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RADC SEISMIC CLASSIFIER DESIGN

Albert H. Proctor, et al

Rome Air Development Center
Griffiss Air Force Base, New York

August 1973

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FOREWORD

This in-house technical report describes work conducted under the Advanced Development Program, Project 692B, Advanced Sensor Technology. The report has been reviewed by Mr. Robert Curtis, Project Engineer, and has been designated as unclassified material.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

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This report describes the design and evaluation of seismic classifiers for distinguishing humans, heavy trucks, armored personnel carriers, helicopters, and C-131 aircraft. The data used to develop these classifiers consisted of many digitized seismometer responses to each of the intrusion targets and was collected by RADC (DCTI) at the West Lee Test Site. RADC (ISCP) analyzed this waveform data and extracted an initial set of 48 features. The On-Line Pattern Analysis and Recognition System (OLPARS) was then used to

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20. ABSTRACT (continued)

develop several seismic classifier designs which are based on different subsets of the initial 48 features.

ABSTRACT

This report describes the design and evaluation of seismic classifiers for distinguishing among humans, heavy trucks, armored personnel carriers, helicopters, and C-131 aircraft. The data used to develop these classifiers consisted of many digitized seismometer responses to each of the intrusion targets and was collected by the Sensor Development Section of the Surveillance and Control Division (DCTI) at the West Lee Test Site. The Interactive Processing Section of the Information Sciences Division (ISCP) analyzed this waveform data and extracted an initial set of 48 features. The On-Line Pattern Analysis and Recognition System (OLPARS) was then used to develop several seismic classifier designs which are based on different subsets of the initial 48 features.

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SECTION I

INTRODUCTION

This report documents the first attempt to design linear classification logic based on seismic waveform data collected at RADC's West Lee Test Site. This decision logic was designed to distinguish among humans, heavy trucks, armored personnel carriers, helicopters, and C-131 aircraft. The classifier design procedure employed the following sequence of tasks:

- Data Collection
- Development of an Interactive Graphics Tool for Data Analysis
- Data Analysis
- Development of an Automatic Segmentation Algorithm
- Feature Hypothesis
- Feature Extraction
- Feature Evaluation
- Classification Logic Design
- Testing Classification Logic with Independent Test Data

This effort was conducted in support of Project 692B of the Advanced Sensor Development Program. The seismic classifier designs discussed in this report are based entirely on data collected by the Sensor Development Section at its West Lee Test Site and made available to the Interactive Processing Section for completion of the remaining tasks of the classifier design procedure.

SECTION II

DATA COLLECTION AND CONVERSION

The seismic data base used to design the October 1st Instrusion Classifier was collected and digitized by DCTI at the West Lee Test Site in the first quarter of 1972. The five classes of intrusions observed were helicopters, armored personnel carriers, C-131 aircraft, heavy trucks, and humans. Background data was also collected and used to determine a suitable detection threshold for the turn-on criteria.

The test procedure, following calibration, consisted of running the intruders along one of five specific paths at several known constant speeds. Each intrusion was repeated with each speed, path, and direction as a check on repeatability. Each intrusion involved only one object, with the exception of humans where there were multiple as well as single intrusions. Each sensor was a three-axis low frequency geophone, Geo-Space Model VLF-LP-3D, with one vertical and two horizontal axes (parallel and perpendicular to the intrusion paths).

As the intrusions were taking place, the seismic transducer signals were relayed by underground cables to the site control center, digitized, and recorded directly on digital tapes in the BAMKI format. This format is capable of packing 45 simultaneous sensor waveforms on the tape. Since the experiment involved 3 three-axis geophones, the BAMKI format sparsely packed 9 of 45 possible channels of digitized waveforms on each tape. Each file on the tape contained one intrusion run, consisting of a number of 320 sample records. First, the data was filtered at 500 Hz and then digitized at 1000 samples per second. Each sample value was quantized to any of 1023 values ranging from -2044 to +2044 in steps of 4. The corresponding strip chart range was ± 10 volts maximum. Each test usually produced three or four magnetic tapes. Although the BAMKI format was able to record all the sensor data in real time, it caused many tape read problems which delayed processing the tape at the Honeywell 635.

While the BAMKI format offered some advantages, it also has many deficiencies. The time required to unpack the 45 simultaneous data channels made the BAMKI format unwieldy for quick access and analysis of the data. These tapes contained aborted runs which should have been deleted but were mixed in with the valid runs. Also a software bug in the PDP-9 magnetic tape driver resulted in a high rate of parity errors when we tried to read these tapes at the Honeywell 635. For these reasons, the seismic data was stripped from the BAMKI tapes, edited, and formatted more simply on other tapes. These new tapes presented the advantages of clean, parity error free data and a simple format which made the data easily accessible.

SECTION III

SEGMENTATION

In order to analyze "clean" data, i.e., data which is truly characteristic of each target class, a criterion was developed to cut data from each run and save only a meaningful portion of the run. This segmentation operation is useful because (1) it presents only the statistically significant data to the decision making stage of logic, thus promising higher recognition rates, and (2) it reduces the amount of time the sensor must be processing data for decisions, thus reducing power requirements and extending sensor life.

Development of a segmentation procedure requires one major step in common with feature design: extensive visual study of the waveforms on hardcopy or graphic displays. In a non-trivial problem, valid features can't be selected and designed until the engineers have a very thorough knowledge of the signal characteristics of each class, and optimally a thorough understanding of the physics behind these characteristics. This in-depth knowledge of the data should allow the design of a reasonable segmentation algorithm and criterions. To gain this required information, signal waveforms were recreated and displayed on interactive graphics devices, such as the CDC 1704 Digigraphics Display and the Tektronics 4002A Graphics Terminal. Estimates of the energy spectrum, using the Fast Fourier Transform, were computed and displayed. Displays and hardcopies of these waveforms and their power spectrums were the tools which enabled the designers to view and analyze the behavior of each class of seismic waveforms.

Since data sementation in the real intrusion detection system will probably be done at the sensor, simplicity and efficiency are of utmost importance. The procedure decided upon begins with calculating the mean value of the entire run, then subtracting that mean from the run (realizable in the field by appropriate capacitive coupling in the sensor's analog output) to eliminate any DC bias. The signal is then full-wave rectified. The average value of each second of the rectified signal is then computed, and a segment of valid data is defined as one for which this one-second average exceeds some threshold θ for five consecutive seconds.

Symbolically, given the samples f_i of a complete intrusion run, the average absolute value, S_k, will be calculated for each consecutive one-second window.

$$S_k = \frac{1}{n} \sum_{i=1}^{n} |f_{nk+i} - \hat{m}|, \text{ for the } k^{th} \text{ second}$$

where $k = 0, 1, \ldots, L-1$

L = the number of seconds in the run

$\hat{m} = \frac{1}{N} \sum_{i=1}^{N} f_i$ = the estimated mean of the run

n = number of samples per one second window and

N = number of samples in complete run

Segment and save the data in the five second interval if and only if S_k is greater than the threshold θ for five consecutive one second windows.

Obviously, strong signals, from either large sources or intrusions near to sensors, will result in a greater number of five-second segments. This is desirable, since these stronger signals represent a better signal-to-noise ratio.

The specific segment lengths and thresholds were based on observation and experimentation. The five-second length precluded the acceptance of spurious bursts of noise or brief signal transients as good data. Also, the second-by-second threshold requirement during the five seconds assured that the entire segment was sufficiently strong, instead of having brief but significant lapses into noise. The possibility of triggering this classifier with impulsive noise, such as explosions, gun-fire, etc. is not likely unless the noise were highly repetitive and sustained over a five second interval.

The threshold, however, required the collection of some statistics. The objective was a threshold which would overlook as much noise as possible, yet which would locate as much valid intrusion data as possible. We selected three representative runs from each data class (including strictly noise runs) and compiled tables of the total time segmented from each run by a variety of thresholds. We then observed, via graphics, the five-second segments selected by thresholds of 20, 30, and 40, and decided that $\theta = 20$ afforded the best balance between noise rejection and significant data segmentation.

SECTION IV

DATA ANALYSIS

Classifier design requires the analysis of graphic representations of digitized waveforms and their transforms for the purpose of hypothesizing measurements or features which may aid in the discrimination of target classes. This is one of the most important steps in the waveform classification problem because the quality of the selected features directly influences the classifier's performance.

Before data analysis can begin, the researcher must develop or have access to a system which will display his data in some graphic form. At the start of ISCP's involvement in the sensor program, in-house personnel developed a waveform analysis software system on the CDC-1700/Digigraphics System. This waveform analysis tool enabled a user to randomly access and display waveforms or waveform segments and perform operations on the data, such as rectifying, integrating, measuring zero crossings, calculating power spectrums, etc. The major deficiency in this system was its lack of a hard copy capability. Unfortunately, shortly after this interactive graphics software system was operational, the CDC-1700/Digigraphics System was phased out.

Effort was redirected to develop a similar interactive capability on the Honeywell 635, using a remote storage tube terminal as the graphics console. Soon after this development started, it was evident that the development time required for an interactive system in the GECOS III multiprogramming environment was not compatible with the schedule for developing this classifier.

Pattern Analysis and Recognition Corporation (PAR) then made their sensor analysis factility [3] available for this effort.

PAR's sensor analysis facility is designed to analyze acoustic data and is built around a NOVA 800 computer with a 9-track tape unit, card reader, 128K word disk, and a Tektronix 4002A display with hardcopy.

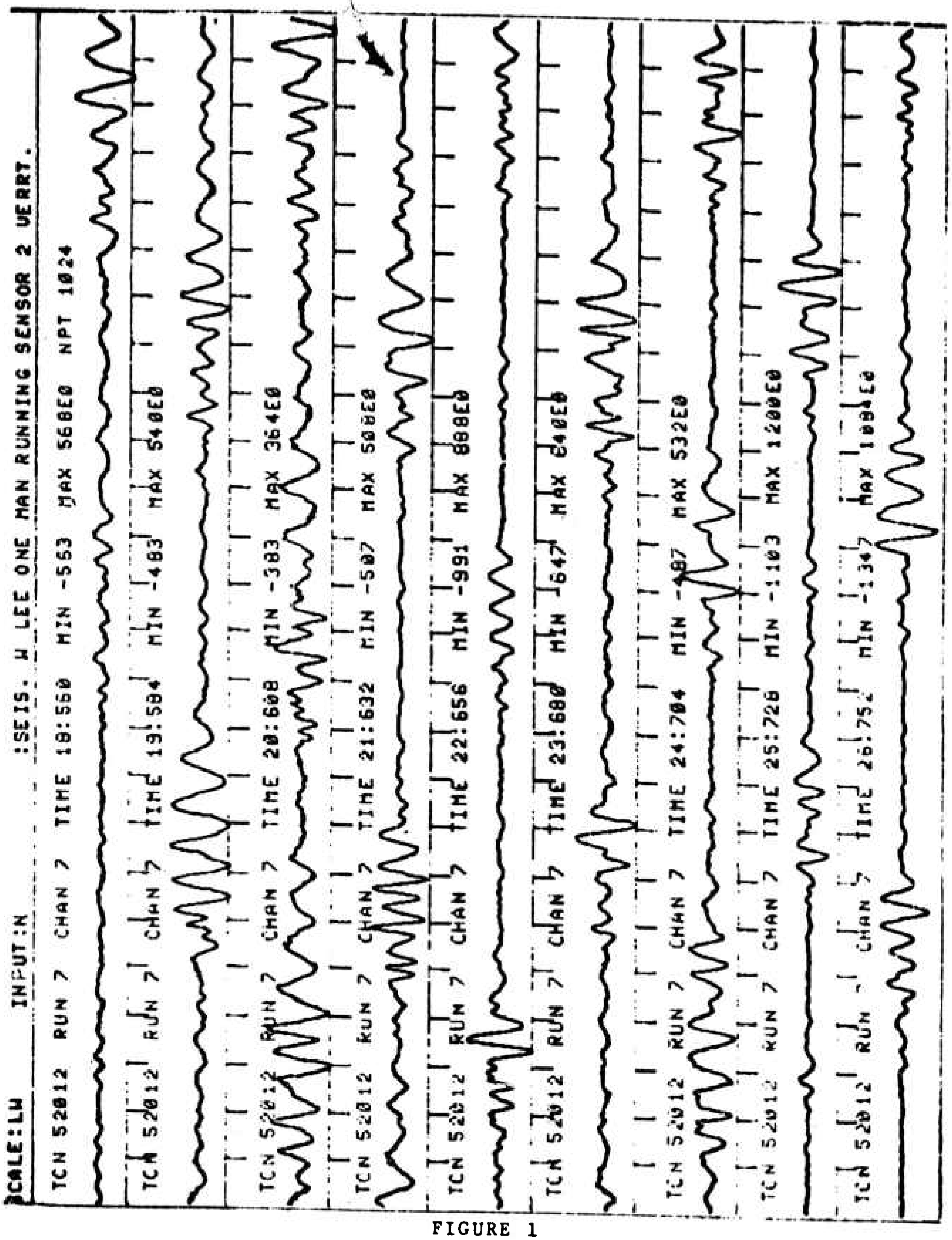
Two software changes had to be made before we could use PAR's facility. First, the BAMKI data stripping program was modified to generate its output on the Honeywell 635's only available nine-track tape drive because the PAR facility's only tape drive was a nine-track unit. Second, PAR modified their system by adding a new input routine to it, which could read the nine-track version of our simplified data format.

Once we were able to process seismic data from a BAMKI tape, using PAR's facility, a production procedure was set u . Three copies of the BAMKI tapes could be left to be processed at night by the 635. Since the Honeywell 635 has only one available nine-track tape drive, only one copy of the BAMKI stripping program was able to execute at a time. Often the BAMKI programs were delayed from executing for long periods of time because the 635's only nine-track tape drive was previously assigned to long batch jobs.

Time domain waveforms and power spectrums for at least one complete run of each intrusion class variation were displayed and hardcopied at the sensor analysis facility. For ground vehicles, these class variations were the different vehicle velocities recorded along each of these paths. For aircraft, these class variations were the different altitudes of the flyovers and the different velocities recorded for each altitude. The class variations for humans were in the number of intruders, path of intrusion, and velocity (feet per second). Examples of time waveform and power spectrum hardcopies for each class are shown in Figures 1 thru 10.

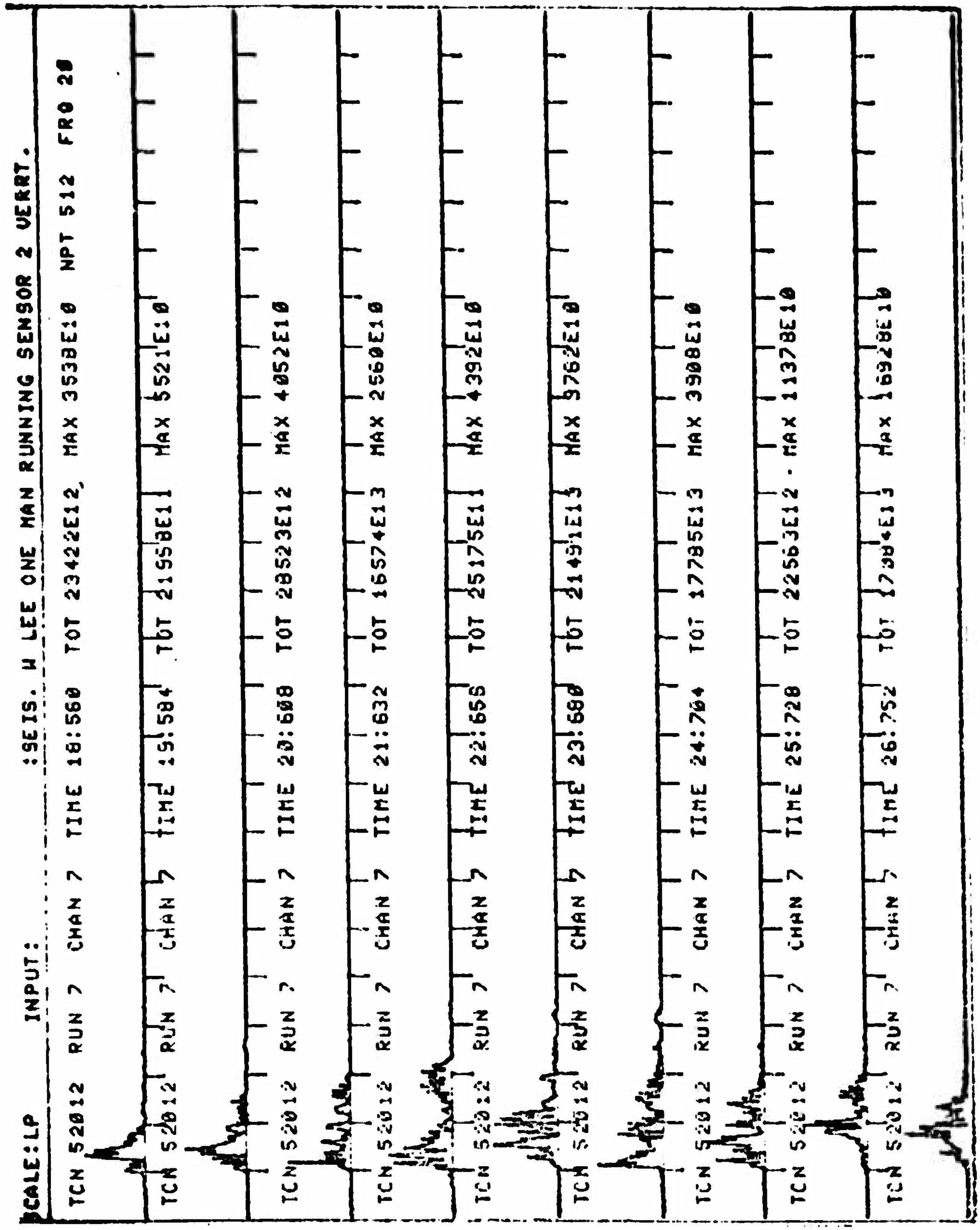
After the hardcopies of the selected intrusion runs were generated, they were added to the hardcopy library. This library consisted of two note books, one containing the time domain waveforms and the other containing power spectrum plots.

