

Lecture 28: Radiation Hazards and SAR (Part 1: Fundamentals)

Mobile Device

DI05011011: Mobile Communication

Agenda for Today

- 1. Introduction to Electromagnetic Radiation
- 2. The Electromagnetic Spectrum
- 3. Ionizing vs. Non-Ionizing Radiation
- 4. Mobile Phones and RF Radiation
- 5. How RF Waves Interact with the Human Body
- 6. Thermal Effects of RF Radiation
- 7. Non-Thermal Effects (Ongoing Debate)
- 8. What is SAR? (Specific Absorption Rate)
- 9. SAR Definition and Formula
- 10. Understanding SAR Values
- 11. Tissue Types and SAR Absorption
- 12. Factors Influencing Radiation Exposure
- 13. Summary
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Introduction to Electromagnetic Radiation

- **Electromagnetic (EM) Radiation** is energy that travels through space at the speed of light in the form of waves.
- It consists of oscillating electric and magnetic fields.
- Characterized by:
 - - **Wavelength:** Distance between consecutive peaks.
 - - **Frequency (Hz):** Number of cycles per second.
 - - **Energy:** Higher frequency = Higher energy.
- Mobile communication relies entirely on transmitting and receiving EM radiation.

The Electromagnetic Spectrum

- The EM spectrum spans from very low frequencies to extremely high frequencies.
- 1. Radio Waves (AM/FM, Mobile Phones)
- 2. Microwaves (Wi-Fi, Radar, Ovens)
- 3. Infrared (Heat)
- 4. Visible Light
- 5. Ultraviolet (UV)
- 6. X-Rays
- 7. Gamma Rays
- Mobile phones operate in the Radio Frequency (RF) and Microwave spectrum (approx. 700 MHz to 39 GHz).

Ionizing vs. Non-Ionizing Radiation

- This is the most critical distinction in radiation safety.
- **Ionizing Radiation (Harmful):**
 - - High energy (UV, X-Rays, Gamma Rays).
 - - Has enough energy to tightly strip electrons from atoms, breaking chemical bonds and damaging DNA directly. Causes cancer.
- **Non-Ionizing Radiation (Safe/Heating):**
 - - Low energy (Radio, Microwave, Infrared, Visible).
 - - Does NOT have enough energy to break molecular bonds or damage DNA.
 - - Primary effect is excitation/heating of molecules.

Mobile Phones and RF Radiation

- Mobile phones are low-power, two-way radio transceivers.
- They contain transmitters that emit RF energy (radiation) via their antennas.
- Because the phone is held close to the head or body, a portion of this RF energy is absorbed by human tissues.
- The amount of power emitted varies dynamically based on distance to the cell tower and data transmission rates.

How RF Waves Interact with the Human Body

- When RF waves penetrate the human body, they interact with tissues, which are largely composed of water.
- Water molecules are polar. The oscillating EM field causes these molecules to vibrate and rotate rapidly.
- This rapid vibration creates friction at the molecular level.
- Friction produces heat. This is the exact same principle used in a microwave oven, but at a vastly smaller power scale.

Thermal Effects of RF Radiation

- The only universally scientifically proven biological effect of RF radiation is **heating (thermal effect)**.
- The human body's thermoregulatory system (blood flow, sweating) can easily dissipate small amounts of localized heat.
- However, excessive RF power could potentially cause tissue damage (e.g., in the eyes, which have poor blood flow).
- Regulatory limits are established well below the threshold where harmful heating occurs.

Non-Thermal Effects (The Debate)

- Some studies suggest that RF radiation might cause biological effects without raising temperature (Non-thermal effects).
- Proposed non-thermal effects include:
 - - Blood-brain barrier permeability changes.
 - - Altered sleep patterns or EEG activity.
 - - Cellular stress responses.
- **Consensus:** The WHO and major health organizations maintain that there is currently no conclusive evidence that low-level, non-thermal RF exposure causes adverse health effects.

What is SAR? (Specific Absorption Rate)

- Because we know RF causes heating, we need a way to measure how much RF energy the body absorbs.
- **Specific Absorption Rate (SAR)** is the measure of the rate at which energy is absorbed by the human body when exposed to a radio frequency (RF) electromagnetic field.
- It provides a standardized metric to evaluate the safety of mobile devices.
- Lower SAR means less energy is absorbed.

SAR Definition and Formula

- SAR is defined as the power absorbed per mass of tissue.
- **Formula:** $SAR = \sigma E^2 / \rho$
- Where:
 - - σ (**sigma**): Electrical conductivity of the tissue (S/m)
 - - **E**: RMS electric field strength (V/m) inside the tissue
 - - ρ (**rho**): Mass density of the tissue (kg/m³)
- **Unit of Measurement:** Watts per kilogram (W/kg).

Understanding SAR Values

- A SAR value represents the maximum exposure condition.
- Phones are tested at their highest possible power level, in various positions against the head and body.
- The SAR value reported for a phone is the highest single value found during all these tests.
- In normal daily use, a phone operates at a fraction of its maximum SAR value.

Tissue Types and SAR Absorption

- SAR is not uniform across the body. Different tissues absorb RF differently.
- Tissues with high water and ion content (like muscle, brain) have higher conductivity and absorb more RF.
- Tissues with low water content (like bone, fat) absorb less RF.
- Frequencies also matter: Lower frequencies penetrate deeper into the body, while higher frequencies (like 5G mmWave) are absorbed mostly by the skin.

Factors Influencing Radiation Exposure

- Even with a phone of a specific SAR rating, your actual exposure depends on:
 - 1. **Distance from Cell Tower:** Poor signal forces the phone to transmit at max power.
 - 2. **Distance from Body:** Using a speakerphone reduces exposure exponentially (Inverse Square Law).
 - 3. **Call Duration:** Longer calls = longer exposure.
 - 4. **Data Transmission vs Voice:** Downloading files uses more continuous power than listening during a call.

- Mobile phones emit non-ionizing RF radiation, which cannot break DNA but can cause localized tissue heating.
- The thermal effect is the only proven biological impact of RF radiation.
- SAR (Specific Absorption Rate) measures how much RF energy the body absorbs.
- SAR is measured in W/kg and represents a worst-case scenario at maximum power.
- Actual exposure depends heavily on usage habits and network conditions.

- In Part 2 of Radiation Hazards and SAR, we will cover:
- **1. SAR Measurement:** How is SAR practically measured in labs using phantoms?
- **2. Regulatory Standards:** ICNIRP and FCC limits.
- **3. Mobile Design:** How engineers design antennas to minimize SAR.