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CANCER AND POWER LINES

Do the all-pervasive low-frequency electromagnetic fields of modern life threaten our health? Most probably not, judging from comparisons with the natural fields present in the environment and in our bodies.

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Epidemiologists[1] in Denver, Los Angeles and Sweden are asking us to believe that magnetic fields of 2 milligauss from power distribution lines are a serious cause of childhood leukemia. What started as a series of sensational articles in *The New Yorker* magazine by Paul Brodeur (later collected into a book[2]), bringing the earliest of these studies to the attention of the general public, has turned into a new growth industry. Several government agencies, not to mention the private electric power industry, have already sponsored multimillion-dollar studies of the problem; a number of small companies selling 60-Hz gaussmeters have sprung into existence and are doing a land-office business; and the public concern over this issue has become a bonanza to groups of people doing epidemiological and biological research on the effects of electromagnetic fields. Hastily contrived legislation in a number of states has legalized the status quo for fields from power lines, and the threat of still more ill-thought-out legislation is on the horizon—mandating, for example, warning labels on toaster ovens and television sets similar to those now found on cigarettes.

The popular articles and epidemiological studies have all been criticized.[3] The studies were retrospective, using data gathered after the fact from secondhand sources. They all suffered from inadequate statistical samples; in some samples the exposed and control groups differed by as little as one case of cancer per year. The studies are mutually inconsistent and self-contradictory, with spot measurements of the fields seldom confirming the historical estimates used in the studies. They are also extremely prone to systematic error. None of the studies involved a reliable quantitative measure of the actual exposure to 60-Hz fields over the daily lives of the individuals. Also, they concentrated on population groups exposed to magnetic fields that are minuscule compared with those occurring naturally on the Earth's surface. To the extent that the fields coupled inside the body are small compared with thermal noise and other unavoidable natural sources, it is foolish to worry about the health effects of fields from power lines. Hence it is useful to examine the physics of the problem.

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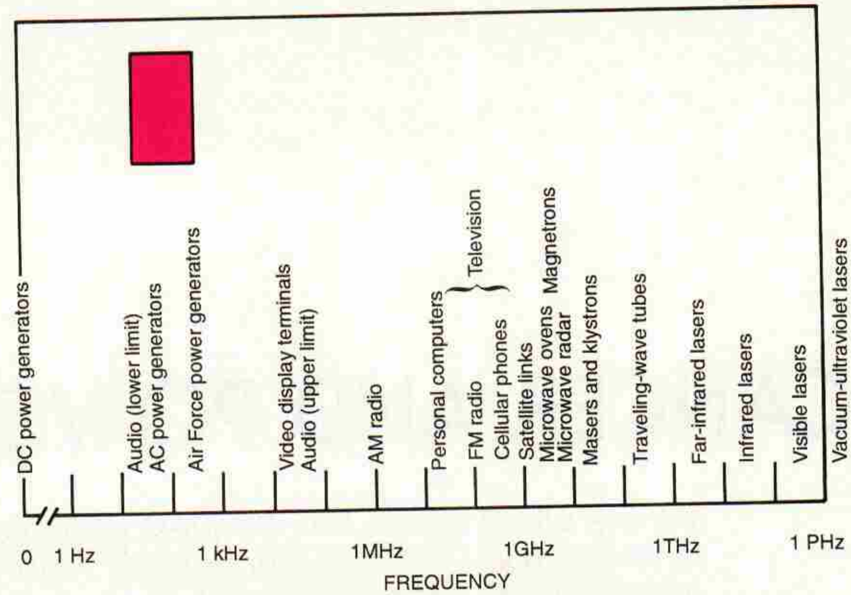
Natural sources of exposure

The Earth's magnetic field is generated predominantly by circulating currents of uncertain origin well below the crust. The field varies over the Earth's surface from about 300 mG at the equator to 700 mG at the poles. A representative value over the continental United States is about 450 mG, about 200 times that from typical distribution lines. The magnetic field has a quasiregular diurnal variation of about 0.1–0.3 mG due to photoionization of molecules in the upper atmosphere. Sudden fluctuations often exceeding 100 mG are correlated with unusual solar activity.

