when the system is turned on, and those done for each measurement.

When the System Is Connected

When the system is first connected, the Reference Position Line and the Reference Level thumbwheels must be set. The Reference Position Line of the 8755S may be set to any convenient graticule line on the screen, but normally it is best left at midscreen. The A/D can read the value of the loss even when the measurement falls off the screen of the 8755S.

One consideration when setting the Reference Position Line is the effect it has on the resolution of data read from the 8755S. Each analog output voltage of the 8755S is read by two channels of the 59313A A/D; a parallel connection of a ±1V and a ±5V full scale channel. The ±1V channel can read the outputs of the 8755S when the beam is within ±2 divisions of the center of the screen. The ±5V channel can read the outputs of the 8755S over the full screen, but it has one-fifth of the resolution of the ±1V channel. For example, when the 8755S is set to 10 dB/div, the ±1V channel can read to ±0.02 dB and the ±5V channel can read to ±0.1 dB resolution. The software effectively "autoranges" the A/D to always read the data to the greatest possible resolution. For those measurements that demand the greatest resolution, set the Reference Position Line so that the calibration and test data fall within the range of the ±1V channel of the A/D (±2 divisions from the center of the screen).

During calibration, when the short or the through is first attached but before it is measured, use the Reference Offset thumbwheels to put the trace on the same graticule as the Reference Position Line. The location of the Reference Position Line isn't critical, as long as the output voltages of the 8755S stay within the range of the A/D during measurement. After adjusting the thumbwheels once, they need not be adjusted again.

When the System Is Turned On

Each time the system is turned on, the measurement program is loaded into the HP 85A by using the built-in data cartridge drive. If you have a data cartridge with the measurement program on it (HP 08755-10001) simply insert the data cartridge into the HP 85A and turn it on. The program is stored under the name "Autost", so it is automatically loaded and executed when the HP 85A is turned on. Alternatively, you may type LOAD "Autost" and press END LINE to load the program, and press the RUN key to begin execution. If you don't have the program already on tape, then refer to Appendix I for a complete program listing. After entering the program, store it under the name "Autost" to take advantage of the autostart feature of the HP 85A controller described above.

Should the program stop running for any reason, such as accidentally touching the keyboard of the HP 85A, the program may often be restarted without losing data by pressing the CONT (continue) key. Should this fail, typing CONT 350 followed by END LINE will restart the program at the plot/print menu (see Screen 7). **CAUTION: If you press the RUN key to restart the program, the computer will lose all stored calibration and measurement data.**

For Each Measurement

When the measurement program is running, the HP 85A prompts the operator to provide the information needed to make measurements. The following paragraphs are a description of the prompts and the information required:

This is a soft key menu. The labels at the bottom of the screen of the HP 85A correspond to the row of four keys just below the screen. Labels k1 through k4 represent unshifted keys and k5 through k8 represent shifted keys. Press the soft key that corresponds to the measurement you wish to make.

```
SELECT MEASUREMENT:

k1: Insertion loss

k2: Return loss

k3: Both




--------------------------------

  INS      RET      BOTH
```

Enter the start frequency, stop frequency, and frequency step for your measurement in GHz. You can measure up to 500 points of insertion or return loss, or 250 points of both. The controller will not accept a stop frequency that is lower than the start frequency or a combination of start frequency, stop frequency, and frequency step that exceeds the maximum allowable number of points. Set both channels of the 8755S to the same resolution (dB/div).

```
              DATA ENTRY

  All frequencies are entered in
  GHz.  Set both channels of the
  8755S to the same sensitivity

START Frequency (GHz)
?
STOP Frequency (GHz)
?
Frequency STEP (GHz)
?
8755 Sensitivity (dB/DIV)
?
```

This is the return loss calibration routine. It is called when return loss measurements are requested. When the prompt appears, connect a short circuit to the test port of the Reflectometer Bridge and press the CONT (continue) key. Next, connect a shielded open to the test port and press the CONT key. A shielded open is preferable to an open connector at high frequencies (above 12 GHz) because it radiates less power and so behaves more like an ideal open circuit.

```
RETURN LOSS CALIBRATION

Connect a SHORT circuit to the
Test Port and press CONT.

Taking data...

Connect a shielded OPEN circuit
to the Test Port and press CONT

Taking data...
```

This is the insertion loss/gain calibration routine. It is called when insertion loss measurements are requested. Connect the "B" detector to the test port of the bridge and press the CONT key.

```
INSERTION LOSS CALIBRATION

Connect the B detector to the
Test Port and press CONT.

Taking data...
```

