



**AN INVESTIGATION OF ELECTRIC AND MAGNETIC  
FIELDS AND OPERATOR EXPOSURE PRODUCED  
BY VDTs: NIOSH VDT EPIDEMIOLOGY STUDY**

**FINAL REPORT**

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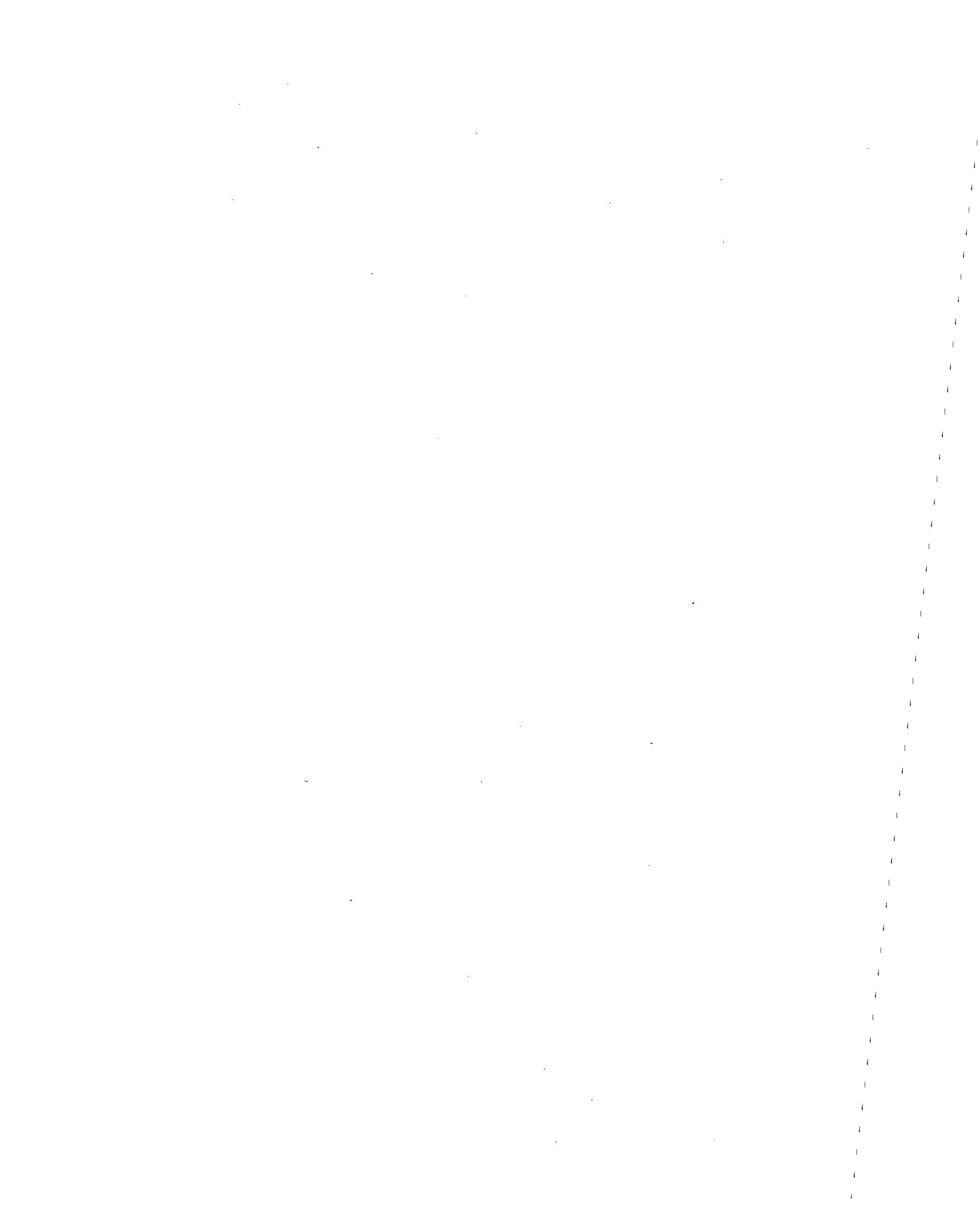
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16. Abstract (Limit: 200 words) Electric and magnetic field emissions of video display terminals (VDTs), both radiofrequency (RF) and extremely-low frequency (ELF), were investigated at AT and T and Bellsouth telephone operator facilities. The purpose of this study was to assess the strength of the electric and magnetic fields produced by the different types of displays to which workers could have been exposed. A total of 96 VDTs, selected at random, and located in nine cities was studied. VDTs produced by Computer Console, Inc. (CCI) and International Business Machines (IBM) were tested. Both types of VDTs produced essentially the same horizontal deflection frequency; CCI units produced a nominal frequency of 15 kilohertz (kHz) and IBM units produced a nominal frequency of 16kHz. Nominal vertical deflection frequencies were 45Hz for the CCI displays and 60Hz for the IBM units. The very low frequency (VLF) RF electric and magnetic field strengths at 30 centimeters from the VDT screens fell predominantly in the range of 1.3 to 8.5 volts per meter and 4.0 to 161 milliamperes per meter, respectively. Measurements of field strengths in the VLF range for non VDT displays (nixie glow tube and light emitting diode) were significantly less. The strength of the fields decreased extremely rapidly with increasing distance from the screen. The authors conclude that VDTs represent a relatively minor contribution to everyday exposure to such fields in the life of the worker.					
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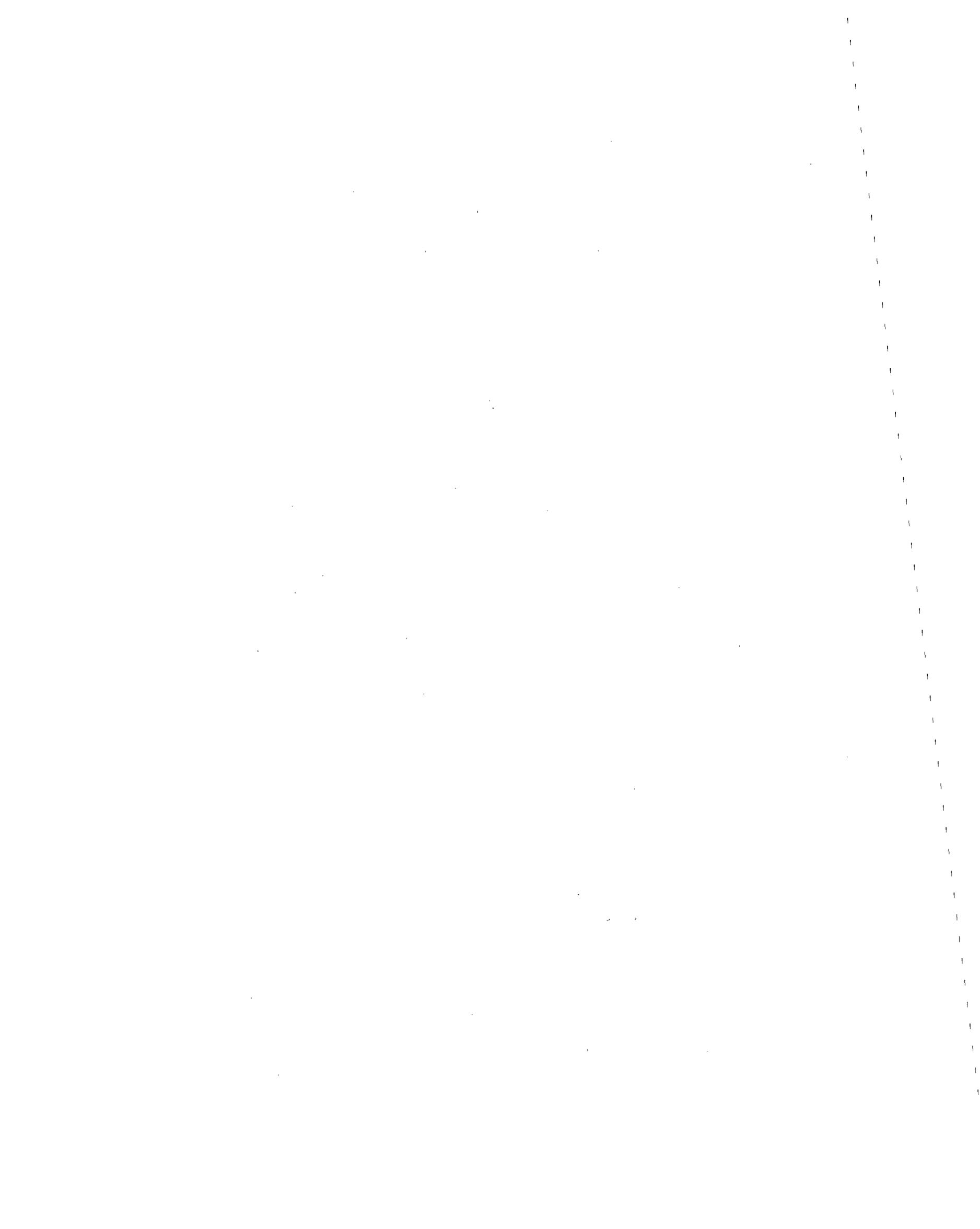


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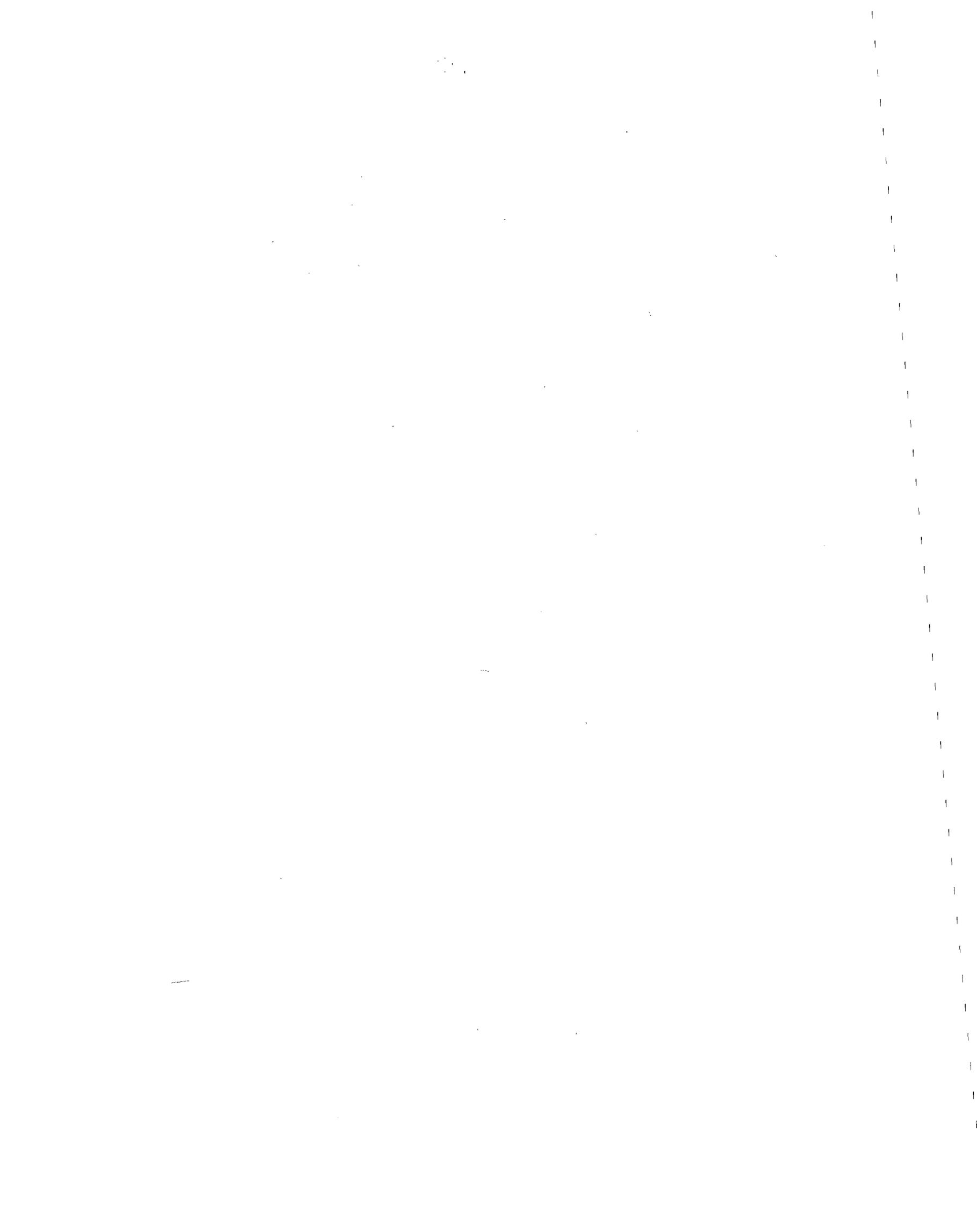
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## NOTE

Portions of this report have been adapted from material contained in the User Manual for the Holaday Industries, Inc. Model HI-3600 VDT radiation survey meter which was developed under contract by Richard Tell Associates, Inc. for Holaday Industries, Inc.



## AN INVESTIGATION OF ELECTRIC AND MAGNETIC FIELDS AND OPERATOR EXPOSURE PRODUCED BY VDTs: NIOSH VDT EPIDEMIOLOGY STUDY

### Summary

This report addresses the subject of electric and magnetic field emissions of video display terminals (VDTs), both radiofrequency (RF) and extremely-low frequency (ELF), at AT&T and Bellsouth telephone operator facilities. The study represents one component of a larger study of possible reproductive effects in VDT operators being conducted by the National Institute for Occupational Safety and Health (NIOSH). The purpose of this study was to assess the strength of the electric and magnetic fields produced by the different types of displays to which participants in the NIOSH study could have been exposed. Because of the study design used in the epidemiology investigation, the exposure evaluation included a study of the fields associated with VDTs and two other forms of displays which do not use cathode-ray-tube technology; these two non-VDT types of displays represent the equipment used by the control population in the NIOSH study. The non-VDT displays were designated as either NGT (nixie glow tube) or LED (light emitting diode) and the VDTs were designated as CCI or IBM, after the names of their manufacturers (Computer Consoles, Inc. and International Business Machines).

A study of 96 displays, selected at random, and located in nine cities, was conducted during April 23 through May 6, 1990. The comprehensive survey included measurements of very-low-frequency (VLF) RF electric and magnetic field emissions associated with the horizontal deflection circuits of the VDTs, at a distance of 30 centimeters (cm) from all accessible surfaces of each VDT. In addition, measurements of the ELF electric and magnetic fields produced by the vertical deflection circuits associated with the vertical refresh of the screen display were measured at a distance of 30 cm. The deflection frequencies were also measured. The amount of electrical current induced in the body by exposure to VDT electric field emissions was determined and contrasted with those currents

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normally induced in individuals by exposure to environmental levels of radio broadcast station signals. For completeness, measurements of the waveforms of the electric and magnetic fields were made for comparison with recommended limits used in Sweden for the time-rate-of-change of magnetic fields. Each display selected for the study was also scanned for the presence of low-energy x-ray emissions.

Instrumentation used in the project consisted of commercially available instruments designed specifically for VDT type field measurements manufactured by Holaday Industries, Inc. Separate instruments, the Model HI-3600-01 and Model HI-3600-02, were used to measure the electric and magnetic fields in the VLF and ELF bands respectively. Prior to the field study, each instrument was subjected to a thorough evaluation relative to its calibration accuracy and all data collected in the study were appropriately corrected for individual instrument response.

It was found that the two different types of VDTs produced essentially the same horizontal deflection frequency, the OCI units with a nominal frequency of 15 kHz and the IBM units nominally 16 kHz. Vertical deflection frequencies were observed to be nominally 45 Hz for the OCI displays and 60-Hz for the IBM units. The results of the study showed that VLF electric and magnetic field strengths at 30 cm from the VDT screens fell predominantly in the range of 1.3-8.5 volts per meter (V/m) and 4.0-161 milliamperes per meter (mA/m) respectively. A single value of 47 V/m was the one outlier compared to the rest of the VLF electric field measurements. Measurement of field strengths in the VLF range for the NGT and LED displays were significantly less, electric fields being about 0.12-1.2 V/m and magnetic fields in the range of 1.3-1.7 mA/m at 30 cm from the displays. The strength of the fields decreases extremely rapidly with increasing distance from the VDT screen. Hence, exposure of individuals using VDTs is strongly related to how far they sit away from the VDT. Clearly, VDT exposure to RF emissions can become more a function

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of the manner in which the VDT is used by the operator, in particular the distance that the operator sits from the display, than of the emission characteristics of the unit.

A survey of the ELF electric and magnetic fields found that the field strengths were generally in the range of 0.61-6.4 V/m and 71-571 mA/m at 30 cm in front of the screens of the VDTs.

Electric fields produced by VDTs can be strongly perturbed by the presence of objects near the VDT, including the operator. The degree to which the operator's body can influence the local strength of the electric field was examined in operators positioned at each of the 96 displays showing that facial exposure is typically greater than that which the rest of the body receives. Because of the complicated manner in which the human body couples with the electric and magnetic fields produced by the VDT as a source, a more fundamental dosimetric parameter, for quantifying exposure, may be the current which is induced in the body by the very nonuniform exposure fields. A study of induced currents in all 96 operators found that, in terms of the magnitude of the currents, an individual's exposure to ambient levels of AM radio broadcast station signals generally results in significantly greater induced currents; hence, in this sense, VDTs represent a relatively minor contribution to everyday exposure.

The magnetic field waveform data indicated that the time-rate-of-change of the magnetic field, represented mathematically by the expression  $dB/dt$ , for locations 50 cm in front of the screen of the VDTs evaluated, ranged from 0.22 to 37.6 millitesla per second; the largest values were associated with the horizontal deflection system in the VDTs.

Examination of the measured electric and magnetic field strength values obtained in this study shows that in no instance do either of the two fields, determined at the position of the operator, exceed any of the

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standards for public exposure to RF fields from any country in the world, including applicable guidelines in the United States. In addition, the values of  $dB/dt$  at a point 50 cm in front of the screen, corresponding to the distance specified by a recent recommendation in Sweden, were, with two exceptions, less than that value presently used by the Swedes as a procurement specification for importing VDTs in Sweden. Based on the findings of this study, it is concluded that typical personnel exposures to VDT, NGT or LED electric or magnetic field emissions in the telephone offices investigated are relatively low, within the range of other exposure data on VDTs reported by other researchers, and are substantially less than any electric and magnetic field exposure limits developed for radiation protection purposes by organizations within the United States and many other countries.

On a comparative basis, the non-VDT type displays are distinctly different in terms of operator exposure levels when compared to the two types of VDTs used by operators in this study for VLF fields; the NGT and LED displays, not possessing internal magnetic field deflection systems, simply do not produce VLF fields above instrumentation background levels. For ELF fields, such a distinction is less clear. For example, the LED displays produced operator ELF magnetic field exposures which were similar to the values found for operators of both the CCI and IBM VDTs, however, the NGT ELF magnetic fields were significantly less than those produced by either of the VDTs. When taken as a whole, operators of non-VDT displays (NGTs + LEDs) would have, on average, been exposed to lower ELF magnetic fields than their counterpart operators at VDT units. For ELF electric fields, the NGT displays produced operator exposure values less than those for the CCI units but similar to those found for the IBM VDTs. It is concluded that, for the most part, the ELF electric fields appear to be principally a function of the room electrical environment, probably being more representative of electrical wiring systems used in the building than of any peculiar characteristic of the display. The ELF electric fields found for the CCI VDTs as a group appear, however, to be

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demonstrably above those values found for the rest of the displays, including the IBMs.

### Background

Video display terminals (VDTs) are found throughout the work environment. VDTs have become so numerous that some organizations simply no longer know how many they own. With the increased use of VDTs, there has been an increase in a number of health and safety issues associated with VDTs. Electric and magnetic field emissions produced by VDTs have driven concerns over their possible role, among other factors, in adverse health effects. Since 1980, for example, approximately a dozen newspaper reports of miscarriage clusters among VDT operators have been described. These anecdotal reports have prompted a number of scientific investigations by scientists in the United States, Canada, Sweden, Norway, Finland and Denmark (see Appendix A for a listing of some of these reports). Most of these studies, however, have been unsuccessful in arriving at any consistent findings suggesting that use of VDTs during pregnancy is an unsafe practice. A recent study (Goldhaber, et al., 1988) has suggested an elevated risk of miscarriage for working women who reported using VDTs for more than 20 hours per week during the first trimester of pregnancy compared to other working women who reported not using VDTs. These authors, however, found no significantly elevated risk for birth defects among women using VDTs. The study included no determinations of actual exposure to VDT electric or magnetic field levels and the authors suggest that the findings might be due to unmeasured factors confounded with high VDT use such as poor ergonomic conditions or job-related stress.

The present study of electric and magnetic fields produced by VDTs was deemed an important aspect to the NIOSH epidemiological study, addressing the question of exposure not treated in most of the existing studies. These data can be used in developing a framework for evaluating the

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possible significance of electric and magnetic fields as they may relate to any potential health effects in the operators of VDTs and interpreting the epidemiological data resulting from the NIOSH study. The study reported here was aimed at accurately determining the strength of the electric and magnetic fields (emissions) of VDTs used by the work population in the NIOSH study and examining these emissions in terms of actual operator exposures so that such exposures can be put in the context of other exposures typically experienced in everyday life.

For purposes of the study, a total of 96 displays were used for examining electric and magnetic fields. The NIOSH epidemiological study identified two populations of workers; those who used conventional VDTs and a control population consisting of individuals using either of two alternative forms of data displays, either nixie glow tube (NGT) type displays or light emitting diode (LED) displays. Neither the NGT or LED displays, as used during the time frame of the NIOSH epidemiological study, employed CRT technology which can produce stray electric and magnetic fields due to their principal of operation. One primary purpose of this study was to characterize the differences in electric and magnetic field aspects of the displays used by both groups of workers in the NIOSH study. Of the total of 96 displays chosen for evaluation by NIOSH, 48 were of the conventional CRT design and 48 were divided equally between the NGT (24) and LED (24) types.

### **Study Objectives:**

This study had several objectives, including the following:

- (1) For a random sample of 96 displays, measurement of the VLF RF electric and magnetic field strengths at a fixed distance from the closest accessible surface of the display for up to six sides (front, top, bottom, left side, right side and rear);

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(2) For the same sample of displays, measurement of the ELF electric and magnetic field strengths at a fixed distance from the closest accessible surface of the display for up to six sides (front, top, bottom, left side, right side and rear), just the same as for the VLF RF fields;

(3) Characterization of the variation of the strength of the electric and magnetic fields, both VLF and ELF, as a function of distance for samples of the types of displays involved in the study;

(4) For each of the displays evaluated in the study, an assessment of the strength of the VLF and ELF electric fields actually impinging on the body surface of a display operator and the strength of the VLF and ELF magnetic fields at the location of the operator's body;

(5) Measurement of the flyback (or sweep) frequency associated with the emissions of the horizontal and vertical deflection systems for each VDT evaluated;

(6) For each display studied, measurement of the magnitude of the RF current which is induced in the body of an operator by the electric fields produced by the display;

(7) Measurement of the waveforms of the electric and magnetic fields produced by the various types of VDTs in the study and determination of the time-rate-of-change of the magnetic field since this parameter has been discussed as a possible parameter of interest in characterizing electric and magnetic field exposure caused by VDTs.

(8) For each display, a search for possible x-ray emissions by conducting a surface scan of the display with a high sensitivity, large area x-ray sensor device.

### Facility Descriptions and Sample Selection

Displays selected for inclusion in the exposure assessment study included both non-CRT type display technology, represented by the NGT and LED displays, and conventional CRT type VDTs. For purposes of this study, NIOSH designated two AT&T telephone offices and a total of eight Bellsouth offices, in the eastern part of the United States as the sites for field measurements. The non-CRT type displays were evenly distributed between offices in Cincinnati, Ohio and Bloomington, Indiana, there being 24 in each office. The VDTs were divided into groups of six each in eight offices in seven cities including Nashville, Tennessee; Forest Park, Georgia; Macon, Georgia; Jacksonville, Florida; Lake City, Florida; Marrero, Louisiana; Bogalusa, Louisiana.

The concentration of NGT and LED units in just two offices was based on operational constraints of gaining access to a sufficient number of displays without significant disruption to the telephone system. Historically, the control population in the NIOSH epidemiological study used either the NGT or LED types of displays alone; more recently, subsequent to the period for which the NIOSH study was concerned, the NGT and LED types of displays were retrofitted with conventional VDTs as a part of the workstation environment. This is in contrast to the equipment configuration which existed during the time the NIOSH study examined possible health effects. Consequently, to facilitate meaningful measurement of the electric and magnetic fields to which operators would have been exposed during the time of the study, special arrangements had to be made to deactivate the VDTs now found in conjunction with the NGT and LED displays. This arrangement, of turning off the associated VDTs during the measurement process for characterizing the emissions and exposure caused solely by the NGT and LED displays, necessitated concentration of this aspect of the measurements at the two locations chosen. Western Electric was the manufacturer of the NGT and LED type displays evaluated.

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Of the conventional VDTs used by participants in the NIOSH epidemiological study, those provided by two manufacturers were evaluated, namely IBM (International Business Machines) and CCI (Computer Consoles Incorporated). The IBM VDTs consisted of the Model 4978 while the CCI units were the Model 4500 and essentially identical Model 4501 and Model 4502. The following table summarizes the number and distribution of the displays evaluated in this study.

### Summary of VDTs Selected for Measurement in NIOSH Study

<u>Display Type</u>	<u>Number of Units</u>	<u>Office Location</u>
NGT	24	Cincinnati
LED	24	Bloomington
IBM 4978	6	Forest Park
IBM 4978	6	Macon
IBM 4978	6	Jacksonville
IBM 4978	6	Lake City
CCI 4501	12	Nashville (two offices)
CCI 4500	6	Marrero
CCI 4502	6	Bogalusa
Total	96	

The displays chosen for evaluation were selected on a random basis. In practice, a floor plan of the office was obtained from the room supervisor which showed the location of each workstation by station number. A random number table was examined to determine which units were to be selected for subsequent measurements. For example, for most of the offices, a total of six VDTs were randomly selected from the larger population of VDTs present in the office.

Each VDT selected for measurement was assigned a unique identification tag to identify it for measurements. At the time of measurements, the manufacturer and model were recorded for each unit as well as whether the VDT was equipped with a glare filter. In practice, once the specific displays were selected for subsequent measurements, individuals who might be using a selected display were assigned another unit to work at to free up the selected unit for the measurement. Area supervisors were

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especially helpful in these reassignments during the course of the project and in acquiring telephone operators to volunteer for participation in the exposure measurement process when this aspect of the protocol was accomplished.

The following sections of this report provide an overview of VDTs and how electric and magnetic emissions are produced, a description of the measurement approach that was used in collecting the data, a discussion of the various types of instrumentation that were used including their calibration, the actual measurement results obtained and a discussion of the results with comparisons between the measured emission and operator exposure levels and various exposure/emission standards. In addition, the induced body currents measured are contrasted with ambient RF fields caused by other ordinary sources, such as broadcast station signals, that also induce RF currents in the body. Estimates of induced current densities and the rate of energy absorption that might exist in an operator of the VDTs are presented, based on theoretical considerations of the measured electric and magnetic field strengths.

### **VDT Electric and Magnetic Field Emissions**

#### **General Description**

Video display terminals (VDTs) and television receivers are quite similar in certain respects. Both are used to display information; the VDT displaying information received from a computer system, word processing system, or other digital information system and the television receiver displaying video information transmitted from television broadcast stations. In conjunction with a keyboard, the VDT serves as the main interface between the operator and a word processor, computer, etc. Television receivers are sometimes used in lieu of VDTs with home computer systems.

## Principles of Operation

VDTs and television receivers use the same basic principles of operation. Both contain a large evacuated glass tube called a cathode-ray tube (CRT), or picture tube in the case of television receivers. The CRT contains a source of electrons (the cathode) at one end and a fluorescent coating on the inside of the viewing screen. Electrons released from the cathode are accelerated by a high voltage (typically in the range of 10 to 25 kilovolts) and are projected onto the fluorescent material of the screen which then emits visible light when it is struck by the fast-moving electrons. The CRT also includes various electrodes for focusing the electron beam and for scanning the beam across the fluorescent screen. Electronic circuitry in the VDT modulates the electron beam to produce the intended images on the screen. The images seen on the screen are actually the result of tiny areas of the phosphors, called pixels, being struck in a controlled manner. Thus each character on the screen is made up of many individual pixels being "turned on and off" by the scanning electron beam. The circuitry leads to the production of electric and magnetic fields (emissions). There are four basic aspects to the electrical environment of VDT emissions: (1) ELF modulated dc (direct current) fields; (2) ELF fields (typically in the range of 45-75 Hz associated with the vertical deflection system); (3) VLF RF fields associated with the horizontal deflection systems; (4) higher frequency, broadband RF fields caused by the digital electronic circuits which are associated with character generation (Roy, et. al, 1983).

### ELF Modulated DC Fields

To accelerate the electron beam toward the screen, a high DC voltage is used. The high voltage is produced by pulsing a transformer (the flyback transformer) which has a high turns ratio and is often derived from the line deflection circuitry, though in some cases it may have a higher frequency depending on the character display system. The drive

pulse is a square wave which produces a high voltage secondary pulse that is rich in harmonic content. The ac components of this dc current pulse flow to ground via the capacitance of the CRT formed by the screen and the resistive coating on the outside of the CRT. This small capacitance provides the filtering necessary for a relatively smooth high-voltage accelerating potential. The field, nevertheless, possesses an ELF modulation component originating from the pulsating output of the flyback transformer/rectifier assembly. Roy et. al (1983) have reported that one method of reducing the ac component of the dc field is to place an RC (resistance-capacitance) series shunt filter between the high voltage transformer output and the CRT. They found that such a filter could, in some VDTs, reduce the ac component of the dc field by as much as 50 dB (a factor of over 300 times).

The modulated dc field is produced by the charge on the face of the CRT and is largely confined to the front of the unit. This field is highly variable, being affected by humidity, capacitance between the CRT and external objects and touching the CRT (Harvey, 1984a). Several investigators have measured the strength of this dc field and found values ranging from a few hundred volts per meter (V/m) to as high as 45 kilovolts per meter (KV/m) at the surface of the body of an operator, and depending on the proximity of the operator to the VDT, closer distances resulting in higher measured incident dc fields (Olsen, 1981; Harvey, 1984b; Nylén et. al, 1984; Bracken et al., 1985). Special treatments of the CRT screen exterior surface to make it conductive can greatly reduce the strength of the dc field component.

### ELF Fields

Extremely-low-frequency (ELF) magnetic fields are caused primarily by the current flowing in the vertical deflection coil and are nearly symmetrical around the coil. ELF electric fields are produced by the same mechanism that produces the dc field; the charge on the VDT screen which

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produces the dc field is actually not constant but builds up and decays by a small amount each time the display is scanned by the electron beam. This occurs at a nominal 60-Hz rate (the typical frequency range of the vertical deflection circuit is 45 to 75 Hz) although harmonics may exist up to several kilohertz (kHz) (Harvey, 1983a). Measurements of the ELF emissions and harmonics in Canada found magnetic field strengths of 100 to 200 mA/m at a position 30 cm in front of the VDT (Canada, 1983). Harvey (1984b) reported measured ELF electric field strengths of between 5 and 60 V/m in an investigation of 5 VDTs. These relatively low values are in the range of other commonly encountered 60-Hz appliances found in the home and office environment.

The vertical deflection circuit operates on the principal that the force exerted on a moving electron is at right angles to both the direction of the electron's motion and the applied magnetic field (known as the Lorentz force in fundamental physics terms). To induce a vertical component to the electron's original direction, the magnetic field must possess a horizontal polarization. Thus, the vertical deflection coils in VDTs and television receivers, tend to generate magnetic fields which are strongly horizontally polarized near the front of the screen. This aspect is important when characterizing the magnetic fields of VDTs; the measurement technique used in assessing the strength of magnetic field emissions obtained in this project incorporated this polarization characteristic.

### **Horizontal Deflection System Fields**

The principal RF component of VDT emissions is caused by the so-called flyback circuitry which is responsible for a rapidly changing current which flows in the horizontal deflection coils of the VDT and causes the electron beam to be rapidly swept to the left side of the screen, ready for another trace across the screen. Figure 1 depicts the normal electron beam scanning across the screen of a VDT. The beam is repetitively

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scanned across the screen through the use of a saw-tooth shaped current waveform flowing in the deflection coils of the VDT. The fact that the electron beam moves down the screen from trace to trace is a function of the vertical deflection circuit discussed above which uses a similar, but much lower frequency, saw-tooth current waveform. Figure 2 illustrates the basic components within a VDT which lead to the production of the electric and magnetic field emissions near the VDT. The rate at which the electron beam is scanned, the flyback frequency, is dependent on the particular design of the VDT but typically falls in the range of 15 to 31 kHz. For television receivers, the flyback frequency is approximately 15.75 kHz. This particular flyback frequency is based on regulations by the Federal Communications Commission (FCC) such that there is standardization within the United States relative to decoding video programming information transmitted by television broadcast stations.

Due to the relatively sharp saw-tooth-like waveform of the current flowing in the horizontal deflection coils of the CRT, the flyback circuit is rich in harmonic production and any instrument intended for accurate assessment of RF exposure fields produced by VDTs must be capable of true rms (root-mean-square) measurement. Figure 3 illustrates the typical saw-tooth-like waveform of the magnetic field produced by the horizontal deflection circuitry current. The strong harmonic content of this type of non-sinusoidal waveform leads to the production of magnetic fields across a range of frequencies thereby necessitating the need for a relatively broadband frequency response in an instrument used to assess the strength of such fields. Approximately 95 percent of the total energy of the flyback circuit emissions is contained within the first five or six harmonics (Roy et al., 1983).

VLF RF magnetic fields near VDTs are also produced by the flyback transformer which is used to step up the voltage pulses that are eventually applied, after rectification (conversion from ac to dc), to the CRT to accelerate the electron beam. Currents flowing within the windings

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of the primary and secondary of the flyback transformer produce magnetic fields, tending to lead to a distortion in the symmetry of the field distribution about the VDT. The magnetic field strength at any given point near a VDT is the resultant of the magnetic fields produced by both the flyback transformer and the deflection coils. Nonetheless, while the flyback transformer can be a potent source of magnetic fields very near to it, the fields found in front of a VDT are generally driven predominantly by the current in the horizontal deflection coils. Because of the contribution of magnetic fields by the flyback transformer, a survey of the magnetic field strengths about a VDT would be expected to reveal differences in the magnitude of the field, depending on the location of the sensor relative to the location of the flyback transformer.

In a manner similar in action to that of the vertical deflection coils, the horizontal deflection coils rely on the Lorentz force to impart a horizontal shift in the direction of the electron beam so that the beam travels across the screen from left to right and back again. To accomplish this, a magnetic field that is vertically polarized is generated by the horizontal deflection coils inside the CRT. The stray fields which can be detected outside the VDT possess a strong vertical polarization characteristic to them, especially in front of the screen.

RF fields caused by the deflection circuitry can produce electric fields at normal operator positions of typically a few volts per meter up to some tens of volts per meter and magnetic fields in the range of a few milliamperes per meter up to several hundred milliamperes per meter (Harvey, 1983b; Guy, 1987a; Boivin, 1986; Joyner et al., 1984; Marha and Charron, 1983). Electric fields are produced by the high voltage lead from the flyback transformer to the CRT and the associated internal components of the CRT to which the high voltage is connected. High potentials on these components, which are varying in amplitude (voltage) quickly in time, give rise to the alternating electric fields near a VDT. The instrumentation selected for use in this project was designed

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specifically for measurement of the RF fields associated with the beam deflection systems in VDTs and television receivers.

### **Broadband RF Fields**

An electronic clock within the VDT which typically operates in the frequency range of 1 to 20 MHz is the source of most of the radiated RF signals from the digital electronics sub-section (Roy et al., 1983). Conventional shielding techniques are the usual method for eliminating or reducing such emissions. Petersen et al. (1980) and Weiss and Petersen (1979) evaluated RF emissions from a number of VDTs and found that RF electric field strengths, measured at a distance of 1.5 meters from the front of the VDT, for those emissions not associated with the flyback circuit, were well below 1 V/m rms, typically less than 0.01 V/m. For VDTs attached to personal computers, the computer system unit, not the VDT, is often the more significant source of these broadband, higher frequency RF fields.

### **Electric and Magnetic Field Lines**

The high-voltage circuitry and deflection coils in a VDT produce electric and magnetic fields which each have their own individual character. Figures 4 and 5 illustrate how the VLF RF electric and magnetic field lines are typically directed near a VDT. There are significant differences in the perturbation effect caused by the presence of the operator relative to electric and magnetic fields. Because of capacitive coupling between the operator and ground, the operator tends to bring the existing ground potential physically up nearer the VDT and emerging electric field lines terminate on the operator. Thus the electric field component of maximum strength will be that which is normal to the surface of the exposed body; components of electric field parallel to the body's surface are shorted out and vanish because of the relatively highly conductive nature of the body tissues. Consequently, measurements

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of operator exposure to electric fields must take into account this polarization characteristic of the surface electric fields to obtain accurate results. In this way a measure of the maximum electric field strength can be obtained. An associated aspect of the conductive nature of the body tissues is that, relative to external electric fields, like those produced near a VDT, the internal fields within the body are greatly reduced in strength.

Because of the perturbing effect of the operator's body on the electric field close to the VDT, it is apparent that the evaluation of electric field emissions will be very dependent on proximity of the operator and/or other nearby objects. An example of how the electric field lines issuing forth from a VDT are perturbed by the proximity of grounded potential surfaces is given in Figure 6. In this case, a glare filter designed for reducing the visual problems of glare on VDT screens and that has a conductive property, such as a conductive coating for reducing dust build-up due to the accumulation of static charge, is attached to the screen of a VDT and the filter is grounded with a wire running to the chassis of the terminal or computer. Because the glare filter is at a relatively low electrical potential with respect to the high-voltage circuitry of the VDT, the electric field lines tend to terminate on the grounded filter rather than the operator, reducing the operator's exposure to electric fields.

In Figure 5 it is seen that the magnetic field lines emerging from the VDT are not perturbed in their orientation with respect to the operator's body; this happens because the body is non-magnetic in nature. Thus, in measuring the VLF magnetic field (that generated by the horizontal deflection system) in front of a VDT, usually the maximum value is associated with vertically polarized lines of flux and the magnetic field sensing probe, normally a loop of some type, must be oriented in such a manner that a maximum number of these magnetic field lines pass through the aperture of the loop.

A related issue is that while the body is non-magnetic, and hence does not perturb the distribution of the magnetic field, the magnetic fields will induce currents, called eddy currents, which circulate around the periphery of the body cross-section which is in a plane normal to the magnetic field lines. This is based on the fact that a magnetic field, which changes in time, induces a current in a conductive material.

Since the electron beam must also be deflected vertically so that it covers the entire surface of the screen during the scanning process, a magnetic field which is directed horizontally is produced by the vertical deflection coils. The horizontal magnetic field produces a vertical force on the electron beam, moving it from top to bottom of the screen. Because the electron beam makes many horizontal scans across the screen before it must be swept back to the top of the screen, the vertical deflection (vertical refresh) frequency is much lower than the horizontal deflection frequency. The different direction of the magnetic field produced by the vertical deflection circuit requires that the magnetic field sensor be oriented at 90 degrees to the direction for maximum field of the horizontal deflection system. Such an orientation was used for the measurements of the ELF magnetic fields.

### **Distinguishing Between VDT Emissions and Operator Exposure**

Because of the perturbing influence of the VDT operator on measured electric field strength values near VDTs, it is important to distinguish between assessments of operator exposure and basic emission characteristics of VDTs. Relative to electric fields, these two properties are not the same.

### **Characterizing VDT Emissions**

For the NIOSH project, one objective was to establish the general emission levels of the VDTs for comparison with other VDT emission data.

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Such measurements, when conducted for numerous VDTs, can be used to determine unusual operating characteristics of particular VDTs within a group. To collect this type of data, it is helpful to minimize unnecessary, extraneous environmental factors. In this way electric field measurements obtained on the VDTs will be as reproducible as possible and can be compared to electric field data collected from other similar VDTs with a maximum of consistency.

Emission characterizations were, therefore, performed without the operator present. Although the literature contains numerous methods by which emission data have been obtained, the principal difference lies in the locations about the VDT at which measurements are performed. An exploration of the surfaces of a typical VDT will reveal areas of particularly intense fields, but these areas are usually on the sides or top of the VDT and are not directly applicable to frontal area exposure where the operator would be positioned. Because of this, a nearly universal measurement location positioned at a point 30 cm directly in front of the VDT screen has been most commonly used and has been recommended in emission characterizations by the Food and Drug Administration (FDA, 1984).

Measurement distances of 50 cm and 1 m have also been used. A value of 30 cm actually represents a quite close distance when compared to the viewing distance used by many, but certainly not all, VDT operators. In fact, a minimum viewing distance closer to 36 cm has been recommended (Diffrient et al., 1981). Nevertheless, because the value of 30 cm has been so often reported in the literature, measurements reported here were obtained at 30 cm.

VDT emission data reported in the literature show that in many instances a fixed screen condition has been used to promote more repeatable measurements. For example, a commonly reported method involves filling the screen with a single character such as an E or M or H and

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adjusting the brightness and contrast controls to their maximum position. In contrast to these precautions, it has also been reported that these measures often seem to have very little, if any, impact on the resulting measured values of electric and magnetic field strength (Roy et al., 1983). Nevertheless, because of peculiarities of some VDTs, a check of the effect of varying the brightness and contrast controls may be instructive. Roy et al. (1983) suggest that CRT performance, which decreases with age, and the type of video generating system used are two possible factors responsible for this phenomenon.

On the more practical side of conducting a large scale survey, however, is the fact that individual adjustments for every VDT can substantially interrupt the flow of work in an office and cause a significant increase in the amount of time required to accomplish the survey. In many cases, depending on the functions of the office, such a disruption of work can represent a major impact, for example, in the telephone operator work environment where workloads are very precisely monitored. While the field strengths of emissions can vary according to the contrast and brightness adjustments, these variable effects can be evaluated statistically in the sense that the variabilities are contained within the normal variance of the fields from a large group of VDTs. Also, performing emission measurements with the preferred settings established by the operator probably reflects a more realistic assessment of the fields (emissions) for that operator than using some predefined set of adjustments. For the study reported here, VDT emissions were measured without any adjustment to the control settings established by the operator; i.e., measurements were performed on the VDTs as they were found at the operator's work-station. In one case, a brief evaluation of the effect of the degree of the screen being filled with characters, as opposed to being blank, on measured fields was conducted during the routine measurements in Nashville.

### Characterizing Operator Exposure

Measuring operator exposure to VDT electric field emissions requires that the measuring instrumentation be supported with a non-conductive holding device. This is to reduce the influence of the surveyor on the measure of fields incident on the VDT operator. The strength of the electric field actually incident on the operator is a function of the anatomical area of the body and the geometry of the operator's body with respect to the VDT and other objects in the room. Generally, the unperturbed field where the operator is normally located will be less than the field incident on the operator. Also the field strength will vary strongly with distance away from the body. For these reasons, the most accurate measure of operator exposure is obtained when the measuring instrument sensor is placed in direct contact with the operator's body but while being held with a non-conductive holder by the individual performing the survey.

When assessing operator exposure levels, it is sometimes difficult to obtain the required measurement simply because the instrument's readout may be hidden from view because it is so close to the VDT operator. This problem was handled during the NIOSH measurements through the use of a remote fiber optic receiver device, permitting the measuring instrument to be read at a distance. In this case, the VDT operator holds the detection instrument directly against their body and the measured electric field value is read remotely by the surveyor via the fiber optic link. This method of determining VDT operator electric field exposure is superior in that it minimizes the influence of the surveyor on the measurement process. Also when the operator performs this self-measurement, the instrument may be held directly without the non-conductive holder since the electric field lines are already terminating on the operator's body. The use of the remote fiber optic receiver proved to be especially useful during the emission measurements as well. Its use allowed for much greater convenience in performing the measures of electric field,

especially beneath the displays, when the sensor had to be held with the normal readout of the instrument facing away from the location that the user was standing; i.e., the sensor could be oriented in any fashion necessary for the measurement and the instrument reading easily determined by observing the readout of the remote receiver typically held in the other hand of the user.

### Induced Body Current

Another aspect of assessing VDT exposure involves the interaction of the electric field with the operator's body such that a very small RF current is induced to flow between the body and any grounded surface or object. The fact that electric fields induce currents in the body has been studied at length by various researchers (Tell et al., 1979; Deno, 1977; Guy and Chou, 1982, Hill, 1985). Figure 7 illustrates how the magnitude of RF current which is induced by external electric fields varies as function of frequency. As can be seen, the induced current is directly proportional to frequency; for a constant electric field strength, if the frequency is doubled, then the induced current is doubled.

The utility in examining induced currents caused by VDTs stems from two points of view. First, induced current may be a better dosimetric measure of exposure than external field strength; different persons sitting at a VDT can exhibit large differences in the surface electric field strength because of body size, shape and the resulting degree of shielding afforded by the body and its configuration relative to a given VDT. Second, by determining the induced current, one can compare these currents to those currents caused by other environmental sources; such comparisons may be helpful in developing a perspective on relative risk represented by electric and magnetic field emissions of VDTs. The frequency range relevant to VDTs is indicated on Figure 7. Using established relations between external electric fields and induced

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currents for uniform exposure conditions, one can compute the required field that would induce the same current as measured in a VDT operator.

Practical constraints on measuring induced currents in the body limit this assessment to those currents flowing through the body to ground. Such currents are those induced principally by the electric fields which couple to the body. Conventionally, measurements can be conducted by contacting the body at various points, such as the ankle or wrist, with one probe of the current measuring instrument and a ground point with the other probe.

Magnetic fields which couple to the body induce electric fields which in turn cause eddy currents about the periphery of the body, being a maximum at the outer edges of the body (Tell et al., 1979). The measurement of these "circulating" currents is limited by the inability to probe the body with appropriate devices. However, the induction of such currents does lend itself to analytical evaluation. Guy (1984) has considered induced currents in an ellipsoidal model of the body where it was assumed that the electric and magnetic fields were polarized in such a way as to couple in an optimum manner with the body model, thereby inducing the greatest current. Tell et al. (1979) and Durney et al. (1986) illustrated the body orientation with respect to the incident fields which would result in maximum induced currents in the body. Although the polarization of the fields typical of exposure to VDT's is not necessarily that which would result in maximum induced currents, such an assumption was made out of conservatism in Guy's worst case analysis (Guy, 1984). Guy also assumed, for purposes of the analysis, that the electric and magnetic fields were uniform over the entire body dimension; this also is far from the actual case for VDT fields since the fields are extremely nonuniform. Thus the analysis will over predict the magnitude of the induced currents. For the case of a flyback frequency of 16.7 kHz, Guy found that the induced current due to the electric field would be 2.74 microamperes/(V/m rms) with a resulting internal current density in the

center (midsection) of the body of  $5.12 \times 10^{-4}$  microamperes/cm<sup>2</sup>. This current is that current one would expect to measure between the body and ground, assuming that the model was a good approximation of the real body. To obtain the total induced body current to ground caused by a uniform electric field, the electric field strength in volts per meter is multiplied by the factor  $2.74 \mu\text{A}/(\text{V}/\text{m})$ . As an example, if the body were uniformly illuminated with an electric field of 4 V/m, then the induced body current to ground would be 11.0  $\mu\text{A}$ . This analysis makes the assumption that the harmonic content, relative spectral amplitude, is similar to that of a VDT.

In the case of magnetic field exposure, Guy (Guy, 1984) determined that the internal current density at the periphery of the body, around the midsection, would be  $1.68 \mu\text{A}/\text{cm}^2$  for a uniform field of 1 A/m. The current density scales directly with the incident magnetic field strength. For example, if a uniform magnetic field of 0.2 A/m was exposing the body having a frequency of 16.7 kHz, the expected current density in the torso of the body would be  $0.34 \mu\text{A}/\text{cm}^2$ . For a more realistic approximation of exposure, comparable to that of an operator sitting or standing in front of a VDT, the expected induced current density would be closer to  $0.16 \mu\text{A}/\text{cm}^2$ . The analysis indicates that a magnetic field of 1 A/m will generate a substantially greater internal current density in the torso than that due to a 1 V/m electric field.

In reality, of course, the exposure fields are far from uniform; only a very limited portion of the body is actually exposed to the maximum field strength. Hence, the above predicted currents and current densities are considerably greater than what would actually occur. Guy (1984), for example, measured only 70 per cent of the current predicted by this very conservative model. A key aspect of the above analysis, however, is that it permits the comparison of exposure of an individual to the emissions of a VDT with that from other sources for which the electric and/or magnetic field strengths are known or can be estimated. One approach for drawing

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comparisons is to evaluate the body to ground current determined for VDT exposures in terms of an equivalent, uniform electric field exposure which would result in the same induced current in the body. In this fashion, the very nonuniform field exposure of the body can be related to the somewhat more uniform exposures commonly experienced from other sources such as AM radio broadcast signals.

Actual body current measurements on humans exposed to uniform electric fields have been reported by Tell et al. (1979), Guy and Chou (1982) and Deno (1977) indicating that, for standing adults, the approximate body to ground current is given by the simple relationship:

$$I_{SC}(\mu A) = 0.3fE \quad [1]$$

where  $f$  is the frequency in kilohertz and  $E$  is the electric field strength in volts per meter. This empirically developed relation seems to accurately predict actual body currents from as low as 60-Hz to the megahertz frequency range. Thus, at VDT frequencies, this relation would result in the following currents for different flyback frequencies:

<u>Flyback Frequency (kHz)</u>	<u>Body Current Expression</u>
15	4.5E
20	6.0E
25	7.5E
31	9.3E

In these expressions, the factor  $E$  is the incident electric field strength in rms volts per meter.

Takemoto et al. (1988) have also investigated the interaction of VDT field emissions with a more sophisticated model of the body composed of a series of 14 prolate spheroids, each representing a different part of the body. In this analysis, measurement data on electric and magnetic fields were obtained from a VDT and used as input to the theoretical model. In this case, field nonuniformity was taken into account. While the results

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were limited to a relatively small portion of the anatomy in the torso, induced current densities can be derived from their data. The computed internal fields were used to compute expected tissue current densities; an average current density of  $8.5 \times 10^{-4} \mu\text{A}/\text{cm}^2$  was determined. This value is related to the measured exposure fields which had maximum values of 0.067 V/m and 13.8 mA/m for electric and magnetic field strengths respectively. These data suggest that current densities resulting from VDT exposures are relatively weak.

