Three HP-IB Configurations for Making Microwave Scalar Measurements

The HP 8620C Option 011 Sweep Oscillator is directly programmable via the Hewlett-Packard Interface Bus (HP-IB). Using any of the solid state plug-ins covering 3 MHz to 18 GHz, it is now relatively easy to configure a calculator controlled microwave test set with the accuracy enhancement, data manipulation capability and simplified operation that calculator control implies.

This application note describes three HP-IB configured systems for measuring the scalar transmission and impedance characteristics of microwave components. One employs the HP 436A Digital Power Meter, another the HP 8755 Frequency Response Test Set, and the third the HP 8410B Network Analyer. The specific hardware requirements are discussed and the relative merits of each approach compared.

APPLICATION NOTE 187-3

THE SOURCE - HP 8620C Opt. 011

All of the analog sweep functions (full band, marker and ΔF sweep) of the HP 8620C can be programmed through the HP-Interface Bus with the frequency limits defined by the selected plug-in and front panel controls. In addition, over 10,000 CW frequencies can be programmed in any band. The digital frequency command from the calculator is fed serially into a storage register in the 8620C Option 011 and converted to the appropriate analog voltage which then tunes the oscillator. Thus, the output frequency changes from fx to fx + 1 in one discrete step with no random frequencies generated during the settling time. Since most instruments are capable of taking measurements in a step by step fashion only as opposed to sampling analog information, programming CW frequencies is the normal mode of operation. Calibrating and testing at the same discrete CW frequencies also permit system frequency response to be normalized out of the measurement.

The output characteristics of the sweeper are defined by the individual plug-in specifications. Several characteristics of the source are key to the results obtained from an HP-IB microwave scalar measurements system.

(A) Frequency accuracy, linearity and stability—important for error correction and narrowband frequency response measurements.

(B) Frequency overlap (less than 20 MHz) at the switch points of the broadband plug-in—frequency gaps or an overlap of several hundred MHz can be totally unacceptable in some measurements.

(C) Harmonic level—This often is the limiting factor in the dynamic range of bandpass measurements when using a broadband detection system. A wideband power sensor or diode will detect the total energy present at any time—fundamental, harmonic and spurious. While the fundamental signal is rejected by the filter, an harmonic can pass through the filter unattenuated. The out-of-band rejection then appears to be only as good as the difference between the fundamental and harmonic.

(D) Power available at the test device—This can limit the upper end of the measurement dynamic range. Power levels up to 40 mw are available in solid state sources today. It should be noted, however, that if dynamic range is critical, a more sensitive analyzer is often a more cost effective choice than a higher power source. For example, the HP 8410B provides a 70 dB, spurious free dynamic range using only a 6 dBm source, whereas 60 dB is the maximum possible dynamic range using the HP 8755 with even a 16 dBm sweeper.

Two Hewlett-Packard sweeper plug-ins in particular—the HP 86222, 10 MHz - 2400 MHz, and the HP 86290A, 2 GHz - 18 GHz—lend themselves to HP-IB applications because of their wide bandwidth and high performance. In addition, the unique compatibility between these plug-ins and the HP 8755 and HP 8410B analyzers is critical to some of the measurements described in this application note. In all the following examples, the 86290A plug-in is used.

CONFIGURATION NO. 1
DIGITAL POWER METER HP 436A

In this set-up, the detection system is comprised of the HP 8481A Power Sensor and the HP 436A Opt. 022 Digital Power Meter covering a frequency range of 10 MHz - 18 GHz. This power meter is a fully HP-IB compatible instrument and can be commanded to listen or talk through the Bus. During the measurement, its digital output is fed back to the calculator and plotted on the HP 9862A Graphic Plotter as a function of frequency.

The block diagram for a transmission measurement is shown below.

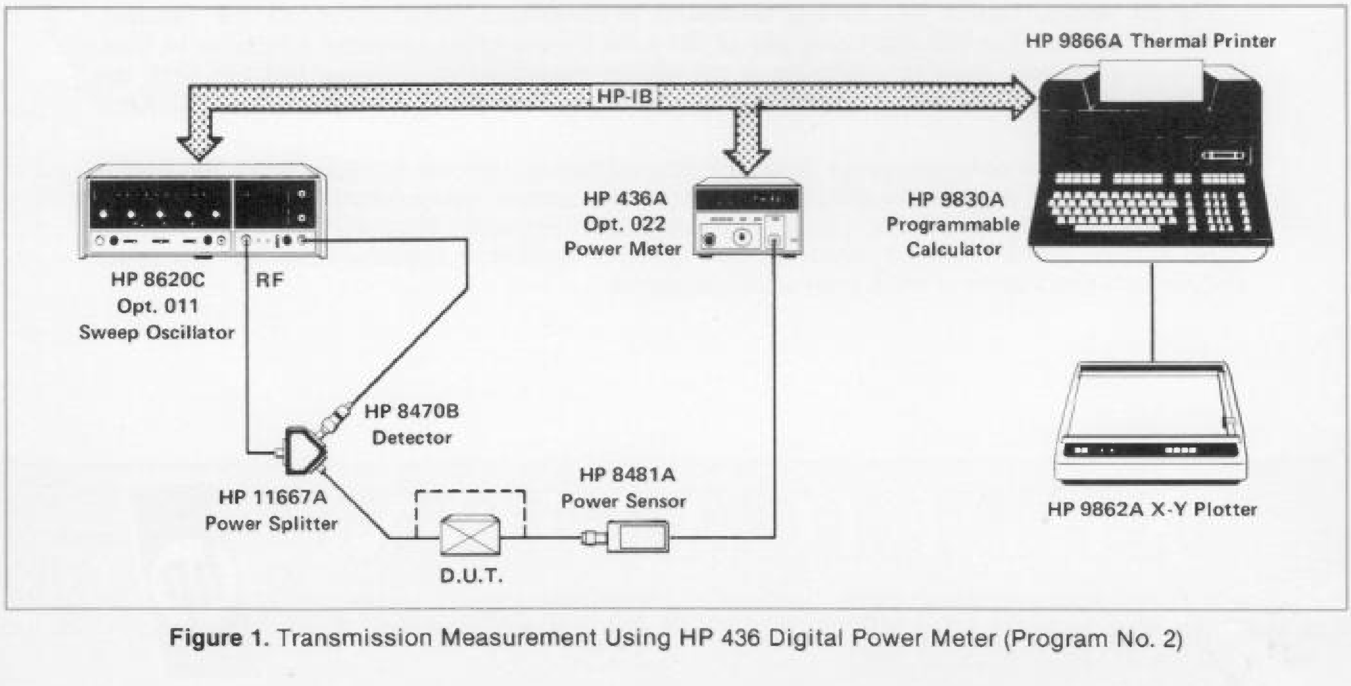

Figure 1. Transmission Measurement Using HP 436 Digital Power Meter (Program No. 2)

The sweeper is leveled using the HP 11667A power splitter (DC-18 GHz) and the HP 8470B Crystal Detector which improves the effective source SWR from about 1.9 to typically 1.2:1 or better. This greatly reduces mismatch errors in a transmission measurement and source match errors in an impedance measurement. Flatness is also improved, but since the system frequency response can be normalized out with the calculator, this is not really a concern. A directional coupler could also be used for leveling purposes and has the advantage of negligible mainline power loss compared to the 6 dB loss of the power splitter. However, the power splitter operates DC to 18 GHz and in most cases has a better effective source match.

The total measurement involves both a calibration and test cycle. Initially, the power sensor is connected directly to the output of the HP 11667A Power Splitter. The RF power is turned off (this is not programmable) and the meter is zeroed. Sensor zero is a programmable function of the 436A and can be written into the software. This insures accurate measurements down to the noise floor of the power sensor used.