Connect the device under test (DUT) to the test port. If measuring insertion loss, connect the "B" detector to the output of the device. The test device must be terminated with a detector or load resistor even when making only return loss measurements. When measuring high return loss on a two-port device, a good load resistor should be used to terminate the device. The data output may be labeled with any combination of letters and numbers up to 32 characters. After entering the label, press the END LINE key.

```
DEVICE MEASUREMENT

Connect the Test Device to the
Test Port and press CONT.


Enter the Device label (up to
32 alphanumeric characters) and
press the END LINE key.
?
Taking data...
```

This menu appears after the test data has been taken. The data may be plotted or displayed on the screen of the HP 85A, or printed on the internal printer. The NEXT key (k4) will begin another measurement sequence using the same frequency points and calibration data. To redefine the measurement parameters, select the RESTART key (k8). New calibration data is taken when the RESTART key is selected.

```
SELECT FUNCTION :

k1: PLOT data and halt program.
    Press (COPY) for hard plot.
    Press (CONT) to resume.

k2: DISPlay tabular data.

k3: PRINT tabular data.

k4: Make NEXT measurement.

k8: RESTART program and recal.
--------------------------------
                          RESTART
 PLOT     DISP     PRINT   NEXT
```

The plots produced by the HP 85A are automatically scaled and positioned so that data takes up the full plotting area (see Figure 3). The vertical scale is always calibrated in dB and the horizontal scale is calibrated in GHz. At the bottom of the plot, the start and stop frequencies as well as the frequency increment per division are given.

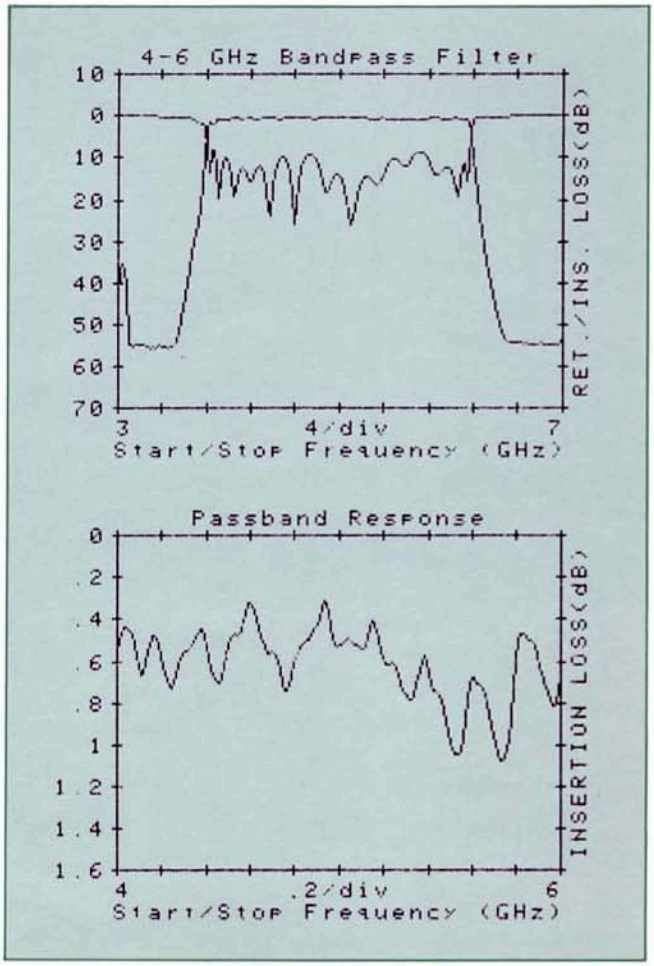

Figure 3. Plotted Data.

When displaying tabular data on the screen, the program displays one screen (16 lines) at a time (Figure 4). Pressing the CONT key will bring another screen of data, until all the data has been displayed. When printed, the tabular data is printed continuously until finished (Figure 5).

Frequency (GHz)	Insertion (dB)	Reflection (dB)
3.00	-41.44	.04
3.20	-55.14	.10
3.40	-55.30	-.11
3.60	-45.08	-.53
3.80	-1.10	-9.97
4.00	-.56	-14.47
4.20	-.56	-16.76
4.40	-.50	-16.67
4.60	-.30	-23.56
4.80	-.62	-12.33
5.00	-.52	-15.47

Press CONT...

Figure 4. Displayed Data.

4-6 GHz Bandpass Filter

Frequency (GHz)	Insertion (dB)	Reflection (dB)
3.00	-41.44	.04
3.20	-55.14	.10
3.40	-55.30	-.11
3.60	-45.08	-.53
3.80	-1.10	-9.97
4.00	-.56	-14.47
4.20	-.56	-16.76
4.40	-.50	-16.67
4.60	-.30	-23.56
4.80	-.62	-12.33
5.00	-.52	-15.47
5.20	-.60	-15.94
5.40	-.62	-13.56
5.60	-.66	-11.61
5.80	-.60	-11.46
6.00	-.66	-13.26
6.20	-12.22	-.50
6.40	-46.38	-.31
6.60	-54.58	-.01
6.80	-55.00	.12
7.00	-53.30	-.06

Figure 5. Printed Data.

