

2. Sources and Nature of Fields and Exposure

2.1. Power Delivery Systems

Power lines are characterized by voltages and currents. Voltage is a measure of the electric potential energy that makes electric charges flow through a circuit. Current is a measure of the rate at which electrical charges flow in a power line or wire. The amount of power that a line transmits is simply the product of its voltage and current. Power systems are designed so that line voltage is held relatively constant over time while currents are permitted to rise and fall with power demand.

The various stages of the system that is used to move electric power from the electric generator to the end user are depicted in Figure 2-1. Electric generators in power stations produce electric power at about 20,000 volts (20 kilovolts or 20 kV). Large “step-up” transformers are used to increase the voltage for efficient long distance power transfer over high voltage transmission lines to load centers. Transmission lines operate at voltages up to **785 kV** and carry current of up to **2000 Amperes** (or Amps). They are usually mounted on metal or wooden structures up to 50 meters in height. Transmission lines terminate at substations where step-down transformers transfer power to lower-voltage distribution lines. Distribution lines deliver power locally through load centers to individual users. Residential distribution systems are comprised of two different circuits: 1) a high voltage (5-35 kV) or “primary” circuit that delivers power from the substation to a local pole-mounted or underground distribution transformer and 2) a low voltage or “secondary” circuit that delivers power from the local transformer to the home. The voltage of the secondary side is low enough (115/230 V) to allow appliances, lighting, and other electrical loads in the home to be operated safely. Commercial and industrial installations often have their own step-down transformers and so obtain their power directly from distribution primaries. Distribution primaries carry currents of up to 900 Amps. 115/230 volt wall-wiring in homes is typically designed to carry currents of up to 30 Amps.

The amount of power lost in the wires during transmission and distribution can be reduced by increasing the voltage at which these lines operate. Transmission and primary distribution voltages have therefore increased over the years as rapidly as high voltage technology has allowed. Figure 2-2 shows this trend for transmission lines.

The length of transmission and distribution lines in service have also increased steadily over the last century in response to increases in population and per capita demand for electricity. Today, there are about 350,000 miles of transmission line and about 2 million miles of distribution line in the U.S. [Minner 87, USDOE 83].

2.2. Electric and Magnetic **Fields**

Although “electric and magnetic fields” may sound mysterious or ominous to some people, scientists have had a good understanding of them since the nineteenth century. Electric and magnetic fields arise from many natural sources. They appear throughout nature and in all living things. Electromagnetic forces are responsible for holding atoms together in molecules of chemical compounds. Processes in the atmosphere produce large static electric fields at the surface of the earth, thunderclouds produce lightning as they discharge stored up charge, and processes in the earth's core give rise to a magnetic field which makes navigation by compass possible. Modern devices such as TV, radio, and microwave ovens depend on electric and magnetic fields for their operation. There are numerous technological uses for electric and magnetic fields.

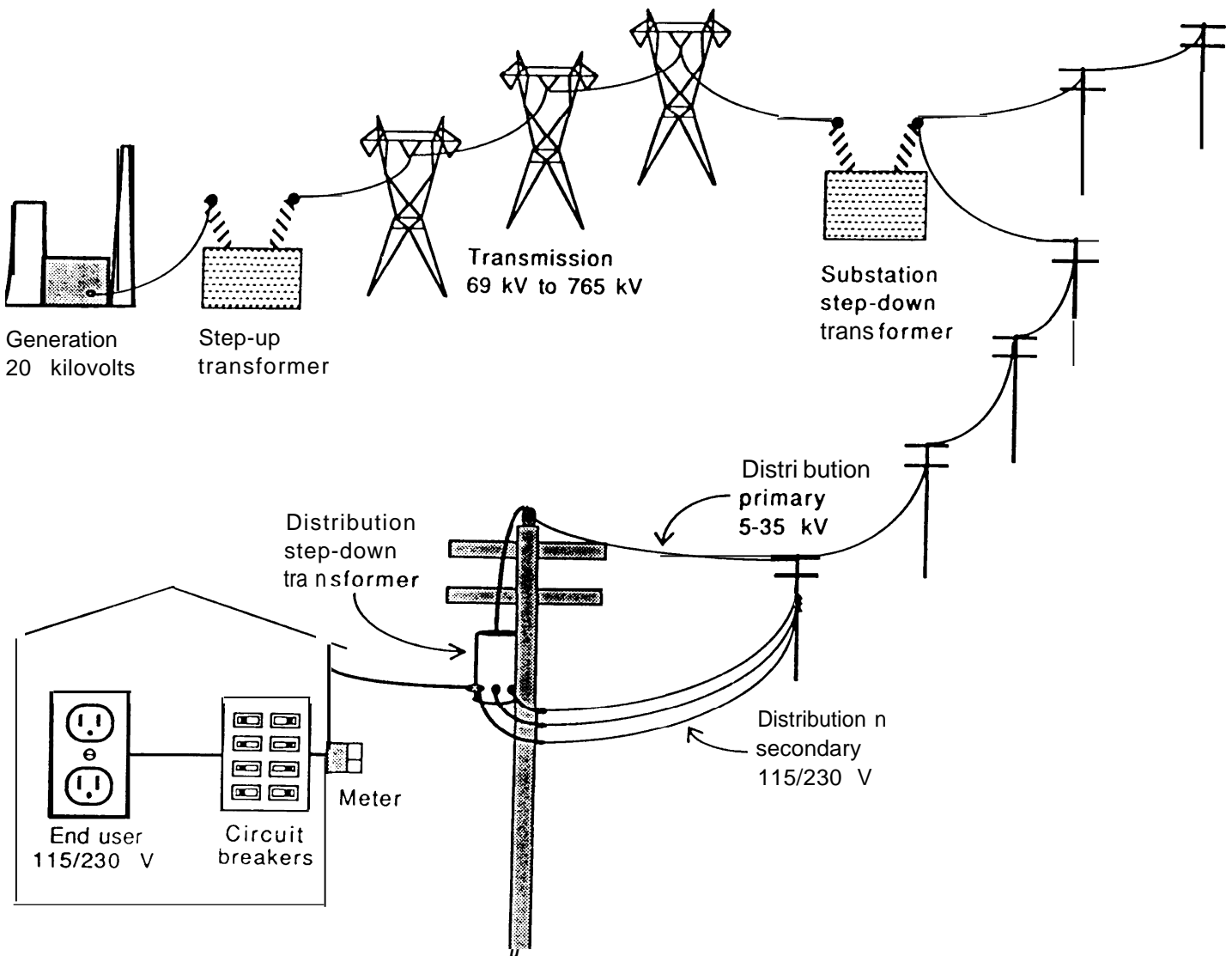


Figure 2-1: Schematic illustration (prepared by the authors) of the stages in the system used to transfer power from the generator via transmission and distribution lines to an end user. Power on transmission lines and distribution systems is delivered using sets of three wires. **While** the voltages on all three wires **oscillate at** power-frequency, the oscillations are not “in phase” with one another. As the voltage on one wire is peaking, the voltage on one of the others is one-third of a cycle ahead and the voltage on the other wire is one-third of a cycle behind. For this reason, the three wires **are** referred to as the three phases of the power network. Although commercial and industrial facilities use three-phase power to run large motors and other heavy loads, the 115 V power in homes is generally supplied by just a **single phase**. Utility companies try to connect **equal** numbers of houses to each phase of a residential distribution network in order to balance the load across the phases.

