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Tracking RFI with an SDR One Source at a Time

The last several years have brought widespread use of pan-adapters, band scopes, and now SDR receivers and software. These and other tools make it even easier for us to track down RFI noise sources. This article describes the basic process and tools you can use to survey and track these sources. Our main focus will be on using an SDR to survey the RFI environment at the station receiver and then taking the SDR out into the field. We'll follow the process up to the point where the direction finding begins.

Finding RF Noise Sources

We all want to enhance our ability to copy the weak ones by increasing our signal-to-noise ratio. We can do that by reducing the noise on each band that we operate. Lowering the noise floor increases the relative signal strength of weak signals. Those of us who live in typical residential environments find that locating and eliminating RFI sources is a never-ending process. It is much like weeding a garden.

RF noise sources can be natural or man-made. We can't do much about natural sources, except with directional antennas. Also, noise sources can be on site or off site. Frequently, multiple noise sources affect a given station. Which source predominates may depend upon band and antenna configuration. Typically it's a case of multiple noise layers, much like an onion. To keep focus, concentrate on identifying and peeling back one layer at a time. Ultimately, the goal is to reduce or eliminate any noise which tends to reduce the signal-to-noise ratio.

Mental Traps to Avoid

1. Keep an open mind. The mind can play tricks. In the beginning you may get a hunch about where or what the RFI source is. The longer you work on a problem, the more that hunch turns into a "fact."

2. Don't focus on one theory too early. Don't automatically assume your source is a power line leak.

3. Don't spend too much time on *what* it is. This may make for an interesting techno-nerd discussion, but you ultimately must figure out *where* it is.

4. Avoid getting angry at device manufacturers for all the RFI being generated. The anger may be warranted, but it distracts from the locating process.

5. Stay focused on the location of the source causing your elevated noise floor. There is no end to the number of devices that generate RF.

6. Don't spend time sniffing and trying to fix every wall wart or appliance in your house until you know a particular device is a source which is raising your receiver's noise floor.

7. Avoid believing in magic. Many of us non-technical types need to continue reminding ourselves: "It is just physics." Somewhere out there is an RFI source producing the offending "signal" that's raising the noise floor on your receiver.

8. Be sure that what you are tracking in the field is what is bothering your radio and affecting your noise floor.

Reduce Your Station's Susceptibility

A good friend of mine, Chuck Hill, KØMV, had a long career in fixing RFI problems for a Fortune 100 company. He points out that devices and installations are often designed without sufficient consideration for proper filtering and shielding. He recommends that, whether it is a computer or a whole ham station, we should start with proper engineering practices. Many of us have stations that we built-up incrementally over many years. We have not necessarily kept up with technical developments. Be sure your station is not unduly susceptible to RFI intrusion. It may be time to drop back for an engineering upgrade.

The US Navy commissioned a comprehensive study of how to do exactly what we contesters are trying to do. It wanted to lower the noise floors at more than 20 radio receiving sites around the world. The program was called, "The Signal-to-Noise Enhancement Program." This effort produced two reports authored by four engineers - all hams. The first report is entitled "The Mitigation of Radio Noise and Interference from On-Site Sources at Radio Receiving Sites" (essentially how to clean up your own station). The second report is, "The Mitigation of Radio Noise from External Sources at Radio Receiving Sites." The authors are Wilbur R. Vincent, W6PUX; George F. Munsch, W5VPQ; Richard W. Adler, K6RWA; and Andrew A. Parker, WV1B. Links to both these reports and other great resources can be found at **www.arrl.org/radio-frequency-interference-rfi** (scroll to bottom of that page to "Naval Postgraduate School RFI Handbooks").

Survey the Existing Noise Floor

There is a big advantage in starting by making a noise floor survey on each band you use. Survey *all* bands to start out. A single RFI source may be affecting multiple bands. So, if the survey shows the same pattern or signature on mul-

tiple bands, you can then pick the most prominent signal for direction finding (DFing). For example, if something prominent on 6 meters has the same pulsing characteristics as what you hear on 20 meters, use the 6-meter signal for DFing.

Rotate and/or switch your usual antennas to see where the noise floor is highest and where the noise floor is lowest. Survey for local noise sources while there is minimal skywave propagation — the higher bands at night and the lower bands during the day. Realize, however, that beam headings on close-in sources can be deceptive. While such beam headings are nice to know and may be correct, a beam's near-field directional pattern is not the same as it normally would be farther away.

