Interim Report *July 1984*

GEOPHYSICAL EFFECTS STUDY (U)

By: HAROLD E. PUTHOFF
SRI INTERNATIONAL

MARSHA ADAMS
TIME RESEARCH INSTITUTE

Prepared for:

DEPARTMENT OF THE ARMY
USAINSCOM
FORT GEORGE G. MEADE, MARYLAND 20755
Attention: LT. COL. BRIAN BUZBY

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Interim Report
Covering the Period 15 November 1983 to 15 July 1984

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SRI Project 6600
ESU 83-147

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CONTENTS (U)

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ILLUSTRATIONS (U)

TABLES (U)

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I OBJECTIVE (U)

(S/CL-3/NF) The objective of this effort is to investigate the possible effects of ambient geophysical/low-frequency electromagnetic factors on remote viewing (RV)* performance as a potential aid to increasing the performance levels of Army INSCOM remote viewers.

---

*(U) RV (remote viewing) is the acquisition and description, by mental means, of information blocked from ordinary perception by distance or shielding.

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II INTRODUCTION (U)

(S/CL-3/NF) SRI International is tasked to conduct a study for Army INSCOM to investigate a potential correlation between remote viewing (RV) performance and ambient geophysical/extremely-low-frequency electromagnetic (ELF) activity. The possibility of such correlation is indicated, for example, by studies showing psychophysiological effects[1,2*] and behavioral changes[3,4] associated with ELF electro-magnetic fields. The geophysical variables of interest include such factors as ELF intensity/fluctuations, ionospheric conditions, geomagnetic indices, sunspot number, and solar emissions (e.g., X rays and solar flares). The questions to be answered in this program are

- Do geophysical/performance correlations exist such that measurement of the ambient geophysical variables could be used as an indicator of expected performance?
- If so, can optimum performance windows be identified?

(U) The structure of the program that will address the above issues consists of

- A literature search.
- Real-time ELF measurements
  - SRI (Menlo Park, California location)
  - Time Research Institute (Los Altos, California field station).
- Real-time geophysical data acquisition via NOAA (National Oceanic and Atmospheric Administration) Westar IV satellite downlink.
- Computer correlation studies of RV performance versus variables of interest.

---

*(U) References are listed at the end of this report.

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III PRESENT STATUS (U)

A. (U) General

(U) In order to accomplish the goals set out in Section II, the program has been designed as a joint effort between SRI International and Time Research Institute of Los Altos, California, with SRI as the prime contractor. Time Research Institute is a research organization that specializes in temporal analysis of geophysical variables and their potential correlation with phenomena of interest, such as weather patterns, earthquakes, and so forth.

(U) With regard to the present effort, Time Research Institute is responsible for establishing the appropriate hardware and software systems for collecting and analyzing data concerning environmental conditions and their correlation with RV performance. The purpose of the correlation study is to determine whether RV performance is enhanced or degraded by measurable changes occurring in the geophysical (including solar-terrestrial) environments. The specific data bases under consideration in this effort are given in Table 1.

(U) Should correlations between geophysical variables and RV performance be found, the application potential of the effort is twofold:

(1) Time periods in which enhanced RV performance might be expected could be identified, resulting in increased quality and accuracy of information obtained through such channels; similarly, time periods in which degraded RV performance might be expected could be avoided. Thus, optimum performance windows would be identified.

(2) An increased understanding of the types of environmental changes that correlate with RV performance could provide clues as to the mechanisms involved in RV functioning. Such knowledge would lead to more focussed research on factors that could enhance RV performance, and would also provide information critical to the development of defensive countermeasures against RV.

Table 1

(U) GEOPHYSICAL DATA BASES

- Solar-Terrestrial
  - Geomagnetic

    Ground-measured indices Ap, K, etc.
    Satellite-measured intensities
  - Solar flux (MHz)

15,400	1,415
8,800	606
4,995	410
2,800	245
2,695	

  - Sunspot number
  - Solar flares
  - Interplanetary magnetic field
  - Solar wind (Pioneer XII)
  - Protons
  - Cosmic ray indices (neutron monitor)
- Ionospheric Measurements
  - Sudden ionospheric disturbances (SIDS)
  - Auroral electrojet
  - Radio propagation quality indices
- ULF/ELF
  - 30 frequencies (from 1 to 30 Hz)

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(U) The tasks listed in Section II (literature search, real-time ELF measurements, real-time geophysical data acquisition via satellite downlink, and correlation studies of RV performance versus geophysical variables of interest) have been prioritized with the goal of producing the longest possible ELF data base during the period of this contract. Therefore, while all of the tasks are being pursued in parallel, ELF-related tasks have been the focus of attention to date.

B. (U) Literature Search

(U) The purpose of the literature search is to acquire and integrate information from recent work done in the field of biological response to ELF and geophysical conditions. Approximately 30 keywords are in use as input to a computerized literature search. Forty manuscripts have been obtained to date and are in the process of being reviewed, plus additional sources of literature have been identified and will be retrieved as priorities permit.

C. (U) ELF Measurements

1. (U) Introduction

(U) Although the ELF frequency range (3 to 300 Hz) has been studied in some detail, many unknowns remain. For example, although it is known that ELF frequencies generated by geophysical means (e.g., electrical storm activity) tend to distribute themselves globally, little information is available on the variation of the ELF environment from location to location. Therefore, local variations may exist that are caused by both manmade sources, and by the geological structure of the area. In the San Francisco Bay Area, manmade sources that generate ELF on a local scale include motors, telephone lines, power lines, and electrical subways [Bay Area Rapid Transit (BART)], and it needs to be determined whether the emission from such sources constitutes a significant contribution to the omnipresent global ELF field.

(U) In order to address the above issue, two ELF monitoring stations are being set up--one at SRI Menlo Park (in the RV Laboratory), the other at the Time Research Institute field station, 17 km distant. It is anticipated that the SRI environment may be a "noisy" one due to the large amount of electronics known to be in the area. Data from the two sites, taking the field site as a reference, are to be compared in order to begin to differentiate the naturally-occurring ELF from the manmade noise occurring at the location where RV is being carried out.

2. (U) Los Altos Site

(U) Since May 1982, Time Research Institute has been operating an ELF monitoring site in Los Altos, collecting data twice daily for the purpose of correlating ELF disturbances with various phenomena of interest. In this period, analysis techniques were developed that are directly applicable to the present task.

(U) One of the first tasks was the upgrading of the Los Altos ELF monitoring site to provide coverage during power interrupts. Research was performed to determine the best power-interrupt system, including generators. The selection criteria chosen for the generator sought to optimize power output, cost effectiveness, and reputation for reliability, with the consideration that this system might serve as a model for additional sites in the client community. On this basis, a 3500-W Kubota generator was bought and installed at the site. A PTI Industries "Datashield" device was also purchased and installed, for use in conjunction with the generator (which must be started manually). This device powers the required electronics for a period of twenty minutes on its own while awaiting generator startup. Furthermore, an automatic alarm telephone dialing system dials up as many as four individuals should a power failure occur while no one is at the site. The two devices working together have protected the system on numerous occasions from power interruptions--including an 8-hr outage planned by Pacific Gas and Electric Company. Thus, since installation of the power-interrupt equipment, there has been no loss of data collection/storage.

3. (U) ELF Data Acquisition Systems

a. (U) Basic System Design

(U) With the requirement that two ELF monitoring sites be implemented for the program--one at SRI and one at Time Research Institute--it was decided that the two systems would be made identical. In this way, differences between the two systems would be minimized, thus reducing the opportunity for artifactual differences between the two system outputs.

(U) Figure 1 is a block diagram of the basic ELF data acquisition system. The ELF signal is collected by an antenna, amplified, and then digitized by an analog-to-digital (A/D) converter so that the signal can be input into an IBM PC Jr. computer for the purpose of analysis by a fast-fourier-transform (FFT) program on at least an hourly basis. The recorded data are then transferred by floppy diskette to an IBM XT computer for further handling.

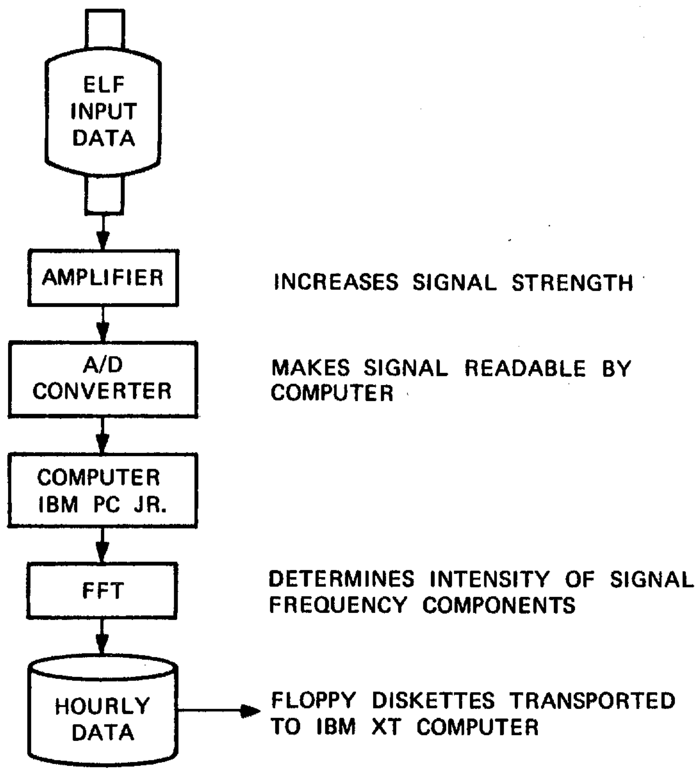

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FIGURE 1 (U) ELF DATA-ACQUISITION SYSTEM

(U) As indicated in the above system description, an integral part of the data acquisition system is computerized record keeping, using IBM systems--both the IBM PC Jr. and the IBM XT. The software is written and compiled on the XT, used as a master system, and then run on the PC Jr. (the PC Jr. is not itself large enough to run a compiler, nor are there compilers written for it). Beyond this, however, in spite of the much publicized "compatibility" between the various

IBM PC systems, some development time had to be expended to ensure that programs compiled on the XT (that were concerned with communication with external devices) could be run on the PC Jr.--because they handle the addressing of communication ports differently.

b. (U) FFT Program

(U) A consultant was hired from the Radioscience Laboratory at Stanford University to critique the ELF system at Time Research Institute as it stood at program start. As part of that critique, he recommended changes in the FFT software to increase its accuracy and running speed. As a result, new FFT software was written in compiled BASIC and then debugged. The program description is given in Appendix A. This task was completed in mid-April.

c. (U) System Electronics

(U) The prototype system of Figure 1 was assembled and installed for our purposes at the Los Altos site. Early tests indicated that modification of the existing electronics was required because (1) the system was sensitive to ground-loop problems, thus the preamplifier had to be redesigned to include an isolation amplifier, and (2) when the new system was installed in mid-June, it was found that a slowly-varying dc level was superimposed on the incoming ELF signal, resulting in excursions that exceeded the limits of the A/D converter at amplification levels required for good signal analysis. Therefore, new circuitry was designed to eliminate the dc problem. With these changes, the ELF detection system is scheduled for completion of testing, debugging, and calibration at the Los Altos site in August, before its sister system is installed at SRI.