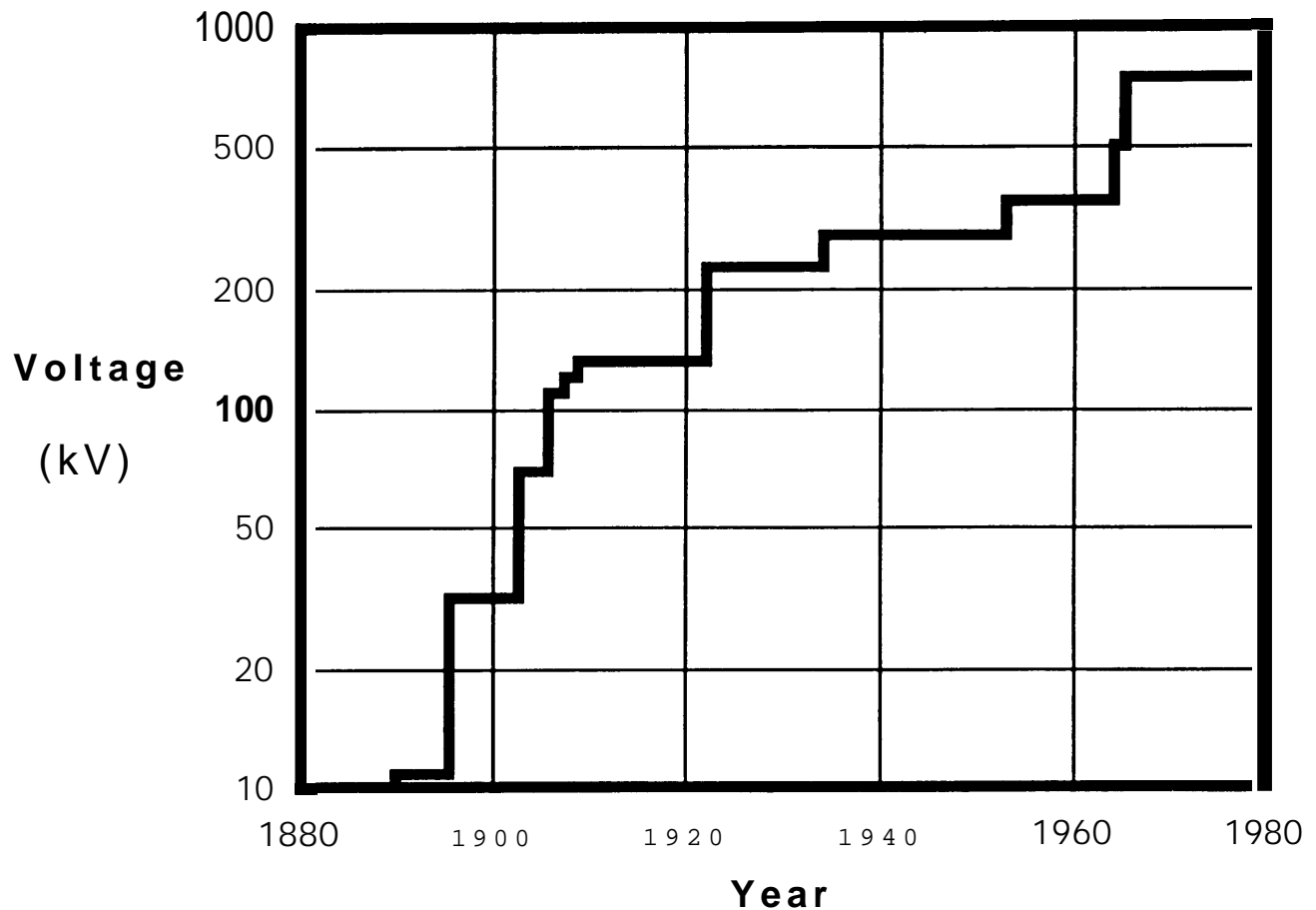


Figure 2-2: Highest 60 Hz transmission voltage in North America. From [Ellert 82].

There are two types of electric and magnetic fields, those that travel or propagate long distances from their source (also called electromagnetic waves) and those that are confined to the immediate vicinity of their source. At distances that are close to a source compared to a wavelength,¹ fields are primarily of the confined type. Confined fields decrease in intensity much more rapidly with distance from their source than do propagating fields. Propagating fields dominate, therefore, at distances that are far from the source compared to a wavelength. The fields to which most people are exposed from radio broadcast antennas are examples of propagating fields since these source are generally much more than one wavelength (1-1 00 meters) removed from inhabited areas. The power-frequency fields that people encounter are of the non-propagating type because power lines and appliances are much closer to people than one 60 Hz wavelength (several thousand kilometers). Only a very miniscule portion of the energy in power lines goes into propagating fields. Because the power-frequency fields of public health concern are not of the propagating type, it is technically inappropriate to refer to them as “radiation”.

¹A wavelength is the distance that a propagating field travels during one oscillatory cycle. For fields in air this distance is c/f where c is the velocity of light and f is the frequency of the oscillating field.

2.2.1. Electric Fields

Many fundamental particles such as electrons and protons carry an electric charge. Protons carry a positive charge and electrons carry a negative charge. Charges of the same sign repel one another whereas charges of opposite sign attract each other. Most of the time most objects have almost exactly the same number of electrons as they do protons. So the effect of the charges cancel and the object has no overall charge. The “static electricity” of clinging clothes is an example of the electric forces that result when objects acquire a small excess of positive or negative charges (this happens in the drier when clothes pick up or lose electrons from one another as they rub together). The “electric field” of a charged object is merely a description of the electric force that the object is capable of exerting on other charges brought into its vicinity. The intensity of the electric field is proportional to the magnitude of this force. Electric fields are represented graphically by sets of “field lines”. The direction of the field lines indicates the direction of the electric force at any point. The density or spacing of the lines corresponds to the intensity of the field. Figure 2-3 shows the electric field that exists between two equal and opposite electric charges. Electric field intensity is measured in units of volts per meter (V/m). One thousand volts per meter is a kilovolt per meter (kV/m). Field intensities are sometimes referred to as “field values” or simply as “fields”.

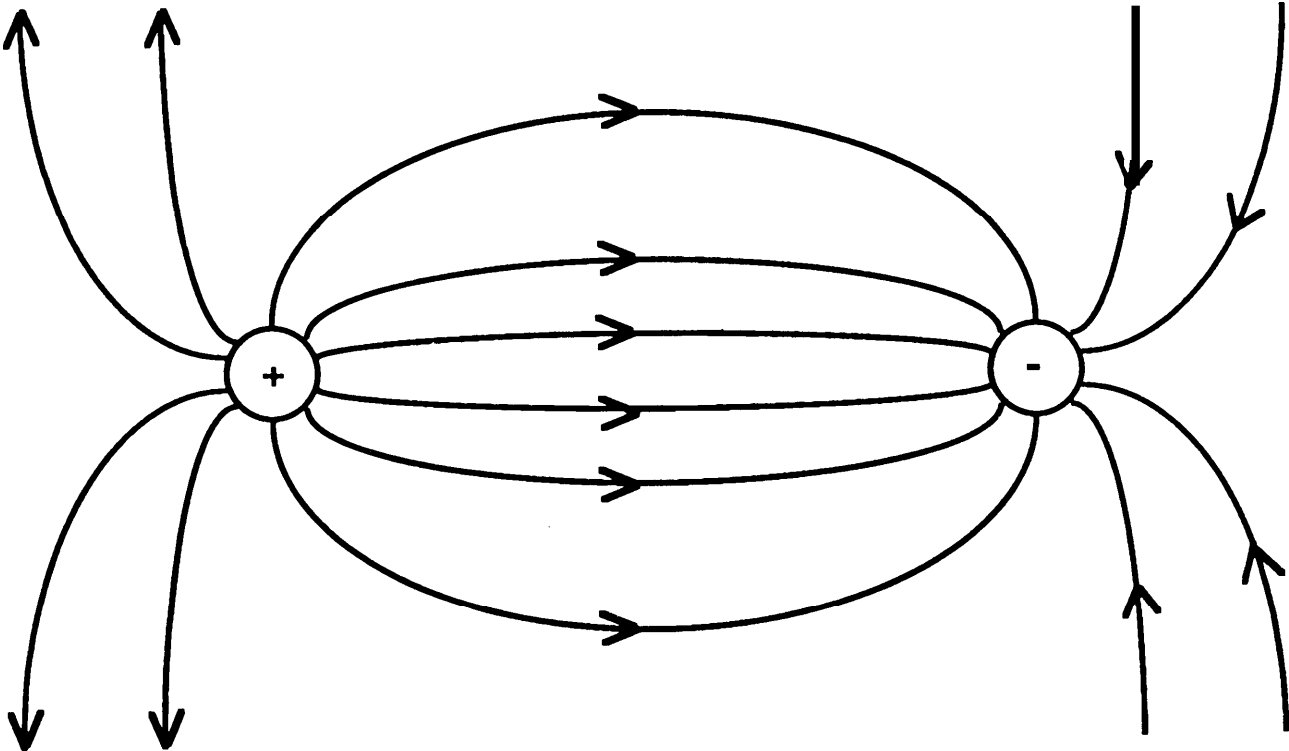


Figure 2-3: The electric field of two equal but opposite charges. A small positively charged particle placed somewhere in this field will experience a force in the direction-of the-local field line (note arrows). The strength of the force is proportional to the spacing between the field lines (field lines closer together means a higher field and thus a larger force on small charged particle).

The electric fields of power lines, wall wiring, and appliances are produced by electric charges that

are “pumped” onto the wires by electric generators. Because the charge in the wire changes from positive to negative at power-frequency, the associated electric fields are dynamic. Dynamic fields can be depicted by taking some time-average measure of their intensity and direction. The most common convention is to use the “root-mean-square” field. Figure 2-4 is a representation of the power-frequency electric field of a household coffee maker obtained using the root-mean-square.

As with fields from other power-frequency sources, the electric field from **a coffee maker** loses intensity rapidly with distance. Figure 2-5 shows how electric field strength changes with distance for electric fields from EHV transmission lines, distribution lines, and typical appliances.

2.2.2. Magnetic Fields

In the nineteenth century, scientists discovered that a current-carrying wire exerts a force on any charged particle moving nearby. This force was called the magnetic force. Its magnitude is proportional to the current in the wire and the velocity and charge of the moving particle. The magnetic field is a mathematical means of representing the magnetic force. Like electric fields, magnetic fields are represented graphically by sets of lines as shown in Figure 2-6.

