How to wire a house for low EMF
Part 2: the specifics

Electromagnetic (EMF) radiation from household wiring can be drastically reduced by good design and wiring practices. This is part 2 of a two-part how-to article.

Keywords: *EMF, EMR, radiation, house, apartment, home, wiring, design, reduce, protect, shield, electric field, magnetic field, healthy house, electrical sensitivity*

Introduction

This article is a catalog with detailed information on how to minimize radiation from the electrical system in a house or apartment. The methods can be used to modify an existing home or when building a new house.

The information is intended for homeowners and electricians. A homeowner can use this article as a basis for discussion with an electrician.

The examples use materials and practices from the United States, but we have tried to write the text so it is usable in all countries.

Not all suggestions are needed or feasible in all situations.

This is part 2 of a two-part article. Part 1 covered basic information needed to understand these instructions, and why they work. It also dispels some myths and misunderstandings that are commonly believed — even by some electricians. Please read part 1 before proceeding. It is available through the link at the end of this article.

A separate meter pedestal

It is best to have the electrical meter on a separate pedestal that is a bit away from the house (perhaps 30 ft/10 meters). The front of the meter should point away from the house (by at least ninety degrees).

Most electrical meters have wireless transmitters in them, or will be replaced with one in the future. They radiate mostly out the front of the meter, hence the need for the meter to point away from the house.

The buried cable from the pedestal to the house should also dampen any microwave frequencies travelling along the cable from the meter's wireless transmitter. (The buried cable will not really help on the lower frequency dirty electricity from the meter's electronics.)

The pedestal should have a small electrical panel with a master breaker, a ground rod and a neutral-to-ground connection (called "bonding"). This feature may reduce the amount of ground current around the house, unless the house is in a dense neighborhood where the ambient level is already high.

An alternative is to mount the meter on a garage or outbuilding. This can work as well as a pedestal.

For apartments it is best if the bank of meters and electrical panels is on the wall to another apartment and at least 30 ft (10 meters) away.

The main electrical panel

The main electrical panel (or "breaker box") controls the electricity as it enters the house from the outside. Most homes have just one electrical panel, but apartment buildings and large homes may have additional sub-panels.

The main electrical panel should be mounted on an exterior wall of a room people spend little time in, such as a utility room or laundry room. If the panel has a meter on it, the panel should be mounted on the outside of the wall so the meter points away. Even better is to mount the meter on a pedestal.

The electrical meter is usually mounted on or next to the main panel.

The main electrical panel has one or more breakers that can be used to shut off the electricity to the entire building. It is also where the "neutral" wire is connected to the ground, called "bonding." More about this later.

The main electrical panel should be mounted on the same exterior wall where the electrical feed enters the house. It should not be mounted in the center of the house.

The panel can be mounted on the inside or the outside of the wall. It is usually best to mount it on the outside, especially if it has an electrical meter on it (wireless meters radiate mostly out the front).

Most building codes require the main electrical panel to have a connection between the neutral and the ground wires, and down to a ground rod. This is called "bonding." Unfortunately, this provides the electricity with an alternative path to run from the neutral wire, down the ground rod, through the soil and back up another ground rod somewhere else. Electricity always runs in complete circles, it doesn't disappear into the ground. This setup can cause ground currents and unbalanced circuits, which can raise the level of EMF in and around the house.

See Part 1 of this article and the book *Tracing EMFs in Building Wiring and Grounding*, by Karl Riley for a more detailed explanation.

Make sure the main electrical panel is of the type that can be configured as either a sub-panel or a master panel. These panels may not be available at your local building supply store. If not, try an electrician's supply store.

Such a panel will have:

- separate bus bars for neutral and ground
- the neutral bus bar is insulated from the steel box (chassis)
- a removable screw or cross-bar connects the two bus bars

Using such a panel gives you the option of separating the neutral and ground there, to reduce ground currents. This works best if there is an electrical pedestal with the master breaker and ground rod a bit away from the house. Then the required bonding can take place there instead (some inspectors may not be comfortable with that, though).

Do not mount electrical panels in contact with metal studs

If a breaker box is mounted in contact with metal studs, it can create a path for electricity to return to the panel via the studs instead of via the neutral wire (or ground wires).

Use some sort of plastic or wood spacer, and no screws that touch both the electrical panel and the studs. Or use a wooden stud.

In some countries the breaker panels are of plastic, so this is not a problem there.

Sub-panels

Apartment buildings usually have separate electrical panels with breakers for each apartment. Large homes or homes that have extra rooms added onto them may also have extra panels.

Any panel that is not the main breaker panel is a sub-panel.

A common mistake is that the sub-panel has a connection between the neutral and ground ("bonding"). It is very easy to make this mistake, since the panels usually (perhaps always) come with the bonding in place. Many panels do not have the ability to remove the bonding and not all supply stores even carry the ones that can. A true sub-panel has these features:

- separate bus bars for neutral and ground
- the neutral bus bar is insulated from the chassis
- a removable screw or cross-bar connects the two bus bars

It is against the U.S. building codes to have bonding on sub-panels because it will make the grounding wire between the sub-panel and the main panel carry electricity (in parallel with the neutral wire). However, many electricians are not aware of that, and they frequently leave the bonding in place on sub-panels.

