NIOSH HEALTH HAZARD EVALUATION REPORT

HETA #2001-0153-2994
Naval Computer and Telecommunications Station
Cutler, Maine

March 2006

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

The Hazard Evaluation and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employers or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by David Sylvain, John Cardarelli and Debra Feldman of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS); and W. Gregory Lotz and David Conover of the Division of Applied Research and Technology (DART). Field assistance was provided by Debra Feldman (medical support), and David Conover (analytical support). Desktop publishing was performed by Robin Smith. Editorial assistance was provided by Ellen Galloway.

Copies of this report have been sent to employee and management representatives at the Cutler Naval Station and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. The report may be viewed and printed from the following internet address: http://www.cdc.gov/niosh/hhe. Copies may be purchased from the National

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Highlights of the NIOSH Health Hazard Evaluation

On February 2, 2001, the American Federation of Government Employees Local 2635 submitted a health hazard evaluation request on behalf of civilian employees at the Naval Computer and Telecommunications Station, Cutler, Maine. The request indicated that electronics workers, technicians, antenna workers, and administrative staff were exposed to radiofrequency (RF) electromagnetic fields (EMF) in the antenna fields and on the transmitter decks. The request also noted that employees suspected that they were incurring eye injuries as a result of exposure to RF fields.

What NIOSH Did

- We measured RF fields and body currents in transmitter buildings and antenna fields.
- We reviewed reports of previous RF radiation hazard surveys at NCTS Cutler.
- We examined medical records, and interviewed employees about health problems related to work..

What NIOSH Found

- RF fields and body currents were well below occupational guidelines in VLF and HF transmitter buildings, and in the HF antenna field.
- The spatial average E-field strength beneath VLF (24 kHz) downleads in the north array exceeded occupational guidelines in four locations.
- The 24 kHz fields at NCTS Cutler can cause shocks and burns in workers who touch conductive objects in the fields.
- The IEEE Exclusion should not be applied to VLF exposures at NCTS Cutler.

What NCTS Managers Can Do

- Advise employees, security staff, contractors, and visitors of potential exposures in VLF antenna arrays.
- Restrict access to, and post warning signs at, all locations where VLF spatial average E-field
- Periodically measure electric and magnetic field strengths as well as induced and contact currents in areas that could be occupied by workers.
- Provide radiation safety training for all personnel (including those not normally considered radiation workers) who perform duties that might require them to go near or into areas where VLF electric field strengths may exceed the MPE.

What the NCTS Employees Can Do

- Do not remain beneath VLF downleads any longer than is absolutely necessary.
- Report all shocks and burns to the Technical Director

CDC Workplace Safety and Health

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for HETA Report #2005-0153-2994

NIOSH

Health Hazard Evaluation Report 2001-0153-2994
Naval Computer and Telecommunications Station
Cutler, Maine
March 2006

David C.Sylvain, M.S., CIH
John J. Cardarelli, Ph.D., CHP, CIH, PE
W. Gregory Lotz, Ph.D.
David L. Conover, Ph.D.
Debra Feldman, MD

SUMMARY

On February 2, 2001, the American Federation of Government Employees (AFGE) Local 2635 submitted a health hazard evaluation (HHE) request on behalf of civilian employees at the Naval Computer and Telecommunications Station (NCTS), Cutler, Maine. The request indicated that electronics workers, technicians, antenna workers, and administrative staff were exposed to radiofrequency (RF) electromagnetic fields (EMF) in the antenna fields and on the transmitter decks. The request noted that employees suspected that they were incurring eye injuries as a result of exposure to RF fields.

In response to the HHE request, a NIOSH team of two industrial hygienists, two research physicists, and a physician conducted a site visit on May 14-16, 2002. During the site visit, the industrial hygienists and physicists conducted environmental monitoring to characterize exposures to electromagnetic radiation at various locations throughout the facility. The NIOSH physician reviewed employee medical records and Occupational Safety and Health Administration (OSHA) Illness and Injury Logs, and conducted the confidential employee interviews on May 15-16, 2002. On October 15, 2002, the NIOSH industrial hygienists returned to the site to characterize very low frequency (VLF) electric fields beneath antenna downleads.

In May 2002, worker exposures to RF fields in the high frequency (HF) transmitter building (Building 400) and antenna field were well below the Institute of Electrical and Electronics Engineers (IEEE) recommendations for occupational (controlled) environments. Field strength measurements were below occupational exposure limits in locations accessible to employees (most were below the limit of detection). Induced and contact currents (wrist and ankle) were nondetectable in the HF transmitter building, and well below IEEE limits at fence lines around HF antennas.

Data from the May 2002 site visit indicate that workers in the VLF transmitter Control Room (T-Deck, Building 100) were not overexposed to electric fields (E-fields) while performing their duties. All spatial average E-field measurements in the VLF Control Room were well below the IEEE exposure limits.

During the October 2002 visit, spatial average E-field strength beneath VLF downleads in the north array exceeded the IEEE maximum permissible exposure (MPE) of 614 volts per meter (V/m) in four locations

approximately 60 feet from the helix house. Wrist and ankle currents at these four locations were well below IEEE limits, as were magnetic flux field measurements.

The 24 kHz fields at NCTS Cutler can cause potentially hazardous RF shocks in workers who touch conductive objects such as vehicles, fencing, metal roofing, supporting guy wire metallic cables, and metallic rigging cables used during painting and maintenance. Effective measures should be taken to reduce potential shock hazards when workers could touch conductive objects in VLF fields.

Worker interviews, medical records, and the OSHA Log did not reveal any findings that could be related to workplace exposures. Health problems reported during confidential employee interviews were not consistent with health problems associated with EMF exposure and presented no consistent pattern.

NIOSH investigators conducted an extensive review of the IEEE "exclusion rule" as it pertains to VLF exposures at NCTS Cutler. (The exclusion rule specifies conditions under which workers may be exposed to electromagnetic field strengths exceeding the MPE.) NIOSH concluded that the exclusion rule (IEEE C95.1 1999, Section 4.2.1) should not be applied at NCTS Cutler where VLF electric field strength exceeds the MPE, i.e., MPEs for field strengths **and** body currents (contact and induced) must be met.

Although no exposure-related health problems were identified, NIOSH investigators concluded that the potential exists for exposure to E-field strengths beneath VLF arrays which exceed the IEEE MPE, and that VLF E-fields can cause potentially hazardous RF shocks in workers who touch metallic objects. Recommendations are provided in this report for training employees, restricting access to areas where RF fields exceeding MPEs may be present, posting warning signs, conducting monitoring, and reporting burns and shocks.

Keywords: NAICS 928110, SIC 9711 (national security). Electromagnetic fields (EMF), nonionizing radiation, radiofrequency radiation, RF, high frequency radiation (HF), very low frequency radiation (VLF), U. S. Navy, telecommunications

Table of Contents

INTRODUCTION

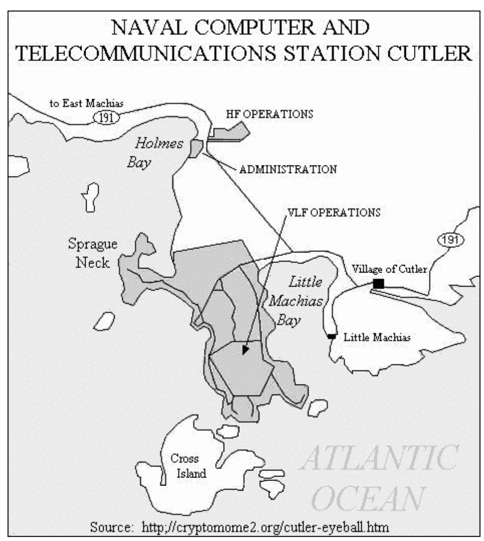
On February 2, 2001, the American Federation of Government Employees (AFGE) Local 2635 submitted a health hazard evaluation (HHE) request on behalf of civilian employees at the Naval Computer and Telecommunications Station (NCTS), Cutler, Maine. The request indicated that electronics workers, technicians, antenna workers, and administrative staff were exposed to radiofrequency (RF) electromagnetic fields (EMF) in the antenna fields and on the transmitter decks. Eye injuries were suspected as a result of exposure to RF fields.

After receiving the HHE request, NIOSH investigators were informed that employees were also concerned that the Navy was using an "exclusion" that allows workers to be exposed to very low frequency (VLF) electric fields at levels which exceed the maximum permissible exposure (MPE) established by the Institute of Electrical and Electronics Engineers (IEEE). In response to employees' concern, the Navy requested an interpretation from the IEEE Interpretations Committee. In August 2000, the Navy received a letter of interpretation (see Appendix); however, the letter failed to resolve the controversy regarding the use of Section 4.2.1 of IEEE C95.1-1999 (i.e., "exclusion rule") as it pertains to VLF exposures at Cutler.

In response to the HHE request, a NIOSH team of two industrial hygienists, two research physicists, and a physician conducted a site visit on May 14-16, 2002. During the site visit, the industrial hygienists and physicists conducted environmental monitoring to characterize exposures to electromagnetic radiation at various locations throughout the facility. The NIOSH physician reviewed employee medical records and the Occupational Safety and Health Administration (OSHA) Illness and Injury Logs and conducted confidential employee interviews on May 15-16, 2002. On October 15, 2002, the NIOSH industrial hygienists returned to the site to characterize VLF electric fields and induced body currents beneath antenna downleads.

BACKGROUND

NCTS Cutler was established on the Maine coast in the early 1960s to provide a communications link with U.S. Navy submarines, ships, and aircraft deployed throughout the Atlantic Ocean, Arctic Ocean, and Mediterranean Sea. The facility contains at least 19 high-frequency (HF; 3 to 30 megahertz (MHz)) antennas and two very-low frequency (VLF; 3 to 30 kilohertz (kHz)) antennas. Since the departure of uniformed Navy personnel in 2000, the communications facility has been operated solely by civilian Navy employees.