The Earth's static electric field is directed downward normal to the earth's surface and is about 120 V/m near ground level, about three times the field from a 12-kV distribution line. Assuming the Earth is a conductor, this value implies a negative charge density on the surface of about 10^{-3} coulomb/km^2. This charge comes from the combination of collisional ionization of air molecules by protons in the Van Allen radiation belt and the molecular photoionization processes mentioned above. Diurnal fluctuations analogous to those encountered for the magnetic field occur in the electric field. Enormous fluctuations in the ionosphere are correlated with solar activity. Thunderstorms generate extreme localized electric field intensities. A typical lightning bolt—of which there are about 40 million a day worldwide—requires a

Frequency ranges for various electromagnetic power generators. The ELF range is in red. (Adapted from ref. 4.) **Figure 1**



field of about 3 MV/m to ionize air and produces peak currents of 10–20 kiloamps.

The nature of ELF electromagnetic fields

Maxwell's equations describe the temporal and spatial dependence of electromagnetic fields and give very good agreement with observed classical phenomena over an enormous range in frequency—certainly from dc to optical frequencies. For atomic dimensions and for frequencies comparable to atomic or molecular transitions, a satisfactory theory requires combining Maxwell's equations with quantum theory. However, for describing the effects of extremely-low-frequency fields at dimensions comparable to or larger than 1 μm (characteristic of the dimensions in cell biology) the classical form of Maxwell's equations should be quite reliable. As I. I. Rabi used to tell his students at Columbia when they had trouble with electronic apparatus, "All you have to do is take Maxwell's equations and apply the boundary conditions!"

Although the solution of Maxwell's equations can be formidable when the electromagnetic wavelengths are comparable to the dimensions of the objects involved, there is enormous simplification in the ELF range. By international convention, the ELF band consists of frequencies between 30 and 300 Hz—thereby including the fundamental through third harmonic of most ac power sources. (See figure 1.) The free-space wavelength of a 60-Hz wave is about 3000 km. One can solve most problems by merely finding the corresponding static solutions, for which the electric and magnetic fields separate. One then obtains the full ELF solution by multiplying the static fields by a sinusoidal time variation. The main difficulty in solving problems related to the cancer controversy is determining what the wiring geometries, currents and voltages actually were so that one can calculate the fields. Nevertheless one may easily evaluate the fields for representative conditions. Most cases of interest involve classic examples treated in textbooks on electromagnetic theory.

In spite of the frequent discussion in the popular press about "emissions" from power lines, there is no significant radiation. The Poynting vector $\mathbf{E} \times \mathbf{H}$ is along the direction of the power line. Human exposure to power lines is a near-field, nonradiative problem. Further, the binding energies of biological molecules must be larger than kT at body temperature; from the Bohr relation, any single-photon dissociation process would require frequencies of more than 6 terahertz. Clearly power-line frequencies are at least 10 billion times too small to produce single-photon dissociation or ionization of such molecules.

Modern urban sources

I recently calculated and measured values for a variety of typical and "worst case" magnetic and electric fields in the urban environment.[4] (See table 1.) The highest ELF fields of large spatial extent in well-populated environments were encountered near electric railroads, not on urban streets. The calculated fields shown in figure 2 are based on maximum engine horsepower ratings and typical trolley wire voltages and geometries. The peak and average magnetic fields for railroads shown in table 1 are from measurements I made at 2-second intervals in the last car of a Washington-to-New Haven Amtrak train. The largest magnetic fields encountered anywhere in the environment were from home appliances. (See figure 3.) But these fields often involve current loops of small diameter and fall off rapidly away from the device. Most people do not spend much time close to the bigger fields.

As was well known to Benjamin Franklin, the presence above the ground plane of a vertical conductor with a sharp point results in a substantial increase in the local electric field over that originally present. Because people are much more conductive than the surrounding air, there can be a significant increase in the electric field at head level. From theoretical analysis and experimental measurement, we know that the actual fields can go up by a factor of about 20 at head level for a well-grounded person. Thus the maximum fields under a power line might be increased from 60 to 1200 V/m. The highest peak electric fields at head level that I studied were 2 m above the tracks of electric railroads and amounted to about 600 V/m. Hence the worst case would be for a person standing barefoot on the wet tracks of an electric railroad; the fields at head level might then amount to approximately 12 000 V/m. (Of course, dangers much worse than induced electric fields lurk in this situation.)

Coupling of ELF fields to the body

Magnetic fields. Because the permeability of living tissue is close to that of free space, magnetic fields go right through the body. However, direct interaction with an applied magnetic field could be important only in the presence of permanent magnetic domains that are big enough to provide an interaction energy large compared with kT. Even then, the interaction would primarily be important with dc fields. Viscous damping by fluids in tissue plasma severely limits[5] the energy coupled to such a magnetic dipole at cellular dimensions for fields oscillating at 60 Hz.

