11

ELECTROMAGNETIC FIELDS IN THE CLASSROOM

by Andrew A. Marino, Ph.D.

Electromagnetic fields (EMFs) are present in every area of our environment, including the classroom and the home. Dr. Marino shows that although they cannot be seen, EMFs may have a powerful effect on those exposed to high doses of them over a period of time. In describing EME sources outside the school, as well as inside the classroom, he answers questions that teachers and other school staff members often ask about the hazards of computers and other classroom equipment.

- *Why are EMFs a problem in the school and workplace?*
- *How do EMFs affect individuals at various ranges from their source?*
- *How much influence should powerlines, television towers, and other power transmitters have on the location of new school buildings?*
- *How does wiring in the walls of a school affect teachers and children in nearby classrooms?*
- *What shielding devices are available to protect individuals from EMFs?*

Many of the factors capable of affecting the school environment adversely, such as radon and lead, can also degrade the environments of homes, offices, and factories. The electromagnetic field (EMF) is another example of a potential hazard that is not unique to the teaching environment, but that also affects society generally. Our science and general outlook have matured to the point where we can begin to understand and confront the problems associated with all these factors. There was a time when the concept of risk to health was associated with what could be seen, for example, a wild animal, a speeding automobile, or the edge of a precipice. Subsequently, the concept was expanded to include unanticipated consequences of something otherwise innocent: cancer due to smoking, birth defects caused by a morning-sickness drug, or heart disease caused by fats in the diet. Now the possible consequences of something unseen, such as benzene in drinking water or asbestos particles in the air, are also recognized to be within the meaning of risk.

EMFs must be included with this latter group of factors, not because the evidence is overwhelming or crystal clear, but because it would be foolish to do otherwise. Unfortunately, the notion of an EMF is somewhat counter-intuitive, and this presents difficulties in obtaining a realistic understanding of the nature and extent of the inherent risks. Nevertheless, it would be profitable to learn to identify the principal sources of classroom EMFs, and to avoid them, because such efforts provide the best protection against the possibility that EMFs could trigger reactions in the body leading to symptoms and disease.

WHAT TEACHERS SHOULD KNOW ABOUT EMFs

Numerous technical descriptions of EMFs are available, but from the viewpoint of the classroom teacher interested in obtaining a reasonable knowledge of the issue to permit a rational response within the teaching environment, I think that there are only seven facts that must be appreciated to gain a basic understanding of the possible hazards associated with field exposure.

First, EMFs are real in the sense that they can be directly measured by the proper instruments. Just as we might measure distance in meters, time in seconds, temperature in degrees centigrade, or speed in miles per hour, the various kinds of EMFs can similarly be expressed in appropriate units. These units are likely to be unfamiliar to the lay person, but their peculiar names should not obscure the fact that EMFs are real and measurable, and, hence, that there is an objective basis for evaluating the strengths of EMFs at particular locations.

Second, although EMFs are real, they are not composed of atoms, and hence do not have many familiar properties such as weight or shape. An EMF is simply a form of energy, like light. An important difference between light and other kinds of EMFs *(Figure 11-1)* is that the means by which the body detects light—the eye— is known, but the means

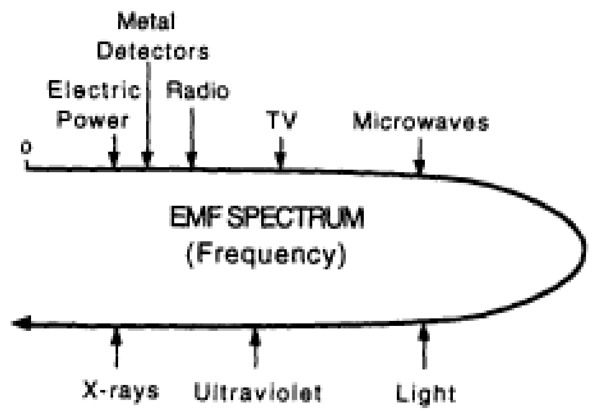

Figure 11-1.
Electromagnetic fields form an infinite spectrum of frequencies. This chart shows the relative location within this spectrum of various familiar uses of EMFs.

Third, since EMFs consist of energy, not matter, they can do things that seem strange if one limits one's thinking to characteristics of material objects. For example, if Johnny adds one apple plus one apple, he winds up with two apples, but if he adds one EMF plus one EMF, he may wind up with two EMFs, a third EMF that is distinct from either of the two original EMFs, or no EMFs at all, depending on the type of EMFs he started with. Such addition and cancellation are basic properties of EMFs.

Fourth, EMFs are created by every electrical device—that is, every device that operates either by battery or by plugging into a wall outlet. For this reason, EMFs in the classroom are not unusual, and it is therefore not their existence that is the object of concern, but rather their cumulative strength and the duration of exposure to them. EMFs are a signature of modern society because, for the most part, they simply did not exist in the everyday human environment prior to the 20th century. It is not possible or desirable to avoid artificial EMFs completely because exposure to them is the price of the myriad benefits made possible by the electrification of society. The focus, therefore, ought to be on the sources of fields in the classroom that are unusual, excessive, or in other ways different from those that exist elsewhere.