d. (U) ELF Electronics/Software Subtasks (Status)

(U) The status of the ELF electronics/software subtasks is as follows:

(U)

- Subject to the requirement that the basic microprocessor units to be used in the program would (1) be able to communicate with an IBM XT, (2) have at least 64K of memory, (3) possess diskette storage capability, and (4) be cost effective, the IBM PC Jr. was selected from among the various alternatives, and two units were purchased.
- Preamplifiers, low bandpass filters, and amplifiers have been designed, and one complete prototype system has been assembled. Amplifiers and filters have been assembled for the second system to be installed at SRI.
- Design specifications have been completed for the ELF antenna. Assembly of this antenna is pending the results of a calibration task (described in Section III.D.3.e).
- A survey of A/D converters that would be compatible with the other system components was completed, and the selected units were purchased.
- Communication between the IBM PC Jr. and the A/D converter has been established, enabling the computer to read the incoming signal.
- Software has been developed and debugged that: (1) reads the communications RS 232 port of the PC Jr. input from the A/D converter, (2) performs FFT analysis of the signal, and then (3) writes half-hourly averages of 19 different frequencies (from 1 to 29 Hz) to a computer diskette. Further software refinements will continue to be made, such as determining daily maximum values for each frequency. This software has been implemented and debugged. The system is ready to begin data acquisition upon implementation of the dc-level-controlling hardware. Minor enhancements of the software will continue.
- The Los Altos system is now in operation and is being tested. It is anticipated that the SRI system will be implemented in August.

e. (U) <u>ELF System Calibration</u>

(U) System calibration is proceeding. The Stanford University consultant mentioned earlier is an expert in the areas of ELF and VLF measurement, antenna design, and spectral analysis. His calibration program is being carried out at the present Los Altos site using specialized, sophisticated instruments from the Stanford Radioscience Laboratory.

(U) As part of the calibration process, certain power-line and power-supply "noise" sources were identified that could have produced artifacts in the historical and ongoing data. Therefore, increased electronic-filtering measures are being incorporated into the system, including software changes to recalibrate past data already in storage.

(U) Finally, as part of the calibration process, three systems are to be monitored simultaneously: (1) the original unmodified Los Altos system on which the historical ELF data have been acquired; (2) a new system (described in this report) using an ELF wire-coil antenna designed by and on loan from the Radioscience Laboratory at Stanford University; (3) the new system, but with a bioantenna (oak tree) as an antenna, which is a procedure recommended by Stanford (see Nature reprint, Appendix B). The results from the calibration tests will be used to calibrate the historical data base, and to fix the final antenna design.

D. (U) Satellite Downlink Geophysical Data-Acquisition System

(U) A near real-time satellite downlink system for solar-terrestrial data has recently become available from NOAA (National Oceanic and Atmospheric Administration). With this unit, it is possible to provide immediate feedback and/or analysis in conjunction with RV sessions. (Normally, there are long delays in procuring solar-terrestrial data; without the downlink, delays of 10 days to 6 months are standard.) The downlink system provides for accumulation of a detailed data base directly on computer diskettes. (See Appendix C for an item-by-item description.)

(U) A satellite controller and a dish antenna for the downlink system were ordered and installed at the Los Altos site early in the project (see Figure 2). At the time of this writing, specifications for data-acquisition software for the IBM PC Jr. have been completed, and first-order software has been written that captures the data to computer diskettes. Because of the large volume of data transmitted each minute, a double-density, double-sided diskette fills in about 21 hours. Disk-

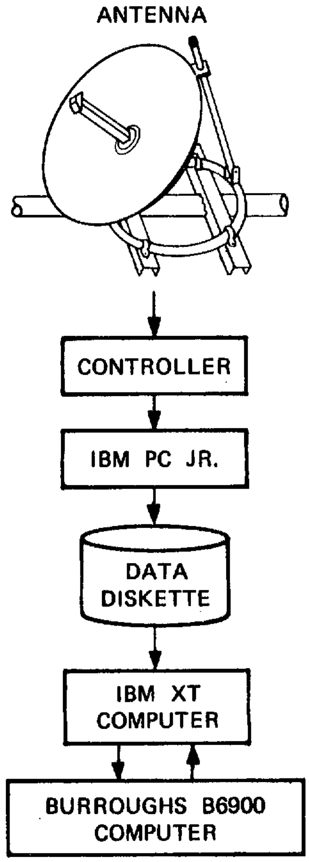

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FIGURE 2 (U) REAL-TIME GEOPHYSICAL DATA ACQUISITION VIA WESTAR IV DOWNLINK

(U)

ettes have been changed on an almost daily basis since early April in order to begin to acquire a long-term data base.

(U) To increase the amount of data that can be stored on a diskette, it is necessary to separate numerical data of interest. The necessary software is now being written that will be able to identify the various data types as they are transmitted, so that only the data of interest will be transferred to an appropriate data file on the diskette. Statistical analysis can then be done on the data in this form.

(U) Other data bases are continuing to be maintained for this project by Time Research Institute. Files of 2800-MHz solar flux, the planetary magnetic activity index (Ap), the Anchorage magnetic index,

(U)

and the Stanford mean solar magnetic field are updated on a weekly or monthly basis as the data are available. ELF data from the "old" system are recorded twice daily; ELF data from the "new" system are being recorded at the following intervals: half-hourly averages (48 times a day), and two sets of half-daily averages (twice a day) at 00:00 and 12:00 UT, and at 04:30 and 16:30 UT. Whole-day averages are also being recorded.

(U) To summarize the status of the satellite-downlink data-acquisition system:

- The downlink-geophysical system is in place and in operation at the Los Altos site.
- Partial data acquisition from the downlink is in place.
- Software for the final data-acquisition system will be completed and implemented in August.

E. (U) Geophysical Data/RV Performance Correlation Analysis

(U) Data for RV sessions are to be analyzed for statistical correlation with respect to the battery of geophysical data sets listed in Table 1, and those acquired by Time Research Institute via measurement (Figure 3). Recording of RV and geophysical data is now in progress. The overall system for data acquisition and analysis of RV performance/geophysical data is depicted in Figure 4. When enough data have been collected toward the end of the contract period, analysis will be performed. The tasks described in earlier sections are in preparation for this task, and therefore have received the bulk of the effort. Certain subtasks in the analysis task, which require a longer leadtime, have, however, already been completed in preparation for the analysis.

(U) The primary statistical program that will be used to scan the data for possible relationships is called EPOCH ANALYSIS. This program reads two files simultaneously. The first file is an event file, the second a data file. The program first reads an event, then scans the data temporally backward and forward in time around the event. This information is stored, a second event is read, and so forth. When all

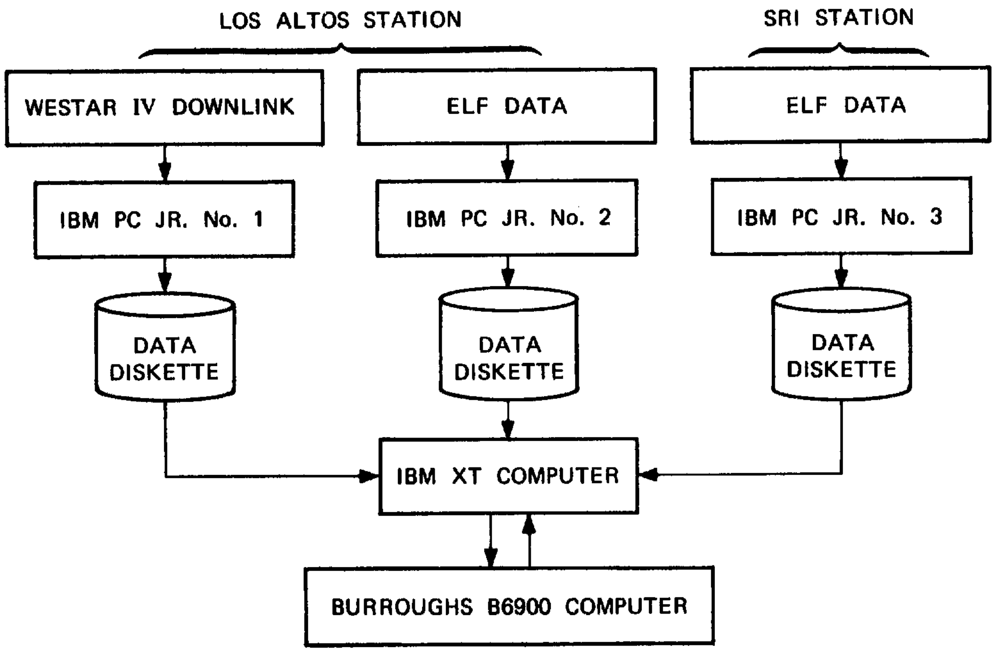

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FIGURE 3 (U) REAL-TIME GEOPHYSICAL DATA-ACQUISITION SYSTEM

(U)

the events and surrounding data have been read, a printout is created that lists appropriate cross-correlation statistics between event and data elements.

(U) Preliminary scans of data generated during an approximate 100-site series with one remote viewer have been carried out. The session quality was graded on a scale of 0 to 3^+, and correlations between solar magnetic field and solar sunspot number were investigated. Some correlation between RV performance and solar sunspot number was found, which, if substantiated by further data, would indicate the possibility that performance might improve immediately after a peak in the sunspot number, and would deteriorate just before the sunspot number peaks in its 27-to-29-day cycle. This result is based on data points that are too small in number to be taken seriously at the point, however, and is mentioned only to give an example of the types of correlations that will be sought out and examined during the course of study.