Next, the sweeper is turned on and stepped across the frequency band of interest and the power level at each frequency measured and stored in the calculator memory. Then, the test device is inserted and the source is stepped through the same frequencies. The measured power levels are subtracted from the calibration data and the difference in dB plotted on the HP 9862A.

The dynamic range of this measurement is a function of the power sensor, source power and source harmonics. In Figure 2, the HP 8481A power sensor was used which has a range of + 20 dBm to approximately -30 dBm (also available is the HP 8484A mount with a range of -20 dBm to -70 dBm). The typical source output power in this frequency range is + 10 dBm, so after losing 6 dB through the power splitter, the resultant dynamic range is 34 dB.

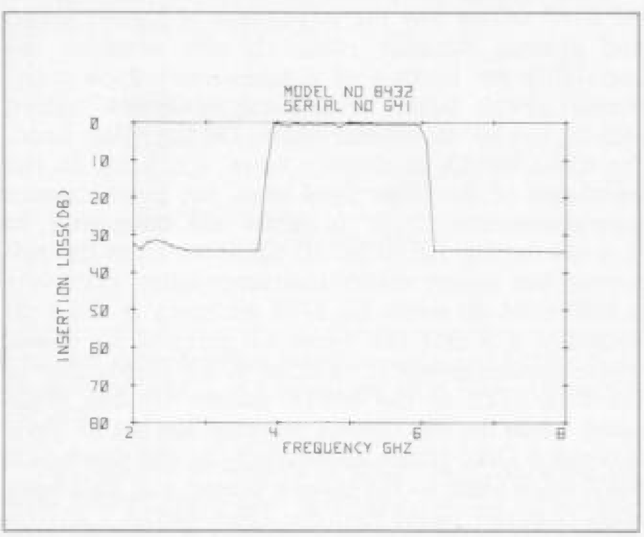

Figure 2. Insertion Loss of a 4-6 GHz Bandpass Filter Using the HP 436A/8481A Power Meter, HP 8620C Opt. 011 Sweeper Mainframe.

Since the harmonics of the HP 86290A RF plug-in in this particular case are down 40 dB, they do not affect the measurement.

This same test set can be used to make scalar impedance (return loss) measurements by simply adding a directional coupler and measuring the power at the reflected port in both calibration and test. However, because of the typical 20 dB coupling factor of broadband couplers the high sensitivity sensor (HP 8484A) must be used or the effective measurement dynamic range will be severely limited.

A significant contribution of the HP 436A/8481A in the 4 to 6 GHz filter transmission measurement is the 1.18 SWR of the mount which reduces the mismatch uncertainty. This is especially valuable in low loss measurements less than 10 dB. Because the 436A is a fully HP-IB compatible instrument and relatively inexpensive compared to broadband network measurement instruments, it is cost effective solution. On the other hand, its dynamic range is somewhat limited and the broadband detector is vulnerable to source harmonics. Also, it takes 100 msec to settle on the top three ranges and as long as 10 sec on the lowest range. If any of these considerations present problems, one of the other two HP-IB configurations may be a better choice. A more complete description of "Automated Power Measurements" can be found in Application Note AN-196.

CONFIGURATION NO. 2
FREQUENCY RESPONSE TEST SET HP 8755

The HP 8755 is designed specifically for making microwave scalar measurements. It covers a frequency range of 10 MHz to 18 GHz. The 8755 requires the RF be modulated at a 27.8 kHz rate for detection. In the case of the 86290A RF plug-in, the modulating drive signal provided by the 8755 can be used for direct modulation of the sweeper since the AM bandwidth, sensitivity and symmetry as well as the ALC loop of the 86290A were designed specifically for this application. This eliminates the need for an external modulator and its associated insertion loss.

The 8755 has three detector channels, each with a + 10 dBm to -50 dBm dynamic range. The absolute signal level or ratio of two detected signals can be displayed on the CRT or output on the rear panel as a calibrated (dB) analog voltage. The 8755 is not programmable, but by monitoring the rear panel voltages with an HP-IB programmable digital multimeter the 8755 can "talk" to the Bus.

The block diagram for a scalar transmission measurement is shown in Figure 3.

Using a ratio measurement for insertion loss (B/R) has the same measurement benefits as leveling the sweeper; i.e., source match is improved and mismatch error uncertainty is reduced. Before the measurement is made, however, the front panel controls of the 8755 need to be set to assure all signals will appear on screen. It is also important that the display is accurately calibrated (dB/div.) since this affects the rear panel voltage calibration.

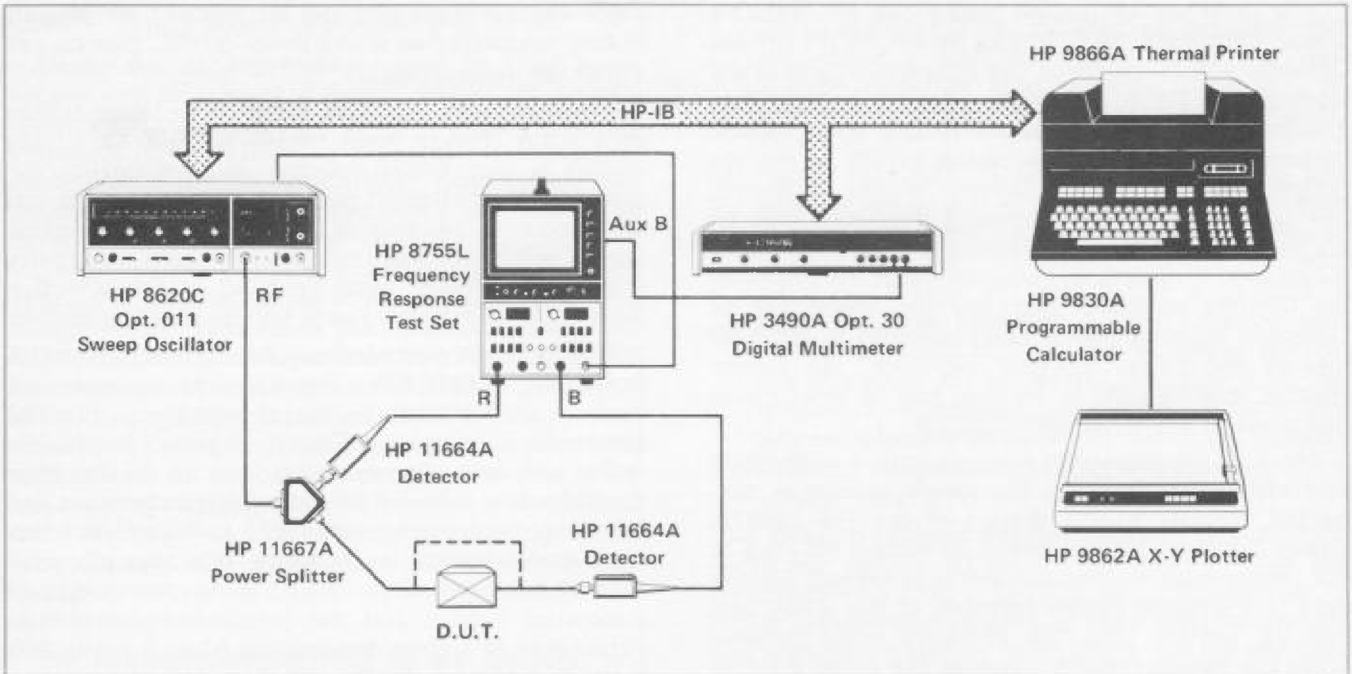

Figure 3. Scalar Transmission Measurement Using the HP 8755. (Program No. 4)

Position control channel B - adjust trace to be two divisions below the top of the CRT.