Fifth, although EMFs originate from devices powered by electricity, they are not strictly localized to the device itself, but rather spread throughout the surrounding space, becoming progressively weaker as the distance from the device increases. In some instances the spreading of the EMF is an important part of the way the electrical device works. For example, a television signal that is emitted from an antenna is intended to spread so that it can be received by a viewer located many miles from the antenna. On the other hand, the EMF from a computer monitor, fluorescent light, tape player, or electric pencil sharpener is not intended to spread from the respective device; it merely does so as a necessary consequence of the way the device functions, just as exhaust gases are unintended consequences of operating an automobile. The distinction between intended and unintended EMFs is useful for understanding why EMFs may be present in particular environments, but it is irrelevant to a consideration of potential health risks. It would be unwise for a school, for example, to be located near a television tower because of the strong EMFs produced there, and it simply doesn't matter that those EMFs were directly intended to occur as a necessary aspect of the operation of the antenna. The rate at which EMFs become weaker as one moves progressively farther from the source depends on various technical factors, particularly the design of the source. The characteristic distance within which the EMF weakens to the point of vanishing may be one mile from a television antenna, 1,000 feet from a radar, 500 feet from a high-voltage powerline, 100 feet from a telephone communications tower, 50 feet from a building transformer, 10 feet from an electric motor, *5* feet from a computer screen, 1 foot from a light bulb, and 3 inches from an electric clock.

Sixth, the progressive widespread exposure to manufactured EMFs that occurred beginning with this century was based on an assumption of safety, not on affirmative scientific evidence that this was the case. For example, there is no published scientific study showing that children in a school located next to a powerline do not, thereby, undergo an increased health risk. Similarly, there is no scientific evidence suggesting that it would be safe for a child to spend many hours in front of a computer monitor. It would be reassuring if there existed a scientific study that could be reasonably interpreted as showing that being exposed repeatedly to even one kind of EMF was not a health risk. Unfortunately, there is no such evidence. Consequently, the question to be asked is whether the evidence suggesting the existence of risk is credible or not. Much of the remaining portion of this chapter is based on my judgment that the existing state of the scientific evidence warrants the inference that EMFs can be a health risk and, for this reason, that steps ought to be taken to avoid exposure.

There is one final point that everyone should know about health risks such as those due to EMFs: *risk* is an inextricable mixture of value judgment and scientific fact. Risk can sometimes be expressed in a scientific study as a number (see the *Appendix* to this chapter), but this does not indicate that risk is a quantitative measurement in the sense that a minute measures an interval of time or an inch an interval of distance. In contrast, the concept of risk contains a markedly important subjective component contributed by the person making the judgment. Suppose, for example, that Dr. X expresses a judgment of safety under a particular set of EMF exposure conditions. Obviously, such a judgment might be discounted if it were true that Dr. X didn't know anything about EMFs, or had a commercial interest in promoting the electrical device that created them. Although it is less obvious, it is equally true that Dr. X's value system is also a pertinent factor in evaluating the opinion. Suppose, for example, Dr. X believed that it was more important to protect the free and unlimited use of EMFs, rather than burdening such free use for the purpose of providing an added margin of protection to a certain group of device users. The amount of evidence needed to convince Dr. X of risk would then be considerably greater than would otherwise be needed, and the interest of such a Dr. X in an exposed subject not getting sick would simply be a lot less than the exposed subject's would be.

WHY EMFs ARE A PROBLEM

Animal studies are frequently used to evaluate the side-effects of potentially harmful substances. The substances are administered to animals, and from observing the levels at which no important effects are produced, judgments may be made concerning the risks to human beings by employing suitable safety factors. Despite the expenditure of large sums of money on bioeffects research by various industries and governmental agencies, safe doses of EMFs have not been established, because animal studies have not disclosed field levels at which no important effects occur. On the other hand, many studies by independent scientists have shown that EMFs of the type and strength typically found in classrooms can cause diverse and significant effects in animals, including effects on growth, healing, and development. (Rivas, Oroza, and Delgado 1987; Hansson 1981; Grissett, Cupper, Kessler, Brown, Prettyman, Cook, and Griner 1977; Marino, Reichmanis, and Becker, *et al.* 1979; 1980) They can also produce potentially dangerous changes in tissues. (Goodman, Henderson 1988; Bawin, Adey 1976) One of the most important characteristics of EMF-induced effects that was discovered in the animal studies is that not every animal responds to EMFs in the same way. For example, when the effects of EMFs on brain electrical activity in rabbits was measured, the results depended on which rabbit was measured. (Becker, Marmno 1982) The field caused increased electrical activity in 14 rabbits, decreased activity in 6, and caused no change in 4. *(Figure 11-2)* Similarly, the effects of EMFs on human brain electrical activity were not the same in each subject. (Bell, Marmno, Chesson, and Struve 1991) Laboratory studies involving exposure of human beings also suggest that EMFs can be hazardous. The findings include: alterations in blood-fat levels from a one-day exposure (Beischer, Grissett, and Mitchell 1973), in performance on various psychological tests (Gibson, Moroney 1974) and body rhythms. (Wever 1970)

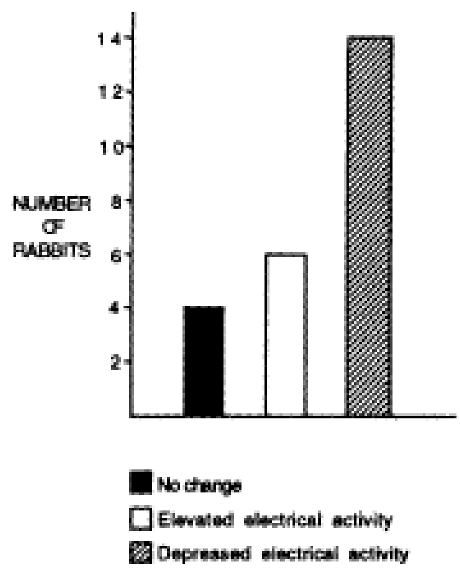

Figure 11-2.

