

IEEE Recommended Practice for Location of Power Line Gap Interference Sources

IEEE Electromagnetic Compatibility Society

Developed by the
Standards Development Committee

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of the
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IEEE SA Standards Board

Abstract: Procedures are described in this recommended practice that may be used by electric utility companies and others to address complaints of interference caused by power line gap noise to radio, television, and other types of wireless communications. A discussion is included on how to determine if a noise may be considered as harmful interference under the FCC rules. Modern noise-locating techniques, equipment, and protocols are also described, including the use of time-domain noise signatures (sometimes referred to as signature analysis) to investigate and identify radio noise in the field, allowing unassociated interference to be ignored unless it needs to be repaired for some other reason (e.g., safety concerns). These techniques enable the identification of which noise source or sources are associated with the reported interference, thus minimizing troubleshooting and repair costs. Troubleshooting and repair recommendations are also included for once all the sources have been identified. Ways to determine and find interference when it is being caused by a source other than electric-utility equipment, such as an electronic consumer device, are also described in this recommended practice. The methods and techniques contained herein have been validated by decades of usage with positive results by a wide range of users, including but not limited to utilities, professional interference investigators, radio engineers, and even the home hobbyist.

Keywords: gap noise, IEEE 1897™, incidental radiators, power line noise, radio frequency interference, radio-noise emissions, unintentional radiators

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Introduction

This introduction is not part of IEEE Std 1897-2024, IEEE Recommended Practice for Location of Power line Gap Interference Sources.

Although the problem has been around since the dawn of radio communications and broadcasting, power line noise interference is on the rise. The proliferation of electrical and electronic devices that are potential victims of power line noise interference, coupled with today's aging grid system and increased dependence on mobile and wireless communications, have each contributed to this increase. Experience has also shown that modern interference-locating methods and equipment, as detailed in this document, are often essential for an effective and economic response to such interference complaints.

It should also be noted that an investigation into an interference complaint has often led the investigators to discover potentially dangerous situations, either in a complainant's home or in their own power equipment. Interference to radio or television reception is often the first warning sign of a failing piece of power equipment on a pole or an appliance in a complainant's home. It could be a heating pad that was left turned on and stuck behind an elderly person's couch, ready to ignite, or an electrical distribution panel with a red-hot bus connection. Many things have been brought to a complainant's attention that could have led to disastrous results if left unattended. Many potentially hazardous situations on utility owned hardware are also first discovered as a result of an interference complaint. From the standpoint of safety, it is important to remember that many electrical failures and fires were preceded by arcs.⁶

⁶See *The Issue of Power line Noise, a Smarter Approach*, from the American Radio Relay League, Inc., ARRL website (www.arrl.org), ©2004. Additional material, figures, and photographs are also used or adopted from various sections throughout the document.

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IEEE Recommended Practice for Location of Power Line Gap Interference Sources

1. Overview

1.1 Scope

This recommended practice describes a procedure that electric utility companies and others may use to respond to reports of interference to radio and/or television reception. It describes procedures to determine if a reported noise is harmful interference to a licensed radio service. It describes modern noise-locating techniques and equipment and protocols that use time-domain noise signatures to investigate and identify radio noise in the field.

1.2 Purpose

This recommended practice is intended to help all parties involved in interference reports to understand the best practices used to assess, identify and repair interference problems and have reasonable expectations about the role and responsibilities of each party. It describes ways that utility staff can interact with a complainant to obtain information that will aid the troubleshooting process and it outlines reasonable timelines that will help everyone involved have reasonable expectations about the process and time it can take to respond to, identify, troubleshoot and repair a noise source. The techniques allow a utility to identify which noise sources are actually associated with the reported interference, minimizing troubleshooting and repair costs. The recommended practice also allows a utility to determine when reported interference is being caused by a source other than electric-utility equipment.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{7,8}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

⁷The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁸The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

2. Normative references

There are no applicable normative references.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁹

amateur [radio] operator: A person named in an amateur operator/primary license station grant on the ULS consolidated licensee database to be the control operator of an amateur station.¹⁰

amateur radio: *See:* **amateur [radio] service**.

amateur [radio] service: A radiocommunication service for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest.¹¹

American Radio Relay League (ARRL): The national association for amateur radio in the United States.

arc: A continuous luminous discharge of electricity across an insulating medium, usually accompanied by the partial volatilization of the electrodes.

arcing: *See:* **arc**.

attenuator: A two-port device that provides a fixed amount of signal loss over a wide range of frequencies (attenuation). These devices have identical attenuation in either direction.

automatic gain control (AGC): A circuit that automatically controls the gain of a radio receiver by applying more gain to weaker received signals and less (or no) gain to stronger received signals.

citizens band radio service: *See:* **citizens bands**.

citizens bands: Frequency bands allocated for short-distance personal or business radio communication, radio signaling, and control of remote devices by radio.

NOTE—The frequency bands may differ from country to country. The bands presently in use in the United States are 26.965 MHz to 27.405 MHz, 72 MHz to 76 MHz, and 462.550 MHz to 467.425 MHz.

conducted emissions: Electromagnetic energy that is propagated along a conductor(s). *See:* **conducted radio noise**.

⁹*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

¹⁰Per FCC 47 C.F.R. §97.3 Definitions.

¹¹Per FCC 47 C.F.R. §2.1 Terms and Definitions.

conducted radio noise: Radio noise that is propagated by conduction from a source through electrical connections.

corona: A luminous discharge due to ionization of the air surrounding a conductor caused by a voltage gradient exceeding a certain critical value.

defect direction finder (DDF): A term and abbreviation roughly synonymous with an “RFI locator.” Also called interference locator, RFI locating receiver, or similar terms. *See: RFI locating receiver.*

direct pickup: The unwanted entrance of over-the-air signals directly into a poorly shielded or otherwise susceptible device (e.g., cable modem, set-top box, test equipment), often without a physical connection to cables and/or other components. Similar to ingress.

directivity (of an antenna): The ratio of the radiation intensity of an antenna in its maximum direction compared to the overall radiation intensity for the antenna.

