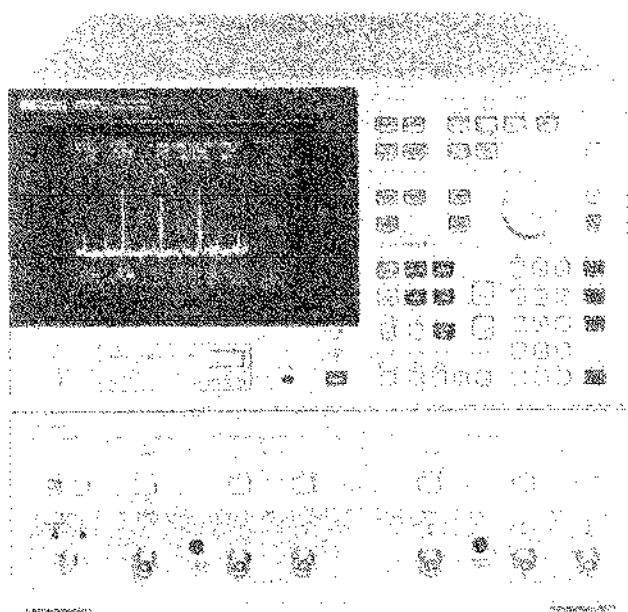


Advanced Filter Evaluation and Limit Testing

with

HP 4195A Network/Spectrum Analyzer



1. INTRODUCTION

Filters play a significant roll in electronic equipment because of the decisive effect they have on the performance of the equipment in which they are used. Filters find extensive use in communication, telecommunication, and consumer electronics. These products are becoming more complicated and require higher quality signal processing. For example, the amount of information sent by telecommunication networks has increased (requiring more stringent performance from the filters used in these systems), and VCR's/TV's require higher quality signal for better picture resolution and quality (sharper vision). As the demand for higher quality and more sophisticated electronic equipment increases, so has the need for accurate high speed testing and characterization of the wide variety of filters used.

Both end users and filter manufactures need to be able to quickly and easily test a wide variety of filters to ever increasingly tighter tolerances. This application note describes how the HP 4195A Network/Spectrum Analyzer is used to test filters, by either measuring the filter's parameters or by using limit lines to perform GO/NO-GO testing. Both of these test techniques can be performed without a computer by using the HP 4195A's **USER PROGRAM** programming function, a BASIC-like language used to control the HP 4195A's operation. An external computer can also be used to develop and down load **USER PROGRAMS** to the HP 4195A over the HP-IB bus and to control the operation of the HP 4195A.

2. FILTER PARAMETER MEASUREMENT

When testing filters, several of the filter's parameters are derived from the filter's measured transmission characteristics. Older network analyzers required using markers or other functions which required several key stroke operations and special operator skill to obtain valid results. The HP 4195A's **USER DEFINE** function gives the user the power of assigning complicated, hard to remember, error prone multiple key and softkey key strokes operations to a single key (keyboard macros), so filter parameters can now be measured and displayed using a single key stroke operation. The **USER DEFINE** function gives the user the power to define a single key stroke function to replace multiple key and softkey operations. As an example, this section shows how to use the **USER DEFINE** keys to find the following parameters:

- 1) -3 dB Band Width
- 2) Insertion Loss
- 3) Center Frequency
- 4) Band Pass Filter Rejection Characteristics

Figure 1 shows the filter test configuration used. A power splitter is required for this measurement. The **USER DEFINE** keys are defined using a **USER PROGRAM**. The program listing for Program 1 is given in the Appendix of this application note. After executing this program, press the '**USER DEFINE**' key. Softkeys defined by a **USER PROGRAM** will be displayed as shown in Figure 2. When the '**USER DEFINED**' key is pressed, each parameter is displayed at the bottom of the screen as shown in Figure 3. When using this technique, a filter's parameters are easily obtained with just a single key stroke, no time consuming, error prone key stroke sequences or function/measurement sequences need be performed.

The HP 4195A can output measurement parameters directly to an HP-IB printer. Figure 3 shows a sample print out of measurement parameters obtained using this technique, the program listing is given in Program 2 in the Appendix of this application note.