There are several different units used to describe magnetic fields. The proper unit of magnetic field intensity is the Ampere per meter (analogous to the V/m for electric fields). Often, magnetic field strength is indicated by a related quantity called the magnetic flux density which is the number of field lines that cross a unit of surface area. The unit of magnetic flux density that is encountered most often in the power-frequency literature is the gauss (G). Sometimes, the magnetic flux density is given in tesla (T). There are 10,000 gauss in each tesla. For fields in air or in biological tissues, the magnetic flux density in gauss is 1/80th of the magnetic field intensity in A/m. The gauss and tesla are large units. Sixty hertz magnetic fields are commonly reported in thousandths of a gauss or milligauss (mG).

Like power-frequency electric fields, magnetic fields from power systems are dynamic and are generally described by some time-averaged quantity such as the root mean square. Figure 2-7 shows the root mean square field of a household coffee maker.

Magnetic field intensity drops off rapidly with distance. Figure 2-8 shows this relationship for magnetic fields from EHV transmission lines, distribution lines, and typical appliances. The magnetic fields around many appliances are stronger than the magnetic fields under either transmission or distribution lines. Appliance fields typically fall off faster with distance, however, than do fields from overhead powerlines. This results from the fact that appliances are less extended in space than are long power lines.

Electric and magnetic fields produced by power lines and other sources can be either measured using a “field meter” or calculated given information on voltage and current. For transmission lines, such calculations can be quite accurate. Published reports describing fields from various sources are listed in Table 2-1.

Recent epidemiological studies relating the incidence of certain cancers to magnetic fields in the household environment [Wertheimer 79, Wertheimer 82, Savitz 87a, Stevens 871 have created a growing need to understand the various sources of magnetic fields in the home. These sources include 1) appliances, 2) wall wiring, 3) ground currents in plumbing, gas lines, and steel girders, and 4) overhead and underground distribution wires [Barnes 87]. The most intense magnetic fields in the home are found

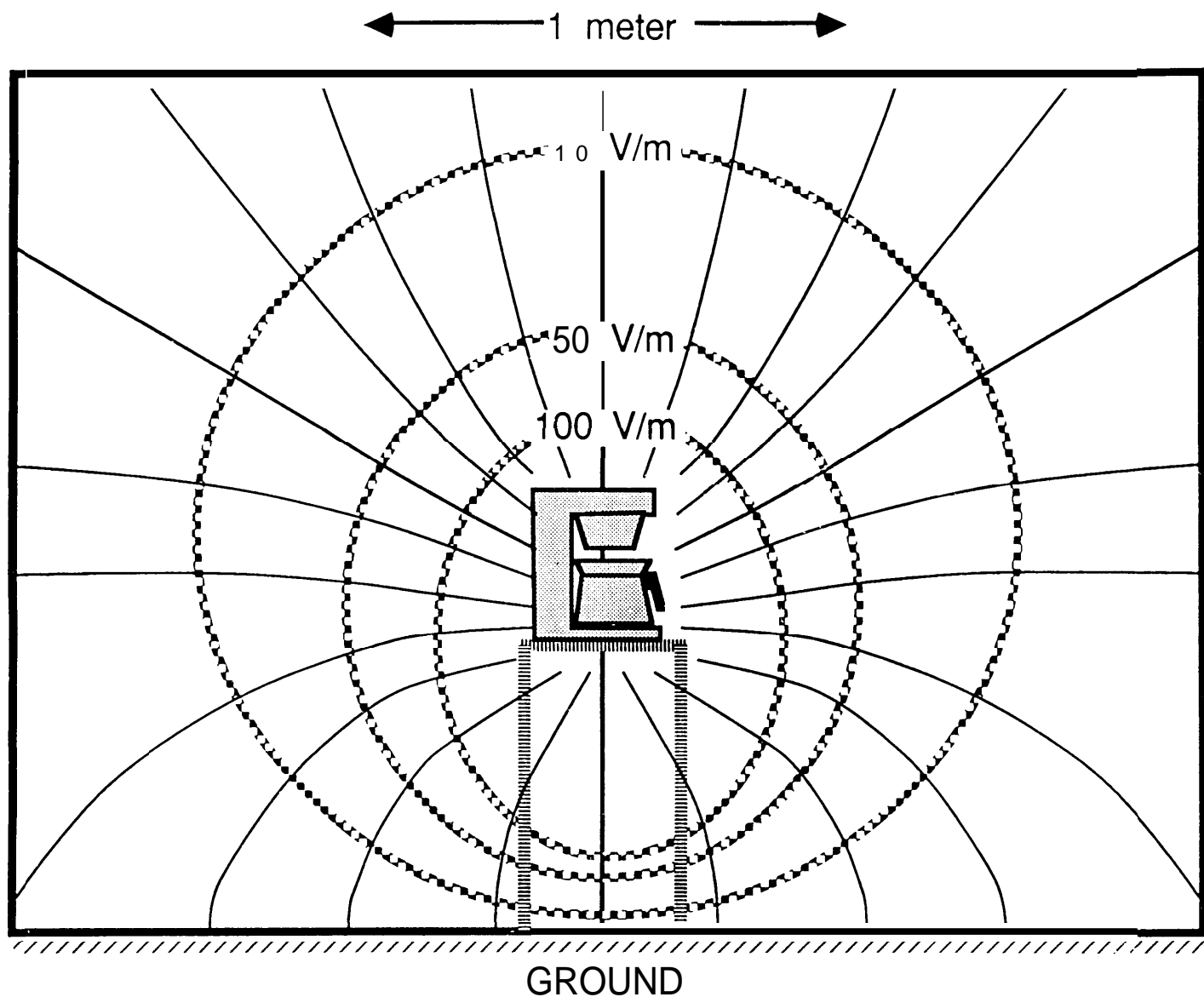


Figure 2-4: Time averaged (root mean square) electric field of a 115 V coffee maker (solid lines). Dotted lines show surfaces of equal field intensity. These differ from equipotential surfaces. Adapted from [Florig 86].

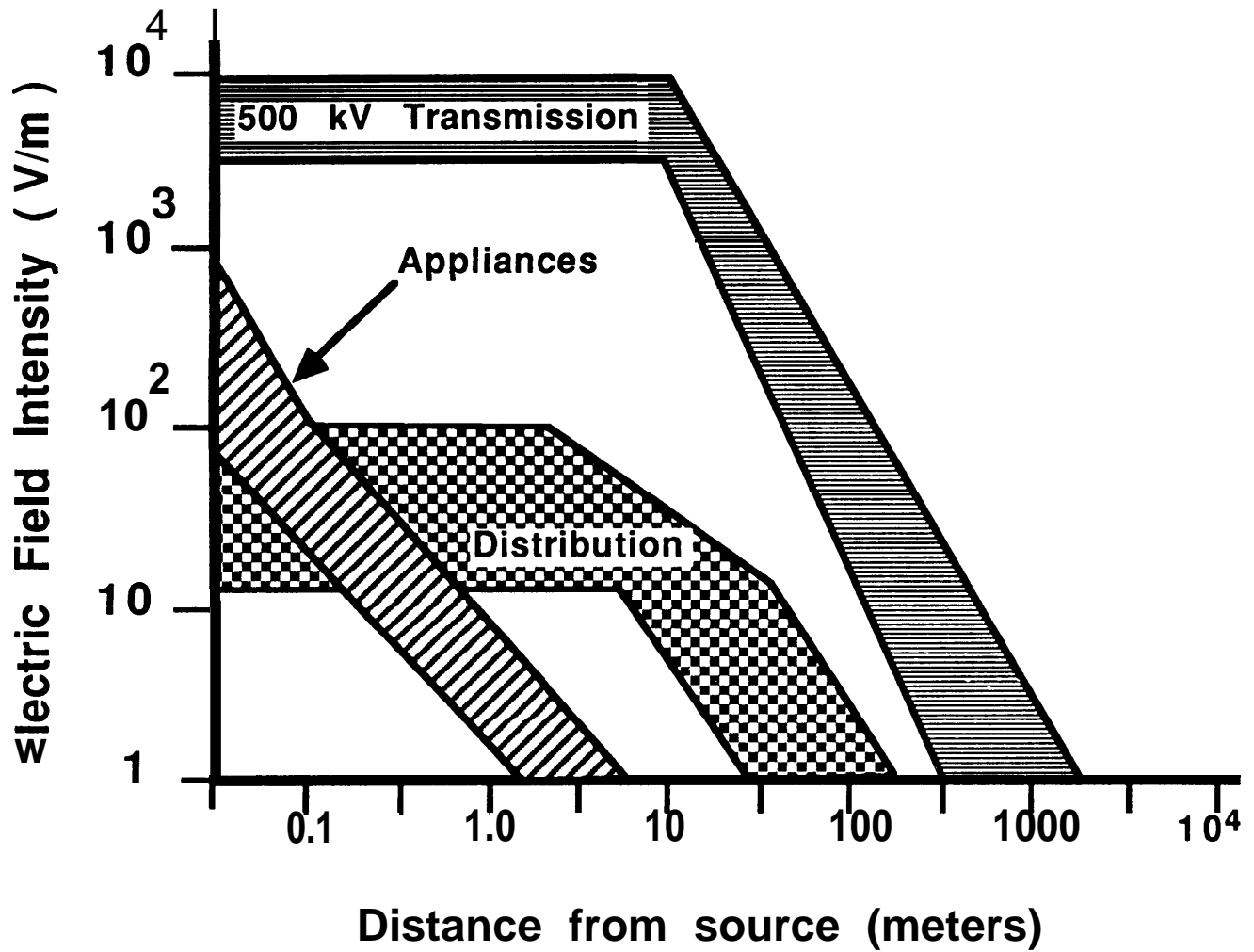


Figure 2-5: Illustration of how the electric field intensity at ground level changes with horizontal distance from three common sources of power-frequency electric fields. The bands represent variation across individual sources in each group. Adapted from [Florig 87a].