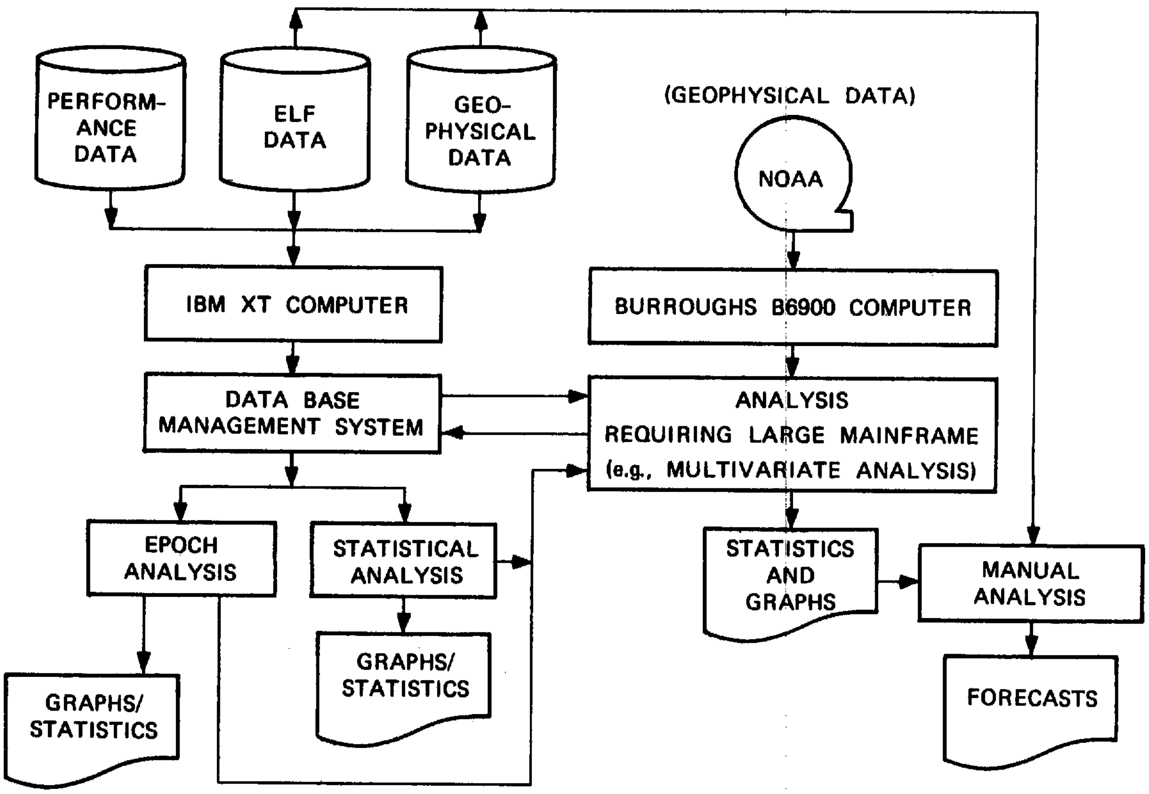

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FIGURE 4 (U) GEOPHYSICAL/PERFORMANCE DATA-ANALYSIS SYSTEM

IV SUMMARY (U)

(U) Approximately 80 percent of the project's data-acquisition tasks have been completed, and all of the equipment and hardware have been purchased and delivered.

(U) System calibration should be completed in the near future, and ELF and downlink-data acquisition will have begun in their final formats.

(U) At the above point, the focus of effort will turn to analysis of past and present geophysical and ELF data, soon to be followed by the initiation of correlation studies of these data against RV performance.

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Appendix A

FAST FOURIER TRANSFORM ROUTINE FOR ELF DATA (U)