Federal Communications Commission: The regulator of radio spectrum in the United States.

ham radio: *See: amateur [radio] service.*

harmful interference: (1) Any emission, radiation or induction that endangers the functioning of a radio navigation service or of other safety services or seriously degrades, obstructs or repeatedly interrupts a radiocommunications service operating in accordance with this chapter.¹² (2) Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [the ITU] Radio Regulations.⁵

high frequency (HF): That portion of the electromagnetic spectrum from 3 MHz to 30 MHz.

hot stick: An electrically insulating stick or pole with a head or hook, as described in IEEE Std C37.42-2016™. Its primary functions are opening or closing fuses and switches or inserting and removing the fuseholder, fuse unit, and disconnecting blade from the device’s support. This stick is generally used for distribution equipment that has a means for utilizing this device.

incidental radiator: A device that generates radio frequency energy during the course of its operation although the device is not intentionally designed to generate or emit radio frequency energy.

ingress: The entrance of over-the-air signals into a cable-TV network, usually caused by degraded shielding effectiveness of the network’s coaxial cables and/or other components. Opposite of signal leakage.

intentional radiator: A device that intentionally generates and emits radio frequency energy by radiation or induction.

interference: (1) An emission that disrupts, impedes or negatively impacts the reception of desired radio communications. (2) The effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy.

log-periodic antenna: Any one of a class of antennas having a structural geometry such that its impedance and radiation characteristics repeat periodically as the logarithm of frequency.

medium frequency (MF): That portion of the electromagnetic spectrum from 300 kHz to 3 MHz.

¹²Per FCC 47 C.F.R. §15.3 Definitions.

noise signature: *See: signature.*

noise: Typically any undesired signal or signals—other than discrete carriers or discrete intermodulation distortion products—in a device, communications circuit, channel or other specified frequency range. *See: interference.*

omnidirectional antenna: An antenna having an essentially non-directional pattern in a given plane of the antenna and a directional pattern in any orthogonal plane.

NOTE—For ground-based antennas, the omnidirectional plane is usually horizontal.

oscilloscope: An instrument for measuring and displaying an electrical quantity (typically voltage) as a function of time. The bandwidth should be at least 10 times the maximum frequency of interest and include triggering capability.

parabolic ultrasonic locator: A device comprising a parabolic-shaped reflector (“dish”), ultrasonic microphone, and accompanying electronic circuitry used to pinpoint the location of ultrasonic audio sources. Synonym: ultrasonic pin-pointer, ultrasonic receiver.

polarization (of a receiving antenna): In a given direction from the antenna, the polarization of the wave received by the antenna.

NOTE—When the direction is not stated, the polarization is taken to be the polarization in the direction of maximum gain.

power line benign emissions: Power line emissions that do not degrade the function of other equipment or systems.

power line emissions: Electromagnetic emissions from power lines in the radio frequency spectrum. Usually unintentional, these emissions may be benign or may negatively impact the function of other equipment or systems.

power line interference: Power line emissions that may cause harmful interference.

power line noise: A common phrase variously used to describe power line RF emissions, power line interference, or audible noise from power lines.

radio and television interference: Impaired reception of a desired radio signal or desired visual image caused by unwanted electromagnetic signal(s). *See: radio interference.*

radio astronomy: Terms and definitions. Astronomy based on the reception of radio waves of cosmic origin.

radio direction finding (RDF): A procedure for determining the bearing, at a receiving point, of the source of a radio signal by observing the direction of arrival and other properties of the signal.

radio interference: Degradation of the reception of a wanted signal caused by radio frequency (RF) disturbance. Synonym: radio frequency interference.

NOTE 1—RF disturbance is an electromagnetic disturbance having components in the RF range.

NOTE 2—The words “interference” and “disturbance” are often used indiscriminately. The expression “radio frequency interference” is also commonly applied to an RF disturbance or an unwanted signal.

radio frequency (RF) energy: Electromagnetic energy at any frequency in the radio spectrum between 9 kHz and 3 000 000 MHz.⁶

radio frequency interference (RFI): *See: harmful interference and radio interference.*

RFI locating receiver: A specialized receiver for the location of power line noise and other sources of interference. Such receivers should include a time-domain display for signature analysis, AM detection, an attenuator or RF-gain control, and a signal-strength indicator. This term may or may not also include the antenna as part of the instrument. It is roughly synonymous with RFI locator or defect direction finder (DDF).

Society of Cable Telecommunications Engineers (SCTE): A non-profit organization that develops standards for the cable telecommunications industry.

signal leakage: The unwanted emission of radio frequency signals from inside of a cable-TV network into the over-the-air environment, usually caused by degraded shielding effectiveness of the network's cables and/or other components. Also called egress.

signature analysis: A technique by which one observes the unique set of visual characteristics of an interference, signal, or noise source as viewed on an oscilloscope or other time-domain display. The source of interference can be attributed to a specific source by matching the signature at the impacted (victim) receiver with that of the suspected interference source. Matching signatures identifies only those sources that are contributing to an interference problem, thus avoiding errors in identification of a source when resolving an interference complaint.

signature: (1) Those characteristics of a waveform that help identify an event or conditions. (2) A set of unique visual characteristics of a signal or noise source as viewed on an oscilloscope or other time-domain display. *see signature analysis.*

spark discharge: The transfer of charge (flow of current) through an air gap requiring a voltage high enough to ionize the air, as opposed to direct contact with a source.

spark: A sudden and irreversible transition from a stable corona discharge to a stable arc discharge. It is a luminous electrical discharge of short duration between two electrodes in an insulating medium. It is generally brighter and carries more current than corona, and its color is mainly determined by the type of insulating medium. It generates radio noise of wider frequency spectrum (extending into hundreds of megahertz) and greater magnitude range than corona. A spark is not classified as corona.

time-domain display: The display of an electrical waveform as amplitude with respect to time. It is generally synonymous with the display produced by an oscilloscope. *See oscilloscope.*

ultra-high frequency (UHF): That portion of the electromagnetic spectrum from 300 MHz to 3 GHz.

ultrasonic frequency: A frequency that is greater than the audio frequency range.

ultrasonic locator: *See: parabolic ultrasonic locator.*

Universal Licensing System (ULS): The consolidated database and application filing system for most wireless radio services in the United States. The ULS supports electronic filing and provides public access to licensing information, weekly Public Notices, FCC rulemakings, processing utilities, a telecommunications glossary, and more.

unintentional radiator: A device that intentionally generates radio frequency energy for use within the device, or that sends radio frequency signals by conduction to associated equipment via connecting wiring, but which is not intended to emit RF energy by radiation or induction.

very-high frequency (VHF): That portion of the electromagnetic spectrum from 30 MHz to 300 MHz.

very-low frequency (VLF): That portion of the electromagnetic spectrum from 3 kHz to 30 kHz.

