# CALIFORNIA STATE UNIVERSITY, FRESNO

# NON-IONIZING RADIATION SAFETY MANUAL

Office of
Environmental Health and Safety

August 2014

# FOREWORD

Notwithstanding any statements made elsewhere in this manual, this document is not to be considered to be official University policy regarding exposure to Non-Ionizing Radiation (NIR). Instead, it is intended to be used as a set of guidelines, for advisory purposes only, for those individuals, both employees and students, who may come in contact with non-ionizing radiation on campus.

The purpose of these guidelines are to provide information to concerned individuals about how to recognize if non-ionizing radiation may be present and what form it is in; what the potential effects of exposure to various types of non-ionizing radiation may be; and finally what steps may be taken in order to reduce exposure to non-ionizing radiation. Also included is a discussion on the use of warning signs and labels.

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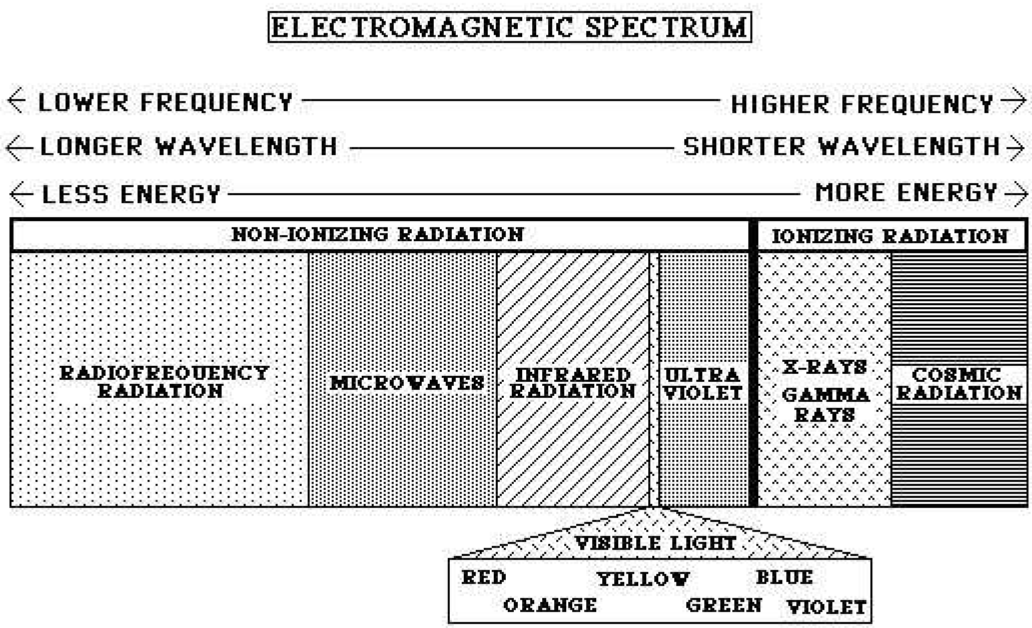
# INTRODUCTION

The modern world is full of devices which, either directly or indirectly, act as sources of non-ionizing radiation (NIR). These sources produce NIR in the electromagnetic spectrum of wavelengths/frequencies ranging from 100 nm to static fields. Many NIR sources are present on campus, either in teaching or research applications or in ancillary equipment.

In general, NIR tends to be less hazardous to humans than ionizing radiation (ionizing radiation has a wavelength less than 100 nm or a photon energy greater than 12.4 electron Volts). However, depending on the wavelength/frequency and the irradiance (or power density) value, NIR sources may present a human health hazard. This manual is intended to provide guidance in maintaining a safe NIR work environment on the campus.




## Non-Ionizing Radiation Safety Policy

It is the policy of the University to provide a workplace safe from the known hazards of NIR by assuring compliance with federal and state safety regulations. Presently, it is not clear if Extremely Low Frequency (ELF) Radiation poses any hazard to human health. However, the ICRP Interim Guidelines on Limits to 50/60 Hz Electric and Magnetic Fields are used by the campus as a precaution. The NIR safety program is upgraded as new regulations and standards become available.

This policy applies to all persons exposed to NIR hazards on campus property. The Office of Environmental Health & Safety, Risk Management and Sustainability (EH&S) has been assigned responsibility for implementing the NIR safety policy.

NOTE: Ionizing radiation, lasers, and coherent light sources are not covered in this manual. For information on the hazards from these sources, see the Radiation Safety Manual, the Laser Safety Manual, and the Laser Safety Training Supplement. Please contact EH&S to obtain these documents or additional information.

**Applicable Regulatory Standards & Guidelines**

| | |
|---|---|
| Non-coherent UV, Visible, Infrared Radiation | Title 8- CCR, ACGIH, ANSI Z136.2 |
| Microwave/Radio Frequency Radiation | FCC OET 65, IEEE C95.1, Title 8-CCR, ACGIH |
| Extremely Low Frequency Radiation | IRPA/INIRC - NIR Protection Guidelines |
| Static Magnetic Fields | ACGIH |

The California Code of Regulations (CCR, Title 8, Section 5085, Subchapter 7, Group 14, Article 104 – Non-ionizing Radiation) establishes MPE (maximum permissible exposure) values for frequencies between 3 MHz and 300 GHz. At present, neither the state nor federal government regulates those frequencies below 3 MHz. The Institute of Electrical and Electronics Engineers (IEEE) C95.1 (2005) Standard recommends MPE values for frequencies between 3 MHz and 3 kHz. This standard is a revision of the American National Standard Institute (ANSI) C95.1 (2005) and is recognized by ANSI as the standard of safety practice.

The International Radiation Protection Association/International Non-Ionizing Radiation Committee (IRPA/INIRC) has published Interim Guidelines on Limits to 50/60 Hz Electric and Magnetic Fields. These guidelines are intended to limit the potential health effects of extremely low frequency (ELF is all frequencies below 3 kHz) radiation exposure. IRPA/INIRC recommends a continuous MPE of 1000 mG (0.1 mT) for exposure to uncontrolled environments over a lifetime. This standard agrees with the permissible magnetic flux exposure for persons wearing cardiac pacemakers recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). NOTE: The ACGIH recommends the electrical field for persons wearing cardiac pacemakers not exceed 1.0 kV/m.

The Federal Communications Commission (FCC) publishes the OET 65 Standard which provides guidance on protection of workers and the public from microwave/RF radiation emissions from transmission towers and other broadcast facilities.

The American National Standards Institute (ANSI) publishes the Z136.2 Standard for the Safe Use of Optical Fiber Communications Systems Utilizing Light Emitting Diodes.

