

# NON-IONIZING RADIATION SAFETY PROGRAM

11/6/17

Subtitle

CONTROLLING EMPLOYEE EXPOSURE TO NON-  
IONIZING RADIATION FROM DC TO 300 GHZ.

# Non-Ionizing Radiation Safety Program

## SUBTITLE

## 1.0 INTRODUCTION

### 1.1 Purpose and Scope

This document is intended to help insure that non-ionizing radiation sources are identified and posted, users are properly trained to work with and around these sources, and measurements are taken to evaluate human exposures. Controls to mitigate hazards are implemented when surveys indicate that exposures can exceed acceptable limits.

This document covers:

- Static (DC) magnetic and electric field.
- Sub-Radiofrequency fields with frequencies below 30 kHz, including power-line fields at 60 Hz
- Radio-frequency (RF) fields and radiation with frequencies from 30 kHz to 300 MHz.
- Microwave radiation with frequencies between 300 MHz and 300 GHz.

The bands of non-ionizing radiation and fields addressed in this document are shown in Table 1.

Voltage, also called electromotive force, causes electrically charged particles to move against the resistance in the wiring of a circuit. Imposing a voltage on any object creates an electric field that extends into the space around the object. If the intensity of the voltage varies with time, the intensity of the electric field around the object also varies with time. The strength of the electric field around an object increases as the voltage imposed on the object increases. An electric field will induce charges to move in any object in which current can flow, including human tissue.

The flow of current creates a second field capable of influencing objects at a distance from the object in which current is flowing. This is the magnetic field. Its strength varies as the strength of the current creating it varies. A magnetic field that varies with time will cause electric current to flow in any conductor as the magnetic field changes. As human tissue is a conductor, a magnetic field that changes strength over time will cause current to flow in a human body.

Electric and magnetic fields can exist separately or as a combined entity known as electromagnetic radiation.

**Table 1. Bands of Radiofrequency and Sub-radiofrequency Fields and Radiation**

Frequency Range	Wavelength Range	Band
0 Hz	—	Static (DC)
3 to 30 Hz	100,000 - 10,000 km	ELF (Extremely Low Frequency)
30 Hz to 300 Hz	10,000 – 1,000 km	SLF (Super Low Frequency)
300 Hz to 3 kHz	1,000 – 100 km	ULF (Ultra Low Frequency)
3 kHz to 30 kHz	100 – 10 km	VLF (Very Low Frequency)
30 kHz to 300 kHz	10 – 1 km	LF (Low Frequency)
300 kHz to 3 MHz	1 km - 100 m	MF (Medium Frequency)
3 MHz to 30 MHz	100 – 10 m	HF (High Frequency)
30 MHz to 300 MHz	10 - 1 m	VHF (Very High Frequency)
300 MHz to 3 GHz	1m – 10cm	UHF (Ultra High Frequency)
3 GHz to 30 GHz	10 cm to 1 cm	SHF (Super High Frequency)
30 to 300 GHz	1 cm to 1 mm	EHF (Extremely High Frequency)

Electric Field amplitudes are displayed in units of volts per meter (V/m). Magnetic Field amplitudes are displayed in units of amperes per meter (A/m), or tesla(T). So long as a magnetic field exists in something that is nonmagnetic, such as air and most biological tissue, tesla can be related directly to amperes per meter. 100  $\mu$ T is about 79.55 amperes per meter.

## 2.0 HAZARDS

Biological effects depend on the frequency and intensity of the electromagnetic radiation. Known biological hazards are:

- Static magnetic fields (0 Hz) with strengths of about 4T can produce a variety of symptoms including nausea, metallic taste in the mouth, and vertigo.
- Electromagnetic fields can induce current flow in the body. The threshold for perception and discomfort from such current flow is frequency dependent. At frequencies from 0 Hz to 100 MHz, a serious electrical shock can occur if the induced current flow in the body is great enough and there is a current path from the body to ground.
- Radiofrequency and microwave energy can cause heating of body tissue, similar to that produced in a microwave oven. Heating effects become significant at frequencies in the MHz and GHz range, especially between about 30 and 300 MHz. High levels of microwave energy are known to cause cataracts and skin burns in humans.

