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ANALYSIS OF AN ELECTRO-OPTICAL SATELLITE OBSERVATION.(U)
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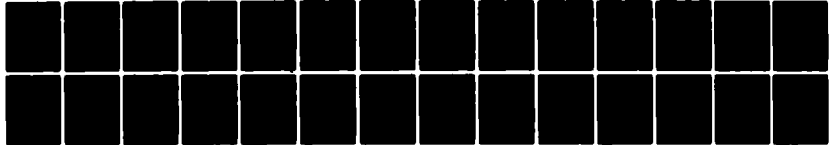
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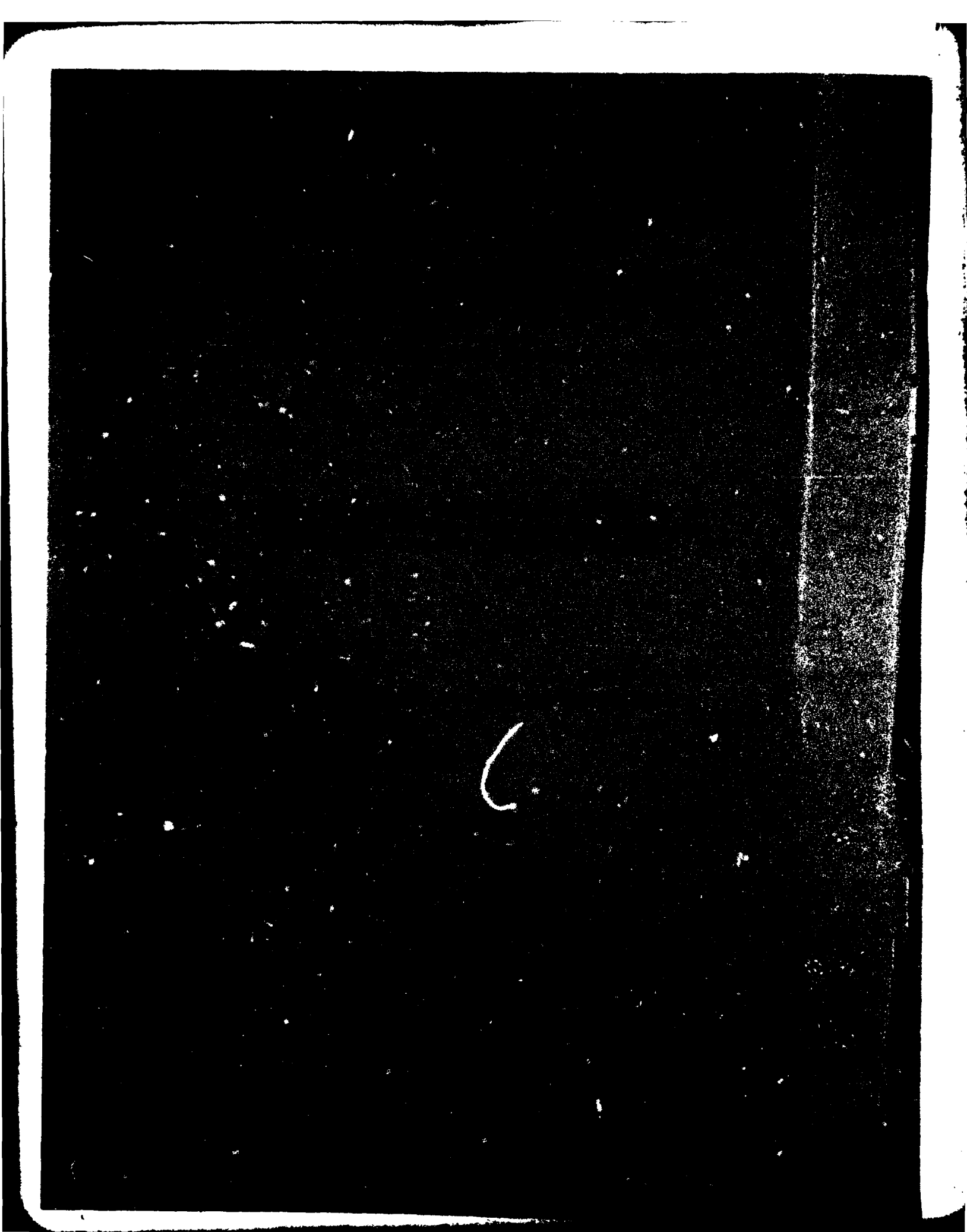
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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY

ANALYSIS OF AN ELECTRO-OPTICAL SATELLITE OBSERVATION

G.J. MAYER
Group 94

PROJECT REPORT ETS-59

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ABSTRACT

A satellite has been observed through an optical telescope with a CCD camera, the electrical signal stored, and later analyzed with the aid of a digital computer. The unresolved satellite image is contained in 3 to 7 picture elements in fifty contiguous data frames. This allows a better understanding of the physical characteristics of the satellite image as viewed through the atmosphere by an electro-optical detector.

This paper describes the data processing programs used to analyze the data, the analysis results, and implications for signal processing design.

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I. INTRODUCTION

A CCD camera has the potential of improving the performance of satellite detection systems by means of higher quantum efficiency, smaller pixel size, and more pixels on a focal plane than EBSICON cameras. An efficient satellite detection processor should be designed to exploit the signal characteristics of the camera it uses as an electro-optical detector. Selected portions of a digital satellite detection processor (IMC Signal Processor) and CCD camera are being developed for the GEODSS advanced technology program. The output of a CCD camera, when observing a satellite, has been digitized, and then analyzed with the aid of a computer. This allowed a detailed study of the electrical signal that the processor would have to use prior to designing the processor.

Satellite ATS-6 was observed with the 31" main GEODSS ETS telescope at the White Sands Missile Range. The CCD camera was at the prime focus and was operated in the stare mode with an 0.1 second integration time. The ETS photometer measured the satellite's brightness as 10.5 Mv. The camera video was digitized to 12 bit resolution, sent to the MODCOMP computer at the ETS and stored on magnetic tape. This tape was brought back to Lexington and placed on the MODCOMP computer here. The tape was read by the MODCOMP and the data transmitted to the HP 9845 graphics computer and stored there. The HP computer was used for all the data analysis.

The satellite observation is contained in fifty contiguous frames. Each frame contains an array of 32×32 picture elements (pixels). The integration time for each frame was 0.1 second. Each pixel has the equivalent field-of-view of $2''.7 \times 2''.7$.

II. DATA PROCESSING

The frames of data were read from the digital tape by the MODCOMP computer and transmitted, on an RS-232C interface¹, to the HP computer. Using this interface the HP computer² was operated to look like a standard terminal to the MODCOMP. The major task of this interface was to write an HP terminal emulator program. This program has to read the data from the interface, store the data, and respond to the MODCOMP with standard terminal handshake commands. The program, "MOD-HP", listed in Appendix A did this at 9600 baud.