Display	-	B/R
DB/Div	-	10 dB
Offset Cal	-	off
Offset dB	-	00
Smoothing	-	off

Now, any ratio where the measurement detector (B) is between + 20 dB and -60 dB compared to the reference detector (R) will stay on screen. This covers all insertion loss measurements using the HP 11667A Power Splitter and return loss measurements using up to a 20 dB coupler.

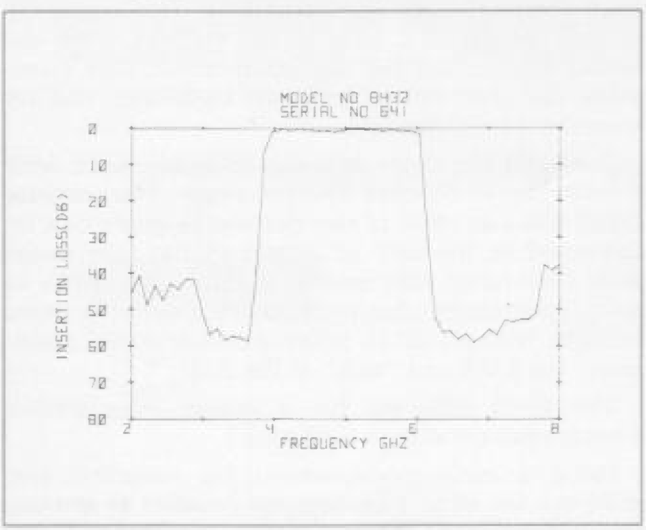

Figure 4. Insertion Loss of a 4-6 GHz Filter Using the Set-Up Shown in Figure 3.

With the B detector connected to the output of the HP 11667A Power Splitter, the sweeper is stepped across the frequency range of interest. At each frequency, the voltage at the AUX B output which is proportional to B/R (normally zero volts in this case) is measured by the HP 3490A Digital Multimeter then stored in the calculator. Next, the test device is inserted, the voltage output at AUX B is measured at the same frequencies and subtracted from the previously stored calibration data. The difference in dB is plotted on the HP 9862A Plotter.

The sensitivity of the HP 8755 Frequency Response Test Set is typically -53 dBm. With a 10 dBm output power and a 6 dB loss through power splitter, the maximum dynamic range for the measurement is 57 dB. Note, however, that in Figure 4 the dynamic range is limited to 40 dB at some frequencies due to the harmonics of the HP 86290A plug-in.

Compared to the power meter measurement, the HP 8755 set-up has the advantage of higher speed and greater dynamic range. It also provides the capability for looking at a measurement on a dynamic swept basis in manual operation before making the HP-IB measurement. On the other hand, the 436A/8481A is slightly more accurate. In the passband of the filter (low loss), the power meter instrumentation error is ± .04 dB compared to ± .1 dB for the HP 8755. 30 dB down from the reference the power meter instrumentation accuracy is still ± .04 dB while the 8755 accuracy is ± 1.1 dB (typically ± .4 dB.) The mismatch error of the power meter measurement is smaller at all points due to the 1.18 SWR of the 8481A mount. On the other hand, while the HP 11664A detector has a 1.33 SWR through 8 GHz, it can be padded (10 dB) down to a SWR equivalent to the power sensor and still have more dynamic range than the 436A/8481A.

If a simultaneous measurement of insertion loss and return loss is desired, the set up in Figure 5 can be used:

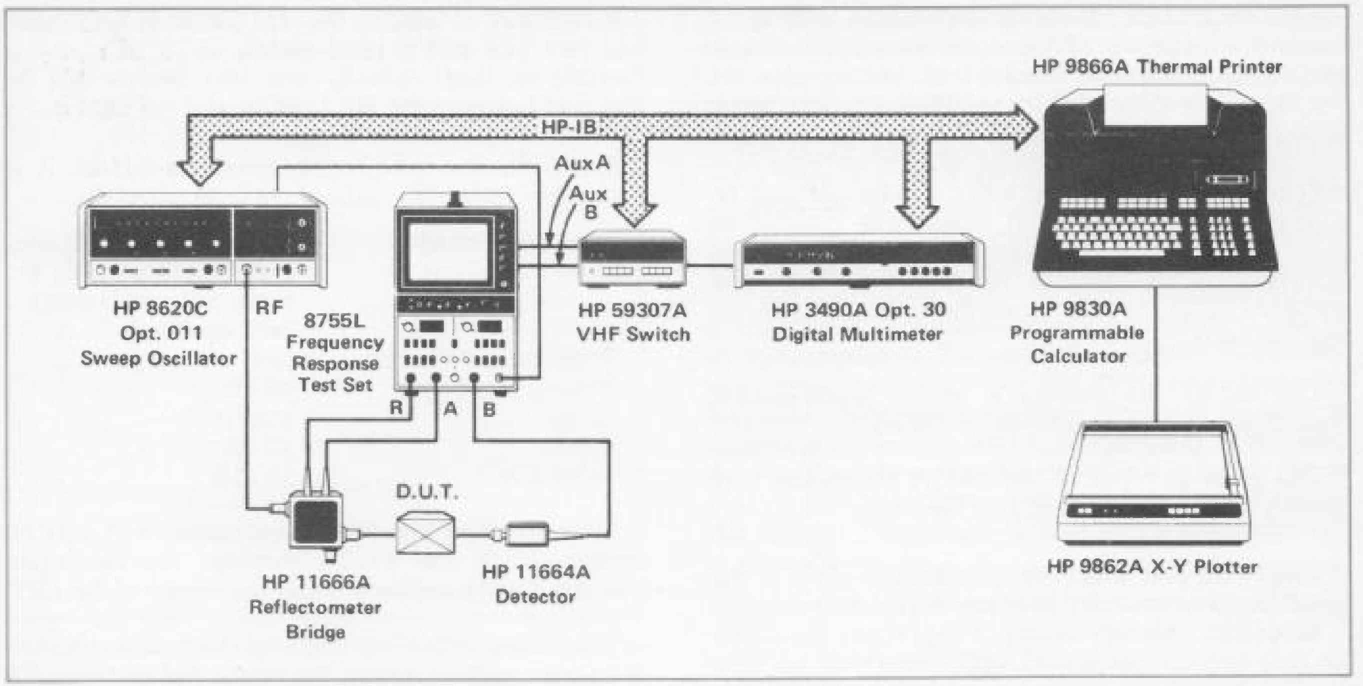

Figure 5. Set-Up for Making Simultaneous Measurements of Insertion Loss and Return Loss using the HP 8755. (Program No. 4)

In this application, the HP 11666A Reflectometer Bridge (40 MHz - 18 GHz) is used. Both insertion loss (B/R) and return loss (A/R), are measured and proportional voltages outputed on the AUX B and AUX A connectors on the rear of the HP 8755. The HP 59307A VHF Switch selects the proper channel and the DMM inputs the sets of data to calculator. The results can then be plotted as in the previous two examples.

