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Non-ionizing Electromagnetic Radiation

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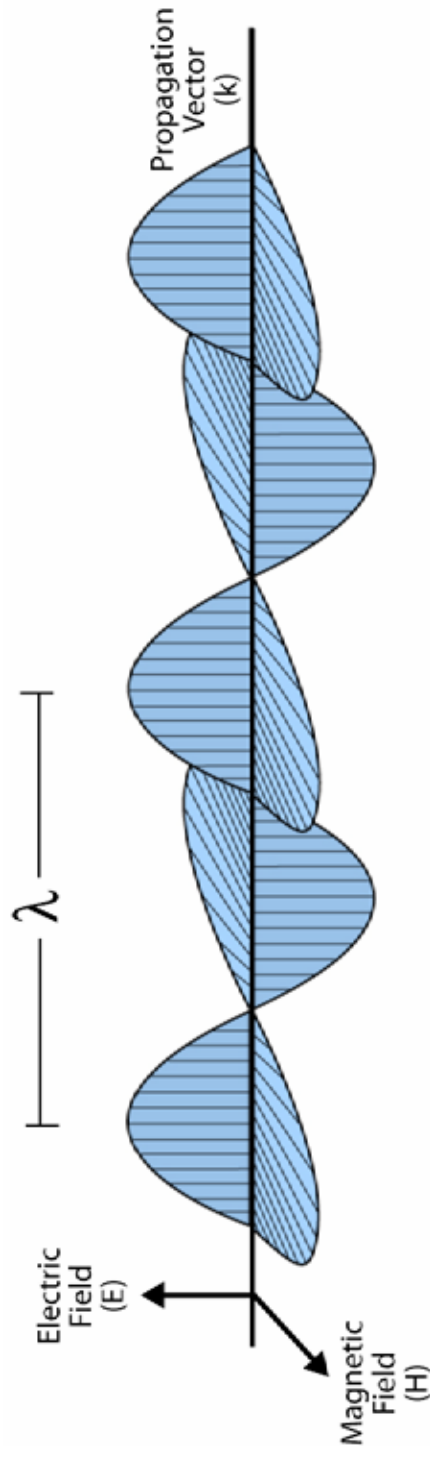


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Section A

*Introduction: Electromagnetic
Radiation*

Electromagnetic Radiation



$$\text{Power Density} = \mathbf{E} \times \mathbf{H}$$

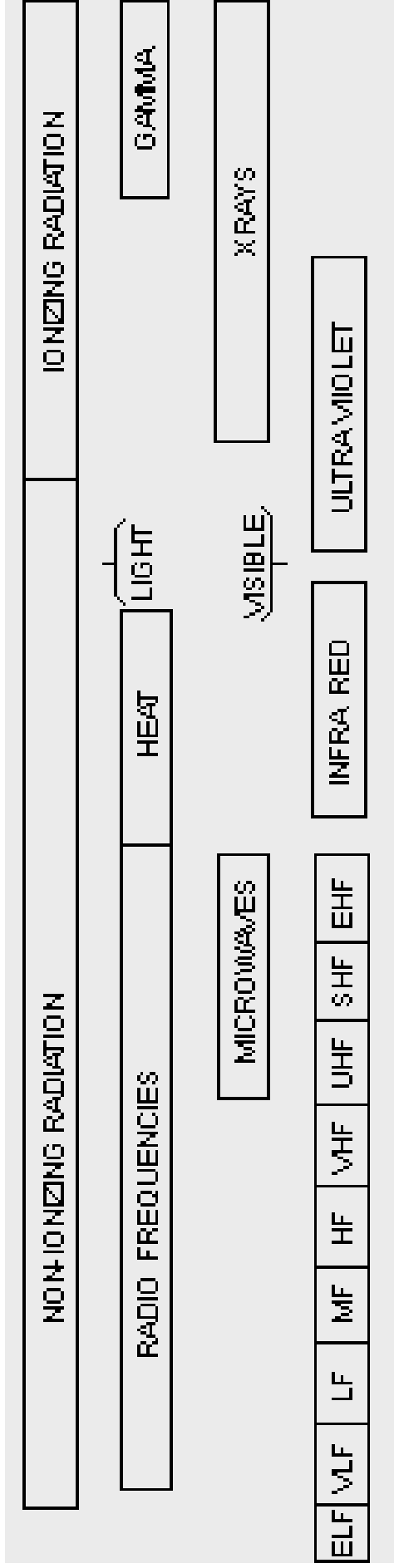
EM Radiation

- ◆ Electromagnetic wave can be characterized by the following:
 - Electric and magnetic field strengths
 - Wavelength
 - Frequency
 - Energy

