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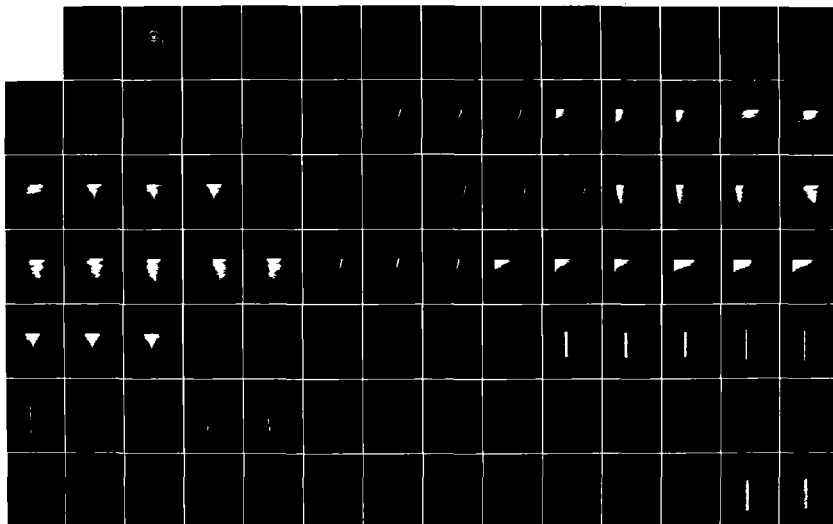
AN ANALYSIS OF A PC-3 MICROPULSATION IN THE GEOMAGNETIC
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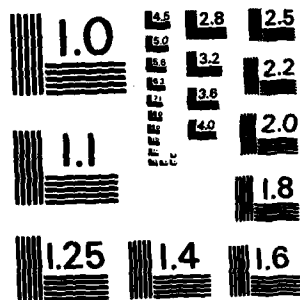
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THESIS

AN ANALYSIS OF A PC-3 MICROPULSATION IN
THE GEOMAGNETIC FIELD

by

Kurt B. Stevens

June 1983

Thesis Advisor:

A. Ochadlick

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Power spectral density (PSD) plots summarizing data segments about two hours long occasionally contained structures found to be artificial and not representative of natural phenomena in the geomagnetic field. Methods to avoid this anomalous behavior in PSD plots are suggested.

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An Analysis of a PC-3 Micropulsation in the Geomagnetic Field

by

Kurt B. Stevens
Captain, United States Air Force
B.S., United States Air Force Academy, 1979

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN PHYSICS

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

→ The Naval Postgraduate School has an ongoing effort to study geomagnetic noise and micropulsations in the ULF frequency range ($0.05 \leq f \leq 10$ Hz). Data is collected by three orthogonally mounted coils at a remote land site and telemetered to the laboratory for computer analysis.

To isolate data containing a micropulsation event, time series plots of the magnetic field were generated. The development of a double running average routine made possible the isolation of micropulsations in large data sets. A type PC-3 micropulsation was found and the coherence, ellipticity and polarization properties were determined as follows: Coherence = 0.99, Degree of Polarization = 0.99 and the micropulsation was elliptically polarized.

Power spectral density (PSD) plots summarizing data segments about two hours long occasionally contained structures found to be artificial and not representative of natural phenomena in the geomagnetic field. Methods to avoid this anomalous behavior in PSD plots are suggested. ↗

TABLE OF CONTENTS

I.	INTRODUCTION -----	8
II.	BACKGROUND -----	10
	A. COLLECTION SYSTEM -----	10
	1. System Calibration -----	11
	B. PREVIOUS SOFTWARE -----	13
	C. ANALYSIS OF INITIAL DATA PLOTS -----	17
III.	TIME SERIES DATA -----	59
	A. TIME SERIES VOLTAGE DATA -----	59
	1. Voltage Software -----	59
	2. Time Series Voltage Data Analysis -----	61
	B. TIME SERIES MAGNETIC FIELD DATA -----	69
	1. Magnetic Field Software -----	69
	2. Smoothed Magnetic Field Data Analysis -----	79
IV.	SYSTEM AND SOFTWARE VALIDATION -----	88
	A. EXPERIMENTAL APPARATUS -----	88
	B. EXPERIMENT RESULTS -----	90
	1. Voltage -----	90
	2. Magnetic Field -----	97
V.	MICROPULSATIONS -----	110
	A. THEORY -----	110
	B. MICROPULSATION DATA ANALYSIS -----	112
VI.	CONCLUSIONS -----	118
	APPENDIX A: VOLTR COMPUTER PROGRAM -----	120
	APPENDIX B: VOLTS COMPUTER PROGRAM -----	126

APPENDIX C: LFVTC1 COMPUTER PROGRAM -----	131
LIST OF REFERENCES -----	139
INITIAL DISTRIBUTION LIST -----	140

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I. INTRODUCTION

This thesis is part of an ongoing effort at the Naval Postgraduate School to analyze ULF geomagnetic noise and micropulsations. The results of the Naval Postgraduate School studies could impact communications systems or systems in which geomagnetic noise and/or micropulsations introduce operational difficulties.

An objective of this thesis was to develop the software necessary for obtaining computer generated plots of geomagnetic field versus time. Then, with the plots, sections of data containing obvious geomagnetic micropulsations were located. Those sections were analyzed to determine the power spectral density (PSD), coherence, degree of polarization and ellipticity of the micropulsation using already developed software [Ref. 1].

After analyzing some of the plots (PSD, coherence, etc.) produced by the software documented in [Ref. 1], it was demonstrated that problems existed in the software. New software was developed to obtain times series raw voltage and geomagnetic field plots. Validation of the software required an on-site experiment. Documented within this thesis is the software to produce time series voltage and geomagnetic field plots and the questions the validation experiment raised concerning the sensing system and software.

Using the newly developed software, a micropulsation event was located. A double running average software routine accentuated the micropulsation to permit the determination of its frequency and amplitude. The micropulsation event was further analyzed to obtain information on coherence, degree of polarization and ellipticity.

II. BACKGROUND

A. COLLECTION SYSTEM

The Naval Postgraduate School has two operating geomagnetic sensing systems. The land site is located at the La Mesa Village Housing Area and has three orthogonally mounted induction coils. The second operating system contains two orthogonally mounted induction coils that can be placed on the bottom of Monterey Bay. When both systems are operating, the data is collected simultaneously. The ground work has been laid for a third system located at Chew's Ridge. Three orthogonal and simultaneous measurements can be taken only between two sites since the School has only five induction coils and a sixth just calibrated. This thesis used data from the La Mesa Village site and the software associated with it.

An induction coil senses the geomagnetic field fluctuations based on Faraday's Law of induction, induced emf $= -N \frac{d\Phi}{dt}$, which describes the relation between the induced emf and the time rate of change of magnetic flux through the coil. N is the number of turns in the coil.

The voltage induced in the coils is sampled 32 or 64 times/second and is amplified approximately one million times. The voltage data undergoes pulse-code-modulation (PCM) for noiseless VHF radio link transmission from the La Mesa Village site, to the recording system in the Geophysics Signal

Processing Laboratory located in Spanagel 531. Data reduction on the Naval Postgraduate School's IBM 3033 computer follows digitization of the PCM data. A block diagram of the system is provided in Figure 2.1. A more detailed description of the system is given in Reference 2.

1. System Calibration

For purposes of documentation, the calibration of the third coil for either the Chew's Ridge or Monterey Bay system is being included in this thesis. The general method of induction coil calibration will be covered here. For a more indepth explanation, see Reference 1.

The sensing coil and its associated electronics are calibrated using a Helmholtz coil apparatus to establish a uniform magnetic field. By placing the sensing coil into the field produced by the Helmholtz coil, one can establish a relationship between the Helmholtz coil magnetic field magnitude and frequency and the coil system voltage. Once the response of the coil system is known for the frequency band of interest, it can be included in the system transfer function used in data reduction.

The experiment to determine the sixth coil system transfer function was done at the La Mesa Village site. A Wavetek Model 142 signal generator supplied a sinusoidal current to a 1.22 meter diameter, 0.61 meter high Helmholtz coil. The current was measured across a 996 ohm resistor in series with the Helmholtz coil. A Hewlett Packard HP-3582A spectrum

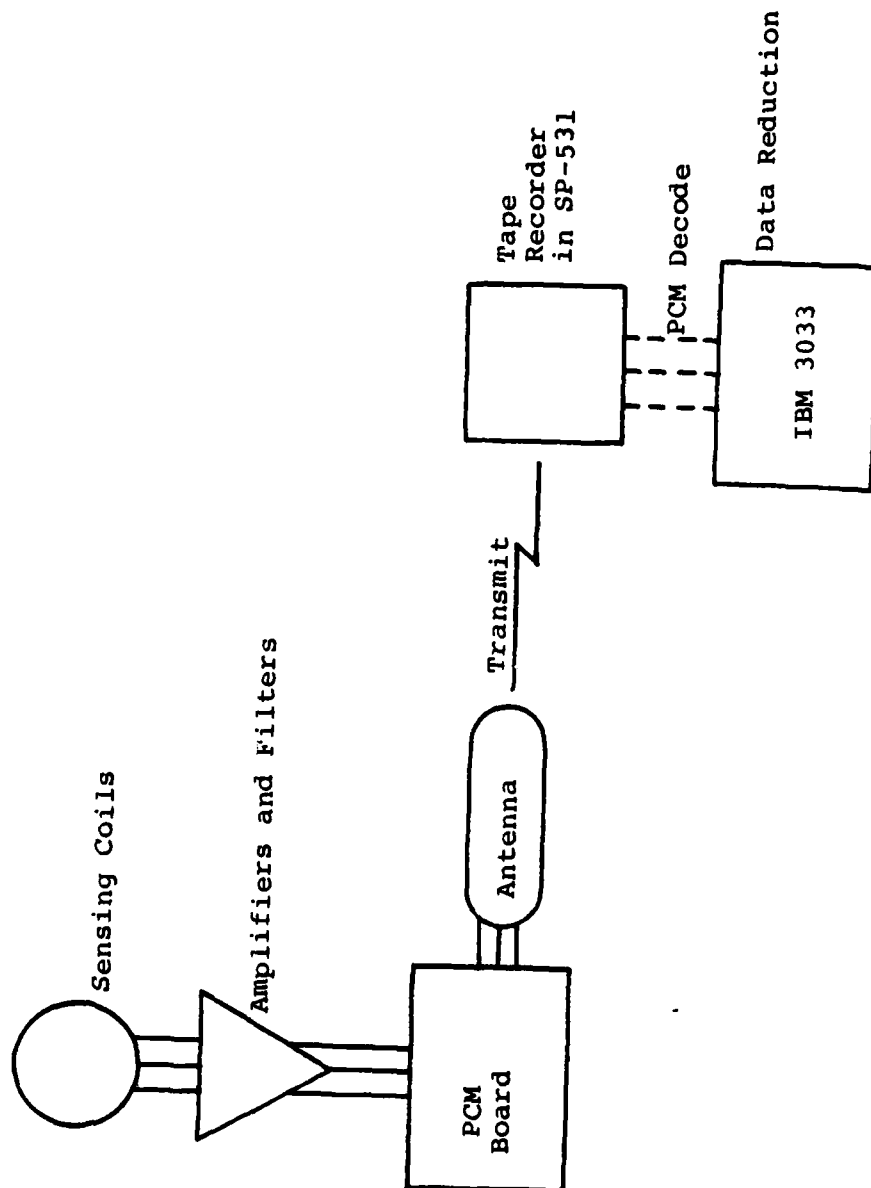


Figure 2.1. System Data Flow

analyzer measured the output voltage of the coil system as a function of frequency.

The experiment measured the response of the coil system in the frequency band .05 hertz to 20 hertz for applied fields of 0.02, 0.2 and 1.0 nanoteslas. The coil system response is shown in Figure 2.2. The transfer function of this coil system corresponds closely to those of coil systems previously calibrated. The only noticable difference is that the 0.02 nanotesla response at 15 hertz is approximately 15 volts/nanotesla higher than those measured before [Ref. 1]. It should be noted that this difference will not influence data analysis in the frequency range of interest. The transfer function algorithm is listed in Table 2.1.

B. PREVIOUS SOFTWARE

Software has been developed (see References 1 and 3), to extract power spectral densities for each coil, coherence between the coils, degree of polarization in the three measurement planes, ellipticity in the three measurement planes and a variety of Stokes parameters. The following is a basic description of the computer code that produces the above mentioned plots. First, the voltage data is read off the digital tape using a subroutine called RD provided by Dr. Tim Stanton of the Oceanography Department. A parameter ISEC, representing the number of seconds one wishes to advance the tape, is frequently used. ISEC establishes the number of

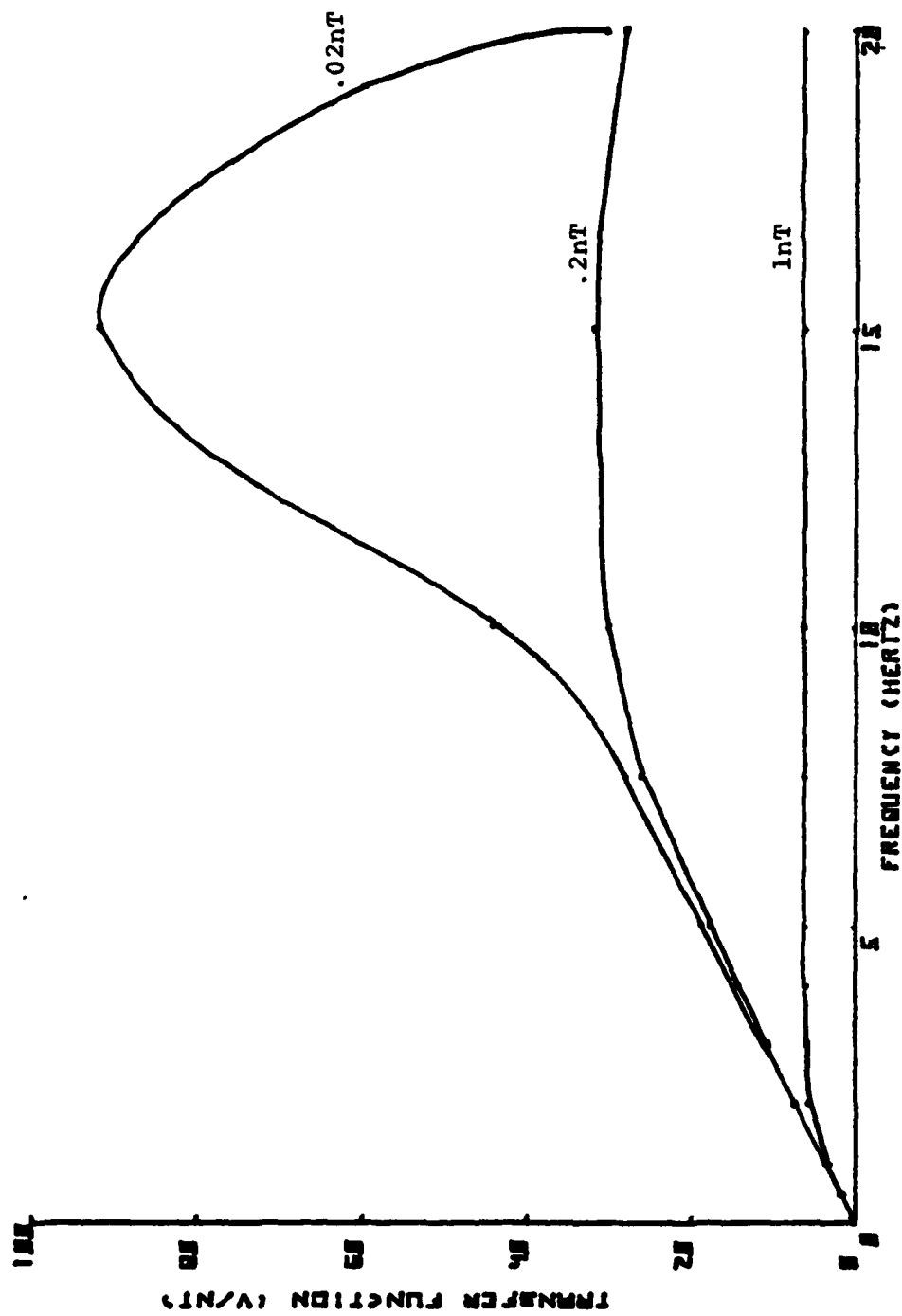


Figure 2.2. Coil Transfer Function

Table 2.1. System Transfer Function Algorithm

```

DC 9 L=1,N
FFQ=FREQ(L)
IF(FRQ.LE.25.)GO TO 1
XX(L)=XX(L)/28.
GC TO 8
1 IF(FRQ.LE.15.)GO TO 2
XX(L)=XX(L)/(105.5-3.14*FRQ)
YY(L)=YY(L)/(181.32-7.588*FRQ)
ZZ(L)=ZZ(L)/(177.26-7.484*FRQ)
GC TO 8
2 IF(FRQ.LE.10.)GO TO 3
XX(L)=XX(L)/(5.958*FRQ-30.97)
YY(L)=YY(L)/(7.166*FRQ-39.99)
ZZ(L)=ZZ(L)/(6.49*FRQ-32.35)
GC TO 8
3 IF(FRQ.LE.7.5)GO TO 4
XX(L)=XX(L)/(3.492*FRQ-6.31)
YY(L)=YY(L)/(4.252*FRQ-10.85)
ZZ(L)=ZZ(L)/(4.044*FRQ-7.89)
GC TO 3
4 IF(FRQ.LE.5.)GO TO 5
XX(L)=XX(L)/(2.6311*FRQ+0.14667)
YY(L)=YY(L)/(3.012*FRQ-1.55)
ZZ(L)=ZZ(L)/(3.184*FRQ-1.44)
GC TO 8
5 IF(FRQ.LE.3.)GO TO 6
XX(L)=XX(L)/(2.6311*FRQ+0.14667)
7 YY(L)=YY(L)/(2.702*FRQ)
ZZ(L)=ZZ(L)/(2.92*FRQ)
GC TO 8
8 XX(L)=XX(L)/(2.72*FRQ)
GC TO 7
8 CONTINUE
TF(L)=(XX(L)*COS0 + YY(L)*COS01)*COS00 + ZZ(L)*COS30
9 CONTINUE

```

times RD is called and the data not stored. Previously, tape advances of approximately 30 seconds or ISEC = 30 were used. Once the tape is advanced the desired amount, data analysis can begin. Each digital tape contains about 90 minutes or 1.728×10^5 pieces of data per axis resulting from the sampling rate of 32 samples/second. Because of the large amount of data, the analysis has to be accomplished in blocks. Data analysis takes place on 256 seconds or 8192 frames of data at a time. RD is called 8192 times and places the voltages for each coil in an array. The voltages are integer values from 0 to 4096 representing -5 volts to +5 volts. Ideally the value 2048 represents 0 volts. The integers between 0-4096 are normalized to ± 5 volts and placed in new complex arrays. These arrays containing 8192 pieces of data are Fourier transformed to the frequency domain where the system transfer function is applied. After applying the transfer function, the calculations begin for a determination of PSD's, coherence, ellipticity, etc. for the first block. After they are complete, the next block of 8192 pieces of data starts through the program. Once the desired amount of data has been processed, a NONIMSL subroutine called DRAWP plots the data. For a more complete description of this software, see Reference 1, Reference 3 and Reference 4.

C. ANALYSIS OF INITIAL DATA PLOTS

Many of the PSD's, coherences, ellipticities and degree of polarization plots produced by the software of Reference 1 and Reference 3 have unexpected characteristics. The PSD's show "humps" that are shown in Figures 2.3-2.5. These "humps" are not characteristic in "normal" PSD's. The coherence plots show a coherence of essentially one degrading to hash in the frequencies greater than 2 hertz, Figures 2.6-2.8. We see a similar behavior in the plots of degree of polarization. These plots indicate a very highly polarized field from 0.02 hertz to 1.0 hertz. Figures 2.9-2.11. The ellipticity plots show a very linearly polarized field for these frequencies in Figures 2.12-2.14.

After examining the time series magnetic field plots, we noted a section of very large magnitude fluctuations (about one to three orders of magnitude greater than the general background) at the beginning of the digital tapes Figures 2.15-2.17. We found that if the digital tape was advanced past these large fluctuations the output (PSD, coherence, etc.) appeared "normal", Figures 2.18-2.29. If the program was executed on just the section containing the large fluctuations, the PSD's had the "humped" characteristic, the coherences were one, the degree of polarization was very high and the ellipticity was linear, Figures 2.30-2.41. This demonstrates that these large fluctuations dominate the output of an analysis in the frequency domain. A tape advance of 300 seconds or ISEC = 300 is

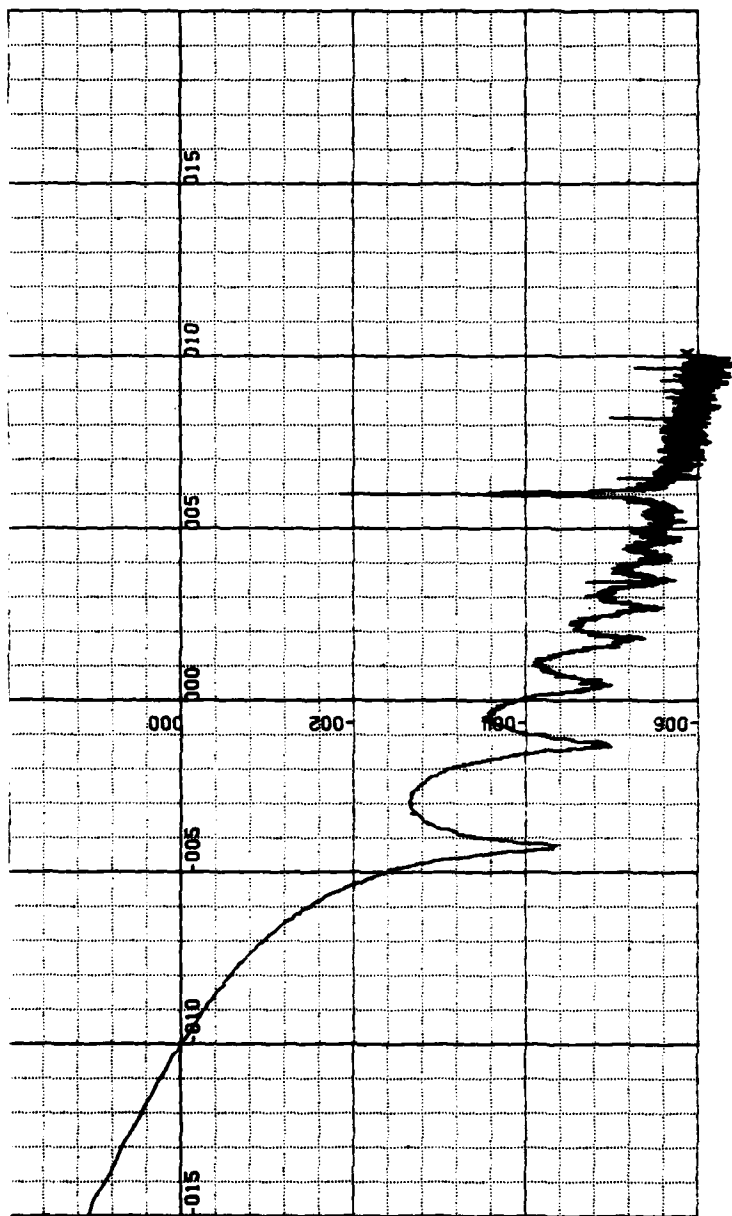


Figure 2.3. PSD X-Coil, 17 August 82, 2240-2348 Local.
Amplitude in dB (REF nT**2/Hz) (20 units/in) vs. Log
Frequency (Hz) (0.5 units/in), 16 Averages

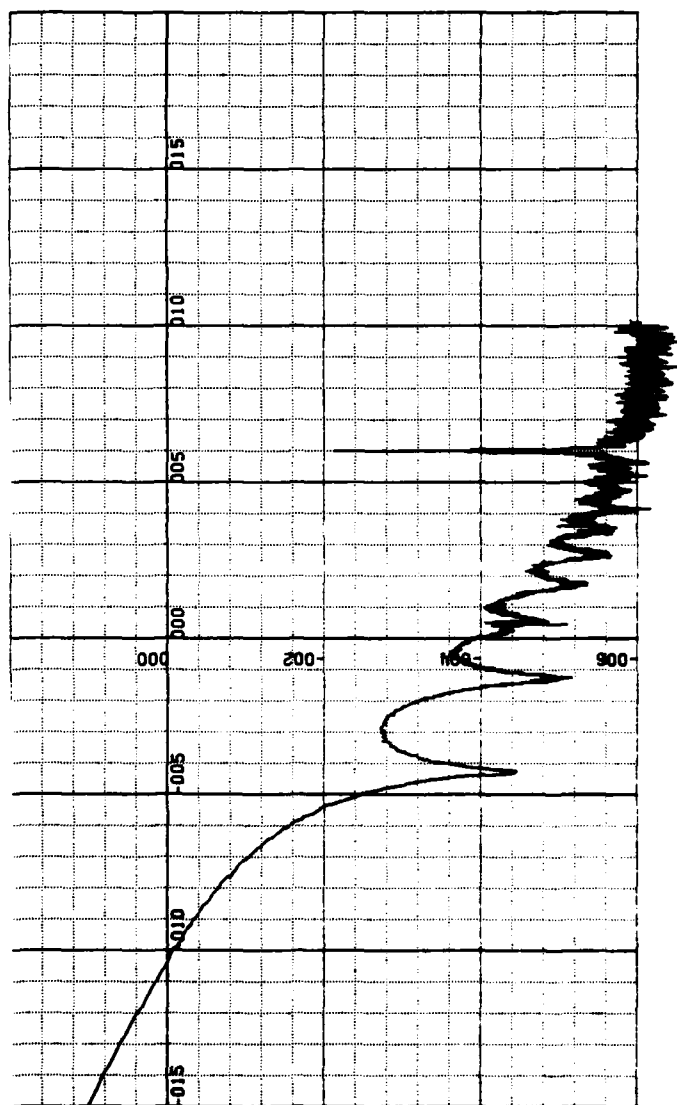


Figure 2.4. PSD Y-Coil, 17 August 82, 2240-2348 Local.
Amplitude in dB (REF $nT^{**}2/Hz$) (20 units/in)
vs. Log Frequency (Hz) (0.5 units/in), 16 Averages

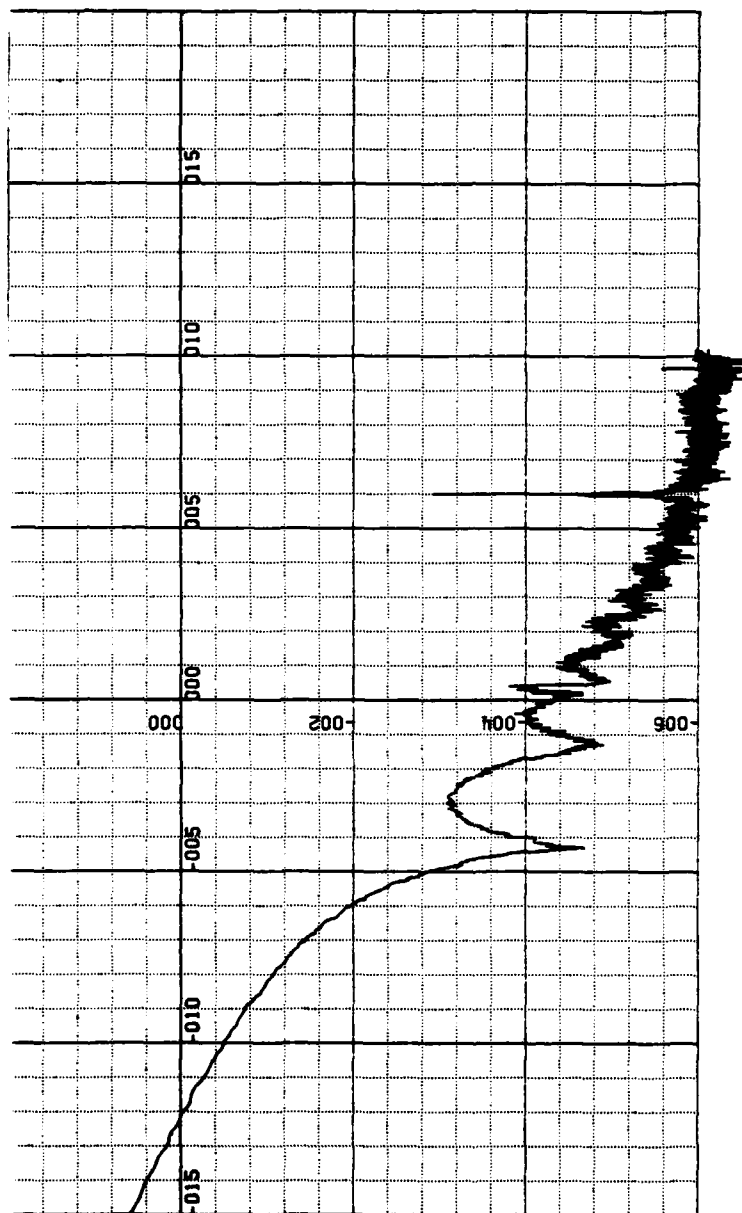


Figure 2.5. PSD Z-Coil, 17 August 82, 2240-2348 Local.
Amplitude in dB (REF nT**2/Hz) (20 units/in) vs.
Log Frequency (Hz) (0.5 units/in), 16 Averages

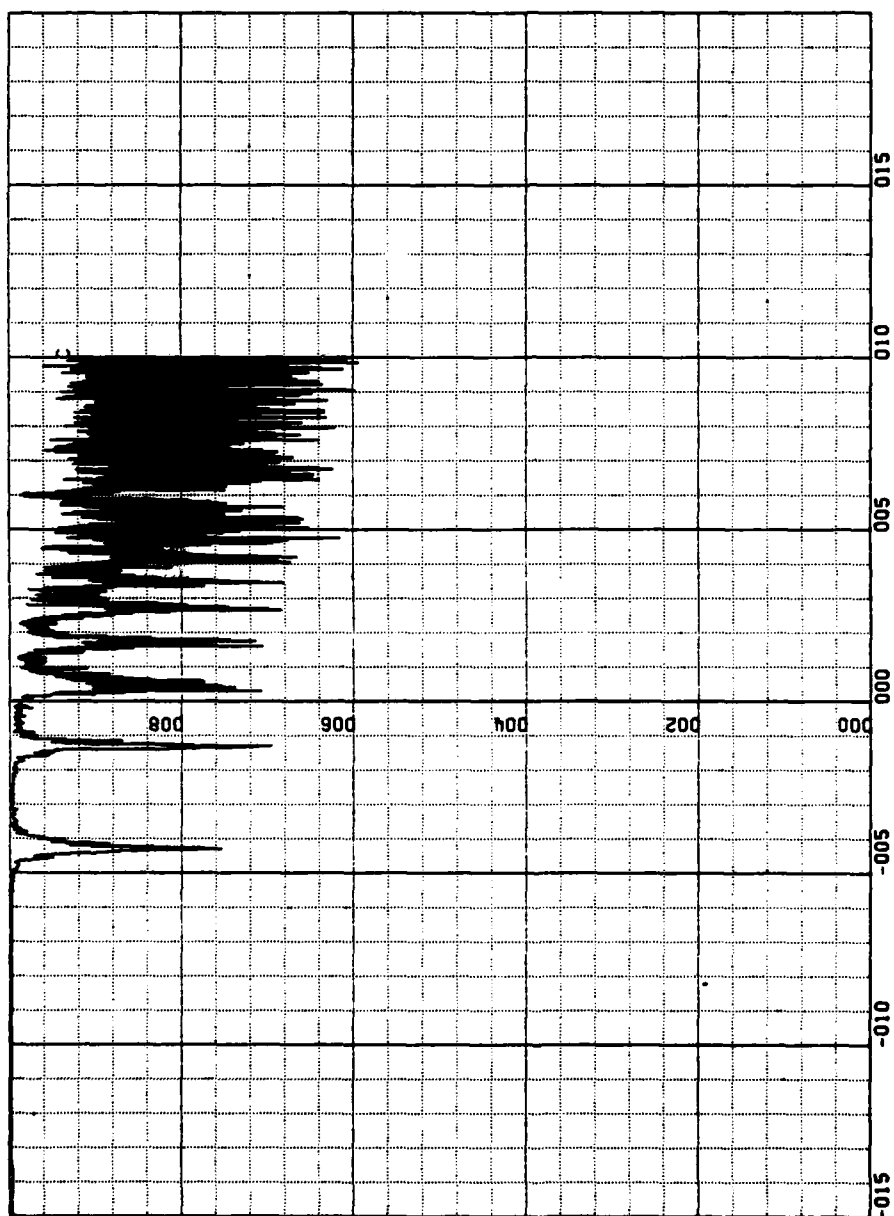


Figure 2.6. Coherence X and Y coils, 17 August 82, 2240-2348 Local.
Coherence X and Y Coil (0.2 units/in) vs. Log Frequency
(Hz) (0.5 units/in), 16 Averages

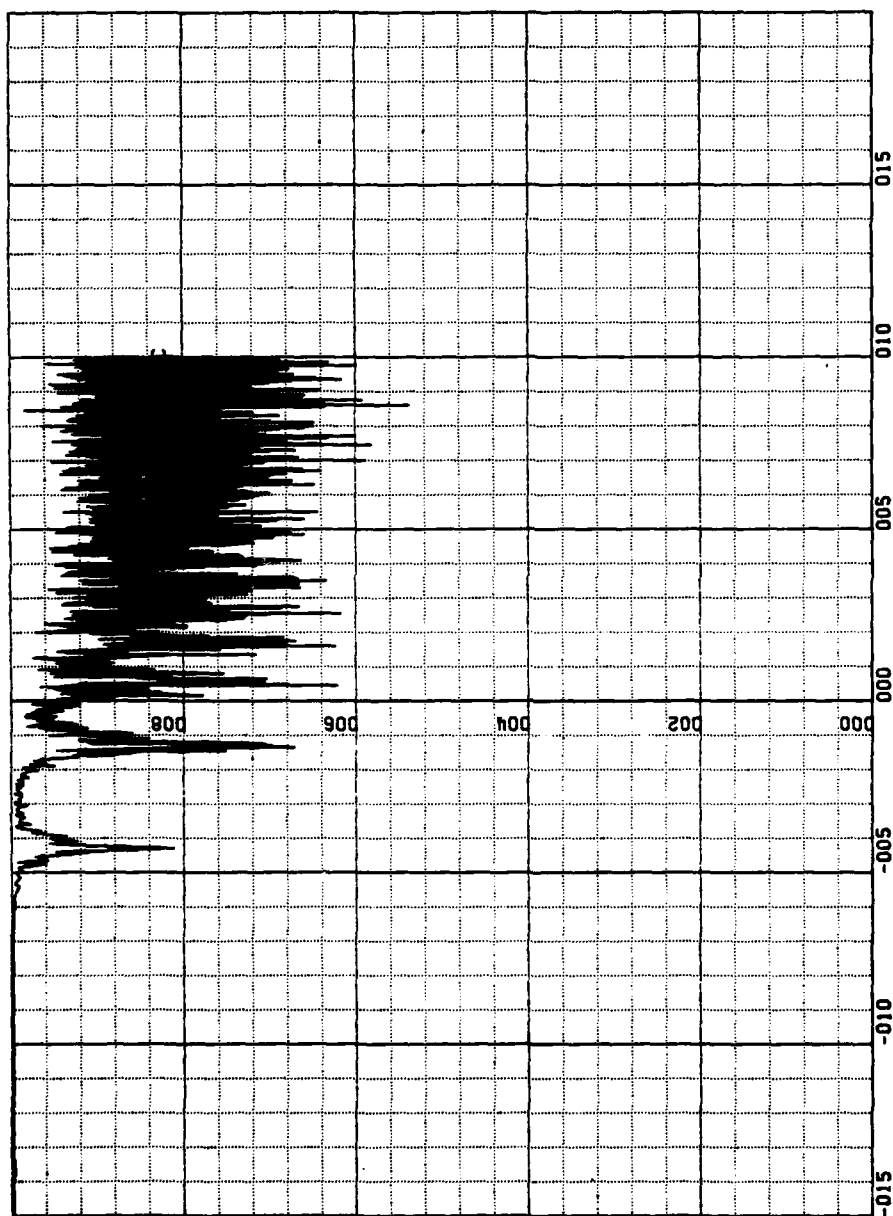


Figure 2.7. Coherence Y and Z Coils, 17 August 82, 2240-2348 Local.
Coherence Y and Z Coils (0.2 units/in) vs. Log Frequency
(Hz) (0.5 units/in), 16 Averages

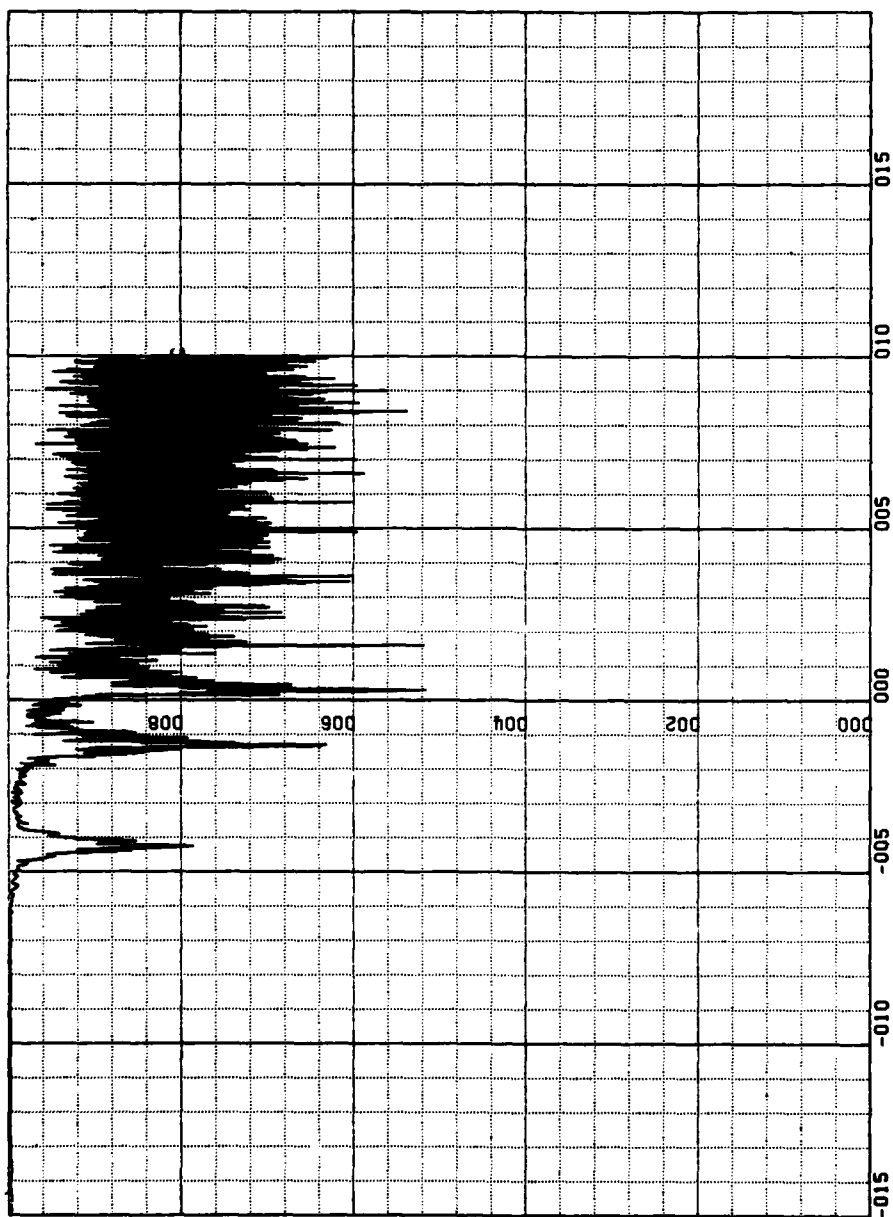


Figure 2.8. Coherence Z and Z Coils, 17 August 82, 2240-2348 Local.
Coherence Z and X Coils (0.2 units/in) vs. Log Frequency
(Hz) (0.5 units/in), 16 Averages