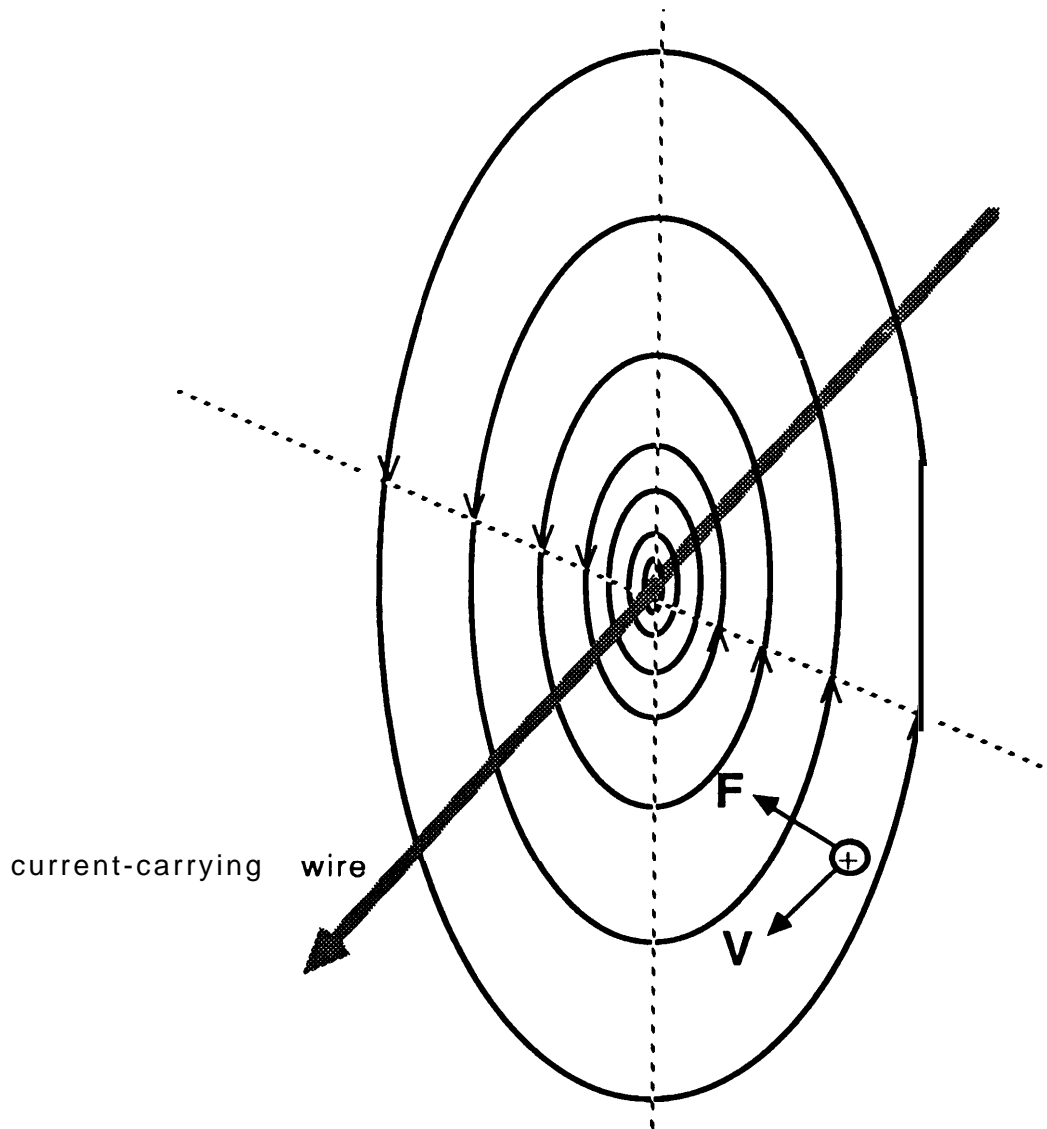


Figure 2-6: The magnetic field of a long straight wire produces a force, F , on a positively charged particle that is moving nearby. The strength of the field is proportional to the spacing between the lines (closer spacing means stronger field). The direction of the magnetic force on a charged particle moving in the field is perpendicular to both the field lines and the particle's direction of motion, V .

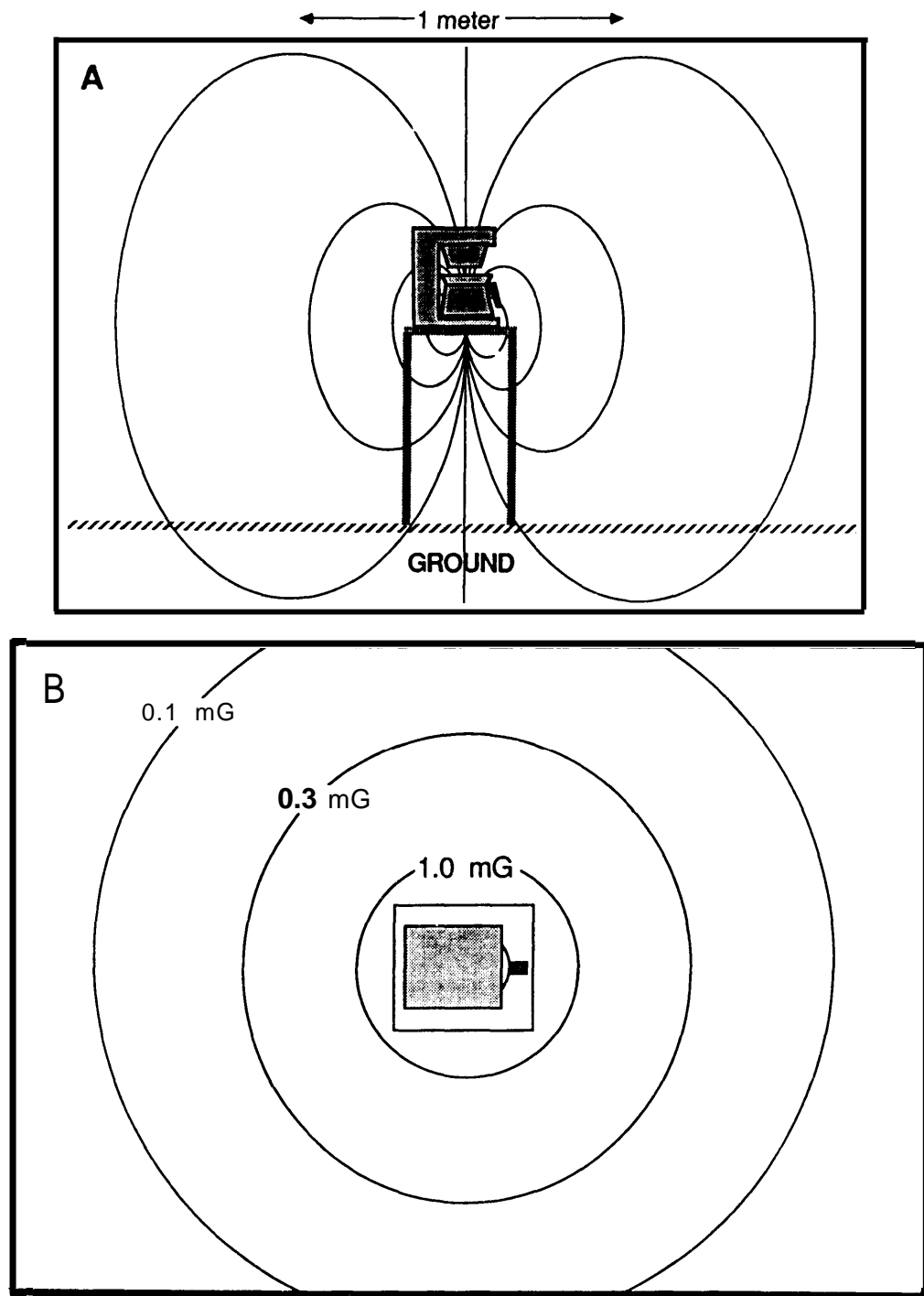


Figure 2-7: Time averaged (root mean square) magnetic field of a coffee maker (A) and top view (B) showing lines of equal flux density. Adapted from [Gauger 85].