At the time of the NIOSH evaluation, NCTS Cutler was staffed and operated by 80 civilian employees, of whom approximately 24 were identified as potentially exposed to RF. These employees work in Building 100, which houses the VLF transmitter (10-12 workers); Building 400, which houses the high-frequency (HF) transmitter (2 workers); and the HF and VLF antenna fields (10 antenna mechanics). Individuals in the fire department, site security, and facilities were identified as having jobs which appeared to involve lesser potential for exposure to RF. These individuals are required to enter the transmitter buildings and antenna fields while performing "rounds," or other duties. The rest of the employees perform administrative and support functions which do not involve RF equipment, or require them to enter areas near RF sources.

The HF transmitter building and antenna field occupy several acres in the vicinity of former Navy housing and support buildings. The HF transmitter broadcasts a ≤ 10 kilowatt (kW) signal at frequencies between 2 and 24 MHz (3 kW when operated at low power). The signals are sent via a system of 19 HF antennas.

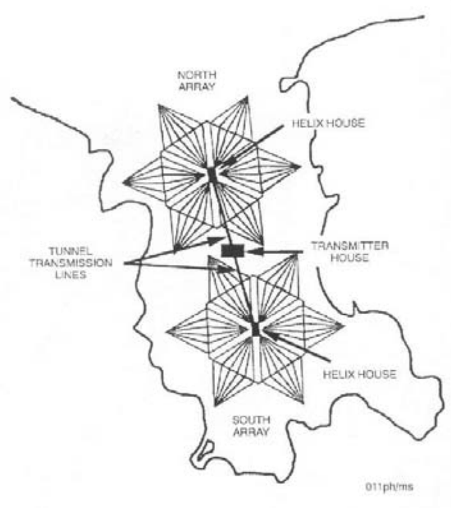


Figure 1. VLF Cutler.

The VLF transmitter broadcasts a ≤ 750 kW signal, at a frequency of approximately 24 kHz. The VLF signal is sent via two star-shaped antenna arrays, located on a 2000-acre peninsula several miles from the HF antenna field (figure 1). Each array is greater than one mile wide; together the two arrays occupy most of the peninsula. At the center of each array is a helix house, which receives the signal from the transmitter located in the "bow-tie area" between the arrays. The signal passes from the helix house to diamond-shaped panels which are suspended between 13 towers in each array. The RF current is carried by 8 cables (conductors) which extend outward from the center of each array. The conductors are supported by a cable which crosses each panel at the center of the diamond.[1] The towers, which are approximately 900 feet in height, are accompanied by a system of 200-foot towers, winches, and counterweights which are used to elevate and support the panels.

Typically, only one array is active at any given time during the summer. During the winter months, signals are broadcast using both arrays. Normally, all 6 panels of the active array are used to broadcast the signal; however, an array may be operated in 4-panel mode if there has been an equipment failure or malfunction, or if maintenance is being performed on an array.

Health Effects of Exposure to Radiofrequency Radiation

Much of what is known about RF biological effects pertains to acute exposure; relatively little is known about the effects of long-term low-level RF exposure. Human and animal studies show that exposure to RF fields above occupational exposure limits may cause harmful biological effects which are accompanied by heating of internal tissues. The extent of heating depends primarily on the RF frequency, intensity of the RF field, and duration of exposure. The incidence and severity of effects of exposure to RF are related to the rate of RF energy absorption in the body, which is referred to as the specific absorption rate (SAR). The SAR is measured in watts per kilogram (W/kg) for the whole body or parts of the body. The SAR depends on many factors, such as the frequency and field strength, size and shape of the exposed worker, and the worker's orientation in the radiation field.[2,3] The human body has a maximum absorption rate in the frequency range from 30 to 300 MHz; outside of this range, the energy absorption rate in the body is much less.

Some researchers have reported that absorption of RF radiation may result in nonthermal effects which occur without a measurable increase in tissue temperature, and at RF field strengths lower than those which cause thermal effects.[4,5] As noted in IEEE C95.1-1999, nonthermal mechanisms, such as the electro-stimulation of excitable cells (nerve stimulation) become important at frequencies between 3 kHz and 100 kHz. Research suggests that fields less than 30 kHz could cause significant biological responses by stimulating the nervous or cardiac systems.[6,7]

Exposure to RF radiation below 0.1 MHz requires special consideration and treatment to prevent electrical shock; induction of RF currents in conductive objects may induce currents through the body of an individual who contacts them. The amount of current that flows through a body depends on how well the individual is electrically grounded and the impedance between the source and the individual.

METHODS

Environmental High Frequency Exposure Assessment

Prior to conducting the onsite visits, NIOSH investigators obtained reports of RF radiation hazard surveys conducted at NCTS Cutler by the Space and Naval Warfare Systems Center (SPAWAR). The reports were reviewed to assess the nature and extent of potential exposures that were characterized during numerous SPAWAR surveys.

In May 2002, NIOSH investigators measured electric (E) and magnetic (H) field strengths for all operating HF transmitters in the HF transmitter building (Building 400) and along the fences around individual HF antennas. All HF transmitters surveyed were operating in the low power mode (3 kW). Measurements inside the transmitter building were obtained on all accessible surfaces of power amplifiers (and related equipment), along the waveguides and at waveguide flanges/couplings, at the mechanical switching matrix (transmitter input and matrix output connectors), and at the point where the antenna Heliax® cable penetrates the outside building wall. The HF transmitter exposure measurement results within the HF transmitter building are presented in Table 1; the results at the HF antennas are presented in Table 2.

Electric Fields

HF electric field strength (E-field) was measured with a Holaday Industries Model HI-3003 meter and Model STE probe. The E-field probe operates in the frequency range of 0.5 to 6000 megahertz (MHz), and measures the E-field in units of square volts per square meter (V^2/m^2). The lower limit of detection for this probe-meter combination is 500 V^2/m^2.

Magnetic Fields

HF magnetic field strength (H-field) was measured with a Holaday Industries Model HI-3003 meter and Model CH probe. The H-field probe operates in the frequency range of 5 to 300 MHz, and provides measurements in units of square amperes per square meter (A^2/m^2). The lower limit of detection for this probe-meter combination is 0.005 A^2/m^2. Electric and magnetic field strengths were surveyed in areas which could be occupied by workers. The maximum field strength obtained during each measurement was recorded.

Induced and Contact Body Currents

Induced and contact body currents were measured at the wrist and ankle at various locations in the HF transmitter building and at the fence line around each operating HF antenna; the maximum current obtained during each measurement was recorded. Body current measurement technology is based on the principle that when RF energy is absorbed, RF currents are induced within the body. During this investigation, wrist and ankle currents were evaluated using a Mission Research Corporation Model MG-4501 body-current detector system which uses a sensor designed to fit around either the ankle or wrist. This system operates from 0.5 to 150 MHz with a dynamic range of 1 to 1000 milliamperes (mA). The lower limit of detection for the current sensor is 1 mA.Very Low Frequency Exposure Assessment

Electric Fields: Transmitter Building

E-field strength in the VLF transmitter building (Building 100) was evaluated using a Holaday Industries Model HI-3603 single-axis meter with a Model HI-3616 remote fiber-optic readout. The E-field meter operates in a frequency range of 2 to 300 kHz, and has a dynamic range of 1 to 2000 V/m. The lower limit of detection for this meter is 0.1 V/m. The maximum E-field strength level obtained during each measurement was recorded.

A dielectric (Plexiglas®) holder was used to support the field meter while making VLF E-field strength measurements. By using the remote fiber-optic readout and dielectric holder, neither the surveyor's body nor a metal probe holder (e.g., photographic tripod) were in the field during measurements. The fiber-optic connection allowed investigators to remain approximately four meters from the measurement location. Use of the remote readout and dielectric holder improved measurement accuracy by minimizing E-field perturbation.

E-field measurements were taken in all three orthogonal planes at distances of 23, 46, and 152 centimeters (cm) [9, 18, and 60 inches] from the cabinet doors which enclosed VLF power amplifiers #2, #3, and #4 (Photo 1). At each location, measurements were taken at heights of 69, 107, and 145 cm (27, 42, and 57 inches) above the floor. For each bank of power amplifiers (#2, #3, and #4), measurements were made in 6 vertical columns (designated as columns A through F). The measurement orientations were: vertical (E-field directed up and down), parallel (E-field parallel to the floor and the face of power amplifier cabinet doors), and perpendicular (E-field parallel to the floor and perpendicular to the cabinet doors). A composite E-field strength measurement was calculated from the three orthogonal measurements by taking the square root of the sum of the squares of the three orthogonal E-field strength measurements. The spatial average (from 69 to 145 cm) for each vertical column (A-F) was calculated for each separation distance (23, 46, and 152 cm) by summing the three composite readings (at 69, 107, and 145 cm above the floor) and dividing by three.

In response to an employee request, additional E-field measurements were conducted at the centerline of some windows in front of power amplifier bank #4. (Previous measurements were made along vertical columns at the left or right side of a door face, as shown in Photo 1.) E-field measurements were taken at separation distances of 23, 46, and 152 cm from the glass windows in the doors. At the 23-cm separation distance, measurements were taken at 69, 107, and 145 cm above the floor for windows #1-#4. Composite field strengths and spatial averages were calculated for the 23-cm separation distance. At separation distances of 46 and 152 cm, measurements were taken only at 145 cm above the floor and only at window #1. Thus, only composite E-field strengths could be determined at the 46 and 152 cm separation distances (spatial average estimates could not be calculated at these distances).

VLF E-field strengths were measured at the T-Deck Central Command center and in the Copper House (Combiner Room). For the T-Deck Central Command center and nearby workbench, measurements were taken at 69, 107, and 145 cm above the floor. Composite field strengths and spatial averages were calculated. In the Copper House, measurements were taken only at 145 cm above the floor; thus, spatial average estimates could not be determined.