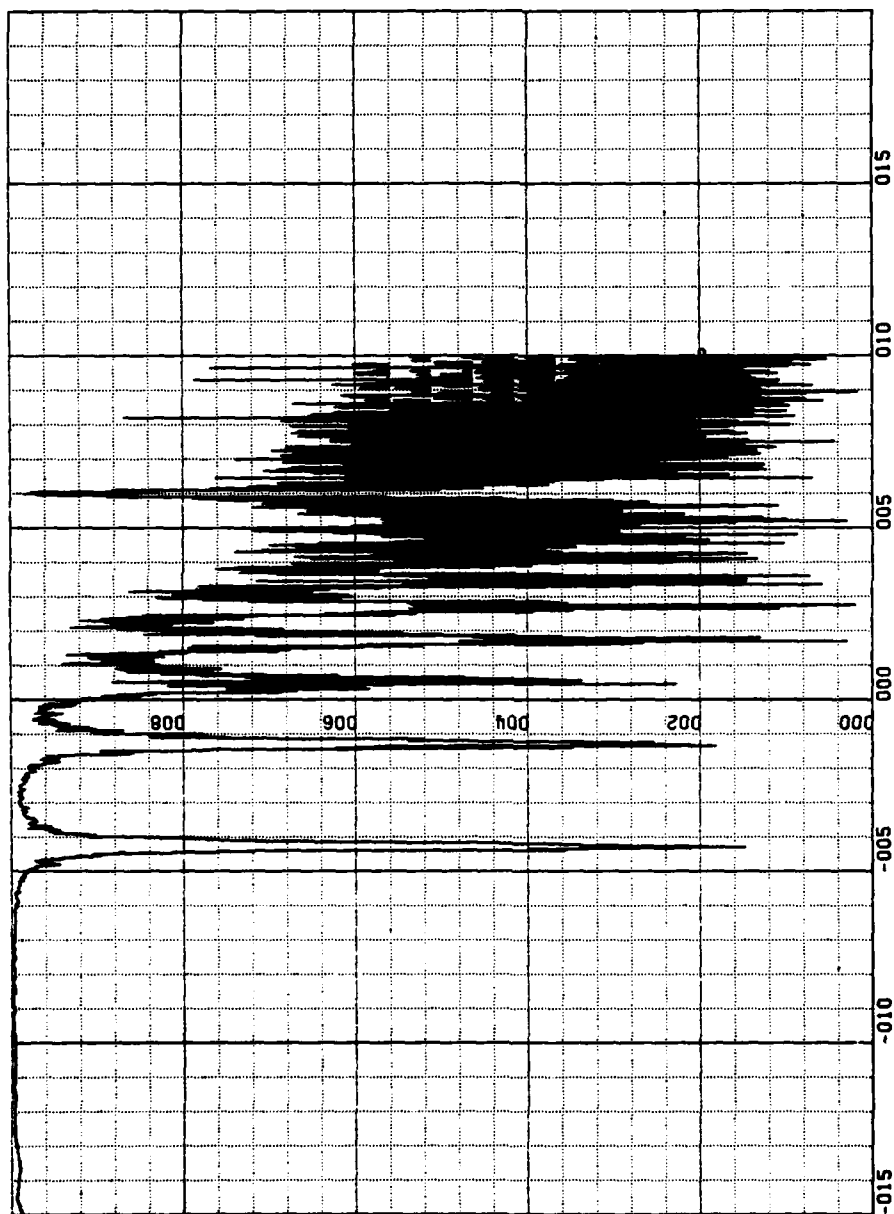


Figure 2.9. Degree of Polarization X-Y Plane, 17 August 82, 2240-2348 Local.
Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz)
(0.5 units/in), 16 Averages

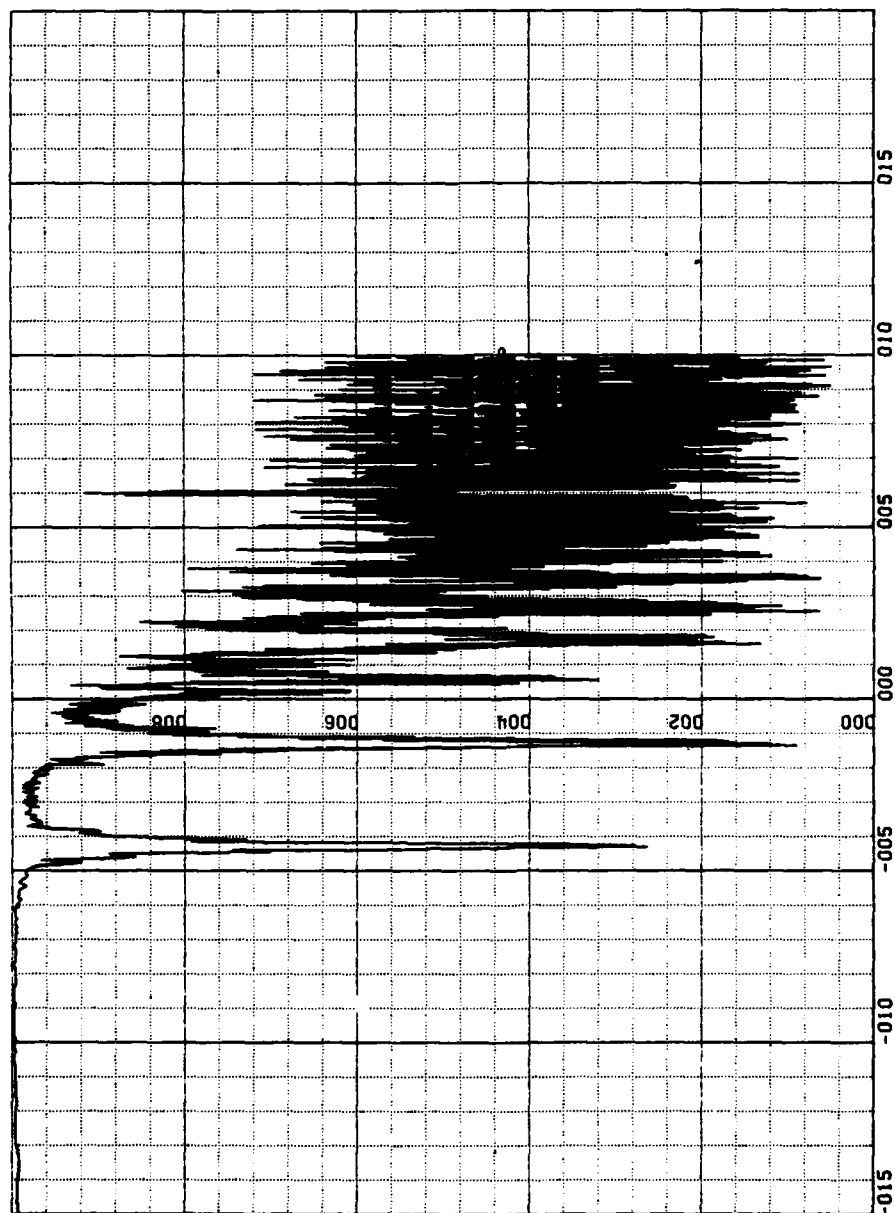


Figure 2.10. Degree of Polarization Y-Z Plane, 17 August 82, 2240-2348 Local.
 Degree of Polarization (0.2 units/in) vs. Log
 Frequency (Hz) (0.5 units/in), 16 Averages

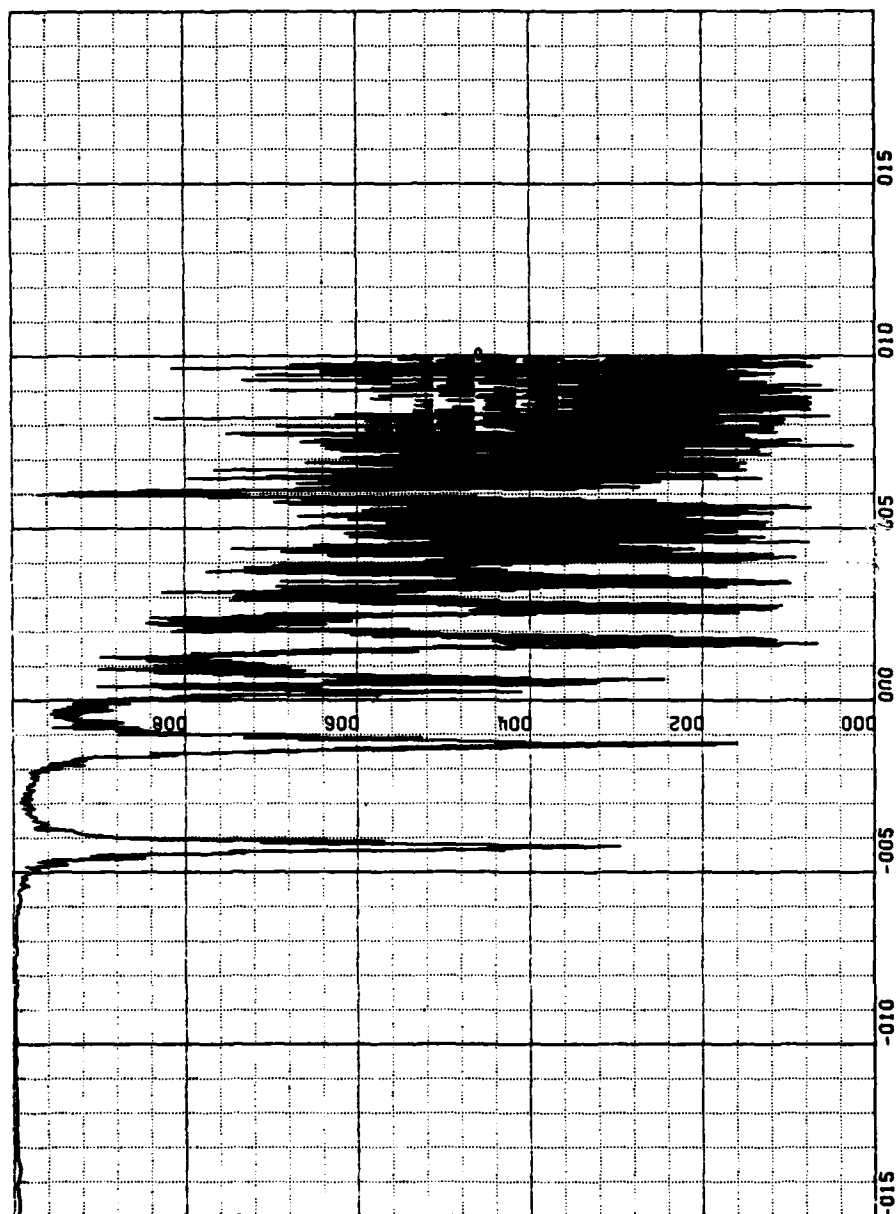


Figure 2.11. Degree of Polarization Z-X Plane, 17 August 82, 2240-2348 Local.
 Degree of Polarization (0.2 units/in) vs. Log Frequency
 (Hz) (0.5 units/in), 16 Averages

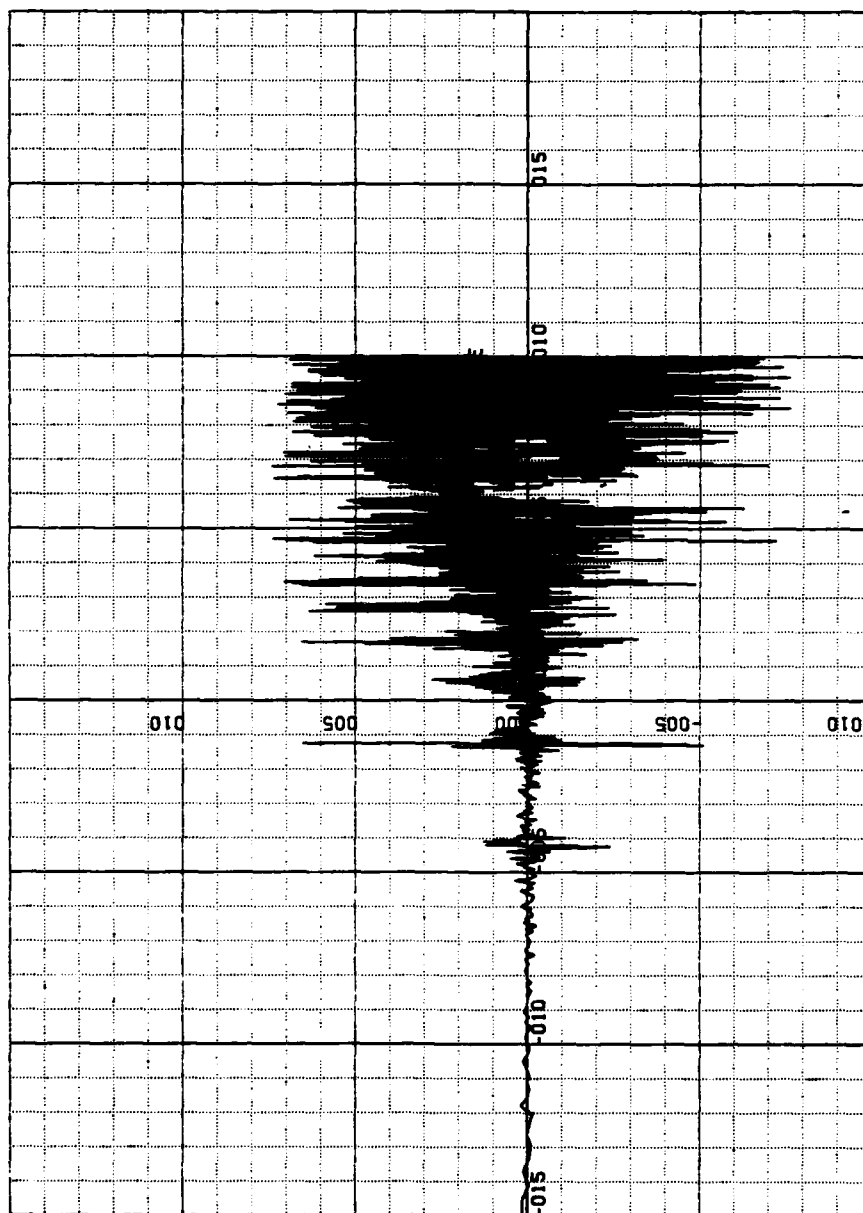


Figure 2.12. Ellipticity X-Y Plane, 17 August 82, 2240-2348 Local.
Ellipticity (0.5 unit/in) vs. Log Frequency (Hz) (0.5 unit/in)
16 Averages

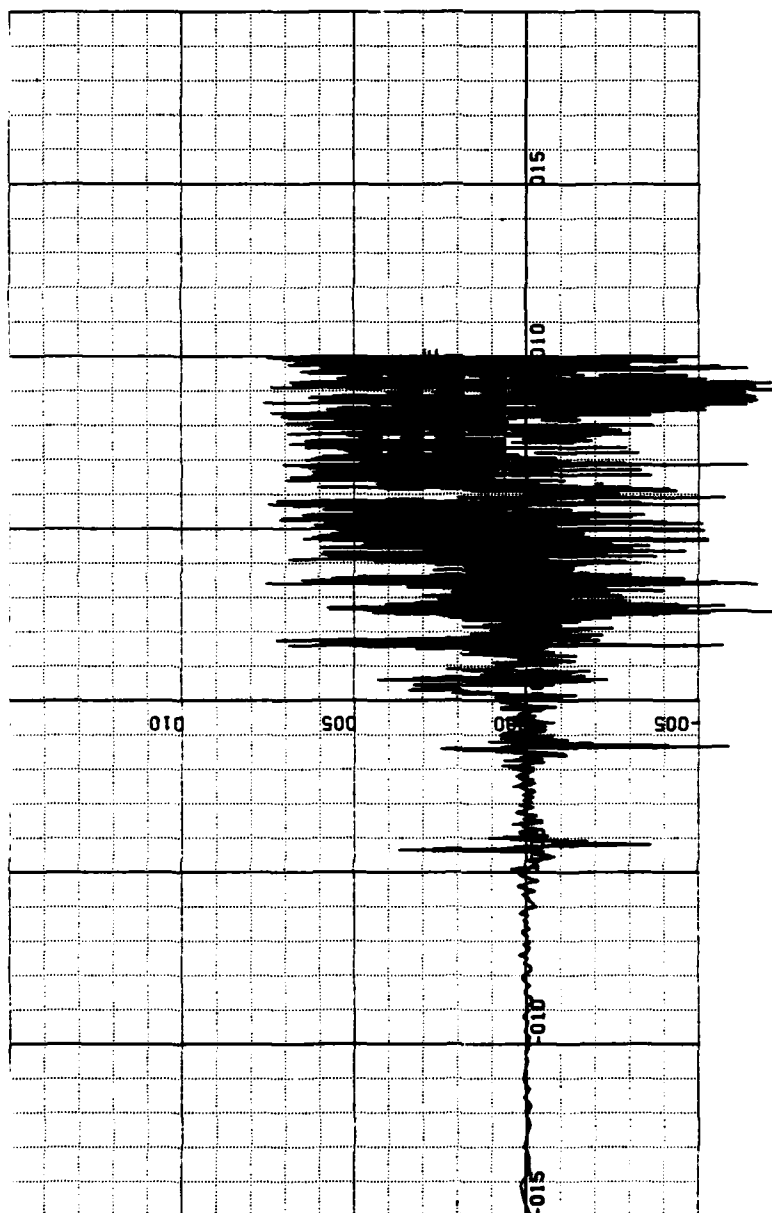


Figure 2.13. Ellipticity Y-Z Plane, 17 August 82, 2240-2348 Local.
 Ellipticity (0.5 units/in) vs. Log Frequency (Hz) (0.5 units/in)
 16 Averages

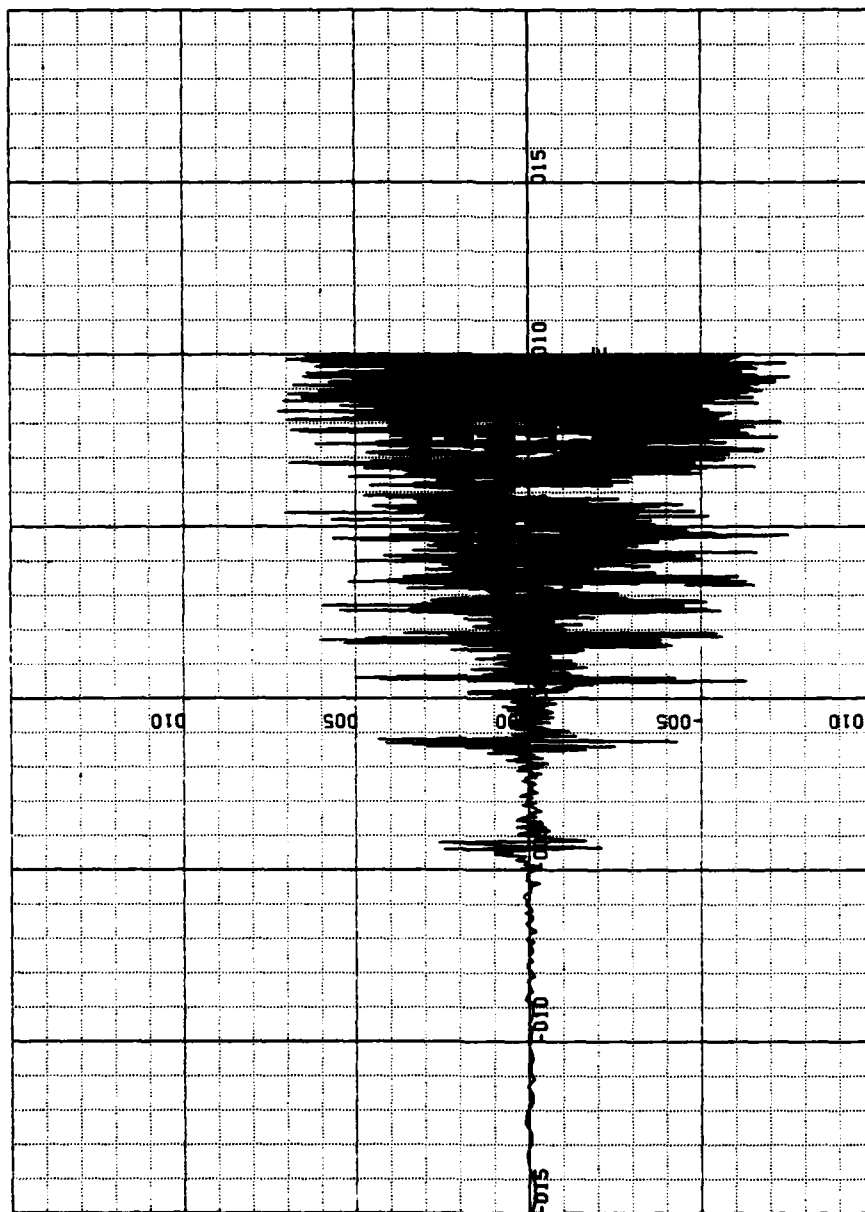


Figure 2.14. Ellipticity Z-X Plane, 17 August 82, 2240-2348 Local.
 Ellipticity (0.5 units/in) vs. Log Frequency (Hz) (0.5 units/in)
 16 Averages

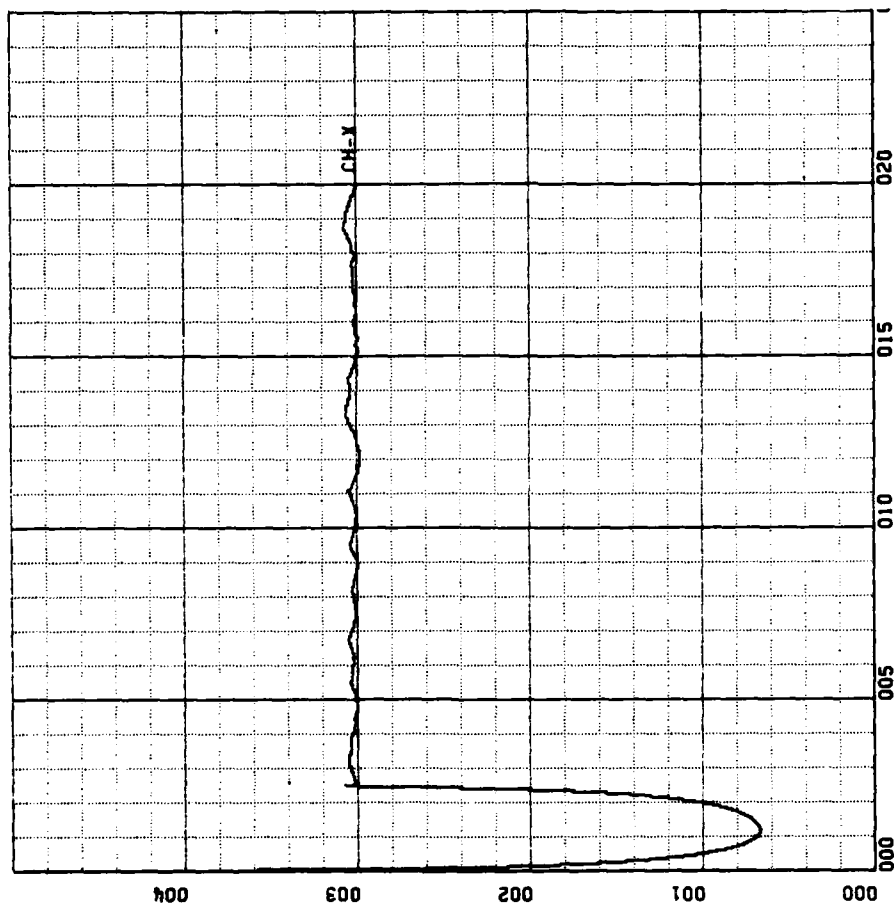


Figure 2.15. X-Coil Magnetic Field, 17 August 82, 2240-2348- Local.
 Amplitude (nanoteslas : 10 units/in) vs. Time (seconds : 500 units/in)
 16 Averages

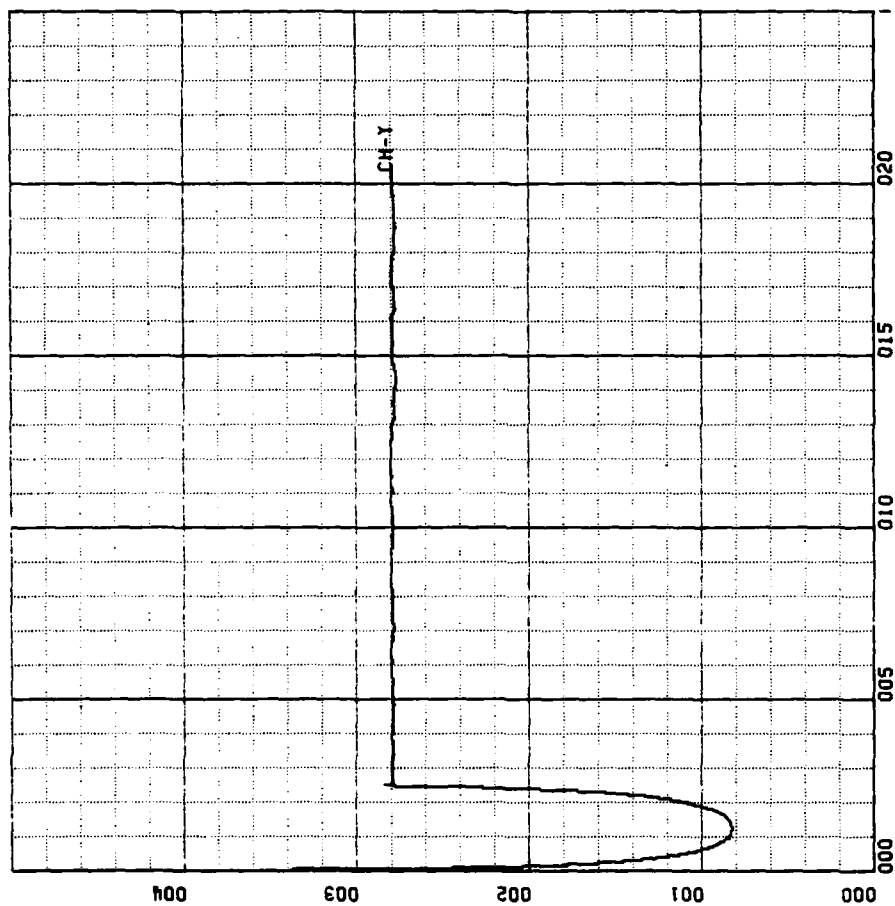


Figure 2.16. Y-Coil Magnetic Field, 17 August 82, 2240-2348 Local.
 Amplitude (nanoteslas : 10 units/in) vs. Time (seconds : 500 units/in)
 16 Averages

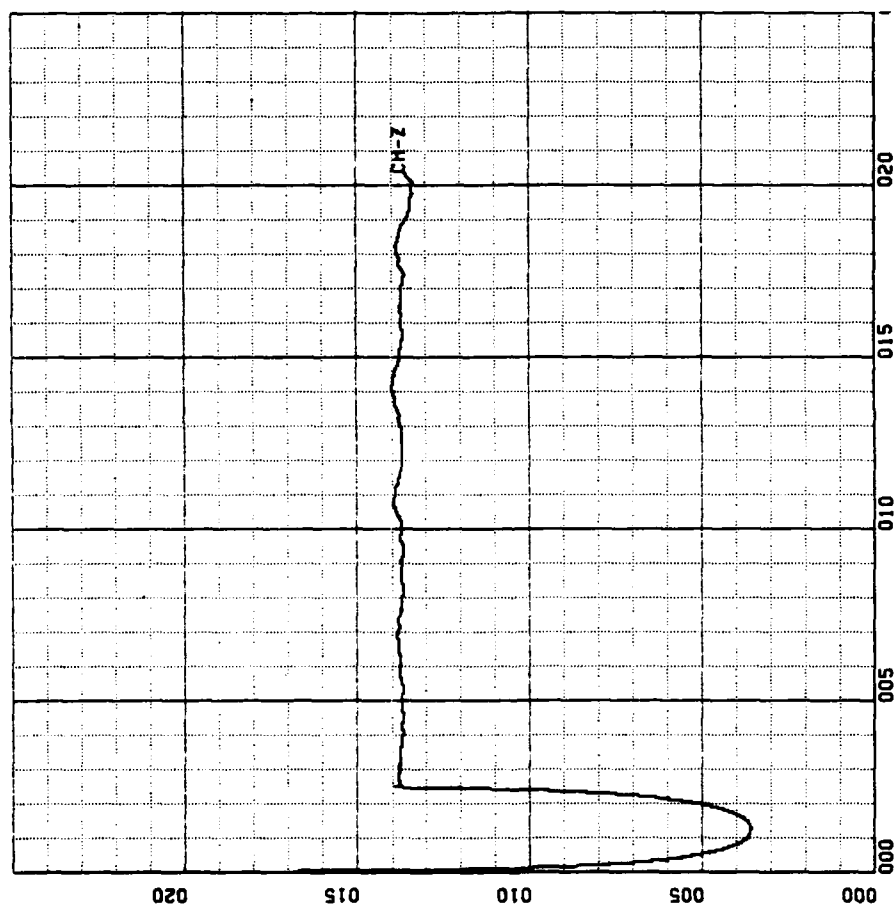


Figure 2.17. Z-Coil Magnetic Field, 17 August 82, 2240-2348 Local.
 Amplitude (nanoteslas : 5 units/in) vs. Time (seconds : 500 units/in)
 16 Averages

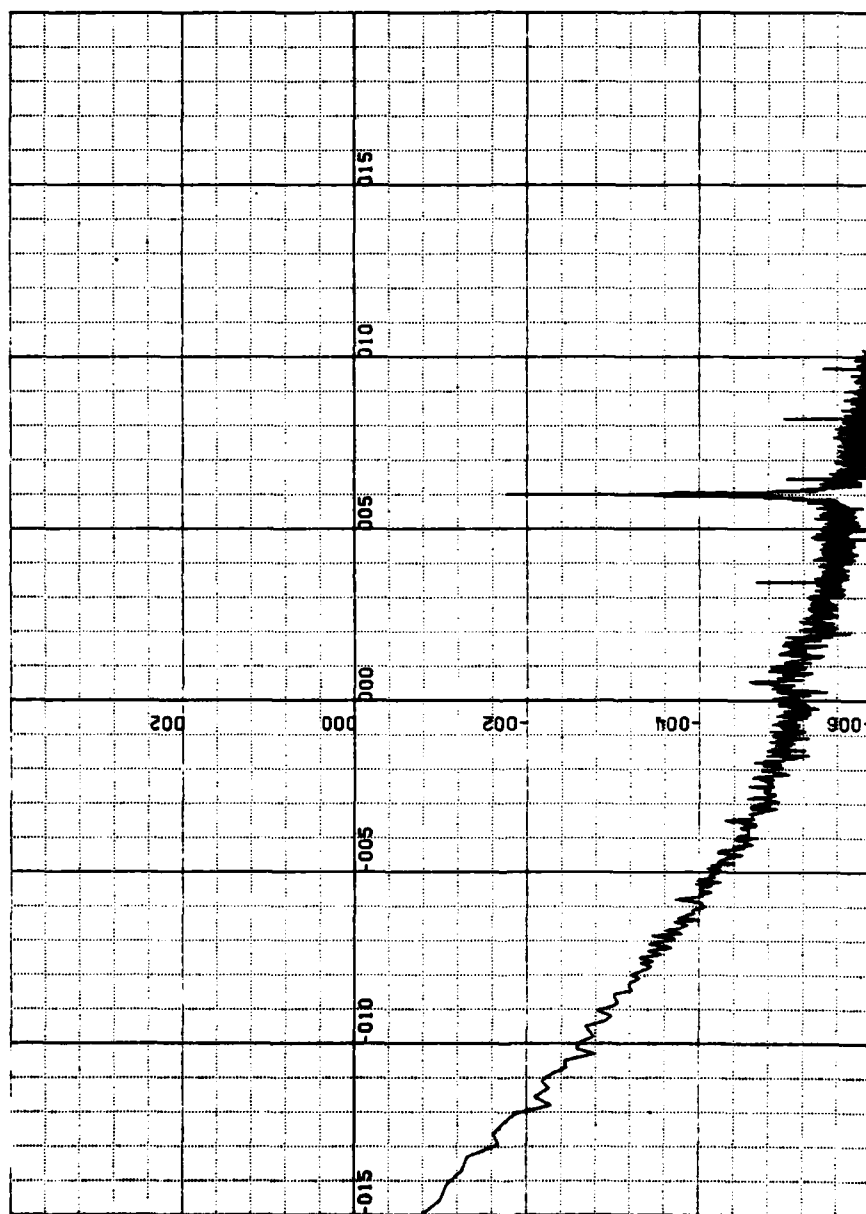


Figure 2.18. PSD X Coil, 17 August 82, 2245-2353 Local.
 Amplitude in dB (REF nT**2/Hz) (20 units/in) vs. Log
 Frequency (Hz) (0.5 units/in), 16 Averages

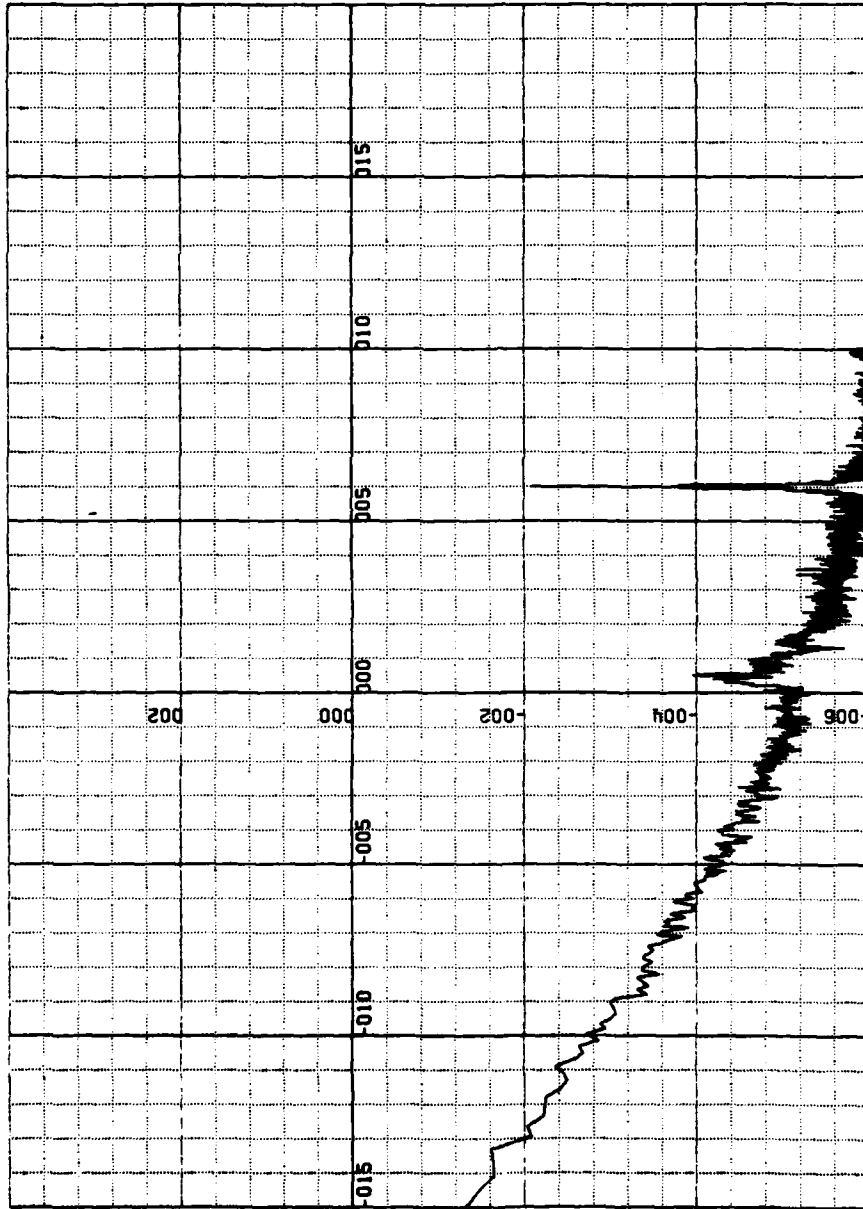


Figure 2.19. PSD Y Coil, 17 August 82, 2245-2353 Local.
 Amplitude in dB (REF nT**2/Hz) (20 units/in) vs. Log
 Frequency (Hz) (0.5 units/in), 16 Averages

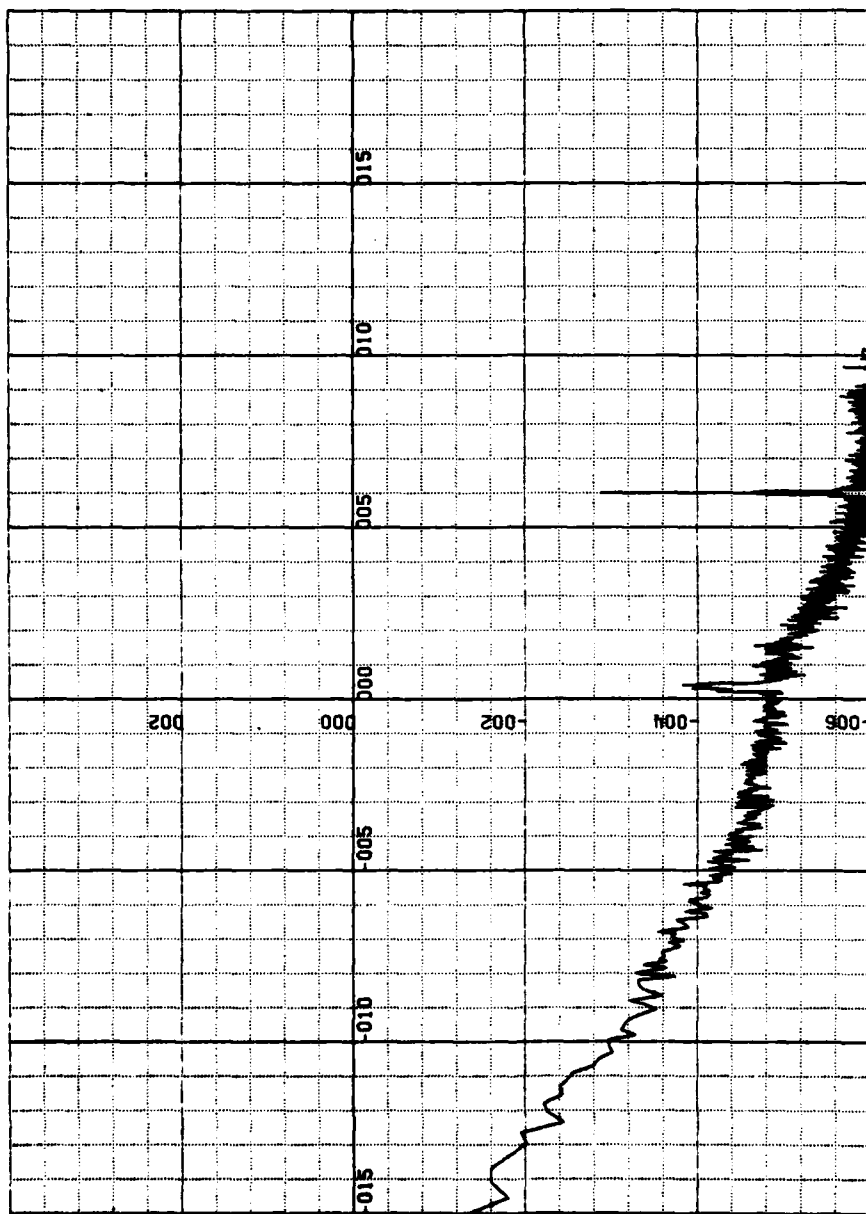


Figure 2.20. PSD Z Coil, 17 August 82, 2245-2353 Local.
Amplitude in dB (REF nT**2/Hz) (20 units/in) vs. Log
Frequency (Hz) (0.5 units/in), 16 Averages

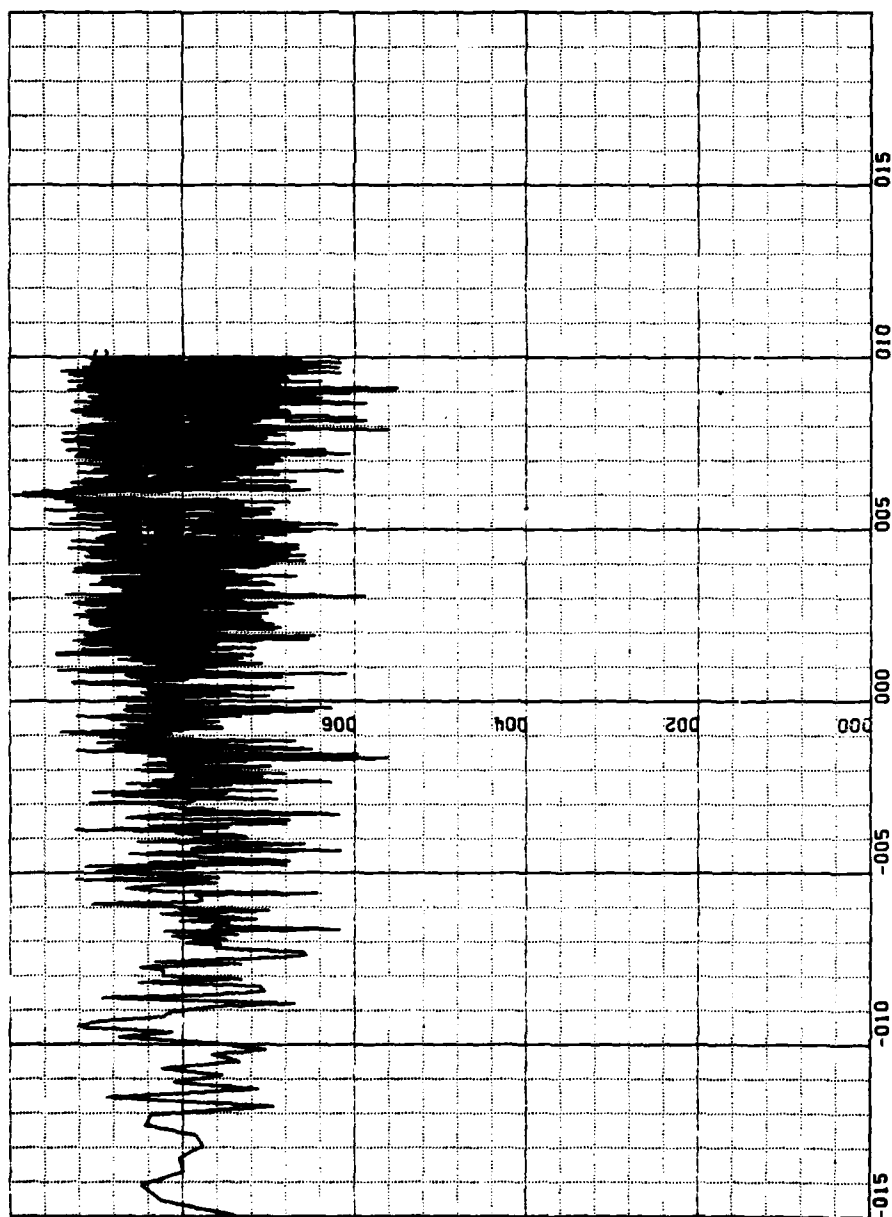


Figure 2.21. Coherence X-Y coils, 17 August 82, 2245-2353 Local.
 Coherence X-Y Coils (0.2 units/in) vs. Log Frequency (Hz)
 (0.5 units/in), 16 Averages

