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Preface

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Acknowledgments and Availability of Report

This report was prepared by C. Eugene Moss and Eric J. Esswein, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Desktop publishing by Ellen E. Blythe.

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SUMMARY

On March 2, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Federal Occupational Health (FOH) office in Seattle, Washington, for technical assistance in assessing exposures to microwave (MW) and radiofrequency (RF) radiation at eight U. S. Army Corps of Engineers (COE) field stations in Washington, Idaho, and Montana. Measurements were performed on MW/RF transmitting sources used in the radio communication network during June 12–20, 1995.

Analysis of the data logged measurements made on towers suggests that COE maintenance workers are not exposed to MW radiation in the 1.7 to 1.8 gigahertz (GHz) region. However, exposure above occupational guidelines can occur from RF sources located either on the COE towers or on adjacent non-COE towers, operating mainly in the 100 to 300 megahertz (MHz) region. Occupational exposure to MW/RF sources located in or around equipment buildings appear to be below guideline values. Workers who climb towers will need to be trained on potential MW/RF exposures and techniques to reduce exposures.

NIOSH investigators determined that COE maintenance workers who climb towers are exposed to electric and magnetic fields that can be in excess of applicable occupational exposure limits. Recommendations for lowering exposures are offered at the end of this report.

Keywords: SIC 4899 (Communication Services, Not Elsewhere Classified) Electromagnetic fields, Radiofrequency, Microwave, safety, MW, RF

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INTRODUCTION

On March 2, 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Federal Occupational Health (FOH) office in Seattle, Washington, for technical assistance in assessing exposures to microwave (MW) and radiofrequency (RF) radiation at eight U. S. Army Corps of Engineers (COE) field stations in Washington, Idaho, and Montana during June 12-20, 1995. These radiation measurements were performed to evaluate potential occupational exposure to COE personnel from MW/RF transmitting sources used in the radio communication network. The FOH office in Seattle provides occupational health consulting services to the COE Seattle district and had asked NIOSH to assist in evaluating occupational MW/RF radiation exposures among workers servicing the network.

BACKGROUND

The Seattle district radio communication network is made up of 16 stations located in Washington, Idaho, and Montana to maintain communication among the COE–operated dams that control water and generate electricity in the three state areas. The network operates in the frequency region from 1.715 to 1.828 Gigahertz (GHz) at a power level of 1 Watt (W). The transmitter operates in a continuous mode and is always on, but the use of the network is quite intermittent. The COE antennas on top of the towers are directional, and workers do not normally operate in the beam path.

Each network station consists of a tower and a small, adjacent equipment building housing electronic components and accessories to operate the transmitter and antenna. There are at least two COE antennas located on each metal tower, typically 50 to 60 feet above the ground; one is used to transmit, the other to receive. At some COE stations, there are other transmitting sources mounted on the COE tower operated either by city, state, COE, or other federal agencies (a "shared" tower configuration). Transmitting sources which are in a shared configuration operate at frequencies and power levels different from those used by the COE network. There are also COE stations which have equipment buildings and towers owned by non–COE agencies (a "non–shared" tower configuration). These non–shared towers have transmitting sources which operate at other frequencies and power levels than the COE sources. In many cases these non–shared towers are located next to the COE towers, creating a potential for radiation emissions to be incident on workers climbing COE towers.

The COE towers are typically serviced at least once per year. During a typical service period, two workers determine communication status between two adjacent stations. After establishing contact and verifying communication and electronic compatibility, one of the two workers moves to another site, and the process is repeated until all of the stations are serviced. While most of the maintenance/service work occurs in the equipment building, it may be necessary to realign the antenna or to check and confirm electrical and mechanical connections on the tower. If it is necessary to climb the tower, the worker dons a safety climbing belt and an ascending device, notifies the other worker on the radio, and ascends the tower.

METHODS

At each of the eight stations, radiation measurements were performed in the equipment building, at the base of the tower, and during a six to nine–minute tower climb. The climber wore a back pack containing battery–powered MW/RF meters, and a datalogger which stored radiation exposure data as a function of time. The climber would come to the tower base where the NIOSH investigator would activate the meters and datalogger in the back pack. Upon completion of the climb, the system would be deactivated, the climber's back pack removed, and the stored data down–loaded to a portable laptop computer. Each climb was videotaped, and the timer on the videotape was compared with the data logged from the MW/RF meters to determine locations where highest levels of radiation were measured.

MW/RF exposures can also occur to maintenance workers from "leaks" in transmitter cabinets, conduits, and transmission cables. These localized exposures exist on the tower from cables leading to the transmitting sources. Such hot–spot readings may be shown on time–intensity figures as peaks lasting less than five seconds and can occur whenever the probes come into contact with these spots.

MW/RF radiation levels were measured using the following equipment:

- A Holaday Model 3002 survey meter using two probes: a model STE for the electric (E) field and a model STH for the magnetic (H) field. The E–field probe is designed to cover the frequency range from 0.5 to 6000 megahertz (MHz) and measures the E–field strength in units of volts squared per meter squared $(V/m)^2$. The lowest meter indicating level (LMIL) for this probe–meter combination system is 500 $(V/m)^2$. The H–field probe is designed to cover the frequency range from 5 to 300 MHz and measures the H–field strength in units of amperes squared per meter squared $(A/m)^2$. The LMIL for this probe–meter combination system is 0.005 $(A/m)^2$.

- A Narda electromagnetic radiation monitor model 8616 connected to either a Narda H–field isotropic probe model 8633 (10 to 300 MHz) or an E–field isotropic probe model 8621B (0.3 to 40 gigahertz [GHz]). Both field probes, when connected to the monitor, measure field intensities in milliwatts per square centimeter (mW/cm^2) over their respective frequency region. The LMIL is 0.05 mW/cm^2 for the 8616/8633 system and 0.01 mW/cm^2 for the 8616/8621B systems.

- A Metrosonics Industrial Hygiene Datalogging System was used to collect the data generated by the MW/RF measurement systems. The Metrosonics system includes the model dl–3200 datalogger and the ms–3200 Metrosoft Software. The menu–driven software controls and sets up the datalogger. The battery–operated datalogger uses a serial RS–232 communication format that collects data at one sample per second. The system can provide statistics for minimum, average, and maximum values. Data from the system was exported to a softwear package to obtain selected time–intensity figures for this evaluation.

- Body currents resulting from exposure to E–fields in the RF frequency region (i.e., frequencies below 300 MHz) were evaluated using a body current detector system. This system is based on the principle that when RF energy is absorbed, electric currents are induced within the body. These body currents can be measured by using a foot current sensor designed to respond only to currents induced by external E–fields. The body currents were measured by having the worker stand on a 6–millimeter thick, 32 by 32–centimeter polyethylene sheet clad on both sides with copper. The current from the upper plate, where the worker stands, passes to the lower copper plate, which is in contact with the ground through a non–inductive carbon resistor located in the center of the bi–layered sensor. The RF current across the resistor is measured with a calibrated RF milliammeter. All current measurements were made with the worker standing on the sensor either in front, or under, the tower structure. The sensor could also be placed in direct contact with the tower structure as a means to determine the current induced onto the tower structure (i.e., contact current) from exposure to either shared or non–shared sources. When used in this contact current mode, body currents could not be recorded. The presence of contact currents merely confirms that currents are being induced on the given tower from some field in the immediate vicinity.

- The source frequencies were measured using an Optoequipment Handi–Counter Model 3000 battery–powered frequency counter. Knowledge of the frequency is critical in evaluating MW/RF exposure relative to occupational standards since the guidelines are frequency dependent.

Workers who climb the tower are not normally exposed to the radiation produced by the COE network, since the transmitted signal is aimed away from the tower. Radiation exposure could occur, however, from other COE or non–COE sources mounted on the COE tower, or from adjacent "non–shared" towers. Furthermore, it was not known for how long any source on any tower ("shared" or "non–shared") would transmit. Unfortunately, the NIOSH investigators did not utilize a frequency analyzer that would have provided information about what signals (frequencies) are produced at a given time. Therefore, precise knowledge of the frequencies from all available sources present in and around the tower and during the actual climb is not available for this evaluation. What is known, however, is the dominant frequency observed by the frequency counter at a given time of the climb. It is those frequencies which are used to compare exposures with occupational criteria.