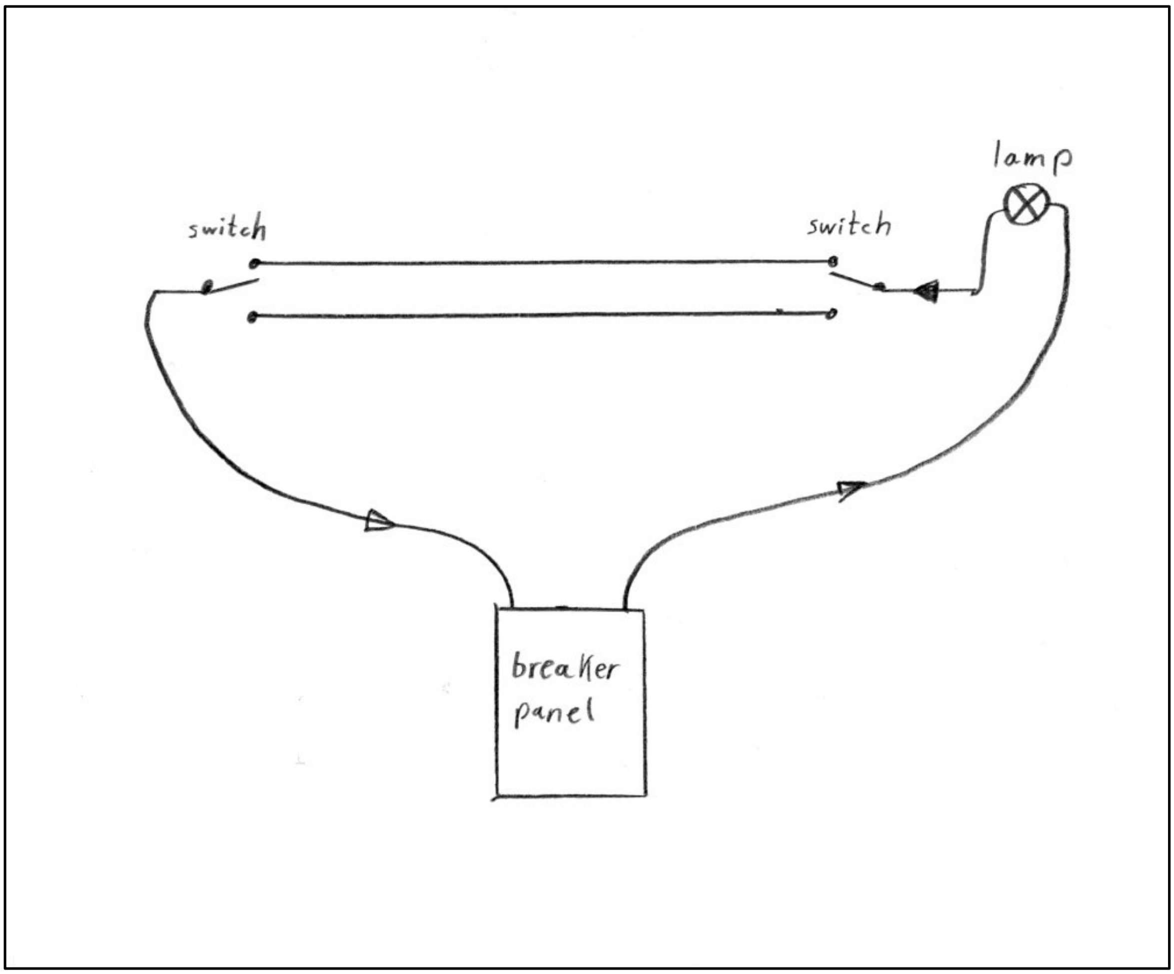
Bonding in a sub-panel can cause electricity to run in strange places that are connected to the grounding system, such as metal water pipes, metal studs, metal air ducts and many other places. Very high electrical and magnetic fields have been the result, but since electricians and building inspectors don't carry gauss meters, these problems are rarely discovered.

Wiring a three-way circuit

A three-way circuit is often used in hallways, so the lights can be turned on and off from each end. This is done with toggle switches instead of regular switches.

Some electricians cut corners and wire the circuit by connecting each toggle switch to the nearest circuit they can find (which are likely two different circuits) and string a two-conductor cable between the two toggle switches.

With such a setup, the current will arrive to the first toggle-switch on one cable, go to the second toggle-switch and then return to the breaker panel on a different cable.

