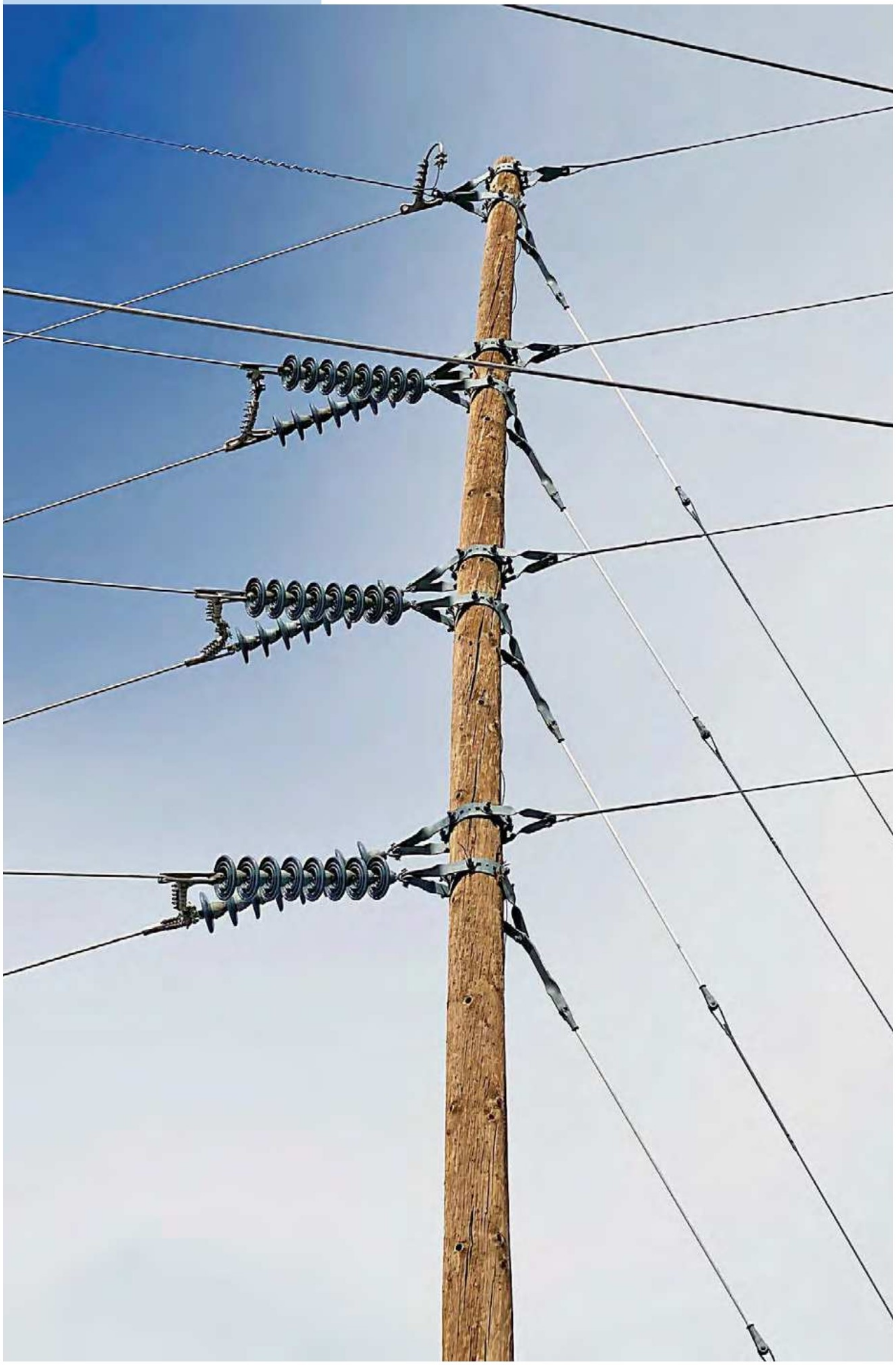
A case study on identifying, locating, and eliminating radio frequency interference (RFI) caused by 60 Hz power lines.

Eliminating Radio Frequency Interference from Power Lines



Richard Kiefer, KØDK

I had a 60 Hz power line noise, which severely limited my ability to hear weak signals on the 20-meter HF ham band. The troublesome noise was S-7 to S-9 in a 6 kHz AM bandwidth on 20 meters. Weak DX stations were diffcult to hear.