EVALUATION CRITERIA

Microwave/Radiofrequency Radiation

Absorption of MW/RF energy can adversely affect a worker's health. Human and animal studies indicate that this type of radiation can cause harmful biological effects due to excessive heating of body tissues. MW/RF radiation can penetrate the body and cause heating of internal tissues. The body's heat sensors are located in the skin and do not readily sense heating deep within the body. Therefore, workers may absorb large amounts of radiation without being immediately aware of the presence of such energy. There have been reports that workers exposed to MW/RF fields from radar equipment, MW/RF heaters and sealers, and radio/TV towers have experienced a warming sensation some time after being exposed.

Many of the observed biological effects of exposure to MW/RF radiation can be attributed to a rise in body temperature. The heating effect of MW/RF within the body depends on the amount of energy absorbed by the skin. The rate of absorption, denoted as the specific absorption rate (SAR), is measured in watts per kilogram (W/kg) for the whole body or parts of the body. The SAR depends on many factors such as the frequency and intensity of the radiation, size and shape of the exposed worker, and the worker's orientation in the radiation field. The human body absorbs maximally in the frequency range of 30 to 300 MHz. Outside this range, much less energy is absorbed by the body from the radiation field.

The most influential standard for occupational exposure to MW/RF radiation is the Institute of Electrical and Equipment Engineers (IEEE) standard published by the American National Standards Institute (ANSI) and known as ANSI C95–1991. The IEEE committee concluded that a SAR of 4 W/kg represents the threshold absorption level above which adverse health effects may arise as body temperature increases. A safety factor of 10 was then applied to reduce this SAR to 0.4 W/kg as the maximum permissible exposure limit, averaged over the entire body. The standard uses dosimetry measurements of MW radiation to calculate the power density limit necessary to achieve an SAR of 0.4 W/kg when averaged over a six–minute period. Table 1 shows the maximum permissible exposures (MPEs) presently considered safe by the IEEE as a function of frequency.

The Occupational Safety and Health Administration (OSHA) has a radiation protection guide (defined as the radiation level which should not be exceeded without careful considerations of the reasons for doing so) of 10 mW/cm^2 averaged over any possible six–minute period (29 CFR

1910.97 [1991]). This standard is applicable for far field measurements and is not useful in evaluating near field exposure scenarios, which are of concern in this evaluation.

Body Currents

In addition to E– and H– field exposure limits, the IEEE C95–1991 committee has adopted a body current limit of 200 milliamperes (mA) as measured through both feet. This value of 200 mA limits the partial body SAR to levels less than 20 W/kg in the extremities and protects against electrical shocks and burns.

RESULTS

Data was collected in two formats. The first format was a walk–around data collection mode and was obtained by measuring incident E– and H–field intensities at various locations in and around the towers, including the equipment buildings. Approximately 200 measurements of this kind were made at the eight stations.

The second collection format was denoted "data–logged results," and consisted of 26 events at the eight stations. The MPEs for the IEEE C95–1991 standard refers to values averaged over any six–minute period for frequencies less than 15 GHz. The data–logged results obtained at the stations were used to determine the maximum six–minute average for both electric and magnetic fields, and compared to the MPE levels.

Adams Ridge

This station is located about 120 miles west of Spokane and sits on approximately 1 acre that is surrounded by an 8' high locked fence area adjacent to a dirt country road. Measurements were performed on June 12–13, 1995. The station is located next to a farmer's equipment barn that contains tractors and typical farming equipment. There are two transmitting sources on this property, the COE microwave network and a Department of Defense (DOD) 1000 W High Frequency (HF) single sideband system that operates within the frequency region from 2 to 30 MHz. Although the COE personnel do not service or come in contact with the DOD system, measurements were performed on the system because of the possibility of it contributing to occupational exposure to COE workers when climbing the tower. All measurements made in the equipment building were below LMIL levels for frequencies at the station. The farmer did not report any electromagnetic interference (EMI) problems and EMF levels in the adjacent farm building were all below LMIL.

Data recorded from tower climb
E–field ranges: 21.2 to 3250 $(V/m)^2$ during a 6:30 minute (min) climb
H–field ranges: 0.002 to 0.05 $(A/m)^2$ during an 8:00 min climb
Maximum body current: 1 mA at tower base during both climbs

Measurements made on DOD Communication System: 2 to 30 MHz, 1000 W
At 10 feet (on ground) from the center of overhead line: 1×10^3 $(V/m)^2$
At feed point 6 feet above ground: 2×10^5 $(A/m)^2$
Tower contact current 12 feet above ground: 19 mA

Figure 1 is a time-intensity plot of the E–field made at Adams Ridge showing the variation of field strength with time during the climb on the COE tower. It is possible that the DOD system had some influence on the E–field exposures while climbing the COE tower. Figure 1 indicates more activity at the beginning and end of the climb than in the middle. The video tape indicates that the climber was on top of the tower around 9:34 and stayed there until 9:36 when the descent began. Since the height of the DOD communication system was lower than the COE tower, this increased activity may be due to the DOD source, or may be due to hot–spots, as explained earlier. The H–field time-intensity plot (Figure 2) was not as active as the E–field.

Creston Butte

This station is located about 40 miles from Spokane and contains a multitude of transmitting sources and towers. The station is located on a small rise and is accessible by a small dirt road. Measurements were made at this station on June 13, 1995, around noon. The entire area is surrounded by a fence and the gates to the site were locked. The equipment building used by the COE for their tower is an old underground bomb shelter located approximately 60 feet from the tower. An attempt was made to document transmitting frequencies in the vicinity of the tower, but the only frequency clearly detected was a police band at 155.24 MHz which COE personnel thought was at 100–110 W. However, it is probably safe to assume that other frequencies were present but were not transmitting during the time of the NIOSH evaluation, which was at 12:30 to 1:15 p.m. Measurements made at the tower base and inside the building were all below LMIL.

Data recorded from tower climb
E–Field ranges: 20.3 to 8.7×10^4 $(V/m)^2$ during a 7 min climb
Maximum body current at tower base: 3 mA

The data logged results, shown in Figure 3, indicate that E–fields were detected only near the end of the climb. Frequency measurements made by NIOSH investigators suggest that these bursts may have been caused by a source radiating near 155 MHz.

Mt. Spokane

This station is located on top of Mt. Spokane approximately 20 miles north of Spokane. There are many buildings and antennae located near the COE site. The two story COE equipment building and tower were built in 1971. Extensive measurements were made on June 14 and June 20, 1995, both inside the building and on the tower. Measurements made outside the building and around other buildings in the immediate area were all below LMIL. The COE tower had three radiating sources: a 1.7–1.8 GHz (COE network), 163.45 MHz (COE communication system), and a 169 MHz (Federal Bureau of Investigation [FBI]) source).

Data recorded inside the equipment building
E–field ranges (1st floor): 0 to 29.2 $(V/m)^2$ during eight different runs
E–field ranges (2nd floor): 0 to 1.06×10^4 $(V/m)^2$ during one run for one hour
H–field ranges (2nd floor): 0 to 2.3×10^{-4} $(A/m)^2$ during one run for one hour
Maximum body current on 1st floor: 0 mA

Data recorded from tower climb
E–field ranges: 0 to 1.49×10^5 $(V/m)^2$ during a 9.5 min climb
H–field ranges: 1.2×10^{-3} to 0.018 $(A/m)^2$ during a 8.2 min climb
Maximum contact current: 430 mA

The maximum E–field measurement inside the building, 1.06×10^4 $(V/m)^2$ (on the second floor), occurred at the end of the run; and the source of that field is unknown. Additional measurements were taken immediately after the data logged results were obtained, but no reading greater than 25 $(V/m)^2$ was obtained. The NIOSH investigators were not able to explain this high inside reading.

