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

K B STEVENS JUN 83

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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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To isolate data containing a micropulsation event, time series plots of the magnetic field were generated. The (continued).
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.
An Analysis of a PC-3 Micropulsation in the Geomagnetic Field

by

Kurt B. Stevens
Captain, United States Air Force
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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.

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ACKNOWLEDGEMENTS

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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 \( = -\frac{N}{dt} \), 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 0.05 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 noticeable 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
FREQ=FREQ(L)
IF(FREQ.LE.25.)GO TO 1
XX(L)=XX(L)/28.
GO TO 3
1 IF(FREQ.LE.15.)GO TO 2
XX(L)=XX(L)/(105.5-3.14*FREQ)
YY(L)=YY(L)/(181.32-7.289*FREQ)
ZZ(L)=ZZ(L)/(177.26-7.484*FREQ)
GO TO 8
2 IF(FREQ.LE.10.)GO TO 3
XX(L)=XX(L)/(3.958*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
XX(L)=XX(L)/(3.492*FREQ-6.31)
YY(L)=YY(L)/(4.252*FREQ-10.65)
ZZ(L)=ZZ(L)/(4.044*FREQ-7.89)
GO TO 3
4 IF(FREQ.LE.5.)GO TO 5
XX(L)=XX(L)/(2.6311*FREQ+0.14607)
YY(L)=YY(L)/(3.012*FREQ-1.55)
ZZ(L)=ZZ(L)/(3.184*FREQ-1.44)
GO TO 8
5 IF(FREQ.LE.3.)GO TO 6
XX(L)=XX(L)/(2.6311*FREQ+0.14607)
6 IF(FREQ.LE.2.72*FREQ)
XX(L)=XX(L)/(2.72*FREQ)
GO TO 8
7 IF(FREQ.LE.2.72*FREQ)
XX(L)=XX(L)/(2.72*FREQ)
GO TO 8
8 CONTINUE
TF(L)=XX(L)*COS0 + YY(L)*COS0 + 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 \( 1.728 \times 10^5 \) 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 \( \pm 5 \) 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 2.5. 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 2.9. 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 2.15. X-Coil Magnetic Field, 17 August 82, 2240-2348 Local.
Amplitude (nanoteslas : 10 units/in) vs. Time (seconds : 500 units/in)
16 Averages
Figure 2.19. 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 2.24. 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, 2245-2333 Local. Degree of Polarization (0.2 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 Z-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 2.33. 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 2.37. 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 2.41. Ellipticity 2-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
referred 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

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC 73</td>
<td>L2 = 1, 2</td>
</tr>
<tr>
<td>DC 74</td>
<td>IS = 1, 65318</td>
</tr>
<tr>
<td>SUMX = 0.0</td>
<td></td>
</tr>
<tr>
<td>SUMY = 0.0</td>
<td></td>
</tr>
<tr>
<td>SUMZ = 0.0</td>
<td></td>
</tr>
<tr>
<td>DC 75</td>
<td>J = 1, 44</td>
</tr>
<tr>
<td>SUMX = Z[X(I+J)] + SUMX</td>
<td></td>
</tr>
<tr>
<td>SUMY = Z[Y(I+J)] + SUMY</td>
<td></td>
</tr>
<tr>
<td>SUMZ = Z[Z(I+J)] + SUMZ</td>
<td></td>
</tr>
<tr>
<td>CONTINUE</td>
<td></td>
</tr>
<tr>
<td>CONTINUE</td>
<td></td>
</tr>
<tr>
<td>CONTINUE</td>
<td></td>
</tr>
<tr>
<td>CONTINUE</td>
<td></td>
</tr>
<tr>
<td>CONTINUE</td>
<td></td>
</tr>
</tbody>
</table>

Z\[X(I)\] = SUMX / 144
Z\[Y(I)\] = SUMY / 144
Z\[Z(I)\] = SUMZ / 144
Q = Q + 1
CONTINUE
CONTINUE
CONTINUE
CONTINUE
CONTINUE
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 3.4. 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)
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 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 Coi 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 3.12a. 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 3.11b. 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 LVFTC1 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 pi 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 3.14. 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>
<thead>
<tr>
<th>FREQUENCY (HZ)</th>
<th>CHART RECORD VOLTAGE (V)</th>
<th>COMPUTER GENERATED VOLTAGE (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FLUXGATE</td>
<td>COIL</td>
</tr>
<tr>
<td></td>
<td>Large Amplitude Oscillation</td>
<td>Small Amplitude Oscillation</td>
</tr>
<tr>
<td>0.1</td>
<td>2.45</td>
<td>0.78</td>
</tr>
<tr>
<td>0.09</td>
<td>2.45</td>
<td>0.80</td>
</tr>
<tr>
<td>0.08</td>
<td>2.45</td>
<td>0.78</td>
</tr>
<tr>
<td>0.07</td>
<td>2.44</td>
<td>0.70</td>
</tr>
<tr>
<td>0.06</td>
<td>2.46</td>
<td>0.77</td>
</tr>
<tr>
<td>0.05</td>
<td>2.45</td>
<td>0.79</td>
</tr>
<tr>
<td>0.04</td>
<td>2.41</td>
<td>0.78</td>
</tr>
<tr>
<td>0.03</td>
<td>2.50</td>
<td>0.82</td>
</tr>
<tr>
<td>0.02</td>
<td>2.50</td>
<td>0.76</td>
</tr>
<tr>
<td>0.01</td>
<td>2.50</td>
<td>0.78</td>
</tr>
</tbody>
</table>

