NATIONAL RADIO ASTRONOMY OBSERVATORY

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TITLE: RECEIVER NOISE TEMPERATURE MEASUREMENT AND CALIBRATION PROGRAMS

AUTHOR(S): James R. Coe

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Distribution: M. Balister
S. Weinreb
J. Payne
P. Napier
R. Lacasse
H. Hvatum
C. Burgess

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# RECEIVER NOISE TEMPERATURE MEASUREMENT AND CALIBRATION PROGRAMS

James R. Coe

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## General

Two programs have been written for the HP 9825 calculator to assist in measuring, plotting and storing receiver noise temperatures, calibration signal levels, and receiver gain.

## Equipment

The equipment required is the HP 9825 calculator with the String-Adv. Programming ROM and the 9862A Plotter - Gen I/O Extended I/O ROM. The 9862A Calculator Plotter is used for plotting the receiver noise temperatures. The receiver output power is measured with an HP 436A Power Meter with Option 022 connected to the calculator with the HP IB Interface 98034A. The power sensor is the HP 8484A which measures a maximum power of 10 microwatts.

## Program Description

The Receiver Noise Temperature, Calibration, and Gain program uses the digital power meter to measure the receiver power output with three different input conditions. These are (1) hot load, (2) cold load and (3) cold load with calibration signal.

The calculator then computes the receiver temperature

$$T\ REC = [(H - C)/(A/B - 1)] - C$$

where: H is the Hot Load Temperature (Kelvins)
C is the Cold Load Temperature (Kelvins)
A is the Receiver Power Out Hot Load On (watts)
B is the Receiver Power Out Cold Load On (watts)
and D is the Receiver Power Out Cold Load + Cal On (watts).

The calibration signal level is computed as:

$$T\ CAL = (H - C)\ (D - B)/(A - B)$$

=) sign error or eq 1

The gain is calculated from the change in power out divided by the change in power in.

$$GAIN = K + 10 \log \left[(A - B)/[1.38 \times 10^{-23} \times (H - C)(F \times 10^{6})]\right] dB$$

where F is the IF Frequency Bandwidth in MHz

and K is the IF Attenuation in dB.

The program can store the receiver data for T REC, T CAL, and GAIN at 10 different frequencies and then plot and tabulate the data vs. frequency. (See sample plot.)

The receiver data can also be recorded on tape and then retrieved and plotted at a later time for comparison purposes. The program updates the file number each time data is recorded. Up to 150 receiver data records can be stored on the tape. An alpha-numeric identified must be assigned to each receiver data record.

The Receiver Data Plot program is used to retrieve and plot recorded receiver data. The user-selected operations are:

(1) LIST DATA FILE, which prints a list of the file numbers and the associated alpha-numeric identification;

(2) LOAD DATA FILE which loads the data from a designated file number on a tape to memory; or

(3) SEARCH DATA FILE which locates the requested file by using the alpha-numeric identification and loads it into memory; and

(4) PLOT which uses the receiver data loaded into memory to prepare a plot of T REC vs. frequency and tabulate the GAIN and T CAL for each frequency.

Operating the Receiver Noise Temperature, Calibration and Gain Program:

Connect the digital power meter to the calculator using the HP-IB plug and cable. Turn power meter on and check calibration. Turn the calculator on. Then insert the tape 8/4/81 RECEIVER MEASUREMENTS. Type &dp 1 and press EXECUTE. When the display reads "T HOT (K)?", type the Hot Load Temperature. Then enter the cold load temperature and the IF bandwidth in MHz in response to the displays "T COLD (K)?" and "BANDWIDTH MHZ?".

The next section of the program zeros the power meter. The display reads "Remove power from sensor." After the sensor is disconnected, press CONTINUE and the power meter zero will be set. Press CONTINUE again if it doesn't reset the first time. "Connect Sensor-Set Level - Press f1" is then displayed. Connect the power meter to the receiver IF output. The maximum level the power meter can read is -20 dBm ($1 \times 10^{-5}$ watts). The display will indicate the power level in watts. To proceed, press special function key f1 labeled LEVEL OK. When the calculator displays "FREQUENCY - MHZ?", type in the number and press CONTINUE. If you are going to make a plot, the frequencies must be in ascending order.

