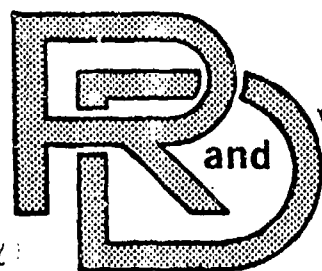


AD A072014

LEVEL



TARADCOM

LABORATORY

TECHNICAL REPORT

TARADCOM-1A-NO. 12412

(6) TARADCOM SIGNAL ANALYSIS PROGRAM,

(11) SEPTEMBER 1978



DDC FILE COPY

by G. A. Fix

Approved for public release,
distribution unlimited.

U.S. ARMY TANK-AUTOMOTIVE
RESEARCH AND DEVELOPMENT COMMAND
Warren, Michigan 48090

79 07 30 101

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ABSTRACT

This report describes an integrated package for evaluating terrain data on the Tektronix 4014 graphics terminals on the Picatinny Arsenal CDC 6500/6600 time sharing system. The program provides the following options: first-to-last point detrending, digital high-pass filter, exponentially weighted running average, no detrending, interpolation, amplitude smoothing, and a GEO window. Terrain data input to the program may be used during processing, rather than the data equations that are contained in the program. Graphics displays include a linear plot of elevation vs. distance, a point plot of amplitude vs. period, and a log-log graph of power spectral density vs. frequency. The model structure, with its capabilities and its limitations, is included along with user instructions for running the program.

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INTRODUCTION

The TARADCOM Signal Analysis Program (TSAP) was developed originally as a BASIC Wang Program by Mr. Robert Daigle of Stevens Institute of Technology and Zoltan J. Janosi of the Applied Research Function of the Survivability Research Division, DRDTA-ZS. The TSAP was converted from BASIC to FORTRAN so as to facilitate running the program in a more commonly known language on the CDC 6500/6600 time sharing system. The following graphics displays were added at the time of conversion: a linear plot of elevation vs. distance, a point plot of amplitude vs. period and a log-log graph of power spectral density vs. frequency.

OBJECTIVE

The objective of this report is to provide a user manual for the TARADCOM Signal Analysis Computer Program with listings of the program, variables, glossary, and flowchart, and instructions for input, output, and running the program.

RUNNING INSTRUCTIONS
FOR
THE SIGNAL ANALYSIS PROGRAM

The following page is a copy of the Tektronix screen showing the interactive command instructions and system responses for running TSAP. After all of the instructions (shown in lower case) have been input, the screen will clear and processing will proceed. Terminal user responses to programmed questions are used as input to TSAP and are the basis for the selection of the available options. The eight questions with possible answers are on page 57-60

After all of the questions have been answered, the screen clears and processing continues.

After the output is finished, the terminal user should key in the following:

BATCH, TEKLD42, LOCAL

E, TEKLD42, S

At this point TEKLD42 is no longer a remote output file. If the same program is to be used, it may be saved at this time. The user should also discard the files created earlier in the terminal session; e.g., in this case C45 should be discarded.

```

attach,mmmm,id=ocelot
PFN IS
PFM
PF CYCLE NO. = 001
...s,mmmm
..save,c45
..catalog,c45,id=ocelot
INITIAL CATALOG
RP = 060 DAYS
CT ID= OCELOT PFN=C45
CT CY= 001 00002112 WORDS.
..etl,1000
..fta,l=c45,l=0,opt=2
12.343 CP SECONDS COMPILATION TIME
..begin,tekch,bchtemp/ciagale,ocelot,lgo,tek45
INITIAL CATALOG
RP = 060 DAYS
CT ID= OCELOT PFN=A132SD
CT CY= 001 00002112 WORDS.
NAME=TEKLD42, DISP=INPUT , ID=NU
..files
--LOCAL FILES--
BCHTEMP IC45 RMMMM SOUTPUT LGO
--REMOTE OUTPUT FILES--
TEKLD42
..attach,tek45,id=ocelot
PFN IS
TEK45
PF CYCLE NO. = 001
..tek45

```

PSD PROGRAM FFT77.7-78.3

NUMBER OF TERRAIN POINTS IS EQUAL TO 2*ANS1.
ANS1: AN INTEGER, MUST BE GREATER THAN OR EQUAL TO 1 AND LESS THAN OR
EQUAL TO 8.
ANS1 = 6

SURVEY INTERVAL IN FEET? ALLOW 4 PLACES PAST DECIMAL.
ANS2 = 1.

ENTER 0 FOR DATA READING,
1 FOR CARD READING,
-1 FOR DATA EQUATIONS.
ANS3 = -1

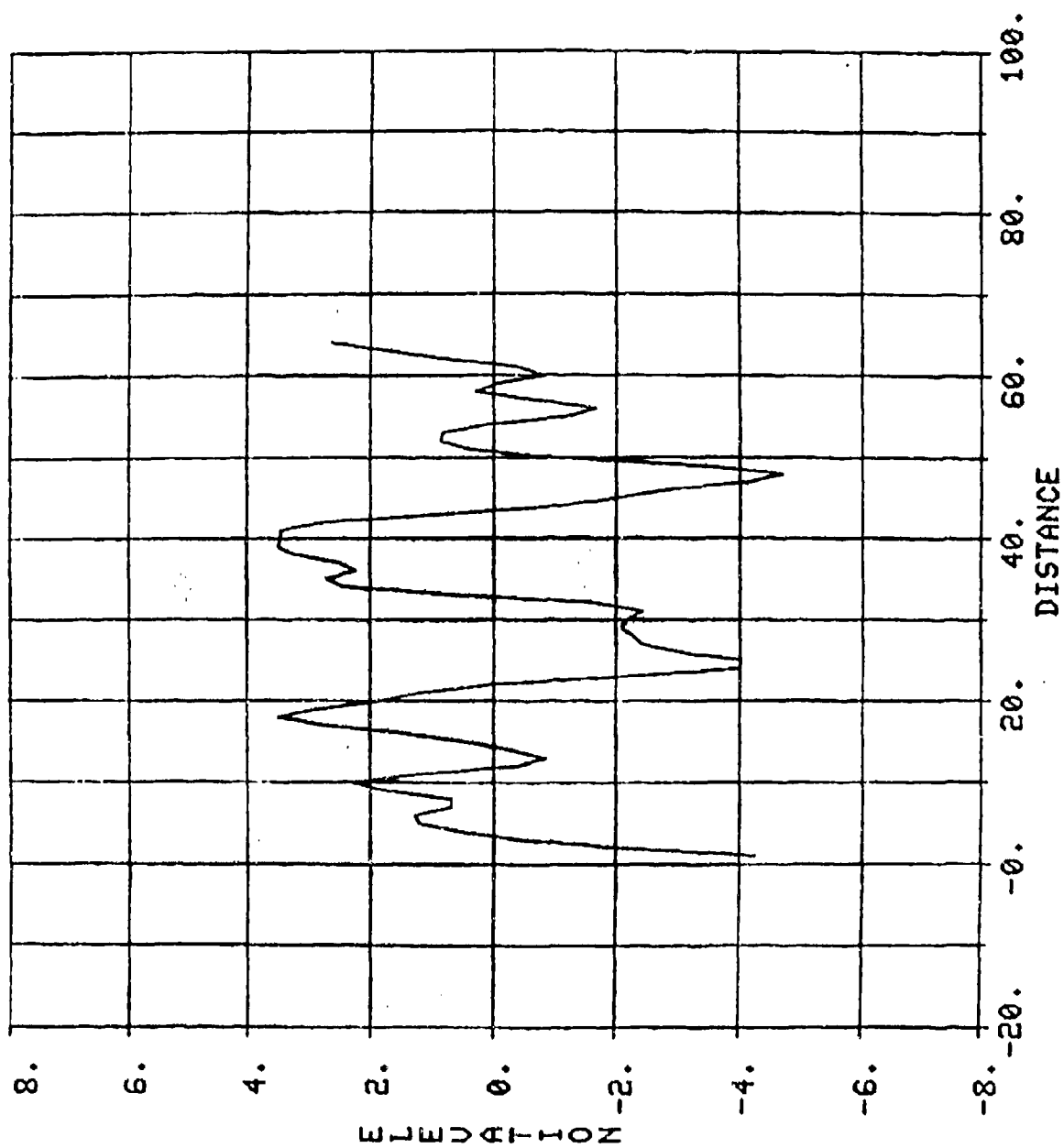
ENTER 1 FOR FIRST TO LAST POINT DETRENDING,
2 FOR DIGITAL HIGH PASS FILTER,
3 FOR EXPONENTIALLY WEIGHTED RUNNING AVERAGE,
4 FOR NO DETRENDING.
ANS4 = 4

DO YOU WANT THE ARRAY PADDED WITH N1 0'S?
ENTER 1 FOR YES,
2 FOR NO.
ANS5 = 2

DO YOU WANT INTERPOLATION?
ENTER 1 FOR YES,
2 FOR NO.
ANS6 = 2

DO YOU WANT AMPLITUDE SMOOTHING?
ENTER 1 FOR YES,
2 FOR NO.
ANS7 = 2

DO YOU WANT A GEO WINDOW?
ENTER 1 FOR YES,
2 FOR NO.
ANS8 = 1

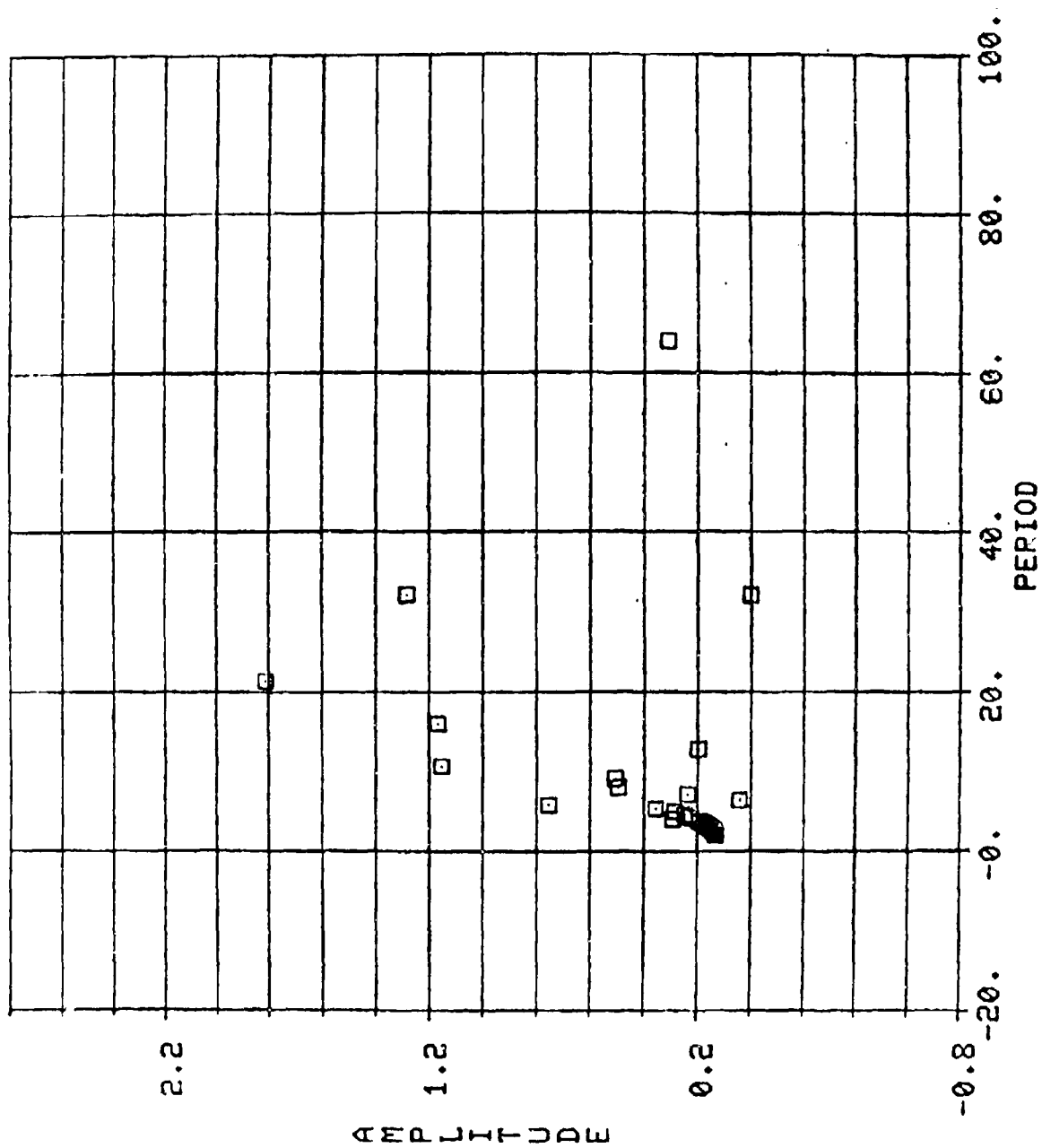


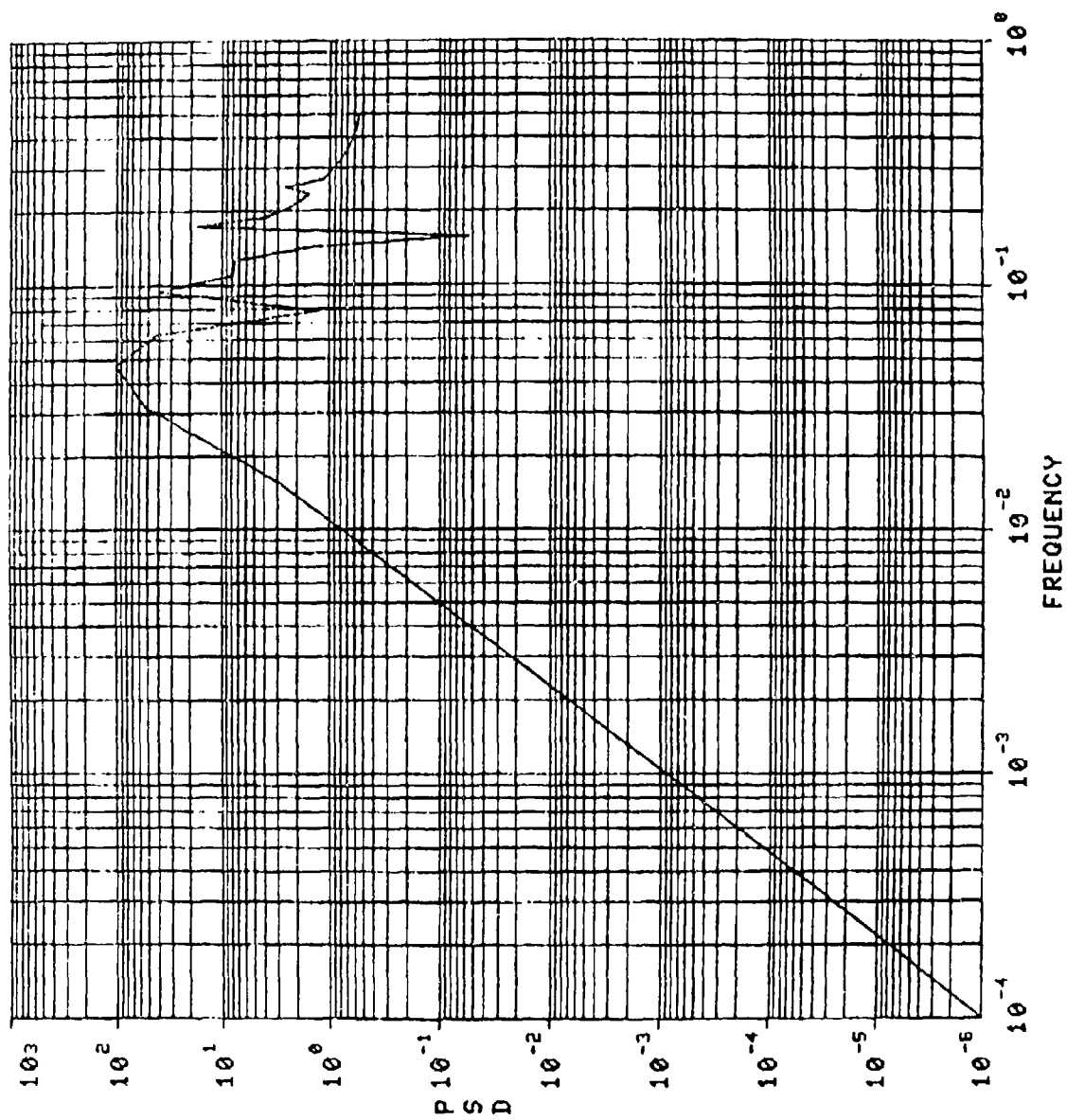
RESULTS WITH UNSMOOTHED F.F.T. AMPLITUDES

RMS = 26.3642 INCHES
AREA UNDER PSD = 4.8269 SQ.FT.

RAU P.S.D. RESULTS

AMPLITUDE	PERIOD	FREQ	PSD
.0000	9999.99	.0001	.000001
.3088	64.00	.0156	3.051327
1.2820	32.00	.0313	52.590853
1.8131	21.33	.0469	105.196496
1.1649	16.00	.0625	43.423355
1.1581	12.80	.0781	1.256323
1.1531	10.67	.0938	42.549612
.5059	8.14	.1094	8.223066
.4958	8.00	.1250	7.867344
.2363	7.11	.1406	1.787266
.0415	6.40	.1563	.055188
.7534	5.82	.1719	18.163052
.3569	5.33	.1875	4.076397
.2847	4.92	.2031	2.594495
.2482	4.57	.2188	1.971405
.2242	4.27	.2344	1.609061
.2927	4.00	.2500	2.742232
.1930	3.76	.2656	1.192123
.1730	3.55	.2813	1.060245
.1654	3.37	.2969	.957560
.1591	3.20	.3125	.875882
.1537	3.05	.3281	.809933
.1492	2.91	.3438	.755142
.1453	2.78	.3594	.712002
.1421	2.66	.3750	.675703
.1394	2.56	.3906	.645013
.1372	2.46	.4063	.621638
.1354	2.37	.4219	.602150
.1341	2.29	.4375	.586827
.1331	2.23	.4531	.575314
.1326	2.17	.4688	.567200
.1324	2.05	.4844	.562554
	2.00	.5000	.560088

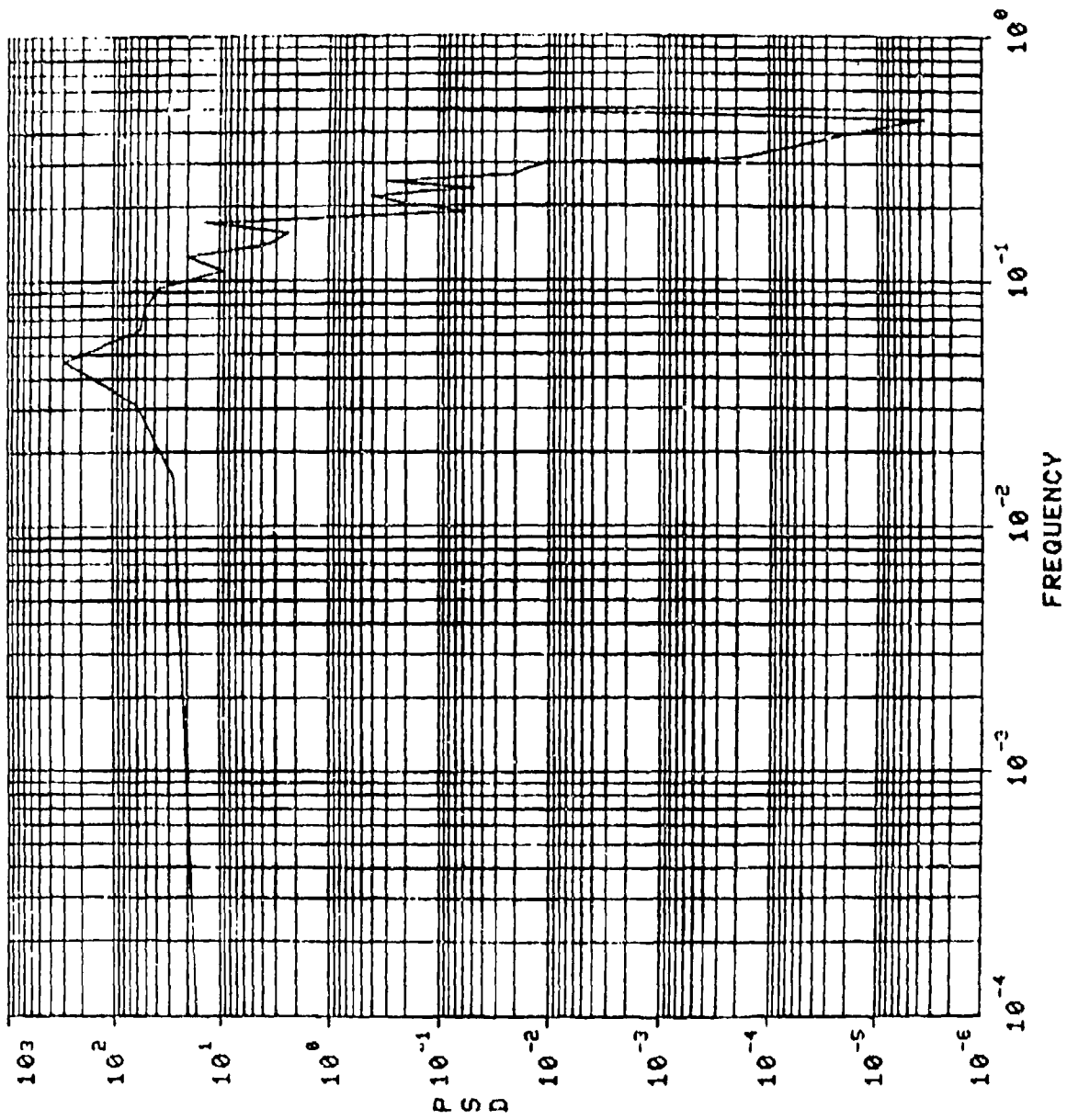




RTS - 37.0157 INCHES
AREA UNDER PSD - 5.5150 SQ.FT.

SMOOTH AMPLITUDES USING G.E.O. WINDOW

AMPLITUDE	PERIOD	FREQ	PSD
.7919	9999.99	.0001	17.178177
.5923	64.00	.0156	26.955978
.5242	32.00	.0313	63.635612
3.3044	21.33	.0469	299.106795
.5569	16.00	.0625	58.139874
.3761	12.80	.0781	51.421545
1.1671	10.67	.0938	37.314302
.5816	9.14	.1094	9.266667
.8775	8.00	.1250	21.038710
.5609	7.11	.1406	3.568027
.5565	6.40	.1563	2.408434
.7239	5.82	.1719	14.552069
.6459	5.33	.1875	.057682
.6223	4.92	.2031	.188050
.1246	4.57	.2188	.425600
.0421	4.27	.2344	.048512
.1952	4.00	.2500	.303244
.3376	3.76	.2656	.026570
.3243	3.55	.2813	.016211
.0294	3.37	.2969	.011441
.0326	3.20	.3125	.000128
.0020	3.05	.3281	.000170
.0016	2.91	.3438	.000270
.0013	2.78	.3594	.000246
.0010	2.67	.3750	.000230
.0009	2.56	.3906	.000200
.0007	2.46	.4063	.000173
.0006	2.37	.4219	.000160
.0005	2.29	.4375	.000086
.0004	2.21	.4531	.000084
.0026	2.13	.4688	.000189
.0427	2.06	.4844	.049975
.3414	2.00	.5000	3.192168



TARADCOM SIGNAL ANALYSIS PROGRAM SAMPLE OUTPUT

PSD PROGRAM FFT77.7-78.3

NUMBER OF TERRAIN POINTS IS EQUAL TO 2*ANS1.
ANS1, AN INTEGER, MUST BE GREATER THAN OR EQUAL TO 1 AND LESS THAN OR
EQUAL TO 8.
ANS1 = 6

SURVEY INTERVAL IN FEET: ALLOW 4 PLACES PAST DECIMAL.
ANS2 = 1.