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>
<thead>
<tr>
<th>FREQUENCY (HZ)</th>
<th>FLUXGATE FIELD (%)</th>
<th>COIL FIELD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large Amplitude Oscillation</td>
<td>Small Amplitude Oscillation</td>
</tr>
<tr>
<td>0.1</td>
<td>87</td>
<td>74</td>
</tr>
<tr>
<td>0.09</td>
<td>87</td>
<td>72</td>
</tr>
<tr>
<td>0.08</td>
<td>87</td>
<td>76</td>
</tr>
<tr>
<td>0.07</td>
<td>87</td>
<td>84</td>
</tr>
<tr>
<td>0.06</td>
<td>87</td>
<td>84</td>
</tr>
<tr>
<td>0.05</td>
<td>87</td>
<td>97</td>
</tr>
<tr>
<td>0.04</td>
<td>87</td>
<td>93</td>
</tr>
<tr>
<td>0.03</td>
<td>87</td>
<td>84</td>
</tr>
<tr>
<td>0.02</td>
<td>87</td>
<td>80</td>
</tr>
<tr>
<td>0.01</td>
<td>86</td>
<td>80</td>
</tr>
</tbody>
</table>
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-Array Voltage, 26 April 83, 0931-0948 Local. Amplitude (volts) vs. time (seconds): 200 units/in.
AN ANALYSIS OF A PC-3 MICROPULSATION IN THE GEOMAGNETIC FIELD
K B STEVENS JUN 83