Static and lower-frequency fields are known to induce malfunctions in medical electronic implants, such as pacemakers, which can malfunction at field strengths well below applicable occupational exposure limits. As a result, in many cases the only precautions required for elevated static and lower frequency ( $f < 30$  kHz) fields are:

1. To warn pacemaker users to stay out of the area.
2. To keep tools and magnetizable objects out of places where elevated static magnetic fields are present.

Tools and compressed-gas cylinders can become uncontrollable and fly like missiles toward magnets in areas where strong static fields and strong field gradients (changes in field strength over distance) exist. These same hazards also apply to individuals with metallic prosthetic implants (e.g., aneurysm clips, pins or hip replacements). Therefore, the NIRSO (Non-Ionizing Radiation Safety Officer) should be informed of medical devices, implants, and special situations (temporary work and/or tools) that are potentially hazardous in strong ( $> 100 \mu\text{T}$ ) static and sub-radiofrequency magnetic fields. Mechanical hazards depend on the field strength and the field gradient, and also on how rapidly the magnetic field strength changes with distance. A supplemental survey method is described in the following text. Static fields can also erase data shared on magnetic media or on the strips of credit or debit cards and badges.

### 3.0 AREAS AND PERSONS TO BE INCLUDED IN THE PROGRAM

The following areas shall be subject to identification and control by this program:

- Steady (DC) magnets that could generate fields above 0.5 mT to the chest under normal-use conditions. Common horseshoe and bar magnets do not need to be inventoried but, for example Faraday rotators with permanent magnets of other larger permanent magnets shall be inventoried.
- Equipment that could create 60 Hz electric fields above 1 kV/m or magnetic fields above 0.1 mT. For electric fields, this is equipment that operates above 2.5 kV without electric field shielding between the source and individuals; for magnetic fields, equipment that operates above 100A. Some cardiac pacemakers can malfunction if subjected to 60 Hz field strengths above 0.1 mT or 1 kV/m.
- All RF or microwave generators capable of radiating over 5 Watts into an open area at frequencies between 3 kHz and 40 GHz (1 Watt above 40 GHz), or of emitting over 100 Watts if the output is normally completely contained by coaxial cables, or dummy or real loads.

**Exemption from the program requirement.** Microwave ovens, household appliances, cellular phones, PDA's and WiFi transceivers do not have to be included in the program. Likewise, equipment that is in storage that cannot emit energy is exempted.

#### 3.1 Definition of FCC Radiofrequency exposure rules and limits

FCC exposure limits are set forth in 47 C.F.R. § 1.1310 and have protections for trained persons who may be exposed as part of their job ("Occupational/Controlled") and untrained persons ("General Population/Uncontrolled").

**Occupational/Controlled Limits (Occupational Limits)** The Occupational Limits apply in situations in which persons are exposed to RF as a consequence of their employment, provided those persons are "fully aware" of the potential for exposure and can "exercise control" over their exposure. For example, wireless technicians and broadcast engineers would likely be in this category due to their experience working with RF exposure and their knowledge of and the ability to avoid the hazards of RF exposure. The Occupational Limits also apply in situations where an individual is transient through a controlled location where the Occupational Limits apply, provided that he or she is made aware of the potential for exposure. "Transient" generally means an incidental passage through an area exceeding the Public MPE Limit (but not the Occupational MPE limit). It does not apply to persons who are not fully aware of the potential for exposure and who must do work in an area exceeding the Public MPE limit.

