

Information pertaining to electric and magnetic fields (EMF) associated with transmission lines is discussed in this appendix. The discussion provides overview of the physical parameters of EMF and also provides a synopsis of issues regarding the potential risk to human health.

K.1 INTRODUCTION

There is a lack of consensus in the scientific community regarding potential public health impacts due to electric and magnetic fields (EMFs) at the levels generated by electric power facilities. Furthermore, there are currently no federal standards or State CEQA standards for defining health risk from EMF and for limiting human exposure to EMFs, from transmission lines or substation facilities in California. As such, EMF is not considered in this EIR as a CEQA issue and no discussion is provided pertaining to potential impacts and a level of significance determination. However, recognizing that there is a great deal of public interest and concern regarding potential health effects from exposure to, EMFs from power lines, information regarding EMFs associated with electric utility facilities and the potential effects to public health and safety is provided in this section. Refer to Section A.3.6 in Appendix A of this EIR for Project-specific information regarding EMF.

K.2 ELECTRIC AND MAGNETIC FIELDS (EMF)

Electric and magnetic fields and the electromagnetic forces they represent are an essential part of the physical world. The earth produces EMFs, mainly in the form of DC (also called static fields). Electric fields are produced by thunderstorm activity in the atmosphere. Near the ground, the DC electric field averages less than 200 volts per meter (V/m). Much stronger fields, typically about 50,000 V/m, occur directly beneath electrical storms. Magnetic fields are thought to be produced by electric currents flowing deep within the Earth's molten core. The DC magnetic field averages around 500 milligauss (mG). The electric field and the magnetic field are considered and depicted in Physics as electric field lines and magnetic field lines, respectively, that surround an electric current in a conductor. The sources of EMFs are the charged fundamental particles of matter (principally electrons and protons). Electromagnetic forces are partly responsible for the cohesion of material substances and they mediate all the processes of chemistry, including those of life itself (e.g., photosynthesis, respiration, etc.). Electric and magnetic fields also occur naturally within animal life-forms in association with nerve and muscle activity. The EMFs in the environment caused by human technological application of the electromagnetic spectrum include uses such as communications, appliances, and the generation, transmission, and local distribution of electricity.

K.2.1 Electric Fields - Strength and Screening

Electric fields from power lines are created whenever the lines are energized. The strength of the field is dependent directly on the voltage. Alternating current (AC) fields induce weak electric currents in conducting objects, including humans. Electric field strength is typically described in terms of kilovolts per meter (kV/m). Electric field strength attenuates (reduces) rapidly as the distance from the source increases. At close proximity beneath large transmission lines, strong electric fields can cause hair on the exposed head or arms to vibrate

slightly at 60 Hz which is felt by some people as a tingling sensation, as well as cause other static electricity effects. EMFs from transmission lines can also in some circumstances cause nuisance shocks from voltages created by EMFs on objects like ungrounded metal pipes (see Section K.3.2. below).

Potential health effects from exposure to electric fields from power lines are typically not of concern since electric fields are easily screened. Anything that is even slightly conducting will have a screening effect which is why houses screen the field inside them and other physical features in the environment, such as trees, hedges, building materials, and even human skin, can provide screening as well, since they are all sufficiently conducting for this purpose. If the screen is grounded, the earth itself is included in the screen.

K.2.2 Magnetic Fields - Strength and Screening

Magnetic fields are produced by current, which is the flow of electricity. Current, which is measured in amperes (amps) can be likened to the volume of water flowing in a hose when the nozzle is open. Anything that uses or carries mains electricity is potentially a source of power-frequency magnetic fields, which modulate the Earth's steady natural fields. The strength of the magnetic-field modulation depends on the current (often referred to as the load) carried by the equipment. In the case of a power line, the strength of the magnetic-field varies according to the demand for power at any given time. Magnetic fields are usually measured in microteslas (μT) or nanoteslas (nT). One nanotesla is one thousandth of a microtesla. One tesla is one newton per ampere meter (1N/Am). Another unit often used is 1 milligauss = 0.1 microteslas. Typical magnetic field strengths for distribution lines in communities vary from 1 to 80 milligauss under the line. Typical magnetic field strengths for transmission lines vary from 1 to 300 milligauss at the edge of the right-of-way.