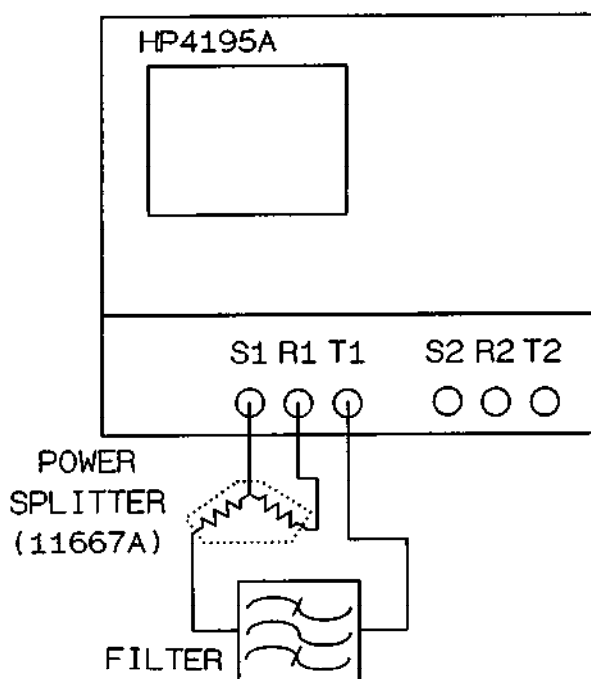
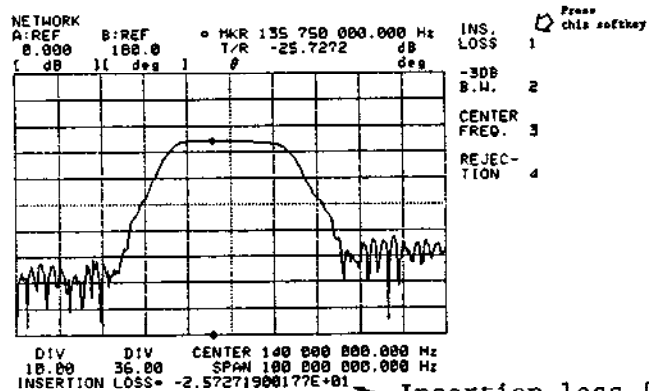
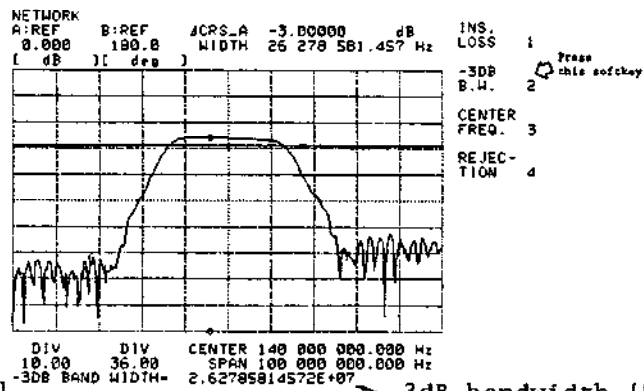


Figure 1. Filter Testing Configuration



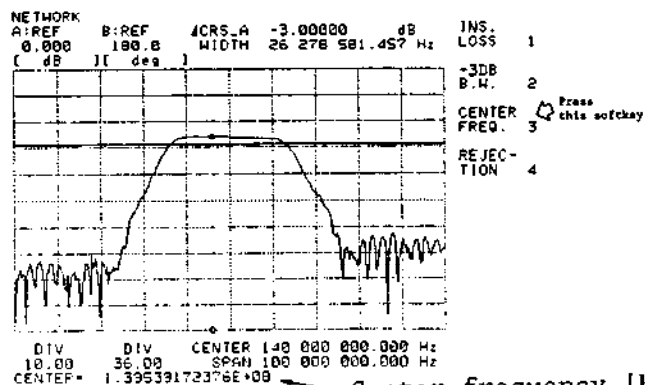
Insertion loss [dB]
is displayed here

(a) Insertion Loss



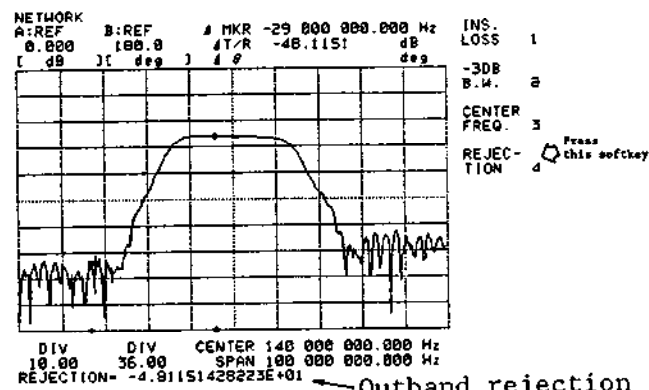
-3dB bandwidth [Hz]
is displayed here

(b) -3dB Bandwidth



Center frequency [Hz]
is displayed here

(c) Center Frequency



Outband rejection [dB]
is displayed here

(d) Rejection

Figure 2. Filter Parameters

```

INSERTION LOSS      [DB]
-2.55817832947E+01

-3DB BAND WIDTH    [HZ]
2.63951934003E+07

CENTER FREQUENCY    [HZ]
1.39858385351E+08

REJECTION           [DB]
-4.68137321472E+01
  
```

Figure 3. Example of Parameter Printout

3. GO/NO-GO TESTING

The HP 4195A can be used to perform GO/NO-GO testing using limit lines. Before running the GO/NO-GO program listed in Program 4, the limit lines setup program, Program 3, must be executed.

