Locating Power Line Noise Using TV Waveforms

The author describes a valuable technique for locating and tracking power-line noise.

Marv Loftness, KB7KK

Some years ago, as a communications engineer for the Bonneville Power Administration (BPA), one of my duties was to investigate complaints of noise from the BPA power lines in the Olympia, Washington district. On an early investigation, I found what proved to be power-line noise near a complainant's home in a rural area. I could hear the noise with my Blonder Tongue 4127 field strength meter (FSM) and, as I rotated my dipole antenna, I could see the FSM meter peak when I pointed in the general direction of the power line.

Viewing the noise pulses on my Tektronix 515A oscilloscope (adjusted to a horizontal time base rate of approximately 60 Hz), I could see a distinctive noise pattern. I observed this when the FSM frequency was set to 75 MHz, as shown in Figure 1. When I moved up in frequency, to the video signal of TV channel 5, I could see that the television pattern was overlaid by the noise pattern, as in Figure 2. Television picture modulation actually consists of many vertical lines, but these are seen blurred together in the figure. The 60 Hz electrical-noise pattern drifted slowly across the 59.94 Hz vertical rate of the TV pattern because of the slight frequency difference in the repetition rates of the patterns. I was amazed at these and the other patterns that I observed.[1]

A most important observation was that, when I tuned my FSM either above or below the TV channel frequency, I could see the noise pattern by itself, without the TV modulation pattern. Later, I found that a single arcing source radiates noise across the complete VHF and UHF TV spectrum, but that the radiation is very much weaker at UHF frequencies.

The noise patterns observed were caused by electrical noise sources, both power line and off power line arcing sources, and the observations led to a real breakthrough for noise-locating—although I didn't realize it at the time.

When I first observed the phenomena, I wondered why there were a number of sharp spikes during each half cycle rather

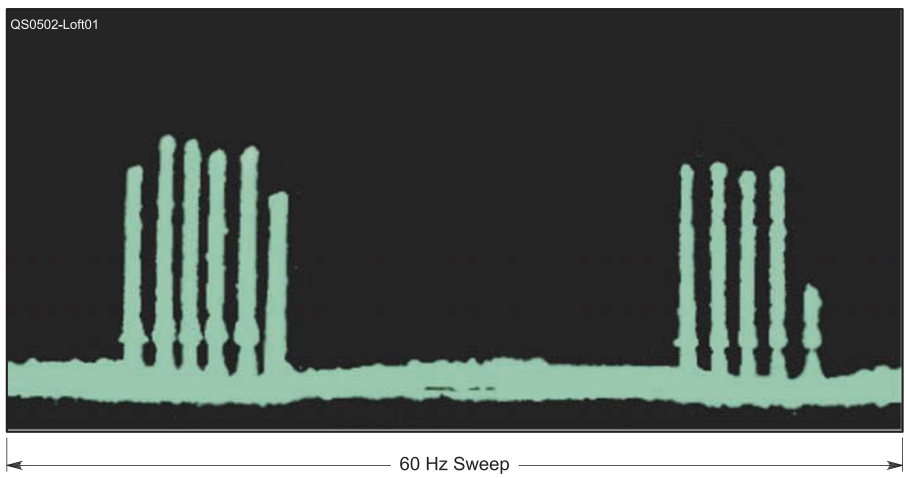


Figure 1—Power line noise pulses detected at 75 MHz, about 2 MHz below the NTSC channel 5 television video carrier.