Effect of EMFs on brain electrical activity in rabbits (8). Brain activity was measured in each rabbit before and after a brief exposure to EMFs. The results showed that the effect of the field varied from animal to animal.

Some people are exposed to higher levels of EMFs because of where they live or work. Many studies of such persons have been performed to determine whether the observed levels of disease were similar to those that would ordinarily be expected irrespective of the fields. (Marino 1993) In such studies (called epidemiological studies), the investigators did not apply or control the fields experienced by the subjects; rather, those subjects who had been exposed because of where they lived or worked were identified and evaluated, thereby permitting estimation of the amount of risk associated with field exposure. The first important epidemiological study appeared in 1979; since then, many studies have demonstrated a positive association between exposure to fields and disease (usually cancer). Pertinent details regarding these studies are summanzed in the *Appendix* to this chapter. Not all studies report an association, but there have been enough reports of associations to implicate exposure to fields as a significant factor in human disease.

Fields do not cause disease in the sense that illness results every time individuals receive a specific dose. The usual observation is that the incidence of cancer is greater among subjects who are exposed to EMFs, compared with those who are not exposed, but not all subjects who are exposed develop cancer, and cancer occurs in some who are not exposed. Thus, exposure to EMFs increases the risk for developing cancer, but does not necessarily cause cancer. Some persons, particularly the old or the young, may be particularly susceptible to field exposure, as is frequently the case with toxic agents.

The health risks due to EMFs go far beyond their role in causing cancer. They extend to other diseases, and also have a role in causing various symptoms that do not fit easily into specific diagnostic categories. It is probably the case that EMFs combine with other noxious stimuli and risk factors, thereby taxing the body's overall resistance to disease. *(Figure 11-3)* According to this theory, symptoms of disease develop when an individual's resistance has been exceeded. The particular manifestations that develop depend on the exact mix of adverse factors, which varies from person to person.

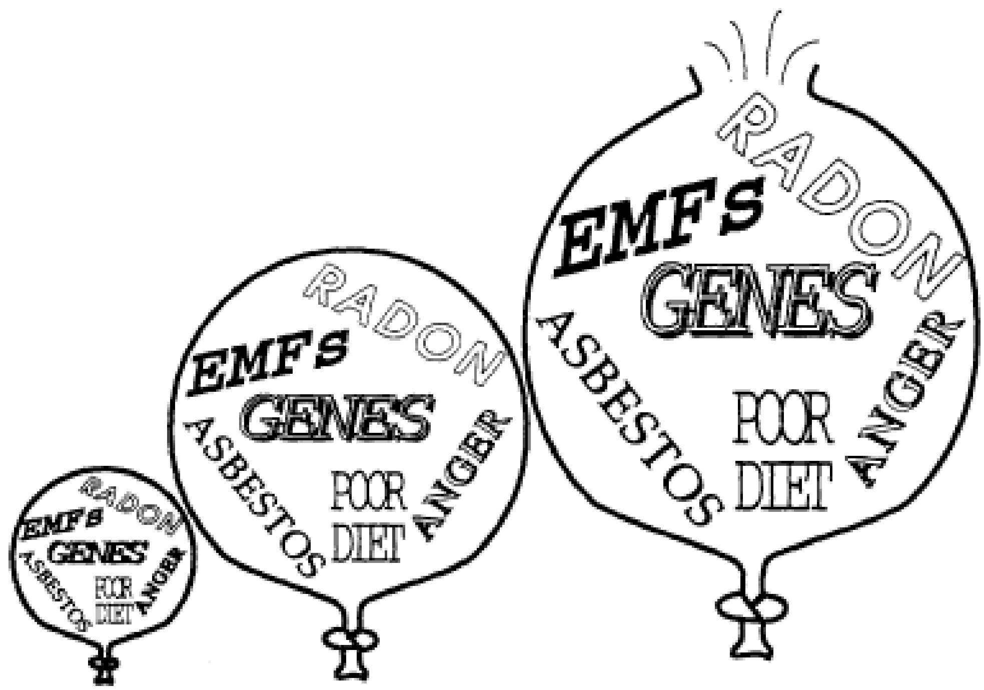

Figure 11-3.
Illustration of the role of EMFs in the total-body-load theory of human disease. No single factor is a complete cause of disease. Each factor adds a burden to the body's adaptive capacity, and disease develops when the body's ability to adapt has been exceeded.

Our present understanding of EMF risks is inadequate in many regards, but perhaps the most glaring shortcoming is the absence of knowledge regarding the effects of EMFs on women. Almost all studies performed to date—both laboratory and epidemiological—have used men as subjects. The most egregious example of this imbalance in the presently available data is that the link between EMFs and breast cancer has been studied in males (see the *Appendix* to this chapter) but not in females. Consequently, judgments of risk to women due to electromagnetic fields must be based solely on extrapolation from animal studies, and from human studies involving children or male subjects.

