Technology Brief 17: Health Risks of EM Fields

Can the use of cell phones cause cancer? Does exposure to the electromagnetic fields (EMFs) associated with power lines pose health risks to humans? Are we endangered by EMFs generated by home appliances, telephones, electrical wiring, and the myriad of electronic gadgets we use every day (Fig. T17-1)? Despite reports in some of the popular media alleging a causative relationship between low-level EMFs and many diseases, according to reports by governmental and professional boards in the U.S. and Europe, the answer is: NO, we are not at risk, so long as manufacturers adhere to the approved governmental standards for ***maximum permissible exposure*** (MPE) levels. With regard to cell phones, the official reports caution that their conclusions are limited to phone use of less than 10 years, since data for longer-term use is not yet available.

Figure TF17-1: Electromagnetic fields are emitted by power lines, cell phones, TV towers, and many other electronic circuits and devices.

Physiological Effects of EMFs

The energy carried by a photon with an EM frequency f is given by $E = hf$, where h is Planck's constant. The mode of interaction between a photon passing through a material and the material's atoms or molecules is very much dependent on f. If f is greater than about 10^{15} Hz (which falls in the ultraviolet (UV) band of the EM spectrum), the photon's energy is sufficient to free an electron and remove it completely, thereby ionizing the affected atom or molecule. Consequently, the energy carried by such EM waves is called ***ionizing radiation***, in contrast with ***non-ionizing radiation*** (Fig. T17-2) whose photons may be able to cause an electron to move to a higher energy level, but not eject it from its host atom or molecule.

Assessing health risks associated with exposure to EMFs is complicated by the number of variables involved, which include: (1) the frequency f, (2) the intensities of the electric and magnetic fields, (3) the exposure duration, whether continuous or discontinuous, and whether pulsed or uniform, and (4) the specific part of the body that is getting exposed. We know that intense laser illumination can cause corneal burn, high-level X-rays can damage living tissue and cause cancer and, in fact, any form of EM energy can be dangerous if the exposure level and/or duration exceed certain

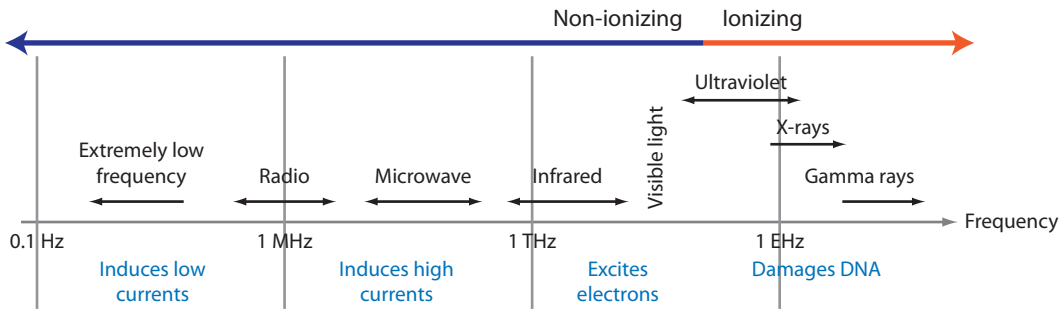

Figure TF17-2: Different types of electromagnetic radiation.

safety limits. Governmental and professional safety boards are tasked with establishing maximum permissible exposure (MPE) levels that protect human beings against adverse health effects associated with EMFs. In the U.S., the relevant standards are IEEE Std C95.6 (dated 2002), which addresses EM fields in the 1 Hz to 3 kHz range, and IEEE Std 95.1 (dated 2005), which deals with the frequency range from 3 kHz to 300 GHz. On the European side of the Atlantic, responsibility for establishing MPE levels resides with the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) of the European Commission.

At frequencies below 100 kHz, the goal is to minimize adverse effects of exposure to electric fields that can cause ***electrostimulation*** of nerve and muscle cells. Above 5 MHz, the main concern is excessive tissue heating, and in the transition region of 100 kHz to 5 MHz, safety standards are designed to protect against both electrostimulation and excessive heating.

Frequency Range $0 \le f \le 3$ kHz:

The plots in Fig. T17-3 display the values of MPE for the electric and magnetic fields over the frequency range below 3 kHz. According to IEEE Std C95.6, it is sufficient to demonstrate compliance with the MPE levels for either the electric field E or the magnetic flux density B. According to the plot for the magnetic field H in Fig. T17-3, exposure at 60 Hz should not exceed 720 A/m. The magnetic field due to power lines is typically in the range of 2–6 A/m underneath the lines, which is at least two orders of magnitude smaller than the established safe level for H.