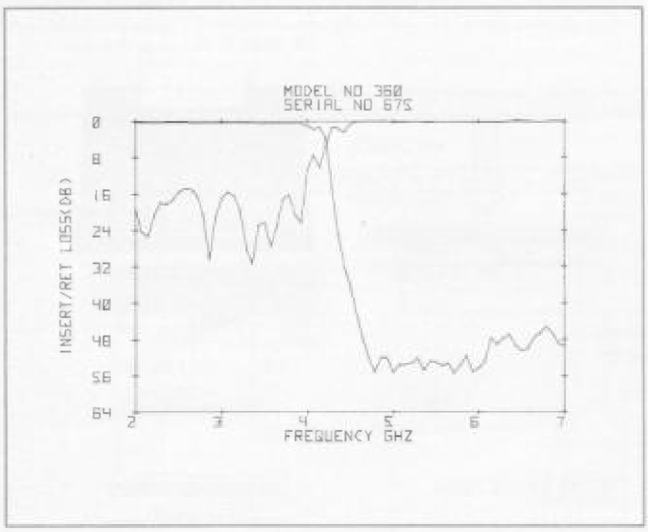

Figure 6. Simultaneous Insertion Loss and Return Loss Measurement of a 4.1 GHz Low Pass Filter Using the HP 8755

The system of Figure 5 must be calibrated for both transmission and reflection. In the first case, the B detector is connected directly to the HP 11666A Reflectometer Bridge output, and the routine is the same as with the power splitter. For the 0 dB return loss calibration, the bridge output is first shorted then open circuited. The DVM measures the AUX A voltage for each case (short/open) at all frequencies. The calculator then stores the linear average of the two readings as the true calibration. This open/short technique dramatically reduces impedance measurement calibration error.

Although the HP 8755 system just described does offer speed and dynamic range advantages, it is still somewhat sensitivity limited (-50 dBm) and vulnerable to source harmonics in multi-octave bandpass measurements. The HP 8410B Network Analyzer System described next makes a significant contribution in both these areas.

CONFIGURATION NO. 3
TUNED NETWORK ANALYZER HP 8410B

The HP 8410B covers the 110 MHz - 18 GHz frequency range. It is capable of measuring the relative amplitude and phase differences between microwave signals. However, in this application note the 8410B is used for making scalar measurements only. This allows one to use much simpler, less expensive test sets than would be needed to assure good phase tracking in complex S-parameter measurements.

The 8410 is a dual channel receiver. The two input signals are converted down to a fixed IF frequency, using harmonic sampling, where their ratio is measured. This IF technique greatly increases system sensitivity. The system is capable of swept frequency operation because the reference channel is always tuned to the incoming signal by means of a phase lock loop. This makes the 8410 immune to the source harmonics which limited the 8755 measurement in the previous test.

The 8410B incorporates automatic frequency range tuning which allows continuous multi-octave measurements to be made with either the HP 86290A, 2-18 GHz plug-in or HP 86222, 10 MHz-2400 MHz plug-in. The 8410B is not programmable, but like the 8755 has analog voltage outputs proportional to the measured ratio. These can also be monitored with the HP-IB compatible 3490A. In fact, at 10 dB/div the sensitivity of this output (0.5V/Div) is the same as the 8755 and the same software used in the previous example can be applied here.

The set-up for making a scalar transmission measurement is shown below in Figure 7.

The pads in front of the 8411A Harmonic Frequency Converter perform two functions:

1) The 10 dB pad improves the effective SWR of the test channel from 2:1 to better than 1.23:1 through 12.4 GHz.

2) They reduce the reference and test channel signals to levels which produce maximum dynamic range.

Since the test channel has a specified range of -10 dBm to -78 dBm, only +6 dBm of source power is needed in this application. A special cable, P/N 08542-60121, is used in the test channel. This cable has low loss and a good match to 18 GHz and is flexible so that virtually any test device can be inserted between the HP 11667A and HP 8411A.

Since we are not programming the 8410B, it is necessary to set the manual controls properly.

Frequency range	- auto (8620C-8410B special interface cable & Freq. Ref. cable must be connected)
Freq. Range Vernier	- CW
Test channel gain	- 40 dB
Mode	- amplitude
dB/div	- 10 dB
video BW	- 10 dHz

Now any insertion loss measurement will stay on screen. With the 8412A display, the resolution (dB/div) always expands about the center of the CRT.

With the padded test channel cable connected to the power splitter output, the 8620C Opt. 011/86290A is stepped across the band. The 8410B measures the ratio of the test and reference channel signals and a proportional voltage is output from the rear of the 8412A display. These voltages are read by the DMM and stored in the calculator. The test device is then inserted, and the measured values subtracted from the calibration data.

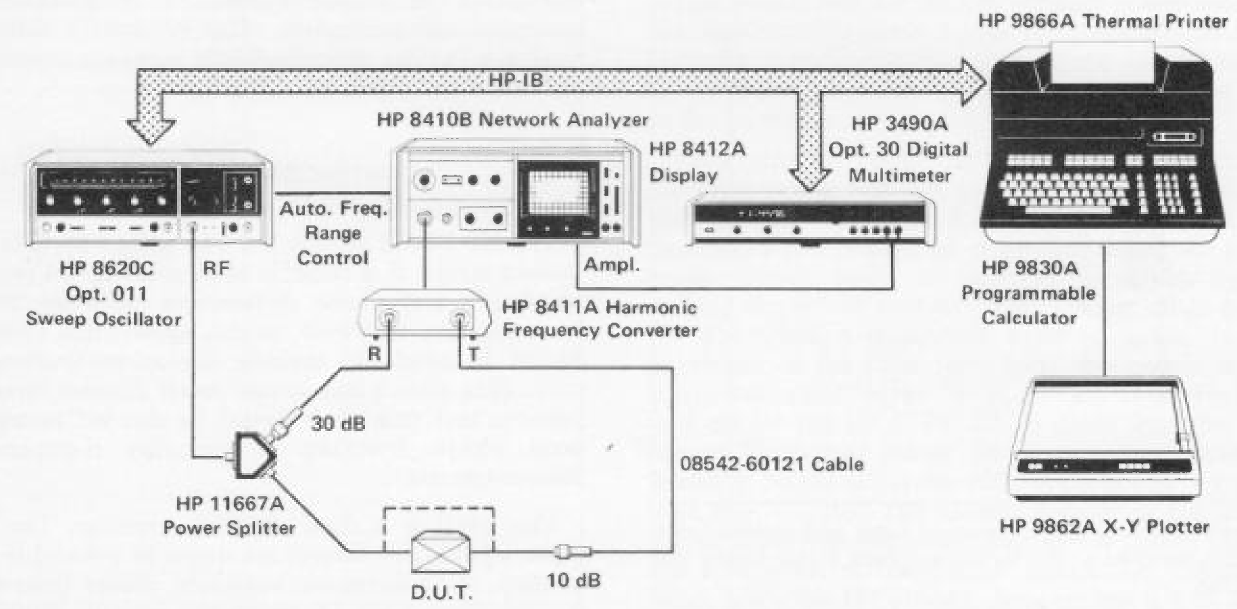

Figure 7. Scalar Transmission Set-Up Using HP 8410B Network Analyzer (Program No. 4)

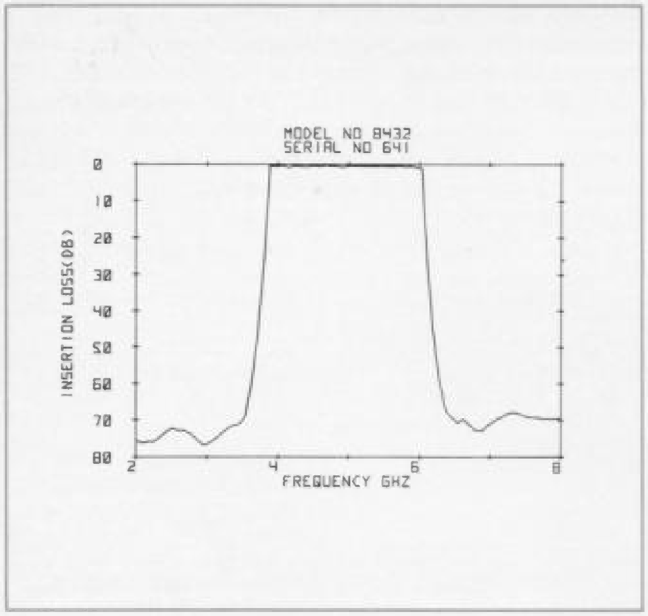

Figure 8. Insertion Loss of 4-6 GHz Filter Using the HP 8410B (Set-up shown in Figure 7.)

