The Electric and Magnetic Field Safety Program

at the University of Toronto

Introduction

Static electric and magnetic fields, as well as variable electromagnetic fields are used extensively at the University of Toronto, primarily for research and in telecommunication.

The University of Toronto is committed to ensure that the use of static electric and magnetic fields and variable electromagnetic fields at the University is carried out in a safe manner with due regard for employees, students, the public and the environment. The University of Toronto Radiation Protection Authority (UTRPA) is charged with ensuring the existence of effective radiation safety programs for each type of radiation. The Radiation Protection Service is charged with the administration of the radiation safety programs.

Health Effects

1. Static magnetic and electric fields

In a work place environment with static magnetic fields above 2 T (tesla), rapid motions can create transient sensory effects. Metallic objects in higher fields can create a projectile hazard. Workers with implanted ferromagnetic or electronic medical devices can suffer from interferences with magnetic fields above 0.5 mT [1, 6, 7, and 8].

Strong static electric fields can create spark discharges in the vicinity of conductors or contact currents that can lead to electrocution. Ungrounded objects can acquire electrical charges if located in strong static electric fields and can also create contact currents.

There are no proven chronic (long term) effects of static electric and magnetic fields with values under the limits in Table 1.

CAUTION: Strong magnetic fields can erase magnetic media, disabled ABM and credit cards, and damage some watches.

2. Time varying electric and magnetic fields (EMF) in the extremely low frequency (ELF) range (1Hz to 3 kHz).

a. Acute effects

Acute effects of exposure to extremely low frequency (ELF) EMFs on the nervous system are: the direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes. There is also strong indirect scientific evidence that Central Nervous System (CNS) functions, such as cognitive processing, can be affected by induced electric fields below the threshold for direct stimulation. In addition, painful currents can occur when a person makes contact with a conducting object at a different electrical potential. All these effects have thresholds, below which they do not occur. The adverse effects can be avoided by meeting appropriate basic restrictions on electric fields induced in the body and on contact current.

Strong electric fields in this frequency range can produce a wide range of safety hazards like spark discharges and contact currents from ungrounded conductors. Prudence shall be taken when handling flammable materials (possible combustion and ignition), or electro-explosive devices (explosion) in strong electric fields.

b. Chronic effects

ELF magnetic fields were classified in 2002 by the World Health Organization in category 2 B as “possibly carcinogenic to humans” This category is used for agents, mixtures and exposure circumstances for which there is *limited evidence* of carcinogenicity in humans and less than *sufficient evidence of* carcinogenicity in experimental animals. The basis for this classification was the epidemiologic results in some studies on childhood leukemia. In the same category 2B (possible carcinogenic to humans) is coffee. Coffee may increase the risk of kidney cancer while at the same time being protective against bowel cancer.

3. EMF in radiofrequency (RF) and microwave range (3kHz to 300 GHz)

a. Acute effects

The most consistent effects of acute RF and microwave exposure on humans are the thermoregulatory responses of the cardiovascular system to RF-induced heating, increasing heat loss from the skin through increased skin blood flow and evaporative heat loss from sweat.

Most recent studies [3] of human subjects, including adults, children and adolescents, have focused on the possible effects of essentially non-thermal exposures to mobile phone type RF, often simulating mobile phone use and so only involving localized exposure of part of the head. A number of non-thermal interaction mechanisms have been proposed but to date none have been experimentally confirmed. A wide range of subjective symptoms including headaches and migraine, fatigue, and skin itches have been attributed to various RF sources both in the home and the workplace. However, the evidence from double-blind provocation studies suggests that the reported symptoms are not causally related to EMF exposure.

Thermally significant RF exposure can impair male fertility and cause increased embryo and fetal losses and increase the incidence of fetal malformations and anomalies. Such effects have not been consistently shown at exposure levels that do not induce temperature elevation of 1°C or more. The studies that have addressed postnatal developmental indices or behavior after prenatal exposure to low level RF radiation have generally reported lack of effects. Effects resulting from long-term exposure during the development of juvenile animals have been addressed in only a few studies, and the data are insufficient for conclusions. Cataracts in the eyes of anesthetized rabbits remain a well-established thermal effect of RF exposure. However, primates appear to be less susceptible to cataract induction than rabbits, and opacities have not been observed in primates following either acute or prolonged exposures.

b. **Chronic effects**

Concerning cancer-related effects, the recent *in vitro* and animal genotoxicity and carcinogenicity studies are rather consistent overall and indicate that such effects are unlikely at specific absorption rate (SAR) levels up to 4 W kg^{-1} [3,4]. With regard to *in vitro* studies of RF effects on non-genotoxic end-points such as cell signaling and gene/protein expression, the results are more equivocal, but the magnitudes of the reported RF radiation induced changes are very small.

