

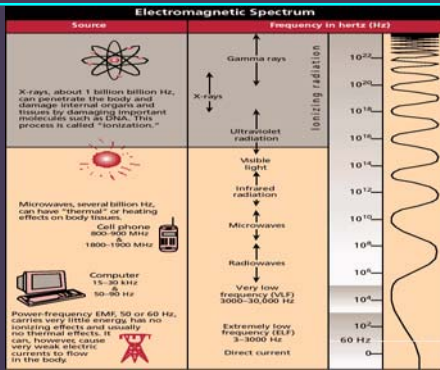
## Extremely Low-Frequency, Radiofrequency, & Related Exposures and Cancer Risks

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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

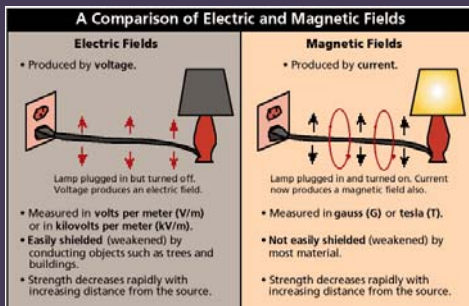
### Electromagnetic Spectrum



### 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

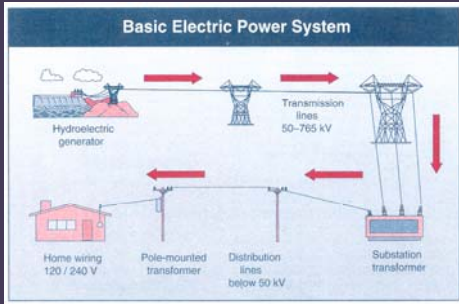
### Electric vs. Magnetic Fields



### 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



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## Measurements and Methods

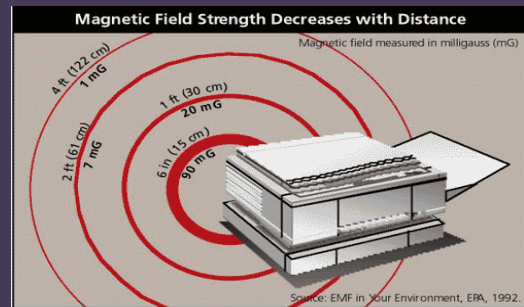
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### Measurement Issues

- 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

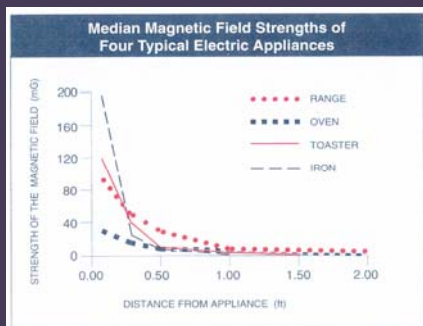
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### ↑ Distance from Source → ↓ MF Levels



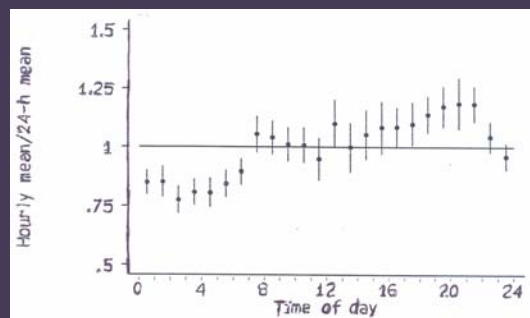
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### Dramatic MF Decline at Short Distances



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### Diurnal Pattern in MF over 24 Hours



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### Important Methodologic Issues

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

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

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### 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

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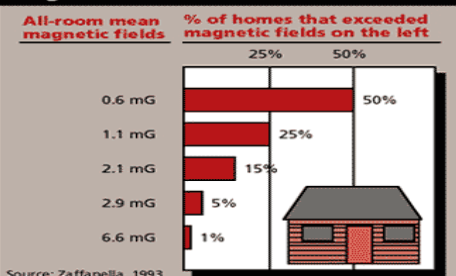
### Childhood Cancer Residential Studies: Guide to Understanding Results - 1

- 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

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### Childhood Cancer Residential Studies: Guide to Understanding Results - 2

**Magnetic Field Measured in 992 Homes**



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### Childhood Cancer Residential Studies: Guide to Understanding Results - 3

- Direct residential measurements and historical estimated magnetic field levels
  - reported in milligauss (mG) or microtesla ( $\mu$ T):  
1 mG = 0.1  $\mu$ T
  - 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

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### 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)

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### 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

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### Childhood Cancer Residential Studies: Results - 3

- By threshold level
  - focus on wire code level in earlier studies
  - focus shifted from >0.2  $\mu$ T to >0.3  $\mu$ T and finally >0.4  $\mu$ 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)

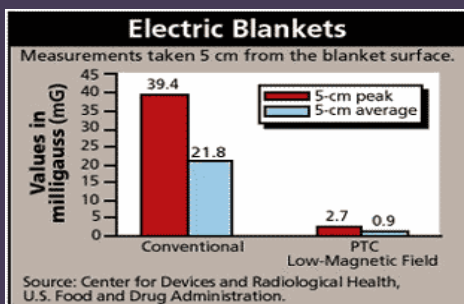
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### Childhood Cancer Appliance Studies: Results

- 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

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### MF Levels: Old Vs. New Electrical Blankets



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### 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)

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## 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

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## 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)

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## 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

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## 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

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## 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)

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## EPIDEMIOLOGICAL STUDIES OF RADIOFREQUENCY (RF) AND MICROWAVE EXPOSURES

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## 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

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## 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

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## 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

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## 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)

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## 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

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## 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

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## Summary ELF and RF Exposures - 1

- **Extremely low-frequency exposures**
  - **power lines & childhood leukemia:** no association below 0.4  $\mu$ T, risk  $\uparrow$  2-fold at  $\geq$  0.4  $\mu$ 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

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## 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

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## 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.

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