JOHNS HOPKINS
BLOOMBERG
SCHOOL of PUBLIC HEALTH

JOHNS HOPKINS
BLOOMBERG
SCHOOL of PUBLIC HEALTH

Non-Ionizing Electromagnetic Radiation

Patrick N. Breysse, PhD, CIH

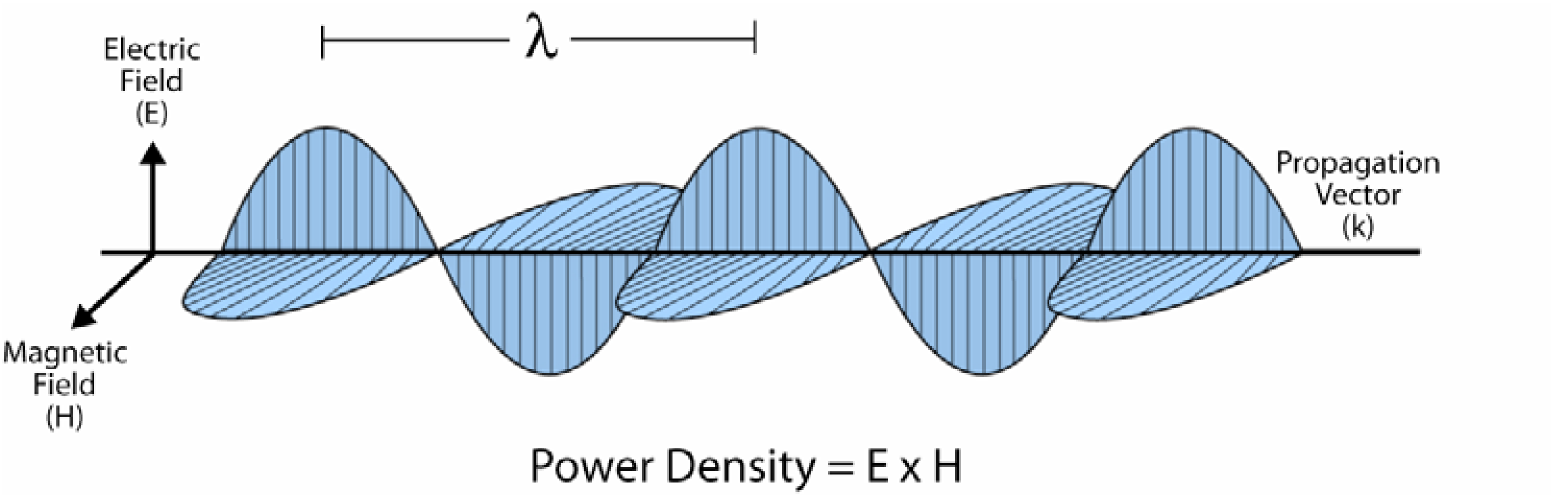
Peter S.J. Lees, PhD, CIH

Johns Hopkins University

Section A

Introduction: Electromagnetic Radiation

Electromagnetic Radiation



EM Radiation

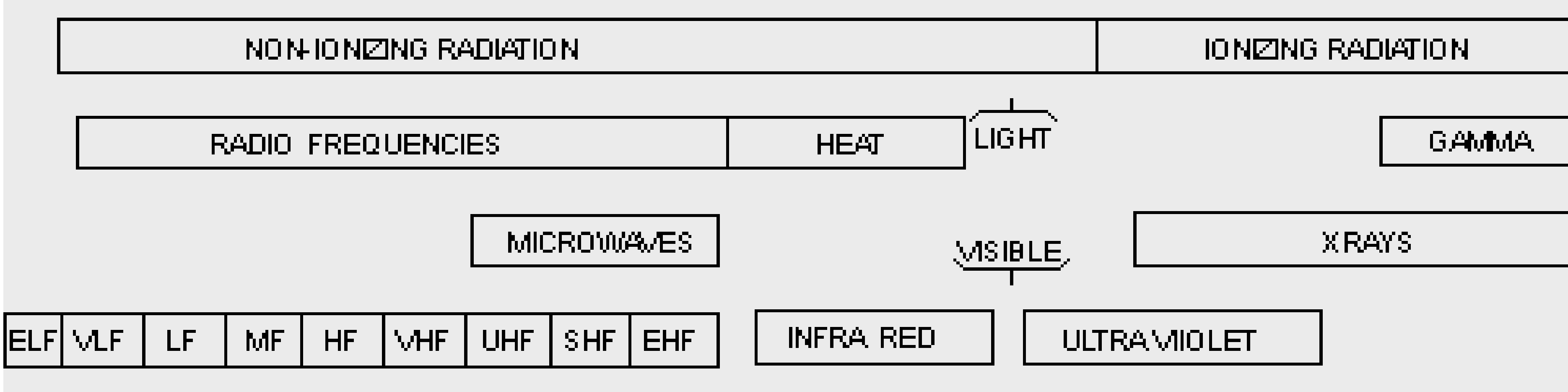
- Electromagnetic wave can be characterized by the following:
  - Electric and magnetic field strengths
  - Wavelength
  - Frequency
  - Energy

