Nonionzing Radiation Exposure to Technicians at a Satellite Communications Facility

Judith Eisenberg

David Sylvain

Srinivas Durgam

Health Hazard Evaluation Report
HETA 2007-0095-3063
U.S. Department of Commerce
Wallops Command and
Data Acquisition Station
Wallops, Virginia
June 2008

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention

NIOSH *National Institute for Occupational Safety and Health*

The employer shall post a copy of this report for a period of 30 calendar days at or near the workplace(s) of affected employees. The employer shall take steps to insure that the posted determinations are not altered, defaced, or covered by other material during such period. [37 FR 23640, November 7, 1972, as amended at 45 FR 2653, January 14, 1980].

CONTENTS

REPORT

APPENDIX

ACKNOWLEDGMENTS

Abbreviations

ACGIH®	American Conference of Governmental Industrial Hygienists
A/m	Amps per meter
FCC	Federal Communications Commission
GHz	Gigahertz
GOES	Geostationary Operational Environmental Satellite
HHE	Health hazard evaluation
Hz	Hertz
IEEE	Institute of Electrical and Electronics Engineers
KHz	Kilohertz
mW/cm2	Milliwatt per square centimeter
MHz	Megahertz
MPE	Maximum permissible exposure
NAICS	North American Industry Classification System
NASA	National Aeronautics and Space Administration
NIOSH	National Institute for Occupational Safety and Health
OEL	Occupational exposure limit
OSHA	Occupational Safety and Health Administration
PEL	Permissible exposure limit
POES	Polar–orbiting Operational Environmental Satellite
REL	Recommended exposure limit
RF	Radio frequency
SAR	Specific absorbed radiation
SATAN	Satellite Tracking Antenna Command System
STEL	Short term exposure limit
TLV®	Threshold limit value
TWA	Time–weighted average
V/m	Volts per meter
VHF	Very high frequency
W/kg	Watts per kilogram
WBU	Wallops Backup Unit
WCDAS	Wallops Command and Data Acquisition Station
WEEL	Workplace environmental exposure level

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a union request for a health hazard evaluation (HHE) at the U.S. Department of Commerce Data Command and Acquisition Station in Wallops, Virginia. The National Weather Service Employees' Organization submitted the HHE request because of two incidents in which employees believed they were exposed to radio frequency (RF) radiation. NIOSH investigators conducted an investigation in March 2007.

What NIOSH Did

- We reviewed incident and maintenance logs.
- We talked to employees confidentially about their health and reviewed their medical records.
- We reviewed an electromagnetic field survey done by a consultant.

What NIOSH Found

- We found that a RF health and safety program did not exist at the time of the incidents, but was in development.
- We found that there was poor communication between management and employees.
- We found that employees were doing repairs that they had not been trained to do.
- We found that employees were using RF survey meters that they had not been trained to use.
- We found that there was a lack of standard documentation requirements for repair and maintenance logs.

What Managers Can Do

- Managers can implement an effective RF health and safety program. They should also enforce training and safety protocols.
- Managers can ensure that employees are trained on how to use and repair equipment.
- Managers should be aware of procedures for prompt referral to medical care if an employee reports possible workplace exposure.
- Managers can enforce proper documentation of repairs and maintenance in their logs.
- Managers should restrict access to areas where spatial average electric field strength may exceed recommended guidelines. Signs should be posted to mark these areas.

- ***What Employees Can Do***

- Employees should not use or repair equipment that they have not been trained on.
- Employees should keep detailed repair and maintenance logs.
- Employees should immediately inform managers of any workplace exposure and then seek medical evaluation without delay.
- Employees should inform medical providers of the nature of their workplace RF exposure.
- Employees should take part in health and safety committees.

Summary

NIOSH was asked to investigate the potential for ongoing nonionizing radiation exposure to electrical technicians after two suspected exposure incidents. Although two employees involved in these incidents reported symptoms consistent with RF exposure, we cannot confirm the exposure as the equipment reportedly used to identify the exposure was not properly calibrated nor were the employees who used these detectors trained on their use. We did not find any evidence of current RF overexposures. WCDAS is developing a RF health and safety program to prevent any future incidents.