Permanent domains of magnetite have been found in living organisms from bacteria to marine animals and humans. Torques on these magnetic domains produced by the Earth's static magnetic field may serve as a navigational tool in some animals. A single magnetite domain is about 500 Å wide and has a magnetic moment μ of about 6×10^{-17} A m^2. Chains of 22 such particles in *Aquaspirillum magnetotacticum* bacteria have been reported, with total magnetic moments μ of about 1.3×10^{-15} A m^2. Even there, the interaction energy $\boldsymbol{\mu} \cdot \boldsymbol{B}$ with the Earth's magnetic field is only about kT at body temperature.[4] The interaction energy of a single isolated domain, like that found in the human adrenal gland,[6] with a field of only 10 mG would be approximately 0.01 kT. Hence direct interaction with magnetic fields from power lines would be swamped by thermal effects.

Electric fields. Charles Polk[7] has noted that the relative values of the conductivity and permittivity of biological tissue with respect to air at power-line frequencies are such that external electric fields are always normal to the surface where they enter the body and the internal field E_{int} is always many orders of magnitude smaller than the external field in air E_{air}. This result comes about by application of boundary conditions derived from Maxwell's equations for the normal component of the electric field across the air–tissue interface. Thus assuming $\sigma_{\text{int}} \gg \omega\varepsilon_{\text{int}}$ and $\omega\varepsilon \gg \sigma_{\text{air}}$,

$$|E_{\text{int}}/E_{\text{air}}| \approx \omega\varepsilon_0/\sigma_{\text{int}} \approx 0.7 \times 10^{-8} \qquad (1)$$

where ω is the angular frequency (evaluated for 60 Hz), ε_0 is the permittivity of free space (approximately that of air), and a value of approximately 0.5 siemens per meter, characteristic of the body's electrolyte, has been used for the internal conductivity σ_{int}. The solution assumes a steady-state variation of the surface charge distribution between the air and the body at the line frequency. The conductivity and permittivity of biological materials vary negligibly over the ELF frequency range, and the assumptions made in equation 1 are good to better than one part in 1000.

For our worst-case scenario—the external electric field of 12 000 V/m near the head of a barefoot railroad-track walker in the rain—the peak internal field in the body's electrolyte would be only about 80 μV/m.

The Lorentz force and Faraday's law

The effective electric fields inside the body due to the magnetic force $q\mathbf{v} \times \mathbf{B}$ on moving charges provide a useful reference.

An astronaut traveling in a west–east orbit 200 miles above the Earth would experience a field of about 0.4 V/m throughout his or her body, while passengers in a jet flying across the country at 500 mph would experience a field of about 0.011 V/m.

Blood flows through the aorta at about 0.6 m/sec during systole. Hence a 10-mG field from a power distribution line would generate electric fields of about 0.6 μV/m in this flow. In contrast, the corresponding electric field in the aorta due to the Earth's static magnetic field would be about 27 μV/m, some 45 times larger. To cite an extreme case, a 20 000-G magnetic resonance imaging magnet acting on aortic blood flow would produce a field of about 1.2 V/m.

Faraday's law states that an electromotive force is induced in a closed conducting loop by a changing magnetic flux. The emf equals the time rate of change of the magnetic flux through the loop and induces a new magnetic field that opposes the change. Taking the magnetic flux to be $\pi r^2 B$, where $B = B_0 \sin 2\pi ft$, we see that the internal field around a circular loop of radius r meters is given by

$$E_{\text{int}} = -0.5\, r\, \mathrm{d}B/\mathrm{d}t = -\pi r f B_0 \cos 2\pi ft \ \ \mathrm{V/m} \qquad (2)$$

where f is the frequency in hertz, t is in seconds and B_0 is the peak magnetic induction in tesla (1 T = 10^4 G). For example, a uniform field of 10 mG rms at f = 60 Hz would produce an rms electric field of $E_{\text{int}} \approx 19$ μV/m over a circular loop of material 10 cm in radius. For a conductivity σ of 0.5 S/m, an rms current density $j = \sigma E$ of approximately 9.5 μA/m^2 would be induced in that loop within the body. The effect depends critically on loop size but can be comparable in importance to the direct coupling of external electric fields.