With the help of several hams and Xcel Energy (our electric utility company), I searched a large urban area at Boulder, Colorado, and found the noise source to be sparking ungrounded hardware on a 115 kV transmission line attached to a wooden pole (see the lead photo) 4.4 miles from my station, and at 600 feet above my antenna. It took 2 years of persistence, hard work, and cooperation of many individuals, but the RFI noise was eventually eliminated.

Identifying RFI's Audio Signature

Listen using the SSB or AM detector of your HF receiver. I prefer the AM detector and 6 kHz bandwidth of my Icom IC-7700 transceiver. Turn off all noise blanking and noise reduction as well as the AGC if possible.

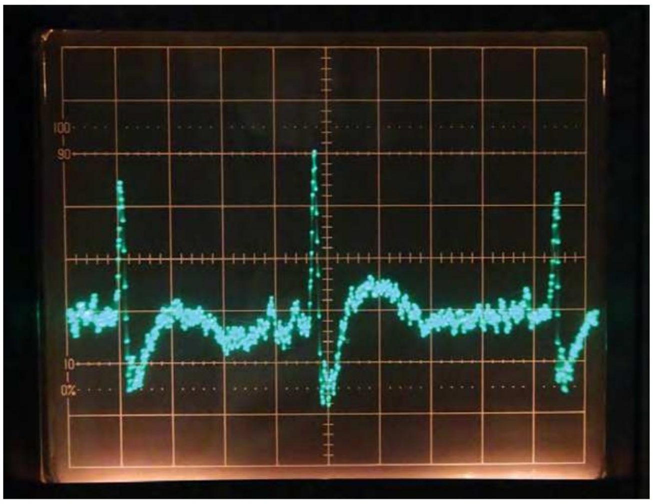


Figure 1 — The oscilloscope display of the power line noise signature at the audio output of IC-7700 receiver, 2 ms/div.

Figure 2 — The Icom IC-7700 receiver power line noise S-8 reading, and spectrum display, using the AM detector, with a 6 kHz bandwidth.

Forming a good mental impression of the noise makes it easier to identify in the field. In my case, the noise had the characteristic crackle of power line noise created by ungrounded or loose hardware on an electric power pole. Characteristically, the noise was intermittent, and often stopped with wet weather and lower temperatures. See **www.arrl.org/qst-in-depth** for additional details.

A positive identifier was the audio signature seen on an oscilloscope (see Figure 1) at the receiver audio output (see Figure 2) and on the Icom IC-7700 receiver spectrum display, using the AM detector, with 6 kHz bandwidth. See also Figure A on the *QST* in Depth web page.

With the scope synced to the power line frequency of 60 Hz, the noise exhibited pulses at a steady 120 Hz rate, indicating that the source of the RFI is the 60 Hz power system. The timing and duty cycle of RFI always provides a clue as to the source. The manual[1] for the Radar Engineers model 243 RFI Locator instrument describes how power line-induced arcing is created.

Determining the Distance

Use a directional antenna at the frequency of the interference to get a bearing on the location, then estimate the distance by its signal strength. Observations with my stacked Yagi antennas indicated that the noise source was far away.

With a directional antenna, you should be able to determine an accurate search vector to within a few degrees if you are careful.

Lacking a directional antenna, you must travel outward from your location in several directions in a vehicle equipped with a short whip antenna. It is best to try to correlate any intermittent characteristics of the noise. Once you get close to the RFI source, you can use a higher-frequency receiver (see Figure 3 and Figures B and C on the *QST* in Depth web page) and very directional antennas to pinpoint the noise.

You can also triangulate to the noise location by using a directional HF antenna from another ham's location. Make sure that you are both hearing the same noise source at the same time. We also eventually triangulated from a third location to pinpoint a peak in noise on a 115 kV transmission line, but that was not the problem. Be careful when listening to what you think is the same RFI source from different locations. See the sidebar, "Signature of the Noise."

Locating the Noise Source

Once you have determined a direction for the search, listen on the HF frequency of interference and travel out in the direction of the noise. When you are close, you can start to walk around with a higher-frequency receiver and directional antenna. We also used receivers at 318 MHz (see Figure B on the *QST* in Depth web page) and 150 MHz (see Figure 3) with

[1]Radar Engineers model 243 RFI Locator manual, battery-powered broadband receiver; **ked-wireless.com/RK_Documents/Radar_Engineers_243_RFI_Locator_Manual_03.18.19.pdf**.