3-1. Limit Line Setting

Limit lines are composed of a series of straight line segments as shown in Figure 4. Each segment is specified by its start and stop coordinates. These coordinates are given as frequency and power level (f,p) or (f',p') for the minimum and maximum limit points. Various shapes of limit lines can be created by modifying the setup program. The frequencies and power levels can be modified by changing lines 300-560 of Program 3, and the number of segment points can be modified in line 270. The following procedure generates and stores the limit lines.

- 1) Before executing Program 3, modify the frequencies and power levels for each segment and set the instrument settings as required.
- 2) Connect the DUT as shown in Figure 1.
- 3) Execute Program 3, the HP 4195A will display the limit lines and the measurement data of the DUT as shown in Figure 5.
- 4) If you want to modify the limit lines, press the **USER DEFINE** key, then move a marker to a point you want to modify and press the softkeys to modify the limit lines displayed on the screen, as shown in Figure 6.
- 5) After setting the limit lines, the limit line data and instrument state (measurement conditions) information must be stored to a file on a floppy disc. Press the '**SAVE/GET**' key and the '**SAVE**' softkey. Choose and enter a file name, and press the '**EXEC/ENTER**' key. The data is saved on the disc and is used for the following GO/NO-GO test procedure.

f_m ; m th frequency of a maximum limit line
 p_m ; m th power level of a maximum limit line
 f'_m ; m th frequency of a minimum limit line
 p'_m ; m th power level of a minimum limit line
 n ; number of segment points

Each value should be modified in line 270-560 of Program 3.

