Feature

# A Smarter Approach to Resolving Power-Line Noise

Experienced investigators provide a planned approach and detailed methods to finding and fixing power-line interference problems.

**By Mike Martin, RFI Services; Riley Hollingsworth, FCC; and Jody Boucher, Northeast Utilities**

Although the problem has been around since the dawn of radio communications and broadcasting, power-line noise issues are on the rise. The proliferation of electrical, electronic, mobile and wireless devices—which are susceptible to power-line noise—have contributed to this increase. The law requires utilities to rectify power-line interference, but this does not have to be a budget-breaking experience. By using proper approaches, utilities find that dealing with a power-line noise complaint is seldom time consuming or expensive.

Power-line noise can interfere with radio communications and broadcasting. Essentially, the power lines or associated hardware generate unwanted radio signals that override or compete with desired radio signals. Power-line noise can impact radio and TV reception, including cable TV head-end pickup and Internet service. Disruption of radio communications, such as amateur radio, can also occur. Loss of critical communications, such as police, fire, military and other similar users of the radio spectrum, can result in even more serious consequences.

**Fig. 1. FCC Part 15 rules require utilities and other operators of "incidental radiators"—such as power lines—cause no harmful interference to licensed operations.**

## Common Household Items That Cause Interference

- Door bell transformers
- Electric blankets
- Heating pads (of all kinds)
- Recessed ceiling light fixtures
- Furnace control circuits
- Refrigerators (becoming a frequent problem)
- TV top and stereo, amplified antennas
- Light dimmers
- Aquarium heaters
- Screw-in photocells
- Low-energy compact (screw-in) fluorescent lights
- Touch control lamps
- Clean air machines (table top and furnace type)

Sparking or arcing across power-line related hardware causes virtually all power-line noise that originates from utility equipment. A breakdown and ionization of air occurs, which results in a current flow between two conductors in a gap. The gap may be caused by broken, improperly installed or loose hardware, which causes inadequate hardware spacing, such as the gap between a ground wire and staple.

### Should Utilities Be Concerned?

There are obvious reasons why utilities should be concerned and aware of potential issues. To begin, interference impacts quality of life. It's a matter of good customer service to be diligent in responding to customer complaints. In addition, arguing or avoiding customers can be time consuming and may lead to litigation. Next, it's in a utility's best interest to act immediately, because most power-line noise is caused by arcing conditions, which can lead to utility equipment or material failures. Last, interference issues must be addressed. FCC regulations require utilities not to cause harmful interference to licensed services and to cease operating any device, upon notification by the FCC, that is causing interference.

### What Does the FCC Require?

FCC Part-15 regulations govern radio and TV noise most likely to come from utility-owned equipment. These rules specify three classes of emitters that may apply to power-company equipment:

- *Incidental emitters*. Most interference complaints from power-company equipment result from an incidental emitter, such as an electric motor or sparking power-line hardware. Incidental emitters don't intentionally generate radio energy but do so incidentally as a result of their operation.
- *Unintentional emitters*. These may be found in some power-company equipment. Unintentional emitters intentionally generate an internal radio signal, but do not intentionally radiate or transmit it. Examples include some types of "switch-mode" power supplies and microprocessors used in some power-company equipment. Unintentional emitters have specific limits on radiated and conducted emissions.
- *Intentional emitters*. These are transmitters that intentionally radiate RF. In general, they are not found in power company equipment, although some remote-reading usage meters may use intentional emitters.

Most radio noise on power-company equipment comes from incidental emitters. These have no specific limits on conducted or radiated emissions. But *all* unlicensed emitters of radio energy have a requirement not to cause harmful interference. If they do, the operator of the device causing the interference must take whatever steps are necessary to correct it.

Keep in mind, electric utilities are responsible for correcting only the noise generated by the equipment and hardware that they actually own. In cases where utility customers use an appliance or device that generates noise, they must correct the problem, even if the noise is conducted and radiated by the utility's power line.