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Appendix A

FAST FOURIER ROUTINE FOR ELF DATA (U)

```
;
;*************************************************************************
;*                                                                       *
;*                      PROGRAM DESCRIPTION                              *
;*                                                                       *
;*************************************************************************
;
;THIS PROGRAM USES THE FAST FOURIER TRANSFORM (FFT) ALGORITHM TO
;CALCULATE THE SPECTRAL MAGNITUDES OF AN ARRAY OF CLOSE-PACKED REAL INPUT
;DATA POINTS.  THE PROGRAM IS ORGANIZED AS FOLLOWS:
;
;       1.  AT THE START, DATA POINTS ARE STORED IN THE REAL ARRAY X(I),
;       WHERE I RUNS FROM Ø TO NX-1.  NX MUST BE AN INTEGRAL POWER OF 2,
;       OF THE FORM NX = 2^MX (IE, MX = LOG2(NX)).  SUCCESSIVE ELEMENTS
;       OF X REPRESENT SUCCESSIVE SAMPLES OF AN INPUT SIGNAL, SAMPLED AT
;       REGULAR INTERVALS OF TIME DT.
;
;       2.  THE REAL ARRAY X(I) IS TREATED FOR THE FFT AS A COMPLEX ARRAY
;       OF NX/2 PAIRS OF REAL AND IMAGINARY ELEMENTS.  THAT IS, THE REAL
;       ELEMENTS OF THE ARRAY ARE THE EVEN-NUMBERED INPUT SAMPLES, AND
;       THE IMAGINARY ELEMENTS OF THE ARRAY ARE THE ODD-NUMBERED INPUT
;       SAMPLES.  AFTER THE FFT IS CALCULATED, AN ADDITIONAL STEP IS USED
;       TO EXTRACT THE SPECTRUM OF THE REAL INPUT DATA.  TRANSFORMING
;       CLOSE-PACKED DATA IN THIS WAY, EVEN THOUGH IT REQUIRES AN
;       ADDITIONAL STEP FOR THE REAL TRANSFORM EXTRACTION, IS FASTER THAN
;       TRANSFORMING A COMPLEX ARRAY OF NX REAL-IMAGINARY PAIRS (2*NX
;       ELEMENTS), WHERE ALL OF THE INITIAL IMAGINARY VALUES ARE ZERO.
;
;       3.  THE FFT IS CALCULATED AS FOLLOWS:
;
;               A.  THE INPUT PAIRS IN X ARE REARRANGED IN BIT-REVERSED
;               ORDER.
;
;               B.  THE FFT IS CALCULATED USING DECIMATION IN TIME, WITH
;               ANGLE ARGUMENTS IN EACH SUB-DFT APPEARING IN NATURAL
;               (IE, INCREASING) ORDER.
;
;               C.  AFTER THE LAST PASS THROUGH THE FFT ALGORITHM, THE
;               ARRAY X CONTAINS SPECTRAL VALUES IN NORMAL ORDER, WITH
;               EACH EVEN POINT A REAL VALUE AND EACH SUBSEQUENT ODD
;               POINT THE CORRESPONDING IMAGINARY VALUE.
;
;       4.  FOLLOWING THE FFT THE REAL TRANSFORM IS EXTRACTED.  NOTE THAT
;       IF THE SAMPLING INTERVAL (THE TIME BETWEEN SUCCESSIVE SAMPLES) IS
;       DT, THEN THE TOTAL SIGNAL INTERVAL PROCESSED IS NX*DT (THE FFT
;       ASSUMES THAT THE MISSING RIGHT END POINT IS THE SAME AS THE FIRST
;       POINT).  THE FFT GENERATES A SPECTRUM CONTAINING VALUES AT
;       INCREMENTS OF DF IN FREQUENCY, WHERE DF = 1/(NX*DT).  IF WE WERE
;       TO TRANSFORM AN ARRAY OF NX COMPLEX DATA POINTS (WHOSE IMAGINARY
;       VALUES WERE ZERO, SINCE WE ARE CONCERNED WITH A REAL SIGNAL) WE
;       WOULD GENERATE NX COMPLEX SPECTRAL POINTS RANGING IN FREQUENCY
;       FROM Ø TO (NX-1)*DF Hz.  HOWEVER, THE POINTS FROM (NX/2+1)*DF Hz
;       TO (NX-1)*DF Hz ARE MERELY THE COMPLEX CONJUGATES OF THE LOWER
;       POINTS, AND CONTAIN NO ADDITIONAL INFORMATION.  THIS IS BECAUSE
;       THE NYQUIST RATE, OR THE HIGHEST UNALIASED FREQUENCY THAT CAN BE
;       SAMPLED, IS 1/2*NX*DF.  WHEN WE TRANSFORM NX REAL CLOSE-PACKED
;       POINTS AND THEN EXTRACT THE REAL TRANSFORM, WE GET ONLY THE LOWER
;       NX/2 COMPLEX SPECTRAL VALUES, WHICH ARE ALL THAT ARE NEEDED.
```

```
;       5.  NEXT, THE SPECTRUM IS CONVOLVED WITH A SHORT WINDOW FUNCTION.
;       THE REAL AND IMAGINARY (EVEN AND ODD) POINTS ARE CONVOLVED
;       SEPARATELY, SINCE THE WINDOW FUNCTION IS A SEQUENCE OF REAL
;       NUMBERS.  WINDOWING IS NECESSARY IF THE SIGNAL FILTERS WE ARE
;       EFFECTIVELY SYNTHESIZING ARE TO HAVE A USEFUL SHAPE.  WITHOUT
;       WINDOWING WE WOULD FIND THAT EACH SPECTRAL FILTER WOULD HAVE A
;       NARROW PASSBAND BUT SIGNIFICANT SIDELOBE RESPONSES.  THAT IS, THE
;       MAGNITUDE OF A SPECTRAL LINE X(I) WOULD DEPEND NOT ONLY ON SIGNAL
;       COMPONENTS NEAR I*DF IN FREQUENCY, BUT ALSO SIGNIFICANTLY ON
;       COMPONENTS AT OTHER FREQUENCIES AS WELL.  WINDOWING BROADENS THE
;       SHAPE OF THE PASSBAND OF EACH SPECTRAL FILTER BUT DECREASES THE
;       SIDELOBE RESPONSES.  THE AMOUNT OF BROADENING AND SUPPRESSION OF
;       SIDELOBES DEPENDS ON THE WINDOW ORDER, OR THE LENGTH OF THE
;       WINDOW FUNCTION WHICH IS CONVOLVED WITH THE RAW SPECTRUM.

;       6.  FINALLY, THE MAGNITUDE OF THE SIGNAL AT EACH SPECTRAL
;       FREQUENCY IS CALCULATED AS THE ROOT SUM OF THE SQUARES OF THE
;       REAL AND IMAGINARY SPECTRAL COMPONENTS (IE, THE VECTOR MAGNITUDE
;       OF EACH COMPLEX SPECTRAL POINT) AND SCALED TO MAKE THE PROCESSING
;       GAIN INDEPENDENT OF THE SIZE OF THE BLOCK LENGTH NX.  WE COULD
;       ALSO CALCULATE THE PHASE OF THE SPECTRAL POINTS BUT THIS
;       INFORMATION ISN'T TOO VALUABLE FOR OUR USE.  NOTE THAT THE
;       HIGHEST MEANINGFUL SPECTRAL FREQUENCY DEPENDS ON THE ANTI-
;       ALIASING LOW-PASS FILTER THAT IS USED WHEN THE SIGNAL IS SAMPLED.
;       THERE IS NOT MUCH MEANING TO SPECTRAL POINTS ABOVE THE FILTER
;       CUTOFF FREQUENCY, WHERE SIGNALS ARE ATTENUATED AND FREQUENCY
;       ALIASING BECOMES A PROBLEM.  THUS, IN THIS PROGRAM WE DO NOT
;       CALCULATE SPECTRAL COMPONENTS ABOVE ABOUT 30 Hz (THE NOMINAL
;       CUTOFF FREQUENCY OF THE LOW-PASS FILTER).
;
;THIS PROGRAM IS WRITTEN IN BASIC FOR THE IBM PC COMPUTER.  HOWEVER, IT
;IS EASILY ADAPTED TO OTHER MACHINES.  FOUR THINGS TO WATCH OUT FOR WHEN
;TRANSFERRING THE PROGRAM TO ANOTHER VERSION OF BASIC ARE:
;
;       1.  ALL ARRAYS START WITH INDEX 0.  THAT IS, THE ARRAY X(NX) RUNS
;       FROM X(0) TO X(NX-1).  ARRAY REFERENCES WILL NEED TO BE CHANGED
;       IF THE PROGRAM IS TO BE USED ON MACHINES WHERE THE FIRST ELEMENT
;       OF ARRAYS HAS INDEX 1.
;
;       2.  ALL VARIABLES WHOSE NAMES START WITH THE LETTERS "I" THROUGH
;       "N" ARE IMPLICITLY INTEGERS (DEFINT I-N STATEMENT).  THESE
;       VARIABLES MAY NEED TO BE RENAMED.  IT IS IMPORTANT THAT LOOP
;       COUNTERS AND ARRAY INDEX VARIABLES BE INTEGERS BECAUSE INTEGER
;       ARITHMETIC (WHERE AVAILABLE) IS FASTER THAN FLOATING-POINT
;       ARITHMETIC.
;
;       3.  THIS PROGRAM USES THE INTEGER DIVISION OPERATOR "\".  THIS
;       MAY BE CHANGED TO "/" IN OTHER VERSIONS OF BASIC.
;
;       4.  THIS PROGRAM USES LOGICAL OPERATORS ("NOT", "AND", "OR") ON
;       INTEGER VARIABLES (NOT LOGICAL VARIABLES) IN THE BIT-REVERSAL
;       ROUTINE.  IF THESE OPERATORS ARE NOT AVAILABLE THE ALTERNATE
;       VERSION OF STATEMENTS 3000-3190 USING ONLY INTEGER ARITHMETIC
;       MUST BE SUBSTITUTED.
;
```

```
;***************************************************************************
;*                                                                         *
;*              CHOICE OF SAMPLING TIME AND BLOCK SIZE                     *
;*                                                                         *
;***************************************************************************
;
;THE SAMPLING TIME DT AND THE BLOCK SIZE NX TOGETHER DETERMINE THE
;NUMBER OF SPECTRAL POINTS CALCULATED AND THEIR SPACING IN FREQUENCY.
;THE CHOICE OF SAMPLING TIME ALSO AFFECTS THE FREQUENCIES AT WHICH POWER-
;LINE HARMONIC INTERFERENCE THAT IS PASSED BY THE ANTI-ALIASING LOW-PASS
;FILTER WILL APPEAR IN THE SPECTRUM.  THE FOLLOWING DISCUSSION ASSUMES
;THAT THE 30 Hz LOW-PASS FILTER WILL BE USED TO ATTENUATE HIGH FREQUENCY
;SIGNAL COMPONENTS BEFORE SAMPLING.
;
;IF THE INPUT SIGNAL THAT IS SAMPLED CONTAINED ONLY FREQUENCIES BELOW
;30 Hz IT WOULD BE SUFFICIENT TO SAMPLE AT THE NYQUIST RATE OF 60 SAMPLES
;PER SECOND.  HOWEVER, SINCE THE FILTER DOES NOT HAVE INFINITE
;ATTENUATION ABOVE 30 Hz IT IS NECESSARY TO SAMPLE AT A SOMEWHAT HIGHER
;RATE, AND THEN DISCARD THOSE SPECTRAL POINTS REPRESENTING SIGNALS ABOVE
;30 Hz.
;
;       1.  ONE CONSIDERATION IN CHOOSING THE SAMPLING RATE IS THE ACTUAL
;       RATE AVAILABLE WITH A GIVEN A/D CONVERTER.  WITH THE CMC BUSSTER
;       D16 A/D CONVERTER, SAMPLING TIMES CAN BE AS SMALL AS 0.0005 s.
;       HOWEVER, IF MORE THAN ONE SIGNAL IS TO BE DIGITIZED AT ONE TIME,
;       THE MINIMUM SAMPLING TIME IS 0.01 s PER CHANNEL, OR A SAMPLING
;       RATE OF 100 SAMPLES/SECOND.  THIS SEEMS LIKE A REASONABLE CHOICE.
;
;       2.  A SECOND CONSIDERATION IS THE EFFECT OF THE SAMPLING RATE ON
;       THE FREQUENCIES OF ALIASED POWER LINE HARMONICS.  ONLY HARMONICS
;       AT 60 AND 120 Hz ARE LIKELY TO BE A PROBLEM.  WITH DT = 0.01 S,
;       THE NYQUIST RATE IS 50 Hz, SO THE SPECTRUM WILL CONTAIN POINTS AT
;       FREQUENCIES FROM 0 TO 50 Hz.  ANY 60 Hz SIGNAL THAT IS DIGITIZED
;       WILL APPEAR IN THE SPECTRUM AT 40 Hz, WHICH POINT WILL BE THROWN
;       OUT, SO 60 Hz INTERFERENCE WON'T BE A PROBLEM.  HOWEVER,
;       INTERFERENCE AT 120 Hz WILL APPEAR AT 20 Hz IN THE SPECTRUM, AND
;       THIS FACT MUST BE KEPT IN MIND WHEN ANALYZING THE DATA.  (HIGHER
;       HARMONICS APPEAR AS:  180 AT 20 Hz, 240 AT 40 Hz, 300 AT 0 Hz,
;       360 AT 40 Hz, AND SO ON.)
;
;GIVEN A SAMPLING TIME DT = 0.01 s, WE CAN CALCULATE THE SPECTRAL SPACING
;FOR DIFFERENT CHOICES OF BLOCK SIZE NX, AND WE FIND THE FOLLOWING:
;
;         NX            DF                  NUMBER OF POINTS <= 30 Hz
;
;         64            1.5625 Hz                   19
;        128            0.7813 Hz                   38
;        256            0.3906 Hz                   76
;        512            0.1953 Hz                  153
;       1024            0.0977 Hz                  307
;       2048            0.0488 Hz                  614
;
```

```
;*************************************************************************
;*                                                                       *
;*                              WINDOWING                                *
;*                                                                       *
;*************************************************************************
;
;AFTER THE SPECTRUM OF THE INPUT SIGNAL HAS BEEN FOUND, IT IS CONVOLVED
;WITH A SHORT WINDOW SEQUENCE TO IMPROVE THE SHAPE OF THE SYNTHESIZED
;FILTERS.  THOUGH THE SPECTRAL VALUES ARE COMPLEX, THE WINDOW SEQUENCE IS
;A SEQUENCE OF REAL NUMBERS, SO THE CONVOLUTION IS DONE SEPARATELY FOR
;THE REAL AND IMAGINARY SEQUENCES IN THE SPECTRUM.  THE CONVOLUTION IS OF
;THE FORM
;
;       X(j) <- W3*[X(j-3)+X(j+3)] +W2*[X(j-2)+X(j+2)]
;                +W1*[X(j-1)+X(j+1)] +WØ*X(j)
;
;WHERE X(j) IS THE REAL OR IMAGINARY SUBSEQUENCE OF THE SPECTRUM, AND THE
;CONVOLUTION IS ILLUSTRATED FOR A 4TH ORDER WINDOW SEQUENCE.  NOTE THAT
;IF THE CONVOLUTION IS TO BE DONE IN-PLACE, A SMALL ARRAY MUST BE USED TO
;HOLD THE PREVIOUS VALUES OF X(j-3), X(j-2), X(j-1), and X(j) FOR USE IN
;SUBSEQUENT CONVOLUTIONS.
;
;THE VALUES TO USE FOR DATA POINTS BEYOND THE ENDS OF THE SPECTRUM ARE
;THE COMPLEX CONJUGATES OF THE POINTS REFLECTED ABOUT THE ENDS, SO THE
;AUXILLIARY ARRAY OF PREVIOUS VALUES MUST BE INITIALIZED AS FOLLOWS:
;
;       Re(-3) = Re(3)            Im(-3) = -Im(3)
;       Re(-2) = Re(2)            Im(-2) = -Im(2)
;       Re(-1) = Re(1)            Im(-1) = -Im(1)
;
;POINTS AFTER THE FAR END OF THE SPECTRUM ARE REFLECTED IN THE SAME WAY,
;BUT SINCE WE WON'T CALCULATE SPECTRAL POINTS ABOVE 3Ø Hz THERE IS NO
;NEED TO WINDOW POINTS THERE.
;
;THE FOLLOWING WINDOW SEQUENCES ARE THE MOST IMPORTANT FOR OUR USE.
;THESE ARE ALL MINIMUM-SIDELOBE WINDOWS WHICH SUPPRESS SIDELOBE RESPONSES
;AS MUCH AS POSSIBLE FOR A GIVEN WINDOW ORDER, AND HAVE BEEN NORMALIZED
;FOR UNITY GAIN.  NOTE THAT THE ORDER-1 WINDOW CORRESPONDS TO NO WINDOW
;AT ALL.  THE ORDER-2 WINDOW IS SIMILAR TO THE HAMMING FUNCTION.
;
;       ORDER          1           2           3            4
;
;       WØ             1.ØØØØØ     1.ØØØØØ     1.ØØØØØØØ    1.ØØØØØØØ
;       W1             Ø          -Ø.42875    -Ø.5895613   -Ø.6727198
;       W2             Ø           Ø           Ø.Ø922278    Ø.1878524
;       W3             Ø           Ø           Ø           -Ø.Ø146337
;
;       HIGHEST        -13 dB      -43 dB      -72 dB       -98 dB
;       SIDELOBE
;
;       3-dB WIDTH     Ø.89 DF     1.3Ø DF     1.61 DF      1.86 DF
;
;       6-dB WIDTH     1.2Ø DF     1.81 DF     2.25 DF      2.62 DF
;
;FOR OUR USE, I THINK THE 3RD-ORDER WINDOW IS THE MOST APPROPRIATE, AND
;THE PROGRAM USES THIS WINDOW FUNCTION.  SINCE W3 = Ø IN THIS CASE, THE
;ACTUAL CONVOLUTION CONTAINS ONLY 3 TERMS.  SINCE WØ = 1, THE LAST TERM
;IS JUST X(j), WITHOUT A MULTIPLICATION.  THUS THE WINDOWING OF EACH
;POINT INCLUDES 5 ADDITIONS AND 2 MULTIPLICATIONS FOR EACH OF THE REAL
;AND IMAGINARY COMPONENTS.  IF ONLY VERY SHORT BLOCKS (SAY NX = 64) ARE
;TO BE PROCESSED, THE 2ND-ORDER WINDOW MIGHT BE MORE APPROPRIATE SINCE
;THE FILTERS ARE A BIT NARROWER IN THAT CASE.
;
```

```
;****************************************************************************
;*                                                                          *
;*                               PROGRAM                                    *
;*                                                                          *
;****************************************************************************
;
;DEFINITIONS:

1000    DEFINT I-N                'VARIABLES STARTING "I"-"N" ARE INTEGERS
1010    NX = 1024                 'DATA BLOCK SIZE
1020    NXM1 = NX-1
1030    DIM X(NX)                 'INPUT DATA ARRAY X(I), I = 0, ..., NX-1