A team of ISCP engineers analyzed the data plots contained in the hardcopy library. By comparing the various plots of the intrusion classes looking for within-class similarities and between-class differences, this team compiled a list of 48 potential features. One very useful data plot used in our analysis was the 40-line power spectrum in which each line represents the power spectrums of consecutive one-second windows. The representation of the data in this format enables the analyst to view and compare changes in the power spectrum throughout the duration of the intrusion. Examples of the 40-line power spectrum are shown in Figures 11 and 12. Figure 11 shows the 40-line power spectrum plot of a C-131 aircraft on a radial path over the test site. The frequency shift in the main peaks of the power spectrum indicates when the C-131 responses went through a doppler shift. A similar data display for the UH-1F helicopter, shown in Figure 12, indicates that the doppler shift is not as pronounced for the helicopter as it was for the C-131.



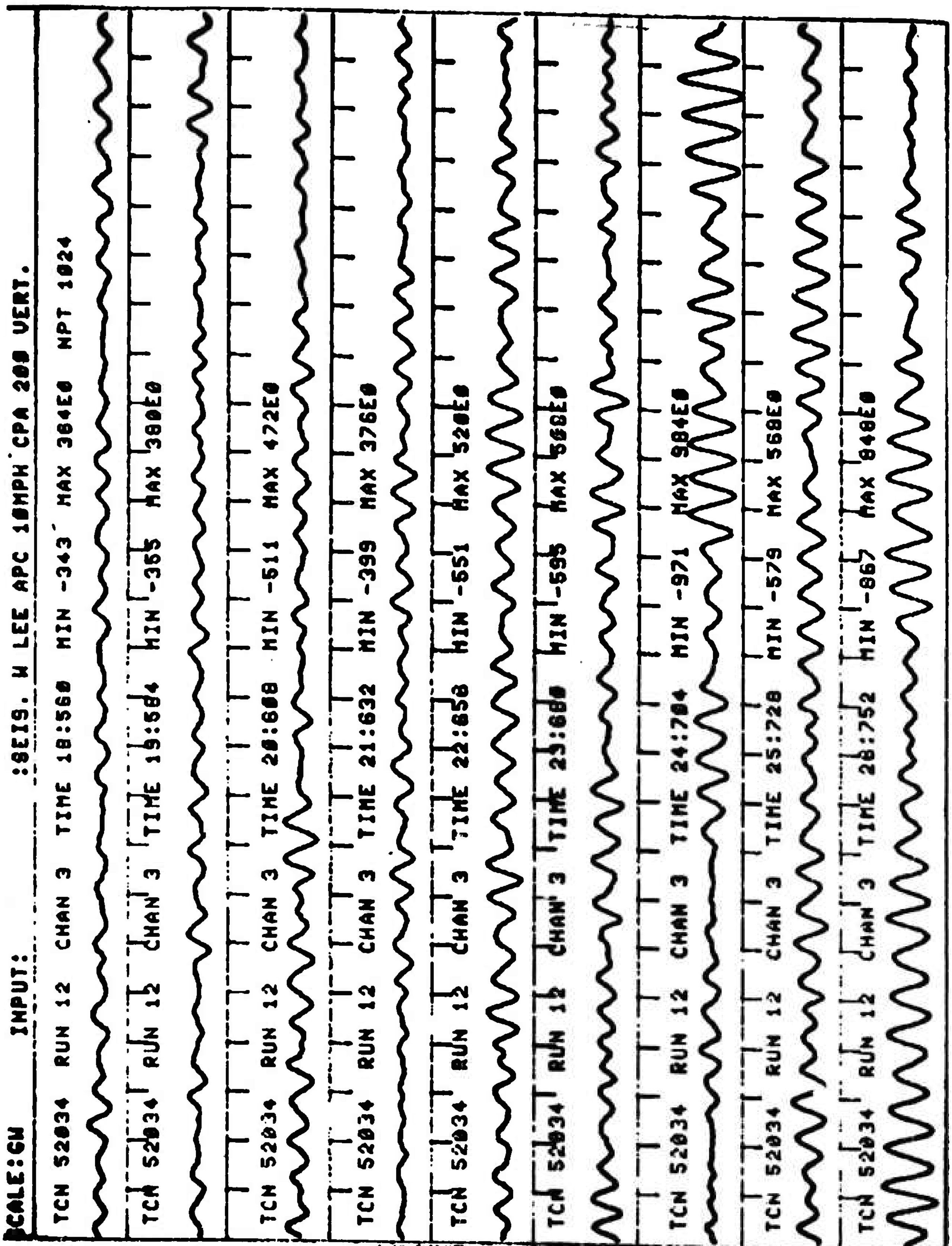
SAMPLE WAVEFORM OF ONE MAN RUNNING

FIGURE 1



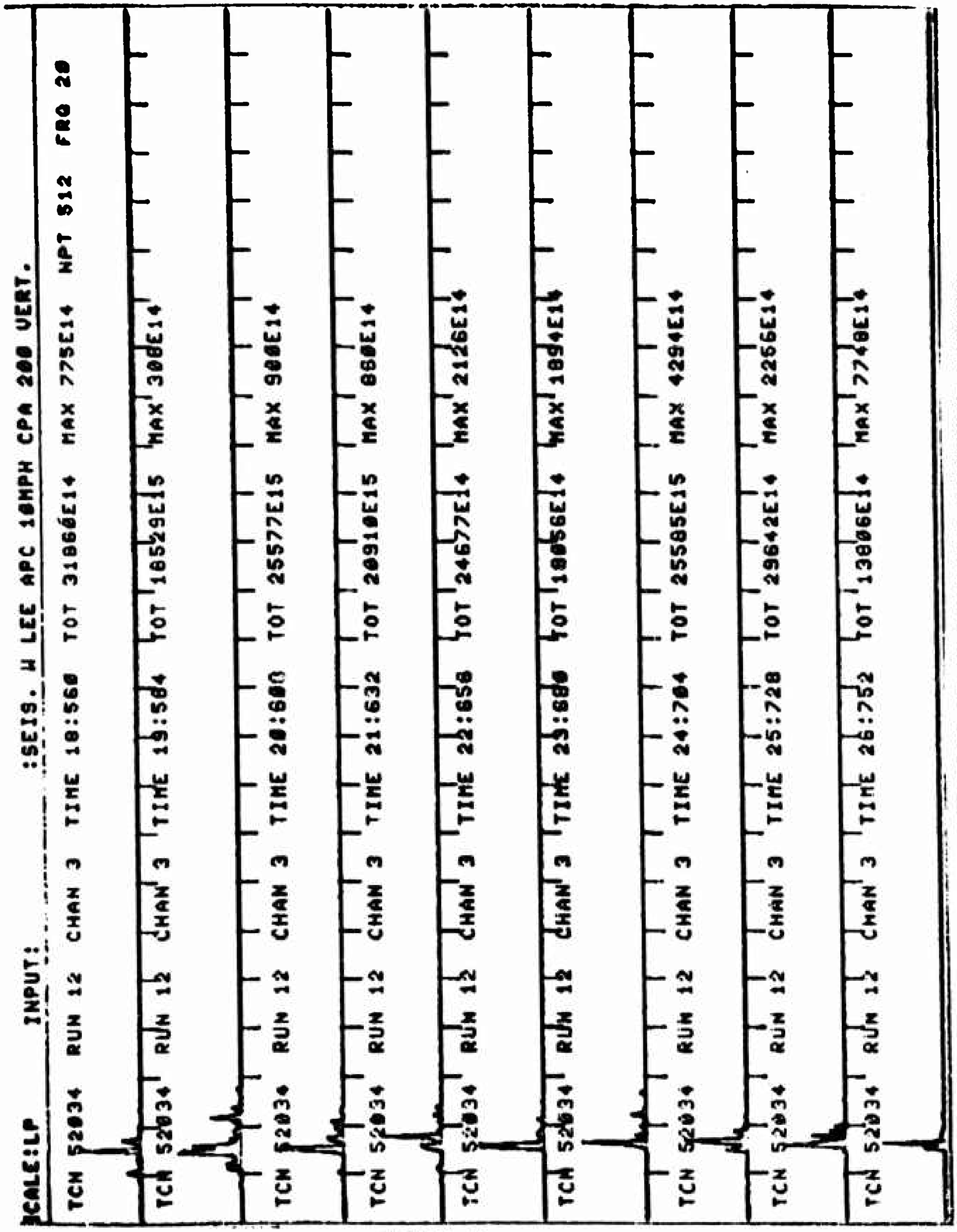
SAMPLE POWER SPECTRUM OF ONE MAN RUNNING

FIGURE 2



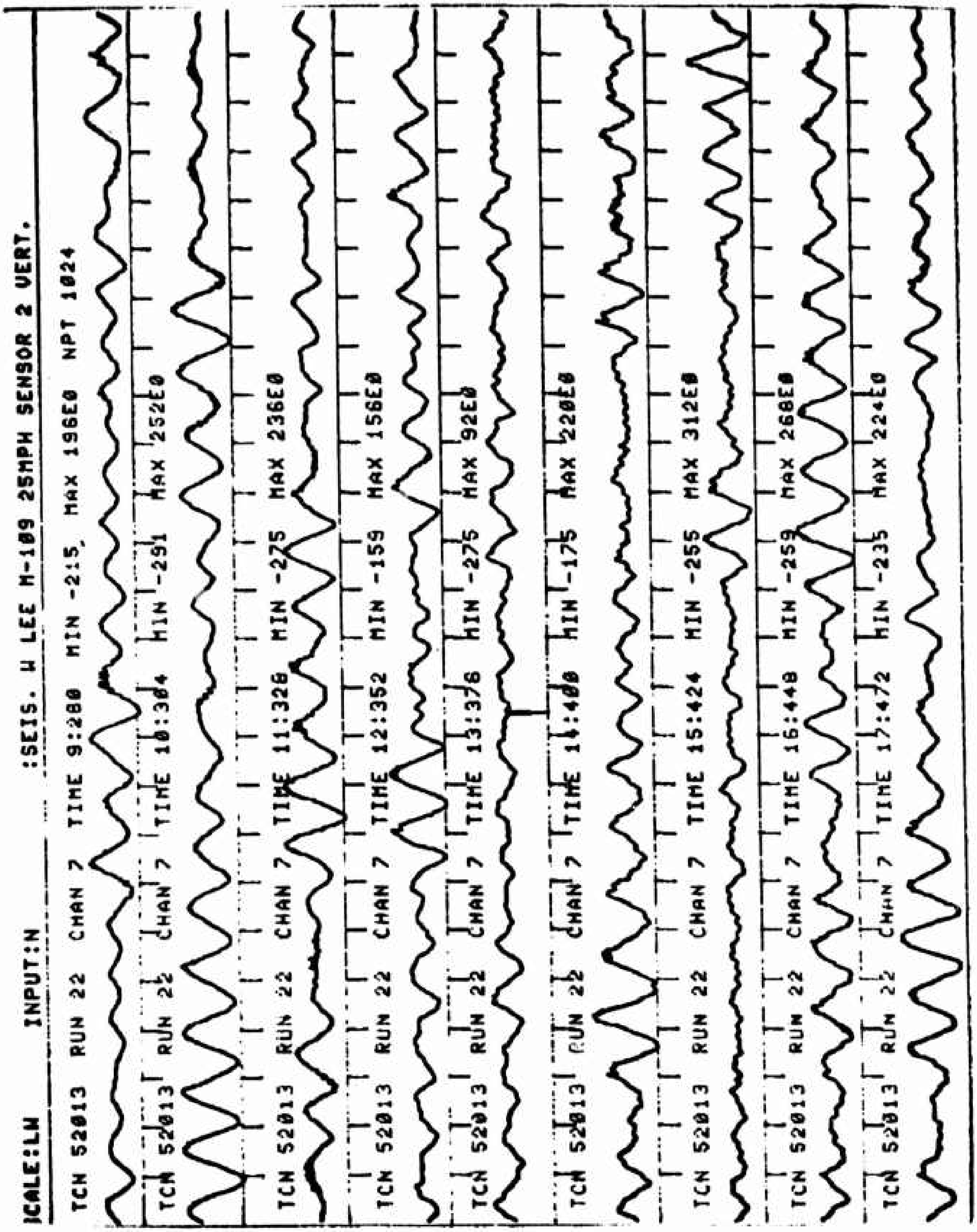
SAMPLE WAVEFORM OF AN ARMOURED PERSONNEL CARRIER

FIGURE 3



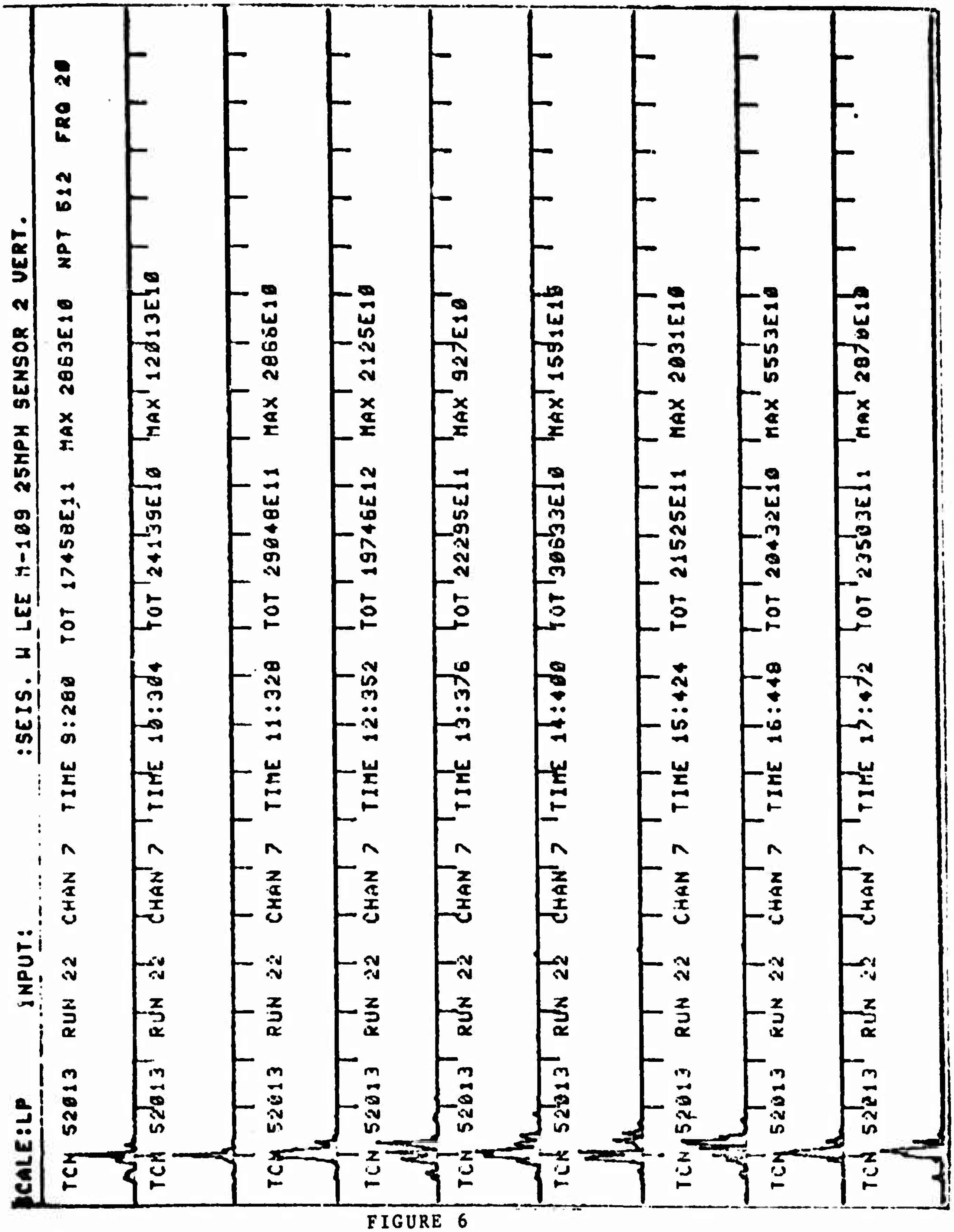
SAMPLE POWER SPECTRUM OF AN ARMOURED PERSONNEL CARRIER