The total IF attenuation in decibels is entered when "IF - ATTENUATION" is displayed. This number is used in the calculation of the GAIN. If the same IF attenuation is used for a set of measurements, it only has to be entered the first time it is requested. Press CONTINUE and the calculator will display "HOT LOAD - CAL OFF". When the hot load is connected to the receiver input, press CONTINUE. The calculator displays the measured power, averages 10 measurements, and displays the average. Then it displays

"COLD LOAD - CAL OFF". Connect the cold load and press CONTINUE. When "COLD LOAD - CAL ON" is displayed, switch the CAL ON and press CONTINUE. The calculator prints the frequency and computes and prints T REC, T CAL and GAIN. It then displays "Select Operation". If you want to repeat the measurement at the same frequency, press key f2, REPEAT. The calculator goes thru the measurement again. When "Select Operation" is displayed, you can go on the next frequency by pressing f3, NEXT FREQUENCY. Measurements can be made at 10 different frequencies and are stored for plotting or recording on tape. When you press the RECORD key, the display is "To Record Data - Enter Identifier". Type in any combination of letters or numerals up to 15 characters including spaces. The calculator will then determine the next data file number, record the file number and the identifier, and record the data.

When PLOT is selected, "Set Up Plotter - Press Continue" is displayed. Set the lower left and upper right on the paper and press CONTINUE. The axis, data and labels will be plotted. When "PLOT TITLE" is displayed, the plotter is in typewriter mode and a title can be added. Push STOP when you are finished typing. The GAIN and T CAL can be added to the plot by pressing CONTINUE as indicated by the display. After making the plot when "Select RECORD or NEW DATA" is displayed, you can record the data on tape by pressing f4, RECORD or take a new set of measurements by pressing f11, NEW DATA.

Operating the Receiver Data Plot Programs:

Turn the calculator on. Insert tape 8/4/81, RECEIVER MEASUREMENTS, type

ℓ press EXECUTE.

When the calculator displays "Select Operation" you can press f6, LIST DATA, f7, LOAD DATA, or f8, SEARCH DATA.

Selecting LIST DATA gives a printout of Data Files and Identifiers. If

LOAD DATA is selected, the calculator displays "Data File No,?". Enter the desired data file number and press CONTINUE. The calculator will display "Data File 'No.' -- 'Identifier' Loaded". After the data is loaded into the calculator memory it can be plotted. The plotting operation is the same as described in the previous section. The only difference is that the plot is labeled with the data file identifier.

If "SEARCH DATA" is selected, the calculator displays "Data File Identifier?". When the identifier is entered, push CONTINUE. The calculator loads the data file list located in file 3, searches the list to find the file number, and loads the file into the calculator memory. It displays "Data File # -- Identifier Loaded". When "Select Operation" is displayed, the data can be plotted by pressing key f9, PLOT.

Marking and Recording the Programs on Tape

Each user should prepare a separate tape to assure that his receiver data files are not erased. Insert a new tape into the calculator and press REWIND. The tape will be marked with file 0 of 500 bytes for the special function keys. Files 1, 2 and 3 will be 5000 bytes for the programs and data file list and files 4 thru 154, 500 bytes long for the receiver data. When the tape stops, perform the following operations:

(1) Type mrk 1, 500 and press EXECUTE.

(2) Type mrk 3, 5000 and press EXECUTE.

(3) Type mrk 150, 500 and press EXECUTE.

(4) Press REWIND.

When the tape stops, remove it and insert tape labeled 8/4/81 RECEIVER MEASURMENTS.

(5) Press LOAD 1 EXECUTE.

(6) Press RUN. (This loads special function keys.)

(7) Press CONTINUE, CONTINUE, CONTINUE.

Remove 8/4/81 tape and insert new tape.

(8) Press RECORD 1 EXECUTE.

(9) Type rck 0 EXECUTE. (This records special function keys on file 0.)