## Non-Ionizing Radiation Safety Program

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**General Population/Uncontrolled Limits (Public Limits)** The more stringent Public Limits apply in situations in which the general public may be exposed to RF, or in which persons exposed as a consequence of their employment may not be “fully aware” of the potential for exposure or cannot “exercise control” over their exposure. For example, this includes not only the general public, but also building workers that may come into contact with RF such as window-washers, HVAC technicians, electricians, roofers, and maintenance workers etc., if these workers have not been trained to safely work in the presence of transmitting RF sources.

**“Fully Aware” and “Exercise Control”** The phrase “fully aware” means that an exposed person has received written and/or verbal information fully explaining the potential for RF exposure resulting from his or her employment. With the exception of transient persons, this phrase also means that an exposed person has received appropriate training regarding work practices relating to controlling or mitigating his or her RF exposure. Such training is not required for transient persons, but they must receive written and/or verbal information and notification (for example, using signs) concerning their exposure potential and appropriate means available to mitigate their exposure. This would include, for example, pointing out and/or using signs to notify persons of the placement of “hidden or stealth” antennas that may be used behind a billboard or on a rooftop. The phrase “exercise control” means that an exposed person is allowed to and know how to reduce or avoid RF exposure by administrative or engineering controls and work practices, such as use of personal protective equipment, avoiding marked areas, or time averaging of exposures.

**RF Exposure Levels that exceed the FCC’s Public Limits** If RF levels are determined by calculation or measurement to exceed the Public Limits in an accessible area then access to those areas must be restricted. Training, restricting access, and signage as described in Appendix A, Table A-3 can all be used to help insure an area is considered a controlled environment. If work must be conducted by workers that are not “fully aware” of their potential for exposure or cannot “exercise control” over their exposure, the licensee must reduce power or cease operation of the transmitter while work is being conducted.

### 3.2 Training Required

Anyone who may reasonably expect to be exposed to fields of radiation emitted by the equipment listed in Section 3.0 shall be trained in “Non-ionizing Radiation”. Training shall be in accordance with the recommendations of IEEE C95.7 and shall include:

- Introduction to RF Safety and Sources
- RF Generators, transmission lines and wave propagations
- Antennas
- Biological Effects and Hazards
- Standards and Regulations
- Elements of an RF Safety Program
- Suspected over-exposure procedures
- RF Signs, alarms and barricades
- Site Evaluation
- Medical implant concerns
- Sources for additional information

The NIRSO and or supervisors may benefit from more in-depth training as also recommended in the C95.7 Recommended Practice.

### 3.3 Surveys

Equipment and locations identified in Section 3.0 shall be evaluated by exposure measurements when the equipment is first setup and after significant modifications that could alter the field strengths emitted. Equipment that is already setup, but not yet evaluated, shall be evaluated as new equipment. The selection of appropriate measurement instruments depends on the frequency of the electromagnetic radiation and surveys should be performed with calibrated instruments and by experienced persons. Results of surveys should be made part of personnel training whenever practical.

### 3.4 Non-Ionizing Radiation Safety Officer

The NIRSO is the person who has the authority to monitor and enforce the control of Non-ionizing radiation hazards and affect the knowledgeable evaluation and control of RF hazards. The NIRSO either performs the stated task or ensures that the task is performed.

## 4.0 OPERATIONAL AND ADMINISTRATIVE CONTROLS

This section contains requirements for dc magnetic and electric fields; sub-radiofrequency fields, including 60 Hz; and radio-frequency/microwave radiation fields (RF/mw).

Engineered controls (e.g., shielding, distance and energy isolation) shall be used to restrict exposure whenever practical. Signs complying with good safety practice recommendations like IEEE C95.2 and C95.7 shall be posted conspicuously at all entrances to areas described in this document.

### 4.1 Static Magnetic Fields (0 Hz)

The controls below apply to work areas where strong dc magnetic field exist. These controls are based on exposure guidelines published by the American Conference of Governmental Industrial Hygienists (ACGIH), which are summarized in Table A-1 of Appendix A.