On January 12, 2007, the National Weather Service Employees Organization submitted a HHE request on behalf of civilian employees at the U.S. Department of Commerce WCDAS, Wallops, Virginia. The request concerned two incidents in which electronic technicians repairing equipment were believed to have been exposed to high levels of nonionizing RF radiation. The request noted that two employees involved in these incidents reported persistent neurological symptoms and that the facility had no RF safety program.

In response to the HHE request, a NIOSH team of a medical officer and two industrial hygienists visited the facility on March 14–15, 2007. During the site visit, the team toured the facility and interviewed employees in a confidential setting. We reviewed OSHA 300 Injury and Illness logs after the site visit along with a report from an RF survey conducted at WCDAS by EME Technology International 2 months (February 28, 2007) after the second incident. This report revealed two measurements that exceeded limits published by IEEE in the C95.1–2005 IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields [IEEE 2005]. One of these measurements was in the waveguide area while the other measurement was taken near the SATAN auxiliary triplexer, an area not routinely accessible to employees.

Aside from reports of warmth and "sunburn" on an exposed extremity that had resolved prior to the site visit, no other medical findings were consistent with workplace RF exposures. Current neurological problems reported during confidential employee interviews were not health effects associated with RF exposure and employees' medical records suggested other causes for some of the reported symptoms.

Other findings of the site visit included lack of consistent training among the electrical technicians for the repairs they were expected to perform, inconsistent documentation of repairs performed during each shift, and lack of adherence to facility policy for immediate medical evaluations of employees after suspected RF exposure.

NIOSH investigators concluded that no evidence exists of ongoing RF overexposure to electrical technicians, but the potential exists for overexposure to RF for employees who work on this equipment without adequate safety training and lack of repair documentation.

Recommendations are provided in this report for training employees, conducting monitoring for RF leaks, and prompt medical evaluation after possible RF overexposure.

Keywords: NAICS 926110 (Administration of General Economic Programs) nonionizing radiation, radio frequency radiation, RF, electromagnetic fields (EMF), burn, neurological effects

INTRODUCTION

On January 12, 2007, the National Weather Service Employees Organization submitted a HHE request on behalf of civilian employees at the U.S. Department of Commerce WCDAS, Wallops, Virginia. The request concerned two incidents in which electronic technicians repairing transmitter equipment were believed to have been exposed to high levels of nonionizing RF radiation. The first incident occurred at the WCDAS site and spanned December 18–23, 2006. The second incident occurred at the WBU facility in Maryland on January 9, 2007.

After these incidents, reportedly the first known RF overexposures in the facility's history, it was discovered that the facility did not have a RF safety program. A joint union–management safety committee was formed to develop a RF safety program and to implement training on the use of RF survey meters. The HHE request also noted that two employees involved in these incidents reported persistent neurological symptoms that they believed were related to their suspected RF exposure.

Background

Wallops WCDAS was built in 1965 on the Delmarva Peninsula and became operational a year later. This facility controls meteorological satellites in geosynchronous and polar orbits, and receives data from them. Originally part of NASA, WCDAS eventually came under the auspices of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration as part of its National Environmental Satellite, Data, and Information Service. The polar system, POES, and the geosynchronous system, GOES, use separate antenna arrays to receive and transmit data. GOES data and images are primarily used in daily televised weather reports. Approximately 11 antennas at this facility are normally in active use. The five GOES antennas normal transmit in the S band frequency range (2025–2107 MHz). POES also uses five antennas for transmit operations. POES has a VHF antenna (148–154 MHz) along with a second VHF antenna as a backup, one antenna working in S band (2020–2120 MHz), and two antennas capable of operating in S frequency bands (2025–2120 MHz) and L frequency band (1750–1850 MHz). The backup center for the GOES system is a 16.4 m antenna located at the Goddard Space Flight Center in Greenbelt, Maryland. The backup facility is maintained in a stand-by mode by WCDAS employees.

INTRODUCTION (CONTINUED)

The WCDAS facility is staffed in shifts scheduled from 7 a.m.–7 p.m. and 7 p.m.–7 a.m. Fifteen employees work on each shift: seven electronic technicians on the GOES system, four electronic technicians on the POES system, three facilities technicians who perform general mechanical repairs, and one manager. The work rotations are 3 days on day shift, 3 days off, 3 days on night shift, then 3 days off. Electronic technicians are grouped into four teams of three people who alternate going out to the backup facility on a monthly basis during the work rotation schedule.

