

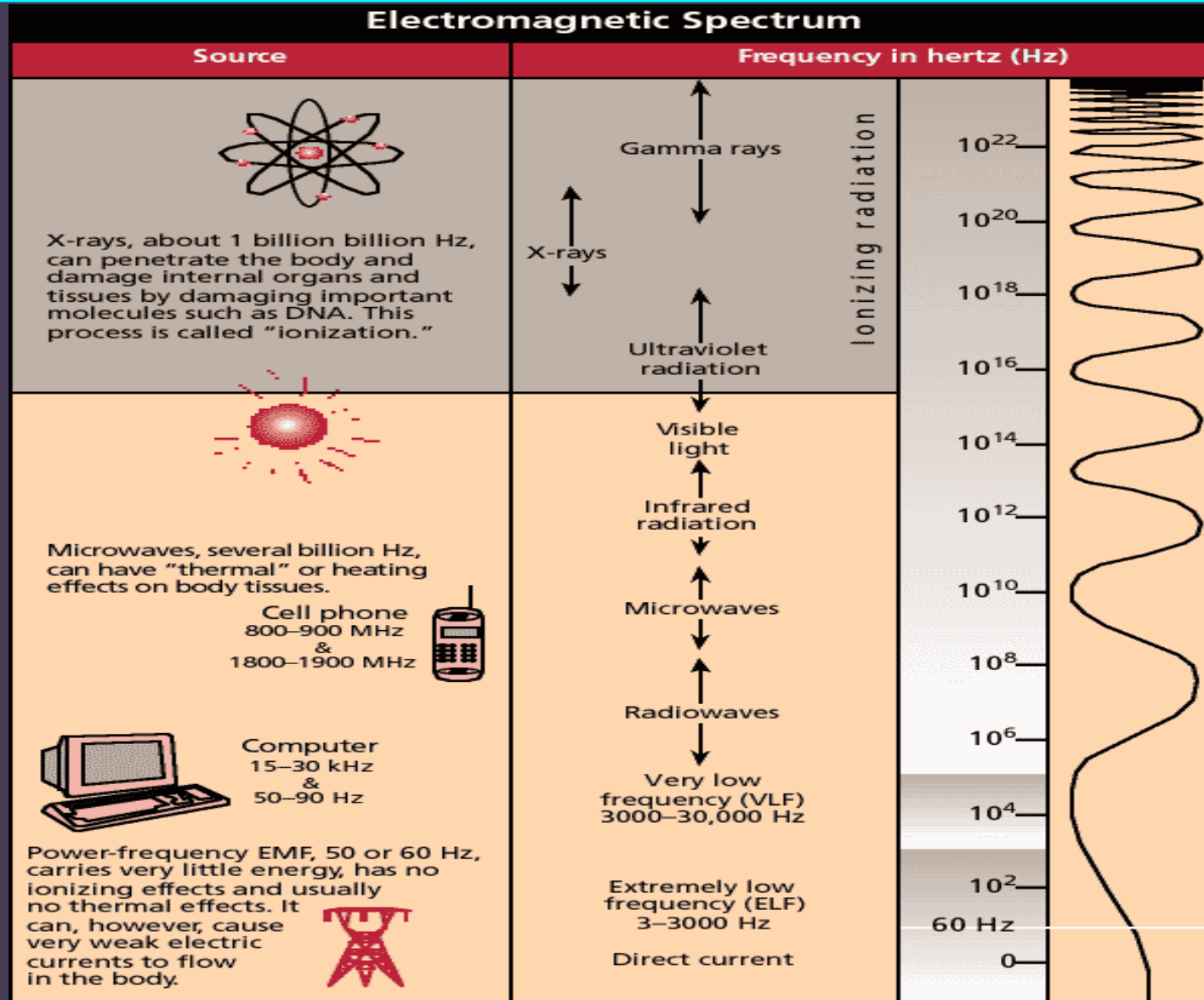
Extremely Low-Frequency, Radiofrequency, & Related Exposures and Cancer Risks

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Radiation Epidemiology Course
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Outline

- I. **Background & Terminology**
- II. **Measurement and methodologic issues**
- III. **Extremely low frequency (power frequency) and related exposures and cancer risks**
- IV. **Radiofrequency and microwave exposures and cancer risks**

Electromagnetic Spectrum



Terminology - 1

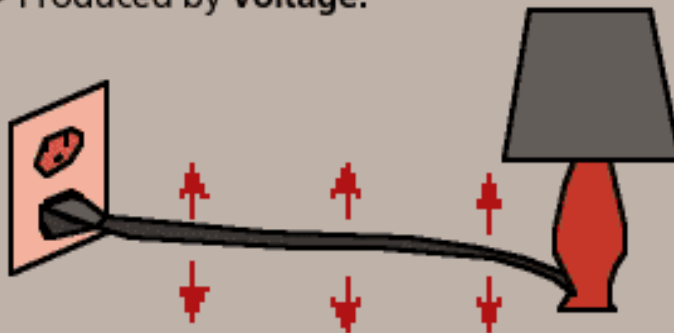
- **Electromagnetic spectrum**
 - Frequency: cycles per second (Hertz)
 - 1 cycle = 1 wavelength
 - as frequency \uparrow , wavelength \downarrow
- **Electric fields**
 - measured in volts per meter
 - easily shielded
- **Magnetic fields (MF)**
 - measured in gauss (G) or tesla (T)
 - not easily shielded

Electric vs. Magnetic Fields

A Comparison of Electric and Magnetic Fields

Electric Fields

- Produced by **voltage**.