ELECTROMAGNETIC FIELDS IN THE CLASSROOM

Sources Outside the School

Sources outside of the school building may result in elevated levels of EMFs inside the school, and the continuous and long-term nature of the exposure they produce is a particularly serious concern. For example, *Figure 11-4* depicts a plot of land that is traversed by a 115,000-volt powerline; three possible locations for a school are shown. Location A is near the powerline and consequently would result in continuous exposure to EMFs stronger than 10 milligauss, Location B would result in exposure above 2 but below 10 milligauss, and Location C would result in less than 2 milligauss. Location C would be the optimal choice for the location of the school based on an intention to limit exposure to EMFs, and there is ample reason to do so because studies have indicated that the long-term addition of about 2 milligauss approximately doubles a child's risk of developing leukemia (see the *Appendix* to this chapter). But C may not be the optimal choice from other viewpoints such as cost or convenience. This example illustrates both the importance of choice of location in relation to existing sources of EMFs in reducing EMF levels inside the school, and the financial or other consequences that may be attendant on the choice to provide such protection.

Radio and television towers, as well as microwave communications antennas also emit EMFs that may burden the school environment. For example, the U.S. Environmental Protection Agency (EPA) measured EMFs in McFarland, California at the request of state officials who were investigating a childhood cancer cluster. (Mantiply, Hankin 1989) The EPA had previously determined the median exposure level in U.S. urban areas due to EMFs originating from television and radio signals. The levels measured at School K were more than twice the median level, and additional EMFs from Voice of America transmitters located about six miles away were also detected. *(Figure 11-5)* The EMF levels at School B were three times the median U.S. urban level (and also contained contributions from VOA transmitters). Unfortunately, the final report is not easily read by the lay person, and the significance of the elevated readings is not discussed in relation to health concerns. Nevertheless, the EPA reports are important because they are the public's only present source of reliable information regarding environmental levels of broadcast EMFs.

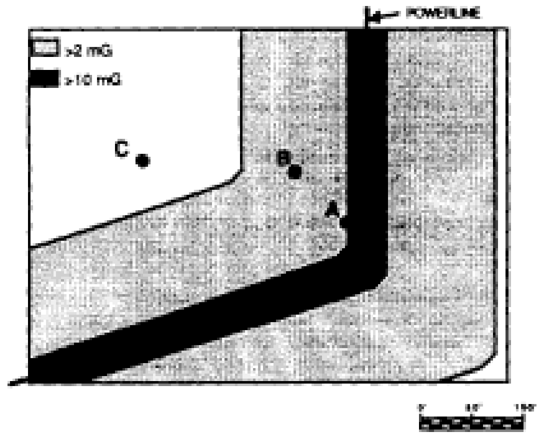

Figure 11-4.
EMF produced by a typical powerline. A 115,000-volt powerline is shown, and the resulting field was calculated under the assumption that the powerline was operating at a normal level. The dark shading indicates the region of strongest field (more than 10 milligauss). The light shading indicates the region where the field is between 2 and 10 milligauss. A, B, and C are possible locations of a new school.

Radio and television towers radiate intense levels of EMFs, and therefore they should not be located near schools. The appropriate separation distance will vary from case to case, but it is difficult to imagine a situation in which it would be appropriate for the distance to be less than 1,000 to 2,000 feet. Communication antennas such as those used by telephone companies, typically emit significantly lower levels of EMFs, and do so in a particular direction (in contrast to radio and television towers, which emit EMFs in all directions). Consequently, depending on the direction in which the EMFs are emitted, it might be appropriate for the distance between a communications antenna and a school to be 100 to 1,000 feet (less, if the EMFs were radiated in a direction away from the school). Once a choice is made to locate a school near a source of EMFs, or to locate a source of EMFs near a school, there are few practical steps that can be taken to shield or otherwise protect the teachers and students.

Sources Within the School

The school itself is a consumer of electric power, which it uses to operate elevators, lights, computers. and many other electrical devices. The conduit for the power is an overhead or underground electrical cable