UNCLASSIFIED
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

<table>
<thead>
<tr>
<th>FREQUENCY (Hz)</th>
<th>20-MG/H COIL FIELD (µT)</th>
<th>EXPECTED COIL FIELD (µT)</th>
<th>EXPECTED RATIO FLUXGATE/COIL</th>
<th>COMPUTER COIL FIELD (µT)</th>
<th>ACTUAL RATIO FLUXGATE/COIL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LARGE AMPLITUDE OSCILLATION</td>
<td>SMALL AMPLITUDE OSCILLATION</td>
<td>LARGE AMPLITUDE OSCILLATION</td>
<td>SMALL AMPLITUDE OSCILLATION</td>
<td>LARGE AMPLITUDE OSCILLATION</td>
</tr>
<tr>
<td>0.1</td>
<td>24.50</td>
<td>7.80</td>
<td>3.04</td>
<td>0.96</td>
<td>8.06</td>
</tr>
<tr>
<td>0.09</td>
<td>24.50</td>
<td>8.00</td>
<td>3.03</td>
<td>0.99</td>
<td>8.09</td>
</tr>
<tr>
<td>0.08</td>
<td>24.50</td>
<td>7.80</td>
<td>3.04</td>
<td>0.96</td>
<td>8.06</td>
</tr>
<tr>
<td>0.07</td>
<td>24.40</td>
<td>7.80</td>
<td>3.02</td>
<td>0.87</td>
<td>8.08</td>
</tr>
<tr>
<td>0.06</td>
<td>24.60</td>
<td>7.70</td>
<td>3.05</td>
<td>0.94</td>
<td>8.07</td>
</tr>
<tr>
<td>0.05</td>
<td>24.50</td>
<td>7.90</td>
<td>3.03</td>
<td>0.98</td>
<td>8.09</td>
</tr>
<tr>
<td>0.04</td>
<td>24.10</td>
<td>7.80</td>
<td>3.01</td>
<td>0.96</td>
<td>8.01</td>
</tr>
<tr>
<td>0.03</td>
<td>25.00</td>
<td>8.20</td>
<td>3.09</td>
<td>1.01</td>
<td>8.09</td>
</tr>
<tr>
<td>0.02</td>
<td>25.00</td>
<td>7.60</td>
<td>3.09</td>
<td>0.92</td>
<td>8.09</td>
</tr>
<tr>
<td>0.01</td>
<td>25.00</td>
<td>7.80</td>
<td>3.09</td>
<td>0.96</td>
<td>8.09</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Notation</th>
<th>Period (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pc1</td>
<td>0.2-5</td>
</tr>
<tr>
<td>Pc2</td>
<td>5-10</td>
</tr>
<tr>
<td>Pc3</td>
<td>10-45</td>
</tr>
<tr>
<td>Pc4</td>
<td>45-150</td>
</tr>
<tr>
<td>Pc5</td>
<td>150-600</td>
</tr>
</tbody>
</table>
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. 105-1310 Local. Amplitude (nanoteslas) 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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (Hz)</td>
<td>0.058</td>
</tr>
<tr>
<td>Peak-to-Peak Amplitude (nT): Amplitude</td>
<td>$\sqrt{x^2 + y^2 + z^2} = 0.37$</td>
</tr>
<tr>
<td>PSD (dB) (Ref lnT$/\mu$T): X-Coil:</td>
<td>-3dB</td>
</tr>
<tr>
<td></td>
<td>Y-Coil: -4dB</td>
</tr>
<tr>
<td></td>
<td>Z-Coil: 1.5dB</td>
</tr>
<tr>
<td>Coherence: X-Y Coils:</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td>Y-Z Coils: 0.99</td>
</tr>
<tr>
<td></td>
<td>Z-X Coils: 0.99</td>
</tr>
<tr>
<td>Degree of Polarization:</td>
<td>X-Y Plane: 0.99</td>
</tr>
<tr>
<td></td>
<td>Y-Z Plane: 0.99</td>
</tr>
<tr>
<td></td>
<td>Z-X Plane: 0.99</td>
</tr>
<tr>
<td>Ellipticity:</td>
<td>X-Y Plane: 0.45 (left hand)</td>
</tr>
<tr>
<td></td>
<td>Y-Z Plane: 0.10 (right hand)</td>
</tr>
<tr>
<td></td>
<td>Z-X Plane: 0.30 (left hand)</td>
</tr>
</tbody>
</table>
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 ± 5V and plotted using the DRAWP subroutine.
//VGLT$IL JGB (1029,0129)" STEVENS SMC 2670",CLASS=G
//#MAIN ORG=NPGVNI,1029P,LINES=165)
//FCMAT PR DDNAME=PLOT,SYSCMS,DEST=LOCAL
//EXEC FRXCLGR PARML=KED="LIST,MAP,XREF",REGION.GO=2048K
//FORT.SYNS DO 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 ZX(165536),ZY(165536),ZZ(165536)
C DIMENSION TIME2165536.
C INTEGER K,15
C INTEGER*4 ITB(12),12*0/
C REAL*4 RTB(28),28*0.
C REAL ALAB(3),*CH-X",*CH-Y","CH-Z"
C REAL*8 TITLE(1)
C EQUIVALENCETITLE(1),RTB(5).
C ARRAYS 'ITB','RTB','ALAB',AND TITLE' ARE USED IN GENERATING
C THE VERTSATEL PLOTTER OUTPUT.
C DATA XX,YY/16384*0."
C DATA ZZ/8192*0.
C K=0
C I5=1
C DC 31 IN1=1,65536
C ZX(1 IN1)=0.0
C ZY(1 IN1)=0.0
C ZZ(1IN1)=0.0
C TIME2(1IN1)=0.0
C 31 CONTINUE
C THE NEXT FIVE LINES SERVE AS A TIME DELAY IN STARTING THE
C DATA ANALYSIS. ISSEC IS THE NUMBER OF SECONDS DELAYED.
C DATA ANALYSIS. ISSEC IS THE NUMBER OF SECONDS DELAYED.
C ISEC=2048
C ITL=ISET32
C DC 55 JJ=1,ITL
C CALL KO(20,IN,203,IEC,IRK)
C 55 CONTINUE
C IFRAME=8192
C NR=8
C FNR=FLOAT(NR)
C DC 70 LI=1,NA
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 BLOWS SEQUENCES UNLESS "NR" REPRESENTS THE NUMBER OF DATA SEQUENCES, ONE
C SEQUENCE CURRENTLY EQUALS 8192 DATA POINTS FOR EACH CHANNEL
C OR 256 SECONDS OF DATA.
READ (5, 3000) TITLE
CALL DRAMP (NPTS, TIME2, ZZY1, ITB, RTB)
RTB(3) = ALAB(3)
READ (5, 3000) TITLE
CALL DRAMP (NPTS, TIME2, ZZY1, ITB, RTB)
RTB(3) = ALAB(2)
READ (5, 3000) TITLE
CALL DRAMP (NPTS, TIME2, ZZY1, ITB, RTB)
RTB(3) = ALAB(1)
READ (5, 3000) TITLE
CALL DRAMP (NPTS, TIME2, ZZY1, ITB, RTB)
READ (5, 3000) TITLE
CALL DRAMP (NPTS, TIME2, ZZY1, ITB, RTB)
STOP
FORMAT (A8)
END
SUBROUTINE RD (IUN, ID, IRS, IREC, IRQ)

