MAJOR SCIENTIFIC TOPICS RELEVANT TO REVISION OF RF GUIDELINES

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The Process in Revising Human Exposure Guidelines For RF Fields

1. Review of **Existing Guidelines** and Standards
2. Review of Current **SCIENTIFIC PROGRESS**
3. Evaluation of **Biological Effects**
4. Identification of **Health Hazards**
5. Assessment of Relative **Risk & Uncertainties**
6. Examination of **Philosophy** of Protection
7. Consideration of **Implementation** in Practice
8. Adoption of **Basic Restrictions**
9. Determination of **Reference Levels** or Permissible Exposure Limits

Overarching Issue for Public Health…

Is There a Health Hazard?

- ***Yes***, with High Degree of Agreement:
  - Acute, High Field Induced **Dielectric Breakdown** (Sparking); High AbsorptionRates Produce Adverse **Thermal Injury** in Tissues
- ***Result*** -> Promulgation of Exposure Guidelines
- ***Challenge*** Today, Comes From:
  - Repeated, Long-Term, Low Level Exposures
  - Possible Delayed Health Effects at Low Levels

Current ICNIRP Whole-Body Guidelines: Scientific Basis and Considerations at High Frequencies

- Threshold for Behavioral Thermal Regulation or Work Schedule Interruption @ 4.0 W/kg (1 ^{o}C).
- Reduction Factor of 50 → 0.08 W/kg for Whole Body

Accounts for Uncertainty and* Philosophical *Approach to Protect Against Any. . .

Hazards or Adverse Effects on Bodily Function and/or Tissue

Current ICNIRP Local Guidelines: Scientific Basis and Considerations at High Frequencies

- Cataract Induction in the Eye – Critical Effect
- Threshold at 100 W/kg (> 15 min)
- Reduction Factor of 50 → 2.0 W/kg in Contiguous Tissue (Ocular Tissues)
- Below Behavioral Thermal Regulation or Interruption of Work Schedule at 4.0 W/kg

Accounts for Uncertainty and* Philosophical *Approach to Protect Against Any. . .

Hazards or Adverse Effects on Bodily Function and/or Tissue

Basic Restrictions in Exposure Guidelines: Frequency (Region) Dependent Interaction

Low Frequencies (1 Hz and 100 kHz): **Induced field and current density** for preventing effects in excitable tissues such as nerves and muscles;

Intermediate Frequency (100 kHz and 100 MHz): **induced field and current density and SAR** for prevention of local heating and whole-body heat stress, and neuromuscular stimulation.

High Frequency (100 MHz and 10 GHz): **SAR** for prevention of whole-body heat stress and local heating.

Very High Frequency (10 and 300 GHz): **power density** for excessive tissue heating near or at the body surface.

Reference Levels and Maximum Permissible Exposure Levels

Quantities in basic restrictions are often **impractical** to measure.

Reference levels or maximum permissible exposure (MPE) -
Introduced for practical exposure assessment purposes.

Reference Levels or Maximum Permissible Exposure -
Physically measurable quantities:

Electric field strength (E),
Magnetic field strength (H),
Power density (S), or SA for whole body,
Current (I) (Including limb and contact currents).

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1. Repeated, Long-Term, Low Level Exposures
2. Possible Delayed Health Effects at Low Levels - Cancer
3. High Risk Groups
4. Children, Fetus and Pregnant Woman
5. Pulsed Power Exposure
6. Averaging Mass or Volume
7. Spatial Average SAR and Power Density
8. THz Waves
9. Exposure Duration (averaging duration)
10. Appropriate Metric Quantity - Induced Field, SAR or Temperature

IARC Classification of RF Fields as Possibly Carcinogenic to Humans

- Data Incomplete and Limited; Bias Cannot be Dismissed.
- Sufficiently Strong Support, Causal Interpretation Possible.
- Increased Risks of 40 to 270% for Glioma (Astrocytoma).
- Increased Risk of 10 to 300% for Acoustic Neuroma.

The Science Remains Confused and Controversial at Low Levels, 2.0 W/kg.