Determine the RFI "Signature"

Keep an RFI log of observations and changes. Do as physicians and other scientific people do. Don't just rely upon your memory of what, for example, the noise floor level was 4 weeks earlier. This practice will allow you to notice patterns in the noise source. Take photos of the scope displays and integrate the photos' dates and times into your RFI log.

Look at both wide and narrow bandwidth displays. Having an RFI "signature" allows you to transition from watching RFI on the station scope to identifying the same source on your portable DF setup (see Figure 1). In this way you will be tracking the source that is actually contributing to your noise floor. On one occasion, I could not seem to get a signature of a particular noise source until I set the SDR display to 3 kHz. Only then did I see 10 dB "spikes" occurring once every 60 Hz. That allowed me to transition confidently to the SDR and DF setup and quickly locate the source. It was a refrigerator that cycled on and off periodically. This was cured by ferrite chokes on the ac power cord.

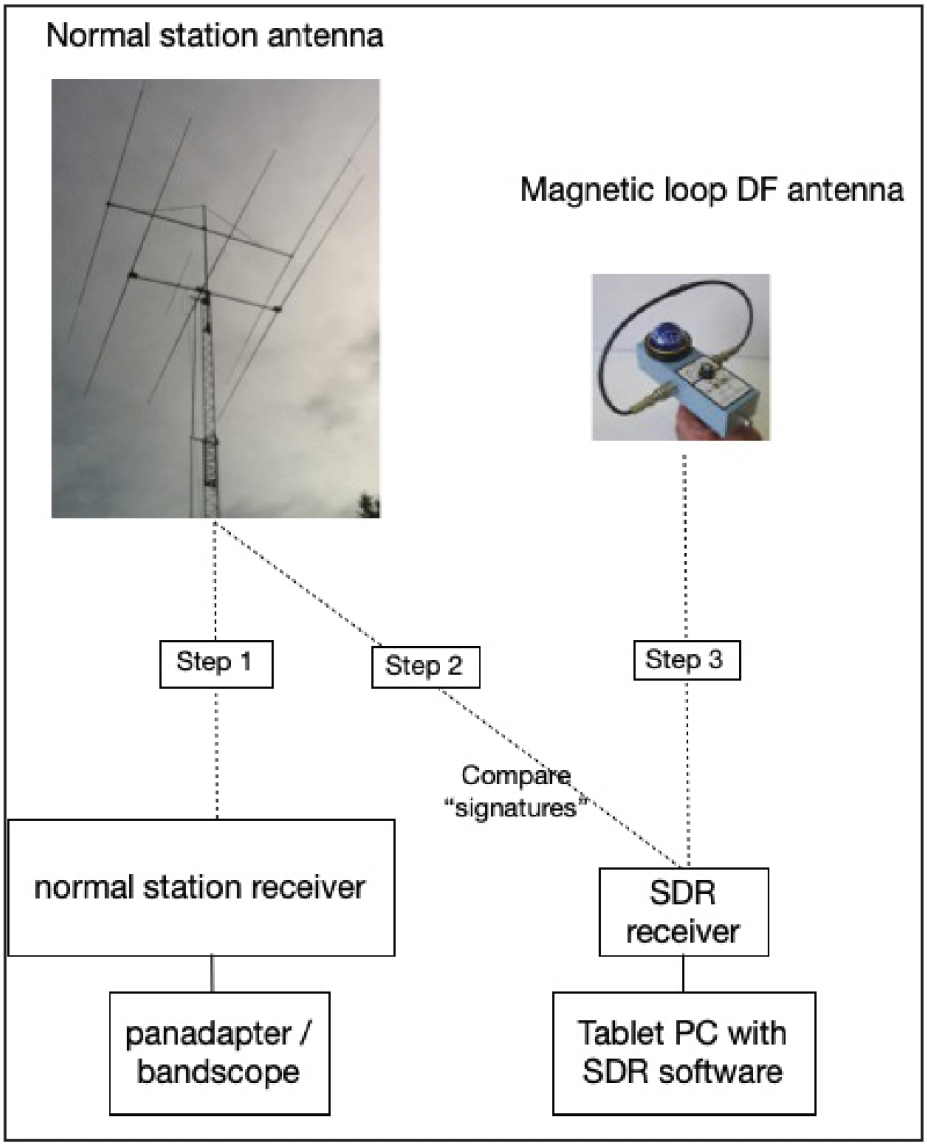

Figure 1 — Block diagram showing three steps of confirming RFI source signature.