A number of clinical studies have reported beneficial results from the Faraday effect through the use of time-varying magnetic fields to speed up fusion of bone fractures.[8] Therapeutic effects are said to occur for induced electric fields of about 0.1–1 V/m with fundamental repetition frequencies of about 15 Hz administered for 12 hours per day. The waveforms generally used consist of periodic pulse bursts of the type shown in figure 4, with peak values of about 20 G. Because the induced electric fields are proportional to dB/dt, they must have strong components distributed throughout the audio spectrum and thus are not ELF fields. For example, the 20-G peak field shown in figure 4 would result in a total rms electric field of 17 V/m over the range from 15 to 20 kHz if applied to a circular area of bone 2 cm in diameter. This field exceeds that induced by power lines by about

Table 1. RMS Magnetic and Electric Fields

Source	Magnetic		Electric	
	Typical	Maximum	Typical	Maximum
	(milligauss)		(volt per meter)	
High-tension lines	20–25*	90†	1000	7000
Electric railroad				
13 kV, 60 Hz	35*	300†	350	700
11 kV, 25 Hz	126*	650†	300	600
Transformer substation	15–25*	—	—	—
Distribution lines (12 kV)	1–3*	20†	5–40	60
Secondary lines (240/120 V)	5–10	100–200†	—	—
Pole-to-home	1	4	—	—
House wiring	0.5–1*	5–10†	1–5	10

Source: Ref. 4. All fields are at body level. Magnetic fields depend on current load as well as geometry. Fields from parallel wires fall off as $1/r^2$ at large distances r from the line. Magnetic fields from current loops and transformers fall off as $1/r^3$. People are shielded from electric fields inside metal railroad cars, but usually not from magnetic fields.

*Measured average values.

†Measured peak values.

six orders of magnitude, and even exceeds the thermal noise discussed below.

Coupling to the cell membrane

Herman Schwan[9] has noted that the internal electric field (equation 2) is amplified when coupled to the cell membrane. Consider a spherical cell with a radius r of 10 μm and a membrane thickness δ of 50 Å (5×10^{-9} m). Because representative values of membrane conductivity range from 10^{-5} to 10^{-7} S/m, the membrane can be considered an insulator with respect to tissue fluid. Solutions of Laplace's equation in this limit show that the membrane field will be about

$$E_{\text{mem}} \approx 1.5\, E_{\text{int}}\, r/\delta \approx 3000\, E_{\text{int}} \qquad (3)$$

where angular variation is ignored. For direct coupling of ELF electric fields, all the voltage drop in going across the cell occurs across the membrane, and the membrane shields the inner portions of the cell from the applied field.

Hence our worst-case limit with $E_{\text{int}} \approx 80\ \mu$V/m (for the barefoot fellow on the railroad tracks) results in a field E_{mem} inside the membrane of approximately 0.24 V/m. For comparison, the electric fields E_{int} of about 19 μV/m induced in a 20-cm-diameter loop of tissue by the Faraday effect from a 10-mG magnetic field from a distribution line would give rise to E_{mem} values of about 0.057 V/m. The largest magnetic fields encountered in my study—650 mG on the 25-Hz Washington-to-New York branch of Amtrak—would generate values of $E_{\text{int}} \approx 515\ \mu$V/m and $E_{\text{mem}} \approx 1.5$ V/m. Comparable values apply to the 60-Hz New York-to-New Haven branch. It doesn't matter too much which of these particular examples one takes; the maximum induced membrane fields will be on the order of 1 V/m for the worst cases encountered.

By contrast, the fields naturally found[10] across the highly insulating cell membranes are 10^7 V/m. The voltage drop across the Purkinje cells in heart muscle fibers is about 0.09 V, and nerve cell membranes typically have potential drops of 0.05 V across them. For a membrane thickness of 50 Å the naturally occurring fields E_{mem} are approximately 10^7 V/m—some six or seven orders of magnitude larger than our worst-case limits.

Thermal fields in tissue

There are natural sources of electrical noise that are unavoidable, the most important of which is the well-known phenomenon of thermal, or Johnson, noise,[11] discovered experimentally by J. B. Johnson at the Bell Laboratories. This noise arises in a resistor from the Brownian motion of electrons and ions. A quantitative theory of thermal noise was first given by Harry Nyquist,[12] who showed that the mean-square voltage across a resistor R in a frequency band Δf is given by