### Locate the Source of Interference

A good first step is to eliminate the device itself as the source of the problem. If the device is suspect, remove the antenna connection to the radio to see whether the noise goes away. Proceed with the following steps to determine if the source of interference is located within the home or business.

1. Go to the main breaker panel or fuse box. Check the presence of the noise with a battery-powered radio.

2. If the noise is present, shut off all power to the premises by turning off the MAIN circuit breaker or by pulling the MAIN fuses or meter. If the noise on the AM radio stops while the power is off, the source of the interference is within the residence. If the noise continues, you can assume it is coming from a point external to the customer's home.

3. Restore the main circuit breaker or fuses or meter.

4. If the noise stopped while the power was off, locate the circuit supplying the power to the noise source using an AM radio as before, and de-energize the individual circuit breakers one at a time until the noise stops.

5. Next, determine what is on the circuit by going from room to room to isolate outlets, appliances and lights until the offending device is found.

If the noise source is not in the customer's home, check with the closest neighbors. If one of the neighbors has a similar problem, ask them to run the breaker test to try to locate the faulty equipment. A household appliance or electrical device rarely causes interference that extends beyond a few houses on a secondary system.

Note that if the source is not in the customer's home or a neighbor's home, the noise is originating from an outside source. Direction-finding techniques may then be used to isolate the noise to a particular residence or an area of the utility's power-line system.

### Common Power-Line Noise Sources

**(Listed in order from most common to least common)**

- Loose staples on ground conductor
- Loose pole top pin
- Ground conductor touching nearby hardware
- Corroded slack span insulators
- Guy touching neutral
- Loose hardware
- Bare tie wire used with insulated conductor
- Insulated tie wire on bare conductor
- Loose crossarm braces
- Lightning arrestors

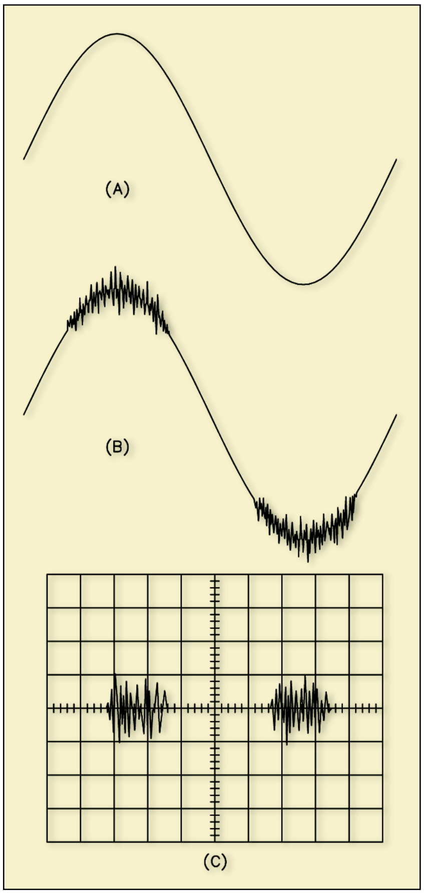


**Fig. 2. The 60-Hz signal found on quiet power lines is almost a pure sine wave (A). If the line or a device connected to it is noisy, this will often put visible noise onto the power-line signal (B). This noise usually is strongest at the positive and negative peaks of the sine wave. If the radiated noise is observed on a scope, the noise will be present during the peaks (C).**

### Identifying Power-Line Noise

Noise that varies with the time of day is related to what people are doing, usually pointing to an electrical device or appliance. Noise from consumer-type devices often comes and goes with periods of human activity, frequently correlating with evenings and weekends. Unless it is associated with climate control or an HVAC system, an indoor RFI source is less likely to be affected by weather than power-line noise. The importance of maintaining a good and accurate interfer-