Compliance with CCR Title 8 is required for all employers in the state of California. Enforcement of these regulations falls to Cal-OSHA, who inspects campus facilities to determine compliance with Title 8. Although the IEEE Standard is not a regulation, it does "...represent a consensus of the broad expertise on the subject within the institute..." and is commonly accepted within the United States as the safety guidance for frequencies between 3 MHz and 3 kHz. The IRPA Interim Guideline is the best guidance available on ELF safety that is based on international scientific consensus. The Swedish government has established a performance based emission standard for computer monitor manufacturers (the MPR-II Standard allows a

MPE of 2.5 mG), but the safety need for this standard has not been accepted by the international scientific community.

**Understanding and Evaluating Non-Ionizing Radiation Hazards**

The properties and hazards of NIR can best be understood by considering the EM spectrum as three broad categories:

- Optical radiation (100 nm to 1 mm)
- Microwave radiation (300 GHz to 300 MHz)
- Radiofrequency and lower frequency radiation (300 MHz to Static Fields)

Basic characteristics of optical radiation (ultraviolet/visible light/infrared):

- Possess small wavelengths, large frequencies, and substantial energy (extreme UV approaches the photon energy of ionizing radiation).
- Optical theory can be applied to an analysis of the radiation field.
- Both thermal and photochemical (biological) effects are possible from exposures (depending on wavelength).
- Exposures normally occur in the far field where the E (electric) and H (magnetic) fields are strongly coupled.
- The inverse square law applies to any analysis of the radiation field.
- Only power density (S) measurements are normally considered in the hazard analysis.
- The radiation interacts readily with surfaces and can easily deposit energy in human tissues.

Basic characteristics of microwave radiation (300 GHz to 300 MHz):

- Possess intermediate wavelengths (1 mm to 1 m), frequencies, and moderate photon energy.
- Microwave theory can be applied to an analysis of the radiation field.
- Both thermal and induced current (biological) effects are possible from exposures.
- Exposures may occur in both the near and far fields.
- In hazard analysis, both E (electrical field) and H (magnetic field) measurements must be considered in addition to the power density (S) measurements.
- This type of radiation resonates (forms standing waves) in tissue dimensions with multiples of 1/2 wavelength (depending on the tissue orientation to the wave plane).

Basic characteristics of Radiofrequency and lower frequency (ELF, static) fields:

- Possess large wavelengths (>1 m), small frequencies, and very low energy.
- Circuit theory can be applied to an analysis of the radiation field.
- In general there is poor energy deposition in human tissue but thermal and induced current (biological) effects are possible.
- Exposures usually occur in the near field where the E and H fields are not coupled.
- The inverse square law may not apply.

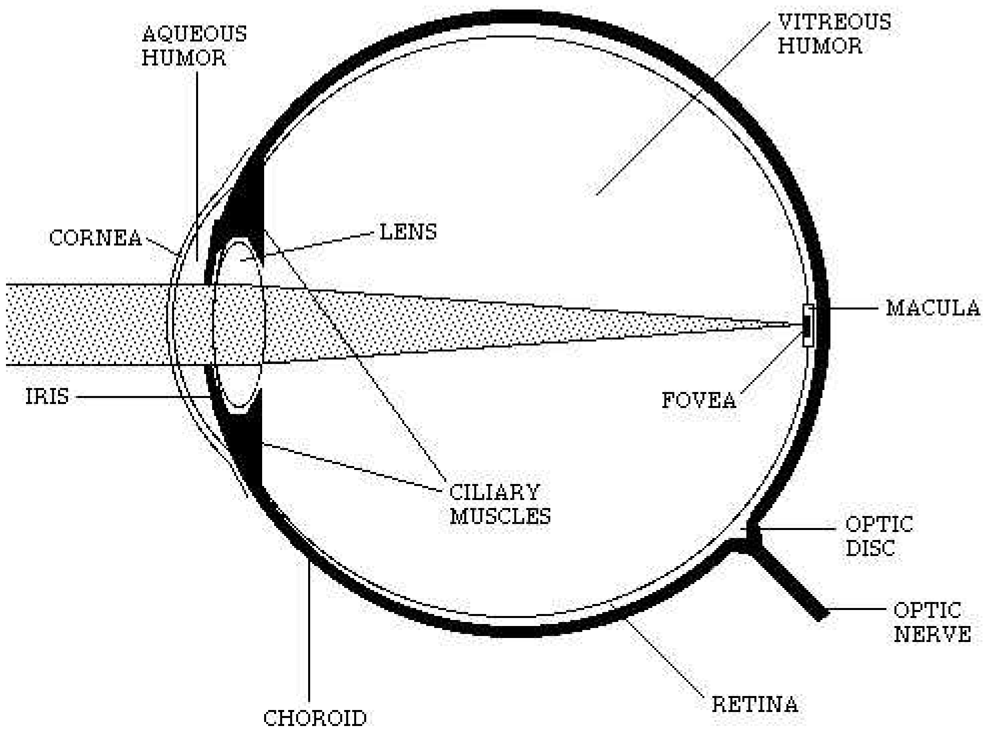
- The E and H measurements must be considered separately for a hazard analysis (of RF).
- At ELF and static fields, the magnetic field dominates the hazard analysis.
- This type of radiation can easily penetrate, but rarely deposit energy in tissue.

## SECTION ONE
## NON-COHERENT LIGHT SOURCE SAFETY

Many devices (or sources) produce either broadband or discrete wavelength radiation between 100 nm and 1 mm. Under certain conditions, these sources may present a health hazard. Factors affecting the potential hazard include: the specific wavelength(s) produced, the irradiance value, the source dimensions, and whether the radiation can access the eye or skin. Sources include (but are not limited to) the following:

- Lamps (filament, discharge, fluorescent, arc, solid state, etc.)
- Plasma sources (welding devices, surface deposition, etc.)
- Heat sources (furnaces, molten glass, open flames, etc.)

Whenever practical, sources of non-coherent light not intended for illumination purposes should be shielded to prevent exposure to the eye or skin. For sources intended to produce exposure (lamps), any unneeded wavelengths (example: ultraviolet emitted from mercury vapor lamps) should be removed with appropriate filtration.



