Dryden Flight Research Center
Edwards, California 93523

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Dryden Centerwide Procedure

Code SH

Chapter 12
Non-Ionizing Radiation Safety

This Chapter Contains Hazardous Operations.

Electronically approved by
Assistant Director for Management Systems

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1.0 PURPOSE OF CHAPTER

This chapter establishes procedures and guidelines, delegates authority, and assigns responsibility for managing the Dryden Flight Research Center Non-Ionizing Radiation Program.

2.0 PROCEDURE SCOPE & APPLICABILITY

Scope: This procedure applies to all non-ionizing radiation operations conducted at Dryden.

Applicability: Compliance with this document is mandatory for all persons under Dryden supervision including civil servants, contractors, and visitors.

3.0 PROCEDURE OBJECTIVES, METRICS, & TREND ANALYSIS

Objective: Identify and eliminate potential non-ionizing radiation mishaps with the desired results of sustained zero non-ionizing radiation mishaps

Metric 1: All lasers and microwave (mw) / radio frequency (rf) sources will be identified and evaluated in order to apply adequate safety controls to prevent a radiation mishap.

Metric 2: All personnel using Class 3b and 4 lasers will be laser trained.

Metric 3: All personnel using mw / rf radiation will be trained.

Trend Analysis: Program review will be accomplished annually. Metrics will be analyzed to determine whether procedural objectives have been met.

4.0 WAIVER AUTHORITY

Requests for waivers and variances to DFRC specific safety documents will be made to the Office of Safety and Mission Assurance, (Code S). Requests for waivers and variances to NASA safety instructions will be made to NASA HQ in accordance with instructions provided by NPR 8715.3, “NASA Safety Manual,” Par. 1-19, “Safety Variance Process,” and Table 1-1: “NASA Safety Risk and Approval Process Matrix.” All requests for waivers and variances to safety instructions, including those to other regulatory agencies, will be coordinated through Code S.

5.0 RESPONSIBILITIES

5.1 Director, Office of Safety and Mission Assurance

The Director, Office of Safety and Mission Assurance, is the official charged with the responsibility for safety programs at DFRC and will:

A. Ensure a continuing surveillance of operations utilizing sources of non-ionizing radiation.

B. Ensure adequate procedures are in place to provide protection to DFRC personnel, the public, and the environment from sources of non-ionizing radiation controlled by DFRC.

5.2 Directorates and Single Letter Offices

Are responsible for ensuring that risk assessments of non-ionizing radiation operations within their area of responsibility are made and that appropriate safety measures are followed when non-ionizing radiation operations are conducted.

5.3 Safety, Health, and Environmental Office

The Chief, Safety, Health, and Environmental Office, has safety oversight responsibilities for Non-ionizing Radiation Programs at DFRC and as such will:

A. Appoint the Laser Safety Officer (LSO) and the Radiofrequency Safety Officer (RFSO).

B. Advise management on safety issues concerning non-ionizing radiation safety.

C. Ensure that the non-ionizing radiation programs conducted at DFRC conform to applicable safety regulations and technical guidelines.

5.4 Laser Safety Officer (LSO) and the Radio Frequency Safety Officer (RFSO)

The LSO and RFSO is appointed by the Chief, Safety, Health, and Environmental Office and functions as a link between the user and the Chief, Safety, Health, and Environmental Office on matters of non-ionizing radiation safety. Duties of the LSO and RFSO are to:

A. Ensure that the DFRC non-ionizing radiation program/s is in compliance within current regulations and standards.

B. Make recommendations to the Chief, Safety, Health, and Environmental Office on items involving the Non-ionizing Radiation Safety Program.

C. Approve proposed Authorized Laser Users (ALUs) after a review of the ALU qualifications.

D. Provide the services and equipment for monitoring non-ionizing radiation sources.

E. Conduct inspections and surveys necessary for an evaluation of the Non-ionizing Radiation Safety Program and report findings to the Chief, Safety, Health, and Environmental Office.

F. Prepare and submit required reports pertaining to non-ionizing radiation operations.

G. Ensure that all persons working on Class 3b & 4 laser projects have appropriate laser eye exams.

H. Ensure that all persons working on Class 3b & 4 laser projects have appropriate laser eye exams.

I. Investigate non-ionizing radiation incidents and accidents and report findings to management and required agencies.

J. Review and up-date, as necessary, this document annually or more frequently if non-ionizing radiation activity so dictates.

K. Maintain inventory of nonionizing radiation systems. Following evaluation of a laser or other nonionizing radiation system for use at DFRC, an inventory form will be generated. The inventory form will have a control number by which the laser can be tracked. A copy of the inventory form will remain with the laser so that if the laser returns to DFRC for a project, the control number can be used to identify the laser being discussed.

L. When all the requirements have been met, authorize the use of the laser and complete DFRC 220-8, Laser Safety Permit, for each Class 3b and 4 laser on site and provide a copy of the permit to the ALU to be posted at the laser site. The LSO must approve initial laser and microwave equipment installation and any movement or reinstallation of such equipment.

M. Evaluate laser operations proposed by the Center's projects and visiting experimenters. In the absence of the LSO, the Chief, Safety, Health, and Environmental Office will designate an alternate or act as the LSO.

N. Perform an annual review of the non-ionizing radiation program and report findings in writing to the Chief, Safety, Health, & Environmental.

O. Establish and maintain a current list of those persons authorized to operate Class 2, 3a, 3b, and 4 lasers under direct supervision.

5.5 Authorized Laser User (ALU)

The ALU is responsible for ensuring compliance with laser safety regulations in the operation of laser equipment. The ALU will:

A. Ensure that the laser project is properly authorized and permitted, when required.

B. Maintain a current inventory of lasers under his/her control including the operational location of portable units and furnish a copy to the LSO. (See D-WK 222-8, Non-Ionizing Radiation Laser Inventory). All lasers will be issued a control number on the inventory form and tracked by this number. A copy of the inventory form must be kept with the laser. If the laser returns to DFRC at a later date, the control number will be used to facilitate approval. If no control number is available, the laser will be required to go through a complete review.

C. Ensure there is appropriate control of laser hazards, including door interlocks, and warning signs and warning bells where applicable.

D. Ensure Standard Operating Procedures (SOPs) are submitted and approved for Class 3b & 4 lasers prior to initial operation and reviewed yearly or sooner whenever procedures are amended due to deviation from the standard operating mode.

E. In the event of an accident involving an injury, take the affected person involved to the Health Unit or have the Health Unit respond and then immediately notify the supervisor and LSO.

5.6 Aircraft Commander

The aircraft commander or pilot-in-command (PIC) has the responsibility of ensuring that the laser is used in accordance with the mission profile and in no case allowing the laser to be operated outside its safe range.

5.7 Authorized User of Microwave / Radiofrequency Equipment

The authorized user of mw / rf equipment is responsible for ensuring compliance with this document and ANSI/IEEE C95.3. Other responsibilities are to:

A. Prepare an initial safety review document for new projects or modifications of existing mw / rf facilities. The safety review will generate an inventory number. This number may be used to identify the source at a later time whether it belongs to DFRC or another

institution. The number will be used for identification and retrieval of former review.

B. Give safety instructions to personnel using mw / rf equipment under supervision.

C. Ensure that appropriate safety controls are in place.

D. Maintain awareness of the output and safety characteristics of the equipment such as frequency, pulsed or continuous wave mode of operation, pulse duration and repetition rate (when applicable), and output power as well as the safety guidance provided by equipment manufacturers.

E. Discuss the planned use of any equipment that generates mw / rf radiation or fields with the RFSO and obtain permission to purchase this equipment before purchasing or fabricating. The rf control requirements and protection measures must be identified prior to purchase. Some equipment may require operational restrictions in order to protect personnel.

