

Finding And Conquering Radio Frequency Interference

Noisy Signal Ruining Your Listening Fun? Track Down And Eliminate That Maddening RFI

by Don Rotolo, N2IRZ

It's a humid late summer's night. I'm trying to stay cool in the shack with my electric fan, but it's not doing much to keep the dials of the Yaesu VR-5000 dry. I'm ready for my favorite show on 9825 kHz, when I hear it: a pervasive, raspy buzzing. It's all over the band, almost covering up the signal. Aargh! Where does it *come* from? Even more important, how do I make it *stop*?

Radio frequency interference (RFI) is the bane of the short-wave listener. Our fragile radio waves dissipate to almost nothing as they travel the ether to our antenna, then are amplified thousands of times to become sounds for our enjoyment. It doesn't take much to interfere with this process—a stray millivolt here or there brings the system to a crashing halt.

The main problem with RFI isn't so much that it interferes with our radio enjoyment, but that it's so darned difficult to get rid of. In many cases, however, using some basic methods we can at least find the source of the problem, which is the first step to eliminating it. In this article, we'll get to understand how electrical devices can interfere with radio reception, some methods that can be used to identify the source of the interference, and suggestions for reducing or eliminating its effects.

In that scene above, it turns out that my old electric fan was the culprit, sending out broadband noise from the sparking of the motor brushes. My super-sensitive receiver picked up that noise and delivered it to the speakers, not “knowing” that it wasn't what I wanted to hear. The solution, in this instance, was to buy a newer fan that has a synchronous AC motor, which has no brushes and is designed to dramatically reduce the RFI it produces.

Electricity And RF Noise

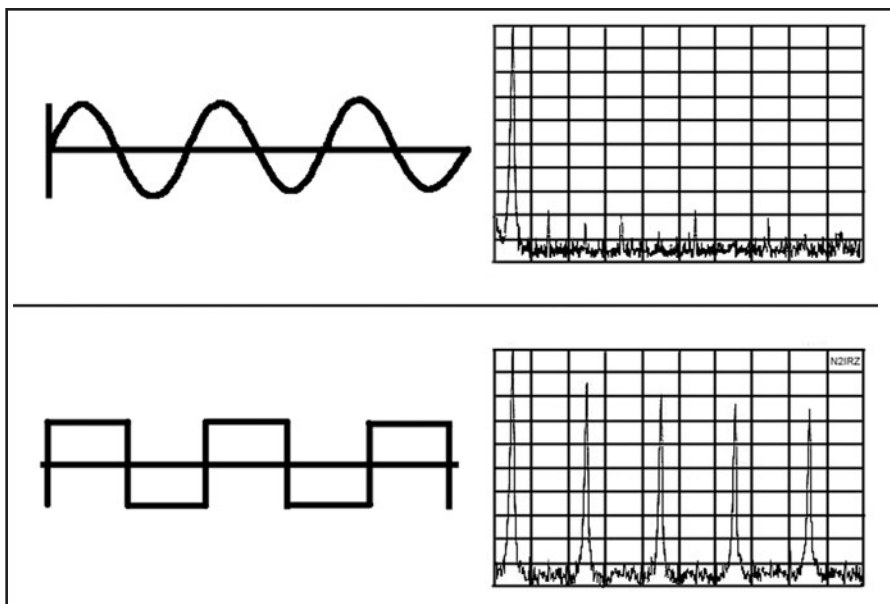
Let's begin by taking a look at electricity and how it can generate radio frequencies. For us, RFI has one very important characteristic that seems obvious: It can be heard on a radio receiver. And why can a receiver “hear” it? Because the frequency of the interference is within the range we call “radio.”

Around the house, we encounter most electricity in one of

Don Rotolo, N2IRZ, is an electrical engineer, amateur radio operator, and tenacious RFI sleuth. He also writes the “Digital Connection” column for *Pop'Comm's* sister magazine, *CQ*.



Common sources of radio frequency interference (RFI) are the power lines and utility equipment outside our homes. Listening to local AM radio in the car can help you pinpoint noisy power line equipment. If this is the source of interference to your receiver, your local power utility company will generally be happy to correct the problem.