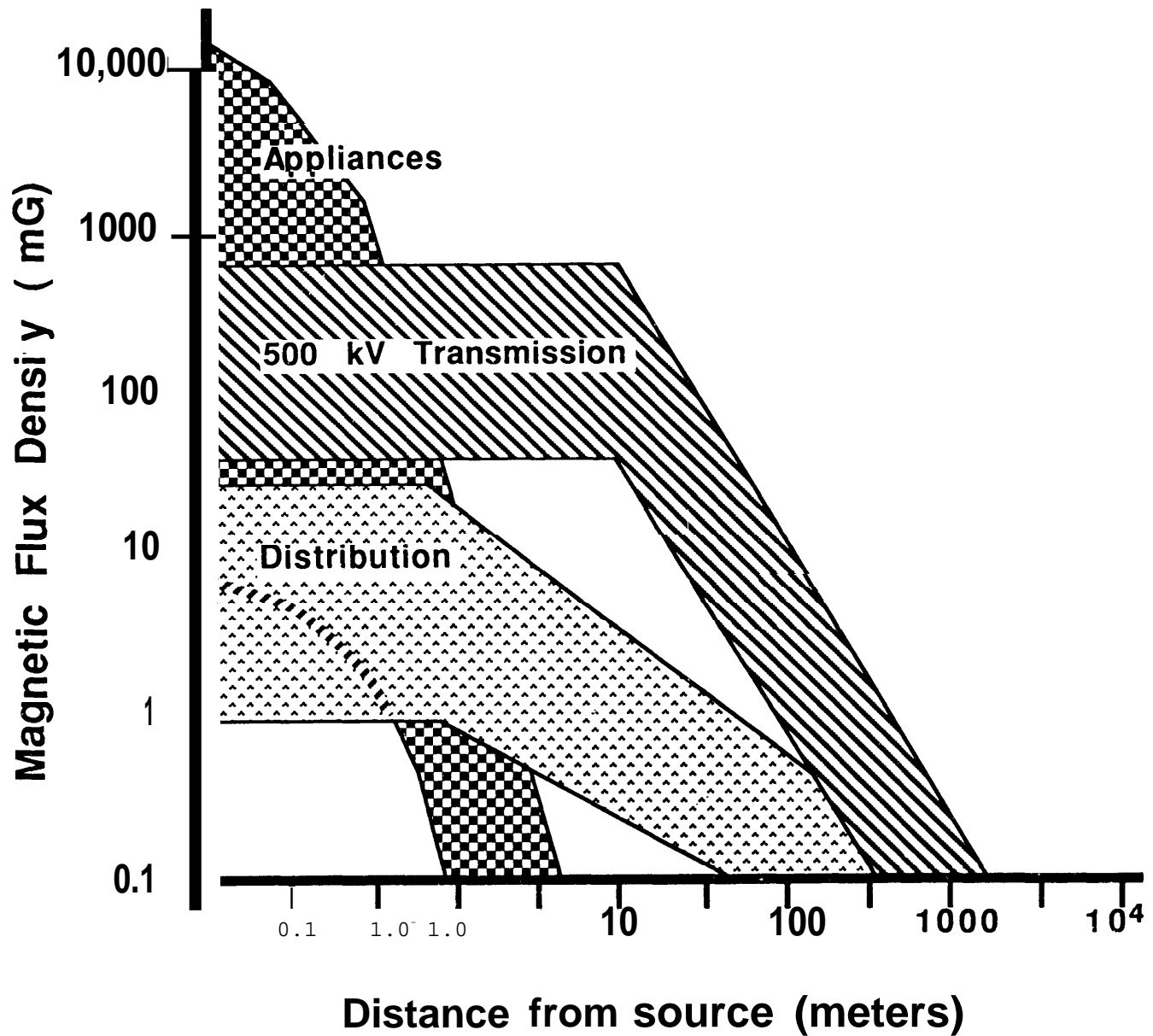


Figure 2-8: Illustration of how the magnetic field intensity at ground level changes with horizontal distance from three common sources of power-frequency magnetic fields. The bands represent variation across individual sources in each group. Adapted from [Florig 87a].

Table 2-1: Summary of published references which contain data on power frequency fields associated with various sources.

Study	Field: Electric (E) Magnetic (M)	Measured (m) Computed (c)	Sources
[Bowman 88]	E, M	m	I, w
[Caola 83]	E	m	T
[Chartier 85]	E	m	w
[Deadman 88]	E, M	m	I, w
[Deno 78]	E, M	c, m	A, T
[Deno 82]	E, M	c, m	A, T
[Deno 87a]	E	c	T
[Deno 87b]	E, M	m	1, 0
[Enk 84]	E, M	m	1, 0
[Gauger 85]	M	m	A
[Florig 86]	E	c, m	A, B, T
[Florig 87b]	E	c	B
[Harvey 87]	E, M	m	1, T
[Heroux 87]	E, M	m	D
[IEEE 88]	M	c, m	D, T
[Jacobs 84]	E	c, m	T
[Kaune 87]	E, M	m	I
[Krause 85]	M	m	I
[Lovsund80 80]	M	m	w
[Male 87]	E, M	c, m	1, w
[Miller 74]	E, M	m	A, 1, 0, T
[Norris 87]	M	c, m	A, B, D
[Savitz 87a]	E, M	c, m	D, I
[Sendaula 84]	E, M	m	T
[--- 85]	E	m	1, T
[Silva 88]	M	m	I
[Stuchly 83]	M	m	A
[Tell 83]	M	m	I
[Tomenius 86]	M	m	D
[Valentino 72]	E, M	m	A, 1, T
[Wertheimer 79, Wertheimer 82]	M	m	A, D

Key to source column:

T - transmission lines B - electric blankets
 D - distribution lines I - ambient indoor
 A - appliances 0- ambient outdoor
 W - work environment

near appliances (particularly those with small motors or transformers such as hairdryers and fluorescent light fixtures). Because appliance fields fall off rapidly with distance and since people generally spend only brief amounts of time very close to **appliances** (with the exception of electric blankets and a few other appliances), appliances are usually not dominant contributors to time-averaged magnetic field exposure. However, since it is not known what aspect of the field, if any, is biologically important, care must be taken in making inferences about “exposure” from this fact.

Magnetic fields from wall wiring can be quite small because the field created by the current in the “hot” side of the line is canceled by the field created by the equal and opposite current in the parallel “neutral” (or ground) wire. This cancellation is greatest when the hot and neutral conductors are close together as they are in ROMEX cable or when both conductors are run through the same conduit. Many older homes have ‘knob and tube’ wiring in which the hot and neutral conductors are separated by many inches. Wall wiring of this type can make significant contributions to the average magnetic field in homes.

Ground currents arise because the neutral (or grounded) wires of distribution lines are usually physically connected to the earth at many points along the line. These connections are made either through metal rods driven into the ground or by direct connection to water lines. Connections to earth are generally made at every distribution transformer and at every service drop (the point where electric lines enter the home). These ground connections provide alternate paths for distribution currents to return to local transformers or substations. This leads to power-frequency currents in water and gas plumbing. Because ground currents are not balanced by equal and opposite currents in parallel conductors, the magnetic fields that they produce can contribute substantially to the overall magnetic field in homes.

Barnes and colleagues found that houses in the Denver area were often close enough to overhead or underground distribution lines that the magnetic fields produced by the lines could account for a large fraction of the fields measured in the homes [Barnes 87]. Their estimates of the contributions of appliances, house wiring, ground currents, and distribution lines to magnetic fields in houses is shown in Table 2-2. Again, because it is not clear what, if any, aspect of the field is biologically important, care should be taken in making inferences about “exposure” from these numbers.

Table 2-2: Sources of 60 Hz magnetic fields in residences. Adapted from [Barnes 87]

Source	Magnetic Flux Density
Appliances	6 mG to 25 G
House wiring	.01 mG to 10 mG
Ground currents	up to 5 mG
Distribution lines	.01 mG to 10 mG

2.2.3. Shielding of Fields

Trees, tall fences, buildings, and most other large structures provide shielding from electric fields. The presence of these structures can, therefore, have a significant effect on the electric fields to which people are exposed. Houses, for instance, attenuate electric fields from nearby power lines by roughly 90% [Florig 86]. Shielding by other objects can be equally great [Deno 87a]. Magnetic fields are shielded only by structures containing large amounts of ferrous or other special metals. Houses, trees, and most other objects, therefore, do not provide appreciable shielding of magnetic fields.

