

# RADIOFREQUENCY ELECTROMAGNETIC FIELDS

Vikram Krishnasamy  
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# Outline

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- Electromagnetic Fields, a Review
- Health Impacts of Radiofrequency EMF
  - ▣ Cellular
  - ▣ Animal
  - ▣ Human
- Conclusions
- Recommendations

# Questions

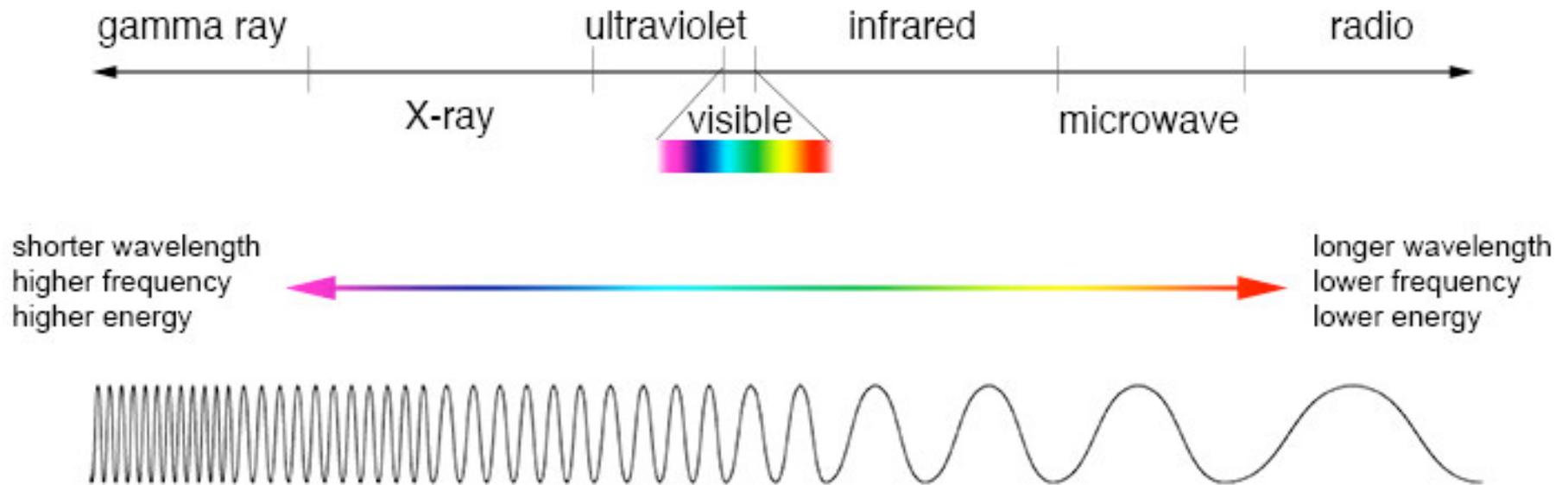
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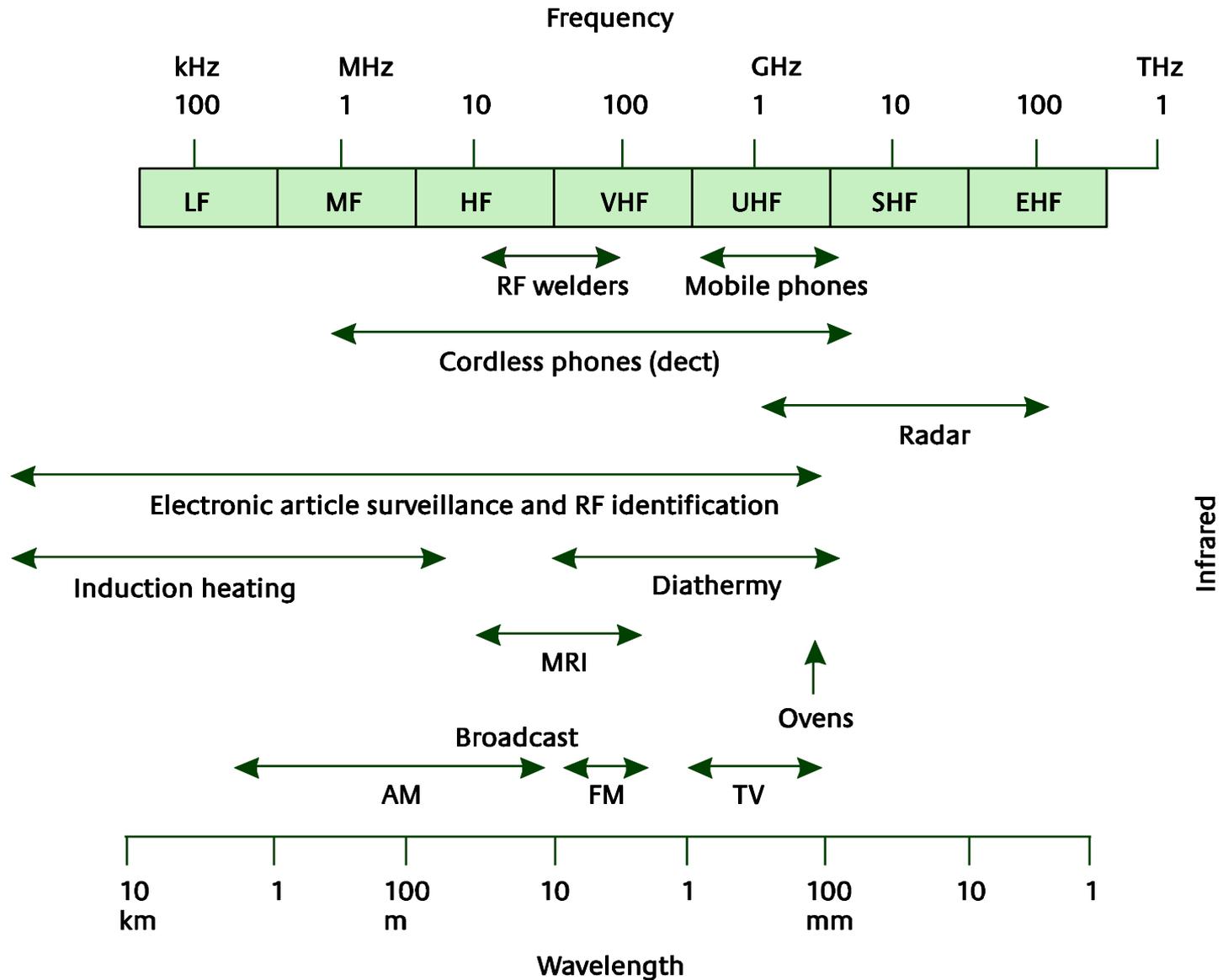
1. What are the health impacts of RF EMF
2. Are there health impacts of Wi-Fi exposures?

