Basic Steps Toward Tracing and Eliminating Power-Line Interference

You don't have to live with power-line interference problems; you can *solve* them. Here's how to turn that *bzzzzzz* into a *sssshhhh*!

By Max Trescott, K3QM
3405 Ridgemont Dr
Mountain View, CA 94040

Power-line noise: You probably heard it before you heard *about* it. On a radio, it sounds like a hummy, buzzy sizzle or roar that may be punctuated by pops and crackles. It can be weak, strong or anywhere in between. Sometimes its strength varies. Power-line noise may intensify during wet weather. It may be stronger in a particular direction; it may appear to come from everywhere at once.

What you've probably heard *about* power-line noise varies from the overly dismal (there's next to nothing you can do to cure it and keep it cured) to the dangerously wacky (you can locate noisy poles by walking around town with a sledgehammer and portable radio, listening for a change in the noise as you bop each pole's base.)

This article explains the causes of power-line noise, how to locate power-line-noise sources, and what to do to make the noise go away and stay away.

Power-Line-Noise Types

Power-line noise comes in two flavors: *corona discharge* and *spark-gap* noise. Corona occurs when the strong electric field associated with a high-voltage conductor ionizes air near the conductor—particularly at sharp edges and projections. The ionized air may glow blue and crackle audibly. Corona also rips apart diatomic oxygen (O_2) and produces triatomic oxygen (O_3, *ozone*), a pungent, corrosive gas that destroys power-line hardware and endangers human health. And corona generates broad-spectrum electromagnetic noise.

Generally, the higher the voltage involved, the stronger the corona. Corona also increases with humidity and precipitation because these make the air more conductive. Corona-induced power-line noise is generally worst during periods of rain or snow, when precipitation hangs as droplets from the bottom of transmission lines. Trying to locate these sources of foul-weather power-line noise is rarely worth the trouble because little can be done to eliminate them.

Spark-gap noise causes most power-line interference. It occurs whenever a spark jumps between two conductors. This occurs when sufficient potential difference exists between the conductors to ionize the air in the gap between them. Ionization decreases the air's resistance. When the air's resistance drops enough to support conduction, a spark jumps the gap and current flows through the ionized air channel. The ionized channel's resistance varies considerably, causing current variations that can be induced into and travel along power lines. The spark also directly radiates noise across a broad frequency spectrum. Under some conditions, sparks can trigger trains of successively weaker pulses. The resulting *damped waves* contain strong harmonic energy and can cause severe interference well into the VHF region.[1] Spark-gap noise generally weakens with frequency (see Fig 1),[2] a characteristic that can be very useful as you track interference. One exception to this rule occurs when the power lines connected to the noise source resonate at a particular frequency or frequencies. The noise may peak at these frequencies (Fig 2).

Much power-line spark-gap noise occurs when sparks jump across spaces between the hardware pieces used to mount cross-arms, insulators, transformers and other equipment to power poles. In most cases, such noise can be eliminated by the power company. Unlike corona, spark-gap noise is usually a fair-weather phenomena; it may disappear during rain because precipitation short-circuits inter-hardware gaps.

Because residential power lines carry 60-Hz ac, the voltage on them passes through two maxima (one positive, one negative) each cycle and through zero twice each cycle—120 maxima and 120 zero crossings per second. Corona and spark-gap noise follow this pattern, generally starting and stopping 120 times per second. This gives power-line noise its characteristic hum or buzz. It usually appears continuously across a broad frequency range, although it may come and go.

How Power-Line Noise Travels

Power-line noise can be transmitted by *conduction*, *induction* or *radiation*. Interference can be conducted through the power lines, and into a receiver power supply. It can travel by induction when the power line carrying the interference is close enough to an antenna or some other part of the receiver circuit to couple the interference into the receiver, or into another power line. It can also travel by radiation: power lines may act as an antenna.