Yagi antenna: *See: Yagi-Uda antenna.*

Yagi-Uda antenna: A linear end-fire array consisting of a driven element, a reflector element, and one or more director elements.

NOTE—The bandwidth of a Yagi-Uda antenna, which is the frequency over which it has high gain, is a small percentage of the center frequency.

3.2 Acronyms and abbreviations

ac	alternating current
AF	audio frequency
AGC	automatic gain control
AM	amplitude modulation
AMI	advanced metering infrastructure
AMP	amplifier
BNC	bayonet Neill-Concelman [connector]
CFR	Code of Federal Regulations
Ch.	channel
dB	decibel
DDF	defect direction finder
DSL	digital subscriber line
DSLAM	digital subscriber line access multiplexer
DTV	digital television
EM	electromagnetic
EMC	electromagnetic compatibility
EMI	electromagnetic interference
FCC	Federal Communications Commission
FEC	forward error correction
FM	frequency modulation
GHz	gigahertz
HF	high frequency
Hz	hertz
kHz	kilohertz
m	meter
MF	medium frequency
MHz	megahertz
ms	millisecond

$\mu\text{V/m}$	microvolt per meter
RDF	radio direction finding
RF	radio frequency
RFI	radio frequency interference
RR	radio regulations
TV	television
TVI	television interference
UHF	ultra high frequency
Vdc	volts (or voltage) direct current
VHF	very high frequency
VLF	very low frequency
VOL	volume
WLAN	wireless local area network

4. The cause and effect of power line noise interference

4.1 General

Power line interference is power line noise that causes interference to radio communications. It is typically caused by arcing or sparking on power lines or related hardware. Contrary to common misconception, it is usually not caused by corona discharge.¹³ The arcing is a result of a defect and not considered to be a normal function of the hardware. Radio frequency (RF) energy is generated by the spark, and the power lines and associated hardware can conduct it and act as an antenna to radiate it. See [Annex A](#) for a more complete discussion of power line noise and its causes.

4.2 The effect of power line noise

Essentially, the power lines or associated hardware improperly generate unwanted radio signals that override or compete with desired radio signals. Power line noise interference can impact broadcast radio and television reception—including cable television (TV) headend pickup and internet service. Disruption of radio communications, such as amateur radio, can also occur. Loss of critical communications, such as police, fire, public safety, aviation, military and other similar users of the radio spectrum can have even more serious consequences. More specialized use of the spectrum can also be affected, such as radio astronomy and very low frequency (VLF) reception. Although less common, power line noise interference can impact non-radio communication, such as residential landline telephone service.

Historically, the most common power line noise interference complaints involve amplitude modulation (AM) broadcast band listeners and amateur radio operators. The characteristic raspy buzz of power line noise is often the first and most obvious symptom in these cases. It is a broadband type of interference and covers a wide, continuous portion of the spectrum. Interference that is heard only in segments of the spectrum is usually not power line related.

The effect of power line noise on other services can vary depending on the type of service and other circumstances (buzzing in an AM radio, for instance). Digital signals degraded by power line-noise interference can cause pixelation, garbled sound, or inability to communicate. In the case of cable television,

¹³Although corona can occur on both distribution and transmission lines and hardware, its potential to cause interference is much lower than that of an arcing source. The reason is that noise from corona is typically only a lower frequency and short range phenomenon.

however, the problem may not be as obvious. The actual source might be located and entering the cable system at a point some distance away from the affected complainant(s). For an in-depth look at the effect of power line noise on cable TV, see [Annex B](#).

5. Power line noise interference and FCC Part 15 Rules

5.1 General

This document cites various Federal Communications Commission (FCC) rules as examples of how regulators treat interference, emissions limits and equipment authorization. The rules in other countries are often similar. For interference that occurs in jurisdictions not regulated by the FCC, other local or regional regulations apply.

Under FCC Part 15 rules, most power line and related equipment is classified as an “incidental radiator.” This term is used to describe equipment that does not intentionally generate any radio frequency energy, but that may create such energy as an incidental part of its intended operation. These rules prohibit harmful interference to a licensed radio service from power lines and related hardware. The FCC has the responsibility to require that utility companies correct interference problems if the interference is caused by electric utility equipment.

It should also be noted that the electric utility is responsible for correcting only that interference generated by the equipment and hardware that it actually controls. In cases where a utility customer uses an appliance or device that generates interference, the operator of the device (the utility customer) is responsible for correcting the interference—even if the noise is conducted and radiated by the power company’s power lines.

See [Annex C](#) for a more complete description of the specific rules that typically apply in power line noise interference cases.

5.2 Compliance with FCC Part 15 rules

The key to addressing radio frequency interference (RFI) from power line gap noise is to identify the specific component that is producing the problem.

Gap noise will always be present on any power distribution system. This is unavoidable. Most gap-noise sources do not cause any interference. When gap noise interferes with the operation of an FCC-licensed radio service, then Part 15 rules require the source to be located and repaired. Frequently, the gap-noise source that causes the most severe interference problems is not the loudest gap noise source in the immediate area. Misdiagnosis can result in the expensive and unnecessary replacement of electrical-distribution equipment.

With the appropriate resources (equipment and experience), it is possible to identify the signature of a specific noise source. With this information, it is then possible to search for the specific interference source with a matching signature.

There have been cases in which a single gap-noise interference source was identified in a matter of minutes, and its repair eliminated the problems. Sometimes there are multiple sources of harmful interference. In some cases, it may be necessary to identify noise sources individually in a sequential approach with repeated evaluations as each interfering source is repaired. The interfering source may be lower in magnitude and masked by the strongest source, if that source does not propagate well to the equipment receiving interference. Repeated evaluations may be needed once the stronger sources are repaired.

For rapid resolution, it is recommended to identify the signature of the interference so that utility resources are not wasted repairing or replacing the wrong equipment. Retaining qualified staff or an experienced noise-interference-locating consultant is more economical than repeated ineffective repairs.