2.3. Electric and Magnetic Induction

The human body contains free electric charges (largely in ion-rich fluids such as blood and lymph) that move in response to forces exerted by charges on and currents flowing in nearby power lines and appliances. The processes that produce these body currents are called electric and magnetic induction.

In electric induction, charges on a power line or appliance attract or repel free charges within the body. Since body fluids are good conductors of electricity, charges in the body move to its surface under the influence of this electric force. For example, a positively charged overhead transmission line induces negative charges to flow to the surfaces on the upper part of the body as shown in Figure 2-9. Since the charge on power lines alternates from positive to negative many times each second, the charges induced on the body surface alternate also. Negative charges induced on the upper part of the body one instant flow into the lower part of the body the next instant. Thus, power-frequency electric fields induce currents in the body as well as charges on its surface. A number of investigators have studied the surface charges and internal currents that are induced by power-frequency electric fields in both people and animals. A review of the electric induction literature has been written by Kaune [Kaune 85].

Magnetic fields are intimately related to electric fields. This relationship was first fully described by physicist James Clerk Maxwell in the nineteenth century. Among other things, Maxwell showed that changing magnetic fields produce electric fields. Because power-frequency circuits contain alternating currents, they produce changing magnetic fields. The electric fields produced by these changing magnetic fields exert forces on electrical charges contained within the body. This process is called magnetic induction.

Magnetically-induced currents flow in loops which is why they are sometimes referred to as “eddy” currents. The nature of magnetic induction is such that currents induced in the body by magnetic fields are greatest near the periphery of the body and smallest at the center of the body (see Figure 2-10). Because magnetic fields have only recently become a human health concern, data on the detailed distribution of magnetically-induced currents in humans and animals is quite sparse compared to the information available on electric induction. Studies of magnetic induction include the theoretical work of Spiegel [Spiegel 76, Spiegel 77] and Kaune [Kaune 86] and measurements by Guy and colleagues [Guy 76]. The lack of detailed data on magnetic induction makes it difficult to compare the body currents induced by the electric and magnetic fields of any given source.

The magnitude of surface charge and internal body currents that are induced by any given source of power-frequency fields depends on many factors. These include the magnitude of the charges and currents in the source, the distance of the body from the source, the presence of other objects that might shield or concentrate the field, and body posture, shape, and orientation. For this reason the surface charges and currents which a given field induces are very different for different animals.

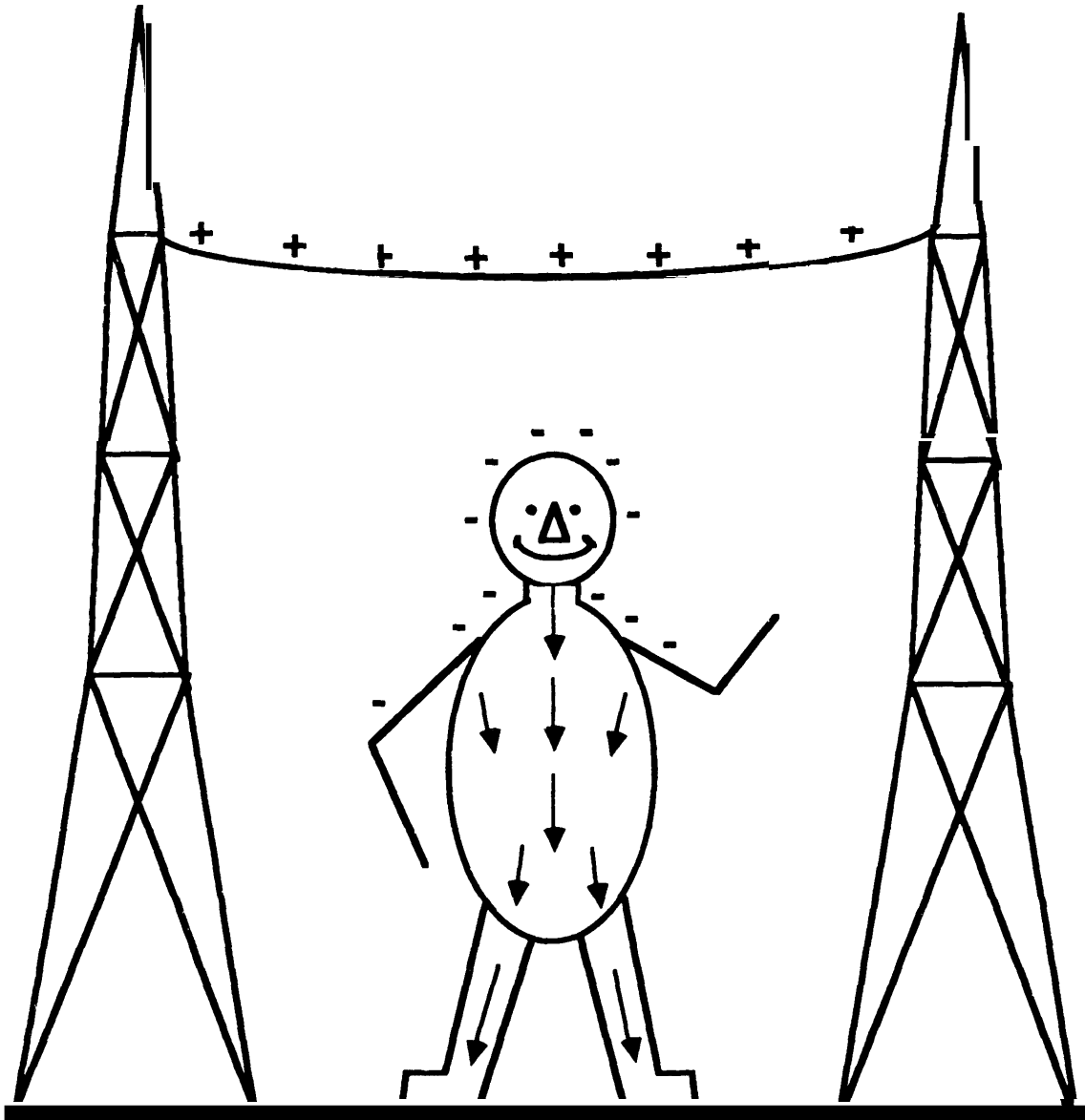


Figure 2-9: A schematic representation of the surface charges and internal currents that are electrically induced by the charges on an overhead power line in a person under the line whose feet are well-grounded. The total current induced to flow from each foot to ground is about 8 microamps per kV/m of applied field (1 microamp is 1 millionth of an ampere). The density of electrically-induced current is the amount of current that passes through a body cross-section perpendicular to the direction of current flow. The current density induced by a 1 kV/m vertical electric field is about 30 nanoamps per square centimeter averaged over the entire volume of the body. One nanoamp is 1 billionth of an ampere.