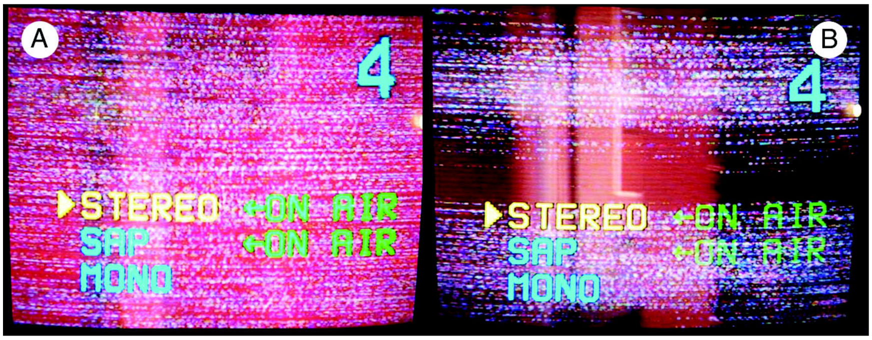


**Fig. 3. The power-line interference (A) is not typical. In this case, the noise occurred as a result of two sources that were out of phase from each other. The interference from each source overlapped on the screen. Once one phase was corrected, the more typical upward drifting horizontal snowy bars can be seen.**

ence log cannot be overstated. Ask the customer to record dates, times and weather conditions. Correlating the presence of the noise with periods of human activity and/or weather often provides important clues to identifying power-line noise.

## Weather-Related Interference

If the interference appears and varies in intensity depending on weather conditions, and if a breaker test excludes sources inside the home, the interference may be caused by faulty components associated with the electrical power lines near the home. Wet weather may temporarily reduce or eliminate the noise by shorting out spark gaps on the power line. Windy weather may cause the noise to vary or even stop for a while, as loose hardware is affected.


**Fig. 4. The Radar Engineers Model 240 HF-UHF RFI Locator is a professional-grade receiver for locating RFI sources. It has a built-in oscilloscope display for recording and observing noise signatures. This receiver operates from 1.8 to 1000 MHz.**

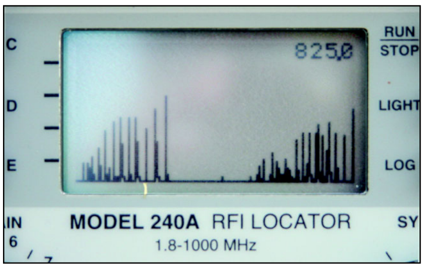


**Fig. 5. This is a typical noise-source signature taken at a complainant's antenna. During the RFI investigation, noise signatures not matching this pattern can be ignored.**

## Is There a Smoking Gun?

Virtually all radio noise originating from utility-company equipment is caused by a spark or arcing. The radio noise is only generated during the times when a breakdown and ionization of air occurs.

Once an ionized path is established in the gap, current flows at all parts of the cycle where the voltage is higher than the breakdown voltage of the gap. This typically occurs only near the positive and negative voltage peaks, the times of highest instantaneous voltage. Sometimes the gap may break down on only one polarity of the waveform.

Because power lines carry 60-Hz ac, the voltage on them passes through two peaks each cycle (one positive and one negative) and passes through zero twice each cycle. This gives 120 peaks and 120 zero crossings in each second. Power-line noise follows this pattern, generally occurring in bursts at a rate of 120 (sometimes 60) bursts per second. This gives power-line noise a characteristic sound that is often described as a harsh and raspy hum or buzz. Because the peaks can occur twice per cycle, true power-line noise usually has a strong 120-Hz modulation.

Typically, power-line noise is a broadband type of noise starting at the low end of the radio spectrum and is usually stronger at lower frequencies. It occurs continuously across each band, up through the spectrum to some upper frequency where it tapers off.

Indoor and power-line noise can be identified with an oscilloscope, which should show the bursts occurring every 1/120 seconds, or 8 1/3 ms. Investigate the suspect noise from a radio's audio output using the AM mode. Use the wide filter settings and tune to a frequency without a station. Power-line noise bursts should repeat every 8.33 ms. If this is not the case, you probably don't have power-line noise (Fig. 2).

Alternately, you can perform a similar test if the noise pattern is visible on a TV set. The noise occurs in two horizontal groups or bands. Typically, these two bands drift slowly upward on the screen. One group is a result of arcing during the positive half of the 60-Hz sine wave. The other group is a result from the negative half of the sine wave.

