"Capacity Building and Strengthening Institutional Arrangement"

Analysis and sampling of air and air pollution

Environmental Impact of Electromagnetic Field (Part 1)

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APAT

Agency for Environmental Protection and Technical Service

SUMMARY

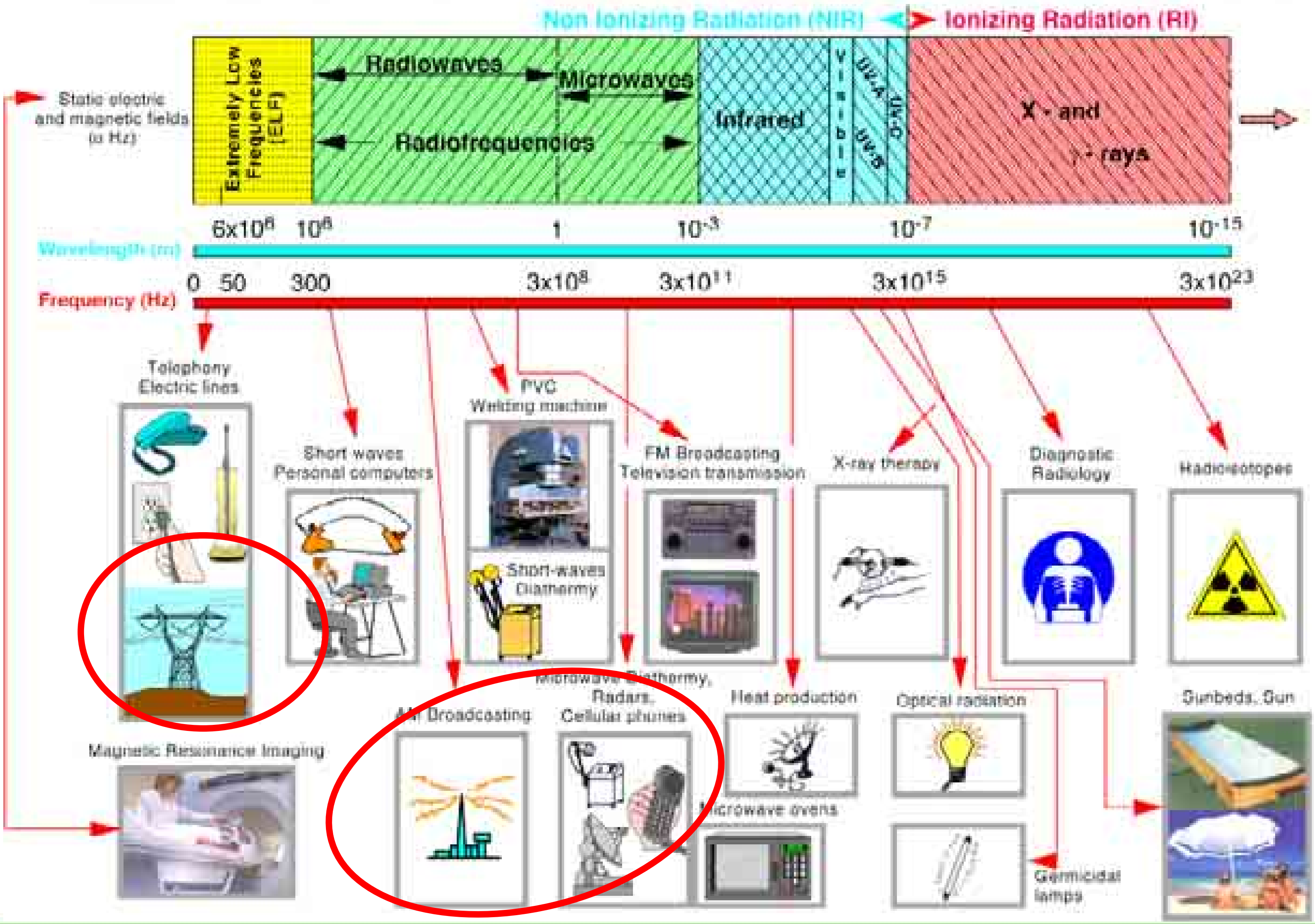
Part I

- Introduction and Rationale
  - Biological effects of Non-Ionising Radiation (coupling mechanisms)
  - General approach for measurements and theoretical evaluation
- Most relevant applications
  - ELF
  - RF / MW