5.3 FCC enforcement

Utilities in the US have a federally mandated responsibility to resolve, within a reasonable time, radio frequency interference problems caused by their equipment. Even if a utility lacks the necessary equipment and expertise, the responsibility remains with the utility to resolve the problem. Consultants are available to help, if necessary. In most countries, any utility that lacks modern-interference-locating equipment and expertise that allows a power line interference complaint to remain unresolved for an extended period of time risks enforcement action (fines). The American Radio Relay League (ARRL) is the national association for amateur radio in the US. ARRL has an informal cooperative agreement with the FCC that allows ARRL to help amateur radio operators that experience RFI work together to resolve RFI problems involving electric utility equipment. Based on the ARRL's experience, most active sources can be located in less than a week.

The cooperative agreement between the FCC and ARRL also enables FCC resources to be best utilized where they are most needed—in enforcement. Under the terms of this agreement, the ARRL provides technical advice and other assistance to the involved utility. Before a case is referred to an FCC Field Office for investigation, it is reviewed by ARRL technical staff or their designees. The ARRL can also provide administrative assistance to the FCC as needed. This agreement reduces the need for FCC enforcement resources, but firm enforcement action may be expected in cases of radio frequency interference caused by power line hardware that are not being reasonably resolved.

6. Customer service and initial complaint-handling procedures

Radio spectrum users can be adversely affected by power line noise. Customer service personnel should be trained to recognize interference complaints and route these issues to the proper personnel. The following keywords can be used to help identify such a complaint:

amateur	FCC	RFI
amateur radio	ham / ham radio	spark or sparking
arc or arcing	hum	stereo
buzz or buzzing	interference	telephone
cable	noise	television
EMI	radio	TV

Once a customer service representative suspects or identifies a call as being related to an interference issue, the complainant should be given a unique tracking number consistent with existing utility trouble-call-reporting practices. This number should be used to aid in identifying the complaint until the issue is resolved. If the complainant later contacts the utility with questions or to seek an update on his or her case, such a tracking number can help easily identify it. Many utilities already use tracking numbers for all customer service complaints.

The customer service representative should also record the complainant's name, address, telephone number, and if appropriate, an email address. If communication is by telephone, the representative should include the best times to call. The representative should also record a general description of the symptoms and problems being experienced. Details might include, but are not limited to, the device that is affected by the interference and the times that it is most likely to be present, the frequency or frequency band affected, and the type of communication service impacted.

The customer service representative should conclude by informing the complainant that his or her complaint is being forwarded to the proper department that handles interference matters. The complainant should be told to expect a follow up call. Although the response time can vary, the phone call should occur within five working days after the complainant's initial contact with the utility. Public safety interference issues should be given a

more rapid response. The complainant should also be given contact information in case he or she wishes to get an update on the case.

7. Utility RFI-locating department, internal procedures, and personnel

7.1 General

WARNING

Contact with power lines of any voltage can cause injury or death.

Under no circumstances should an untrained investigator attempt to investigate interference purportedly caused by power lines. Additionally, under no circumstances should anyone manipulate or make modifications to power lines unless they are trained power company employees or trained agents of the power company. Failure to follow these warnings may result in injury or death.

See [Annex D](#) for a more complete discussion on this important topic.

Once an interference complainant's trouble call information has been taken by a utility's customer service representative, there should be a clearly defined internal process by which the representative can forward that trouble call to the designated department or person that handles RFI issues. The case tracking number and all pertinent information collected during the initial call should be included in this process. Ideally, this information should be forwarded within one working day of receiving the complaint. A knowledgeable RFI representative should be assigned to each case.

It is recommended that the RFI representative also review and follow the recommendations in [9.2](#), [9.3](#), and [9.4](#) of this document before contacting the complainant.

The assigned RFI representative should contact the complainant for a full briefing about the problem as quickly as possible. At this time, the RFI representative should review with the complainant the utility's investigative process and time frame for field study and resolution. The representative should be prepared to schedule the next step in the process.

In most situations, it is best to meet face-to-face with the complainant, and the complainant will be expected to cooperate. The investigator should make a reasonable effort to schedule a meeting at a time when the interference is likely to be present. It is important to understand that interference can occur at any time during the day or night. It may also change with weather conditions such as rain, cold or wind.

Also, at this time, it is particularly important to determine if the interference is intermittent, and if so, at what times and under what circumstances the interference is likely to be present. The problem might be weather-related or otherwise might necessitate other special handling in scheduling. When the interference is intermittent, it is recommended that the complainant keep a log of operating times and interference episodes to determine if there is a pattern. See [Annex E](#) for a questionnaire and a convenient procedure checklist. The RFI investigator should determine that the interference is active before visiting the complainant. The complainant should understand that if the interference is not occurring, the investigator cannot find it.

7.2 An ideal RFI department

An ideal RFI department should have:

- The proper RFI-locating equipment. Equipment examples appear in [Clause 11](#) of this document.

- Properly trained and knowledgeable personnel. RFI investigators should be familiar with the equipment and its use. As described in 9.1, it is recommended that investigators take a power-line-noise-interference locating and mitigation workshop or, depending on local utility capability and experience, be properly trained and qualified internally. Because of the nature of RFI issues, it is not uncommon for a utility RFI department to rely upon mentoring in the development of novice investigators. It is further recommended that RFI investigators periodically practice their locating skills with random power line noise sources. Although this document provides recommended procedures, real skill and confidence often only come with practice.
- Extensive RFI locating expertise produces the most efficient, effective and lowest cost results.

It should be emphasized that modern locating techniques, such as signature analysis, are often key to timely location and resolution of power line interference complaints. Although it is essential that the locating equipment have this capability, the personnel using it should also be skilled in its use. [Clause 8](#) contains additional information on modern interference locating techniques and signature analysis.

7.3 The six steps to successful RFI resolution

There are six essential steps to every successful RFI resolution. An ideal RFI department should address each of these steps in the order shown:

- a) **Observe:** The RFI investigator should always first observe the interference as it affects the complainant's equipment.
- b) **Analyze:** Identify the signature of the interference to compare with sources found in the field.
- c) **Locate:** It is important to correctly locate the source of the interference. The tools and methods described in this document are consistent with a modern approach that can help locate interference problems.
- d) **Identify solution(s):** Utility personnel should be familiar with standards and practices employed by their organization to resolve and prevent future interference problems.
- e) **Repair:** Utility personnel should work with the RFI investigator to eliminate the interference.
- f) **Verify:** The RFI investigator should confirm with the complainant or complainant that the interference has been eliminated.