ENTER 0 FOR DATA READING,
1 FOR CARD READING,
-1 FOR DATA EQUATIONS.
ANS3 = -1

ENTER 1 FOR FIRST TO LAST POINT DETRENDING,
2 FOR DIGITAL HIGH PASS FILTER,
3 FOR EXPONENTIALLY WEIGHTED RUNNING AVERAGE,
4 FOR NO DETRENDING.
ANS4 = 1

DO YOU WANT THE ARRAY PADDED WITH N1 0'S?
ENTER 1 FOR YES,
2 FOR NO.
ANS5 = 2

DO YOU WANT INTERPOLATION?
ENTER 1 FOR YES,
2 FOR NO.
ANS6 = 2

DO YOU WANT AMPLITUDE SMOOTHING?
ENTER 1 FOR YES,
2 FOR NO.
ANS7 = 2

DO YOU WANT A GEO WINDOW?
ENTER 1 FOR YES,
2 FOR NO.
ANS8 = 2

THE FOLLOWING DATA EQUATION WAS USED:

$$Y = 4.27 \sin(3/2 \cdot \pi \cdot (T/42.7) + 1.83 \sin(-1/2 \cdot \pi \cdot (T/18.3) + .41 \sin(T/2/4$$

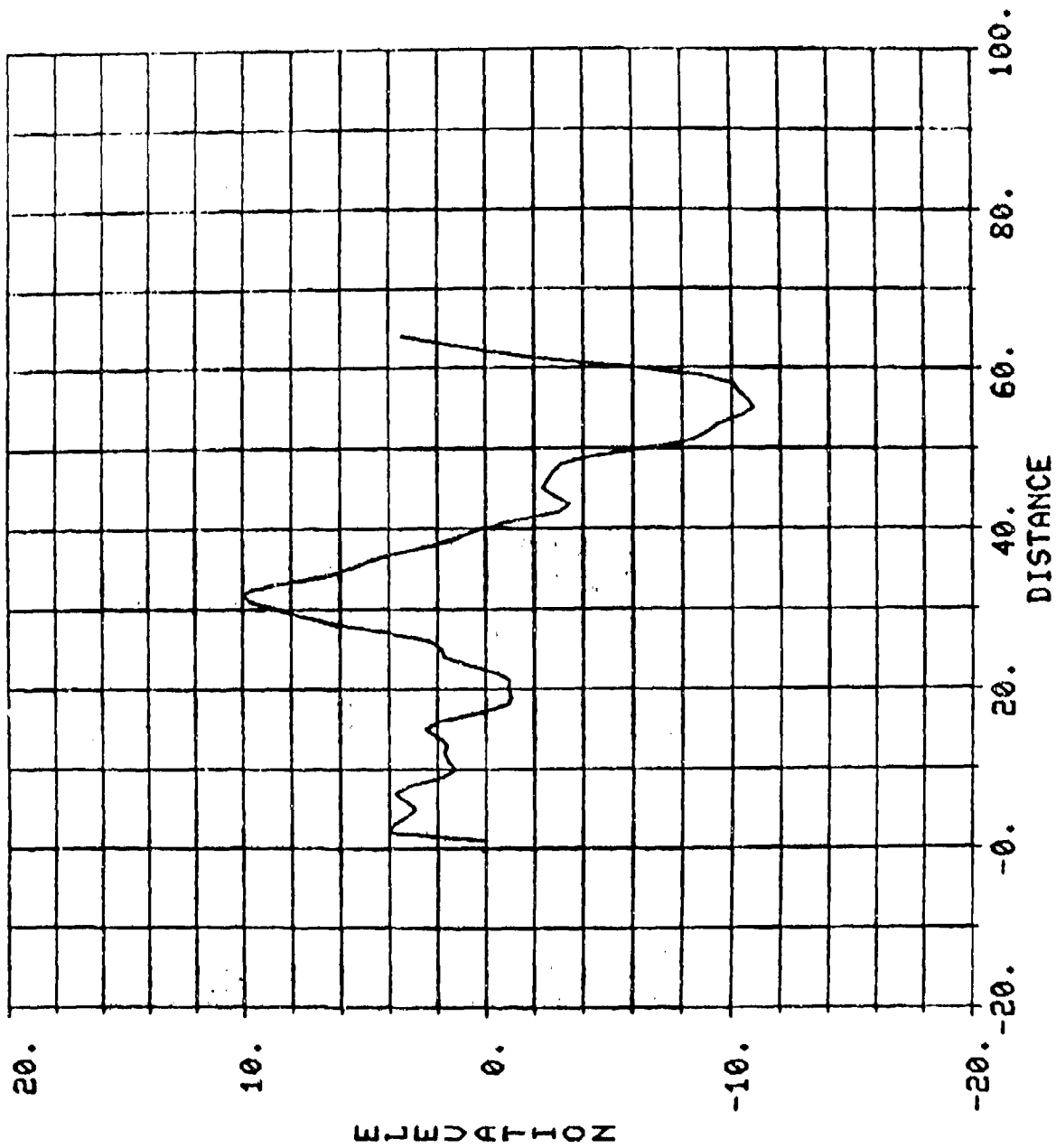
$$+ 3.2 \sin(T/32.)) + 1.6 \sin(T/16.) + .8 \sin(T/8.)$$

FIRST TO LAST POINT DETRENDING

RELATIVE MAXIMUM AND MINIMUM PROFILE VALUES

1	4.64
5	2.93
7	3.73
10	1.28
12	1.72
13	1.62
15	2.43
16	-1.81
19	-0.96
20	-0.96
21	10.01
22	-3.44
45	-2.13
55	-18.83
64	3.47

GPS FROM DE-TRENDED ZERO MEAN TERRAIN DATA - 1773.900 INCHES

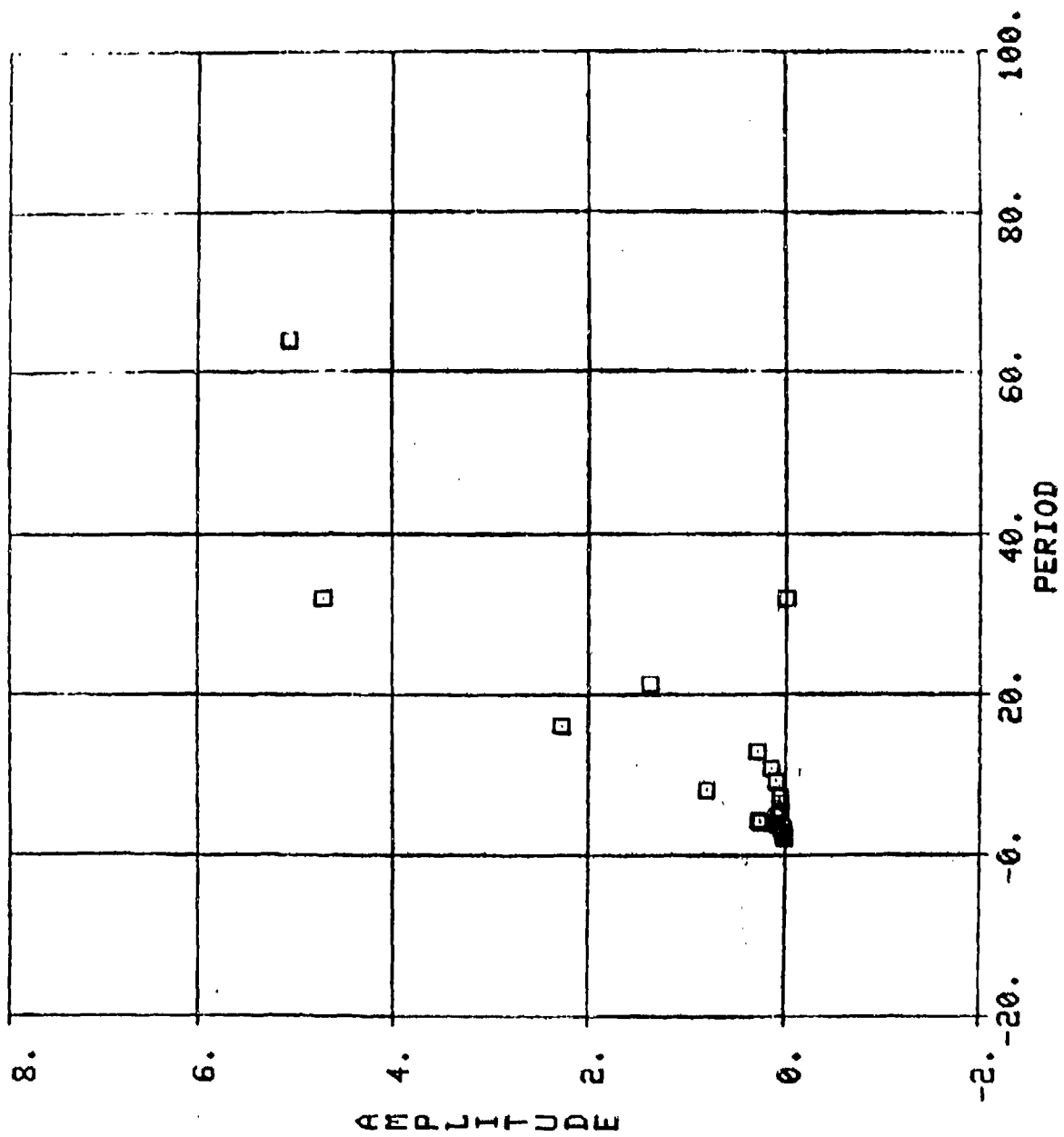


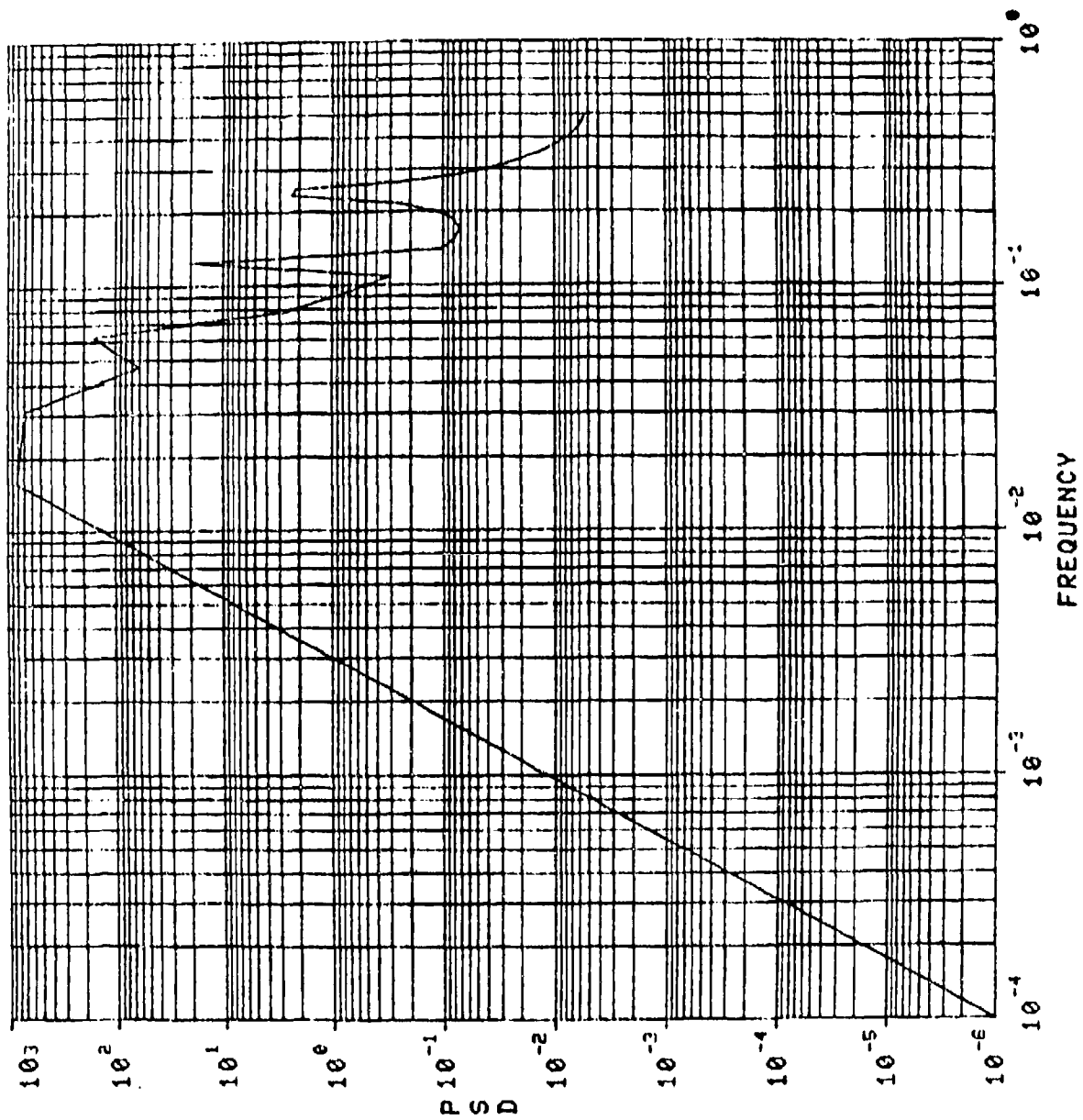
.0132	2.13	.4832	.003609
.0131	2.08	.4844	.003465
.0130	2.00	.5000	.003543

RESULTS WITH UNSMOOTHED F.F.T. AMPLITUDES
 RMS = 63.1765 INCHES
 AREA UNDER PSD 27.7172 SQ.FT.

RAW P.S.D. RESULTS

AMPLITUDE	PERIOD	FREQ	PSD
.0000	9999.99	.0001	.000001
5.0419	64.00	.0156	813.469217
4.8325	32.00	.0313	784.619345
1.3801	21.33	.0459	60.950738
2.2707	16.00	.0625	165.001759
.2890	12.80	.0781	2.672752
.1513	10.67	.0938	.732771
.1377	9.14	.1094	.385645
.7396	8.00	.1250	20.458387
.0559	7.11	.1408	.103723
.0495	6.40	.1563	.078538
.0472	5.82	.1719	.071440
.0502	5.33	.1875	.068716
.0614			
.0614	4.92	.2031	.128726
.0938	4.57	.2188	.281161
.2682	4.27	.2344	2.312305
.2585	4.00	.2500	2.132264
.0860	3.76	.2656	.236536
.0518	3.56	.2813	.088203
.0376	3.37	.2969	.045161
.0298	3.20	.3125	.023351
.0249	3.05	.3281	.019854
.0216	2.91	.3438	.014869
.0197	2.78	.3594	.011909
.0176	2.67	.3750	.009275
.0163	2.56	.3896	.008466
.0153	2.46	.4053	.007654
.0145	2.37	.4219	.006741
.0139	2.29	.4375	.005820
.0135	2.21	.4531	.005053





TARADCOM SIGNAL ANALYSIS PROGRAM SAMPLE
INPUT DATA

..E.P. DITH.S

..L.R

```

100#      RP637 13 NOV 76
110# 401
120#1.0
130# 6.95 6.93 6.99 7.00 6.99 7.04 7.07 7.07 7.10 7.12
140# 7.12 7.14 7.12 7.11 7.10 7.06 7.02 7.00 6.95 6.89
150# 6.84 6.82 6.79 6.73 6.72 6.72 6.69 6.68 6.68 6.68
160# 6.71 6.71 6.71 6.72 6.76 6.80 6.82 6.87 6.87 6.87
170# 6.89 6.91 6.90 6.93 6.93 6.96 7.00 7.03 7.03 7.06
180# 7.06 7.03 7.05 7.08 7.06 7.07 7.04 6.99 7.01 6.99
190# 6.96 6.95 6.93 6.89 6.88 6.88 6.84 6.83 6.83 6.83
200# 6.83 6.81 6.82 6.81 6.78 6.82 6.82 6.81 6.81 6.82
210# 6.83 6.85 6.90 6.90 6.90 6.93 6.94 6.94 6.95 6.92
220# 6.92 6.96 6.94 6.91 6.93 6.94 6.91 6.93 6.92 6.89
230# 6.86 6.83 6.78 6.73 6.72 6.70 6.73 6.74 6.73 6.71
240# 6.72 6.71 6.71 6.73 6.74 6.73 6.72 6.75 6.73 6.71
250# 6.74 6.77 6.73 6.77 6.76 6.75 6.78 6.81 6.81 6.83
260# 6.87 6.88 6.88 6.91 6.91 6.91 6.94 6.99 6.98 7.04
270# 7.05 7.02 7.07 7.13 7.12 7.13 7.17 7.13 7.13 7.16
280# 7.17 7.17 7.22 7.22 7.22 7.24 7.28 7.26 7.25 7.23
290# 7.23 7.28 7.30 7.28 7.28 7.29 7.30 7.28 7.29 7.32
300# 7.33 7.35 7.38 7.41 7.39 7.39 7.40 7.41 7.43 7.44
310# 7.44 7.47 7.49 7.48 7.50 7.54 7.55 7.53 7.57 7.57
320# 7.60 7.69 7.73 7.75 7.79 7.84 7.84 7.88 7.92 7.96
330# 7.98 7.95 7.95 7.97 7.96 7.95 7.95 7.94 7.93 7.89
340# 7.88 7.85 7.79 7.80 7.81 7.81 7.80 7.81 7.86 7.85
350# 7.88 7.89 7.90 7.90 7.94 7.95 8.00 8.02 8.04 8.10
360# 8.15 8.15 8.20 8.21 8.19 8.25 8.27 8.25 8.26 8.27
370# 8.28 8.29 8.32 8.31 8.31 8.35 8.38 8.38 8.44 8.44
380# 8.47 8.49 8.51 8.53 8.54 8.57 8.61 8.63 8.68 8.69
390# 8.71 8.74 8.78 8.78 8.82 8.84 8.84 8.89 8.91 8.93
400# 8.93 8.98 8.98 9.02 9.05 9.09 9.11 9.16 9.17 9.19
410# 9.19 9.19 9.22 9.22 9.22 9.19 9.19 9.21 9.23 9.24
420# 9.27 9.29 9.32 9.31 9.37 9.39 9.38 9.40 9.44 9.41
430# 9.44 9.48 9.46 9.50 9.52 9.54 9.56 9.61 9.60 9.65
440# 9.74 9.76 9.74 9.76 9.81 9.81 9.82 9.83 9.86 9.88
450# 9.87 9.91 9.92 9.93 9.93 9.97 9.96 9.95 9.95 9.95
460# 9.97 9.98 9.99 10.01 10.03 10.02 10.07 10.07 10.06 10.06
470# 10.05 10.07 10.10 10.10 10.12 10.12 10.16 10.17 10.16 10.20
480# 10.20 10.19 10.22 10.23 10.24 10.26 10.29 10.30 10.31 10.36
490# 10.40 10.43 10.50 10.52 10.56 10.58 10.61 10.62 10.66 10.71
500# 10.67 10.68 10.69 10.69 10.71 10.75 10.78 10.79 10.88 10.88
510# 10.86 10.85 10.84 10.80 10.81 10.75 10.71 10.70 10.67 10.63
520# 10.66 10.70 10.71 10.74 10.77 10.80 10.82 10.85 10.86 10.88
530# 10.89

```

```

000100      PROGRAM FFI777 (INPUT=75,OUTPUT=75,TAPE20=120,
000110      C*****CHANGE ALL "256"TO"256"*****
000120      &TAPE1=OUTPUT,TAPE33=120,DERUG,TAPE61=100,TAPE62=100)
000130      DIMENSION GO(7),A1(256,8),A2(256,8),W1(256,4),W2(256,4)
000140      DIMENSION K22(21,K33(2),KK(72),XY(41,10)
000150      DIMENSION RAY(2,100),XLAR(1),YLAR(1)
000160      DIMENSION RAY1(2,100),XLAR1(1),YLAR1(1)
000170      DIMENSION RAY2(2,100),XLAR2(1),YLAR2(1)
000180      INTEGER ANS1,ANS3,ANS4,ANS5,ANS6,ANS7,ANS8
000190      INTEGER R,C,RO,CO,R1,C1,R2,C2,R3,C3,P2
000200      REAL K22,K33,K9,KK
000210      DATA XX/410*0./
000220      DATA GO/-,1476,-,1707,-,1817,1,-,1817,-,1707,-,1476/
000230      CALL CONNEX(5,INPUT)
000240      CALL CONNEX(6,OUTPUT)
000250      CALL INITT(300)
000260      CALL CHRSTZ(3)
000270      C$ STORES(W1,W2,I1,I2,J,K,J1,K1)
000280      PI=3.14159265
000290      PRINT(1,100)
000300      FORMAT(16X,"PSP0 PROGRAM FFI77.7-78.3".//)
000310      PRINT(1,120)
000320      FORMAT(1X,"NUMBER OF TERRAIN POINTS IS EQUAL TO 2**ANS1.",/1X,
&"ANS1, AN INTEGER. MUST BE GREATER THAN OR EQUAL TO 1 AND LESS THAN
&N OR",/1X,"EQUAL TO 8.",/1X,"ANS1 = ")
000340      READ *,ANS1
000350      WRITE(2,150)ANS1
000360      IF(ANS1.LE.1)GOTO 9999
000370      150  FORMAT(1X,13)
000380      PRINT(1,170)
000390      170  FORMAT(1X,"SURVEY INTERVAL IN FEET2 ALLOWS 4 PLACES PAST DECIMAL,"000400
&,/1X,"ANS2 = ")
000410      READ *,ANS2
000420      WRITE(2,180)ANS2
000430      180  FORMAT(1X,F9.4)
000440      PRINT(1,200)
000450      200  FORMAT(1X,"ENTER 0 FOR DATA READING.",/1X,"1 FOR CARD READING.",
&,/6X,"-1 FOR DATA EQUATIONS.",/1X,"ANS3 = ")
000460
000470

```

	READ *,ANS3	000480
C	WRITE(2,210) ANS3	000490
210	FORMAT(1X,12)	000500
	PRINT(1,220)	000510
220	FORMAT(1X,"ENTER 1 FOR FIRST TO LAST POINT DETRENDING",/,7X,"2 FOR DIGITAL HIGH-PASS FILTER",/,7X,"3 FOR EXPONENTIALLY WEIGHTED RUNNING AVERAGE",/,7X,"4 FOR NO DETRENDING",/,1X,"ANS4 = ")	00000520
	READ *,ANS4	00000530
C	WRITE(2,330) ANS4	000540
330	FORMAT(1X,12)	000550
	PRINT(1,340)	000560
340	FORMAT(1X,"DO YOU WANT THE ARRAY PADDED WITH N1 OBS?",/,1X,"ENTER 1 FOR YES",/,7X,"2 FOR NO",/,1X,"ANS5 = ")	000570
	READ *,ANS5	000580
C	WRITE(2,350) ANS5	000590
350	FORMAT(1X,12)	000600
	PRINT(1,370)	000610
370	FORMAT(1X,"DO YOU WANT INTERPOLATION?",/,1X,"ENTER 1 FOR YES",/,7X,"2 FOR NO",/,1X,"ANS6 = ")	000620
	READ *,ANS6	000630
C	WRITE(2,390) ANS6	000640
390	FORMAT(1X,12)	000650
	PRINT(1,400)	000660
400	FORMAT(1X,"DO YOU WANT AMPLITUDE SMOOTHING?",/,1X,"ENTER 1 FOR YES",/,7X,"2 FOR NO",/,1X,"ANS7 = ")	000670
	READ *,ANS7	000680
C	WRITE(2,450) ANS7	000690
450	FORMAT(1X,12)	000700
	PRINT(1,460)	000710
460	FORMAT(1X,"DO YOU WANT A GEO WINDOW?",/,1X,"ENTER 1 FOR YES",/,7X,"2 FOR NO",/,1X,"ANSR = ")	000720
	READ *,ANSR	000730
C	WRITE(2,470) ANSR	000740
470	FORMAT(1X,12)	000750
	CALL HDCOPY	000760
	CALL NEWPAG	000770
	CALL HOME	000780
C	REWIND 2	000790
		000800
		000810
		000820
		000830
		000840
		000850

C	READ(2,150)ANS1	000860
C	READ(2,180)ANS2	000870
C	READ(2,210)ANS3	000880
C	READ(2,330)ANS4	000890
C	READ(2,350)ANS5	000900
C	READ(2,390)ANS6	000910
C	READ(2,450)ANS7	000920
C	READ(2,470)ANS8	000930
	WRITE(20,800)	000940
800	FORMAT(1X,20X,"PSD PROGRAM")	000950
	N1=2**ANS1	000960
	E=36./ANS2	000970
	IF=INT(E)	000980
	WRITE(20,810)ANS2	000990
810	FORMAT(1X,"SURVEY INTERVAL = ",EQ.4,"FEET")	001000
	IF(ANS4.NE.3)GOTO 1440	001010
	N1=N1+2*E	001020
	C***CARD READING WILL BE INTRODUCED AT A LATER TIME	001030
1440	IF(ANS3.EQ.1)GOTO 9999	001040
	IF(ANS3.EQ.0)GOTO 1600	001050
C		001060
C	FOR ANS3=-1, INITIALIZE TERRAIN DATA ARRAY	001070
C		001080
	I1=1	001090
	IF(ANS4.GE.2)GOTO 1470	001100
1470	NZ=N1	001120
	DO 1560 I=1,NZ	001130
C	FOR NO PADDING	001140
	IF(ANS5.EQ.2)GOTO 1510	001150
	I2=N1+1	001160
	CO=1+INT((I2-.5)/256)	001170
	RO=I2-256*(CO-1)	001180
	A1(RO,CO)=0	001190
1510	X=I-1	001200
	I2=2*PI*X*ANS2	001210
	I2=I+1-I1	001220
	CO=1+INT((I2-.5)/256)	001230
	RO=I2-256*(CO-1)	001240

C		001250
C	THE DATA EQUATIONS WHICH FOLLOW IMMEDIATELY MAY BE SUBJECT TO	001260
C	REPLACEMENT.	001270
C		001280
	1550 A1(R0,C0)=2.5*SIN(-PI/2.+T2/25.)+1.6*SIN(T2/16.)	001290
	8+1.15*SIN(-PI/2.+T2/11.5)+.8*SIN(T2/8.)+.6*SIN(-PI/2.+T2/6.)	001291
	8+.4*SIN(T2/4.)	001300
	A2(R0,C0)=A1(R0,C0)	001310
1560	CONTINUE	001320
	WRITE(1,1570)	001330
	1570 FORMAT(1X,"THE FOLLOWING DATA EQUATION WAS USED:"/,3X,	001340
	8WY=2.5*SIN(-PI/2.+T2/25.)+1.6*SIN(T2/16.)+1.15*SIN(-PI/2.+T2/11.5)	001350
	82/11.5)+.8*SIN(T2/8.)+.6*SIN(-PI/2.+T2/6.)+.4*SIN(T2/4.)")	001360
C		001370
C	FOR CASES WITHOUT ZERO PADDING.	001380
C		001390
	IF(ANS5.EQ.2)GOTO 1580	001400
	ANS1=ANS1+1	001410
	N1=2**ANS1	001420
1580	CONTINUE	001430
C		001440
C	FOR CASES OTHER THAN DATA READING	001450
C		001460
	IF(ANS6.EQ.2)GOTO 1680	001470
	GOTO 1650	001480
C	*****	001490
C	*****	001500
C		001510
C	READ TERRAIN PROFILE DATA.	001520
C		001530
	1600 DO 1620 JB=1,41	001540
	READ(33,1610)(XX(JB,JG),JG=1,10)	001550
	1610 FORMAT(10F6.2)	001560
	1620 CONTINUE	001570
	JB=1	001580
	JG=1	001590
	NZ=N1+1	001600

00	1645	I0=1,NZ	001610
	I1=I0		001620
	IF (ANS4,GE,2)GOTO 1630		001630
	I1=I0-IF		001640
	IF (I1,LT,.5)GOTO 1640		001650
1630	CO=INT((I1-.1)/256)+1		001660
	RO=I1-256*(CO-1)		001670
	AI(RO,CO)=XX(JB,JG)		001680
	Z(RO,CO)=XX(JB,JG)		001690
1640	JG=JG+2		001700
	IF (JG,GT,10)JR=JR+1		001710
	IF (JG,GT,10)JG=1		001720
1645	CONTINUE		001730
C			001740
C	SPREAD OUT ARRAY TO TWICE ITS ORIGINAL LENGTH.		001750
C			001760
1650	DO 1670 K=1,N1		001770
	I=N1+2-K		001780
	CO=1+INT((I-1)/256)		001790
	RO=I-256*(CO-1)		001800
	J=2*I-1		001810
	CI=1+INT((J-1)/256)		001820
	RI=J-256*(CI-1)		001830
	AI(PI,CI)=AI(RO,CO)		001840
1670	CONTINUE		001850
	ANS1=ANS1+1		001860
	N1=2**ANS1		001870
	ANS2=ANS2/2		001880
C			001890
C	1ST AND LAST POINT LINEAR INTERPOLATION		001900
C			001910
	AI(2,1)=.5*(AI(1,1)+AI(3,1))		001920
	I1=N1-1		001930
	CI=1+INT((I1-1)/256)		001940
	RI=I1-256*(CI-1)		001950
	I2=N1		001960
	C2=1+INT((I2-1)/256)		001970
	R2=I2-256*(C2-1)		001980

I3=N1+1	001990
C3=1+INT((I3-1)/256)	002000
R3=I3-256*(C3-1)	002010
A1(R2,C2)=.5*(A1(R1,C1)+A1(R3,C3))	002020
C	002030
C FOR CASES OF INTERPOLATION	002040
C	002050
IF (ANS6.EQ.1) GO TO 3200	002060
1680 CONTINUE	002070
C	002080
C SELECT DETRENDING METHOD	002090
C	002100
GO TO (3900,3600,4050,1690)ANS4	002110
C*****	002120
C*****	002130
C RETURN TO 1690 AFTER DETRENDING	002140
C THE FOLLOWING DO LOOP COMPUTES THE AVERAGE VALUE OF THE	002150
C GIVEN TERRAIN POINTS. THIS WILL THEN BE SUBTRACTED FROM	002160
C EACH INDIVIDUAL POINT VALUE SO THAT THE NEW AVERAGE OF	002170
C THE TERRAIN POINTS WILL BE ZERO.	002180
C THIS IS DONE FOR THE PURPOSE OF INITIALIZING THE VALUES	002190
C USED IN THE FAST FOURIER TRANSFORMATION. (ASK ZOLTAN.)	002200
C CHECK LATER FOR POINT OF ENTRY INTO THIS PROGRAM SECTOR.	002210
C	002220
1690 ST=A1(1,1)	002230
C	002240
C COMPUTE AVERAGE	002250
C	002260
DO 1700 IO=2,N1	002270
CO=(INT((IO-1)/256)+1)	002280
RO=IO-256*(CO-1)	002290
C	002300
C ST IS THE SUMMATION OF THE VALUES OF THE TERRAIN POINTS	002310
C	002320
ST=ST+A1(RO,CO)	002330
1700 CONTINUE	002340
Y=ST/(N1)	002350
A1(1,1)=A1(1,1)-Y	002360