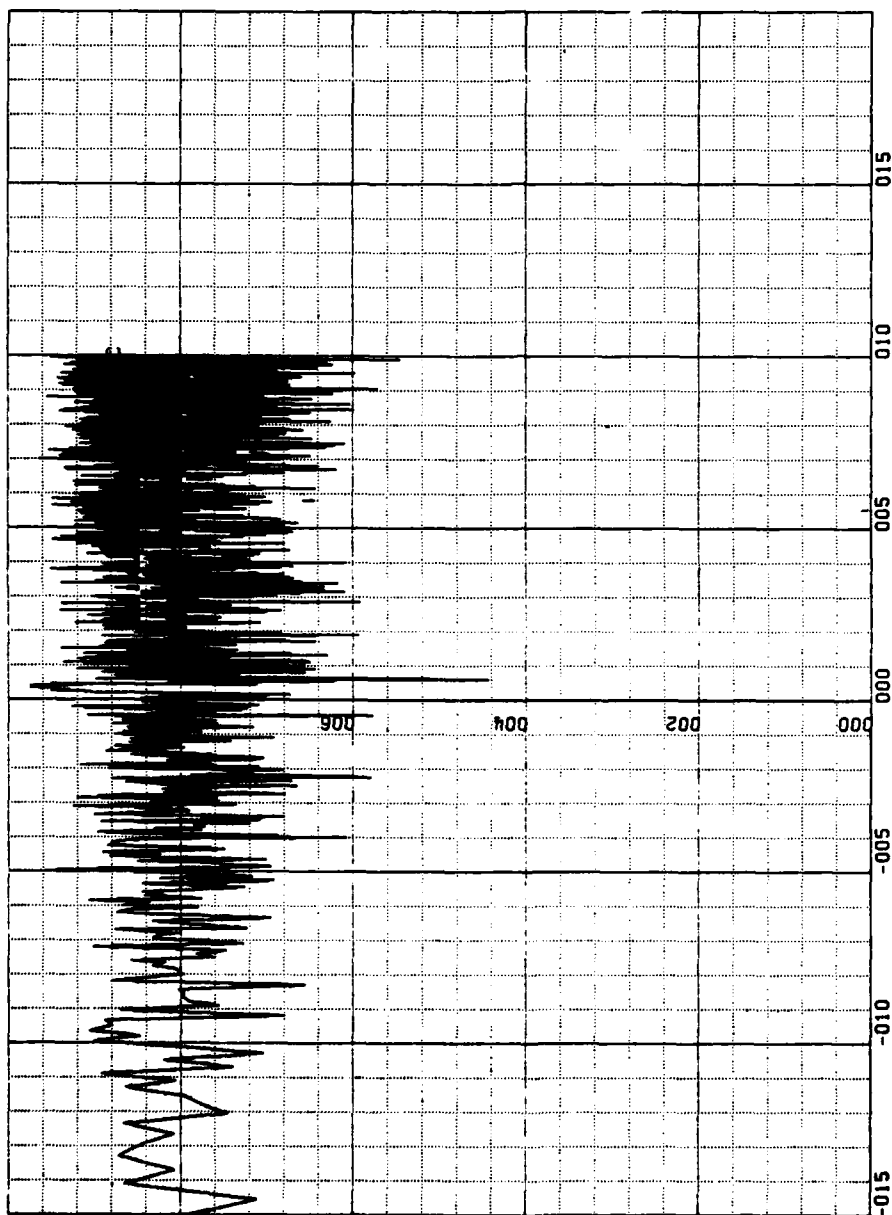


Figure 2.22. Coherence Y-Z Coils, 17 August 82, 2245-2353 Local
 Coherence X-Y Coils (0.2 units/in) vs. Log Frequency (Hz)
 (0.5 units/in), 16 Averages

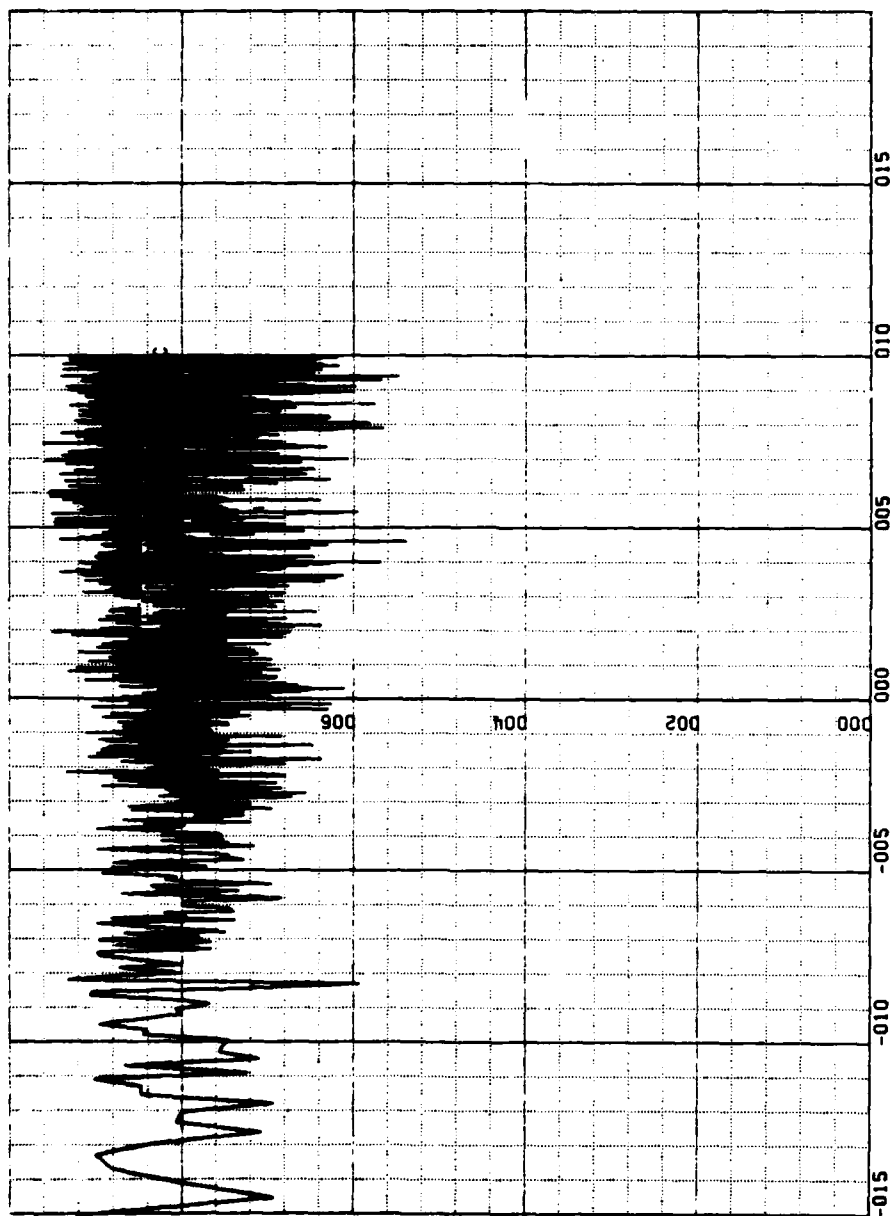


Figure 2.23. Coherence Z-X Coils, 17 August 82, 2245-2353 Local.
Coherence Z-X Coils (0.2 units/in) vs. Log Frequency (Hz)
(0.5 units/in), 16 Averages

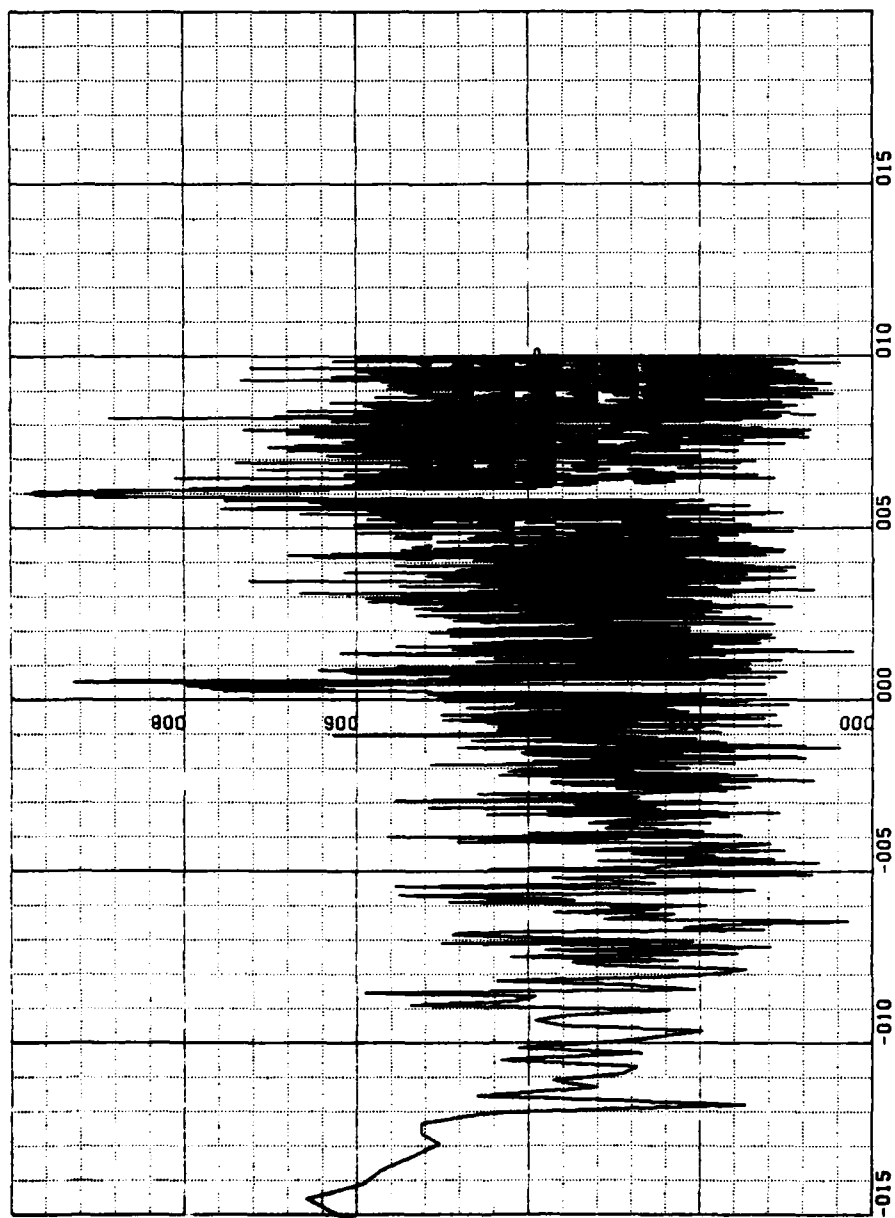


Figure 2.24. Degree of Polarization X-Y Plane, 17 August 82, 2245-2353 Local.
 Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz)
 (0.5 units/in), 16 Averages

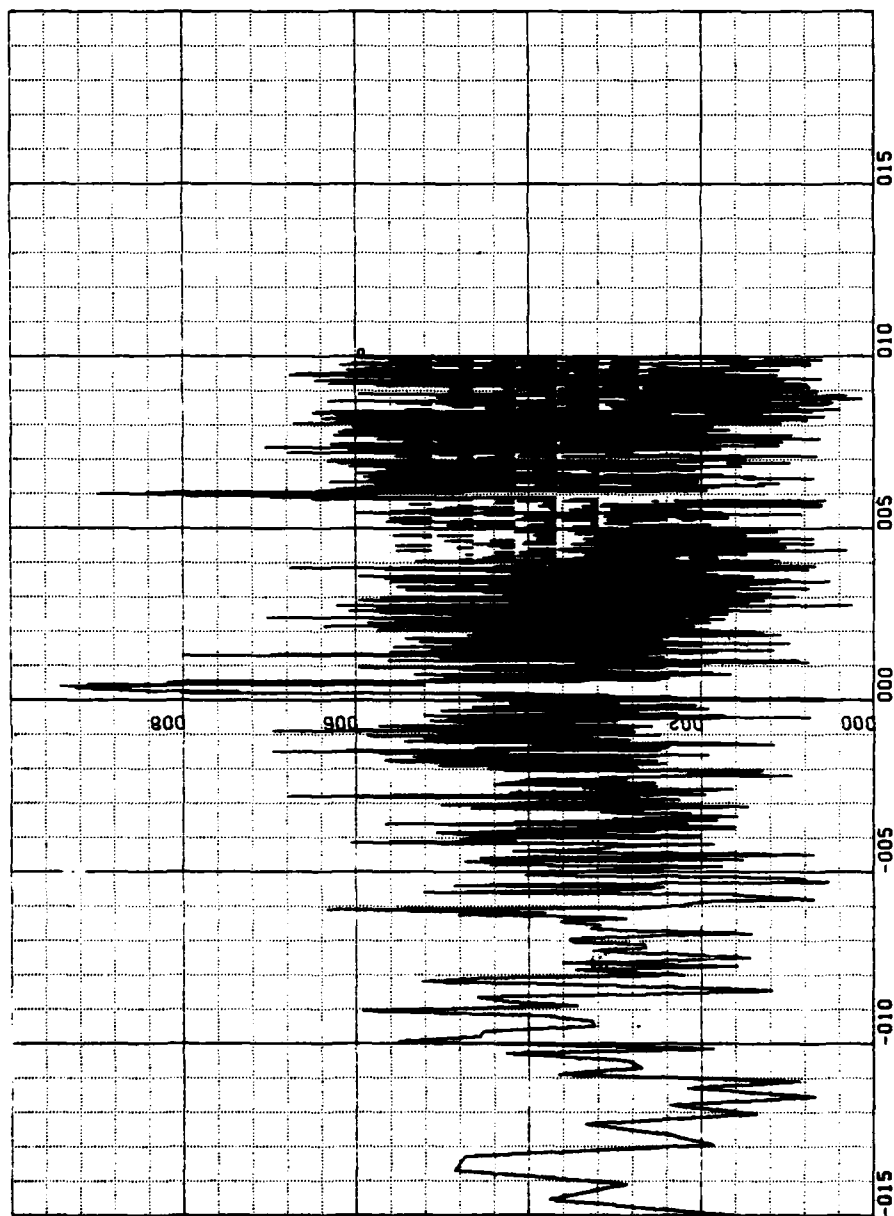


Figure 2.25. Degree of Polarization Y-Z Plane, 17 August 82, 2245-2353 Local.
 Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz)
 (0.5 units/in), 16 Averages

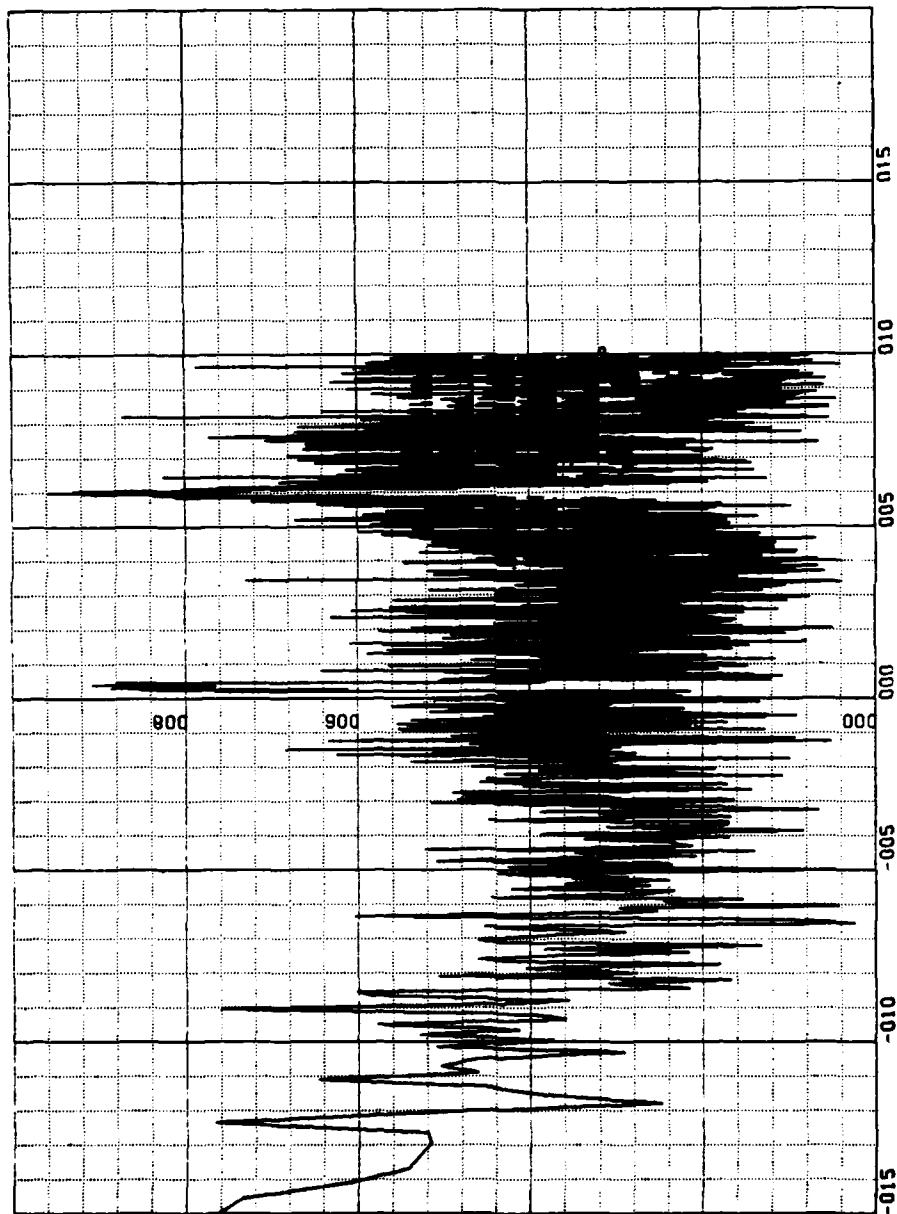


Figure 2.26. Degree of Polarization Z-X Plane, 17 August 82, 2245-2353 Local.
 Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz)
 (0.5 units/in), 16 Averages

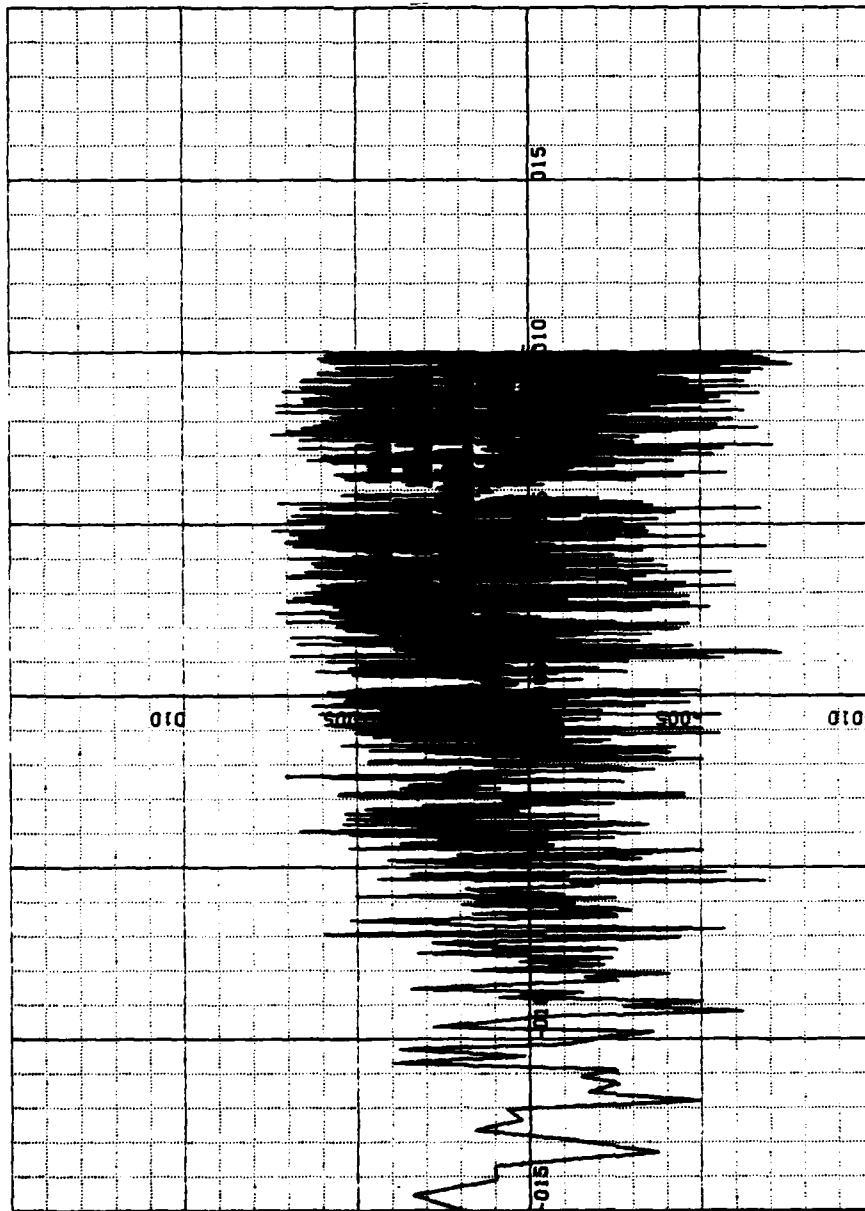


Figure 2.27. Ellipticity X-Y Plane, 2245-2353 Local.
 Ellipticity (0.5 units/in) vs. Log Frequency (Hz)
 (0.5 units/in), 16 Averages

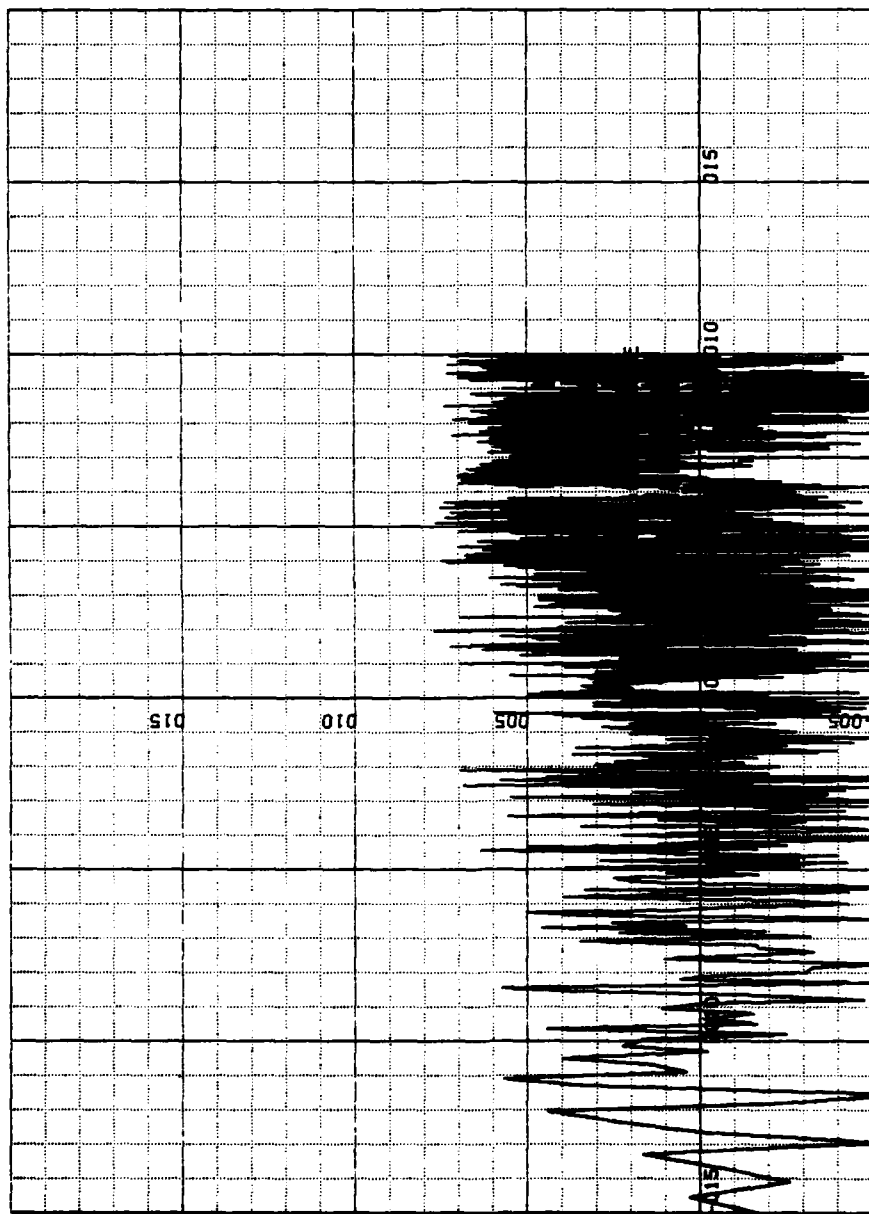


Figure 2.28. Ellipticity Y-Z Plane, 17 August 82, 2245-2353 Local.
 Ellipticity (0.5 units/in) vs. Log Frequency (Hz) (0.5 units/in)
 16 Averages

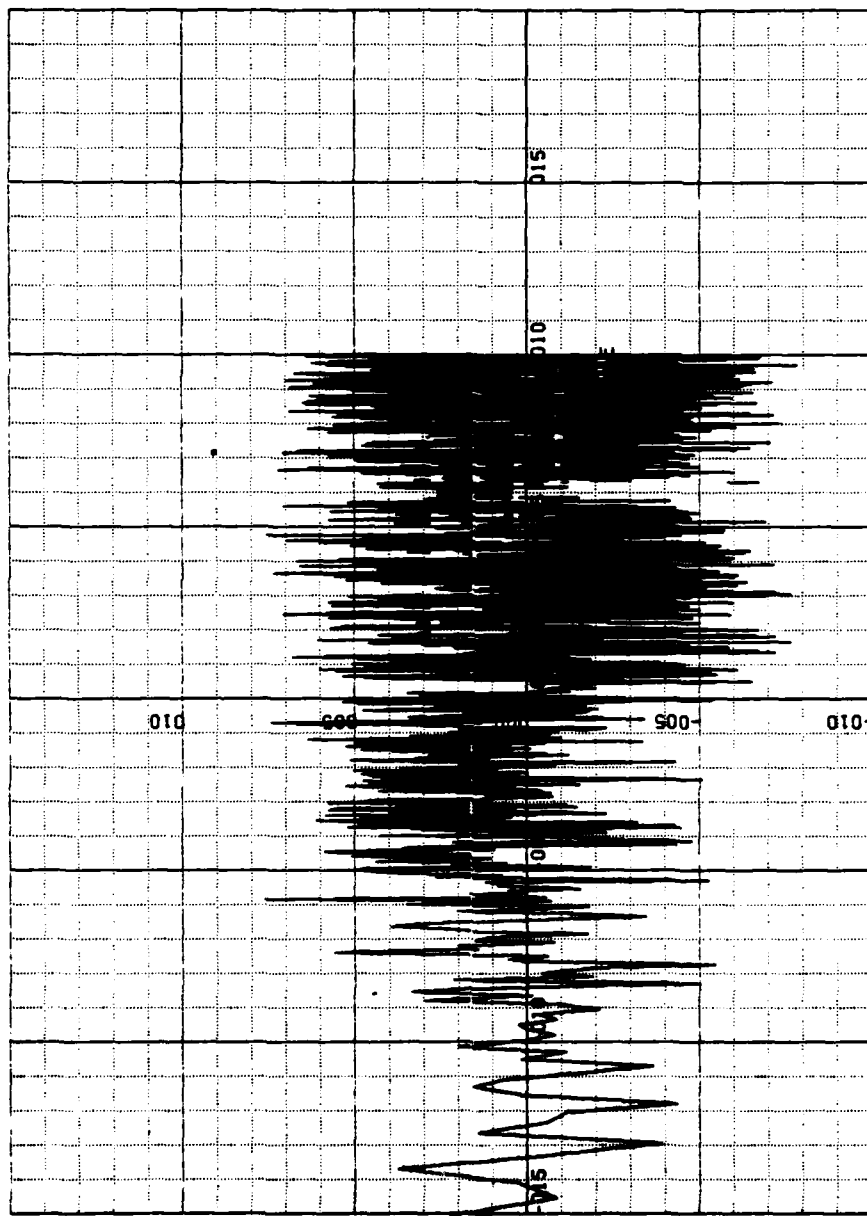


Figure 2.29. Ellipticity 2-X Plane, 17 August 82, 2245-2353 Local.
 Ellipticity (0.5 units/in) vs. Log Frequency (Hz)
 (0.5 units/in), 16 Averages

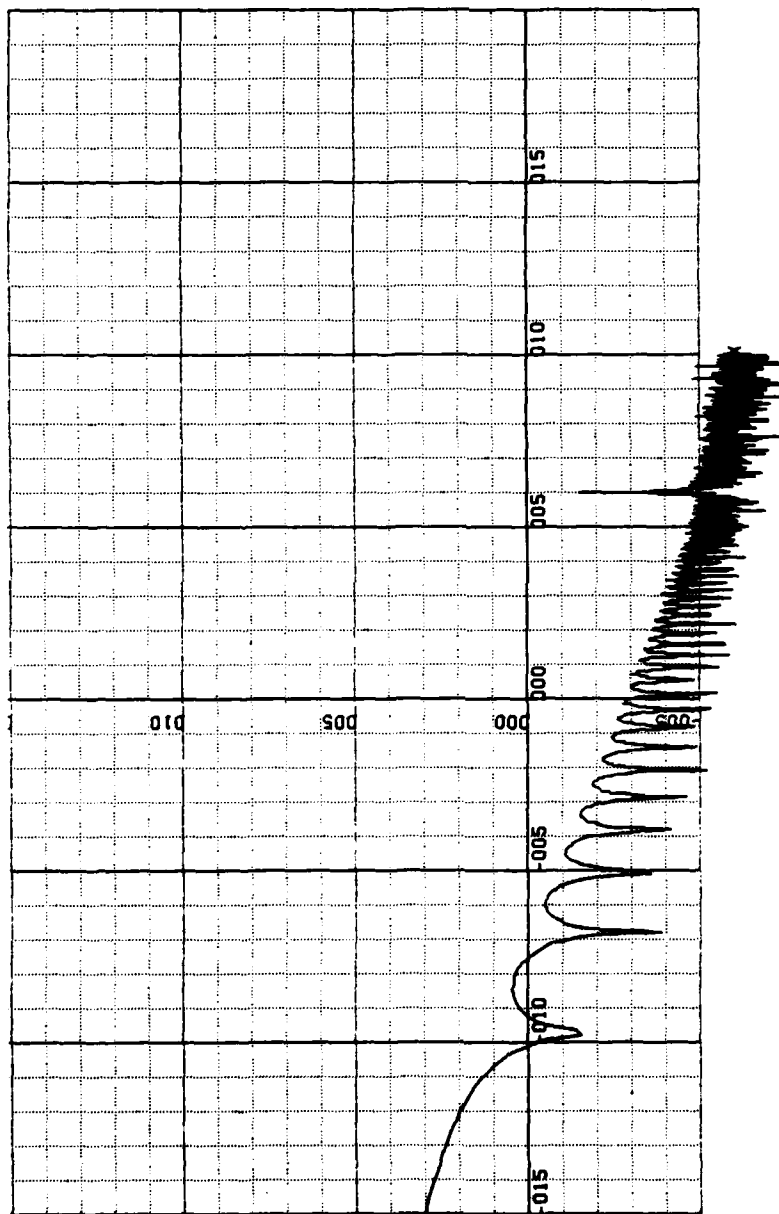


Figure 2.30. PSD X Coil, 17 August 82, 2240-2250 Local.
Amplitude in dB (REF nT**2/Hz) (50 units/in) vs. Log
Frequency (Hz) (0.5 units/in), 2 Averages

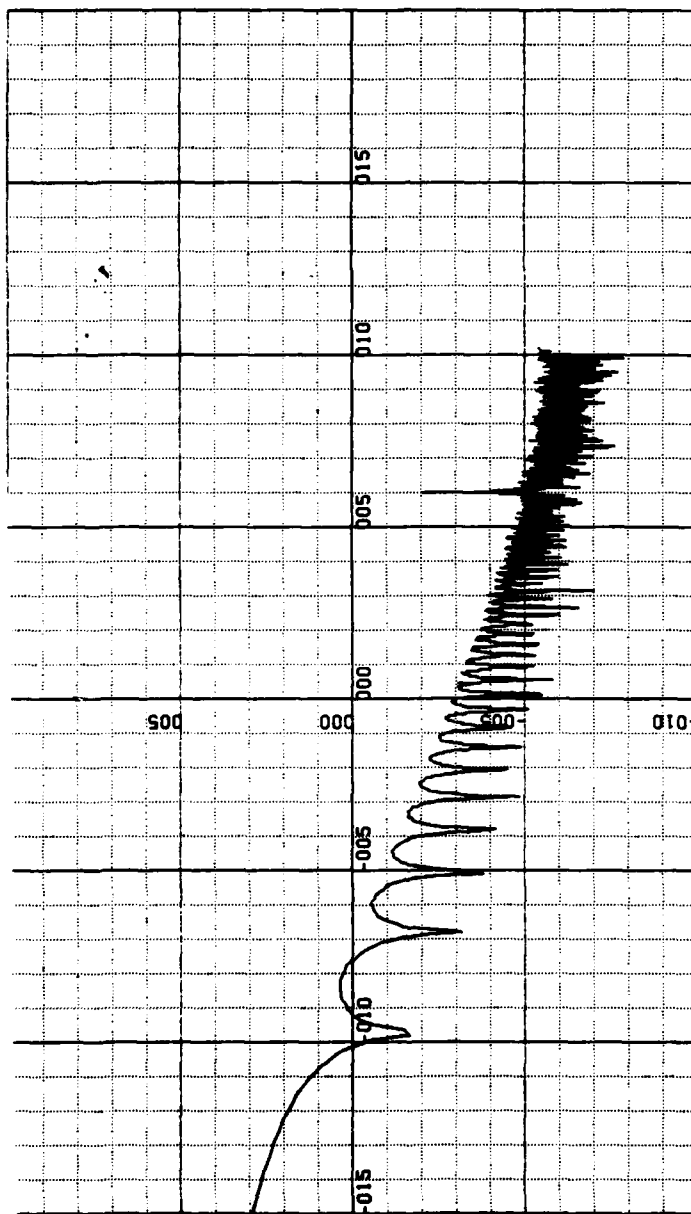


Figure 2.31. PSD Y Coil, 17 August 82, 2240-2250 Local.
 Amplitude in dB (REF nT^{**2}/Hz) (50 units/in) vs. Log
 Frequency (Hz) (0.5 units/in), 2 Averages

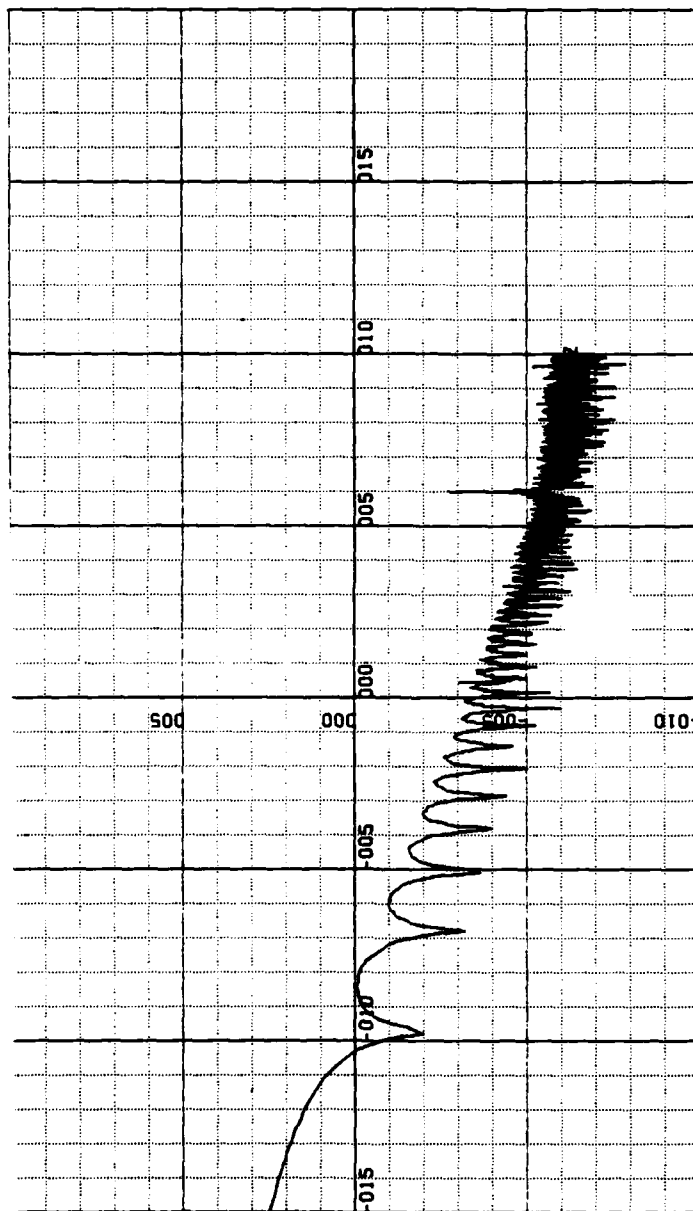


Figure 2.32. PSD Z Coil, 17 August 82, 2240-2250 Local.
Amplitude in dB (REF nT**2/Hz) (50 units/in) vs. Log
Frequency (Hz) (0.5 units/in), 2 Averages

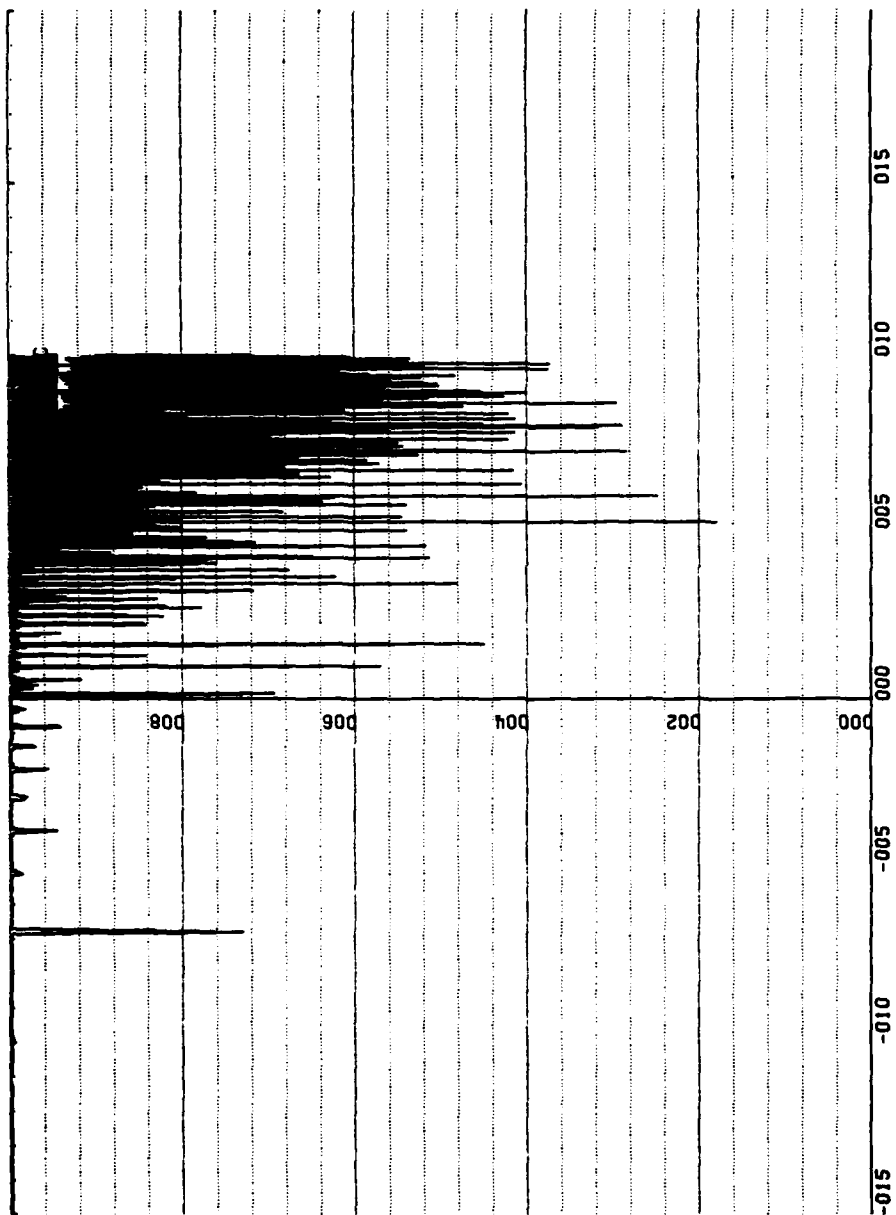


Figure 2.33. Coherence X-Y Coils, 17 August 82, 2240-2250 Local.
Coherence X-Y Coils (0.2 units/in) vs. Log Frequency (Hz)
(0.5 units/in), 2 Averages