Conduction and induction are usually responsible for only lower-frequency interference because the conducted current decreases rapidly with frequency. Above 100 MHz, for example, conducted power-

> **Sources of Power-Line Spark-Gap Noise**
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> Most power-line noise comes from sparks that jump gaps in the hardware used to mount cross-arms and other hardware to power-pole tops. Even if sufficiently tightened at installation time, this hardware can loosen as wood expands and contracts with temperature and humidity changes. Sparking can also occur across the film of corrosion that builds up on power-pole hardware as it weathers and ages. Power companies constantly evaluate new hardware that better resists loosening and reduces spark-gap problems.
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> Power-line insulators may break down under the aging influences of sun, precipitation, dust and pollution. As a result, carbon tracks form across insulators, causing power-line leakage that may generate intense spark-gap noise. Power utilities combat this by periodically hosing down insulators, and through continuing research in insulator materials with greater breakdown resistance.
>
> Perhaps surprisingly, pole transformers rarely generate power-line noise. Investigation usually reveals that noise from a transformer-bearing pole comes from sparking between pieces of the hardware used to mount the transformer to the pole.—*K3QM*

[1]Notes appear on page 46.

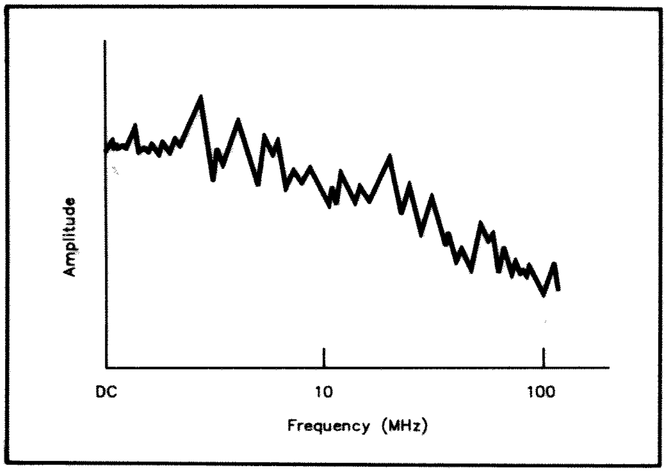

Fig 1—Spark-generated interference generally decreases in strength with rising frequency. The text describes how this characteristic can help you localize an interference source.

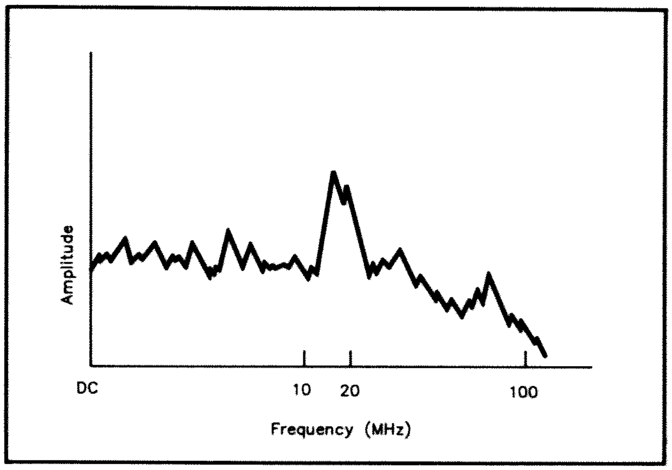

Fig 2—Spark-generated interference may not generally decrease in strength with rising frequency when power lines associated with the noise source resonate and peak the noise at one or more frequencies.

line interference is usually only a problem if the distance between the noise source and the receiver is less than the distance spanned by six to eight power-line poles.[3]

Power-line interference in the VHF and UHF ranges almost always occurs because of direct radiation from a spark-gap noise source. Although cases have been documented of objectionable interference traveling up to 30 miles by radiation, most power-line noise sources can usually be found within one or two miles of the receiver. Radio amateurs are more likely to pick up line noise from farther away because hams generally use better receivers and antennas than the general public.

Tracking Interference from Sources Inside Your Home

After you've decided to track down the source of spark-gap noise, make sure the interference isn't coming from *your* house. (Quite a few power-line noise complaints stem from sources within complainants' homes!) The easiest way to check this is to turn off your house's power at its entrance panel. Before you cut the power, get a battery-powered receiver—a portable AM radio should work just fine—and tune in the interference. If the noise goes away as you cut the power, the noise source almost certainly exists *in your own house* and is not a power-company problem.