	A1(2,1)=A1(2,1)-Y	002370
	B1=A1(1,1)	002380
	B2=A1(2,1)	002390
	X=B1*B1+B2*B2	002400
C		002410
C	Y DESIGNATES THE AVERAGE TERRAIN POINT VALUE	002420
C		002430
	WRITE(20,1710)	002440
1710	FORMAT(1X,"RELATIVE MAXIMUM & MINIMUM PROFILE VALUES")	002450
	PRINT(1,1720)	002460
1720	FORMAT(///,1X,"RELATIVE MAXIMUM AND MINIMUM PROFILE VALUES",/)	002470
	IO=1	002480
	WRITE(20,1730) IO,B1	002490
1730	FORMAT(1X,13,5X,F6.2)	002500
	PRINT(1,1740) IO,B1	002510
1740	FORMAT(1X,13,5X,F6.2)	002520
	RAY1(1,1)=IO	002530
	RAY1(2,1)=B1	002540
	IO1=IO	002550
C		002560
C	SUBTRACT AVERAGE FROM INDIVIDUAL PTS.	002570
C		002580
	DO 1800 IO=3,N1	002590
	CO=(INT((IO-1,1)/256)+1)	002600
	RO=IO-256*(CO-1)	002610
	A1(RO,CO)=A1(RO,CO)-Y	002620
	B3=B2-B1	002630
	B4=A1(RO,CO)-B2	002640
	IF (B3*B4.GT.0) GOTO 1770	002650
C		002660
C	PRINT RELATIVE MAX OR MIN	002670
C		002680
	WRITE(20,1750) IO=1,B2	002690
	PRINT(1,1740) IO=1,B2	002700
1770	X=X+(A1(RO,CO))**2	002710
	IO1=IO1+1	002720
	RAY1(1,IO1)=IO=1	002730
	RAY1(2,IO1)=B2	002740

C	COMPUTATION OF THE FAST FOURIER TRANSFORMATION FOLLOWS.	003120
C	BOB DAIGLE DERIVED THE ALGORITHM FROM A MORE COMPLEX RENDIX	003130
C	PROGRAM, FOR MORE INFORMATION ON THE RENDIX PROGRAM	003140
C	CONTACT TOM WASHBURN. FOR MORE INFORMATION ON THE	003150
C	FAST FOURIER TRANSFORMATION CONTACT ZOLTAN JANOSI.	003160
C		003170
	N=N1	003180
	N2=N/2	003190
C		003200
C	SAVE N1	003210
C		003220
	N9=N1	003230
C		003240
C	W=0	003250
C		003260
	W1(1,1)=1.	003270
	W2(1,1)=0.	003280
C		003290
C	W=1	003300
C		003310
	W1(2,1)=COS(2*PI/N2)	003320
	W2(2,1)=-SIN(2*PI/N2)	003330
	I=2	003340
C		003350
C	PRINT(1,1940)W1(2,1),W2(2,1)	003360
1940	FORMAT(1X,F3.1,3X,F3.1)	003370
C	COMPUTE W=2 THRU W=(N/2)	003380
C		003390
	N4=N1/4	003400
	DO 2000 I=3,N4	003410
	K=1+INT((I-.5)/256)	003420
	J=I-256*(K-1)	003430
	K1=1+INT((I-1.5)/256)	003440
	J1=I-1-256*(K1-1)	003450
	W1(J,K)=W1(J1,K1)*W1(2,1)-W2(J1,K1)*W2(2,1)	003460
	W2(J,K)=W2(J1,K1)*W1(2,1)+W1(J1,K1)*W2(2,1)	003470
C		003480

C	PRINT(1,1950)1,W1(J,K),W2(J,K)	003490
1950	FORMAT(1X,I4,5X,F7.4,5X,F7.4)	003500
C		003510
	WRITE(20,1950)1,W1(J,K),W2(J,K)	003520
2000	CONTINUE	003530
	L=1	003540
	ANS1=ANS1-1	003550
2050	M=0	003560
C		003570
C	PRINT(1,2100)1	003580
2100	FORMAT(1X,I3)	003590
C		003600
	P2=INT(2**((ANS1-1)*0.5))	003610
	K=0	003620
C		003630
C	REVERSE BITS OF K	003640
C		003650
2110	K1=K	003660
	K8=0	003670
	K9=N4	003680
C		003690
C	THIS PROGRAM SEGMENT WILL REVERSE BITS OF K AND STORE IN K8	003700
C		003710
	00 2200 I=1,ANS1	003720
	K2=INT(K1/2.)	003730
	IF((K1-2*K2),1,0.5)GOTO 2170	003740
	K8=K8+K9	003750
2170	K9=K9/2	003760
	K1=K2	003770
2200	CONTINUE	003780
C		003790
C	PRINT(1,2240)K,K8	003800
2240	FORMAT(1X,I4,3X,I4)	003810
C		003820
C	WRITE(1,2240)K,K8	003830
	I=K8+P2+1	003840
	I2=1+INT((I-.5)/256)	003850
	I1=I-256*(I2-1)	003860

K22(1)=N1(I1,I2)	003870
K22(2)=N2(I1,I2)	003880
N1=0	003890
2250 J=K+N1+P2+1	003900
J2=1+INT((J-.5)/256)	003910
J1=J-256*(J2-1)	003920
K33(1)=A1(J1,J2)*K22(1)-A2(J1,J2)*K22(2)	003930
K33(2)=A1(J1,J2)*K22(2)+A2(J1,J2)*K22(1)	003940
I=K+N1+1	003950
I2=1+INT((I-.5)/256)	003960
I1=I-256*(I2-1)	003970
A1(J1,J2)=A1(I1,I2)-K33(1)	003980
A2(J1,J2)=A2(I1,I2)-K33(2)	003990
A1(I1,I2)=A1(I1,I2)+K33(1)	004000
A2(I1,I2)=A2(I1,I2)+K33(2)	004010
C	004020
C	004030
2260 FORMAT(1X,I4,3X,F8.2,3X,F8.2,5X,I4,F8.2,3X,F8.2)	004040
C	004050
WRITE(20,2260)I1,J1,A1(J1,J2),A2(J1,J2),A1(I1,I2),A2(I1,I2)	004060
N1=N1+1	004070
IF(N1,J1,P2)GOTO 2250	004080
K=K+2*P2	004090
M=M+1	004100
IF(M.LT.2*(L-1))GOTO 2110	004110
L=L+1	004120
IF(L.LE.ANS)GOTO 2050	004130
C	004140
C	004150
C	004160
C	004170
DO 2300 J=1,N2	004180
K=J-1	004190
K1=K	004200
K8=0	004210
K9=N4	004220

DO 2290 I=1,ANSI	004230
K2=INT(K1/2.)	004240
IF((K1-2*K2).LT.0.5)GOTO 2280	004250
K8=K8+K9	004260
2280 K9=K9/2.	004270
K1=K2	004280
2290 CONTINUE	004290
IF(K8,LE,K)GOTO 2300	004300
C	004310
C	004320
C	004330
J8=K8+I	004340
J7=1+INT((J8-.5)/256)	004350
J6=J8-256*(J7-1)	004360
J2=1+INT((J-.5)/256)	004370
J1=J-256*(J2-1)	004380
X=A1(J1,J2)	004390
A1(J1,J2)=A1(J6,J7)	004400
A1(J6,J7)=X	004410
X=A2(J1,J2)	004420
A2(J1,J2)=A2(J6,J7)	004430
A2(J6,J7)=X	004440
2300 CONTINUE	004450
C1=1+INT((N2+.5)/256)	004460
R1=N2+1-256*(C1-1)	004470
A1(R1,C1)=A1(J1,J2)	004480
A2(R1,C1)=A2(J1,J2)	004490
DO 2400 K=1,N4	004500
M=N2+2-K	004510
SZ=SIN(2*PI*(K-1)/N)	004520
CZ=COS(2*PI*(K-1)/N)	004530
C1=1+INT((K-.5)/256)	004540
R1=K-256*(C1-1)	004550
C2=1+INT((M-.5)/256)	004560
R2=M-256*(C2-1)	004570
Z1=.5*(A1(R1,C1)+A1(R2,C2))-5*S7*(A1(R1,C1)-A1(R2,C2))+	004580
6.5*C7*(A2(R1,C1)+A2(R2,C2))	004590
77=.5*(A2(R1,C1)-A2(R2,C2))-5*S7*(A2(R1,C1)+A2(R2,C2))-	004600

6.5*Z*(A1(R1,C1))-A1(R2,C2))	004610
SZ=SIN(2*PI*(M-1)/N)	004620
CZ=COS(2*PI*(M-1)/N)	004630
Z3=.5*(A1(R2,C2)+A1(R1,C1))-5*SZ*(A1(R2,C2)-A1(R1,C1))+	004640
6.5*CZ*(A2(R2,C2)+A2(R1,C1))	004650
Z4=.5*(A2(R2,C2)-A2(R1,C1))-5*SZ*(A2(R2,C2)-A2(R1,C1))-	004660
6.5*CZ*(A1(R2,C2)-A1(R1,C1))	004670
A1(R1,C1)=Z1	004680
A2(R1,C1)=Z2	004690
A1(R2,C1)=Z3	004700
A2(R2,C1)=Z4	004710
2400 CONTINUE	004720
N3=N2+1	004730
CALL NEWBAG	004740
CALL CHRSTZ(3)	004750
CALL HOME	004760
PRINT(1,2450)	004770
2450 FORMAT(//,27X,"RAW P.S.D. RESULTS",//,15X,"AMPLITUDE PERIOD	004780
6 FREQ PSD")	004790
P1=0.	004800
K=0	004810
F1=0.	004820
A=0.	004830
P7=9999.99	004840
P=PZ	004850
F=0.	004860
P4=0.	004870
C	004880
C PRINT *,X,I1,I2,A1,A2"	004890
C	004900
C	004910
DO 2600 I=1,N3	004920
C	004930
C PERIOD AND FREQUENCY	004940
C	004950
2460 IF(1.EQ.1)GOTO 2470	004960
P=ANS2*N/(I-1.)	004970
2470 F=1./P	004980
C	004990

C	AMPLITUDE	004990
C		005000
	I2=1+INT((I-.5)/256)	005010
	I1=I-256*(I2-I)	005020
C		005030
C	PRINT *,X,I1,I2,A1(I1,I2),A2(I1,I2)	005040
C	X=A1(I1,I2)**2+A2(I1,I2)**2	005050
C		005060
C	COMPUTE AMPLITUDE	005070
C		005080
C	A=SQRT(X)*2/N	005090
C		005100
C	COMPUTE POWER SPECTRAL DENSITY	005110
C		005120
C	G=X*2*ANS2/N	005130
C		005140
C	STORE UNSMOOTHED PSD	005150
C		005160
	A1(I1,I2)=G	005170
	P1=P1+G	005180
	P4=P4+G	005190
	F1=F1+G	005200
	K=K+1	005210
	IF(N/I,I1,I1.999)GOTO 2490	005220
C		005230
C	MAINTAIN MIN 1 FT PERIOD INTERVAL FOR PRINTOUT	005240
C		005250
C	IF(PZ-N/I,I1,I1.999)GOTO 2490	005260
C		005270
	2490 F=F1/K	005280
	IF(F.1T.0001)GOTO 2500	005290
	P=P1/F	005300
	2500 G=P4	005310
	IF(G.1I.0.000001)G=0.000001	005320
	IF(P.GT.9000.)RAY2(1,I)=2**ANS1	005330
	IF(P.GT.9000.)RAY2(2,I)=0.	005340
	IF(P.GT.9000.)GOTO 2510	005350
	RAY2(1,I)=P	005360

RAY2(2,I)=A	005370
2510 RAY(1,I)=F	005380
RAY(2,I)=G	005390
WRITE(1,2530)A,P,F,G	005400
2530 FORMAT(15X,F6.4,5X,F7.2,5X,F6.4,4X,F11.6)	005410
WRITE(20,2550)A,P,F,G	005420
2550 FORMAT(1X,4(F7.2,3X))	005430
RAY(1,I)=F	005440
RAY(2,I)=G	005450
P4=0.	005460
K=0	005470
F1=0	005480
A=0.	005490
PZEN/I	005500
2600 CONTINUE	005510
C	005520
C AREA UNDER PSD	005530
C	005540
P3=P1/(ANS2*N)	005550
P1=12.*SORT(P3)	005560
WRITE(1,2700)	005570
2700 FORMAT(///,1X,"RESULTS WITH UNSMOOTHED F.F.T. AMPLITUDES")	005580
WRITE(1,2750)P1,P3	005590
2750 FORMAT(//,1X,"RMS = ",F9.4,1X,"INCHES",/,1X,"AREA UNDER PSD = ",	005600
F9.4,1X,"SQ.FT.")	005610
CALL HRCOPY	005620
CALL NEWPAG	005630
XLAR2(1)=5*PERIOD	005640
YLAR2(1)=9*AMPLITUDE	005650
CALL INITI(300)	005660
CALL GLOT(RAY2,N3,XLAR2,6,YLAR2,9,2,1,10,10,10,1,1,IFLG,1.)	005670
CALL HRCOPY	005680
CALL NEWPAG	005690
XLAR(1)=9*HFFREQUENCY	005700
YLAR(1)=3*HPSD	005710
CALL NEWPAG	005715
CALL INITI(300)	005720
CALL GLOT(PAY,N3,XLAR,9,YLAR,3,2,1,10,10,10,2,2,IFLG,0.)	005730

CALL HDCCPY	005740
CALL NEWPAG	005750
CALL CHRSTZ(3)	005760
CALL HOME	005770
IF (ANS8.EQ.2) GOTO 9999	005780
PRINT(1,2850)	005790
2850 FORMAT(//,17X,"SMOOTH AMPLITUDES USING G.E.O. WINDOW",//, 615X,"AMPLITUDE",3X,"PERIOD",7X,"FREQU",11X,"PSD")	005800
P1=6.	005810
C	005820
C	005830
C	005840
X=SQRT(.856)	005850
DO 3150 I=1,N3	005860
A=0.	005870
R=0.	005880
DO 3050 K=1,7	005890
J=I+(K-4)	005900
IF (J.GT.0) GOTO 2900	005910
J=J+N3	005920
GOTO 3000	005930
2900 IF (J.LI.N3+.5) GOTO 3000	005940
J=J-N3	005950
3000 CO=1+INT((J-.5)/256)	005960
RO=J-256*(CO-1)	005970
A=A+GO(K)*A1(RO,CO)	005980
R=R+GO(K)*A2(RO,CO)	005990
3050 CONTINUE	006000
X=A+A+R*R	006010
G=.856*X*.2+ANS2/N	006020
IF (G.LT..000001) G=.000001	006030
A=SQRT(X)*2/N	006040
P=9999.99	006050
IF (LI.LI.J.5) GOTO 3100	006060
P=ANS2*N/(I-1.)	006070
3100 F=1./P	006080
WRITE(1,2530) A,P,F,G	006090
RAY(1,I)=F	006100
	006110

RAY(2,I)=G	006120
P1=P1+G	006130
3150 CONTINUE	006140
P3=P1/(ANS2*N1)	006150
P1=12.*SORT(P3)	006160
C	006170
C	006180
C	006190
WRITE(1,2750)P1,P3	006200
C	006210
C	006220
C	006230
N1=N9	006240
XLAB1(1)=9HFREQUENCY	006250
YLAB1(1)=3HPSD	006260
CALL HD COPY	006270
CALL NEWPAG	006280
CALL INITI(300)	006290
CALL GPLOT(RAY,N3,XLAB,9,YLAB,3,2.,1.,10.,10.,2.,2.,IFLG,0.)	006300
CALL HD COPY	006310
CALL CHRISZ(3)	006320
GOTO 9999	006330
C*****	006340
C*****	006350
3200 PRINT(1,3300)	006360
3300 FORMAT(1X,"CUBIC INTERPOLATION TO HALVE SURVEY INTERVAL")	006370
I=4	006380
IO=I-3	006390
CO=1+INT((IO-1.)/256)	006400
RO=IO-256*(CO-1)	006410
I1=I-1	006420
C1=1+INT((I1-1.)/256)	006430
R1=I1-256*(C1-1)	006440
I2=I+1	006450
C2=1+INT((I2-1.)/256)	006460
R2=I2-256*(C2-1)	006470
YZ=A1(R0,CO)	006480
YI=A1(R1,C1)	006490

Y2=A1(R2,C2)	006500
NN=N1-2	006510
DO 3500 I=4,NN,2	006520
I3=I+3	006530
C3=1+INT((I3-1.)/256)	006540
R3=I3-256*(C3-1)	006550
Y3=A1(R3,C3)	006560
CC1=Y1-Y2	006570
CC2=.5*(Y2-Y2)-CC1	006580
CC3=(Y3-Y2-3*CC1)/6-CC2	006590
C=1+INT((I-1.)/256)	006600
R=I-256*(C-1)	006610
A1(R,C)=Y2+1.5*CC1+.75*CC2-.375*CC3	006620
YZ=Y1	006630
Y1=Y2	006640
Y2=Y3	006650
3500 CONTINUE	006660
GO TO 1680	006670
C*****	006680
C*****	006690
3600 N1=2**ANSI+2*E	006700
GO TO 3900	006710
3610 PRINT(1,3620)	006720
3620 FORMAT(1X,"W.F.S. DIGITAL RECURSIVE FILTER".//)	006730
X1=A1(4,1)	006740
Y1=X1	006750
X2=A1(3,1)	006760
Y2=X2	006770
X3=A1(2,1)	006780
Y3=X3	006790
X4=A1(1,1)	006800
Y4=X4	006810
W6=N1+1	006820
DO 3700 I=5,N6	006830
C0=INT((I-1.)/256)+1	006840
R0=I-256*(C0-1)	006850
X0=A1(R0,C0)	006860
A1(R0,C0)=.5*(A1(R0,C0)-4*X1+6*X2-4*X3+X4)-(-3.871195*Y1+	006870
85.619810*Y2-3.625898*Y3+.877285*Y4)	006880

WRITE(1,3640)X0,A1(R0,C0)	006890
3640 FORMAT(1X,F8.3,5X,F8.3)	006900
X4=X3	006910
X3=X2	006920
X2=X1	006930
X1=X0	006940
Y4=Y3	006950
Y3=Y2	006960
Y2=Y1	006970
Y1=A1(R0,C0)	006980
3700 CONTINUE	006990
N1=2**ANS1	007000
N6=N1+1	007010
DO3800 I=1,N6	007020
C0=INT((I-1,J/256)+1	007030
R0=I-256*(C0-1)	007040
J=I+E	007050
C1=INT((J-1,)/256)+1	007060
R1=J-256*(C1-1)	007070
A1(R0,C0)=A1(R1,C1)	007080
A2(R0,C0)=0.	007090
3800 CONTINUE	007100
ANS4=5	007110
C*****	007120
C*****	007130
3900 PRINT(1,3910)	007140
3910 FORMAT(///,1X,"FIRST TO LAST POINT DETRENDING",/)	007150
N1=2**ANS1	007160
I8=INT(N1/256.)+1	007170
IA=N1-256*(I8-1)	007180
X=(A1(IA,I8)-A1(1,1))/(N1-1)	007190
IF(N1.LT.2)GOTO 9999	007200
DO 4000 I0=2,N1	007210
C0=INT((I0-1,)/256)+1	007220
R0=I0-256*(C0-1)	007230
A1(R0,C0)=A1(R0,C0)-(I0-1)*X	007240
4000 CONTINUE	007250

```

AAZ=ANS4-2 007260
AZ=ABS(AA7) 007270
IF(AZ,LT,.1)GOTO 3610 007280
GOTO 1690 007290
C*****007300
C*****007310
C EXPONENTIALLY WEIGHTED RUNNING AVERAGE 007320
C 007330
4050 PRINT(1,4060) 007340
4060 FORMAT(1X,"EXPONENTIALLY WEIGHTED RUNNING AVERAGE",//) 007350
L=30 007360
D=.5 007370
N1=2**ANS1+2*E 007380
IE=INT(E) 007390
DO 5000 I=1,IE 007400
KK(I)=EXP(-ANS2*I/L) 007410
D=D*KK(I) 007420
5000 CONTINUE 007430
D=D*2 007440
PRINT(1,5010)F,I 007450
5010 FORMAT(1X,4HE = ,F7.3,10X,4HL = ,I3,//) 007460
N8=IE+1 007470
N9=N1+1-IE 007480
DO 5120 I1=NR,N9 007490
C0=(INT((I1-1)/256)+1) 007500
R0=I1-256*(C0-1) 007510
SU=A2(R0,C0)+1 007520
DO 5050 J=1,IE 007530
L2=J 007540
I0=I1+L2 007550
C1=(INT((I0-1)/256)+1) 007560
R1=I0-256*(C1-1) 007570
S2=A2(R1,C1) 007580
I0=I1-L2 007590
C2=(INT((I0-1)/256)+1) 007600
R2=I0-256*(C2-1) 007610
S3=A2(R2,C2) 007620
SU=SU+(S2+S3)*KK(J) 007630
5050 CONTINUE 007640

```

I=I-IF	007650
C1=1+INT((I1-1)/256)	007660
R1=I1-256*(C1-1)	007670
A2(R1,C1)=0	007680
A1(R1,C1)=A2(R0,C0)-(SU/D)	007690
WRITE(1,5110) L1,A2(R0,C0),A1(R1,C1)	007700
5110 FORMAT(1X,I3,6X,F10.6,6X,F10.6)	007710
5120 CONTINUE	007720
N1=2**ANS1	007730
C	007740
C NOW DO 1ST TO LAST POINT OF-TRENDING	007750
C	007760
GOTO 3900	007770
C*****	007780
C*****	007790
9999 STOP	007800
END	007810

INDEX OF VARIABLES FOR SIGNAL ANALYSIS PROGRAM
(VARIABLE NAME AND PROGRAM LINE NUMBERS)

A	483Q, 5090, 5370, 5400, 5420, 5490, 5890, 6000, 6030, 6060, 6110
AAZ	7260, 7270
AZ	7260, 7270, 7280
ANS1	180, 320, 330, 340, 350, 360, 370, 860, 960, 1410, 1420, 1860, 1870, 3550, 3610, 3720, 4130, 4230, 5330, 6700, 7000, 7160, 7380, 7730
ANS2	410, 420, 430, 870, 970, 990, 1200, 1880 4960, 5130, 5550, 6030, 6080, 6150, 7410
ANS3	180, 470, 480, 490, 880, 1040, 1050, 1070
ANS4	180, 540, 550, 560, 890, 1010, 1100, 1630, 2110, 7110, 7260
ANS5	180, 600, 610, 620, 900, 1140, 1400
ANS6	180, 660, 670, 680, 910, 1470, 2060
ANS7	180, 720, 730, 740, 920
ANS8	180, 780, 790, 800, 930, 5780
Al(.)	130, 1190, 1290, 1310, 1680, 1840, 1920, 2020, 2230, 2330, 2360, 2370, 2380, 2390, 2620, 2640, 2710, 2760, 3080, 3090, 3930, 3940, 3980, 4000, 4030, 4060, 4390, 4400, 4410, 4480, 4580, 4640, 4680, 4700, 4890, 5040, 5050, 5170, 5990, 6480, 6490, 6500, 6560, 6620, 6740, 6760, 6780, 6800, 6860, 6870, 6890, 6980, 7080, 7190, 7240, 7690, 7700

A2(,)	130, 1310, 1690, 3090, 3930, 3940, 3990, 4010, 4030, 4060, 4420, 4430, 4440, 4490, 4590, 4600, 4650, 4660, 4670, 4690, 4710, 5040, 5050, 6000, 7090, 7520, 7580, 7620, 7680, 7690, 7700
B	6000, 6020
B1	2380, 2400, 2490, 2510, 2540, 2630, 2750
B2	2390, 2400, 2630, 2640, 2690, 2700, 2740, 2750, 2760, 2780, 2790, 2820
B3	2630, 2650
B4	2640, 2650
C	6610, 6620, 6630
CC1	6580, 6590, 6600
CC2	6590, 6600, 6630
CC3	6600, 6630
CO	190, 1160 1170, 1180, 1220, 1230, 1290, 1310, 1660, 1670, 1680, 1690, 1790, 1800, 1840, 2280, 2290, 2330, 2600, 2610, 2620, 2640, 2710, 2760, 3010, 3020, 3080, 3090, 5970, 5980, 5990, 6000, 6400, 6410, 6480, 6840, 6850, 6860, 6870, 6890, 6980, 7030, 7040, 7080, 7090, 7220, 7230, 7240, 7500, 7510, 7520, 7690, 7700
CZ	4530, 4590, 4610, 4630, 4650, 4670

C1 190, 1820, 1830, 1840, 1940, 1950,
 2020, 3040, 3050, 3090, 4460, 4470,
 4480, 4490, 4540, 4550, 4580, 4590,
 4600, 4610, 4640, 4650, 4660, 4680,
 4690, 6430, 6440, 6490, 7060, 7070,
 7080, 7560, 7570, 7580, 7660, 7670,
 7680, 7690, 7700

C2 190, 1970, 1980, 2020, 3060, 3070,
 3080, 4560, 4570, 4580, 4590, 4600,
 4610, 4640, 4650, 4660, 4670, 4700,
 4710, 6470, 6480, 6510, 7610, 7620,
 7630

C3 190, 2000, 2010, 2020, 6540, 6550,
 6560

D 7380, 7430, 7450, 7700

E 970, 980, 1020

F 4860, 4970, 5200, 5280, 5300, 5380,
 5400, 5420, 5440, 6100, 6110, 6120

F1 4820, 5200, 5280, 5480

G 5130, 5170, 5180, 5190, 5310, 5320,
 5400, 5420, 5450, 6040, 6050, 6110,
 6130, 6140

GO() 5990, 6000

I 1120, 1190, 1210, 1780, 1790, 1800,
 1810, 2960, 3010, 3020, 3030, 3340,
 3410, 3420, 3430, 3440, 3450, 3520,
 3720, 3840, 3850, 3860, 3950, 3960,
 3970, 4030, 4060, 4230, 4910, 4950,
 4960, 5010, 5020, 5260, 5330, 5340,
 5360, 5370, 5380, 5390, 5440, 5450,
 5500, 5870, 5910, 6070, 6080, 6110,
 6120, 6380, 6390, 6420, 6450, 6520,
 6530, 6600, 6610, 6830, 6840, 6850,
 7020, 7030, 7040, 7050, 7400, 7410,
 7420