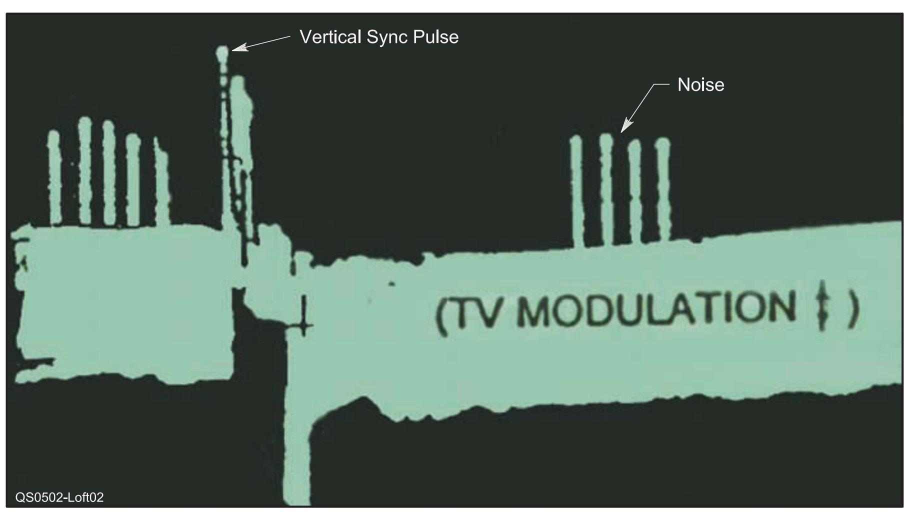


Figure 2—An NTSC channel 5 television video pattern, at the vertical rate (59.94 Hz). The noise pattern can be clearly seen.

[1]Notes appear on page 46.

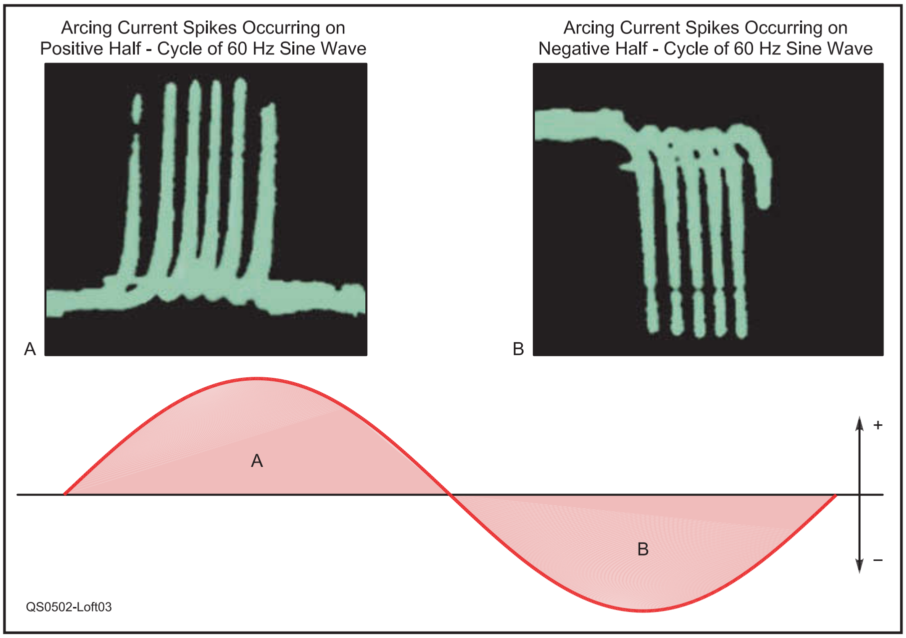


Figure 3—The relationship of the arcing current spike groups to the power line sine wave of 60 Hz.

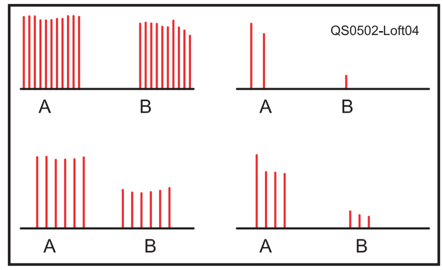


Figure 4—Examples of RF noise pulses, after detection by a TV field strength meter. The pulses will appear as spikes on each half-cycle of the power line ac waveform.