(10) Insert 8/4/81 tape.

(11) Press LOAD 2 EXECUTE.

(12) Insert new tape.

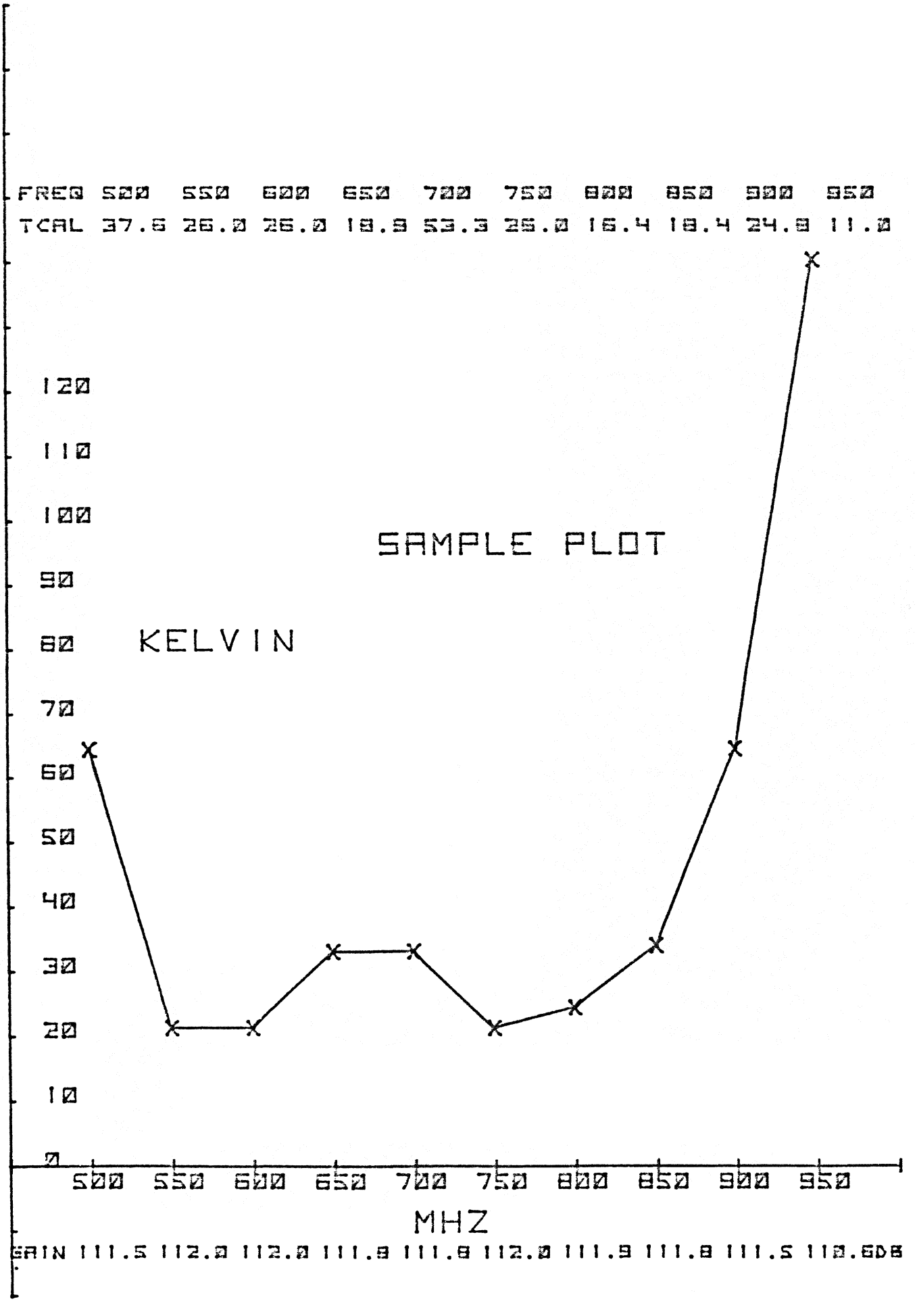
(13) Press RECORD 2 EXECUTE.