F. Ensure that workers are not exposed to fields or radiation above the levels specified in this document.

G. Maintain an inventory of all mw/rf sources under your control.

H. Evaluate exposures to non-ionizing radiation and fields arising from equipment to be inventoried. Contact the Safety, Health & Environmental Office for assistance with this task

6.0 LASER SAFETY CONTROLS

6.1 Laser Classification

Lasers are classified by the ability of the primary laser beam or reflected primary laser beam to cause biological damage to the eye or skin. Multi-wavelength users will be classified at their highest or most dangerous level of output. For complete explanation of laser classifications, see ANSI Z136.1, for Safe Use of Lasers. In general, the classifications are as follows:

A. Class 1 Lasers – Considered to be incapable of producing damaging radiation levels and are, therefore, exempt from any control measures or other forms of surveillance with the exception of applicable requirements for embedded lasers.

B. Class 2 Lasers – Low power and divided into two subclasses, 2 and 2a. A Class 2 laser emits in the visible portion of the spectrum (0.4 – 0.7 μm) and eye protection is normally afforded by the aversion response, including the blink reflex.

C. Class 3a Lasers – Medium power lasers and laser systems. A Class 3a laser normally would not produce a hazard if viewed for only momentary periods with the unaided eye. This class of laser may present a hazard if viewed using collecting optics.

D. Class 3b Lasers – Medium powered lasers and laser systems. A Class 3b laser can produce a hazard if viewed directly. This includes intra-beam viewing of specular reflections. This class laser does not usually produce a hazardous diffuse reflection.

E. Class 4 Lasers – Are high power and a hazard to the eyes and skin from direct beam and to the eyes from diffuse reflection. Class 4 lasers can also be a fire hazard.

6.2 Laser Safety Controls

A. Permits – Lasers classified as 3b or 4 must have a DFRC laser permit and approved Standard Operating Procedure (SOP) in place before they may be operated.

B. Establish and maintain a current list of those persons authorized to operate Class 3b and 4 lasers under direct supervision.

C. Purchase Requests – All purchase requests for Class 2, 3a, 3b, and 4 lasers must be submitted to and approved by the LSO prior to purchase.

D. Laser Tracking – Anyone responsible for bringing non-ionizing radiation equipment onto the DFRC site will notify the LSO. This individual will provide the LSO with the following specifications for the laser: laser type, power, class, manufacturer, wavelength, beam type, beam diameter, beam divergence, model number, serial number, and, if pulsed, the pulse frequency, pulse duration, duty cycle, and purpose of the equipment.

E. Medical Surveillance – Laser personnel both, government and non-government, who work with Class 3b and 4 lasers or who are permitted by an ALU to be in designated laser control areas must receive a thorough ophthalmologic examination before the laser work begins. Incidental personnel, (those persons who are unlikely to be exposed to damaging laser energy but are associated with the laser program and who, at times, may be near laser operations) will be given a visual acuity exam. The ALU will arrange with the Health Unit for the examinations. Follow-up exams will be required as follows:

1) Immediately following a confirmed or suspected accident has occurred involving an actual or suspected eye injury.

2) A follow-up examination is required at the conclusion of the person’s employment or when there is no expectation that the employee will again be exposed to laser radiation.

F. Equipment Compliance – Laser equipment to be operated at DFRC or on DFRC aircraft will comply with performance standards of 21 CFR 1040.10 and 1040.11 unless specific exemption is obtained from the U.S. Department of Health and Human Services, Food, and Drug Administration (FDA).

6.3 Worksite Safety Controls

A. Labels – All lasers must bear a laser hazard classification label. If the manufacture's label is not present and the laser class is unknown, the ALU will consult the LSO to determine the proper classification. The LSO will place the appropriate label on the laser.

B. Warning Signs – Laser laboratories and other ground based laser locations must be posted with appropriate warning sign/s. The requirements for laser warning signs are given in ANSI Z136.1 and ANSI Z535.1, .2, and .3. (See Appendix A to this document for details concerning the content of signs.)

C. Laser Operators – Only qualified and authorized persons are allowed to operate lasers or laser systems.

D. Laser Beam Path – Lasers will be mounted so that the beam path is not eye level for standing or seated personnel. Exceptions must be approved by LSO. Personnel will not look into the primary beam. Specular reflections from the beam are to be avoided.

E. Beam Termination – Laser beams will be terminated at the end of their useful path by a material that is non-reflective and fire resistant.

F. Laser Alignment – Aiming or aligning the laser with the eye by looking along the axis of the beam must be avoided. Power will be turned down to Class 1 where possible for alignment or the beam path may be traced with a paper card while wearing laser goggles.

G. Personal Protective Equipment – When the energy output of the laser could damage the eyes or skin, personnel will wear protective equipment such as laser safety eyewear and clothing. Reflective items such as watches and rings must be removed.

H. Secondary Beams – If a secondary beam can emerge from the aperture of a laser, it is essential that it be covered. Likewise, an unused beam resulting from the use of a beam splitter will be terminated.

I. Laser Enclosures – Windows, doorways, and portals of laser laboratories must be covered to prevent hazardous laser radiation from being transmitted to outside passages.

J. Non-beam Hazards – Personnel will take suitable precautions to avoid other types of hazards associated with the use of lasers such as electrical, cryogenic, toxic, or corrosive material.

K. Ventilation – A specialized local ventilation system will be required at laser targets that produce toxic fumes or gasses, or for Laser Doppler Velocimeter seed material.

L. Housekeeping – Housekeeping is especially important in laser laboratories. All combustible material, flammable liquids, and reflective materials will be properly stored. Aisles and exits will be marked and kept clear.

M. Firing Systems – Laser electronic firing systems must incorporate a "fail safe" system design so that accidental pulsing of a stored charge is avoided.

N. Waste Materials – The ALU or designee will notify the Safety, Health, and Environmental Office when it is necessary to dispose of any hazardous waste.

7.0 LASER PROCEDURES

7.1 Indoor Laser Operation

A. The ALU will comply with the SOP written for the laser being used, if it is a Class 3b or 4 laser.

B. The ALU will follow all of the Laser Safety Engineering, Administrative Controls, and Personal Protective Equipment Controls written above in Section 6.2 and 6.3.

C. The ALU will obtain and follow all of the controls on the Laser Safety Permit if the laser is a Class 3b or 4.

D. When a laser is used in a hangar, the ALU must know the NHZ of the laser so that that distance can be cordoned off with Safety Caution tape.

E. A sign denoting the characteristics of the laser must be posted on the tape (for hangar use) or in the best place for it to be seen. The appropriate laser sign will be posted on the door if being used in a laboratory.

F. When used in a hangar where there are other operations also occurring, the ALU must notify the individuals what is being done and explain the hazard of the operation.

G. When laser are used at Dryden, the LSO must be notified (via telephone or email, preferably 24 hours in advance) prior to commencing the operation.

7.2 Outdoor Laser Operation

A. Nominal Hazard Zone (NHZ) – The LSO will establish the NHZ for outdoor lasers if not available as part of the project documentation or if not furnished by the manufacturer.

   1) The NHZ will be clearly posted with laser warning signs, and demarcated and identified as a laser hazard area. A combination of physical barriers and screening may be used to delineate the NHZ. Personal protective equipment is recommended for Class 3b lasers and required for Class 4 lasers for persons within the NHZ.

   2) Only authorized personnel will operate outdoor laser equipment or will be allowed in the NHZ.

B. Beam Path – The laser beam path will not be maintained at or near eye level without specific authorization from the LSO. The beam will be confined and terminated whenever possible. Directing the beam toward vehicles, manned structures, or aircraft, is prohibited unless proper clearance is obtained and adequate training and protective equipment is provided and used by all personnel within the target area.

C. Laser Isolation – When outdoors, laser equipment not in use will be disabled in a manner that prevents unauthorized use. A lockout device or the removal of an electrical source fuse meets this requirement.