$$\langle V^2 \rangle = 4RkT\,\Delta f \qquad (4)$$

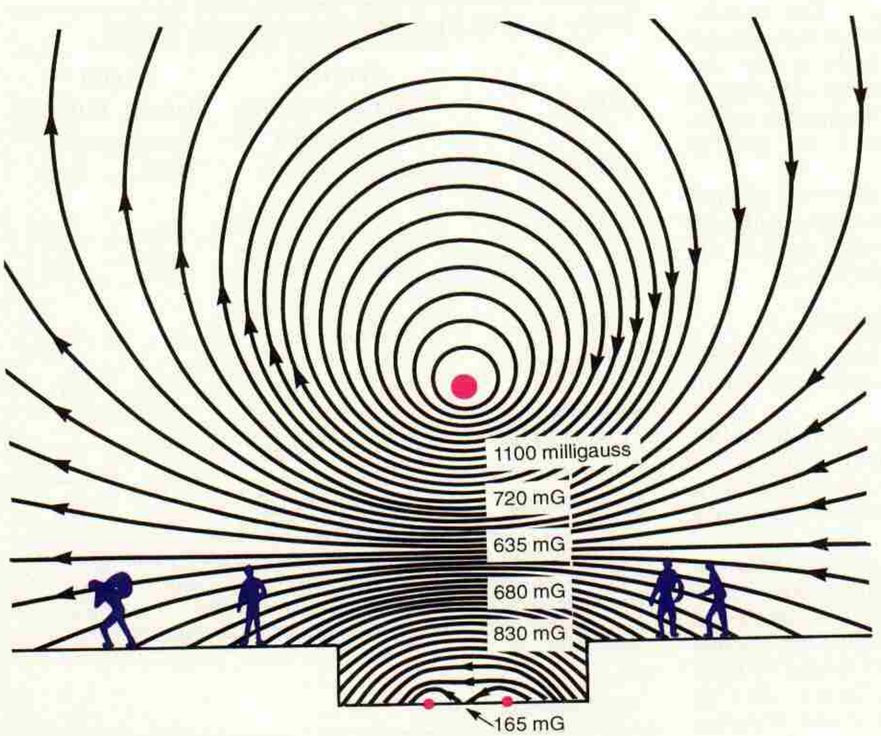
This result is quite general and has been checked experimentally for frequencies from near dc through the microwave region.[13]

Robert Adair[14] has applied Nyquist's formula to estimate the unavoidable fields in the cell due to thermal noise. If one considers the resistor to be a cube of tissue of length d placed between the plates of a capacitor, then $R = \rho/d$ and the thermal electric field becomes

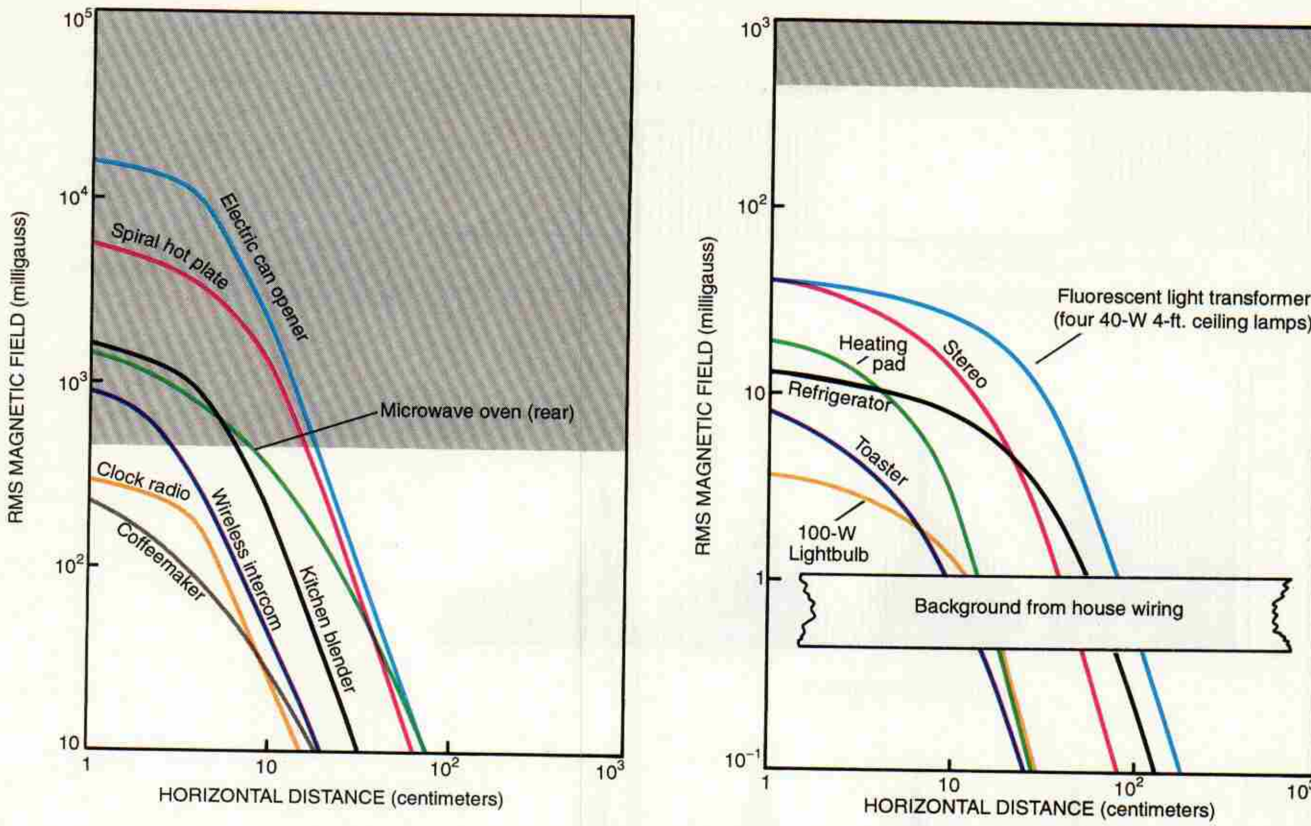
$$E_{kT} = \frac{V_{\text{rms}}}{d} = \left(\frac{2}{d}\right)\left(\frac{\rho k T\,\Delta f}{d}\right)^{1/2} \approx 0.020\ \text{V/m} \qquad (5)$$

