ELF Fields: The Continuing Debate

DAVID BARON
Holaday Industries, Inc.

At RF and microwave frequencies, a general consensus exists that IEEE C95.1-1991 (Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz) and its ANSI equivalent reasonably describe the MPEs (maximum permissible exposures) to electromagnetic fields in that frequency range. Not everyone agrees with the levels or some of the conditions that apply, but most accept the standard.

Low-frequency electric and magnetic fields, especially those in the ELF (extremely low frequency) range, continue to be a matter of public concern. At these frequencies, agreement is not universal. This range covers ELF, VLF (very low frequencies), VF (voice frequencies) and LF (low frequencies).

The Swedish guidelines (MPR II) for evaluating fields from VDTs and computer monitors have caused a de facto revision in these band designations. While the Swedish guidelines refer to Band I (5 to 2,000 Hz) and Band II (2,000 to 400,000 Hz), many refer to them as ELF and VLF. These designations cause further confusion when one notes that most of the Swedish Band II falls within the 3,000 Hz and up range of the IEEE C95.1 standard, though with vastly differing limits.

EPIDEMIOLOGICAL STUDIES

The current interest in low-frequency fields dates back to 1979 when an epidemiological study by Nancy Wertheimer and Ed Leeper was published in the American Journal of Epidemiology. The subject was the incidence of childhood cancer in the Denver area. Children living near "high current" electrical supply wiring were found to have two to three times the expected incidence of leukemia, lymphoma, and tumors of the nervous system. The study was widely criticized, among other reasons, for its use of wiring codes. This was a classification system which attempted to describe past exposure to ELF magnetic fields by visually evaluating several factors relating to the electrical distribution connections to the child's home.

Health risks as a result of exposure to VLF and ELF are still subjects of debate.

Several subsequent studies have attempted to duplicate the Wertheimer-Leeper study and address the flaws in the research. The intriguing result is that these studies have tended to show a continuing small, but often statistically significant, increase in the incidence of various cancers with varying types of wiring codes but not any demonstrable correspondence with measured magnetic fields.

More recently, a study published in the January 15, 1995 issue of the American Journal of Epidemiology indicates a possible higher risk for brain cancer, but no increased association between ELF fields and leukemia, although leukemia has been one of the major diseases associated with exposure to ELF magnetic fields.

The varying results and general ambiguity of many studies is in marked contrast to the comparative history of the investigation into the hazards of smoking. Smoking studies showed a dose-response trend (higher exposures result in greater incidence) which does not appear clearly in the ELF fields data. As studies on smoking improved in their methodology, the relative risks increased rapidly, ultimately ending up in the 20 to 30 times range. This same type of development was predicted for the EMF studies some years ago: that relative risks would either move toward one (no effect) or above ten (significant effect). This has not happened.

According to general consensus, the studies have become more rigorous but with basically the same results: perhaps a one and one-half to three times increase in the odds ratio (increase in risk). These increased risks are for cancers with normally low incidence of perhaps 3 in 10,000 per year. If the rate doubles, the incidence is 6 in 10,000 per year. Does one switch to candles, move to the woods, or both?

STANDARDS DO EXIST

Two scientifically-based standards or guidelines currently address ELF electric and magnetic fields. The controversy and debate flares over whether the stated maximum levels are safe or not. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is the successor to the Non-Ionizing

Radiation Committee of the IRPA (International Radiation Protection Association). This organization, working through the World Health Organization of the U.N., has developed a series of guidelines covering non-ionizing EMF exposure for laser radiation, UV exposure, RF fields (100 kHz to 300 GHz), airborne ultrasound, and for 50- and 60-Hz electric and magnetic fields. The guidelines were originally approved in May 1989 and reaffirmed in 1993, based on a review of current developments and studies in this area. The magnetic field exposure limits (Table 1) range from 0.1 mT (1 gauss) for continuous exposure to the general public to 25 mT (250 gauss) for occupational exposure to the limbs. Electric field exposure ranges from 5 to 10 kV/m.

