



# Electric and Magnetic Fields

## What are EMF?

Electric and magnetic fields (EMF) are invisible fields surrounding anything that generates, carries, or uses electricity. The majority of electricity is transmitted as alternating current (AC), which fluctuates in strength and direction 60 times per second (i.e. at a frequency of 60 Hertz [Hz]). EMF at this frequency is often referred to as extremely low frequency (ELF) EMF or just EMF.

Electric fields are produced by voltage and measured in units of kilovolts per meter (kV/m). Electric fields are blocked by everyday grounded conductive objects, such as trees, fences, and buildings. Magnetic fields are not blocked by most common materials. Magnetic fields are created by the flow of electrical currents and are measured in units of milligauss (mG). Importantly, however, the strength of both electric fields and magnetic fields decreases rapidly with increasing distance from the source.

## What are Common Sources and Levels of EMF in Our Homes and Communities?

Given that electricity powers most buildings and many devices in our modern world, we are continually exposed to EMF in our daily lives. EMF from household appliances, electrical wiring and power lines are all around us. Buildings (e.g., homes, schools, businesses) have a background EMF level as a result of the combined exposure from multiple EMF sources. Inside buildings, the strongest sources of magnetic fields are from electrical appliances when in use. Table 1 describes 1) the typical magnetic field levels from various appliances and 2) how quickly the strength of magnetic fields decreases with distance. Magnetic fields from outdoor sources, such as transmission and distribution lines also decrease very rapidly with distance.

**TABLE 1: Magnetic Fields Measured from Appliances at Various Distances**

Typical magnetic field levels (mG) from appliance

Source	Distance from Source*		
	6 inches	1 foot	2 feet
Washing Machine	20	7	1
Blender	70	10	2
Dishwasher	20	10	4
Vacuum Cleaner	300	60	10
Electric Can Opener	150	150	20

Source: EMF Questions and Answers (NIEHS 2002).

\*Number represents median magnetic field level from typical appliances.

## What Do Health and Scientific Agencies Say About EMF?

Many prominent health and scientific organizations, including the International Agency for Research on Cancer (IARC), and the European Scientific Committee on Health, Environmental, and Emerging Risks (SCHEER), have conducted weight-of-evidence reviews of research on EMF and their potential health effects. **Based on their evaluations, none of these organizations have determined that exposure to EMF at the levels encountered in everyday life, including those associated with this project, cause any adverse health effects. These conclusions are grounded in decades of rigorous scientific research and analysis.**

*Overall, existing studies do not provide convincing evidence for a causal relationship between EMF exposure and self-reported symptoms.*

- SCENIHR

*The potential health effects of extremely low frequency EMF has been studied extensively. While some people are concerned that long term exposure to extremely low frequency EMF may cause cancer, the scientific evidence does not support such claims.*

- Health Canada

## How Does the Scientific Review Process Evaluate Research on EMF?

When assessing if exposure to EMF affects human health, scientists review all relevant research published in peer-reviewed scientific and medical journals. Each study is evaluated for its strengths and limitations before being analyzed collectively in what is called a weight-of-evidence review. This approach typically incorporates three key types of studies: animal studies; laboratory studies of cells and tissues, and epidemiological studies, which examine health outcomes in human populations.

## Are There EMF Exposure Standards and Guidelines?

Neither the federal government nor the State of Illinois nor Missouri has established standards for limiting exposure to EMF. However, scientific research on EMF has been ongoing for more than 50 years and two scientific organizations—the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the International Committee on Electromagnetic Safety (ICES)—have developed exposure guidelines for exposure to EMF. The purpose of these guidelines is to protect the public and workers from exposures to levels far higher encountered in communities, workplaces and this project based on the only established direct effect of EMF exposure – nerve stimulation.

The ICNIRP and the ICES guidelines for 60-Hz magnetic fields are 2,000 and 9,040 mG, respectively and guidelines for 60-Hz electric fields are 4.2 and 5.0 kV/m, respectively. The Institute for Electrical and Electronics Engineers (IEEE) provides guidance regarding induced electrostatic effects related to electric fields from transmission lines. When conductive objects – like vehicles or fences – are not electrically grounded, electric fields from transmission lines can cause electrical charge to build-up in these objects. While typically very small and not harmful, these electrical charges can discharge in the form of electrical currents when contacted or connected to electrical ground. In the IEEE National Electrical Safety Code (NESC), electrical currents induced by electric fields should be limited to 5 milli-amperes (mA) for large vehicles and equipment under the transmission line.

## Do EMF Interfere with Pacemakers or Other Implanted Cardiac Devices?

Patients with cardiac pacemakers and implanted cardioverter defibrillators ask if EMF will interfere with their devices. Modern pacemakers, ICDs, and other implantable medical devices incorporate advanced technologies such as hermetic shielding, electrical filters, and programmable settings to minimize potential interference from any EMF source, including power lines. In general, compliance with the ICNIRP standards provides protection against harmful interference (ICNIRP, 2010 and EN 550527-1, 2016). Manufacturers also provide guidelines to help users avoid potential interference and other issues. Patients can contact their physician and the manufacturer of their device if they have questions about any source of EMF.