Health Canada considers that:" At present, there is no scientific basis for the premise of chronic and/or cumulative health risks from RF energy at levels below the limits outlined in Safety Code 6. Proposed effects from RF energy exposures in the frequency range between 3 kHz and 300 GHz, at levels below the threshold to produce thermal effects, have been reviewed. At present, these effects have not been scientifically established, nor are their implications for human health sufficiently well understood. Additionally, a lack of evidence of causality, biological plausibility and reproducibility greatly weaken the support for the hypothesis for such effects. Thus, these proposed outcomes do not provide a credible foundation for making science-based recommendations for limiting human exposures to low-intensity RF energy." [4]

University of Toronto limits for exposure to Static Electric and Magnetic Fields

In Canada there are no limits established for static electric and magnetic fields. The Ontario Ministry of Labour uses American Conference of Governmental Industrial Hygienists (ACGIH) limits [6]. These limits are presented in table 1. It should be mentioned that these limits are similar to the limits recommended by the International Commission of Non-Ionizing Radiation Protection (ICNIRP) [1].

Table 1 – Static Electric and Magnetic Field Limits

Exposure	Ceiling Value
Whole body (general work place) [6]	Magnetic field 2T (20,000Gs)
Whole body (special worker training and controlled work place environment) [6]	Magnetic field 8T (80,000Gs)
Limbs [6]	Magnetic field 20 T (200,000Gs)
Medical device wearers [6]	Magnetic field 0.5 mT (5Gs)
General Public – exposure to any part of the body [1]	Magnetic field 0.4 T (4000Gs)
Electric field in air (occupational exposure) [6]	Electric field 25,000 V/m
Contact currents from touching ungrounded objects that acquired electric charge in a strong static electric field [6]	Electric current 1 mA

Intervention levels at the University of Toronto are established at 1/10 of the values from table 1, except for medical device wearers. The limits for static magnetic field for medical device wearers remain at 0.5 mT, unless specified by the medical doctor who approved the implementation of the medical device.

University of Toronto limits for exposure to sub-radio frequency EMFs (1 Hz to 3 kHz)

For EMF with frequency from 1 Hz to 3 kHz, the University of T will apply the limits recommended by ICNIRP. There are very small differences between ICNIRP and ACGIH limits. The ICNIRP limits are presented in tables 2, 3 and 4.

Table 2 – EMF Limits in the Range from 1 Hz to 3 kHz – Occupational

Frequency range	E electric field strength (V/m)	H magnetic field strength (A/m)	B magnetic field density	
			micro T	mGs
1 – 10 Hz	20 000	$2 \times 10^5 / f^2$	$2.5 \times 10^5 / f^2$	$25 \times 10^5 / f^2$
10 - 25 Hz	20 000	$2 \times 10^4 / f^2$	$2.5 \times 10^4 / f^2$	$25 \times 10^4 / f^2$
0.025 -0.1 kHz	500/f	20/f	25/f	250/f
60 Hz	8333	333	417	4166
0.1 – 0.4 kHz	5000	200	250	2500
0.4 – 1 kHz	2000/f	80/f	100/f	1000/f
1 – 3 kHz	2000	80	100	1000

f in Hz or kHz, as indicated in the frequency range column.

Table 3 – EMF Limits in the Range from 1 Hz to 3 kHz – General Public

Frequency range	E electric field strength (V/m)	H magnetic field strength (A/m)	B magnetic field density	
			microT	mGs
1 – 10 Hz	10 000	$4 \times 10^4 / f^2$	$5 \times 10^4 / f^2$	$50 \times 10^4 / f^2$
0.01 – 0.025 kHz	10 000	4/f	5/f	50/f
0.025 – 0.1 kHz	250/f	4/f	5/f	50/f
60 Hz	417	67	83	833
0.1 – 0.4 kHz	250/f	40	50	500
0.4 – 1 kHz	250/f	16/f	2/f	20/f
1 – 3kHz	250/f	16	20	200

f in Hz or kHz, as indicated in the frequency range column.