Continued

EM Radiation

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

- 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 (>100keV)

Continued

EM Radiation

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

Continued

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

Continued

Non-Ionizing vs. Ionizing

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

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

Continued

Sources of RF/MW Exposure

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

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)

Continued

EM Field Concepts

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

- PD = Power density (mW/cm^2)
- 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/cm^2?

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

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

Inverse Square Law

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

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

Continued

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?

$$I_2 = 100\, mW / cm^2 \left(\frac{3ft}{6ft} \right)^2$$

$$= 25\ mW / cm^2$$

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

Continued

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

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
  - Occular damage

Continued

Health Concerns

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

Continued

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/cm^2
- 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)

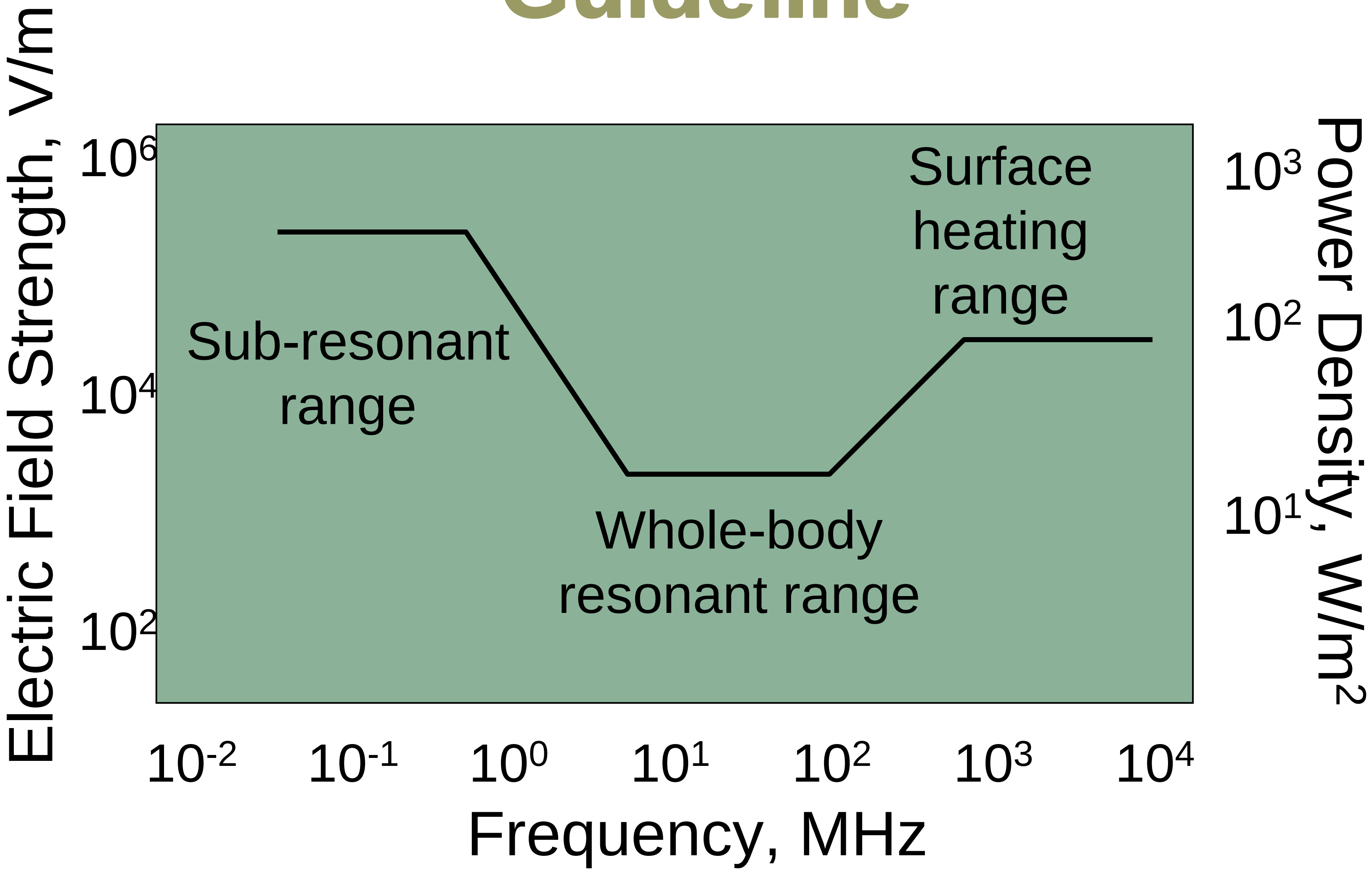
- The *specific absorption rate* is defined as the rate of energy deposition per unit mass, W/kg
- Defines absorbed energy dose
- Analogous to a biomarker of chemical exposure