FIGURE 4



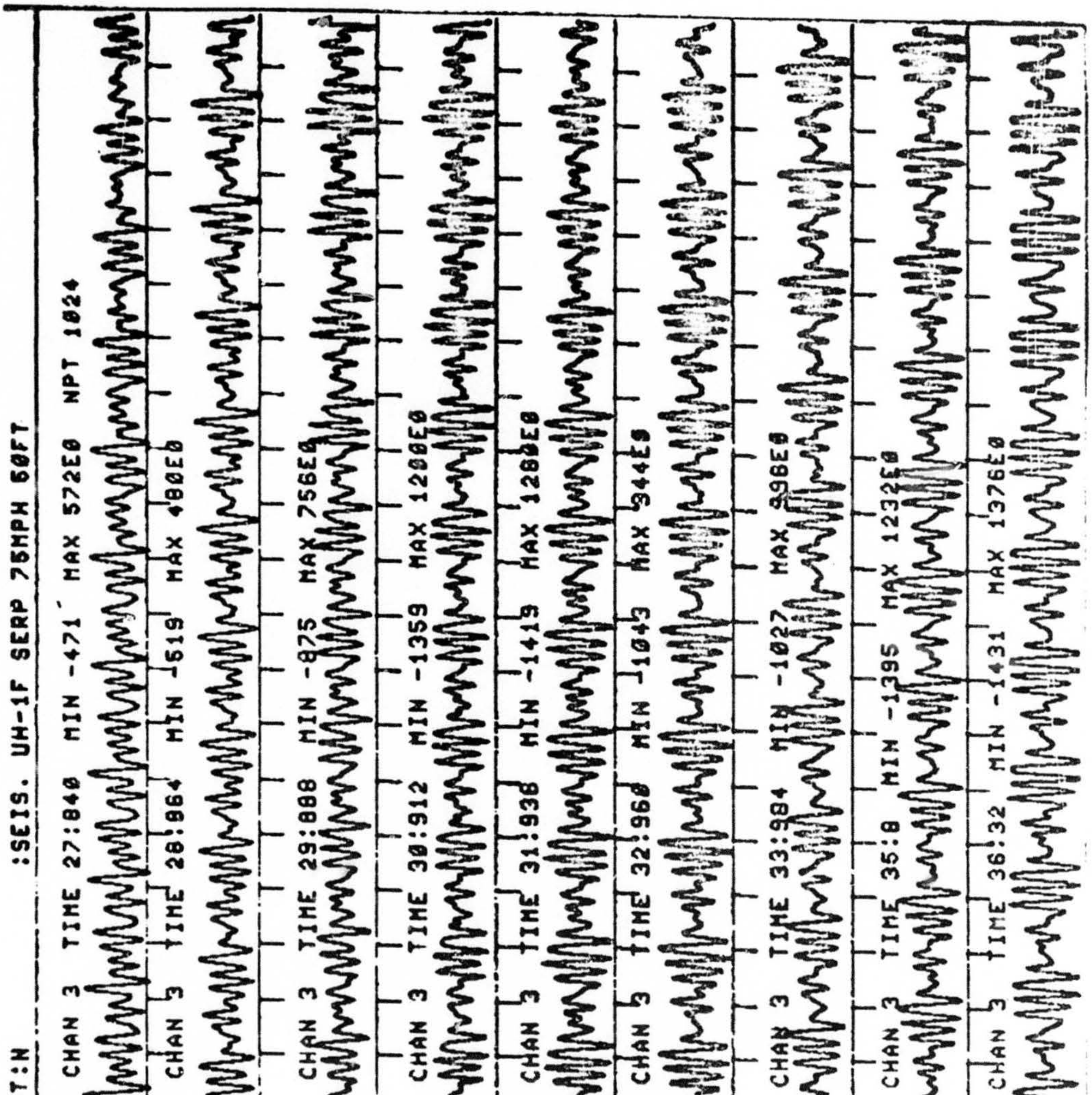
SAMPLE WAVEFORM OF AN M-109 TRUCK

FIGURE 5



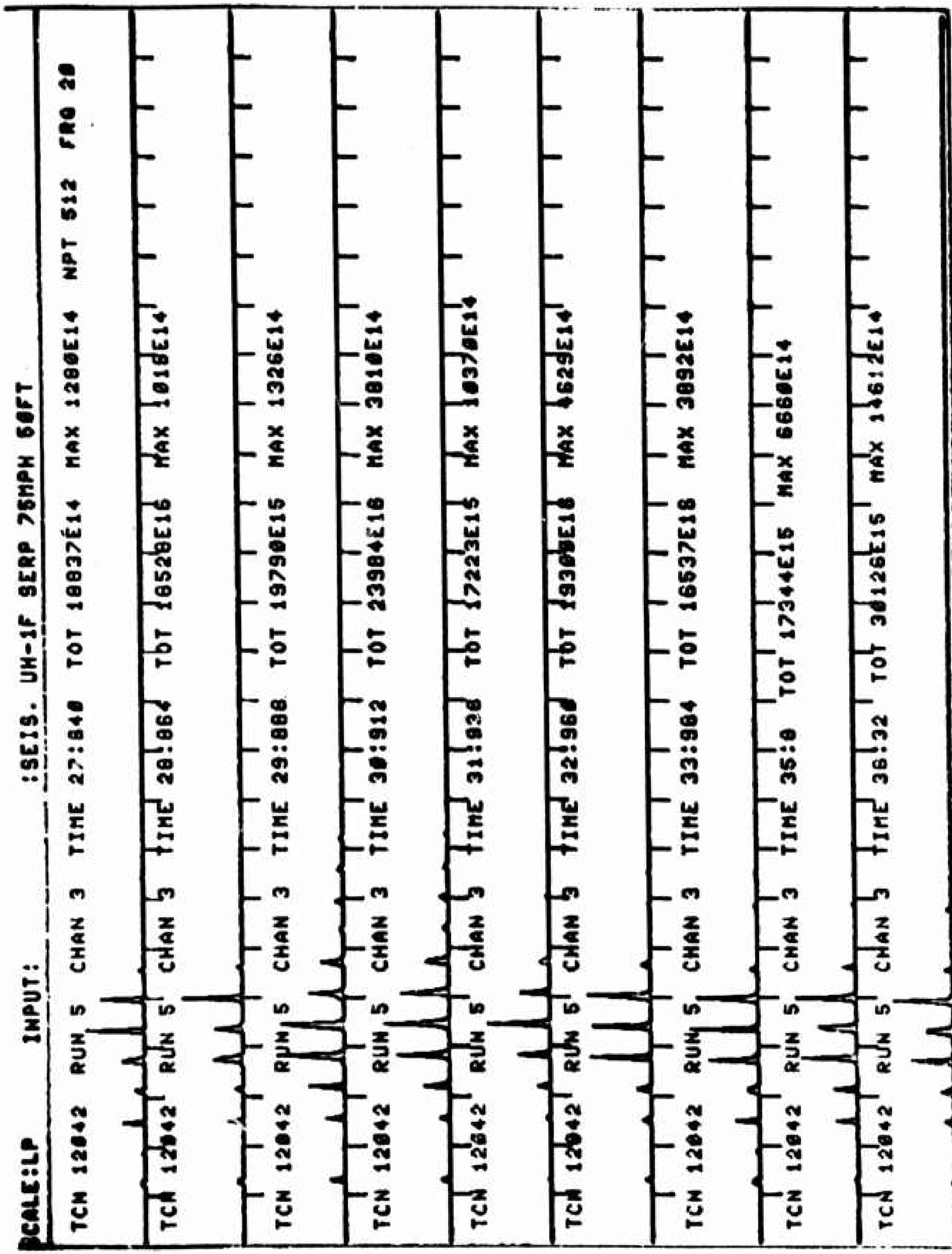
SAMPLE POWER SPECTRUM OF AN M-109 TRUCK

FIGURE 6



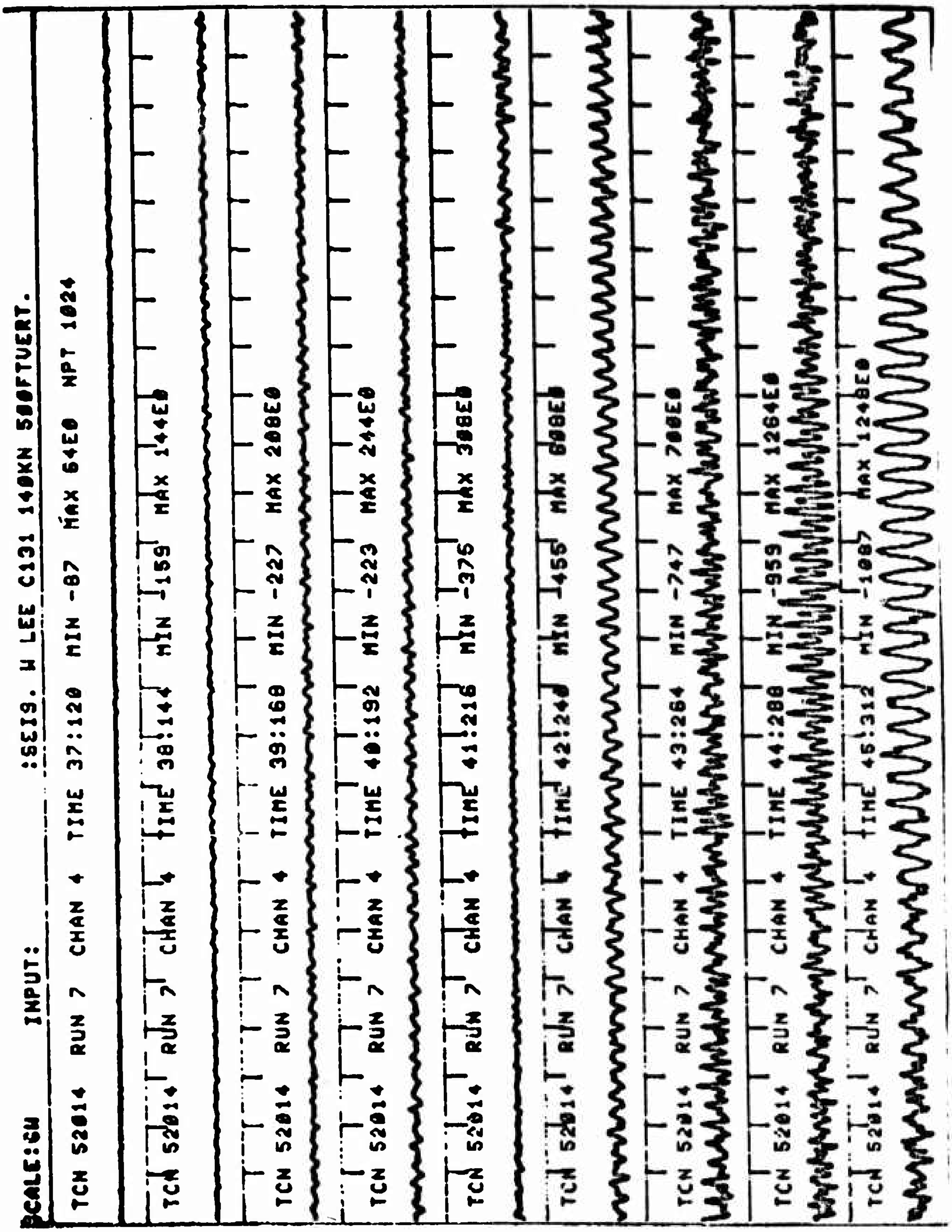
SAMPLE WAVEFORM OF A UH-1F HELICOPTER

FIGURE 7



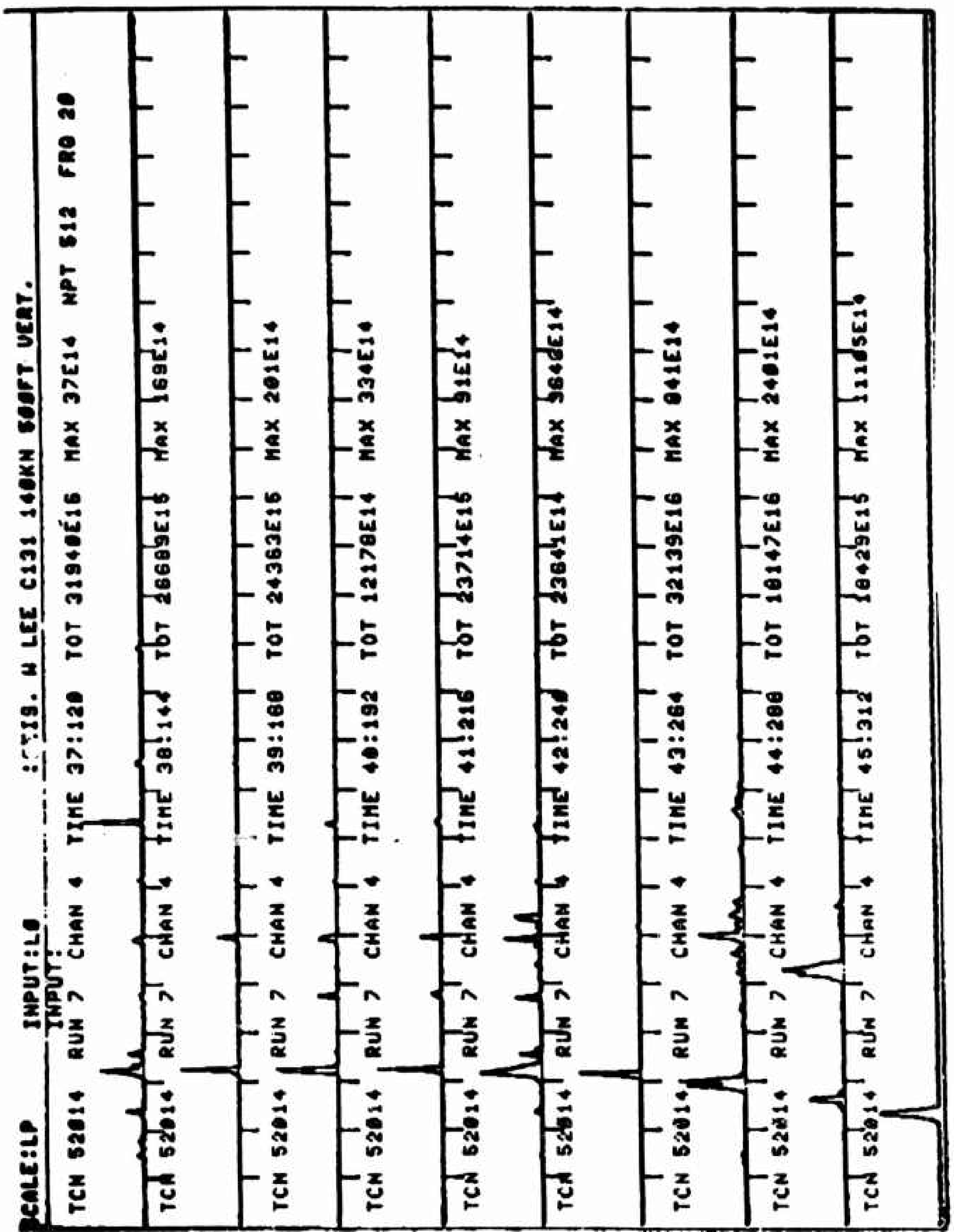
SAMPLE POWER SPECTRUM OF A UH-1F HELICOPTER

FIGURE 8



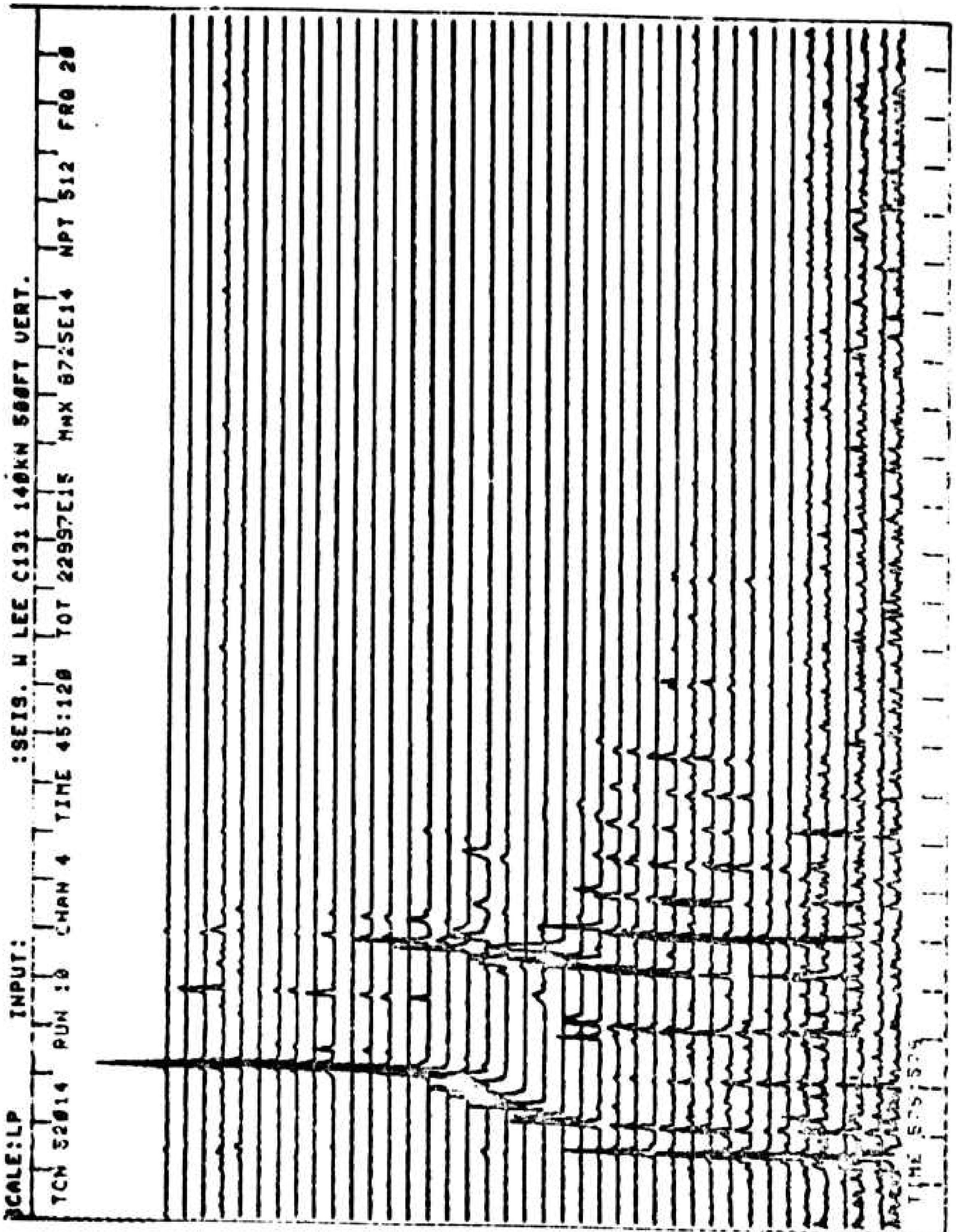
SAMPLE WAVEFORM OF A C-131 AIRCRAFT

FIGURE 9



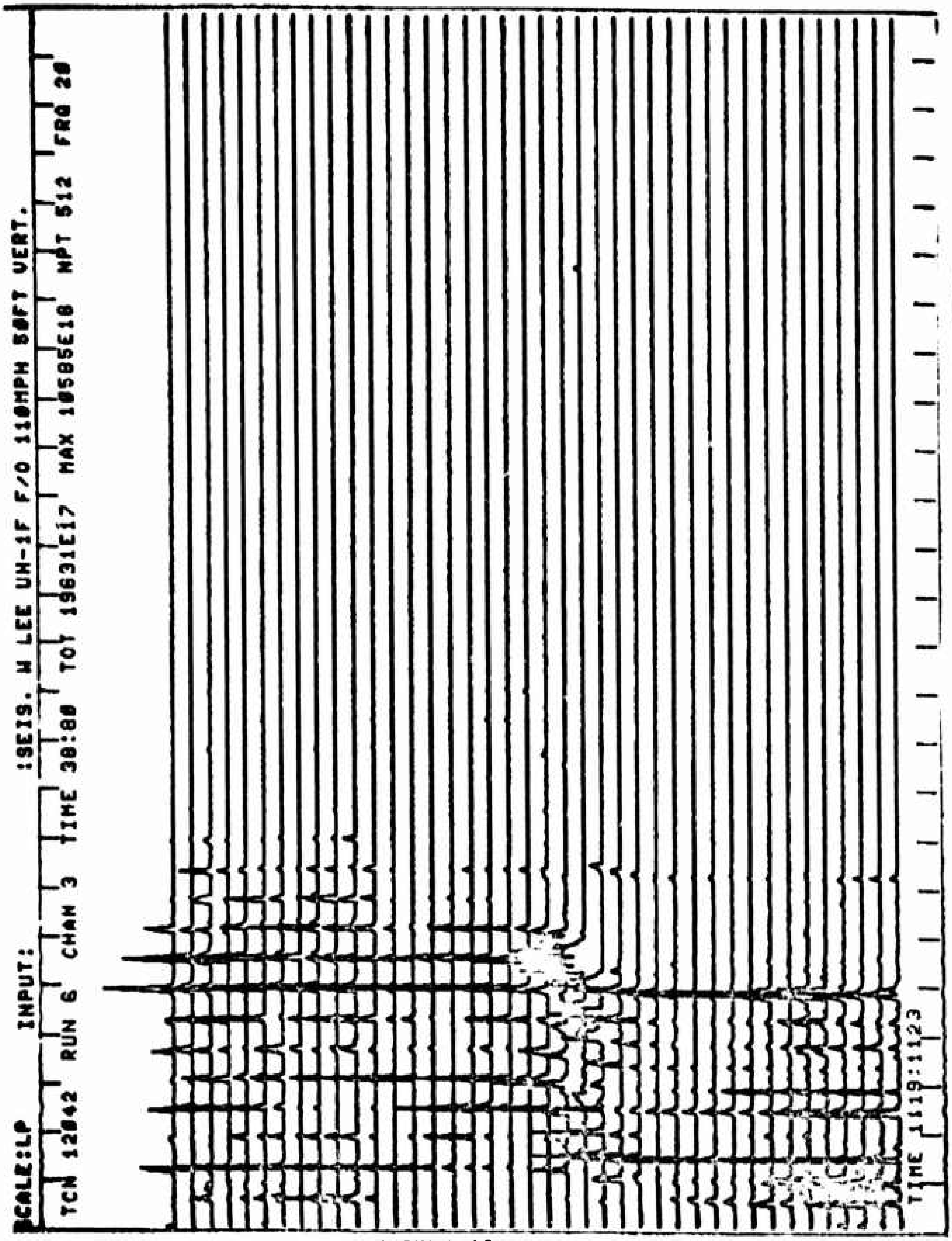
SAMPLE POWER SPECTRUM OF A C-131 AIRCRAFT

FIGURE 10



SAMPLE 40 LINE POWER SPECTRUM OF A C-131 AIRCRAFT

FIGURE 11



SAMPLE 40 LINE POWER SPECTRUM OF A UH-1F HELICOPTER

FIGURE 12

SECTION V

FEATURE DEFINITION

Several man-months of studying seismic waveforms on graphics and hardcopy displays produced a set of 24 features for consideration. These features were extracted from one-second (actually 1024 samples, or 1.024 seconds) segments of data and from five-second segments (5120 samples, 5.120 seconds) of data. The two different lengths were selected to evaluate the effect of segment length on classification success. The FFT routine required the number of samples used to be a power of two. Therefore, the one-second window size was chosen to contain 1024 samples instead of 1000. These 24 features taken over the two segment lengths produced a total of 48 features.