The dynamic range of this measurement is greater than 70 dB because of the sensitivity of the 8410 and the fact that it is tuned only to the source fundamental and not limited by harmonics. The accuracy is a function of the 8412A recorder output (.03 dB/dB). 30 dB down from the reference the typical accuracy is better than ± 0.5 dB which is comparable to the 8755. With the padding in the test channel, the mismatch uncertainty is also comparable to both the power meter and 8755 measurements. The 8410B system has the additional advantage that phase measurements can also be made if the appropriate test set (HP 8743A, Opt. 018) is substituted for the power splitter shown.

The set-up shown in Figure 7 costs about $5,000 more than the 8755 system. The performance advantages of the 8410B are 30 dB more sensitivity, greater than 70 dB spurious free dynamic range, and the capability to add phase. Source harmonics will not, of course, affect an 8755 measurement of a broadband attenuator where the insertion loss of all frequencies is the same (as opposed to a band-pass measurement). Also, for 8755 measurements less than an octave a low-pass filter can be used to eliminate harmonics. But in a wideband swept test, the tuned receiver (8410B) provides a dynamic range that cannot be approached by a broadband detection system regardless of how much source power is available.

Reflection measurements can be easily made by replacing the 11667A Power Splitter in Figure 7 with the HP 11692D Dual Directional Coupler (Fig. 9).

The coupling of the HP 11692D (20 dB) reduces the padding necessary compared to the transmission measurement. Since the test and reference channels are only 10 dB apart during the open/short calibration, the test channel gain should be reduced from 40 dB to 30 dB for this set-up. It is not possible to measure insertion loss and return loss simultaneously using the 8410B. On the other hand, the high sensitivity of the Network Analyzer makes it one of the only instruments suitable for return loss measurement on small signal amplifiers which require input levels of -30 dBm to -40 dBm.

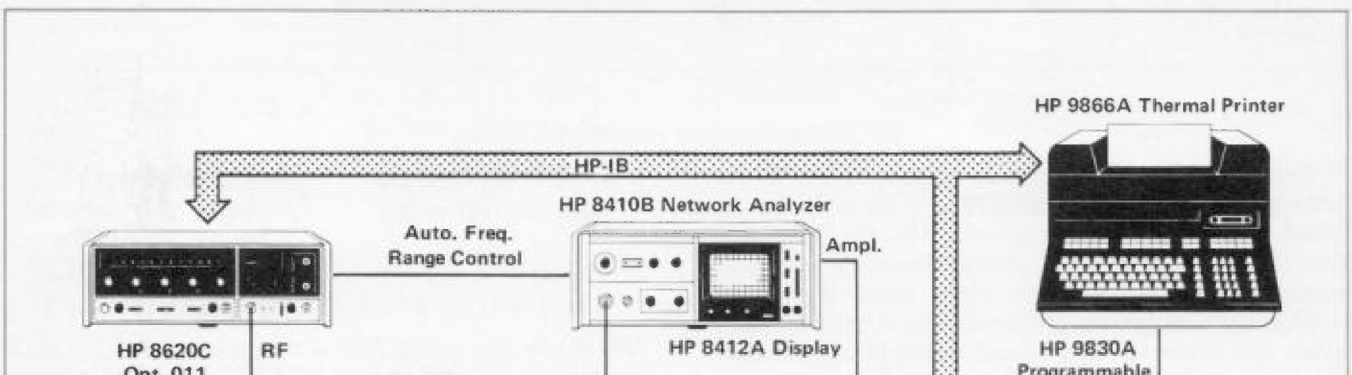

Figure 9. Reflection Measurements Using the 8410B (Program No. 4)

COMPARISON SUMMARY OF 3 HP-IB CONFIGURATIONS

(Using HP 86290A 2-18 GHz Plug-in, 6 dB Power Splitter, 4-6 GHz Band Pass Filter Measurement)

Instrument	HP 436A	HP 8755	HP 8410B
Frequency Range	10 MHz - 18 GHz	10 MHz - 18 GHz	110 MHz - 18 GHz
Dynamic Range	34 dB w/8481A mount 50 dB w/8484A mount or Sweeper harmonic level, whichever is less	54 dB or Sweeper harmonic level, whichever is less	>70 dB (>60 dB >12.4 GHz) Not affected by sweeper harmonics
Accuracy Instrument	±.02 dB for 1 dB meas. ±.04 dB for 34 dB meas.	±0.1 dB for 1 dB meas. ±1.1 dB for 57 dB meas. (±.4 dB Typ)	±.03 dB for 1 dB meas. ±2 dB for 70 dB meas. (±1 dB Typ)
SWR (Affects mis-match error)	1.18 (1.28> 12.4 GHz)	1.33 (1.5> 8 GHz) 1.2 w/10 dB Pad but lose 10 dB dyn. range (1.33> 12.4 GHz)	1.23 w/10 dB Pad which is always recommended since no dyn. range is lost (1.38> 12.4 GHz)
Speed (Per Freq. Step)	<100 msec Top Three (10 dB) Ranges <1 sec 30 to 40 dB <10 sec. Bottom 10 dB	10 msec - 8620C/86290A but typically limited by DMM & Calc. (400 msec w/3490 DMM & 9830 Calc.	10 msec - 8620C/86290A but typically limited by DMM & Calc. (400 msec w/3490 DMM & 9830 Calc.
Miscellaneous	Direct HP-IB CW Only Single channel Accurate absolute pwr. meas. 200 ft. extension cables avail. Amplitude Only	Not Programmable Can sweep test DUT in manual Ratio capability + simultaneous trans./refl. meas. ~±1 dB Abs. Power meas. >200 ft. ext. cables avail. Amplitude Only	Not Programmable Can sweep test DUT in manual Ratio capability No abs. power 25 ft. ext. cable avail. Can add phase meas. capability
Approx. Prices, HP-IB Compatible Sub-system (Excl. sweeper plug-in and calc. but inc. DMM if required.)	$6,000	$10,000	$15,000

PROGRAMMING CONSIDERATIONS

The programs listed in this application note are written around the HP 86290A, 2-18 GHz Broadband Sweeper. Its wide bandwidth, together with precision frequency accuracy, stability and harmonic purity, make it an ideal general purpose source for a microwave measurement system. However, any other HP 8620 family plug-in can be used by making a few simple software changes.

The subroutine which converts a particular measurement frequency to the analog voltage which tunes the oscillator, must include the bandwidths and switch points of the plug-ins used. The 86290A values appear at the beginning of each program. The use of any plug-in besides the 86290A is accomplished by simply re-defining these variables. For example, if you are using the HP 8621B multi-band drawer with two oscillators installed, say the HP 86330B (1.8 to 4.2 GHz) and HP 86341A (3.2 to 6.5 GHz), and desire to test anywhere between 1.8 and 6.5 GHz, the following changes should be made in either the 9820A or 9830A calculator programs:

R (8) or D (1) = 1.8
R (9) or D (2) = 3.2
R (11) or D (4) = 2.4
R (12) or D (5) = 3.7
R (14) or D (7) = 4.0 (or any frequency between 3.2 and 4.2)
R (15) or D (8) = 6.5

Or, if you are using just a single band plug-in such as the HP 86250B (8.0 to 12.4 GHz) only four array variables need to be changed:

R (8) or D (1) = 8.0
F (11) or D (4) = 4.4
R (14) or D (7) = 12.4
R (15) or D (8) = 12.4

All other values can remain unchanged since they will not be used in the frequency setting subroutine when only one or two bands are involved.

