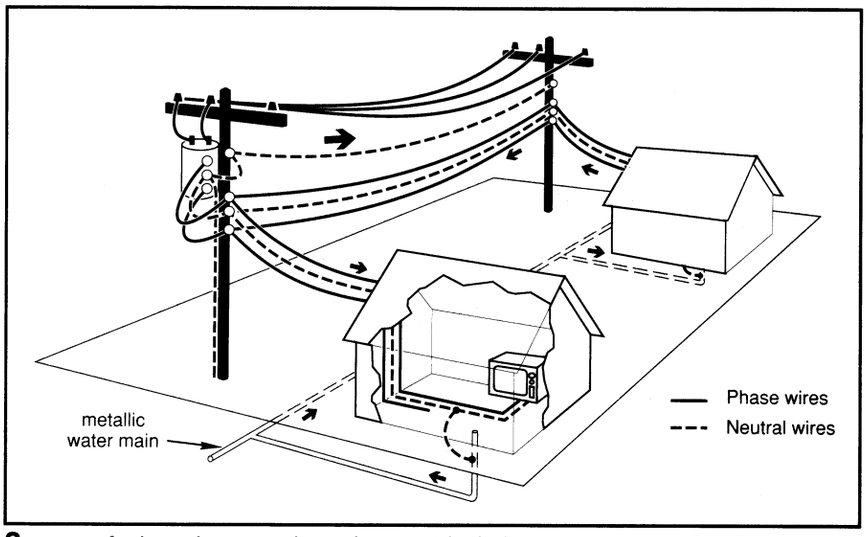
EMFs RUN AGROUND

Mapping magnetic fields from water pipes and other homely sources

By JANET RALOFF



EPRI

Sources of a home's magnetic environment include appliances, overhead power lines, and grounding connections to metallic water pipes. Fields in the home will vary over time, depending on how much current is passing through the electrically conductive sources. Additional contributors to a home's magnetic background may include unusual wiring in the walls, underground power lines, and any nearby high-voltage transmission lines.

Spurred by a simmering controversy over the potential carcinogenicity of magnetic fields, the U.S. electric power industry launched a nationwide survey in late 1990 to map fields associated with the alternating currents that power America's homes.

Completed late last year, this study not only characterized fields generated by power lines and household appliances, but also turned up a few surprises. Chief among them: A significant share of the total background magnetic field in a home may trace to electrical "grounds"—typically the attachment of a home's wiring to metallic water pipes.

At present, no one knows whether electromagnetic fields (EMFs) play a role in human cancer or other ailments, though several epidemiologic studies over the years have suggested that possibility (SN: 9/28/91, p.202). Studies in animals and cell-culture assays have even hinted at a mechanism by which the magnetic fields associated with household current might foster breast malignancies (SN: 7/3/93, p.10).

But because no one yet knows which attributes of a field might affect health most, the Electric Power Research Institute (EPRI), funded by more than 600 of the nation's electric utilities, attempted to quantify everything it could about the home's magnetic environment. The EPRI study not only identified major sources of magnetic fields, but also determined their frequencies, strengths, and how they fall off with distance.

"We're just digesting the results," says Stanley Sussman, who manages electric and magnetic field studies for EPRI at its headquarters in Palo Alto, Calif.

However, the institute expects these new data to "serve as a valuable resource for future research, both in helping resolve uncertainties about health effects and in establishing priorities for [magnetic] field mitigation," observes EPRI's Karl Stahlkopf.

Indeed, though EPRI won't release a final report on the survey until this fall, it has already begun issuing research contracts to resolve a host of questions spawned by its new findings.

The median strength of 60-hertz magnetic fields detected in the 1,000 randomly selected homes across the country that EPRI surveyed measured about 0.5 milligauss (mG). That's roughly one-thousandth the intensity of the geomagnetic field at middle latitudes on Earth's surface. (However, this analogy is somewhat like comparing apples and oranges, since Earth's magnetic field is static, while those due to alternating current oscillate at one or more characteristic frequencies.) Overall, EPRI observed considerable variation between homes, with some 5 percent of those surveyed registering background

averages of at least 2.7 mG.