### Measurement Approach Used in Study

#### VLF Fields at 30 cm

For each of the selected displays, measurements of the VLF RF electric and magnetic fields associated with the horizontal deflection system of VDTs were accomplished at a fixed distance of 30 cm directly in front of the screen and at 30 cm from the sides, top and rear of each unit. In many cases, the display was situated on a support platform and measurement was made relative to that surface. The sensor was centered on each of the surfaces measured. Electric field strengths were determined by measuring the radial component of the field, i.e., the component of the electric field directed radially outward from the screen toward the position of an operator. The measurement for this part of the study, however, was performed with the VDT operator absent from the VDT so that they did not influence the measurement process. Figure 8 illustrates the orientation of the field sensor as used for measuring the VLF electric fields around a VDT; in each measurement, the plane of the electric field sensor was oriented such that the maximum radial electric field component was aligned for a maximum reading.

A similar procedure was used for the measurement of the VLF magnetic field strength. The measurement was conducted at 30 cm from each accessible surface of the VDT by determining the magnitude of the

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vertically polarized magnetic field. Both electric and magnetic field strengths were measured with the VDT contrast and brightness controls set at their normal position as found when the survey was performed. Figure 9 illustrates the orientation of the field sensor as used for measuring the VLF magnetic fields around a VDT; in this case, the plane of the magnetic field sensing loop was aligned for maximum coupling of the emerging vertically polarized magnetic field lines found in front of the screen with the aperture of the sensor. This same alignment was used for all accessible positions about the VDT as shown in Figure 9. While the polarization of the VLF magnetic field at other locations besides the front of the screen can exhibit differences, generally, it was observed that the greatest field strength was noted when the instrument was oriented for horizontal polarization. In the interest of uniformity in the data collection process and timeliness in completing the measurements, this single sensor orientation was used for all positions about the VDT being investigated.

### **ELF Magnetic Fields**

A similar procedure was used to determine the magnetic field strength associated with the vertical deflection system within the VDTs. Again, the measurement was conducted at 30 cm in front of and from the surfaces of accessible sides of the VDT. Because of the difference in the polarization of the ELF magnetic fields, the field sensor was oriented in the way shown in Figure 10; it was in the indicated orientations that the maximum ELF magnetic field strength was determined.

### **ELF Electric Fields**

The procedure used to determine the strength of the ELF electric fields was essentially identical to that employed for assessing VLF electric fields; i.e., a measurement of the radially directed field was performed by orienting the field sensing paddle of the instrument normal

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to the VDT surfaces as illustrated in Figure 8. The only difference was that the instrument was turned such that the front surface of the meter was facing the VDT being evaluated. This was a peculiarity of the instrument in that the opposite side of the sensor paddle is used for ELF electric fields as opposed to the measurement of VLF electric fields.

### **Electric and Magnetic Fields vs. Distance**

The variation of VLF and ELF electric and magnetic field strength with distance in the range of 10-100 cm from the front of the display screen was determined for a total of ten displays. The measuring instrument was held by a non-conductive handle or support stand in front of each display for determining the electric field strength. In this case, the instrument was oriented so that the radial component of the electric field was incident on the displacement type sensor employed in the instrument (see the section on instrumentation for details of the instrumentation used in the project). Field-distance variations were determined for one each of the NGT and LED displays and for four each of the IBM and CCI VDTs (one in each facility visited).

### **Flyback (Sweep) Frequencies**

For each type of VDT surveyed, the flyback frequencies (the rate at which the electron beam inside the CRT is scanned in the horizontal and vertical dimensions) were measured. This was accomplished by using a portable, digital multimeter (Fluke Model 8060A) with a frequency counter function. The multimeter was connected to the analog output jack of the Holaday Industries Model HI-3600 field strength meter, configured for VLF and ELF fields, with the meter in the magnetic field measuring mode. By holding the field strength meter near the VDT, sufficient signal level from either the horizontal or vertical deflection circuits was obtained for a frequency reading.

### Measuring Operator Exposure

In addition to the large scale survey of VDTs for VLF and ELF electric and magnetic field emission levels at 30 cm, measurements were conducted of the actual electric field strengths incident on VDT operators as well as the strength of the magnetic fields at the location of the body. This was accomplished for the total of 96 displays evaluated in this project. The measurements were performed by having the VDT operator hold the field strength meter against their abdomen, chest and face while they were seated in their normal operating position. In a limited number of LED and NGT measurements only, NIOSH personnel were used for the exposure measurements and assumed the normally used position taken by the telephone operators. During the measurement procedure, the operator participating in the measurements wore the associated headset that is required for communication on the phone system and the headset was plugged into the workstation in its normal fashion. Measurements at three anatomical locations were accomplished for completeness in examining potential inhomogeneity in the exposure of the body. A Holaday Industries Model HI-3615 Fiber Optic Receiver was connected to the Model HI-3600 field strength meter to allow reading the meter at a distance. Figure 11 shows the position of the field strength meter for the measurement of operator VLF electric field exposure at the chest in which case the operator is holding the sensor. Figures 12 and 13 illustrate the self-measurement of VLF electric and magnetic field exposure of the face; in this case, a fiber optic remote receiver unit is used to remotely observe the meter reading. While the operator participated directly in measuring the VLF and ELF electric field exposures, most of the VLF and ELF magnetic fields measurements were conducted as shown in Figure 14 where the instrument was held by one of the survey team. The rationale behind the face position measurement was to explore differences in body surface electric field strengths due to the shape of the body and its ability to provide a shielding function in some cases.

### Induced Body Currents

The amount of RF current induced to flow in the body of the VDT operator was determined for a total of 96 operators of VDTs and NGT or LED displays in this study. The technique used is applicable only to the currents induced by the external electric field. Currents were measured by applying a conductive wrist band to the arm of the operator as illustrated in Figure 15. The wrist band was connected to one input terminal of a Fluke Model 8060A digital multimeter, in microampere ( $\mu\text{A}$ ) measurement mode, while the other test lead was connected to the chassis of the display (ground potential). In this fashion, the amount of current flowing from the body to ground could be directly read with the in-series connected meter. This method follows that of Guy (1987a) who examined the waveforms of the induced currents and determined that the measured current was principally due to the RF component of the electric fields via capacitive coupling between the operator and the VDT electric field source.

Since the magnitude of the induced current depends on the degree of coupling between the operator and the electric field source, three different hand positions were chosen for evaluation of the induced currents. These positions consisted of the hands on the keyboard associated with the particular display, placing the tip of a finger in contact with the screen of the display as if the operator were pointing to a particular word displayed on the screen and placing the hand flat against the screen for a maximum contact area. Figure 16 shows an operator using the keyboard with the wristband attached for the induced current measurement while the induced current is being measured with the multimeter. Figure 17 shows the measurement configuration with the operator pointing to the screen. Figure 18 illustrates the measurement of induced current with the hand in flat contact with the screen. The keyboard measurement is more representative of typical induced current values that are normally experienced by the VDT operators using the

equipment in the telephone operator's work environment and thus are most representative of long-term exposure.

A conventional conductive wristband, normally designed for reducing static charge buildup on workers with solid-state components, was modified by removing the current limiting resistor to permit accurate measurement of the current flowing from the wrist to ground.

### Electric and Magnetic Field Waveforms

An added aspect to this study was the measurement of the waveforms of the electric and magnetic fields produced by the various VDTs in the various telephone operator facilities. Careful examination of the electric and magnetic field waveforms permits determining the rate at which the field strength is changing. In the case of the magnetic field, this aspect of the waveform may be of some significance relative to the ability of the field to induce currents in the body of the operator. Currents induced by magnetic fields circulate in the cross section of the tissue via eddy currents and are directly proportional to the time-rate-of-change (the derivative) of the field denoted mathematically by the expression  $dB/dt$ . The greater the rate of change of the field, the greater the magnitude of the induced current, assuming the peak magnitude of the field remains the same. This issue has played a significant role in the recommendation of placing limits on the rate of change of magnetic fields by the Swedes (MPR, 1988) as well as a precise measurement method for determining the rate of change (MPR, 1987). For the horizontal deflection system in a VDT, during the relatively slowly changing magnetic field strength related to the time that the electron beam travels across the screen from left to right, one value of induced current will exist; during the very rapid retrace of the beam back to the left side of the screen, during a few microseconds, a considerably greater value of induced current will exist. See Figure 3 which illustrates the slower trace period compared to the rapid retrace (flyback) period. It is the retrace

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period, and the corresponding rate of change of the field during this time, which controls the maximum peak currents that will be induced in the body by the magnetic field rather than the root-mean-square (rms) magnitude of the field. This is a crucial concept since magnetic field waveforms having the same rms value but different rise and fall times can induce substantially different peak currents.

Extremely limited data exist to suggest that any particular values of dB/dt may be relevant to the production of biological effects, either in laboratory test animals or humans. Nevertheless, for purposes of procurement of office equipment for government offices, the Swedes have implemented a procurement specification which, among other factors, places a limit on the time-rate-of-change of the magnetic fields emitted by VDT's. This specification calls for a maximum value of dB/dt  $\leq 25$  mT/sec measured at a distance of 50 cm from the VDT but is not scientifically based; the specification was derived, rather, from extensive measurements performed on different models of VDT's, produced by a variety of manufacturers, and observing the distribution of VDT's having various values of dB/dt associated with the entire population of VDT's studied (SSI, 1986). For example, Paulsson et al. (1984) found in a study of 44 VDT's that the time-rate-of-change of magnetic field ranged from a low of 7 mT/sec to a high of 170 mT/sec. On the basis of this and other studies, it was concluded that a peak-to-peak value of magnetic field equal to 200 nanotesla or 160 mA/m peak-to-peak and a time-rate-of-change of the magnetic field of 50 mT/second could be relatively easily achieved with present day technology when designing or modifying existing VDT's. When adopted as a procurement specification, a limit of 25 mT/s was chosen. So, this procurement specification must be viewed more as a statement of technologically achievable, or desirable, levels of magnetic fields rather than a level associated with scientific information related to adverse health effects. Waveform data were collected for the VDTs used in the NIOSH study so that a comparison could be made with the Swedish suggested limit on dB/dt.

### X-Radiation Emissions

Any device capable of accelerating electrons to an energy level of several thousand electron volts can be a source of x-radiation. VDTs and television receivers operate with high voltages typically in the range of 12 to 25 kilovolts (kV) to accelerate the electron beam toward the screen. Normally, x-ray production in VDTs and television receivers is of inconsequential effect; the thickness and absorbing properties of the so-called face plate of the CRT attenuates any possible x-ray emissions to undetectable levels. In the 1960's, considerable attention was focused on x-ray leakage in some television receivers due principally to defects in the manufacture of certain high-voltage power supply components (Braestrup and Mooney, 1959; Callender and White, 1961; Ciuciura, 1959; Bourne, 1959; Hayashi et al., 1964). The potential for x-ray production from television receivers, though now not a real problem, led to the development by the Food and Drug Administration (FDA) of a performance standard for x-ray emissions (FDA, 1973). This standard specifies that exposure rates produced by a television receiver shall not exceed 0.5 milliroentgens per hour (mR/hr) at a distance of 5 cm from any point on the external surface of the receiver.

X-radiation emission varies exponentially with distance from the source; hence, the intensity of x-rays, like RF emissions, decreases rapidly with increasing distance. Sets exhibiting detectable x-ray intensities equal to the FDA standard on the surface would result in lower exposure levels at normal operator positions. While the FDA standards apply to television receivers, video monitors and video projectors, they do not apply specifically to VDTs per se. However, some VDT manufacturers use the 0.5 mR/hr specification in their quality control programs during manufacture. Discussions with FDA personnel indicated that, conceptually, any type of "video display" could be covered by the standard; this would then, presumably, apply to any type of VDT used for graphics display purposes.

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Each of the 96 displays surveyed in this project were evaluated for possible x-ray emissions using a procedure outlined by the FDA (FDA, 1984). The technique involved the surface scanning of each VDT using a large area, high sensitivity x-ray detector. This instrument, designed after a prototype device developed at the FDA and called the Stoms meter after the individual who developed it, was designed to measure x-rays from color television receivers but is an excellent instrument for rapidly determining whether a VDT has any x-ray leakage. The instrument is not absolutely calibrated, but is used as a screening tool to simply determine if the x-ray emissions of a set are above background levels. In practice, the background readings of the instrument were taken at several locations throughout the VDT work area at least eight feet away from any VDT and then the instrument was moved across all accessible surfaces of each VDT. The instrument meter was observed for any upscale reading above the ambient background during the scanning process which would indicate the possibility of x-ray leakage. Typically the screen surface, left and right sides, top, rear and bottom of each display, if accessible, were scanned with the Stoms meter. Figure 19 shows the use of the Stoms meter as used in performing a general surface scan of a VDT. While the Stoms meters used in this study were constructed by personnel of the FDA, a commercial version of the instrument is available from Wm. B. Johnson & Associates (Research Park, Boonton Avenue, Montville, NJ 07045) and is designated as the Model TVX-1 monitor.

In the event that an upscale reading was observed from a surface scan, another instrument, a Victoreen Model 440RF/C, was available to be used for quantitatively evaluating the possible x-ray emissions of the VDT. The Model 440RF/C is designed specifically for the measurement of x-radiation from television receivers in conformance with the FDA standard (FDA, 1973) but is somewhat less sensitive than the Stoms meter. The Model 440RF/C has a very slow time response and requires a substantial amount of time to complete a thorough surface scan of a VDT. Hence, the two instrument approach was selected for use in this study.

## Instrumentation Used in the Study

### Electric and Magnetic Fields

The HI-3600-01 VDT Radiation Survey Meter, used for the VLF field related measurements in this project, is designed specifically to measure electric and magnetic field emissions produced by VDTs, computer monitors, television receivers and other devices using CRT's for information or data display. The HI-3600-01 VDT Radiation Survey Meter has been designed to permit rapid and accurate measurement of the electric and magnetic fields generated by VDTs and is presently the instrument of choice for such surveys.

The HI-3600-01 VDT Radiation Survey Meter consists of a sensor module which is mated to a readout module that controls the instrument and provides for indication of the measured field parameters via a liquid crystal display (LCD). Microprocessor technology is incorporated in the HI-3600 (the meter module) to provide for automatic range changing (manual range changing may be selected) and automatic zeroing of the instrument.

For the measurement of ELF fields, a model HI-3602 ELF input module was used in conjunction with another Model HI-3600 readout module. Although the input modules are interchangeable, using two separate instruments proved more time-efficient than having to change the input modules for measurement of VLF or ELF fields. During the data collection phase of this project a total of four instruments were used, two configured for VLF field measurements and two for ELF measurements. The ELF configured meter is designated as the Model HI-3600-02.

The unique nature of the VDT as a source of electric and magnetic fields demands that rather innovative approaches be taken to accurately assess the magnitude of the emissions (see the above section on VDT electric and magnetic field emissions for more explanation of the

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characteristics of VDTs). Building on the pioneering contributions of S. M. Harvey at the Research Division of Ontario Hydro (Canada) (Harvey, 1982; 1983a; 1983b; 1984a; 1984b; 1985), the HI-3600 VDT Radiation Survey Meter incorporates technology described in a report developed by A.W. Guy, Director of the Bioelectromagnetics Research Laboratory, Center for Bioengineering, at the University of Washington for the National Institute for Occupational Safety and Health (NIOSH). This report (Guy, 1987a), describes the basic concepts upon which the Holaday HI-3600 was developed.

The HI-3600-01 is a single axis (responsive to one polarization component at a time) field-strength meter designed to be responsive to the complex (non-sinusoidal) electric and magnetic fields generated by VDTs over a broad frequency range. It directly displays the root-mean-square (rms) value of the electric and magnetic field strengths on a LCD screen. Figure 20 shows the HI-3600-01 with its paddle-like sensor.

Electric fields are measured through the employment of a so-called displacement current sensor as illustrated in Figure 21. A displacement current sensor operates on the principle that two parallel conductive flat-plate electrodes, when electrically connected together, will exhibit a displacement current which flows between the two plates when immersed in an electric field. This can be visualized by remembering that the electric field between two such plates must be zero when they are connected together; i.e., because they are at the same potential there can be no electric field between them (an electric field exists when the potential on the two electrodes is different). Another way of viewing this phenomenon is to understand that when immersed in an electric field, the external field causes a redistribution of electric charge on the two electrodes and this redistribution of charge is in reality just a flow of current, a displacement current, between the two plates.

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The HI-3600-01 and HI-3600-02 use this principle to detect electric fields by measuring the displacement current caused by the ambient field between two closely spaced circular disks. By placing such a detector in a known electric field, the displacement current can be related directly to the magnitude of the field causing it, permitting its calibration. A circular sensing plate surrounded by a "guard ring" is used in the instrument sensors and the displacement current developed between this smaller diameter disk and a closely spaced eight inch circular disk electrode is sensed and converted to equivalent electric field strength. Because the larger electrode is used as a reference in the measurement process, for accurate measurements of electric fields, the sensor must be oriented in such a way that incident field lines which strike the smaller disk are aligned perpendicular to the disk's surface.

It is important to realize, however, that when the user holds the HI-3600, there is generally an enhancement in the density of electric field lines striking the sensor plate and thus the reading will be in error relative to a free-field measurement. To reduce this user perturbation effect (the instrument appears to be more sensitive because the body tends to cause an intensification of the electric field distribution near it), the HI-3600 should be held with a non-conductive holder so as to avoid direct electrical connection between the user and the instrument. An optional nonconductive support handle (Holaday Industries PN 490945) was used in the project which provides for the required degree of decoupling between the user's body and the instrument.

VLF magnetic fields are measured through the use of a three-turn loop wound about the periphery of the circular electric field sensing electrodes. This loop is shielded from electrostatic fields, insuring that its response is due solely to the magnetic field. Open circuit loops are frequency sensitive devices which provide an output that is proportional to the time rate of change of the magnetic field fluxing through the aperture of the loop. In contrast to this, in the case of the

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HI-3600-01 design, the loop sensor has been resistively loaded to produce a relatively flat response over the frequency range of interest for VDT emissions and an output that is proportional to the magnitude of the magnetic field. Figure 22 depicts the frequency response of a compensated (loaded) loop sensor showing a frequency region over which the response is essentially flat. Thus, the HI-3600-01 is capable of accurately measuring the strength of magnetic fields from all kinds of VDTs, regardless of their frequency of operation.

The Model HI-3600-02 uses a similar loop sensor but one having approximately 2000 turns of wire. Again, the loop is compensated to control its frequency response producing a relatively flat response over the frequency region of interest. The Model HI-3600-02 was originally designed for electric transmission line applications but proves to be an excellent device for determining the ELF emissions produced by the vertical deflection systems of VDTs.

Measurements of the magnetic field strength are considerably less difficult since the presence of the human body does not perturb the magnetic field. In this case, the instrument is generally held so that the sensor paddle is in an orientation which yields the maximum reading on the LCD screen. For most VDTs, including the ones evaluated in this project, this will be in a horizontal position with the paddle facing upward with the center of the paddle located at a distance of 30 cm from the front of the VDT screen for the VLF magnetic field component and in a vertical orientation for sensing the ELF magnetic field component (see Figures 9 and 10 which illustrate these orientations). Because the body does not influence the magnetic field, the user may, if desired, directly hold the HI-3600 for these measurements.

Care should be taken in positioning the sensor for both electric and magnetic field measurements because the spatial variation in both fields near the VDT surface is very rapid. Because of the finite size of the

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sensing loop, magnetic field measurements will be representative of averages of the field strength over the area of the sensing loops. As the distance between the probe and the screen is decreased, greater error will exist in the indicated value of magnetic field strength. This spatial averaging error diminishes rapidly with distance from the VDT since the field rapidly becomes more uniform.

Because the electric and magnetic field gradients are so great near the VDT, significant error may occur if extra care is not exercised when attempting repeated measurements at a specific location. This is apparent when holding the instrument without a tripod or supporting device very near the screen and attempting to obtain a constant reading of field strength. To enhance the repeatability of field measurements near the VDTs evaluated in this project, a special nonconductive stand (Holiday Industries PN 490957) which provides electrical isolation for the meter was used in determining the variation of electric and magnetic field strengths with distance. Orientation of the instrument on the nonconductive stand for measurement of the VLF magnetic fields produced by a VDT is shown in Figure 23. In the case of fixed distance measurements at 30 cm from accessible surfaces of the VDTs, a foam rubber spacing device (PN 470443) was used as a spacer to insure an exact 30 cm spacing. Use of this device is illustrated in Figures 24 and 25 for the measurement of electric and magnetic fields respectively. Table 1 gives specifications for the Holiday Industries Model HI-3600-01 VDT meter and Table 2 gives the specifications for the Model HI-3600-02 ELF field meter which was used for the measurement of the ELF electric and magnetic fields produced by the vertical deflection system.

### Field Waveforms

For the measurement of field waveforms, use was made of the analog output jack on both the HI-3600-01 and HI-3600-02. This jack provides an analog signal which is produced by the electric or magnetic field waveform

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prior to detection by the instrument. The output signal represents the instantaneous field strength of the field and can be observed on an oscilloscope. During the survey, measurements were made of the waveforms of both the electric and magnetic fields associated with both the horizontal and vertical deflection circuits. The approach used in the measurements consisted of using a digital oscilloscope (Tektronix Model 2230) connected to the analog output signal of the appropriate meter to capture the waveform. A laptop computer (Toshiba Model T-1000) was used to transfer the waveform data from the oscilloscope via the RS-232 serial interface between the computer and the oscilloscope. A conventional telecommunications software package was used to send instructions to the digital oscilloscope. The waveforms were transferred to a floppy disk in the computer for subsequent analysis and plotting. The measurement setup shown in Figure 30 was used for capturing the waveforms of magnetic and electric fields.

For recording the magnetic field waveforms, the above approach proved straightforward. For electric field waveforms, however, the electrical connection required between the analog output jack of the field meter and the digital oscilloscope modified the electric field response of the instrument, tending to increase the readings. This is because the instrument is no longer isolated electrically from the environment as it normally is when held via the dielectric handle with no other connections to the instrumentation. With the attachment of the oscilloscope, the displacement current sensor of the instrument becomes referenced to a much larger ground plane and hence, the sensor appears electrically larger and thus more sensitive than otherwise. To compensate for this unavoidable perturbation, the electric field waveform amplitude data were corrected by multiplying by the ratio of the free-space measured electric field when the oscilloscope was not connected to the meter to the indicated value while the cable was attached. Although such an approach is not precise, it yields values of the measured electric field waveform amplitudes which

are approximately correct despite the undesired impact of changing the meter's response characteristic through the electrical connection process.

### Calibration

Instrument accuracy was derived from a field calibration using a one meter diameter pair of Helmholtz coils for establishing an accurately known magnetic field strength and a pair of parallel electric field plates for creating a known electric field strength. In the case of the Helmholtz coils, a precisely controlled and measured sinusoidal current is driven through the coils and, based on the dimensions of the coils, the magnetic field strength in milliamperes per meter (mA/m) is calculated (Tell, 1983). Figure 26 diagrammatically illustrates the use of a Helmholtz coil system for establishing a known magnetic field strength and Figure 27 shows the actual Helmholtz coil pair used to evaluate the response of the various instruments used in this project. Spatial variation of the magnetic field within the principal volume used for calibration in the Helmholtz coil system was determined to be less than about three percent.

For electric fields, a sinusoidal voltage impressed across the parallel plates is directly measured and, using the spacing between the plates, the electric field strength in volts per meter (V/m) is determined as the voltage difference divided by the spacing (Mantiply, 1984). Figure 28 shows the use of the parallel plates, spaced 50 cm apart for these calibrations, for calibrating the electric field response of the HI-3600-01 and HI-3600-02. In each case, both currents and voltages in the calibration set-ups are determined with a true rms detector responsive over the frequency range of calibration desired.

The HI-3600-01 and HI-3600-02 indicate magnetic field strength in units of milliamperes per meter (mA/m). Other alternative units are sometimes referred to in connection with magnetic field measurements,

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these being gauss (G) and tesla (T), or some derivative thereof. Magnetic field strength may be converted to different units through the following relations:

$$1 \text{ mG} = 0.1 \text{ } \mu\text{T} = 79.6 \text{ mA/m} \quad [2]$$

$$1 \text{ mT} = 796,000 \text{ mA/m} \quad [3]$$

$$1 \text{ A/m} = 1.256 \text{ } \mu\text{T} \quad [4]$$

The HI-3600 also provides for monitoring the waveform of the signal coming from the sensor preamplifier circuit in the input module. Connection of an oscilloscope to the output jack for the analog signal will allow observation of the preamplifier output. It is through the use of this signal that the flyback frequency and waveforms of electric and magnetic fields were measured. Figure 29 shows the HI-3600-01 being used with a portable digital multimeter having a frequency counting feature to determine the horizontal flyback frequency.

Each instrument used in the project was subjected to a calibration check by measuring the indicated response of the meter to applied electric and magnetic fields of known magnitude across the frequency range of interest for the study. In addition, the value of the analog output signal was determined in relation to the strength of the field to which the instrument was subjected. This analog output calibration then insured accurate measurements of the field waveform magnitudes in that voltages measured on the digital oscilloscope used in the project could be directly related to the instantaneous field strength of the field.

Applied fields for the calibration were produced by a B&K Precision Model 3020 sweep/function generator used to drive the Helmholtz coils or the parallel electric field plates. For the measurement of current flowing in the magnetic field coils, the signal from the function

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generator was passed through a resistor having a resistance of 50.89 ohms. A Fluke Model 8060A true rms multimeter was used to measure the voltage drop occurring across the resistor from which the current flowing in it was calculated using Ohm's Law. In the case of the electric field plates, the voltage impressed across the plates was directly measured with the digital multimeter.

In total, a combination of six instrumentation configurations for measuring electric and magnetic fields was used during the project. Table 3 summarizes the various instruments used and their serial numbers. Each configuration was evaluated for its response. The results of these evaluations are given for a selection of the instrument configurations in Figures 31 through 35 which illustrate the measured frequency responses. Based on the data obtained from the calibration phase, correction factors were derived to be used with each instrument configuration in correcting the data obtained during the measurement phase of the project. The correction factor is that number which when multiplied by the indicated meter reading yields the correct field strength value. Correction factor data are summarized in Table 4 for the instrument configurations used in the study; the VLF band corrections are for a frequency of 15 kHz since this corresponds closely to the measured VLF flyback frequencies. For the ELF band, correction factors are given for 45 Hz and 60-Hz, these corresponding to the measured sweep frequencies of the vertical deflection systems in the two types of VDTs characterized in the study. As the data were collected, the exact instrument being used for the measurement was recorded to permit proper correction of the data. In each instance, the measured field strengths for each display were corrected for instrument response according to the data in Table 4. Approximately 3856 field strength measurements were accomplished not including the waveform measurements.

## Measurement Results

### VLF and ELF Electric and Magnetic Field Emission Results

The survey results are provided in Appendix B which lists the measurement results for each display evaluated in the project. Appendix B indicates the flyback frequency associated with the horizontal and vertical deflection systems if the display was a VDT. This information is noted as VLF Sweep and ELF Sweep and is given in units of kilohertz and hertz respectively. It was found that the two types of VDTs had essentially the same horizontal deflection frequencies, the CCI displays operating at nominally 15 kHz while the IBM units operated at nominally 16 kHz. The vertical refresh frequencies for the two types were different, the CCI operating at nominally 45-Hz and the IBM at 60-Hz. Appendix B shows the measured electric and magnetic VLF and ELF field strengths for points 30 cm from each accessible surface.

For convenience in viewing the data, summary tables have been prepared which give the geometric mean values for the electric and magnetic field strengths at 30 cm for each type of VDT along with the geometric standard deviation of the measured values to indicate the nature of the variability of the data. It was determined that most of the emissions and operator exposure data were not normally distributed; for this reason, these statistical summary tables, Tables 5-8, present the geometric mean (a measure of central tendency) and the geometric standard deviation (a measure of the variance) for all the emission and exposure data contained in Appendix B for the NGT, LED, CCI and IBM displays respectively. Lower and upper limits, which define the range within which 68 percent of the values lie, can be obtained as follows:

Lower limit = Geometric Mean + Geometric Standard Deviation

Upper limit = Geometric Mean × Geometric Standard Deviation

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The values indicated in these tables have been adjusted to the appropriate number of significant figures based on the the observations obtained in the measurement process. Inspection of Tables 5-8 indicates that the measured mean VLF electric field strengths determined at 30 cm in front of the displays ranged from a low of 0.08 V/m for the LED displays to a high of 4.2 V/m for the CCI units. A single outlier value of 47 V/m was found for one of the IBM VDTs. The corresponding VLF magnetic field strengths ranged from an average of 1.4 mA/m to 99 mA/m for the NGT and CCI units respectively.

The measured mean ELF electric field strengths ranged from a low of 0.38 V/m to a high of 1.9 V/m at 30 cm in front of the screen for the LED and CCI units. Average ELF magnetic field strengths were determined to range from 30 mA/m to 314 mA/m at 30 cm in front of the screen for the NGT and CCI units.

Inspection of Tables 5-8 provides a perspective on the spatial distribution of the electric and magnetic emissions about the VDTs sampled in this project. In a general sense, the data indicate that the VLF electric field was, for the most part, maximum in front of the screen compared to the sides, top, rear or bottom. In the case of the NGT and LED displays, however, position did not seem to be consistently related to the strongest field strength. For the VLF magnetic fields, again the NGT and LED units showed no one position which was characteristically high but in the case of the VDTs, the frontal value of field was strongest but did not demonstrate as great a difference in field value when compared to other positions as did the VLF electric field. One possible explanation for this observation is that the material from which the case of the VDT is made has less impact on the magnetic field than on the electric field. For example, with an all metal case the electric field tends to be significantly reduced in strength at locations other than in front of the screen. A metal case will have much less effect in shielding the magnetic field component. Tables 5-8 indicate that for the VDTs, the VLF emissions

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were strongest in front of the display. But the ELF data show a less consistent pattern; sometimes the strongest fields were to the side or back of the unit. During the survey measurements, the materials used in the construction of the VDT cases was not determined.

### Effects of Screen Condition on Measured Fields

While conducting measurements at the downtown Nashville location, a brief evaluation of the potential effects of the degree that the screen was filled with characters might have on the measured field strengths was accomplished. In this test, the CCI VDT was placed in the so-called maintenance mode which established a screen substantially filled with characters. This mode could be toggled on and off thereby alternately producing a clear (blank) screen. The field sensors were established at a distance of 50 cm from the VDT screen and produced the following results:

<u>Field Measured</u>	<u>Screen Blank</u>	<u>Screen Filled</u>
ELF E-field	1.23	1.21
ELF H-field	146	137
VLF E-field	0.92	0.93
VLF H-field	44.1	43.9

These results suggest that there is little difference in measured fields as a function of the extent to which the screen is filled with characters.

### Emission Levels vs. Distance Results

The strength of the RF emissions caused by VDTs is critically dependent on the distance from the VDT. This variation with distance was studied with ten displays (8 VDTs, one NGT and one LED) to provide some perspective on the issue of exposure levels that exist at close and far distances. These data are presented for the ELF and VLF magnetic fields and ELF and VLF electric fields of the CCI displays in Figures 36 through 39. Similar plots for the spatial variation of the ELF and VLF fields for

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the IBM displays measured are given in Figures 40 through 43. In each instance, the general trend is that the field strength decreases rapidly with increasing distance from the screen of the VDT. A deviation from this trend, seen in Figures 38, 40 and 42 for the ELF electric field, is likely due to the contribution of ambient 60-Hz electric fields within the room.

Each figure illustrates the rapid decrease in field strengths for both the electric and magnetic fields as the distance from the screen is increased. As can be seen from these plots, the field strengths fall exponentially with distance. An analysis of the data from which these figures were developed for the CCI VDTs shows that for a doubling of the distance between the screen surface and the position of the field sensor, for areas closest to the screen (within the range of 10 to 40 cm), the VLF electric field strength typically decreases by a factor of 3.0-6.1 times the field strength at the closer distance. The VLF magnetic field strength decreases by a factor of between 2.9 and 4.8 for a similar doubling of distance. For ELF electric fields the corresponding reduction values for a doubling of distance are, for the CCI VDTs, 2.0 to 3.6; the reduction values for ELF magnetic fields range from 2.5 to 5.4.

A similar analysis of the data for the IBM units shows the following field reduction factors for a doubling of distance:

<u>Field</u>	<u>Reduction factor</u>
VLF-E	3.3-7.1
VLF-H	1.9-7.2
ELF-E	2.8-6.7
ELF-H	1.9-5.1

Hence, exposure of individuals using VDTs is strongly related to how far they sit away from the VDT. Clearly, VDT exposure to the electric and magnetic field emissions of conventional VDTs often becomes more a function of the manner in which the VDT is used by the operator than of the emission characteristics of the unit.

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Of particular interest is the presentation of the variation of VLF magnetic field strength for the IBM VDT shown in Figure 41. These data include four different IBM VDTs as identified in the figure but they suggest that there are two substantially different populations of VDTs; some producing significantly greater values of magnetic field than others, all of the same model number. This was observed during the collection of emission data at 30 cm and was verified in the distance variation data given here. Upon a brief investigation, it was determined that the actual CRT chassis inside the cabinet was produced by two different manufacturers, Zenith and Motorola. For two VDTs so investigated, specifically stations 1004 and 1006 at Forest Park, Georgia, it was found that the Zenith CRT assembly produced the lesser of the magnetic fields, typically by a factor of about 15 times. Figure 41 shows a somewhat greater difference between the stations investigated for that figure. While it cannot be proved from these limited data, there is strong reason to believe that the IBM VDTs consisted of units of both CRT assemblies and that one could predict with good confidence the type of assembly in the VDT from the measured VLF magnetic field strength at 30 cm.

Figures 44 and 45 show the measured spatial variation of electric and magnetic fields respectively for the NGT displays. These plots of the field strength suggest that the displays are not significant sources of ELF fields since the field shows no characteristic decrease with increasing distance. Similar plots of the electric and magnetic field variation for the LED displays, in Figures 46 and 47, also support the intuitive view that these units would not be expected to exhibit significant VLF fields since they do not possess magnetic deflection system like those in conventional VDTs. These data are more suggestive that the measured fields were representative of the 60-Hz environment within the room where the measurements were taken. Normal 60-Hz fields arise from electrical wiring within the building and, to some extent, possible outside sources such as overhead electric power distribution lines in the vicinity.

### VDT Operator Electric and Magnetic Field Exposure Results

The influence of the operator on the spatial distribution of the electric field lines emitted by a VDT is illustrated in Figure 4. Data on the body surface values of electric field strength were obtained for 96 different operators at randomly selected units. The results are statistically summarized in Tables 5-8 and indicate that, for the sample of operators used in the measurements, the strength of the VLF electric field on the chest had a mean value of between 60 and 74 percent of the value on the face for the IBM and CCI VDTs. For both VLF and ELF electric fields, the mean field strength at the face was greater than the strength at the chest. Mean values for the VLF electric field strength ranged between 0.54 and 1.4 V/m at the face while the ELF field ranged between 0.78 and 1.9 V/m. These data suggest that substantial distortion of the local electric field strength occurs due to the body shape, size and proximity of the operator to the VDT being evaluated.

Interestingly, the mean values of magnetic field strength were greatest at the face with mean values for the VLF field ranging between 6.7 and 42 mA/m and mean values for the ELF field ranging between 76 and 82 mA/m. Physically, it would appear that the head of the operator tends to be somewhat closer to the VDT and tends to attract electric field lines toward the face, thus decreasing the intensity of the electric field lines terminating on the rest of the body. Also, the apparent closer distance accounts for the greater value of magnetic field at the face, the chest and abdomen being farther from the source of magnetic fields. Importantly, the operator exposure values are generally significantly less than the values for electric and magnetic field emissions determined for 30 cm in front of the display; this observation supports the contention that operator exposure levels are quite low.

Exposure data for the NGT and LED displays contrast sharply with that from the VDTs in that the field strength values, are generally

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substantially less. This is likely because the NGT and LED displays do not contain VLF field sources and any ELF emissions which may exist are at or near the 60-Hz background level in the rooms where the measurements were conducted. One exception to this observation is that the ELF magnetic field exposure levels associated with the LED displays were approximately the same as for the CCI and IBM VDTs.

It should be noted that due to the measurement protocol used, any potential influence that nearby, adjacent VDTs might exert on the operator exposure would, in general, be taken into account. This is because, on average, there were workstations in which adjacent VDTs were being used during the time of the measurements.

### Induced Body Current Results

Measurements of body currents induced by capacitive coupling between the operator and the VDT are also summarized in Tables 5-8 for measurements conducted on all 96 displays. Values of induced currents are given for the condition of the hands on the keyboard of the VDT, when the operator pointed with a finger at a spot on the screen of the display and with one hand placed flat against the screen of the VDT, maximizing the capacitive coupling and thus maximizing the induced current. For a total of 24 CCI VDTs, the average value of the maximum induced body current was determined to be 88 microamperes ( $\mu\text{A}$ ) with the hand placed flat against the screen surface and 69  $\mu\text{A}$  for the IBM VDTs. These values are consistent with the findings of Guy (1987b). With the hands on the keyboard, a more typical situation for a VDT operator, the average induced body current was only 4.1  $\mu\text{A}$  and 0.38  $\mu\text{A}$  for the CCI and IBM VDTs respectively, substantially less than the screen contact measurement. For the finger touching the screen, the induced currents were intermediate in value, being 15  $\mu\text{A}$  for the CCI units and 6.6 for the IBM units. The measured currents were found to be highly variable from operator to operator. A maximum induced current of 424  $\mu\text{A}$  was measured with the hand

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on the screen for one operator while a minimum, with the hands on the keyboard, of 0.02  $\mu\text{A}$  was found for another.

Appendix A and Tables 5-8 show that induced currents found for the NGT and LED displays were extremely low with mean values between 0.008 and 0.014  $\mu\text{A}$ , regardless of hand position. This finding is indicative that there are no high voltage sources within these displays comparable to the high voltage supply contained in conventional VDTs.

The digital oscilloscope was used to verify the frequency of the induced currents measured with the digital multimeter. The oscilloscope was simply connected to the wrist band such that the oscilloscopic display was that of the voltage drop across the internal impedance of the scope. The waveform was captured so that the period of the voltage waveform, corresponding to the current waveform, could be determined. This is not a highly precise way of determining the frequency of the current but was sufficient for establishing that the current was related to the horizontal deflection circuit produced fields. Figure 48 presents a representative plot of the observed current waveform obtained through this approach. The period identified as T in the plot is related to the frequency through the relation:

$$f = 1/T \quad [5]$$

Each current waveform period was determined by analyzing the number of digital data points stored within the digital oscilloscope corresponding to the current spikes and multiplying by the time interval between successive data points. This process yielded the following results for currents measured in various cities:

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<u>City</u>	<u>VDT Type</u>	<u>Period (<math>\mu</math>s)</u>	<u>Frequency (kHz)</u>
Nashville	CCI	58.0	17.241
Forest Park	IBM	63.2	15.823
Macon	IBM	63.0	15.873
Jacksonville	IBM	63.0	15.873
Lake City	IBM	63.0	15.873
Marrero	CCI	66.6	15.015
Bogalusa	CCI	68.5	14.598

These data confirm that the wrist currents measured were due to the VLF electric field and not the ELF fields present. Because the induced current waveform is directly related to the time-derivative of the electric field (for example the waveform of Figure 54), it will possess a bi-polar characteristic as seen in Figure 48 (see section on field waveforms below).

### Field Waveform Measurement Results

Graphical representation of the measured electric and magnetic field waveforms were developed from the digital oscilloscope data and are presented for several different types of displays in Figures 49-68 for VLF and ELF magnetic and electric fields. Each waveform is plotted as a function of time, illustrating the peak-to-peak excursions of the associated field strengths. Figures showing the magnetic field waveform of the VDTs indicate the time-rate-of-change (dB/dt) value which was determined by analysis of the waveform. The dB/dt value is given in terms of milliamperes per meter per microsecond normalized to one milliampere per meter rms magnetic field strength. Thus, by knowing the rms magnetic field strength as indicated on the measuring instrument, the correct value of dB/dt can be deduced.

The indicated waveforms were obtained with the field sensor oriented for the maximum indicated rms magnitude of the magnetic or electric field; in this sense, the measurement technique differs with that specified in the Swedish recommended measurement procedure in which three orthogonal magnetic field loop sensors are to be positioned at many specific distances

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and directions from the VDT under test. This difference in measurement approach will undoubtedly result in some difference in the resulting values.

The analysis of the waveform data to obtain dB/dt was accomplished by examining the slope of the magnetic field between the minimum and maximum values of the instantaneous field. Specifically, the transition time between points on the waveform corresponding to 20 percent above the minimum point and 20 percent down from the maximum amplitude of the field were used since in this central 60 percent of the transition, the slope is the greatest. The objective of this exercise was to find the greatest value of dB/dt since magnetic field induced currents are proportional to dB/dt.

As an example, Figure 49 shows the measured VLF magnetic field waveform obtained from a CCI VDT in Nashville. The sharply rising part of the waveform occurs during the rapid flyback of the electron beam to the left side of the CRT screen. In this case, a value for dB/dt of 0.560 mA/m/ $\mu$ s/(mA/m rms) was determined. In this case, the waveform measurement was made with the sensor positioned at 30 cm from the front of the screen but in other instances, the sensor was positioned at the surface of the screen to investigate whether any significant differences might be observed in the waveforms.

The VLF electric field waveform for the same CCI VDT is shown in Figure 50, illustrating the pulse like nature to the electric field due to the flyback transformer action. The instantaneous value of the electric field strength can be determined by reading the vertical axis of the plot. It is observed that the electric field changes polarity rapidly during its pulse and this leads to a bipolar character to the associated induced currents.

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For comparison, the ELF magnetic field waveform is shown for the above CCI VDT in Figure 51. In this case, the dB/dt value is substantially less than with the VLF field, despite the much larger values of magnetic field. This is due to the much slower time associated with the transition of the field to control the vertical sweep of the electron beam on the screen of the VDT. In this figure, it can be seen that dB/dt for the ELF magnetic field is more than 200 times smaller than the VLF produced dB/dt.

Finally, Figure 52 shows the measured ELF electric field determined for the CCI VDT. This waveform is essentially similar to a 45 Hz sine wave.

Similar waveform data are presented for IBM VDTs in Figures 53-55. Of notable interest is the dB/dt value derived from Figure 55 which is for the IBM VDT but which yields a substantially greater value of 3.99 mA/m/ $\mu$ s/(mA/m rms). This is presumably a function of the unique oscillatory nature of the magnetic field waveform. While this unit produced the highest value of dB/dt of any of the VDTs evaluated, it also produced among the weakest rms values of magnetic field in front of the screen. Thus, the rms value of the field produced by the deflection system of a VDT does not necessarily correlate with the rate at which the field changes. From a magnetic field induced current perspective, a unit such as this one could result in actually greater induced eddy currents in the body of the operator than another unit exhibiting a much stronger rms value of field but with a lower dB/dt value.

Figure 56 is another waveform plot of the magnetic field for another IBM VDT, apparently of the same design as the unit in Figure 55. Here the value of dB/dt is somewhat less (2.75 mA/m/ $\mu$ s/(mA/m rms)). But the same waveform, when observed from a distance of 30 cm, as seen in Figure 57, has deteriorated substantially because of the rapid fall-off in field strength with distance from the screen. In this case, the waveform was

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not solid enough to carry out the dB/dt analysis. The associated VLF electric field waveform, shown in Figure 58, of the same VDT (station 1028 in Macon) is very similar to that of the other electric field waveforms presented. Figures 59 and 60 show the measured waveforms of the ELF magnetic and electric fields respectively.

Since the NGT and LED displays do not use magnetic field deflection in their operation, one would not expect to see the same type of waveforms for these displays. Such is the case as seen in Figures 61-64. In fact, the output of the sensors is so low and the gain of the digital oscilloscope was so high for these recordings that a residual signal, apparently related to the circuitry of the ELF and VLF meters, was observed in the graphical results. For example, in Figure 64, internal noise spikes appear, spaced in time corresponding to a frequency of about 7.5 Hz. Discussions with personnel at Holaday Industries suggested that this anomaly was probably due to the manner in which the instruments are programmed to take readings; 7.5 Hz is the approximate cycling rate that the analog to digital converter uses to update the readout. Presumably, because of the circuit power demands, a noise signal can appear on the analog output when observing for very low level fields near the internal noise level of the instrument.

Figures 65 through 68 complete the views of waveforms for the LED displays. These waveforms are very similar in character to those produced by the NGT displays discussed above. With the gain on the oscilloscope turned up, because of the very low field strengths indicated on the field sensors, the internal noise spike is again visible in the recordings.

The waveform data obtained from all of the measurements conducted during the field study have been summarized in Table 9. In this table the value of dB/dt obtained by placing the sensor at the surface of the screen is compared to the value with the sensor placed at 30 cm in front of the screen of the VDT. Table 9 reveals that, except for one apparent

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discrepancy, the values of dB/dt, whether determined at the screen surface or at 30 cm, are no greater than 20 percent different from one another. The actual percentage differences in the data ranged from 0 to 19.8, barring the one exception associated with the IBM VDT in Macon for the ELF field. These data support the proposition that, for practical purposes, magnetic field waveforms for evaluating dB/dt can be obtained by placing the field sensor on the surface of the VDT screen. Generally, much cleaner waveforms can be obtained by placing the sensor next to the screen since the magnetic field is so much stronger at this point, thereby reducing the potential of noise on the detected waveform observed from a distance. Table 9 clearly illustrates that the greatest values for the time-rate-of-change of the magnetic field are those associated with the horizontal deflection system VLF fields.

For practical comparison of the dB/dt values to the Swedish procurement specification, two transformations are necessary. First, the values must be converted to equivalent units of millitesla per second (mT/s) and secondly, they must be referenced to a distance of 50 cm from the screen. dB/dt in units of mT/s can be obtained by multiplying dB/dt in units of mA/m/ $\mu$ s by the factor 1.256. Next, by evaluating the spatial variation in the VLF magnetic field with distance, the rms field at 50 cm can be estimated by taking the appropriate ratios. For the VDTs listed in Table 9, values for dB/dt in units of mT/s were derived for a distance of 50 cm using the larger of the two indicated values of dB/dt specified in units of mA/m/ $\mu$ s/(mA/m rms). Table 10 contains the results and indicates that in units of millitesla per second, values for dB/dt for VLF emissions range from a low of 9.03 mT/s to a high of 37.6 mT/s. For ELF emissions the low and high values were 0.25 mT/s and 1.8 mT/s.

### X-Radiation Measurement Results

Although considerable time was expended in conducting the survey for possible x-radiation leakage, none of the 96 displays evaluated were

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determined to produce detectable x-ray levels above the background of the large area scanning Stoms meter. On one occasion, near the beginning of the field measurement phase, one Stoms meter began to malfunction. This meter was subsequently replaced with another unit which continued to function properly throughout the remainder of the project. Because no above background levels were found in the survey, the Victoreen Model 440RF/C was not needed. The FDA established limit for x-ray leakage is 0.5 mR/hr which is equivalent to half scale deflection on the lowest range of the Model 440RF/C.

This finding is consistent with other studies which have examined x-ray emissions from VDT's (Paulsson et al., 1984; Ontario Hydro, 1985). In both of these studies, for example, the authors found that measurements using very sensitive techniques were required to detect any ionizing radiation emissions from VDT's. In the Ontario Hydro study, it was found that the only radiation emissions that could be detected from some units was that due to the radioactivity, principally potassium-40, contained in the glass of the picture tube, or CRT. This was surmised since the measurement was independent of the VDT being turned on.

### **Discussion of Measurement Results**

#### **Comparison of Data to Values in the Technical Literature**

To form a perspective on the data collected in this study, the data here may be compared to those of other researchers who have explored electric and magnetic fields near VDTs. The literature contains a surprisingly large amount of data on field strengths which may be used for comparison. Table 11 is a compilation of data taken from numerous technical reports and the scientific literature. In this table, the mean values, and associated standard errors, for the rms electric and magnetic field strengths as determined via measurement at a distance of 30 cm from the front of the VDT screen are given along with the range of the values,

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i.e., the maximum and minimum field strengths. The first column lists the number of units for which each researcher reports data.

Inspection of Table 11, as a reference, shows that the values of electric and magnetic field emissions of the various VDTs in the various telephone operator offices visited in this study fall generally within the observations of others, determined in other office environments in the United States as well as several other countries.

The measurement protocol used in the project provided for additional measurements to be made if any of the selected displays were found to be equipped with glare filters, especially those that might be grounded. In no instance, for any of the 96 displays examined, was a glare filter of any type attached to the unit.

The one outlier value of 47 V/m for an IBM VDT may be due to inadequate grounding of the CRT because of a loose ground strap on the VDT chassis. In any event, this higher value was not indicative of the field strength typically found in front of the VDTs.

### Spatial Distribution of Fields

For the VDTs investigated in this project, VLF magnetic fields were generally strongest directly in front of the screen or on top of the display. VLF electric field strengths were always strongest in front of the screen, this finding probably being due to the conductive nature of the VDT cabinet acting as a form of electrostatic shield. The evaluation of operator exposure levels revealed that almost categorically, operator exposures are less than the frontal emission measurement data for VDTs, usually significantly lower. While it is true that in some instances, measured field strengths were strongest in directions other than to the front of the screen, the data tend to suggest that, for routine survey measurements of VDT emission levels, a single measurement with the sensor

placed at 30 cm in front of the screen is probably sufficient for documenting field levels relevant to potential exposure of VDT operators. Certainly, the actual operator exposure measurements include contributions of fields produced by adjacent VDTs and thus, in effect, take into account the fact that an operator's exposure may be derived, in part, from not only fields generated by the VDT the operator is using but also, nearby units used by others. The data showing the strong spatial variation of field strengths with distance from the VDT support the contention, however, that any given operator's exposure is predominated by the unit they are using. Exhaustive evaluations of the spatial variation of VDT produced fields appear, therefore, unnecessary from a practical perspective.

#### Comparison of Measurement Results with Exposure/Emission Standards

To provide a means of judging the potential significance of the measured electric and magnetic field emissions found in this study, the literature was reviewed to compile information on suggested exposure or emission limits. The exposure standards reviewed here apply to humans for the purpose of establishing safe working or living environments where electric and magnetic fields exist. The exposure limits compiled in this report are those found that correspond most closely to the predominant frequency range of VDTs. In some cases, the standards apply to occupational exposure environments and in other cases, to the general living environment; often standards for this latter case are referred to as general population or public exposure limits.

Based on practices used in the ionizing radiation community, occupational and public exposures to RF fields are usually differentiated. Generally, occupational exposure limits are higher, i.e., more permissive, than public limits. This is because of the greater uncertainties associated with the general public; in the work place,

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employees are generally healthier, and the possible exposure to potentially hazardous physical agents is usually under much better control. For example, employers can inform workers of situations which should be avoided; this is not the case for the general population as a whole. Regardless of these considerations, however, it is informative to examine some of the various recommended exposure guides that apply to different organizations and/or countries.

Table 12 summarizes the RF field exposure standards found in the literature that either directly apply to the frequency range appropriate to VDT emissions or pertain to a frequency range close to that of interest. From the literature searched, only one reference was found that offered a quantitative emission limit as a guideline specific to VDTs (Telecom, 1986). The standards listed in Table 12 are applicable to occupationally exposed personnel and the general public as noted.