IA	7180, 7190
IB	7170, 7180, 7190
IE	980, 1640, 7400, 7410, 7480, 7490, 7540, 7660
IO	1610, 1620, 1640, 2270, 2280, 2290, 2480, 2490, 2510, 2530, 2550, 2590, 2600, 2610, 2690, 2700, 2720, 2730, 6390, 6400, 6410, 7210, 7220, 7230, 7240, 7550, 7560, 7570, 7590, 7600, 7610
IOI	2550, 2720, 2730, 2740, 2800, 2810, 2820, 2880
II	270, 1120, 1210, 1620, 1640, 1650, 1660, 1670, 1930, 1940, 1950, 3860, 3870, 3880, 3970, 3980, 3990, 4000, 4010, 4030, 4060, 5020, 5040, 5050, 5170, 6430, 6440, 6450, 7660, 7670, 7680
I2	270, 1150, 1160, 1170, 1210, 1220, 1230, 1960, 1970, 1980, 3030, 3040, 3050, 3060, 3070, 3850, 3860, 3870, 3880, 3960, 3970, 3980, 3990, 4000, 4010, 4030, 4060, 5010, 5020, 5040, 5050, 5170, 6460, 6470
I3	1990, 2000, 2010, 6540, 6550, 6560
J	270, 1810, 1820, 1830, 3430, 3460, 3490, 3520, 3900, 3910, 3920, 4030, 4060, 4180, 4190, 4370, 4380, 5920, 5930, 5940, 5960, 5970, 5980, 5990, 7060, 7070, 7080, 7540, 7550, 7640
JB	1540, 1550, 1580, 1680, 1690, 1710

JG	1550, 1590, 1680, 1690, 1700, 1710, 1720
J1	270, 3450, 3460, 3470, 3920, 3930, 3940, 3980, 3990, 4030, 4060, 4380, 4390, 4400, 4420, 4430
J2	3910, 3920, 3930, 3940, 3980, 3990, 4060, 4370, 4380, 4390, 4400, 4420, 4430
J6	4360, 4400, 4410, 4430, 4440
J7	4350, 4360, 4400, 4410, 4430, 4440
J8	4340, 4350, 4360
K	140, 200, 270, 1650, 1770, 2200, 3420, 3430, 3440, 3450, 3460, 3470, 3520, 3620, 3660, 3670, 3680, 3730, 3740, 3750, 3760, 3770, 3800, 3830, 3840, 3870, 3880, 3900, 3930, 3940, 3950, 3980, 3990, 4000, 4010, 4090, 4190, 4200, 4210, 4220, 4240, 4250, 4260, 4270, 4280, 4300, 4340, 4500, 4510, 4520, 4530, 4540, 4550, 4810, 5210, 5280, 5470, 5910, 5920, 6000, 6010, 7420, 7640
KK	140, 200, 7420, 7430, 7640
K1	270, 3440, 3450, 3460, 3470, 3660, 3730, 3740, 3770, 4200, 4240, 4250, 4280
K2	3730, 3740, 3770, 4240, 4250, 4280
K8	3670, 3750, 3840, 4210, 4260, 4300, 4340

K9	200, 3680, 3750, 3760, 4220, 4260, 4270
K22()	140, 200, 3870, 3880, 3930, 3940
K33()	140, 200, 3930, 3940, 3980, 3990, 4000, 4010
L	3540, 3580, 3610, 4110, 4120, 4130, 7360, 7420, 7460
L1	7500, 7510, 7520, 7560, 7600, 7660, 7710
L2	7550, 7560, 7600
M	3560, 4100, 4110, 4510, 4560, 4570, 4620, 4630
N	3180, 3190, 4520, 4530, 4620, 4630, 4960, 5090, 5510, 5220, 5260, 5500, 5550, 6060, 6090, 6160
NN	6510, 6520
NZ	1110, 1120, 1600, 1610
N1	590, 1020, 1110, 1150, 1420, 1600, 1770, 1780, 1870, 1930, 1960, 1990, 2270, 2350, 2590, 2780, 2790, 2810, 2900, 2950, 3180, 3210, 3230, 3400, 3890, 3900, 3950, 4070, 4080, 6230, 6250, 6520, 6710, 6830, 7010, 7020, 7170, 7180, 7190, 7200, 7210, 7220, 7390, 7490, 7740
N2	2950, 2960, 3190, 3320, 3330, 4180, 4460, 4470, 4510, 4730

N3	4730, 4910, 5670, 5870, 5930, 5950, 5960, 6300
N4	3400, 3410, 3680, 4220, 4500
N6	6820, 6830, 7010, 7020
N8	7480, 7500
N9	3230, 6250, 7490, 7500
P	4850, 4960, 4970, 5300, 5330, 5350, 5360, 5400, 5420, 6060, 6090, 6100, 6110
PI	280, 1200, 1280, 1290, 1350, 1360, 3320, 3330, 4520, 4530, 4620, 4630
PZ	4840, 4850, 5260, 5500
P1	4800, 5180, 5550, 5560, 5590, 5830, 6140, 6160, 6170, 6210
P2	190, 3610, 3840, 3900, 4080, 4090
P3	5550, 5560, 5590, 6150, 6160, 6200
P4	4870, 5190, 5310, 5460
R	6620, 6630
RO	190, 1180, 1230, 1290, 1310, 1670, 1680, 1690, 1800, 1840, 2290, 2330, 2610, 2620, 2640, 2710, 2760, 3020, 3080, 3090, 5980, 5990, 6000, 6410, 6480, 6850, 6860, 6870, 6890, 6980, 7040, 7080, 7090, 7230, 7240, 7510, 7520, 7690, 7700

RAY(,)	150, 5380, 5390, 5440, 5450, 5730, 6110, 6120, 6310
RAY1(,)	160, 2530, 2540, 2730, 2740, 2810, 2820, 2890
RAY2(,)	170, 5330, 5340, 5360, 5370, 5670
R1	190, 1830, 1840, 1950, 2020, 3050, 3090, 4470, 4480, 4490, 4550, 4580, 4590, 4600, 4610, 4640, 4650, 4660, 4670, 4680, 4690, 6450, 6500, 7080, 7090, 7570, 7580, 7670, 7680, 7690, 7700
R2	190, 1980, 2020, 3070, 4570, 4580, 4590, 4600, 4610, 4640, 4650, 4660, 4670, 4700, 4710, 6470, 6500, 7610, 7620
R3	190, 2010, 2020, 6550, 6560
ST	2230, 2310, 2330, 2350
SU	7530, 7640, 7700
SZ	4520, 4580, 4600, 4620, 4640, 4660
S2	7640
S3	7630, 7640
T2	1200, 1280, 1290, 1300, 1350, 1360
W1(,)	130, 3270, 3320, 3360, 3460, 3470, 3490, 3520, 3870
W2(,)	130, 3280, 3330, 3360, 3460, 3470, 3490, 3520, 3880

X	1190, 1200, 2400, 2710, 2900, 2910, 2920, 4390, 4410, 4420, 4440, 5050, 5130, 5870, 6030, 6040, 6060, 6260, 7190, 7250
XLAB()	150, 5700, 5740, 6300
XLAB1()	160, 2830, 2880, 6250
XLAB2()	170, 5640, 5670
XO	6860, 6890, 6940
XX(,)	140, 210, 1550, 1680, 1690
X1	6740, 6750, 6870, 6930, 6940
X2	6760, 6770, 6870, 6920, 6930
X3	6780, 6790, 6870, 6910, 6920
X4	6800, 6810, 6870, 6910
Y	1350, 2350, 2360, 2370, 2420, 2620
YLAB()	150, 5710, 5740, 6310
YLAB1()	160, 2840, 2880, 6260
YLAB2()	170, 5650, 5670
YZ	6480, 6570, 6580, 6590, 6620, 6630
Y1	6490, 6570, 6630, 6640, 6750, 6870, 6980
Y2	6500, 6580, 6640, 6650, 6770, 6880, 6960, 6970

Y3	6560, 6590, 6650, 6790, 6880, 6950, 6960
Y4	6810, 6880, 6950
Z1	4580, 4680
Z2	4600, 4690
Z3	4640, 4700
Z4	4660, 4710

GLOSSARY OF VARIABLES
FOR
SIGNAL ANALYSIS PROGRAM
(VARIABLE NAME AND DESCRIPTION)

<u>VARIABLE</u>	<u>DESCRIPTION</u>
A	Amplitude
ANS1	The number of terrain points is equal to 2^{ANS1} where $1 \leq \text{ANS1} \leq 8$.
ANS2	The length of the survey interval in feet, ANS2 allows 4 places to the right of the decimal point.
ANS3	The code for type of input data is as follows: 0 for data equations 1 for card reading -1 for data equations
ANS4	The code for type of detrending is as follows: 1 for first to last point detrending 2 for digital high pas filter 3 for exponentially weighted 4 for no detrending
ANS5	The code for padding the array with N1 0's is: 1 for yes 2 for no
ANS6	The code for interpolation is: 1 for yes 2 for no
ANS7	The code for amplitude smoothing is: 1 for yes 2 for no

VARIABLEDESCRIPTION

ANS8	The code for GEO window is: 1 for yes 2 for no
A1(,)	Storage array for terrain evaluation data.
A2(,)	Storage array for terrain evaluation data.
B1	Relative maximum and minimum profile values.
B2	Relative maximum and minimum profile values.
C	The ordinate of the point A1(R,C).
CO	The ordinate of the point A1(RO,CO).
C1	The ordinate of the point A1(R1,C1).
C2	The ordinate of the point A2(R2,C2).
C3	The ordinate of the point A1(R3,C3).
E	The quantity 36 divided by the length of the survey interval in feet.
F	Frequency.
F1	The summation of the frequencies.
G	Power spectral density.
GO()	The coefficients of the GEO window.
IA	The abscissa of the point A1(IA,IB)
IB	The ordinate of the point A1(IA,IB)

VARIABLEDESCRIPTION

J	The abscissa of the point W1(J,K) .
JB	The abscissa of the point XX(JB,JG) .
JG	The ordinate of the point XX(JB,JG) .
J1	The abscissa of the point W1(J1,K1) and of A1(J1,J2) .
J6	The abscissa of the point A2(J6,J7) .
J7	The ordinate of the point A2(J6,J7)
K	The ordinate of the point W1(J,K)
K1	The ordinate of the point W1(J1,K1) .
N1	Number of terrain points.
N2	Number of terrain points divided by 2.
P	period
PI	3.14159265
PZ	9999.99
Pl	Root mean square.
P3	Area under psd.
P4	The summation of the power spectral densities.
R	The abscissa of the point A1(R,C) .
RO	The abscissa of the point A1(RO,CO) .

<u>VARIABLE</u>	<u>DESCRIPTION</u>
RAY(,)	Storage array for frequencies and psd's.
RAY1(,)	Storage array for terrain points and maximum and minimum profile values.
RAY2(,)	Storage array for periods and amplitudes.
R1	The abscissa of the point A2(R1,C1).
R2	The abscissa of the point A2(R2,C2).
R3	The abscissa of the point A1(R3,C3).
ST	The summation of the values of the terrain point.
W1(,)	Stored values of $(e^{-j})^{2\pi/N}$
W2(,)	Stored values of $(e^{-j})^{2\pi/N}$
X	RMS from detrended zero mean terrain data.
XLAB()	Storage for disruption "FREQUENCY" of x - axis used in graphics display.
XLAB1()	Storage for disruption "DISTANCE" of x - axis used in graphics display.
XLAB2()	Storage for disruption "PERIOD" of x - axis used in graphics display.
XX(,)	Terrain profile data array.
Y	The value of the data equation; the average terrain point value.
YLAB()	Storage for disruption "PSD" of y - axis used in graphics display.

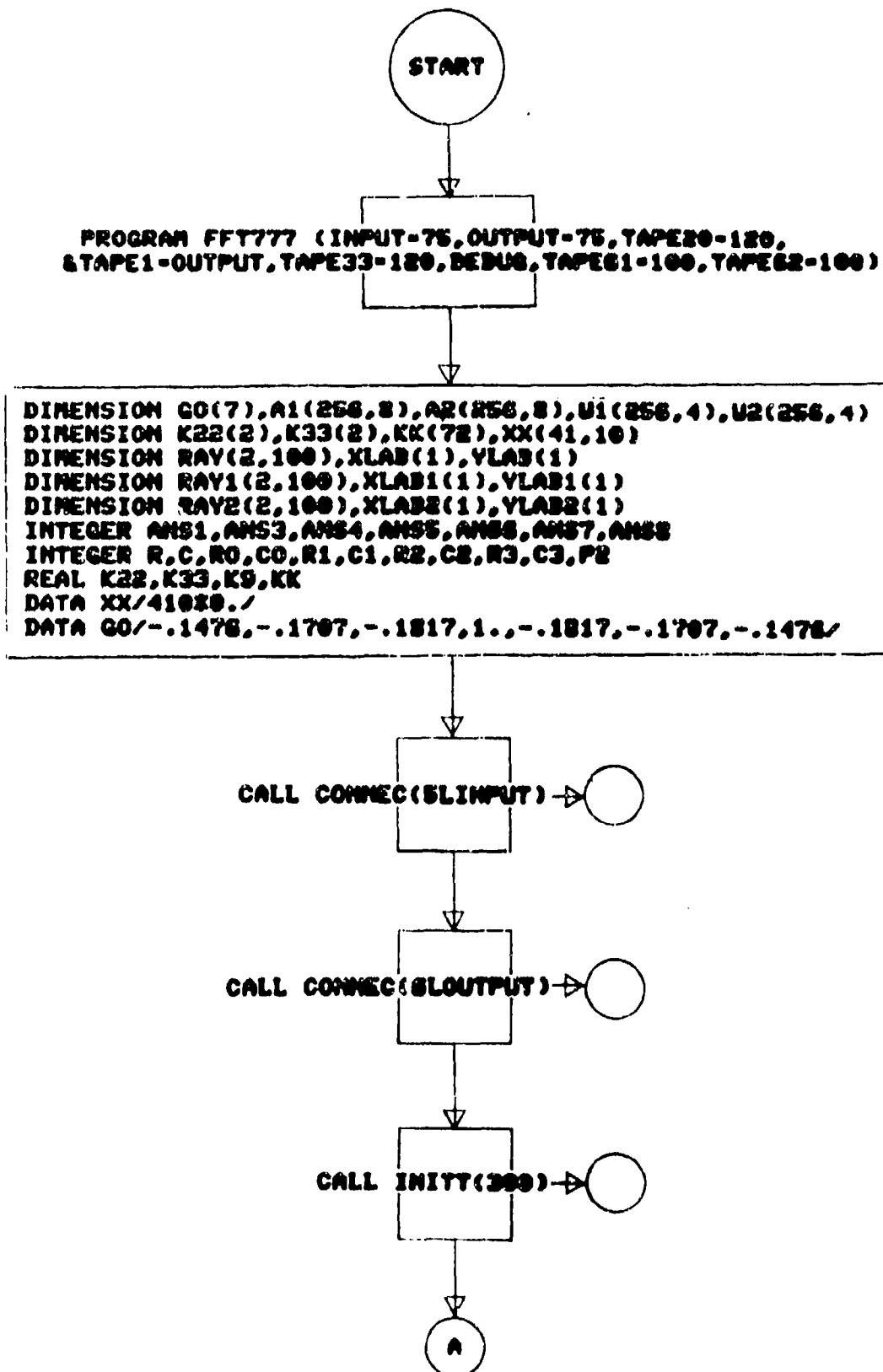
VARIABLE

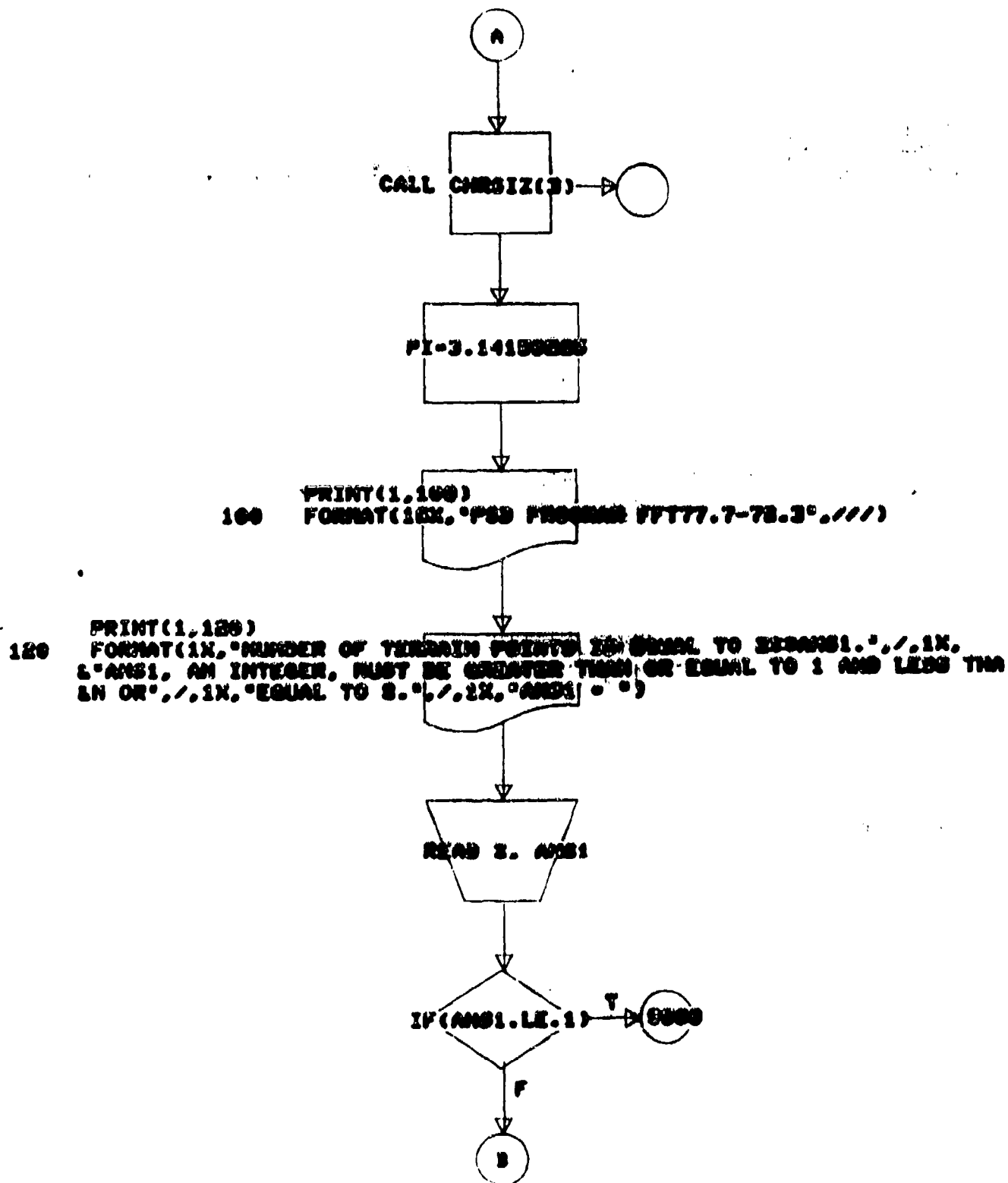
DESCRIPTION

YLAB2()

Storage for disruption "AMPLITUDE" of y - axis
used in graphics display.

FLOWCHART FOR SIGNAL ANALYSIS PROGRAM





PRINT(1,170)
 170 FORMAT(1X,"SURVEY INTERVAL IN FEET? ALLOW 4 PLACES PAST DECIMAL."
 &/,1X,"ANS2 = ")

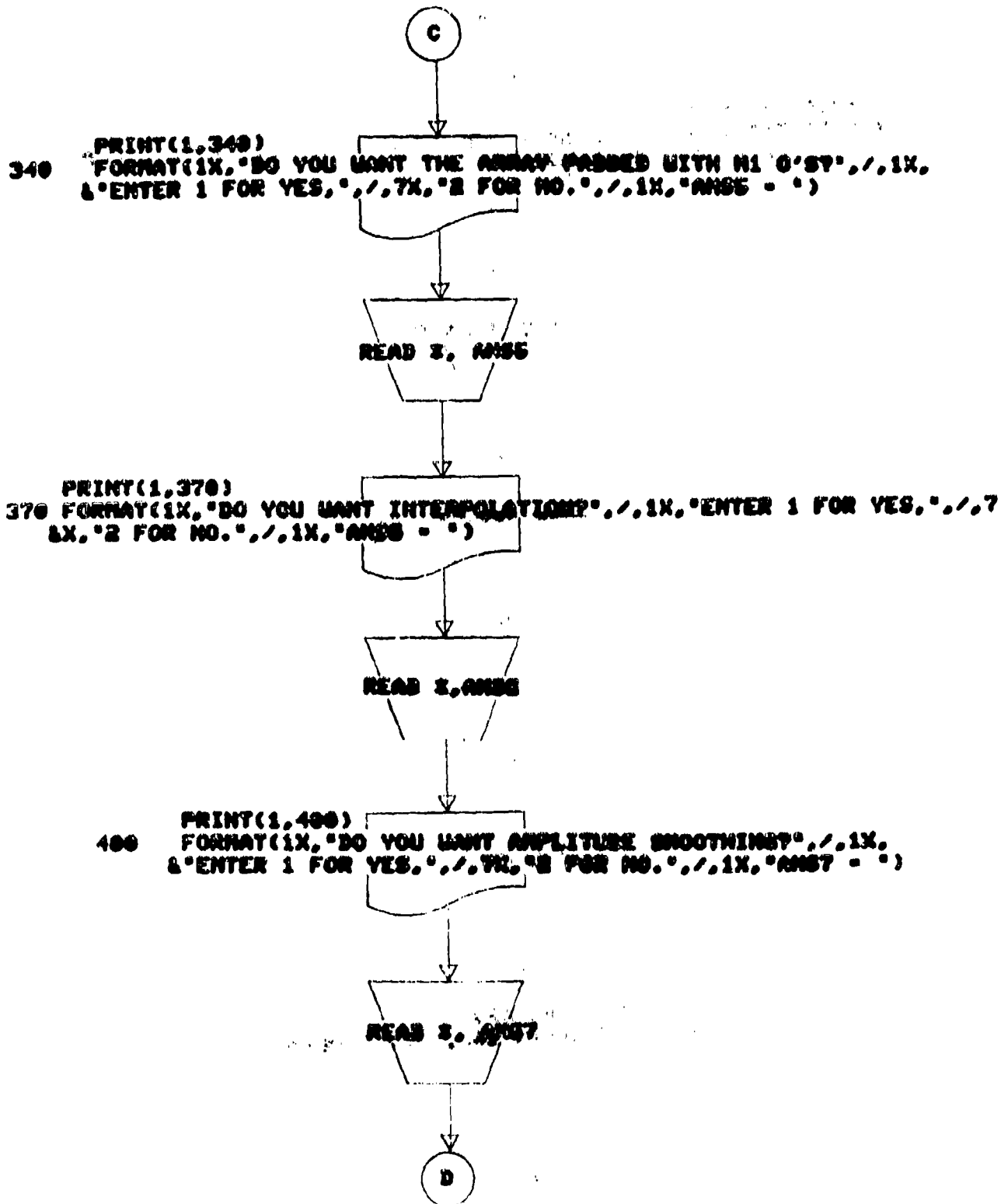
READ 2,ANS2

PRINT(1,200)
 200 FORMAT(1X,"ENTER 0 FOR DATA READING,./,7X,"1 FOR CARD READING,."
 &/,6X,"-1 FOR DATA EQUATIONS,./,1X,"ANS3 = ")

READ 2,ANS3

PRINT(1,220)
 220 FORMAT(1X,"ENTER 1 FOR FIRST TO LAST POINT DETRENDING,./,7X,"2 FO
 &R DIGITAL HIGH PASS FILTER,./,7X,"3 FOR EXPONENTIALLY WEIGHTED RU
 &NNING AVERAGE,./,7X,"4 FOR NO DETRENDING,./,1X,"ANS4 = ")

READ 2,ANS4



```

PRINT(1,450)
450 FORMAT(1X,'DO YOU WANT A GEO WINDOW?','1X','ENTER 1 FOR YES','1X',
&,'2 FOR NO','1X','ANSR = ')