## Ultraviolet Radiation

Ultraviolet (UV) radiation is defined as having a wavelength between 10 nm and 400 nm. Specific wavelength "bands" are defined by the CIE (Commission International de l'Eclairage or International Commission on Illumination) as follows:

Physical Definition

- Extreme UV (10 nm to 100 nm)
- Vacuum UV (100 nm to 200 nm)
- Far UV (200 nm to 300 nm)
- Near UV (300 nm to 400 nm)

Photobiologic Definition

- UV-C (100 nm to 280 nm)
- UV-B (280 nm to 315 nm)
- UV-A (315 nm to 400 nm)

## Ultraviolet Skin Hazards

Ultraviolet (UV) radiation is a known carcinogen for human skin. In addition to cancer induction, erythema (sunburn), and skin aging are also known products of ultraviolet skin exposure. Because the biological effects are dependent on the time of exposure, the specific UV wavelength, and the susceptibility of the individual exposed, it is considered prudent to prevent any unnecessary skin exposure to UV sources. Elimination of unnecessary skin exposure is reinforced by the fact that most individuals will receive substantial UV exposure from the sun during normal outdoor activities over a human lifetime.

UV radiation causes biological effects primarily through photochemical interactions. The UV wavelengths that produce the greatest biological effects fall in the UV-B, but other wavelengths can also be hazardous.

Skin protection is not difficult in theory, as most clothing tends to absorb some of the UV wavelengths. However, in practice, it is often difficult to properly motivate individuals to use appropriate skin protection unless they know they are receiving an erythema (sunburn) dose.

Protection of the skin from UV radiation hazards is best achieved though the use of clothing, gloves, and face shields. The use of UV skin blocks (creams or lotions) is considered inadequate for protection against the high irradiance of man-made UV radiation sources.

## Ultraviolet Eye Hazards

Various components of the human eye are susceptible to damage from extended exposure to direct/reflected UV exposure from photochemical effects. The UV wavelength is the determining factor as to which part(s) of the eye may absorb the radiation and suffer biological effects.

**Absorption of UV wavelengths in the Human Eye**

| Wavelength | Cornea | Aqueous | Lens | Vitreous |
|---|---|---|---|---|
| 100 nm - 280 nm | 100% | 0% | 0% | 0% |
| 300 nm | 92% | 6% | 2% | 0% |
| 320 nm | 45% | 16% | 36% | 1% |
| 340 nm | 37% | 14% | 48% | 1% |
| 360 nm | 34% | 12% | 52% | 2% |

The cornea is like the skin in that it can be "sunburned" by exposure to too much UV radiation. This is called keratoconjunctivitis (snow blindness or welders flash), a condition where the corneal (epithelial) cells are damaged or destroyed. This condition usually does not present until 6 to 12 hours following the UV exposure. Although very painful (often described as having sand in the eyes) this condition is usually temporary (a few days) because the corneal cells will grow back. In very severe cases, the cornea may become clouded and corneal transplants may be needed to restore vision. Exposure to the UV-C and UV-B present the greatest risk to the cornea.

The lens of the eye is unique in that it is formed early in human development and is not regenerated should it become damaged. For normal vision, it is essential that the lens remains clear and transparent. Unfortunately, UV-A exposure is suspected as a cause of cataracts (clouding of the lens).

To protect the human eye from exposure to UV wavelengths, all that is usually needed is a pair of polycarbonate safety glasses or a polycarbonate face shield. This protective eyewear should be worn whenever there is a potential for ongoing UV radiation exposure. Contact the Office of Environmental Health & Safety, Risk Management and Sustainability (EH&S/RMS) for information and advice on appropriate UV protective eyewear.

**Visible Light Hazards**

All visible light (400 to 780 nm) entering the human eye is focused upon the sensitive cells of the retina where human vision occurs. The retina is the part of the eye normally considered at risk from visible light hazards.

Any very bright visible light source will cause a human aversion response (we either blink or turn our head away). Although we may see a retinal afterimage (which can last for several minutes), the aversion response time (about 0.25 seconds) will normally protect our vision. This aversion response should be trusted and obeyed. NEVER STARE AT ANY BRIGHT LIGHT SOURCE FOR AN EXTENDED PERIOD. Overriding the aversion response by forcing yourself to look at a bright light source may result in permanent injury to the retina. This type of injury can occur during a single prolonged exposure. Welders and other persons working with plasma sources are especially at risk for this type of injury.

**NOTE: The aversion response cannot be relied upon to protect the eye from Class 3B or 4 laser exposure (see the Laser Safety Manual for more information).**

Visible light sources that are not bright enough to cause retinal burns are not necessarily safe to view for an extended period. In fact, any sufficiently bright visible light source viewed for an extended period will eventually cause degradation of both night and color vision. Appropriate protective filters are needed for any light source that causes viewing discomfort when viewed for an extended period of time.

For these reasons, prolonged viewing of bright light sources (plasma arcs, flash lamps, etc.) should be limited by the use of appropriate filters. Traditionally, welding goggles or shields of the appropriate "shade number" will provide adequate protection for limited viewing of such sources. Please contact EH&S/RMS for advice on appropriate eye protection.

The blue light wavelengths (400 to 500 nm) present a unique hazard to the retina by causing photochemical effects similar to those found in UV radiation exposure. Visible light sources strongly weighted towards the blue should be evaluated by EH&S/RMS to determine if special protective eyewear is needed.

## Infrared Radiation

Infrared (or heat) radiation is defined as having a wavelength between 780 nm and 1 mm. Specific biological effectiveness "bands" have been defined by the CIE (Commission International de l'Eclairage or International Commission on Illumination) as follows:

- IR-A (near IR) (780 nm to 1400 nm)
- IR-B (mid IR) (1400 nm to 3000 nm)
- IR-C (far IR) (3000 nm to 1 mm)

## Infrared Radiation Hazards

Infrared radiation in the IR-A that enters the human eye will reach (and can be focused upon) the sensitive cells of the retina. For high irradiance sources in the IR-A, the retina is the part of the eye that is at risk. For sources in the IR-B and IR-C, both the skin and the cornea may be at risk from "flash burns." In addition, the heat deposited in the cornea may be conducted to the lens of the eye. This heating of the lens is believed to be the cause of so called "glass blowers" cataracts because the heat transfer may cause clouding of the lens.

- Retinal IR Hazards (780 to 1400 nm) - possible retinal lesions from acute high irradiance exposures to small dimension sources.
- Lens IR Hazards (1400 to 1900 nm) - possible cataract induction from chronic lower irradiance exposures.
- Corneal IR Hazards (1900 nm to 1 mm) - possible flashburns from acute high irradiance exposures.
- Skin IR Hazards (1400 nm to 1 mm) - possible flashburns from acute high irradiance exposures.