Electric Fields: North Array

During the second site visit in October 2002, NIOSH investigators conducted VLF E-field and body current measurements beneath downleads in the North Array. Measurements were made while the North Array was operating in 4-panel mode at 494 kW, 1,700 amps radiated power. E-field strength was measured with a Holaday Industries Model HI-3638 ELF/VLF single axis electric field meter with HI-4416 remote fiber-optic readout. Measurements were made with the VLF E-field meter (2 to 400 kHz frequency range) which has a dynamic range of 1 – 40,000 V/m. The lower limit of detection for this meter is 1 V/m. A dielectric (Plexiglas®) holder was used to support the field meter while making VLF E-field strength measurements (Photo 2). Three orthogonal E-field strength measurements (vertical, perpendicular, parallel) were made at three heights (91, 124, and 157 cm above ground level) at four locations beneath downleads. The maximum field strength for each orthogonal measurement was recorded and used to calculate composite E-field strengths and spatial averages. Due to time constraints, additional measurements were made at the 124-cm height only. Since vertical E-field strengths were the highest beneath the downleads, screening measurements were made in the vertical orientation to identify the boundaries of areas where E-field strengths exceeded 614 V/m (IEEE recommended exposure limit). Additional E-field screening measurements were made in the vicinity of the painters' shack near the North Helix House.

Induced body current measurements

Induced body currents were measured at the wrist and ankle at the four locations where E-field spatial averages were determined. Ankle and wrist currents were evaluated using Holaday Industries Model HI-3702 clamp-on induced current meter, with an HI-4416 remote fiber-optic system readout. The HI-3702 measures RF induced body currents using a clamp-on current sensor providing accurate readings in any position. The HI-3702 uses fiber optic technology to eliminate perturbations of the field, and a thermally-based true RMS-DC converter circuit. The frequency response from 9 kHz to 110,000 kHz covers the major part of ANSI/IEEE C95.1-1991 frequency range. The dynamic range is from 2 to 1000 milliamps. The lower limit of detection for this meter and sensor is 2 mA. The maximum induced current level obtained during each measurement was recorded.

Magnetic Fields

Magnetic field strength was measured in the VLF transmitter building with a Holaday Industries Model HI-3637 isotropic VLF magnetic field meter. The H-field probe operates in the frequency range of 2 to 400 kHz, with a dynamic range of 6 nanotesla (nT) to 400,000 nT [0.06 milligauss (mG) to 4,000 mG]. The lower limit of detection for the sensor is 6 nT. Magnetic field strengths were surveyed either touching or at 20.3 to 25.4 cm (8 to 10 inches) from the cabinet door windows of operating power amplifiers. The maximum H-field strength measured at each window was recorded.

Medical

On May 15 and 16, 2002, the NIOSH physician was available for confidential medical interviews with any worker on or offsite. The physician reviewed the Occupational Safety and Health Administration (OSHA) Illness and Injury Logs for the site, and medical records for riggers/antenna workers in Building 100. These records for eleven workers were selected for review because this job classification was reported to have the highest potential exposure to E- and H-fields; thus, these workers were expected to be at greatest risk of experiencing adverse health effects. The medical records for other electronics workers, technicians, and administrative staff were not reviewed because E- and H-field strength measurements, and field observations, indicated that potential EMF exposures for these individuals were nondetectable, or below occupational guidelines; thus, even if health abnormalities were found among these workers, a workplace relationship could not have been determined.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended

Exposure Limits (RELs),[8] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[9] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[10]

Guidelines for limiting RF exposure have been developed by several voluntary organizations and government agencies in the United States and elsewhere.[2,11,12,13] Three fundamental concepts that apply to these guidelines are: (1) understanding the difference between ***emission*** and ***exposure*** limits; (2) spatial averaging; and (3) time averaging.

Emission vs. Exposure Limits

Emission limits are the maximum power output authorized by the Federal Communications Commission (FCC) for companies or individuals who apply for a license to transmit signals (e.g., radio and television stations, amateur radio operators). It is important to note that transmitting signals are often not emitted at the maximum power output; therefore, the emission limit (maximum power output) may not be directly related to specific exposure measurements in the field. (Note: the FCC does not have jurisdiction over transmitting facilities operated by the Federal government.)

Exposure limits apply to workers and the general public, and are designed to prevent harmful effects from exposure to electromagnetic radiation (such as RF). Unlike emission limits, exposure limits are relevant only to locations that are accessible to workers or the public. Exposures can often be controlled by (1) limiting or restricting access to areas by appropriate means (e.g., fences, warning signs, etc), (2) instituting procedures that restrict the time an individual could be near an RF source, or (3) requiring that work on or near such sources be performed while the transmitter is turned off or while power is appropriately reduced.

Spatial Averaging

The exposure limits shown in Table 3 are based on a ***whole-body*** averaged SAR. A spatially-averaged RF field is accepted as the most accurate estimate to compare to exposure guidelines. This means that ***spot measurements*** exceeding the stated exposure limits do not imply noncompliance if the spatial average of RF fields over the body does not exceed the limits. Further discussion of spatial averaging as it relates to field measurements can be found in Section 3 of FCC Bulletin 65,[14] and in the reference documents of the American National Standards Institute/Institute of Electrical and Electronics Engineers (ANSI/IEEE), and the National Council on Radiation Protection and Measurements (NCRP).

Time Averaging

Another feature of exposure guidelines is that exposures may be averaged over specific time periods, with the average not to exceed the limit for continuous exposure. To properly apply field measurements to the exposure limits, one must consider the length of time the individual is exposed. For example, during any given six-minute period, workers could be exposed to twice the applicable limit for three minutes as long as they were not exposed at all for the preceding or following three minutes. Similarly, a worker could be exposed at three times the limit for two minutes as long as no exposure occurs during the preceding or subsequent four minutes.

Occupational Exposure Limits

OSHA requires each employer to furnish employees a place of employment that is free from recognized hazards that cause, or are likely to cause, death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Although not all hazardous chemicals or physical agents have specific OSHA exposure limits, employers are required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

OSHA has limited exposure criteria for controlling occupational exposure to RF and NIOSH has none. Because the OSHA RF Standard has not been revised since it was established in June 1974, it does not incorporate the most up-to-date information. For example, the OSHA RF Standard does not address the fact that biological effects of RF are frequency dependent, a fact which is noted in the ACGIH TLVs® for Radiofrequency and Microwave Radiation[3] and the IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz (IEEE C95.1-1999).[2] In 2001, the ACGIH TLVs® were revised to reflect the same criteria as IEEE C95.1-1999.[3]

The IEEE Standard is widely referenced in regard to occupational exposure to RF. The IEEE subcommittee, which prepared IEEE C95.1-1999, concluded that an SAR of 4 W/kg represents the energy absorption rate above which adverse health effects may occur.[2] In terms of human metabolic heat production, 4 W/kg represents a moderate activity level (e.g., housecleaning or driving a truck) and falls well within the normal range of human thermoregulation. A safety factor of 10 was incorporated to give an SAR of 0.4 W/kg as the maximum permissible energy absorption rate, averaged over the entire body. The guideline uses dosimetry data to calculate the electric and magnetic field strength limits at a specified frequency necessary to achieve an SAR of 0.4 W/kg when averaged over a 0.1 hour (6 minute) period for occupational exposures. The resulting maximum permissible exposure (MPE) for occupational settings is 614 V/m for electric fields at frequencies between 0.003 and 3.0 MHz.[2]

Induced current occurs in freestanding workers who are not in contact with metallic objects; contact current occurs when a worker touches a metallic object. For frequencies in the range of 0.1 to 100 MHz, IEEE adopted an induced and contact current limit of 100 mA for ankles or wrists. This value limits the partial-body SAR to levels less than 20 W/kg in the extremities, and protects against RF shocks and burns. From 0.1 to 100 MHz, induced and contact current measurements (squared values) are averaged over any 6-minute period to determine compliance with the 100 mA limit. Induced and contact currents also have a ceiling value of 500 mA (with no time averaging) to protect against RF shocks and burns.

Electro-stimulation of biological tissues is the dominant effect for exposures to frequencies below 0.1 MHz; thus, the primary exposure parameter below 0.1 MHz is internal body current rather than RF field strength.[2] For frequencies in the range of 0.003 to 0.1 MHz, the IEEE committee has adopted an induced and contact current limit for occupational (controlled) exposure of 1000(f) mA for ankles or wrists, where "f" is the frequency in MHz. For example, for occupational (controlled) exposure at 24 kHz, the induced and contact current limit is 24 mA. From 0.003 to 0.1 MHz, induced and contact current measurements (squared values) are averaged over any 1-second period to determine compliance with the 1000(f) mA limit. As noted in the IEEE Standard, induced and contact current limits may not provide adequate protection against startle reactions and burns due to transient discharges that may occur when making or breaking contact with an energized object.

The IEEE C95.1-1999 exposure guidelines for controlled environments have been applied for this HHE. Controlled exposure limits apply to persons exposed as a consequence of their employment, provided they are fully aware of the potential for exposure and can exercise control over their exposure. For workers who lack awareness, safety training, or control, the uncontrolled exposure limits prescribed for the general population are applied. Uncontrolled exposure limits apply to situations in which the general public may be exposed, or in which persons are exposed as a consequence of their employment but may not be fully aware of the potential for exposure or can not exercise control over their exposure. Regardless of which category is used, the consensus of the scientific community is that exposure to RF radiation below recommended guidelines is safe.

RESULTS

HF Transmitter Building and Antenna Field

Electric and magnetic field strengths, as well as induced and contact currents, were measured in areas that could be occupied by workers. A "worst-case" assumption was made that workers would be exposed continuously to HF sources during any 6-minute averaging period.

Inside the HF transmitter building, the electric and magnetic field strengths were nondetectable, i.e., below 22 V/m and 0.07 A/m (500 V^2/m^2 and 0.005 A^2/m^2, respectively) (Table 1). At the HF antenna sites, the magnetic field strength was nondetectable, and the electric field strength ranged from nondetectable to 70 V/m (5000 V^2/m^2) (Table 2). All electric and magnetic field strength levels were below the IEEE occupational (controlled) exposure limits (Table 3).

Induced and contact currents (wrist and ankle) inside the HF transmitter building were below the limit of detection, i.e., less than 1 mA (Table 1). At the HF antenna sites, current levels ranged from nondetectable to 20.6 mA (Table 2), which are below the IEEE occupational (controlled) exposure limit of 100 mA.