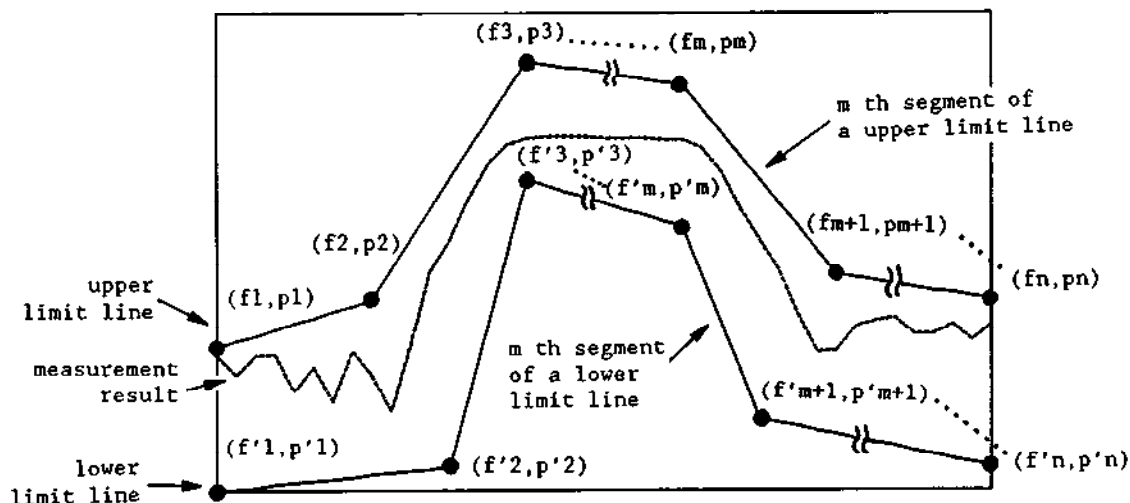


Figure 4. Segments for Limit Line

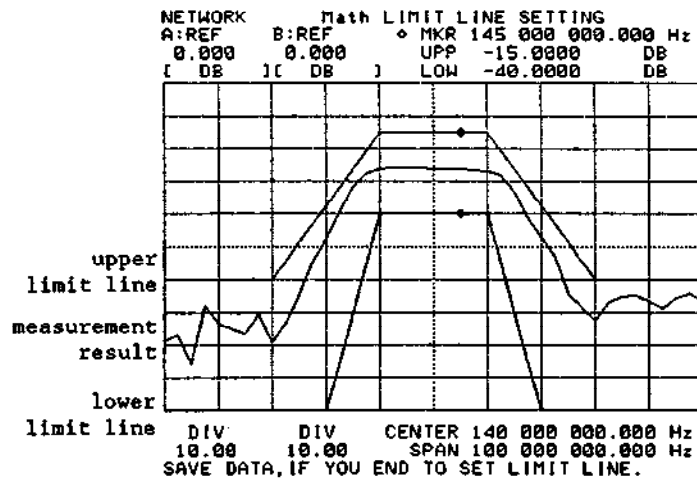


Figure 5. Limit Lines

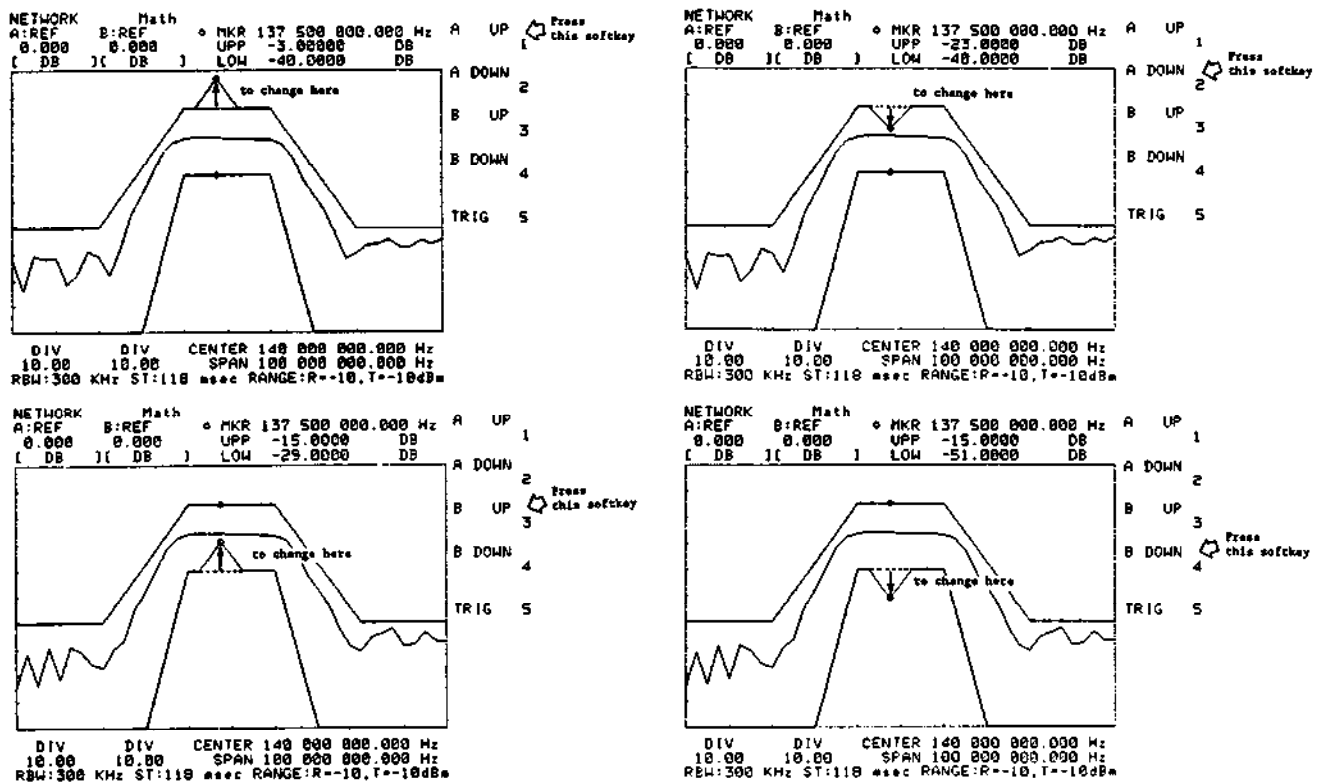


Figure 6. Limit Line Modification

3-2. GO/NO-GO Testing

After executing Program 3 to set the limit lines, the HP 4195A is ready to perform GO/NO-GO filter testing. Connect a DUT as shown in Figure 1 and execute Program 4. The GO/NO-GO test procedure is as follows:

- 1) When the program is executed, the program displays the catalog of files on the disc and then pauses.
- 2) Recall the stored limit line and instrument state data. Press the 'GET' softkey and select the data file that you stored the data in and press the 'EXEC/ENTER' key.
- 3) Press the 'PROGRAM' key and the 'CONT' softkey, the HP 4195A will start the GO/NO-GO test. Figure 7 shows some sample results of a GO/NO-GO test of a bandpass filter.
- 4) Change the DUT and press the 'CONT' key to continue the GO/NO-GO testing.

The HP 4195A's **USER FUNCTION** can be used to easily set the limit lines for filter testing. Using the HP 4195A's built-in floppy disc drive, the limit line data and instrument states are stored for recall as required anytime. GO/NO-GO testing of a variety of devices can be accomplished easily and quickly using the HP 4195A!