D. Atmospheric Hazards – The operation of Class 3b or 4 lasers or laser systems during rain, snowfall, fog, or dusty atmospheres may produce hazardous reflections near the beam. In such conditions, the LSO will evaluate the conditions, terminate operations, or specify the use of appropriate PPE.

E. DoD Document 316-98, *Laser Range Safety*, requires that when doing laser operations where the laser beam has the potential of striking an orbiting craft, the Program Manager or LSO will contact the Laser Safety Clearing House to obtain a “Site Window” clearance. This clearance may be obtained from the

   Orbital Safety Officer
   U.S. Space Command, J3SOO
   1 NORAD Road, Suite 9-101
   Cheyenne Mountain AFB CO
   80914, Stop 4

F. When lasers are used at Dryden, the LSO must be notified (via telephone or email, preferably 24 hours in advance) prior to commencing the operation.

7.3 Aircraft Laser Operations (Class 3b & 4 lasers)

A. Program Identification – Programs at DFRC that propose to use airborne lasers will be identified early in the system development phase in order to allow time for the Program Manager and LSO to review safety requirements and resolve compliance issues.

B. Hazard Analysis – A written preflight hazard analysis will be prepared by a qualified person/s for each airborne laser operation. The hazard analysis will be reviewed by the LSO assigned to the mission and at a minimum will include the following:

   1) Potential catastrophic events and procedures for high-speed laser shut down.

   2) Special hazards associated with the laser operation and mission profile, and control measures to address these hazards to include safety for crewmembers, the aircraft, and the public at large.

   3) Other factors such as atmospheric effects of beam propagation, transmission through intervening materials, the use of optical viewing aids, electrical hazards, use of cryogenic materials, toxic vapors, etc.

   4) All the controls for outdoor laser operations in Section 7.2 above will also be followed when lasers are operated on aircraft where the beam is emitted outside of the aircraft.

C. FAA requires a 6-month advance notice in order to use a Class 3b or 4 laser when the laser is emitting outside and into FAA airspace.

D. The factors concerning the NHZ are defined in this procedure in Section 7.2.A above.

E. Atmospheric hazards are defined in this procedure in Section 7.2.D. above.

7.4 Modification of Laser Systems

The LSO is responsible to for reviewing and approving proposed modifications to permitted lasers where such modifications could affect output power or operating characteristic and potentially make the laser more hazardous. The LSO will ascertain what class the laser will be assigned and what control measures are required.

7.5 Personal Protective Equipment

7.5.1 Eye Protection

Appropriate protective eyewear will be available for use whenever personnel could be exposed to levels of laser radiation above the Maximum Permissible Exposure (MPE) established in the ANSI Z136.1 Standard. In multi-wavelength operations, alternate controls may be necessary. The LSO will ensure that:

A. Laser eyewear is clearly labeled with the optical density values and the useful wavelengths.

B. Eyewear is periodically inspected to ensure serviceability.

7.5.2 Skin Protection

Protective gloves, clothing, and shields will be used to prevent exposure of the skin when levels of laser radiation are above the MPEs for skin as established by the ANSI Z136.1 Standard.

7.6 Associated Hazards (Non-Beam Hazards)

7.6.1 Laser Generated Air Contaminants (LGAC)

Three major control measures are used to reduce LGAC hazards. They are exhaust ventilation, isolation of the process, and respiratory protection. Hazards that LGAC may pose are:

A. Vaporized target materials from high-energy laser cutting, drilling, and welding operations, which may be toxic or explosive.

B. Gases that flow through laser systems or by-products of laser reactions such as bromine, chlorine, fluorine, and hydrogen cyanide. These gases can be extremely toxic or explosive.

C. Gases or vapors from cryogenic coolants may cause cold burns, asphyxiation, or become an explosive hazard.

7.6.2 Explosions

High-pressure arc lamps, filament lamps, and capacitor banks in laser equipment will be enclosed in housings, which can withstand the maximum explosion pressures resulting from lamp disintegration. The laser target and elements of the optical train that may shatter during laser operation must also be enclosed or equivalently protected to prevent injury to operators and observers. Components such as electrolytic capacitors may explode if subjected to voltages higher than

their ratings with the result that ejected metal may bridge live electrical parts. Such capacitors will be tested to make certain that they can withstand the highest probable potentials should other circuit components fail, unless the capacitors are adequately contained so as not to create a hazard.

7.6.3 Radiation (non-beam)

A. X-rays – X-rays generated by high voltage (over 15 KV) power supply tubes will be identified and the information provided to the LSO.

B. Ultraviolet Radiation – UV radiation emitted from laser discharge tubes and pumping lamps are required to be suitably shielded so that personnel exposures are maintained within the TLV® specified by the American Conference of Governmental Industrial Hygienists (ACGIH).

7.6.4 Electrical

The laser resonator and electro-optical elements will be designed so that no exposed metallic element is above ground potential. Other electrical safety factors include the following

A. Installation – Laser equipment will meet the electrical safety requirements of NFPA 70, (NEC). The intended application of the laser equipment determines the method of electrical installation and connection to the power supply circuit (for example, conduit vs. flexible cord).

B. Shock – Live parts of circuits and components with peak open-circuit potentials over 50 Volts are considered hazardous. Such circuits require positive protection against contact. For equipment intended for general use, interlock switches (and capacitor bleeder resistors, if applicable) or their equivalent will be installed to remove the voltage from accessible live parts to permit servicing. Bleeder resistors will be of such size and rating as to carry the capacitor discharge current without burnout or mechanical injury. Circuits and components with peak open-circuit potentials of 2500 Volts or more will be adequately covered or enclosed if an appreciable capacitance is associated with the circuits.

If servicing of equipment requires entrance into an interlocked enclosure within 24 hours of the presence of high voltage within the unit, a solid metal grounding rod will be utilized to ensure discharge of high-voltage capacitors. The grounding rod will be firmly attached to ground prior to contact with the potentially live point. A resistor ground rod (for example, a large-wattage ceramic resistor)

may be used prior to application of the previously mentioned solid conductor-grounding rod to protect circuit components from overly rapid discharge, but will not be used as a replacement.

C. Ground – The frames, enclosures, and other accessible non-current-carrying metallic parts of laser equipment will be grounded. Grounding will be accomplished by providing a reliable, continuous metallic connection between the parts to be grounded and the grounding conductor of the power wiring system.

D. Electrical Fire – Components in electrical circuits will be evaluated with respect to fire hazards. Enclosure, barriers or baffles of non-metallic material will comply with "Polymeric Materials for use in Electric Equipment," Underwriters Laboratories Standard, UL746C.

E. Markings – The user will ensure that each laser is permanently marked with its primary electrical rating in Volts, frequency, and Watts or amperes.

7.6.5 Flammability of Laser Beam Enclosures

Enclosure of Class 4 laser beams can result in potential fire hazards if enclosure materials are exposed to irradiances exceeding 10 W/cm^2 for total beam powers exceeding 0.5 W. Plastics and paper products are excluded, but their use at DFRC is not recommended unless program essential.

7.6.6 Liquid Cryogenic Coolants

In liquid form, these coolants may cause tissue damage if splashed in the eyes or into the shoes. Personal protective equipment must be worn when handling this material.

7.6.7 Laser Dyes

Certain laser dyes are highly toxic or carcinogenic. Care must be taken when handling and preparing dye solutions, and during operations where dye lasers are in use. An MSDS for dye compounds must be available to laser personnel.

When laser dyes are used on aircraft, secondary containment must be provided for the system.

Preparation of dye solutions with flammable solvents must be done in a fume hood certified for flammable materials.

7.6.8 Noise

Noise from certain lasers, such as excimer lasers, may be of such intensity that noise control is necessary. See DCP-S-009, Chapter 18, Hearing Conservation.

7.6.9 Hazardous Waste Disposal

Contact the LSO at the Safety, Health, and Environmental Office for hazardous waste pick-up.