To operate at this high a rate, each data word was read as a character string. The character strings were stored on HP tape cassettes as the data word was being read. The 1024 character strings from each frame were separated by markers. Once all fifty frames of the character strings were stored on tape, the HP computer was disconnected from the MODCOMP, and was operated independently from then on.

Two tape cassettes were required to store all the character strings. All the character strings were then read off the tapes and stored on one floppy disc using the "COPY" program listed in Appendix A. The character strings cannot be used in programs, but must be converted to the numbers they represent. The program "READ", Appendix A, read the character strings off the disc, converted the character strings to numbers and stored

1. Hewlett Packard, "Serial I/O Interface-98036A," 1977.

2. Hewlett Packard, "I/O ROM Programming System 45B," 1979.

these on tape. The "COPY" program was again used to transfer data from tape to disc.

To insure that the data stored on the disc was accurate, a print-out of the data stored on the MODCOMP tapes was compared to the data stored on the HP disc. The data was identical in frame-to-frame and entry-to-entry comparisons. The first data entry in each frame of both the MODCOMP and HP data was the same, but was not a valid data value. To avoid problems in data processing the value of the first data entry, in each frame, was set to the mean of the data of each frame and is then called a valid data frame.

Now the data is ready to be analyzed. The first data analysis program is "MAXAMP" listed in Appendix B. "MAXAMP" finds the maximum amplitude in each frame and prints the frame number, amplitude, and array position. A sample of "MAXAMP" output is shown in Figure 1. The frame number, e.g. T11V01:F stands for CCD-DIGITIZER test #11 (T11), valid data frame (V), frame number (01), and stored on floppy disc (F). The pixel array position is numbered from 1 to 1024 in each data frame.

The next data analysis program listed in Appendix B is "FREDIS" which plots the frequency distribution of amplitudes for each frame. Figure 2 contains plots from two of the fifty frames. The amplitude scale adjusts for each frame depending on the maximum amplitude. The occurrence scale also adjusts

FRAME			POSITION
T11V10:F	MAXIMUM AMPLITUDE	185	276
T11V11:F	MAXIMUM AMPLITUDE	182	276
T11V12:F	MAXIMUM AMPLITUDE	163	276
T11V13:F	MAXIMUM AMPLITUDE	159	277
T11V14:F	MAXIMUM AMPLITUDE	224	277
T11V15:F	MAXIMUM AMPLITUDE	176	277
T11V16:F	MAXIMUM AMPLITUDE	208	277
T11V17:F	MAXIMUM AMPLITUDE	173	277
T11V18:F	MAXIMUM AMPLITUDE	147	277
T11V19:F	MAXIMUM AMPLITUDE	180	277
T11V20:F	MAXIMUM AMPLITUDE	172	276
T11V21:F	MAXIMUM AMPLITUDE	143	276
T11V22:F	MAXIMUM AMPLITUDE	144	276
T11V23:F	MAXIMUM AMPLITUDE	143	276
T11V24:F	MAXIMUM AMPLITUDE	175	276
T11V25:F	MAXIMUM AMPLITUDE	184	276

Fig. 1. "MAXAMP" sample output.

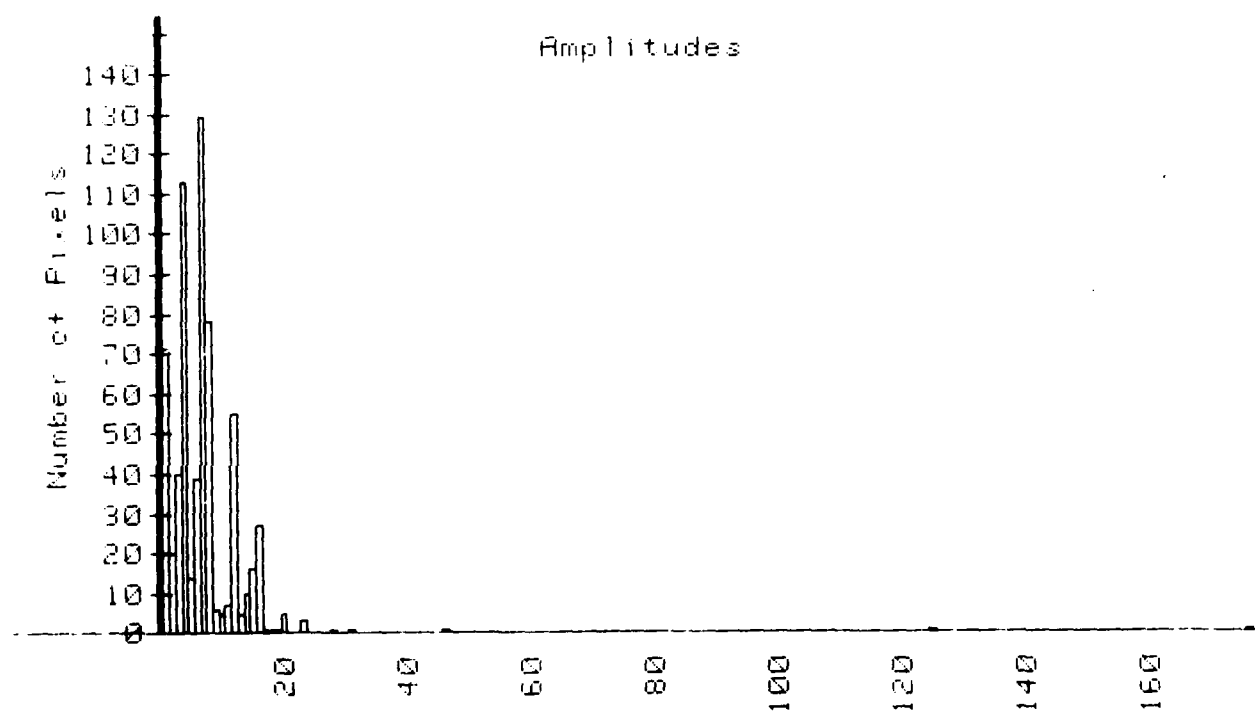
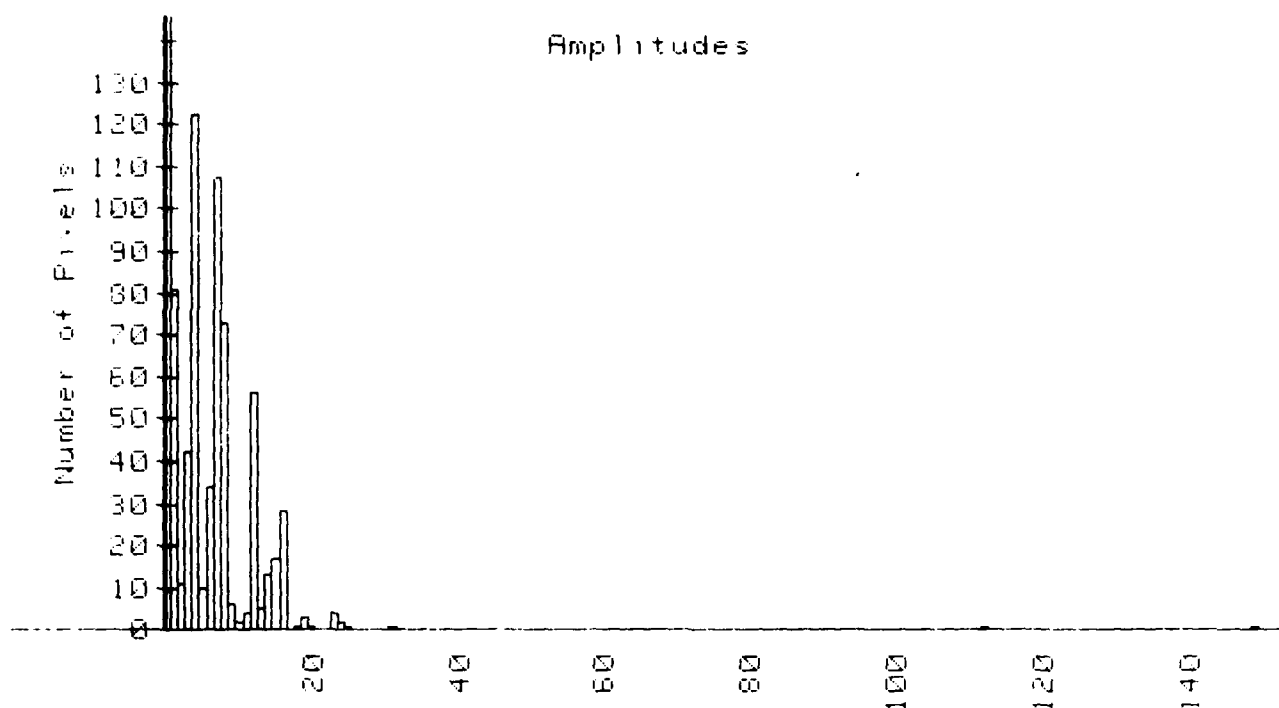