Power lines running through a neighborhood proved the biggest single contributor to overall levels, when the house was considered as a whole. On average, these external sources produced an internal background of 0.2 to 0.5 mG, though their share occasionally ran as high as 2 mG.

Electrical-grounding systems within a home proved the next biggest overall contributor. While in retrospect this might come as no surprise, prior to the survey, few EMF analysts had given grounds much thought, Sussman says.

The three-wire, 240-volt electrical service that enters most U.S. homes from a nearby transformer at the street consists of two 120-volt "hot" lines and one "cold," or neutral, wire. The general expectation is that after running through most appliances in the home, the current – now at about zero volts – will return to the outside transformer via that neutral wire.

But the National Electrical Code requires that electricians "ground" the neutral wire as it enters a residence – by attaching it to metal water pipes, where available, and to a metal pole driven into the soil. (Electricians may establish additional grounding connections within the house – typically to metal shielding associated with telephone and cable-TV lines.)

These grounding connections that bridge the wiring and pipes (which constitute an additional pathway by which a current may travel) force both systems to carry precisely the same voltage – something they might not have done otherwise. The result: Individuals who touch grounded elements of both the electrical and plumbing system – such as in a kitchen, bathroom, or basement – receive no shock.

However, owing to this bridging, some share of a home's return current can shunt from the neutral wire to the ground system. Current always takes the path of least resistance. And especially in cases where the neutral wire's connection at the entry to the house has corroded or come loose, the water pipes may provide a lower-resistance return path to the outside transformer than the neutral wire does.

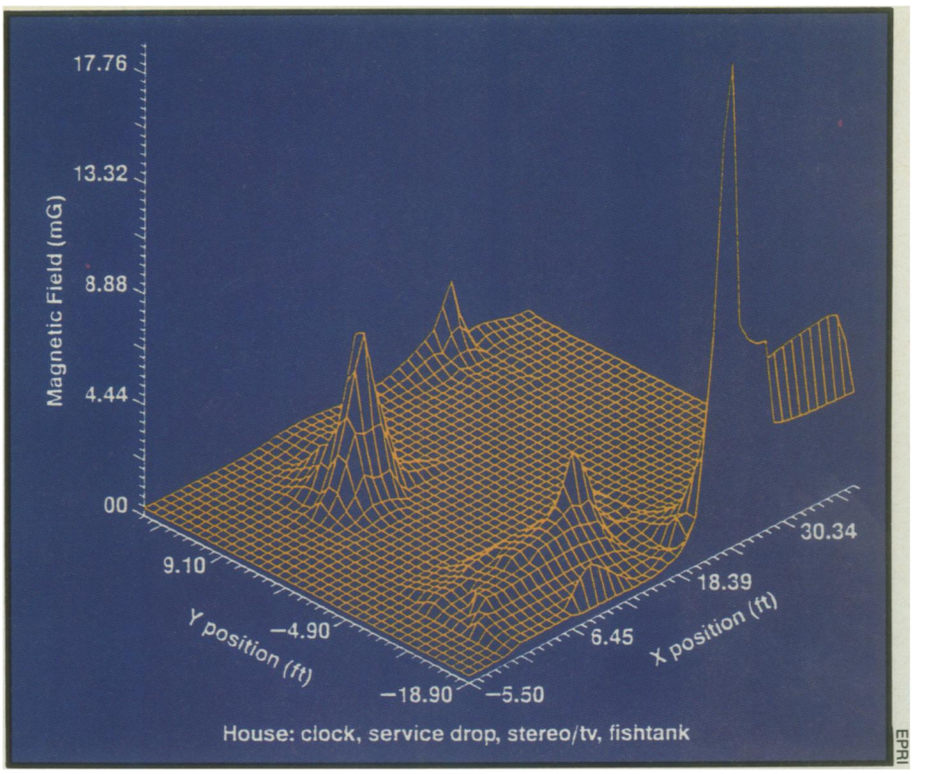
Indeed, Sussman told SCIENCE NEWS, "our survey showed that in many homes, a significant portion of that [return] current does in fact flow on water pipes, as opposed to this neutral wire heading back to the transformer and distribution system."