The potential hazard is a function of the following:

- The exposure time (chronic or acute)
- The irradiance value (a function of both the image size and the source power)
- The environment (conditions of exposure)

Evaluation of IR hazards can be difficult, but reduction of eye exposure is relatively easy through the use of appropriate eye protection.  As with visible light sources, the viewing of high irradiance IR sources (plasma arcs, flash lamps, etc.) should be limited by the use of appropriate filters.  Traditionally, welding goggles or shields of the appropriate “shade number” will provide adequate protection for limited viewing of such sources.

Specialized glassblowers goggles may be needed to protect against chronic exposures.

Please contact EH&S/RMS for advice on appropriate eye protection.

# SECTION TWO
## MICROWAVE AND RADIOFREQUENCY RADIATION SAFETY

### Microwave/RF Radiation Sources

The campus contains many potential sources of microwave/RF radiation exposure. Some of these sources (primarily antennas) are designed to emit microwave/RF radiation into the environment. Other types of sources (co-axial cables, waveguides, transmission generators, heaters, and ovens) are designed to produce or safely contain the microwave/RF radiation, but may present a hazard should they leak for some reason. A third type of source (primarily power supplies) may create microwave/RF radiation as a byproduct of their operation.

### Factors Affecting Exposure to Microwave/RF Radiation

The hazards from exposure to microwave/RF radiation are related to the following parameters:

- Frequency of the source
- Power density at the point of exposure
- Accessibility to the radiation field
- Does the exposure occur in the near or far field
- Orientation of the human body to the radiation field

This combination of factors is used in both evaluating and mitigating the hazard.

### Potential Bioeffects of Exposure to Microwave/RF Radiation

In general, most biological effects of exposure to microwave/RF radiation are related to the direct heating of tissues (thermal effects) or the flow of current through tissue (induced current effects). Non-thermal effects resulting in carcinogenesis, teratogenesis, etc. have been demonstrated in animals but have not been proven by epidemiological studies on humans. The following biological effects have been demonstrated in humans:

- Cataract formation (from eye exposure).
- RF (induction) burns.
- Burns from contact with metal implants, spectacles, etc.

### Standards for Microwave/RF Radiation Exposure Protection

A large number of standards have been developed for use in protecting individuals against overexposure to microwave/RF radiation. These standards often address only specific frequency bands or exposure conditions. In an effort to address the potential for microwave/RF radiation exposure at the University, the following table of exposure standards was developed. The table is a synthesis of several regulatory standards and guidelines (as indicated).

Radio Frequency Exposure Standards
(Derived from ACGIH TLV, CCR Title 8, IRPA NIR, FCC OET 65, and IEEE C95.1)

## OCCUPATIONAL EXPOSURE LIMITS

All exposures averaged over 0.1 hour (6 minutes)

| Frequency Band | E field (V/m) | H Field (A/m) | S (mW/cm$^2$) |
|---|---|---|---|
| <3 kHz | 5000 | 80 (1000 mG) | N/A |
| 3 kHz - 100 kHz | 614 | 1.63 | 100 |
| 100 kHz-1.34 MHz | 614 | 1.63 | 100 |
| 1.34 MHz - 3 MHz | 614 | 1.63 | 100 |
| 3 MHz - 30 MHz | 1842/f | 4.89/f | $900/f_2$ |
| 30 MHz - 100 MHz | 61.4 | 0.163 | 1 |
| 100 MHz - 300 MHz | 61.4 | 0.163 | 1 |
| 300 MHz - 3 GHz | N/A | N/A | f/300 |
| 3 GHz - 15 GHz | N/A | N/A | f/300 |
| 15 GHz - 30 GHz | 137 | 0.36 | 5 |
| 30 GHz - 300 GHz | 137 | 0.36 | 5 |

Where: f = frequency in MHz

## NON-OCCUPATIONAL EXPOSURE LIMITS

All exposures averaged over 0.5 hour (30 minutes)

| Frequency Band | E field (V/m) | H Field (A/m) | S (mW/cm$^2$) |
|---|---|---|---|
| <3 kHz | 5000 | 80 (1000 mG) | N/A |
| 3 kHz - 100 kHz | 614 | 1.63 | 100 |
| 100 kHz-1.34 MHz | 614 | 16.3/f | 100 |
| 1.34 MHz - 3 MHz | 823.8/f | 16.3/f | $180/f_2$ |
| 3 MHz - 30 MHz | 823.8/f | 16.3/f | $180/f_2$ |
| 30 MHz - 100 MHz | 27.5 | $158.3/f_{1.688}$ | 0.2 |
| 100 MHz - 300 MHz | 27.5 | 0.0729 | 0.2 |
| 300 MHz - 3 GHz | N/A | N/A | f/1500 |
| 3 GHz - 15 GHz | N/A | N/A | f/1500 |
| 15 GHz - 30 GHz | N/A | N/A | f/1500 |
| 30 GHz - 300 GHz | N/A | N/A | 5 |

Where: f = frequency in MHz

Key to Reference Standards

- International Non-ionizing Radiation Committee (INIRC) of the International Radiation Protection Association (IRPA) - Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields (1998).
- Institute of Electrical and Electronics Engineers (IEEE) Publication C95.1 - Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz (2005).
- California Code of Regulations, Title 8 - Industrial Relations, Division 1 - Department of Industrial Relations, Chapter 4 - Division of Industrial Safety, Subchapter 7 - General Industry Safety Orders, Group 14 - Radiation and Radioactivity, Article 104 - Non-ionizing Radiation, Section 5085 - Radio frequency and Microwave Radiation.
- American Conference of Governmental Industrial Hygienists (ACGIH) , Threshold Limit Values for Chemical Substances and Physical Agents , Physical Agents Section , Sub-Frequency (30 kHz and below) Magnetic Fields & Sub-Frequency (30 kHz and below) and Static Electric Fields.
- Federal Communications Commission Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields , OET Bulletin 65, Edition 97-01, 1997.

**Identifying and Controlling Microwave/RF Radiation Hazards**

The Office of Environmental Health & Safety, Risk Management and Sustainability (EH&S/RMS) will work with you to identify and assess the microwave/RF radiation hazards in your work area. Because of the difficulties of performing actual microwave/RF radiation surveys (near field measurements, cost of equipment, etc.), it is often necessary to use calculations and/or computer models to replace actual measurements in evaluating the hazard.

**Antennas and Antenna Arrays**

Operation of radio, television, microwave, and other related communication systems using electromagnetic radiation, and carrier-current systems require prior review and approval by Technology Services and the Office of Environmental Health & Safety, Risk Management and Sustainability (EH&S/RMS). Technology Services, in coordination with EH&S/RMS, will advise you on licensing requirements, operational issues, FCC regulations and the appropriate exposure model to use in your hazard assessment process. Please provide EH&S/RMS with a copy of your hazard assessment for regulatory review. Technology Services coordinates all FCC applications with the Office of the Provost and maintains all campus-approved licenses. EH&S/RMS, in coordination with Technology Services, maintains an inventory of all transmission antennas on campus. Please contact EH&S/RMS before you place a new transmission antenna in or on any campus building or location.