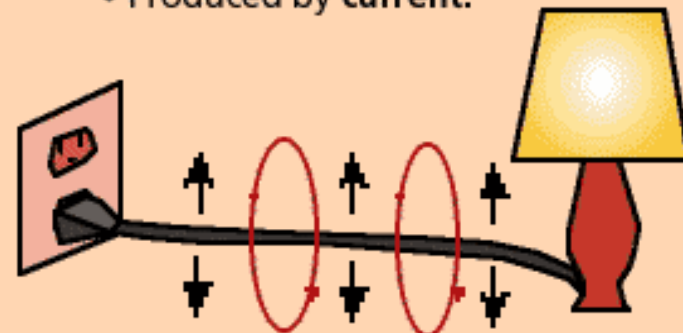


Lamp plugged in but turned off.
Voltage produces an electric field.

- Measured in **volts per meter (V/m)** or in **kilovolts per meter (kV/m)**.
- **Easily shielded** (weakened) by conducting objects such as trees and buildings.
- Strength decreases rapidly with increasing distance from the source.

Magnetic Fields

- Produced by **current**.



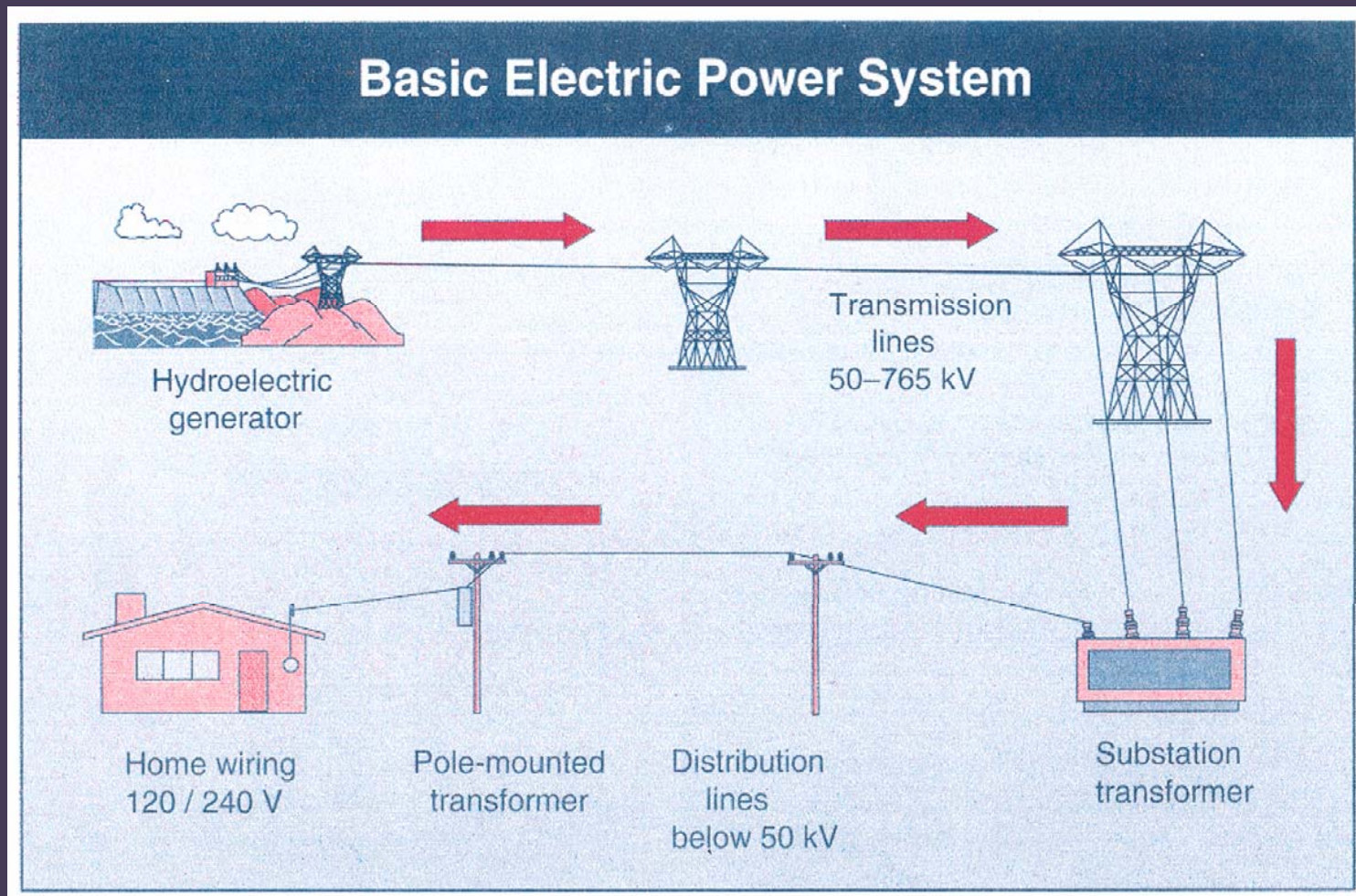
Lamp plugged in and turned on. Current now produces a magnetic field also.