Long-Term Monitoring

Offending signals come and go. Intermittent noise can be a challenge. The RFI log helps you to remember and track the signals. The characteristics of the signal source are used for identification. These may include: broadband versus discrete; associated signals on the spectrum; steady versus pulsing; modulated or not; patterns for times of day when active; direction; associated with device activity (TV, street light, new neighbor, appliance activity, solar panel construction, etc.). Sometimes a discrete signal source outside of an amateur band may produce in-band RFI. If surveying includes looking outside a ham band, consider using a broadband antenna. If the source is intermittent, knowing when it is likely to be active will allow you to go hunting in the field when the source is likely to be active.

The key is to *be sure* you are detecting the *same noise source* on your portable radio and DF setup when you make the transition from your station's regular antennas into the field.

Tools and Techniques

RFI Log. The log should contain

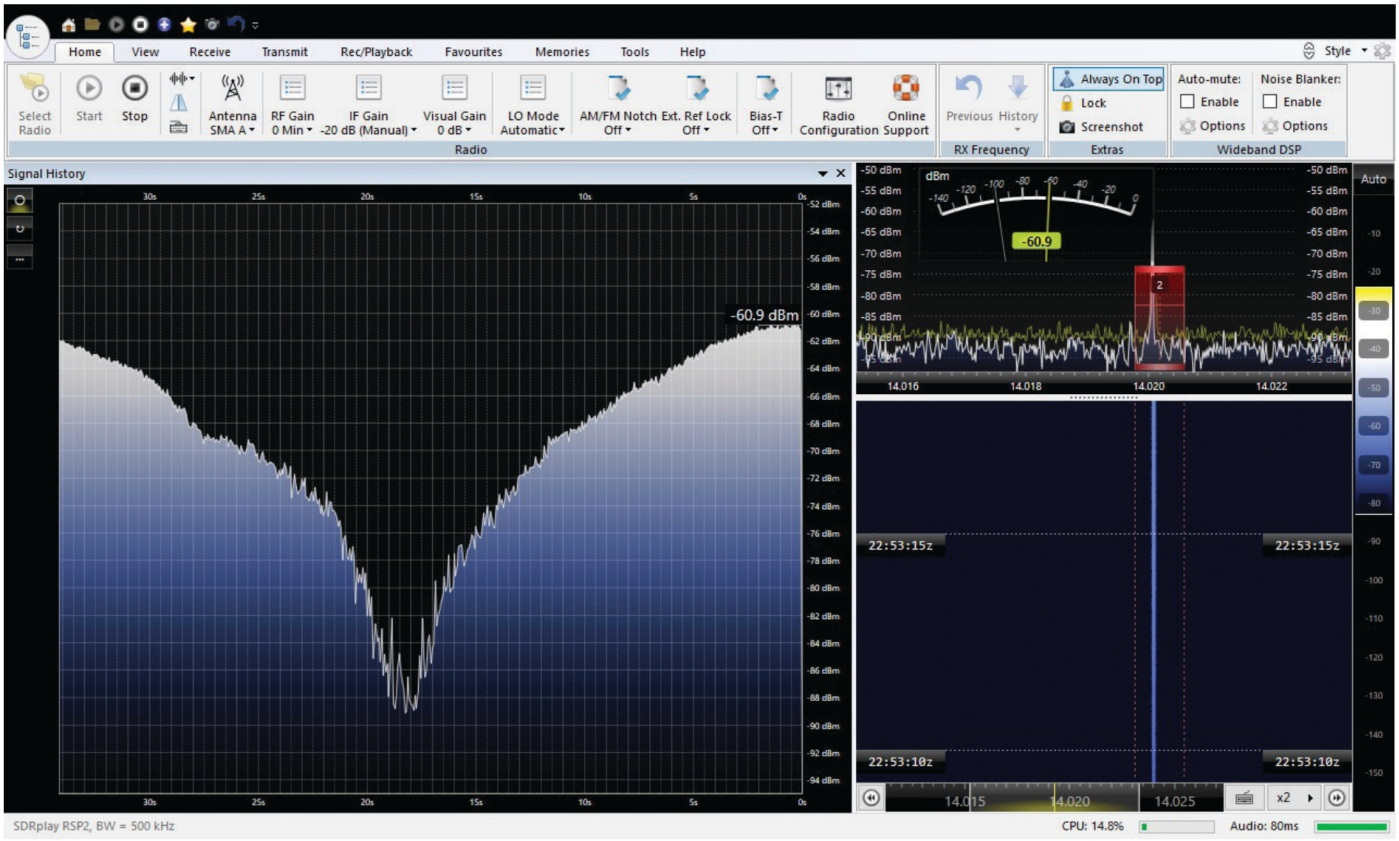

Figure 2 — A screenshot from a tablet PC. This demonstrates using a magnetic loop to null a signal on 14.020 MHz. The loop was slowly rotated 180° by hand. This created a 28 dB broadside null as displayed on *SDRConsole*. The carrier was generated with an Elecraft XG3 RF Signal Source.