Usually, it is best to perform this test at the lower VHF TV channels and with an antenna (as opposed to a cable hookup). The positive and negative power-line noise burst also may have slightly different characteristics. This can cause each half of the cycle to have a slightly different pattern on the screen. As you turn the channel selector to higher frequency channels, the interference should diminish. If the interference can be observed on UHF

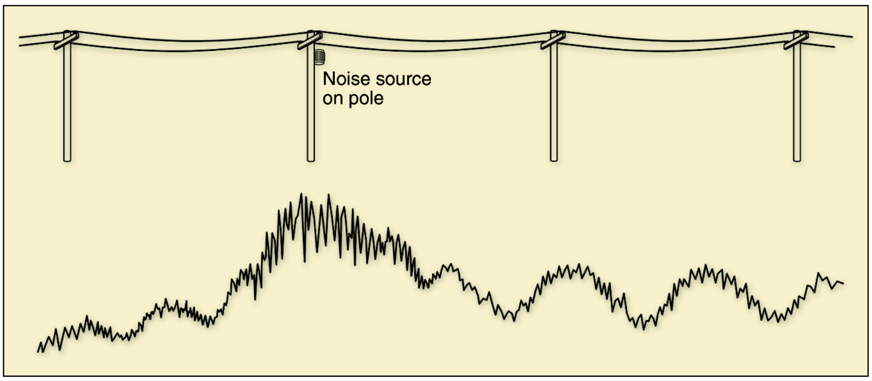


**Fig. 6. Power-line noise can exhibit peaks and nulls that can fool the unwary RFI investigator. These peaks generally get closer together when close to the source of the noise.**

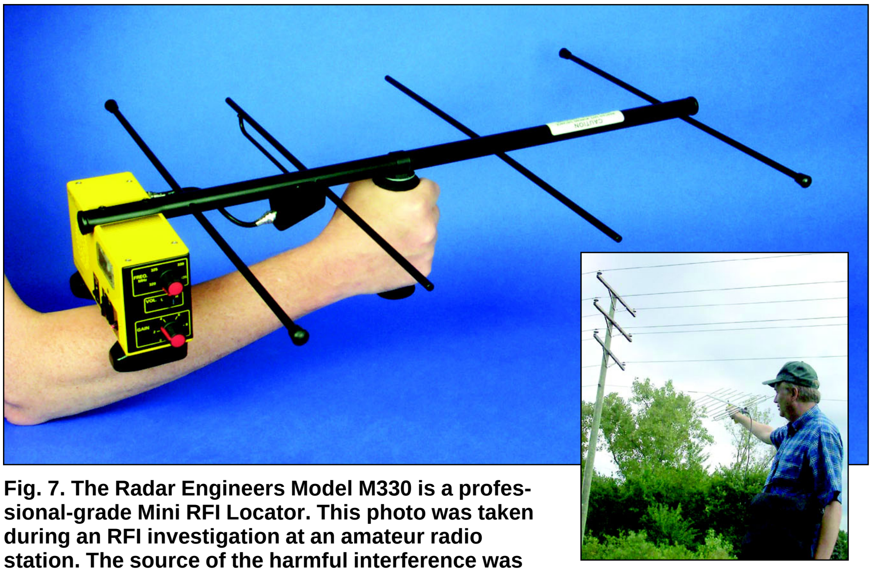

**Fig. 7. The Radar Engineers Model M330 is a professional-grade Mini RFI Locator. This photo was taken during an RFI investigation at an amateur radio station. The source of the harmful interference was traced to this pole. The Model M330, which operates from 320 to 340 MHz, is ideal for locating the source pole once the search has been narrowed down to several poles.**

channels, the source is probably relatively near (Fig. 3).

## Locating Power-Line Noise

A simple step-by-step procedure handout, plus instructions for "locating inside sources" and "locating the residence" can be downloaded from www.rfiservices.com. Providing it to your complainant as a first step can reduce your on-site investigations by as much as 65%.