VLF Transmitter Building and Antenna Field

VLF (24 kHz) E-field strength was measured at the power amplifier banks in the VLF Transmitter Control Room and Copper House. The VLF sources were on continuously during any 6-minute time period; therefore, electric field strength measurements did not need to be corrected for duty factor. Power amplifier bank measurements were made along the sides (left and right) of door faces, and along the centerline of door faces in response to an employee request.

Along the sides of door faces for power amplifier banks #2 to #4, the spatial average E-field strength for the power amplifier banks ranged from 115.0 to 4.5 V/m (23 cm to 152 cm separation distances, respectively) (Table 6 and Figure 2). The spatial average values decreased with increasing separation distance from the door face (i.e., 23, 46, and 152 cm from door). The spatial average values for the power amplifier banks were below the occupational (controlled) exposure limit of 614 V/m.

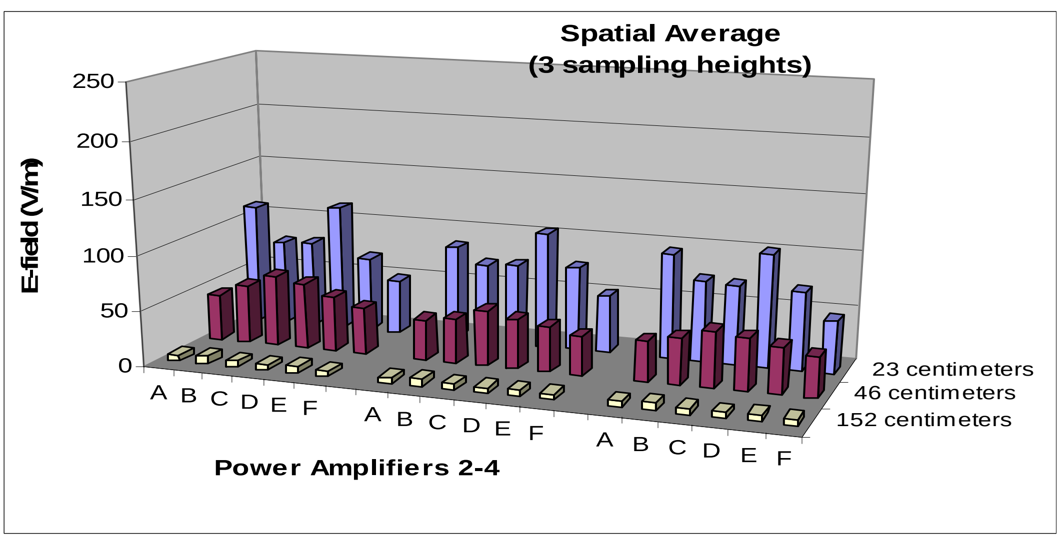


Figure 2.

Along the centerline of door faces for power amplifier bank #4, spatial average values ranged from 246.1 to 210.4 V/m at 23 cm from windows #1 - #4. These spatial averages are below the IEEE MPE of 614 V/m. For separation distances of 46 and 152 cm from window #1, measurements were only taken at 145 cm above the floor. Thus, spatial averages could not be determined. Likewise, spatial averages could not be determined for measurements (with only one field orientation i.e., perpendicular) at 23 and 46 cm from windows #1 - #4.

VLF E-field strength was also measured in the VLF transmitter control room at the T-Deck Command Center and nearby workbench (Photos #3 and #4), and in the Copper House. The spatial average was 0.2 V/m at the T-Deck Command Center and the workbench, which is close to the detection limit (0.1 V/m) of the meter used in these measurements. In the Copper House, the composite E-field strength (at 145 cm above the floor) was 80.9 V/m at the T-15 Light Switch (Photo #5), 50.9 V/m at the T16 Service Phone Jack, and 3.5 V/m at Compressor 1 (Photo #6). The spatial average values for the T-Deck Command Center and workbench are below the IEEE C95.1 MPE of 614 V/m. Measurements taken in the Copper House are also below the MPE.

The spatial average VLF E-field strengths and induced body currents measured beneath downleads in the North Array are presented in Tables 4 and 5. VLF spatial average E-fields ranged from 842 V/m to 922 V/m in four locations. All these values exceed the IEEE E-field strength limit of 614 V/m. The ankle current measured at these four locations ranged from 1.64 mA in an individual standing with arms at his sides, to 3.5 mA while standing on one foot with both arms raised (Photos #7, #8, #9). Wrist currents in all postures ranged from 1.02 mA to 1.47 mA. Magnetic flux field measurements ranged between 8 microtesla (μT) and 10 μT (80 mG to 100 mG), well below the occupational limit of 1000 μT (10,000 mG).

Medical

Six workers chose to meet with the NIOSH physician for confidential directed interviews. The interviewed workers were from a variety of occupations, including firefighter, environmental engineer, and mechanic. Length of employment at NCTS Cutler of those interviewed ranged from five to 32 years. Workers were asked about health problems that they attributed to the worksite.

Four workers reported having health problems that they attributed to the workplace; two workers denied any health problems related to their work. The health problems attributed to the workplace by those interviewed included inflammatory joint disease, multiple myeloma (a type of bone marrow cancer), headaches, dizziness/vertigo, and intermittent visual disturbances. There was concern by some of those interviewed that other workers may have work-related problems, including cancer, eye problems, and work-related stress problems (such as post-traumatic stress syndrome). None of the interviewed employees reported increased absences from work or changing jobs, work areas, or work practices as a result of health problems.

Review of the eleven riggers/antenna workers' medical records did not reveal any findings that could be related to the workplace, or to exposure to EMF. The NIOSH physician read the electrocardiograms (ECGs) in the medical records using standard clinical criteria.[15] The review of the electrocardiogram reports found no consistent pattern of clinically significant cardiac arrhythmias or changes. Sinus arrhythmia was found in four ECGs. Sinus arrhythmia is one of the most common arrhythmias and, in the majority of people, is a harmless normal variant. While the NIOSH physician also found a "left anterior hemiblock," and "nonspecific ST and T wave changes," (read by a cardiologist as "silent myocardial infarction") there was no consistent pattern of changes when looking at the overall reports.

The review of the OSHA logs did not reveal any entries that were related to HF or VLF exposure. The health problems that were reported during the interviews presented no consistent pattern which appeared to be related to exposure in the workplace.

DISCUSSION

The NIOSH site visit in May 2002 found worker exposures to RF fields in the HF transmitter building (Building 400) and antenna field to be well below IEEE recommendations for occupational (controlled) environments. Field strength measurements were below occupational exposure limits in locations accessible to employees (most were below the limit of detection). Induced and contact currents (wrist and ankle) were nondetectable in the HF transmitter building and well below IEEE limits at fence lines around HF antennas.

Survey data indicate that workers in the VLF transmitter Control Room (T-Deck, Building 100) are not overexposed to E-fields while performing their duties. All spatial average E-field measurements in the Control Room were well below the IEEE exposure limits. Although spatial averages are not available at 46 and 152 cm distances, comparison of composite field strengths measured at these distances at amplifier #1 demonstrates the rapid decrease in field strength that occurs with increasing distance. It should be noted that the sampling locations, although accessible to workers, are not areas where workers would remain for the full 6-minute period on which the IEEE MPEs are based; thus, actual time-weighted worker exposures to E-fields emitted by the power amplifiers are expected to be much less than the spatial averages which were measured during this survey.

Spatial averages at the T-Deck Command Center and work bench were both 0.2 V/m, which clearly indicate that RF exposures are insignificant at these locations. In the Combiner Room (Copper House), composite measurements were made in three locations at a height of 145 cm, approximately one foot from the chain link fence. Composite measurements of 3.5, 51, and 81 V/m were made at compressor #1, T-16 phone jack, and T-15 light switch respectively. These measurements suggest that spatial average field strengths are well below the MPE at floor level in the Combiner Room. An employee noted that, on one occasion, he had been directed to climb a ladder above the height of the fence in the Combiner Room to perform a work task. Because E-field measurements were not made above the fence during this survey, it is unclear whether the worker's exposure may have been significantly greater when he climbed above the fence. However, the report of a worker being instructed to climb a ladder above the fence appeared to indicate a need for training supervisors and employees regarding the hazards of VLF exposure, as well as implementing standard operating procedures (SOPs) to prevent unnecessary exposures.

Spatial average E-field strength beneath VLF downleads in the north array exceeded the IEEE C95.1 MPE of 614 V/m in four locations approximately 60 feet from the helix house. According to information available to the NIOSH team, the areas where NIOSH measured E-field strengths above the MPE are not commonly occupied by workers. A key point regarding this finding is that high field strength does not necessarily imply worker overexposure; an individual must be present in the field for a sufficient period of time for an overexposure to occur. Nevertheless, these are areas that are *accessible* to workers, such as security officers, maintenance staff, and groundskeepers. It was reported that security officers sometimes park near the helix building and remain in the parked vehicle. Warning signs should be posted to alert workers of the possible presence of elevated E-fields; physical barriers (e.g., fencing) should be used to demarcate areas where excessive E-fields could be present. In order to establish the boundaries of areas where E-field strengths may exceed the MPE, monitoring should be conducted under various combinations of operational parameters and weather conditions to determine the "worst case" scenario. Operational parameters that should be considered include operational mode (6-panel versus 4-

panel), power output, and amperage. Variations in these parameters are likely to result in changes in the exact location and strength of E-fields beneath the downleads.

Although workers expressed concern that they might be exposed to elevated RF fields during 4-panel operation, most people in Building 100 are not likely to be exposed to any fields above background regardless of what mode the system was operating in. Operating in 4-panel mode, or using higher power on a single array, affects only a few small areas on the site; in these areas, work practice precautions are needed to ensure that worker exposures remain below the MPE. These modes of operation do increase field strengths in some limited areas (e.g. bow-tie area and downlead area), but they do not turn low exposure areas of the facility into high exposure areas.