```

```

READ 2,ANSR

```

```

CALL HSCOPY

```

```

CALL NEWPAS

```

```

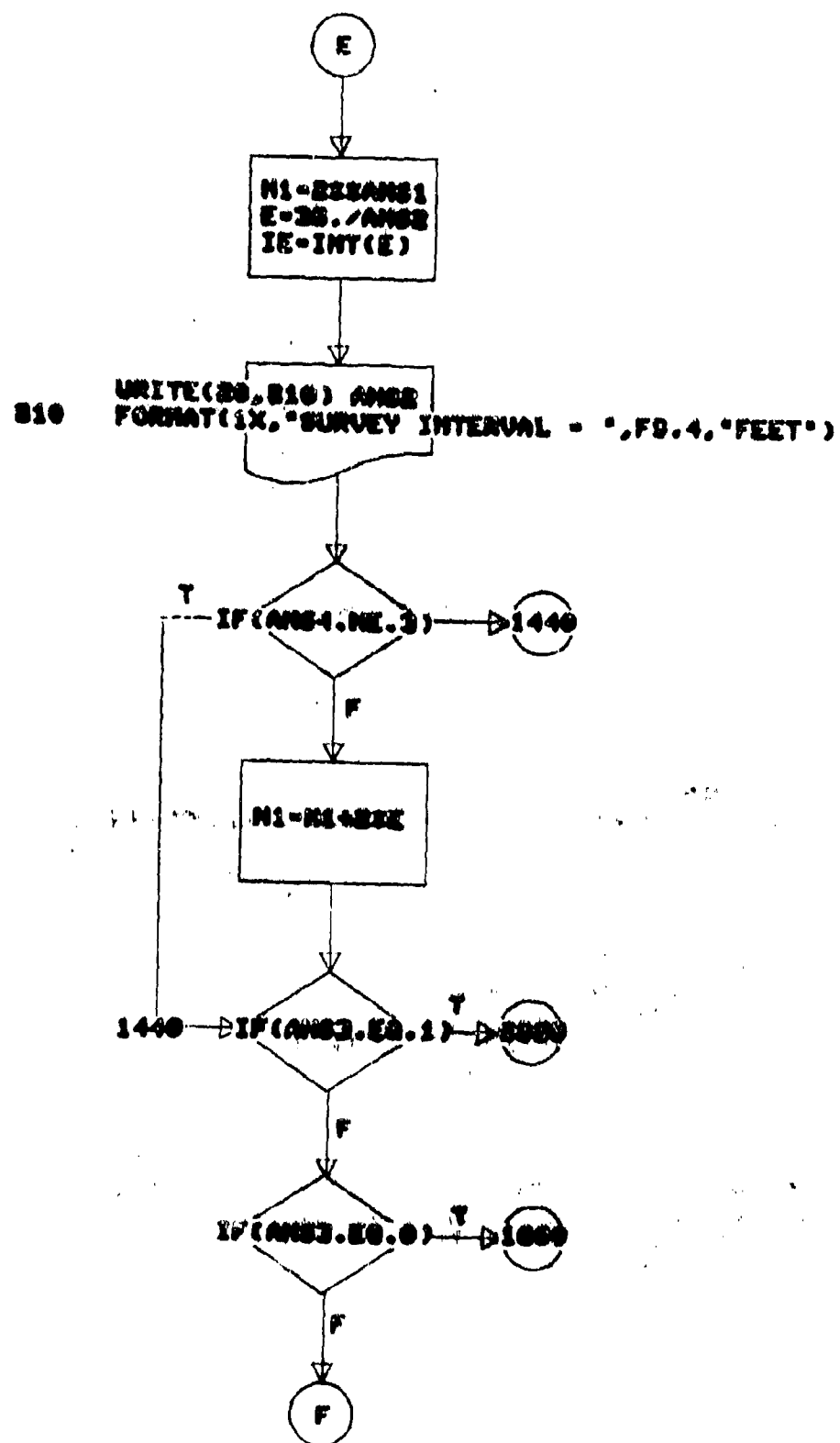
CALL HOME

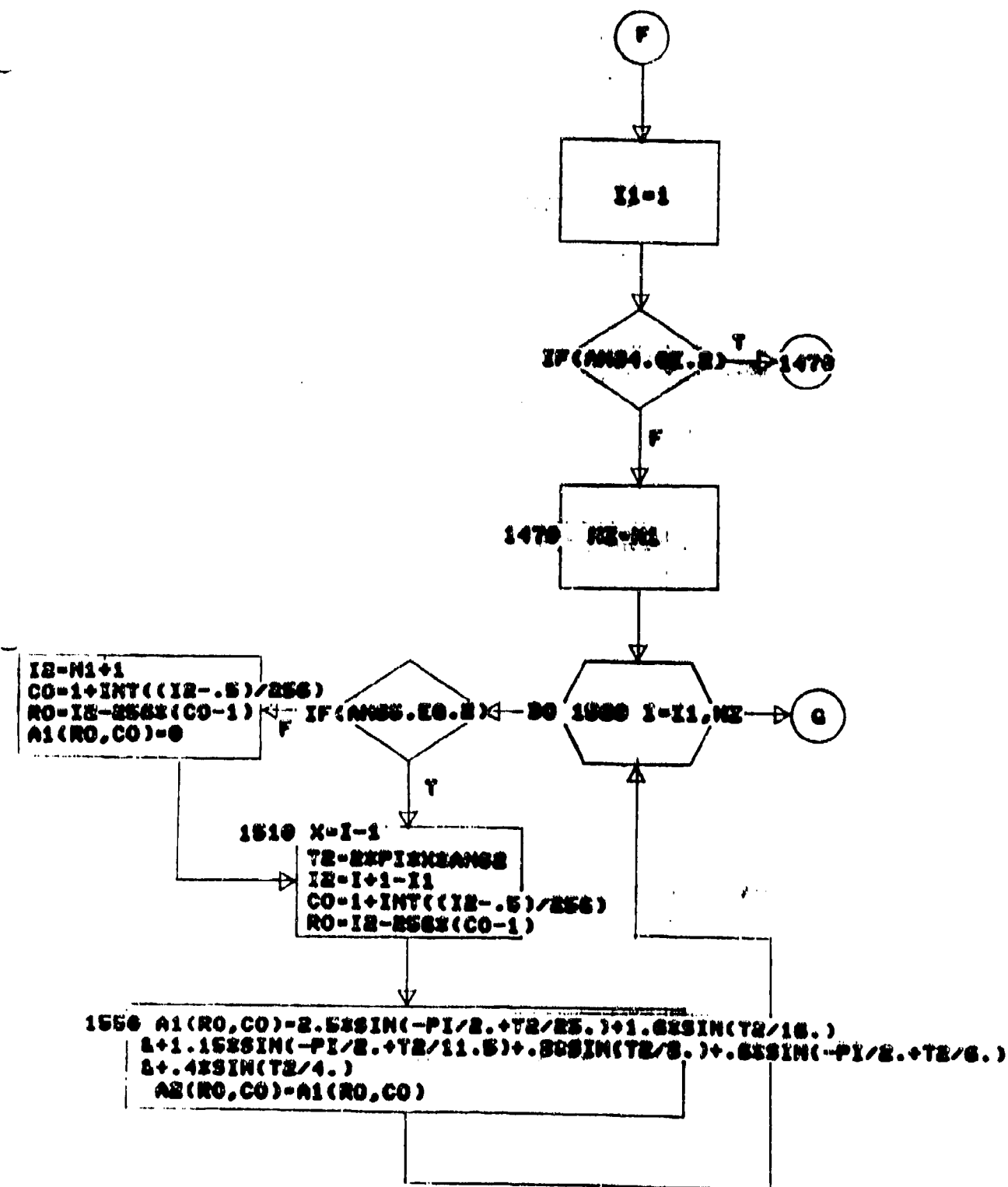
```

```

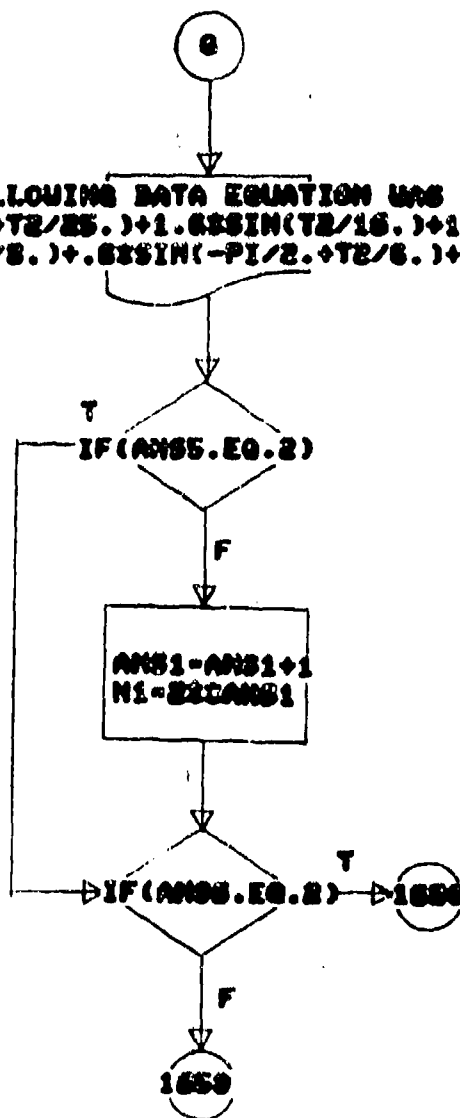
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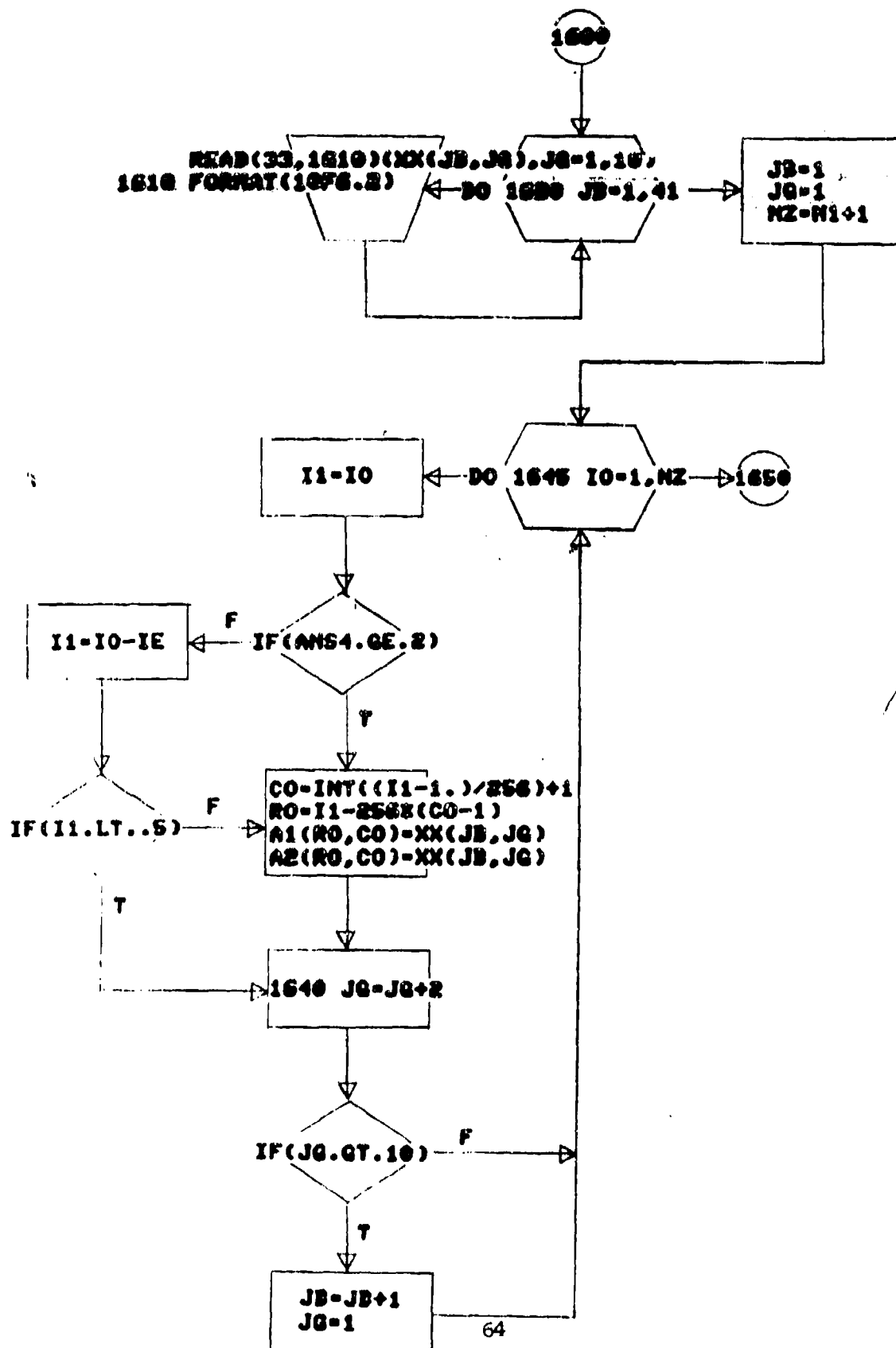
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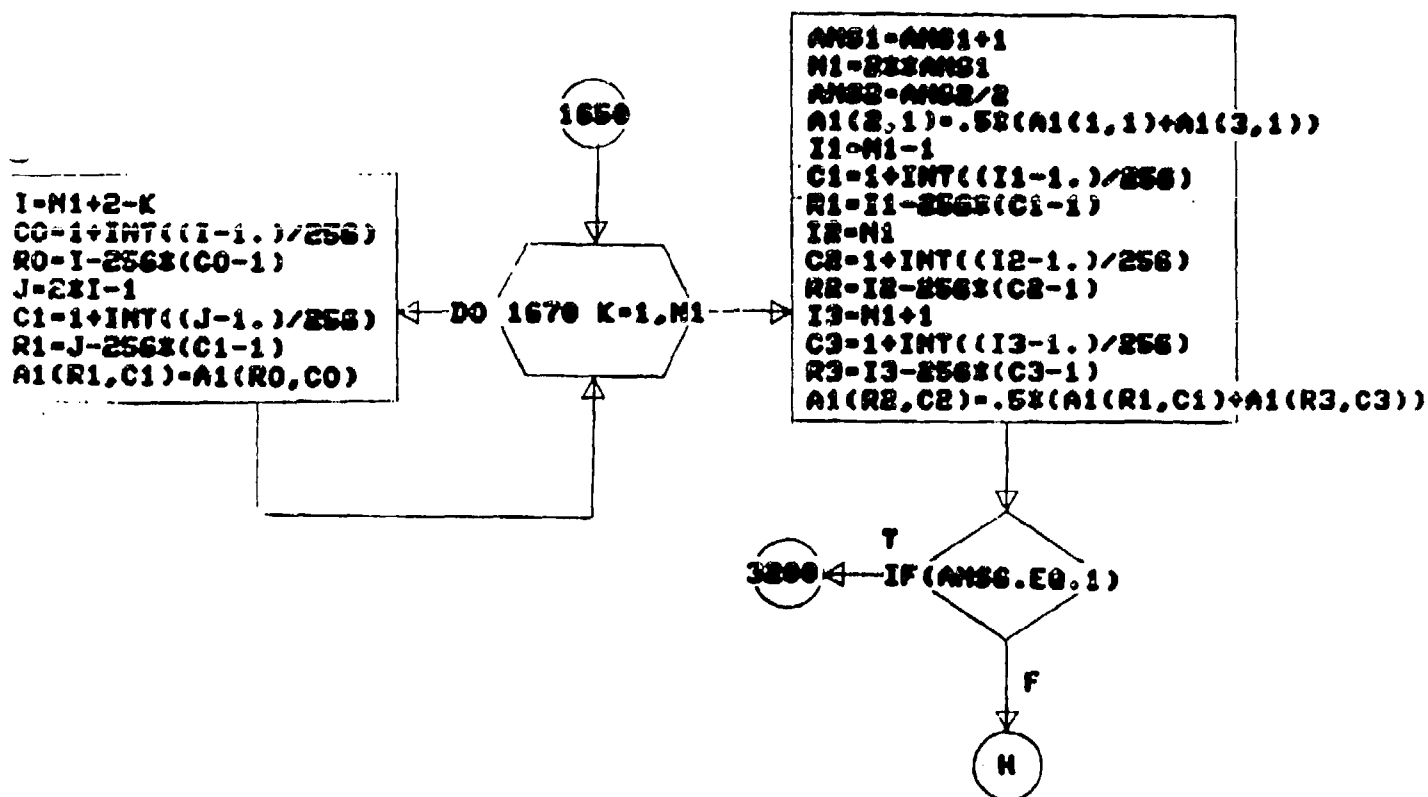


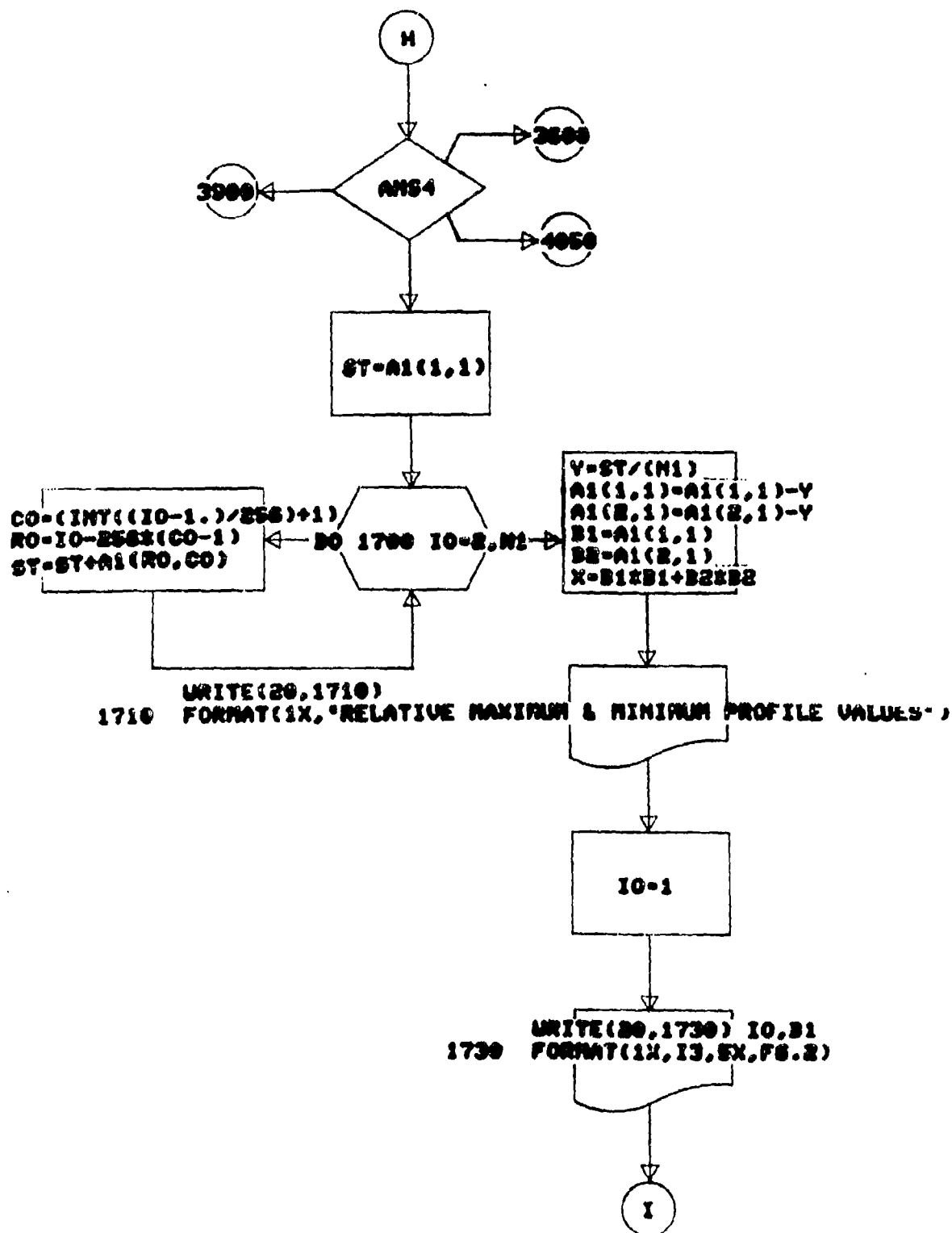


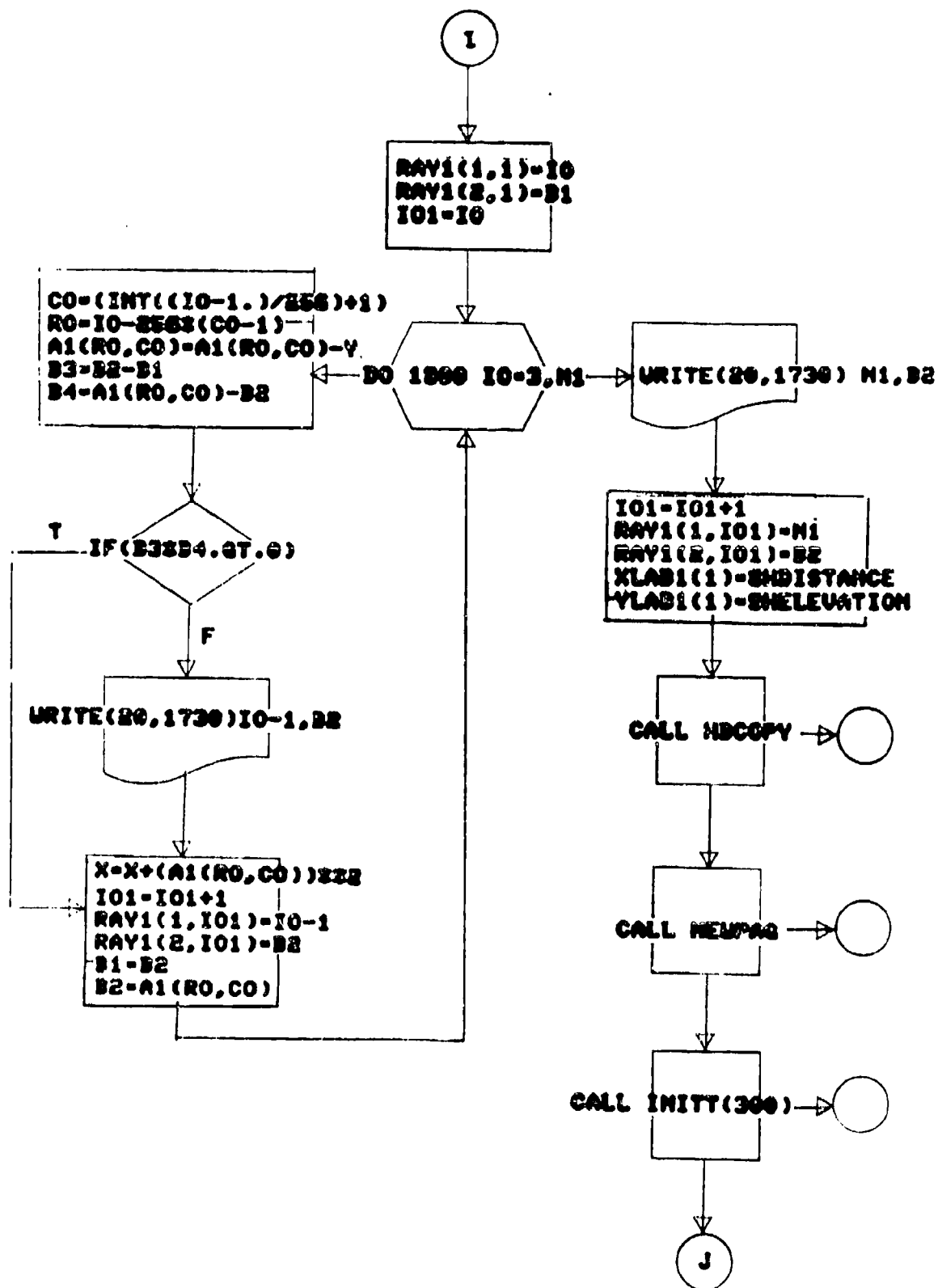
1570 WRITE(1,1570)
 1570 FORMAT(1X,"THE FOLLOWING DATA EQUATION WAS USED: ",/,1X,
 1'Y=2.5X SIN(-PI/2.+TZ/25.)+1.6X SIN(TZ/15.)+1.15X SIN(-PI/2.+TZ/11.5
 &2/11.5)+.8X SIN(TZ/8.)+.8X SIN(-PI/2.+TZ/6.)+.4X SIN(TZ/4.)")

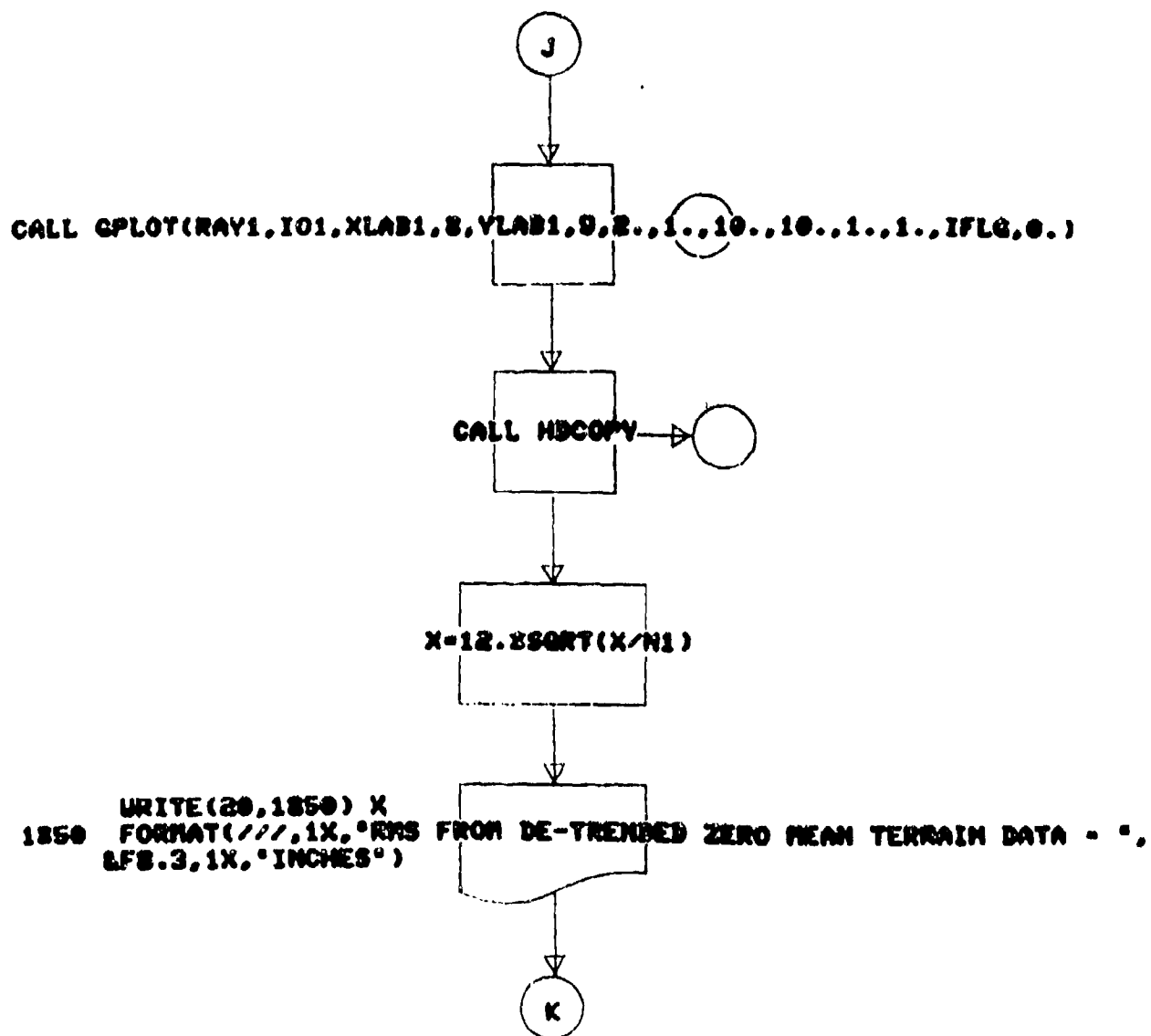


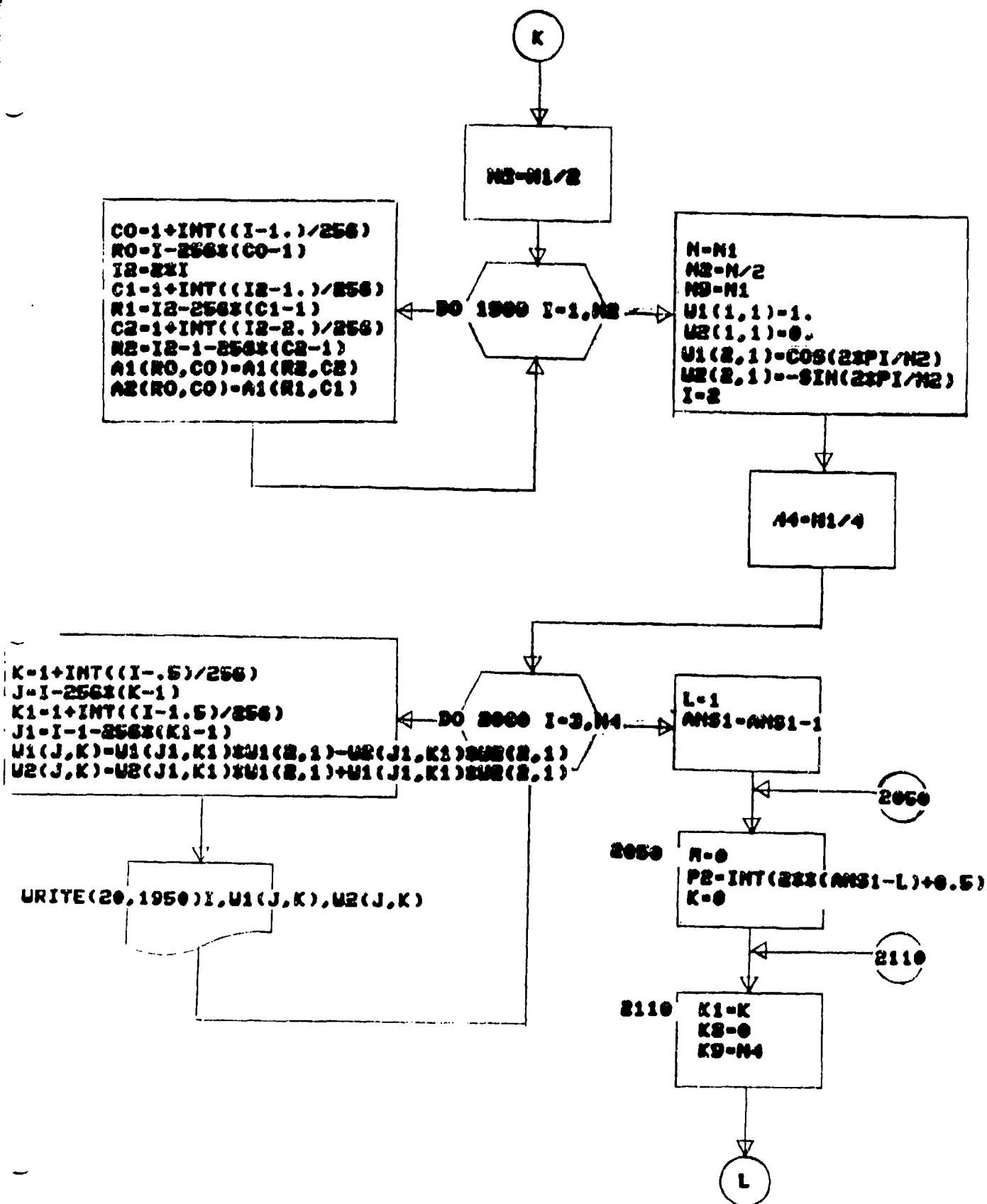


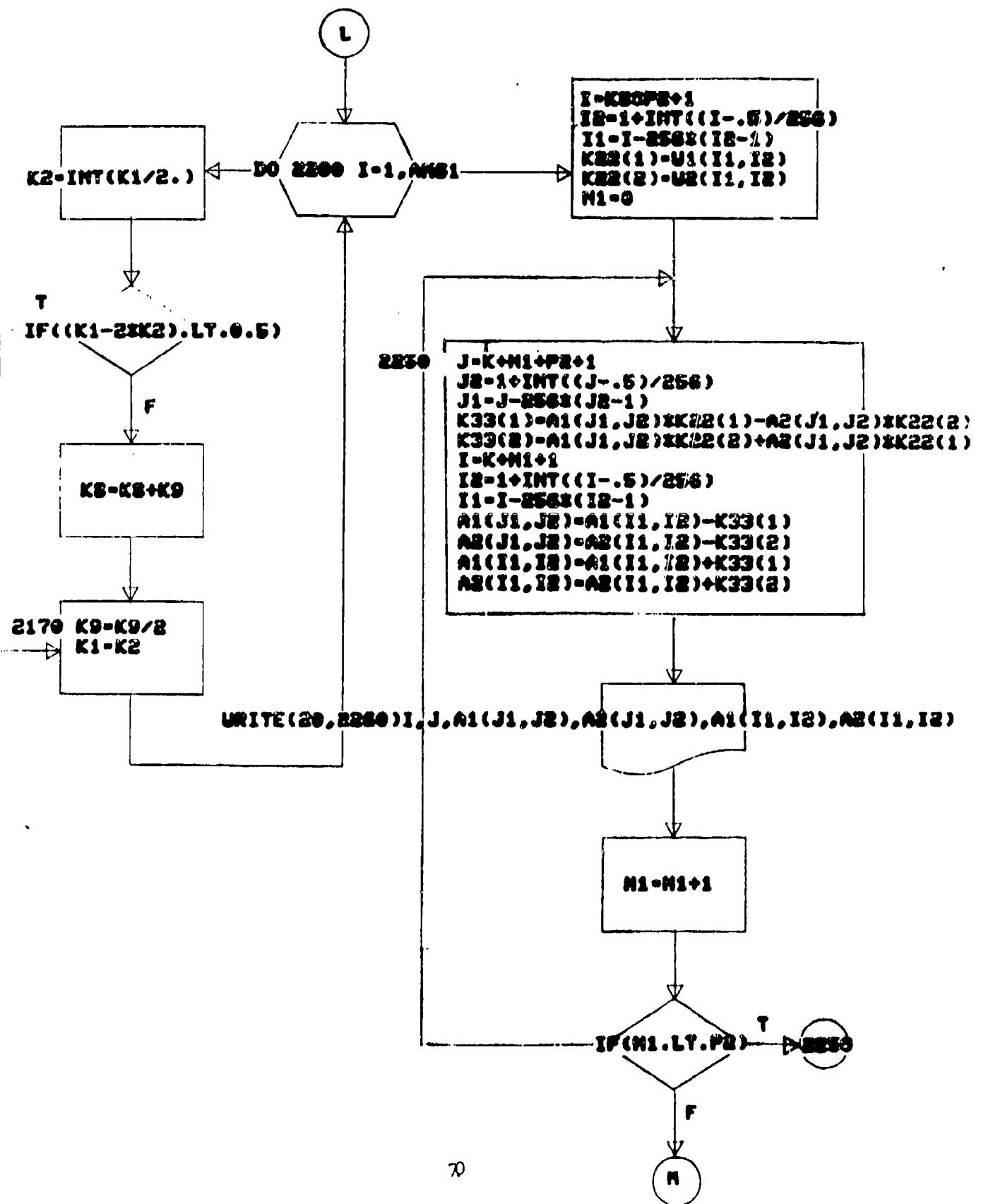


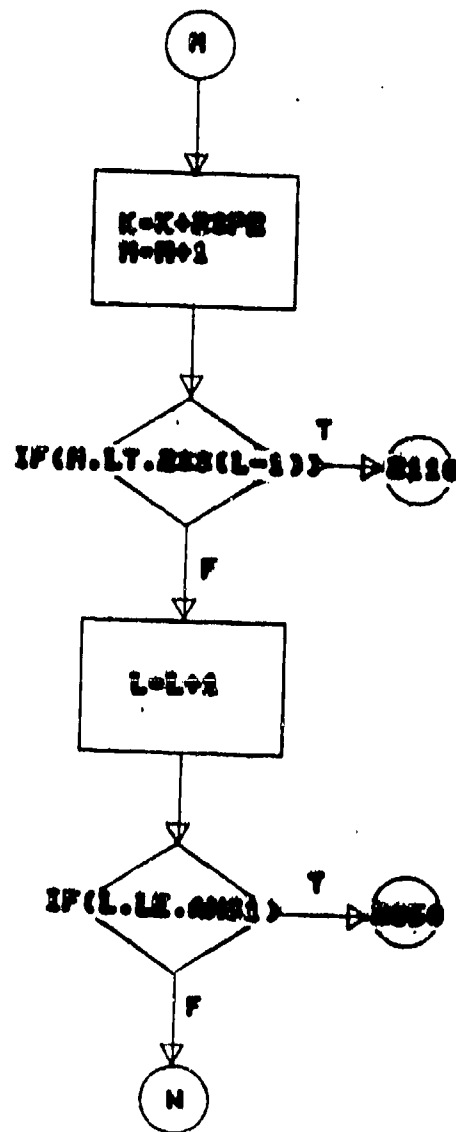


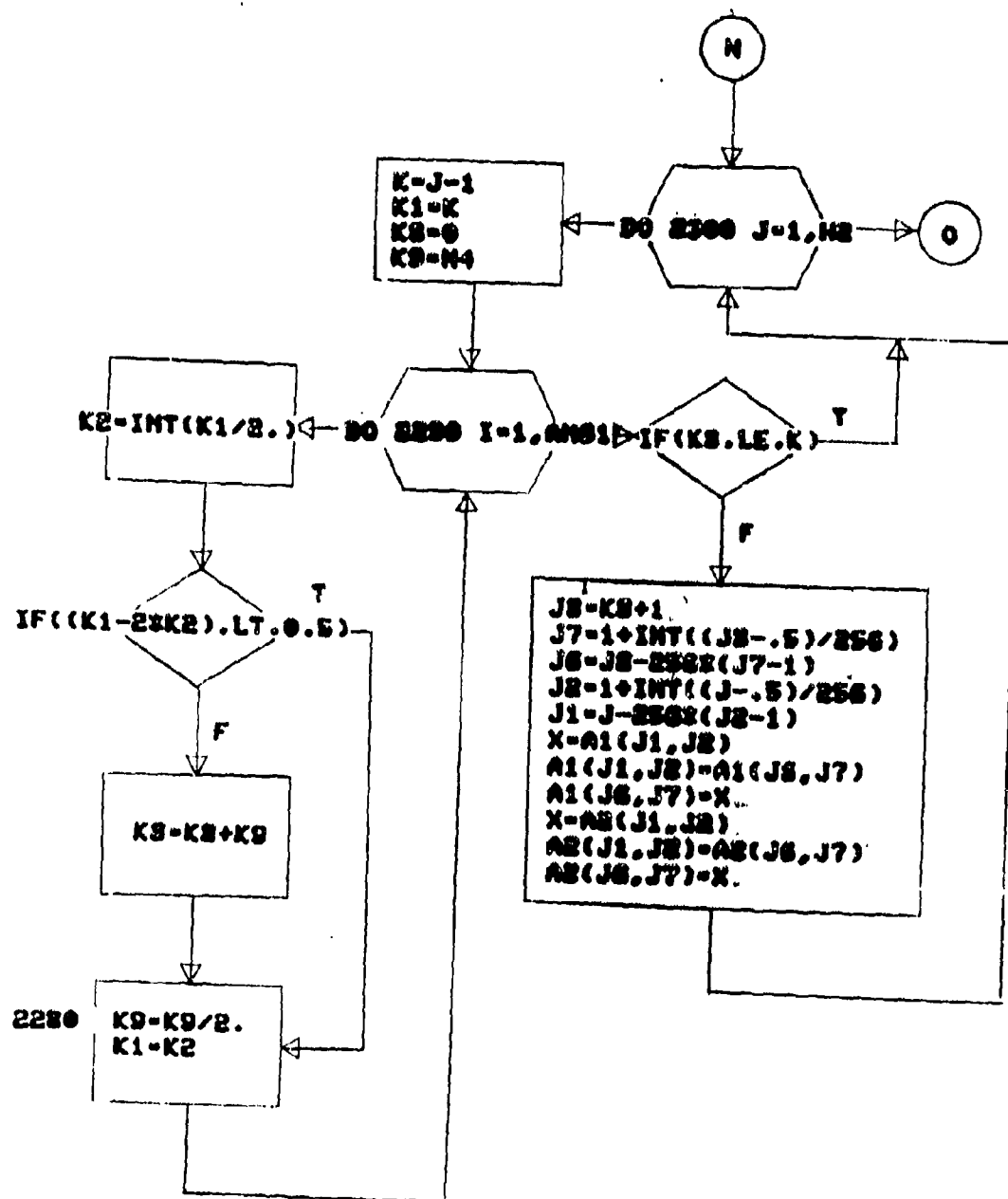


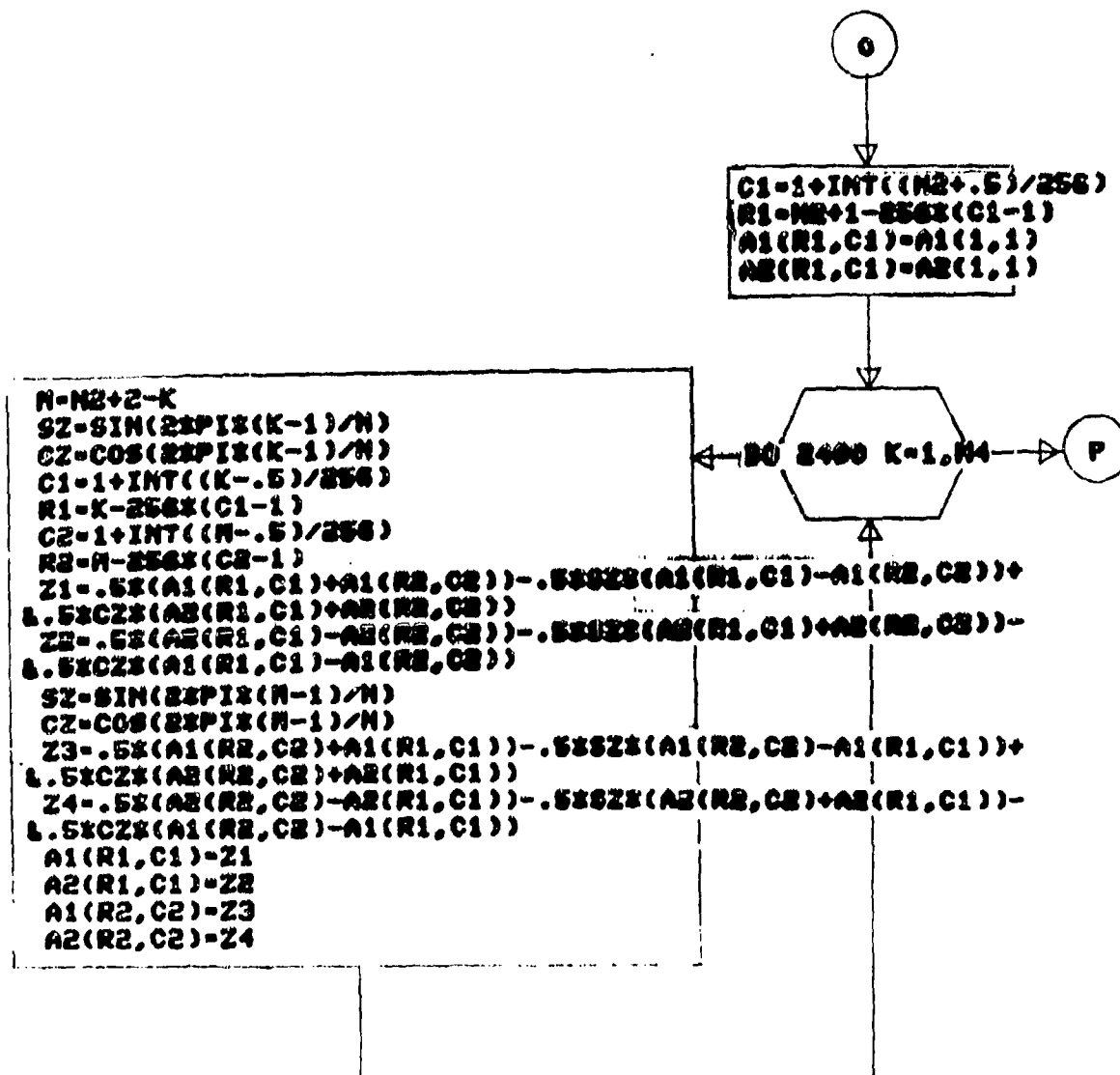


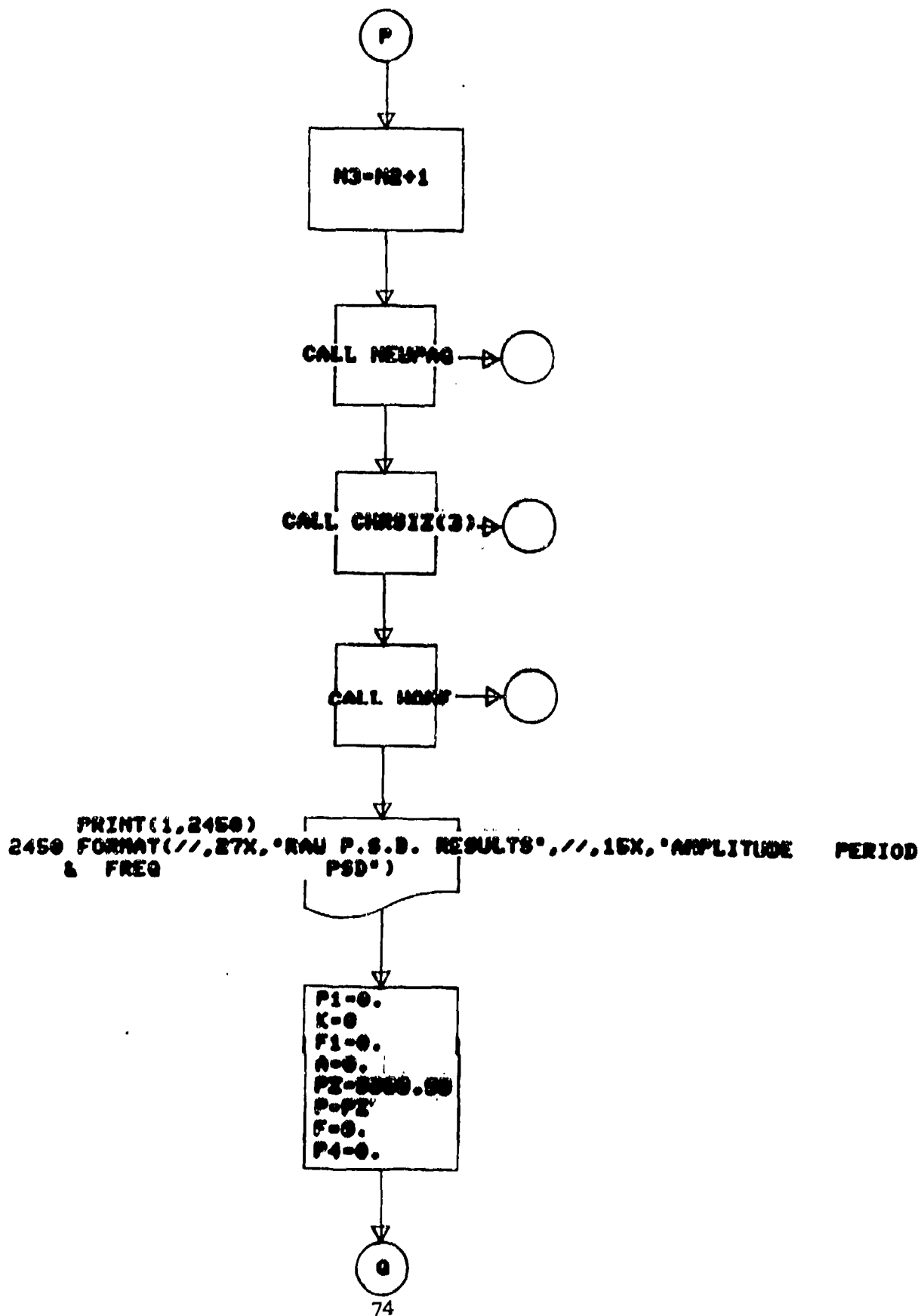


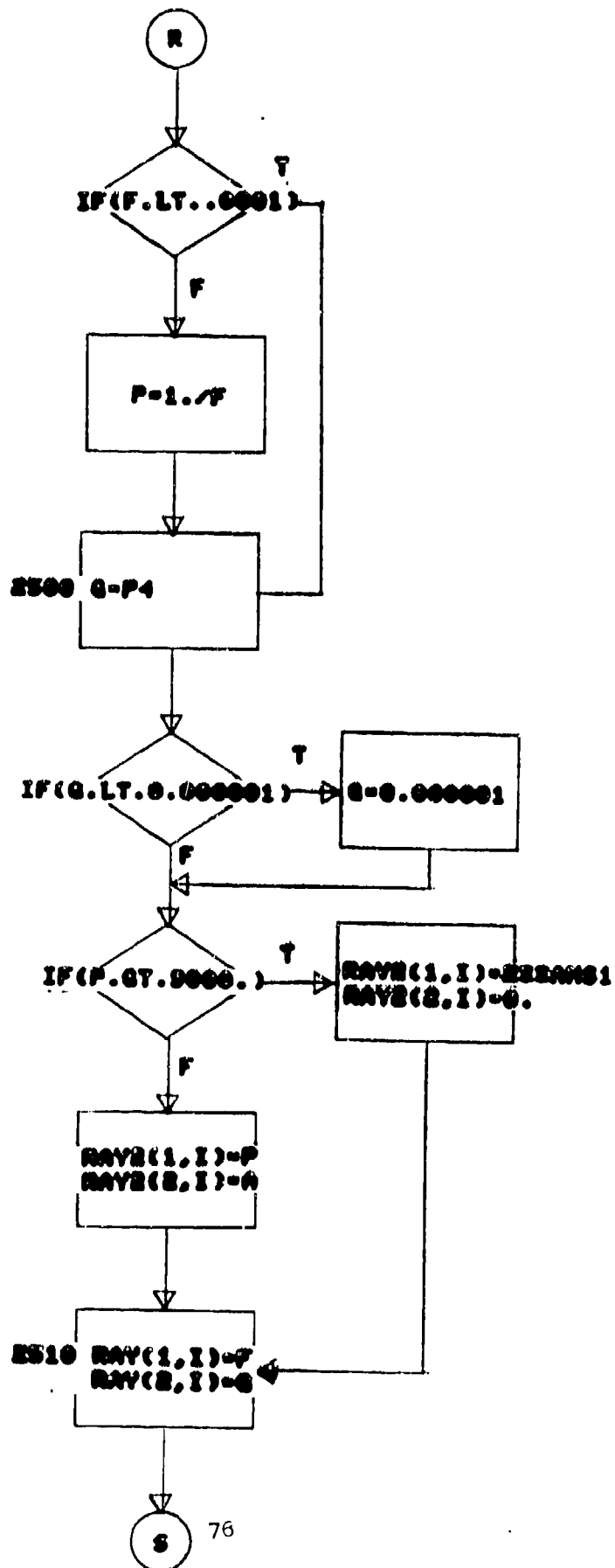


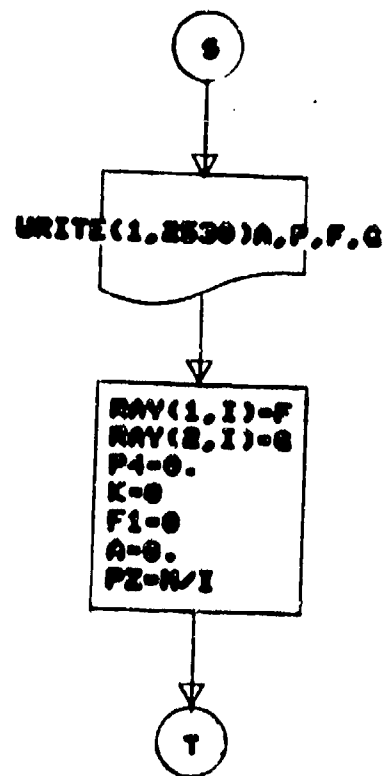


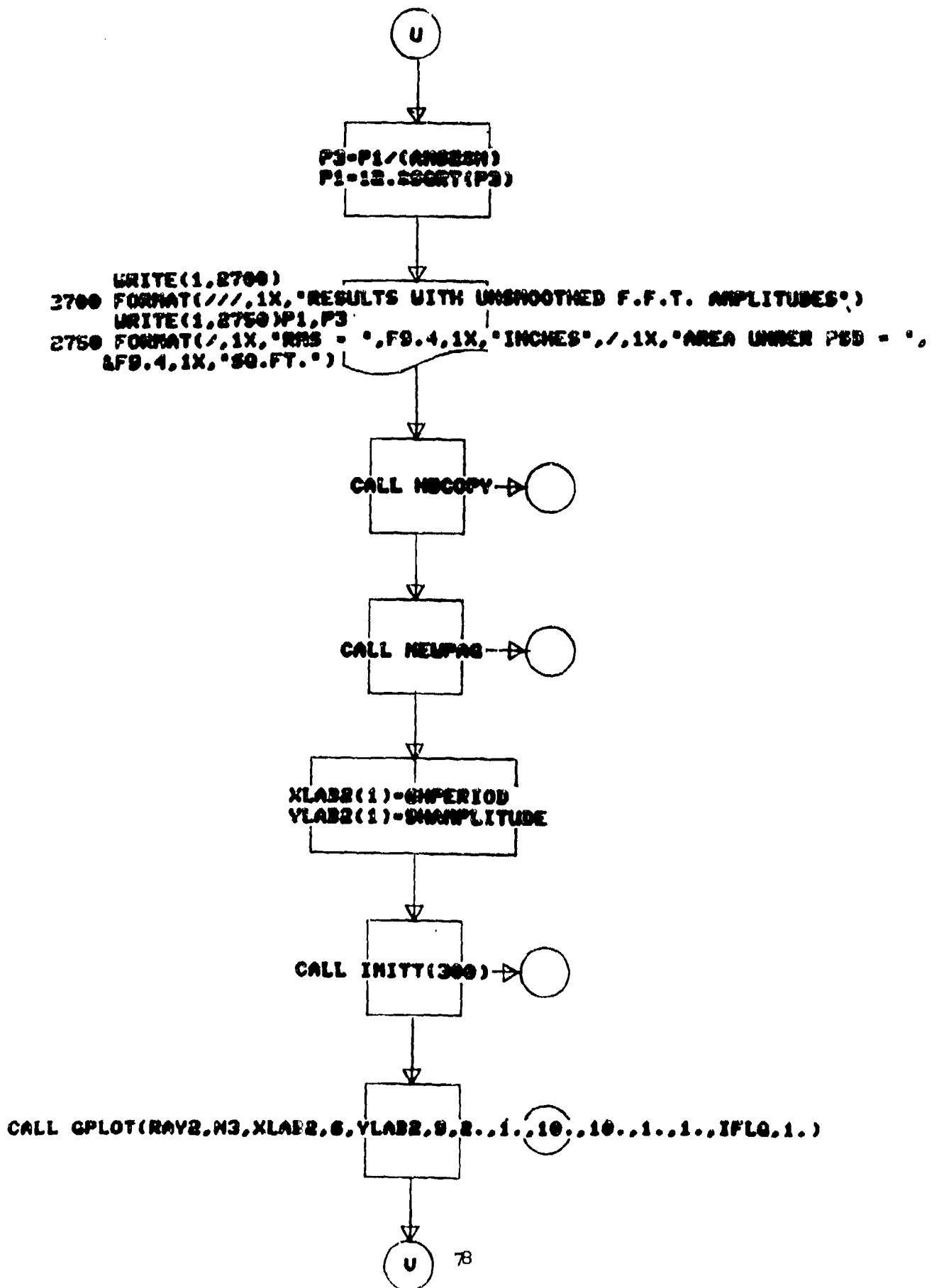


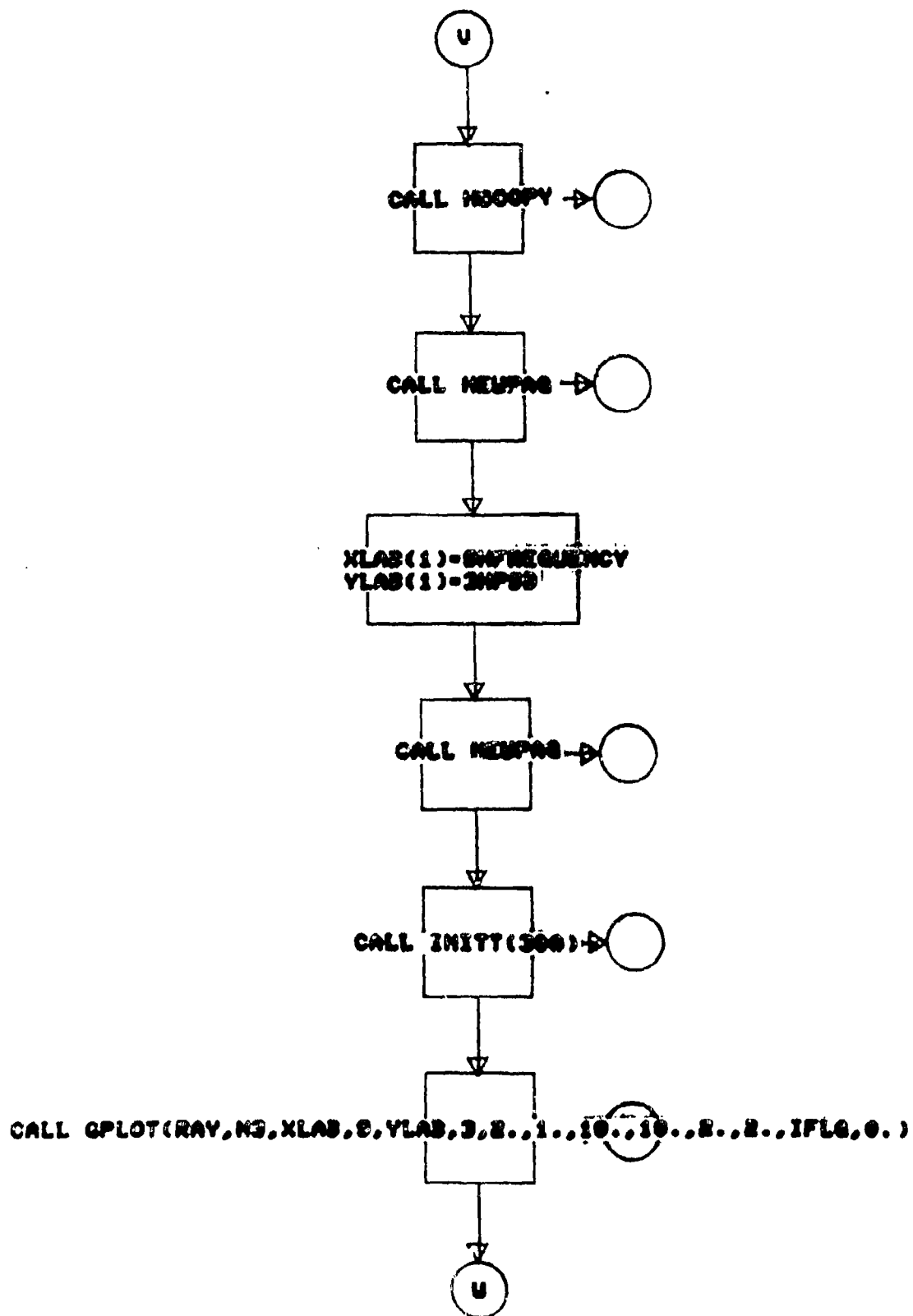


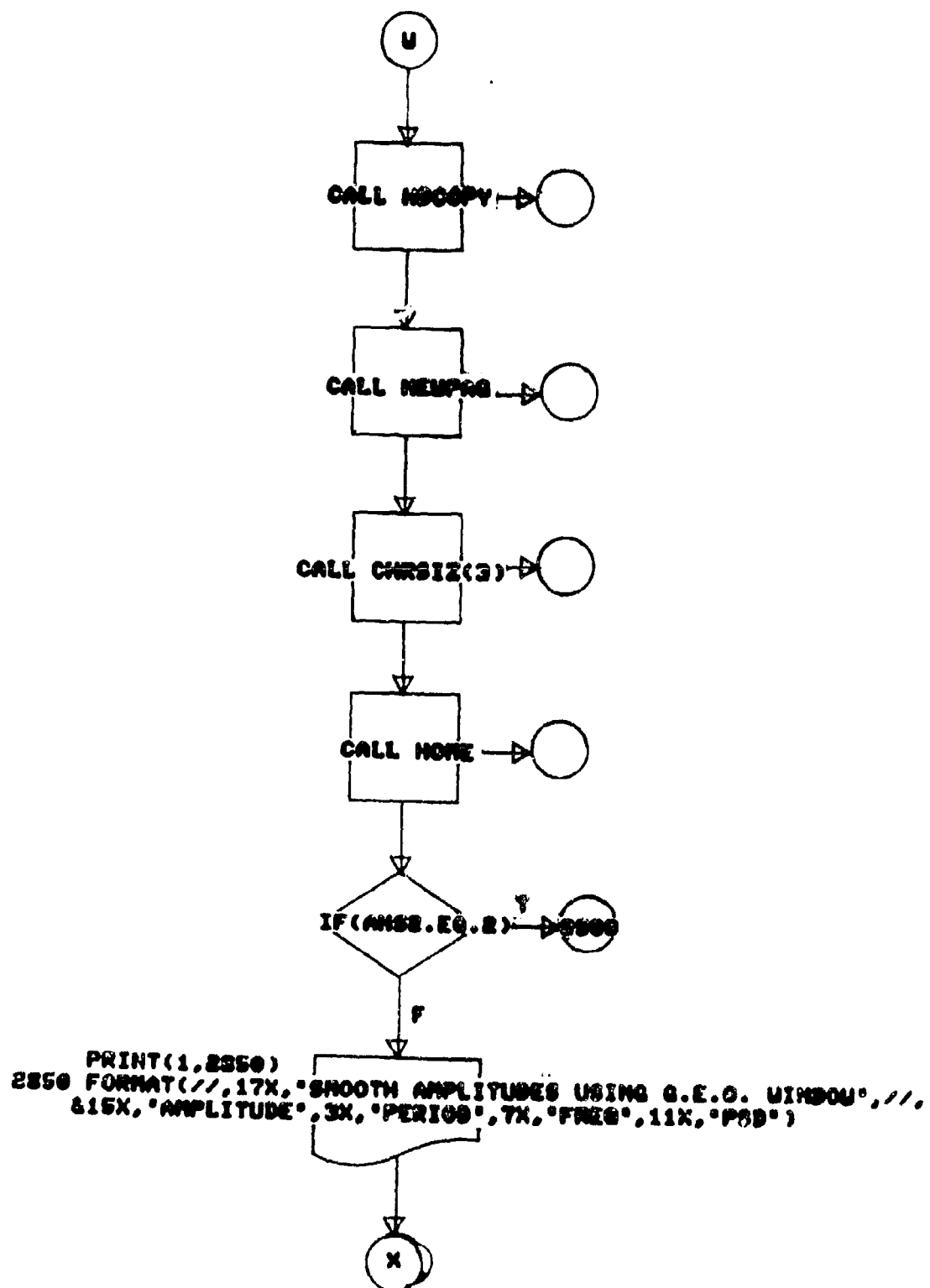


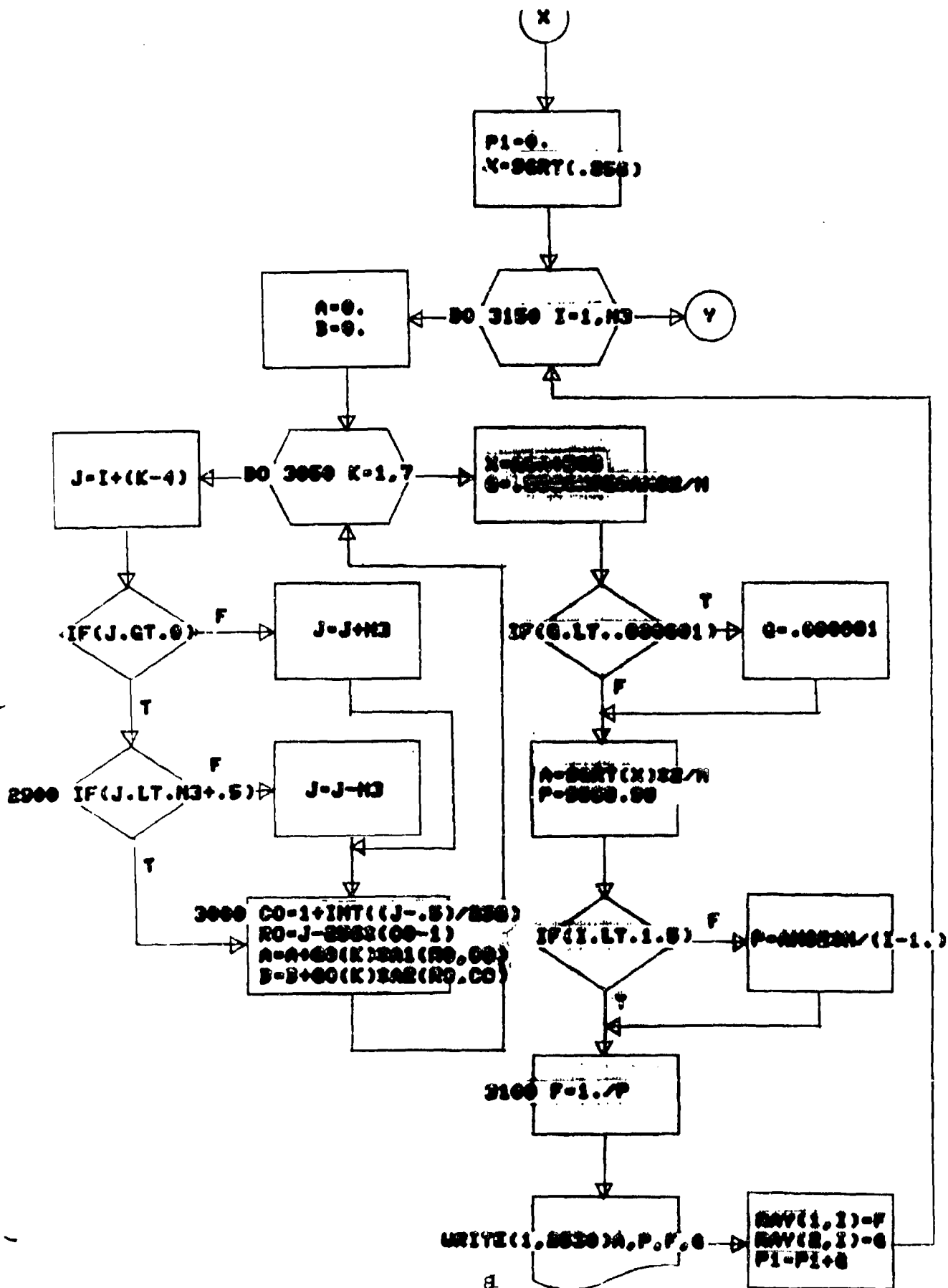


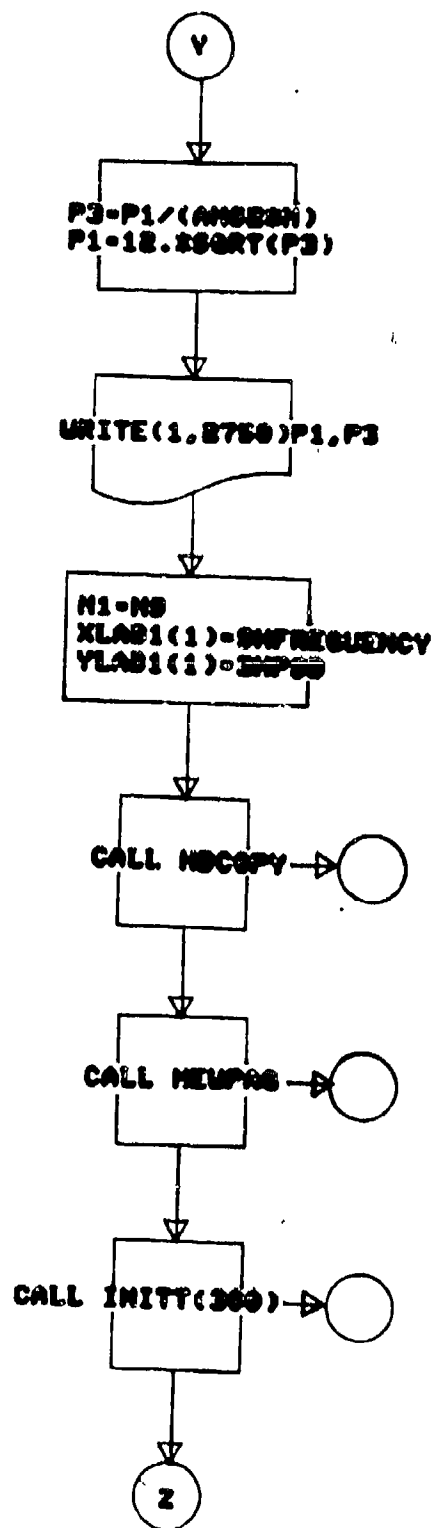


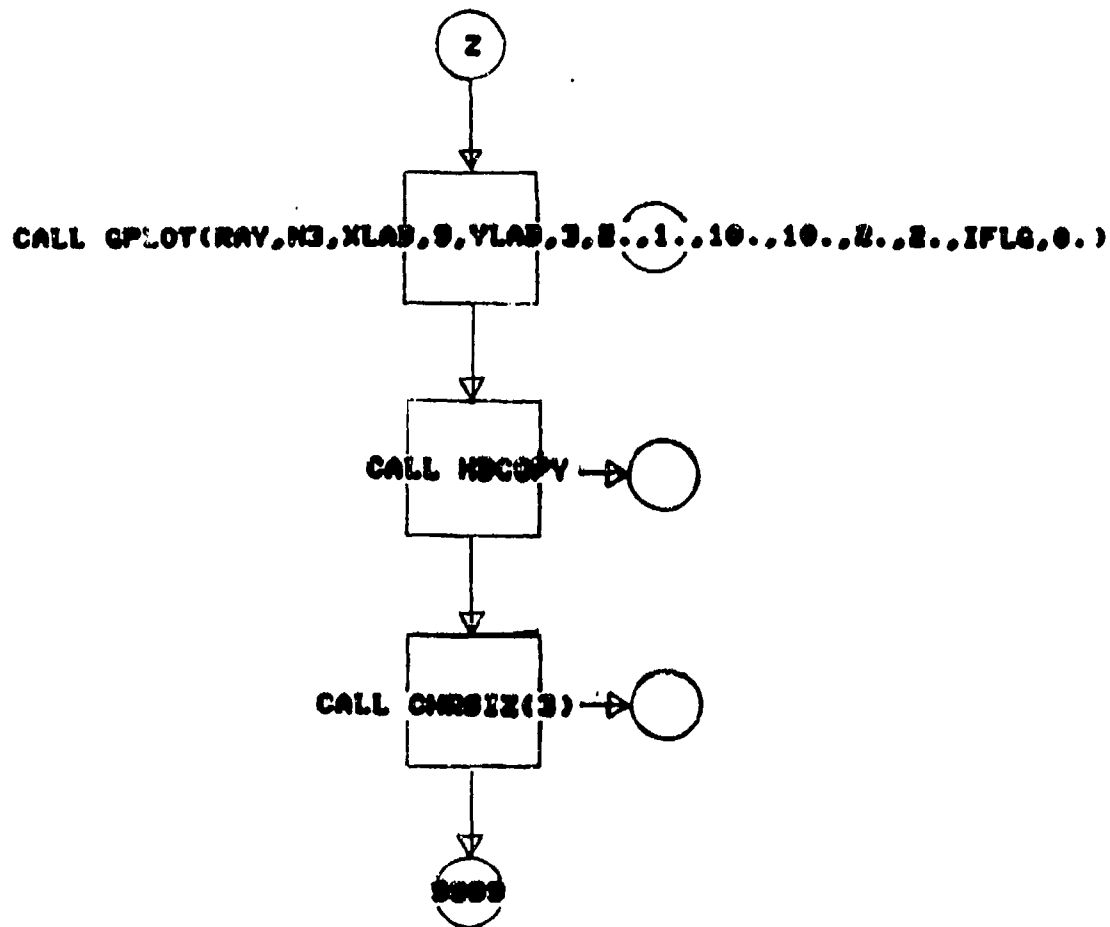












3200

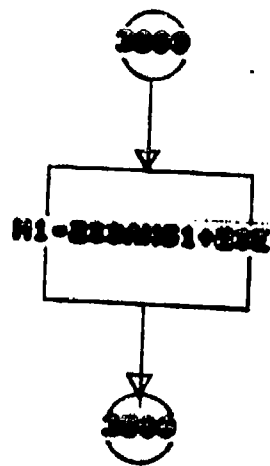
3200 PRINT(1,3300)
3300 FORMAT(1X,"CUBIC INTERPOLATION TO HALVE SURVEY INTERVAL")

I=4
IO=I-3
CO=1+INT((IO-1.)/256)
RO=IO-256*(CO-1)
I1=I-1
C1=1+INT((I1-1.)/256)
R1=I1-256*(C1-1)
I2=I+1
C2=1+INT((I2-1.)/256)
R2=I2-256*(C2-1)
YZ=A1(RO,CO)
Y1=A1(R1,C1)
Y2=A1(R2,C2)
NN=N1-2

I3=I+3
C3=1+INT((I3-1.)/256)
R3=I3-256*(C3-1)
Y3=A1(R3,C3)
CC1=Y1-Y2
CC2=.5*(Y2-Y3)-CC1
CC3=(Y3-Y2-3*CC1)/8-CC2
C=1+INT((I-1.)/256)
R=I-256*(C-1)
A1(R,C)=YZ+1.5*CC1+.75*CC2-.375*CC3
YZ=Y1
Y1=Y2
Y2=Y3

DO 3500 I=4,NN,2

1000



3010

PRINT(1,2000)
2000 FORMAT(1X,'U.E.S. DIGITAL RECURSIVE FILTER',/)

X1=A1(4,1)
Y1=X1
X2=A1(3,1)
Y2=X2
X3=A1(2,1)
Y3=X3
X4=A1(1,1)
Y4=X4
N2=N1+1

CO=INT((I-1.)/256)+1
RO=I-256*(CO-1)
X0=A1(RO,CO)
A1(RO,CO)=.52(A1(RO,CO)-42X1
+42X2-42X3+X4)-(-3.8711982Y1+
7.8128102Y2-3.625882Y3
+8772852Y4)

DO 3700 I=5,N2

N1=22222221
N2=N1+1

WRITE(1,3640)X0,A1(RO,CO)
3640 FORMAT(1X,F8.3,5X,F8.3)

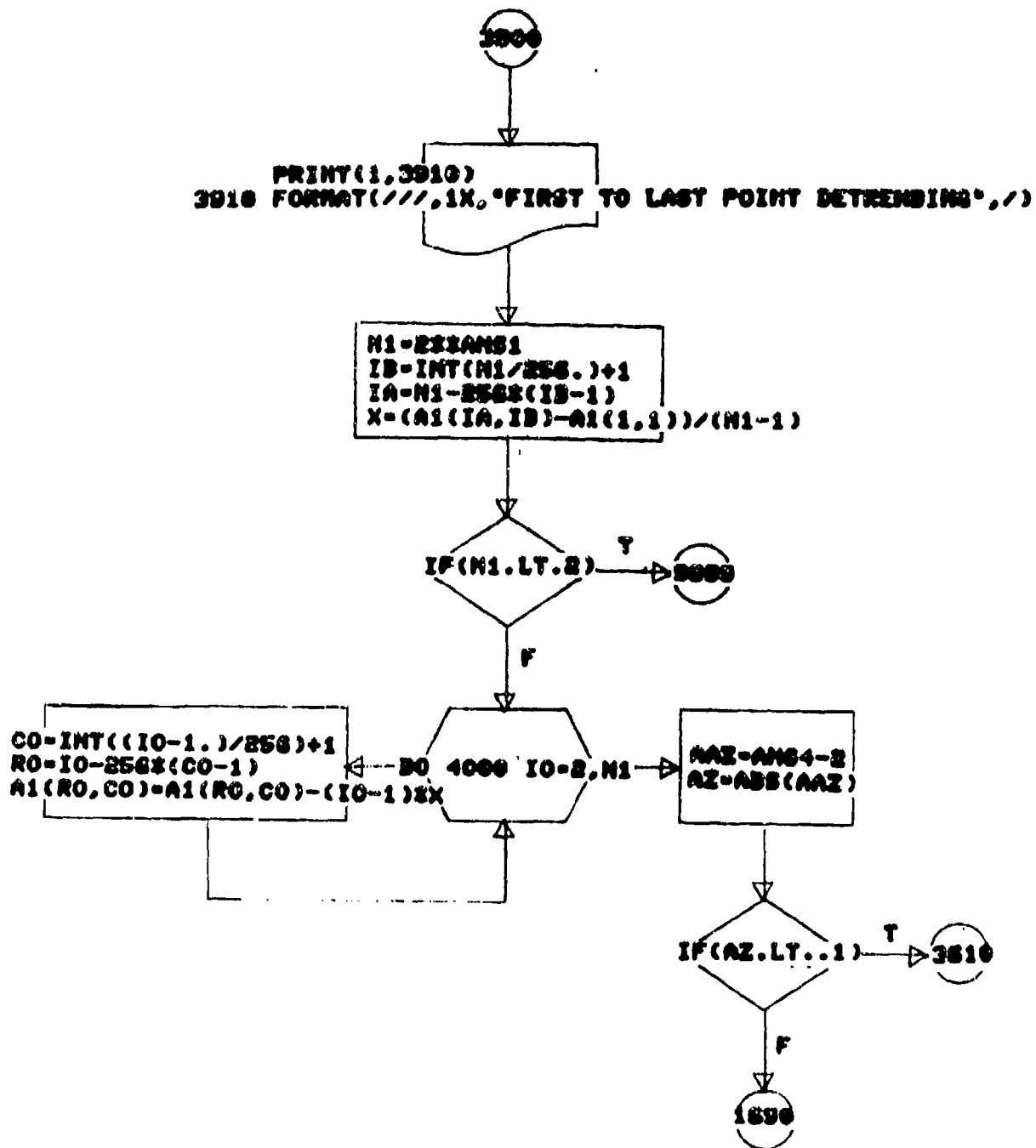
X4=X3
X3=X2
X2=X1
X1=X0
Y4=Y3
Y3=Y2
Y2=Y1
Y1=A1(RO,CO)

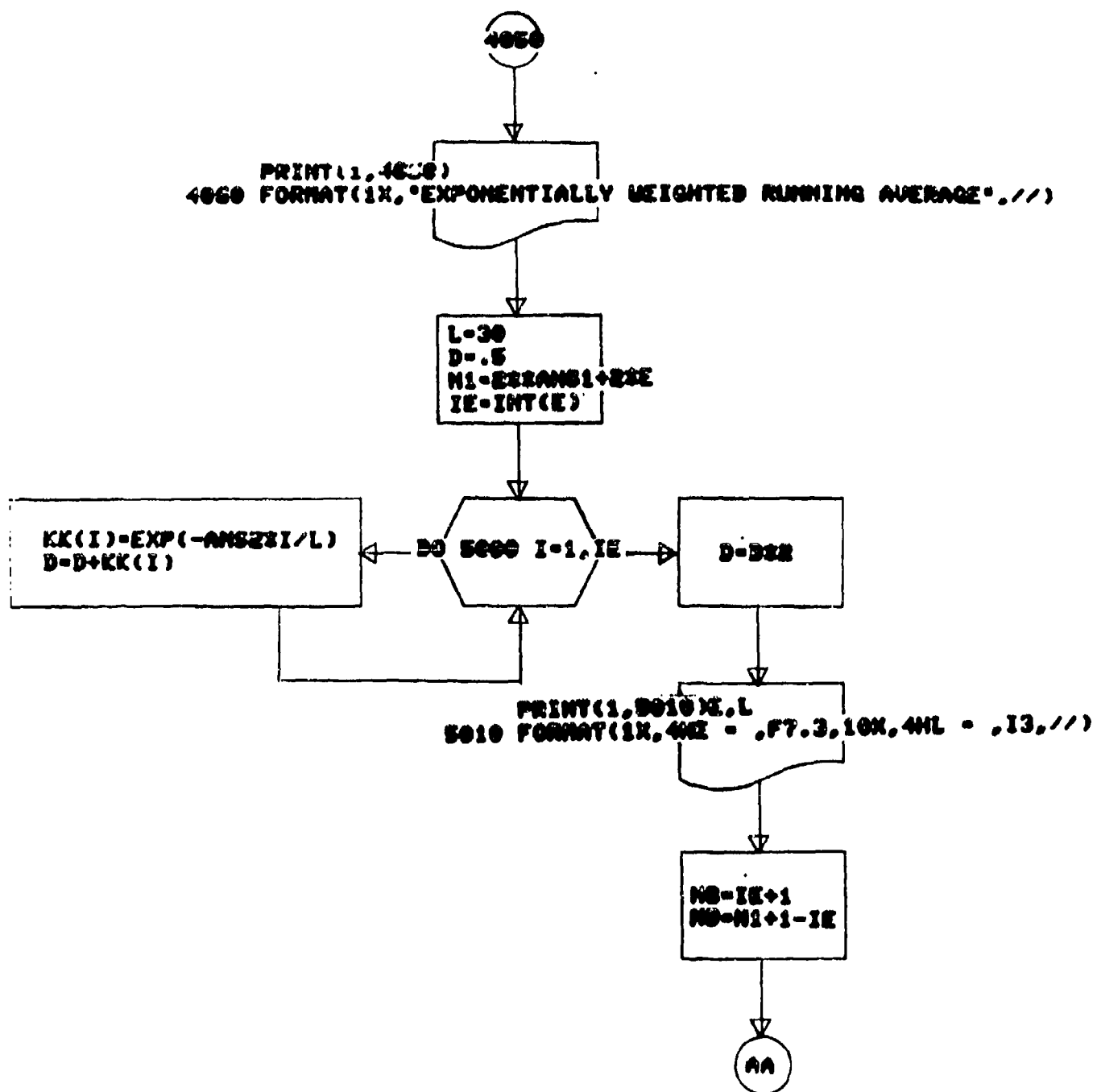
CO=INT((I-1.)/256)+1
RO=I-256*(CO-1)
J=I+1
C1=INT((J-1.)/256)+1
R1=J-256*(C1-1)
A1(RO,CO)=A1(R1,C1)
A2(RO,CO)=0.

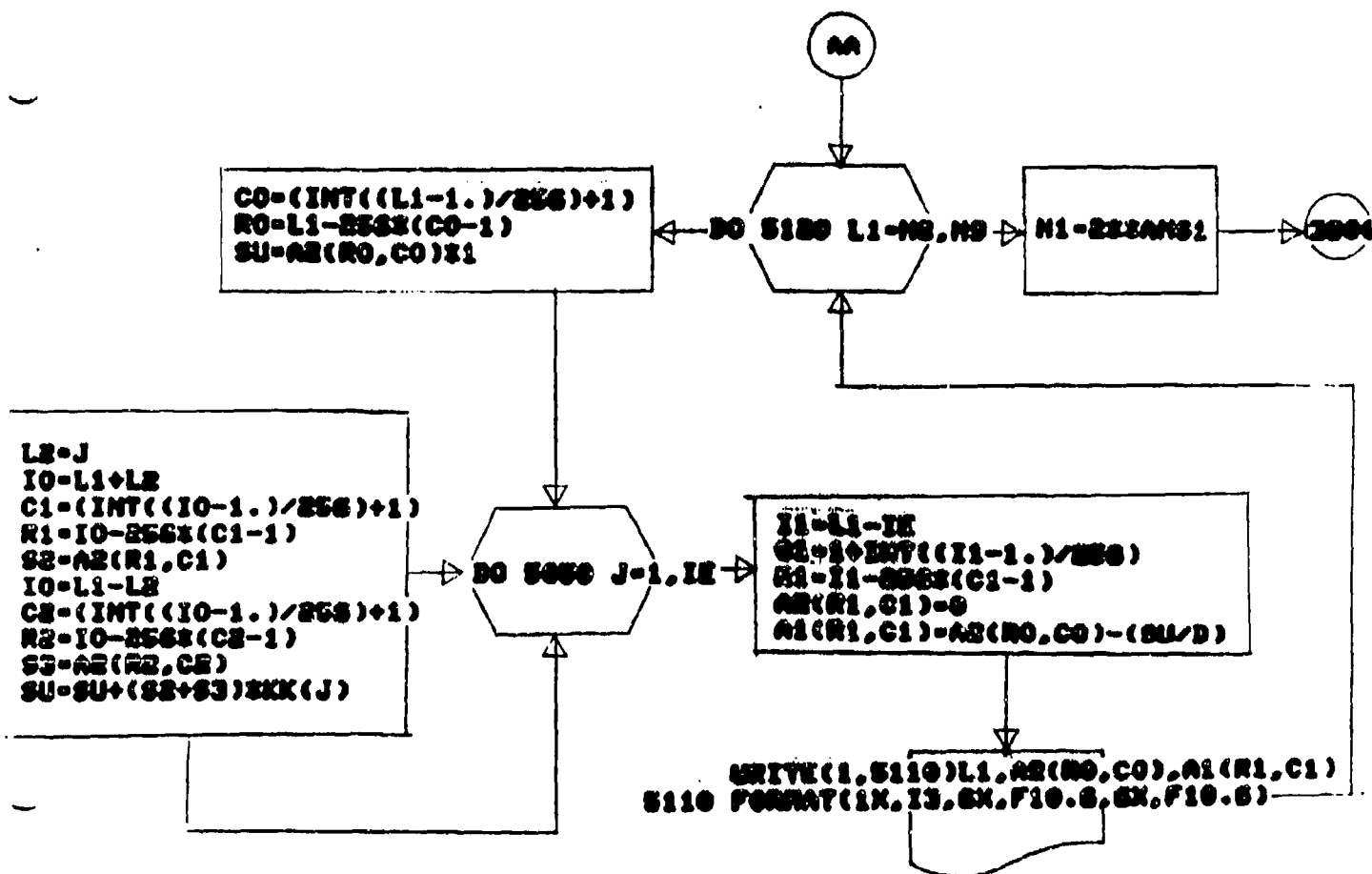
DO 3800 I=1,N2

ANS4=5

3900









INDICATE CALL SUBROUTINE, THE STEPS OF WHICH ARE NOT INCLUDED IN THE FORTRAN PROGRAM, BUT ARE IN MAIN STORAGE. AFTER PROCESSING, CONTROL IS RETURNED TO THE MAIN PROGRAM.

APPENDIX I

TERRAIN CHARACTERIZATION

BY

ZOLTAN J. JANOSI

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U.S. ARMY TANK-AUTOMOTIVE RESEARCH & DEVELOPMENT LABORATORY
U.S. ARMY TANK-AUTOMOTIVE RESEARCH & DEVELOPMENT COMMAND**

TERRAIN CHARACTERIZATION

OBJECTIVE:

The objective of this research is to characterize random terrain profiles by several parameters such as predominant frequency (CPS) content as a function of vehicle velocity, power spectral density (PSD), frequency (CPF), PSD slope and a "detrending parameter".

Additionally, natural terrain possesses a roll statistic or natural offset and research will be conducted to identify it in terms of a vehicle's geometric properties and the autocorrelation function between terrain profiles which are different but possess the same root-mean-square (RMS) level.

SCIENTIFIC APPROACH:

There are many statistical methods for analyzing random data. This task will investigate the techniques developed for time-dependent data and apply them to time-independent but spatially dependent data to develop autocorrelation functions, root-mean-square values, and power-spectral-density plots for terrain profiles.

PROGRESS:

A. BACKGROUND

Investigations this year were focused on the analysis of terrain geometry by means of statistical techniques. The use of statistics is traditional and well documented in many references. A terrain profile as measured along a line of finite distance is one sample record, $y(x)$. A random process is the collection $\{y(x)\}$, of all sample records contained within the boundary of the terrain unit under investigation.

The validity of the statistical analysis depends on two properties exhibited by the random process: stationarity and ergodicity. To clarify this, assume the existence of a finite collection of sample records from a random process, and now examine the value of each sample record $y(x)$ at some arbitrary point x_1 . The mean value of the random process at x_1 is:

$$\mu_y(x_1) = \frac{1}{N} \sum_{k=1}^N y_k(x_1).$$