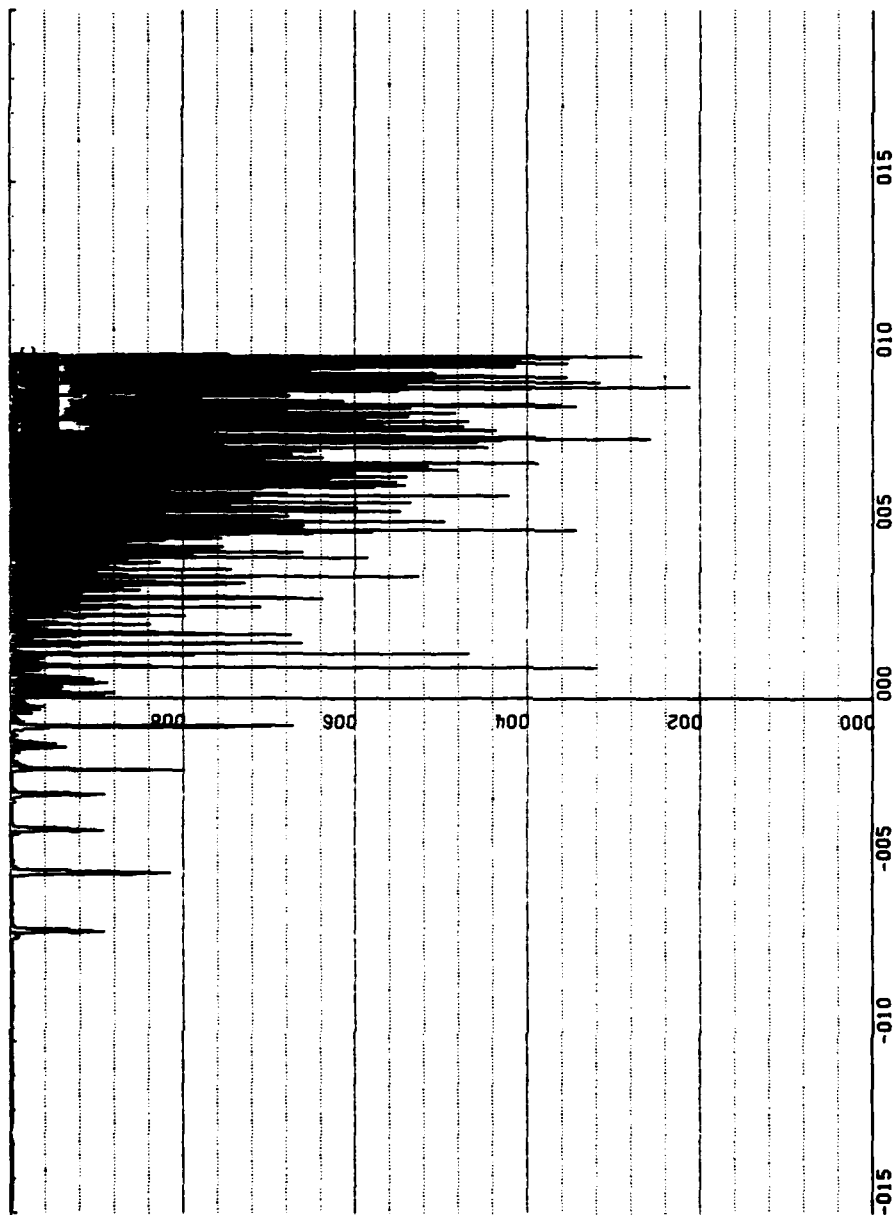


Figure 2.34. Coherence Y-Z Coils, 17 August 82, 2240-2250 Local.
 Coherence Y-Z Coils (0.2 units/in) vs. Log Frequency (Hz)
 (0.5 units/in), 2 Averages

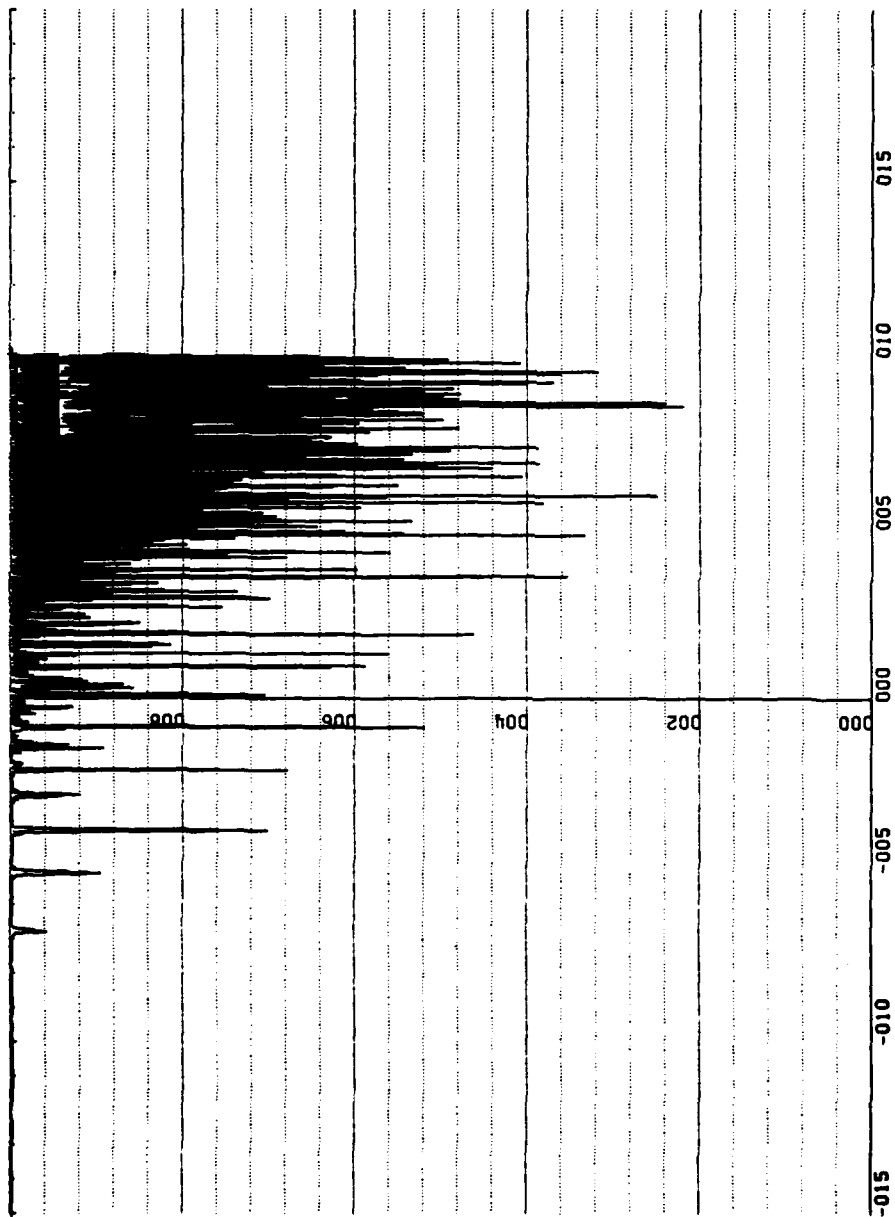


Figure 2.35. Coherence Z-X Coils, 17 August 82, 2240-2250 Local.
Coherence Z-X Coils (0.2 units/in) vs. Log Frequency (Hz)
(0.5 units/in), 2 Averages

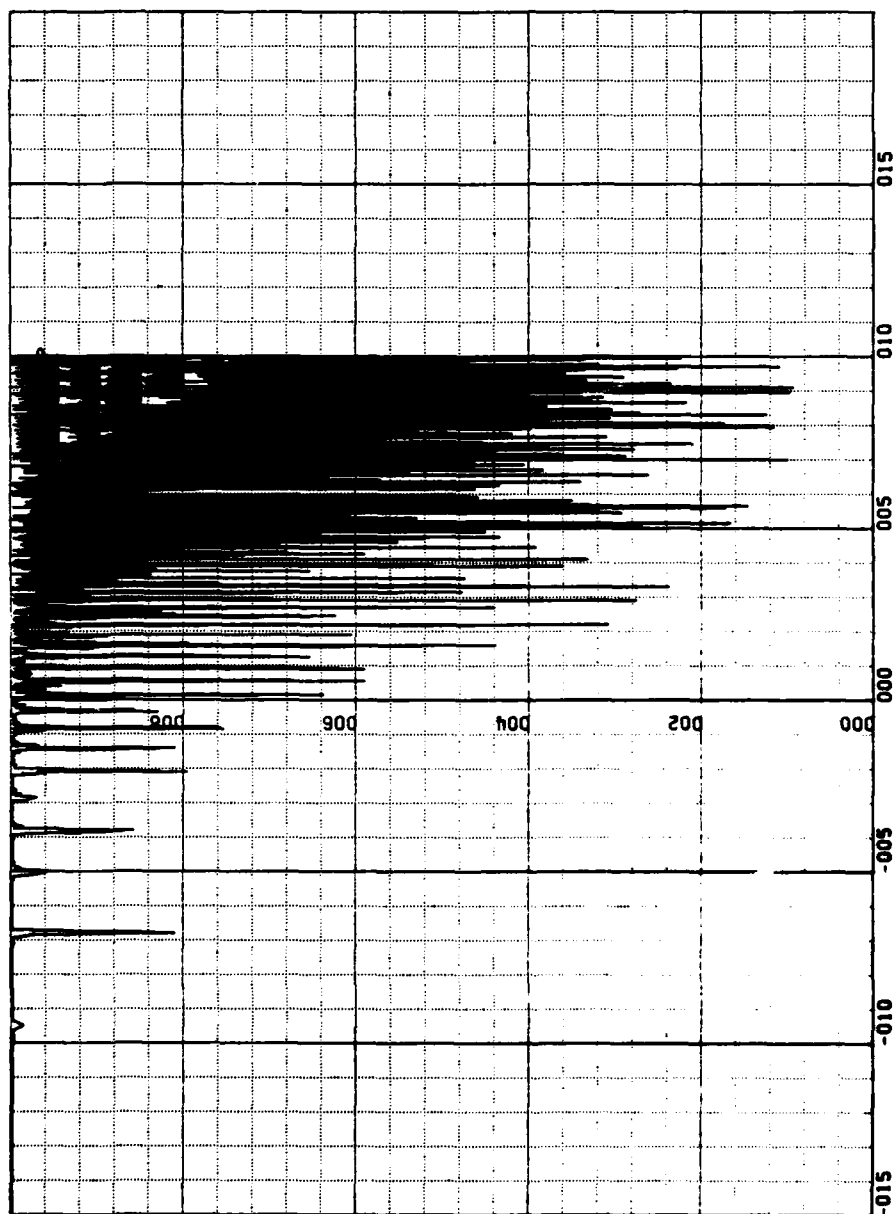


Figure 2.36. Degree of Polarization X-Y Plane, 17 August 82, 2240-2250 Local.
 Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz)
 (0.5 units/in), 2 Averages

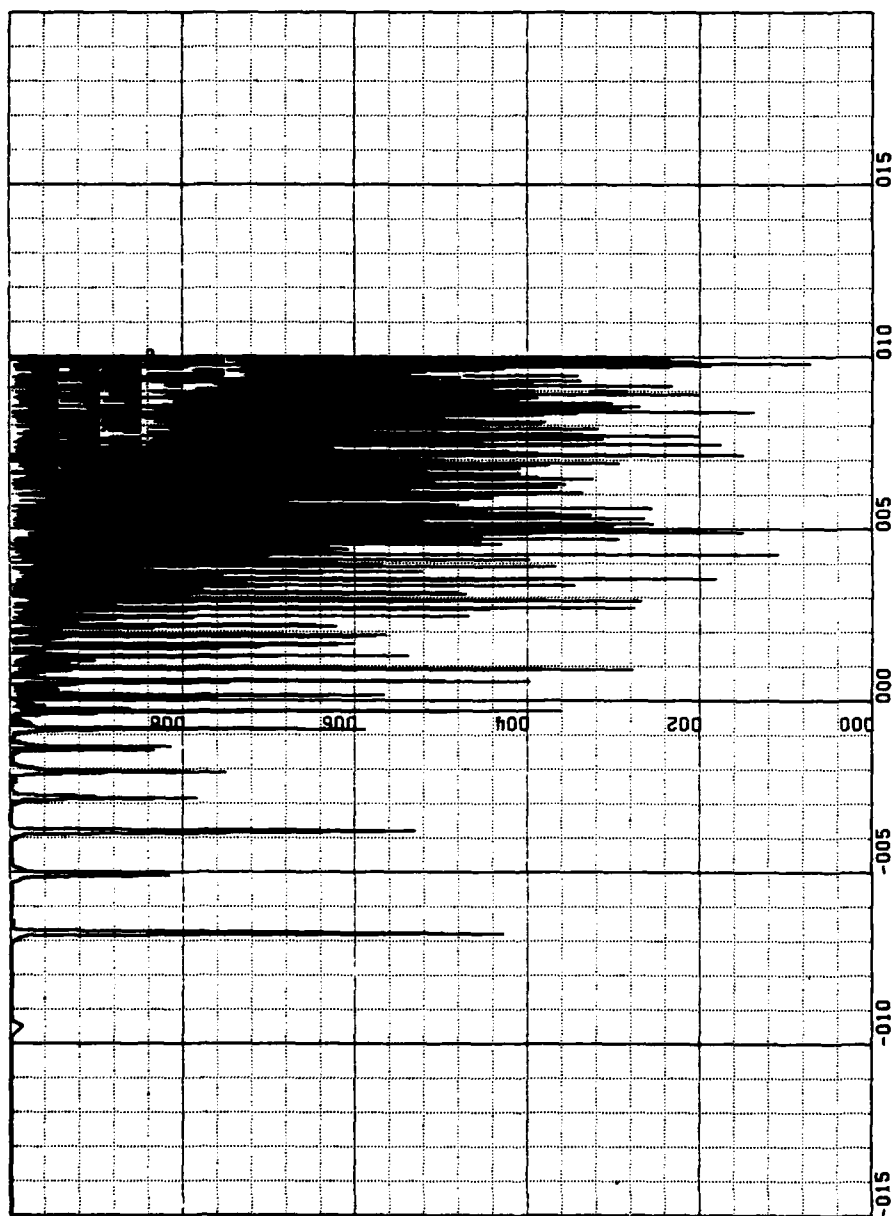


Figure 2.37. Degree of Polarization Y-X Plane, 17 August 82, 2240-2250 Local.
 Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz)
 (0.5 units/in), 2 Averages

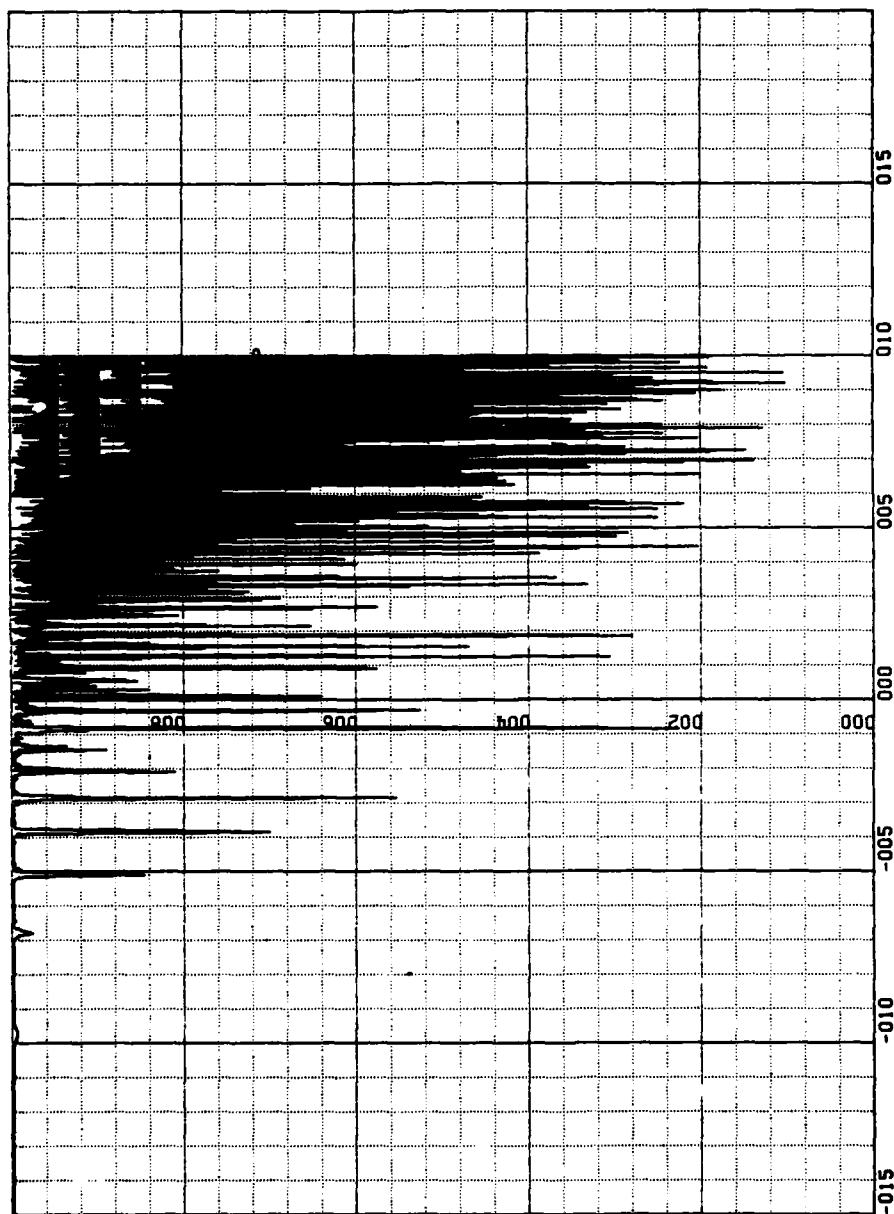


Figure 2.38. Degree of Polarization Z-X Plane, 17 August 82, 2240-2250 Local.
 Degree of Polarization (0.2 units/in) vs. Log Frequency (Hz)
 (0.5 units/in), 2 Averages

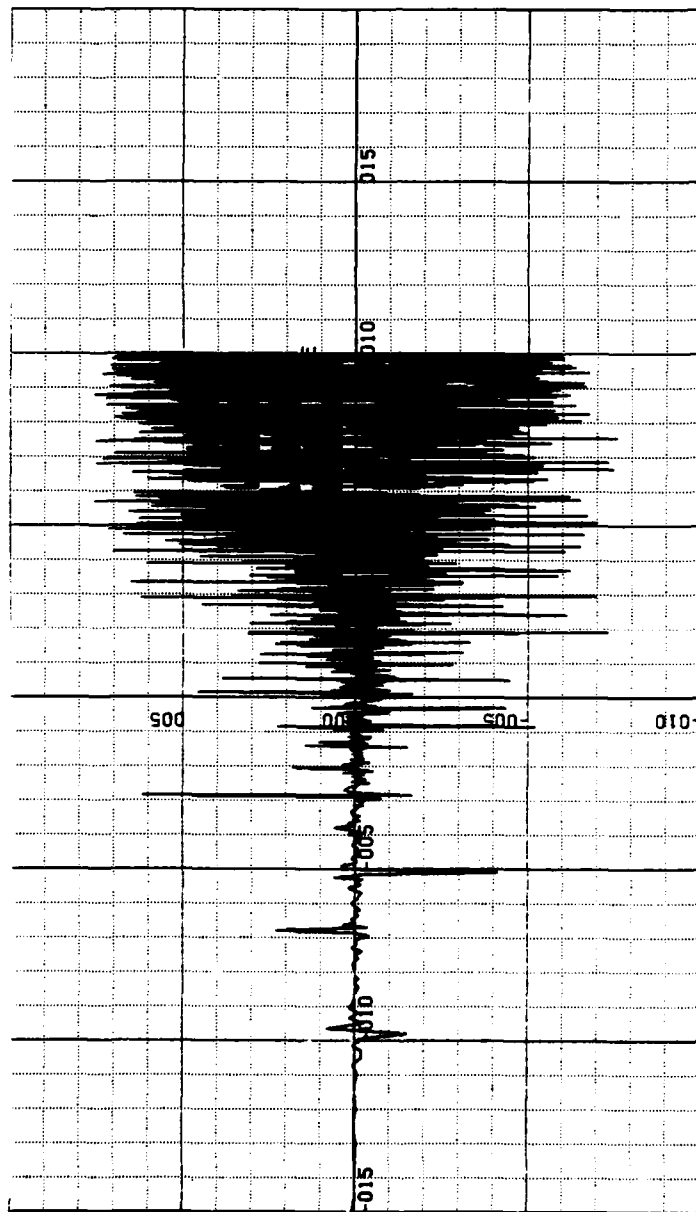


Figure 2.39. Ellipticity X-Y Plane, 17 August 82, 2240-2250 Local.
 Ellipticity (0.5 units/in) vs. Log Frequency (Hz) (0.5 units/in)
 2 Averages

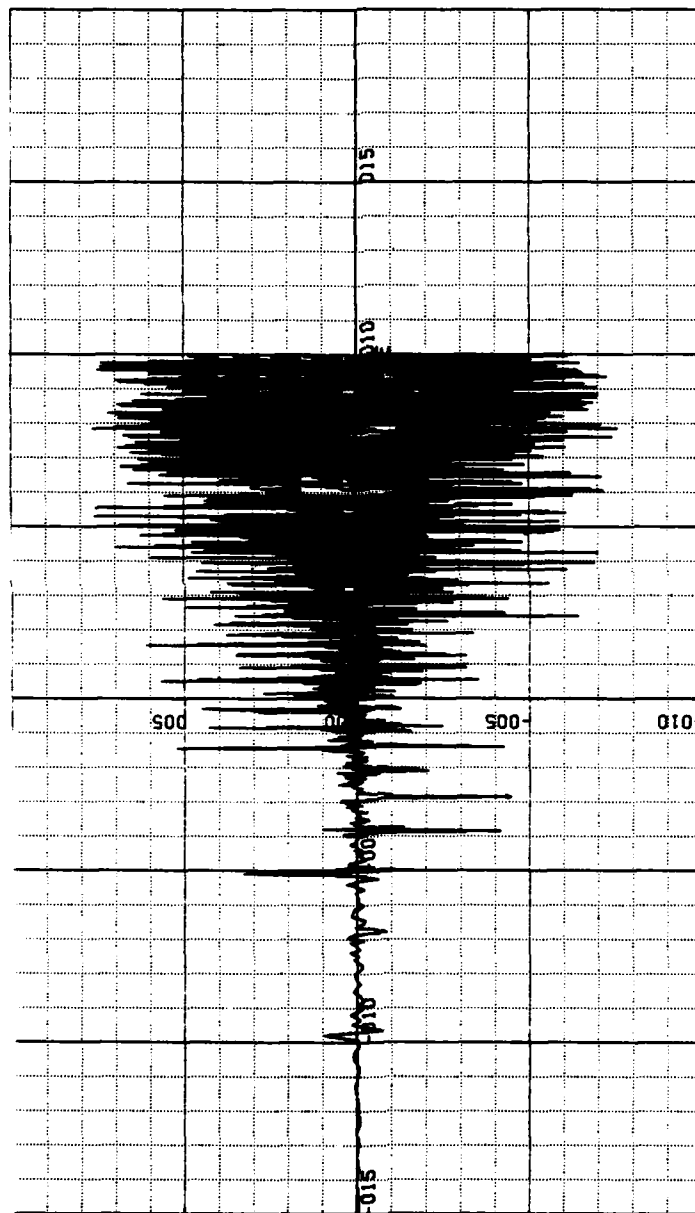


Figure 2.40. Ellipticity Y-Z Plane, 17 August 82, 2240-2250 Local.
 Ellipticity (0.5 units/in) vs. Log Frequency (Hz) (0.5 units/in)
 2 Averages

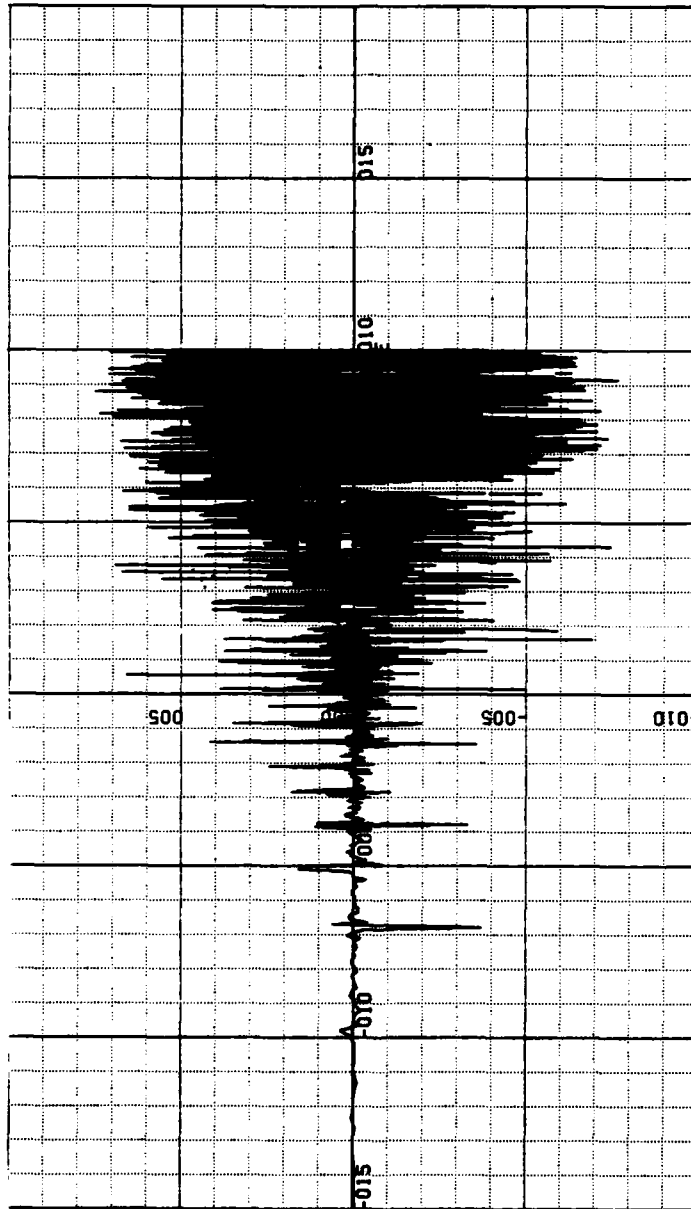


Figure 2.41. Ellipticity Z-X Plane, 17 August 82, 2240-2250 Local.
Ellipticity (0.5 units/in) vs. Log Frequency (Hz)
(0.5 units/in), 2 Averages

recommended at the beginning of the programs producing the above mentioned plots. Time series plots should also be made to provide a further check.

An explanation of the source of the large fluctuations is that the PCM to digital conversion begins before the actual PCM data starts on the tape. The decoding equipment considers the noise on the section of tape before the PCM data starts as signal.

The above analysis clearly proves that the "hump" like structure in the PSD's and the "nice" behavior observed in the corresponding coherence, ellipticity and degree of polarization are artificial and do not represent any real phenomena in the geomagnetic field. Thus, the data in Figures 2.3-2.14 and Figures 2.30-2.41 does not appear to be reliable. Unfortunately, this artificially induced, and therefore unphysical, behavior of the polarization has been published recently [Ref. 7]. The conclusion found in Reference 7 that

Geomagnetic fluctuations in land are well polarized below 1.0 Hz and that the polarization is quite frequently, though not consistently, linear. The situation under the sea is similar. Furthermore, a land-sea coherence study in the horizontal plane showed very high coherence below 1.0 Hz.

are not substantiated by the physical data. Plots of the artificially induced behavior are published in References 1, 2, and 3.

The 4 Hz peak present in the PSD's shown in Figures 2.18-2.20 is the result of 60 Hz aliasing. 60 Hz magnetic fields generated by local power lines exist at the measurement site. Digitization at a 32 Hz or 64 Hz rate of the analog voltages from the sensing coils shifts the true frequency of the power line signals down at 4 Hz. The 60 Hz aliasing results in the anomalous behavior at 4 Hz seen in the coherence, degree of polarization and ellipticity plots shown in Figures 2.21-2.29.

Another peak is present at about 1.2 Hz for the PSD's in Figures 2.18-2.20. For this data set, the 1.2 Hz signal correlates with a 1.2 Hz signal identified in the time series data. The origin of the 1.2 Hz signal is unknown. The 4 Hz and 1.2 Hz peaks are of little concern in this study since both are well above the frequency of the micropulsation analyzed.

Another "suspicious" feature of the PSD's is the large amount of hash appearing from 2 to 10 hertz. We will gain further insight into this problem in analyzing the time series voltage data.

From the analysis of the abnormal behavior in the PSD's, coherence, etc., future coil data sets should receive a balanced treatment between the time domain and the frequency domain to avoid misinterpretation.

III. TIME SERIES DATA

A. TIME SERIES VOLTAGE DATA

1. Voltage Software

The importance of time series data as a check became evident when we uncovered the problem with the initial PSD's, coherences, etc. Computer code was developed to produce both unsmoothed and smoothed times series voltage plots. The reason for producing both smoothed and unsmoothed voltage plots will become apparent in the time series voltage analysis section. Time series voltage plots could provide a means of monitoring the data for system "glitches" which might later produce erroneous PSD's, etc., and suspicious features on time series magnetic field plots.

The Fortran computer program that produces the voltage plots is compiled and run on the Naval Postgraduate School IBM 3033 VM or "batch" system. Both the unsmoothed voltage program (VOLTR) and the smoothed voltage program (VOLTS) require 2.048 megabytes of core memory and approximately 15 minutes of central processor unit (CPU) time to run. These figures provide a comfortable margin to insure that the program does not "bomb" due to lack of core or run time.

The design of both VOLTR and VOLTS is the same with the exception that a smoothing algorithm is applied to the data in the case of VOLTS. Both programs have incorporated in them the digital tape advance package using ISEC as the number of

seconds one wishes to advance the tape. Data is read off the digital tape in blocks of 8192 frames by the subroutine RD referenced earlier. As before, this data is in integer form and represents voltages between +5 volts by numbers between 0 and 4096. The integer representing 0 volts is ideally 2048, however, I found that the "real" zero values wander. The reason for this "wander" is not understood. For good results, the following values worked well for the respective coils.

X-coil : zero = 1966

Y-coil : zero = 2085

Z-coil : zero = 2539

The voltage values normalized to +5 volts are placed in new real arrays. At this point the next block of data is read off the digital tape and goes through the same process. VOLTR and VOLTS analyze eight blocks or 34 minutes of data. The linear arrays holding the voltage data are dimensioned to 65,536 elements given a sampling rate of 32 samples/second. For every one of the 65,536 voltage values there is a time value in another array. Thus four arrays are required to handle the data, three arrays containing voltage data and one that contains the respective times for each of the measurements. At this point, the VOLTR program calls the NONIMSL subroutine DRAWP to plot the data. The VOLTS program uses a smoothing algorithm to reduce the amount of high frequency hash.

The smoothing algorithm is a double running point average executed on all three axes of data. Since I was

interested in periods of approximately 10-45 seconds, I averaged over 144 points. With a running average over 23 percent of the oscillation, the unwanted background can be removed without destroying the oscillations. Averages greater than 50 percent of the period would partially remove the oscillation of interest. The construction of the algorithm makes changing the number of points averaged over trivial. One need only change a loop index and three divisors to obtain a different average. The smoothing algorithm is provided as Table 3.1. The computer code for both VOLTR and VOLTS is attached in Appendix A and Appendix B.

2. Time Series Voltage Data Analysis

One can gain a great deal of insight into the contents of the data by looking at the smoothed and unsmoothed voltage products. Figures 3.1-3.3 are unsmoothed voltage plots representing the first 34 minutes of the digital data tape GMDT 11 recorded 17 August 82, 1301-1408 local time. A one minute tape advance was used in producing this data. Immediately one notices the large amount of 60 hertz aliasing in the time series unsmoothed voltage. The 60 hertz aliasing appears as 4 hertz because of the 32 sample/second sampling rate. The sensing system has a low pass filter that should be improved to remove the aliasing problem. The 4 hertz background can be seen more clearly in Figures 3.4-3.6. Above the 60 hertz aliasing background, we see voltage spikes ranging in magnitude from 1 volt to over 4 volts. Expanding the time scale to 50

Table 3.1. Smoothing Algorithm

```

DC 73 L2=1,2
Q=0
DC 74 IS=1,65318
SUMX=0.0
SUMY=0.0
SUMZ=0.0
DC 75 J=1,144
SUMX=ZZX1(Q+J)+SUMX
SUMY=ZZY1(Q+J)+SUMY
SUMZ=ZZV1(Q+J)+SUMZ
75 CCNTINUE
ZZX1(IS)=SUMX/144.
ZZY1(IS)=SUMY/144.
ZZV1(IS)=SUMZ/144.
C=Q+1
74 CCNTINUE
73 CCNTINUE

```

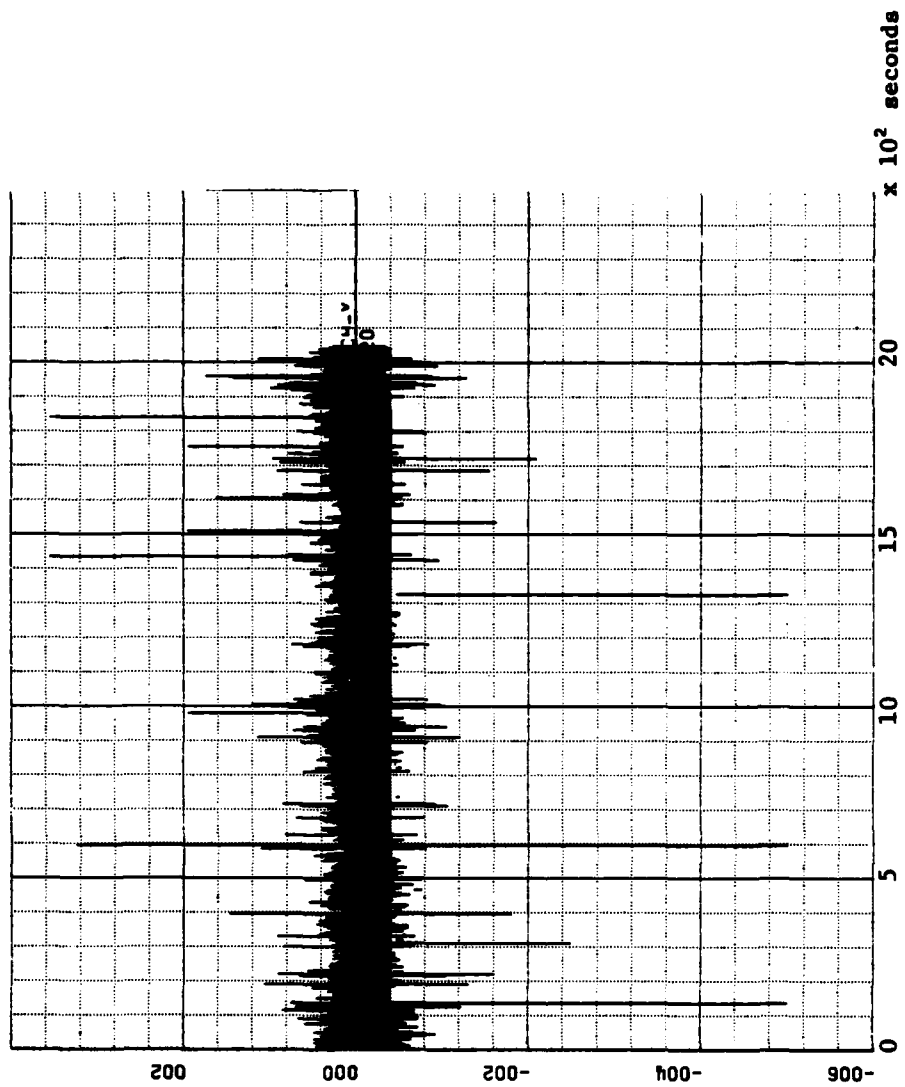


Figure 3.1. X Coil Voltage, 17 August 82, 1302-1336 Local.
Amplitude (volts : 2 units/in) vs. Time (seconds : 500 units/in)

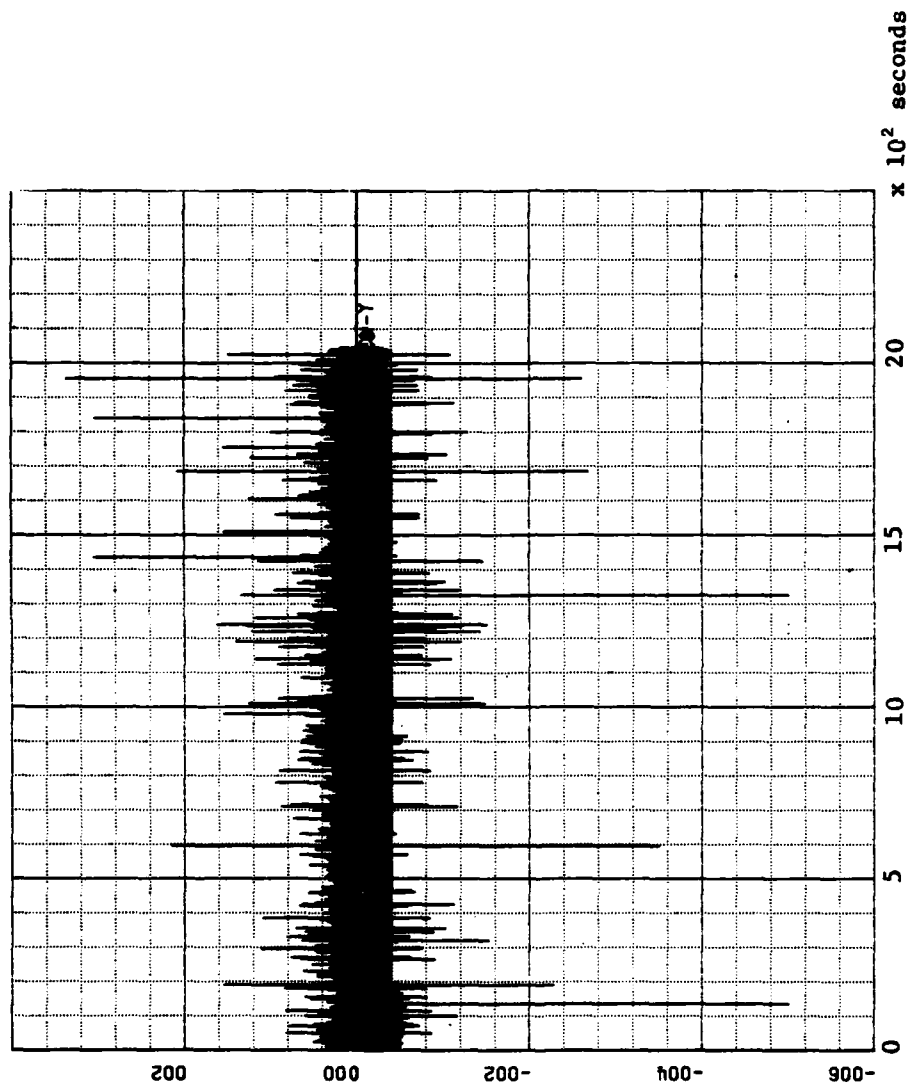


Figure 3.2. Y Coil Voltage, 17 August 82, 1302-1336 Local.
Amplitude (volts : 2 units/in) vs. Time (seconds : 500 units/in)

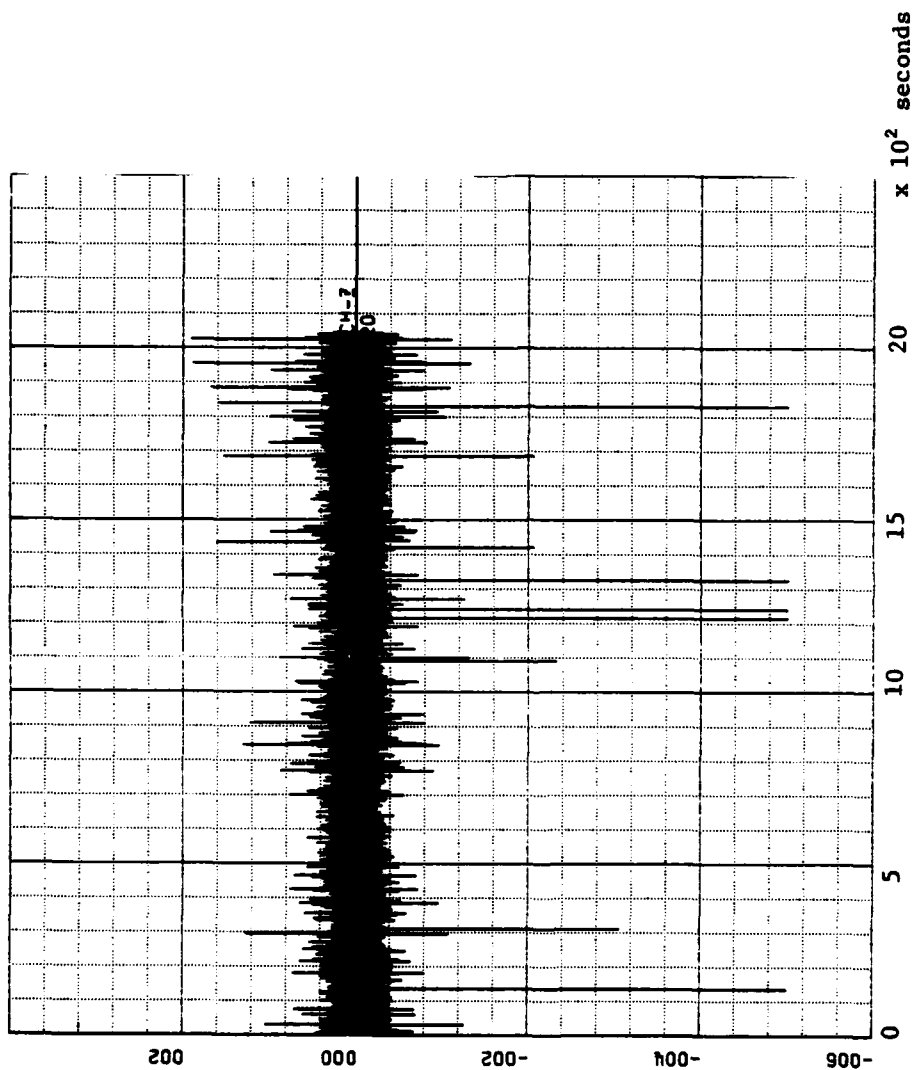


Figure 3.3. Z Coil Voltage, 17 August 82, 1302-1336 Local.
Amplitude (volts : 2 units/in) vs. Time (seconds : 500 units/in)