# What is Radiofrequency Electromagnetic Radiation?



# Spectrum





# Radiofrequency Fields

- Radiofrequency refers to the parts of the EM spectrum used for radio communications purposes and that are below the infrared region
- These frequencies are in the range of 100kHz to 300GHz
  - ▣ Definitions vary
- The FCC and the International Telecommunications Union have dedicated specific bands within this range for specific purposes
  - ▣ Certain frequencies are reserved for cell phones
  - ▣ Certain frequencies are left for Wi-Fi

# Sources of RF Fields

- Exposed to RF fields from many sources:
  - ▣ Radio and TV transmitters
  - ▣ Telecommunications links, satellite communications
  - ▣ Mobile phones and base stations
  - ▣ Wireless applications like Wi-Fi, cordless telephones
  - ▣ Occupational exposures
- People are exposed continuously to RF field sources

# Exposures – Waveform Properties

- Important to look at signal characteristics when examining human exposure
- Original waveforms from source are sinusoidal
- Signal fading
- Source dependent considerations
  - ▣ Properties of EM fields change with distance

# Measuring RF Field Sources

- There is no single method to measure the electric and magnetic field strengths of an RF source
  - ▣ Characteristics of sources vary greatly
  - ▣ The magnitude of electric/magnetic fields vary throughout space and time
  - ▣ Other factors involved
  - ▣ Approaches also differ whether in the near field or the far field region
  - ▣ However, there are standard protocols for measuring EM field strength

# RF Field Measurement Instruments

- 2 types of instruments for measuring: broadband and narrowband
- Recently, personal exposure meters for measuring the strengths of environmental RF signals have become available
  - ▣ However these can be altered by the presence of field strengths of the body

# RF Dosimetry

- RF sources give rise to electric and magnetic fields
  - ▣ Fields can induce currents or raise temperature inside the body
- Assess both the physical quantities of the fields (electric, magnetic) and dosimetric quantities (induced current density or rise in temperature)
- Physical quantities can be measured directly while dosimetric quantities are generally measured indirectly

# RF Dosimetry

- Dosimetry – Process of determining internal quantities relating to exposure in tissues, such as electric field strength, induced current density and energy absorption rate, from external fields
- The role of dosimetry is to evaluate the induced electric fields in the body
  - ▣ Using SAR
  - ▣ Correlate with the biologic effect of concern