Fig. 2. "FREDIS" output for two frames.

depending on the number of pixels, excluding the zero amplitude, for which there are from 350-400 pixels in each frame.

The program "PEAKS" examines a frame of data and prints out the location and amplitude of any pixel whose amplitude is above a selected level. Figure 3 is a sample of "PEAKS" output. A program listing of "PEAKS" is in Appendix B. The frame number is given and the selected level (e.g. 19). The row, column, array position (as in "MAXAMP" output), and corresponding amplitude are listed.

Program "DATAST", Appendix B, prints out the amplitude values of any frame by row and column. An asterisk is placed next to amplitudes above a selected amplitude. The output is displayed on the CRT or printed on the line printer. A sample of output from frame #11 is shown in Figure 4. The top line of each pair is array elements 1 to 16 and the second line is array elements 17 to 32. In this frame the satellite pixels have amplitudes of 182, 112, 32, and 40. An isolated pixel of noise with amplitude 32 is one array line above this.

The "FRAME" program (Appendix B) allows a 13 x 11 pixel array around the satellite image of any frame to be displayed. After the array of pixels is displayed, the amplitudes are plotted first in column and then in row. Figure 5 is a print-out of the array of pixels around the satellite image from

T11V03:F	PEAKS ABOVE	19	
ROW	COLUMN	POSITION	AMPLITUDE
3	10	291	32
20	9	276	56
20	10	308	28
21	9	277	158
21	10	309	35
21	11	341	47
22	9	278	23
22	10	310	20
23	9	279	28

T11V08:F	PEAKS ABOVE	19	
ROW	COLUMN	POSITION	AMPLITUDE
2	6	162	20
3	8	227	23
4	27	836	23
10	3	74	23
16	10	304	23
20	9	276	112
20	10	308	24
21	8	245	25
21	9	277	149
21	10	309	31
25	13	409	24

T11V22:F	PEAKS ABOVE	19	
ROW	COLUMN	POSITION	AMPLITUDE
2	7	194	33
5	23	709	23
7	3	71	20
7	7	199	22
9	30	937	20
13	22	685	23
15	4	111	20
16	11	336	20
20	8	244	24
20	9	276	144
21	9	277	125
21	10	309	32
22	11	342	24
23	11	343	20
21	14	447	24

Fig. 3. "PEAKS" sample output.

0	12	7	1	0	1	16	1	0	1	14	1	3	7	7	0
0	0	1	4	0	0	8	14	1	5	1	6	7	0	0	3
4	0	0	15	0	0	12	7	0	14	1	0	4	4	0	0
7	0	0	0	7	8	7	0	14	0	0	0	6	12	0	0
4	0	6	0	0	1	16	0	0	7	12	7	8	0	14	6
0	0	1	6	7	0	1	18	0	3	0	8	8	0	4	1
0	0	0	0	8	6	4	0	7	8	0	1	3	8	1	0
3	7	0	7	0	7	6	0	7	4	12	0	6	4	0	0
0	0	1	3	0	3	4	1	0	0	0	4	4	0	0	9
1	0	0	3	7	1	7	0	0	7	3	4	0	0	7	0
0	4	0	4	4	0	0	4	5	16	0	3	14	7	0	0
0	7	0	0	0	0	2	7	0	8	7	1	0	7	7	0
0	12	4	0	7	16	16	0	8	0	12	1	0	0	0	4
4	0	1	4	8	0	0	12	1	6	1	6	5	0	0	0
4	7	9	0	0	0	12	0	1	0	15	6	0	14	4	7
0	0	0	12	13	0	0	7	12	0	12	4	1	1	0	14
14	12	0	32*	0	0	16	6	0	0	11	1	8	0	0	7
1	0	0	0	7	0	0	16	4	4	0	7	4	15	0	0
0	0	1	8	7	8	1	15	182*	32*	15	12	1	7	7	0
0	0	14	8	8	8	12	15	12	0	7	12	1	0	4	0
7	0	0	14	4	0	0	19	112*	40*	7	14	0	12	12	12
4	1	16	14	3	8	16	4	0	0	0	4	4	12	0	0
0	12	0	0	16	14	1	0	17	18	12	3	7	15	7	0
0	4	0	0	0	12	7	0	12	16	2	0	1	0	0	0
4	0	0	7	4	0	7	8	7	1	0	4	7	4	0	0
1	14	3	4	0	7	16	0	4	0	12	7	0	0	12	0
0	2	14	12	4	6	15	0	0	4	7	0	7	8	4	1
0	8	6	13	1	1	2	4	7	0	1	7	0	7	0	0

Fig. 4. "DATAST" sample output.