If cutting the power does not stop the noise, turn the power back on and skip to "Tracking Interference from Sources Outside Your Home." If cutting the power reveals that the noise comes from an in-house source, turn the power back on and confirm that you can once again hear the noise in your monitor receiver. Then turn the main power off again. Next, turn off all the *individual* house circuits. (Keeping the MAIN switch off while you do this is safer than doing it with the MAIN switch turned on.) Then turn the MAIN switch back on. Next, isolate the noise-generating circuit(s) by turning the individual house circuits on one at a time. When you activate one that brings back the noise, turn it off again and note that circuit. Work through the remaining circuits likewise to determine if any more are noisy. Once you've worked through the entire service panel, turn everything back on except the noisy circuit(s). You should hear no line noise in your monitor receiver. Turning any suspect circuit(s) back on should make the noise return. After you've determined the circuit(s) involved, identify which room(s) that circuit powers.

Once you've identified the room(s) involved, identifying the offending appliance(s) is easy. *Unplug*—don't just turn off[4]—all appliances, and switch off all lights, in the suspect room(s). Plug them back in and switch them back on one at a time. When you activate one that brings back the noise, turn it off and note that appliance or light. Work through the remaining appliances and lights likewise to determine if any more are noisy. Once you've worked through everything in the room(s) served by the noisy power circuit(s), power everything back up except the noisy circuit(s). You should hear no line noise in your monitor receiver. Powering up any suspect lights or appliances should make the noise return. The sidebar "Possible Line-Noise Sources in the Home" lists some of the more likely suspects.

If you can't locate the faulty appliance, track down the interference source by carrying the receiver around the house to find where the noise is strongest. You may be able to save time by using the receiver's mediumwave-antenna directivity to get an idea of the noise source's direction (see the sidebar, "Direction-Finding with a Portable Radio").

Even with everything in a powered circuit turned off and unplugged, it's possible—though highly unlikely—that faulty wiring may continue to power the noise source. For example, a lighting switch installed in the fixture neutral lead (incorrect and dangerous wiring) instead of its hot lead may allow a hot-to-ground gap in the fixture to receive ac even with the switch turned off (Fig 3).

Tracking Interference from Sources Outside Your Home

If your investigation suggests that the line noise probably comes from a source outside your house, quieting the noise will involve help from the power company. Many power companies have field-investigation units that track interference sources. There's a stronger incentive for doing such work than helping power customers achieve quiet radio

Possible Line-Noise Sources in the Home

Determining that power-line noise comes from somewhere inside your house is one thing; finding the device responsible is another. Here are just a few of the common household devices that can cause power-line noise when functioning normally:

- electric motors, including those in saws, vacuum cleaners, garbage disposals, hair dryers, clocks, water pumps, furnace blowers, microwave ovens, model cars and trains, air conditioners, sewing machines, shavers, mixers and blenders
- thermostats, including those in air heating and cooling systems, electric blankets, and water and fish-tank heaters
- air ionizers, purifiers, humidifiers and dehumidifiers
- fluorescent lights
- TVs
- computers and TV games
- TV booster amplifiers
- doorbell transformers
- neon signs
- light-dimmer switches
- scanners
- gas- and oil-appliance igniters

Anything that uses ac power may generate power-line interference if it malfunctions.—*K3QM*

Direction-Finding with a Portable Radio

Use a portable radio, preferably one that covers AM, FM and shortwave, as your primary tool for locating noise sources. Starting at the lowest frequency receivable on the radio, find a clear spot on the dial and listen for the noise. Switch to higher-frequency bands until you determine the highest band on which you can still hear the noise. If you have a choice, listen in AM or an SSB mode. FM detectors generally reject or greatly suppress AM noise, which power-line noise is, so avoid listening in the FM mode if you can.*