# RF Fields and the Body

- When the body is exposed to radio waves, some of the energy is absorbed
  - ▣ This is a direct effect that leads to heating of the body tissues
  - ▣ This heating is governed by a quantity known as the specific energy absorption rate (SAR), units of  $W/kg$
  - ▣ SAR is derived from electric field strength, the conductivity, and the density of tissues
  - ▣ SAR provides a measure of the power absorbed from the radiation per kilogram body tissue

# Dosimetric Assessment of SAR

- SAR is averaged either over the whole body or over a small sample volume or mass of tissue
- Usually averaged over 1 or 10g
- Experimental evaluation of SAR
  - ▣ Difficult to measure the internal induced electric field strength inside human body non-invasively
  - ▣ Phantoms are used to replicate human head or body
  - ▣ Experimental exposure systems
  - ▣ Numerical techniques using computer models

# Age Dependence in Dosimetry Studies

- Rise in the use of telecommunications devices amongst the young has led to calls for research into the difference in the exposure of children and adults
- 2 key factors are different
  - ▣ physical size of the body
  - ▣ properties of tissues as a function of age
- Head exposure
- Whole-body SAR

# Quantities and Units

- Quantity of EM energy per unit area per second is call the Power Density
- Often expressed as  $W/m^2$
- Power density decreases with increasing distance from source
  - ▣ Follows inverse square law
  - ▣ Rapid decrease in power as you move away from source
- Other measures include Electric Field Strength (V/m) and Magnetic Field Strength (A/m)

# Factors Affecting Human Exposure

- Power density – depends on output power
- Distance from source
- Tissue type – reflection, absorption, transmission
  - ▣ SARs different in different parts of the body
- Frequency
- Volume and duration of exposure

# Guidelines for Exposures

- 2 main international organizations set guidelines for exposures
- ICNIRP and the IEEE
- Reference Levels
- Basic Restrictions

# Dosimetric Considerations in Studies

- Epidemiological studies – challenges to assessing exposure of individuals in these studies
  - ▣ Use questionnaire information or billing records to derive estimates of the time and duration of use as the main exposure surrogate
- Experimental studies
  - ▣ Need to use a well-characterized exposure system to determine SARs
  - ▣ A need to use cage controls as well as sham-exposed animals

# Health Effects

- The widespread adoption of mobile phone technologies and wireless internet has caused concern regarding health consequences
- However, this is not new
  - ▣ There has been concern about possible effects since the mid-20<sup>th</sup> century and likely earlier

# Health Effects

- There have been numerous national and international reviews regarding this issue
- The majority have said that the weight of the evidence does not show that there are adverse effects from exposures below current guidelines (ICNIRP)
- However, all say that further and better research is needed

# Mechanisms for Effects

- Thermal mechanisms seem to be the dominant cause of adverse effects over the RF spectral range
- There may be other mechanisms but the evidence has not borne this out
  - ▣ Some authors have described other effects but the mechanisms have not been elucidated

# Cellular Studies

- ▣ Advantages of using in vitro systems over experimental animal or human studies
- ▣ Disadvantages
  - ▣ Many of the published studies can be criticized for poor dosimetry and inadequate experimental controls
  - ▣ Positive findings should be considered preliminary until verified by repeat studies

# Cellular Studies – Genotoxic Effects

- The evidence that exposure to RF fields has a direct genotoxic effect is weak
- The weight of the evidence is not consistent
- Multiple studies have conflicting results

# Cellular Studies – Potential Carcinogenesis

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- Cell transformation
- Cell proliferation
- Apoptosis

# Cellular Studies – Other Changes in Cellular Processes

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- Gene expression
- Intracellular signaling
- Membrane effects
- Direct effect on proteins

# Cellular Studies – Summary

- Results of similar studies remain divergent
- Lack of replication of studies
  - ▣ When replication does occur, study results differ
- No consistent pattern of exposure conditions on cells that consistently show effects

# Animal Studies

- ▣ Performed using inbred strains of mice or rats
- ▣ Advantages of in vivo
- ▣ Allow for multigenerational studies
- ▣ Extrapolation to humans is not straightforward
- ▣ Study design is again important

# Animal Studies – Brain and Nervous System

- Considered sensitive targets for the effects of RF fields
- Cellular physiology, neurotransmitters, electrical activity
- Blood-brain barrier
- Autonomic Functions
- Behavior Studies

# Animal Studies – Endocrine System

- Previous studies have shown consistent changes in endocrine function due to thermal impacts (above guideline levels)
- Recent research has focused on mobile phone signal and melatonin
- Weight of evidence is against changes in melatonin levels
- Not enough information on other hormones