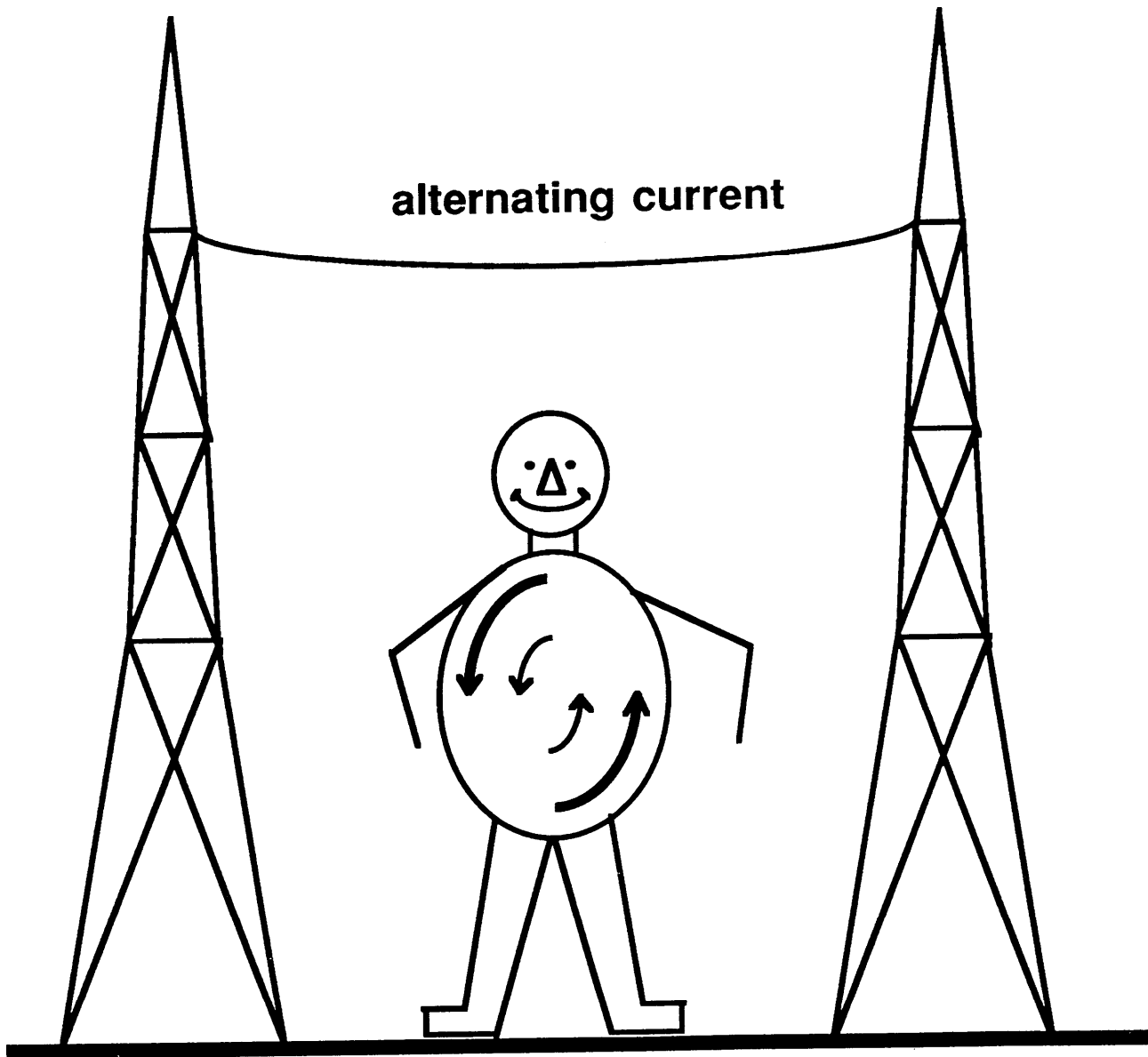


Figure 2-10: A schematic representation of the pattern of currents induced in the body of a person standing under a transmission line by the alternating magnetic field set up by the current flowing in that line. A 60 Hz magnetic field with a flux density of one gauss will induce currents in the periphery of the body with a current density of about 100 nano Amps per square centimeter. The current density at the center of the body is zero.

2.4. Contact Currents

Besides direct electric and magnetic induction, another source of power-frequency exposure is contact currents. Contact currents are the currents that flow into the body when physical contact is made between the body and a conducting object carrying an induced voltage. Examples of contact current situations include contacts with vehicles parked under transmission lines and contacts with the metal parts of appliances such as the handle of a refrigerator. Contact currents are important because they often produce high current densities in the tissue near the point of contact. Although contact currents result in exposure to some of the most intense currents, they are also among the briefest, usually lasting only as long as it takes to open the door of the car or refrigerator.

If a person touches a vehicle parked under an overhead power line, the body provides a path to the ground through which charge induced on the vehicle by the electric field of the power line can flow. The magnitude of contact current depends on a number of factors including the local field intensity, the size and shape of the contacted object, and how well grounded the contacted object and the person are. The largest contact currents are drawn by well-grounded persons who touch large metal objects that are well-insulated from ground. The most common contact currents are imperceptibly small (less than .2 milliamps). Under the right circumstances, however, contact currents can be annoying or even painful. To protect the public from life-threatening contact currents, the American National Standards Institute (ANSI) has recommended that overhead lines be designed so that contact currents from even very large vehicles do not exceed 5 milliamps [ANSI 77]. Because 5 milliamps delivers a very unpleasant shock to an adult and is above the “let-go” threshold for some children, there is some concern that the ANSI limit is not conservative enough. The let-go threshold is the current above which a person loses voluntary muscle control and cannot “let go” of a gripped contact.

Contact currents associated with appliances are also usually imperceptibly small. An upper limit on appliance contact current is given by the appliance short-circuit current, which is the contact current that would flow into a person who has wet hands and is well-grounded. Measurements indicate that typical appliance short-circuit currents lie in the range of 1-100 μA (1 μA = 1 millionth of an Amp) [Florig 86]. Short-circuit currents for new appliances are currently limited by ANSI standard to .5 mA (1 mA = 1 thousandth of an Amp) for portable appliances and to .75 mA for stationary units. It is apparent from available data that appliance manufacturers have no trouble meeting these requirements. While contact currents typically flow for only short periods of times (for example, while your hand is on the refrigerator door), the currents involved and the associated fields in the body can be quite high compared to those induced by the fields of overhead power lines.

2.5. Measuring “Dose”

Although it is possible to measure or compute the fields and induced currents to which people are exposed, scientists do not know which, if any, of these quantities might be related to human health impact. Scientists do not know whether we should be concerned with the strength of the field, the change in field strength over time, the currents induced in the body, or some other variable. Uncertainty is common when dealing with environmental risks, but the case of electromagnetic fields differs from that of most environmental agents. For most known of potential hazards, such as chemicals, one can safely assume that if some of the agent is bad, more of it is worse. Unfortunately, as we explain in later sections, much of the biological experimental evidence about power-frequency fields suggests that the more-is-worse assumption cannot always be justified.

The problem involves the definition of dose: identifying which, if any, aspect of the field can affect health. With a chemical, dose is typically defined as the amount that gets into people, or, if the body is able to metabolize or get rid of the chemical, the *rate* at which the chemical enters the body. Although some human epidemiological studies of the bioeffects of power-frequency fields have suggested a dose measure that is proportional to the long-term average of peoples' magnetic field exposure, other studies have suggested very different measures of dose. Examples, described in detail in Section 3 include:

- . Frequency and intensity "windows": Experiments in which biological effects are seen only in specific narrow ranges of field intensity and frequency, [Bawin 76, Blackman 85a].
- . Time thresholds: Experiments in which field effects are observed only after several weeks of exposure [Wilson 81, Wilson 83],
- . Transient responses: Studies in which field exposure induces a biological effect for only a short time after a change in the exposure [Byus 86].
- Field threshold: Effects that appear only when the field strength exceeds some threshold value [Liboff 84].

Although **each** of these experiments involves a different protocol and biological system, together they suggest that one may be unjustified in making the simple assumption that dose is proportional to field strength or to time spent in the field.

2.6. Comparing Human Exposures from Different Sources

As explained in Section 2.5, there is no accepted measure of the biological effectiveness of power-frequency fields. Comparisons of peoples' exposures to different sources of power-frequency fields, therefore, cannot be made on the basis of relative contribution to effective dose. Given the current state of the health effects science, comparisons between sources can be based only on those physical quantities that are amenable to measurement or theoretical estimates. These include electrical quantities such as induced surface charge and internal currents as well as quantities that describe exposure duration, how often an exposure occurs, and the numbers of people exposed. Although these quantities may not relate in any simple way to the possible public health impact of a given source, one can use them to get some idea of how similar or different peoples' exposures to various sources are. In the next few pages, peoples' exposures to power line fields and appliances are compared in six ways using 1) body-average current density, 2) body-average surface electric field, 3) body-average magnetic field, 4) peak current density, 5) typical exposure duration, and 6) the fraction of the total population exposed. Eight different exposure situations, each involving electric and magnetic fields from just one type of source, are chosen for comparison. These are:

1. Induction from transmission line fields in a person standing on the right-of-way (RoW) of a 500 kV line.
2. Induction from transmission line fields in a person inside a house located between the edge of the RoW and 100 meters from the centerline of a 500 kV line.
3. Contact current from an automobile parked within 100 m of the centerline of a 500 kV line.
4. Contact current from a typical appliance (e.g. toaster, refrigerator)
5. Induction from an electric blanket.
6. Induction from an electric shaver.
7. Induction from indoor background fields that arise from appliances plumbing, and wall wiring.

8 Induction from distribution line fields in a person standing beneath a 35 kV distribution line.

Exposure comparisons for these eight situations are presented in Figures 2-11 and 2-12. Exposure estimates are calculated from information in many of the sources referenced in sections 2.2, 2.3, and 2.4 as well as other data [Florig 87b, ICRP 75, Juster 79]. The range of values indicated for each of the entries in these figures represents both uncertainty in the various factors needed to estimate the dose (dosimetric factors) and variability across the exposed population. Note that the scale in each figure is logarithmic.