Part II

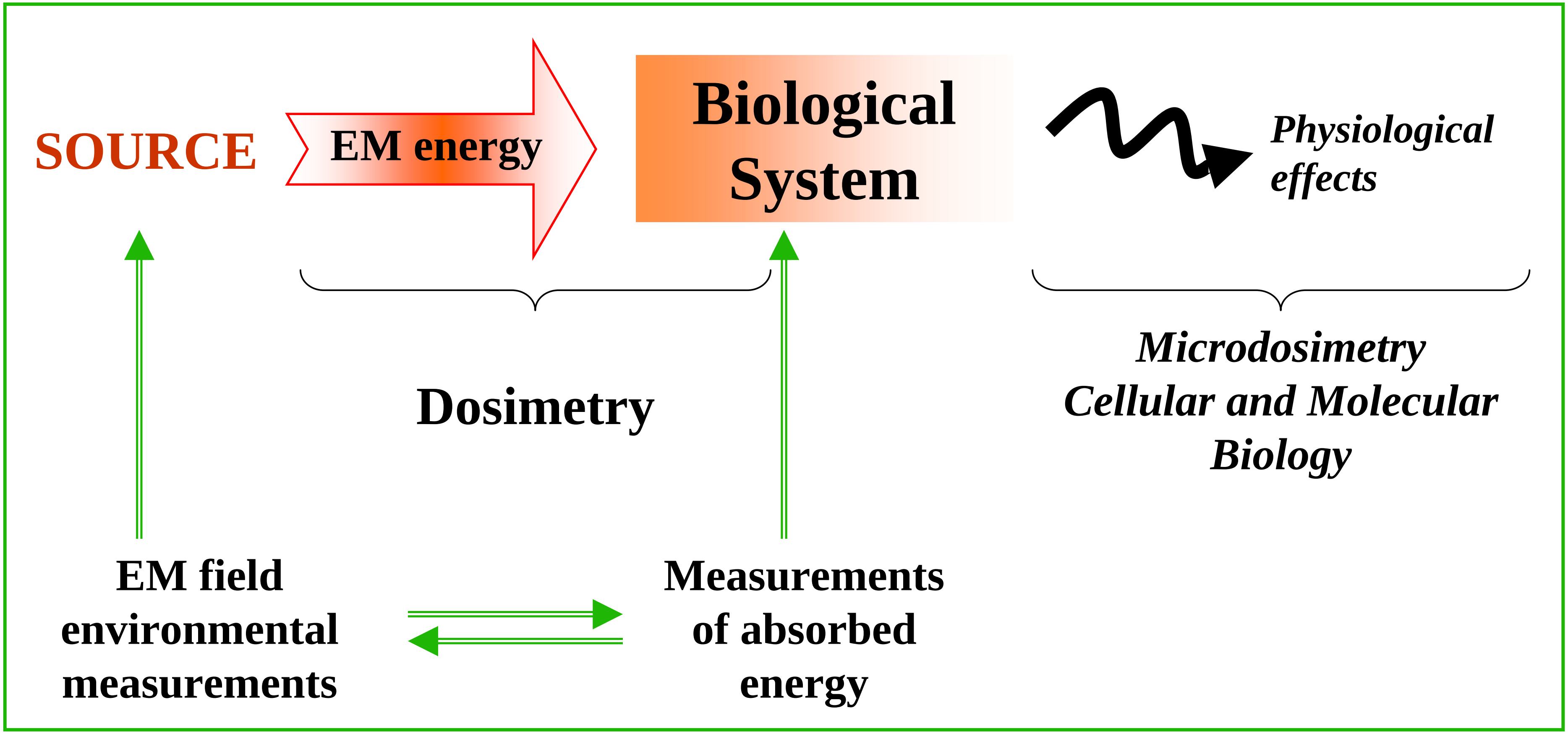
- Theory of Measurements
  - Technical aspects of Environmental Measurements (different modalities)
  - Instruments
- Standards, Guidelines and Regulations

electromagnetic radiation and some typical applications



WHAT'S THE PROBLEM ?

Electromagnetic fields interact with living matter !!!



General approach …

- It is possible to measure the E (V/m) and H (A/m) fields incident on the biological system, in air (reference levels);
- It is NOT possible to measure the absorbed power and the induced current inside the human body (basic restrictions);

BUT …

- It is possible to perform:
  - Numerical and theoretical evaluation of induced field distributions (E (V/m) , SAR (W/kg) , currents) by specific numerical codes (simulations)
  - Experimental evaluation on simplified models constituted by biological equivalent materials (dielectric parameters)

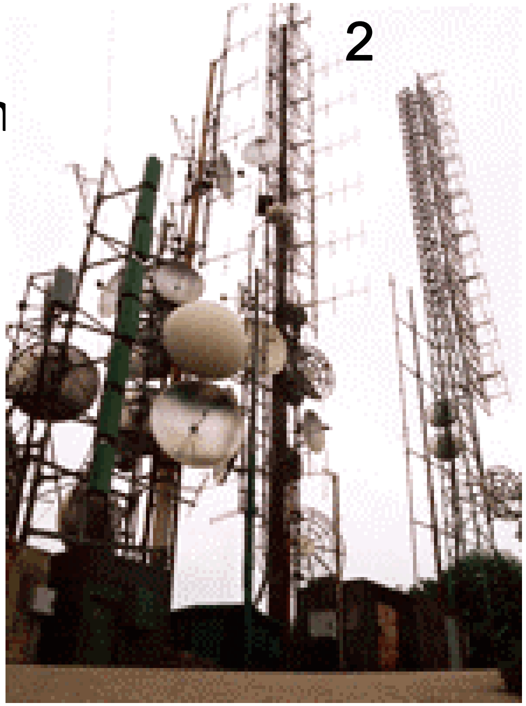
The DOSIMETRY is the description of the relationship between external E (V/m) , H (A/m) and EMF and the fields and currents induced in the body

Most relevant applications (!)