A sine wave and a square wave in both the Time and Frequency domains. Note that the sine wave is a single frequency, while the square wave is made of several frequencies, all odd multiples of the fundamental frequency. These harmonics can extend well into the shortwave bands, causing interference.

three forms: direct current (DC), which is what we get from batteries, alternating current (AC), which we get from the power mains and wall outlets, and static electricity, which are those miniature lightning bolts we get when touching metal in a very dry climate.

DC does not produce RFI at all. Since the voltage changes very slowly, or not at all, there are no opportunities to hear this kind of electricity on a radio receiver. In technical terms, we can say that the frequency is too low to cause interference. If we start turning DC on and off, however, that changes things, as the switching action can generate electrical noise.

AC, the 50 or 60 Hertz (cycles per second) we have coming from the wall socket, also has a frequency too low to cause RFI, at least for the kinds of receivers we're using. That doesn't mean that something powered by AC can't interfere—mains-powered equipment (such as an electric blanket) is by far the most frequent source of RFI—but the AC supply *itself* isn't what's causing the interference.

Lastly, we have that pesky static electricity. Rubbing your feet on the carpet and touching some metal or another person creates a small spark, too small (and infrequent) to be anything other than a mildly painful nuisance. The spark does actually generate a broad spectrum of radio frequencies, but these are far too faint for our receivers to pick up. But we can't dismiss this phenomenon, since it

helps explain one major source for the kind of noise that really does interfere with our radio reception.

Let's take an extreme example of static electricity: lightning. By far the most powerful release of energy in the natural world that all of us have experienced, significant electromagnetic fields are created when thousands of amperes of current flow. Since the energy release is so quick, the frequencies generated reach well into the radio bands. That is, the faster the voltage changes, the higher the frequencies created, and lightning is pretty darn fast. Now let's look at the electrical theory behind that statement.

Generating Radio Waves

A pure sine wave consists of one frequency. When we look at the waveform in the time domain (Voltage vs. Time), it describes a sinusoidal wave that changes somewhat gradually from one voltage peak to the other, and when we look at it in the frequency domain (Voltage vs. Frequency) it shows a single spike of energy at the fundamental frequency.

A square wave, which has very fast transitions from one voltage to the other, looks in the time domain like a series of square "teeth." In the frequency domain we see not only that spike at the fundamental, but a series of spikes of energy at odd multiples of the fundamental.

For example, a square wave at 100 Hz will have a series of spikes (or harmon-

ics) at 300 Hz, 500 Hz, 700 Hz, and so on at odd multiples of the fundamental. These harmonics will normally decrease in amplitude as the frequency gets higher. The rate of this decrease is determined by how steep the slope of the line is during the transition from one voltage to the other, also known as the slew rate (in units of volts per microsecond). This means that a square wave with steep slopes will have more high-frequency energy than one with shallower slopes. This phenomenon isn't limited to square waves; in fact, any waveform that is not a pure sine will have some harmonics somewhere.

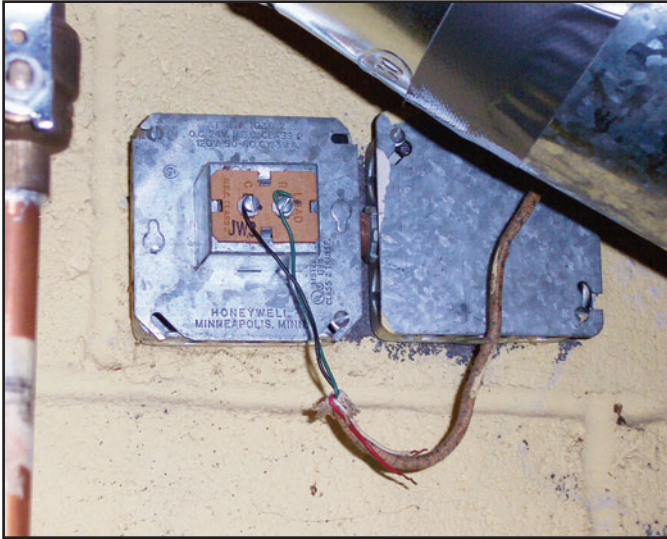
The reason for these odd harmonics comes down to simple math: If you add the voltages of odd harmonics of the fundamental frequency, they form a square wave. The higher these frequency harmonics go, the more square (steeper sloped) the waveform is. To see this illustrated, point your browser to <http://tinyurl.com/PopCommSquare> (click on the image to see the animation).

