From power lines to mobile phones: are non-ionizing electromagnetic fields hazardous?

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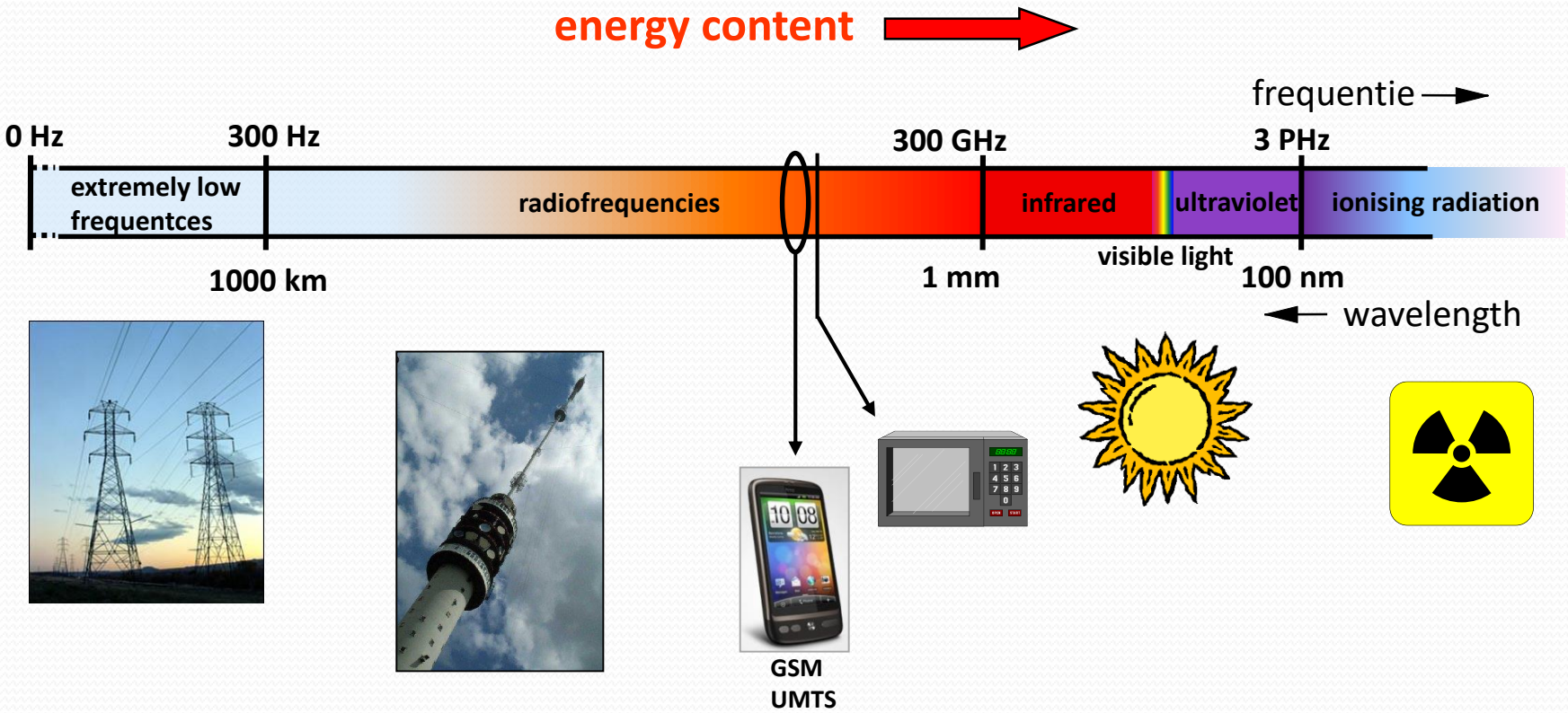
Electromagnetic spectrum

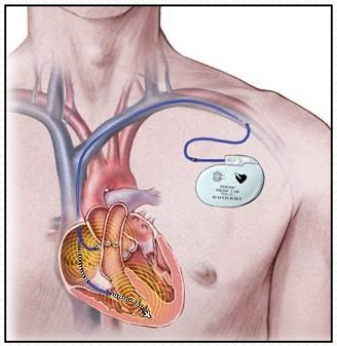


Frequencies

- 0 Hz - 300 GHz
- Especially important:
  - 50 Hz (electricity)
  - kHz - GHz (radiofrequencies)