Table 4 Reference levels for time varying contact currents from conductive objects from 1Hz to 3 kHz

Exposure characteristics	**Frequency range**	**Maximum contact current (mA)**
Occupational	up to 2.5 kHz	1.0
	2.5–3 kHz	0.4*f
General Public	up to 2.5 kHz	0.5
	2.5–3 kHz	0.2*f

f is the frequency in kHz

Intervention levels at the University of Toronto are established at 1/10 of the values from tables 2, 3 and 4.

University of Toronto limits for exposure to radio frequency (RF) and Microwave EMFs (3 kHz to 300 GHz)

The limits recommended by Canada Safety Code 6 will be applied at the University of Toronto in this frequency range. They are presented in tables 5, 6 and 7.

Table 5- Induced and Contact Current Limits from 3 kHz to 110 MHz

Exposure characteristics	Frequency range	Maximum induced current (mA)	
Controlled environment		Through both feet	Through each foot and hand grip and each foot
	0.003 – 0.1 MHz Average time 1s	2000*f	1000*f
	0.1 – 110 MHz Average time 6 min	200	100
Uncontrolled environment	0.003 – 0.1 MHz Average time 1s	900*f	450*f
	0.1 – 110 MHz Average time 6 min	90	45

f is frequency measured in MHz

Table 6 - Exposure Limits for Controlled Environments from 3 kHz to 300 GHz

Frequency (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (W/m^2)	Averaging time (min)
0.003 - 1	600	4.9		6
1 - 10	600/f	4.9/f		6
10 - 30	60	4.9/f		6
30 - 300	60	0.163	10*	6
300 – 1 500	$3.54* f^{0.5}$	$0.0094* f^{0.5}$	f/30	6
1 500 – 15 000	137	0.364	50	6
15 000 – 150 000	137	0.364	50	$616000/f^{1.2}$
150 000 -300 000	$0.354* f^{0.5}$	$9.4 \times 10^{-4} * f^{0.5}$	$3.33 \times 10^{-4} * f$	$616000/f^{1.2}$

f is frequency measured in MHz

* Power density limit is applicable at frequencies greater than 100 MHz.

Table 7 - Exposure Limits for Uncontrolled Environments from 3 kHz to 300 GHz

Frequency (MHz)	Electric field strength (V.m)	Magnetic field strength (A/m)	Power density (W/m^2)	Averaging time (min)
0.003 - 1	280	2.19		6
1 - 10	280/f	2.19/f		6
10 - 30	28	2.19/f		6
30 - 300	28	0.073	2*	6
300 – 1 500	$1.585*f^{0.5}$	$0.0042*f^{0.5}$	f/150	6
1 500 – 15 000	61.4	0.163	10	6
15 000 – 150 000	61.4	0.163	10	$616000 / f^{1.2}$
150 000 -300 000	$0.158*f^{0.5}$	$4.21 \times 10^{-4} * f^{0.5}$	$6.67 \times 10^{-5} f$	$616000 / f^{1.2}$

f is frequency measured in MHz
* Power density limit is applicable at frequencies greater than 100 MHz.

Intervention levels at the University of Toronto are established at 1/10 of the values in tables 5, 6 and 7.

Controls

a. Hazard identification

Generally a safety factor of 10 was introduced in calculating the limits presented in tables 1 to 7, however, these are considered ceiling values and should never be reached.

The supervisors will receive training in identifying the EMF hazards. Examples of devices that can produce electric and magnetic fields above the limits are presented in Appendix A. When new equipment producing large EMFs is bought or manufactured, and installed in a University of Toronto controlled area the Radiation Protection Service must be informed.