Continued

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

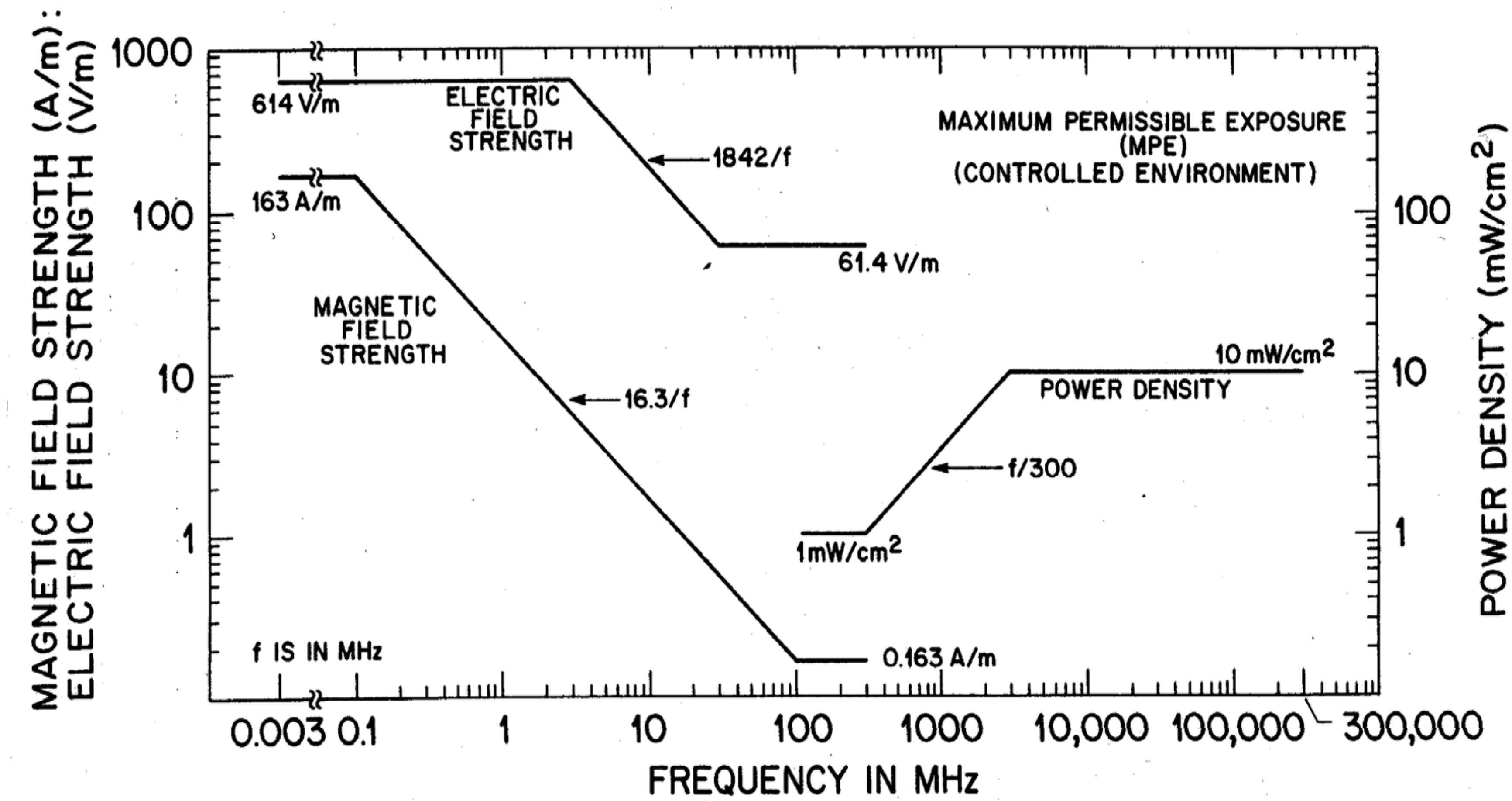


Fig A2
Graphic Representation of Maximum Permissible Exposure in Terms of Fields and Power Density for a Controlled Environment.