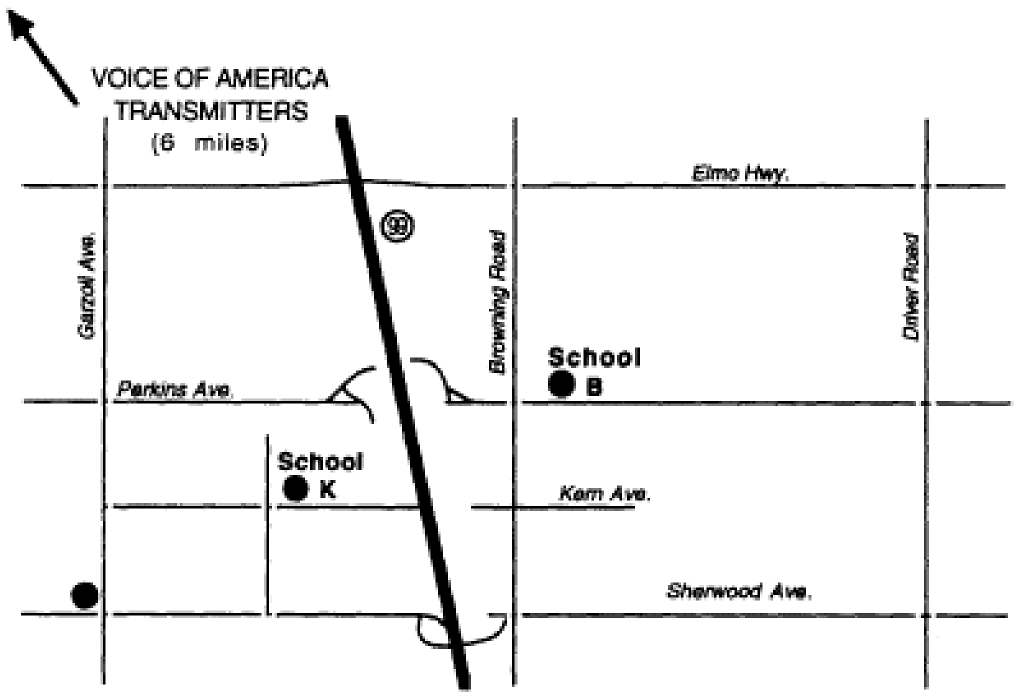

Figure 11-5.
Location of two schools in McFarland, California in relation to Voice of America transmitters. The EMFs from radio and television antennas were found to be much greater than those arising from the Voice of America transmitters. The radio and television EMFs at both schools, however, were significantly higher than typical urban background levels.

originating from the local electric power grid, and ending in an electrical distribution station within the school at which the power is transformed into ordinary line voltage, and then distributed via the school wiring system. The school electrical system itself is sometimes located adjacent to classrooms, thereby resulting in high levels of EMFs within the nearby classrooms. To reduce this exposure, the feed from the power grid should be underground, and the transformers and switching circuitry should be located away from classrooms or offices. If the desirability of such a separation is appreciated prior to construction of the school, it is frequently possible to effect reduction in exposure to EMFs from this source at relatively low cost. The situation is more complicated if an attempt is made to mitigate exposure as a remedial step.

A further source of significant EMFs in the classroom is the school wiring itself. Whatever electric power is consumed in a classroom will inevitably result in EMFs, and thus the exposure to the EMFs arising from that source is a necessary consequence of enjoyment of the benefits provided by electricity. On the other hand, if classrooms are wired in sequence, then all of the electricity consumed in the classroom at the end of a line of wiring must first pass through the wiring in the walls of the upstream classrooms. The result is that the fields produced in the end-of-the-line classroom arise only from the electricity used in that classroom, whereas the fields in the upstream classrooms receive an additional contribution from all of the electricity flowing through the wires in the wall on the way to the downstream classrooms. In a four-classroom sequence, for example, the fields in the classroom closest the to source would receive EMFs about four times as great as the classroom furthest away. Proper attention to the type and configuration of classroom wiring can reduce the fields, and, hence, the resulting exposure.

A measurement of classroom exposure to EMFs produced by the electrical power system are shown in *Figure 11-6.* (Ungichian 1990) To obtain the data shown in *Figure 11-6*, the teachers each wore a small device that measured the EMFs to which they were exposed, and stored the measured values for later analysis; the average value over one school day is shown. For example, the third-grade teacher in School No. 1 was exposed to an average EMF of the type produced by the electrical power system (and the various devices that are operated by being plugged into an electrical outlet) of about 1.3 milligauss. In contrast, on the same day the teacher at School No.2 was exposed to an EMF more than twice as strong, but the teacher at School No. 4 experienced an EMF that was approximately equal to the typical U.S. mean background level.

The average EMF exposure levels such as those shown in *Figure 11-6,* are highly dependent on the activities of the individual teacher, which electrical devices are used by the teacher and the length of time of their use, as well as the distribution of EME sources at or near the school. Thus, it could not be concluded from *Figure 11-6A* that the EMFs at School Nos. 3 and 4 were less than those present in the other schools. This is clearly demonstrated in *Figure 11-6B,* which depicts data obtained during four successive weeks at School No. 3: all of the measured exposure levels were significantly greater than the levels initially measured in the 5th-grade classroom. An insight into the typical exposure pattern of an individual teacher can be obtained from *Figure 11-7.* The

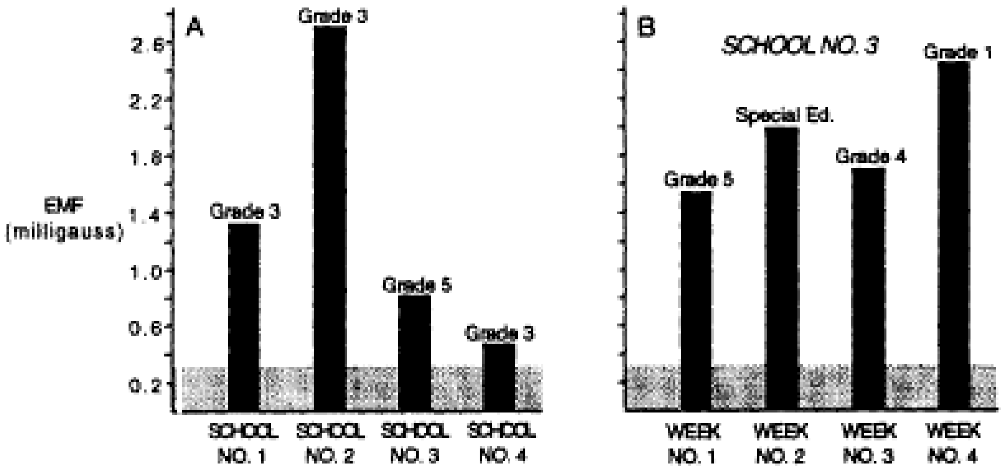

Figure 11-6.
EMFs in typical elementary schools in Florida. The measurements were made using a recording device worn by classroom teachers throughout the school day. Graph A shows the average results of measurements made on the same day in four different schools. Graph B shows average measurements made at weekly intervals in School No. 3. The shading indicates the overall average background EMF of the type measured.

teacher was in one classroom except for 12:20 to 12:40 p.m. when she was in the school lunchroom, and after 1:50 p.m. when she was on car duty in front of the school and then in the school office.