0	4	0	0	4	12	7	4	0	0	7
0	7	0	1	24	7	1	8	12	13	0
1	7	7	0	0	14	16	7	15	1	7
1	7	15	13	0	28	24	24	12	0	8
6	4	0	0	7	163	95	4	0	16	7
3	16	4	5	7	36	31	4	12	0	3
8	7	8	12	11	2	0	0	7	1	4
0	4	1	1	0	12	3	7	0	0	12
4	8	12	0	0	15	4	7	7	7	0
23	7	9	0	0	2	4	0	0	0	6
8	7	0	0	3	0	0	0	16	4	1
0	4	0	0	7	0	0	0	7	0	0
4	4	0	0	4	0	7	4	0	0	0

Fig. 5. "FRAME" sample output.

frame #12. Figure 6 is a plot of the amplitude in the sixth column of Figure 5. The dashed line is a level at an amplitude of 19. Figure 7 is a plot of amplitudes in the fifth row of Figure 5. The dashed line is also at an amplitude of 19.

Appendix C contains the pixels (5 x 6) surrounding the satellite image for frames 1 through 12. These were obtained using a modified version of program "FRAME".

COLUMN

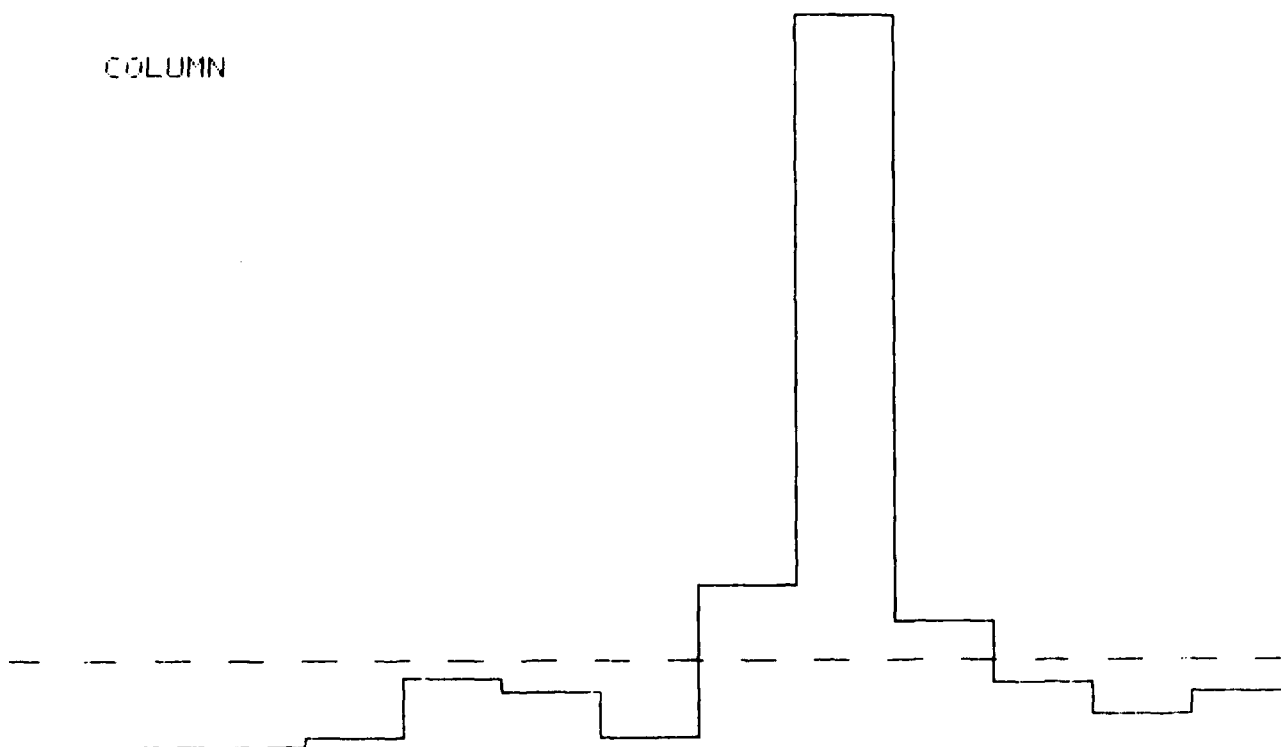


Fig. 6. "FRAME" output, column plot.

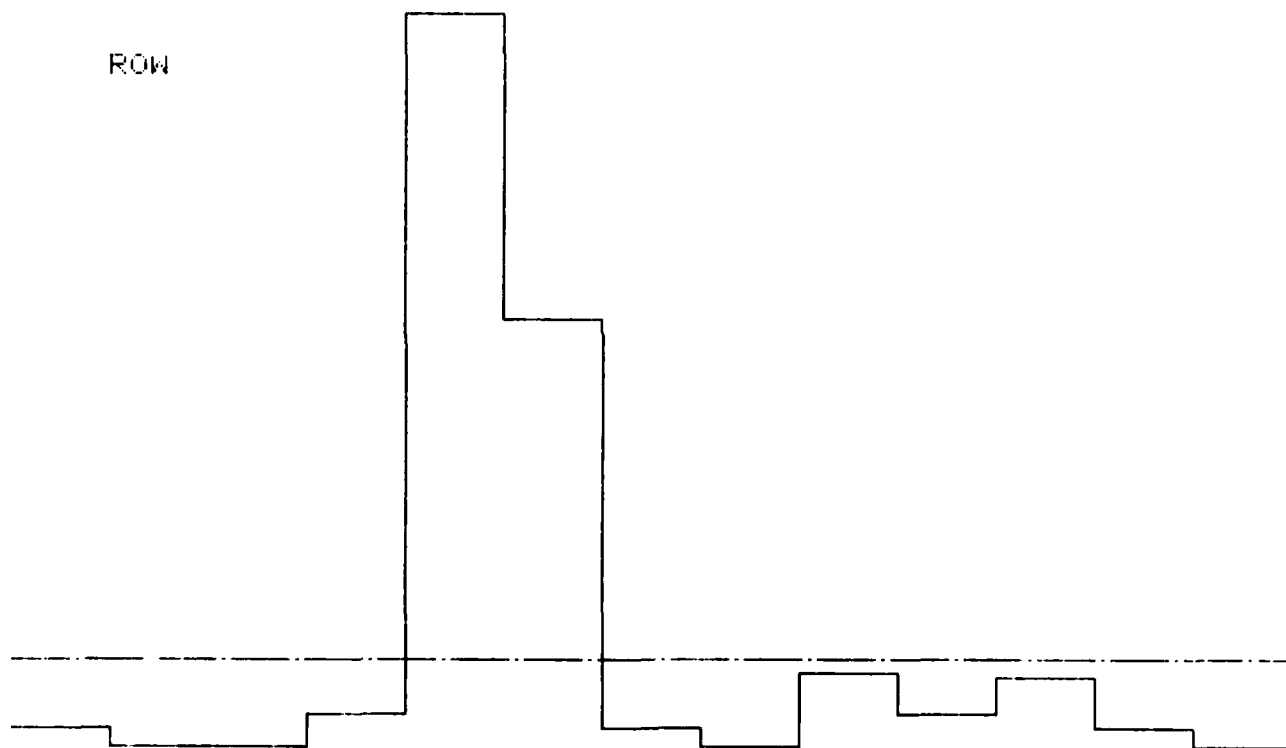


Fig. 7. "FRAME" output, row plot.