a listing of all observations, including dates, times, frequencies, receiver and scope settings, antenna settings, weather conditions, noise floor readings, RFI characteristics, comments, and a plan for your next steps. Try to assign a descriptive term to each RFI source under investigation. That will help you to keep focused on each RFI source as a separate "project" to be completed. Capture screen images and video with a digital camera. Note day and time of these photos in the RFI log for future reference and comparison.

Direction Finding Loop. Before getting started on an actual hunt, practice using your DF antenna to locate a known signal source. Remember, assuming you use a magnetic loop, the null in the antenna pattern is used to determine direction, as it is narrower than the peak. This null is broadside to the loop (see Figure 2). For example, you could use a signal generator or other signal source and practice nulling and using an attenuator. I use an Elecraft XG3 for this purpose. You can either build your own loop or purchase one. Upon the recommendation of an electric utility RFI investigator on the RFI Reflector (KB4T), I purchased National RF's HFDF Vector Gun and have been extremely satisfied with it. It contains a built-in 30 dB attenuator. Consider mounting the loop on a rigid tripod for increased accuracy (see Figure 3). This will permit repetition of your DF readings. As you rotate the DF antenna, move slowly, because there will probably be some latency in what you see on the SDR display. Recently, WD8DSB developed a portable flag loop antenna that's unidirectional (see **https://sites.google.com/site/portableflagantenna/**).

Step Attenuator. Step attenuators can be helpful as you get closer

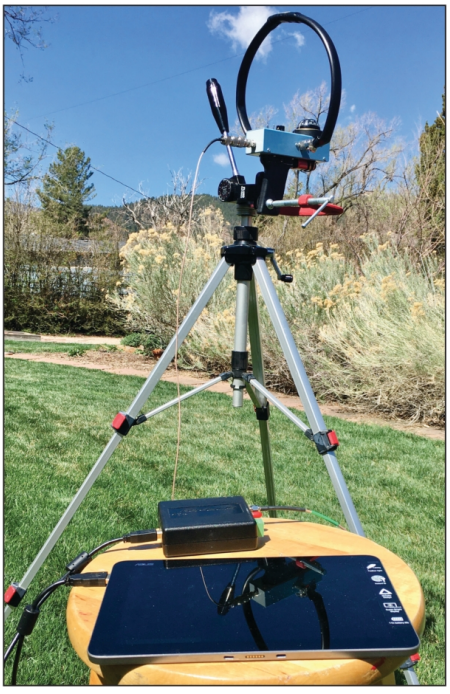

Figure 3 — A magnetic loop antenna (National RF HFDF Vector Gun) secured by a clamp to a tripod feeding an SDR receiver (SDRplay RSP2) connected to tablet PC (ASUS Transformer Mini T102) running *SDRConsole*.

to the noise source. The stronger the source, the less accurate your DF capability may get as the strength meter is pushed into its more logarithmic ranges. Sometimes the measuring device simply gets overloaded or swamped. National RF and others sell ready-made step attenuators.

Preamplifier. DF loops usually require some kind of preamplifier to operate properly. The National RF HFDF has a built-in preamplifier.

Portable Receiver to Use in the Field. Such a receiver ought to have a relative strength meter, capability to receive in the ranges of HF bands and modes you operate as well as in the VHF range. It should also receive AM. I started using the Tecsun PL660. It is nice, because it is very portable, has SSB, CW, and AM, and covers the ham bands as well as the aircraft band in the 118 – 137 MHz range. It has a segmented LED S-meter, but it lacks a spectrum scope and other display functions of an SDR. Panadapters with spectrum and waterfall displays greatly assist in determining an RFI source's signature. The high-end professional electrical utility market has devices available from Radar Engineers (Model 243). SDR receivers used with SDR software have continued to develop. They are now an extremely capable, useful and inexpensive tool for RFI tracking. With an SDR, SDR software and a small portable computer we can now identify an RFI source's signature and track it down in the field. As shown in Figure 1, it goes like this: (1) Start by looking at the RFI on a normal station receiver and antenna. (2) Change receivers (with the same station antenna) to the SDR being sure you are seeing the same RFI source. (3) Change to the DF loop. And, voilà, (4) you are ready to go off to locate the same RF source that is on your radio. The SDR receiver I use is SDRPlay's RSP2. There are many others.