What's more, he notes, in situations where a community water system links pipes from one home to another, the return current running through grounded water pipes at one residence can enter an adjacent home, driving up magnetic fields there – even if all power to the second home is shut off.

Overall, EPRI's survey indicates that the share of a home's magnetic fields due to currents traveling through grounding systems averages 0.02 to 0.4 mG – but can exceed 1 mG.

Internal wiring, by contrast, generally proved an insignificant source of magnetic fields – except in those homes with a particular, obsolete form of wiring.

Ordinarily, the wires carrying current throughout a house are bundled together



Contour map of magnetic fields in one living room. While background levels generally fell well below 0.5 mG, a resident could encounter much higher fields near the wall outlet (service drop), analog clock, and stereo/TV stand. An aquarium motor generated fields that, even inches away, registered almost 20 mG.

Weak, persistent EMFs may dominate

The general rule for gauging the magnitude of electromagnetic fields is fairly straightforward: They fall off in proportion to the square of the distance from their source (or as $1/r^2$, where r = distance).

But what does this mean?

At a distance of 10 feet, for example, the magnetic field associated with a balanced electric current – such as the pair of wires in an appliance cord – would equal just 1 percent of the flux measured at a distance of 1 foot. At 20 feet, the field would register only about 0.25 percent of the value at 1 foot. And by 30 feet, the field would have dropped off to just 0.1 percent of the flux at 1 foot.

But this rule doesn't apply to fields induced by uncanceled electrical currents, such as those generated by electrical grounding systems. These fall off linearly with distance (or as 1/r), explains Gary Johnson at EPRI's lab in Lenox, Mass. So, at a distance of 10 feet from a ground current, the associated magnetic field retains 10 percent of the strength measured at 1 foot. Indeed, at 30 feet from a ground current, the associated magnetic field will have retained 30 times its strength measured at 1 foot as compared to a field associated with the balanced currents of a power cord a similar distance away.

As a result, Johnson points out, even small magnetic fields associated with ground currents can end up – at several yards from the source – contributing far more to a home's overall EMF background than appliances that may produce far larger fields, but that fall off more quickly with distance, such as microwave ovens and electric clocks.

– J. A. Raloff

(along with a separate ground wire) within a heavy plastic wrapper or metal conduit. Because the currents in the bundle's hot and neutral wires run in opposite directions, their corresponding magnetic fields tend to cancel each other out.

However, in 7 percent of the homes that EPRI surveyed, the hot and neutral wires took separate paths through the walls, held in place by a series of tubes and knobby insulators affixed to wall studs. The separation of these wires — by inches to a foot or more — limits the self-cancellation of their associated magnetic fields.

The relatively high fields associated with grounding-system currents result from the similarly wide separation of paths taken by current-carrying water pipes and the electrical system (see sidebar, this page).

Loops of wire built into the floors or ceilings of homes to provide radiant heating also can generate uncanceled magnetic fields. So can the chassis of major appliances — such as refrigerators, TVs, water heaters, and furnaces — when they become a conduit for ground currents.

Certain other indoor sources also can provide substantial, if very localized, inputs to a home's magnetic environment. For instance, motors and the circuitry associated with household appliances generated the highest peak fields measured.

At a distance of 10.5 inches, EPRI data show, magnetic fields generated by refrigerators average 2.6 mG, color TVs 7 mG, electric ranges 9 mG, analog clocks and clock radios 14.8 mG, and microwave ovens 36.9 mG. However, these fields drop rapidly with distance — far more so than they do from grounding systems (see sidebar, p.125). For instance, at a distance of about 2 feet, the average magnetic field set up by a refrigerator's motor dropped to just 1.1 mG. Roughly 4 feet from the appliance it registered 0.4 mG.