- Measured in **gauss (G)** or **tesla (T)**.
- **Not easily shielded** (weakened) by most material.
- Strength decreases rapidly with increasing distance from the source.

Terminology - 2

- **Current = movement of electric charge**
 - AC = electric power ‘alternates’ at 60 Hz (50 Hz) inducing weak currents in humans and other conductors
 - DC = ‘direct current’ flows from batteries to appliance (doesn’t induce currents)
- **Voltage = potential to do work**
- **Power = product of volts and currents**
- **Conductor = material that carries current**
- **Load = electric power needed by homes, businesses, schools, etc.**

Electric Power: From Power Plant to Home

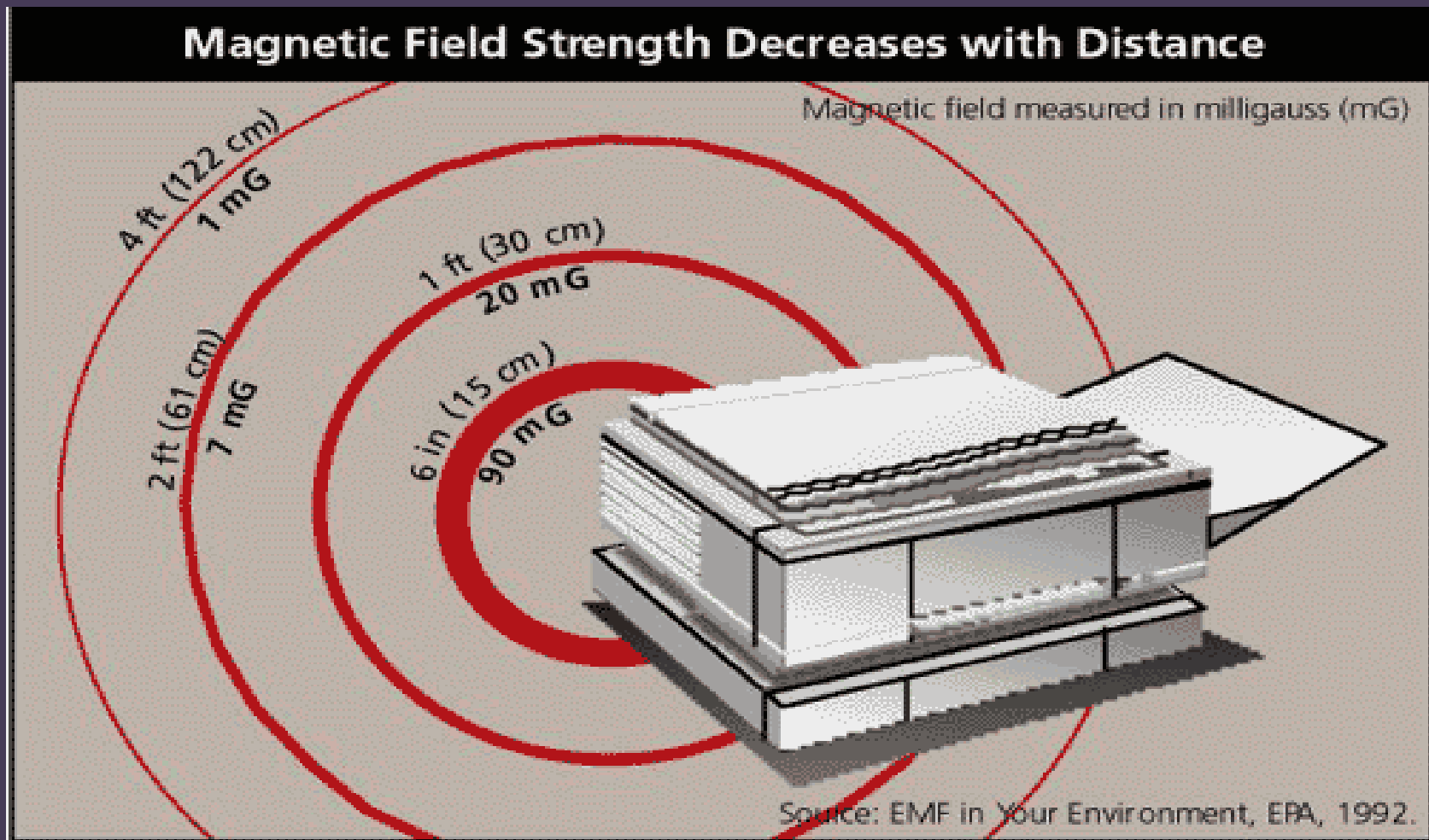


Measurements and Methods

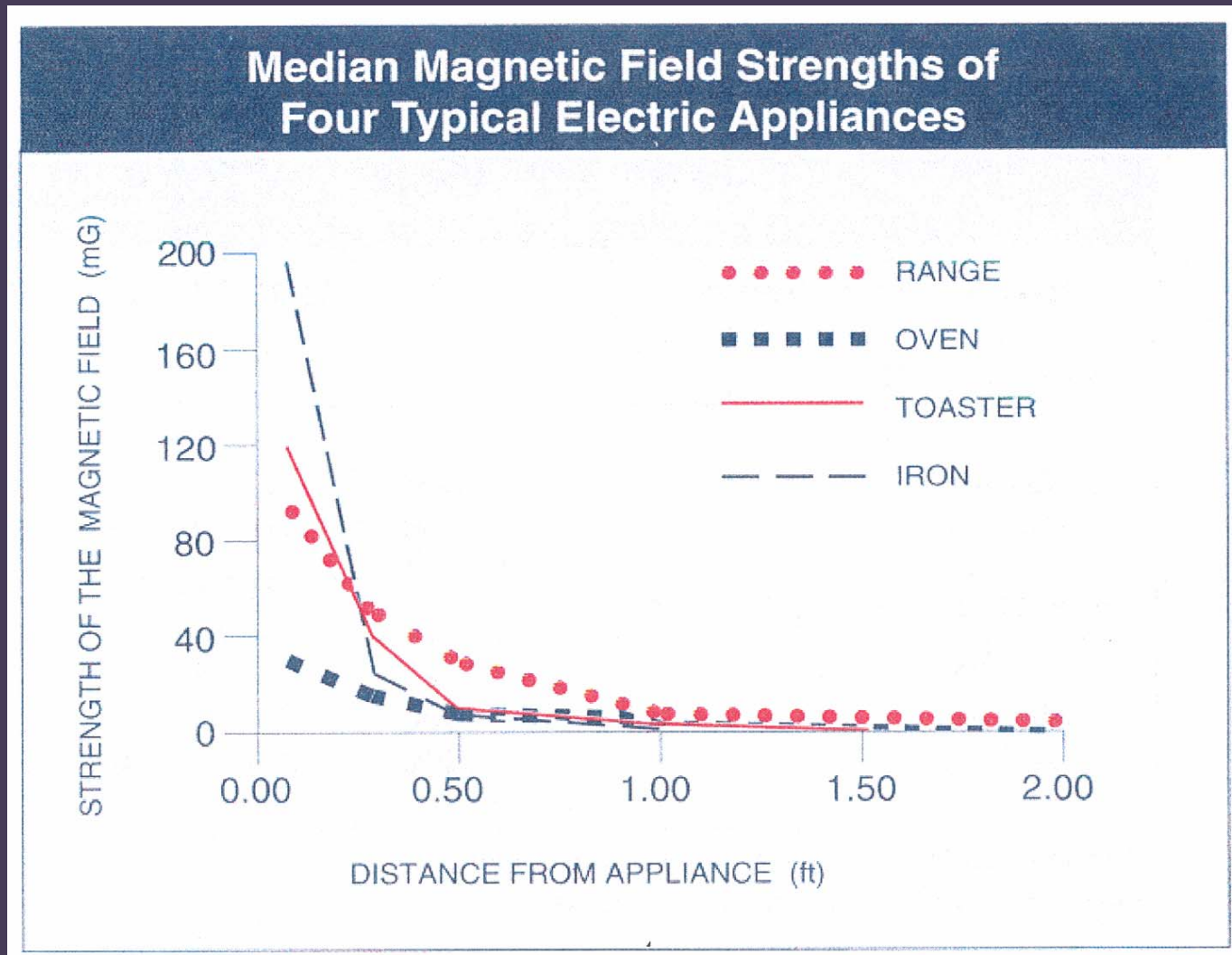
Measurement Issues

- **Determine distance from source**
- **Consider time-related variation**
- **Identify relevant metric(s)**
- **Characterize all sources of exposure**
- **Combine exposures from different sources into a single metric if possible**
- **Assess reproducibility & validity of measurement over time**

