# GUIDELINES FOR EXPOSURE TO SUB-RADIOFREQUENCY ELECTRIC AND MAGNETIC FIELDS

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## Introduction

The International Non-Ionizing Radiation Committee (INIRC) of IRPA and the American Conference of Governmental Industrial Hygienists (ACGIH) have recommended guidelines for exposure limits (ELs) for sub-radiofrequency (sub-RF, defined as 30 kHz and less) electric and magnetic fields. The ACGIH refers to ELs as "Threshold Limit Values," or TLVs, and limits its guidance to the workplace.

Separate ELs are established for the electric and magnetic components of sub-RF electromagnetic fields because exposures of practical interest occur in the "near zone," where the two components behave independently.

## Backqround

The SI unit for the electric field strength, E, is the volt per meter, V/m, while the magnetic flux density, B, is desribed by the tesla (T). The background static electric field is about 130 V/m, while oscillating fields range up to about 1000 V/m (20 kV/m during thunderstorms) with frequencies up to about 1000 Hz. Amplitudes generally decrease with increasing frequency. The typical atmospheric field at 50-60 Hz is only about $10^{-4}$ V/m.[(1)] Man produces sub-RF fields primarily from electric power generation, transmission, and use. Fields are typically about 10 kV/m directly under the conducting wires of transmission lines and 1 or 2 kV/m at the edge of the line right-of-way. By contrast, electric fields from building wiring and electrical appliances typically range only up to 100 V/m. Visual display terminals (VDTs) can produce fields of about 10 V/m or less at 10-15 kHz, due to the high-voltage circuit flyback transformer.[(5)]

The earth's static magnetic field is about 50 $\mu$T. Power-frequency flux densities of about 10 $\mu$T can occur very near electrical appliances. The home has levels of about 0.1 $\mu$T. Some occupational environments, such as those where induction heaters are in use, may have flux densities of 10-100 mT.

## Dosimetry and Measurement

Guidance on measuring power-frequency fields has been developed.[(7)] Portable monitors, from simple spot measuring devices to dosimetric devices with on-board computers, are finding increasing use in epidemiologic studies.

Field Effects in Man

Sub-RF electric fields can induce fields and currents within the body. Hair vibration or other sensory stimuli may occur in fields greater than 10 kV/m. Currents induced in metal structures may produce shocks when humans contact the structure and permit a path to ground.

A grounded person in an electric field experiences a short-circuit current of approximately $I = 15 \times 10^{-8} f W^{2/3} E_o$, where I is in $\mu$A, f is the frequency in Hz, W is the weight in grams, and $E_o$ is the electric field strength in V/m.[6] Thus, a 70 kg person would have a total short-circuit current of about 153 $\mu$A in a 10 kV/m, 60-Hz field. Studies of models indicate that current densities induced in a grounded, erect person exposed to a 10 kV/m, 60-Hz vertical electric field are 0.55 $\mu$A/cm2 through the neck and 2 $\mu$A/cm2 through the ankles.

Time-varying magnetic fields induce electric currents directly as the magnetic flux density and the frequency of oscillation, and inversely as the radius of the current loop. The current density at the perimeter of an adult torso can be approximated by $J = 0.24 f B_o$, where J is in A/$m^2$, f is in Hz, and $B_o$ is in T. The maximum current density induced by normal residential field levels is thus of the order of 1 $\mu A/m^2$.

Bioloqical Effects

Biological effects from sub-RF electric and magnetic fields have been demonstrated by in vitro and in vivo laboratory studies. However, no convincing studies have demonstrated adverse health effects. Moreover, a great many studies have led to findings of no effects. The many excellent reviews[1-4] offer a comprehensive discussion.

Human Studies

Occupational health effects of electric fields have been studied mainly in electric utility workers. Again, the references[1-4] contain excellent summaries of these.

A number of epidemiologic studies have identified an increased risk of cancer among those employed in "electrical occupations," such as electricians, engineers, or radio repairmen. The associations were not consistent among the studies, which often involved small numbers of cases.[1] Other deficiencies of these studies are stated in the report.

A more recent review[9] considered eleven separate studies of electrical workers. The most consistent finding was a small increase in the risk of leukemia. The authors warned that the results are equivocal with respect to cause, because electrical workers are also exposed to agents besides fields, some of which may be leukemogenic. In contrast, a case-control study of deaths due to primary brain cancer or leukemia found an increased risk of brain cancer but no increased risk of leukemia among electrical workers.[10]

Occupational studies are underway now (1992) in the U.S., Canada, and other countries. Results will become available over the next few years.

## The Basis for Exposure Guidelines

Although there is little hard evidence for adverse effects from sub-RF fields, the growing concerns of workers and the public have prompted both INIRC and ACGIH to set guidelines.

Both groups developed guidance by limiting induced current densities in the body to levels that occur normally, i.e., up to about 10 $mA/m^2$ (higher levels can also occur naturally in the heart). Certain biological effects have been demonstrated in laboratory studies at field strengths below those permitted by the exposure guidelines; however, there is no convincing evidence now that occupational exposure to these field levels leads to adverse health effects.[2]

## The INIRC Guideline ELs

The INIRC recommended electric field exposure limits of 10 kV/m for a whole working day with a short-term limit of 30 kV/m.[8] Interim times and field strengths are related by the formula, $t = 80/E$, where t is in hours and E is in kV/m. The limits for magnetic flux density for occupational exposure were set at 0.5 mT for the entire workday, 5 mT for exposures of two hours or less, and 25 mT for exposure to limbs.

## The ACGIH TLVs

The ACGIH TLV[11] for occupational exposure to sub-RF electric fields limits exposure to 25 kV/m for frequencies from 0 Hz to 100 Hz. For frequencies of 100 Hz to 4 Khz, the TLV is given by

$$E_{TLV} = 2.5 \times 10^6 / f \quad \text{(V/m, r.m.s.)}$$

where f is in Hz. A limit of 625 V/m applies to frequencies from 4 kHz to 30 kHz. Because electromagnetic interference may occur in some models of heart pacemaker in power-frequency electric fields as low as 2 kV/m, exposures of workers with pacemakers are limited to 1 kV/m.

The TLV for sub-RF magnetic fields was revised in 1992 to be in consonance with the American National Standards Institute at frequencies above 300 Hz. For fields from 1 to 300 Hz, routine occupational exposure is limited to

$$B_{TLV} = 60 / f \quad \text{(mT, r.m.s.)}$$

where f is the frequency in Hz. The TLV at 60 Hz is thus 1 mT. For frequencies from 300 Hz to 30 kHz, the TLV is 0.2 mT, which corresponds to a magnetic field strength of 163 A/m.

Below 1 Hz, the TLV is 60 mT.

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