where the resistivity $\rho = 1/\sigma$ is approximately 2 Ω m for tissue; d is about 20 μm, corresponding to a cubical volume the size of a cell; kT has been evaluated at body temperature; and a bandwidth Δf of 100 Hz has been assumed.

This value for the thermal-noise field is about 1000 times the internal electric field estimated to be caused by a power line and 40 times the electric field directly coupled into the barefoot fellow on the railroad tracks. To induce fields at the cellular level equal to those from thermal noise would require an external electric field of



Electric trains produce among the highest ELF fields of large spatial extent in well-populated areas. In this drawing a current (red) of 500 A flows into the paper through the trolley wire and is returned in equal amounts by the rails. (Adapted from ref. 4.) **Figure 2**



Magnetic field vs distance for some home appliances. The shaded background begins at 450 milligauss, the Earth's static field over North America. Left: Appliances producing peak magnetic fields exceeding 100 milligauss. Right: Appliances producing peak magnetic fields less than 100 milligauss. (Adapted from ref. 4.) **Figure 3**

about 3 MV/m—the corona discharge limit in air. A person immersed in that large an electric field would literally glow in the dark.

Two points should be made regarding the result in equation 5:

▷ The bandwidth Δf is not well known. If there is a natural biological filtering process that limits Δf to some lower value, such as 15 Hz, then only induced fields within that bandwidth should be considered; note, however, that the filtering process would attenuate applied fields as well as thermal fields.

▷ Although the noise field decreases with the square root of the volume, it is the noise field that actually exists within cell volumes that is important. For example, the noise field from equation 5 should be compared with the field induced by the Faraday effect in a loop $2\pi r$ in circumference and not in something that is $(2\pi r)^{3/2}$ times smaller. However, there can be variations in cell size and shape. Doubling the diameter reduces the noise by 2.8, and so forth.

Although no direct measurements of thermal noise at the cellular level have been reported in the literature, it is clear from fundamental principles that such noise fields must exist.