Most relevant application for the environmental exposure of population:

1. power lines (ELF)
   (rural and suburban areas)

2. broadcasting, TV transmissions an
   telecommunications (RF & MW)
   (urban and suburban areas)



ELF and RF

ELF and RF: two different "exposure problems"

- *Several considerable physics quantities (several physics aspects)*
- *Several biological effects (coupling mechanism)*
- *Several measurement techniques and instruments*

WHY ?

ELF and RF

$$c = f * \lambda = cost$$

ELF:

f = 50 Hz ➡ **λ = 6000 km**

⬇

Near field condition:

E (V/m) and H (A/m) act separately and in an indipendent way

RF e MW:

f = 1 MHz ÷ 2 GHz

➡ **λ = 300 m ÷ 15 cm**

⬇

Far field condition:

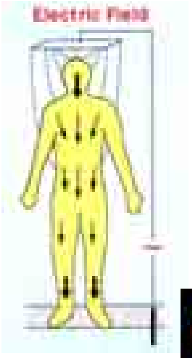
E (V/m) and H (A/m) are bound by the characteristic impedence of air ($E/H = Z0 = 377\ \Omega$)

coupling mechanisms between fields and body

There are <u>three</u> established <u>basic coupling mechanisms</u> through which time-varying electric and magnetic fields interact directly with living matter (UNEP/WHO/ IRPA 1993):

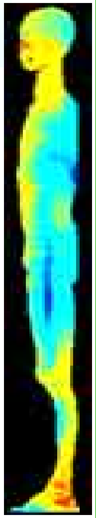
- coupling to low-frequency electric fields
- coupling to low-frequency magnetic fields

ELF



- absorption of energy from electromagnetic fields

RF & MW



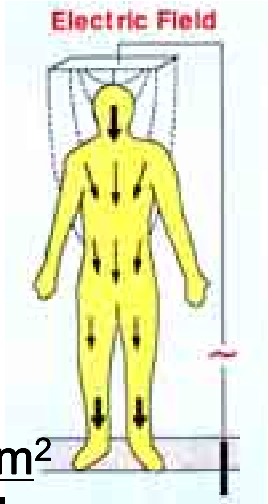
ELF

simple consideration about ELF field characteristic

- In this frequency range the electric and magnetic part of EM field can be considered acting in a separate manner
- An external electric field is greatly attenuated inside the body and perpendicularly oriented to the surface,
  - This is due to the dielectric characteristics (high conductivity and permittivity) of the body tissues with respect to air,
- On the contrary, the magnetic field penetrate the body virtually unperturbed and induced electric fields and currents inside the tissues.

It’ s really important the knowledge (measure) of the only magnetic field.

ELF: *coupling to low-frequency electric fields*



- For sinusoidal electric fields at frequencies below about 10 MHz, the magnitude of the induced current density increases with frequency.

- The induced current density distribution varies inversely with the body cross-section and may be relatively high in the neck and ankles.

  - The exposure level of 5 kV/m (general public) corresponds, under worstcase conditions, to an induced current density of about 2 mA/m^2 in the neck and trunk of the body if the E-field vector is parallel to the body axis*2

  - However, the current density induced by 5 kV/m will comply with the basic restrictions under realistic worstcase exposure conditions *2

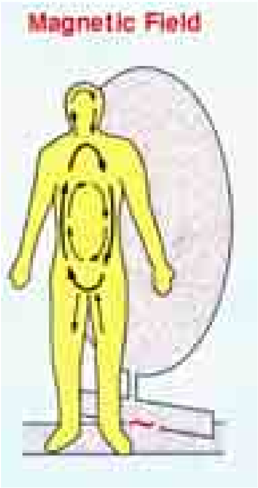
- For purposes of demonstrating compliance with the basic restrictions, the reference levels for the electric and magnetic fields should be considered separately and not additively. This is because, for protection purposes, the currents induced by electric and magnetic fields are not additive.

* ICNIRP, Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields, 1997.

*2 (ILO 1994; CRP 1997).

ELF:

coupling to low-frequency magnetic fields



The physical interaction of time-varying magnetic fields with the human body results in

- induced electric fields
- circulating electric currents

The magnitudes of the induced field and the current density are proportional to

- the body cross-section,
- the electrical conductivity of the tissue,
- the magnitude of the magnetic flux density.

$$J= pRfsB$$

If there are these conditions:

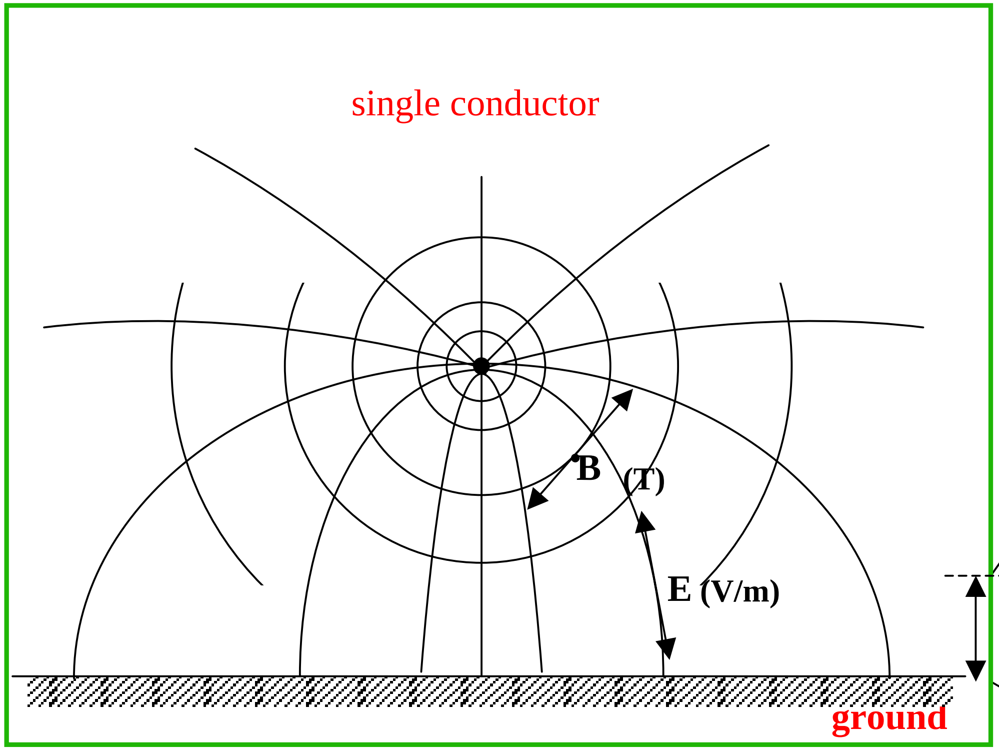
B=100 mT ; s=0,2 S/m (uniform) ; f= 50 Hz

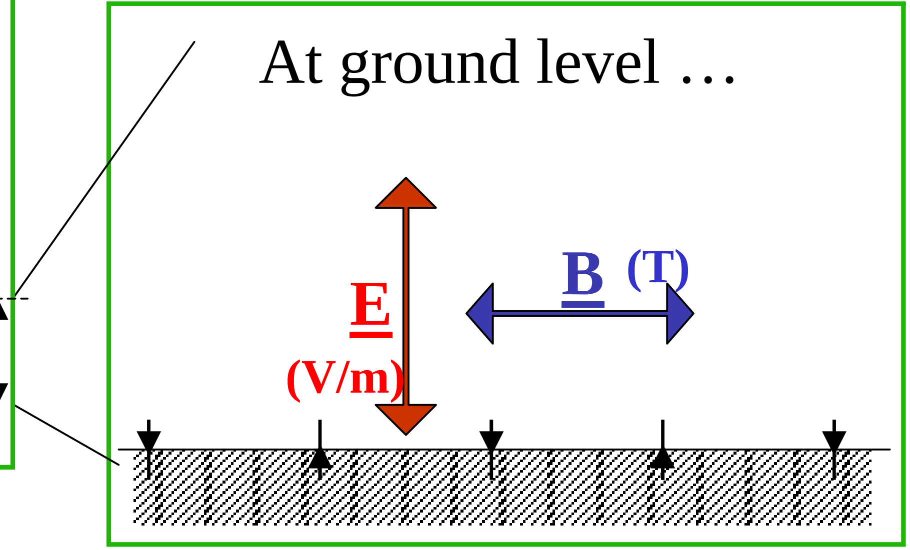
J varies from 0,2 to 2 mA/m^2 in the peripheral regions of body (CRP 1997).

For a given magnitude and frequency of magnetic field, the strongest electric fields are induced where the *loop dimensions* are greatest.

The exact path and magnitude of the resulting current induced in any part of the body will depend on the electrical conductivity of the tissues.