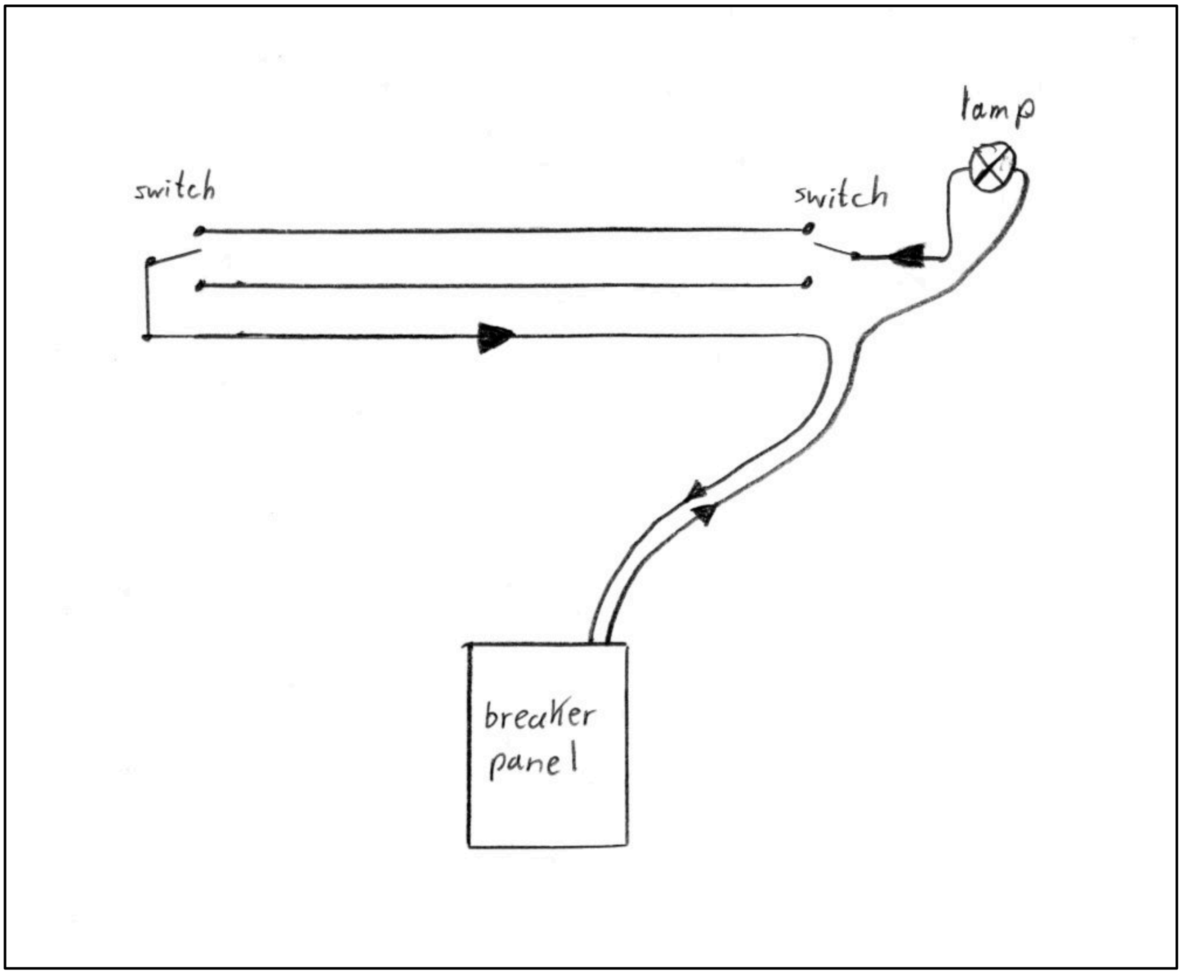


Incorrectly wired three-way switch, where the current is unbalanced and thus creates a strong magnetic field along the entire path of the current.

Since the current does not return on the same cable, the circuit will radiate much more than it should (see Part 1 of this article).

Also, since the neutral wires of the two different circuits are connected to each other, more EMF problems can happen. Electrical currents from other appliances on these circuits may also travel across the link between the two circuits to cause further unbalance and radiation.

The U.S. National Electric Code (NEC) forbids crosslinking neutral wires from different circuits.



Correctly wired three-way switch.

The correct way to wire a three-way circuit is with a three-conductor wire. Any electrician's handbook should have the diagram. It is simple enough to do correctly, but some electricians like to do it the bad way because it is a little simpler and they don't have to go pick up a piece of three-conductor wire. For them to see, their little short cut works just as well.

Beware of wall boxes serving more than one circuit

Sometimes there are wires from two or more circuits going to the same wall box. This may happen when there is a row of switches in the same wall box.

It is easy for the electrician to just connect all the neutrals together right there. He may do it automatically, not thinking they are different circuits. It may simply be a bad habit. It seemingly works fine that way, so why not?

But the crosslinked neutrals from different circuits can create horribly unbalanced circuits, with high magnetic fields. And it is against the U.S. National Electric Code.

Keep neutral and ground separate

The neutral wires are connected to the ground in the main breaker box (bonding) as mentioned before.

Since the neutral wire is connected to the ground, some people think of it as a sort of alternative ground. It is not. Horrible problems with magnetic fields have been created because the neutral wire was connected to other neutrals or ground wires, or even studs or metal pipes. This has created alternative paths for the electricity and thus unbalanced circuits.

Also, the further the neutral wire gets from the bonding point, the more the voltage will rise above ground potential — especially if the circuit serves a high-wattage appliance, such as a stove or refrigerator.

Routing the wires for less EMF

The radiation from the wires is reduced by distance. Just adding an extra foot (30 cm) of distance can make a big difference.