8. Modern noise-locating techniques

8.1 General

Locating power line noise interference quickly is crucial for a utility to solve these problems in an economic and timely fashion. The procedures and specialized locating equipment described in this document are consistent with modern interference-locating techniques. In many cases, power line noise interference sources can be quickly located. Furthermore, the ability to match noise signatures enables the RFI investigator to identify the interfering noise source or sources from the many that may be encountered during the investigation.

Radio direction finding (RDF) is the most common method used for locating power line noise interference sources. A handheld directional antenna, such as a VHF or UHF Yagi array,¹⁴ should be used within its specified frequency range. Directional antennas offer accuracy and efficiency when locating sources. An attenuator should be used between the antenna and the receiver if the receiver does not have one. Use as much attenuation as possible, consistent with the ability to observe or hear the noise on the test instrumentation, to reduce the area of search. Typically, more and more attenuation will be needed upon approaching the source.

¹⁴A Yagi-Uda antenna is also called a “Yagi” or “Yagi antenna” in this document.

8.2 The signature or fingerprint method

Each sparking interference source exhibits a unique pattern. An interfering source can be determined from the many sources encountered by comparing the characteristics between the noise signature pattern taken at the complainant's premises with those found in the field. It therefore isn't surprising that a pattern's unique characteristic is often called its "fingerprint" or "signature." See [Figure 1](#) for an example. On the left is an unknown source of interference at the complainant's antenna. During the RFI investigation, noise signatures not matching this interference pattern should be ignored, such as the pattern shown on the right. Once the matching signature originally shown on the left is found, the interfering noise source has been located. See [Annex I](#) for additional examples of noise signatures.

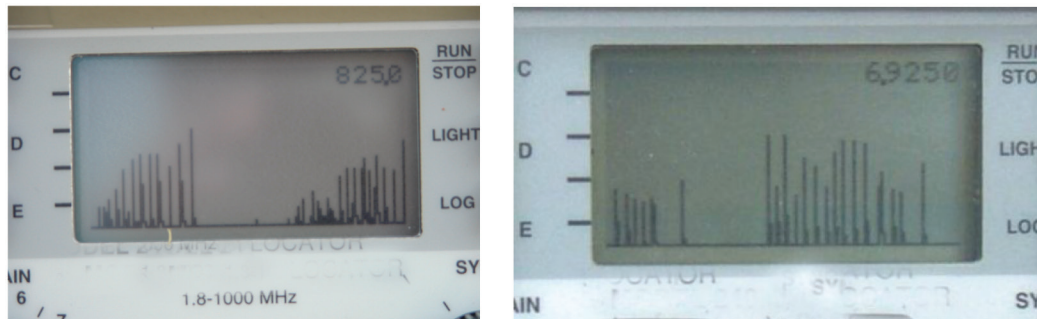


Figure 1—Two different noise signatures are shown on the displays of modern interference RFI locating receivers

Noise signature matching using an oscilloscope¹⁵ (time domain) display can be a very powerful technique and a real money saver for a utility. Even though an RFI investigator may encounter several different noise sources in the field, this method helps identify the sources that are actually causing the interference problem. The utility need only correct the interference sources generated by utility equipment affecting the complainant's reception.

Time domain patterns show many important facts about the source(s) affecting the complainant's equipment. They can reveal the number of simultaneous sources, determine which source is the strongest, and even provide an indication as to the relative gap size across which the spark is occurring. In terms of an RFI complaint, this means the time domain display can help an experienced investigator determine which source is having the most impact on the victim device.

To resolve interference complaints, the most economical approach for an electric utility is to use the techniques described in this recommended practice to correlate noise sources near the complainant with the actual interference at the complainant's location and equipment. Other techniques that do not use a signature analysis technique to correlate noise sources and interference might locate a number of nearby noise sources that are not affecting a complainant's radio or television reception. It is not usually necessary to repair minor noise sources that are not causing actual harmful interference. Electric utilities have been known to spend thousands of dollars repairing noise sources that are not causing actual interference, so it is often more cost effective to use trained personnel and/or a consultant and signature noise locating equipment similar to the equipment described in this recommended practice to identify the actual source or sources of interference than it would be to try to identify all possible noise sources and fix them all.

¹⁵An oscilloscope is a test instrument used to measure the waveform of electrical and electronic signals. The instrument uses an internal or external display, which shows the waveform's amplitude in the vertical axis versus time in the horizontal axis. As such, the pattern produced by an oscilloscope is often referred to as a time-domain display. For the purposes of this document, an oscilloscope is used to display and match the unique noise signature of an arcing noise or other source of interference. The terms "oscilloscope" and "time-domain display" also appear in [Clause 3](#).

See [Annex I](#) for additional photos. An additional noise signature method, unique to the DSL industry, is also described in [Annex J](#).

8.3 Locating techniques versus FCC requirements and expectations

The Federal Communications Commission (FCC) has an expectation that utilities should resolve power line harmful interference complaints in a reasonable and timely fashion. While most utilities have sufficient resources and expertise to manage interference investigations, conflicting priorities and resource allocations might occasionally lead to undesirable results such as misdiagnosis of cause, unnecessary labor use, unnecessary hardware replacement, and prolonged resolution of the actual issue. Those undesirable results might lead to a loss in confidence by the complainant, the FCC, and other regulatory bodies in the utility's ability to resolve the issue.

While it is not specifically in the FCC's jurisdiction to direct a utility how to locate and resolve sources of harmful interference, the use of modern locating techniques, including signature analysis, has been shown to be very effective in identifying the harmful source(s). As such, it is prudent for a utility to determine that staff has access, either internally or externally, to the proper locating equipment and expertise for identifying the harmful interference sources. Once the harmful interference source has been identified, the utility should engineer a solution, then prioritize and schedule the work resources to eliminate the harmful source in a timely manner. The equipment and procedures described in this document are consistent with modern interference-locating techniques, including the use of signature matching techniques.

9. Preliminary steps prior to an investigation

9.1 Understanding the equipment

As previously discussed, it is important to be familiar with the operation of the interference-locating equipment before undertaking a power line noise RFI investigation. Whenever possible, it is also recommended that utility personnel investigating such complaints attend a power-line-interference-locating workshop. At a very minimum, it is recommended the investigator read the appropriate owner's manuals of noise-locating equipment and practice using it with actual power line noise sources. Driving around while listening to the RFI locating receiver with a whip antenna will often identify noise sources for practice. Either an HF or VHF antenna can be used. Tune the receiver to a frequency with no other stations or signals present and suitable for the antenna in use.