A RF survey of the WCDAS facility was completed by a third party consultant, EME Technology International, in February 2007. WCDAS also used this consultant to provide employee training on the use of the RF survey meter. WCDAS has also implemented a joint management-union safety committee; this committee is developing a comprehensive RF safety and training program for the facility.

ASSESSMENT

In response to the HHE request, a NIOSH team of two industrial hygienists and a physician visited the site at the WCDAS on March 15–16, 2007. During the visit, the industrial hygienists toured the facility and the equipment involved in the first of the two possible exposure incidents. The NIOSH team did not visit the site of the second incident as it occurred at the backup facility (WBU) in another state and the same personnel service both systems. Repair and maintenance logs were also reviewed. Confidential employee interviews were conducted on March 15, 2007; all current electronic technicians were invited to participate. Employee medical records, OSHA 300 Illness and Injury logs, and the EME Technology International RF survey report were reviewed subsequent to the site visit.

RESULTS

Seven electronic technicians participated in the voluntary interviews. NIOSH staff were available so that both day and night shift personnel could participate in interviews. One employee was interviewed by phone during the site visit. NIOSH staff interviewed employees involved in both reported overexposure incidents.

All participants were male, from 38 to 57 years of age (average of 46 years), and their employment duration as satellite electronic technicians ranged from 12.5 to 34 years (average of 19 years). Several participants had employment experience as satellite technicians prior to working at WCDAS. The interviews covered the employees' medical history, possible exposure incidents, health effects they associated with the incidents, and prior safety training.

Information obtained during the employee interviews reconstructed the two possible exposure incidents. The first incident occurred at the WCDAS facility starting on December 18, 2006, when the HR–1 transmitter could not be brought up to full power due to a low filament current fault. This resulted in the replacement of a klystron tube on that transmitter. Over the next 6 days, electronic technicians on both day and night shifts attempted to bring the transmitter up to full power with the new klystron tube but were unable to do so due to continued calibration errors. On December 23, 2006, while conducting repairs one employee felt his arm get warm; this alerted him that there might have been an RF exposure. Two employees obtained a RF survey meter (with an unknown calibration date), which they had never used before. When they took this instrument to the transmitter they were repairing, they report that the instrument "pegged" at 20 mW/cm^2. After obtaining the high reading on the instrument, these employees notified their coworkers that they too might have been exposed to RF radiation. The next morning, another electronic technician who did have experience using the RF survey meter scanned the same area with the same klystron tube in the system. He measured a "minimal reading on the 0.1 scale," which did not indicate a RF leak. This employee corrected an air–flow fault due to improper duct placement on the klystron tube and then fixed a sensor that had been installed backwards. Upon completing these repairs, this employee was then able to bring the transmitter up to full power.

The second incident occurred at the backup facility in Greenbelt, Maryland on January 9, 2007. On that day, the electronic technicians were asked to check the waveguide for RF leakage. None had been trained to use the RF survey meter and the one who handled it stated he had used such a device only once or twice in the past. It was reported that the survey meter "pegged" near the waveguide, indicating a leak; a missing flange bolt was reported to be the source of the leak. In addition, other flange bolts were reported to be only hand tight, and lacked lock washers. The employees were ordered to shut down the transmitter upon discovery of the missing bolt. They had been in the transmitter shelter for an hour prior to shutdown. The bolt was replaced shortly after the incident and no further exposures were reported. None of the employees reported any thermal or other adverse health effects at the time.

Two employees involved in the first incident in December reported resolved thermal effects consistent with exposure to S-band RF radiation. One employee reported immediate warmth and redness on his arm while the second employee stated the onset of his "sunburn" was approximately 6 hours after the presumed exposure.

Employees involved in both incidents reported persistent symptoms such as fatigue (2), blurred vision (2), headache (2), decreased night vision (1), decreased libido (1), unilateral muscle weakness (1), and unilateral extremity parasthesias (1).

Employees who believed they were overexposed during the two incidents did not receive immediate medical evaluations, and only one underwent a neurological evaluation, which occurred several weeks after the incident. Review of medical records provided by two employees revealed non–occupational causes for the some of these symptoms. None of the employees had undergone visual acuity testing in the year prior to the incident; some had not undergone visual acuity testing for several years. Therefore, it is difficult to determine what, if any, changes occurred to their vision as a result of the reported overexposure incident. The two employees who did see an ophthalmologist after the exposure incidents had no evidence of cataract, a clouding of the lens of the eye, which has been reported in animal studies to occur at very high RF exposures. Adult onset of nearsightedness can be an early warning of cataract formation but adult onset of farsightedness, blurred near vision, can occur as part of the normal aging process of the eye. Several employees mentioned that they were waiting to find a physician who was an "RF expert" to perform their medical evaluation.