A directional receiving antenna is helpful, though not essential. Most AM-broadcast-band receivers contain a ferrite-bar-based antenna, and such antennas are very directional. (You can determine the alignment of your set's antenna if you know the location of a local AM station's antenna relative to you. Tune in the station and rotate the radio for maximum signal strength, and note which of the radio's dimensions [front or side] points toward the station. This same alignment will prevail when you rotate the radio to maximize the sound of the noise you're tracking, and will give you an indication of direction in which the noise source is located.†)

Most AM/FM/SW portables use an extendable whip antenna for shortwave and FM. Although these antennas are omnidirectional when vertical, they can be somewhat directional when horizontal. To use this characteristic, turn the radio on its side so that its antenna is horizontal, hold the radio close to your chest, and point the antenna in front of you. Turn slowly until the noise signal peaks. The noise source should now be directly in front of you.—*K3QM*

*Pinpointing a noise source is easier at VHF, but most AM/FM/SW radios, and 2-m Amateur Radio gear, afford only VHF *FM* reception. Snag: FM radios don't receive line noise (a form of AM) well. Unsnag: An air-band (108- to 136-MHz) receiver may help you end run this problem, because air-band stations use AM to avoid FM's *capture-effect* suppression of the weaker signal[s] when two or more stations transmit simultaneously. In the August 1991 *Potomac Valley Radio Club Newsletter*'s "A Line Noise 'Sniffer' That Works," Bill Leavitt, W3AZ, describes his success in using a "$20 aircraft radio receiver that Radio Shack makes" (apparently the Jetstream AM/VHF-Air, #12-601). Leavitt cautions that the radio's relative unshieldedness requires that it be mounted in a metal box with its whip antenna removed to allow the attachment of a Yagi for directional reception, and that switchable input attenuation is necessary to keep the set's AGC from broadening peaks and nulls.—*Ed.*

†Because such antennas are *bidirectional*, taking a single directional bearing with an AM set's antenna can't tell you whether a noise source is behind or ahead of you. So, when tracking noise, move a hundred yards or so and take another bearing. Imagine where the bearing lines intersect to determine the approximate location of the noise source.—*Ed.*]

or TV reception: Fixing spark-gap problems early on can keep more serious problems, such as burned poles, from developing later on.

In considering calling the power company for help, consider these alternatives: (1) stop tracking the noise and call the power company to ask for their help in finding the noise source and (2) investigate further to find out more about the noise before calling the power company. Alternative 1 requires less work on your part (and is your prerogative as a power-company customer, of course). Alternative 2 is arguably the better of the two, though, because the more you can tell the power company about the noise and its possible source, the faster they'll be able to fix the problem. (Telling your power company that strong spark-gap interference emanates from, say, "Pole 2156" gets a repair crew off to a considerably better start than a vague "I'm getting some interference" call.) This is especially so in cases of *intermittent* interference—interference that, according to Murphy's Law, (naturally) falls frustratingly silent when the repair crew arrives—and interference that does not occur during regular business hours. (Power crews can track noise during off hours, but may need management approval to do so.) Tracking interference can also lead to self-improvement: It hones your direction-finding skills, valuable in foxhunting or tracking a jammer.

Whether or not you've located the interference source, the power-company personnel who answer your call will probably ask you questions about the interference. What kind of device is affected? What does the interference look and/or sound like? When does it occur? At what frequency? Be prepared to give as much information as you can, because the person recording the information may be merely completing a form and may know nothing about radio interference. Also be ready to provide a daytime phone number so a complaint investigator can follow up with questions. You may also be asked if you're willing to demonstrate the interference.

Tracking Power-Line Interference

Determine the general direction from which the interference comes. If your antenna is directional, rotate it to peak the noise. Naturally, the narrower your antenna's beamwidth, the better, but even an antenna with relatively broad directivity (such as an HF tribander) can provide a useful bearing. Rotate the antenna 180° from the noise peak and check again to see if the signal is louder from that direction. It's entirely possible to get a strong reading off the back of a beam and start searching in the wrong direction! (If your antenna isn't directional, or if your directional antenna is not rotatable, don't despair. You may still successfully locate the noise; keep reading!)