(14) Press ERASE EXECUTE.

(15) Press special function key f5, EXECUTE.

This last step loads the proper number into the data file list (file 3) so that the first data file begins with file 4.

Distribution:
M. Balister
G. Behrens
C. Brockway
W. Brundage
R. Lacasse
C. Moore
R. Norrod


FREQ 500 550 600 650 700 750 800 850 900 950
TCAL 37.6 26.0 26.0 18.8 53.3 26.0 16.4 18.4 24.8 11.0
120
110
100
90
80
70
60
50
40
30
20
10
0
SAMPLE PLOT
KELVIN
500 550 600 650 700 750 800 850 900 950
MHZ
GAIN 111.5 112.0 112.0 111.8 111.8 112.0 111.9 111.8 111.5 110.6DB

Tape 8/4/81
RECEIVER MEASUREMENTS
File 2

```
0: dsp "RECEIVER
 DATA PLOT";
 wait 1000
1: dim A[10],
 B[10],C[10],
 D[10],N,B$[15]
2: dim G,A$[150,
 15];dim C$[15];
 ldk 0;sfg 14;
 fxd 0
3: "OPERATION":d
 sp "Select Oper
 ation";stp
4: "LIST DATA
 FILE":dsp "List
  Data File";
 fxd 0
5: fxd 0;ldf 3,
 G,A$
6: for X=4 to G;
 prt A$[X],X;
 next X;spc 2;
 gto "OPERATION"
7: "LOAD DATA
 FILE":
8: ent "Data
 File No?",G;if
 flg13;gto "OPER
 ATION"
9: if 4>G;jmp -1
10: if G>154;
 jmp -2
11: ldf G,A[*],
 B[*],C[*],D[*],
 N,B$
12: dsp "Data
 File",G,"",B$,
 "Loaded";wait
 3000;gto "OPERA
 TION"
13: "SEARCH DATA
  FILE":
14: ent "Data
 File Identifier
 ?",C$;if flg13;
 jmp 0
15: ldf 3,G,A$;
 for X=4 to G
16: if A$[X]=C$;
 X→G;ldf G,A[*],
 B[*],C[*],D[*],
 N,B$;jmp 2
17: next X;dsp
 "Data File not
 Found";wait
 1000;jmp 2
18: dsp "Data
 File",G,"",B$,
 "Loaded";wait
 3000;gto "OPERA
 TION"
19: gto "OPERATI
 ON"
20: "PLOT":
21: dsp "To Plot
 -Set Up Plotter
 -Press CONTINUE
 ";fxd 0;stp ;
 2D[1]-D[2]→U
22: scl U,D[N]+
 D[2]-D[1],-20,
 180;axe U,0,
 D[2]-D[1],10;
 plt D[1],A[1]
23: csiz 1,1,
 1.2;for X=1 to
 N;plt D[X],A[X]
 ,2;cplt -.3,-
 .3;lbl "X"
24: cplt -.7,.3;
 next X
25: csiz 1,1,
 1.2;for X=1 to
 N;plt D[X],0,1;
 cplt -2,-1;lbl
 D[X];next X
26: csiz 1.5,1,
 1.2;plt D[N/2];
 -10,1;lbl "MHZ"
27: csiz 1,1,
 1.2;for Y=0 to
 120 by 10;plt
 2D[1]-D[2],Y,1;
 cplt 1,0;lbl Y
28: next Y
29: csiz 1.5,1,
 1.2;plt U,80,1;
 cplt 5,0;lbl
 "KELVIN"
30: cplt 3,3;
 lbl B$;dsp "PLO
 T TITLE";ptyp
31: dsp "To prin
 t GAIN&TCAL
 press Continue"
 ;stp ;fxd 1
32: csiz .8,1,
 1.2;plt U,-14,
 1;lbl "GAIN";
 for X=1 to N;
 plt D[X],-14,1
33: cplt -2,0;
 lbl C[X];next
 X;lbl "DB"
34: csiz .8,1,
 1.4;plt U+10,
 150;lbl "FREQ";
 for X=1 to N;
 plt D[X],150,1
35: fxd 0;plt
 D[X],150,1;lbl
 D[X];next X
36: fxd 1;plt U+
 10,145,1;lbl
 "TCAL";for X=1
 to N;plt D[X],
 145,1
37: plt D[X],
 145,1;lbl B[X];
 next X
38: gto "OPERATI
 ON"
39: end
*14133
```