The rationale and definitions of the features are given below, in the order in which they appear in the vector data. That is, component 1 of the vector is the average $\bar{R}$ for one second. Any DDC offset present was subtracted before all processing.

NO.	DEFINITION AND RATIONALE
1.	$\bar{R}$ for one second (Average R for each half-second of a contiguous one-second segment): R is defined as the ratio of the maximum absolute signal amplitude during a half-second interval to the average absolute

amplitude for that half second. This feature appeared a likely candidate for distinguishing the class of humans, whether one or several, walking or running. The impact of a heel gives a sharp, strong spike in the signal, which decays to noise level considerably before the next heel impact. This effect produces a significantly higher value of R than does a vehicle or aircraft, since the latter usually produces high spikes only when the signal is strong enough to produce a high RMS value.

2. $\overline{R^2}$ for one second (average R^2 for the two half seconds): Although any information contained in R (e.g., a threshold) will map uniquely into R^2, squaring R made the distinction between humans and all other classes more obvious to the operator, and eventually to OLPARS.

3. $\overline{R}$ for five seconds (average R for 10 contiguous half-second segments).

4. $\overline{R^2}$ for 5 seconds.

NO.	DEFINITION AND RATIONALE (continued)
5.	Harmonic spacing for one second (the most frequently occurring pairwise spacing between the six largest peaks in the power spectrum above 40 Hz): This feature was suggested by the evenly spaced harmonics that were evident in aircraft waveforms.
6.	Harmonic occurrences in one second (the number of times that the spacing of component 5 above occurred in the one second spectrum): The C-131 usually evidenced harmonics at 20-Hz intervals, the UH-1F helicopter at 12.5 Hz intervals.
7.	The ratio of the energy between 1 and 20 Hz to that between 21 and 40 Hz for one second (hereafter symbolized by: E_{1-20}/E_{21-40}): Although the jeep and APC spectra overlapped considerably, the jeep spectrum did extend somewhat lower than the APC spectrum, which usually dropped off below 20 Hz.
8.	E_{41-60}/E_{21-40} for one second: An attempt to separate trucks from APCs.

NO.	DEFINITION AND RATIONALE (continued)
9.	The number of points in the one second power spectrum which are below 25% of the maximum: A coarse amplitude histogram was taken to estimate the value of amplitude information,
10.	The number of points in the one second power spectrum which are $\geq$25% and <50% of the maximum.
11.	Number as in 9 and 10 of points $\geq$50% and <75%.
12.	Number of spectral points $\geq$75% of maximum.
13.	The ratio of the energy above 100 Hz to that below in the one-sec. power spectrum(i.e. $E_{101-511}/E_{1-100}$): Aircraft tend to produce more energy above 100 Hz than do any other classes.
14.	E_{1-5}/E_{1-60} for the first second: To estimate the value of spectral distribution information.
15.	E_{6-10}/E_{1-60}, first second.
16.	E_{11-15}/E_{1-60}, first second.
17.	E_{16-20}/E_{1-60}, first second.
18.	E_{21-25}/E_{1-60}, first second.
19.	E_{26-30}/E_{1-60}, first second.
20.	. . .

No.	DEFINITION AND RATIONALE (continued)
25.	E_{56-60}/E_{1-60}, first second.
26.	The number of peaks in the first one second power spectrum which exceed 10% of the maximum peak.
27.	Harmonic spacing for the 5-second ensemble average of 5 successive one-second power spectra (see No. 5).
28.	The number of times the spacing of No. 27 occurs in the 5-second ensemble average (see no. 6).
29-48.	Components 29-48 are extracted just as components 7-26, in that sequence, except that the spectra observed consist of an ensemble average of 5 consecutive one-second power spectra instead of a single one-second spectrum.

SECTION VI

FEATURE EXTRACTION

Once the list of 48 features had been compiled, a batch program was written for the Honeywell 635 to extract these features from the unpacked data tapes. This batch program consists of the main "control" program, a Fast Fourier Transform (FFT) subroutine, a double up algorithm, and a number of feature extraction subroutines.

Data cards direct the control program as to which and how many runs and channels are to be processed. The control program then monitors the specified input data tape channels and calls the feature extraction subroutines when the monitored data channel satisfies the automatic segmentation criteria. The first subroutines called extract features from the time domain waveform segment in the data array X. After these features are extracted, the double up algorithm is called three times to help calculate five consecutive one-second power spectra of the data in X. Since the waveform segments do not have an imaginary component, the double up algorithm enables the FFT to calculate two power spectra with one call to subroutine DOUBLE. After the power spectra are returned, their ensemble average is computed.

The X array will then contain two power spectra of interest, the spectrum for the 1st second and the average spectrum for the five seconds of data. The subroutines which extract features from these two power spectra are then called . After all the feature extraction subroutines are called, a labeled feature vector is punched out on cards.

After completion of the feature extraction program, the output data deck is taken to the CDC-1604B computer where the feature vectors are transferred to an OLPARS compatible tape.

Listings of the feature extraction program and its subroutines are provided in Appendix A.

SECTION VII

FEATURE EVALUATION

The first step in using the On-Line Pattern Analysis and Recognition System (OLPARS) is to evaluate the discriminatory quality of the extracted features. This enables us to use fewer measurements to achieve a satisfactory classifier design. The OLPARS provides two suboptimal methods for ranking the discriminatory power of the extracted features. Each of these methods provides three types of rankings. The first type uses a significance measure of a particular feature, Xp, for discriminating class i from class j and is designated by $M_{ij}(Xp)$. The second type of ranking uses a significance measure of X_p for discriminating class i from all other classes and is designated $M_i(X_p)$. The last type uses a measure of the overall significance of X_p for discriminating all classes and is designated $M(X_p)$.

The first method in OLPARS for ranking features is the discriminant measure, which is particularly useful when the class conditional probability distributions are unimodal. These discriminant measures, using feature X_p, are defined as follows:

$$M_{ij}(\chi_p) = \frac{\left[\bar{\chi}_p^{(i)} - \bar{\chi}_p^{(j)}\right]^2}{(N_i-1)\left[\hat{\sigma}_p^{(i)}\right]^2 + (N_j-1)\left[\hat{\sigma}_p^{(j)}\right]^2}$$

$$M_i(\chi_p) = \sum_{j\neq i}^{K} M_{ij}(\chi_p)$$

$$M(\chi_p) = \sum_{i=1}^{K} M_i(\chi_p) = \sum_{i=1}^{K}\sum_{j\neq i}^{K} M_{ij}(\chi_p)$$

where $\bar{\chi}_p^{(j)}$ = the estimated mean of class j along measurement χ_p.

$\hat{\sigma}_p^{(j)}$ = the estimated standard deviation of class j along measurement χ_p.

N_j = the number of samples from class j.

The other OLPARS feature evaluation method is the probability of confusion measure. It is valid for any probability distribution since it essentially measures the overlap of the class conditional probabilities.

Since the functional forms of the class conditional probabilities are not known, OLPARS estimates the marginal class distributions using the sample data. The range for feature χ_p is divided into cells of width Δ. The probability that a sample from class j will occupy the γ^{th} cell along the range of feature χ_p is given by:

$$P_{\gamma p}^{(j)} = \int_{\gamma^{th}\ cell} P(\chi_p | C_j) d_{x_p}$$

The probability of confusion measures using feature χ_p are defined as follows:

$$M_{ij}(\chi_p) = 1 - \left[\sum_{\gamma=1}^{N_p} \min_{i:j} \left\{ P_{\gamma p}^{(i)} , P_{\gamma p}^{(j)} \right\} \right]$$

$$M_i(\chi_p) = \sum_{\substack{j=1 \\ j \neq i}}^{K} M_{ij}(\chi_p)$$

$$M(\chi_p) = \sum_{i=1}^{K} M_i(\chi_p) = \sum_{i=1}^{K} \sum_{j \neq i}^{K} M_{ij}(\chi_p)$$

where N_p = the number of cells along measurement χ_p

and K = the number of classes.

The ranking of extracted features based on these evaluation techniques provides the information required to rationally choose initial subsets of the 48 features for logic design. Logic design is an iterative process in which many designs, based on modified versions of the initial feature subsets, are generated and tested. Features which appear to discriminate between the more troublesome classes are added, while superfluous features which rank high for the same easily discriminated classes are eliminated.

For this five-class problem, the top fifteen features, rank-ordered by the probability of confusion measure, $M_{ij}(\chi_p)$, are shown in Appendix B.

SECTION VIII

CLASSIFICATION LOGIC

The classifiers designed by ISCP for this pattern recognition problem consist solely of sets of linear discriminants for ease of hardware implementation. The logic for these classifiers is based on the pairwise Fisher Linear Discriminant Technique. For each pair of classes i and j, a unit vector d_{ij} is computed such that projections of the data onto d_{ij} maximize the ratio of the between-class scatter to the within-class scatter. The direction d_{ij} which maximizes this ratio is given by Reference [5].

$$\underset{\sim}{d}_{ij} = \alpha \, W_{ij}^{-1} \, \underset{\sim}{\Delta}_{ij}$$

where $W_{ij} = (N_i - 1)\, C_i + (N_j - 1)\, C_j$

C_{ij} = Estimated covariance matrix for class i

$\underset{\sim}{\Delta}_{ij} = \underset{\sim}{\mu}_i - \underset{\sim}{\mu}_j$

μ_i = Estimated mean vector of class i

N_i = Number of vectors in class i

and α is a normalizing constant so that $|\underset{\sim}{d}| = 1$

OLPARS computes d_{ij} and an initial threshold, Θ_{ij}, to distinguish between all pairs of classes. These thresholds may be adjusted, if necessary, to obtain optimal discrimination along each $\underset{\sim}{d}_{ij}$:

For example, the inner product of an unknown input feature vector, $\underset{\sim}{x}$, is taken with the discriminant $\underset{\sim}{d}_{AH}$ for the pair of APCs and helicopters, compared with the threshold θ_{AH} for the pair of APCs and helicopters.

If $\langle \underset{\sim}{d}_{AH}, \underset{\sim}{x} \rangle = \sum_{i=1}^{\kappa} x_i \underset{\sim}{d}_{AH} > \theta_{AH}$ increment the counter for the APC class.

If $\langle \underset{\sim}{d}_{AH}, \underset{\sim}{x} \rangle = \sum_{i=1}^{\kappa} x_i \underset{\sim}{d}_{AH} < \theta_{AH}$ increment the counter for the helicopter class.

If $\langle \underset{\sim}{d}_{AH}, \underset{\sim}{x} \rangle = \sum_{i=1}^{\kappa} x_i \underset{\sim}{d}_{AH} = \theta_{AH}$ increment the counter for the class with the larger number of samples in the design set.

where κ = Size of the feature space.

After all the pairwise decisions are made, a binary vote is cast by each comparator and the final decision is determined by the class counter that received the most votes. In case of ties, the decision is given to the class involved in the tie which has the highest a priori probability. The resultant classification scheme is diagrammed in Figure 13.

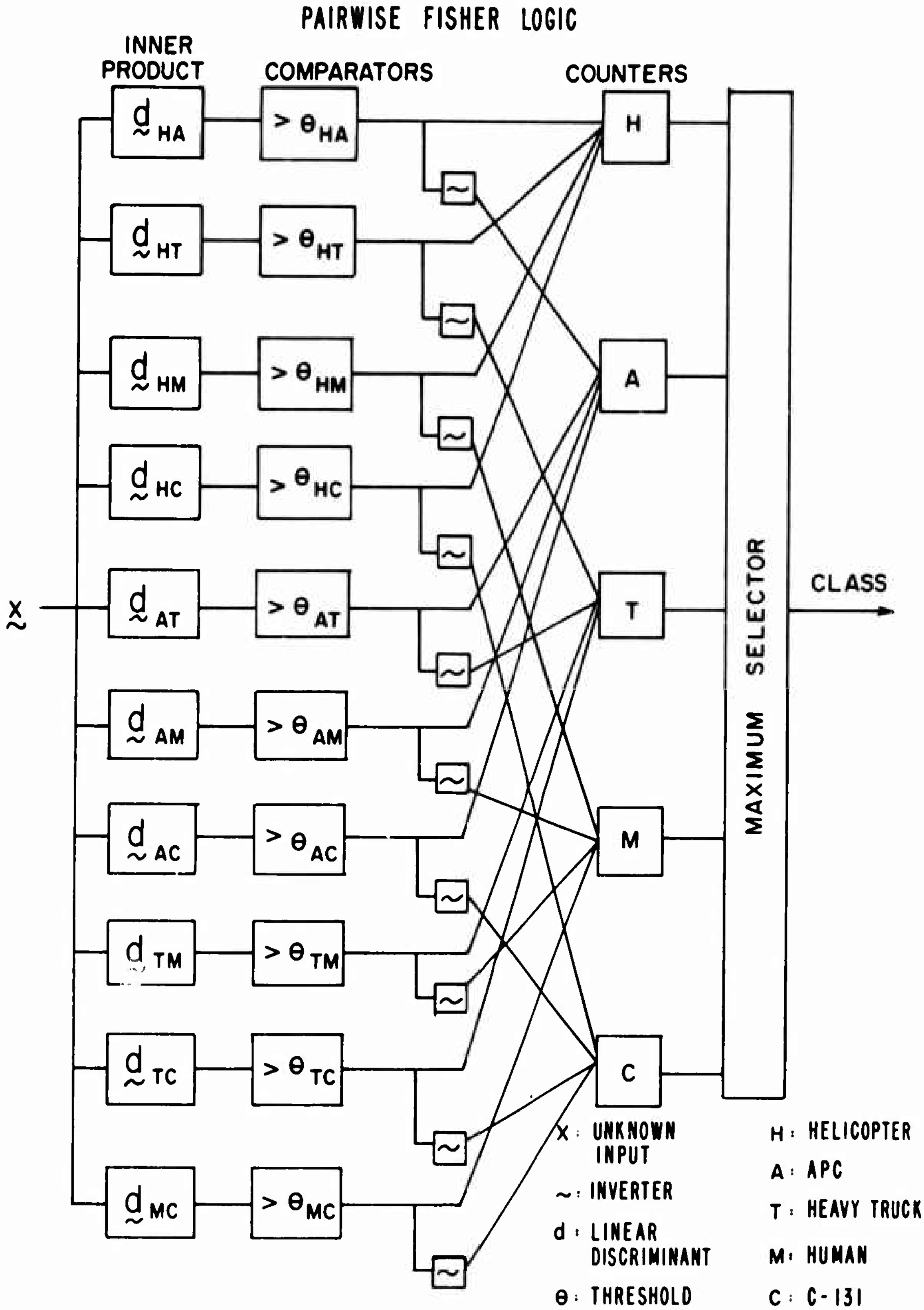

PAIRWISE FISHER LOGIC
INNER PRODUCT
COMPARATORS
COUNTERS
d HA
d HT
d HM
d HC
d AT
d AM
d AC
d TM
d TC
d MC
> θ HA
> θ HT
> θ HM
> θ HC
> θ AT
> θ AM
> θ AC
> θ TM
> θ TC
> θ MC
H
A
T
M
C
MAXIMUM SELECTOR
CLASS
x
x : UNKNOWN INPUT
~ : INVERTER
d : LINEAR DISCRIMINANT
θ : THRESHOLD
H : HELICOPTER
A : APC
T : HEAVY TRUCK
M : HUMAN
C : C-131

Figure 13.

SECTION IX

RECOGNITION RATES

Four classifiers were designed using 16, 22, 33, and 44 features. With the exception that feature 46 is missing from the 44 feature design, each design is based on a subset of the features used in the higher order designs. Figure 14 lists the features used for each design.

These classifiers were evaluated with the design data set and an independent test data set. The design set consisted of 715 vectors: 133 vectors from the class of helicopters; 176 for APCs; 135 for heavy trucks; 136 for humans; and 135 represented C-131s. The independent test set was comprised of 607 vectors: 159 for helicopters; 171 for APCs; 16 for heavy trucks; 129 for humans; and 132 for C-131s. The design and test confusion matrices from the resulting evaluation of each classifier are shown in Figures 15 thru 18.