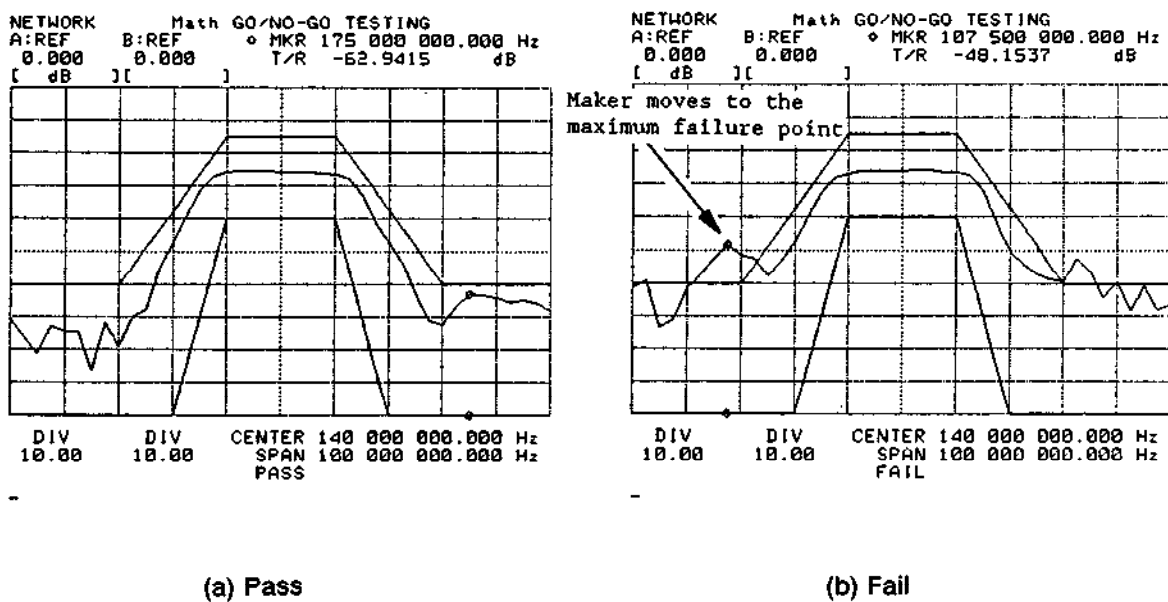


Figure 7. Results of GO/NO-GO testing

4. Advanced Filter Tests

The HP 4195A, with its many outstanding features, can be used to perform advanced test procedures on filters.

4-1. Multi-Device Measurement and Multi-Output Filter Measurement

The HP 4195A can be used to increase your measurement speed by being used with a handler to compare a test device with a standard device. Because the HP 4195A has two output channel ports and four input ports, three devices can be connected simultaneously to the HP 4195A for testing. Figure 8 shows the configuration for testing multiple devices.

The HP 4195A with its multi-inputs can measure multi-output filters such as state variable filters. Figure 9 shows a configuration for testing multi-output filters.