In addition to the ROM's included with the HP-IB (59405A, Opt. 20, 21, or 30), several others are required for the programs listed in the application note: HP 11220A and HP 11221A ROM's for the HP 9820A calculator and HP 11271B (plotter control) and HP 11274B (string variable ROM's for the use with the HP 9830A calculator.

The programs provided for the HP 436A Digital Power Meter are for a single channel transmission measurement shown in Figure 1. A description and program examples of more complex HP-IB configured systems can be found in Application Note 196, "Automated Measurements Using the 436A Power Meter". The programs listed for the HP 8755 or HP 8410B, on the other hand, provide the flexibility of measuring insertion loss, return loss, or both. The choice is made during the execution of the program. When inputs such as frequency limits, number of points, etc., are requested, the program will continue after the appropriate number has been entered and the "Execute" key punched on the 9830A or the "Run Program" key on the 9820A. If a command such as "connect device" is displayed, the 9830A will continue after typing "space bar" and "execute". The procedure for the 9820A is again "run program". The program will handle the most general set-up (Figure 5) of a "simultaneous" transmission/reflection measurement where a programmable switch selects the appropriate 8755 auxiliary output during both calibration and test. However, it also works for just a transmission or reflection measurement (Figures 3, 7, 9) since when the switch is not on the HP-IB, the calculator will still step through the associate switch command statements.

Following a complete calibration and measurement cycle, after the results have been plotted, the calculator will display "connect device/insert paper". When this is completed, the next measurement can be made on another device and a separate plot generated. Or, if one device is to be compared to another, the plotter pen could be changed to a different color and the two measurements superimposed. It is also simple to modify the program to draw "go/no-go" limits on the plot for rapid comparison to a specification in, say, a production line application.

PROGRAM NO. 1
9820A CALCULATOR/436A POWER METER

```
0.
"2-18GHZ TEST SE
T--436"⊢
1:
"ADDRESSES--8620
C=&;436=-(LSTN),
M(TLK)"⊢
2:
"12/2/75"⊢
3:
"LOW LMTS OF BAN
DS";2→R8;6→R9;12
→R10⊢
4:
"WIDTHS OF BANDS
";4.2→R11;6.4→R1
2;6→R13⊢
5:
"SWITCHPTS";6.1→
R14;12.2→R15;
FMT Y3,Z;WRT 13⊢
6:
ENT "F-START(GHZ
)",A,"F-STOP(GHZ
)",B,"NO. OF PTS
.",R5;(B-A)/(R5-
1)→C⊢
7:
IF (2>A)+(A>18)+
(2>B)+(B>18);
DSP "OUT OF RANG
E";DSP ;DSP ;
DSP ;GTO -1⊢
8:
ENT "MAX LOSS(DB
)",Y;GSB "ZERO"⊢
9:
DSP "CONN THRU--
RF ON";STP ⊢
10:
A→X;0→R4⊢
11:
"CAL";GSB "FSET"
⊢
12:
GSB "MTR"⊢
13:
R3→R(16+R4);IF (
X+C→X)≤B;R4+1→R4
;GTO "CAL"⊢
14:
"NEXT";ENT "MODE
L NO.",R6,"SERIA
L NO.",R7;DSP "P
APER";STP ⊢
15:
GSB "AXES"⊢
16:
GSB "ZERO"⊢
17:
A→X;0→R4;DSP "CO
NN DUT--RF ON";
STP ⊢
18:
"MEAS";GSB "FSET
"⊢
19:
GSB "MTR"⊢
20:
PLT X,R(16+R4)-R
3;IF (X+C→X)≤B;R
4+1→R4;GTO "MEAS
"⊢
21:
PEN ;GTO "NEXT"⊢
22:
"ZERO";DSP "TURN
 RF OFF";STP ⊢
23:
CMD "?U-","Z1I"⊢
24:
CMD "?M5";FMT 4X
,FXD 4.0;RED 13,
Z⊢
25:
IF ABS Z>2;GTO -
2⊢
26:
CMD "?U-","9+DI"
,"?M5";RDB 13→Z⊢
27:
IF 84≤Z;GTO -1⊢
28:
RET ⊢
29:
"MTR";CMD "?U-",
"T","?M5";FMT 3X
,FLT 12.0;RED 13
,R3;RET ⊢
30:
"FSET";(X>R14)+(
X>R15)→R3⊢
31:
10(X-R(8+R3))/R(
11+R3)→R7;IF R7>
9.999;9.999→R7⊢
32:
CMD "?U&";FMT "M
1V",FXD *.3,"EB"
,FXD *.0;WRT 13,
R7,R3+1;RET ⊢
33:
"AXES";(B-A>4)+(
B-A≤4)(B-A)/4→R3
⊢
34:
SCL A-.15(B-A),B
,1.1Y,-.1Y;AXE A
,Y,R3,-Y/8;AXE B
,0,R3,-Y/8⊢
35:
LTR A+.3(B-A),1.
08Y,321;PLT "FRE
QUENCY(GHZ)"⊢
36:
LTR A+.01(B-A),1
.03Y,211;FXD 1+(
B-A≤2);PLT A;.25
→R2⊢
37:
(B-A>4)(INT ((B-
A)R2)+A)+(B-A≤4)
(R2(B-A)+A)→R3⊢
38:
LTR R3-.02(B-A),
1.03Y;PLT R3;IF
(R2+.25→R2)≤.75;
GTO -1⊢
39:
LTR B-.05(B-A),1
.03Y;PLT B⊢
40:
LTR A-.10(B-A),.
85Y,232;PLT "INS
ERTION LOSS(DB)"
;0→R2;FXD (Y≤30)
+(10>Y)⊢
41:
LTR A-.045(B-A),
.99Y-R2,211;PLT
Y-R2;IF (R2+Y/4→
R2)≤Y;GTO +0⊢
42:
FXD 0;LTR A+.2(B
-A),-.05Y,321;
PLT "MODEL NO.";
PLT R6;PLT "
SERIAL NO.";PLT
R7⊢
43:
RET ⊢
44:
END ⊢
R235
```