Effects: direct vs indirect

- Direct: action EM field on cells, tissues, organs and organism
- Indirect: effects caused by influence on non-biological matters, e.g. interference of electr(on)ic equipment



Effects: short vs long term

- Short: during or shortly after exposure
  - Low frequencies: induced electric field
  - High frequencies: generation heat, effects on brain functions

- Long: weeks to years after exposure
  - Mainly cancer

Biological and health effects

- Biological effect ≠ health effect
- Biological effect:
  - Any influence of a chemical, physical or biological factor on the resting state of a biological system
- Health effect:
  - Organism out of balance

Meaning of effects

- Not every biological effect is harmful!
  - E.g.: visible radiation on retina leads through biological effects to vision

Static fields

- Electric (E)
  - Volts per meter (V/m) or
  - Kilovolts per meter (kV/m = 1000 V/m)

- Magnetic (B)
  - Tesla (T) or
  - Microtesla ($\mu T = 10^{-6}$ T)

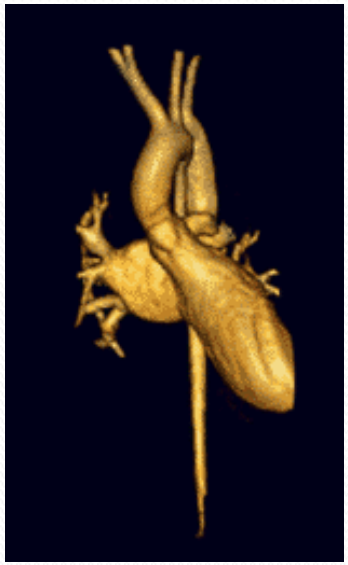
Static E-fields

- Electric charge on surface
- Also by friction
- Charge → local E-field (up to 500 kV/m)
- Effects:
  - Movement of hairs
  - Perception at 10-45 kV/m
  - Discharge

- Annoyance, no adverse effects

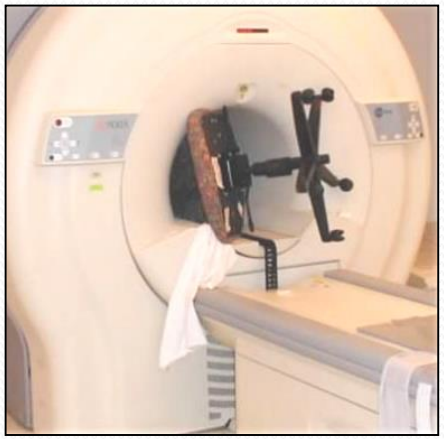
Static B-fields

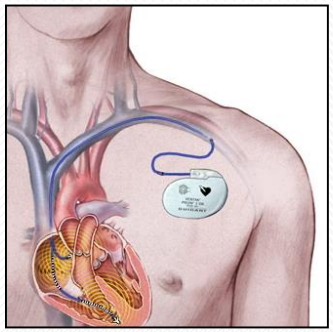
- Movement charged particles through B-field (e.g. in blood) → electric potentials and currents
  - Heart contraction, blood flow through aorta
- Magnetohydrodynamic force (slows blood flow)
  - In aorta calculated:
    - 5% at 10 T
    - 10% at 15 T
- Earth magnetic field: 48 μT
- Fridge magnet: several millitesla



Static B-fields

- Magnetomechanical effects
  - Orientation magnetic anisotrope structures in field (compass needle)
- Movement ferro-metal objects
- Force and torsion metal objects
  - In gradient fields





Static B-fields: effects

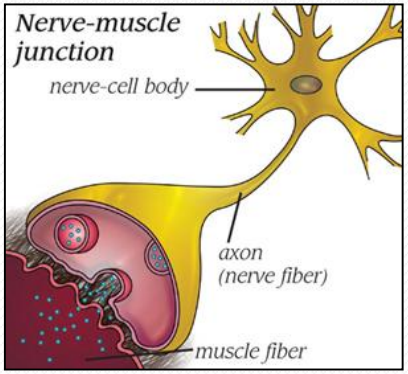
- Fast movement in strong B-field: headache, vertigo, nausea > 2 T