File 0
Special function keys

```
f1: *sfg1

f2: *cont"REPEAT
 "

f3: *cont"NEXT F
 REQ."

f4: *cont"RECORD
 "

f5: dimG,A$[150,
 15];3→G;rcf3,G,
 A$

f6: *cont"LIST D
 ATA FILE"

f7: *cont"LOAD D
 ATA FILE"

f8: *cont"SEARCH
  DATA FILE"

f9: *cont"PLOT"

f11: *run"NEW DA
 TA"
```

Variables - Line Nos

FILE NO. OF DATA FILE
G 2 5 6
8 9 10 11
12 15 15 16
16 18

NUMBER OF DIFF FREQ
N 1 11 16
22 23 25 26
32 34 36

OFFSET FOR X-AXIS
U 21 22 22
29 32 34 36

INDEX
X 6 6 6
6 15 16 16
17 23 23 23
24 25 25 25
25 32 32 33
33 34 34 35
35 35 36 36
37 37 37

INDEX
Y 27 27 27
28

TREC ARRAY
R[*]1 11 16
22 23

TCAL ARRAY
B[*]1 11 16
37

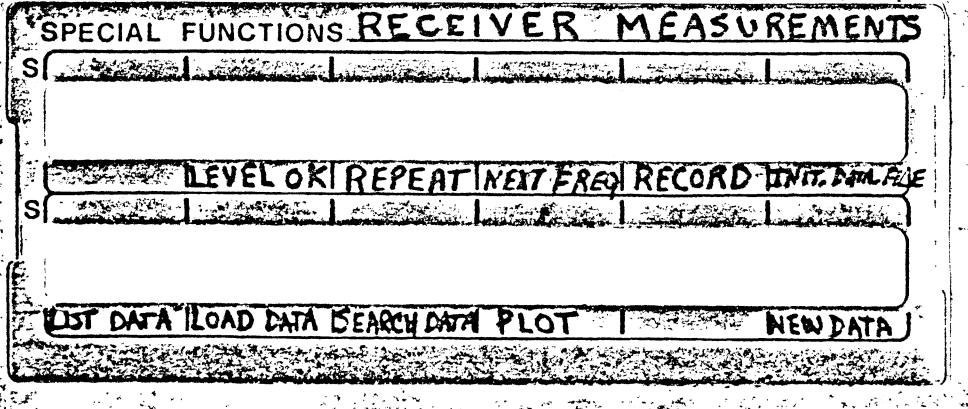
GAIN ARRAY
C[*]1 11 16
33

FREQ ARRAY
D[*]1 11 16
21 21 22 22
22 22 22 22
23 25 25 26
27 27 32 34
35 35 36 37

DATA IDENTIFIER ARRAY
A$ 2 5 6
15 16

DATA IDENTIFIER
B$ 1 11 12
16 18 30

DATA IDENTIFIER
C$ 2 14 16



Tape 8/4/81

RECEIVER MEASURE

file 1

```
 0: "This program
   uses the 436A
   Power meter to
   Measure  Noise
   Temperature":
 1: "The Noise
   Temperature,T
   Cal,&Gain are
   computed by
   mesuring the ":
 2: "output power
   changes with
   a hot load,
   cold load, &
   cold load +
   cal.":
 3: "This tape
   has Special
   function Keys
   file 0;RECEIVER
    DATA PLOT file
   2":
 4: "and 150 data
   files located
   in files 5 thru
   155.":
 5: "The data
   files are autom
   atically assign
   ed and can be
   recalled using
   ":
 6: "the program
   in file 2.":
 7: dsp "REC NOIS
   E TEMP,CAL,&
   GAIN";ldk 0;
   sfg 14;wait
   1000
 8: "NEW DATA":
 9: enp "T HOT
   (K)?",H;enp "T
   COLD (K)?",C;
   enp "BANDWIDTH
   MHZ?",F;spc 2
10: dim A[10],
   B[10],C[10],
   D[10],N,B$[15];
   0→N→A→B→D
11: dev "pmrd",
   713;rem 7
12: "pmz":dsp
   "Remove power
   from sensor";
   stp
13: wrt "pmrd",
   "Z1T";fmt 2,3x,
   f5.0;red "pmrd.
   2",Z
14: "verify zero
   ":if abs(Z)>2;
   gto "pmz"
15: wrt "pmrd",
   "9+AI";fmt 3,b;
   red "pmrd.3",Z
16: "verify unze
   ro":if Z>84;
   gto -1
17: "preset/ret"
   ;wrt "pmrd",
   "9D+V"
18: wait 2000;
   dsp "Connect
   Sensor-Set Leve
   l-Press f1";wait
   2000
19: "pmr":
20: fmt 1,1x,b,
   1x,f5.0,1x,f3.0
21: wrt "pmrd",
   "9A-T";wait
   (R=73)4000;red
   "pmrd.1",R,P,E;
   P10↑E→P
22: if P>=1*1e-
   5;dsp "OVER
   RANGE";gto -1
23: if not f1a1;
   flt 3;dsp P;
   gto -2
24: "NEXT FREQ."
   :
25: N+1→N;ent
   "FREQUENCY-Mhz?
   ",D[N];ent "IF
   ATTENUATION?",K
26: "REPEAT":if
   f1a2;cfg 2;gto
   "NEW DATA"
27: dsp "HOT
   LOAD- CAL OFF";