7.6.10 Working Space

The ALU will ensure sufficient room for personnel to work and maneuver freely during laser operations.

7.6.11 Ergonomics

Some laser operations require repetitive hand, wrist, and arm movements that could cause medical problems. If repetitive motion is necessary, the ALU must be aware of the associated problems and be familiar with proper ergonomic solutions. See DCP-S-009, Chapter 19, Ergonomics, for further information.

8.0 MICROWAVE / RF RADIATION SAFETY CONTROLS

8.1 Warning Signs

Warning signs for rf and mw hazards must be posted on the access panels of irradiated enclosures of equipment and on entrances to areas where exposures exceed the limits specified in ANSI / IEEE C95.3, Measurement of Potential Hazardous Electrical-magnetic Fields-RF and Microwave. (See the Appendix A for specific sign layout)

Signs indicating an rf or mw hazard exists are also required on:

A. Equipment that could create 60Hz electric fields above 2.5 kV/m and does not have electric field shielding

B. Permanently installed rf equipment capable of radiating over 1 W into an open area at frequencies between 3 kHz and 300 GHz or emitting 100 W if output is completely enclosed by coaxial cables, wave-guides, dummy, or real loads

C. Satellites and permanently installed communications transmitters

D. Portable radios (transmitters) over 7 W. (some frequencies may be exempt; check with LSO

E. Induction heaters

F. Main power-supply rooms of buildings

8.2 Exposure Limits

A. Exposure limits referring to rf and mw radiation in the frequency range 30 kHz to 300 GHz represent conditions under which it is believed that nearly all workers may be repeatedly exposed without adverse health effects.

B. Exposure limits to rf and mw radiation, for contact with objects exposed to such fields, are given in Table 3 and Figure 1 as a function of frequency, f, in MHz.

C. Access should be restricted to limit the RMS rf body current and potential for rf shock or burn as given in Table 3.

D. The TLV®, is a recommended limit from the American Conference of Governmental Industrial Hygienists and is given for the frequency range 30 kHz to 300 GHz in terms of Root Mean Square (RMS) electric (E) and magnetic (H) field strengths, the equivalent plane-wave free-space power densities (S), and induced currents in the body which can be associated with exposure to such fields or contact with objects exposed to such fields. The TLV should be used as a guideline for a conservative approach, if needed, and is given in Table 1.

E. For freestanding individuals (no contact with metallic objects), rf current induced in the human body, as measured through each foot, should not exceed the ceiling values in Table 3.

The RF Radiation Hazard Calculation Worksheet (D-WK 248-8) is available to contribute in the hazard calculation for a mw / rf source.

Table 1:
ACGIH Radiofrequency / Microwave Threshold Limit Values (TLV)
for Occupational / Controlled Exposures

Electromagnetic Fields f=frequency in MHz				
Frequency MHz	**Power Density, S (mW/cm²)**	**Electric Field Strength, E (V/m)**	**Magnetic Field Strength, H (A/m)**	**Averaging Time E², H², or S (minutes)**
30 kHz -100kHz		614	163	6
100 kHz – 3 MHz		614	16.3/f	6
3 MHz – 30 MHz		1842/*f*	16.3/f	6
30 MHz – 100 MHz		61.4	16.3/f	6
100 MHz – 300 MHz	1	61.4	0.163	6
300 MHz – 3 GHz	f/300			6
3 GHz – 15 GHz	10			6
15 GHz – 300 GHz	10			$\frac{616{,}000}{f^{1.2}}$

The exposure values in terms of electric and magnetic field strengths are the values obtained by spatially averaging values over an area equivalent to the vertical cross-section of the human body, (projected area).

Table 2:
Maximum Exposure Limits for Radiofrequency and Microwave for the General Population / Uncontrolled Exposure

Frequency Range MHz	**Electric Field Strength, E (V/m)**	**Magnetic Field Strength, H (A/m)**	**Power Density, S (mW/cm²) ***	**Averaging Time E², H², or S (minutes)**
0.30 – 1.34 MHz	614	1.63	100	30
1.34 – 30 MHz	824/*f***	2.19/f	$180/f^2$	30
30 – 300 MHz	27.5	0.073	0.2	30
300 – 1500 MHz			f/1500	30
1500 – 100,000 MHz			1	30

* = Plane wave equivalent power density
**** f = frequency in MHz**

Table 3: Induced and Contact Radiofrequency Currents Maximum Current (mA)

Frequency	Through Both Feet	Through Either Foot	Contact	Averaging Time
30 kHz – 100 kHz	2000f	1000f	1000f	1 second
100 kHz – 100 MHz	200	100	100	6 minutes

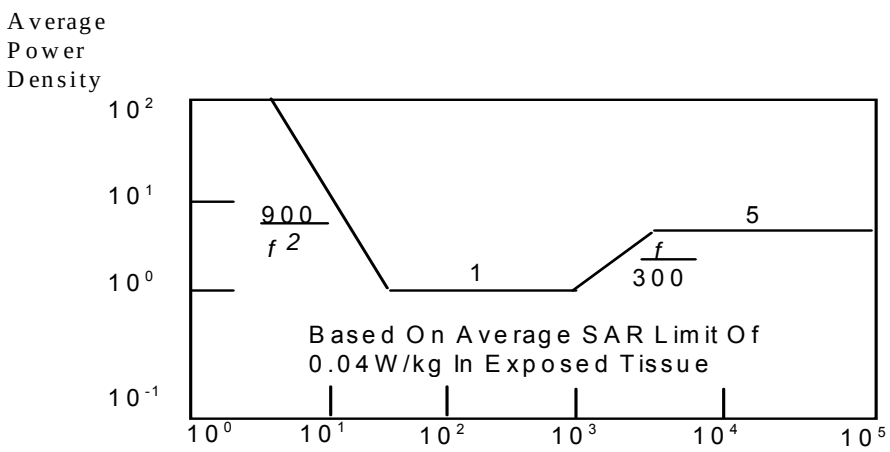
I = 1000f mA for (0.03< f <0.1 MHz) averaged over 1 second
I = 100 mA for (0.1 < f <100 MHz) averaged over six minutes, subject to a ceiling value of 500 mA
mA = milliampere
I = Induced current

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

Additional exposure limits for specific applications can be found in Appendix A.

Figure 1:
Radiofrequency Protection Guide for
Whole-Body Exposure of Human Beings

Note: *f* = frequency in MHz



8.3 Investigation of RF Incidents

A. The supervisor must investigate and document incidents involving personnel exposure that may exceed the exposure limits given in Table 1.

B. For personnel exposures occurring at, or above, five times the adjusted exposure limits in Table 1 the following additional actions are required:

1) Radiofrequency EMF measurements for documentation of the rf exposure that may have been received
2) Medical examination and recommendations for medical follow-up
3) Documentation providing a description of the circumstances surrounding the exposure incident, statements from personnel involved in that incident, and recommendations to prevent similar occurrences
4) All incidents should be reported to the LSO or RFSO immediately.

8.4 Microwave / RF Project Safety Review

A. Prior to installing new mw / rf equipment or modifying existing equipment, a Project Safety Review document must be submitted by the Authorized User to the RFSO for review. The document will include:

1) A description of the system and its application
2) A diagram showing the beam path
3) Operating Parameters
   - Frequency antenna dimension :
   - antenna type
   - power output
   - pulse description
   - polarization of transmitted wave
   - antenna gain
4) Standard Operating Procedure (SOP) designed to minimize hazards to personnel.

B. Microwave / rf projects will be reviewed by the RFSO prior to initial operation and on an annual basis or when the researcher's project deviates from approved Standard Operating Procedures.

8.5 Operational Microwave / RF Safety

The following safety precautions and procedures must be taken when working near mw / rf equipment:

A. Standard Operating Procedures (SOPs) must be posted near all operational equipment (where possible, otherwise available when requested). The SOP will outline radiation protection procedures for the equipment in use. The SOP will be reviewed and approved by the RFSO.