THIS PROCEDURE FURNISHED BY DR. TIM STANTON,
DEPARTMENT OF OCEANOGRAPHY.
READ DATA FROM IUN, ALIGN, CHECK & RETURN

IUN = TAPE NUMBER, EG 20
ID = INTEGER & ARRAY 16 LONG, (VALUES 0-4095, SUBTRACT 2048) * 5
(2028 = GIVES VOLTAGE)
IRS = NUMBER OF RESINS ALLOWED (ERRORS)
IREC = COUNTER OF RECORDS (FRAMES OF DATA)
     BLOCK 512 BITS, 32 BITS = RECORD
     800 BPI TAPE UNLABED
     IRQ = NUMBER OF ACTUAL RESINS (ERRORS)

INTEGER * 2 IO(16), IP(16)
DATA IRK /0/
IF (IREC .EQ. 0) IS = 0
IF (IR = 0)
FORMAT (16Z)
IF (IS .NE. 0) GO TO 50
READ (IUN, 20, END=900) IP
IREC = IREC +1
IS = IS +1
IF (IS .LT. 17) GO TO 50
READ (IUN, 20, END=900) IP
I.-4

C 50 ICH=IMASK(IP(IS),3,0)+1
C 55 FORMAT (18,54) ICH,IS,IN,IREC
C 55 WRITE (6,70) ICH,IS,IN,IREC
C 60 IF (ICH,NE.1) GO TO 40
C 70 DO 100 I=1,16
C 80 IRQ=SHIFT(IP(IS),4)
C 90 IF (ICHEQ.1) GO TO 80
C 100 IER=IER+1
C 100 WRITE (6,70) IN,IREC,I,ICH,IER
C 110 FORMAT (1 UNIT*,13, RECORD*,16, CHAN & DATA CH*,214,
C 120 ERRORS*,17)
C 130 IS=IS+1
C 130 IF (ISLT.17) GO TO 100
C 140 READ (13,20,END=900) IP
C 150 IRECR=IREC+1
C 160 CONTINUE
C 170 IF (IER,NE.01) GO TO 150
C 180 IRR=IRR+1
C 190 IF (I1R,L.1R5) GO TO 120
C 200 WRITE (16,110)
C 210 FORMAT (1 STOPPED IN SUB RX BECAUSE OF IRR.GT.*,16, AT L110*)
C 220 IRQ=IRR
C 230 STOP
C 240 WRITE (16,130) IREC,IRR
C 250 FORMAT (1 RESYNC AT FRAME*,16, WITH TOTAL ERRORS*,17)
C 260 IER=0
C 270 IRQ=IRR
C 280 GO TO 50
C 290 CONTINUE
C 300 RETURN
C 310 WRITE (16,810) IN,IREC
C 320 FORMAT (1 END OF UNIT*,13, AT REC*,17)
C 330 STOP
C 340 END
C 350 FUNCTION SHIFT (IN,NPLC)
C 360 RETURNS SHIFTED VALUE OF 1*2 WORD IN
C 370 -VE LEFT,+VE RIGHT SHIFT
C 380 INTEGER * 2 IN
C 390 IP=IN
C 400
```plaintext
IF (IP.LT.0)  IP=IP+65536  
IF (NPLC.LT.0) GO TO 30  
SHIFT=IP/(2**IABS(NPLC))  
RETURN  
30 
SHIFT=IP/(2**IABS(NPLC))  
IF (SHIFT.GT.65535) ISHIFT=MOD(ISSHIFT,65536)  
RETURN  
END  
FUNCTION IMASK(IN,IBL,IBR)  
Masks 1*2 word in outside bits IBL & IBR  
INTEGER * 2 IN,IO  
ID=IN  
IF (IBR.EQ.0) GO TO 50  
IO=SHIFT(IN,IBR)  
ID=IO  
50 
IO=SHIFT(IO,IBL-15-IBR)  
ID=IO  
IMASK=ISHIFT(IO,15-IBL)  
RETURN  
END  
/*
/GO.SYSIN DD *  
/LA MESA VILLAGE 17 AUG 82 1324-1358 LOCAL  
/X COIL AMP IN VOLTS  
/Y COIL AMP IN VOLTS  
/Z COIL AMP IN VOLTS  
/LA MESA VILLAGE 17 AUG 82 2240-2314 LOCAL  
/X COIL AMP IN VOLTS  
/Y COIL AMP IN VOLTS  
/Z COIL AMP IN VOLTS  
/LA MESA VILLAGE 17 AUG 82 1324-1358 LOCAL  
/X COIL AMP IN VOLTS  
/Y COIL AMP IN VOLTS  
/Z COIL AMP IN VOLTS  
/*
/GO.FT2WFOO1 DD UNIT=3400-4, VOL=6MDT11, DISP=OLD,KEEP,  
/LABEL=1 IN,LINE  
/OCC=1 KEEP=FB, LRECL=32, BLSIZE=512, DEN=21  
/GO.SYSUMP 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 ± 5V. A double 144 point running average is applied to the data. The DRAW subroutine plots the data.
PROGRAMMABLE INSTRUMENT SYSTEMS

C  THE FOLLOWING SUBPROGRAMS ARE USED TO GENERATE
C    THE OUTPUT DATA FROM THE PROGRAM.
C
C    THE FOLLOWING VARIABLES ARE DEFINED:
C
C    REAL
C       XX, YY, ZZ