SOFTWARE OVERVIEW

The first step in making a measurement is to define the parameters to be measured. Possible measurements include insertion loss/gain, return loss, or both. In any event, the system must know the start and stop frequencies for the measurement and the frequency step between points to be measured.

Two separate calibration routines are used for insertion loss and return loss measurements. Insertion loss measurements are calibrated with a "through." Data is taken at each frequency point of interest by setting the frequency of the sweeper and reading the desired outputs of the 8755S. This data is stored as a reference and used to remove the transmission path frequency response errors of the system.

Return loss measurements are calibrated with an open/short averaging technique. A short circuit and an open circuit are measured at the test port for each frequency of interest. The linear average of the open and short (not the dB average) is stored as the return loss calibration. Subtracting the calibration data from the test data removes the reflection path frequency response errors as well as calibration error due to directivity and source mismatch.

After calibration, the system is ready to measure the test device. Again, the sweeper is tuned to each frequency of interest and the desired outputs of the 8755S are read into the controller. The calibration data points are subtracted from the measured test data. The data (insertion loss, return loss, or both) is now ready to be formatted and presented.

The controller uses the test data to generate either a graphical plot or a table of values. If a plot is selected, the controller uses the internal CRT as a plotter and creates a graphical presentation of the test device characteristics. The user may transfer this plot directly to the internal printer if hardcopy is desired. Tabular data may be generated for the same test device, again with the option of sending the formatted test results to the CRT or the printer.

Appendix I of this note contains a complete annotated listing of the measurement program and a list of all of the variables used in the program and their function. The measurement program is quite modular and is easily modified by the user of the system. If you choose to use the HP 8620C Sweep Oscillator mainframe instead of the 8350A, the necessary changes in configuration and software can be found in Appendix III.

APPENDIX I
PROGRAM LISTING[1]

```
100 ! ------- AN 155-3 --------
110 !
120 ! Last changed 10/21/80 JAB
130 !
140 ! Uses: 8350A,8755C,47310A
150 !       Any Sweeper Plug-in
160 !
170 ! HP 85A must have:
180 !       HP-IB Interface
190 !       I/O ROM
195 !       Print/Plot ROM
200 !       At Least 16K RAM
210 !
220 ! -------------------------
230 !       MAIN PROGRAM
240 ! -------------------------
250 !
260 GOSUB 670 ! INITIALIZE
270 GOSUB 830 ! PLUG-IN
280 GOSUB 950 ! START/STOP
290 IF N#1 THEN GOSUB 1370 ! REF
300 IF N#2 THEN GOSUB 1670 ! INS
310 GOSUB 1870 ! MEASURE
320 !
330 ! Soft-key menu for output
340 !
350 BEEP                                   ┐
360 CLEAR                                  │
370 DISP "SELECT FUNCTION :"               │
380 DISP                                   │
390 DISP "k1: PLOT data and halt program." │
400 DISP "    Press (COPY) for hard plot." │
410 DISP "    Press (CONT) to resume."     │ ....Display menu
420 DISP                                   │
430 DISP "k2: DISPlay tabular data."       │
440 DISP                                   │
450 DISP "k3: PRINT tabular data."         │
460 DISP                                   │
470 DISP "k4: Make NEXT measurement."      │
480 DISP                                   │
490 DISP "k8: RESTART program and recal."  ┘
500 ON KEY# 1," PLOT" GOTO 2230    ┐
510 ON KEY# 2," DISP" GOTO 3170    │
520 ON KEY# 3," PRINT" GOTO 3330   │ ....Key labels and branch line numbers
530 ON KEY# 4," NEXT" GOTO 310     │
540 ON KEY# 8,"RESTART" GOTO 570   ┘
550 KEY LABEL
560 GOTO 560 ....Loop until soft key is pressed
570 OFF KEY# 4
580 OFF KEY# 8
590 GOTO 280
600 !
610 ! -------------------------
620 !         SUBROUTINES
630 ! -------------------------
640 !
650 !         <INITIALIZE>
660 !
670 OPTION BASE 1
680 DIM S$[32],P$[24]  ┐ ....Dimension variables
690 SHORT R(1000),D(8) ┘
700 SET TIMEOUT 7;5000     ┐ ....HP-IB error trapping
710 ON TIMEOUT 7 GOTO 3690 ┘
720 ABORTIO 7
```