NOTE—When using any equipment with rechargeable batteries, verify the batteries have a full charge the day before a planned field investigation. Some receivers may require an overnight charge when depleted. It is important to bring extra batteries for equipment that does not use rechargeable batteries. Experience has also shown that a spare antenna cable and set of connector adapters can save valuable time during a field investigation.

9.2 Review the documentation

Documentation in some cases from the complainant often includes a detailed history of the complaint and other pertinent information. Review this information carefully. It is important to understand that power line interference is often intermittent and/or weather related. Efficiency would dictate that the investigation be planned during a time of high probability that the interference will be present. Power line interference can vary with precipitation, humidity, wind or temperature. If the interference is intermittent, make note of any information that might indicate when it is most likely to be active or present.

9.3 Contact the complainant

Contact the complainant in advance of the investigation. A telephone call is usually the most convenient and recommended practice for this step (see interview questions in 9.4). Some important key points to consider during the initial discussion should include:

- In some cases when the problem is not power line related, the complainant may be able to locate and correct an interference problem without a service call. See [Annex F](#) for instructions that can be given to the complainant in some situations.
- Identify and arrange for a mutually convenient time to begin the investigation.
- It is important to stress to the complainant that he or she be present and available at least during this initial phase. It can also be advantageous for the complainant to be present during subsequent phases in some cases. The complainant should identify and provide access to the affected equipment, as a minimum. If necessary to facilitate the investigation, the complainant can route his or her antenna feed line to an accessible area for easier access by utility personnel. If outdoors, the complainant should protect the connector from weather and the elements.¹⁶
- The selected time for the investigation should have a high probability of the interference being present during the investigation. Power line noise is often weather dependent, so it's wise to check the forecast. Power line interference can only be investigated when it is active.
- If appropriate, request that the complainant maintain a log that includes time, interference levels, frequencies, and weather conditions. Interference bearings (compass headings) are also helpful if the complainant has a rotatable antenna and can provide them. The *Radio and TV Interference Questionnaire* shown in [Annex E](#) may be used or a variation of it adopted as appropriate.
- If the complainant is some distance away, checking the weather conditions and confirming with the complainant just before departure may save a wasted trip.

9.4 Interview the complainant

9.4.1 General

The objectives of the initial interview are to gather information about the interference and brief the complainant about what happens next. The investigator should keep detailed notes on what is discussed during this interview. First gather as much information as possible from the complainant. Once the complainant has fully described the problem, the next step is to brief the complainant on the process and the associated company's policies. The investigator should gather as much information as possible, but keep an open mind because the true source can't be determined until it is found.

Describe the utility's process for conducting an investigation. In his or her notes, the investigator should specifically note that the complainant was briefed on all relevant company policies, including what happens if the source is not owned by the utility. The investigator should confirm that the complainant understands that if the source is not utility-owned, the utility may not be able to resolve the problem **or divulge location or description details.**

¹⁶The FCC will typically close cases in which a complainant fails to be reasonably cooperative with the utility or an FCC agent. Examples may include, but are not limited to, an unwillingness to provide access to the affected equipment, not allowing utility personnel to observe the problem as it affects that equipment, or an unwillingness to provide access to the antenna in order to facilitate signature analysis.

The utility should have an established policy about cases in which the source is not utility owned. The investigator should also be familiar with the utility's policy regarding non-utility-owned sources.¹⁷

9.4.2 Looking for clues

Experience has shown that other noise sources are often mistaken for power line interference. Depending on the specifics of the case, the complainant may be able to provide some important clues to help distinguish noise generated by a consumer device from true power line noise. The following summarizes some key points to help identify true power line noise interference during the initial contact with a complainant. If the reported problem is not consistent with these characteristics, the problem may be something other than power line noise and therefore not the utility's responsibility.

- **What is being heard? What equipment is affected by it? How can it be determined if the interference is present?** Answers to these questions may provide clues to help determine if the interference is power line related.
- **Is the interference relatively constant while tuning across the affected band?** This is an important characteristic of power line noise. As an example, it should not vary in regular and repeating peaks and nulls or noise level, which is a characteristic of a consumer electronic device. Power line noise will also gradually begin to taper off as the tuning goes into higher frequencies. Generally, the closer the noise source, the higher in frequency it can be heard. At very close range, noise can be heard at 1000 MHz and higher. Noise that can be heard at 400 MHz is typically less than 400 m (1/4 mi) away. Noise that diminishes at a lower frequency, however, can be much further away. For example, if it diminishes at 4 MHz, it can be two or more kilometers (1.2 mi) away. Depending on the specific circumstances of the complaint, ask the complainant what frequencies are being affected and how high in frequency the interference can be heard, keeping mind that a complainant may not have a receiver that can tune higher frequencies.
- **Is the interference present in the AM broadcast band?** It should be noted that the typical reduced sensitivity of AM broadcast receivers and antennas can make it difficult or impossible to hear power line noise in some cases. A receiver's automatic gain control (AGC) can make this especially true in the presence of strong nearby broadcast stations.
- **Does the interference vary with the time of day?** Interference might correlate to what people are doing, usually pointing to some electrical device or appliance. Solar systems also produce noise that varies with the amount of sunlight shining on the solar panels, to noise from solar systems may also vary with time of day and, to some extent, with the weather. Noise from consumer devices will often come and go with periods of human activity. It will frequently correlate with evenings and weekends. It is not reliable to assume that interference that occurs on a schedule is power line noise. If the complainant keeps an interference log, its value cannot be overstated. This log should include a record of the date, time, and weather conditions when the interference occurs and the highest frequency and signal strength of the interference. Correlating the presence of the interference with periods of human activity and/or weather can provide important clues when trying to identify power line noise or when to look for it.
- **Is the interference affected by weather?** If the interference appears and varies in intensity depending on weather conditions (dry or damp weather, or wind), and if the breaker test (see [Annex F](#)) excludes a source 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 or by causing wooden structures to swell, tightening loose hardware as it does. Windy weather might cause the noise to vary or even stop for a while, as loose hardware is affected.

¹⁷It should be further noted that the FCC does not require utilities to locate non-power line sources. However, should a utility choose to do so, the FCC does request that the source device be reported to the Commission for statistical purposes. Once a source has been positively identified, the Commission may contact a manufacturer, depending on the circumstances of a particular case or the number of reports they receive concerning a particular device.