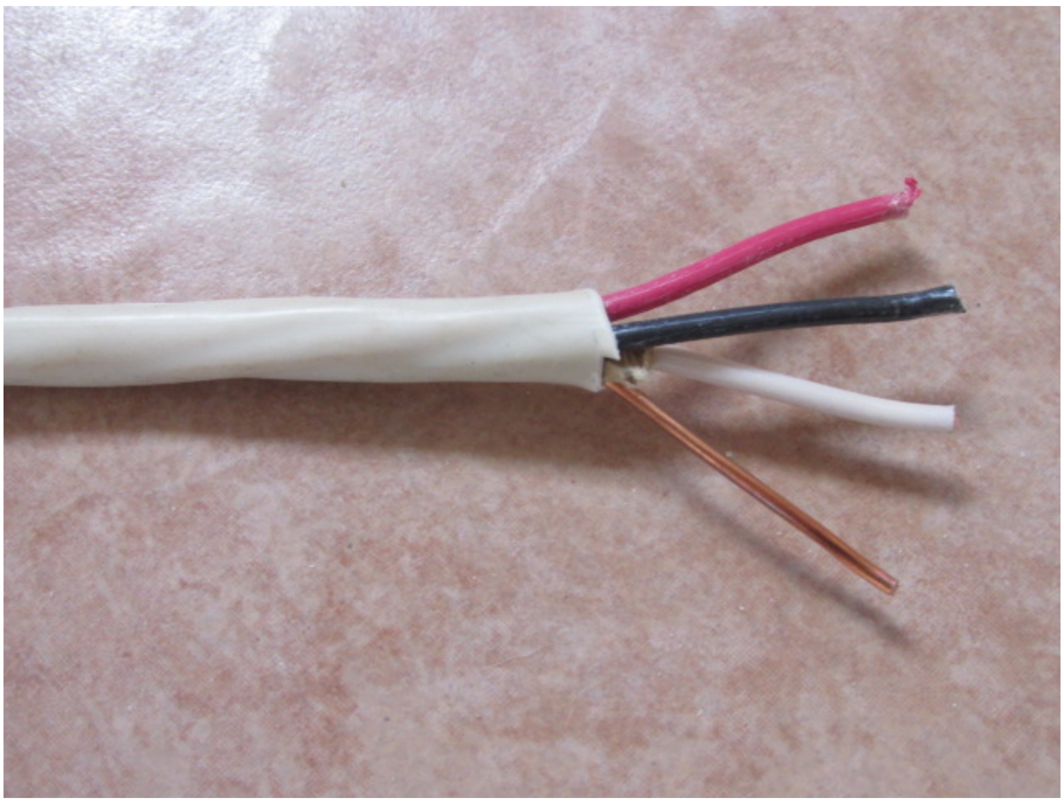
When installing or upgrading household wiring, consider routing the cables to keep them further away from places where people spend a lot of time. This is especially important around the bed. Avoid installing cables crossing under the floor or over the ceiling; instead follow the top of the walls.

Twisted wires

Twisting the hot and neutral wires around each other enhances the shielding effect of having the two wires run close together (see Part 1). Twisted wires are commonly used in cables for computer networks and telephone cables. It is not commonly done for household wires, though doing so reduces the magnetic field by about 90% (this is not as impressive as it sounds). Twisting the wires does not reduce the electrical field.

Cables with twisted wires can sometimes be bought ready-made. In America, some brands of three-conductor cables (12/3 and 14/3) are already twisted — not because they reduce the EMF, but for production reasons. Close inspection of the cable will show if the wires are twisted under the protective sleeve. The extra (usually red) wire is simply not connected to anything, or could be connected to ground in the end closest to the breaker panel (do not connect in both ends).

It is simple to twist your own wires, using a variable-speed power drill. Measure how long the cable needs to be, then cut off a piece of cable that is about 20% longer (because it will shrink from the twisting). Mount one end of the cable in the chuck of the power drill (instead of a drill bit) and attach the other end to a tree or let a helper hold it. Then slowly turn the drill so the whole cable becomes twisted.



The twisted pattern can be seen through the sleeve on this ROMEX 14/3 cable. According to the color coding used in the United States, the black wire is "hot," the white wire is "neutral," the red wire is not used and the bare copper wire is for the ground.

Twisting an electrical cable using a slow-moving variable-speed power drill.

About one turn per inch (25 mm) is good. Do not twist it too tight as that would make the insulation thicker and possibly cause the cable to overheat in extreme situations (max current on a hot day).

Shielding the wires with aluminum foil

Some people with environmental sensitivities cover the walls with aluminum foil to seal in fumes from the building materials and contaminations absorbed by the walls. If the walls of the house are covered with aluminum foil, it will also shield the electrical field from the wires in the wall. It will do that regardless whether the foil is grounded or not.

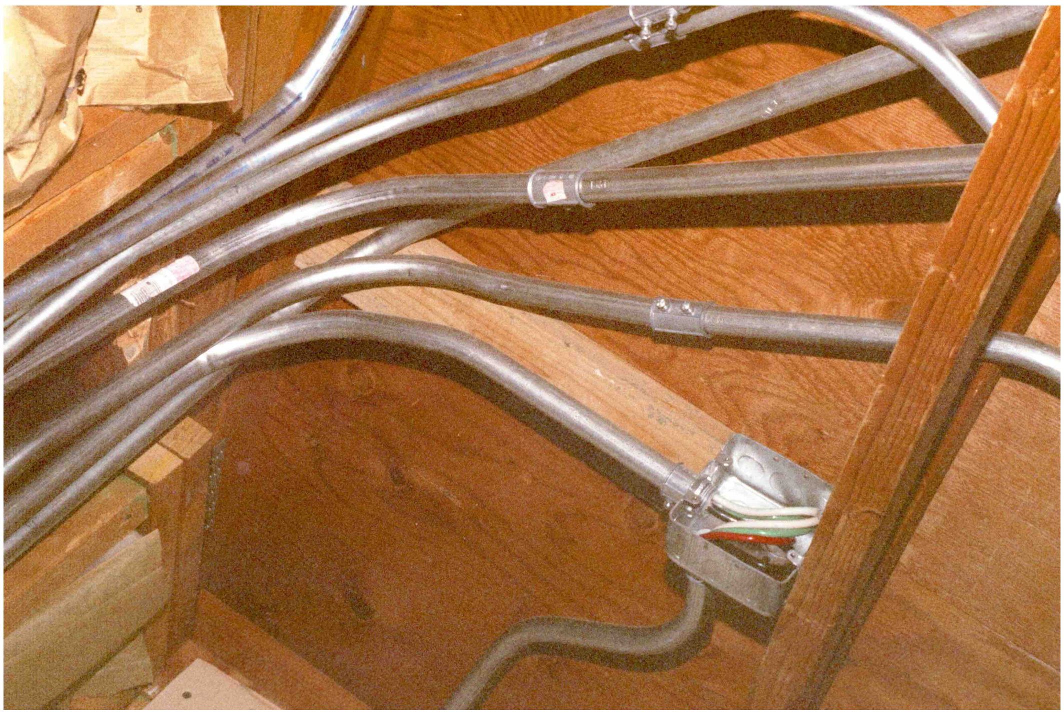
Thin aluminum will not shield magnetic fields, but if the wires are also twisted then both the magnetic and electric fields will be reduced.