**Wireless Local Area Networks (WLAN)**

Radio frequency based wireless local area networks based on the IEEE 802.11b Standard are becoming available on the campus. Wireless LAN systems (indoor and outdoor) are very safe when properly installed and used. WLAN systems operate on extremely low power (less than that of a cell phone). It is important that only approved equipment be used to build a campus operated WLAN.

Construction or modification of campus operated WLAN equipment must be reviewed and approved by ITS and EH&S/RMS in order to prevent potential hazardous conditions from existing. The placement of base station antennas should be high on a wall or on the ceiling. This not only increases the useful range of the system, but also allows for a separation distance of 50 cm, which is sufficient of safe operation. In general, persons should avoid direct contact with antennas attached to computer cards. A separation distance of 10 cm is sufficient for safe operation.

**Other Potential Microwave/RF Radiation Sources (Leakage Sources)**

For waveguides, co-axial cables, generators, sealers, and ovens, probably the most important aspect of controlling microwave/RF radiation hazards is a careful physical inspection of the source. Leaking sources will normally show misalignment of doors or plates, missing bolts, or physical damage to plane surfaces. Sources, which are suspected of leaking, should be repaired and then surveyed with appropriate instrumentation to verify they are no longer leaking. Contact EH&S/RMS if you need assistance with evaluating microwave/RF radiation leakage hazards.

**Microwave Ovens**

Because of the large number of microwave ovens used and their presence in nearly every Department, EH&S/RMS has special concerns about safety with these devices. Specific guidance on microwave oven safety can be found in the Appendix C in the back of this manual. It is very unusual for a commercial microwave oven to leak, but misuse, damage, and interlock failures have caused ovens to leak. Any microwave oven suspected of leaking will be surveyed, upon request, by EH&S/RMS. Please contact EH&S/RMS if you would like your ovens surveyed.

**Power Supplies**

Many high voltage power supplies operate in the microwave or radiofrequency regions. If damaged, or not properly shielded, these sources can leak, producing unintended microwave/RF radiation exposure. Most of the time, the leakage from these sources is minimal and does not present a hazard. However, if you have an indication of microwave/RF radiation leakage (RF interference with other equipment or documentation warning of interference), please contact EH&S/RMS for a survey.

## SECTION THREE
## EXTREMELY LOW FREQUENCY RADIATION SAFETY

### What is ELF Radiation?

Whenever a current passes through a wire, a magnetic field is produced. Because electric power generation in the United States changes polarity at 60 Hz (cycles per second), the magnetic fields generated also alternate at 60 Hz. Since about 1980, these 60 Hz magnetic fields (and their frequency harmonics) have been suspected of causing various types of negative health effects. These magnetic fields are commonly called extremely low frequency (or ELF) fields.

### Does ELF Present a Human Health Hazard?

The most accurate answer is that no one really knows. Although some health effects have been statistically related to ELF exposure, these effects are poorly understood and may exist only as statistical or scientific errors. Some research studies, which originally indicated ELF health effects, could not be duplicated. Much of the data supporting effects is from epidemiological studies and the effects found were slightly outside the boundaries of statistical error. What can be determined from this information is that any real effect (and the corresponding hazard) must be relatively small.

### Are there Protection Standards for ELF Exposure?

In the absence of conclusive data, the International Radiation Protection Association/International Non-Ionizing Radiation Committee (IRPA/INIRC) have produced an interim exposure guideline. Although the US Government and the State of California have no regulations on exposure to ELF, the University has adapted the IRPA/INIRC guidelines in order to address employee concerns.

**The IRPA/INIRC Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields**

| Exposure Type | Electric Field Strength in $kV/m^2$ | Mag. Flux Density in mT |
|---|---|---|
| **Occupational** | | |
| Working Day (8 hours) | 10 | 0.5 (5 Gauss) |
| Short Term | 30* | 5** (50 Gauss) |
| Extremities (limbs) | --- | 25 (250 Gauss) |
| **Non-Occupational** | | |
| Continual - 24 hours/day*** | 5 | 0.1 (1 Gauss) |
| A few hours/day**** | 10 | 1 (10 Gauss) |

*The duration of exposure to fields between 10 and 30 $kV/m^2$ may be calculated from the formula **t < 80 E**, where **t** is the duration in hours per work day and **E** is the electric field strength in $kV/m^2$.

**Maximum exposure duration is 2 hours per workday.

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

****These values can be exceeded for a few minutes each day provided precautions are taken to prevent indirect coupling effects.

## What is a normal ELF Field?

Since even the wiring for electric lights will generate ELF magnetic fields, these fields are present in virtually every room of every building on campus. The ELF field intensity is a function of the amperage passing through the wiring. In general, transformers and large motors will produce the most intense fields. Mechanical spaces and machine shops normally have the most intense fields and these may (rarely) exceed the non-occupational exposure limit. Laboratories and offices usually do not have intense fields and a reasonable average value for these areas has been measured at about 3 to 5 mG (milliGauss). So normally, the ELF fields employees are exposed to are less than 1% of the non-occupational exposure limit.

## Who Should I Call if I Have ELF Concerns?

The Office of Environmental Health & Safety, Risk Management and Sustainability is available to address questions on ELF exposure. A number of training documents are available to explain what is (and is not) known about ELF exposure and health effects. Please contact EH&S/RMS if you would like copies of these documents.

EH&S/RMS is also available, upon request, to perform ELF surveys of specific equipment or work areas. Survey reports will characterize the ELF field intensity in the areas surveyed, but cannot specifically address the hazards of fields found to be in excess of the IRPA/INIRP Guidelines.

EH&S/RMS will normally recommend that exposure to fields in excess of the guidelines be mitigated so as to prevent exposure above the IRPA/INIRP Guidelines to employees or students. Since there is no legal requirement to control ELF exposure, the implementation of such recommendations is at the discretion of the Department.

# SECTION FOUR
## STATIC MAGNETIC FIELD SAFETY

Many sources (devices) on campus produce static magnetic fields. Static magnetic fields result from either fixed magnets or the magnetic flux resulting from the flow of direct current (DC). Sources producing these fields include (but are not limited to) the following:

- Nuclear Magnetic Resonance (NMR) imaging and spectroscopy devices
- Electron Paramagnetic Resonance (EPR, ESR, EMR) devices
- Helmholtz Coils, Solenoids, DC Motors, etc.