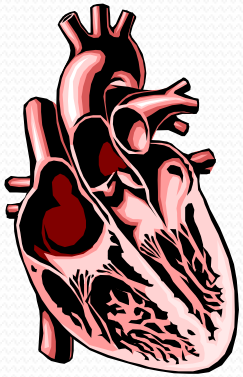
ELF fields

- Exposure everywhere where electricity is present
- Relatively high:
  - Overhead powerlines
  - At work, e.g.
    - Electricity industry
    - Chlorine industry
    - Electronics repair

ELF: short term effects

- Influence on nervous system





- Induction phosphenes
  - Sensation of flashes of light

ELF: long term effects

- 50 / 60 Hz data
- Primarily aimed at cancer

Epidemiological studies

- Studies on population groups
- In general: no effect
- Weak association:
  - Living near overhead power lines / exposure to ELF magnetic fields and childhood leukaemia
  - Indications neurodegenerative diseases (occupational exposures)

- However:
  - No causal relationship, not supported by experimental studies
  - No biological mechanism

ELF and childhood leukaemia

- Association between living near overhead power lines, exposure to field strength > 0,2 - 0,4 µT
- Recent HCN report: OR ~2.7
- No causal relation
- No experimental evidence
- Other factors?

IARC classification

- International Agency for Research on Cancer (IARC):
  ELF magnetic fields “possibly carcinogenic to humans”
- Meaning:
  - NOT: ELF magnetic fields are carcinogenic
  - But: it cannot be excluded that they are
- Same classification: many chemicals, hot drinks, pickeled vegetables

Government recommendation

- Letter Environment Ministry (VROM) to local authorities (2006)
- Not compulsory
- Measures in new situations: distance to overhead power lines such that children will not be exposed to magnetic field > 0.4 µT
- Creates dilemma: are people in existing situations less protected?

RF fields

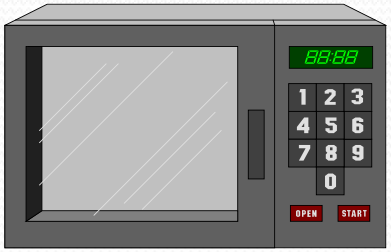
- Broad spectrum, many applications
  - Radio, tv

  - Mobile telecommunication

  - Heating

RF fields: mechanisms

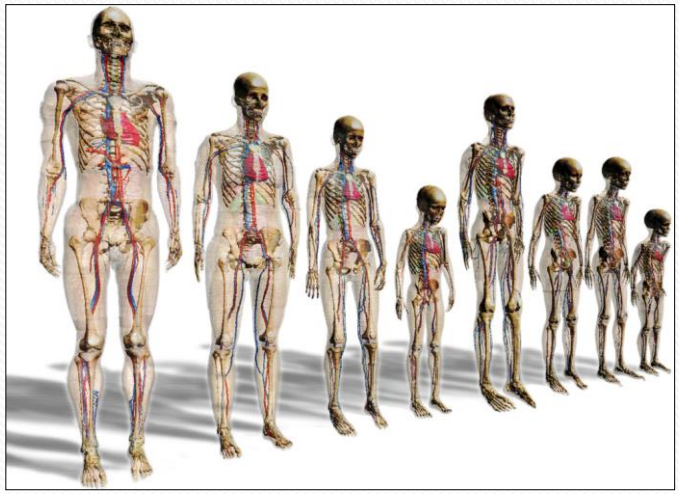
- Main effect: heating



- Non-thermal effects?
  - Brain functions

SAR

- SAR = Specific Absorption Rate: measure for uptake of energy
  - Amount of energy per kg body weight (W/kg)
- Calculated with models (virtual family)

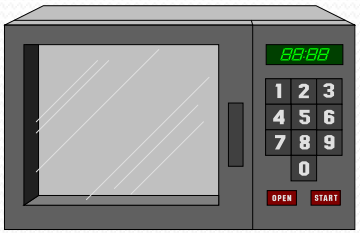


RF: body temperature

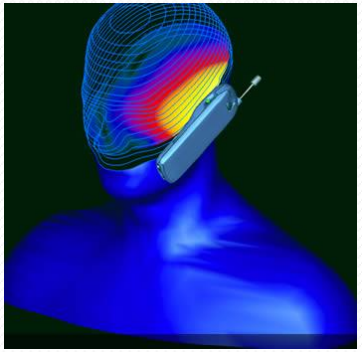
- Metabolic heat production body:
  ~1 W/kg (rest) - ~10 W/kg (heavy work)
- Volunteer studies
  - SAR 4 W/kg: increase 0,1 - 0,5 °C
  - Influence of
    - Environmental factors
    - work
    - Bad health
- Experimental animals
  - Influence behaviour with SAR > 4 W/kg