B. Only individuals who have been instructed in the potential hazards of mw / rf radiation and in safe procedures will be permitted to work in the vicinity of the equipment.

C. Microwave / rf warning signs must be posted, as applicable.

D. Personnel must be restricted from the area immediately in front of any radiating antenna.

E. Transmissions with an unterminated wave guide must be avoided.

F. Free space transmission within buildings must be avoided. During those test procedures where such transmissions are required, make certain that personnel are not being exposed to the radiated beam.

8.6 Measurement and Evaluation of Radiofrequency (rf) Fields

A. Evaluation of rf hazards should be done using the measurement procedures and techniques recommended in IEEE C95.3-1991, as basic guidance. That requirement does not preclude using other rf measuring and evaluation methodologies.

B. Records of surveys, reports, calculations, and control measures imposed will be maintained for each fielded rf emitter that is capable of exceeding the exposure limits in Table 1.

C. Where multiple rf emitters may be collocated in fixed arrangements, such as on roof tops or at communication sites, rf evaluation data should include a determination of the weighted contribution from expected simultaneously-operated emitters to ensure that personnel are not exposed to effective rf levels above the exposure limit.

D. A rule of thumb is that the predominant electric and magnetic fields around an object exist independently at distances less than about one wavelength from the source. This is called the “near field.” The combination of electromagnetic radiation predominates at distances greater than about one wavelength. This is called the “far field.”

E. For both pulsed and non-pulsed fields, the power density, the squares of the field strengths, and values of specific absorption rates (SARs) or input power as applicable, are averaged over any 0.1 hr period.

F. Measurements to determine adherence to the recommended protection guides will be made at distances 5 cm. or greater from any object (refer to ANSI / IEEE C95.3.)

8.7 RF Safety Categories

Radiofrequency sources and systems should be categorized according to their potential for producing exposures in accessible areas above established conservative action levels or exposure limits. This allows appropriate controls to be established for each category. The controls may be engineered or administrative. The categories are given in Table 8.

RF Category	Exposure Condition	Control Actions Required
1	Operational characteristics of sources would not cause the action level to be exceeded	None, unless maintenance or other conditions alter the category
2	Operational characteristics of sources could cause the action level to be exceeded, but would not cause the exposure limit to be exceeded in accessible areas.	Time and spatial averaging should be used to properly evaluate exposure.
3	Potential to exceed the controlled area exposure limit in accessible areas, if mitigating controls are not applied.	
4	Exposure will exceeded the controlled area exposure limit in accessible areas.	Restrict source output or prevent personnel access.

9.0 TRAINING & CERTIFICATION

A. Class 2 and 3a laser training – Orientation training is recommended for persons working with or around Class 2 or 3a lasers.

B. Class 3b and Class 4 laser training – Training is required for all employees working with or around Class 3b and 4 lasers. Only trained individuals will be considered certified and permitted to operate Class 3b and Class 4 lasers.

C. Personnel who routinely work directly with equipment that emits mw / rf levels in excess of the exposure limits in Table 1 or whose work environment contains equipment that routinely emits levels in excess of the exposure

limits, are required to receive training so that they are aware of the potential hazards of rf.

D. All training must be completed before assignment to such work areas. Laser, rf, and mw training is required only once; however, refresher training should be given once every three years and may be incorporated into other periodic safety training programs.

E. The scope of training and the choice of training topics will be determined by the LSO or RFSO.

10.0 MANAGEMENT RECORDS & RECORD RETENTION

A. Authorized Laser User – The Authorized Laser Users are tasked to keep records such as orders and personnel exposure levels, receipts and inventories. After a project is completed NPD 1441.1, Records Retention Schedules, will be used as a guide for disposition of the records.

B. Radiation Safety Officer – The RSO, LSO, and RFSO are responsible for maintaining a copy of records and receipts such as approval requests and authorizations, procurement, inventories, surveys, calibrations, and any other records that pertain to laser, mw, or rf operations. After a project is completed NPD 1441.1, Records Retention Schedules, will be used as a guide for disposition of the records.

11.0 RELEVANT DOCUMENTS

11.1 Authority Documents

NPD 8700.1	NASA Policy for Safety and Mission Success
NPR 8715.3	NASA Safety Manual w/ Changes through Change 1, 6/19/02.
NPD 8710.2D	NASA Safety and Health Program Policy. This NPD establishes polices for NASA wide safety and health programs.
29 Code of Federal Regulations (CFR), Part 1910.97	"Non-Ionizing Radiation." While this CFR is an authority document, it is somewhat limited in specific instructions for developing and maintaining a non-ionizing radiation safety program.
ANSI Z136.1	Safe Use of Lasers. DFRC accepts this Standard as authority for establishing the DFRC Laser Safety Program. Reference copies are available in the Safety, Health, and Environmental Office.
ANSI Z136.2	Safe Use of Optical Fibers Communication Systems Utilizing

	Laser Diode and LED Sources. DFRC accepts this Standard as authority for establishing the DFRC Laser Safety Program. Reference copies are available in the Safety, Health, and Environmental Office.
ANSI Z136.6	American National Standard for Safe Use of Lasers Outdoors. DFRC accepts this standard as authority for establishing the procedures to be followed during outdoor laser operations. Reference copies are available in the Safety, Health, and Environmental Office.

11.2 Reference Documents

21 CFR 1040.10 and 1040.11	Specifies manufacturer's requirements for certification of equipment, hazard information, and warning labels. DFRC will purchase and use only non-ionizing radiation equipment meeting the requirements of this CFR.
National Fire Protection Association 70: National Electrical Code (NEC)	This code establishes the majority of safety procedures used in an industrial setting such as that found at DFRC. It provides specific procedures for nearly every electrical application. Every person working with electrical sources or equipment at DFRC must have access to this document. For interpretations or questions regarding NEC, contact the Safety, Health, and Environmental Office.
NPD 1441.1	Records Retention Schedule will be used for disposition of non-ionizing radiation records.
Department of Defense (DoD) Document 316-98	Laser Range Safety. This document covers requirements that must be met during open-air laser operations conducted on DoD controlled ranges or test facilities.
American Conference of Governmental Industrial Hygienists (ACGIH)	Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. This document sets the Threshold Limit Values (TLVs®) and Biological Exposure Indices (BEIs®) for mw and rf exposure. See Table 1 of this document for TLV® values.
ANSI/IEEE C95.3	Measurement of Potential Hazardous Electrical-magnetic Fields – RF and Microwave. This document is used as a guideline for DFRC microwave safety.
ANSI Z136.4	American National Standard Recommended Practice for Laser Safety Measurements for Hazard Evaluation. DFRC accepts this Standard as a guidance document for the measurement of lasers for hazard evaluation.

ANSI Z535.1, .2, & .3	Environmental and Facility Safety Signs. This series of Standards set requirements for design, color, and criteria for warning signs.
Underwriters Laboratories UL746C	Polymeric Materials – Use In Electrical Equipment Evaluation. This document covers requirements for parts made of polymeric materials that are used in electrical equipment and describe the various test procedures and their use in the testing of such parts and equipment.