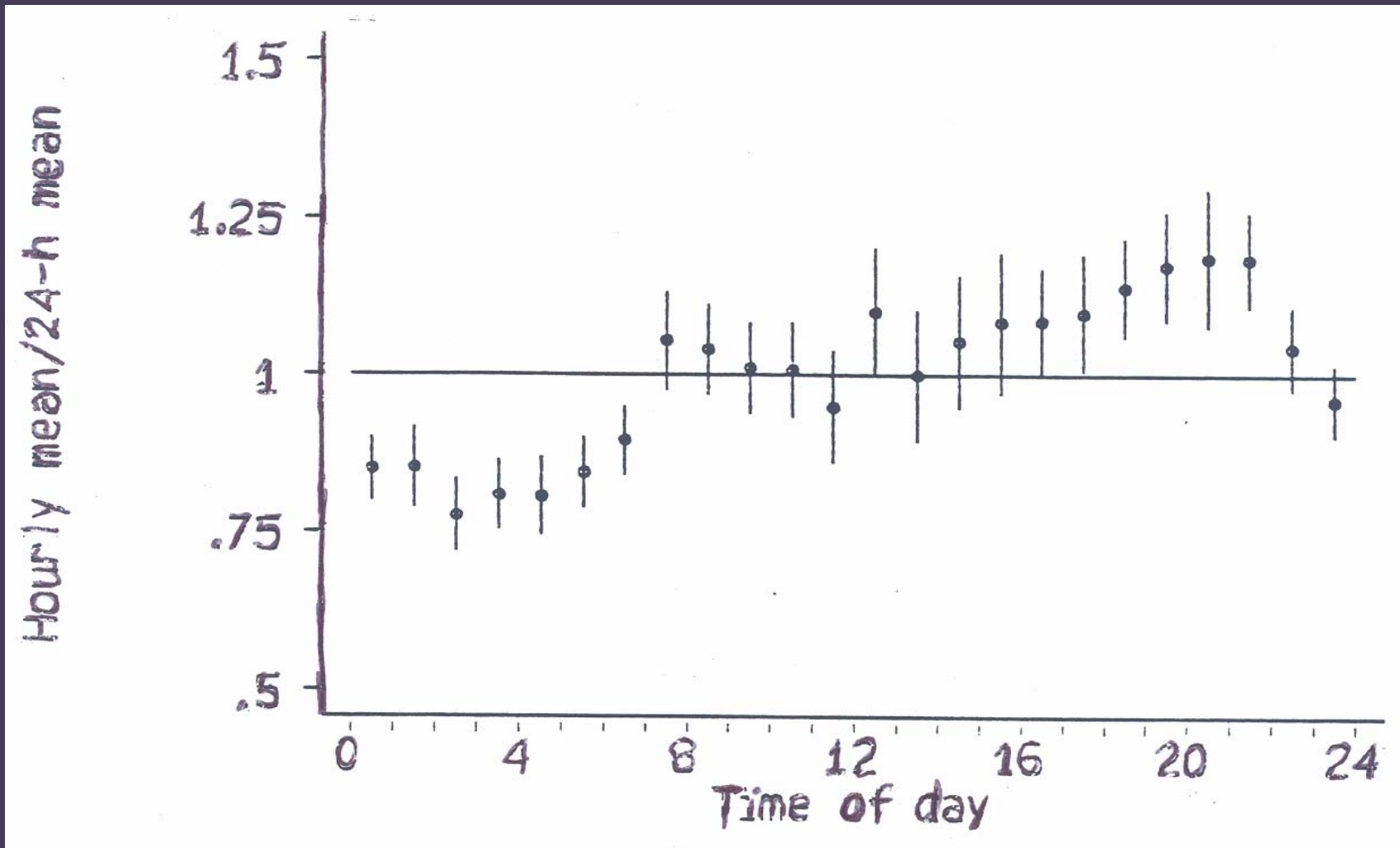
↑ Distance from Source → ↓ MF Levels



Dramatic MF Decline at Short Distances



Diurnal Pattern in MF over 24 Hours



Important Methodologic Issues

- Retrospective nature of exposure assessment (case-control studies)
- Selection bias
- Confounding
- Measurement error
- Reporting bias
- Small increases or decreases in risk

**EPIDEMIOLOGICAL STUDIES
OF EXTREMELY
LOW-FREQUENCY (ELF)
MAGNETIC FIELD EXPOSURES**

Childhood Cancer Residential Studies: Historical Summary

- 1979 - Wertheimer-Leeper
- 17 subsequent studies
 - 9 several types of cancer
 - 7 leukemia only
 - 2 brain only
- Study size increased over time
- Exposure assessment improved
- Variation, but overlap in measurements