Examination of the measured electric and magnetic field strengths reported in Appendix B and Tables 5-8 show that in no instance do either of the two fields, determined at the position of the operator, exceed any of the standards in Table 12, even the extremely stringent Polish and Czechoslovakian standards for the general public (Poland, 1972; Czerski, 1985). Based on this finding, it is observed that typical personnel exposures to VDT electric and magnetic field emissions that are relevant to exposure of telephone operators in the NIOSH epidemiology study are relatively low, within the range of other exposure data reported by other researchers, and are generally substantially less than any electric and magnetic field exposure limits developed for radiation protection purposes by organizations within the United States and many other countries.

Unfortunately, there are very few standards which have been established for exposure to ELF magnetic fields. Driven principally by public concern, several states have developed regulations on the strength of 60-Hz electric and magnetic fields produced by electric power

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transmission lines at the edge of the right-of-way. A total of seven states have done so, six of these placing limits only on the electric field (ranging from 1 to 3 kilovolts per meter at the edge of the right-of-way); recently Florida included limits on magnetic field strength as well, placing the limit at 0.015 mT at the edge of the right-of-way for 230 kilovolt transmission lines. These limits have all been set on the basis of maintaining the status quo, i.e., not letting the field levels exceed present values as found near transmission lines; they have not been set on the basis of scientific insight about biological effects. As one can see, the 0.015 mT figure (equivalent to 150 milligauss or 11,940 mA/m) is a large value when compared to typical VDT emission values (TDHSR, 1989). Similarly, the state of New York has recently proposed an interim magnetic field limit of 200 mG (equivalent to 15,920 mA/m) for new transmission line right-of-ways (Microwave News, 1990).

The International Radiation Protection Association (IRPA) has also studied the issue of ELF exposure and developed recommendations on exposure criteria (IRPA, 1990). These new guidelines are summarized below:

### Summary of IRPA ELF Exposure Guidelines for 50/60-Hz

<u>Exposure characteristics</u>	<u>Electric field strength</u>		<u>Magnetic flux density</u>	
	<u>kV/m (rms)</u>		<u>mT(rms)</u>	<u>mA/m(rms)</u>
<b>Occupational</b>				
Whole working day	10		0.5	398,000
Short term	30 <sup>a</sup>		5 <sup>b</sup>	3,980,000
For limbs	—		25	19,900,000
<b>General Public</b>				
Up to 24 h/day <sup>c</sup>	5		0.1	79,600
Few hours/day <sup>d</sup>	10		1	796,000

<sup>a</sup> The duration of exposure to fields between 10 and 30 kV/m may be calculated from the formula  $t \leq 80/E$ , where  $t$  is the duration in hours per work day and  $E$  is the electric field strength in kV/m.

<sup>b</sup> Maximum exposure duration is 2 hours per work day.

<sup>c</sup> This restriction applies to open spaces in which members of the general public might reasonably be expected to spend a substantial part of the day, such as recreational areas, meeting grounds, and the like.

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<sup>d</sup> These values can be exceeded for a few minutes per day provided precautions are taken to prevent indirect coupling effects.

The IRPA ELF field limits are based solely on immediate, adverse reactions that might occur from excessively high induced current densities in the body. In particular, the fields have been set on the basis of limiting the current densities to below those levels typical of endogenous current densities. IRPA recognized that there appears to be an emerging literature developing around the hypothesis that 50/60-Hz fields may be associated with cancer but took the position that such studies do not "establish" that such a relation exists and that "present data do not provide any basis for health risk assessment useful for the development of exposure limits."

Similarly, the American Conference of Governmental Industrial Hygienists (ACGIH) has recently published a notice of intended changes (for 1990-91) for inclusion in its Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices handbook (ACGIH, 1990) which include trial limits for electric and magnetic fields below 30 kHz. For routine occupational exposure, ACGIH recommends a maximum magnetic field not to exceed:

$$B \text{ (mT)} = 60 \text{ mT}\cdot\text{Hz}/f \text{ (f in Hz)} \quad [6]$$

For example, at a frequency of 15 kHz, this relation yields a maximum exposure of 0.004 mT or the equivalent of 40 mG or 3.2 A/m. For electric fields in the frequency range 4 kHz to 30 kHz, the ACGIH limit is 625 V/m.

The Soviets are noted for having among the most stringent standards for electric and magnetic fields of any country in the world. For 50-Hz fields, the Soviet occupational limit is 5000 V/m for electric fields. No specification is placed on the strength of the magnetic field.

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In 1989 the British National Radiological Protection Board (NRPB, 1989) published recommendations on exposure which included the ELF range. The recommended maximum electric field strength at 60-Hz is 10.2 kV/m with a maximum magnetic field flux density of 2 mT. In addition, a specification of maximum induced body current at 60-Hz of 1.04 mA is contained in the recommendations. No distinction is made between occupational and general population exposure.

The West Germans (Germany, 1986) include ELF field limits in their standard which at 60-Hz correspond to an electric field strength of 19.2 kV/m and a magnetic flux density of 4.62 mT (3,679,000 mA/m). This standard is based principally on the electrophysiological insights of Bernhardt (1979).

Poland, similar to the Soviet Union, has regulations (Szmigielski, 1989) which set limits on 50-Hz electric fields for workers of 15 kV/m for 8 hours/day and 20 kV/m for 2 hours/day. For the general public, the Polish limits specify a maximum electric field of 10 kV/m but no buildings are to be constructed where fields exceed 1 kV/m.

The ELF fields summarized in Tables 5-8 for the 96 display units evaluated do not approach any of the ELF limits described above.

Although the scientific basis for establishing recommended limits on the time-rate-of-change of magnetic fields is essentially nonexistent, the results contained in Table 10 may be compared to the Swedish recommended value of 25 mT/s for dB/dt (MPR, 1988). A prime observation is that those fields produced by the vertical deflection systems in VDTs result in values of dB/dt that are typically between 20 and 100 times smaller in magnitude than the dB/dt values associated with the horizontal deflection systems. The largest value of dB/dt for ELF magnetic fields at 50 cm (found in Table 10) is 0.69 mT/s. Thus, in none of the VDTs examined, did the ELF time-rate-of-change for the magnetic field approach the 25 mT/s value given in

MPR (1988). For the VLF emissions, two VDTs of those evaluated exhibited values for dB/dt at 50 cm greater than 25 mT/s, one of these only marginally. The differences in dB/dt for the IBM VDTs is presumably due to the differences in the design of the two types of CRT assemblies which produced very noticeable differences in the waveform of the VLF magnetic field as discussed above.

### Implications of Induced Body Currents

When an individual is immersed in an electric and/or magnetic field, electrical currents are induced in the body. Figure 7 illustrates the general frequency dependence of such an induced current produced by exposure to an electric field that is polarized with the long axis of the body. In the VLF range pertinent to VDT operation, for an adult, the induced RF current in the body will be approximately  $9 \mu\text{A}/(\text{V}/\text{m})$ . The data upon which Figure 7 was produced, however, are relevant to the case of uniform, whole-body exposure. This is not the case with VDT exposure fields; because of the highly non-uniform field strengths around a VDT, the body simply cannot ever be uniformly exposed over its full extent. Thus, when a measurement of the maximum electric field is made at the location of a VDT operator, generally only a very limited portion of the body is actually exposed to this value. The rest of the body is typically exposed to significantly lesser values of field strength. The summarization tables (Tables 5-8) illustrate this point for three anatomical regions.

Nevertheless, the magnitude of induced currents in VDT operators probably provides a better dosimetric parameter for comparing exposures than simply the incident field strength. Due to the rather complicated capacitive coupling effect by which the body electrically couples to the VDT source and results in an induced current, it is not a simple matter to estimate the induced current just by the incident field strength alone. For example, two different operators can experience significantly different induced currents when using the same VDT. By comparing currents

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between operators, a more meaningful measure of relative exposure can be achieved. Also, by noting the current, exposure to VDTs can be compared to other RF radiation sources in the environment which lead to induced currents in the body. Such a comparison may be useful in developing a perspective on relative risk associated with electric and magnetic field emissions of VDTs.

Numerous types of electric and magnetic field sources are found in the environment today including AM and FM radio, VHF and UHF TV broadcasting, radar, satellite communications earth stations, microwave point-to-point radio, land-mobile radio such as cellular telephones, and amateur radio stations as well as VDTs. Despite the number of categories of source types, the RF radiation environment in urban areas is dominated by signals produced by broadcast stations; broadcast stations are generally quite powerful and exist for the purpose of providing signals for reception by the public. A normal background of RF signals is made up of a multiplicity of signals being broadcast by many different stations. Generally the accumulative power densities associated with these many signals are very low, at least for the majority of individuals who are exposed. In some instances, however, exposure which takes place in the immediate area of a high power source can be substantial. Thus, public exposure to RF sources comes about from two kinds of situations, the low-level multi-source environment and the high-level, close proximity situation.

The Environmental Protection Agency (EPA) has studied the issue of the broadcast contribution to normal RF exposure in 15 U.S. cities (Tell and Mantiply, 1980). This study made use of extensive environmental measurements of ambient RF field strengths throughout the various broadcast bands within each city. Using these measured data, computerized propagation models were constructed that were then exercised to compute the expected RF field strengths at the many census enumeration districts (CEDs) within each metropolitan area. Using a computer automated database of population, exposures could be assigned to the population within each

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of the CEDs and thereby, accumulative population exposures could be estimated. Figure 69 illustrates the population in the 15 cities in the study exposed to various ranges of RF power densities contributed by the very-high-frequency (VHF) and ultra-high-frequency (UHF) broadcast bands. Figure 69 is based on approximately 14,000 individual field strength measurements at 486 measurement sites in 15 large cities. Expected power densities were computed for 46,789 CEDs.

Two key findings from this study were (1) that approximately 99 percent of the population are exposed to RF fields with power densities less than 1 microwatt per square centimeter ( $\mu\text{W}/\text{cm}^2$ ) (equivalent to about 2 V/m) and (2) that the median exposure of the population is about 0.005  $\mu\text{W}/\text{cm}^2$  (about 0.14 V/m). Figure 69 illustrates that most people are exposed most of the time in the power density range of only 2 to 5 nanowatts per square centimeter ( $\text{nW}/\text{cm}^2$ ) (0.09-0.14 V/m), a very low value.

Figure 69 pertains to higher frequency broadcast fields but Table 13 provides the cumulative population exposure found during the study in the AM standard broadcast band (0.535 to 1.605 MHz). Inspection of Table 13 reveals that less than a tenth of a percent of the population are apparently exposed to RF fields in the AM band with field strengths greater than about 2.5 V/m (Hankin, 1986). These data relating to AM radio broadcast signals were used to compare exposures to VDTs with ambient radio signals.

Table 13 indicates that the median electric field strength to which the population is routinely exposed is about 0.28 V/m. The median field strength is that value to which half of the population is exposed less than and the other half is exposed greater than. Reference to Figure 7 reveals that, in the AM radio broadcast band, RF electric fields will induce about  $300 \mu\text{A}/(\text{V}/\text{m})$ ; 1 V/m will induce about 300  $\mu\text{A}$ . Thus, a field of 0.28 V/m is expected to induce about  $[300 \mu\text{A}/(\text{V}/\text{m})][0.28 \text{ V}/\text{m}] = 84 \mu\text{A}$  of

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total current in an adult of normal height. Shorter persons will have a reduced magnitude of induced current. When this value of current is compared to that value measured for VDT operators in this study, it is apparent that normal use of the VDTs by telephone operators results in significantly lower values of current being induced in the body than already exists due to exposure to local AM radio broadcast stations. As an example, 98 percent of the population are exposed to AM radio electric fields greater than 0.07 V/m; this electric field strength results in a RF current induced in the body of about 21  $\mu\text{A}$ . For normal keyboard contact at the VDT, the largest mean value of induced current of 7.6  $\mu\text{A}$  (for the CCI VDTs) can be compared to the expected value of 21  $\mu\text{A}$  that exists in most of the population due to AM broadcasting. Even if the maximum value of mean induced current determined with the hand in direct contact with the screen of the VDT is used in the comparison, 115  $\mu\text{A}$  from Table 7, this is comparable to about 0.38 V/m exposure from an AM radio station. By reference to Table 13, approximately 34 percent of the population are exposed to this value of AM radio electric field strength or greater. This value of electric field strength is also in the range of the approximate electric field strength found around AM broadcast stations within about one to four miles of the station's transmitting antenna. Figure 70 shows the electric field strength as a function of distance from AM radio broadcast stations which are operating at the maximum power level (50 kilowatts) for AM stations authorized by the Federal Communications Commission. Approximately three percent of the United States population are estimated to be exposed to AM radio field strengths of 1 V/m or greater (see Table 13) and, hence, experience induced RF currents of about 300  $\mu\text{A}$  on a more or less continuous basis.

While the waveforms and fundamental frequencies of VDTs differ from those of other environmental sources of RF fields to which everyone is exposed, the result of this analysis is that, in terms of the magnitude of the electrical currents which are induced by the fields, VDTs represent a minor contribution to everyday exposure. Presently, the issue of any

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difference between the particular induced current waveforms produced by VDT fields and those of other sources, such as AM radio broadcast signals, on possible biological effects at the current levels determined in this study remains unresolved.

Electrical currents induced by exposure to magnetic fields are more difficult to assess since these currents do not flow to ground through the body. Rather, the currents circulate about the periphery of the body as illustrated in Figure 71 adapted from the work of Reilly on peripheral nerve stimulation by magnetic fields (Reilly, 1990). Since present technology does not permit a direct noninvasive method for measuring these circulating currents, theoretical approaches are used.

It is of interest to examine the dosimetric implications of the currents which may be induced by exposure of an individual to commonly encountered electromagnetic fields produced by AM radio broadcast stations and the two different types of VDTs evaluated in this project. Table 14 provides a summary of this comparison in terms of induced currents, induced current densities, and the resulting rates of energy absorption or specific absorption rate (SAR) in the tissues of the body. The electric field induced body current to ground for AM radio broadcast signals has been projected on the basis of the earlier relation between electric field strength and frequency (equation 1). In this case, reference has been made to Table 13 for selecting electric and magnetic fields to which 80 percent of the population are always exposed. This is equivalent to about 0.16 V/m for electric fields and 0.42 mA/m for magnetic fields. The currents shown for the two VDTs correspond directly to the average measured values for the hands placed on the keyboard, the most usual situation for the telephone operators. This comparison again shows that the normal electric field induced currents during operation of the VDTs is small compared to that existing most of the time from exposure to ambient AM radio signals in the urban environment.

These induced currents have been used to project the current density that would be expected to flow in the abdominal region of the body by dividing the currents by an effective area of 600 cm<sup>2</sup>. This area corresponds to the human adult model used by Guy (1984). For this assumed area of the body, Table 14 indicates a greater current density for common exposure to AM radio signals when compared to either VDT.

Since the electric field over the body is very nonuniform, it is reasonable to argue that VDT exposure is essentially a case of partial body exposure. If all of the induced current, produced by electric field exposure, were to flow through the wrist, a much higher local current density would result as shown in Table 14. An effective wrist cross-sectional conductive area of 10.1 cm<sup>2</sup> has been assumed following the work of Gandhi et al. (1986) and Chen and Gandhi (1988). In this comparison, the local current densities in the wrist are slightly greater for the case of placing the hand against the screen of the VDT as opposed to assuming that the AM radio induced body current flows through the wrist. Either situation, however, would not be typical of long-term exposure.

The current density induced by a magnetic field was computed from the relation

$$J = \sigma E \quad \text{where} \quad [7]$$

$J$  is the current density expressed in amperes per square meter (A/m<sup>2</sup>),  $\sigma$  is the tissue conductivity in siemens per meter and  $E$  is the electric field in volts per meter in the tissue. For a cylindrical tissue section, and sinusoidally varying magnetic fields, the resulting internal current density is given by

$$J = \sigma \mu_0 \pi r H f \quad \text{where} \quad [8]$$

$\mu_0$  is the magnetic permeability of tissue ( $4\pi \times 10^{-7}$ ),  $r$  is the radius

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(meters) of the circular area about which the eddy currents circulate, H is the applied magnetic field strength (A/m) and f is the frequency in Hz. For all of these calculations,  $\sigma$  was assumed to be 0.6 siemens per meter. The above relation was used to compute the expected current density at the periphery of the body from the AM radio broadcast signal magnetic field since the current density will be greatest for the largest value of r.

In the case of the saw-tooth shaped waveform of the magnetic fields produced by VDTs a different calculational approach was taken. The rms current density was determined from the relation:

$$J(\text{rms}) = [(J_1^2 t_1 + J_2^2 t_2)/T]^{1/2} \quad [9]$$

Here,  $J_1$  and  $J_2$  refer to the current densities associated with the short and long transitions of the sawtooth waveform, having transition times of  $t_1$  and  $t_2$  respectively. T is the total period of the waveform.

The individual values of J were determined from the relationship:

$$J = [\sigma \mu_0 r/2] dH/dt \quad [10]$$

The value of  $dH/dt$ , the time rate of change of the magnetic field strength, was taken directly from an analysis of the waveform data measured for one CCI and one IBM VDT evaluated in the project. The above relationship yields the instantaneous peak current densities from which the rms value is then determined as described above. Table 14 shows that the AM radio signal will produce the larger value of circulating current density at the periphery of the abdomen. Table 14 provides footnotes indicating the orientation of the body that was assumed for the calculations.

Finally, SAR values were computed from the current densities for comparison between the VDTs and AM radio signal exposures. SAR was

computed from the relation:

$$\text{SAR (W/kg)} = J^2/\sigma\rho \quad \text{where} \quad [11]$$

J is the current density in  $\text{A/m}^2$ ,  $\sigma$  is the conductivity in siemens per meter and  $\rho$  is the density of tissue (taken here to be  $1040 \text{ kg/m}^3$ ). This approach follows the method outlined by Tell (1990) in a treatment evaluating the significance of locally enhanced field strengths associated with RF hotspots caused by reradiation from various objects exposed to ambient RF fields.

Using this relationship, SARs were computed and are shown in Table 14 for several situations of interest. In the case of VDT exposure, the SARs are extremely small, ranging between  $3.1 \times 10^{-12} \text{ W/kg}$  and  $1.2 \times 10^{-5} \text{ W/kg}$ . When compared to those values of SAR most often cited in electromagnetic field exposure standards, the estimated SARs that might result from using either of the VDTs in this study are at least six orders of magnitude less.

### Comparison of VDTs to TV Receivers

Probably the device producing electric and magnetic fields most similar to those of a VDT is the common television (TV) receiver. The TV receiver employs circuits almost identical to those found in most VDTs. Thus, electric and magnetic fields produced by the deflection coils and the high-voltage wiring in the set are virtually identical to those of VDTs; a notable exception is that many TV sets exhibit stronger field strengths at given distances than VDTs at the same distance. This disparity in field strengths is often due to the fact that the picture tubes are larger, often times flatter, requiring more deflection forces on the electron beam to deflect it across the wide angle of the screen and thus greater magnetic fields and the fact that most TVs are color, using higher accelerating voltages.

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A mitigating factor for exposure to TV generated electric and magnetic fields is the generally greater viewing distance compared to that when using a VDT; none the less, some individuals may routinely remain very close to the picture tube, particularly children using high technology video games. Harvey (1983b) and Boivin (1986) have reported on RF emissions of TV receivers. Table 11 indicates field strengths of 8.6 V/m (Boivin, 1986) for electric field strengths and Harvey (1983b) has reported magnetic field strengths of 1000 mA/m and 380 mA/m for the vertical and horizontal flyback frequency components respectively. These data show that the emissions measured from some TVs can exceed those of typical VDTs.

### Comparison of VDT Fields With Other Sources

AM radio stations are, of course, not the only sources of RF energy in our environment to which one can be exposed. A multitude of intentional and unintentional sources lead to electromagnetic field exposures which may have relevance, or comparability, to VDT emissions.

Television broadcast stations, for example, transmit signals which must provide synchronization with the scanning electron beam contained inside the TV receiver picture tube so that the picture displayed on the TV is in synchrony with the video programming which originates at the TV station. To accomplish this, the TV signal, which is in the frequency range of 54-806 MHz) includes information, in the form of amplitude modulated pulses called synchronization pulses (or synch pulses for short), which are interpreted by the TV receiver as trigger signals to begin each horizontal scan of the electron beam across the screen and each vertical retrace when the beam must start tracing another path from the top of the screen. These synchronization pulses, particularly the 60-Hz vertical refresh signal, produce instantaneous peak field strengths repeating at a rate of 60 times per second and 15,750 times per second for vertical and horizontal scan triggering respectively.

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TV stations must, by FCC regulations (FCC, 1984), provide a sufficient signal strength to insure sufficiently high quality picture reception in the city of license. Such so-called grade A signal quality is specified as signals having an electric field strength of at least 0.005 V/m for channels 2-6, at least 0.007 V/m for channels 7-13 and at least 0.01 V/m for ultra-high-frequency (UHF) channels (14-69).

Some VLF radio stations used as navigational aides produce emissions to which some individuals may be exposed, at least on an intermittent basis. These include both LORAN and OMEGA stations operated by the U.S. Coast Guard. LORAN systems (long range radio navigation) transmit signals at 100 kHz using vertically polarized antennas, similar to those employed by AM radio stations. The LORAN system works on the basis of using pulsed signals, pulsed at a repetition rate of 10 Hz, from several different stations positioned at widely separated geographical points. Using receivers which can discriminate the phase differences in the received signals, a user can determine his position at sea or in the air. The OMEGA system operates in the frequency band of 10-14 kHz, also using large vertically polarized antennas. This system, which can produce electromagnetic fields directly in the same frequency range as VDT's, uses intermittent signals (on for periods of about 1 second) on several frequencies to provide navigational assistance for both ships and aircraft, similar to the LORAN system but due to propagation considerations (how well the radiated signal travels about the earth's surface with low attenuation), can provide longer range coverage than LORAN. Presently, there are eight functional OMEGA stations in existence in the world compared to 13 chains of LORAN systems (master and slave stations) consisting of between 3 and 5 transmitting stations each.

McEnroe (1980) and Gailey (1987) have investigated the field strengths near both LORAN and OMEGA transmitting stations. Their data indicates that on the transmitter sites of these stations, rms electric field strengths in the range of 1 to 4400 V/m can be found with corresponding magnetic fields

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commonly in the range of 0.01 to 2.9 A/m. At very close distance to the radiating structure of the antennas, considerably more intense fields can be measured with maximum fields being in the range of several kilovolts per meter for electric fields and 6 A/m for magnetic fields. A fundamental difference between the fields of these two VLF sources is that the fields of the LORAN systems are pulsed; thus, the average field strengths from LORAN systems are considerably less than the instantaneous peak levels. For example the ratio of peak to average field strengths for LORAN stations is in the range of 11.8 to 17.5 as determined from the data of Gailey (1987).

VLF communications systems operated by the NAVY include stations in the 18 to 20 kHz frequency range. An example includes the radio station NAA at Cutler, Maine, which operates on a frequency of 17.8 kHz, being identical with some VDT flyback frequencies, and uses a 2,000,000 watt transmitter. In the environment of this transmitter site, ambient RF fields will be significantly stronger than those typically experienced by VDT operators. For this power, expected electric and magnetic field strengths are 6 V/m and 16 mA/m respectively at a distance of one mile from the station; these field strengths rise to 24 V/m and 64 mA/m at 0.25 miles from the source.

Another source of occupational exposure to pulsed, low frequency electric and magnetic fields has been associated with radar transmitter modulators by Jokela (1988). Jokela has found that the modulators which are used to amplitude modulate the source of microwaves into a series of pulses, that are eventually transmitted by the radar for surveillance functions, can produce significant peak magnetic field levels near the modulator units in the range of 150 mA/m rms. These pulsed fields occur at the pulse repetition frequency of the radar, but because of the rapid transition times of the pulse the magnetic fields extend over a relatively wide frequency range of 20-2000 kHz; independent of the pulse modulator emissions, the radar signal radiated from the antenna consists of a pulsed

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microwave signal. Jokela also has measured the pulsed electric fields 50 cm from a radiotherapy accelerator unit and found rms electric fields of 0.35 V/m in the frequency range of 4-40 kHz.

Any current source which is pulsed or switched on and off with rapid switching times will produce magnetic fields in the RF range. Switching type power supplies, now being used in electronic equipment because of their higher efficiency and small sizes, are one source of VLF fields which is becoming more common in consumer product applications.

A good example of the electric and magnetic fields which can arise from interrupted currents, with which many individuals have some experience, is the electrical ignition systems for automobile engines. The electrical arc created in the gap of the distributor, which occurs when the spark plugs ignite the fuel-air mixture within the cylinders of the engine, produces broadband RF signals which can often be heard over the car's AM radio receiver. The impact of the radio noise, or static, caused by these RF fields has been investigated by numerous researchers, including Shepherd (1974) and others, and is normally mitigated through the use of special suppression devices like resistive ignition cables and filters. Nonetheless, rather intense RF fields can be caused by this common source at very close distances to the engine and have been the subject of concern over interference to some cardiac pacemakers worn by individuals doing automotive repair work. Paulsson et al. (1984) report values of peak-to-peak magnetic field strength near an automobile running at a high idle speed of 400 mA/m and time-rates-of-change of the magnetic field of 12800 A/m/sec (0.016 mT/s peak-to-peak). The dominant area of the frequency spectrum created by the ignition system investigated was centered around 12 kHz.

Another very common source of RF fields in the VLF range is the fluorescent light. These lights consist of two electrodes separated by the light column filled with a gas mixture containing argon and mercury. RF

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fields are emitted during the alternating-current electric discharge produced by pulses of high-potential current from the electrodes. The pulsed current flowing in the ionized gas column generates RF emissions which extend over a very wide frequency range. Clark (1961) has examined the peak field strengths at a distance of three feet from a 8 ft, 4-unit fluorescent lamp and reported peak values of 0.1 V/m electric fields. Adams et al. (1974) measured radiated magnetic fields from a fluorescent light fixture at a distance of 3 m (9.84 ft) and determined that the fields peaked at harmonics of the 60-Hz line frequency with strengths varying in the range of 6.3 mA/m rms to 0.001 mA/m depending on frequency between 60-Hz and 4 kHz.

Most people are unaware that VLF magnetic fields are so frequently experienced due to everyday living activities. Examples include devices in which magnetic fields are used for sound production like magnetic ear phones, telephone receivers and high-fidelity loud speaker systems. In these instances, audio frequency range currents are used in conjunction with an electromagnet assembly to create a varying magnetic field which, in turn, causes some form of mechanical diaphragm to move. Rapid movement of the diaphragm causes sound waves to be created at the same frequency as the applied electrical signal. As an example, Paulsson et al. (1984) mentioned values of magnetic field strengths of 480 mA/m peak-to-peak with a dB/dt value of 6400 A/m/sec (8 mT/s) measured at 30 cm from a high fidelity loudspeaker for frequencies less than 20 kHz. Detectable levels of fields associated with the stereo pilot signal at 19 kHz and its harmonic at 38 kHz were also noted. Recently, Baumann and Alagarsamy (1990) presented data from measurements of the magnetic fields produced by stereo headphones. Their data indicate that magnetic fields as great as 225 nT (equivalent to 280 mA/m field strength) were possible at a distance of 4 cm from the headphones when operated at a sound pressure level of 95 dB.

## Conclusions

This report has elaborated on how VDT's work and how, through the action of the various electronic circuits, incidental electric and magnetic emissions are produced. A substantial amount of data on the characteristics of these emissions, including field strengths, frequencies and waveform peculiarities has been provided showing that VDTs are at the same time not unusual sources of exposure of individuals to electric and magnetic fields and yet, are unique in some respects. More specifically, VDTs can lead to exposures not dissimilar to that experienced near common television receivers. Television sets were found to possess even stronger emissions in some cases. But the unique character of the electric and magnetic field waveforms and exact frequency spectra (the spectrum caused by the fundamental flyback frequency and its associated harmonics) do make the VDT different in these respects.

Taken as a class, the non-VDT type displays are distinctly different in terms of operator exposure levels when compared to the two types of VDTs used by operators in this study for VLF fields. Table 15 is a simplified summary of the measurement results for frontal emissions, chest exposure and induced currents for the NGT, LED, CCI and IBM displays. The NGT and LED displays, not possessing internal magnetic field deflection systems, simply do not produce VLF fields above instrumentation background levels. For ELF fields, such a distinction is less clear. For example, the LED displays produced operator ELF magnetic field exposures which were similar to the values found for operators of both the CCI and IBM VDTs. For ELF electric fields, the NGT displays produced operator exposure values less than those for the CCI units but similar to those found for the IBM VDTs. It is concluded that, for the most part, the ELF electric fields appear to be principally a function of the room electrical environment, probably being more representative of electrical wiring systems used in the building than of any peculiar characteristic of the display. The ELF electric fields found for the CCI VDTs as a group appear, however, to be

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demonstrably above those values found for the rest of the displays, including the IBMs. Table 15 summarizes the measurement results in a simplified format for easier comparison between the NGT, LED, CCI and IBM displays for frontal emissions, chest exposure and keyboard induced currents. The results imply that the greatest difference in overall exposure would exist between operators of the NGT and CCI displays; in terms of VLF field exposure, both the NGT and LED displays are markedly lower than either the CCI or IBM VDTs.

Nevertheless, when compared to other sources of electric and magnetic fields commonly found in the workplace and the home environment, it was suggested that personal exposure to VDT produced fields could be compared by examining the electrical currents which are induced in the body by alternating electric and magnetic fields. Use of the induced current as an index of exposure, despite the fact that it does not differentiate various waveforms, facilitates the comparison of exposures caused by a wide variety of sources, especially sources which lead to highly nonuniform exposure over the body, like that of a VDT. When viewed in this context, it is found that induced currents can be categorized as those caused by exposure to the electric field and those caused by the magnetic field. While the currents induced by the electric field generally lead to currents which flow throughout the body and through body contact, like the feet or hands, to grounded surfaces, those currents that are magnetically induced generally circulate about the periphery of the body or exposed object (arm, hand, abdomen, etc.).

Measurements of currents flowing between operators of the displays examined and ground showed that very measurable differences exist between the VDTs (both CCI and IBM types) and the non-VDT displays represented by the NGT and LED displays. The VDTs produced consistently significantly greater induced currents.

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By considering the currents typically induced by AM radio broadcast stations, as an example, it was found that normal exposure to VDT's in the workplace is not significantly different from that induced virtually all of the time by ambient radio station signals to which everyone is exposed. Exposures in the vicinity of some low frequency communications and radio-navigation stations which use high powers and frequencies very similar to the VDT range could cause substantially greater induced currents than caused by the VDT.

When the field strengths found near VDT's are compared to various standards which specify maximum safe human exposure to electric and magnetic fields one is also impressed by the generally wide margin which exists between the limits and VDT exposure levels. Examination of the measured electric and magnetic field strengths reported in summary Tables 5-8 and in Appendix B shows that in no instance do either of the two RF fields, determined at the position of the operator, exceed any of the standards in Table 12, even the extremely stringent Polish and Czechoslovakian standards for the general public. Based on this finding, it is concluded from measurements on 96 displays comprised of both VDT and non-VDT type displays that typical personnel exposures to electric and magnetic fields are (1) relatively low, (2) within a relatively confined range of magnitudes reported by many researchers, (3) are not highly dissimilar to exposures commonly encountered from radio stations and other devices routinely found in the home or workplace and (4) are generally substantially less than any electromagnetic field exposure limits developed for radiation protection purposes by organizations within the United States and many other countries. In addition, measures of dB/dt, the time-rate-of-change of the magnetic field, were found to be, with three exceptions for the units examined, nominally equal to or less than the recommended limit for VDTs imported in Sweden.

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Table 1. Specifications of the Holaday Industries Model HI-3600-01 VDT survey meter.

Sensors:	Concentric plate displacement current electric field sensor  8 inch diameter magnetic field sensing loop  Switch selectable between electric and magnetic fields
Sensitivity:	Electric fields - 0.1 - 2000 volts/meter Magnetic fields - 0.001 - 2.000 amperes/meter
Features:	Three autoselect or manually selected field strength ranges Max hold feature stores and displays highest reading
Response:	True rms field measurement for accurate measurement of non-sinusoidal waveforms
Frequency Response:	Electric fields: +/- 0.5 dB, 10 kHz to 100 kHz +/- 2 dB, 2 kHz to 300 kHz Magnetic fields: +/- 0.5 dB, 12 kHz to 200 kHz +/- 2 dB, 8 kHz to 300 kHz
Zero Adjustment:	Automatic zero setting via a front panel ZERO pad which controls an internal microprocessor
Power:	Two (2) nine-volt alkaline batteries (NEDA 1604A, Duracell MN1604, or equal)
Output:	Liquid crystal display, preamplifier output via phono jack (analog signal from sensor/preamplifier equal to 1 mV/(mA/m)) , digital fiber optic signal (for remote reading via connection to HI-3615 Fiber Optic Receiver)

The HI-3600-01 VDT Radiation Survey Meter package includes the HI-3600 readout module, HI-3601 VDT sensor assembly, batteries, fitted carrying case, and a user manual.

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Table 2. Specifications of the Holaday Industries Model HI-3600-02 ELF survey meter.

Sensors:	Concentric plate displacement current electric field sensor  8 inch diameter magnetic field sensing loop  Switch selectable between electric and magnetic fields
Sensitivity:	Electric fields: 1 - 199 kV/m Magnetic fields: 10 mA/m - 1999 A/m
Features:	Three autoselect or manually selected field strength ranges Max hold feature stores and displays highest reading
Response:	True rms field measurement for accurate measurement of non-sinusoidal waveforms
Frequency Response:	Electric fields: +/- 0.5 dB, 50 Hz to 700 Hz Magnetic fields: +/- 0.5 dB, 50 Hz to 200 Hz
Zero Adjustment:	Automatic zero setting via a front panel ZERO pad which controls an internal microprocessor
Power:	Two (2) nine-volt alkaline batteries (NEDA 1604A, Duracell MN1604, or equal)
Output:	Liquid crystal display, preamplifier output via phono jack (analog signal from sensor/preamplifier equal to 1 mV/(mA/m) or 0.1 mV/(mA/m)), digital fiber optic signal (for remote reading via connection to HI-3615 Fiber Optic Receiver)

The HI-3600-02 ELF Survey Meter package includes the HI-3600 readout module, HI-3601 VDT sensor assembly, batteries, fitted carrying case, and a user manual.

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Table 3. Summary of field instruments used and serial numbers.

<u>Frequency Band</u>	<u>Meter SN</u>	<u>Sensor SN</u>
VLF	54700	54802
VLF	55501	55349
VLF	54599	54820
ELF	55014	58493
ELF	55501	60088
ELF	54599	61068

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Table 4. Summary of correction factors used for correcting the field strength data obtained with various instrument configurations of the Holaday Industries meters.

<u>Band</u>	<u>Frequency</u>	<u>Meter/Sensor SN</u>	<u>Correction Factor</u>	
			<u>E-field</u>	<u>H-field</u>
VLF	15 kHz	54700/54802	0.964	0.941
ELF	45 Hz	55014/58493	1.120	0.999
ELF	60 Hz	55014/58493	1.053	0.966
VLF	15 kHz	55501/55349	1.028	1.050
VLF	15 kHz	54599/54820	1.095	0.954
ELF	45 Hz	55501/60088	1.159	1.021
ELF	60 Hz	55501/60088	1.097	0.991
ELF	45 Hz	54599/61068	1.244	1.030
ELF	60 Hz	54599/61068	1.172	0.997

Analog output calibration factors:

<u>Band</u>	<u>Meter/Sensor SN</u>	<u>E-fields</u>	<u>H-fields</u>
		<u>V/m/(mV out)</u>	<u>mA/m/(mV out)</u>
ELF	55014/58493	0.881	9.53
VLF	54700/54802	1.005	0.992

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Table 5. Statistical summarization of data on emission field strengths, operator exposure levels and induced currents for 24 NGT displays. Indicated values are the geometrical means and (geometrical standard deviations).

<b>NGT Emission Field Strength Statistical Summary, N=24</b>				
Position	VLF-E (V/m)	VLF-H (mA/m)	ELF-E (V/m)	ELF-H (mA/m)
Top	0.137 (1.814)	1.38 (1.036)	1.19 (1.687)	30.0 (1.691)
Front	0.077 (2.05)	1.36 (1.044)	0.470 (1.400)	30.3 (1.724)
Bottom	0.056 (1.987)	1.38 (1.036)	0.351 (1.328)	32.7 (1.826)
Back	0.059 (1.505)	1.38 (1.036)	0.452 (1.436)	33.6 (1.737)
Left side	0.044 (1.353)	1.39 (1.023)	0.282 (1.223)	43.7 (1.787)
Right side	0.048 (1.204)	1.37 (1.034)	0.388 (1.175)	44.2 (1.772)

<b>NGT Operator Exposure Statistical Summary, N=24</b>				
Position	VLF-E (V/m)	VLF-H (mA/m)	ELF-E (V/m)	ELF-H (mA/m)
Abdomen	0.177 (1.636)	1.6 (1.0)	0.405 (1.92)	32.4 (2.01)
Chest	0.099 (1.653)	1.6 (1.0)	0.308 (1.530)	33.0 (1.877)
Face	0.147 (1.515)	1.6 (1.0)	0.813 (1.417)	32.6 (1.808)

<b>NGT Induced Current Statistical Summary, N=24</b>	
Hand Location	Induced Current ( $\mu$ A)
Hands on keyboard	0.019 (1.021)
Finger touching screen	0.018 (1.024)
Hand placed flat on screen	0.019 (1.022)

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Table 6. Statistical summarization of data on emission field strengths, operator exposure levels and induced currents for 24 LED displays. Indicated values are the geometrical means and (geometrical standard deviations).

<b>LED Emission Field Strength Statistical Summary, N=24</b>				
<b>Position</b>	<b>VLF-E (V/m)</b>	<b>VLF-H (mA/m)</b>	<b>ELF-E (V/m)</b>	<b>ELF-H (mA/m)</b>
Top	0.160 (1.391)	1.6 (1.0)	1.270 (1.885)	69.6 (1.855)
Front	0.114 (1.161)	1.604 (1.012)	0.376 (1.103)	72.3 (1.682)
Bottom	0.196 (1.147)	3.811 (1.439)	0.409 (1.059)	62.2 (2.01)
Back	0.524 (1.582)	1.6 (1.0)	12.2 (1.534)	79.0 (1.607)
Left side	0.113 (1.092)	1.620 (1.026)	0.449 (1.229)	59.2 (2.83)
Right side	0.110 (1.052)	1.621 (1.026)	0.471 (1.309)	55.2 (2.61)

<b>LED Operator Exposure Statistical Summary, N=24</b>				
<b>Position</b>	<b>VLF-E (V/m)</b>	<b>VLF-H (mA/m)</b>	<b>ELF-E (V/m)</b>	<b>ELF-H (mA/m)</b>
Abdomen	0.081 (1.346)	1.97 (1.150)	0.351 (1.175)	62.4 (2.79)
Chest	0.059 (1.475)	1.53 (1.067)	0.299 (1.107)	69.6 (2.70)
Face	0.073 (1.957)	1.39 (1.025)	0.317 (1.105)	80.4 (2.57)

<b>LED Induced Current Statistical Summary, N=24</b>	
<b>Hand Location</b>	<b>Induced Current (<math>\mu</math>A)</b>
Hands on keyboard	0.014 (1.009)
Finger touching screen	0.008 (1.007)
Hand placed flat on screen	0.009 (1.009)

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Table 7. Statistical summarization of data on emission field strengths, operator exposure levels and induced currents for 24 CCI displays. Indicated values are the geometrical means and (geometrical standard deviations).

<b>CCI Emission Field Strength Statistical Summary, N=24</b>				
Position	VLF-E (V/m)	VLF-H (mA/m)	ELF-E (V/m)	ELF-H (mA/m)
Top	3.06 (1.31)	61.4 (3.11)	3.23 (1.588)	401. (4.11)
Front	4.22 (1.54)	98.9 (2.61)	1.85 (1.633)	314. (1.216)
Bottom	0.302 (3.45)	15.9 (3.04)	1.65 (4.654)	172. (2.23)
Back	2.46 (1.75)	62.2 (2.11)	4.25 (1.762)	507. (2.10)
Left side	0.749 (1.55)	82.6 (1.332)	2.09 (2.56)	504. (2.13)
Right side	1.10 (1.95)	82.5 (1.461)	8.49 (1.678)	487. (1.712)

<b>CCI Operator Exposure Statistical Summary, N=24</b>				
Position	VLF-E (V/m)	VLF-H (mA/m)	ELF-E (V/m)	ELF-H (mA/m)
Abdomen	0.544 (1.683)	17.4 (1.741)	0.845 (3.610)	62.30 (1.590)
Chest	1.05 (1.399)	14.8 (1.903)	1.020 (1.987)	80.6 (1.653)
Face	1.41 (1.424)	41.7 (1.597)	1.90 (1.894)	81.6 (1.597)

<b>CCI Induced Current Statistical Summary, N=24</b>	
Hand Location	Induced Current ( $\mu$ A)
Hands on keyboard	4.13 (4.42)
Finger touching screen	14.6 (3.10)
Hand placed flat on screen	87.8 (2.19)

Table 8. Statistical summarization of data on emission field strengths, operator exposure levels and induced currents for 24 IBM displays. Indicated values are the geometrical means and (geometrical standard deviations).

<b>IBM Emission Field Strength Statistical Summary, N=24</b>				
Position	VLF-E (V/m)	VLF-H (mA/m)	ELF-E (V/m)	ELF-H (mA/m)
Top	0.177 (1.567)	27.5 (2.01)	0.560 (1.483)	232. (2.62)
Front	3.26 (2.07)	22.1 (4.68)	1.78 (1.929)	236. (2.14)
Bottom	0.086 (1.745)	2.21 (1.32)	0.839 (2.31)	46.9 (2.08)
Back	0.151 (1.455)	16.4 (2.10)	0.708 (1.889)	140. (1.909)
Left side	0.139 (1.755)	11.8 (2.57)	0.453 (2.03)	306. (1.888)
Right side	0.115 (1.566)	15.6 (1.391)	1.25 (2.31)	205. (1.928)

<b>IBM Operator Exposure Statistical Summary, N=24</b>				
Position	VLF-E (V/m)	VLF-H (mA/m)	ELF-E (V/m)	ELF-H (mA/m)
Abdomen	0.142 (1.710)	3.98 (1.852)	0.429 (1.698)	57.7 (2.12)
Chest	0.328 (1.864)	4.23 (2.13)	0.506 (1.780)	66.6 (2.12)
Face	0.543 (1.682)	6.72 (3.00)	0.779 (1.867)	76.4 (1.918)

<b>IBM Induced Current Statistical Summary, N=24</b>	
Hand Location	Induced Current ( $\mu$ A)
Hands on keyboard	0.377 (4.65)
Finger touching screen	6.64 (1.968)
Hand placed flat on screen	69.1 (1.600)

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Table 9. Summary of measures of maximum dB/dt for various VDTs obtained at the surface of the VDT and at 30 cm in front of screen. Maximum refers to area of waveform in which the greatest rate of change of the magnetic field occurs.

VDT	Band	City	Station	dB/dt (mA/m/μs/(mA/m rms))		% difference*
				Surface	@ 30 cm	
IBM	VLF	Forest Park	1006	0.336	0.321	4.6
IBM	ELF	Forest Park	1006	0.00284	0.00319	11.6
IBM	ELF	Macon	1028	0.00297	0.0613	182
IBM	VLF	Macon	1028	2.75	**	
IBM	VLF	Jacksonville	139	0.442	0.479	8.0
IBM	ELF	Jacksonville	139	0.00268	0.00306	13.2
IBM	VLF	Lake City	426	3.99	**	
IBM	ELF	Lake City	426	0.00287	0.00312	8.3
CCI	VLF	Marrero	48	0.429	0.446	-3.9
CCI	ELF	Marrero	48	0.00300	0.00268	11.3
CCI	VLF	Bogalusa	45	0.514	0.550	6.8
CCI	ELF	Bogalusa	45	0.00286	0.00275	3.9
CCI	VLF	Nashville 1	13	0.533	0.560	4.9
CCI	ELF	Nashville 1	13	0.00288	0.00236	19.8
CCI	VLF	Nashville 2	1399	0.429	0.429	0.0
CCI	ELF	Nashville 2	1399	0.00308	0.00319	3.5

\* Percent difference is defined as the absolute difference between the values of dB/dt obtained at the screen surface and at 30 cm divided by the average of the two values.

\*\* Waveform not sufficiently defined to determine accurate value of dB/dt

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Table 10. Derived values of dB/dt expressed in units of millitesla per second applicable to a distance of 50 cm from the screen of the VDT.

<u>VDT</u>	<u>Band</u>	<u>City</u>	<u>Station</u>	<u>dB/dt (mT/s) @ 50 cm</u>
IBM	VLF	Forest Park	1006	9.0
IBM	ELF	Forest Park	1006	0.69
IBM	ELF	Macon	1028	1.8
IBM	VLF	Macon	1028	10.0
IBM	VLF	Jacksonville	139	16.
IBM	ELF	Jacksonville	139	0.61
IBM	VLF	Lake City	426	17.
IBM	ELF	Lake City	426	0.25
CCI	VLF	Marrero	48	24.
CCI	ELF	Marrero	48	0.52
CCI	VLF	Bogalusa	45	25.
CCI	ELF	Bogalusa	45	0.48
CCI	VLF	Nashville 1	13	38.
CCI	ELF	Nashville 1	13	0.25
CCI	VLF	Nashville 2	1399	20.
CCI	ELF	Nashville 2	1399	*

\* ELF magnetic field not measured as a function of distance

Table 11. A summary of VDT electromagnetic field emission data from the technical literature.<sup>+</sup>

No.	Units	Band	VDT/TV	RMS E Field Strength (V/m)			RMS H Field Strength (mA/m)			Reference
				Mean(+/- SD)++	Min.	Max.	Mean(+/- SD)	Min.	Max.	
44		VLF	VDT				50.0 (45.5)	0.72	172.8	Paulsson(1984)
3		VLF	VDT				56.7 (46.5)	25	110	Harvey(1983b)
5		VLF	VDT	12.4(13)	4	35				Harvey(1984a)
54		VLF	VDT	0.48*	0.05	2.64				Harvey(1984b)
38		VLF	VDT			20**				Marha(1983)
21		VLF	VDT	6.92(2.13)	3.0	10.2	49.3 (14.5)	30	76	Guy(1987a)
11		VLF	VDT	0.83(0.83)	0.22	2.7	27.8 (26.6)	0.26	76	Roy(1983)
11		VLF	VDT(color)	1.31(0.83)	0.39	3.1	33.4 (23.0)	7.3	78	Joyner(1984)
39		VLF	VDT	1.96(2.98)	0.2	15	20.4 (17.6)	0.3	76	Joyner(1984)
39		VLF	VDT	6.4 (1.5)		47				Boivin(1986)
52		VLF	TV	8.6 (0.5)		21				Boivin(1986)
3		ELF	VDT				85.3 (26.9)	54	103	Stuchly(1983)
7		ELF	VDT				260 (52.6)	200	350	Jutilainen(1986)
4		ELF	VDT	12.0(12.4)	3	30				Harvey(1982)
3		ELF	VDT				293 (234)	120	560	Harvey(1983b)
5		ELF	VDT	30.0(24)	10	65				Harvey(1984a)
86		VLF	VDT		<1	4.4				Canada(1983)

\* Equivalent median unperturbed field strengths derived from a measurement of perturbed field.

\*\* Measured at 20 cm in front of the screen

+ Measured at 30 cm in front of the screen.

++ Arithmetic means and standard deviations given in this table

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Table 12. Selected standards for exposure to radiofrequency fields pertinent to the VDT frequency range. E = electric field strength; H = magnetic field strength; B = magnetic field flux density; Occ = occupational; GenP = general public.

Standard/ref	Occ	GenP	E(V/m)	H(A/m)*	B( $\mu$ T)	f(MHz)
ACGIH(1990)	X		614	1.63	1.98	0.03-3
ANSI(1982)	X	X	632	1.58	1.98	0.3 -3
Australia(1985)	X		194	0.515	0.647	0.3 -9.5
Australia(1985)		X	87	0.23	0.29	0.3 -9.5
Canada(Stuchly, 1989)	X		600	4.0	5.0	0.01-1.2
Canada(Stuchly, 1989)		X	280	1.8	2.3	0.01-1.2
Czech(Czerski, 1985)	X		50	-	-	0.03-30
Czech(Czerski, 1985)		X	5	-	-	0.03-30
IRPA(1988)	X		614	1.6/f	2.0/f	0.1 -1
IRPA(1988)		X	87	0.23/f <sup>1/2</sup>	0.24/f <sup>1/2</sup>	0.1 -1
Italy(Grandolfo, 1986)	X		140	0.36	0.45	0.1 -10
Germany(1986)	X	X	1500	2500	3141	0.03**
MASS(1983)		X	275	0.729	0.916	0.3 -3
NATO(1979)	X		1000	2.6	3.3	0.01-1
NRPB(1989)	X	X	614	4.89/f	6.14/f	0.03-1
Poland(Szmigielski, 1989)	X		70	10	12	0.1 -10
Poland(Szmigielski, 1989)		X	20	-	-	0.1 -10
Portland(1987)		X	283	0.707	0.888	0.1 -3
Seattle(1989)		X	283	0.707	0.888	0.1 -3
Telecom(1986)	X	X	87	0.23	0.288	0.010 - 10
USAF(1987)	X	X	632	1.58	1.98	0.01-3
USSR(1984a)	X		50	5.0	6.3	0.06-1.5
USSR(1984b)		X	25	-	-	0.03-0.3

\* 1A/m = 12.57 mG in free space and most biologic media

\*\* Values given are for 30 kHz but vary according to formula in standard.

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Table 13. Cumulative population exposure in the AM standard broadcast band (0.535-1.605 MHz).

Electric Field Strength (V/m)	Magnetic Field* Strength (mA/m)	Cumulative Percent of Population**
0.07	0.19	2.0
0.12	0.32	5.9
0.16	0.42	19.2
0.20	0.53	33.5
0.25	0.66	44.8
0.28	0.74	51.2
0.35	0.93	66.0
0.45	1.2	75.9
0.50	1.3	81.3
0.63	1.7	87.7
0.79	2.1	92.6
1.00	2.7	97.0
2.51	6.6	99.9

\*Plane wave equivalent magnetic field strengths derived from the electric field strengths.

\*\* For example, 2 percent are exposed to less than 0.07 V/m, 33.5 percent are exposed to less than 0.2 V/m, etc.

Source: (Hankin, 1986).

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Table 14. Summary of dosimetric comparison of AM radio broadcast exposure with VDT exposure for electric and magnetic fields in terms of induced currents, current densities and specific absorption rates (SARs). All currents, current densities and SARs are in rms units.