Once you've eliminated the possibility of an internal noise source, always start the RTVI locating process at the interference site using the customer's equipment. Whether a TV interference (TVI) or radio frequency interference (RFI) complaint, monitor the customer's equipment while the problem is active.

## Finding the Source

Attach a Defect Direction Finder (DDF) receiver to the customer's antenna (Fig. 4). This specialized equipment enables you to monitor the symptoms as received by the customer's antenna. The setup should include a broadband AM receiver that covers the frequency range affected by the problem, an oscilloscope (scope) and an attenuator or RF gain control to adjust the RF signal level. With these tools, utility personnel can monitor the sound and pattern produced by the RTVI source(s).

Scope patterns show many important facts about the source(s) affecting the customer's equipment. They can reveal the number of simultaneous sources, determine which source is the strongest, and even provide an indication as to the size of gap across which the spark is occurring. When working with TVI complaints, the scope can show which source is having the most impact on the TV picture.

## Signature or Fingerprint Method

Each sparking interference source exhibits a unique pattern. By comparing the characteristics between the pattern taken at the customer's residence with those found in the field, it can be determined which is the offending source because each provides its own "fingerprint" or "signature" (Fig. 5).

Interference locating receivers, such as the Radar Engineers Model 240 shown in Fig. 4, have a built-in oscilloscope display and waveform memory, providing the ability to toggle between the pattern saved at the customer's house and those obtained from sources located in the field.

Once armed with the customer's noise fingerprint, start the search in front of the customer's residence. Travel in a circular pattern around the customer's house, block-by-block, street-by-street, until you find the noise pattern matching the one recorded at the customer's house. Use VHF or UHF if you can hear the RFI at these frequencies. The longer wavelengths associated with the AM Broadcast Band (and even HF) can create misleading "hot spots" along a line when searching for a noise source.

At these frequencies, you may find that the noise peaks at certain poles with different types of hardware mounted on them. As a general rule, only use the lower frequencies when you are too far away from the source to hear the offending RFI at VHF or UHF. Work at the highest frequency on which the noise can be heard. As you approach the source, keep increasing the frequency (Fig. 6). Once you've matched the pattern obtained at the customer's house with one in the field, you're close to locating the structure containing the source.

## An Amateur Radio Complaint

Imagine you have received a complaint from an amateur radio operator. The rules are still pretty much the same as with the TVI complaint:

The source must be active at the time of our investigation.

- Observe the symptoms on the customer's equipment.
- Start the investigation by verifying the source is not located in the customer's residence.
- Connect the DDF receiver to the customer's antenna before investigating the area outside his house.

In this example, however, tune the DDF receiver, while connected to the customer's radio antenna, to the offending frequency. Observe and record the noise pattern for future viewing. Once ready to begin the hunt, start traveling in a circular pattern away from the customer's house until you find the matching noise fingerprint. If the customer has a rotating antenna, use it to your advantage. Determine the direction of the noise source from the customer's house and reduce travel to a minimum.

Whether the complaint is TVI or RFI, a rotating antenna is always helpful. Instead of traveling spirally away from the house to find the noise, you can focus searching in one direction.

Another important clue can be obtained by tuning the DDF receiver to higher frequencies. Listen to the noise at VHF and UHF and make note of the frequency at which it starts to diminish. This frequency can provide an important clue to the proximity of the source. The closer the source, the higher in frequency you can receive it. If the noise can be heard at 440 MHz, you can expect it to be relatively near—perhaps within less than a quarter-mile radius. If it diminishes around 4 MHz, however, the source can be more than one mile away.


**Fig. 8. The Radar Engineers Model 250 Parabolic Pinpointer is used to find an RFI source on a utility pole. The clear-plastic parabola is an "ear" connected to an ultrasonic detector that lets utility personnel listen to a power-line arc.**

## An Important Rule

By now, you can see a tremendous improvement in noise locating efficiency. Perhaps the most difficult hurdle to overcome in this process is to ignore those noises not affecting the customer's equipment. An important rule for efficient and economic RFI troubleshooting is to locate and repair only the source causing the complaint.