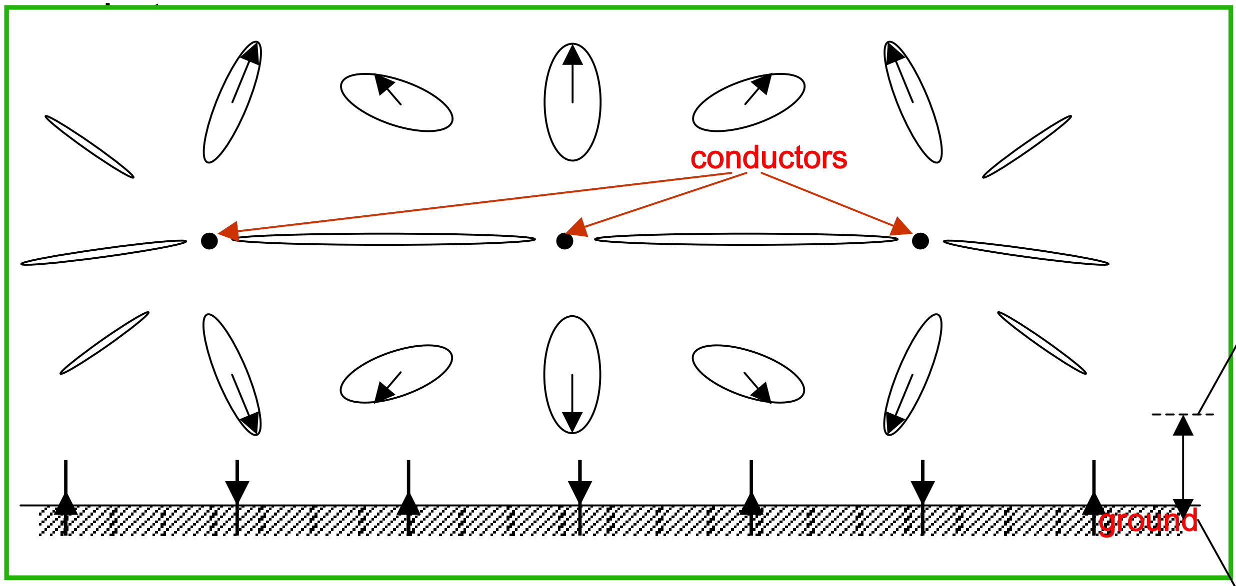
Electric and magnetic field lines of a single conductor

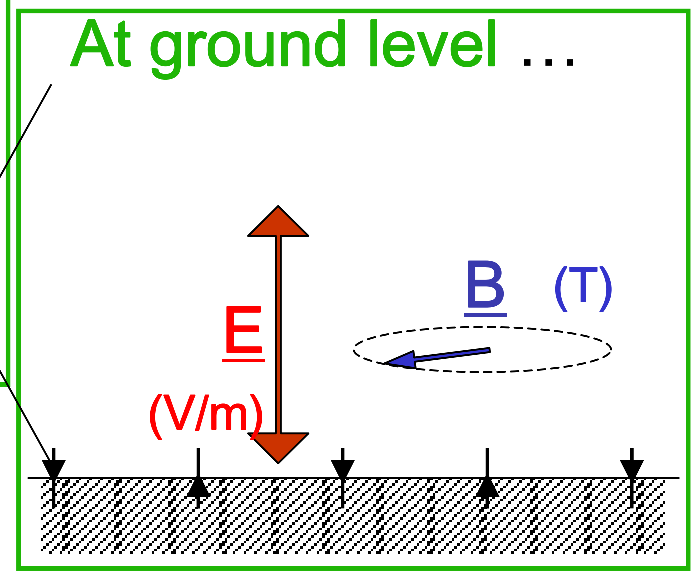




Electric and magnetic field lines of a 3-phase transmission line

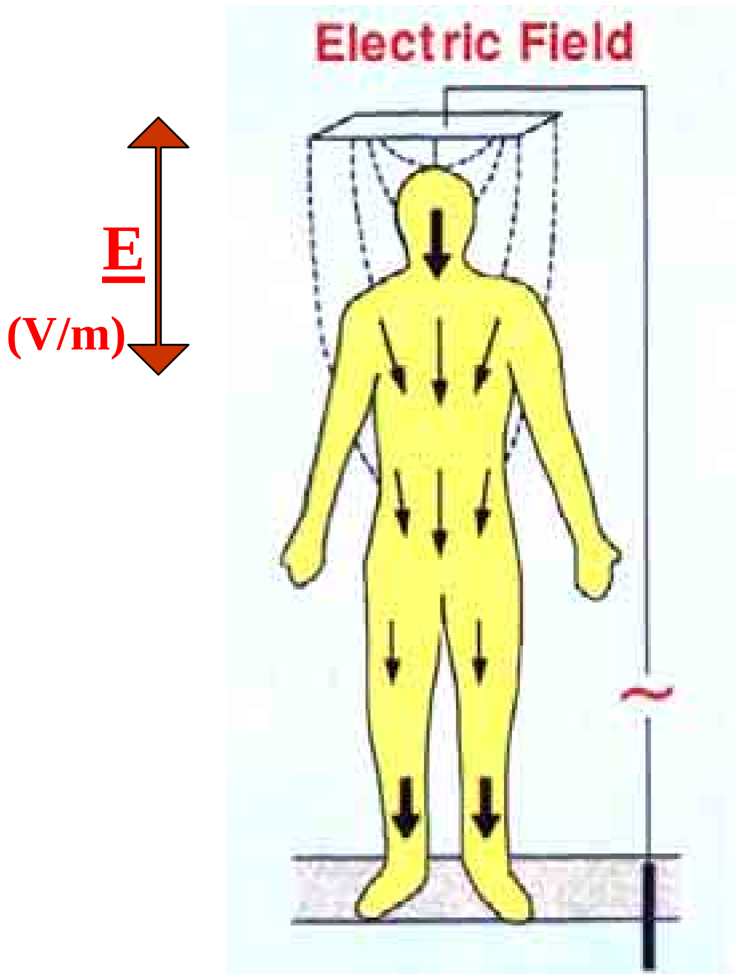
The electric field vector rotates and traces an ellipses in the plane perpendicular to the conductors. The period of rotation coincides with the period of the AC voltage applied to the