This is also called the first moment. The correlation (called the autocorrelation function) between two points x_1 and $x_1 + \Delta$ is defined as:

$$R_y(x_1, x_1 + \Delta) = \frac{1}{N} \sum_{k=1}^N y_k(x_1) y_k(x_1 + \Delta).$$

To be very rigorous, these expressions are valid only in the limit as $N \rightarrow \infty$. The random process $y(x_1)$ is weakly stationary if $\mu_y(x_1)$ and $R_y(x_1, x_1 + \Delta)$ are invariant as x_1 varies over all x ; i.e., $\mu_y(x_1) = \mu_y$ and $R_y(x_1, x_1 + \Delta) = R_y(\Delta)$ for all points x within the collection of sample points. This means that the mean value of the elevation for the terrain unit is constant and that the autocorrelation function is dependent only on the separation distance between two points. Note that if Δ is zero, then the square root of the autocorrelation function is the RMS of the terrain profile. In order for a random process $\{y(x)\}$ to be strongly stationary, all higher order moments and joint moments for the autocorrelation function must be invariant with respect to the variable x . For many practical applications, a verification of weak stationarity justifies the assumption of strong stationarity. In any case, the collection of all higher order moments and joint moments can be used to establish a complete family of probability distribution functions that describe the random process.

Consider the k th sample record $y_k(x)$. The mean value and autocorrelation function of k th sample record is given by:

$$\mu_y(k) = \frac{1}{X} \int_0^X y_k(x) dx \text{ and } R_y(\Delta, k) = \frac{1}{X} \int_0^X y_k(x) y_k(x + \Delta) dx$$

If the random process $\{y(x)\}$ is stationary, and $\mu_y(k)$ and $R_y(\Delta, k)$ are constant for all values of k , then $\mu_y(k) = \mu_y$ and $R_y(\Delta, k) = R_y(\Delta)$, and therefore the process is ergodic. Note that only stationary random processes can be ergodic.

Therefore, if it is assumed that a terrain unit is a random process that is both stationary and ergodic, then all the necessary information can be obtained from one sample terrain profile.

B. COMPUTATIONAL PROCEDURES:

Making these assumptions allows the statistical analysis of a single terrain profile to produce a root-mean-square

roughness value and a power spectral density distribution plot which portray the characteristics of the terrain unit which is geographically associated with the sample. The general process is as follows:

1. Conduct a survey in the area for which information is required. Establish a path (not necessarily absolutely straight) between 400 - 600 feet long and determine the elevation of the profile at one foot intervals.
2. Detrend the raw data by removing low frequency information. Normally a cut off frequency of .0166 cycles/ft is used. (Detrending is discussed later).
3. Set the detrended profile to have a zero mean.
4. Calculate the autocorrelation function. The square root of the autocorrelation function with Δ equal to zero is the RMS of the profile.
5. Operate on the autocorrelation function using Fourier Transforms to yield raw power spectral density estimates.
6. Apply smoothing coefficients and calculate the central frequency for each PSD estimate. (PSD is established for a various frequency/band).
7. Graphic presentation.

Steps 2 through 6 have been written into a computer program, using basic language for a Wang 2200 series computer. Raw survey data are entered in a data block and the finished product consists of a listing of smoothed power spectral density estimates and associated center frequencies. Terrain profiles up to 699 feet long may be processed, with up to 200 autocorrelation coefficients. At the operator's discretion, any one of four methods of detrending may be used or he may ignore detrending.

Steps 3, 4, 5, and 6 are well documented in many references. All authorities agree, so there is little need for discussion. However, Step 2, detrending, is not as clear cut. There are several techniques available, none of which are ideal. However, detrending is important because it drastically alters the RMS value and the shape of the PSD plot. It is necessary because of the statistical nature of the data reduction process. In order for the

process to identify all frequencies which are present, the sample record must be several times longer than the wave length of the lowest frequency. Since the frequency content is unknown, all frequencies below a certain limit must be eliminated and a sample record length several times longer than the wave length of the cut off frequency must be used. If the removal of long wave length information, or a net change in elevation, is not accomplished, the reduction process will distribute the associated "power" throughout the entire spectrum of the PSD plot. Furthermore, if a net change in elevation does occur, it will invalidate the assumption of ergodicity. This, of course, destroys the value of the analysis.