   0→A→P;cfg 1;
   stp
28: for X=1 to
   10;wrt "pmrd",
   "9A-T";wait
   (R=73)4000;red
   "pmrd.1",R,P,E
29: P10↑E→P;if
   P>=1e-5;dsp
   "OVER RANGE";
   gto -1
30: P/10+A→A;
   flt 3;dsp P;
   next X
31: dsp "Ave.Pwr
   .Hot Load",A;
   wait 2000
32: dsp "COLD
   LOAD - CAL OFF"
   ;0→B→P;stp
33: for X=1 to
   10;wrt "pmrd",
   "9A-T";wait
   (R=73)4000;red
   "pmrd.1",R,P,E
34: P10↑E→P;if
   P>=1e-5;dsp
   "OVER RANGE";
   gto -1
35: dsp P;P/10+
   B→B;next X
36: dsp "Ave.Pwr
   .Cold Load",B;
   wait 2000
37: dsp "COLD
   LOAD-CAL ON";
   0→D→P;stp
38: for X=1 to
   10;wrt "pmrd",
   "9A-T";wait
   (R=73)4000;red
   "pmrd.1",R,P,E
39: P10↑E→P;if
   P>=1e-5;dsp
   "OVER RANGE";
   gto -1
40: dsp P;P/10+
   D→D;next X
41: dsp "Ave.Pwr
   .Cold Load+Cal"
   ;D;wait 2000
42: fxd 0;prt
   "FREQUENCY",
   D[N];spc 2;fxd
   2
43: (H-C)/(A/B-
   1)-C→A[N];prt
   "T REC",A[N];
   spc 2
44: (H-C)(D-B)/
   (A-B)→B[N];prt
   "T CAL",B[N];
   spc 2
45: K+10log((A-
   B)/1.38e-23(H-
   C)(F*10↑6))→C[N
   ]
46: fxd 1;prt
   "GAIN",C[N],
   "DB";spc 2
47: dsp "Select
   Operation";stp
48: jmp -1
49: "RECORD";dim
   G,A$[150
50: ent "T  co
   rd Data-Enter
   Identifier";B$;
   if not f1a13;
   ldf 3;G,A$
51: if not f1a13
   ;G+1→G;B$→A$[G]
   ;rcf 3,G,A$;
   rcf G,A[*],B[*
   ],C[*],D[*],N,
   B$
52: dsp "Select
   Operation";stp
53: jmp -1
54: "PLOT":
55: dsp "To Plot
   -Set Up Plotter
   -Press CONTINUE
   ";fxd 0;stp ;
   2D[1]-D[2]→U
56: scl U,D[N]+
   D[2]-D[1],-20,
   180;axe U,0,
   D[2]-D[1],10;
   plt D[1],A[1]
57: csiz 1,1;
   1.2;for X=1 to
   N;plt D[X],A[X]
   ,2;cplt -.3,-
   .3;lbl "X"
58: cplt -.7,.3;
   next X
59: csiz 1,1;
   1.2;for X=1 to
   N;plt D[X],0,1;
   cplt -2,-1;lbl
   D[X];next X
60: csiz 1.5,1,
   1.2;plt D[N/2],
   -10,1;lbl "MHZ"
61: csiz 1,1;
   1.2;for Y=0 to
   120 by 10;plt
   2D[1]-D[2],Y,1;
   cplt 1,0;lbl Y
62: next Y
63: csiz 1.5,1,
   1.2;plt U,80,1;
   cplt 5,0;lbl
   "KELVIN"
64: dsp "PLOT
   TITLE";prtyp
65: dsp "To prin
   t GAIN,TCAL
   Press Continue"
   ;stp ;fxd 1
66: csiz .8,1,
   1.2;plt U,-14,
   1;lbl "GAIN";
   for X=1 to N;
   plt D[X],-14,1
67: cplt -2,0;
   lbl C[X];next
   X;lbl " DB"
68: csiz .8,1,
   1.4;plt U+10,
   150;lbl "FREQ";
   for X=1 to N;
   plt D[X],150,1
69: fxd 0;plt
   D[X],150,1;lbl
   D[X];next X
70: fxd 1;plt U+
   10,145,1;lbl
   "TCAL";for X=1
   to N;plt D[X],
   145,1
71: plt D[X],
   145,1;lbl B[X];
   next X
72: dsp "Select
   RECORD or NEW
   DATA";stp
73: jmp -1
74: end
*21659
```