11.3 Forms

DFRC 220-8	Laser Safety Permit
D-WK 221-8	Laser User Experience & Qualification Record
D-WK 222-8	Laser Inventory
D-WK 248-8	RF Radiation Hazard Calculation Worksheet
D-WK 249-8	RF / Microwave Radiation Survey Record

12.0 ABBREVIATIONS, ACRONYMS, & DEFINITIONS

12.1 Abbreviations

A/m	Ampere per meter
E	Electric Field Strength
EM	Electromagnetic
eV	Electron Volt
F	Frequency
GHz	gigaHertz
H	Magnetic Field Strength
Hz	Hertz
I	Induced current
J/cm^2	Joules per centimeter square
kHz	kiloHertz
mA	milliAmpere
mHz	megaHertz
Mw	microwave
mW/cm^2	milliWatt per centimeter square
Rf	radiofrequency

S	Power density
T_{avg}	Averaging time
V/m	Volts per meter
W	Watts
W/m^2	Watts per meter square

12.2 Acronyms

ACGIH	American Conference of Governmental Industrial Hygienist
AFOSH	Air Force Occupational Safety and Health
ALU	Authorized Laser User/s
ANSI	American National Safety Institute
BEI	Biological Exposure Indices
CFR	Code of Federal Regulations
DoD	Department of Defense
FDA	Food and Drug Administration
LASER	Light Amplification by Stimulated Emission of Radiation
LGAC	LASER Generated Air Contaminant
LSO	Laser Safety Officer
NFPA	National Fire Protection Association
NEC	National Electric Code
NHZ	Nominal Hazard Zone
PIC	Pilot in Command
RFSO	Radiofrequency Safety Officer
RMS	Root Mean Square
SAR	Specific Absorption Rate
SOP	Standard Operating Procedure
TLV®	Threshold Limit Value
UL	Underwriters Laboratories

12.3 Definitions

Action Level (AL)	An applicable fraction of the exposure limit of the electric and magnetic field strength, the incident power density, contact and induced current and contact voltage used to initiate controls before regulatory limits are achieved. It is suggested that action levels for occupational controlled exposures be set at the general population exposure level.

	Using 20% of the ACGIH threshold limit value (TLV) is also recommended, whichever is more conservative.
Averaging Time (T_{avg})	The time period over which exposure is averaged for determining compliance with an exposure limit value.
Controlled Environment	Locations where rf exposures may exceed the levels given in Table 2 for non-occupational mw / rf workers, but should not exceed the levels in Table 1. Generally, controlled environments represent areas that may be occupied by personnel who accept potential exposure as a condition of employment or duties, by individuals who knowingly enter areas where such levels are to be expected, and by personnel passing through such areas. Existing physical arrangements or areas, such as fences, or perimeters may be used in establishing controlled environments.
Electric Field Strength (E)	The magnitude of the electric field component of an electromagnetic wave expressed in units of Volts per meter (V/m).
Exposure, Partial Body (E)	Partial-body exposure results when rf EMS is substantially non-uniform over the body. Fields that are non-uniform over volumes comparable to the human body occur due to highly directional sources, reradiating sources, standing waves, or in the antenna's near-field region.
Far-Field Region	The region far enough from an antenna that the radiated power per unit area decreases with the square of the range. In the far-field region, the field has a predominantly plane-wave character; i.e., uniform distributions of electric and magnetic fields in planes transverse to the direction of propagation.
Fluence	The energy density of the EMF when integrated over the duration of the exposure, usually expressed in units of joules per square centimeter (J/cm^2).
Hertz (Hz)	The unit for expressing frequency. One hertz equals one cycle per second. Commonly used multiples are kilohertz (kHz), megahertz (MHz), and gigahertz (GHz).
Human Resonance Range	The frequency region where absorption of rf energy in the body as a whole is enhanced. For sizes ranging from a baby to an adult, peak absorption varies depending on the individual's size relative to the wavelength and orientation relative to the polarization of the field. The exposure limits have been established to cover the range of human sizes, shapes, and positions.
Magnetic Field	The magnitude of the magnetic field component of an

Strength (H)	electromagnetic wave expressed in units of amps per meter (A/m).
Near-Field Region	A region generally in close proximity to an antenna or other radiating structure in which the electric and magnetic fields do not exhibit a plane-wave relationship, and the power does not decrease with the square of distance from the source but varies considerably from point to point. The near-field region is further subdivided into the reactive near field, which is closest to the radiating structure and contains most or nearly all of the stored energy, and the radiating near field, where the radiating field predominates over the reactive field but lacks substantial plane-wave character and is complicated in structure. For most antennas, the outer boundary of the reactive near-field region is considered to occur at a distance of one-half wavelength from the antenna surface.
Nonionizing Radiation	That part of the electromagnetic spectrum where the energy of individual photons is insufficient to ionize matter, typically defined as 12.4 electron Volts or less.
Permissible Exposure Limit (PEL)	The PEL is established for the protection of personnel. There are no expectations that any adverse health effects will occur with exposures that are within the PEL, even under repeated or long-term exposure conditions. The PEL is enforceable by OSHA.
Plane Wave	An EM wave characterized by mutually orthogonal electric and magnetic fields that are related by the impedance of free space (377 ohms). For plane waves, S, E, and H exhibit the following relationship: $S = E^2 /3770 = 37.7\ H^2$ where S is in units of mW/cm^2 E is in V/m, and H is in A/m
Power Density (S)	Radiated power per unit area, expressed in units of Watts per square meter (W/m^2) or milliWatt or microWatts per square centimeter (mW/cm^2 or uW/cm^2). The term, plane-wave-equivalent power density, refers to the magnitude of S that would exist for an EM wave in free space having the same E or H fields.
Radiofrequency (rf)	The rf region is defined as extending from 3 kHz to 300 GHz.
Re-Radiated Field	Re-radiated fields are sometimes called reflected or scattered fields. The scattering object is sometimes called a re-radiator, or a secondary or parasitic radiator.

RF “Hot Spot"	A highly localized area of relatively intense rf EMF that manifests itself as: • Intense electric or magnetic fields immediately adjacent to conductive objects immersed in lower intensity ambient fields, or • Localized areas where there exists a concentration of rf fields caused by reflections or narrow beams produced by high-gain radiating antennas or other highly directional sources. • For both descriptions, the fields are characterized by very rapid changes in field strength. Radiofrequency hot spots are normally associated with very non-uniform exposure of the body (partial-body exposure). The term rf hot spots should not be confused with an actual thermal hot spot in an absorbing body.
Root-Mean-Square (rms)	The effective value, or the heating value, of a periodic EM wave. The rms value for E or H fields is obtained by taking the square root of the mean of the squared values for E or H over an area equivalent to the vertical cross-section of the human body (projected area).
Specific Absorption Rate (SAR)	The time rate at which rf energy is imparted to an element of biological body mass. Average SAR in a body is the time rate of the total energy absorbed divided by the total mass of the body. SAR is expressed in units of Watts per kilogram (W/kg). Specific absorption (SA) refers to the amount of energy absorbed over an exposure time period and is expressed in units of joules per kilogram (J/kg).
Uncontrolled Environments	Locations where rf exposures do not exceed the exposure limits in Table 2. Such locations generally represent living quarters, workplaces, or public access areas where personnel would not expect to encounter higher levels of rf energy.

APPENDIX A – RF / MICROWAVE CHARACTERISTICS & CONTROLS

The following is additional information concerning rf / mw characteristics and controls. Table 9 represents wavelength ranges for frequency ranges.

1.0 ADDITIONAL EXPOSURE LIMITS

Access should be restricted to limit the RMS rf body current and potential for rf shock or burn as given in Table 4 for occupational/controlled exposures and Table 5 for general population/uncontrolled exposure. These limits may not protect against the startle reaction and burns caused by transient discharges when contacting an energized object. In controlled environments, mitigative measures can be taken to reduce the probability of hazardous conditions. Such measures may include protective gloves, awareness programs so that individuals are alerted to the possible presence of induced currents between the human body and conductive objects, and work practices that lessen the probability of receiving unexpected shocks or burns.