Detrending is often called filtering. The type of filter which is of interest in terrain profile analysis would be a high pass filter; i.e., those frequencies lower than the cut off frequency are filtered out and those above the cut off frequency are passed. Unfortunately, there are no ideal mathematical filters; no mathematical data manipulation will entirely eliminate the frequencies lower than the limit and leave the higher frequencies unchanged. There is always some distortion of information on the pass side of the filter and some passing of information on the filter side. The best that can be done is to look for the filter with the sharpest possible cut off characteristics and minimal distortion on the "pass" side. Much of the effort in FY76 was directed to this end. Several filtering techniques were investigated but only two proved to be promising.

One such numerical filter is known as the running average. It is a two sided filter that detrends without a phase shift and is able to remove linear trends as well as long wave length information. The filter calculates a correction factor for each point in the survey. The correction factor is then subtracted from the value of each survey point to yield a corrected value. The series of corrected values forms a new "detrended" profile devoid of long wave length information. The correction factor for each survey point is calculated by summing the elevations at a given number of points ahead of and behind the point to be detrended, plus the value of the point itself and dividing the sum by the total number of points. The mathematical expressions are as follows:

$$y_m(X) = \frac{1}{l+1} \sum_{k=-l/2}^{k=l/2} y(X + K\Delta X); K = -\frac{l}{2}, (-\frac{l}{2} + 1), \dots, 0, \dots, \frac{l}{2}$$

where:

- $y_m(X)$ = the correction factor to be subtracted from the ordinate of the surveyed point
- l = number of survey points
- $l \cdot \Delta X$ = length of running average
- $y(X)$ = value of any point in the original survey
- X = horizontal distance
- ΔX = measurement interval

Note that the raw values are used throughout the process. The previously corrected values are ignored during detrending. The detrended profile is generated by:

$$Y(X) = y(X) - y_m(X)$$

where:

$Y(X)$ = the ordinate of the detrended survey point. This technique generates a unique correction factor for each survey point.

The cut off frequency of this filter is controlled by the number of survey points and measurement interval included in the averaging. For example, if the survey interval is one foot and the filter looks ahead and behind 30 points, then the cut off frequency is approximately .0166 cycles/ft (corresponding to a 60 foot length). The error function concerning this process is:

$$\delta(\alpha) = \frac{1 - 2 \sin(\alpha D/2)}{\alpha D}$$

where:

$$D = (l + 1)\Delta X$$

l = number terms for averaging

ΔX = survey interval

Ω = frequency

Figure 1 shows a plot of the error function for filters which look ahead and behind 33, 50, and 70 survey points. It shows that the filters have sharp cut off characteristics but that they also distort frequency amplitudes in the pass side of the filter. For each error function shown, the first zero error point occurs very nearly at the frequency whose wave length is equal to the length of the running average. Thereafter, the filter alternately over and under estimates the amplitudes. The maximum over estimation is almost 50%; the maximum under estimation is a little more than 20%. However, the decay characteristic quickly reduces the distortion to $\pm$ a few percent.

The second filter, introduced by Van Deusen, is a modification of the running average. It is termed a "moving two sided exponentially weighted average." A correction factor is calculated in the same manner except that the values used in the calculation are weighted proportionally to their distance from the point being detrended. The more distant points are less influential than nearby points. The weighting is accomplished by an exponential factor. Mathematically the filter expression is:

$$y_n(X) = \frac{\sum_{l=0}^E \{y(X + l \cdot \Delta X) + y(X - l \cdot \Delta X)\} \exp(-\frac{l \cdot \Delta X}{\lambda})}{\sum_{l=0}^E \exp(-\frac{l \cdot \Delta X}{\lambda})}$$

where: $y(X)$ = elevation at the point X

$y_n(X)$ = correction factor

l = step number

ΔX = measurement interval

λ = weighting constant

then:

$$\bar{Y}(X) = y(X) - y_n(X)$$

where:

$\bar{Y}(X)$ = value of detrended profile point.