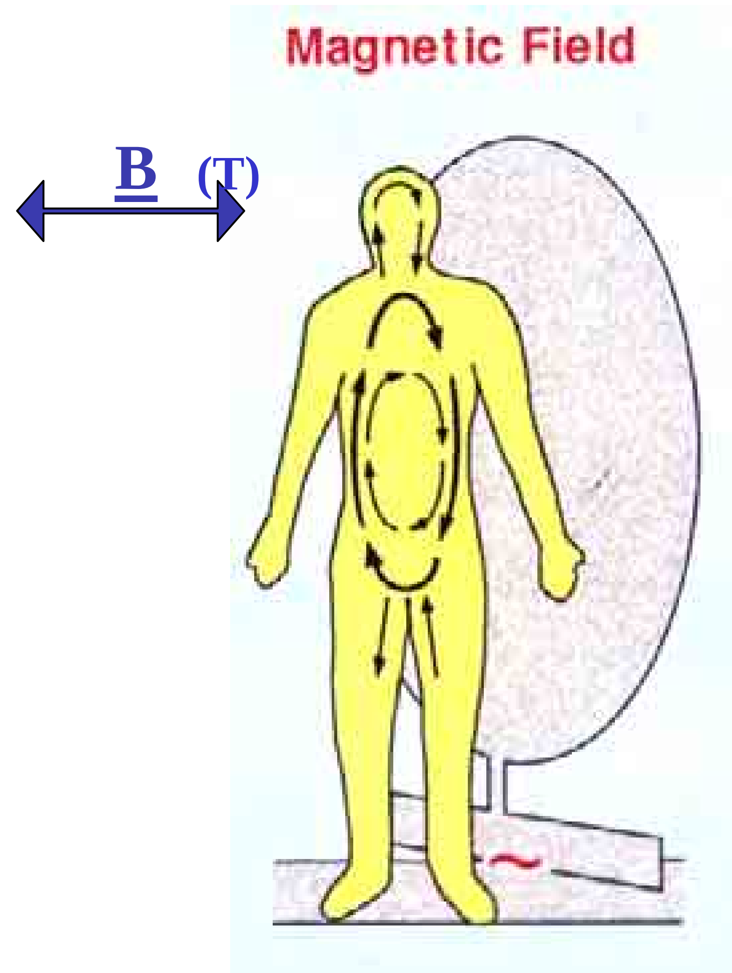




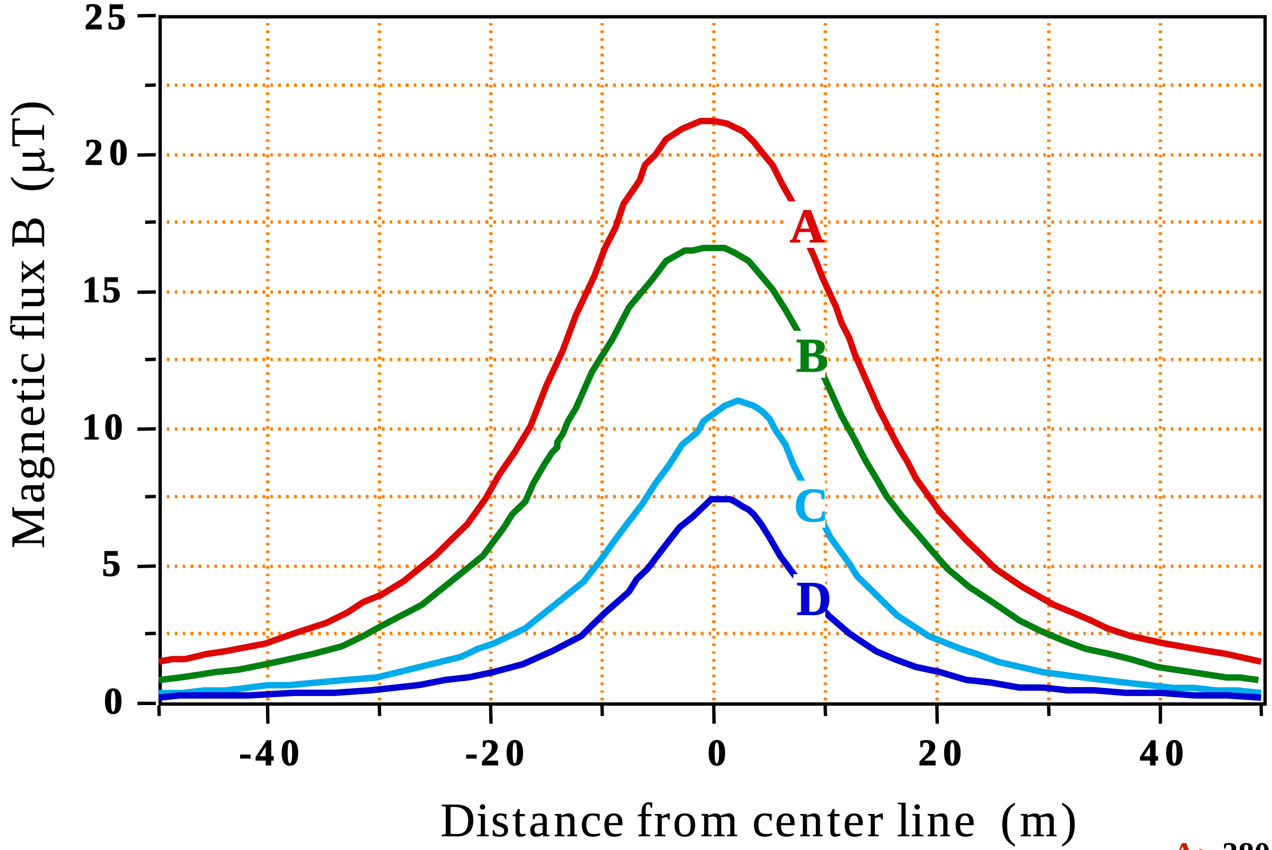
Electric field vector is almost linearly polarized and vertical, B vector is still tracing an ellipses with horizontal main axis