FEATURE LIST FOR EACH DESIGN

44 FEATURE DESIGN

1	2	3	4	5	6	7	8	9	10
11	13	14	15	16	17	18	19	20	21
22	23	25	26	27	28	29	30	31	32
33	35	36	37	38	39	40	41	42	43
44	45	47	48						

33 FEATURE DESIGN

1	2	3	4	5	6	14	15	16	19
20	21	23	25	27	28	29	30	31	32
33	36	37	38	39	40	41	42	43	44
45	46	47							

22 FEATURE DESIGN

3	4	5	6	14	15	16	25	27	28
29	30	31	37	38	39	42	43	44	45
46	47								

16 FEATURE DESIGN

3	4	27	28	29	30	31	37	38	39
42	43	44	45	46	47				

FIGURE 14

	ASSIGNED CLASS					
		H	A	T	M	C
TRUE CLASS	H	125	2	3	2	1
	A	0	172	3	1	0
	T	0	2	133	0	0
	M	0	1	0	133	2
	C	0	0	0	1	133

Probability of Correct Classification = .973

CONFUSION MATRIX FOR THE DESIGN SET

USING 44 FEATURES

	ASSIGNED CLASS					
		H	A	T	M	C
TRUE CLASS	H	121	12	3	2	21
	A	4	137	27	3	0
	T	1	3	12	0	0
	M	0	5	0	123	1
	C	7	1	1	1	122

Probability of Correct Classification = .848

CONFUSION MATRIX FOR THE TEST SET

USING 44 FEATURES

LEGEND:
H - HELICOPTER
A - APC
T - HEAVY TRUCK
M - HUMAN
C - C-131

FIGURE 15

		ASSIGNED CLASS				
		H	A	T	M	C
TRUE CLASS	H	125	1	4	2	1
	A	4	168	3	1	0
	T	0	4	131	0	0
	M	0	1	0	131	4
	C	1	0	0	0	134

Probability of Correct Classification = .963

CONFUSION MATRIX FOR THE DESIGN SET

USING 33 FEATURES

		ASSIGNED CLASS				
		H	A	T	M	C
TRUE CLASS	H	127	3	4	4	21
	A	9	135	23	4	0
	T	3	1	12	0	0
	M	0	5	0	123	1
	C	7	0	1	1	123

Probability of Correct Classification = .856

CONFUSION MATRIX FOR THE TEST SET

USING 33 FEATURES

LEGEND:
H - HELICOPTER
A - APC
T - HEAVY TRUCK
M - HUMAN
C - C-131

FIGURE 16

		ASSIGNED CLASS				
		H	A	T	M	C
	H	121	2	4	4	2
	A	2	170	3	1	0
TRUE CLASS	T	0	3	132	0	0
	M	0	1	0	133	2
	C	1	0	0	2	132

Probability of Correct Classification = .962

CONFUSION MATRIX FOR THE DESIGN SET

USING 22 FEATURES

		ASSIGNED CLASS				
		H	A	T	M	C
	H	128	4	5	4	18
	A	3	144	20	4	0
TRUE CLASS	T	1	3	12	0	0
	M	0	5	0	123	1
	C	11	1	5	0	115

Probability of Correct Classification = .860

CONFUSION MATRIX FOR THE TEST SET

USING 22 FEATURES

LEGEND: H - HELICOPTER; A - APC; T - HEAVY TRUCK; M - HUMAN; C - C-131

FIGURE 17

		ASSIGNED CLASS				
		H	A	T	M	C
TRUE CLASS	H	120	2	4	4	3
	A	3	170	2	1	0
	T	1	4	130	0	0
	M	2	1	0	129	4
	C	1	0	2	1	131

Probability of Correct Classification = .951

CONFUSION MATRIX FOR THE DESIGN SET

USING 16 FEATURES

		ASSIGNED CLASS				
		H	A	T	M	C
TRUE CLASS	H	129	2	5	4	19
	A	6	142	19	4	0
	T	1	3	12	0	0
	M	1	6	0	121	1
	C	11	1	6	0	114

Probability of Correct Classification = .853

CONFUSION MATRIX FOR THE TEST SET

USING 16 FEATURES

LEGEND:
H - HELICOPTER
A - APC
T - HEAVY TRUCK
M - HUMAN
C - C-131

FIGURE 18

Note that the probability of correct classification using the design set increases monotonically as the number of features is increased; while using the test set, it reaches its maximum value for 22 features and drops off. Foley [2] points out a statistical trap involved with using the probability of error on the design as a measure of the true performance of the system when the ratio of the sample size to feature size is small. The probability of error or correct classification on the test set is the better measure and indicates that the probability of correct classification of 0.86 for the 22-feature design is the best performance.

The essential difference between the 22-feature design and the 16-feature design is that the former is based on measurements of both one and five second data segments, whereas, the latter is based solely on measurements of five second segments. Therefore, the exclusion of one second measurements not only reduces the dimensionality of the decision logic from 22 to 16, but it also simplifies feature extraction by elimination of the one second phase of the extraction process. The trade-off between the slightly superior performance of the 22-feature design (Pcc on the test set of 0.86) versus the simplicity and ease of implementation of the 16-feature design clearly ranks the 16 feature design ahead of the 22-feature design.

The linear discriminants for the 16-feature logic design are given in Appendix C. These linear discriminants contain the ten weight vectors with their respective thresholds and, together, with the block diagram in Figure 13, completely define the pairwise Fisher logic for the 16-feature design.

SECTION X

DISCUSSION AND RECOMMENDATIONS

In many waveform classification problems, the classifier is designed entirely from features extracted from a waveform data base which is representative of each class. To insure that the data base is representative, data must be collected for a sufficient number of runs of each intrusion variation (speed, path, direction, etc.), so that the data for each variation is truly representative. Emphasis must be placed on the generality of a data base and not on its size alone. For example, to design a classifier which will detect most trucks, the data base must contain data from a wide variety of different type trucks, all operating at a number of sampled speeds and carrying loads which vary from maximum capacity to empty. The wider the variety of vehicles within a class, the more complex the data analysis becomes because all the variations and the possible combinations of the variations have to be sampled and analyzed for each variety of vehicles.

The main goal of this effort is the development of a seismic classifier which will satisfy an acceptable error criteria regardless of where the classifier is located. The seismometer response to an intrusion target is the signal which results from the convolution of the target signature with the impulse response of the earth. The earth's impulse responses differ greatly throughout the world because they are determined by the geology and terrain of the locale. These impulse responses or transfer characteristics are not necessarily constant between two points in a locality but may change periodically as a function of the seasonal variations. Seasonal variations in the transfer characteristics are caused by changes in either the height of the water table, the depth of the frost line, or amount of snow cover. Therefore, it may not be realistic to believe that one seismic logic design might perform satisfactorily in any location or for an extended period of time in a locality which has extreme seasonal variations.

The key to the general seismic classifier design problem is the discovery of waveform features which contain adequate discriminatory information and are invariant to geographical location and seasonal variation. This report does not shed any light on the theory that such features exist, but it does exercise the procedures required to determine their existence. The importance of the data collection and data analysis procedures cannot be over emphasized. Before data analysis can yield meaningful results, the data base must contain data collected from selected test sites which are representative of the various types of terrain, geology, and seasonal variations found throughout the world.

APPENDIX A

BATCH PROGRAM LISTINGS

```
C          PROGRAM TO STRIP SPECIFIED DATA CHANNELS FROM A BAMKI TAPE
C          AND WRITE A NEW TAPE WITH A SIMPLIFIED FORMAT,
      COMMON IDAT(320, 7),JCOUNT(45)
      COMMON /JAZZ/IA(1858) ,IEOF,IBORT,IPARTY
      COMMON/JIM/LA(326)
      COMMON/AVERGF/IAVG(45),LCOUNT(45),IJK,NTIMES,IPRINT
      DIMENSION KCOUNT(45)
      IPARTY=0
      IBORT=0
      IJK=0
      READ 1001,NUM,(KCOUNT(J),J=1,NUM)
 1001 FORMAT(40I2)
      READ 1003,NREC,NTIMES
 1003 FORMAT(2I5)
      READ 1001,IPRINT
      DO 400 I=1,NUM
      IND=KCOUNT(I)
      WRITE(6,1006) I,IND
 1006 FORMAT(10X,7HRECORD ,I2,17H IS FROM CHANNEL ,I2)
  400 LCOUNT(IND)=I
      DO 3 J=1,45
    3 JCOUNT(J)=0
      DO 1005 N=1,NREC
      CALL SPAWN(N,NUM,KCOUNT)
      IF(IEOF.EQ.1) GO TO 1004
      IF(IBORT.NE.0) GO TO 1005
      IF(IJK.NE.0) GO TO 1005
      DO 1000 J=1,NUM
      LA(4)=IAVG(J)
      DO 500 I=7,326
  500 LA(I)=IDAT(I-6,J)
      CALL PROC
 1000 CONTINUE
 1005 CONTINUE
 1004 IF(IJK.EQ.0) GO TO 1007
      IF(IBORT.NE.0) GO TO 1007
      DO 65 I=1,NUM
      IND=KCOUNT(I)
      KEND=JCOUNT(IND)
      DO 66 J=KEND,320
   66 IDAT(J,I)=0
      LA(4)=IAVG(I)
      DO 67 J=7,326
   67 LA(J)=IDAT(J-6,I)
   65 CALL PROC
 1007 CALL WEF
      CALL WEF
      CALL WEF
      STOP
      END
```

```
      SUBROUTINE SPANN(JPARM,NUM,KCOUNT)
C
      COMMON/JIM/LA(326)
      COMMON /JAZZ/IA(1656) ,IEOF,IBORT,IPARTY
      COMMON IDAT(320, 7),JCOUNT(45)
      COMMON/AVERGE/IAVG(45),LCOUNT(45),IJK,NTIMES,IPRINT
      DIMENSION IOD(4),JOD(32),JP(14)
      DIMENSION KCOUNT(45),MASK(3),KONST(3)
      DIMENSION FAVG(45)
      DATA IHALF/262144/
      DATA (JP(I),I=1,14)/1,21,1,12,22,30,1,12,1,12,31,39,40,45/
      DATA KM/077777770000/
      DATA(MASK(I),I=1,3)/077770000000,000077770000,000000007777/
      DATA (KONST(I),I=1,3)/16777216,4096,1/
      DATA MASKA,MASKB/077777000000,000000777777/
40    FORMAT(8(2X,I12))
      CALL BELLRD
      IF(IEOF.EQ.1) RETURN
      IF(JPARM.NE.1) GO TO 2
      LA(3)=AND(IA(2),MASKA)/IHALF
      LA04C=AND(IA(2),MASKB)
      ISAMP=NTIMES
      NTIMES=1000/ISAMP
      RECORD=0.
2     IOD(1)=AND(IA(1),MASKA)/IHALF
      IOD(2)=AND(IA(1),MASKB)
      IOD(3)=AND(IA(2),MASKA)/IHALF
      IOD(4)=AND(IA(2),MASKB)
      IF(LA04C.NE.IOD(4)) GO TO 7
      IF(LA(3).EQ.IOD(3)) GO TO 5
      IF(IBORT)6,19,10
  5   IF(IBORT)6,8,5000
  6   CALL BSF
      CALL WEF
      IBORT=1
      GO TO 5000
  7   IF(LA(3).EQ.IOD(3)) GO TO 11
      IF(IBORT)6,19,10
 11   IF(IBORT)6,12,10
 19   IF(IJK.EQ.0) GO TO 9
      DO 65 I=1,NUM
      IND=KCOUNT(I)
      KEND=JCOUNT(IND)
      DO 66 J=KEND,320
 66   IDAT(J,I)=0
      LA(4)=IAVG(I)
      DO 67 J=7,326
 67   LA(J)=IDAT(J-6,I)
 65   CALL PROC
      GO TO 9
 12   CALL BSF
```

```
      9    CALL WFF
     10    IBORT=0
           RECORD=0.
           IJK=0
      8    LA(1)=IOD(1)
           LA(2)=ISAMP
           LA(3)=IOD(3)
           LA04C=IOD(4)
           LA(5)=AND(IA(228),MASKB)
           LA(6)=AND(IA(229),MASKA)/IHALF-40
           IF(LA(6).GE.0) GO TO 3
           LA(5)=LA(5)-1
           LA(6)=1000+LA(6)
      3    IF(IJK.GT.0) GO TO 444
           DO 50 J=1,NUM
           IND=KCOUNT(J)
     50    JCOUNT(IND)=1
    444    IC=2
           DO 1000 NN=1,8
           DO 800 MM=1,10
           DO 400 K=1,9,2
           JBE=JP(K)
           JPE=JP(K+1)
           M=0
           IC=IC+1
           DO 400 J=JBE,JPE
           M=M+1
           IF(M.LT.4) GO TO 401
           IC=IC+1
           M=1
    401    IF(JCOUNT(J).EQ.0) GO TO 400
           I1=AND(IA(IC),MASK(M))
           I1=I1/KONST(M)
           IF(I1.GE.2048) I1=OR(I1,KM)
           J1=JCOUNT(J)
           L1=LCOUNT(J)
           IDAT(J1,L1)=I1
           JCOUNT(J)=JCOUNT(J)+1
    400    CONTINUE
           IF(MM-2)600,700,800
    600    JBE=JP(11)
           JPE=JP(12)
           GO TO 402
    700    JBE=JP(13)
           JPE=JP(14)
    402    M=0
           IC=IC+1
           DO 500 J=JBE,JPE
           M=M+1
           IF(M.LT.4) GO TO 501
           IC=IC+1
           M=1
```

```
  501 IF(JCOUNT(J).EQ.0) GO TO 500
      I1=AND(IA(IC),MASK(M))
      I1=I1/KONST(M)
      IF(I1.GE.2048) I1=OR(I1,KM)
      J1=JCOUNT(J)
      L1=LCOUNT(J)
      IDAT(J1,L1)=I1
      JCOUNT(J)=JCOUNT(J)+1
  500 CONTINUE
 800  CONTINUE
      NNP=4*NN
      NN4=NNP-3
      DO 900 KZ=NN4,NNP,2
      IC=IC+1
      KZP=KZ+1
      JOD(KZ)=AND(IA(IC),MASKA)/IHALF
 900  JOD(KZP)=AND(IA(IC),MASKB)
 1000 IC=IC+5
      IF(IPRINT.EQ.0) GO TO 64
      WRITE(6,45)(IOD(I),I=1,4)
   45 FORMAT(1H0,4(2X,O10))
      WRITE(6,46)(JOD(I),I=1,32)
   46 FORMAT(10X,O12,2I10,2X,O12)
   64 IJK=IJK+1
      DO 5001 I=1,NUM
      IF(IJK.NE.NTIMES) GO TO 20
      IJK=0
      RECORD=RECORD+1.
      DO 48 M=1,NUM
      FMEAN=0.
      DO 60 J=1,320
      FDAT=IDAT(J,M)
   60 FMEAN=FDAT+FMEAN
      FMEAN=FMEAN/320.
      FAVG(M)=((RECORD-1.)*FAVG(M)+FMEAN)/RECORD
      WRITE(6,47) FMEAN,FAVG(M)
   47 FORMAT(10X,14HRECORD MEAN = ,F12.4, 16H PARTIAL MEAN = ,F12.4)
   48 IAVG(M)=FAVG(M)+0.5
   20 IF(IPARTY.NE.1) GO TO 5001
      IND=KCOUNT(I)
      WRITE(6,111) IND
  111 FORMAT(5X,8HCHANNEL ,I2)
      KEND=JCOUNT(IND)-1
      WRITE(6,40) (IDAT(J,I),J=1,KEND)
 5001 CONTINUE
      IPARTY=0
 5000 RETURN
      END
```