- **Is the interference coming from inside the premises?** Many interference cases initially reported as power line noise are actually traced to a consumer device located inside the complainant's home or premises. If critical loads such as medical equipment being used in a home are not involved, ask the complainant to turn off the main breaker in the premises while listening to the interference with a battery-powered portable receiver. If the interference goes away, the complainant can further isolate the source by restoring the main breaker to the on position, turning off all of the breakers and then turning each back one, one at a time. If critical loads are involved, however, consider disconnecting individual loads only. Once the circuit is known, the complainant can start turning off and unplugging items connected to that circuit, one at a time, to see when the interference goes away.
- **Is the interference complaint about an analog TV?** Over-the-air analog television has largely been phased out in most countries, including the United States. It is therefore unlikely that an analog TV complaint will be encountered. However, some consumers still use analog TVs (usually with a digital-to-analog converter) and many digital televisions can still be made to operate in analog mode. Interference to analog TVs usually looks like two horizontal groups of dots and dashes that drift slowly upward through the picture. As a new group forms at the bottom, the top group rolls off the top of the screen. In some cases, power line interference can be a single group of dots and dashes, or the group can alternate in width from wide to narrow. (This is a result of arcing differences during the positive and negative peaks of the 60 Hz sine wave as will be shown in Figure 4). See Figure 2 for a photo of power line interference to analog television. As previously noted, the interference typically appears as horizontal groups of noise-like dots and dashes that drift upward through the picture.

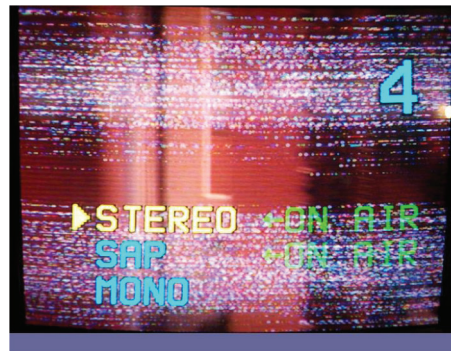


Figure 2—Interference to analog television

- **Is the interference complaint about a digital TV (DTV)?** Although power line interference to DTV can result in picture breakup (“pixelation” or “tiling”), freezing or picture loss, interference can be much easier to identify when using an analog television. *Breakup or picture loss in DTV does not necessarily indicate power line interference, because any number of issues can cause pixelation or tiling in digital video signals. In fact, interference to digital TV from power line gap noise has proven to be very rare in practice. These issues are more typically caused by weak signals.* However, if a power line interference to DTV is suspected but uncertain, then switch the TV to the analog mode if possible and tune to an unused channel (no signal). If power line interference is present, it might show up on screen similar to what is shown in Figure 2, but without a background picture (only noise/snow). Pixelation and loss of picture to a digital TV is shown in Figure 3. As this photo indicates, interference to digital television looks quite different than in the previous analog case shown in Figure 2. In this case, the pixelation or tiling is caused by a weak signal at the antenna input to the digital TV set.

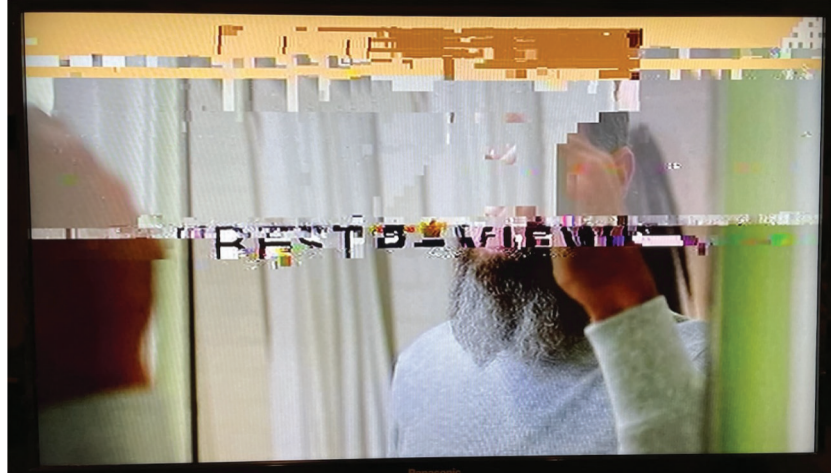


Figure 3—Interference to digital television

- **Is this a cable-system problem?** Cable-TV networks are intended to be closed networks but power line interference is still possible. When this happens, the sparking source is typically within close proximity to network equipment. The interference might also indicate a defect or problem with the network's integrity. See [Annex G](#) for additional information concerning this type of problem. Other considerations have previously been discussed in [Annex B](#).
- **Does the interference complaint concern wireless local area network (WLAN) communications?** Experience has shown that most WLAN interference issues are not power line related. Nonetheless, utilities might be blamed and therefore involved in the resolution of such issues. See [Annex H](#) for additional details and recommendations.

10. On-site field investigation procedures

10.1 Initial steps

If input from the complainant leads the investigator to believe that the source may be external to the complainant's premises, it is often useful to perform a quick survey of the neighborhood prior to meeting with the complainant. Listen to various radios for genuine power line noise at many frequencies simultaneously in the vicinity of the complainant's premise (e.g., AM, HF, aircraft band at 120 MHz).

Once at the site of the complaint, begin the investigation by observing the interference as it affects the complainant's equipment. Also review the complainant's interference log, if offered, and any other documentation he or she may have. Verify the interference is active and isolate any internal RFI sources that may be present in the complainant's premises. If there is any doubt as to whether or not the interference could be caused by an in-house consumer device, request the complainant temporarily turn off the suspected devices or main breaker to the premises. If the interference goes away or changes in any way, identify and remove the source before proceeding. See [Annex F](#) for additional information and locating procedures in this case.

10.2 Verify the complaint to be consistent with power line noise

10.2.1 General

It is important to observe the interference on the complainant's affected equipment. Verify the interference to be consistent with power line noise to the greatest extent possible. The importance of careful attention to the interference as it affects the complainant's equipment cannot be overstated.

10.2.2 Identifying interference from consumer and electronic devices

The objective is to determine if the interference is from utility-owned equipment. Although it is not the responsibility of a power company to locate or fix non-power line sources, some utilities will help do so as a matter of goodwill. Perhaps even more importantly, locating an RFI source in the complainant's premises can sometimes uncover a serious shock or fire hazard.