The magnetic field produced by a current in a conductor falls with distance from the conductor according to various physical variables and mathematical functions. For example, the inverse square of distance function ($1/r^2$) is obeyed for either a single circuit or a two-circuit but untransposed phasing transmission line. This means that the field strength is reduced to a quarter at double the distance from the line, and at three times the distance, the field is reduced to a ninth, and so on. The inverse cube of distance function ($1/r^3$) is obeyed for a transmission line with transposed phasing, or for a domestic appliance. Per this function, at double the distance the field is reduced to an eighth, and at three times the distance the field is reduced to a twenty-seventh, and so on. Where there is more than one current forming part of one or more electrical circuits, there is also partial cancellation between the magnetic fields produced by the individual currents, and that cancellation generally becomes better at greater distances. Overall, the magnetic field is highest at the point of closest approach to the conductors and falls quite rapidly with distance. Therefore, overhead lines produce a magnetic field which peaks underneath the conductors and falls rapidly with distance at either side. In addition, magnetic fields (as well as electric fields)

depend on the clearance above ground of the line. The minimum ground clearance of a 400 kV line is 7.6 m, dropping to 5.5 m for low-voltage distribution lines, but it is rare for lines to be this low, and the ground-level field falls rapidly with the height of the line above ground. In summary, the maximum fields that are produced by a line occur directly underneath the line, underneath the lowest point of the conductors, which is usually towards the middle of each span (National Grid EMF Unit, 2006).

Unlike electric fields, magnetic fields are little affected by physical features and much harder to screen. The two ways to screen magnetic fields include use of “high permeability” alloys such as mu-metal, or use of a conducting screen such as aluminum. The magnetic field induces currents in the conducting screen which generates its own magnetic field which partially cancels the original field. However, this usually requires quite thick metal plates to be effective.

K.2.3 Power Lines and Frequencies

The two basic types of power lines are transmission lines and distribution lines. Transmission lines are high-voltage power lines that allow electric power to be carried efficiently over long distances from electrical generation facilities to substations near urban areas. In the United States, most transmission lines use alternating current (AC) and operate at voltages between 50 and 765 kV (1kV or kilovolt = 1,000 V). Utilities companies use lower-voltage distribution lines to bring power from substations to businesses and homes. Transformers change the high voltages used by transmission lines to the lower voltages used by distribution lines. Distribution lines operate at voltages below 50 kV. For residential customers, these levels are further reduced to 120/240 V once the power reaches its destination.

The frequency of an AC power line is determined by the rate at which electric and magnetic fields change their direction each second defined by the term Hertz (Hz). One Hertz equals one cycle per second. For power lines in the United States, the frequency of change is 60 times per second and is defined as 60 Hertz. The electromagnetic spectrum covers an enormous range of frequencies from direct current at near-zero Hz to gamma rays at 10^{22} Hz. The higher the frequency, the shorter the distance between one wave and the next, and the greater the amount of energy in the field. Microwave frequency fields, with wavelengths of several inches (ca. 2,450 MHz), have enough energy to cause heating in conducting material. Still higher frequencies like X-rays (ca. 10^{17} Hz) cause ionization—the breaking of molecular bonds, which damages genetic material. In comparison, power frequency fields have wavelengths of more than 3,100 miles (5,000 km) and consequently have very low energy levels that do not cause heating or ionization.

K.2.4 Public Exposure to EMFs

Public exposure to EMFs in developed areas is widespread and encompasses a very broad range of field intensities and durations. In developed areas, EMFs are prevalent from the use of electronic appliances or equipment and existing electric power lines. In general, distribution lines exist throughout developed portions of the community and represent the predominant source of public exposure to power line EMF. Transmission lines are much less prevalent in most developed areas and therefore they generally represent a much lower contribution to overall public exposure to power line EMF. In undeveloped and natural areas, only low level naturally occurring EMFs exist. Measurable EMFs are not present except in the vicinity of existing power line corridors.