High Risk Groups

1. **High (Occupational Settings) RF Exposures**

   - MRI, Welding, RF Sealing

2. **Persons with Electromagnetic Hypersensitivity**

- **Symptoms as headache and fatigue are common and nonspecific.**
- **Provocation experiment showed that test subjects could NOT distinguish RF exposure from sham exposure .**
- **Hypersensitivity and subjective symptoms MAY BE REAL.**
- **Whether they are associated with RF use must await further study.**

THz Frequencies

- **Attractive Features**
- Low Photon Energy and Good Penetration
- Low Scattering and Propagation Loss in Air
- Good Beam Coherence and Broad Bandwidth
- Spectral fingerprints for Characterization
- **Limited to Dry and Non-polar Materials**
- Non-Biological Materials
- Subcutaneous or In Vitro Cancer Detection
- DNA and RNA Structures

THz Frequencies Between IR and MM Waves

- TREAT SEPARATELY ?
- TREAT LIKE IR or MM WAVE ?

Thresholds for Single RF Pulse Irradiation

1. Auditory Effect - 16 mJ/kg (10 µs)
2. Evoked Body Movement - 750 J/kg (50 ms)
3. Convulsion (Stun & Seizure) - 28 kJ/kg (350 ms)

Pulsed RF Fields

- Peak electric field, peak power and SA for single pulse or multiple pulses;
- Prevention of dielectric breakdown
  - peak field;
- Prevention of microwave auditory effect or other
  - peak power, pulse width, SA;
- Basic restriction and reference levels appear adequate, to date.

Summary List of Exposure Parameters

- Source Type, Frequency (Wavelength), and Location
- Near or Far Field, Local, Partial or Whole Body
- Modulation and Duration of Exposure
- Incident Electric-Field (V/m) and Magnetic-Field (A/m) Strengths, and Incident Power Density (W/m^2)
- Average or Peak Value
- (Same exposure or incident field does not provide the same field inside biological systems of different size, species, or constitution.)

Summary List of Dosimetric Quantities

- Induced Electric-Field Strength (V/m) and
  Magnetic-Field Strength (A/m)
- Induced Current Density (J/m^2)
- Deposited Power Density (W/m^3)
- Specific Absorption Rate (SAR; W/kg)
- Specific Absorption (SA; J/kg)
- Distribution of Induced Fields and SAR
- (Note - SAR and induced field serve as index for comparison and extrapolation of experimental results from tissue to tissue, animal to animal, animal to human, and from human to human.)

Induced Field is the Primary Cause of interaction of electromagnetic fields with biological systems

- Function of Physical Configurations of the body or biological system under exposure.
- Depends on electromagnetic properties of tissue -- Complex Permittivity.

In tissues with finite electrical conductivity σ, induced field can produce:

Conduction current with density, $\mathbf{J} = \sigma\mathbf{E}$, and Absorption gives rise to Joule or dielectric heating.

Example: FDTD - Numerical Computation of Induced Field and SAR

- Computational domain:

  Anatomical models with 3-D grid; 1x1x1 mm voxels.
- Heterogeneous property of biological material:
  (parametric, Cole-Cole)
- Berenger's PML (8-layered) as absorption boundary for *Maxwell's equations*.
- Validated – **Topic of Greatest Scientific Progress**

- (Good also for Computation of ***biological heat*** generation and ***thermoelastic pressure*** waves)