Only one employee reported having training and experience using an RF survey meter but this was prior to his employment at WCDAS, and he was not one of the employees who used the survey meter at the time of the first incident. Employees reported that they were not aware of any standard protocol for performing repairs, and record keeping of maintenance logs was inconsistent.

OSHA 300 logs were reviewed for 2004–2006. There 2004 log contained no entries. The 2005 log contained two entries regarding musculoskeletal injuries. The 2006 log documented 11 employees reporting exposure to high levels of RF radiation in the HR–1 antenna shelter between December 18, 2006, and December 23, 2006. This correlates with the date of the first incident described above. None of these employees were marked as having missed any days of work due to their presumed exposure nor did any require a job transfer or duty restriction.

NIOSH Review of RF Survey Report

The consultant's survey consisted of (1) taking spot measurements of electric field power densities near antennas where technicians

RESULTS (CONTINUED)

performed normal maintenance activities, and (2) providing two one–day RF safety training classes for site personnel. The consultant's report noted that two leaks were identified. One was described as a "small" leak of 1.48 mW/cm^2 at a flange on the 18–Meter B antenna; the second was a leak along the 16.4–Meter HR–1 antenna waveguide, where the power density was determined to be approximately 15 mW/cm^2. No leaks were detected at other GOES or POES antennas during normal transmit operations.

Electric field measurements (not spatially averaged) within one foot of the SATAN auxiliary command antenna indicated 20 mW/cm^2. These measurements were obtained inside an unoccupied controlled area that was demarcated by a plastic chain that encircled the antenna to serve as an awareness barrier.

DISCUSSION

Health Effects of Exposure to Radio frequency Radiation

Human and animal studies show that exposure to a RF field above OELs may cause harmful biological effects as a result of 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 the health effects are related to the rate of RF energy absorption in the body which is referred to as the SAR. The SAR is measured in 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 [ACGIH 2001; IEEE 2005]. The thermal effects can manifest as a subjective sensation of warmth on the exposed area or burns ranging from minor sunburn or first degree burn to more extensive tissue damage.

The lens of the eye is sensitive to heat, and animal studies have suggested that thermal effects from RF overexposure might be a risk factor for later development of cataracts. Studies on rabbits revealed mixed results with respect to the development of cataract after both acute and chronic RF exposure. Those studies that did show cataract development had RF dosing at very high, near fatal, levels. The studies also revealed cases of iritis and keratitis, inflammatory reactions of different parts of the eye. Non–human primate, sheep, and dog studies revealed no cataract development [Elder 2003]. The development of nearsightedness (inability to see objects at a distance clearly), has not been reported in the medical literature as being associated with RF exposure. Few human studies

have delineated the risks of adverse eye effects due to RF exposure. Studies of U.S. military radar and microwave workers revealed no association between RF exposure and ocular effects [Cleary 1965; Shacklett 1975; Hathaway 1977].

Although anecdotal reports have described persistent neurological symptoms such as headache, nausea, dizziness, and fatigue after RF overexposure, no definitive data show this relationship. Many of these symptoms are subjective and may be the result of heightened awareness of the perceived overexposure, rather than the fact that the symptoms are the result of the exposure itself. This issue compounds the lack of objective data. This level of heightened awareness in which those experiencing any type of symptom may tend to focus more intently because of the perceived RF overexposures was illustrated by a U.S. Air Force review that showed that out of 330 reports of suspected workplace RF overexposures in 1984 only 58 were shown to have exceeded the MPE [USAF 1984; IEEE 2002].

Post–exposure Medical Evaluations

It should be standard procedure that suspected workplace overexposure to RF be followed by a prompt medical evaluation and appropriate specialty referral if needed. The current policy at WCDAS is for employees to be seen at the NASA occupational health clinic if the exposure occurs between 8 a.m. and 4 p.m. on weekdays and to be transported to the nearest emergency department if the exposure occurs on nights or weekends. This procedure was not followed subsequent to either of the reported incidents. Employees who did seek care at the clinic at a later date were referred to their primary care physicians for initial evaluation.