The supervisors of work places in all areas controlled by the University of Toronto with fields possible at levels above University of Toronto intervention limits shall contact the Radiation Protection Service (RPS). The RPS will perform measurements to identify the high field areas and compare the results with values from tables 1 to 7. All areas found with values above the intervention levels will be considered controlled areas. Controlled

areas will be marked with appropriate warning signs for electric or magnetic field, and access will be restricted to trained personnel.

b. Warning signs and access controls

All rooms, areas, enclosures with magnetic fields density above 0.5 mT will have a sign indicating restricted access for persons with medical implanted devices that may interfere with magnetic field. Examples of these signs are presented in Appendix B – Electric and magnetic fields warning signs.

All rooms, areas and enclosures with values of electric and/or magnetic fields above the University of Toronto intervention levels will be marked with similar signs with the ones presented in Appendix B.

All rooms, areas and enclosures with values of electric and magnetic fields above the University of Toronto intervention levels will be secured to prevent unauthorized access. This can be achieved with walls, doors, barriers, fences, etc.

c. Training

All persons with access to the EMF controlled areas will receive training covering: EMF hazards identification, health effects, signs, engineering control measures, operating procedures.

Periodic refresher training will be delivered. The refresher training will cover: changes in the regulations and in the University of Toronto EMF safety program, changes in work procedures, etc.

d. Personal Protective Equipment (PPE)

Tools used in magnetic fields above the intervention levels will be made of non-magnetic materials.

If a persons needs to perform work in an area that may have values close to the values from tables 1 to 7, the person shall wear personal protective equipment and a field warning instrument with visible and audio signal.

e. Work place inspections

An annual inspection of all existing areas with EMFs above the intervention levels. will be performed by a Radiation Safety Officer (RSO) In addition, all new equipment or devices that can produce high levels of EMFs will be inspected by the RSO before the equipment or device is used.

In performing a workplace inspection involving EMF hazards, the check sheet in Appendix C will be used.

Appendix A – Example of equipment and devices that can produce EMFs

Appendix B – Warning signs

Appendix C – Inspection check list

References

[1] Guidelines on Limits of Exposure to Static Magnetic Fields – ICNIRP, 2009 Health Physics Society

[2] Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz to 100 kHz) – Draft, ICNIRP, July 29, 2009

[3] Exposure to high frequency electromagnetic fields, biological effects and health consequences (100 kHz-300 GHz) – ICNIRP 16/2009

[4] Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz - Safety Code 6 (2009), Health Canada

[5] Technical Guide for Interpretation and Compliance Assessment of Health Canada's Radiofrequency Exposure Guidelines, Health Canada 2009

[6] 2009 TLVs and BEIs – Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices, American Conference of Governmental Industrial Hygienists - ACGIH, ISBN -978-1-882417-95-7 @ 2009

[7] Safety Rules for the Use of Static Magnetic Fields at CERN, Revision June 2005

[8] Static Magnetic Fields – Fermi Lab EH&S Manual, Rev. 12/05

Appendix A – Example of equipment and devices that can produce EMFs at the University of Toronto

Source	Frequency	Potential for Over-exposure?
Nuclear Magnetic Resonance Facilities	Static and hundreds of MHz	Yes
Power Plant	60 Hz	Yes
Transformers	60 Hz	Yes
Laboratory EMF Generators	13.56 MHz	Yes
Video Display Terminal (VDT)	0.015 - 0.3 MHz	No
Dielectric Heater	1 - 100 (typically 27.12) MHz	Yes
Diathermy Applicator	13.56, 27.12, 915, 2,450 MHz	Yes
Communications Transmitters: FM Radio	88 – 108 MHz	Yes
Communications Transmitters: VHF TV	54 - 72, 76 - 88, 174 – 216 MHz	Yes
Communications Transmitters: UHF Radio	470 – 890 MHz	Yes
Communications Transmitters: Dish Antenna	800 - 15,000 MHz	Yes
Cordless Telephone	46 - 5,800 MHz	No
Cellular Telephone	824 - 850, 900, 1,800, 1,900 MHz	No
Microwave Oven	915 and 2,450 MHz	No*
*Federal legislation requires that microwave ovens be constructed to meet stringent microwave leakage limits and to have safety interlocks. When these interlocks are defeated, for example, during repair work, there is a risk of overexposure to microwave radiation.		

Appendix B – Warning signs

DANGER

STRONG MAGNETIC FIELD

Pacemaker/Prosthetic Users

Pacemaker and metal prosthetic users are at risk of serious injury or death. Such users must stay at least 4.6 meters (15 feet) away from the magnet until safety at a closer distance is identified by a physician and medical device manufacturer.