Exposure parameter	Exposure source		
	Common AM radio <sup>a</sup>	CCI VDT	IBM VDT
E-field induced body to ground current ( $\mu\text{A}$ )	48	4.1 <sup>b</sup>	0.38 <sup>b</sup>
E-field induced current density in abdominal region, $A_e = 600 \text{ cm}^2$ ( $\mu\text{A}/\text{cm}^2$ )	0.080	0.0068	0.00063
E-field induced current density in wrist (hand on screen or all body current passing through wrist, for AM radio) ( $A_e = 10.1 \text{ cm}^2$ ) ( $\mu\text{A}/\text{cm}^2$ )	4.8	8.7	6.8
H-field induced circulating current density ( $\mu\text{A}/\text{cm}^2$ )	0.041 <sup>c</sup>	0.032 <sup>d</sup>	0.0044 <sup>d</sup>
E-field induced SAR in wrist, hand on screen or all body current passing through wrist for AM radio (W/kg)	$3.6 \times 10^{-6}$	$1.2 \times 10^{-5}$	$7.5 \times 10^{-6}$
H-field induced SAR at body periphery (W/kg)	$2.7 \times 10^{-10}$	$1.7 \times 10^{-10}$	$3.1 \times 10^{-12}$
H-field induced SAR in wrist, $A_e = 10.1 \text{ cm}^2$ (W/kg)	$5.1 \times 10^{-13}$	$1.2 \times 10^{-9}$	$5.1 \times 10^{-10}$

<sup>a</sup> Those field strengths to which 80 percent of the population are always exposed ( $E = 0.16 \text{ V/m}$ ;  $H = 0.42 \text{ mA/m}$ , see Table 13)

<sup>b</sup> Based on measured currents with hands on keyboard (normal operating position)

<sup>c</sup> Computation assumes horizontally polarized magnetic field passing through a side-view cross section of the body with an 'effective' radius of 0.413 m (radius of circle with the same area as an ellipse with  $a = 0.195 \text{ m}$  and  $b = 0.875 \text{ m}$ ). Conductivity = 0.6 S/m.

<sup>d</sup> Computation assumes vertically polarized magnetic field passing through a horizontal cross section of the body trunk with an 'effective' radius of 0.138 m (radius of circle with the same area as an ellipse with  $a = 0.195 \text{ m}$  and  $b = 0.098 \text{ m}$ ). Conductivity = 0.6 S/m.

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Table 15. Simplified summary of measurement results for frontal emissions, chest exposure and induced currents for the NGT, LED, CCI and IBM displays. Values given in units of geometric means and standard deviations.

**Frontal Emissions Summary**

Display	VLF-E (V/m)	VLF-H (mA/m)	ELF-E (V/m)	ELF-H (mA/m)
NGT	0.077 (2.05)	1.36 (1.044)	0.470 (1.400)	30.3 (1.724)
LED	0.114 (1.161)	1.60 (1.012)	0.376 (1.103)	72.3 (1.682)
CCI	4.22 (1.536)	99.0 (2.61)	1.85 (1.633)	314. (1.216)
IBM	3.26 (2.07)	22.1 (4.68)	1.78 (1.929)	236. (2.14)

**Chest Exposure Summary**

Display	VLF-E (V/m)	VLF-H (mA/m)	ELF-E (V/m)	ELF-H (mA/m)
NGT	0.099 (1.653)	1.6 (1.0)	0.308 (1.530)	33.0 (1.877)
LED	0.059 (1.475)	1.53 (1.067)	0.299 (1.107)	69.6 (2.70)
CCI	1.05 (1.399)	14.8 (1.903)	1.02 (1.987)	80.6 (1.653)
IBM	0.328 (1.864)	4.23 (2.13)	0.506 (1.780)	66.6 (2.12)

**Keyboard Induced Current Summary**

Display	Induced Current ( $\mu$ A)
NGT	0.019 (1.021)
LED	0.014 (1.009)
CCI	4.13 (4.42)
IBM	0.377 (4.65)

# Interlaced Scanning in a Cathode Ray Tube

Trace is left to right

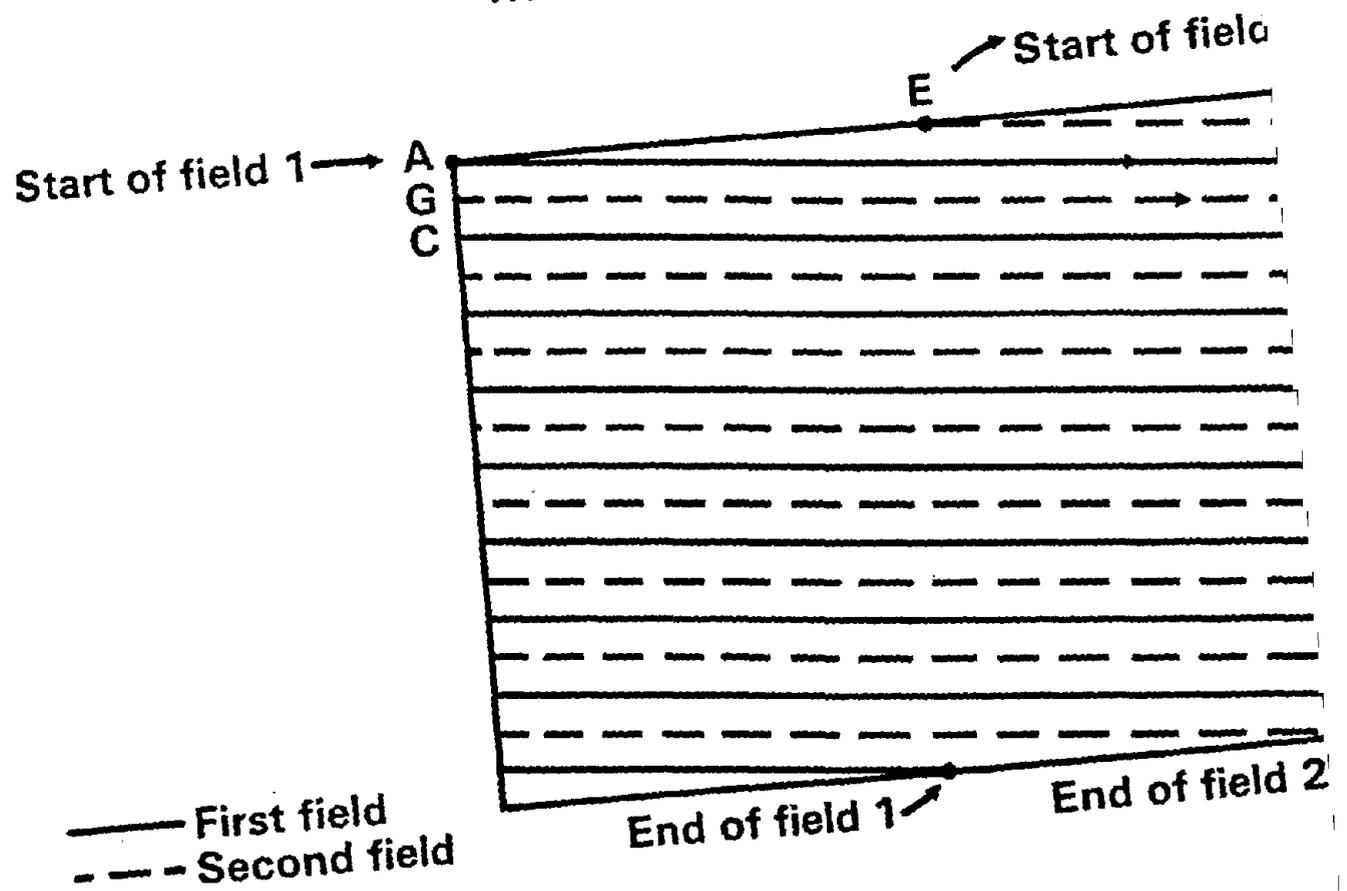


Figure 1. Illustration of the horizontal and vertical scanning of the electron beam in a CRT.

## High Voltage and Deflection Circuits in a VDT

Circuit operation produces electric and magnetic field emissions

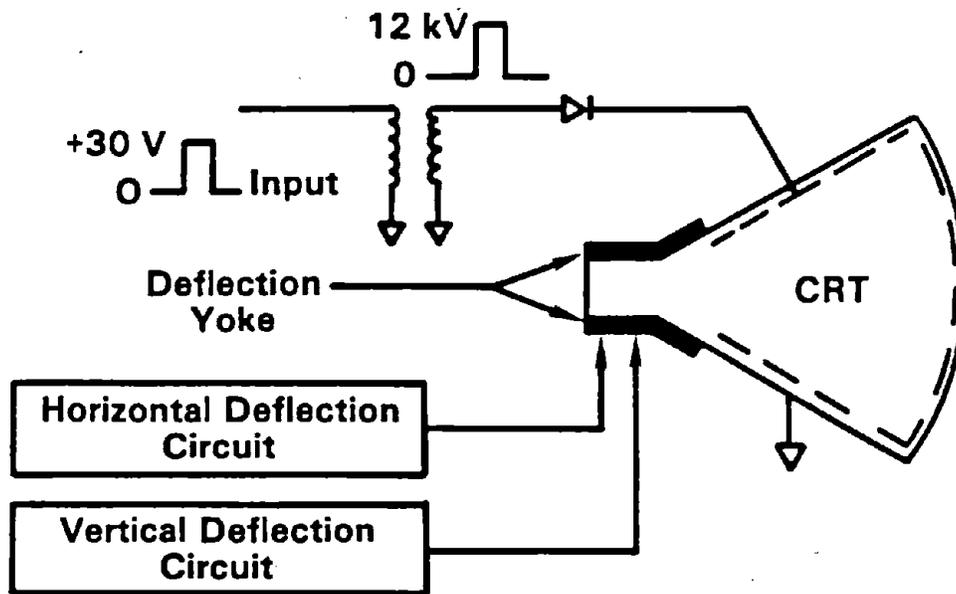


Figure 2. Block diagram of the horizontal and vertical deflection systems in a conventional VDT.

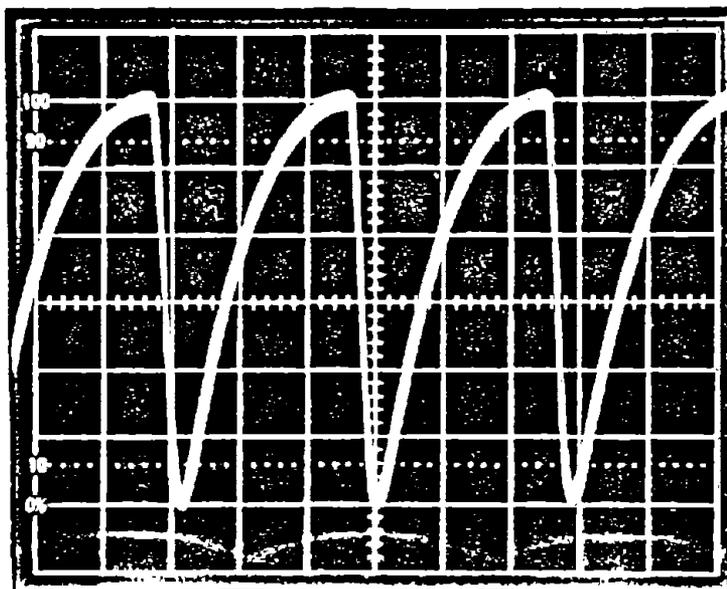


Figure 3. Sawtooth waveform of the magnetic field produced by current flowing in the horizontal deflection coils. During the shorter transition of the field, the electron beam is deflected back to the left side of the screen to begin another trace. Vertical axis is proportional to magnetic field and horizontal axis is time. Curvature in long transition is partially due to instrumentation response and individual characteristic of particular VDT.

## VDT Electric Field Lines Incident on VDT Operator are Perpendicular to the Body Surface

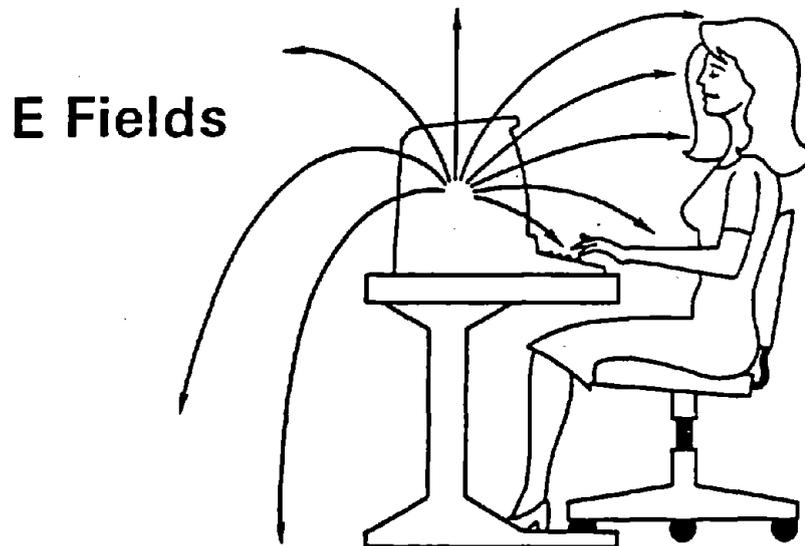


Figure 4. Illustration of the spatial distribution of the electric fields near a VDT with an operator present. The presence of the body perturbs the electric field lines which tend to terminate on grounded surfaces.

## VDT Magnetic Field Emissions are Unperturbed by the Presence of the Operator

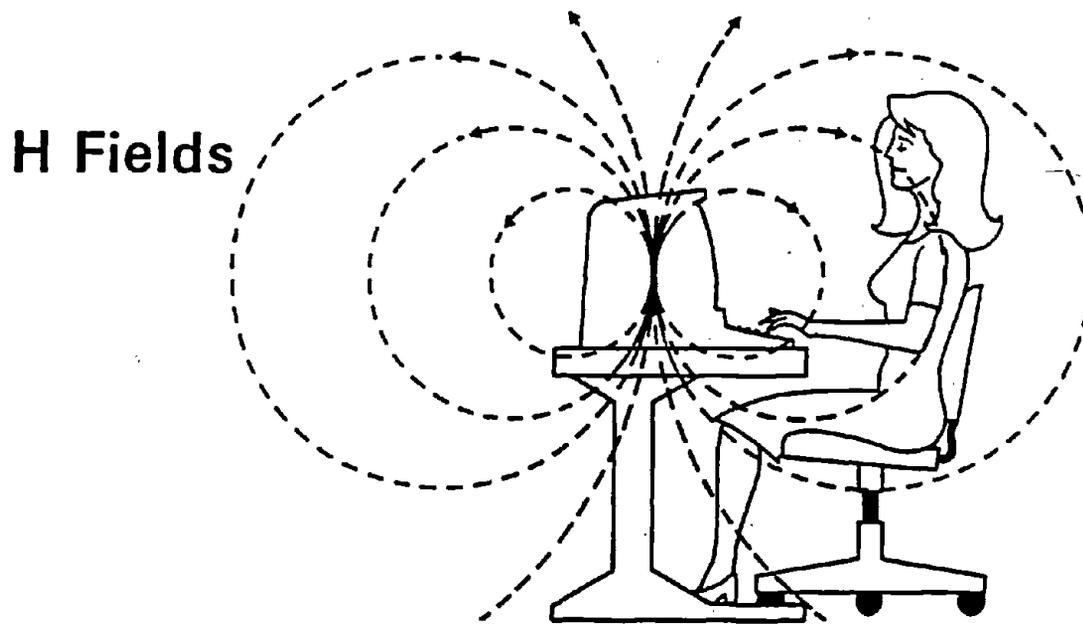


Figure 5. Illustration of the spatial distribution of the magnetic fields near a VDT. The presence of the operator does not perturb the magnetic field lines.

**VDT Electric Field Lines Normally Incident on  
VDT Operator, Tend to Terminate on the  
Grounded Filter Rather than the Operator**

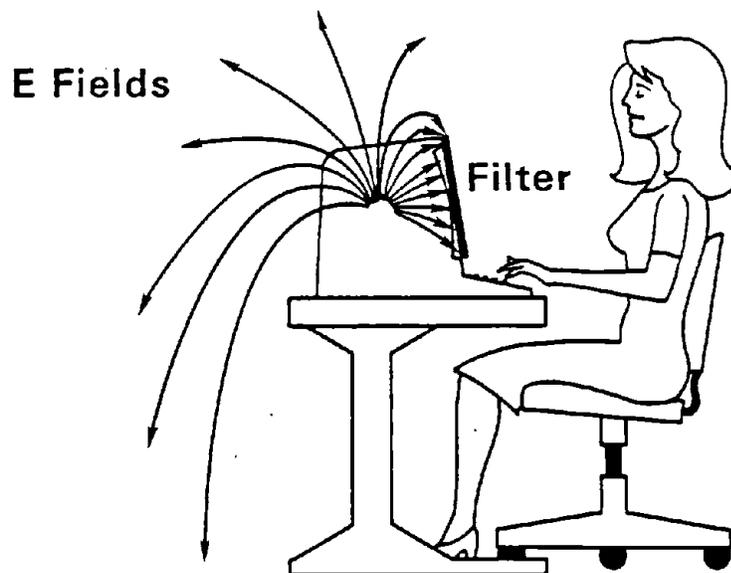


Figure 6. A grounded glare filter will tend to reduce the number of electric field lines which would normally terminate on the body of the operator.

### Theoretical and Measured Short Circuit Body Current of Grounded Man Exposed to VLF-MF Electric Field Parallel to Body Axis

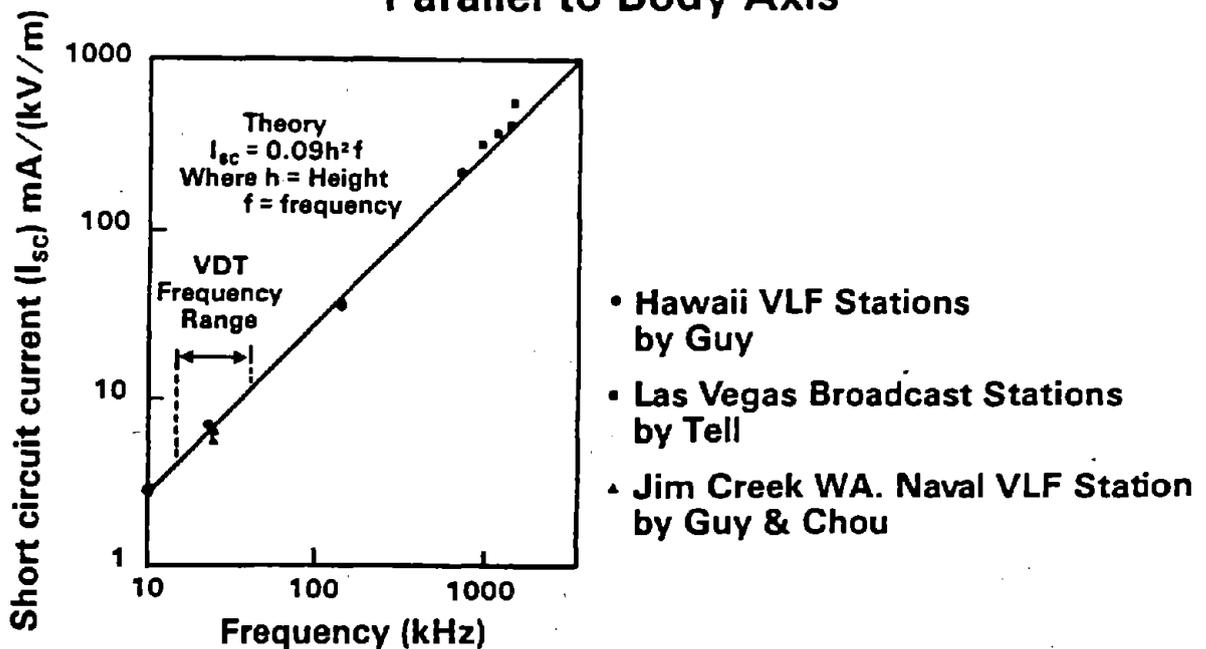


Figure 7. Electric field induced current in the body as a function of frequency. Induced current varies in direct proportion to the applied field frequency.

## Orientation of Sensor for RF Electric Fields

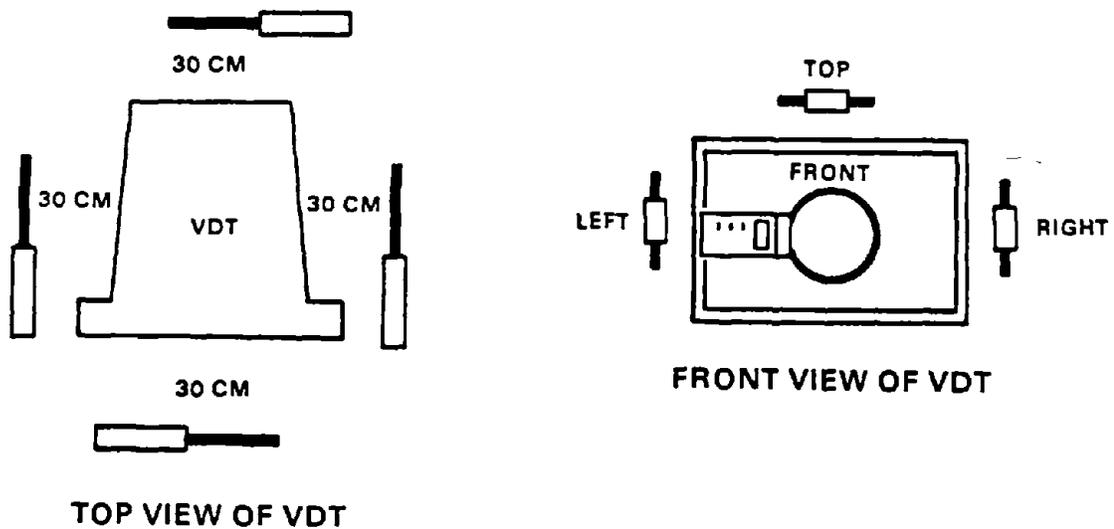


Figure 8. Orientation of the field sensor that was used for measuring the predominant VLF (horizontal deflection) electric field strength at different points near a VDT. This corresponds to the same sensor orientation for ELF electric fields except that the sensor paddle was reversed due to the design of the instrument (see text).

## Orientation of Sensor for RF Magnetic Fields

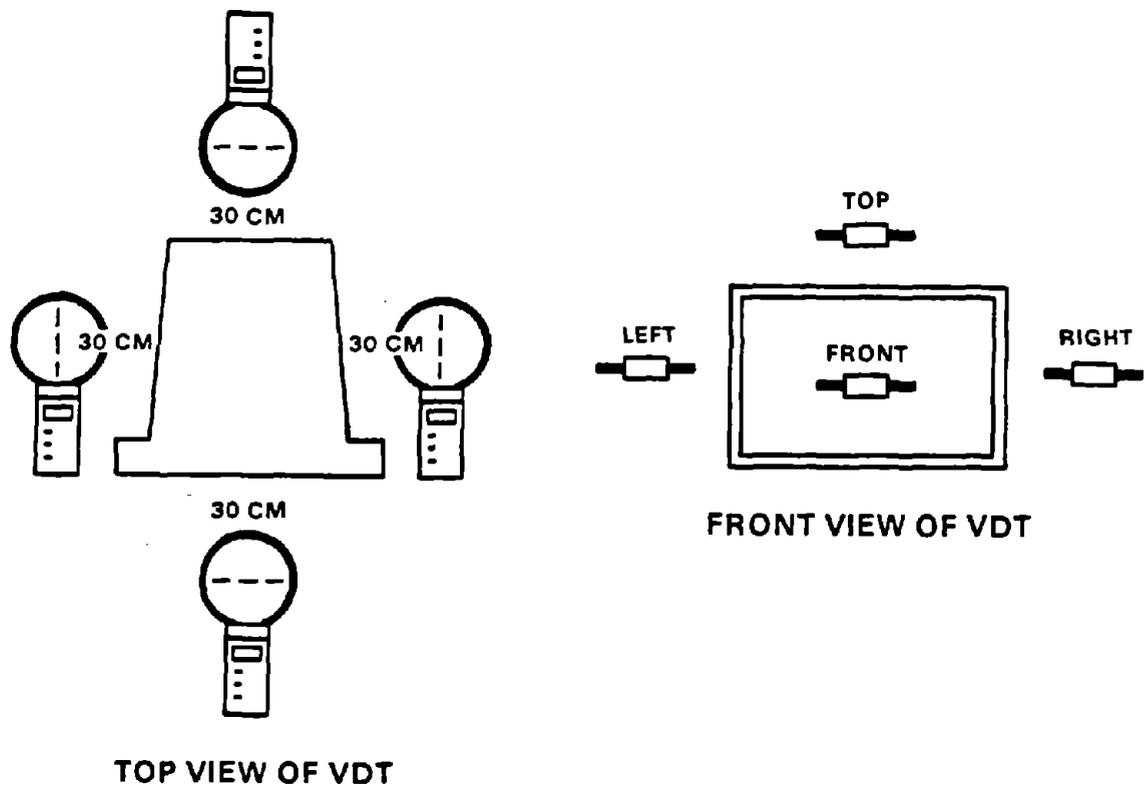


Figure 9. Orientation of the field sensor that was used for measuring the predominant VLF (horizontal deflection) magnetic field strength at different points near a VDT.

## Orientation of Sensor for ELF Magnetic Fields

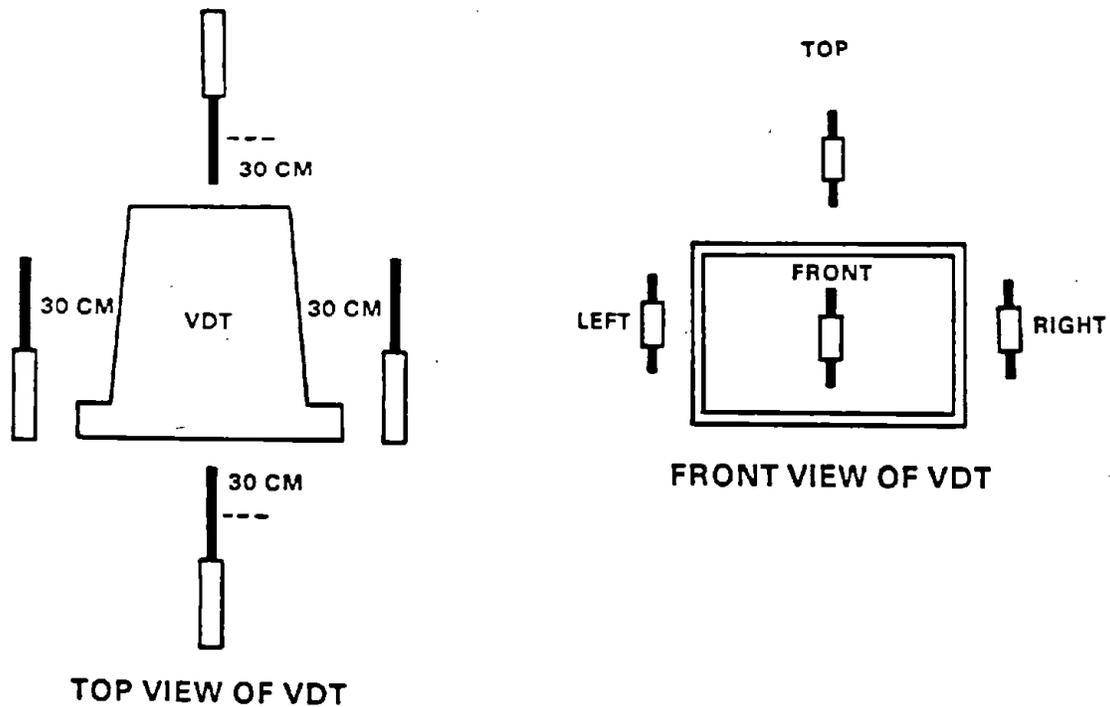


Figure 10. Orientation of the field sensor that was used for measuring the predominant ELF (vertical deflection) magnetic field strength at different points near a VDT.



Figure 11. Positioning of the field sensor for the self-measurement of the VLF electric field incident on the body surface of the VDT operator (chest position).

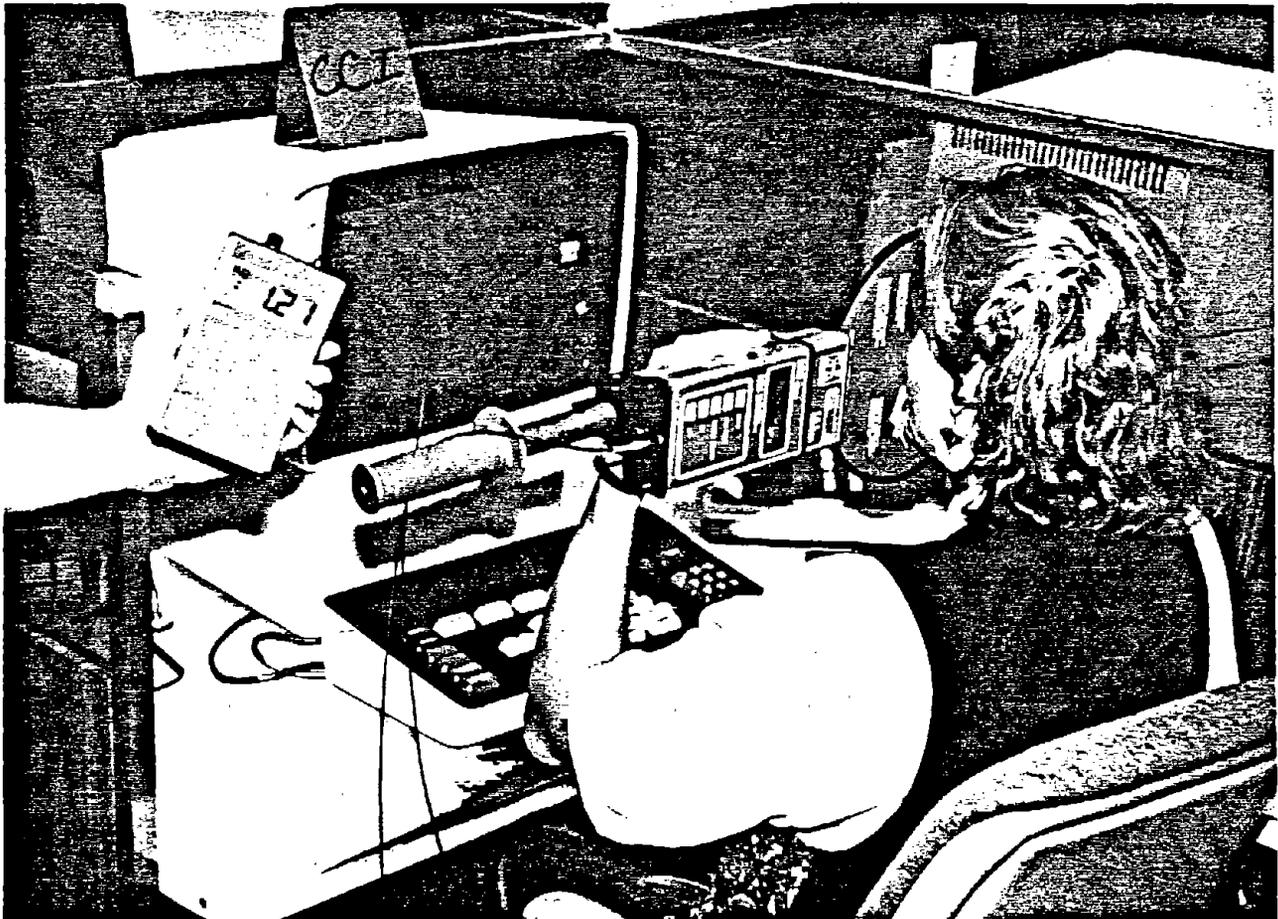


Figure 12. Positioning of the field sensor for the self-measurement of the VLF electric field incident on the body surface of the VDT operator (face position).



Figure 13. Positioning of the field sensor for the self-measurement of the ELF magnetic field incident on the body surface of the VDT operator (face position).



Figure 14. Positioning of the field sensor for the measurement of the VLF magnetic field incident on the body of the VDT operator.

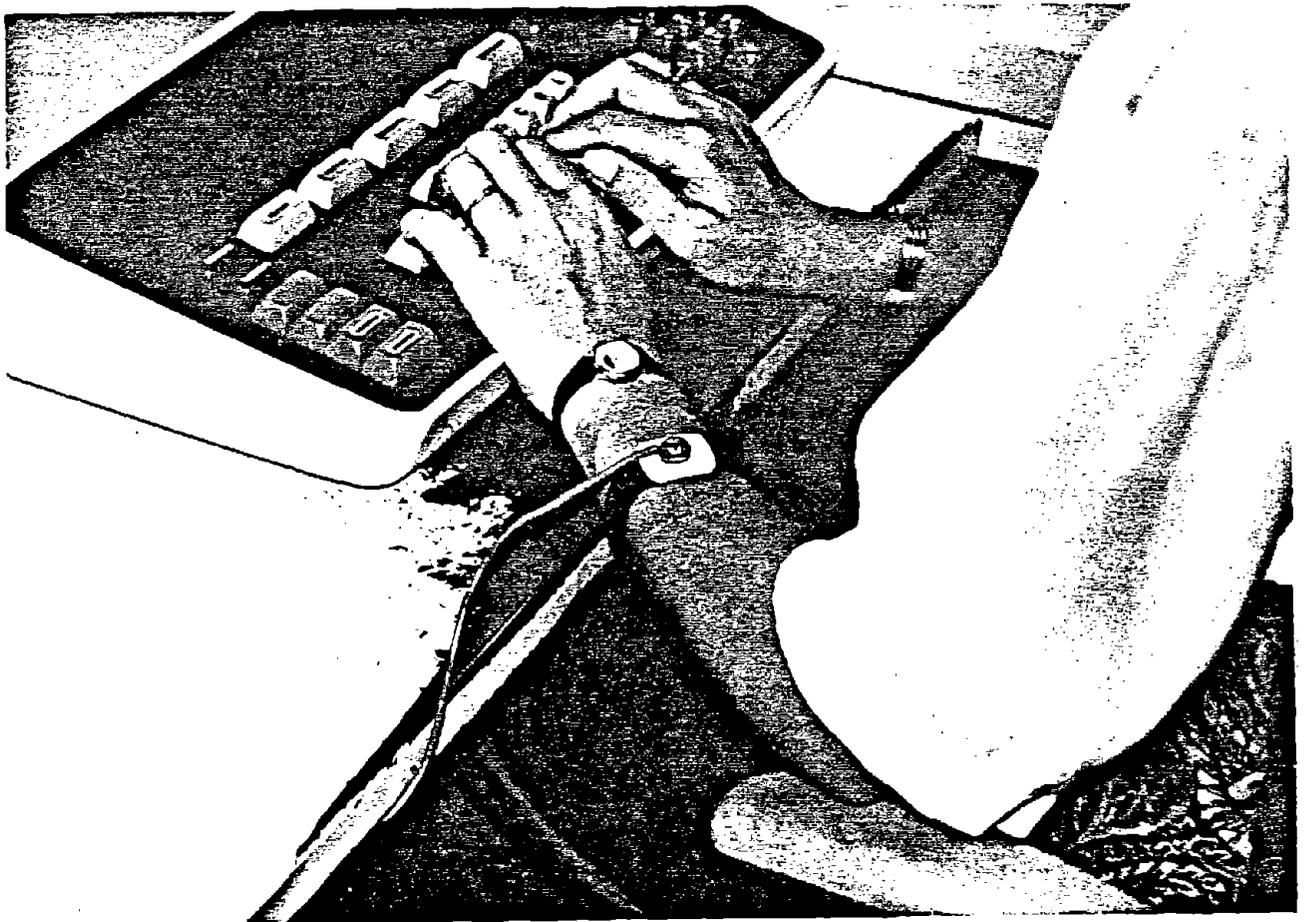


Figure 15. Close-up photograph showing the conductive wrist band for measurement of electric field induced body current. One of three hand positions used for determining induced current was with the hands on the keyboard.



Figure 16. Measurement of the electric field induced current in the operator was accomplished through the use of a conductive wrist band connected to a digital multimeter.

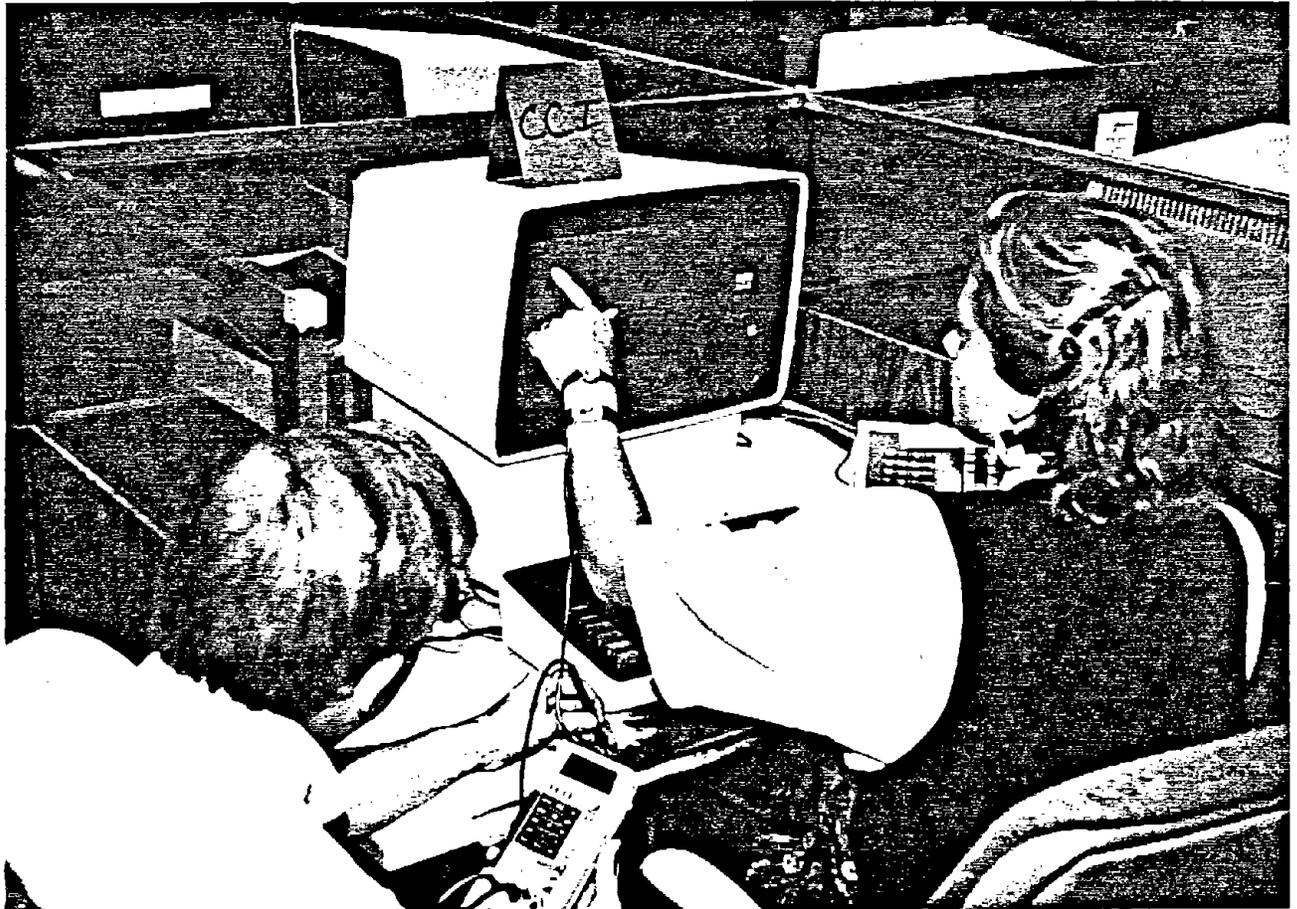


Figure 17. One of three hand positions used for determining the electric field induced current was pointing to a spot on the screen of the display.



Figure 18. The third of three different hand positions used for determining induced current was with the hand placed flat against the screen of the VDT. In this position the capacitive coupling to the electric field source is greatest.

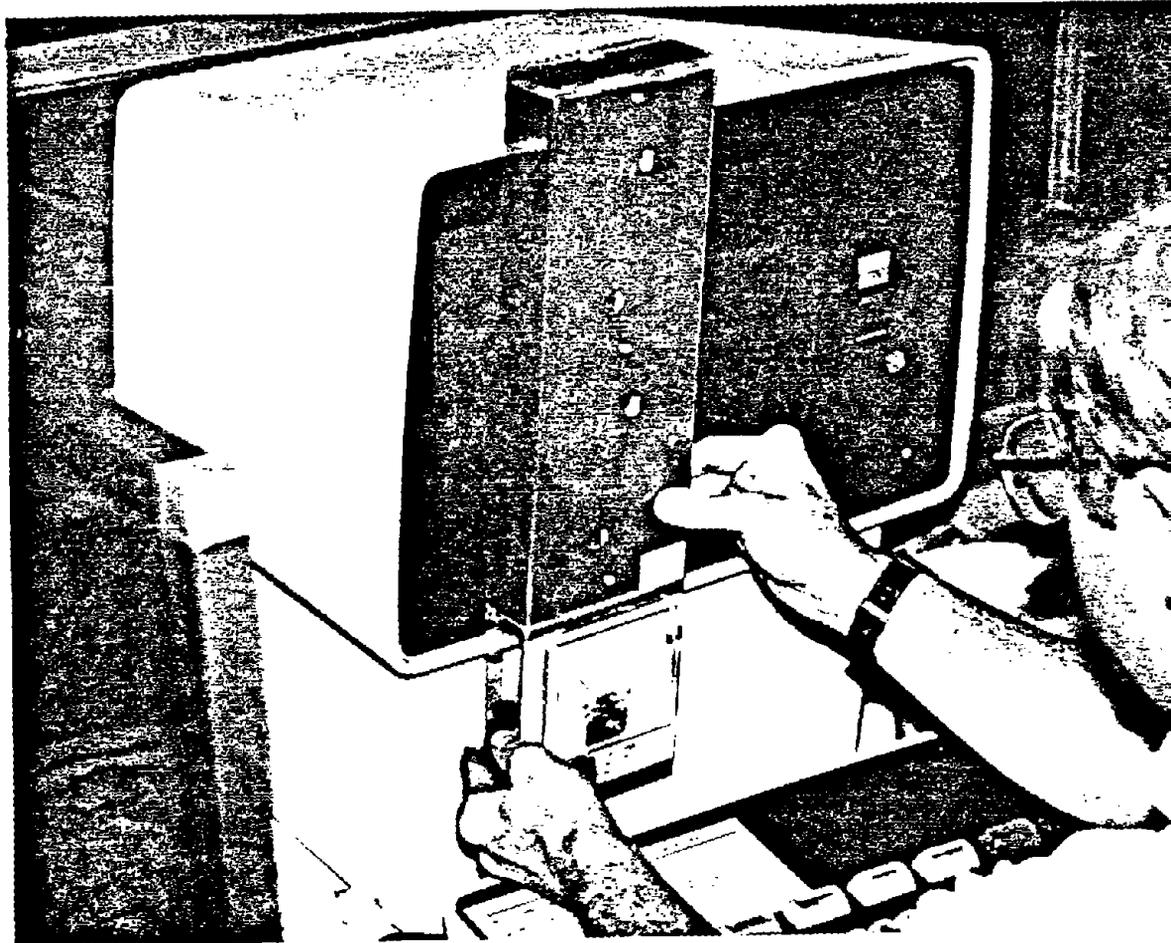


Figure 19. Using the Stoms planar scanning meter for detection of possible low energy x-radiation leakage from the VDT.

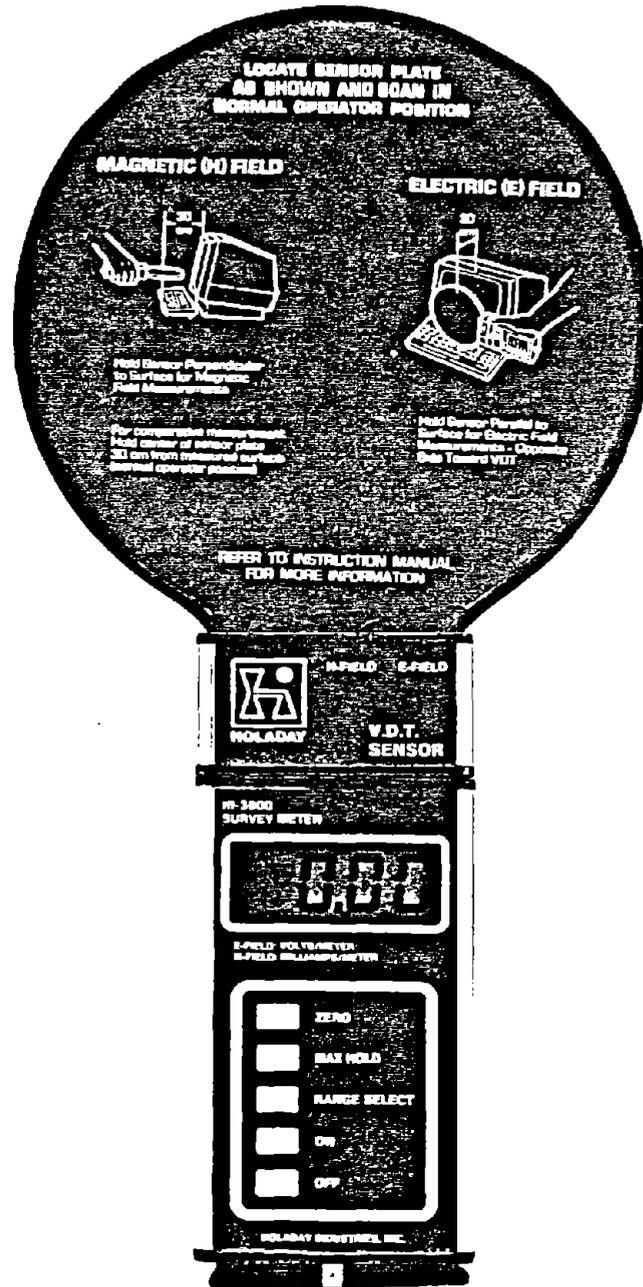
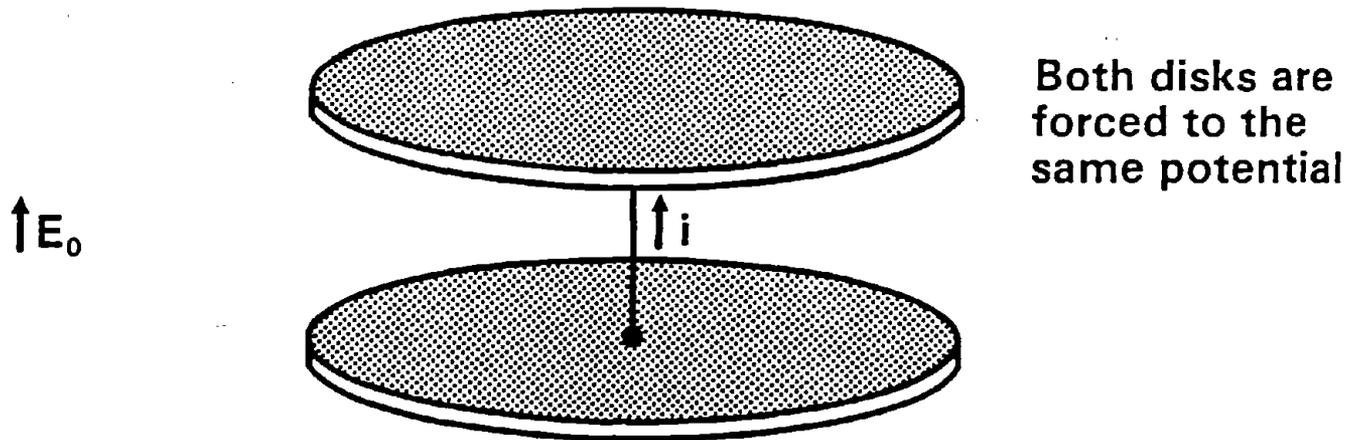


Figure 20. Photograph of the Holaday Industries Model HI-3600 VDT survey meter.

## Measurement of Electric Field Strength via Displacement Current Sensor

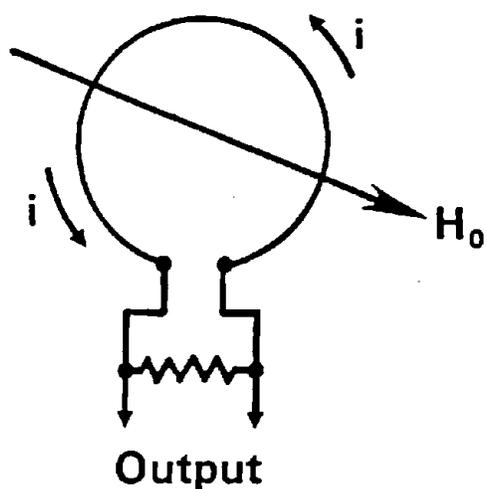


**A displacement current  $i$  flows between the shorted disks to maintain zero electric field between the disks**

Figure 21. Principle of operation of a displacement current sensor for measuring the strength of an electric field.

## Measurement of Magnetic Field Strength via Induced Loop Current

Compensated Loop



Tailored frequency response with loop loading

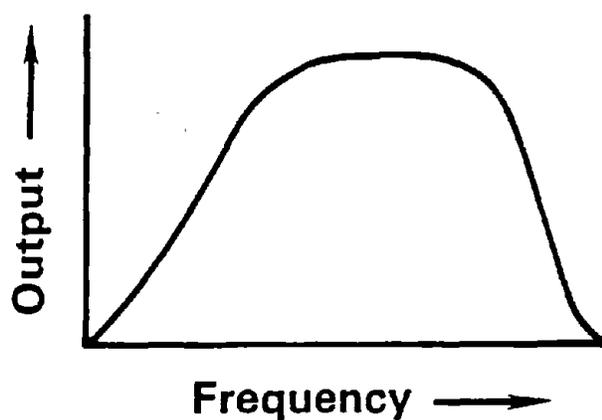


Figure 22. The frequency response of a compensated (loaded) loop for measuring magnetic fields. The loop loading produces a shaped frequency response that is flat in a given frequency range.

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Figure 23. Variation of electric and magnetic field strength with distance from a display was accomplished with a nonconductive stand to hold the field strength meter.