EM Radiation

$$f = \frac{c}{\lambda} \text{ and } E = hf$$

- ◆ f = frequency (Hz, sec^{-1})
- ◆ λ = wavelength (cm)
- ◆ c = speed of light (3×10^{10} cm/sec)
- ◆ h = Planck's constant (4.13×10^{-15} eV-sec)
- ◆ E = photon energy (eV)



Non-Ionizing Radiation

Ionizing Radiation

EM Radiation

- ◆ *Ionizing radiation* (expressed as photon energy)
 - X-rays (>100 eV)
 - Gamma-rays (>100 keV)

EM Radiation

- ◆ *Optical radiations* (expressed as wavelength)
 - UV (0.4 –0.1um)
 - Visible (0.7–0.4 um)
 - Infrared (300–0.7 um)

EM Radiation

- ◆ *Radio frequency radiations* (expressed as frequency)
 - Microwaves (300 MHz–300GHz)
 - Radio frequency (300 Hz–300 MHz)
 - Extremely Low Frequency (ELF) (30 Hz–300 Hz)

Non-ionizing vs. Ionizing

- ◆ Ionizing
 - EM energy with sufficient energy to create ions (~12 eV)
 - Can cause direct genetic damage

Non-ionizing vs. Ionizing

- ◆ Non-ionizing
 - Less energy
 - Cause changes in vibration and rotational energies
 - Dissipated as heat



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Section B

Sources

<http://www.osha-slc.gov/SLTC/radiofrequencyradiation/rfpresentation>

Sources of RF/MW Exposure

- ◆ Dielectric heaters
- ◆ Induction heaters
- ◆ Microwave heaters
 - Including microwave ovens
- ◆ Broadcast communications
 - AM/FM
 - VHF/UHF

Sources of RF/MW Exposure

- ◆ Radar
- ◆ Diathermy
- ◆ Cell phones
- ◆ Cathode ray tubes (VDTs)
- ◆ Baby monitors
- ◆ Wireless web
- ◆ Magnetic resonance imagers (MRIs)



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Section C

Measurement Concepts

EM Field Concepts

- ◆ Power density (PD)
 - Radiant power per unit area
(mW/cm^2 or W/m^2)
- ◆ Electric fields (E)
 - Units (V/m)
- ◆ Magnetic field (H)
 - Units (A/m)

EM Field Concepts

$$PD = \frac{E^2}{3770} = 37.7 H^2$$

- ◆ PD = Power density (mW/cm²)
- ◆ E = Electric field (V/m)
- ◆ H = Magnetic field (A/m)

Example

- ◆ What are the E and H field strengths for a PD equal to 10 mW/cm²?

$$E = \sqrt{(3770)(10 \text{ mW} / \text{cm}^2)} = 194 \text{ V} / \text{m}$$

$$H = \sqrt{\frac{10 \text{ mW} / \text{cm}^2}{37.7}} = 0.52 \text{ A} / \text{m}$$

Inverse Square Law

- ◆ Applies to energy radiation
- ◆ Describes the change in energy as a function of distance

$$I_2 = I_1 \left(\frac{d_1}{d_2} \right)^2$$

Inverse Square Law

- ◆ I_1 and I_2 are the intensities and distances 1 and 2 respectively
- ◆ d_1 and d_2 are distances 1 and 2, respectively

Inverse Square Law: Example

- ◆ If the power density three feet from an antenna is 100 mW/cm^2 , what is the power density six feet away?

$$\begin{aligned} I_2 &= 100 \text{ mW / cm}^2 \left(\frac{3 \text{ ft}}{6 \text{ ft}} \right)^2 \\ &= 25 \text{ mW / cm}^2 \end{aligned}$$

Near Field vs. Far Field

- ◆ Near field
 - Close to source relative to its size and wavelength
 - Need to measure E field and H field separately
 - Inverse square law does not apply
 - Significant spatial variability
 - Can be subdivided into radiating and non-radiating near field regions

Near Field vs. Far Field

- ◆ Far field
 - Distance far from the antenna relative to its size and wavelength
 - Assume antenna is a point source
 - Inverse square law applies
 - E, H, or PD can be measured because they are interchangeable



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Section D

Standards and Guidelines

Health Concerns

- ◆ RF/MW energy can penetrate deeper into tissues than optical radiations
- ◆ Energy deposition creates thermal (heating) stresses
 - Heat stress
 - Depressed spermatogenesis
 - Ocular damage

Health Concerns

- ◆ Thermal effects well documented
- ◆ Heat is perceived only at high exposures

Health Concerns

- ◆ Athermal effects
 - Occur at exposure levels below which thermal effects exist
 - Not well documented
 - Behavioral
 - CNS effects
 - Reproductive effects
 - Cancer
 - Subject of more research