28799 WORDS OF MEMORY USED BY THIS COMPILATION

```
                                          1         LBL     SUBROUTINE TO READ BAMKI TAPE
                                            2       SYMDEF  BELLRD
                                            3       SYMREF  BSF
                               000000       4       BLOCK   JAZZ
                               000000       5 JZ    BSS     1859
                               003503       6 IBORT BSS     1
                               003504       7 IPARTY BSS    1
                               000000       8       USE     PREVIOUS
                               000000       9 BELLRD SAVE
     000000  000002710000     010
     000001  000035630000     010
     000002  000035754000     010
     000003  000035741000     010
     000004  777776 2350 07   000      10           LDA     =-2,DL
     000005  000033 7550 00   010      11           STA     STR
     000006  000001 0010 00   000      12           MME     GEINOS
     000007  05 0000 000000   000      13           RTB
     000010  000031 000032    011      14           ZERO    FC,DCW
     000011  000033 000000    010      15           ZERO    STR
     000012  000002 0010 00   000      16           MME     GEROAD
     000013  000033 2350 00   010      17           LDA     STR
     000014  000040 3750 00   010      18           ANA     =0070000000000
     000015  000041 1150 00   010      19           CMPA    =0030000000000
     000016  000023 6000 00   010      20           TZE     ABORT
     000017  000042 1150 00   010      21           CMPA    =0040000000000
     000020  000026 6000 00   010      22           TZE     EOF
     000021  000000 2350 07   000      23           LDA     =0,DL
     000022  000027 7100 00   010      24           TRA     RETURN
   END OF BINARY CARD SUBROUTI
     000023  000001 2350 07   000      25 ABORT     LDA     =1,DL
     000024  013504 7550 00   030      26           STA     IPARTY
     000025  000030 7100 00   010      27           TRA     RETURN+1
     000026  000001 2350 07   000      28 EOF       LDA     =1,DL
     000027  013502 7550 00   030      29 RETURN    STA     JZ+1858
     000030  000001710000     010      30           RETURN  BELLRD
     000031  000000000001     000      31 FC        BCI     1,000001
     000032  010000 013502    030      32 DCW       IOTD    JZ,1858
                     000033            33 STR       BSS     2

    ERROR LINKAGE

     000035  000000000000     000
     000036  222543435124     000

      LITERALS

     000040  070000000000     000
     000041  030000000000     000
     000042  040000000000     000
   END OF BINARY CARD SUBROUTI
                                       34           END
   43 IS THE NEXT AVAILABLE LOCATION.
```

```
          1          LBL      SUBROUTINE TO WRITE OUTPUT TAPE ( 7 TRACK VERSION )
                                               2          SYMDEF   PROC,WEF,BSF
                              000000           3          BLOCK    JIM
                              000000           4 JZ       BSS      326
                              000000           5          USE      PREVIOUS
                              000000           6 PROC     SAVE     0,1
   000000  000004710000    010
   000001  000000220003    000
   000002  000000221003    000
   000003  000333630000    010
   000004  000333754000    010
   000005  000333741000    010
   000006  000001740000    010
   000007  000002741000    010
   000010  000000 2200 03  000         7          LDX0     =0,DU
   000011  000000 2210 03  000         8 BIG      LDX1     =0,DU
   000012  010000 2360 10  030         9 LOOP     LDQ      JZ,0
   000013  000015 6050 00  010        10          TPL      G01
   000014  000001 1760 07  000        11          SBQ      =1,DL
   000015  000024 7360 00  000        12 G01      QLS      20
   000016  000022 7370 00  000        13          LLS      18
   000017  000001 0600 03  000        14          ADX0     =1,DU
   000020  010000 2360 10  030        15          LDQ      JZ,0
   000021  000023 6050 00  010        16          TPL      G02
   000022  000001 1760 07  000        17          SBQ      =1,DL
END OF BINARY CARD SUBROUTI
   000023  000024 7360 00  000        18 G02      QLS      20
   000024  000022 7370 00  000        19          LLS      18
   000025  000070 7550 11  010        20          STA      IA,1
   000026  000001 0600 03  000        21          ADX0     =1,DU
   000027  000001 0610 03  000        22          ADX1     =1,DU
   000030  000243 1010 03  000        23          CMPX1    =163,DU
   000031  000012 6010 00  010        24          TNZ      LOOP
   000032  000001 0010 00  000        25          MME      GEINOS
   000033  15 0000 000000  000        26          WTB
   000034  000064 000065   011        27          ZERO     FC,DCW
   000035  000066 000000   010        28          ZERO     STR
   000036  000002 0010 00  000        29          MME      GEROAD
   000037  000001710000    010        30          RETURN   PROC
                              000040  31 WEF      SAVE
   000040  000042710000    010
   000041  000333630000    010
   000042  000333754000    010
   000043  000333741000    010
   000044  000001 0010 00  000        32          MME      GEINOS
   000045  55 0000 020001  000        33          WEF
END OF BINARY CARD SUBROUTI
   000046  000064 000000   010        34          ZERO     FC
   000047  000066 000000   010        35          ZERO     STR
   000050  000002 0010 00  000        36          MME      GEROAD
   000051  000041710000    010        37          RETURN   WEF
                              000052  38 BSF      SAVE
```

```
      000052  000054710000    010
      000053  000333630000    010
      000054  000333754000    010
      000055  000333741000    010
      000056  000001 0010 00  000      39          MME     GEINOS
      000057  47 0000 020001  000      40          BSF
      000060  000064 000000   010      41          ZERO    FC
      000061  000066 000000   010      42          ZERO    STR
      000062  000012 0010 00  000      43          MME     GEROAD
      000063  000053710000    010      44          RETURN  BSF
      000064  000000000002    000      45  FC      BCI     1,000002
      000065  000070 000243   010      46  DCW     IOTD    IA,163
                        000066         47  STR     BSS     2
                        000070         48  IA      BSS     163

     ERROR LINKAGE

      000333  000000000000    000
      000334  475146232020    000
   END OF BINARY CARD SUBROUTI
                                       49          END
    336 IS THE NEXT AVAILABLE LOCATION.
   GMAP VERSION/ASSEMBLY DATES    JMPA 110171/102971       JMPB 110171/102971
   THERE WERE     NO  WARNING FLAGS IN THE ABOVE ASSEMBLY
```

```
                 LBL       SUBROUTINE TO WRITE OUTPUT TAPE ( 9 TRACK VERSION )
                                                    SYMDEF   PROC,WEF,BSF
                             000000                 BLOCK    JIM
                             000000            JZ   BSS      326
                             000000                 USE      PREVIOUS
                             000000            PROC SAVE
     000000  000002710000      010
     000001  000646630000      010
     000002  000646754000      010
     000003  000646741000      010
     000004  000000 2200 03    000                  LDX0     =0,DU
     000005  000000 2210 03    000             BIG  LDX1     =0,DU
     000006  010000 2360 10    030             LOOP LDQ      JZ,0
     000007  000011 6050 00    010                  TPL      GO1
     000010  000001 1760 07    000                  SBQ      =1,DL
     000011  000024 7360 00    000             GO1  QLS      20
     000012  000022 7370 00    000                  LLS      18
     000013  000001 0600 03    000                  ADX0     =1,DU
     000014  010000 2360 10    030                  LDQ      JZ,0
     000015  000017 6050 00    010                  TPL      GO2
     000016  000001 1760 07    000                  SBQ      =1,DL
     000017  000024 7360 00    000             GO2  QLS      20
     000020  000022 7370 00    000                  LLS      18
     000021  000163 7550 11    010                  STA      IA,1
     000022  000001 0600 03    000                  ADX0     =1,DU
END OF BINARY CARD SUBROUTI
     000023  000001 0610 03    000                  ADX1     =1,DU
     000024  000243 1010 03    000                  CMPX1    =163,DU
     000025  000006 6010 00    010                  TNZ      LOOP
     000026  000001 0010 00    000                  MME      GEINOS
     000027  15 0L00 L00000    000                  WTB
     000030  000152 000154     011                  ZERO     FC,DCW
     000031  000157 000000     010                  ZERO     STR
     000032  000002 0010 00    000                  MME      GEROAD
     000033  000155 2350 00    010                  LDA      DCW9
     000034  000156 7550 00    010                  STA      DCW91
     000035  000000 2200 03    000                  LDX0     =0,DU
     000036  000000 2210 03    000                  LDX1     =0,DU
     000037  010000 2360 10    030             LOOP9 LDQ     JZ,0
     000040  000024 7360 00    000                  QLS      20
     000041  000020 7370 00    000                  LLS      16
     000042  010001 2360 10    030                  LDQ      JZ+1,0
     000043  000024 7360 00    000                  QLS      20
     000044  000020 7370 00    000                  LLS      16
     000045  010002 2360 10    030                  LDQ      JZ+2,0
END OF BINARY CARD SUBROUTI
     000046  000024 7360 00    000                  QLS      20
     000047  000004 7370 00    000                  LLS      4
     000050  000426 7550 11    010                  STA      JA,1
     000051  000014 7370 00    000                  LLS      12
     000052  010003 2360 10    030                  LDQ      JZ+3,0
     000053  000024 7360 00    000                  QLS      20
```

```
000054  000020 7370 00  000          LLS     16
000055  010004 2360 10  030          LDQ     JZ+4,0
000056  000024 7360 00  000          QLS     20
000057  000010 7370 00  000          LLS     8
000060  000427 7550 11  010          STA     JA+1,1
000061  000010 7370 00  000          LLS     8
000062  010005 2360 10  030          LDQ     JZ+5,0
000063  000024 7360 00  000          QLS     20
000064  000020 7370 00  000          LLS     16
000065  010006 2360 10  030          LDQ     JZ+6,0
000066  000024 7360 00  000          QLS     20
000067  000014 7370 00  000          LLS     12
000070  000430 7550 11  010          STA     JA+2,1
END OF BINARY CARD SUBROUTI
000071  000004 7370 00  000          LLS     4
000072  010007 2360 10  030          LDQ     JZ+7,0
000073  000024 7360 00  000          QLS     20
000074  000020 7370 00  000          LLS     16
000075  010010 2360 10  030          LDQ     JZ+8,0
000076  000024 7360 00  000          QLS     20
000077  000020 7370 00  000          LLS     16
000100  000431 7550 11  010          STA     JA+3,1
000101  000011 0600 03  000          ADX0    =9,DU
000102  000504 1000 03  000          CMPX0   =324,DU
000103  000106 6000 00  010          TZE     OUTPUT
000104  000004 0610 03  000          ADX1    =4,DU
000105  000037 7100 00  010          TRA     LOOP9
000106  000001 0010 00  000   OUTPUT MME     GEINOS
000107  15 0000 000000  000          WTB
000110  000153 000156   011          ZERO    FC9,DCW91
000111  000161 000000   010          ZERO    STR9
000112  000002 0010 00  000          MME     GEROAD
000113  000001 0010 00  000          MME     GEINOS
END OF BINARY CARD SUBROUTI
000114  55 0000 020001  000          WEF
000115  000152 000000   010          ZERO    FC
000116  000157 000000   010          ZERO    STR
000117  000002 0010 00  000          MME     GEROAD
000120  000001710000    010          RETURN  PROC
                000121        WEF    SAVE
000121  000123710000    010
000122  000646630000    010
000123  000646754000    010
000124  000646741000    010
000125  000001 0010 00  000          MME     GEINOS
000126  55 0000 020001  000          WEF
000127  000153 000000   010          ZERO    FC9
000130  000161 000000   010          ZERO    STR9
000131  000002 0010 00  000          MME     GEROAD
000132  000122710000    010          RETURN  WEF
                000133        BSF    SAVE
000133  000135710000    010
```

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        000134   000646663000     010
        000135   000646754000     010
        000136   000646741000     010
    END OF BINARY CARD SUBROUTI
        000137   000001 0010 00   000      92             MME       GEINOS
        000140   47 0000 020001   000      93             BSF
        000141   000152 000000    010      94             ZERO      FC
        000142   000157 000000    010      95             ZERO      STR
        000143   000002 0010 00   000      96             MME       GEROAD
        000144   000001 0010 00   000      97             MME       GEINOS
        000145   47 0000 020001   000      98             BSF
        000146   000153 000000    010      99             ZERO      FC9
        000147   000161 000000    010     100             ZERO      STR9
        000150   000002 0010 00   000     101             MME       GEROAD
        000151   000134710000     010     102             RETURN    BSF
        000152   000000000002     000     103 FC          BCI       1,000002
        000153   000000000003     000     104 FC9         BCI       1,000003
        000154   000163 000243    010     105 DCW         IOTD      IA,163
        000155   000426 000220    010     106 DCW9        IOTD      JA,144
                          000156          107 DCW91       BSS       1
                          000157          108 STR         BSS       2
                          000161          109 STR9        BSS       2
                          000163          110 IA          BSS       163
                          000426          111 JA          BSS       144

      ERROR LINKAGE

        000646   000000000000     000
        000647   475146232020     000
    END OF BINARY CARD SUBROUTI
                                          112             END
     650 IS THE NEXT AVAILABLE LOCATION.
    GMAP VERSION/ASSEMBLY DATES    JMPA 110171/102971        JMPB 110171/102971
    THERE WERE     NO   WARNING FLAGS IN THE ABOVE ASSEMBLY
```

```
C          SEISMIC SENSOR DATA FEATURE EXTRACTOR
C          NINE TRACK MAGNETIC TAPE VERSION
C     ALBERT H. PROCTOR     12 SEPTEMBER 1972     HONEYWELL 635 FORTRAN IV
C     NCHAN IS THE MAXIMUM NUMBER OF DATA CHANNELS TO BE PROCESSED
C     FROM ONE RUN OR THE NUMBER OF MAG TAPE PASSES.
C     NRUNS IS THE NUMBER OF RUNS TO BE PROCESSED IN THE NEXT PASS.
C     ITRESH IS THE THRESHOLD VALUE FOR THE ABSOLUTE AVERAGE DEVIATION
C     FROM THE MEAN FOR EACH 1.024 SECOND WINDOW.
C     IRUN IS AN ARRAY CONTAINING THE RUN NUMBERS TO BE PROCESSED IN
C     THE NEXT PASS.
C     ICHAN IS AN ARRAY CONTAINING THE CHANNEL NUMBERS TO BE PROCESSED
C     FOR EACH RUN IN THE NEXT PASS.
      DIMENSION JHEAD(6),IBUF(6144),JTAIL(6),ITEMP(6),ICHAN(20),IRUN(20)
      DIMENSION X(6144),FEAT(100)
      EQUIVALENCE (X,IBUF),(JHEAD(7),IBUF(1))
      IFC=1
      READ(5,1001)NCHAN
      DO 21 KCHAN=1,NCHAN
      READ(5,1000)  NRUNS, ITRESH
1000  FORMAT(2I5)
      READ(5,1001)   (IRUN(I),I=1,NRUNS)
1001  FORMAT(40O2)
      READ(5,1003) (ICHAN(I),I=1,NRUNS)
1003  FORMAT(40I2)
      WRITE(6,1004) NRUNS,ITRESH
 1004 FORMAT(1HO,1X,7HRUNS = ,I3,3X,8HITRESH =,I5)
      WRITE(6,1008)(IRUN(I),I=1,NRUNS)
 1008 FORMAT(1HO,1X,4HRUNS,5X,16(2X,O2))
      WRITE(6,1012)(ICHAN(I),I=1,NRUNS)
 1012 FORMAT(2X,8HCHANNELS,1X,16(2X,I2))
      CALL REW
      DO 20 I=1,NRUNS
      NVECT=0
   1  CALL RD9(JHEAD(1),ICHAN(I),0,0,IFC,IEOF)
      IF(IEOF.NE.0) GO TO 1
      IF(JHEAD(3).EQ.IRUN(I)) GO TO 2
      CALL FSF
      GO TO 1
2     ISTART=321
      JSTART=1
3     ISHIFT=0
      DO 40 J=ISTART,5120,320
      IF(J.EQ.1) GO TO 31
      DO 30 II=1,6
      JII=J+II-7
  30  ITEMP(II)=IBUF(JII)
  31  CALL RD9(IBUF(J-6),ICHAN(I),0,0,IFC,IEOF)
      IF(IEOF.NE.0) GO TO 20
      IF(J.EQ.1) GO TO 40
      DO 4 II=1,6
```

```
      JII=J+II-7
      JTAIL(II)=IBUF(JII)
    4 IBUF(JII)=ITEMP(II)
   40 CONTINUE
      DO 6 J=JSTART,5120,1024
      L=J+1023
      MEAN=JTAIL(4)
      ISUM=0
      DO 5 K=J,L
5     ISUM=ISUM+IABS(IBUF(K)-MEAN)
      ISUM=ISUM/1024
      PRINT 2001,ISUM
 2001 FORMAT(10X,20I5)
      IF(ISUM.GE.ITRESH) GO TO 6
      ISHIFT=L
6     CONTINUE
      JTAIL(5)=JTAIL(5)-4
      JTAIL(6)=JTAIL(6)-800
      IF(JTAIL(6).GE.0) GO TO 81
      JTAIL(6)=1000+JTAIL(6)
      JTAIL(5)=JTAIL(5)-1
   81 PRINT 1005,JTAIL,ICHAN(I)
 1005 FORMAT(1X,O12,2X,I5,2X,O12,2X,4(I5,2X))
      IF(ISHIFT.EQ.0) GO TO 8
      JJ=1
      JSTART=1
      IF(ISHIFT.GE.5120) GO TO 70
      IDIF=5120-ISHIFT
      JSTART=IDIF/1024
      JSTART=JSTART*1024+1
      ISHIFT=IDIF/320
      ISHIFT=5121-(ISHIFT*320)
      DO 7 J=ISHIFT,5120
      IBUF(JJ)=IBUF(J)
7     JJ=JJ+1
70    ISTART=JJ
      GO TO 3
    8 DO 100 J=1,5120
  100 X(J)=IBUF(J)
      L=1
      SUM1=0.
      SUM2=0.
      DO 10 J=1,1024,512
      CALL RSQAR(X(J),X(5121),R)
      SUM1=SUM1+R
   10 SUM2=SUM2+R*R
      FEAT(L)=SUM1/2.
      L=L+1
      FEAT(L)=SUM2/2.
      L=L+1
```

```
      DO 11 J=1025,5120,512
      CALL RSQAR(X(J),X(5121),R)
      SUM1=SUM1+R
   11 SUM2=SUM2+R*R
      FEAT(L)=SUM1/10.
      L=L+1
      FEAT(L)=SUM2/10.
      L=L+1
      L1=1
      L2=1025
      DO 200 J=1,3
      M=2*(J/3)
      CALL DOUBLE(X(L1),X(L2),M)
      L1=L1+2048
  200 L2=L2+2048
      DO 9 J=513,1024
    9 X(J)=(X(J-512)+X(J)+X(J+1536)+X(J+2048)+X(J+3584))/5.
      CALL HARMON(X,6,40,4,FEAT(L),FEAT(L+1))
      L=L+2
      CALL BINRAT(X,2,FEAT(L),FEAT(L+1))
      L=L+2
      CALL THRESH(X,2,4,FEAT(L))
      L=L+4
      CALL SPECVT(X,12,101,FEAT(L),FEAT(L+12))
      L=L+13
      CALL PEKPIK(X,2,0,1,FEAT(L))
      L=L+1
      CALL HARMON(X(513),6,40,4,FEAT(L),FEAT(L+1))
      L=L+2
      CALL BINRAT(X(513),2,FEAT(L),FEAT(L+1))
      L=L+2
      CALL THRESH(X(513),2,4,FEAT(L))
      L=L+4
      CALL SPECVT(X(513),12,101,FEAT(L),FEAT(L+12))
      L=L+13
      CALL PEKPIK(X(513),2,0,1,FEAT(L))
      PRINT 2000,(FEAT(IND),IND=1,L)
 2000 FORMAT(10X,10E10.3)
      PUNCH 1005,JTAIL,ICHAN(I)
      M=1
      DO 12 J=1,L,6
      L1=J+5
      IF(L1.GT.L) L1=L
      PUNCH 2002,(FEAT(IND),IND=J,L1),M
 2002 FORMAT(6E12.4,I8)
   12 M=M+1
      NVECT=NVECT+1
      ISTART=1
      JSTART=1
      GO TO 3
```

```
       20   PRINT 2003,NVECT
       2003 FORMAT(20H     TOTAL VECTORS = ,I5)
        21  CALL REW
            STOP
            END