PROGRAM NO. 2
9830A CALCULATOR/436A POWER METER

```
10 REM 2-18GHZ MICROWAVE TEST SET-436A
20 REM ADDRESS--8620C=&, 436A=-(LSN),M(TLK)
30 REM   12/2/75
40 DIM D[8]
50 DIM C[150]
60 REM D(1,2,3)=LOW LIMITS OF BANDS 1,2,3
70 REM D(4,5,6)=WIDTH OF BANDS 1,2,3
80 REM D(7,8)=BAND SWITCH POINTS
90 D[1]=2
100 D[2]=6
110 D[3]=12
120 D[4]=4.2
130 D[5]=6.4
140 D[6]=6
150 D[7]=6.1
160 D[8]=12.2
170 DISP "START FREQ(GHZ)";
180 INPUT F1
190 DISP "STOP FREQ(GHZ)";
200 INPUT F2
210 IF F1<2 OR F2>18 THEN 930
220 DISP "NUMBER OF POINTS";
230 INPUT P
240 P1=(F2-F1)/(P-1)
250 DISP "MAX LOSS(DB)";
260 INPUT Y
270 Y=-Y
280 S=-20
290 GOSUB 960
300 DISP "CONNECT THRU--RF ON",SPA32;
310 INPUT Z$
320 FOR R7=0 TO P-1
330 F=F1+R7*P1
340 GOSUB 840
350 GOSUB 1080
360 C[1+R7]=M
370 NEXT R7
380 DISP "MODEL NO.";
390 INPUT M
400 DISP "SERIAL NO.";
410 INPUT L
420 DISP "INSERT PAPER",SPA32;
430 INPUT Z$
440 GOSUB 560
450 GOSUB 960
460 DISP "CONNECT DUT--RF ON",SPA32;
470 INPUT Z$
480 FOR R7=0 TO P-1
490 F=F1+R7*P1
500 GOSUB 840
510 GOSUB 1080
520 PLOT F,M-C[1+R7]
530 NEXT R7
540 PEN
550 GOTO 380
560 REM SCALING AND LABELING
570 SCALE F1-0.25*(F2-F1),F2+0.1*(F2-F1),1.2*Y,-0.12*Y
580 W=(F2-F1/2)+(F2-F1 <= 2)*(F2-F1)/4
590 XAXIS 0,W,F1,F2
600 XAXIS Y,W,F1,F2
610 YAXIS F1,Y/-8,Y,0
620 YAXIS F2,Y/-8,Y,0
630 DEG
640 IF (F2-F1) <= 2 THEN 670
650 FOR X1=F1 TO F2 STEP INT((F2-F1)/5+0.8)
660 GOTO 680
670 FOR X1=F1 TO F2 STEP 0.25*(F2-F1)
680 PLOT X1-0.04*(F2-F1),+1.05*Y,1
690 LABEL (*,2.5,1.7,0,0.7)X1
700 NEXT X1
710 FOR Y1=Y TO 0 STEP INTY/-8
720 PLOT F1-0.12*(F2-F1),Y1+0.02*Y,1
730 LABEL (*,2.5,1.7,0,0.7)ABS(Y1)
740 NEXT Y1
750 PLOT F1-0.15*(F2-F1),0.8*Y,1
760 LABEL (*,2.5,1.7,+90,0.7)"INSERTION LOSS(DB)"
770 PLOT F1+0.35*(F2-F1),+1.1*Y
780 LABEL (*,2.5,1.7,0,0.7)"FREQUENCY GHZ"
790 PLOT F1+0.35*(F2-F1),-0.04*Y
800 LABEL (*,2.5,1.7,0,0.7)"SERIAL NO"L
810 PLOT F1+0.35*(F2-F1),Y*(-0.12),1
820 LABEL (*,2.5,1.7,0,0.7)"MODEL NO"M
830 RETURN
840 REM FSET SUBROUTINE
850 B=(F>D[7])+(F>D[8])+1
860 H=10*(F-D[B])/D[3+B]
870 IF H<9.999 THEN 890
880 H=9.999
890 CMD "?U&"
900 OUTPUT (13,910)H,B
910 FORMAT "M1V",F1000.3,"EB",F1000.0
920 RETURN
930 DISP "OUT OF RANGE"
940 WAIT 3000
950 GOTO 170
960 REM   ZERO SUBROUTINE
970 DISP "TURN RF OFF",SPA32;
980 INPUT Z$
990 CMD "?U-","Z1I","?M5"
1000 ENTER (13,1010)Z
1010 FORMAT 4X,F4.0
1020 IF ABSZ>2 THEN 990
1030 CMD "?U-","9+DI","?M5"
1040 ENTER (13,1050)Z
1050 FORMAT B
1060 IF Z >= 84 THEN 1030
1070 RETURN
1080 REM   READ METER SUBROUTINE
1090 CMD "?U-","T","?M5"
1100 ENTER (13,1110)M
1110 FORMAT 3X,E12.0
1120 RETURN
1130 END
```

PROGRAM NO. 3
9820A CALCULATOR/8755 OR 8410B ANALYZER

```
0:
"2-18GHZ TEST SE
T--8755 OR 8410B
"⊢
1:
"ADDRESSES--8620
C=&;3490=6(LSTN)
,V(TALK);59307=7
"⊢
2:
"12/2/75"⊢
3:
"LOW LMTS OF BAN
DS";2→R8;6→R9;12
→R10⊢
4:
"WIDTHS OF BANDS
";4.2→R11;6.4→R1
2;6→R13⊢
5:
"SWITCHPTS";6.1→
R14;12.2→R15⊢
6:
ENT "F-START(GHZ
)",A,"F-STOP(GHZ
)",B,"NO. OF PTS
.",R5;(B-A)/(R5-
1)→C⊢
7:
IF (2>A)+(A>18)+
(2>B)+(B>18);
DSP "OUT OF RANG
E";DSP ;DSP ;
DSP ;GTO -1⊢
8:
ENT "MAX LOSS(DB
)",Y,"INS=1,RL=2
,BTH=3",R1⊢
9:
IF R1=1;GTO "THR
U"⊢
10:
DSP "CONNECT SHO
RT";STP ⊢
11:
0→R2;CMD "?U7","
A2"⊢
```

```
12:
"OPEN";A→X;0→R4⊢
13:
"CALR";GSB "FSET
"⊢
14:
GSB "DMM"⊢
15:
(R2=0)R3+R2(20
LOG ((10↑(R(16+R
4)/20)+10↑(R3/20
))/2))→R(16+R4)⊢
16:
IF (X+C→X)≤B;R4+
1→R4;GTO "CALR"⊢
17:
IF R2=1;GTO +3⊢
18:
1→R2;DSP "CONNEC
T OPEN";STP ⊢
19:
GTO "OPEN"⊢
20:
IF R1=2;GTO "NEX
T"⊢
21:
"THRU";CMD "?U7"
,"A1";DSP "CONNE
CT THRU";STP ⊢
22:
A→X;(R1=3)R5→R4⊢
23:
"CALX";GSB "FSET
"⊢
24:
GSB "DMM"⊢
25:
R3→R(16+R4);IF (
X+C→X)≤B;R4+1→R4
;GTO "CALX"⊢
26:
"NEXT";ENT "MODE
L NO.",R6,"SERIA
L NO.",R7;ENT "P
APER";GSB "AXES"
⊢
27:
(R1=3)R5→R4;0→R2
⊢
```

```
28:
DSP "CONN DUT";
STP ⊢
29:
"PLT2";A→X⊢
30:
"MEAS";GSB "FSET
"⊢
31:
GSB "DMM"⊢
32:
PLT X,20(R(16+R4
)-R3);IF (X+C→X)
≤B;R4+1→R4;GTO "
MEAS"⊢
33:
PEN ;IF (R1=3)(R
2=0);CMD "?U7","
A2";1→R2;0→R4;
GTO "PLT2"⊢
34:
IF R1=3;CMD "?U7
","A1"⊢
35:
GTO "NEXT"⊢
36:
"FSET";(X>R14)+(
X>R15)→R3⊢
37:
10(X-R(8+R3))/R(
11+R3)→R7;IF R7>
9.999;9.999→R7⊢
38:
CMD "?U&";FMT "M
1V",FXD *.3,"EB"
,FXD *.0;WRT 13,
R7,R3+1;RET ⊢
39:
"DMM";CMD "?U6",
"M3R4F0T1E","?V5
";FMT *;RED 13,R
3;RET ⊢
40:
"AXES";(B-A>4)+(
B-A≤4)(B-A)/4→R3
⊢
```

```
41:
SCL A-.15(B-A),B
,1.1Y,-.1Y;AXE A
,Y,R3,-Y/8;AXE B
,0,R3,-Y/8⊢
42:
LTR A+.3(B-A),1.
08Y,321;PLT "FRE
QUENCY(GHZ)"⊢
43:
LTR A+.01(B-A),1
.03Y,211;FXD 1+(
B-A≤2);PLT A;.25
→R2⊢
44:
(B-A>4)(INT ((B-
A)R2)+A)+(B-A≤4)
(R2(B-A)+A)→R3⊢
45:
LTR R3-.02(B-A),
1.03Y;PLT R3;IF
(R2+.25→R2)≤.75;
GTO -1⊢
46:
LTR B-.05(B-A),1
.03Y;PLT B⊢
47:
LTR A-.10(B-A),.
85Y,232;PLT "RET
URN/INSERT LOSS(
DB)";0→R2;FXD (Y
≤30)+(10>Y)⊢
48:
LTR A-.045(B-A),
.99Y-R2,211;PLT
Y-R2;IF (R2+Y/4→
R2)≤Y;GTO +0⊢
49:
FXD 0;LTR A+.2(B
-A),-.05Y,321;
PLT "MODEL NO.";
PLT R6;PLT "
SERIAL NO.";PLT
R7⊢
50:
RET ⊢
51:
END ⊢
R199
```