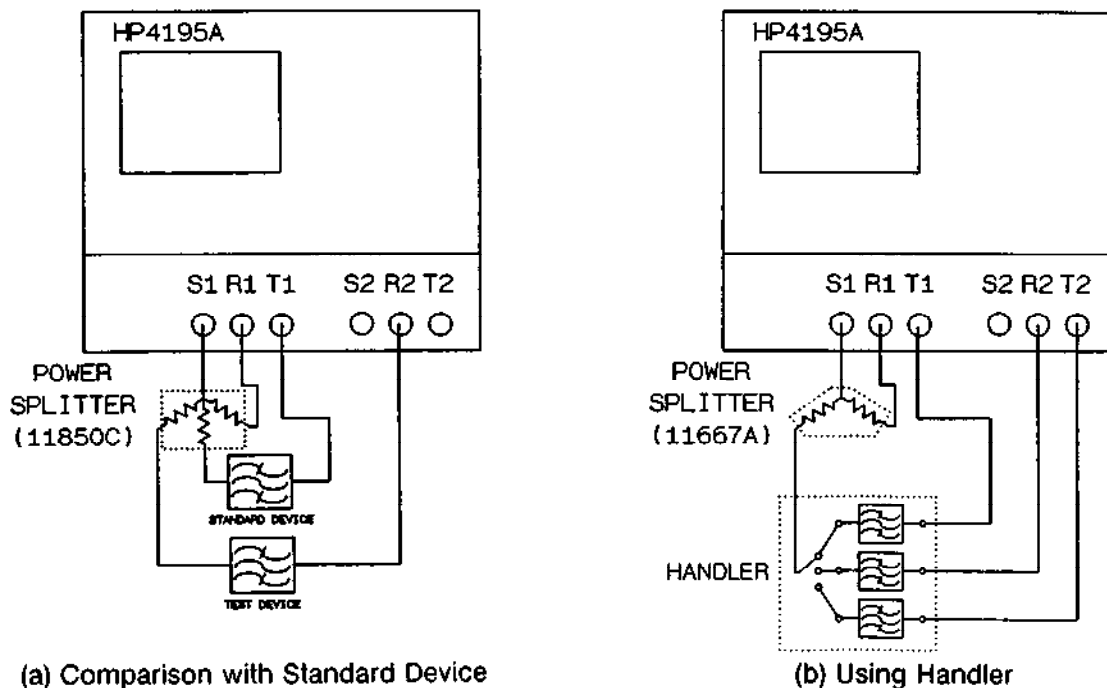


Figure 8. Example of Configuration for Multi-device Measurement

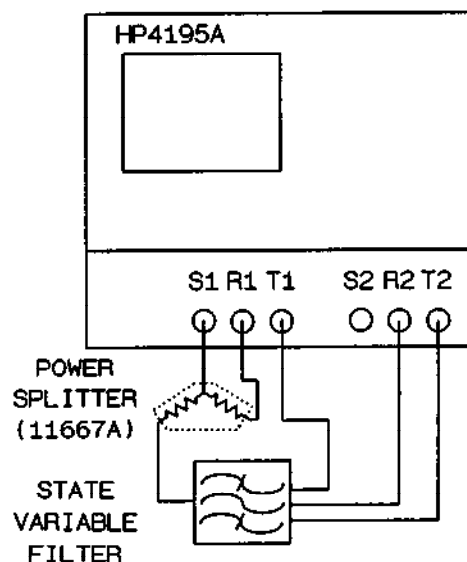


Figure 9. Example of Configuration for a State Variable Filter Testing

4-2. Phase Measurement

For filter test, in addition to measuring transmission characteristics, phase characteristics must also be measured. For example, Group Delay (derivative of phase with respect to frequency) represents phase nonlinearity, and phase nonlinearity degrades the quality of the signal.

The HP 4195A with its high accuracy and resolution can perform precise Group Delay measurements. Figure 10 shows some sample results of Group Delay measurements. The HP 4195A can simultaneously measure Group Delay and Transmission characteristics.

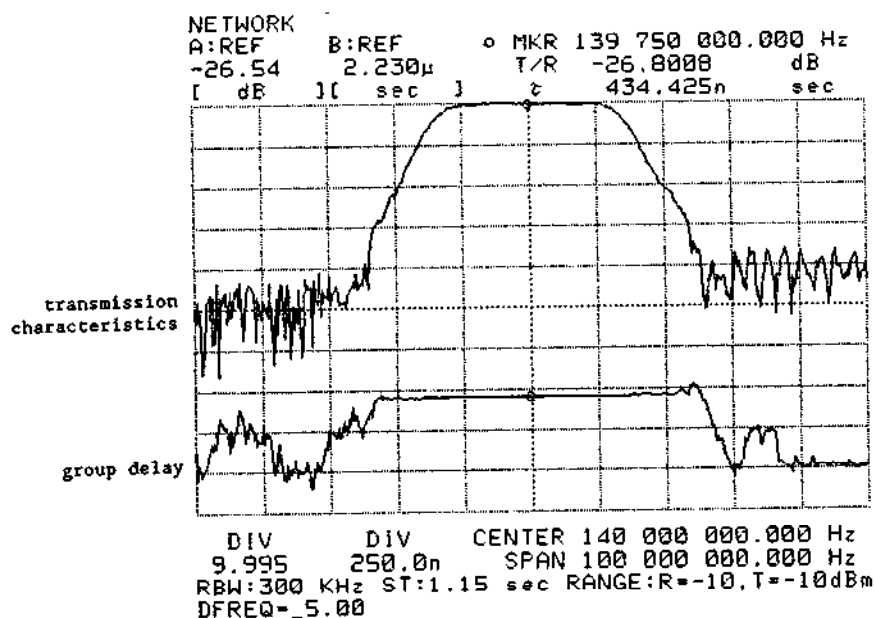


Figure 10. Group Delay and Transmission Characteristic

5. Conclusion

The HP 4195A, with its ability to provide precision transmission and phase measurement, is a very powerful tool for testing filters. The HP 4195A's **USER FUNCTION** provides for flexible, easy operation, so it can quickly and easily perform parameter measurement and GO/NO-GO testing. The flexible operation of the HP 4195A allow it to be quickly reconfigured to meet the test requirements of various test devices.

Program 1. USER DEFINE key Definition

```

100 |*****
110 |* FILTER TEST *
120 |* FINDING PARAMETER *
130 |* FOR HP 4195A FEB.19.1988 *
140 |* YOKOGAWA-HEULETT-PACKARD, LTD *
150 |*****
160 |***** SETTING MES. CONDITION *****
170 |*****
180 |***** | SINGLE SWEEP
190 |***** | TRACE B OFF
200 |***** | CENTER FREQ. 140 MHZ
210 |***** | SPAN 100 MHZ
220 |***** | SI OSC. LEVEL -10 DBM
230 |***** | R1 ATTEN. 0 DB
240 |***** | T1 ATTEN. 0 DB
250 |***** | RES. BW 10 KHZ
260 |***** | DEFINE USER DEFINE KEY *****
270 |***** | R0=MKRA;DISP "INSERTION LOSS",R0"
280 |***** | R1=MKRA;DISP "CENTER",R0"
290 |***** | R2=MKRA;DISP "REJECTION",R0;DEL T1"
300 |***** | R3=MKRA;DISP "LOSS",R0"
310 |***** | R4=MKRA;DISP "B.W.",R0"
320 |***** | R5=MKRA;DISP "CENTER FREQ.",R0"
330 |***** | R6=MKRA;DISP "T10W",R0"
340 |***** | R7=MKRA;DISP "T10W",R0"
350 |***** | R8=MKRA;DISP "T10W",R0"
360 |***** | R9=MKRA;DISP "T10W",R0"
370 |*****