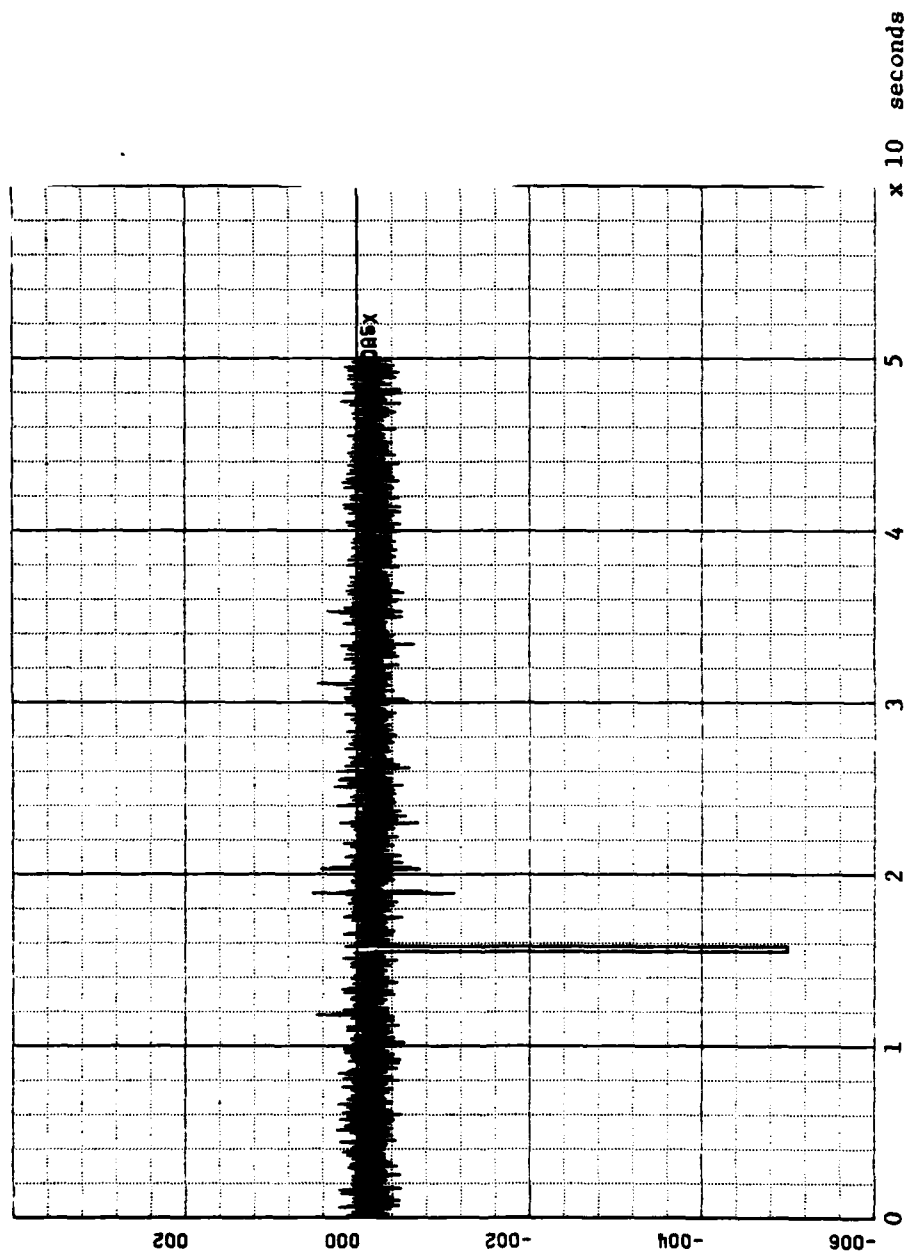


Figure 3.4. X-Coil Voltage, 17 August 82, 1322-1323 Local.
Amplitude (Volts: 2 units/in) vs. Time (seconds : 10 units/in)

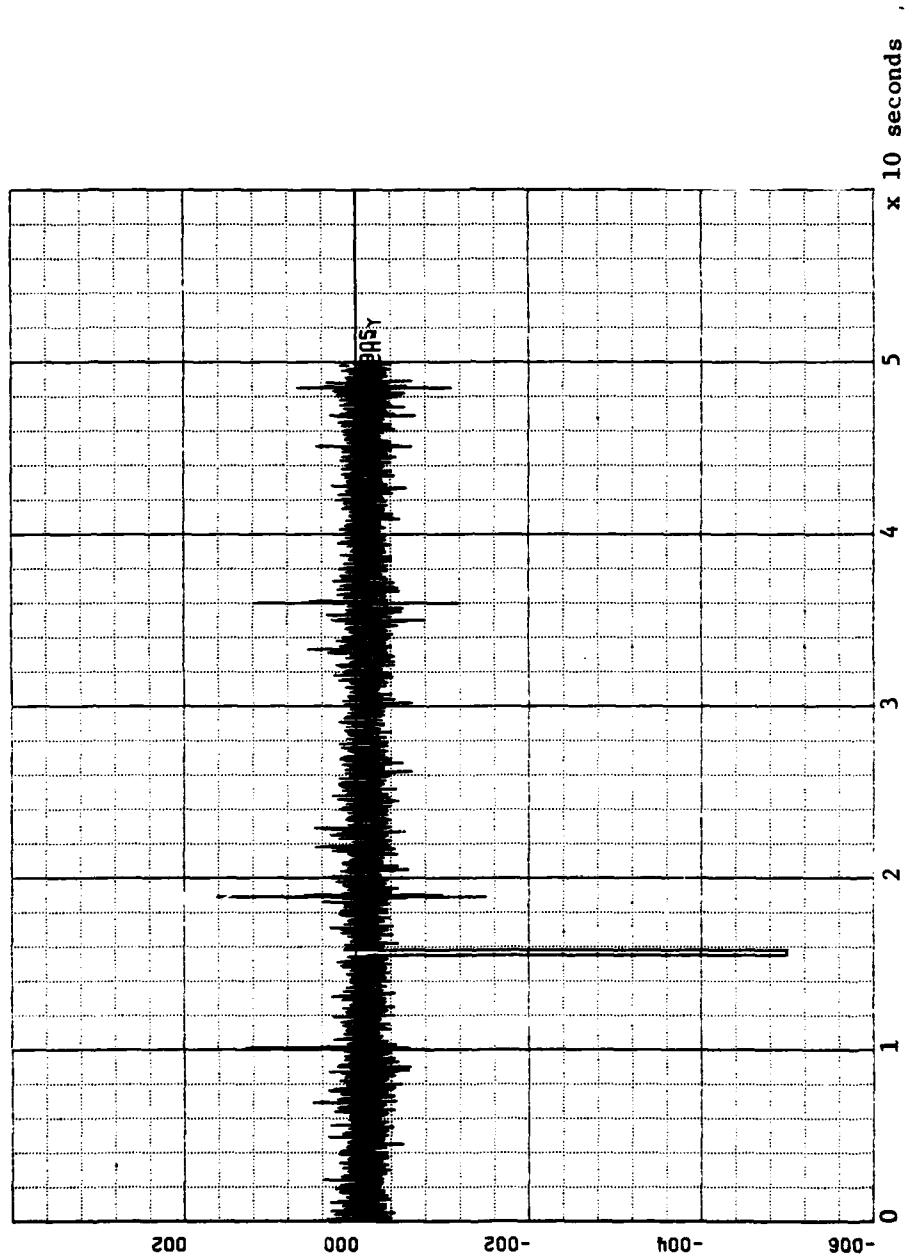


Figure 3.5. Y-Coil Voltage, 17 August 82, 1322-1323 Local.
Amplitude (volts : 2 units/in) vs. Time (seconds : 10 units/in)

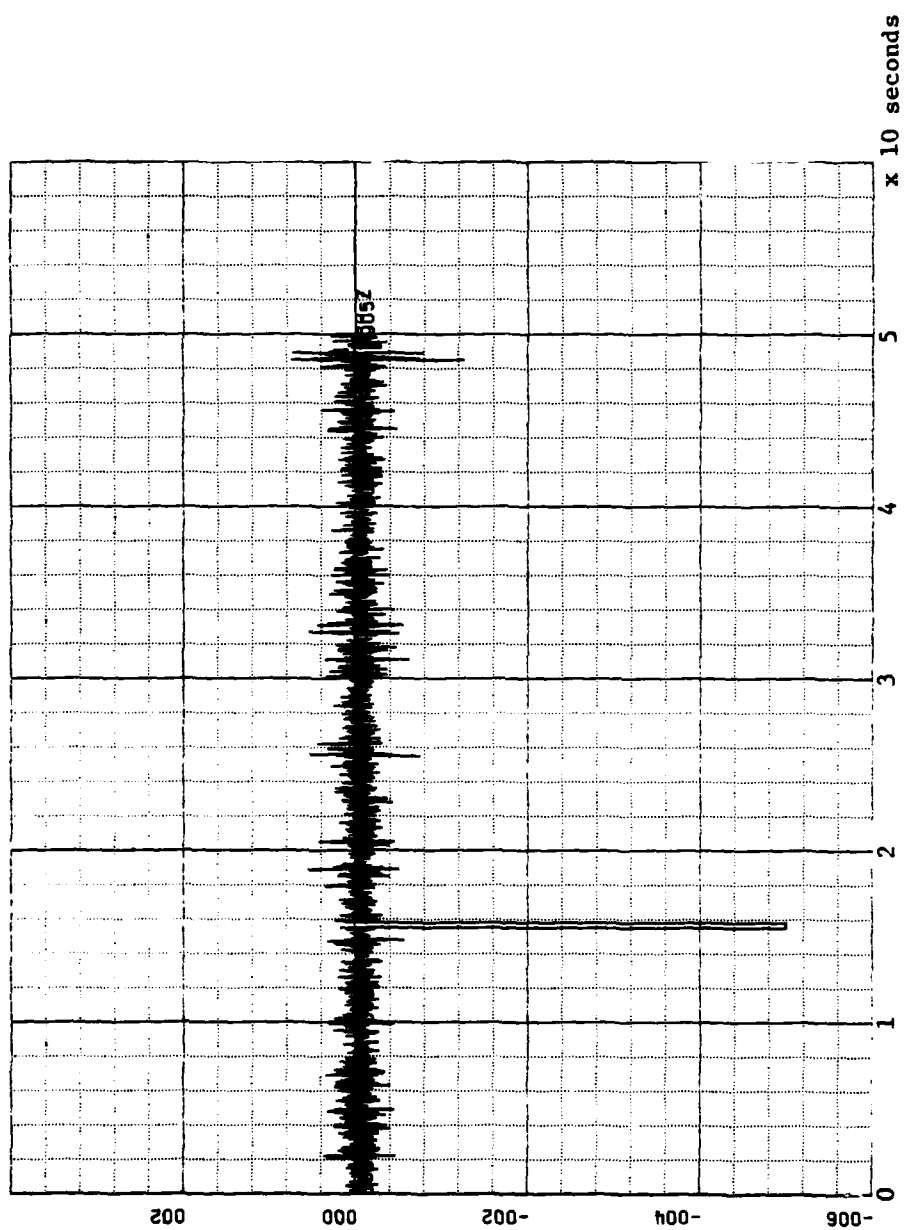


Figure 3.6. Z-Coil Voltage, 17 August 82, 1322-1323 Local.
Amplitude (volts : 2 units/in) vs. Time (seconds : 10 units/in)

seconds of data, the structure of the voltage spikes becomes apparent in Figures 3.4-3.6. The "square well" shape is characteristic of PCM dropouts or instances during the PCM to digital conversion synchronization is lost between the tape recorder containing the PCM tape and the decoding unit. We do not know whether PCM dropouts always occur on all three channels, but current evidence suggests dropouts are simultaneous on all channels.

Figures 3.7-3.9 again show the first 34 minutes of GMDT 11 only smoothed by the 144 point running average. The smoothing algorithm removes the 60 hertz aliasing. The PCM dropouts appear as "glitches" in the otherwise quasi sinusoid characteristic of a micropulsation.

We should note that the unusually large amount of hash present between 2 hertz and 10 hertz in the PSD's and the average slope of the PSD curve for those frequencies may in part be due to the PCM dropouts that occur on the tapes. A "deglitching" algorithm could be developed to remove the sudden large amplitude structures injected by the system into the voltage data if hardware modifications fail.

B. TIME SERIES MAGNETIC FIELD DATA

1. Magnetic Field Software

The time series magnetic field software is basically the same as that which produces the PSD's, etc. [Ref. 1 and Ref. 3]. The differences begin after the forward Fourier transform and the application of the transfer function. We

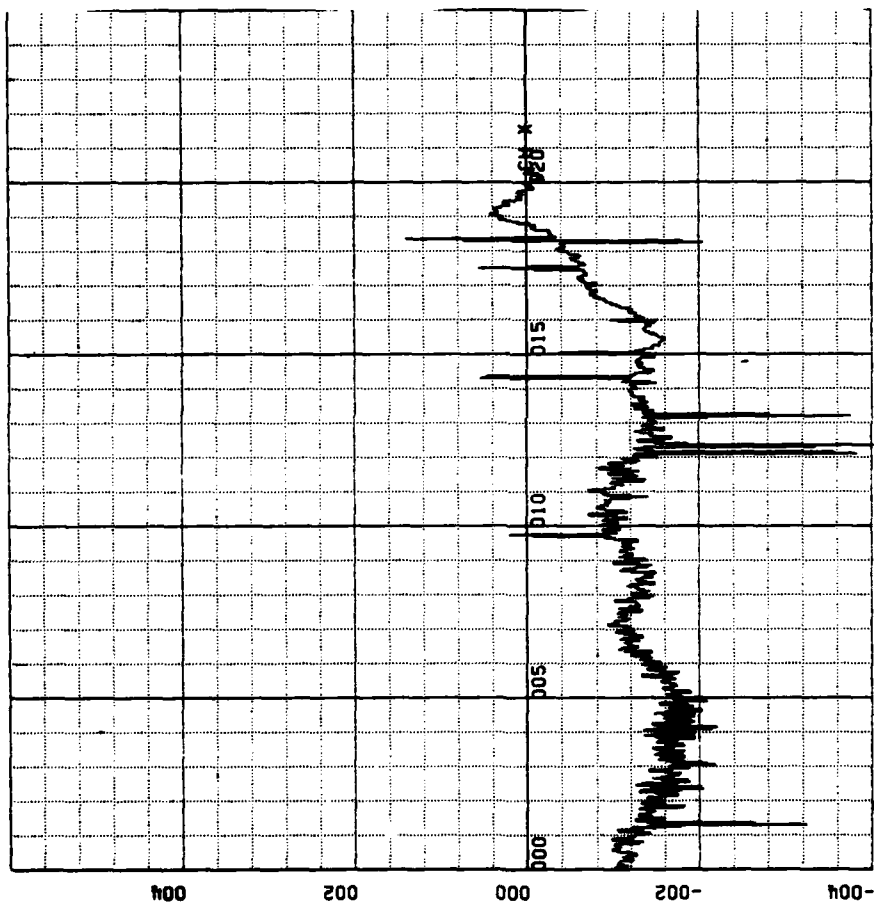


Figure 3.7. X Coil Voltage, 17 August 82, 1302-1336 Local.
Amplitude (volts : 0.2 units/in) vs. Time (seconds : 500 units/in)

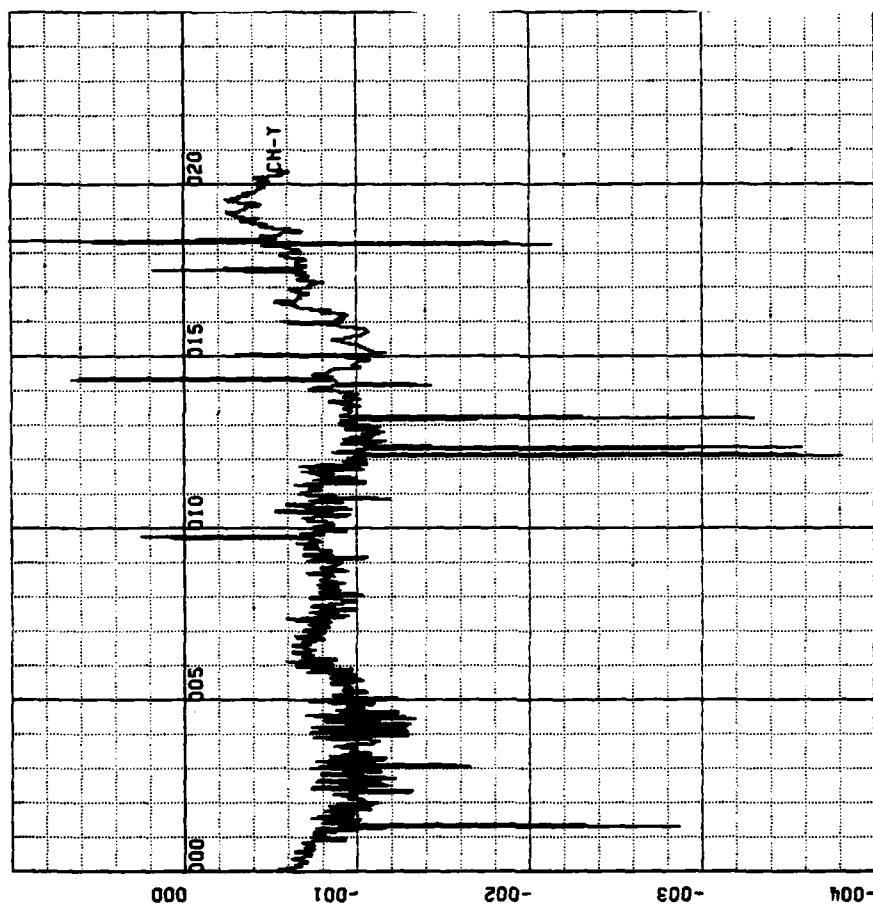


Figure 3.8. Y Coil Voltage, 17 August 82, 1302-1336 Local.
Amplitude (volts : 0.1 units/in) vs. Time (seconds : 500 units/in)

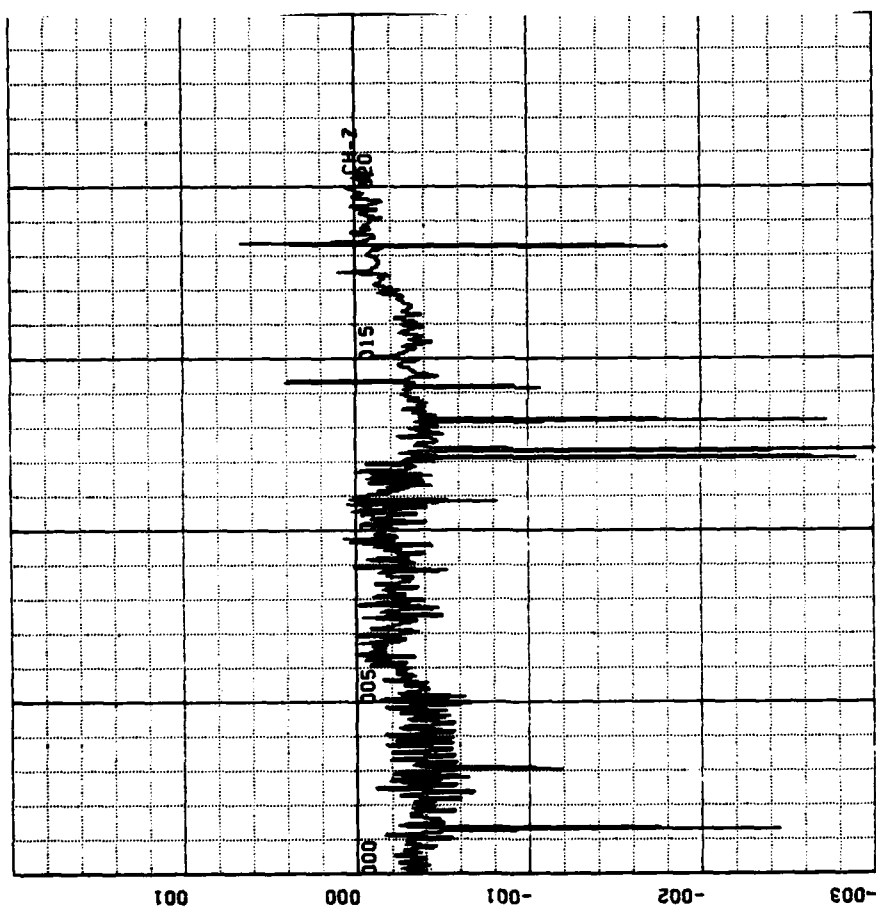


Figure 3.9. Z Coil Voltage, 17 August 82, 1302-1336 Local.
Amplitude (volts : 0.1 units/in) vs. Time (seconds :500 units/in)

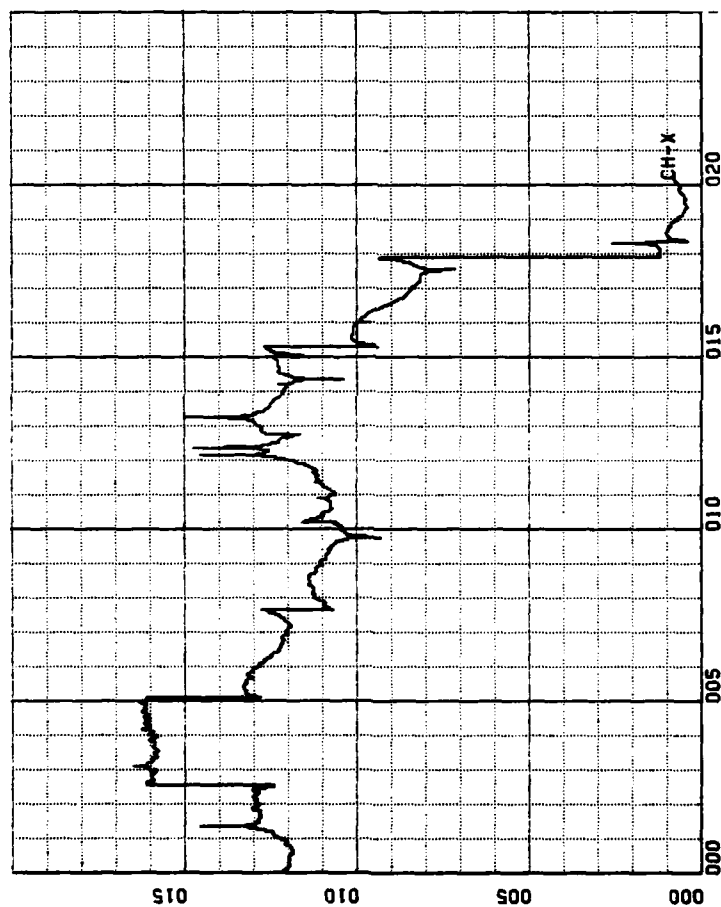


Figure 3.10a. X-Coil Magnetic Field, 17 August 82, 1302-1336 Local.
 Amplitude (nanoteslas : 5 units/in) vs. Time (seconds : 500 units/in)
 8 point smoothing

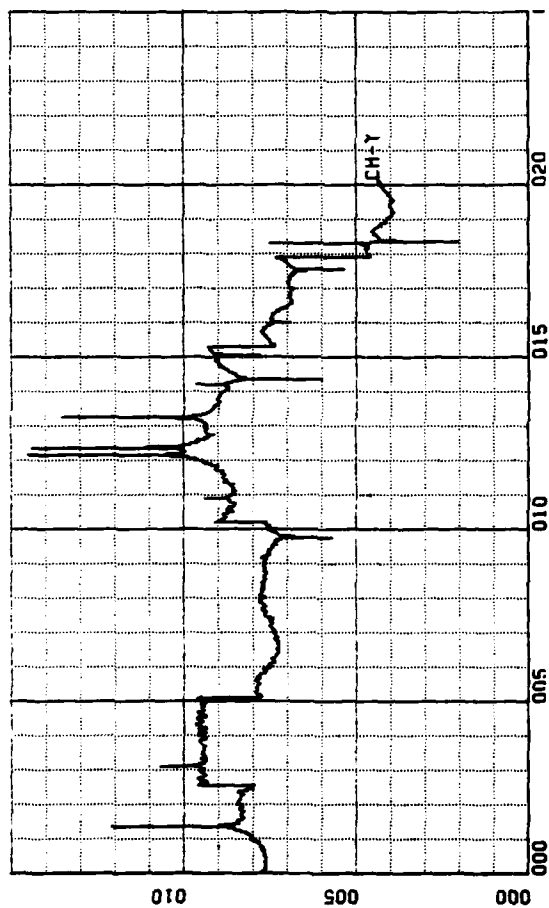


Figure 3.11a. Y-Coil Magnetic Field, 17 August 82, 1302-1336 Local.
 Amplitude (nanoteslas : 5 units/in) vs. Time (seconds : 500 units/in)
 8 point smoothing

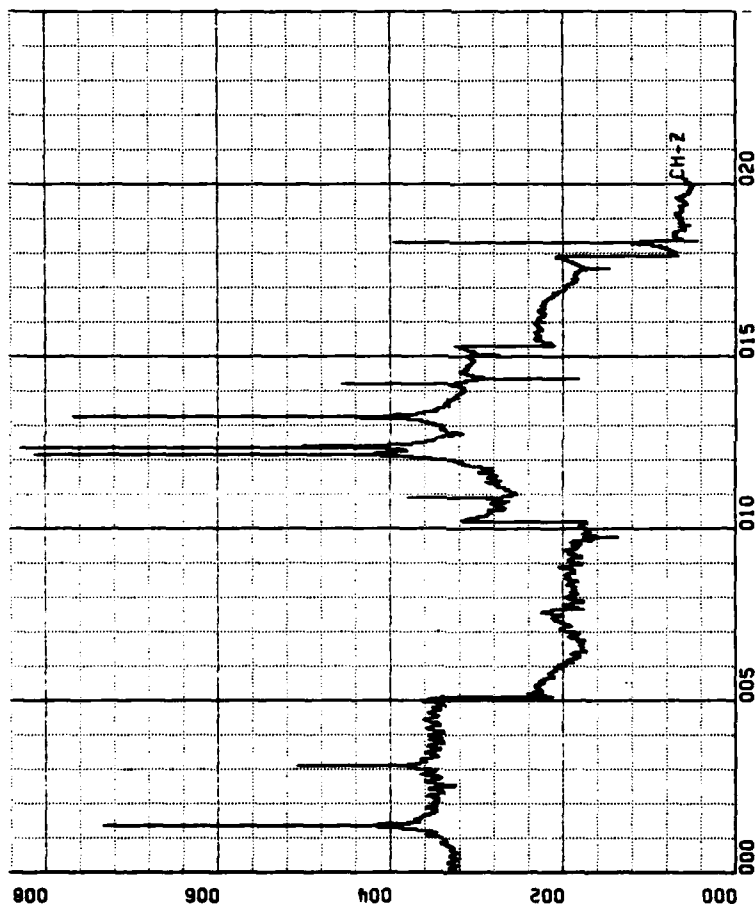


Figure 3.12a. Z-Coil Magnetic Field, 17 August 82, 1302-1336 Local.
 Amplitude (nanoteslas : 2 units/in) vs. Time (seconds : 500 units/in)
 8 point smoothing

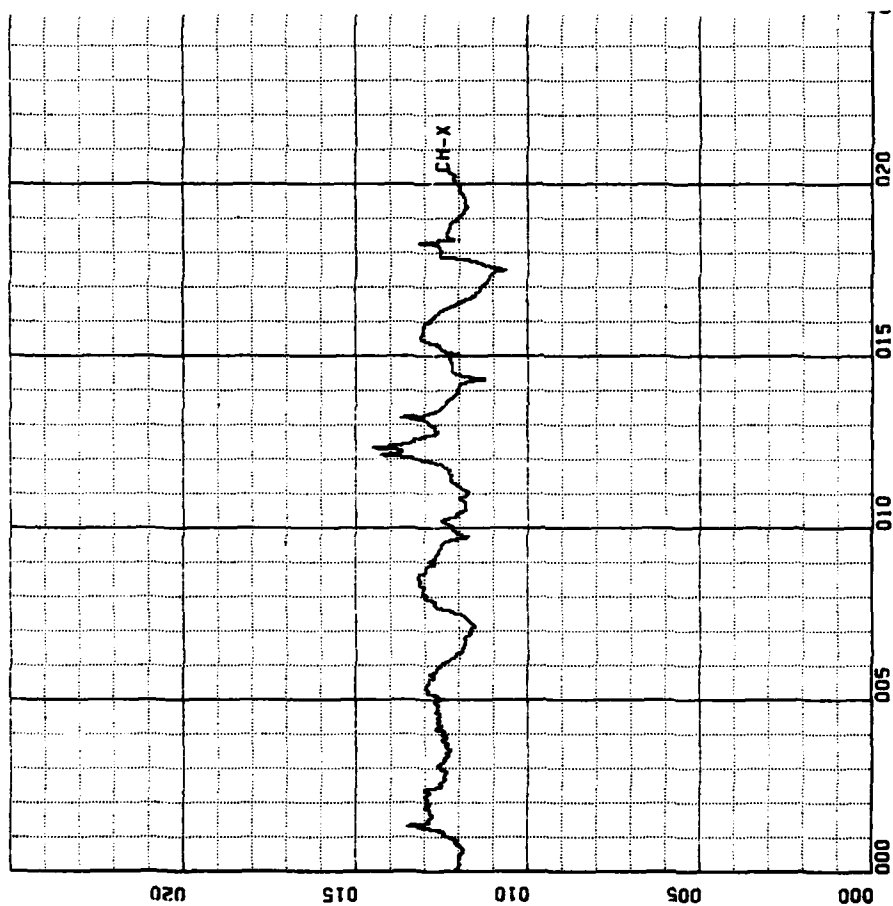


Figure 3.10b. X Coil Magnetic Field, 17 August 82, 1302-1336 Local.
 Amplitude (nanoteslas : 5 units/in) vs. Time (seconds : 500 units/in)
 144 point smoothing

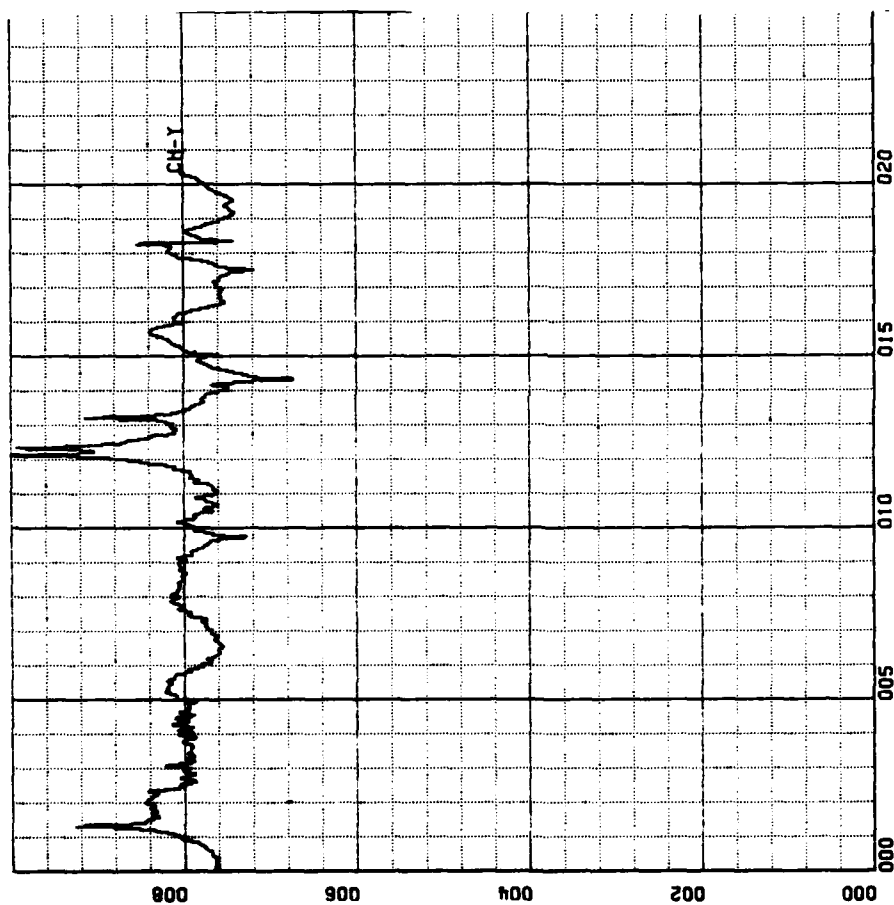


Figure 3.11b. Y Coil Magnetic Field, 17 August 82, 1302-1336 Local.
 Amplitude (nanoteslas : 1 unit/in) vs. Time (seconds : 500 units/in)
 144 point smoothing

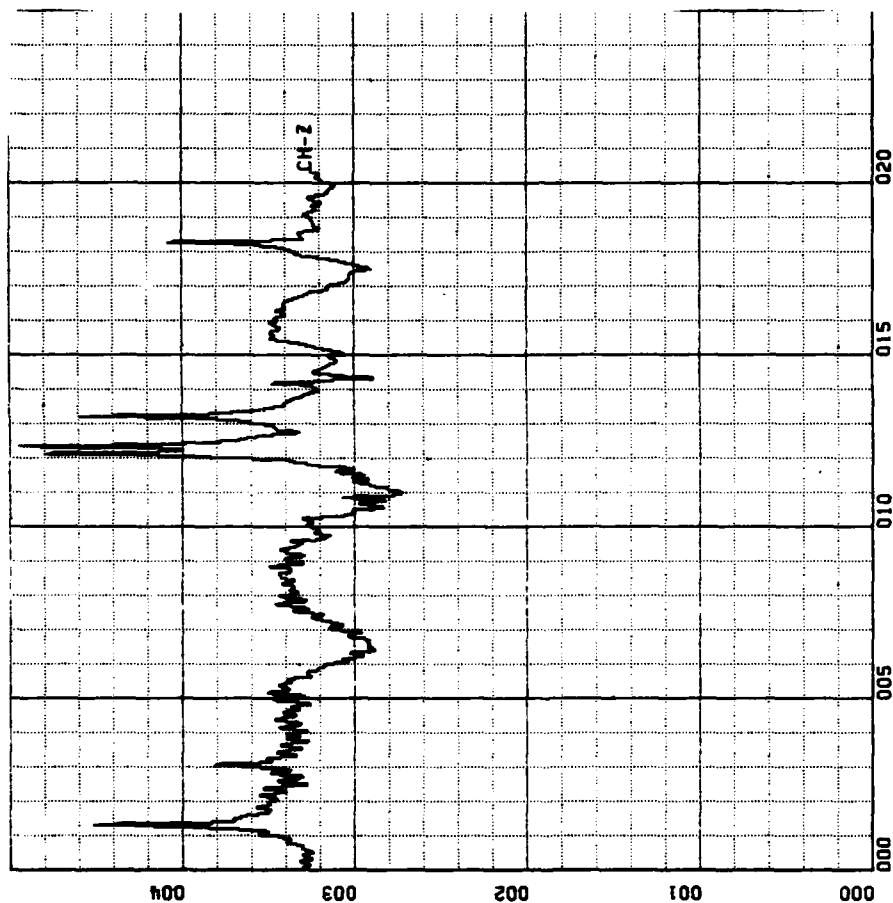


Figure 3.12b. Z Coil Magnetic Field, 17 August 82, 1302-1336 Local,
 Amplitude (nanoteslas : 1 unit/in) vs. Time (seconds : 500 units/in)
 144 point smoothing

should note that the transfer function as designed ignores phase information since it is just a least squares fit to data like that of Figure 2.2. Once the transfer function is applied, the reverse transform is performed. We obtain the complex absolute values of the magnetic field data (in nanoteslas) and place the data in new real arrays. To insure that there are no discontinuities between blocks of data, Figures 3.10a, 3.11a and 3.12a, all the blocks are connected to the first by adding or subtracting a constant to each element, Figures 3.10b, 3.11b, 3.12b. The data now undergoes the same 144 point double running average as the voltage to bring out fluctuations with periods of 10-45 seconds. Again DRAWP is used to plot the data. The computer program LVFTCl produces the smoothed magnetic field plots. It is provided in Appendix C.

2. Smoothed Magnetic Field Data Analysis

Again looking at the first 34 minutes of digital data tape GMDT 11, we see in the magnetic field data the same exceptional structures as seen in the voltage data, Figures 3.10-3.12. The glitches, however, do highlight one problem rather well. From Figures 3.7-3.9 we note that positive voltage spikes produce negative magnetic field spikes. This would indicate a π phase shift is introduced either in the transfer functions or in the digital Fourier transform. After investigating another digital tape GMDT 3A, 18 August 82, 0121-0251 local, we see another behavior. Figures 3.13-3.15

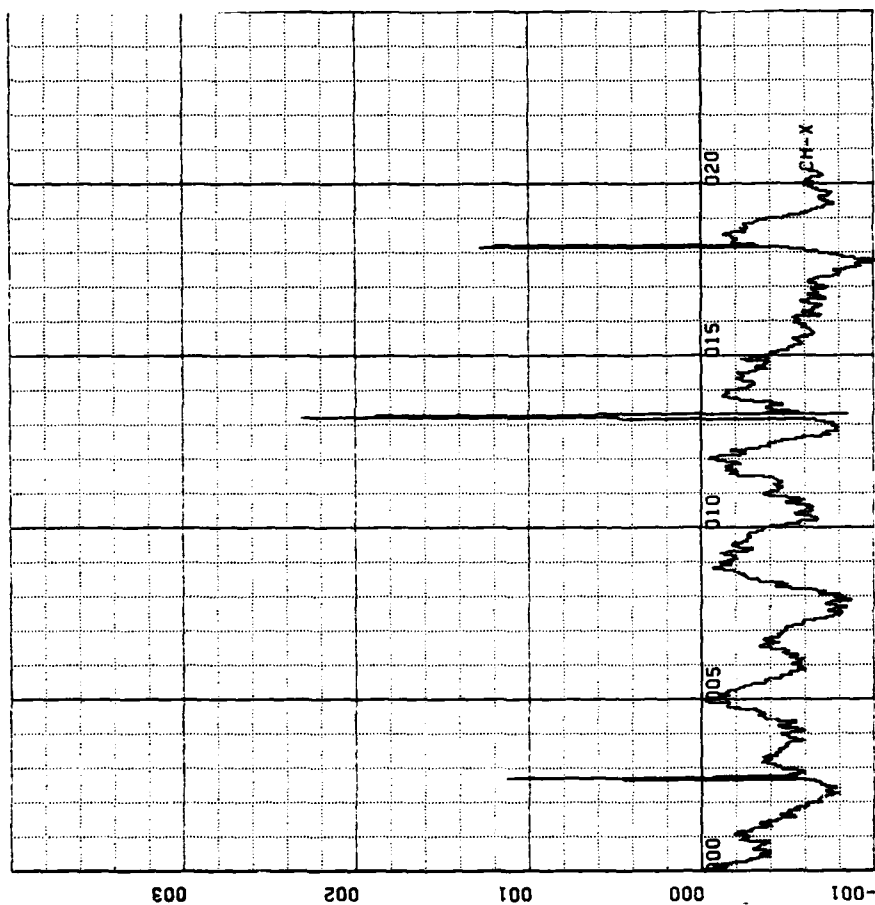


Figure 3.13. X Coil Voltage, 17 August 82, 2241-2315 Local.
Amplitude (volts : 0.1 units/in) vs. Time (seconds : 500 units/in)

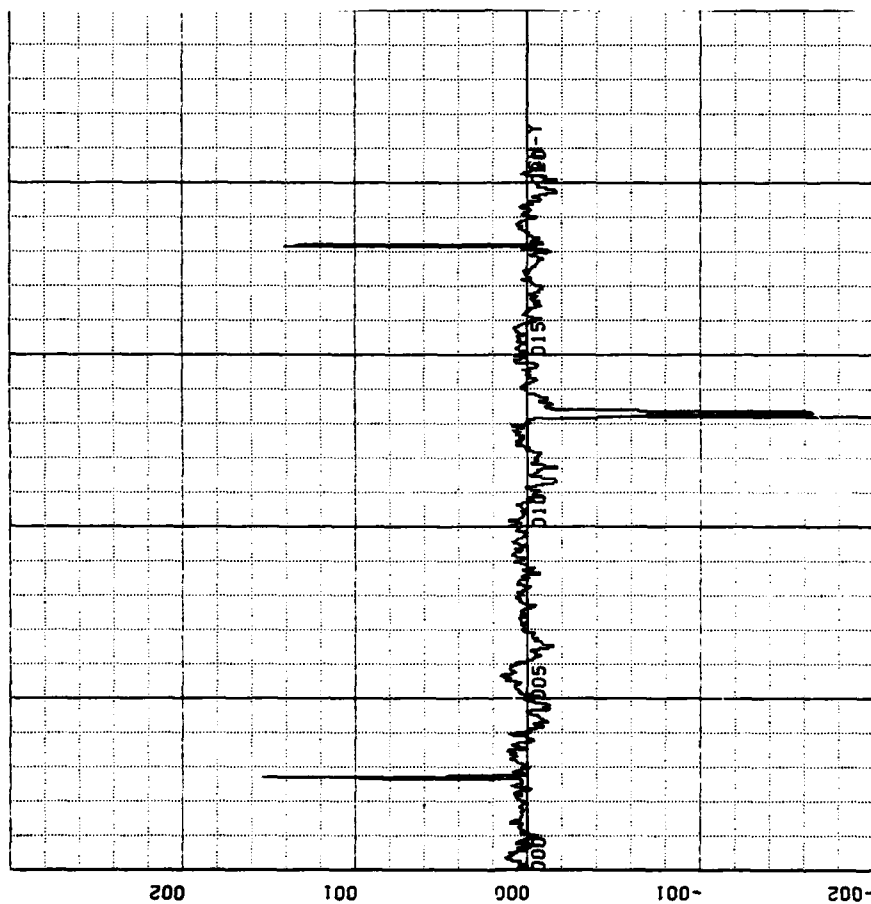


Figure 3.14. Y Coil Voltage, 17 Voltage 82, 2241-2315 Local.
Amplitude (volts : 0.1 units/in) vs. Time (seconds : 500 units/in)

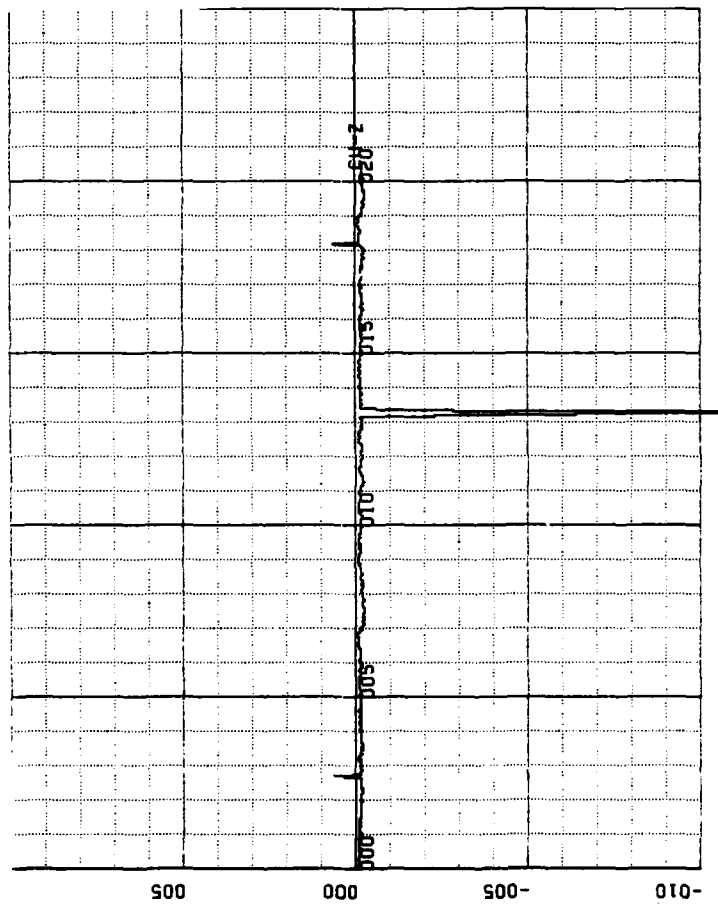


Figure 3.15. Z Coil Voltage, 17 August 82, 2241-2315 Local.
Amplitude (volts : 0.5 units/in) vs. Time (seconds : 500 units/in)

are the smoothed voltages for the first 34 minutes of data on GMDT3A after a one minute tape advance. Figures 3.16-3.18 are the smoothed magnetic fields for the same time period. The X-coil voltages show three positive spikes while the X-coil magnetic field shows three negative spikes. This supports the theory of a pi phase shift. However, the Y-coil voltage shows two positive spikes and one negative spike, while the Y-coil magnetic field has three positive spikes. Thus it appears we have a rather arbitrary phase problem that may find its origin in the transfer functions that do not maintain the correct phase.