Heating by RF fields

- ‘Microwave effect’
  - Microwave: high power (1000 W)
  - Cell phone: low power (0.25 W)



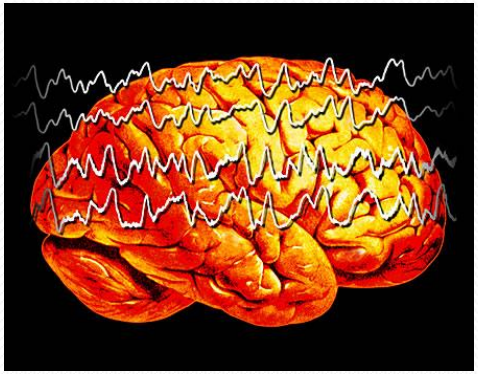
- Temperature increase cell phone:
  - In skin max. 0.2 °C
  - In brain max. 0.1 °C



- No heating from base station

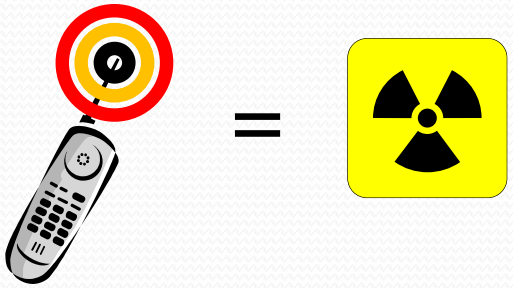
Effects on brain functions

- Influence on brain activity during sleep / waking
  - Field strength > 100 x higher than under GSM-antennas
  - No influence on feeling rested and on health
- Influence on cognitive functions (memory, reaction speed, etc.)
  - Temporary effects
  - Inconsistent, sometimes improvement
  - No adverse health effect



“Electrosensitivity”

- Non-specific, frequently occurring symptoms
  - Headache
  - Insomnia
  - Concentration problems
- More specific complaints
  - Tingling feeling
  - Tinnitus
  - Pain in skin and body parts
- No causal relationship with exposure
- Relation with expectation of exposure



Long term effects

- Exposure workers
  - High field strengths
- Mainly: possible effects of long (continuous) exposure of population to low field strengths

Exposure workers

- Operators sealing equipment (20 - 100 MHz):
  - Exposure to 3 to 5 times limit values:
    - Numbness of hands
    - Effects in nervous system

RTV transmitters and cancer

- Real long term exposure
- Studies in number of countries
- No relation demonstrated

GSM and brain tumours

- Epidemiological studies: conclusions Health Council (June 2016)
  - No proven relation between longterm frequent use of mobile telephone and increased risk for head and neck tumours
  - But cannot be excluded

- Animal experiments
  - Induction tumours by RF fields unlikely

Conclusions

- Only established effect: generation of heat
- Living near base station, use mobile phone:
  - No relation with cancer demonstrated
  - No relation with other diseases or symptoms
- Effects can never be 100% excluded
- More research, especially long-term studies

IARC classification

- International Agency for Research on Cancer (IARC):
  RF electromagnetic fields “possibly carcinogenic to humans”
- Meaning:
  - NOT: RF fields are carcinogenic
  - But: it cannot be excluded that they are

Exposure limits

- Health effects possible, therefore
- Exposure limits needed
- Can only be based on short term effects
- Distinction between
  - Basic restrictions
  - Reference levels

Basic restrictions

- Maximum values of parameters that may cause direct effects
  - Static fields: strength magnetic field
  - ELF fields: internal electric field strength
  - RF fields: absorption of energy
- In EU Directive on EMF exposure of workers: Exposure Limit Values (ELV)