K.2.5 The EMF and Public Health Risk Issue

A substantial amount of research investigating both electric and magnetic fields has been conducted over the past 20 years; however, much of the body of national and international research regarding EMF and public health risks remains contradictory or inconclusive. Research related to EMF can be grouped into three general categories including cellular level studies, animal and human experiments, and epidemiological studies. These studies have provided mixed results, with some studies showing an apparent relationship between magnetic fields and health effects while other similar studies do not. For example, some epidemiological studies have suggested that a link may exist between exposure to power frequency EMFs and certain types of cancer, primarily leukemia and brain cancer. Other studies have found no such link. Laboratory researchers are studying how such an association is biologically possible. The beginning of this health concern issue can generally be attributed to publication of the results of a 1979 epidemiological study by Nancy Wertheimer and Ed Leeper (1979). This study claimed to observe an association between the wiring configuration on electric power lines outside of homes in Denver and the incidence of childhood cancer. However, criticism of the study noted that Wertheimer and Leeper did not actually measure magnetic fields from power lines. Instead, they classified the homes according to their wiring code. The wiring code was then used as a surrogate for the powerline magnetic field, which was unmeasured and unknown. Following publication of the Wertheimer and Leeper study, there have been many epidemiological, laboratory, and animal studies regarding EMF that have been conducted. The following websites provide numerous references regarding studies that have been conducted:

- World Health Organization, 2006. <http://www.who.int/peh-emf/project/en/>
- Medical College of Wisconsin, 2005. <http://www.mcw.edu/gcrc/cop/powerlines-cancer-FAQ/toc.html>
- EMF RAPID, 2006. <http://www.niehs.nih.gov/emfrapid/home.htm>

- National Institute of Environmental Health Sciences, National Institutes of Health, 2006. <http://www.lessemf.com/pamphlet.html>

AC fields create weak electric currents in the bodies of people and animals. This is one reason why there is a potential for EMFs to cause biological effects. Currents from electric and magnetic fields are distributed differently within the body. The amount of this current, even if a person is directly beneath a large transmission line, is extremely small (millionths of an ampere). The current is too weak to penetrate cell membranes; it is present mostly between the cells. Extremely Low Frequency (ELF) fields are known to interact with tissues by inducing electric fields and currents in these tissues. However, the electric currents induced by ELF fields commonly found in our environment are normally much lower than the strongest electric currents naturally occurring in the body such as those that control the beating of the heart.

Currents from 60-Hz EMF's are weaker than natural currents in the body, such as those from the electrical activity of the brain and heart. Some scientists argue that it is therefore impossible for EMFs to have any important effects. Other scientists argue that, just as a trained ear can pick up a familiar voice or cry in a crowd, so a cell may respond to induced current as a signal, lower in intensity yet detectable even through the background "noise" of the body's natural currents. Numerous laboratory studies have shown that biological effects can be caused by exposure to EMFs. In most cases, however, it is not clear how EMFs actually produce these demonstrated effects (EMF-Link, 2006a.). Table K-1 provides some reference values for electric field strengths generated by common household items at a distance of 12 inches.

TABLE K-1
TYPICAL 60-HZ ELECTRIC FIELD VALUES FOR
HOUSEHOLD ITEMS AT 12 INCHES DISTANCE

Household Item	Electric Field Strength (kV/m)
Electric Blanket	0.25
Broiler	0.13
Stereo	0.09
Refrigerator	0.06
Iron	0.06
Hand Mixer	0.05
Coffee Pot	0.03

Table K-2 provides some reference values for magnetic field strengths generated by common household items. The table illustrates the phenomenon described in Section K.2.2. above, that magnetic field strength drops off as a mathematical function with distance. The

following website is a good source of additional values for magnetic field strength values from sources in the workshop and the office environments (EMF-Link, 2006b).