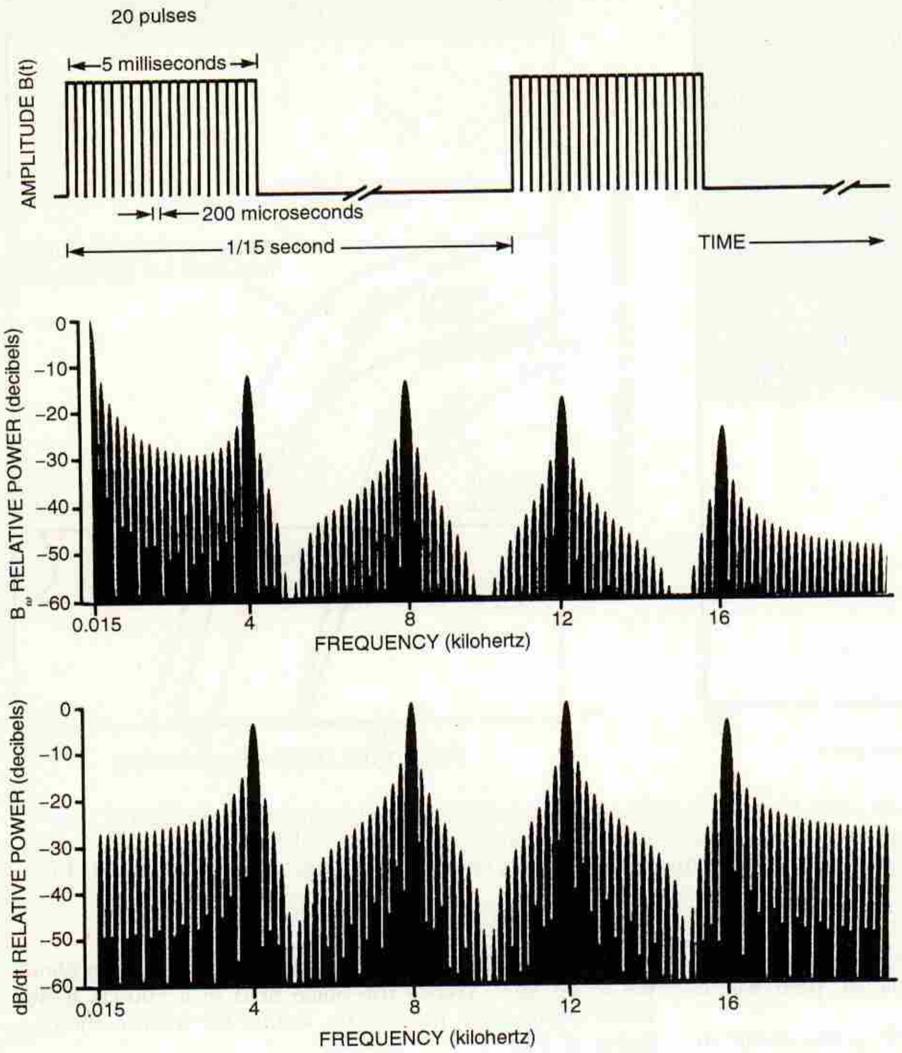
Thermal fields in the cell membrane. Because it has been suggested that induced ELF fields from power lines might cause cellular changes by affecting interactions (such as those involving calcium-ion efflux) in cell membranes, it is important to estimate the thermal fields at the membrane level. Assuming the cell is spherical, the membrane resistance is simply $R_{mem} = \rho\delta/4\pi r^2$, where δ is the membrane thickness, $\rho = 1/\sigma$ is approximately 10^5–10^7 Ω m, and r is the cell radius. Taking $r \approx 10$ μm and $\delta \approx 50$ Å, the membrane resistance varies from about 0.4 to 40 MΩ. Hence the noise field in a 100-Hz bandwidth inside the membrane would be within about a factor of 3 of

$$E_{kT} \approx 280 \text{ V/m} \qquad (6)$$

where the main uncertainty is in the membrane resistivity. This value is some 300 times the induced fields estimated above for the worst-case external magnetic fields.

Large aggregates of cells. James Weaver and R. Dean Astumian[15] have suggested that membrane noise might be vastly reduced in large aggregates of cells electrically connected by gap junctions. Such aggregates occur in major organs such as the heart and liver but are not found with platelets and white cells in the bloodstream—the cells affected in leukemia. If the gap-junction resistance R_{jcn} were zero, the cell membranes in the aggregate would be in parallel electrically, and the net resistance would decrease to R_{mem}/N, where N is the number of cells. From the Nyquist formula, the noise would then decrease by $\sqrt{N}$. (The bandwidth would not be reduced by the increased membrane capacitance, because the net RC time constant does not change.) However, this result holds only if R_{jcn} actually is zero—an assumption that hardly justifies extrapolating the results to millions of cells, as Weaver and Astumian do.

Measured values of R_{jcn} between pairs of cells[16] range from about 0.1 MΩ to at least 8 MΩ and in some cases to as much as 8 GΩ. I used R_{jcn} values of approximately 0.1–8 MΩ with normal membrane resistances R_{mem} of 10 MΩ to 1 GΩ in a computer model of long-chain aggregates.



Fractured-bone therapy uses magnetic induction fields with periodic waveforms like that shown at top. The amplitude is 20 G. Relative power spectra of the magnetic field (middle) and the electric field induced by d*B*/d*t* (bottom) are also shown. For normalization, $B_\omega(15\text{ Hz}) = 0.119\, B_{max}(t) = 2.38$ G. (Adapted from ref. 4.) **Figure 4**

Asymptotic limits for the reduced membrane resistance $(R_{jcn}R_{mem})^{1/2}$ were quickly reached as the chains lengthened, and ranged from 2 to 10 MΩ. Because this is about the range of membrane resistance used to evaluate equation 6, the large-aggregate assumption is not apt to affect our noise argument significantly. If R_{mem} really is much larger than R_{jcn} in relevant cases, it is probable that the values of membrane resistance (and hence thermal noise) were underestimated in obtaining equation 6. Similar conclusions[4] apply to the increased amplification factor (corresponding to $1.5\, r/\delta$ in equation 3) derived by Weaver and Astumian for large aggregates of cells.