III. ANALYSIS OF DATA

Analysis of the output of the "MAXAMP" program indicates that the highest amplitude of the satellite image moves between two adjacent pixels. Over the fifty frames, the highest amplitude switches 15 times between the two pixels, spends an equal amount of time in each and there is no periodicity to the switches. The range of highest amplitudes is 127 to 224 with a mean of 165. The mean of highest amplitude in one pixel is 162, while the other pixel's highest amplitude mean is 169.

Examining the output of "FREDIS" shows that in all frames most of the pixels have amplitudes from 0 to 17. The mean of the amplitudes from each of fifty frames ranges from 4.4 to 4.9. This is strongly due to the large number of pixels (350 to 400) in each frame with amplitudes of zero. The distributions of all fifty frames are similar. All frames have less than 20 pixels above an amplitude of 19.

The output of "PEAKS" shows that in every frame the pixels with amplitudes greater than 28 are either those of the satellite image or of isolated pixels. There are 532 pixels that have amplitudes greater than 19 in the fifty frames. Most of these pixels are either those of the satellite image or isolated pixels. However, 12 of the pixels in 10 of the fifty frames have an adjacent pixel greater than 19. In half of these cases the adjacent pixels are vertically related and in half horizontally.

The pixels with amplitudes greater than 39 are all those of the satellite image.

The output of "DATAST" shows that the noise is uncorrelated from pixel to pixel and from line to line. Eight-four percent of the pixels with an amplitude greater than 8 have no adjacent pixel with amplitude greater than 8. Ninety-three percent of the pixels with amplitude greater than 12 have no adjacent pixel with amplitude greater than 12.

The output of "FRAME" gives information primarily about the pixels associated with the satellite image. Table 1 is a summary of the distribution of satellite image pixels by frames. The distribution of energy from the satellite image is very dynamic. The distribution changes significantly in periods of 0.1 sec to 0.3 sec. In 61.5% of the frames the energy distribution doesn't fit a circular Gaussian function.

TABLE 1

NUMBER OF SATELLITE PIXELS FOR FIFTY FRAMES

Amplitude Higher Than	Satellite Pixels	Number of Frames
24	3	10
	4	25
	5	12
	6	2
	7	1
29	2	1
	3	19
	4	28
	5	2
32	2	17
	3	31
	4	2
34	2	21
	3	27
	4	2
39	2	29
	3	21
49	1	3
	2	44
	3	3
99	1	16
	2	34

IV. SIGNAL PROCESSING CONSIDERATIONS

After reviewing the analysis results, it is apparent that the satellite image is not stable over time periods as short as 0.2 sec. The instability of the image could result from three primary sources: satellite motion, telescope jitter, and atmospheric seeing. During the time of data collection, the ATS-6 satellite was a three-axis stabilized geosynchronous satellite. Its reflected light vs. time had been measured by several observers at the ETS and was found to be steady throughout the night, as would be expected from this type of satellite. Therefore satellite motion didn't account for the image instability observed in the data. The fifty frames of data were carefully scrutinized to detect any indication of telescope jitter. Telescope jitter would be detected in the data, if the pixels which contain the satellite image shifted together in the same direction. There is no observable correlation between the maximum amplitude pixel shift direction and the other satellite image pixels' shift direction. Calculating the centroid of the satellite pixels shows that the centroid movement is in random directions rather than in one or two orthogonal directions that would characterize telescope jitter. Atmospheric seeing is therefore the leading candidate as the source of the image instability. Although few measurements of atmospheric seeing with time constants as short as 0.1-0.2 sec, and with two-dimensional spatial resolution as fine as 2"7 have

been reported, one reference³ does report the characteristic image fluctuation seen in this data as atmospheric seeing. Many other reports on atmospheric seeing describe image fluctuation similar to that observed in this data. Atmospheric seeing will affect stellar images in the same fashion. A signal processing system that removes stars by comparing a star field at one time with the same star field at a time 0.2 sec later or longer, must incorporate a technique to reduce false alarms due to the star image instability. These false alarms are located adjacent to star images, and a guard band around each star that inhibits detections would remove these false alarms.

Although the resolution of the telescope is 1"0 or smaller and the pixel resolution is 2"74, the satellite image is in 3 to 7 pixels. Most of the energy is in 2 to 3 pixels, however in 74% of the frames the energy is in 4 to 5 pixels. In more than half the frames the distribution of satellite energy doesn't fit into a circular function. There is little correlation from frame-to-frame of the spatial distribution of satellite energy. This requires that predictions of satellite SNR and system detection performance be modified to incorporate these physical realities.

3. MIKESELL, A.H. et al, "The Scintillation of Starlight", JOSA, 41, 689-695, 1951.

The star and satellite images are in several adjacent pixels (at a 2".74 pixel size), while the noise is only one pixel long. This is an excellent discriminant between the satellite and high amplitude noise that competes with the satellite signal. If a threshold level of 28 was used with the pixels in the fifty frames, the threshold crossings would be due to the satellite (adjacent threshold crossings) or to the noise (isolated threshold crossings). The isolated threshold crossings could then be removed and only the satellite threshold crossings would remain. As the threshold is lowered, noise threshold crossings will be more frequent and false alarms due to noise will start to reappear. At a threshold of 28, 100% of the noise false alarms are removed; at a threshold of 12, 93%; and at a threshold of 8, 84%. The remaining false alarms due to noise can be removed by additional processing (streak, slope, velocity, etc.).

V. CONCLUSIONS

The analysis of a satellite image as seen by a CCD camera mounted on the 31" prime focus at the ETS has been accomplished. The complexity of the image as a function of spatial distribution and time can be clearly seen. The seeing effects were worse than what had previously been expected at the ETS. The utility of having a digitized, stored signal from a sensor before designing a signal processor that uses that particular sensor, is obvious.