Reference levels

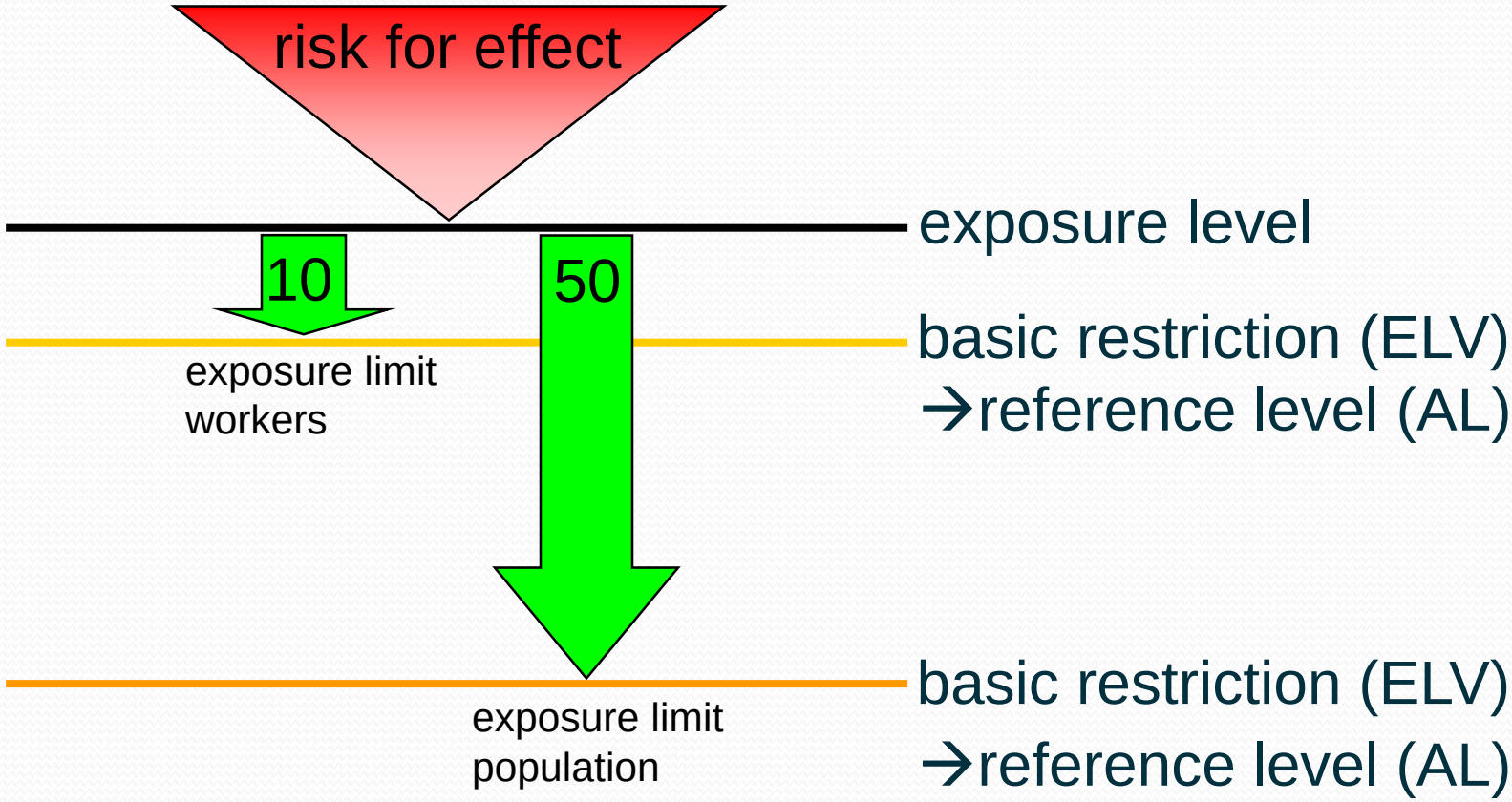
- Electric field and energy uptake in body cannot be measured directly
- Levels of electric and magnetic field strength derived for location of exposure
- Tool
- In EU Directive: Action Levels (AL)

Workers vs population

- Workers
  - Homogenous
  - Healthy
  - Informed

- General population
  - Heterogenous (elderly, children)
  - Differences health, heat tolerance
  - Unaware of exposure

Safety factors



Guidelines

- Recommendations ICNIRP (International Commission on Non-Ionizing Radiation Protection) (1998, 2010 [ELF])
- Recommendations EU (1999)
  - Exposure general population
  - Not compulsory, but introduced in product standards
- EU Directive (2013)
  - Exposure workers
  - Compulsory
  - Transposed in national law by 1 July 2016