This means that if we have some voltage that changes rapidly—perhaps a bolt of lightning or a poorly designed switching power supply in a computer—we can hear the signal in our receivers. By definition, if you don't like it, it's interference. The bottom line is that the majority of RFI comes from AC-powered devices in our homes which are improperly generating electrical signals having steep-sloped waveforms, thus creating RF energy that makes it into our sensitive receivers as interference.

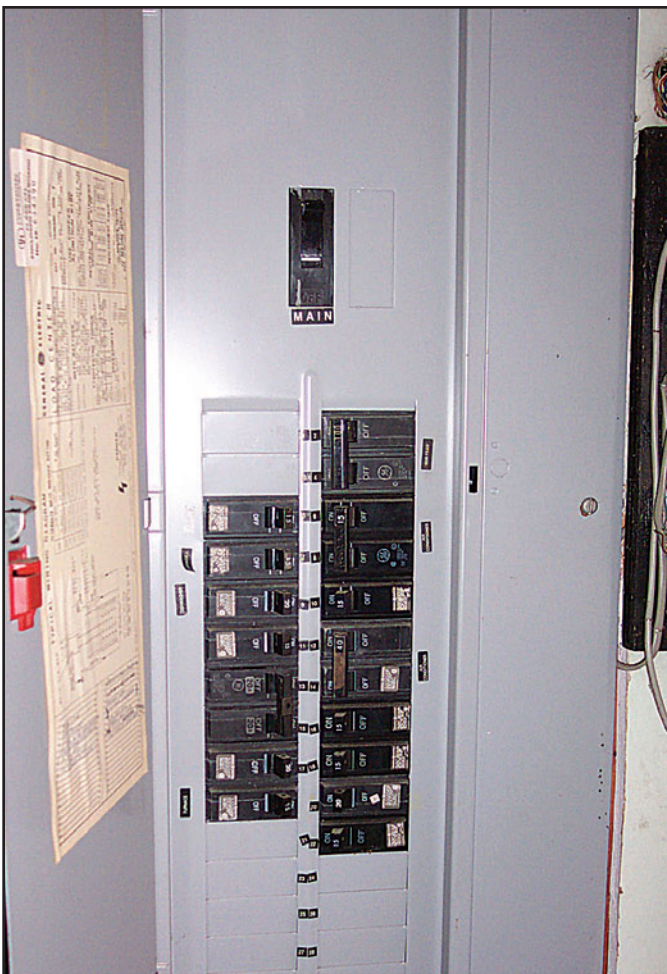
Sometimes we can use this effect to our advantage. Older receivers, where the tuning system was analog, often make use of this phenomenon by including something called a crystal frequency marker generator circuit. A stable quartz crystal is made to oscillate at 100 kHz (typically) and the waveform is purposely "squared off"; this generates a series of "marker" tones or signals every 200 kHz, which are used to calibrate the analog frequency dial.

The marker generator in my old Heathkit SB-102 ham transceiver is audible and usable throughout the HF ham bands. Normally the markers are switched off, though, unless I want to calibrate, because it does affect reception. Today's digitally tuned receivers don't have much use for this, since they're usually pretty close to the indicated frequency.

When we buy electrical devices, we assume they don't cause RFI. It's the job



Small power transformers, such as this one used for doorbells or heating thermostats, tend to become noisy over time. These can be hard to pinpoint, since they're often hidden behind piping in the cellar.



The main circuit breaker panel or fuse box for your home is the first place to start when you're searching out RFI. Switch off one circuit at a time until the interference stops—whatever is causing the problem will be on that circuit.

of the circuit designer to understand the effects of these unwanted frequencies and manage them so that they don't cause interference. What this means in a practical sense is that any time you encounter RFI, it's often caused by some electrically powered device that is either malfunctioning or poorly designed. There are some exceptions, however; for example, any naturally generated noise (like lightning) that we cannot control, or interference caused by intentional emitters (such as a radio transmitter). Often these are either momentary in effect or easily identified. There are weird cases of interference where two or more transmitted signals are "mixed" to some other frequency, but these are extraordinarily rare and beyond the scope of this article.

Finding The Source

Now that we know how some of these interfering radio frequencies are generated, how do we find their source? To start with, it's important to understand that RFI can get into your receiver in three ways: radiation, induction, or conduction. Radiation is picked up by the antenna, induction is picked up by wiring and components within the receiver, and conduction is the passage of electrical signals through the power and other wires leading into the receiver.