[1]This program is available on a tape cartridge from Hewlett-Packard. Order part number HP 08755-10001.

```
730 CLEAR 7
740 LOCAL 7
750 REMOTE 7
760 S0=719 ! Sweeper Select
770 A0=710 ! A/D Select
780 CRT IS 1
790 RETURN
800 !
810 !   <PLUG-IN BAND LIMITS>
820 !
830 OUTPUT S0 ;"IP"..........Preset Sweeper
840 OUTPUT S0 ;"OPFA"..........Interrogate Start Frequency
850 ENTER S0 ; L
860 L=L/1000000000..........Store as Low Frequency limit
870 OUTPUT S0 ;"OPFB"..........Interrogate Stop Frequency
880 ENTER S0 ; U
890 U=U/1000000000..........Store as High Frequency limit
900 OUTPUT S0 ;"MD1FI0ST100MS"..........Modulation on, CW Filter off, Sweep time 100ms
910 RETURN
920 !
930 !       <DATA ENTRY>
940 !
950 CLEAR
960 DISP "SELECT MEASUREMENT:"
970 DISP
980 DISP "k1: Insertion loss"
990 DISP                                  ..........Display menu
1000 DISP "k2: Return loss"
1010 DISP
1020 DISP "k3: Both"
1030 ON KEY# 1,"  INS" GOTO 1080
1040 ON KEY# 2,"  RET" GOTO 1090          ..........Key labels and branch line numbers
1050 ON KEY# 3," BOTH" GOTO 1100
1060 KEY LABEL
1070 GOTO 1070..........Loop and wait for soft key
1080 N=1 @ GOTO 1110..........For Insertion Loss only
1090 N=2 @ GOTO 1110..........For Return Loss only
1100 N=3..........Both Insertion and Return Loss
1110 CLEAR
1120 DISP "            DATA ENTRY"
1130 DISP
1140 DISP " All frequencies are entered in"
1150 DISP " GHz.  Set both channels of the"
1160 DISP " 8755S to the same sensitivity."
1170 DISP
1180 DISP "START Frequency (GHz) ";
1190 INPUT A                              ..........Enter Start Frequency
1200 IF A>U OR A<L THEN BEEP @ GOTO 1180..........Compare it to Plug-in frequency range
1210 DISP "STOP Frequency (GHz) ";
1220 INPUT B                              ..........Enter Stop Frequency
1230 IF B>U OR B<L THEN BEEP @ GOTO 1210..........Compare it to Plug-in range
1240 IF A>B THEN BEEP @ GOTO 1110..........Stop must be higher than Start frequency
1250 DISP "Frequency STEP (GHz) ";
1260 INPUT C
1270 P=(B-A)/C+1..........Calculate number of frequency points
1280 IF P<=1 OR P>500-(N=3)*250 THEN BEEP @ GOTO 1250..........500 points of Insertion or Return Loss,
1290 DISP "8755 Sensitivity (dB/DIV) ";                        250 points of both
1300 INPUT S
1310 S=S/100
1320 GOSUB 3990 ! Start/Stop
1330 RETURN
1340 !
1350 !    <RETURN LOSS CAL.>
1360 !
1370 CLEAR
1380 DISP "    RETURN LOSS CALIBRATION"
1390 DISP
1400 DISP "Connect a SHORT circuit to the"  ..........Prompt message
1410 DISP "Test Port and press CONT."
1420 BEEP
```

```
1430 PAUSE
1440 DISP "Taking data..."
1450 FOR I=0 TO 1.....Outer loop, I = 0 for short, I = 1 for open
1460 GOSUB 3950 ! CW mode
1470 FOR X=1 TO P.....Inner loop, done for each frequency point
1480 C2=1.....Select channel for A/R
1490 GOSUB 3800 ! Read A/D
1500 GOSUB 3880 ! Increment F
1510 IF I=0 THEN R(X)=R2 ELSE R(X)=20*LGT((10^(R(X)/20)+10^(R2/20))/2).....Linear average of
1520 NEXT X                                                                  short & open
1530 IF I=1 THEN 1620
1540 GOSUB 3990 ! Start/Stop
1550 DISP
1560 DISP "Connect a shielded OPEN circuit"
1570 DISP "to the Test Port and press CONT."  .....Prompt message
1580 BEEP
1590 PAUSE
1600 DISP "Taking data..."
1610 NEXT I
1620 GOSUB 3990 ! Start/Stop
1630 RETURN
1640 !
1650 !   <INSERTION LOSS CAL.>
1660 !
1670 CLEAR