```

Program 2. Parameter Printing

```

100 |*****
110 |* FILTER TEST *
120 |* PRINT PARAMETER *
130 |* FOR HP 4195A FEB.19.1988 *
140 |* YOKOGAWA-HEULETT-PACKARD, LTD *
150 |*****
160 |***** INITIALIZING *****
170 |***** | SINGLE SWEEP
180 |***** | CENTER FREQ. 140 MHZ
190 |***** | SPAN 100 MHZ
200 |***** | SI OSC. LEVEL -10 DBM
210 |***** | R1 ATTEN. 0 DB
220 |***** | T1 ATTEN. 0 DB
230 |***** | RES. BW 10 KHZ
240 |***** | TALK ONLY
250 |***** | TRACE B OFF
260 |*****
270 |***** | FINDING PARAMETER *****
280 |***** | MEAS. LOOP TOP <----->
290 |***** | R0=MKRA;R0=MKRA
300 |***** | R1=MKRA;WIDTH1;DLCURS=-3;R1=WLID
310 |***** | R2=MKRA;WIDTH1;DLCURS=-3;R2=(LCURS+LCURS)/2
320 |***** | R3=MKRA;SHKR-CENTER-SPAN/3;R3=DMKRA
330 |***** | PRINTING DATA *****
340 |***** | INSERTION LOSS (DB)"
350 |***** |
360 |***** |
370 |***** |
380 |***** |
390 |***** |
400 |***** |
410 |***** |
420 |***** |
430 |***** |
440 |***** |
450 |***** |
460 |***** |
470 |***** |
480 |***** |
490 |***** |
500 |***** |
510 |***** |
520 |*****

```

Program 3. Limit Line Setting

```

100 I *****
110 I> FILTER TEST LIMIT LINE SETTING *
120 I> PROGRAM FOR HP 4195A *
130 I> FEB. 3. 1988 *
140 I> YOKOGAWA-HEWLETT-PACKARD, LTD. *
150 I *****
160 I ***** SETTING INSTRUMENT STATE *****
170 SUNZ I SINGLE SWEEP
180 CMT "LIMIT LINE SETTING"
190 CENTER=140 MHZ I CENTER FREQUENCY
200 SPAN=100 MHZ I SPAN
210 OSC1=-10 I TEST SIGNAL LEVEL (-50 THRU +15)
220 ATT1=0 I REF ATT. (50,40,30,20,10 OR 0)
230 ATT1=0 I TEST ATT. (50,40,30,20,10 OR 0)
240 RBW=300K I RES BW (300K, 100K, 30K, 10K, 300, 100, 30, 10 OR 3) requirements.
250 NBP=41 I NUMBER OF POINT (Z THRU 401)
260 I ***** DEFINING NUMBER OF SEGMENTS *****
270 R9=6 I NUMBER OF SEGMENT POINTS (Z THRU 401 & LESS THAN NOP)
280 R19=R9-1 I NUMBER OF LINE SEGMENTS
290 I ***** DEFINING SEGMENTS *****
300 I ***** I UPPER LIMIT LINE FREQ.
300 RAX(1)=START
310 RAX(2)=110M
320 RAX(3)=130M
330 RAX(4)=150M
340 RAX(5)=170M
350 RAX(6)=STOP
360 I *****
370 RB(1)=START
380 RB(2)=120M
390 RB(3)=130M
400 RB(4)=150M
410 RB(5)=160M
420 RB(6)=STOP
430 I *****
440 RC(1)=-50
450 RC(2)=-60
460 RC(3)=-15
470 RC(4)=-15
480 RC(5)=-60
490 RC(6)=-60
500 I *****
510 RDX(1)=-100
520 RDX(2)=-100
530 RDX(3)=-40
540 RDX(4)=-40
550 RDX(5)=-100
560 RDX(6)=-100
570 I ***** INITIALIZING AND PAUSING *****
580 CPA0:DPB0:SPC0:SPD0
590 MTH0:MTH00
620 I ***** STORING INST. STATE TO REGISTERS *****
630 R0=CENTER
640 R1=SPAN
650 R2=START
660 R3=STOP
670 R4=OSC1
680 R5=ATT1
690 R6=ATT1
700 R7=RBW
710 R8=NOP

720 R18=R8-1
730 I *****
740 RZ0=SPAN/(NOP-1) ***** CALCULATING LIMIT LINES *****
750 I ***** I UPPER LIMIT LINE CALCULATION *****
760 FOR R90=1 TO R19 *****
770 R91=R90+1 *****
780 R51=(RAX(R90)-RB(1))/RZ0+1 *****
790 R52=(RAX(R91)-RB(1))/RZ0+1 *****
800 FOR R92=R51 TO R52 *****
810 C(R92)=RZ0*(R92-R51)*(RC(R91)-RC(R90))/(RAX(R91)-RAX(R90))+RC(R90) *****
820 NEXT R92 *****
830 R51=(RAX(R90)-RB(1))/RZ0+1 ***** LOWER LIMIT LINE CALCULATION *****
840 R52=(RAX(R91)-RB(1))/RZ0+1 *****
850 FOR R92=R51 TO R52 *****
860 D(R92)=RZ0*(R92-R51)*(RDX(R91)-RDX(R90))/(RAX(R91)-RAX(R90))+RDX(R90) *****
870 NEXT R92 *****
880 NEXT R90 ***** MEASUREMENT *****
890 I *****
900 SUTRS *****
910 I ***** SETTING DISPLAY CONDITIONS *****
920 SPCHS *****
930 SCL1:REF=0:DIV=10 *****
940 SCL2:REF=0:DIV=10 *****
950 I ***** SETTING EDIT SOFTKEYS *****
960 DF1"R51"=(MKR-START)/(SPAN/(NOP-1))+1:(R51)-A(R51)+1" *****
970 DF2"R51"=(MKR-START)/(SPAN/(NOP-1))+1:(R51)-A(R51)+1" *****
980 DF3"R51"=(MKR-START)/(SPAN/(NOP-1))+1:(R51)-B(R51)+1" *****
990 DF4"R51"=(MKR-START)/(SPAN/(NOP-1))+1:(R51)-B(R51)+1" *****
1000 LBL1"A UP"LBL2"A DOWN"LBL3"B UP"LBL4"B DOWN"LBL5"-- *****
1010 CPA1:DPB1:SPC1 *****
1020 DMA=A:DMB=B *****
1030 PRMA"UP"PRMB"LOW"UNITA" DB"UNITB" DB" *****
1040 MTHA1:MTHB1 *****
1050 I ***** ENDING *****
1060 DISP "IF DONE, PLEASE SAVE YOUR DATA." *****
1070 BEEP *****
1080 CNT"" *****
1090 END *****