Tune in the noise on your portable radio. At first, you may not be able to hear the noise on the portable, especially if you originally located the interference using your ham-station gear and a high-gain, direction-

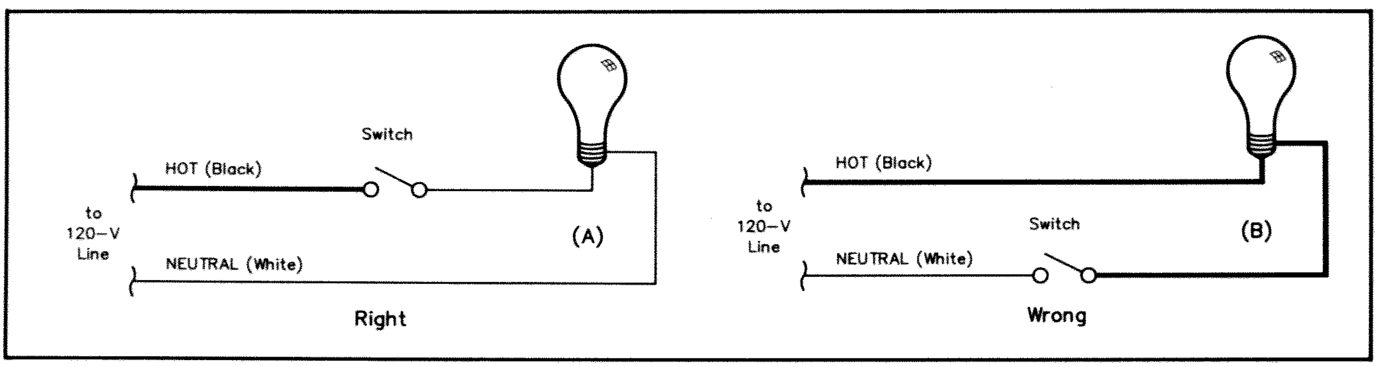

Fig 3—Correct light-switch wiring (A) interrupts the hot connection between the light fixture and the ac line. Incorrect wiring (B) leaves the fixture and much more of the wiring connected to the hot ac wire whether the switch is on or off. Turning the switch off in B cannot quiet line noise caused by hot-to-ground sparking in the light fixture.

Don't Bang on Power Poles

Ham folklore holds that banging hard on suspected power poles can sometimes fix power-line noise. This is *wrong*: Although it may momentarily stop the noise or change it, such "tapping" doesn't actually *improve* anything that can go wrong on a pole. The noise *always* returns! Banging on power poles is *dangerous*: It can damage a pole, make a pole-hardware problem worse or even knock out power! And banging on power poles is *illegal*: Power-company hardware is neither your property nor your responsibility.

Tracking power-line noise is one area where power-company and ham expertise overlap, and most power companies will welcome your direction-finding input. But when the time comes to evaluate and repair power-company hardware, *leave the job to the experts.* Don't hit—or climb!—power-company property.—*K3QM*

al antenna atop a tall support. If the portable's whip or directional AM antenna doesn't let you hear the noise at ground level, try enhancing reception with a small, portable Yagi (such as a three- or four-element 2-m antenna). If you don't have such an antenna, or you still can't hear the noise despite receiving-system enhancements, follow the power lines in your area in all directions until you start to hear it. Most power-line-noise sources cause interference only within a mile or two, so you should be able to pick up the noise signal relatively quickly. But expect to get some exercise! If you consider driving instead of walking, keep in mind that a car may be more of a liability than an asset if it generates electrical noise that's stronger than the noise you're tracking. Having to shut off a car while taking noise-strength readings may be such a hassle that tracking the noise on foot may be easier and faster if your receiving setup can be carried easily.

Once you pick up the noise on your portable radio, keep following the power lines. Periodically switch to higher receive frequencies to see if the noise is now audible at higher frequencies. Because spark-gap-noise strength decreases with frequency, you should be able to hear the noise at increasingly higher frequencies as you near its source. An increasing line-noise S-meter reading at a single frequency *may* indicate that you're getting closer to the source, but can be misleading because conducted noise is generally stronger at corner and transformer poles.[5]

If you can hear the noise at 2 m, a small, four-element Yagi antenna can be very helpful in locating the noise source because it is sensitive to polarization in addition to being azimuthally directional. A Yagi noise-receive antenna usually produces the loudest noise signal when held horizontally. When you're within 100 feet or so of the noise source, however, vertical polarization may provide a stronger signal. Thus, be sure to shift antenna polarization at intervals to determine which produces the strongest noise.