1680 DISP "  INSERTION LOSS CALIBRATION"
1690 DISP
1700 DISP "Connect the B detector to the"  .....Prompt message
1710 DISP "Test Port and press CONT."
1720 BEEP
1730 PAUSE
1740 DISP "Taking data..."
1750 GOSUB 3950 ! CW mode
1760 FOR X=1 TO P.....Loop. Done for each frequency point
1770 C2=2.....Select channel for B/R
1780 GOSUB 3800 ! Read A/D
1790 GOSUB 3880 ! Incr. F
1800 IF N=3 THEN R(X+P)=R2 ELSE R(X)=R2.....Store in calibration array
1810 NEXT X
1820 GOSUB 3990 ! Start/Stop
1830 RETURN
1840 !
1850 !    <DEVICE MEASUREMENT>
1860 !
1870 CLEAR
1880 DISP "       DEVICE MEASUREMENT"
1890 DISP
1900 DISP "Connect the Test Device to the"  .....Prompt message
1910 DISP "Test Port and press CONT."
1920 BEEP
1930 PAUSE
1940 DISP
1950 DISP "Enter the Device label (up to "
1960 DISP "32 alphanumeric characters) and"  .....Prompt message
1970 DISP "press the END LINE key."
1980 INPUT S$.....Get the name of the device
1990 DISP "Taking data..."
2000 M1=-INF @ M2=INF.....Initialize the max and min loss values
2010 GOSUB 3950 ! CW mode
2020 FOR X=1 TO P.....Loop. Done for each frequency point
2030 IF N=1 THEN C2=2 ELSE C2=1.....Select A/R or B/R Channel
2040 GOSUB 3800 ! Read A/D
2050 X1=X+P+(N=3)*P.....Calculate array index
2060 R(X1)=R2-R(X).....Store corrected loss
2070 M1=MAX(M1,R(X1))
2080 M2=MIN(M2,R(X1)).....Compare with max and min loss
2090 IF N#3 THEN 2160.....If both Insertion and Return Loss are requested, continue
2100 C2=2.....Select B/R Channel
2110 GOSUB 3800 ! Read A/D
2120 X1=X+3*P.....Calculate array index
```

```
2130 R(X1)=R2-R(X+P)..........Store corrected loss
2140 M1=MAX(M1,R(X1))
2150 M2=MIN(M2,R(X1))..........Compare with max and min loss
2160 GOSUB 3880 ! Incr. Freq
2170 NEXT X
2180 GOSUB 3990 ! Start/Stop
2190 RETURN
2200 !
2210 !       <PLOT DATA>
2220 !
2230 GOSUB 2350 ! Initialize
2240 GOSUB 2470 ! Compute scale
2250 GOSUB 2580 ! Label scale
2260 GOSUB 2700 ! Label freq.
2270 GOSUB 2870 ! Label dev.
2280 GOSUB 2940 ! Label loss
2290 GOSUB 3050 ! Plot data
2300 PAUSE
2310 GOTO 360 ! Return
2320 !
2330 !        Initialize
2340 !
2350 GRAPH
2360 GCLEAR
2370 SCALE -185,1065,-1150,100
2380 PEN 1
2390 XAXIS -1000,100,0,1000
2400 YAXIS 1000,125,-1000,0..........Draw a box
2410 XAXIS 0,-100,0,1000
2420 YAXIS 0,-125,-1000,0
2430 RETURN
2440 !
2450 !      Compute Scale
2460 !
2470 FOR I=1 TO 8..........Loop and read full scale range values
2480 READ M3
2490 IF M3>=M1-M2+M3/10 THEN GOTO 2510..........Pick the smallest range that will fit the data
2500 NEXT I
2510 RESTORE 2520
2520 DATA .8,1.6,4,8,16,40,80,160..........Possible full scale ranges
2530 M4=(M1+M2)/2-(M1+M2)/2 MOD (M3/8)+M3/2..........Calculate the highest value on the plot
2540 RETURN
2550 !
2560 !        Label Scale
2570 !
2580 M5=M4..........Start at the top of the plot
2590 LDIR 0..........Define label origin and direction
2600 LORG 8
2610 FOR I=0 TO -1000 STEP -125
2620 MOVE -30,I
2630 LABEL VAL$(ABS(M5))..........Loop and label each division
2640 M5=M5-M3/8
2650 NEXT I
2660 RETURN
2670 !
2680 !      Label Frequency
2690 !
2700 LDIR 0
2710 LORG 3
2720 MOVE 0,-1030
2730 LABEL VAL$(A)..........Label Start frequency
2740 MOVE 1000,-1030
2750 LORG 9
2760 LABEL VAL$(B)..........Label Stop frequency
2770 T$=VAL$((B-A)/10)&"/div"
2780 LORG 6
2790 MOVE 500,-1030
2800 LABEL T$
2810 MOVE 500,-1095..........Label Frequency Step
2820 LABEL "Start/Stop Frequency (GHz)"