- Caution signs shall be posted in areas where magnetic field strengths could exceed 0.5 mT, warning individuals with pacemakers or other medical electronic implants to keep out and warning individuals with magnetizable implants to check with management before entering.
- People with metallic medical implants shall be kept out of areas where field strengths exceed 3 mT.
- Danger signs warning individuals about tool hazards shall be posted in area where fields exceed 3 mT and in areas where a potential mechanical hazard exists.

### 4.2 Sub-radiofrequency Fields (1 Hz - 30 kHz, including 60 Hz power frequency)

The controls below apply to work areas where sub-radiofrequency fields exist. These controls are based on the Physical Agent Threshold Limit Values published by the ACGIH (summarized in Table A-1 of Appendix A).

- People with pacemakers or other medical electronic implants shall be kept out of areas where electric fields exceed 1 kV/m, as demonstrated by measurement or calculation. Caution signs shall be posted at the entrances to these areas advising individuals with medical electronic implants to keep out.

## Non-Ionizing Radiation Safety Program

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- People with pacemakers or other medical electronic implants shall be kept out of areas where magnetic fields exceed 0.1 mT, as demonstrated by measurement or calculation. Caution signs shall be posted at the entrances to these areas advising individuals with medical electronic implants to keep out.
- Areas where whole-body exposures to sub-radiofrequency fields exceed 25 kV/m or 1 mT shall be limited by positive means such as locked enclosures, interlocks, or safety chains. In addition, warning signs shall be posted in these areas.

### 4.3 Radio-Frequency/Microwave Radiation and Fields (30 kHz to 300 GHz)

The controls below apply to work areas where Radio-Frequency/microwave radiation (RF/mw) and fields exist. These controls are based on FCC OET Bulletin 65 and IEEE C95.2 and C95.7.

- Signs warning of RF/mw hazards shall be posted on the access points of towers or rooftops where individuals could be exposed to radiation or field strengths above the FCC limits for General Public/Uncontrolled persons specified in Table A-2 of Appendix A. Signs shall be posted in these areas as shown in Table A-3 of Appendix A. Notice signs shall be posted when General Public/Uncontrolled limits are exceeded.
- Caution signs shall also be posted in areas where the Occupational/Controlled limits from the FCC could be exceeded. These signs should be conspicuously posted where those field levels exist or could exist. Some form of barrier should also be installed to restrict access to that area.
- Warning signs shall also be posted if continuous wave RF/mw exceeds 10 times the applicable power density or the square of the electric field strength limits given in Table A-2. These areas MUST have a barrier installed that complies with industry standard “Lockout/Tagout” controls to insure no persons can access those areas when the RF/microwave source is activated.

RF/mw wearable monitors are available for trained persons to use; however, wearers should be aware of the product's limitations as well as its capabilities. Effective detection angles, frequency response and out-of-band frequency response should be known. Some products designed for use in RF/mw frequencies will false alarm when exposed to sub-radio frequency fields, negating confidence from the user of that device. Units should be carefully evaluated before depending on them to help control employee exposure.

## 5.0 REQUIREMENT SOURCE DOCUMENTS

47 C.F.R. § 1.1307

47 C.F.R. § 1.1310

FCC OET Bulletin No. 65

IEEE C95.2-1999, IEEE Standard for Radio-Frequency and Current Flow Symbols

IEEE C95.7-2014, IEEE Recommended Practice for Radio Frequency Safety Programs, 3 kHz to 300 GHz

## APPENDIX A

### Exposure Criteria

The tables in this appendix give exposure criteria for ac and dc magnetic fields. There are no Occupational Safety and Health Administration (OSHA) regulations for any of the fields of radiation covered in this document. The 1975 Swimline decision by the Occupational Safety and Health Review Commission voided OSHA's original (1910.97) nonionizing radiation standard. However, the 1987 *United Auto Workers (UAW) and Brock vs. General Dynamics Land Systems Division* decisions allowed OSHA to enforce consensus standards through the General Duty Clause of the Act when there is no standard for a specific hazard.