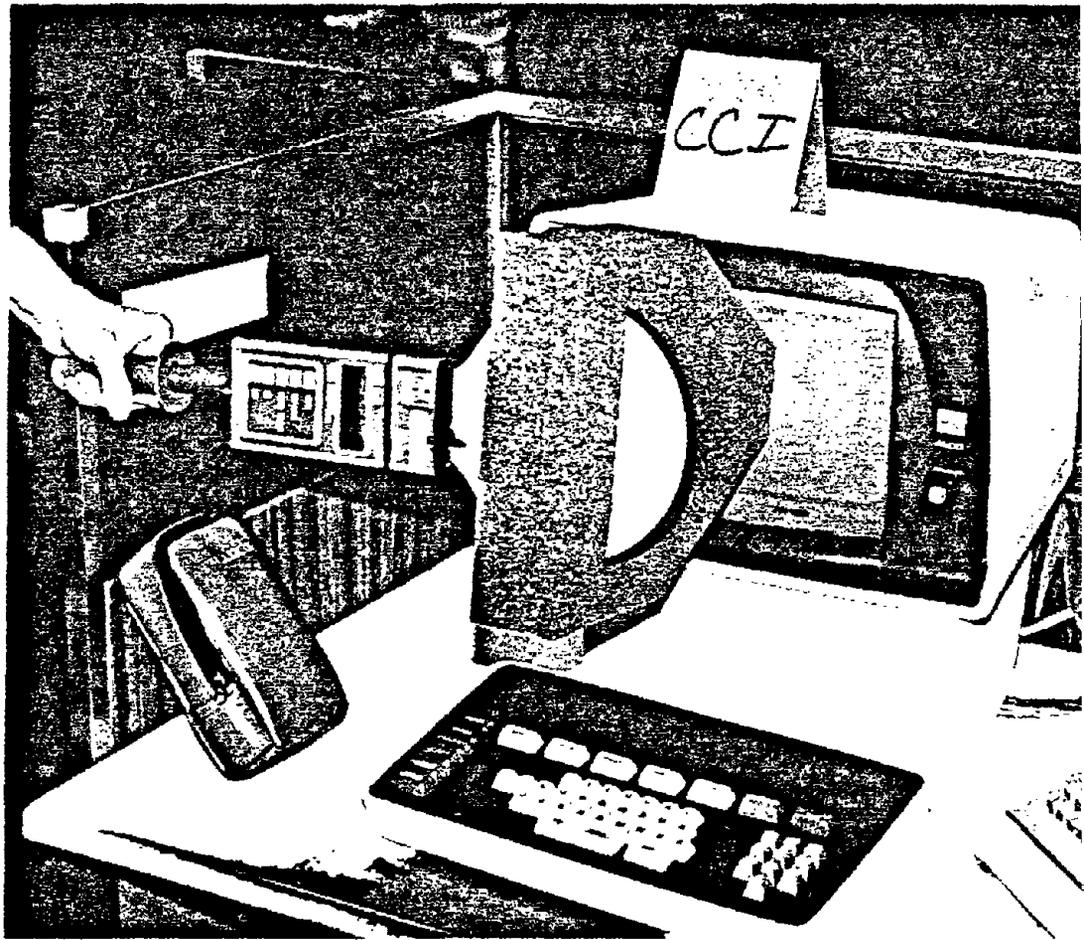


Figure 24. For measurements of electric field emissions, a special spacing device was used to position the sensor surface 30 cm from the surface of the display.



Figure 25. For measurements of magnetic field emissions, a special spacing device was used to position the center of the loop sensor 30 cm from the surface of the display.

## Method for Calibrating the HI-3600 Magnetic Field Response Using 3 Turn Helmholtz Coils

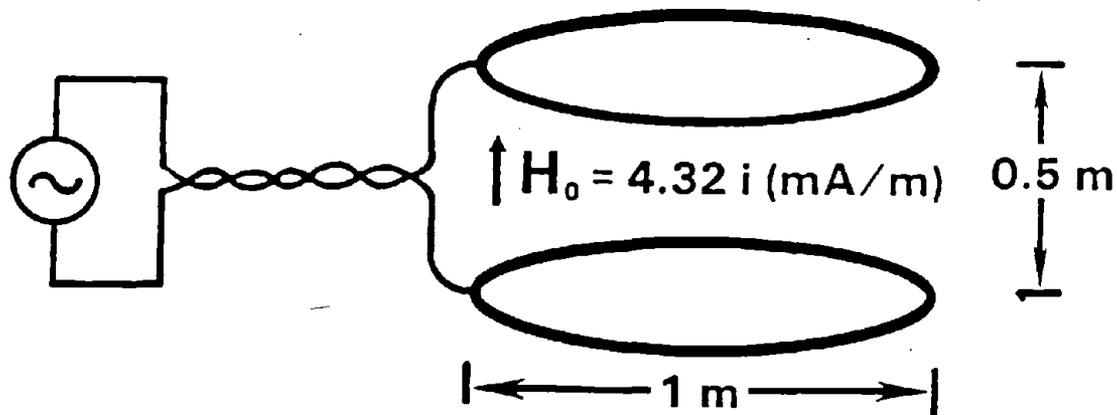


Figure 26. Diagram of one-meter diameter Helmholtz coil system for generating a magnetic field of known strength for calibrating the field sensors.

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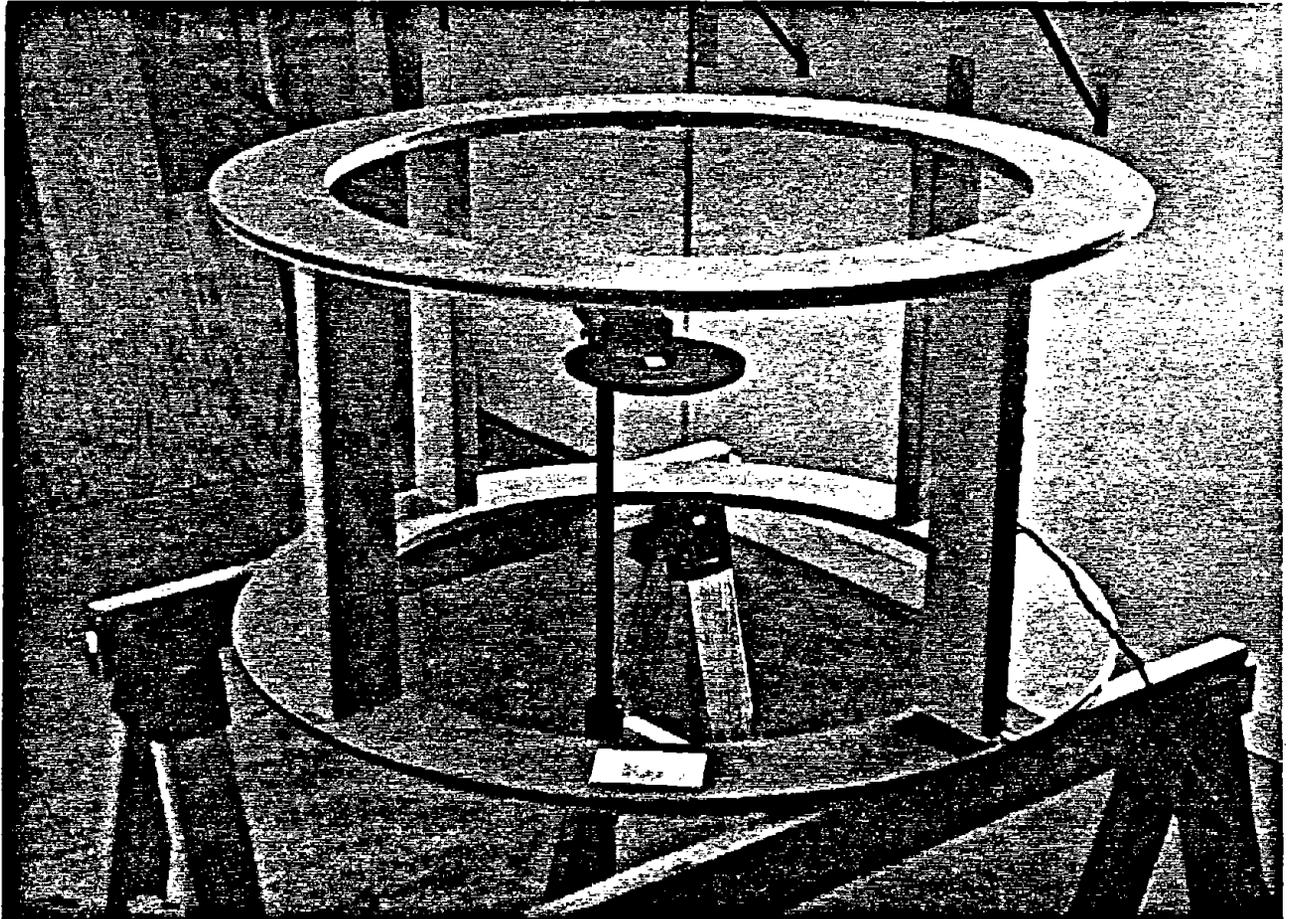


Figure 27. Photograph of the one-meter Helmholtz coil system used to evaluate the response of the magnetic field sensors.

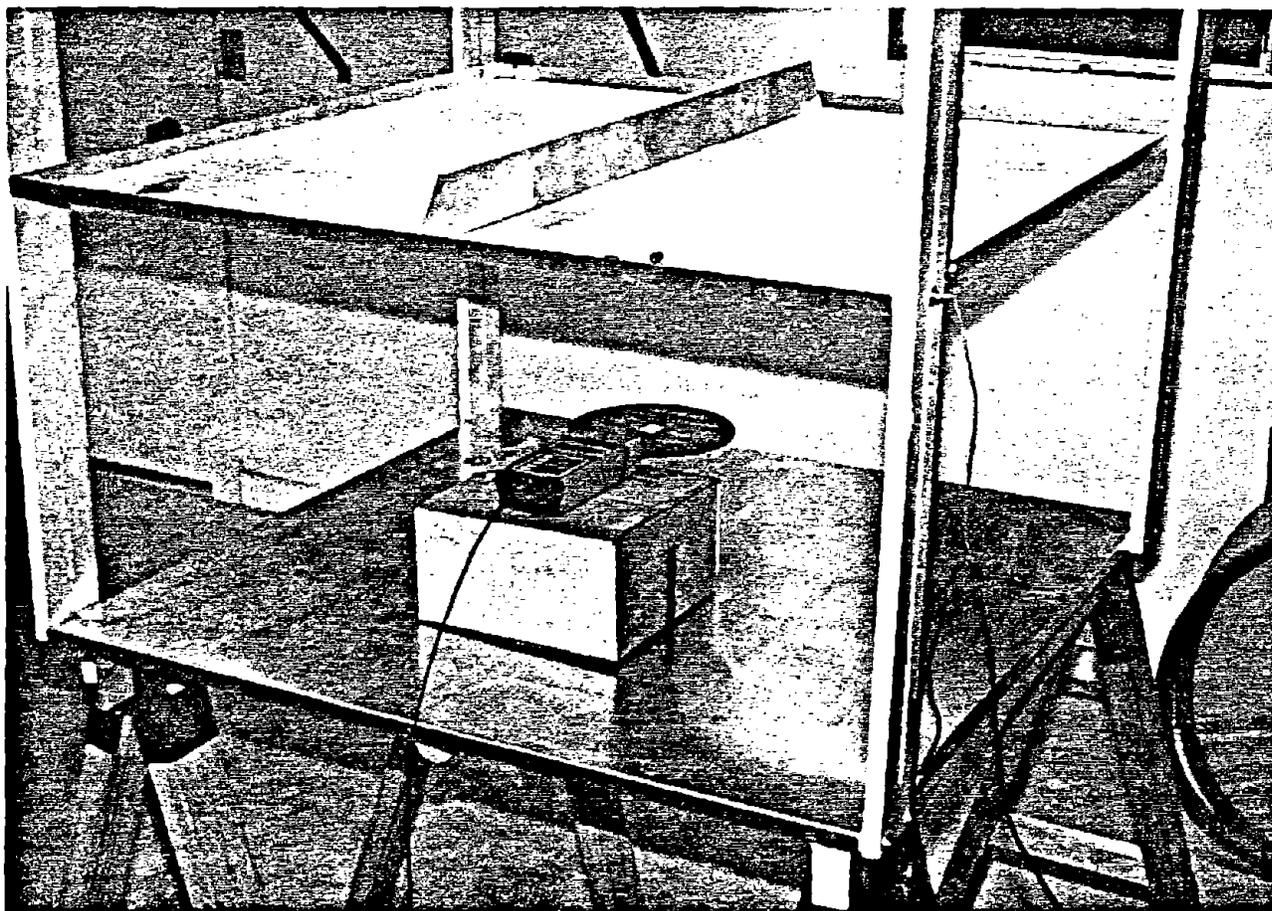


Figure 28. Photograph of the one-meter square parallel plates used to develop a known electric field strength for evaluating the electric field sensors used in the project.



Figure 29. Horizontal and vertical deflection frequencies were determined by using a frequency counter feature on the Fluke Model 8060A digital multimeter connected to the analog output signal of the field sensors.

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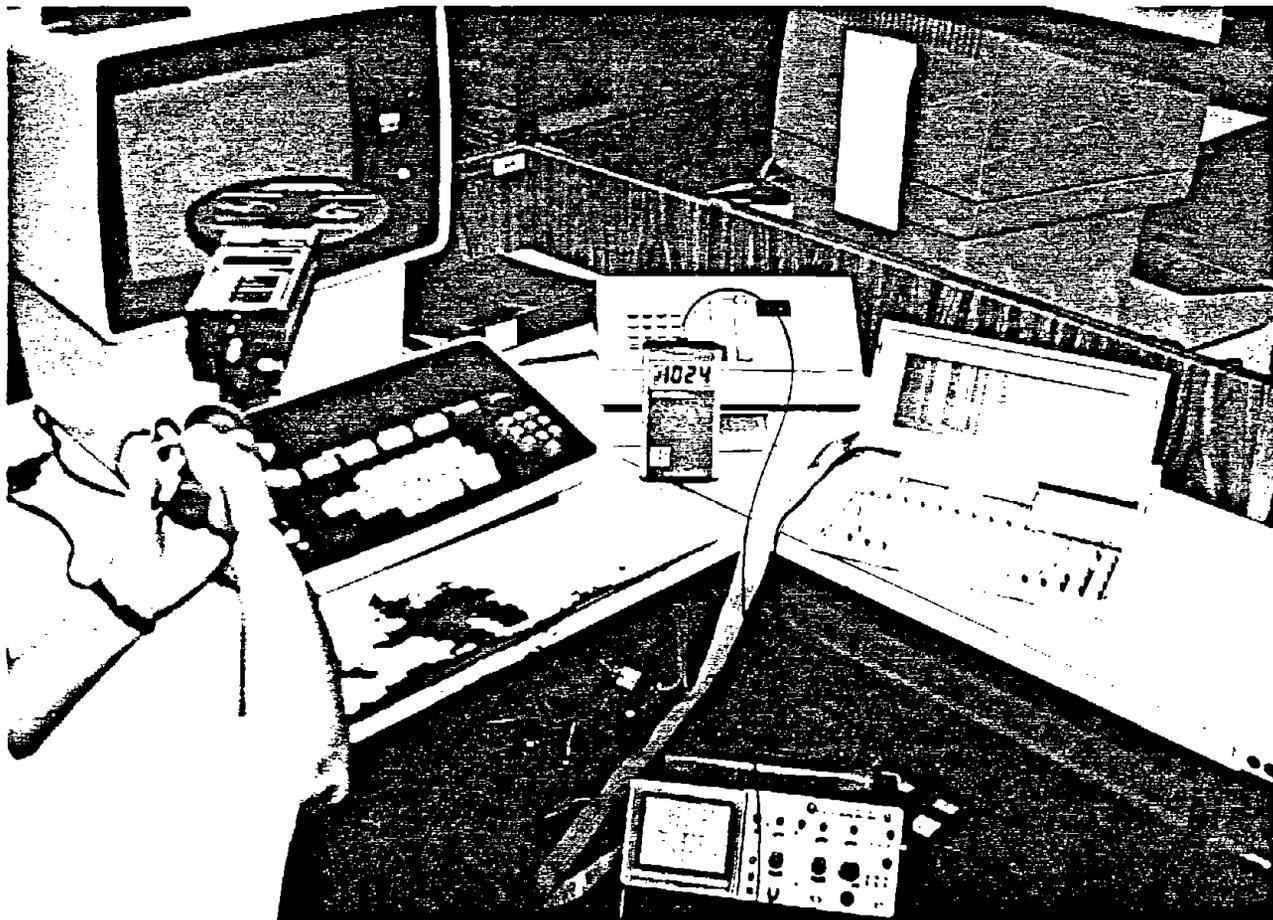


Figure 30. Using the HI-3600 analog output with a digital oscilloscope and laptop computer to measure and store the waveform of electric and magnetic fields of a VDT.

VLF ELECTRIC FIELD FREQUENCY RESPONSE  
OF HOLADAY INDUSTRIES MODEL HI-3600  
Meter S/N 54700, Sensor S/N 54802

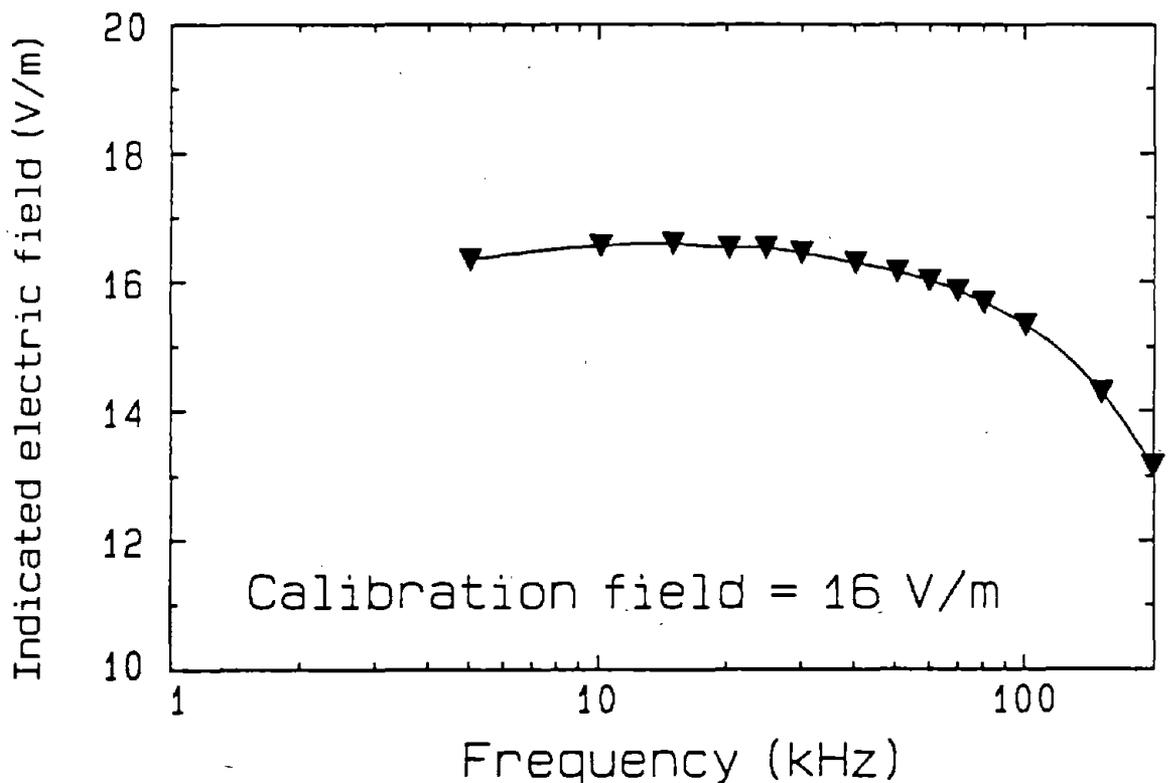


Figure 31. VLF electric field frequency response of the Holaday Industries Model HI-3600-01, meter s/n 54700, sensor s/n 54802.

VLF MAGNETIC FIELD FREQUENCY RESPONSE  
OF HOLADAY INDUSTRIES MODEL HI-3600  
Meter S/N 54700, Sensor S/N 54802

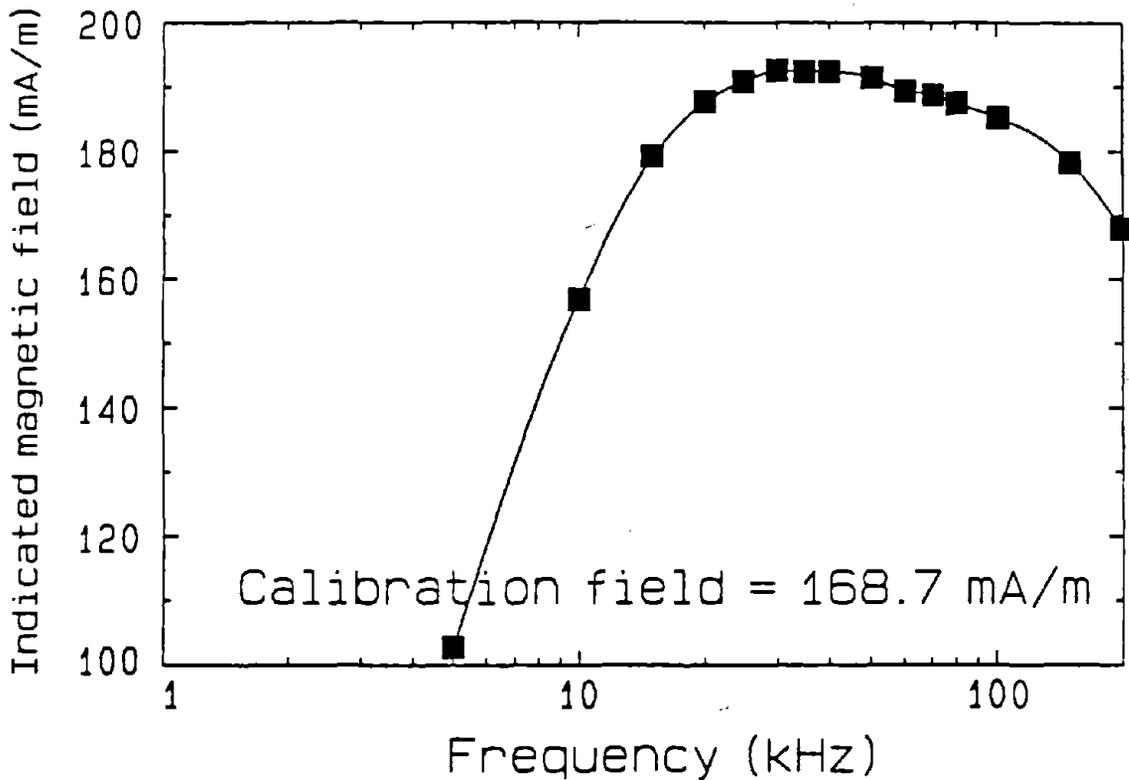


Figure 32. VLF magnetic field frequency response of the Holaday Industries Model HI-3600-01, meter s/n 54700, sensor s/n 54802.

ELF ELECTRIC FIELD FREQUENCY RESPONSE  
OF HOLADAY INDUSTRIES MODEL HI-3602  
Meter S/N 55014, Sensor S/n 58493

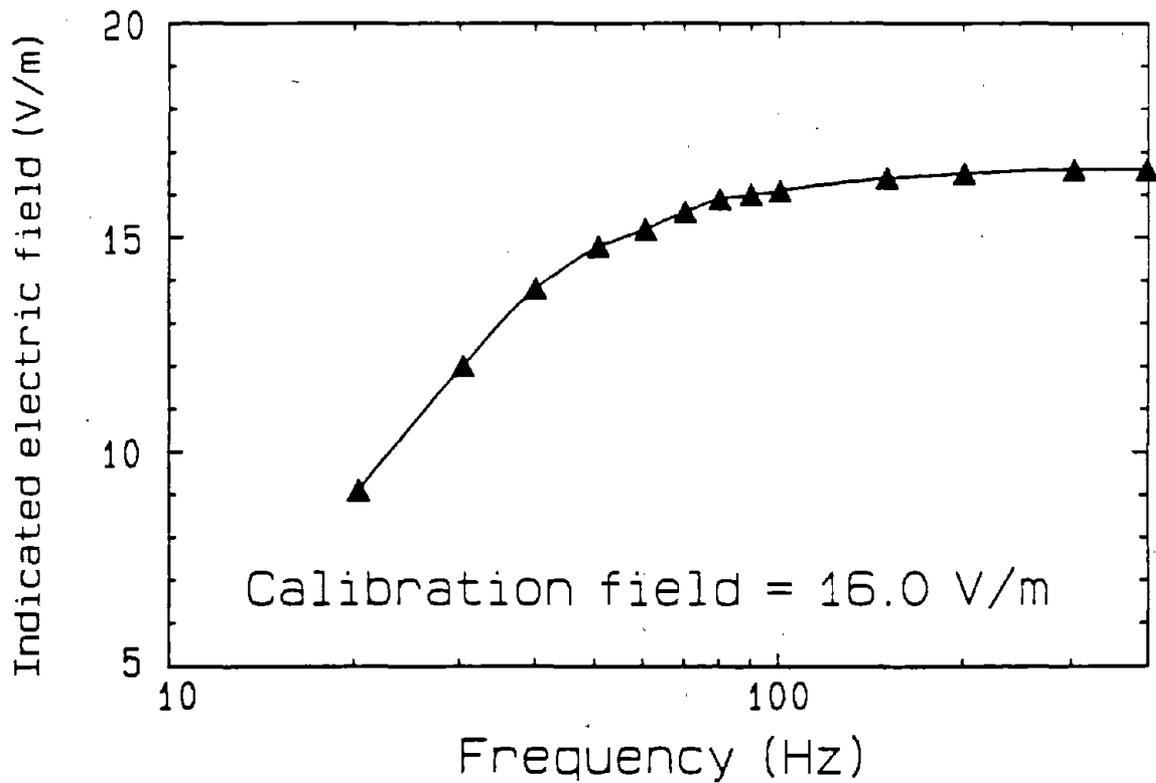


Figure 33. ELF electric field frequency response of the Holaday Industries Model HI-3600-02, meter s/n 55014, sensor s/n 58493.

ELF MAGNETIC FIELD FREQUENCY RESPONSE  
OF HOLADAY INDUSTRIES MODEL HI-3602  
Meter S/N 55014, Sensor S/n 58493

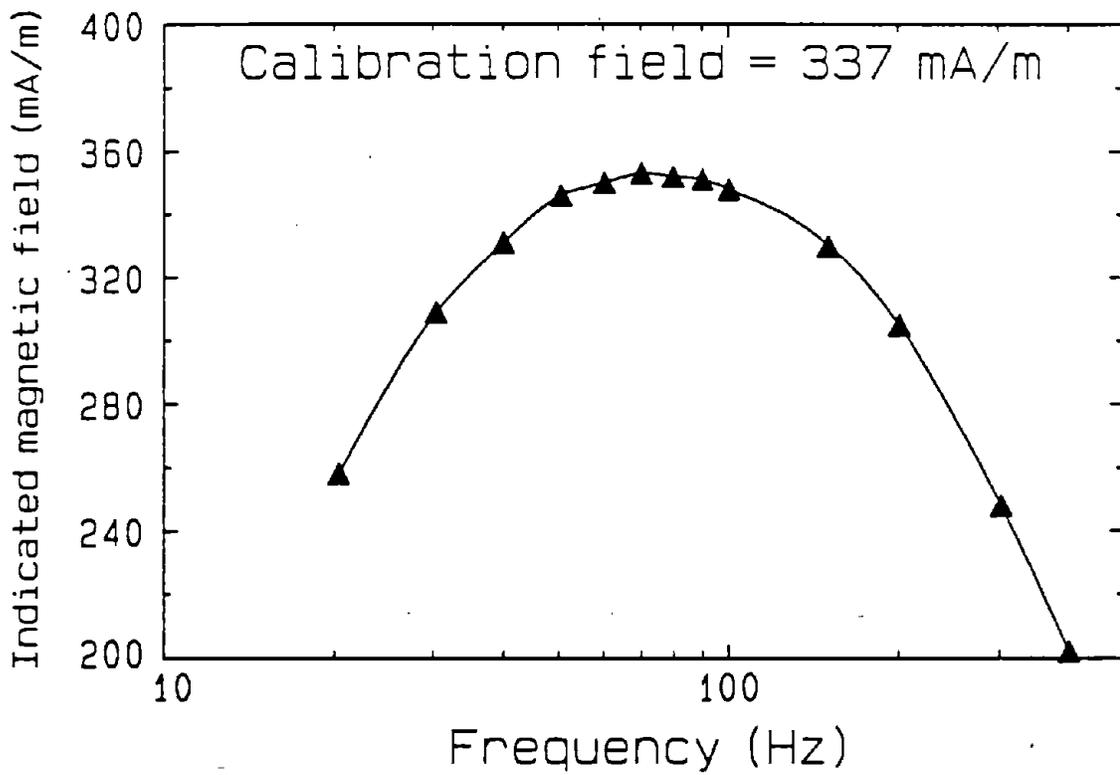


Figure 34. ELF magnetic field frequency response of the Holaday Industries Model HI-3600-02, meter s/n 55014, sensor s/n 58493.

ELF MAGNETIC FIELD FREQUENCY RESPONSE  
OF HOLADAY INDUSTRIES MODEL HI-3602  
Meter S/N 55501, Sensor S/n 60088

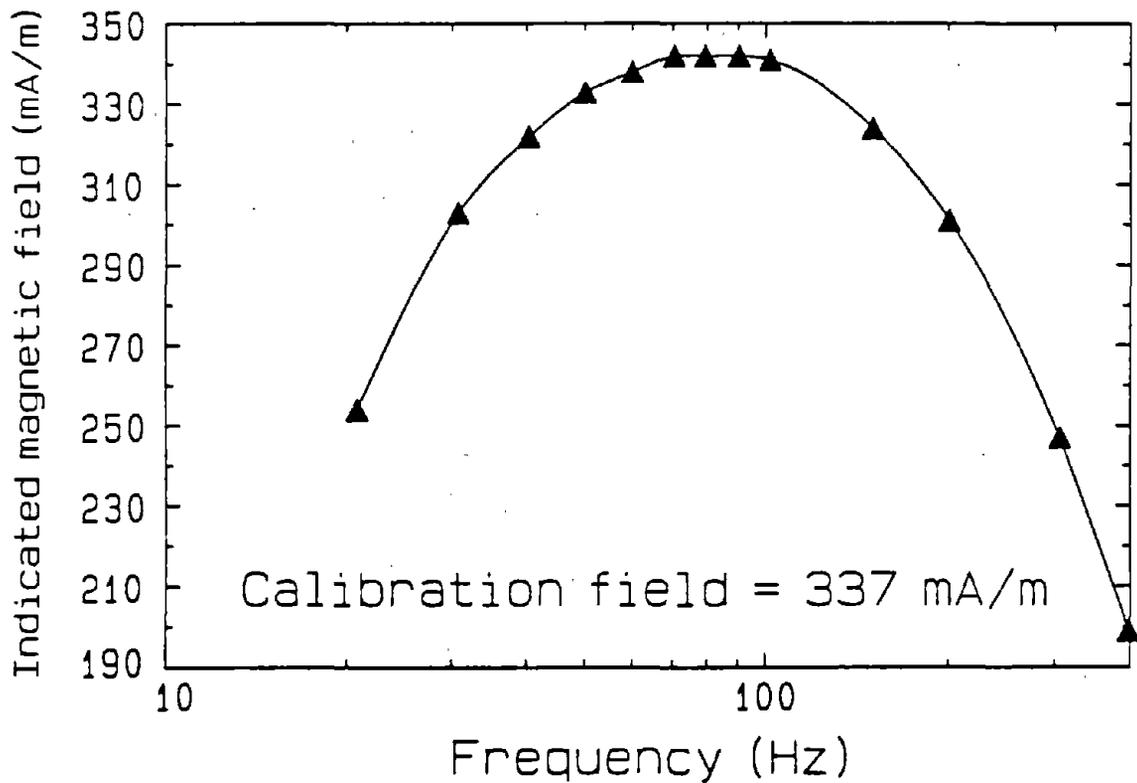


Figure 35. ELF magnetic field frequency response of the Holaday Industries Model HI-3600-02, meter s/n 55501, sensor s/n 60088.

### SPATIAL VARIATION OF ELF MAGNETIC FIELD FOR CCI VIDEO DISPLAY TERMINALS

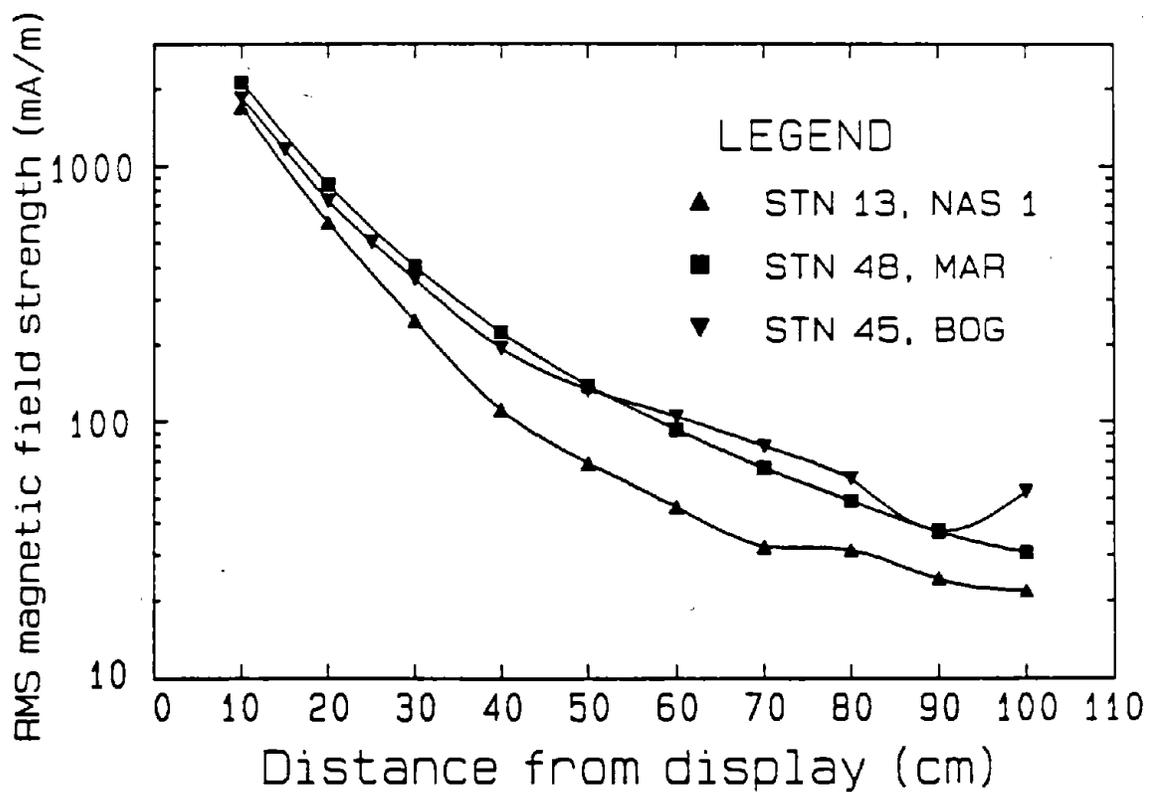


Figure 36. Spatial variation of ELF magnetic fields (vertical deflection) for three CCI VDTs.

### SPATIAL VARIATION OF VLF MAGNETIC FIELD FOR CCI VIDEO DISPLAY TERMINALS

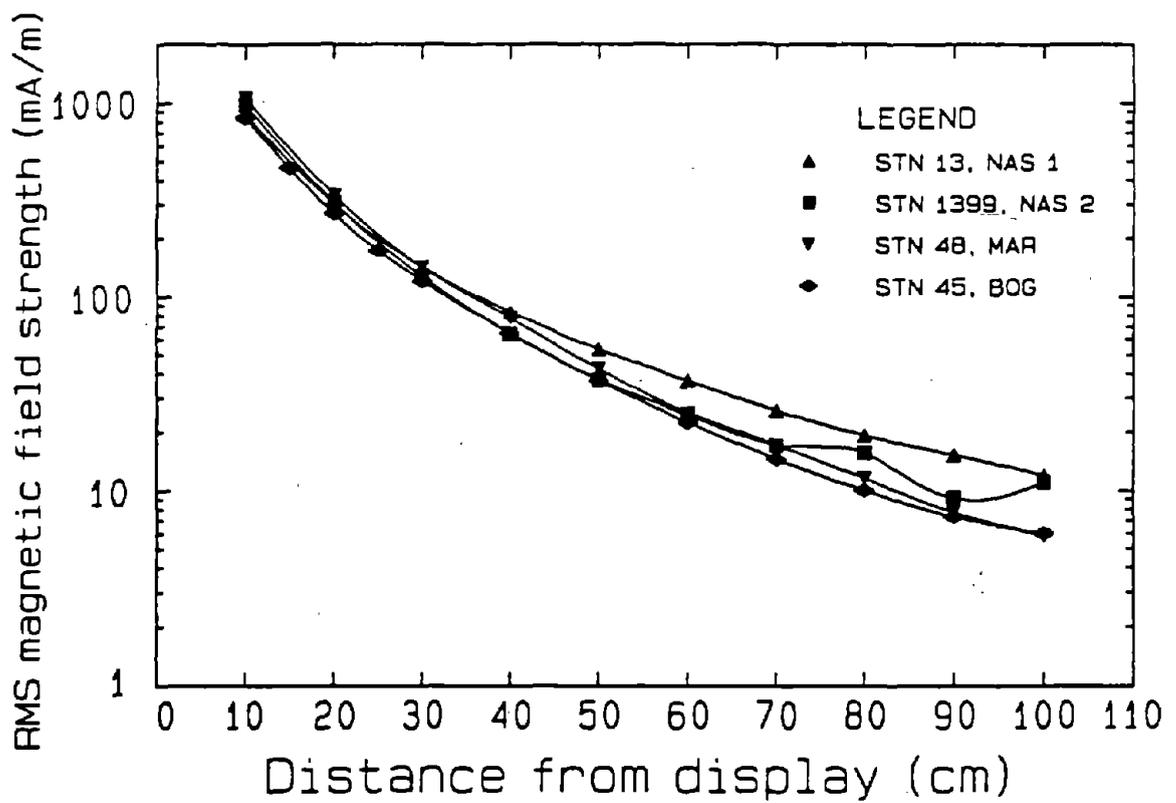


Figure 37. Spatial variation of VLF magnetic fields (horizontal deflection) for four CCI VDTs.

### SPATIAL VARIATION OF ELF ELECTRIC FIELD FOR CCI VIDEO DISPLAY TERMINALS

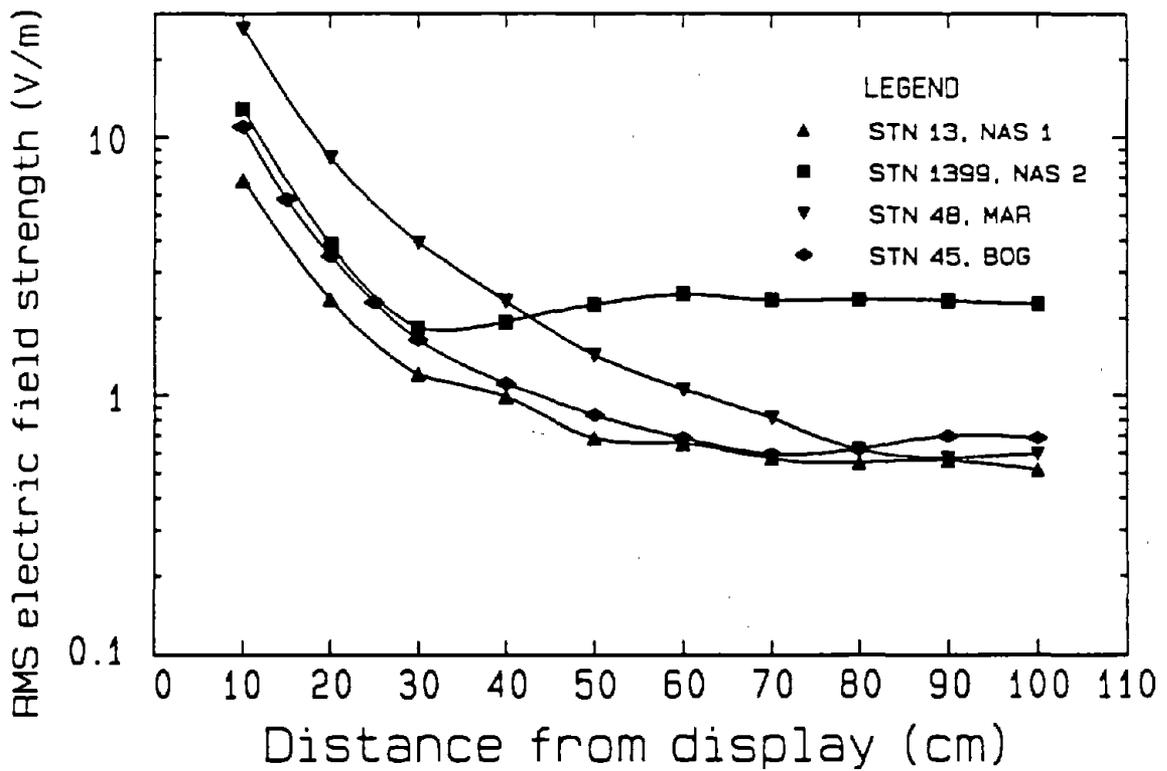


Figure 38. Spatial variation of ELF electric fields for four CCI VDTs.

### SPATIAL VARIATION OF VLF ELECTRIC FIELD FOR CCI VIDEO DISPLAY TERMINALS

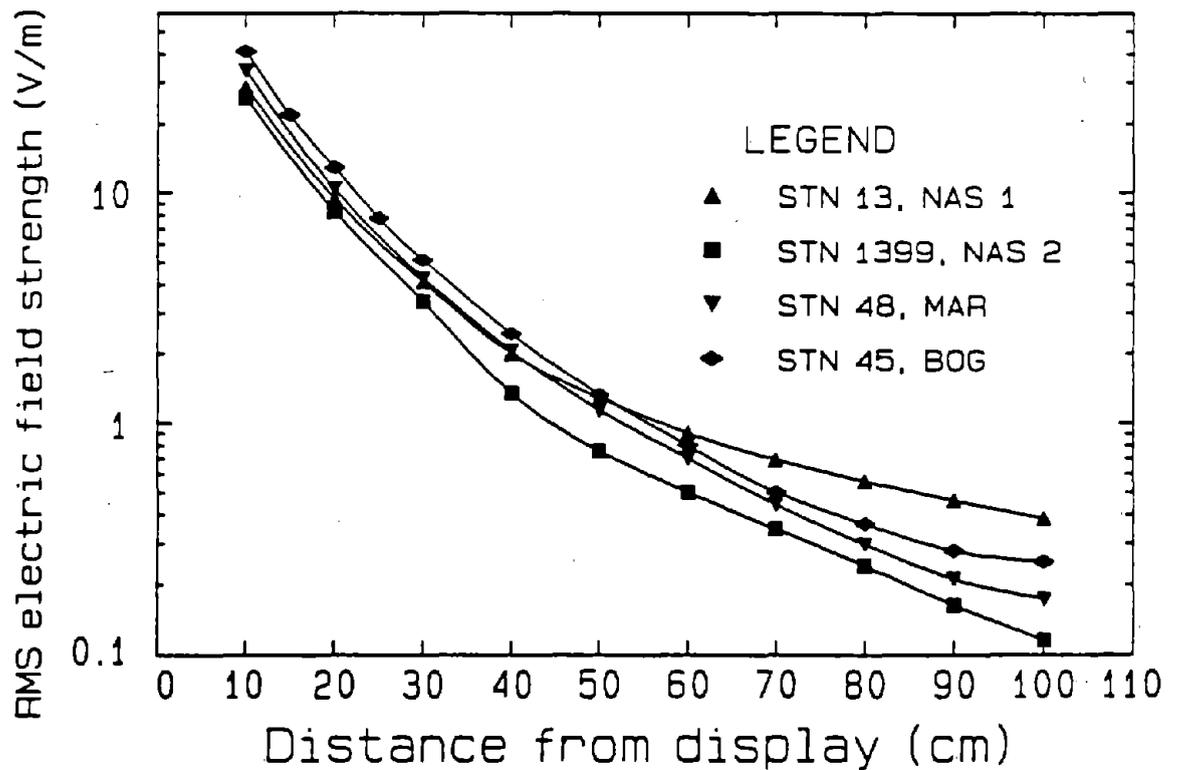


Figure 39. Spatial variation of VLF electric fields for four CCI VDTs.

### SPATIAL VARIATION OF ELF MAGNETIC FIELD FOR IBM VIDEO DISPLAY TERMINALS

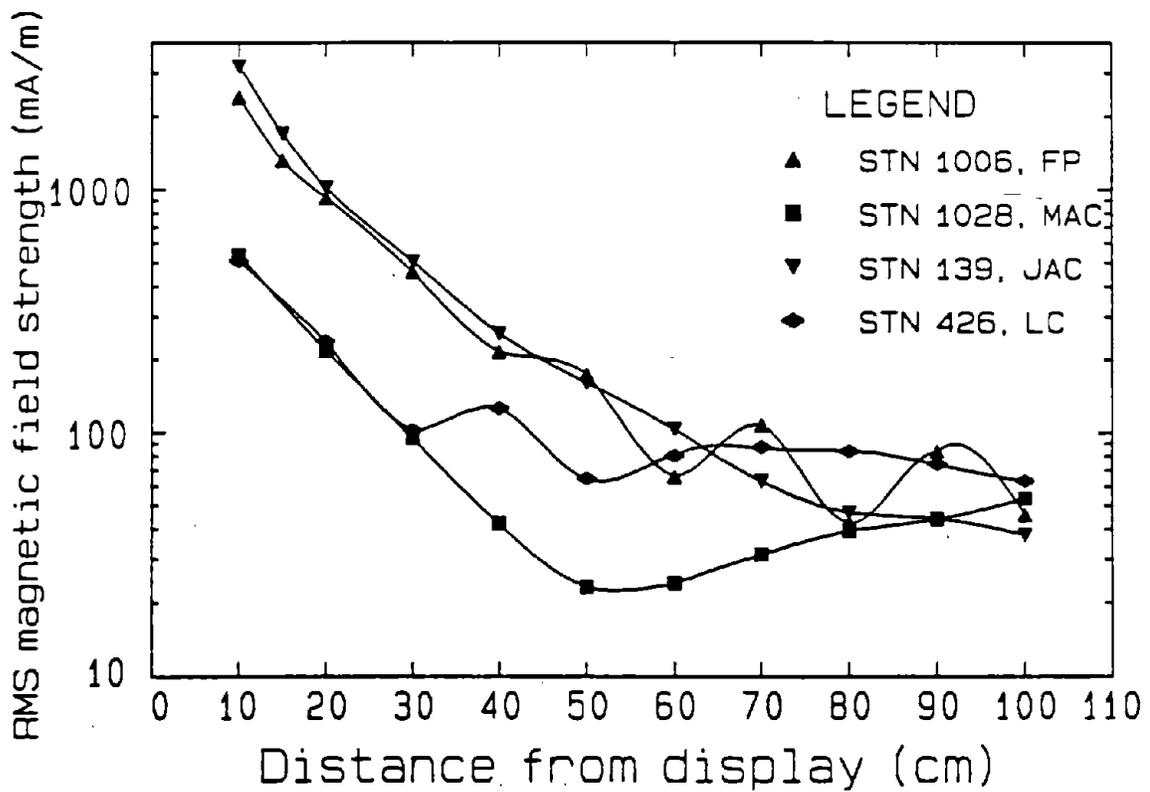


Figure 40. Spatial variation of ELF magnetic fields for four IBM VDTs.

## SPATIAL VARIATION OF VLF MAGNETIC FIELD FOR IBM VIDEO DISPLAY TERMINALS

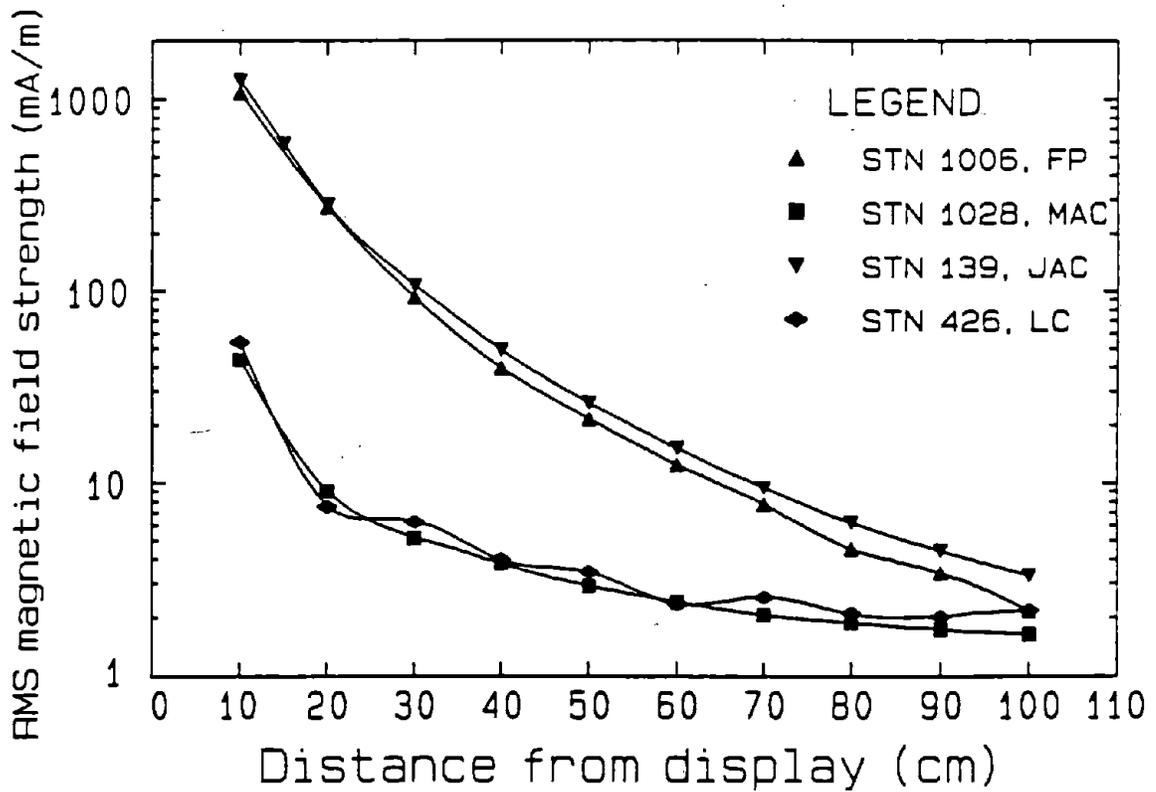


Figure 41. Spatial variation of VLF magnetic fields for four IBM VDTs. Data support supposition that there are two different designs used for the same model.