# Animal Studies – Auditory System

- Concerns have been raised as to whether these exposures could have an adverse effect
- Weight of the evidence is against adverse effects on hearing and auditory function in animals
- Studies have looked at both young and adult animals

# Animal Studies – Cancer

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- Weight of the studies are against genotoxicity in animal models
- Evidence argues against increased cancer risk
- Evidence against increased risk in tumor prone animals

# Animal Studies – Heme / Immune Systems

- Various frequencies tested
- Different cell lines
- Some studies show positive effects
- Some studies show no effects
- More research is needed

# Animal Studies – Reproduction and Development

- Testicular function
  - ▣ Mixed studies. Well done studies show no effect
- Pregnancy outcome and development
  - ▣ No consistent adverse effects
  - ▣ More research is needed

# Human Studies



- Gold standard of evidence are randomized controlled trials
- For many reasons, RCTs are unlikely
- Rely mainly on case-control and cohort studies

# Human Studies – Neurocognitive Effects

- Provocation studies
  - Method for investigating the possible effects of RF field exposure on cognitive performance and nervous system function
  - Do not reveal mechanisms
- Cognitive and performance studies
  - Studies in children
  - Mobile phone base station signals
- EEG studies
  - Resting EEG studies
  - Sleep EEG studies

# Human Studies – Neurocognitive Effects

- Auditory and Vestibular Studies
  - Few studies
  - Evidence tends towards no acute or chronic effects though some studies have shown positive results
  
- Developmental Effects
  - Few studies
  - Unable to draw robust conclusions
  - More research is needed

# Human Studies – Reproduction

- Male sexual function and fertility
  - Limited studies
  - Cross-sectional
  - Some show decreases in sperm quality measures
  - Others show no changes
  - Recall bias is an issue
  - Need further studies with better exposure assessments
- Female sexual function and fertility
  - Limited studies
  - No conclusions can be drawn

# Human Studies – Cancer

- Occupational Exposures
  - ▣ Mixed evidence of increased risk
  - ▣ Problems with many of the studies
- Residence near RF transmitters
  - ▣ Weight of the evidence against increased risk of cancer among children exposed to RF fields from radio/television/mobile phone base stations
  - ▣ Limitations in studies however

# Mobile Phones



- Extremely controversial
- We will not get into this here because of the complexities

# Mobile Phone Base Stations

- Networks are divided into areas called cells
  - ▣ Each cell has a base station
- Main coverage for each cell is provided by macrocell base stations covering distances of 1-10 km
- Antennas are usually mounted on tall structures to avoid obstructions (buildings)
- The height of these structures limits exposures

# Mobile Phone Base Stations

- Exclusions zones are specified
  - ▣ Due to high output powers around these zones
- Multiple studies have been done to assess potential exposure level
  - ▣ Show power density levels are well below threshold values set by guidelines

# Wireless Local Area Networks

- WLAN technologies operate in frequency bands of around 2.4 and 5 GHz
- License exempt and the bandwidth is shared between multiple users
- Technical standards are produced by the Institute of Electrical and Electronic Engineers (IEEE).
- Wi-Fi is the most popular technology for the wireless portion of networks

# Exposures to Wi-Fi

- Multiple studies have been done assessing Wi-Fi exposures
- Levels are well below guidelines
- Given low duty cycles, exposures are lower
- Much lower than mobile phone exposures

# Studies on Health Effects of Wi-Fi

- Overall many studies have been done in this frequency range
- The use of Wi-Fi as the exposure source is more limited as this is a more recent technology
- There are too few studies of Wi-Fi directly to draw robust conclusions on health effects

# Studies on Health Effects of Wi-Fi

- In vivo studies in rats generally do not show shown adverse effects
- Some show changes in EEG but the implications of this remain unclear and there were flaws in these studies
- Some in vitro studies show changes in sperm quality

# Recommendations

- Controversial issue
- Committee should monitor future studies which are currently ongoing and will provide more information
- Committee should invite experts from this area to present to the council

# Precautionary Principle

- Interpretations of the precautionary principle vary
- The goal of this commission is to provide scientific advice
- The precautionary principle is a policy mechanism best left to entities with legislative authority

# Glossary

- EMF – Electromagnetic Fields
- FCC – Federal Communications Commission
- SAR – Specific Absorption Rate
- ICNIRP – International Commission on Non-ionizing Radiation Protection
- IEEE – Institute of Electrical and Electronics Engineers
- RF – Radiofrequency
- WLAN – Wireless Local Area Network

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\* There are numerous references; I have not included them all for the sake of space.