Lamda is an independent variable which is chosen to establish the cut off frequency. Then in actual computation, a limit on the value of the exponent is set that causes λ to be limited to some finite number E . Van Deusen chose to cut off computation when the absolute value of the exponent exceeded 3. By adjusting the value of lamda and the limit on the value of the exponent, filter characteristics can be modified over a wide range. If values are assigned which cause a rapid decline in the value of the survey points used in computing $\bar{Y}(X)$, the error function will exhibit a general under estimation of amplitudes in the pass side of the filter. An example of this phenomenon of weighting is shown in Figure 2 for three different values of Lamda.

The considerable effort was directed at investigating the weighting constant and its effect on optimizing filter characteristics. The result is an improved filter which has better cut off characteristics and limits distortion in the pass side of the filter to less than 10%. The error function is shown in Figure 3. The summation of terms for averaging is stopped when the absolute value of the exponent exceeds 1.2 with Lamda = 30. The filter parameters were chosen to less severely depress the values of the survey points in computing $\bar{Y}(X)$. Note that some of the oscillatory characteristics of the straight running average error function are evident. This improved filter has been incorporated in the PSD computer program and is regularly used for detrending field survey data.

The most noticable effect of detrending techniques occurs in the calculation of the RMS value of a profile. Even slight changes can cause large variations in the RMS value. If we wish to be very precise, then even the improved filter cannot stand alone because it does pass some low frequency information which ideally it should not. Additional filtering can be done graphically on the final plot of the PSD. The square root of the area under the PSD plot is the RMS of the profile. By subtracting the area in the low frequency end of the plot from the total area, the profile can be further detrended. This combination of numerical and graphical filtering produces RMS values as close to the true values as possible with the statistical analysis technique.

FUTURE PLANS:

As a result of the work described here, a computer program is available that produces RMS and PSD data from terrain profile survey data. The procedure uses an improved mathematical filter to eliminate undesirable wave lengths and slopes. It also smoothes the PSD plots by reducing the side lobes which occur due to the limited length of the surveyed profile.

The procedure is based on the Wiener-Khinchin equation which states that the PSD is the Fourier transform of the autocorrelation function. Hence, one calculates the autocorrelation function first. (The practical application was first published by Blackman and Tukey).

However, a more direct approach, the computation of the Fourier transform of the profile itself, is now a practical proposition because a new, faster computational method has been developed for the performance of Fourier transform calculations.

It is, therefore, recommended that the application of the Fast Fourier Transform method to terrain profile analysis be undertaken next.

attenuation
**ERROR FUNCTION FOR RUNNING
AVERAGE DETRENDING**

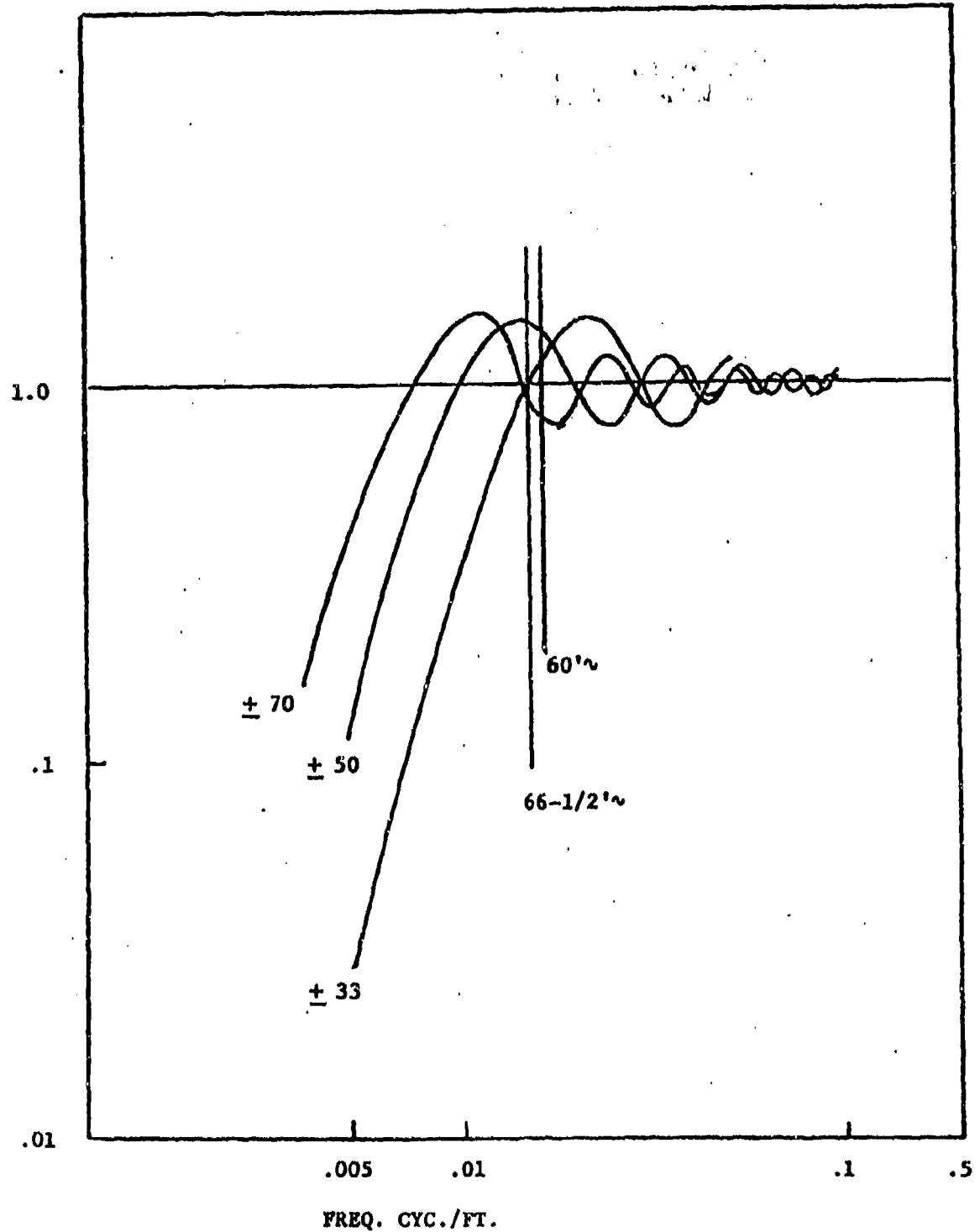


FIGURE 1

MOVING TWO SIDED

EXPONENTIALLY WEIGHTED AVERAGE

FILTER GAIN WEIGHTING CONSTANT CUT OFF AT $S \times Y/L > 3$

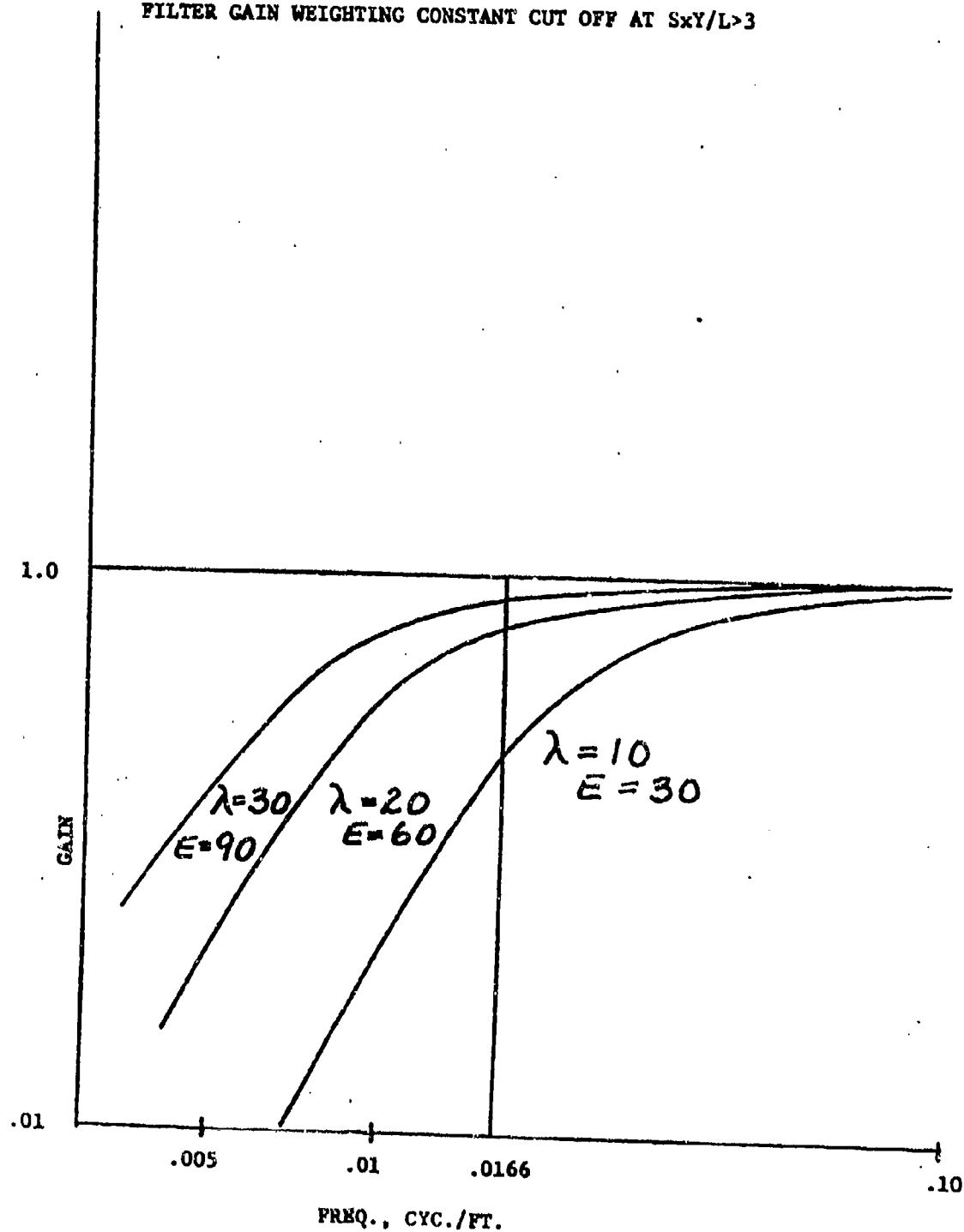


FIGURE 2

MOVING TWO SIDED
EXPONENTIALLY WEIGHTED AVERAGE

FILTER GAIN WEIGHTING CONSTANT CUT OFF AT $S_{xy}/L > 1.2$

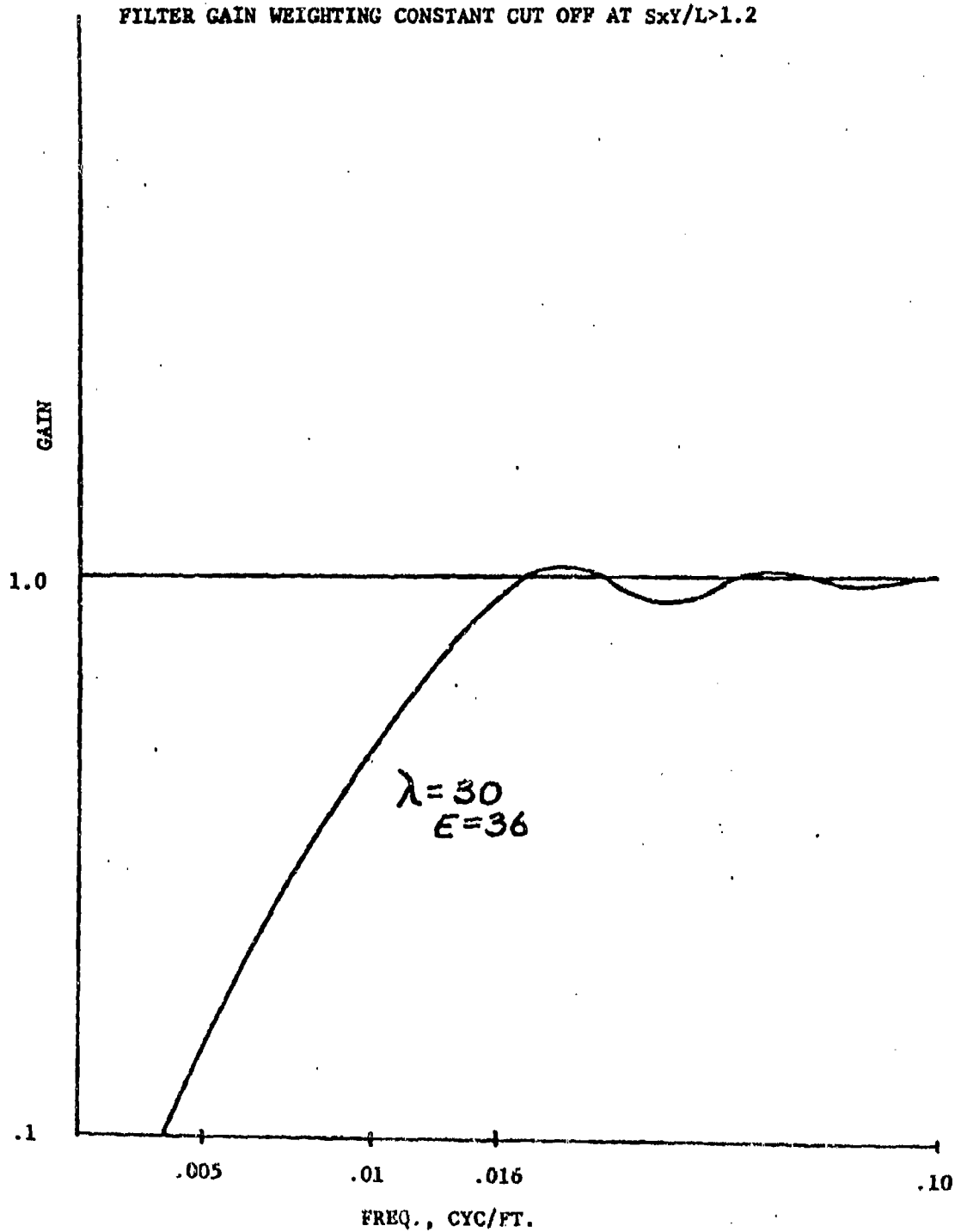


FIGURE 3
102

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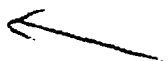
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20. ABSTRACT (Continue on reverse side if necessary; and identify by block number) The objective of this report is to provide a user manual for the Signal Analysis Computer Program. The TARADCOM Signal Analysis Program (formerly called the Fast Fourier Transform Program) was developed originally as a BASIC Wang Program by Robert Daigle and associates. The TSA computer program has been converted from BASIC to FORTRAN and various graphics		

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displays, such as linear plot of evaluation vs. distance, a point plot of amplitude vs. periods, and a log-log graph of power spectral density vs. frequency, have been added.

Terrain data input to the program may be used in processing, rather than data equations that are contained in the program. Options available during processing include: first to last point detrending, digital high pass filters, exponentially weighted running average, no detrending, interpolation, amplitude smoothing, and a GEO window. The results of the TSAP include, besides graphics displays, amplitudes, periods, frequencies, power spectral densities, and RMS values.



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