As you get extremely close to the noise source, you may notice the noise peak in strength, and then decrease as you pass a particular power pole or wire span. VHF reception with a Yagi is particularly useful in such cases because sharp antenna directivity can help you determine exactly which pole generates the noise. Try sweeping the beam vertically. You may discover that the signal is loudest with the antenna pointed at the top of a particular pole.

Time and effort spent localizing the noise is worthwhile even if you can't identify a specific pole as the source. In addition to being grateful that you've narrowed the search to a particular area, your power company's repair crew will be able to find and fix the problem all the faster.

Although you'll probably find your local power company quite responsive to your request for help, don't expect them to fix the problem immediately. A few weeks may pass before a crew can be assigned to quiet even a well-defined noise source—perhaps longer if the noise source has yet to be identified. So, don't wait until the week of an important contest before calling the power company for help! (The sidebar "If the Power Company is Unresponsive" suggests what to do if your diplomatic requests for help meet with little or no response.)

If the Power Company is Unresponsive

Friendly, intelligent interaction between you and your local power company is one more vote for good relations between power utilities and Amateur Radio as a whole. In the unlikely event that your local power company doesn't respond positively to your request for help, you can file a complaint with your state public-utilities commission. Such commissions, usually based in state capitals, mediate consumer complaints in addition to reviewing and approving the utility-rate structures that determine how much we pay for electricity. Recourse to your public-utilities commission is a last resort that you should take only *after* you've done your best to work productively with your local power company.—*K3QM*

After They Fix the Problem

When you report a power-line-noise problem to the local power company, ask them to notify you when they solve it. (Of course, if the line noise is severe, you'll probably know anyway!) After you're notified that the problem has been fixed, check to be sure the interference is gone.

In most cases, the noise will be totally gone. You may still hear noise, however, for a couple of reasons. First, the original source may still be generating some noise because the power company may be unable to totally eliminate it. Don't assume that this is the case, however. If you still hear noise, contact the power company again.

Another possibility is that an additional noise source, now no longer masked by noise from the cured source, may be audible. Again, if you consider the noise a problem, contact the power company.

You may not be able to eliminate all the line noise you can hear, and may opt instead to go after only the most severe problems. In my case, I eliminated two major, fairly constant S8 noise sources. Since then, I've heard what I believe is power-line noise, occasionally peaking at S6, from several other directions. These sources are usually considerably weaker and disappear altogether in the evening. If they become severe—and therefore worth the effort to find them—I'll be out tracking them down!

In the meantime, it's comforting to know that something can be done about power-line noise—that, in most cases, it *can* be fixed!

Thanks

Special thanks to Deep Gupta, N6XHY, of the Electric Power Research Institute, and Wally Hanifin of Pacific Gas and Electric, for providing input and reviewing this article.

Notes

[1]Damped waves weren't always our enemies; we once *communicated* with them! But the horrendous interference caused by damped-wave emission compelled amateur and commercial radio users alike to adopt *undamped* emission—*continuous waves*, or CW—over the spark transmission commonly used during radio's infancy.—*Ed.*

[2]W. Nelson, *Interference Handbook* (Wilton, CT: Radio Publications Inc, 1981), p 24. [Available as #6015 from The ARRL Bookshelf, this book, written by a power-company investigator with over 30 years of experience, is a must-read for anyone interested in or beset with radio-frequency interference (RFI).—*Ed.*]

[3]T. Gonen, *Electrical Power Transmission System Engineering* (New York: John Wiley, 1988).

[4]The power switch in some consumer devices disconnects the device circuitry from its power supply while leaving the supply connected to the ac line. Power-supply components can generate noise, so merely turning off such a device leaves a potential noise source connected to the line.—*Ed.*

[5]*Interference Handbook*, p 59. See note 2.