Shielding the wires with steel conduit

Encasing the wires in steel conduit shields both the magnetic and the electric fields, but at a much higher cost. It takes a lot of extra labor time to install metal conduit.

In America, the EMT conduits work just as well as the heavier IMC conduits. EMT is better than the flexible MC (metal clad) cables because MC does not make a tight connection with wall boxes.

When pulling conduit through walls with metal studs, it is best to insulate the conduit as it passes through each stud. This can be done by wrapping a short length of garden hose around the conduit, or with some other kind of flexible and durable plastic. Steel electrical boxes should also be insulated from the studs they are mounted on. This all reduces the possibility of stray electricity.



Metal conduits spreading out across the ceiling near the breaker panel in a house.

Metal conduits mounted on the outside wall, under a porch roof, since it was not possible to install them inside the existing wall.

It is possible to replace the wiring in an existing house, though it may be difficult to access some areas. It may be necessary to install exposed conduit either on the inside or outside of a wall. Sometimes cosmetic covers can be installed to make it look better. Some wiring may not be needed and can simply be disconnected at the breaker panel.

If steel conduits are not available, water pipes of steel or copper can be used instead.

Switching off circuits

If the breaker is turned off for a circuit, it is no longer energized. This can reduce the magnetic and electrical fields in a room. Some people keep the breakers off for their bedroom for that reason.

There are electronic switches available that automatically disconnect the electricity to a circuit when it is not needed and turn it back on when needed again. These switches are installed in the breaker box and work by placing low voltage DC electricity on the wires to detect when a lamp is turned on. It may be acceptable to install one of these in a rented apartment or house.

All breakers and switches turn off the "hot" wire, but not the "neutral." Disconnecting just the "hot" wire greatly reduces the electric field, since the neutral wire carries a very low voltage (usually just one volt). However, leaving the neutral wire connected can still be a problem.

The neutral wire sometimes has a higher voltage on it, especially in large apartment buildings and office buildings. The neutral wire can also carry "dirty electricity" that radiates off the wires, even at a nominally low voltage.

Kill switches

The best protection is to install a "kill switch," which is a double-poled switch that disconnects both the hot and the neutral wires where they enter the room, so all the wiring in the room is isolated from the grid.

The switch looks like an ordinary wall switch and is usually located by the door. The electrician should make sure to route the cable carefully, so the part before the switch doesn't run along or across the room, since this part of the cable will still radiate when the switch is off.

In the United States and Canada, the type of switch used for 240 volt circuits is suitable, readily available and will be familiar to any electrician. (In North America, 240 volt circuits consist of two phases and no neutral. Most other countries do it differently.)

Kill switches are mostly installed in bedrooms, since that is the room that needs the lowest EMF level. If more than one circuit serves the walls around the room, they must each have their own switch.

If there are wires passing through the bedroom to other rooms, they will need to be re-routed, shielded in metal conduit or disconnected also. Also consider sleeping in a different room.

Before you go to the expense of installing a kill switch, you can try to see if it will help by fully disconnecting the circuit at the breaker box. This is done by flipping the breaker AND disconnecting the neutral wire from the bus bar (best to cap it with a wire nut or electrical tape).

Kill switches look like ordinary switches.
Here there are two kill switches in the upper switch panel,
because there are two circuits in the room.
The lower switch is for a ceiling light.

Whole-house kill switch

A more radical kill switch is one that disconnects the entire house. It can be used to disconnect power at night. People who are extremely electrically sensitive can keep it off all the time, except when electricity is briefly needed, such as when running a washing machine.

Three-poled whole-house kill switch to disconnect the two phases and the neutral to a home in the USA. In areas served by three phases (most of Europe), a four-poled switch is needed. This box is mounted below the master panel on an outbuilding.

Such a switch is the most effective if located a bit away from the house (say, 30 ft or 10 meters) as it can then better reduce stray electricity in the soil below the house.

Light dimmers

Do not allow any light dimmers anywhere in the house. They all work by rapidly turning the power to the light bulb on and off thousands of times a second. This creates powerful spikes in the electricity (dirty electricity) that can travel on the wiring to every room in the house, even those on different circuits.