Specific Sources of EMFs

If an electrical device operates by means of batteries (for example, a cellular telephone) or plugs into a wall outlet, it is a source of EMPs and merits consideration with regard to the conditions under which it is

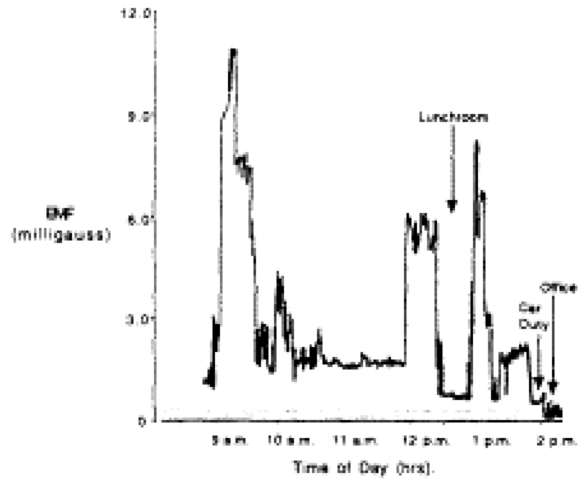

Figure 11-7.

The EMF experienced by a third grade teacher at School No. 2 during the course of the school day. The teacher was in one classroom, except where otherwise indicated. Shading shows the overall average background EMF of the type measured.

used, with the viewpoint of minimizing or eliminating exposure to the resulting EMFs. Computer screens and TV monitors are a significant source of EMFs *(Figure 11-8)*, and this fact should be considered in a decision regarding when and how the device is to be located and used. Many companies now market devices that reduce EMF exposure from computer screens and monitors, but none of the devices provides complete protection. Moreover, the federal government has not set standards by which a consumer could determine the nature and extent of the protection provided. Nevertheless, some objective testing procedures do exist, and have been adhered to by various manufacturers. These devices should be standard equipment on all computer screens and video monitors in the school room, not because the protection they provide is perfect, but because it would be imprudent to do otherwise.

All cellular telephones on the market today produce extraordinarily high levels of EMFs, compared with the levels present when the device is not operating. *(Figure 11-9)* From the point of view of the welfare of a passively exposed child, it is difficult to rationalize permitting repeated exposure for the benefit of the user of the cellular telephone.

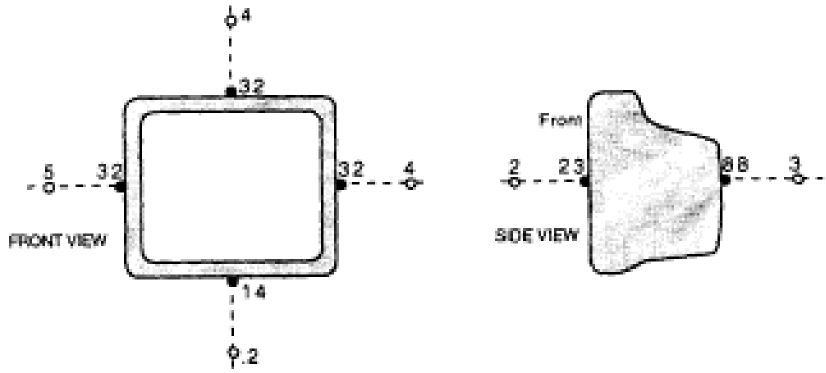

Figure 11-8.
EMF (in milligauss) produced at the surface (solid dot) and at one foot in each direction (open dot) by a Macintosh SE computer (data from Electrical Power Research Center, Iowa State University). Because of the type of measuring instrument that was used, only a portion of the EMF produced by the computer was measured. The fields were reduced an average of 71% following installation of a magnetic-field shield inside the computer (Fairfield Engineering, Fairfield, IA).

SUMMARY AND RECOMMENDATIONS

Electromagnetic fields of the type produced by common and familiar devices may result in relatively high doses of field exposure, and can produce a significant risk to health. High EMF doses can come about as a result of either short exposure to high-strength EMFs, or long-term exposure to low-strength EMFs. Presently, there is no reasonable evidence suggesting what might be regarded as a safe dose of any type of EMFs, but considerable evidence exists indicating that EMFs have profound effects on animal and human physiology, and are associated with the occurrence of disease in human subjects (cancer has been studied most). Taken as a whole, this evidence indicates that one's personal risk comes into being when the dose of EMFs received is greater than the average background exposure that is a necessary consequence of the extent of the electrification of modern society. Therefore, for the individual, the goal is to identify the sources of EMFs in one's personal environment, and to minimize the resulting exposure by modifying the extent or nature of the use of the device with the ultimate aim of achieving a kind of parity in EMF dose received with that of other members of society. Then, an individual's risk of EMF-related disease would be no greater than that of others, and it is not possible to improve