Mark Earley with the National Fire Protection Association (NFPA) in Quincy, Mass., notes that some plumbers have already begun responding to homeowners' concerns about ground currents by recommending the removal of grounding connections from water pipes. "And that is outright dangerous," asserts Earley, who serves as secretary of NFPA's National Electrical Code committee.

Realizing that individuals and professionals might begin resorting to such questionable practices, EPRI convened a workshop at Michigan State University in East Lansing last November to begin discussing what might be done to safely and legally reduce magnetic fields attributable to ground currents.

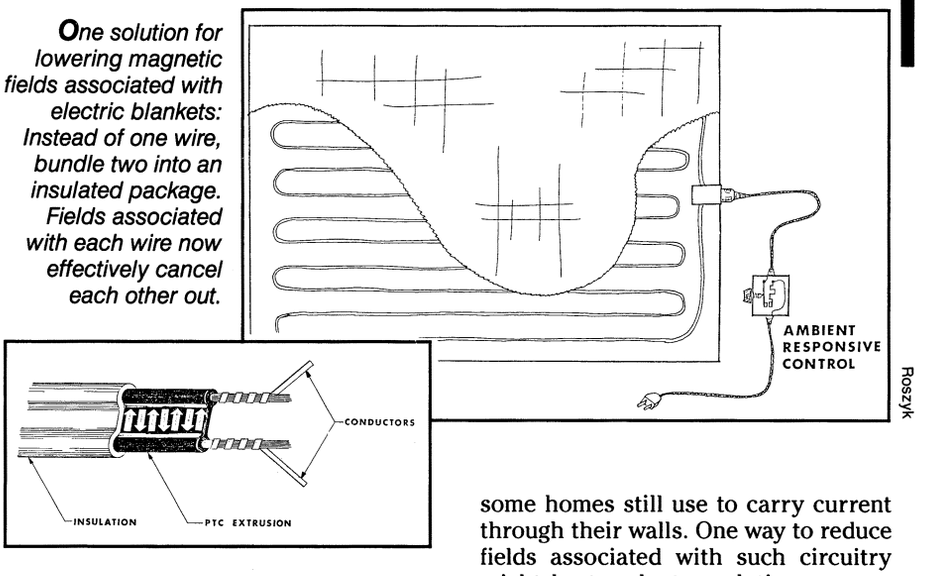
Fire-safety officials there agreed that one strategy permitted under electrical codes is the installation of an insulating link in the water-supply system. But safety-code representatives emphasized that to maintain protection against fires and electrocution — the reason for electrical grounding in the first place — such a current-interrupting insulator must be placed more than 10 feet outside the point at which the pipes enter a building, recalls Donald Cushman, who directs EMF programs for Rochester (N.Y.) Gas and Electric Co.

"I have recommended this insulating link," says Cushman, whose utility performs EMF surveys for its customers. Since there is no scientific evidence demonstrating that residential EMFs constitute a health hazard, customers must foot the cost of digging up a patch of yard and replacing some 12 to 18 inches of the some homes still use to carry current through their walls. One way to reduce fields associated with such circuitry might be to adopt a solution conceptually similar to the blanket's — rewiring with bundled pairs of hot wires.

EPRI's Stanley Sussman cited the Sunbeam blanket as an example of one way appliance manufacturers and utilities will be looking to reduce exposures through rewiring. Alternatively, safety engineers may cut exposures to unavoidable fields by shielding workers with materials that effectively screen them out. "The problem is, we don't have such materials right now," he observes. — *J.A. Raloff*

The electric-blanket syndrome

One solution for lowering magnetic fields associated with electric blankets: Instead of one wire, bundle two into an insulated package. Fields associated with each wire now effectively cancel each other out.