Figure 4 indicates that there was consistent MW/RF activity associated with the climb on June 14, 1995. This activity was probably due to either the 162.45 or the 169 MHz sources (shared sources) or from other, unknown sources on adjacent towers (non–shared sources). During this climb, contact currents as high as 430 mA were observed. The E–field data logged results on June 20 were very high and support the need that workers who climb towers at transmitting facilities, such as found at Mt. Spokane, need to be aware of the real potential for exposure.

Albani Falls Dam

Since this site had one of the highest COE towers in the network, it was decided to have the climber wear two monitors and detectors (one for the E–Field and the other for the H–Field) so that only one climb would be necessary. Measurements were made at this station on June 15, 1995. Since there were no other towers in the immediate area, any EMFs detected would have to be related to sources on the towers. The sources identified were the 1.7–1.8 GHz COE network, the 163.45 MHz communication system, and the 109 MHz Dam communication frequency. During a portion of the approximate 18 min climb, the probes and detectors were held outside of the metal tower structure to determine if it made any difference in detecting radiation (it did not). All radiation levels inside the equipment buildings were below LMIL. The COE frequency of 163.45 MHz was not on during the climb, but after the climb was completed it was activated and measurements were made near the tower base by utilizing both the contact current meter and the frequency counter. The contact current meter displayed 35 mA.

Data recorded from tower climb
E–field ranges: 142 to 3600 $(V/m)^2$ during a 18:00 min climb
H–field ranges: 9×10^{-4} to 4.9×10^{-3} $(A/m)^2$ during a 18:00 min climb
Maximum body current at tower base during climbs: 5 mA

The E and H fields were very low. The bulk of the E–field activity, as shown in Figure 5, occurred in 6 peaks, each lasting one to 2 seconds, while the H–field activity was limited to just one peak. The most dominant frequencies observed were either the 109 or 153.45 MHz signal. Since the climbing tower rungs became compressed with height, the climber had extreme difficulty in climbing in tight quarters with a backpack having probes protruding from the pack. The video tapes show that the probes were trapped in metal structures on the tower resulting in hot–spot indications.

Black Mountain

Measurements were made at this site on June 16, 1995. This site, located at the top of a mountain, had several towers located close to the COE tower with approximately 10 transmitting sources. The sources identified as being shared on the COE tower (in addition to the 1.7–1.8 GHz network source) were a 160 MHz source operated by the Union Pacific Railroad, 172.5 MHz Border Patrol (BPA) source, and several State of Idaho frequencies.

Data recorded from tower climb
E–field ranges: 10 to 1190 $(V/m)^2$ during a 9:25 min climb
H–field ranges: 0.0 to 0.36 $(A/m)^2$ during a 9:20 min climb
Maximum body current near tower base for at least 2 minutes during climbs: 70 mA

Figure 6 shows the time-intensity plot for the E–field. Both the electric and magnetic field time intensity plots were quite active during the climb time. It was estimated, using the frequency counter, that the 160 and 172.5 MHz sources were probably responsible for this activity during the climb time. However, other unrecognized frequencies, probably from the nearby towers, were also present at the same time interval. Measurements in and around several of the equipment buildings produced radiation levels below LMIL.

Libby Dam

This site was unique in that the COE antennae were not located on a metal tower. Rather, the sources were mounted on top of the dam's wall and access to the sources, as well as the equipment area, was through a door on the dam's roadways. Measurements were made at this station on June 17, 1995, in front and back of the COE sources since they were directly accessible to NIOSH investigators. Available sources were the 171 MHz source for the Water Work, the 6GHz BPA sources mounted on the Dam's front, the 1.7–1.8 GHz COE network, local COE broadcast system at 530 MHz or 1610 MHz, and the COE communication at 163.45 MHz. No data–logging was done at this site, instead measurements were recorded manually.

Data recorded manually

Recorded E–field: All antennae measurements taken in front and on sides were below LMIL

Recorded H–field: range 0.0 to 19.4 $(A/m)^2$ along back, front center, and perimeter of the antenna. This maximum result was confirmed (twice) by turning off the 1.7–1.8 GHz network and measuring zero.

Maximum body current near antenna base: 6 mA

COE workers normally do not work on towers in such a way that they are in front of the antennae. At Libby Dam, the location of the sources presents a potential situation that could result in worker exposure to the COE network. The Holaday meters do not respond to H–fields above 300 MHz, the high fields that were recorded were artifacts (this last statement has been verified by the manufacturer). Therefore, measurements made at this station at extremely close distances to the antennae clearly showed that the outputs of concern for tower climbers were not associated with the microwave system of 1.7 to 1.8 GHz, but rather were due to frequencies other than 1.7 to 1.8 GHz.

King Mountain

This site had only one tower but there were six different sources located on it. These included the 1.7–1.8 GHz COE network, Northern Light 47 MHz source operating at 60 to 75 watts, an unknown source operating around 170 MHz at 110 W, COE communication at 164 MHz at 55 W, a ham radio digital feed at 223 MHz at 10 W, 2–meter digital feeder at 145 MHz at 35 W, and a BPA source at 169 MHz operating around 5 W. On June 19, 1995, only H–field data–logged results were made at the station as shown in Figure 7. Since the H–field cannot be recorded above 300 MHz, then the fields measured were due to the presence of the other sources on the towers. Magnetic field measurements were also made at the tower base, 20 feet above the base, and 30 feet above the base to see how the level might change with distance above ground.

Data recorded on tower

H–field results: 0.0 to 0.85 $(A/m)^2$ near antenna edge during a 10:25 min climb

1×10^{-4} to 1.4×10^{-4} $(A/m)^2$ at tower base over 5 min samples

9×10^{-4} to 2.5×10^{-3} $(A/m)^2$

20 feet above tower base over 6 min sample

9×10^{-4} to 1.6×10^{-3} $(A/m)^2$

30 feet above tower base over 5 min sample

Due to time constraints, no E–field, body or contact current data was taken at the station.

Tony Mountain

This site contained a 70–foot tower constructed in 1982, that was difficult to reach due to numerous fallen trees that had to be cleared using a hand saw. There were three sources at this tower; 1.7 to 1.8 GHz COE network, a 171–172 MHz source operating at 35–50 W, and the Forest Service communication system. Due to an impeding rain storm in the afternoon of June 19, 1995, a climb was not performed. One H–Field measurement was performed at the tower base and very little activity was seen. Levels measured were 1×10^{-4} to 4×10^{-4} $(A/m)^2$. No frequencies were observed during this measurement and all E– and H–field strength measurements in and around the equipment building were below LMIL. Body current levels at the tower base were zero.

DISCUSSION

Tower Measurements

The maximum six–minute averages for both the E– and H–field were determined for each climb (Table 1). While measurements of the frequencies were made on the incident radiation field exposing the tower with a frequency counter, it was impossible in a multi–source environment, without using a frequency analyzer, to determine for how long a given frequency signal was on. In this evaluation, a number of communication sources operate in the same IEEE frequency bands as shown in Table 2. Unfortunately, not all of the MW/RF sources at a given station were emitting during the measurement periods. It is possible, however, to assume a worst case for worker exposure to human resonance frequencies (i.e., 30 to 300 MHZ) or the maximal absorbing range. Almost all of the frequencies encountered in this evaluation were in this region, except for the 1.7–1.8 GHz area. Using this assumption the E–field measured at Mt. Spokane and the H–fields measured at Black and King Mountains exceeded the MPE for these frequency regions. While the assumptions made for this type of an analysis has its limitations, it does suggest that at certain times the MW/RF levels encountered by COE maintenance workers can exceed occupational exposure guidelines. Although COE maintenance personnel climb towers very infrequently, they still need to be informed that exposures above occupational guidelines are possible.