Signature of the Noise

It is extremely important to correlate any intermittent characteristics of the noise. Your search may find many noisy poles, only one of which correlates with your RFI. Don't ask the power company to investigate the many noisy poles that do not correlate with your noise signature. This is time consuming and costly for the power companies, and it can be met with resistance. Narrow the search to the actual correlated noise source. — *Ed*.

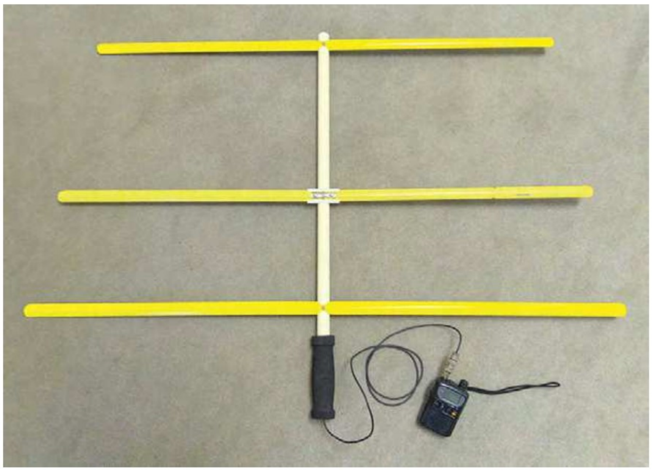


Figure 3 — The RFI receiver system for 150 MHz, using a tape measure-type antenna and an Icom IC-IQ7A receiver.

handheld Yagi antennas. We also verified with an ultrasonic acoustic dish receiver to spot specific insulators and hardware.

Check for coincidence by listening to both ends of the path simultaneously; listen to your home receiver over a cell phone. If both have the same audio characteristics, and are coincident in time, you have located the RFI.

In my case, the problem pole was screaming loudly at 150 and 300 MHz, and with the acoustic receiver, we could hear it from 600 feet away. The wood transmission pole (see the lead photo) had sparking hardware that was audible at 50 feet away.

It is very useful to have a signature for your own interference which can be used for comparison in the field. We used the Radar Engineers model 243 RFI Locator (see Figure A on the *QST* in Depth web page) with a reference signature recorded from my antenna. We found and bypassed many noise sources with similar signatures that were not an exact signature match.

Approaching Partners

The best way to resolve a power line caused RFI problem is to work jointly with your local power company to locate the noise source, and then convince them to fix it. If you try to find the problem yourself, then suggest where they might look, the power company can quickly verify your findings and will be more likely to fix the problem. In my case, it took 2 years, even with the full cooperation of the power company, to find and correct the problem.

It is important to note that a transmission line carries very high voltage — typically 115 to 345 kV — over long distances, and it terminates only in substations. A distribution line originates at a substation and usually carries less than 10 kV and supplies neighborhoods. Most ham RFI problems are caused by hardware on the poles of neighborhood distribution lines.

A Case Study

In early 2018, a strong power line noise appeared on the 20-meter band on a bearing of 240 degrees from my antenna. It was loud but intermittent. I probed around with my 318 MHz EMI finder (Figure B on the *QST* in Depth page) and located some noisy poles within a mile of my antenna. I called Jeremy Matzek, the Services and RFI Investigator for Xcel Energy, and he found some additional possibilities.

Fixing False Leads

After Xcel's line crews had quieted the hardware on several noisy poles (see the *QST* in Depth web page) to no effect, Jeremy and I were both a little frustrated. Clues came in by noticing that the noise was always about two S-units stronger on my upper Yagi antenna at 100 feet compared to the lower Yagi at 55 feet. This indicated that the noise source was farther away than we were searching.

I was also able to hear the same noise at the ham shack of Joe Woods, ADØI, who is located 1.5 miles to my west, but almost in line with my bearing to the RFI. I verified that Joe was hearing the same noise by listening to my receiver and his simultaneously over the phone. So, with his antenna pointed in the same direction as mine, it became apparent that the noise was farther away than 1.5 miles.

Because the noise was only S-3 on Joe's Icom IC-7300 with his three-element Yagi at 50 feet, the noise appeared to be much farther west than we thought.

Better Techniques

Knowing that the noise was farther away than the area in which we had been looking, we started to search the residential neighborhoods of north Boulder at over 2 miles from my antenna.

