RADIOFREQUENCY ELECTROMAGNETIC FIELDS

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Outline

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

1. What are the health impacts of RF EMF

2. Are there health impacts of Wi-Fi exposures?
What is Radiofrequency Electromagnetic Radiation?
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 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
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
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 called 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-20th 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

- Cell transformation
- Cell proliferation
- Apoptosis
Cellular Studies – Other Changes in Cellular Processes

- 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

- 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
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 affects 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
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
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


References

- Martin Gledhill. Exposures to Radiofrequency Fields from WiFi in New Zealand Schools. EMF Services and the New Zealand Ministry of Health; 2014.
References


References


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