The pixel size of a camera is important to the detection system; as too small a pixel will cause the satellite energy to be spread over many pixels and thus reduce the SNR, or if the pixel is too big the night sky will contribute additional noise and also lower the SNR. The image size depends on the atmospheric seeing, therefore, the selection of pixel size depends on the seeing expected at a site. The ideal way to measure seeing at the ETS would be to use an automated version of what was done in this report. The microprocessor based PVDS system would be ideal for this purpose and could provide a short exposure measure of seeing. Using a CCD camera mounted on the cassegrain position of the 31" ETS telescope would provide even more detail of the image intensity distribution. Binary stars could be viewed to eliminate some observing uncertainties and data could be collected on a regular basis.

ACKNOWLEDGMENTS

I would like to acknowledge that R. Martinson designed the digitizer and MODCOMP interface, and that M. MacDonald and L. Eaton installed and tested the equipment at the ETS. E. Rork operated the telescope console, E. Freedman the MODCOMP, and D. Kostishack and N. Pong the CCD camera.

The typing of this report was carefully done by G. Jodice and the figures were pasted-up by J. Surabian.

APPENDIX A

```

10 DIM D$(500) (3621) ! "MOD-HP"
20 CREATE "T11F01",1,10000
30 ASSIGN #1 TO "T11F01"
40 RESET 10
50 WRITE IO 10,5;1
60 WAIT WRITE 10,4;64
70 WAIT WRITE 10,4;203
80 WAIT WRITE 10,4;32+7
90 READ IO 10,4;R4
100 WRITE IO 10,5;0
110 WAIT READ 10,4;R !READY
120 WRITE IO 10,7;0 !TRIGGER
130 !
140 ! SET UP THE 98036A TO INTERRUPT ON INPUT DATA
150 !
160 WRITE IO 10,5;128+4
170 F=IOFLAG+10+
180 S=IOSTATUS+10+
190 PRINTER IS 16
200 PRINT "I/O FLAG 1 ",F,"I/O STATUS 1 ",S
210 READ IO 10,5;R5
220 READ IO 10,6;R6
230 STATUS 10;V
240 PRINT "R4 0 ",R4,"R5 146 ",R5,"R6 248 ",R6,"V 402 ",V
250 I=0 !INDEX FOR WORDS COMING OVER
260 BEEP
270 BEEP
280 TOPEN 10,2 GOSUB Getinput
290 Loop: ! WAIT FOR DATA FROM MODCOMP
300 ON KBD 1 GOTO 310
310 K#=KBD$
320 EX=POS(K$,CHR$(255)&CHR$(21))
330 IF EX<>0 THEN 440
340 GOTO Loop
350 Getinput: ! GET INPUT FROM INTERFACE
360 I=I+1
370 IF I>500 THEN Loop
380 D$(I)=TBUF$
390 IF POS(D$(I),CHR$(5)) THEN OUTPUT 10;CHR$(6)
400 PRINTER IS 16
410 PRINT I
420 WAIT 900
430 RETURN
440 FOR I=1 TO 500
450 PRINT #1;I,D$(I)
460 NEXT I
470 END

```

"MOD-HP"

APPENDIX A

```

10  FOR W=10 TO 50                                ! "READ"
20  DIM D$(200)(320),P(321),O(200),F(1024)
30  X$=VAL$(W)
40  W1$="T11F"&X$:F8"
50  W2$="T11D"&X$:T15"
60  ASSIGN #1 TO W1$
70  ON END #1 GOTO 680
80  St=0
90  D=0
100 FOR I=1 TO 200                                ! READ STRING FROM TAPE (I)
110 READ #1;I,D$(I)
120 D$(I)=D$(I)[1,319]&CHR$(13)
130 PRINTER IS 16
140 FOR J=1 TO 200                                ! BREAK STRING INTO VARIABLES (J)
150 IF J>1 THEN 290
160 P(1)=POS(D$(I),CHR$(13))
170 Lf=POS(D$(I)[1,P(1)],CHR$(10))
180 L=LEN(D$(I)[1,P(1)])
190 IF Lf<>0 THEN 240
200 IF L<2 THEN 280
210 O(1)=VAL(D$(I)[1,P(1)])
220 D=1
230 GOTO 290
240 IF L<3 THEN 280
250 O(1)=VAL(D$(I)[2,P(1)])
260 D=1
270 GOTO 290
280 O(1)=-1
290 J1=J+1
300 P(J1)=POS(D$(I)[P(J)+1],CHR$(13))
310 IF P(J1)=0 THEN 480
320 P(J1)=P(J1)+P(J)
330 L=LEN(D$(I)[P(J)+1,P(J1)])
340 IF L<4 THEN 460
350 Lf=POS(D$(I),CHR$(10))
360 IF Lf<>0 THEN 390
370 G=1
380 GOTO 430
390 G=2
400 D$(I)[P(J)+G,P(J1)]=TRIM$(D$(I)[P(J)+G,P(J1)])

```

"READ"

APPENDIX A

```

410 L=LEN(D$(I)(P(J)+G,P(J1)))
420 IF L<6 THEN 460
430 O(J1)=VAL(D$(I)(P(J)+G,P(J1)))
440 D=D+1
450 GOTO 470
460 O(J1)=-1
470 GOTO 500
480 S=D
490 GOTO 510
500 NEXT J
510 Ss=0
520 Cs=St+1-Ss
530 Cf=St+S
540 D=0
550 IF (O(1)=-1) AND (S=0) THEN 670
560 FOR K=Cs TO Cf
570 L=K-St+Ss
580 IF O(L)=-1 THEN 600
590 GOTO 640
600 L=L+1
610 Cf=Cf-1
620 Ss=Ss+1
630 GOTO 580
640 F(K)=O(L)
650 NEXT K
660 St=St+S
670 NEXT I
680 FOR M=1 TO 32
690 FOR N=M TO 1023+M STEP 32
700 IMAGE #,4D
710 PRINT USING 700;F(N)
720 NEXT N
730 PRINT LIN(1)
740 NEXT M
750 ON END #2 GOTO 790
760 CREATE W2$,1,9000
770 ASSIGN #2 TO W2$
780 PRINT #2;F(*)
790 NEXT W
800 END

```

"READ" (Cont.)

```

10 FOR I=10 TO 50
20 I$=VAL$(I)
30 T$="T11D"
40 P1$=":T15"
50 P2$=":F"
60 F1$=T$&I$&P1$
70 F2$=T$&I$&P2$
80 PRINT F1$,F2$
90 COPY F1$ TO F2$
100 NEXT I
110 END

```

"COPY"