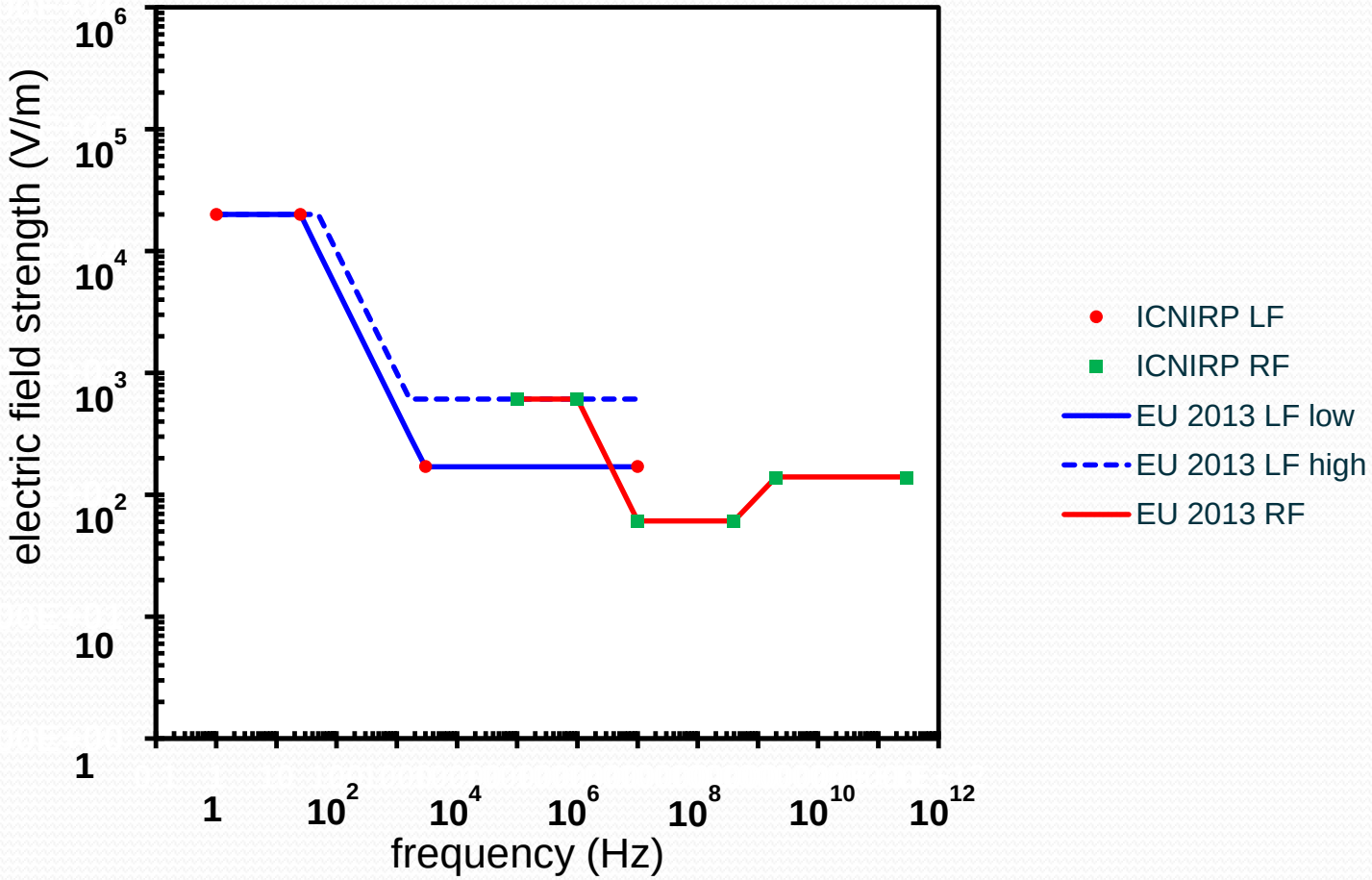
ELF: exposure guidelines ICNIRP

- Based on acute effects:
  - Electric field induced in central (brain, spinal cord) and peripheral nerve system
  - Phosphenes

High frequencies: heat

- Basis: heating whole body < 1 °C, then: SAR < 4 W/kg
  - Workers (reduction factor 10):
    max SAR 0.4 W/kg
  - General population (reduction factor 50):
    max SAR 0.08 W/kg

Reference / action levels



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