PROGRAM NO. 4
9830A CALCULATOR/8755 OR 8410B ANALYZER

```
10 REM 2-18GHZ MIC[illegible] [illegible]
20 REM ADRESS--8620C-[illegible]
30 DIM D[8]
40 DIM C[150]
50 DIM B[150]
60 REM D(1,2,3)=LOW LIMITS OF BANDS 1,2,3
70 REM D(4,5,6)=WIDTH OF BANDS 1,2,3
80 REM D(7,8)=BAND SWITCH POINTS
90 D[1]=2
100 D[2]=6
110 D[3]=12
120 D[4]=4.2
130 D[5]=6.4
140 D[6]=6
150 D[7]=6.1
160 D[8]=12.2
170 DISP "START FREQ(GHZ)";
180 INPUT F1
190 DISP "STOP FREQ(GHZ)";
200 INPUT F2
210 IF F1<2 OR F2>18 THEN 1410
220 DISP "NUMBER OF POINTS";
230 INPUT P
240 P1=(F2-F1)/(P-1)
250 DISP "INS LS=1,RET LS=2,OR BOTH=3";
260 INPUT N
270 DISP "MAX LOSS(UP TO 80 DB)";
280 INPUT Y
290 Y=-1*Y
300 S=-20
310 Q=0
320 J=0
330 IF N=2 THEN 380
340 DISP "CONNECT THRU",SPA32;
350 CMD "?U7","A1"
360 K=1
370 GOTO 440
380 DISP "CONNECT SHORT",SPA32;
390 CMD "?U7","A2"
400 K=2
410 GOTO 440
420 DISP "CONNECT OPEN",SPA32;
430 K=3
440 INPUT Z$
450 GOTO 480
460 N=1
470 CMD "?U7","A1"
480 FOR R7=0 TO (P-1)
490 F=F1+R7*P1
500 GOSUB 1250
510 REM MEAS 8755 AUX B(A1)IF K=1,AUX A(A2)IF K>1
520 REM DMM SUBROUTINE
530 CMD "?U6","M3R4F0T1E"
540 CMD "?V5"
550 IF J=1 THEN 1340
560 REM K=1 FOR THRU CAL
570 REM K=2 FOR SHORT  CAL
580 REM K=3 FOR OPEN CAL
590 IF K=2 THEN 640
600 IF K=3 THEN 670
610 ENTER (13,620)C[1+R7]
620 FORMAT 4X,E12.0
630 GOTO 690
640 ENTER (13,650)B[1+R7]
650 FORMAT 4X,E12.0
660 GOTO 690
670 ENTER (13,650)A
680 B[1+R7]=20*LGT((10↑(B[1+R7]/20)+10↑(A/20))/2)
690 NEXT R7
700 PEN
710 REM   INSERT"DISP "CHANGE DETECTOR";"HERE IF WANT TO MEASURE INSERTION AND
720 REM   RETURN LOSS OF DUT W 8755(N=3)BUT DO NOT HAVE 59307 SWITCH TO SELECT
730 REM   AUX A AND AUX B OUTPUTS.THIS WILL ALLOW TIME TO MOVE DETECTOR INBETWEEN
740 REM   THRU/SHORT CAL AND REFL/TRANS MEAS STEPS.
750 IF Q=0 THEN 800
760 Q=3-Q
770 CMD "?U7","A2"
780 IF Q=1 THEN 460
790 N=3
800 IF N=1 THEN 830
810 IF K=1 THEN 380
820 IF K=2 THEN 420
830 DISP "CONNECT DEVICE INSERT PAPER";
840 J=1
850 INPUT T$
860 REM SCALING AND LABELING
870 SCALE F1-0.25*(F2-F1),F2+0.1*(F2-F1),1.2*Y,-0.12*Y
880 W=(F2-F1)/2)+(F2-F1 <= 2)*(F2-F1)/4
890 XAXIS 0,W,F1,F2
900 XAXIS Y,W,F1,F2
910 YAXIS F1,Y/-8,Y,0
920 YAXIS F2,Y/-8,Y,0
930 DEG
940 IF (F2-F1) <= 2 THEN 970
950 FOR X1=F1 TO F2 STEP INT((F2-F1)/5+0.5)
960 GOTO 980
970 FOR X1=F1 TO F2 STEP 0.25*(F2-F1)
980 PLOT X1-0.04*(F2-F1),+1.05*Y,1
990 LABEL (*,2.5,1.7,0,0.7)X1
1000 NEXT X1
1010 FOR Y1=Y TO 0 STEP INTY/-8
1020 PLOT F1-0.12*(F2-F1),Y1+0.02*Y,1
1030 LABEL (*,2.5,1.7,0,0.7)ABS(Y1)
1040 NEXT Y1
1050 PLOT F1-0.15*(F2-F1),0.3*Y,1
1060 IF N=3 THEN 1120
1070 IF N=2 THEN 1100
1080 LABEL (*,2.5,1.7,+90,0.7)"INSERTION LOSS(DB)"
1090 GOTO 1140
1100 LABEL (*,2.5,1.7,+90,0.7)"RETURN LOSS(DB)"
1110 GOTO 1140
1120 LABEL (*,2.5,1.7,+90,0.7)"INSERT/RET LOSS(DB)"
1130 Q=2
1140 PLOT F1+0.35*(F2-F1),+1.1*Y
1150 LABEL (*,2.5,1.7,0,0.7)"FREQUENCY GHZ"
1160 DISP "MODEL NO?";
1170 INPUT M
1180 DISP "SERIAL NO ?";
1190 INPUT L
1200 PLOT F1+0.35*(F2-F1),-0.04*Y
1210 LABEL (*,2.5,1.7,0,0.7)"SERIAL NO"L
1220 PLOT F1+0.35*(F2-F1),Y*(-0.12),1
1230 LABEL (*,2.5,1.7,0,0.7)"MODEL NO"M
1240 GOTO 480
1250 REM FSET SUBROUTINE
1260 B=(F>D[7])+(F>D[8])+1
1270 H=10*(F-D[B])/D[3+B]
1280 IF H<9.999 THEN 1300
1290 H=9.999
1300 CMD "?U8"
1310 OUTPUT (13,1320)H,B
1320 FORMAT "V",F1000.3,"EB"-F[illegible]"M1
1330 RETURN
1340 ENTER (13,1350)M
1350 FORMAT 4X,E12.0
1360 IF N>1 THEN 1390
1370 PLOT F,S+(C[1+R7]-M)
1380 GOTO 690
1390 PLOT F,S+(B[1+R7]-M)
1400 GOTO 690
1410 DISP "OUT OF RANGE"
1420 WAIT 3000
1430 GOTO 170
1440 END
```

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