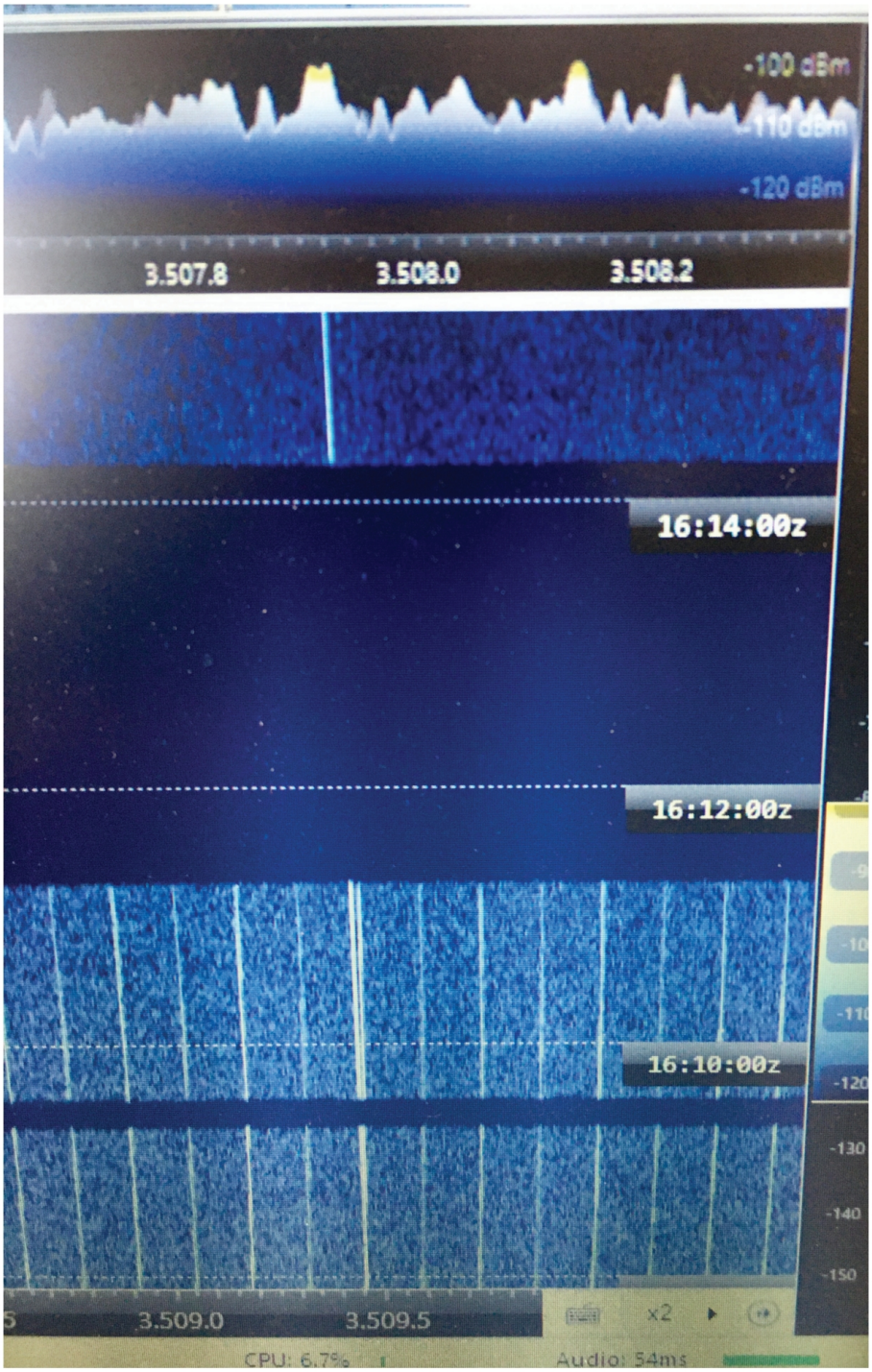

Figure 4 — A screenshot from *SDRConsole*. The RFI source is a refrigerator. At 1611:30, I cut all power to the house. At 1614:15, the power is switched back on. The refrigerator is off because it has not yet restarted.