C       RTB, RTI, AB, ALAB, AVE1, AVE2, AVE3, AVE4
C       CHX, CHY, CHZ, TOT
C       TITLE1, TITLE2, TITLE3, TITLE4

C    INTEGER
C       K, M, N, M1, M2, M3, M4, M5, M6
C    "INT"
C       SUMX, SUMY, SUMZ, SUMT, SUMAVE1, SUMAVE2, SUMAVE3, SUMAVE4
C    "DO"
C       M1 = 1
C       N = 1
C       M1 = 1
C       M2 = 1
C       M3 = 1
C       M4 = 1
C       M5 = 1
C       M6 = 1
C       M7 = 1
C       M8 = 1
C
C    EXECUTION COUNTER:
C
C   THE NEXT FIVE LINES REPRESENT A TIME DELAY IN STARTING THE
C   DATA ANALYSIS
C
C   DATA ANALYSIS
C
C   PROCEDURE
C
C   DO LOOP ENDING WITH STATEMENT TO ENABLE THE PROGRAM TO
C   PROCESS A LARGE AMOUNT OF DATA BY REPEATING THE PROCESS IN
C   BLOCKS.
**NR** represents the number of data sequences.

1 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 and strips out the sync code, and sorts out the data by coil channel.

DO 60 JJ=1,IFRAME
   CALL RDI(20,JN,1000,IREC,IRK)
   XX(JJ)=IN(2)
   YY(JJ)=IN(3)
   ZZ(JJ)=IN(4)
   CONTINUE
   N=8192
   FM=FLOAT(N)
   DELTAT=1./32.
   DC 20 J=1,N
      XX(J)=XX(J)-1966.*5./1966.
      YY(J)=YY(J)-2085.*5./2085.
      ZZ(J)=ZZ(J)-2939.*5./2939.
   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 IS=1,6192
   ZZ1(IS)=XX(IS)
   ZZ2(IS)=YY(IS)
   ZZ3(IS)=ZZ(IS)
   TIME2(IS)=DELTAT*FLOAT(IS)+[256.0*FLOAT(K)]
   IS=IS+1
   CONTINUE

**Double Running Point Average**

DO 73 IZ=1,2
   Q=0
   DO 74 JS=1,65318
      SUMX=0.0
      SUMY=0.0
      SUMZ=0.0
   CONTINUE
   DO 75 JS=1,144
      SUMX=ZZ1(JS)+SUMX
      SUMY=ZZ2(JS)+SUMY
      SUMZ=ZZ3(JS)+SUMZ
   CONTINUE
   SUMX=SUMX/144.
   SUMY=SUMY/144.
   SUMZ=SUMZ/144.
VERSATEC PLOT OF V - TIME SERIES VOLTAGE SMOOTHED

NPTS=2041/DeltaT +1.

"NPTS" DETERMINES NUMBER OF POINTS NECESSARY IN ORDER FOR
THE 0 TO 2041 SECS RANGE TO BE PLOTTED.

FOR THE FOLLOWING "ITB" AND "RTB" VALUES REVIEW THE WRITE-UP
FOR THE SUBROUTINE PROCEDURE "DRAW".

ITB(3)=20
ITB(4)=0
ITB(12)=0
RTB(1)=0.0
RTB(2)=0.0
RTB(3)=ALAB(1)
READ(5,3000)TITLE
CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
RTB(3)=ALAB(2)
READ(5,3000)TITLE
CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
RTB(3)=ALAB(3)
READ(5,3000)TITLE
CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
ITB(3)=7
ITB(4)=5
ITB(12)=0
RTB(3)=ALAB(1)
READ(5,3000)TITLE
CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
RTB(3)=ALAB(2)
READ(5,3000)TITLE
CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
RTB(3)=ALAB(3)
READ(5,3000)TITLE
CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
3000 FORMAT(6A8)
STOP
END

//GU. SYSIN DO *
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
VTH00970
VTH02090
VTH01000
VTH02100
VTH01020
VTH02110
VTH01030
VTH02120
VTH01040
VTH02130
VTH01050
VTH02140
VTH01060
VTH02150
VTH01070
VTH02160
VTH01080
VTH02170
VTH01090
VTH02180
VTH01100
VTH02190
VTH01110
VTH02200
VTH01120
VTH02210
VTH01130
VTH02220
VTH01140
VTH02230
VTH01150
VTH02240
VTH01160
VTH02250
VTH01170
VTH02260
VTH01180
VTH02270
VTH01190
VTH02280
VTH01200
VTH02290
VTH01210