Light fixtures

It is best to install regular light fixtures, as they provide the most flexibility to avoid unhealthy light sources — now and in the future.

Avoid installing fluorescent light fixtures. Those kinds of lights and their ballasts are a problem for many sensitive people.

Avoid 12 volt track lighting. The built-in transformer produces EMF and "dirty" 12 volt DC (i.e. DC electricity with high frequency spikes). Some of the tracks widely separate the plus and minus, which means they may radiate more powerfully.

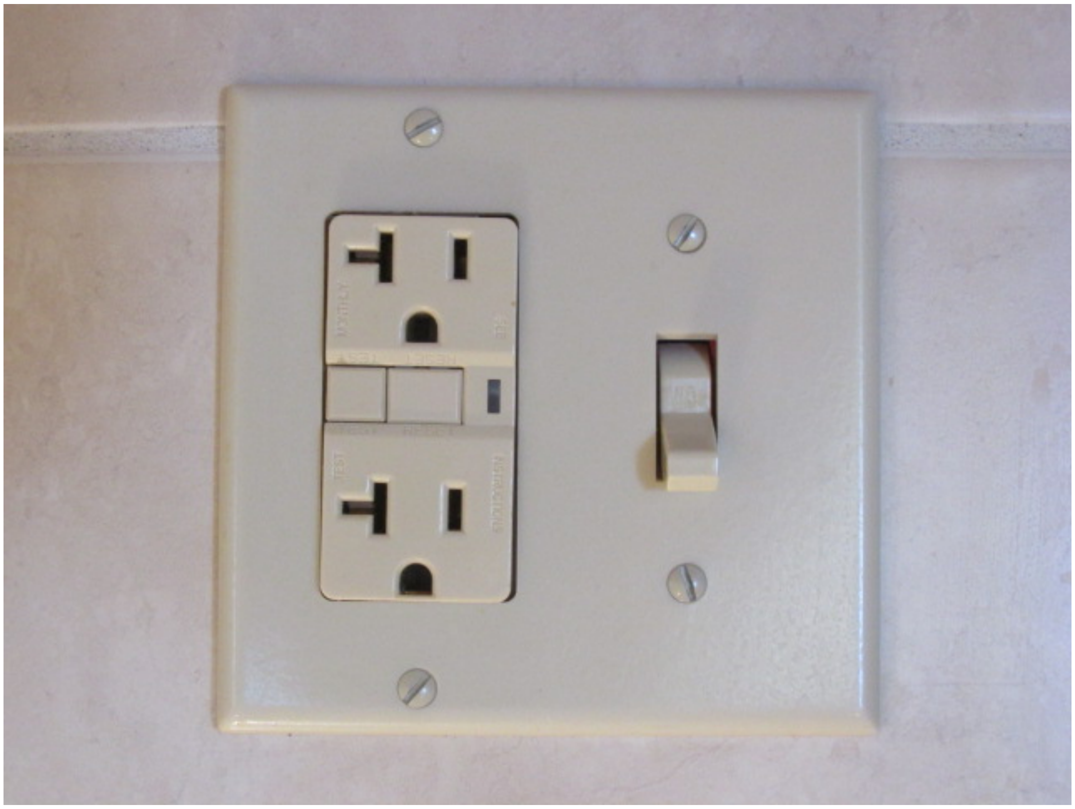
The exception to the no-12-volt lighting rule is if the 12 volt DC electricity comes from a battery, and that battery is charged by a no-EMF charger. (In practice that means a solar system designed with zero-EMF components. See elsewhere on this website for details.)

Ground fault breakers (GFCI/RCD/FI)

The building codes in the United States specify that electrical outlets in "wet" areas (kitchens, bathrooms, porches, etc.) must have special GFCI (Ground Fault Circuit Interrupt) outlets to protect people against electroshock. These are also called Residual Current Devices, RCD.

These GFCI outlets contain electronics that control the breaker. Their electronics radiate all the time, whether the outlet is used or not, and regardless whether it is tripped or not. Some models have better designed electronics that radiate much less than others. The Cooper brand has for more than a decade been the best (at least as of 2016).

Another measure is to put each GFCI on a switch, so it is totally off when the outlet is not needed.



GFCI outlet controlled by a switch, so it is only on when actually needed.

Building codes often require outdoor outlets to be GFCI protected. If these outlets are on separate breakers (which is common), the breakers can simply be left off when not needed.

In parts of Europe it is common to have switches for each outlet and use whole-house versions of the GFCI (called RCD, HFI or FI in some of these countries).

The arc fault (AFCI) breaker

Building codes in the United States started requiring arc fault breakers in 2008. These AFCI (Arc Fault Circuit Interrupters) are required to protect any circuit that serves a bedroom.

The AFCI has a tiny built-in computer that monitors the line voltage to detect arcing (i.e. tiny sparks that could cause a fire). AFCIs are installed in the breaker box, not in the outlet boxes (see picture).

We have tested one brand of AFCI breaker and found it was more radiant than most GFCIs. Some brands may be better, but you'll have to use one that fits the breaker panel.

Since the AFCI is mounted in the breaker box, it may be acceptable to have it there. An option is to disconnect that circuit. Another option is to install a regular breaker, once the house has passed inspection and accept a slightly higher risk of a fire.

AFCI breaker in a breaker panel. It serves the bedroom and can be recognized by the red test button.