Current OSHA Standard

- ◆ Currently - 10 mW/cm²
- ◆ Based on 1966 American National Standards Institute (ANSI) Guideline
- ◆ Protects against excess thermal load
- ◆ Exposures are averaged over a six-minute period

Current Exposure Guidelines

- ◆ American Conference of Governmental Industrial Hygienists (ACGIH) has a Threshold Limit Value (TLV)
- ◆ Institute for Electrical and Electronics Engineers (IEEE) publishes a Maximum Permissible Exposure (MPE) Limit
- ◆ Both are based on limiting Specific Absorption Rate (SAR) below 0.4 W/kg

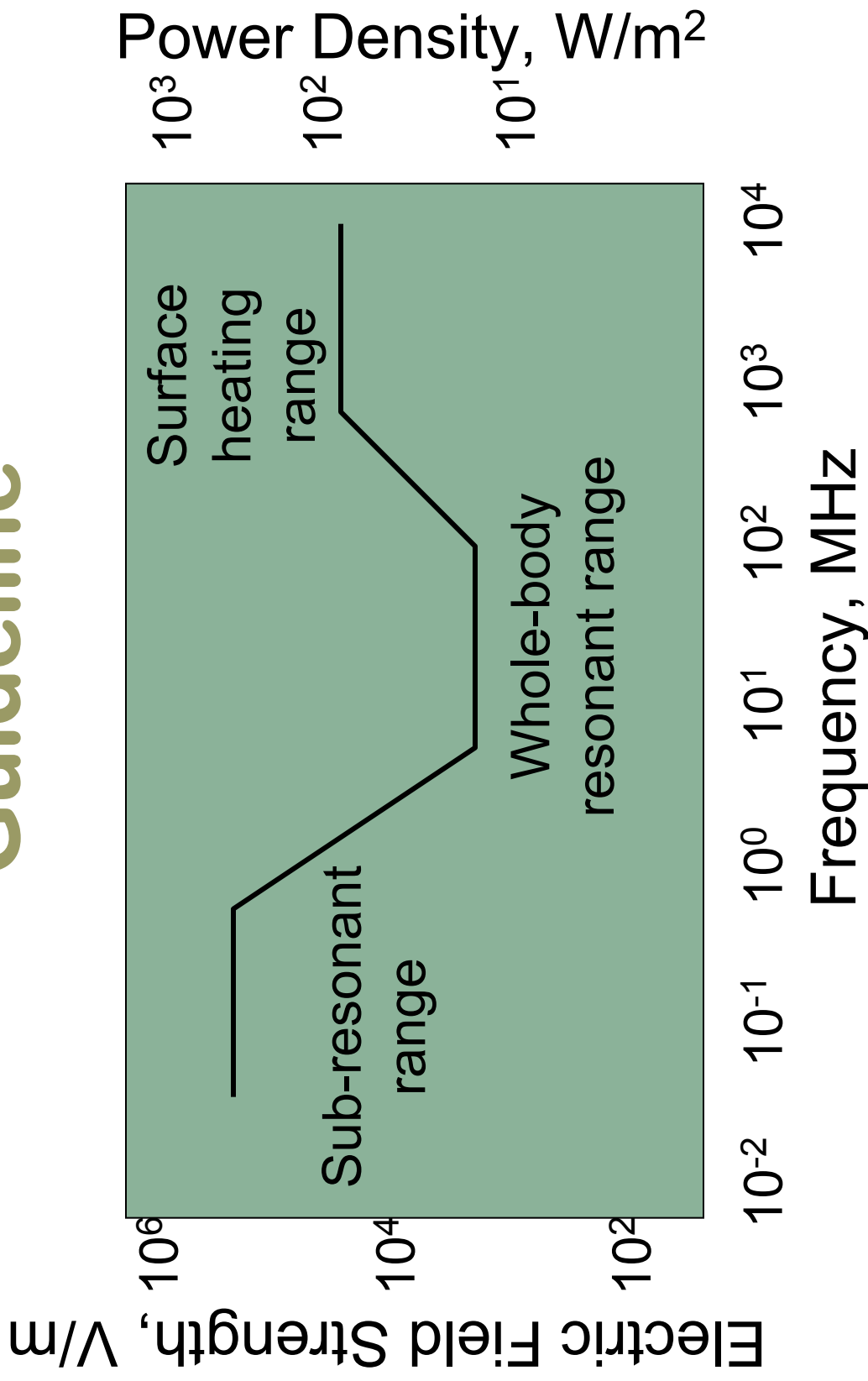
Specific Absorption Rate (SAR)

- ◆ The *specific absorption rate* is defined as the rate of energy deposition per unit mass, W/kg
- ◆ Defines absorbed energy dose
- ◆ Analogous to a biomarker of chemical exposure

Specific Absorption Rate (SAR)