VTH02300
VTH01220
VTH02310
VTH01230
VTH02320
VTH01240
VTH02330
VTH01250
VTH02340
VTH01260
VTH02350
VTH01270
VTH02360
VTH01280
VTH02370
VTH01290
VTH02380
VTH01300
VTH02390
VTH01310
VTH02400
VTH01320
VTH02410
VTH01330
VTH02420
VTH01340
VTH02430
VTH01350
VTH02440
VTH01360
VTH02450
VTH01370
VTH02460
VTH01380
VTH02470
VTH01390
VTH02480
VTH01400
VTH02490
VTH01410
VTH02500
VTH01420
VTH02510
VTH01430
VTH02520
VTH01440
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

//GU.FT20F001 DD UNIT=34U-4, VOL=SER=GMOT3A, DISP=(OLD,KEEP),
  LABEL=([],NLIN),
  DCB=(RECFM=FB,LRECL=32,BLKSIZE=512,DEN=2)
//GU.SYSOUT DD SYSOUT=A
APPENDIX C
LFVTC1 COMPUTER PROGRAM

Appendix C contains the LFVTC1 computer program that provides smooth time series magnetic field plots. LFVTC1 uses the subroutine RD to strip voltage data off digital tapes. The voltage data is normalized to ±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.
/*...
...*/

INTEGER K, 14, 15, 0
REAL SUMX, SUMY, SUMZ, SUMT, AVEL, AVE2, AVE3, AVE4
REAL CONSTX, CONSTY, CONSTZ, CONSTT
INTEGER ITB(121, 120)/
REAL RTB128(28*0.0)/
REAL ALAB(4), CH-X', 'CH-Y', 'CH-Z', 'TGT'/
REAL TITLE(12)/
EQUIVALENCE(TITLE(1), RTB128(1))

ARRAY 'ITB', 'RTB1', 'ALAB', 'TITLE', and 'TITLE' are used in generating
VERTICAL PLOTTER OUTPUT.

DATA XZ1, TF/16384+10.00/.
DATA XZ2, T1/16384+0.00/.
DATA XZ1, ZY1/16384+0.00/.
DATA XZ2, ZT1/16384+0.00/.
DATA XZ1, ZY1/16384+0.00/.
DATA XZ2, T1/16384+0.00/.
K=0
14=
CONSTX=0.0
CONSTY=0.0
CONSTZ=0.0
SUMX=0.0
SUMY=0.0
SUMZ=0.0
AVE1=0.0
AVE2=0.0
AVE3=0.0
AVE4=0.0

/*...*/
TWOPI=6.2831853
COS60=COS(TWOPI/6.)
COS30=COS(TWOPI/12.)
D=16.75*TWOPI/360.
COSD=COS(D)
COS1=COS(90-D)*TWOPI/360.)

O IS THE DECLINATION OR MAGNETIC VARIATION AT THE MAGNETOMETER SITE.

DO 31 IN1=1,65536
   22XI(IN1)=0.0
   22Y(IN1)=0.0
   22Z(IN1)=0.0
   TIME2(IN1)=0.0
31 CONTINUE

THE NEXT FIVE LINES SERVE AS A TIME DELAY IN STARTING THE DATA ANALYSIS.

SEC=60
IL=INSEC/32
DO 55 JL=1,IL
   CALL RD(20,IN,200,IREC,IRR)
55 CONTINUE

FRAME=8192
NR=0
FIN=FLOAT(NR)
DO 70 LI=1,NR

THE DO LOOP ENDING WITH STATEMENT TO ENABLE 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.
A 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,FRAME
   CALL RC(20,IN,1000,IREC,IRR)
   X(JJ)=INI(2)
   Y(JJ)=INI(3)
   Z(JJ)=INI(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)
DELTAT=1./32.
DELTAF=1./(FN*DELTAT)
DC 20 CONTINUE FREQ(J)=DELTAF*FLOAT(J)
C YYIJ=REAL(YYIJ)
C ZZIJ=(ZZIJ)-2539.1*5./2539.
C
C XX* IS THE X-COIL DATA, YY* IS THE Y-COIL DATA,
C ZZ* IS THE Z-COIL DATA, AND 'TF' IS THE PROJECTION OF THE
C NORTH-SOUTH COMPONENT (XX) AND THE VERTICAL COMPONENT (ZZ)
C ON THE TOTAL GEOMAGNETIC FIELD VECTOR.
C
20 CONTINUE
DC 21 J=1,N
FREQ(J)=ALOG10(FREQ(J))
21 CONTINUE

C THE NEXT FOUR STATEMENTS PERFORM AN FFT ON THE INPUT
C TIME SERIES DATA. SEE THE WRITEUP ON 'FOURT' FOR
C FURTHER INFORMATION.
C
CALL FOURT(XX,N1,-100,WORK)
CALL FOURT(YY,N1,-100,WORK)
CALL FOURT(ZZ,N1,-100,WORK)
C