TABLE K-2
TYPICAL 60-HZ MAGNETIC FIELD VALUES (IN MILLIGAUSS)
WITH DISTANCE FROM HOUSEHOLD ITEMS¹

Item	1.2 Inches Distant	12 Inches Distant	39 Inches Distant
Microwave Oven	750 to 2,000	40 to 80	3 to 6
Clothes Washer	8 to 400	2 to 30	0.1 to 2
Electric Range	60 to 2,000	4 to 40	0.1 to 1
Fluorescent Lamp	400 to 4,000	5 to 20	0.1 to 3
Hair Dryer	60 to 20,000	1 to 70	0.1 to 3
Television	25 to 500	0.4 to 20	0.1 to 2

¹ Source: Pacific Gas and Electric Company (2005)

In summary, it is possible that future studies will provide sufficient information to establish whether EMFs are a hazard to human health. The newer studies may also show that factors other than EMFs were responsible for effects reported in earlier studies. It is also possible that, even with more research, there will be no scientific resolution to the EMF issue in the near future. As such, the future course of the EMF and public health risk issue will likely involve factors such as: 1) reevaluating the meaning of existing scientific evidence, 2) speculation about the possible results of future studies, and 3) individual perceptions about the relative importance of various potential health risks.

K.3 OTHER RELATED PUBLIC CONCERNS

Other public concerns related to electric power facility projects, are both safety and nuisance issues, and include: 1) radio/television/electronic equipment interference; 2) induced currents and shock hazards; and 3) potential effects on cardiac pacemakers. Each of these concerns is described below.

K.3.1 Radio/Television/Electronic Equipment Interference

Although solar and atmospheric EMF can generate high frequency energy that may interfere with broadcast signals or electronic equipment, this is generally not a problem for transmission lines. The Institute of Electrical and Electronic Engineers (IEEE) has published a design guide (IEEE, 1971) that is used to limit conductor surface gradients so as to avoid electronic interference.

Gap discharges or arcs can also be a source of high frequency energy. Gap discharges occur when an arc forms across a gap in loose or worn line hardware. It is estimated that over 90

percent of interference problems for electric transmission lines are due to gap discharges. Line hardware is designed to be problem-free, but wind motion, corrosion, and other factors can create a gap discharge condition. When identified, gap discharges can be located and remedied by utilities.

Electric fields from power lines do not typically pose interference problems for electronic equipment in businesses since the equipment is shielded by buildings and walls. However, magnetic fields can penetrate buildings and walls thereby interacting with electronic equipment. Depending upon the sensitivity of equipment, the magnetic fields can interfere with equipment operation.

K.3.2 Induced Currents and Shock Hazards

EMF can induce voltages and currents on conductive objects, such as metal roofs or buildings, fences, and vehicles. When a person or animal comes in contact with a conductive object a perceptible current or small secondary shock may occur. Secondary shocks cause no physiological harm; however, they may present a nuisance.

K.3.3 Cardiac Pacemakers

A public concern issue pertaining to electric fields from transmission lines has been the possibility of interference with cardiac pacemakers. There are two general types of pacemakers: asynchronous and synchronous. The asynchronous pacemaker pulses at a predetermined rate. It is generally immune to interference because it has no sensing circuitry and is not exceptionally complex. The synchronous pacemaker, however, pulses only when its sensing circuitry determines that pacing is necessary. Interference from transmission line electric field may cause a spurious signal on the pacemaker's sensing circuitry. However, when these pacemakers detect a spurious signal, such as a 60 Hz signal, they are programmed to revert to an asynchronous or fixed pacing mode of operation, returning to synchronous operation within a specified time after the signal is no longer detected. Cardiovascular specialists do not consider prolonged asynchronous pacing a problem, since some pacemakers are designed to operate that way. Periods of operation in this mode are commonly induced by cardiologists to check pacemaker performance. So, while transmission line electric fields may interfere with the normal operation of some of the older model pacemakers, the result of the interference is generally not harmful, and is of short duration.