Table 4:
Induced and Contact Radiofrequency Currents for Occupational / Controlled Exposures, Maximum Current (mA)

Frequency Range	Through Both Feet	Through Either Foot	Contact Current	Averaging Time Period
30 kHz – 100 kHz	2000 * f	1000 * f	1000 * f	1 second
100 kHz – 100 MHz	200	100	100	6 minutes*

f in MHz
I = induced current
* I^2 is averaged over a 6 minute period (e.g., for either foot or hand contact, $I^2 * t \leq 60{,}000\ mA^2$ minutes, subject to a ceiling limit of 500 mA

Table 5:
Induced and Contact Radiofrequency Currents for General Population / Uncontrolled Exposures, Maximum Current (mA)

Frequency Range	Through Both Feet	Through Either Foot	Contact Current	Averaging Time Period
0.030 MHz – 0.100 MHz	900 * f	450 * f	450 * f	1 second
100 kHz – 100 MHz	90	45	45	6 minutes*

f in MHz
I = induced current

* I^2 is averaged over a 6 minute period (e.g., for either foot or hand contact, I^2 *t ≤ 60,000 mA^2 minutes, subject to a ceiling limit of 500 mA).

Peak power exposure limitations are provided for pulsed conditions where each pulse is less than 100 milliseconds (msec) and there are no more than 5 pulses in the time averaging period. Those limits are given to prevent unintentionally high exposure and to preclude high SAR for decreasingly short widths of pulses. If there are more than 5 pulses during any time period equal to the averaging time, or if the pulse durations are greater than 100 msec, the time-averaged power density should not exceed the exposure limits given in Table 6.

For exposure to rf pulses in the frequency range of 0.1 to 300,000 MHz, exposure is limited by either a peak (temporal) E field of 100 kV/m for each pulse or in terms of a peak power density value for each single pulse, whichever is more limiting. A maximum exposure to five such pulses, with a pulse repetition rate of at least 100 msec, is permitted during any period equal to the averaging time. For low frequencies and short pulses, 100 kV/m will be the more conservative limit. For high frequencies and longer pulses, peak power density will be more conservative. The limitation on rf fields under pulsed conditions, (less than 100 msec), means that the exposure limit as averaged over any 100 msec is reduced by a factor of five, and a maximum of five such pulses is permitted during any period equal to the averaging time. For example, in the microwave region for exposure to a single pulse, the SAR over any 6-minute period is limited to 28.8 J/kg per pulse (spatial average) with a maximum of five such pulses (i.e., (5) (28.8 J/kg) = 144 J/kg), which is equivalent to a SAR of 0.4 W/kg over a 6-minute period. In the case of exposure to pulsed rf fields, the control is the same for controlled and uncontrolled exposure and is given in Table 6.

Table 6:
Exposure Limit for RF Peak Electric Field and Pulsed RF Fields

Frequency Range (f) (MHz)	Peak Electric Field (E) (kV/m)	Peak Power Density/Pulse for Pulse Durations < 100 msec (mW/cm^2)
0.1 – 300000	100	(PEL) (T_{avg})/(5) (pulse width)

Implicit in the exposure limit definition of a whole-body averaged SAR of 0.4 W/kg for a controlled environment and 0.08 W/kg for an uncontrolled environment, is the assumption that spatial peak SARs may occur that exceed the whole-body averaged values by a factor of more than 20 times. The values provided in Table 7 allow for equating substantially non-uniform field exposure or partial-body exposure to an equivalent uniform field exposure.

For exposure of parts of the body, the spatially averaged PELs may be relaxed provided the peak value of the mean squared field strength does not exceed 20 times the square of the allowed spatially averaged values at frequencies below 300 MHz, or the equivalent power density levels do not exceed the levels shown in Table 7 as averaged

over the T_{avg}, periods given for frequencies above 300 MHz. The rules for relaxation of the limits for partial-body exposure do not apply for direct exposure of the eyes, but the SAR exclusion rules below, can still be used to show conformance to the exposure limit, despite localized power density values above the specified whole-body average. In such cases, exposures to the eyes are limited by the basic exposure criteria of a whole-body averaged SAR of 0.4 W/kg (controlled environment) or 0.08 W/kg (uncontrolled environment), and spatial peak SARs of 8 W/kg (controlled environment) or 1.6 W/kg (uncontrolled environment) as averaged over any one gram of tissue.

Table 7:
Exposure Limit for Partial Body Exposure, Controlled, and Uncontrolled Exposures

Frequency Range (f) (MHz)	Peak Value of Mean Squared Field (V^2/m^2 or A^2/m^2)	Equivalent Power Density (mW/cm^2) Controlled	Equivalent Power Density (mW/cm^2) Uncontrolled
0.1 – 300	$< 20\ E^2$ or $< 20\ H^2$		
300 – 6000		<20	4
6000 – 96,000		$<20*(f/6000)^{0.25}$	f/1500
96,000 – 30,0000		40	20

2.0 SAR EXCLUSION RULE

The exposure limits in this section may be relaxed by reference to SAR limits through calculations or measurements, as follows:

2.1 Controlled Environment Exclusion

At frequencies between 3 kHz and 100 kHz, the exposure limit can be exceeded if it can be shown that the peak rms current density as averaged over any 1 cm^2 area of tissue and over 1 second does not exceed 0.035(f) mA/cm^2 where f is in kHz. At frequencies between 100 kHz and 6 GHz, the exposure limit may be exceeded if the exposure conditions can be shown to produce SARs below 0.4 W/kg as averaged over the whole body, and spatial peak SAR values not exceeding 8 W/kg as averaged over any one gram of tissue; except for the hands, wrists, feet, and ankles where the spatial peak SAR shall not exceed 20 W/kg as averaged over any 10 grams of tissue, and the induced body currents conform with the values in Table 4.

At frequencies above 6 GHz, where body absorption is quasi-optical and body resonance considerations do not apply, the exposure limits may be relaxed using the time-averaged limits for partial-body exposures.

3.0 UNCONTROLLED ENVIRONMENT EXCLUSION

At frequencies between 3 kHz and 100 kHz, the exposure limit can be exceeded, if it can be shown that the peak rms current density as averaged over any 1 cm^2 area of tissue and over 1 second does not exceed 0.015(f) mA/cm^2 where f is in kHz. At frequencies between 100 kHz and 6 GHz, the exposure limit may be exceeded if the exposure conditions can be shown to produce SARs below 0.08 W/kg as averaged over the whole body, and spatial peak SARs not exceeding 1.6 W/kg as averaged over any one gram of tissue; except for the hands, wrists, feet, and ankles where the spatial peak SAR shall not exceed 4 W/kg as averaged over any 10 grams of tissue, and the induced body currents conform with the values in Table 5.

At frequencies above 6 GHz, where body absorption is quasi-optical and body resonance considerations do not apply, the exposure limits may be relaxed using the time-averaged limits for partial-body exposures.

4.0 LOW-POWER DEVICE EXCLUSION

At frequencies between 100 kHz and 1.5 GHz, the exposure limits given in Tables 1 through 7 may be exceeded under the following conditions for devices in which the radiating structure is not maintained within 2.5 cm of the body:

Controlled environment low-power device exclusion pertains to devices that emit rf energy under the control of an aware user. That exclusion addresses exposure of the users. At frequencies between 100 kHz and 450 MHz, the exposure limit may be exceeded if the radiated power is 7 Watts, or less. At frequencies between 450 and 1500 MHz, the exposure limit may be exceeded if the radiated power is (7) (450/f) Watts, or less, where f is in MHz.

Table 8:
Wavelength Range for Different Frequency Ranges

Frequency Range	Wavelength Range	Name
> 300 GHz	< 1mm	
30 GHz – 300 GHz	10 mm – 1 mm	Extremely high frequency (EHF)
3 GHz – 30 GHz	10 cm – 1 cm	Super high frequency (SHF)
300 MHz – 3 GHz	1 m – 10 cm	Ultra high frequency (UHF)
30 MHz – 300 MHz	10 m – 1 m	Very high frequency (VHF)
3 MHz – 30 MHz	100 m – 10 m	High frequency (HF)
300 kHz – 3 MHz	1 km – 100 m	Medium frequency (MF)
30 kHz – 300 kHz	10 km – 1 km	Low frequency (LF)
3 kHz – 30 kHz	100 km – 10 km	Very low frequency (VLF)
300 Hz – 3 kHz	1000 km – 100 km	Voice frequency
>0 – 300 Hz	> 1000 km	Extremely low frequency (ELF)
0 Hz	--	Static

5.0 WARNING SIGNS

The following signs comply with FCC rules. The signs are also in compliance with ANSI/IEEE C95.3, Measurement of Potential Hazardous Electrical-magnetic Fields-RF, and Microwave.