Roszyk

A single wire threaded serpentine-fashion throughout a fleecy cover: For nearly 50 years, electric-blanket manufacturers used this simple, inexpensive circuit design to warm bodies snuggling underneath. However, wires carrying current in opposite directions were separated by inches — too far apart to effectively cancel out each other's magnetic field. "So you got a substantial [magnetic] field under the wire," recalls engineering consultant Leon M. Roszyk, a former vice president for research and development at the Schaumburg, Ill.-based Sunbeam Corp.

Responding to consumer concerns about EMFs, Sunbeam introduced in 1989 a simple change to the radiant-heating system in its blankets. Instead of a single wire, it began snaking a bundled pair within the panels of its warming coverlets. Separated by a mere 1/32-inch, each wire carried precisely the same amount of current as its mate, though in the opposite direction. The change reduced magnetic fields associated with the blankets by 95 percent or more, Roszyk notes — to between 0.3 and 2.3 mG.

The circuitry in Sunbeam's pre-1989 blankets is analogous to the radiant heating systems embedded in the floors and ceilings of some homes. It also simulates, on a small scale, the now-obsolete knob-and-tube wiring that

water line with heavy plastic. It's relatively expensive, Cushman notes – generally costing about $300 to $500 per home. But he adds that where it has been used, this insulator has cut ground currents in the home "to where [magnetic] fields from them have essentially disappeared."

This strategy offers little help, however, in limiting the fields associated with imbalanced current loads carried by the primary-distribution lines that run down urban thoroughfares. These lines transmit power from the local substation to the neighborhood transformer, which in turn feeds a cluster of residences.

Unlike the wiring in a home, this primary-distribution system has four wires, three of them hot. Also unlike a home's wiring, this system lacks a dedicated ground wire. So for safety purposes, electric utilities periodically establish grounding paths to the primary system's neutral wire – at each transformer, for instance.

In at least one aspect, this primary-distribution system is analogous to the much simpler wiring in a home: Its current-carrying wires transmit voltage at "phase angles" that are designed – as a team – to cancel each other out, explains Gary Johnson, a General Electric Co. physicist at EPRI's High-Voltage Transmission Research Center in Lenox, Mass. When all the current is carried on the primary's hot wires, they balance out – creating magnetic fields that decrease quickly with distance.

Indeed, even when an imbalance exists between the currents carried on the hot wires, the fields should still balance because the neutral wire's job is to carry the "current difference."

At least, that's the theory.

In practice, however, currents flowing along the primary system are seldom truly balanced. And when imbalanced, they – and associated ground currents – result in a less-than-complete cancellation of the primary system's magnetic fields.

The magnetic field associated with ground currents due to this small current imbalance falls off slowly. As a result, though it represents just a small share of the field close to the distribution line, it frequently constitutes the primary system's biggest magnetic-field contribution in a house located several hundred yards away.

Stewart J. Maurer of the New York (City) Institute of Technology has begun analyzing the problem with computer models. In a technical report he prepared for the Empire State Electric Energy Research Corp., published last January, Maurer notes that locally, the magnitude of a power line's current going into the ground tends to depend on how well grounded the customers are that draw lots of electricity, and on how much resistance their soil offers any current traveling through it.

EPRI has already begun analyzing ways to minimize magnetic fields associated with electrical grounding systems.

One scheme under consideration is the development of a five-wire system for the primary distribution of electricity. It would carry separate ground and electrically insulated neutral wires. The neutral wire could then be dedicated to serving just one function – the unimpeded transmission of any imbalanced current back to an electrical substation. This should eliminate current leaks to ground and the resulting development of associated magnetic fields.

Of course, the answer isn't that simple, Johnson concedes. Utilities still don't know what it might take to mesh a five-wire system with their existing electrical equipment, nor how, if at all, the incorporation of such a system might jeopardize safety.

Indeed, Sussman says, these are among a broad range of EMF-mitigation issues that EPRI plans to explore over the next few years. □