### SPATIAL VARIATION OF ELF ELECTRIC FIELD FOR IBM VIDEO DISPLAY TERMINALS

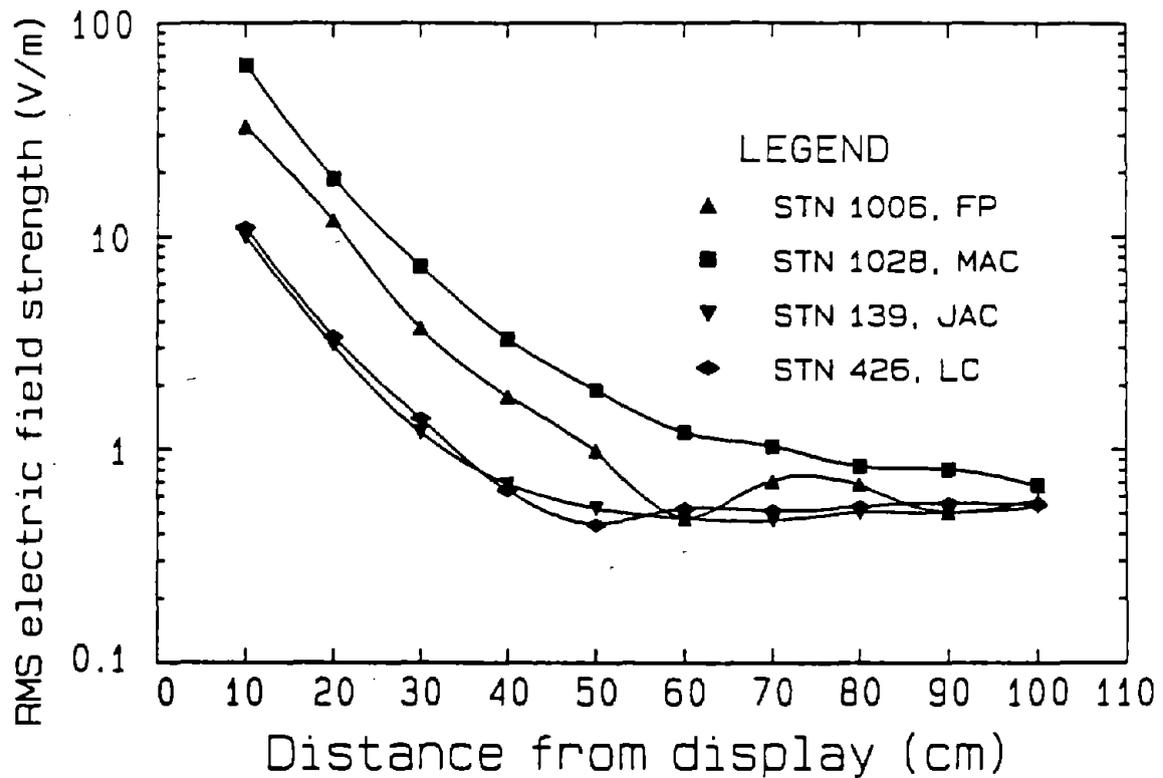


Figure 42. Spatial variation of ELF electric fields for four IBM VDTs.

### SPATIAL VARIATION OF VLF ELECTRIC FIELD FOR IBM VIDEO DISPLAY TERMINALS

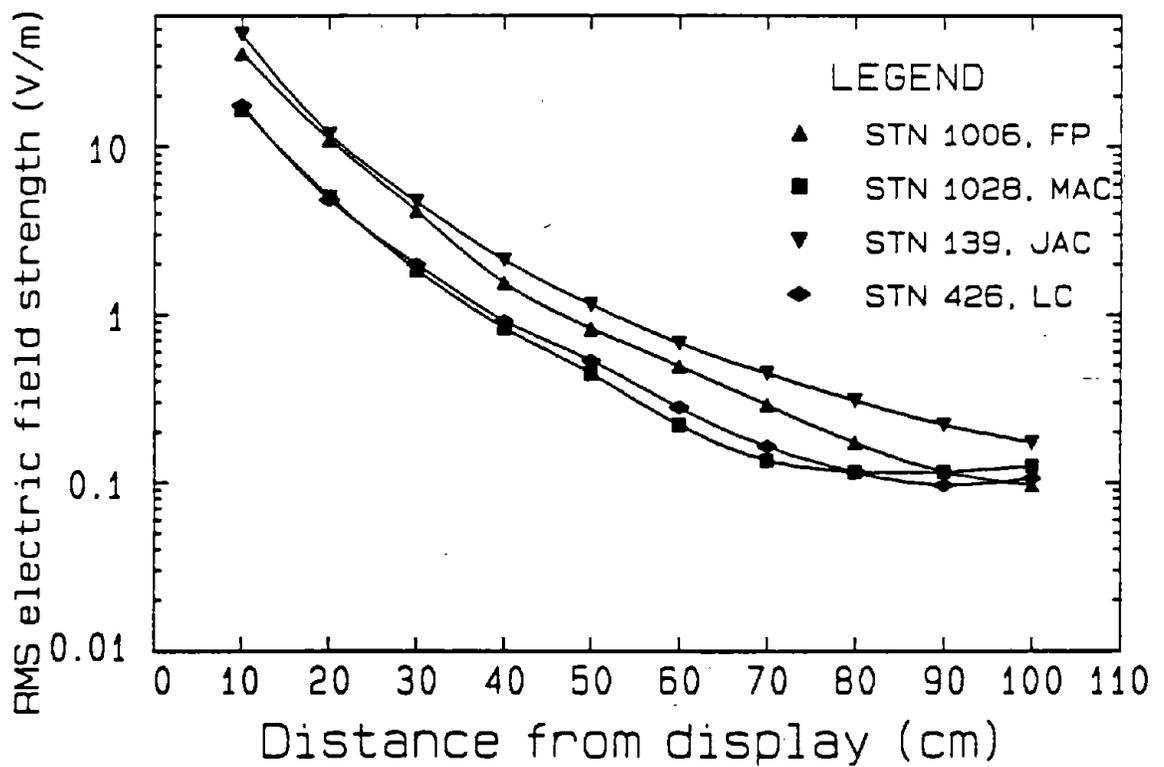


Figure 43. Spatial variation of VLF electric fields for four IBM VDTs.

SPATIAL VARIATION OF ELECTRIC FIELD  
FOR NGT DISPLAY, STATION 352  
CINCINNATI

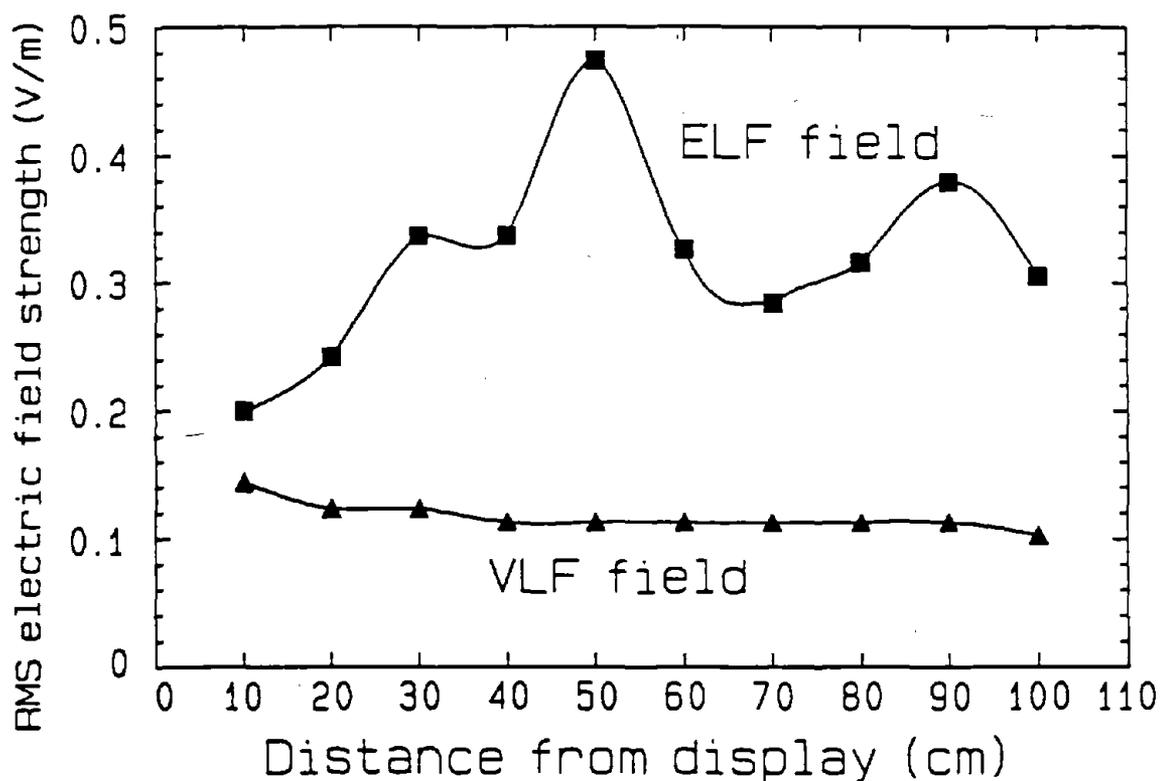


Figure 44. Spatial variation of electric fields measured in the ELF and VLF bands for the NGT display.

SPATIAL VARIATION OF MAGNETIC FIELD  
FOR NGT DISPLAY, STATION 352  
CINCINNATI

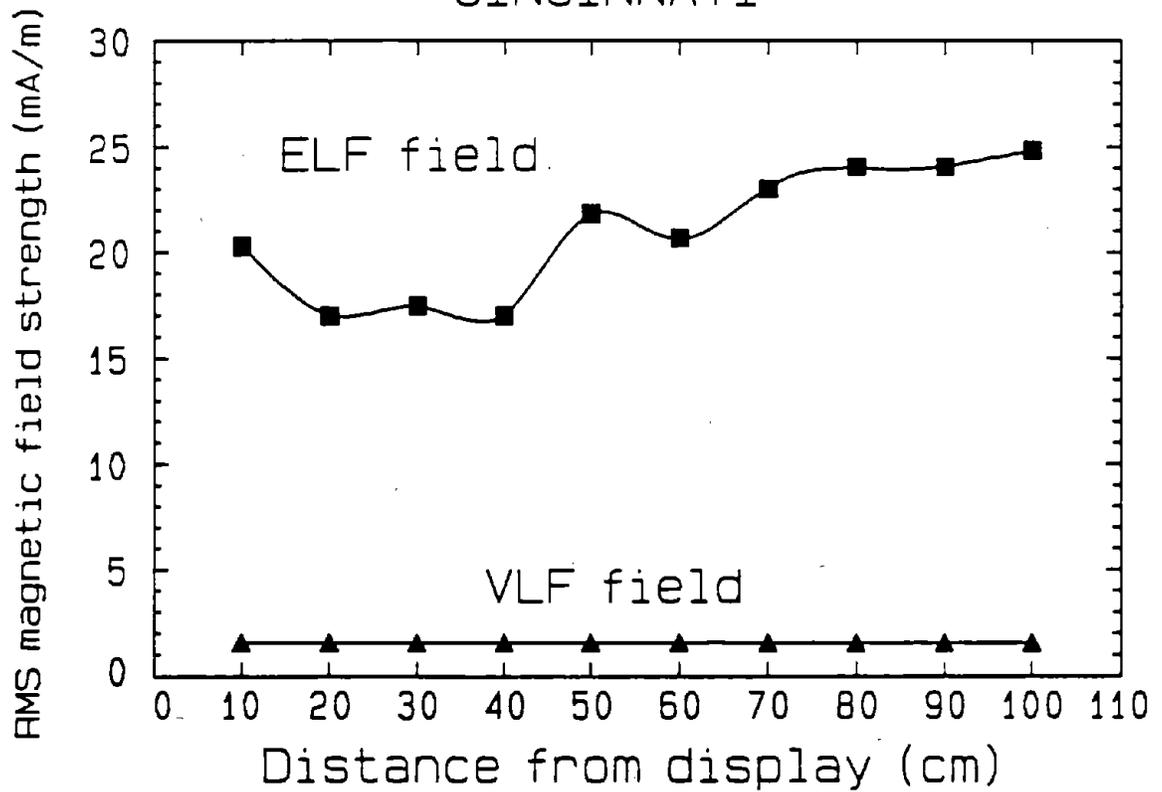


Figure 45. Spatial variation of magnetic fields measured in the ELF and VLF bands for the NGT display.

SPATIAL VARIATION OF ELECTRIC FIELD  
FOR LED DISPLAY, STATION 40  
BLOOMINGTON

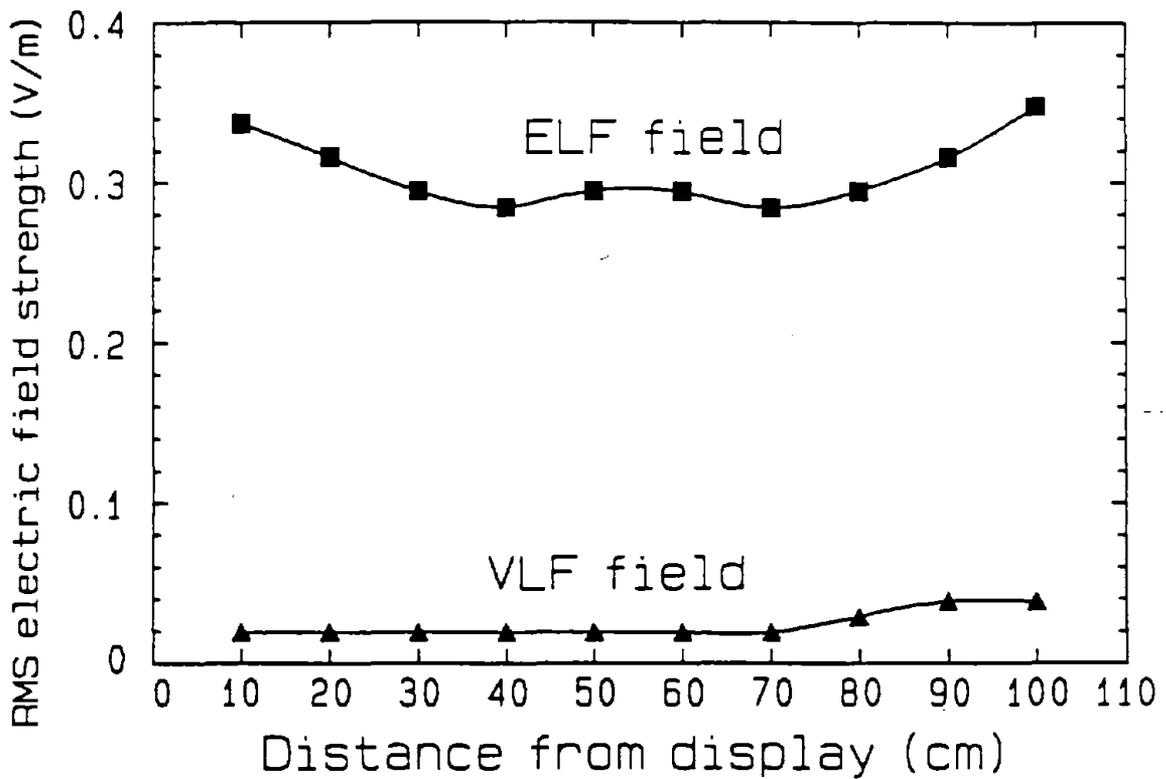


Figure 46. Spatial variation of electric fields measured in the ELF and VLF bands for the LED display.

SPATIAL VARIATION OF MAGNETIC FIELD  
FOR LED DISPLAY, STATION 40  
BLOOMINGTON

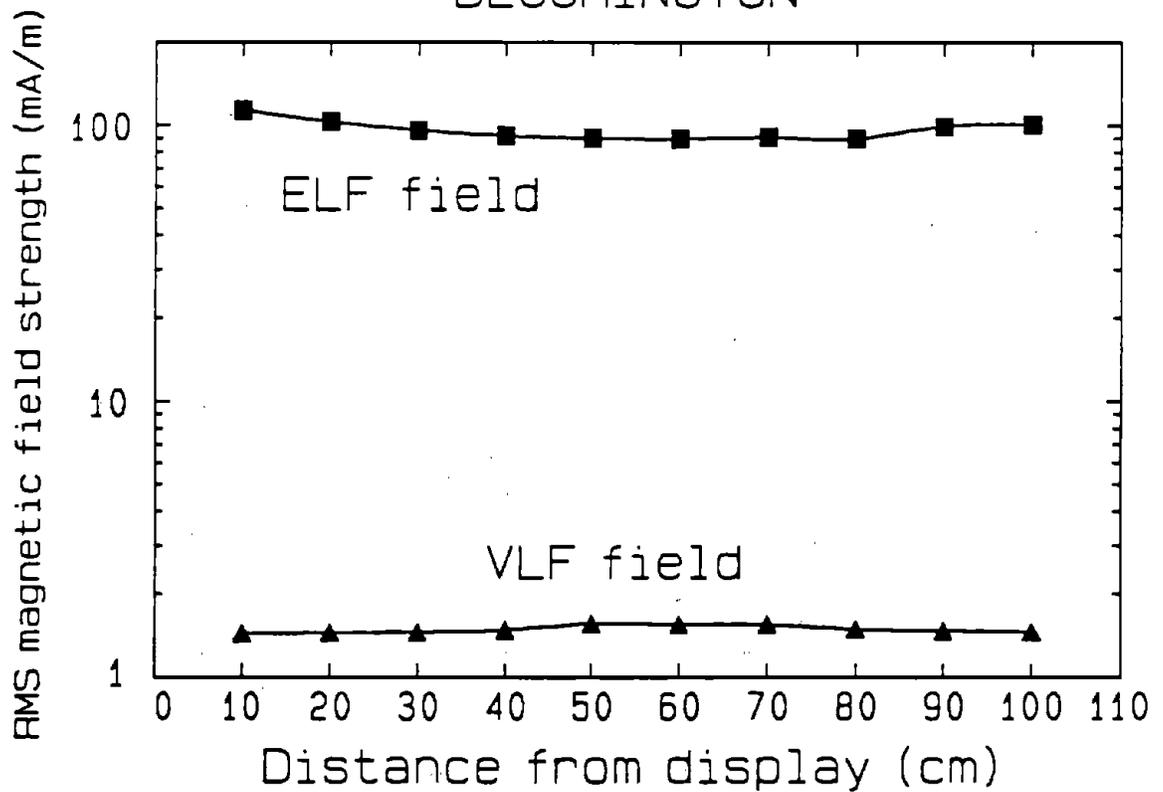
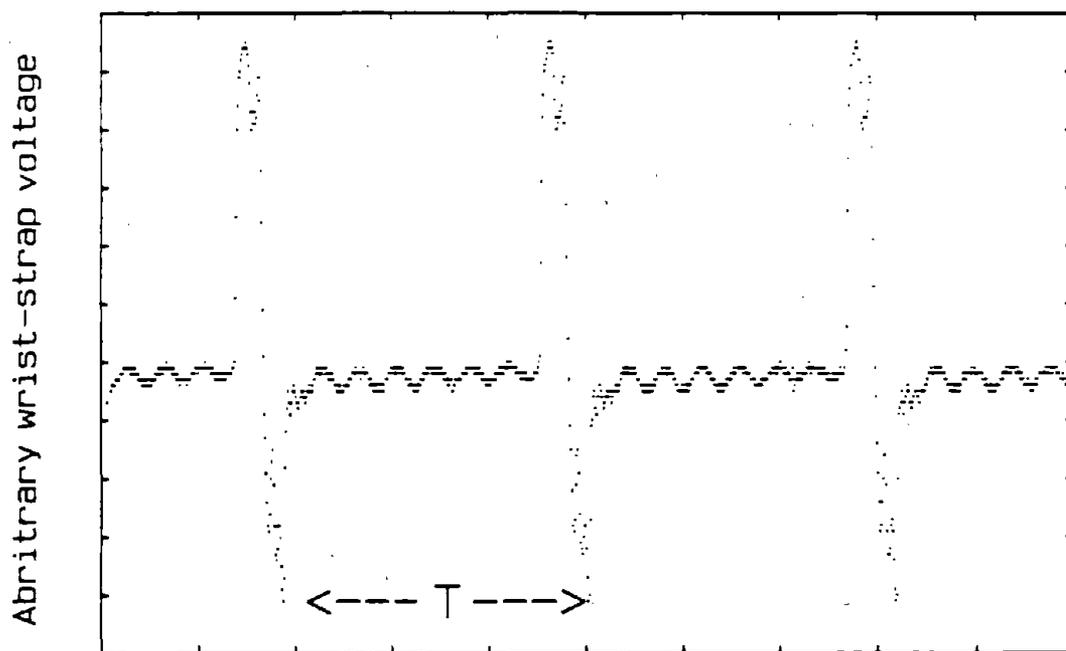


Figure 47. Spatial variation of magnetic fields measured in the ELF and VLF bands for the LED display.

REPRESENTATIVE WRIST CURRENT  
WAVEFORM MEASUREMENT FOR  
DETERMINING FREQUENCY

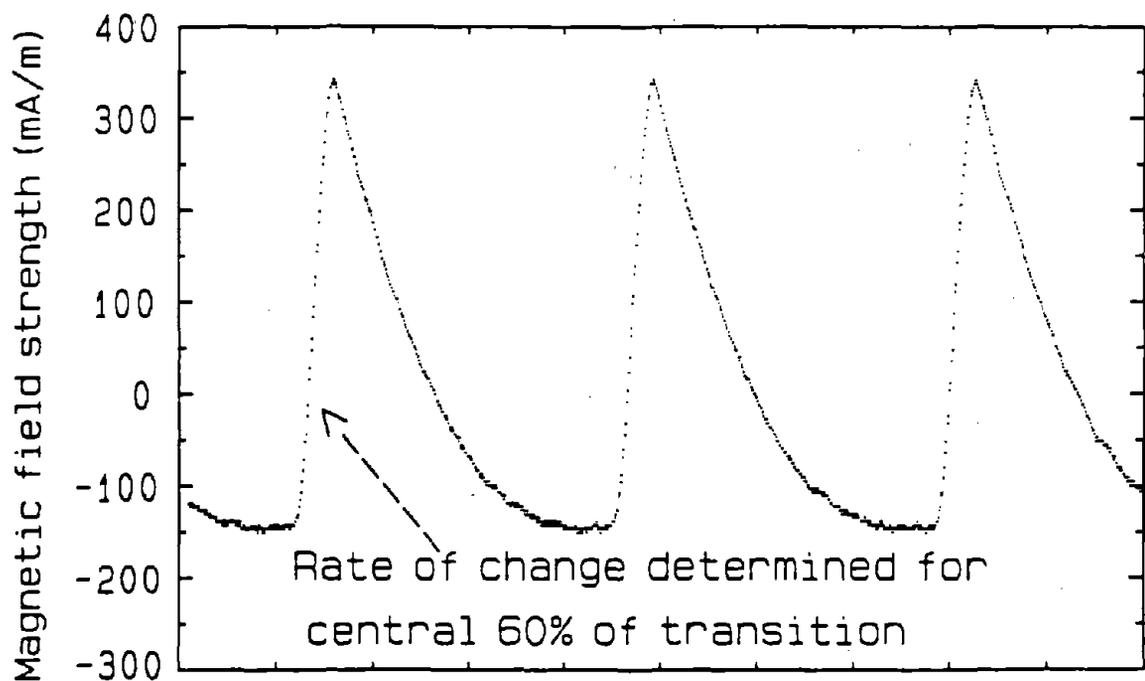


Time per division = 20  $\mu$ s

Measured on IBM, station 139, Jacksonville

Figure 48. Example wrist current waveform measurement for determining frequency of the current.

VLF MAGNETIC FIELD WAVEFORM  
AT 30 CM FROM CCI VDT  
STATION 13, NASHVILLE

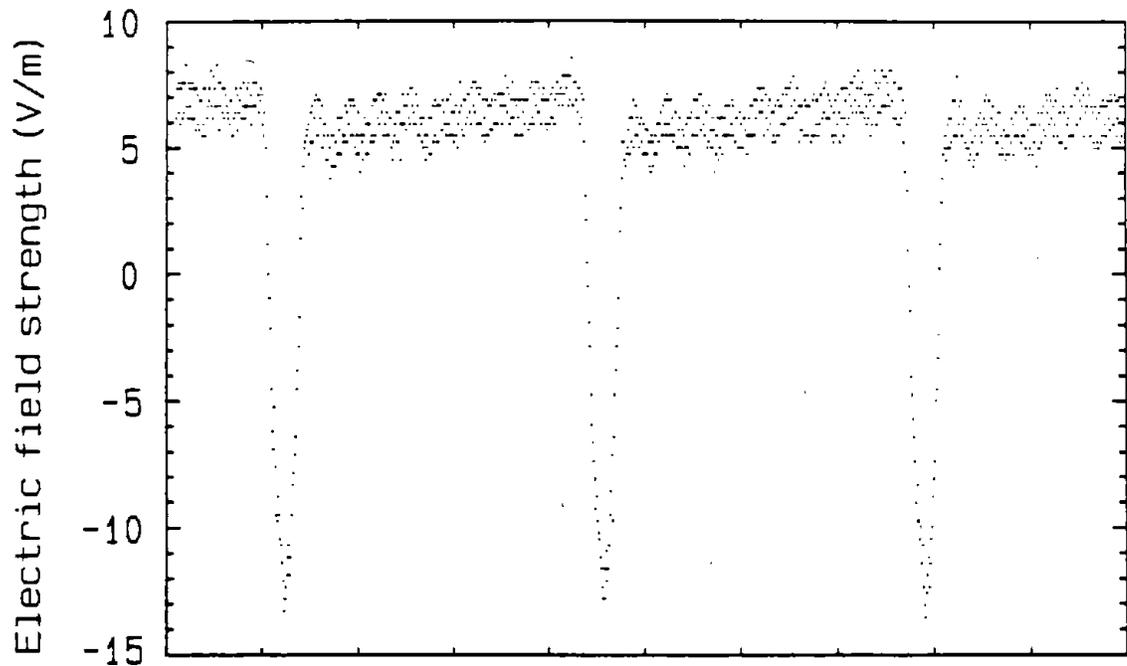


Time per division = 20  $\mu$ s

$dB/dt = 0.560 \text{ mA/m}/\mu\text{s}/(\text{mA/m rms})$

Figure 49. Measured VLF (horizontal deflection) magnetic field waveform determined at 30 cm for the CCI VDT, station 13, Nashville.

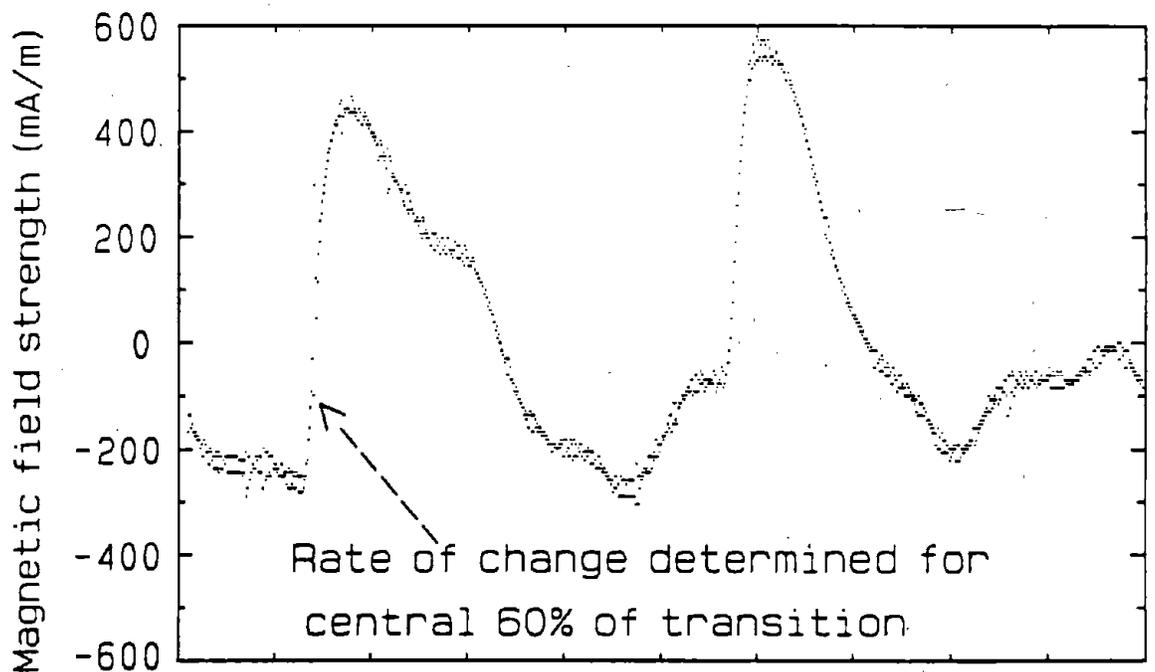
VLF ELECTRIC FIELD WAVEFORM  
AT 30 CM FROM CCI VDT  
STATION 13, NASHVILLE



Time per division = 20  $\mu$ s

Figure 50. Measured VLF (horizontal deflection) electric field waveform determined at 30 cm for the CCI VDT, station 13, Nashville.

ELF MAGNETIC FIELD WAVEFORM  
AT 30 CM FROM CCI VDT  
STATION 13, NASHVILLE



Time per division = 5 ms

$dB/dt = 0.00236 \text{ mA/m}/\mu\text{s}/(\text{mA/m rms})$

Figure 51. Measured ELF (vertical deflection) magnetic field waveform determined at 30 cm for the CCI VDT, station 13, Nashville.

ELF ELECTRIC FIELD WAVEFORM  
AT 30 CM FROM CCI VDT  
STATION 13, NASHVILLE

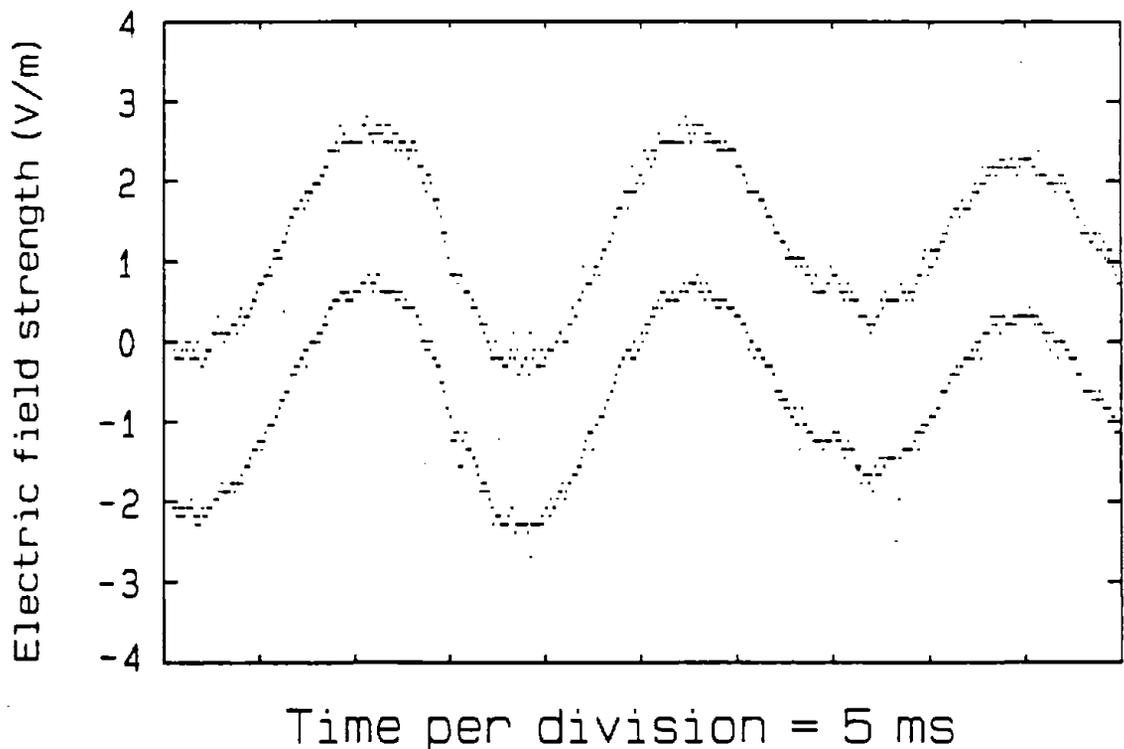
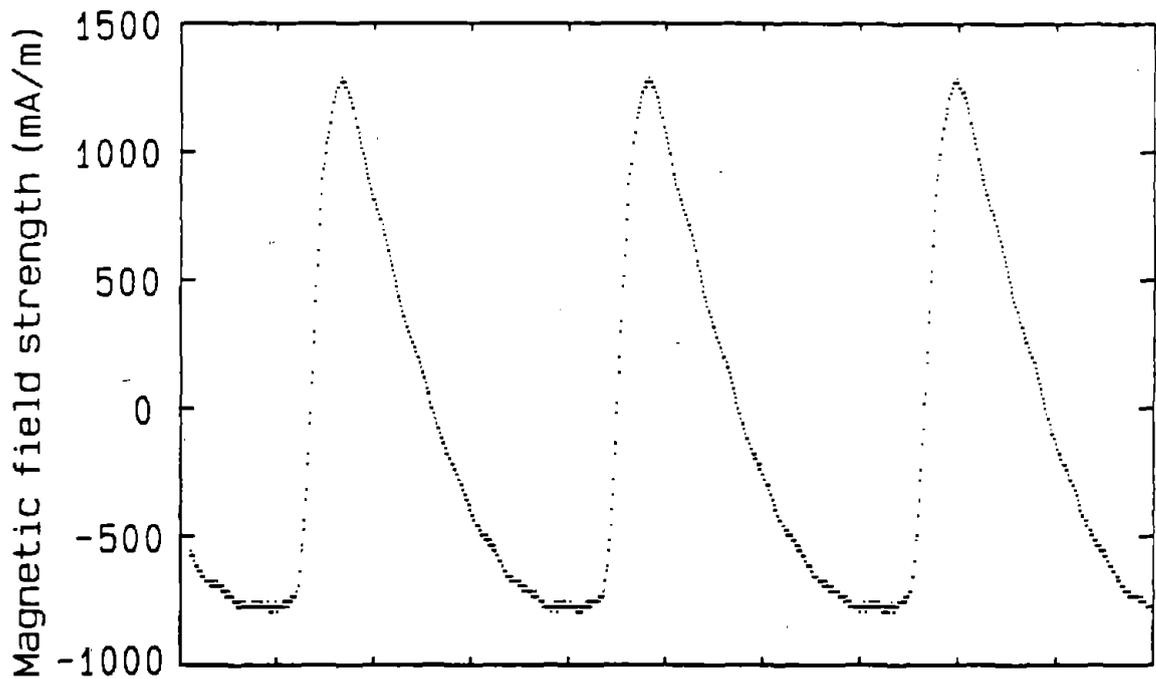


Figure 52. Measured ELF (vertical deflection) electric field waveform determined at 30 cm for the CCI VDT, station 13, Nashville.

VLF MAGNETIC FIELD WAVEFORM  
AT SCREEN SURFACE OF IBM VDT  
STATION 1006, FOREST PARK



Time per division = 20  $\mu$ s

$dB/dt = 0.336 \text{ mA/m}/\mu\text{s}/(\text{mA/m rms})$

Figure 53. Measured VLF (horizontal deflection) magnetic field waveform determined at the screen surface for the IBM VDT, station 1006, Forest Park.

VLF ELECTRIC FIELD WAVEFORM  
AT SCREEN SURFACE OF IBM VDT  
STATION 1006, FOREST PARK

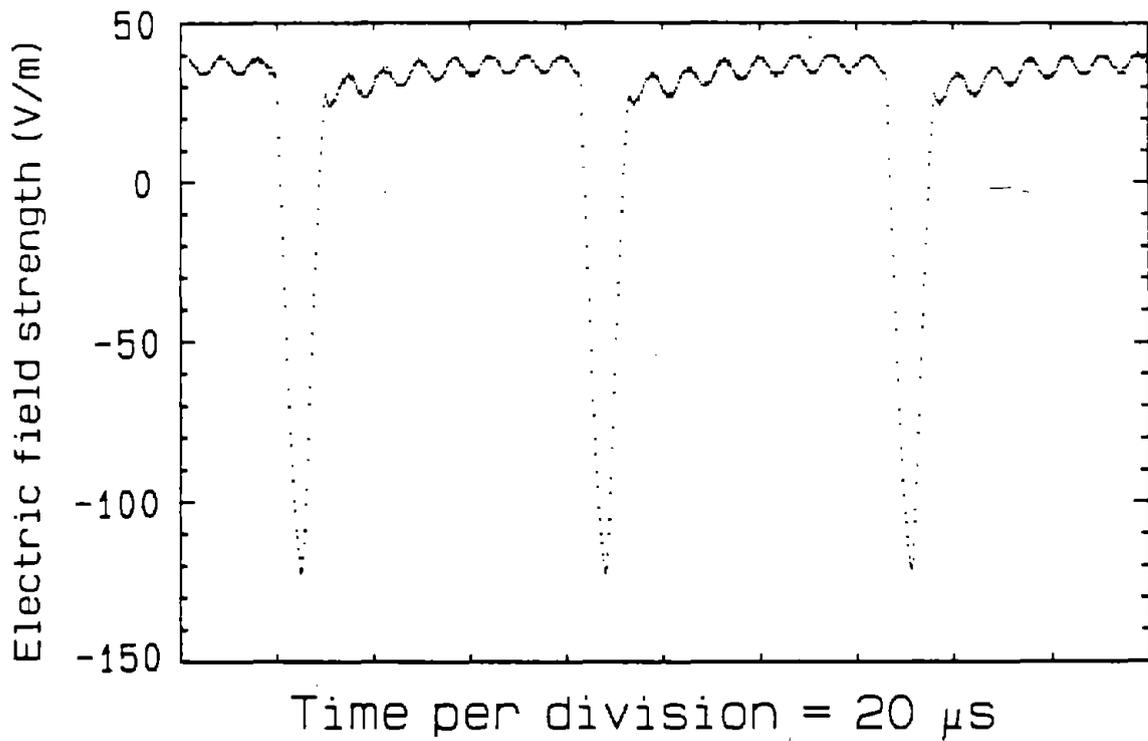
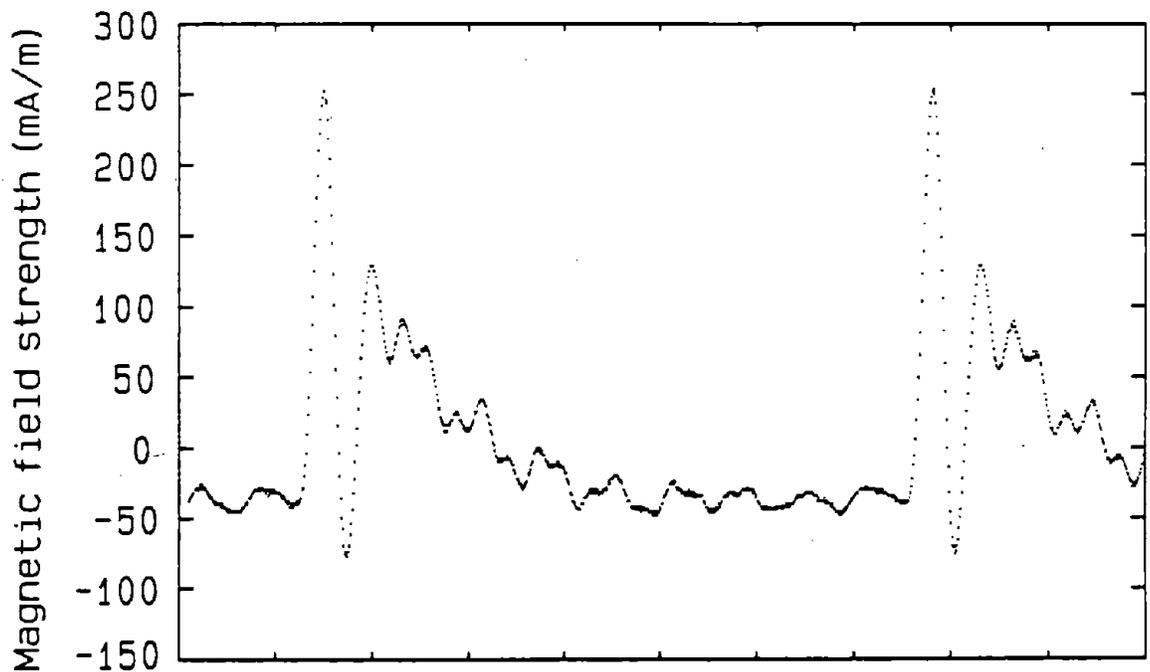


Figure 54. Measured VLF (horizontal deflection) electric field waveform determined at the screen surface for the IBM VDT, station 1006, Forest Park.

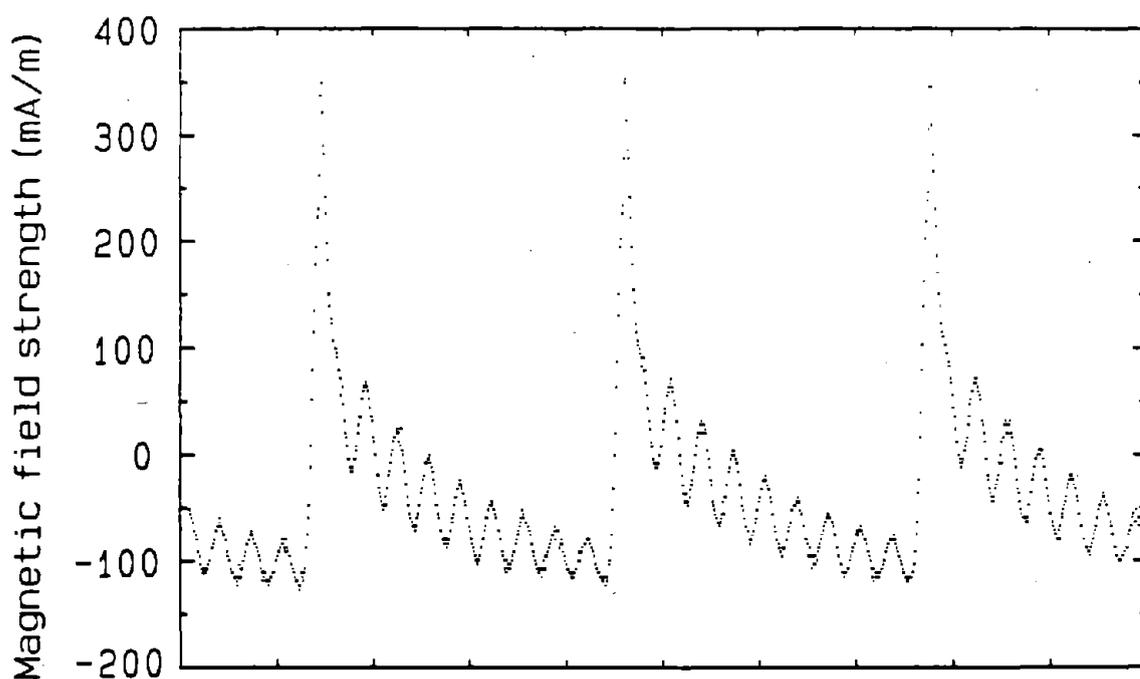
VLF MAGNETIC FIELD WAVEFORM  
AT SCREEN SURFACE OF IBM VDT  
STATION 426, LAKE CITY



Time per division =  $10 \mu\text{s}$   
 $\text{dB}/\text{dt} = 3.99 \text{ mA/m}/\mu\text{s}/(\text{mA/m rms})$

Figure 55. Measured VLF (horizontal deflection) magnetic field waveform determined at the screen surface for the IBM VDT, station 426, Lake City.

VLF MAGNETIC FIELD WAVEFORM  
AT SCREEN SURFACE OF IBM VDT  
STATION 1028, MACON



Time per division = 20  $\mu$ s  
 $dB/dt = 2.75 \text{ mA/m}/\mu\text{s}/(\text{mA/m rms})$

Figure 56. Measured VLF (horizontal deflection) magnetic field waveform determined at the screen surface for the IBM VDT, station 1028, Macon.

VLF MAGNETIC FIELD WAVEFORM  
AT 30 CM FROM IBM VDT  
STATION 1028, MACON

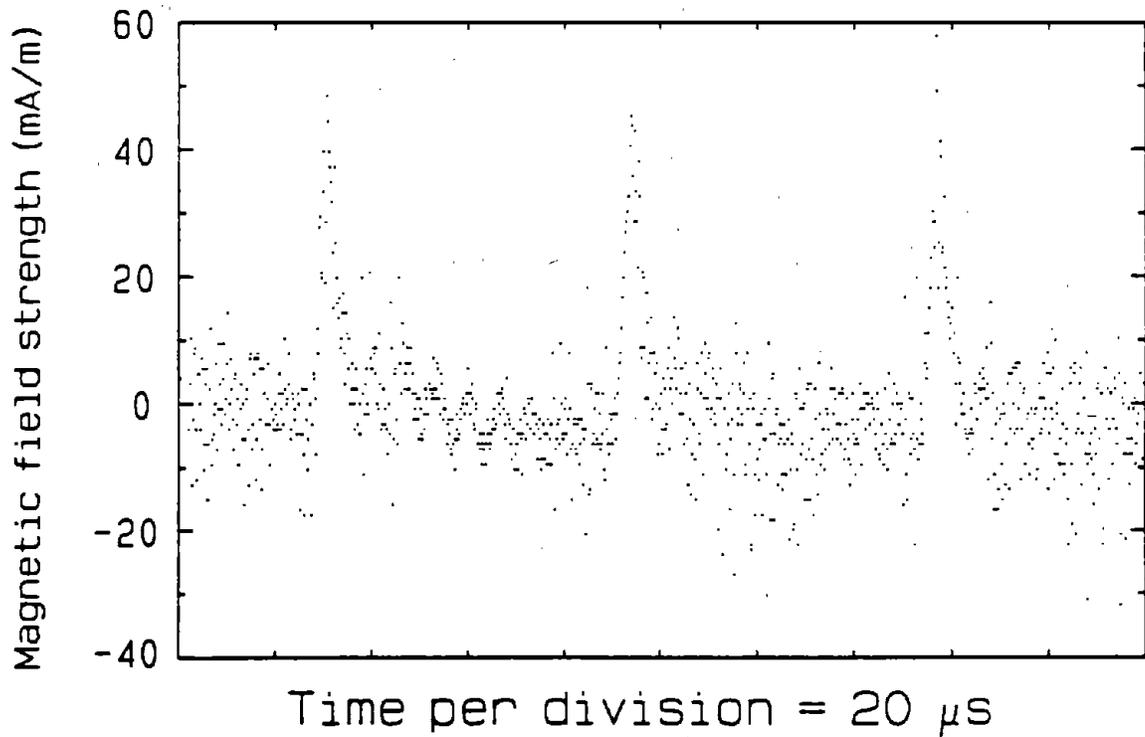


Figure 57. Measured VLF (horizontal deflection) magnetic field waveform determined at 30 cm for the IBM VDT, station 1028, Macon.

VLF ELECTRIC FIELD WAVEFORM  
AT SCREEN SURFACE OF IBM VDT  
STATION 1028, MACON

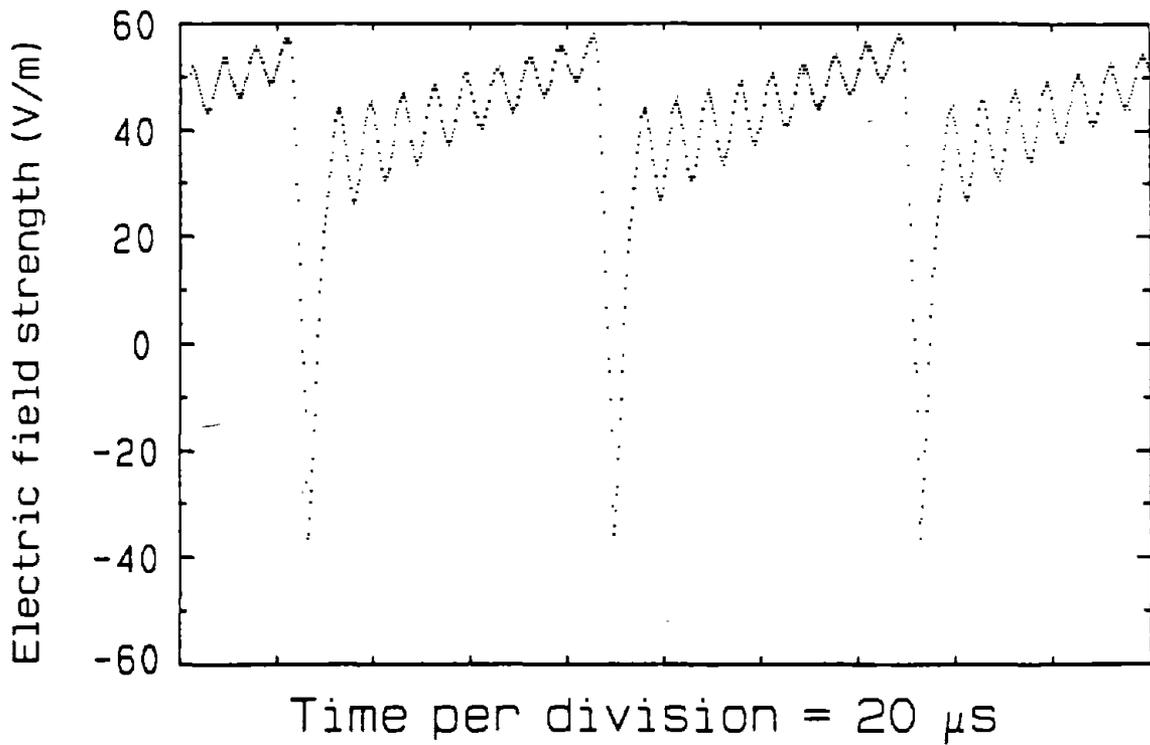
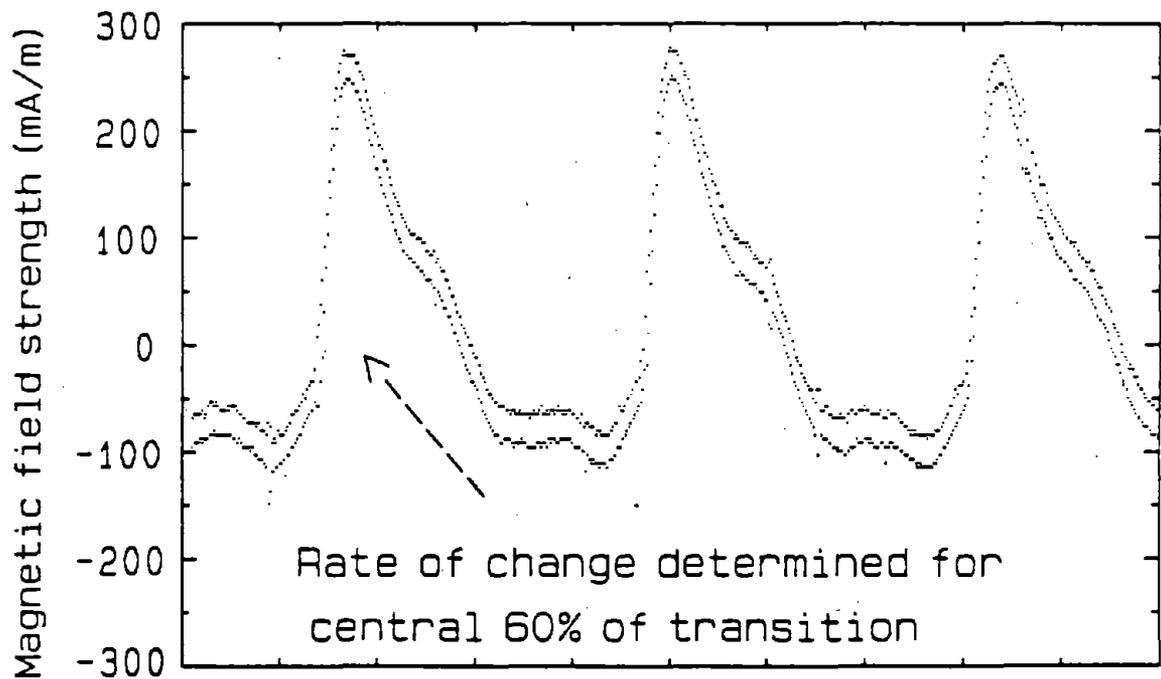


Figure 58. Measured VLF (horizontal deflection) electric field waveform determined at the screen surface for the IBM VDT, station 1028, Macon.