From Figures 3.16-3.18 we note exceptional features that do not correspond to voltage spikes. The exceptional features are separated by time periods of 256 seconds which is the size of the blocks analyzed. These features persist with the data block connection scheme and 144 point smoothing. Their origin is not understood. Some data blocks look like Figure 3.19 with the end points having about the same value. However, some have end points as illustrated in Figure 3.20. The varying end point values are also shown in Figures 3.10a, 3.11a and 3.12a. This may be a source of the large amount of hash between 2 hertz and 10 hertz seen in the PSD's.

After looking at the magnetic field data it was obvious a validation experiment was needed for the sensing system and software.

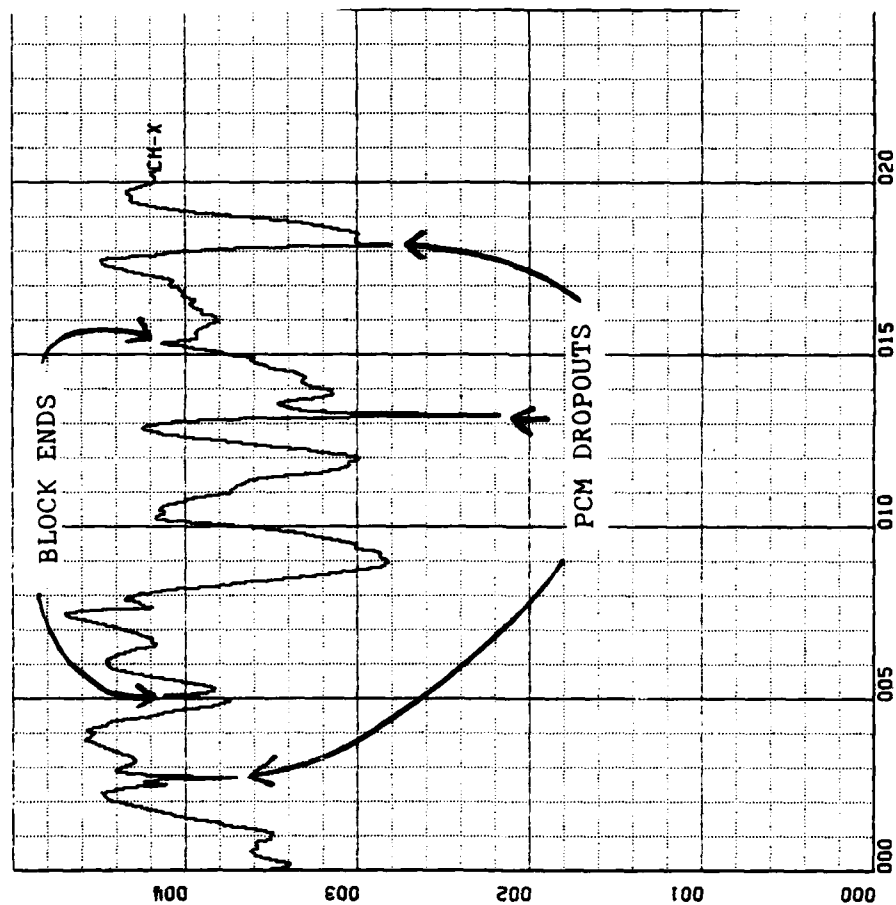


Figure 3.16. X Coil Magnetic Field, 17 August 82, 2241-2315, Local.
Amplitude (nanoteslas : 1 unit/in) vs. Time (seconds : 500 units/in)

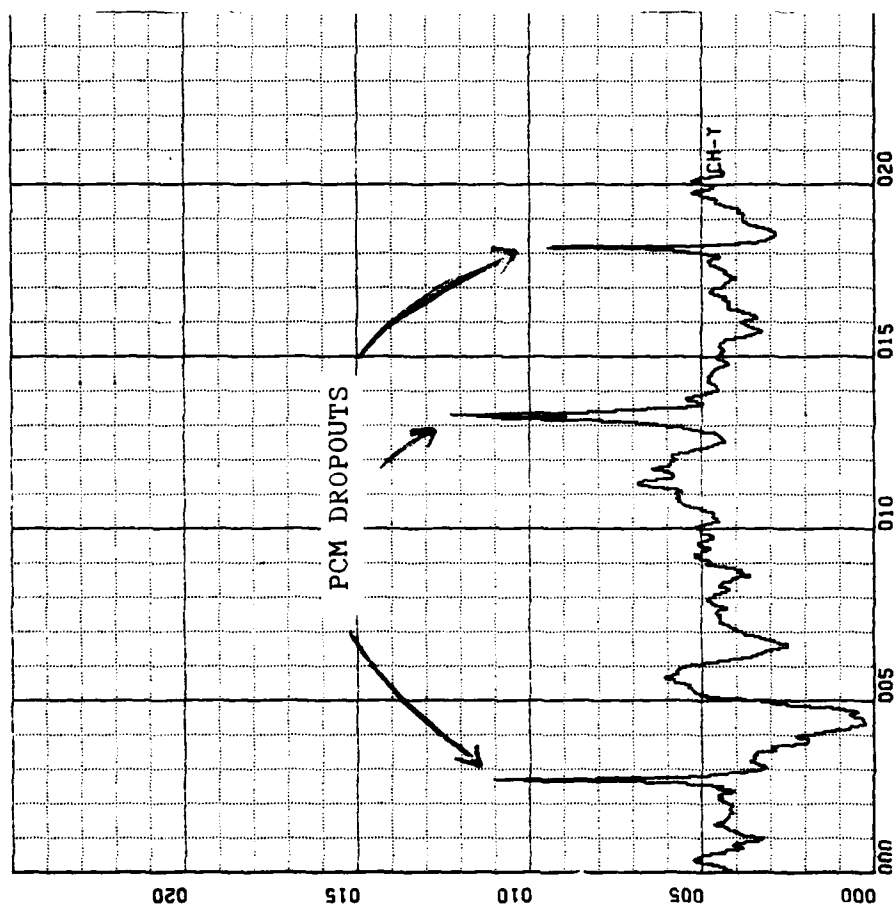


Figure 3.17. Y Coil Magnetic Field, 17 August 82, 2241-2315 Local.
Amplitude (nanoteslas : 0.5 units/in) vs. Time (seconds : 500 units/in)

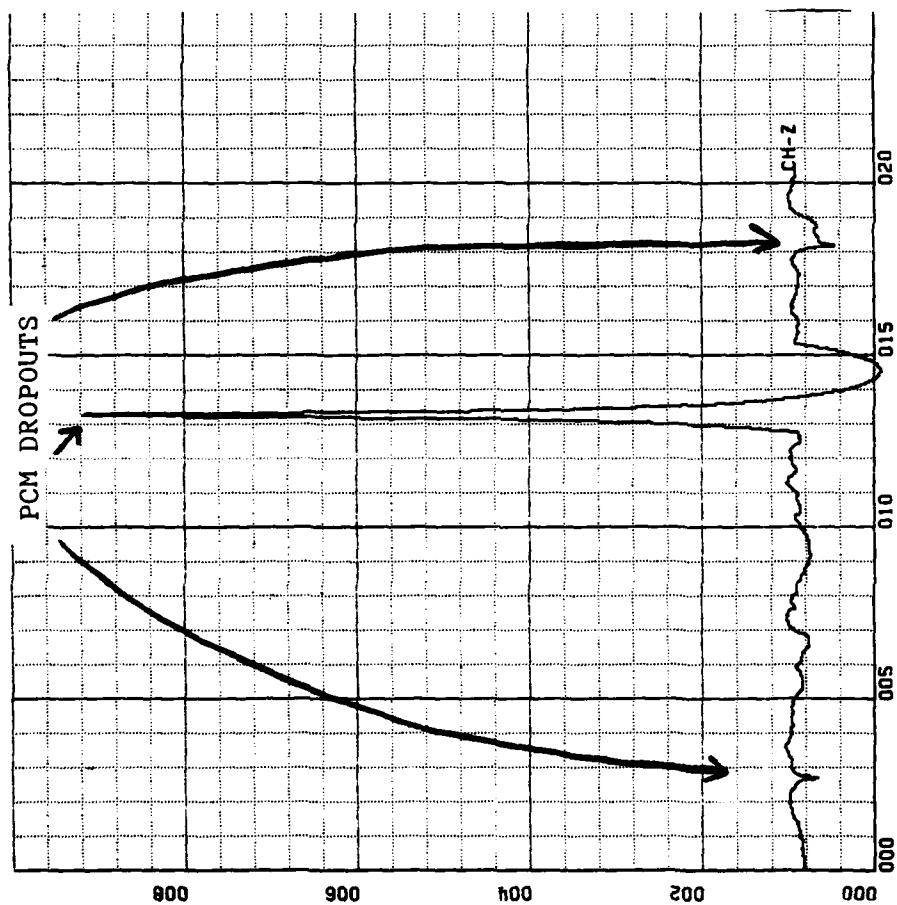


Figure 3.18. Z Coil Magnetic Field, 17 August 82, 2241-2315 Local.
Amplitude (nanoteslas : 2 units/in) vs. Time (seconds : 500 units/in)



Figure 3.19. One Frame of Data with End Points Having the Same Value

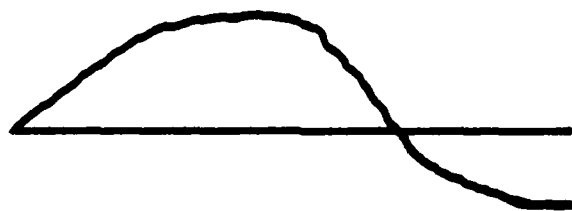


Figure 3.20. One Frame of Data with End Points Having Different Values

IV. SYSTEM AND SOFTWARE VALIDATION

A. EXPERIMENTAL APPARATUS

The inconsistencies in phase between the time series voltage and magnetic field plots prompted an experiment to validate the sensing system and software. The sensing apparatus consisted of the X-coil and a Schoenstadt fluxgate magnetometer. The sensing axis of both sensors were horizontal and oriented North-South. Figure 4.1 shows the test set-up. Instead of an on axis arrangement, the set-up shown was used because of limited resources. The fluxgate magnetometer is closer to the source since it has less sensitivity at the frequency of interest than the coils. Recorded on the usual X-channel was the output from the X-coil. The Y-channel contained data from the coil after passing through an additional Krohn-Hite model 3321 lowpass filter with a 10 hertz cutoff. On the Z-channel was the output from the fluxgate magnetometer. All three channels were recorded simultaneously and a 64 sample/second sample rate was used. An on-site chart recorder monitored the fluxgate and double filtered coil voltage output real time. The experiment produced two digital data tapes each approximately 46 minutes in length denoted GMTT1A and GMTT1B.

Artificial magnetic fields were introduced into the region by applying sinusoidal currents from a Wavetek signal generator to a cylinder (diameter = 0.13m) wrapped with 150 turns of wire. Location of the source is noted in Figure 4.1. The

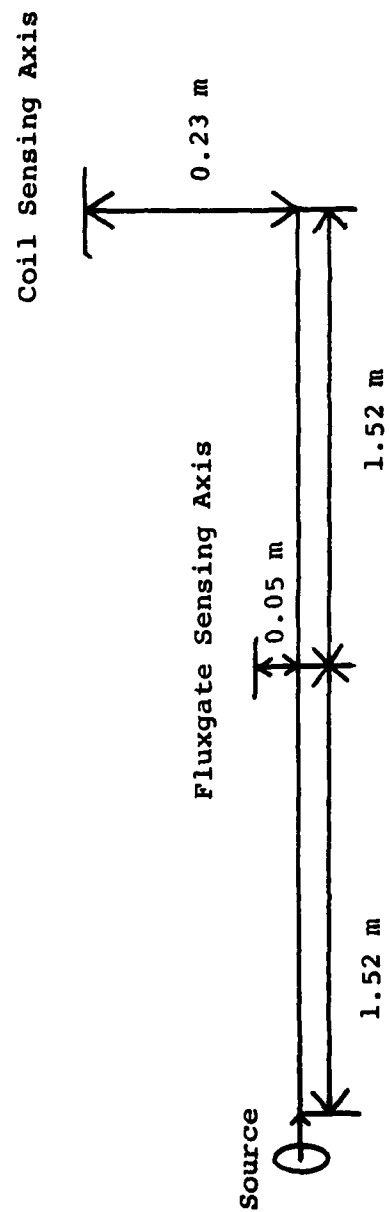


Figure 4.1. Test Arrangement

applied sinusoidal currents varied in frequency from 0.005 hertz to 10 hertz. For each frequency, two magnitude currents were applied to the source to demonstrate a linear response with amplitude.

The fluxgate magnetometer output is correct in phase and amplitude to at least 1 hertz. The transfer function between voltage and magnetic field for the fluxgate magnetometer is a constant of 10 nanoteslas/volt. Thus the fluxgate provides an excellent check for the coil transfer functions, the RD data stripping subroutine and the digital fourier transform.

B. EXPERIMENT RESULTS

1. Voltage

From the real time chart record of voltage for the fluxgate and double filtered coil, we can check the computer generated voltages using VOLTR and VOLTS. Table 4.1 shows the chart record and computer generated voltages for the fluxgate and double filtered coil at various frequencies. Only the large amplitude oscillations are measured for the double filtered coil because of poor signal-to-noise, for the small amplitude oscillations.

Table 4.1 shows good agreement between the chart record and computer output for the double filtered coil. However, the fluxgate magnetometer voltages undergo a constant transformation of 0.831 from chart record to computer plot. This may be explained by a problem in the data stripping

Table 4.1. Coil and Fluxgate Voltage

FREQUENCY (HZ)	CHART RECORD VOLTAGE (V)			COMPUTER GENERATED VOLTAGE (V)		
	FLUXGATE		COIL	FLUXGATE		COIL
	<u>Large Amplitude Oscillation</u>	<u>Small Amplitude Oscillation</u>	<u>Large Amplitude Oscillation</u>	<u>Large Amplitude Oscillation</u>	<u>Small Amplitude Oscillation</u>	<u>Large Amplitude Oscillation</u>
0.1	2.45	0.78	0.90	2.00	0.60	0.90
0.09	2.45	0.80	0.76	1.98	0.60	0.83
0.08	2.45	0.78	0.69	2.00	0.60	0.70
0.07	2.44	0.70	0.66	2.00	0.60	0.68
0.06	2.46	0.77	0.50	1.97	0.60	0.50
0.05	2.45	0.79	0.40	2.20	0.75	0.40
0.04	2.41	0.78	0.40	2.15	0.70	0.37
0.03	2.50	0.82	0.30	2.02	0.65	0.33
0.02	2.50	0.76	0.20	2.03	0.60	0.31
0.01	2.50	0.78		1.96	0.57	

Double filtered coil and fluxgate magnetometer voltages,
real time and computer generated.

algorithm. The present agreement between the chart record and computer generated voltages is shown in Table 4.2.

Another more serious problem became obvious during the examination of the computer generated voltage plots. For approximately the first 20 minutes of data recording the fluxgate magnetometer was not connected to the PCM board. Figures 4.2-4.4 show the two respective sensing devices. Figures 4.2 and 4.3 both contain "real" signal while Figure 4.4 does not contain "real" signal until the amplitude discontinuity indicating connection of the fluxgate magnetometer to the PCM board. Figures 4.2-4.4 indicate that "pick-up" is occurring probably between the channels at the PCM board. The amplitude of the cross-talk voltage is about 0.15 volts peak-to-peak at the frequency of 0.1 hertz. The amplitude of the "real" signal on the double filtered coil is 0.29 volts at 0.1 hertz. Thus 51 percent of the "real" signal is coupled to the disconnected channel. Coupling between channels of this magnitude raises serious questions about the computer generated data, especially for coherence. Discovering the amount of the channel pick-up if the channel is loaded requires further experimentation.

Figures 4.5-4.7 show an interesting feature of the coil data versus fluxgate magnetometer data. On the channels containing the coil output we see noise on top of the signal. This noise is not present on the channel containing the fluxgate magnetometer data. Since all three channels passed

Table 4.2. Percent Agreement Between the Chart Record
and Computer Generated Voltages

<u>FREQUENCY (HZ)</u>	<u>FLUXGATE FIELD (%)</u>		<u>COIL FIELD (%)</u>	
	<u>Large Amplitude Oscillation</u>	<u>Small Amplitude Oscillation</u>	<u>Large Amplitude Oscillation</u>	<u>Small Amplitude Oscillation</u>
0.1	87	74	100	
0.09	87	72	94	
0.08	87	76	99	
0.07	87	84	98	
0.06	87	84	100	
0.05	87	97	100	
0.04	87	93	92	
0.03	87	84	94	
0.02	87	80	69	
0.01	86	80		

0.1 Hz with 60 Hz Aliasing

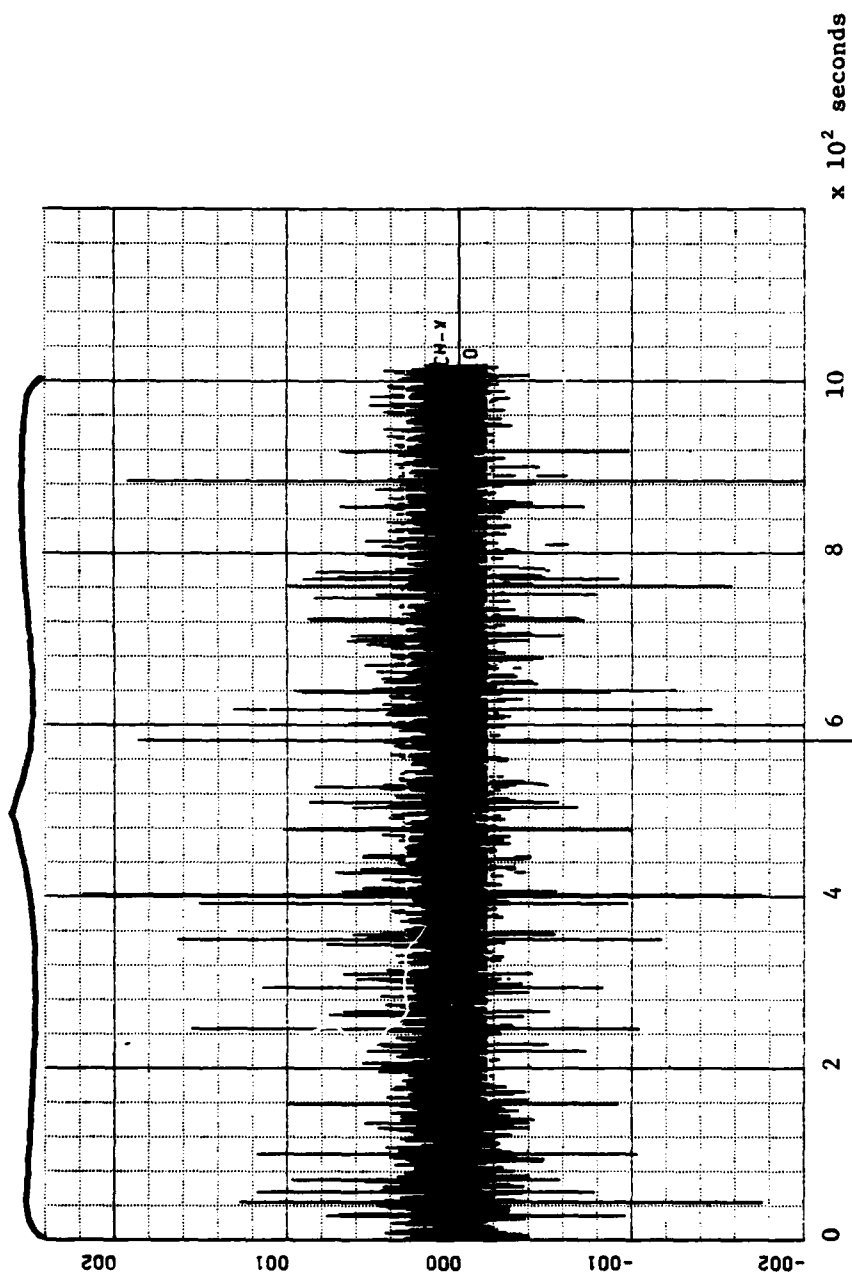


Figure 4.2. X-Coil Voltage, 26 April 83, 0931-0948 Local.
Amplitude (volts : 1 unit/in) vs. Time (seconds : 200 units/in)

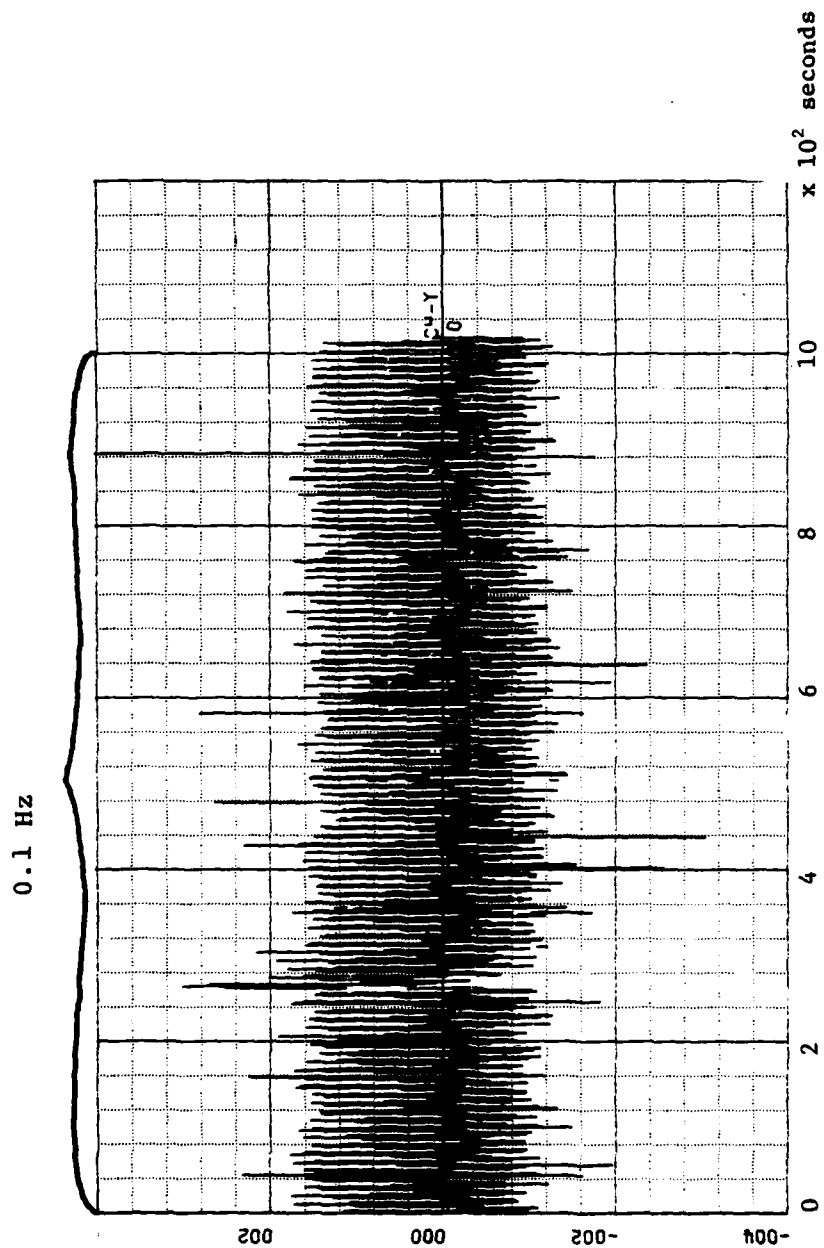


Figure 4.3. Filtered X-Coil Voltage, 26 April 83, 0931-0948 Local.
Amplitude (volts : 0.2 units/in) vs. Time (seconds : 200 units/in)

AD-A132 443 AN ANALYSIS OF A PC-3 MICROPULSATION IN THE GEOMAGNETIC
FIELD(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA
K B STEVENS JUN 83

AN ANALYSIS OF A PC-3 MICROPULSATION IN THE GEOMAGNETIC
FIELD(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA
K B STEVENS JUN 83

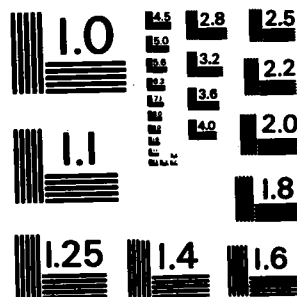
22

UNCLASSIFIED

F/G 8/14

NL

END
DATE
TIME
4 3



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

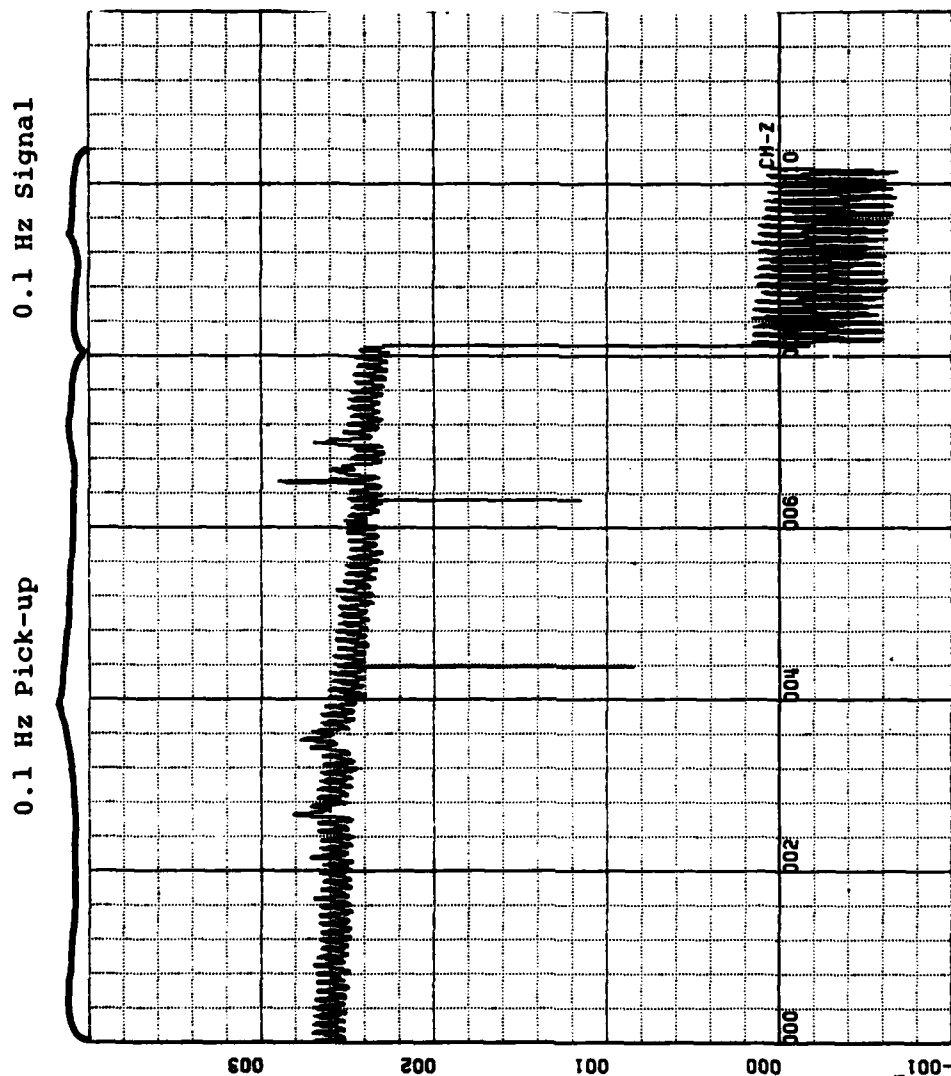


Figure 4.4. Fluxgate Voltage, 26 April 83, 0931-0948 Local.
Amplitude (volts : 1 unit/in) vs. Time (seconds : 200 units/in)

through the PCM encoder and decoder, the noise is probably in the coil amplifiers or the coils themselves. An experiment to investigate the true origin of the noise should be done.

2. Magnetic Field

Given the dipole equation [Ref. 6] and the experimental arrangement in Figure 4.1, the ratio of magnitude of the magnetic field seen by the fluxgate to that seen by the coil can be calculated. From the geometry in Figure 4.1 the field at the coil would be a factor of 8 less than that seen by the fluxgate. This is because the source is a dipole and the field of a dipole falls off as $1/R$. Detailed consideration of the geometry gives a ratio of approximately 8.09. Table 4.3 contains the magnetic field measured at the fluxgate magnetometer. Using the ratio calculated from the geometry, the expected magnetic field amplitude at the coil is listed in Table 4.3.

A modified form of computer code LFVTC1 generated the magnetic field versus time plots for the test tapes. Table 4.3 shows the computer generated peak-to-peak magnetic field values read from the computer plots. From Table 4.3 it appears that the coil magnetic field amplitude is in error by a factor of approximately three (with exception to the low frequencies). One can conclude that a problem exists in the software.

Figures 4.8-4.9 show the magnetic field data for the second seventeen minutes of digital data tape GMTT1A. Figure 4.9 is the magnetic field measured by the fluxgate magnetometer

Table 4.3. Measured and Computer Generated Magnetic Field Magnitudes

FREQUENCY (Hz)	KNOWN FLUXGATE FIELD (mT)			EXPECTED COIL FIELD (mT)			EXPECTED RATIO FLUXGATE/COIL			COMPUTER COIL FIELD (mT)			ACTUAL RATIO FLUXGATE/COIL		
	LARGE AMPLITUDE OSCILLATION	SMALL AMPLITUDE OSCILLATION		LARGE AMPLITUDE OSCILLATION	SMALL AMPLITUDE OSCILLATION		LARGE AMPLITUDE OSCILLATION	SMALL AMPLITUDE OSCILLATION		LARGE AMPLITUDE OSCILLATION	SMALL AMPLITUDE OSCILLATION		LARGE AMPLITUDE OSCILLATION	SMALL AMPLITUDE OSCILLATION	
0.1	24.50	7.80		3.04	0.96		8.06	8.12		1.08	0.30		22.69	26.00	
0.09	24.50	8.00		3.03	0.99		8.09	8.08		1.00	0.35		24.50	22.86	
0.08	24.50	7.80		3.04	0.96		8.06	8.12		0.98	0.30		25.00	26.00	
0.07	24.40	7.00		3.02	0.87		8.08	8.05		0.98	0.32		24.89	21.88	
0.06	24.60	7.70		3.05	0.94		8.07	8.19		0.90	0.30		27.33	25.67	
0.05	24.50	7.90		3.03	0.98		8.09	8.06		0.76	0.35		32.23	22.57	
0.04	24.10	7.80		3.01	0.96		8.01	8.12		0.28	0.24		86.07	32.5	
0.03	25.00	8.20		3.09	1.01		8.09	8.12		0.32	0.14		78.13	58.57	
0.02	25.00	7.60		3.09	0.92		8.09	8.26		0.64	0.24		39.06	31.67	
0.01	25.00	7.80		3.09	0.96		8.09	8.12		0.40	0.14		62.50	55.71	

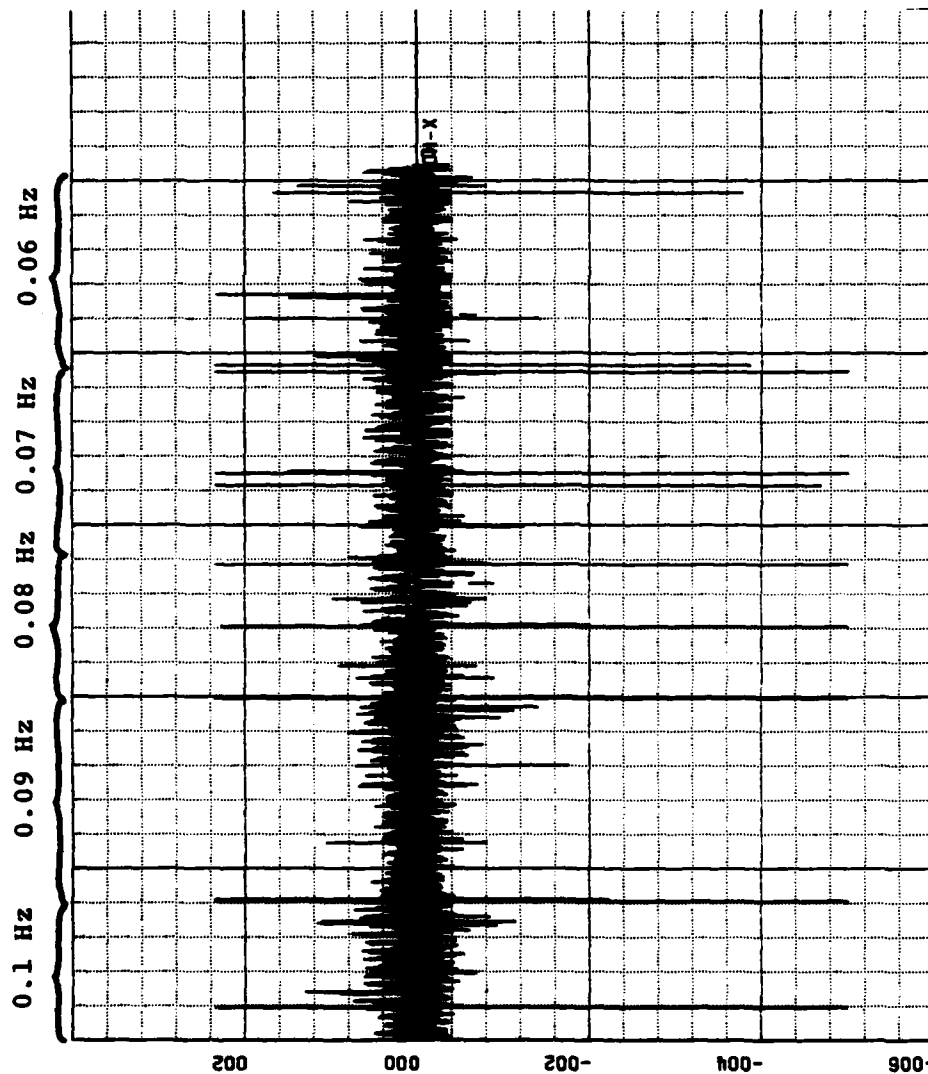


Figure 4.5. X-Coil Voltage, 26 April 83, 0948-1005 Local.
Amplitude (volts : 2 units/in) vs. Time (seconds : 200 units/in)

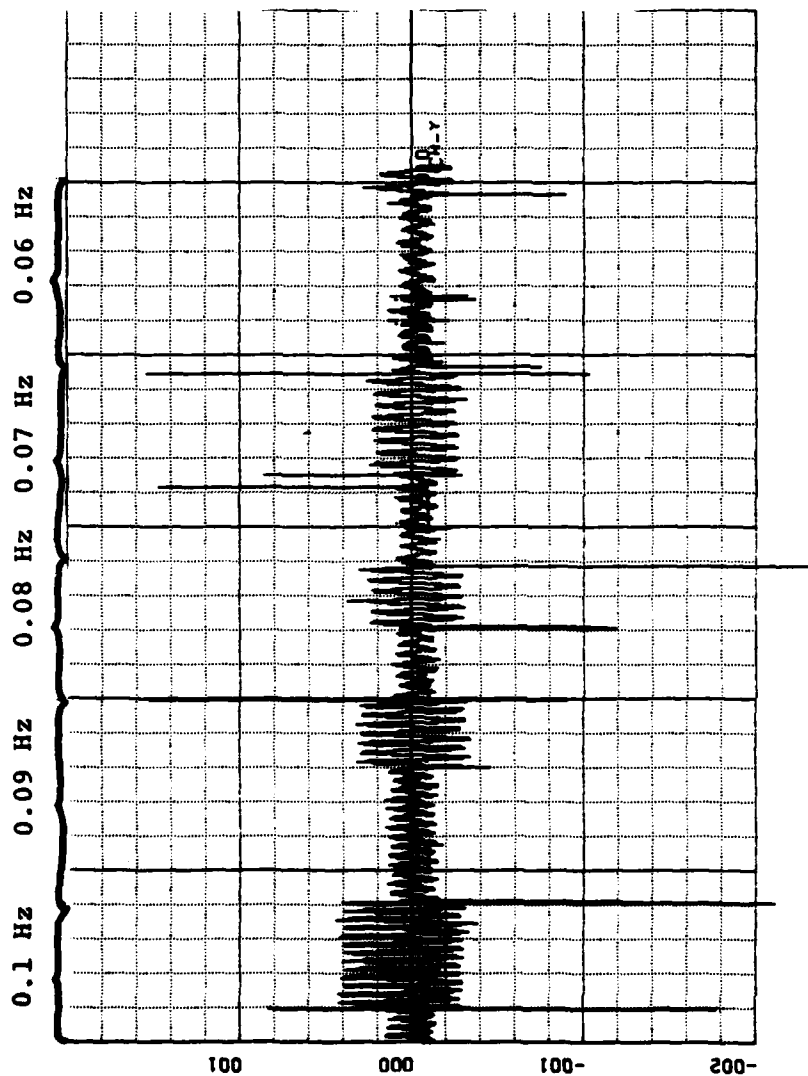


Figure 4.6. Filtered X-Coil Voltage, 26 April 83, 0948-1005 Local.
Amplitude (volts : 1 unit/in) vs. Time (seconds : 200 units/in)

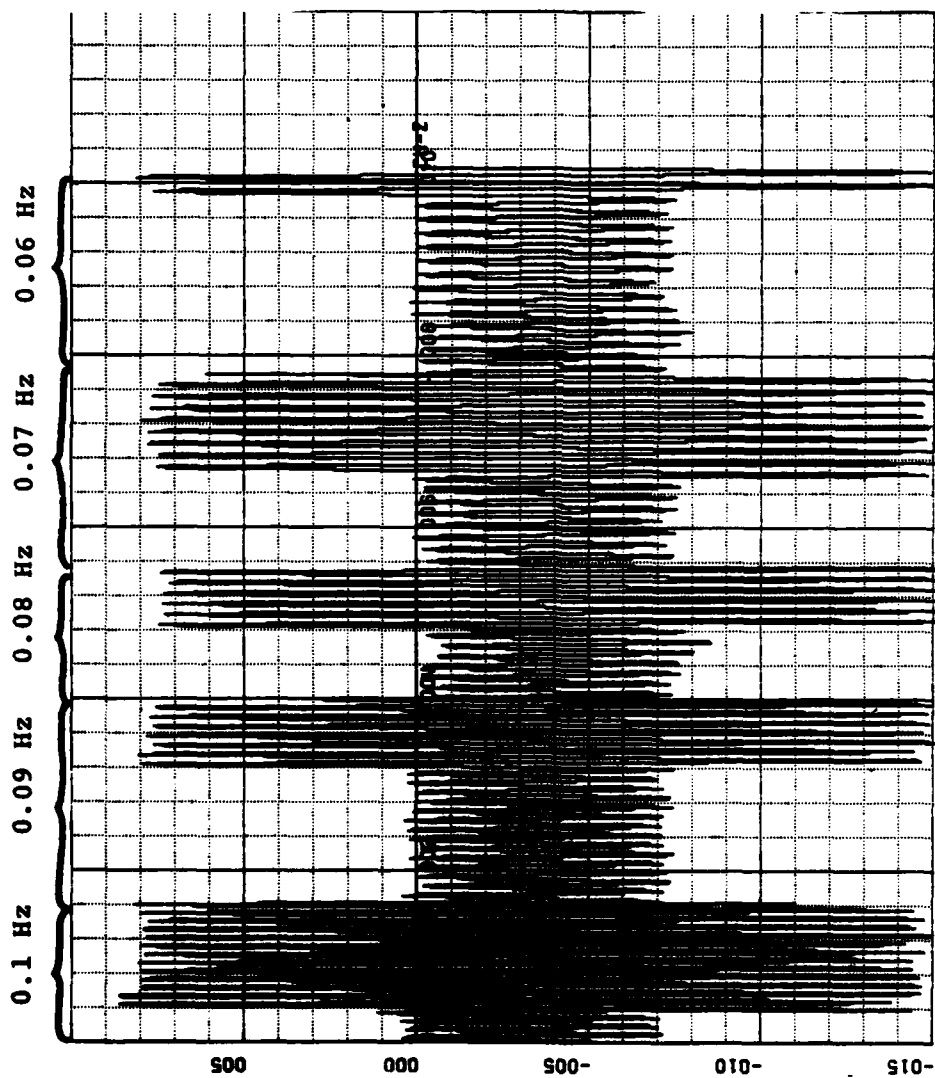


Figure 4.7. Fluxgate Voltage, 26 April 83, 0948-1005 Local.
Amplitude (volts : 0.5 units/in) vs. Time (seconds : 200 units/in)

and Figure 4.8 is the magnetic field seen by the coil. For the coil we see discontinuities every 256 seconds corresponding to the block size of data. This indicates that the problems in the data block end points, as mentioned in Section III, do exist. It is not clear how to deal with this.