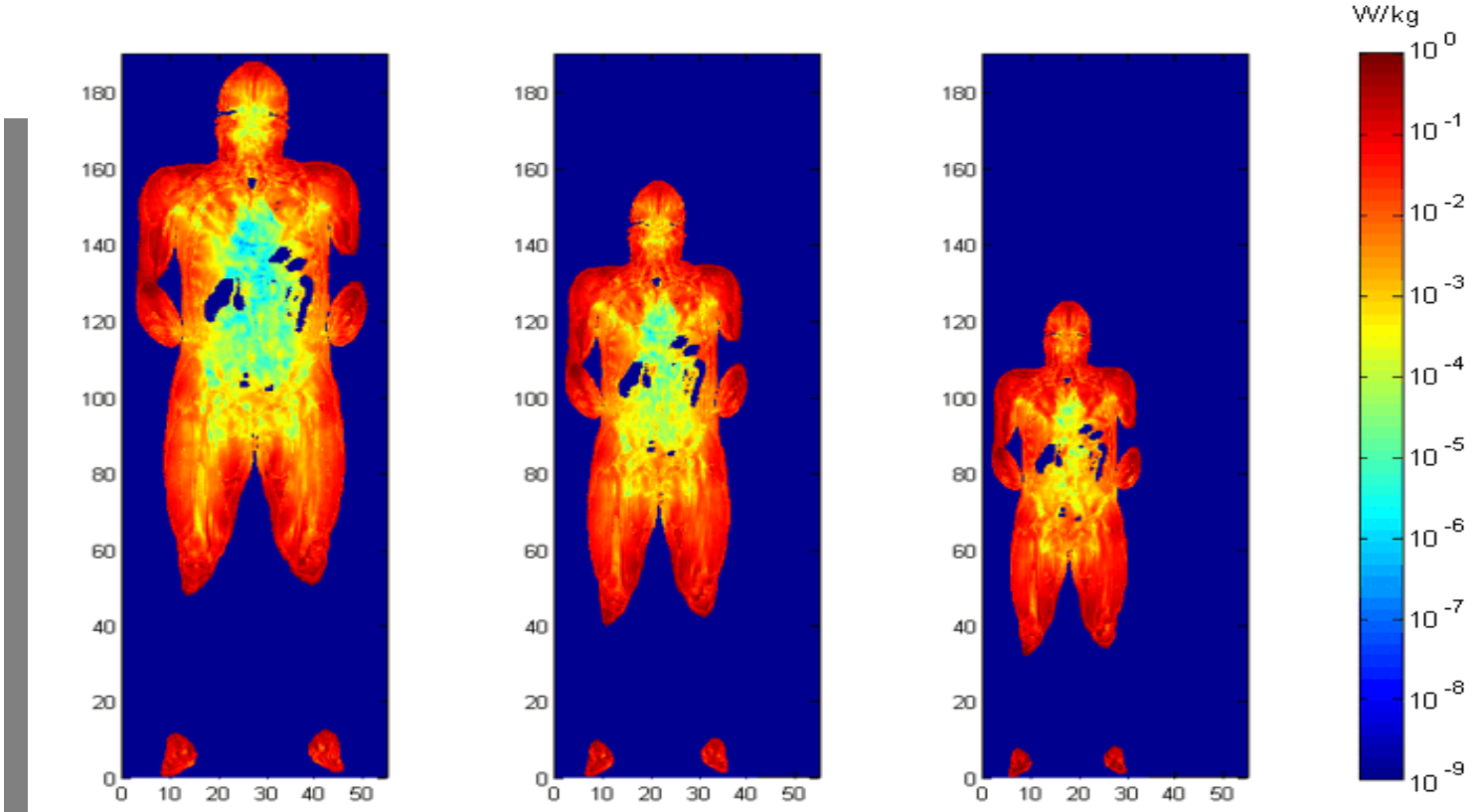
SAR Distributions for 3 Sizes of Scaled Human Bodies at 900 MHz

E_{inc} = 42 V/m Plane Wave

Adult 13-yr old 7-yr old

SAR Distributions in Scaled Human Bodies at 2.45 GHz

E_{inc} = 61 V/m Plane Wave



Adult 13-yr old 7-yr old

Averaging Mass in Guidelines: A Scientific Look

ICNIRP: 2.0 W/kg in 10 g of Contiguous Tissue

- Volume (Mass) of Ear and Eyeball ~ 10 g
- SAR Based on 10 g Mass (=10 cm^3 Volume)
  - Neglects Anatomic Detail & Tissue Type.
  - Does not account for Wide SAR Variations, especially at Higher Frequencies.
  - Current Advance in Dosimetry Provide 1 mm^3.

10 cm^3 = 10,000 mm^3

SUMMARY REMARKS

Major Scientific Topics Relevant to Revision of RF Guidelines are HIGH LIGHTED.

However, Specific Ways to Address Them or What Impact Would They Have on the Revised Guidelines are Subject to Further Deliberations.