1040    DT = 0.01                 'INPUT SAMPLE TIME IN SECONDS
1050    DF = 1./(DT*NX)           'SPECTRAL LINE SPACING IN Hz
1060    NMAX = 30./DF             'NUMBER OF HIGHEST SPECTRAL LINE <= 30 Hz

1100    NF = NX\2                 'FFT SIZE (NR OF COMPLEX POINTS)
1110    MF = LOG(NF)/LOG(2.)      'NF = 2^MF
1120    NFD2 = NF\2
1130    NFM1 = NF-1
1140    DIM CA(NF)                'COSINE AND SINE ARRAYS,
1150    DIM SA(NF)                '  ANGLES FROM 0 TO 180*(NX-1)/NX
1160    PI2 = 6.2831853

1200    W1 = -0.5859613           'WINDOW COEFFICIENTS
1210    W2 = 0.0922278

;****************************************************************************
;
;CALCULATE SINE AND COSINE ARRAYS:
;
;THIS NEED BE DONE ONLY ONCE.  NOTE THAT THE FFT ROUTINE USED SINES AND
;COSINES FROM 0 TO <180 DEGREES IN STEPS OF 360/NF DEGREES, AND THE REAL
;TRANSFORM EXTRACTION ROUTINE USES SINES AND COSINES UP TO <90 DEGREES IN
;STEPS OF 360/NX DEGREES.  THUS THE ODD NUMBERED POINTS IN THESE ARRAYS
;FOR ANGLES ABOVE 90 DEGREES ARE NOT USED.  IF MEMORY SPACE IS A PROBLEM,
;THE ARRAYS CAN BE CONDENSED AND ONLY POINTS FROM 0 TO <180 DEGREES IN
;STEPS OF 360/NF CALCULATED FOR USE BY THE FFT.  IN THIS CASE, THE VALUES
;USED BY THE REAL TRANSFORM EXTRACTION WILL HAVE TO BE CALCULATED AS
;NEEDED.  IT IS ALSO POSSIBLE TO USE A TABLE CONTAINING VALUES FOR ANGLES
;ONLY FROM 0 TO 45 DEGREES, BUT THIS MAKES THE LOOKUP PROCEDURE SOMEWHAT
;MORE COMPLICATED, INVOLVING A POSSIBLE CHANGE OF SIGN OR EXCHANGE OF SIN
;AND COS VALUES DEPENDING ON THE SEMIQUADRANT OF THE ANGLE.

1500    DA = PI2/NX               'ANGLE INCREMENT
1510    FOR J = 0 TO NFM1         'CALCULATE SINES AND COSINES
1520      A = DA*J
1530      CA(J) = COS(A)
1540      SA(J) = SIN(A)
1550    NEXT J

;****************************************************************************
;
;SAMPLE INPUT DATA INTO ARRAY X:
;
;THIS CODE MUST BE WRITTEN TO SAMPLE THE INPUT SIGNAL EVERY 0.01 SECOND
;AND STUFF SUCCESSIVE VALUES INTO X.  ONLY NX VALUES NEED BE TAKEN.
;ENTER HERE TO START PROCESSING A NEW BLOCK OF DATA.

;2000   CODE YET TO BE WRITTEN
```

```
;*************************************************************************
;
;BIT REVERSAL:
;
;THE REAL COMPACT SAMPLES IN X ARE NOW TREATED AS A COMPLEX ARRAY OF NF
;(REAL,IMAGINARY) PAIRS.  PAIRS AT BIT-REVERSED ADDRESSES ARE NOW SWAPPED
;PRIOR TO THE FFT ROUTINE.
;
;THE FOLLOWING ROUTINE USES LOGICAL OPERATORS.

3000    K = 1                       'INITIAL BIT-REVERSED ADDRESS
3010    FOR J = 1 TO NFM1           'SCAN ALL ADDRESSES EXCEPT THE FIRST
3020      L = NFD2                  'INITIAL BIT MASK
3030      IF NOT(K AND L) GOTO 3070 'THIS BIT SET?
3040        K = K AND NOT L         '  YES - CLEAR IT,
3050        L = L\2                 '  SHIFT MASK RIGHT,
3060        GOTO 3030               '  AND CONTINUE
3070      K = K OR L                'BIT WAS CLEAR, SET IT
3080      IF K <= J GOTO 3190       'SKIP IF ADDRESS SAME OR ALREADY DONE
3090      J2 = J+J                  'ARRAY ADDRESS OF LOWER REAL COMPONENT
3100      K2 = K+K                  ;ARRAY ADDRESS OF UPPER REAL COMPONENT
3110      T = X(J2)                 'SWAP REALS
3120      X(J2) = X(K2)
3130      X(K2) = T
3140      T = X(J2+1)               'SWAP IMAGINARIES
3150      X(J2+1) = X(K2+1)
3180      X(K2+1) = T
3190    NEXT J

;THE FOLLOWING VERSION USES ONLY INTEGER ARITHMETIC BUT IS A BIT LESS
;EFFICIENT.
;
;3000   FOR J = 1 TO NFM1           'SCAN ALL ADDRESSES EXCEPT THE FIRST
;3010     K1 = J                    'INITIALIZE DIVISOR
;3020     K = 0                     'INITIALIZE BIT-REVERSED ADDRESS
;3030     FOR I = 1 TO MF           ;BIT-REVERSE ALL MF BITS
;3040       K2 = K1\2
;3050       K = (K-K2)*2+K1
;3060       K1 = K2
;3070     NEXT I
;3080     IF K <= J GOTO 3190       'SKIP IF ADDRESS SAME OR ALREADY DONE
;3090     J2 = J+J                  'ARRAY ADDRESS OF LOWER REAL COMPONENT
;3100     K2 = K+K                  ;ARRAY ADDRESS OF UPPER REAL COMPONENT
;3110     T = X(J2)                 'SWAP REALS
;3120     X(J2) = X(K2)
;3130     X(K2) = T
;3140     T = X(J2+1)               'SWAP IMAGINARIES
;3150     X(J2+1) = X(K2+1)
;3180     X(K2+1) = T
;3190   NEXT J
```

```
;***************************************************************************
;
;FFT ROUTINE:
;
;THIS ROUTINE USED DECIMATION IN TIME.  THE COMPLEX DATA INPUT IS IN BIT-
;REVERSED ORDER.
;
;       1.  THE OUTER LOOP MAKES MF PASSES THROUGH THE DATA.  THE INITIAL
;       NUMBER OF SUB-DFT'S IS 1, AND DOUBLES ON EACH PASS.  THE INITIAL
;       INCREMENT IN ANGLE BETWEEN SUB-DFT'S IS 18Ø DEGREES, AND HALVES
;       ON EACH PASS.
;
;       2.  THE MIDDLE LOOP PROCESSES THE SUB-DFT'S.  AT EACH SUB-DFT
;       ANGLES INCREASE IN NATURAL ORDER AS Ø (I=1); Ø, 9Ø (I=2); Ø, 45,
;       9Ø, 135 (I=3); Ø, 22.5, 45, ... (I=4); AND SO ON.
;
;       3.  THE INNER LOOP CALCULATES THE BUTTERFLIES FOR A GIVEN ANGLE
;       IN EACH SUB-DFT.  EACH DECIMATION-IN-TIME BUTTERFLY HAS THE FORM
;
;               Re(j) <- Re(j)+[Re(k)*C+Im(k)*S]
;               Im(j) <- Im(j)+[Im(k)*C-Re(k)*S]
;               Re(k) <- Re(j)-[Re(k)*C+Im(k)*S]
;               Im(k) <- Im(j)-[Im(k)*C-Re(k)*S]
;
;       WHERE C AND S ARE THE COSINE AND SINE OF THE ANGLE.

32ØØ    LM = 1                    'INITIAL NUMBER OF SUB-DFT'S = 1
321Ø    LM2 = LM+LM
322Ø    IDA = NF                  'INITIAL ANGLE INCREMENT = 18Ø DEG
323Ø    FOR I = 1 TO MF           'OUTER LOOP
324Ø      IA = Ø                  'INITIAL SUB-DFT ANGLE = Ø DEGREES
325Ø      FOR L = 1 TO LM         'MIDDLE LOOP
326Ø        C = CA(IA)            'LOOK UP COS AND SIN FOR THIS ANGLE
327Ø        S = SA(IA)
328Ø        FOR J=L-1 TO NFM1 STEP LM2 ;INNER LOOP
329Ø          JR = J+J            'ARRAY ADDRESS OF LOWER REAL COMPONENT
33ØØ          JI = JR+1           'ARRAY ADDRESS OF LOWER IMAG COMPONENT
331Ø          KR = JR+LM2         'ARRAY ADDRESS OF UPPER REAL COMPONENT
332Ø          KI = KR+1           'ARRAY ADDRESS OF UPPER IMAG COMPONENT
333Ø          TR = X(KR)*C+X(KI)*S 'BUTTERFLY
334Ø          TI = X(KI)*C-X(KR)*S
335Ø          X(KR) = X(JR)-TR
336Ø          X(KI) = X(JI)-TI
337Ø          X(JR) = X(JR)+TR
338Ø          X(JI) = X(JI)+TI
339Ø        NEXT J                'END OF INNER LOOP
34ØØ        IA = IA+IDA           'BUMP ANGLE
341Ø      NEXT L                  'END OF MIDDLE LOOP
334Ø      LM = LM2                'DOUBLE NUMBER OF SUB-DFT'S
343Ø      LM2 = LM2+LM2
344Ø      IDA = IDA\2             'HALVE ANGLE INCREMENT
345Ø    NEXT I                    'BOTTOM OF OUTER LOOP
```

```
;*************************************************************************
;
;EXTRACT CLOSE-PACKED REAL DATA TRANSFORM:
;
;NOW WE MUST EXTRACT THE SPECTRUM OF THE INPUT DATA AS IF IT HAD BEEN
;CALCULATED FROM A SEQUENCE OF NX COMPLEX INPUT VALUES ALL OF WHOSE
;IMAGINARY COMPENENTS WERE ZERO.  THE ALGORITHM FOR THIS IS AS FOLLOWS:
;
;       1.  FOR POINTS j = 1, 2, ..., NF/2-1 CALCULATE
;
;               Re(j) <-  Re(j)+Re(k)-[Re(j)-Re(k)]*S+[Im(j)+Im(k)]*C
;               Im(j) <-  Im(j)-Im(k)-[Re(j)-Re(k)]*C-[Im(j)+Im(k)]*S
;               Re(k) <-  Re(j)+Re(k)+[Re(j)-Re(k)]*S-[Im(j)+Im(k)]*C
;               Im(k) <- -Im(j)+Im(k)-[Re(j)-Re(k)]*C-[Im(j)+Im(k)]*S
;
;       WHERE k = NF -j,  A = j*36Ø/NX DEGREES, C = COS(A), AND
;       S = SIN(A).
;
;       WE ALSO HAVE THE SPECIAL POINTS:
;
;               Re(Ø) <-  [Re(Ø)+Im(Ø)]
;               Im(Ø) <-  Ø
;
;               Re(NF/2) <- Re(NF/2)*2
;               Im(NF/2) <- -Im(NF/2)*2
;
;       AND (THOUGH THESE VALUES ARE NOT CALCULATED):
;
;               Re(NF) <- [Re(Ø)-Im(Ø)]*2
;               Im(NF) IS UNKNOWN

35ØØ    X(Ø) = X(Ø)*2.           'SPECIAL CASE FOR X(Ø)
351Ø    X(1) = Ø.
352Ø    FOR J = 1 TO NFD2-1      'LOOP FOR GENERAL CASE
353Ø      JR = J+J               'ARRAY ADDRESS OF LOWER REAL COMPONENT
354Ø      JI = JR+1              'ARRAY ADDRESS OF LOWER IMAG COMPONENT
355Ø      KR = NX-JR             'ARRAY ADDRESS OF UPPER REAL COMPONENT
356Ø      KI = KR+1              'ARRAY ADDRESS OF UPPER IMAG COMPONENT
357Ø      C = CA(J)              'LOOK UP COS AND SIN FOR THIS ANGLE
358Ø      S = SA(J)
359Ø      RS = X(JR)+X(KR)       'REAL SUM
36ØØ      RD = X(JR)-X(KR)       'REAL DIFF
361Ø      QS = X(JI)+X(KI)       'IMAG SUM
362Ø      QD = X(JI)-X(KI)       'IMAG DIFF
363Ø      TR = QS*C-RD*S         'TERM FOR REALS
364Ø      TI = RD*C+QS*S         'TERM FOR IMAGS
365Ø      X(JR) = RS+TR
366Ø      X(JI) = QS-TI
367Ø      X(KR) = RS-TR
368Ø      X(KI) = -QS-TI
369Ø    NEXT J                   'BOTTOM OF LOOP
37ØØ    X(NF) = X(NF)*2.         'SPECIAL CASE FOR X(NF/2)
371Ø    X(NF+1) = X(NF+1)*2.
```

```
;***************************************************************************
;
;WINDOW SPECTRAL DATA TO IMPROVE FILTER SHAPE:
;
;SEE THE DISCUSSION OF WINDOWING ABOVE.  THIS ROUTINE IS FOR A 3RD-ORDER
;WINDOW FUNCTION.

3800    R2 = X(4)                 'INITIALIZE PREVIOUS VALUE ARRAY, Re(2)
3810    R1 = X(2)                 '  Re(1)
3820    R0 = X(0)                 '  Re(0)
3830    Q2 = -X(5)                '  Im(2)
3840    Q1 = -X(3)                '  Im(1)
3850    Q0 = -X(1)                '  Im(0) = 0.
3860    FOR J0 = 0 TO NMAX*2 STEP 2 'WINDOW POINTS <= 30 Hz
3870      J1 = J0+1               'ADDRESS OF IMAG COMPONENT
3880      X(J0) = (R2+X(J0+4))*W2+(R1+X(J0+2))*W1+R0 'REAL COMPONENT
3890      X(J1) = (Q2+X(J1+4))*W2+(Q1+X(J1+2))*W1+Q0 'IMAG COMPONENT
3900      R2 = R1                 'SHIFT PREVIOUS ARRAY
3910      R1 = R0
3920      R0 = X(J0+2)            '  AND INSERT NEW VALUE
3930      Q2 = Q1
3940      Q1 = Q0
3950      Q0 = X(J1+2)
3960    NEXT J                    'END OF LOOP

;***************************************************************************
;
;CALCULATE MAGNITUDES:
;
;THE MAGNITUDE OF EACH SPECTRAL VECTOR IS CALCULATED AS
;
;       MAGNITUDE(j) = SQRT[Re(j)*Re(j)+Im(j)*Im(j)]*SF
;
;WHERE SF = 1/NX IS A SCALING FACTOR, USED FOR 2 REASONS:
;
;       1.  THE SCALING FACTOR SETS THE PROCESSING GAIN.  WITH SF = 1/NX,
;       THE GAIN FOR A SINGLE-COMPONENT SIGNAL IS 1.  THAT IS, IF THE
;       INPUT SIGNAL IS A SINE-WAVE AT FREQUENCY n*DF WITH PEAK AMPLITUDE
;       1.0, THE SPECTRUM AT FREQUENCY n*DF WILL ALSO BE 1.0.
;
;       2.  THE SCALING FACTOR MAKES THE PROCESSING GAIN INDEPENDENT OF
;       THE BLOCK SIZE NX, SO THE SAME SIGNAL CAN BE PROCESSED WITH
;       DIFFERENT BLOCK SIZES IN ORDER TO GENERATE DIFFERENT SPECTRA WITH
;       VARYING FREQUENCY RESOLUTION, BUT THE MAGNITUDE OF A NARROW-BAND
;       SIGNAL COMPONENT WILL BE THE SAME IN EACH SPECTRUM.
;
;NOTE THAT MAGNITUDES ARE ONLY CALCULATED FOR SPECTRAL POINTS <= 30 Hz.
;MAGNITUDES ARE STORED AT THE BOTTOM OF THE ARRAY X, IN THE FIRST NMAX
;POINTS.
;
;THIS ROUTINE CAN BE INCLUDED IN THE WINDOWING ROUTINE ABOVE WITH A SMALL
;INCREASE IN PROGRAM EFFICIENCY, BUT IT IS SHOWN SEPARATELY HERE FOR
;CLARITY.

4000    SF = 1./NX                'SCALE FACTOR
4010    FOR J = 0 TO NMAX         'PROCESS POINTS <= 30 Hz
4020      J2 = J+J                'ADDRESS OF REAL COMPONENT
4030      K2 = J2+1               'ADDRESS OF IMAG COMPONENT
4040      X(J) = SQRT(X(J2)*X(J2)+X(K2)*X(K2))*SF 'CALCULATE MAGNITUDE
4050    NEXT J                    'BOTTOM OF LOOP

;END OF PROGRAM.
;
```

```
;****************************************************************************
;*                                                                          *
;*                         TESTING THE PROGRAM                              *
;*                                                                          *
;****************************************************************************
;
;THE BEST WAY TO TEST THE PROGRAM IS TO GENERATE A SYNTHETIC INPUT ARRAY
;OF DATA POINTS CONTAINING SIGNALS AT KNOWN FREQUENCIES, AND PROCESS THEM
;AND CHECK THAT THE RESULTING SPECTRUM IS CORRECT.  TO GENERATE A SIGNAL
;ARRAY WHICH CONTAINS A SIGNAL AT A FREQUENCY Q*DF USE THE FOLLOWING CODE
;BEFORE THE BIT-REVERSAL ROUTINE:

2ØØØ    Q = ...                   'FREQUENCY IN UNITS OF DF
2Ø1Ø    DP = PI2*Q/NX             'PHASE INCREMENT PER SAMPLE
2Ø2Ø    FOR I = Ø TO NXM1         'DATA GENERATION LOOP
2Ø3Ø      X(I) = SIN(DP*I)        'CALCULATE A DATA POINT
2Ø4Ø    NEXT I                    'END OF LOOP

;Q IS A REAL NUMBER, AND SHOULD BE CHOSEN SO THAT Ø <= Q <= NX/2.  NOTE
;THAT THE ARRAY X WILL CONTAIN Q CYCLES OF A SINEWAVE SIGNAL.
;
;AFTER PROCESSING, THE SPECTRUM SHOULD CONTAIN ONLY COMPONENTS NEAR THE
;FREQUENCY Q*DF.  THAT IS, SPECTRAL LINES X(J) SHOULD BE SMALL EXCEPT FOR
;J NEAR Q.  IF Q IS AN INTEGER, THE SPECTRAL LINE X(Q) SHOULD BE 1 AND
;ALL THE OTHERS SHOULD BE Ø (OR OF ORDER 1E-6, DEPENDING ON THE ROUND-OFF
;ERRORS IN THE PROCESSING).  USING NON-INTEGER VALUES OF Q WILL RESULT IN
;A SPECTRUM WITH A CLUSTER OF RESPONSES NEAR X(INT(Q)) BUT LINES FAR AWAY
;FROM Q SHOULD BE SMALL.  THE FALLOFF IN RESPONSE IN THE SPECTRUM AS ONE
;MOVES AWAY FROM THE LINE X(INT(Q)) DEPENDS ON THE EFFECTIVENESS OF THE
;WINDOW FUNCTION, AND THE SHAPE OF THE SYNTHESIZED FILTER RESPONSE CAN BE
;PLOTTED BY USING VARIOUS VALUES OF Q.
;
;NOTE THAT IF NMAX < Q <= NX/2, THE SIGNAL GENERATED LIES IN THE UPPER
;PART OF THE SPECTRUM, WHICH IS THROWN AWAY (DON'T EXAMINE SPECTRAL LINES
;X(J) WHERE J > NMAX, AS THEY HAVEN'T BEEN CALCULATED).  ALSO, IF
;NX/2 < Q < NX, THE SIGNAL WILL BE ALIASED IN THE SPECTRUM, APPEARING AT
;A FREQUENCY OF NX/2-Q.
;
;****************************************************************************
```

