# Radiofrequency Safety Guide

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MIT EHS
ENVIRONMENT · HEALTH · SAFETY

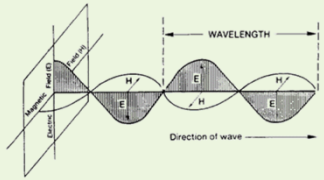
## Delegation of Authority

MIT has a standing Institute **Committee on Radiation Protection** to oversee all uses of radiation at the Institute and its associated off campus locations. They give the RPP authority to stop any experiment or process involving radiation that is deemed unsafe.

## Sources of RF: Radar, Cell Towers, FM Radio, Industrial

- **Intentional radiator**: A device that intentionally generates and emits radio frequency energy.
- **Unintentional radiator.** A device that generates radio frequency energy but which is not intended to emit RF energy by radiation or induction.

## Bands of RF and sub-RF Fields and Radiation and Wave Terminology




Comprised of an Electric Field and a Magnetic Field component (which are orthogonal to each other in the far field), the free space power density may be represented as follows: $S = \frac{|E|^2}{\eta} = \eta|H|^2$

| Common Name | | Frequency Range | Wavelength Range | Band Name |
|---|---|---|---|---|
| Infrared | | >300 GHz | <1 mm | Infrared / Quasi-Optical |
| Microwave (MW) | Radiofrequency (RF) | 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) |
| Sub Radiofrequency | | 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 |
| | | 30 Hz–300 Hz | ≥1000 km | Extremely low frequency (ELF) |
| Static | | 0 Hz | -- | Static |

| Microwave Frequency Bands | |
|---|---|
| Designation | Frequency range |
| L band | 1 to 2 GHz |
| S band | 2 to 4 GHz |
| C band | 4 to 8 GHz |
| X band | 8 to 12 GHz |
| Ku band | 12 to 18 GHz |
| K band | 18 to 26.5 GHz |
| Ka band | 26.5 to 40 GHz |
| Q band | 30 to 50 GHz |
| U band | 40 to 60 GHz |
| V band | 50 to 75 GHz |
| E band | 60 to 90 GHz |
| W band | 75 to 110 GHz |
| F band | 90 to 140 GHz |
| D band | 110 to 170 GHz |

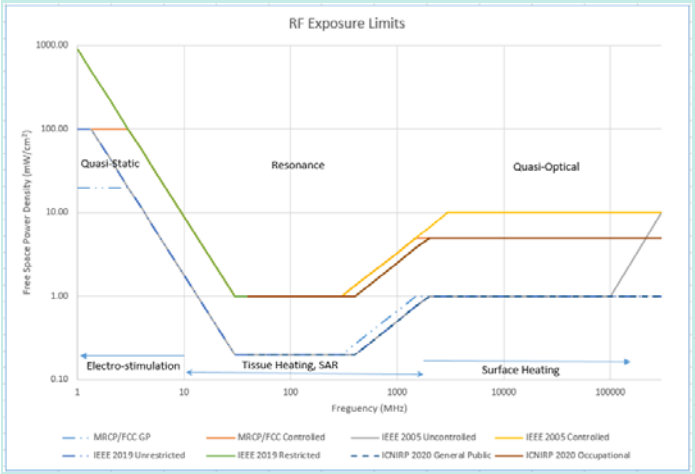
## Exposure Limits as a Two Tiered System

**Uncontrolled environments** are locations where there is unrestricted access by the public. There are no expectations that the exposure levels exceed the MPEs for the uncontrolled environment. (also known as **General Public**)

**Controlled environments** are locations where there is exposure to persons who are aware of the potential for exposure. The levels may exceed the MPE for the uncontrolled environment but may not exceed the MPEs for the controlled environment.

## RF Exposure Limits (a function of wavelength, spatial average, and time average)

Depiction of IEEE, MA, and ICNIRP Limits



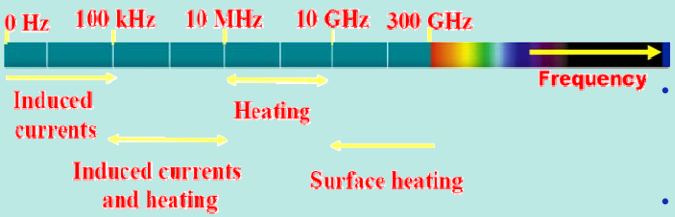

MA RCP regulations (105 CMR 122)

| Frequency Range | General Public Power Density (30 min average) ($mW/cm^2$) | Controlled Environs Power Density (6 min average) ($mW/cm^2$) |
|---|---|---|
| 0.3 – 3 MHz | 20 | 100 |
| 3 – 30 MHz | $180/f^2$ | $900/f^2$ |
| 30 – 300 MHz | 0.2 | 1.0 |
| 0.3 – 1.5 GHz | $f/1500$ | $f/300$ |
| 1.5 – 100 GHz | 1.0 | 5 |

- MPE's are for a spatial average along the body.
- All MPE's are time averaged based on Thermal Regulation concepts.