Metal walls, foiled walls

Some MCS houses have walls covered with plates of steel or aluminum foil. If such walls accidentally become energized, the electrical field in the house will greatly increase and people can receive electric shocks. The walls can be accidentally energized in a variety of ways, such as by hammering a nail into the wall where it hits an electrical wire and brings it into electrical contact with the metal wall.

The conventional protection method is to connect the metal walls to the house wiring's ground, perhaps through the ground prong on one or more electrical outlets. If the walls become energized, they will immediately short to ground and trip the breaker.

Another common way is to use steel wall boxes for the electrical outlets and ground the walls through every single outlet box.

Both of these two methods may turn the walls into giant antennas that radiate whatever "dirty electricity" frequencies are travelling on the house ground wires. There may also be weak currents running from circuit ground to circuit ground across the metal walls.

There are some alternatives:

1. Protect all outlets in the room or house with GFCI/RCD/FI, so they will detect any problems. This may not solve the nail-in-the-wall scenario, though.

2. Install a whole-house GFCI/RCD/FI.

3. Connect the walls to separate grounding wires that go directly to the ground rod that also serves the main breaker box. This can still dump frequencies on the walls.

4. Connect the walls to a totally separate ground rod. This is not as good at detecting a short and may not pass inspection in some areas.

5. Not connecting the metal walls to anything at all and accept the small extra risk. Several houses have these "floating walls," and the inspectors are not likely to notice.

6. Have the walls not connected to anything and then install a custom built device that instantly connects the walls to the regular electrical ground if the wall potential rises about 10 or 20 volts. This is a new and untested idea, but the most elegant on this list. A building inspector is unlikely to understand and approve this method. The needed device is not available commercially and not approved by any authority.

It is best to use plastic outlet boxes rather than steel boxes, since the steel boxes will need to be grounded and it will be difficult to ensure they do not touch the metal walls.

Older houses

Older houses may not have ground wires in the cables going to the electrical outlets. You may see that some outlets do not have the third ground prong, while some outlets are the newer type with a ground. If your home has both kinds, it is best to get it checked out as some (or all) of the grounded outlets may be fake. They may have the neutral wire connected to both the neutral prong *and* the ground prong, or the ground prong is simply not connected to anything.

Having proper ground available on all outlets helps lowering the electrical fields around appliances, such as refrigerators and washing machines, as well as metal lamps.

Some American houses that were wired before the 1950s may have "knob and tube wiring" where the hot and neutral wires were run widely apart. This type of wiring produces high magnetic and electric fields, and should be fully replaced. There are not many houses with this any longer.

Apartments

Apartments are difficult because the neighbors are so close. Shared walls, ceilings and floors usually contain wires controlled by the neighbors. Dirty electricity (high frequency transients) can easily travel between the apartments on the phase, neutral and ground wires. The neutral and ground wires can be several volts above the actual ground potential because the wires tend to go longer distances from the ground rod. Larger buildings also tend to have more electronics (computers, televisions, etc.) that each dump small amounts of current on the ground wires.

Since you probably do not own the entire building (or even any of it) it is much more difficult to make changes.

It is usually best to choose an apartment as far away from the bank of electrical meters as possible. Both to avoid the meters and the cables carrying electricity to the other apartments.

Use instruments to measure the magnetic and electrical fields from wiring hidden in the walls, ceiling and floor. If the wiring can't be modified, consider using galvanized steel plates to cover the radiant surfaces. Steel will dampen both the RF, electrical and magnetic fields (aluminum and copper will not).

It may help to turn off the breakers to the bedroom at night. A landlord may be willing to let an electrician install an automatic switch in the breaker box. A kill switch (that disconnects both wires) is better, but also a more involved installation.

It is unlikely that the landlord will pay for any modifications to the apartment, and what you cannot take with you when you move out becomes the property of the landlord.

More advanced measures

There are more advanced methods that can be used to further reduce the EMF in some cases.

An isolation transformer may reduce the amount of electricity running in the soil under the house, but it is costly to install and wastes electricity (losses in the transformer).

Filters can be installed to dampen dirty electricity coming into the house on the electric wires from the outside. There are some low-cost plug-in filters available that may help, but it is limited what they can accomplish. In some cases, they make things worse. More effective filters must be installed by an electrician and can be costly (especially for the American 120 volt systems as the current is higher).