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IEOF   DOES NOT APPEAR IN READ, DATA, COMMON OR LEFT OF EQUALS (=)
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R      DOES NOT APPEAR IN READ, DATA, COMMON OR LEFT OF EQUALS (=)
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23842 WORDS OF MEMORY USED BY THIS COMPILATION
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01 04-04-73 17,811

```
      SUBROUTINE DOUBLE(X,Y,NUM)
C      THIS SUBROUTINE ENABLES THE CALCULATION OF THE
C      POWER SPECTRUMS OF TWO REAL WAVEFORM SEGMENTS
C      WITH ONE CALL TO THE FFT SUBROUTINE.
      DIMENSION X(1024),Y(1024),S1(1024),S2(1024),TAB(780)
      IF(NUM-1) 30,25,30
25    DO 27 J=1,1024
27    Y(J)=0.
30    CALL  FFT(10,-1.0,X,Y,S1,S2,TAB)
      IF(NUM-1) 285,400,285
285   DO 300 K=2,512
      L=1026-K
      A=X(K)+X(L)
      B=X(K)-X(L)
      C=Y(K)+Y(L)
      D=Y(K)-Y(L)
      X(K)=(A*A+D*D)*.25
300   Y(K)=(C*C+B*B)*.25
      X(1)=0.
      X(513)=0.
      DO 320 K=2,512
      M=K+512
320   X(M)=Y(K)
      RETURN
400   DO 450 K=2,512
      A=X(K)*X(K)
      B=Y(K)*Y(K)
450   X(K)=A+B
      X(1)=0.
      RETURN
      END
```

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S1      DOES NOT APPEAR IN READ, DATA, COMMON OR LEFT OF EQUALS (=)
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S2      DOES NOT APPEAR IN READ, DATA, COMMON OR LEFT OF EQUALS (=)
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TAB     DOES NOT APPEAR IN READ, DATA, COMMON OR LEFT OF EQUALS (=)
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23721 WORDS OF MEMORY USED BY THIS COMPILATION
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```
      SUBROUTINE FFT(NSTAGE,SIGN,XR,XI,SCRAT1,SCRAT2,SCRAT3)
C     ALBERT H. PROCTOR     21 JANUARY 1972     HONEYWELL 635 FORTRAN IV
C     NSTAGE IS THE LOG BASE 2 OF N WHERE N IS THE NUMBER OF DATA POINTS
C     TO BE PROCESSED.
C     SIGN IS THE TRANSFORM/INVERSE TRANSFORM FLAG.
C     SIGN IS -1. FOR THE TRANSFORM AND 1. FOR THE INVERSE TRANSFORM.
C     XR WILL CONTAIN THE REAL PART OF EITHER THE INPUT OR OUTPUT DATA.
C     XI WILL CONTAIN THE IMAGINARY PART OF EITHER THE INPUT OR OUTPUT DATA.
C     SCRAT1 AND SCRAT2 ARE SCRATCH ARRAYS OF LENGTH N.
C     SCRAT3 CONTAINS THE COSINE TABLE OF LENGTH 3/4 N.
      DIMENSION XR(2),XI(2),SCRAT1(2),SCRAT2(2),SCRAT3(2)
      DATA LSTAGE/0/
      IF(SIGN)12,11,11
   11 ASSIGN 6 TO ISIGN
      GO TO 13
   12 ASSIGN 7 TO ISIGN
   13 IF(NSTAGE-LSTAGE)14,5,14
   14 LSTAGE=NSTAGE
      N=2**NSTAGE
      N2=N/2
      FLTN=N
      PHI2N=6.2831853/FLTN
      NPI=N2+1
      NPI1=NPI+1
      N4=N/4
      NPI2=N4+1
      N3PI2=3*N4+1
      SCRAT3(1)=1.
      SCRAT3(NPI2)=0.
      SCRAT3(NPI)=-1.
      SCRAT3(N3PI2)=0.
      DO 1 I=2,N4
      FI=I-1
      TEMP=FI*PHI2N
      TEMP=COS (TEMP)
      SCRAT3(I)=TEMP
      ISUB=N2+I
      ISUB1=NPI1-I
      SCRAT3(ISUB)=-TEMP
    1 SCRAT3(ISUB1)=-TEMP
    5 L=1
      DO 3 J=1,NSTAGE
      NI=L
      L=2*L
      N2J=N/L
      NP=N2J
      DO 2 I=1,NI
      IN2J=(I-1)*N2J
      IN2K=IN2J+1
      IN2JI=IN2K+N4
      W1=SCRAT3(IN2K)
```

```
        GO TO ISIGN,(6,7)
  6     W2=-SCRAT3(IN2JI)
        GO TO 8
  7     W2= SCRAT3(IN2JI)
  8     DO 2 IR=1,NR
        ISUB=IR+IN2J
        ISUB1=ISUB+IN2J
        ISUB2=ISUB1+N2J
        ISUB3=ISUB+N2
        WR=W1*XR(ISUB2)-W2*XI(ISUB2)
        WI=W2*XR(ISUB2)+W1*XI(ISUB2)
        SCRAT1(ISUB)=XR(ISUB1)+WR
        SCRAT2(ISUB)=XI(ISUB1)+WI
        SCRAT1(ISUB3)=XR(ISUB1)-WR
        SCRAT2(ISUB3)=XI(ISUB1)-WI
  2     CONTINUE
        DO 3 IR=1,N
        XR(IR)=SCRAT1(IR)
  3     XI(IR)=SCRAT2(IR)
        IF(SIGN)10,9,9
  9     DO 4 IR=1,N
        XR(IR)=XR(IR)/FLTN
  4     XI(IR)=XI(IR)/FLTN
 10     RETURN
        END
```

23647 WORDS OF MEMORY USED BY THIS COMPILATION

```
      SUBROUTINE HARMON (PS,NPEAKS,ISTART,MARGIN,SPACE,COUNT)
C      THIS SUBROUTINE DETERMINES THE MOST FREQUENTLY OCCURRING
C      PAIRWISE SPACING BETWEEN THE LARGEST PEAKS IN THE POWER
C      SPECTRUM AND THE NUMBER OF TIMES IT OCCURRED.
      DIMENSION PS(512),KCOUNT(20),ITAB(20),IFREQ(10)
      DO 9 I=1,NPEAKS
      LPEAK=ISTART
      PEAK=PS(ISTART)
      JSTART=ISTART+1
      DO 1 J=JSTART,512
      IF(PEAK.GE.PS(J))GO TO 1
      LPEAK=J
      PEAK=PS(J)
    1 CONTINUE
      IF(PEAK.LT.0.) GO TO 17
      IFREQ(I)=LPEAK
      PS(LPEAK)=-PEAK
      JSTART=LPEAK+1
    2 DO 4 J=JSTART,512
      PSJ=PS(J)
      IF(PSJ.LT.0.) GO TO 5
      DIF=ABS(PS(J-1))-PSJ
      IF(DIF.GE.0.) GO TO 4
      TEST=50.*(PEAK-ABS(PS(J-1)))
      IF(TEST.GT.PEAK) GO TO 5
      PS(4)=-PSJ
      JJJ=J+1
      DO 3 JJ=JJJ,512
      PSJ=PS(JJ)
      IF(PSJ.LT.0.) GO TO 5
      DIF=ABS(PS(JJ-1))-PSJ
      IF(DIF)3,33,33
    3 PS(JJ)=-PSJ
      GO TO 5
    4 PS(J)=-PSJ
      GO TO 5
   33 JSTART=JJ+1
      PS(J)=-PSJ
      GO TO 2
    5 JSTART=LPEAK-1
    6 DO 8 JJ=1,JSTART
      J=JSTART-JJ+1
      PSJ=PS(J)
      IF(PSJ.LT.0.) GO TO 9
      DIF=PSJ-ABS(PS(J+1))
      IF(DIF.LE.0.) GO TO 8
      TEST=50.*(PEAK-ABS(PS(J+1)))
      IF(TEST.GT.PEAK) GO TO 9
      PS(J)=-PSJ
      JJJ=J-1
      DO 7 JJJJ=1,JJJ
```

```
      J=JJJ-JJJJ+1
      PSJ=PS(J)
      IF(PSJ.LT.0.) GO TO 9
      DIF=PSJ-ABS(PS(J+1))
      IF(DIF)77,77,7
    7 PS(J)=-PSJ
      GO TO 9
    8 PS(J)=-PSJ
      GO TO 9
   77 JSTART=J-1
      PS(J)=-PSJ
      GO TO 6
    9 CONTINUE
      GO TO 18
   17 NPEAKS=I-1
   18 DO 10 I=1,512
   10 PS(I)=ABS(PS(I))
      CALL SORTUP(IFREQ,NPEAKS)
      K=0
      DO 11 I=1,20
   11 KCOUNT(I)=0
      N1=NPEAKS-1
      DO 15 I=1,N1
      JSTART=I+1
      DO 15 J=JSTART,NPEAKS
      IDIF=IFREQ(J)-IFREQ(I)
      MIN=IDIF-MARGIN
      MAX=IDIF+MARGIN
      IF(K.EQ.0) GO TO 13
      DO 12 KK=1,K
      IF(ITAB(KK).LE.MAX.AND.ITAB(KK).GE.MIN) GO TO 14
   12 CONTINUE
      IF(K.GE.20) GO TO 15
   13 K=K+1
      ITAB(K)=IDIF
      KK=K
   14 KCOUNT(KK)=KCOUNT(KK)+1
   15 CONTINUE
      IND=1
      MAXMUM=KCOUNT(1)
      DO 16 I=2,K
      IF(MAXMUM.GE.KCOUNT(I)) GO TO 16
      IND=I
      MAXMUM=KCOUNT(I)
   16 CONTINUE
      COUNT=KCOUNT(IND)
      SPACE=ITAB(IND)
      RETURN
      END
```

23751 WORDS OF MEMORY USED BY THIS COMPILATION

```
      SUBROUTINE SORTUP (IRAY,N)
C      THIS SUBROUTINE IS CALLED BY HARMON TO ORDER THE
C      N LARGEST PEAKS ACCORDING TO THEIR AMPLITUDES.
      DIMENSION IRAY(N)
      N1=N-1
      DO 2 I=1,N1
      IND=I
      LITTLE=IRAY(I)
      JSTART=I+1
      DO 1 J=JSTART,N
      IF(IRAY(J).GE.LITTLE) GO TO 1
      LITTLE=IRAY(J)
      IND=J
    1 CONTINUE
      ITEMP=IRAY(I)
      IRAY(I)=LITTLE
    2 IRAY(IND)=ITEMP
      RETURN
      END
```

23709 WORDS OF MEMORY USED BY THIS COMPILATION

```
      SUBROUTINE THRESH (PS,ISTART,LEVELS,PIST)
C      THIS SUBROUTINE COMPARES THE AMPLITUDES OF
C      ELEMENTS IN THE POWER SPECTRUM AGAINST A NUMBER
C      OF EQUALLY SPACED THRESHOLDS AND RETURNS THE
C      NUMBER OF ELEMENTS WHICH FALL BETWEEN THESE
C      THRESHOLDS.
      DIMENSION PS(512),PIST(LEVELS)
      PEAK=PS(ISTART)
      SMALL=PEAK
      JSTART=ISTART+1
      DO 1 J=JSTART,512
      SMALL=AMIN1(SMALL,PS(J))
    1 PEAK=AMAX1(PEAK,PS(J))
      DIVIDE=(PEAK-SMALL)/FLOAT(LEVELS)
      DO 3 J=1,LEVELS
    3 PIST(J)=0.
      DO 4 I=ISTART,512
      IND=(PS(I)-SMALL)/DIVIDE+1.
      IF(IND.GT.LEVELS) IND=LEVELS
    4 PIST(IND)=PIST(IND)+1.
      RETURN
      END
```

23780 WORDS OF MEMORY USED BY THIS COMPILATION

```
      SUBROUTINE RSQAR(X,SCRAT,R)
C      THIS SUBROUTINE CALCULATES R, WHERE R IS DEFINED
C      AS THE RATIO OF THE MAXIMUM DEVIATION FROM THE
C      MEAN TO THE AVERAGE DEVIATION FROM THE MEAN IN A
C      GIVEN 1/2 SECOND WINDOW OF THE TIME WAVEFORM.
      DIMENSION X(512),SCRAT(512)
      SUM=0.
      DO 10 I=1,512
   10 SUM=SUM+X(I)
      SUM=SUM/512.
      DO 20 I=1,512
   20 SCRAT(I)=ABS(X(I)-SUM)
      XMAS=0.
      SUM=0.
      DO 40 L=1,512
      XMAS=AMAX1(XMAS,SCRAT(L))
   40 SUM=SUM+SCRAT(L)
      R=(512.*XMAS)/SUM
      RETURN
      END
```

23648 WORDS OF MEMORY USED BY THIS COMPILATION

```
      SUBROUTINE BINRAT(PS,ISTART,FEAT1,FEAT2)
C      THIS SUBROUTINE CALCULATES THE RATIOS OF ENERGY
C      BETWEEN ONE AND TWENTY HERTZ AND BETWEEN FORTY-ONE
C      AND SIXTY HERTZ TO THE ENERGY BETWEEN TWENTY-ONE
C      AND FORTY HERTZ.
      DIMENSION PS(512)
      SUM1=0.
      SUM2=0.
      SUM3=0.
      ISTOP=ISTART+19
      DO 1 I=ISTART,ISTOP
      SUM1=SUM1+PS(I)
      SUM2=SUM2+PS(I+20)
    1 SUM3=SUM3+PS(I+40)
      FEAT1=SUM1/SUM2
      FEAT2=SUM3/SUM2
      RETURN
      END
```

23648 WORDS OF MEMORY USED BY THIS COMPILATION

```
      SUBROUTINE SPECVT(PS,NVECT,ITH,VECT,REATEB)
C      THIS SUBROUTINE CALCULATES THE RATIO OF ENERGY
C      ABOVE A SPECIFIED FREQUENCY TO THE ENERGY BELOW
C      AND ALSO CREATES A VECTOR WHOSE COMPONENTS
C      CONTAIN NORMALIZED ENERGY VALUES FRON CONSECUTIVE
C      FREQUENCY BINS OF THE POWER SPECTRUM,
      DIMENSION PS(512),VECT(NVECT)
      DO 1 I=1,NVECT
    1 VECT(I)=0.
      SUM=0.
      DO 5 I=1,NVECT
      J=5*I-3
      K=5*I+1
      DO 2 L=J,K
    2 VECT(I)=VECT(I)+PS(L)
    5 SUM=SUM+VECT(I)
      DO 6 I=1,NVECT
    6 VECT(I)=VECT(I)/SUM
      RGYBT=0,
      RGYAT=0,
      DO 3 I=1,ITH
    3 RGYBT=RGYBT+PS(I)
      J=ITH+1
      DO 4 I=J,512
    4 RGYAT=RGYAT+PS(I)
      REATEB=RGYAT/RGYBT
      RETURN
      END
```

23715 WORDS OF MEMORY USED BY THIS COMPILATION

```
      SUBROUTINE PEKPIK(PS,ISTART,THRESH,COUNT)
C      THIS SUBROUTINE CALCULATES THE NUMBER OF PEAKS
C      IN A POWER SPECTRUM WHICH ARE ABOVE SOME SPECIFIED
C      PERCENTAGE OF THE MAXIMUM PEAK,
      DIMENSION PS(512)
      XMIN=PS(ISTART)
      XMAS=XMIN
      INIT=ISTART+1
      DO 1 I=INIT,512
      XMIN=AMIN1(XMIN,PS(I))
    1 XMAS=AMAX1(XMAS,PS(I))
      TEST=(XMAS-XMIN)*THRESH
      COUNT=0,
      PSMIN=PS(I)-XMIN
      IF(PSMIN.GT.TEST) GO TO 2
      ISWIT=0
      GO TO 3
    2 ISWIT=1
    3 DO 5 I=2,512
      PSMIN=PS(I)-XMIN
      IF(ISWIT.EQ.1) GO TO 4
      IF(PSMIN.GT.TEST) ISWIT=1
      GO TO 5
    4 IF(PSMIN.GT.TEST) GO TO 5
      ISWIT=0
      COUNT=COUNT+1,
    5 CONTINUE
      RETURN
      END
```

23778 WORDS OF MEMORY USED BY THIS COMPILATION

```
 1        LBL      FSF,REW, SUBROUTINE TO SKIP RECORDS AND REWIND MAG TAPES
 2 *      AL PROCTOR, ISCP, RADC
                                           3          SYMDEF   FSF,REW
                        000000             4 FSF      SAVE
   000000  000002710000    010
   000001  000033630000    010
   000002  000033754000    010
   000003  000033741000    010
   000004  000001 0010 00  000             5          MME      GEINOS
   000005  45 0000 020001  000             6          FSF
   000006  000030 000000   010             7          ZERO     FC
   000007  000031 000000   010             8          ZERO     STATUS
   000010  000002 0010 00  000             9          MME      GEROAD
   000011  000031 2350 00  010            10 LOOP1    LDA      STATUS
   000012  000011 6050 00  010            11          TPL      LOOP1
   000013  000001710000    010            12          RETURN   FSF
                        000014            13 REW      SAVE
   000014  000016710000    010
   000015  000033630000    010
   000016  000033754000    010
   000017  000033741000    010
   000020  000001 0010 00  000            14          MME      GEINOS
   000021  70 0000 020001  000            15          REW
   000022  000030 000000   010            16          ZERO     FC
 END OF BINARY CARD FSF00002
   000023  000031 000000   010            17          ZERO     STATUS
   000024  000002 0010 00  000            18          MME      GEROAD
   000025  000031 2330 00  010            19 LOOP2    LDA      STATUS
   000026  000025 6050 00  010            20          TPL      LOOP2
   000027  000015710000    010            21          RETURN   REW
   000030  000000000001    000            22 FC       BCI      1,000001
                        000031            23 STATUS   BSS      2

  ERROR LINKAGE

   000033  000000000000    000
   000034  266220202020    000
 END OF BINARY CARD FSF00003
                                          24          END
   36 IS THE NEXT AVAILABLE LOCATION.
 GMAP VERSION/ASSEMBLY DATES    JMPA 110171/102971      JMPB 110171/102971      JI
 THERE WERE    NO  WARNING FLAGS IN THE ABOVE ASSEMBLY
```