The first 300 seconds of Figures 4.8-4.9 is expanded in Figures 4.11-4.12. With the expanded data a phase difference between coil and fluxgate can be determined. By checking the phase difference, we can determine whether the phase independent transfer function is introducing error. For the 0.1 hertz field plotted in Figures 4.10-4.11 the coil lags the fluxgate by approximately 72 degrees. In Figures 4.12-4.13 we see that at 0.01 hertz the coil sensitivity has fallen and a reliable phase difference between the fluxgate and coil cannot be made. Figure 4.14 shows the relationship between phase angle and frequency.

The above experiment shows the advantages of having a real time "ground truth" record. With this, one can avoid "working in the blind". Computer products will have a check. Thus, a multi-channel chart recorder should be purchased to graph in real time the x, y, and z inputs to the PCM board. In addition, electronic circuitry should be developed and incorporated so that the chart records represent at least a low pass filtering of the coil voltages. Ideally, conversion of voltage to magnetic field could occur in real time at this point given the appropriate electronics.

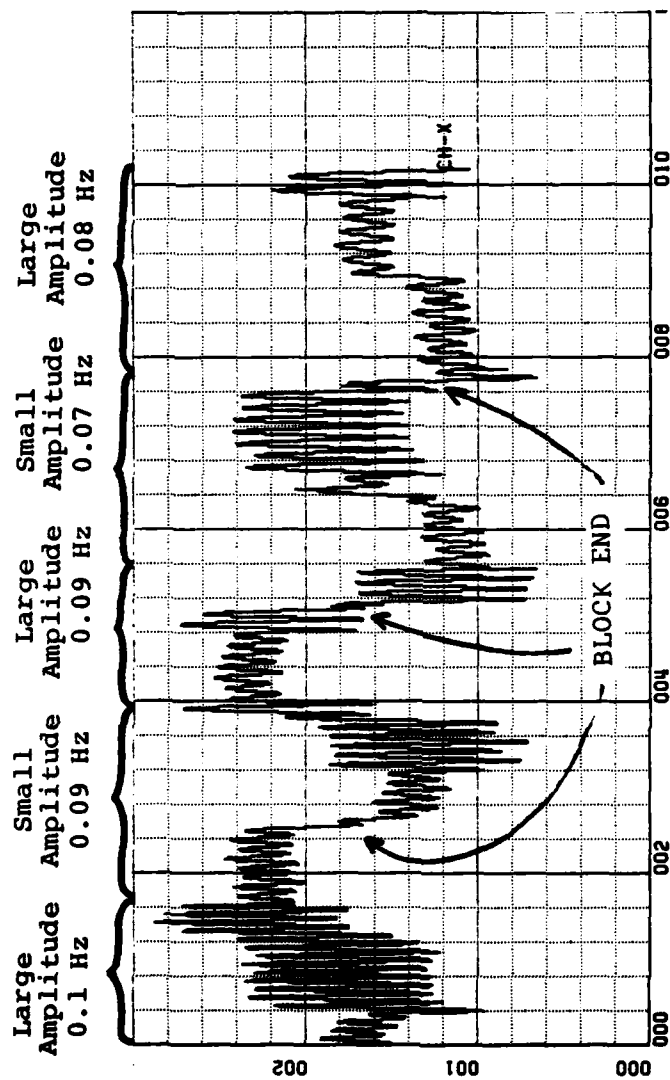


Figure 4.8. X-Coil Magnetic Field, 26 April 83, 0948-1005 Local.
Amplitude (nanoteslas : 1 unit/in) vs. Time
(seconds : 200 units/in)

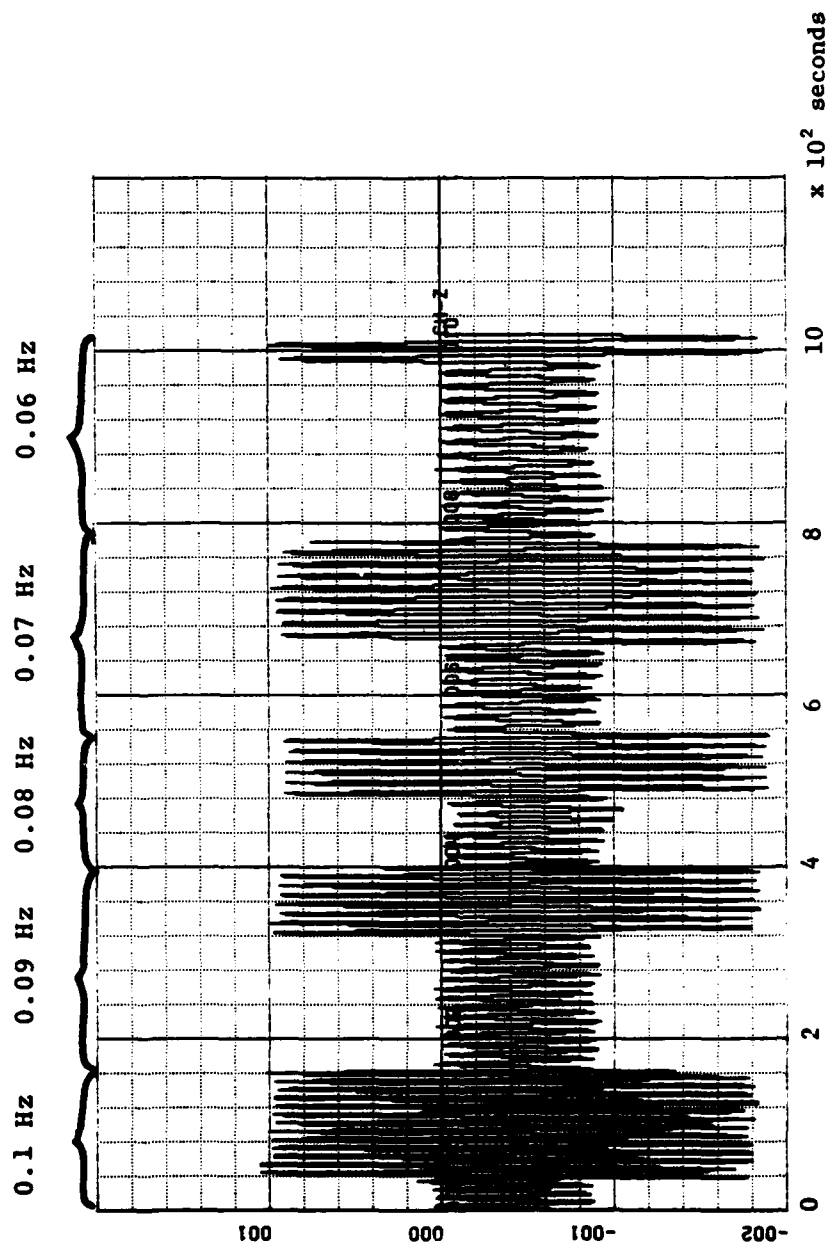


Figure 4.9. Fluxgate Magnetic Field, 26 April 83, 0948-1005 Local.
Amplitude (nanoteslas : 10 units/in) vs. Time
(seconds : 200 units/in)

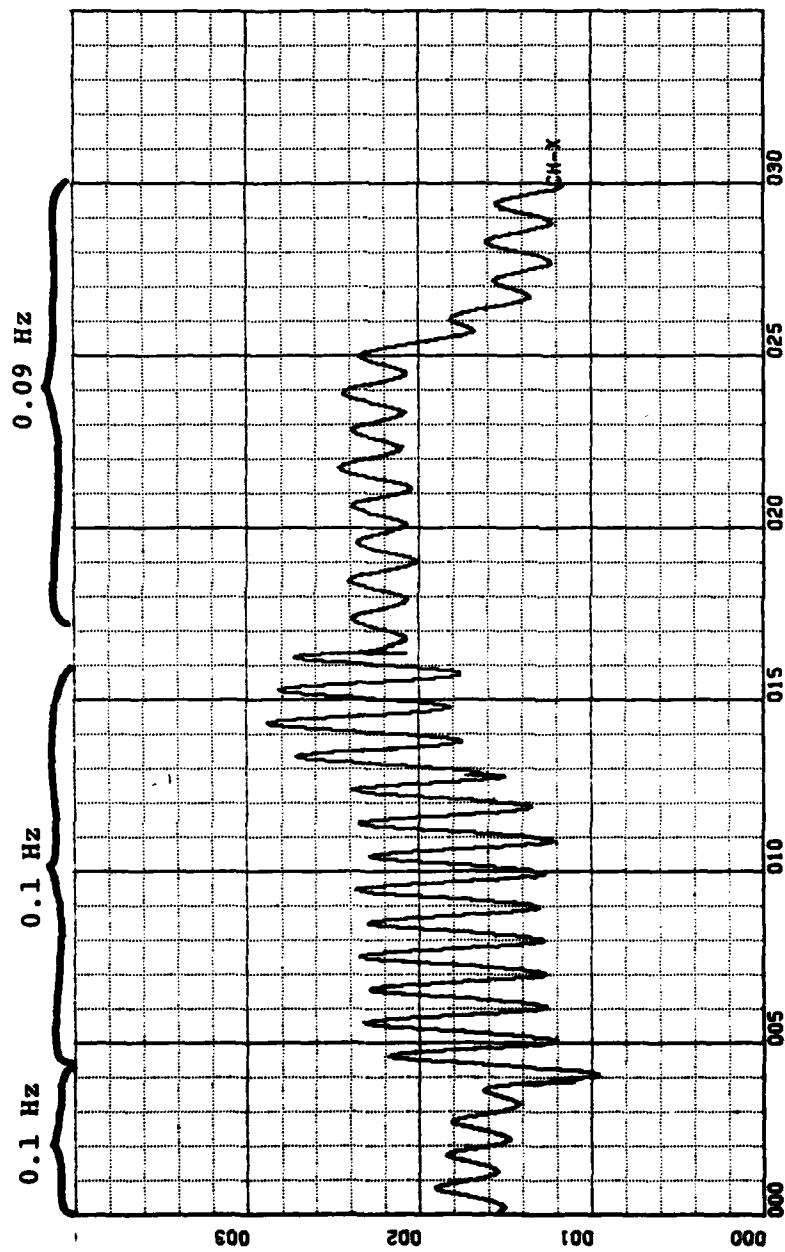


Figure 4.10. X-Coil Magnetic Field, 26 April 83, 0948-0953 Local.
Amplitude (nanoteslas : 1 units/in) vs. Time (seconds : 50 units/in)

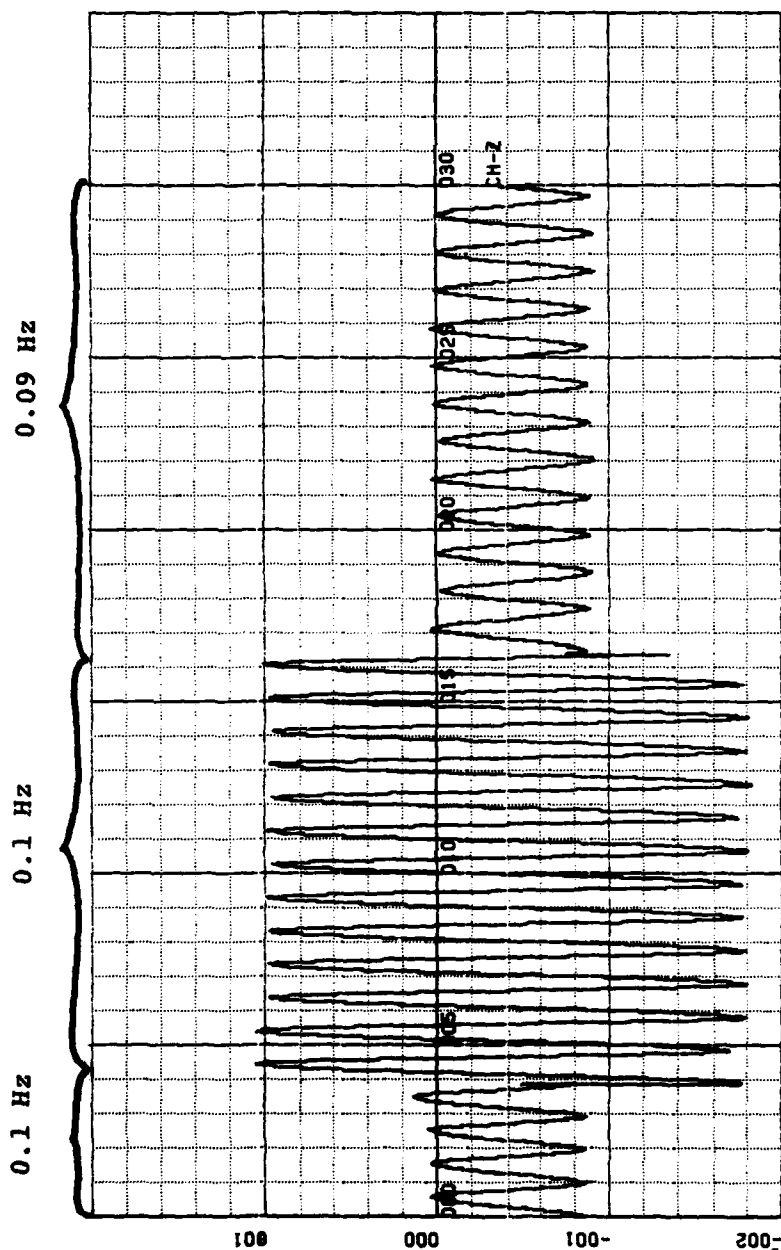


Figure 4.11. Fluxgate Magnetic Field, 26 April 83, 0948-0953 Local.
Amplitude (nanoteslas : 10 units/in) vs. Time (seconds : 50 units/in)

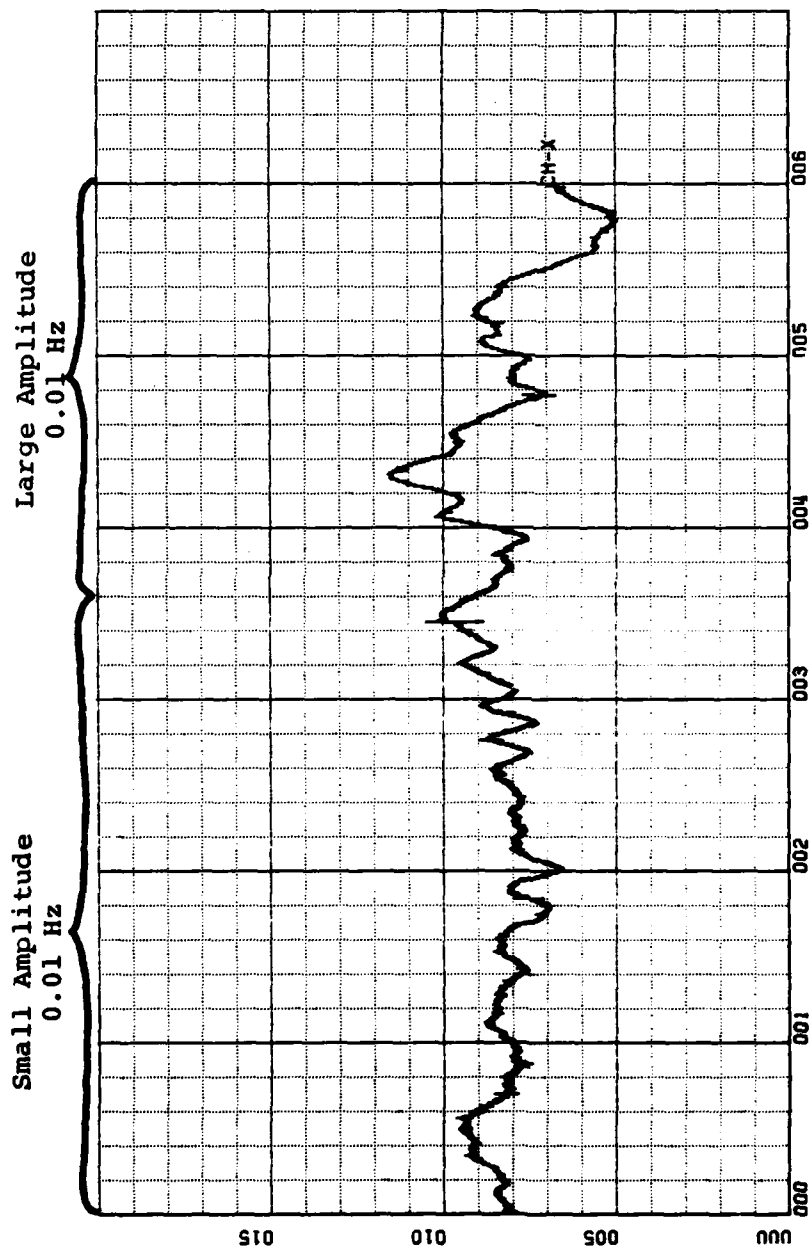


Figure 4.12. X-Coil Magnetic Field, 26 April 83, 1023-1033 Local.
Amplitude (nanoteslas : 0.5 units/in) vs. Time (seconds : 100 units/in)

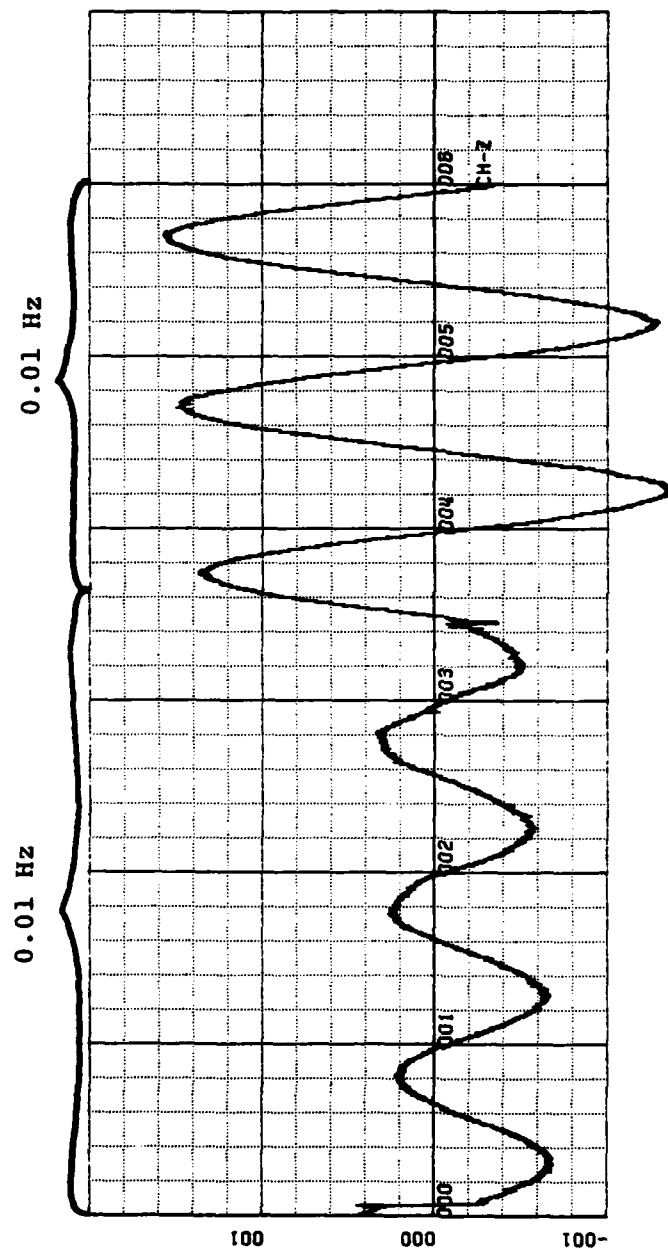


Figure 4.13. Fluxgate Magnetic Field, 26 April 83, 1023-1033 Local.
Amplitude (nanoteslas : 10 units/in) vs. Time (seconds : 100 units/in)

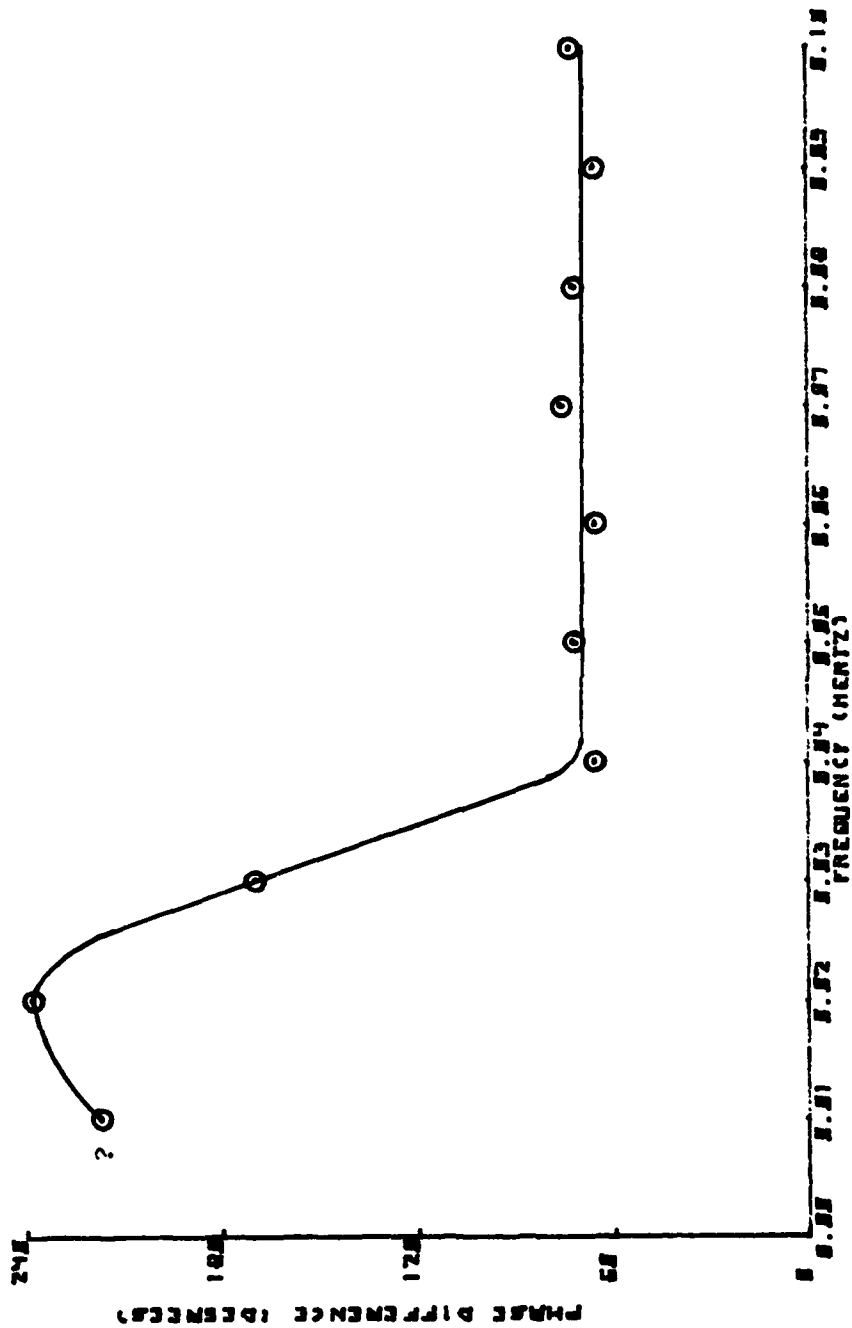


Figure 4.14. Phase Lag of Coil with Respect to Fluxgate

V. MICROPULSATIONS

A. THEORY

Currently there is no theory that completely models the observed micropulsations and geomagnetic noise. It is generally accepted that the generating mechanism for micropulsations is an interaction between the solar wind and the earth's magnetosphere [Ref. 5]. The observed micropulsations are classified by their period and regularity [Ref. 5]. Table 5.1 shows the micropulsation classification. The smoothing algorithm applied to the magnetic field data is designed to highlight micropulsations with periods between 10-45 seconds. Specifically we are interested in micropulsations classified as Pc 3. Pc 3 micropulsations are generally regular and have a more or less distinct period. Thus in the PSD plots we will be able to identify the micropulsation by an apparent anomaly at its frequency. Micropulsations have amplitudes of approximately 0.5 nT. This small amplitude is very small compared to a main magnetic field value of 50,000 nT, hence the term "micro" pulsations. Geomagnetic fluctuations are a combination of micropulsations and a general background noise. Micropulsation events grow out of the ever present background. The time series magnetic field plots will provide a means of obtaining the frequency of the micropulsation.

Table 5.1. Micropulsation Classification

<u>Notation</u>	<u>Period (seconds)</u>
Pc1	0.2-5
Pc2	5-10
Pc3	10-45
Pc4	45-150
Pc5	150-600

B. MICROPULSATION DATA ANALYSIS

The first 1200 seconds of data after a 60 second tape advance on digital data tape GMDT 11, 17 August 82, 1301-1408 Local, may contain a micropulsation event. Figures 3.10-3.12 show the first 34 minutes of GMDT 11 after a 60 second advance. To determine whether the regular pulsations we see in the first third of Figures 3.10-3.12 (disregarding the suspicious "cusps") is a micropulsation, the scale must be expanded. Figures 5.1-5.3 show the regular pulsations on an expanded scale. From Figures 5.1-5.3 the period of the oscillation is calculated to be 17.2 seconds. Thus this section of data contains a type Pc 3 micropulsation.

Executing the computer code LANDXYZ [Ref. 1] on this section of data, we generate the PSD, coherence, degree of polarization, and ellipticity. Table 5.2 contains the amplitude, frequency, coherence, etc. for the micropulsation.

At the frequency of the micropulsation one would expect a good coherence, degree of polarization and ellipticity since the coil system is oriented arbitrarily with each coil sensing the micropulsation. The observed micropulsation exhibits a high coherence as shown in Table 5.2. The observed micropulsation has a high degree of polarization. Micropulsations are generally considered to be left-hand elliptically polarized [Ref. 5]. The observed micropulsation is elliptically polarized.

If the errors in phase and amplitude that were shown to exist in Section IV are constant, then that should not be a

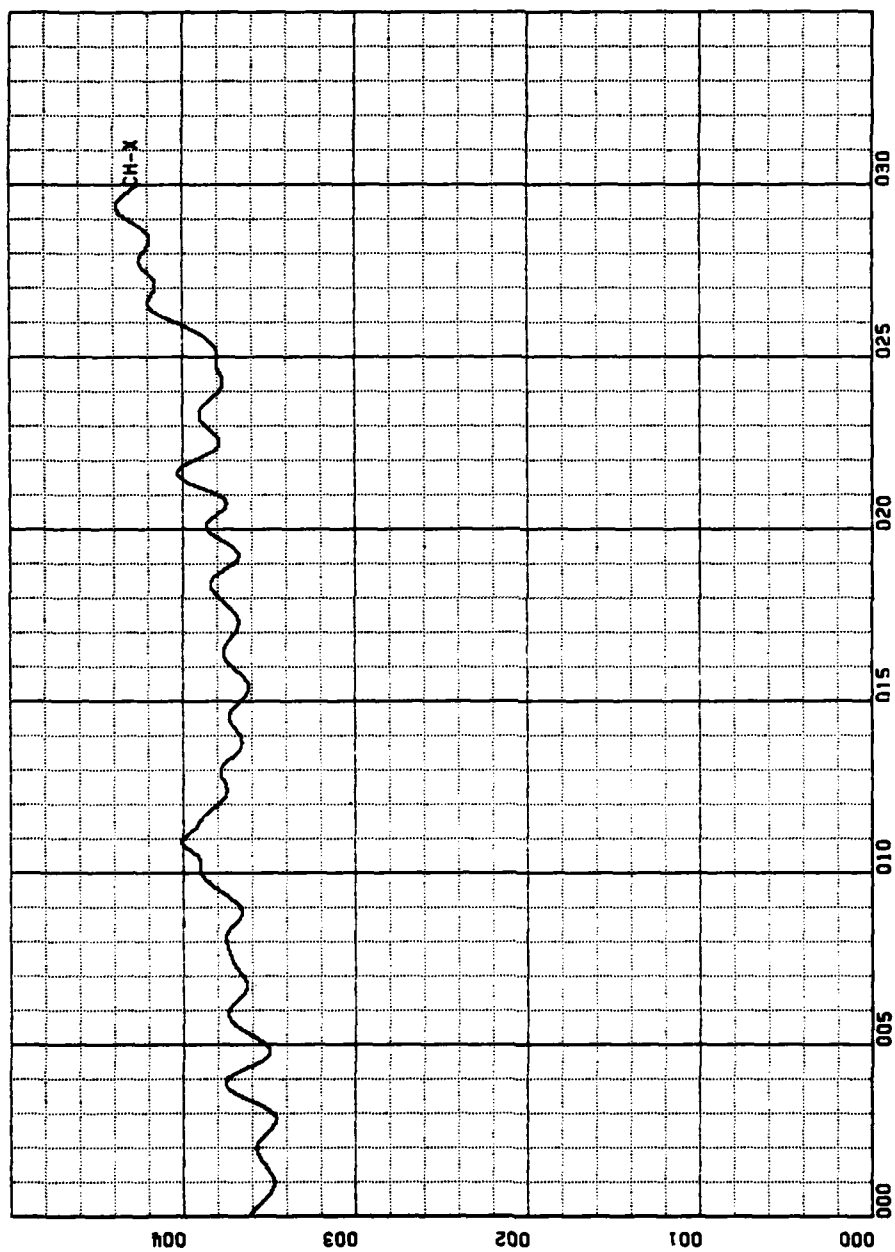


Figure 5.1. X-Coil Magnetic Field, 17 August 82, 1305-1310 Local.
Amplitude (nanoteslas : 1 unit/in) vs. Time (seconds : 50 units/in)

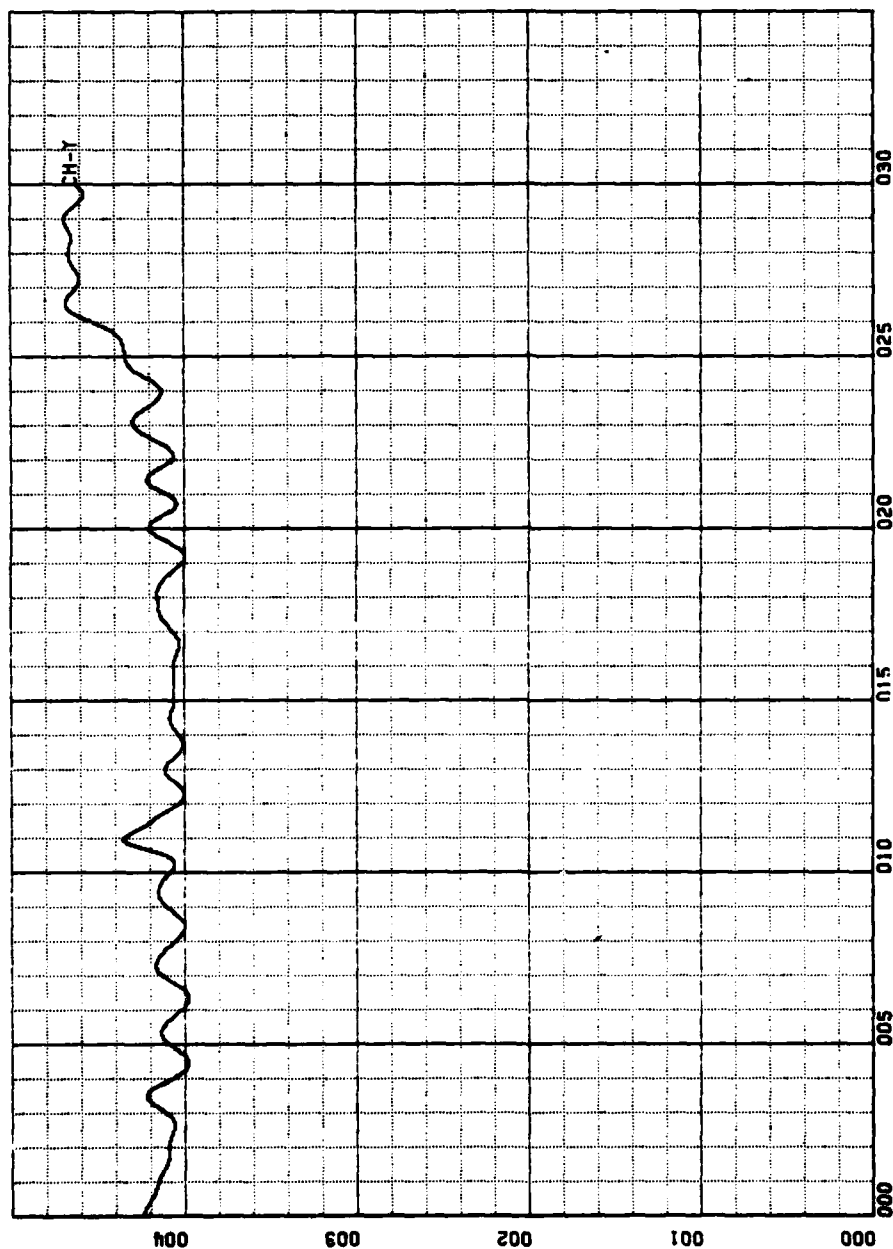


Figure 5.2. Y Coil Magnetic Field, 17 August 82, 1305-1310 Local.
Amplitude (nanoteslas : 1 unit/in) vs. Time (seconds : 50 units/in)

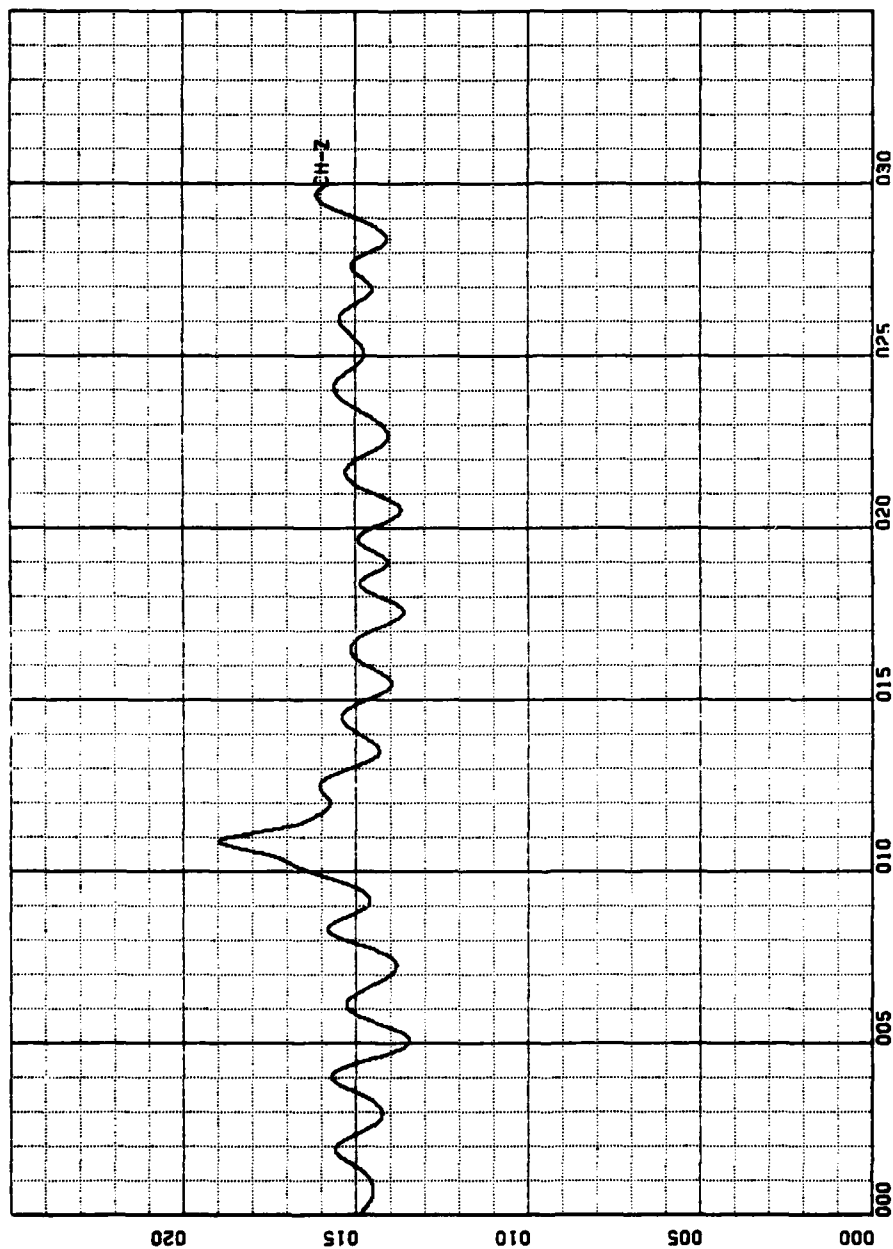


Figure 5.3. Z Coil Magnetic Field, 17 August 82, 1305-1310 Local.
Amplitude (nanoteslas : 0.5 units/in) vs. Time (seconds : 50 units/in)

Table 5.2. Observed Micropulsation Properties

Frequency (Hz): 0.058

Peak-to-Peak Amplitude (nT): Amplitude $= \sqrt{X^2 + Y^2 + Z^2} = 0.37$

PSD (dB) (Ref $1 \text{ nT}^2/\text{Hz}$): X-Coil: -3dB
 Y-Coil: -4dB
 Z-Coil: 1.5dB

Coherence: X-Y Coils: 0.99
 Y-Z Coils: 0.99
 Z-X Coils: 0.99

Degree of Polarization: X-Y Plane: 0.99
 Y-Z Plane: 0.99
 Z-X Plane: 0.99

Ellipticity: X-Y Plane: 0.45 (left hand)
 Y-Z Plane: 0.10 (right hand)
 Z-X Plane: 0.30 (left hand)

serious problem since we are dealing with a single frequency.
Thus, the observed micropulsation exhibited definite structure
decidedly different than the background.

VI. CONCLUSIONS

A type PC-3 micropulsation event of peak-to-peak amplitude (0.37 nT) and period (17.2 seconds) was identified in a section of data. At the frequency of the micropulsation, the coherence between the three orthogonal coil sensors was about 0.99 for the xy-pair, 0.99 for the xz-pair, and 0.99 for the yz-pair. The degree of polarization was 0.99. The ellipticity was about 0.30.

The origin of the regular "hump"-like structure in the PSD's of previous coil data was found to be artificial and not representative in any way of natural phenomena in the geomagnetic field. Previous conclusions based on a frequency domain analysis of coil data characterized by a regular "hump" structure (strong or weak) in the PSD plots are known to be unsubstantiated.

Compared to a PSD frequency domain analysis of the data set, an analysis of geomagnetic field fluctuations in the time domain easily identifies data sets containing a micropulsation event. A double running average routine developed and applied to the time series data sets was found to be helpful in highlighting the micropulsation.