Appendix B

ULF TREE POTENTIALS AND GEOMAGNETIC PULSATIONS (U)

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Appendix B

ULF TREE POTENTIALS AND GEOMAGNETIC PULSATIONS

HIGH-SENSITIVITY measurements of ultra-low-frequency (ULF; frequencies less than 5 Hz) geomagnetic pulsations[1] usually require elaborate receiving antennas ranging from large air-cored coils[2] through multi-turn steel, or mumetal-cored solenoids[3-5] to small superconducting loops immersed in liquid helium[6]. Pairs of electrodes inserted in the ground have also been used as antennas[7,8]. The need for a large spacing between the electrodes (varying from hundreds to thousands of metres) and the difficulty of calibrating the measurements absolutely have resulted in the almost universal use of the more compact and easily calibrated coil-type antennas in recent years. I describe here a new method for measuring ULF geomagnetic pulsations, which requires a minimum of elaborate equipment. The method is based on the use of trees, or, more specifically, on the use of pairs of electrodes inserted into trees, as ULF receiving antennas.

There are several reasons that this new method of measurement may be of interest. The equipment is simple and thus the method could lead to more widespread observations of ULF geomagnetic pulsation phenomena. The method of measurement also provides new information about tree potentials, that is, it shows that some, and perhaps all, of the ULF components of these potentials are induced by ULF geomagnetic field fluctuations and do not originate in the trees themselves. Finally, although it is not clear at present what effect induced ULF electric fields may have on the growth and other vital processes in a tree, the link between these ULF electric fields and geomagnetic field fluctuations suggests that some environment-related changes in trees could also be influenced by changes in geomagnetic activity. These changes may have a natural origin (for example, the changes that occur during a solar cycle[9]) or they may be caused by a variety of human activities (by modern d.c.-powered mass transit systems, which can produce large amplitude ULF electromagnetic fields[10]).