We started to use the Radar Engineers model 243 RFI Locator with a signature taken from my antenna. We eventually found a 115 kV transmission line on metal towers on the west side of Boulder at about 3.5 miles from my antenna, and it emitted noise with the same signature. The strength of the RFI peaked at two of the towers on the line, so we focused investigations there. At the towers we had strong noise at 14 MHz with the correct signature using the model 243, but very little noise at 300 MHz. We could also hear sparking in the ultrasonic dish when pointed at connecting hardware and insulators on the towers. We also triangulated to these towers from the ham location of Max Greenlee, KDØGF, where the noise was 20 dB over S-9. We thought that hearing the noise at 14 MHz, with the correct signature, and with triangulation, was justification to replace some hardware and insulators on the two metal towers. But that was just one of the false leads we fixed.

Figure 4 — A well-equipped lineman ready to climb the power pole with spikes.

Finding and Fixing the RFI Source

We had good evidence that the problem was somewhere on the 115 kV transmission line because of the matching signature. We also observed that when it snowed or rained, the noise at my receiver and on the transmission line both went away. The line is about 4 miles long, about half in the city and half in the mountains, with a substation at each end. The noise source could be anywhere along the line or at either of the two substations. We also knew that the amplitude of the noise would rise and fall at regular intervals as you travel along the transmission line due to 14.2 MHz standing waves. Though, in this case, we could not drive the full length of the line because it goes over the top of Sanitas Mountain.

Eventually, Jeremy found a wooden pole (see the lead photo) with very noisy hardware on the other side of Sanitas Mountain in Sunshine Canyon. From 600 feet away, on the canyon floor, we could hear the noise loudly with our acoustic dish, and at 150 and 300 MHz. With binoculars, we could see a ground

Lessons Learned

Consider the lessons we learned.

- Figure out if your noise is caused by the 60 Hz power line to determine if you need to get the power company involved. Be aware that if the power company determines their equipment is not the problem, you are on your own.
- Most power line RFI is created by loose or ungrounded hardware on wood poles.
- Insulators are usually not the problem, unless you can see damage with binoculars.
- In most cases, you will be able to hear the broad RF noise spectrum produced by hardware sparking at VHF or UHF frequencies. If you cannot hear the noise loudly at 300 MHz, you are probably at the wrong spot.
- The hardware of metal towers is usually not the problem. Even though we could hear noise at 14 MHz, and acoustic noise on the metal tower insulators in west Boulder, we could not hear much noise at 300 MHz.
- Use instrumentation in the field that can listen on the ham band of interference.
- Have instrumentation that can display a noise signature to make a positive identification.
- Use acoustic location to confirm and pinpoint the exact pole and hardware.
- Use the aiming sight on an ultrasonic dish to pinpoint specific metal brackets and insulators. The acoustic dish is much more directional than a five-element 318 MHz handheld Yagi.
- Getting time coincidence by listening simultaneously in the field and at home can be crucial in getting a positive identification on a noise source.
- Use triangulation on the band of interest from another ham's location to point a directional antenna at the same RFI source.
- Be prepared to spend a lot time finding the problem.
- Use the right equipment; guesswork leads to wasted time.
- The higher your antenna, the farther away the noise can be.
- The weather can be a factor; it can make the noise intermittent. Variable weather conditions can also be helpful in correlating your noise with noise in the field.
- First, try to find the problem yourself, to the limit of your ability. Then get the power company involved.

wire on the side of the pole that was broken in two places. We hiked to the pole through snowdrifts in January 2020. We could hear sparking noise by ear from 50 feet away. Loose, ungrounded hardware was sparking loudly. We could easily pinpoint all pieces of sparking hardware on the pole using the optical sight on the acoustic dish.

A short video (available at **ked-wireless.com/RK_Documents/noisy_transmission_pole_crackling-2.MOV**) shows the noisy power pole. You can clearly hear the sparking that was causing the RFI.

Xcel Energy Fixes the Hardware

A few weeks later, three Xcel Energy line crew members (see Figure 4) were air lifted by helicopter to the hillside location of the pole to fix the problem by splicing the ground wire, reconnecting the hardware, and tightening the bolts on all metal hardware. As soon as the transmission line was energized, the RFI had been fixed with no more noise on 20 meters.

Acknowledgments

I would like to acknowledge all who provided assistance, advice, and support over the 2-year process of identifying, locating, and eliminating my 20-meter RFI. Thanks to Jeremy Matzek, Services Investigator of Xcel Energy; Larry Benko, WØQE; Tom Thompson, WØIVJ; Paul Cianciolo, W1VLF; Ira Stoler, K2RD; Frank Haas, KB4T; RFI consultant Mike Martin, K3RFI; Joe Woods, ADØI; Max Greenlee, KDØGF, and Fred Horning of Radar Engineers Company.

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