APPENDIX B

```

10 PRINT "FRAME"," ", " ", "POSITION" ! "MAXAMP"
20 FOR I=10 TO 50
30 DIM F(1024)
40 I$=VAL$(I)
50 V$="T11V"&I$&":F"
60 ASSIGN #1 TO V$
70 ON END #1 GOTO 100
80 READ #1;F(*)
90 Max=0
100 FOR M=1 TO 32 ! OUTPUT DATA (M)
110 FOR N=M TO 1023+M STEP 32
120 IF F(N)>Max THEN 140
130 GOTO 160
140 Max=F(N)
150 Max=N
160 NEXT N
170 NEXT M ! NEXT M
180 PRINT V$,"MAXIMUM AMPLITUDE",Max,Max
190 PRINT LIN(1)
200 NEXT I
210 END

```

"MAXAMP"

```

10 PRINTER IS 16 ! "FREDIS"
20 PRINT PAGE;" This program allows the user to enter a frame of data and ha
ve a"
30 PRINT " frequency distribution computed and drawn."
40 PRINT LIN(1);" After the distribution, a beep will sound. The chart will
"
50 PRINT "remain on the screen and the program will halt until you press CONT
."
60 PRINT "This will give you time to digest the information on the screen."
70 PRINT LIN(1);" If you want the output of this program dumped from the CRT
"
80 PRINT "to the internal thermal printer, then answer Y to the question below
."
90 PRINT "If you don't want hardcopy answer N. Then press CONT."
100 INPUT "Do you want hardcopy (Y/N)?",A$
110 IF UPC$(A$)="Y" THEN Yhard
120 IF UPC$(A$)="N" THEN Nhard
130 BEEP
140 GOTO 100
150 Yhard: Hardcopy=1
160 GOTO 180
170 Nhard: Hardcopy=0
180 N=224
190 CALL Driver(N,Hardcopy)
200 END
210 SUB Driver(N,Hardcopy)
220 RANDOMIZE
230 DIM A(N),L$(N),Units$(30),V(1024)

```

"FREDIS"

APPENDIX B

```

240 INPUT "Which frame 01 to 50?",Fr$
250 V$="T11V"&Fr$&":F"
260 ASSIGN #1 TO V$
270 READ #1;V(*)
280 Max=V(1)
290 FOR J=1 TO 1024
300 Max=MAX(Max,V(J))
310 NEXT J
320 MAT A=ZER
330 High=0
340 Lhigh=4096
350 FOR K=1 TO 1024
360 IF (V(K)>High) AND (V(K)<Lhigh) THEN 380
370 GOTO 390
380 High=V(K)
390 NEXT K
400 FOR J1=1 TO 1024
410 IF V(J1)=High THEN 430
420 GOTO 440
430 A(High)=A(High)+1
440 NEXT J1
450 IF High=0 THEN 490
460 Lhigh=High
470 High=0
480 GOTO 350
490 PRINTER IS 0
500 PRINT
510 PRINT V$
520 PRINT "MAX AMP"
530 PRINT Max
540 PRINTER IS 16
550 FOR I=20 TO Max STEP 20
560 L$(I)=VAL$(I)
570 NEXT I
580 Units$="Number of Pixels"
590 Title$="Amplitudes"
600 N=Max
610 CALL Bar(A(*),L$(*),N,Units$,Title$)
620 BEEP
630 PAUSE
640 IF Hardcopy=1 THEN DUMP GRAPHICS
650 EXIT GRAPHICS
660 SUBEXIT
670 SUB Bar(A(*),L$(*),N,Units$,Title$)
680 PLOTTER IS "GRAPHICS"
690 GCLEAR
700 GRAPHICS
710 PEN 1
720 Sum=0

```

! ENTER THE TITLES

"FREDIS" (Cont.)

APPENDIX B

```

730 Max=A(1)
740 FOR I=1 TO N
750 Sum=Sum+A(I)
760 Max=MAX(Max,A(I))
770 NEXT I
780 Ly=LGT(Max)
790 SETGU
800 LOCATE 15,120,40,95          ! Set screen boundaries and scale
810 CLIP 0,123,40,100
820 MOVE 61.5,97
830 LORG 5
840 LABEL USING 850;Title$
850 IMAGE #,K
860 SCALE 0,N+.5,0,Max+Max/10
870 Xtic=0                      ! No tic marks on horizontal axis
880 Testytic=FRACT(Ly)+(Ly<0)
890 Ytic=10^(INT(Ly)-1)*(1+1.5*((Testytic>.39794) AND (Testytic<.69897))+4*((Te
stytic>=.69897) AND (Testytic<=.87506))+6.5*(Testytic>.87506))
900                             ! Compute the vertical tic marks
910 CALL Laxes(Xtic,Ytic,0,0,1,1,2,0,N+.5,0,Max+Max/10)
920 LORG 4
930 FIXED 1
940 FOR I=0 TO N
950 MOVE I-.5,0
960 IPLOT 0,A(I),-1            ! Draw the bar for the ith data item
970 IPLOT 1,0
980 IPLOT 0,-A(I)
990 MOVE I,A(I)
1000 NEXT I
1010 DEG
1020 IMAGE K
1030 LDIR 90                   ! Rotate the label 90 degrees
1040 SETGU
1050 LORG 5
1060 MOVE 5,70
1070 LABEL USING 1020;Units$   ! Write the display units being
1080                             ! used along the vertical axis
1090 CLIP 0,123,0,100
1100 SETUU
1110 FOR I=1 TO N

```

"FREDIS" (Cont.)

APPENDIX B

```

1120 MOVE I,-Max/20
1130 LORG 8
1140 PEN 1
1150 LDIR 90
1160 LABEL USING 1020;L$(I)
1170 NEXT I
1180 BEEP
1190 SUBEXIT
1200 SUB Laxes(Xtic,Ytic,Xorg,Yorg,Xmaj,Ymaj,Minticsize,Xmin,Xmax,Ymin,Ymax)
1210 IF (Xmin>Xmax) OR (Ymin>Ymax) THEN SUBEXIT
1220 Xfudge=.02*(Xmax-Xmin)
1230 Yfudge=.02*(Ymax-Ymin)
1240 AXES Xtic,Ytic,Xorg,Yorg,Xmaj,Ymaj,Minticsize
1250 DEG
1260 IF NOT Xtic THEN Labely
1270 Labelx:IF SGN(Xtic)=-1 THEN Parx
1280 LDIR 90
1290 LORG 8
1300 GOTO 1330
1310 Parx: LDIR 0
1320 LORG 6
1330 FOR I=Xorg TO Xmax STEP ABS(Xtic)
1340 MOVE I,Yorg-Yfudge
1350 LABEL USING 1360;I
1360 IMAGE #,K
1370 NEXT I
1380 Labely: IF NOT Ytic THEN SUBEXIT
1390 IF SGN(Ytic)=-1 THEN Pary
1400 LDIR 0
1410 LORG 8
1420 GOTO 1450
1430 Pary: LDIR -90
1440 LORG 6
1450 FOR I=Yorg TO Ymax STEP ABS(Ytic)
1460 MOVE Xorg-Xfudge,I
1470 LABEL USING 1360;I
1480 NEXT I
1490 SUBEXIT

```

! Rotate the labels 90 degrees

"FREDIS" (Cont.)