### Factors Affecting Static Magnetic Field Hazards

Under certain conditions, sources of static magnetic fields can present health hazards. Factors affecting the potential hazards include:

- Magnetic flux intensity associated with the source
- Design of the magnetic field source
- Accessibility of the magnetic field
- Equipment/hazardous materials associated with the magnetic field source

Sources of large static magnetic fields may require appropriate controls to mitigate potential hazards. For sources intended to produce human exposure to the magnetic field (such as MRI devices), it is critical that safety precautions cover not only the user of the device, but also the research subject.

### Bioeffects of Exposure to Static Magnetic Fields

There are no known adverse bioeffects for flux densities within the ACGIH (American Conference of Governmental Industrial Hygienists) exposure limits. Implanted medical devices present a potential hazard to individuals exposed to fields above the ACGIH limits (see following section on kinetic energy hazards).

### Kinetic Energy Hazards

Due to the large fields associated with NMR magnets, ferrous objects can be accelerated toward the magnet with sufficient energy to seriously injure persons and/or damage the magnet. As a precaution, even small metal objects (screws, tools, razor blades, paper clips, etc.) should be kept at least 1.5 meters from the magnet (or anywhere the field exceeds 30 G). Large ferrous objects (equipment racks, tool dollies, compressed gas cylinders, etc.) should be moved with care whenever the field approaches 300 G. There are many recorded instances in which large objects have been drawn towards and even into the bore of the magnet.

## Standards for Exposure to Static Magnetic Fields

The ACGIH and International Council on Non-Ionizing Radiation Protection (ICNIRP) have set guidelines for continuous exposure to static electromagnetic fields as indicated in the table below:

Note: 1 Gauss (G) = 0.1 millitesla (mT)

| | |
|---|---|
| 5 G | Highest allowed field for implanted cardiac pacemakers. |
| 10 G | Watches, credit cards, magnetic tape, computer disks damaged. |
| 30 G | Small ferrous objects present a kinetic energy hazard. |
| 600 G | Allowed TWA for routine exposure (whole body). |
| 6000 G | Allowed TWA for routine exposure (extremities). |
| 20,000 G (2T) | Whole body ceiling limit (no exposure allowed above this limit). |
| 50,000 G (5T) | Extremity ceiling limit (no exposure allowed above this limit). |

NOTE: TWA exposure time is normally only a concern for extremely high field exposures to the whole body.

## Magnetic Field Measurements

NMR magnets commonly produce core fields from 0.2 T to 20 T. These fields decrease in intensity as the distance from the core increases. A field strength map of the area surrounding the magnet should be developed and posted for use by staff. If the magnetic fields in your laboratory have not yet been evaluated, please call the Office of Environmental Health & Safety, Risk Management and Sustainability (EH&S/RMS) to schedule a survey.

## Posting of Magnetic Field Hazards

All access points to rooms containing magnets fields in excess of 5 G shall be marked with magnetic field hazard signs (available from EH&S/RMS). The 5 G threshold line shall be clearly identified with floor tape or equivalent markings. The location of the 5 G line will vary with the operating frequency and resulting magnetic fields. As an example, one vendor indicates the following values for their NMR spectroscopy equipment:

Operating frequency of 200 MHz - 5 G threshold line @ 1.3 meters
Operating frequency of 500 MHz - 5 G threshold line @ 3.5 meters
Operating frequency of 800 MHz - 5 G threshold line @ 6.0 meters

**Access Restrictions**

Persons with cardiac pacemakers or other implanted medical devices shall be restricted to areas outside the 5 G threshold line. Security (locked doors) and proper door markings shall be maintained to prevent unauthorized access to the magnet area.

## Cryogenic Gas Issues

**Types and Expansion Ratios** - The cryogenic (liquefied) gases used with NMR magnets are Liquid Nitrogen (-320˚ F) and Liquid Helium (-452˚ F). If these liquids are raised to room temperature, the resulting gases expand to hundreds of times their liquid volumes, possibly displacing the air in the room (LN = 694/1, LH = 700/1).

**Quench** - Quench is the (normally unexpected) loss of superconductivity in a NMR magnet resulting in rapid heating through increased resistance to the high current. This can violently damage the magnet and cause rapid venting of large volumes of He/N gas into the room, quickly resulting in an oxygen deficient atmosphere. To avoid a quench situation, use cryogen level sensors and always refill or de-energize the magnet if low cryogen levels are indicated on the sensors. NOTE: Quench conditions can result from ferrous objects being drawn into the magnet bore.

**Personal Protective Equipment (PPE)** - When handling cryogens, use insulated gloves and face shields or other splash eye/face protection, closed-toed shoes, and lab coats.

**Dewars** - The containers used for transporting cryogens should be made of metal. Glass dewars can easily implode, causing seriously injury. All dewars should have appropriate pressure vents. Unvented containers can rupture as the liquid warms and expands. All transfers of cryogens should be continuously attended to prevent spills or frozen valves.

**Room Ventilation** - Generally speaking, five complete room air changes per hour is considered adequate for managing small spills or releases of cryogens. In the event of a major release, the staff should immediately leave the room and the room doors should be left open. If the risk of a catastrophic release exists, auxiliary ventilation should be considered to prevent the formation of an oxygen deficient atmosphere.

**Bioeffects of Cryogen Exposure** - Direct contact with the skin or eye tissues can cause severe damage through frostbite (tissue damage from freezing). If the frostbite is severe, the damaged tissues may need to be amputated. Inhalation of concentrated cryogen gases may cause loss of consciousness and (eventually) death through oxygen deprivation (asphyxiation).

## Electrical Safety Issues

**Power Supplies** - Although the power supplies used for NMR magnets operate at relatively low voltages (about 10 V), the current used is very large (about 100A). High amperage is extremely dangerous if allowed to come into contact with tissues.

**Cables, Wires, and Connectors** - All cables, wires, and connectors should be properly insulated to prevent contact with the operating current. These should be inspected on a regular basis to assure the integrity of the insulation. In order to prevent arcing; never break connections without first turning off the power to the circuit being handled.

**LOTO (Lock Out, Tag Out) -** Cal-OSHA requires all workers to follow LOTO procedures when working on equipment which is activated by a hazardous energy source. Contact EH&S/RMS for information on LOTO requirements.

**Qualification of Electrical Workers -** Cal-OSHA requires that persons who work on electrical equipment be properly qualified. Contact EH&S/RMS for information on qualification requirements.