It is important to understand that many electrical devices (such as electrical motors, tools, and appliances), can cause interference. Battery chargers, switch-mode power supplies and electric fences are also common sources. The types of interference differ greatly from one electrical device to another. Interference caused by a computer, for example, is not the same as that produced by a household appliance. Although it can often be difficult, if not impossible to identify a consumer type device by its characteristic sound, these sources are usually not difficult to find. If the source is determined not to be power line related, again refer to [Annex F](#) for procedures and techniques to locate consumer and electronic devices.

10.2.3 Identifying interference from power lines

The first and most obvious clue that power line noise is affecting a radio receiver is the characteristic raspy sound or buzz. As noted previously, the RFI investigator should be familiar with this distinctive sound before conducting the investigation. Assuming the sound is consistent with power line noise interference, next tune across the spectrum. Power line noise should be relatively constant with respect to frequency. Interference that can sound like power line noise but varies in regular and repeating peaks and nulls, every 60 kHz or so, for example, is not power line noise. The most likely source in this case is a nearby Part 15 device, such as a switch-mode power supply. The interference should also be present in the AM broadcast band. It may not however be audible due to the typical reduced sensitivity of AM broadcast receivers and antennas. Strong local broadcast stations can also affect a receiver's automatic gain control (AGC) action, thereby further reducing its ability to hear power line noise interference.

Clues to help identify power line interference have previously been discussed in [9.4](#). Some highlights and additional considerations from this discussion include:

- The signature of the interference should be consistent with that of power line noise. See [Figure 1](#) and [Annex I](#) for signatures from power line and other sources.
- Interference from power lines is typically a broadband noise starting at the low end of the radio spectrum. Power line noise interference is usually stronger on lower frequencies. It occurs continuously across each band, including the AM broadcast band, and up through the spectrum to some upper frequency where it will taper off. It will not just affect a portion or only specific frequencies within an amateur band, for example.
- The interference should remain relatively constant while tuning across the spectrum. If it exhibits peaks and nulls and regular and repeating intervals, or appears across a portion of spectrum with a clearly discernable frequency occupancy, it is not power line gap-noise interference.
- Power line interference is often affected by weather. Power line interference often diminishes with rain, moisture or high humidity. Interference that varies with periods of human activity is most likely to be caused by a consumer device. Indoor consumer devices tend to be less affected by weather.
- Power line noise will usually occur in bursts at a rate of 120 bursts per second. In some cases, it will occur at a rate of 60 bursts per second. The noise bursts are clearly visible with an oscilloscope that is connected to the audio output of a receiver. The bursts occur every $8 \frac{1}{3}$ milliseconds (ms) or $16 \frac{2}{3}$ ms. Alternating noise bursts will often exhibit unique characteristics, i.e., every other noise burst will exhibit similarities to each other (see [Figure 4](#)). The 60 Hz signal found on quiet power lines is almost a pure sine wave, as shown in [Figure 4](#). Please also note the following:

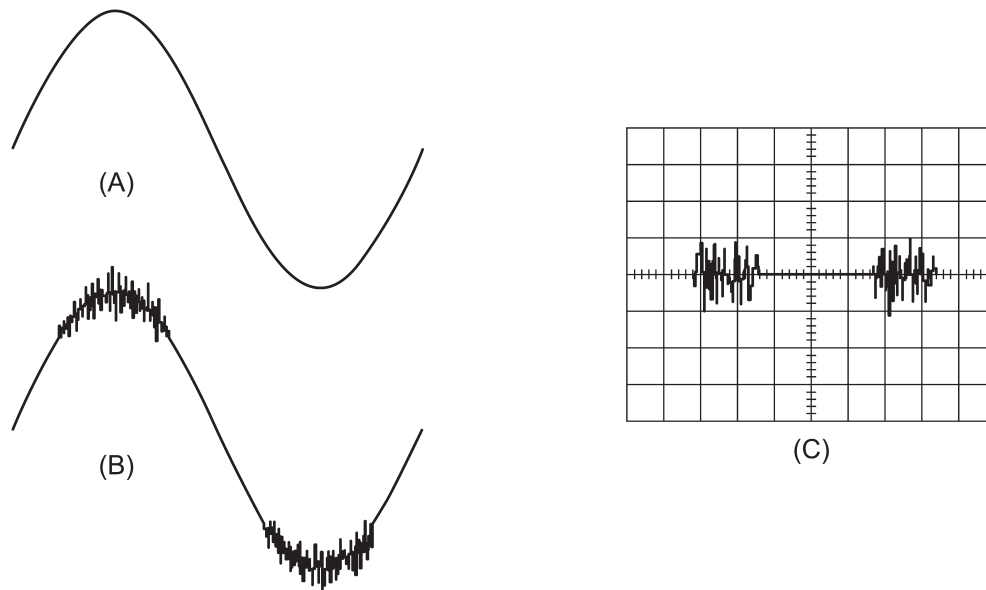


Figure 4—The 60 Hz signal on quiet power lines as shown in (A). Visible noise on the power line signal, as shown in (B). The noise will be present during the peaks, as shown in (C)

- If the line, or an arc source connected to it, is noisy, this will often put visible noise onto the power line signal, as shown in [Figure 4](#).
- This noise is usually strongest at the positive and negative peaks of the sine wave. If the radiated noise is observed on an oscilloscope or other time-domain display, the noise will be present during the peaks, as shown in [Figure 4](#).
- Refer to [Annex A](#) for additional explanation.
- If there is any doubt as to the nature or origin of the interference, listen to it while temporarily disconnecting power from the premises or a circuit. If the interference goes away, it is not utility-caused power line noise. Judgment and utility policy should dictate the use of this technique. In-premises interference sources should be dealt with promptly by the owner and/or a licensed electrician. See [Annex F](#) for locating procedures in this case.

10.3 Locating the source of power line interference

10.3.1 General

All on-site investigations should begin the same way. Determine that the problem is present and appears consistent with power line noise to the best extent possible:

- Verify that the interference is active by observing its effect on the complainant's equipment.
- Verify that the interference is consistent with power line noise. Refer to [9.4](#) and [10.2.3](#) for some telltale characteristics. When using an RFI locating receiver with an oscilloscope display, connect it to the complainant's antenna. Verify that there are noise bursts consistent with power line interference. When using the RFI locating receiver, the noise bursts can be synchronized only at power line frequencies on the display.
- Record the noise signature in the receiver's memory. A hand drawn sketch or photo may be substituted if the receiver does not have this capability.