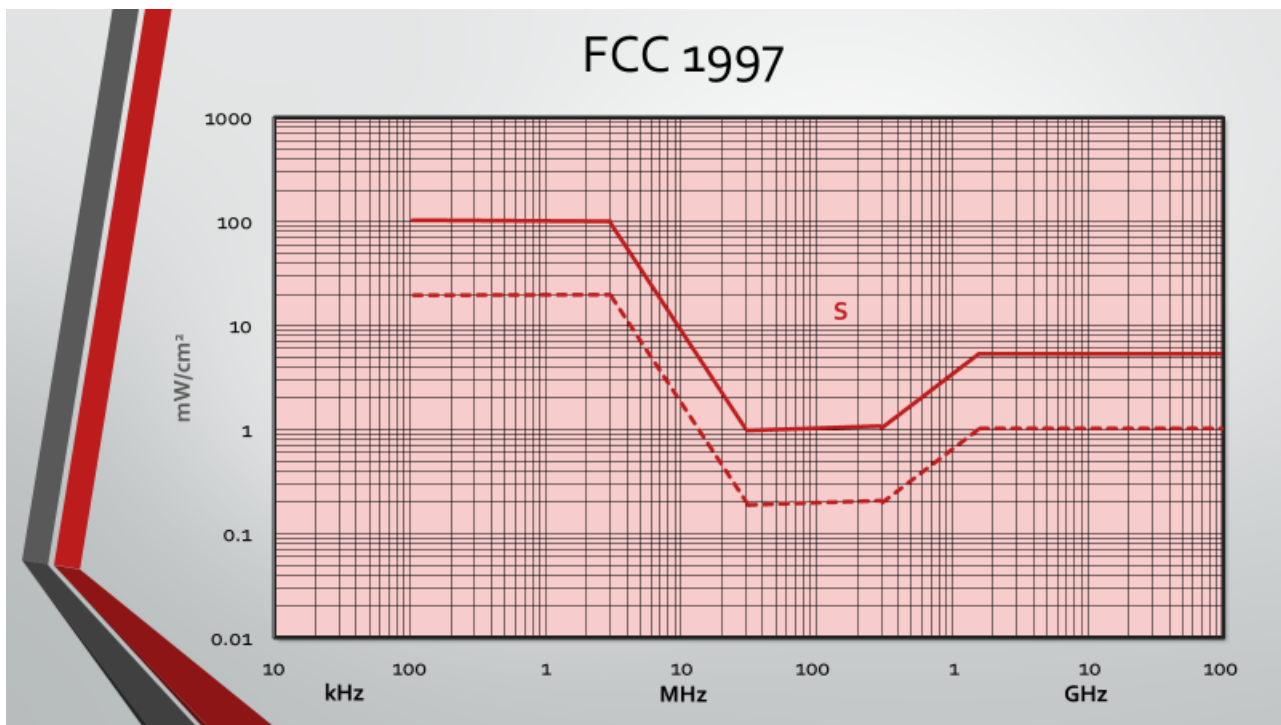


Figure 1 - FCC 47 C.F.R. § 1.1310 Whole-body Exposure Limits



**Table A-1. Exposure Guidelines for DC and AC fields below 100 kHz (ACGIH TLV)**

Part A – Electromagnetic Fields				Permissible Exposure	
Frequency	Exposure Group	Exposure Duration	Exposed part of Body	Electric (kV/m)	Magnetic (mT)
DC	Occupational	8 Hr. TWA	All	-	60
DC	“	Ceiling	All	-	2000
DC	“	8 Hr. TWA	Limbs	-	600
DC	“	Ceiling	Limbs	-	5000
1 to 300 Hz	“	Ceiling	All	-	60/f(Hz)
1 to 300 Hz	“	Ceiling	Arms & Legs	-	300/f(Hz)
1 to 300 Hz	“	Ceiling	Hands & Feet	-	600/f(Hz)
300 Hz to 100 kHz	“	Ceiling	All	-	0.2
DC to 220 Hz	“	Ceiling	All	25	-
220 Hz to 3 kHz	“	Ceiling	All	$5.525 \times 10^6/f$	-
3 kHz to 100 kHz	“	Ceiling	All	1.842	-