The dominant exposures associated with climbing tower are not associated with the 1.7 to 1.8 GHz system but are due to frequencies in the 30 to 300 MHZ range produced by COE shared and non–shared tower sources. The NIOSH investigators found that there is more occupational exposure from MW/RF sources located on non–shared towers than from COE shared towers. These findings may make controlling MW/RF occupational exposure even more difficult for COE safety personnel.

While contact currents as high as 430 mA were measured (when the meter was placed in direct contact with the tower), those levels were not on a worker. In contrast, worker's body currents near the ground were much lower. There is no easy way to measure actual body currents to workers during climbing activities. The presence of the contact currents only indicates that currents are being induced on towers from some nearby fields, as well as from sources located on the tower itself. Moreover, the strengths of the contact currents vary from station to station depending on a number of parameters, such as power level being absorbed by the tower, construction and location of the tower, and the manner in which the meter was applied to the metal tower surface.

Site Measurements

All MW/RF levels were below the LMIL either in the equipment buildings, the ground around the tower structure, outside the equipment buildings, and in the immediate vicinity of parked vehicles. All body current measurements taken at non–tower locations were below 1 mA.

CONCLUSIONS

Analysis of the data–logged measurements made on selected towers suggests that COE maintenance workers are not exposed to MW radiation emitted by their microwave system in the 1.7 to 1.8 GHz region. However, occupational exposure above occupational guideline limits can occur to workers from RF sources operating mainly in the 100 to 300 MHZ region, located either on the COE towers or on adjacent non–COE towers. Exposure to MW/RF from sources located in and around the equipment buildings appears to be quite low. COE maintenance workers who need to climb towers to perform their tasks will need to be informed (trained) about the potential for exposure and techniques to reduce that exposure. While this evaluation did show a potential to exceed the MW/RF occupational guidelines, it should be noted that due to the manner in which the data was collected, these measurements should not be used to predict future exposures.

RECOMMENDATIONS

THE FOLLOWING RECOMMENDATIONS ARE OFFERED TO REDUCE OCCUPATIONAL EXPOSURES AND SAFETY RISKS TO WORKERS WHO PERFORM MAINTENANCE OF THE COE MICROWAVE FACILITIES:

1. THE USE OF A TOWER CLIMBING LOG FOR EACH STATION WOULD BE USEFUL IN BETTER ESTIMATING EXPOSURE POTENTIAL TO RF SOURCES. THIS LOG WOULD CONTAIN CLIMBING DATES, REASON FOR THE CLIMB, APPROXIMATE CLIMB TIME, AND A DESCRIPTION OF THE ACTUAL TASK PERFORMED.

2. DISCUSSIONS WITH THE COE WORKERS INDICATE THAT THEY ARE NOT REQUIRED TO HAVE ANNUAL PHYSICALS. IT SEEMS REASONABLE THAT CLIMBING 30 TO 90 FT TOWERS, CARRYING HEAVY ELECTRONIC EQUIPMENT AND CUTTING AND MOVING TREES THAT FALL ON ROADS, ARE JOB TASKS THAT REQUIRE WORKERS BE IN GOOD PHYSICAL SHAPE. WORKERS INVOLVED WITH SUCH ACTIVITIES SHOULD HAVE SOME FORM OF MEDICAL SURVEILLANCE (SUCH AS ANNUAL PHYSICALS).

3. IT WAS OBVIOUS THAT THE COE WORKERS ARE OFTEN AT REMOTE LOCATIONS BY THEMSELVES. CONSIDERATIONS SHOULD BE GIVEN TO HAVING AT LEAST TWO WORKERS AT EACH LOCATION AS PART OF A “BUDDY” SYSTEM. THIS IS ESPECIALLY IMPORTANT IN CASES WHERE SOMEONE FALLS DOWN A LADDER, BREAKS BONES TRIPPING OVER LOGS, OR CUTS THEMSELVES WITH A SAW. THE USE OF A GLOBAL POSITIONING SYSTEM (GPS) TO HELP LOCATE A WORKER TO WITHIN A FEW METERS WOULD ALSO BE USEFUL. FURTHERMORE, THE USE OF A “BUDDY” SYSTEM WOULD IMPROVE THE FIRST AID PROGRAM, SINCE IT PROVIDES A WAY FOR TIMELY FIRST AID TO BE RENDERED THAT THE CURRENT WORK ARRANGEMENT DOES NOT PROVIDE.

4. COE SHOULD TAKE STEPS TO DEVELOP A MW/RF SOURCE INVENTORY FOR EACH COE TOWER. IT MAY ALSO BE USEFUL TO HAVE DETAILS ON ALL SOURCE CHARACTERISTICS AT ALL THE TOWERS INDEPENDENTLY WHETHER THEY ARE COE OR NON–COE SOURCES. IN THIS WAY WORKERS WILL HAVE MORE KNOWLEDGE OF THEIR EXPOSURE POTENTIAL.

5. IT IS STRONGLY SUGGESTED THAT THE PRACTICE OF USING HAND SAWS TO CUT TREES WHICH HAVE FALLEN ACROSS ROADS BE IMMEDIATELY TERMINATED, AND PORTABLE GAS SAWS BE PURCHASED. IN ADDITION TO THE HAZARDS ASSOCIATED WITH CUTTING LARGE TREES, COE NEEDS TO CONSIDER THE ERGONOMIC CONCERNS ASSOCIATED WITH MOVING THE PARTS OF THE CUT TREES. THERE MAY BE A NEED TO USE WINCHES ON TRUCKS TO ASSIST IN THE MOVEMENT OF LARGE TREE PARTS. IT IS REALIZED THAT THE USE OF GAS SAWS MAY REQUIRE THE NEED TO HAVE A HEARING CONSERVATION PROGRAM, IN ADDITION TO WEARING OF GLOVES AND PROTECTIVE EYEWEAR; HOWEVER, IN THE OPINION OF THE INVESTIGATORS THE ADVANTAGES OF SUCH AN ACTION FAR OUTWEIGH THE DISADVANTAGES.

6. ANY MAINTENANCE OPERATIONS AT FIELD STATIONS THAT REQUIRE WORKERS TO SPEND LONG TIMES (SUCH AS SEVERAL HOURS PER DAY) ON TOWERS MAY NEED TO BE STUDIED BY COE TO MINIMIZE POTENTIAL OCCUPATIONAL MW/RF EXPOSURES.

7. COE SHOULD DEVELOP OTHER TECHNIQUES TO IDENTIFY MAINTENANCE PROBLEMS ON TOWERS BESIDES CLIMBING. SUCH MONITORING TECHNIQUES COULD INCLUDE THE USE OF TV CAMERAS OR SPECIAL BINOCULARS.

8. COE SHOULD DEVELOP INDUCED AND CONTACT CURRENT MONITORING PROGRAMS FOR WORKERS WHO ARE REQUIRED TO CLIMB TOWERS. THIS DATA CAN BE USED TO TRAIN WORKERS AND DEVELOP PROGRAMS THAT MINIMIZE OCCUPATIONAL EXPOSURE TO MW/RF SOURCES.

9. After 1998, OSHA will require construction industries to use full body harnesses for workers on towers. COE safety personnel may wish to investigate the incorporation of harnesses in their fall protection programs. Experience has shown that harnesses offer better worker protection against falls than safety belts.

References

1. IEEE [1991]. Safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz. Institute of Electrical and Electronics Engineers Standard C95.1–1991.