The ULF measurements reported here were stimulated by the work of Burr on relatively steady-state tree potentials[11]. Burr recorded these potentials for more than a decade using a pair of specially-designed non-polarisable electrodes inserted in the cambium of an unspecified tree (which was probably a maple). The electrodes were about a metre apart along the long axis of the tree and Burr observed diurnal, 27-d, and seasonal variations, as well as a suggestion of a correlation with sunspot activity, in their potential difference.

Most of Burr's observations were at frequencies far below the frequency range for ULF geomagnetic pulsations. One series of measurement obtained, however, during an electrical storm suggested that ULF variations of tree potentials might occur on occasion. I therefore began a search for variations with frequencies predominantly in the Pc 1 geomagnetic pulsation range (0.2–5 Hz). These frequencies correspond approximately to the delta regime for human brain waves.

The measurements were made using a large native oak, *Quercus lobata*, that was located near conventional ULF recording equipment at a site on the Stanford University campus. This latter equipment uses 20,000 turn steel-cored solenoids as ULF antennas and it operated continuously throughout the interval during which the tree measurements were made. Thus, simultaneous measurements of ULF geomagnetic pulsations using both conventional loop antennas and a tree 'antenna' were obtained at the one location.

Two steel nails were used as electrodes. Following Burr's configuration, they were inserted about 0.05 m into the tree along the long axis, with a spacing of 0.76 m. The lower electrode was approximately 1 m above the ground, and the two electrodes faced toward the geomagnetic west. Because the tree was not completely vertical, a line joining the two electrodes would have been inclined approximately 20° toward the geomagnetic east. The diameter of the tree midway between the two electrodes was 0.65 m.

A resistance of about 5 kΩ was typically observed between the electrodes, increasing to about 10 kΩ if polarisation was allowed to occur. A d.c. potential difference was also observed that varied from day to day but whose absolute value was usually in the range 10 to 100 mV, with the upper electrode positive. The electrodes were connected to a low-frequency high-gain amplifier through an *RC* filter ($R=22$ MΩ, $C=50\ \mu$F). The amplifier was usually set for 50 db gain, and its output was filtered (0.02–7 Hz) before being recorded, generally without additional amplification, on a chart record and on analog magnetic tape.

The ULF signals measured by this system were undoubtedly induced in the tree 'antenna' and not in the shielded cabling between the electrodes and the recording system: when the electrodes were disconnected from the tree and connected to an equivalent 5 kΩ resistor, without any other change in the wiring or configuration of the system, only a steady low level of white noise (typical resistor thermal noise) was observed.

Similarities between the ULF signals recorded conventionally and with the tree 'antenna' were immediately apparent on the chart records. More detailed analysis confirmed that Pc 1 pulsation events recorded by the two systems were very nearly identical in all their important

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characteristics. Figure 1, for example, shows spectrograms of a sequence of four Pc 1 pulsation events that occurred during the interval 1200 to 1500 UT on 17 January 1976, and which were received by the tree 'antenna' (*a*) and the conventional north–south solenoid antenna (*b*). With the exception of a lower signal-to-noise ratio for the tree measurements, the two Pc 1 pulsation records are closely alike. It will also be noticed that the lower frequency Pc 2/Pc 3 geomagnetic activity (frequencies in the range 0.02 to 0.2 Hz) is recorded similarly by both systems. The amplitude of the ULF pulsations in the tree potentials is very small. For the Pc 1 pulsations shown in Fig. 1, the maximum amplitude of the potential fluctuations was about 0.1 mV.

The nearly identical occurrence and spectral characteristics of ULF events measured by the tree electrodes and by the conventional ULF equipment indicated that the tree potentials were largely induced by ULF time variations of the geomagnetic field. To investigate this possibility, a portable planar search coil powered by a 1 Hz signal generator was moved around the tree near the electrodes. It was found that a 1 Hz oscillation of the potential difference between the tree electrodes was produced only when the search coil was orientated with its moment vector in the north–south direction. When the two electrodes were moved to the north face of the tree, a response from the electrodes could be obtained only when the search coil moment vector was orientated in the east–west direction. These results, and the observations of natural Pc 1 pulsations, can possibly be best understood by considering the tree/electrode pair combination to form a collection of conducting loop antennas in which e.m.fs may be induced by magnetic field fluctuations in the appropriate direction. The conducting paths are provided by the conducting material of the tree (and the cambium in particular[11]), and, for field fluctuations in a particular direction, the area of the relevant loop antenna is defined by the intersection of the tree with a vertical plane perpendicular to the particular field direction and passing through the two electrodes. Thus, in the measurements reported here, the Pc 1 pulsation events observed in the tree potentials were produced by Pc 1 pulsations of the north–south component of the geomagnetic field.

Further tests showed that the tree potentials could only be detected in a living tree. Thus, when a tree dies, the potentials gradually disappear as the wood dries and loses its conductivity.

In conclusion, measurements with tree electrodes show that trees may be used as 'antennas' to detect ULF geomagnetic pulsations. The measurements also show that ULF tree potentials are largely produced by ULF fluctuations of the geomagnetic field (the remaining component of the potentials is probably thermal noise). Presman[12] noted that electromagnetic fields usually have an adverse effect on living processes. If the ULF geomagnetic pulsations have any adverse effect on the growth of trees (and, as we have seen, they must induce electric currents in the living material) these effects could possibly be observed in tree ring data. Pc 1 geomagnetic pulsation occurrences vary markedly over a solar cycle[9] and thus, if these particular pulsations effect tree growth, a solar cycle in tree ring data could occur. LaMarche and Fritts[13] searched unsuccessfully for a relation between tree ring data and sunspot numbers. The phase of the Pc 1 pulsation solar cycle, however, differs by several years from the sunspot cycle and, assuming the two cycles affect tree ring data, they may tend to obscure each other's effects. Furthermore, other geomagnetic pulsations and higher-frequency electromagnetic signals have their own cycles of occurrence, and their effects on tree ring formation, if any, could add further to the complexity of the tree ring data. Studies of these possible effects are

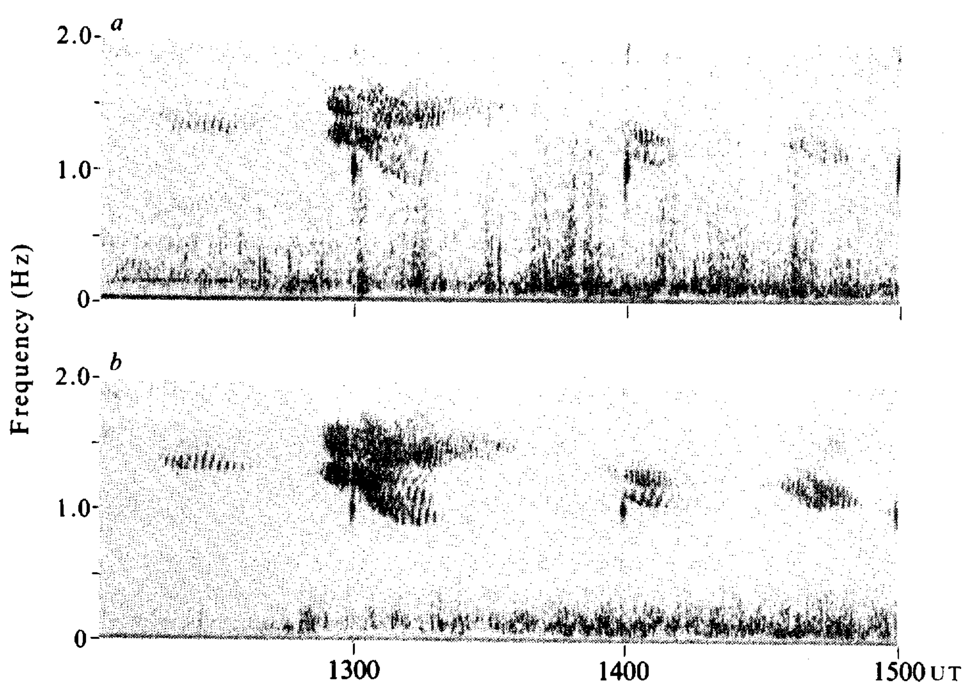

Fig. 1 Spectrograms of a series of Pc 1 geomagnetic pulsation events recorded at Stanford, California, using tree potentials (*a*) and a conventional solenoid antenna (*b*). Short intervals of a 1 Hz calibration signal appear at the start of each hour. The vertical lines in the upper spectrogram are caused either by local electromagnetic transients or by natural sferics; similar lines occur in the lower spectrogram, but they are not as obvious because the background noise is comparatively suppressed.

desirable, because the tree ring data could provide a unique record of past ULF and higher-frequency geomagnetic activity.

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Appendix C

FORMAT FOR SATELLITE BROADCAST OF SPACE ENVIRONMENT SERVICES (U)

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Appendix C

FORMAT FOR SATELLITE BROADCAST OF SPACE ENVIRONMENT SERVICES (U)

(15 February 1984)

There are seven sixty character lines. Each is followed by a carriage return and a line feed.
123456789012345678901234567890123456789012345678901234567890

In the examples of lines, CAPITAL letters are caption information that appears as it does in the broadcast. Small letters represent data that are explained below. The : indicates the 61st space (: is not broadcast). Any data not available for broadcast will be replaced by ***.

LINE ONE - GOES X-RAY AND TOTAL MAGNETIC FIELD
(1 min values broadcast each minute)

```
doy hhmm GOES6 lx.x GOES5 lx.x BOU TF ggggg GAMMAS             :
347 2153 GOES6 B2.0 GOES5 B2.0 BOU TF 55397 GAMMAS
```

where doy = day of year, such as 347

hhmm = hours and minutes, such as 2153

lx.x = x-ray level,(1 min avg), expressed with the B,C,M,X scale, where B = 10^{-7} watts / meter^2, C = 10^{-6} M = 10^{-5} and X = 10^{-4}.
X-rays are measured in a 1-8 angstrom channel on the GOES geosynchronous satellites. An increase in X-ray levels indicates solar flare activity.
In the example B2.0 = 2.0 * 10^{-7} watts / meter^2.

ggggg = Boulder mag field in gammas,(1 min avg), such as 55397

LINE TWO....GOES GEOSYNCHRONOUS MAGNETIC DATA
(1 minute values broadcast each minute)

GOES5 HPsgggg HEsgggg HNsgggg GOES6 HPsgggg HEsgggg HNsgggg :
GOES5 HP+0123 HE-0023 HN+0033 GOES6 HP+0123 HE-0023 HN+0033

where sgggg = sign (+ for positive, - for negative) and value (in gammas) of the magnetic field components at geosynchronous altitudes (approximately 22,000 miles). These are measured by the GOES 5 (W075) and GOES 6 (W135) satellites. These components are HP (parallel to the Earth's rotation axis,+ is north), HE (directed earthward, + is down) and HN (perpendicular to the other two, ie east or west, + is west). Example +0123.