Childhood Cancer Residential Studies: Guide to Understanding Results - 1

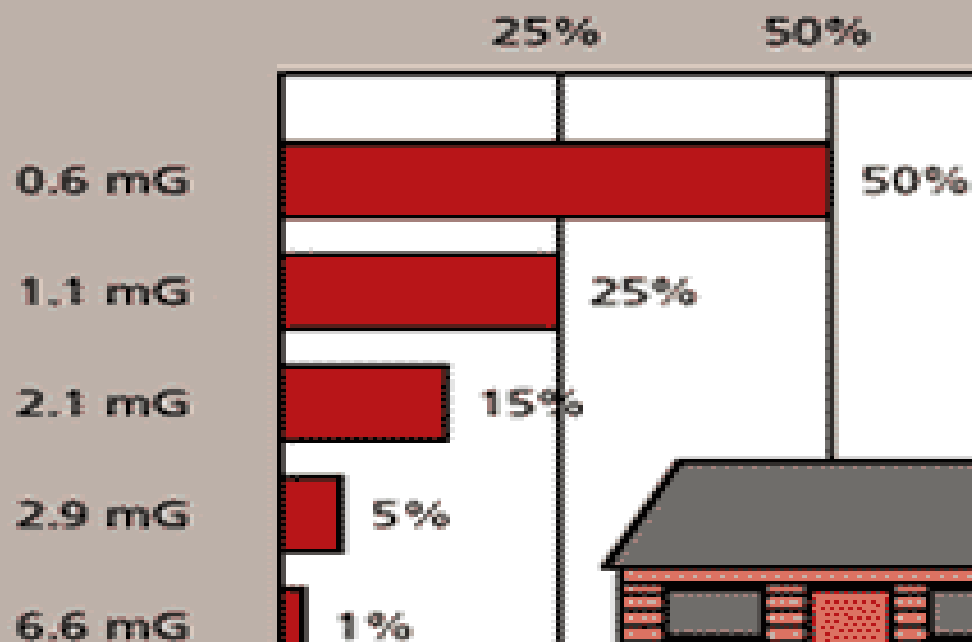
- **Residential measurements**
 - **direct measures**
 - “spot” (30-second) measurements
 - 24-hr measurements
 - **proxy measures**
 - wire codes (power line distance, thickness, configuration)
 - historical estimated exposures (transmission line distance & load)
 - distance of residence from transmission lines
- **Personal monitoring**

Childhood Cancer Residential Studies: Guide to Understanding Results - 2

Magnetic Field Measured in 992 Homes

**All-room mean
magnetic fields**

**% of homes that exceeded
magnetic fields on the left**



Source: Zaffanella, 1993

Childhood Cancer Residential Studies: Guide to Understanding Results - 3

- **Direct residential measurements and historical estimated magnetic field levels**
 - reported in milligauss (mG) or microtesla (μT):
1 mG = 0.1 μT
 - most studies use categorical measures
 - residential magnetic field levels generally higher in North America than Europe
 - within North America, field levels increase with increasing latitude

Childhood Cancer Residential Studies: Results - 1

- By type of cancer
- Early Studies (1979,1988)
 - 2 Denver (N cases = 30-155)
 - ↑ leukemia, brain, lymphoma (RR = 1.9 - 3.3)
- More Recent Studies (1996-2006)
 - 16 North America, Europe, Australia, Japan (N cases = 115 - 2,226)
 - ↑ leukemia only; found in some (not all) studies (N cases = 115-1,094; RR = 1.0 – 6.2)

Childhood Cancer Residential Studies: Results - 2

- **By type of measurement**
 - **Early studies (Denver): wire codes (1979, 1988) or spot measurements (1988)**
 - **Scandinavian studies (1993-97): historical estimated levels from registry data**
 - **North American, German, UK, Australian, Japanese: direct measurements**