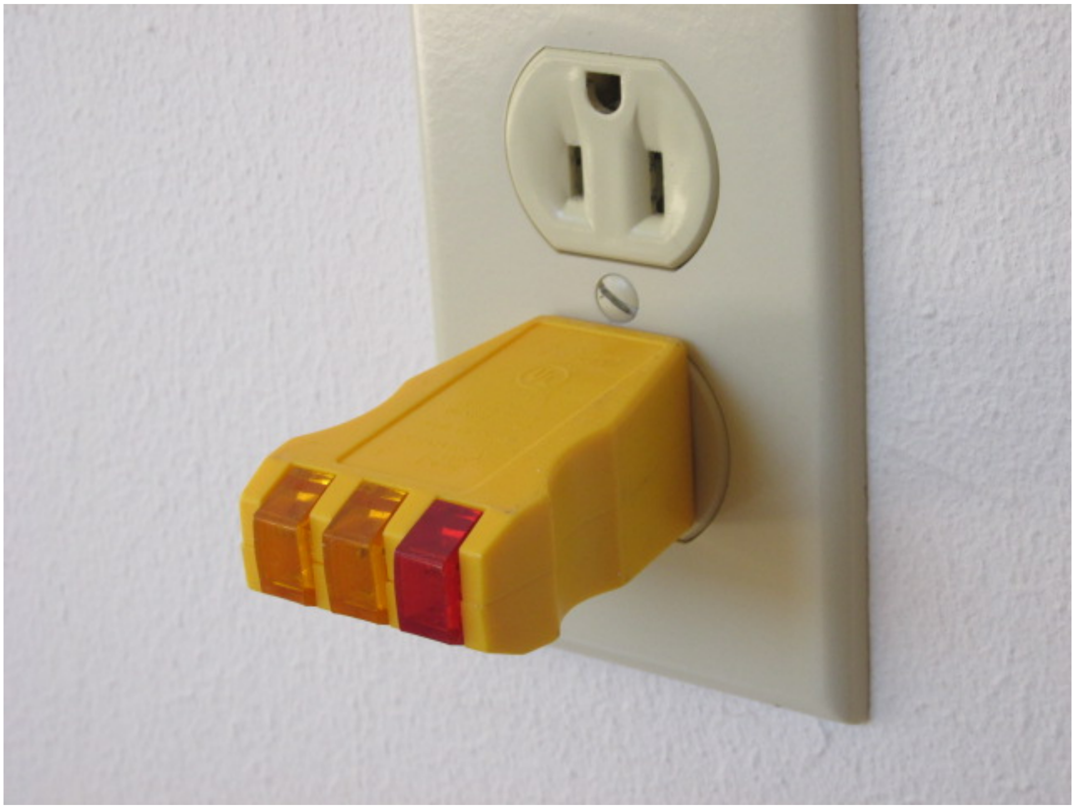
DC (Direct Current) electricity can be used in a house instead of regular AC (Alternating Current). In praxis this will work well only with a well-designed solar system (not with a 12-volt battery charger or a converter, as they produce lots of "dirty DC").

Such exotic measures are rarely needed and require detailed information to install correctly. They are not covered in this article. DC solar systems are extensively covered elsewhere on this website (see below).

Check the work

Mistakes happen even for conscientious electricians, and some of this may be new to whomever does the work.

Your local hardware store should have a handy little outlet tester for about $5. Simply plug it into every single electrical outlet in the whole house. It comes with instructions and is very easy to use, just watch the indicator lights to verify each outlet is wired correctly.



A simple low-cost outlet tester.

It checks to see if the wires have been swapped, if any wire is missing or the ground does not work.

It will not detect if there are any unbalanced circuits, dirty electricity, or the ground and neutral wires have been swapped.

Get a gaussmeter (teslameter) and measure around the house with all the breakers off. Then turn all the breakers on, but make sure all lights and appliances are fully unplugged. You should get similar readings with the meter whether the breakers are all on or all off.

Then turn on various lights and appliances, and measure around the house again. You'll probably get higher readings near the appliances, but further away the levels should be close to what they were with the breakers off.

If there are any problems, try turning off all the breakers, except one. Then measure again. Turn on a second breaker and measure again. You should be able to identify which circuit is causing the higher reading. There may be multiple circuits with problems. There may be more than one problem on the same circuit. Troubleshooting can be difficult.

Beware of inappropriate grounding "solutions"

Because of incorrect wiring, often compounded by changes to a building over time, electricity may be running along metal water pipes, metal gas pipes, metal air channels, etc. This is both a shock hazard and creates high magnetic fields because the circuits are not balanced.

Some electricians may simply say that more grounding is the solution. They connect the electrified water pipe (or whatever) to the ground, and, presto, the shock hazard is gone. But the current will still be running, even though the voltage is lower. It is a common mistake to believe that the ground is a sort of trash can to send wild electricity into. Electricity doesn't disappear, it always runs in a circuit to return to its source.

More grounding can actually make things worse, as it can increase the amount of stray electricity and thus unbalanced circuits, with higher magnetic fields the result. An extreme example of that is a very elaborate $75,000 "EMF protection" grounding system that was sold in Sweden until a court prohibited further sale. (The story is told elsewhere on this website, see the link below.)

Hiring people to do the work

A competent and open-minded electrician should be able to do this work. Working with metal conduit is something any electrician should be familiar with, since it is standard practice for commercial buildings in the United States and other places.

Print out a copy of this article and give it to the electrician you are considering hiring for the job, then see if he is comfortable with it all. A good electrician can also provide helpful information during the planning.

There are electricians who are slobs or unwilling to learn something new, even though they are great at talking up their skills. Remember, they all have to sell themselves or they won't get any work.

Since parts of the work are a little different than what they are used to, electricians may be reluctant to provide a firm bid on the job. Or their bid may be higher than reasonable, to be sure they are covered. It may be cheaper to hire on a time and materials basis instead.

Some electricians will claim anything they are unfamiliar with as "dangerous" (even a simple kill switch!) in order to avoid what they are unfamiliar with and still get the job. In that case, get a second opinion to see if your project really is dangerous or not.

More information

We highly recommend the book *Tracing EMFs in Building Wiring and Grounding,* by Karl Riley for detailed information about unbalanced circuits, stray electricity and how to track down problems in existing wiring.

More articles about reducing electromagnetic radiation, including Part 1 of this article, can be found on www.eiwellspring.org/lowemfhousing.html.

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