For RFI that is conducted, in many cases it is easier to filter the interfering signal than to find and fix it. We'll talk about conduction filters in a moment. If you can hear the interference with the antenna disconnected, it's getting in through conduction or induction.

For RFI that is delivered by induction, we can simply move the receiver farther from the interference source, since the strength of the interference decreases with the cube of the distance (a cube is a number times itself, times itself again). We can also shield the receiver itself against interference. Again, we'll talk about that in a moment.

Most of the RFI we encounter is radiated, making it more difficult to eliminate since the antenna that receives the interference is also receiving the desired signal. In this case, resolving the RFI requires that we find and eliminate the source of the interference.

The process is relatively easy for interference sources in our own living quarters or in other areas we can control. When the interference originates outside our property, however, we may need to tread delicately, since accusing a neighbor and making demands is probably not going to end happily. Let's start at home.

Most RFI sources are powered by the AC mains. Assuming you can hear the interference, just switch off circuit breakers (or remove fuses), one at a time, until the noise goes away. When you find the right circuit, unplug everything on that circuit, one at a time, to find the specific problem device. In nearly 75 percent of the cases I've investigated, this simple technique found the interference. Common culprits are computers and electric heating devices, but stories abound of doorbell and thermostat transformers putting out broadband noise caused by internal sparking.

Some Detective Work

If you've shut down the entire house's electricity and still hear the noise, it's time for some basic detective work. The power utility company's wires and equipment are wonderful sources of RFI—just drive around listening to AM broadcast

radio to find noisy power lines. Power line connections and transformers are notorious for continuous noise with a buzzing sound, since the power line frequency modulates the noise somewhat. If you trace the problem to noise power equipment, your local power company will generally be happy to come out and fix it. Not only is it good business (noisy equipment means failing equipment), but they are required by the FCC to keep their system from generating RF noise. Just be sure to supply the utility pole tag number when contacting them, and make a note of the nearest cross street.

While finding an RFI source outside your home can be as easy as driving in your car while listening to AM broadcast, it can also present a problem difficult enough to drive Sherlock Holmes crazy. The very first step in finding a source of interference is getting a better idea of where to look. To get started in radio direction finding (RDF), disconnect your regular antenna and connect a directional antenna instead, one you can hold in your hands. This can be a home-made dipole on a wooden stick, or a commercially built Yagi beam or log-periodic. (If your radio is a handheld, it's even easier. Read on.)

Radio Direction Finding

To build such a dipole, start with a connector of the type you need for your receiver's antenna, such as PL-259, with a short piece of coaxial cable attached, perhaps six feet long. At the other end, bare the center conductor and separate it from the braid by about two inches. Connect two pieces of wire, each about three feet long, one to the center conductor and the other to the braided shielding, and attach the whole "T"-shaped assembly to some wood. The dimensions are not critical, and you can just use what you have handy. (If you're unclear on this, illustrations abound on the Internet and in hobby resource books.)

While listening to the interference, slowly rotate the antenna. When the interference is loudest, the *flat* of the T is facing towards the interference source; at its quietest, the *arms* of the T are facing the source. This will be a subtle difference, so you need to concentrate and listen carefully, perhaps using headphones. If you have a variable RF gain control (or an in-line variable attenuator), use it now to make the signal very weak, so the differences become more obvious. You might also travel several hundred yards away to

let the interfering signal get weak enough to track this way.

If you have a handheld radio, you can use your body to block the noise signal while again turning in a circle. Hold the antenna vertical, a few inches from your body, right about chest level. The noise will be loudest when you are facing the source and quietest when the source is behind your back. If the signal doesn't vary enough to find the direction, wrap the antenna and upper part of the radio loosely in aluminum foil, which should cut down the signal enough for you to get a direction.

While these RDF techniques are useful, they're not foolproof. It takes some skill and practice to do this well, and without a means of making the signal very weak, it may not work at all. You can also get a lot more information on the Internet by searching for "radio direction finding" and "finding radio interference."

The ideal situation is found with a highly directional antenna like a Yagi beam with several elements, along with a variable RF attenuator. Note that you can also get RDF equipment that uses the Doppler effect to find a noise source. One such device is the Ramsey Electronics DDF-1. At \$170, it's not for everyone, but

perhaps someone in your local radio club has something like it.