LINE THREE....INDICES

Minute 0

1MEV p.pE+p 10MEV p.pE+p 100MEV p.pE+p PCA aa.aDB NTRN nnnn :
1MEV 3.1E+0 10MEV 2.5E+0 100MEV 1.2E+0 PCA 00.0DB NTRN 0451

where p.pEp = number of protons / (sec*cm^2*ster) at greater than 1MEV, 10MEV,or 100MEV energies (5 min avg), such as 3.1E+0

aa.a = DB of polar cap absorption at 30 MHZ as measured at Thule, (15 Min value), such as 00.0

nnnn = Thule neutron monitor data in millivolts (15 min value). The background level is 460 to 470 mv. Significant deviations are + or - 10% or less than 410 mv and greater than 510 mv. A sharp increase that lasts for a few tens of minutes to hours is a Ground Level Event that is caused by relativistic particles associated with solar flares. A significant decrease that lasts for several hours to several days is a Forbush Decrease. This decrease is the scattering of background cosmic rays due to plasma density enhancements and associated magnetic field enhancements in the near earth solar wind. These enhancements may or may not be solar flare related.

Minute 1

```
doy hh-hh K k/ggg BO Knnnn nnnn PL Knnnn nnnn 10CM rrr       :
347 18-21 K 3/033 BO K3334 333* PL K4334 433* 10CM 104
```

where doy = day of year (current day), such as 347

hh-hh = beginning and ending hours (in Universal Time or Z) for the 3 hr period of the K index to follow, such as 18-21

k/ggg = Boulder K value / Gammas of deflection from the quiet day curve, such as 3/033

nnnn nnnn = K indices determined so far for this day (Boulder or planetary). The first value is for 00Z-03Z, and each index is for the 3 Hr period following the K index preceding it. Missing values will have an *. Example 3324 333* or 4334 433*

rrr = 10 CM solar radio flux in Solar Flux Units, (10^{-22} watts / (meter^2*Hz)) as measured by Ottawa at approximately 1700Z each day. This value is for the doy indicated at the start of the line. Until this value is available *** will be broadcast. Example 104

Minute 2

```
doy BO Aaaa Knnnn nnnn PL Aaaa Knnnn nnnn TEDttt          :
346 BO A017 K3334 4323 PL A024 K4333 4434 TED***
```

where doy = day of year (yesterday), such as 346

aaa = A index (Boulder or Planetary) for yesterday, such as 017, or 024

nnnn nnnn = K indices (Boulder or Planetary) for yesterday, (starting at 00-03Z) missing values will contain *. Example 3334 4323 or 4333 4434

ttt = Total Energy Deposition, an estimate of the total power being dissipated in one hemisphere's auroral atmosphere by precipitating particles. The units are gigawatts. This is a daily average for the doy indicated. Estimates are made using particle data from Tiros satellites. Daily averages vary from near 005 on a quiet day up to about 100 on a very active day. If this data is unavailable *** will be used. Example ***

Minute 3

```
doy 10CM rrr 90 DAY MEAN mmm SSN sss XRAY BGD lx.x          :
346 10CM 104 90 DAY MEAN 110 SSN 090 XRAY BGD B2.5
```

where doy = day of year (yesterday), Such as 346
rrr = 10 CM solar radio flux in Solar Flux Units, for 1700Z on doy indicated, such as 104
mmm = 90 day mean of the 10 CM Solar radio flux through yesterday, such as 110
sss = Sun Spot Number for yesterday, such as 090
lx.x = Xray Background level for yesterday expressed on the B,C,M,X scale, where B = 10^{-7} watts / meter^2 C = 10^{-6}, M = 10^{-5}, and X = 10^{-4}. In the example, B2.5 = 2.5 * 10^{-7} watts / meter^2.

Minute 4

```
doy GOES5 (W075) FLUENCE 1MEV f.fE+f 10 MEV f.fE+f          :
346 GOES5 (W075) FLUENCE 1MEV 2.8E+4 10 MEV 5.2E+3
```

where doy = day of year (yesterday), such as 346
f.fE+f = daily total fluence (protons / (cm^2*day*ster)) greater than 1MEV or 10MEV (as indicated) expressed as an exponential number, such as 2.8E+4, or 5.2E+3

LINE FOUR....HOURLY IONOSPHERIC DATA
Each 24 hour set of data will take 3 minutes to transmit (8 hours of data per line). EMPTY indicates that no data is being transmitted.

```
sss ddddd doy hh nn.n nn.n nn.n nn.n nn.n nn.n nn.n nn.n    :
BOU TEC   347 16 09.5 14.0 20.3 22.8 22.3 22.8 **** ****
```

where sss = station identifier such as BOU:
ddddd = data identifier, such as TEC (Total Electron Count),FOF2 (Critical Frequency of the F2 Layer), M3000 (Optimum Frequency for a Single Hop 3000 KM Transmission), FMIN (Minimum Usable Frequency), or FOES (Critical Frequency of the Sporadic E Layer).
hh = hour of first data group, such as 16
nn.n = data group. There are eight consecutive data groups. Missing data, or data not yet determined will have ****. Data for TEC is in units of 10^{+16} electrons / meter^2, for the others it is MHZ. Example 09.5

LINE FIVE....FORECASTS AND WARNINGS

Minute 0

doy-doy Mnn/nn/nn Xnn/nn/nn Pnn/nn/nn 10CMrrr/rrr/rrr/rrr :
348-350 M01/01/01 X01/01/01 P01/01/01 10CM102/100/098/***

where doy-doy = day of year, first and last days of the forecast
nn/nn/nn = percent probability for occurrence of activity on the first, second, and last day of the forecast. These apply to M flares, X flares, or Proton events as indicated. Example 01/01/01
rrr/rrr/rrr/rrr = forecast 10 CM solar radio flux for the 3 forecast days, such as 102/100/098/*** The last group of rrr is for the last doy plus one and will be *** until approx 18z on the first doy. At this time values will be added.

Minute 1

doy-doy AFaaa/aaa/aaa APaaa/aaa/aaa Kkkkk kkkk kkkk kkkk :
348-350 AF018/015/015 AP020/020/020 K**** **33 3444 3333

where doy-doy = day of year, first and last days of the forecast
aaa/aaa/aaa = forecast A values for the forecast period,either AF, or AP as indicated. Example 018/015/015, or 20/20/20
kkkk kkkk kkkk kkkk = Forecast KP values (without the 0,+,or-). The first of these 16 consecutive K values is for 00Z through 03Z on the first doy listed. Once a forecast K value has been measured it will appear in line two and the forecast value in this line will be replaced by an *. Example **** ***3 3444 3334. At approximately 18Z the remaining values will be updated with a new forecast.

Minute 2

IIIIIIIIIII... :
MAGALERT MINOR

where IIIII...= Description of forecast magnetic activity
This will usually be: which indicates:

This will usually be:	which indicates:
MAGQUIET	only sporadic weak geomagnetic activity

MAGALERT JJ/KK or MAGALERT MINOR JJ/KK	increase in or continued high magnetic activity (JJ/KK are the first and last calendar days of activity)
MAGNIL	end of active period or beginning of period of very low activity (used to end alerts)

Minute 3

IIIIIIIIIIII...
PROTONNIL

where IIIII...= Description of forecast proton activity
This will usually be: which indicates:

PROTONQUIET	no proton enhancements measured in, or forecast for the near earth environment.
PROTON FLARE ALERT JJ/KK QXXYY	Protons expected near earth because the solar region located in quadrant Q (1=NE, 2=SE, 3=SW, 4=NW), Central meridian distance XX, latitude YY, has a 15% or greater probability of a proton flare from days JJ to KK
PROTON ARRIVAL ALERT PP/FF HHmm	Protons expected near earth on day PP from flare which occurred on day FF at HHmm
PROTONALERT JJ/KK	Protons expected to meet the SESC alert criteria (see line 6 ALERTS) in the near earth environment from days JJ to KK
PROTONNIL	end of active period or begining of period of very low activity (used to end alerts)

LINE FIVE....FORECASTS AND WARNINGS (continued)

Minute 4

```
IIIIIIIIIIII...                                         :
SOLQUIET
```

where IIIII...= Description of forecast solar activity
This will usually be: which indicates

SOLQUIET	only sporadic weak solar activity, (class C or smaller flares)
SOLALERT JJ/KK	M Class flares, or an increase in M level activity from days JJ to KK
MAJOR FLARE ALERT JJ/KK QXXYY	region located at QXXYY (see minute 3) has a 15% or greater prob of X class flares from days JJ to KK
SOLNIL	end of active period or begining of period of very low activity (used to end alerts)

LINE SIX....ALERTS
(rotates through all activated alerts)

```
IIIIIIIII.                                              :
ALERT NIL
```

where IIIII...= descriptive text of alert conditions that are met
These are The current alerts

0.ALERT NIL (when no alerts are turned on)
1.245 MHZ BURST > 100 SFU
2.245 MHZ RADIO NOISE STORM > 5 TIMES BKGND
3.10 CM FLARE > 100% ABOVE BKGND
4.TYPE II RADIO BURST
5.TYPE IV RADIO BURST
6.SUSPECTED PROTON FLARE
7.PROTON EVENT 10 PART/CM2*SEC*STER > 10 MEV
8 PROTON EVENT 100 PART/CM2*SEC*STER > 100 MEV

(the numbers are transmitted with the alerts)

9.XRAY >= M5
10.XRAY >= X1
11.A INDEX >= 20 (BOU) (forecast or observed)
12.A INDEX >= 30 (BOU) " " "
13.A INDEX >= 50 (BOU) " " "
14.K INDEX >= 4 (BOU) (fcst, obsvd,or in progress)
15.K INDEX >= 5 (BOU) " " " " "
16.K INDEX >= 6 (BOU) " " " " "
17.K INDEX >= 5-5 (BOU) " " " " "
18.SUDDEN STORM COMMENCEMENT (forecast or observed)
19.STRATWARM
20.SST ALERT: RADIATION >= 10 MILLIREMS (forecast or observed)

LINE SEVEN...MESSAGES

IIIIIIIII...

where IIIII...= unformatted message with up to 60 characters will sometimes be broadcast in this line. Messages that will take more than one line will be broadcast sequentially over several minutes. These sequential messages will start with MMMM at the beginning of the first line. NNNN at the beginning of a line will indicate that the message is complete.

In the future routine products will be transmitted using this line at preselected times. A tentative schedule of these products follows:

PRODUCT	TIME
Current message schedule	00Z
SMM (Solar Maximum Mission) Observing Plan	01Z,07Z,13Z,19Z
Region Report (body of 0030Z report)	02Z,08Z,14Z,20Z
27 Day Forecast	03Z,09Z,15Z,21Z
SGAS (Solar Geophysical Activity Summary) (body of 0245Z report)	04Z,10Z,16Z,22Z
SDF (Report of Solar and Geophysical Activity..formerly Space Disturbance Forecast) (text portion of 2200Z report)	05Z,11Z,17Z,23Z
GEOALERT (body of 0330Z GEOALERT)	06Z,12Z,18Z

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