With one exception, all interviewed workers expressed concern about what they considered to be inadequate "worker safety" and "workplace hygiene" training (in addition to 6 formal medical interviews, the NIOSH physician conducted approximately 15 informal interviews/conversations). A major concern expressed by employees was that, prior to the departure of uniformed Navy personnel from the base, a regular schedule of formal health and safety training had existed for all personnel; however, this formal training had been discontinued following the departure of uniformed personnel. Interviewed workers described dissatisfaction with the current safety program, which they stated had been pared down to a number of written documents which are read and signed, without any chance for interaction or discussion. Workers expressed a general sense that they were not being fully informed of the hazards associated with work activities. These comments, and the fact that management expressed a need for training materials during the closing conference, caused NIOSH investigators to conclude that a comprehensive, effective training program is not being implemented at NCTS Cutler.

VLF: Shock and Burn Hazards

NIOSH measurements (Table 4) under the VLF downleads (outside North Helix Array) showed dominant vertical E-fields with spatial average E-field strengths ranging from 842-922 V/m. The vertical E-field strengths were at least 99% of composite averages for these measurements. Data in Table 5 for normal stance (arms at sides, both feet on ground), show ankle and wrist induced current measurements (1.0 to 1.8 mA) that are in good agreement with data in the scientific literature.

Measured ankle and wrist induced currents are well below the IEEE 24 mA current limit at 24 kHz. However, when a worker touches electrically conductive objects in an RF field near 24 kHz, special consideration and treatment are required to prevent electrical shock. The amount of current that will flow through a body depends on how well the individual is electrically grounded and the impedance between the RF source and the individual. The 24 kHz fields produced at NCTS Cutler can cause potentially hazardous RF currents to flow through workers who are touching conductive objects such as vehicles, fencing, metal roofing, supporting guy wire metallic cables, and metallic rigging cables used during painting and maintenance tasks. IEEE does not specify numerical RF field strength limits to prevent all possible shock and RF burn effects because of the wide variety of conducting objects in the environment and the opportunities for human contact. Rather, IEEE recommends that when such shock and RF-burn conditions may exist, action should be taken to prevent their occurrence.

NIOSH measurements confirmed that E-field strengths at worker-accessible locations exceed the IEEE limits, and that workers may touch conductive objects while performing their normal duties (e.g., water blasting, repainting towers, and maintenance). During these duties, measures should be taken to reduce potential shock hazards when workers could touch conductive objects in VLF fields. These measures should include worker awareness training, appropriate work practices, proper equipment grounding, restricting access, reduced power, shielding, and other RF safety program requirements. Particular attention should be given to rigging operations where long metal cables near transmitters may pose shock hazards to personnel who potentially could touch the cables (whether intentionally or not). Shock hazards and mitigation methods at NCTS Cutler are discussed in a Navy report by Peder Hansen (Navy, SPAWAR Systems Center).[16]

IEEE Exclusions

IEEE guidelines were derived from an extensive review of the peer reviewed literature. The intent of these guidelines is to protect exposed human beings from harm by any mechanism, including those arising from excessive elevations of body temperature. However, the potential harm that may result from exposure below 0.1 MHz is not related to excessive increases in body temperature; rather, it results from electro-stimulation of excitable cells at very low frequencies, such as those encountered at NCTS Cutler. Since the relationship between SAR and the thresholds for excitable cell stimulation is not linear between 0.003 and 0.1 MHz, a constant SAR (such as the SAR that is a basis for preventing excessive heating of body tissues) cannot be used to establish protective guidelines below 0.1 MHz.[2]

In 1999, the Navy requested an interpretation regarding the applicability of Exclusions and MPEs at Navy VLF transmitter stations.[17] On August 23, 2000, the IEEE SC-4, SCC-28 Interpretations Working Group provided a written interpretation, which was reaffirmed in a subsequent letter dated February 27, 2003.[18,19] (Appendix). The interpretation states that below 100 kHz, "where the dominant effect is nerve stimulation, the appropriate cross section area is considerably less than it is for assessing SAR. For this reason, selecting a cross section area for body currents below 100 kHz based upon SAR considerations is not supported by research on nerve stimulation effects below 100 kHz."[18] The IEEE response further states that it is necessary to meet the controlled induced and contact current MPEs (IEEE C95.1, Table 1, Part B) when the controlled field strength MPEs are exceeded. However, the NIOSH investigators did not find the IEEE Interpretations Working Group responses to be entirely consistent or sufficient in clarifying whether or not the exclusions of C95.1-1999, Section 4.2.1 apply to the areas of electric field strength exposure on the NCTS Cutler station that exceed the MPE.

The IEEE C95.1-1999 Standard, Section 4.2.1 states that "At frequencies between 0.003 and 0.1 MHz the SAR exclusion rule, stated above, does not apply." It goes on to state that "…the MPE in controlled environments can still be exceeded if it can be shown that the peak rms current density …does not exceed $35f mA/cm^2$, where f is the frequency in MHz." As noted above, from the comments of the Interpretations Working Group, it is not possible to determine current density in the situation at NCTS Cutler. Based on all of these inputs, the NIOSH investigators conclude that the exclusion of Section 4.2.1 should not apply to the areas where the electric field strength exceeds the MPE. Thus, MPEs for **both** field strengths and currents (contact and induced) must be met.

CONCLUSIONS

Electric and magnetic field strengths, as well as induced and contact body currents, were below IEEE Guidelines in the HF transmitter building and along fence lines in the HF antenna field. Likewise, inside the VLF Transmitter Control Room and Combiner Room, electric field strengths were well below IEEE guidelines. VLF electric field strength exceeded the MPE at four locations beneath downleads; due to variability in RF fields beneath VLF downleads, the potential for exposure is not well defined in these locations. It seems that certain work practices (e.g., remaining in a parked vehicle near downleads) and/or insufficient training and guidance creates the potential for worker exposure to electric field strengths in excess of IEEE MPEs beneath the VLF arrays.

Field strength MPEs, as well as induced and contact body current MPEs, must be met for VLF exposures. Contact body currents must be measured for towers climbers and other workers contacting towers or other metal objects in the VLF field. These objects include metal objects on the towers, and counterweights; as well as metal objects on the ground, such as in buildings, vehicles, winches, guy wires, etc.

This evaluation did not reveal a consistent pattern of clinically significant work-related illness or injury at NCTS Cutler. Examination of medical records for individuals whose potential exposures were the highest (i.e., riggers/antenna workers) did not reveal any consistent pattern of disease or abnormalities.

RECOMMENDATIONS

In order to improve working conditions and reduce potential RF exposures at NCTS Cutler, the following recommendations are offered by the NIOSH investigators.

1. Only personnel who have a need to enter the antenna fields should be allowed to enter these areas where potentially hazardous RF fields may be present. Security staff, contractors, visitors, etc. should be advised of potential exposures that may be encountered in the VLF antenna arrays.

2. Locations in the VLF antenna field where spatial average E-field strength may exceed IEEE Guidelines should be restricted (e.g., fenced-off) and posted with warning signs. Due to variability of VLF field strength, a conservative (worst-case) approach should be used when demarcating areas where field strengths may exceed the IEEE MPEs. Signs should conform to the design recommended by American National Standards Institute (ANSI) standard, ANSI C95.2-1982. Warning signs should be visible at all points along fence lines, clearly identify RF radiation hazard, and indicate areas where entry is prohibited. All employees should be made aware that stray fields may occur at varying locations within the VLF antenna field.

3. For VLF and HF sources, electric and magnetic field strengths as well as induced and contact body currents should be measured periodically in areas that could be occupied by workers. These exposure parameters should also be measured when changes are made such as retuning, constructing new antennas/towers, modifying existing antennas/towers, installing new power amplifiers (and related waveguide/coaxial equipment) or modifying existing power amplifiers (and related waveguide/coaxial equipment). The field strength and current meters should be recalibrated at least once a year (or as recommended by the manufacturer).

4. All personnel should receive radiation safety training if they operate, maintain, or repair RF radiation sources that are capable of emitting levels at or exceeding the MPE.[20] Training should be conducted when an individual is first employed and annually thereafter. A training record should be maintained which contains a brief outline of the instructions for each training session, and a list of individuals who received the training. Training sessions should include instruction concerning:

- exposure potential associated with specific pieces of equipment
- biological effects associated with exposure to field strengths exceeding the MPE
- proper use of protective equipment, and devices such as barriers, signs, and lights
- proper equipment grounding
- shock hazards, especially during rigging operations
- accident-reporting procedures
- routine radiation-safety surveys, and procedures for maintaining an operational log for recording radiation-safety-related events (such as radiation-zone violations or overrides of warning signs or safety interlocks).

5. All personnel who perform duties that might require them to go near or into areas where electric field strengths may exceed the MPE should also receive radiation safety training, even though they would not normally be considered radiation workers. This would include painters and other maintenance workers, groundskeepers, security personnel, and others who perform work tasks or have a work-related reason to be in the vicinity of the towers or down leads. Training should be conducted and recorded as for the radiation workers in recommendation #4.

6. All shocks and burns should be reported to the NCTS Cutler Technical Director. A formal record of all shocks, burns, and incidents ("near misses") should be maintained and reviewed at least annually to determine if existing safety procedures need to be revised or if new procedures need to be developed. This formal review process should be utilized to determine if a pattern of injury exists among NCTS employees and contractors.

7. A joint health and safety committee, consisting of management and employees representatives should be established to meet on a regular basis to deal with health and safety issues. The safety committee would form the basis for a joint effort to develop and maintain a comprehensive safety and health program at NCTS Cutler to effectively address the safety and health of all employees (Navy and contractors).

REFERENCES

1. Hansen P [1994]. Technical report 1681, VLF Cutler hollow core cable repair/replacement. World Wide Web [URL=http://www.spawar.navy.mil/sti/publications/pubs/tr/1681/tr1681.pdf]. Date accessed: January 29, 2003.

2. IEEE [1999]. IEEE standard for safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz. IEEE Std C95.1, 1999 Edition. New York, NY: The Institute of Electrical and Electronics Engineers, Inc.

3. ACGIH [2001]. Documentation of the physical agents threshold limit values, 7th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

4. Cleveland RF Jr., Uleck JL [1999]. Questions and answers about biological effects and potential hazards of radiofrequency electromagnetic fields. Washington, DC: Federal Communications Commission, Office of Engineering and Technology, OET Bulletin 56, 4th ed.