Resonance effects

Some argue that steady-state oscillatory fields could have a larger biological effect than dc or fluctuating fields as a result of some resonance process that occurs by remarkable coincidence at the power-line frequency. This mechanism, of course, could not work simultaneously in the United States at 60 Hz and in Europe at 50 Hz. It is possible in principle to make the bandwidth small enough in the Nyquist formula (equation 4) that thermal noise becomes negligible over that band compared with the induced electric field. However, the thermal electric field depends on the square root of the bandwidth; reducing the bandwidth by a factor of 100 only reduces the noise by a factor of 10. Decreasing the bandwidth means sharpening the resonance by the same factor. Although very slow variations in the permittivity and conductivity of tissue with frequency have been reported,[17] they are inadequate to produce the required effects. To reduce thermal noise to the level of the electric fields induced in a 20-cm-diameter loop of body tissue by a 60-Hz field of 2 mG, one needs to reduce the bandwidth assumed in the previous examples by a factor of about a million—from 100 Hz to 10^{-4} Hz. Nothing approaching that sharp a resonance looks even remotely plausible.

Nevertheless some researchers have reported producing strange "window" effects on the efflux of calcium ions through 1-μm-diameter channels in cell membranes using ELF magnetic fields in the presence of the Earth's static fields.[18] The results are of marginal statistical significance, the "resonant" frequencies vary from paper to paper, and sometimes the frequencies depend on the presence of dc magnetic fields that are either coaxial or perpendicular to the applied field. Others[19] have reported resonances, at harmonics of the cyclotron frequency, in studies of ion efflux through cell membranes and of cell motility in the presence of applied 100-G magnetic fields. Models proposed to explain the window data have ranged from cyclotron resonance (in which the Faraday effect presumably produces an accelerating electric field) to coherent electric dipole radiation emitted from quantized harmonic-oscillator states of bound ions.

Classical cyclotron resonance can be of no consequence in these weak-magnetic-field experiments with heavy ions moving in viscous fluids. It is a simple matter to show that the cyclotron orbit radii are too large by many orders of magnitude for any such model to make sense at cellular dimensions with ions such as Ca^{2+}. Collision and diffusion effects further rule out cyclotron resonance models for such free ions in living tissue.[4]

At the opposite extreme in complexity, V. V. Lednev[20] has proposed a quantum mechanical model based on a three-dimensional isotropic harmonic oscillator in which a Ca^{2+} charge bound to oxygen ligands in calcium-binding proteins has vibrational levels that are widely spaced compared with the cyclotron resonance frequency in an applied magnetic field. An applied constant field splits the first excited state of the oscillator into two levels that are separated by the cyclotron resonance frequency. An alternating magnetic field collinear to the static field is then applied at a frequency near the cyclotron resonance. Lednev argues that the ELF magnetic field drives a coherent mixed state of the two magnetic sublevels to emit electric dipole radiation in the infrared, a process that would be resonant at harmonics of the cyclotron frequency. However—and quite apart from a number of other flaws in the model that I won't enumerate here—the oscillator can't radiate under the conditions assumed. One can calculate the transition probabilities exactly from quantum theory. Assuming the first energy level is approximately kT at body temperature (as would be needed for significant excited-state population), the radiative lifetime for each magnetic substate is about 2 seconds. For the conditions in a cell, these states would be collisionally killed long before any significant electric dipole radiation occurred.[4,21]

Estimates suggest that the thermal fields in these ion-efflux experiments would be much greater than any induced electric fields from the Faraday effect. Because the results from these experiments have not been consistent and involve marginal signal-to-noise levels, it seems likely that the window effects may result from some form of systematic error.[22] Certainly the theories used to explain them do not make much physical sense.

On balance

It is my opinion that the dangers to human health from low-level ELF fields have been exaggerated beyond reason. I base this conclusion on considerations ranging from the underlying physics to the inconsistent epidemiological data and lack of concrete biological results. It is appalling that close to a billion dollars has already been spent on this problem. I by no means conclude that no further research should be conducted on biological interactions with ELF fields; however, nothing in the available data suggests the need for any sort of crash program. There are far more urgent things to support in the present national concern over the economy, and unwarranted hysteria could end up trivializing concern over legitimate dangers to health such as cigarette smoking and the AIDS epidemic.

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