ELF MAGNETIC FIELD WAVEFORM  
AT 30 CM FROM IBM VDT  
STATION 1028, MACON



Time per division = 5 ms

$\text{dB}/\text{dt} = 0.0613 \text{ mA/m}/\mu\text{s}/(\text{mA/m rms})$

Figure 59. Measured ELF (vertical deflection) magnetic field waveform determined at 30 cm for the IBM VDT, station 1028, Macon.

ELF ELECTRIC FIELD WAVEFORM  
AT 30 CM FROM IBM VDT  
STATION 1028, MACON

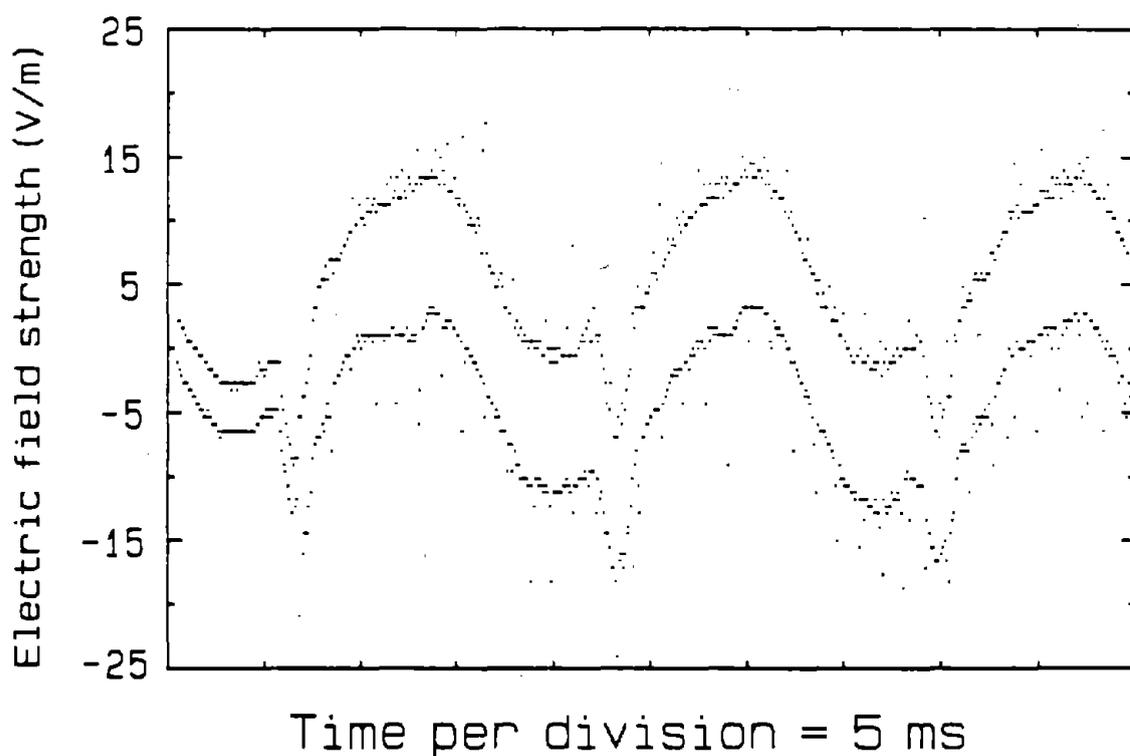


Figure 60. Measured ELF (vertical deflection) electric field waveform determined at 30 cm for the IBM VDT, station 1028, Macon.

VLF MAGNETIC FIELD WAVEFORM  
AT SURFACE OF NGT DISPLAY  
STATION 352, CINCINNATI

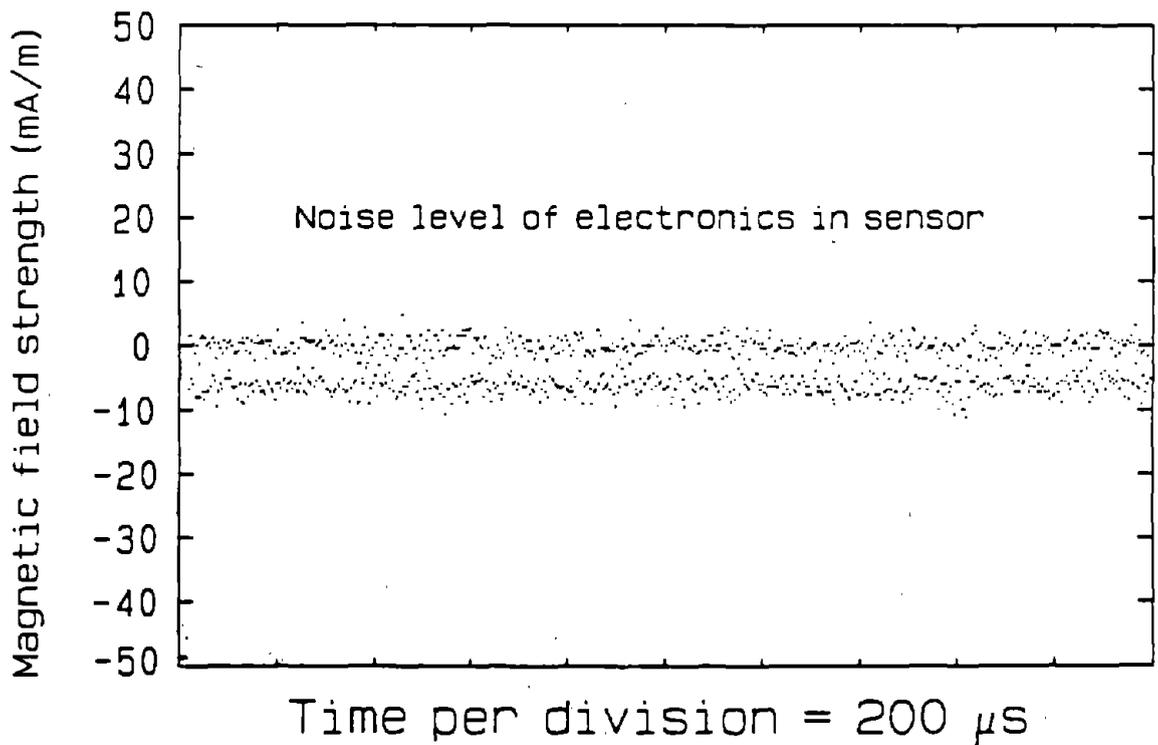
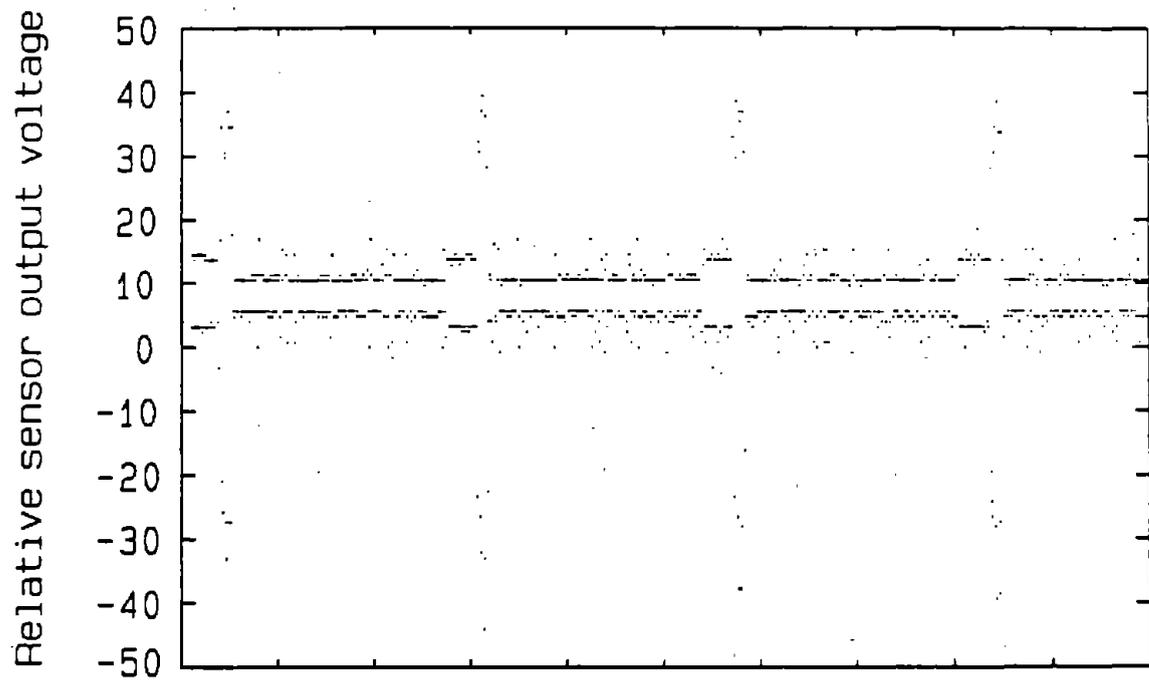


Figure 61. Measured VLF magnetic field waveform determined at the surface of the NGT display, station 352, Cincinnati.

VLF ELECTRIC FIELD WAVEFORM  
AT SCREEN SURFACE OF NGT DISPLAY  
STATION 352, CINCINNATI



Time per division = 50 ms  
Internal noise spikes of sensor  
repeat at approximately 7.5 Hz

Figure 62. Measured VLF electric field waveform determined at the surface of the NGT display, station 352, Cincinnati.

ELF MAGNETIC FIELD WAVEFORM  
AT SURFACE OF NGT DISPLAY  
STATION 352, CINCINNATI

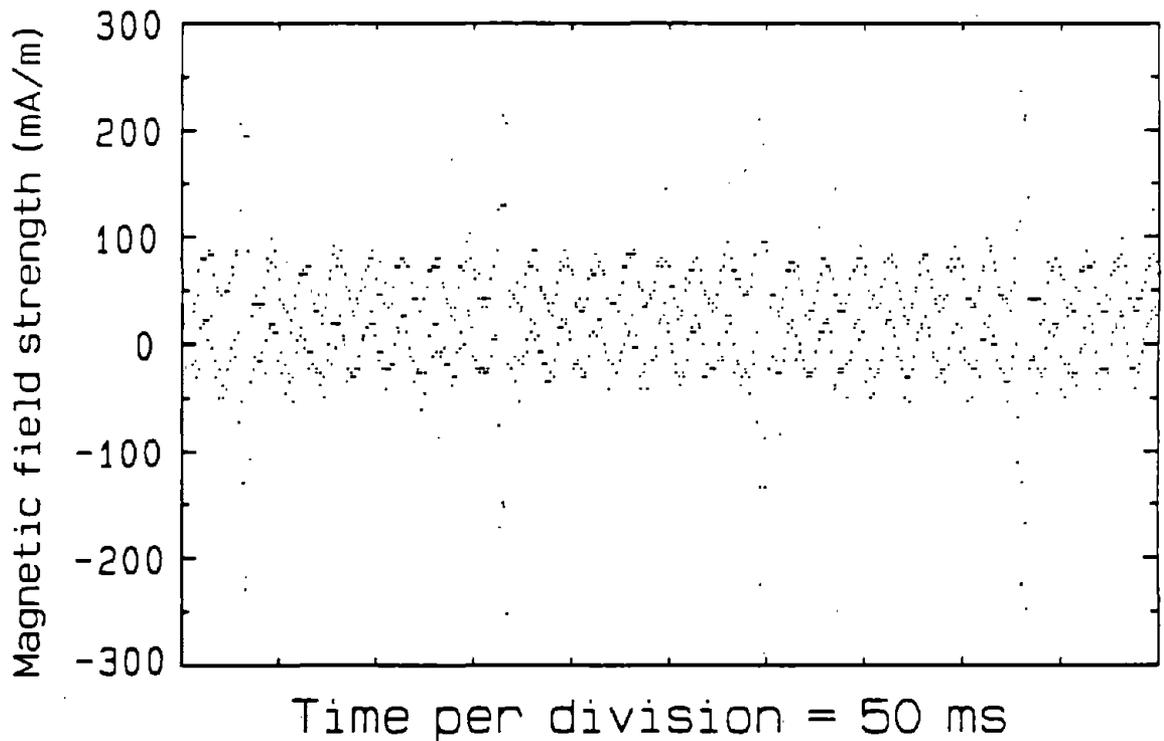


Figure 63. Measured ELF magnetic field waveform determined at the surface of the NGT display, station 352, Cincinnati.

ELF ELECTRIC FIELD WAVEFORM  
AT SURFACE OF NGT DISPLAY  
STATION 352, CINCINNATI

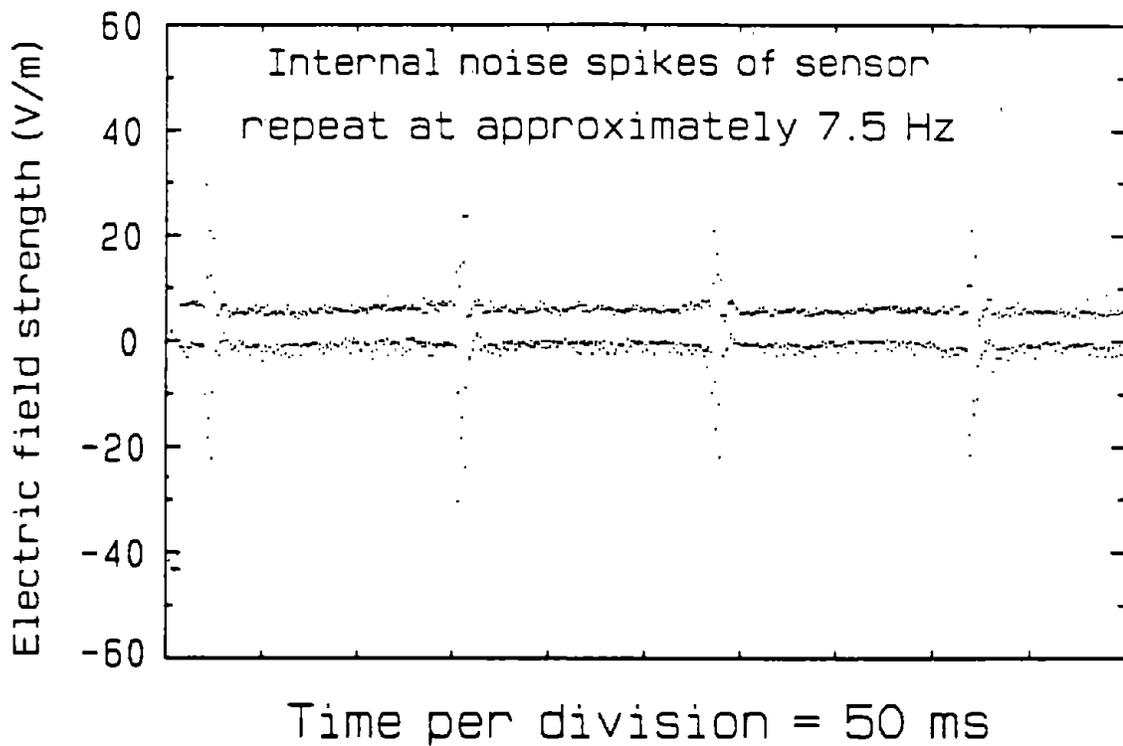


Figure 64. Measured ELF electric field waveform determined at the surface of the NGT display, station 352, Cincinnati.

VLF MAGNETIC FIELD WAVEFORM  
AT 30 CM FROM LED DISPLAY  
STATION 408, BLOOMINGTON

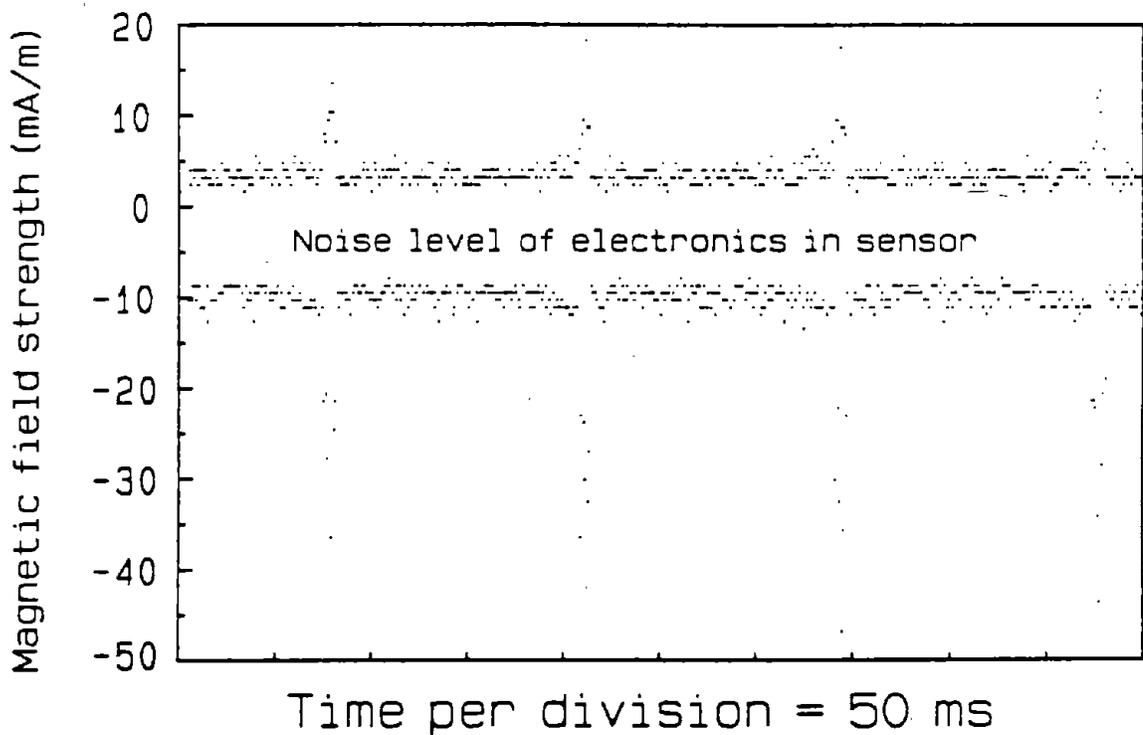
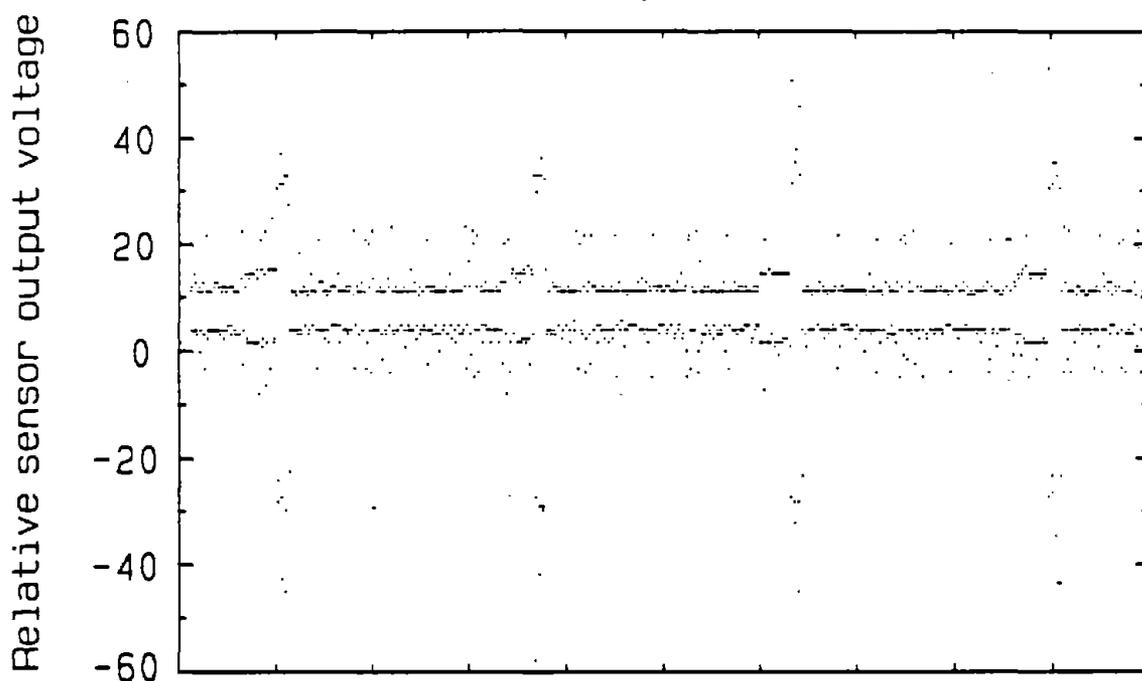


Figure 65. Measured VLF magnetic field waveform determined at 30 cm for the LED display, station 408, Bloomington.

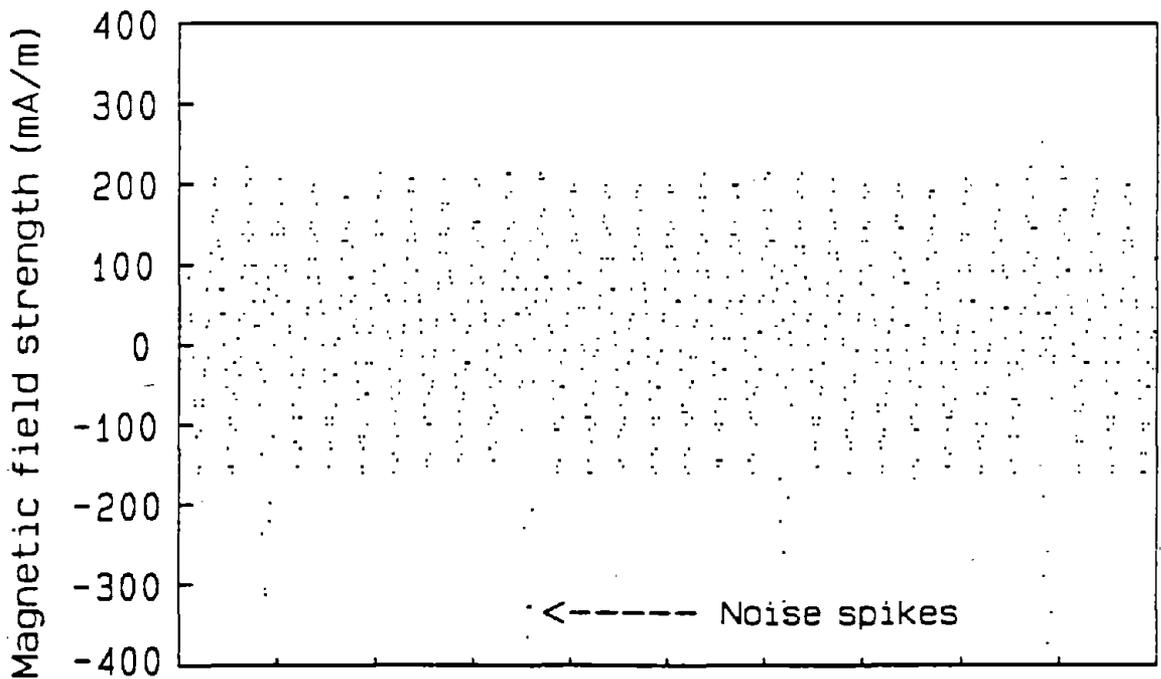
VLF ELECTRIC FIELD WAVEFORM  
AT 30 CM FROM LED DISPLAY  
STATION 408, BLOOMINGTON



Time per division = 50 ms  
Internal noise spikes of sensor  
repeat at approximately 7.5 Hz

Figure 66. Measured VLF electric field waveform determined at 30 cm for the LED display, station 408, Bloomington.

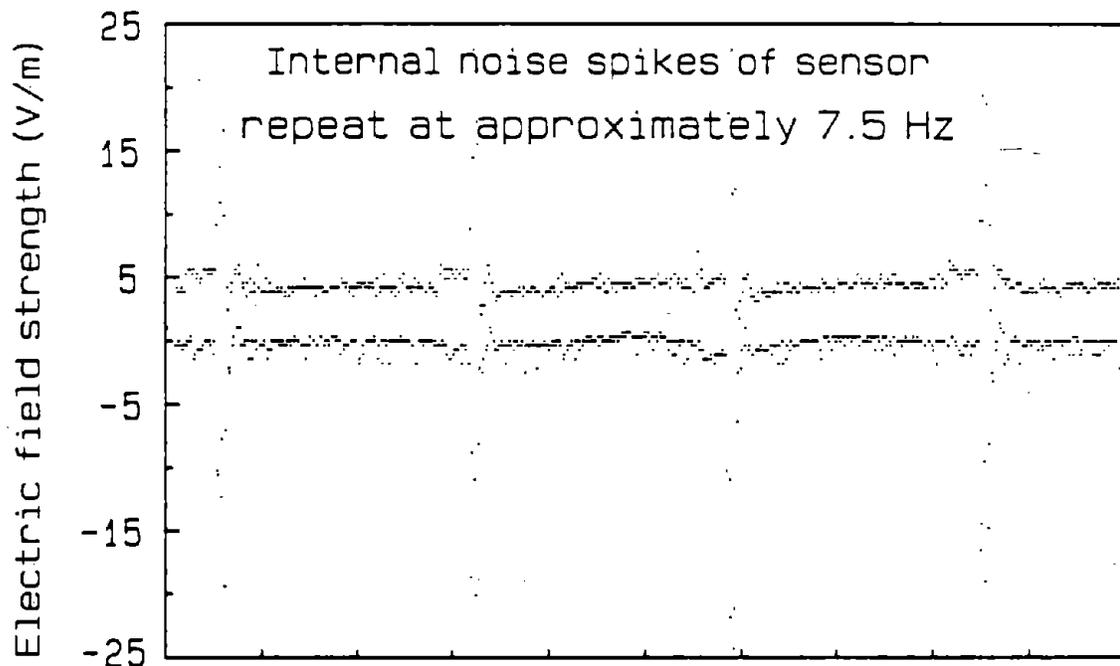
ELF MAGNETIC FIELD WAVEFORM AT 30 CM  
FROM LED, STATION 408, BLOOMINGTON



Time per division = 50 ms

Figure 67. Measured ELF magnetic field waveform determined at 30 cm for the LED display, station 408, Bloomington.

ELF ELECTRIC FIELD WAVEFORM  
AT 30 CM FROM LED DISPLAY  
STATION 408, BLOOMINGTON



Time per division = 50 ms

Figure 68. Measured ELF electric field waveform determined at 30 cm for the LED display, station 408, Bloomington.

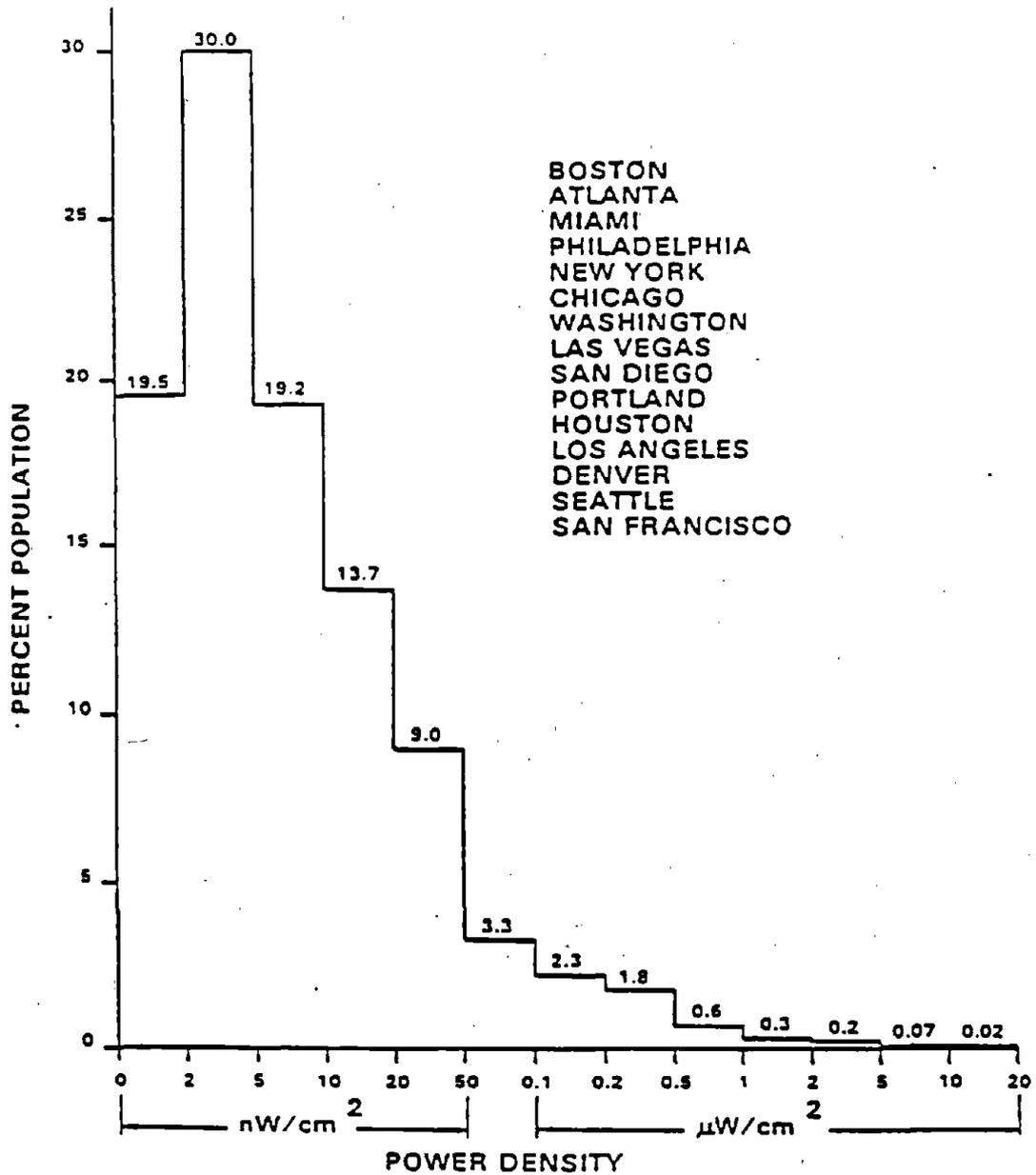


Figure 69. From combined data for cities listed, percentages of population exposed to various ranges of RF power densities contributed by VHF and UHF broadcast bands. From EPA study of FM and TV broadcasting (Tell and Mantiply, 1980).

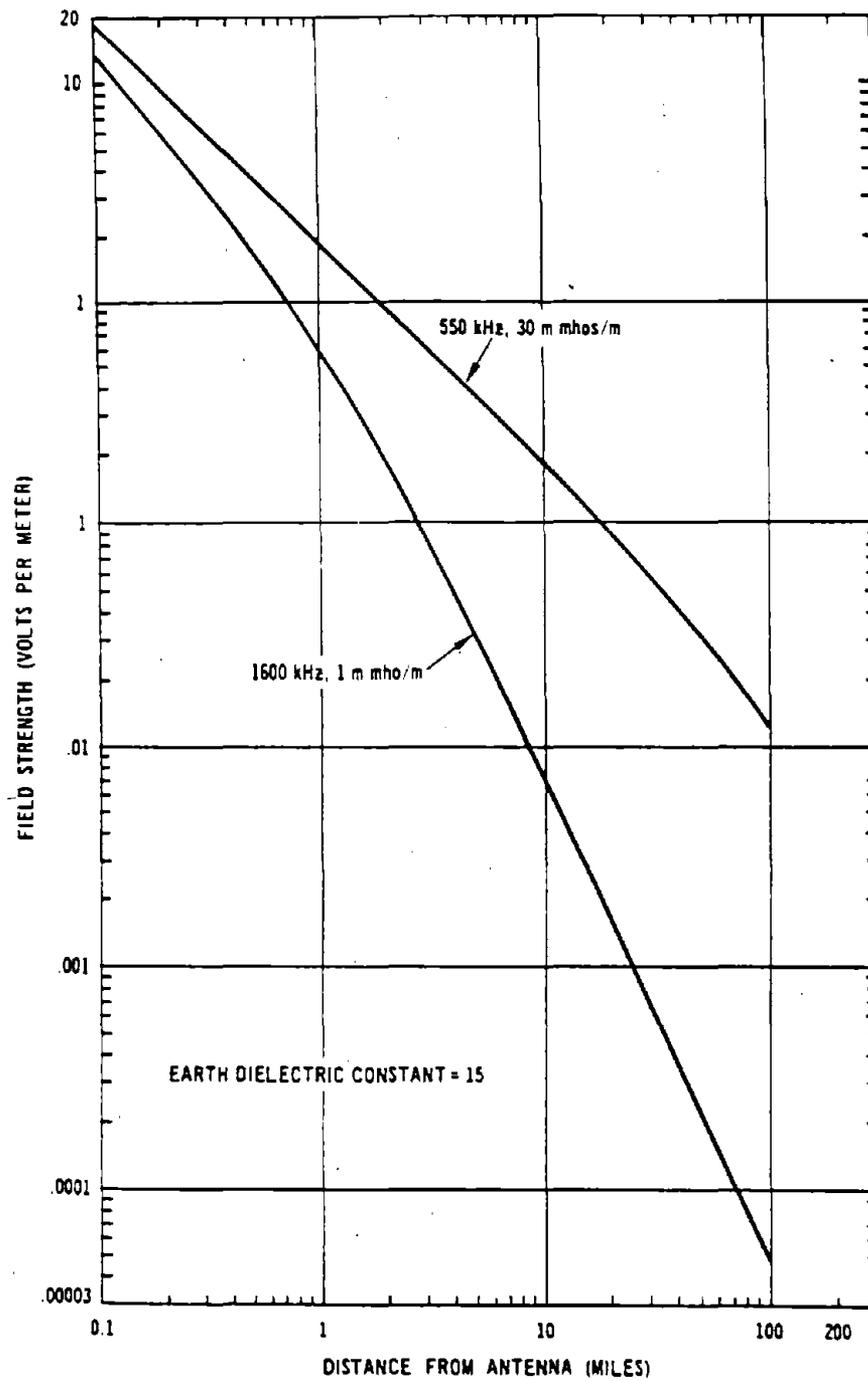


Figure 70. Ground-wave electric field strength of a 50 kilowatt AM radio broadcast station. Signal strength depends on the soil conductivity.

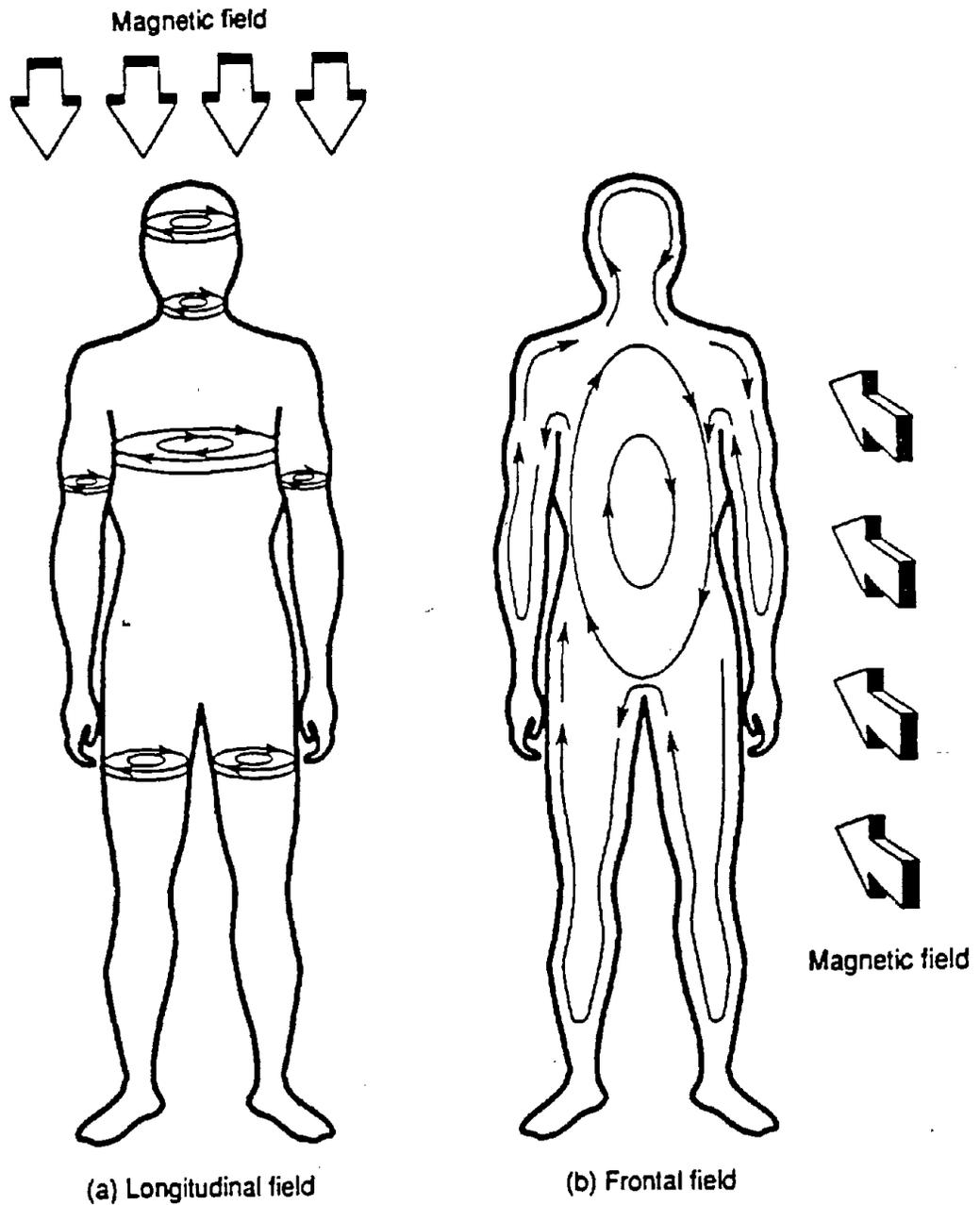


Figure 71. Distribution of internally induced electric fields from whole-body exposure to time-varying magnetic fields. Magnetic field direction is parallel to long axis of body in part (a), and perpendicular to front of body in (b). Direction of internal E-field and induced current reverses every 1/2 cycle of the magnetic field. Source: Reilly, 1990.

**LAST PAGE OF REPORT**

**AN INVESTIGATION OF ELECTRIC AND MAGNETIC  
FIELDS AND OPERATOR EXPOSURE PRODUCED  
BY VDTs: NIOSH VDT EPIDEMIOLOGY STUDY**

**FINAL REPORT**

**Appendixes A & B**

**September 18, 1990**

**Prepared for**

**National Institute for Occupational Safety and Health  
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Industrywide Studies Branch  
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**AN INVESTIGATION OF ELECTRIC AND MAGNETIC FIELDS AND  
OPERATOR EXPOSURE PRODUCED BY VDTs: NIOSH VDT EPIDEMIOLOGY STUDY**

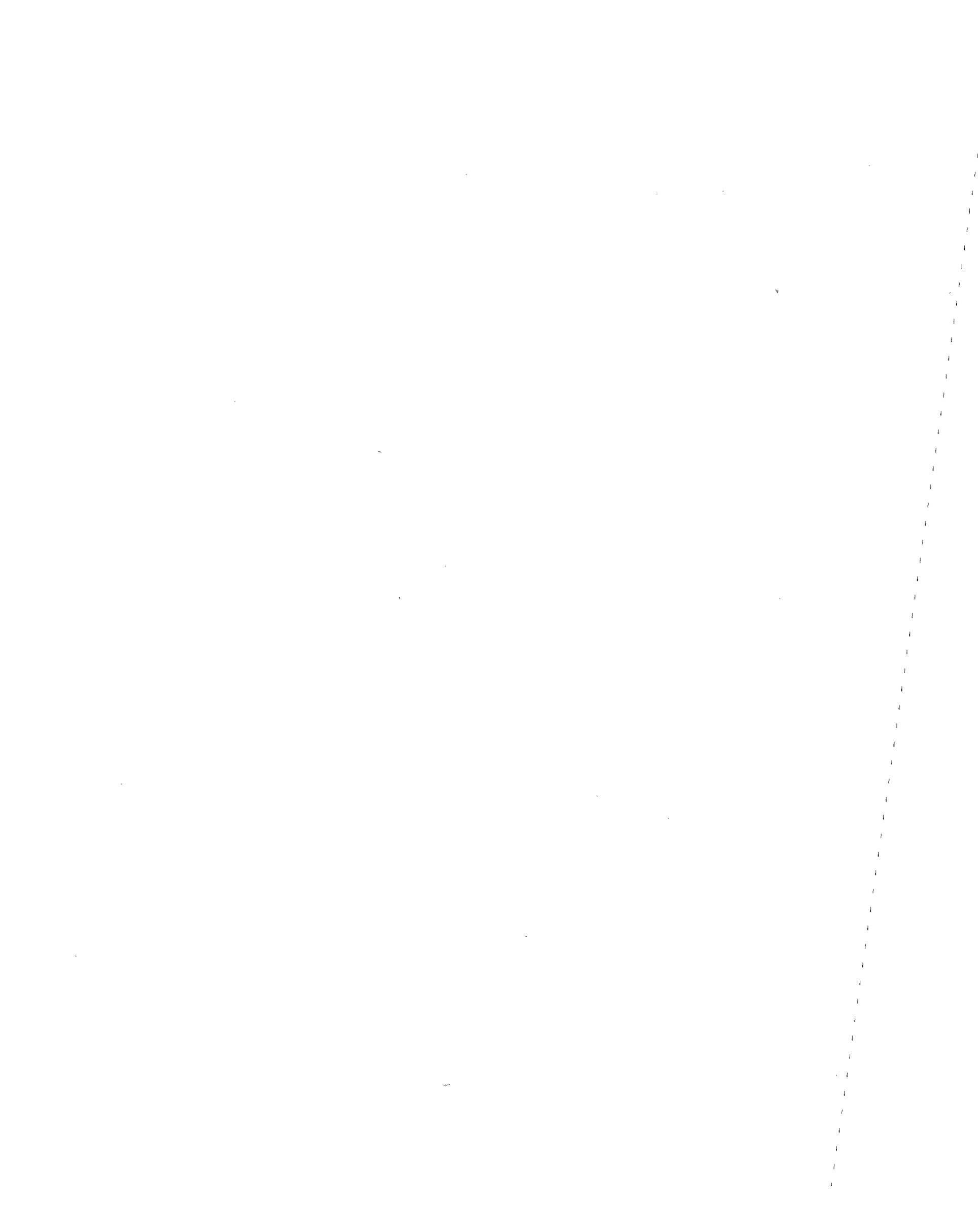
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NIOSH study..... 4



**Appendix A**  
**List of Epidemiological Studies**  
**Related to VDT Workers**



NIOSH VDT Electric and Magnetic Fields, Appendixes, page 2 A

Bjerkedal, T. and J. Egenaes (1986). Video display terminals and birth defects, a study of pregnancy outcomes of employees of the Postal-Giro-Center, Oslo, Norway. In Work with Display Units 86, (B. Knave and P. G. Wideback, eds.), Elsevier Science Publishers B. V. (North Holland), pp. 111-114.

Bryant, H. E. and E. J. Love (1989). Video display terminal use and spontaneous abortion risk. International Journal of Epidemiology, Vol. 18, No. 1, pp. 132-138.

Butler, W. J. and K. A. Brix (1986). Video display terminal work and pregnancy outcome in Michigan Clerical Workers. Presentation at the American Public Health Association annual meeting, Las Vegas, NV, September 24, 25 pages.

Ericson, A. and B. Kallen (1986). An epidemiological study of work with video screens and pregnancy outcome: I. A registry study. American Journal of Industrial Medicine, Vol. 9, pp. 447-457.

Ericson, A. and B. Kallen (1986). An epidemiological study of work with video screens and pregnancy outcome: II. A case-control study. American Journal of Industrial Medicine, Vol. 9, pp. 459-475.

Goldhaber, M. K., M. R. Polen and R. A. Hiatt (1988). The risk of miscarriage and birth defects among women who use visual display terminals during pregnancy. American Journal of Industrial Medicine, Vol. 13, pp. 695-706.

Kurppa, K., P. C. Holmberg, K. Rantala, T. Nurminen and L. Saxen (1985). Birth defects and exposure to video display terminals during pregnancy. Scandinavian Journal of Work and Environmental Health, Vol. 11, pp. 353-356.

McDonald, A. D., N. M. Cherry, C. Delorme and J. C. McDonald (1986). Visual display units and pregnancy: evidence from the Montreal survey. Journal of Occupational Medicine, Vol. 28, No. 12, December, pp. 1226-1231.

Nielsen, C. V., L. Brandt, L. Helsing, B. Waldstrom and L. Nielsen (1989). The Effect of VDT Work on the Course of Pregnancy-A Study in Reproductive Epidemiology. Draft translation press release describing the study. Released October 16, 1989, rhus City Hall. The authors are with the Institute of Public Health (Socialmedicinsk Institut, SMI), rhus Univeristy, and Industrial-Medicine Clinic, rhus Municipal Hospital. 11 pages.

Nurminen, T. and K. Kurppa (1988). Office employment, work with video display terminals, and course of pregnancy. Scandinavian Journal of Work and Environmental Health, Vol. 14, pp. 293-298.



NIOSH VDT Electric and Magnetic Fields, Appendixes, page 3 A

Westerholm, P. and A. Ericson (1987). Pregnancy outcome and VDU-work in a cohort of insurance clerks. In Work with Display Units 86, (B. Knave and P. G. Wideback, eds.), Elsevier Science Publishers B. V. (North Holland), pp. 104-110.