5. NIOSH/OSHA [1979]. Joint NIOSH/OSHA Current Intelligence Bulletin 33--Radiofrequency (RF) sealers and heaters: potential health hazards and their prevention. U. S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, NIOSH. U. S. Department of Labor, Occupational Safety and Health Administration. Cincinnati, OH: DHEW (NIOSH) Publication No 80-107.

6. Bernhardt JH [1979]. Biologic effects of electromagnetic fields. Zeitschrift fur Naturforschung 34:616-627.

7. Bailey WH, Su SE, Bracken TD, Kavet R. [1997]. Summary and Evaluation of Guidelines for Occupational Exposure to Power Frequency Electric and Magnetic Fields. Health Physics 73: 433-445.

8. NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

9. ACGIH [2004]. 2004 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

10. CFR [1997]. 29 CFR 1910.1000. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

11. NCRP [1986]. Biological effects and exposure criteria for radio frequency electromagnetic fields, Report 86. Bethesda, MD: National Council on Radiation Protection and Measurements, pp.1-382.

12. ICNIRP [1998]. Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz), Health Physics, 74 (4): 494-522.

13. NRPB [1993]. Board Statement on Restrictions on Human Exposure to Static and Time-Varying Electromagnetic Fields and Radiation, Documents of the NRPB, Vol. 4, No. 5, Chilton, Didcot, Oxon, UK: National Radiological Protection Board.

14. OET [1997]. Evaluating Compliance with FCC-Specified Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields, Bulletin 65. U.S. Federal Communications Commission, Office of Engineering and Technology.

15. Scheidt S, Erlebacher JA [1986]. Basic Electrocardiography. West Caldwell, New Jersey: CIBA-GEIGY.

16. Hansen P [2001]. VLF Cutler radiation hazard measurements May 2001. SPAWAR Systems Center. May 23, 2001.

17. Commanding Officer, Space and Naval Warfare Systems Center, North Charleston, SC [1999]. Letter (October 7, 1999) from Kevin Charlow to the IEEE-SA Standards Board requesting interpretation of IEEE Exclusion, Sections 4.2.1 and 4.2.2.

18. Hatfield JB [2000]. Letter of interpretation (August 23, 2000) from J.B. Hatfield, Chairman, SC-4, SCC-28 Interpretations Working Group to Commanding Officer, Space and Naval Warfare Systems Center, North Charleston, SC.

19. Hatfield JB [2003]. Letter of interpretation (February 27, 2003) from J.B. Hatfield, Chairman, SC-4, SCC-28 Interpretations Working Group.

20. DeFrank JJ, Bryan PK, Hicks Jr CW, Sliney DW. Textbook of military medicine, Chapter 15, Nonionizing radiation. World Wide Web [URL=http://chppm-www.apgea.army.mil/rfup/website/Chap15.htm]. Date accessed: December 7, 2004.

PHOTOGRAPHS

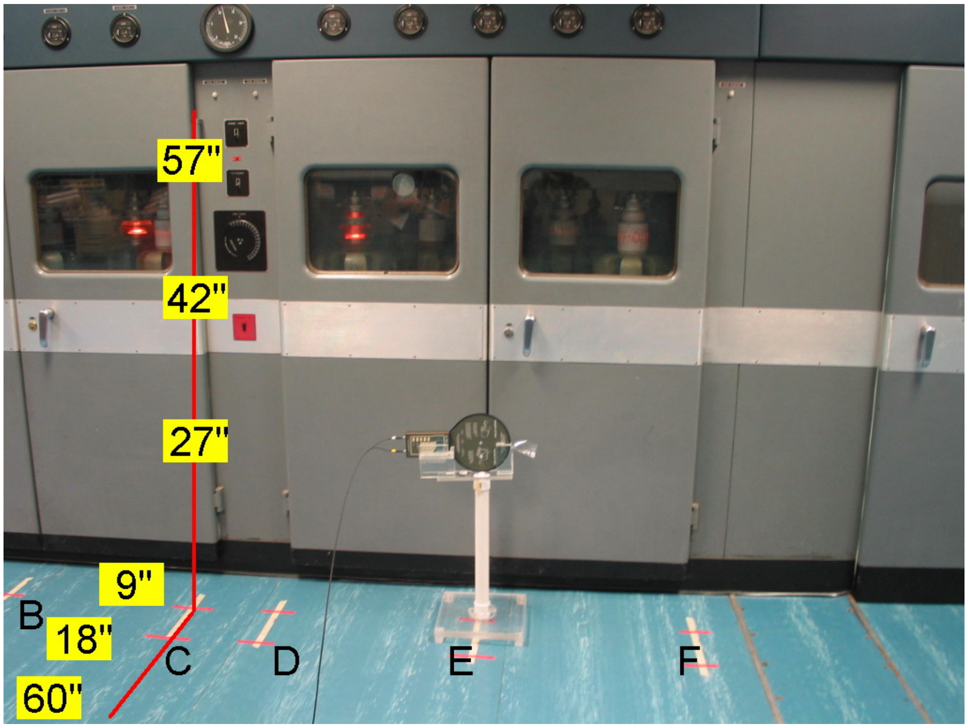


Photo 1. E-field measurement (perpendicular orientation) showing floor and height locations. Taped areas represent other measurement locations.

Photo 2. Instrument set-up for E-field strength measurements in the North Array (vertical orientation shown). Tripod (left side) has dielectric positioner (plastic pipe) which allows a reproducible spatial measuring location to be maintained in vertical perpendicular and parallel orientations (vertical orientation shown)

Photo 3: E-Field measurement location near the VLF transmitter control room desk.

Photo 4: E-Field measurement location near VLF Transmitter control room desk

Photo 5: E-Field measurement located in the Combiner Room Entry (Copper Room) near the T-15 switch

Photo 6: NIOSH investigators setting-up E-Field measurement located in the Combiner Room Entry (Copper Room) near the dry air compressor. (Note: Investigators were at least 4 meters from the instrument during measurements.)

Photo 7: Ankle current measurement located directly beneath the lowest point of one of the main leads to the VLF antenna. Both feet are grounded.

Photo 8: Ankle current measurement located directly beneath the lowest point of one of the main leads to the VLF antenna. Both arms raised to maximize potential body current measurements.

Photo 9: Ankle current measurement located directly beneath the lowest point of one of the main leads to the VLF antenna. Both arms raised while standing on one foot to maximize potential body current measurements.

Table 1.
Naval Computer and Telecommunications Station (NCTS), Cutler, Maine
HF Field Strength & Current Measurements: Inside HF Transmitter Building
May 2002
HETA 2001-0153-2994

Transmitter S/N or Location	Antenna Configuration	Output Power (kW)	Frequency (MHz)	H-Field Max. (A^2/m^2)	H-Field Location*	E-Field Max. (V^2/m^2)	E-Field Location*	Contact Current (Wrist) Max. (mA)	Contact Current Location*	Induced Current (Wrist/Ankle) Max. (mA)	Induced Current Location*
B-14 Power Amplifier	Q-4	3	15.957	ND	1	ND	2	ND	3	NM	4
B-18 Power Amplifier	SC-3	3	11.685	ND	5	ND	6	ND	7	NM	8
B-16 Power Amplifier	K-3	3	6.724	ND	9	ND	10	ND	11	NM	12
SLS4- Switching Matrix	NA	NA	NA	ND	13	ND	14	ND	15	NM	16
Antenna Heliax Building Penetration	NA	NA	NA	ND	17	ND	18	NM	19	ND	20

ND = not detectable: electric field strength below 500 V^2/m^2, magnetic field strength below 0.005 A^2/m^2, contact/induced current below 1 mA.
NM = not measured
NA = not applicable

*Measurement Locations:

1 - 3, 5 -7, 9 -11: Exposure was assessed on all accessible surfaces of power amplifiers (and related equipment), along waveguide and at waveguide flanges/couplings.

13 - 15: Exposure was assessed at mechanical switching matrix (transmitter input & matrix output connectors).

17, 18, 20: Exposure was assessed where the antenna Heliax® cable penetrates the outside building wall.

Table 2.
Naval Computer and Telecommunications Station (NCTS), Cutler, Maine
HF Field Strength & Current Measurements: At HF Antennas Sites
May 2002
HETA 2001-0153-2994

Antenna Configuration	Output Power (kW)	Frequency (MHz)	H-Field Max. (A^2/m^2)	H-Field Location	E-Field Max. (V^2/m^2)	E-Field Location	Contact Current (Wrist) Max. (mA)	Contact Current (Wrist) Location	Induced Current (Wrist/Ankle) Max. (mA)	Induced Current (Wrist/Ankle) Location
SC-3	3	11.6855	ND	1	500	2	NM	3	3.9	4
SC-1	3	13.227	ND	5	ND	6	NM	7	ND	8
K-3	3	6.724	NM	9	5000	10	NM	11	ND	12
Q-4	3	15.957	NM	13	ND	14	NM	15	ND	16
K-1	3	15.019	NM	17	ND	18	NM	19	ND	20
Q-3	3	16.1203	NM	21	ND	22	NM	23	12	24
K-2	3	4.833	NM	25	ND	26	NM	27	ND	28
H-3	3	6.706	NM	29	1500	30	NM	31	20.6	32
Q-1	3	10.865	ND	33	ND	34	NM	35	ND	36
H-2	3	8.971	ND	37	ND	38	NM	39	ND	40

ND = not detectable: electric field strength below 500 V^2/m^2, magnetic field strength below 0.005 $(A/m)^2$, contact/induced current below 1 mA.
NM = not measured.
NA = not applicable.

Measurement Locations1-2, 4: at fence line surrounding antenna.
5-6, 8, 10, 12: at fence line surrounding antenna.
14, 16, 18, 20, 22, 24, 26, 28, 30, 32-34, 36-38, 40: at fence line surrounding antenna.