**Home Built Equipment -** Must be designed and maintained so as to meet safety standards. Enclosures with proper grounding and safety markings are required for all home built electronics.

**Bioeffects of Electrical Exposure -** Current moving across a break in an electrical circuit may cause a high temperature arc to occur. Depending on the current, this arc can exceed 10,000˚ F, causing severe burns. Blast effects resulting from the vaporization of copper or other metals in the arc can throw people and equipment across rooms, causing severe trauma injuries. Even if an arc is not struck, current flowing through tissues can result in burns, “blow out” injuries, and possible cardiac failure (depending on the line frequency). Every effort must be made to follow good electrical safety practices and avoid direct contact with live current.

**Radiofrequency Radiation (RF) Issues**

**RF Sources -** The RF source being used for the NMR should be commercially produced or equivalent quality if assembled in the laboratory. Units that are lab built or modified should be checked to assure they are safe and do not leak radiation.

**Waveguides and Coils -** Should be carefully checked to assure there are no gaps or loose bolts that will allow leakage of the radiation. Care should be taken to avoid direct contact with coils to avoid RF burns.

**RF Measurements -** If the RF fields in your laboratory need evaluation, please call the Office of Environmental Health and Safety (ORS) to obtain a survey.

**Bioeffects -** Exposure to high level RF fields can cause heating and damage of tissues. Skin burns can occur from direct contact with RF coils.

## Other Hazard Issues

**Tripping Hazards -** Cables and wires lying about on the floor can present tripping hazards. Please make every effort to keep cables in trays or covered by bridges.

**Fire Protection -** A Class C fire extinguisher should be kept nearby to deal with electrical fires. The power must be shut down before attempting to fight an electrical fire. All staff should be trained in fire protection and evacuation procedures.

**Earthquake Concerns -** Magnet assemblies may weigh several tons and must be restrained so they will not move about or tip over during an earthquake. Their placement should take into account structural steel support members. Power supplies should also be secured to prevent movement in an earthquake.

**Ergonomic Concerns -** The prolonged use or improper ergonomic setup of VDT stations may cause eye or neck strain problems. Back injuries may result from the use of improper lifting procedures or lifting heavy objects without assistance

## USE OF NIR HAZARD SIGNS AND WARNING LABELS

Depending on the accessibility and level of NIR hazards, it may be necessary to mark rooms or other areas with appropriate warning signs (static magnetic fields, UV light, etc.). Please consult with EH&S/RMS on the need for such signs prior to placing them. Please refer to Appendix E for the appropriate design of warning signs. EH&S/RMS provides these and other custom NIR signs upon request. Please contact EH&S/RMS for assistance with warning signs.

Warning labels should be placed on equipment to indicate the presence of specific NIR hazards (UV light, RF fields, etc.). Again, please consult with EH&S/RMS on the need for such labels prior to placing them. EH&S/RMS provides these labels upon request. Please contact EH&S/RMS for assistance with warning labels.

# APPENDIX A

NIR Emergency Response Procedure

In the event of an accident involving an NIR source, immediately do the following:

1. Using caution first shut down the source of the NIR radiation and then lock out/tag out the power supply.

2. Provide for the safety of personnel (first aid, evacuation, etc.) as needed.

   NOTE: If an eye injury is suspected, have the injured person keep their head upright and still to restrict any bleeding in the eye. A physician should evaluate eye injuries as soon as possible.

3. Obtain medical assistance for anyone who may be injured.

   Emergency Medical Assistance **911**
   University Health Service (non-urgent medical care) 8-2734
   Saint Agnes Occupational Health Center (non-urgent medical care) 450-7777

4. If there is a fire, leave the area, pull the fire alarm, and contact the university police department by calling 911. Do not fight the fire unless it is very small and you have been trained in fire fighting techniques.

5. Inform the Office of Environmental Health & Safety, Risk Management and Sustainability (EH&S/RMS) as soon as possible.

   (During normal working hours, call these numbers)

   EH&S/RMS Office number - 8-7422
   Radiation Safety Officer - 8-7394

   After normal working hours, call 911 or 8-8400 to contact the University Police Department (they have an EH&S/RMS emergency call list).

6. Inform the Principal Investigator (PI) as soon as possible. If there is an injury, the PI must submit a report of injury to Risk Management.

7. After an accident, do not resume use of the NIR source until released to do so by the Office of Environmental Health & Safety, Risk Management and Sustainability (EH&S/RMS).

# APPENDIX B

## Microwave Oven Safety Guidelines

- Do not operate the oven if it is damaged or does not operate properly. It is imperative that the oven door seals properly and that there is no damage to the door seal, hinges, latches, or oven surfaces.

- Ovens used for food preparation must be cleaned on a regular basis to prevent biological contamination, fire potential, and door seal damage.

- Ovens used for laboratory applications cannot be used for food preparation. Conversely, food preparation ovens should never be used for other applications.

- Do not use aluminum foil or any metal containers, metal utensils, metal objects, or objects with metal or foil trim in the oven. Such items can cause arcing, damaging the oven and creating a fire or burn hazard. A classic item, which is often overlooked, is the metal handle on the paper Chinese food box.

- Do not heat objects that are sealed as they may explode, damaging the oven and blowing off the door.

- Never heat any flammable or combustible liquid in the oven. A fire and/or explosion may result.

- Be careful when removing containers from the microwave. Containers or their contents may be very hot, resulting in burns or spills of hot materials.

- If a fire should start inside the oven, leave the door closed, disconnect the power cord and call the university police department at 911.

- Never make adjustments to or tamper with any component of the oven. Do not try to perform repairs on your own. The oven operates on high voltage and amperage that can be lethal if improperly handled.

- Generally speaking, commercially available microwave ovens are very safe and reliable, regardless of the manufacturer. All ovens produced for sale in the United States must meet a strict FDA/CDRH product performance requirement that limits their microwave leakage during service to 5 $mW/cm^2$ at 5 cm from any oven surface.

- If your oven is damaged or you have a reason to believe it may be leaking, please contact EH&S/RMS at 8-7422 to arrange a survey of the oven.