Coupling to low-frequency electric and magnetic fields





Magnetic Field produced by power lines



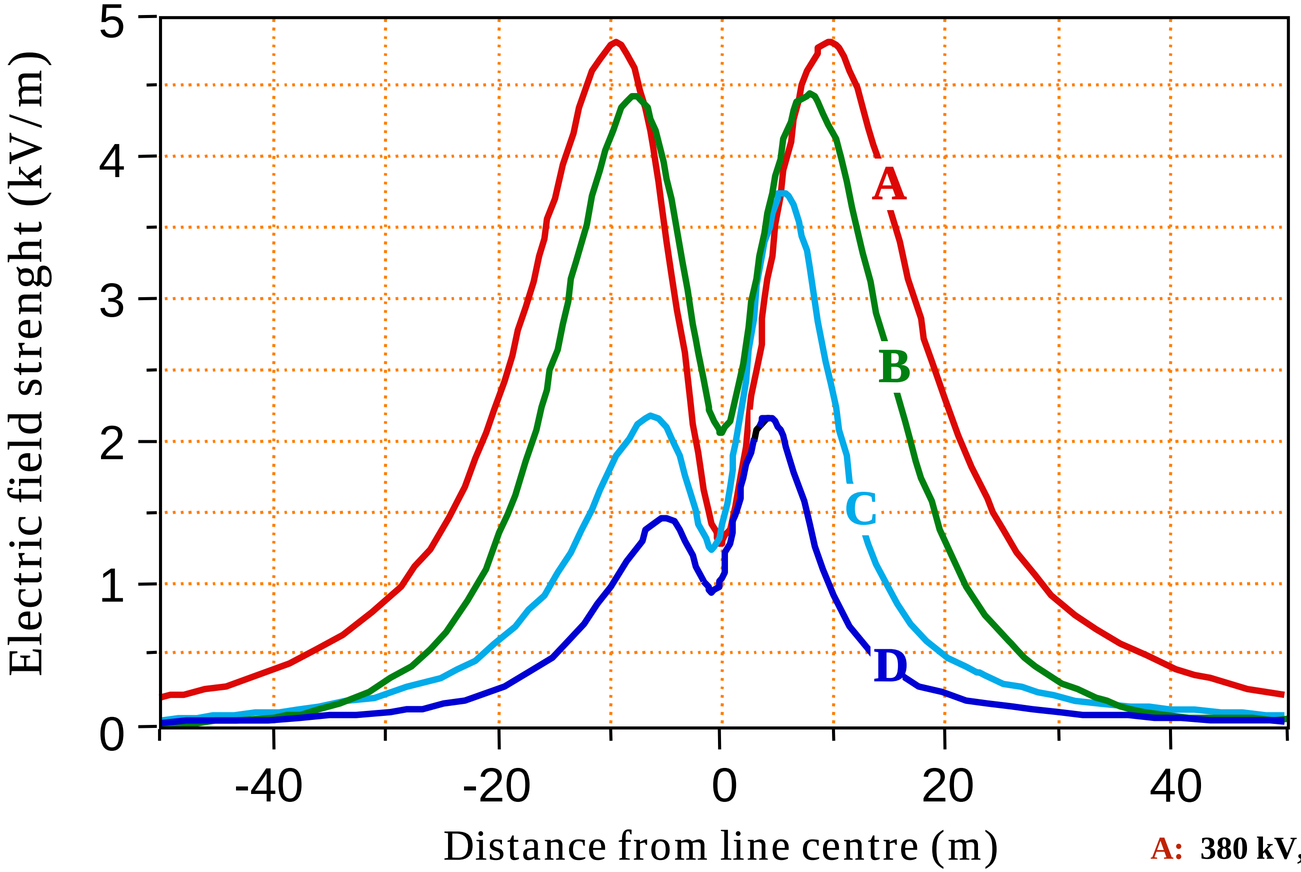
A: 380 kV, 1500A – single terna

B: 380 kV, 1500A – double …

C: 220 kV, 550 A – single terna

D: 132 kV, 375 A – single terna

Electric Field produced by power lines



A: 380 kV, 1500A – single terna
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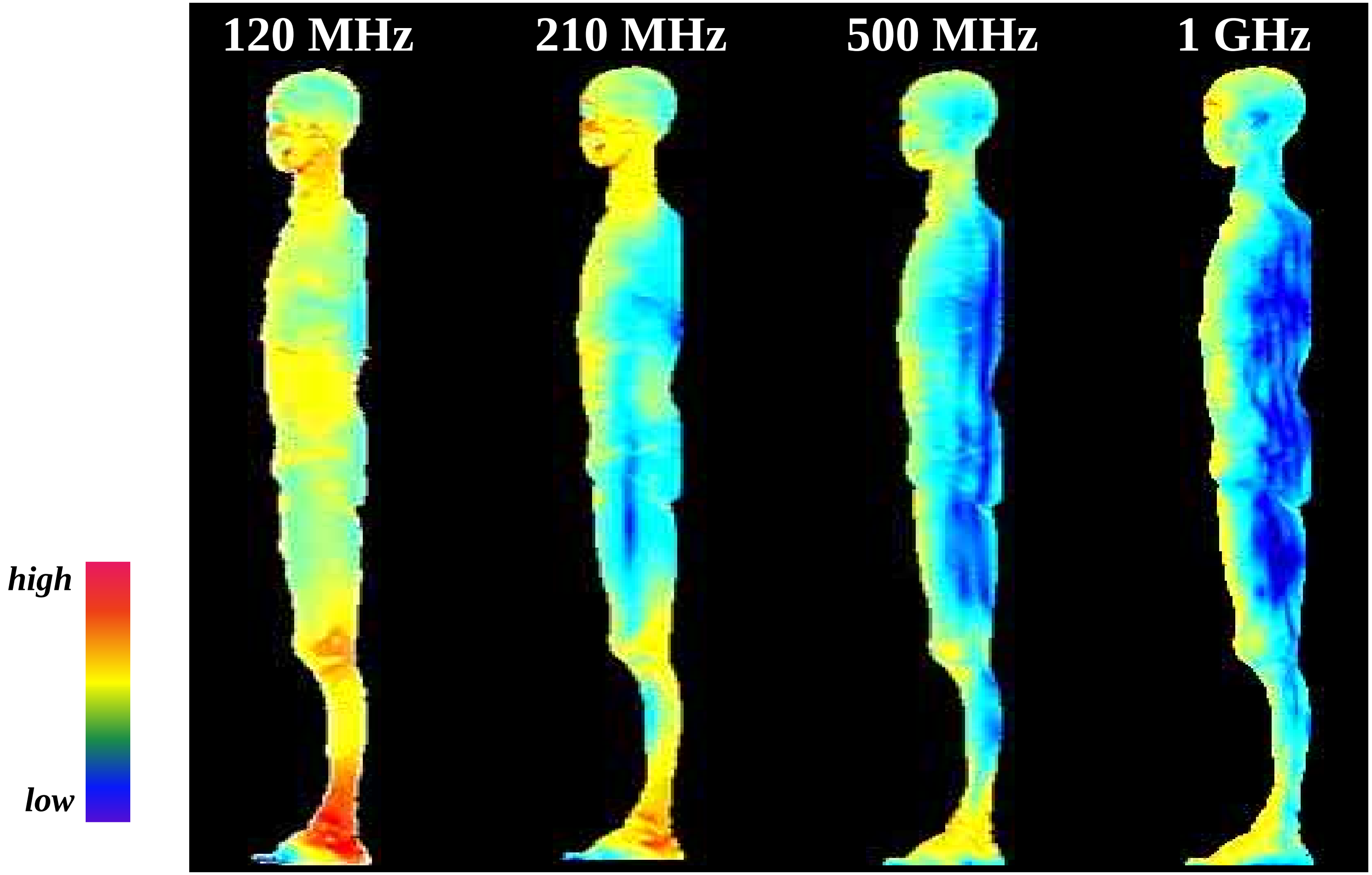
RF and MW coupling mechanism 1/2



"A semi-automatic method for developing a numerical model of dielectric anatomy by MRI",
L Sandrini, M Mazzurana, A Vaccari, C Malacarne, L Cristoforetti, R Pontalti
Institute of Physics, London, 27-28 Feb 03

RF and MW coupling mechanism 1/2

What is RF absorption function?

The RF absorption is function of frequency (f) and it can be divided into 4 regions:

- 100 kHz <f<20 MHz: the absorption decreases with f and it’s signficative in the region of neck and legs;
- 20 MHz <f<300 MHz: high values of absorption can involve all body; it’s possible to find partial resonances ;
- 300 MHz <f< diversi GHz: the absorption is local, significative but not uniform;
- f>10 GHz: surface absorption.