- ◆ SARs less than 0.4 W/kg are considered protective for thermal effects
 - This level incorporates a ten-fold safety factor

Generic Human Exposure Guideline



Current Exposure Guidelines

- ◆ Absorption envelope
 - SAR is frequency dependent
 - Three exposure regions
 1. Sub-resonant range
 2. Whole-body resonant range
 3. Surface heating range
 - Body absorbs RF/MW differently at different frequencies

Averaging Time

- ◆ Six-minute averaging time generally used for exposure limits
- ◆ Based on cooling time constants derived from animal experiments
- ◆ Longer exposures can be compensated for by the body's thermoregulatory mechanisms

IEEE C95.1-1991

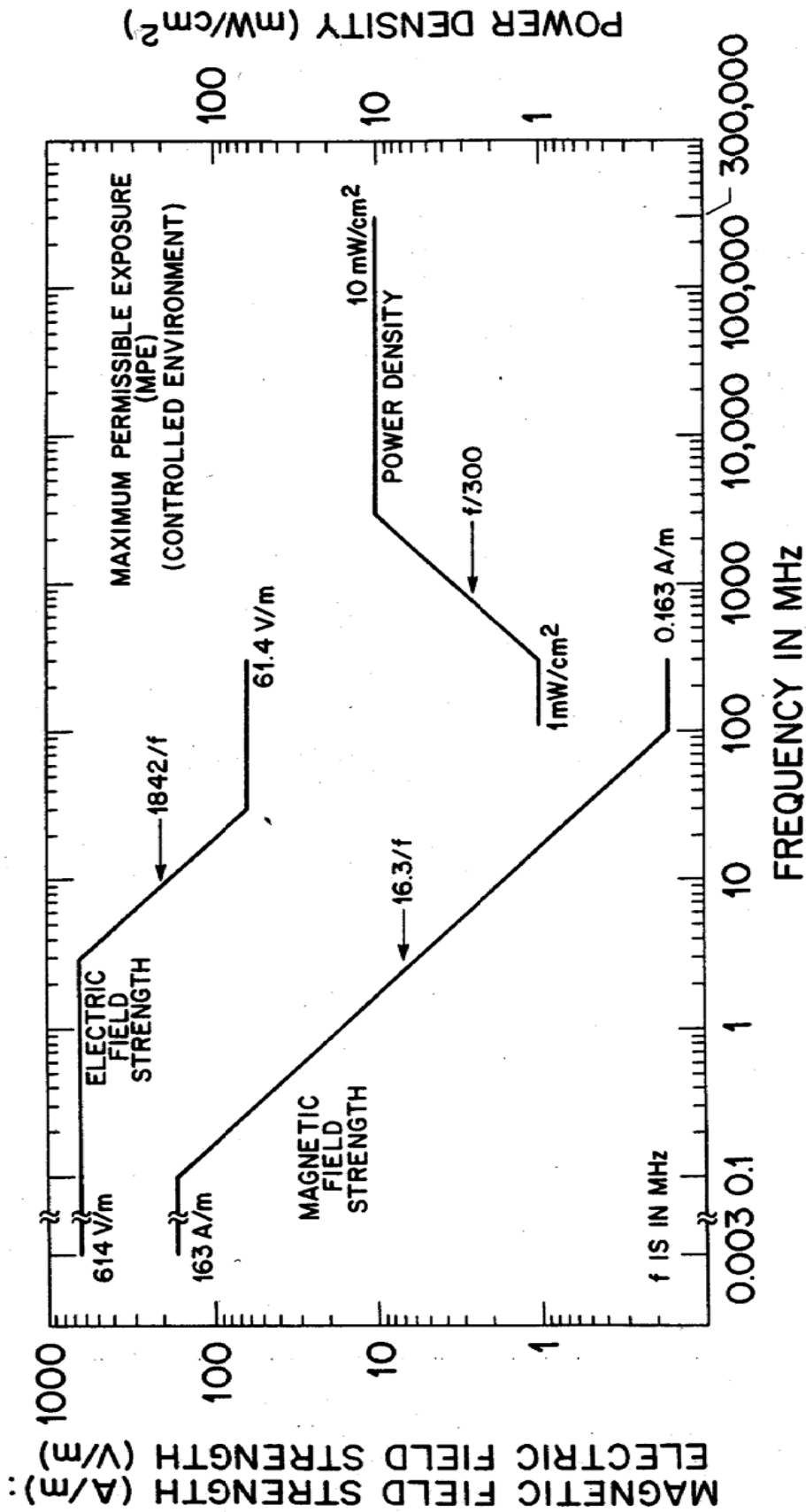


Fig A2
 Graphic Representation of Maximum Permissible Exposure in Terms of Fields and Power Density for a Controlled Environment.