## Biological Effects

Biological effects are principally heating in the mid to higher frequencies and Electro-stimulation in the lower frequency




- 3 - 100 kHz: Exposure to high electric field intensities may result in shock/startle response, electrostimulation of biological tissue, or even burns.
- 100 kHz - 6 GHz (the resonance frequency range for humans is 30-300 MHz): Biological effects are caused by tissue heating.
- 6 - 300 GHz: Most of the energy is dissipated at the surface.

## Registration, Safety Plans, and Hazard Assessments

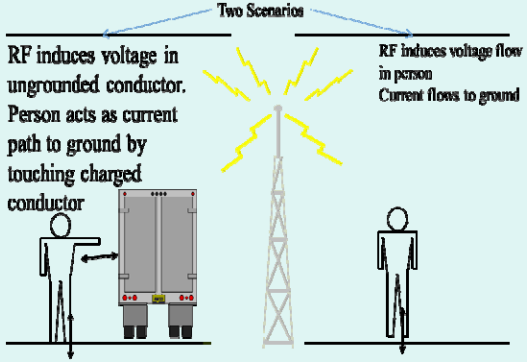
- Any group or organization with an intentional radiator system exceeding 10 watts ERP (Effective Rated Power) is to contact EHS Radiation Protection if registration, safety plan development, and RF Hazard assessment is required
- Based on this review, a determination as to whether a RF survey will be required to verify the conditions would be made. RF surveys may be made in accordance with a test plan as appropriate.
- The EHS Radiation Protection Program may provide assistance in plan development, RF field measurements and performance of calculations to support the program or project.
- Licensing by the FCC or submission of frequency allocation is the responsibility of the user.
- Operation of an intentional, unintentional, or incidental radiator is subject to the conditions that no harmful interference is caused (EMI).

## RF Surveys and Evaluation




- RPP has capabilities to perform RF assessments across the RF spectrum and includes frequency and time domain along with broad band and personal monitoring.
- Likewise, RPP can perform assessments on Unintentional irradiator, such as induction heating, Plasma etching and other.

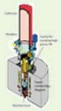
## Induced & Contact Current – Electric Shock




- An RF burn can occur when RF current enters through a small cross-section of the body.
- RF burns can occur at any RF frequency.
- The conditions for an RF burn can even exist on systems not subject to RFR control.
- Potential locations for RF burn are: Antennas, cables, connectors, all RF circuits, and microphones - bare metal.

## Ancillary Hazards

- Electrical
- Strong Magnetic Fields
- UV from plasma

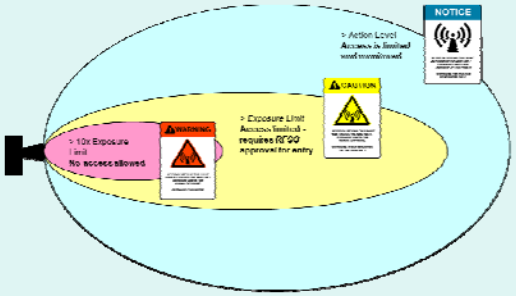


Examples include Kylstrons and Gyrotrons

## EIRP, ERP and Gain

- Effective radiated power (**ERP**) is the product of the power supplied to the antenna and its gain relative to a half-wave dipole in a given direction.
- Equivalent Isotropically Radiated Power (**EIRP**) is relative to an isotropic emitter.
- Antenna Gain, G is the ratio of the transmit/receive power in a particular direction to that of an Isotropic antenna.

## Postings, Warning Signs, and Controls





Types of controls that could be implemented include:

- Sector (azimuth and elevation) blanking,
- warning signs and lights,
- demarcation of keep out zones,
- spotters,
- time limitations (both in terms of operation duration and time of day),
- interlock systems,
- training

## Wave Guides Are Used To Channel RF Check for Leakage!!!


- Waveguide leaks are mostly found at the flanges that join two pieces together.
- Flexible and mechanically stressed waveguide can leak from any surface.
- If waveguide is not pressurized a leak may go un-noticed.

## 9 Traits of a Positive Safety Culture

1. Leadership Safety Values and Actions
2. Problem Identification
3. Personal Accountability
4. Work Processes
5. Continuous Learning
6. Environment for Raising Concerns
7. Effective Safety Communication
8. Respectful Work Environment
9. Questioning Attitude

**Radiation Protection Program**
**for more information, go to:** http://ehs.mit.edu/radiological

Rev 2.0 06/11/2020