Table 3. IEEE Occupational Guidelines Relevant to NCTS Cutler Sources*

Frequency (MHz)	Electric Field strength (E) (V/m)	Magnetic Field strength (H) (A/m)	Power Density (S) (mW/cm^2) E-field	Power Density (S) (mW/cm^2) H-field	Induced Current** (Ankle/Wrist) (mA)	Contact Current** (Wrist) (mA)
0.003 – 0.1	614	163	Not applicable†		1000f	1000f
3 – 30	1842/*f*	16.3/*f*	$900/f^2$	$10{,}000/f^2$	100	100

Notes:
* The exposure values in terms of electric and magnetic field strengths are the mean values obtained by spatially averaging the squares of the fields over an area equivalent to the vertical cross section of the human body (projected area). These exposure limits are applicable during any consecutive six-minute exposure period.

"*f*" is the frequency in MHz.

† These plane-wave equivalent power density values, although not appropriate for near-field conditions, are commonly used as a convenient comparison with MPEs at higher frequencies, and are displayed on some instruments in use.

** It should be noted that current limits given above may not adequately protect against startle reactions and burns caused by transient discharges when contacting an energized object.[2]

Table 4
Naval Computer and Telecommunications Station (NCTS), Cutler, Maine
VLF E-Field Measurement (Outside North Helix Array)
E-Field Measurements (V/m)
May 2002
HETA 2001-0153-2994

Location	Height above ground	Distance from Building Edge (feet)	Magnetic Bearing from Tower (degree M)	Vertical (V/m)	Parallel (V/m)	Perpendicular (V/m)	COMPOSITE AVG (V/m)	SPATIAL AVG. (V/m)
V18E Lead	157.5 cm (62 inches)	60	110	830	38.5	43	832.0	842.2
	124.5 cm (49 inches)	60	110	840	14.2	76	843.6	
	91.5 cm (36 inches)	60	110	840	121	63	851.0	
V18D Lead	157.5 cm (62 inches)	60	140	870	--	--	870 *	848.1 *
	124.5 cm (49 inches)	60	140	840	11	75	843.4	
	91.5 cm (36 inches)	60	140	830	0.5	35	830.7	
V18C	157.5 cm (62 inches)	60	225	930	67	72	935.2	922.0
	124.5 cm (49 inches)	60	225	920	10	11	920.1	
	91.5 cm (36 inches)	60	225	910	32	20	910.8	
V18B	157.5 cm (62 inches)	60	270	880	77	49	884.7	874.6
	124.5 cm (49 inches)	60	270	870	52	14	871.7	
	91.5 cm (36 inches)	60	270	860	39	107	867.5	

* estimated E-Field measurement

Table 5
Naval Computer and Telecommunications Station (NCTS), Cutler, Maine
VLF Body Current and Magnetic Field Measurements (Outside North Helix Array)
May 2002
HETA 2001-0153

Induced Body Currents (mA)					
Body Posture (Ankle measurements)	**Ankle Current (mA)**	**Body Posture (Wrist measurements)**	**Wrist Current (mA)**	**H-Field (microT)**	
Normal stance[1]		Normal stance[1]		8	for all heights
both arms raised with both feet grounded		arms up	1.25		
both arms raised standing on one foot					
Normal stance[1]	1.64	Normal stance[1]		8	for all heights
both arms raised with both feet grounded	2.1	arms up	1.3		
both arms raised standing on one foot	3.06				
Normal stance[1]	1.8	Normal stance[1]	1.13	10	for all heights
both arms raised with both feet grounded	2.24	arms up	1.34		
both arms raised standing on one foot	3.02				
Normal stance[1]	1.74	Normal stance[1]	1.02	8	for all heights
both arms raised with both feet grounded	2.8	arms up	1.47		
both arms raised standing on one foot	3.5				

1. Normal stance: arms at sides, both feet on ground.

Table 6
VLF Transmitter Control Room
Naval Computer and Telecommunications Station (NCTS), Cutler, Maine
E-Field Measurements (V/m)
May 2002
HETA 2001-0153

23 cm from Door Face		**Power Amplifier 2**					
Distance above floor	E-Field orientation	A	B	C	D	E	F
145 cm	Vertical	41.1	62	47.9	37	58.3	33.5
	Parallel	204	111	105	216	87.3	69
	Perpendicular	109	46.8	106	102	40.6	42.3
	Composite	**234.9**	**135.5**	**156.7**	**241.7**	**112.6**	**87.6**
107 cm	Vertical	36.7	58.4	24.1	25.4	52.9	34.1
	Parallel	49	16.5	42.3	61.2	19.8	27.8
	Perpendicular	41.9	34.8	34.6	49.2	38.6	6.7
	Composite	**74.2**	**70.0**	**59.7**	**82.5**	**68.4**	**44.5**
69 cm	Vertical	13.8	21.1	7.6	6.4	19.7	13.4
	Parallel	2.1	5	11.4	10.2	6.2	7.3
	Perpendicular	13.9	15.6	14.6	17	14.2	6.7
	Composite	**19.7**	**26.7**	**20.0**	**20.8**	**25.1**	**16.7**
	Spatial Average	***109.6***	***77.4***	***78.8***	***115.0***	***68.7***	***49.6***
23 cm from Door Face		**Power Amplifier 3**					
145 cm	Vertical	33.5	52	45.7	25.6	47.7	31.1
	Parallel	152	98.4	94.8	190	90	73.8
	Perpendicular	62.1	52.4	103	94.3	64.3	53.5
	Composite	**167.6**	**123.0**	**147.3**	**213.7**	**120.5**	**96.3**
107 cm	Vertical	33	55.1	23	26.8	58.6	34.2
	Parallel	47.8	16	39.7	57.6	18.3	28.1
	Perpendicular	42.6	36.3	29.4	48	53.7	3.4
	Composite	**72.0**	**67.9**	**54.5**	**79.6**	**81.6**	**44.4**
69 cm	Vertical	12.9	19.9	6.3	6	19.2	13.1
	Parallel	3.3	5.2	10.9	10	4.1	7
	Perpendicular	12.8	14.1	14.5	17.9	17.7	7
	Composite	**18.5**	**24.9**	**19.2**	**21.4**	**26.4**	**16.4**
	Spatial Average	***86.0***	***71.9***	***73.7***	***104.9***	***76.2***	***52.4***

Table 6 VLF Transmitter Control Room Naval Computer and Telecommunications Station (NCTS), Cutler, Maine E-Field Measurements (V/m) May 2002 HETA 2001-0153							
23 cm from Door Face		**Power Amplifier 4**					
Distance above floor	E-Field orientation	A	B	C	D	E	F
145 cm	Vertical	27.6	48.5	40.9	26.8	48.4	33
	Parallel	164	92.4	92.1	175	82.4	67.1
	Perpendicular	104	70.2	90.5	98.8	44.5	34.6
	Composite	**196.1**	**125.8**	**135.4**	**202.7**	**105.4**	**82.4**
107 cm	Vertical	34.3	56.5	21.3	24.3	60.4	32.5
	Parallel	46.6	16.5	42	61.7	19.9	28.4
	Perpendicular	43.6	35	35.6	48.7	49.9	2.6
	Composite	**72.5**	**68.5**	**59.0**	**82.3**	**80.8**	**43.2**
69 cm	Vertical	13.1	20.1	7.6	5.4	19.5	13.4
	Parallel	2.9	5	10.8	10.9	3.8	7.4
	Perpendicular	13	14.7	14.1	18.1	16.4	6.8
	Composite	**18.7**	**25.4**	**19.3**	**21.8**	**25.8**	**16.7**
	Spatial Average	***95.8***	***73.2***	***71.3***	***102.3***	***70.7***	***47.5***
46 cm from Door Face		**Power Amplifier 2**					
145 cm	Vertical	24.2	43.6	23.3	22.8	41	23.2
	Parallel	71.1	35.5	52.3	84.3	38.5	25.4
	Perpendicular	15.8	67.6	76.8	3.4	60.4	59
	Composite	**76.7**	**87.9**	**95.8**	**87.4**	**82.5**	**68.3**
107 cm	Vertical	12.8	19.4	10	9.9	19.1	12.5
	Parallel	33.1	18.5	28.6	43.5	21.2	13.2
	Perpendicular	1.5	23.6	38.1	12.7	19.2	23.5
	Composite	**35.5**	**35.7**	**48.7**	**46.4**	**34.4**	**29.7**
69 cm	Vertical	10.9	19.4	10	9.9	19.1	12.5
	Parallel	8.2	18.5	28.6	43.5	21.2	13.2
	Perpendicular	5.6	23.6	38.1	12.7	19.2	23.5
	Composite	**14.7**	**35.7**	**48.7**	**46.4**	**34.4**	**29.7**
	Spatial Average	***42.3***	***53.1***	***64.4***	***60.1***	***50.4***	***42.6***

Table 6
VLF Transmitter Control Room
Naval Computer and Telecommunications Station (NCTS), Cutler, Maine
E-Field Measurements (V/m)
May 2002
HETA 2001-0153

46 cm from Door Face				**Power Amplifier 3**			
Distance above floor	E-Field orientation	A	B	C	D	E	F
145 cm	Vertical	20.7	36.5	21.6	19	35.5	20.7
	Parallel	57.4	30	47	67.5	40.8	22
	Perpendicular	6.5	51	72.1	9.3	46.4	54.4
	Composite	**61.4**	**69.5**	**88.7**	**70.7**	**71.3**	**62.2**
107 cm	Vertical	11.9	19.3	10.4	12	19.8	13.4
	Parallel	32.5	17.3	28.8	42	21.9	12.7
	Perpendicular	1.6	22.8	33.7	12.7	18.8	24.4
	Composite	**34.6**	**34.5**	**45.5**	**45.5**	**35.0**	**30.6**
69 cm	Vertical	10.1	15.1	4.8	4.9	15	10.1
	Parallel	7.7	2.9	10.4	12.3	4.9	4.6
	Perpendicular	5.4	2.7	11.9	11.3	4.5	2.7
	Composite	**13.8**	**15.6**	**16.5**	**17.4**	**16.4**	**11.4**
	Spatial Average	***36.6***	***39.9***	***50.3***	***44.5***	***40.9***	***34.7***
46 cm from Door Face				**Power Amplifier 4**			
Distance above floor	E-Field orientation	A	B	C	D	E	F
145 cm	Vertical	16.5	37.4	21.3	17	35.8	21.1
	Parallel	56.6	32.8	47.9	74.3	42.1	25.1
	Perpendicular	1.9	52.8	67.6	5.1	49.4	54.4
	Composite	**59.0**	**72.5**	**85.5**	**76.4**	**74.1**	**63.5**
107 cm	Vertical	11.8	19.6	8.5	9.9	21.6	14.2
	Parallel	32.2	16.4	29.3	43.6	21.3	13.2
	Perpendicular	2.1	24	36.6	12.4	18.7	26.2
	Composite	**34.4**	**35.1**	**47.6**	**46.4**	**35.6**	**32.6**
69 cm	Vertical	10.1	15.7	4.8	4.3	15.4	10.3
	Parallel	8.1	2.9	10.8	13	4.9	5.1
	Perpendicular	5.7	2.4	12.5	11.4	3.7	2.7
	Composite	**14.1**	**16.1**	**17.2**	**17.8**	**16.6**	**11.8**
	Spatial Average	***35.8***	***41.2***	***50.1***	***46.9***	***42.1***	***36.0***