Detailed conclusions about the geomagnetic field from the coil measurements require a balance of analysis in the frequency and time domain.

An accurate reproduction of a time series plot for the geomagnetic field oscillations will require modification to the existing software.

Comparisons in the time or frequency domain between any pair of coils in the orthogonal system might be misleading as a result of cross talk between electrical inputs. The suspicion of cross talk is based on the observed pick-up on an unloaded input of the contents of an adjacent loaded and active input.

Further micropulsation studies should continue. This initial investigation of the coherence, polarization, and ellipticity features of micropulsation events shows promise that with more data, one might suggest novel physical mechanisms and models for the origin of micropulsations.

APPENDIX A
VOLTR COMPUTER PROGRAM

Appendix A contains the VOLTR computer program that provides unsmoothed time series voltage plots. VOLTR uses the subroutine RD to strip voltage data off digital tapes. The integer voltage data is normalized to $\pm 5V$ and plotted using the DRAWP subroutine.

```

//VGLISL JOB (1029,0129), STEVENS SMC 2670, CLASS=G
//*MAIN ORG=NPVMI,1029P,LINES=(65)
//*FORMAT PR,DNAME=PLOT,SYSVECTR,DEST=LOCAL
//EXEC PR,IXCLGP,PARM=LKED=LIST,MAP,XREF,REGION.GD=2048K
//FORT,SYNIN DD
INTEGER*2 IN(16)
C ARRAY IN IS USED IN READING DATA FROM TAPE
C REAL*4 XX(8192),YY(8192),ZZ(8192)
C THE ABOVE REAL*4 ARRAYS ARE USED TO ORDER INPUT DATA AND
C INITIALLY REPRESENT VOLTAGE - TIME SERIES INFORMATION.
C DIMENSION ZZ(165536),ZZY(165536),ZZV(165536)
C DIMENSION TIME(165536)
C INTEGER K,IS
C INTEGER*4 ITB(12)/12*0/
C REAL*4 RTB(128)/28*0.0/
C REAL ALAB(3)/CH-X,CH-Y,CH-Z/
C REAL*8 TITLE(12)
C EQUIVALENCE(TITLE(1),RTB(5))
C ARRAYS ITB,RTB,ALAB,AND TITLE ARE USED IN GENERATING
C THE VERTISATEC PLOTTER OUTPUT.
C DATA XX,YY/16384*0./
C DATA ZZ/8192*0./
C K=0
C IS=1
C DC 3 1 IN1=1,65536
C ZZ(1:IN1)=0.0
C ZZV(1:IN1)=0.0
C ZZV(1:IN1)=0.0
C TIME(1:IN1)=0.0
C 31 CCNT INUE
C THE NEXT FIVE LINES SERVE AS A TIME DELAY IN STARTING THE
C DATA ANALYSIS. ISEC IS THE NUMBER OF SECONDS DELAYED.
C ISEC=2048
C ITL=1 ISEC*32
C DC 55 JJ=1,ITL
C CALL KD(20,IN,200,IKEC,IRK)
C 55 CCNT INUE
C IFRAME=8192
C NR=8
C FNR=FLOAT(NR)
C DC 70 LI=1,NR
C THE DO LOOP ENDING WITH STATEMENT 70 ENABLES THE PROGRAM TO
C PROCESS A LARGE AMOUNT OF DATA BY REPEATING THE PROCESS IN
C BLOCKS.
C NR REPRESENTS THE NUMBER OF DATA SEQUENCES. ONE
C SEQUENCE CURRENTLY EQUALS 8192 DATA POINTS FOR EACH CHANNEL
C OR 256 SECONDS OF DATA.

```

VTH00010
VTH00020
VTH00030
VTH00040
VTH00050
VTH00060
VTH00070
VTH00080
VTH00090
VTH00100
VTH00110
VTH00120
VTH00130
VTH00140
VTH00150
VTH00160
VTH00170
VTH00180
VTH00190
VTH00200
VTH00210
VTH00220
VTH00230
VTH00240
VTH00250
VTH00260
VTH00270
VTH00280
VTH00290
VTH00300
VTH00310
VTH00320
VTH00330
VTH00340
VTH00350
VTH00360
VTH00370
VTH00380
VTH00390
VTH00400
VTH00410
VTH00420
VTH00430
VTH00440
VTH00450
VTH00460
VTH00470
VTH00480

```

C C C THE DO LCCP ENDING WITH 60 READS THE DATA FROM THE PCM FRAME
C C C STRIPS OUT THE SYNC CODE, AND SORTS OUT THE DATA BY COIL
C C C CHANNEL.
C C C DO 60 JJ=1,IFRAME
C C C CALL RDI(20,IN,1000,IREC,IRR)
C C C XX(JJ)=IN(2)
C C C YY(JJ)=IN(3)
C C C ZZ(JJ)=IN(4)
C C C CCNT INUE
C C C N=8192
C C C FN=FLOAT(N)
C C C DELTAT=1./32.
C C C DO 20 J=1,N
C C C THE FOLLOWING CALCULATIONS NORMALIZE THE DATA TO +5V AND -5V.
C C C XX(JJ)=(XX(JJ)-1966.)*5./1966.
C C C YY(JJ)=(YY(JJ)-2085.)*5./2085.
C C C ZZ(JJ)=(ZZ(JJ)-2539.)*5./2539.
C C C XX IS THE X-COIL DATA, YY IS THE Y-COIL DATA,
C C C ZZ IS THE Z-COIL DATA
C C C NORTH-SOUTH COMPONENT (XX) AND THE VERTICAL COMPONENT (ZZ)
C C C CONTINUE
C C C DC 91 I3=1,8192
C C C ZZXI(I3)=XX(I3)
C C C ZZVI(I3)=YY(I3)
C C C ZZV(I3)=ZZ(I3)
C C C TIME2(I3)=(DELTAT*FLOAT(I3))+(256.0*FLOAT(K))
C C C I2=I3+1
C C C CCNT INUE
C C C K=K+1
C C C 70 CCNT INUE
C C C VERSATEC PLOT OF V - TIME SERIES VOLTAGE
C C C NPIS=2048./DELTAT+1.
C C C NPIS DETERMINES NUMBER OF POINTS NECESSARY IN ORDER FOR
C C C THE 0 TO 2047 SECS RANGE TO BE PLOTTED.
C C C FOR THE FOLLOWING ITB AND KTB VALUES REVIEW THE WRITE-UP
C C C FOR THE SUBROUTINE PROCEDURE 'DRAWP'.
C C C ITB(3)=20
C C C ITB(4)=8
C C C ITB(7)=1
C C C ITB(12)=0.0
C C C RTB(1)=0.0
C C C RTB(2)=0.0
C C C RTB(3)=ALAE(1)
C C C READ(5,300C)ITILE
C C C CALL DRAWP(NPIS,TIME2,ZZXI,ITB,RTB)
C C C RTB(3)=ALAE(2)

```

VTH00490
 VTH00500
 VTH00510
 VTH00520
 VTH00530
 VTH00540
 VTH00550
 VTH00560
 VTH00570
 VTH00580
 VTH00590
 VTH00600
 VTH00610
 VTH00620
 VTH00630
 VTH00640
 VTH00650
 VTH00660
 VTH00670
 VTH00680
 VTH00690
 VTH00700
 VTH00710
 VTH00720
 VTH00730
 VTH00740
 VTH00750
 VTH00760
 VTH00770
 VTH00780
 VTH00790
 VTH00800
 VTH00810
 VTH00820
 VTH00830
 VTH00840
 VTH00850
 VTH00860
 VTH00870
 VTH00880
 VTH00890
 VTH00900
 VTH00910
 VTH00920
 VTH00930
 VTH00940
 VTH00950
 VTH00960

VTH00970
VTH00980
VTH00990
VTH01000
VTH01010
VTH01020
VTH01030
VTH01040
VTH01050
VTH01060
VTH01070
VTH01080
VTH01090
VTH01100
VTH01110
VTH01120
VTH01130
VTH01140
VTH01150
VTH01160
VTH01170
VTH01180
VTH01190
VTH01200
VTH01210
VTH01220
VTH01230
VTH01240
VTH01250
VTH01260
VTH01270
VTH01280
VTH01290
VTH01300
VTH01310
VTH01320
VTH01330
VTH01340
VTH01350
VTH01360
VTH01370
VTH01380
VTH01390
VTH01400
VTH01410
VTH01420
VTH01430
VTH01440

```

READ(5,3000)TITLE
CALL DRAMP(NPTS,TIME2,ZZV1,ITB,RTB)
RTB(3)=ALAB(3)
READ(5,3000)TITLE
CALL DRAMP(NPTS,TIME2,ZZV1,ITB,RTB)
ITB(3)=7
ITB(4)=5
ITB(12)=0
RTB(3)=ALAB(1)
READ(5,3000)TITLE
CALL DRAMP(NPTS,TIME2,ZZX1,ITB,RTB)
RTB(3)=ALAB(2)
READ(5,3000)TITLE
CALL DRAMP(NPTS,TIME2,ZZV1,ITB,RTB)
RTB(3)=ALAB(3)
READ(5,3000)TITLE
CALL DRAMP(NPTS,TIME2,ZZV1,ITB,RTB)
FORMAT(6AB)
STOP
END
SUBROUTINE RD(IUN,IO,IKS,IKQ,IKQ)
THIS PROCEDURE FURNISHED BY DR. TIM STANTON,
DEPARTMENT OF OCEANOGRAPHY.
READ DATA FROM IUN, ALIGN, CHECK & RETURN
IUN=TAPE NUMBER, EG 20
IO=INTEGER*2 ARRAY, 16 LONG, (VALUES 0-4095, SUBTRACT 2048)*5
IRS= NUMBER OF RECORDS ALLUMED (ERRORS)
IKQ= COLNTER OF RECORDS (FRAMES OF DATA)
BLOCK 512 BITS, 32 BITS = RECORD
800 BPI TAPE UNLABELED
IKQ= NUMBER OF ACTUAL RES INCS (ERRORS)
INTEGER * 2 IO(16), IP(16)
DATA IKR /0/
IF (IKQ.EQ.0) IS=0
FORMAT (16A2)
IF (IS.NE.0) GO TO 50
READ (IUN,20,END=900) IP
IS=IS+1
IF (IS.LT.17) GO TO 50
IF (IUN,20,END=900) IP

```

3000

CCCCCCCCCCCCCCCC

20

40

```

50      IS=1
55      IREC=IREC+1
C      ICH=IMASK(IP(IS),3,0)+1
C      WRITE(6,55) ICH,IS,IUN,IREC
C      FORMAT('1' RESYNCH ICH,IS,IUN,IREC ',418)

      IF (ICH.NE.1) GO TO 40
      DO 100 I=1,16
      IQ(I)=ISHIFT(IP(IS),4)
      ICH=IMASK(IP(IS),3,0)+1
      IF (ICH.EQ.1) GO TO 80
      IER=IER+1
      WRITE(6,70) IUN,IREC,I,ICH,IER
      FORMAT('1' UNIT ',13,' RECORD ',16,'CHAN & DATA CH ',214,
$      ' ERRORS ',17)
      IF (IS.LI.17) GO TO 100
      READ(IUN,20,END=900) IP
      IS=1
      IREC=IREC+1
      CONTINUE
C
100      IF (IER.EC.0) GO TO 150
      IRR=IRR+1
      IF (IRR.LI.IRS) GO TO 120
      WRITE(6,110)
      FORMAT('1' STOPPED IN SUB RD BECAUSE GF IRR.GT.',16,' AT L110')
      IRQ=IRR
      STOP
      CONTINUE
120      WRITE(6,130) IREC,IRR
130      FORMAT('1' RESYNC AT FRAME ',16,' WITH TOTAL ERRORS ',17)
      IER=0
      IRQ=IRR
      GO TO 50
      CONTINUE
150      RETURN
900      WRITE(6,510) IUN,IREC
910      FORMAT('1' END OF UNIT ',13,' AT REC ',17)
      STOP
      END

FUNCTION ISHIFT(IN,NPLC)
      RETURNS SHIFTED VALUE OF I*2 WORD IN
      -VE LEFT,+VE RIGHT SHIFT
C
C
C      INTEGER * 2 IN
      IP=IN

```

VTH01450
 VTH01460
 VTH01470
 VTH01480
 VTH01490
 VTH01500
 VTH01510
 VTH01520
 VTH01530
 VTH01540
 VTH01550
 VTH01560
 VTH01570
 VTH01580
 VTH01590
 VTH01600
 VTH01610
 VTH01620
 VTH01630
 VTH01640
 VTH01650
 VTH01660
 VTH01670
 VTH01680
 VTH01690
 VTH01700
 VTH01710
 VTH01720
 VTH01730
 VTH01740
 VTH01750
 VTH01760
 VTH01770
 VTH01780
 VTH01790
 VTH01800
 VTH01810
 VTH01820
 VTH01830
 VTH01840
 VTH01850
 VTH01860
 VTH01870
 VTH01880
 VTH01890
 VTH01900
 VTH01910
 VTH01920

VTH01930
 VTH01940
 VTH01950
 VTH01960
 VTH01970
 VTH01980
 VTH01990
 VTH02000
 VTH02010
 VTH02020
 VTH02030
 VTH02040
 VTH02050
 VTH02060
 VTH02070
 VTH02080
 VTH02090
 VTH02100
 VTH02110
 VTH02120
 VTH02130
 VTH02140
 VTH02150
 VTH02160
 VTH02170
 VTH02180
 VTH02190
 VTH02200
 VTH02210
 VTH02220
 VTH02230
 VTH02240
 VTH02250
 VTH02260
 VTH02270
 VTH02280
 VTH02290
 VTH02300
 VTH02310
 VTH02320
 VTH02330
 VTH02340

```

30      IF (IP,LT,0) IP=IP+65536
        IF (NPLC,LT,0) GO TO 30
        ISHIFT=IP/(2**IABS(NPLC))
        RETURN
        ISHIFT=IP*(2**IABS(NPLC))
        IF (ISHIFT.GT.65535) ISHIFT=MOD(ISHIFT,65536)
        RETURN
        END
        FUNCTION IMASK(IN,IBL,IBR)
          MASK 1*2 WORD IN OUTSIDE BITS IBL & IBR
          INTEGER * 2 IN,IO
          IO=IN
          IF (IBR.EQ.0) GO TO 50
          IT=ISHIFT(IN,IBR)
          IO=IT
          IP=ISHIFT(IO,IBL-15-IBR)
          IO=IP
          IMASK=ISHIFT(IO,15-IBL)
          RETURN
          END
50
/*GO,SYSIN DD *
LA MESA VILLAGE, 17 AUG 82, 1324-1358 LOCAL
X COIL AMP IN VOLTS
LA MESA VILLAGE, 17 AUG 82, 2240-2314 LOCAL
Y COIL AMP IN VOLTS
LA MESA VILLAGE, 17 AUG 82, 1324-1358 LOCAL
Z COIL AMP IN VOLTS
LA MESA VILLAGE, 17 AUG 82, 1324-1358 LOCAL
X COIL AMP IN VOLTS
LA MESA VILLAGE, 17 AUG 82, 1324-1358 LOCAL
Y COIL AMP IN VOLTS
LA MESA VILLAGE, 17 AUG 82, 1324-1358 LOCAL
Z COIL AMP IN VOLTS
/*
//GO.FT20F001 DD UNIT=3400-4,VOL=SER=GMDT11,DISP=(OLD,KEEP),
//          LABEL=(11,NL,IN)
//          DCB=(RECFM=FB,LRECL=32,BLKSIZE=512,DEN=2)
//GO.SYSDUMP DD SYSOUT=A
//
//
  
```

APPENDIX B
VOLTS COMPUTER PROGRAM

Appendix B contains the VOLTS computer program that provides smoothed time series voltage plots. VOLTS uses the subroutine RD to strip voltage data off digital tapes. The integer voltage data is normalized to $\pm 5V$. A double 144 point running average is applied to the data. The DRAWP subroutine plots the data.

```

//VLIS$IL JOB (1029,0129), 'STEVENS' SMC 2670', CLASS=G
//*MAIN OR G=NPGVPM1, 1029P, LINES=165)
//*FORMAT PR, DDNAME=PLOT, SYSVECTOR, DEST=LUCAL
// EXEC FR IXCLGP, PARM.LKED='LIST,MAP,XREF', REGION.GC=2048K
//*FORT. SYSIN DD *
C   INTEGER*2 IN(16)
C   ARRAY IN IS USED IN READING DATA FROM TAPE
C   REAL*4 XX(8192), YY(8192), ZZ(8192)
C   THE ABOVE REAL*4 ARRAYS ARE USED TO ORDER INPUT DATA AND
C   INITIALLY REPRESENT VOLTAGE - TIME SERIES INFORMATION.
C   DIMENSION ZZXL(65536), ZZYL(65536), ZZVL(65536)
C   INTEGER K, 5, 15
C   REAL SUMX, SUMY, SUMZ, AVE1, AVE2, AVE3, AVE4
C   REAL GER*4 ITB(12)/12*0.0/
C   REAL*4 RTB(28)/28*0.0/
C   REAL ALAB(4)/CH-X, CH-Y, CH-Z, TOT, /
C   EQUIVALENCE(TITLE(1), RTB(5))
C   ARRAYS ITB, RTB, ALAB, AND TITLE ARE USED IN GENERATING
C   THE VERTSATEC PLOTTER OUTPUT.
C   DATA XX, YY, ZZ*0.0/
C   DATA ZZ/8192*0.0/
C   K=0
C   IS=1
C   SUMX=0.0
C   SUMY=0.0
C   SUMZ=0.0
C   DO 31 IN1=1, 65536
C   ZZXL(IN1)=0.0
C   ZZYL(IN1)=0.0
C   ZZVL(IN1)=0.0
C   TIME2(IN1)=0.0
C   CONTINUE
C   THE NEXT FIVE LINES SERVE AS A TIME DELAY IN STARTING THE
C   DATA ANALYSIS
C   ISEC=60
C   ITEL=ISEC*32
C   DO 55 JJ=1, ITEL
C   CALL RDI(20, IN, 200, IREC, IRR)
C   CCNT INUE
C   IFRAME=8192
C   NR=8
C   FNR=FLOAT(NR)
C   DO 70 LI=1, NR
C   THE DO LOOP ENDING WITH STATEMENT 70 ENABLES THE PROGRAM TO
C   PROCESS A LARGE AMOUNT OF DATA BY REPEATING THE PROCESS IN
C   BLOCKS.

```

VTH00010
 VTH00020
 VTH00030
 VTH00040
 VTH00050
 VTH00060
 VTH00070
 VTH00080
 VTH00090
 VTH00100
 VTH00110
 VTH00120
 VTH00130
 VTH00140
 VTH00150
 VTH00160
 VTH00170
 VTH00180
 VTH00190
 VTH00200
 VTH00210
 VTH00220
 VTH00230
 VTH00240
 VTH00250
 VTH00260
 VTH00270
 VTH00280
 VTH00290
 VTH00300
 VTH00310
 VTH00320
 VTH00330
 VTH00340
 VTH00350
 VTH00360
 VTH00370
 VTH00380
 VTH00390
 VTH00400
 VTH00410
 VTH00420
 VTH00430
 VTH00440
 VTH00450
 VTH00460
 VTH00470
 VTH00480

```

C C C C C C
      *NR: REPRESENTS THE NUMBER OF DATA SEQUENCES.
      *I SEQUENCE CURRENTLY EQUALS 8192 DATA POINTS FOR EACH CHANNEL
      OR 256 SECONDS OF DATA.

      THE DO LOOP ENDING WITH 60 READS THE DATA FROM THE PCM FRAME
      STRIPS OUT THE SYNC CODE, AND SORTS OUT THE DATA BY COIL
      CHANNEL
      DO 60 JJ=1,IFRAME
        CALL RD(20,IN,1000,IREC,IKR)
        XX(JJ)=IN(2)
        YY(JJ)=IN(3)
        ZZ(JJ)=IN(4)
      60 CONTINUE
      FN=FLOAT(N)
      DELTAT=1./32.
      DO 20 J=1,N
        XX(J)=XX(J)-1966.)*5./1966.
        YY(J)=YY(J)-2085.)*5./2085.
        ZZ(J)=ZZ(J)-2539.)*5./2539.
      20 CONTINUE
      *XX: IS THE X-COIL DATA, *YY: IS THE Y-COIL DATA,
      *ZZ: IS THE Z-COIL DATA
      *NORTH-SOUTH COMPONENT (XX) AND THE VERTICAL COMPONENT (ZZ)
      DO 91 I3=1,8192
        ZZXI(I3)=XX(I3)
        ZZVI(I3)=YY(I3)
        TIME2(I3)=(DELTAT*FLCAT(I3))+(256.0*FLOAT(K))
        I5=I3+1
      91 CONTINUE
      K=K+1
      70 CONTINUE
      DO 73 L2=1,2
        Q=0
        DO 74 IS=1,65318
          SUMX=0.0
          SUMY=0.0
          SUMZ=0.0
          DO 75 J=1,144
            SUMX=ZZXI(I3+J)+SUMX
            SUMY=ZZVI(I3+J)+SUMY
            SUMZ=ZZVI(I3+J)+SUMZ
          75 CONTINUE
          ZZXI(I3)=SUMX/144.
          ZZVI(I3)=SUMY/144.
          ZZVI(I3)=SUMZ/144.

```

VTH00490
 VTH00500
 VTH00510
 VTH00520
 VTH00530
 VTH00540
 VTH00550
 VTH00560
 VTH00570
 VTH00580
 VTH00590
 VTH00600
 VTH00610
 VTH00620
 VTH00630
 VTH00640
 VTH00650
 VTH00660
 VTH00670
 VTH00680
 VTH00690
 VTH00700
 VTH00710
 VTH00720
 VTH00730
 VTH00740
 VTH00750
 VTH00760
 VTH00770
 VTH00780
 VTH00790
 VTH00800
 VTH00810
 VTH00820
 VTH00830
 VTH00840
 VTH00850
 VTH00860
 VTH00870
 VTH00880
 VTH00890
 VTH00900
 VTH00910
 VTH00920
 VTH00930
 VTH00940
 VTH00950
 VTH00960

VTH01450
 VTH01460
 VTH01470
 VTH01480
 VTH01490
 VTH01500
 VTH01510
 VTH01520
 VTH01530
 VTH01540
 VTH01550
 VTH01560
 VTH01570
 VTH01580

Z COIL AMP IN VOLTS
 LA MESA VILLAGE, 17 AUG 82, 1302-1336 LOCAL
 X COIL AMP IN VOLTS
 LA MESA VILLAGE, 17 AUG 82, 1302-1336 LOCAL
 Y COIL AMP IN VOLTS
 LA MESA VILLAGE, 17 AUG 82, 1302-1336 LOCAL
 Z COIL AMP IN VOLTS
 7*
 //GO.FT20F001 00 UNIT=3400-4, VOL=SER=GMDT3A, DISP=(OLD,KEEP),
 // LABEL=111NLINJ
 // DCB=(RECFM=FB, LRECL=32, BLKSIZE=512, DEN=2)
 //GO.SYSDUMP DD SYSOUT=A
 //*
 //

APPENDIX C

LFVTC1 COMPUTER PROGRAM

Appendix C contains the LFVTC1 computer program that provides smoothed time series magnetic field plots. LFVTC1 uses the subroutine RD to strip voltage data off digital tapes. The voltage data is normalized to $\pm 5V$. The voltage data is fast fourier transformed using the FOURT subroutine. The transfer function is applied and forward transform taken. The resulting magnetic field data undergoes a double 144 point running average and is plotted using the DRAWP subroutine.

```

//LFVTSLL JOB (1029,0129), 'STEVENS, SMC 2670', CLASS=G
//*MAIN GR=PGVPL,1029P,LINES=(65)
//*FORMAT PR DDNAME=PLOT,SYSECTIR,DEST=LOCAL
//*EXEC PR TXCLGP,PARMLKED='LIST,MAP,XREF',REGION.GO=2048K
//*FURT SYSIN DD *
      INTEGER+2 IN(16)
      ARRAY+IN, IS USED IN READING DATA FROM TAPE
      C COMPLEX*8 XX(8192),YY(8192),ZZ(8192),IF(8192)
      C THE ABOVE COMPLEX*8 ARRAYS ARE USED TO ORDER INPUT DATA AND
      C INITIALLY REPRESENT VOLTAGE - TIME SERIES INFORMATION.
      C DIMENSION TIME(8192),FREQ(8192),WORK(16384),FRQ2(8192)
      C DIMENSION ZX(8192),ZY(8192),ZV(8192),ZT(8192)
      C DIMENSION ZZ(165536),ZZY(165536),ZZV(165536)
      C DIMENSION ZZT(165536),TIME2(165536)
      C THE MAGNITUDE DATA AND ARE EVENTUALLY CONVERTED TO POWER SPECTRAL
      C DENSITY INFORMATION. ZX,ZY,ZV, AND ZT REPRESENT MAGNITUDE
      C VALUES.
      C INTEGER K,14,15,Q
      C REAL SUMX,SUMY,SUMZ,SUMT,AVE1,AVE2,AVE3,AVE4
      C REAL CONST1,X,CONSTY,CONSTZ,CONSTT
      C REAL GER*4 I(8192)/12*0./
      C REAL *4 RTB(28)/28*0./
      C REAL ALAB(14)/CH-X,'CH-Y','CH-Z','TCT'
      C EQUIVALENCE(I,TITLE(1),RTB(5))
      C ARRAYS+ITB,'RTB',ALAB, AND 'TITLE' ARE USED IN GENERATING
      C THE VERTSATEC PL OTTER OUTPUT.
      C DATA ZZ,IF/16384*(0.:0.)//
      C DATA ZZY/16384*(0.:0.)//
      C DATA ZZX,ZY,ZV/16384*0./
      C DATA ZT,TIME,FREQ/16384*0./
      C K=0
      C 14=1
      C 15=1
      C CONSTY=0.0
      C CONSTZ=0.0
      C CONSTT=0.0
      C SUMX=0.0
      C SUMY=0.0
      C SUMZ=0.0
      C SUMT=0.0
      C AVE1=0.0
      C AVE2=0.0
      C AVE3=0.0
      C AVE4=0.0

```

```

MAG000010
MAG000020
MAG000030
MAG000040
MAG000050
MAG000060
MAG000070
MAG000080
MAG000090
MAG000100
MAG000110
MAG000120
MAG000130
MAG000140
MAG000150
MAG000160
MAG000170
MAG000180
MAG000190
MAG000200
MAG000210
MAG000220
MAG000230
MAG000240
MAG000250
MAG000260
MAG000270
MAG000280
MAG000290
MAG000300
MAG000310
MAG000320
MAG000330
MAG000340
MAG000350
MAG000360
MAG000370
MAG000380
MAG000390
MAG000400
MAG000410
MAG000420
MAG000430
MAG000440
MAG000450
MAG000460
MAG000470
MAG000480

```

MAG00490
MAG00500
MAG00510
MAG00520
MAG00530
MAG00540
MAG00550
MAG00560
MAG00570
MAG00580
MAG00590
MAG00600
MAG00610
MAG00620
MAG00630
MAG00640
MAG00650
MAG00660
MAG00670
MAG00680
MAG00690
MAG00700
MAG00710
MAG00720
MAG00730
MAG00740
MAG00750
MAG00760
MAG00770
MAG00780
MAG00790
MAG00800
MAG00810
MAG00820
MAG00830
MAG00840
MAG00850
MAG00860
MAG00870
MAG00880
MAG00890
MAG00900
MAG00910
MAG00920
MAG00930
MAG00940
MAG00950
MAG00960

```

TWOPI=6.2831853
COS60=COS(TWOPI/6.)
COS30=COS(TWOPI/12.)
D=16.75*TWOPI/360.
COSD=COS(D)
COSDI=COS(DI90.-D)*TWOPI/360.)
D IS THE DECLINATION OR MAGNETIC VARIATION AT THE MAGNETOMETER
SITE
DO 31 IN1=1.65536
ZZXI(IN1)=0.0
ZZYI(IN1)=0.0
ZZVI(IN1)=0.0
ZZTI(IN1)=0.0
TIME2(IN1)=0.0
31 CONTINUE
THE NEXT FIVE LINES SERVE AS A TIME DELAY IN STARTING THE
DATA ANALYSIS
ISL=60
ITL=150
DO 55 JJ=1,ITL
CALL RD(20,IN,200,IREF,IRR)
55 CONTINUE
IFRAME=8192
NR=8
FAR=FLOAT(NR)
DO 70 LI=1,NR
THE DO LOOP ENDING WITH STATEMENT 70 ENABLES THE PROGRAM TO
PROCESS A LARGE AMOUNT OF DATA BY REPEATING THE PROCESS IN
BLOCKS
NR REPRESENTS THE NUMBER OF DATA SEQUENCES TO BE AVERAGED.
1 SEQUENCE CURRENTLY EQUALS 8192 DATA POINTS FOR EACH CHANNEL
OR 256 SECONDS OF DATA.
THE DO LCCP ENDING WITH 60 READS THE DATA FROM THE PCM FRAME
STRIPS OUT THE SYNC CODE, AND SORTS OUT THE DATA BY COIL
CHANNEL
DO 60 JJ=1,IFRAME
CALL RD(20,IN,1000,IREF,IRR)
XX(JJ)=IN(2)
YY(JJ)=IN(3)
ZZ(JJ)=IN(4)
60 CONTINUE
THE FOLLOWING SECTION GENERATES THE TIME AND FREQUENCY
ARRAYS AND NORMALIZES THE INPUT PCM DATA TO VOLTAGE FORM
IN PREPARATION FOR FAST FOURIER TRANSFORM TO THE FREQUENCY
DOMAIN.
N=8192
FN=FLOAT(N)

```

MAG00970
MAG00980
MAG00990
MAG01000
MAG01010
MAG01020
MAG01030
MAG01040
MAG01050
MAG01060
MAG01070
MAG01080
MAG01090
MAG01100
MAG01110
MAG01120
MAG01130
MAG01140
MAG01150
MAG01160
MAG01170
MAG01180
MAG01190
MAG01200
MAG01210
MAG01220
MAG01230
MAG01240
MAG01250
MAG01260
MAG01270
MAG01280
MAG01290
MAG01300
MAG01310
MAG01320
MAG01330
MAG01340
MAG01350
MAG01360
MAG01370
MAG01380
MAG01390
MAG01400
MAG01410
MAG01420
MAG01430
MAG01440

```

DELTAT=1./32.
DELTAF=1./ (FN*DELTAT)
DO 20 J=1,N
  TIME(J)=DELTAT*FLOAT(J)
  FREQ(J)=DELTAF*FLOAT(J)
  XX(J)=(XX(J)-1966.*5./1966.
  XX(J)=REAL(XX(J))
  YY(J)=(YY(J)-2085.*5./2085.
  YY(J)=REAL(YY(J))
  ZZ(J)=(ZZ(J)-2539.*5./2539.
  ZZ(J)=REAL(ZZ(J))
  *XX* IS THE X-COIL DATA, *YY* IS THE Y-COIL DATA,
  *ZZ* IS THE Z-COIL DATA, AND *TF* IS THE PROJECTION OF THE
  NORTH-SOUTH COMPONENT (XX) AND THE VERTICAL COMPONENT (ZZ)
  ON THE TCTAL GEOMAGNETIC FIELD VECTOR.
CONTINUE
DO 21 J=1,N
  FREQ(J)=ALOG10(FREQ(J))
CONTINUE
THE NEXT FOUR STATEMENTS PERFORM AN FFT ON THE INPUT
TIME SERIES DATA. SEE THE WRITEUP ON 'FOURT' FOR
FURTHER INFORMATION.
CALL FOURT(XX,N,1,-1.0,WORK)
CALL FOURT(YY,N,1,-1.0,WORK)
CALL FOURT(ZZ,N,1,-1.0,WORK)
THE NEXT BLOCK OF STATEMENTS APPLY THE SYSTEM (VOLTAGE TO
B-FIELD) TRANSFER FUNCTION TO THE TRANSFORMED FREQUENCY
DOMAIN DATA. THIS BLOCK ENDS AT STATEMENT 9.
THE TRANSFER FUNCTION CONVERTS VOLTS TO NANOTESLAS (GAMMAS).
***WARNING*** THIS TRANSFER FUNCTIONS YIELDS AN INACCURATE
PHASE. USE A DIFFERENT TRANSFER FUNCTION IF PHASE INFORMATION
NEEDED.
DC 9 L=1,N
FREQ=FREQ(L)
IF (FREQ.LE.25.1) GO TO 1
XX(L)=XX(L)/28.
GO TO 8
1 IF (FREQ.LE.15.1) GO TO 2
XX(L)=XX(L)/(105.5-3.14*FREQ)
YY(L)=YY(L)/(181.32-7.588*FREQ)
ZZ(L)=ZZ(L)/(177.26-7.484*FREQ)
GO TO 8
2 IF (FREQ.LE.10.1) GO TO 3
XX(L)=XX(L)/(5.958*FREQ-30.97)
YY(L)=YY(L)/(7.166*FREQ-39.99)
ZZ(L)=ZZ(L)/(6.49*FREQ-32.35)
GO TO 8
3 IF (FREQ.LE.7.5) GO TO 4

```

MAGO1450
MAGO1460
MAGO1470
MAGO1480
MAGO1490
MAGO1500
MAGO1510
MAGO1520
MAGO1530
MAGO1540
MAGO1550
MAGO1560
MAGO1570
MAGO1580
MAGO1590
MAGO1600
MAGO1610
MAGO1620
MAGO1630
MAGO1640
MAGO1650
MAGO1660
MAGO1670
MAGO1680
MAGO1690
MAGO1700
MAGO1710
MAGO1720
MAGO1730
MAGO1740
MAGO1750
MAGO1760
MAGO1770
MAGO1780
MAGO1790
MAGO1800
MAGO1810
MAGO1820
MAGO1830
MAGO1840
MAGO1850
MAGO1860
MAGO1870
MAGO1880
MAGO1890
MAGO1900
MAGO1910
MAGO1920

```

XX(L)=XX(L)/13.492*FRQ-6.31)
YY(L)=YY(L)/(4.252*FRQ-10.85)
ZZ(L)=ZZ(L)/(14.044*FRQ-7.89)
GO TO 8
4 IF (FRQ.LE.5) GO TO 5
  XX(L)=XX(L)/(2.6311*FRQ+0.14667)
  YY(L)=YY(L)/(3.012*FRQ-1.55)
  ZZ(L)=ZZ(L)/(3.184*FRQ-1.44)
GO TO 8
5 IF (FRQ.LE.3) GO TO 6
  XX(L)=XX(L)/(2.6311*FRQ+0.14667)
  YY(L)=YY(L)/(2.702*FRQ)
  ZZ(L)=ZZ(L)/(2.92*FRQ)
GO TO 8
6 XX(L)=XX(L)/(2.72*FRQ)
GO TO 7
8 CCNT INUE
9 IF (L)=(XX(L)*COSD + YY(L)*CUSD1)*COS60 + ZZ(L)*COS30
  CCNT INUE
  CALL FOURT(XX,N,1,1,1,WORK)
  CALL FOURT(YY,N,1,1,1,WORK)
  CALL FOURT(ZZ,N,1,1,1,WORK)
  DO 57 J=1,N
    XX(J)=XX(J)/FN
    YY(J)=YY(J)/FN
    ZZ(J)=ZZ(J)/FN
    IF (J)=TF(J)/FN
  57 CCNT INUE
  ZY1(13)=1,N
  ZY1(13)=CABS(YY(13))
  ZY1(13)=CABS(ZZ(13))
  ZY1(13)=CABS(TF(13))
  CCNT INUE
56 THE NEXT 44 LINES OF CODE CORRECT DATA BLOCK END JUMPS.
  IF (K.NE.0) GO TO 36
  DO 66 IS=8048,8192
    SUMX=ZY1(13)+SUMX
    SUMY=ZY1(13)+SUMY
    SUMZ=ZY1(13)+SUMZ
    SUMT=ZY1(13)+SUMT
  66 CCNT INUE
  CCNSTX=SUMX/144.
  CCNSTY=SUMY/144.
  CCNSTZ=SUMZ/144.
  CCNSTT=SUMT/144.
  DO 67 IS=1,8192

```

MAGO1930
MAGO1940
MAGO1950
MAGO1960
MAGO1970
MAGO1980
MAGO1990
MAGO2000
MAGO2010
MAGO2020
MAGO2030
MAGO2040
MAGO2050
MAGO2060
MAGO2070
MAGO2080
MAGO2090
MAGO2100
MAGO2110
MAGO2120
MAGO2130
MAGO2140
MAGO2150
MAGO2160
MAGO2170
MAGO2180
MAGO2190
MAGO2200
MAGO2210
MAGO2220
MAGO2230
MAGO2240
MAGO2250
MAGO2260
MAGO2270
MAGO2280
MAGO2290
MAGO2300
MAGO2310
MAGO2320
MAGO2330
MAGO2340
MAGO2350
MAGO2360
MAGO2370
MAGO2380
MAGO2390
MAGO2400

```

ZZXI(I4)=ZXI(I5)
ZZVI(I4)=ZVI(I5)
ZZTI(I4)=ZTI(I5)
I4=I4+1
67 CONTINUE
36 CONTINUE
SUMX=0.0
SUMY=0.0
SUMZ=0.0
SUMT=0.0
DO 68 IS=1,144
SUMX=ZXI(I5)+SUMX
SUMY=ZVI(I5)+SUMY
SUMZ=ZTI(I5)+SUMZ
SUMT=ZTI(I5)+SUMT
68 CONTINUE
AVE1=SUMX/144.
AVE2=SUMY/144.
AVE3=SUMZ/144.
AVE4=SUMT/144.
DO 69 IS=1,8192
ZZXI(I4)=ZXI(I5)+{(CONSTX-AVE1)}
ZZVI(I4)=ZVI(I5)+{(CONSTY-AVE2)}
ZZTI(I4)=ZTI(I5)+{(CONSTZ-AVE3)}
ZZTI(I4)=ZTI(I5)+{(CONSTT-AVE4)}
I4=I4+1
69 CONTINUE
37 CONTINUE
TIME2(I5)={DELTA*FLOAT(I3)}+(256.0*FLOAT(K))
IS=IS+1
91 CONTINUE
70 CONTINUE
C THE FOLLOWING LINES OF CODE PERFORMS A DOUBLE RUNNING POINT
C AVERAGE ON THE DATA.
DC 73 L2=1,2
Q=0
DO 74 IS=1,65318
SUMX=0.0
SUMY=0.0
SUMZ=0.0
SUMT=0.0
DC 75 J=1,144
SUMX=ZZXI(I4+J)+SUMX
SUMY=ZZVI(I4+J)+SUMY

```


MAG02890
MAG02900
MAG02910
MAG02920
MAG02930
MAG02940
MAG02950
MAG02960
MAG02970
MAG02980
MAG02990
MAG03000
MAG03010
MAG03020
MAG03030
MAG03040
MAG03050
MAG03060
MAG03070
MAG03080
MAG03090
MAG03100
MAG03110
MAG03120
MAG03130
MAG03140
MAG03150
MAG03160
MAG03170
MAG03180
MAG03190
MAG03200
MAG03210

```

CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
ITB(12)=1
RTB(3)=ALAB(4)
READ(5,3000)TITLE
CALL DRAWP(NPTS,TIME2,ZZI1,ITB,RTB)
3000 FORMAT(6A8)
STOP
END
/*
//GO.SYSIN DC *
LA MESA VILLAGE, 18 AUG 82, 1825-1859 LOCAL
X COIL AMP IN NT
LA MESA VILLAGE, 18 AUG 82, 1825-1859 LOCAL
Y COIL AMP IN NT
LA MESA VILLAGE, 18 AUG 82, 1825-1859 LOCAL
Z COIL AMP IN NT
LA MESA VILLAGE, 18 AUG 82, 1825-1859 LOCAL
TCTAL FIELD AMP IN NT
LA MESA VILLAGE, 18 AUG 82, 1825-1859 LOCAL
X COIL AMP IN NT
LA MESA VILLAGE, 18 AUG 82, 1825-1859 LOCAL
Y COIL AMP IN NT
LA MESA VILLAGE, 18 AUG 82, 1825-1859 LOCAL
Z COIL AMP IN NT
LA MESA VILLAGE, 17 AUG 82, 1825-1859 LOCAL
TCTAL FIELD AMP IN NT
/*
//GO.FT20F001 DD UNIT=3400-4,VOL=SER=GMDT21,DISP=(OLD,KEEP),
// LABEL=(1,1,1,1)
// DCB=(RECFM=FB,LRECL=32,BLKSIZE=512,DEN=2)
//GO.SYSDJMP DD SYSOUT=A
//
//

```

LIST OF REFERENCES

1. Pogue, E. W., "Experimental Observations of Geomagnetic Micropulsations: Land and Sea", Master's Thesis, Naval Postgraduate School, Monterey, September 1982.
2. Gritzke, A. R. and Johnson, R. H., "Ocean Floor Geomagnetic Data Collection System", Master's Thesis, Naval Postgraduate School, Monterey, December 1982.
3. Fisher, J. T., "Coherence in the Horizontal Plane of the Geomagnetic Field in the Frequency Range of 0-10 Hz", Master's Thesis, Naval Postgraduate School, Monterey, December 1982.
4. Schweiger, J. M., "Evaluation of Geomagnetic Activity in the MAD Frequency Band (.04 to .06 Hz)", Master's Thesis, Naval Postgraduate School, Monterey, September 1982.
5. Jacobs, J. A., "Geomagnetic Micropulsations", p. 35-39, Springer-Verlay, 1970.
6. Jackson, J. D., "Classical Electrodynamics", p. 145-148, John Wiley and Sons, Inc., 1962.
7. Moose, P. A. and Thomas M. E., "Polarization Characteristics of Geomagnetic Fluctuations", Transactions American Geophysical Union, vol. 64, no. 18, p. 212, May 1983.

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1

END

DATE
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