Figure 5—A typical electrical noise pattern as seen on a TV image.

than a single spike, and this is my explanation: When the voltage in the 60 Hz sine wave reaches a critical level, an arc fires across the gap. This single current burst has an extremely sharp rise-time—in the nanosecond range. This burst or spike then causes an immediate voltage drop across the impedance in series with the arcing gap, and the arc is immediately extinguished. The power line 60 Hz sine wave is still rising; the voltage across the gap instantly builds again to the firing point and it causes another arcing burst.[2] This alternate firing and extinguishing maintains itself as long as there is sufficient voltage in the sine wave to cause the air to break down and hence cause another current discharge.

As time went on, I found that there were many variations of these electrical noise patterns, but each with characteristics that identified them as power-line related occurrences. These patterns are described in the guidelines listed below. I found that the arcing patterns, either from a source on the power line or those propagated into the line from an ac appliance in a home (or other location), exhibited a signature two-group spike pattern. A sparking home device could be a defective doorbell transformer or a fish-tank heater (two of many possibilities). The arcs of such devices, of course, are related to the power line that furnishes the voltage for their cyclic 60 Hz arcing.

The following guidelines describe some factors that should be considered. The individual spikes seen in the groups usually result from small arcs across gaps commonly of 0.25 inch or less. Because of their small size, arcing in these gaps is sometimes called "sparking." The arcs, when occurring on the ac line, are found mostly in loose hardware or loose insulator connections. These connections are associated directly with the power line, or in other metal parts located within the electric field of the power line (but not touching the power line). An example could be the junction of two metal cross-arm braces on a wooden pole. With proper detection equipment, the arcing current discharges will be detected as noise voltages that you can hear in your receiver or see on an oscilloscope.

Some Noise Observation Guidelines

1) A pattern of 60 Hz electrical arcing results from two groups of current spikes with one group for each half cycle (A and B) of the 60 Hz voltage wave, as seen in Figure 3. The *current* patterns can be observed in the laboratory, but not in your vehicle.

2) The radio-frequency (RF) noise pulses, *after detection* in your FSM, will appear as positive pulses (rising above the horizontal baseline trace on the oscilloscope screen) on each half cycle of the power line 60 Hz frequency, as shown in the examples of Figure 4.

3) The extremely sharp pulses of arcing current on a power line cause sharp radio frequency noise pulses that radiate from the metal parts (electrodes) associated with the arc gap. (An electrode might be a guy wire, a loose nut, a corroded wire on the line, or a loose clamp or connection on a power line device, for example.) When one of these electrodes is connected to the power line, the radio-frequency interference (RFI) radiating from the line will really disturb the electromagnetic environment. You have probably observed this in your ham shack. Also, the noise from electrical arcing sources located off the line in a home or at other locations will

propagate into, and re-radiate, from the power-line conductors.

4) As seen on an oscilloscope screen, one of the individual groups of a pair will often have lower amplitude than the other group, and it will have fewer spikes.

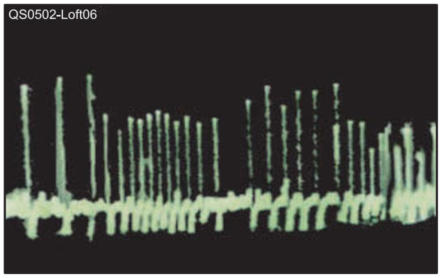
5) A group in a pair usually has a somewhat rectangular shape but, occasionally you will see groups with rounded or triangular shaped characteristics. If the groups in the pair consist of sharp spikes, however, and if the A group is different in some degree from the B group and if a noise pattern drifts across a TV video pattern, *you know you are looking at electrical noise*. The noise resulting from pattern (1) of Figure 4 will cause a TV video interference picture very much like that seen in Figure 5.

6) If two or more sources are present they will have different patterns. Sometimes the difference is minor, but more often, it is pronounced, as in Figure 6.