```

```
2830 RETURN
2840 !
2850 !       Label Device
2860 !
2870 MOVE 500,30
2880 LORG 4
2890 LABEL S$.....Label device description
2900 RETURN
2910 !
2920 !        Label Loss
2930 !
2940 LDIR 90
2950 LORG 6
2960 IF N=1 THEN P$="INSERTION LOSS(dB)"
2970 IF N=2 THEN P$="RETURN LOSS (dB)"  .....Select appropriate label
2980 IF N=3 THEN P$="RET./INS. LOSS(dB)"
2990 MOVE 1025,-500
3000 LABEL P$
3010 RETURN
3020 !
3030 !         Plot Data
3040 !
3050 FOR X=0 TO P-1.....Loop for each frequency point
3060 PLOT X*1000/(P-1),-(M4-R(1+X+(N=3)*P+P))*1000/M3 .....Scale and plot data
3070 NEXT X
3080 PENUP
3090 IF N<3 THEN RETURN .....Return if plotting Insertion or Return Loss only
3100 FOR X=0 TO P-1
3110 PLOT X*1000/(P-1),-(M4-R(1+X+3*P))*1000/M3.....Otherwise, finish plotting data
3120 NEXT X
3130 RETURN
3140 !
3150 !      <DISPLAY DATA>
3160 !
3170 FOR X1=0 TO P STEP 11.....Display 11 lines at a time
3180 CLEAR
3190 ON N GOSUB 3460,3500,3540.....Write heading on screen
3200 FOR X2=1 TO 11.....Loop for each of the 11 lines
3210 X=X1+X2.....Calculate array pointer
3220 IF X>P THEN GOTO 3260.....Exit if all data has been displayed
3230 F=(B-A)*(X-1)/(P-1)+A.....Calculate frequency
3240 ON N GOSUB 3580,3580,3610.....Display data
3250 NEXT X2
3260 DISP "Press CONT..."
3270 PAUSE.....Stop after 11 lines and prompt
3280 NEXT X1
3290 GOTO 360 ! RETURN
3300 !
3310 !       <PRINT DATA>
3320 !
3330 CRT IS 2.....Define printer as CRT device
3340 DISP TAB((32-LEN(S$))/2);S$.....Print device label
3350 ON N GOSUB 3460,3500,3540.....Print heading
3360 FOR X=1 TO P.....Do for each frequency point
3370 F=(B-A)*(X-1)/(P-1)+A .....Calculate frequency
3380 ON N GOSUB 3580,3580,3610
3390 NEXT X
3400 DISP @ DISP @ DISP @ DISP
3410 CRT IS 1.....Restore CRT and printer
3420 GOTO 360 ! RETURN
3430 !
3440 !        Formatting
3450 !
3460 DISP "    Frequency      Insertion"
3470 DISP "       (GHz)          (GHz)"  .....Insertion Loss heading
3480 DISP "--------------------------------"
3490 RETURN
3500 DISP "    Frequency     Reflection"
3510 DISP "       (GHz)          (dB)"  .....Return Loss heading
3520 DISP "--------------------------------"
```

```
3530 RETURN
3540 DISP "Frequency  Insertion  Reflection"
3550 DISP "  (GHz)       (dB)       (dB)"
3560 DISP "--------------------------------"
3570 RETURN
3580 IMAGE 6X,DD.DD,7X,4D.DD
3590 DISP USING 3580 ; F,R(P+X)
3600 RETURN
3610 IMAGE X,DD.DD,5X,4D.DD,5X,4D.DD
3620 DISP USING 3610 ; F,R(3*P+X),R(2*P+X)
3630 RETURN
3640 !
3650 ! ------------------------
3660 !   HP-IB TIMEOUT ERROR
3670 ! ------------------------
3680 !
3690 BEEP
3700 DISP "HP-IB ERROR... Check connections"
3710 PAUSE
3720 !
3730 ! ------------------------
3740 !     DEVICE DEPENDENT
3750 !       SUBROUTINES
3760 ! ------------------------
3770 !
3780 !    <A/D READ ROUTINE>
3790 !
3800 IMAGE "H",D,"AJ"
3810 IMAGE #,W
3820 OUTPUT A0 USING 3800 ; 2^(C2-1)
3830 ENTER A0 USING 3810 ; R2
3840 IF C2<3 AND ABS(R2)>1000 THEN C2=C2+2 @ GOTO 3820
3850 IF C2<3 THEN R2=S*R2/5 ELSE R2=S*R2
3860 RETURN
3870 !
3880 !  <INCREMENT FREQUENCY>
3890 !
3900 OUTPUT S0 USING "K" ; "UP"
3910 RETURN
3920 !
3930 !        <CW MODE>
3940 !
3950 OUTPUT S0 ;"CW";A;"GZ"
3960 OUTPUT S0 ;"SS";C;"GZ"
3970 RETURN
3980 !
3990 !  <RETURN TO START/STOP>
4000 !
4010 OUTPUT S0 ;"FA";A;"GZ"
4020 OUTPUT S0 ;"FB";B;"GZ"
4030 RETURN
4040 END
```