ATM/Credit Cards

The magnetic field can disable ATM and credit cards and damage watches. Keep ATM and credit cards away from the strong magnetic field.

Post this sign, before the magnet is energized, in all rooms and passageways that will contain a 5-gauss magnetic field. varian Pub. No. 87-250305-00 A0491

Extreme Caution!

IRON or other FERRO MAGNETIC OBJECTS must not be brought into the vicinity of the magnetic field as very strong attractive forces exist!

No Admission

for persons with PACE-MAKERS and other metallic implants.

Part No. Z 36007
Z 4K 3641

⚠ DANGER

STRONG MAGNETIC AND RADIO FREQUENCY FIELDS ARE PRESENT

PACEMAKER AND PROSTHETIC HAZARD

Operation of certain cardiac pacemakers can be inhibited resulting in death or serious injury to the user.

Pacemaker and metal prosthetics users should establish safety requirement with their physician and pacemaker manufacturer before entering.

Magnetic items can suddenly fly towards the magnet and cause serious damage or personal injury.

Keep all tools, equipment, and personal items containing steel, iron, and other magnetic material at least 2 meters (6 feet) away from the magnet.

The magnetic field can disable credit and ATM cards and damage watches.

Keep credit and ATM cards away from the strong magnetic field.

PLACE THIS SIGN ON ACCESS DOORS TO NMR SPECTROMETER ROOM.

varian® Pub. No. 87-250301-00 A0589

5-GAUSS WARNING

STRONG MAGNETIC FIELD

Pacemaker, Metallic Implant Hazard

Strong magnetic and rf fields are present that can cause serious injury or death to persons with implanted or attached medical devices, such as pacemakers and prosthetic parts. Such persons must not go closer to the magnet than this sign until safety at a closer distance is identified by a physician or device manufacturer.

Magnetic Media, ATM/Credit Cards

Strong magnetic fields are present that can erase magnetic media, disable ATM and credit cards, and damage some watches. Do not take such objects closer to the magnet than this sign.

varian


DANGER
HIGH VOLTAGE
DO NOT USE
EMERGENCY ONLY
DANGER
13.800
VOLTS

Appendix C - Inspection check list for EMF safety

Checklist for workplaces with high electric and magnetic fields

Required for laboratories with equipment that can produce electric or magnetic fields above the limits specified below at any accessible point

Static magnetic or electric field

Sign on the door indicating" Danger Magnetic or Electric Field Hazard"	Y	N	N/A
Line on the floor around the equipment indicating H=400A/m (B=0.5 mT)	Y	N	N/A
No person wearing pacemaker allowed in the marked region	Y	N	N/A
Visitors are informed that credit cards, analog watches can be affected	Y	N	N/A
Second line on the floor around the equipment indicating H=40kA/m (50 mT)	Y	N	N/A
No person wearing ferrous implants allowed in the second marked region	Y	N	N/A
No ferrous object aloud in the second marked region	Y	N	N/A
Line on the floor around the equipment indicating E=10,000 V/m	Y	N	N/A
No person without protection allowed in the marked region	Y	N	N/A

Extremely Low Frequency (ELF) 1Hz-100kHz electromagnetic field (EMF)

Sign on the door indicating EMF Hazard	Y	N	N/A
Line on the floor around the equipment indicating H=16A/m (B=20 microT)	Y	N	N/A
No person without protection allowed in the marked region	Y	N	N/A
Line on the floor indicating E=87 V/m	Y	N	N/A
No person without protection allowed in the marked region	Y	N	N/A

Radiofrequency (RF) and microwave EMF (100 kHz - 300 GHz)

Sign on the door indicating EMF Hazard	Y	N	N/A
Line on the floor around the equipment indicating H=0.073 A/m (B=0.1 microT)	Y	N	N/A
No person without protection allowed in the marked region	Y	N	N/A
Line on the floor indicating E=28 V/m	Y	N	N/A
No person without protection allowed in the marked region	Y	N	N/A
Line on the floor indicating induced current I=45mA	Y	N	N/A
No person without protection allowed in the marked region	Y	N	N/A