7) The pattern for a particular noise source will usually persist for at least 20 minutes as you move along the power line. Sometimes, it will last for hours, but almost always long enough for you to find a source structure, or to identify an off-line source location, using an efficient locating system.[3]

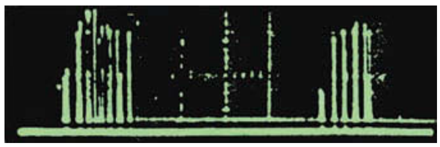
8) As you move up to *higher* and higher frequencies, a pattern will remain *substantially the same*. This is most important to the investigator, because it means that as you travel along a line to observe the noise, it will continue to appear at higher and higher frequencies, as you get closer to the source. This can be seen in Figure 7.

The eight factors referenced above were observed by the author over a period of several years. I found that I had acquired valuable information that I utilized for the development of new and improved locating equipment and the design of an efficient and rapid noise-locating system. This article does not address "corona" RF noise, which occurs mainly on HV transmission lines. It is, however, treated in the reference cited in Note 3.

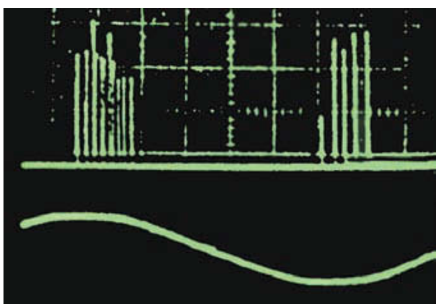


A B A1 B1

Figure 6—Two noise patterns, representative of two power line noise sources. Patterns A and A1 are both half-cycles of one pattern; B and B1 are of another pattern.



(A)



(B)

Figure 7—Noise patterns at 50 MHz and at 500 MHz, with a 60 Hz reference trace. Note that the pattern remains substantially the same in shape and format. The pattern at A is at 50 MHz. The pattern at B is at 500 MHz, with a 60 Hz reference trace. As one gets closer to a noise source, the pattern appears at higher frequencies.

Notes

[1]The NTSC TV vertical field rate is 59.94 Hz, so the resultant beat frequency with the almost identical 60 Hz power line sine wave causes the power line noise to slowly drift through the TV waveform at a 0.06 Hz rate. The TV waveform sync pulses ensure good oscilloscope synchronization and the lock to the TV waveform makes noise observation easy.—*Ed.*

[2]The visble high voltage discharge or arc is actually a plasma—essentially a stream of ionized air.—*Ed.*

[3]M. Loftness, *AC Power Interference Handbook*, Percival Technology, Tumwater, WA, 2003. Available from the ARRL Bookstore, order no. 9055. Telephone toll-free in the US 888-277-5289, or 860-594-0355, fax 860-594-0303; **www.arrl.org/shop/**; **pubsales@arrl.org**.

Photos by the author.

A native of Anacortes, Washington, Marv Loftness, KB7KK, was first licensed in the late 1940s, with the call W7SWP. He served as a radio instructor/technician in the US Army Air Corps during WW II and joined the Civil Aeronautics Authority, in Hawaii, after the war. Returning to Washington to work for the Bonneville Power Administration (BPA), as a communications engineer for the Olympia district, he developed an interest in power line noise and became an electromagnetic compatibility (EMC) engineer. As a BPA EMC engineer he developed rapid detection noise-locating equipment. Marv is a consultant to power companies and owns a research and development company, Percival Technology. He has a BA from Pacific Lutheran University and is a Fellow of the Power Engineering Society of the Institute of Electrical and Electronics Engineers (IEEE). He can be reached at **m.loftness@att.net**.

Strays

In November, ARRL Course Grants Manger Dan Miller, K3UFG, became a CERT (Citizens Emergency Response Team) graduate, thanks to Paul (K1PJB) and Lynn (KA2IIW) Benyeda, who coordinate CERT in Connecticut.

CHARLIE BROWN, N9RU

Congratulations!* Andy Anderson, W5UBU (center), received the 75 year ARRL membership plate that's attached to his life member plaque at the Deming (NM) Amateur Radio Club hamfest in September. At the left is Carol Brown, N5CMB, and at the right is New Mexico SM Bill Wetherford, KM5FT, who made the presentation.—*tnx KM5FT