C THE NEXT BLOCK OF STATEMENTS APPLY THE SYSTEM (VOLTAGE TO
C B-FIELD) TRANSFER FUNCTION TO THE TRANSFORMED FREQUENCY
C DOMAIN DATA. THIS BLOCK ENDS AT STATEMENT 9.
C
C THE TRANSFER FUNCTION CONVERTS VOLTS TO NANOESLAS (GAMMAS).
C **WARNING** THIS TRANSFER FUNCTION YIELDS AN INACCURATE
C PHASE USE A DIFFERENT TRANSFER FUNCTION IF PHASE INFORMATION
C NEEDED.
C
DC 9 L=1,N
FRO=FREQ(L)
1 IF(FRO.LE.-25.1) GO TO 1
XX(L)=XX(L)/28.
GO TO 8
1 XX(L)=XX(L)/1105.5-3.14*FRO
YY(L)=YY(L)/1182-7.58*FRO
ZZ(L)=ZZ(L)/1177.26-5.8*FRO
GO TO 8
2 XX(L)=XX(L)/15.958*FRO-30.97
YY(L)=YY(L)/117.166*FRO-39.99
ZZ(L)=ZZ(L)/16.49*FRO-32.35
GO TO 8
3 IF(FRO.LE.7.5) GO TO 4

MAGO0970
MAGO0980
MAGO0990
MAGO1000
MAGO1010
MAGO1020
MAGO1030
MAGO1040
MAGO1050
MAGO1060
MAGO1070
MAGO1080
MAGO1090
MAGO1100
MAGO1110
MAGO1120
MAGO1130
MAGO1140
MAGO1150
MAGO1160
MAGO1170
MAGO1180
MAGO1190
MAGO1200
MAGO1210
MAGO1220
MAGO1230
MAGO1240
MAGO1250
MAGO1260
MAGO1270
MAGO1280
MAGO1290
MAGO1300
MAGO1310
MAGO1320
MAGO1330
MAGO1340
MAGO1350
MAGO1360
MAGO1370
MAGO1380
MAGO1390
MAGO1400
MAGO1410
MAGO1420
MAGO1430
MAGO1440
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+0.1467)
   YY(L) = YY(L) / (3.012*FRQ+1.55)
   ZZ(L) = ZZ(L) / (3.184*FRQ+1.4)
   GO TO 8
5 IF (FRQ.LE.3.) GO TO 6
   XX(L) = XX(L) / (2.6311*FRQ+0.1467)
   YY(L) = YY(L) / (2.7028*FRQ)
   ZZ(L) = ZZ(L) / (2.92*FRQ)
   GO TO 8
6 XX(L) = XX(L) / (2.72*FRQ)
   GO TO 7
8 CONTINUE
   IF (LI = (XX(L)*COSD + YY(L)*COSD1)*COS60 + ZZ(L)*COS30
9 CONTINUE
   CALL FOURT (XX, N1, 1, 1, WORK)
   CALL FOURT (YY, N1, 1, 1, WORK)
   CALL FOURT (ZZ, N1, 1, 1, WORK)
   CALL FOURT (TF, N1, 1, 1, WORK)
   DO 57 J = 1, N
      XX(J) = XX(J) / FN
      YY(J) = YY(J) / FN
      ZZ(J) = ZZ(J) / FN
      TF(J) = TF(J) / FN
   57 CONTINUE
   DO 56 J3 = 1, N
      XX(J3) = ABS (XX(J3))
      YY(J3) = ABS (YY(J3))
      ZZ(J3) = ABS (ZZ(J3))
      TF(J3) = ABS (TF(J3))
   56 CONTINUE
   THE NEXT 64 LINES OF CODE CORRECT DATA BLOCK END JUMPS.
   IF (K = NE. 0) GO TO 30
   DO 66 IS = 8048, 8192
      SUMX = 2*X(IS)+SUMX
      SUMY = 2*Y(IS)+SUMY
      SUMZ = 2*Z(IS)+SUMZ
      SUMT = 2*TF(IS)+SUMT
   66 CONTINUE
   CONS1 = SUMX/144.
   CONS1 = SUMY/144.
   CONS1 = SUMZ/144.
   CONS1 = SUMT/144.
   DO 67 IS = 1, 8192
   MAG01450
   MAG01460
   MAG01470
   MAG01480
   MAG01490
   MAG01500
   MAG01510
   MAG01520
   MAG01530
   MAG01540
   MAG01550
   MAG01560
   MAG01570
   MAG01580
   MAG01590
   MAG01600
   MAG01610
   MAG01620
   MAG01630
   MAG01640
   MAG01650
   MAG01660
   MAG01670
   MAG01680
   MAG01690
   MAG01700
   MAG01710
   MAG01720
   MAG01730
   MAG01740
   MAG01750
   MAG01760
   MAG01770
   MAG01780
   MAG01790
   MAG01800
   MAG01810
   MAG01820
   MAG01830
   MAG01840
   MAG01850
   MAG01860
   MAG01870
   MAG01880
   MAG01890
   MAG01900
   MAG01910
   MAG01920
<table>
<thead>
<tr>
<th>Line</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>37</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>38</td>
<td>SUMX=0.0</td>