K.4 METHODS TO REDUCE EMF

EMF levels from transmission lines can be reduced in three primary ways including shielding, field cancellation, or increasing the distance from the source. Shielding for electric fields, was described previously under Section K.2.1. It was noted that shielding is effective for the electric fields because they can be blocked by most materials, but is of limited effectiveness for magnetic fields.

Magnetic fields resultant from transmission lines can be reduced either by cancellation or by increasing the receptor (i.e., human, animal, or electrical equipment) distance from the source. Cancellation typically is achieved in one of two ways depending on the facility. For a single transmission line circuit consisting of three “phases” (i.e., the three separate conductors on a transmission tower), the configuration of these three conductors can reduce magnetic fields. Due to the three conductors being relatively close together, the cancellation of the respective fields from each wire is enhanced. This technique has practical limitations because of the potential for short circuits if the wires are placed too close together. There are also worker safety issues to consider if spacing is reduced. For a double transmission line circuit (i.e., more than three phase wires), cancellation can be accomplished by arranging phase wires from the different circuits near each other.

The distance between the source of fields and the receptor can be increased by either placing the wires higher above ground, laying deeper underground and underwater cables, or by increasing the width of the ROW. As described previously, for transmission lines, these methods can prove effective in reducing fields because the reduction of the field strength drops rapidly with distance.

K.5 POLICIES, STANDARDS, AND REGULATIONS

A number of counties, states, and local governments have adopted or considered regulations or policies related to EMF exposure. The reasons for these actions have been varied; in general, however, the actions can be attributed to addressing public reaction to and perception of EMF as opposed to responding to the findings of any specific scientific research. Following is a brief summary of regulatory activity regarding EMF.

K.5.1 International Guidelines

The International Radiation Protection Association (IRPA), in cooperation with the World Health Organization, has published Section 8 of the June 13, 1995, draft of the report of NCRP Scientific Committee 89-3 on Extremely Low Frequency Electric and Magnetic Fields, which contains its conclusions and recommendations guidelines for electric and magnetic field exposures. Neither of these organizations has any governmental authority nor recognized jurisdiction to enforce these guidelines. These are based on the 1989 IRPA approved interim EMF exposure guidelines prepared by its International Non-Ionizing Radiation Committee. The guidelines recommended the following limits for occupational exposure and for exposure of the general public in Table K-3.

The IRPA committee based its recommendations on the premise that the existing literature does not provide evidence that EMF exposures at present-day levels have a public health impact that would require corrective action. Its summary position was that “although some epidemiological studies suggest an association between exposure to 50/60 Hz fields and

TABLE K-3
IRPA CONCLUSIONS AND RECOMMENDATIONS
FOR INTERIM EXPOSURE GUIDELINES

Exposure	Electric Field Strength	Magnetic Field Strength at Edge of ROW
<i>Occupational:</i> Whole Working Day	10 kV/m	0.5 mT (=5,000 mG)
Short Term	30 kV/m	5.0 mT (=50,000 mG)
Restricted to Limbs	-	25.0 mT (=250,000mG)
<i>General Public:</i> Up to 24 hours/day		0.1 mT (=1,000 mG)
Few hours/day	10 kV/m	1.0 mT (=10,000mG)

Source:

cancer, others do not. Not only is this association not proven, but present data do not provide any basis for health assessment useful for the development of exposure limits.”

Further, the IRPA guidelines were developed “primarily on established or predicted health effects produced by currents induced in the body by external EMFs,” and those limits correspond to induced current densities that are generally at, or slightly above, those attributable to normal excitation currents occurring physiologically in the body. Thus, the IRPA-recommended exposure limits are orders of magnitude greater than field levels that may create a risk, in the light of extensive evidence reviewed in this report. For the general public, the limits are 4.2 kV/m for electric fields, and 830 mG for magnetic fields. (Micro Wave News, 2006).