**APPENDIX B**

**Compilation of Electric and Magnetic Field Emission,  
Operator Exposure and Induced Current Data  
for 96 VDT, NGT and LED Displays Evaluated in NIOSH Study**



Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 302

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.07	0.05	0.05	0.05	0.05	NA
VLF H (mA/m)	1.4	1.4	1.4	1.4	1.4	NA
ELF E (V/m)	0.62	0.45	0.34	0.23	0.23	NA
ELF H (mA/m)	36	22	16	84	79	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.12	0.06	0.07
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.42	0.27	0.43
ELF H (mA/m)	35	32	26

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.01
Hand placed flat on screen	0.01

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 303

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.08	0.07	0.05	0.04	NA	0.05
VLF H (mA/m)	1.4	1.4	1.4	1.4	NA	1.4
ELF E (V/m)	0.66	0.45	0.89	0.45	NA	0.42
ELF H (mA/m)	14	19	19	21	NA	46

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.30	0.21	0.10
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	2.1	1.2	1.5
ELF H (mA/m)	21	26	24

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.01
Hand placed flat on screen	0.01

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 304

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.09	0.05	0.05	0.05	0.05	NA
VLF H (mA/m)	1.3	1.3	1.3	1.3	1.3	NA
ELF E (V/m)	0.91	0.33	0.36	0.50	0.34	NA
ELF H (mA/m)	29	26	25	22	34	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.25	0.22	0.22
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.33	0.45	0.70
ELF H (mA/m)	27	27	28

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.0
Finger touching screen	0.0
Hand placed flat on screen	0.0

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 307

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.18	0.10	0.05	0.07	NA	0.05
VLF H (mA/m)	1.3	1.3	1.4	1.3	NA	1.4
ELF E (V/m)	1.7	0.56	0.34	0.74	NA	0.45
ELF H (mA/m)	39	42	13	37	NA	41

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.20	0.10	0.14
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.18	0.29	1.2
ELF H (mA/m)	38	42	45

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.03
Finger touching screen	0.03
Hand placed flat on screen	0.04

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 308

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.07	0.07	0.08	0.07	0.05	NA
VLF H (mA/m)	1.4	1.3	1.4	1.4	1.4	NA
ELF E (V/m)	0.60	0.45	0.30	0.28	0.33	NA
ELF H (mA/m)	46	32	28	64	40	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.28	0.07	0.11
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.73	0.32	0.47
ELF H (mA/m)	37	35	32

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.01
Hand placed flat on screen	0.01

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 310

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.14	0.07	0.05	0.05	0.05	NA
VLF H (mA/m)	1.3	1.4	1.3	1.3	1.4	NA
ELF E (V/m)	1.0	0.60	0.36	0.43	0.33	NA
ELF H (mA/m)	33	34	22	27	34	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.23	0.08	0.13
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	1.0	0.36	0.62
ELF H (mA/m)	33	35	33

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.01
Finger touching screen	0.01
Hand placed flat on screen	0.00

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 313

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	1.3	1.2	1.2	0.07	NA	0.05
VLF H (mA/m)	1.4	1.3	1.4	1.4	NA	1.4
ELF E (V/m)	1.3	0.68	0.29	0.50	NA	0.59
ELF H (mA/m)	43	42	30	50	NA	67

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.23	0.08	0.14
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.33	0.23	1.2
ELF H (mA/m)	38	39	50

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.0
Finger touching screen	0.0
Hand placed flat on screen	0.0

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 316

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.12	0.05	0.05	0.05	0.05	NA
VLF H (mA/m)	1.4	1.4	1.4	1.4	1.4	NA
ELF E (V/m)	0.91	0.28	0.38	0.23	0.22	NA
ELF H (mA/m)	40	31	32	32	80	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.07	0.06	0.09
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.47	0.16	0.57
ELF H (mA/m)	41	33	34

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.02
Hand placed flat on screen	0.05

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 317

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.16	0.09	0.05	0.07	NA	0.05
VLF H (mA/m)	1.4	1.4	1.4	1.4	NA	1.4
ELF E (V/m)	2.0	0.66	0.29	0.62	NA	0.33
ELF H (mA/m)	30	24	33	24	NA	34

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.21	0.06	0.12
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.42	0.18	0.91
ELF H (mA/m)	36	31	23

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.06
Finger touching screen	0.08
Hand placed flat on screen	0.05

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 318

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.10	0.08	0.05	0.03	0.05	NA
VLF H (mA/m)	1.4	1.4	1.4	1.4	1.4	NA
ELF E (V/m)	1.0	0.35	0.34	0.29	0.23	NA
ELF H (mA/m)	23	29	42	34	90	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.25	0.06	0.12
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.35	0.26	0.80
ELF H (mA/m)	104	96	92

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.01
Finger touching screen	0.01
Hand placed flat on screen	0.02

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 319

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.21	0.09	0.05	0.07	NA	0.05
VLF H (mA/m)	1.4	1.4	1.4	1.4	NA	1.4
ELF E (V/m)	1.8	0.69	0.35	0.62	NA	0.38
ELF H (mA/m)	19	20	43	34	NA	48

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.08	0.07	0.11
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.46	0.19	0.96
ELF H (mA/m)	34	31	24

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.07
Finger touching screen	0.03
Hand placed flat on screen	0.04

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 321

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.19	0.07	0.05	0.07	NA	0.05
VLF H (mA/m)	1.4	1.4	1.4	1.4	NA	1.4
ELF E (V/m)	2.1	0.56	0.33	0.67	NA	0.38
ELF H (mA/m)	16	22	44	29	NA	45

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.12	0.20	0.25
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.60	0.25	0.68
ELF H (mA/m)	34	29	31

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.07
Finger touching screen	0.09
Hand placed flat on screen	0.09

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 325

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.20	0.10	0.05	0.08	NA	0.05
VLF H (mA/m)	1.4	1.3	1.4	1.4	NA	1.3
ELF E (V/m)	2.7	0.82	0.49	0.73	NA	0.43
ELF H (mA/m)	26	29	30	28	NA	37

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.21	0.09	0.17
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.83	0.25	0.87
ELF H (mA/m)	31	32	27

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.0
Finger touching screen	0.0
Hand placed flat on screen	0.0

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 328

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.10	0.07	0.05	0.08	0.03	NA
VLF H (mA/m)	1.4	1.4	1.4	1.4	1.4	NA
ELF E (V/m)	0.89	0.40	0.25	0.39	0.27	NA
ELF H (mA/m)	43	48	33	59	36	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.24	0.21	0.33
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.14	0.23	0.86
ELF H (mA/m)	33	37	37

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.01
Finger touching screen	0.01
Hand placed flat on screen	0.01

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 329

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.16	0.08	0.05	0.05	NA	0.05
VLF H (mA/m)	1.4	1.4	1.4	1.3	NA	1.3
ELF E (V/m)	1.8	0.54	0.34	0.56	NA	0.38
ELF H (mA/m)	58	73	108	71	NA	153

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.22	0.20	0.10
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.36	0.47	0.80
ELF H (mA/m)	103	94	84

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.06
Hand placed flat on screen	0.07

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 337

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.16	0.19	0.05	0.07	NA	0.07
VLF H (mA/m)	1.4	1.3	1.3	1.4	NA	1.4
ELF E (V/m)	2.2	0.64	0.38	0.47	NA	0.36
ELF H (mA/m)	57	63	52	46	NA	100

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.21	0.21	0.33
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.35	0.33	1.2
ELF H (mA/m)	76	76	74

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.0
Finger touching screen	0.0
Hand placed flat on screen	0.0

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 342

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.10	0.07	0.05	0.07	0.05	NA
VLF H (mA/m)	1.4	1.3	1.4	1.4	1.4	NA
ELF E (V/m)	1.3	0.38	0.61	0.35	0.42	NA
ELF H (mA/m)	64	80	146	61	87	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.07	0.07	0.11
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.25	0.28	0.83
ELF H (mA/m)	67	62	58

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.03
Finger touching screen	0.02
Hand placed flat on screen	0.01

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 345

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.14	0.07	0.05	0.05	NA	0.05
VLF H (mA/m)	1.4	1.3	1.3	1.4	NA	1.3
ELF E (V/m)	1.4	0.49	0.30	0.41	NA	0.35
ELF H (mA/m)	83	100	101	103	NA	42

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.22	0.07	0.22
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.13	0.30	1.2
ELF H (mA/m)	108	111	108

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.0
Finger touching screen	0.0
Hand placed flat on screen	0.0

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 348

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.09	0.07	0.05	0.19	0.05	NA
VLF H (mA/m)	1.4	1.4	1.4	1.4	1.4	NA
ELF E (V/m)	0.80	0.29	0.35	0.45	0.26	NA
ELF H (mA/m)	19	13	15	13	19	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.27	0.09	0.10
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.35	0.34	0.63
ELF H (mA/m)	15	14	14

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.03
Finger touching screen	0.01
Hand placed flat on screen	0.01

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 349

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.19	0.09	0.05	0.07	NA	0.04
VLF H (mA/m)	1.4	1.4	1.4	1.4	NA	1.4
ELF E (V/m)	2.4	0.55	0.28	0.73	NA	0.33
ELF H (mA/m)	25	30	27	17	NA	21

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.24	0.07	0.16
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.16	0.27	1.3
ELF H (mA/m)	11	11	14

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.01
Finger touching screen	0.01
Hand placed flat on screen	0.0

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 351

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.19	0.07	0.05	0.07	NA	0.03
VLF H (mA/m)	1.3	1.3	1.4	1.4	NA	1.4
ELF E (V/m)	2.2	0.73	0.43	0.55	NA	0.38
ELF H (mA/m)	16	17	35	16	NA	21

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.08	0.07	0.21
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	1.0	0.63	0.91
ELF H (mA/m)	8.1	11	14

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.01
Hand placed flat on screen	0.03

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 352

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.08	0.02	0.02	0.02	0.02	NA
VLF H (mA/m)	1.5	1.5	1.5	1.5	1.4	NA
ELF E (V/m)	0.49	0.23	0.25	0.29	0.26	NA
ELF H (mA/m)	25	18	21	22	40	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.08	0.08	0.11
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.34	0.27	0.48
ELF H (mA/m)	12	21	27

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.0
Finger touching screen	0.0
Hand placed flat on screen	0.0

Location: Cincinnati

Display type: NGT      VLF Sweep = -      ELF Sweep = -

Serial/station number: 358

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.10	0.04	0.05	0.05	0.05	NA
VLF H (mA/m)	1.4	1.3	1.4	1.4	1.4	NA
ELF E (V/m)	1.2	0.33	0.27	0.66	0.27	NA
ELF H (mA/m)	10	14	27	23	18	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.25	0.07	0.22
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.49	0.43	1.0
ELF H (mA/m)	15	16	15

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.0
Finger touching screen	0.0
Hand placed flat on screen	0.0

Location: Cincinnati

Display type: NGT      VLF Sweep = -                      ELF Sweep = -

Serial/station number: 361

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.11	0.04	0.05	0.05	NA	0.05
VLF H (mA/m)	1.3	1.3	1.3	1.3	NA	—
ELF E (V/m)	0.49	0.43	0.29	0.35	NA	0.33
ELF H (mA/m)	22	22	22	23	NA	25

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.25	0.20	0.19
VLF H (mA/m)	1.6	1.6	1.6
ELF E (V/m)	0.36	0.27	0.53
ELF H (mA/m)	21	21	22

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.01
Finger touching screen	0.01
Hand placed flat on screen	0.01

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 413

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.21	0.14	0.25	0.56	NA	0.12
VLF H (mA/m)	1.6	1.6	4.4	1.6	NA	1.6
ELF E (V/m)	2.9	0.45	0.39	13	NA	0.48
ELF H (mA/m)	185	155	138	177	NA	132

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.04	0.04	0.18
VLF H (mA/m)	1.6	1.4	1.4
ELF E (V/m)	0.33	0.30	0.30
ELF H (mA/m)	147	170	205

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.01
Finger touching screen	0.01
Hand placed flat on screen	0.01

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 402

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.15	0.13	0.20	0.58	0.11	NA
VLF H (mA/m)	1.6	1.6	4.8	1.6	1.7	NA
ELF E (V/m)	0.94	0.36	0.43	14	0.56	NA
ELF H (mA/m)	46	39	25	44	139	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.12	0.04	0.04
VLF H (mA/m)	2.3	1.6	1.4
ELF E (V/m)	0.53	0.31	0.34
ELF H (mA/m)	35	50	62

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.01
Finger touching screen	0.0
Hand placed flat on screen	0.0

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 403

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.12	0.11	0.20	0.42	NA	0.11
VLF H (mA/m)	1.6	1.7	5.4	1.6	NA	1.7
ELF E (V/m)	1.2	0.43	0.41	12	NA	0.39
ELF H (mA/m)	45	30	89	50	NA	153

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.10	0.08	0.05
VLF H (mA/m)	1.9	1.6	1.4
ELF E (V/m)	0.30	0.26	0.33
ELF H (mA/m)	36	55	66

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.01
Finger touching screen	0.0
Hand placed flat on screen	0.01

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 404

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.11	0.11	0.19	0.51	0.14	NA
VLF H (mA/m)	1.6	1.6	4.8	1.6	1.6	NA
ELF E (V/m)	0.44	0.34	0.39	13	0.45	NA
ELF H (mA/m)	55	52	19	33	158	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.09	0.03	0.03
VLF H (mA/m)	2.1	1.5	1.4
ELF E (V/m)	0.41	0.32	0.30
ELF H (mA/m)	52	64	80

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.01
Hand placed flat on screen	0.01

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 405

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.13	0.11	0.19	0.64	NA	0.10
VLF H (mA/m)	1.6	1.6	5.0	1.6	NA	1.6
ELF E (V/m)	1.8	0.34	0.39	17	NA	0.37
ELF H (mA/m)	57	31	32	63	NA	175

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.10	0.05	0.04
VLF H (mA/m)	2.4	1.6	1.4
ELF E (V/m)	0.38	0.30	0.37
ELF H (mA/m)	46	60	83

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.01
Hand placed flat on screen	0.01

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 406

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.12	0.12	0.21	0.35	0.11	NA
VLF H (mA/m)	1.6	1.6	4.9	1.6	1.7	NA
ELF E (V/m)	1.3	0.35	0.38	7.1	0.49	NA
ELF H (mA/m)	40	49	11	61	191	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.08	0.08	0.18
VLF H (mA/m)	1.9	1.5	1.4
ELF E (V/m)	0.31	0.29	0.34
ELF H (mA/m)	35	51	65

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.0
Finger touching screen	0.0
Hand placed flat on screen	0.0

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 408

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.22	0.11	0.17	0.49	0.11	NA
VLF H (mA/m)	1.6	1.6	5.7	1.6	1.6	NA
ELF E (V/m)	1.1	0.37	0.44	17	0.46	NA
ELF H (mA/m)	85	125	65	95	157	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.04	0.08	0.09
VLF H (mA/m)	1.7	1.7	1.4
ELF E (V/m)	0.30	0.29	0.31
ELF H (mA/m)	1.1	1.3	1.6

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.01
Finger touching screen	0.02
Hand placed flat on screen	0.02

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 411

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.11	0.12	0.17	0.69	NA	0.11
VLF H (mA/m)	1.6	1.6	3.5	1.6	NA	1.7
ELF E (V/m)	2.4	0.43	0.39	14	NA	0.45
ELF H (mA/m)	151	131	114	166	NA	130

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.09	0.08	0.07
VLF H (mA/m)	1.72	1.42	1.34
ELF E (V/m)	0.41	0.30	0.30
ELF H (mA/m)	121	143	169

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.01
Finger touching screen	0.0
Hand placed flat on screen	0.0

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 415

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.13	0.12	0.21	0.89	NA	0.11
VLF H (mA/m)	1.6	1.6	6.4	1.6	NA	1.7
ELF E (V/m)	1.4	0.35	0.41	19	NA	0.86
ELF H (mA/m)	102	102	86	115	NA	96

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.09	0.08	0.05
VLF H (mA/m)	1.8	1.4	1.4
ELF E (V/m)	0.34	0.30	0.30
ELF H (mA/m)	118	125	134

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.0
Finger touching screen	0.0
Hand placed flat on screen	0.0

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 416

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.13	0.12	0.21	0.23	0.10	NA
VLF H (mA/m)	1.6	1.6	1.9	1.6	1.6	NA
ELF E (V/m)	0.45	0.37	0.48	8.1	0.35	NA
ELF H (mA/m)	107	114	111	107	69	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.09	0.04	0.03
VLF H (mA/m)	2.1	1.5	1.4
ELF E (V/m)	0.38	0.30	0.31
ELF H (mA/m)	132	146	147

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.01
Hand placed flat on screen	0.01

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 417

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.13	0.12	0.20	0.93	NA	0.10
VLF H (mA/m)	1.6	1.6	3.3	1.6	NA	1.6
ELF E (V/m)	2.1	0.41	0.42	20	NA	0.39
ELF H (mA/m)	111	106	109	118	NA	55

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.10	0.04	0.03
VLF H (mA/m)	2	1.5	1.3
ELF E (V/m)	0.37	0.27	0.31
ELF H (mA/m)	131	150	156

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.01
Finger touching screen	0.01
Hand placed flat on screen	0.0

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 421

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.11	0.12	0.20	0.27	NA	0.11
VLF H (mA/m)	1.6	1.6	4.2	1.6	NA	1.6
ELF E (V/m)	1.1	0.39	0.44	7.8	NA	0.71
ELF H (mA/m)	117	101	110	115	NA	95

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.05	0.04	0.09
VLF H (mA/m)	1.7	1.4	1.3
ELF E (V/m)	0.41	0.35	0.29
ELF H (mA/m)	117	130	133

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.01
Hand placed flat on screen	0.01

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 422

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.17	0.11	0.16	0.67	0.11	NA
VLF H (mA/m)	1.6	1.6	3.4	1.6	1.6	NA
ELF E (V/m)	1.4	0.35	0.42	13	0.66	NA
ELF H (mA/m)	103	102	100	106	25	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.09	0.04	0.07
VLF H (mA/m)	2.7	1.7	1.4
ELF E (V/m)	0.27	0.27	0.30
ELF H (mA/m)	101	105	110

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.01
Hand placed flat on screen	0.01

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 423

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.16	0.12	0.21	0.60	NA	0.11
VLF H (mA/m)	1.6	1.6	1.6	1.6	NA	1.6
ELF E (V/m)	2.1	0.42	0.43	13	NA	0.38
ELF H (mA/m)	115	99	105	115	NA	123

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.09	0.09	0.11
VLF H (mA/m)	2.2	1.6	1.4
ELF E (V/m)	0.31	0.29	0.33
ELF H (mA/m)	109	113	116

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.01
Hand placed flat on screen	0.02

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 424

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.12	0.11	0.20	0.20	0.11	NA
VLF H (mA/m)	1.6	1.6	5.0	1.6	1.6	NA
ELF E (V/m)	0.38	0.33	0.39	3.9	0.33	NA
ELF H (mA/m)	106	100	92	103	10	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.09	0.09	0.23
VLF H (mA/m)	2.1	1.7	1.4
ELF E (V/m)	0.39	0.30	0.30
ELF H (mA/m)	104	110	112

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.04
Finger touching screen	0.02
Hand placed flat on screen	0.03



Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 425

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.14	0.11	0.24	0.44	NA	0.12
VLF H (mA/m)	1.6	1.6	1.7	1.6	NA	1.6
ELF E (V/m)	1.8	0.34	0.39	12	NA	0.42
ELF H (mA/m)	122	113	119	124	NA	11

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.09	0.08	0.20
VLF H (mA/m)	2.1	1.7	1.4
ELF E (V/m)	0.39	0.26	0.30
ELF H (mA/m)	111	117	123

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.0
Finger touching screen	0.0
Hand placed flat on screen	0.0

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 427

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.13	0.11	0.16	0.87	NA	0.11
VLF H (mA/m)	1.6	1.6	3.4	1.6	NA	1.6
ELF E (V/m)	1.2	0.43	0.42	18	NA	0.48
ELF H (mA/m)	91	87	82	84	NA	47

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.05	0.05	0.03
VLF H (mA/m)	1.7	1.5	1.4
ELF E (V/m)	0.39	0.30	0.29
ELF H (mA/m)	98	108	110

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.02
Hand placed flat on screen	0.01

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 429

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.31	0.12	0.21	0.54	NA	0.11
VLF H (mA/m)	1.6	1.6	3.7	1.6	NA	1.6
ELF E (V/m)	2.0	0.39	0.42	14	NA	0.35
ELF H (mA/m)	86	79	73	83	NA	29

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.10	0.09	0.05
VLF H (mA/m)	1.7	1.5	1.4
ELF E (V/m)	0.41	0.30	0.38
ELF H (mA/m)	85	44	89

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.01
Finger touching screen	0.01
Hand placed flat on screen	0.01

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 431

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.28	0.11	0.20	0.60	NA	0.11
VLF H (mA/m)	1.6	1.6	4.1	1.6	NA	1.6
ELF E (V/m)	2.0	0.35	0.41	14	NA	0.45
ELF H (mA/m)	14	76	82	82	NA	16

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.07	0.05	0.12
VLF H (mA/m)	2.1	1.5	1.4
ELF E (V/m)	0.29	0.31	0.31
ELF H (mA/m)	80	87	88

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.0
Finger touching screen	0.0
Hand placed flat on screen	0.01

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 434

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.16	0.12	0.13	0.66	0.11	NA
VLF H (mA/m)	1.6	1.6	4.5	1.6	1.6	NA
ELF E (V/m)	0.88	0.37	0.39	13	0.44	NA
ELF H (mA/m)	60	58	47	62	31	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.09	0.05	0.08
VLF H (mA/m)	1.9	1.5	1.4
ELF E (V/m)	0.38	0.32	0.27
ELF H (mA/m)	63	64	66

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.01
Hand placed flat on screen	0.01

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 437

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.21	0.06	0.21	0.52	NA	0.11
VLF H (mA/m)	1.6	1.6	2.8	1.6	NA	1.6
ELF E (V/m)	2.3	0.35	0.39	12	NA	0.44
ELF H (mA/m)	15	62	65	64	NA	19

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.07	0.09	0.21
VLF H (mA/m)	1.9	1.5	1.4
ELF E (V/m)	0.29	0.42	0.43
ELF H (mA/m)	68	73	74

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.03
Finger touching screen	0.02
Hand placed flat on screen	0.03

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 444

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.29	0.12	0.21	0.79	0.12	NA
VLF H (mA/m)	1.6	1.6	3.8	1.6	1.6	NA
ELF E (V/m)	0.54	0.44	0.39	15	0.45	NA
ELF H (mA/m)	44	23	21	33	19	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.10	0.03	0.05
VLF H (mA/m)	1.7	1.4	1.4
ELF E (V/m)	0.31	0.27	0.32
ELF H (mA/m)	18	22	31

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.01
Finger touching screen	0.0
Hand placed flat on screen	0.0

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 445

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.26	0.12	0.21	1.1	NA	0.11
VLF H (mA/m)	1.6	1.6	3.5	1.6	NA	1.6
ELF E (V/m)	4.0	0.36	0.38	22	NA	0.67
ELF H (mA/m)	50	41	26	38	NA	19

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.10	0.09	0.11
VLF H (mA/m)	2.5	1.6	1.4
ELF E (V/m)	0.32	0.27	0.32
ELF H (mA/m)	34	37	44

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.01
Finger touching screen	0.0
Hand placed flat on screen	0.0

Location: Bloomington

Display type: LED      VLF Sweep = -      ELF Sweep = -

Serial/station number: 458

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.16	0.11	0.20	0.23	0.11	NA
VLF H (mA/m)	1.6	1.6	4.9	1.6	1.6	NA
ELF E (V/m)	0.57	0.34	0.42	4.6	0.39	NA
ELF H (mA/m)	58	71	69	62	79	NA

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.09	0.08	0.05
VLF H (mA/m)	1.8	1.5	1.4
ELF E (V/m)	0.30	0.31	0.30
ELF H (mA/m)	112	115	133

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	0.01
Hand placed flat on screen	0.01

A

Location: Nashville - Welch Road

Display type: CCI      VLF Sweep = 14.997 kHz      ELF Sweep = 45.72 Hz

Serial/station number: 81974/50

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	2.8	3.6	1.6	1.4	0.90	3.7
VLF H (mA/m)	36	1.2	36	186	111	108
ELF E (V/m)	5.5	2.6	4.1	4.1	11	8.6
ELF H (mA/m)	335	293	617	2900	1540	1158

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.68	0.82	1.1
VLF H (mA/m)	15	12	40
ELF E (V/m)	0.44	0.75	1.5
ELF H (mA/m)	48	56	50

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	7.8
Finger touching screen	13
Hand placed flat on screen	81

Location: Nashville - Welch Road

Display type: CCI      VLF Sweep = 14.997 kHz      ELF Sweep = 45.72 Hz

Serial/station number: 82101/12

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	2.7	4.0	1.7	2.1	0.49	2.2
VLF H (mA/m)	11	124	39	117	57	83
ELF E (V/m)	7.0	4.9	1.4	4.5	1.6	12
ELF H (mA/m)	127	182	481	747	68	956

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.68	1.3	1.6
VLF H (mA/m)	26	12	53
ELF E (V/m)	2.9	1.6	0.95
ELF H (mA/m)	23	26	30

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	13
Finger touching screen	16
Hand placed flat on screen	65

Location: Nashville - Welch Road

Display type: CCI      VLF Sweep = 14.998 kHz      ELF Sweep = 45.73 Hz

Serial/station number: 89028/2

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	7.4	8.5	0.15	1.7	1.2	3.8
VLF H (mA/m)	206	124	9.7	46	107	63
ELF E (V/m)	3.1	3.4	0.85	3.4	4.7	16
ELF H (mA/m)	311	256	521	3094	1702	1402

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.53	0.87	1.5
VLF H (mA/m)	31	5.9	41
ELF E (V/m)	0.30	0.49	1.1
ELF H (mA/m)	56	45	49

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	3.3
Finger touching screen	3.7
Hand placed flat on screen	30

Location: Nashville - Welch Road

Display type: CCI      VLF Sweep = 14.994 kHz      ELF Sweep = 45.71 Hz

Serial/station number: 89997/7

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	3.1	1.6	0.25	1.4	3.1	0.77
VLF H (mA/m)	21	143	63	171	103	135
ELF E (V/m)	2.9	2.2	1.2	7.3	7.0	5.7
ELF H (mA/m)	421	322	411	2318	1478	874

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.79	0.90	1.3
VLF H (mA/m)	26	9.2	48
ELF E (V/m)	0.32	0.37	0.79
ELF H (mA/m)	31	32	40

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	14
Finger touching screen	25
Hand placed flat on screen	121

Location: Nashville - Welch Road

Display type: CCI      VLF Sweep = 14.997 kHz      ELF Sweep = 45.72 Hz

Serial/station number: Serial number removed from unit/13

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	3.2	3.8	0.77	2.4	0.68	2.4
VLF H (mA/m)	5.1	129	21	132	64	39
ELF E (V/m)	5.2	1.8	0.63	8.5	0.90	11
ELF H (mA/m)	118	257	536	945	129	1032

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.45	1.3	1.9
VLF H (mA/m)	20	4.8	62
ELF E (V/m)	0.57	0.52	1.8
ELF H (mA/m)	26	34	36

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.08
Finger touching screen	0.8
Hand placed flat on screen	7.3

Location: Nashville - Welch Road

Display type: CCI      VLF Sweep = 14.996 kHz      ELF Sweep = 45.72 Hz

Serial/station number: Serial number removed from unit/44

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	4.1	4.7	1.9	2.7	0.51	4.0
VLF H (mA/m)	54	160	84	103	69	53
ELF E (V/m)	5.0	5.7	3.4	5.3	2.1	23
ELF H (mA/m)	457	206	272	761	90	974

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.39	1.1	1.6
VLF H (mA/m)	38	7.3	59
ELF E (V/m)	0.68	1.2	2.0
ELF H (mA/m)	26	39	48

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.51
Finger touching screen	18
Hand placed flat on screen	89

Location: Nashville - Downtown

Display type: CCI      VLF Sweep = 14.997 kHz      ELF Sweep = 45.72 Hz

Serial/station number: 05027/1399

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	2.5	3.3	0.57	6.8	0.91	1.1
VLF H (mA/m)	42	120	13	72	115	82
ELF E (V/m)	7.1	2.0	1.4	8.8	3.7	4.8
ELF H (mA/m)	515	376	533	187	710	489

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.79	0.81	0.83
VLF H (mA/m)	23	33	20
ELF E (V/m)	4.4	6.9	9.1
ELF H (mA/m)	101	114	98

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	9.7
Finger touching screen	7.4
Hand placed flat on screen	65



Location: Nashville - Downtown

Display type: CCI      VLF Sweep = 14.997 kHz      ELF Sweep = 45.72 Hz

Serial/station number: 05182/1412

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	3.3	6.1	0.83	4.1	1.12	0.93
VLF H (mA/m)	57	98	104	26	125	72
ELF E (V/m)	1.6	1.4	23	2.4	2.8	4.2
ELF H (mA/m)	455	341	235	455	644	463

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.96	0.87	0.97
VLF H (mA/m)	12	23	22
ELF E (V/m)	7.9	0.79	2.9
ELF H (mA/m)	80	123	123

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	9.0
Finger touching screen	9.0
Hand placed flat on screen	107

Location: Nashville - Downtown

Display type: OCI      VLF Sweep = 14.997 kHz      ELF Sweep = 45.72 Hz

Serial/station number: 94328/1382

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	3.5	5.3	1.3	2.2	1.2	0.65
VLF H (mA/m)	70	89	56	38	104	26
ELF E (V/m)	3.3	2.2	45	5.5	9.6	16
ELF H (mA/m)	424	315	201	410	494	405

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	1.1	0.96	1.3
VLF H (mA/m)	10	20	22
ELF E (V/m)	6.1	1.0	2.4
ELF H (mA/m)	85	89	85

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	2.3
Finger touching screen	8.4
Hand placed flat on screen	86

Location: Nashville - Downtown

Display type: CCI      VLF Sweep = 14.998 kHz      ELF Sweep = 45.73 Hz

Serial/station number: 94501/0756

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	2.4	4.9	0.58	1.5	0.71	0.58
VLF H (mA/m)	32	83	48	8.6	63	73
ELF E (V/m)	1.2	1.9	14	1.3	0.68	12
ELF H (mA/m)	394	271	192	325	461	407

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.78	1.0	1.7
VLF H (mA/m)	6.7	13	19
ELF E (V/m)	0.88	3.7	0.58
ELF H (mA/m)	64	82	89

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	5.3
Finger touching screen	8.6
Hand placed flat on screen	73

Location: Nashville - Downtown

Display type: CCI      VLF Sweep = 14.997 kHz      ELF Sweep = 45.72 Hz

Serial/station number: 94505/1391

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	2.6	4.1	0.72	1.5	0.67	0.60
VLF H (mA/m)	16	99	18	23	60	79
ELF E (V/m)	1.55	1.39	25	11	9.0	3.2
ELF H (mA/m)	537	300	256	392	604	439

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.97	1.5	1.3
VLF H (mA/m)	13	27	26
ELF E (V/m)	16	1.4	3.1
ELF H (mA/m)	110	122	111

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	10
Finger touching screen	15
Hand placed flat on screen	96

Location: Nashville - Downtown

Display type: CCI      VLF Sweep = 14.997 kHz      ELF Sweep = 45.72 Hz

Serial/station number: 95179 (?)/1375

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	2.5	3.9	1.5	3.2	0.60	0.70
VLF H (mA/m)	72	68	69	47	82	76
ELF E (V/m)	3.7	1.3	12	4.4	10	16
ELF H (mA/m)	402	327	253	477	577	428

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.35	0.85	1.1
VLF H (mA/m)	8.1	28	30
ELF E (V/m)	6.3	2.7	8.6
ELF H (mA/m)	69	89	83

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	6.2
Finger touching screen	11
Hand placed flat on screen	58



Location: Forest Park

Display type: IBM      VLF Sweep = 15.840 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 34632/1014

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.13	2.1	0.07	0.22	0.08	0.10
VLF H (mA/m)	22	4.3	1.9	28	3.9	26
ELF E (V/m)	0.45	4.5	0.57	2.3	0.41	0.78
ELF H (mA/m)	135	109	57	108	91	152

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.10	0.14	0.21
VLF H (mA/m)	2.1	2.0	2.1
ELF E (V/m)	0.27	0.30	0.67
ELF H (mA/m)	91	86	115

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.06
Finger touching screen	3.4
Hand placed flat on screen	80

Location: Forest Park

Display type: IBM      VLF Sweep = 15.844 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 35817/1025

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.14	1.8	0.07	0.26	0.08	0.07
VLF H (mA/m)	24	5.8	2.0	43	6.7	26
ELF E (V/m)	0.79	1.4	1.6	1.6	0.67	1.5
ELF H (mA/m)	179	193	129	122	287	119

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.13	0.14	0.22
VLF H (mA/m)	1.6	2.1	2.0
ELF E (V/m)	0.36	1.0	1.2
ELF H (mA/m)	155	166	179

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.09
Finger touching screen	5.7
Hand placed flat on screen	85

Location: Forest Park

Display type: IBM      VLF Sweep = 15.839 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 35819/1038

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.15	1.8	0.07	0.14	0.08	0.07
VLF H (mA/m)	26	4.6	1.9	20	6.0	11
ELF E (V/m)	0.42	2.0	1.8	0.53	1.3	1.4
ELF H (mA/m)	83	71	41	42	152	127

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.07	0.14	0.34
VLF H (mA/m)	2.5	2.8	2.2
ELF E (V/m)	1.2	0.84	1.1
ELF H (mA/m)	58	69	80

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.63
Finger touching screen	1.7
Hand placed flat on screen	40

Location: Forest Park

Display type: IBM      VLF Sweep = 15.844 kHz      ELF Sweep = 60.01 Hz

Serial/station number: 35882/1006

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.16	4.2	0.19	0.28	0.20	0.14
VLF H (mA/m)	27	81	1.9	8.3	27	10
ELF E (V/m)	0.42	4.8	1.9	1.1	0.61	3.3
ELF H (mA/m)	393	420	91	167	339	326

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.23	0.46	0.53
VLF H (mA/m)	4.4	9.9	11
ELF E (V/m)	0.82	0.80	1.1
ELF H (mA/m)	102	52	134

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.07
Finger touching screen	8.9
Hand placed flat on screen	55

Location: Forest Park

Display type: IBM      VLF Sweep = 15.845 kHz      ELF Sweep = 60.02 Hz

Serial/station number: 36026/1030

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.16	47	0.07	0.13	0.10	0.14
VLF H (mA/m)	30	103	2.4	39	13	19
ELF E (V/m)	0.43	1.4	1.5	1.0	0.90	0.52
ELF H (mA/m)	527	571	51	245	723	416

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.16	0.49	0.66
VLF H (mA/m)	13	6.7	19
ELF E (V/m)	0.86	1.2	1.1
ELF H (mA/m)	128	130	191

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.02
Finger touching screen	2.8
Hand placed flat on screen	51

Location: Forest Park

Display type: IBM      VLF Sweep = 15.844 kHz      ELF Sweep = 60.01 Hz

Serial/station number: 36151/1004

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.13	1.9	0.09	0.11	0.66	0.07
VLF H (mA/m)	3.4	5.3	3.3	27	8.0	8.8
ELF E (V/m)	0.50	3.3	0.86	1.6	0.53	1.2
ELF H (mA/m)	136	127	71	144	218	100

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.12	0.31	0.37
VLF H (mA/m)	2.5	2.4	2.0
ELF E (V/m)	0.32	0.34	0.72
ELF H (mA/m)	77	84	52

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.04
Finger touching screen	5.2
Hand placed flat on screen	51

Location: Macon

Display type: IBM      VLF Sweep = 15.845 kHz      ELF Sweep = 60.02 Hz

Serial/station number: 93809/1006

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.12	1.9	0.07	0.09	0.09	0.07
VLF H (mA/m)	22	4.2	1.8	19	5.2	17
ELF E (V/m)	0.46	1.3	0.42	0.26	0.37	0.54
ELF H (mA/m)	152	123	21	87	179	87

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.10	0.19	0.55
VLF H (mA/m)	2.2	2.4	5.1
ELF E (V/m)	0.29	0.34	0.45
ELF H (mA/m)	12	26	42

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.92
Finger touching screen	1.5
Hand placed flat on screen	27

Location: Macon

Display type: IBM      VLF Sweep = 15.840 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 93812/1017

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.11	2.0	0.07	0.09	0.08	0.10
VLF H (mA/m)	11	4.0	1.6	15	3.4	12
ELF E (V/m)	0.42	3.1	0.42	0.34	0.31	0.31
ELF H (mA/m)	87	88	20	65	120	83

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.08	0.25	0.60
VLF H (mA/m)	2.0	1.9	2.2
ELF E (V/m)	0.39	0.61	0.83
ELF H (mA/m)	20	16	28

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.31
Finger touching screen	4.6
Hand placed flat on screen	43

Location: Macon

Display type: IBM      VLF Sweep = 15.840 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 93899/1035

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.14	1.8	0.08	0.11	0.08	0.07
VLF H (mA/m)	15	5.9	1.7	23	5.2	23
ELF E (V/m)	0.42	1.6	0.89	0.71	0.38	1.1
ELF H (mA/m)	132	117	13	102	201	125

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.22	0.24	0.56
VLF H (mA/m)	3.4	2.6	2.7
ELF E (V/m)	0.29	0.42	0.50
ELF H (mA/m)	25	23	20

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	11
Finger touching screen	11
Hand placed flat on screen	44

Location: Macon

Display type: IBM      VLF Sweep = 15.840 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 93901/1018

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.12	2.0	0.07	0.13	0.08	0.08
VLF H (mA/m)	23	4.6	1.8	19	4.4	9.4
ELF E (V/m)	0.39	1.5	0.47	0.45	0.27	0.46
ELF H (mA/m)	134	121	12	92	195	85

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.09	0.46	0.59
VLF H (mA/m)	2.4	3.1	2.2
ELF E (V/m)	0.31	0.38	0.46
ELF H (mA/m)	33	39	36

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.49
Finger touching screen	8.9
Hand placed flat on screen	91

Location: Macon

Display type: IBM      VLF Sweep = 15.840 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 94590/1028

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.10	1.3	0.08	0.11	0.09	0.23
VLF H (mA/m)	18	4.6	2.0	20	3.8	21
ELF E (V/m)	0.49	6.4	0.67	0.93	0.29	4.7
ELF H (mA/m)	134	108	23	81	178	107

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.10	0.18	0.25
VLF H (mA/m)	2.8	2.5	2.4
ELF E (V/m)	0.32	0.76	1.5
ELF H (mA/m)	22	29	48

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	2.7
Finger touching screen	7.3
Hand placed flat on screen	50

Location: Macon

Display type: IBM      VLF Sweep = 15.840 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 94607/1022

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.15	2.1	0.10	0.12	0.08	0.08
VLF H (mA/m)	15	6.1	1.8	28	4.6	18
ELF E (V/m)	0.84	6.4	1.1	0.72	0.25	1.0
ELF H (mA/m)	117	117	22	122	178	66

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.11	0.48	1.05
VLF H (mA/m)	3.5	3.0	3.6
ELF E (V/m)	0.56	1.3	2.6
ELF H (mA/m)	24	19	29

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.14
Finger touching screen	7.8
Hand placed flat on screen	55

Location: Jacksonville

Display type: IBM      VLF Sweep = 15.841 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 30434/124

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.20	4.6	0.07	0.19	0.26	0.09
VLF H (mA/m)	45	108	2.6	12	31	14
ELF E (V/m)	0.56	1.0	0.95	0.49	0.78	0.78
ELF H (mA/m)	421	512	65	277	641	358

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.20	0.55	0.71
VLF H (mA/m)	5.9	7.3	18
ELF E (V/m)	0.34	0.39	0.67
ELF H (mA/m)	62	88	99

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.78
Finger touching screen	12
Hand placed flat on screen	128

Location: Jacksonville

Display type: IEM      VLF Sweep = 15.840 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 30491/132

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.16	4.4	0.08	0.14	0.18	0.15
VLF H (mA/m)	32	91	2.3	10	27	12
ELF E (V/m)	0.58	1.4	0.43	0.35	0.44	3.2
ELF H (mA/m)	447	474	53	211	602	286

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.30	0.55	0.61
VLF H (mA/m)	4.5	7.1	10
ELF E (V/m)	0.35	0.32	0.49
ELF H (mA/m)	70	73	64

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	2.9
Finger touching screen	6.0
Hand placed flat on screen	69



Location: Jacksonville

Display type: IBM      VLF Sweep = 15.844 kHz      ELF Sweep = 60.02 Hz

Serial/station number: 30518/139

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.31	5.1	0.07	0.14	0.16	0.10
VLF H (mA/m)	47	100	2.9	10	30	15
ELF E (V/m)	0.50	1.6	1.0	0.42	0.57	1.9
ELF H (mA/m)	511	510	72	327	619	340

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.19	0.72	1.6
VLF H (mA/m)	10	2.7	30
ELF E (V/m)	0.69	0.42	1.1
ELF H (mA/m)	71	87	104

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	2.4
Finger touching screen	13
Hand placed flat on screen	105

A

Location: Jacksonville

Display type: IBM      VLF Sweep = 15.844 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 30533/136

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.16	4.8	0.07	0.19	0.18	0.10
VLF H (mA/m)	34	101	2.5	1.6	32	13
ELF E (V/m)	1.8	0.61	0.44	0.88	1.4	0.97
ELF H (mA/m)	411	515	26	486	607	457

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.74	1.5	0.88
VLF H (mA/m)	12	37	6.4
ELF E (V/m)	0.39	0.65	0.55
ELF H (mA/m)	130	218	181

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	1.2
Finger touching screen	15
Hand placed flat on screen	148

Location: Jacksonville

Display type: IBM      VLF Sweep = 15.841 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 30628/120

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.54	4.6	0.07	0.31	0.22	0.14
VLF H (mA/m)	113	124	3.5	21	79	18
ELF E (V/m)	0.55	1.5	0.41	0.35	0.63	3.7
ELF H (mA/m)	524	521	76	310	646	344

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.28	0.58	0.59
VLF H (mA/m)	4.1	16	18
ELF E (V/m)	0.29	0.32	0.48
ELF H (mA/m)	79	131	106

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.75
Finger touching screen	21
Hand placed flat on screen	148

Location: Jacksonville

Display type: IBM      VLF Sweep = 15.840 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 91-94748/130

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.12	2.1	0.16	0.15	0.15	0.07
VLF H (mA/m)	23	4.2	1.8	13	4.3	9.7
ELF E (V/m)	0.59	3.4	1.1	1.4	0.42	0.92
ELF H (mA/m)	94	104	22	82	174	181

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.10	0.14	0.34
VLF H (mA/m)	2.6	2.0	2.0
ELF E (V/m)	0.44	0.31	0.29
ELF H (mA/m)	13	30	38

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.33
Finger touching screen	6.5
Hand placed flat on screen	65

Location: Lake City

Display type: IBM      VLF Sweep = 15.845 kHz      ELF Sweep = 60.02 Hz

Serial/station number: 29735/408

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.25	4.7	0.07	NA	0.28	0.11
VLF H (mA/m)	42	97	2.4	NA	32	14
ELF E (V/m)	0.39	0.97	0.53	NA	0.48	0.30
ELF H (mA/m)	320	409	119	NA	476	367

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.18	0.35	0.69
VLF H (mA/m)	4.4	4.9	30
ELF E (V/m)	0.47	0.30	0.32
ELF H (mA/m)	79	47	77

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.11
Finger touching screen	5.1
Hand placed flat on screen	37

Location: Lake City

Display type: IBM      VLF Sweep = 15.844 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 29744/418

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.28	4.6	0.05	NA	0.18	0.15
VLF H (mA/m)	59.9	95	1.8	NA	31	18
ELF E (V/m)	1.0	1.0	0.46	NA	0.44	1.1
ELF H (mA/m)	248	484	79	NA	513	404

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.15	0.51	0.77
VLF H (mA/m)	3.4	6.0	18
ELF E (V/m)	0.31	0.30	1.3
ELF H (mA/m)	65	69	70

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.14
Finger touching screen	16
Hand placed flat on screen	80

Location: Lake City

Display type: IBM      VLF Sweep = 15.842 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 30592/437

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.25	4.8	0.07	NA	0.23	0.27
VLF H (mA/m)	34	97	2.2	NA	19	17
ELF E (V/m)	0.48	1.0	0.41	NA	0.48	4.8
ELF H (mA/m)	525	474	117	NA	515	377

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.11	0.24	0.67
VLF H (mA/m)	7.9	6.5	27
ELF E (V/m)	0.29	0.30	0.36
ELF H (mA/m)	97	123	124

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.37
Finger touching screen	10
Hand placed flat on screen	125

Location: Lake City

Display type: IBM      VLF Sweep = 15.842 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 30593/426

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.14	2.1	0.83	NA	0.08	0.19
VLF H (mA/m)	29	6.1	1.9	NA	6.2	24
ELF E (V/m)	0.46	1.4	19	NA	0.33	2.6
ELF H (mA/m)	142	134	50	NA	171	188

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.12	0.16	0.24
VLF H (mA/m)	3.0	2.2	2.5
ELF E (V/m)	2.1	2.3	3.1
ELF H (mA/m)	87	93	99

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	1.1
Finger touching screen	4.2
Hand placed flat on screen	89

Location: Lake City

Display type: IBM      VLF Sweep = 15.840 kHz      ELF Sweep = 60.00 Hz

Serial/station number: 30598/402

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.51	4.8	0.07	NA	0.22	0.23
VLF H (mA/m)	93	125	5.4	NA	27	22
ELF E (V/m)	0.48	0.92	0.57	NA	0.46	0.64
ELF H (mA/m)	513	486	48	NA	515	428

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.08	0.36	1.0
VLF H (mA/m)	3.8	8.3	38
ELF E (V/m)	0.27	0.32	0.53
ELF H (mA/m)	99	160	180

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.12
Finger touching screen	4.1
Hand placed flat on screen	53

Location: Lake City

Display type: IBM      VLF Sweep = 15.844 kHz      ELF Sweep = 60.02 Hz

Serial/station number: 30612/412

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	0.22	4.2	0.07	NA	0.14	0.24
VLF H (mA/m)	29	81	2.0	NA	18	15
ELF E (V/m)	1.3	1.0	0.76	NA	0.57	3.8
ELF H (mA/m)	471	483	138	NA	441	406

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.10	0.41	0.70
VLF H (mA/m)	13	3.5	19
ELF E (V/m)	0.32	0.44	1.4
ELF H (mA/m)	123	176	106

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.51
Finger touching screen	12
Hand placed flat on screen	122

Location: Marrero

Display type: CCI      VLF Sweep = 14.998 kHz      ELF Sweep = 45.73 Hz

Serial/station number: 06316/53

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	2.4	5.9	0.09	3.4	0.62	2.5
VLF H (mA/m)	134	143	8.81	81	78	105
ELF E (V/m)	3.9	2.2	0.64	2.4	1.3	7.5
ELF H (mA/m)	488	352	102	341	558	257

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.33	1.3	1.8
VLF H (mA/m)	19	20	38
ELF E (V/m)	0.30	0.71	1.2
ELF H (mA/m)	47	88	66

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	1.3
Finger touching screen	6.3
Hand placed flat on screen	46

Location: Marrero

Display type: CCI      VLF Sweep = 14.998 kHz      ELF Sweep = 45.73 Hz

Serial/station number: 06536/48

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	2.0	4.7	1.2	7.9	0.68	0.67
VLF H (mA/m)	185	136	13	128	168	92
ELF E (V/m)	3.6	4.0	1.6	8.0	1.3	11
ELF H (mA/m)	535	412	99	482	486	416

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.34	1.1	2.1
VLF H (mA/m)	27	41	104
ELF E (V/m)	0.36	2.1	3.3
ELF H (mA/m)	90	156	155

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	5.6
Finger touching screen	19
Hand placed flat on screen	84

Location: Marrero

Display type: CCI      VLF Sweep = 14.997 kHz      ELF Sweep = 45.72 Hz

Serial/station number: 94747/27

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	3.3	5.3	0.08	2.6	0.70	0.73
VLF H (mA/m)	132	125	6.0	80	91	-132
ELF E (V/m)	4.0	1.2	0.50	2.3	1.0	8.4
ELF H (mA/m)	498	342	101	522	514	199

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.66	1.2	2.2
VLF H (mA/m)	23	20	42
ELF E (V/m)	0.34	0.64	1.2
ELF H (mA/m)	72	83	101

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.49
Finger touching screen	6.6
Hand placed flat on screen	65

Location: Marrero

Display type: CCI      VLF Sweep = 14.997 kHz      ELF Sweep = 45.72 Hz

Serial/station number: 94840/17

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	3.6	5.2	0.08	3.3	0.84	0.89
VLF H (mA/m)	108	117	8.3	41	92	105
ELF E (V/m)	2.7	1.3	0.51	3.0	0.51	8.3
ELF H (mA/m)	459	304	90	337	513	210

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.82	1.3	1.4
VLF H (mA/m)	15	7.7	29
ELF E (V/m)	0.30	0.63	1.7
ELF H (mA/m)	76	77	88

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.34
Finger touching screen	10
Hand placed flat on screen	85

Location: Marrero

Display type: CCI      VLF Sweep = 14.997 kHz      ELF Sweep = 45.73 Hz

Serial/station number: 94883/49

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	2.9	4.4	0.08	2.7	0.61	0.81
VLF H (mA/m)	136	123	15	78	72	113
ELF E (V/m)	2.3	1.1	0.39	1.9	2.1	9.3
ELF H (mA/m)	415	321	79	300	590	532

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	1.1	1.1	1.42
VLF H (mA/m)	26	11	49
ELF E (V/m)	0.37	0.57	2.1
ELF H (mA/m)	95	123	130

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	15
Finger touching screen	22
Hand placed flat on screen	128

Location: Marrero

Display type: CCI      VLF Sweep = 14.997 kHz      ELF Sweep = 45.72 Hz

Serial/station number: 94961/18

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	3.6	6.0	0.10	3.4	1.2	0.54
VLF H (mA/m)	162	118	1.7	51	53	64
ELF E (V/m)	5.4	1.3	0.38	8.6	2.5	9.7
ELF H (mA/m)	445	368	33	384	570	311

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.99	1.7	2.6
VLF H (mA/m)	3.5	16	33
ELF E (V/m)	1.9	1.3	2.4
ELF H (mA/m)	71	103	120

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	15
Finger touching screen	25
Hand placed flat on screen	157

Location: Bogalusa

Display type: CCI      VLF Sweep = 14.690 kHz      ELF Sweep = 43.72 Hz

Serial/station number: 06504/44

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	4.1	1.9	0.08	1.9	0.56	1.3
VLF H (mA/m)	150	131	2.1	71	79	104
ELF E (V/m)	2.1	1.2	3.9	3.9	1.6	6.8
ELF H (mA/m)	505	365	97	306	662	613

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.19	0.55	0.64
VLF H (mA/m)	31	6.0	43
ELF E (V/m)	0.31	0.87	2.2
ELF H (mA/m)	72	114	115

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	0.66
Finger touching screen	280
Hand placed flat on screen	424

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Location: Bogalusa

Display type: CCI      VLF Sweep = 14.692 kHz      ELF Sweep = 43.73z

Serial/station number: 06526/22

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	2.8	5.1	0.14	1.4	0.49	0.96
VLF H (mA/m)	130	126	7.0	48	75	115
ELF E (V/m)	2.4	1.5	0.46	5.2	0.82	4.6
ELF H (mA/m)	459	355	82	310	431	266

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.44	2.0	2.3
VLF H (mA/m)	17	32	85
ELF E (V/m)	0.52	0.88	2.1
ELF H (mA/m)	56	113	107

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	14
Finger touching screen	23
Hand placed flat on screen	114

Location: Bogalusa

Display type: CCI      VLF Sweep = 14.690 kHz      ELF Sweep = 43.72 Hz

Serial/station number: 06782/45

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	2.8	5.6	0.1	1.5	0.56	1.5
VLF H (mA/m)	140	125	13	68	74	99
ELF E (V/m)	3.4	1.7	0.41	4.0	1.2	11
ELF H (mA/m)	511	347	91	387	472	531

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.39	0.83	1.5
VLF H (mA/m)	14	5.2	40
ELF E (V/m)	0.31	0.76	1.4
ELF H (mA/m)	95	117	135

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	11
Finger touching screen	18
Hand placed flat on screen	121

Location: Bogalusa

Display type: CCI      VLF Sweep = 14.697 kHz      ELF Sweep = 43.74 Hz

Serial/station number: Serial number undetermined/09

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	3.7	6.2	0.08	1.1	0.90	0.95
VLF H (mA/m)	4.7	130	8.1	66	72.7	81
ELF E (V/m)	2.6	2.0	0.41	2.4	0.95	11
ELF H (mA/m)	420	332	101	253	605	414

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.47	1.6	1.8
VLF H (mA/m)	17	21	60
ELF E (V/m)	0.41	1.2	2.0
ELF H (mA/m)	92	111	103

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	12
Finger touching screen	28
Hand placed flat on screen	150

Location: Bogalusa

Display type: CCI      VLF Sweep = 14.697 kHz      ELF Sweep = 43.74 Hz

Serial/station number: Serial number undetermined/16

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	2.0	3.7	0.09	8.0	0.48	0.72
VLF H (mA/m)	211	161	6.8	169	57	98
ELF E (V/m)	3.6	1.5	0.39	7.2	1.5	6.9
ELF H (mA/m)	525	413	108	335	592	399

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.31	1.1	1.2
VLF H (mA/m)	27	23	57
ELF E (V/m)	0.41	0.92	1.2
ELF H (mA/m)	102	135	135

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	15
Finger touching screen	16
Hand placed flat on screen	96

Location: Bogalusa

Display type: CCI      VLF Sweep = 14.702 kHz      ELF Sweep = 43.76 Hz

Serial/station number: Serial number undetermined/24

**Emission RMS Field Strength Values**

Field	Top	Front	Bottom	Back	Left	Right
VLF E (V/m)	3.3	1.4	0.13	1.6	0.40	0.40
VLF H (mA/m)	136	137	6.8	21	94	102
ELF E (V/m)	2.3	0.73	0.49	2.6	0.75	3.1
ELF H (mA/m)	409	298	86	338	570	309

**Operator Exposure RMS Field Strength Values**

Field	Abdomen	Chest	Face
VLF E (V/m)	0.19	0.46	0.74
VLF H (mA/m)	22	26	89
ELF E (V/m)	0.30	0.54	1.7
ELF H (mA/m)	48	73	55

**Operator RMS Induced Currents**

Hand Position	Induced Current (uA)
Hands on keyboard	9.5
Finger touching screen	166
Hand placed flat on screen	400

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