Table 1 Summary of E– and H–Field Measurements at eight COE MW/RF Stations on June 12–20, 1995 National Institute for Occupational Safety and Health HETA 95–0177								
Tower Location	Tower Type	MW/RF Sources at Site	Duration of Tower Climb (minutes)	Data Range from Tower Climb		Maximum Body (B) or Contact (C) Current (mA)	Highest 6 min Average	
				Electric Field $(V/m)^2$	Magnetic Field $(A/m)^2$		E $(V/m)^2$	H $(A/m)^2$
Adams Ridge	Non–Shared	1.7–1.8GHz @ 1 W (COE) 2 to 30 MHz @ 1000 W (DOD)	6.5 8.0	21.2 to 3250	$2x10^{-3}$ to 0.05	1 (B) 19 (C)	5200	.003
Creston Butte	Shared and Non–Shared	1.7–1.8GHz @ 1 W (COE) 155.24 MHz @ 110 W (police)	7.0	20.3 to $8.7x10^4$	Not Taken	3 (B)	2530	—
Mt. Spokane	Shared and Non–Shared	1.7–1.8GHz @ 1 W (COE) 163.45 MHz @ ? W (COE) 169 MHz @ ? W (FBI)	9.5 8.2	0 to $1.49x10^5$	$1.2x10^{-3}$ to 0.018	482 (C)	4900	.006
Albani Falls Dam	Shared	1.7–1.8GHz @ 1 W (COE) 163.45 MHz @ ? W (COE) 109 MHz @ ? W (COE)	18.0	142 to 3600	$9x10^{-4}$ to $4.9x10^{-3}$	5 (B) 35 (C)	190	.001
Black Mountain	Shared and Non–Shared	1.7–1.8GHz @ 1 W (COE) 160 MHz @ ? W (UPR) 172.5 MHz @ 5 W (BPA) Unknown Idaho State sources	9.3 9.2	10 to 1190	0 to 0.36	70 (B)	110	.09
Libby Dam	Shared	1.7–1.8GHz @ 1 W (COE) 171 MHz @ ? W (Water Works) 6GHz @ ? W (BPA) 163.45 MHz @ ? W (COE) 530 and 1610 MHz	No Climb	LMIL	0 to 19.4	6 (B)	—	—
King Mountain	Shared	1.7–1.8GHz @ 1 W (COE) 47 MHz @ 75 W (NorthL) 170 MHz @ 110 W ? 163.45 MHz @ 55 W (COE) 223 MHz @ 10 W (Ham) 145 MHz @ 35 W (Ham) 169 MHz @ 5 W (BPA)	10.25	Not Taken	0 to 0.85	Not Taken	—	.048

TABLE 1
SUMMARY OF E– AND H–FIELD MEASUREMENTS AT EIGHT COE MW/RF STATIONS ON JUNE 12–20, 1995
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
HETA 95–0177

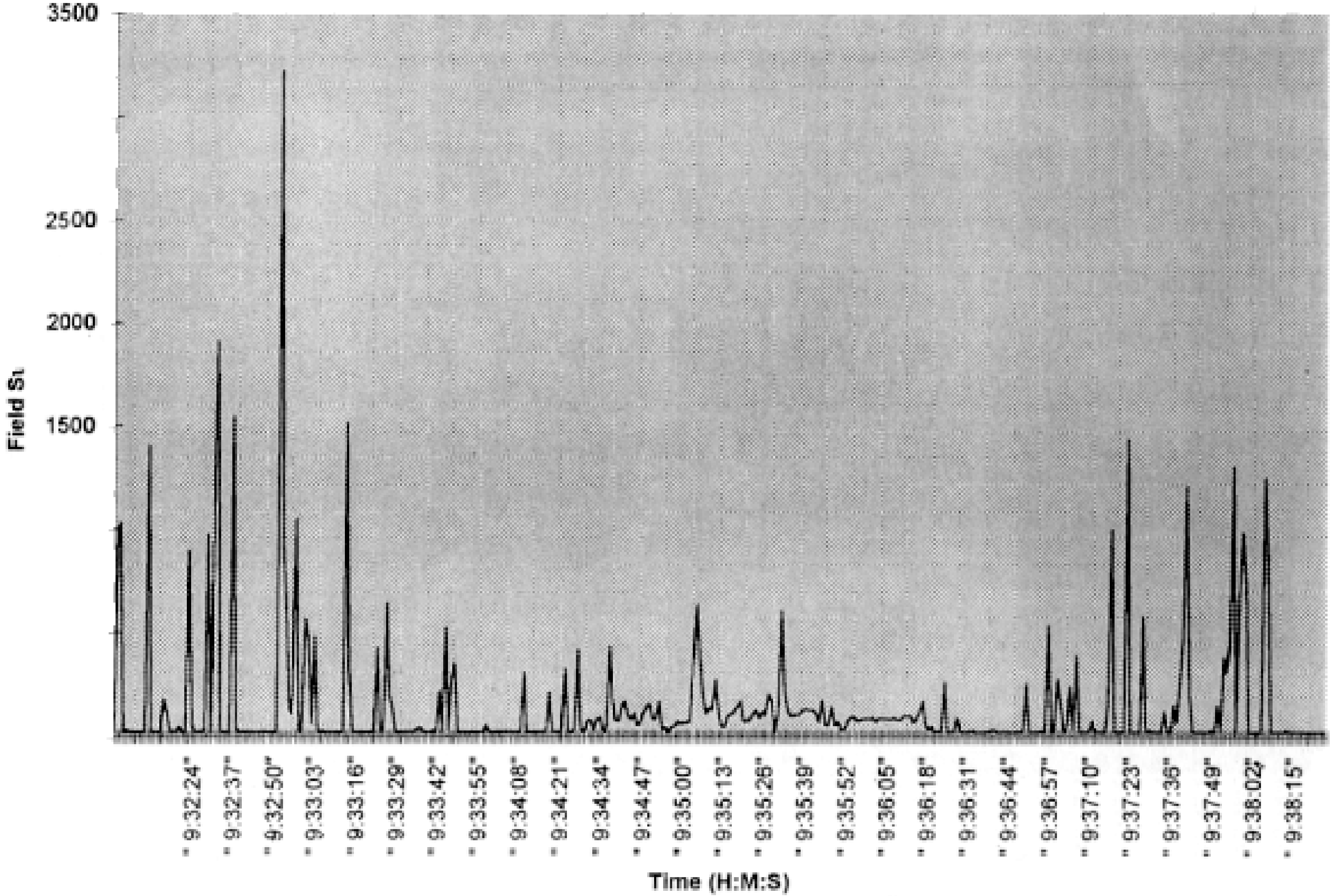
TOWER LOCATION	TOWER TYPE	MW/RF SOURCES AT SITE	DURATION OF TOWER CLIMB (MINUTES)	DATA RANGE FROM TOWER CLIMB		MAXIMUM BODY (B) OR CONTACT (C) CURRENT (MA)	HIGHEST 6 MIN AVERAGE	
				ELECTRIC FIELD $(V/M)^2$	MAGNETIC FIELD $(A/M)^2$		E $(V/M)^2$	H $(A/M)^2$
TONY MOUNTAIN	SHARED	1.7–1.8GHZ @ 1 W (COE) 171 MHZ @ 50 W ? U. S. FOREST SERVICE ?	NO CLIMB	NOT TAKEN	$1x10^{-4}$ TO $4x10^{-4}$	0 (B)	—	—

? = UNKNOWN OR ESTIMATED

TABLE 2. RF AND MICROWAVE IEEE OCCUPATIONAL EXPOSURE GUIDELINES

FREQUENCY RANGE (MHZ)	ELECTRIC FIELD STRENGTH $(V/M)^2$	MAGNETIC FIELD STRENGTH $(A/M)^2$	POWER DENSITY E–FIELD/H–FIELD (mW/cm^2)
0.003 – 0.1	377,000	26,600	
0.1 – 3	377,000	$(16.3/f)^2$	
3 – 30	$(1842/f)^2$	$(16.3/f)^2$	
30 – 100	3770	$(16.3/f)^2$	
100 – 300	3770	0.027	1.0
300 – 3,000			f/300
3,000 – 15,000			10
15,000 – 300,000			10

f = frequency in MHz
MHz = megahertz
V/m = Volts per meter
A/m = Amps per meter
mW/cm^2 = Milliwatts per square centimeter