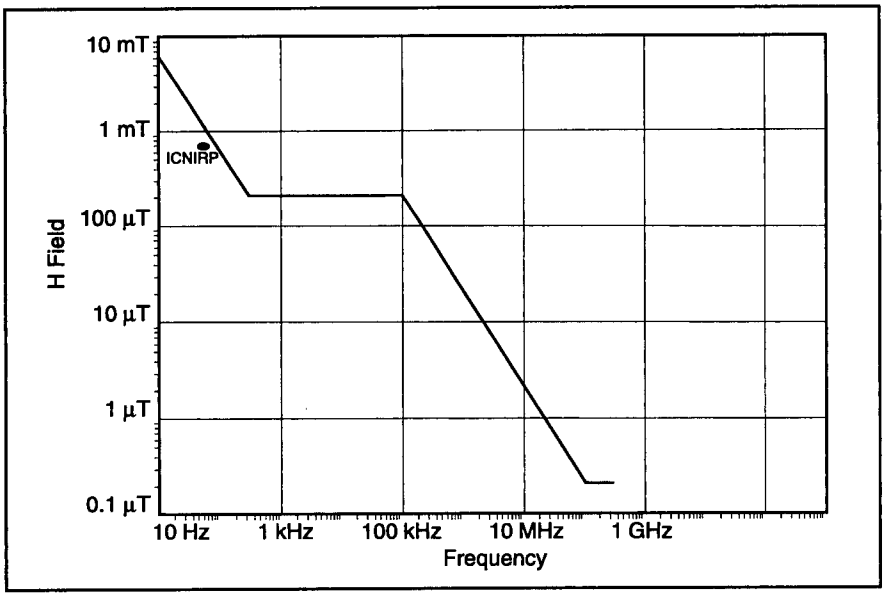

Figure 1. *ACGIH Magnetic Field Limits.*

Exposure Characteristics	Electric Field Strength kV/m	Magnetic Flux Density mT
Occupational		
Whole working day	10	0.5
Short-term	30	5
For limbs	--	25
General Public		
Up to 24 hrs/day	5	0.1
Few hours per day	10	1.0
Note: Short-term occupational exposure defined as less than 2 hours/day		

Table 1. *ICNIRP Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields.*

Sub-Radio Frequency Magnetic Fields (30 kHz and below)		
	H [mT] = 60/f [Hz] (1 < f < 300)	H [mT] = 0.2 (300 Hz < f < 30 Hz)
Sub-Radio Frequency Electric Fields (30 kHz and below)		
	E [V/m] = 25 kV/m (0 < f < 100 Hz)	E [V/m] = 2.6 x10^6/f [Hz] (100 Hz < f < 4 kHz)

Table 2. *ACGIH Threshold Limit Values and Biological Exposure Indices.*

While studies continue on some aspects of electric field exposure, the focus of concern and research is on magnetic fields.

A second set of guidelines has been published by the American Conference of Governmental Industrial Hygienists (ACGIH) in the *Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices.* These are guidelines for exposure to a broad range of potentially hazardous substances and physical agents. The ACGIH biological exposure indices cover the full range of non-ionizing electromagnetic fields from dc (0 Hz) to 300 GHz. This continuous series of guideline values generally agrees with the IEEE C95.1 standard but continues below the 3 kHz lower limit of the IEEE standard. Both standards address the lower exposure limits necessary due to human body resonances between 30 and 300 MHz. Below this band, the acceptable exposures increase due to the reduced interaction between biological tissue and the fields. Table 2 outlines the guideline levels for low-frequency fields (the ACGIH guidelines refer to these as Sub-Radio Frequency). Figures 1 and 2 show the field levels as functions of frequency. The limit at 60 Hz is 1 mT (10 gauss) compared to the ICNIRP value of 0.5 mT (5 gauss). The ACGIH guideline allows for a five-fold increase above the whole-body values for exposure to the extremities only.

WHAT LIMITS TO USE?

How does one resolve existing guidelines with newspaper and magazine articles and TV features that claim that values a thousand times less than the guidelines are dangerous? In Sweden, the guideline for electric and magnetic field exposures from VDUs (video display units, or VDTs in the U.S.) recommends limits at power frequencies of 0.25 µT (2.5 milligauss). The electric field guideline limits are 25 V/m.

Continued on page 258

The controversy at the higher end of the low-frequency range (practically everything other than the power line area) is much less. Two reasons account for this. First, there are few sources of any significance to the general public. The only exception is the computer monitor or VDT. Second, the values generated by the VDT are generally very low. The values of most monitors and VDTs are near or below even the Swedish guidelines, and hence are orders of magnitude below the ACGIH and IEEE MPEs. The high field sources in the VLF range are occupational exposures evaluated according to these science-based standards, and the MPE levels are generally accepted.

In the ELF range, a number of surveyors and consultants refer to ranges of "typical" values when evaluating ELF fields. There are several published lists of fields measured from common sources. Most date from a pamphlet published by the Department of Engineering and Public Policy at Carnegie Mellon University, *Electric and Magnetic Fields from 60 Hertz Electric Power: What Do We Know about Possible Health Risks?* (1989). An article in the August 1990 issue of the *IEEE Spectrum*, "Electromagnetic Fields: The Jury's Still Out," also lists common field levels. The Carnegie Mellon publication proposed the concept of "prudent avoidance." Prudent avoidance is defined as "limiting exposures which can be avoided with small investments of money and effort." The prudent avoidance concept has been criticized by those at both ends of the techno-political EMF spectrum. This broad-spectrum criticism says a lot about the value of looking for a prudent, common-sense approach to ELF field issues.