K.5.2 National Guidelines

Although the U.S. EPA has conducted investigations into EMF related to power lines and health risks, no national standards have been established. Several bills addressing EMF have been introduced at the congressional level and have provided funding for research; however, no bill has been enacted that would regulate EMF levels.

K.5.2.1 The EMF RAPID Program

The National EMF Research and Public Information Dissemination (RAPID) Program was established by Congress as part of the Energy Policy Act of 1992 to address the question of whether EMF produced by the generation, transmission, and use of electricity poses a risk to human health. The RAPID Program directed the National Institute of Environmental Health Sciences (NIEHS) to submit a report to Congress on the Program’s findings and conclusions about health concerns related to EMF. The NIEHS released its report to Congress in June of 1999. The report concluded that the “NIEHS believes that the probability that ELF-EMF

exposure is truly a health hazard is currently small.” The report also suggested that the electric industry continue its current practices, such as educating the public about EMF, and siting and designing power lines to reduce magnetic fields.

K.5.2.2 NAS Working Group Report

The National Academy of Sciences (NAS) also was involved in the RAPID Program. In May 1999, the NAS/National Research Council committee released an evaluation of the research conducted under the RAPID Program and the 1998 NIEHS Working Group Report (Edison Electric Institute, 2006). Conclusions of the NAS committee include:

- “The results of the EMF-RAPID Program do not support the contention that the use of electricity poses a major unrecognized public health danger.”
- “Labeling power-frequency magnetic fields as a class 2B human carcinogen (possible human carcinogen) conveys to the public a conclusion that our committee believes is not supported by the underlying research.”
- There is no need that “further special research program focused on possible health effects of power-frequency magnetic fields be funded.”

K.5.3 State of California EMF Exposure Guidelines

K.5.3.1 California EMF Program

The California EMF Program’s charge is to support research and provide education about whether exposure to EMF generated by the use of electricity can affect human health. The program goal is to foster a rational and fair approach to dealing with the potential hazards, if any, of exposure to EMF. This goal is accomplished through research, policy analysis, education, and technical assistance. California Public Utilities Commission (CPUC) Decision D.93-11-013 created the California Electric and Magnetic Fields (EMF) Program to research and provide education and technical assistance on the possible health effects of exposure to electric and magnetic fields from powerlines and other uses of electricity. In addition to funding research and policy analysis on this issue, the EMF program provides education and technical assistance to government agencies, professional organizations, businesses, and members of the general public. Under the CPUC decision, this program is funded by money provided by the State’s investor-owned utilities, and is based in the California Department of Health Services (DHS). The California EMF Program produces periodic reports to the CPUC, and its goal is to make its research, policy analysis, and educational products useful to the CPUC in future decision-making. (California EMF Program, 2006).

K.5.3.2 CPUC Guidelines

Although not applicable to the proposed Trans Bay Cable Project, based on the California EMF Program, the CPUC requires that utilities use “low-cost or no-cost” mitigation measures for facilities requiring certification under General Order 131-D. The decision directed the utilities to use a 4 percent benchmark on the low-cost mitigation. The CPUC did not adopt any specific numerical limits or regulation on EMF levels related to electric power facilities. In Decision D.93-11-013, the CPUC addressed mitigation of EMF of utility facilities and implemented the following recommendations (California Public Utilities Commission, 2002):

- No-cost and low-cost steps to reduce EMF levels
- Workshops to develop EMF design guidelines
- Uniform residential and workplace programs
- Stakeholder and public involvement
- A four-year education program
- A four-year non-experimental and administrative research program
- An authorization of federal experimental research conducted under the National Energy Policy Act of 1992.

K.6 SUMMARY

Currently, there is no scientific consensus about the EMF human health risk issue except for a general agreement that better information is needed. Induced currents from AC fields have been a focus for research on how EMFs could affect human health. This is because epidemiological studies have found associations between increased cancer risk and power-line configurations which are thought to be surrogates for magnetic fields. No such associations have been found with measured electric fields.

K.7 REFERENCES

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