Employees should not wait to find an "RF expert" as few, if any, such medical specialists exist and they may not be available on an urgent, post-exposure basis. More importantly, such specialization is not necessary to perform a basic medical evaluation. No specialized knowledge of RF is required to care for thermal injuries or to perform a basic neurological evaluation in cases of complaints of headache or visual changes. The purpose of the initial evaluation is to diagnose and treat life-threatening or serious injuries, stabilize minor injuries, and, if indicated, arrange for timely follow up care with the proper specialist. An initial evaluation will assist in follow-up medical care by documenting the employee's condition at the time of the incident to compare to subsequent examinations if the employee develops a chronic

Discussion (continued)

condition that could be ascribed to the incident. Delays in seeking medical care place the employee at risk for a worse outcome due to untreated injuries and make it more difficult to later link the development of symptoms to the incident.

NIOSH Review of RF Survey Report

Based on information in the survey report and observations of waveguides and related equipment during the NIOSH site visit, NIOSH investigators concluded that additional monitoring for the purpose of calculating spatial average power densities at leak locations was not indicated. Additionally, the survey of the SATAN auxiliary command antenna indicated spot power density measurements of 20 mW/cm^2. These results indicate some risk of occupational exposure to RF radiation in this area. The consultant and later NIOSH investigators noted that a more secure or substantial barrier and appropriate signage should be placed around the SATAN antenna to warn individuals of the potential RF hazard. Additional information concerning exposure assessment and relevant evaluation criteria is provided in the appendix of this report.

Conclusions

Two employees reported thermal injuries consistent with overexposure to RF. Other adverse health effects reported by employees have not been substantiated in the medical literature as being associated with RF overexposure. RF sampling done by employees at the time of the incidents did not provide a reliable estimate of RF exposures because the RF survey meter had not been calibrated, and these employees had little or no experience using this equipment. WCDAS supervisors did not follow the facility policy requiring prompt medical evaluation of employees following any exposure incidents at the facility.

Recommendations

Based on the observations and findings of this evaluation, the following recommendations are offered to better protect the employees at WCDAS:

1. Establish a joint health and safety committee, consisting of management and employees representatives to meet regularly to deal with health and safety issues. The health and safety committee would form the basis for a joint effort to develop and maintain a comprehensive health and safety program at WCDAS to effectively address employees' health and safety. Use

RECOMMENDATIONS (CONTINUED)

IEEE Standard C95.7–2005, Recommended Practice for Radio Frequency Safety Programs 3 kHz to 300 GHz, as a reference for developing and implementing guidelines and procedures for the WCDAS radio frequency health and safety program.

2. Instruct employees to perform repairs following protocols to be set forth in the RF health and safety program and to attempt such repairs only if they have been trained to do so.

3. Keep detailed maintenance logs so that each shift is aware of the repair efforts of the prior shift and the condition of the equipment at the start of each shift.

4. Instruct employees to immediately report any suspected overexposure incidents to the shift supervisor. The employee should proceed directly to the occupational health clinic or to the local hospital emergency department as per facility policy for an initial medical evaluation.

5. Refer employees to the appropriate medical specialist based on the nature of symptoms (i.e., vision disturbances should be evaluated by an ophthalmologist or neurologist, headaches by a neurologist, anxiety by a psychiatrist, etc). Delays in seeking medical care in search of an "RF expert" may be detrimental to the employee as well as ultimately unnecessary.

6. Provide all personnel with radiation safety training if they operate, maintain, or repair RF radiation sources that are capable of emitting levels at or exceeding the MPE. Conduct training when an individual is first employed and annually thereafter. Maintain a training record that 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
- Incident reporting procedures
- Routine radiation-safety surveys and procedures for maintaining an operational log for recording radiation-safety-related events

7. Provide radiation safety training for all personnel who perform duties that might require them to go near or into areas where electromagnetic field strengths could exceed the MPE even though they would not normally be considered radiation workers. This includes painters and other maintenance workers,

Recommendations (continued)

groundskeepers, and security personnel. Training should be conducted and recorded as for the radiation workers in recommendation #5.