Heading for both Insertion and Return Loss

Insertion or Return Loss

Both Insertion and Return Loss

HP-IB error trap

Output format

Enter format

Trigger the proper channel

Read the A/D

If overrange, read the low resolution channel

Scale the reading

Increment the frequency

Set the 8350 to CW mode

Program the step size

Program Start and Stop frequencies

APPENDIX II

CALIBRATING THE 59313A

This program is used to calibrate the 59313A. To run the program, do the following:

- Set the A/D to an HP-IB address of 10 (decimal).
- Disconnect all four rear panel inputs.
- Set the Select Code of the HP-IB interface to 7 (decimal).
- Connect the HP-IB cable to the HP 85A.
- Load program "Cal" into the HP 85A and press RUN.

The program will display four numbers across the screen of the HP 85A. These are the readings of channel 1, 2, 3, and 4, respectively, of the A/D. The HP 85A will read and update these numbers continuously.

To calibrate the 59313A, perform the following procedure while running the calibration program:

- Turn the back panel CAL switch to the "0" position. Using a small screwdriver, adjust the front panel ZERO controls until the HP 85A reads zero for each channel.
- Turn the CAL switch to the "−1" position and adjust the GAIN controls of channels 1 and 2 until they read −1000 on the HP 85A.
- Turn the CAL switch in the "−5" position and adjust the GAIN controls of channels 3 and 4 until they read −1000 on the HP 85A.
- Reconnect the four rear panel input cables.

The 59313A is now calibrated and ready for use in the system.

CALIBRATION PROGRAM

```
100 ! ---------- Cal ----------
110 !
120 ! HP P/N 08755-10001,REV A
130 ! Last changed: 10/21/80
140 !
150 ! Uses:          59313A only
160 !
170 ! HP 85A must have:
180 !           HP-IB Interface
190 !           I/O ROM
200 !           Standard 16K RAM
210 !
220 ! ------------------------
230 !
240 SET TIMEOUT 7;1000
250 ON TIMEOUT 7 GOTO 510                    ..... Initialize the HP-IB error trap
260 ABORTIO 7
270 CLEAR 7
280 LOCAL 7                                  ..... Clear the HP-IB interface of any error conditions
290 REMOTE 7
300 A0=710                                   ..... Select code of the A/D
310 FOR N=1 TO 4                             ..... Loop for each of the 4 A/D channels
320 GOSUB 440                                ..... Read the A/D
330 D(N)=C3                                  ..... Temporarily store the A/D reading
340 NEXT N
350 IMAGE 4(6D)
360 DISP USING 350 ; D(1),D(2),D(3),D(4)     ..... Display the 4 readings
370 GOTO 310                                 ..... Loop continuously
380 !
390 ! ****** SUBROUTINES ******
400 !
410 !          <READ A/D>
420 !
430 IMAGE "H",D,"AJ"
440 OUTPUT A0 USING 430 ; 2^(N-1)            ..... Trigger the channel of the A/D
450 IMAGE #,W
460 ENTER A0 USING 450 ; C3                  ..... Read the value
470 RETURN
480 !
490 !      <HP-IB ERROR TRAP>
500 !
510 DISP "HP-IB ERROR... Check connections"
520 BEEP                                     ..... Display error message
530 END
```

APPENDIX III

USING THE HP 8620C SWEEP OSCILLATOR

The 8620C Option 011 Sweep Oscillator may be used in this system in place of the 8350A sweeper. Any 86200 series Plug-in may be used with the 8620C without adapters, but it will not accept any 83500 series Plug-ins. The recommended Plug-in for this system when using the 8620C mainframe is the 86290B, with a frequency range of 2 to 18.6 GHz and a power output of +10 dBm. Only the frequency and the operating mode (Full Band, Marker Sweep, etc.) can be programmed on the 8620C mainframe, and these functions are programmed differently than on the 8350A. Differences in the connection diagram, the operation of the system, and the software are described below.

Connection

The 8620C does not have built-in 27.8 kHz modulation, and so requires an additional cable to provide the necessary modulating signal from the 8755S. Connect the front-panel MODULATOR DRIVE output of the 8755S to the rear-panel EXT AM input of the 8620C mainframe with a four foot BNC cable (HP 11170C). Set the controls of the 8620C and the 8629B as follows:

Back Panel

1 kHz SQUARE WAVE .....OFF
RF BLANKING .....ON
DISPLAY BLANKING .....ON
PL-NORM-FM .....FM

Front Panel

MODE .....AUTO
TRIGGER .....INT
SWEEP TIME .....set for good display
MARKERS .....INTEN
START/STOP MARKERS ..frequency range of interest
RF .....ON

Operation

When using the system under automatic control, first set the sweeper to Marker Sweep mode in the 2-18.6 GHz band (Band 4) and position the Start and Stop Markers for the frequency range of interest. The controller returns the sweeper to this mode between measurements so the operator can check for loose connections and other problems as the measurement proceeds. Because the frequency of the sweeper is set directly under program control, the position of the Start and Stop Markers have no effect on the accuracy of the measurement.