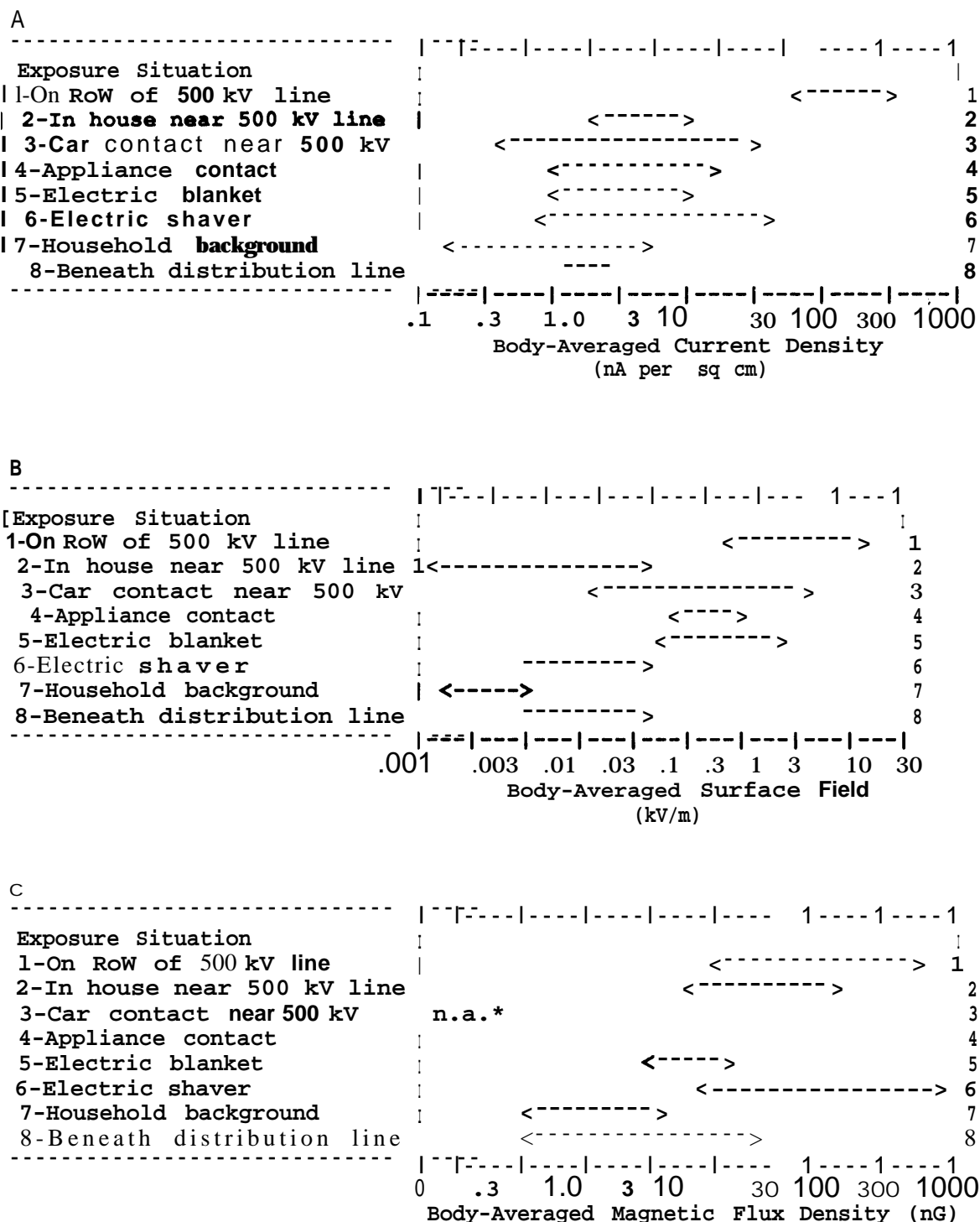
The most important message that these figures convey is that a ranking of different exposure situations along one dimension can look quite different from the ranking along another dimension. Exposures in transmission line rights-of-way, for instance, score high on the intensity-related dimensions but low on the duration and prevalence dimensions.

2.7. Sources of Exposure at Non-Power Frequencies

Power-frequency fields are only one component of the non-ionizing electric and magnetic fields that people regularly encounter. Electric and magnetic fields at higher frequencies are produced by a wide variety of modern devices such as stereo headphones (about 1 kHz), TV sets (about 20 kHz), AM radio transmitters (about 1 MHz), CB radios (about 30 MHz), FM radio and TV transmitters (about 100 MHz) and microwave ovens (about 2 GHz)².

Scientists do not know whether fields at these higher frequencies are either more or less biologically effective than power-frequency fields. There is evidence that VLF-modulated high frequency fields can produce effects similar to those of ELF fields. Many of these higher-frequency sources induce more intense currents in the body than are induced by most power-frequency sources. For example, the 20 kHz electric field at 1 meter from a television set, induces body currents that are comparable in magnitude to those induced by a power-frequency electric field of 3 kV/m.

²1kHz = 1 thousand cycles per second, 1 MHz. 1 million cycles per second, 1GHz = 1 billion cycles Per second.



*contact currents themselves produce negligible magnetic field. Of course the magnetic fields from the nearby 500 kV line would be comparable to those of exposure situations C1 and C2.

Figure 2-11: Three different exposure measures applied to 8 exposure situations. Exposure measures are A) the density of electrically and magnetically-induced currents averaged over the body, B) the induced electric field averaged over the body surface, and C) the average magnetic field within the body. Ranges represent the span of typical values.

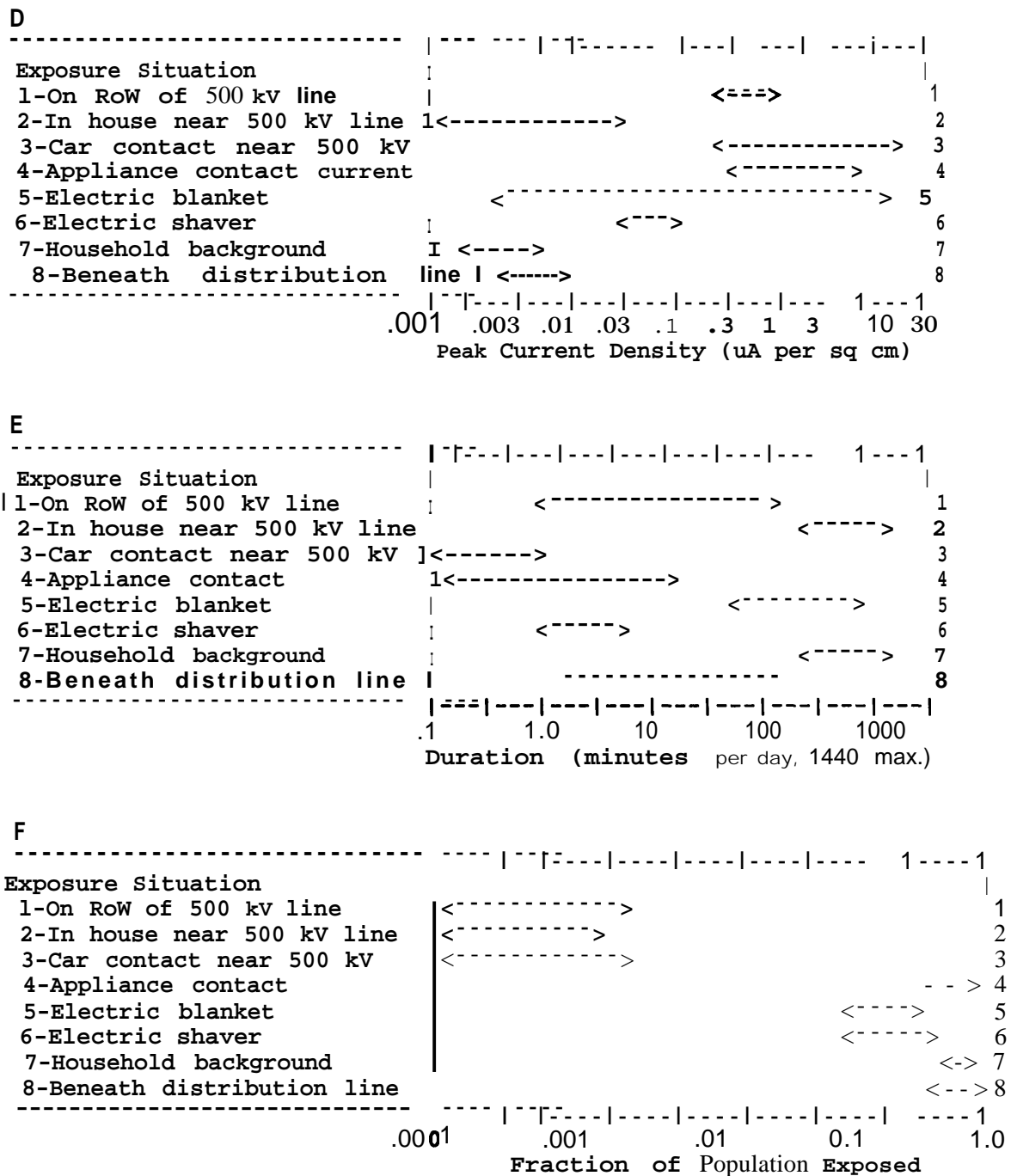


Figure 2-12: Three more exposure measures applied to 8 exposure situations. Exposure measures are D) peak electrically or magnetically induced current density anywhere in the body, E) the duration of the field encounter and F) the fraction of the population that regularly encounter the exposure situation. Ranges represent the span of typical values.