## Locating the Utility Source

Head in the direction from which the antenna indicated the noise was the strongest. After a few blocks, you might expect to receive a noise with the exact pattern as the one recorded at the complainant's house. Now, reduce the signal level on the DDF receiver. In most cases with a modern DDF receiver, simply turn the RF gain control down to achieve a minimum signal level (as indicated by the receiver's signal strength meter) and still have a clear noise pattern on the scope. If the receiver does not have an RF Gain control, an attenuator between the antenna and receiver can be used to reduce the signal level at the receiver's input.

If the signal level increases, you are approaching the source. Continuously adjust the gain to accommodate changes in the signal level. The importance of this rule cannot be overstated.

## Directional Antennas

With an omni directional or whip antenna, you must move to determine the direction of the higher signal level. If you use a handheld or vehicle-mounted Yagi (directional) antenna, you can follow the direction of the strongest signal to the noise source. This will greatly reduce the amount of time and travel distance required during the hunt.

Radio Direction Finding (RDF) techniques typically offer the best and most efficient approach to locating most power-line noise sources. A handheld Yagi works at VHF and UHF within a specified frequency range. Not only are VHF and UHF antennas typically smaller, but direction headings are more reliable. An attenuator is required between the antenna and the receiver if the receiver does not have one (Fig. 7).

## Pinpointing the Source

The investigator must be able to pinpoint the source on the structure down to a component level. An investigator also can use a hot-stick-mounted device to find the source. An ultrasonic dish is useful for pinpointing the source of an arc. An unobstructed direct line-of-sight path is required between the arc and the dish. It is only useful for pinpointing a source once it has been highly localized and is ideally suited for pinpointing the arcing hardware once the offending pole has been isolated (Fig. 8).

## Common Source and Locating Misperceptions

Note that transformers are not listed among the most common power-line noise culprits. Despite their reputation, only a small percentage of transformers are actually found to be the cause of an RTVI complaints. Many times transformers are replaced because they are believed to be RTVI sources, when in reality, the transformers' loose hardware merely needs to be tightened. Sometimes, locaters are fooled by the hardware associated with a transformer pole. A transformer pole has a driven ground conductor, lightning arrestor, and often a down guy or other hardware that can act as an antenna to radiate noise. This can cause a high level of noise at the pole, but it is actually being generated by another source.

Corona discharge also gets a bad rap as another RTVI source when it rarely, if ever, is a source of power-line noise. Corona discharge is defined as the partial breakdown of the air that surrounds an electrical element such as a conductor, hardware or insulator. Corona typically is nothing more than a minor annoyance, as corona noise is usually confined to lower frequencies. This noise does not propagate far from the source because it is a low-current phenomenon that does not couple into adjacent wires. Hence, corona cameras are not recommended for locating RTVI sources.

Another type of equipment that has little directional locating capability is thermal/infrared detectors. Ultrasonic detectors, on the other hand, are very useful but often misunderstood. As previously discussed, they are not practical for finding the general source location, but they can be of great assistance in pinpointing the exact noise source once the structure is located.

## How to Fix

RFI repairs on the utility system usually involve eliminating an arc of some type. Arcs can occur due to loose hardware, cracked insulator, tracking, corrosion between two pieces of metal, or a loose tie wire.

Long-term repairs eliminate arcing by replacing the offending part, tightening hardware, or cleaning to prevent tracking. Freezing and thawing can cause hardware to loosen, especially in colder climates. Helical spring washers added to the bolts can absorb the expansion and contraction of wood poles and maintain hardware tension to prevent gaps from forming.

New products and materials for line

construction are constantly evolving in the industry. For example, polymer construction of various types of post top insulators, dead ends and fused cut outs provide higher Basic Insulation Level, lighter weight and are less prone to stress cracks. Vice top polymer insulators are far superior to wire ties that can arc when loose, especially in cases involving covered wire.


## Acknowledgments and Resources

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RFI Services provides locating and consulting services. Visit its Web site at www.rfiservices.com for additional information. Help is also available from the ARRL at http://www.arrl.org/tis/info/utility.html.


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