Software

The portions of the measurement program affected by the change of sweepers are the Plug-in Band Limits subroutine and the Sweeper Interface subroutine. Replace the subroutines in the measurement program with those listed below:

8620C SUBROUTINES

```
800 !
810 !   <PLUG-IN BAND LIMITS>
820 !
830 RESTORE 890 @ RESTORE 900
840 FOR I=1 TO 8
850 READ D(I) ..... Read the frequency limits for the 86290 Plug-in
860 NEXT I
870 READ L ..... Lower frequency limit
880 READ U ..... Upper frequency limit
890 DATA 2,6,12,4.2,6.4,6.6 ..... Low frequency limits and band switch points
900 DATA 6.1,12.2,2,18.6 ..... High frequency limits and overall frequency limits
910 RETURN
3870 !
3880 !  <INCREMENT FREQUENCY>
3890 !
3900 F=F+C ..... Increment frequency variable
3910 GOTO 4060 ..... Set the sweeper to the frequency in 'F'
3920 !
3930 !         <CW MODE>
3940 !
3950 F=A ..... Start frequency
3960 OUTPUT S0 ;"M1" ..... Put the sweeper in CW mode
3970 RETURN
3980 !
3990 !  <RETURN TO START/STOP>
4000 !
4010 OUTPUT S0 ;"M8B4" ..... Put the sweeper in Marker Sweep mode
4020 RETURN
4030 !
4040 !      <SET FREQUENCY>
4050 !
4060 B1=1+(F>D(7))+(F>D(8)) ..... Compute the correct band of the sweeper
4070 V1=10000*(F-D(B1))/D(B1+3) ..... Compute the tuning voltage
4080 IF V1>9999.5 THEN 4120 ..... If the frequency is high, use the other format
```

```
4090 IMAGE "M1B",D,"V",4Z,"E"
4100 OUTPUT S0 USING 4090 ; B1,V1.....Output the band number and tuning voltage
4110 RETURN
4120 V1=MIN(V1,10999)
4130 IMAGE "M1B",D,"V:",3Z,"E".....Use this format for tuning voltages >10 volts
4140 OUTPUT S0 USING 4130 ; B1,V1-10000
4150 RETURN
4160 END
```

APPENDIX IV

LIST OF VARIABLES

A ..... Start frequency (GHz)
B ..... Stop frequency (GHz)
C ..... Frequency step (GHz)
P ..... Number of points
L ..... Lower frequency limit of plug-in (GHz)
U ..... Upper limit (GHz)
S ..... Scale factor of 8755S (dB/div)
N ..... Mode (1 = return, 2 = insertion, 3 = both)
R[*] ..... Data array (dB)
M1 ..... Maximum loss (dB)
M2 ..... Minimum loss (dB)
M3 ..... Total plot range (dB)
M4 .....Maximum plot value (dB)
M5 ..... Temporary loss variable (dB)
A0 ..... A/D select code
S0 ..... Sweeper HP-IB select code
C2 ..... A/D Channel number
R2 ..... A/D reading (dB)
X, X1, X2, I ..... Loop and temporary variables
S$ ..... Device label
P$ ..... "Type of measurement" label

8620C ONLY

F ..... Current sweeper frequency
B1 ..... Sweeper band number
V1 ..... Sweeper tuning voltage
D[1-3] ..... Sweeper lower band limits (GHz)
D[4-6] ..... Band widths (GHz)
D[7-8] ..... Switching points of bands (GHz)

For more information, call your local HP Sales Office or nearest Regional Office: **Eastern** (201) 265-5000; **Midwestern** (312) 255-9800; **Southern** (404) 955-1500; **Western** (213) 970-7500; **Canadian** (416) 678-9430. Ask the operator for instrument sales. Or write Hewlett-Packard, 1501 Page Mill Road, Palo Alto, CA 94304. **In Europe:** Hewlett-Packard S.A., 7, rue du Bois-du-Lan, P.O. Box, CH 1217 Meyrin 2, Geneva, Switzerland. **In Japan:** Yokogawa-Hewlett-Packard Ltd., 29-21, Takaido-Higashi 3-chome, Suginami-ku, Tokyo 168.

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DATA SUBJECT TO CHANGE

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