APPENDIX B

```

10    DIM F(1024)                                ! "PEAKS"
20    F$="T11V22:F"
30    L=19
40    PRINTER IS 0
50    PRINT F$,"PEAKS ABOVE",L
60    PRINT
70    PRINT "ROW","COLUMN","POSITION","AMPLITUDE"
80    PRINTER IS 16
90    ASSIGN #1 TO F$
100   ON END #1 GOTO 120
110   READ #1;F(*)
120   FOR M=1 TO 32                                ! OUTPUT DATA (M)
130   C=0
140   FOR N=M TO 1023+M STEP 32
150   C=C+1
160   IF F(N)>L THEN 200
170   IMAGE #,4D," "
180   PRINT USING 170;F(N)
190   GOTO 250
200   IMAGE #,4D,"*"
210   PRINT USING 200;F(N)
220   PRINTER IS 0
230   PRINT M,C,N,F(N)
240   PRINTER IS 16
250   NEXT N
260   PRINT LIN(1)
270   NEXT M                                ! NEXT M
280   PRINTER IS 0
290   PRINT LIN(3)
300   END

```

"PEAKS"

APPENDIX B

```

10  DIM F(1024)                                ! "DATAST"
20  INPUT "AMPLITUDES HIGHER THEN",L
30  FOR J=10 TO 50
40  PRINT LIN(3)
50  PRINT "FRAME NUMBER",J
60  PRINT LIN(3)
70  S$=VAL$(J)
80  ASSIGN #1 TO "T11V"&S$&":F"
90  ON END #1 GOTO 110
100 READ #1;F(*)
110 FOR M=1 TO 32                                ! OUTPUT DATA (M)
120 FOR N=M TO 1023+M STEP 32
130 IF F(N)>L THEN 170
140 IMAGE #,4D," "
150 PRINT USING 140;F(N)
160 GOTO 190
170 IMAGE #,4D,"*"
180 PRINT USING 170;F(N)
190 NEXT N
200 PRINT LIN(1)
210 NEXT M                                       ! NEXT M
220 NEXT J
230 END

```

"DATAST"

APPENDIX B

```

10  INPUT "LEVEL",L
20  FOR I=10 TO 50
30  DIM F(1024)
40  I$=VAL$(I)
50  V$="T11V"&I$:F"
60  ASSIGN #1 TO V$
70  ON END #1 GOTO 90
80  READ #1;F(*)
90  GRAPHICS
100 LINE TYPE 1
110 SCALE 0,12,0,15
120 FOR M=15 TO 25
130 C=0
140 FOR N=M TO 1023+M STEP 32
150 C=C+1
160 IF F(N)<L THEN 200
170 MOVE M-15,C
180 LABEL F(N)
190 IF C=13 THEN 210
200 NEXT N
210 NEXT M
220 WAIT 3000
230 GCLEAR
240 SCALE 0,13,0,230
250 FOR M=19 TO 22
260 WAIT 200
270 C=0
280 GCLEAR
290 MOVE 0,L
300 LINE TYPE 4
310 DRAW 13,L

```

! "FRAME"

! DATA FROM DISC

! LABEL AMPLITUDES

! PLOT COLUMNS

! PLOT LEVEL

"FRAME"

APPENDIX B

```
320  LINE TYPE 1
330  MOVE 1,150
340  LABEL "COLUMN"
350  MOVE 0,0
360  FOR N=M TO 1023+M STEP 32
370  C=C+1
380  PLOT C-1,F(N)
390  PLOT C,F(N)
400  NEXT N
410  WAIT 500
420  MOVE 0,0
430  NEXT M
440  GCLEAR
450  MOVE 0,0
460  FOR N1=239 TO 335 STEP 32
470  MOVE 0,L
480  LINE TYPE 6
490  DRAW 13,L
500  LINE TYPE 1
510  MOVE 1,150
520  LABEL "ROW"
530  MOVE 0,0
540  FOR M=1 TO 13
550  N=N1+M
560  PLOT M-1,F(N)
570  PLOT M,F(N)
580  NEXT M
590  MOVE 0,0
600  WAIT 500
610  GCLEAR
620  NEXT N1
630  NEXT I
640  END
```

! PLOT ROWS
! PLOT LEVEL

"FRAME" (Cont.)

APPENDIX C

5	7	0	7	14	1	8	15	0	3
16	24	19	16	16	1	16	16	12	3
9	25	48	16	16	0	20	33	28	7
12	127	115	7	7	12	79	156	16	15
0	0	13	7	6	0	5	16	12	0
0	15	2	7	3	12	7	0	0	0

FRAME 1

7	8	12	7	6
7	14	47	16	16
0	28	35	20	8
0	56	158	23	28
0	8	19	7	0
7	4	5	16	4

FRAME 3

0	0	3	15	7
15	20	16	8	1
7	24	38	16	7
0	127	121	16	12
0	11	22	16	15
0	4	13	4	0

FRAME 5

FRAME 2

5	16	6	7	1
7	16	15	16	3
0	32	48	15	15
7	120	160	12	6
4	7	16	20	1
3	32	8	3	1

FRAME 4

11	0	0	12	0
7	16	28	0	12
0	31	38	13	8
0	159	125	16	8
7	16	28	14	4
1	7	1	4	12

FRAME 6

SATELLITE IMAGE FRAMES 1-6

APPENDIX C

0	1	6	7	7	12	16	12	14	0
16	16	13	4	6	16	8	16	16	12
12	31	32	23	16	0	24	31	7	15
6	172	120	3	4	0	112	149	16	8
0	12	31	3	7	7	0	25	3	4
20	0	0	0	0	4	0	6	4	3

FRAME 7

1	3	15	7	15
0	14	24	14	12
1	24	31	7	0
12	156	111	16	12
0	15	28	12	7
0	7	7	14	7

FRAME 9

1	12	14	3	4
11	15	7	12	0
0	32	40	18	1
0	182	112	17	7
6	15	19	0	8
16	1	0	1	7

FRAME 11

FRAME 8

6	4	16	4	7
4	15	16	15	8
4	32	28	26	7
8	185	96	14	0
0	12	12	6	4
1	8	3	0	4

FRAME 10

24	7	1	8	12
0	14	16	7	15
0	28	24	24	12
7	163	95	4	0
7	36	31	4	12
11	2	0	0	7

FRAME 12

SATELLITE IMAGE FRAMES 7-12

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