```

These instrument settings should be modified according to measurement requirements.

The number of segment points can be modified.

The frequencies and power levels of each segment of limit lines should be modified for the measurement requirements.

Program 4. GO/NO-GO Testing

```

100 |*****
110 |* FILTER TEST (60 NOGO) PROGRAM *
120 |*      FOR HP 4195A *
130 |*      FEB.8.1988 *
140 |* YOKOGAWA-HEWLETT-PACKARD, LTD. *
150 |*****
160 |***** INITIALIZING AND PAUSING *****
170 CMT "GO/NO-GO TESTING"
180 DP#0;DPB#0;SPC#0;SPD#0 DISP A,B,C,D OFF
190 CAT      DISC CATALOG
200 DISP "PLEASE GET MEAS. CONDITION DATA"
210 PAUSE
220 |***** SETTING INSTRUMENT STATES *****
230 CENTER=R0      | CENTER FREQ.
240 SPAN=R1        | SPAN
250 OSCI=R4        | OSC. LEVEL
260 ATRI=RS        | REF ATT.
270 ATTI=RS        | TEST ATT.
280 RBN=R7         | RES BW
290 NOP=R8         | NUMBER OF POINTS
300 |***** SETTING LIMIT LINES *****
310 SPC#6
320 SCL1:REF=0;DIV=10 | DISP SCALE REF. FOR A
330 SCL2:REF=0;DIV=10 |      FOR B
340 DP#1;DPB#0;SPC1;SPD1 | DISP A-ON,B-OFF,C-ON,D-ON
350 DMB=(C-NA);(MA-D) | USER MATH B DEFINE
360 PRMB"";UNITB"" | USER MATH LABEL ENTRY
370 MTMA#;INTHB1 | MATH A-OFF,B-ON
380 |***** GO/NO-GO TESTING *****
390 SVTR# | ** MEAS. LOOP TOP <-----+
400 MCF1;MKCRZ;MKMN |
410 IF MKRB<=0 THEN 430 |
420 DISP "      PASS      " |
430 DISP "      FAIL      " |
440 PAUSE |
450 GOTO 390 | ** MEAS. LOOP END --> --> --+
460 END

```



For more information, call your local HP sales office listed in the telephone directory white pages. Ask for the Electronic Instrument Department, or write to Hewlett-Packard U.S.A. - P.O. Box 10301, Palo Alto, CA 94303-0890. Europe - Hewlett-Packard S.A. P.O. Box 529, 1180 AM Amstelveen, The Netherlands. Canada - 6877 Goreway Drive, Mississauga, L4V 1M8, Ontario. Japan - Yokogawa-Hewlett-Packard Ltd., 3-29-21, Takaido-Higashi, Suginami-ku, Tokyo 168. Far East - Hewlett-Packard Asia Headquarters, 47/F China Resources Building, 26 Harbour Road, Wanchai Hong Kong. Australasia - Hewlett-Packard Australia Ltd., 31-41 Joseph Street, Blackburn, Victoria 3130 Australia. Latin America - Hewlett-Packard Latin America Headquarters, 3495 Deer Creek Rd., Palo Alto, CA 94304. For all other areas, please write to: Hewlett-Packard Intercontinental Headquarters, 3495 Deer Creek Rd., Palo Alto, CA 94304.