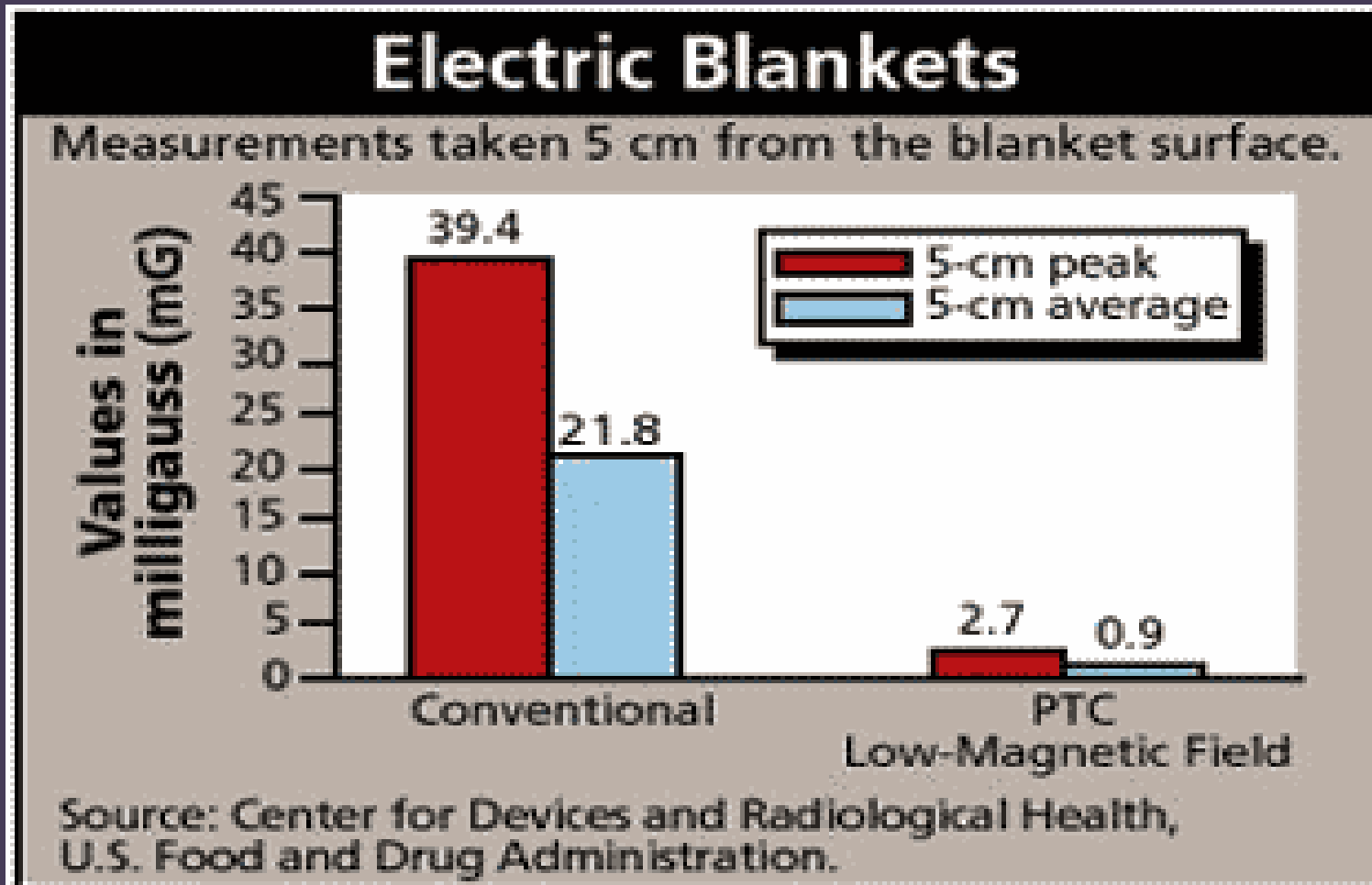
Childhood Cancer Residential Studies: Results - 3

- **By threshold level**
 - focus on wire code level in earlier studies
 - focus shifted from $>0.2 \mu\text{T}$ to $>0.3 \mu\text{T}$ and finally $>0.4 \mu\text{T}$ in later studies
- **By metric or time of day**
 - most studies: time-weighted average
 - German study: median and night-time risks
 - NCI study: explored alternative metrics (but central tendency showed highest risks)

Childhood Cancer Appliance Studies: Results

- **5 studies: all interviewed mothers to assess prenatal and postnatal exposure information**
 - **leukemia (4 studies)**
 - ↑ risks: use of prenatal (2 studies) & postnatal (3) electric blankets, hair dryers (2), TV watching (2)
 - no consistent dose-response
 - TV linked with duration, not distance
 - MF measured levels at typical distances not greater than ambient MF levels
 - **brain (3 studies)**
 - little consistency among results

MF Levels: Old Vs. New Electrical Blankets



Adult Cancer Residential Studies: Results

- 4 leukemia studies
 - all studied exposures from transmission lines
 - no association for 3, small ↑ risk for 1
- 4 brain tumor studies
 - all studied exposures from transmission lines
 - none showed evidence of an association
- 9 breast cancer studies
 - direct measurements (3), wire codes (4), and distance from transmission lines (5)
 - no association for 8; small ↑ for 1 (subgroups)

Adult Occupational Studies: Results - 1

■ Leukemia studies

- **job title** meta-analysis: RR = 1.2 all leukemia, RR = 1.4 CLL workers in electrical occupations
- **job measurements**: ↑ risks in 5/10, RR = 1.5 – 2.5, ↑ AML in 2, ↑ CLL in 2

■ Brain tumor studies

- **job title** meta-analysis: RR = 1.2 total brain, RR = 1.4 gliomas for workers in electrical occupations, RR = 1.7 in electrical engineers
- **job measurements**: ↑ risks in 5/10, RR = 1.3 – 3.1, little evaluation of brain tumor subtypes

Adult Occupational Studies: Results - 2

- Male breast cancer

- 5 case-control studies: 2 significantly ↑ risks (OR = 1.8, 2.2)
- 14 cohort studies: some limited in power, 2 significantly ↑ risks (RR = 2.1, 4.9)

- Female breast cancer

- 6 case-control studies: 2 significantly ↑ risks (PMA=1.38; OR=1.14 whites, OR=1.34 blacks)
- 10 cohort studies: 1 significantly ↑ risks (RR = 1.14)