Table 6
VLF Transmitter Control Room
Naval Computer and Telecommunications Station (NCTS), Cutler, Maine
E-Field Measurements (V/m)
May 2002
HETA 2001-0153

152 cm from Door Face				**Power Amplifier 2**			
Distance above floor	E-Field orientation	A	B	C	D	E	F
145 cm	Vertical	2.9	4	1.4	1.5	4	2.9
	Parallel	4.7	1.9	4.6	6.2	4.7	0.5
	Perpendicular	4.3	8.7	5.5	1.9	6.1	6.4
	Composite	**7.0**	**9.8**	**7.3**	**6.7**	**8.7**	**7.0**
107 cm	Vertical	0.9	1.5	1.2	1.2	1.5	1
	Parallel	3.8	1.4	3.5	4.8	3.7	0.4
	Perpendicular	3.1	6.6	4.5	1.7	4.5	4.9
	Composite	**5.0**	**6.9**	**5.8**	**5.2**	**6.0**	**5.0**
69 cm	Vertical	1	1.1	0.9	0.9	1	0.8
	Parallel	2.7	1.5	2.4	3.3	2.6	0.5
	Perpendicular	2.1	4.5	3.2	1.6	3	3.3
	Composite	**3.6**	**4.9**	**4.1**	**3.8**	**4.1**	**3.4**
	Spatial Average	***5.2***	***7.2***	***5.7***	***5.2***	***6.3***	***5.2***

152 cm from Door Face				**Power Amplifier 3**			
Distance above floor	E-Field orientation	A	B	C	D	E	F
145 cm	Vertical	1.8	3.5	1.5	1.5	3.5	2.6
	Parallel	4.1	1.6	3.7	5.4	4	0.2
	Perpendicular	3	7.3	4.6	1.3	5.2	5.8
	Composite	**5.4**	**8.3**	**6.1**	**5.8**	**7.4**	**6.4**
107 cm	Vertical	1.1	1.7	1.4	1.3	1.5	1.1
	Parallel	3.6	1.5	3.3	4.6	3.6	0.4
	Perpendicular	3	6.2	4	1.4	4.8	5.1
	Composite	**4.8**	**6.6**	**5.4**	**5.0**	**6.2**	**5.2**
69 cm	Vertical	0.9	1	1	1	1.1	1
	Parallel	2.6	1.1	2.3	3.1	2.6	0.4
	Perpendicular	1.9	4.2	2.9	1.5	3.2	3.4
	Composite	**3.3**	**4.5**	**3.8**	**3.6**	**4.3**	**3.6**
	Spatial Average	***4.5***	***6.4***	***5.1***	***4.8***	***6.0***	***5.1***

Table 6
VLF Transmitter Control Room
Naval Computer and Telecommunications Station (NCTS), Cutler, Maine
E-Field Measurements (V/m)
May 2002
HETA 2001-0153

152 cm from Door Face				**Power Amplifier 4**			
Distance above floor	E-Field orientation	A	B	C	D	E	F
145 cm	Vertical	2.5	3.6	1.5	1.4	3.5	2.6
	Parallel	4.2	1.7	4.1	5.4	4.3	0.3
	Perpendicular	3.1	7.4	4.9	1.5	5.9	5.9
	Composite	**5.8**	**8.4**	**6.6**	**5.8**	**8.1**	**6.5**
107 cm	Vertical	1.1	1.7	1.3	1.2	1.5	1.1
	Parallel	3.9	1.6	3.4	4.8	3.8	0.5
	Perpendicular	3	6.4	3.8	1.5	4.9	5.2
	Composite	**5.0**	**6.8**	**5.3**	**5.2**	**6.4**	**5.3**
69 cm	Vertical	0.9	1	0.9	1	1.1	0.9
	Parallel	2.8	1.1	2.4	3.2	2.7	0.4
	Perpendicular	2	4.3	3.1	1.6	3.2	3.4
	Composite	**3.6**	**4.5**	**4.0**	**3.7**	**4.3**	**3.5**
	Spatial Average	***4.8***	***6.6***	***5.3***	***4.9***	***6.3***	***5.1***

IEEE

STANDARDS COORDINATING COMMITTEE 28
(NONIONIZING RADIATION)

August 23, 2000

Commanding Officer,
Space and Naval Warfare Systems Center,
P.O. Box 190022
North Charleston, SC 29419-9022
Attention: Kevin J. Charlow and Wayne C. Hammer (Code 323)

Dear Sir:

You have requested an interpretation of **IEEE Std C95.1, 1999 Edition** (C95.1,1999) regarding an apparent contradiction between Induced and Contact current maximum permissible exposures (MPE) shown in **Part B** of **Tables 1 & 2**, respectively, and peak rms current density MPEs shown in section **4.2 Exclusions**.

Two sets of exclusions can be applied to interpretation of induced and contact current MPE limits. Section 4.1.1 (a) (3) and Section 4.1.2 (a) (3) of C95.1, 1999 state that induced current measurements are not required if the spatially averaged electric field strength does not exceed the MPE shown in C95.1, 1999, **Table 1, Part A**, for frequencies of 0.45 MHz or less and **Table 2, Part A**, for frequencies of 0.2 MHz or less, and does not exceed the limits shown in **Figure E.6**, or **Figure E.7**, respectively, at frequencies greater than 0.45 MHz or 0.2 MHz, respectively.

Other exclusions regarding induced and contact current MPE limits are found in Section **4.2 Exclusions**. Section 4.2.1 and 4.2.2 Exclusions only apply to

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

AUG 30 2000

Table 1, Part A and **Table 2, Part A**, and specify that electromagnetic field MPEs in controlled environments and uncontrolled environments, respectively, may be exceeded over a frequency range from 0.003 to 0.1 MHz, if it can be shown that peak rms current density, as averaged over any 1 cm^2 area of tissue in 1 s does not exceed $35f mA/cm^2$ or $17.5f mA/cm^2$, respectively, where f is the frequency in MHz. In all other situations **Table 1, Part B**, or **Table 2, Part B**, C95.1,1999 governs.

Body currents below 100 kHz are in the frequency range where the dominant effect changes, with increasing frequency, from nerve stimulation to tissue heating. Note that Sections 4.2.1 and 4.2.2 of C95.1, 1999 do not specify specific values for the conductive cross section area of the wrist or ankle. At lower frequencies, where the dominant effect is nerve stimulation, the appropriate cross section area is considerably less than it is for assessing SAR. For this reason, selecting a cross section area for body currents below 100 kHz based upon SAR considerations, is not supported by research on nerve stimulation effects below 100 kHz. Therefore, below 100 kHz, it is necessary to apply induced and contact body current limits of **Table 1, Part B**, or **Table 2, Part B**, C95.1,1999, as appropriate for determining the MPE. An apparent paradox between the MPE limits and exclusions for body currents will, hopefully, be resolved during the present standard revision process.

Sincerely,

J. Hatfield

James B. Hatfield,
Chairman, SC-4, SCC-28 Interpretations Working Group

Participating Working Group Members:
Jules Cohen, Om Ghandi, A.W. Guy, Patrick Reilly, Richard Tell, Marvin Ziskin.

INTERNATIONAL COMMITTEE *on* ELECTROMAGNETIC SAFETY

IEEE

FEBRUARY 27, 2003

Dear Sir:

You have requested a clarification of our August 23, 2000 interpretation of **IEEE Std C95.1, 1999 Edition** (C95.1, 1999) regarding an apparent contradiction between Induced and Contact current maximum permissible exposures (MPE) shown in **Part B** of **Tables 1 & 2**, respectively, and peak rms current density MPEs shown in section **4.2 Exclusions**.

We wish to reaffirm our previous interpretation that below 100 kHz it is necessary to apply induced and contact body current limits of **Table 1, Part B**, or **Table 2, Part B**, C95.1, 1999, as appropriate, for determining the MPE and ignore the current density exclusion clause in Section **4.2.1**.

In the light of the above considerations, Section **4.2.1 (b)** can be interpreted such that the MPE in controlled environments for electric field strengths can be exceeded, so long as the total current does not exceed the MPE limit.

Sincerely,

J. Hatfield

James B. Hatfield,
Chairman, SC-4, SCC-28 Interpretations Working Group

Participating Working Group Members: Quirino Balzano, Jules Cohen, A.W. Guy, R.C. Petersen, Richard Tell, Marvin Ziskin

cc: Eleanor Adair
Wayne Hammer

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
4676 Columbia Parkway
Cincinnati, OH 45226-1998

National Institute for Occupational Safety and Health

NIOSH

**Delivering on the Nation's promise:
Safety and Health at work for all people
through research and prevention**

To receive NIOSH documents or information
about occupational safety and health topics
contact NIOSH at:

1-800-35-NIOSH (356-4674)
Fax: 1-513-533-8573
E-mail: pubstaft@cdc.gov
or visit the NIOSH web site at:
http://www.cdc.gov/niosh

S A F E R • H E A L T H I E R • P E O P L E™