Variables - Line No's

```
PWR - HOT LOAD ON
A    10   27   30
30   31   43   44
45
PWR - COLD LOAD ON
B    10   32   35
35   36   43   44
44   45
TEMP - COLD LOAD
C    9    43   43
44   45
PWR - COLD LOAD + CAL
D    10   37   40
40   41   44
EXPONENT PWR MTR READG
E    21   21   28
29   33   34   38
39
IF FREQ BW (MHZ)
F    9    45
FILE NO. OF DATA FILE
G    49   50   51
51   51   51   51
TEMP OF HOT LOAD
H    9    43   44
45
IF ATTENUATION (DB)
K    25   45
NUMBER OF DIFF FREQ
N    10   10   25
25   25   42   43
43   44   44   45
46   51   56   57
59   60   66   68
70
PWR METER READING
P    21   21   21
22   23   27   28
29   29   29   30
30   32   33   34
34   34   35   35
37   38   39   39
39   40   40
RANGE OF PWR MTR
R    21   21   28
28   33   33   38
38
OFFSET FOR X-AXIS
U    55   56   56
63   66   68   70
INDEX
X    28   30   33
35   38   40   57
57   57   58   59
59   59   59   66
66   67   67   68
68   69   69   69
70   70   71   71
71
INDEX
Y    61   61   61
62
PWR METER ZERO
Z    13   14   15
16
T REC  ARRAY
A[*]10   43   43
51   56   57
T CAL  ARRAY
B[*]10   44   44
51   71
GAIN  ARRAY
C[*]10   45   46
51   67
FREQ  ARRAY
D[*]10   25   42
51   55   55   56
56   56   56   56
56   57   59   59
60   61   61   66
68   69   69   70
71
DATA IDENTIFIER ARRAY
A$   49   50   51
51
DATA IDENTIFIER
B$   10   50   51
51
```