Occupational Studies: Cancer in Offspring

- Childhood cancer in relation to parental occupational exposure
 - **case-control studies**: a few reported ↑ risk of specific childhood cancers and parental employment in 'electrical' occupations; methods and findings not consistent
 - **cohort studies**: most studies of adverse effects in offspring have evaluated physiotherapists, but most studies are too small to assess cancer risk

Outcomes Other than Cancer

- Limited data on outcomes other than cancer, results not clear or consistent
 - neurodegenerative diseases
 - amyotrophic lateral sclerosis
 - Alzheimer's disease
 - suicide and depression
 - reproductive disorders
 - spontaneous abortion
 - low birth weight
 - congenital malformations
 - cardiac effects
 - heart rate
 - cardiovascular disease mortality

Experimental Data

- **Experimental evidence**
 - **Voluminous literature, no replication of positive studies (Portier and Wolfe (eds) NIH Publ No. 98-3981, Research Triangle Park, NC, NIEHS, 1998**
 - **Large, well-controlled studies all negative (Boorman GA et al. 1997, 1999, 2000a, b; McCormick et al. 1999)**

EPIDEMIOLOGICAL STUDIES OF RADIOFREQUENCY (RF) AND MICROWAVE EXPOSURES

Adverse Effects of RF Exposures Data

- **Known:**

- whole or partial body heating

- **Suspected:**

- cancer

- brain & CNS tumors linked with cell phones
- childhood leukemia associated with radio/TV transmitters and base stations
- brain tumors, leukemia & other cancers associated with radar

- cardiovascular disease
- adverse reproductive outcomes
- cataracts

Cell Phones & Adult Brain Tumors

- 1984 – cell phones introduced: analog (800 MHz), digital (900 MHz), & improved digital (1800 GHz)
- 1993-96 – 4 case-control studies initiated
- 1998 – IARC multi-country case-control study
- 1999 – Swedish study: ipsilateral cell phone use
↑ temporal/occipital brain tumors
- 2001 – 3 other studies reported no association

Cell Phones & Brain and Other Cancers

- 2003 – present: results reported by individual studies included in IARC coordinated effort
- 2006 – case-control study of cell phones and non-Hodgkin lymphoma: little evidence of ↑ risk
- 2007-2008: IARC meta-analysis/pooled analysis results to appear
- 2008: IARC monograph on RF exposures to be published

Other RF Exposures and Cancer Risk

- Occupational studies: results inconsistent, the few excesses linked with exposures other than RF, and/or methodological shortcomings
 - aircraft industry (Barron and Baraff, 1958)
 - U.S. Moscow embassy employees (Lilienfeld et al, 1978)
 - U.S. Navy (Robinette et al, 1980)
 - Polish military (Szmigielski et al, 1988, 1996)
 - Amateur radio operators (Milham, 1988)
 - Canadian/French utility workers (Armstrong et al 1994)
 - U.S. Air Force (Grayson, 1996)
 - Motorola workers (Morgan et al 2000)

Other RF Exposures and Outcomes Other than Cancer

- **Reproductive outcomes: results inconsistent and/or methodological shortcomings**
 - inconsistent findings among female plastic welders and physiotherapists using diathermy equipment
 - no excess of Down syndrome among offspring of male radar workers

Other RF Exposures and Experimental Data

- **Experimental evidence**
 - many studies show thermal effects (temperature rising 1-2°C), other physiological effects, and occasional damage to eye or testis
 - RF/microwave exposures below threshold for thermal effects: studies generally demonstrate little evidence of increased cancer risks

Summary ELF and RF Exposures - 1

- **Extremely low-frequency exposures**
 - **power lines & childhood leukemia**: no association below 0.4 μT , risk \uparrow 2-fold at $\geq 0.4 \mu\text{T}$; no experimental support
 - **power lines & other childhood or adult cancers**: no evidence of associations
 - **electrical appliances and cancer risk**: little evidence supporting associations with childhood or adult cancers
 - **occupational exposures**: some evidence for modest increases of leukemia & brain tumors in electrical workers
 - **experimental studies**: no evidence of cancer risks

Summary ELF and RF Exposures - 2

- **Radio-frequency exposures**
 - **cell phones and adult malignant and benign brain & CNS tumors: little evidence of elevated risks**
 - **cell phones and other cancers: 1 study showed little evidence of link for non-Hodgkin lymphoma**
 - **base stations & wireless networks: little evidence of elevated risk of childhood leukemia from the limited data**
 - **occupational studies: little evidence of increased cancer risks**
 - **experimental studies: limited evidence of carcinogenicity**

References

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Ahlbom A, Green A, Kheifets L, Savitz D, Swerdlow A. ICNIRP. Epidemiology of health effects of radiofrequency exposures. Environ Health Perspect 2004;112:1741-54.

Valberg PA, van Deventer TE, Repacholi MH. Workgroup report: Base stations and wireless networks – radiofrequency (RF) exposures and health consequences. Environ Health Perspect 2007;115:416-24.