3500
2500
2000
1500
Field St
9:32:24
9:32:37
9:32:50
9:33:03
9:33:16
9:33:29
9:33:42
9:33:55
9:34:08
9:34:21
9:34:34
9:34:47
9:35:00
9:35:13
9:35:26
9:35:39
9:35:52
9:36:05
9:36:18
9:36:31
9:36:44
9:36:57
9:37:10
9:37:23
9:37:36
9:37:49
9:38:02
9:38:15
Time (H:M:S)

Figure 2. H–field at Adams Ridge on 6/13/95

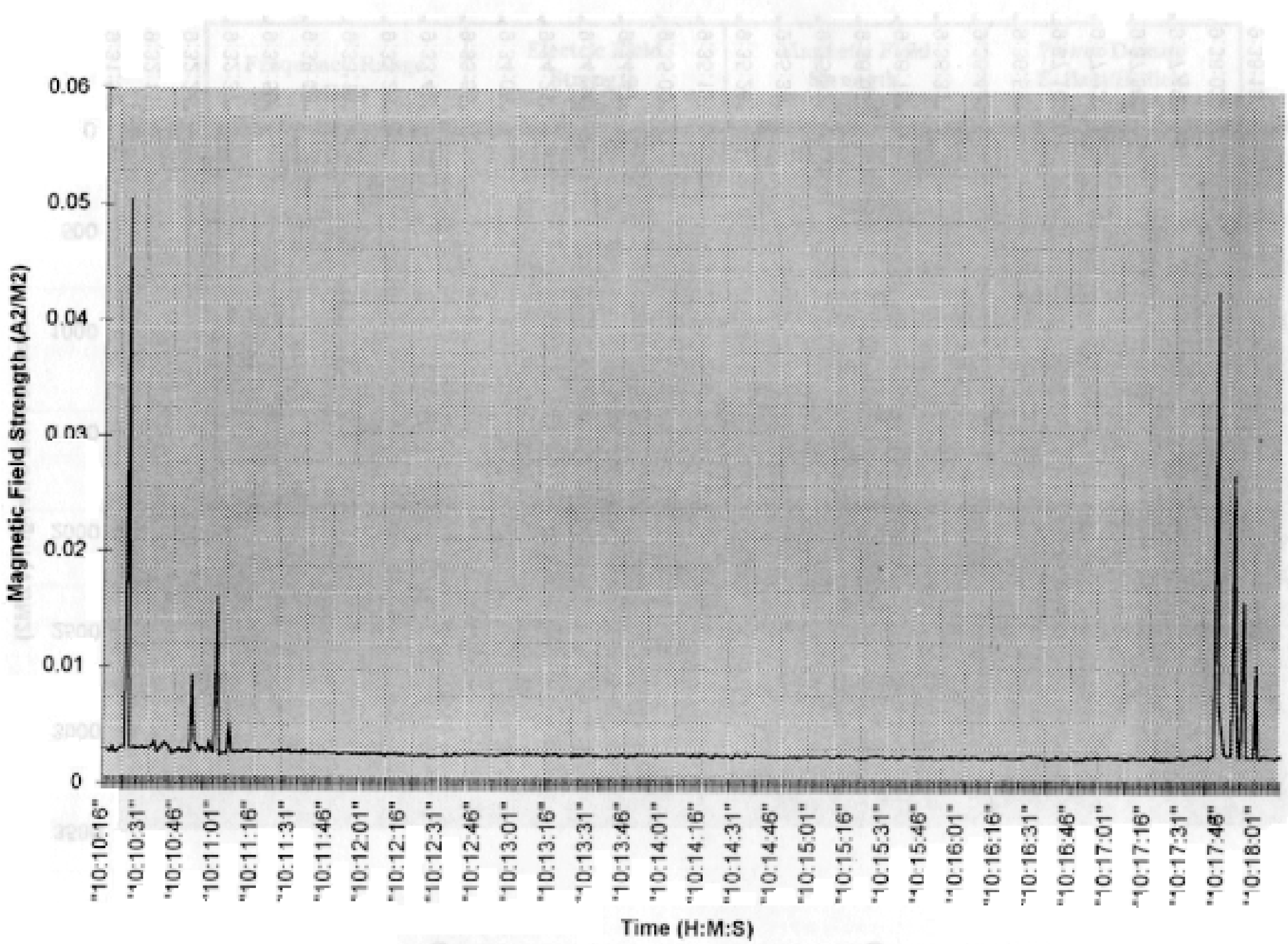


Figure 3. E–Field at Creston Butte on 6/13/95

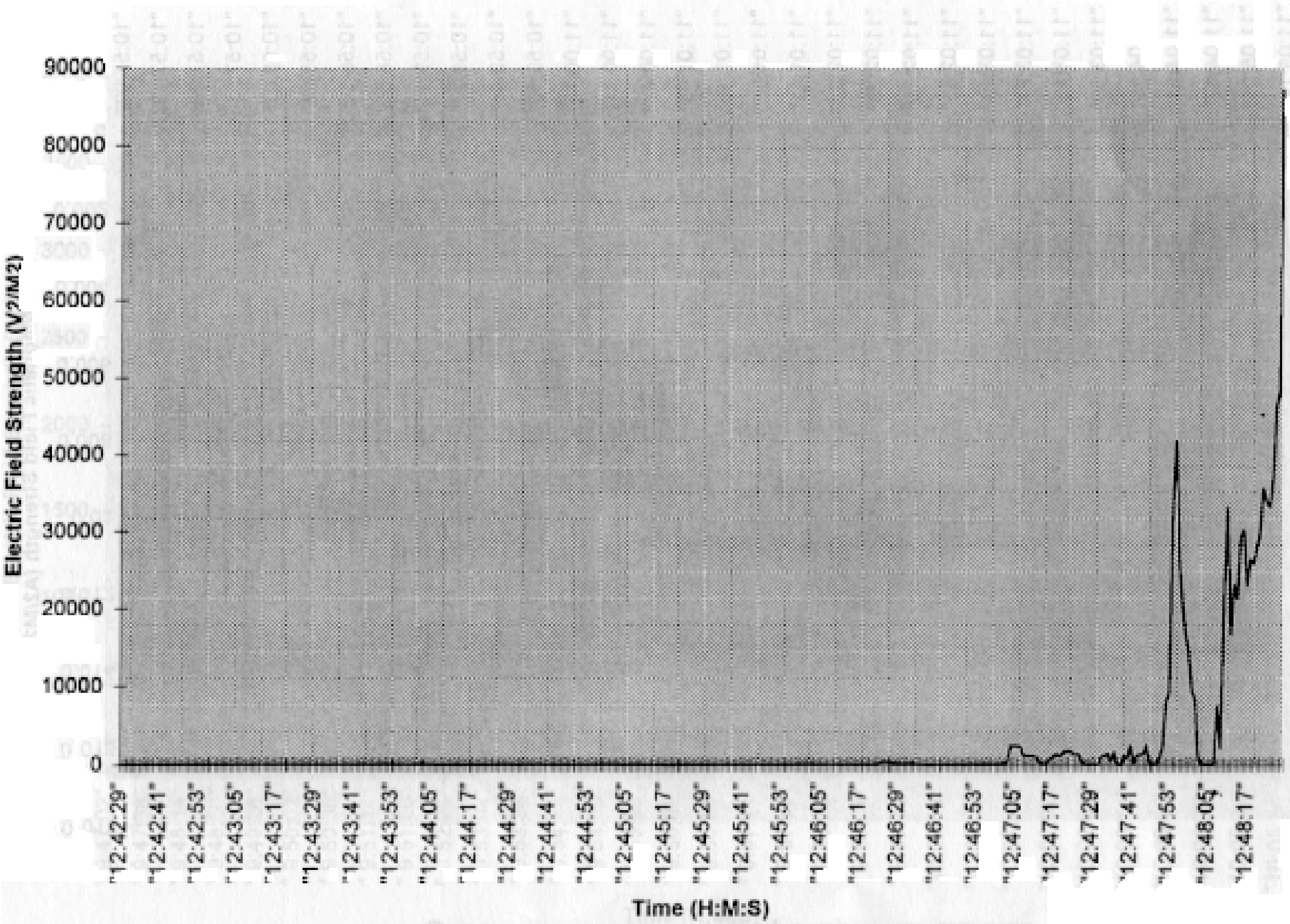


Figure 4. H–Field at Mt. Spokane on 6/20/95

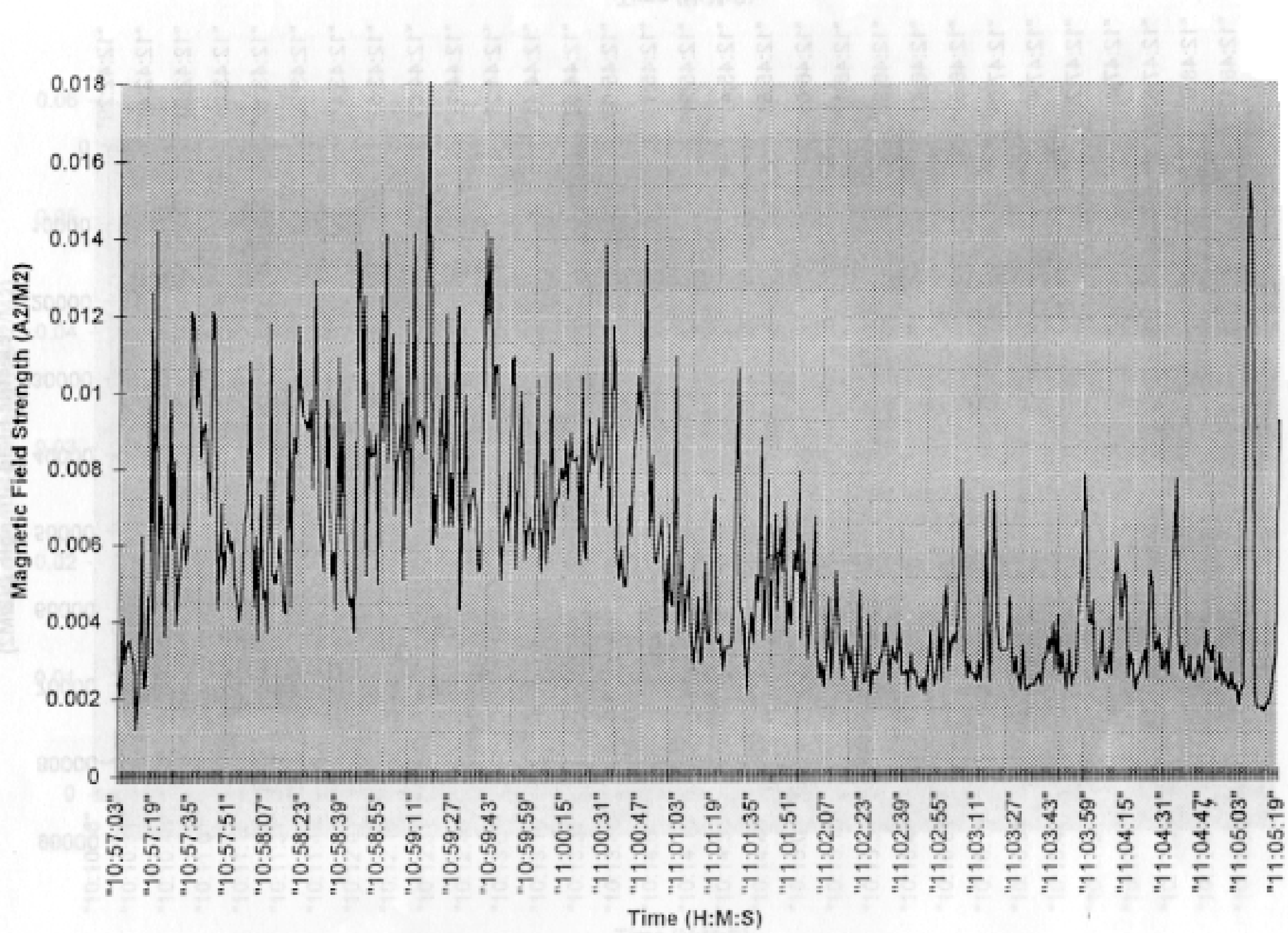


Figure 5. E–Field at Albani Falls on 6/15/95