**NOTE: Wearers of implanted medical devices are limited to 0.1 mT and/or 1 kV/m at powerline frequencies.**

Part B – Induced and Contact Currents	
Frequency Range	Contact Current
1 Hz to 2.5 kHz	1.0 mA
2.5 to 100 kHz	0.4f mA (f in kHz)

















**Table A-2. FCC Limits for Maximum Permissible Exposure (47 C.F.R. § 1.1310)**

<b>A. Limits for Occupational/Controlled Exposure</b>				
Frequency Range (MHz)	Electric Field Strength (E) V/m	Magnetic Field Strength (H) A/m	Power Density (S) mW/cm <sup>2</sup>	Averaging Time  E  <sup>2</sup> ,  H  <sup>2</sup> or S (minutes)
0.3 - 3.0	614	1.63	(100)*	6
3.0 – 30	1842/f	4.89/f	(900/f <sup>2</sup> )*	6
30 - 300	61.4	0.163	1.0	6
300 - 1500	--	--	f/300	6
1500 – 100,000	--	--	5.0	6
<b>B. Limits for General Population/Uncontrolled Exposure</b>				
Frequency Range (MHz)	Electric Field Strength (E) V/m	Magnetic Field Strength (H) A/m	Power Density (S) mW/cm <sup>2</sup>	Averaging Time  E  <sup>2</sup> ,  H  <sup>2</sup> or S (minutes)
0.3 - 1.34	614	1.63	(100)*	30
1.34 – 30	824/f	2.19/f	(180/f <sup>2</sup> )*	30
30 - 300	27.5	0.073	0.2	30
300 - 1500	--	--	f/1500	30
1500 – 100,000	--	--	1.0	30







f = Frequency in MHz

\* = Plane-wave equivalent power density

**Table A-3. Warning Signs to be Posted Where Potential Non-Ionizing Radiation Hazards Exist**

Frequency	Field	Situation	Signal Word	Symbol	Typical Wording
Static	Electric	Field greater than 5 kV/m			Strong Electric Field. Insulating garments and equipment required and authorized personnel only.
“	“	Field greater than 15 kV/m			As above
“	Magnetic	Field greater than 0.5 mT			Strong Magnetic Field. No persons with implanted medical devices allowed.
“	“	Field greater than 3 mT			Very strong Magnetic Field. No persons with implanted medical devices, implants or magnetic media.
1 Hz to 3 kHz	Electric	Field greater than 1 kV/m			Strong Electric Field. No persons with implanted medical devices allowed.
“	“	Field greater than 5 kV/m			Strong Electric Field. Insulating garments and equipment required and authorized personnel only.
1 Hz to 3 kHz	Magnetic	Field greater than 0.1 mT			Strong Magnetic Field. No persons with implanted medical devices allowed.
“	“	Field greater than 1 mT			Very strong Magnetic Field. No persons with implanted medical devices, implants or magnetic media.

**Table A-3 (Continued). Warning signs to be Posted Where Potential Non-Ionizing Radiation Hazards Exist**

3 kHz to 300 GHz	Electric or Magnetic	Field greater than General Public Limits			Areas beyond this sign can exceed Untrained worker limits. Do not access if unsure.
“	“	Field greater than Occupational Limit			Areas beyond this sign can exceed human limits. Do not access unless fully aware and trained.
“	“	Field greater than 10x Occupational Limit			Areas beyond this sign exceed safe levels. Insure source is de-energized, locked out and tagged out.

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