## Do EMF from Transmission Lines Impact Farming Operations?

The National Electrical Safety Code (2023) requires that transmission line conductors be raised high enough above the ground that people do not receive harmful shocks even from contact with large objects such as large farm equipment (e.g., combine harvester). A large number of studies have explored the potential effects of transmission lines and EMF on livestock including cattle, sheep, swine, and poultry to evaluate whether exposure to EMF has adverse effects on health, reproductive performance, behavior, and production (e.g., Malkemper et al., 2018, Pophof et al., 2023). These studies, like studies of people, have not shown that exposure to EMF is harmful to livestock.

## Do EMF from Transmission Lines Affect Solar and Wind Farms, GPS, or AM/FM Radio Signals?

People also often have questions about whether and how EMF from transmission lines might interact with solar and wind generation facilities as well as GPS navigation and AM, FM and TV reception. Wind and solar facilities are used to generate the same 60-Hz electricity that will flow on Project transmission lines and hence will also be sources of EMF at a frequency of 60-Hz. As such, Project-related transmission line EMF are not expected to affect solar or wind facilities. Along with EMF, transmission lines also can create audible noise (AN) (which can be heard as a hissing or crackling sound). This AN is most often heard on or nearby the transmission ROW for 345-kV and above transmission lines, and the noise levels decrease with distance from the line. The same phenomenon that creates AN also creates radio noise (RN) that has the potential to interfere with radio reception. The potential for RN to interfere with communications is most likely for AM radio because RN from transmission lines can be in the same frequency band as AM broadcasts. FM radio, TV and GPS operate at much higher frequencies than AM and so interference from RN is unlikely from these sources. The physical towers of transmission lines may potentially interfere with high-precision GPS applications (such as real time kinematic [RTK] or differential GPS [DGPS]). However, such issues are unlikely and can generally be resolved, if encountered.

## More information about EMF Health Research is available at:

### **Bancroft JB, Morrison A, Lachapelle G.**

Validation of GNSS under 500,000 V Direct Current (DC) transmission lines. *Comp. and Electronics in Agriculture*. 2012.

### **Bipole III Transmission Project: Effects on GPS Technical Report.**

A report of the Manitoba Hydro project by Pollack and Wright. 2011.

### **Health Canada.**

Power lines and electrical products: Extremely low frequency electric and magnetic fields. 2022.

### **International Agency for Research on Cancer (IARC).**

IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Volume 80: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields. Lyon, France: IARC Press, 2002.

### **International Commission on Non-Ionizing Radiation Protection (ICNIRP).**

ICNIRP Statement - Guidelines for Limiting Exposure to Electromagnetic Fields (1 Hz to 100 kHz). *Health Phys.* 2010.

### **International Committee on Electromagnetic Safety (ICES).**

IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz (IEEE Std. C95.1): Corrigenda 2. New York: IEEE, 2020.

### **Malkemper EP, Tscheulin T, Vanbergen AJ, Vian A, Balian E, Goudeseune L.**

The impacts of artificial electromagnetic radiation on wildlife (flora and fauna). Current knowledge overview: a background document to the web conference. A report of the EKLIPSE project. 2018.

### **Lachapelle, G. et al., Manitoba Hydro DC-Line GNSS Survey Report 2011.**

Pophof B, Henschenmacher B, Kattnig DR, Kuhne J, Vian A, Ziegelberger G. Biological Effects of electric, magnetic, and electromagnetic fields from 0 to 100 MHz on fauna and flora: Workshop Report. *Health Phys.* 2023.

### **Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR).**

Opinion on Potential Health Effects of Exposure to Electromagnetic Fields (EMF). Brussels, Belgium: European Commission, 2015.

### **Scientific Committee on Health, Environmental and Emerging Risks (SCHEER).**

Potential Health Effects of Exposure to Electromagnetic Fields (EMF): Update with Regard to Frequencies between 1 Hz and 100 kHz. Brussels, Belgium: Commission E, 2024.

### **Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP).**

A report of the Rockdale to West Middleton 345 kV Transmission Line. 2009.

### **World Health Organization (WHO).**

Environmental Health Criteria 238: Extremely Low Frequency (ELF) Fields. Geneva, Switzerland: World Health Organization, 2007.

### **World Health Organization (WHO).**

Radiation: Electromagnetic Fields. Geneva, Switzerland: World Health Organization.

*This brochure was prepared by scientists and engineers at Exponent, Inc., an international scientific and engineering firm, to present a current summary of the status of EMF research as reflected in reviews by science and health organizations. This brochure is limited to the scientific literature reviewed and may not include all information in the public domain.*