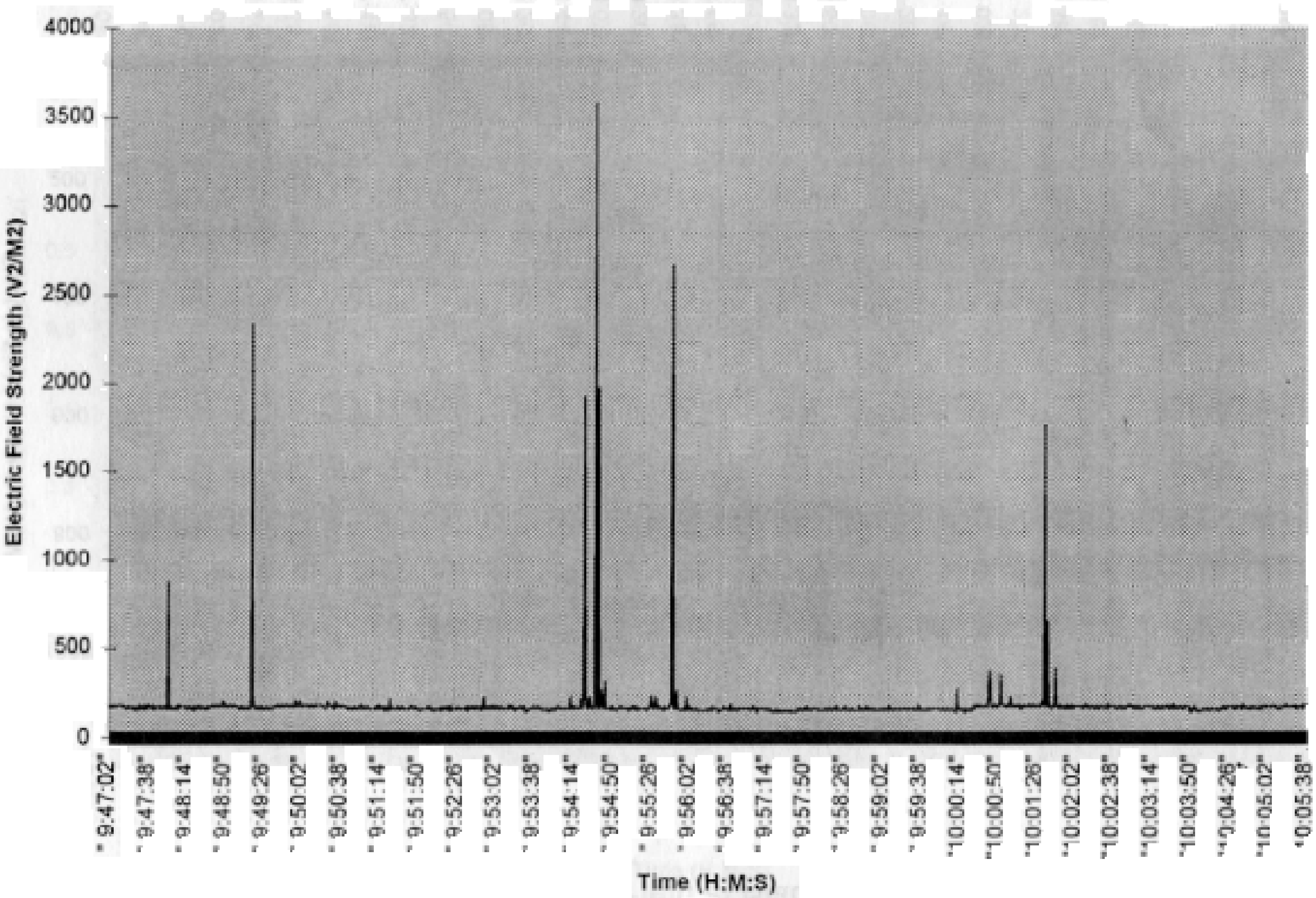


Figure 6. E–Field at Black Mt. on 6/16/95

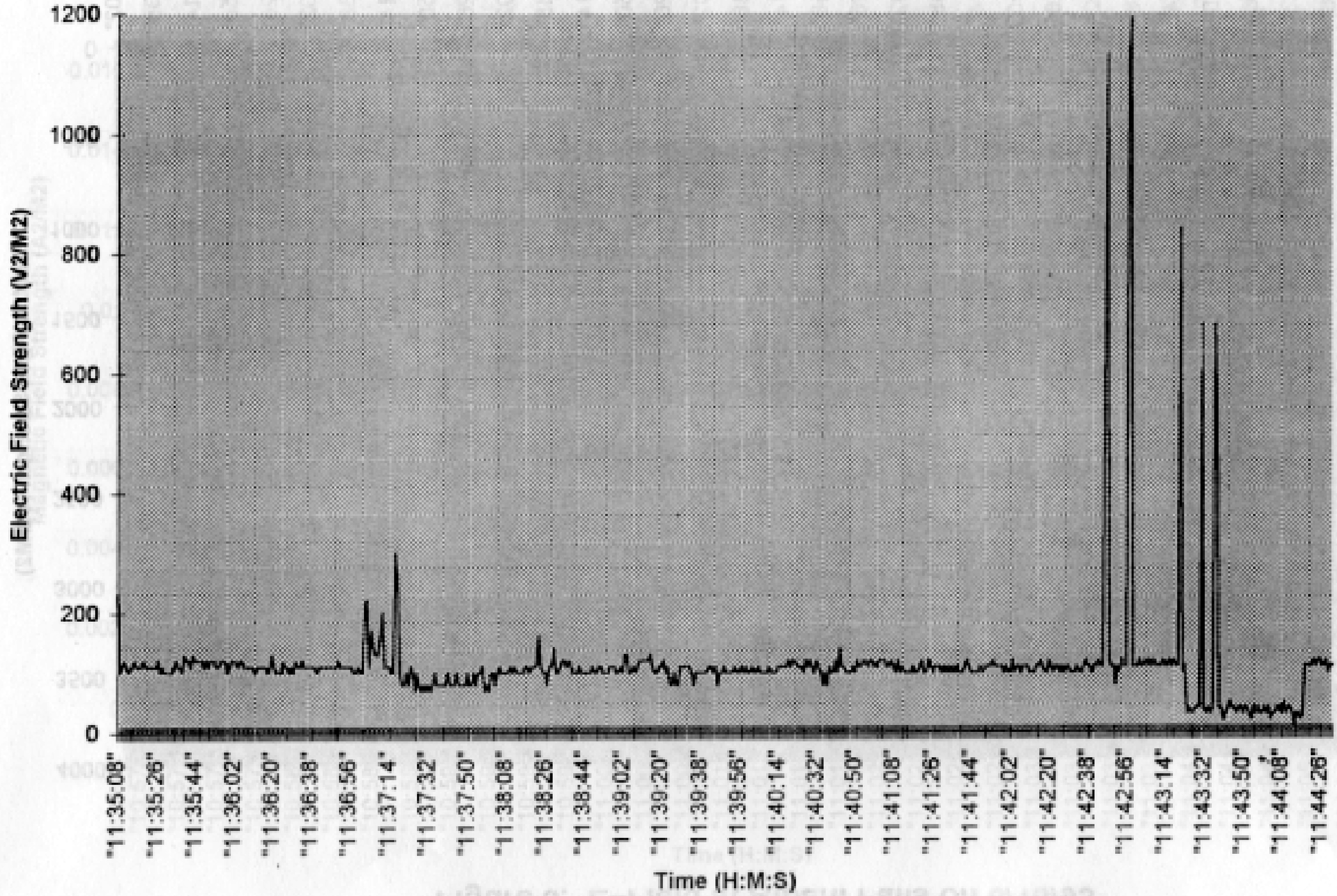
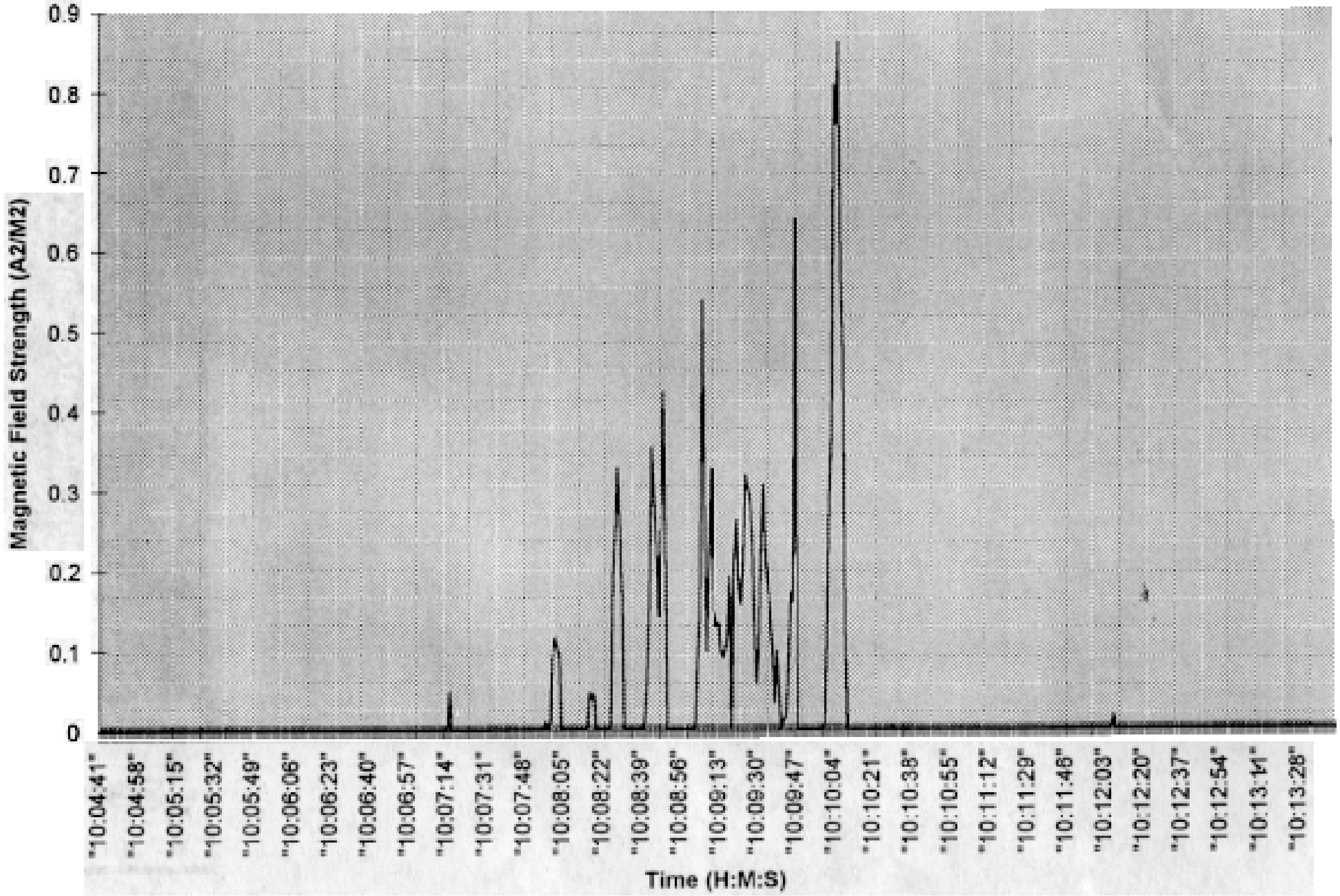


Figure 7. H–Field at King Mt. on 6/19/95



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