Intermittent Noises

What about those cases where the interference comes and goes? If it stays around long enough, the techniques above might catch it, but if it's fleeting, it sometimes helps to keep a log of when it can be heard. After several days or weeks, check the log and see if you can detect a pattern.

For example, some time ago I was hearing a loud noise all across the band, up to about 8 MHz, that lasted almost exactly five minutes. It only happened a few times a day, usually in the morning and just before dinner during the week, and at odd times on weekends. After keeping a log for almost a month, it dawned on me that the times corresponded to my neighbors' comings and goings: Every time they opened or closed their garage door, there was noise.

I explained my suspicions to my neighbor, Ralph (we're good friends, and he's an electrical engineer), and when we opened his garage door, you could actually hear the light bulb "sizzling"—the light bulb on his electric garage door opener was arcing and wiping out my

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radio. Removing the bulb, we found that the dot of solder on the bottom was partly melted and burned away. Installing a new bulb fixed that one.

Knowing the typical sources of interference will help you track a specific culprit. In addition to transformers, computers, heating appliances (and other big



If you have electric heat, the thermostat contacts can become dirty or worn over time. The minuscule arcing that occurs at the load contacts will generate RFI. Other heating appliances, such as electric blankets, can also generate RFI. For intermittent noise, keep a log to help identify patterns.

power users), other causes include gas-line engines (which can sound like a playing card being hit by bicycle spokes), fluorescent light bulbs (both tube and compact type), and electric motors.

If your detective hits a wall, by the way, the American Radio Relay League www.arrl.org maintains teams of volunteer Technical Specialists who will help you investigate RFI problems. Contact your Section Manager or ARRL Headquarters for more information.

A Good Grounding

OK, so now we've found the source of the interference, but it's not as simple as unplugging whatever it is. Now what?

The first step is to ground your equipment with a good RF ground. The third prong of the electrical outlet is a good safety ground, but it is often a poor RF ground. RF travels on the outer skin of a wire, and long thin wires have a high impedance at RF frequencies. Instead, run braided wire (such as the shield of RG-8 wire) to a dedicated RF ground (such as a cold water pipe made from copper, or an eight-foot-long ground rod driven into the soil) keeping the connection as short as possible and avoiding tight bends. If this isn't easily done, search the Internet for other ideas for RF grounds. You still need the safety ground, but the RF ground will help with interference.

The RF ground will also help reduce interference from Induction. The metal case of the receiver conducts electrical fields to the RF ground. For magnetic fields, you need something that conducts magnetism (like steel, but not aluminum),

but you don't need a "ground," just "wrapping" the circuitry with a magnetic shield is sufficient.

Filters And Chokes

For conduction, you can get power filters for AC and DC power lines. Available commercially at places like RadioShack and similar, these have inductors and capacitors which filter out conducted noise. The filters for DC are made for automotive applications, while the AC filters are for computers and other sensitive equipment. You can make a filter if you like; again, just do a search on the Internet or consult the *ARRL Handbook* for details. If the filter you get can be grounded, connect it to your RF ground for best effectiveness. You can also get ferrite beads or other shapes that will help choke off stray RF on the power leads.

Ferrites can also be helpful in choking off any stray RF on your antenna line. Amidon (www.amidoncorp.com) is a well-known supplier of ferrite toroids and other products which can be used for this purpose.

The Noise Bridge

If you're technically inclined, you can build a noise bridge, which uses a second antenna to receive the "noise." You then subtract the noise from the signal + noise, leaving only the signal. These devices can reduce—but not eliminate—noise of a periodic or modulated nature, but not background "hiss." An Internet search will bring up several circuits, or you can check out the one in the *Interference Handbook* (By William R Nelson, WA6FQC, ISBN 0-933616-01-5) in Chapter 7. You can also buy one commercially; offerings include the Ten-Tec (www.tentec.com) model 1051 (\$19) and MFJ www.mfjenterprises.com model MFJ-202B (\$80).

Keep On Plugging Till You Can Unplug

Now that you're armed with some basic tips and remedies, get sleuthing. But remember, if your efforts aren't panning out, you don't have to just "live with it." Most RFI can be cured, often inexpensively, so if you're stumped reach out to the ARRL, as mentioned before, before you throw up your hands in defeat. We all experience RFI at some point or another, but we shouldn't let it decrease our listening enjoyment.

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