Using these concepts, measurements can be made at the office or home, and compared with published guidelines and with typical measurements. Office background measured values are typically within most acceptable ranges. Large pieces of electrical utilization equipment (motors, transformers, even some office equipment) may cause high localized fields. An electrical distribution feeder running inside an office wall is another possible source of locally higher field levels. Often simple re-arrangements can reduce the higher fields to which some workers may be exposed. However, it may be difficult to move an office area where VDTs have distorted displays if the office is located directly over the main transformer vault for the building. Localized sources, such as copy machines, must always exist in an office environment. At home, an appliance such as a refrigerator, range or microwave oven will also cause locally higher fields (Figure 3).

Assuming one values the benefits of these devices, they should continue to be used. An intelligent approach is to look for the minimum field areas of the home or office. If these seem to be excessive, it may be necessary to look for a wider-ranging, more pervasive source of the fields. A reasonable background level lets one look at the localized sources and decide on an acceptable level based on personal convenience and benefits derived, contrasted to potential health considerations.

	Band I (5-2,000 Hz)	Band II (2-400 Hz)
Electric Field	25 V/m	2.5 V/m
Magnetic Field	250 nT (2.5 mG)	25 nT (.25 mG)
NOTE: Measured at 50 cm		

Table 3. *Swedish Guidelines for Office Equipment (VDTs).*

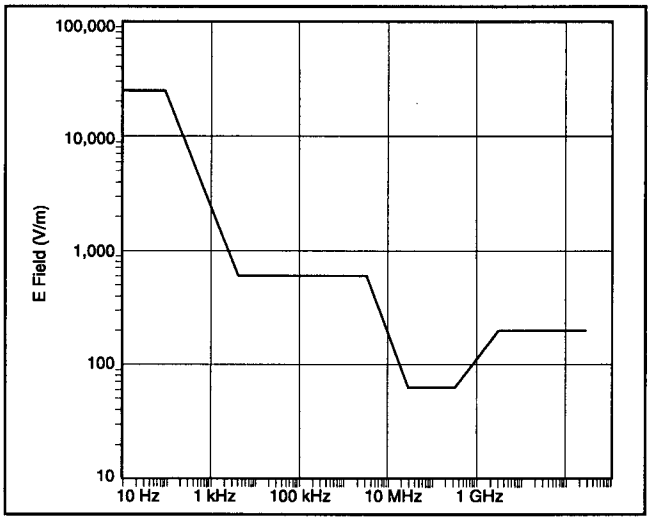

Figure 2. *ACGIH Electric Field Limits.*

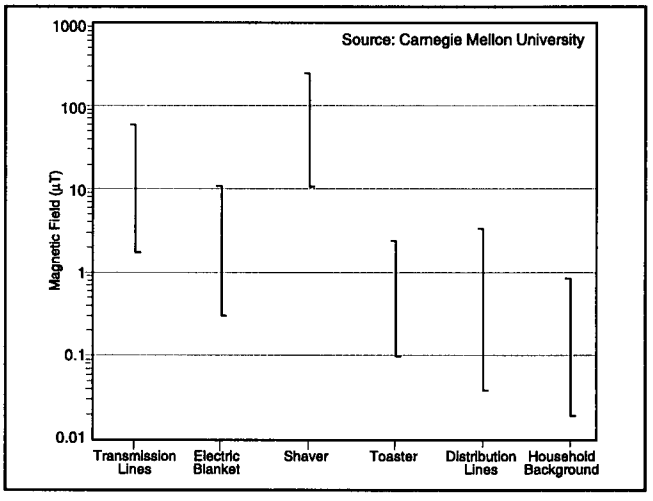

Figure 3. *Approximate Magnetic Field Strengths.*

DAVID BARON *has been a vice president of Holaday Industries since 1985, and currently heads the customer service division. He is a member of the IEEE EMC and Power Engineering societies, and is on IEEE SCC28, subcommittees 2 (Non-ionizing Radiation, Terminology and Units of Measurement) and 3(0-3 kHz, Safety Levels with Respect to Human Exposure). Mr. Baron received his bachelor's degree in electrical engineering from the University of Minnesota in 1964 and is a Registered Professional Engineer in Minnesota. (612) 934-4920.*