```
     1          LBL      READ9TRK,SUBROUTINE TO READ 9 TRACK DECODED TAPES
     2 *        JIM ROACH, ISCP,RADC
                                              3         SYMDEF   RD9
                             000000           4         USE      PREVIOUS
                             000000           5 RD9     SAVE     0,1,2,3,4,5
        000000   000010710000      010
        000001   000000220003      000
        000002   000000221003      000
        000003   000000222003      000
        000004   000000223003      000
        000005   000000224003      000
        000006   000000225003      000
        000007   003045630000      010
        000010   003045754000      010
        000011   003045741000      010
        000012   000001740000      010
        000013   000002741000      010
        000014   000003742000      010
        000015   000004743000      010
        000016   000005744000      010
        000017   000006745000      010
        000020   000002 2350 11    000        6         LDA      2,1
        000021   003044 7550 00    010        7         STA      BUF
        000022   000007 4500 31    000        8         STZ      7,1*
   END OF BINARY CARD READ9TRK
        000023   000006 2350 31    000        9         LDA      6,1*
        000024   003043 7550 00    010       10         STA      FC
        000025   000000 2200 03    000       11         LDX0     =0,DU
        000026   003041 2350 00    010       12         LDA      DUMMY
        000027   000134 7550 00    010       13         STA      TALLY
        000030   003040 2350 00    010       14         LDA      DUMMYB
        000031   000133 7550 00    010       15         STA      TALLYB
        000032   000001 0010 00    000       16         MME      GEINOS
        000033   03 0000 000000    000       17         RT9
        000034   003043 000135     011       18         ZERO     FC,DCW
        000035   000136 000000     010       19         ZERO     STR
        000036   000002 0010 00    000       20         MME      GEROAD
        000037   000136 2350 00    010       21         LDA      STR
        000040   000002 7350 00    000       22         ALS      2
        000041   777400 3750 03    000       23         ANA      =0777400,DU
        000042   211400 1150 03    000       24         CMPA     =0211400,DU      9 TRACK EOF
        000043   000047 6010 00    010       25         TNZ      LOOP
        000044   000001 2350 07    000       26         LDA      =1,DL
        000045   000007 7550 31    000       27         STA      7,1*
   END OF BINARY CARD READ9TRK
        000046   000132 7100 00    010       28         TRA      EXIT
        000047   003050 2360 00    010       29 LOOP    LDQ      =1472
        000050   000006 7360 00    000       30         QLS      6
        000051   000134 7520 06    010       31         STCQ     TALLY,06
        000052   003050 2360 00    010       32         LDQ      =1472
        000053   000006 7360 00    000       33         QLS      6
        000054   000133 7520 06    010       34         STCQ     TALLYB,06
```

```
       000055  000133 2350 52   010       35 RUN     LDA      TALLYB,SC
       000056  000134 7550 52   010       36         STA      TALLY,SC
       000057  000055 6070 00   010       37         TTF      RUN
       000060  000001 0600 03   000       38         ADX0     =1,DU
       000061  000004 1000 03   000       39         CMPX0    =4,DU
       000062  000047 6010 00   010       40         TNZ      LOOP
       000063  000000 2240 03   000       41         LDX4     =0,DU
       000064  000000 2230 03   000       42         LDX3     =0,DU
       000065  000003 2360 31   000       43 START   LDQ      3,1*
       000066  000124 6000 00   010       44         TZE      NEXT
       000067  003051 1760 00   010       45         SBQ      =1
       000070  003052 4020 00   010       46         MPY      =109
   END OF BINARY CARD READ9TRK
       000071  000000 6230 06   000       47         EAX3     0,QL
       000072  000000 2200 03   000       48         LDX0     =0,DU
       000073  000140 2360 13   010       49 BEGIN   LDQ      IA,3
       000074  003053 2350 00   010       50         LDA      =0
       000075  000022 7370 00   000       51         LLS      18
       000076  003044 7550 70   010       52         STA      BUF,*0
       000077  000001 0600 03   000       53         ADX0     =1,DU
       000100  000022 7370 00   000       54         LLS      18
       000101  000022 7350 00   000       55         ALS      18
       000102  000030 7310 00   000       56         ARS      24
       000103  003044 7550 70   010       57         STA      BUF,*0
       000104  000001 0630 03   000       58         ADX3     =1,DU
       000105  000001 0600 03   000       59         ADX0     =1,DU
       000106  000000 2220 03   000       60 LOOPX   LDX2     =0,DU
       000107  003053 2350 00   010       61         LDA      =0
       000110  000140 2360 13   010       62         LDQ      IA,3
       000111  000014 7370 00   000       63 LOOPY   LLS      12
       000112  000030 7350 00   000       64         ALS      24
       000113  000030 7310 00   000       65         ARS      24
   END OF BINARY CARD READ9TRK
       000114  003044 7550 70   010       66         STA      BUF,*0
       000115  000001 0600 03   000       67         ADX0     =1,DU
       000116  000001 0620 03   000       68         ADX2     =1,DU
       000117  000003 1020 03   000       69         CMPX2    =3,DU
       000120  000111 6010 00   010       70         TNZ      LOOPY
       000121  000001 0630 03   000       71         ADX3     =1,DU
       000122  000506 1000 03   000       72         CMPX0    =326,DU
       000123  000106 6010 00   010       73         TNZ      LOOPX
       000124  000001 0610 03   000       74 NEXT    ADX1     =1,DU
       000125  000506 2250 03   000       75         LDX5     =326,DU
       000126  003044 0450 0    010       76         ASX5     BUF
       000127  000001 0640 03   000       77         ADX4     =1,DU
       000130  000003 1040 03   000       78         CMPX4    =3,DU
       000131  000065 6010 00   010       79         TNZ      START
       000132  000000171000 0   010       80 EXIT    RETURN   R09
                           000133         81 TALLYB  BSS      1
                           000134         82 TALLY   BSS      1
       000135  000140 002700    010       83 DCW     IOTD     IA,1472
                           000136         84 STR     BSS      2
```

```
                         000140          85 IA       BSS      1472
      003040  000140 2700 40   010       86 DUMMYB   TALLYB   IA,1472,0
  END OF BINARY CARD READ9TRK
      003041  000140 2700 00   010       87 DUMMY    TALLY    IA,1472,0
                         003042          88 LOCO     BSS      1
                         003043          89 FC       BSS      1
                         003044          90 BUF      BSS      1

     ERROR LINKAGE

      003045  000000000000     000
      003046  512411202020     000

       LITERALS

      003050  000000002700     000
      003051  000000000001     000
      003052  000000000155     000
      003053  000000000000     000
  END OF BINARY CARD READ9TRK
                                         91          END
  3054 IS THE NEXT AVAILABLE LOCATION.
 GMAP VERSION/ASSEMBLY DATES    JMPA 110171/102971        JMPB 110171/102971
 THERE WERE     NO  WARNING FLAGS IN THE ABOVE ASSEMBLY
```

```
C       SEISMIC SENSOR FEATURE TAPE GENERATOR
C       THIS IS THE CDC 1604 PROGRAM WHICH CONVERTS DATA CARDS TO
C       AN OLPARS COMPATIBLE MAGNETIC TAPE.
      PROGRAM ALSDATA
       DIMENSION X(130),IX(130),NUM(20),INAME(20),LFOR(20),IHEAD(7)
      EQUIVALENCE(X,IX)
      READ 1007,ISKIP
 1007 FORMAT(I5)
      READ 1000,LFOR
      READ 1000,INAME
 1000 FORMAT(10A8)
      READ 1001,NDIM,ITOT,NUM
      NP3=NDIM+3 $ NLO=NDIM+1
 1001 FORMAT(25I3)
      DO 7 I=1,ISKIP
    7 READ TAPE 10
      DO 1 IDUM=1,ITOT
      ITOP=NUM(IDUM)
      DO 2 I=1,ITOP
      READ 1006,IHEAD
 1006 FORMAT(1X,I12,2X,I5,2X,O12,2X,4(I5,2X))
      READ LFOR,(X(J),J=1,NDIM)
 1002 FORMAT(15(1X,F3.0))
      IX(NDIM+1)=IHEAD(1)*100000+IHEAD(3)*10000+IHEAD(7)*1000+IHEAD(5)
      IX(NDIM+2)=INAME(IDUM).AND.778
      IX(NDIM+3)=INAME(IDUM)
      WRITE TAPE 10,(X(JJ),JJ=1,NP3)
    2 CONTINUE
    1 CONTINUE
      PAUSE
      END FILE 10
      REWIND 10
      PRINT 1005
 1005 FORMAT(1H1)
    6 READ TAPE 10,(X(KK),KK=1,NP3)
      IF(EOF,10)4,5
    5 PRINT 1003,(X(KK),KK=1,NDIM)
 1003 FORMAT(1X,10E11.3)
      PRINT 1004,(X(KK),KK=NLO,NP3)
 1004 FORMAT(1X,I10,2(1X,A8),//)
      GO TO 6
    4 REWIND 10
      END
```

APPENDIX B

PROBABILITY OF CONFUSION MEASURES

PAIR C/H RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	27	.2165970482
2	5	.3068226121
3	46	.3732664996
4	29	.3880813144
5	24	.3964912281
6	35	.4010025063
7	7	.4328599276
8	43	.4407128933
9	21	.4484544695
10	13	.4613756614
11	3	.4906711222
12	42	.5032024506
13	14	.5131161236
14	44	.5141186299
15	39	.5157894737

PAIR C/A RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	47	.1407407407
2	25	.1777777778
3	46	.1975589225
4	6	.3091750842
5	35	.3121212121
6	13	.3153619529
7	24	.3385942761
8	27	.3649831650
9	28	.3835437710
10	42	.3838383838
11	14	.3832154882
12	36	.3911616162
13	5	.4061868687
14	39	.4077861953
15	29	.4292929293

PAIR M/A RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	4	.0561497326
2	3	.0635026738
3	46	.2376336898
4	1	.2516711230
5	45	.2650401069
6	2	.3091577540
7	24	.3629679144
8	23	.3723262032
9	31	.3983957219
10	32	.4044117647
11	43	.4124331551
12	44	.4278074866
13	22	.4776069518
14	26	.4799465241
15	39	.4986631016

PAIR M/T RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	43	.0294662309
2	38	.0368191721
3	44	.0589324619
4	45	.0813180828
5	16	.0958605664
6	42	.0960784314
7	37	.1326797386
8	22	.1547930283
9	21	.1552287582
10	29	.1839869281
11	20	.1844226579
12	39	.2139978213
13	23	.2141612200
14	15	.2213507625
15	7	.2430827887

PAIR T/A RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	37	.0528619529
2	29	.1239898990
3	15	.1548400673
4	38	.1654882155
5	16	.2099326599
6	7	.2109427609
7	36	.2450336700
8	42	.3030723906
9	14	.3070286195
10	35	.3277356902
11	43	.3739898990
12	20	.3907407407
13	13	.4133838384
14	41	.4287878788
15	19	.4436026936

PAIR M/H RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	3	.1114551084
2	4	.1116209642
3	28	.1258292791
4	43	.1416961521
5	27	.1560703229
6	6	.1620964175
7	21	.1868089341
8	5	.2001879699
9	31	.2449690402
10	32	.2453007519
11	41	.2606700575
12	19	.2757076515
13	44	.2904135338
14	1	.3104820876
15	2	.3405572755

PAIR C/T RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	38	.0518518519
2	16	.0962962963
3	39	.1037037037
4	17	.2296296296
5	46	.2370370370
6	37	.2444444444
7	47	.2518518518
8	25	.2666666667
9	45	.2740740741
10	44	.2740740741
11	24	.3555555556
12	15	.3629629630
13	23	.3851851852
14	43	.4000000000
15	22	.4222222222

PAIR C/M RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	42	.1402505447
2	43	.2583877996
3	6	.2655773420
4	29	.2873638344
5	28	.2956427015
6	20	.3023965142
7	31	.3097494553
8	4	.3177559913
9	32	.3179193900
10	3	.3248910675
11	47	.3321895425
12	26	.3467320261
13	27	.3769607843
14	21	.3907952070
15	25	.3983660131

PAIR A/H RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	5	.1431989064
2	27	.1660970608
3	28	.2137303486
4	6	.2252648667
5	41	.3320232399
6	19	.3413790157
7	40	.4427973342
8	18	.4636876282
9	43	.4642002734
10	21	.4959415584
11	47	.5037593985
12	17	.5260167464
13	42	.5320403281
14	3	.5331937799
15	20	.5337064251

PAIR T/H RANKINGS

RANKING	MEASUREMENT	CONFUSION
1	16	.1048175996
2	38	.1195210248
3	29	.1272626009
4	7	.1490392648
5	37	.1493734336
6	27	.2309663046
7	15	.2608187134
8	5	.2683375104
9	17	.3206349206
10	39	.3874129769
11	45	.4200501253
12	40	.4253411306
13	18	.4409356725
14	3	.4774157616
15	42	.4802005012

APPENDIX C

LINEAR DISCRIMINANTS

```
                                FISHER LOGIC

                                NODES IN SET
                  WEL H    APC A    BIG T    MEN M    131 C

        PAIR  1            + NODE APC A      - NODE HEL H           FISHER

                                 COEFICIENTS
 3.96813970E-02 -9.68449165E-04 -4.89501481E-03  5.46598674E-02 -2.72921703E-01
 6.97331329E-03 -8.28998958E-03  6.64553796E-02  2.90634536E-01 -4.76369896E-02
-4.58998220E-02  6.04166410E-01  7.42977735E-02 -4.74997161E-01 -4.54152691E-01
-1.58537605E-01
                                 THRESHOLDS
-3.90074135E 00

        PAIR  2            + NODE BIG T      - NODE HEL H           FISHER

                                 COEFICIENTS
 4.69708409E-02 -1.93562543E-03  1.48660333E-04  6.44628818E-03 -4.76223767E-02
 1.23024713E-01 -4.70777325E-03  3.53239344E-01  2.90515473E-01  5.56283819E-02
 1.04713262E-02 -4.10778187E-01 -5.20485980E-01 -4.10062826E-01 -3.99207157E-01
-2.79211913E-02
                                 THRESHOLDS
-2.17537000E 00

        PAIR  3            + NODE BIG T      - NODE APC A           FISHER

                                 COEFICIENTS
-2.64713167E-02  6.06509398E-03  1.03361576E-04 -3.82463038E-03 -8.76089367E-02
 1.13450048E-01 -9.34415560E-04  6.31070976E-01  4.86526098E-01  1.89365433E-02
 4.34608519E-02 -3.72815440E-01 -3.80115643E-01 -2.24040779E-01 -7.54861956E-02
 4.60801884E-02
                                 THRESHOLDS
-4.34867354E-01
```

```
*****************************************************************************************
*                                                                                       *
*        PAIR  4             + NODE MEN M      - NODE HEL H          FISHER             *
*                                                                                       *
*****************************************************************************************
                                       COEFICIENTS
 2.31412790E-02 -8.29361174E-04 -4.87289242E-04  1.56959376F-02  2.45615090E-01
-7.35585459E-02 -2.31964098E-03 -5.11421164E-01 -5.83638325F-01 -2.47784696E-02
-6.03075430E-02  4.75379822E-01  2.85305202E-01  5.51895298F-02  1.28423779E-01
-1.06921944E-02
                                       THRESHOLDS
-9.64285189E-01
*****************************************************************************************
*                                                                                       *
*        PAIR  5             + NODE MEN M      - NODE APC A          FISHER             *
*                                                                                       *
*****************************************************************************************
                                       COEFICIENTS
 6.38509813E-02 -2.92688890E-03 -1.22036734E-04  1.63364582F-03  7.74779748E-02
-8.68381015E-02 -1.97395633E-05 -3.60530052E-01 -3.92612416F-01 -4.50913730E-02
-8.48406086E-02  3.15413584E-01  1.80348321E-01  4.55909276F-01  5.89007129E-01
 4.70808742E-02
                                       THRESHOLDS
 2.35755267E-01
*****************************************************************************************
*                                                                                       *
*        PAIR  6             + NODE MEN M      - NODE BIG T          FISHER             *
*                                                                                       *
*****************************************************************************************
                                       COEFICIENTS
-5.50894445E-02  5.73911040E-03  1.72406718E-04  1.92032559F-03  3.15769992E-02
-1.18786829E-01  4.18998653E-04 -1.85814095E-01 -1.76911342F-01 -2.15106346E-02
 9.75774688E-02  4.46816622E-01  4.81252016E-01  5.63346962F-01  3.96430146E-01
 1.57187128E-02
                                       THRESHOLDS
 1.42390262E-01
*****************************************************************************************
*                                                                                       *
*        PAIR  7             + NODE 131 C      - NODE HEL H          FISHER             *
*                                                                                       *
*****************************************************************************************
                                       COEFICIENTS
 9.81440973E-02 -4.44773076E-03  1.46881055E-04 -9.54345732F-04  2.58345800E-01
 2.16534455E-03 -9.81695737E-04 -2.62143802E-01 -7.81897234F-01 -1.10873436E-01
-2.93516114E-01  2.31881216E-01  1.00293123E-01 -1.48426786F-02  2.84237662E-01
 1.52302180E-02
                                       THRESHOLDS
-1.45736931E-01
```

```
**************************************************************************
*                                                                        *
*        PAIR  8            + NODE 131 C     - NODE APC A        FISHER  *
*                                                                        *
**************************************************************************
                                   COEFICIENTS
 3.68751710E-02 -1.93352649E-03  1.11484727E-04 -5.66834421F-03  5.10667510E-02
 2.60469141E-04  1.73549076E-04  8.67489587E-01 -4.34033285F-01 -5.31094909E-02
-1.56387985E-01  4.40291408E-02  4.92898694E-02  7.95402735F-02  1.30704837E-01
 4.13118158E-03
                                   THRESHOLDS
 1.77654615E-01
**************************************************************************
*                                                                        *
*        PAIR  9            + NODE 131 C     - NODE BIG T        FISHER  *
*                                                                        *
**************************************************************************
                                   COEFICIENTS
-3.29124399E-02  3.38280485E-03  2.10909619E-04 -5.81299678F-03  4.30942207E-02
-6.16253086E-04  3.21567445E-04 -6.88160741E-01 -6.40371320F-01 -2.87653123E-01
-1.14154548E-01  7.20820436E-02  2.92250744E-02  6.36615539F-02  8.64491945E-02
 4.63701435E-03
                                   THRESHOLDS
-6.68589073E-02
**************************************************************************
*                                                                        *
*        PAIR 10            + NODE 131 C     - NODE MEN M        FISHER  *
*                                                                        *
**************************************************************************
                                   COEFICIENTS
-1.45109285E-02  1.15913285E-03  4.11714251E-05 -1.46447234F-02  3.46032284E-02
 2.98863360E-04  7.81958367E-04  1.11012423E-01 -7.58692477F-01 -2.96591145E-01
-5.60288311E-01 -6.88661871E-02 -5.03450867E-02 -3.53279527F-02  4.21597498E-03
 2.27725816E-03
                                   THRESHOLDS
 1.83859536E-01
END OF THIS LOGIC SET
```

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[3] Foley, D. H., Caruso, P.J., et. al., "Time Domain Analysis," Final Report to Contract F30602-72-C-0227, RADC-TR-72-292, Vol. II, Nov. 1972.

[4] Foley, D. H., Roberts, D., "Improved Seismic Classifiers," RADC-TR-72-172, July 1972, AD 744489.

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