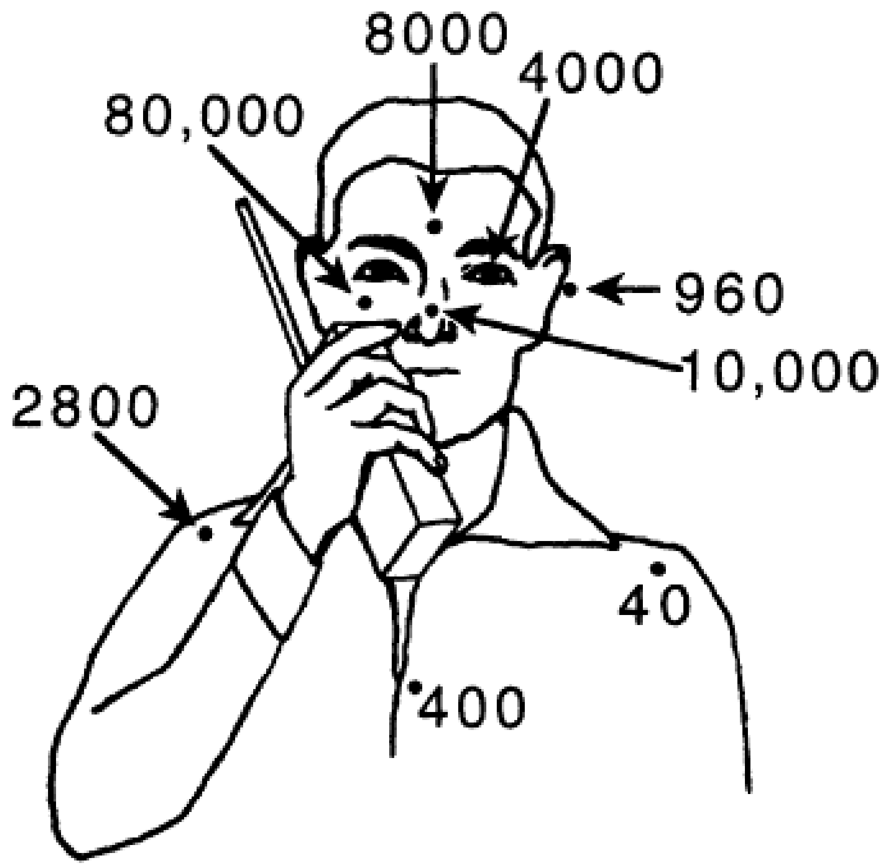

Figure 11-9.

EMF exposure in the vicinity of the face and head of a user of a cellular telephone. The illustration is based on measurements by the EPA and has been scaled to represent a typical cellular telephone. The data is expressed with reference to the median U.S. exposure levels to broadcast EMFs, as determined by the EPA. For example, the typical shoulder-level EMF exposure (right side) is 2,800 times greater than the median U.S. exposure level.

on this degree of risk while still enjoying the benefits of modern society. Further, as is true of smoking, not everyone exposed to EMFs develops disease, and not all disease is attributable to EMFs; consequently, it's clear that other factors must function as co-causes in bringing about any particular symptom or disease. The total-body-load theory of disease *(Figure 11-3)* provides a rational basis for self-protection even when EMF exposure is unavoidable. Consequently, **it** is prudent to survey one's environment, work habits, and the activities of others that potentially impact on one's work environment, and to eliminate gratuitous or otherwise avoidable EMF exposure.

EMF audits ought to be conducted in each classroom by competent and independent engineers for the purpose of identifying the devices, activities, and outside sources of EMFs that result in significant classroom exposure of teachers and students. Such an audit should include both the type of EMFs associated with the electrical power system, and broadcast EMFs such as those from television and radio towers, and cellular telephones. Much of the present exposure experienced by teachers and pupils is unnecessary in the sense that **it** could easily be reduced or eliminated. Other sources of EMF exposure such as the nearby powerline or television antenna cannot be easily moved, and, where they are concerned, the question of what, if anything, ought to be done to reduce EMF exposure should be a joint decision involving both those responsible for producing the EMFs, and those who are subjected to it. Only when the interests of both groups are represented can an appropriate balance between risks and benefits be struck.

Some devices—cellular telephones, for example—simply should not be operated routinely around children because they result in very high EMF levels in the vicinity of the user.

Shielding devices of various kinds are presently on the market, and they should be considered in the construction of schools and the operation of equipment within schools. For example, glasses, windows, and glazed panels that pass light but block other EMFs such as those from radio and television antennas are available and could be used to lessen significantly the levels of such EMFs in individual classrooms. Similarly, shields that provide some protection against EMFs from computer monitors are available. Presently, such devices do not provide complete protection, but the amount of EMF exposure reduction that they can bring about warrants their routine use in the classroom to minimize exposure of teachers and students. It is likely that the extensive use of even the present generation of imperfect devices would lead both to better devices, and to appropriate redesigns of computer equipment and monitors, thereby eliminating the problem at its source.

REFERENCES

Bawin, S. M., and W. R. Adey, 1976, "Sensitivity of calcium binding in cerebral tissue to weak environmental electric fields oscillating at low frequency." *Proceedings of the National Academy of Science,* 73:1999-2003.

Becker, R. 0., and A. A. Marino, 1982, *Electromagnetism & Life,* Albany, NY: State University of New York Press, p. 99

Beischer, D. C., J. D. Grissett, and R. E. Mitchell, 1973, *Exposure of Man to Magnetic Fields Alternating at Extremely Low Frequency,* Pensacola, FLA, Naval Aerospace Medical Research Laboratory.