</tr>
<tr>
<td>39</td>
<td>SUMY=0.0</td>
</tr>
<tr>
<td>40</td>
<td>SLMT=0.0</td>
</tr>
<tr>
<td>67</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>68</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>69</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>70</td>
<td>CONTINUE</td>
</tr>
<tr>
<td>71</td>
<td>THE FOLLOWING LINES OF CODE PERFORMS A DOUBLE RUNNING POINT AVERAGE ON THE DATA.</td>
</tr>
<tr>
<td>73</td>
<td>DC L2=1.2</td>
</tr>
<tr>
<td>74</td>
<td>DO J=1,144</td>
</tr>
<tr>
<td>75</td>
<td>SUMX=ZXL(J)+SUMX</td>
</tr>
<tr>
<td>76</td>
<td>SUMY=ZYL(J)+SUMY</td>
</tr>
<tr>
<td>77</td>
<td>END</td>
</tr>
</tbody>
</table>

Note: The code snippet appears to be from a numerical analysis or scientific computing context, possibly related to data processing or statistical analysis.
SUMZ=ZZVL(Q+J)+SUMZ
SUMT=ZZT1(Q+J)+SUMT
75 CONTINUE
ZZX1(IS)=SUMX/144;
ZZV1(IS)=SUMV/144;
ZZZ1(IS)=SUMZ/144;
74 CONTINUE
CONTINUE
VERSATEC PLOT OF B - MAGNETIC FIELD (SMOOTHED)
NPTS=2041/DELTAT+1.
"NPTS" DETERMINES NUMBER OF POINTS NECESSARY IN ORDER FOR
THE 0 TO 2041 SEC RANGE TO BE PLOTTED.
FOR THE FOLLOWING 'ITB' AND 'RTB' VALUES REVIEW THE WRITE-UP
FOR THE SUBROUTINE PROCEDURE 'DRAWP'.
 ITB(3)=20
 ITB(7)=1
 ITB(12)=0
 RTB(1)=0.0
 RTB(2)=0.0
 RTB(3)=ALAE(1)
 READ(5,3000)TITLE
 CALL DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)
 READ(5,3000)TITLE
 CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
 READ(5,3000)TITLE
 CALL DRAWP(NPTS,TIME2,ZZZ1,ITB,RTB)
 ITB(12)=1
 RTB(3)=ALAE(4)
 READ(5,3000)TITLE
 CALL DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)
 ITB(3)=7
 ITB(4)=5
 ITB(12)=0
 RTB(3)=ALAE(1)
 READ(5,3000)TITLE
 CALL DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)
 RTB(3)=ALAE(2)
 READ(5,3000)TITLE
 CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
 RTB(3)=ALAE(1)
 READ(5,3000)TITLE
 MAGO2410
 MAGO2420
 MAGO2430
 MAGO2440
 MAGO2450
 MAGO2460
 MAGO2470
 MAGO2480
 MAGO2490
 MAGO2500
 MAGO2510
 MAGO2520
 MAGO2530
 MAGO2540
 MAGO2550
 MAGO2560
 MAGO2570
 MAGO2580
 MAGO2590
 MAGO2600
 MAGO2610
 MAGO2620
 MAGO2630
 MAGO2640
 MAGO2650
 MAGO2660
 MAGO2670
 MAGO2680
 MAGO2690
 MAGO2700
 MAGO2710
 MAGO2720
 MAGO2730
 MAGO2740
 MAGO2750
 MAGO2760
 MAGO2770
 MAGO2780
 MAGO2790
 MAGO2800
 MAGO2810
 MAGO2820
 MAGO2830
 MAGO2840
 MAGO2850
 MAGO2860
 MAGO2870
 MAGO2880
 MAGO2890
 MAGO2900
CALL DRAWP(NPTS, TIME2, ZZV1, ITB, RTB)
ITB(12)=1
RTB(31)=ALAB(4)
READ(5, 3000) TITLE
CALL DRAWP(NPTS, TIME2, ZZV1, ITB, RTB)
3000 FORMAT(6(A8))
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
//TOTAL 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
//TOTAL FIELD AMP IN NT
/*
//GO.FT20F001 DD UNIT=3,4000-4, Vol=SER=GMST21, DISP=(OL), KEEP),
// LABEL=11, NL=0 INI
// DEC=1RECPC=2, LREC=32, BLKSIZE=512, DEN=2)
//GO.SYSJMP DD SYSOUT=A
//*/
LIST OF REFERENCES


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   Washington, DC 20361
END
DATE
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