Frequency Range 3 kHz $\le f \le$ 300 GHz:

At frequencies below 500 MHz, MPE is specified in terms of the electric and magnetic field strengths of the EM energy (Fig. T17-4). From 100 MHz to 300 GHz (and beyond), MPE is specified in terms of the product of E and H, namely the power density S. Cell phones operate in the 1–2 GHz band; the specified MPE is 1 W/m^2, or equivalently 0.1 mW/cm^2.

Bottom Line

We are constantly bombarded by EM energy, from solar illumination to blackbody radiation emitted by all matter. Our bodies absorb, reflect, and emit EM energy all the time. Living organisms, including humans, require exposure to EM radiation to survive, but excessive exposure can cause adverse effects. The term *excessive exposure* connotes a complicated set of relationships among such variables as field strength, exposure duration and mode (continuous, pulsed, etc.), body part, etc. The emission standards established by the Federal Communications Commission in the U.S. and similar governmental bodies in other countries are based on a combination of epidemiological

studies, experimental observations, and theoretical understanding of how EM energy interacts with biological material. Generally speaking, the maximum permissible exposure levels specified by these standards are typically two orders of magnitude lower than the levels known to cause adverse effects, but in view of the multiplicity of variables involved, there is no guarantee that adhering to the standards will avoid health risks absolutely. The bottom line is: use common sense!

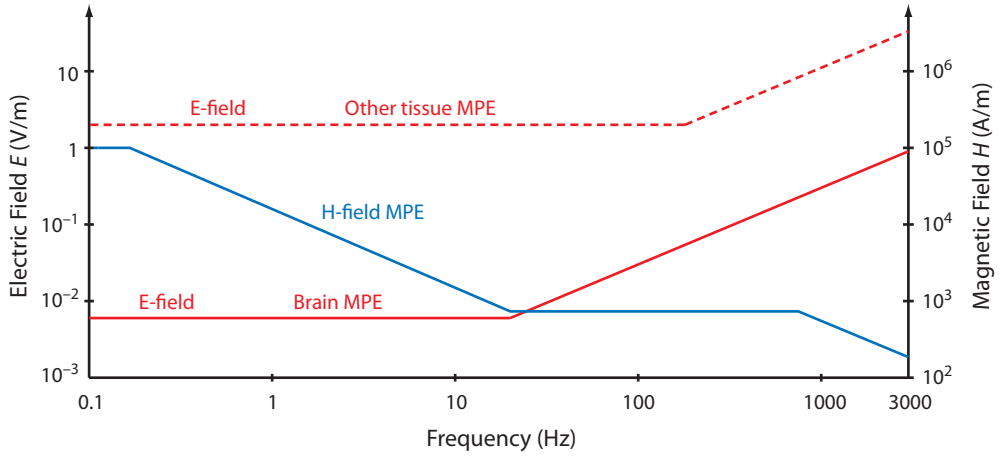

Figure TF17-3: Maximum permissible exposure (MPE) levels for E and H over the frequency range from 0.1 Hz to 3 kHz.

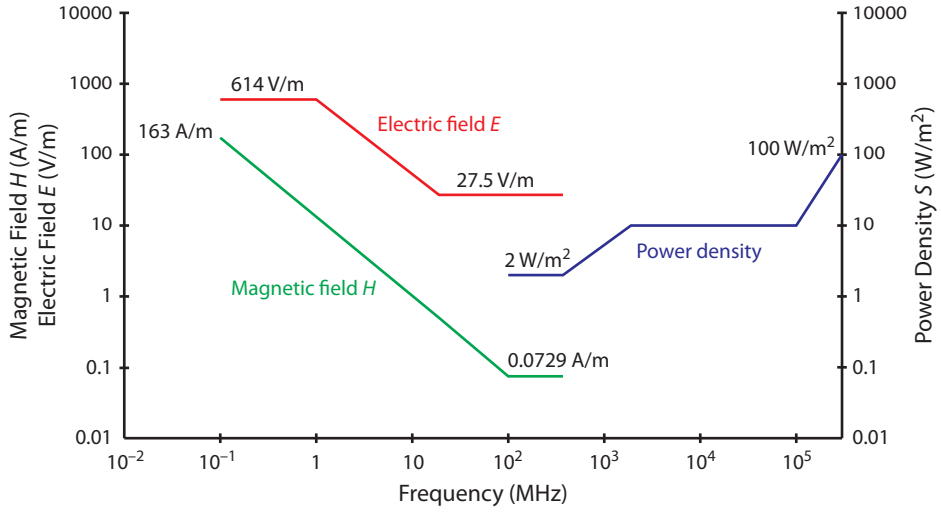

Figure TF17-4: MPE levels for the frequency range from 10 kHz to 300 GHz.