# APPENDIX C
## USEFUL NIR FORMULAS

frequency/wavelength relationship

$c = \lambda \nu$ or $\lambda = c / \nu$ or $\nu = c / \lambda$

where:
- $c = 3 \times 10^8$ m/s
- $\lambda$ = wavelength (m)
- $\nu$ = frequency (Hz)

energy/frequency relationship

$Q = h \nu$

where:
- $h = 6.626 \times 10^{-34}$ (Js)
- or $h = 4.136 \times 10^{-15}$ (eVs)
- Q = energy in (J or eV)
- $\nu$ = frequency (Hz)

power density/electric & magnetic field relationship

$S = E H$

$S\ (\mathrm{mW/cm^2}) = 37.7 \times H^2 = E^2 / 3{,}770$

$E / H = 377\ \Omega$ (ohm)

where:
- S = power density ($W/m^2$)
- E = electric field (V/m)
- H = magnetic field (A/m)

magnetic flux density/permeability & magnetic field relationship

$B = \mu H$

$1\ T = 10^4$ G (Gauss)

$1\ A/m = 1.26\ \mu T = 12.6$ mG

where:
- B = magnetic flux density (T)
- $\mu = 1.26 \times 10^{-6}$ (H/m)
- H = magnetic field (A/m)

magnetic field/current & distance relationship

$H = \mu I / 2 \pi r$

where:
- H = magnetic field (A/m)
- $\mu = 1.26 \times 10^{-6}$ (H/m)
- I = current (A)
- r = radius (m)

antenna gain

$G / A = 4 \pi / \lambda^2$ or $G = A (4 \pi / \lambda^2)$

where:
- G = gain (numerical)
- A = area of antenna ($m^2$)
- $\pi = 3.1416$
- $\lambda$ = wavelength (m)

far field power density

$S = G P / 4 \pi r^2 = A P / \lambda^2 r^2$

where:
- P = power output (W)
- S = power density ($W/m^2$)
- r = distance from antenna (m)
- $\lambda$ = wavelength (m)
- A = area of antenna ($m^2$)

defining far field

$FF = D^2 / 4 \lambda$ (for a circular antenna) where: $D = \sqrt{P G / 4 \pi}$

$FF = G \lambda / 4 \pi n$ (for other antenna shapes) $n$ = eff. Factor (assume 0.8)

assume the near field power density to be constant a 4 P for safety purposes

near field power density

$S = 16 P / \pi D^2 = 4 P / A$ where:

$P$ = average power (W)
$D$ = antenna distance (m)
$A$ = area of antenna ($m^2$)
$S$ = power density ($W/m^2$)

limit of the near field

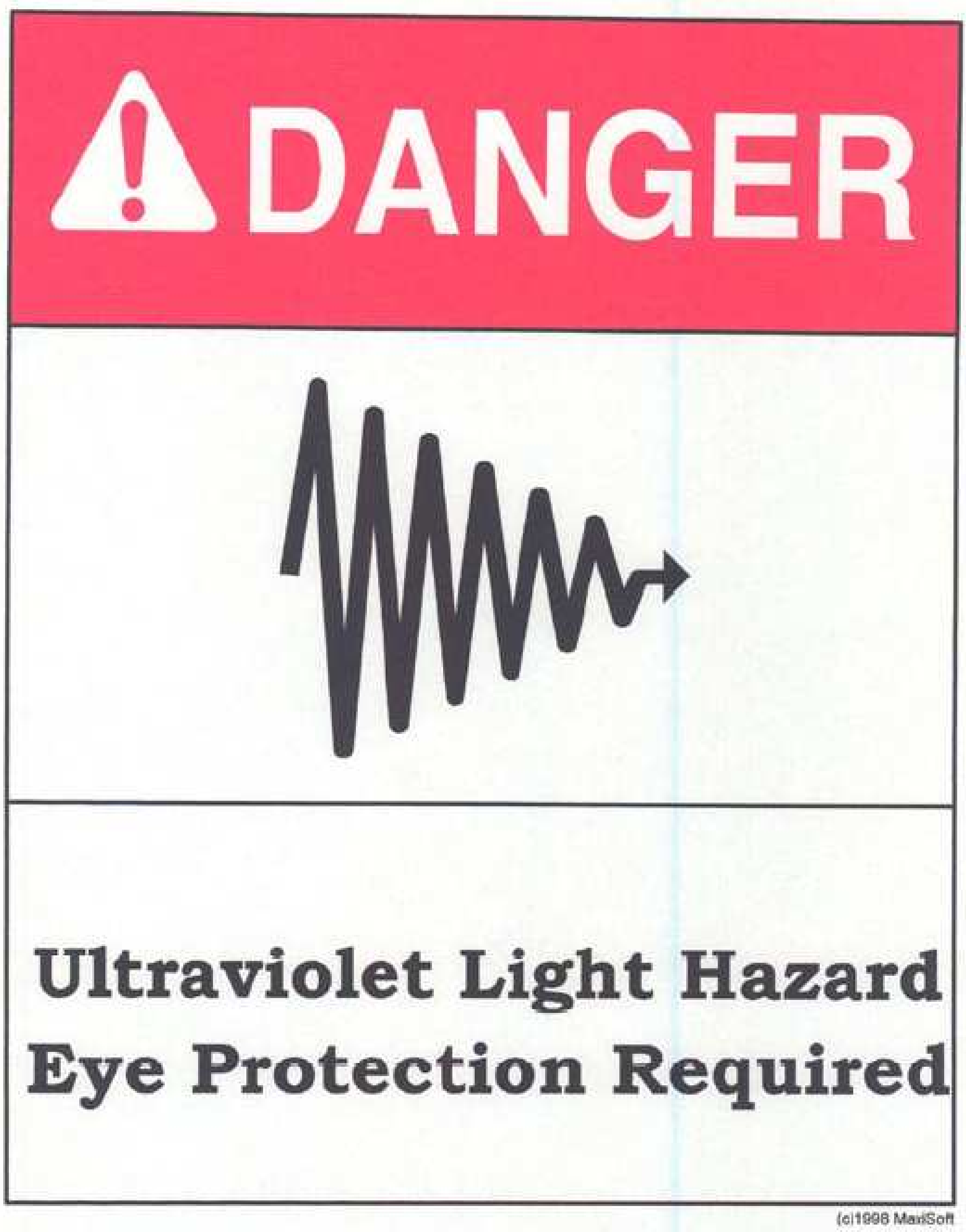
$NF = \pi D^2 / 8 A = A / 2 \lambda$ where:

$NF$ = limit (m)
$D$ = antenna distance (m)
$A$ = area of antenna ($m^2$)
$\lambda$ = wavelength (m)

**APPENDIX D**

Design of NIR Warning Signs


CAUTION
Radio Frequency
Hazard
(c)1998 MaxiSoft


DANGER
Ultraviolet Light Hazard
Eye Protection Required
(c)1998 MaxiSoft


CAUTION
MICROWAVE HAZARD
NO ENTRY WHILE
ENEGIZE
(c)1998 MaxiSoft