8. Calibrate, maintain, and use all RF survey meters per manufacturer specifications to ensure accurate measurements.

9. Access to locations where spatial average electric field strength may exceed IEEE Guidelines should be restricted and posted with signs per IEEE C95.2–1999, IEEE Standard for Radio–Frequency Energy and Current–Flow Symbols. These areas include the controlled area around the SATAN Auxiliary Command antenna, high power amplifier shelters, and ladders providing access to waveguides and antennas. Signs should be visible at all possible points of access, should clearly identify the RF radiation hazard, and indicate areas where entry is restricted.

References

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

Cleary SF, Pasternak BS, Beebe GW [1965]. Cataract incidence in radar workers. Arch Env Health *11*:179–182.

Elder JA [2003]. Ocular effects of radio frequency energy. Bioelectromagnetics Supplement 6:S148–S161.

Hathaway JA, Stern N, Soles EM, Leighton E [1977]. Ocular medical surveillance on microwave and laser workers. J Occup Med *19*:683–688.

IEEE [2005]. Safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz. Institute of Electrical and Electronics Engineers Standard C95.1 – 2005.

IEEE Committee on Man and Radiation (COMAR) [2002]. Medical aspects of radiofrequency radiation overexposure. Health Phys *82*(3):387–391.

Shacklett DE, Tredici TJ, Epstein DL [1975]. Evaluation of possible microwave–induced lens changes in the United States Air Force. Aviat Space Environ Med *46*:1403–1406.

USAF OEHL Report [1984]. The medical results of human exposures to radiofrequency radiation. Brooks Air Force Base, TX; USAF Occupational and Environmental Health Laboratory, Aerospace Medical Division (AFSC); Report 85–029CV111ARA.

Appendix: Occupational Exposure Limits and Health Effects

In evaluating the hazards posed by workplace exposures, NIOSH investigators use both mandatory (legally enforceable) and recommended OELs for chemical, physical, and biological agents as a guide for making recommendations. OELs have been developed by Federal agencies and safety and health organizations to prevent the occurrence of adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. However, not all workers will be protected from adverse health effects even if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the exposure limit. Also, some substances can be absorbed by direct contact with the skin and mucous membranes in addition to being inhaled, which contributes to the individual's overall exposure.

Most OELs are expressed as a TWA exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended STEL or ceiling values where health effects are caused by exposures over a short period. Unless otherwise noted, the STEL is a 15-minute TWA exposure that should not be exceeded at any time during a workday, and the ceiling limit is an exposure that should not be exceeded at any time.

In the U.S., OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits, while others are recommendations. The U.S. Department of Labor OSHA PELs (29 CFR 1910 [general industry]; 29 CFR 1926 [construction industry]; and 29 CFR 1917 [maritime industry]) are legal limits enforceable in workplaces covered under the Occupational Safety and Health Act. NIOSH RELs are recommendations based on a critical review of the scientific and technical information available on a given hazard and the adequacy of methods to identify and control the hazard. NIOSH RELs can be found in the NIOSH Pocket Guide to Chemical Hazards [NIOSH 2005]. NIOSH also recommends different types of risk management practices (e.g., engineering controls, safe work practices, worker education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects from these hazards. Other OELs that are commonly used and cited in the U.S. include the TLVs recommended by ACGIH, a professional organization, and the WEELs recommended by the American Industrial Hygiene Association, another professional organization. The TLVs and WEELs are developed by committee members of these associations from a review of the published, peer-reviewed literature. They are not consensus standards. ACGIH TLVs are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2007]. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2007].

Outside the U.S., OELs have been established by various agencies and organizations and include both legal and recommended limits. Since 2006, the Berufsgenossenschaftliches Institut für Arbeitsschutz (German Institute for Occupational Safety and Health) has maintained a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the U.S. [http://www.

hvbg.de/e/bia/gestis/limit_values/index.html]. The database contains international limits for over 1250 hazardous substances and is updated annually.

Employers should understand that not all hazardous chemicals have specific OSHA PELs, and for some agents the legally enforceable and recommended limits may not reflect current health-based information. However, an employer is still required by OSHA to protect its employees from hazards even in the absence of a specific OSHA PEL. OSHA requires an employer to furnish employees a place of employment 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))]. Thus, NIOSH investigators encourage employers to make use of other OELs when making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminate or minimize identified workplace hazards. This includes, in order of preference, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) personal protective equipment (e.g., respiratory protection, gloves, eye protection, hearing protection). Control banding, a qualitative risk assessment and risk management tool, is a complementary approach to protecting worker health that focuses resources on exposure controls by describing how a risk needs to be managed [http://www.cdc.gov/niosh/topics/ctrlbanding/]. This approach can be applied in situations where OELs have not been established or can be used to supplement the OELs, when available.

