RF Safety Research: from Radar to Cell Phone

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Outline

- RF safety research trend
- Ionizing vs Non-ionizing Radiation
- Biological complexity
- Engineering complexity
  - Measurement of field intensity
  - SAR measurement methods
  - Animal exposure systems
  - In Vitro exposure methods
- Current Research Activities
- Conclusions
RF Safety Research

- Radar: Whole body
- Broadcasting: Whole body
- Microwave Oven: Partial body
- Police Radar: Partial body
- Mobile Communication
  - Mobile phones: Partial body
  - Base stations: Whole body
SOURCE

QUANTITIES AND UNITS

E (Volts/meter) (V/m)
P (milliwatts/square centimeter) (mW/cm²)
H (amperes/meter) (A/m)

SPECIFIC ABSORPTION RATE (SAR) (W/kg)

\[ P = \frac{E^2}{1200\pi} \] or \[ P = 12\pi H^2 \]
NEED FOR SCALING

SOURCE IN ENVIRONMENT

SURVEY METER

BIOLOGICAL INSTRUMENT

FIELD STRENGTH METER

FILTER

TEMPERATURE SENSOR

LAB SOURCE

T R

T R

T R
Biological Complexity

• In vivo study
  – species
  – strain
  – sex
  – age
  – extrapolation from animal to humans

• In vitro study
  – monolayer
  – cell suspension
  – isolated tissue
  – Extrapolation to in vivo
Engineering complexity

- Far Field
- Near Field
- RF Dosimetry
- Resonance
- Modulation
  - CW, Pulsed
  - AM, FM, TDMA, CDMA
- Artifacts
- Temperature Control
NBS Energy Density Meter
Dielectric Properties of tissues

1. High water content tissues: muscle, skin, liver, spleen, kidney, brain

2. Low water content tissues: fat, bone, tooth, nail, hair
NCRP definition (1981)

Specific Absorption Rate

The time derivative of the incremental energy absorbed by an incremental mass contained in a volume element of a given density.
\[ \text{SAR} = \sigma \frac{E_t^2}{\rho} = f(x,y,z,t) \]

at a given infinitesimal region

\[ E_t = \text{electric field in tissue (V/m)} \]
\[ \sigma = \text{electrical conductivity (S/m)} \]
\[ \rho = \text{density of tissue (kg/m}^3) \]

\[ E = \left( \frac{\rho \text{ SAR}}{\sigma} \right)^{1/2} \text{ V/m} \]
\[ j = \left( \sigma \rho \text{ SAR} \right)^{1/2} \text{ A/m}^2 \]

Heating Rate = \( \frac{\text{SAR}}{69.77c} \) °C/min
SAR can be calculated by measuring:

1. Electric field
2. Temperature rise
Specific Absorption Rate

\[
\text{SAR} = 4186 \ c \ \Delta T / t \ (W/kg)
\]

\[
c = \text{specific heat (kcal/kg} \cdot \text{°C)}
\]

\[
\Delta T = \text{temperature rise (°C)}
\]

\[
t = \text{exposure time (sec)}
\]
Point SAR

1. E field probes
2. Non-perturbing temperature sensors
E-filed probe for cell phone SAR determination
Metallic Temperature Sensor Problems:

1. Interference
2. Intensification
3. Perturbation
Non-perturbing probes:

1. Liquid crystal
2. GaAs
3. Narda
4. Vitek-101
5. Luxtron
Vitek Probe
SAR near a UHF trunk-mount antenna

[Guy and Chou, 1986]
Use 4 Vitek probes to measure SAR in the human phantom
2 Dimensional SAR

1. Liquid crystal sheet
2. Thermography
3. MRI
Scaled man models
MAN BACK $h=1.58m$ $E^2=1V^2/m^2$ $sf=5.95$ $f=24.1MHz$

INTENSITY SCAN

C-C' $W=12.8\mu W/kg$

E-E' $W=8.49\mu W/kg$

D-D' $W=7.77\mu W/kg$

E''-E''' $W=4.25\mu W/kg$
MAN FRONT $h = 1.74 \, \text{m}$ $H^2 = 1 \, \text{A}^2/\text{m}^2$ $sf = 4.62$ $f = 31.0 \, \text{MHz}$

**INTENSITY SCAN**

- $F - F'$
  - $W = 2.22 \, \text{W/kg}$

- $G - G'$
  - $W = 1.51 \, \text{W/kg}$

- $H - H'$
  - $W = 1.56 \, \text{W/kg}$
THERMOGRAMS AND POWER ABSORPTION DENSITY PER WATT INPUT POWER IN SPHERICAL PHANTOM 60 CM FROM CENTER OF EXPOSURE CHAMBER. (DRINKING POSITION, LIMBS IN CONTACT) C SCANS, 1 DIV = 2 CM; B SCANS, 1 DIV = 2 CM HORIZONTAL, 1 DIV = 2.5°C VERTICAL; NET INPUT POWER / EXPOSURE PERIOD INDICATED UNDER EACH SCAN.
LOW THRESHOLD

APERTURE RADIATOR

C SCANS

MEDIUM THRESHOLD

B

A

SCANS

8.15 mW/cm³ PEAK PER mW/cm² INC. POWER

SECTION A-A

RAT EXPOSED TO 918 MHz RADIATION
0.8 kg MONKEY  h = 0.45 m  P_{inc} = 1 mW/cm^2
2450 MHz

A-A'
W = 3.29 W/kg

B-B'
W = 2.71 W/kg

C-C'
W = 2.87 W/kg

D-D'
W = 5.95 W/kg
Bird flying through a microwave beam from a solar power satellite
Averaged SAR

1. Calorimetry