Bell, G., A. A. Marino, A. Chesson, and F. Struve, 1991, "Human sensitivity to weak magnetic fields, *The Lancet,* 338: 1521-1522.

Gibson, R. S., and W. F. Moroney, 1974, *The Effects of Extremely Low Frequency Magnetic Fields on Human Peiformance,* Pensacola, FIA, Aerospace Medical Research Laboratory.

Goodman, R., and A. S. Henderson, 1988, "Exposure of salivary gland cells to low-frequency electromagnetic fields alters peptide syntheses," *Proceedings of the National Academy of Science,* 85:3928-3932.

Grissett, J. D., J. L. Cupper, M. J. Kessler, R. J. Brown, G. D. Prettyman, L. L. Cook, and T. A. Griner, 1977, *Exposure of Primates for One Year to Ekctric and Magnetic Fields Associated with ELF Communications Systems,* Pensacola, FLA: Naval Aerospace Medical Research Laboratory.

Hansson, H-A., 1981, "Lamellar bodies in Purkinje nerve cells induced by electric field," *Brain Research* 216: 187-191.

Lambdin, D. L., 1979, *An Investigation of EnergyDensities in the Vicinity of Vehicles with Mobile Communications Equ~pment and Near a Hand-Held Walkie Talkie,* ORP/EAD 79-2, Las Vegas NV, U.S. Environmental Protection Agency.

Mantiply, E. D., and N. N. Hankin, 1989, *Radiofrequency Radiation Survey in the McFarland Cailfornia Area,* U.S. Environmental Protection Agency, EPA/520/6-89/022.

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Marino, A. A., 1993, "Electromagnetic fields, cancer, and the theory of neuroendocrine-related promotion," *Bioelectrochemistry & Bioenergetics* 29: 255-276.

Marino, A. A., M. Reichmanis, and R. 0. Becker, 1979, "Fracture healing in rats exposed to extremely-low-frequency electric fields," *Clinical Orthopedics & Related Research,* 145: 239-244.

Marino, A. A., M. Reichmanis, R. 0. Becker, B. Ullrich, andJ. M. Cullen, 1980, "Power frequency electric field induces biological changes in successive generations of mice," *Experientia* 36: 309

Rivas, L., M. A. Oroza, andJ. M. R. Delgado, 1987, "Influence of electro-magnetic fields on body weight and serum chemistry in second generation mice," *Medical Sci. Research* 15: 1041-1042.

Ungichian, V., 1990, *Sandpiper Shores 60-Hertz Magnetic Field Pro]ect,* Florida Atlantic University.

Wever, R., 1970, "The effects of electric fields on circadian rhythms in man," *L~fe Sci. Space Research* 8: 177-187.

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APPENDIX

Summary Of The Peer-reviewed Scientific Literature Dealing With The Link Between Exposure To Electromagnetic Fields And Cancer

The studies listed establish that exposure to electromagnetic fields, regardless of frequency, has been consistently linked with increased risk for cancer. For further details and a complete citation of the references cited in this table see *Marino 1993* listed in the REFERENCES section of this chapter.

Reference from Marino 1993	**Place and time**	**Parameter evaluated**	**Increased risk due to EMF**
69	Denver, CO 1950-73	Childhood cancer	*130%
70	Denver, CO 1976-83	Childhood cancer	*50%
71	Seattle, WA 1981-84	Leukemia	50%
73	Rhode Island, 1964-78	Childhood leukemia	10%
74	Los Angeles, CA, 1980-87	Childhood leukemia	*70%
75	Stockholm, 1958-73	Childhood tumors	*110%
76	England, 1971 -83	Cancer Lung cancer (female)	0 *80%
77	Sweden, 1960-73	Cancer (males) Cancer (females)	*15% *8%
80	Polish military, 1971 -80	Cancer Leukemia & lymphoma	*200% *590%
81	New Hampshire, 1952-77	Leukemia	*240%
83	Canada, 1965-73	Leukemia -	*250%
84	Sweden, 1961 -73	Leukemia	0
85	Washington, California, 1979-84	Leukemia	*80%

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Reference from Marino 1993	**Place and time**	**Parameter evaluated**	**Increased risk due to EMF**
86	Sweden, 1977-82	Leukemia	*280%
87	USA, 1983-87	Male breast cancer	*80%
88	Montreal, 1976-83	Melanoma	*170%
95	Greater Denver, CO, 1967-77	Cancer	*30%
96	England, 1 983-85	Leukemia Lymphoma	20% 20%
97	London, 1 965-80	Leukemia	20%
98	USA	Leukemia	*150%
99	France, 1 984-88	Leukemia	*300%
100	New Zealand, 1980-84	Leukemia	*60%
101	England & Wales, 1973	Leukemia	*130%
102	USA, 1985-86	Brain cancer	*40%
91	Maryland, 1969-82	Brain cancer	*120%
103	USA 1978-81	Brain cancer	*130%
104	East Texas, 1969-78	Brain cancer	*360%
105	Washington, 1950-79	Leukemia	*4Q%
106	Washington state, California, 1971 -83	Leukemia	*90%
107	London, 1961 -79	Leukemia	*20%
108	Los Angeles, 1972-79	Leukemia	30%
109	Wisconsin, 1963-78	Leukemia	0
101	England & Wales, 1970-72	Leukemia	0
110	Finland	Leukemia	20%

*Statistically significant increase ($P < 0.05$)