SDR Software. My only interest in SDR and SDR software has been how it can help me track RFI. Things may have changed since I last compared the various SDR software options, but I found that *SDR Console* (PC compatible) has the best features useful for RFI tracking. These features include a spectrum display, a waterfall display, and a signal history — plus the ability to observe either a very broad or very narrow slice of spectrum. The waterfall display can be adjusted to display 5 minutes of activity across the spectrum slice, and signal history can be set to record 7 minutes

of activity within the passband. Also, a frequency's signal history can be stored in a buffer for up to 48 hours for later export and analysis. These capabilities provide plenty of data for RFI source analysis and data from which to create an RFI source signature. *SDR Console*'s developer is Simon Brown, G4ELI, who regularly revises this software. While you can download and use it for free, I am sure he appreciates contributions. Recently the software was changed, so it now requires even less hardware. With the recent changes, I can now run it on a lightweight tablet PC, making it perfect for tracking RFI. In one hand I hold the RSP2 under the tablet PC and in the other I hold the loop antenna.

Portable tablet or laptop PC. I have a nice little ASUS Transformer Mini T102 tablet PC with Windows 10, and it runs the recent version of *SDR Console* smoothly.

SDR Software general comments. Spend time learning how the SDR software operates. Make note of and use the same settings from day to day. Be sure you identify and eliminate any artifacts that might be coming from laptop or SDR software. Use minimal RF/IF gain settings on the SDR software. Run a full range of captures over all of the bands of interest, using your everyday antennas, and a consistent set of SDR software/hardware settings at several points in the day. Set up the SDR software and let it run at various times of the day and night. That way you will see trends and patterns.

"Power Off at Home" Test

The key to eliminating a noise source is locating it. In all cases, the first step is to determine whether the noise is coming from your own house. You can eliminate most internal sources by switching off the main power at the service panel. But, before doing so, be sure you have the receiver powered by a battery at the ready so you can see what happens to the receiver's noise floor when you shut off power in your house.

Start by listening to your radio when the noise is on. Measure the noise level or strength of RFI. Take a photo of the scope and refer to it in the RFI Log.

Turn off all power to your house at the service panel. With no power to the house look at the SDR's waterfall display and/or signal history. Do you see any difference? See Figure 4. Hope that the RFI goes away, because this would mean the RFI source is within your own house and your own control. If the RFI disappears, you can help to locate it by restoring the main switch and then switching your breakers on one by one as you check to see when the noise returns. Note that the "power off test" does not completely eliminate all in-house noise sources. UPS, battery chargers, and other devices are designed to stay running on battery power even after ac voltage is turned off and may still be generating in-house RFI.

The "power off test" requires some practical considerations. If other family members, for example, are in the home at the time, you'd be surprised how unsettling a power loss may be for them. Also, be ready to quickly restart and reset clocks and computers after turning the power back on. The more times you run this power-off test, the faster you can get everything restored (as if nothing unusual has happened). At my house I can do it in less than 5 minutes. Better yet, recruit a member of your "posse" to staff the service panel, having a way to communicate as each branch of the AC circuit is turned on or off.

Resources

The *RFI reflector* on **contesting.com** is an incredible resource. Follow this reflector and you will learn a lot. The list has various levels of discussion. Some newbie questions, but generally contributions from engineers who have spent entire careers locating and eliminating RFI. The reflector's archives extend back 22 years! Using the Search function will often yield a solution to your exact problem. **http://lists.contesting.com/archives//html/RFI/**.

RFI Book, 3rd Ed., Mike Gruber, editor, ARRL, 2010. (especially chapters 2, 3, and 4.)

The ARRL's *Radio Frequency Interference (RFI)* web page, **www.arrl.org/radio-frequency-interference-rfi**, is an excellent place to gather RFI information.

The Mitigation of Radio Noise and Interference from on-site Sources at Radio Receiving Sites, Wilbur R. Vinson, et al., Naval Postgraduate School, 2009.

The Mitigation of Radio Noise from External Sources at Radio Receiving Sites, 6th Ed., Wilbur R. Vinson, et al., Naval Postgraduate School, 2007.

Grounding and Bonding for the Radio Amateur: Good Practices for Electrical Safety, Lightning Protection, and RF Management, H. Ward Silver (NØAX), ARRL, 2017.

Visit **http://k9yc.com/KillingReceiveNoise.pdf** and other superb articles and application notes regarding eliminating RFI.

Visit**www.nk7z.net/rfi-snapshots/** and other excellent resources at **www.nk7z.net**.