Figure 2:
Category 1 Areas

Figure 1 is used for Category 1 areas to mark locations where rf field levels may exceed the FCC MPE limits for **General Population/Uncontrolled** exposure but are definitely below the FCC MPE limits for Occupational/Controlled exposure.

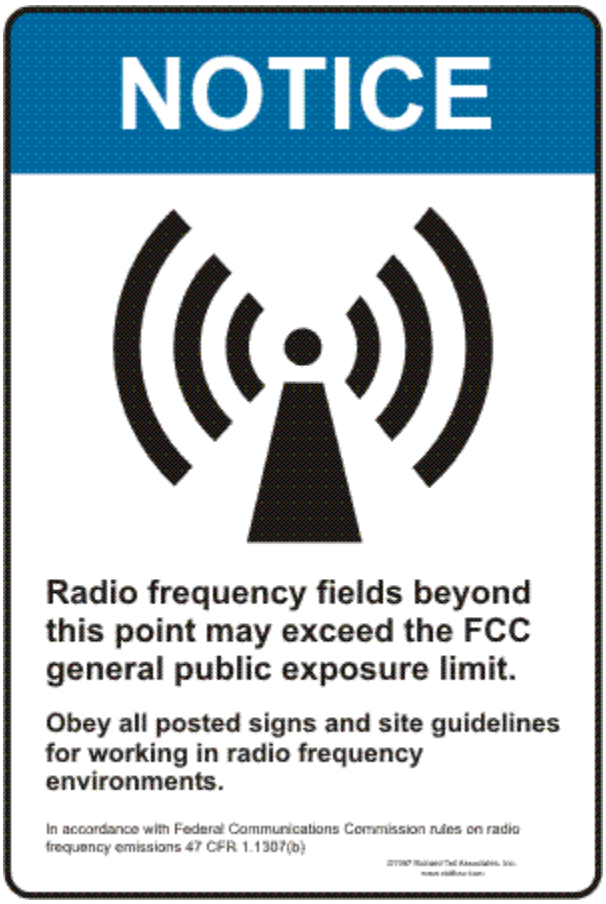


Figure 3:
Category 2 & 3 Areas

Figure 2 is applicable to Category 2 and possibly Category 3 areas to mark locations where rf field levels in some areas of the site may exceed the FCC MPE limits for **Occupational / Controlled exposure.**

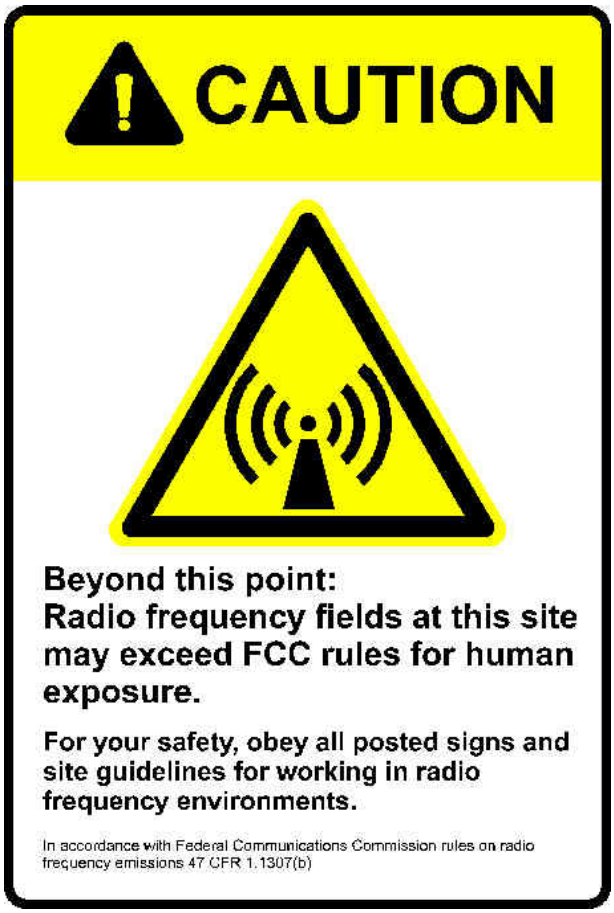


Figure 4:
Category 2 & 3 Towers

Figure 3 is applicable to Category 2 and possibly Category 3 towers. Use this sign at the base of towers. It is ideal for applications where the rf field levels on the ground beneath the tower are insignificant and the risk potential is for personnel that climb the tower.

NOTE: This sign is not appropriate for AM antenna towers.

Figure 5:
Category 3 & 4 Areas

Figure 4 is applicable to Category 4 and possibly Category 3 areas. Use this sign to mark locations where rf field levels in some areas of the site exceed the FCC MPE limits for Occupational/Controlled exposure.

The strong language used on this sign is designed to mark areas with high rf field levels.

Figure 6:
Category 3 & 4 Towers

Contact currents and rf burn signs can result from excessive rf contact currents. Contact currents, and potentially modest shocks, can occur when a person touches a tower guy wire. Guy wires are normally insulated from the tower close to the attachment point on the tower. However, unless an additional insulator is used a few feet above the ground (just out of reach of an adult), significant rf contact currents can flow from the guy wire through the person making contact. This is because the guy wire can act as a receiving antenna and pick up substantial energy from the transmitting antennas.

Figure 5 is applicable to Category 4 and possibly Category 3 areas. Use this sign near guy wires that do not have an insulator a few feet above the ground at sites with high power antenna systems.

Figure 7:
AM Tower Sites

Figure 6 is applicable above 10 times the exposure limit. Use this sign at AM tower sites. The location depends on the type of fencing that is used. Use a sign near a feed wire if it is within reach of a person standing on the ground.

Radiofrequency burns are a very serious concern when working near an AM radio tower. Very high rf voltages and currents are present on the tower, at the feed wire from the tuning "hut" and inside the tuning hut near the tuning circuits. These high levels are also present inside the phasor cabinet.

Figure 8:
FCC tower Registration Number

The Federal Communications Commission has required that towers be registered since 1996. The Commission requires that the tower registration number be posted on each tower.

Figure 7 represents the suggested registration posting. The suggested sign is comprised of a 12" x 8" aluminum sign and a set of vinyl numerals.

The sign has rounded corners and a mounting hole in each corner and is manufactured with a special UV-resistant coating applied to the surface to increase life in outdoor environments.

Contact the rf Safety Officer for further information.

Radiofrequency warning signs are required at all access points in which levels exceed the controlled and uncontrolled environment exposure limits listed in Tables 1 and 2. In areas where access to levels greater than 10 times the controlled environment exposure limits may exist, warning signs alone do not provide adequate protection. Other warning devices, such as flashing lights, audible signals, barriers, or interlocks, are required depending on the potential risk of exposure.

Chapter 12 History Log
IPP Review Date: 09-22-08

This page is for informational purposes and does not have to be retained with the document.

Status Change	Document Revision	Effective Date	Page	Description of Change
Baseline		07-09-04		Replaces DCP-S-024
Admin. Change	Baseline	05-12-05	All	• Separates each chapter of the document into individual files • Minor formatting corrections
Admin. Change	Baseline	11-16-06	All	• Updated form numbers: DFRC 220 to DFRC 8-220 DFRC 221 to WK 8-221 DFRC 222 to WK 8-222 • Minor formatting changes
Revision	A	12-08-08	All	• Major rewrite to describe the current program at Dryden • Incorporated microwave and rf controls, protective measures, training • Deleted sample forms • Updated Relevant Documents lists