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 [ACGIH 2007] and the IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz (IEEE C95.1-2005) [IEEE 2005]. In 2001, the ACGIH TLVs were revised to reflect the same criteria as an earlier version of the IEEE Standard, IEEE C95.1-1999 [ACGIH 2001].

Guidelines for limiting RF exposure have been developed by several voluntary organizations and government agencies in the United States and elsewhere [NCRP 1988; NRPB 1993; ICNIRP 1998; IEEE 2005]. 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.

The IEEE Standard is widely referenced in regard to occupational exposure to RF. The IEEE subcommittee, which prepared IEEE C95.1-2005, concluded that an SAR of 4 W/kg represents the energy absorption rate above which adverse health effects may occur [IEEE 2005]. 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 MPE for occupational settings is 614 V/m for electric fields at frequencies between 0.003 and 3.0 MHz [IEEE 2005].

The IEEE C95.1-2005 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 (Table 1). For workers who lack awareness, safety training, or control, the uncontrolled exposure limits prescribed for the general population are applied (Table 2). 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 cannot 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.

Table 1. MPE for an occupational (controlled) environment*

Frequency (MHz)	Electric Field strength (E) (V/m)	Magnetic Field strength (H) (A/m)	Power Density (S) (mW/cm^2)
100 – 300	61.4	0.163	1‡
300 – 3000	–	–	*f* /300‡

Table 2. MPE – No RF safety program (uncontrolled environment)

Frequency (MHz)	Electric Field strength (E) (V/m)	Magnetic Field strength (H) (A/m)	Power Density (S) (mW/cm^2)
100 – 400	27.5	0.0729	0.2†
400 – 2000	–	–	*f* /2000†
2000 – 5000	–	–	1†

Notes for Tables 1 and 2:

* 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 6-minute or 30-minute exposure period as indicated for the frequency ranges shown in the tables.

"*f*" is the frequency in MHz
‡ 6–minute averaging time
† 30–minute averaging time

Emission vs. Exposure Limits

Emission limits are the maximum power output authorized by the 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 Federal Communications Commission 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 Tables 1 and 2 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 [OET 1997]. and in the reference documents of the American National Standards Institute, IEEE, and the National Council on Radiation Protection and Measurements.

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 6-minute period, workers could be exposed to twice the applicable limit for 3 minutes as long as they were not exposed at all for the preceding or following 3 minutes. Similarly, a worker could be exposed at three times the limit for 2 minutes as long as no exposure occurs during the preceding or subsequent 4 minutes.

References

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

ACGIH [2007]. 2007 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

AIHA [2007]. 2007 Emergency response planning guidelines (ERPG) & workplace environmental exposure levels (WEEL) handbook. Fairfax, VA: American Industrial Hygiene Association.

CFR. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

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

IEEE [2005]. Safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz. Institute of Electrical and Electronics Engineers Standard C95.1–2005.

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.

NIOSH [2005]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005–149. [http://www.cdc.gov/niosh/npg/]. Date accessed: November 2007.

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.

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.

Acknowledgements and Availability of Report

The Hazard Evaluations 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.

This report was prepared by Judith Eisenberg, David Sylvain and Srinivas Durgam of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies. Desktop publishing was performed by Robin Smith. Editorial assistance was provided by Ellen Galloway. Health Communication assistance was provided by Stefanie Evans.

Copies of this report have been sent to employee and management representatives at Wallops Command and Data Acquisition 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 Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161.

Below is a recommended citation for this report:
NIOSH [2008]. Health Hazard Evaluation Report: Nonionizing radiation exposure to technicians at a satellite communication facility, Wallops, VA. 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, NIOSH HETA No. 2007-0095-3063.

NIOSH *National Institute for Occupational Safety and Health*

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-CDC-INFO (1-800-232-4636)

TTY: 1-888-232-6348

E-mail: cdcinfo@cdc.gov

or visit the NIOSH web site at: **www.cdc.gov/niosh.**

For a monthly update on news at NIOSH, subscribe to NIOSH eNews by visiting **www.cdc.gov/niosh/eNews.**

SAFER • HEALTHIER • PEOPLE™